EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE

CERN - PS DIVISION

PS/ PA/ Note 93-04 (PPC)

PROCEEDINGS OF THE FIRST PS PERFORMANCE DAY (PPD)

Edited by D. Manglunki

Abstract

The first PS Performance Day was held in Eloise (Haute Savoie) on the 3rd of February 1993, under the sponsorship of the PS Performance Committee.

The aims were: to improve mutual information, to promote analysis and discussion, to define MD priorities and finally to outline problems, all issues facing the machine physicists throughout the PS complex.

The talks were grouped by beams : LHC-type proton beam, East Hall, Isolde, heavy ions, antiprotons and leptons. The meeting was concluded by a series of summaries where each machine spokesman exposed in three transparencies the present performances, '93 MD schedule and specific problems of his machine. Here are the contributions from the machine physics teams, preceded by an abstract.

PS Performance Day (PPD), held in Eloise (Haute Savoie), February 3rd, 1993.

Geneva, Switzerland
23 February, 1993

Version 7.1

PS Performance Day, Eloise, 3-Feb-1993

Time	Duration	Speaker		Machine	Beam	Title	Page
08:20						*Bus leaves CERN*	
09:30	**00:10**	K.Hübner				Opening address	
		Session 1 (Chairman: M.Bouthéon)					
09:40	**00:20**	J.Boillot	*	All	All	Improvements in Operation	1
10:00	**00:10**	M.Vretenar		RFQ2	LHC	RFQ2 past & future expected performance	15
10:10	**00:10**	D.Warner		LINAC	LHC	Expected performance of Linac II with RFQ2	21
10:20	**00:05**					*Discussion on Linac II and RFQ2*	
10:25	**00:10**	K.Schindl		PSB	LHC	PSB high beam density for LHC (past, future)	27
10:35	**00:10**	R.Cappi		PS	LHC	PS emittance conservation at injection energy	35
10:45	**00:05**					*Discussion on machine physics in PS/PSB for LHC*	
10:50	**00:30**					**Coffee break**	
		Session 2 (Chairman: D.J.Simon)					
11:20	**00:15**	S.Hancock	*	PS	LHC	Flat-topped bunches	43
11:35	**00:15**	M.Martini	*	PSB/PS	LHC	PS/PSB/TT2 emittance measurement comparisons	49
11:50	**00:20**	K.Schindl	*	LI/PSB/PS	LHC	Test end 1993	63
12:10	**00:10**	E.Wildner		PSB	Proton	Commissioning of ISOLDE beam	73
12:20	**00:10**	H.Schönauer		PSB	Proton	Problems with 3.10^{13} ppp for ISOLDE	81
12:30	**00:05**					*Discussion on proton beam for ISOLDE*	
12:35	**00:15**	C.Steinbach	*	PS	Proton	New slow extraction 61	87
12:50	**01:40**					**Lunch break**	

* indicates that a 5' discussion time is included in the talk duration.

PS Performance Day, Eloise, 3-Feb-1993

Time	Duration	Speaker		Machine	Beam	Title	Page
		Session 3 (Chairman: B.Allardyce)					
14:30	**00:15**	C.Hill	*	LINAC	Ions	Lead ion source	95
14:45	**00:15**	N.Rasmussen	*	PSB	Ions	Beam dynamics of ion acceleration	101
15:00	**00:15**	D.Manglunki	*	LEAR	Ions	Ion cooling and stacking; foreseen studies	107
15:15	**00:15**	G.Tranquille	*	LEAR	Ions/Pbar	Electron cooling. Status and future developments	115
15:30	**00:20**	V.Chohan	*	AAC	Pbar	AAC performance, problems and near-future plans	125
15:50	**00:10**	S.Baird		LEAR	Pbar	High energy problems and prospects in LEAR	137
16:00	**00:10**	M.Chanel		LEAR	Pbar	Low energy problems and prospects in LEAR	143
16:10	**00:05**					*Discussion on pbar operational beams*	
16:15	**00:15**	U.Oeftiger	*	LEAR	Pbar	Impedance measurements	147
16:30	**00:30**					**Tea break**	

* indicates that a 5' discussion time is included in the talk duration.

PS Performance Day, Eloise, 3-Feb-1993

* indicates that a 5' discussion time is included in the talk duration.

PS Performance Day - 3 Feb. 93

Improvements in Operation

(J.Boillot)

Introduction:

For several years we notice a slight degradation of machine performance (3 or 4% on the fault rates) but we especially encounter important problems and difficulties during machine setting-up and MD sessions.

Machine physicists are spending a large fraction of their time helping the operation team to solve technical problems during machine setting-up and MD sessions but also during routine operation.

2 special PPC meetings were held on this subject on 14.4.92 & 13.05.92 in order to discuss and propose improvements or to encourage actions already undertaken by OP group in several domains: partial tests, machine schedule, operational aspects, controls. In particular the efficiency of MD sessions depends of these improvements.

Then PPC comments and recommendations were presented in the PS Technical Meeting 25 held on 3rd June 1992.

The object of this presentation is to review the status of these different improvements before starting a new year of operation.

Improvements in Operation

1. Operation statistics

Historic (running hours, fault rates)

Beam availabilities in 1992

2. Improvements

2.1 Partial tests

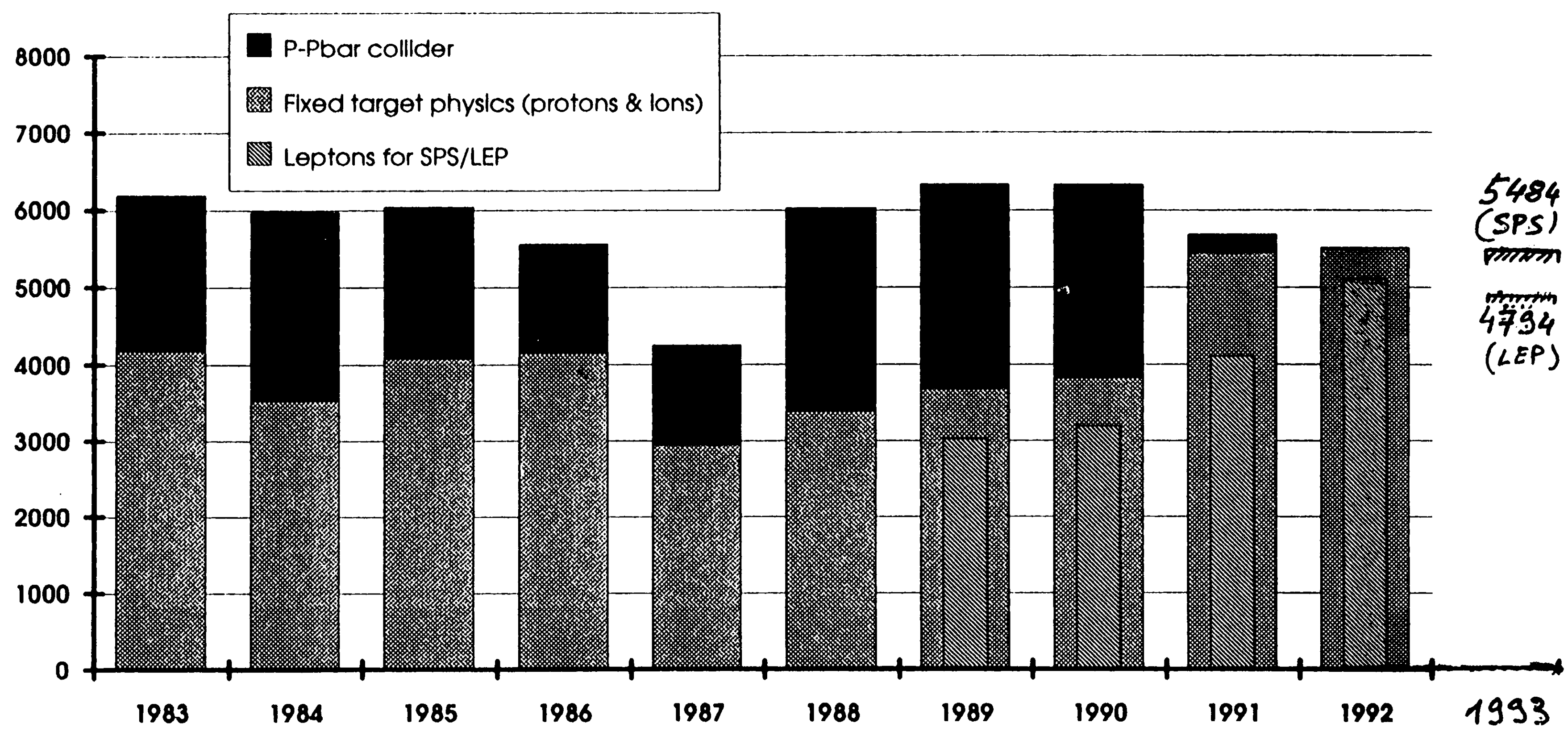
2.2. Machine schedule

2.3. Documentation

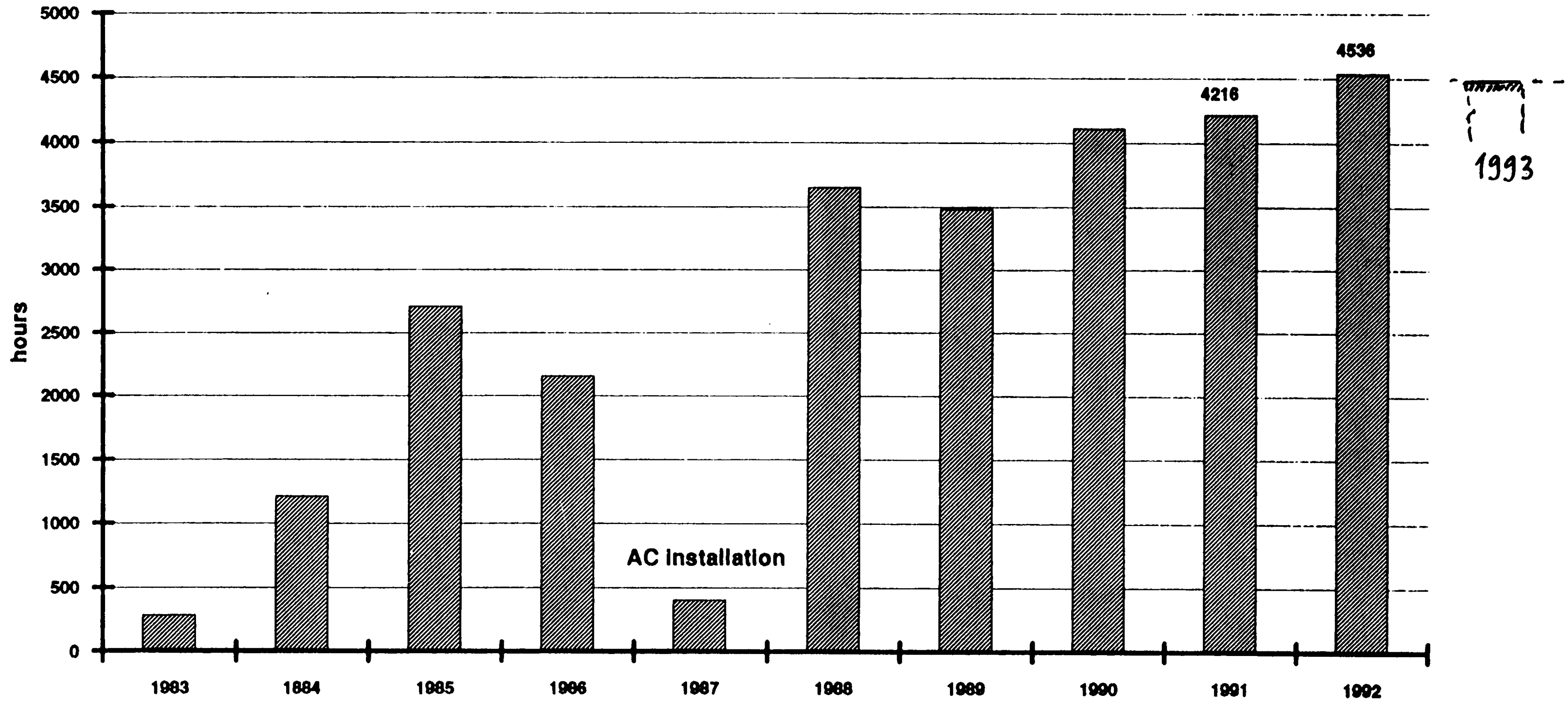
2.4. Operational aspects

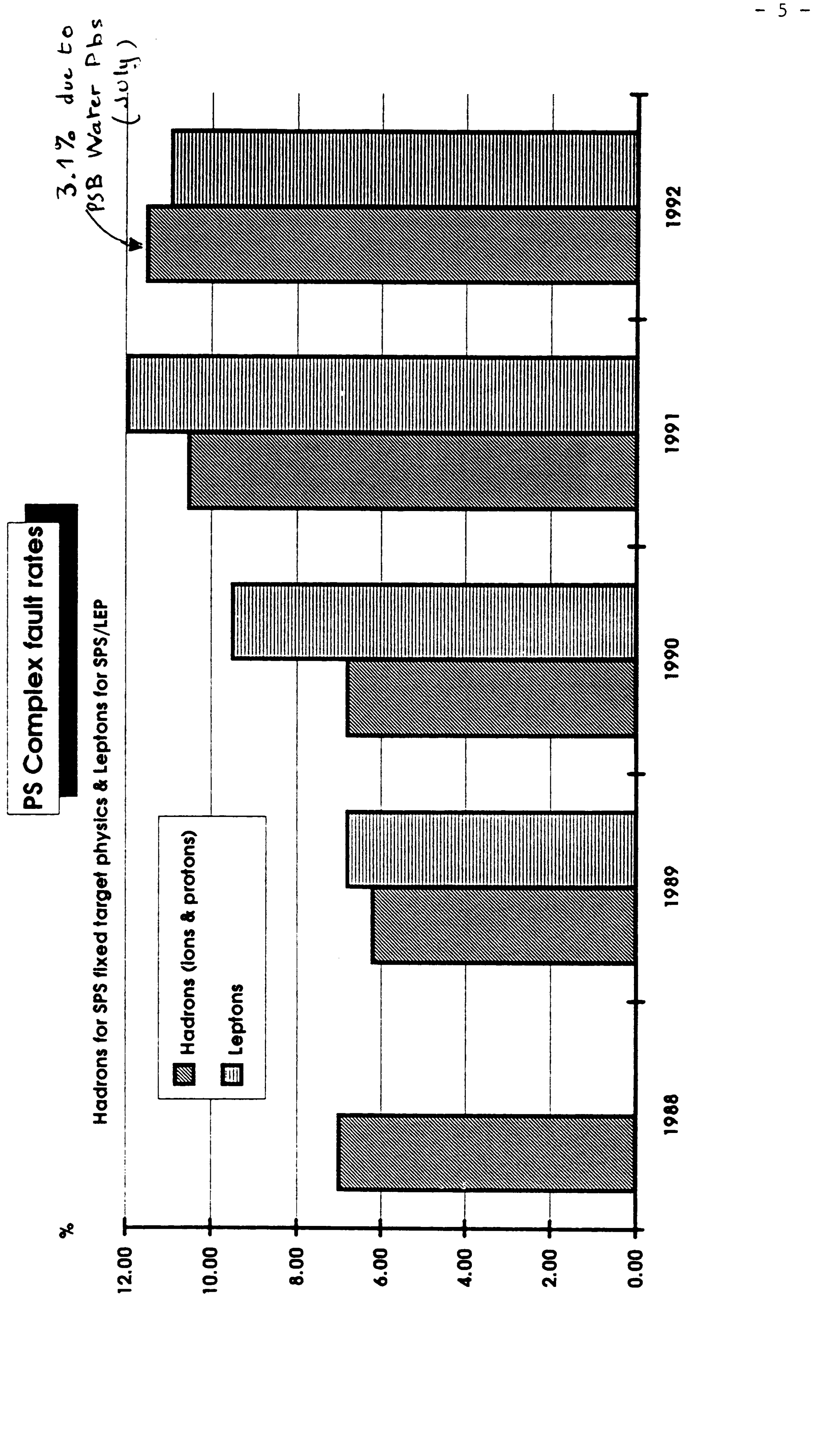
2.5. Control problems

PS Complex - Running hours for SPS Physics and LEP



LEAR - Hours for physics




PS Complex fault rates
Hadrons for SPS fixed target physics & Leptons for SPS/LEP
%
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Hadrons (Ions & protons)
Leptons
1988
1989
1990
1991
1992
3.1% due to PSB Water Pbs (July)

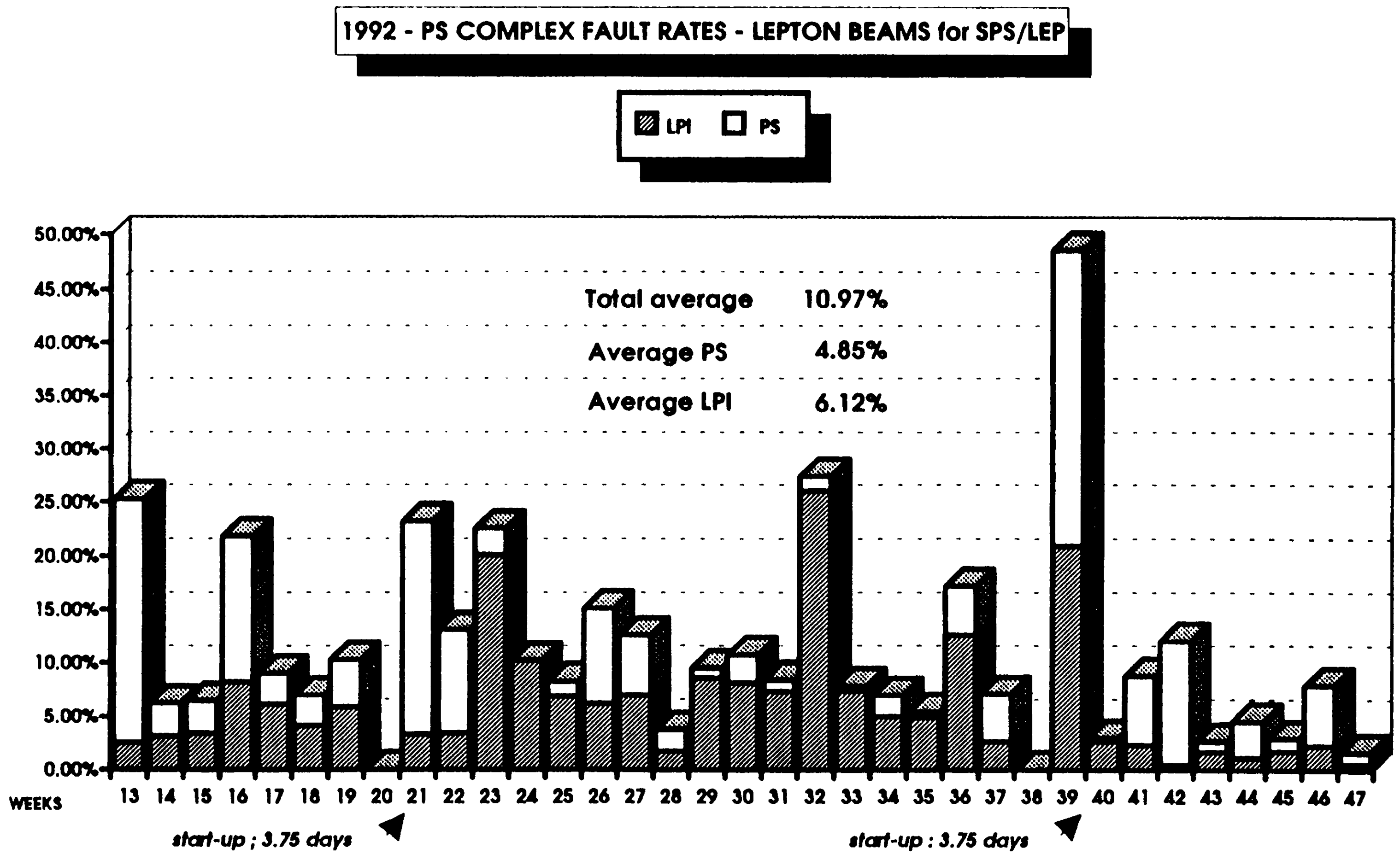
1992 - PS Complex beam statistics

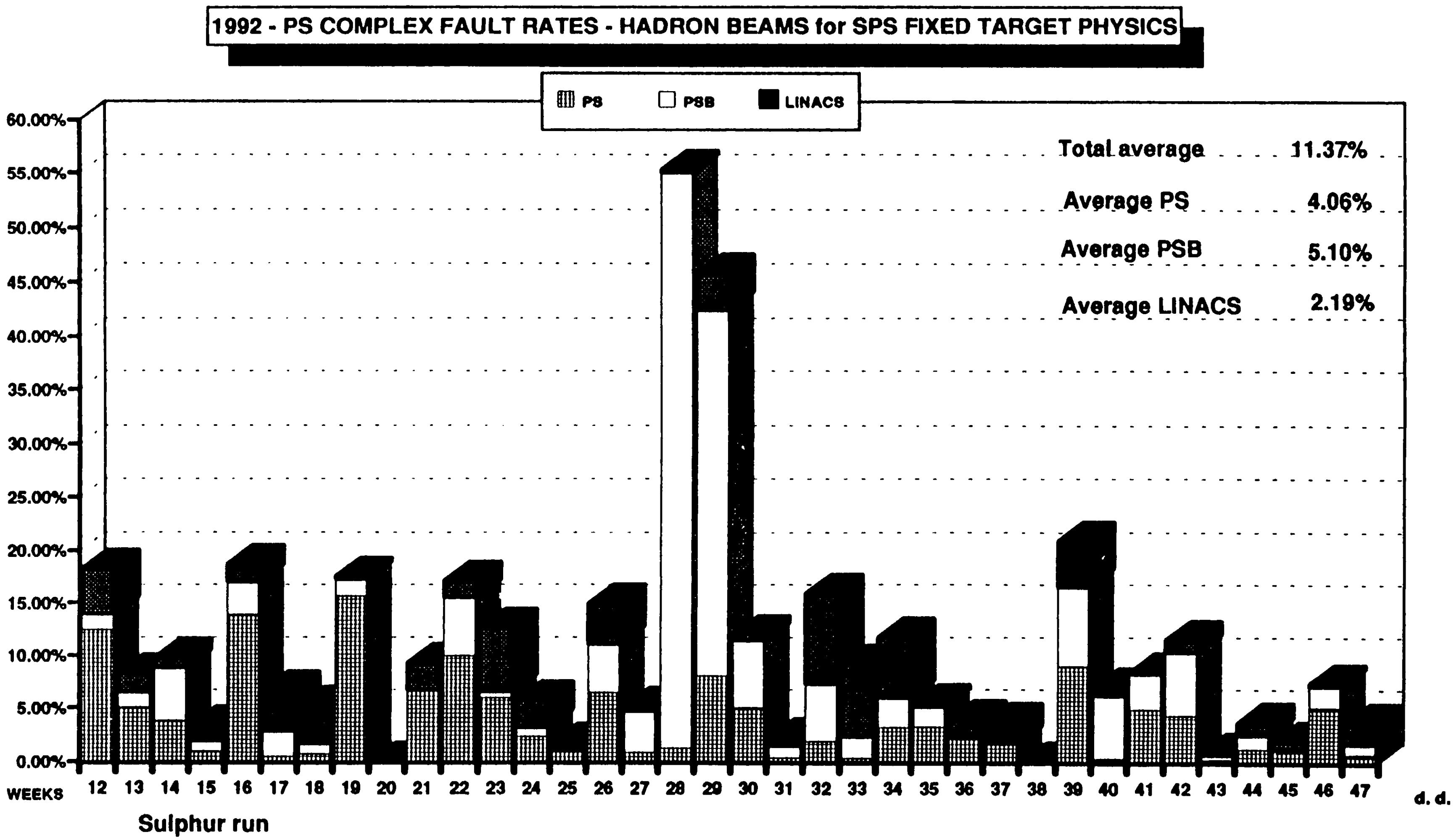
Beams	Run duration	Machines	Durations of faults	Fault rates
LEPTONS for SPS/LEP (e+ e-)	209.87 days	LPI PS **TOTAL**	12d 17h 21' 10d 3h 13' 22d 20h 34'	6.06% 4.83% 10.89%
HADRONS for SPS fixed target physics (protons)	217.87 days	LINACS PSB PS **TOTAL**	4d 18h 26' 11d 2h 46' 8d 17h 36' 24d 14h 49'	2.19% 5.10% 4.01% 11.30%
HADRONS for South Hall physics (antiprotons & protons)	182.79 days	AAC PS LEAR LINAC1 **TOTAL**	4d 15h 14' 3d 15h 39' 11d 8h 59' 1d 11h 28' 21d 3h 20'	2.54% 2.00% 6.22% 0.81% 11.56%

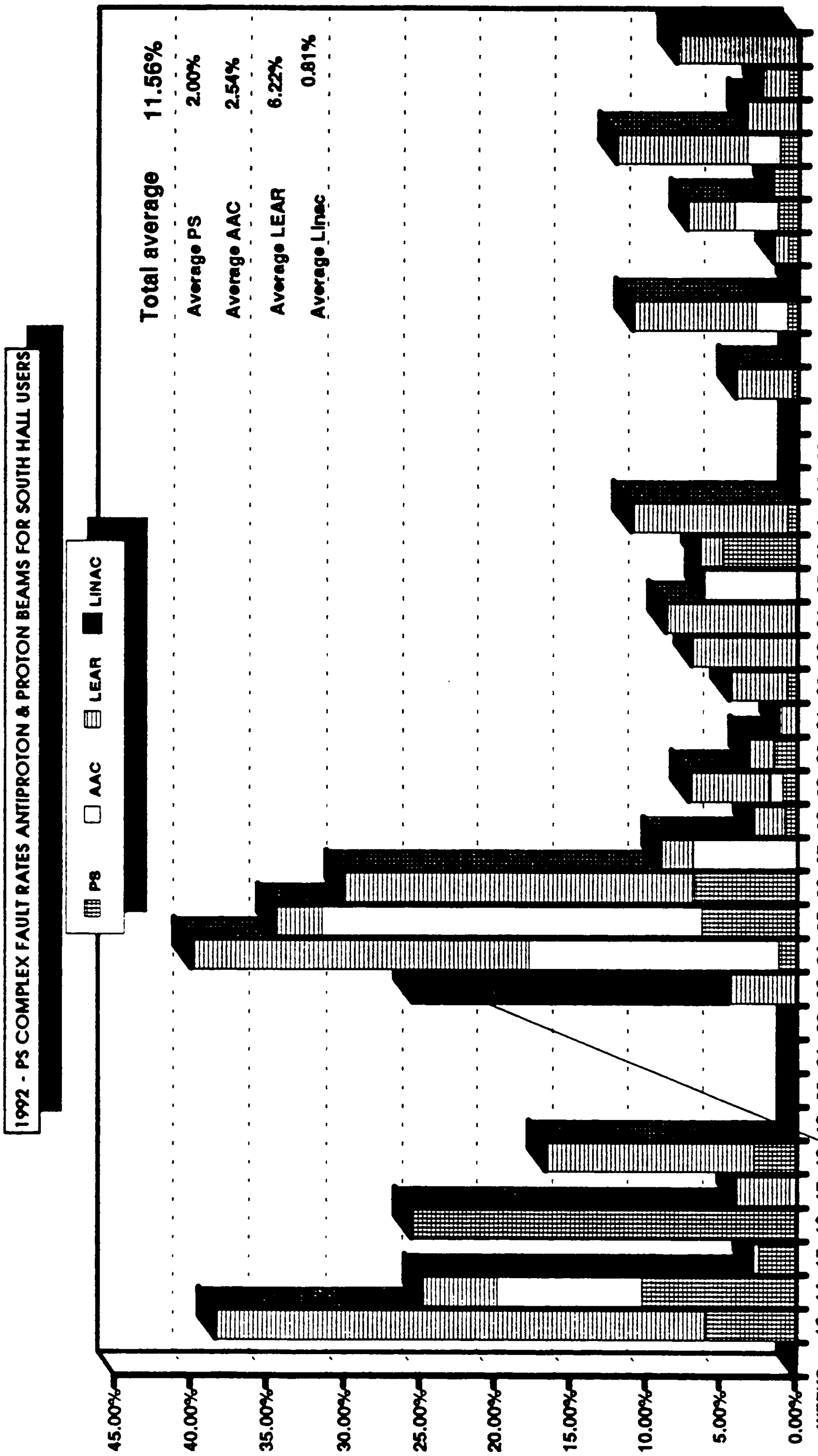
PS	**Hours scheduled**	**%**	**Faults (h)**	**Fault rates**
Physics	5984	93.53%	see above:	~11%
Machine development (PS, PSB, Linac2)	166 →	2.59%	33.4	20.12%
Machine setting-up	174	2.72%	49	28.16%
Start - Stop	74	1.16%		
TOTAL	6398			

d.d.

d.d.


1992 - PS COMPLEX FAULT RATES - LEPTON BEAMS for SPS/LEP
LPI
PS
Total average 10.97%
Average PS 4.85%
Average LPI 6.12%
50.00%
45.00%
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
WEEKS
13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
start-up ; 3.75 days
start-up : 3.75 days


1992 - PS COMPLEX FAULT RATES - HADRON BEAMS for SPS FIXED TARGET PHYSICS
PS
PSB
LINACS
Total average 11.37%
Average PS 4.06%
Average PSB 5.10%
Average LINACS 2.19%
60.00%
55.00%
50.00%
45.00%
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
WEEKS
12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
Sulphur run
d. d.


1992 - PS COMPLEX FAULT RATES ANTIPROTON & PROTON BEAMS FOR SOUTH HALL USERS
PS
AAC
LEAR
LINAC
Total average 11.56%
Average PS 2.00%
Average AAC 2.54%
Average LEAR 6.22%
Average Linac 0.81%
45.00%
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
WEEKS
13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51
Linac1 for PS189

Partial tests:

The aim of the partial tests is to make sure the hardware and software will be in working order for the setting-up. These tests should be as complete as possible to avoid testing with beam what can be tested without it, minimising machine irradiation and setting-up time. Two proposals were made in order to improve the situation: the use of a checklist (under the initiative of the OP group) and a more detailed information about the schedule, directed to the specialists (software, power, instrumentation, etc...) involved.

.1 Coordination by OP Group (all the PS groups + technical Divisions involved in these tests)

ex: machines now closed during 3 or 4 days at the end of the shutdown in order to allow tests during day-time

.2 Checklists; we started the use of checklists in 1992 with lepton operation then with other operations.

.3 Information about the schedule: 1 member of each PS group attends the PS schedule meeting

.4 Better follow-up of machine problems (review after each machine period under OP responsability)

MACHINE SCHEDULE

1. More time should be given to parallel MD time. J.Boillot will see the PS physics coordinator to discuss with him the possibilities of taking a few PHY25 cycles. For example for the PS machine, one cycle/supercycle, 8 hours/week, should be a reasonable minimum.

2. start-ups must be better co-ordinated to reduce the time lost by engineers.

Better start-up planning in 1993 (spread out over 3 weeks)

DOCUMENTATION

1. Instrumentation

An instrumentation catalog for the PS machine, to be written with the collaboration between the OP and BD groups, could be helpful. This already exists for the PSB and LPI machines.

2. Operation: 1) Updating of documentation / beam

2) Improve documentation on timing processes

Operational aspects:

1. The function of "Technical Supervisors" (follow-up of breakdowns, link with CO and BD, definition of check-lists...) should be promoted.

in 1993: 3 former operation technicians on PSB/Linacs, PS, LPI

~65% on operation

Description of this function: follow-up of operation, of technical problems, coordination with specialists, active participation to MD, documentation, training of newcomers, etc

2. Some time during quiet operation periods should be devoted to measurements of beam parameters. This would prevent the slow degradation of beam quality and would make sure the hardware and software stays operational and that the operators are trained on it.

Several operators (~6) are involved on beam or machine parameter measurements (ex: emittances, orbits, Q, chromaticity...)

3. An active participation of the operation staff to MD and improvement of beam perfomance should be highly promoted and awarded.

In 1992, we continued to increase the participation of operators to MD on the different machines

Consequence of 2. & 3.: more difficult to carry out a 2nd job during shiftwork

Control problems:

1. More rigour should be applied in particular for data treatment and saving. Actions in this direction have already been successfully taken and should continue.

Several actions are proposed and studied by NOAS & CO

1.1 **PPM** 1) simplification of LPI PPM; then try to apply this simplification to PSB & PS

2) extension to 24 users

1.2 **ARCHIVES** Try to have virtual machines without coupling (LPI, PSB...) (with facilities of copy)

1.3 **New GFA** (more vectors and number of functions)

2. The control exploitation team should be reinforced during the starting-ups, maybe with a continuous presence in the MCR.

This team is now completed to 5 technicians

3. A powerful tool to debug timing problems is strongly desired.

3.1 New intervallometer developed and installed by CO (LPI, Linacs,...)

3.2 simplification of timing processes (ex: LPI)

3.2 improve documentation (OP Group)

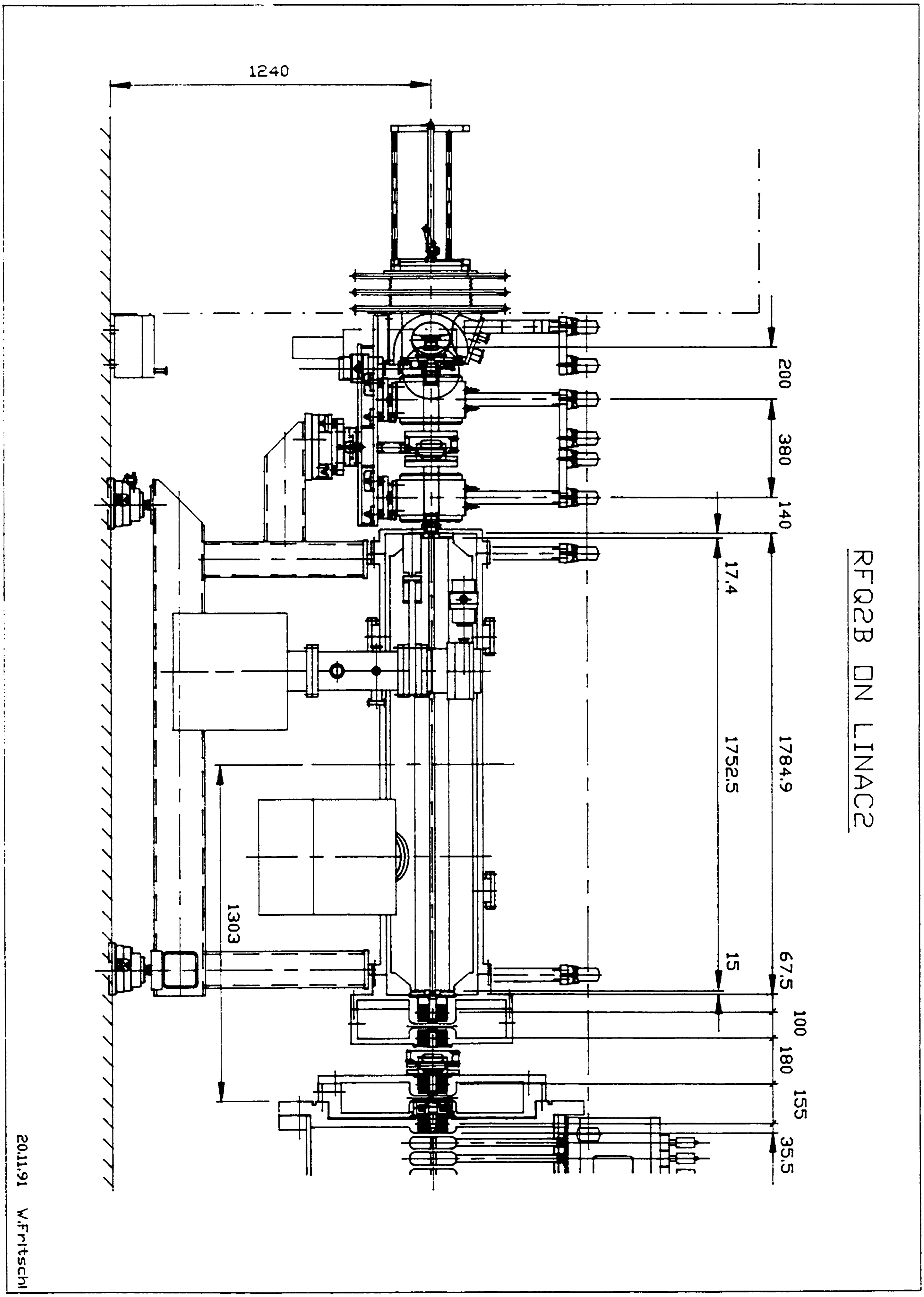
RFQ2 PAST AND FUTURE EXPECTED PERFORMANCES

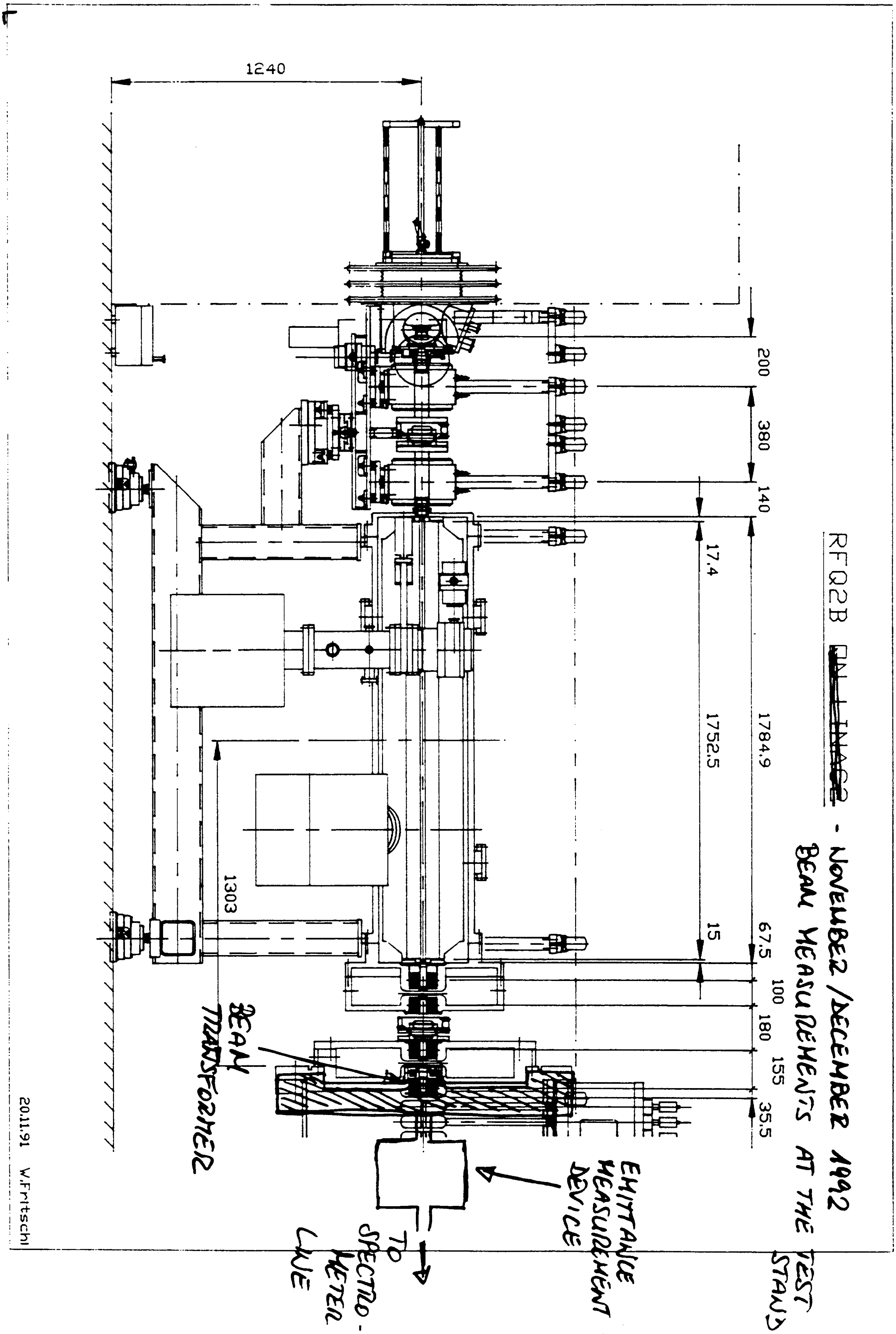
M.Vretenar - PS Performance Day 3.2.1993

The RFQ2B complex, consisting in a duoplasmatron proton source, a 90 kV DC accelerating column, a Low Energy Beam Transport section, a Radio Frequency Quadrupole (RFQ2), and a Medium Energy Beam Transport section, is being installed at the front end of Linac 2, replacing the old 750 kV column and the following transfer line.

This complex, terminated in a measurement line, has been extensively tested in an experimental hall during the months of November and December 1992; the measurements have confirmed a beam current of 200 mA, registered at a position corresponding to the entrance of Linac 2. The measured transverse emittances, about 0.6 π mm mrad (90%, rms, normalized), allow for an efficient matching to the linac acceptance; measures of the energy spread showed that a good longitudinal matching can be achieved by means of the two bunching cavities in the MEBT line. Conditioning of the RFQ up to the high RF voltage required for space charge handling (178 kV peak, corresponding to 2.5 times the Kilpatrick limit) appeared to be a difficult task, but could nevertheless be achieved during the operation at the test stand.

Once installed at Linac 2, the RFQ2B should be able to show again the performances observed at the test stand (no modifications have been made to the hardware, and all the components have been transferred as a whole, without changing the alignment); the emittances are optimized for injection into Linac 2 and cannot be improved (for example, a smaller transverse emittance would lead to space charge problems in the linac), while the overall current, being roughly proportional to the voltage level in the RFQ, will depend from the success of the cavity conditioning; eventually, conditioning to levels higher than the nominal one would improve the RFQ transmission, up to a saturation level, not yet reached during the tests.


RFQ2B ON LINAC2
1240
200
380
140
17.4
1752.5
1784.9
1303
15
67.5
100
180
155
35.5
20.11.91 W.Fritschl



RFQ2B - NOVEMBER/DECEMBER 1992
BEAM MEASUREMENTS AT THE TEST STAND
1240
200
380
140
17.4
1784.9
1752.5
1303
15
67.5
100
180
155
35.5
BEAM TRANSFORMER
EMITTANCE MEASUREMENT DEVICE
TO SPECTROMETER LINE
20.11.91 W.Fritschl

(82)

Q's 215, 205, 153, 8C

B1 & B2 2000, 2500

IM 15 = 194

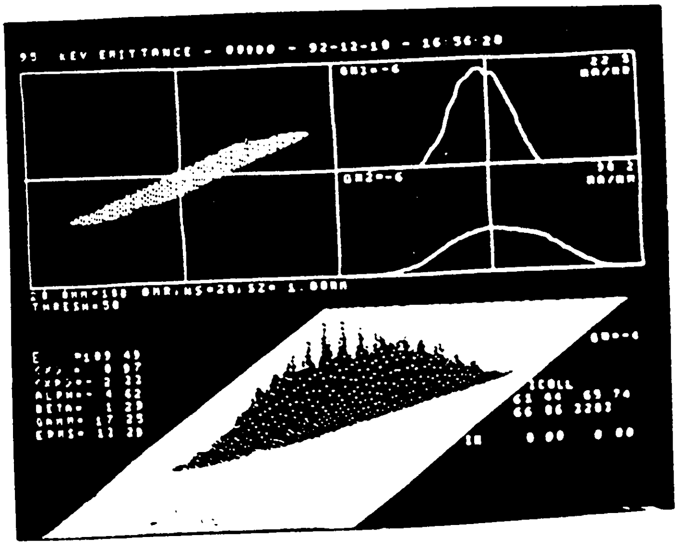
IN 20 = 185

Posn of RFQ 0.7 mm to right (horizontally)

0.0 mm Vertically

RFQ level. 3500

Horz. # 3094

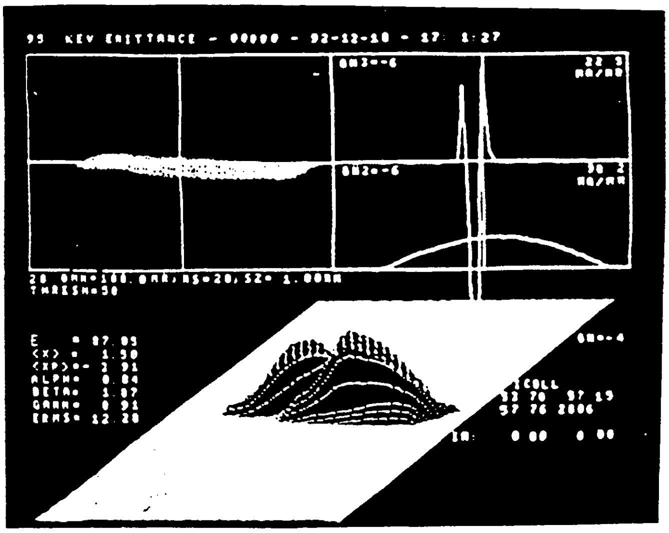


$\langle x \rangle = 0.97$

$\langle x' \rangle = -2.32$

$\alpha_x = -4.62$

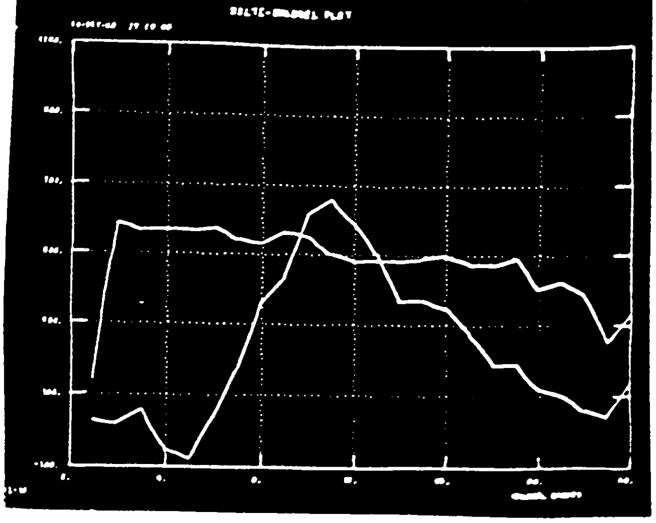
Vert # 3095



$\langle y \rangle = 1.50$

$\langle y' \rangle = -3.91$

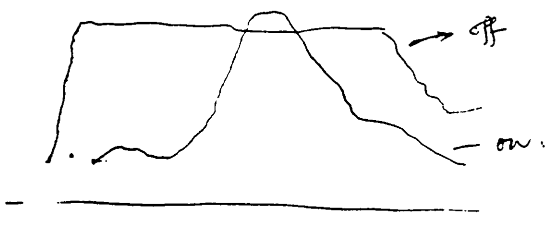
$\alpha_y = 0.84$

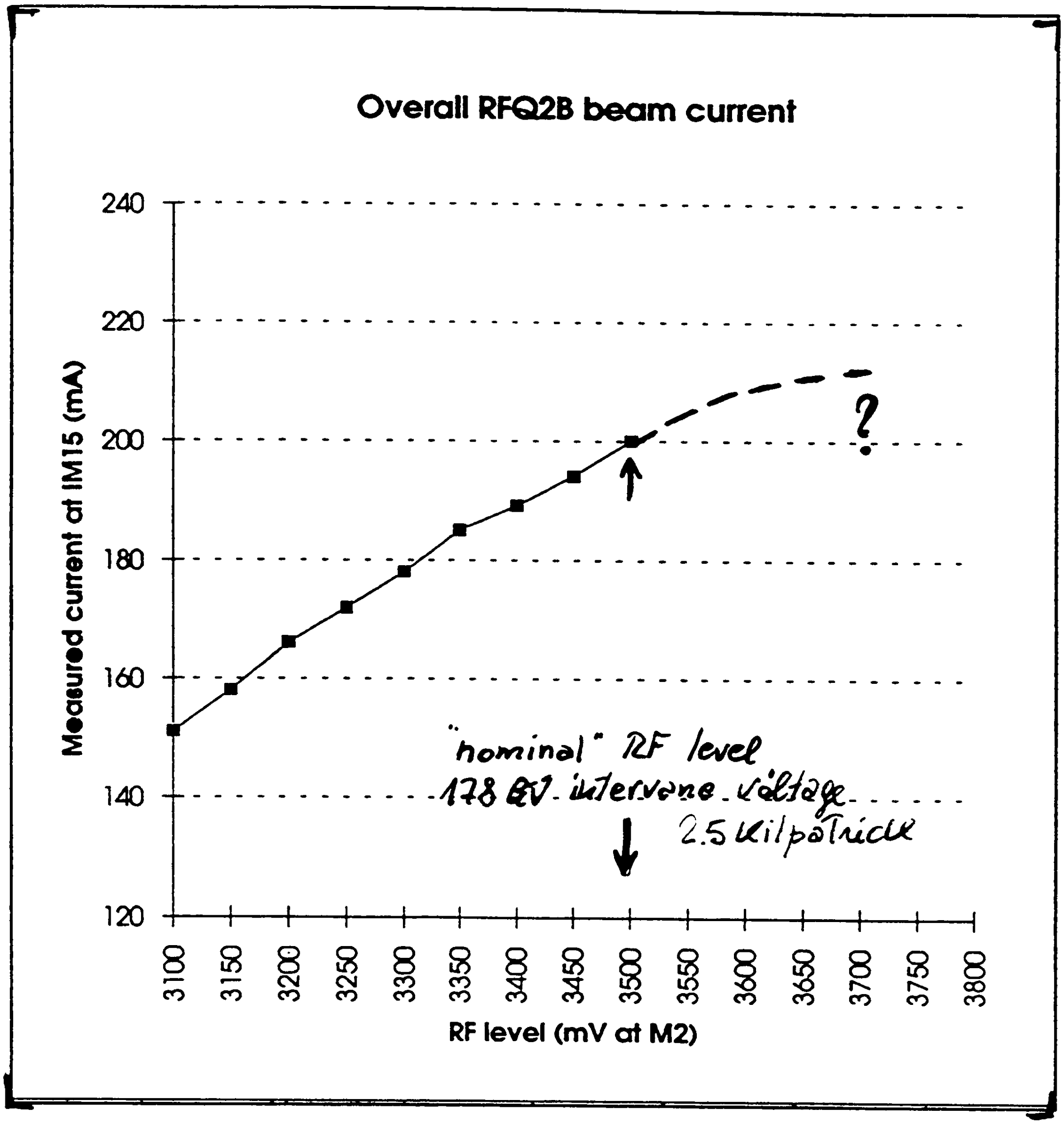


Bunchers off and on

2.66 Kev/mm.

wires are 0.2 mm apart




Overall RFQ2B beam current
Measured current at IM15 (mA)
240
220
200
180
160
140
120
3100
3150
3200
3250
3300
3350
3400
3450
3500
3550
3600
3650
3700
3750
3800
RF level (mV at M2)
?
"nominal" RF level
178 kV intervane voltage
2.5 Kilpatrick

PS PERFORMANCE DAY, ELOISE, 3-Feb-1993

Expected Performance of Linac 2 with RFQ2

D. Warner

SUMMARY of material on Transparancies

The first transparancy lists design features particular to this high current 50 MeV linac with reference to the 1976 conference papers. These features included the synchronous phase law, FOFO system, Input matching in six dimensions, continuity in dynamics, fully stabilised structure, full control of rf up to 150 mA beam current, beam handling and comprehensive beam measurements at 50 MeV, and other advanced ancillary systems such as controls and mechanical engineering, to match. The overall criterion for the dynamics was proper beam containment in the strong space-charge regime.

The performance at start up in 1979 was as expected with very few problems, except perhaps the difficulty of obtaining ideal longitudinal matching for the highest currents, which has had no incidence on the beam energy spread provided for the PSB.
After 13 years of trouble-free operation it is logical to extend the high current capabilities by installing the RFQ2, to meet the immediate LHC requirements.

For operation during 1992 , two distinct beams were successfully provided: I = 140 mA, tp =120 μs and I = 170mA, tp< 40μs. Both beams fulfilled the emittance and energy spread requirements of the PSB and the beam quality "hoped" for the tests in 1993, is a modest extrapolation of the high current case of 1992, to 180 mA.
Recent computations reinforce this hope, as better beam conditions and matching will apply at the linac2 for the improved (and measured) beam quality from the RFQ2.

There are predictable problems with such a major upheaval at the 750 keV level:

RF power limitations-longer term developments required

Input matching in presence of some neutralization

Possible beam misalignments at input

Obtaining correct Linac 2 settings e.g. focusing, RF levels and phases, perhaps drift-tube misalignments- could be longer term programme.

Beam matching at 50 MeV- tank 3 involved in longer term?

