BWA/lmg PS/DR Note 2001-019 (Min.)
06.04.2001

Minutes of the PS Technical Meeting No. 119 held on 4th April 2001

NUFACT

Present: *B.W. Allardyce, B. Autin, S. Baird, J. Boillot, J. Bosser, R. Cappi, M. Chanel, J.P. Delahaye, B. Frammery, R. Garoby, M. Giovannozzi, J. Gruber, K. Hanke, H. Haseroth, J. Lettry, A. Lombardi, M. Lindroos, S. Maury, K.D. Metzmacher J.P. Potier, H. Ravn, J.P. Riunaud, H. Schönauer, K. Schindl, F. Voelker*

cc. *K. Hübner, M. Martini*

1. J.P. Delahaye opened the meeting by stressing that the objective today was not to hear detailed technical descriptions of the work under way on Nufact, but to find out if the resources requested by the studies can be supplied by the Division (or from external sources), especially in 2001 and 2002. The SPL as part of the Nufact study is important to us because it can also bring benefits to the PS beams as a prelude to a later Neutrino Factory.

2. H. Haseroth summarised the various stages of Nufact which are under study. He stressed the good progress on SPL, targets to stand 4 MW beam power, pion collection and cooling and the accumulator/compressor rings. He noted that the HARP experiment will furnish crucial results this year which may significantly affect the design of the final facility. He also showed the latest ideas on locating the facility on the CERN site.

3. R. Garoby briefly presented SPL, including new ideas on how best to use the LEP hardware. He noted that work on a test stand in Bldg. 152 will start soon for the 352 MHz room temperature part of the linac. The manpower needed for the SPL work seems to be available, mostly in the RF Group, and is compatible with normal operational duties.

4. H. Ravn showed the present ideas on targets capable of withstanding the 4 MW beam power (of which ~1 MW is lost in the target). Tests are planned at BNL and ISOLDE this year. These trough tests can be covered by existing personnel. However, further Hg-jet tests lack the necessary manpower.

   A horn test lab will be set-up to enable new ideas on pion collection to be tested; this will involve staff outside the Division.

5. J. Lettry showed some results of Hg-jet tests and explained the magnetohydrodynamic effects now being studied.

6. F. Voelker explained the power supply for the horn (the so-called 40/400 horn) which needs a peak current of 300 kA at 50 Hz. According to his requests there seem to be manpower resources missing for this aspect of Nufact.

7. M. Giovannozzi presented the muon test line which it is hoped can be built in order to demonstrate the principle of ionisation cooling; such a line would be quite short and would aim to show a 10% improvement in the emittance. The test line could be constructed in TT1, and cost estimates were available; it would be a fairly expensive line. An alternative line might be possible at PSI, and at first sight this looks more attractive in terms of the resources required, but it is still being studied.

8. B. Autin explained that muon beam experiments were important also to test options concerning the horns and targets and that a muon test facility is needed. He mentioned the curved decay channel and the 88 MHz cooling test. An evaluation of the effort on instrumentation is needed.

9. K. Hanke showed how muon cooling works and why we need it. He explained how the 88 MHz test would be made and the layout of the experiment.

10. H. Schönauer presented the accumulator and compressor rings and their possible layout in the ISR tunnel. The studies are at an advanced stage, but further lattice calculations are needed. Studies on a 30 GeV fast-cycling synchrotron will follow as soon as the report on the accumulator and compressor rings has been published.

11. H. Haseroth then presented the resources requested in each of the areas:

    - For the accumulator/compressor rings studies, there may be some incompatibility between the request for PS staff and the other responsibilities of the people concerned.
    - For target studies (Hg-jet) there seems to be a serious lack of manpower.
    - The availability of F. Voelker within the PO Group will be reviewed for progress on the horn power supply.
    - An evaluation of BD participation to evaluate instrumentation is needed by J. Bosser.
    - A Scientific Associate is needed for plasma lens studies, as an alternative to the horn.
    - A Fellow is needed to work on ionisation cooling in addition to the PS Staff working on this subject.
    - There seems to be missing AE manpower for studying the muon test line options, but this would be relieved if the test line were to be at PSI.
    - The muon test facility is much later than 2001, but it will require a great deal of effort from several groups, especially RF for the cavities.

The transparencies shown can be seen at:

B.W. Allardyce

PS Technical Meeting
TOPIC : Nufact

Summary of resources needed in 2001/2

H. Haseroth

SPL (in 2001):

CERN “standard” MANPOWER:

2 man.years (RF only – from 6 part-time

VISITORS

~ 1 man.year

STUDENTS

1 man.year

CERN “R. & D” MANPOWER

2 man.years in 2002

Note: All Manpower supposed to double every year.

REQUEST FOR RESOURCES FOR THE NEUTRINO FACTORY STUDIES
PS/RF GROUP (19/03/2001 R. Garoby)

SYSTEM	SUBJECT	RESOURCES in 2001	RESOURCES in 2002
SPL	Participation to the tests of RFQs under constructions at Saclay and Legnaro		Time & travels…
	Development of DTL and SCDTL structures	150 kCHF	200 kCHF
	Development of chopper and amplifier	50 kCHF	200 kCHF
	Beam dynamics studies and optimisation; halo studies		
	Pulsed test of superconducting cavities for reduced beta; development of servo-system for field stabilisation		100 kCHF
	Modification of LEP hardware for pulsed operation; tests	50 kCHF	
	Development of SC reduced beta cavities	300 kCHF *(SL)*	500 kCHF *(SL)*
High gradient RF cavities for muons	Prototype system (114 MHz cavity modified for 88 MHz), with 2 MW driver amplifier in North Hall RF test place	150 kCHF *(+ 125 kCHF from ASACUSA)*	50 kCHF
	SC solenoid development	50 kCHF	400 kCHF
	Design of a real system *		50 kCHF
	Amplifier dev. with industry *		???
200 MHz system for RLA 1	Development and test of SC cavity in an horizontal cryostat	0 kCHF *(paid by Cornell…)*	500 kCHF *(SL)*
CERN "**standard**" MANPOWER**		2 man.years (RF only – from 6 part-time)	4 man.years (RF only – from 10 part-time)
VISITORS**		~ 1 man.year	> 2 man.years
STUDENTS**		1 man.year	> 2 man.years
CERN "R. & D" MANPOWER**		0	2 man.years

PDAC

(including Horst + Michel, Massimo, Elias, Roberto, etc.):

2 m/y.

