EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
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CERN - PS DIVISION

PS/ PA/ Note 95-03 (PPC)

Proceedings of the PS Performance Day (PPD'95)

Edited by D. Manglunki

Abstract

It was the occasion for machine physicists to exchange information and to outline their problems.
This year the emphasis was put on the lead ion beams, the high intensity proton beams, and various special activities (CLIC, Energy amplification test beam...).
These proceedings include, in addition to a copy of the transparencies that have been shown on the day, summaries and tables which are intended to be used as a reference for machine performances and beam time requests for machine development sessions.

The PS Performance Day was held in Rolle, Canton de Vaud, Switzerland, on February 2nd, 1995.

Geneva, Switzerland
17 February, 1995

PPD95 Programme

Time	Duration	Discussion(*)	Speaker	Title
08:15				*Bus leaves CERN*
09:00	**00:10**		R.Cappi	Opening address
			Session A (Chairman: D.J.Simon)	
09:10	**00:15**	00:05	J.Boillot	Statistics of PS complex operations in 1994
09:30	**00:15**	00:05	M.Vretenar	Lead ion beam in the Linac 3
09:50	**00:15**	00:05	H.Schönauer	Lead ion beam in the PSB
10:10	**00:15**	00:05	D.Manglunki	Lead ion beam in the PS
10:30	**00:15**	00:05	E.Brouzet	The PS lead ion beam, as seen from the SPS
10:50	**00:30**			**Coffee break**
			Session B (Chairman: R.Cappi)	
11:20	**00:35**	00:10	K.Schindl	PS complex proton beams for LHC
12:05	**00:10**	00:05	M.Vretenar	High intensity beam stability issues in Linac 2
12:20	**00:15**	00:05	H.Schönauer	ISOLDE and neutrino production beams
12:40	**00:15**	00:05	E.Wildner	Transfer lines to PS and to ISOLDE
13:00	**01:30**			**Lunch break**
			Session C (Chairman: B.Allardyce)	
14:30	**00:10**	00:05	M.Martini	Correction of injection oscillations in the PS
14:45	**00:25**	00:05	M.Chanel	Results and prospects of LEAR's Pb ion MD
15:15	**00:10**	00:05	J.P.Riunaud	Fast Extraction in 61 for Energy Amplification Tests
15:30	**00:15**	00:05	J.Y.Hémery	Experimental areas
15:50	**00:15**	00:05	G.Daems	Controls rejuvenation and impact on machine operations and developments
16:10	**00:30**			**Tea break**
			Session D (Chairman: M.Bouthéon)	
16:40	**00:25**	00:05	H.Braun	The CERN Linear Collider CLIC
17:10	**00:10**	00:05	M.Vretenar	Linac 2 & 3 summaries
17:25	**00:10**	00:05	H.Schönauer	PSB summary
17:40	**00:10**	00:05	J.P.Potier	LPI summary
17:55	**00:10**	00:05	C.Metzger	AAC summary
18:10	**00:10**	00:05	M.Chanel	LEAR summary
18:25	**00:10**	00:05	R.Cappi	PS summary
18:40	**00:10**		D.J.Simon	Closing address
18:50	**00:40**			(reserve)
19:30				Cocktail
20:00				Dinner
22:00				Bus to CERN

Note:
These summaries consist of 4 subjects:
** Beam performance list*
** List of expected improvements and MDs in 1995*
** Update on problems listed in 1993*
** List of (maximum 3) current problems*

(*) not included in the talk duration

jb - PPD - 2 February 1995

PS COMPLEX PERFORMANCE IN 1994

In 1994, the running time of the PS Complex exceeded 6400 hours with an increase in the number of hours devoted to physics. The beam availability for the CPS users was comprised between 88 and 93%. This relatively low performance is mainly due to the difficulties encountered during the general start-up in March and April which contributed by 3% in the global fault rate.

The improvement of the performance, especially on the proton beams for SPS and ISOLDE, took time and needed a strong effort from all the specialists concerned, generally involved in parallel in other projects. After numerous optimisations carried out during several months on the Linac2, Booster and PS, good results were obtained with the intensity delivered to SPS fixed target physics reaching 2.4 to 2.5 10^{13} protons per PS cycle. The proton intensity for ISOLDE also reached 2.6 to 3 10^{13} protons per pulse.

The lepton beams ran well with a good regularity and continued to use 2 successive cycles of the PS supercycle.

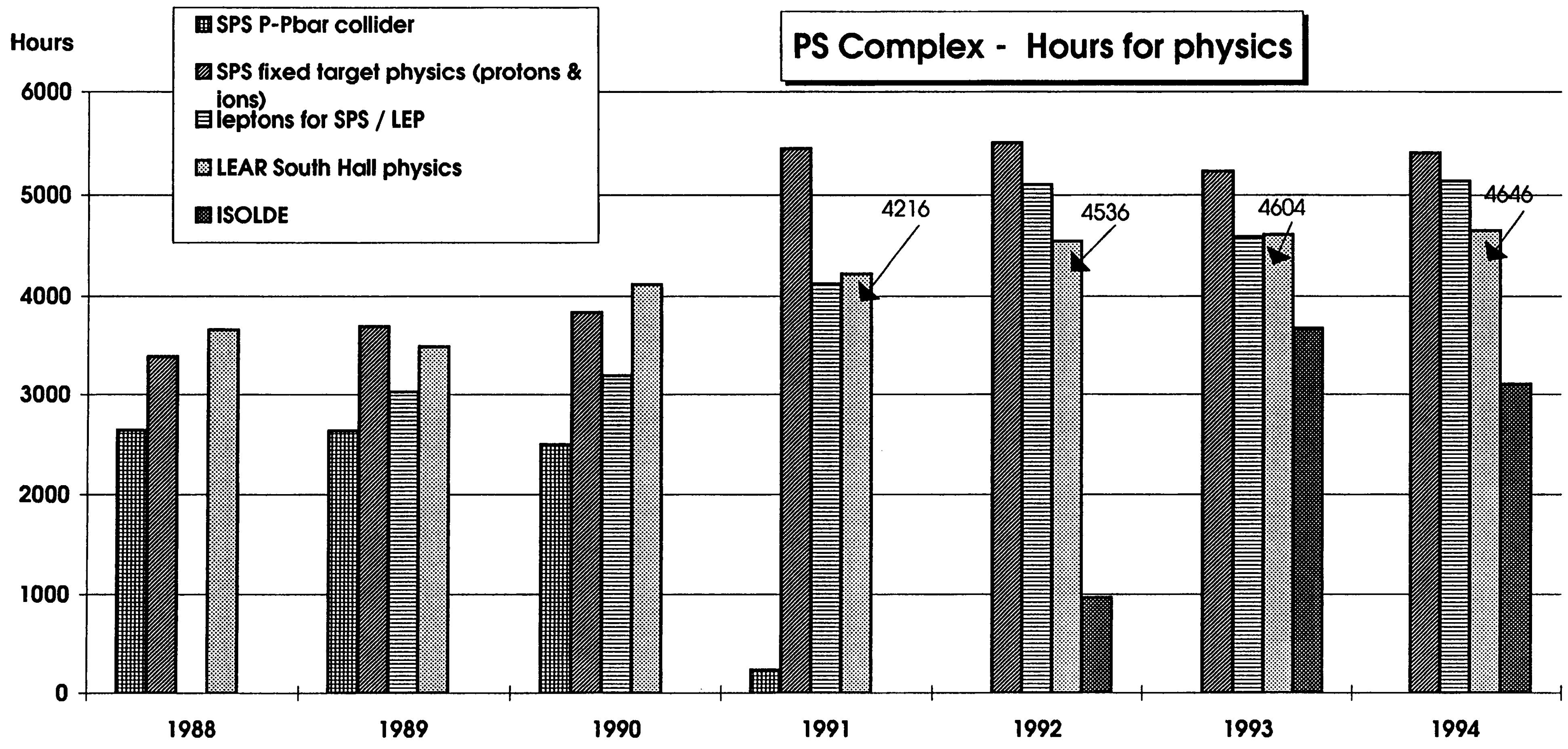
After a careful commissioning with Pb ions of Linac3, PSB and PS the operational run was very successful for these beams serving SPS fixed target physics for the first time. An average of 1.2 10^{10} charges of Pb^{82+} per cycle was currently provided for SPS with a record of 1.7 10^{10} charges.

Apart from the classical slow extraction of protons at 24 GeV/c for the East Hall test experiments, a fast extracted beam was set up for the energy amplifier test installed in the t7 line. This test experiment was successfully supplied with beam of variable intensities between 3 10^{8} and 2 10^{9} protons per cycle at 9 different energies.

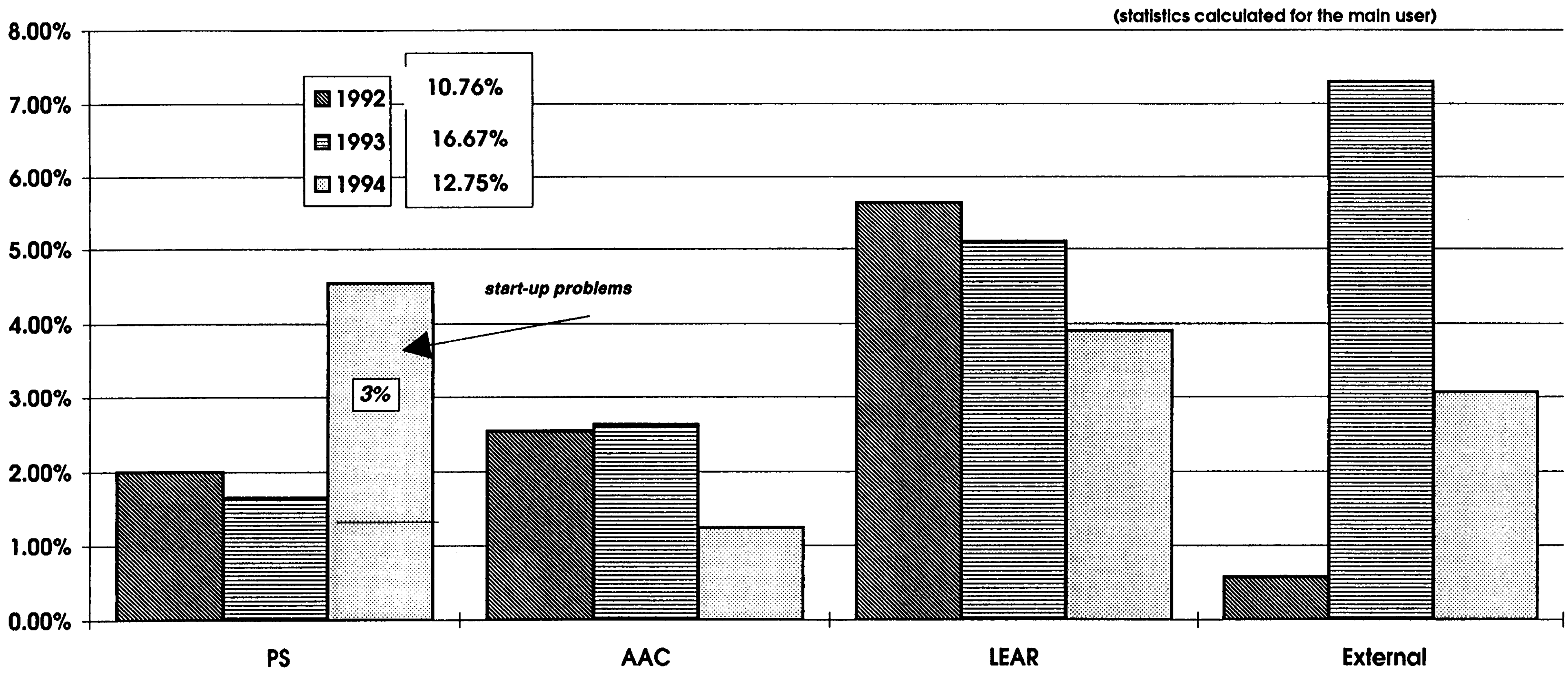
LEAR ran for 9 different experiments with a record of 2687 spills delivered for physics. The transfer efficiency from AAC to LEAR was maintained at an high level between 70% and 95%. Unfortunately about 10% of the spills extracted at 200 MeV/c were destroyed by a phenomenon (called "ghost") always under investigation. AAC worked well over this year with an average stacking rate of 1.9 10^{10} pbars/h and the stack reached a maximum of 1.07 10^{12} antiprotons. Another good performance was achieved in LEAR with a record beam intensity of 7.34 10^{10} reaching the 1315 MeV/c momentum required by Jetset experiment.

BEAMS produced by the PS COMPLEX in 1994

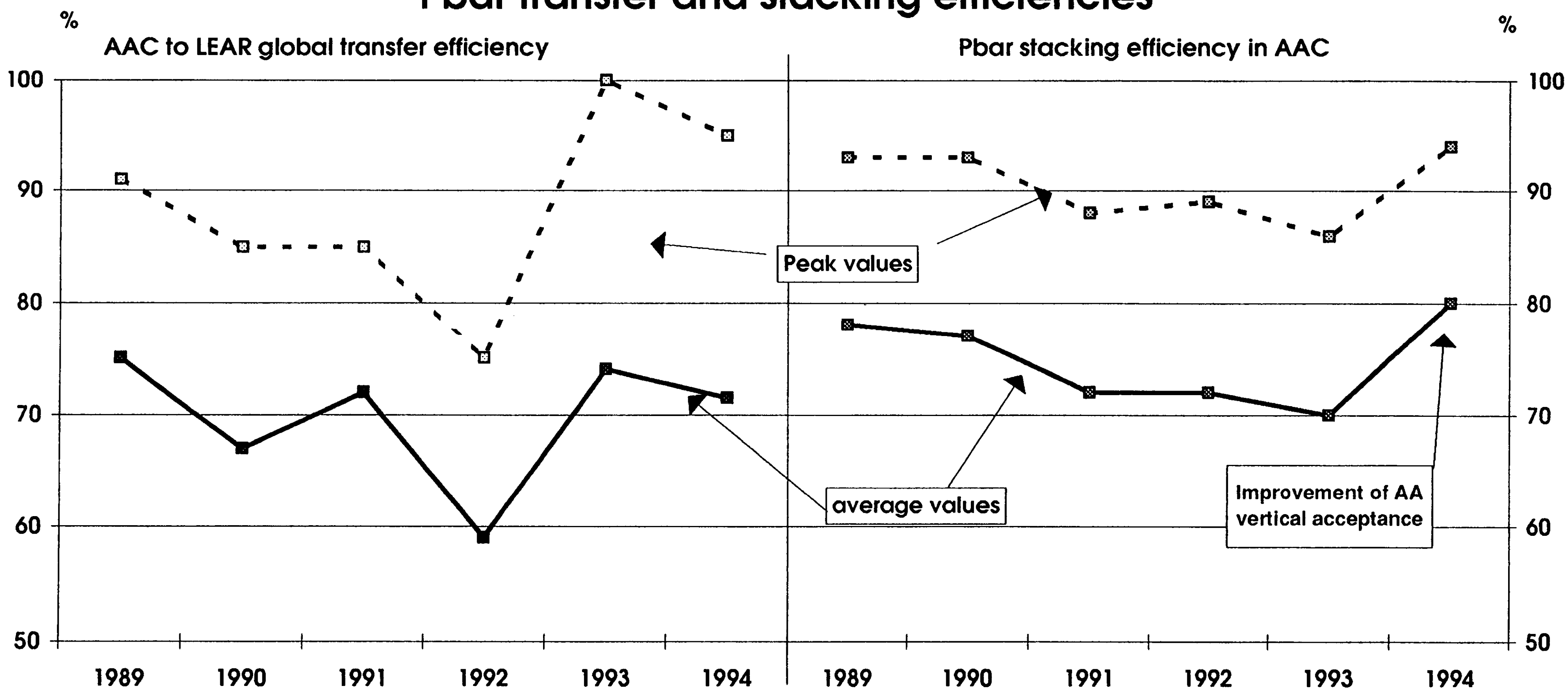
Beam	av. intensity/cycle	Records or performance	availability
Leptons			
e+e- --->SPS - LEP	1.8 E11 *(2cycles: 1 e+, 1 e-)*		88.3%
Protons			
SPS	1.5 to 2.5 E13		88%
ISOLDE 71 experiments	6 & 2.5 E13	3 E13 / PSB cycle	93.6%
EAST HALL (slow extr.) 43 experiments	3 E11		
EAST HALL (energy amplifier)	5 E8 to 5 E9	9 energies	
Pb ions			
Pb53+ (charges)	1.33 E10 (Booster)	2 E10 / cycle (Booster)	
Pb82+ (charges) ---> SPS	1.2 E10 (TT2)	1.7 E10 / cycle (TT2)	92.3%
Antiprotons			
AAC	*stacking rate:* *1.9 E10 pbar/h*	*Max. Stack.: **1.07 E12** pbars*	
		AAC-LEAR transfer effic ---> **90%**	
LEAR & SOUTH HALL		7.34 E10 pbars at 1315 MeV/c	87.3%
11 experiments		2687 spills	


PS Complex - Hours for physics
Hours
6000
5000
4000
3000
2000
1000
0
SPS P-Pbar collider
SPS fixed target physics (protons & ions)
leptons for SPS / LEP
LEAR South Hall physics
ISOLDE
4216
4536
4604
4646
1988
1989
1990
1991
1992
1993
1994

Antiproton beam for South Hall experiments - Fault rates

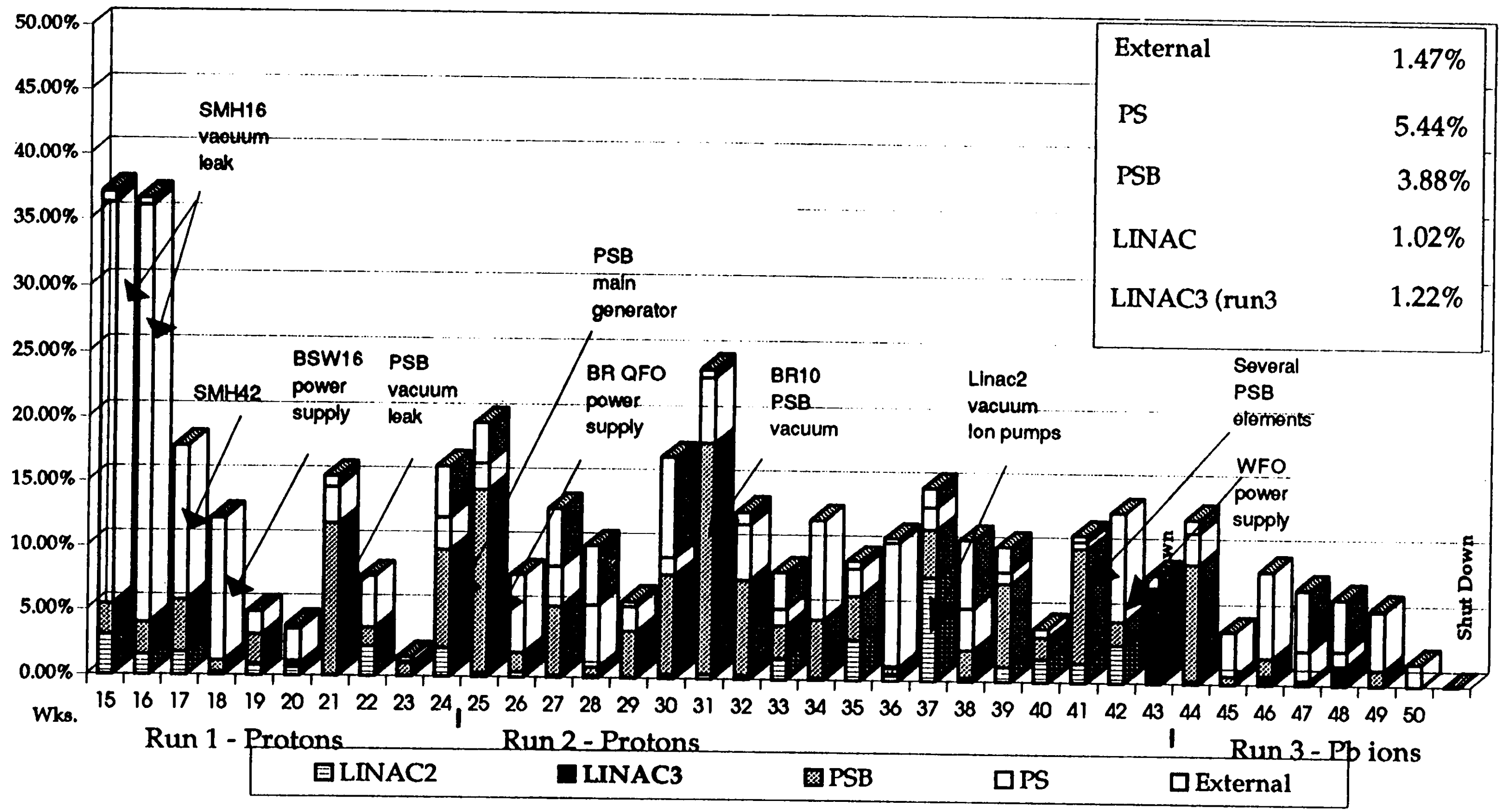


Pbar transfer and stacking efficiencies



1994-PS Complex fault rates- Hadron beams for SPS

Total Average 12.03%



FLTSFT.XLC

PS Complex fault rates

Hadrons (ions & protons) for SPS & Leptons for SPS/LEP

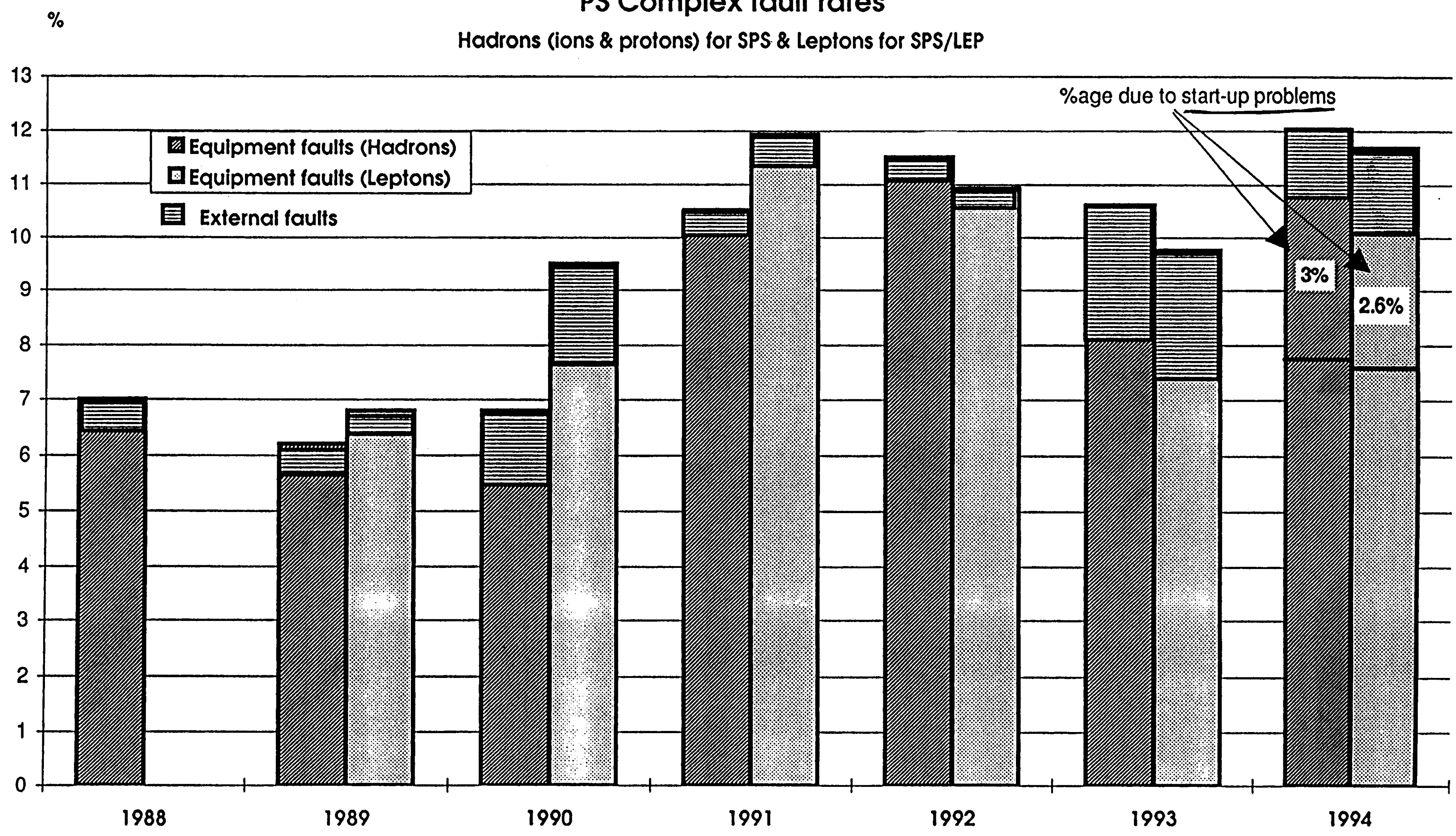


Fig.9

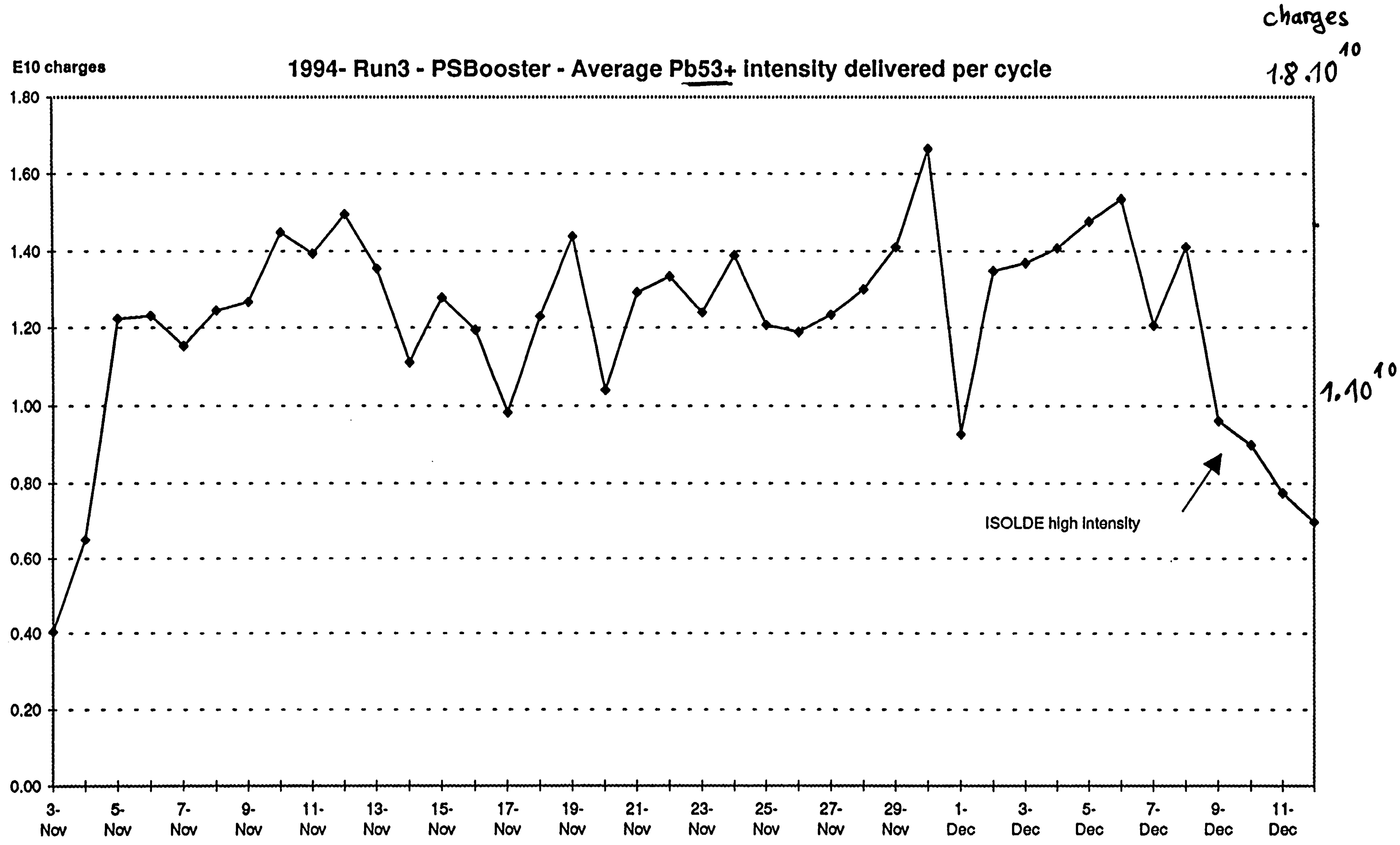


FIG. 13

ION94.XLS

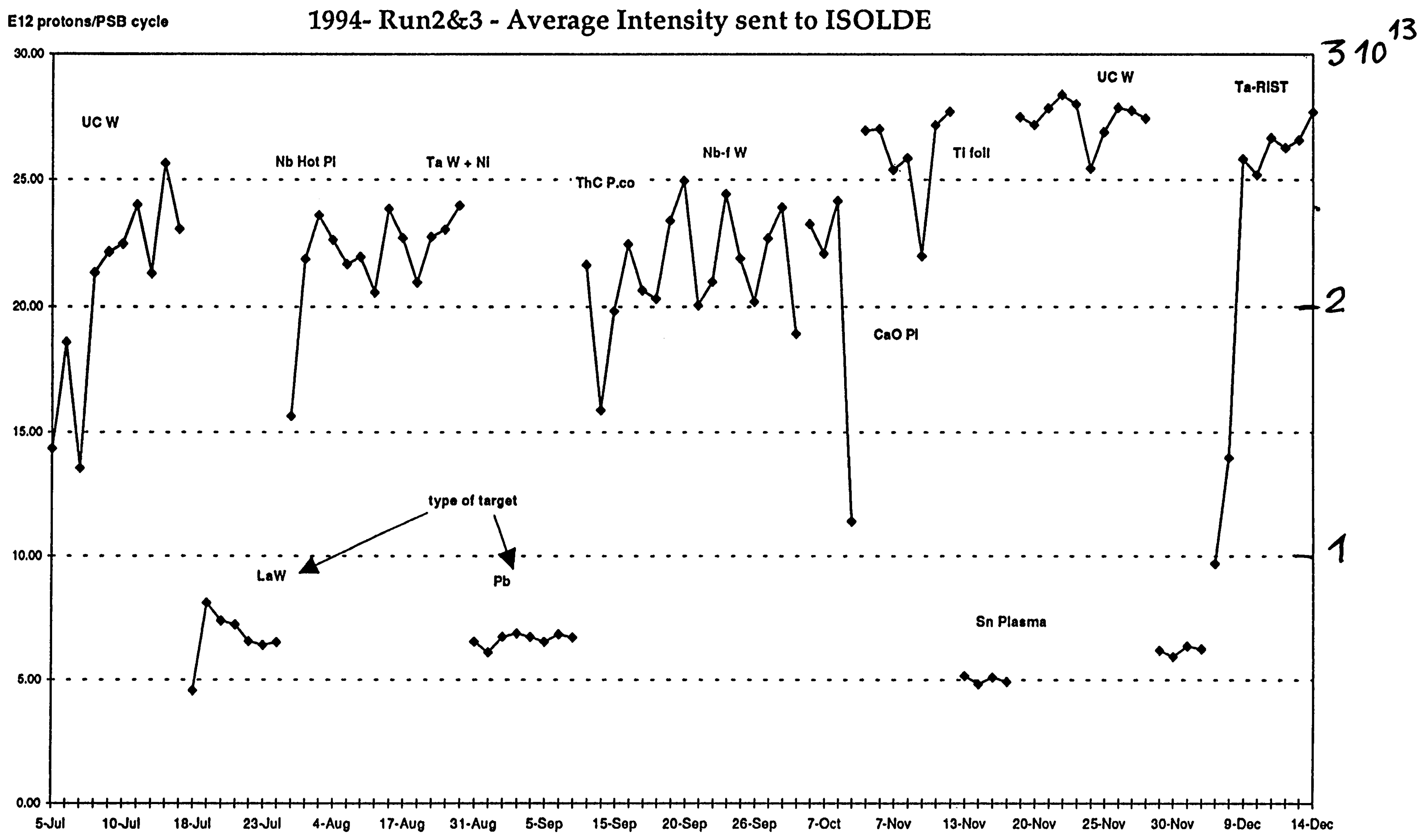


FIG. 14

RUN2&3.XLS

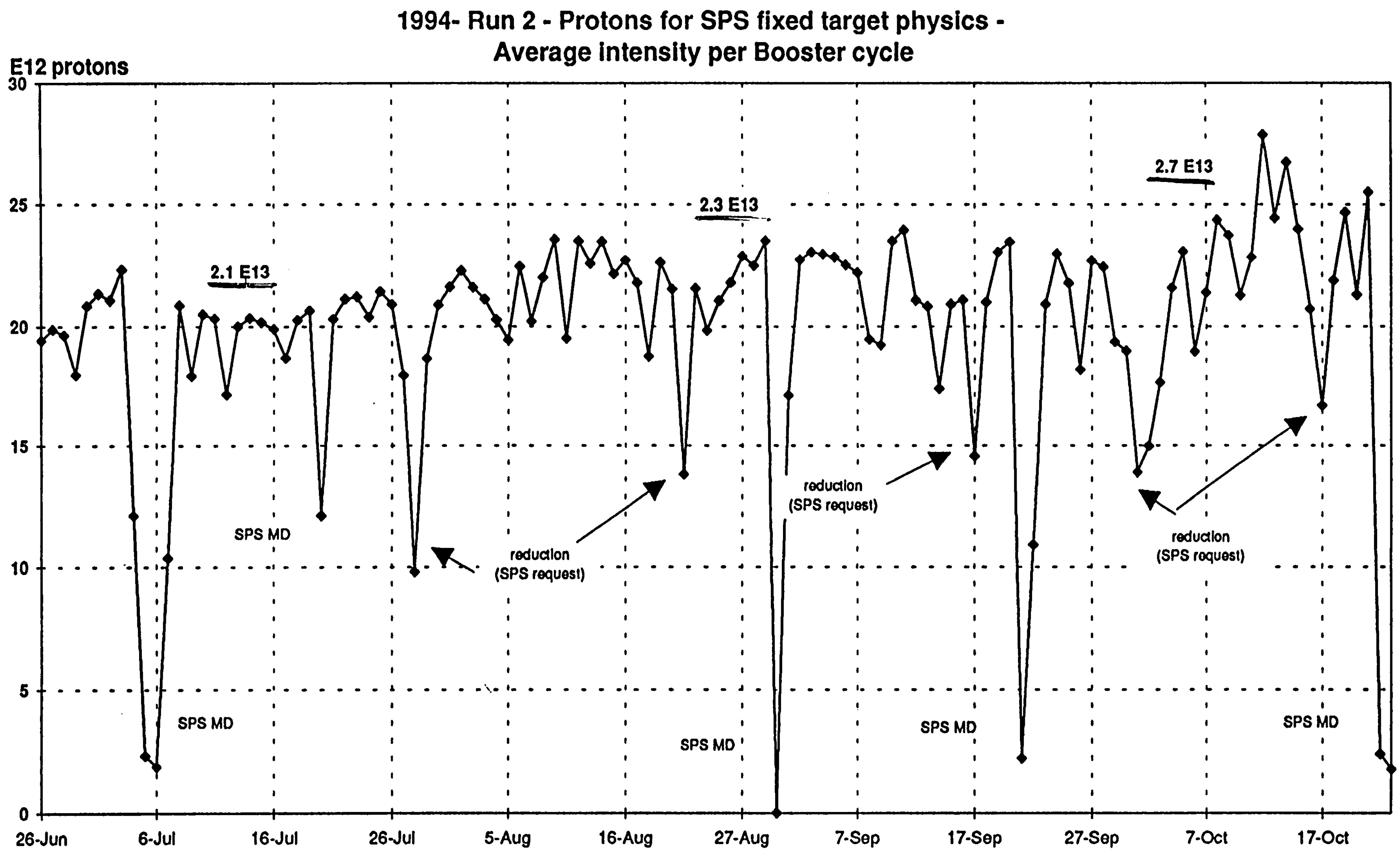
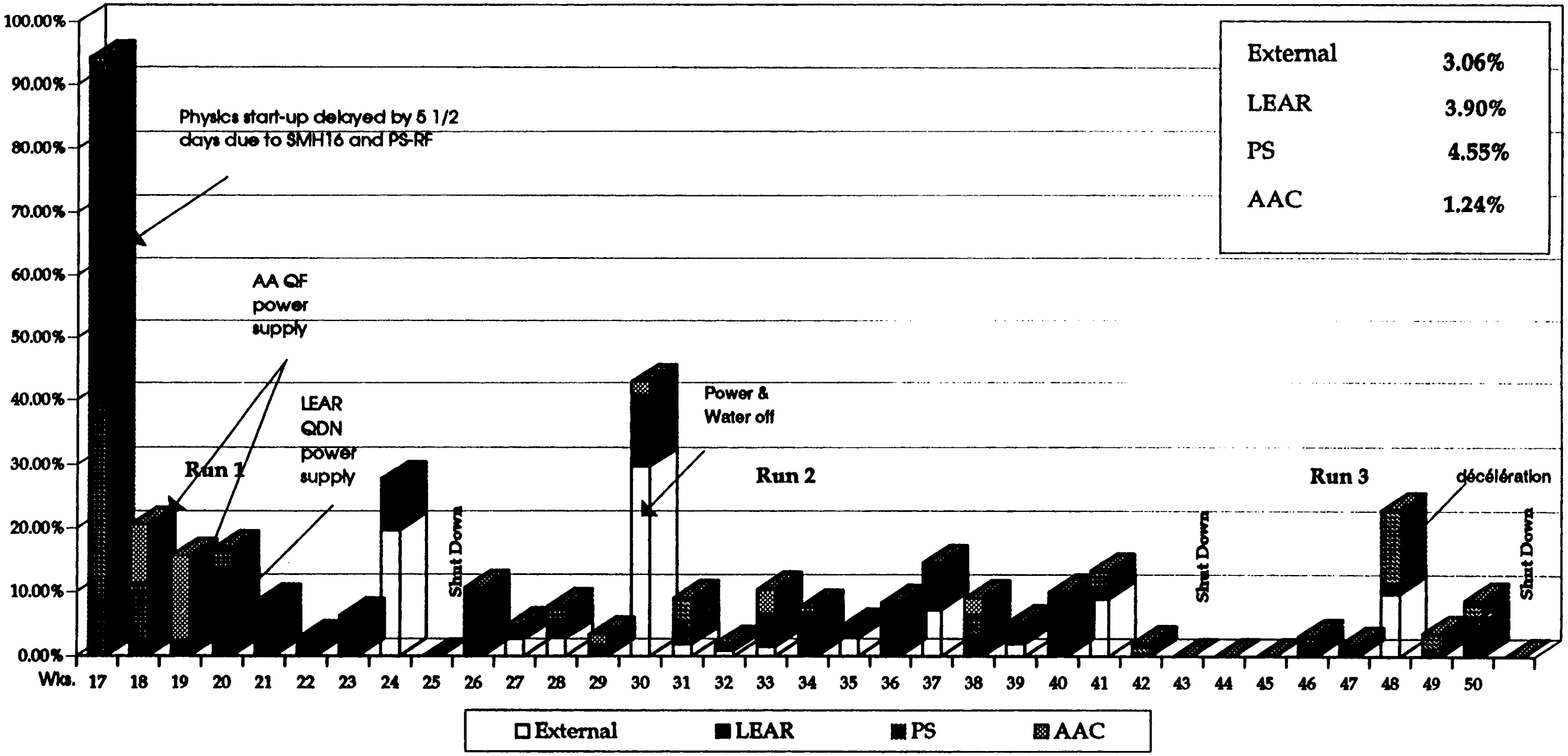


FIG. 12

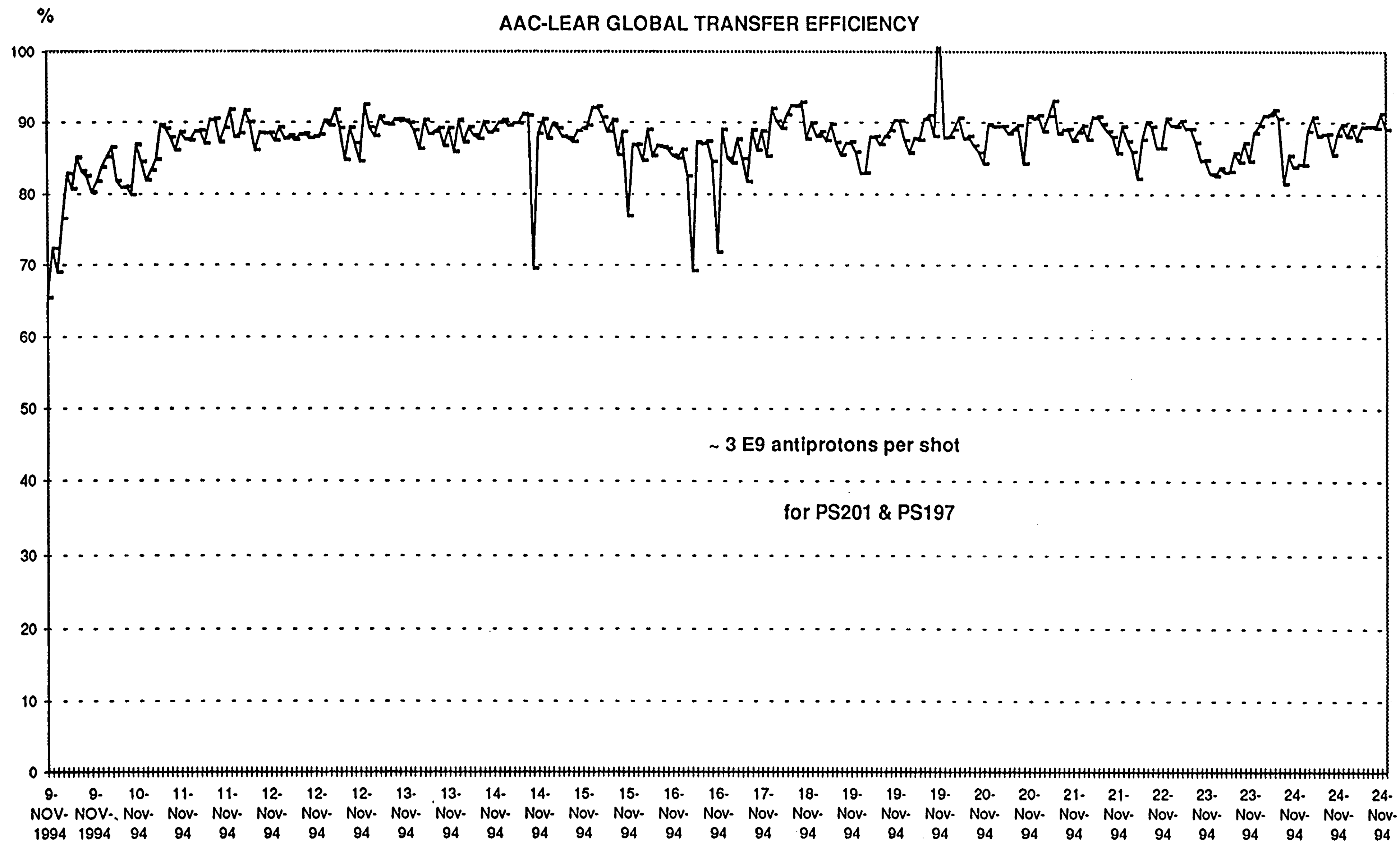
PERIOD2.XLS

1994-PS Complex fault rates- antiproton beams for South Hall Physics

Total Average 12.75%



FLTPBAR.XL(


AAC-LEAR GLOBAL TRANSFER EFFICIENCY
%
100
90
80
70
60
50
40
30
20
10
0
~ 3 E9 antiprotons per shot
for PS201 & PS197
9-NOV-1994
9-NOV-1994
10-Nov-94
11-Nov-94
11-Nov-94
12-Nov-94
12-Nov-94
12-Nov-94
13-Nov-94
13-Nov-94
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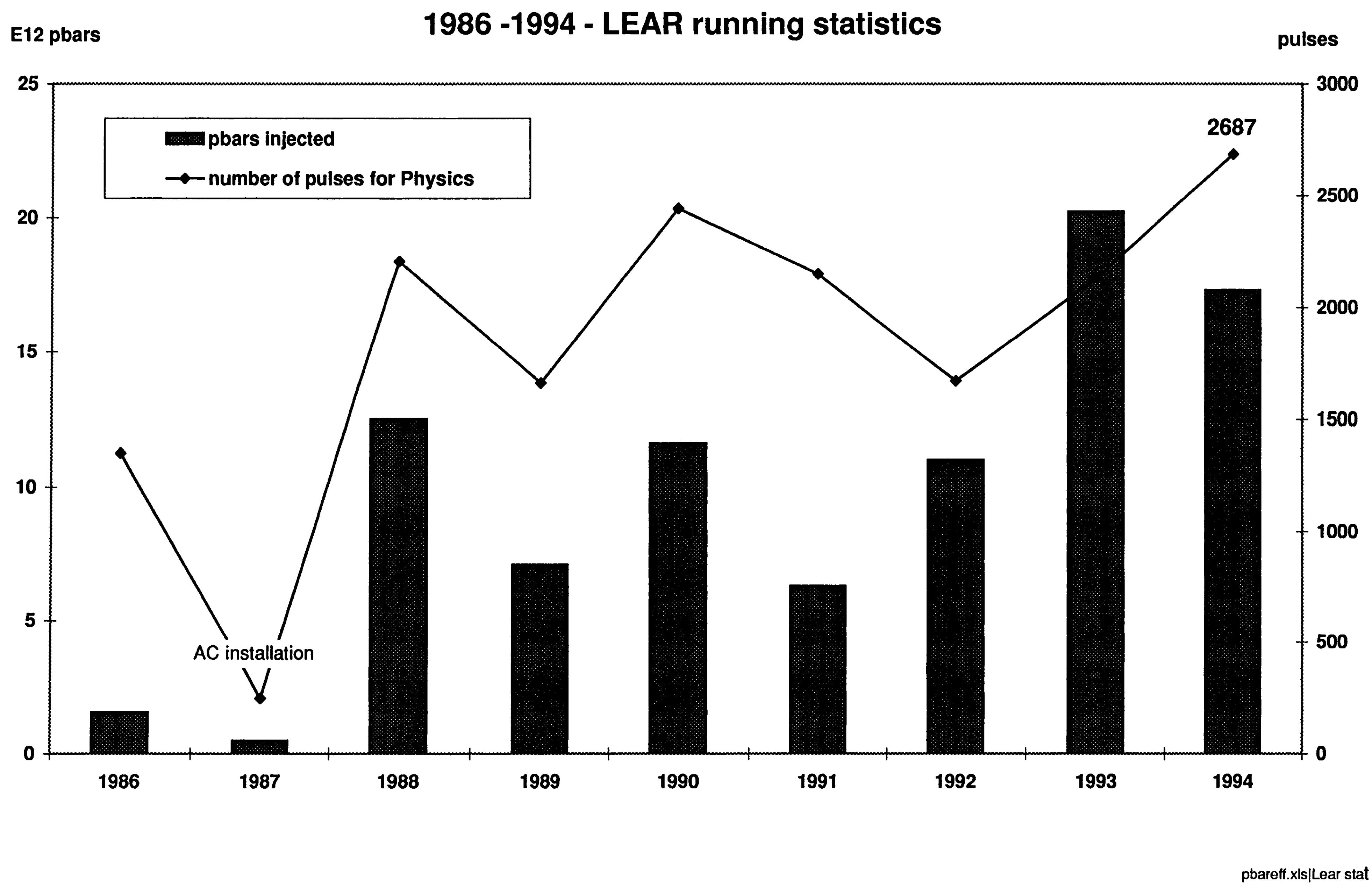
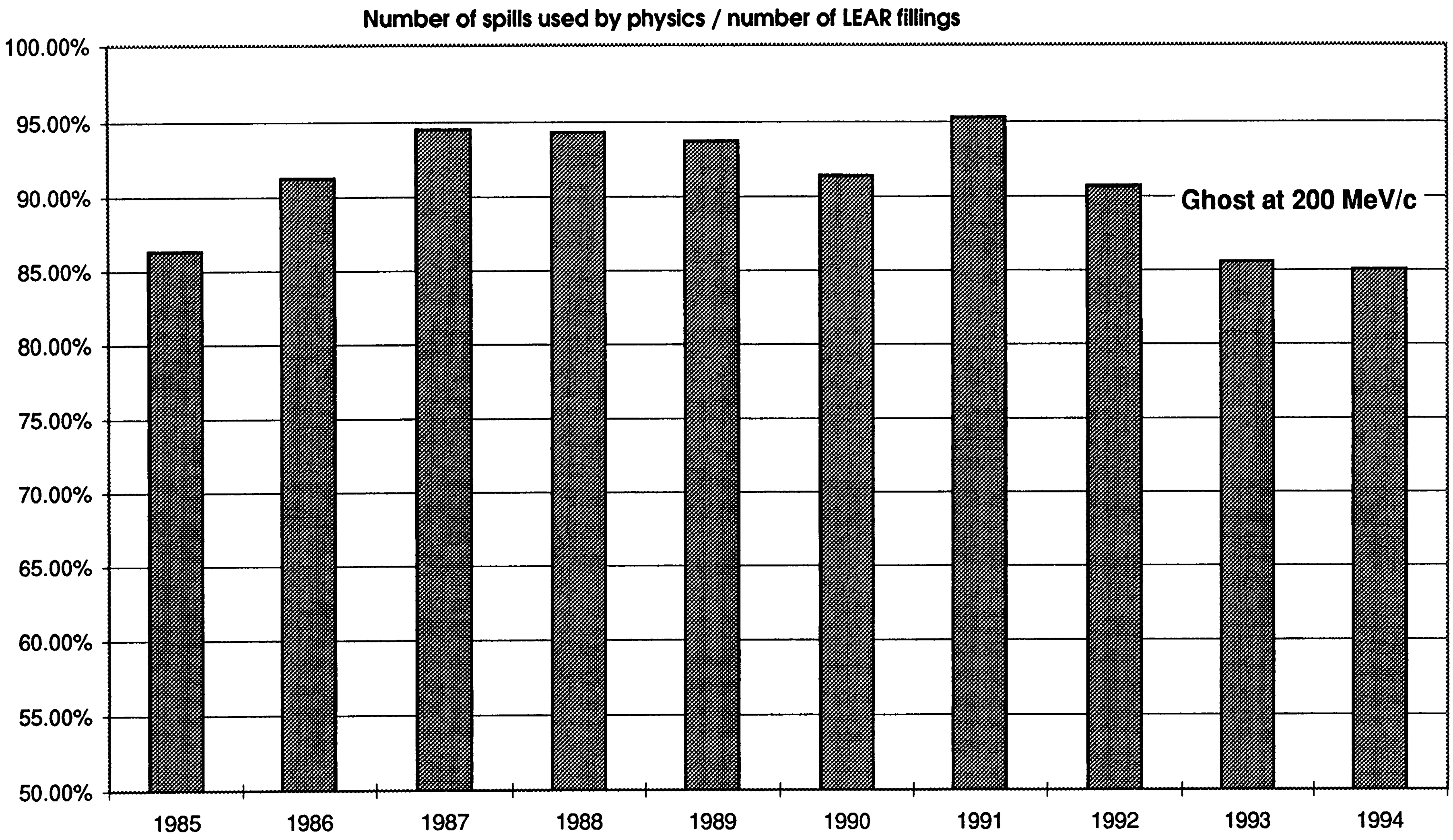
24-Nov-94
24-Nov-94


1986 -1994 - LEAR running statistics
E12 pbars
pulses
25
20
15
10
5
0
3000
2500
2000
1500
1000
500
0
pbars injected
number of pulses for Physics
2687
AC installation
1986
1987
1988
1989
1990
1991
1992
1993
1994
pbareff.xls|Lear stat

LEAR Operation efficiency



PBAREFF.XLS

LEAD ION BEAM IN LINAC 3

M.Vretenar

The year 1994 has seen the installation and commissioning of the Lead Ion Linac (Linac 3). An ECR ion source, working in the pulsed afterglow mode, produces a distribution of charge states centered on Pb^{27+}. This charge state is then selected by a spectrometer and accelerated in the linac structures, an RFQ and three tanks of the interdigital-H type (IH), up to 4.2 MeV/u. At this energy, the beam is stripped to Pb^{53+}. The unwanted charge states coming out of the stripper are eliminated in a filtering line before the transport to the PSB.