D.J.W. / 4 Feb 1993

PS PERFORMANCE DAY, ELOISE, 3-Feb-1993

Expected Performance of Linac 2 with RFQ2

D. Warner

Linac 2 Design Features for High Current Operation: the FIRST Proton Linac Designed for I> 100 mA

References : Proc. LINAC76, Warner and Weiss, pp 245 ; Warner, pp 49.

a) Phase Law , Φ_S = -35° to -25° in Tank 1- giving increased longitudinal acceptance.

b) FODO System with pulsed quadrupole focusing calibrated to gradients>100T/m (input tank 1) and with ample beam apertures throughout , diameters>= 20mm.

c) Input beam matching in six dimensions especially the longitudinal plane (Double Drift Harmonic Buncher).

d) Only slight discontinuities in dynamics (between cavities)- transverse matching across discontinuities.

e) Accelerating field stabilised against local cavity tuning errors and particularly against transient beam loading errors (first ever below 5 Mev).

f) RF System with full cavity phase and field level control corresponding to >150 mA proton beam loading (>2 MW/output amplifier).

g) Beam transport at 50MeV to handle large longitudinal space charge effect on energy spread i.e. three debunchers including one at 405 MHz.

h) Beam Measuring in three phase planes close to linac 2 and at handover point to PSB.

i) User friendly controls system and other ancillary systems (e.g. mechanical engineering) to match.

THE BASIC CRITERION APPLIED WAS THAT THE BEAM MUST BE CONTAINED BY CONTINUOUSLY VARYING FORCES MATCHED TO THE SPACE CHARGE DEFOCUSING FORCES.

PERFORMANCE AT START UP

References; LINAC79 , Boltezar and 8 others, "The New CERN 50 MeV Linac", p66; D.Warner, "Calibration During Installation.......", p304; Other papers on Beam Optics, 750 keV Column Formation, Measuring Lines, RF System, Beam Loading Compensation.

a) Beam performance at 50 MeV as expected as regards

current (>150mA),

transverse emittance (ε^*_{rms}< 1.5 mm mrad in both planes at 125 mA),

beam current stability O.K. and RF pulse stability O.K

exceptionally reliable on start up.

b) Beam performance unexpected as regards

much smaller emittance than expected at 750 keV. Values about twice as great used in design computations (Ref. LINAC76)

hence emittance increase factor much larger than expected in transverse planes but keeping the absolute values of emittance within promised values for PSB.

too small transverse emittance makes it impossible to match beam properly in longitudinal plane (enhanced space-charge defocusing) which leads to large longitudinal emittance increase. **There was enough debunching capability to meet the PSB energy spread requirements (<+- 150keV) so the longitudinal emittance has never been a critical parameter for linac 2 operation.**

TIME PASSES UNTIL THE FIRST PROPOSALS FOR USING EXISTING CERN ACCELERATORS AS LHC INJECTION CHAIN (1988/89?).

IT WAS LOGICAL THAT I SHOULD PREFER AND PROMOTE THE HIGH CURRENT CAPABILITIES, WITH THE PROMISE OF BETTER BEAM CHARACTERISTICS IF THE RFQ2 WAS SUCCESSFUL.

(FOR LHC, AN EXISTING ACCELERATOR WITH IMPROVEMENTS FORESEEABLE MUST BE PREFERRED TO A COMPLETELY DIFFERENT SET-UP USING H^- IONS.)

THE RELEVANCE OF THE LONG PREAMBLE ON LINAC 2 HIGH CURRENT DESIGNED FEATURES IS THAT ALL OF THESE POINTS HAVE TO BE RECONSIDERED IN ORDER TO PROVIDE BEST CONDITIONS FOR LHC.

OPERATIONAL AND HIGH INTENSITY BEAMS IN 1992

Will be treated later in some detail by P. Tetu -brief summary only here:

Operational Beam at Measuring Lines before PSB
I = 140 mA, H ε^*_{rms} = 1.5 mm mrad,V ε^*_{rms} = 1.4 mm mrad , DW/W +- 150 keV.
Pulse Duration <120 µs

High Intensity Beam at Measuring Lines before PSB
I = 170 mA, H ε^*_{rms} = 1.7 mm mrad,V ε^*_{rms} = 1.6 mm mrad , DW/W +- 150 keV.
Pulse Duration <40 µs

(High Intensity Beam at Measuring Lines before PSB-"**Hoped**", for LHC tests in 1993
I = 180 mA, H ε^*_{rms} = 1.7 mm mrad,V ε^*_{rms} = 1.6 mm mrad , DW/W +- 150 keV
Pulse Duration <60 µs.)

PERFORMANCE WITH RFQ2 IS BASED ON MORE THAN HOPE!

A recent multiparticle computation (by Alessandra Lombardi) from source to 50 MeV using PARMILA gives following results:

Starting with I = 225 mA, ε^*_{rms} =0.40 mm mrad from source, results at input to linac tank 1 are I = 207mA and ε^*_{rms} =0.87 and 0.72 mm mrad for H and V planes respectively. The longitudinal emittance, $\varepsilon_{l;rms}$ = 258 deg keV (21degx12.3keV). **All these results are consistent with the measurements on the RFQ2 test stand.**

At 50 MeV, I = 197 mA, ε^*_{rms} =0.95 and 0.94 mm mrad for H and V planes respectively, with $\varepsilon_{l;rms}$ = 502 deg keV (5.8 deg x 87 keV) .

We can be more confident with these results than with 1976 results as :

Input beam based on measurements

Input transverse emittance much larger and leads to easier space charge containment in longitudinal plane.

More uniform filling of longitudinal emittance and two real matching bunchers.

Larger input phase spread chosen (45deg half width, cf 35 deg in1976) eases space charge problem, so reasonable beam containment immediately in tank1.

However we treat these results as corresponding to ideal adjustments of the linac 2 parameters, which have not yet been achieved.

PREDICTABLE PROBLEMS TO OBTAIN DESIRED PERFORMANCE FOR LHC

RF power limitations with present settings of amplifiers- difficulties above 170 mA beam current.
Recall that at 200 mA, acceleration from 0.75 to 50 Mev requires 9.85 MW for the beam and 2.7 MW for the cavity excitation i.e. 12.55MW = 5x2.51 MW.
Suggestion of W. Pirkl: a test stand aiming for amplifier settings giving in longer term 3.5MW/ amplifier.

Beam matching at input : easier in principle than with DDHB, as measured values available-**but does neutralization perturb settings.**

Beam (mis)alignment at input: this is varied by moving the complete RFQ2 assembly and optimising beam quality.
Systematic variations of linac focusing and measurement of 50 MeV beam positions required (as reported in LINAC79, p304).

Linac 2 settings to achieve high current operation: (back to first transparancy), the performance will rely critically on other linac 2 parameter adjustments e.g. focusing, RF levels and phases, and perhaps drift-tube alignment.
Plan is to start RFQ2 injection with previous settings-a complete review of the theoretically ideal adjustments will take somewhat longer.

Matching at 50 MeV-Ideal performance of Linac 2 at 200 mA probably gives problems in following transfer line. Can adjustment using tank 3 also as a matching element, be foreseen?

D.J.W / 3 Feb 1993

PSB High Proton Beam Density for LHC

K.Schindl

The LHC requires a transverse proton beam density (ratio intensity to emittance) more than twice over today's performance of the PSB. For this reason, the PS will be filled with two PSB batches. Even then, the beam requirements of $N=1.8\ 10^{12}$ p/ring in $\varepsilon^*=2.5\ \mu m$ are at the edge of today's performance. Such a dense beam was indeed obtained with the following ingredients:

- Special settings of source and RF of Linac2, yielding I=165 mA at PSB entrance;
- 3-turn betatron stacking (*multiturn injection*);
- enhanced coupling by skew quadrupoles on Qx - Qy = -1 to get a round beam;
- third-order stopband compensation;
- optimisation of working point at 50 MeV (best results with Qx,Qy = 4.28, 5.45);
- bunch flattening with h=10 cavities to reduce space charge.

The resulting space-charge tune spread extends over ~ 0.3 in either direction of the tune diagram. On paper, *single-turn injection* appears better suited to produce a round and bright beam. However, attempts employing this technique did not succeed, for reasons not yet completely understood; elucidating them will certainly be a worthwhile exercise for later studies. The main issues for the *1993 Booster MD programme* for LHC are:

- How to make use of the even brighter beam expected from Linac2 with RFQ2;
- hardware tests and commissioning of the prototype h=1 (h=2) cavities in ring 3.

Both are needed to prepare the end-1993 LHC Injector Beam Test.

KS 2/93

PSB High Proton Beam Density for LHC

Proposed Scheme

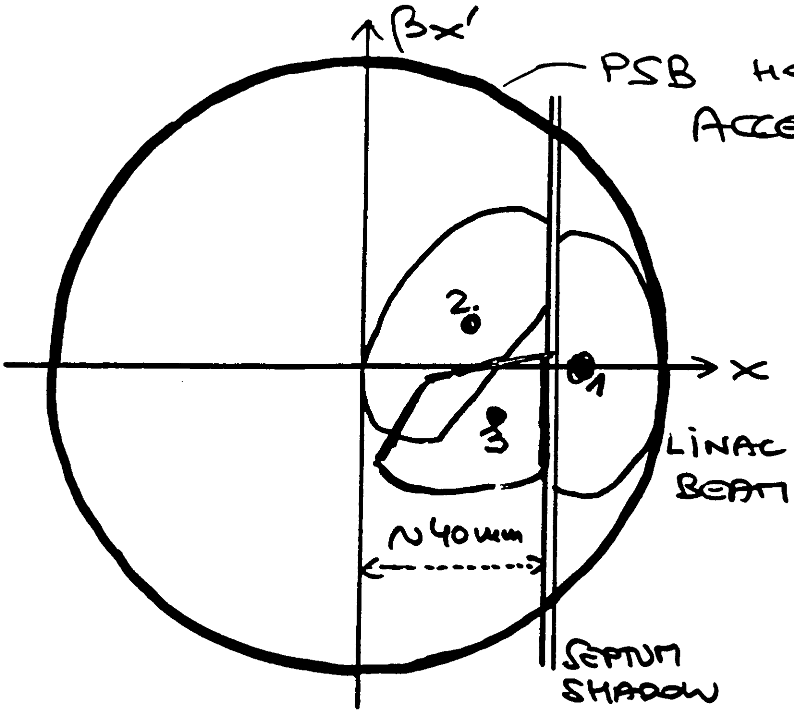
- Double-batch filling to reduce space charge in the PSB (50 MeV)
- Increase of PSB energy to 1.4 GeV to reduce space charge in PS

Requirements on PSB

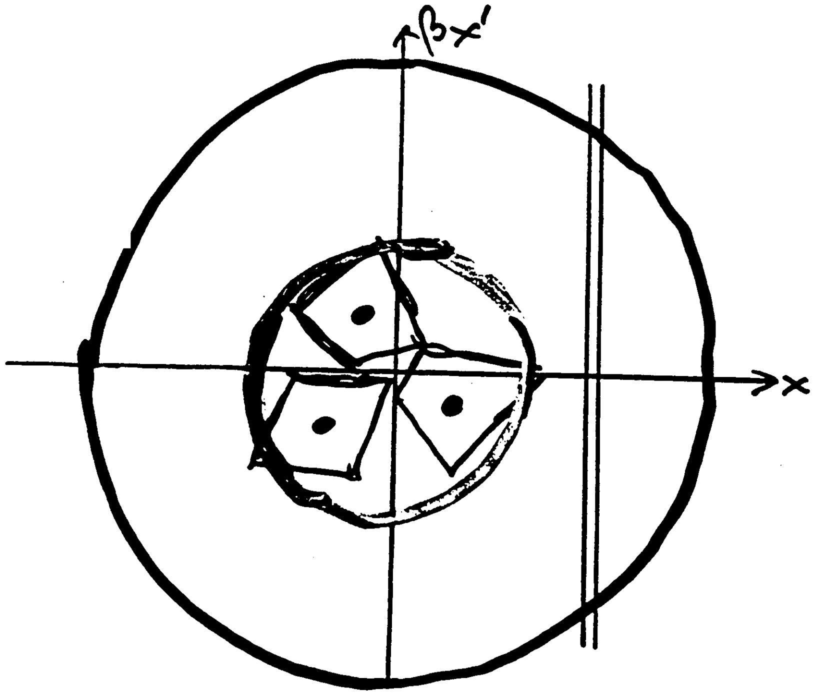
- 1,8 10 ^{12} p/ring *(3.6 10^{12} p/ring single-batch)*
- $\varepsilon^* = 2{,}5\ \mu m$
- $\Delta Q \sim 0.32$ at 50 MeV *($\Delta Q \sim 0.64$ single-batch)*

Injection: Single-turn vs. multi-turn injection

	Single-turn	**Multi-turn (~3)**
Horizontal phase plane	No dilution - matched +	dilution: large ε_x anticipated −
Limited by LINAC2 current?	**Hard** limit: N/ring < 1.04*I[mA]*10^{10} **(requires I > 200 mA)** −	**Soft** limit: N/ring ~ 0.4*turns*I[mA]*10^{10} +
Allows painting to reduce space charge?	yes (but less than H^-) +	to some extent: hor. dilution + enhanced linear coupling ?

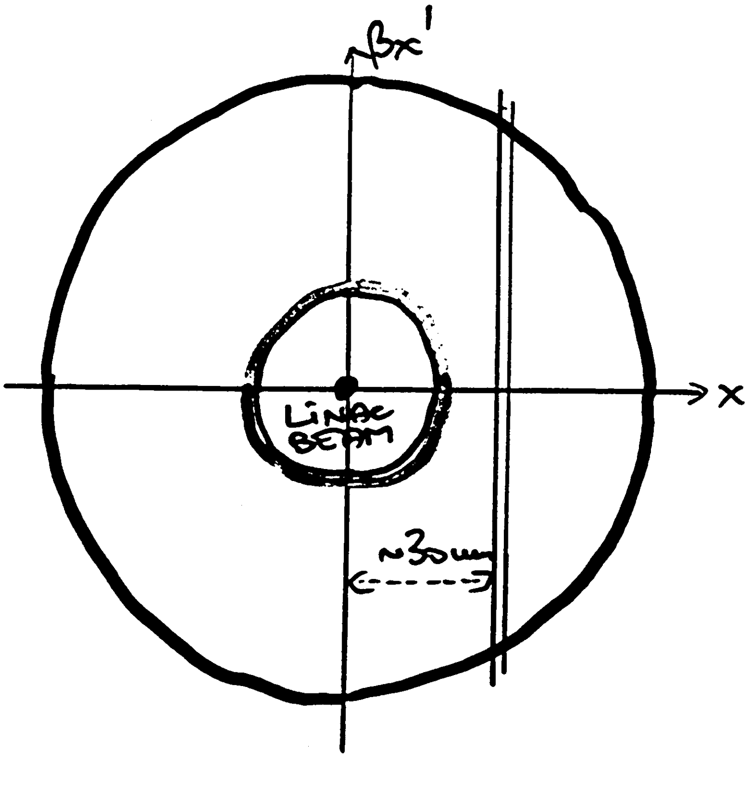


MULTI-TURN:
BEAM CUT REPETITIVELY BY SEPTUM



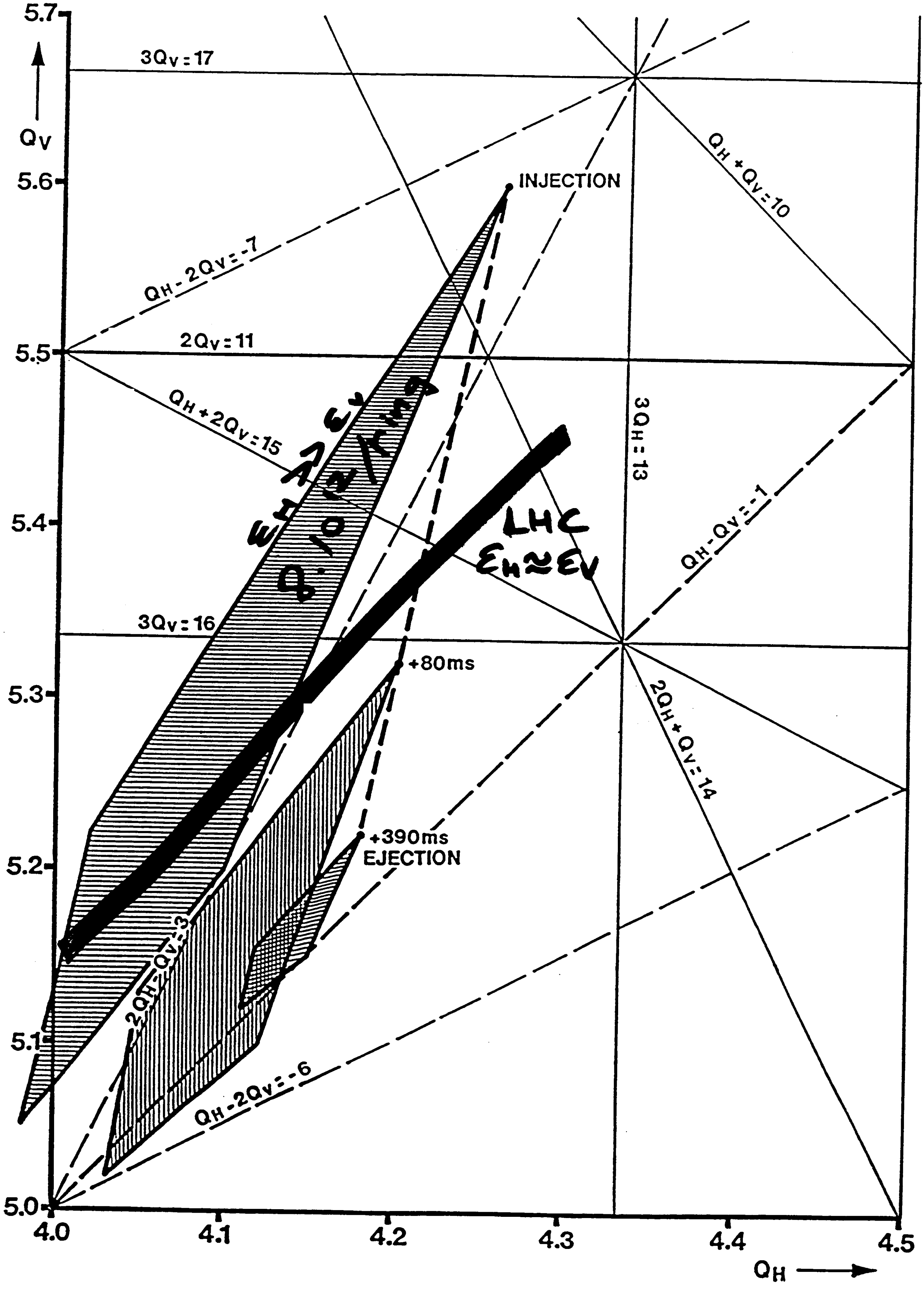
MULTI-TURN:
3 TURNS IN PHASE PLANE AFTER INJECTION

LARGE HORIZ. EMITTANCE



SINGLE-TURN:
BEAM MATCHED

SMALL HORIZ. EMITTANCE



5.7
5.6
5.5
5.4
5.3
5.2
5.1
5.0
Q_V
4.0
4.1
4.2
4.3
4.4
4.5
Q_H
$3Q_V = 17$
$Q_H + Q_V = 10$
INJECTION
$Q_H - 2Q_V = -7$
$2Q_V = 11$
$Q_H + 2Q_V = 15$
$3Q_H = 13$
$\varepsilon_H > \varepsilon_V$
8.10^{12}/ring
LHC
$\varepsilon_H \approx \varepsilon_V$
$Q_H - Q_V = -1$
$3Q_V = 16$
+80ms
$2Q_H + Q_V = 14$
+390ms
EJECTION
$2Q_H - Q_V = 3$
$Q_H - 2Q_V = -6$

KS 2/93

Results obtained

Common parameters:

- Linac current 165 mA @ PSB entry (pulse length ~ 20 μs)
- Stopbands 3 Qy = 16, 2 Qy = 11, Qx + 2Qy =15, 2Qx + Qy = 14 corrected
- Bunch-flattening cavity (h=10) operating
- Emittances measured by BEAMSCOPE

	Single-turn	**Multi-turn**	LHC required
Best Qx, Qy @ 50 MeV	4.29, 5.30	4.27, 5.44	
Linear Coupling *enhanced*	no	yes	
Anticipated N-acc./ring	$1{,}5\ 10^{12}$	?	$1{,}8 \cdot 10^{12}$
ε^*	1.5 μm	>> 2.5 μm	2.5μm
Obtained: N-acc./ring	$1{,}35\ 10^{12}$	**$1{,}9\ 10^{12}$**	
ε^* $((\varepsilon_x^* + \varepsilon_y^*)/2)$	2.75 μm	**2.5 μm (almost round)**	

Studies (on LHC proton beam) in 1993, PSB PRIOR.

- Multi-turn injection with brighter(?) Linac beams HIGH
- Commissioning of prototype h=1 (+ h=2) cavities HIGH
- Acceleration of dense beam with prototype h=1 (+ h=2) cavities and shaping of the cycle HIGH
- Try other rings MEDIUM
- *If time left:* Elucidate unresolved phenomena in single-turn injection LOW

$I_{LINAC} = 165\,mA$

```
BEAMSCOPE EMITTANCES 16/ 7/1991      22:48
D 5000              USER ME1    PLS LINE  39
RING P/P HOR. EMITTANCE  VERT. EMITTANCE
     E10 PHYSICAL(NORM)  PHYSICAL (NORM)
```

$\varepsilon_H \quad (\varepsilon_H^*) \qquad \varepsilon_V \quad (\varepsilon_V^*)$ @ 95 %

```
  3  131     7.3 ( 13.3)       10.9 ( 19.7)
```

SINGLE-TURN INJECTION

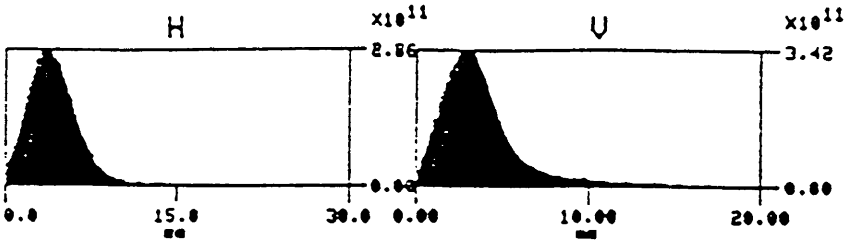
$1{,}3 \cdot 10^{12}\,p$

$Q_{H_0} = 4.29$

$Q_{V_0} = 5.30$

h=10 CAVITIES ON

AMPLITUDE PROFILES



$\varepsilon^*(95\%) \approx 5 \ldots 6 * \varepsilon^*(r.m.s.)$

```
BEAMSCOPE EMITTANCES 17/ 7/1991       0: 3
D 5000              USER ME2    PLS LINE  40
RING P/P HOR. EMITTANCE  VERT. EMITTANCE
     E10 PHYSICAL(NORM)  PHYSICAL (NORM)


  3  180     7.8 ( 14.1)        5.6 ( 10.1)
```

THREE-TURN INJECTION

$1{,}8 \cdot 10^{12}\,p$

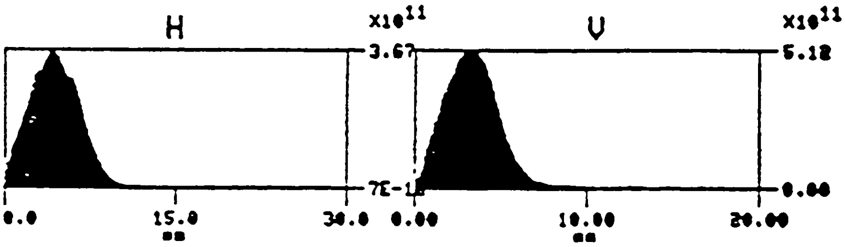
$Q_{H_0} = 4.28$

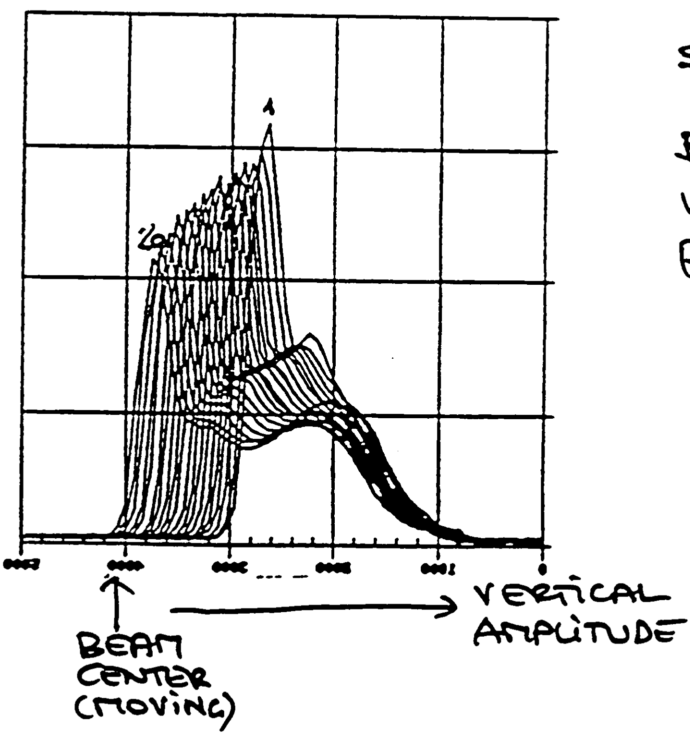
$Q_{V_0} = 5.44$

h=10 CAVITIES ON

LINEAR COUPLING ENHANCED

AMPLITUDE PROFILES

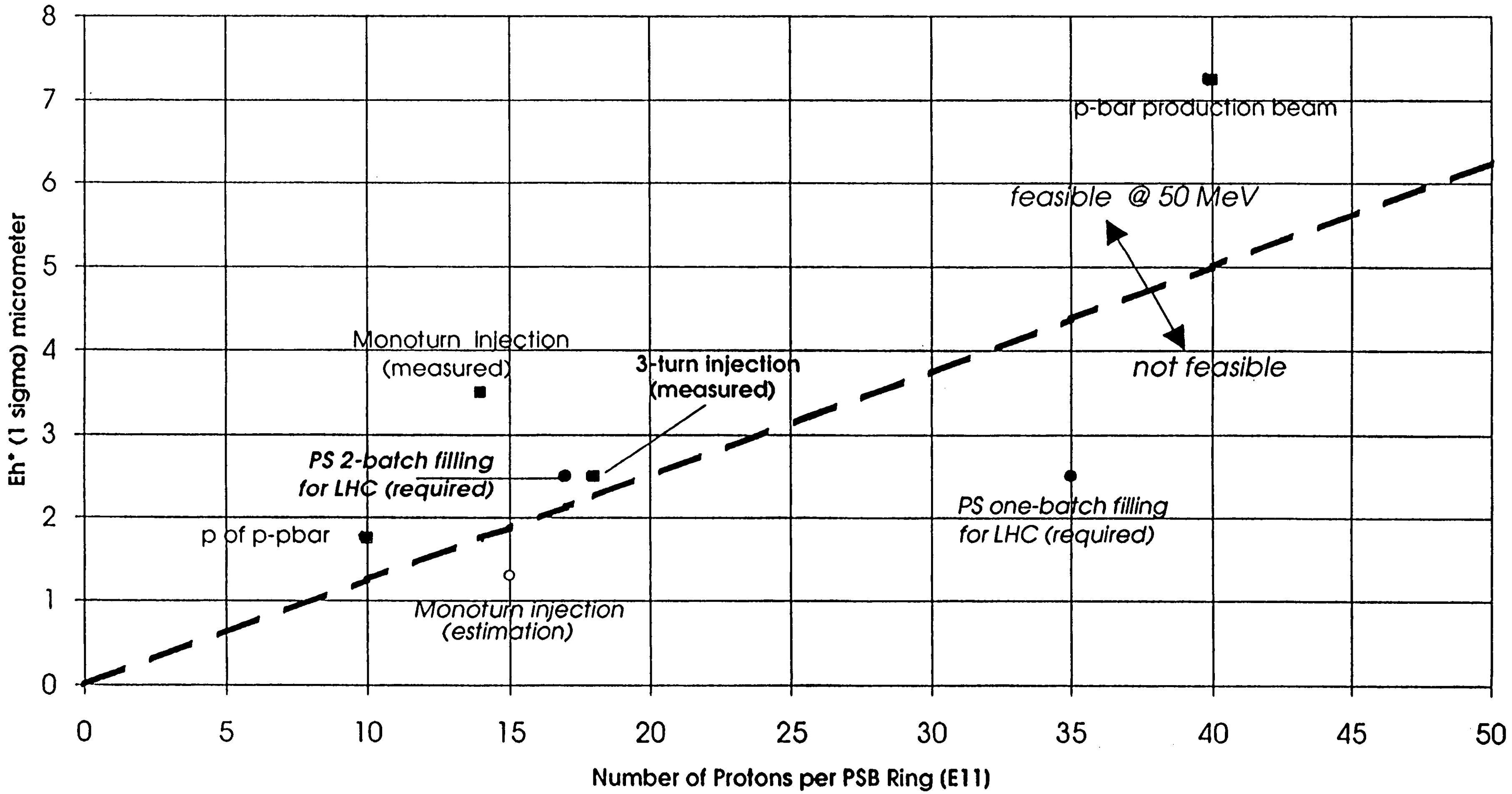




SINGLE-TURN:

BUILD-UP OF VERTICAL DOUBLE-HUMP RIGHT FROM INJECTION

Fig.2: Normalised Horizontal r.m.s. Emittance in PSB vs. Number of protons per Ring



PPday93/RC

PS for LHC
Emittance conservation at injection energy

R. Cappi (speaker)

Abstract

Transverse emittance conservation is a major concern in the LHC injector chain composed by LINAC, PSBooster, PS and SPS.

Emittance blow up budget is very tight everywhere (in the PS for example it is only 20%) moreover the beam will be exceptionally dense (a factor 3 more than the present ones).

It is foreseen to inject into thePS, 2 PSB batches , spaced by 1.2 s . During this time the beam (1st batch) will circulate at injection energy under strong space charge regime. Applying standard formulae (Laslett) one can calculate the incoherent tune shift $\Delta Q_{i,x,y}$, i.e. the tune depression suffered by the particle in the center of the bunch, as ~ - 0.45 , a rather large value indeed.

What will be the corresponding emittance blow up in such conditions?

Unfortunately present tracking programs are too slow to track the beam for such a long time.

At beginning of '92 it was then decided ,at the PS, to organize a machine experiment campaign using special beams simulating the LHC beam space charge conditions to actually measure the emittance blow up.

After having adjusted the LINAC for the highest peak current, the PSB reduced the multiturn injection to 3 turns to obtain the brightest beam ,which was then accelerated into the PS and kept at constant energy (T=1GeV) for ~1.5 s .

By varying the RF voltage it was possible to change the peak bunch current and consequently $\Delta Q_{i,x,y}$ in a range from -0.2 to ~ -0.4.

The emittance measurements were performed with wire scanners and scrapers.

This presentation relates the results of these experiments.

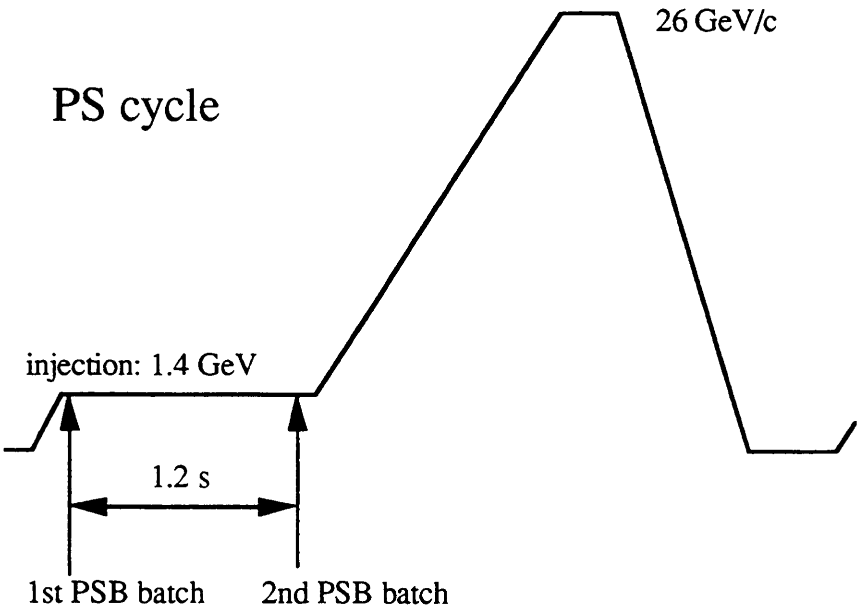
PS for LHC
Emittance conservation at injection energy

LINAC	**PSB**	**PS**
H.Charmot	G.Cyvogt	R.Cappi (*speaker*)
Ch.Hill	K.Schindl	M.Martini
F.Nitsch	H.Schonauer	J.P.Riunaud
	E.Wildner	C.Saulnier

PS for LHC :

1.5 10^{13} ppp ; $\varepsilon^*_x \approx \varepsilon^*_y \approx 2.5\ \mu m$; 140 bunches

...a 8 times brighter beam than present...



Why 1.4 GeV instead of today 1 GeV?
What's the problem?

the problem is

Space Charge

$$\Delta Q_{i_{x,y}} \approx - \frac{\hat{I}_b}{(\beta\gamma)^2 \quad \varepsilon^*_{x,y}}$$

inserting LHC num. values at 1 GeV:

$$\Delta Q_{i_y} \approx -0.45$$

Remarks:

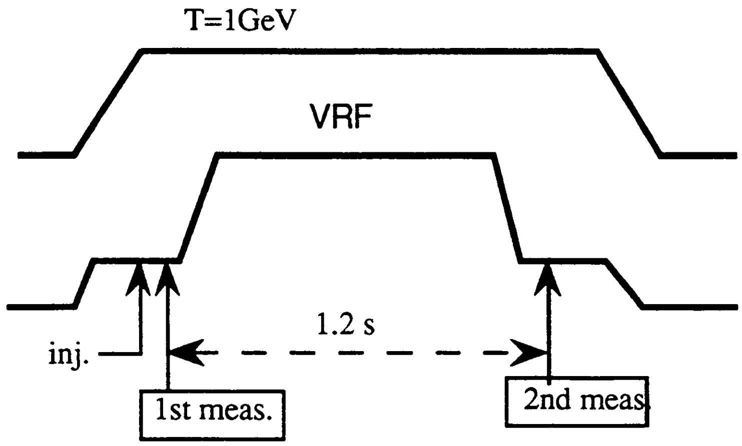
- The LHC beam will stay in these conditions for 1.2 s (now 20 ms)
- In the LHC project the allowed PS $\varepsilon_{x,y}$ budget :

$$\frac{\varepsilon_{\text{after extraction}}}{\varepsilon_{\text{before injection}}} \leq 1.2 \quad !$$

Q : What will be the $\varepsilon_{x,y}$ blow up?

Experiments at 1 Gev to simulate LHC beam conditions

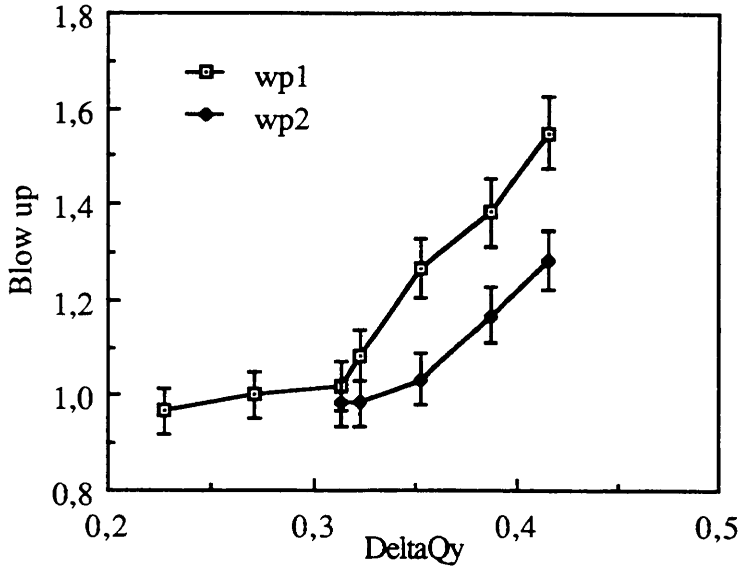
$$\Delta Q_i \propto \hat{I}_b \propto V_{RF}^{1/4}$$



$\hat{I}$

- S.U. LINAC for high density
- Optimise PSB inj.
- " PSB acceleration
- " PS injection
- " transv. feedback
- " work. point
- measure w. flying wire
- " " scrapers
- " bunch shape
- etc. etc.

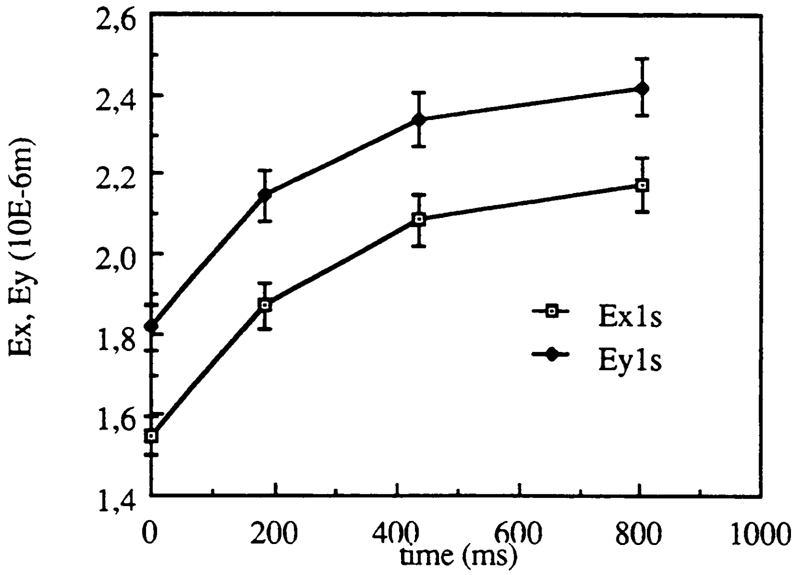
RESULTS



wp1 : 6.22, 6.22

wp2 : " , 6.28

$$\text{Blow up} = \frac{\langle \varepsilon_f \rangle}{\langle \varepsilon_i \rangle} \quad \text{where } \langle \varepsilon \rangle = \frac{\varepsilon_x + \varepsilon_y}{2}$$



Conclusions

♠ Now we know much better where we are

♦ We have to reduce $\Delta Q \mapsto 0.3$

♣ How : 1) reduce $\hat{I}_b$ (flat-topped bunches, see S.H.)
2) increase $(\beta\gamma)^2$ i.e. $T \mapsto 1.4$ GeV

♥ A more complete simulation will be obtained at the end of '93 with the "LHC test"

Other sources of ε blow up:

- PSB-PS matching
- Injection errors
- Transv. instabilities
- Transition crossing
- 26 GeV/c deb.-rebunching
- PS-SPS matching, etc.

...all under study...

Flat-topped Bunches

S. Hancock

3 February 1993

Abstract

Flat-topped bunches have been reproducibly generated in the PS by combining the effect of a phase modulation of the RF with some voltage at a VHF frequency which is slightly offset from a harmonic of the beam revolution frequency. The method affords a reduction of space charge induced tune shift which may be of interest in the LHC era when double batch injection from the Booster will see bunches "lingering" at low energy in the PS.

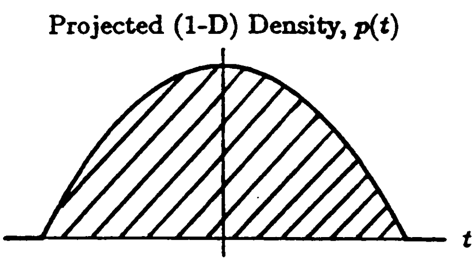
MOTIVATION

$$\text{(Laslett) Tune shift, } \Delta Q \propto -\frac{1}{B_f}$$

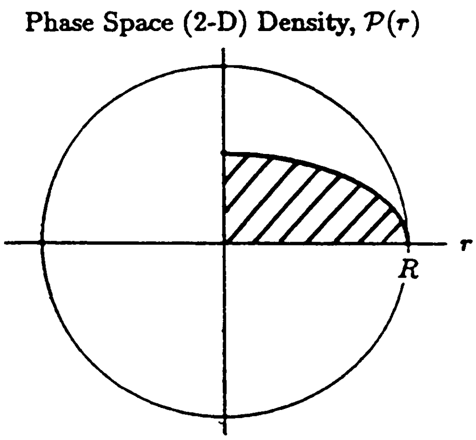
$$\text{Bunching factor, } B_f = \frac{\text{DC beam current}}{\text{Peak beam current}}$$

Can increase B_f

- by employing second-harmonic cavities to modify the bucket, but this
  - "wastes" RF voltage
  - introduces phasing complications
- by modifying the distribution of particles in phase space.



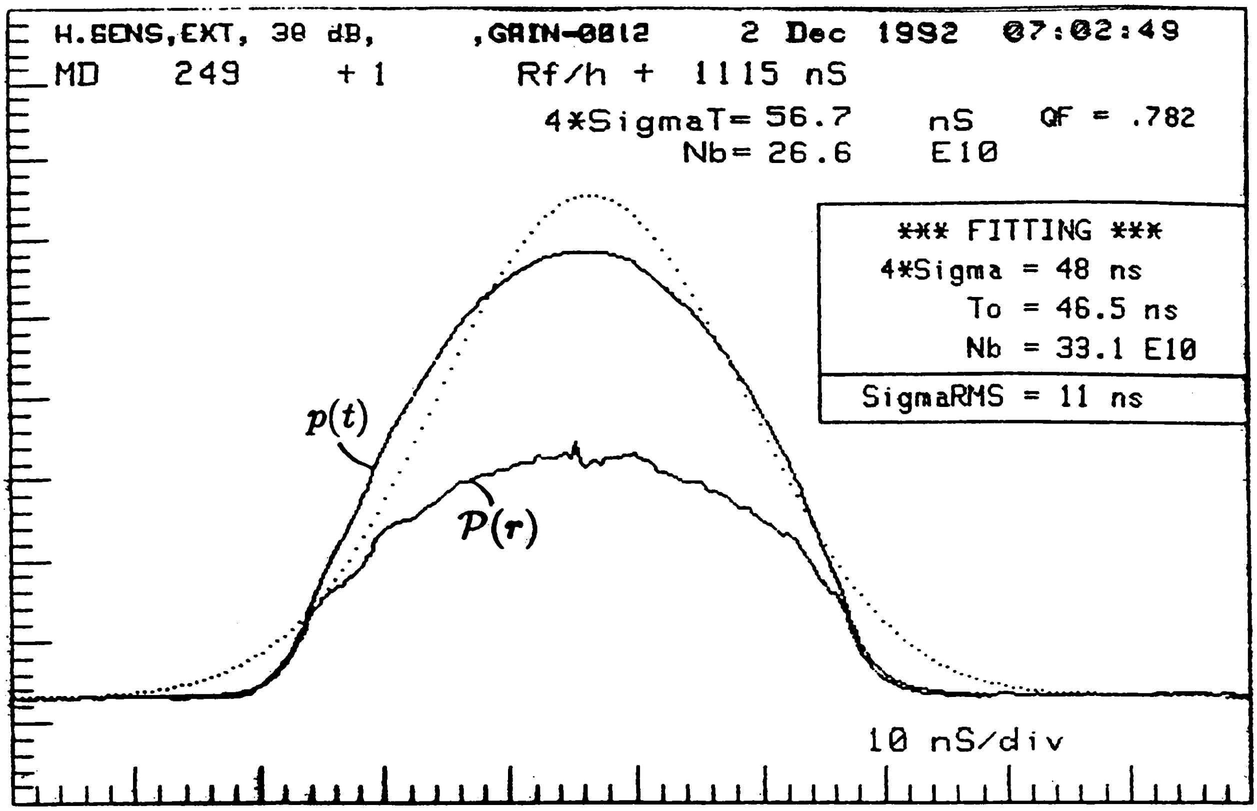
$p(t)$ = Line charge density function

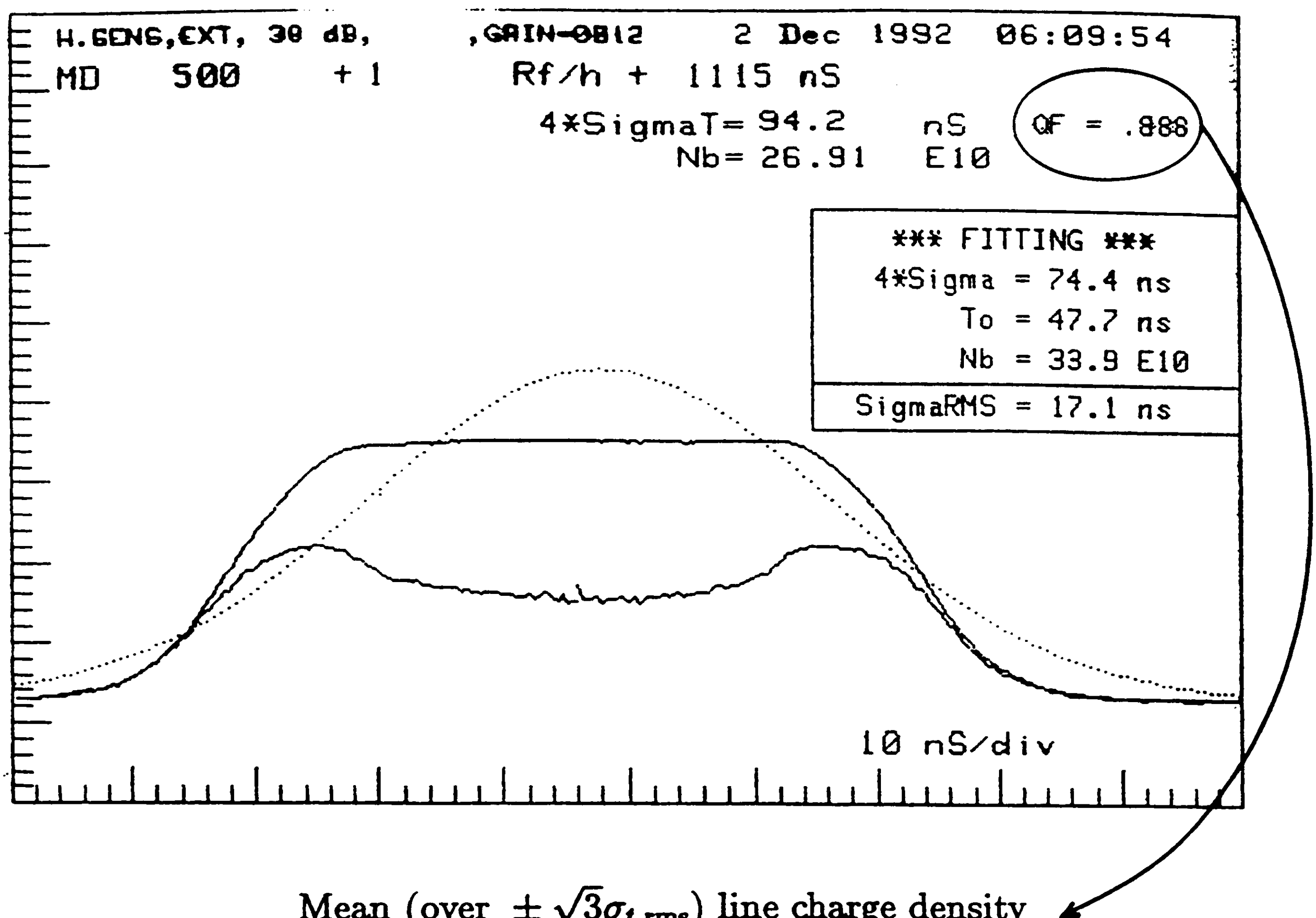


$$\mathcal{P}(r) = -\frac{1}{\pi}\int_r^R \frac{p'(t)}{\sqrt{t^2 - r^2}}\mathrm{d}t$$

[Krempl, MPS/Int. BR/74-1]

$$p(t) = \text{Rectangular} \Rightarrow \mathcal{P}(r) \propto \frac{1}{\sqrt{R^2 - r^2}} \quad \text{i.e., a "hollow bunch".}$$

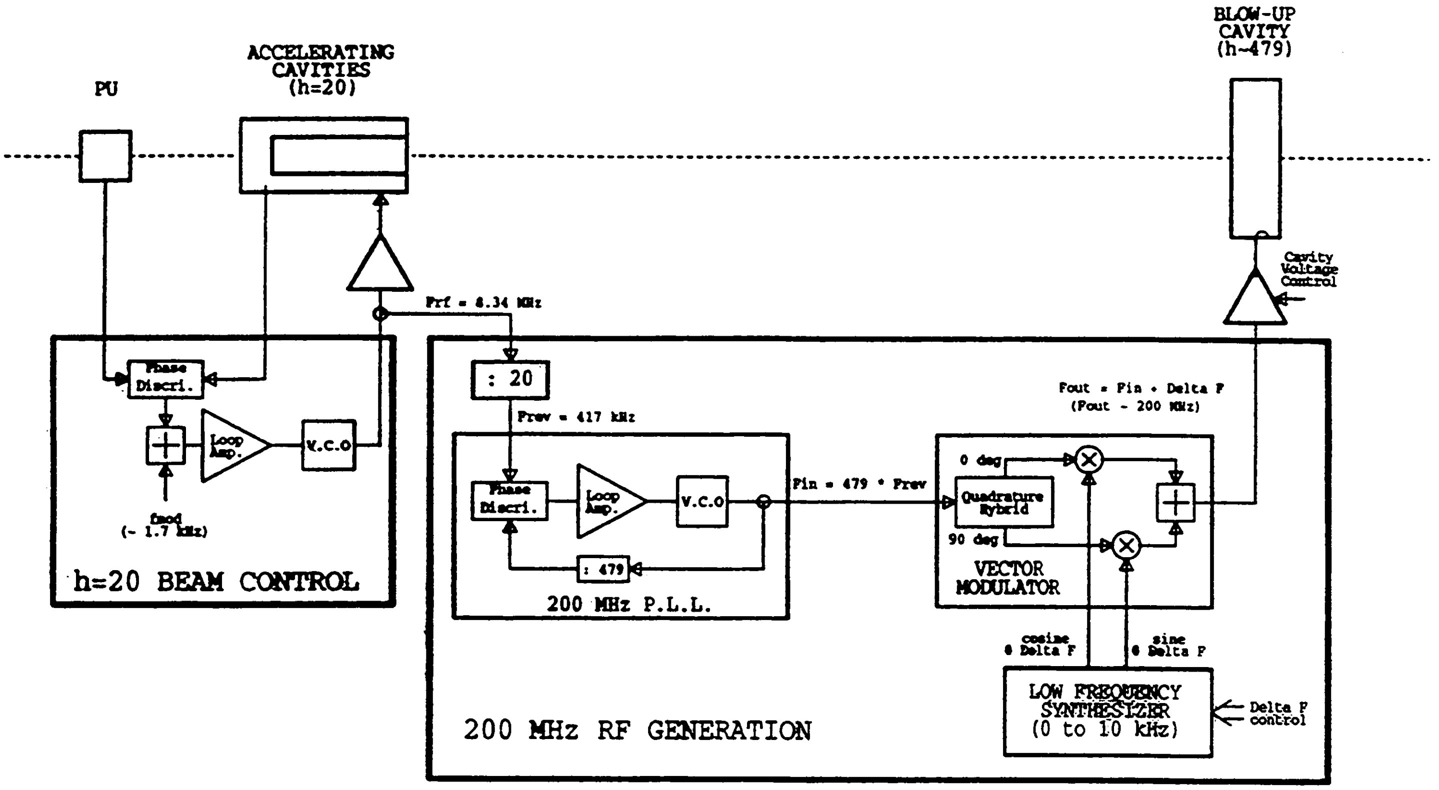


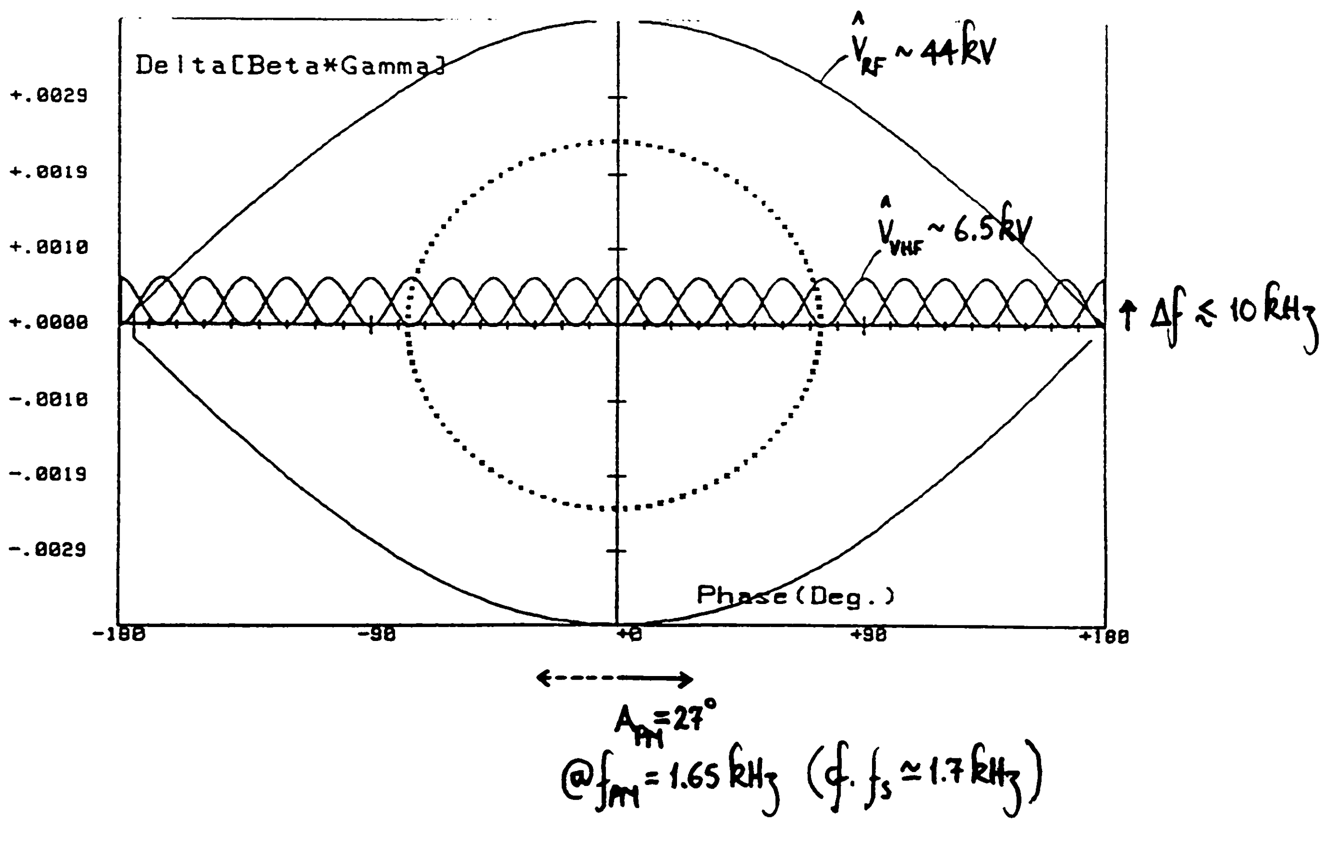


$$Q_f = \frac{\text{Mean (over } \pm\sqrt{3}\sigma_{t,\text{rms}}\text{) line charge density}}{\text{Peak line charge density}}$$

$$p(t) = \text{Rectangular} \;\Rightarrow\; Q_f = 100\%$$
$$p(t) = \text{Parabolic} \;\Rightarrow\; Q_f = 80\%$$
$$p(t) = \text{Gaussian} \;\Rightarrow\; Q_f = 66\%$$

METHOD


PU
ACCELERATING CAVITIES (h=20)
BLOW-UP CAVITY (h~479)
Cavity Voltage Control
Prf = 8.34 MHz
: 20
Prev = 417 kHz
Phase Discri.
Loop Amp.
V.C.O
fmod (~ 1.7 kHz)
h=20 BEAM CONTROL
Fin = 479 * Prev
: 479
200 MHz P.L.L.
Fout = Fin + Delta F
(Fout ~ 200 MHz)
0 deg
Quadrature Hybrid
90 deg
VECTOR MODULATOR
cosine Delta F
sine Delta F
LOW FREQUENCY SYNTHESIZER (0 to 10 kHz)
Delta F control
200 MHz RF GENERATION


Delta[Beta*Gamma]
+.0029
+.0019
+.0010
+.0000
-.0010
-.0019
-.0029
Phase (Deg.)
-180
-90
+0
+90
+180
$\hat{V}_{RF} \sim 44$ kV
$\hat{V}_{VHF} \sim 6.5$ kV
$\uparrow \Delta f \lesssim 10$ kHz
$A_{PM} = 27°$
@$f_{PM} = 1.65$ kHz (cf. $f_s \simeq 1.7$ kHz)

MD OBJECTIVES

Demonstrate that flat-topped bunches may be formed

- reproducibly
- at high intensity
- in well-filled buckets

and that these bunches

- yield a beneficial reduction in space charge induced tune shift
- are stable ~~under closed-loop~~ conditions.