The situation could drastically change depending on HARP results.

Target:

Trough test completion (H.Barbero, N. Chritin)

5 man-month

MHD tests:

6 month technical student and link to pump industry (2 month study, >~20kCHF).

Impulse transfer, cavitation shock waves recognition: tests and simulation under preparation.
Needs: test "and purchase" of these codes (AF), strain gauges (collab from the states ? AF received the cost estimate for a strain gauges system: including
readout ~ 60kCHF.

5 man-month

Jacques Lettry:	3 man-month
A:Fabich (Doct. Stud.)	12 man-month
A. Bernadon (Techn. Stud.)	6 man-month

Target development resources for 2001/2002

This is people in addition to those presently working and materials which has to be committed in 2001 with payment extending well into 2002.

1 Physicist post doc. for setting up test experiments.
0.25 Senior target and laboratory technician
0.25 Mechanics (service contract)

0.15.1 Metallurgist

Budget personnel

1 FTE Designer engineer (service contract)	12*8000	96000
1 FTE Technical draughtsman	12*5000	60000
1 FTE Physicist post doc. for calculations on target materials in general.	12*6000	72000
0.5 FTE Technical student	6*3600	21600
1 FTE Mechanics (service contract)	12*5000	60000

Budget materials

Stores		10000
Transport		2000
Travels	5*3*2000	30000
Microphone system		10000
Fiberoptic strain gauges		10000
3PC's Jet control system or for the personnel mentioned above	3*3000	9000
On-line Hg-jet chamber and pumping system. Chamber and stand may also be used for other target concepts.		100000
Total		**480600**

Horn power supply:

F. Voelker	0.4 man years
G. Grawer	0.3 man years
electrician	1.0 man years
electronician	1.0 man years

Horn

Mainly outside division

Scientific associate for plasma lens studies

40/80 MHz capture, phase rotation, cooling:

A. Lombardi	0.6
K. Hanke	0.6
B. Holzer	0.7

1 fellow, expert on beam dynamics, to work with/for Klaus Hanke on cooling experiment simulations.

Components of the cooling channel , rf cavity tests, absorber tested , solenoid designed.

Muon test line in TT1

5 MCHF + 10 m/y

Concerning the muon beam line, Bruno discussed with Roberto and it seems desirable that the group AE commits itself not only to the proton part but also to the target, horn and decay channel.

Cavities for the muon test facility

Estimate: 2 years and 1 MCHF for the first cavity

2 years and 1 MCHF for the first amplifier

0.5 MCHF per sc solenoid…

at least 4 years for a series of 5-10 systems, provided adequate manpower and money is made available

PS Technical Meeting

TOPIC : Nufact

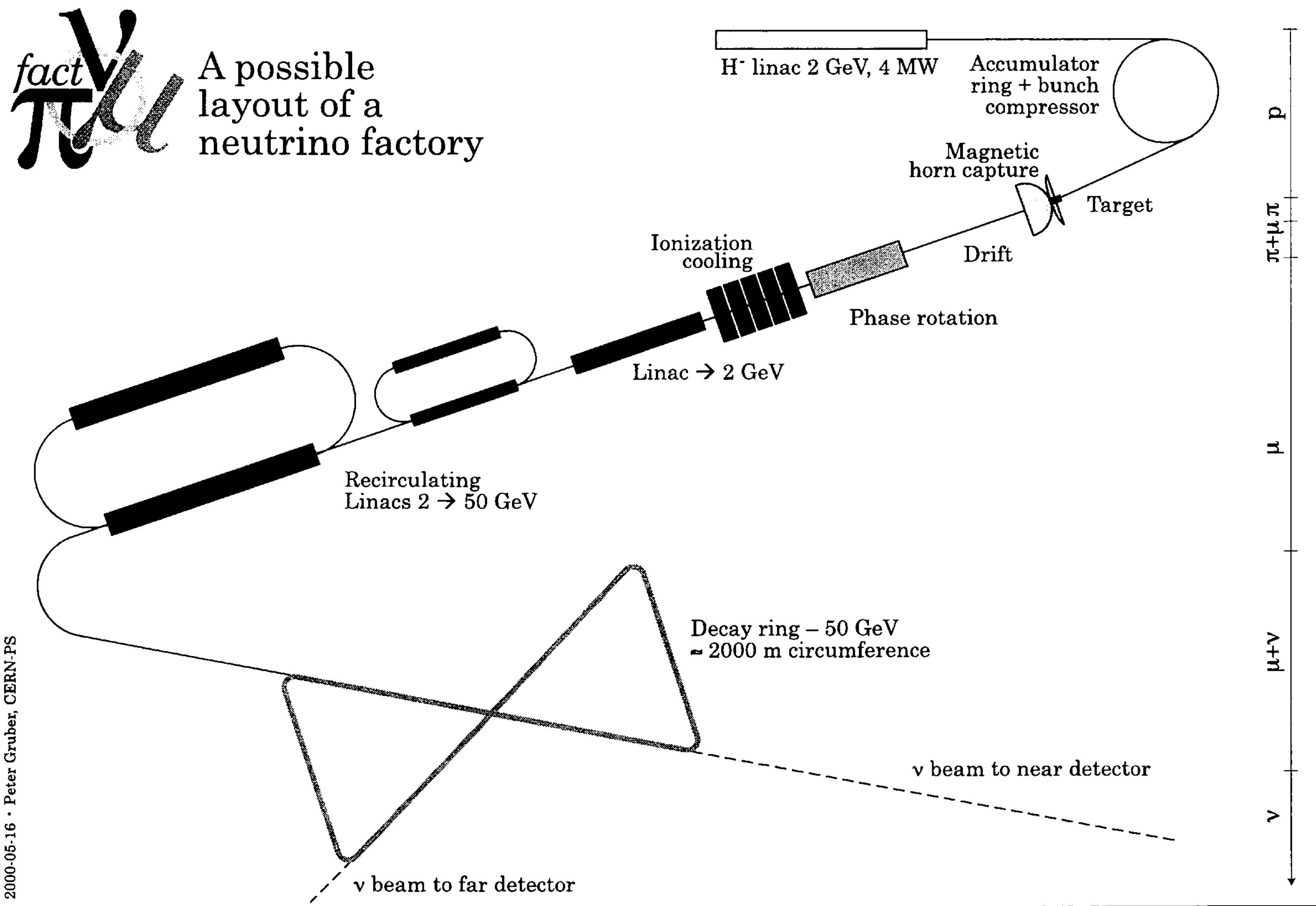
Presentation of the latest thinking

(I have 10 min for the presentation

$\Longrightarrow$ You have 1/2 min / slide)

H. Haseroth

A possible layout of a neutrino factory



There are not too many options for the basic elements: Where are we CERN-specific?