The commissioning of the linac has been concentrated in one and a half month, from the installation of the RFQ at the end of April 1994 to the first injection of Lead in the PSB on June 15th. Some further improvement during the month of July allowed to achieve a satisfactory performance, with a current of about 22 μA delivered to the PSB, inside transverse emittances of 1.2 mm mrad (4rms, normalised). The main remaining problem concerning beam quality is the emittance growth by about a factor 2 observed in the IH tanks, which is believed to be due to misalignment of some linac element, either before or inside the IH cavities.

The 1995 shut-down is devoted to a strong consolidation program. In particular, the alignment of some elements will be revised and the position diagnostics will be improved, in order to reduce the emittance growth. From the end of March Linac 3 will restart operation mainly for MD's, to find again the performance and to improve beam quality, to test different charge states or ions, and to set-up the following machines. The long term future of Linac 3 will see the operation at 10 Hz for accumulation and cooling in a LEAR-like machine, and the possible upgrade of the source to a Laser-driven system.

LEAD ION BEAM IN LINAC3

❶ Linac 3 Overview

❷ 1994 Commissioning Milestones
Summary of Beam Performance

❸ Shut-down Activities
1995 Expected Performance
Longer term plans

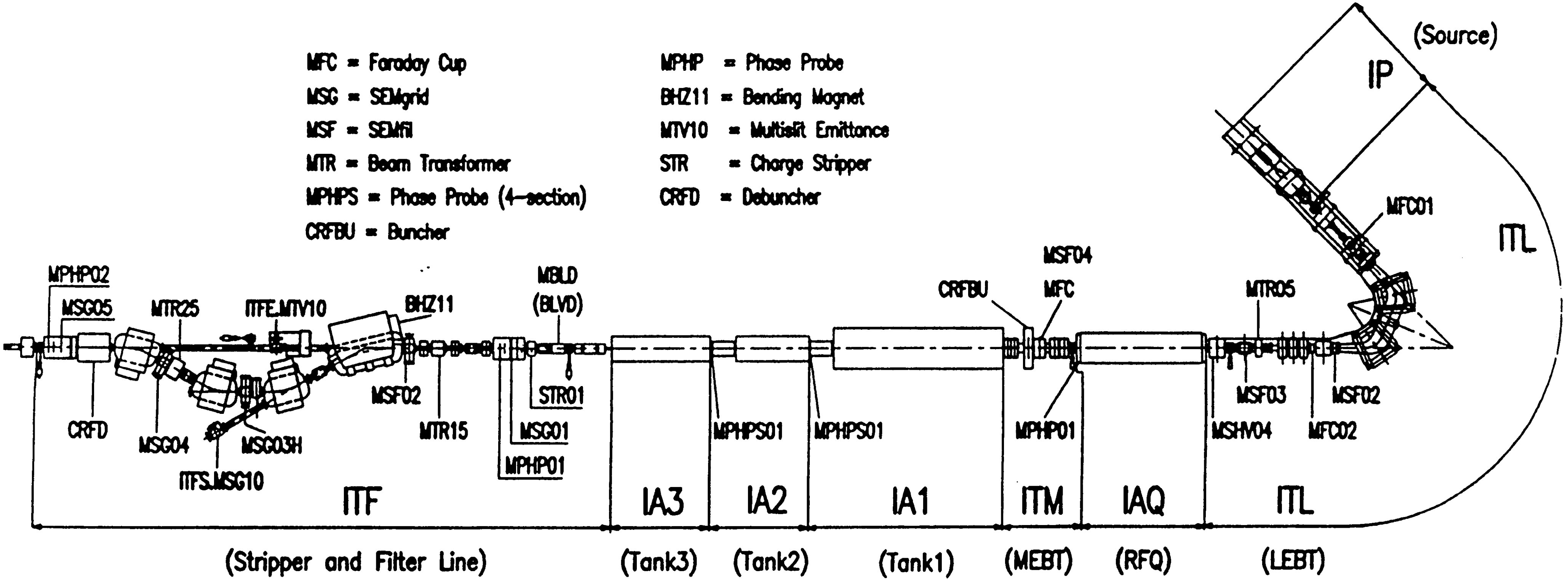
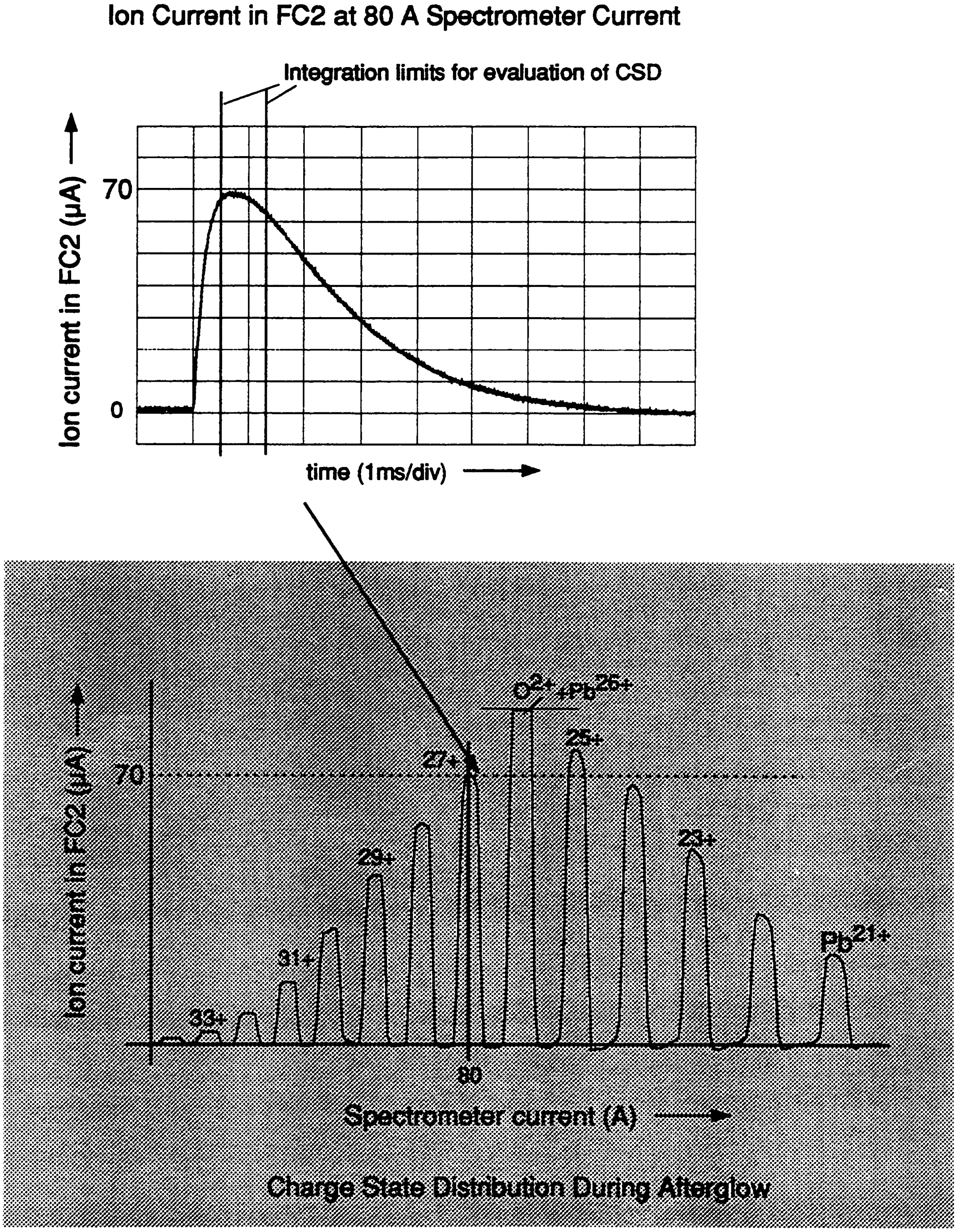


Fig. 1 Layout of Linac 3 showing positions of beam monitors.

Charge State Distribution of Lead Ions from ECR Ion Source

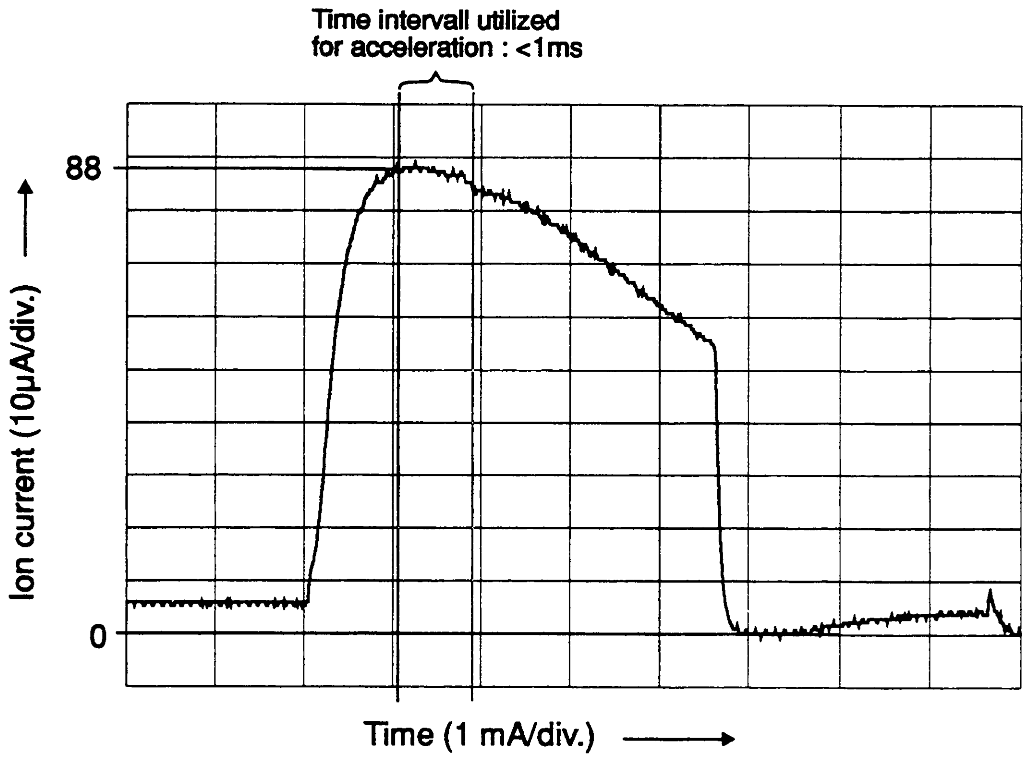


K. Langbein 13.4.94

M

Current of Pb^{27+} Ions During Afterglow

(Electrical current measured in Faraday cup 2 after spectrometer)



Acceleration Voltage: 20.8 kV

Forward microwave power (14 GHz): 1.25kW

Reflected microwave power : ca. 50 W

Tuner position: 5036

Current in coil "injection" : 900 A

Current in coil "extraction" : 920 A

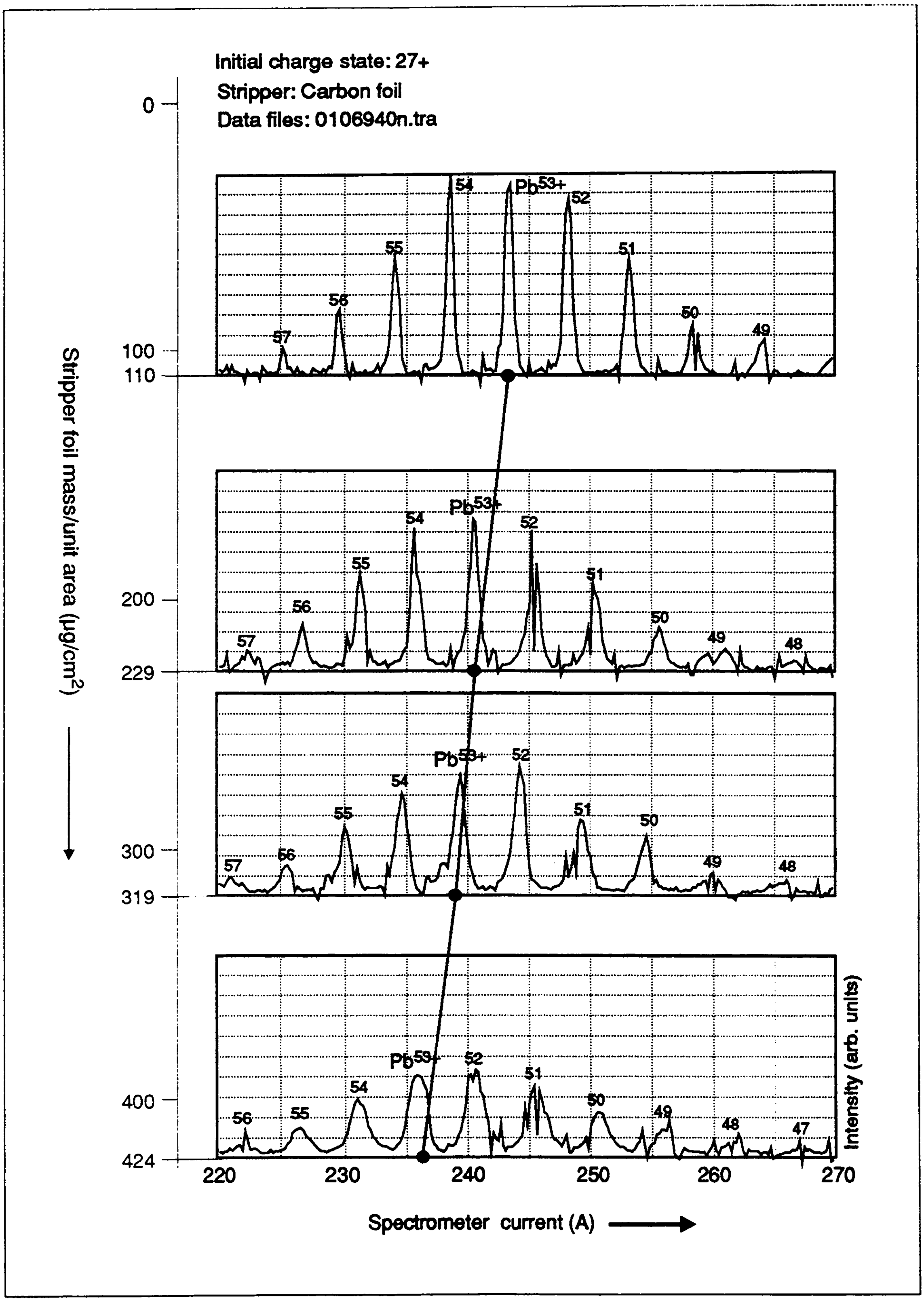
O_2 Pressure at inlet valve: $1.2x10^{-5}$ mbar

Heating power of lead sample : 3 W

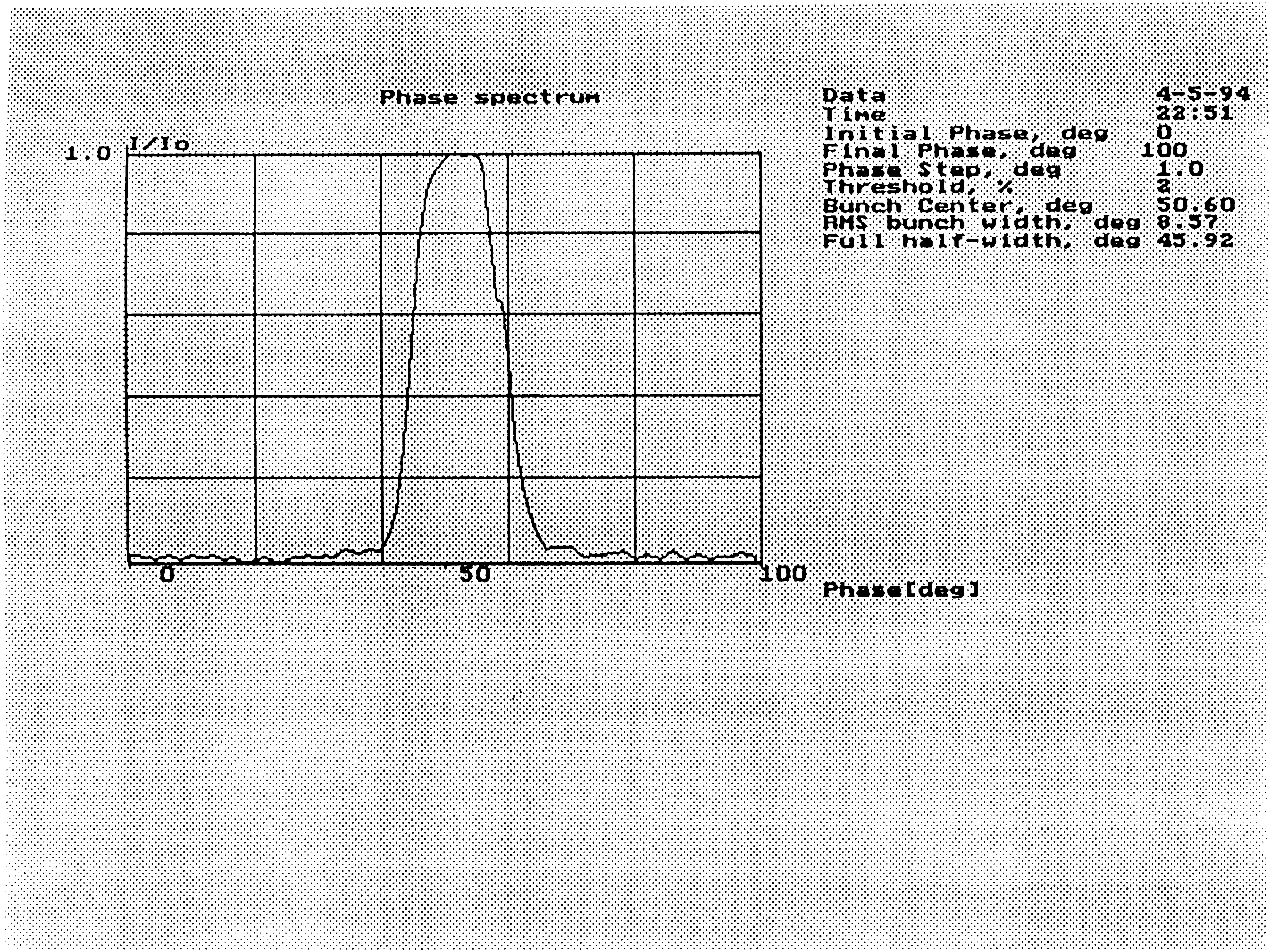
Data file: 210494.tra

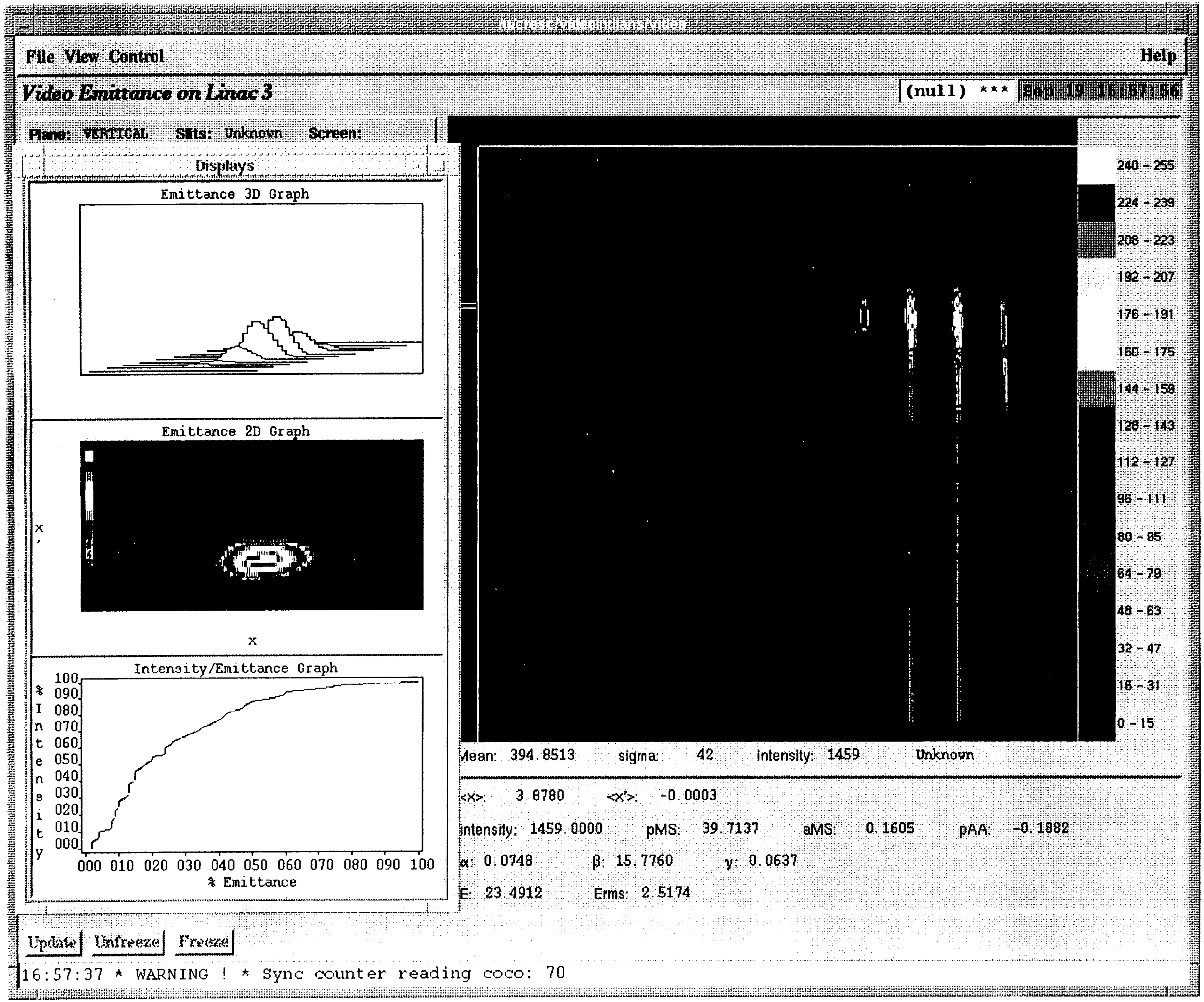
K. Langbein 3.6.94

Charge State Distribution of Lead Ion Beam at 4.2 Mev/u after Stripping



K. Langbein 2.6.94


Phase spectrum
1.0
I/Io
0
50
100
Phase[deg]
Data 4-5-94
Time 22:51
Initial Phase, deg 0
Final Phase, deg 100
Phase Step, deg 1.0
Threshold, % 2
Bunch Center, deg 50.60
RMS bunch width, deg 8.57
Full half-width, deg 45.92


File View Control
Help
Video Emittance on Linac 3
(null) ***
Plane: VERTICAL Slits: Unknown Screen:
Displays
Emittance 3D Graph
Emittance 2D Graph
x'
x
Intensity/Emittance Graph
% Intensity
100 090 080 070 060 050 040 030 020 010 000
000 010 020 030 040 050 060 070 080 090 100
% Emittance
240 - 255
224 - 239
208 - 223
192 - 207
176 - 191
160 - 175
144 - 159
128 - 143
112 - 127
96 - 111
80 - 95
64 - 79
48 - 63
32 - 47
16 - 31
0 - 15
Mean: 394.8513 sigma: 42 intensity: 1459 Unknown
<x>: 3.8780 <x'>: -0.0003
intensity: 1459.0000 pMS: 39.7137 aMS: 0.1605 pAA: -0.1882
α: 0.0748 β: 15.7760 γ: 0.0637
E: 23.4912 Erms: 2.5174
Update
Unfreeze
Freeze
16:57:37 * WARNING ! * Sync counter reading coco: 70

1994 MILESTONES

29.4	beam at 250 keV/u (RFQ,ITM)
3.5	full current out of RFQ
25.5	beam at 1.8 MeV/u (Tank 1)
26.5	beam at 3.1 MeV/u (Tank 2)
27.5	beam at 4.2 MeV/u (Tank 3)
31.5	beam stripped to Pb53+
5.6	beam at the end of L3 region
12.6	beam in the meas. lines at PSB
15.6	beam injected in PSB (10 μA)
11.7	current increased to 22 μA
14.11/ 15.12	Physics Run with Lead Ions

MEASURED PERFORMANCE OF LINAC 3 IN 1994

Point of measure	ITL	ITM	ITF	ITF	LTB	
Elements	source + line	RFQ + line	IH tanks	stripper + filter	trans. lines	
Charge State	Pb^{27+}	Pb^{27+}	Pb^{27+}	Pb^{53+}	Pb^{53+}	
Energy	2.67	250	4280	4200	4200	keV/u
Current	80	70	60	22	22	µA
Transmission	-	88	86	19	>95	%
Hor. Emittance	0.24	0.32	0.8	~0.9	1.2	mm mrad
Ver. Emittance	0.24	0.38	0.8	~0.9	1.2	mm mrad
Emittance growth	-	45	110	10	33	%
Long. Emittance	-	~8	<21	-	-	deg keV
Energy Spread	-	8	24	-	2.5	keV
Phase Spread	-	13-20	2.5-4	-	-	deg

- emittances are 4 times rms, normalised
- degrees are relative to 100 Mhz
- energy and phase spread are for 2 rms

Design Parameters (Lead Linac Yellow Report, April 1993):

Current 20 µA
Emittance 1µm
Energy Spread 2.1 keV/u

LEAD LINAC IN 1995

- Loaded shut-down program (interventions on source, RFQ, ITM, IH, stripper, RF,...)

- To improve beam quality:
  1. Emittance: beam misalignment at the input and/or inside the IH is believed to be responsible for the large emittance growth.
     - new bellows to be installed on the intertank triplets for more precise alignment of IH tanks
     - revised phase probe electronics for study of steering
  2. Current: source settings giving higher current will be tried, but at the cost of a lower source stability

LEAD LINAC IN 1995 - 2

- Run for physics only at the end of October

- Linac 3 start-up around end of March

  6 months time to

  - Find again performance
  - Try improving Emittance & Current
  - Try : other charge states (25+?)
    other ions (...)
  - Deliver beam for setting-up the other machines

LINAC 3 FOR LHC

- 10 Hz operation for accumulation and cooling into LEAR (...) will be possible in the next future (mid 1996?)
- The Laser Ion Source study and test aim at the production of mA's of ion current on short pulses (monoturn injection)

Lead Ion Beam in the PSB

Abstract:

Accleration of Pb^{53+} was the major charge - and challenge - to the PSB in 1994. The problems related to the commissioning of the new and to the limits of the existing hardware are presented. The most important limit appeared to be (and still is) the quality of the vacuum, in spite of the effort that has gone into its improvement. Two pressure bumps around leaking bellows caused a beam lifetime against charge exchange processes at injection energy of only 30-40 ms instead of the 60 ms assumed for the design. Hence fastest possible RF capture and acceleration were of of utmost importance. Its optimisation is outlined and the rsults presented: injecting at a main field slope of 1.8 T/s and performing two harmonic number changes (one on the flat top for convenience of the PS) the nominal performances could be exceeded. All scheduled milestone dates have been met.

Principal Initial Problems and Achievements:

• Injection steering with scintillator screens only proved to be more difficult than anticipated	Steering beam through Injection line tedious, even for one ring
• Incorrect injection optics due to limit of one power supply	Provisorial solution since 09/94: 25% more injected
• PPM between Linac 2 and Linac 3	new timings required
• Vacuum leaks ->pressure bumps -> ion life time shorter than anticipated	40 ms at best at injection energy (60 ms nominal)
• Main quadrupole power supplies unstable at fast rising cycles	Limit to Bdotdot: 75 V/ms (150 foreseen)
• Injection and capture at Bdot=1.8T/s: B-train (clock of GFAD's) incorrect due to eddy currents in magnet end plates; jitter haunts synchronisation Optimisation strategy	Individual • frequency program corrections (GFADs) • Voltage and Phase programs (GFASs) • B-field corrections (GFADs)
• 1st and 2nd RF harmonic change : h=20 in PS !	• Harmonic Nr program • Voltage programs
• *All deadlines have been met:*	• 1st injection 15/06 • 4 Rings to PS 29/08
• During Ion Run : Vacuum improvement by regular flashing of Ti Subl. pumps; *but unexpected impact of high-intensity ISOLDE operation on vacuum pressure and accelerated intensity*	Accelerated intensity can vary 1.3 - 1.6E10 ch *Constraint on future scheduling ?*
• Attempts to global steering correction by transfer matrix inversion	Theor. matrix fails; experimental matrix unreliable
• *Nominal Performances exceeded:*	*3 E8 Ions accelerated*

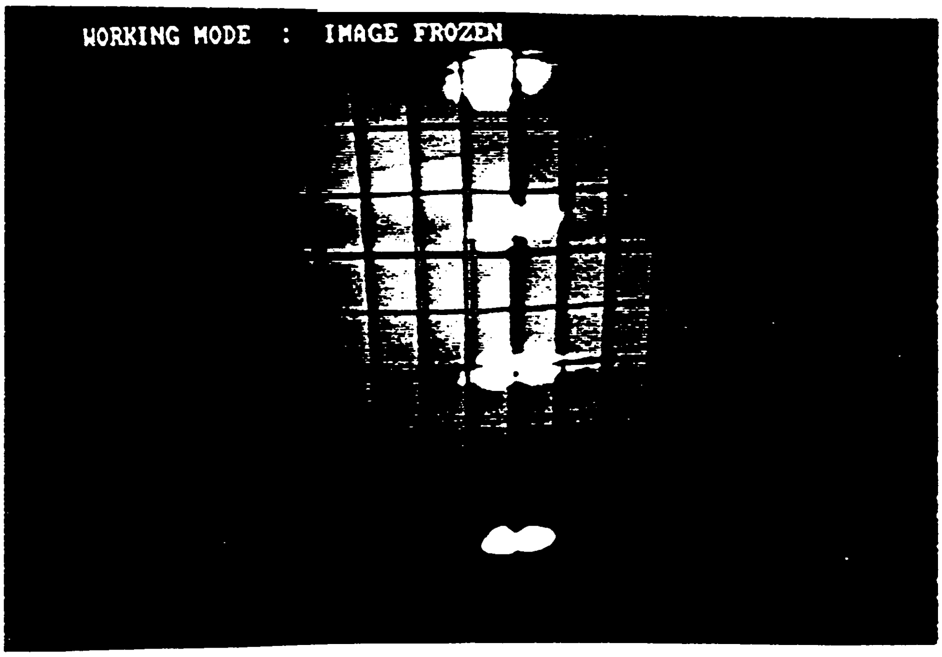
Tasks for 1995:

- Vacuum improvement shut-down
  leaky bellows replaced
- Improved scintillator screen observation:
  - CCD cameras
  - SW improvements
- B-Train generation improvement
  - 2 sensing coils
- Global Injection Line Steering
  - Correct matrix
  - optics to be revisited

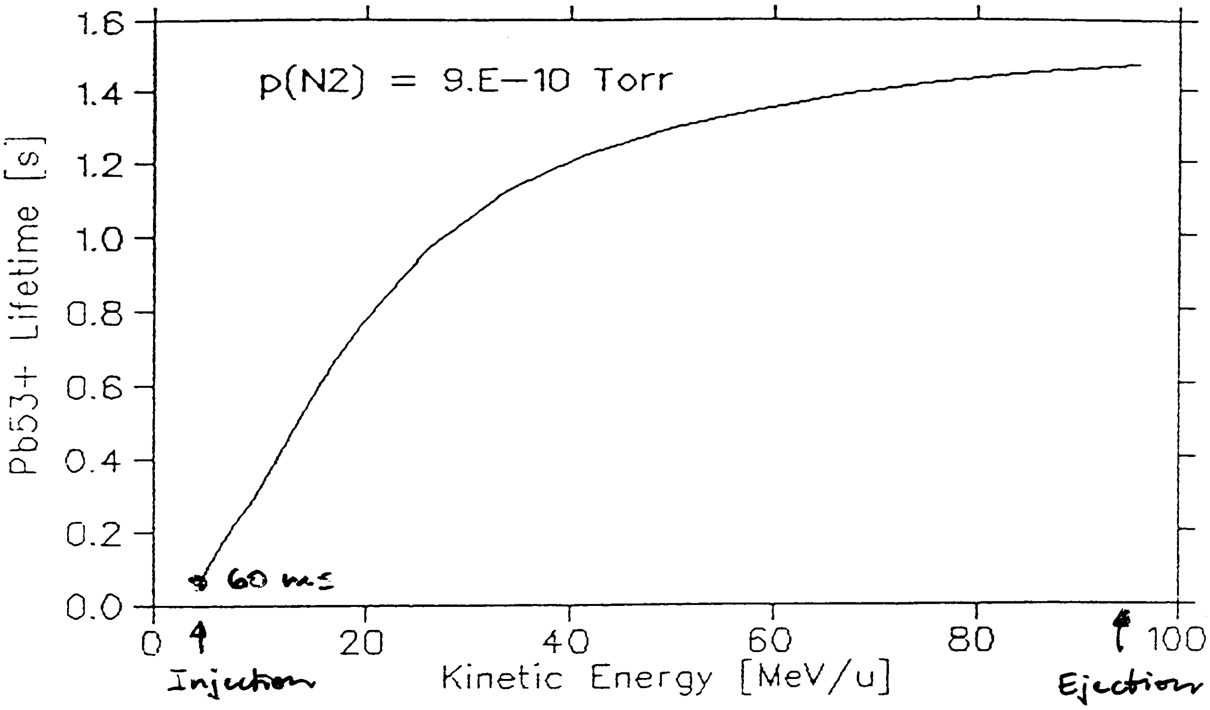
Injection Line Steering:

Example of one of the better Scintillator Screens (no beam spot would be visible on a copy of the less good screens) :

BI.MTV30 (first screen after distribution over the 4 ring levels) with Video Freeze

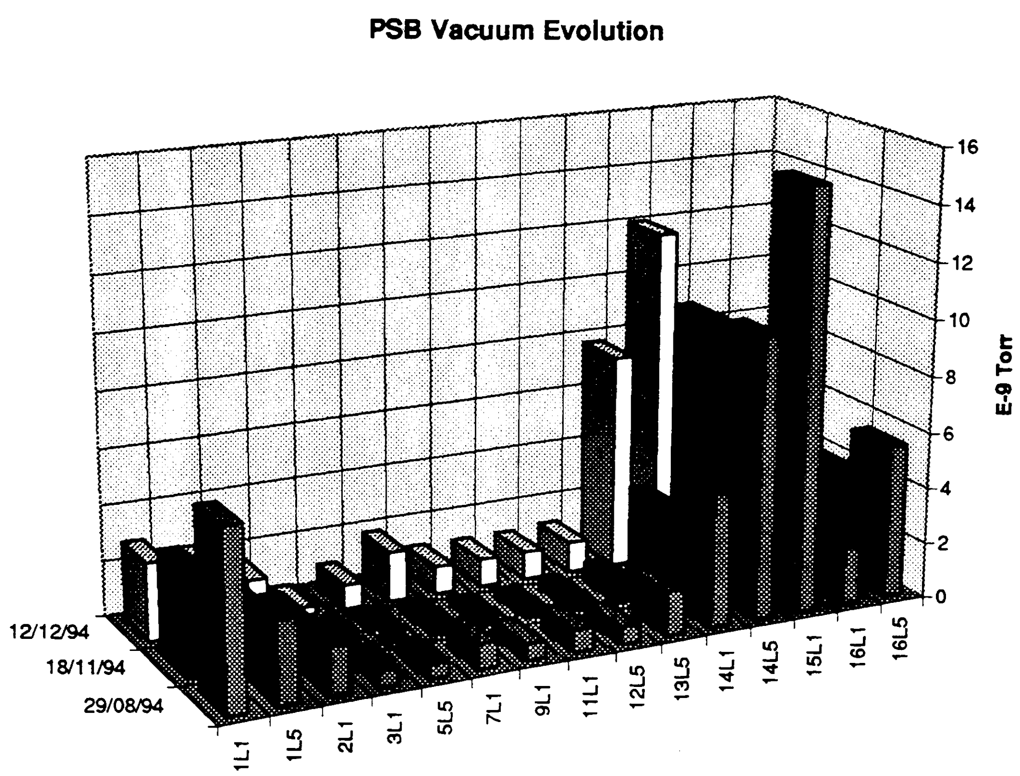


Prediction of Pb 53+ Lifetime as a Function of Energy:



Vacuum Gauge Records at :

- **First Acceleration in PS**
- **After Flashing of all Ti Sublimation Pumps**
- **Typical pressure at the End of the run**



Fast Capture of Ions: Calculations

3.1 Capture of Ions

The best capture efficiency [3] is obtained with a stationary bucket, that is, when the stable phase angle is zero. If, on the contrary, the beam is accelerated during capture, the gain of time obtained does not outweigh the low capture efficiency then experienced.

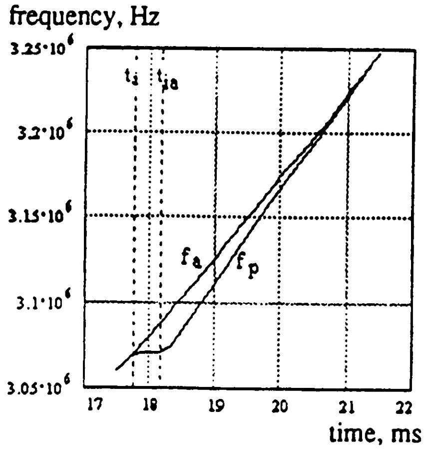


Fig.2. Acceleration frequency (f_a) for $\Delta R = 0$ and programmed frequency (f_p) versus time. Capture takes place in the interval t_i to t_{ia}.

Due to the increasing bending field, the above mentioned constraint means that the trajectories of the particles are spirals approaching the centre of the accelerator and hence, their revolution frequencies increase, but very slightly. To return to a correct orbit again the acceleration frequency subsequently has to increase more rapidly in order to join the field derived frequency i.e., the one for which $\Delta R = 0$. This is illustrated in fig. 2 where f_p is the programmed frequency and f_a is the field derived frequency. Since the phase loop, by nature, reacts very slowly to a frequency input but rapidly to a phase program, it is advantageous to program the stable phase angle as well as the frequency input to the phase loop.

The evolution of the radial error which appears during capture is shown in figure 4. In the time interval (t_i to t_{ia}) where capture takes place, the mean radius of the beam decreases approximately linearly and thereafter increases due to the programmed frequency until the error becomes zero.

The optimum value of the slope dB/dt is determined by a compromise between the longitudinal and transversal losses.

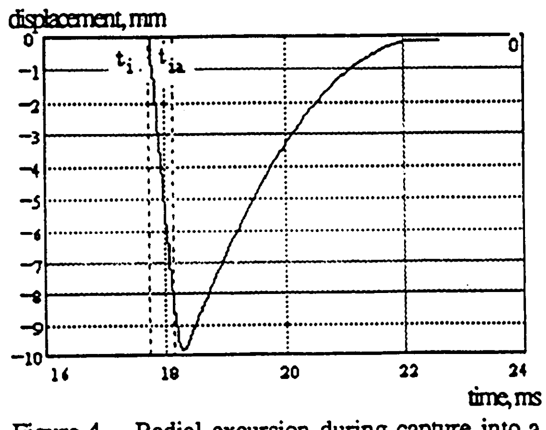


Figure 4. Radial excursion during capture into a stationary bucket.

3.3 Capture Efficiency

The energy spread (2σ) of the injected beam is small, approximately ±5 keV so the gap voltage needed for capture is only a fraction of the voltage needed later on, when the bucket shrinks due to the fast acceleration. During capture the gap voltage rises adiabatically up to a value (3 kV) which is necessary

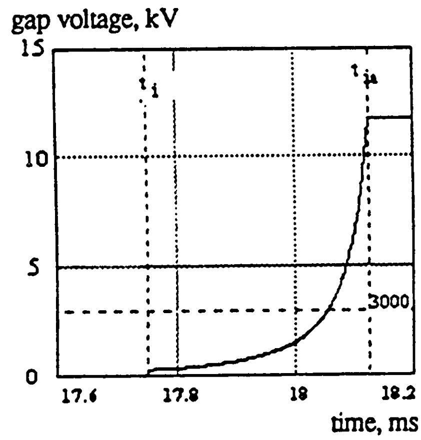


Figure 5. The Iso-adiabatic gap voltage function i.e., the function which ensures constant adiabaticity during capture.

for a good efficiency, and afterwards we let it contin adiabatically up to the maximum possible value (kV). This is illustrated in fig. 5.

For calculation of the longitudinal captu efficiency a program has been developed [5]. By thi the particle trajectories are tracked backwards from tl separatrix of the final moving bucket at $t = t_k$ to tl very beginning of the capture. The locus of the en of the trajectories encloses an area (see fig. 6) whi includes all the particles of the injected beam whi are captured in the bucket at $t = t_k$. This area is in tl following called a capture region. Particles lyir outside the capture regions are lost.

The injected ion beam lies in a ribbon of the width 1 keV symmetrically around zero energy deviation so tl captured parts have shapes of parallellograms and tl capture efficiency can easily be calculated.

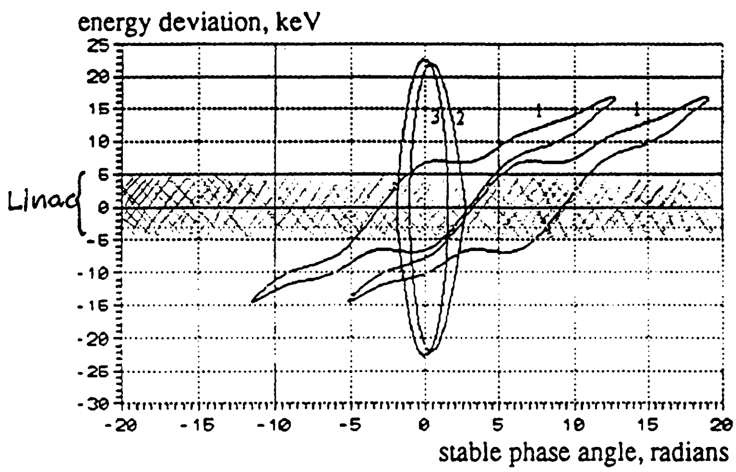
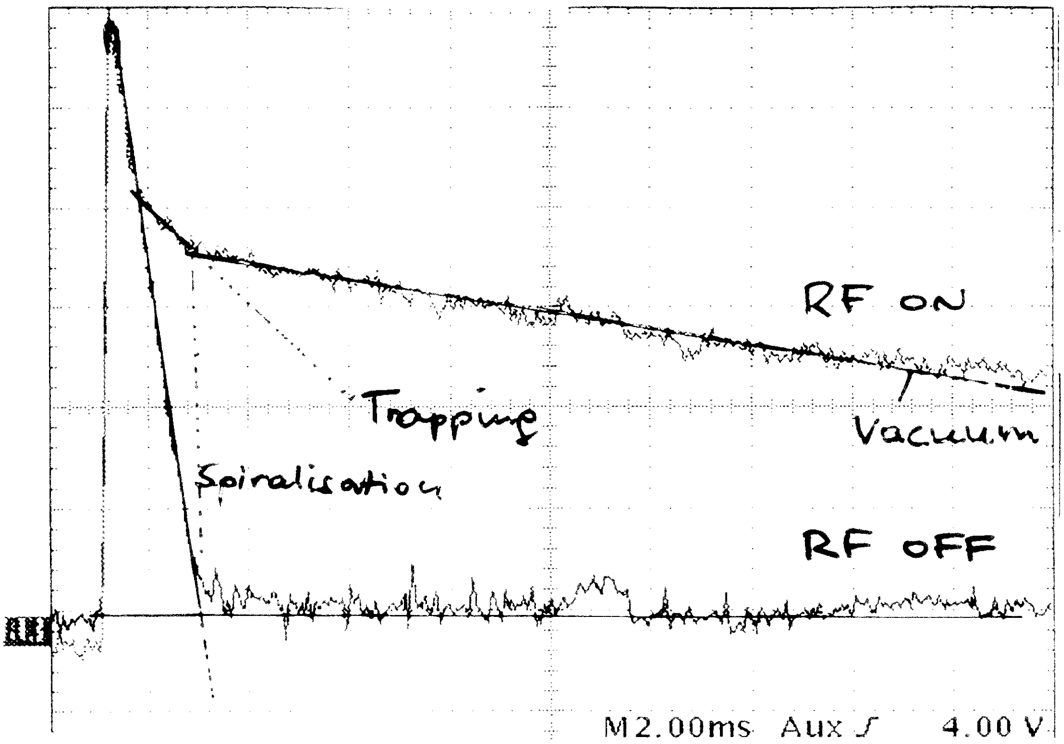


Figure 6. Capture regions (1) for two adjacent buckets. Additionally one final bunch at $t = t_k$ (2), and one bunch at the end of capture (3) at $t = t_{ia}$ are shown.