$V_{RF} \rightarrow 4V_{RF}$ for 800 ms

	Q_f [%]	$\mathcal{E}$[1] before [π.mm.mrad]	$\mathcal{E}$ after [π.mm.mrad]	$\Delta\mathcal{E}/\mathcal{E}$
Quasi-parabolic	75	7.83	10.0	1.28
Flat-topped	86	7.79	9.14	1.17

[1] $\mathcal{E} = \frac{1}{2}(\mathcal{E}_h + \mathcal{E}_v)$ $[Q_h = Q_v = 6.22]$.

$$B_f \text{ increase} \sim 1.3 \Rightarrow \frac{\Delta(\beta\gamma^2)}{\beta\gamma^2} \sim 0.3$$

$$\Rightarrow \frac{\Delta T}{T} \sim 0.3\gamma\left[(\gamma+1)^{-1} + 2(\gamma-1)\right]^{-1}$$

$$\Rightarrow \Delta T \sim 0.25 \text{ GeV at } T = 1 \text{ GeV}$$

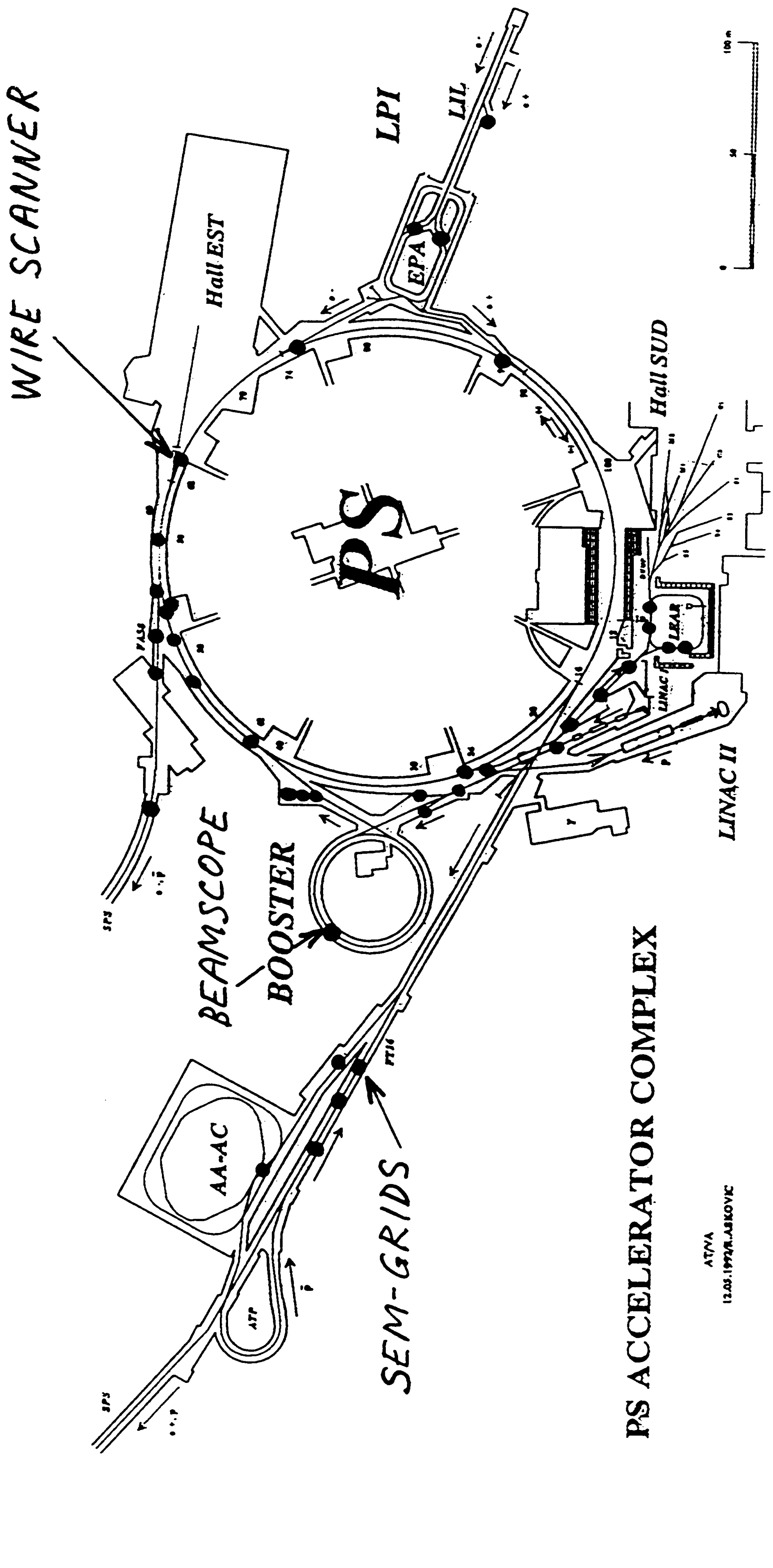
3 February 1993

PSB/PS/TT2 EMITTANCE MEASUREMENT COMPARISON

M. Martini

Abstract

BEAMSCOPE, fast wire scanners and SEM-grids are the three devices routinely used in the PS complex to measure transverse beam dimensions or emittances. BEAMSCOPE measures betatron amplitude distributions while wire scanners and SEM-grids measure projected distribution of a beam. Their main characteristics and principle of measurement are briefly described, and some of the recent improvements are shown. Emittances measurements of proton beams for SPS (fixed target experiments) with these devices have been extensively performed in the PS booster and PS, and in the TT2 transfer line between PS and SPS. The results are reported for comparisons.



PS ACCELERATOR COMPLEX

PSB BEAMSCOPE

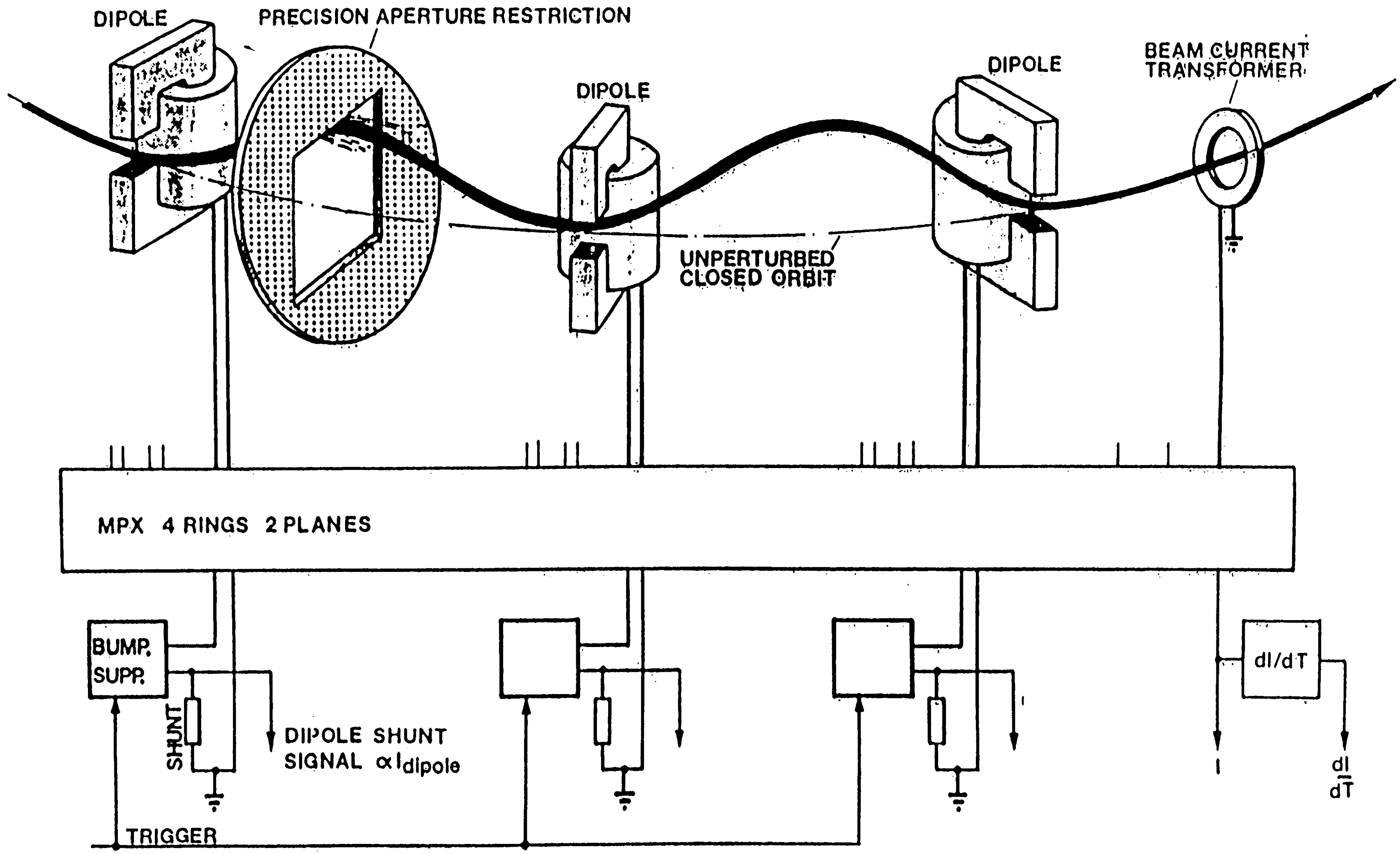
(BEam AMplitude Scraping by Closed Orbit PErturbation)

Overview

- Purpose: measurement of beam betatron amplitude distribution and emittance in a ring.
- Particles: hadrons.
- Energy range: 50 MeV to 1 GeV.
- Intensities: 10^8 to $2\ 10^{13}$ (destructive measurement).
- Principle:
  - a local closed-orbit bump deflects the circulating beam into a fixed scraper where it is gradually lost.
  - The beam current and the bump amplitude at the scraper are recorded (vs time), yielding the beam radius (95% of the beam). Derivative of the beam current signal gives the betatron amplitude distribution.
  - Emittance (95%) is evaluated from lattice parameters computed prior to each measurement. The horizontal emittance measurement is spoilt by the reaction of beam control system.
  - Emittance (95%) is transformed numerically to emittance (2σ) of the projected density.

Existing device (PS booster)

- 4 beam transformers and 24 dipoles (3 per plane and per ring) multiplexed to 3 bumper supplies.
- 5 measurements channels (3 for the bumps, 2 for the beam current and its derivative).
- Controls resident in a dedicated NORD-100 computer.
- 16 cycles are required to measure both horizontal and vertical beam emittances in the 4 rings.

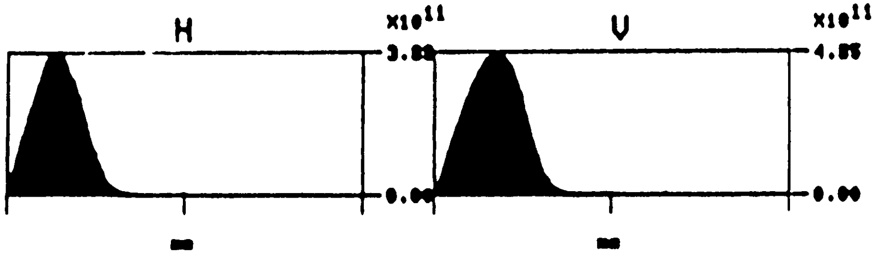


"Artist's view" of Beamscope measurement system.

```
BEAMSCOPE EMITTANCES 29/ 6/1992    16:50  PROJECTION EMITTANCES (2 sigma)
USER  37 (MD )                    D 5000  H:  Ivanov Fit, V: Abel Transf.
RING P/P HOR. EMITTANCE  VERT. EMITTANCE  HOR. EMITTANCE  VERT. EMITTANCE
     E10 PHYSICAL(NORM)  PHYSICAL (NORM)  PHYSICAL(NORM)  PHYSICAL (NORM)

 3  184    8.0 ( 14.4)      5.4 (  9.8)    4.9 (  8.8)      5.4 (  9.7)
```

AMPLITUDE PROFILES



Amplitude profiles of the beam in the PSB,
at 1 GeV, measured by Beamscope

PS FAST WIRE SCANNER

Overview

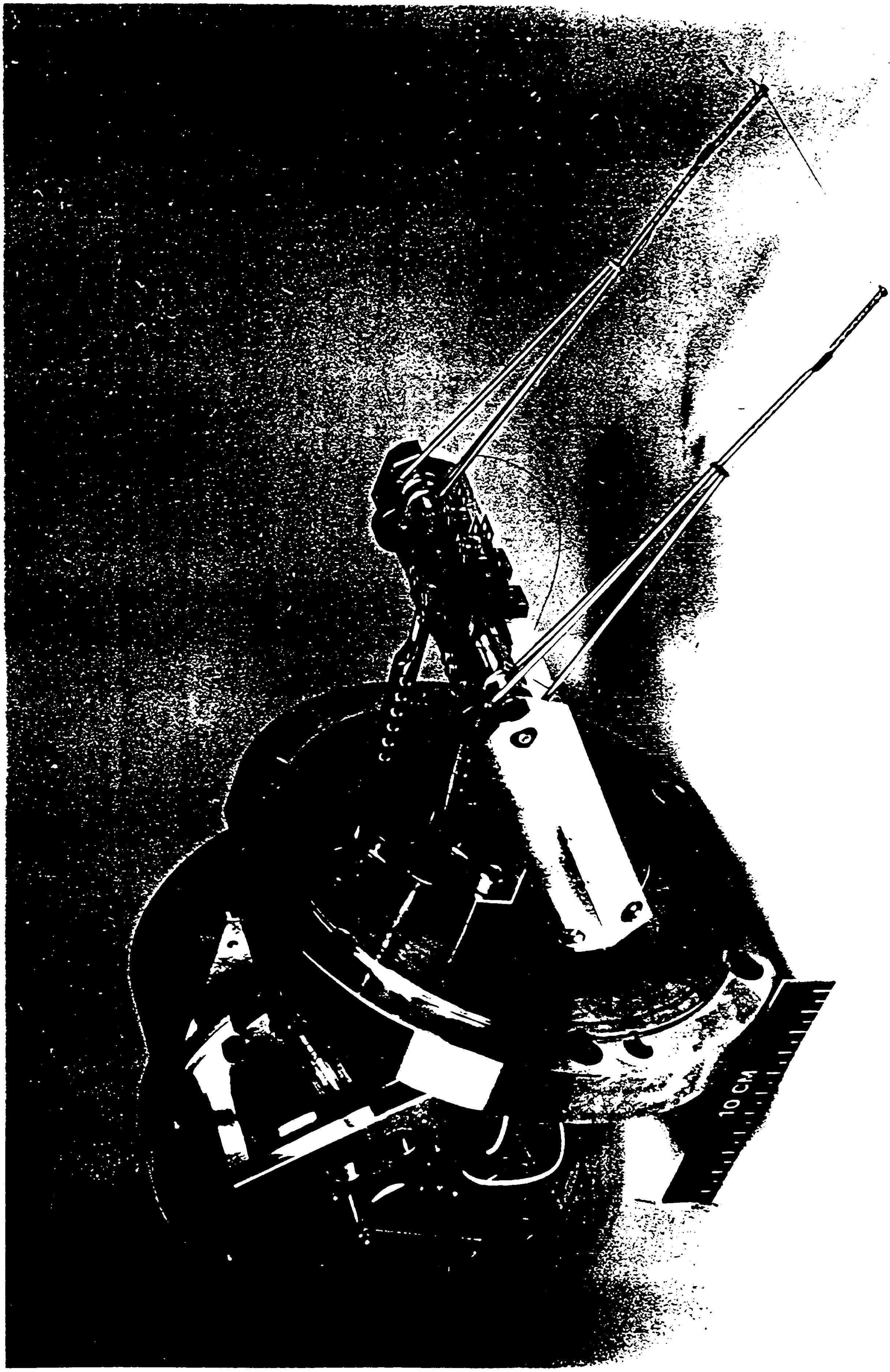
- Purpose: measurement of beam profile (projected density) and emittance in a ring.
- Particles: hadrons and leptons.
- Energy range: > 1 GeV.
- Intensities: 10^9 to 2 10^{13} (non destructive measurement).
- Principle: a wire crosses the beam. Secondary particles induce a signal (vs time) through a scintillator and a photomultiplier, yielding the beam profile. Emittance (2σ) is calculated assuming known lattice parameters.

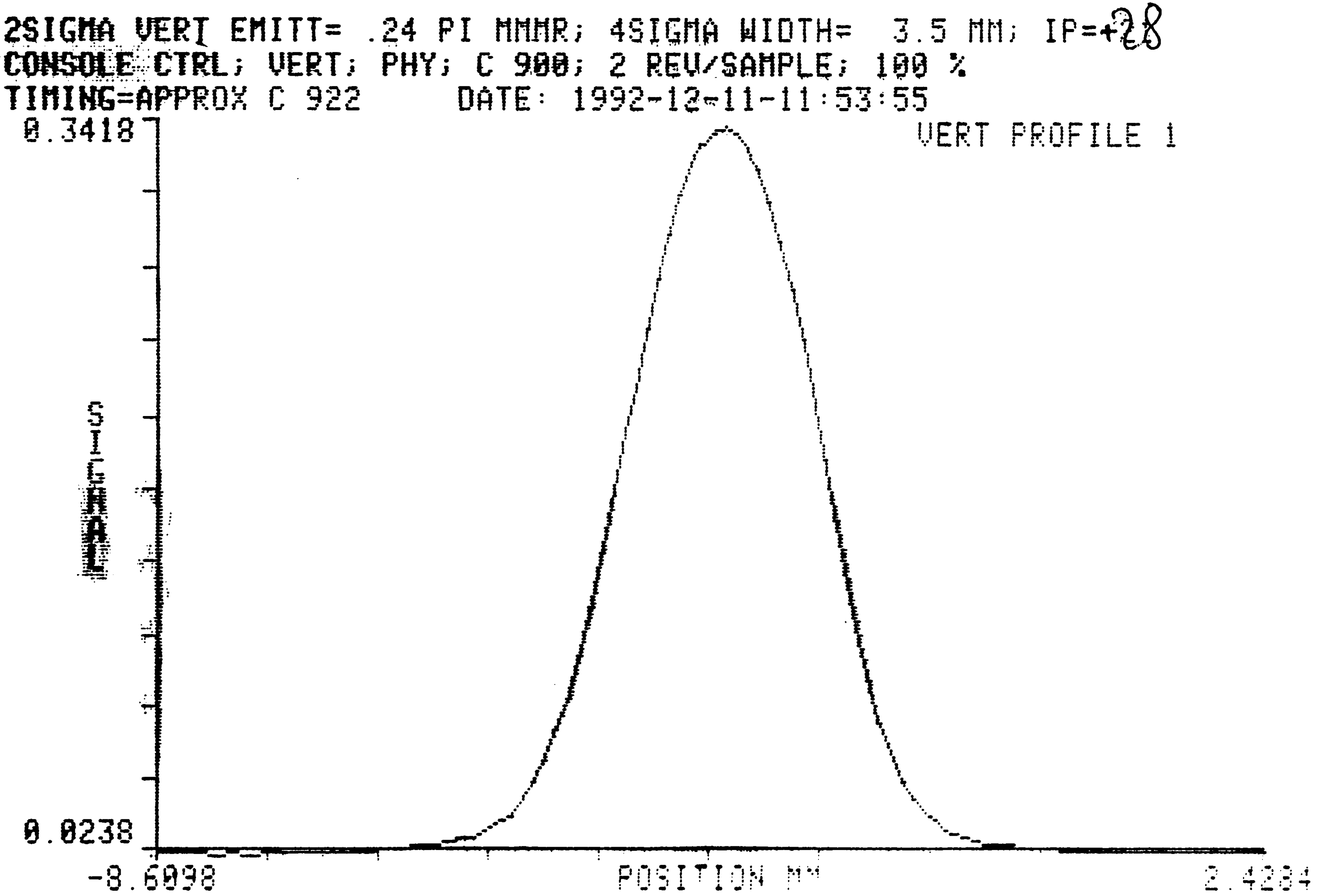
Existing device (PS ring)

- 1 horizontal (SS 54) and 1 vertical (SS 89).
- 50 μm Be wire, velocity: 20 m/s (life time: a few hundreds strokes).
- Controls based on LeCroy computer linked to the consoles.
- 1 measurement per plane and cycle.
- No simultaneous measurements possible in both planes.

New device (1993)

- 1 horizontal (SS 64) and 1 vertical (SS 75).
- 20 twisted 7 μm C wire, velocity: 10 m/s, 15 m/s or 20 m/s (life time: some thousands strokes).
- Better position resolver, more linear and wider dynamical range of photomultipliers.
- Controls based on DSC (VME crate) linked by Ethernet to the application program on workstations.
- 2 measurements possible per plane and cycle.
- Simultaneous measurements possible in both planes.


10 CM


2SIGMA VERT EMITT= .24 PI MMMR; 4SIGMA WIDTH= 3.5 MM; IP=+28
CONSOLE CTRL; VERT; PHY; C 900; 2 REV/SAMPLE; 100 %
TIMING=APPROX C 922 DATE: 1992-12-11-11:53:55
VERT PROFILE 1
0.3418
0.0238
SIGNAL
-8.6098
POSITION MM
2.4284

PS TRANSFER LINE SEM-GRIDS

(Secondary Emission Monitor)

Overview

- Purpose: measurement of beam profile (projected density), emittance and matching in a transfer channel.
- Particles: hadrons and leptons.
- Energy range: > 50 MeV.
- Intensities: 10^7 to 2 10^{13} (non destructive measurement).
- Principle: An array of ribbons or wires is placed in the beam path. The secondary emission current from each ribbon or wire is detected, yielding the beam profile. Emittance (2σ) is calculated from 3 beam profiles acquired at different monitors, assuming known transfer matrix between the monitors.

Existing devices

About 100 monitors installed in the PS complex: Booster, PS , TT70, TT2, AC, LPI, LEAR, Linacs, CLIC. For example:

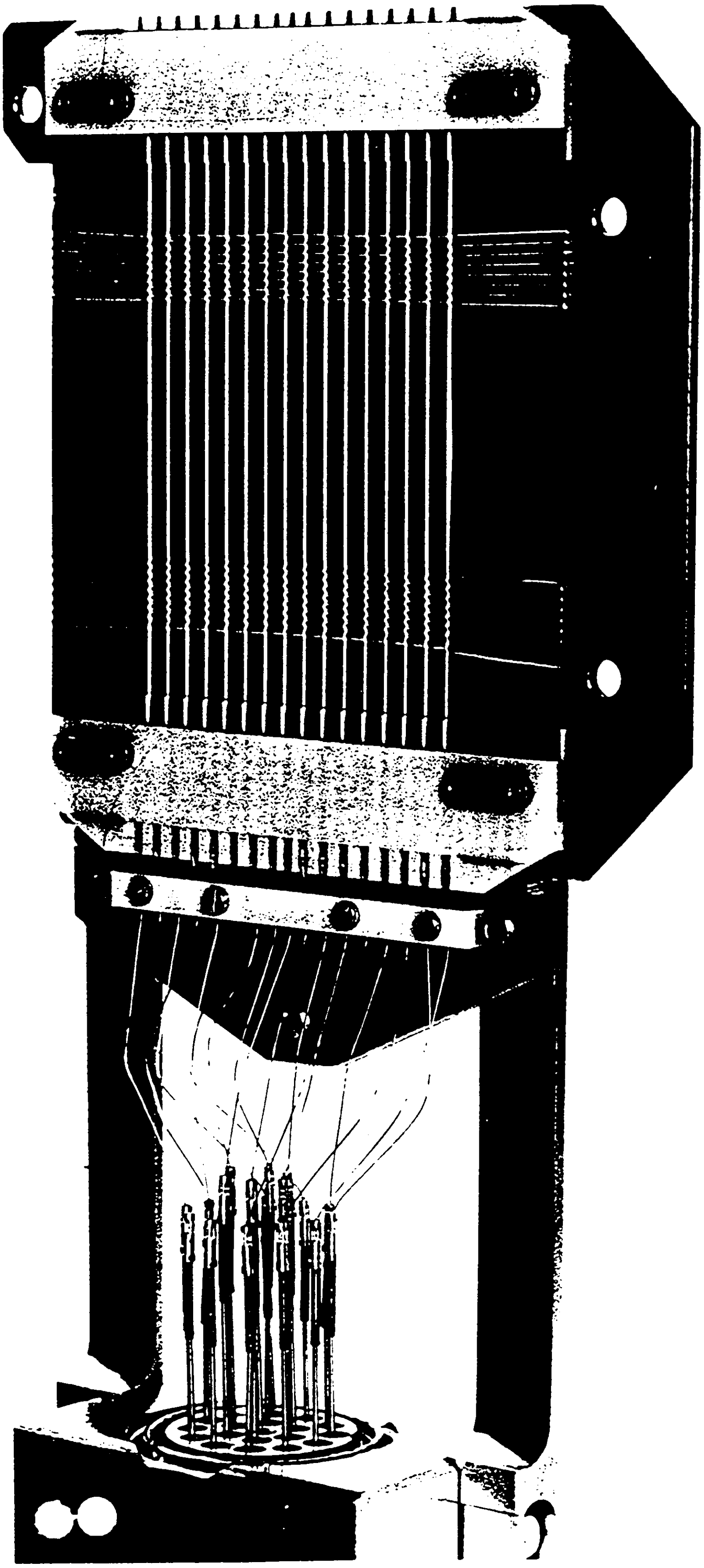
TT2 transfer Line

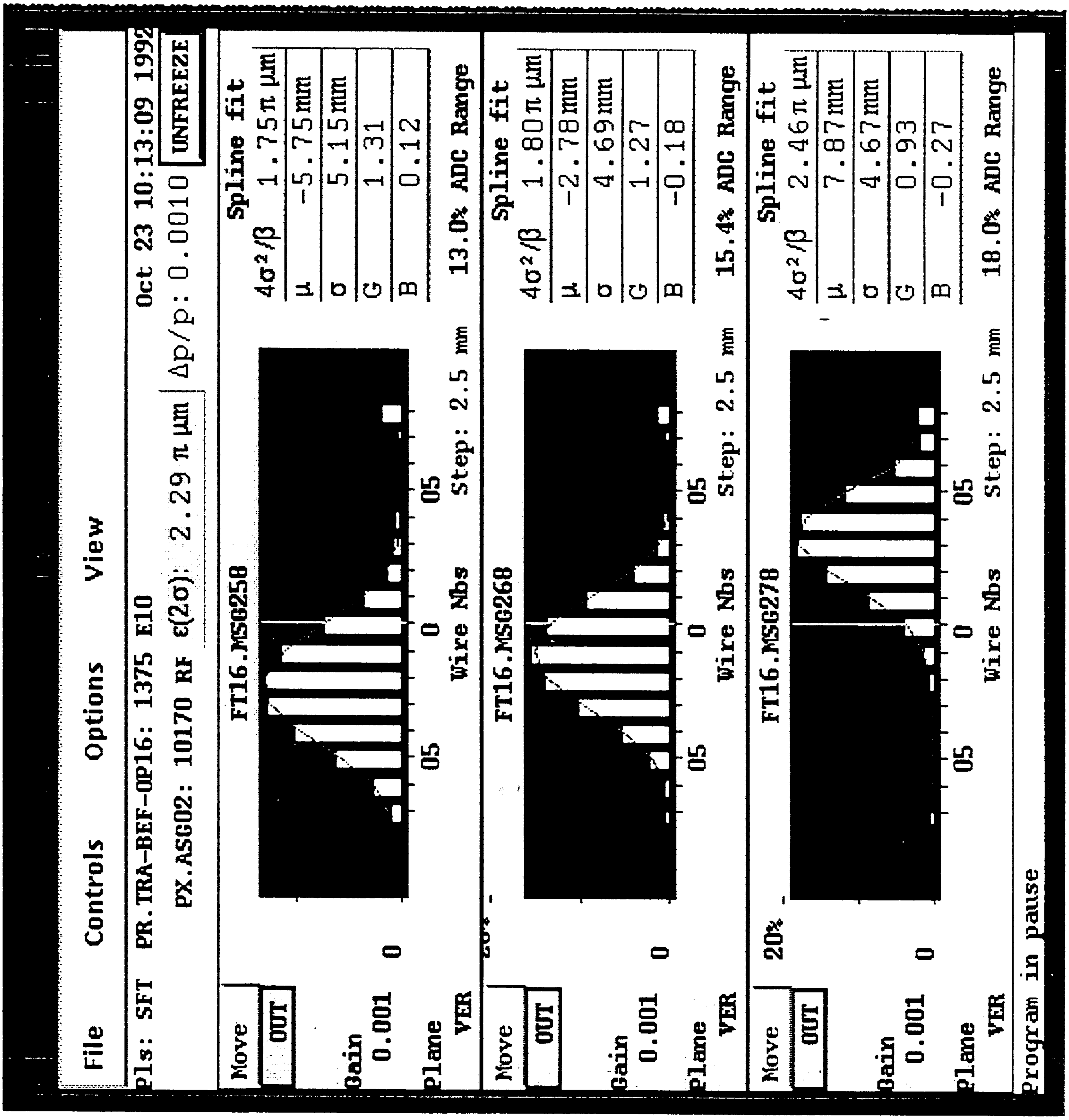
- 3 horizontal and 3 vertical SEM-grid monitors.
- Grids with 16 ribbons (7 μm Ti) spaced 2.5 mm.
- Controls based on DSC (VME crate) linked by Ethernet to a standard application program on workstations.
- No simultaneous measurements possible in both planes.

New device (1993)

TT2 transfer Line

- 3 horizontal and 3 vertical SEM-fil monitors.
- Grids with 45 wires (2 μm W) spaced 0.5 or 0.25 mm.
- Better resolution (to measure beam widths of about 3 mm for LHC).
- Controls: same as above.




File
Controls
Options
View
Pls: SFT PR.TRA-BEF-OP16: 1375 E10
Oct 23 10:13:09 1992
PX.ASG02: 10170 RF ε(2σ): 2.29 π µm
Δp/p: 0.0010
UNFREEZE
Move
OUT
Gain
0.001
Plane
VER
FT16.MSG258
Wire Nbs
Step: 2.5 mm
Spline fit
4σ²/β 1.75 π µm
µ -5.75 mm
σ 5.15 mm
G 1.31
B 0.12
13.0% ADC Range
Move
OUT
Gain
0.001
Plane
VER
FT16.MSG268
Wire Nbs
Step: 2.5 mm
Spline fit
4σ²/β 1.80 π µm
µ -2.78 mm
σ 4.69 mm
G 1.27
B -0.18
15.4% ADC Range
Move
OUT
20%
Gain
0.001
Plane
VER
FT16.MSG278
Wire Nbs
Step: 2.5 mm
Spline fit
4σ²/β 2.46 π µm
µ 7.87 mm
σ 4.67 mm
G 0.93
B -0.27
18.0% ADC Range
Program in pause

COMPARISON OF NORMALIZED VERTICAL EMITTANCE

SFT — PS beam intensity (E10)	Beamscope 1 GeV	SMG 42 1 GeV	SMG 48-52-54 1 GeV	Wire scanner 1 GeV	Wire scanner 3.5 GeV/c	Wire scanner 14 GeV/c	SMG TT2 14 GeV/c
780	13.2 µm	23.0 µm	10.7 µm	10.8 µm	11.0 µm	13.4 µm	23.9 µm
1080	17.2 µm	26.4 µm	14.3 µm	14.5 µm	14.8 µm	17.9 µm	28.4 µm
1330	22.4 µm	29.8 µm	17.5 µm	18.4µm	20.9 µm	23.9 µm	31.3 µm
1600	25.8 µm	31.8 µm	19.9 µm	21.9 µm	23.1 µm	26.9 µm	34.3 µm
1880	28.2 µm	28.7 µm	22.6 µm	26.4 µm	26.9 µm	29.8 µm	41.8 µm

COMPARISON OF NORMALIZED HORIZONTAL EMITTANCES

SFT PS beam intensity (E10)	Beamscope 1 GeV	SMG 42 1 GeV	SMG 48-52-54 1 GeV	Wire scanner 1 GeV	Wire scanner 3.5 GeV/c	Wire scanner 14 GeV/c	SMG TT2 14 GeV/c
780	19.7 µm	20.6 µm	16.6 µm	17.3 µm	13.7 µm	23.6 µm	25.4 µm
1080	16.3 µm	24.8 µm	21.0 µm	23.8 µm	19.7 µm	25.1 µm	26.9 µm
1330	24.9 µm	28.4 µm	25.3 µm	28.5 µm	26.2 µm	31.0 µm	26.9 µm
1600	21.0 µm	28.9 µm	29.5 µm	31.1 µm	29.2 µm	37.0 µm	28.4 µm
1880	26.9 µm	32.0 µm	36.7 µm	36.1 µm	31.5 µm	37.0 µm	28.4 µm

Influence of momentum spread discarded for wire scanner and SEM-grids (not for BEAMSCOPE)

B. Vandorpe

Partial Test of the PS Complex as LHC Proton Injector

K.Schindl

Results of several 1992 PS+PSB+Linac2 joint MD sessions suggest that a proton beam of the required transverse density can indeed be produced, in spite of the severe space-charge and stability limits in these three machines. The proposed filling scheme of the LHC foresees major modifications and additions to the PS proton complex, none of which - except the RFQ - is yet implemented. Thus an uncomfortable high degree of extrapolation and scaling is needed, rendering the positive results rather uncertain. A dedicated Machine Development session is proposed, for which most of the new hardware items will be provisionally implemented (prototypes, ad-hoc modifications). In particular, this MD will provide an opportunity to test:

- how to further optimise the beam brightness of Linac2 now equipped with an RFQ;
- acceleration of this beam in the PSB (ring 3) with prototype RF systems h=1, h=2;
- two-batch filling of the PS, at 1.4 GeV, with the first batch dwelling for 1.2 sec;
- emittance conservation during acceleration (h=8) in the PS;
- measuring the output emittance of this beam by means of new SEMfils in TT2.

A comparison of the "full scheme" with the proposed test demonstrates that most of the unknown issues will in fact be addressed by the test, which is scheduled for a two-week period in December 1993.

KS 2/93

Partial Test of the PS Complex as LHC Proton Injector (End 1993)

The PS Scheme for filling the LHC - a reminder

Beam specifications at PS output (TT2) are

- Number of protons per bunch — 10^{11} (1,67 10^{11})
- bunch spacing — 15 (25) ns
- transverse emittance (ε^* r.m.s) — 3.0 μm
- ε_L — 0.5 eVs

Proposed Scheme

- Double-batch filling of PS to reduce space charge in PSB (50 MeV)
- Increase of PSB energy to 1.4 GeV to reduce space charge on the 1.4 GeV front porch in PS (first batch dwelling for 1.2 sec)

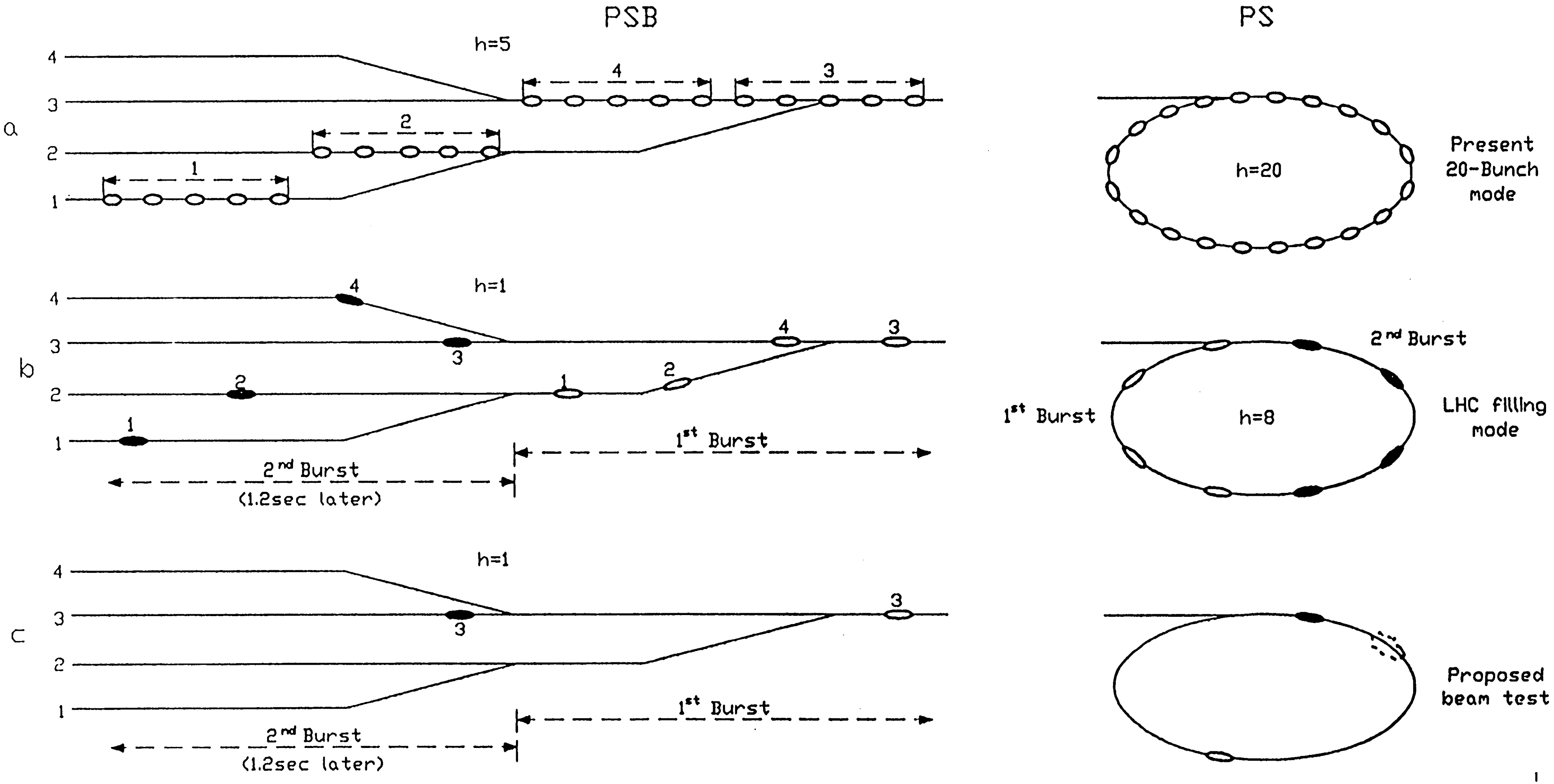
Major Hardware additions/modifications

Item	Purpose
RFQ2	Increase LINAC2 current from 140 to 180-200 mA; increase brightness
h=1 RF system PSB (0.6-1.75 MHz)	Required for double-batch filling of PS
h=2 RF system PSB (1.2 - 3.9 MHz)	Bunch-flattening to reduce space charge in PSB near 50 MeV
PSB 1GeV ==> 1.4 GeV	To reduce space charge Q-spread in PS
Fixed-frequency re-bunching cavities in PS: h=140 (66.8 MHz) or h=84+168 (40+80 MHz)	Provide bunch spacing required by LHC: 15 ns or 25 ns at 26 GeV/c
Additional beam profile devices, e.g. a second set of wire-scanners in PS, high-resolution SEMfils in TT2	Precise measurements of small-emittance LHC-type beams

LHC ($L=1.65\ 10^{34}\ cm^{-2}\ sec^{-1}$)

Acceler.	Energy Intensity *ε – norm.*	cycling RF *harmonic*	Special features
RFQ	0.75 MeV 200 mA p *0.5 µm*	1.2 sec 200 MHz	0.6 µm
LINAC2	50 MeV 200 mA p *1.2 µm*	1.2 sec 200 MHz	DTL <30µs
PSB 2 pulses	1.4 GeV 7.2E12 1.8E12 p/r *2.5 µm*	1.2 sec 0.6-1.8 MHz *h=1/h=2*	4 rings 3-turn inj.
PS 3 pulses	26 GeV/c 1E11 p/b 1.4E13 *3.0 µm*	3.6 sec 66 MHz *h=8=>140* *140 b*	transition *harmonic* *change* 4.5 m bunch spacing
SPS 2 * 12 pulses	450 GeV 1E11 p/b 4E13 *3.5 µm*	16.8 sec 200 MHz *h=4620* *1540 b*	Two s.c. lines to LHC (3 km)
LHC	7.7 TeV ● 1E11 p/b 4.7E14/rin ● *3.75 µm* ● 15ns bunch spacing	10 min 400 MHz *h=36540* *4700 b/r*	load Dyn. aperture ~6 σ

PSB-PS Recombination Schemes



Why this beam test?

MD's done so far very encouraging, but still an uncomfortably large degree of extrapolation: a closer check with the hardware actually available is required.

Full Scheme vs. proposed Beam Test

Full Scheme	Test
RFQ2 installed	RFQ2 installed (1993 shut-down)
Linac2 200 mA in 20 μs in PPM	Linac2 200 mA in 20 μs, dedicated
PSB h=1, all rings	PSB h=1 prototype in ring 3
PSB h=2, all rings	PSB h=2 prototype in ring 3
PSB accelerating to 1.4 GeV on all cycles (except ISOLDE)	PSB accelerating one ring to 1.4 GeV on two cycles during 14.4 sec (Bρ +26%)[1]
PSB to PS line: all elements at 1.4 GeV and pulsed (ejection, recombination, transfer, injection PS, all +26%)	PSB to PS line: only elements dealing with level 3 to be increased by 26%, on 2 cycles in 14.4 sec[1,2]
Two PSB cycles to fill PS (2*4 bunches)	Two PSB cycles to fill PS? (2*1 bunches)
In PS, acceleration of 8 bunches on h=8 to 26 GeV/c	In PS, acceleration of 1 (2?) bunches on h=8 to 26 GeV/c
De-bunching and re-bunching on h=140 (h=84) in PS at 26 GeV/c for LHC bunch spacing: 15 ns (25 ns)	Ejection of 1 (2) bunches and transverse profile measurement on new SEMfil in TT2

[1]This cycling keeps power dissipation manageable

[2]Elements concerned are: BESMH, BT3DVT10, BTQNO40, BTBHZ10, PISMH42, and kickers BEKFA, PIKFA45

"Uncharted Territory" to be explored by the Test

- Optimum injection into PSB & beam behaviour near 50 MeV with increased LINAC2 beam brightness
- A new harmonic in PSB: new cavities, modified bunch spectrum and impedances, immunity against beam loading
- Beam behaviour in PSB between 1 and 1.4 GeV
- Two-batch filling of PS: Controls, Timing & Co
- Two-batch filling of PS: Conservation of transverse emittances on 1.4 GeV front porch
- Conservation of transverse emittances in PS during acceleration (on h=8, careful programming dB/dt), and on crossing transition

Territory remaining uncharted

- PSB beam behaviour under new conditions in rings other than 3
- Phenomena due to the full intensity (8 bunches = 1,44 10^{13}, instead of 2 bunches) in PS: coupled-bunch modes, beam loading, etc.
- Difficulties arising from the de-bunching re-bunching process (h=8 ==> 140) at 26 GeV

Resources for Beam Test

	Total Cost (kFr)		Cost "a fonds perdu"	
	kFr	man-months	kFr	man-months
PSB Main Supply upgrading to 1.4 GeV B from 6870 to 8670 G	70	5	35	2.5
RF h=1, h=2 cavities in PSB ring 3 (prototypes)	100-150	18	50	9
PSB-PS transfer (level 3) supplies upgrading +26%	15	4	15	4
Kickers (BE3KFA10)	10	2	10	2
Total Test	**195-235**	**29**	**110**	**17.5**

Question: will we get the money?

Tentative Schedule of a two-week test

An MD session, scheduled for 3. -16. December 1993, is approved.

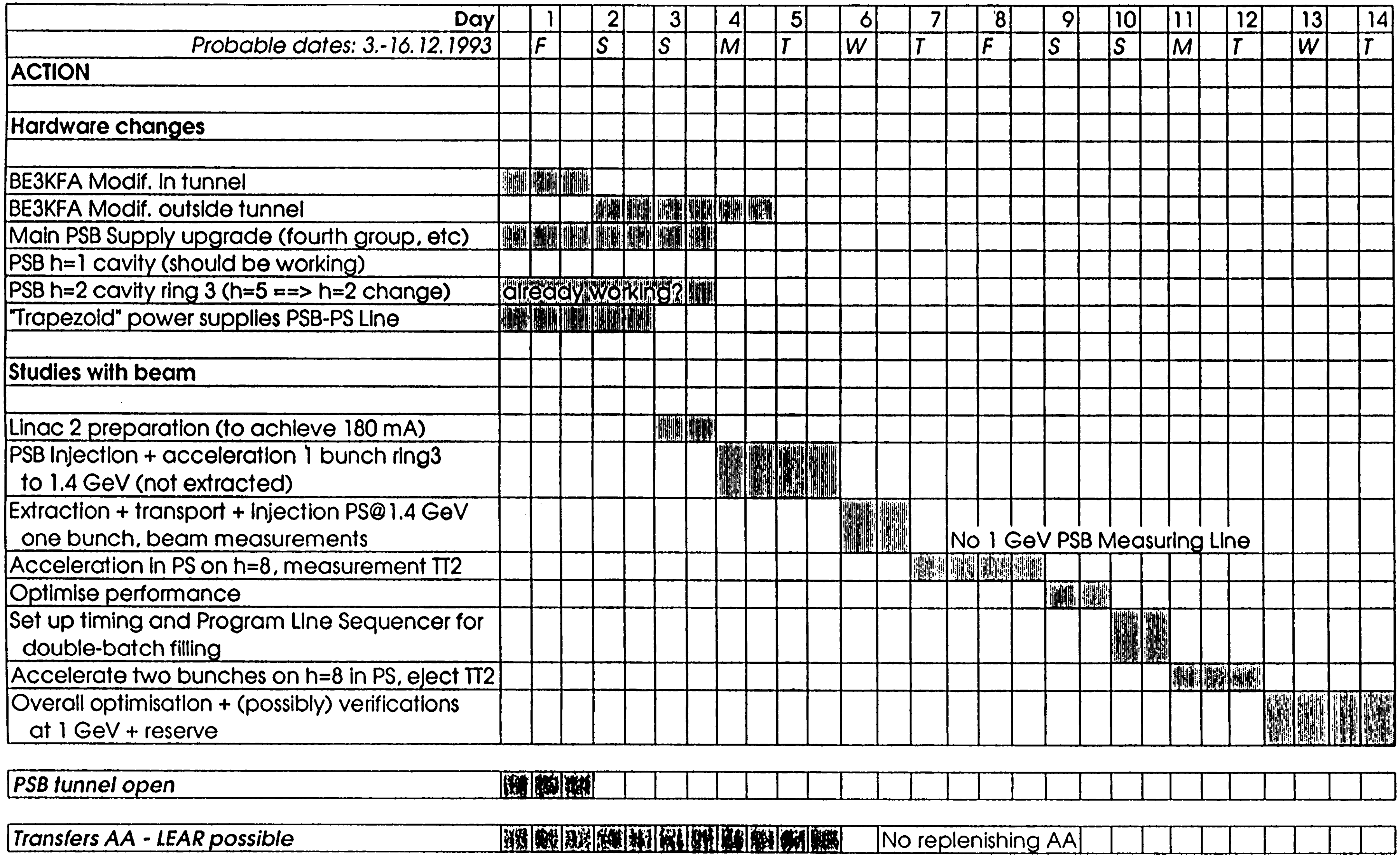


Fig.5: Tentative Schedule for the LHC proton injector test in the PS Complex

PLANNING DE MISE EN SERVICE DES NOUVEAUX MODULES BEAM CONTROL EN 1993

R. Garoby 12/1/93

			Janvier	Fevrier	Mars	Avril	Mai	Juin	Juillet	Aout	Septembre	Octobre	Novembre	Decembre
								Debut test h=1 avec faisceau				Prep. Plomb et test LHC 93	Prep. Plomb et test LHC 93	Test 1.4 GeV protons pour LHC
PSB	h=1	PUISSANCE	Installation cavite		Test / cycle machine			Disponible pour faisceau						
		Excitation en boucle ouverte (DFP +DDS)					12/05/93							
		Beam Control h=1 anneau 3						9/06/93			1/09/93	6/10/93 12/10/93 27/10/93	1/11/93 et 24/11/93	3/12/93 Jusqu'au 16/12/93
	h=2	PUISSANCE	Installation cavite		Test / cycle machine			Disponible pour MD						
		Excitation par Beam Control h=1								23/08/93			1/11/93	3/12/93 Jusqu'au 16/12/93
	h=5	Tests Beam Controls Plomb						9/06/93		23/08/93	1/09/93	6/10/93 12/10/93 27/10/93	1/11/93	
RS	h=20	Test modif. Beam Control Ions									1/09/93			
	h=8	Beam Control h=8 protons										6/10/93 12/10/93 27/10/93	1/11/93 et 24/11/93	3/12/93 Jusqu'au 16/12/93

Comissioning of ISOLDE Beam, E.Wildner

Abstract:

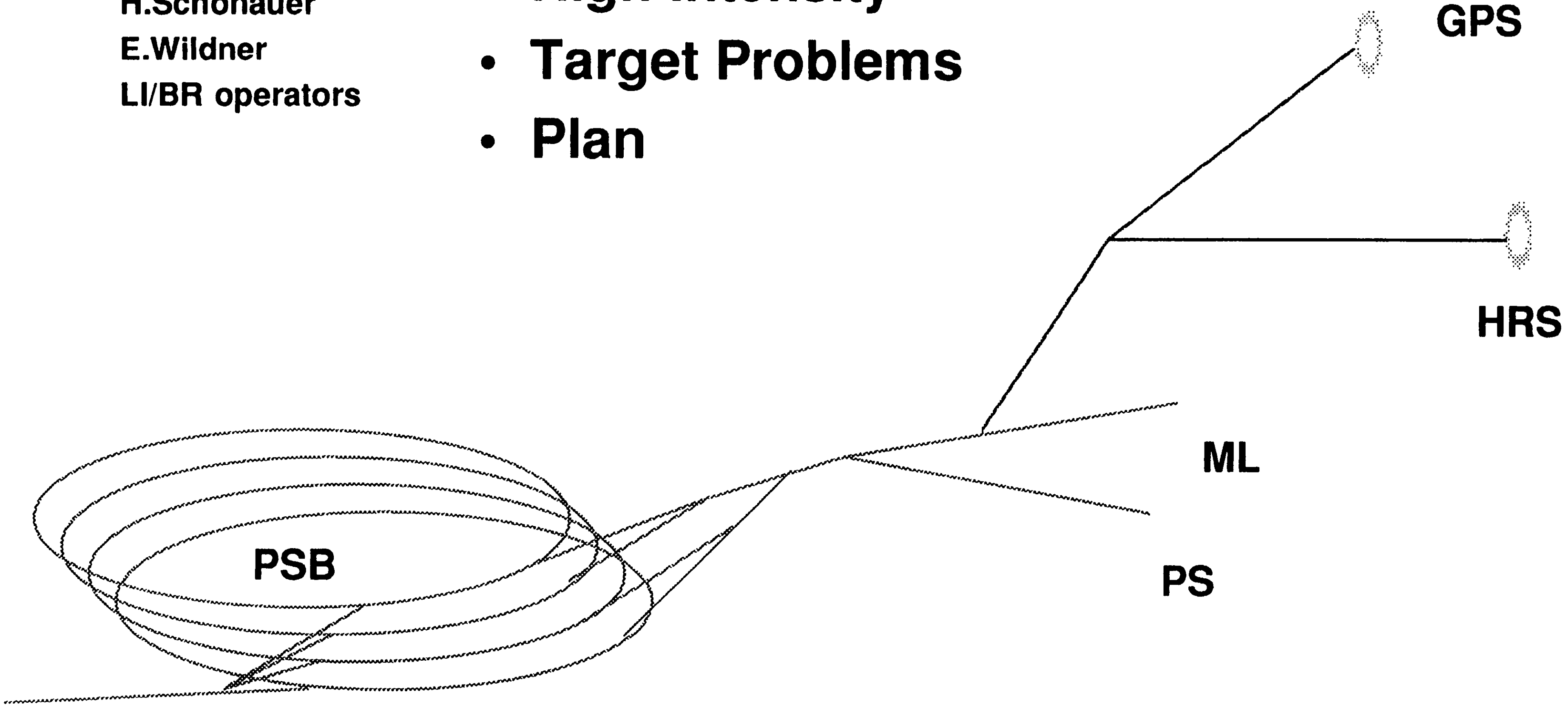
The ISOLDE beam performances are very near to the design values. However to keep the performance needs intense surveillance and care. Automatic surveillance of beam intensitis and losses, careful steering and optics optimization are subject to our present attention. In addition, the bunched Booster beam seems to cause some problems for the liqud targets. Optics calculations to distribute the particles optimally in the target is one way of trying to remedy this. Tests are carried out in close collaboration with the ISOLDE team.