2.2 GeV Proton Driver

$\approx$350 MCHF

Target for 4 MW

Collection of pions with horn

40/80 MHz capture/cooling system

No Be windows for RF cavities

NO-Cooling scheme studied

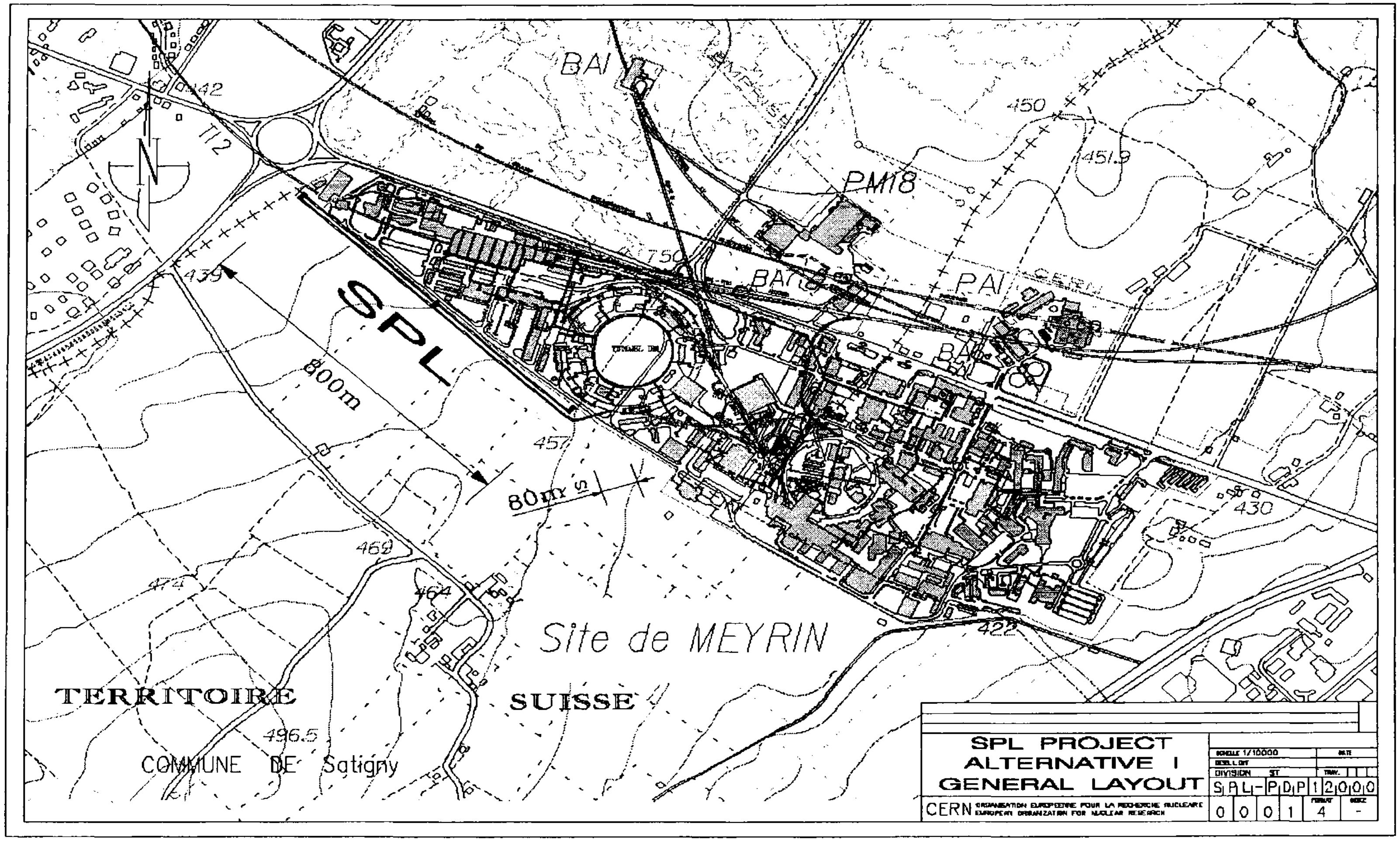
RLAs: Some discussions about acceptances

Layout on CERN site possible

Detector locations being investigated: H. Wenninger et al.