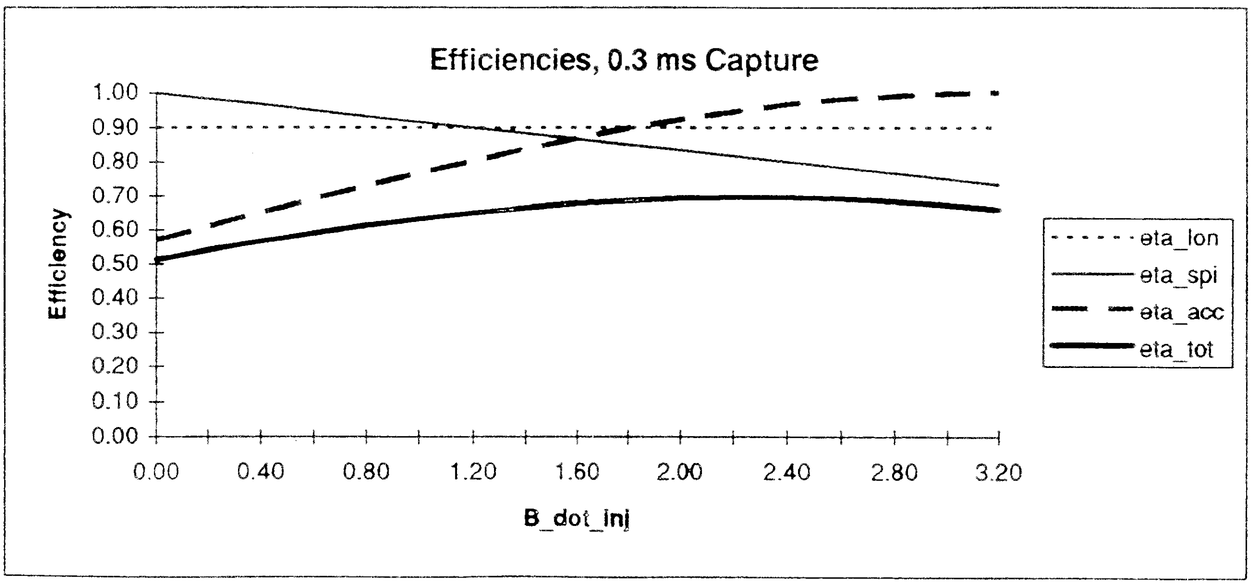
Principal loss mechanisms at Pb Ion capture:



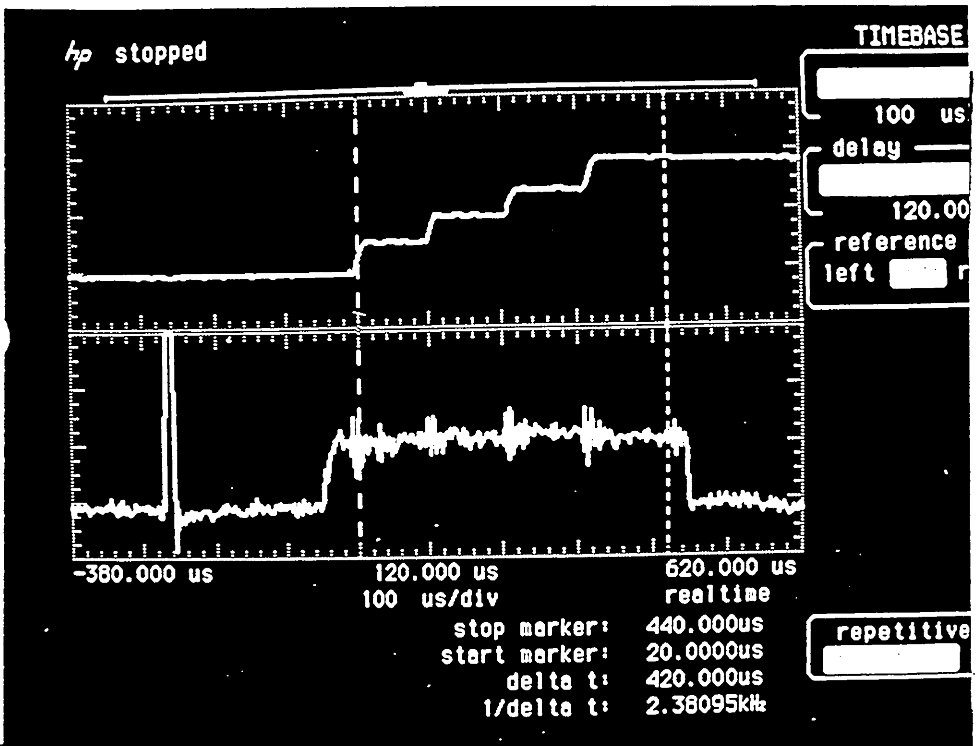
Optimisation of Fast-Capture Parameters

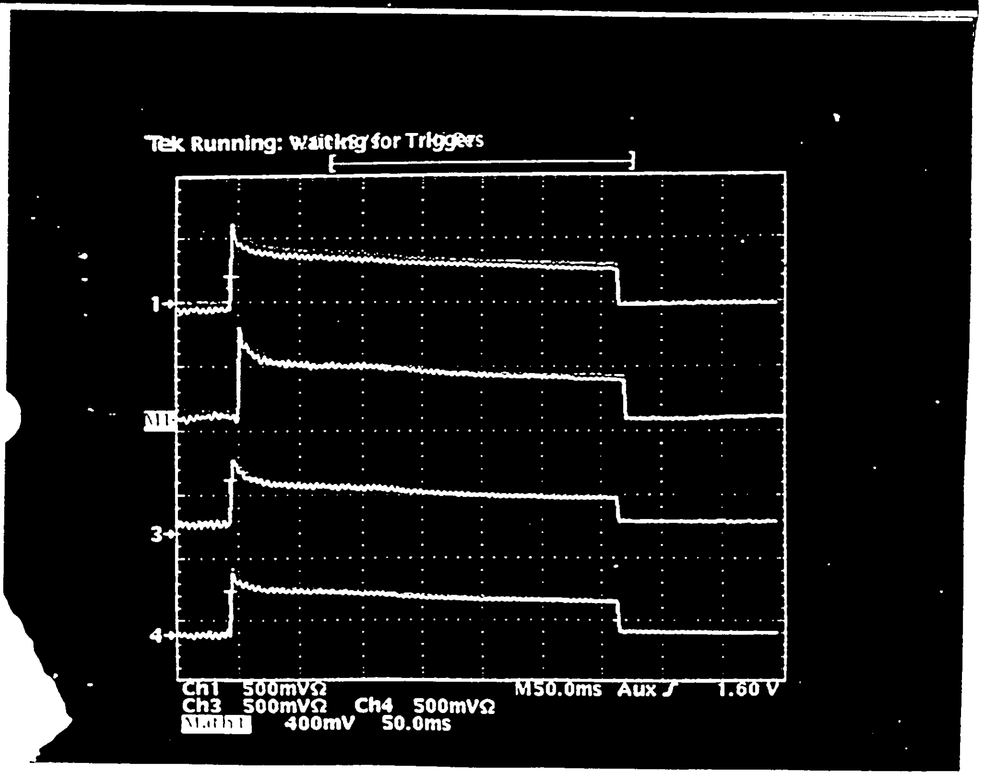
eta_lon: Longitudinal capture efficience, depends on capture duration
eta_spi: Spiralisation loss (vacuum chamber completely filled at injection)
eta_acc: Vacuum loss due to parabolic field rise (with respect to linear slope of Bdotmax)

Parameter	Value	Unit	Comment
tau_inj	0.040000	sec	Vacuum Lifetime
t_spi0	0.001125	sec	
B_dot_max	3.2	T/s	
t_rise	0.045	sec	
B_dotdot	71.11111	T/s^2	75 kV/sec
delta_B	0.072	T	
delta_B	720	Gauss	



N.B.: The double recapture for RF harmonic number change is not noticable; loss is basically due to vacuum processes.





Typical Performance and Impact of Sublimation Pump Flashing

Ions to PS (E7) | MDION ** Nov 18 19:32:40 *)

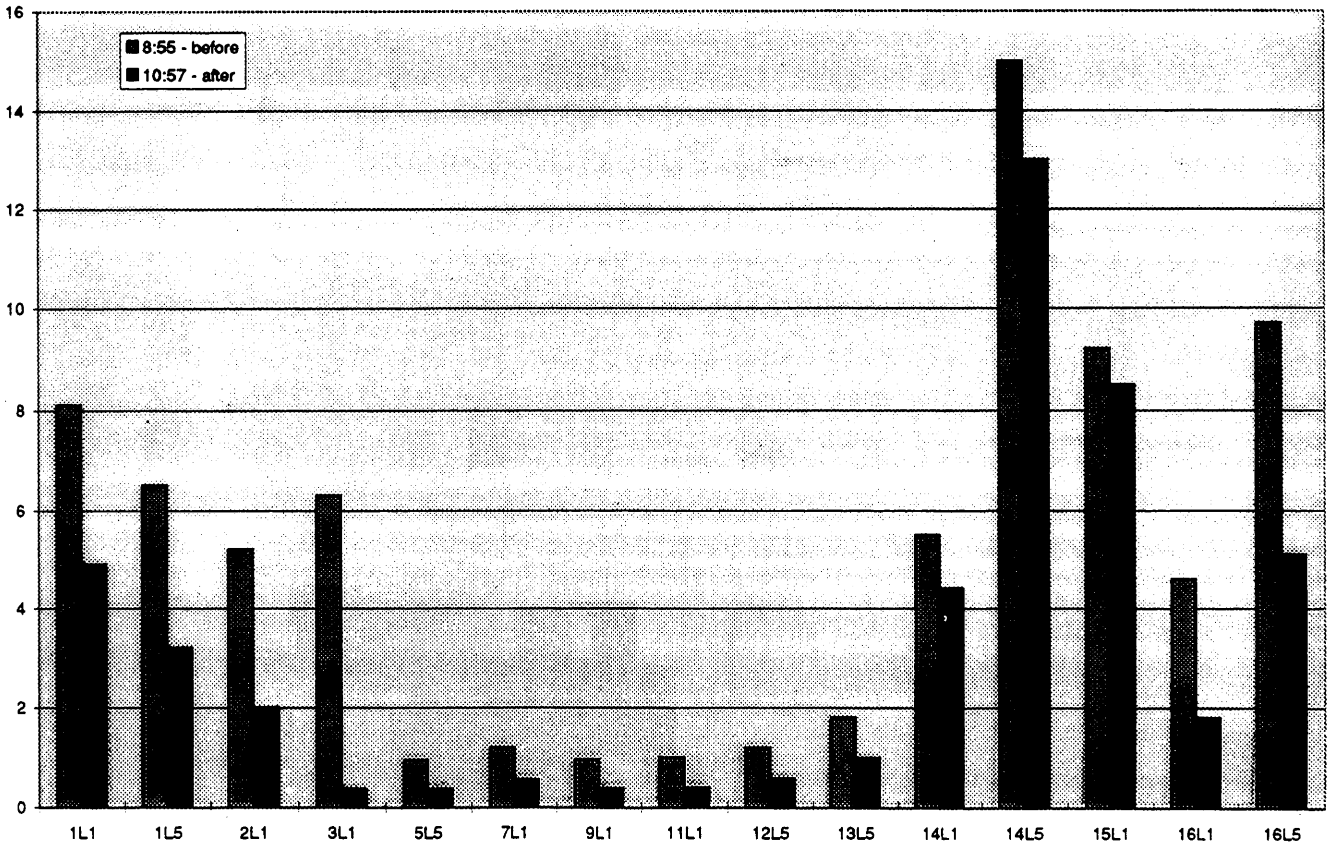
Transfo names	RING 1		RING 2		RING 3		RING 4		SUM	
ITB.TRA55	1583	0%	1421	0%	1372	0%	1223	0%	5599	0%
BI.TRA10	1808	114%	1481	104%	1478	108%	1402	115%	6169	110%
BI.TRA20	1395	77%	1206	81%	1237	84%	1348	96%	5186	84%
INJECTION	1132	81%	934	77%	821	66%	733	54%	3620	70%
CAPTURE	642	57%	680	73%	507	62%	582	79%	2411	67%
BEF.DEBUN	541	84%	619	91%	421	83%	524	90%	2105	87%
AFT.DEBUN	535	99%	573	92%	375	89%	484	92%	1967	93%
ACCELER	470	88%	473	83%	342	91%	432	89%	1717	87%
BT.TRA	0	0%	0	0%	0	0%	0	0%	1613	94%
BTP.TRA									1586	98%
BTM.TRA										
BTY.TRA112										
Number of turns	19.0		19.0		19.0		19.0		Send Ring 3 to all rings	

~1300 before flash

Update | Unfreeze | Freeze | All Lines | Asynchronous

*) Flashing all Ti sublimation pumps a.m.

PSB VACUUM 18/11/94 in 1E-9 mbar



Pb $^{53+}$ performances achieved in 1994 compared with the nominal ones of the design study CERN 93-01:

Machine	Stage	Charges	Ions	Ions Nominal
Linac3 Pb $^{53+}$	After Stripper	$4.7\ 10^{10}$	$9.0\ 10^{8}$	$9.25\ 10^{8}$
PSB	injected	$3.0\ 10^{10}$	$5.7\ 10^{8}$	
	accelerated	$1.6\ 10^{10}$	$3.0\ 10^{8}$	$2.22\ 10^{8}$
	transferred	$1.5\ 10^{10}$	$2.8\ 10^{8}$	
PS	accelerated	$0.9\ 10^{10}$	$1.1\ 10^{8}$	$1.48\ 10^{8}$

<u>Lead ion beam in the PS</u>

<u>**D.Manglunki**</u>

Abstract

The PS machine has been delivering lead ions to the SPS during the first run, in autumn 1994.
Some modifications were needed to cope with specific lead ion problems: vacuum sensitivity (new in-situ bakeable magnetic septa, installation of a number of sublimators), low intensity (new digital beam control with a radial loop involving the "sensitive" pick-up), and longer revolution period at injection (pulse-to-pulse modulation of the injection kicker timing).

20 bunches of Pb53+ ions, totalising some 1E10 charges, are injected from the PSB at a kinetic energy of 95.4 MeV/u, corresponding to the same magnetic rigidity as the now standard 1 GeV protons. They are accelerated to 4.25 GeV/u on a new 1.2 seconds long magnetic cycle, then ejected towards the SPS after a voltage reduction has decreased their energy spread. The ions are fully stripped to Pb82+ in TT2 by a 0.5 mm thick Aluminium foil which has to move in and out of the beam path to prevent a blow-up of the positron beam that goes through the same channel. The intensity after the stripper amounts to 1.2e10 charges/pulse.

Four ion cycles were used in the 19.2 seconds supercycle which ended with the lepton cycles. A degradation of the lifetime - and thus of the resulting intensity - of the ions has been observed in the presence of leptons in the supercycle. This is caused by an outgassing of the vacuum chamber induced by the synchrotron radiation.

Lead Ions in the PS

D.Manglunki, 2/2/95

- PS machine modifications
- PS operations
  - Choice of energies
  - Injection
  - Acceleration
  - Extraction
  - Stripping
- Cycles and Supercycle
- Instrumentation
- Control
- Performances and remaining problems

PS Machine modifications

- Vacuum
  - Septa 16 and 58 bakeable in situ
  - Installation of sublimators
- Injection kicker timing ppm'd
  - allow switching from p^+ to Pb^{53+} injection
- RF H20LI
  - Digital beam control, derived from B-train
  - Radial loop added in a later stage

Choice of energies

- BT/BTP lines are not PPM ("1 GeV p^+")
  - Inject Pb^{53+} (no stripping between PSB and PS)
  - at 807 Gauss in PS
- Maximum field in 1.2 seconds is 9512 Gauss
  - "20 GeV/c p^+"
  - Accelerate Pb^{53+} (Q/A=0.25) in PS
- Stripping to Pb^{82+} in TT2 at 4.25 GeV/u

Injection

- PSB delivers 10^{10} charges in 20 bunches
  - 4 rings on h=5
    (good surprise for PS, 40 bunches in design report)
  - "SFT-like" injection
- Revolution time in PS is 5μs
  - Longer kicker (longer fall and rise times: 45->75 ns)

Acceleration

- Harmonic = H20LI
  - New digital beam control
  - with "special" radial loop
- No transition ($1.10 < \gamma < 5.56 < \gamma_{tr} = 6.12$)
  - No doublets, triplets, or RF phase jump
  - No PFW needed in principle, but ...
- but close to transition
  - $\eta = 0.005$ at extraction
  - $\Delta p/p = 200\ \Delta f/f$
- Maximum dB/dt = 2.2 T/s

Extraction

- Voltage reduction to decrease $\Delta p/p$
  - Bunch rotation available but energy not guaranteed
  - Bunch length = 6 to 11 ns
  - $\Delta p/p = 0.7$ to $0.3\ 10^{-3}$
- Single turn fast extraction FE16I
  - Same optics as O^{8+} or S^{16+}
  - Equivalent p^+ 20GeV/c up to stripper, then 13GeV/c
- Revolution time in PS is 2.13μs
  - no modification of extraction kicker

Stripping

- **Aluminium foil in TT2 (2.0 mm -> 0.5 mm)**
  - energy loss: 0.7% with 2.0 mm
    - (compensated by energy increase on the ion cycle)
  - transverse emittances blow-up: factor 2 with 2.0 mm
- **Ppm movement**
  - to avoid disturbing e^+ and p^+ beams to SPS
  - 700 ms displacement time
  - already broke once, lead to "strippophobia"
- **Partially stripped ions (Pb^{81+})**
  - 0% with 2mm stripper
  - 5-20% (?) with 0.5 mm stripper
- **Two transformers**
  - no losses
    (but backscattering made us think so for a while)

Cycles and supercycle

- **3 cycles had to be created:**
  - Proton cycle at 20GeV/c to simulate Pb^{53+} ions for PS
    - needs PFWs
    - => on Pb cycles as well to keep same B field
  - Proton cycle at 13 GeV/c to simulate Pb^{82+} ions for SPS
  - Actual ion cycle
- **Supercycle**
  - 19.2 seconds
  - 4 ion cycles (SFT) in beginning
  - leptons at the end, perturb ions
    - (note: 8-bunch operation helped a lot our commissioning)
  - at least one TST (13GeV/c protons) in case SPS asks for it

Instrumentation

- **In the transfer lines**
  - **Fluorescent screens**
  - **SEMgrids**
  - **Beam Current Transformers**
- **In the PS ring**
  - **One "Sensitive" Pick-up**
  - **Beam Current Transformer**
  - **Wall gap monitor**
  - **Flying wire (but strips the Pb beam)**

Control

- **8 users / 5 HEWP limitation**
  - **Juggling with MD, TST, ... HEA, HEB, ...**
  - **Use of buffers**
  - **Help from C.Rubbia's tests in East Hall (HEB)**
- **Passerelle/Excel**
  - **Fast setting-up of transfer line ("archive")**
  - **Easy to modify a whole line by a few %or less**

Where are we now?

- **After 1st physics run**
- **Nominal performance out of PS**
  - **Transverse emittances <2µm (?)**
  - **$\Delta p/p < 0.1\%$**
  - **N> 1.5E8 ions/pulse after stripper**
- **Remaining issues**
  - **30% losses between PSB and PS**
  - **50% losses between PS and SPS**
  - **Quadrupole in front of stripper**

LEAD IONS IN SPS (1994)

(Résumé de la présentation au PPD)

La transmission totale entre le CPS et la somme des intensités chez les physiciens a été en 1994 d'environ 20% (à comparer à 25% pour le soufre en 1992).
Elle se décompose approximativement ainsi :

- 60 % entre le CPS et le faisceau circulant sur le palier d'injection du SPS
- 70 % de transmission interne SPS entre basse et haute énergie
- 50 % entre faisceau haute énergie du SPS et total reçu par les physiciens.

Paramétre fondamental pour l'amélioration de l'ensemble de ces transmissions :
les émittances transversales du faisceau reçu.
Problème fondamental pour ces émittances mesurées par le SPS dans TT10 :
elles sont 2 à 3 fois plus grandes que celles mesurées par le CPS en TT2, avec ou sans le stripper de 0.5 mm.

Ce problème doit être étudié et résolu avec le faisceau de simulation protons, avant la période d'opération en ions de fin 95.
(Le SPS prévoit l'installation de 2 BCT's en TT10 pour faciliter le diagnostic)

Stripper a employer en 95 :

- 0.5 mm tant que le problème ci-dessus n'est pas résolu
  (Efficacité d'environ 80 % mais gonflement d'émittance négligeable)
- 1 mm par la suite, pour une efficacité de pratiquement 100 %.

1 OBSERVATIONS / MEASUREMENTS

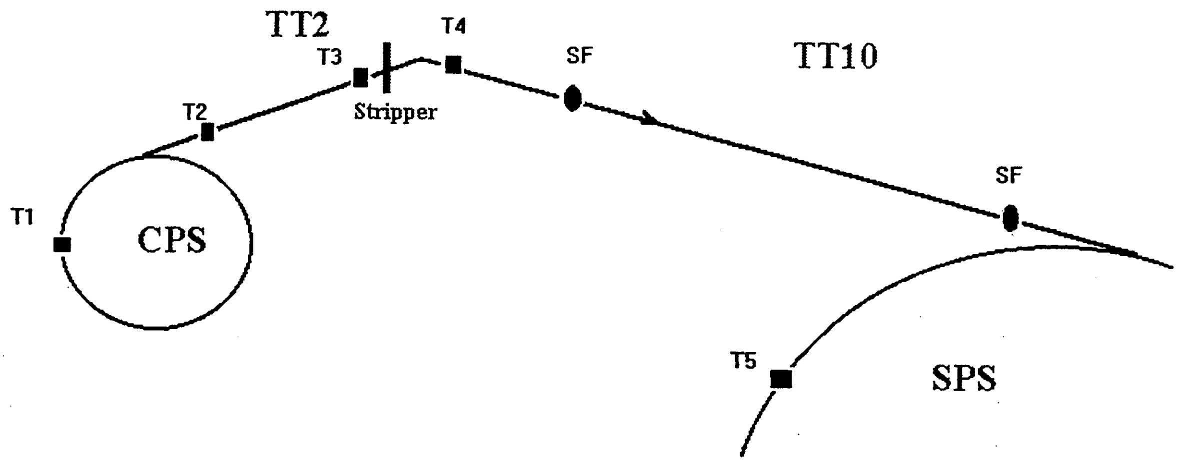
A - History:

1-10 nov: SU
11 nov- 12dec: PHYSICS

Start with 2mm Al sheet stripper
Thursday 2nd nov: current wrong on last TT2 Qpole
Wednesday 9th Nov: right current on the last TT2 Qpole
Wednesday 16th Nov: go to .5mm thick Al stripper
Monday 12th Dec: change to 1mm Al stripper (after end of Physics)

B - Observations/measures

√ Lot of measurements done during run
√ Discrepancy between CPS and TT10 intensity readings
√ CPS : 3 transformers in TT2, well tested showing the predicted increase of charges due to the stripper ($Pb^{53+} \rightarrow Pb^{82+}$)
√ SPS : TT10 SEM's give same intensity reading with stripper IN or OUT, but slightly lower than Pb^{53+} intensity measured in TT2
√ Up to 72% of "injected" beam accelerated to 158Gev/n
√ -



T :transformers
SF :split foils

2 RESULTS

Transmission in TT10

Proton (with BCT):

emittances < 2π

No losses in TT10 (5%) if $\Delta p/p \leq \pm 10^{-3}$

Pb $^{82+ \text{ or } 53+}$ (with Split Foils):

2mm stripper : 23% loss in TT10, 35% loss at injection

.5mm stripper: 20% " 12% "

No stripper : 20% "

Emittances

TT10:

Pb $^{53+}$: 3.2pi 1.9pi

Pb $^{82+}$: 4 pi 2.8pi 2mm stripper

Pb $^{82+}$: 3 pi 2. pi .5mm stripper

Pb $^{82+}$: 3.5pi 2.5pi 1mm stripper

Remark:

Strong discrepancy (factor 3) between CPS (TT2) and SPS emittances numbers, even worse if beam emittance is measured in CPS.

In Fixed Target, CPS TT2 numbers are 80-50% lower

Scrapping in CPS

1mm stripper:

TT10 emittance	CPS	TT10 SEM	Injected in SPS
3.5pi 2.5pi	$6\ 10^9$	$5.2\ 10^9$	$6\ 10^9$
2pi 1.5pi	$3.5\ 10^9$	$4.1\ 10^9$	$4.5\ 10^9$

Injection in SPS
First 20 turns:
2mm stripper: 15-20% losses
.5mm stripper: almost no losses

Transmission at high energy
* "target" intensities readjusted after comparison with protons and ions, and taking into account the quartz counting in front of T4
Remains nevertheless 20% lower than T4 quartz counts
*Reasonable losses in transfer lines
75% transmission along North lines, splitters included
*50% transmission between "on targets" and circulating beam at high energy
* No pathological problem at extraction
(75% computed efficiency)

Total transmission
Pb 82+ numbers (1994)
Σtgts / before extraction ≈ 50%
Acceleration efficiency ≈ 70%
SPS circulating / CPS (Pb^{82+}) ≈ 60%
Σtgts / ΣTT10 (split foils) ≈ 35%
Σtgts / CPS (Pb^{82+}) ≈ 20%

S^{16+} numbers (1992)
Σtgts / ΣTT10 (split foils) ≈30%
Σtgts / CPS ≈25%

Main problems during run :-

1. Temperature effects of fast VCO — Fixed.
2. Non-linearity of radial PU system — Fixed.

Operational Results.

With capture optimised : 80% capture efficiency
NB. losses in front porch ~10%
at transition ~5%

→ 68% total acceleration efficiency

Question:

Optimised capture with V_{RF} =. 700kV ±5×10⁻⁴ bucket
for beam with ±4×10⁻⁴

— In principle: best capture voltage for bucket with ±8×10⁻⁴

But V_{RF} > 700kV start to get losses on flat bottom

Why? $\frac{\Delta p}{p}$ increases ∴ more aperture ?
Noise effects increasing with V_{RF} ?

This point is being studied at the moment.

3 CONCLUSION

COLLIMATED BEAMS AT CPS OR SMALLER BEAMS (THINNER STRIPPER) ARE BETTER TRANSMITTED AND INJECTED (TAILS IN DISTRIBUTION LOST IN TT10 OR AT INJECTION?)

SEM READINGS NOT FULLY UNDERSTOOD
NEED MORE RELIABLE BEAM MONITORING

NEED MORE SYSTEMATIC MEASUREMENTS BEFORE AND DURING NEXT ION RUN

1995

SEM: 1 TANK AT THE BEGINING OF NORTH TRANSPORT AND 1 AT BEGINING OF WEST CHANNEL WILL BE EQUIPED WITH 3 DIFFERENT NEW FOILS (AL, AL+AU, TI) FOR CALIBRATION STUDIES

BCT'S: GOOD HOPE FOR 2 LOW INTENSITY CURRENT TRANSFORMERS IN TT10 FOR THE 1995 ION RUN

PS Performance Day 2/2/1995

PS Complex Proton Beams for LHC

K.Schindl

1) The rôle of the PS for LHC - a reminder

2) The Upgrading Project under scrutiny: Beam Test (end 1993) and results

3) MD's for 1995(6)

4) Studies for later

ABSTRACT PPD 2/2/95

PS COMPLEX PROTON BEAMS FOR LHC

K.Schindl

The proposed scheme for filling the LHC with protons requires small-sized beams with a brilliance (intensity/emittance ratio) about twice the one obtained with operational PS beams. The brilliance may be raised by this factor by means of

(i) double-batch filling of the PS, which in turn asks for

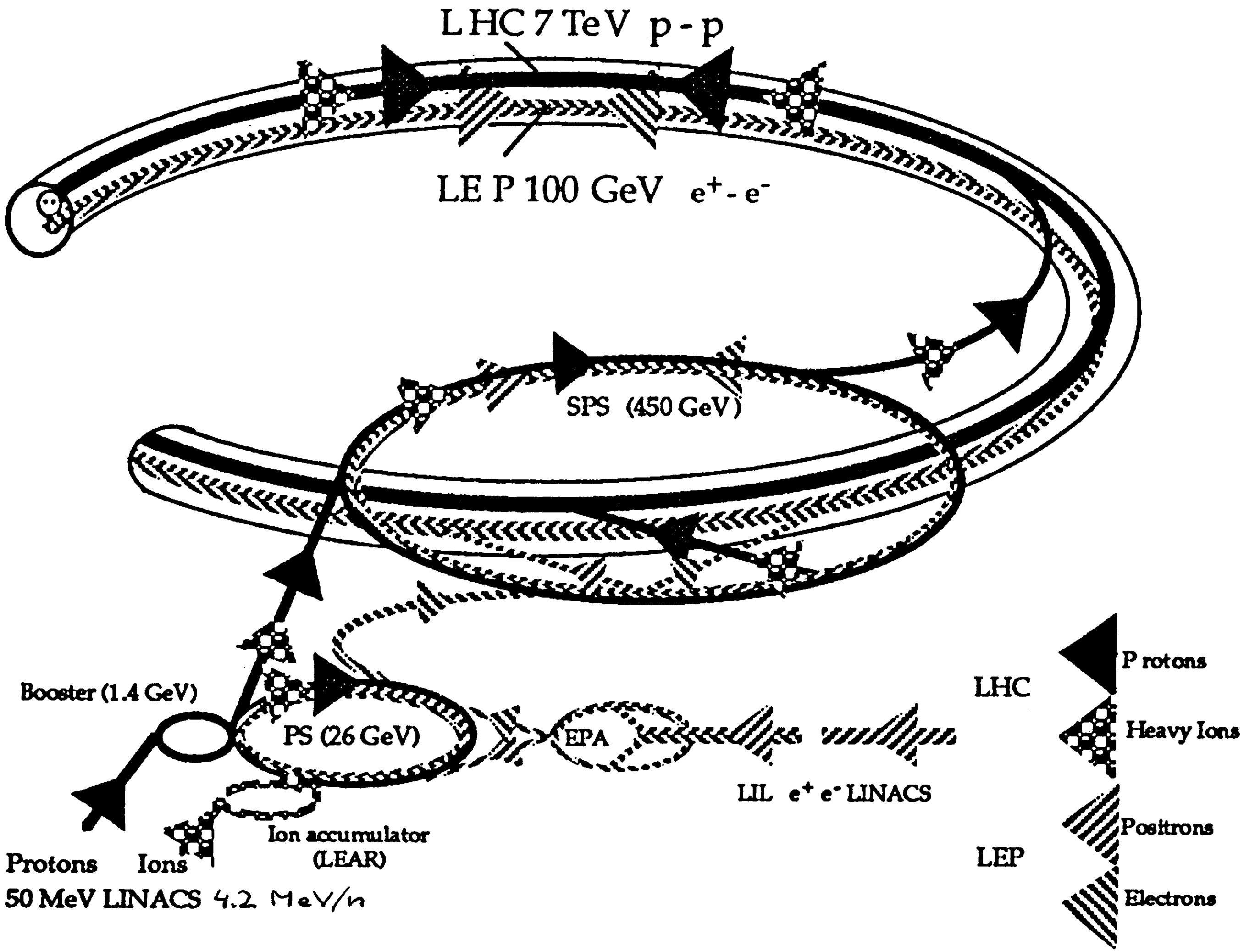
(ii) accelerating one bunch per PSB ring (and thus 8 in the PS);

(iii) increasing the PSB-PS transfer energy to 1.4 GeV.

A two-weeks' beam test end 1993 succeeded in corroborating most of the ingredients of the scheme. In particular, an intensity enabling the LHC to be filled up to its beam-beam limit was produced within the nominal LHC emittances (scaled to PS exit) of 3 micro-meter (r.m.s, normalised). Thanks to these results, there is now a project proposal "PS for LHC - protons" under scrutiny and awaiting formal approval. In parallel, some of the more delicate issues - and there are still quite a few - will be addressed by a vigorous MD and study programme in the coming years. There are several reasons to plead for an early approval and fast implementation of this project:

(i) it enables the SPS crew to study the crucial beam dynamics issues (with possibly heavy consequences on the hardware) with the real LHC injector beam at a sufficiently early stage;

(ii) it would be clearly beneficial for diminishing beam losses in the PSB and PS, one of the major concerns in the complex.


LHC 7 TeV p - p
LEP 100 GeV e+ - e-
SPS (450 GeV)
Booster (1.4 GeV)
PS (26 GeV)
EPA
LIL e+ e- LINACS
Ion accumulator
(LEAR)
Protons
Ions
50 MeV LINACS 4.2 MeV/n
LHC
Protons
Heavy Ions
LEP
Positrons
Electrons

The LHC Proton Injector Chain

		NOMINAL		BEAM-BEAM	
LHC	T [TeV]	7.0		7.35	
	B [T]	8.65		9.0	
	$\mathcal{L}$ [$cm^{-2}s^{-1}$]	10^{34}		2.5 10^{34}	2 experiments
12 pulses	p/bunch	10^{11}		1.67 10^{11}	25 ns spacing
14.4 sec	ε* [μm]		3.75		filling 3'/ring
450 GeV					Two s.c. transfer lines
SPS	p/pulse	2.5 10^{13}		4.05 10^{13}	
	p/bunch	10^{11}		1.67 10^{11}	
	ε* [μm]		3.5		s.c. cavities 6 MV, 400 MHz
3 pulses					
3.6 sec					
26 GeV/c					
PS	p/pulse	0.84 10^{13}		1.4 10^{13}	RF systems 40/80 MHz 25 ns spacing
	ε* [μm]		3.0		
2 pulses					
1.2 sec					
1.4 GeV					
PS Booster	p/ring	1.05 10^{12}		1.8 10^{12}	1 to 1.4 GeV
(4 rings)	ε* [μm]		2.5		RF systems h=1, h=2
50 MeV					
Linac 2	[mA]	180		180	length 20 μs
	ε* [μm]		1.2		
750 keV					
RFQ	[mA]	200		200	
	ε* [μm]		0.5...1		

New Hardware

KS 10/6/94

ε* (normalised r.m.s. emittance) = $(\beta\gamma)*\sigma^2/\beta$

LHC Proton Injector Chain: Fundamental Choices

- **Why 3-turn betatron stacking into PSB?**

  Single-turn injection (fast kicker) didn't work out, while 3-turn injection did. H^- injection is not compatible with Pb injection (compulsory multi-turn), but is a serious option for later (if no Pb in PSB).

- **Why double-batch filling of PS?**

  With only one batch to fill the PS, the beam in the PSB would suffer, at 50 MeV, a space-charge tune spread of $\Delta Q \sim 1$; this is reduced to about 0.5 with two batches.

- **Why acceleration on harmonic 1 in PSB?**

  The four bunches from four rings can be arranged into 1/2 of the PS circumference; this trick only works with one bunch per ring.

- **Why increase the PSB output energy from 1 to 1.4 GeV?**

  The first PSB pulse dwells for 1.2 sec on the PS front porch until the second pulse arrives. At 1 GeV, $\Delta Q > 0.3$, leading to emittance growth on the front porch; at 1.4 GeV, $\Delta Q \sim 0.2$, no blow-up.

- **Why 40 MHz (and 80 MHz) cavities in the PS**

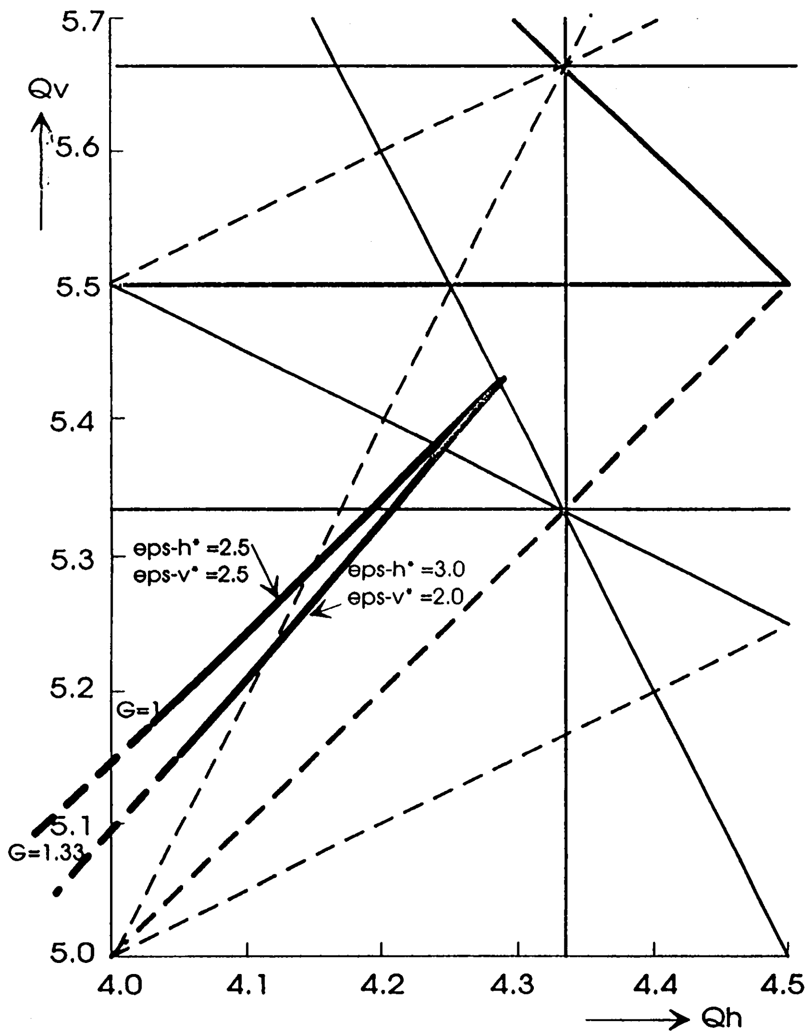
  At 26 GeV/c, the 8 (16) bunches are de-bunched, followed by re-bunching with the 40 MHz cavities. This impresses on the beam the LHC bunch spacing of 25 ns.

- **Why 400 MHz cavities in the SPS?**

  Required to shorten the bunch length to < 2 ns before transfer to the LHC, so as to fit into the LHC buckets.

PSB TUNE DIAGRAM AND SPACE CHARGE AT 50 MeV

PSB Tune Diagram



Laslett tune shift for LHC beam in PSB at 50 MeV, N = 2E12 p, Bf = 0.55

- **Injection:** The high-brilliance proton (not H^-) beam (160 mA in $\varepsilon_{x,y}$ = 1.2 μm from Linac 2) is betatron-stacked (horizontal, 3 turns) yielding ε_x*~ 3 μm, ε_y*~ 2 μm, N = 2.10^{12} p/ring.

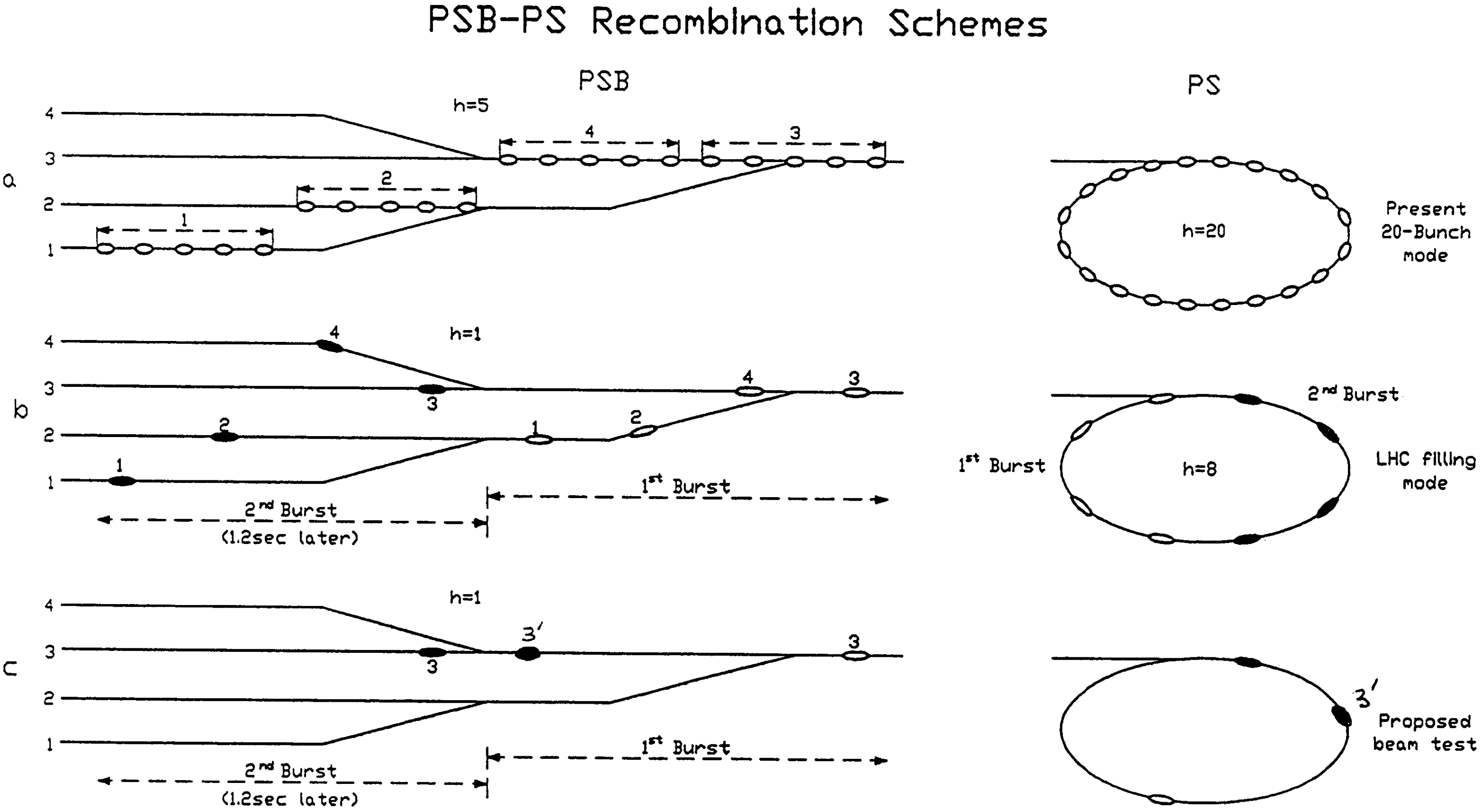
- **Space-charge tune shift $DQ_{x,y}$ at 50 MeV:** the tune shift is maximum after RF trapping.

  $\Delta Q_{x,y}$ for the LHC beam above: thick red line

  $\Delta Q_{x,y}$ for a round beam (ε_x*, ε_y*~2.5 μm): black.

- **Tune diagram:** shown are all stop-bands up to 3rd order; three of them have to be compensated in order to lodge the beam in the Q_x-Q_y diagram.

$\varepsilon_{x,y} = (\beta\gamma)\, \sigma^2/\beta_{x,y}$



PSB-PS TRANSFER SCHEMES

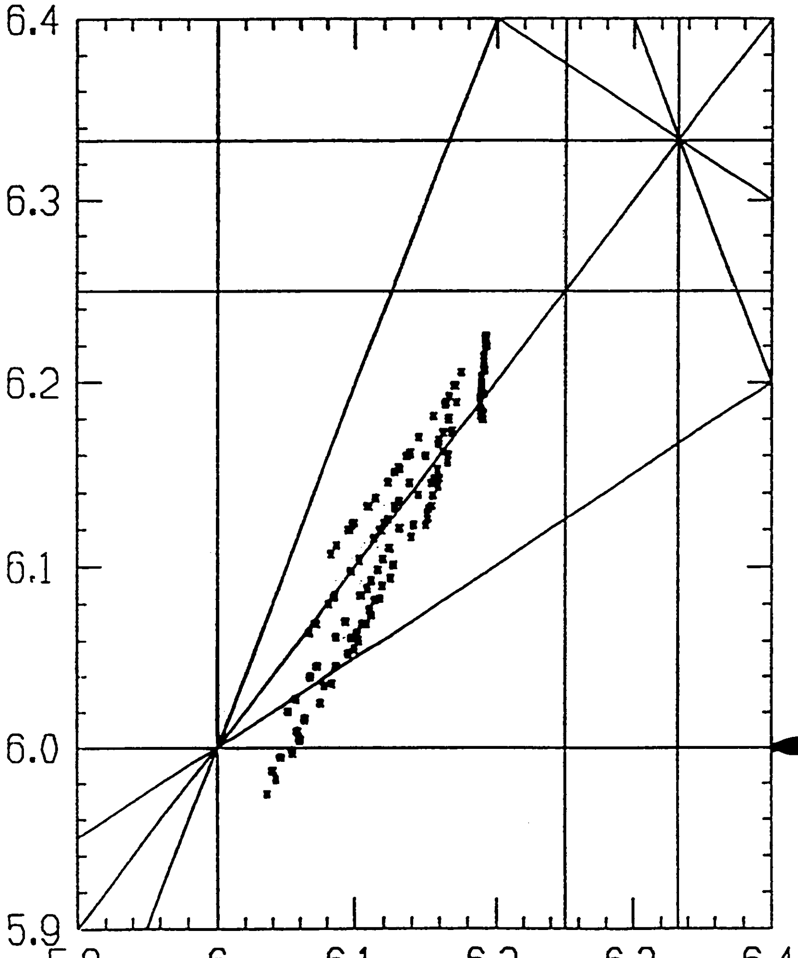
Standard Scheme - Single-Batch Filling (top): The four-ring PSB uses the fundamental RF system (h=5) to accelerate 5 bunches in each ring. Ejecting (horizontally) and recombining (vertically) one ring (1/4 of PS circumference) after the other, a single PSB pulse completely fills the PS with 20 bunches.

LHC Filling Scheme - Two-Batch Filling (centre): With the fundamental RF system changed to h=1, only one bunch per ring is accelerated; specially adjusted kicker timings enable filling of 1/2 of the PS ring, the other half being filled by the 2nd pulse, 1.2 s later.

LHC Test - Two-Batch Filling (bottom): A single bunch is accelerated in PSB ring 3, followed by a 2nd bunch 1.2 s later. The position of the second bunch with respect to the first one could be changed, in order to simulate some of the aspects of the Final Scheme, such as the influence of the PS injection kicker rise-time on the horizontal emittance (bunch position 3' in the sketch).

Space-Charge Tune Spread of the LHC Beam in the PS

1.4 GeV front porch
1.4 10^{13} protons in 8 bunches
$\varepsilon_x^* / \varepsilon_y^* = 3.5/1.75$ µm
$\Delta p/p = 2.5\ 10^{-3}$ (2σ)
bunch length 190 ns ⇒ 220 ns WITH CONTROLLED BUNCH BLOW-UP IN PSB !