Comissioning of the ISOLDE beam

Participants

- G.Cyvoct
- E.Jensen
- N.Rasmussen
- K.Shindl
- G.Schneider
- H.Schönauer
- E.Wildner
- LI/BR operators

- Performances
- High Intensity
- Target Problems
- Plan



Performance

❄ Satisfactory:

✦ $1.5 \cdot 10^{19}$ p ~ 1/4 of the PSB production 1992

	Operational	Design	Peak
Intensity on target [10e13 ppp]	3.0	3.2	3.0
Intensity in PSB [10e13 ppp]	3.1		3.2
Emittance (95%) [π mm mrad]	H: 30 V: 18	H: <50 V: <30	
Beam dimension at target [mm]	H: 5 V: 7	H: 4 V: 4	
Beam loss ring to target [10e12 ppp]	1.5	0.8	

✦ Good alignment of the four rings (ISOLDE foil irradiation tests)

❄ However:

✦ High intensity and repetition rate need careful surveillance and optimisation.

✦ Target problems due to PSB high intensity bursts

Commissioning of the ISOLDE Beam

❄ **High Intensity:**

- ✦ $3{\cdot}10^{13}$ ppp, up to 7 times per supercycle of 14.4s
- ✦ Peak: 11 pulses per out of 12, supercycle length 14.2s

❄ **Loss at extraction $1.5{\cdot}10^{12}$ ppp:**

- ✦ No measurable loss in beamline after extraction
- ✦ Review of extraction steering going on

❄ **Surveillance of intensity and losses (current transformers):**

- ✦ Risk for target destruction and radiation

❄ Rigorous use and logging of **BLMs:**

- ✦ To minimize radiation damage

❄ **Steering on target** difficult without pickups:

- ✦ Two last dipole pairs for ISOLDE target scan
- ✦ Screens are destructive devices

❄ **Beamsize on target** slightly different from theory:

- ✦ ISOLDE autoradiographic test
- ✦ Semfils could be a solution

❄ **Burning of screen** in front of target:

- ✦ Movable screen or regular change of screens (monthly)

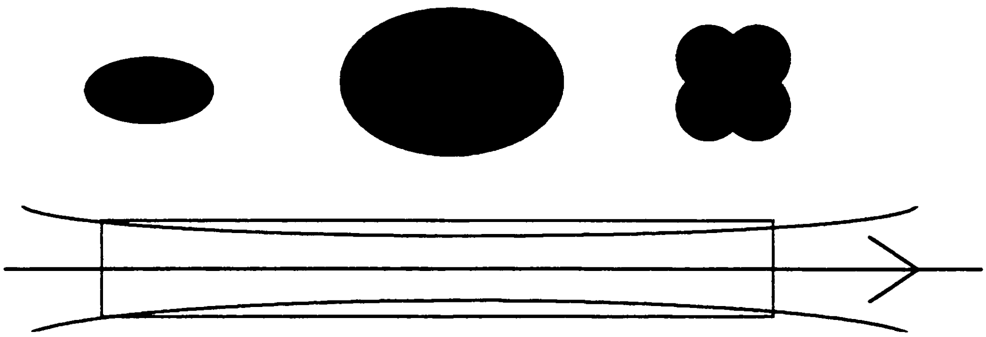
Target Problems

❄ In liquid targets:

✦ Evaporation or splashing due to bunched beam above $I_p = 5 \cdot 10^{12}$ ppp once per supercycle (14.4s)

❄ Stretching of the beam not foreseen for the moment

❄ Try to distribute particles optimally in target



❄ Diagnostics and checking for development:

✦ No way of verifying from PSB; screen not enough

✦ ISOLDE autoradiography; time consuming

❄ ISOLDE target development:

✦ Shielding in target container

✦ Increase target mass

Plan

250 shifts scheduled ~ 90 days:

April-May experiments using solid targets
 No problems, optics checking
June experiments using liquid targets
 Development and studies

Tests (PSB and ISOLDE MD) possible before and after target change

@ Optics optimization and tests for particle distribution in target

@ Modifications of ejection steering
 # Beam loss minimization
 # Separation of beams on target

@ Development of automatic surveillance help for operation

@ Definition of improved possibilities for beam diagnostics, Semfils, Pickups

Performance

❄ Satisfactory:

✦ $1.5 \cdot 10^{19}$ p ~ 1/4 of the PSB production 1992

	Operational	Design	Peak
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Beam loss ring to target [10e12 ppp]	1.5	0.8	

✦ Good alignment of the four rings (ISOLDE foil irradiation tests)

❄ However:

✦ High intensity and repetition rate need careful surveillance and optimisation.

✦ Target problems due to PSB high intensity bursts

File [HOS] ELOISE ABSTRACT

ISOLDE BEAM: Problems with >3.E13 p/p

H. Schonauer

During only a few weeks of ISOLDE operation at the end of 1992, 1.45E19 p's, about 1/4 of the total number of protons accelerated in 1992, has been sent to the ISOLDE target. As a consequence, the average level of induced radioactivity as measured by TIS at the end of december 1992 has doubled with respect to the value of the preceding year.
In 1993, about 1.E20 p's are expected, and the danger of machine contamination becomes reality.

This sheds som light on the fact that t h e problem is not so much the production of the high intensity (as long as the nominal value of 3.2E13 p/p is not exceeded) but the losses ocurring at these intensity levels. The table lists and the photo of the 4 beam transformer signal shows a few loss mechanisms encountered in the PSB.
Of these, losses at energies above 3-400 Mev are most harmful, and are caused by marginal stability of the dual RF system (11 nested loops) and the damper systems operating at their limits.
Studies and hardware development in this domain have gained importance and wil have to be done jointly by RF and HI group.

Ejection loss at the septum may damage it and render it ultimately irreparable. Again, a more detailed analysis has to be done. It may well turn out the ejecton kicker flat top will have to be improved.

ISOLDE Beam : Problems

5-8 c/Sc >3 10^{13} p/p 2000 h/yr = 10^{20} p/yr

The problem is NOT the production of this intensity (although this level requires constant care) but the accompanying *LOSSES* !

Loss Mechanisms in PSB :

#	Type	%	Occurrence	Cure
1	Injection	40	Septum, 1st Bending	none
2	Capture	10	Beamscope Aperture	none
3	Stopbands	15	< 150 MeV	a.f.a.p. done
4 4 a	Long. Instab. (Dual RF stab)	5-10 >10	0.4-1 GeV ; B.A.	Improve LFB Prog. Vrf h=5,10
5	Slow Loss	3-5	Diffusion out of bucket Spurious transverse inst.	Vrf incr, Prog ϕh=10 Transv.Damper
6	R4 "µwave" instability	0-5	590 MeV; B.A.	Septa damped, ϕrf h=10 prog.
7	Ejection Loss	< 1 3-4	Halo scraped inner sept.fce outer edge: kicker flat top, V	Loss collimator 94? Sept. pos., kicker

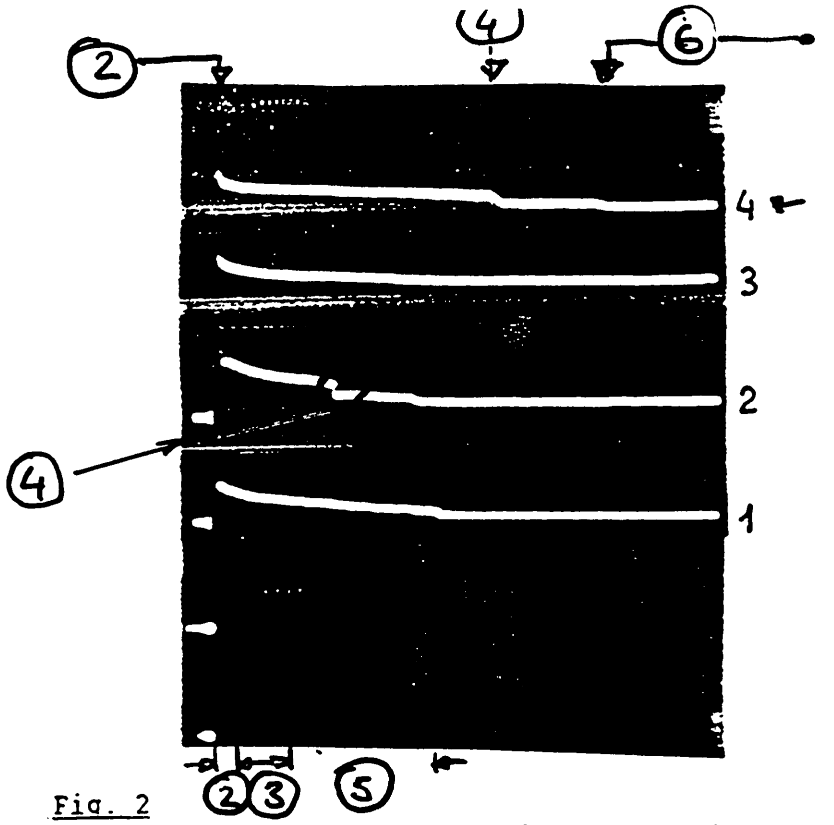


Fig. 2
Normalised beam transformer signals for rings (top to bottom) 4 to 1.

(#)... loss mechanism of preceding page

BEAMSCOPE EMITTANCES 13/11/1989 23:42
D 5000 USER ME1 PLS LINE 39

RING	P/P E10	HOR. EMITTANCE PHYSICAL(NORM)	VERT. EMITTANCE PHYSICAL (NORM)
1	821	30.6 (55.4)	17.1 (30.9)
2	864	32.7 (59.1)	16.4 (29.7)
3	961	27.9 (50.5)	16.9 (30.6)
4	819	31.9 (57.8)	16.0 (29.0)

Σ= 3465

← Performance achieved!

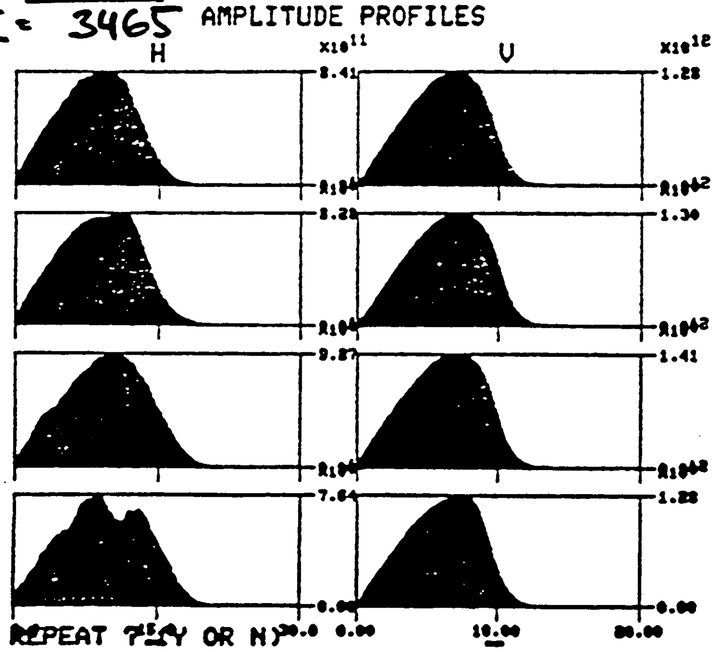


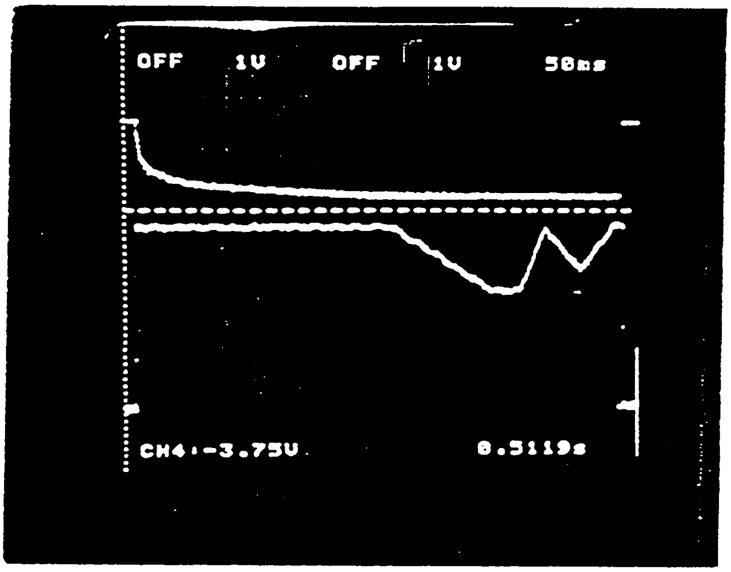
Fig. 3
Beamscope emittances and betatron amplitude profiles.

18/6/92

High Intensity for ISOLDE

ME2

Ring 2, VRF1 adjustement



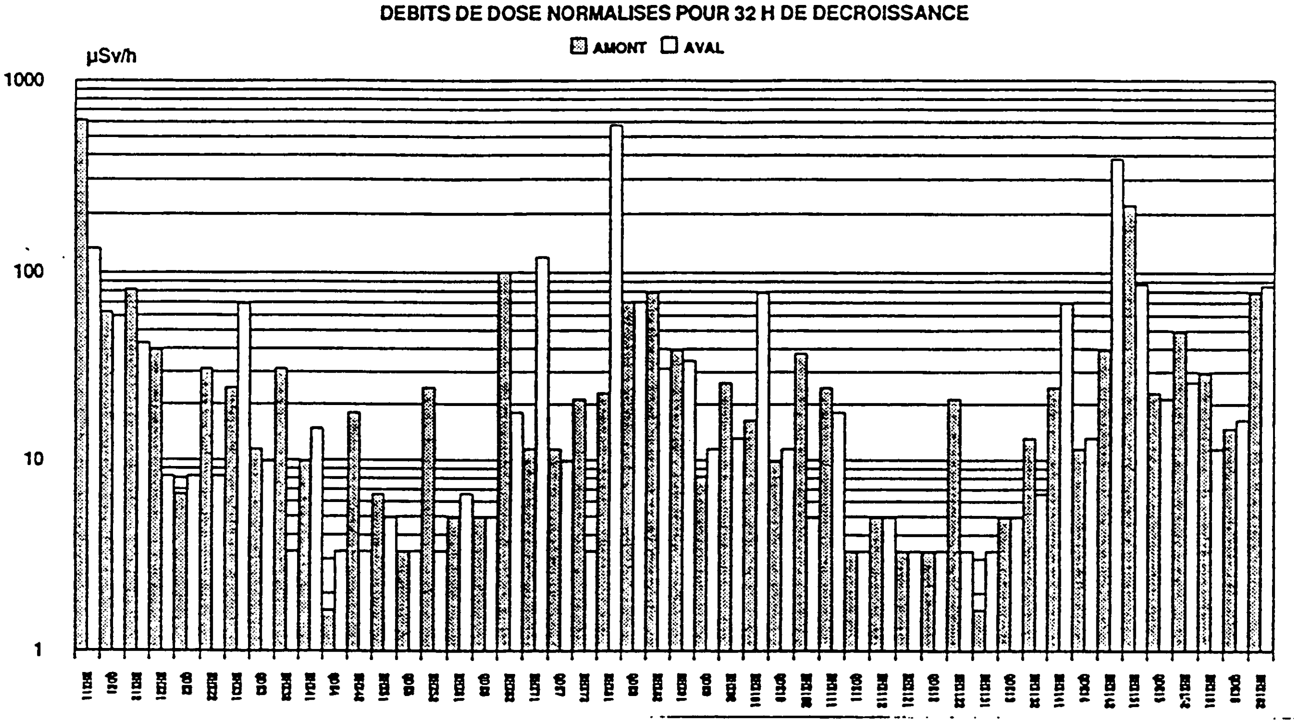
$I_p \doteq 800$

VRF1

Ring 2

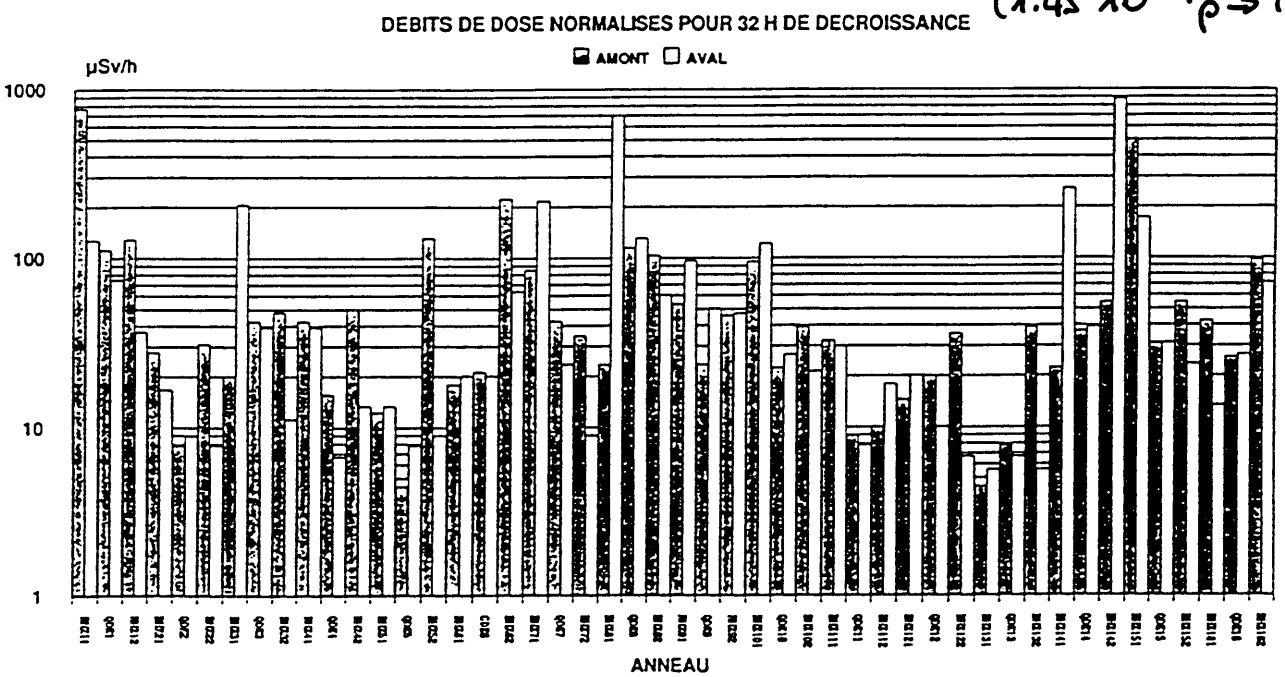
RING SURVEY BOOSTER

END 1991 $\Sigma = 3.2$ mS/h



END 1992 $\Sigma = 7.3$ mS/h

($1.45\ 10^{19}$ p → ISOLDE)



NEW SLOW EXTRACTION 61

Ch. Steinbach

Abstract

The slow extraction from the CERN PS to the East Area was completely rebuilt in March 1992. The new layout benefits from several improvements. The losses on the magnetic septa are suppressed by means of a novel concept applied to the third-integer resonance optics. The vacuum has been improved (in view of future lead ion acceleration) by means of a reduction in the number of septa and a change in technology (bakability, no organic material, 316LN stainless steel tank). Synchrotron radiation damage during lepton cycles is avoided by installing the septa on the inner side of the machine aperture.

In the East Area, the beam is split between 2 targets feeding 4 secondary beams. The experimental hall is being overhauled. 20 to 30 physics groups use it each year for detector development and calibration.

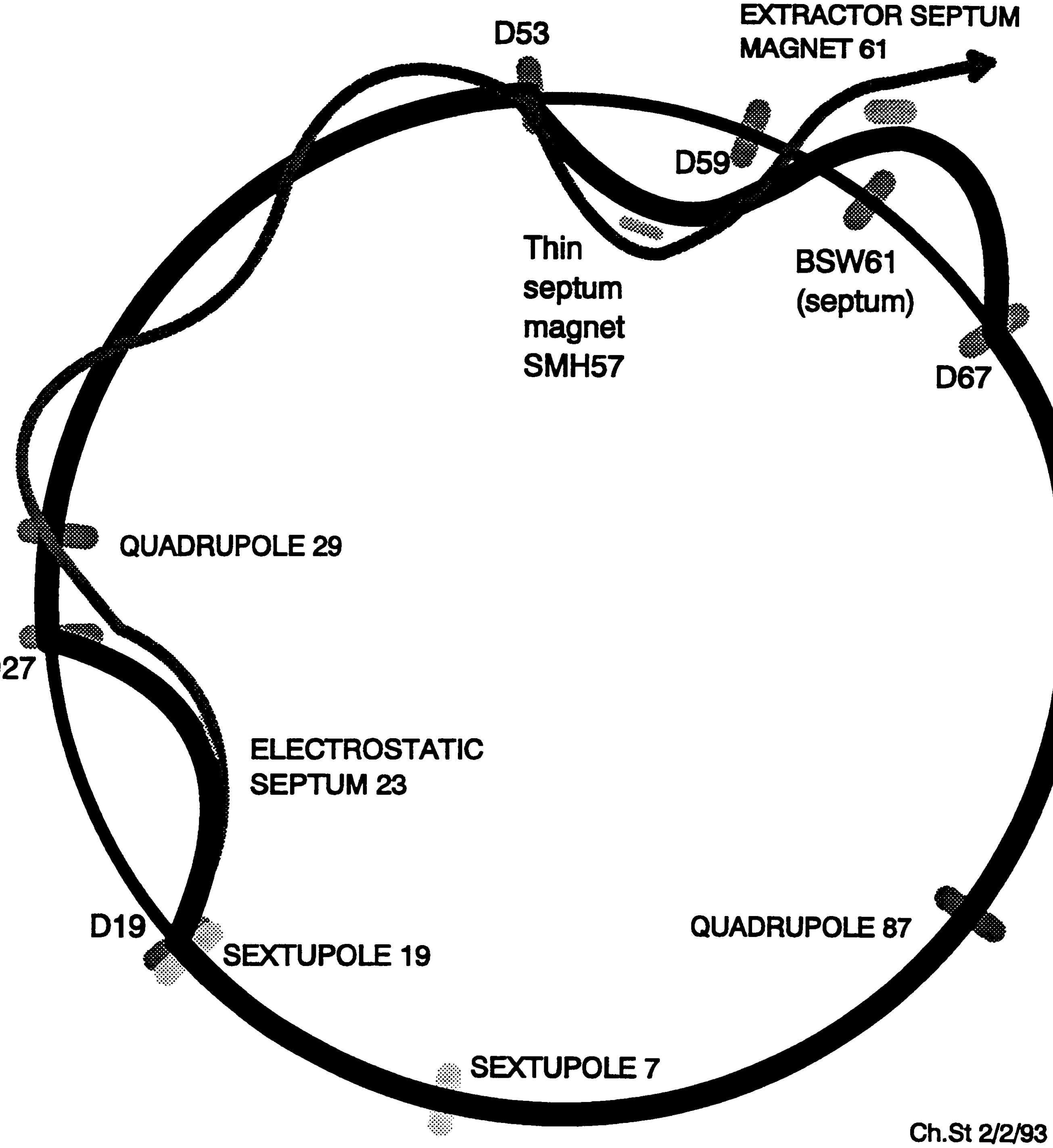
SE61 EXTRACTION

MAIN CHARACTERISTICS

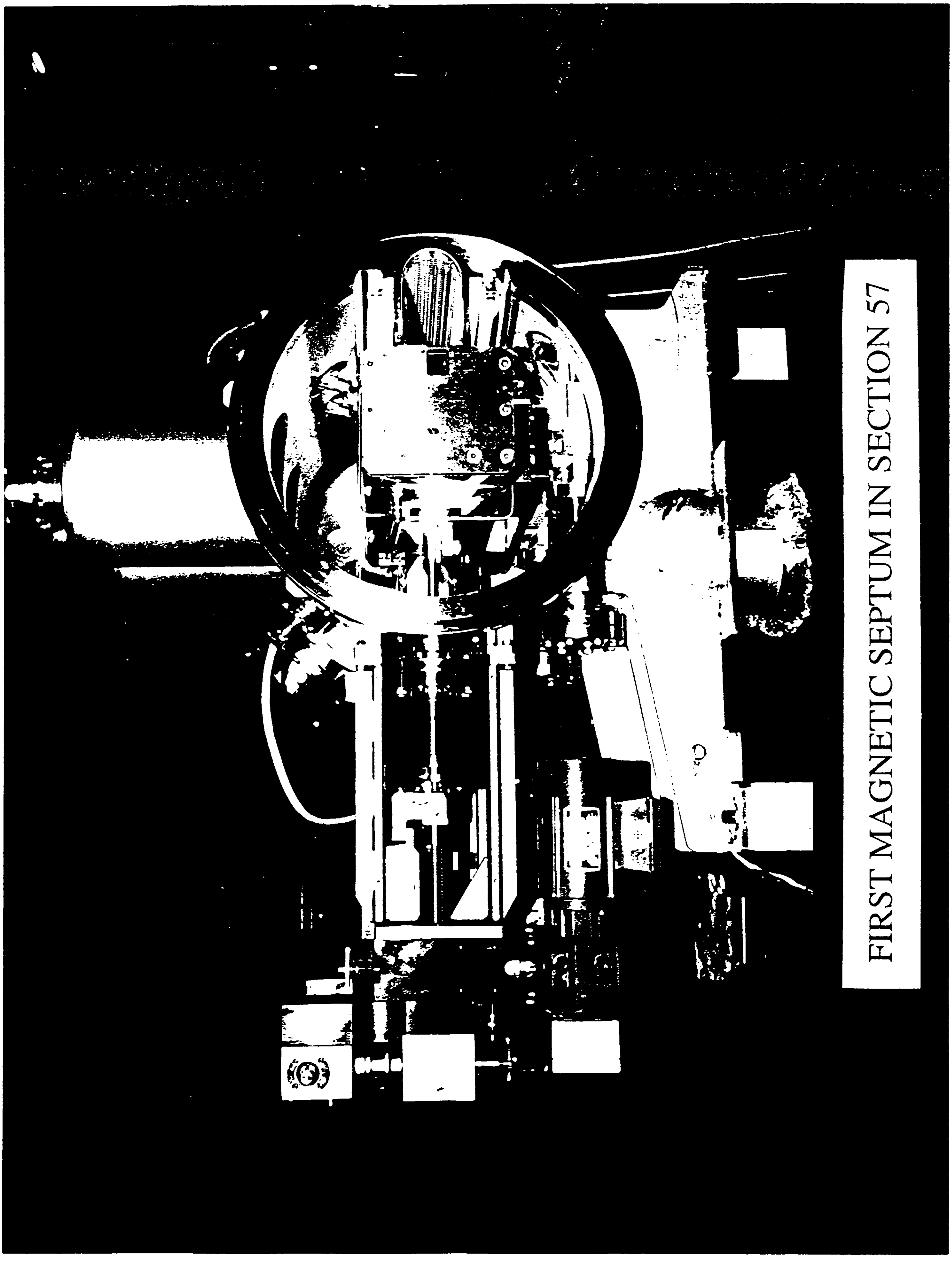
- slow extraction to the EAST HALL (fast extraction also available, not ppm),
- recent design and construction (last year),
- Third integer resonance,
- 14 elements in the PS ring,
- systematic losses due to chromatic effects at the thin septum magnet are avoided through adjustment of local dispersion coefficients,
- protection of the septa from synchrotron radiation during lepton cycles,
- reduced number of septa for less maintenance (only one septum magnet in vacuum instead of 3 before),
- improved vacuum (for ion acceleration): the thin septum magnet is bakable, the tank is made of vacuum fired 316 LN stainless steel and there is no organic material in vacuum.

Ch.St 1/2/1993

PS SLOW EXTRACTION SE 61



Ch.St 2/2/93



FIRST MAGNETIC SEPTUM IN SECTION 57

PERFORMANCES

Due to East Area radiation limitations, the intensity is restricted to 20 10^{10} p/s.

EFFICIENCY

Not known with precision, estimated above 95%. Losses are practically limited to the electrostatic septum straight section.

EMITTANCES FOR A 30 10^{10} PPP

	circulating	extracted	
Horizontal:	.5	~ .1	$\pi\mu$rad
Vertical:	.4	.8	$\pi\mu$rad

MOMENTUM SPREAD

total $\Delta p/p$:	.3 %
Instantaneous $\Delta p/p$:	.08 %

SPILL LENGTH

maximum:	500 ms
standard:	400 ms

DUTY FACTOR

at present <50% (for unknown reason).

Ch.St 1/2/1993

EAST HALL (courtesy of D.J.Simon)

LAY-OUT

The extracted beam is split between 2 targets feeding 4 momentum analyzed beams:

- t7	(south branch)	≤ 10	GeV/c
- t9	(north branch)	≤ 15	GeV/c
- t10	(")	≤ 5	GeV/c
- t11	(")	≤ 3.5	GeV/c

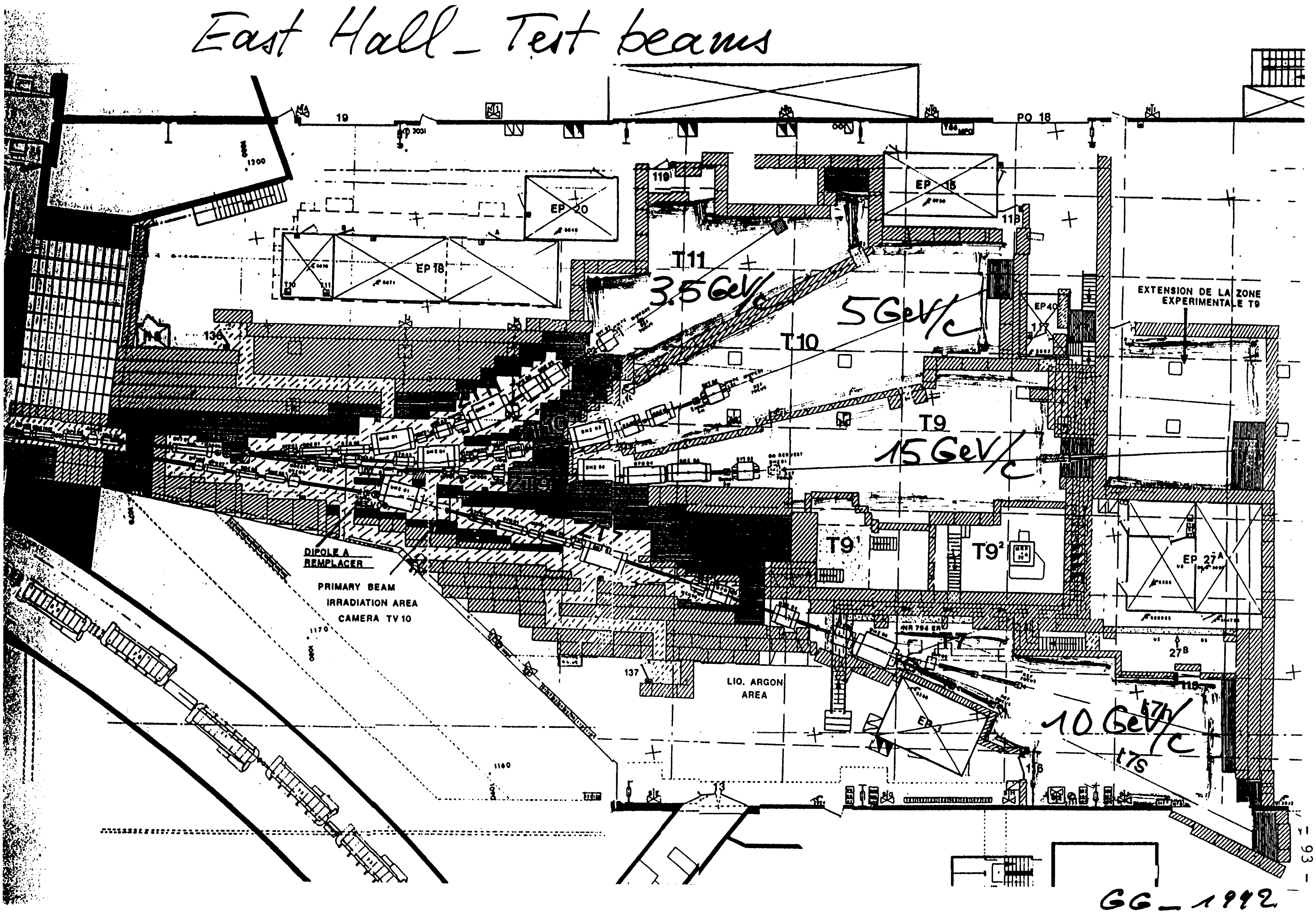
USERS

20 to 30 groups (100 to 150 physicists) / year mainly for detector development and calibration.

Schedule for 1993: 29 weeks

RENOVATION IN PROGRESS

- upgrading of some beam transport elements,
- new control system for secondary beams,
- overhaul of Cerenkov counters,
- general cleaning.


East Hall _ Test beams
19
PO 18
EP 20
EP 18
EP 15
T11
3.5 GeV/c
T10
5 GeV/c
T9
15 GeV/c
EP 40
EXTENSION DE LA ZONE EXPERIMENTALE T9
T9¹
T9²
EP 27A
27B
DIPOLE A REMPLACER
PRIMARY BEAM
IRRADIATION AREA
CAMERA TV 10
LIQ. ARGON AREA
T7
10 GeV/c
GG _ 1992

PS Performance Day
3rd February 1993

Lead Ion Source

The lead ion source furnished by IN2P3 and contracted out to GANIL has recently been received at CERN. The main differences between this source and the sulphur source are briefly described before showing in a table the contractual performance obtained at GANIL. A typical beam current pulse (in the afterglow mode) and a charge species spectrum complete the performance description. Suggestions for performance improvements, both in the long and short term would seem to indicate an interesting running-in period for the source.

(Note added to abstract:-

The sulphur source was of the MAFIOS type and had basically no iron in the magnetic circuit for the mirror field. The CAPRICE has a steel flux return yoke and field concentrating pole pieces giving, apart from a saving in power, a mirror field with much stronger gradients. This gradient is believed to be the 'secret' of the source.)

Charles Hill

The *GANIL* Lead Ion Source

General Characteristics

Steel bodied Electron Cyclotron Resonance source type 'CAPRICE' with 2 mirror solenoids and Fe-Nd-B permanent magnet hexapole.

Microwave frequency 14.5 GHz.

Can be used for most elements.

'Micro Oven' for evaporation of solid samples.

Operates in the pulsed 'afterglow' mode.

Demonstrated Performance

(Pilot gas Oxygen, Lead pure $_{208}Pb$ isotope)

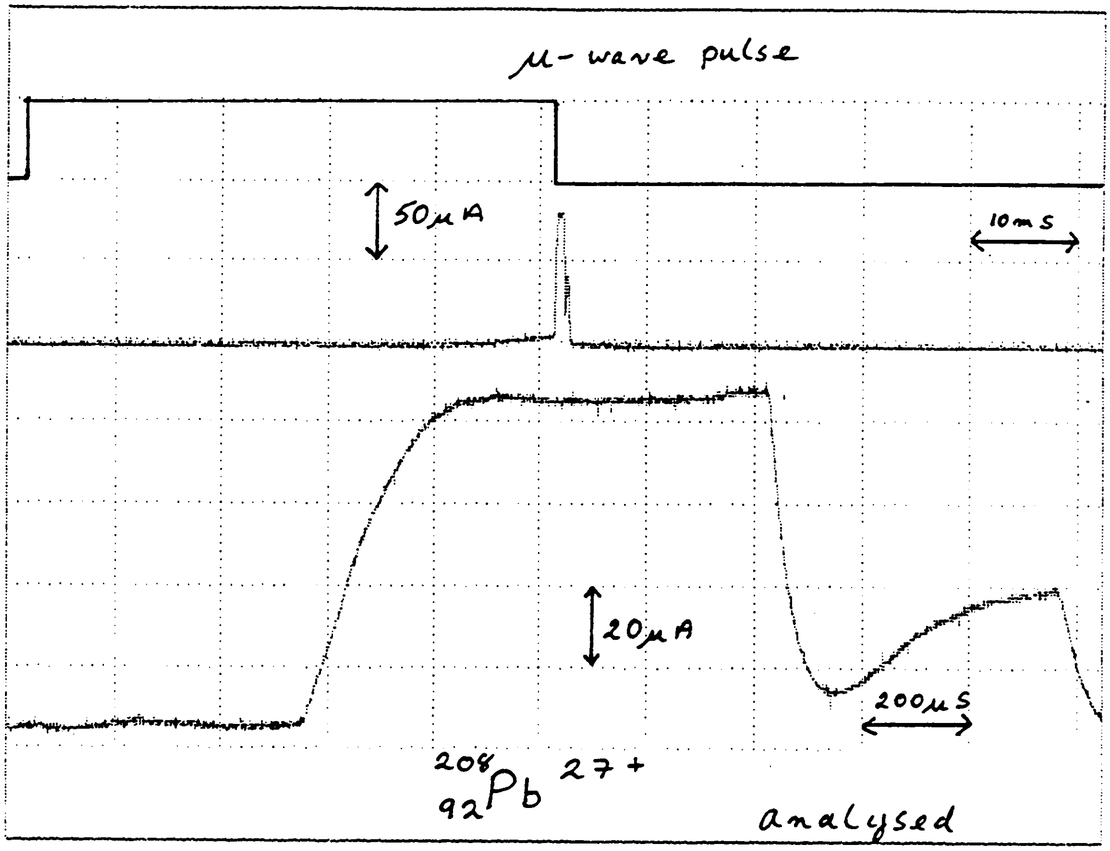
Energy	2.5keV/u
Current	>80μA for ions from Pb^{25+} to Pb^{28+}
Usable pulse	>600μs
Repetition rate	10Hz
RF duty cycle	50%
RF power	≈ 1.25kW
DC power	≈ 60kW
Start up time	≈ 2 hours
Stability	good, pulse to pulse.

Source has operated for two weeks without stop, estimated life of lead charge about 60 days.

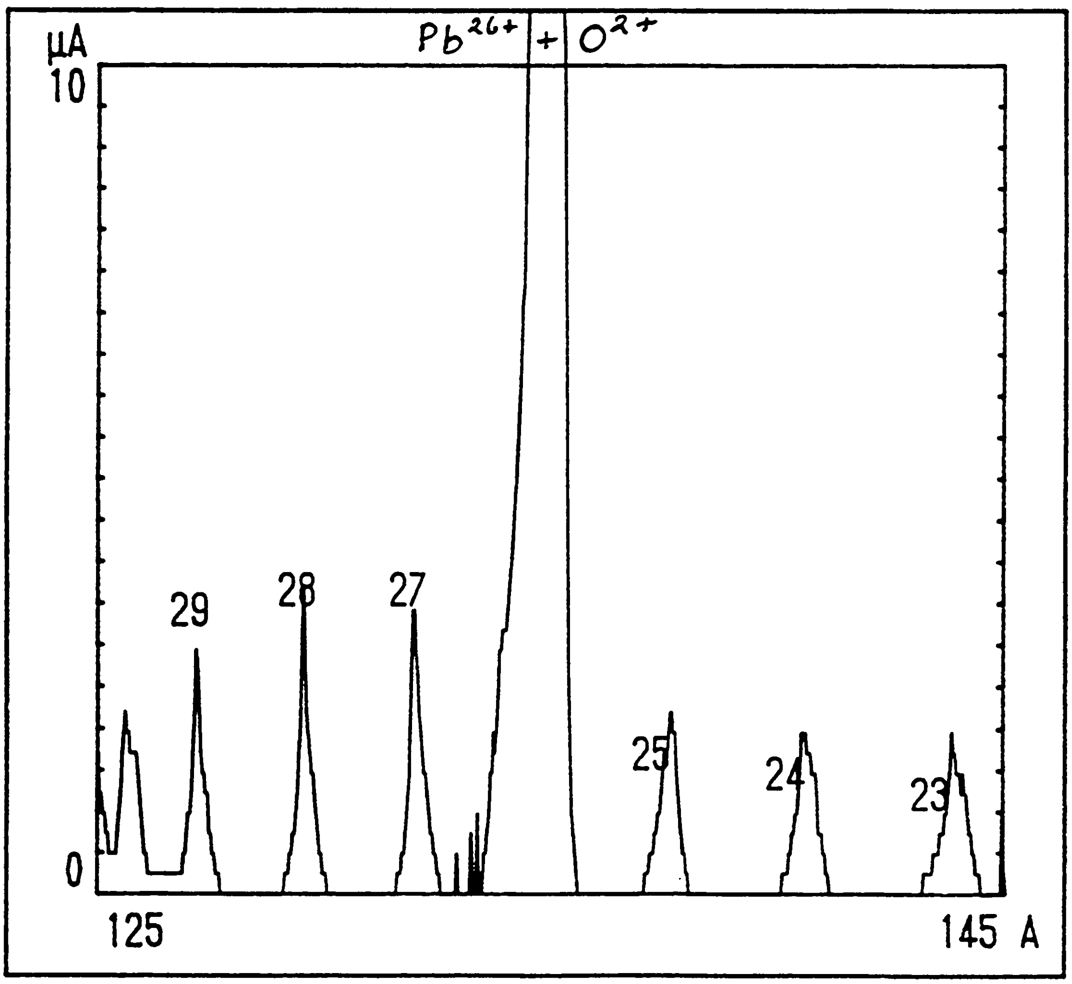
Maximum current observed at 10Hz for Pb^{27+} 90-100μA.

Charge state tunable, even Pb^{29+} >80μA.

Source Output 21-10-1992

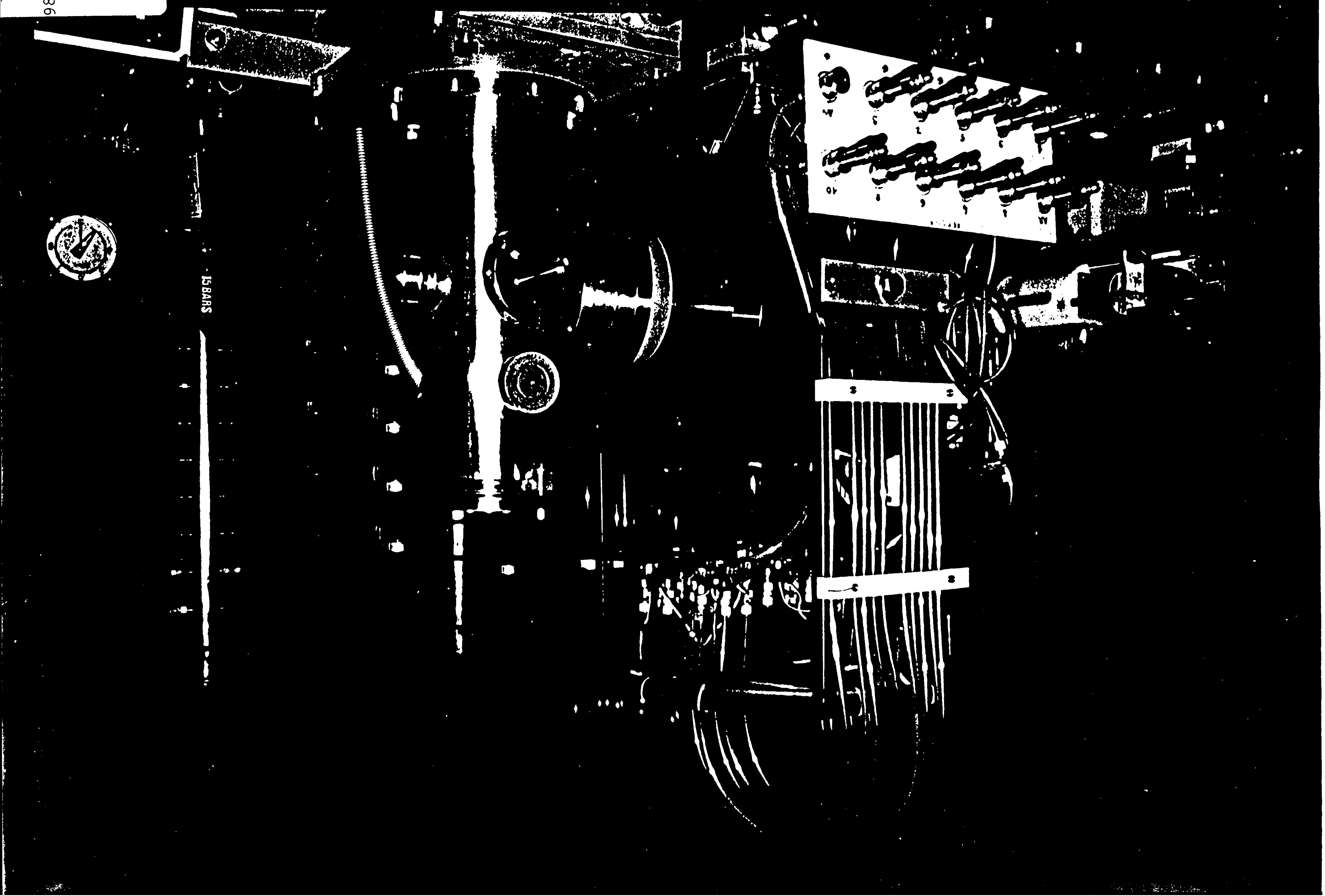


GANIL - source CERN - 14.5 GHz



phf (W)	1222
bp1 (A)	1037
bp2 (A)	1132
ssg (V)	5.06
sss (V)	0.08
ssl (V)	0.07
tg1 (V)	0.0
tg2 (V)	4.9
ht1 (kV)	20.0
ht2 (kV)	0.0
it1 (mA)	4.27
it2 (mA)	0.00
date	1021
heure	1510
metal	800
accord	5004
ion	PB
support	0

208 PB


15 BARS

Performance Improvements

Short term

Contractual performance demonstrated, CERN will need to follow learning curve to tune source to Linac3. Some gain possible

Can play off pulse length and amplitude, tune source to utilisation.

Reduce repetition rate, at 1Hz, short optimisation 110μA PB^{28+}

At lower rep. rate can increase RF pulse, some indications of gains based on experience with sulphur source

Small gains in number of particles by optimising charge state to rest of the linac.

Longer term

GANIL are used to dc type sources, this one their first and only pulsed device. We need to follow the learning curve under pressure from operation.

Better understanding of 'afterglow' - Shirkov

Secondary emitter in plasma (cf. Geller's gadget for sulphur)

Increase RF frequency to 18GHz, possible gain 50% but development required.

Benefit from improvements in ECR technology, especially now that industry is becoming interested in these sources. (Conferences)

Conclusion

We need to learn to use the source as we did with sulphur.

Beam Dynamics of Ion Acceleration.

N.Rasmussen

Abstract.

Lead ions readily exchange charges with the residual gas. In particular at low energies. If the vacuum is not sufficiently good, the transmission through the PSB of these particles will suffer considerably due to longitudinal and transverse losses.

One means of improving the transmission is to reduce the capture time and speed up the acceleration at lower energies. This implies capture at a high Bdot which also gives rise to some losses.

We have studied the losses due to the reduction in longitudinal acceptance induced by the high Bdot, in machine experiments with a low intensity beam of small dimensions.

The ion beam will have large transverse dimensions and therefore means to reduce the spiralisation induced by the high Bdot have been investigated by calculations. A reduction of the duration of the capture process appears most promising. This gives rise to some longitudinal loss but a good compromise seems possible.

In order to reduce the rise time of the magnetic induction, succesful tests with the main power supply have been made to investigate operation with a higher Bdot.

The digital beam control of which the main feature is the digital frequency generation, is breafly described.

Beam Dynamics of Ion Acceleration.

Topics: ☞ Losses at capture and immediately after

☞ Machine studies at increased dB/dt

☞ Calculations to minimize spiralisation.

☞ Digital Beam Control.

□ *Ion acceleration.* Pb^{53+}.

■ Expected problem: Particle loss at low energies due to charge exchange with the residual gas.

■Example: The transmission through the PSB with a non-hydrogen residual gas pressure of 9×10^{-10} torr and the actual ion cycle is <30%. With a fast cycle (258ms) it becomes ≅60%.

■Remedy (apart from an improved vacuum): Accelerate to higher energies as fast as possible.

This implies capture at high dB/dt which in turn gives rise to losses,

☞ transverse -- due to spiralisation ($\phi_S = 0$)

☞ longitudinal -- due to a reduced bucket area

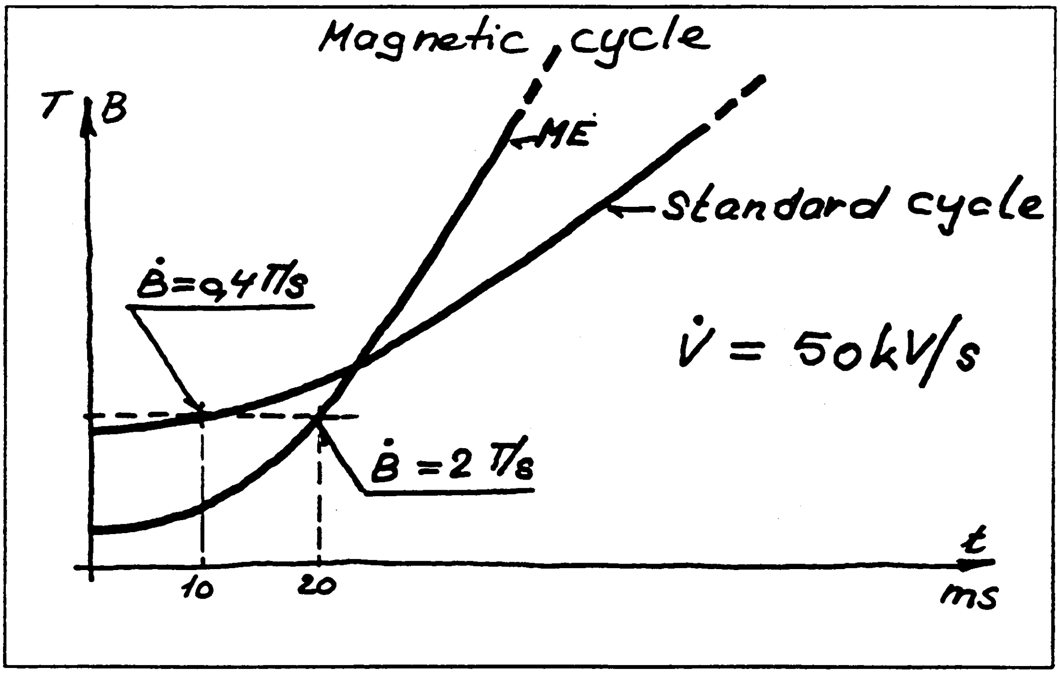
We have studied the longitudinal losses in machine experiments (ME's).