The Main Subsystems

The Linac



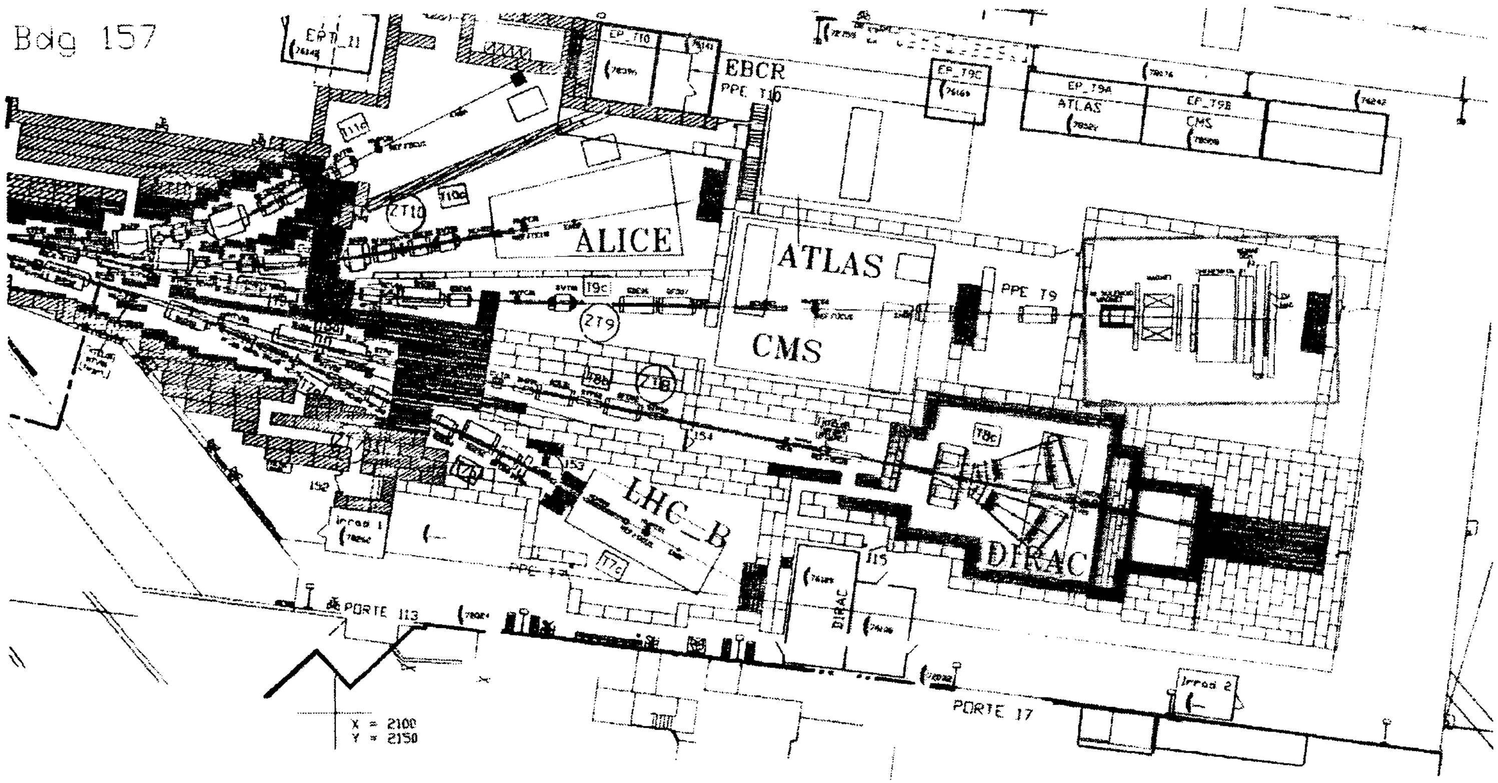
TARGET

Equipment and expertise on liquid mercury technology exists at CERN and we believe that this is the most promising direction.

Some preliminary tests have been done

Some will be done

Collaboration with BNL



Layout of the experiment to study Hadron Production for

the Neutrino Factory

and for the Atmospheric Neutrino Flux

Targets to be measured in HARP Experiment

material	thin target (cm)	thick target (cm)
Solid		
Be	0.81	40.70
C	0.76	38.00
Al	0.79	39.44
Cu	0.30	15.00
Sn	0.45	22.36
W	0.19	9.58
Pb	0.34	17.05
Cryogenic		
H2	14.36	
N2	2.18	
O2	1.59	

Thin Target = 1/50 Interaction Length
Thick Target = 1 Interaction Length

PION collection: HORN

A major advantage of horns is that the parts exposed to the beam are rather simple, inexpensive and can be radiation hard.

A horn will collect only one sign of pions.

The horn design will be rather different from those used for high-energy beams, such as CNGS and NUMI.

MUON Yield without and with Cooling

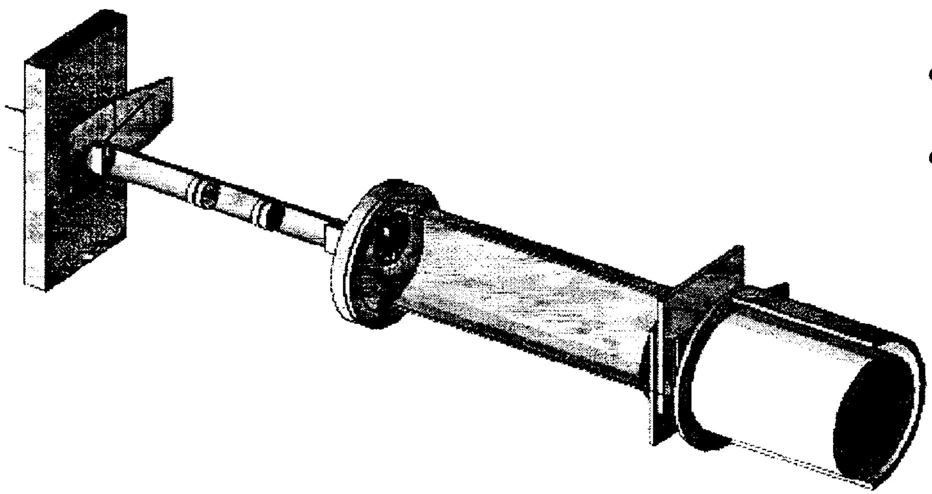
	NOCOOL	with cooling
long. emittance	0.05 eVs	0.05 eVs
rotation	6.7×10^{19}	6.7×10^{19}
44 MHz	6.8×10^{19}	
88 MHz	7.3×10^{19}	1.2×10^{21}
176 MHz	5.5×10^{19}	1.0×10^{21}

Note: Calculations have still to be made with the detailed field configurations!