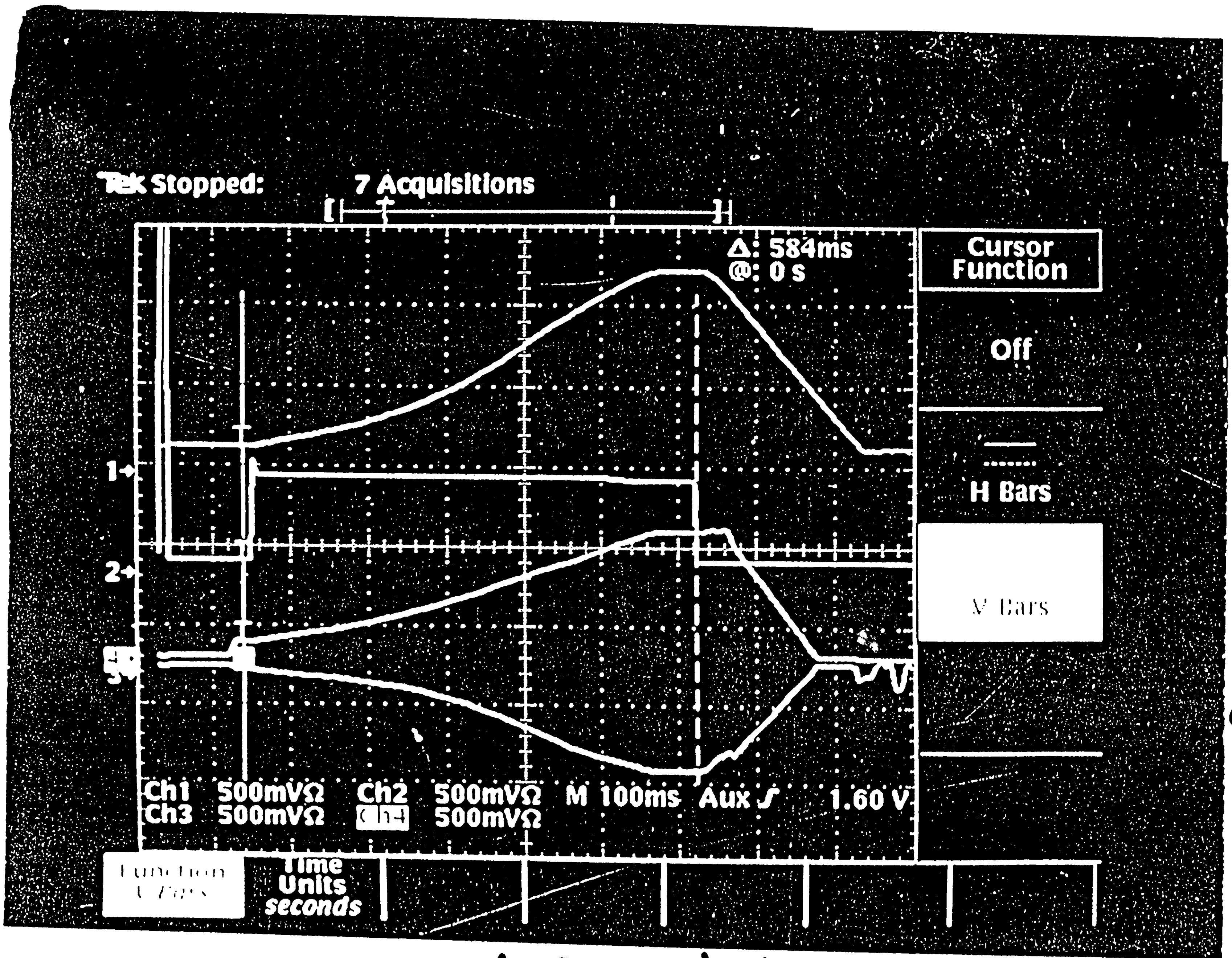


FOR SAME INTENSITY
NORMALISED EMITTANCE
BUNCH LENGTH } ΔQ_{inc} [1.4GeV] ≈ 0.66 ΔQ_{inc} [1.0GeV]

FINAL SCHEME vs. TEST CONDITIONS

Final Scheme	LHC Test
Linac 2 180 mA for 20 μs	160 mA for 20 μs
h=1,2 cavities in 4 PSB rings	h=1,2 prototypes in ring 3
PSB to 1.4 GeV, all cycles	PSB to 1.4 GeV, few cycles
PSB-PS line: all to 1.4 GeV	PS level magnets to 1.4GeV
Two PSB pulses to fill PS	Two PSB pulses to fill PS
PS: Bunch splitting h=8 to 16	Bunch splitting h=8 to 16
Acceleration of 8(16) bunches on h=8 (16) to 26 GeV/c	Acceler. of 1(2) bunches on h=8(16) to 26 GeV/c
Debunching-rebunching to h=84 at 26 GeV/c in PS for LHC bunch spacing of 25 ns	Not tested because no h=84 (40) MHz cavities in the PS
Ejection of 81 LHC bunches in the line leading to the SPS	Ejection of 1(2) long bunches

PSB ⇒ 1.4 GeV
h = 1
9/12/93



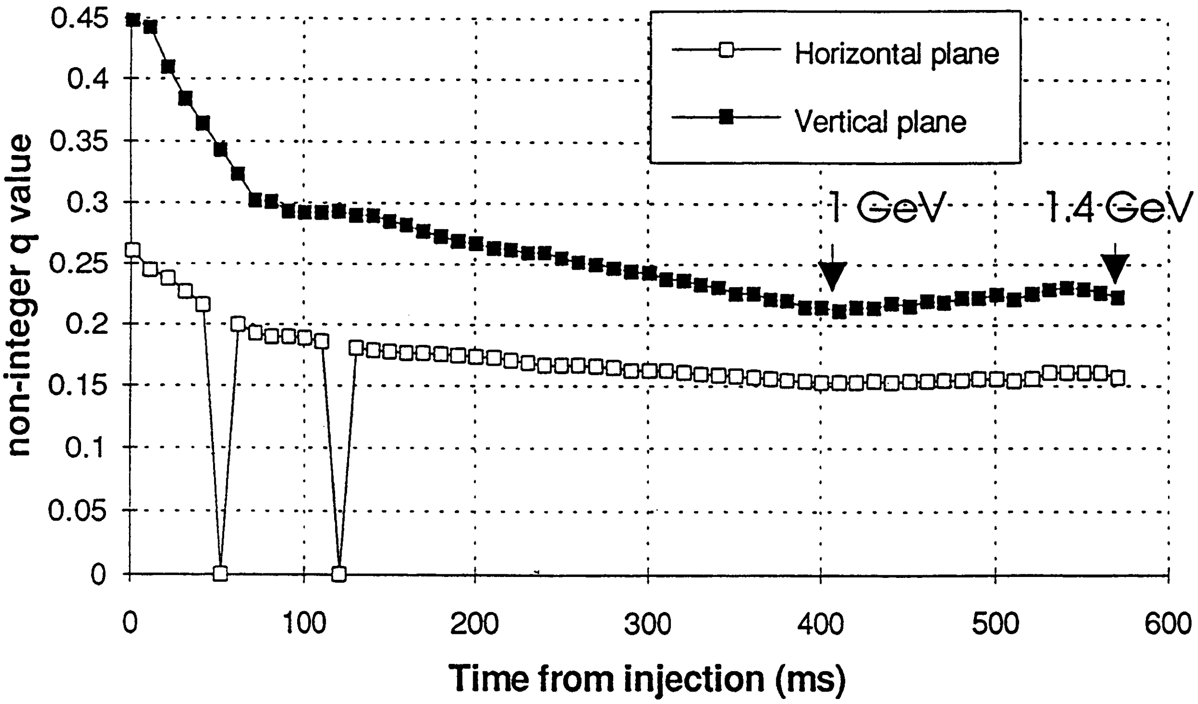
I_B MAIN MAGNET CURRENT

N_p (RING 3) $\sim 2.10^{12}$

QD

QF

100 ms/DIV

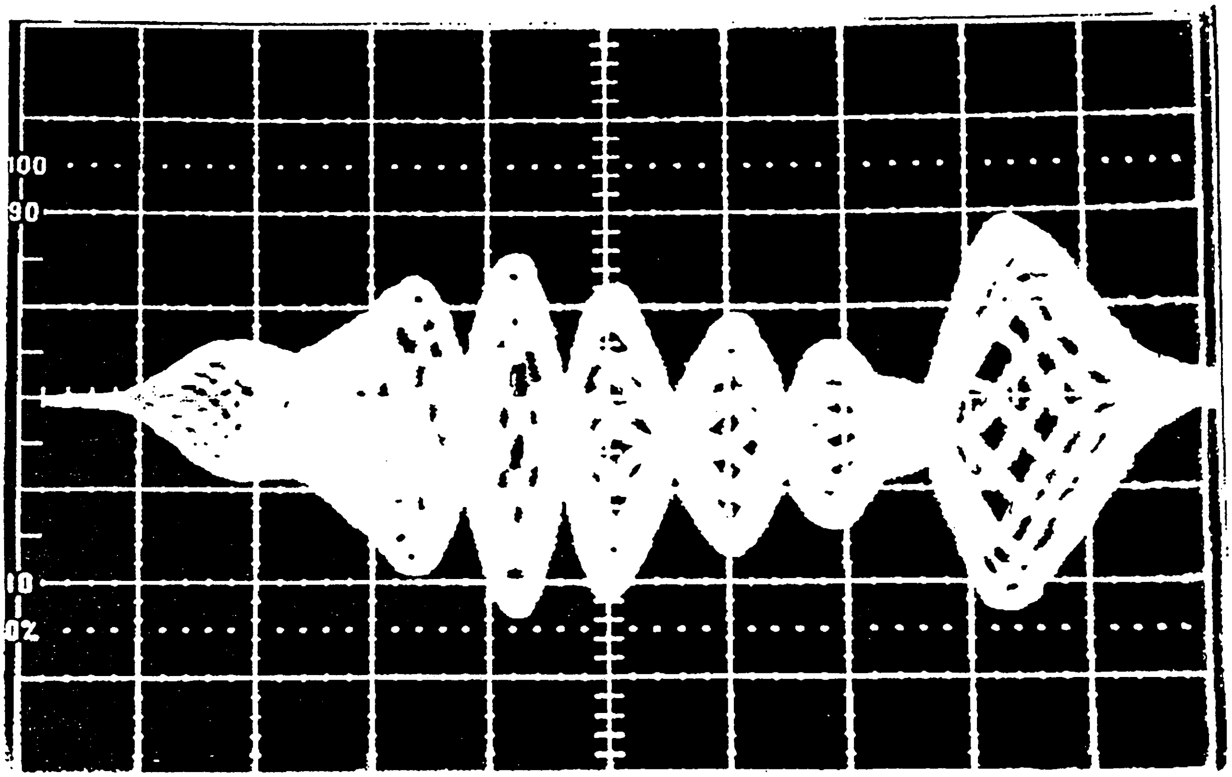


PSB Q-MEASUREMENT: MAGNETS LINEAR UP TO 1.4 GeV

The betatron tunes Q_x (= $4+q_x$), Q_y (= $5+q_y$), are measured along the 1.4 GeV acceleration cycle, by repetitive FFT-analysis of coherent oscillations.

- Near injection energy (50 MeV), tunes are programmed so as to cope with a space-charge tune shift of $\Delta Q_y \sim 0.4$ which during acceleration shrinks proportional to $1/\beta\gamma^2$.

- The field of the main dipoles (up to 0.87 T) and the gradients of the main quadrupoles (up to 5.4 T/m) stay strictly proportional to the respective excitation currents between 1 and 1.4 GeV: this is demonstrated by the fact that Q-values are constant in this energy range.



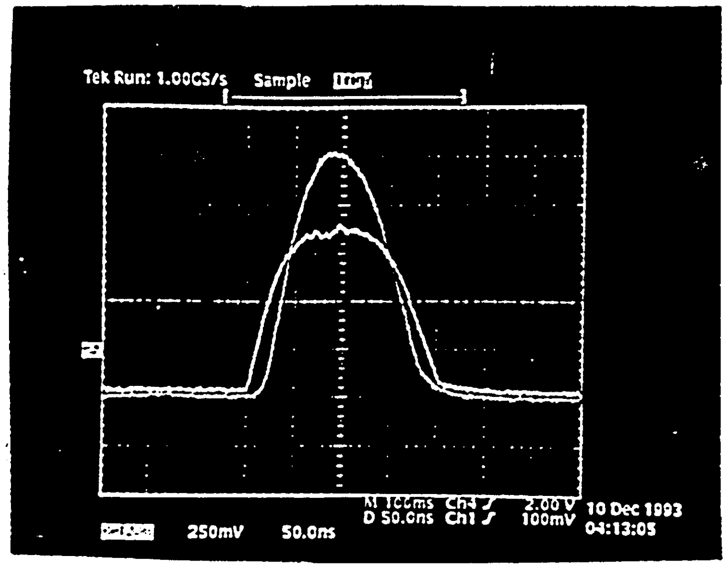
PS FRONT PORCH: HORIZONTAL INSTABILITY

The behaviour of the "beam-beam limit" LHC beam differs markedly between a 1 GeV and a 1.4 GeV front porch.

1.4 GeV: Transverse blow-up negligible, space-charge $\Delta Q \sim 0.2$, no instabilities.

1 GeV: ~ 20 % transverse blow-up (because of $\Delta Q \sim 0.35$ at the lower energy) and - a curiosity rather than an unsolvable problem - occasional horizontal instabilities followed by beam loss.

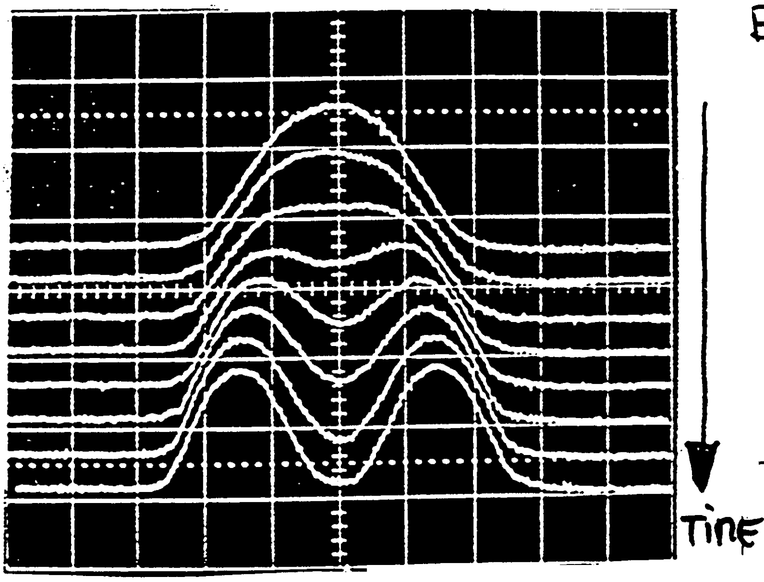
Photo: Signal from a horizontal beam position monitor on several consecutive turns, 20 ns/Div. The long (200 ns) bunch oscillates with a high-order head-tail mode (m=6), caused by the resistive wall impedance.



CONTROLLED BUNCH BLOW-UP BEFORE EXTRACTION FROM PSB TO IMPROVE THE "BUNCHING FACTOR" (DECREASE SPACE CHARGE) AT INJECTION INTO PS

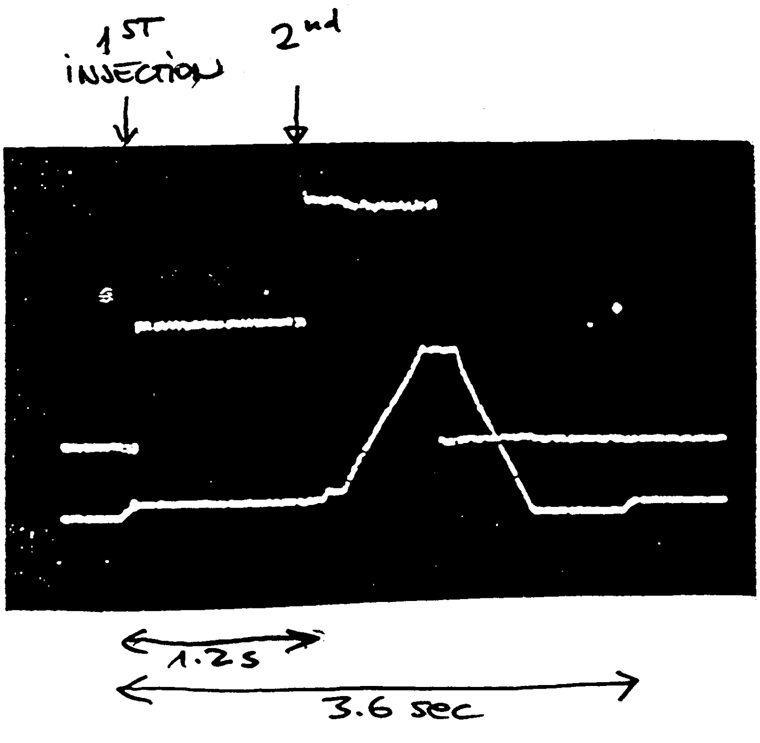
UPPER TRACE: BUNCH BEFORE BLOW-UP

LOWER TRACE: BUNCH AFTER BLOW-UP



BUNCH SPLITTING h=8 ⇒ 16 AT THE END OF PS PLATEAU (1 GeV OR 1.4 GeV). THE HIGHER BUNCH HARMONIC EASES DEBUNCHING – REBUNCHING (h = 16 ⇒ 84) TO OBTAIN 25 ns BUNCH SPACING AT 26 GeV/c.

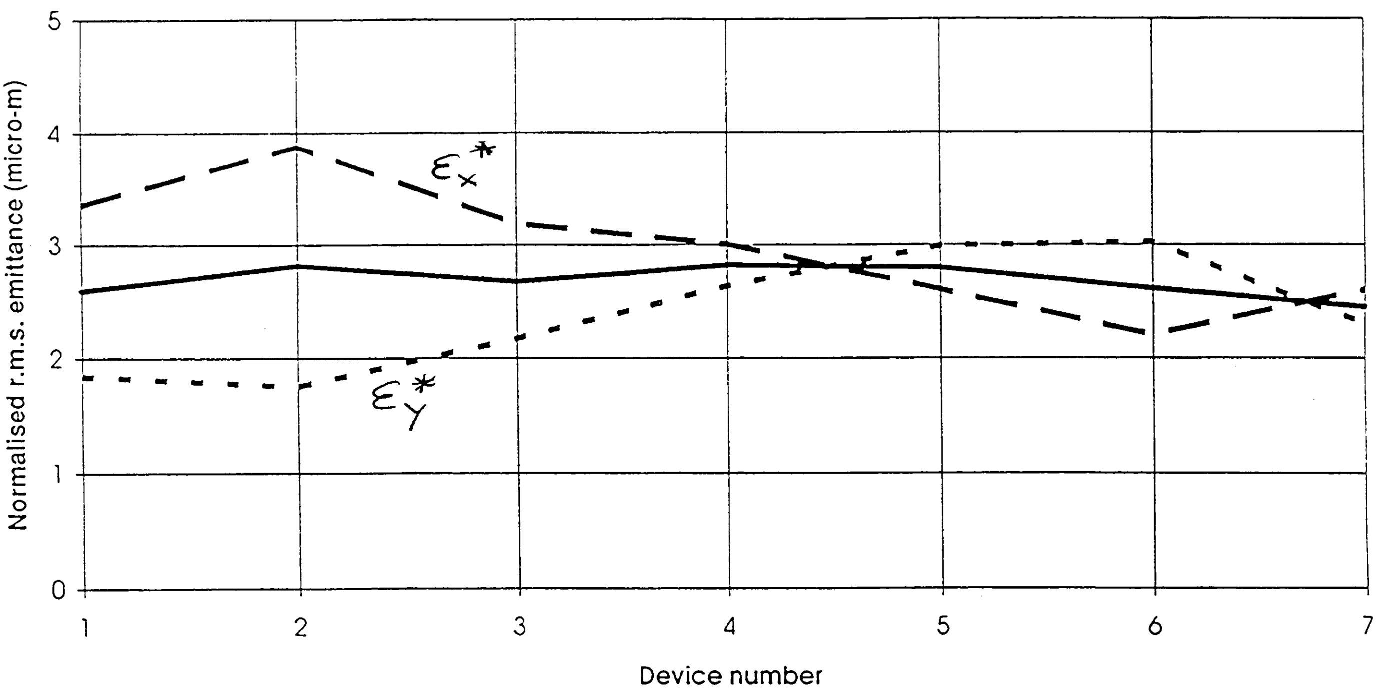
SHOWN ARE BUNCH SHAPES (1 SWEEP EVERY ~2 ms)



DOUBLE-BATCH FILLING OF PS.

UPPER TRACE: BEAM TRANSFORMER SHOWING THE TWO INJECTIONS AND ACCELERATION TO 26 GeV/c

LOWER TRACE: THE PS MAGNET CYCLE (REP. TIME 3.6 sec) WITH ITS 1.4 GeV INJECTION PLATEAU.



EMITTANCES IN PSB AND PS

Normalised r.m.s. emittances (in μm) for the "beam-beam limit" LHC beam ($1.8\ 10^{12}$ p lodged in 1/8 of the PS circumference, and corresponding to 84/8 = 10.5 LHC bunches of $1.7\ 10^{11}$ p each).

Broken line: ε_x*

Dotted line: ε_y*

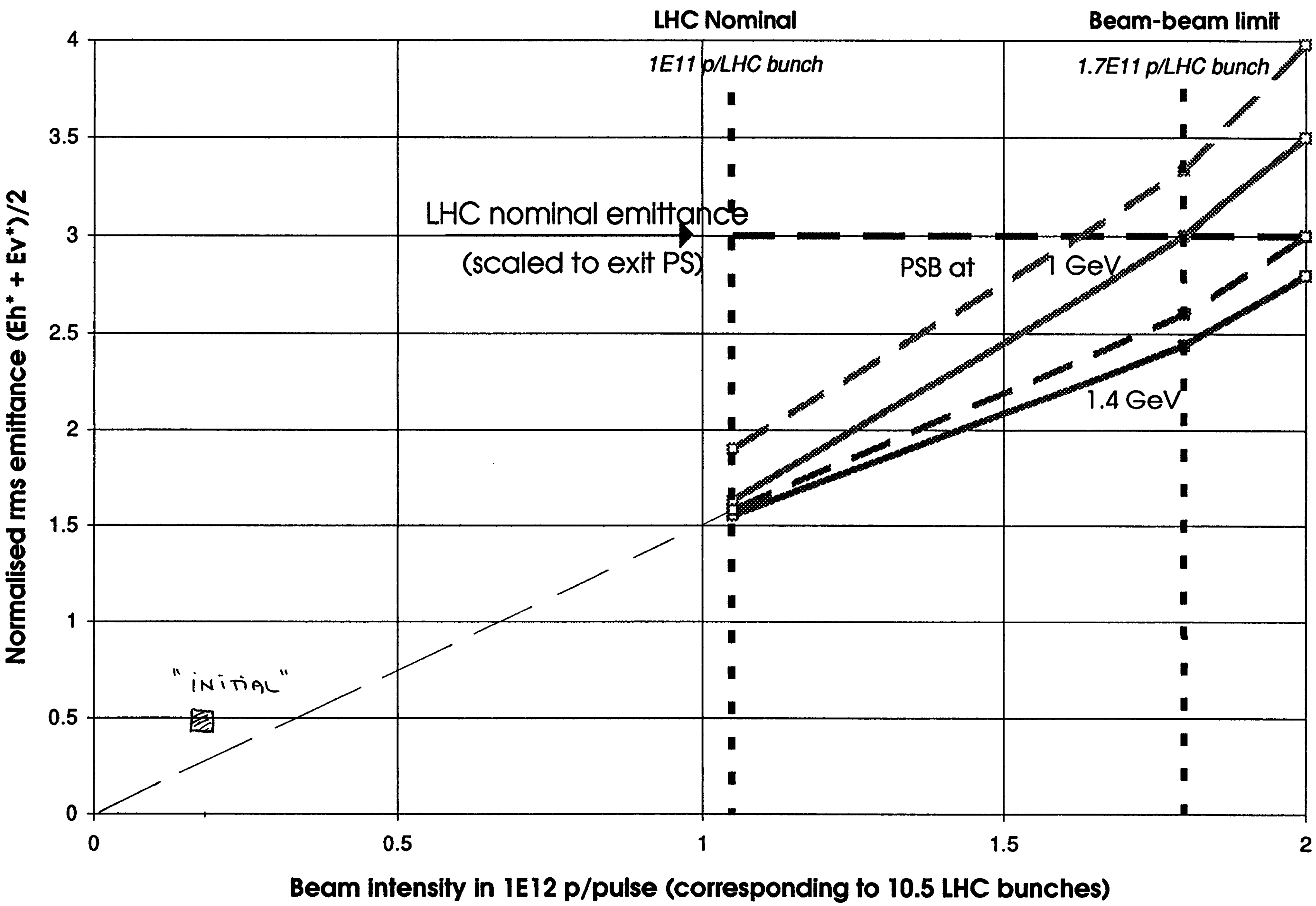
Full line: mean emittance (ε_x* + ε_y*)/2

Abscissa: numbers indicate measurement devices.

At PSB exit (device numbers 1,2) ε_x* > ε_y* (residual of the horizontal betatron stacking), but in the PS (3,4,5,6) the beam tends to become round during acceleration, due to linear coupling, and stays so after ejection in the line to the SPS. Note that

- the mean emittance (ε_x* + ε_y*)/2 is almost invariant along the chain;
- its value is below 3 μm, the LHC limit scaled to PS ejection at 26 GeV/c.

Emittance vs Intensity for LHC at PS exit (26 GeV/c)



KS 7.5.94

PS for LHC (Protons): Milestones

LHC proton beam to SPS: 1999
Other beams (SFT, Pb, ISOLDE,...): always available

		1996	1997	1998	1999	Comments
PSB	h=5/10	operation	operation			
	h=1/2	low intensity ring 3	high intensity ring 3	operation all rings	operation	"Big bang" March 1998
	1.4 GeV		main supply test	acceleration no ejection	operation	smooth transition 1999
PS	h=20	operation	operation			
	h=8/16		testing (intensity increasing)	operation	operation	"Big bang" March 1998
	Injection 1.4 GeV				operation	
	h=84 (40 MHz)	prototype	prototype used for SPS studies	prototype used for SPS studies	operation	LHC bunch spacing 25 ns
	h=168 (80 MHz)			testing	operation	bunch shortening to ~ 4 ns for SPS

PS for LHC - Protons: MD's 1995(6)

Machine	Priority	Study
Linac2	2	Produce 180 mA (20 μs) at PSB entry (alignment, RF chains, matching etc) in PPM with 140 mA (120 μs)
	3	Review of space-charge dominated optics Linac2 - PSB
PSB	2	Beam stability with kicker impedance as for LHC
	2	Analysis of longitudinal modes (in-phase n=0) with h=5 and h=10 systems
	2	Production and behaviour of an LHC-type beam in rings 1,2,4
	2	Controlled bunch flattening with h=1 and h=10 at ejection
	3	Make 1 GeV Measurement Line working
	2	Better recombination of four rings: ABS, optics errors,...
PS	3	Narrowing $2Q_y = 12$ on 1 GeV front porch
	2	Debunching - rebunching studies at 26 GeV/c
	1	Provide beams enabling the SPS to study μ-wave instability
	2	Optics issues between PS and SPS (PS non-linear fields, transport of beams with large momentum spread,...)
Combined	2	Improve correspondence between beam profile measurement devices: Beamscope, SEMs, wire scanners,...
	2	How to produce "initial" beam: 1.67 10^{10} p/LHC bunch in $\varepsilon^* = 0.75$ μm (at LHC collision), 0.6 μm (at 26 GeV/c)

PS for LHC - Protons: Issues for later

- Acceleration of highest intensities (ISOLDE, SFT) with the new harmonics (h=1,2 in PSB, h=8,16 in PS)
- Bunch splitting from h=1 to h=2 in the PSB at highest intensities (SFT)
- Transverse coherent instabilities with the new RF harmonics in PSB and PS: Do the feedback systems work?

HIGH INTENSITY BEAM STABILITY ISSUES IN LINAC 2

M.Vretenar

Problems in the transfer between Linac 2 and booster are present since many years. The situation seems to have degraded recently, during 1993 and mainly during the first period of the 1994 run, until a mysterious improvement in the month of October. The only evidence is an instability of linac beam position at the booster input, consisting in an irregular long-term drift and in a much smaller jitter. Its origin is still not clear, because the beam is stable in position when observed at the linac output and the beam energy is as well stable. The main directions where the studies are pursued are the analysis of the 80m long transfer line, where disturbances due to the ppm or to stray fields can occur, and a realignment of the low energy linac section during this shut-down. This should reduce the amplitude of betatron oscillations in the linac tanks and hopefully improve the general stability of the beam. But this instability in position is surely not the only responsible for the problems observed, as demonstrates the case of October, when the transfer improved dramatically without any special intervention from the linac side and with no difference observed in the linac beam parameters, emittance and energy spread, which are measured at the booster input position.

HIGH INTENSITY BEAM STABILITY ISSUES IN LINAC2

MV 1.2.95

(A)

Linac 2 seen from the Booster → 2 problems :

(1) [mainly hor.] instability in beam position at PSB input

⇔ { - long-Term drift [→ re-adjustment of inj.]
- jitter

(2) phantoms = unexplained situations like :

- PSB complaining but Linac beam ok
- PSB happy and Linac beam still ok (no changes!)
  (case of the miraculous buncher Autumn '94)

⇒ there is something not completely understood in the transfer Linac / Booster

(B) SOME HISTORY

- Problems and discussions exist since the construction of Linac & Booster! (almost 20 yrs.)
- More problems since the 1993 run (installation of RFQ, new controls)
- Even worse in 1994 (new PSB controls, Lead start-up), until <u>October</u>

(C) WHERE CAN THE PROBLEM BE ?

- The beam is stable in position at the exit of the linac (→ slide)
- There are instabilities (<1mm jitter, some mm drift) at the PSB input, after 80m of transfer line

<u>Hypothesis</u>:

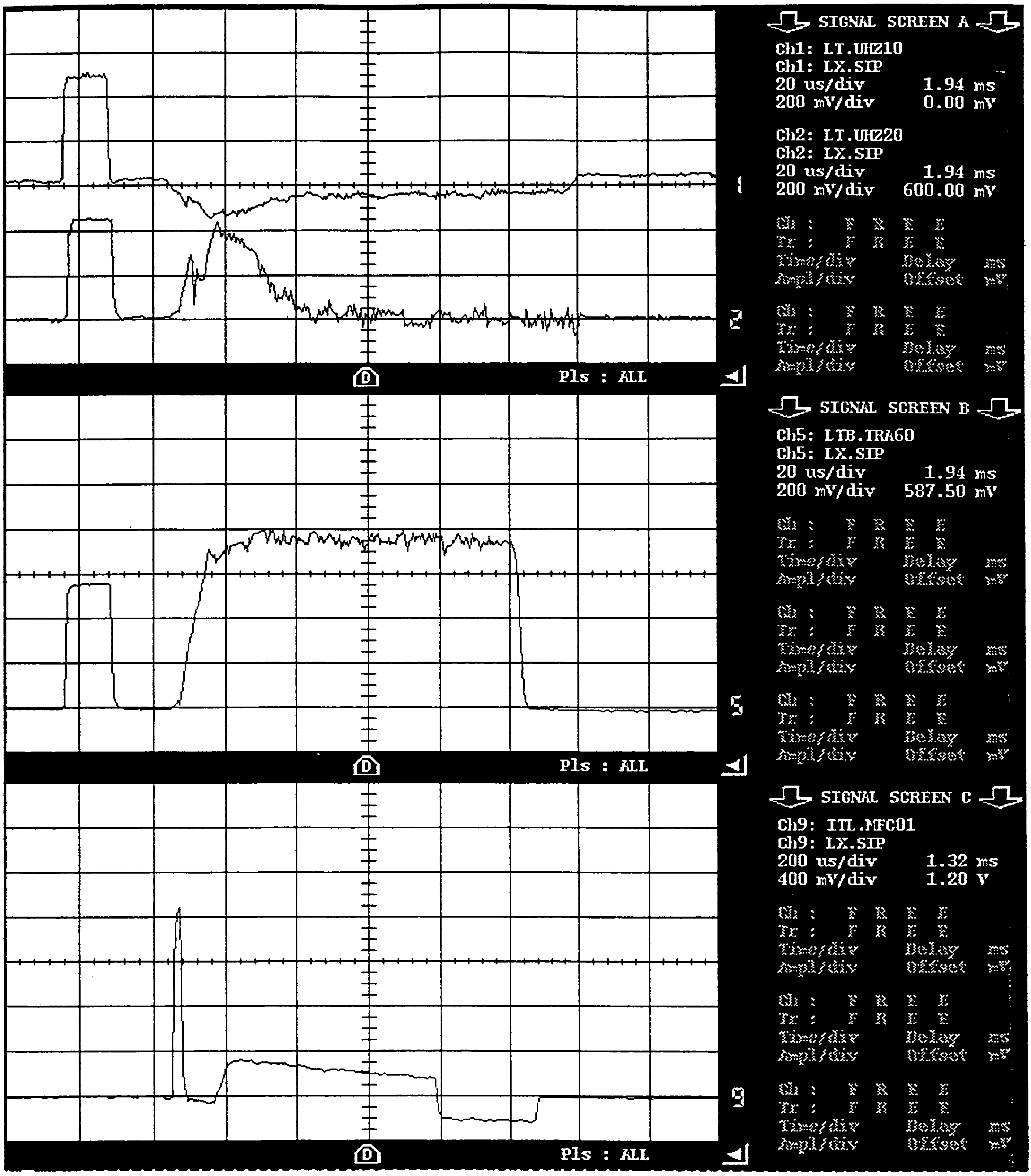
(1) ENERGY is stable (measured with LBS spectrometer)

(2) PROBLEMS with the TRANSFER LINE (stray fields, ppm-related problems, controls...)

(3) BEAM is MISSTEERED IN THE LINAC (due to misalignment of source or RFQ or linac drift tubes). Can this have an effect on PSB injection ?

CERN/PS nAos virtual scope

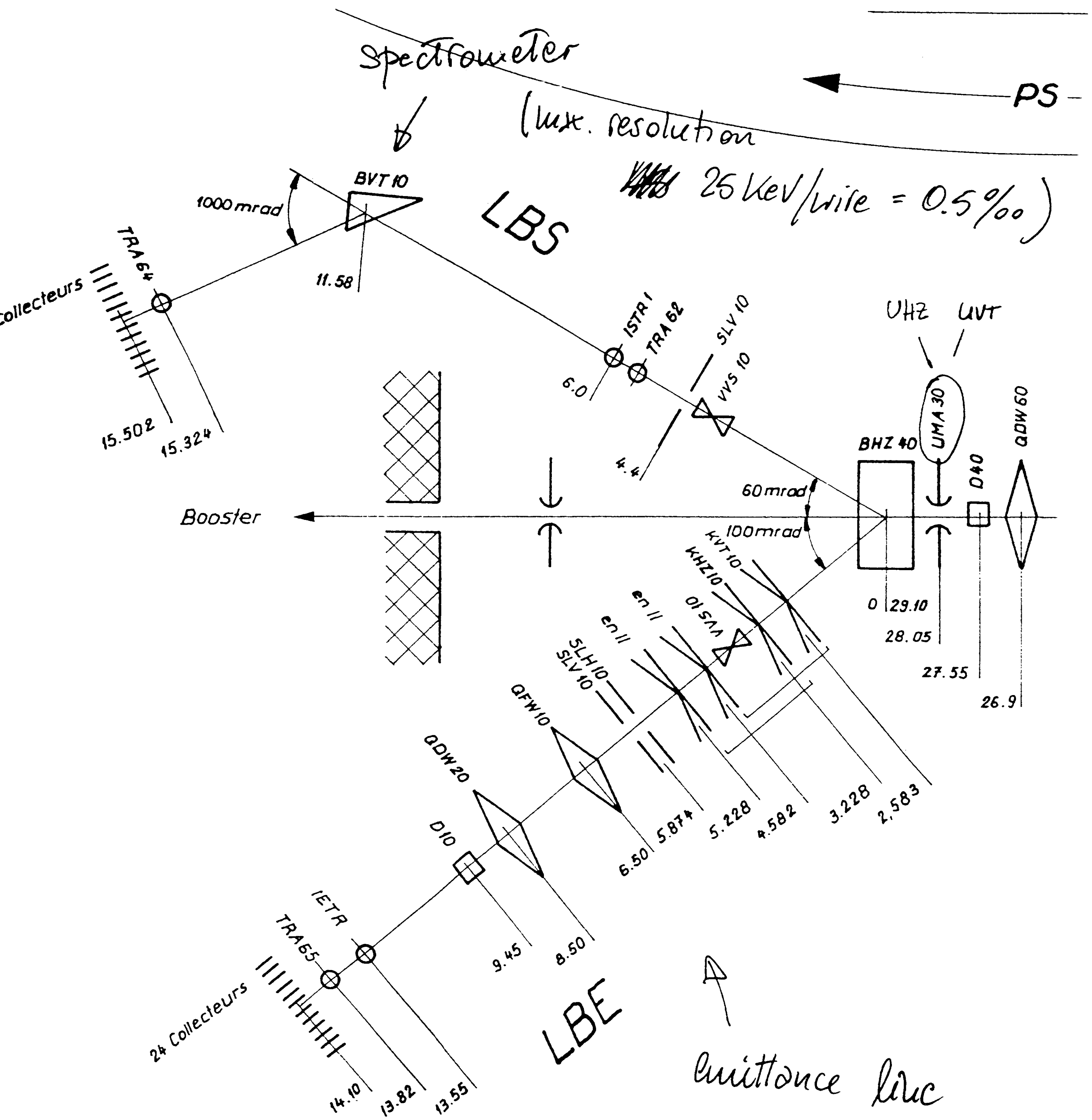
Calibration : 1mm/100mA



Thu Jul 14 15:08:39 1994

~~Production beam~~ (ISOGPS) : pick-ups before the bending =>
=> the ~~re is~~ beam during the first 30µs comes out with a different trajectory

D) THE LINAC - MEASUREMENT LINES



(E) ACTIVITIES

(1) This shut-down :

Analysis of beam position at the entrance of the RFQ, installation of a steering dipole in front of RFQ, alignment of beam at RFQ input
⇒ Hopes for a better beam steering all along the linac, with positive effects on injection

(2) Calibration of Spectrometer
(Magnet refurbished, work is going on for the field probe).

(3) Closer contact between Linac & Booster Supervisors, to improve understanding of transfer Linac / Booster

(4) Try to profit from the high current linac beam prepared for LHC during normal operation

ISOLDE and Neutrino Production Beams

Abstract:

PS Statistics of average proton intensity shows for the SFT (neutrino production) beam a stepwise increase from 2.1E13 to 2.7E13 ppp. The reasons for this unusually low figures are analysed. Grosso modo they can be related to the pressure to meet the schedule of the Lead Ion Project in the first phase, and some subtle problems with new hardware. As from october, the performances of last year were reached again.
In the second part, loss control is addressed as one of the crucial long-term problems.

Short Term Problems: Baisse of Performances in 1994 Principal Reasons:

1.	Other priorities and deadlines to be met:	• Pb Ions • Controls Commiss.
2.	Interference with Ion installations	• Pb Distributer Ceramic chamber • Main PS fast rise
3.	Instability of trajectories of Linac 2 beam: in particular after start-up; Spectrometer Measurement perturbed by Pb Settings (Hysteresis)	Difficult / impossible Injection optimisation
4.	PPM of Linac 2	frequently unnoticed
5.	Insufficient RF Voltage, unrel. calibration	o.k. later in year
6.	Hidden Controls Problems , mainly HW PPM "USER" changes in calibration factors	p.ex.: • GFADs, • MPS acquisition (diff. local/remote)
7.	Some application progs. not fully operational	• improved later in yr
8.	Errors in prog. of dynamic working point (not confirmed, intermittent)	Qh possibly too high Loss on 2Qh+Qv=14?
9.	Hidden Linac2 properties ?	contested by experts
10.	Standing dual RF system stability problems	≥ 2.5 E13 ppp
11.	Long. octupole in-phase modes in Ring 4	aged tube ?
12.	Bad hor. C.O. (already 93); Vert. Deform. in R3	Hot spot in 7L2
13.	Residuals from 1.4 GeV Test	foc. errors in transfer

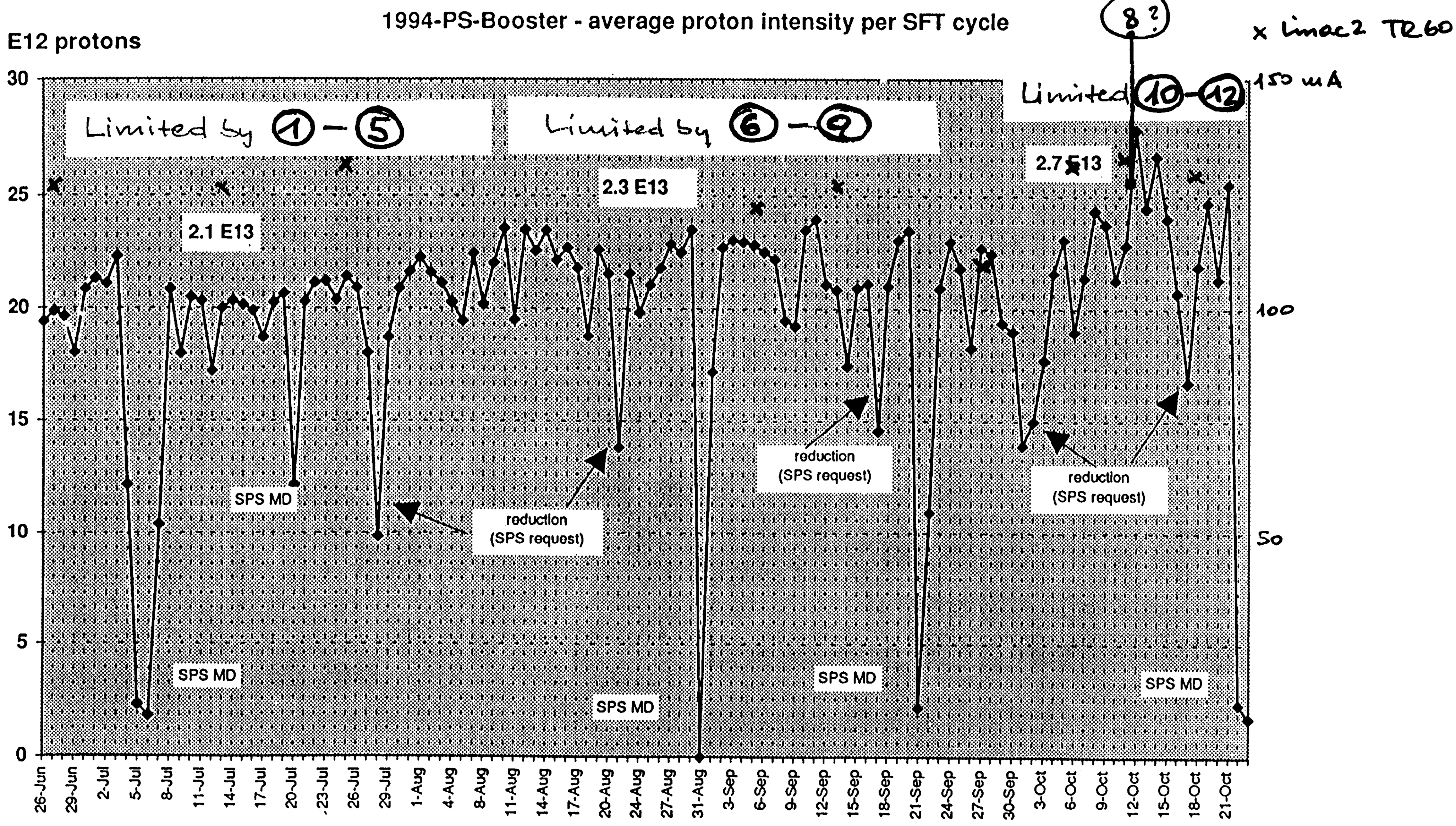
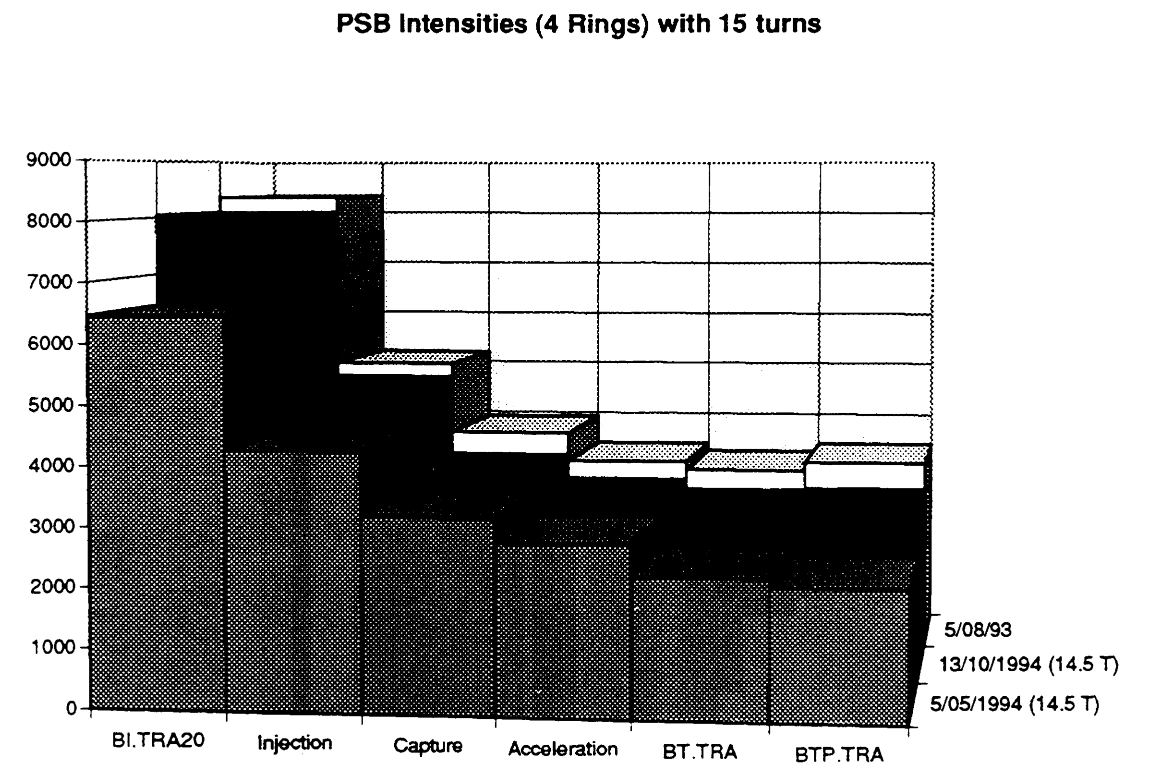
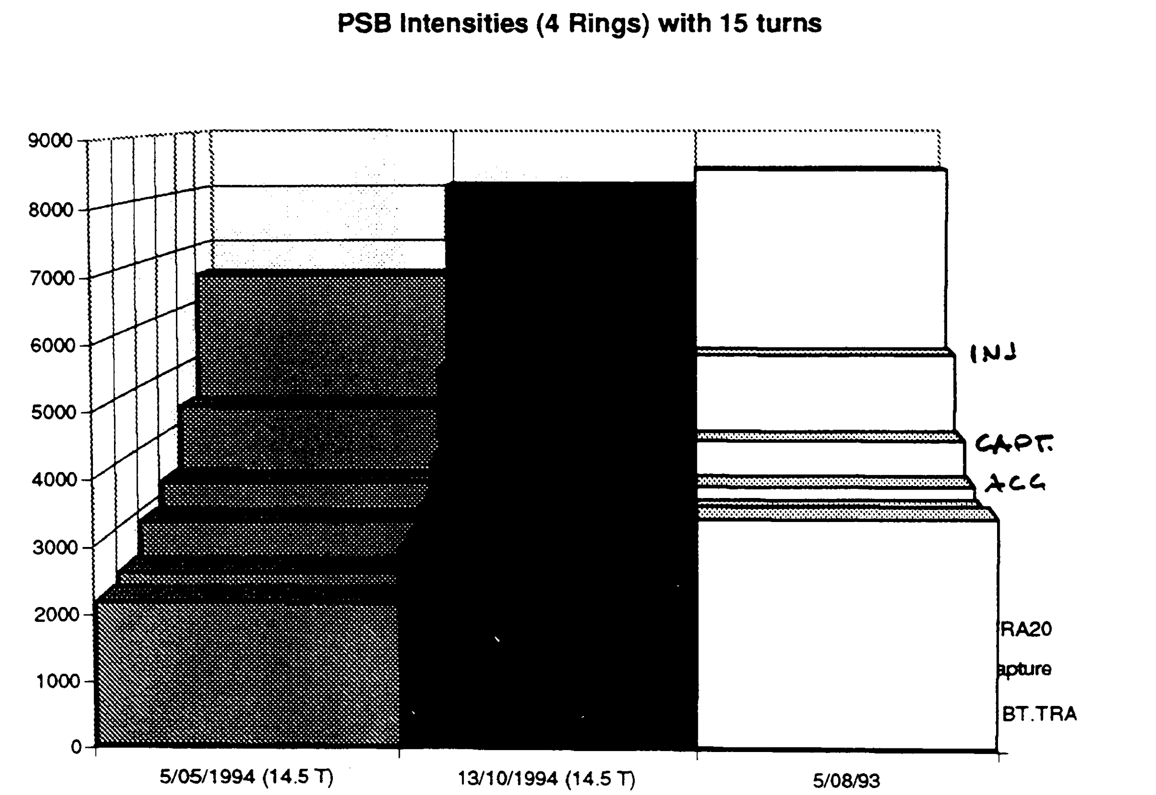

1994-PS-Booster - average proton intensity per SFT cycle
E12 protons
30
25
20
15
10
5
0
Limited by 1 - 5
Limited by 6 - 9
Limited 10 - 12
8 ?
x linac2 TR60
150 mA
100
50
2.1 E13
2.3 E13
2.7 E13
SPS MD
reduction
(SPS request)
26-Jun
29-Jun
2-Jul
5-Jul
8-Jul
11-Jul
14-Jul
17-Jul
20-Jul
23-Jul
26-Jul
29-Jul
1-Aug
4-Aug
8-Aug
11-Aug
14-Aug
17-Aug
20-Aug
24-Aug
27-Aug
31-Aug
3-Sep
6-Sep
9-Sep
12-Sep
15-Sep
18-Sep
21-Sep
24-Sep
27-Sep
30-Sep
3-Oct
6-Oct
9-Oct
12-Oct
15-Oct
18-Oct
21-Oct