□ *ME with capture at increased dB/dt.*

Essential conditions:

☞ Low beam intensity, ($1.6 x 10^{12}$ protons/p).
(No space charge effects)

☞ High dB/dt (2T/s was the highest obtainable at the time).

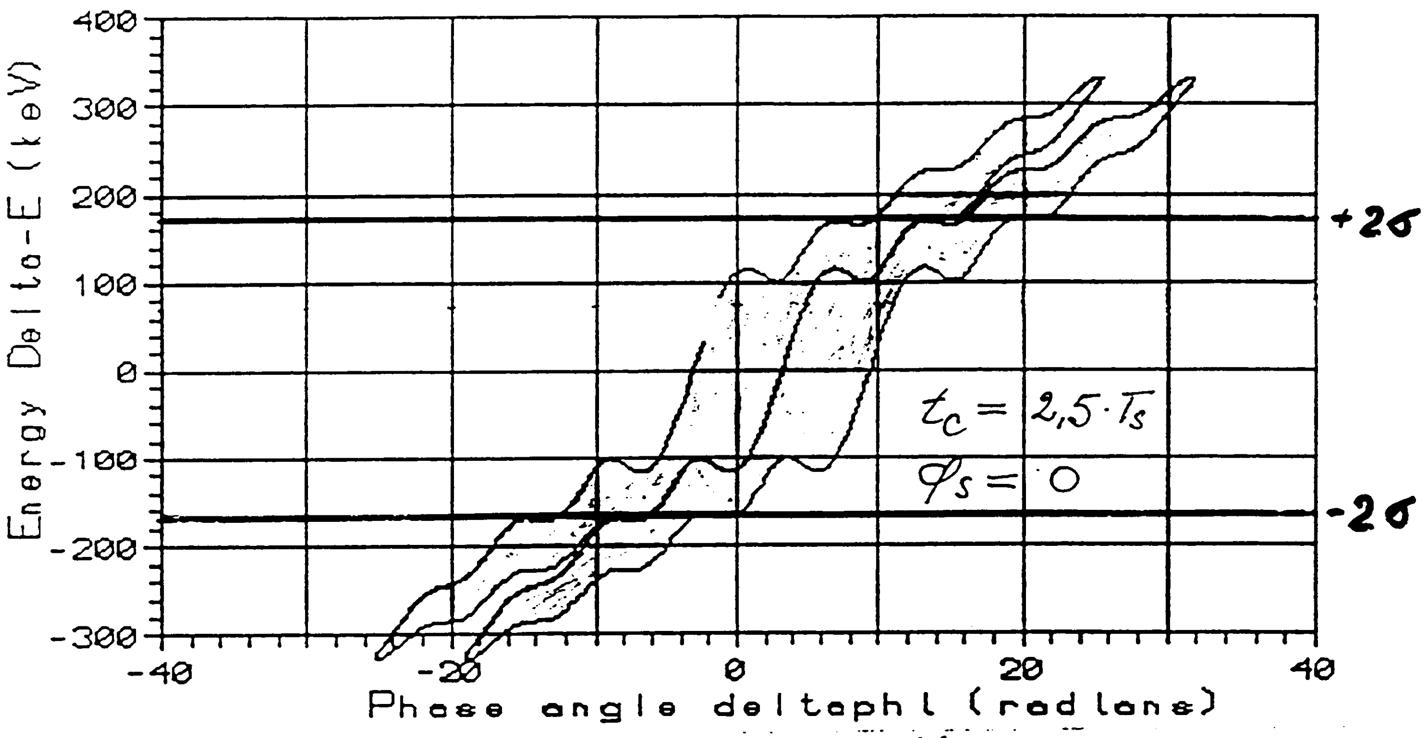


The capture efficiency was 75% as compared to 92% at standard conditions. Since the transverse beam dimensions were small the additional losses were due to the reduced bucket area.

A higher gap voltage increases the bucket area and thus improves the efficiency.

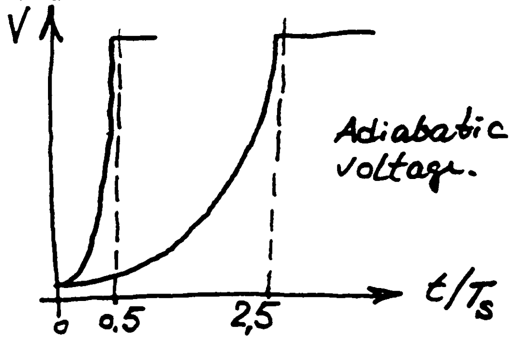
(Ref. PS/HI/ME 92-02 and 92-01).

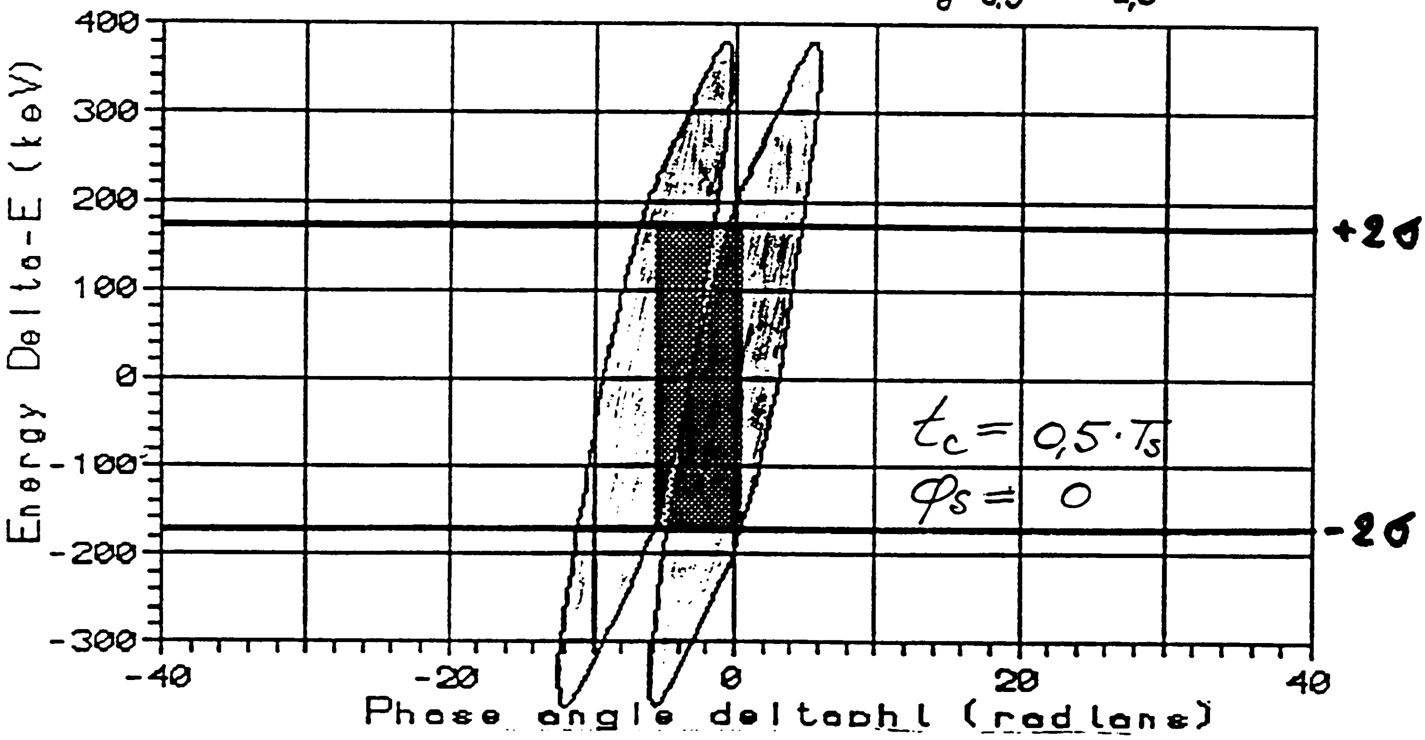
Calculations to find the best method of minimizing losses due to spiralisation.



Capture regions at standard conditions (for 2 buckets)

(T_S is the period of the sync. oscillation at the end of capture).





Capture regions with a compressed adiabatic voltage function. (for 2 buckets)

Ref PS/HI Note 92-09)

Legend to the transparency no 3

Capture regions.

This transparency shows a phase plane immediately before trapping. The curves plotted, are locii of the particles which at the end of the trapping process end up on a separatrix. The locii of two adjacent buckets are shown.

Particles inside the curves will be trapped those outside, not.

The first plot is made for a duration of the capture of 2.5 periods of the synchrotron oscillation. That is, the gap voltage rises "adiabatically" to the nominal gap voltage within this time.

The second plot is made for a 5 times shorter duration. The losses are reasonably low in particular if one considers that they occur to particles in the tails of the density distribution of the injected beam.

The Radial displacement during capture is reduced considerably, in fact by a factor 5 so there is hope that we may reduce the losses due to spiralisation of a beam with large transverse dimensions.

☐ *Magnetic cycle.*

In order to reach a high dB/dt in a short time we may increase the dV/dt of the main magnet supply.

Tests have been made to investigate operation with higher dV/dt. A maximum of 125kV/s is possible with 3 groups of the main power supply active.
(Ref. PS/PO Note 92-8)

☐ *Digital Beam Control.*

The acceleration frequency is generated by a digital generator which is controlled by the B-train so as to keep the beam on the correct orbit.

Advantages:

- We avoid noise problems in the radial loop (which becomes obsolete).
- Is largely made with industrial components standardised with the PS equipment.

Problems:

- Coarsely incremented B-train gives rise to longitudinal losses (problem to be solved). The implementation of a phase loop will solve this problem.

Schedule:

- Test equipment (with protons) for one ring in june 93.
- Final installation at the end of 93.
- Tests with lead ions in 94.

(Ref. PS/RF/Min.91-x4, 30 Mars 1992)

Ion Cooling and Stacking; Foreseen Studies

D.Manglunki

3 February 1993

Abstract

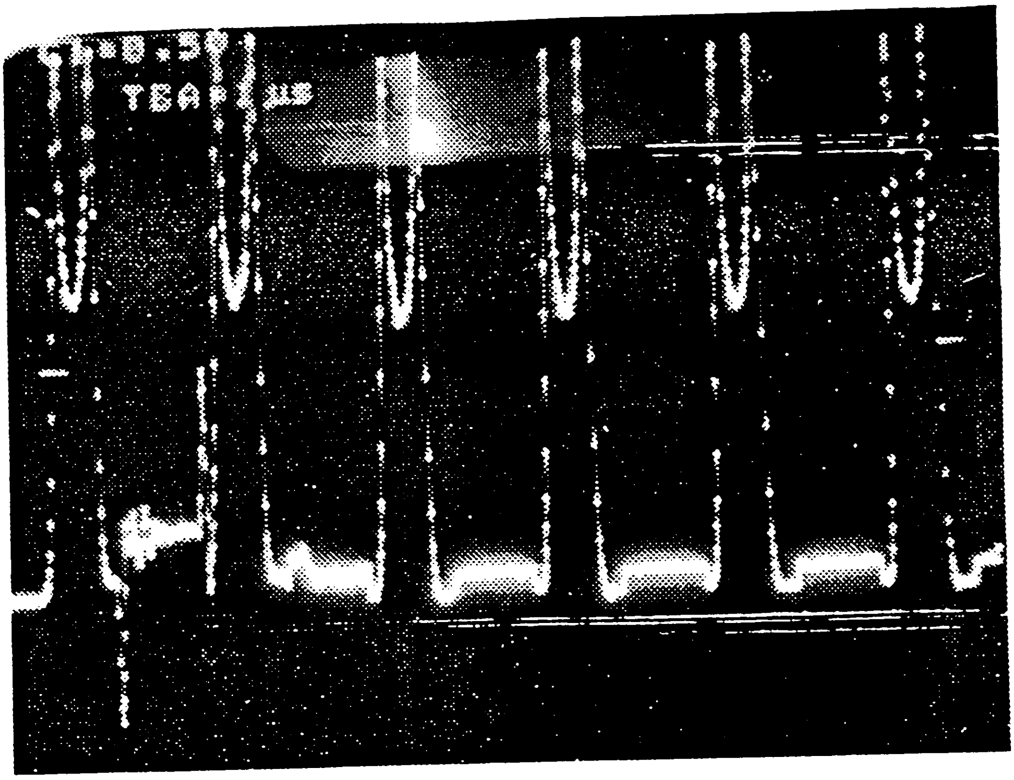
Since the first machine experiments in 1988, oxygen ions have been injected, stacked, cooled, accelerated and ultra-slowly extracted from LEAR. The latest machine experiments were devoted to studying the highest obtainable densities, searching for instabilities, measuring lifetimes and emittances, and especially to measuring the electron cooling times. Extrapolation for cooling times of lead ions is also presented.

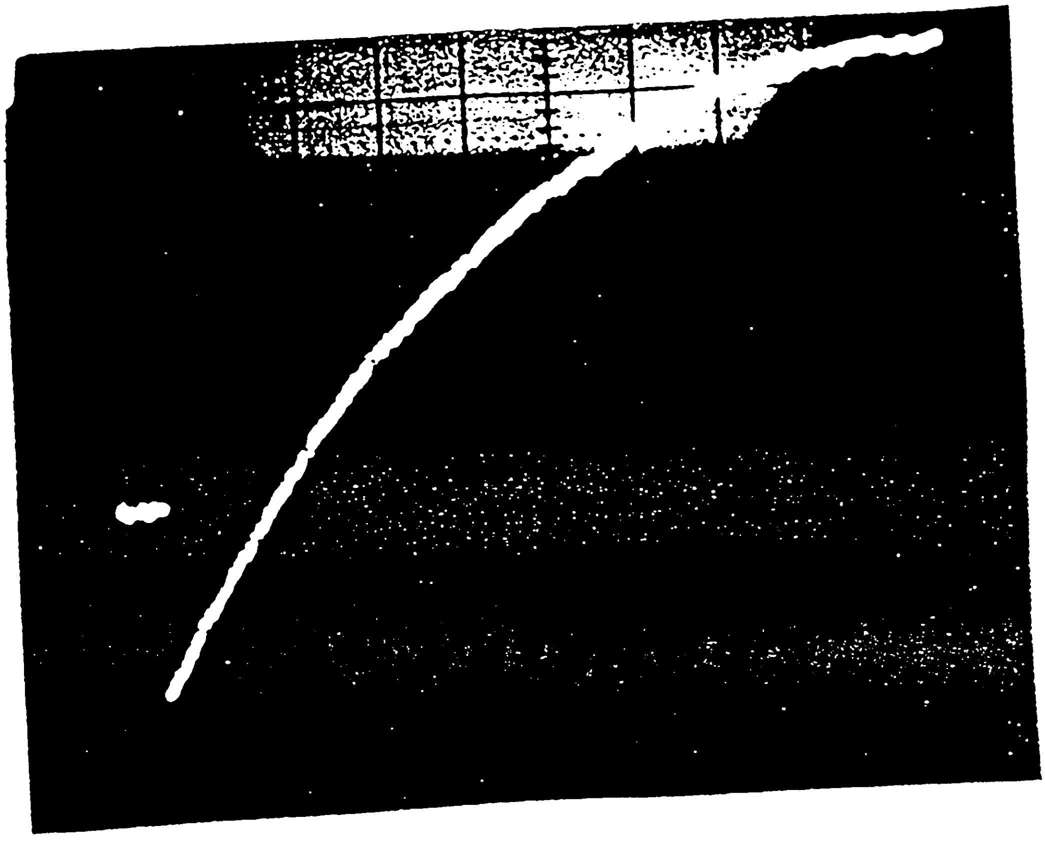
Milestones

- August 1988 ("just for fun")
  - O^{8+} injected at 11.4 MeV/u
  - O^{6+} injected at 7.15 MeV/u
  - First tests of longitudinal stacking ("multi-injection") in LEAR
  - First cooling of heavy ions
- November 1989 (EULIMA)
  - O^{8+} injected at 11.4 MeV/u
  - Up to 1.3 10^{10} stacked charges
  - Acceleration to 438 MeV/u
  - Ultra-slow (15 ') extraction on C1
  - (Unsuccessful) tests of transverse stacking
- May 1992 (LHC)
  - Simplified multi-injection
  - Studies of
    - Maximum density
    - Instabilities
    - Electron cooling
    - Lifetimes
    - Impedance measurements

Multi-injection

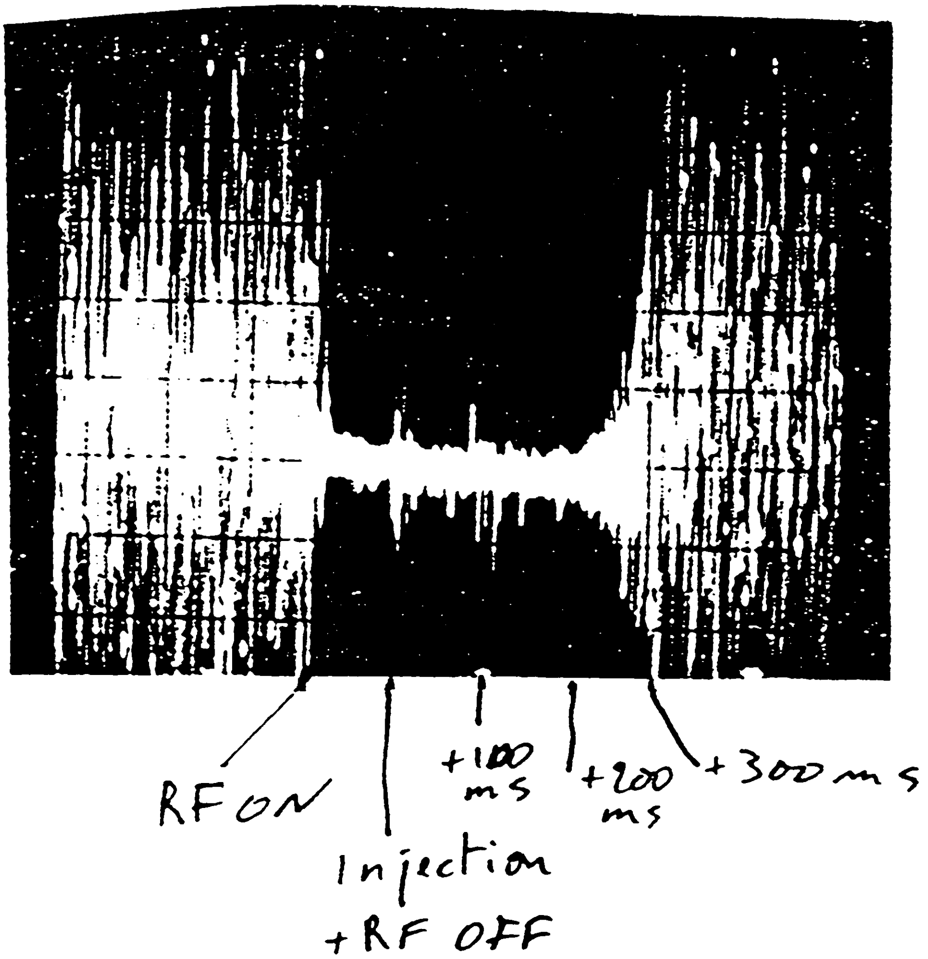
- Method
  - ➨ First batch is injected (2-5 10^8 charges)
  - ➨ Beam is bunched on h=1
  - ➨ New batch is injected on unstable RF phase; coasting beam unperturbed by short kicker pulse
  - ➨ Debunching allows beam merging
  - ➨ Ecool permanently applied during whole process
  - ➨ Restart from bunching on h=1...
- Limitations
  - ➨ Intensity limited by particles leaking out of the bucket, kicked outside the machine during injection
  - ➨ Slow process

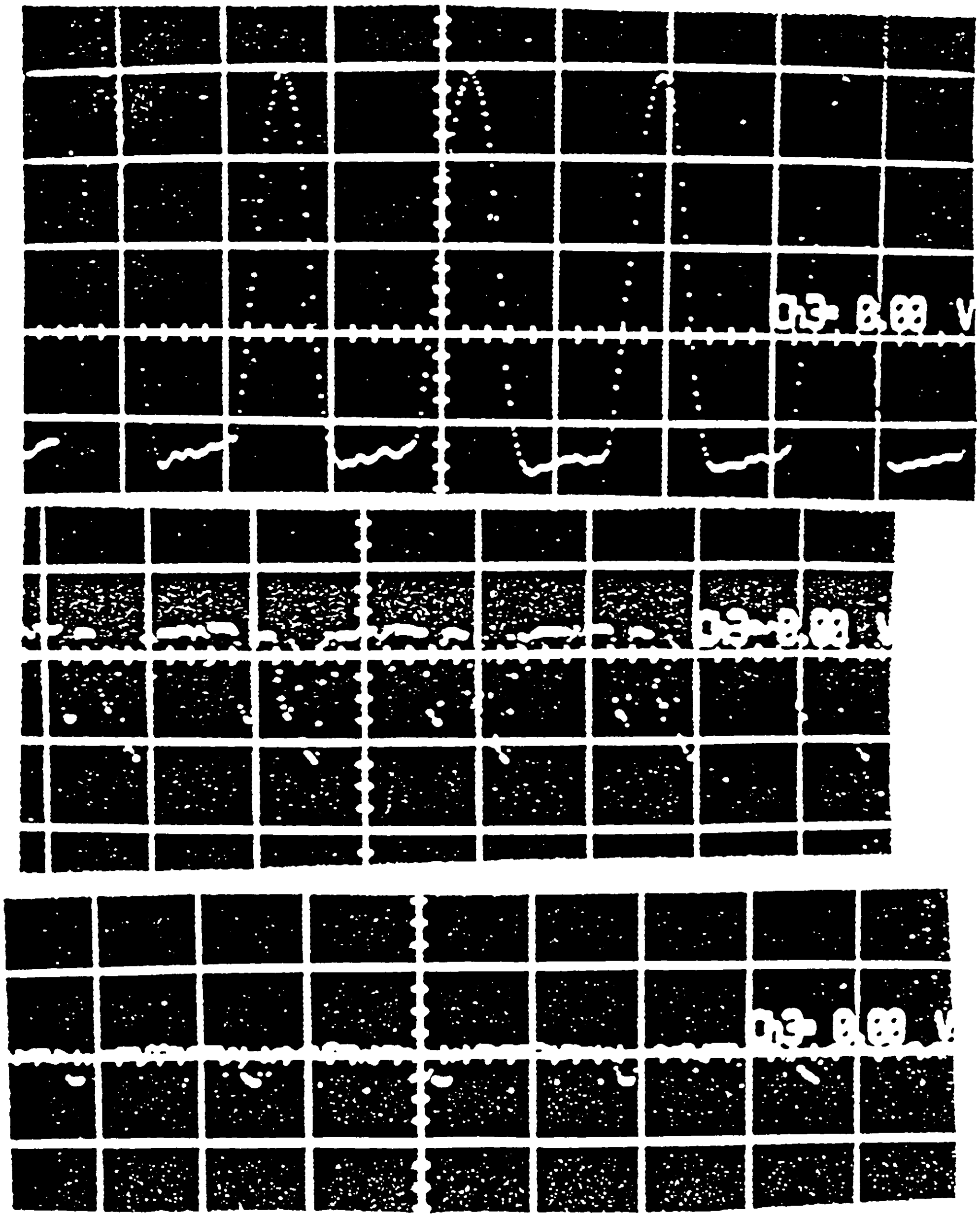




Achieved in 1992

- **Maximum stacked intensities**
  - ➡ 6.4 10^{10} charges of O^{8+}
  - ➡ 4.8 10^{10} charges of O^{6+}
- **Transverse emittances**
  - ➡ For O^{8+} :
    - $\varepsilon_H = 7.0\ \pi$ mm mrad
    - $\varepsilon_V = 12.0\ \pi$ mm mrad
  - ➡ For O^{6+} :
    - $\varepsilon_H = 6.1\ \pi$ mm mrad
    - $\varepsilon_V = 8.2\ \pi$ mm mrad
- **Longitudinal spread**
  - ➡ For O^{8+} : $\Delta p/p = 6\ 10^{-4}$
  - ➡ For O^{6+} : $\Delta p/p = 8\ 10^{-4}$
- **Lifetime measurements**
  - ➡ 90 minutes for O^{8+}
  - ➡ 4.3 minutes for O^{6+} (stripping)
- **Instabilities**
  - ➡ Transverse: beam lost without damper
  - ➡ Longitudinal: self-bunching


RF ON
Injection
+ RF OFF
+100 ms
+200 ms
+300 ms



Comparison of measured cooling times for different ion species; estimation for Pb

Particle	Z^2/A	Beta	Gamma	e- current (A)	Tcool (s)	$\frac{1}{\tau_{cool}}\beta^4\gamma^5\frac{A}{Z^2}\frac{1}{I_{e^-}}$
O8+	4.00	0.155	1.012	0.305	0.600	8.30E-04
O6+	2.25	0.123	1.008	0.15	1.250	5.59E-04
p+	1.00	0.310	1.052	2.4	3.600	1.38E-03
Pb53+	13.50	0.094	1.004	0.057	0.127	8.30E-04
Pb53+	13.50	0.094	1.004	0.057	0.188	5.59E-04
Pb53+	13.50	0.094	1.004	0.057	0.076	1.38E-03

What next ?

- No ions in PS complex in '93 , so ... no ion MD in LEAR either!
- Studies on paper
  - ➡ LHC filling schemes
  - ➡ Multiturn injection (is it needed?)
  - ➡ Acceleration with high dB/dt
- p+ simulations
  - ➡ Study new electron cooler
  - ➡ Test "Russian Stacking"
  - ➡ Impedance measurements
- Wait for Pb ions in autumn '94!

Electron Cooling : Status and Future Developments

G.Tranquille

The electron cooling device has been used routinely in the 'pulsed mode' of operation on the low energy cycle at LEAR and has improved the overall duty cycle of the machine as well as the circulating beam characteristics. Longitudinal stacking of oxygen ions was also made possible with the use of electron cooling and a series of measurements were made to compare the longitudinal cooling times for the different particle types.

For determining the cooling efficiency alignment checks between the ion and electron beams are now possible by using the electrostatic pick-ups, and with protons the neutral hydrogen channel is also used to estimate the beam profile as well as the alignment.

For the future we will install a variable intensity electron gun on LEAR in order to be able to modify on-line the cooling strength. In conjunction with this project we have to change our solenoid compensation scheme and implement a feedback system to correct the electron beam energy when the intensity is varied or the electron beam space charge is neutralised.

Electron Cooling : Status and Future Developments

1992 was devoted to the reliable operation of the electron cooling device and to the development of the relevant diagnostics for use in determining the efficiency of the electron cooling process.

-'pulsed mode' of operation was used routinely for low energy operations (≤308 MeV/c)

-'time sharing' operation for PS 196 (Penning trap)

- longitudinal stacking of oxygen ions (see Django)

-longitudinal cooling time measurements from the analysis of the Schottky power density evolution when cooling is switched on

-electron and ion trajectories measurement for beam alignment check

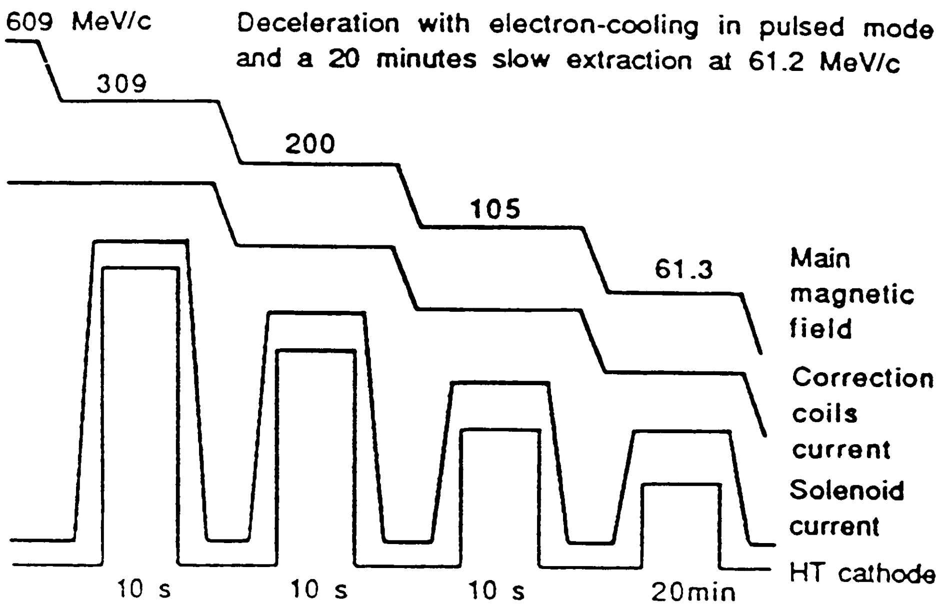
-neutral hydrogen channel used for alignment checks and profile measurements

-beam stability diagnostics via BTF measurements (see Uwe)

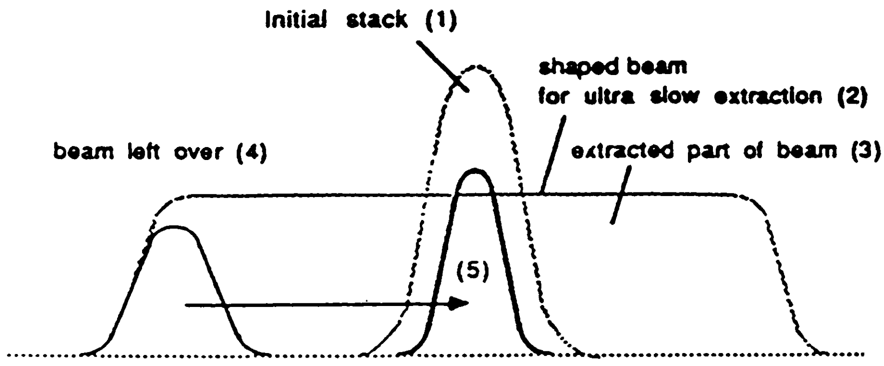
Just before Xmas the linear test bench setup was successfully operated.

Typical parameters for electron cooling

Ion beam momentum (MeV/c/n)	116.0	147.0	308.6	200.0	105.0	61.2
Ion type	O^{8+}	O^{6+}	p/$\bar{p}$	p/$\bar{p}$	p/$\bar{p}$	p/$\bar{p}$
Electron beam energy (keV)	4.12	6.22	27.2	11.78	3.27	1.1
Electron beam current (A)	0.305	0.150	2.4	0.640	0.094	0.019
Solenoid field (G)	173.	216.	448.	293.	154.	90.



Typical cycle for low energy operation



Principle of the time-sharing mode of operation.
At the end of stochastic extraction, electron cooling sets the beam left over(4) to the right frequency for deceleration(5).

Comparison of electron and stochastic cooling

	e-cooling	stochastic cooling
deceleration time to 61.2 MeV/c	7 minutes	20 minutes
final $\Delta P/P$	0.05%	0.2%
transverse emittances	3π mm mrad	10π mm mrad
lifetime at 105 MeV/c	24 hours	6 hours
lifetime at 61.2 MeV/c	30 minutes	5 minutes

Because of electron cooling one sees that :

- the emittances in each plane are substantially reduced
- the beam lifetime is increased
- the overall duty cycle is significantly improved.

In 1993 we have four major projects :

1. a variable intensity electron gun for the on-line control of the cooling force

2. a new compensation scheme for the electron cooler solenoid and toroids

3. an electron beam neutralisation scheme to facilitate the operation of the new gun.

4. a feedback system to correct the electron beam energy when the electron beam intensity is varied or the electron beam is neutralised

On the test bench we will test different collector configurations, carry on the beam neutralisation studies (we hope to have a spare set of electrodes during the year), and continue our electron beam transverse velocity measurements started at CAPT Lipetsk.

The variable intensity electron gun

- three electrode gun

  cathode with Pierce shield

  steering anode (controls the beam intensity)

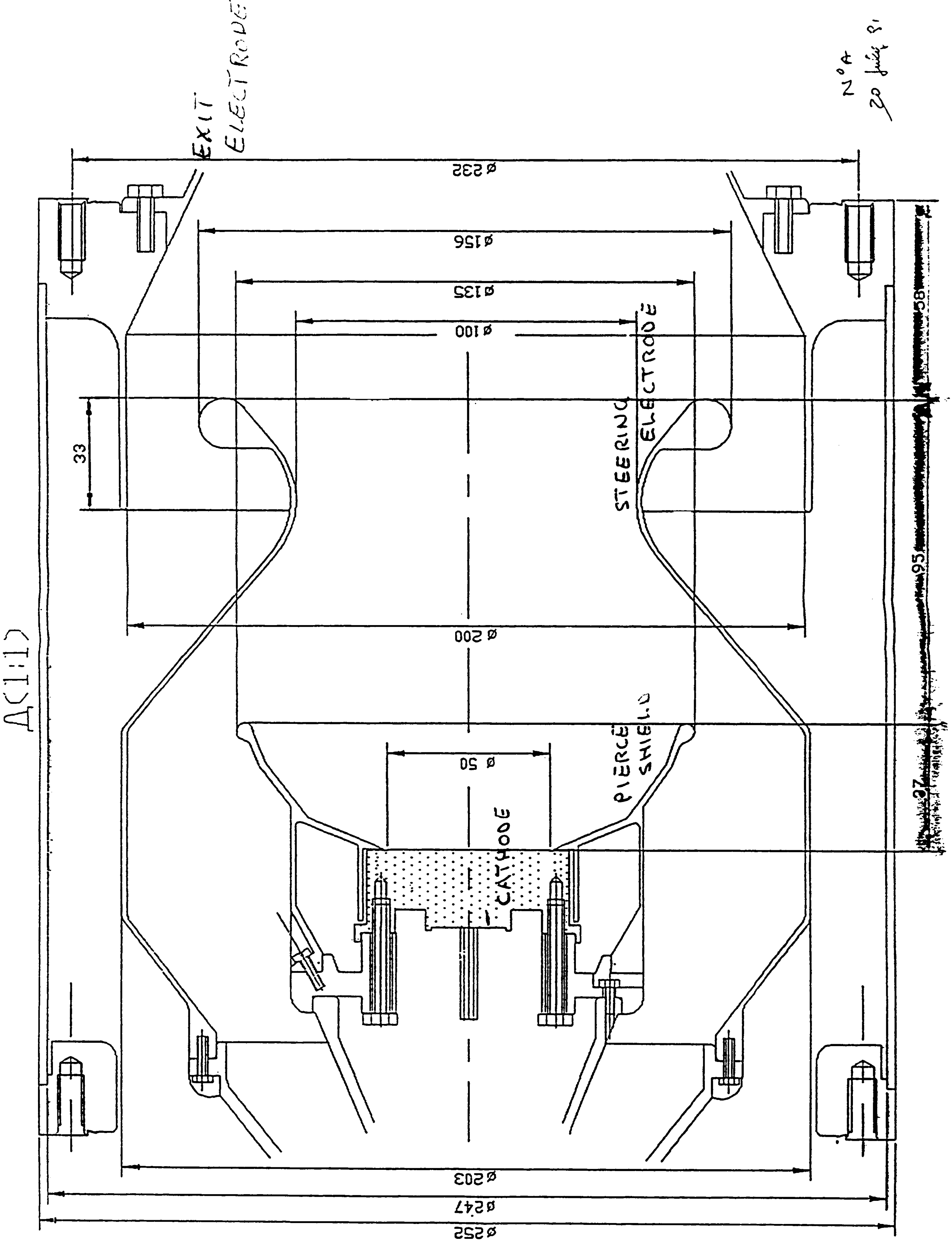
  exit anode (controls the final energy)

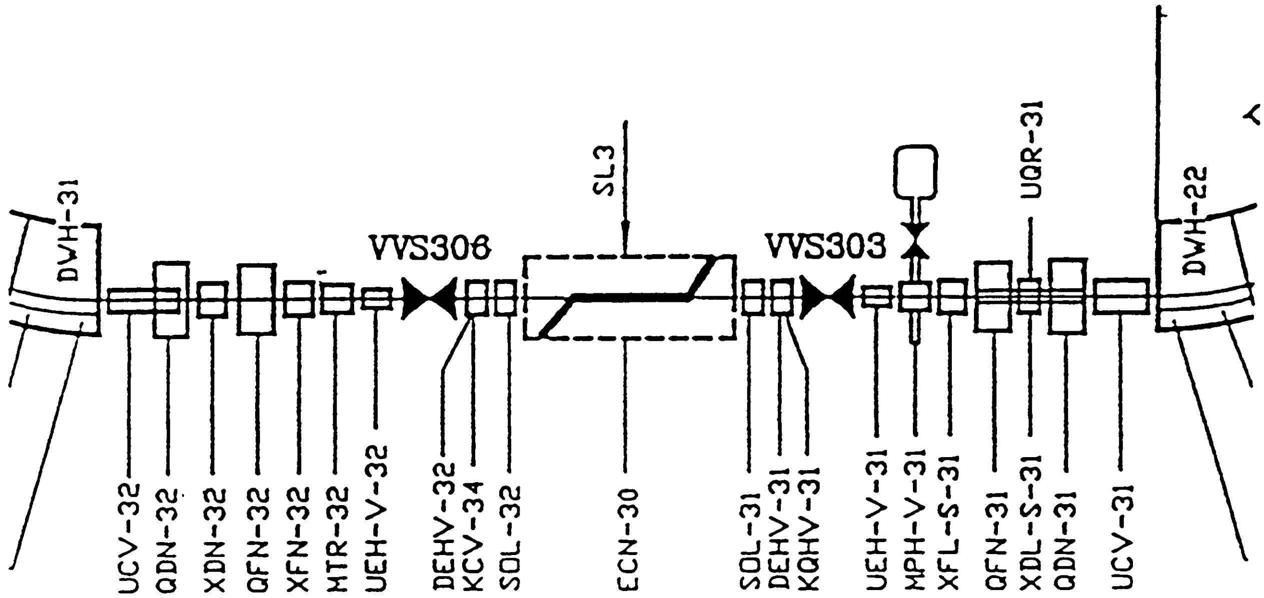
- only two HT power supplies needed (steering anode can be varied on-line , ON/OFF possible)

- fixed magnetic field (operation easier but the field has to be high => may have problems at low energies)

Main parameters of the new gun

electron energy	<=2.3 keV	2.3 - 7 keV	7 - 20 keV	- 30 keV
gun perveance	.125-5	.125-5	.125-1	.125-.5
electron current	.01-.53 A	.07-2.93 A	.35-2.85 A	.65-2.6 A
steering electrode voltage	-1.45 to 8.1 kV	-4.3 to 25.6 kV	-12.5 to 11.5 kV	-18.6 to 17.3 kV


A(1:1)
EXIT ELECTRODE
STEERING ELECTRODE
PIERCE SHIELD
CATHODE
ø232
ø156
ø135
ø100
ø200
ø50
ø203
ø247
ø252
33
58
95
27
N°A



DWH-31
VVS306
SL3
VVS303
UQR-31
DWH-22
UCV-32
QDN-32
XDN-32
QFN-32
XFN-32
MTR-32
UEH-V-32
DEHV-32
KCV-34
SOL-32
ECN-30
SOL-31
DEHV-31
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UEH-V-31
MPH-V-31
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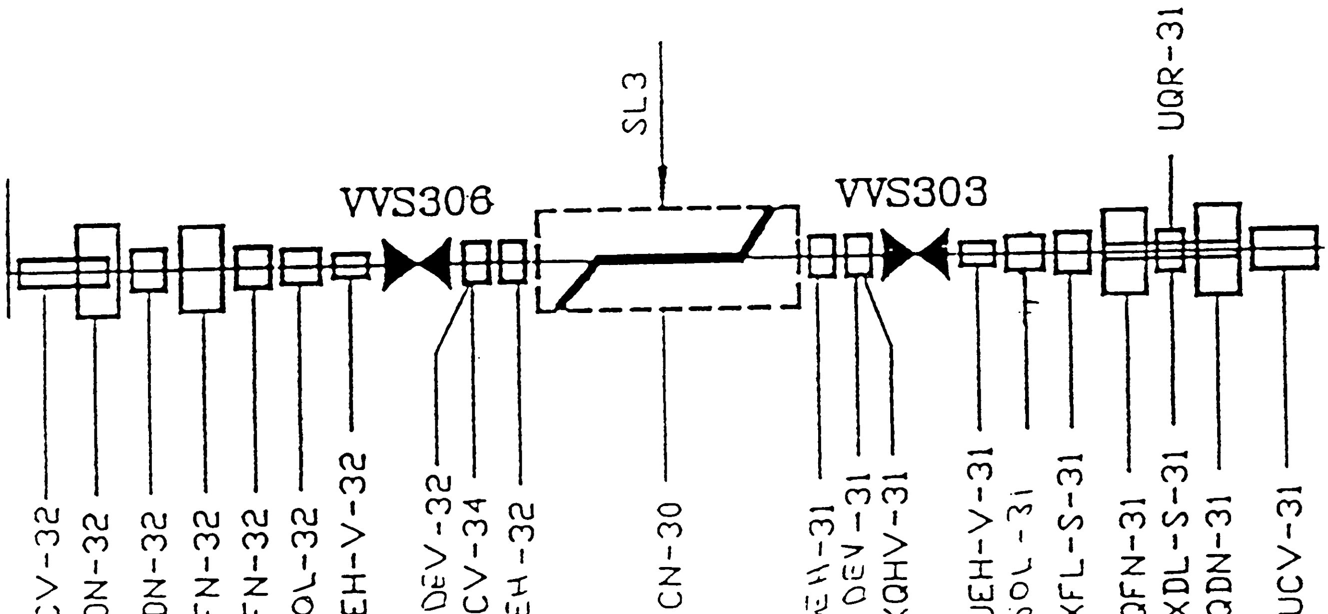
QFN-31
XDL-S-31
QDN-31
UCV-31



SL3
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DEV-32
KCV-34
DEH-32
ECN-30
DEH-31
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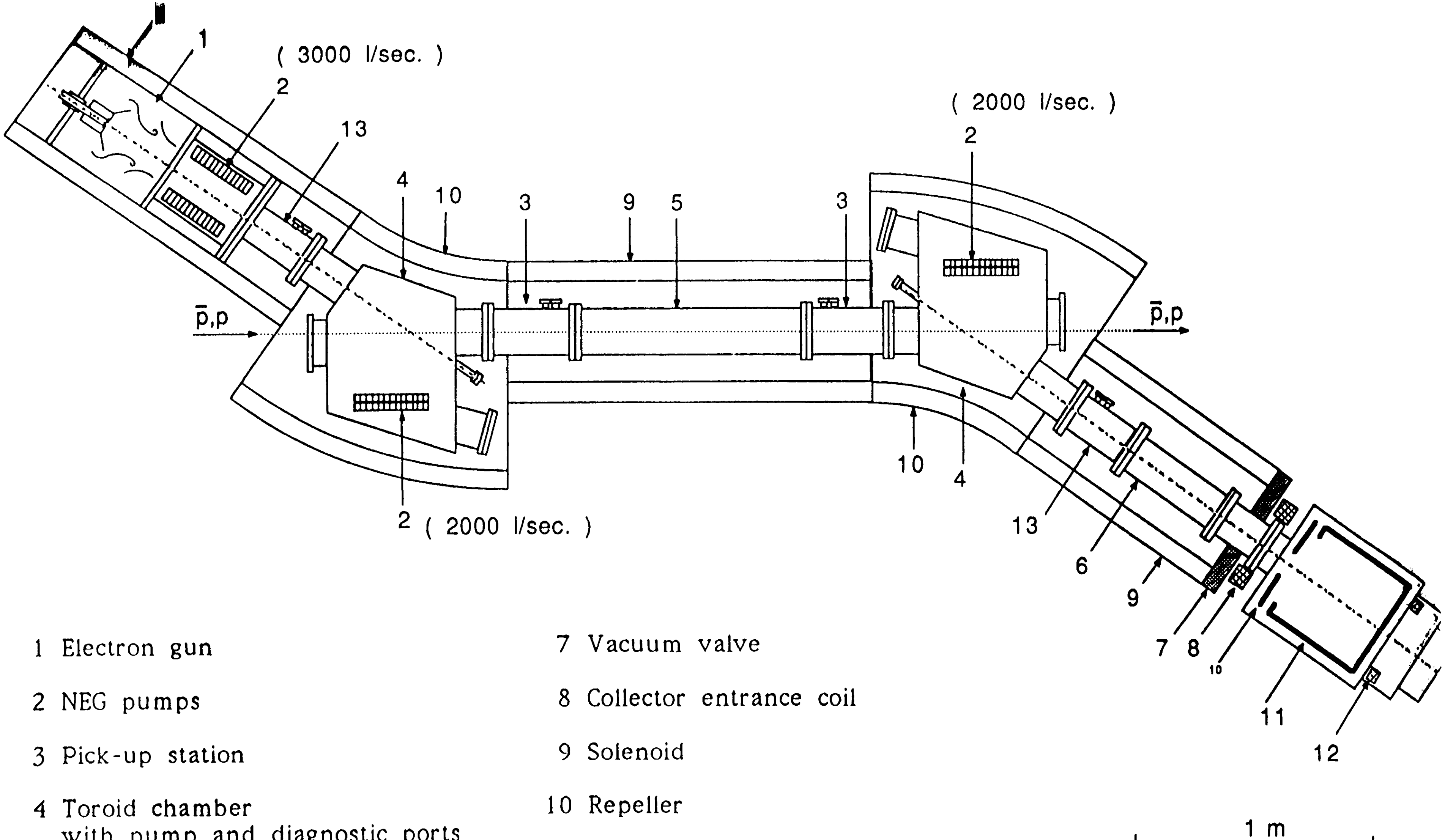


1 Electron gun

2 NEG pumps

3 Pick-up station

4 Toroid chamber
with pump and diagnostic ports

5 Central drift tube

6 Collector drift tube

7 Vacuum valve

8 Collector entrance coil

9 Solenoid

10 Repeller

11 Collector

12 Collector end coil

13 Neutralisation electrodes

Chohan/03Feb93/00

AAC Performance, Problems and Near-Future Plans

V. Chohan

Abstract

After reviewing the definition of the Performance of the Antiproton Source Complex of target area, AC and AA rings, it is proposed to re-examine this definition in light of the LEAR-only operation. In particular, the dependency attribution factors to global production quantity and particular quality in operation identified. Using the two quality criteria of 12E9 /hr/Cycle antiproton storage and the Complex Efficiency from AC Injection to final AA storage, comparisons are made between 1990 Collider run period to August 1992, as well as comparisons between August and December 1992. Using the new criteria, it is shown that it has been possible to achieve reasonable performance in 1992, but serious degradation has been observed towards the end of the year. The general and particular issues related to these problems, highly dominated by multifarious stochastic cooling systems, are elucidated and the near future activities and plans that need to be seriously pursued identified.

Chohan/03Feb93/01

AAC PERFORMANCE, PROBLEMS & NEAR FUTURE PLANS

Performance Definitions:

The Final Figure of Merit has always been the Number of Antiprotons Stored in the AA Stack on a shot to shot basis.

However, the quantity of antiprotons required for physics is NOT the same from 1992 onwards compared to 1989-90 in the heyday of the Collider; hence, the so-called Performance should be split into two broad lists of factors of dependency attribution , i. e., based on Quantity & Quality and then, the Performance Criterion re-examined.

QUANTITY FACTORS

- PS Primary beam Intensity on target
- Collector Lens Used

QUALITY FACTORS

- Goodness and quality of 26 GeV bunches impinging the target (no leaky buckets & beam between target or jitter & missing bunches etc..)
- Goodness of Bunch Rotation in AC :(the 'pseudo <dp> fast cooling') using h=6 two rf cavities
- The true AC Cooling Systems (9)
- h=1 rf system in AC
- Efficient beam transfer AC to AA
- Pre-cooling Systems(2) in AA
- h=1 rf system in AA
- Stack tail cooling system in AA
- Stack Core Cooling Systems of AA

Reminder :

1990: Operational ~17E9 per hour per prod. cycle

can be reduced to

1991/2: Operational ~12E9 per hour per prod.cycle

QUANTITATIVELY without forgoing QUALITY

So, the Performance Criterion in the LEAR-only era should be based on Ideal Stacking Rate per Hour, per cycle of the order of 12E9/hr

AND

Reasonable overall AC Injection to AA Stacked Efficiency on a shot to shot basis.

Chohan/03Feb93/03

PERFORMANCE INDICATORS & DEPENDENCY IN A SNAPSHOT

1990-11-15-08:42:49

STACK 487.26E9 PBARS ACCUMULATION YLD*1E7: 43.87
Normalised Accuml. Rate:105.321E9/HR
PS-INT:17.07E12 ACCUMULATION: 53.265E9/HOUR
TF9012:16.28E12 : 71.014E6/SHOT
TF9053:16.01E12 SUPERCYCLE 3.0/6 CYCLES
BEAM TO TARGET 98% Missing SRF 1.12
AC INJ:137.86E06
TF5309:4136 E07 pions
AA INJKI:216.9 KV SUM
AA SPTM 3869.5 AMP

PS Intensity & Intensity on Target

Stacking Rate per shot & per Hour

Dependency on no. of PS Cycles per ~~hour~~ Supercycle

GENERAL AAC PERFORMANCE CHECK
1990-11-14-22:10:12 STACK 3.83E11

	Q	95% EMITTANCE, p mm mrad	
	AT PEAK	AT PEAK	AVERAGE
HOR.	2.255	1.8	2.1
VERT.	2.2607	1.2	1.4

TRANSFORMERS	
PS-IP	16.87
TF9012	16.04
TF9053	15.81
TF5309	4324

PS Intensity & Intensity on Target

"Goodness" of AA Stack Core in H, V and dp

PEAK AT 1855.06 kHz
MEAN AT 1855.08 kHz, rms WIDTH 105 Hz

AC EMITTANCE	
H 4	V 4

"Goodness" of bunch Rotation& all Cooling Effort in AC : (dp, H & V)

	ACAA			ACN			ACATL	
YIELD	57.9	EFF.		57.9	EFF.		56.7	EFF.
AC 5.3	9.01	1.00		9.18	1.00		8.97	1.00
AC 1.5	7.52	.83		7.62	.83		7.46	.83
AC 5.3				6.93	.75	.90		
AC .18				6.45	.70	.93		
AA .21	5.90	.65	.78					
PR .21	6.72	.74	1.13					
PR.052	5.80	.64	.86					
ST .21	5.74	.63					.07	0
ST.052	3.75	.41	.64					
STACKED							7.38	.82
LOSS E7/h				27				

Yield: A figure of Merit For the Collector Lens

Efficiency of Bunch Rotation

"goodness" of Pre-cooling and St.tail systems

Efficiency of beam transfer AC to AA

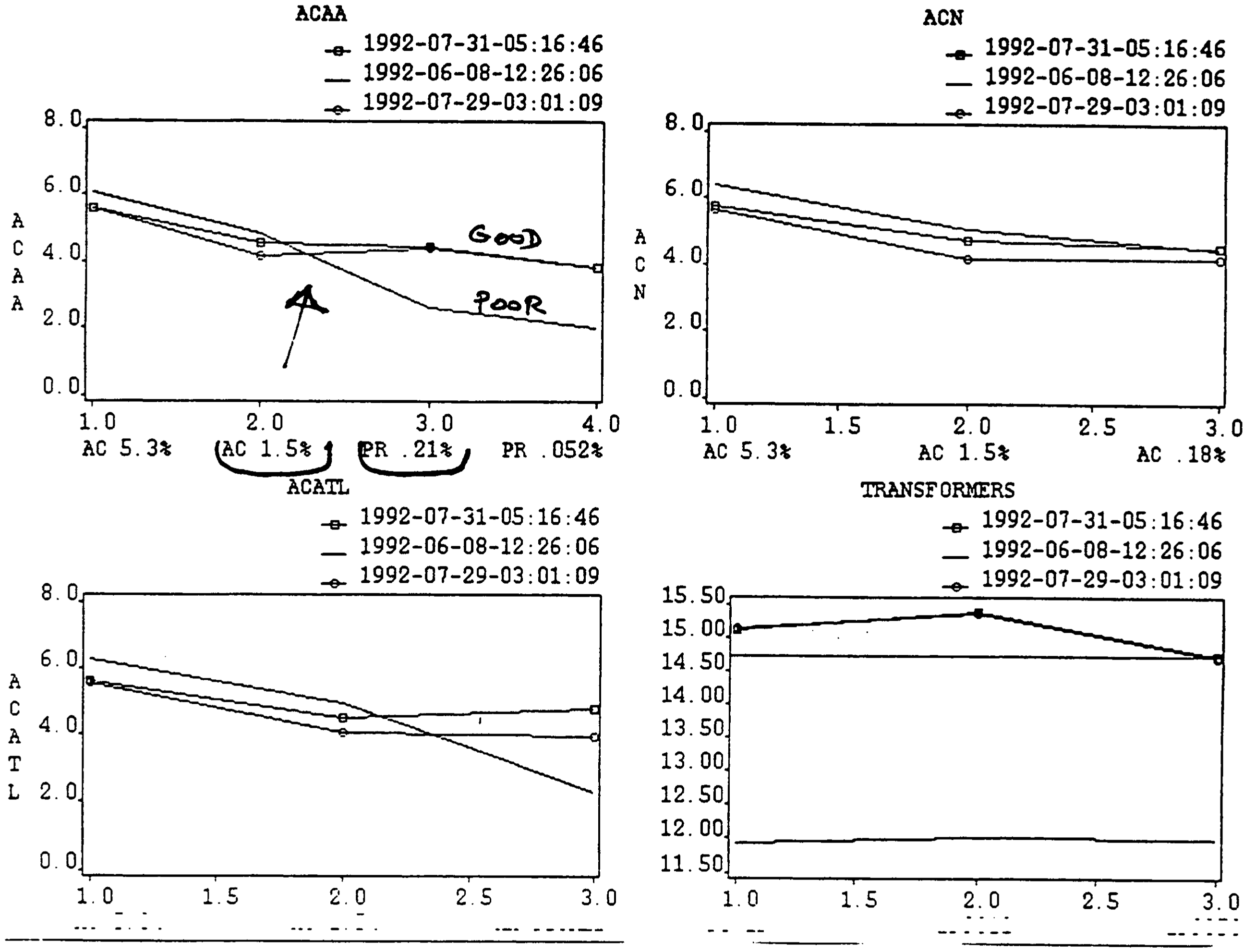
Losses, "leakage" in Tail

Overall Efficiency: AC Inj to storage in AA Core

Overall Loss Rate

FINAL FIGURE OF MERIT: Storage in AA per shot

GRAPHICAL VISUALISATION OF IMPROVEMENT IN AC TO AA TRANSFER EFFICIENCY



1992-07-31-09:44:24

STACK 484.69E9 PBARS ACCUMULATION YLD*1E7 33.19
Normalised Accuml. Rate 72 614E9/HR
PS-INT:14.95E12 ACCUMULATION: 12 102E9/HOUR
TF9012:15.27E12 48 409E6/SHOT
TF9053:14.64E12 SUPERCYCLE 1 /6 CYCLES
BEAM TO TARGET 95% Missing SRF 4.95
AC INJ: 82.82E06
TF5309:2484.6E07 pions
AA INJKI:227.2 KV SUM
AA SPTM 3857.4 AMP

PLS EVENTS: 114

LI LENS:483 8 KA & 4 19 KV

GOOD & REASONABLE PERFORMANCE

GENERAL AAC PERFORMANCE CHECK
1992-07-31-05:16:46 STACK 4.76e+11

	Q AT PEAK	95% EMITTANCE, p mm mrad AT PEAK	AVERAGE
HOR.	2.2549	2.9	2.9
VERT.	2.2608	1.7	1.7

TRANSFORMERS	
PS-IP	15.09
TF9012	15.36
TF9053	14.72
TF5309	2345

PEAK AT 1855.13 kHz
MEAN AT 1855.13 kHz, rms WIDTH 105 Hz

AC EMITTANCE	
H 5	V 3

	ACAA			ACN			ACATL	
YIELD	38.0	EFF.		39.2	EFF.		37.9	EFF.
AC 5.3%	5.55	1		5.73	1		5.58	1
AC 1.5%	4.50	0.81		4.66	0.81		4.50	0.80
AC 5.3%				4.86	0.84	1.04		
AC .18%				4.44	0.77	0.91		
AA .21%	3.99	0.71	0.88					
PR .21%	4.40	0.79	1.10					
PR.052%	3.80	0.68	0.86					
ST .21%	3.76	0.67					0.01	0.00
ST.052%	2.68	0.48	0.70					
STACKED							4.75	0.85
LOSS E7/h				84				

QUANTITATIVE COMPARISON
NOV-1990 & AUG-1992

GENERAL AAC PERFORMANCE CHECK
1990-11-14-22:10:12 STACK 3.83E11

	Q	95% EMITTANCE, p mm mrad	
	AT PEAK	AT PEAK	AVERAGE
HOR.	2.255	1.8	2.1
VERT.	2.2607	1.2	1.4

TRANSFORMERS	
PS-IP	16.87
TF9012	16.04
TF9053	15.81
TF5309	4324

PEAK AT 1855.06 kHz
MEAN AT 1855.08 kHz, rms WIDTH 105 Hz

AC EMITTANCE	
H 4	V 4

	ACAA			ACN			ACATL	
YIELD	57.9	EFF.		57.9	EFF.		56.7	EFF.
AC 5.3	9.01	1.00		9.18	1.00		8.97	1.00
AC 1.5	7.52	.83		7.62	.83		7.46	.83
AC 5.3				6.93	.75	.90		
AC .18				6.45	.70	.93		
AA .21	5.90	.65	.78					
PR .21	6.72	.74	1.13					
PR.052	5.80	.64	.86					
ST .21	5.74	.63					.07	0
ST.052	3.75	.41	.64					
STACKED							7.38	.82
LOSS E7/h				27				

Even though the Quantity factors are very different, the Quality factor→Overall Eff. is reasonable.