MUon SCATtering experiment

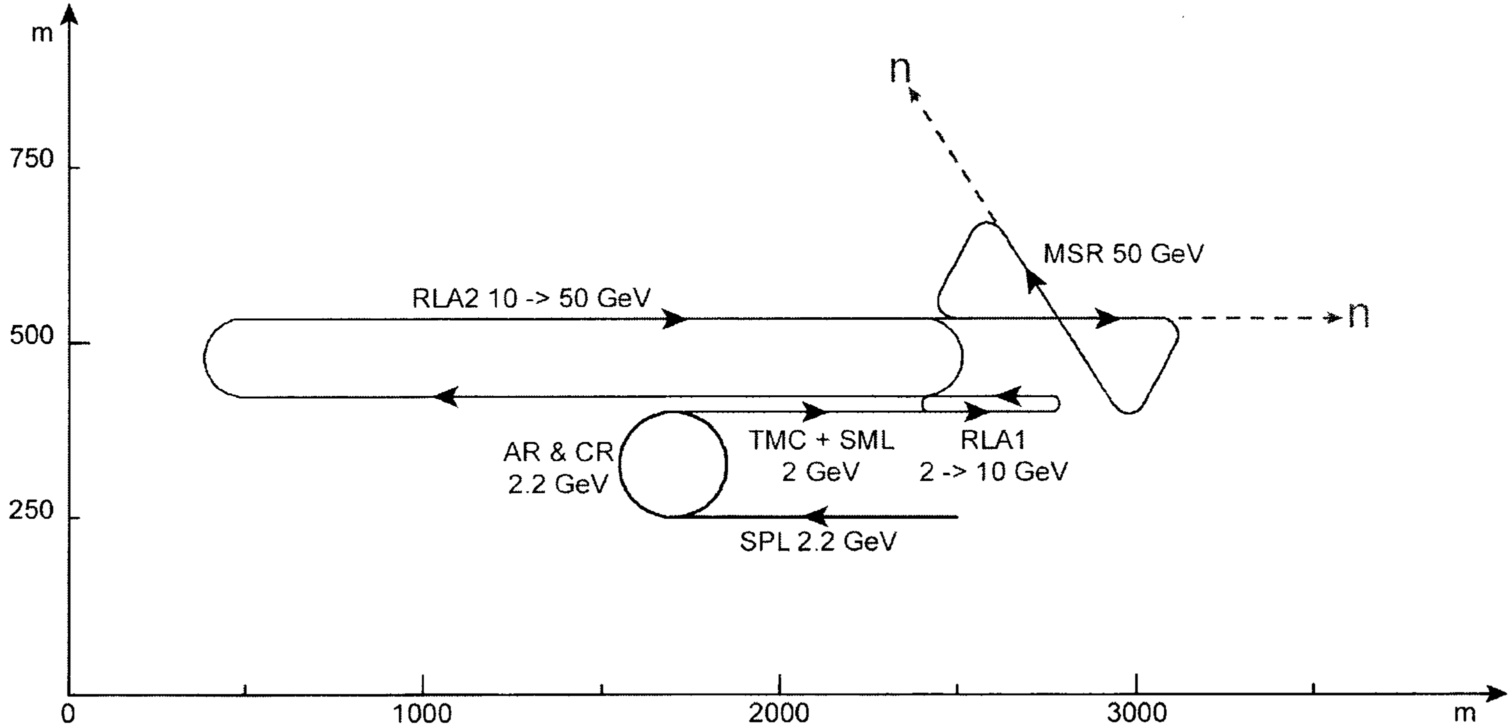
(RAL, TRIUMF, CERN et al.

- Multiple scattering of muons is important input parameter for cooling simulations
- Only 55year old electron data available
- First measurement with muons



- Compare with existing (e^-) data and Moliere theory
- Increase precision
- Input for new scattering models

Preliminary Layout of Neutrino Factory

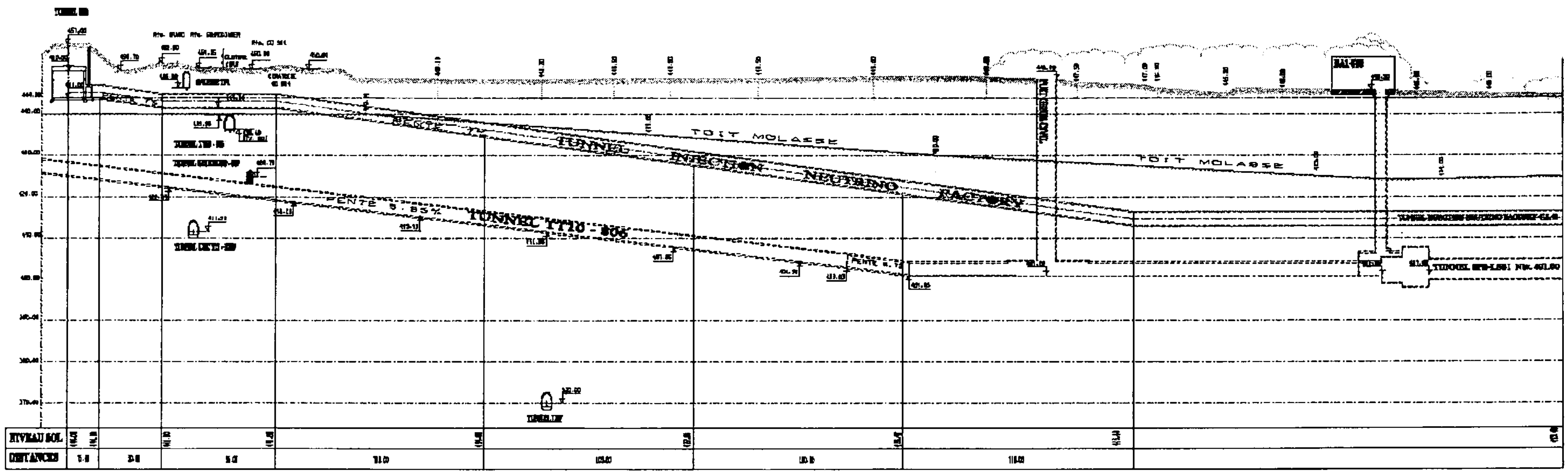


SPL: Superconducting Proton Linac
AR: Accumulator Ring
CR: Compressor Ring
TMC: Target + pion/Muon Collection

SML: Superconducting Muon Accelerator
RLA: Recirculating Linear muon Accelerator
MSR: Muon Storage Ring