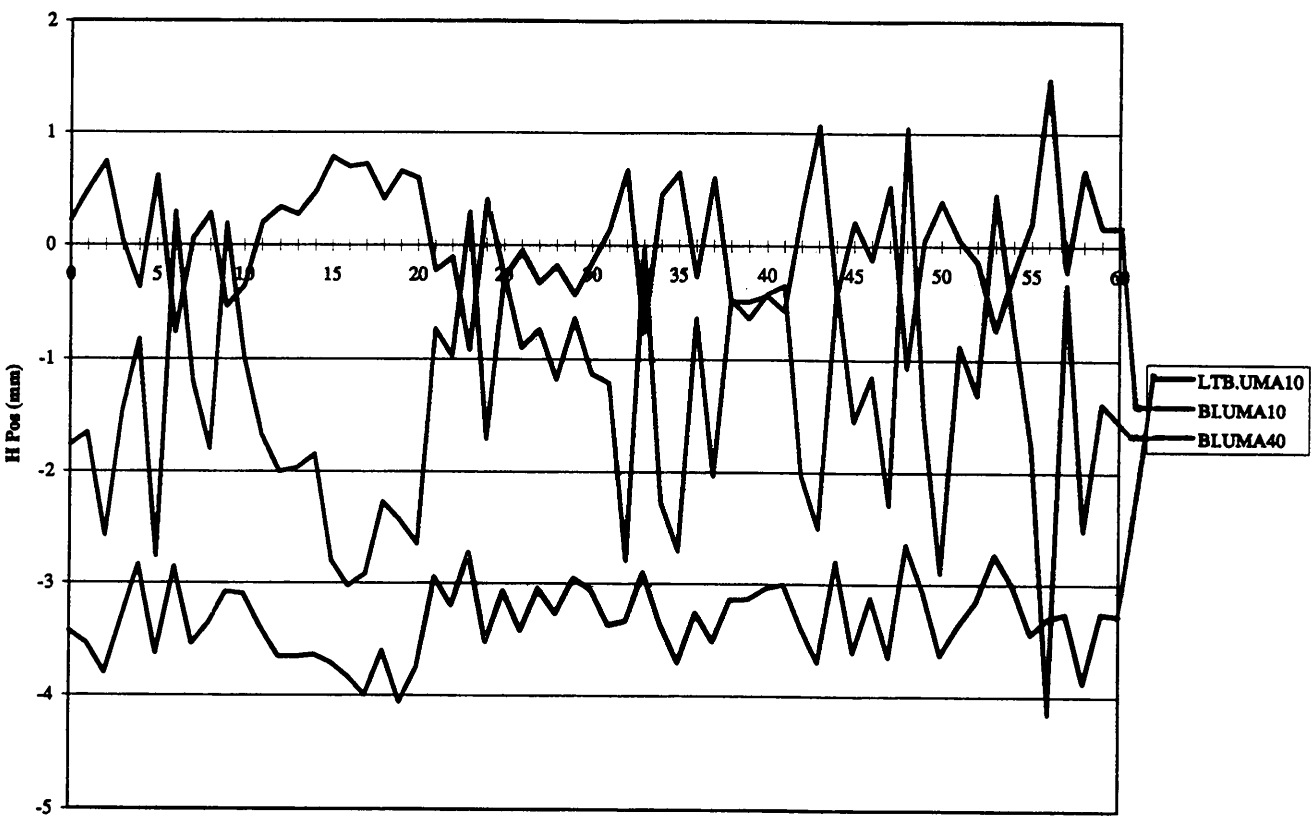
Fig. 14

2

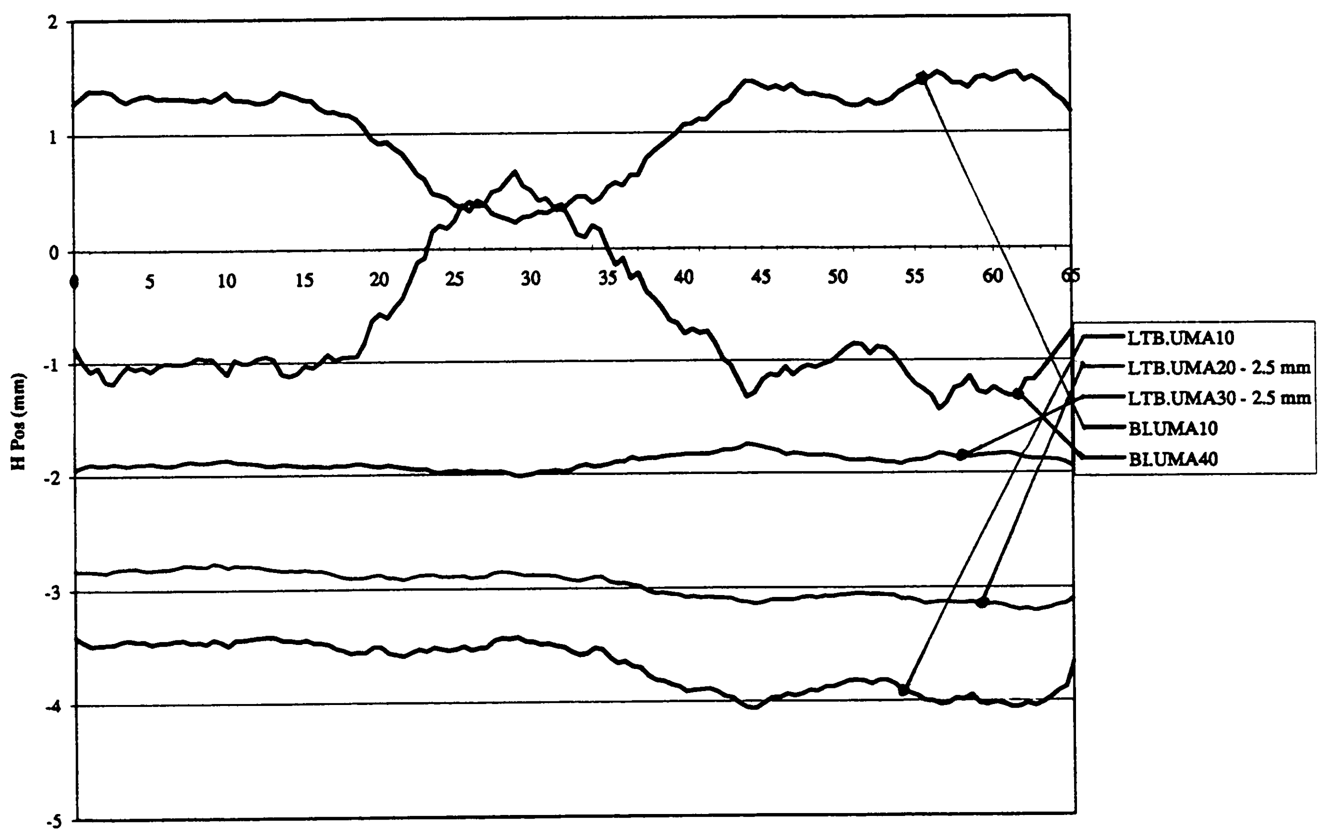

PSB Intensities (4 Rings) with 15 turns
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
BI.TRA20
Injection
Capture
Acceleration
BT.TRA
BTP.TRA
5/08/93
13/10/1994 (14.5 T)
5/05/1994 (14.5 T)


PSB Intensities (4 Rings) with 15 turns
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
5/05/1994 (14.5 T)
13/10/1994 (14.5 T)
5/08/93
INJ
CAPT.
ACC
RA20
apture
BT.TRA

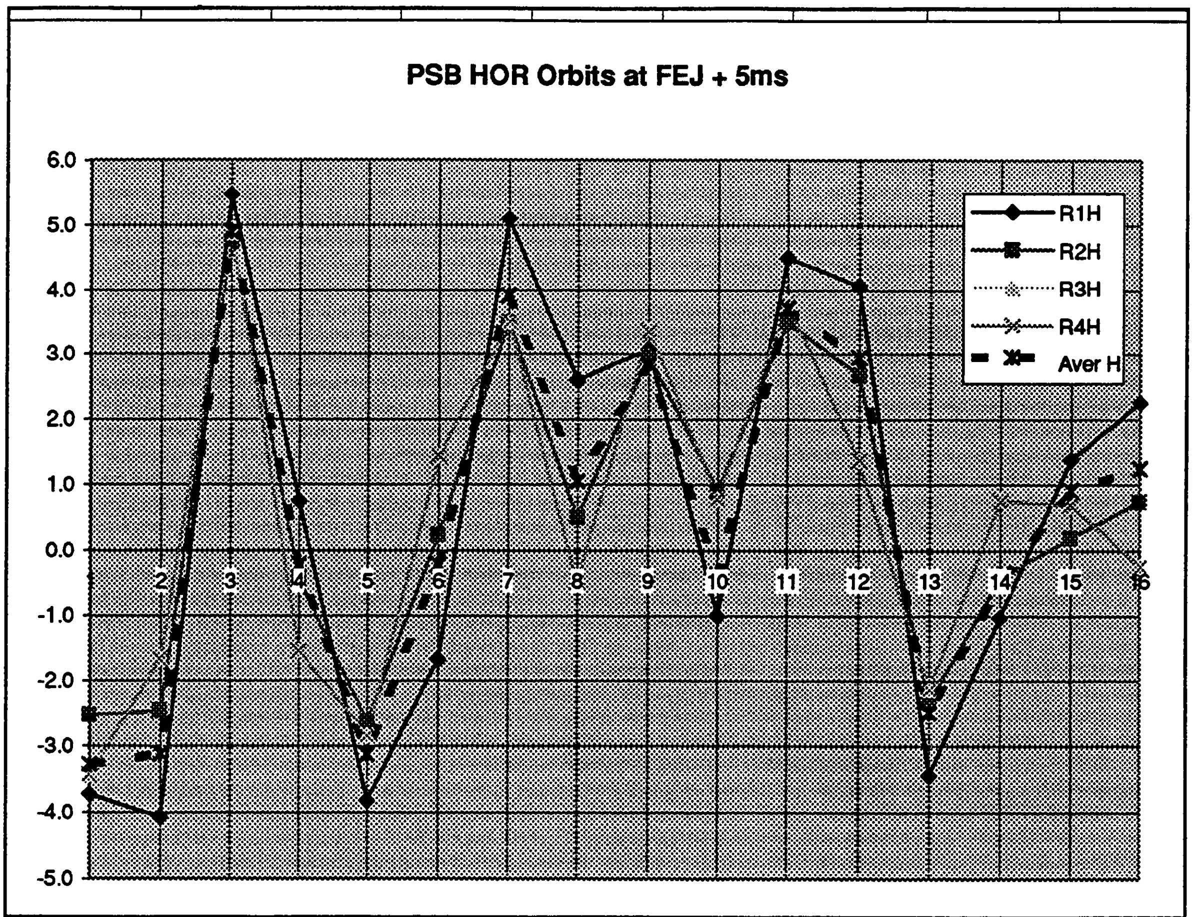
Booster injection (1 pt per mn)

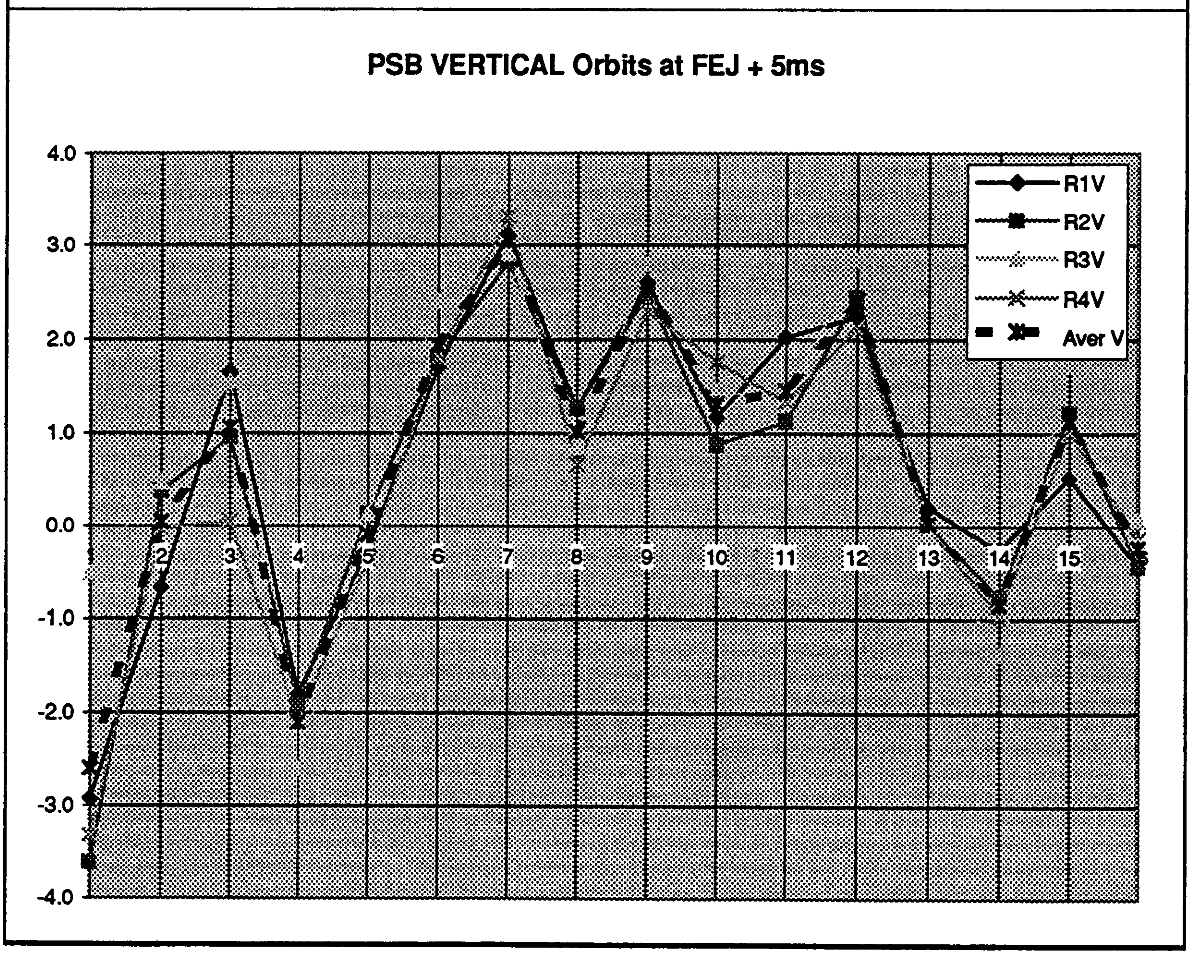


Booster Injection (1 pt per 30 mn, mean 20 pts)

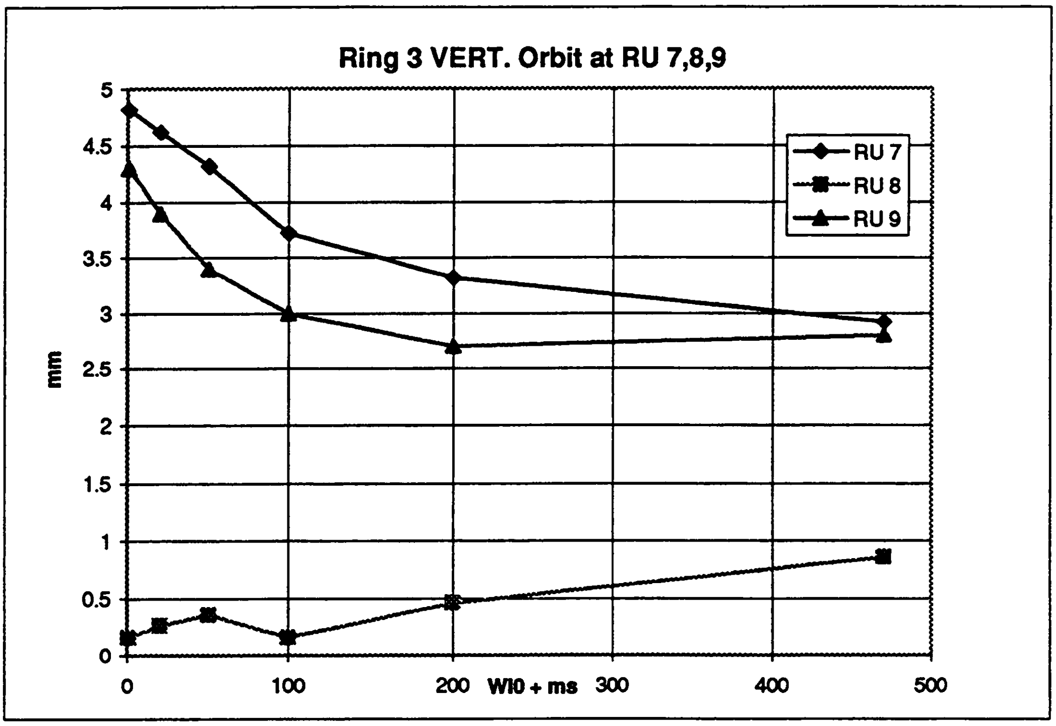


Ad 3. : Records of Linac2 Trajectories (Dec 94)
Note the magnification between BI.UMA40 and LTB.UMA10





Ad 12.: Aperture limits due to closed orbit



Ad 12.: Evolution of a local c.o. distortion in Ring 3; as the curves ressemble the Q_V-programme, the c.o. might be sensitive to the time.

The hot spot recorded in Section 7L2 can be explained by this deformation.

Long-Term Problems (once performance restablished): *Loss control*

A glance at the graph of the evolution of personal dose during maintenance, radation surveys and number of protons accelerated in the last years shows an intriguing step in personal dose; this however may reflect more the unusual amount of shutdown work in preparation of the acceleration of lead ions, in particular in the vacuum sector, and there are indications that in this year shutdown the dose will be about the same, as the vacuum system needs consolidation. But the growing radioactive contamination as a consequence of ISOLDE operation cannot be denied, and the following measures are to be considered:

- **Improved longitudinal stability (would remove part of the losses at > 200 MeV:**
- **Loss collimation**
- **Transfer Lines**

- **better understanding**
- **h=1/h=2 system**
- **Two-stage system hard to implement**
- **Wire Septum (1stage)**
- **Autom.Beam Steering**
- **more diagn. ISOLDE**

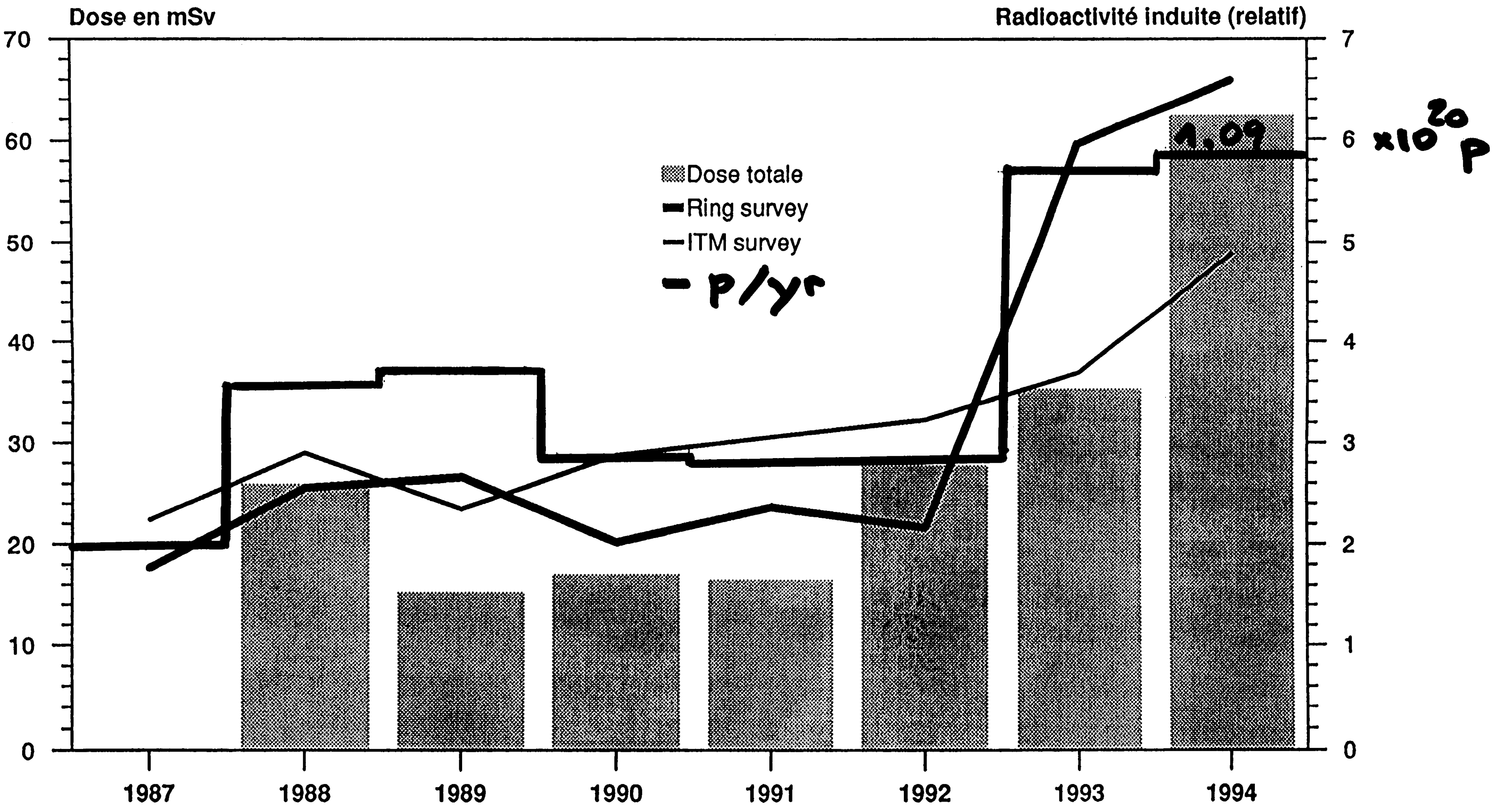
There is a number of loss mechanisms in the PSB (cf. Proc. of the 1st PPD, PS/PA/Note 93-04, pp 82,83). Some of them, like injection loss, are inherent, others like loss on stopbands and diffusion out of the bucket are difficult to reduce, even if, as is hoped, the longitudinal instabilities will be better controlled in the future.

A conventional loss collimator system has to consist at least of two stages to be efficient - which is hard to retrofit into a lattice like the one of the Booster. Single stage (septum-type) collimators will be studied and compared to the possbilities of the conventional ones. In any case, there is a conflict with the Beamscope window, the present aperture limit, which is and cannot be designed to become a true collimator. Hence the installation of a performant loss collimator requires the removal of Beamscope and its replacement by another, preferrably mechanical, device.

For loss reduction in the transfer lines, in particular in the recombination of the four rings, Automated Beam Steering looks promising as it can help avoiding "quick fixes" of transfer errors that may take a long time to be corrected by systematic manual procedures.

The transfer to ISOLDE suffers still from losses, likely due to deviations of the real optics from the theoretical one and due to alignment errors caused by soil settling.

DOSE COLLECTIVE ANNUELLE
BOOSTER



8

Transfer Lines to PS and to ISOLDE

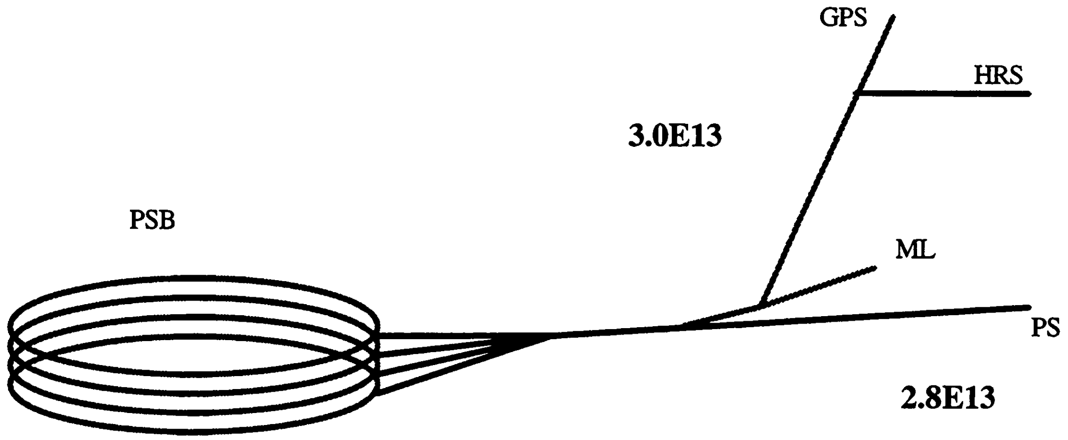
E.Wildner

Abstract

The transfer of the beam from the Booster to the PS and to the ISOLDE targets is not trivial since the beam intensity is high and losses have to be kept at a minimum. A satisfactory recombination and steering of the four Booster beams to satisfy the PS and the ISOLDE requirements is a heavy task for the operation team. During -94 studies have been made to verify the optics in the lines, with new calculations and measurements. The steering and recombination of the beams to the PS have been automated. The result is promising. For the ISOLDE beamline the lack of instrumentation makes the steering task very difficult. However, a fixed sem grid is going to be installed in front of the targets. The new HRS beam line was successfully set up and tested.

In -95 an operational application program will be installed for the steering to the PS. Optics for the ISOLDE line will be checked again and the results compared with the readings on new sem grids. For the ISOLDE steering, we will continue to fight for a reasonable method to guide the beam. An automatic beam shaping program is planned, that will help us to focus the beam on the targets according to the requests from the ISOLDE experiments.

Transfer Lines to PS and to ISOLDE



Outline

Problems

Solutions

What has been *done*

What is going on or *planned*

What would be needed to be able to continue *improvements*

Main Participants:

G.Cyvoct	J.-M.Elyn
E.Jenssen	G.-H.Hemelsoet
N.Rasmussen	O.Jenssen
K.Schindl	J.-M.Nonglaton
G.Schneider	E.Ovalle
H.Schonauer	R.Steerenberg
E.Wildner	V.Vicente

Task

Correct position/angle and beam envelope at a certain point (PS injection, ISOLDE GPS/HRS targets)

Beam transfer with minimum loss

ISOLDE:

Protons

2.7-3.0 E13 ppp, loss 0.3 E11

PS:

Protons

2.8 E13 ppp, loss 2.5 E12 ppp

Lead Ions

1.4 E10 cpp, loss 0.4 E10 cpp

PS

Problems

- Beamlosses (Pb, p)
- Optics not perfectly understood on semgrids in ML
- Steering on-line impossible (optimization in the PS necessary at the same time, line is not entirely PPM)
- Steering extremely complex and timeconsuming

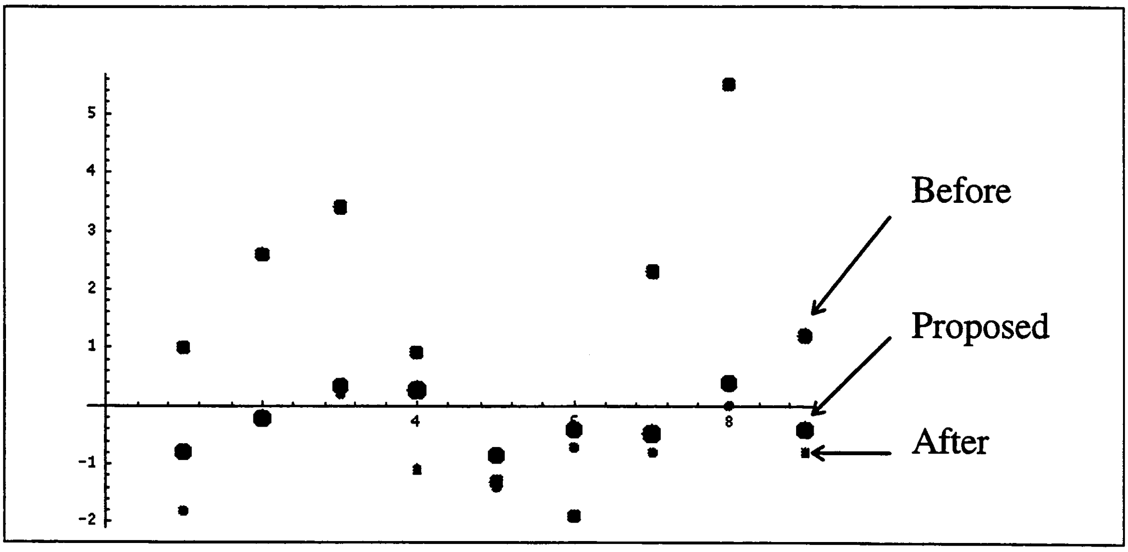
PS

Solutions

Done

Symbolic Computing APS

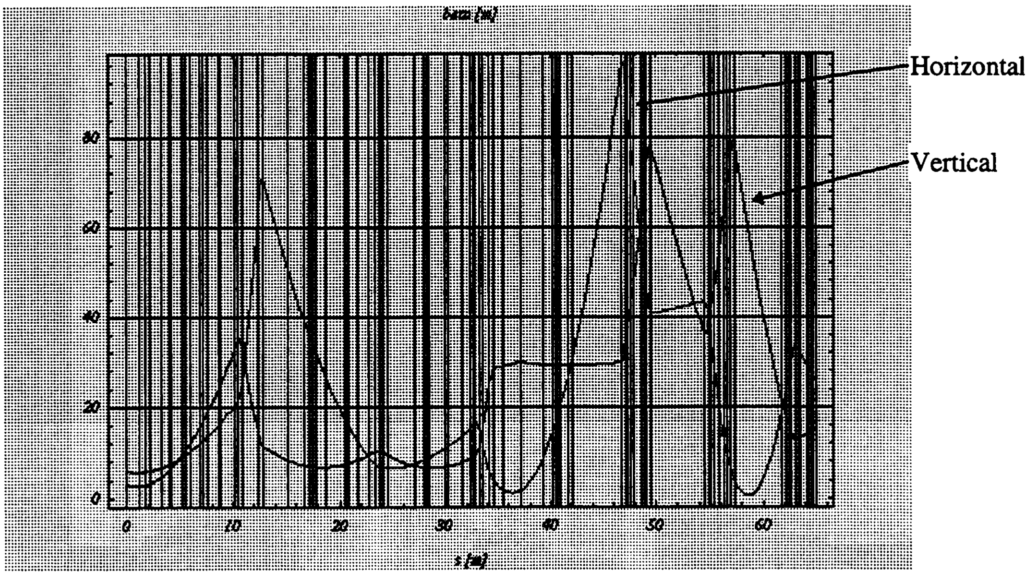
- Recalculation of optics
- Pickup position verification
- Development of automatic Recombination and Steering procedure (to be used with the automatic correction of the PS injection oscillations). B.Autin
- Discovery of wrong dipole setting in the beamline (800 MeV)



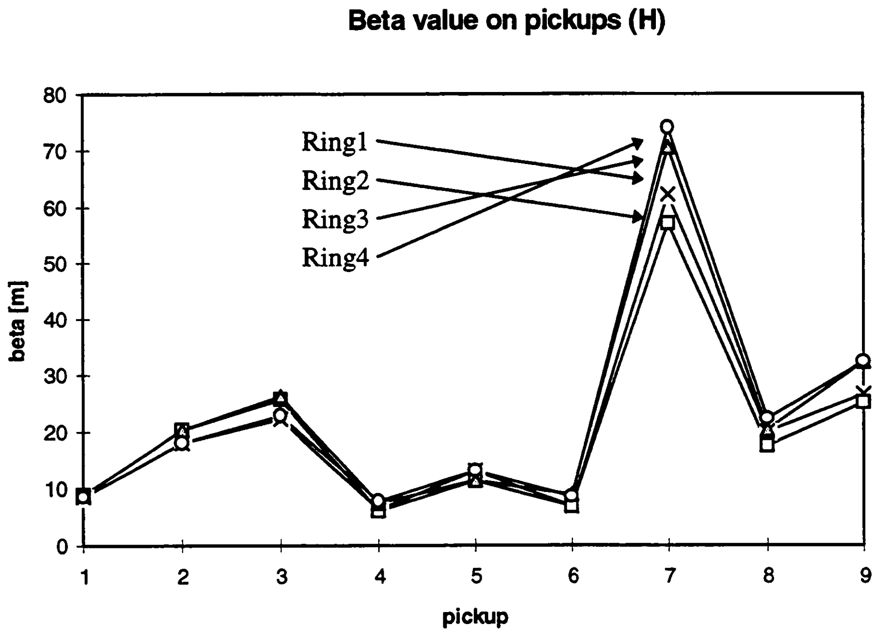
Ring 2 horizontal (MD 15/12 -94)

Solutions

Done (cont.d)



Optics calculation for ring 3



Differences in β values between rings.

Solutions

Done (cont.d)

- Discovery of wrong Quadrupole setting in the beamline (1.4 GeV)

Planned/going on

- BTU upgrade
- Transformer checks
- Put the ML line into operation (optics verification and deconvolution of contributions from dp/p due to dispersion at semgrids)
- Application program for automatic steering

ISOLDE

Problems

- ●Beamlosses (p)
- ●Optics does not correspond to observations
- ●Steering on-line is destructive, imprecise and very timeconsuming (Scintillator Screens).
- ●Alignement problems: if beam on screen center, it does not pass through the beam line!
- ●Different optics/distribution of particles have to be set up according to target type

ISOLDE

Solutions

Done

●MD to veryfy optics with semgrids near target:
- ☹Theoretical Optics $\neq$ Observed Optics
- ☺The four beam well aligned

●Discovery of wrong Quadrupole setting in the beamline (1.4 GeV)

●Calculations to distribute particles by different steering for different rings.
- ☹Too small acceptance in beamline

●Setting up of HRS
- ☹Misalignment between PS and ISOLDE (15mm)
- ☺No major problems. PPM ok!

Planned/going on

●Fixing ML line

●Permanent semgrid near target

●Alignement (laser and mechanical), Centering of beam on quad axis by changing quad current values.

●Application program for automatic beam spot shaping

CONCLUSION

PS

Good beam instrumentation essential, there is hope!

Pickups (+ alignement)

Semgrids in ML

ISOLDE

We lack basic Instrumentation for a reasonable operation of the ISOLDE beam line. The requirements on the surveillance of beam losses are tough; we send very high intensity and many pulses to ISOLDE.

Correction of injection oscillations in the PS

M.Martini

Abstract

Correction of coherent oscillations at the PS injection are crucial to prevent emittance blow-up and to keep the particle losses at a low level. The method of correction uses two successive single turn trajectories and requires two corrector magnets per plane. It is based on the generic algorithms for beam steering, valid for trajectory correction in transfer lines, closed orbit correction, and coherent oscillation correction.

The technique of beam steering consists of providing the operator with a graphic user interface which triggers trajectory measurements, calls a symbolic algorithm of correction (Micado) and sends calculated currents to specified correctors. All the manipulations are performed using an application program that has been written and integrated in the standard PS controls system.

A programme of activities for 1995 of the Automatic Beam Steering (ABS) in the PS machine and transfer channels is presented.

Automatic Beam Steering

Achievements in 1994:

- **Coding of *Mathematica* generic algorithms for beam steering:**
  - trajectory correction in transport channel
  - correction of coherent oscillations
  - closed orbit correction
- **Operational correction of coherent oscillations at injection into the PS (*Motif* program on Workstation, by M. Arruat)**

Correction Method

Correction of coherent oscillations using two successive turns, with unknown closed orbit and tune.

- **Measurement vector *b* (*n* monitors)**

$$b=\left\{\frac{x_{i,t}-x_{i,t+1}}{2\sin\pi Q}\right\}_{i=1..n}$$

- **Unknown correction vector *x* (*m* correctors)**
- **Minimize norm of residual vector *r***

$$r=Ax+b$$

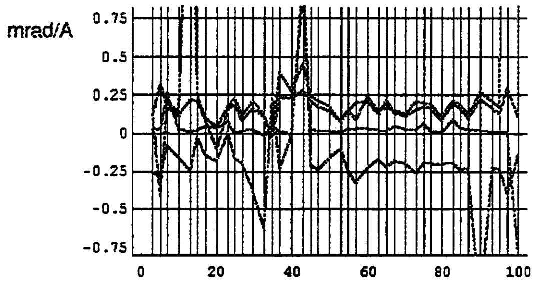
- **with the correction matrix *A (n,m)***

$$A=\left\{\sqrt{\beta_i\beta_j}\,\sin\Delta\mu_{ij}\right\}_{j=1..m}^{i=1..n}$$

Corrector Calibration (11/10/94)

- 4 corrector magnets: DHZ40, SMH42, and DVT40, DVT50
- Magnet calibration measurement with the 40 PS pick-ups
- Measurements k_j [mrad/A] reliable between PU47-PU85:

	DVT40	DHZ40	DVT50	SMH42	
k_j	0.151	0.163	-0.151	0.0296	optics meas.
	0.155	0.155	-0.155	0.0309	magnetic meas.



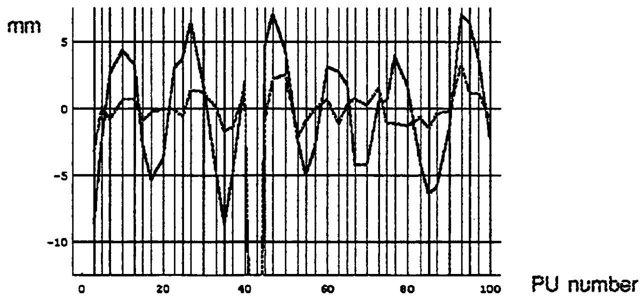
$$k_j = \frac{1}{\sqrt{\beta_i \beta_j}\sin\Delta\mu_{ij}} \frac{\Delta x_i}{\Delta I}$$

10^{12} *p/bunch*

PPD Rolle 02 Fev 95

Horizontal Correction (7/11/94)

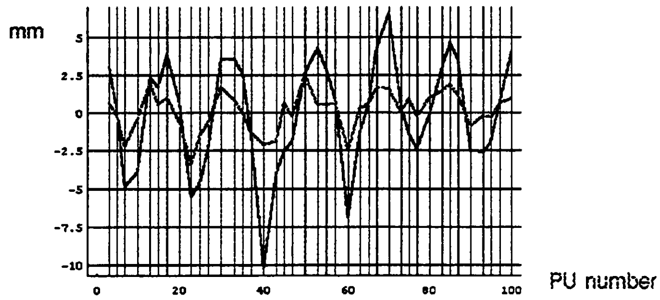
- Difference between 2 consecutive turns (1st-2nd) [mm]
- 2 correctors used (DHZ40, SMH42)
- PU 43 discarded for correction calculation



10^{11} *p/bunch*

Vertical Correction (7/11/94)

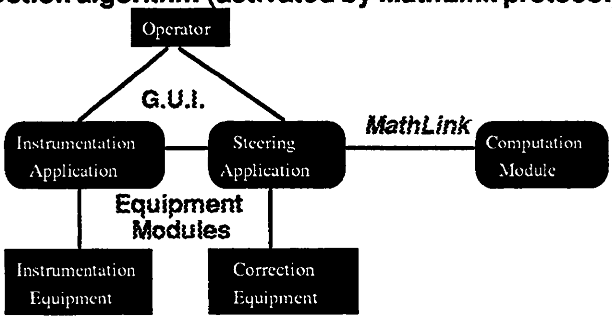
- **Difference between 2 consecutive turns (1st-2nd) [mm]**
- **2 correctors used (DVT40, DVT50)**
- **No pick-up discarded for correction calculation**



10^{11} *p/bunch*

Software Architecture

- **Instrumentation application: program for the control of the equipment and the acquisition of beam trajectories**
- **Steering application: communication program between the instrumentation application and the computation module**
- **Computation module: *Mathematica* session executing the correction algorithm (activated by *MathLink* protocol)**



Program for 1995

Goals:

- Injection into and ejection from the PS of all particles: e^+, e^-, *p*, *p-bar*, Pb^{n+}
- Closed orbits

Remarks:

- Ambitious but Feasible: existing software to be ported in new environment
- Limitation: lack of instrumentation in certain areas:
  - replace screens by pick-up's
  - observation of Pb^{n+}

MD IONS Pb(53+) IN LEAR (Dec 1994)

M. CHANEL

ABSTRACT

The goals of this machine developement was to measure the lifetime and cooling time of lead ions P_b^{53+} in LEAR with different machine conditions. After a review of the differents setups and problems related to electron cooling and machine, the ways we have tried to overcome these problems the first result are shown. Some possible explanations are given on the too short lifetime observed with electron cooling. The subjects to study during years 1995/1996 are listed

PPD ROLLE 2 fevrier 1995

GOALS OF THIS MD

1-INJECT P_b^{53+} IONS THROUGH LOOP E0 / LINE E2.

2-MEASURE WITH DIFFERENT MACHINE SETUP :

a-LIFETIME

b-COOLING TIME

3-LEAR SETUP

CHANGE TWISS PARAMETER AT ECOOL.

CHANGE ELECTRONS CURRENT OF ECOOL.

WHEN?

IN november 1994 ..Only four days instead of 7 days expected due to a faulty bellow in BHN20.(Preparation work with protons)

IN December 1994 (14th to 20th).Two days with protons to verify the machine and to finish preparation work . Delayed by ECR source fault . Start on Friday afternoon(Pb^{53+})

ELECTRON COOLING

Cooling time

$$\frac{1}{\tau} = \frac{1}{k}\frac{Q^2}{A}\eta_c L_c r_e r_p \frac{j}{e}\frac{1}{\beta^4 \gamma^5 \theta^3}.$$

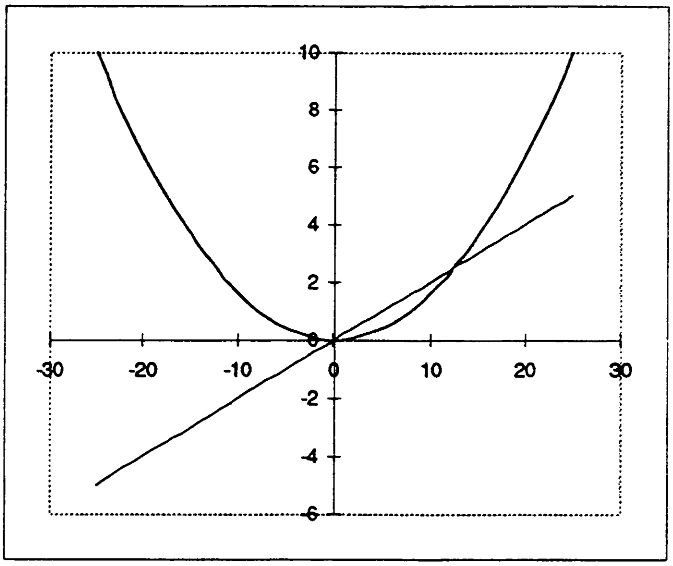
k : a constant ditribution depending on the ditributions of ions and electrons.
Q=53, A=208 :charge and mass number of the ions.
η_c=0.018 :the fraction of the circonference occupied by the cooling section
$L_c \cong 10$:The coulomb logarithm.
$r_e = 2.8\,10^{-13} cm^{-2}$, $r_p = 1.5\,10^{-16} cm^{-2}$:the classical electron and proton radii.
j(=0.02A/cm-2):The current density of the electron beam[up to 0.5 A/30 cm2] which correspond to an electrons density of $0.45 electrons / cm^3$.
$e = 1.6\,10^{-19} C$
$\theta(\approx 4mrad)$: the angular spread between the ion and electron.

This formula with the numbers indicated gives a cooling time for lead ions of 65 ms. But there is a lot of uncertainties.

k???, $Q^2 / A \rightarrow Q^{1.5} / A$, $\theta(\approx 4mrad)$

this formula shows the importance of the Twiss parameter at the ecooler (large β), the importance of the electrons and ions distribution (k), the importance of the electron current

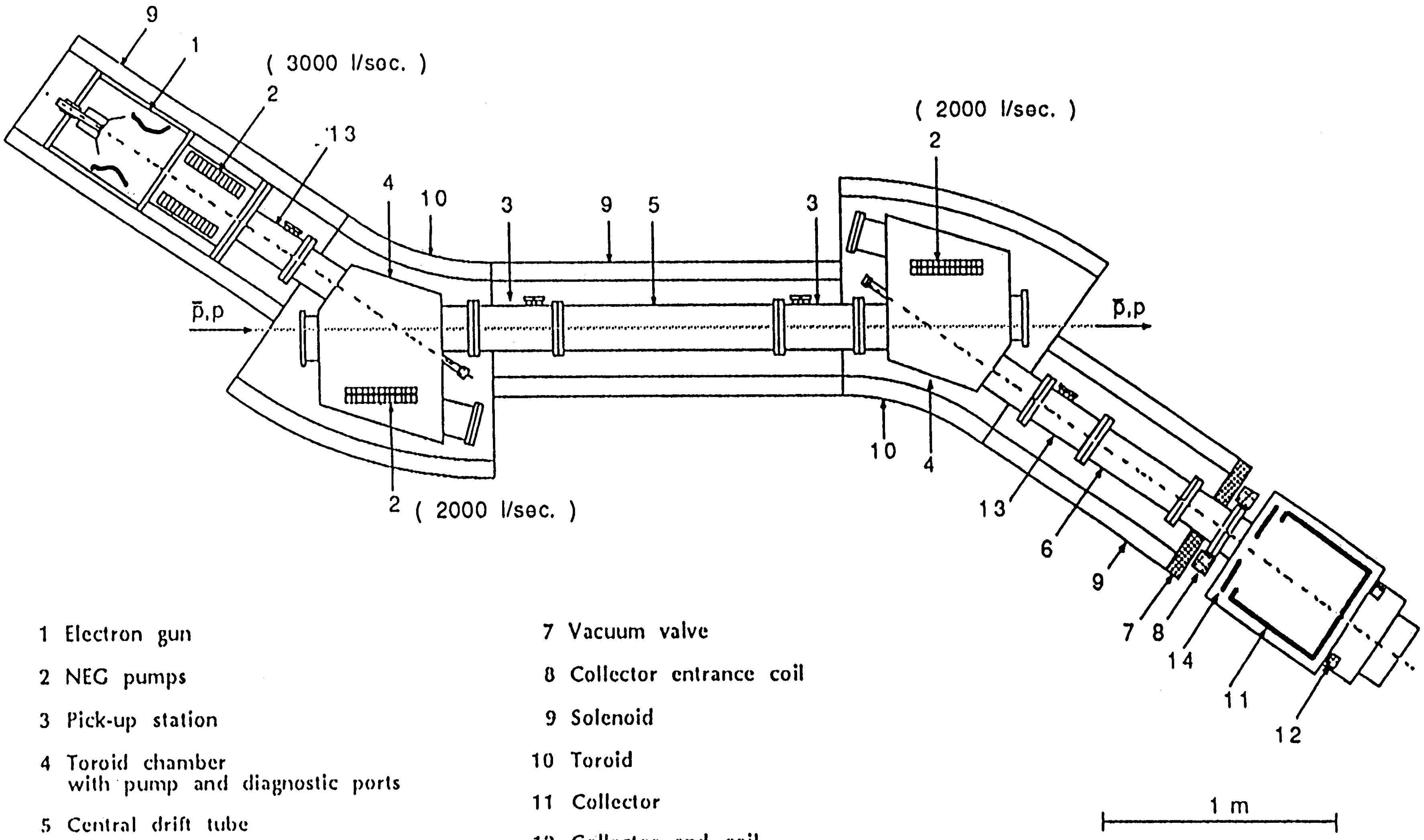
Some features



Space charge effect(blue) in the electron beam , and curve (magenta) of the ion beam position D*dp/p.

This curve shows the importance of having a zero dispersion at ecooler.
As the cooling forces are proportionnal to the cubic power of the energy difference between ions and electrons we try to compensate the space charge effect by trapping ions in the potentiel of the electrons beam . This seems to be very difficult as the compensated beam is very unstable. Progress have been made recently to understand the phenomena and to try stabilisation system.
Unfortunatly there is a partial neutralisation due to vacuum tube diameter difference along the trajectory of the beam. This rendered our measurements difficult as the electron beam shows de-neutralisation process within period of 10 to 40s.
With high current we need also the pulser to eject the ions accumulated at the cathode.

The electron cooling device



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

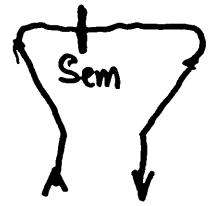
10 Toroid

11 Collector

12 Collector end coil

13 Neutralisation electrodes

14 Repeller



LINAC 3.

The linac gives a beam of ~20 μA for 400μs at 4.2MeV / u
This means $1.2\,10^8$ charges per turn in lear.

INJECTION RESULTS.

E0 line.

There was difficulties with the injection line E0 due to saturation of E0bhn02/03 . We never succeeded to have the beam passing thru the line in the center of semgrid 02 and correctly centered at the exit of the line. The current in BHN02.03 correspond to computation to have the beam in the center of the semgrid 02 but 2% lower to have it at the exit ???? Semgrid seems to be in correct position. Nevertheless there was a halo around the beam until Charles changed the stripper foil. We took a lot of time to understand but ....

E2 line.

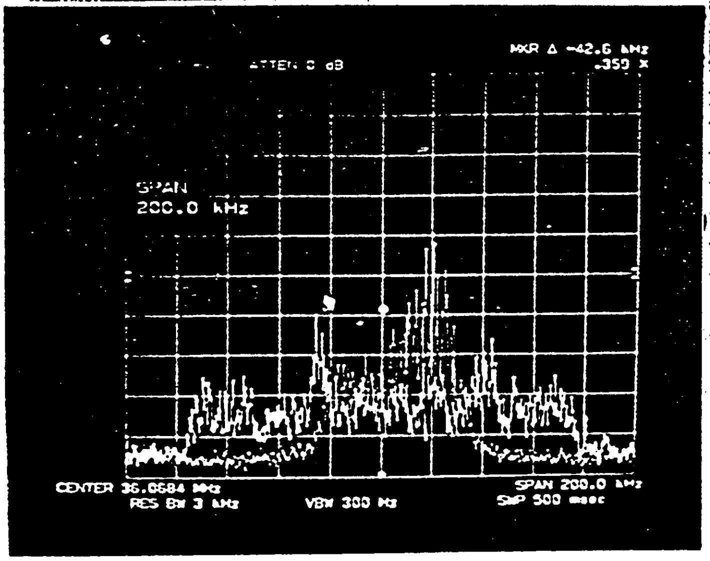
No major problem to steer the beam.