GENERAL AAC PERFORMANCE CHECK (REMOVED POOR SHOTS)
1992-08-23-18:08:58 STACK 7.45E11

	Q	95% EMITTANCE, p mm mrad	
	AT PEAK	AT PEAK	AVERAGE
HOR.	2.2545	3.7	3.7
VERT.	2.2605	1.4	1.6

TRANSFORMERS	
PS-IP	14.84
TF9012	15.39
TF9053	14.94
TF5309	2313

PEAK AT 1855.15 kHz
MEAN AT 1855.12 kHz, rms WIDTH 121 Hz

AC EMITTANCE	
H 6	V 4

	ACAA			ACN			ACATL	
YIELD	41.9	EFF.		41.1	EFF.		41.2	EFF.
AC 5.3	6.28	1.00		6.12	1.00		6.15	1.00
AC 1.5	5.20	.82		5.05	.82		5.08	.82
AC 5.3				4.77	77	.94		
AC .18				4.48	.73	93		
AA .21	4.54	.72	.87					
PR .21	5.35	.85	1.17					
PR	4.61	.73	.86					
ST	4.69	.74					09	.01
ST.052	3.31	.52	.71					
STACKED							4.45	.72
LOSS E7/h				461				

Notable Points:

- **PS Primary Intensities : ~1.7E13 vs 1.5E13 so fewer pbars**
- **Yields : 34 mm Lithium Lens vs. Horn so reduced collection hence, an overall reduction in stacking rate per shot expected**
- **Reasonable Overall Efficiency but marked Loss Rate in 1992**
- **Larger Core Emittances & rms width in 1992**
- **Larger AC Horiz. emittance in 1992**

QUALITATIVE COMPARISON
AUG-1992 & DEC-1992

GENERAL AAC PERFORMANCE CHECK (REMOVED POOR SHOTS)
1992-08-23-18:08:58 STACK 7.45E11

	Q	95% EMITTANCE, p mm mrad	
	AT PEAK	AT PEAK	AVERAGE
HOR.	2.2545	3.7	3.7
VERT.	2.2605	1.4	1.6

TRANSFORMERS	
PS-IP	14.84
TF9012	15.39
TF9053	14.94
TF5309	2313

PEAK AT 1855.15 kHz
MEAN AT 1855.12 kHz, rms WIDTH 121 Hz

AC EMITTANCE	
H 6	V 4

	ACAA			ACN			ACATL	
YIELD	41.9	EFF.		41.1	EFF.		41.2	EFF.
AC 5.3	6.28	1.00		6.12	1.00		6.15	1.00
AC 1.5	5.20	.82		5.05	.82		5.08	.82
AC 5.3				4.77	.77	.94		
AC .18				4.48	.73	.93		
AA .21	4.54	.72	.87					
PR .21	5.35	.85	1.17					
PR.[illegible]	4.61	.73	.86					
ST [illegible]	4.69	.74					.09	.01
ST.052	3.31	.52	.71					
STACKED							4.45	.72
LOSS E7/h				461				

reasonable

GENERAL AAC PERFORMANCE CHECK (REMOVED POOR SHOTS)
1992-12-10-19:55:22 STACK 7.70E11

	Q	95% EMITTANCE, p mm mrad	
	AT PEAK	AT PEAK	AVERAGE
HOR.	2.2547	3.5	4.5
VERT.	2.2599	2.0	2.4

TRANSFORMERS	
PS-IP	14.99
TF9012	15.52
TF9053	15.06
TF5309	2210

PEAK AT 1855.08 kHz
MEAN AT 1855.12 kHz, rms WIDTH 121 Hz

AC EMITTANCE	
H 6	V 6

	ACAA			ACN			ACATL	
YIELD	40.6	EFF.		41.7	EFF.		41.3	EFF.
AC 5.3	6.13	1.00		6.20	1.00		6.23	1.00
AC 1.5	4.74	.77		4.74	.76		4.80	.77
AC 5.3				4.35	.70	.91		
AC .18				4.01	.64	.92		
AA .21	4.67	.76	.98					
PR .21	5.07	.82	1.08					
PR.052	4.73	.77	.93					
ST .21	3.65	.59					.16	.02
ST.052	2.91	.47	.61					
STACKED							2.90	.46
LOSS E7/h				554				

Poor !

Notable Points:

- Similar Primary Intensities and Yields with same Collector
- Similar Measurement conditions with 2/3 prod. cycles regime
- Similar value of Stored Beam in AA
- Poorer Bunch Rotation Efficiency in Dec.'92
- AC Emittances still not as notable as in 1990
- Core Transverse Emittances worse in Dec.'92
- Loss Rate slightly worse in Dec. (>1.1E7/shot) compared to Aug. (0.9E7/shot) but would not sufficiently explain the poor overall efficiency, hence a pointer to problems in AA Cooling Systems

Chohan/03Feb93/06

CERTAIN MAIN ISSUES

1. It cannot be stated too often that the AAC is a complex of storage rings (with multifarious Cooling Systems) and all that entails, i.e. CUMULATIVE EFFECTS that finally get reflected in the final Figure of Merit, the stacking rate. Optimisation of any system or process usually depends on the preceding process, hence a sequential manner in tackling problems and optimisation is more than often mandatory.
2. Just because we can keep the LEAR clients happy doesnot necessarily mean that the AAC is functioning in a qualitatively good manner; often tendency to compensate quality by quantity, complacency in permitting losses through the chain (starting from PSB ?...to final stack Core !), etc . This is eventually CERN's financial loss because finally, the uptime for production & storage is that much longer.
3. Sequential systems and their inter-dependency, needing continuous follow-up by experts who are not necessarily all in the main AAC group or even in the Division and who are having different priorities; for example, in March/April '92, being last in priority after other beams was a serious hinderance in good functioning of the complex for that run. Eventually, the Operation Team (whether its the shift technician or the Supervisor or, both !) GIVES up and lets things run poorly.
5. For the last run of 1992, poor functioning could be attributed to gradual degradation of Cooling Systems and being too often running in Economy modes so experts could not be chased with problems - a case of compensating quality by quantity.

Chohan/03Feb93/07

PARTICULAR RECENT PROBLEMS & OBSERVATIONS

1. "Cooldown" Tunes do work for reducing transverse emittances before transfers but NOT for stacking beyond 8E11 like in 1990

3. Best "loss control" possible only at "accumulation" tunes with a new value of skew current (indirect coupling compensation ?..)

3. Large losses during Stacking as well as during Economy Mode, particularly above ~ 5.5E11 , as was done often Aug-Dec. 1992. With more power in 2-4 GHz L-core system , one can stack beyond 7.5E11 but with very high losses.
   Loss figures during stacking & with Accum. Tunes :

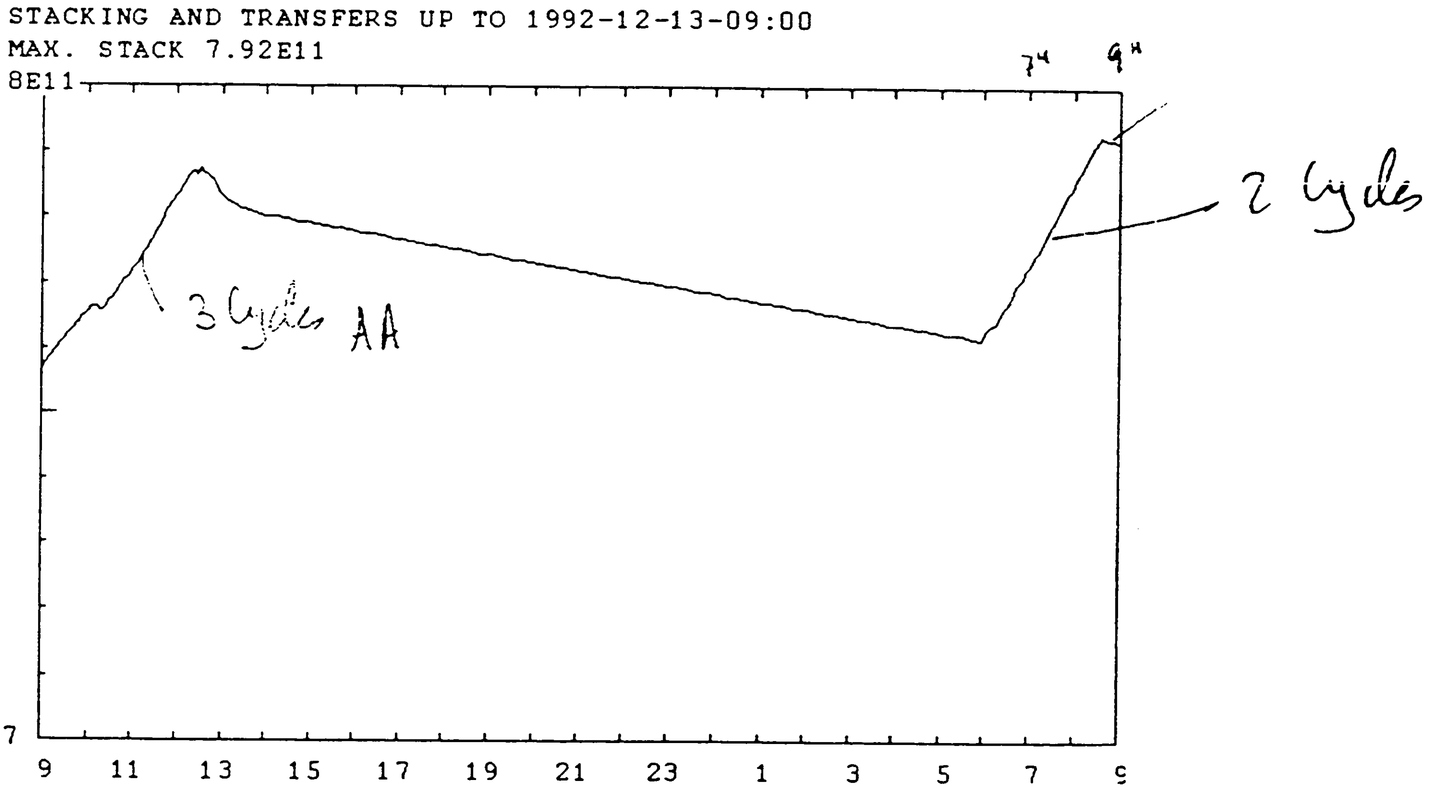
   >1.3 E7 /shot or ~ 6 to 7E9/hour with 2/3 prod. cycles
   >1.9 E7 /shot or > 11 E9/ hour with 3/3 prod. cycles

   Losses in Economy Mode::
   at 7 or 8E11 in core: ~ 1E9 /hr with QSK at -7.4 A
   ~1.4E9 /hr with QSK at -6.4 A (nominal)
   at 9E11 in core: ~ 2E9 /hr with QSK at -7.4 A

4. Stacking Rate per shot WORSENS if we have 3 prod. cycles instead of 2, implying cooling saturation. This, observed in the last run at values > 5 to 6E11 in core. For these higher stacks, the stacking rate per hour, per cycle was rather mediocre, ~ 6 to 7.5E9 instead of 10 or 12E9 /hr/cycle early in the year.

Chohan/03Feb93/07b

WORSENING ACCUMULATION FOR THREE PRODUCTION CYCLES INSTEAD OF TWO, IMPLYING COOLING SATURATION AT ~ 8E11



Chohan/03Feb93/08

NEAR FUTURE ACTIVITIES & PLANS

1. During February, complete hardware checks of each of the eighteen or so cooling systems. This sort of activity is primordial , otherwise , we would start-up in March in the same poor state as we left off in December. Some Amplifiers have been left off for a long while now & need serious time-intensive attention. 1 day/system could easily mean the whole month of February.

2. NORMAL POLARITY initially at start-up with Setting-Up/ Adjustments, tests, commissioning or improvement of certain diagnostic instrumentation , eg., new digital 'scope, beam blow-up , etc

3. NORMAL POLARITY, both AC & AA Rings:
   (a) Longitd. cooling systems in AC: loop gain tests & checks, notch filters , phase compensation etc... . Need pbars (few E6 particles) on a shot to shot basis like normal running. Estimated at least 3 days of development.
   (b) Checks of AA Core Cooling Systems with a small stack of 2E11, BTF's etc. Need Stack build-up time + at least 2 days of development work.

4. REVERSE POLARITY IN AC Ring only::
   (a) Transverse Cooling systems in AC: thorough, extensive check-outs, probably first time since a few years, so nearly like starting with a new machine, with loop gain tests etc.. At least, 2 'long' days estimated for this work.
   (b) Studies pertaining to observed longitudinal instabilities in the AC, i.e., studies of longitudinal impedance of the AC Ring , with and without the presence of Cooling. Eventual evaluation of (Z/n) may have heavy ion cooling implications for the AC ring. Time Estimation ~ 1 long day.
   (c) Heavy ion cooling in AC simulation ,evaluation tests.

LEAR High Energy Performance

S.Baird

3 February 1993

Abstract

The performance of LEAR at momenta above 609 MeV/c is outlined and some limiting factors are given.

Two modes of operation are in use, ultra-slow extraction and internal target operation, the performance in both domains is given.

In general the machine runs well, however, the following areas are places where some improvements could be found:

1/ Saturation in the main magnets and lack of power in sextupoles lead to problems extracting the beam above 1600 MeV/c. Further study of the sextupole corrections at high momenta is needed.

2/ For extraction at momenta above 1900 MeV/c the current septa (magnetic and electrostatic) are operated at (and above) maximum levels. This gives problems to obtain efficient extraction efficiencies...

3/ The longitudinal stochastic cooling will not cool at injection momentum for intensities above 2 10^{10}.

4/ In order to compensate for a lower than predicted target density, PS2020 would like to reach circulating beams of 1 10^{11} pbars instead of the 5 10^{10} attained at present. This can only be done by injection two pbar pulses into LEAR. This is only possible if the longitudinal emittance of the first pulse can be reduced before injection of the second. In order to accelerate 1 10^{11} pbars after a double injection, longitudinal cooling is essential. The double injection mode has been tested and must be made operational. The longitudinal cooling system at 609 MeV/c must be improved to cope with intensities up to 1 10^{11} particles

5/ The transfer and deceleration efficiency for pbars in the PS must be improved. The average efficiency has fallen from 74% to 59% over the last 3 years and the maximum transfer efficiency has fallen from 95 to 75%

LEAR High Energy Performance

Two modes

- Ultra slow extraction for PS197 1200,1950 MeV/c
- Internal target operation PS202 1000-2000 MeV/c
  No extraction, maximum circulating beam intensity

Machine

- 5 10^{10} pbars injected and stored at 609 MeV/c
- 4.5 10^{10} pbars have been accelerated and stored
- Transverse cooling is OK at all momenta
- Long. cooling 609 MeV/c does not work > 2 10^{10} particles. After acceleration longitudinal cooling is OK
- Machine is "linear" up to 1600 MeV/c.
- >1600 MeV/c saturation effects plus lack of "ommph" in sextupoles... problems to control chromaticity (V)
- Beam lifetime > 609 MeV/c excellent (st.cooling on)

Ultra Slow extraction operation

1200 MeV/c

- **Extraction efficiency 60-70%, similar to medium momentum performance. 3 hour spills.**

1950 MeV/c

- **Extraction efficiency 30-40%**
  Lack of "ommph" in sextupoles, excitation extraction resonance, plus non zero vertical chromaticity.
  Lack of "ommph" in extraction septa.....
  Magnetic septa 100%! Electrostatic septum 140%!!!!

- **However PS197 very happy at 1950 MeV/c**
  3 hour spills ≈200,000 pbars/sec for ≈6 10^9 injected

Internal target operation (1000 - 2000 MeV/c)

- **Luminosity - target density ← beam intensity**
- **PS202 target density is low (factor 4)**
  Originally 5 10^{10} pbars in LEAR refill every 24 hours.
  Now >1 10^{11} requested but runs are >72 hours!!!
- **Change beam momentum on demand is available**
- **5 10^{10} pbars have been injected and stored**
  4.5 10^{10} at operating momentum with gas jet

Stochastic Cooling

- **Transverse planes OK up to 5 10^{10}**
- **Long. Plane OK < 2 10^{10} at 609 MeV/c**
  OK up to 5 10^{10} >1000 MeV/c
- **Equilibrium between gas jet and cooling systems is a delicate balance. Only losses during gas jet operation are "due to" nuclear interactions in gas jet.**

Damper

- **OK up to 5 10^{10}, setting gain delicate at 609 MeV/c.**

Injection

- **5 10^{10} single shot, 0.35 eVs (8-10% of AA stack)**
  Need > 1 10^{11} stored.... Longitudinal stacking.
  System tested OK for small pulses.... But longitudinal cooling in LEAR at 609 MeV/c must work for pulses >1 10^{11}.

Conclusions

Machine runs very well up to 2000 MeV/c

- Lifetime - excellent
- Acceleration 95 - 100% (up to 5 10^{10})
- Extraction efficiency - good up to 1600 MeV/c
  - improvement above ?
- Store 5 10^{10} pbars for jet target operation for several days
  Need to increase injected intensity ?

Developments needed for 1993

- Chromaticity studies needed to improve extraction efficiency
- Longitudinal cooling improvements to increase injected beam intensity (>1 10^{11})
- Put into operation "two shot" injection
- Good (>75%) pbar transfer efficiency is essential especially for internal target operation .

Lear:low energy status and further developments

Abstract: Lesperformances de LEAR a basse energie sont decrites.
Les etudes et developements en1992 et prevus pour 1993 sont indiques.

M. CHANEL PS/AR ELOISE 93

5-Stochastic cooling

Adjusted begining of the year ,nothing later

1993:Improvement of notches , phase of system, bandwith for p>200MeV/c and repair cryo amplifier at 105 Mev/c

Systematic measurement of cooling time,emittance limit and systems characteristics

6-Ultra-slow extraction

Constant effort to maintain good efficiency and high duty factor...to be continued with possibly a try to decrease low frequency ripple.After the tests of 1992,put the real time remote program for spill control in operation.

7-Fast extraction

Improve the transfo measurement for efficiency estimation for traps at 105Mev/c or eventually lower momentum.

8-Extracted beam at very low momentum

Measurement on the extraction line by means of scintillator,secondary emission foils(CsI or Al).Calibration of Sec. emission foil in slow .Use them to measure fast and semi-slow extracted beams.

» 2 Deceleration

Systematic measurement of tune during deceleration and ajustment when needed . Long job,onr measure per cycle >Improved in 1993 by multimeasurement during deceleration.

Continuation of work on deceleration to 61.2 MeV/c

» 3-Chromaticity-Dispersion

Systematic measurement and correction on flat top (kick method).A new program has been used measuring tune=f(dp/p),orbit=f(dp/p).It has been found a vertical dispersion due to skew quad..The Qh+Qv=5 has now been compensated by turning a main quad which is at the rigth phase....to be continued

» 4-Orbits..Bumps

Still the correction of 1991..or before.Nothing foreseen except catatrosph..Better not to change too much for scanning even if we didn't do it at LE last years.

Some change in dipoles with the come back of ecool's one.

1-Performances

1-1: deceleration: in operation
-with 5e9 ,from 609 to200MeV/c,>95%
-with 3e9 ,from 200 to 105 MeV/c,~90%
-whatever at 105 MeV/c ,about 1e9 at 61.2 MeV/c

1-2: ultra slow extraction: always and again extraction of one hour with fluxes asked by the physicists . For low energy (-309 Mev/c:~2E6p/s -200MeV/c:1e6p/s -105MeV/c:1e4 to2e5p/s) . Extraction time limited by max. number of part. stored in the machine divided by asked flux,life time . Extraction efficiency is typically better than 70%(200 MeV/c) over one spill . Duty factor(ripple) is better than 93%(200MeV/c) with ripple compensator .

1-3: Slow extraction:This year we were asked to extract a certain number of particles(~5e8) in less than 10 min (irradiation of dense material) .This was done at the end of a normal spill ,saving mainly time.

1-4: fast extraction :For Feeding of PenningTraps. ~10% of the circulating beam is extracted in batch of 50 to 200ns . Operation at 105 MeV/c under Ecool.

1-5: semi-slow extraction:This consist of extracting the beam by a resonant process (same as 1.1) but in 500microsec . To increase difficulty this was done at 61.2 MeV/c . We think we succeeded to extract in one shot about 50% of the beam ,unfortunatly It was not possible to decelerate properly in the RFQ,even after having synchronized the extraction on a quiet ps cycle(E),on the 50 Hz....and long tests and tries...

Experience PS189 has stopped .

IMPEDANCE MEASUREMENTS AT LEAR

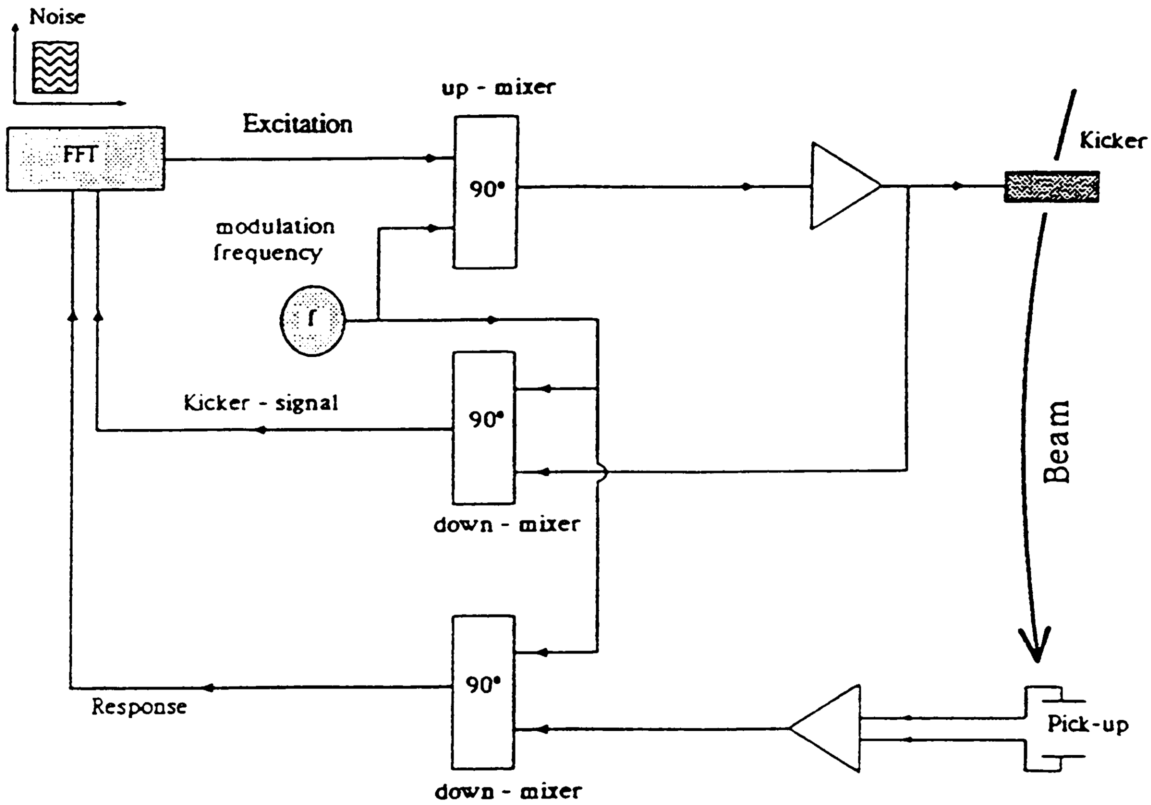
U. Oeftiger

PS PERFORMANCE DAY, 03.02.1993

ABSTRACT

At the CERN Low Energy Antiproton Ring (LEAR) high-density beams are obtained with electron and stochastic cooling. We have tried to determine the characteristics of the beam and its environment in a regime where the cooling force is present and where the impedance is space-charge dominated. Methods used include beam transfer function measurements and Schottky scans. Plots of the resulting longitudinal coupling impedance at different harmonics and of the momentum distribution width against number of particles are shown. The effect of the gain of the transverse feedback system on the beam stability is figured in the transverse inverted response diagram.

Impedance measurements at LEAR:



BTF : $\quad r_{\parallel,\perp} := \dfrac{\text{beam response}}{\text{excitation signal}}$

without coupling impedances:

- longitudinal: $\quad \Im m\{r^{\circ}_{\parallel}\} \sim \dfrac{\partial \Psi}{\partial \omega}$
- transverse: $\quad \Im m\{r^{\circ}_{\perp}\} \sim \Psi$ ← particle distribution

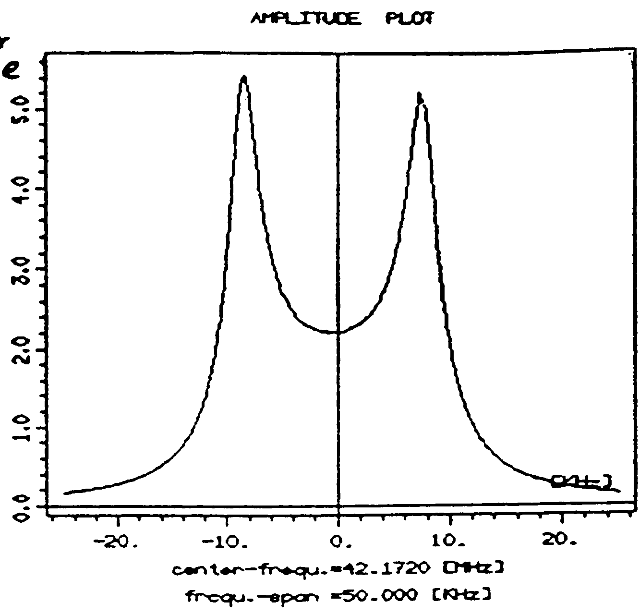
with coupling impedance:

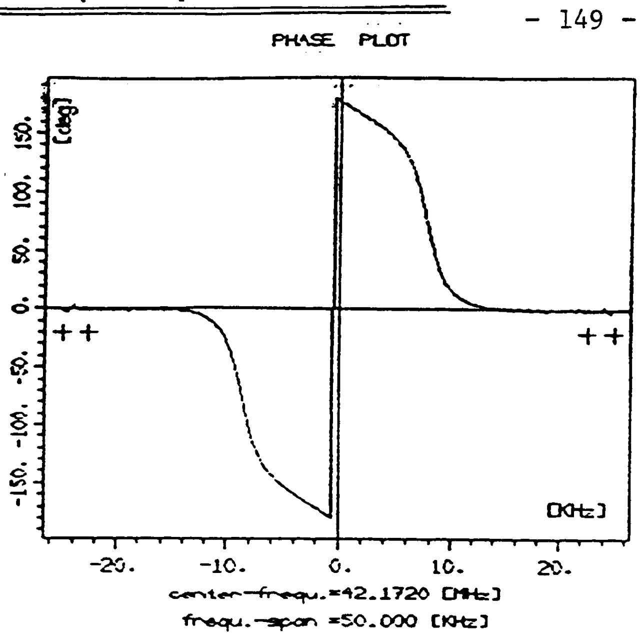
$$(r_{\parallel,\perp})^{-1} = (r^{\circ}_{\parallel,\perp})^{-1} + Z_{\parallel,\perp}$$

$Z_{\parallel,\perp}$ ≙ coupling impedance vector, if normalization correct

Measurement with p^+, longitudinal

linear scale



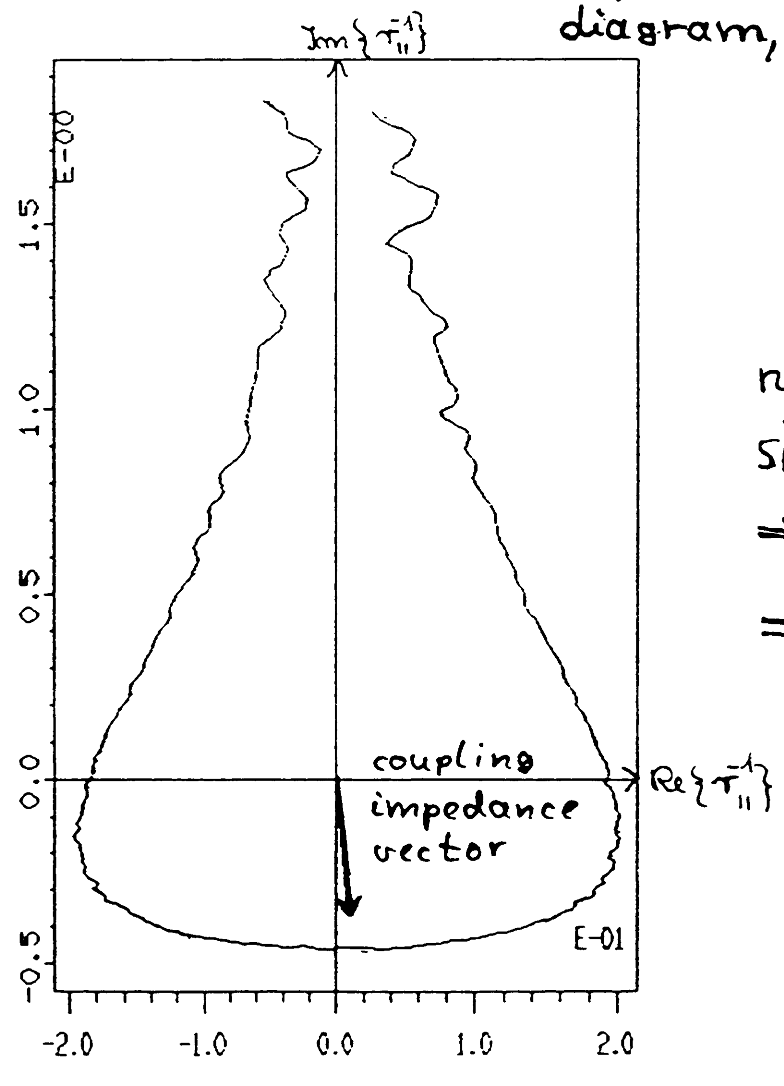


$N \approx 10^{10}\ p^+$

$p_0 \approx 200\ MeV/c$

harm. no: 53

inverted response diagram, not calibrated !

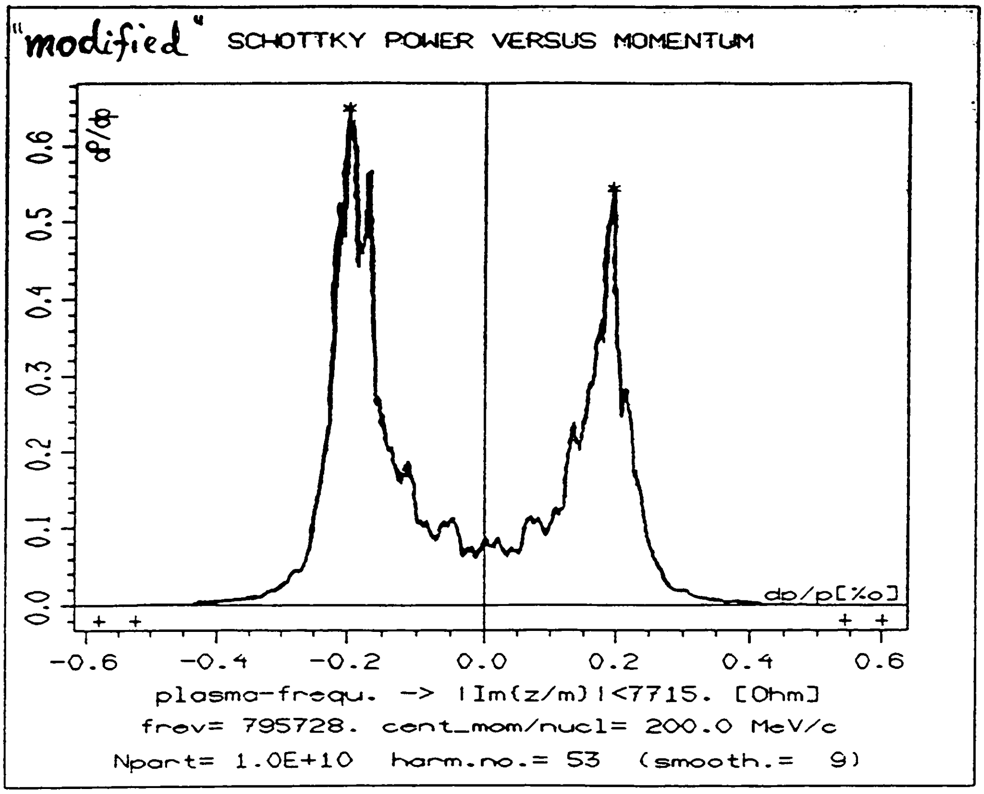


now:

shift curve by $-Z_{\parallel}$

$\Rightarrow (\tau_{\parallel}^{0})^{-1}$

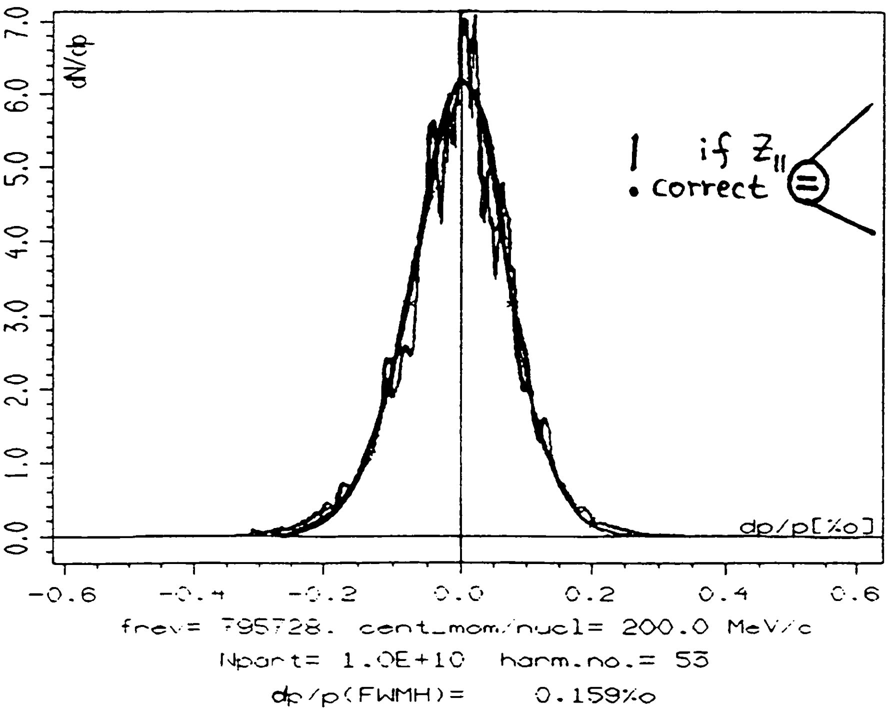
$\Rightarrow \psi(\omega) \sim \int \Im m\{\tau_{\parallel}^{0}(\omega)\} d\omega$



without coupling impedance $Z_{\parallel}$

$\int Im\{Z_{\parallel}^{0}\} d\omega$

True momentum distribution:

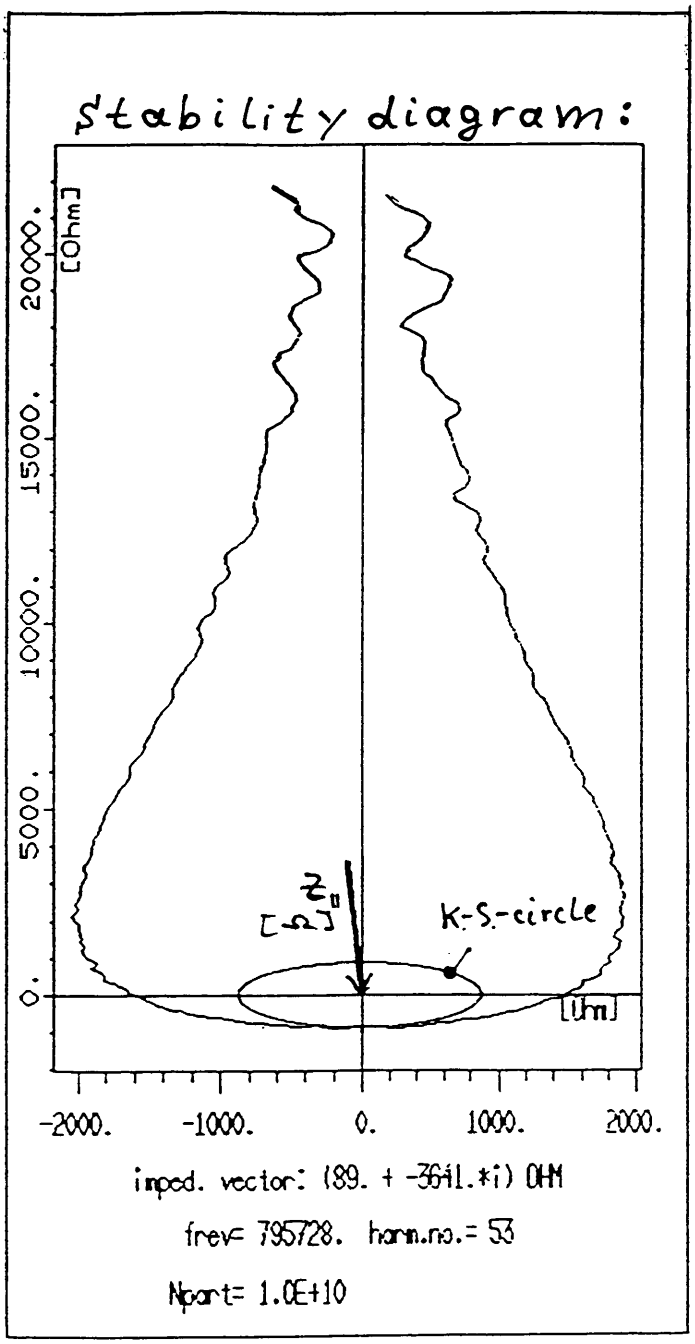


! if $Z_{\parallel}$ correct (=)

smooth curve: calculated from BTF

noisy curve: calculated from Schottky

⇝ calibration of inverted response and $Z_{\parallel}$

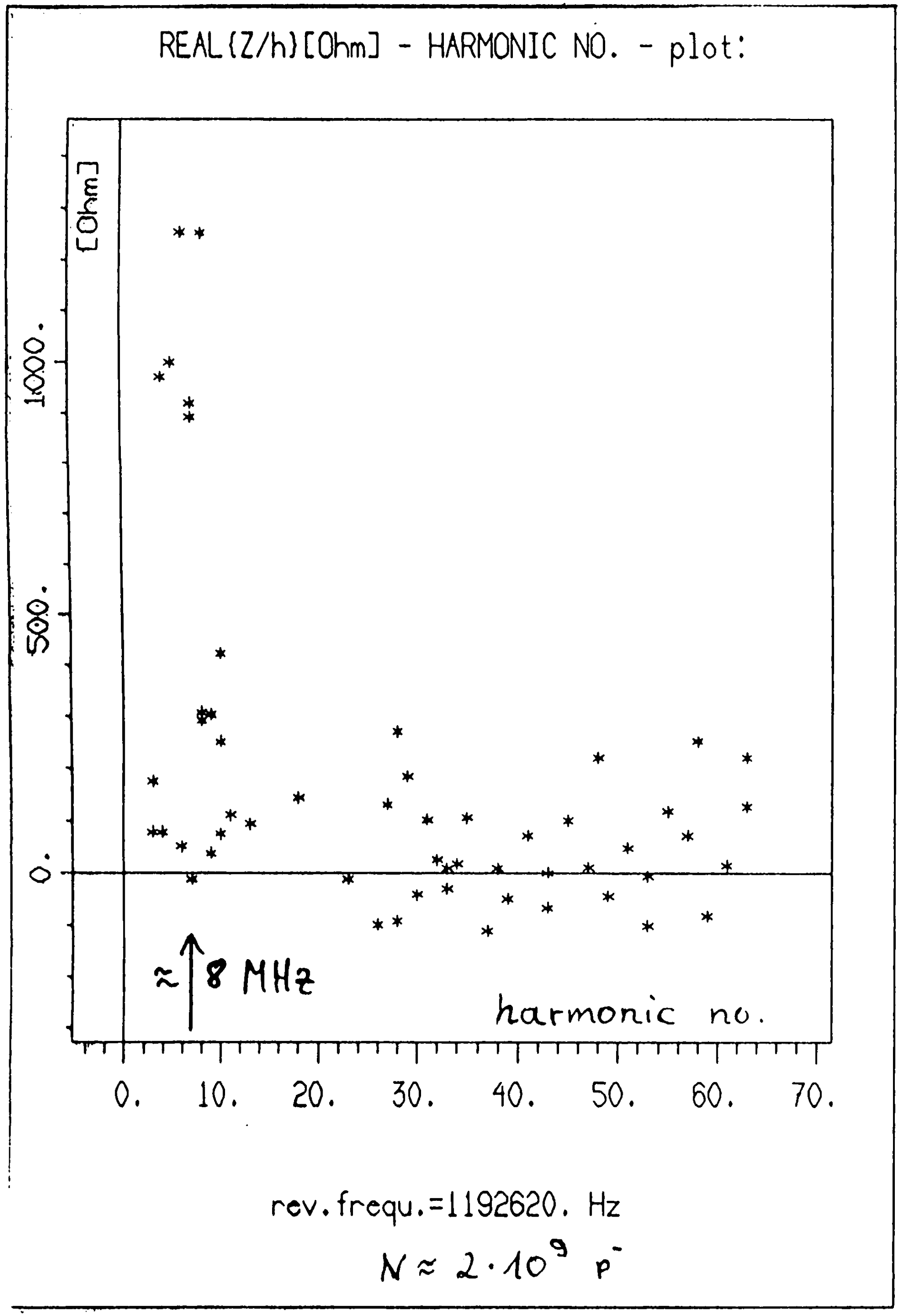


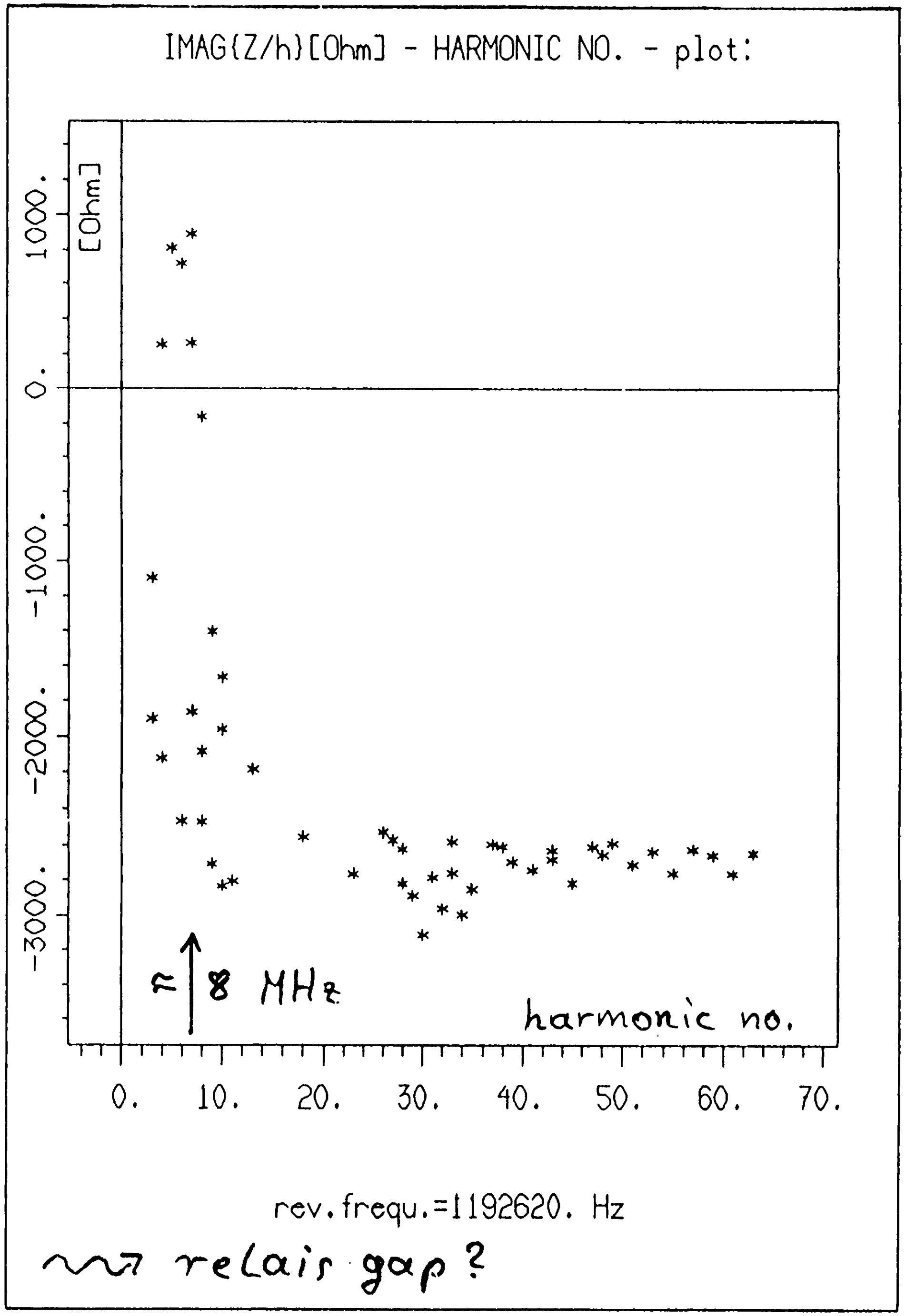
$Re\{Z_{\parallel}/m\} \approx 90\ \Omega$

$Im\{Z_{\parallel}/m\} \approx -3{,}6\ k\Omega$

space charge forces dominating (→ Im)

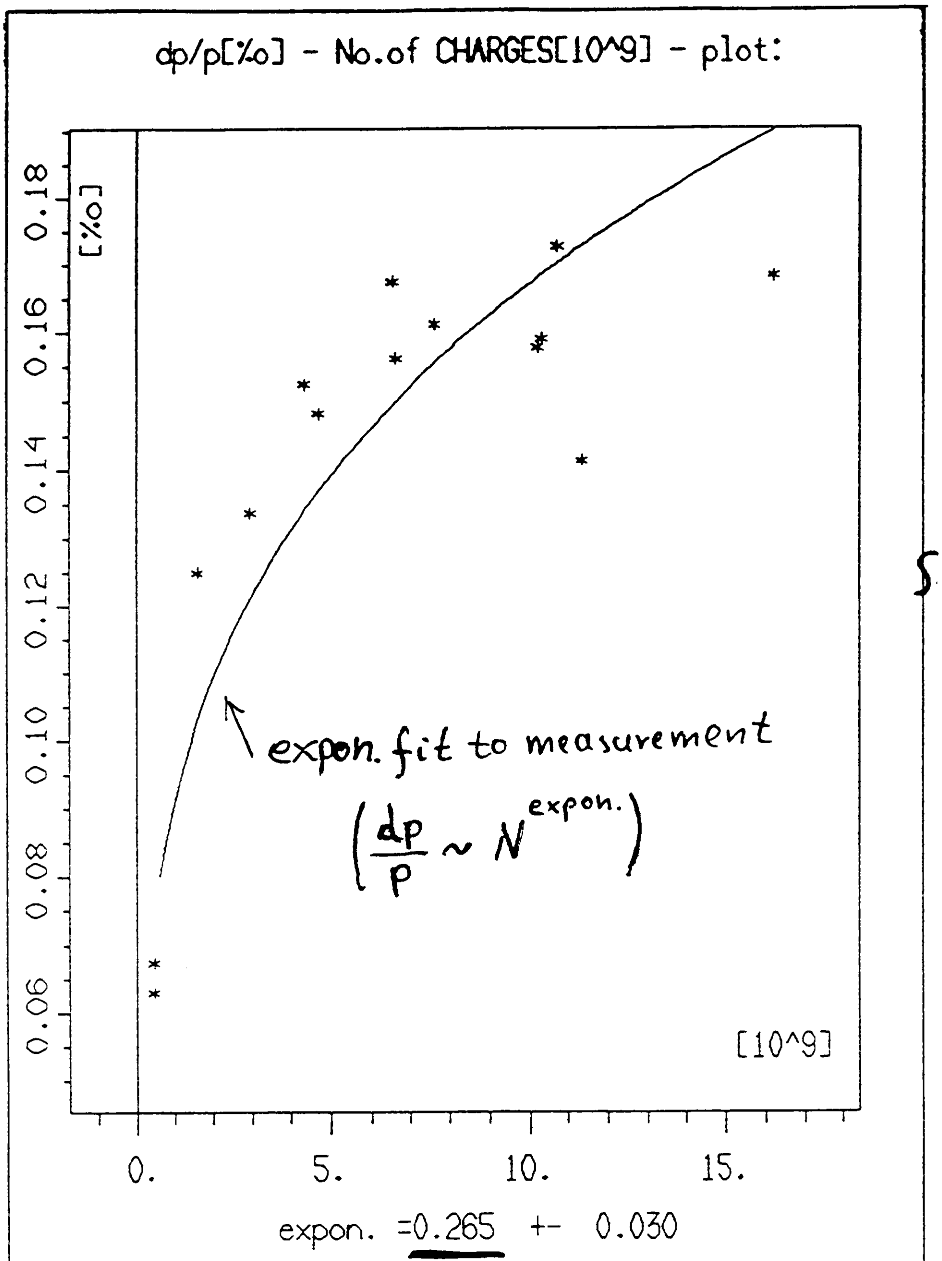
beam chamber (→ Re)





measurement with p^- , longitudinal coupling impedance , $p_0 \approx 309\ MeV/c$

p^+ at $p_0 \approx 200\ \frac{MeV}{c}$

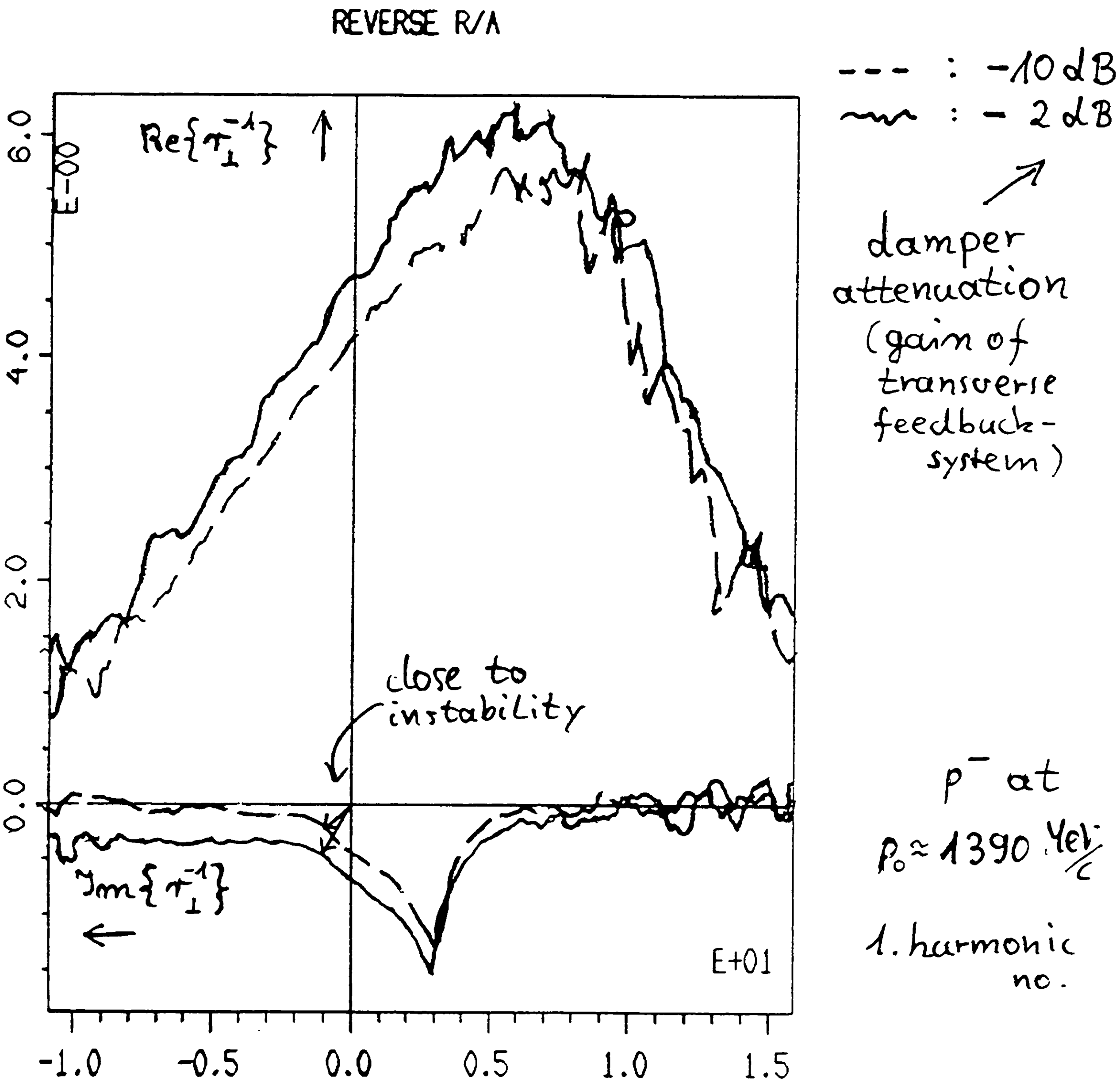


$\frac{dp}{p}$ calculated from long. BTF-meas.

computer simulation with "INTREQ":

$\Rightarrow \frac{dp}{p} \sim N^{\underline{0,211}}$

Transverse:



inverted response diagram

conclusion:

longitudinal BTF:

→ true particle momentum distribution

→ longitudinal coupling impedance

transverse BTF:

→ adjustment of transverse feedback system

to be done:

→ understand influence of transv. feedback and e⁻-cooler on BTF
⇒ transverse coupling impedance

→ behavior of long./transv. coupling impedance due to other parameters (part. no., energy, cooling-param. ...)