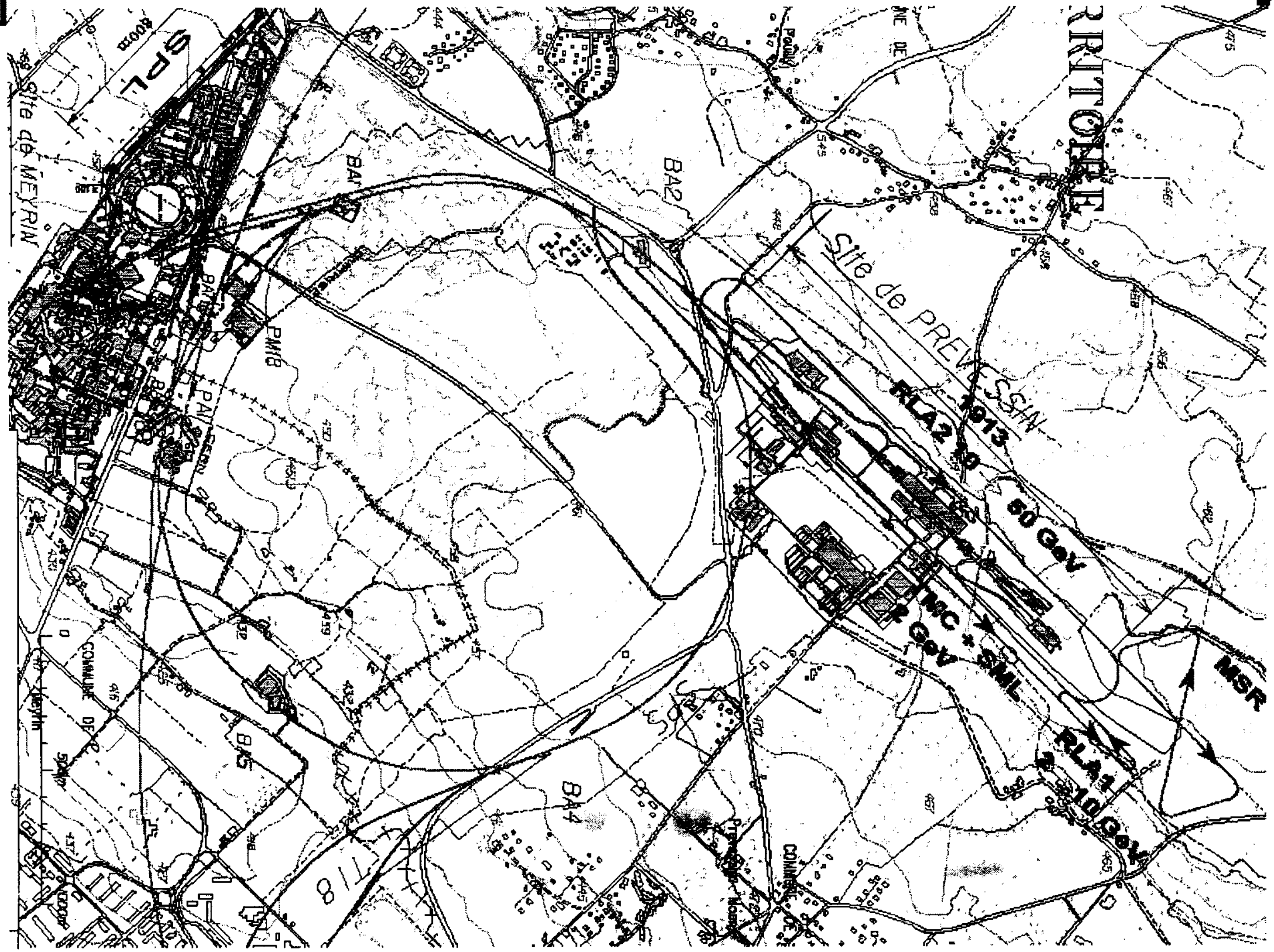
E. Keil

Preliminary Layout of Proton Transfer Tunnel



H = 1:2000 L = 1:1000

Preliminary Layout of Neutrino Factory



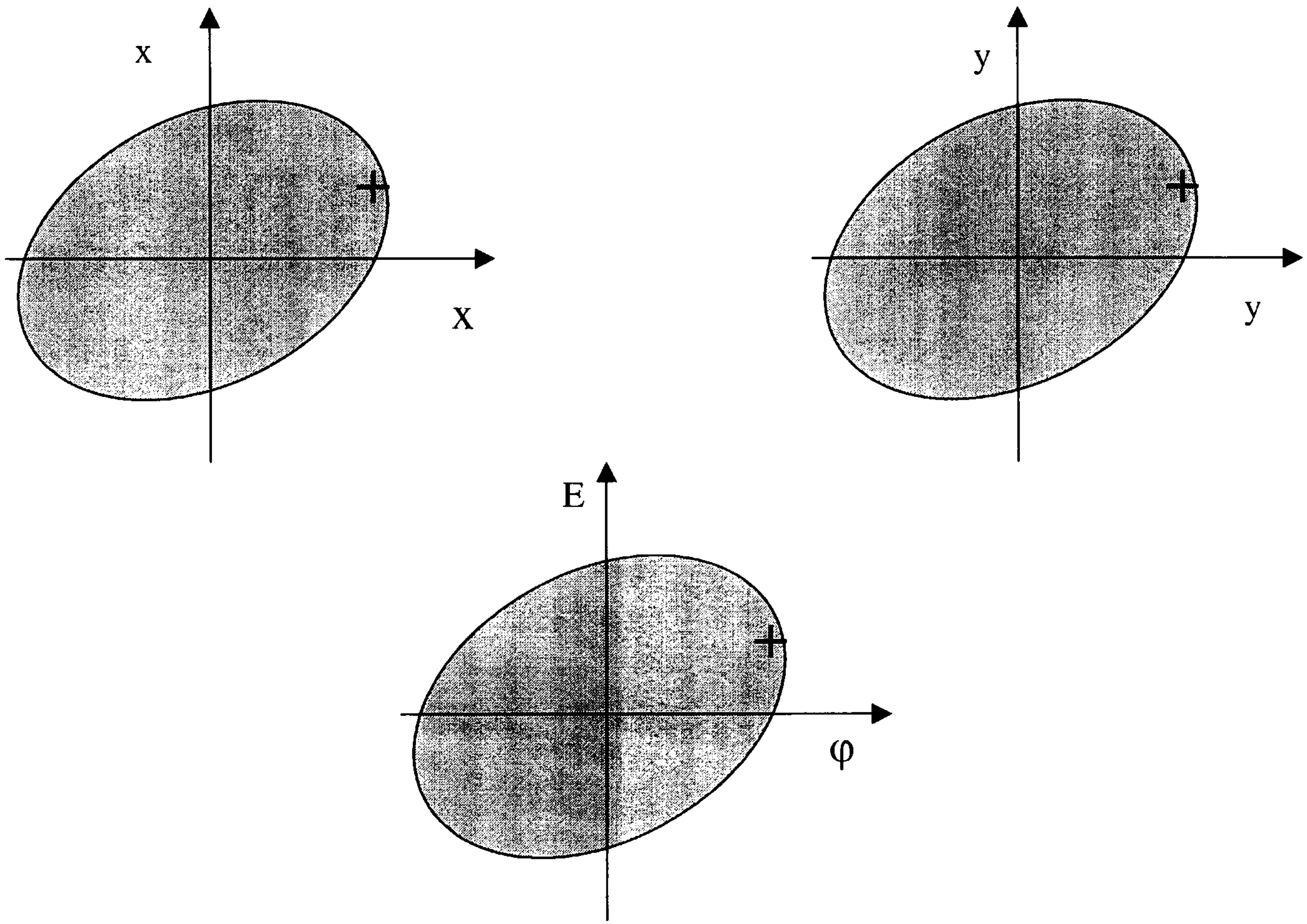
Conclusions

- *There is a scheme for a neutrino factory that seems well adapted to CERN. It is by no means final and requires still a lot of work in order to assess the feasibility.*