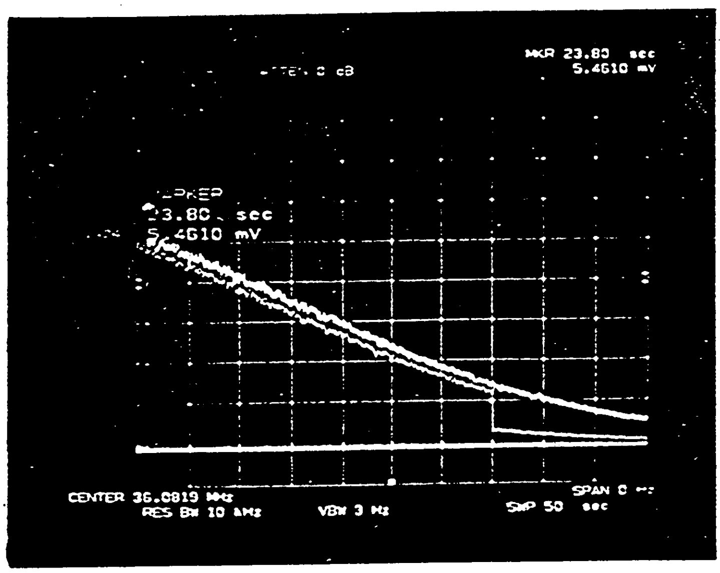
Injection

there was difficulties to have a good matching for all the machine. But we always succeeded to inject between $5\,10^7$ and 10^8 charges/injection. The injection used was the one turn injection (1.8 microsec. max). Normally we should inject ~$2\,10^8$ charges/injection.Multi injection was tried and ~$4\,10^8$ charges were injected at maximum but no effort was put on this . Multiturn injection was not tried due to lack of time despite the good bumper power supply prepared by PA-kicker group.

Beam in LEAR

revolution frequency :361 kHz. means β=0.095
$B\rho$=same as $B\rho$ for 347.6MeV/c protons.





injection Sans ecool avec/sans RF

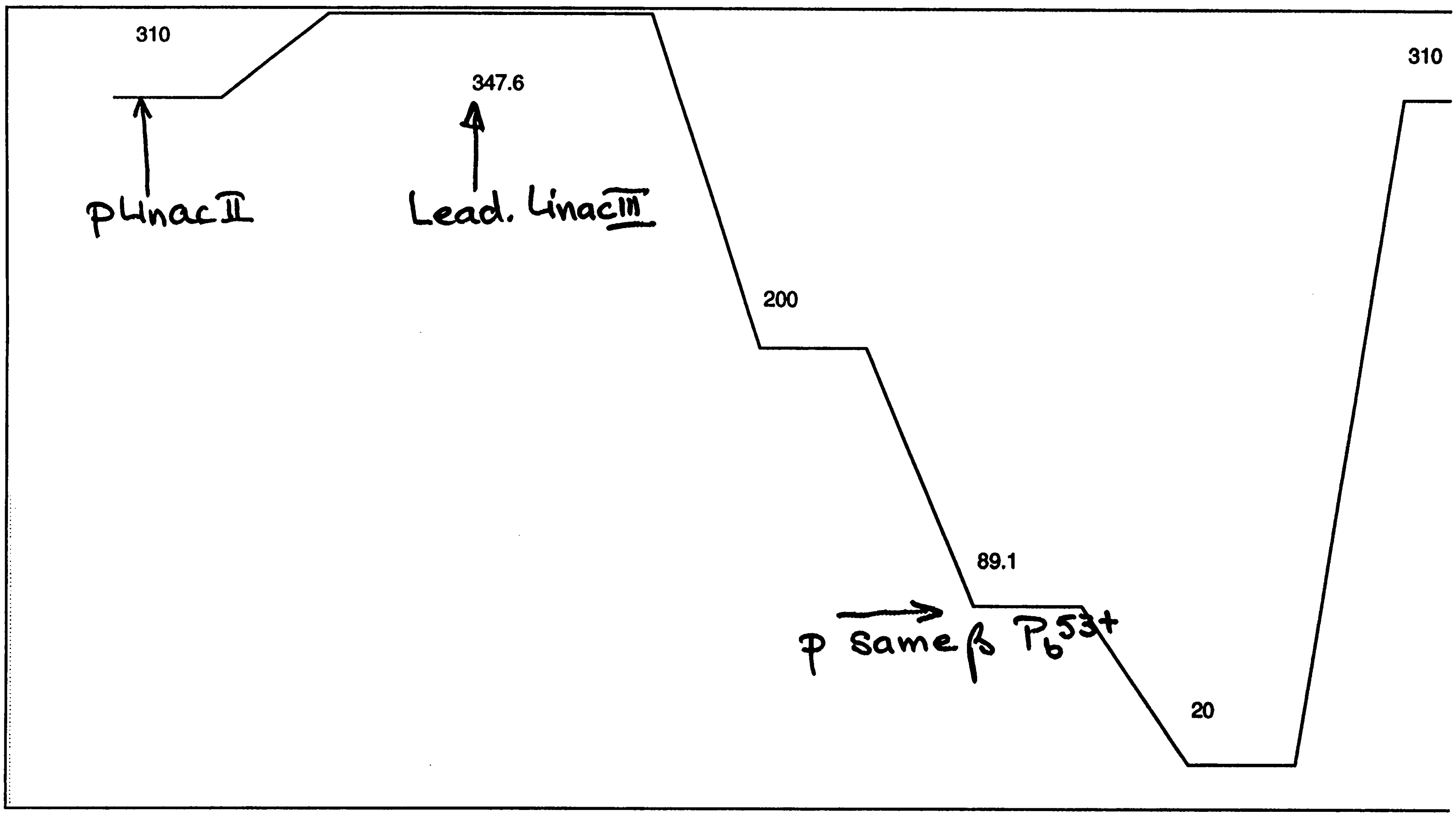
Lifetime without ecool 23 sec.with ecool between 2 and 10sec. Taken with longitudinal Schottky noise.

Then long. measurement has been taken for lifetime, beam dimension, cooling time.

Longitudinal cooling time taken with longitudinal Schottky noise. The beams reaches an equilibrium of $\frac{Dp}{p} < 210^{-4}$ in less than 100ms.

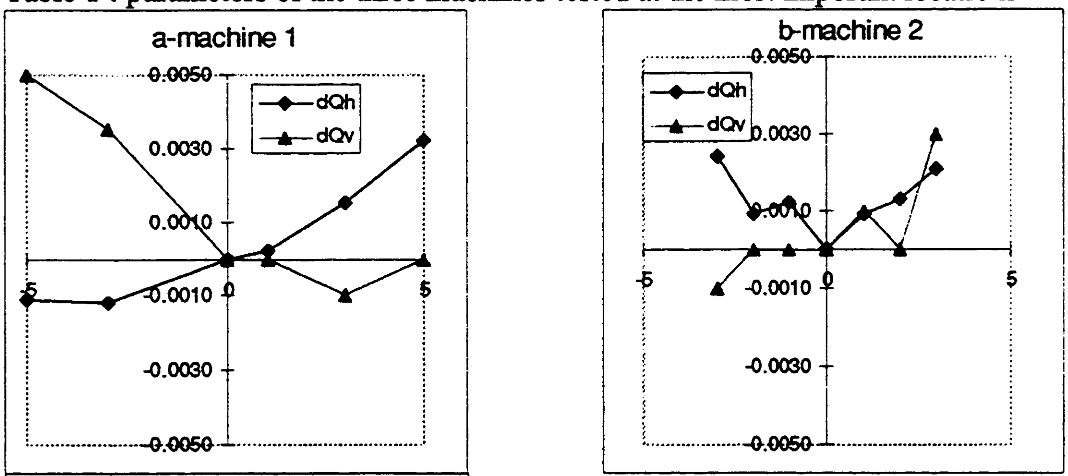
Horizontal cooling time taken with BIPM. Equilibrium of ~ 3 πmmmrad is reached in less than 1sec for most of the measurements. But depends on the emittance after injection and cooler conditions.

LEAR LEAD IONS CYCLE



parameters	machine 1 (D#0,β small)	machine 2 (D=0,β small)	machine 3 (D=0,β large)
Qh	2.315	2.46	1.8
Qv	2.620	2.42	2.42
(kf,kd) ss2/4	(1.2655, 1.3838)	(1.0205, 1.2271)	(0.9745,1.1285)
(kf,kd) ss1/3	(1.2655,18382)	(1.490,1.465)	(0.945,1.31)
(Δkf,Δkd) ss1/3	(0,0)	(0.285,0.2379)	(0,0.1815)
D ss1/3	3.51	0	0
βh ss1/3	1.9	1.31	10.3
βv ss1/3	6.36	8.05	6.5
D ss2/4	3.51	9.77	9.6
βh ss2/4	1.9	9.63	6.35
βv ss2/4	6.36	11.88	14.8
natural (ξh,ξv)	(-1.35,-2.73)	(-1.23,-2.8)	(-0.97,-2.45)
$1/\gamma_{tr}^2$	-0.05	0.125	0.127
D BIPM	-0.5	0.2	0.35
βh BIPM	9.7	5.0	6.4

Table 1 : parameters of the three machines tested at the most imporant locations.



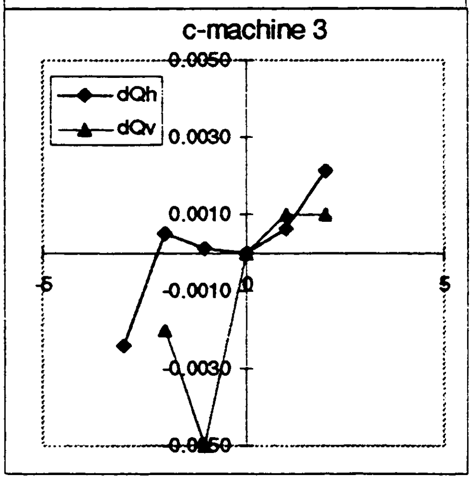


Figure 1: Measurements of tune versus momentum for the three machine after adjustment of chromaticity to small value .

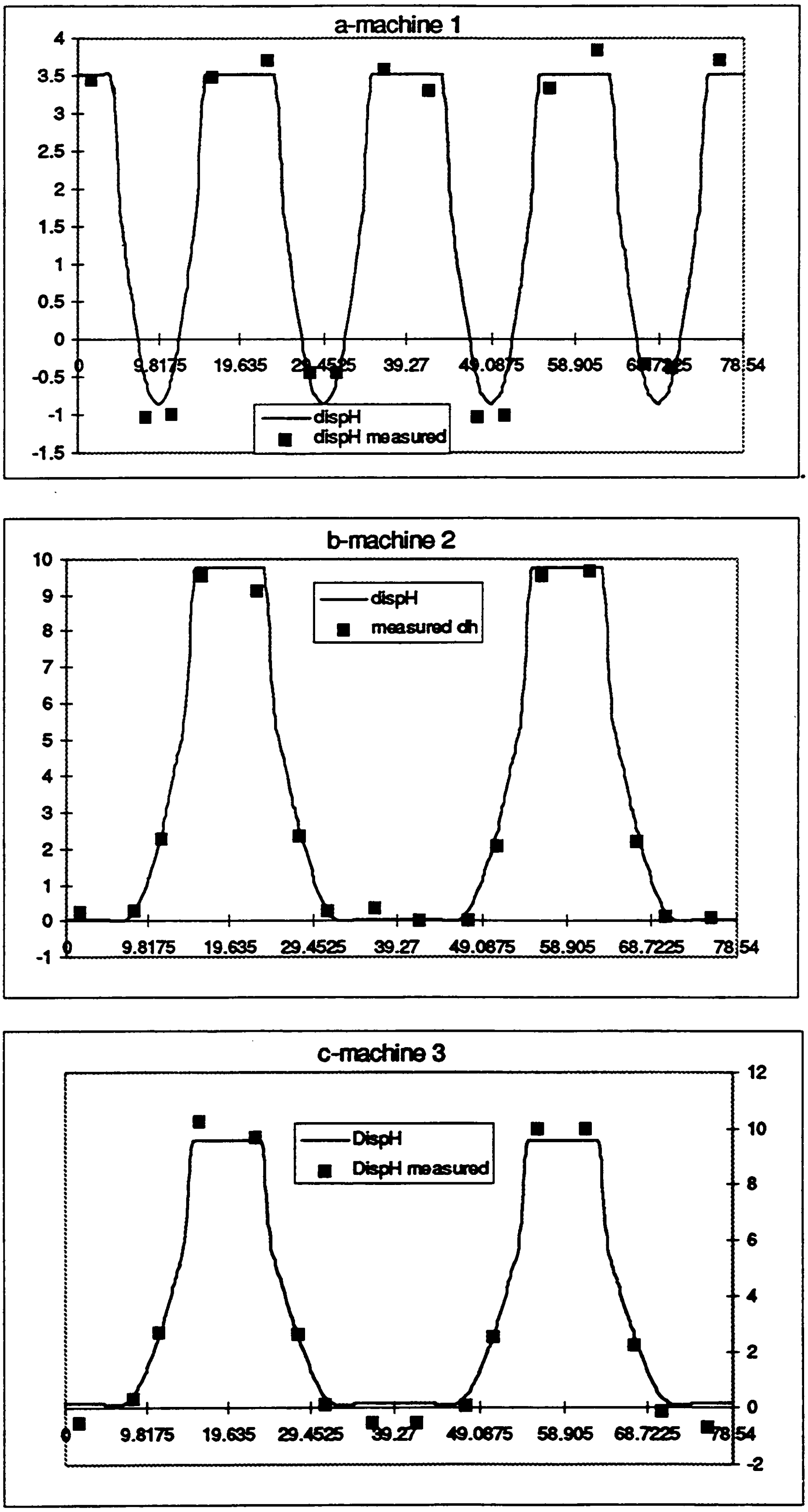
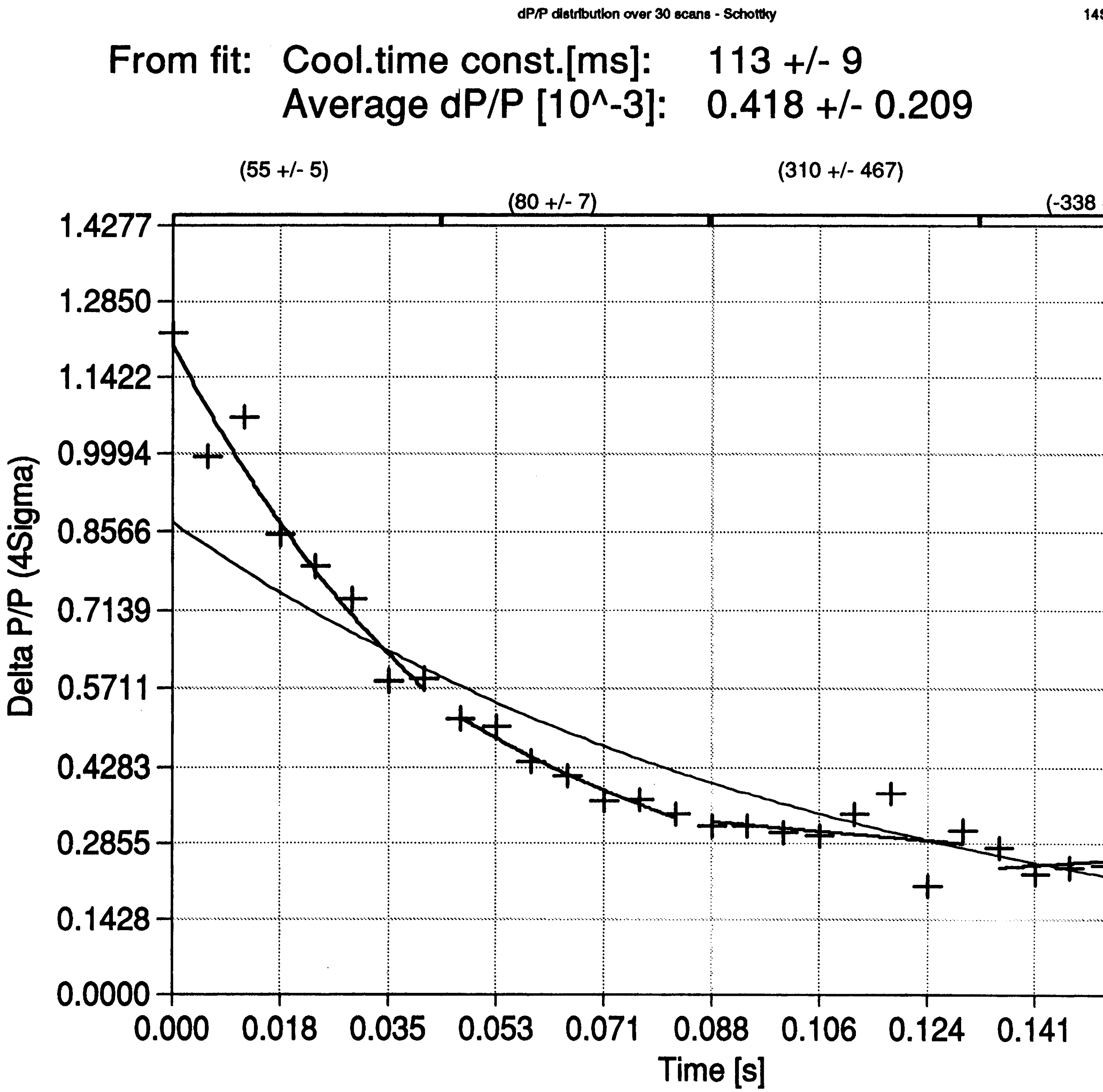
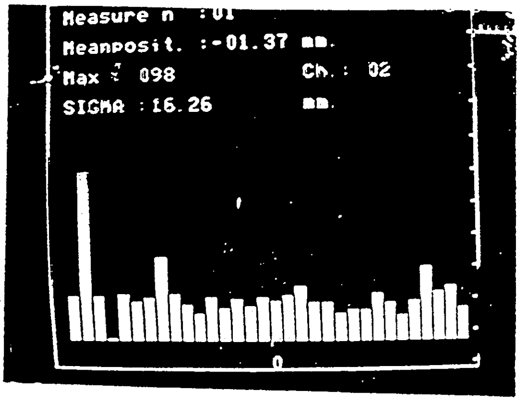
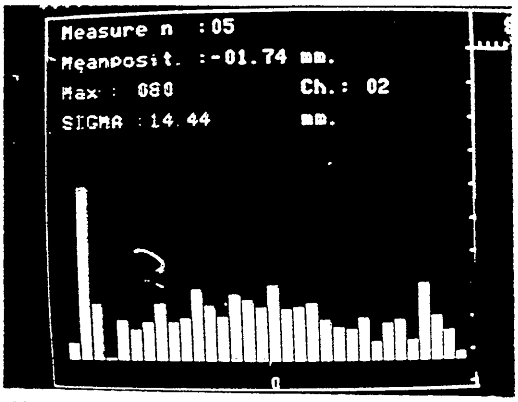


figure 2: dispersion theoretical curve and measurement points for the three machines tested..

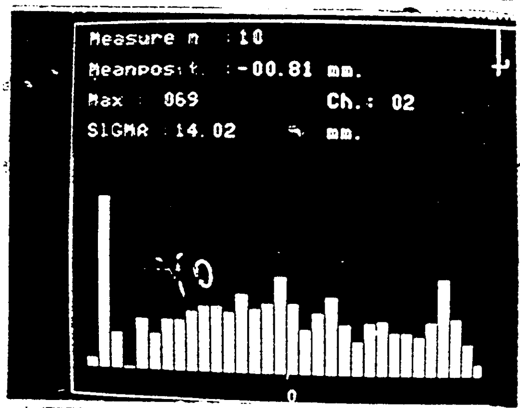

dP/P distribution over 30 scans - Schottky
From fit: Cool.time const.[ms]: 113 +/- 9
Average dP/P [10^-3]: 0.418 +/- 0.209
(55 +/- 5)
(80 +/- 7)
(310 +/- 467)
Delta P/P (4Sigma)
1.4277
1.2850
1.1422
0.9994
0.8566
0.7139
0.5711
0.4283
0.2855
0.1428
0.0000
0.000
0.018
0.035
0.053
0.071
0.088
0.106
0.124
0.141
Time [s]



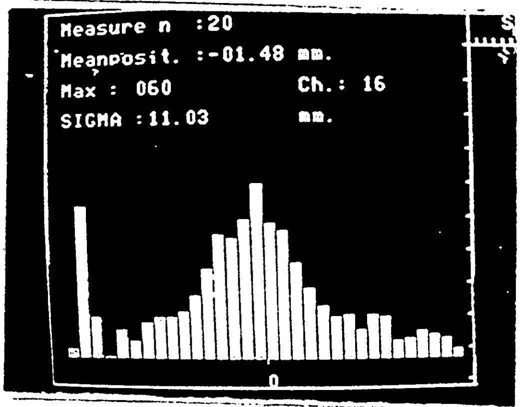
t=0



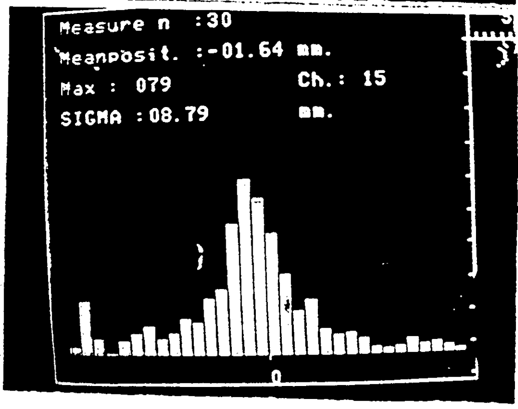
t=150ms



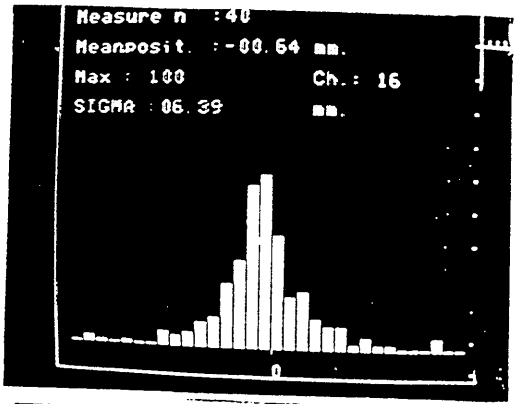
300



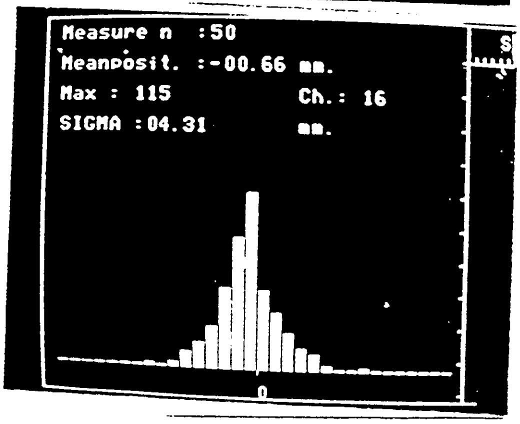
600



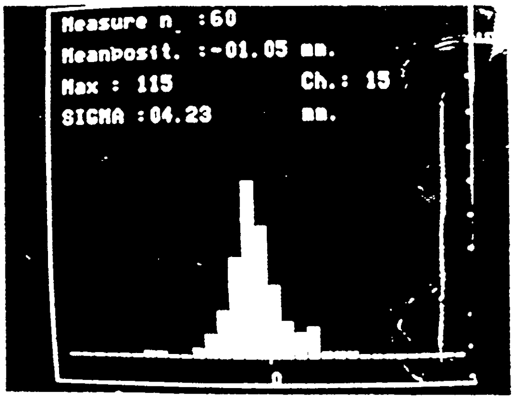
900



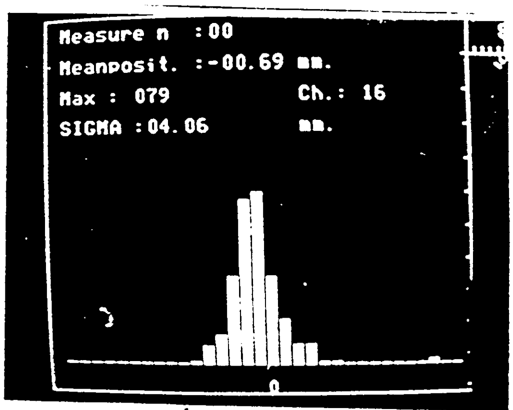
1200



1500

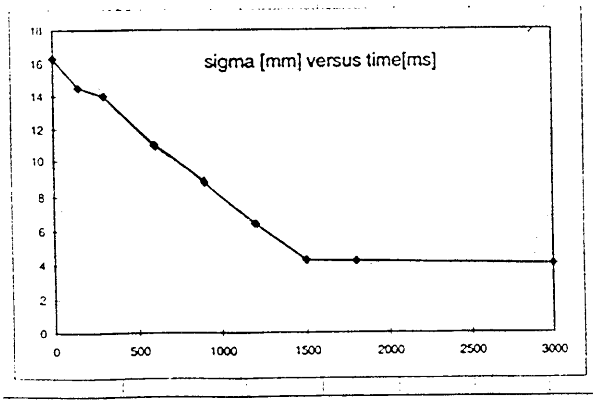


1800



3000

MACHINE1 47mA=Ic



MACHINE 1 : D=3.6,betah=1.9,betav=5.3								
V0[kV]	Vg[kV]	I-elect.[mA]	lifetime[s]	limit sigmaH [mm]	limit of H emittance [pimmmrad]	Hor. cooling time[s]	photo No	comments
2402	1350	24.8	11.2	4.65	2.10	4	5	TauH=TauV~1.5 s
2405	1500	29	8.9	2.51	0.61	2.3	6	
2412	1750	36.6	8.7	4.03	1.58	2.1	7	
2418	2000	44.7	8.25	3.9	1.48	1.9	8	
2425	2250	53.36	7.32	3.47	1.17	1.5	9	
2431	2500	62.5	6.35	3.11	0.94	1	10	
1500	2000	44.7	18				11	
1500	0	0	23				12	

table..: measurements on machine 1

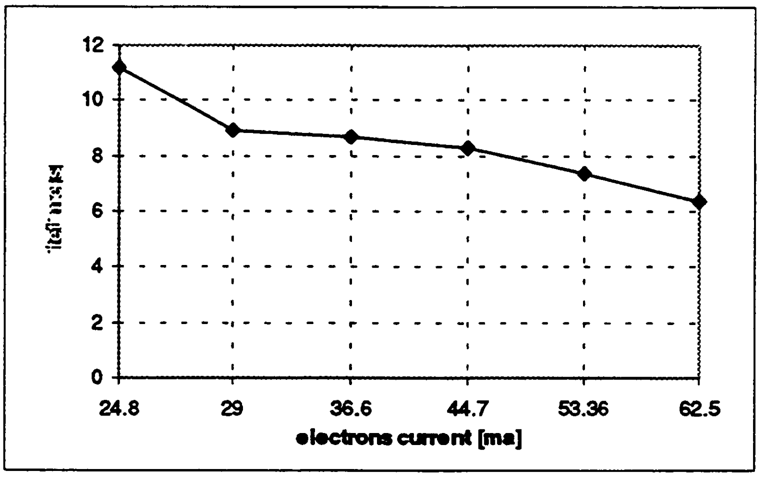


figure :lifetime of the beam versus electrons current.

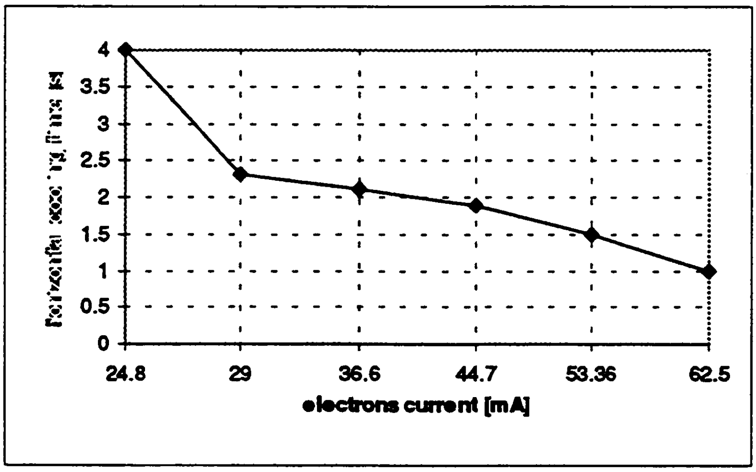


figure : Horizontal cooling time versus electrons current.

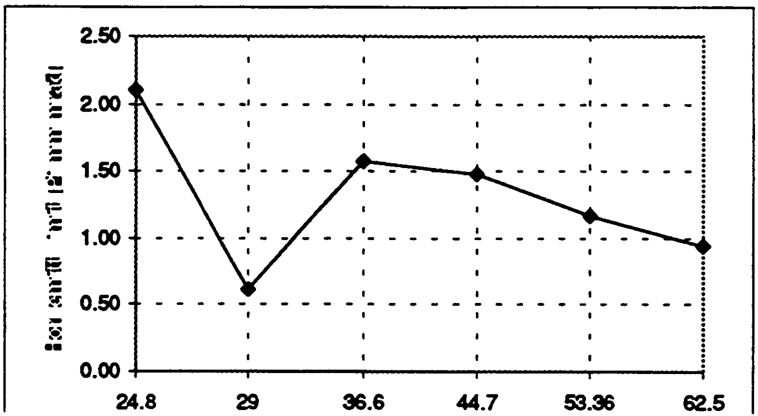


figure ..: emittance at equilibrium versus electrons current.

MACHINE 2 with D=0,Betah=1.3,betaV=6.5								
V0[kV]	Vg[kV]	electrons current [mA]	lifetime [s]	limit sigmaH [mm]	limit of H emittance [pimmmrad]	Hor. cooling time[s]	photo No or file No	comments
2416	2000	44.7	6.3	3.81	3.02	0.8	Dm1-Pb12/13	with p0=+5e-04 taulife=7.5
2426	2500	60	5.6	2.93	1.79	0.8	DM2-Pb14	
2451	3000	90	7.1	5.61	6.56	0.8	DM3-Pb15	modulation of HT,dp/p~1e-3
2449	3000	90	5.3	4.8	4.80	0.8	DM4-Pb16	solenoid to 270A
2469	3500	110	5.3				DM5?	solenoid to 270A

table ..a:first set of measurements with machine 2

MACHINE 2 with D=0,Betah=1.3,betaV=6.5								
V0[kV]	Vg[kV]	electrons current [mA]	lifetime [s]	limit sigmaH [mm]	limit of H emittance [pimmmrad]	Hor. cooling time[s]	photo No/file No	comments
2462	3500	103.5					Pb17	
2474	4000	126.5	5	3.81	3.02	0.8	JB6-Pb18	Is=270,Vn4=-3500,pinst=40s
2484	4500	151	4.2	3.2	2.13	0.9	JB7-Pb19	Is=270,Vn4=-3500,pinst=35s
2495	5000	176	4.3		0.00		JB8-Pb20	Is=280,Vn4=-3200,pinst=51s
2507	5500	204	3.8	2.8	1.63	1	JB9-Pb21	Is=260,Vn4=-3200,pinst=20s
2518	6000	232	3.8	2.71	1.53	0.7	JB10-Pb22	Is=260,Vn4=-3200,pinst=25s
2540	7000	260	2.7	2.88	1.73	0.8	JB11-Pb23/24	Is=260,Vn4=-3200,pinst=16s
2562	8000	300	2.78	2.74	1.56	0.8	JB12-Pb25/26	Is=260,Vn4=-3200,pinst=10s
2583	9000	330	2.15	2	0.83	0.6	JB13-Pb27/28	Is=260,Vn4=-3200,pinst=10s
2632	9000	330	2	2.06	0.88	0.7	JB14-Pb29/30	Is=260,Vn4=-3200,pulseur On
2665	11000	410	2.2	2.4	1.20	0.7	JB15-Pb31/32/	Is=260,Vn4=-3200,pulseur On
2632	11000	330	2.3	2.4	1.20	0.7	JB15'-Pb34/35	Is=260,Vn4=-3200,pulseur Off,pinst=5s
2626	11000	330	1.7	4.07	3.45	1	JB17-Pb36/37	Is=280,Vn4=-3100,pulseur Off,pinst=5s,shaker=(1KHz,-1dbm)
2639	11000	330	4	4.1	3.50	1	JB18-Pb38/39	Is=280,Vn4=-3100,pulseur Off,pinst=stable,shaker=(500Hz,-1dbm)

table ..b:second set of measurements with machine 2

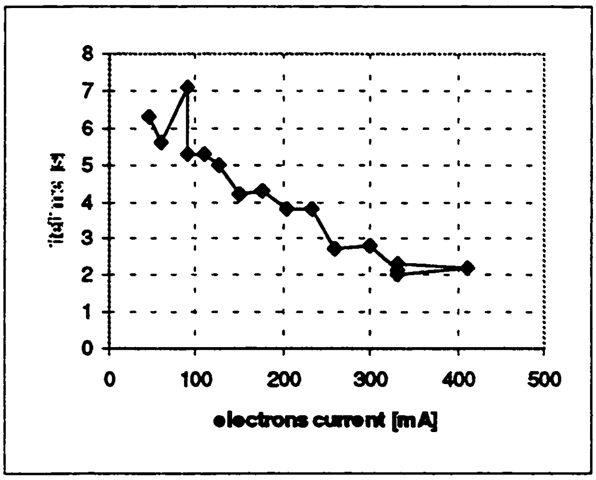


Figure 2: lifetime versus electrons current

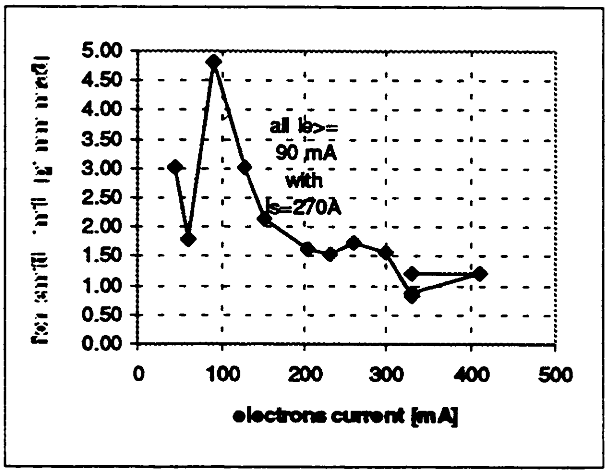


Figure 1:emittance limit versus electrons current

MACHINE 3 with D=0,Betah=10,betaV=6.5								
V0[kV]	Vg[kV]	electrons current [mA]	lifetime [s]	limit sigmaH [mm]	limit of H emittance [pimmmrad]	Hor. cooling time[s]	photo No/file No	comments
2416	1995	45	4.8	3.4	1.7784615	0.9	Jb19-Pb40	
2426	2300	55	6	3.03	1.4124462	0.75	JB20-Pb41	
2451	3000	82	5	???	????	???	JB21-Pb42	

Table.. :Measurements taken with machine 3.

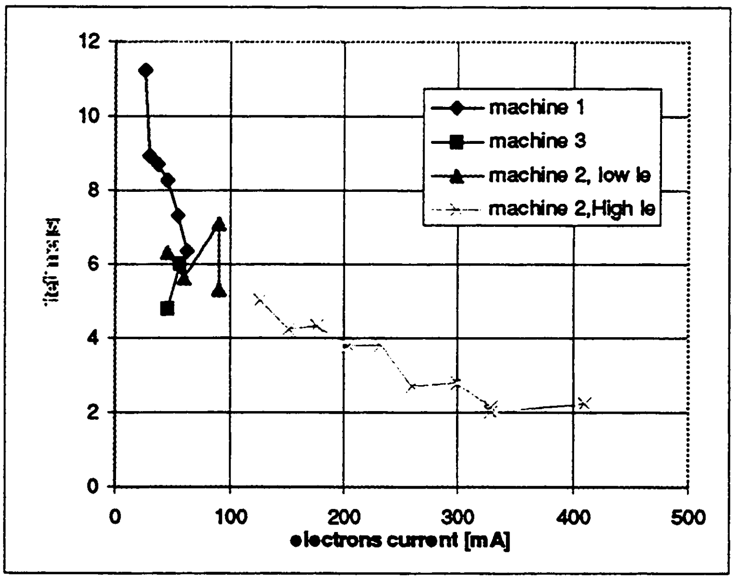


Figure ..:All the lifetime measurements taken with the different machines collected on the same graph, versus electrons current.

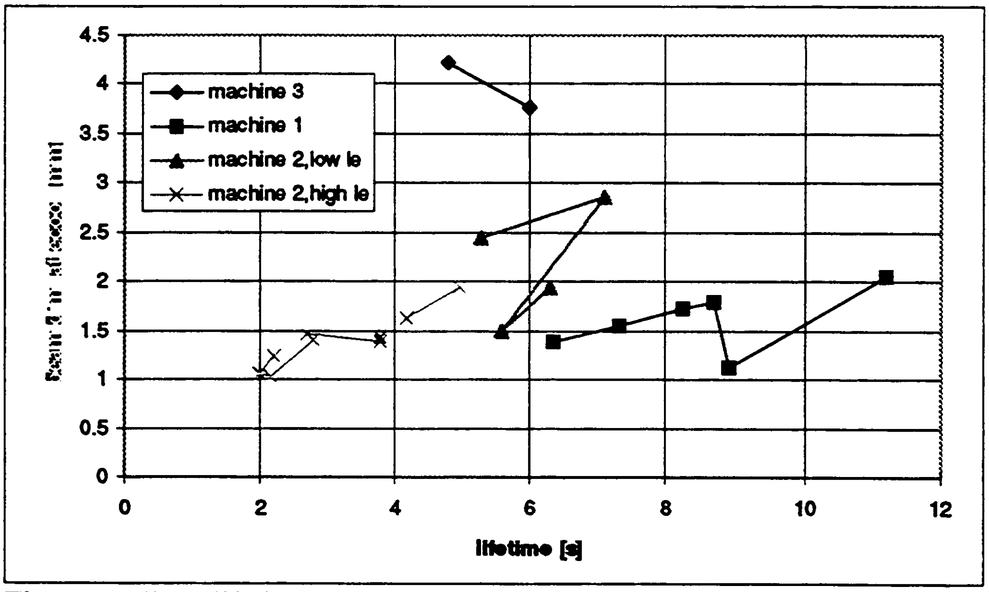


Figure ..:All the lifetime measurements taken with the different machines collected on the same graph, versus the beam dimension at ecool.

LIFETIME COMMENTS.

Vacuum.

measured lifetime ~23s. Due to charge exchange with the residual gas. Could be explained by a physical pressure of $5\,10^{-12}$ Torr of pure N2 or $3\,10^{-11}$ Torr of pure H2.

Bad vacuum in two sections due to leak (VVS402-in november and JETSET since a long time ago).

Also long linac3 pulse (400 microsec) lost in BHN10 which increase locally the vacuum.

The measured lifetime agrees fairly well with computations .

Electrons present but no cooling.

the presence of electrons increases the vacuum locally (or the presence of ions capture in the space charge potential of ecool beam). This decrease the lifetime by ~20%.

Electrons present ,cooling but recombination.

this is possible when the ions have the same speed as the electrons (a small energy difference ~0.2 eV). Measurements give 2 to 5 s lifetime depending on electrons current and temperature. There are three possibilities:

radiative recombination:Calculations give a lifetime value greater than 200 s.

two body recombination: calculations give a lifetime very_high, but proportionnal to square of electrons density. It becomes effective for density > $10^9 e/cm^3$

dielectronic recombination: It involves one electron from the ion and one electron from the beam. It has a resonant behaviour. Measurements have been done recently for different other ions with different charge state but no lifetime is shorter than 100s in LEAR conditions.......

9 WHAT TO DO NEXT

-ask from the LINAC3 a shorter pulse (20 to 40 μs max) . Possibly other lead ions charge state (54+,52+). Perhaps later, other ions type.

-compute the E0-E2 line and the matching at injection into LEAR.

-improve the vacuum in LEAR.

-improve the knowledge of the machines 2 and 3.

-stabilise the electron beam with high current and solenoid to 600G(400A).

-try multiturn injection to increase the number of particles injected.

-have vertical emittance measurements.

-improve the measurements with Shottky signals.

-improve the measurements with the BIPM.

-understand the ions losses mecanism by theory and/or by measurements in different conditions.

-improve the electron beam stability at high current.

Beam for the Energy Amplifier Test in the PS East Area

J.P.Riunaud

Abstract

Following C. Rubbia's proposal of an Energy Amplifier, a test was performed in the PS East Area with a low energy proton beam in order to check simulations of the model and to measure the energy gain as a function of the beam energy.

This test required fast extracted beams of low kinetic energy (.6 to 2.7 GeV), low intensity (0.5 to 5 10^9 protons) and short duration (<500 ns), delivered via the existing slow extraction channel and the transfer line currently used for 24 GeV/c beams. Special care was taken to reduce multiple scattering in the beam transport and to adapt beam steering and optics to the unusal low current provided by the power supplies. The t7 area was modified to house beams lines leading to a calorimeter or to a beam dump and was shielded to admit these proton intensities. Beams were produced by acceleration or deceleration of one PSB ring injected in the PS and extracted using the fast Kicker KFA71/79 together with 2 septa SMH57 and SMH61, with the associated orbit bump and tune adjustments.

The test was performed without impairing other CPS operations and the other three East Area beam lines could alternatively be supplied with slow extracted beams, for half week periods.

Beam for the Energy Amplifier Test in the PS East Area

Goal of the Test:

- Check Energy Gain against simulations
- Plot Energy Gain versus beam energy

Beam for the Energy Amplifier Test

Outline

- Users Requirements
- Beam in the PS
- Fast extraction FE61
- Beam in the East Area
- Features, Limitations, Results

Users Requirements

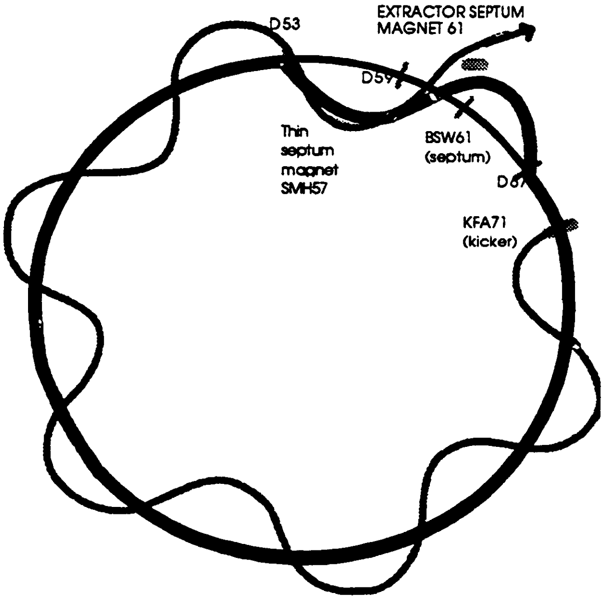
- **Beam characteristics**
  - 10^9 protons, fast extracted, one shot / supercycle
  - at 3.5 GeV/c and then lower momenta
  - Beam diameter < 5 cm at calorimeter target window
- **Measurements and observations**
  - Beam Intensity with few % precision
  - Beam position and profile
  - Trigger derived from beam

Beam in the PS

- **Setting up of CPS magnetic cycle**
- **Injection of one PSB ring**
- **Acceleration or deceleration**
- **Fast extraction of one bunch in Slow extraction channel**

Fast Extraction FE61

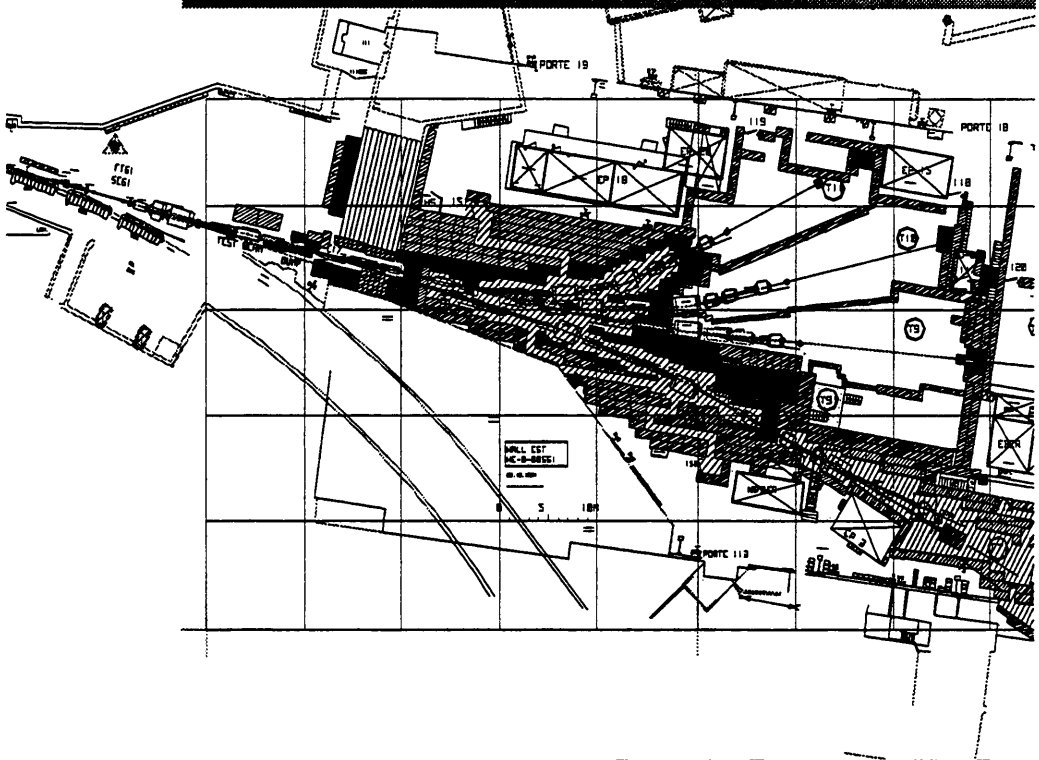
- Elements
  - Fast kicker KFA71/79
  - Some dipolar elements of Slow Extraction 61
- Adjustments
  - Qx = 6.10 for proper phase advance & Dispersion H
  - Best Transmission expected: 40 %



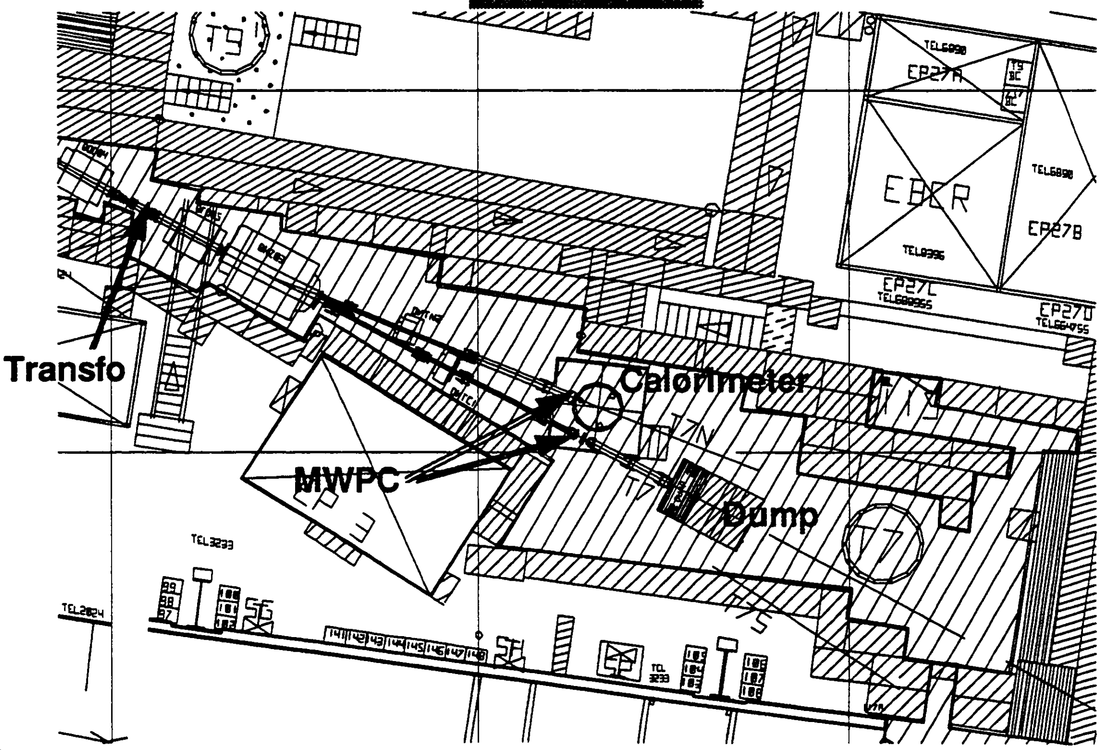
Beam in the East Area

- Shielding for primary proton beam down to Dump/Calorimeter
- Same beam transport elements as for Slow Extraction 61, down to t7 area
- Reduction of multiple scattering
- Focusing and steering adjusted to avoid too low power supply currents

Beam transport in East Area



t7 Area



Some features

PS provided

- Adjustment of beam focusing & steering up to dump/calorimeter
- Hardware for Beam Request
- Means to switch from dump to calorimeter and vice-versa
- Monitoring signals to be acquired and treated by users
- No data logging

Limitations

- Accuracy of intensity measurement
- Power supply stability at unusual low currents
- Beam size at low energy
- Radiation level in t7 area

Results

Several beams provided:

- Intensities of .5 to 5.10^9 protons (1 to 2 bunches)
- at 9 different energies
  .6, .7, .8, .9, 1.0, 1.2, 1.5, 2.0, 2.7 GeV (kinetic energy)
- in parallel with other operations

To be published in PAC 95

- Fast extracted Proton Beams at Low Energy in the CPS East Area. L. Durieu, R. Cappi, J.-Y. Hémery, M. Martini, J.-P. Riunaud, C. Steinbach

CERN PPD Rolle 02 Fev 95

General Comment

Within a few months, such a test has been discussed, implemented and successfully carried out,

although it required

- a major modification of the East Area,
- time sharing with other users,
- satisfaction of a demanding client.