→ faster data acquisition
⇒ development of impedances and momentum distribution during cooling

LIL PERFORMANCE AND POSITRON STUDIES

L. Rinolfi

1 LIL performance

1.1 Electron beam

For the LEP operation, the beam is produced from a thermionic gun, at an energy of 80 keV. It is accelerated up to 500 MeV then injected into EPA. The nominal intensity is 5.10^9 e^- per pulse at the end of LIL, working at 100 Hz. This provides an accumulation rate of 73.10^9 $e^-/(s \times bunch)$. Since 4 bunches are filled up, that corresponds to a value of 300.10^9 e^-/s.

For the machine studies, a maximun value of 120.10^9 $e^-/(s \times bunch)$ has been reached. Also an energy of 700 MeV is available at the end of the LIL. The reliability of the linac has been improved by deflecting the e^- beam, with a bump, around the target without moving the latter.

1.2 Positron beam

For the LEP operation, the electron primary beam is produced as mentionned above except that now the beam charge is 30 nC at the converter instead of 1 nC for the described above beam. With a primary beam energy of 200 MeV, the positrons are produced and captured at 4 MeV. Then they are accelerated up to 500 MeV as before. The nominal value is 1.10^9 e^+ per pulse at the end of LIL. This provides an accumulation rate of 5.4×10^9 $e^+/(s \times bunch)$. Since 8 bunches are filled up that corresponds to a value of 43.10^9 e^+/s.

For the machine studies, a maximun charge of 82 nC has been transported up to the target. The peak performance achieved for the positrons is an accumulation rate of 8.1×10^9 $e^+/(s \times bunch)$ or 65.10^9 e^+/s.

2 Positron studies

Apart the reliability of the linac, the main effort is dedicated to the studies to improve the production and the capture of e^+. In this respect, a Positron Working Group was set-up in 1992. Collaborators are from LURE (Orsay), PSI (Villigen) and CGR-MeV (Paris). The main studies concern the better understanding of the LIL optics and the measurement of the micro-bunch length of the primary beam. The possibility to implement a spectrometer line together with a chicane is under investigations. Tracking studies have been performed.

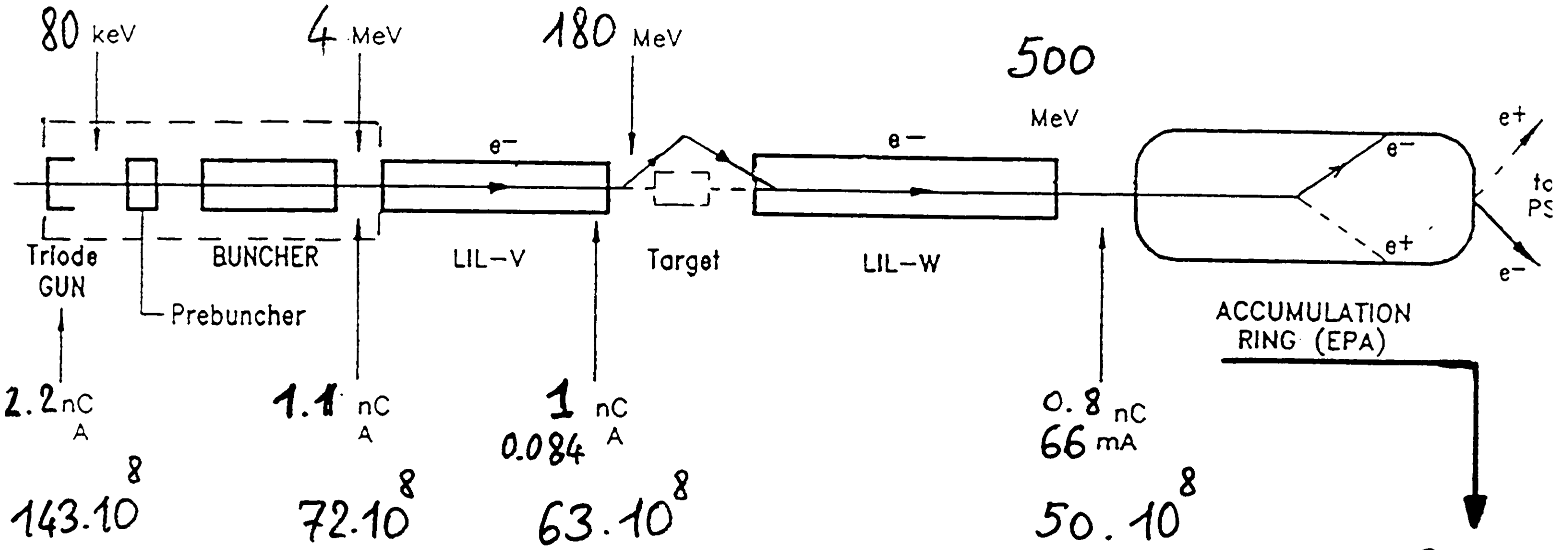
A comparison between simulations and experimental results were done last year and a good agreement was found. Last improvements allowed to increase the normalised yield up to $3.10^{-2}/(GeV)$. It corresponds to the number of e^+ within a momentum spread of $\pm 1\%$ divided by the number of e^- on the converter times the primary beam energy (0.2 GeV for LIL).

3 From LIL to LEA

In 1992, a new LIL Experimental Area was built. It receives electron beams under various conditions either between LEP filling time or during MD sessions. Two physics experiments concerning the LHC detectors are under development. One is the radiation damage of scintillating fibers (LAA) and another one is the responses of different crystals foreseen for calorimeters (L3P).

e^- Beam at LIL

• LEP operation



$73\ 10^9\ e^-/b \times s$

$30\ 10^{10}\ e^-/s$

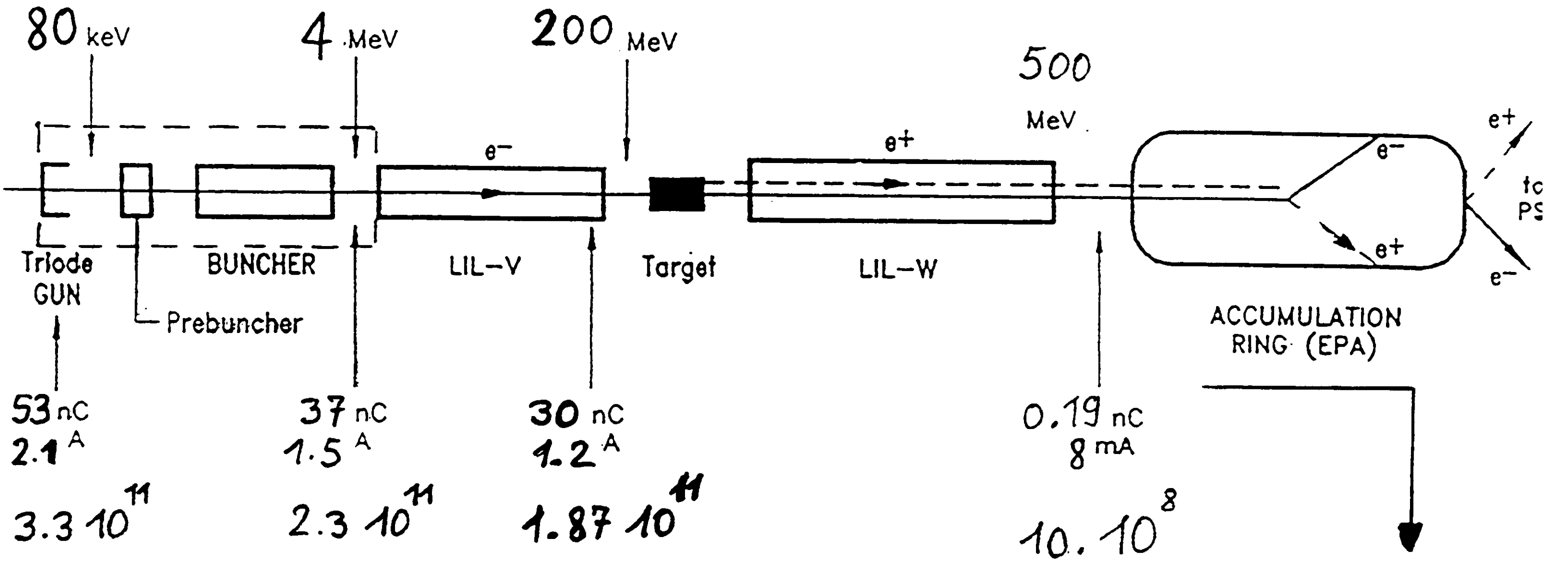
• Max value at the end of LIL

$165\ 10^8\ e^-/\text{pulse}$

$120\ 10^9\ e^-/b \times s$

e^+ Beam at LIL

• LEP operation



$5.4\ 10^{9}\ e^+/b{\times}s$

$4.3\ 10^{10}\ e^+/s$

• Max value on the target

Gun : $1.35\ 10^{12} = 220$ nC

Target : $5.1\ 10^{11} = 82$ nC

• Max value at the end of LIL

$16 \times 10^{8}\ e^+/\text{pulse}$ →

$8.1\ 10^{9}\ e^+/b{\times}s$

$6.5\ 10^{10}\ e^+/s$

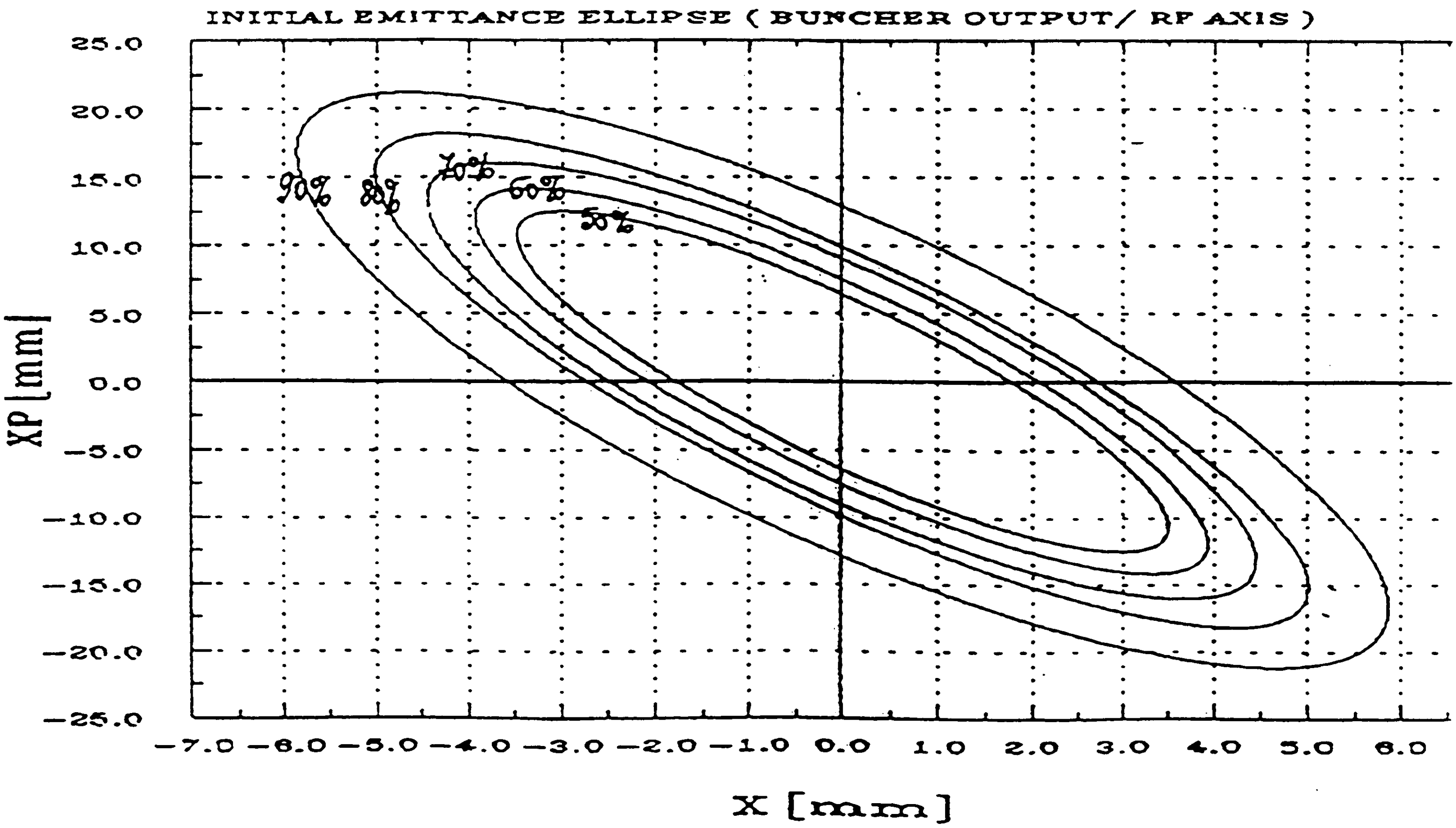
e^- Beam emittance at LIL

90% of particles

$x_{MAX/2} \cong 6\,mm$

$\theta_{MAX/2} \cong 21\,mrad$

$\mathcal{E} \simeq 76$ mm.mrad



Measured beam emittance at the buncher output

(Method of 3 gradient)

e^+ Studies at LIL

	Accelerating mode	Decelerating mode
Buncher efficiency	0.70	0.70
e^- linac efficiency	0.75	0.75
Primary beam energy (MeV)	200	200
Charge on the target (nC)	30	30
e^+ after the first bending (10^8)	12.2	13.2
Yield (10^{-2})	0.59	0.64

Table 3: Measured beam characteristics of LIL e^+ beam.

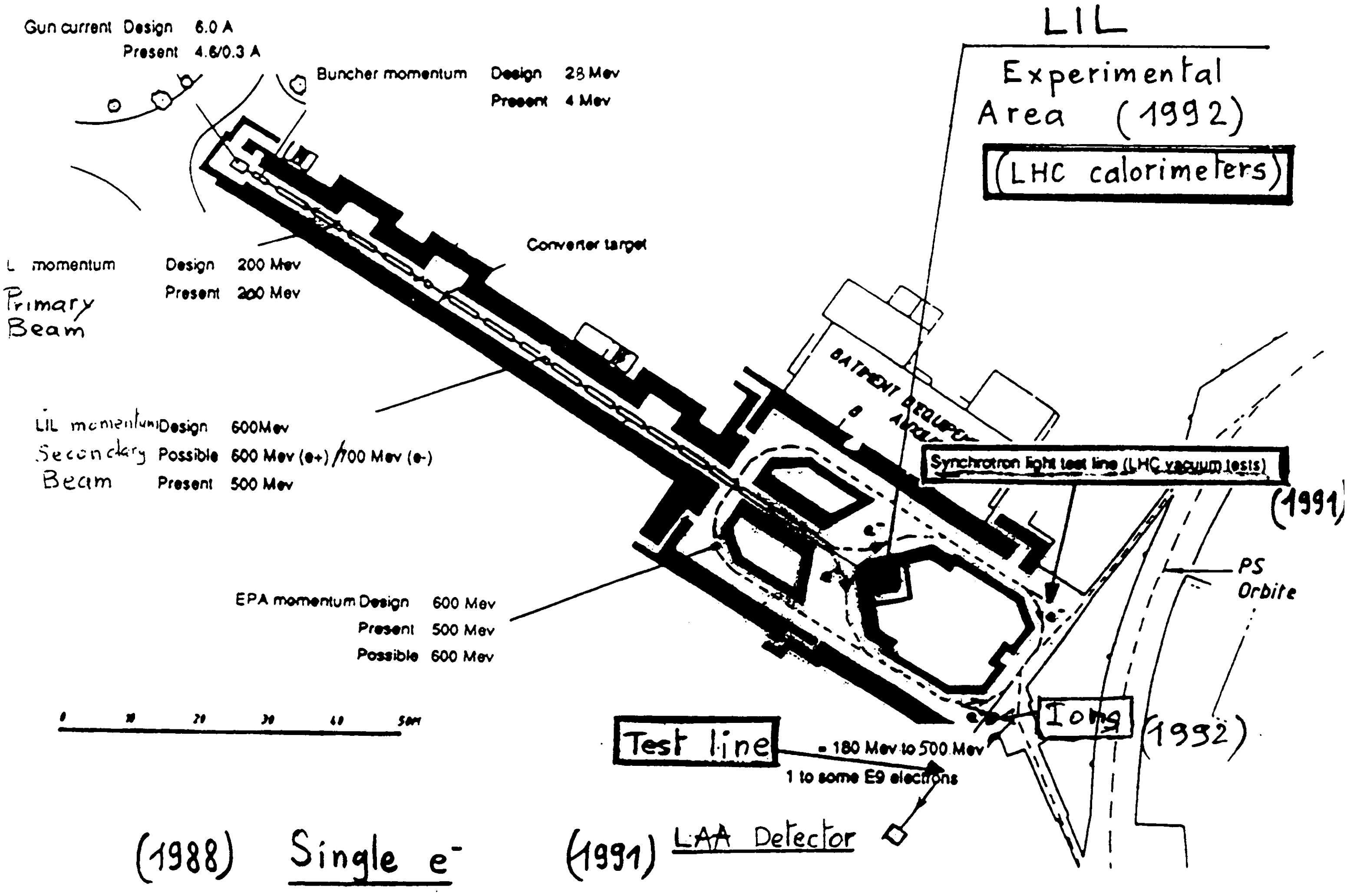
		Unresolved yield	Resolved yield	Normalized yield
Tracking results	acc. mode	$1.22 \cdot 10^{-2}$	$0.48 \cdot 10^{-2}$	$2.40 \cdot 10^{-2}$
	dec. mode	$1.20 \cdot 10^{-2}$	$0.66 \cdot 10^{-2}$	$3.30 \cdot 10^{-2}$
Experimental results	acc. mode	$0.59 \cdot 10^{-2}$	$0.49 \cdot 10^{-2}$	$2.45 \cdot 10^{-2}$
	dec. mode	$0.64 \cdot 10^{-2}$	$0.44 \cdot 10^{-2}$	$2.20 \cdot 10^{-2}$ ←

Table 4: Comparison of simulations and measurements.

Exper. 11 Dec. 1992	dec. mode	0.75	0.6	$3 \cdot 10^{-2}$

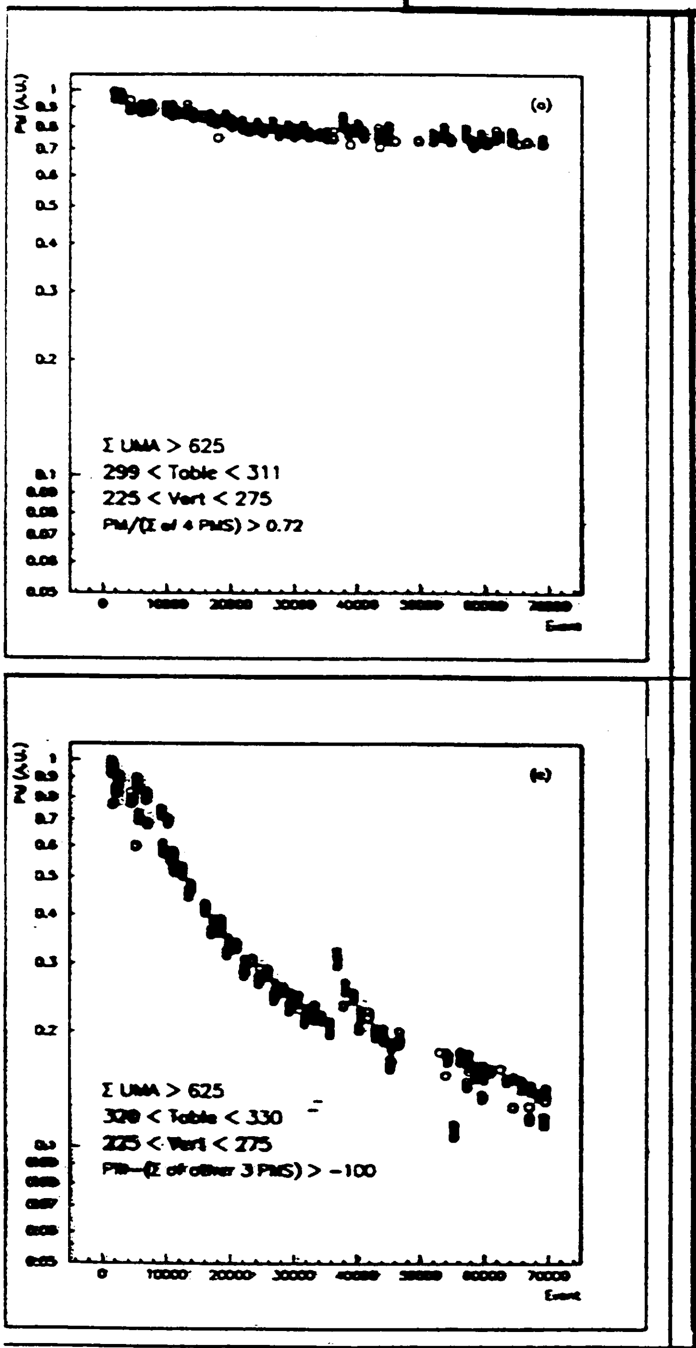
From LIL to LEA

LEP **I**njector **L**inac → **L**IL **E**xperimental **A**rea



LHC calorimeters

LAA experiment

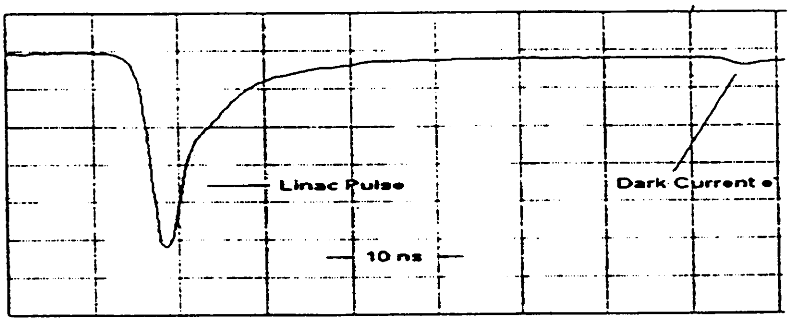


igure 3: Radam II data with cuts.

Scintillating fiber

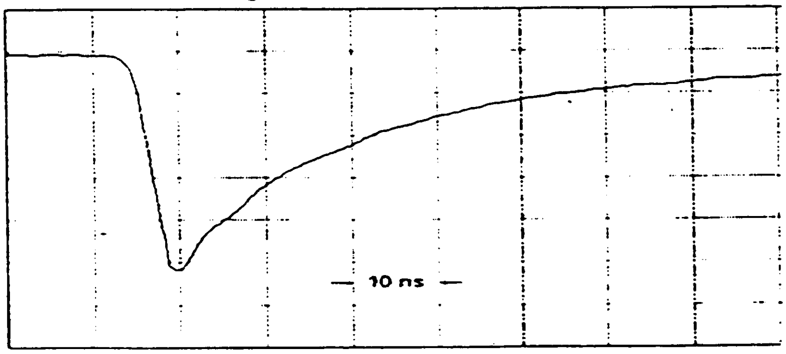
L3P experiment

An additional problem was that the 130 m cable run (of RG58) from the PMT to the control room, caused serious degradation of the fast components of the scintillation signal. This problem was solved with the help of the LiL group, who allowed us to use a section of low-loss coax cable. With this cable it was possible to observe fast rise times: The figure below shows the digitized Cerenkov light signal observed with a PbF_2 crystal (10 ns/division) along with a dark current "after pulse"



Cerenkov light from PbF_2 observed at LiL

During the two days of testing, we recorded several thousand waveforms from four different CeF_3 crystals, as well as from PbF_2 and BaF_2 as controls. A sample CeF_3 waveform is shown in the figure below



Scintillation light from CeF_3 observed at LiL

Crystals

PPCday Feb3,93

EPA STATUS

J.P.Potier

Summary

- LPI performances are still 2 times higher than SPS present requests => no pressure on high charge production

- Performances recorded in 89 are still valid (see global tables) except the maximum charge per bunch

- In 92 **most** of the EPA study time was devoted to **ion studies** and beam production at different momenta for **LHC test** vacuum chamber irradiations at different critical energies. Other subjects were mainly on :

  1. Longitudinal impedances

  2. Vertical apertures

  3. Optical studies to change EPA α_p to 0 even negative values

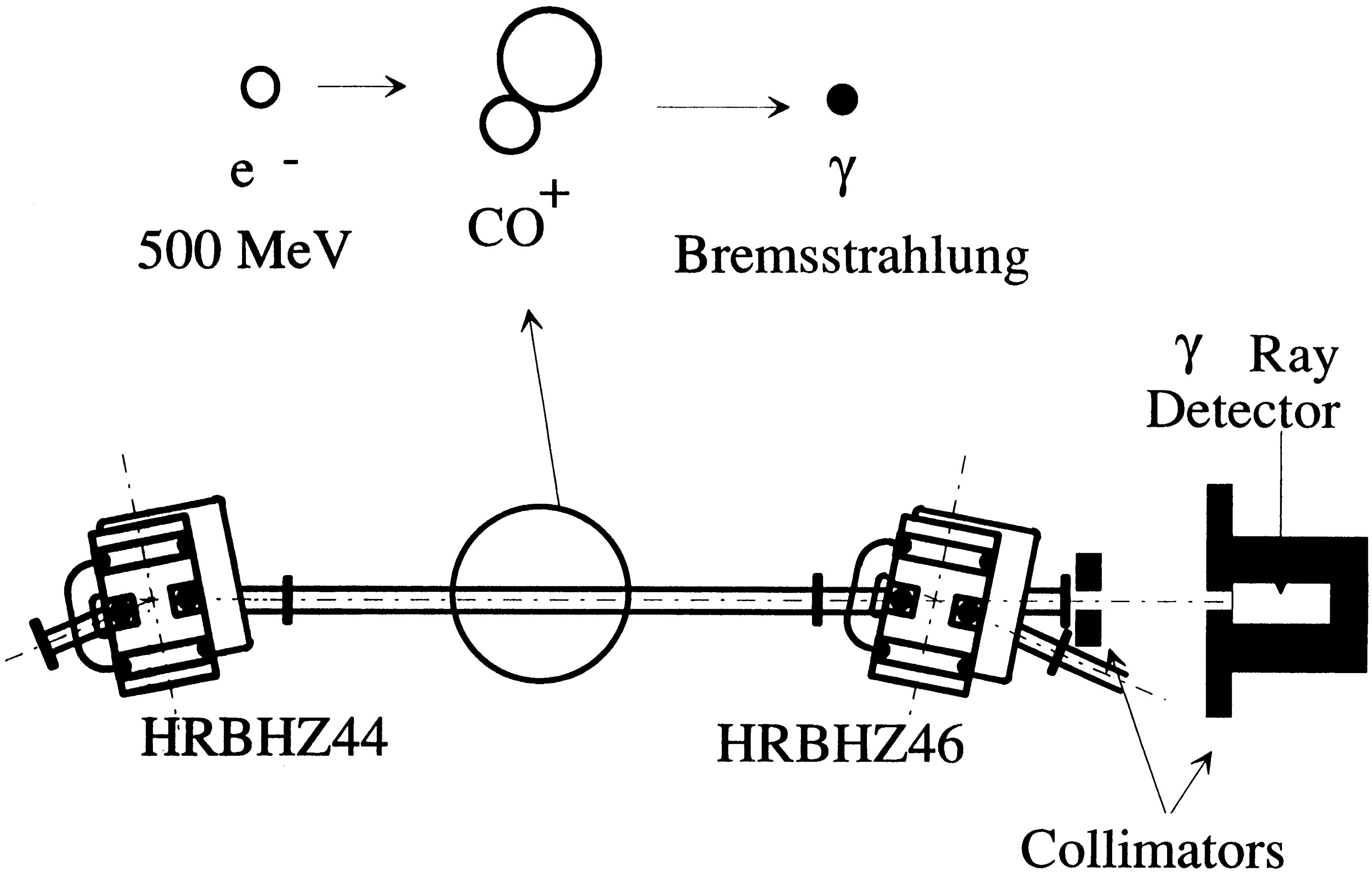
Ion studies

These studies on Bremsstrahlung Detection of Trapped Ions are performed by P.Tavares from LNLS/ Campinas (collaboration with Brazil). One of the detectors is sketched on figure 1 and an exemple of counting with the gamma detector shown on figure 2.

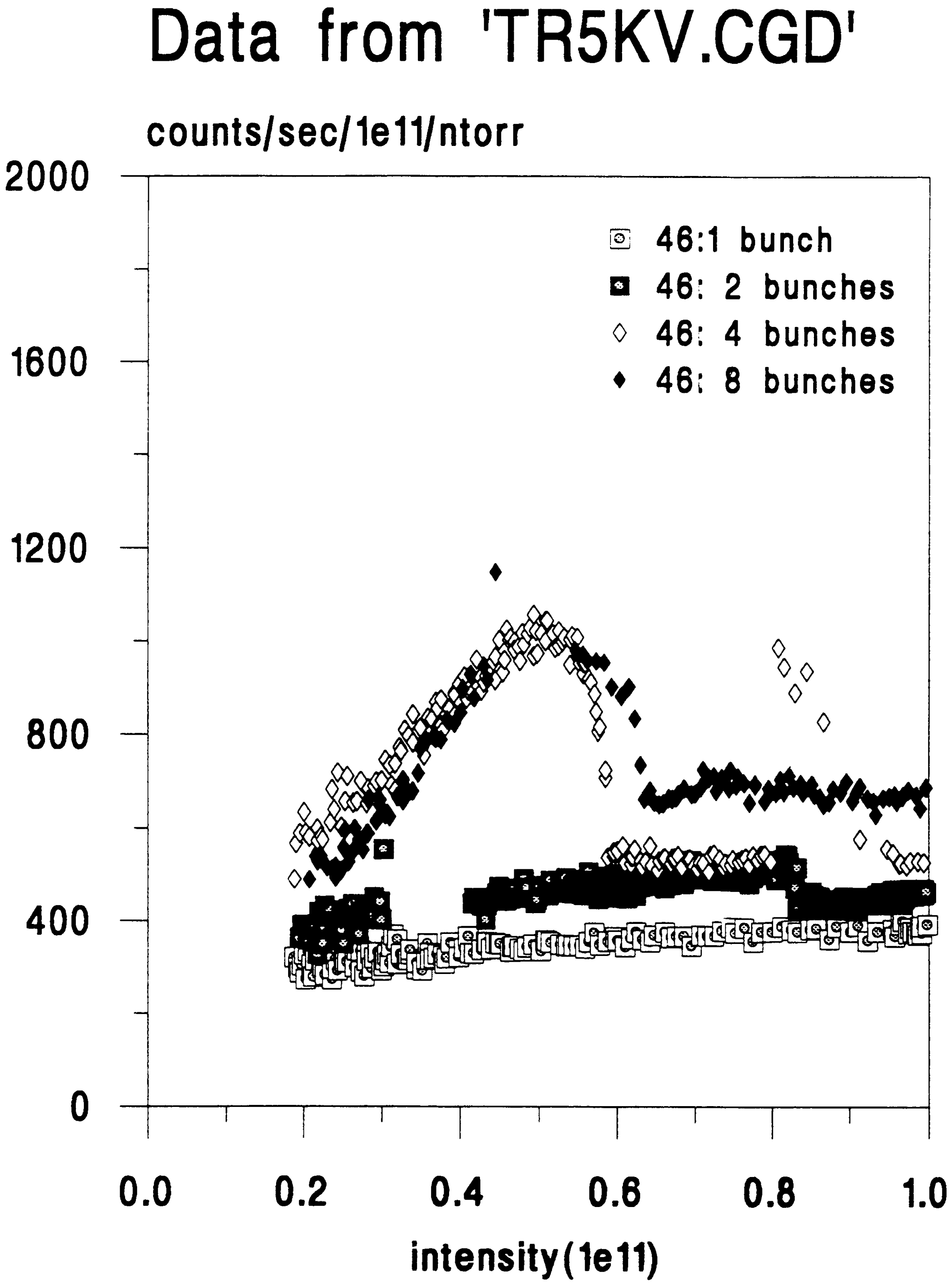
These measurements and their analysis, object of a thesis, will be detailled in a PS Seminar, by P.Tavares, february 10, 93. Everybody is welcome to attend!

LHC test vacuum chamber samples irradiations (for AT/VA)

EPA, initially designed to run from 400 MeV to 650 MeV have been successfully run from 200 MeV to 565 MeV to simulate the synchrotron light produced in LHC and SSC at injection and storage and irradiate vacuum chamber material samples to study their desorpsion coefficients.
These experiments shows that EPA, apart from intensity limits linked partially to aperture restriction (see below), is working reasonably well at low momenta. Some minor injection timing problems appearing when the damping time is long will be fixed this shut down.
Irradiation results are interesting and experiments will proceed in 93 on new vacuum chamber materials.



Bremsstrahlung Detection of Trapped Ions


Data from 'TR5KV.CGD'
counts/sec/1e11/ntorr
2000
1600
1200
800
400
0
46:1 bunch
46: 2 bunches
46: 4 bunches
46: 8 bunches
0.0
0.2
0.4
0.6
0.8
1.0
intensity(1e11)

1 EPA longitudinal impedances

Date	Momentum Mev	Particle	$(Z/n)_0$// ohms	$\Delta\sigma_{so}/\sigma_{so}$	Comment
1986	500	e-	14 for 8 modules (giving 21ohms for 12 modules)	0.07 to 0.17	only 8 over 12 modules installed only
1987	500	e-	21	0.10 to 0.18	all 12 modules in
1988	600	e-	14.5	~0.0	all 12 modules in
1991	500	e+	14.8	~0.0	2 modules modified to reduce their impedance
1992	500	e+	13.9	~0.0	same as in 1991

Conclusion:

1. Longitudinal impedance results are now in agreement with impedance model Q=1, f=635 Mhz, Rs=3.9 kohms. Agreement between calculated equilibrium bunch length at zero charge is correct.
2. Accuracy too small from 1991 onward due to maximum charge per bunch limitation: It was not possible to observe the impedance reduction due to the modification of 1 injection kicker (supposed to be~2 ohms).

2. EPA Vertical aperture

The maximum number of positrons possible per bunch was reduced from 28 E10 e+ in 1987 down to 18 E10 e+ in 89 (a factor still 6 above SPS/LEP requests). No easy tests on acceptances were possible, as EPA had at this time only 1 vertical corrector !

In 92 the ion clearing electrode system was replaced (corrosion of HV feedthru) and 2 special electrodes (CLE 32 and CLE64 used to measure ion collection current) found at 10 mm of the axis in place of 20 mm (vertical acceptance then limited from 27 down to 10 E-06 rad*m on axis).

With the 2 vertical correctors available (installed for LHC irradiation tests) the vertical aperture was explored (see graph on which the experimental aperture as weel as the theoretical one is shown) and found limited to 5 mm on the top side in some area, at least in 32 and 64). Inspection in the vacuum chamber shows that the electrostatic screen of the electrodes were placed at 5 mm of the axis giving an acceptance of 2.4 E-06 rad*m!. Aperture will be checked at startup.

3. EPA momentum compaction change

This subject is purely academic on EPA. It consists in optics changes to reduce α_p and its first derivative versus dP/P to zero even negative and observe, if possible, the effects on the bunch length and the effective impedance. These tests were initiated by L.Rivkin and done with him A.Hofmann and P.Tavares. A reduction from 0.032 down to 0.0032 was reached during the first session in dec 92and good agreement between expected and measured synchrotron frequency. Studies will continue in 93.

LEPTON INTENSITY LIMITATIONS AND 8 BUNCH MODE

PS Performance Day 03/02/1993

J.P. Riunaud PS/PA

The number of leptons delivered by the CPS to the SPS within one supercycle is not limited by the capability of leptons accumulation in EPA. The present production rates and accumulation times can make available, at 500 MeV, 6 10^{10} e+/bunch in 4 bunches and 2 positron cycles per supercycle of 14.4 s. Twice this amount can be made available in electrons.

A first limitation occurs at low energy, namely the transverse mode coupling instability, driven by the imaginary part of the CPS transverse impedance. At 500 MeV, the threshold of this instability is reached, in the CPS operating conditions, when the bunch population approches 4 10^{10} particles/bunch.

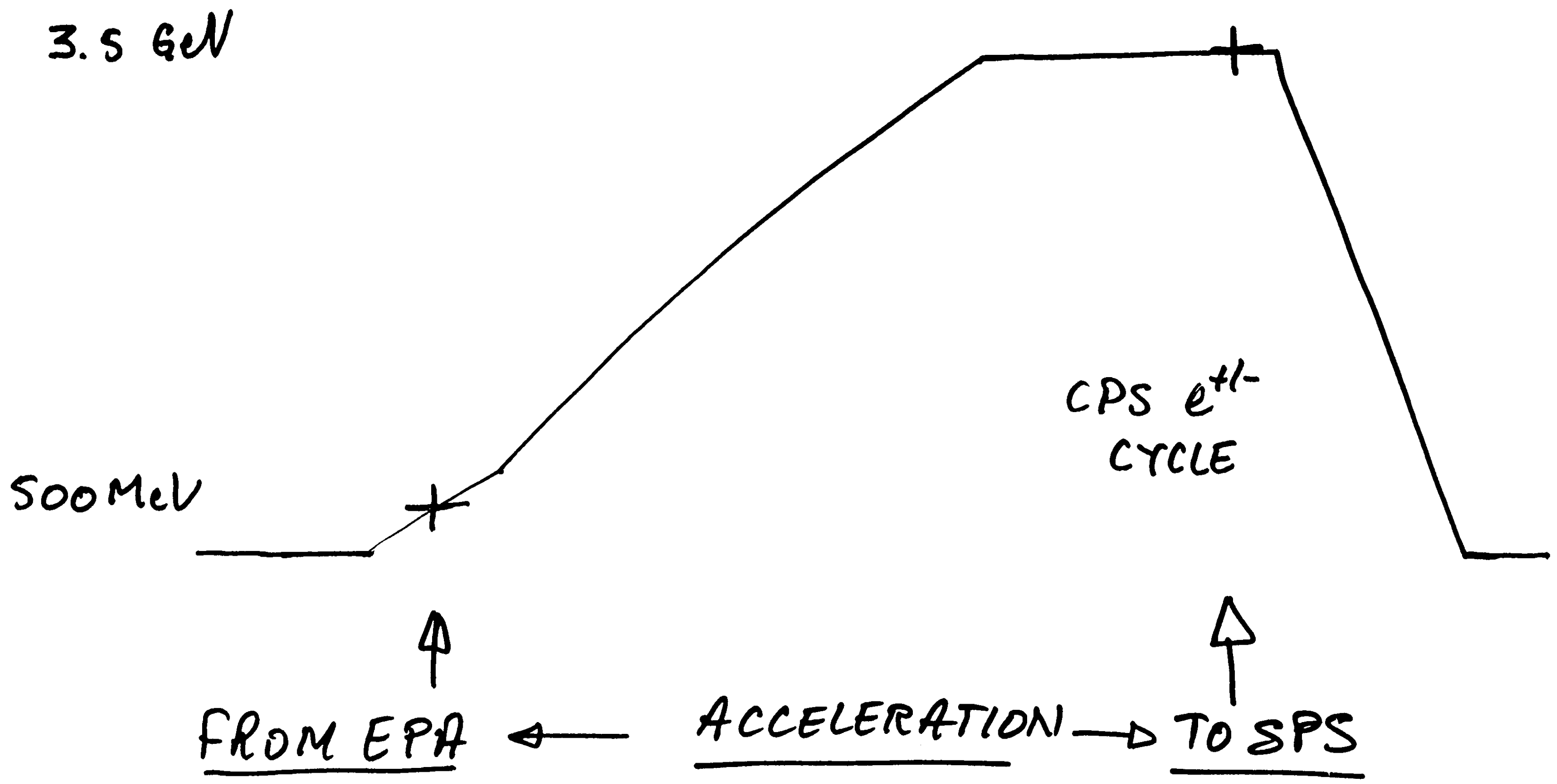
A second limitation, due to positive ions trapped by the beam, affects the electron beams at 3.5 GeV. It strongly depends on the vacuum and on the bunch spacing. With an average vacuum of 2 10^{-8} T and 4 regularly spaced electron bunches, the electron beam suffers vertical instabilities when the bunch population reaches 4 10^{10} electrons/bunch. With 8 electron bunches this threshold is lowered down to 2.5 10^{10} electrons/bunch. However, with a strong coupling between the 2 transverse planes and the use of a transverse feedback, one could extract stable electron bunches of 5 10^{10}.

Finally, large longitudinal bunch dimensions is of prime importance for the amount of particle accepted by SPS at 3.5 GeV. The largest rms relative energy spread transmissible without losses through the CPS extraction chanel and tranfer line acceptance is 10^{-3}. The longest total bunch length achieved at 3.5 GeV is 4.4 ns. It is limited by the losses due to quantum life time following the voltage reduction on the flat-top. With these bunch dimensions, the SPS is limited by the beam break-up instability at injection to a maximum of 2.5 10^{10} particles/bunch.

In the standard transfer scheme between CPS and SPS, 4 bunches are transferred on each of 2 consecutive cycles, for each type of particles. Another transfer scheme has been tested last year aiming at providing the same amount of particles per supercycle to the SPS, with only 2 cycles for both types of particles. In this scheme 8 bunches are transferred in two batches of 4 bunches. The SPS RF harmonic number is modified and set to a multiple of 8 so that no rephasing is required in the CPS between the 2 batches. This 8 bunch scheme reduces the lepton operation tuning time in the SPS as only 2 cycles have to be set-up, and makes 2 cycles of 1.2 s available in the supercycle. It remains, for 1993, to achieve it with the nominal CPS bunch intensity of 2.5 10^{10} and to make it operational througout the whole chain up to LEP.