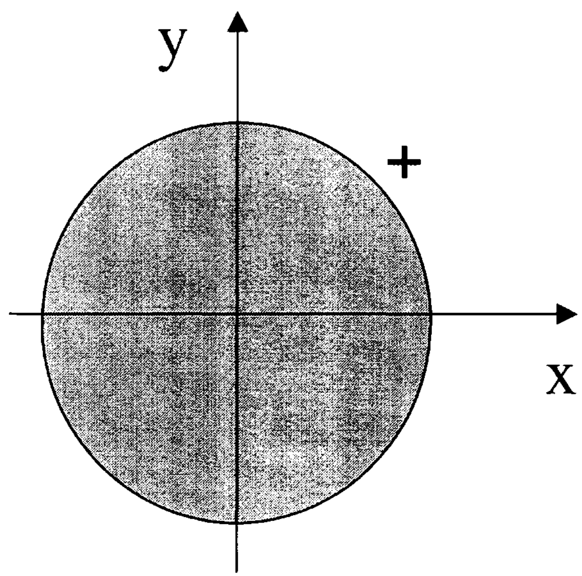
- *Future work may well show that some elements of this scenario need substantial modification or even replacement by other components.*

- *The results of the HARP experiment expected for this year may also provoke some modifications.*

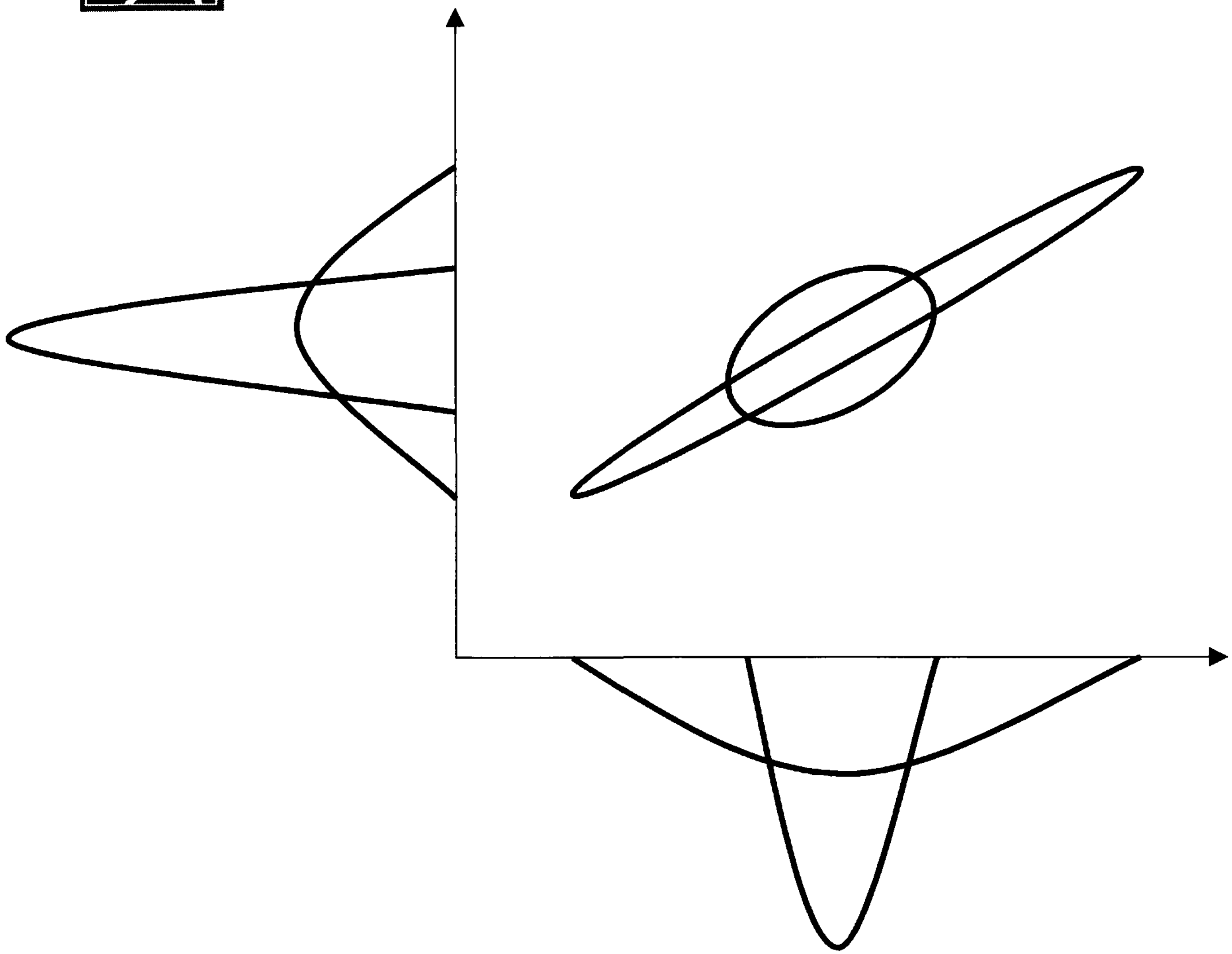
Take one particle at the edge of the distribution...