Experimental Areas in the PS Complex

Presented at the PS Performance Day at Rolle (PPD 95)

I - TOPOLOGY and MAIN PARAMETERS

The *Experimental Area* section (EA) of the *PS-PA group* is first in charge of the design of the beam lines in the South and East Halls.
The EA section also performs the commissioning of the beam optics and the follow-up of the beam conditions while experimenters are taking data.

In 1994, more than 4000h of beam time have fed 55 groups of experimenters. This community includes about 500 members. Their equipment are distributed over the 15 zones of both halls.

II - TOOLS

The software tools for matching, tracking and survey are TRANSPORT, TURTLE, and SEBLAY/BEACH as well as MAD which covers the 3 functions.

At present, no software is available to treat either a "Y" shape transfer line layout nor the transport of 2 different beam sources in one run. These features apply to beam lines which are split or to fractions of beam which escape from aperture limits as scattered primary or secondary beams (i.e. collimators).

III - PERSPECTIVES

South Hall
Two new experiments will run this year, and do require specific beam optics.

The high intensity which was delivered last year, as peak value, will be requested as routine operation for the S4 line.

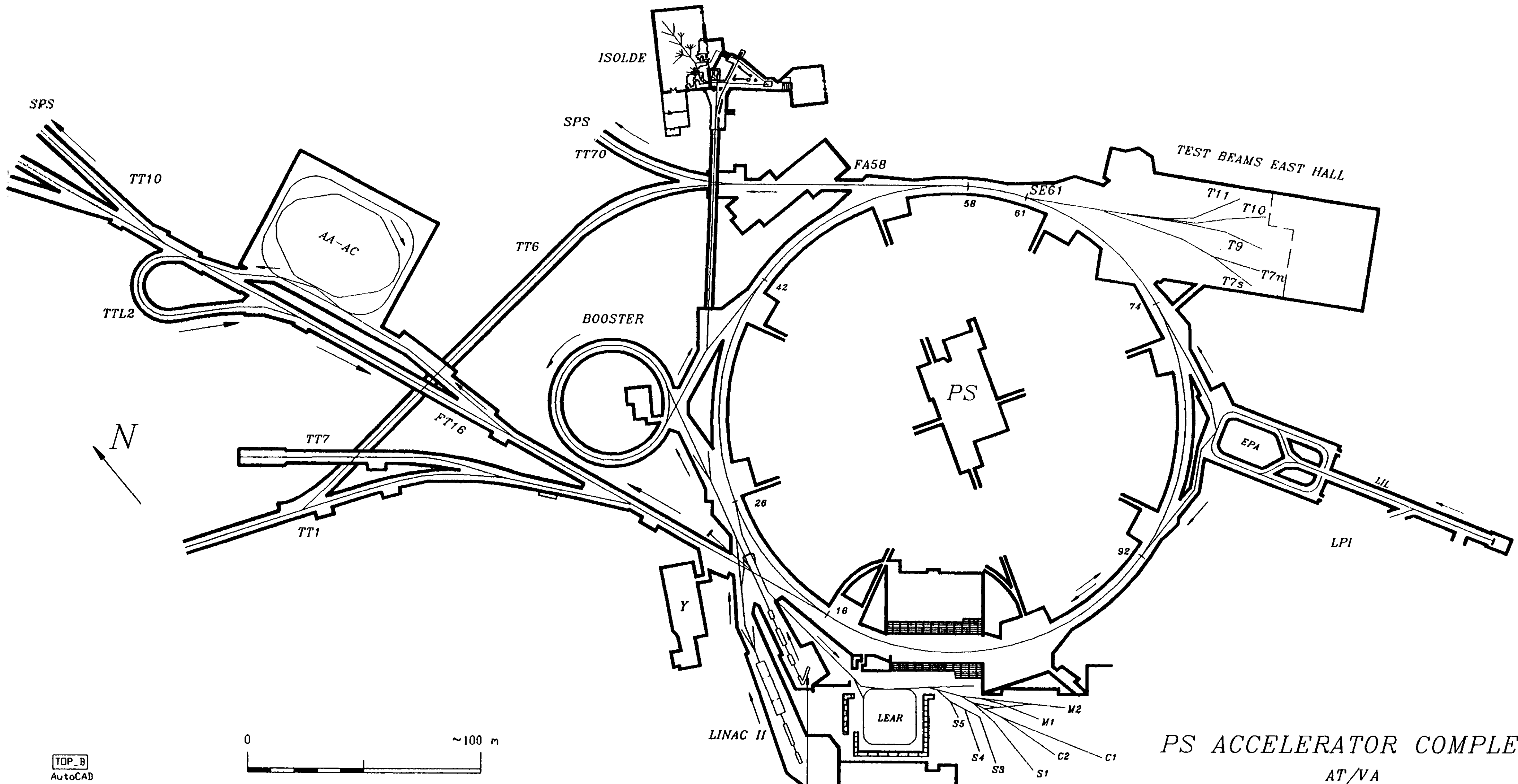
A new experiment would like to come early next year and preliminary studies are carried out to find the best location on a beam line.

Drastic modifications of the layout of this hall should be proscribed as it will close at the end of 1996.

East Hall
An official request from DIRAC experiment has been received and may run in 1997. A 24 GeV/c beam of 1E11 protons per pulse is to be supplied. Four months shut-down of the zone is required to make the necessary modifications.

ALICE experiment (LHC/Lead ions) has requested to settle down on a dedicated beam line in 1996. They will firstly use secondary beams, and if available, a primary lead ion beam. They are also keen on using a 25ns beam structure.

The demand of beam time should increase for test purposes and calibration of detectors related to experiments for LHC. Preliminary contacts are taking place with ATLAS and CMS to formalize their needs. Over the past year, the total beam time request was 1.3 of the availability for the East Hall beams.



PS ACCELERATOR COMPLEX

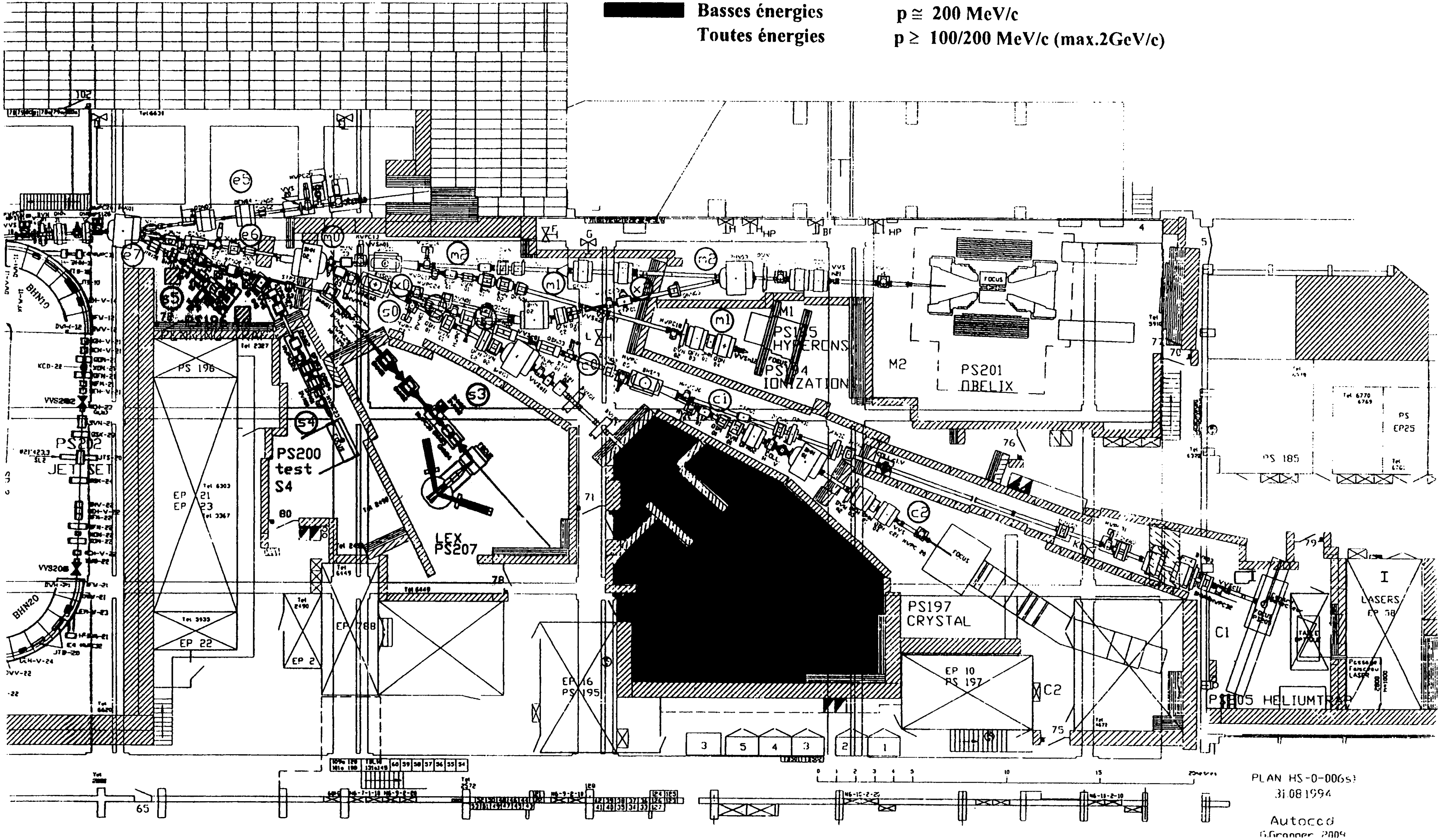
AT/VA
12.05.1992/R.ASKOVIC

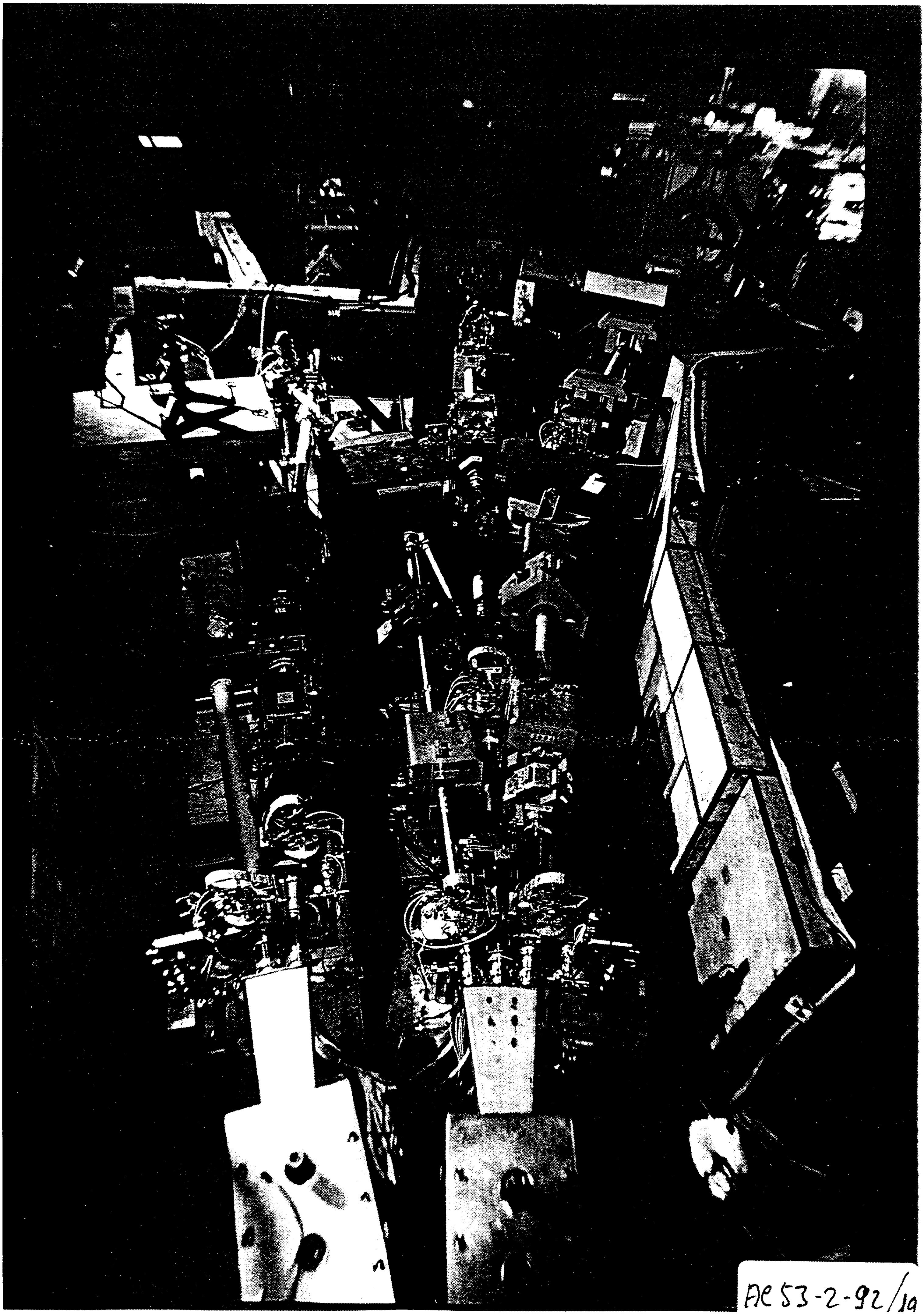
PS/PA
18.02.1993/G.GRANGER

FT61
SE61
TEST BEAM DUMP
e17
HS
EP 18
EP 20
EP 15
EP 40
EP 39
EP 3
T11
T10
T9
T9
T9E
T7
t7
EBCR
NR-794
HALL EST
HE-0-006S1
03.11.1994
0 5 10m

LEAR EXPERIMENTAL AREA

Très bassses énergies	p ≤ 105 MeV/c
Basses énergies	p ≅ 200 MeV/c
Toutes énergies	p ≥ 100/200 MeV/c (max.2GeV/c)





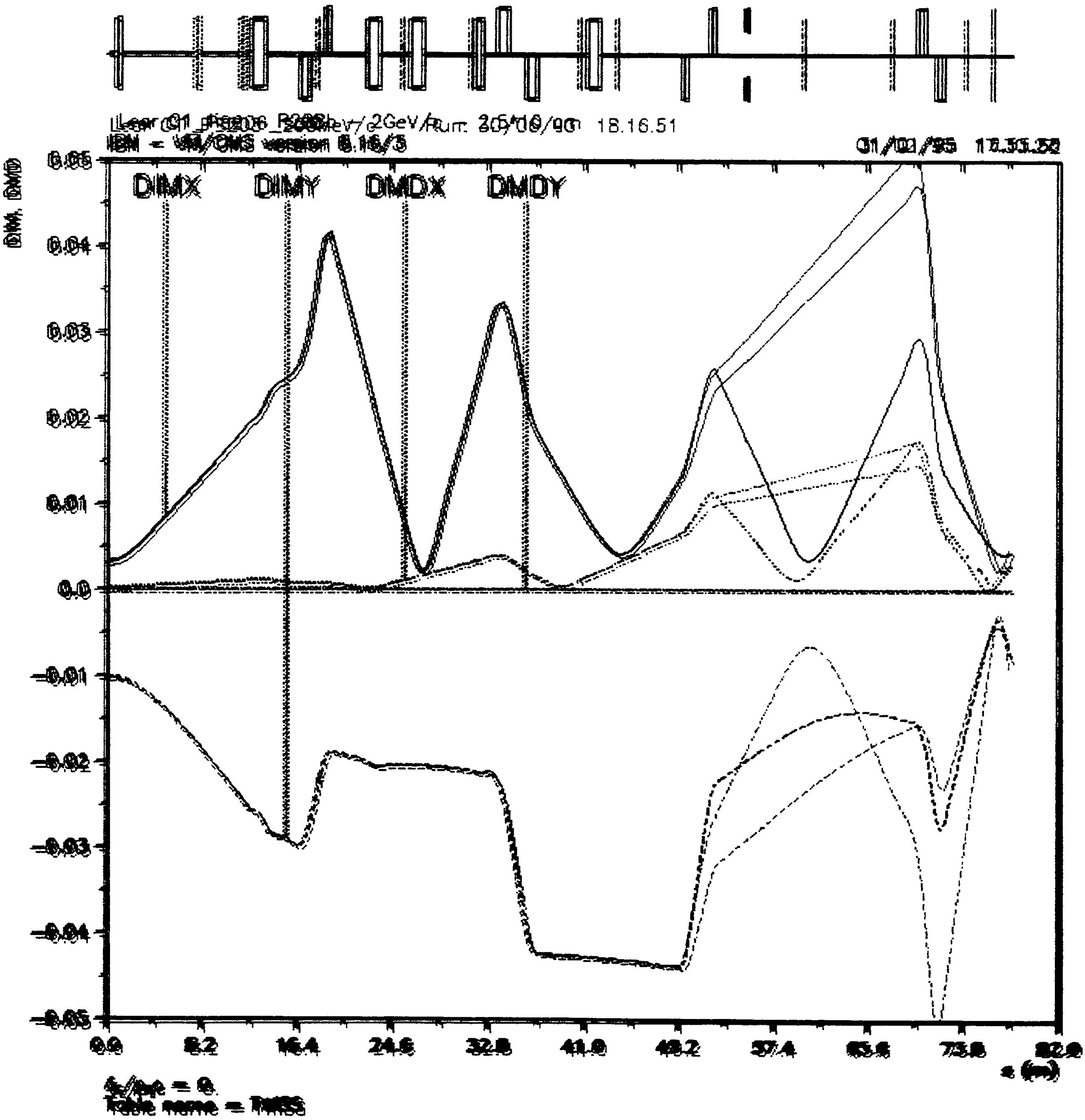
AC 53-2-92/19

JYH - 28/1/95

PS-PA-EA

	EAST	SOUTH	total
FACILITIES & POPULATION			
Beam Lines	4	8	12
Exp. Zones	7	8	15
Groups	43	12	55
Physicists	200	300	500
Active Elements Inventory			
Splitters	1	3	4
Deflection	89°	480°	569°
Bendings	19	15	34
Correctors	9	34	43
Quadrupoles	28	42	70
Collimators	9	3	11
Monitors	31	37	68
Power (MW)	4	5	9

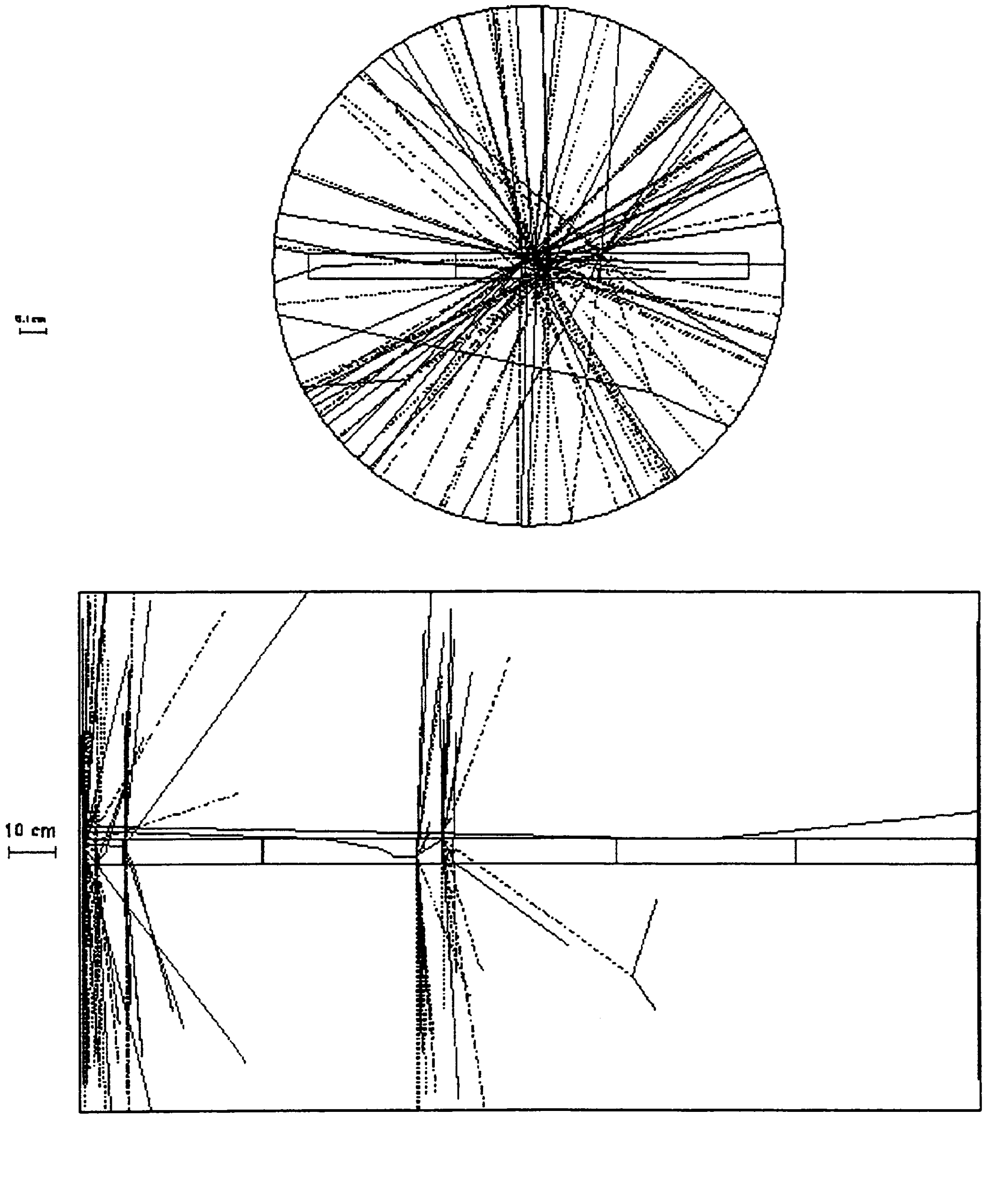
MAD tool

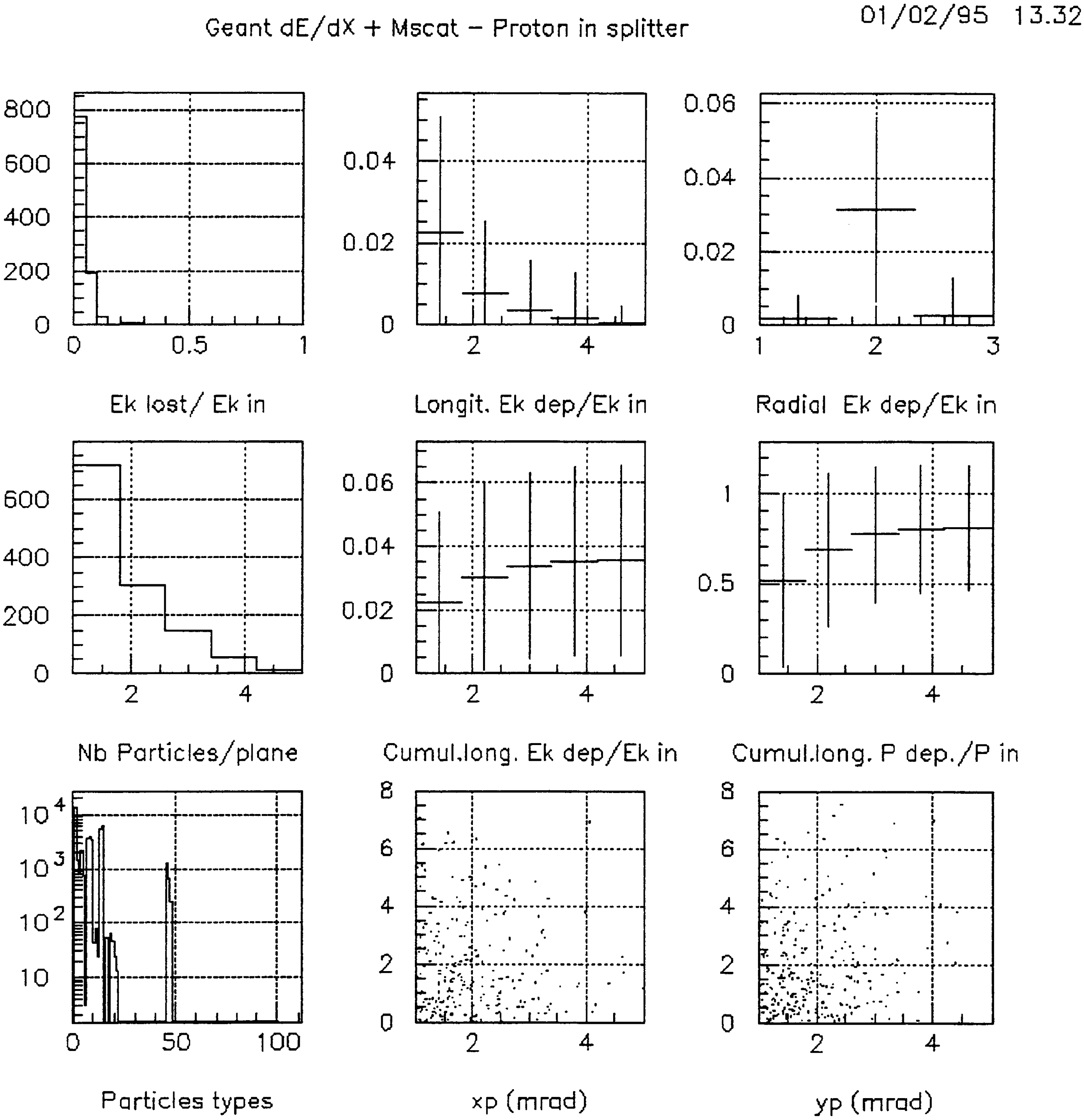

DIMX
DIMY
DMDX
DMDY
DIM, DMD
0.05
0.04
0.03
0.02
0.01
0.0
-0.01
-0.02
-0.03
-0.04
-0.05
0.0
8.2
16.4
24.6
32.8
41.0
49.2
57.4
65.6
73.8
82.0
s (m)
δE/pc = 0.
Table name = TWISS

PPD 95 - PS-PA-EA / jyh

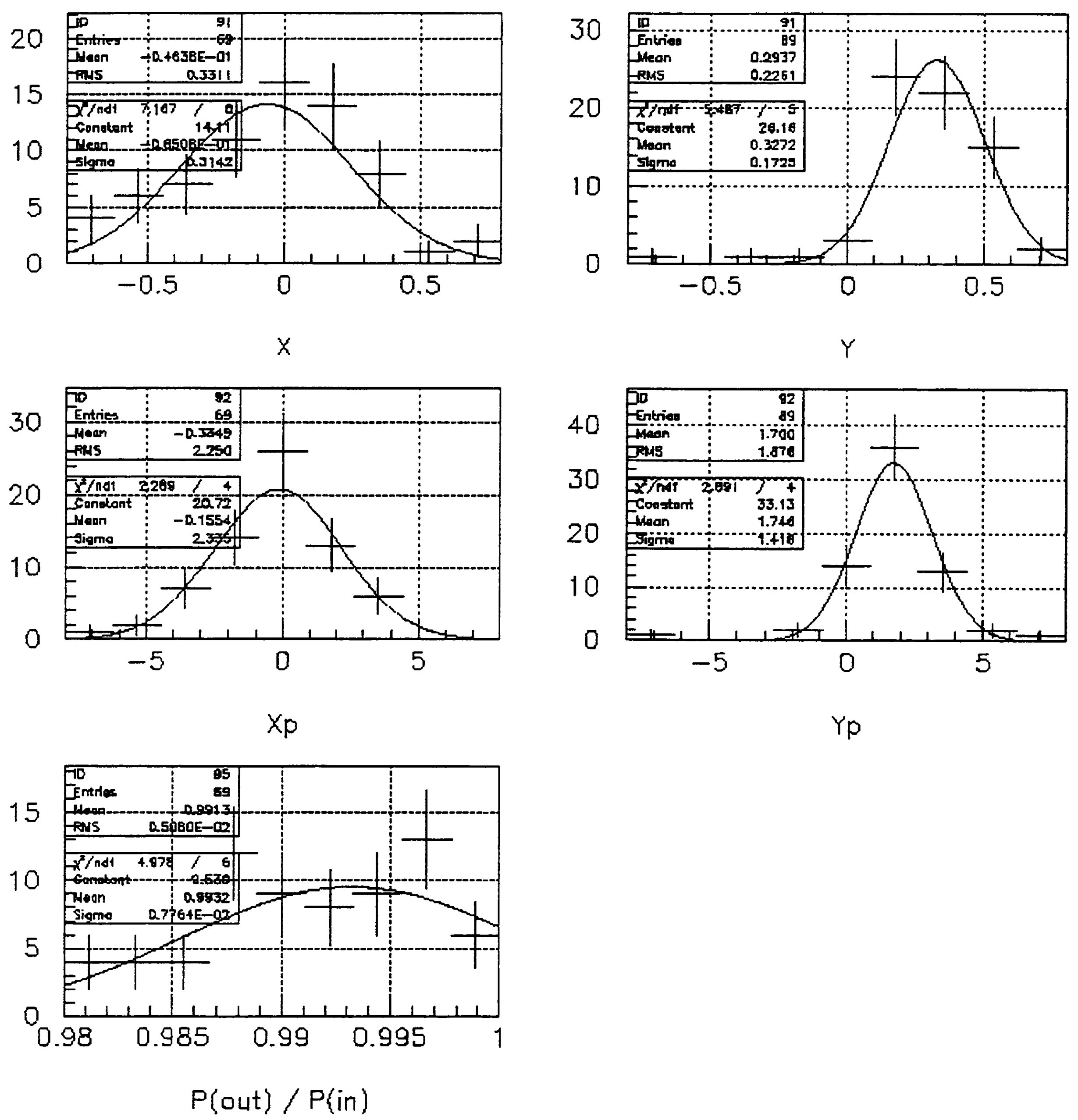
GEANT Simulation Tool

24 GeV/c proton beam at splitter

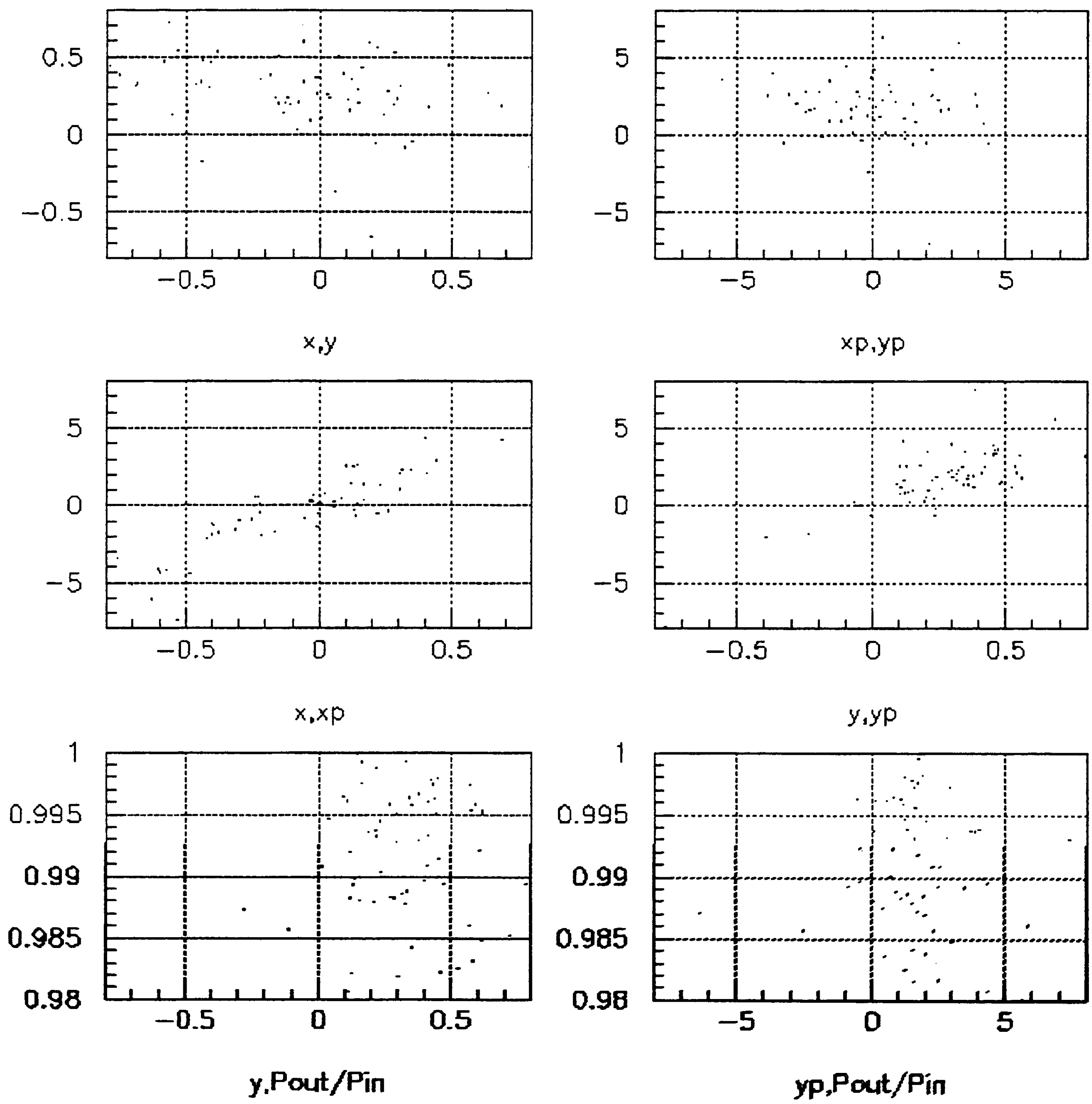



Geant dE/dX + Mscat – Proton in splitter
01/02/95 13.32
Ek lost/ Ek in
Longit. Ek dep/Ek in
Radial Ek dep/Ek in
Nb Particles/plane
Cumul.long. Ek dep/Ek in
Cumul.long. P dep./P in
Particles types
xp (mrad)
yp (mrad)

Geant dE/dX + Mscat – Protons at monitor



Geant dE/dX + Mscat – Protons at monitor



JYH - 31/1/95

PS-PA-EA

from 1995 onwards

SOUTH

PS209-M1	beam optics + installation
Pakis-M1	beam optics + installation
P285-S4	high intensity
P283-SL2	installation
"PS185"	new layout for 96

EAST

DIRAC	beam halo suppression "installation"
ALICE	preliminary studies secondary beams + primary Pb82+ 25ns bunched beam
ATLAS	negociations...preliminary studies...
CMS	negociations...preliminary studies...

Redesign the East Hall Layout?

PS performance day Rolle 2nd February 1995

Controls Rejuvenation and Impact on Machine Operations and Developments

Gilbert DAEMS

CERN

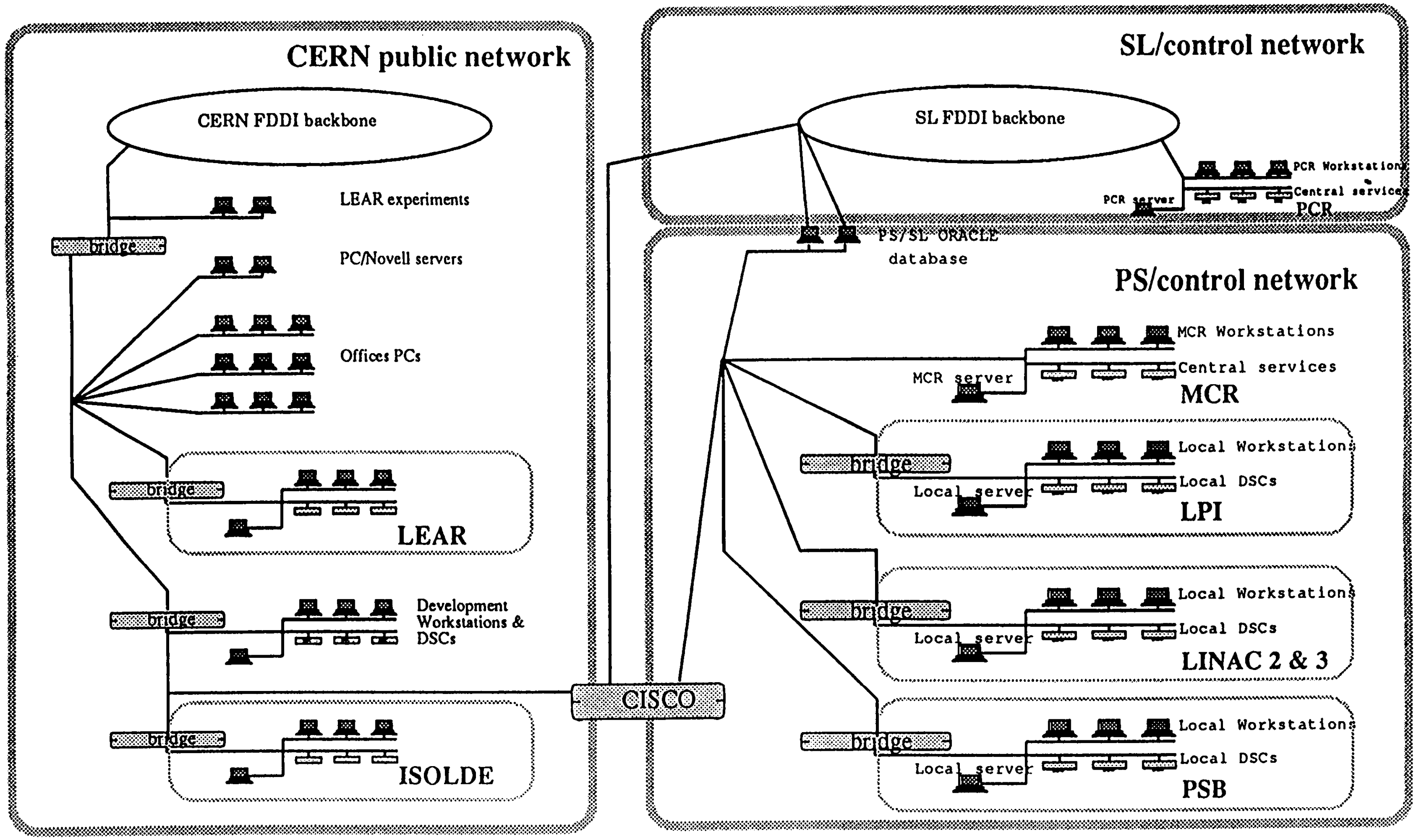
Controls Rejuvenation and Impact on Machine Operation and Developments

- Some dates of controls conversion
  - 1992: LPI
  - 1993: LI2/LI3
  - 1994: PSB
  - 1995: CPS-1
  - 1996: CPS-2

SUMMARY

- -Architecture
- -hardware innovations
- -timing
- -software innovations
    - -workstations
    - -tools
    - -alarm program
    - -miscellaneous

Control System Architecture



Architecture

- Large distributed system
- Easy integration of distributed parameters in A.P., displays, intelligent programs
- Access from anywhere (but under control for outside access)
- Network traffic separation between control and public (interconnection via router= filter)
- Capability to log systematically who is doing control (user and from where)

Hardware Innovations

- VME based with high power of local processing and uniform ethernet & IP network
- 1553-bus for communication with local intelligent systems based on G64 (power converters, RF, mechanical movement)
- GFAS & GFAD
  - Powerful graphics editor
  - high number of vectors
  - variety of implementation possibilities
- Systematic acquisition at 1Khz rate of
  - Analog & digital signals
  - with generic graphical display
- Instrumentation
  - VME based = powerful SW treatment
  - SW protocol = clear red line CO/BD groups
  - where possible acquisition every 1ms for analog data

TIMING

- TG8 : 8 channel complex multipurpose module
  - 256 programmable actions, 20 MHz external clock, internally cascadable
  - multipulse (each pulse= different OB-name), intern intervallometer(+/- 1 msec)
- MTG :
  - 1 cable timing distribution
    - 3 PLS-telegrams
    - 1 Khz clock
    - Calendar (time and date)
    - Timing events from SW programming or external inputs
  - hot backup with ON-line switching
- Unique 10Mhz clock (E -11stability) source for
  - C & D trains,TSM,RF,TG8,MTG
- New timing model:
  - "intervals" expressed in 7 digits (usec)
  - capability of reading back "time" from TSM (usec)
  - multi-DSC "linked timing" (master/slave) via a separate SW layer
  - links can be PPM and can include multipulses

WORKSTATIONS

- Uniform operator interface
  - for all machines unique interface
  - default locations on the whole screen for working sets, A.P., knobs, error log
  - standard background colors (status, tolerance checks, reference checks)
  - standard application frame (trajectories, semgrids, sampled data)
- Generic functionality's
  - knobs, working sets (parameters lists), global commands
  - references, archives, logs
  - programs & window manager per machine
  - easy switching between 8 operational contexts (= 8 users or beams)
  - introduction of "process" (= subset of machine, specialist access)
- Data driven for automatic lay-out configuration---> easy evolution

GENERAL PURPOSE TOOLS

- References and tolerances
  - permanent status indication on working sets parameters
  - global manipulation commands
- Archives
  - 1 beam = 1 user
  - 24 users = independent archives
  - copy command
- New workstation based SOS interface (analog & video)
- New digitized analog observation system (NAOS)
- Integration of commercial tools
  - Mathematica
  - Wingz
- Diagnostics tools (Knowledge based BCD Checker,etc.)

ALARM PROGRAM

- Oriented for survey of
  - machine parameters (E-M)
  - machine equipment
  - controls systems (HW, interrupts, DSC, SW tasks, etc.)
- Integration of RESET and SETUP possibilities via Knowledge based software package
- Easy access to exploitation tools
  - Equipinfo
  - diagnostics programs
  - documentation, etc.

MISCELLANEOUS

- Read only parameters for data integrity
  - MIN/MAX
  - Scaling factors
  - modes
  - etc.
- Suppression of reservation

CONCLUSIONS

- Most of the mentioned items and innovations are based on previous experience and identified needs.
- New computer technologies made it possible to construct a highly modulated , flexible and powerful system.
- Rethinking of operation methods and suppression of the “virtual machine” coupling (=24 USERS) allowed not only a clearer beam definition but also the use of flexible and easy to use operational tools (archives and references)
- The integration of controls data in commercial tools like Mathematica & Wingz permits a wide range of personnal applications
- The connection with the office automation network makes the specific control system accessible to a wide range of people and/or applications

The CERN linear collider CLIC - H.Braun

A short overview of linear collider work in general and of CLIC in particular is given. The CLIC test facility CTF is described and its achievements concerning high power 30 GHz prototype tests and single bunch performances are reported together with a summary of CTF R&D activities. The layout of a two beam experiment planned to be performed with CTF is shown.