$e^{+/-}$ INTENSITY LIMITATIONS

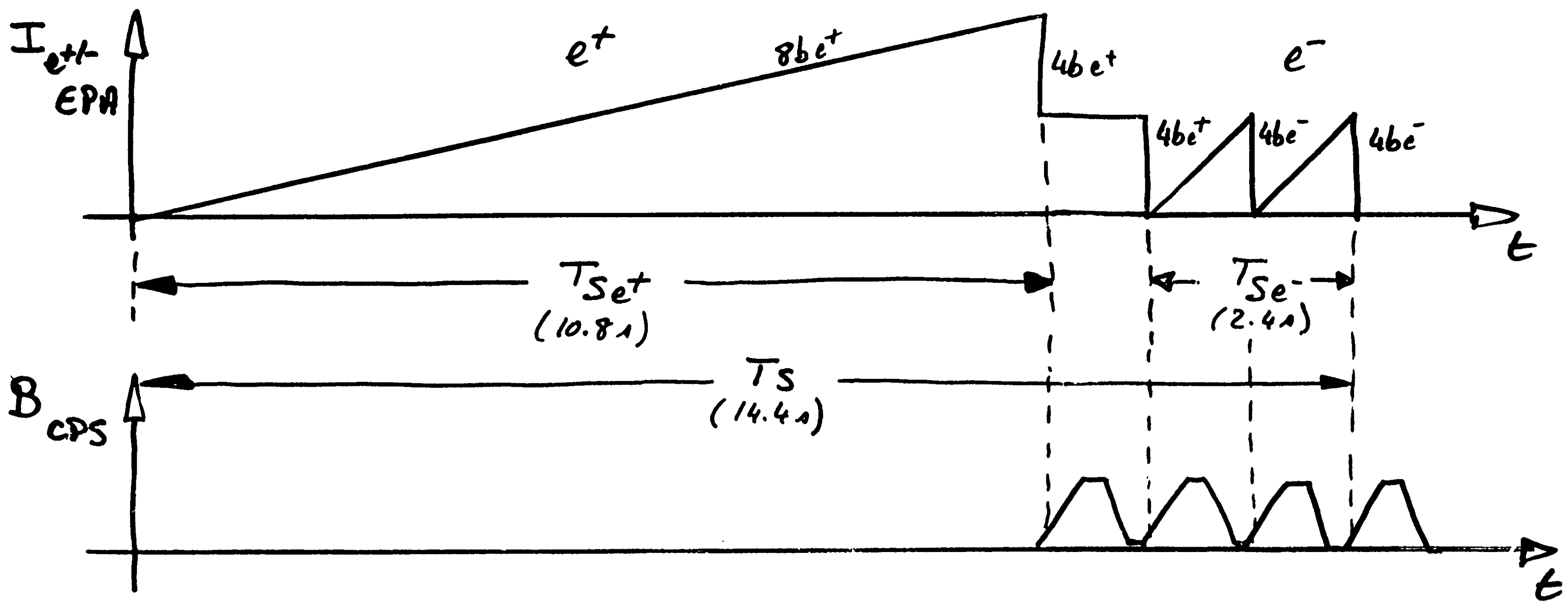
JPR 3.2.93



NUMBER OF PARTICLES DELIVERED TO SPS IN ONE SUPERCYCLE

NUMBER OF PART./BUNCH; BUNCHES/CYCLE; CYCLES/SUPERCYCLE

$$\Delta N_{T_S} = N_b \times K_b \times N_c$$



POTENTIAL LIMITATIONS OF $\Delta N_{TS} = N_b \cdot K_b \cdot N_c$

① EPA PRODUCTION RATES $\frac{dN_{e^+}}{dt}$ AND $\frac{dN_{e^-}}{dt}$

$$(N_b \times K_b \times N_c)_{e^+} \leq \left[\frac{dN_{e^+}}{dt}\right]_{MAX} \times T_{Se^+}$$

$$\leq 5.4 \times 10^9 \times 8 \times 10.8 = 4.7 \times 10^{11} \ e^+/\text{SUPERCY.}$$

	N_b	K_b	N_c
e^+	6×10^{10}	4	2
e^-	12×10^{10}	4	2

$$(N_b \times K_b \times N_c)_{e^-} \leq \left[\frac{dN_{e^-}}{dt}\right]_{MAX} \times T_{Se^-}$$

$$\leq 4.9 \times 10^{10} \times 8 \times 2.4 = 9.4 \times 10^{11} \ e^-/\text{SUPERCYC.}$$

⇨ NOT LIMITING

② TRANSVERSE MODE COUPLING INSTABILITY IN THE CPS

$$N_b \leq \frac{32}{3} \cdot \frac{\pi^{3/2}}{c\,e} \cdot \frac{|\eta|\, R}{|I_m(Z_\perp)|\,\langle\beta_\perp\rangle} \cdot E \cdot \left(\frac{\sigma_E}{E}\right)$$

for BUNCHES of $4\sigma_t > 1.1$ ns

$\langle\beta_\perp\rangle \sim \frac{R}{Q}$

$Q = 6.25$

$R = 100$ m

$|I_m(Z_\perp)| \sim \frac{2R}{b^2} \cdot \left|\frac{Z_{\parallel}}{n}\right|$

$\left|\frac{Z_{\parallel}}{n}\right| = 17\,\Omega$

$b = 3.5 \times 10^{-2}$ m

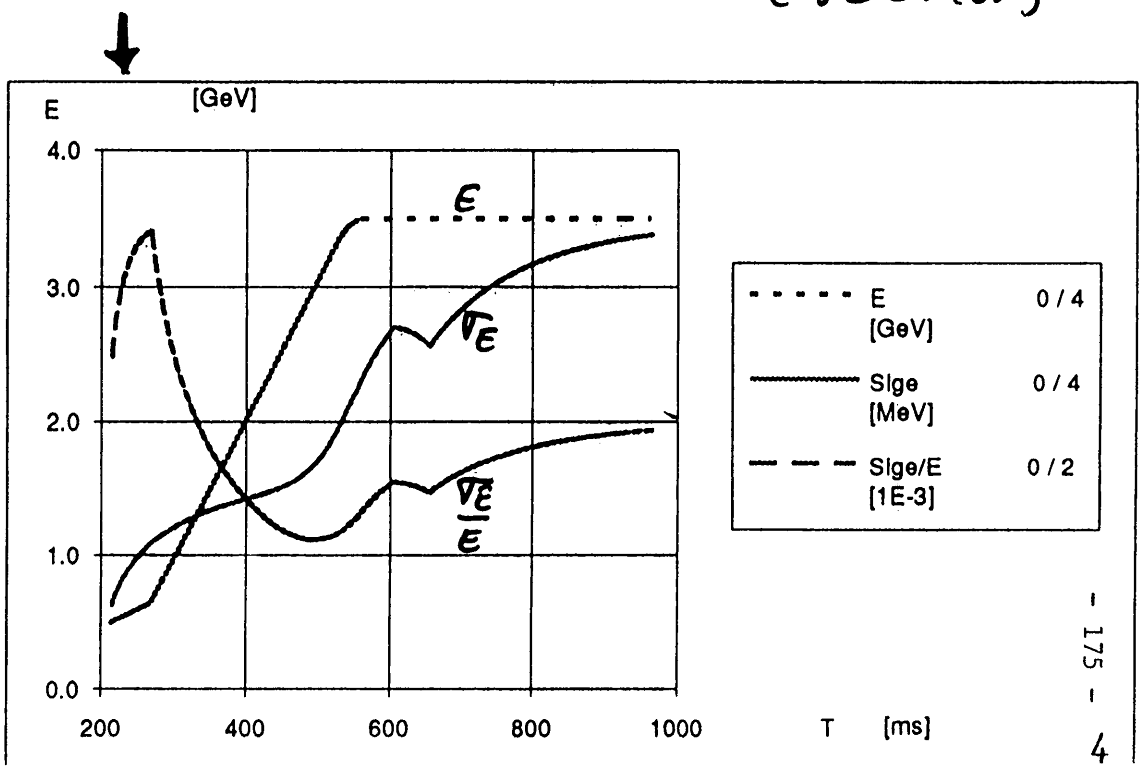
$|\eta| = .027$

$E = 500$ MeV

$\frac{\sigma_E}{E} = 10^{-3}$

$N_b \leq 4 \times 10^{10}$

WORST CASE : INJECTION (500 MeV)



③ COHERENT VERTICAL INSTABILITIES DUE TO TRAPPED IONS$^+$

- ONLY WITH e^- BEAMS
- WORSE AT 3.5 GeV, VERTICAL PLANE
- DEPENDS ON VACUUM
- DEPENDS ON N_b AND ON BUNCH SPACING (k_b)

LIMITS:

$k_b = 4$ $N_{b_{e^-}} \leq 5 \times 10^{10}$ | WITH GOOD VACUUM [2×10^{-8} T]

$k_b = 8$ $N_{b_{e^-}} \leq 2.5 \times 10^{10}$ ↓ 5×10^{10}

WITH
- H/V COUPLING
- TRANSVERSE FEEDBACK

(4) BEAM CHARACTERISTICS AT 3.5 GeV

$$\Delta N_{TS} = \overbrace{\frac{\sigma_E}{E} \cdot 4\sigma_t \cdot \frac{dN}{d\varepsilon_l}}^{N_b} \cdot K_b \cdot N_c$$

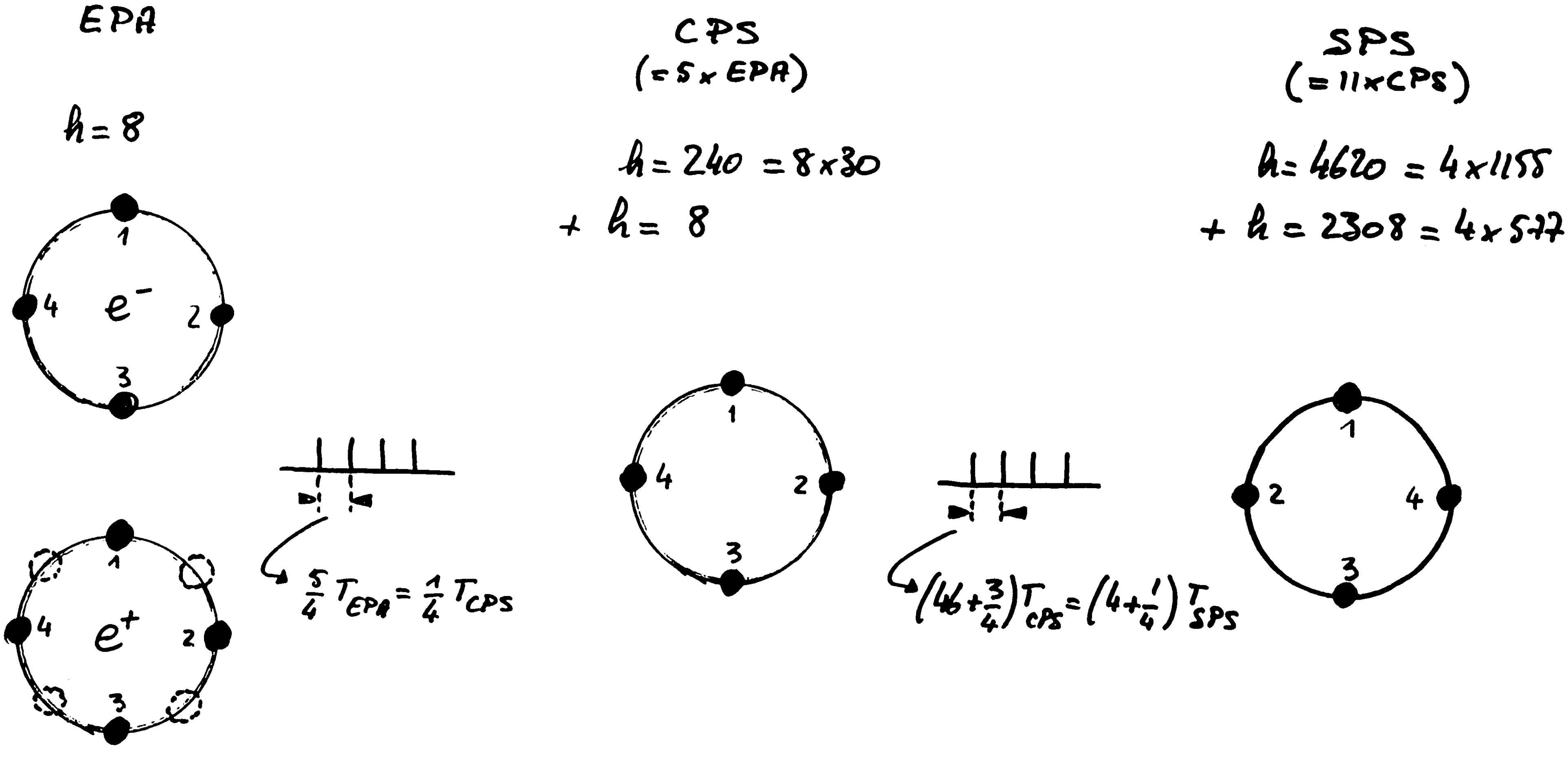
- $\frac{\sigma_E}{E}$ LIMITED TO 10^{-3} BY CPS EXTRACTION AND TRANSFER CHANNEL ACCEPTANCE

- $4\sigma_t$ LIMITED TO 4.4 ns BY QUANTUM LIFE TIME IN THE CPS

- $\frac{dN}{d\varepsilon_l}$ LIMITED TO THE MAX. DENSITY ACCEPTED BY SPS (BEAM BREAK-UP INSTABILITY AT INJECTION)

  $N_b \leq 2.5 \times 10^{10}$ in a bunch of $\frac{\sigma_E}{E} = 10^{-3}$, $4\sigma_t = 4.4$ ns

- K_b, N_c SEE TRANSFER SCHEMES

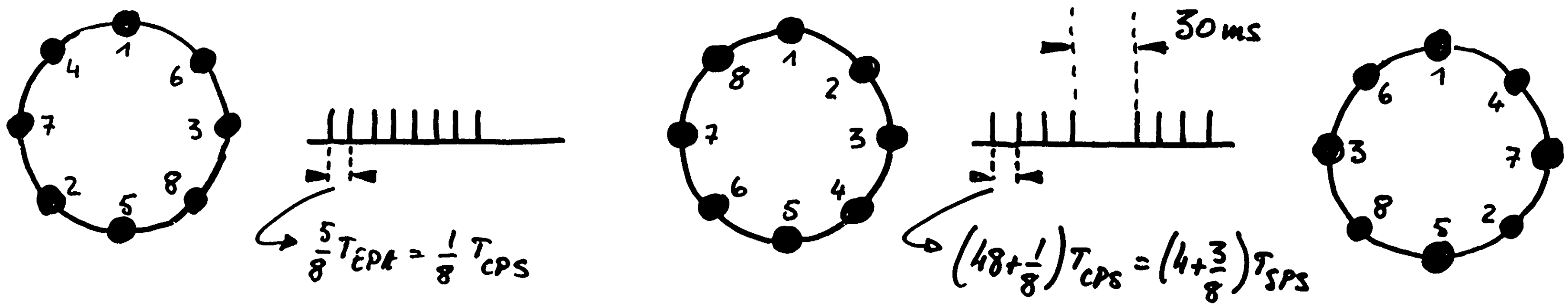


4 BUNCH TRANSFER SCHEME

$K_b = 4$
$N_c = 2$

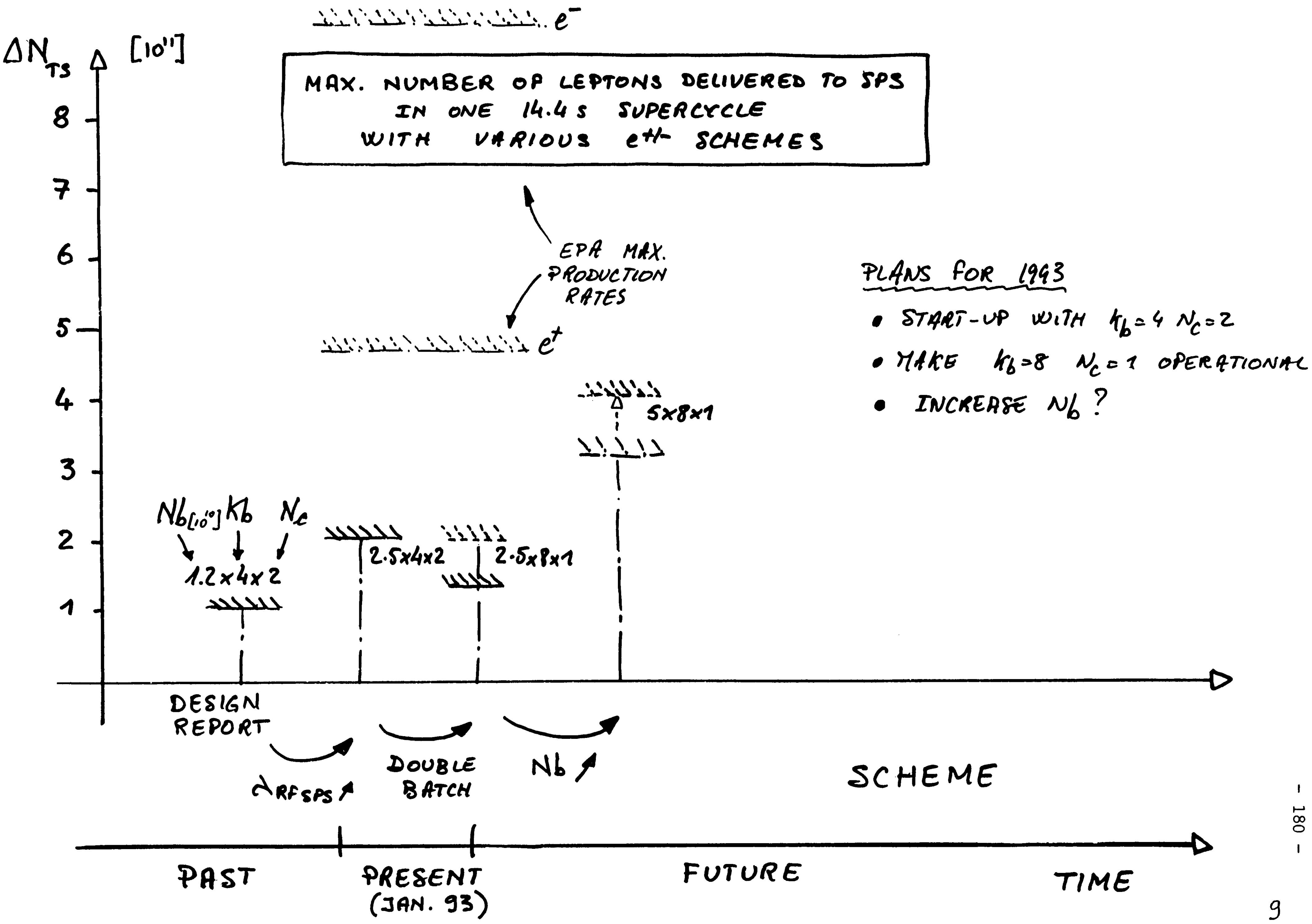
7

EPA	CPS (= 5 x EPA)	SPS (= 11 x CPS)
$h = 8$	$h = 240 = 8 \times 30$	$h = 4616 = 8 \times 577$
	$+ h = 8$	$+ h = 2312 = 8 \times 289$
		$+ h = 8120 = 8 \times 1015$



8 BUNCH TRANSFER SCHEME

$K_b = 8$
$N_c = 1$

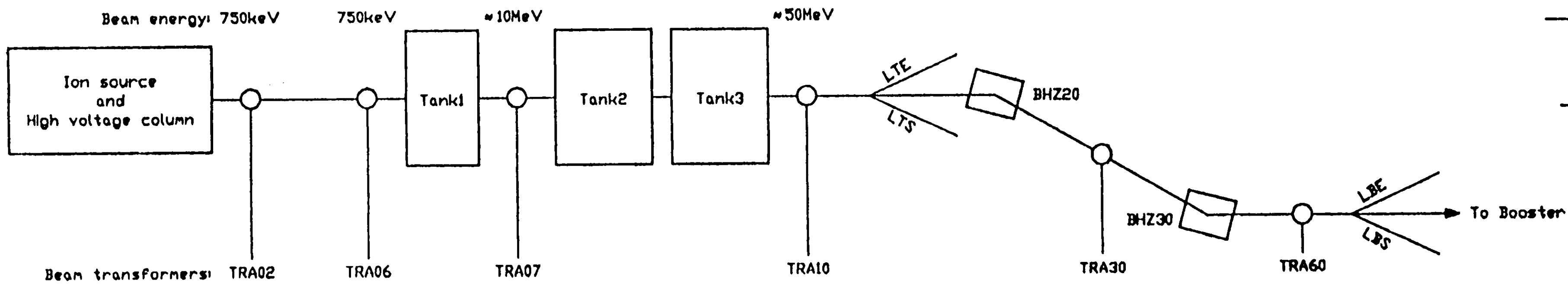


MAX. NUMBER OF LEPTONS DELIVERED TO SPS IN ONE 14.4 s SUPERCYCLE WITH VARIOUS e+/- SCHEMES
ΔN_TS [10^11]
8
7
6
5
4
3
2
1
e-
e+
EPA MAX. PRODUCTION RATES
Nb[10^10] Kb Nc
1.2x4x2
2.5x4x2
2.5x8x1
5x8x1
DESIGN REPORT
λRFSPS ↗
DOUBLE BATCH
Nb ↗
SCHEME
PAST
PRESENT (JAN. 93)
FUTURE
TIME
PLANS FOR 1993
• START-UP WITH Kb=4 Nc=2
• MAKE Kb=8 Nc=1 OPERATIONAL
• INCREASE Nb ?

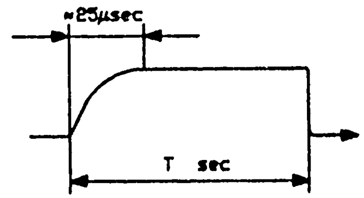
9

LINAC BEAM CHARACTERISTICS

1) Sketch of the Linac area (no scale)



2) Beam shape



Beam characteristics at 1.2 sec. repetition rate		Operation beam in 1992	High intensity beam in 1992	High intensity beam hoped in 1993
Relativistic beta x beta (output of the linac)		≈ 0.33	≈ 0.33	≈ 0.33
Pulse current	TRA Ø2 (in mAmp.)	350	424	-
	TRA Ø6 " "	190	250	≈ 200
	TRA Ø7 " "	150	190	-
	TRA 10 " "	150	180	190
	TRA 30 " "	142	172	-
	TRA 60 " "	140	170	≈ 180
Longitudinal emittance at 1σ (deg. x keV)		6500	7000	≈ 7000
Energy spread	At the linac output (keV)	± 350	± 380	≈ 380
	After the debuncher (keV)	± 150	± 150	± 150
Normalized horizontal emittance ε^* (mm mrad)		1.5	1.7	≤ 1.3
Normalized vertical emittance ε^* (mm mrad)		1.4	1.6	≤ 1.3
Pulse duration T (μsec)		< 120	< 40	< 60

Linac schedule (guide line)

1993

	February			March		
Wk	6	7	8	9	10	11
	8 – 14	15 – 21	22 – 28	1 – 7	8 – 14	15 . 1

Beam in the Linac 2 area → | Beam in the PS area |

RFQ tests (with RF)

RFQ tests (with beam)

← Beam at 50 MeV ——

Ions source tests

18/2 ← Beam at 10 MeV (if possible)

← High intensity beam optimization —— - - - - - - →

beam ready → for operation

← Emittance measuring lines ready (LTS then LTE)

← Running in of the new control system —— × — Control system optimization ——

—— Linac settings from the Linac control room —— - - - - - - →

← Linac settings from the MCR. ——

BEAM IN THE BOOSTER AREA

2/2/93

SOME PROBLEMS REMAINING TO BE SOLVED

1. FOR HIGH INTENSITY BEAM
   LACK OF RF POWER TO COMPENSATE THE BEAM LOADING EFFECT IN THE 3 TANKS

2. INSTABILITY OF THE HORIZONTAL PLANE OF THE BEAM, OWING TO THE PS FRINGING FIELD EFFECT ALONG THE LTB LINE

3. NEW AND UNEXPECTED PROBLEMS WITH THE RFQ (i.e. Alignment)

MD's 1993 :

Prime Time	Topic	Customer	Remarks/Requirements/ Contribution	Total hrs estimated
Y	'LHC' Beam 1.8E12p	LHC	RFQ2 + Linac >180 mA	2 x 5
	Emittance Meas'mt/Comparison	LHC	PS SEM Grids, Flying Wire	
Y	LHC Test 1.4 GeV	LHC	cf. Note, incl. prep h=1,2	cf. K.S.!
Y	High-Intensity Tuning, Loss Analysis & Reduction	ISOLDE	h=10 Cavitiy programming Septum position	4 x 5
	Steering/Focusing Transfer Line	ISOLDE	Fine tuning, customer desiderata.	
Y	Capture at large Bdot	Pb Ions	Fast Acceleration at low energy	2 x 5
Y	Main Power Supply : Operate with 4 Groups	Pb Ions LHC	PO Group	2 x 5
	PPM Scintillator Screens	Pb Ions	OP, CO Groups	
	Integer Stopband Compensation	PSB	Successful at ISIS	

PSB Summary

Performances 1992 :

User Name	Beam Type Destinatn	Nr of Rings	Nr of p tot.	Nr of p/ring	Norm. H	Emitt V	Comments	Limits
SFT	SPS Fixed Target Ph.	4	2.5E13	6.2E12	45 pi	25 pi		
AA	p production	4	1.8E13	4.6E12	30 pi	15 pi	RF dipole recombin. h=10 phase inverted	PS
PHY	Test beam East Hall	1	0.3E12	0.3E12	10 pi	5 pi	Shaving for stability	
TST	Test beam for AAC	1	1.5E11	1.5E11	14 pi	2 pi	Shaving	
ISO	ISOLDE	4	3.2E13	8.3E12	55 pi	30 pi	Nominal	LIMIT 1,(2)
MD	PSB LHC Test Beam	1		1.75E12	9 pi	10 pi	Linac 165 mA	LIMIT 2
IONS	O8+/S16+	4		4.0E10e			discontinued	Ion Source Beam Diagn.

LIMIT 1 : Longitudinal stability is marginal at higher intensities due to
- coupling between rf beam control loops of dual RF system (11 per ring): difficult to control, lack of understanding
- Coupled-Bunch Long. Feedback not designed for acceleration to 1 GeV
- Instability of unknown type (GHz signals ?) in Ring 4, causing blowup and sometimes loss of a few % beam.

LIMIT 2 : "Classical" transverse space charge limit.
At high intensity also the longitudinal space charge drastically reduces bucket area (and forces to slowed-down acceleration cycle)

3 PROBLEMS :

i) Marginal stability of dual RF system : Actually the intensity limit, tedious operation, losses

ii) Longitudinal coupled-bunch instabilities : Damper to be improved

iii)Loss management (related to (i) & (ii) in the ring - to be analysed in ejection & transfer - kickers ?)

iv)RF Voltage : with 13 kV: bucket is too small

v) (For LHC: New horizontal emittance measurement device - preferably mechanical)

PPday Feb 3,93

LPI Machine Summary

1-Performances

Present LPI operation performances are summarized below

	Present Users requests	Operational values	Maximum values	**8 bunches transfer with 3.5 E10 e+/- at SPS exit**
LPI accumulation rat in 10^9 $e^+/(s*bunch)$	3.5	5.4	8.0	4.2
LPI accumulation rat in 10^10 $e^-/(s*bunch$	3.2	4.9	12.0	4.9

Remarks

Present users requests: In fact the LPI is tuned for the operational values shown above, but the accumulation is stopped at half the total time available.

8 bunches transfer scheme: If we assume 3.5 E10 e+/- per bunch and an efficiency of .58 between LPI and SPS to LEP extraction line

Conclusion

With the **present** requests we have good margins, but as soon as requests on positron production is increased we will have to spend time and money.

1993 LPI STUDIES SCHEDULE

The study program is defined up to week 17. After it is indicative

PPDay93

Startup tests week 13 (12)
Front-end tests
LILV optics
EPA closed orbit and apertures
EPA intensity limits

	Jan				Feb							Mar	
	1	2	3	4	5	6	7	8	9	10	11	12	13
30	4	11	18	25	1	8	15	22	1	8	15	22	29
Tue													startup
Wed			S	H	U	T			LIL	LIL	LIL	LPI	with
Thu									gun	buncher	RF	start up	beam
Fri				O	W	N			tests	tests	tests	tests	
Sat													
Sun													

Mechanical lock ------> | <-- LPI controlled access

Week 14 Studies
345MeV 10h
test(LHC)
Ion critical mass
Ion freq excitation

	Apr				May						Jun		
	14	15	16	17	18	19	20	21	22	23	24	25	26
Mo	5	12	19	26	3	10	17	24	Whitsun	7	14	21	28
Tu					LEP								
We		S.U.			Start up								
Th					with							S.U.	
Fr					beam								
Sa				1. May									
Su	Easter												

Week 17 Studies
micro bunch meas @ 5 & 200 MeV
LILW optics
tests of 500 MeV parasitic mode(LHC)
EPA impedances
Ion studies ?

	Jul				Aug						Sep		
	27	28	29	30	31	32	33	34	35	36	37	38	39
Mo	5	12	19	26		9	16		30	6	13	20	27
Tu													
We													
Th													
Fr													
Sa													
Su													

Week 34 Studies
micro bunch meas @ 5 & 200 MeV
LILW optics measurements
Positron production versus phase and accel gradient
LHC irradiations

Week 38Studies
Positron studies
EPA performances @ 321 MeV and below
Injection modelling studies

	Oct				Nov						Dec		
	40	41	42	43	44	45	46	47	48	49	50	51	52
Mo	4	11	18	25		8	15			6	13	20	27
Tu													
We													
Th													
Fr													
Sa												Xmas	New Y.
Su													

Week 44 Studies
Positron studies
LPI reference data
LHC irradiations

Week 47
LHC irradiations
Week 48
LIL and EPA studies

Week 49 & 50
LIL and EPA studies
CTF Studies

Legend: **LPI MDs** | **PS MDs** | **Production** | **LEP MDs**

g:\home\p\potier\lpiperfo\lpmd93.xls 2/02/93 %t

Major problems

Performances OK

As they are high enough in respect to users requests... **Not yet performances problem, but one must remember** that increasing positron production, our closest bottle-neck, will need time and money to develop and implement.

Controls

OK during lepton production for LEP, but still improvements needed for instrumentation which is still the bottle-neck for studies.

Man Power for studies "The ballad of the poor experimentalist" (traditional song)

In the present operation scheme, MD periods of 60 to 70 h are allocated every 1 to 4 months. The use of such a long study period, with only 2 to 3 people involved in LPI studies, is completly unefficient.

Chohan/03Feb93/00

AAC Performance, Problems and Near-Future Plans:

Summary talk at the end of the day:

V. Chohan

Abstract

The principal issues of the AAC Performance described in the earlier session are summarised here with the addition of some other very important technical issues, related to the whole infrastructure necessary for the operation of the Antiproton Collector & Accumulator Complex. The planned 1993 running schedule is shown and the three most important worries, as perceived by the author, are exposed.

11.Dec.92 /SB version 1.1

1993 PBAR SCHEDULE

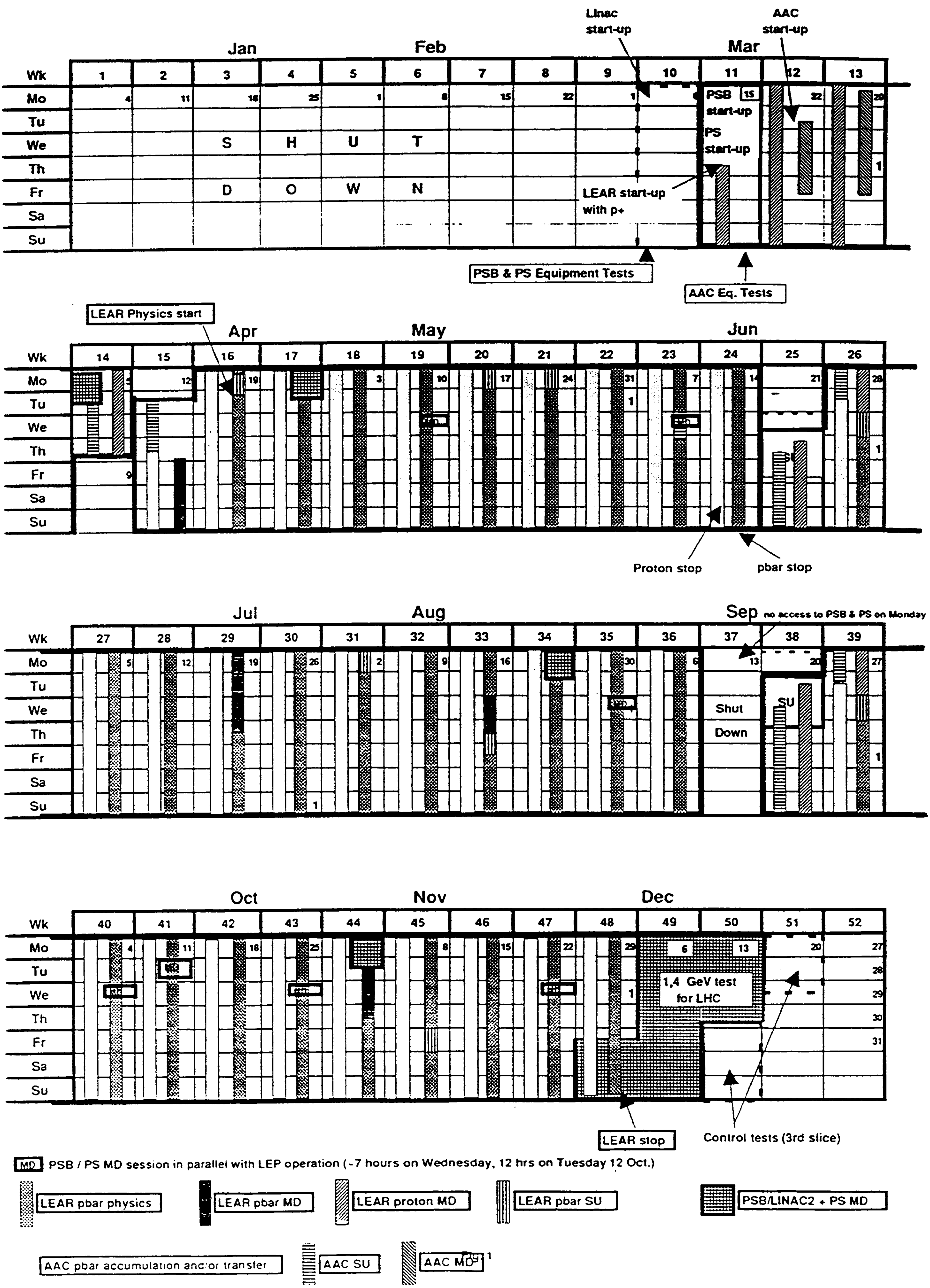


Fig. 1

03/02/93 Chohan/01summmary

AAC SUMMARY

- Studies to re-establish reasonable performance of the AAC in the LEAR era, with a reduction in quantity of antiprotons required but maintaining a reasonable quality and performance of the chain of processes in the complex from target to the stack core. **At least aim for the overall AC injection to Core efficiencies of the order of > = 75 %**
- **Development and studies in all cooling systems in both rings and concerning all planes.** While some system verifications, tests and development can be done in normal polarity (AA Core Studies, AC Longitudinal systems in all 3 bands etc), a substantial work can only be accomplished in Reverse Polarity of the AC ring, particularly for the transverse systems of all 3 bands in AC as well as studies related to longitudinal instabilities and evaluation of longitudinal impedance in the AC, with and without the presence of cooling in the AC Ring.
- **Prior to Studies with beam, a thorough hardware verification and tests are necessary in the shutdown and should be pursued with most urgency because of the number of systems and the effort involved per system.**
- For the AA Precooling and Stack tail systems, some improvement can be expected after these verification & development activities in the shutdown as well as after the start-up in March/April 1993.
- For Core Cooling Systems, an improvement in functioning beyond 5 to 6E11 in core seems necessary. After the problems in 1992 in Core 2-4GHz Longitudinal system, the purchase of a new amplifier, commissioning & tests in operation will be necessary in 1993.
- Tests/improvements or commissioning of certain necessary beam instrumentation systems, e.g., pbar coh. Osc. digital 'scope , Beam blowup system for setting-up in AC etc..

FOR THE ANTIPROTON PRODUCTION AREA AND IN PARTICULAR, for a Reliable, durable Pbar Production for the LEAR-era operation:

(1) Thicker magnetic horn development and beam tests in situ + development of sufficient backups & completion of the 20 mm Li lens inventory as a secondary , reliable spare.
(2) In situ tests of radiation-hard magnet BHZ6024 and study + development of a reserve QF7040, a necessary element in the AC to AA beam transport line.
(3) Support for life-time tests of plasma lenses in the laboratory (in conjunction with Univ. of Erlangen etc) which has direct iimplications and time-scales for (1) above.
(4) Remote-handling aspects and issues related to target area and implications for (1) & (2) above

03/02/93 Chohan/02summmary

Three Most Important Worries (Very Personal)

→ • **Cooling Systems** - very complex and needing sustained follow-up **during running and hardware maintenance & follow-ups in shut-downs**

→ • **Reserves/backups/Spares/Expertise** (Equipment &/or Human):A predictable consequence of certain physics programmes being run down and Priorities

For CERN & its reputation IT IS A NEW WAY OF WORKING

i.e., crisis-oriented functioning , hoping nothing goes wrong, tackling serious problems when you get them; but the **USERS should at least be told about it honestly so that they do not expect physics-time ~ 90% of scheduled-time as always.**

** Current AAC 'hot' issues: remote-handling, backup magnet(s), cryogenics, etc , all (in theory) issues which are farmed out to other CERN Divisions !

→ • **Good, Motivated, knowledgeable Operating Crew** to see us through to late-nineties.

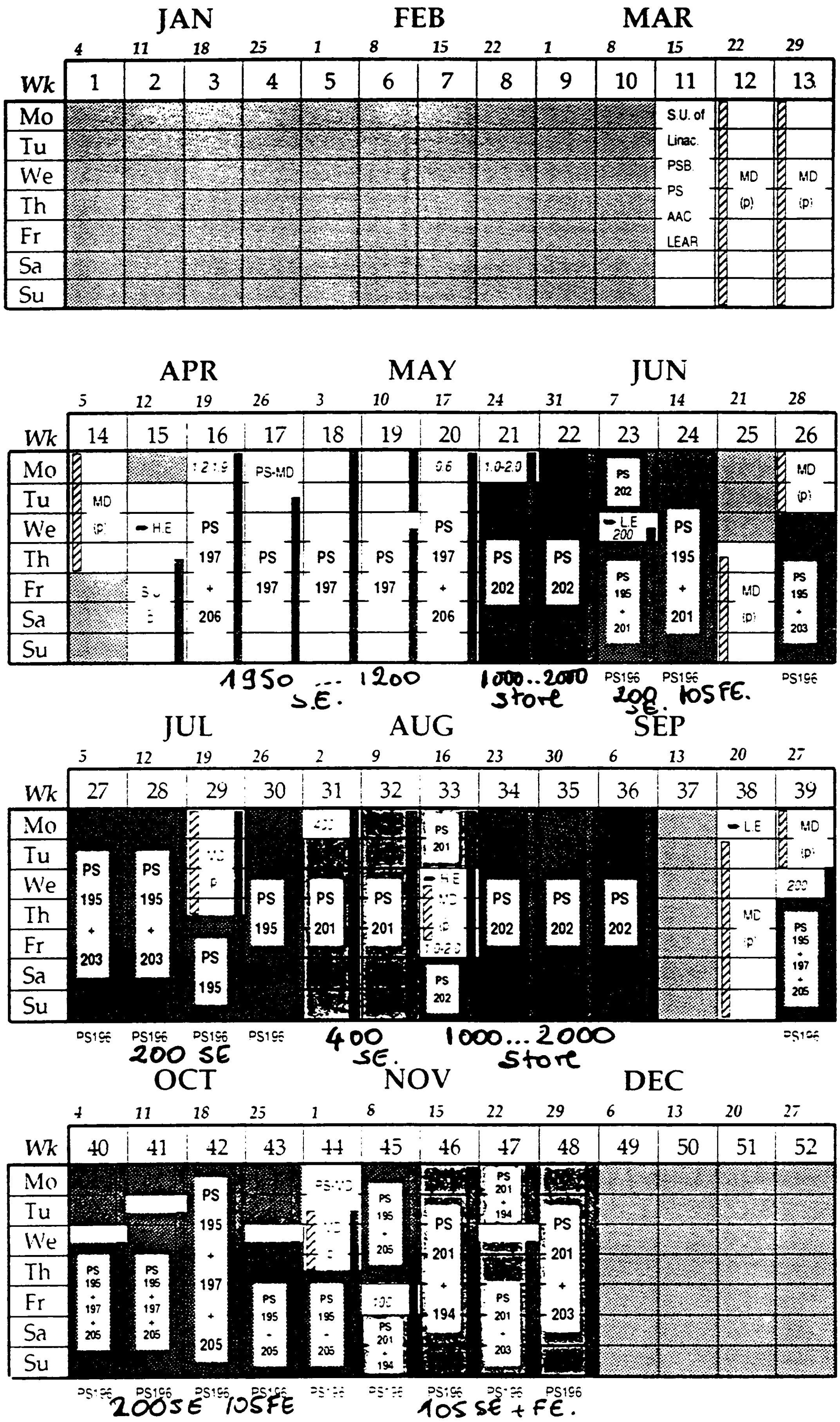
INCLUDES MACHINE PHYSICISTS/SUPERVISORS

LEAR SUMMARY

Abstract: Le programme de 1993 est presente . Le demarrage et les developpements de la machine LEAR sont passes en revue . Quelques commentaires personnels sont ajoutes .

M. CHANEL PS/AR ELOISE 93

LEAR SCHEDULE 1993



Version 1.6 - 24 November 1992
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PS197 HE 7 sem , PS195 , PS 202 , PS201
E 7 sem 12 sem 6 sem 6 sem.

1-Startup(march..april)

The main goal is to restart all operations after the shut-down,after the change of the gun of ecool,the modifications on the stochastic cooling....

Week 11: Restart with high energy cycle,tests of main power supply,btrain control....first tests of new gun ???

Week 12(1/2):injection on high energy cycle from linac2,acceleration tests with high Npart. ,adjust stochastic cooling and systematic measurements on machine and cooling .In parallel tests of ecool ...

Weeks 12(1/2)13,14(1/2):reset to low energy cycle ..injection,deceleration,scooling,transverse plane measurement

A lot of work on e-cooling but remembering the main goal is to have at least the same kind of operation as last year.The insertion of variable perveance,neutralisation and feedback is envisaged if tests aresufficiently advanced

BTF measurement in all planes .Find if the damper action is correct .Play with different parameters .

Measurement on extraction line (slow fast extr.) with different detectors.

Week 15:restart operation to pbar on HE cycle. Tests on transfer thru ps ,trajectory in injection line and matching in lear.

2-June and September MD's

Continuation on Low Energy cycle with ecool,BTF, Slow and fast extraction measurements .

Of course ,the problems encountered during the operation has to be solved.

3-All over year operation

Maintain good efficiency of slow extraction ,good beam characteristics for Jetset(beam dimensions)

4-The requests

- **4-1 : pbar transfers** : The transfer efficiency has decreased by ~30% in mean value this last two years leading to electricity and nerves consumption Remember that an efficiency of 90% of transfer will be very helpful for jetset

4.2 : Operations efficiency : The continuous optimisation of machines and beams by a sufficient number of people well qualified is also an ecologist action...not only a physicist one.!

COMMENTAIRES PERSONNELS

Nous constatons depuis quelques temps une croissance polynomiale sinon exponentielle du nombre de reunions,concernant un nombre croissant de personnes , demandant des efforts supplementaires sans commune mesure avec les resultats ,meme escomptes.Avec moins de ces reunions chaque personne aura ainsi plus de temps pour le travail productif.

Un travail en equipe autonome autour d'une entite est de mon point de vue nettement plus efficace et valorisant que la creation de structures fermees sur un sujet donne d'autant que le nombre de passerelles neces- saires a l'information devient rapidement trop nombreux .

Nous constatons que nous devenons incapables de faire des travaux avec court delai a cause de l'utilisation de filieres incontrolables et consommatrice de temps d'argent.de nerfs et de longues specifications sauf par des moyens detournes(amitie.connaissance.services rendus....)

Nous constatons aussi chez nous comme dans les les ensembles dits a economie d'echelle une augmentation devenant tentaculaire de l'administration.N'oublions pas que nous sommes un centre de recherche en physique des particules ,pas en administration......

POSTES VACANTS
RECRUTEMENT INTERNE
(Titulaires Seulement)

Page 1

25.01.1993

Admi 14/29

PS+SL 6/29.

Titre (Activité)	Numéro du poste	Filière de Carrière	Date of Public.	Remarq.
Analyste de Systèmes (AIS)	AS-MI-91-117-IN	VII	26.11.91	
Assistant(e) Administratif(ve) (Bibliothèque)	AS-SI-CD-92-50-IN	IV	18.06.92	
Assistant(e) Administratif(ve) (Archives)	AS-SI-AR-92-54-IN	V	19.06.92	
Technicien/Ingénieur Technicien (Electronique)	AS-MI-92-55-IN	VI	19.06.92	
Assistant(e) Administratif(ve) (Approvisionnement)	AS-LO-GE-92-81-IN	V	20.10.92	
Assistant Technique/Ingénieur-Tech. (Electronique)	ECP-PI-MC-91-93-IN	V ou VI	28.10.91	
Technicien/Assistant Technique	ECP-LI-91-95-IN	IV ou V	28.10.91	
Assistant(e) Administratif(ve)	ECP-ADM-92-49-IN	IV	27.05.92	
Assistant(e) Administratif(ve)	PPE-UO-92-44-IN	IV	04.05.92	
Techn./Assistant Tech. (Electromécanique/Electronique)	PPE-ALD-GS-92-74-IN	IV or V	09.09.92	
Pour plus d'information, veuillez contacter F. Cliff, PE, tél. 3653				
Techn./Assistant Tech. (Mécanique/Electromécanique)	AT-MA-92-9-IN	V	04.03.92	
Technicien/Assistant Technique (Contrôle de Qualité)	MT-SM-91-84-IN	V	21.10.91	
Technicien (Thermodynamique)	MT-SM-91-85-IN	IV	21.10.91	
Technicien (Electronique/Programmation)	MT-CAE-91-86-IN	IV	14.10.91	
Pour plus d'information, veuillez contacter P.W. Berry, PE, tél. 3232				
Assistant Technique/Ingénieur-Tech. (Electronique)	SL-BI-91-109-IN	V ou VI	21.11.91	
Assistant Technique/Ingénieur-Tech. (Electronique)	SL-BI-91-110-IN	V ou VI	12.11.91	
Technicien/Ingénieur-Tech. (Electricité/Electronique)	SL-RFL-92-42-IN	V ou VI	07.04.92	
Technicien/Assistant Technique (Electronique)	PS-CO-91-90-IN	V	08.11.91	
Assistant Tech./Ingénieur-Technicien (Electronique)	PS-LP-91-91-IN	V ou VI	08.11.91	
Assistant Tech./Ingénieur-Tech. ([illegible])	PS-RF-91-100-IN	V ou VI	08.11.91	
Pour plus d'information, veuillez contacter E. Mosselmans, PE, tél. 4125				
Employé(e) Administratif(ve) (Service Affaires Juridiques)	AG-LS-91-106-IN	III	08.11.91	
Ingénieur (Electronique ou Electricité)	CN-CE-AE-92-83-IN	VII	26.11.92	B
Asst. Admin./Asst. Admin. Supérieur (Chef du service Visites Publiques)	DG-CP-ME-92-78-IN	VI	30.09.92	B
Employé(e) Administratif(ve) (Approvisionnements)	FI-A-91-116-IN	IV	26.11.91	
Employé(e) Administratif(ve)	FI-F-CP-92-52-IN	III	15.05.92	
Employé(e) ou Assistant(e) Administratif(ve) (Achats)	FI-A-92-84-IN	IV	11.12.92	
Asst. Tech./Ingénieur-Tech.	TIS-GS-92-70-IN	V or VI	29.07.92	B
Pour plus d'information, veuillez contacter S. Datta-Cockerill, PE, Tel. 4127				
Technicien/Assistant Technique (Maintenance du Site)	ST-DI-MS-91-82-IN	V	09.10.91	
Asst. Tech./Ingénieur-Tech. (Electron./Communications)	ST-MC-AC-91-87-IN	V ou VI	25.10.91	
Pour plus d'information, veuillez contacter H. Koch, PE, PE, Tel. 7049				

14/29
SL+PS = 6

B = Comité de sélection en préparation

PS Summary

R.Cappi

Abstract

A program of the main PS-MD's activities for 1993 is given (1st transp.). One can notice that, particularly in the 2nd half of the year, many hours will be spent to prepare the LHC Test foreseen in December.

Concerning the PS beam performance, in the 2nd transparency there is a list of the main beam parameters with their connected problems. If we can (still) say that the PS satisfies its clients, we can also say that simultaneous optimum conditions on the different users, as was done in the past, are now practically impossible to achieve.

The main reason is personnel reduction (3rd transp.) of machine specialists as well as hardware specialists.

The machine fault rate has doubled (from 6 to 12%) in the last 3 years and the fault rate during MD's and SU's is >>30%. As an example: the results of the space charge studies (see "PS for LHC; Emittance Conserv. at Inj. Energy"/RC) were obtained during a time"window" of ~5 hours out of a total time of ~60 hours (5x12 h.of dedicated MD time in '92) spent in trying to simultaneously optimise LINAC, PSB, PS, instrumentation, etc. An efficiency of 10% compared to 50% that we used to have few years ago.

This is characteristic of a system close to instability where small perturbations produce"catastrophic" effects.

If we jump into a cahotic layer how long it will take to come back ?...this is the question...

PS Beams

Operational beams

	part.	cp [GeV]	I_b [p/p]	k_b	ε^*_x [µm]	ε^*_y [µm]	ε_l [eVs]	dp/p [10^{-3}]	t_b [ns]	specialties	problems
SFT	p	14	$2.5\ 10^{13}$	420	11	7	0.1	1	5	5tCT, I record, ad.deb., h=420	coll.effects., lossy extr.
e+e-	e+e-	3.5	10^{11}	4	0.05	0.01	0.01	1 (1σ)	1.1 (1σ)	h=8+240, J_F var. (R.wiggler)	trapped. ions, TMCI
AA	p	26	$1.6\ 10^{13}$	5	13	9	2	2.5	20	funn./merg.,h=20,10, 12,...20, b.rot.	coll.effects., γ_t cross., large ε_v
TST	p	3.5	$2\ 10^{10}$	1	4	1.5	0.5	1.3	70	h=20,6	
LEAR	pbrs	0.6	10^{10}	1	2	2	.2	2.4	160	decel.,h=10	A lim., transf.eff. 80%
PHY	p	24	$3\ 10^{10}$	deb.	3	2		1-3	(0.4s)	new,(ES int.pos.)	
MD/LHC	p	1.7	$2\ 10^{12}$	5	2.5	2.5	0.15	1.4	48	bright beam	

Other beams

	part.	cp [GeV]	I_b [p/p]	k_b	ε^*_x [µm]	ε^*_y [µm]	ε_l [eVs]	dp/p [10^{-3}]	t_b [ns]	specialties	problems
IONS	O,S	10	10^{10}	16	7	5	0.4	1.2	20	f_{RF}(B) b.c.	instrum. (low intens.)
MD/lep	p	14	$3\ 10^{11}$	1-20	2	2	0.18	2	4	bunch rotat.	
MD/spsrf	p	26	10^{13}	deb.	8	8	120	1.2	-	spec. debunch.	spec.dp/p meas.
MD/ionsim	p	20	$5\ 10^{10}$	20	2	2	0.2	2	4	bunch rotat.	
SppbarS	p,pbrs	26	10^{11}	1	4	2	0.5	3	4	bright beam, sp.b.rot., h=6/12,sp. synchr.	the most difficult beam !

NB: $\varepsilon^* = \beta\gamma\,\sigma^2 / \beta_c$

...and still we satisfy our clients...

1993 PS COMPLEX SCHEDULE

1993 PS-MD's FORECAST

e+e-
Trapped ion effects

pbars
decel. optim.

LHC
1GeV with RFQ2
26 GeV/ deb. rebunching
Trans. crossing
Flat-topped bunches
Transv. instabilities

LHC test preparation
Pow. supplies tests
Controls (double inj.)
Instr. commissioning
new wire scanner
new TT2 SEM Grids

Pb project
new b.c. h=20

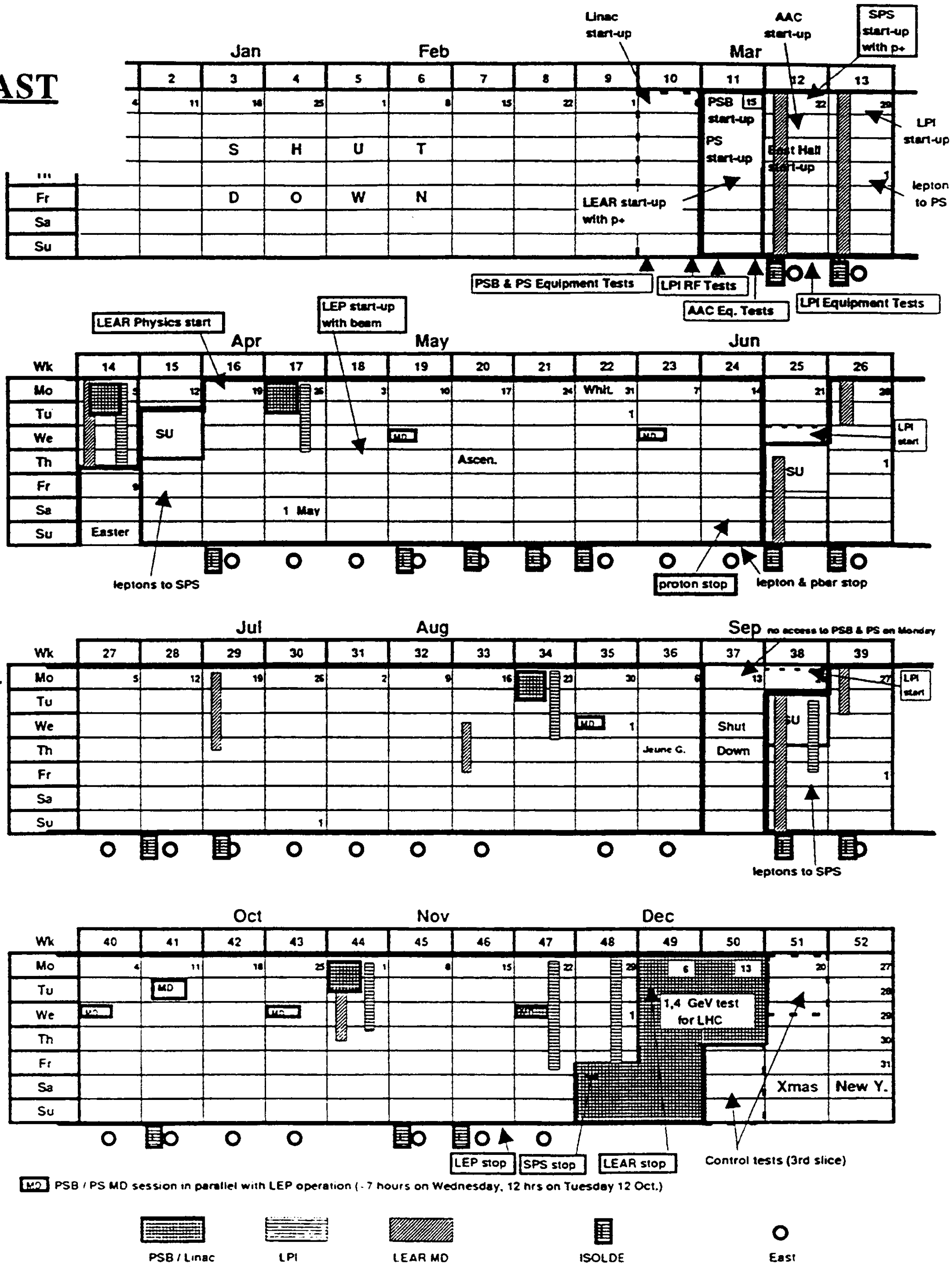
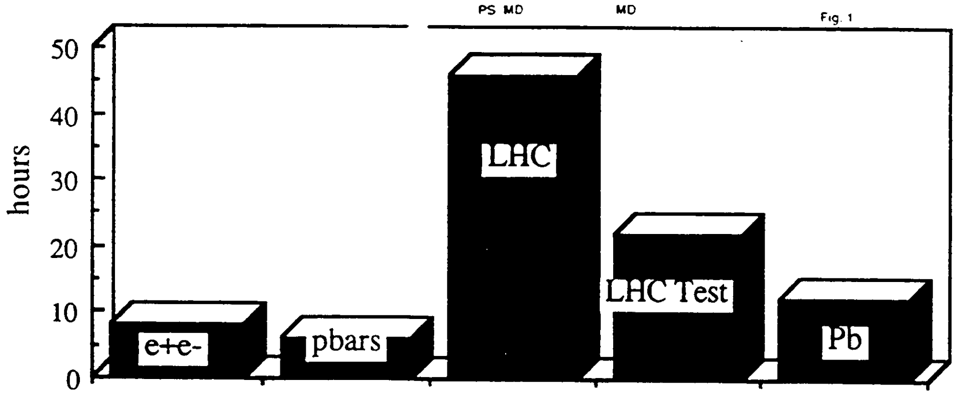
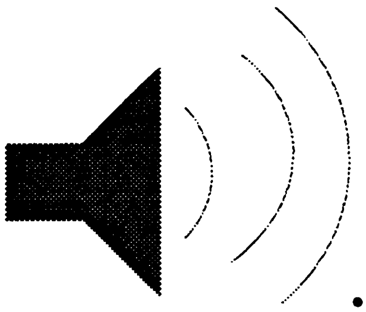


Fig. 1





...SOME PROBLEMS...

*Personnel reduction vs performance

- deterioration of integrated performance
- no simultaneous optimisation (...radiation damage)
- necessity to define priorities
- needs for a better budget & policy for ext. visitors
- reduced creativity / developments / studies

* Necessity of improving work efficiency

- new operational schemes
- "powerful" controls (e.g. archiving...)

*HW ageing

- needs of consolidation

LIST OF PARTICIPANTS TO THE PS PERFORMANCE DAY

ALLARDYCE, Brian
AUTIN, Bruno
BAIRD, Simon
BOILLOT, Jean
BOUTHEON, Marcel
BRAUN, Hans-Heinrich
BROUZET, Etienne
CAPPI, Roberto
CASPERS, Friedhelm
CHANEL, Michel
CHOHAN, Vinod
CYVOCT, Georges
DAEMS, Gilbert
DEKKERS, Daniel
DELAHAYE, Jean-Pierre
DUMOLLARD, Danièle
DURIEU, Luc
EVANS, John
FRAMMERY, Bertrand
GAREYTE, Jacques
GAROBY, Roland
GELATO, Giovanni
GIANNINI, Roberto
GRUBER, Jacques
HANCOCK, Steven
HASEROTH, Helmut
HEMERY, Jean-Yves
HILL, Charles
HUBNER, Kurt
KOZIOL, Heribert
LANGBEIN, Klaus
LEFEVRE, Pierre
LEY, Rudolf
MANGLUNKI, Django
MARTINI, Michel
MAURY, Stephan
MOEHL, Dieter
OEFTIGER, Uwe
PACE, Alberto
PEDERSEN, Flemming
PERRIOLLAT, Fabien
PIRKL, Werner
PLASS, Gunther
POTIER, Jean-Pierre
RASMUSSEN, Niels
RINOLFI, Louis
RIUNAUD, Jean-Pierre
SAULNIER, Claude
SCHINDL, Karlheinz
SCHNEIDER, Gerhard
SCHONAUER, Horst
SIMON, Daniel
STEINBACH, Charles
TAVARES, Pedro
TETU, Pierre
TRANQUILLE, Gérard
ULLRICH, Hanns
UMSTATTER, Hans-Horst
VRETENAR, Maurizio
WARNER, David
WILDNER, Elena