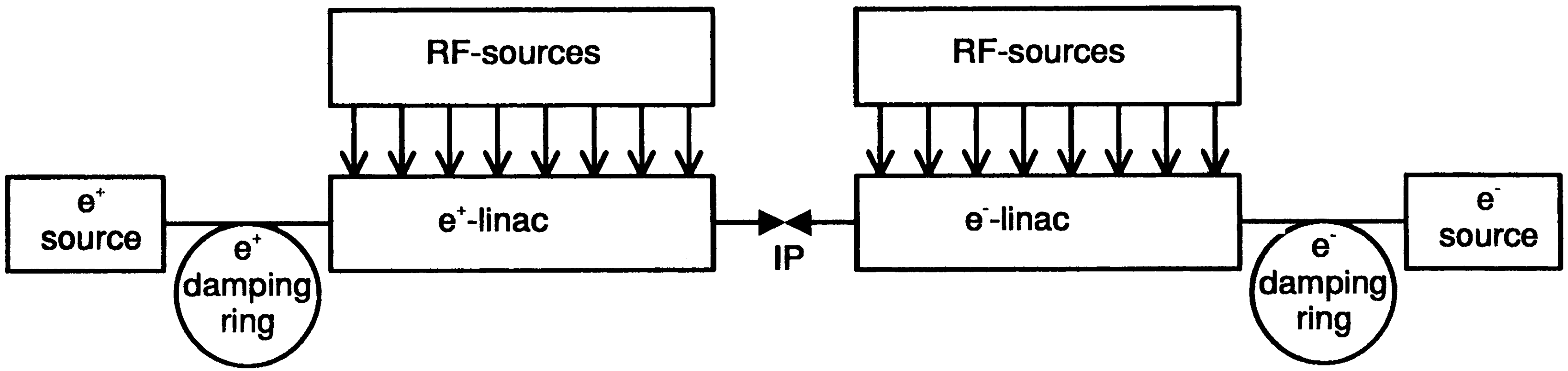
Particle physics wants e^+/e^- collider to complement LHC

Requirements: E_{CMS}=0.5-1 TeV, L=10^{33}-10^{34} cm^{-2}

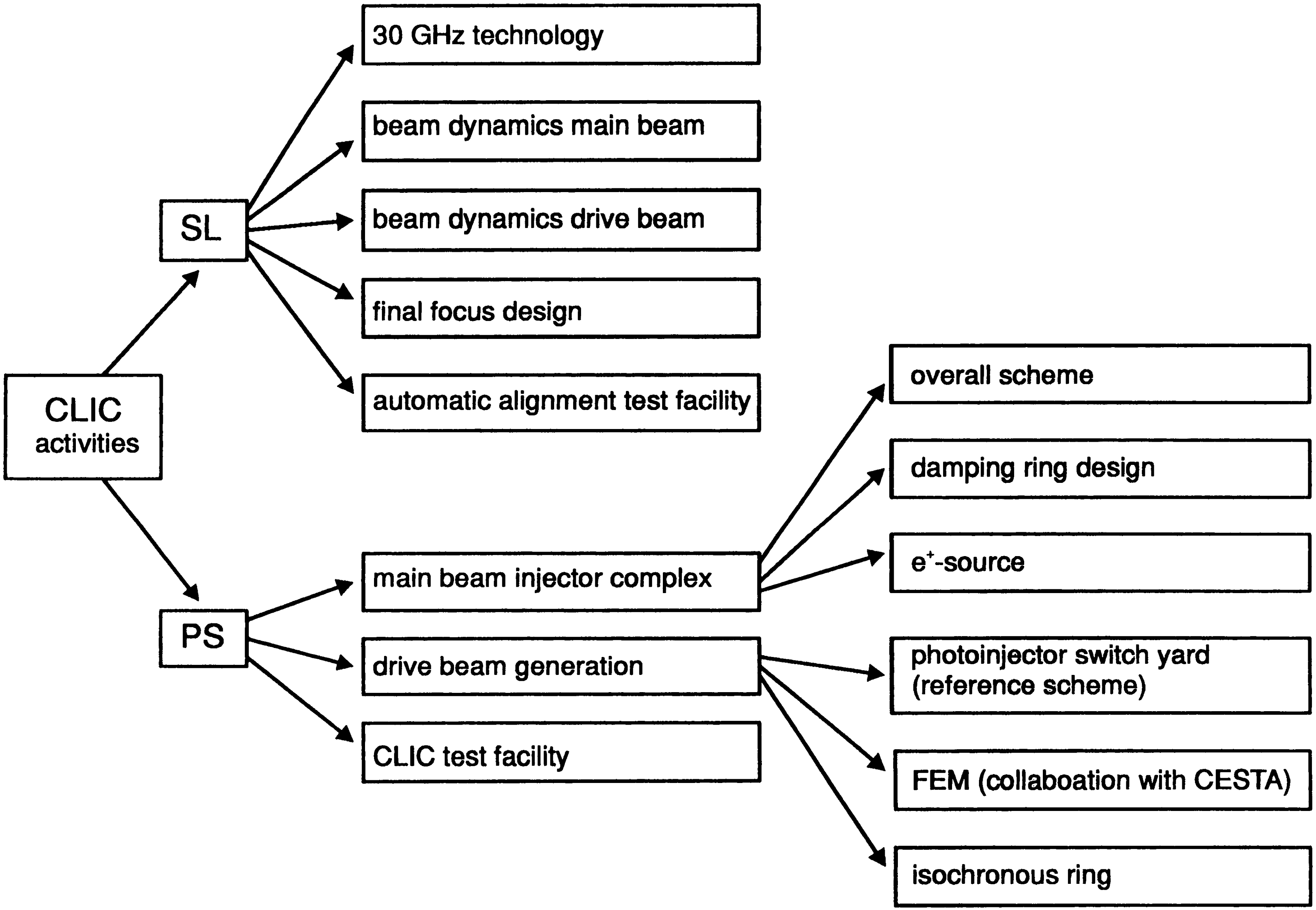
These beam energies cannot be achieved with circular machines because of excessive

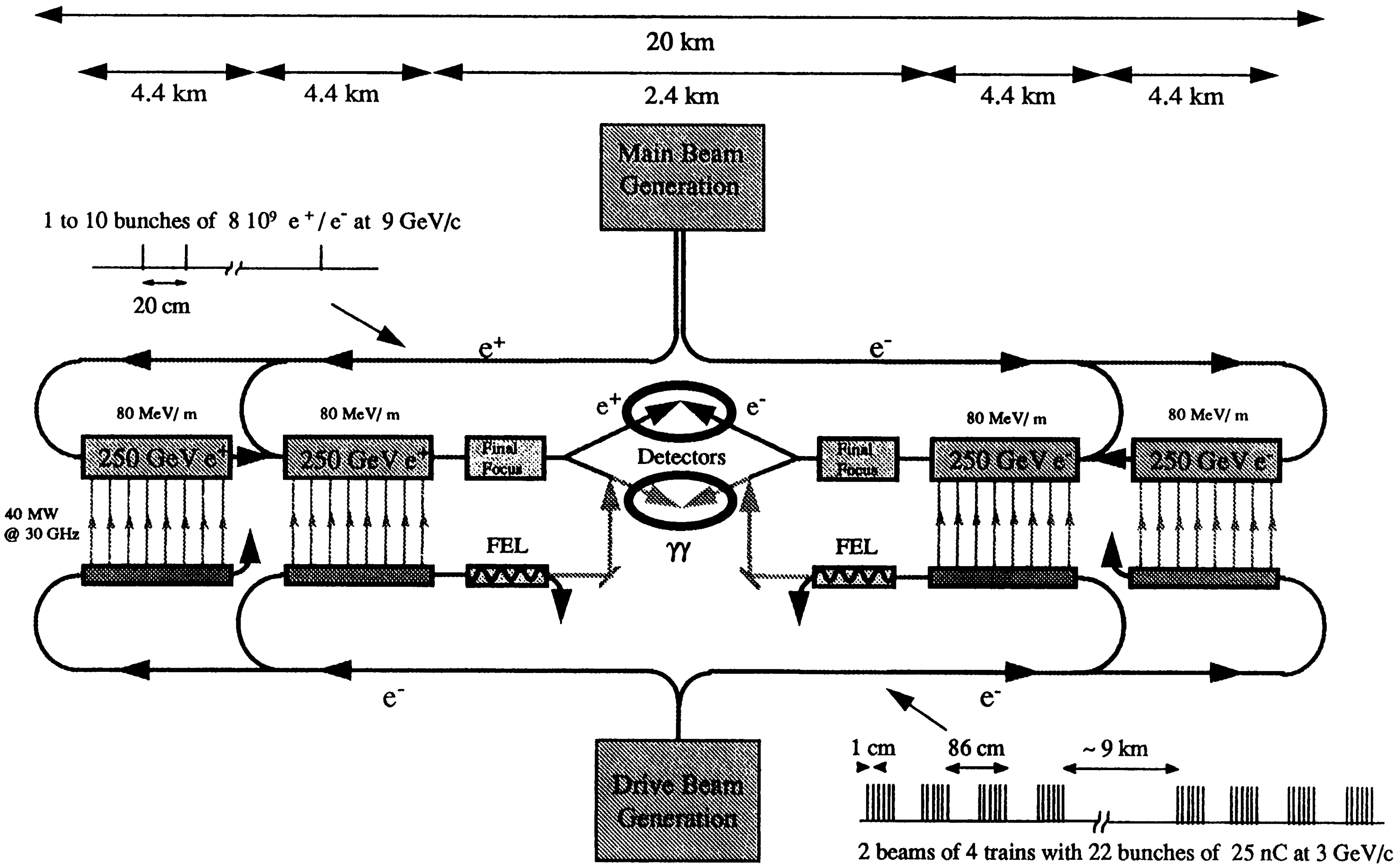
Synchrotron radiation

→ Linear Collider



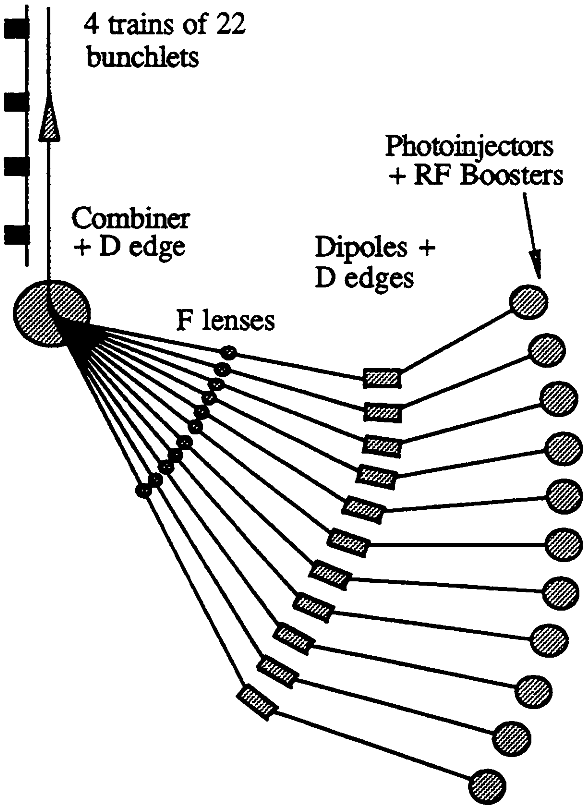
	Frequeny [GHz]	Acc. gradient [MV/m]	Features	Advantages	Problems
TESLA (intern. coll.)	1.3	25	Superconducting RF-Cavities	best physics conditions	requires 25MV/m s.c.-cavities for 1/5 of present costs
SBLC (DESY)	3	21	S-Band technology	well known technology	30 km of RF sections, 4900 klystrons & modulators multibunch instabilities
NLC/JLC (SLAC/KEK)	11.4	50/40	X-Band technology	Good physics conditions with reasonable length	X-band klystron development 7778 klystrons & modulators multibunch instabilities
VLEPP (Russia)	14	108	stopped due to economical / political situation		
CLIC (CERN)	30	80	RF power generated by high charge, 3GeV, drive beam	Shortest overall length, no active RF elements in tunnel	drive beam generation, tolerances, transverse wakefields~ν^3


CLIC activities
SL
PS
30 GHz technology
beam dynamics main beam
beam dynamics drive beam
final focus design
automatic alignment test facility
main beam injector complex
drive beam generation
CLIC test facility
overall scheme
damping ring design
e+-source
photoinjector switch yard (reference scheme)
FEM (collaboation with CESTA)
isochronous ring



Schematic Layout of the CLIC complex at 1 TeV c.m.

Drive Beam generation by magnetic Switch-Yard



Merging bunches in
a beam switch yard

- Creation of 22 bunchlets with 11 photocathode rf guns at S-band.

- Acceleration to moderate (~ 40 MeV) energy by S-band rf boosters. Each bunchlet has a different energy (from 25 to 50 MeV).

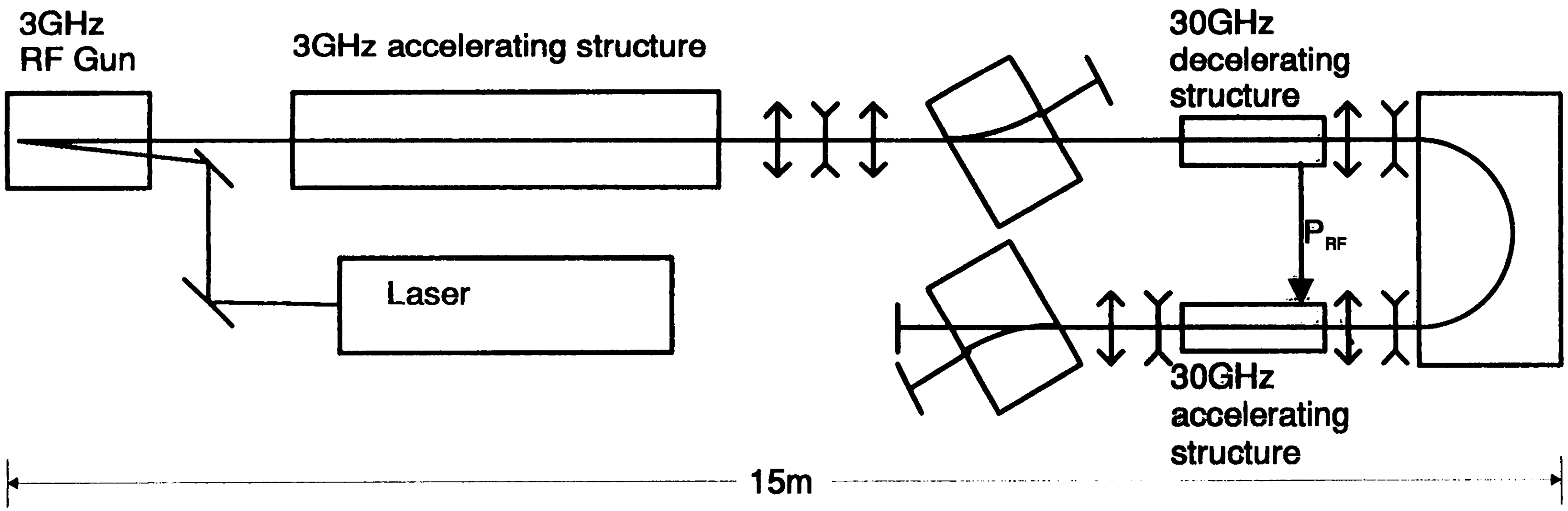
- Magnetic compression and recombination in a "Switch-Yard" of the 11 + 11 bunchlets in a single trajectory.

- Post-acceleration of the train to 3 GeV in a SC linac at 350 MHz with beam loading compensation.

CLIC Test Facility CTF

Objectives:

- Generation of 60MW RF pulses at 30GHz to test 30GHz components ✓
- Study production of high charge, short electron bunches (σ_t<3ps, q>40nC)
- Test of beam monitors



Performances

- 30 GHz power pulses of 76MW were produced with a 8ns long train of 24 bunches 3nC each. This corresponds to a field of 123MV/m in the decelerating structure and 82MV/m in the accelerating structure (both a prototypes of the CLIC main linac structure). No signs of breakdowns were observed. Thus we have shown that our structures can work at the CLIC design gradient.
- The transfer structure foreseen to extract the RF power from the drive beam was tested with 60MW pulses. It also behaved well. Thus all major CLIC high power components are tested at nominal field values.
- Single bunch charges of 35nC were achieved with the present gun. However, the bunch length at high charges is still to high (σ_t=8ps at 35nC). A magnetic bunch compressor will be installed soon and a new RF gun is under construction. Improving the single bunch performance is the main objective of CTF '95.

beam monitor tests

- CLIC prototype high resolution BPM's
- TESLA prototype BPM's (specific feature: design has to be adopted for installation in cryostat)
- Prototype button for high bandwidth BPM (Uppsala collaboration)
- Prototype of 10GHz bandwidth, low impedance WCM

R&D in the framework of CTF

→ Photocathode development: Cs_2Te a material of good quantum efficiency, fast time response and long lifetime. Has been already adopted by several other laboratories.

→ RF gun: Ensemble of $1^1/_2$ cell gun, solenoid and 4 cell booster to accelerate high charge bunches in 30cm to 11MeV. Gun runs routinely with a peak field of 100MV/m on the photocathode.

→ RF gun with $2^1/_2$ cells: Higher single bunch charges, lower beam loading.

→ Programmed LIPS: RF pulse compression without power spike. Allows for higher field gradients in 3GHz structures.

→ Beam loading compensation system.

→ Laser pulse train generation: Two stages of optical splitters, one polarization splitter stage and double pulse amplification in the laser gives a maximum of 48 light pulses in 16ns.

→ Magnetic bunch compressor

→ Transition/Cerenkov radiation monitors in combination with streak camera: Extremely versatile instrument to measure bunch profiles in all three coordinate axes.

→ High bandwidth BPM: Development of monitor to measure bunch to bunch position variations. Collaboration with Uppsala University.

→ High bandwidth, low impedance WCM: allows to measure charge distribution in bunch train.

→ Emittance measurement: Quadrupole doublet scan with beam profiles from TCM and error analysis

→ HOM detection system: Useful in the study of multibunch wakefield effects.

→ High charge accelerating structure. Collaboration with LAL/Orsay.

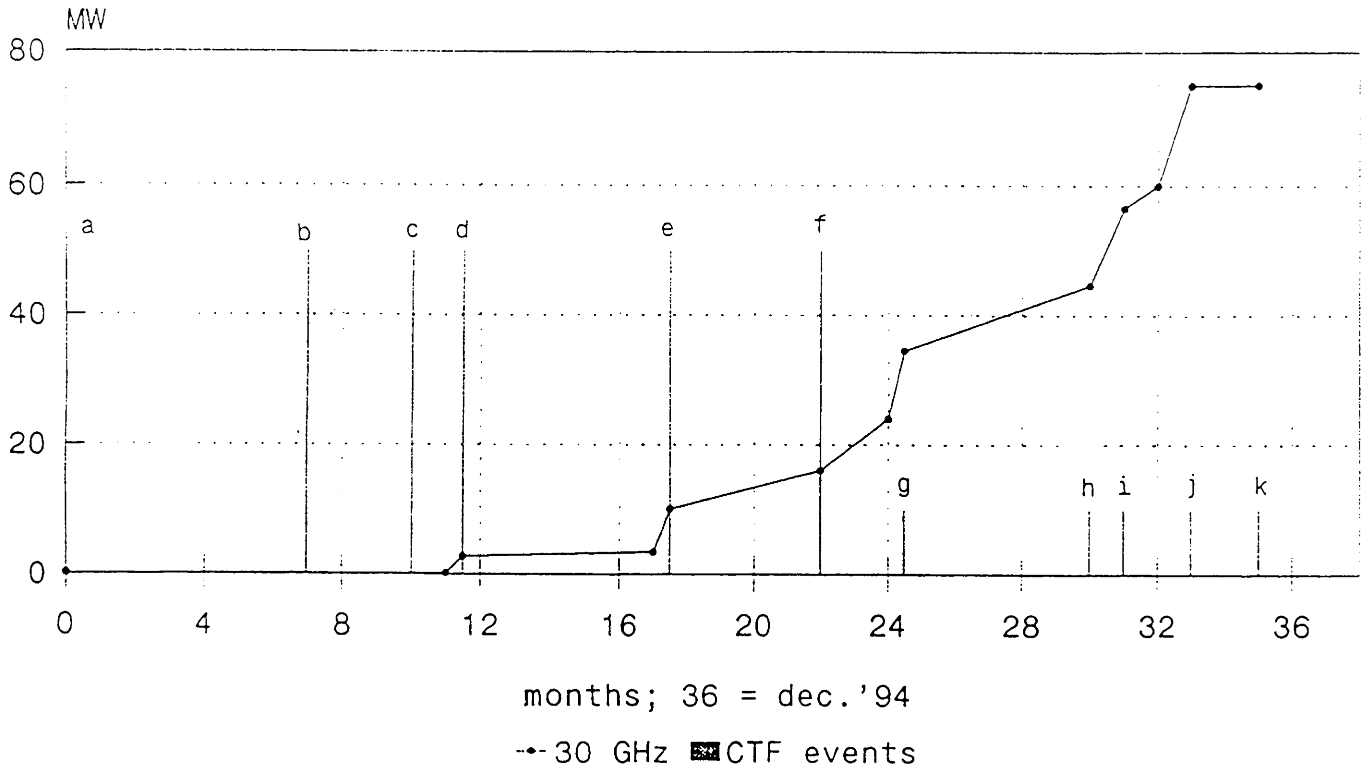
→ Measurement software: Mainly based on passerelle NICE/PS-control system.

→ Operational

→ Under development/construction

The increase of the 30 GHz peak power

Power generated by the TRS



a : dec.'91; beam line in U - shape; long (13 ns) laser pulse at 209 nm; CsI cathode.

b : start of synchro laser

c : rf gun put in front of accelerating section LAS

d : train of 8 bunches, 2.3 nC/b; end 1992

e : two trains of 8 bunches, 1.3 nC/b

f : start use of Cs2Te; laser at 262 nm and 8+-2 ps FWHH.

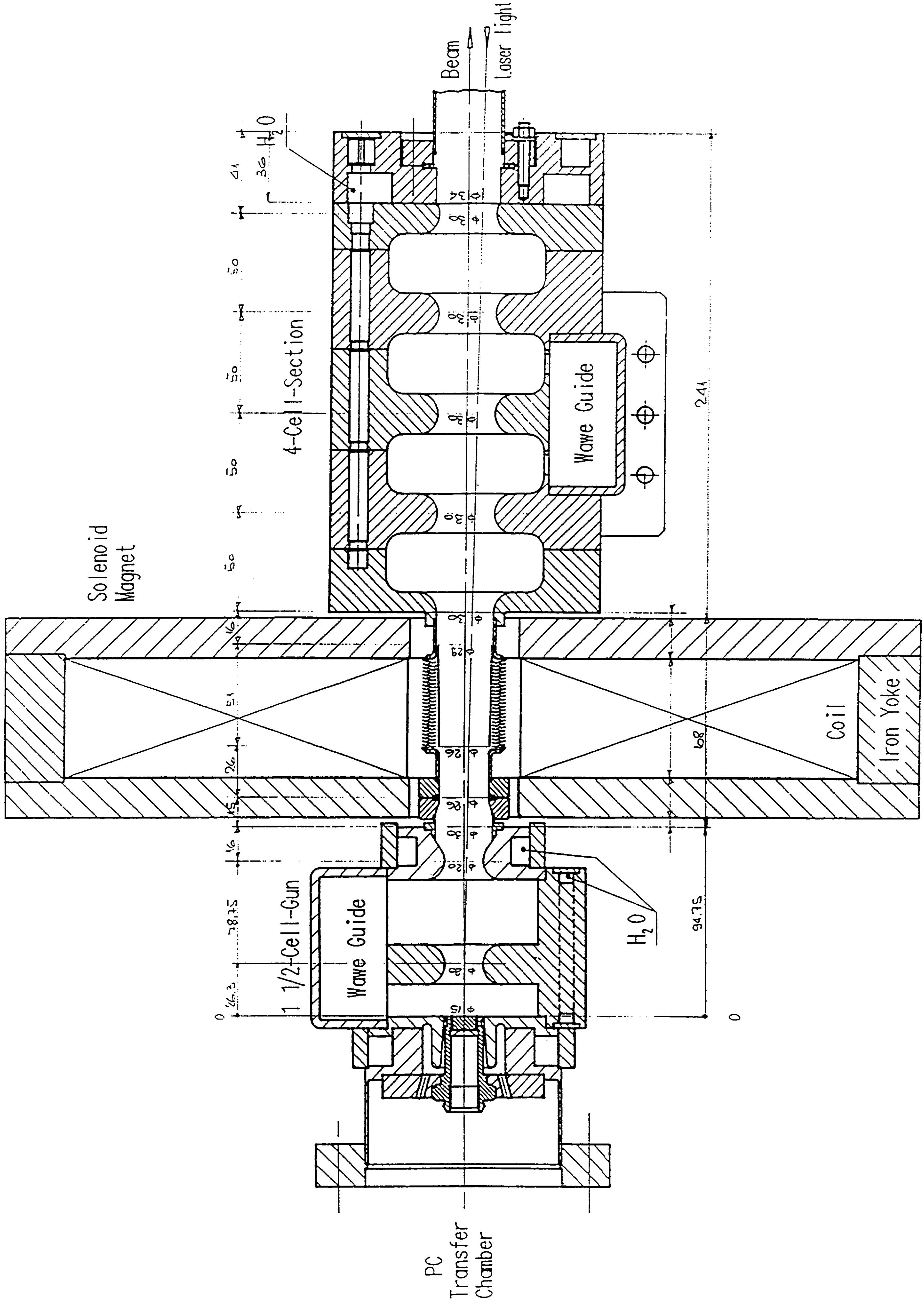
g : train of 24 bunches, 1.6 nC/b; end 1993

h : train of 24 b's, 1.8 nC/b; with booster

i : train of 24 b's, 3.2 nC/b; KLY98 feeding gun and booster

j : train of 48 bunches, 1.3 nC/b; KLY97 with LIPS

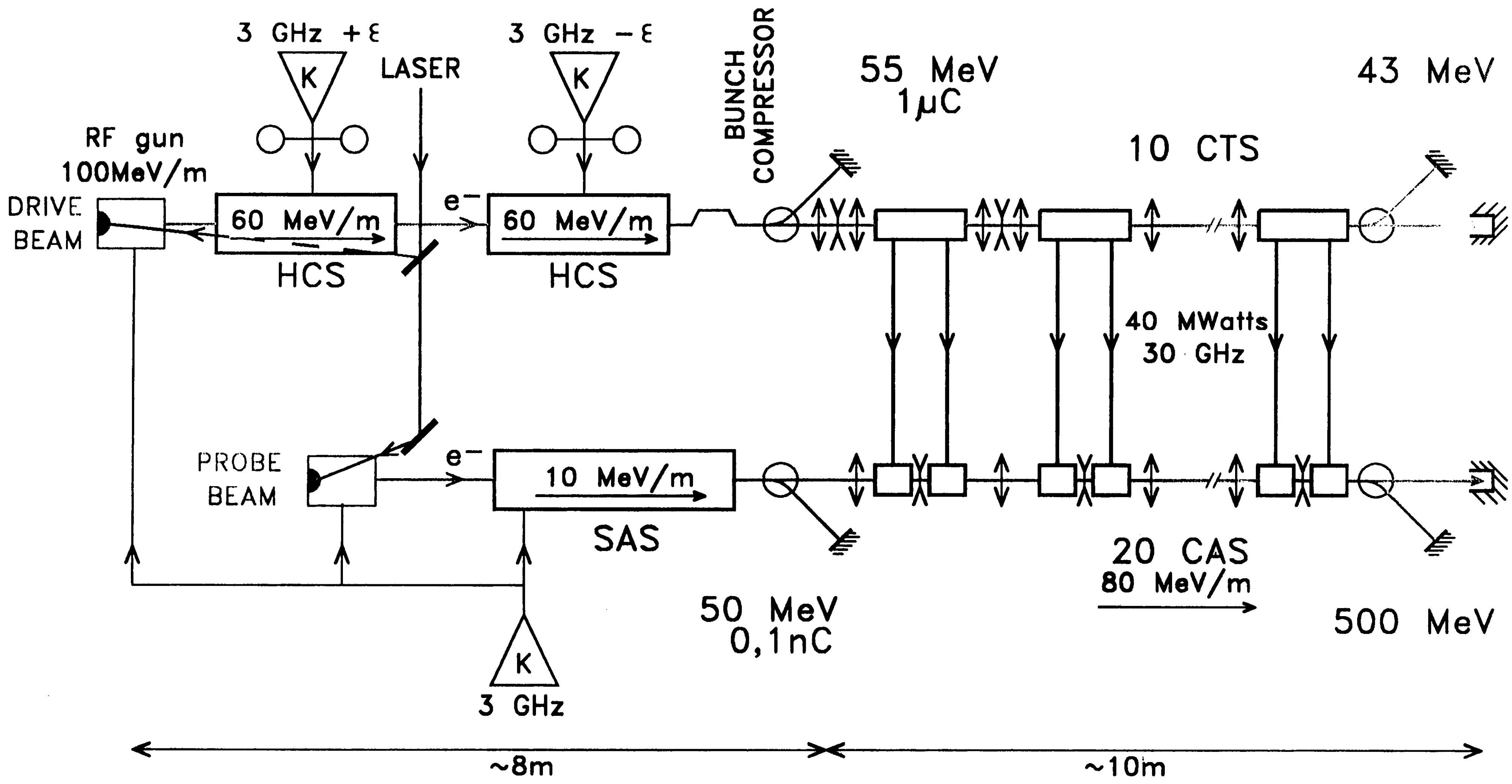
k : train of 24 bunches, 3.3 nC/b; end 1994



ORGANISATION EUROPEENNE POUR
LA RECHERCHE NUCLEAIRE
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
GENEVE

Gun assembly

A DEMONSTRATION OF THE TWO BEAM ACCELERATION SCHEME IN THE CLIC TEST FACILITY



SAS: STANDARD ACCELERATING STRUCTURE
HCS: HIGH CHARGE SECTION

CTS: 30GHz CLIC TRANSFER STRUCTURE
CAS: 30GHz CLIC ACCELERATING STRUCTURE

LINAC 2 & 3 SUMMARY

M.Vretenar

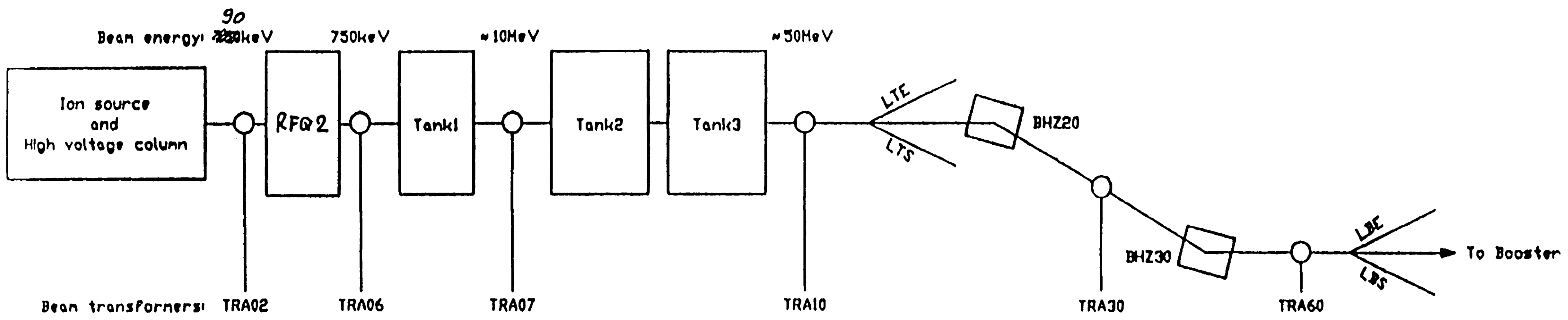
The table of Linac 2 performance during 1994 is presented (the Linac 3 table was presented during the dedicated Linac 3 talk). Linac 2 delivered during 1994 an operation beam of about 130 mA and a high intensity beam for LHC tests of 190 mA at linac output. The main lines for 1995 MD's at Linac 2 are the analysis of the transfer linac/booster and the continuation of the high intensity studies for LHC. The remaining problems happen to be the same for both linacs: alignment and beam trajectory at the entrance and inside the tanks in Linac 2 and in Linac 3, and the behaviour of the long common transfer line.

LINAC 2 BEAM PERFORMANCE IN 1994

		Operation mode (typical values)	High Intensity mode (ppm, 50% of pulses)	
Currents	TRA02	250	350	mA (p^+,H_2^+)
	TRA06	155	220	mA
	TRA07	142	195	mA
	TRA10	140	190	mA
	TRA60	130	170 (*)	mA
Linac Transmission (10/6)		90	86	%
Pulse Duration		<120	60	μsec
Pulse Rise Time		20	30	μsec
Norm. Hor. Emittance (LTE)		1.7	1.8	μm
Norm. Ver. Emittance (LTE)		1.2	1.0	μm
Longitudinal Emittance (1σ)		6.1	7.3	deg MeV
Energy Spread (1σ)		± 170	± 200	keV

(*) transport to TRA60 not optimised for high intensity

1) Sketch of the Linac area (no scale)



EXPECTED IMPROVEMENTS AND MD's IN 1995 - LINAC 2

- Beam re-aligned at the input position of RFQ, installation of a steering magnet: beam trajectory inside the linac is expected to improve, with beneficial effects both on the operation beam and on the high intensity beam

- Continuation of work on the LBS spectrometer for more reliable energy measurement

- MD's:
    1. for *all the beams*, analysis of the beam trajectory in the linac after the source/LEBT/RFQ re-alignment

    2. for the *operation beam*, common MD with PSB on optimisation of transfer Linac/Booster

    3. for the *high intensity LHC beam*:
       transport of the high current (180 mA?) to the Booster,
       more studies on the RF system performance with high beam load,
       more detailed study of linac parameter space (for example, RF setting)

SOME PROBLEMS REMAINING TO BE SOLVED

(1993)	(1995)
1. FOR HIGH INTENSITY BEAM LACK OF RF POWER TO COMPENSATE THE BEAM LOADING EFFECT IN THE 3 TANKS	ok now! (but close to limi[t])
2. INSTABILITY OF THE HORIZONTAL PLANE OF THE BEAM, OWING TO THE PS FRINGING FIELD EFFECT ALONG THE LTB LINE	since 1993: - double ppm - improved shield but ....
3. NEW AND UNEXPECTED PROBLEMS WITH THE RFQ (i.e. Alignment)	!

SOME PROBLEMS REMAINING TO BE SOLVED

1. alignment and beam trajectory in the linac

2. transfer line from linac to booster, specially for ions (ppm protons/ions, equipment, diagnostics,...)

3. ...

PS Performance Day **H. Schönauer 2/2/1995**

PSB Summary

PSB Performances October - December 1994

User Name	Beam Type Destination	Nr of Rings	Nr of p tot.	Nr of p/ring	Norm. H	Emitt V	Comments	Limits
SFTPRO	SPS Neutrino Ph.	4	2.70E+13	6.20E+12	45 pi	25 pi	even intensity in all rings	Limit 1 capture
AA	pbar production	4	1.80E+13	4.60E+12	30 pi	15 pi	RF dipole recomb h=10 phase inv.	
ISOGPS	ISOLDE	4	3.00E+13	8.00E+12	55 pi	30 pi		LIMIT 1 (2) capture (?)
MDION	Pb 53+	4	1.7 E+10 (charges)					Ion Source Vacuum

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 (requires frequent readjusting at very high intensities)
- Instability of unknown type (GHz signals ?) in Ring 4, causing blowup and sometimes loss of a few % beam
- Recently octupole in-phase modes seen

LIMIT 2 : "Classical" transverse space charge limit.
At high intensity also the longitudinal space charge drastically reduces bucket area

PSB MD's 1995 :

Topic	Customer	Remarks/Requirements/ Contribution	Prime Time	Total hrs estimated
h=5/h=10 Dual RF System: - study of basic properties: gap-derived or beam-derived h=10 phase; - test cases for theory - new HW: Synchr. Detector for quadr./octup. modes; new mode analyzer	ISOLDE, SFT	relevant also for futur h=1, h=2 system S. Koscielniak / TRIUMF collab.	Y	20 8 (3/95)
Loss Analysis	PSB	Septum position, BLM	Y	10 10
Steering and Focusing inTransfer Lines	SPS, ISOLDE	ABS improvement ISOLDE line optics to be reviewed SEM grid measurem'ts at target position	Y Y	6 6 8
Transverse Stability with New Kicker Cables Damper Tuning	PSB, LHC			8
ISOLDE HRS beam line	ISOLDE			8
Scintillator Screens Inj. Line CCD cameras	Pb Ions	Test of new SW developments	Y	4 10
Ion Injection Steering Improved Focussing (?)	Pb Ions	Correction from Screen Position (Matrix Inversion)	Y	10 4
B-Train Generation	Pb Ions	Test of NMR markers	Y	4
Ion Lifetime Measm'ts	Pb Ions	At varying Energy, with AT	Y	8
LHC "Initial" Beam in 4 Rings	LHC	RFQ2 + Linac >180 mA in ppm		10
Emittance Meas'mt/Comparison	LHC	PS SEM Grids, Flying Wire		10
Controlled bunch flattening	LHC	on Flat top: h=1 + h=10		
Beam Transfer Function Measurement	PSB	Momentum distribution of injected beam measured in the ring		50
Integer Stopband Compensation	PSB	Started in 93; Successful at ISIS		10

3 PROBLEMS : 1993

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)

*) 1994 we were happy if we had 12 kV real !

3 PSB PROBLEMS:

i) Marginal stability of dual RF system: limit to highest intensities, tedious operation, losses; Longitudinal coupled-bunch instabilities

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

consequence

iii) Lack of beam diagnostics in ISOLDE beam line:

Beam transformer in HRS line *(essential part of Watchdog!)*

SEM grids and/or PUs

LPI 94 summary

J.P.Potier, L.Rinolfi

Beam performances in 94 (same as 93)

	Max present Users requests**	Operational values	Max. values
LPI accumulation rate in E09 $e^+/(s*bunch)$	3.5	5.4	8.0
LPI accumulation rate in E09 $e^-/(s*bunch)$	32.0	49.0	120.

** Corresponding to 2.8 E11 leptons in 8 bunches on the usual 14.4 s supercycle

- Faults statistics = 4.8 % (external faults removed).

- *During 1994 a feedback was successfully introduced on beam momentum to compensate for residual drifts (mainly thermal) and improve beam production stability.*

Remark

Present users requests: In fact the LPI is tuned approximately for the operational values shown above, but the accumulation is stopped before the end of the total time available by an intensity limiter.

Conclusions

Performances OK .As they are high enough in respect to users requests... **But one must remember** that increasing the positron production, our closest LPI bottle-neck, will need time and money to develop and implement.

1994 Studies

In 94 the study time was devoted mainly to:

LPI

- e+ tuning, operational conversion factor back to 5 E-03 at 1.8*E10 on the converter target.

  RF conditioning on ACS25 with LIPS after the 94 startup and at the end of 94 showing a limitation on the maximum local accelerating field to 20 MV/m (< 9MV/m average).

- Experiments on LILV to feed the Pre-Buncher and Buncher from MDK13 avoiding the use of MDK03.

- Fault fixing on MDKs and different subsystems.

LHC

Irradiation of LHC vacuum chamber samples at different critical energies, at room temperature and in a cryostat at about 2 deg K after LEP stop. Good accumulation of 4.5 E11 / 8 bunches obtained at 308 MeV/c.

LEA

LEA (Lil Experimental Area) irradiations for RD36 & RD25 (both for the CMS detector) and RD3 (ATLAS detector).

Hall 174

Tests on strengthened pulsed solenoids have been performed in order to validate their design. A good behavior was obtained during a 300 h test at 6 kA.

LPI 95 study program

LPI studies

After startup, as usual, beam machine parameters will be measured then tests on 4 bunches and 8 bunches transfer mode performed with the CPS.

Our main focus in 1995 will be to get a better control of the injection and accumulation process and to develop modeling facilities (*with the help of a VSNA from august 95 on*). Our main subjects will be:

- Injection trajectories measurements and analysis in the injection septum area and during the first turns in EPA.
- Test of automatic beam steering in LIL and at EPA injection .
- Transverse positron emittance measurements in the LIL->EPA transfer line.

LHC irradiation

The cold bore experiment will continue in the synchrotron light line using periods of 3 to 4 days (1 for cooling and 2 to 3 for data taking) using 308 MeV e- beams during MD time of weeks 20, 27, 41 and the dedicated time of weeks 47 & 48 after LEP stop.

LEA activities

After the running in of the new power supply for HI.BSH00, it will be possible to *share the electron beam in PPM between LEP production and LEA irradiation*. This will ease the carrying out of the experiments. Two new requests have been made for 95 RD40 (CMS detector) and RD2 (ATLAS detector), RD36 started in 94 for CMS, will continue.

Hall 174

Tests on strenghthened pulsed solenoids will continue as well as the development of a conical solenoid (for positron capture improvement)

Major problems 1993 and nowadays

The performances of the LPI are safely above the requests of the users and apart from studies aiming at improving the availability (our major hardware effort) and the operation of the LPI, there is no pressure and consequently no priority.

Controls

In 93: *"OK during lepton production for LEP, but improvements still needed for instrumentation which is still the bottle-neck for studies".*

In 94 the instrumentation still remains the weak point during studies.

Man Power for studies

In 93: *"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 completely inefficient."*

In 94 the situation was still the same and could became tighter in 95.

AAC Summary

Rapporté par: C. Metzger PS/AR

Sommaire: 1994 a été une bonne année pour l'exploitation du complexe de production d'antiproton AAC. Les performances sont comparées avec celles des années précédentes et nos préoccupations antérieures sont commentées au vu des résultats. La liste des demandes de développements et d'expériences à faire sur ces machines ainsi que les problèmes actuels sont présentés.

Performances

Comparaison des stastistiques des années 1992 à 1994

	1992	1993	1994
Heures programmées	5897 h.	5563 h.	5657 h.
Heures réalisées	5599 h.	4963 h.	5539 h.
Disponibilité	94.95 %	89.22 %	94.72 %
Heures en mode économique	2399 h.	1438 h.	2235 h.
Temps de pannes	12j.10h.05m.	25j.14h.53m.	11j.07h.57m.
Intensité maximun	>9 10^{11}	8.61 10^{11}	1.116 10^{12}
Taux de production	1.29 10^{10}	1.79 10^{9}/h.	1.909 10^{10}/h.
Nb. heures de production	1986 h.	2305 h.	1931 h.
Nb. antiprotons produits	25610 10^{9}	41251 10^{9}	36879 10^{9}
Nb. antiprotons extraits	18347 10^{9}	27320 10^{9}	24767 10^{9}

A l'exception du mois d'avril pendant lequel les problèmes généraux de démarrage ont entravé la marche des machines, le complexe AAC a fonctionné avec une disponibilité moyenne de 96.64 % pendant les autres mois de l'année.

machines ainsi q [illegible]

- [illegible]
- [illegible]
- [illegible]

[illegible]

[illegible]

Améliorations et développements en 1995.

1. **Taux de production:**
   Comprendre la cause de la diminution et retrouver le taux de production optimum.

2. **Système de refroidissement stochastique:**
   Entretien des systèmes et contrôle des performances

3. **Refroidissement stochastique de faiseaux groupés:**
   Sur AC en parasite pendant l'exploitation. Mesures systématiques et études des instabilités mises en évidence en 1994.

4. **Acceptance dynamique:**
   Test de mesure pour déterminer si le collecteur d'antiprotons est une machine adéquate pour l'étude de la dynamique non linéaire. Important pour le LHC.

Problèmes antérieurs et leurs solutions.

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

C'est toujours le cas mais cela n'a pas posé de problèmes particuliers.

2. ***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 fuctioning, 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, cryogenics,etc, all issues which are farmed out to other CERN Divisions!

Pour le moment nous n'avons pas eu de conséquences notables de ce « news way of working ». Est-ce de la chance?
En ce qui concerne les manipulateurs et plus généralement la zone cible: la consolidation de cette zone est terminée. Nous disposons de manipulateurs en ordre de fonctionnement et deux cornes magnétiques montées sur berceau prêtes à être installées. Ces cornes ont été testées en laboratoire et ont subi avec succès 10^6 pluses de 400kV.

3. ***Good, motivated, knowledgeable operating Crew** to see us through to late-nineties.*

La question reste ouverte. Jusqu'à présent pas d'ennuis majeurs mais quelques contrariétés pendant les démarrages (voir Problèmes actuels point 2).

Problèmes actuels.

1. **Baisse du taux de production:**
   La cause de cette atténuation n'a pas encore était identifiée:
   ⇒ lentille lithium?
   ⇒ cible?
   ⇒ optique?

2. **Démarrage du complexe AAC:**
   Le personnel travaillant actuellement sur les machines de production d'antiprotons et ayant une connaissance globale de ces machines diminue d'année en année. Ceci se fait sentir en particulier lors des démarrages par des pertes de temps dues à la méconnaissance des systèmes.

3. **Organisation des mesures d'acceptance dynamique:**
   Dans le programme actuel nous ne disposons pas suffisament de temps pour effectuer ces mesures lors des démarrages.
   Est-il possible de les faire en parasite sans perturber l'exploitation?

LEAR

before , after PPD1995

M.CHANEL

ABSTRACT

After a review of the performance of lear during the two last years, three problems to be solved during the next year are listed .

ROLLE 02/02/1995

LEAR D'AVANT

1993/94

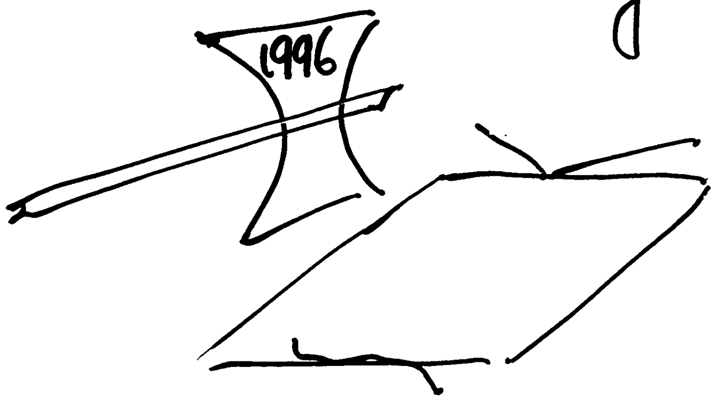
P MeV/c	Exp.	Flux $\times 10^3 s^{-1}$	Extime h	Stack 10^9	Limit.
1940	X Barrel PS 208	100 200	>2h	5	Extime
1440...1445	PS185	500...1000	2h	8...10	
310	PS201	>2000	~1^h	>10	stack
200	PS195 PS197 PS205	600-800 30-50 10	1,2	4-5	stack 
105	PS201 PS197 PS207	100-200 10 300..500	0,8 " 0,5	2-3	Stack lifetime
FE 65	PS196 PS200T	1-2 shots 10 shots	– –	2-3	→ 10^6 in trap.
20 p: 1200...1800	Jetset	–	Store ~30h	73 3×70 ~50	lifetime 36h.

– If $p \lesssim 36$ MeV/c ecool ok.

LEAR D'APRÈS

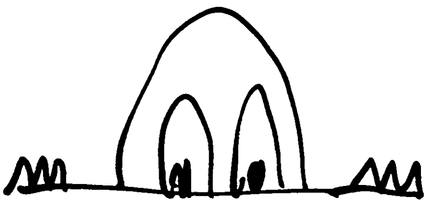
1995/96

1 - Motivation. malgré



2 - Ions Plomb MD.

3 -



- élément instable!
- ions pockets
- charged dust. .

PS Beams in 1994

2.02.95

user	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]	peculiarities	problems
SFT	p	14	$2.5\ 10^{13}$	420	11	7	0.1	1	5	5t.CT, very high Ip, ad.deb., h=420 recapt.	coll.effects., lossy extraction
SPP/SPN	e+e-	3.5	10^{11}	4 or 8	0.05 x $\beta\gamma$	0.01 x $\beta\gamma$	0.01	1 (1σ)	1.1 (1σ)	h=8+240, J_E var. (Rob.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. compress.	coll.effects.,lossy inj., large ε_v
TST	p	3.5	$2\ 10^{10}$	1	4	1.5	0.5	1.3	70	h=20,6	
LEAR	pbars	0.6	10^{10}	1	2	2	.2	2.4	160	decel. to low energy, h=10	A_l lim., transf.eff. 80%
PHY	p	24	$3\ 10^{10}$	deb.	3	2		1-3	(0.4s)	ES in int.pos.	
MD/LHC	p	26	$2\ 10^{12}$	1	3	3	0.15	1.4	48	bright beam, 1.4GeV inj. energy, <20% $\varepsilon_{x,y}$ b.u.	sp.ch., h-t inst., HE nonlin.
MD/FE61	p	1.2-3.5	10^{9}-10^{10}	1-5	2.5	.6	.3	1.5	30	various energies, special tr. line optics	low extr. eff. (~20%)
Pb IONS	Pb53+	5.1	$1.6 10^{8}$	20	2.2	1	0.04	0.4	11	stipped to 82+in TT2	30% vacuum losses, $\varepsilon_{x,y}$ b.u.
MD beams											
MD/ionsim	p	13	$5\ 10^{11}$	20	4	3	0.4	3.5	6	bunch rotation	
MD/spsµw	p	26	$2\ 10^{12}$	20	3	2	0.2	0.44	4.4	bunch rotation, low ε_l	

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

For ion beams: cp[GeV/amu] and ε_l [eVs/amu]

Forecast of PS beam studies in 1995

LHC project:

*** SPS microwave instabilities

*** Nonlinearities issues at 26 GeV/c

** ABS at injection

* Debunching (& rebunching) at 26 GeV/c

* Compensation of $2Q_{x,y} = 12$

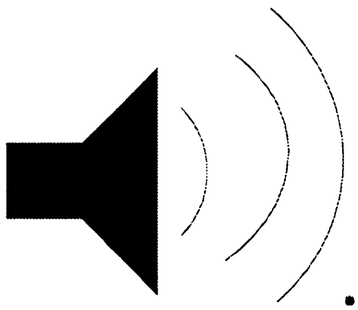
Others

*** SE61 with Pb ions...and without ES23

!!*** High intensity (SFT) beam optimisation

!!*** Instr. cal. in TT2, TT10 =>SPS with p & Pb

from PPD 1993



...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

PROBLEMS IN PS PERFORMANCE

Integrated performance

☞no daily follow up of the main beam parameters

☞one techn. supervisor is not enough

Peak performance (MD's)

☞2.5 consoles are not enough (interference)

☞SOS in a very poor status

☞no archiving (yet)

Instrumentation

☞essential instruments are not in an operational status (e.g. meas. targets, WS, ..)

PPD - 2 février 1995

QUELQUES CONCLUSIONS
"OPERATION DES MACHINES = PRIORITE No. 1 du PS "

Objectifs 1995

• Bonne efficacité générale ≈ 90 % (Ah ! démarrages...)
* Challenge : seulement deux demi-semaines d'arrêt*

→ Protons : hautes intensités !
(neutrinos SPS → ≥ 1997)

Emittances	→ →	SFT :	2,5 x 10^{13} ppp
		Isolde :	3 x 10^{13} ppp
structure		Prod. pbar :	1,5 x 10^{13} ppp

Pertes : étudier, réduire ...
(LI, PSB, PS, transferts ...)
Actions (entre autres) :

ABS team
PSB "task force"

→ Zônes expérimentales :

Est : étudier demandes
(dimésons-ions Pb/Alice, faisceaux secondaires ...)

→ Projets :

D067 (CO) PS1, PS2
D070 (Pb) à terminer
D082 (consolidation) : continuer

préparation PS pour LHC : décision
En cours : cavité 40 MHz ... (+ MD's)

→ R + D : CLIC/CTF :

- très bons résultats 1994
- décisions
- Laser ion experiment

→ antiprotons :

- bonnes efficacités (cf 1994)
-résoudre l'instabilité à LEAR (200 MeV/C ps 195)
"Fantôme"!

14 semaines à 200 MeV/c en 1995 (spills 1 h - 10^6 pbar/s)

•MD's

•spécialistes "sur le pont"

- Futur des pbars : fin 1996 (?)
  (décision finale : 1995)

→ <u>ions plomb</u> :

- faisceau déjà ≈ OK...
  - consolider (réserves, vide au PSB, dégazage ?)
  - strippers; émittaces TT2/TT10
  - organiser cycles au PSB (supercycle PSB")

- ions Pbar dans LEAR (LHC ...)
  - premiers résultats positifs
  - continuer en 1995-96 ?

→ $e^{\pm}$, e^{-} pour LEP : ≈ OK

maintenir les performances.

List of participants:

B.W. Allardyce	PS
B. Autin	PS
S. Baird	PS
J. Boillot	PS
M. Bouthéon	PS
H. Braun	PS
E. Brouzet	SL
P. Bryant	PS
R. Cappi	PS
F. Caspers	PS
M. Chanel	PS
V. Chohan	PS
G. Cyvoct	PS
G. Daems	PS
D. Dekkers	PS
J.P. Delahaye	PS
F. Di Maio	PS
L. Durieu	PS
T. Eriksson	PS
A. Faugier	SL
B. Frammery	PS
R. Garoby	PS
R. Giannini	PS
M. Giovannozzi	PS
J. Gruber	PS
S. Hancock	PS
H. Haseroth	PS
J.Y. Hémery	PS
K. Hübner	DG
E. Jensen	PS
K. Kissler	SL
H. Koziol	PS
K. Langbein	PS
R. Ley	PS
D. Manglunki	PS
M. Martini	PS
C. Metzger	PS
D. Möhl	PS
H. Mulder	PS
S. Myers	SL
F. Pedersen	PS
F. Perriollat	PS
W. Pirkl	PS
J.P. Potier	PS
N. Rasmussen	PS
J. Riche	PS
L. Rinolfi	PS
J.P. Riunaud	PS
K. Schindl	PS
G. Schneider	PS
H. Schönauer	PS
D. Simon	PS
C. Steinbach	PS
E. Tanke	PS
G. Tranquille	PS
H. Ullrich	PS
H. Umstatter	PS
M. Vretenar	PS
D. Warner	PS
E. Wildner-Malandain	PS