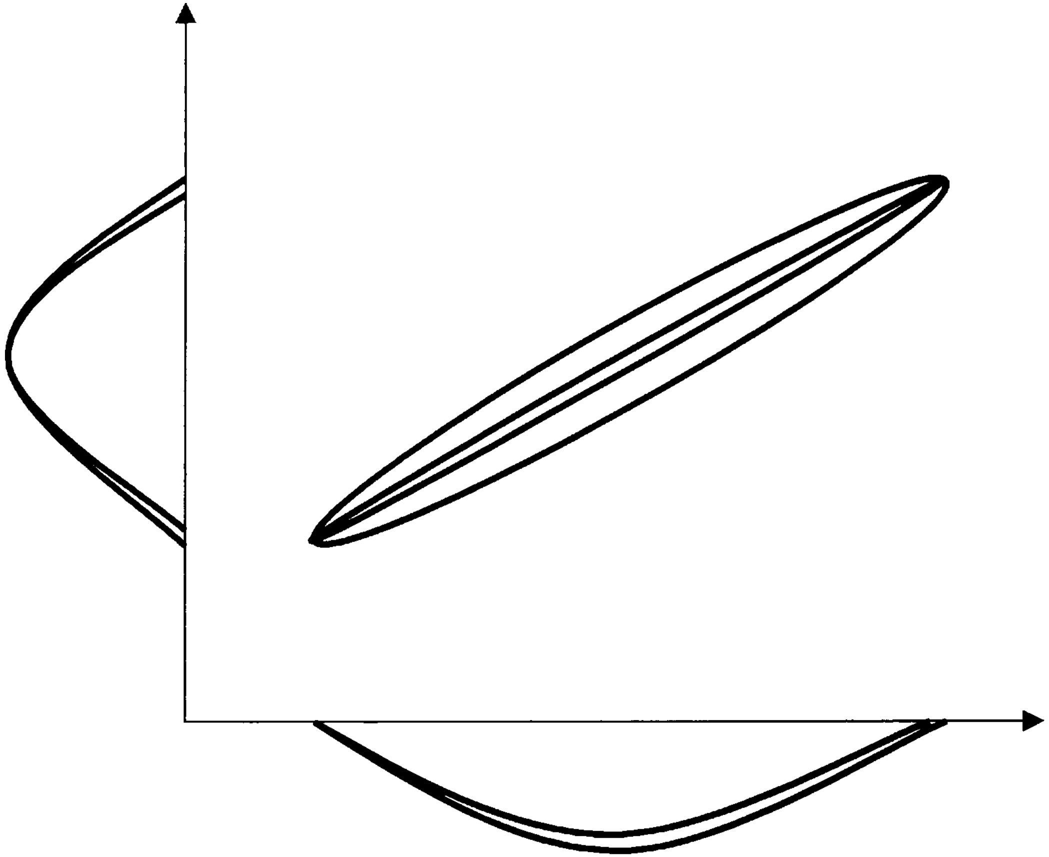
…it is obviously NOT in the acceptance of a round vacuum chamber



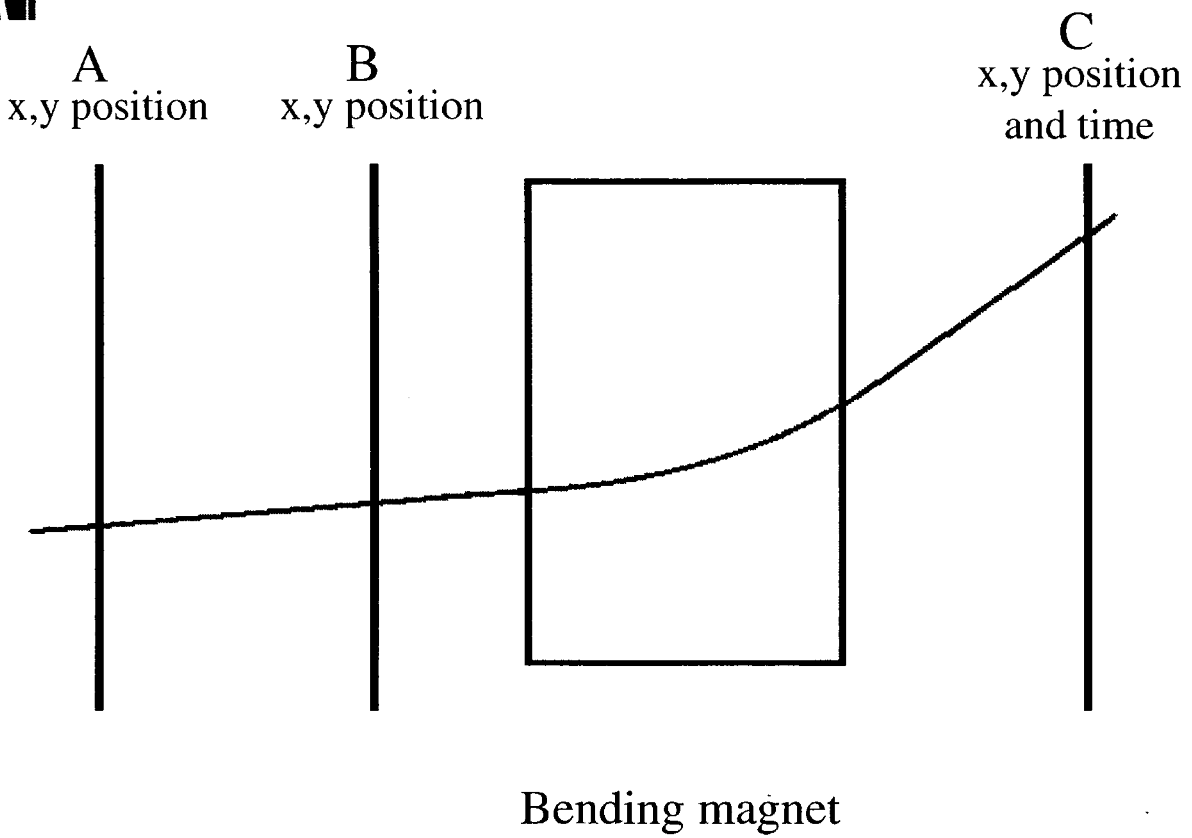
Example in a 2D case:
Do not claim the red ellipse is “cooled”!



Example in a 2D case:
Red ellipse IS "cooled"!



How to measure the 6D coordinates of a single particle?



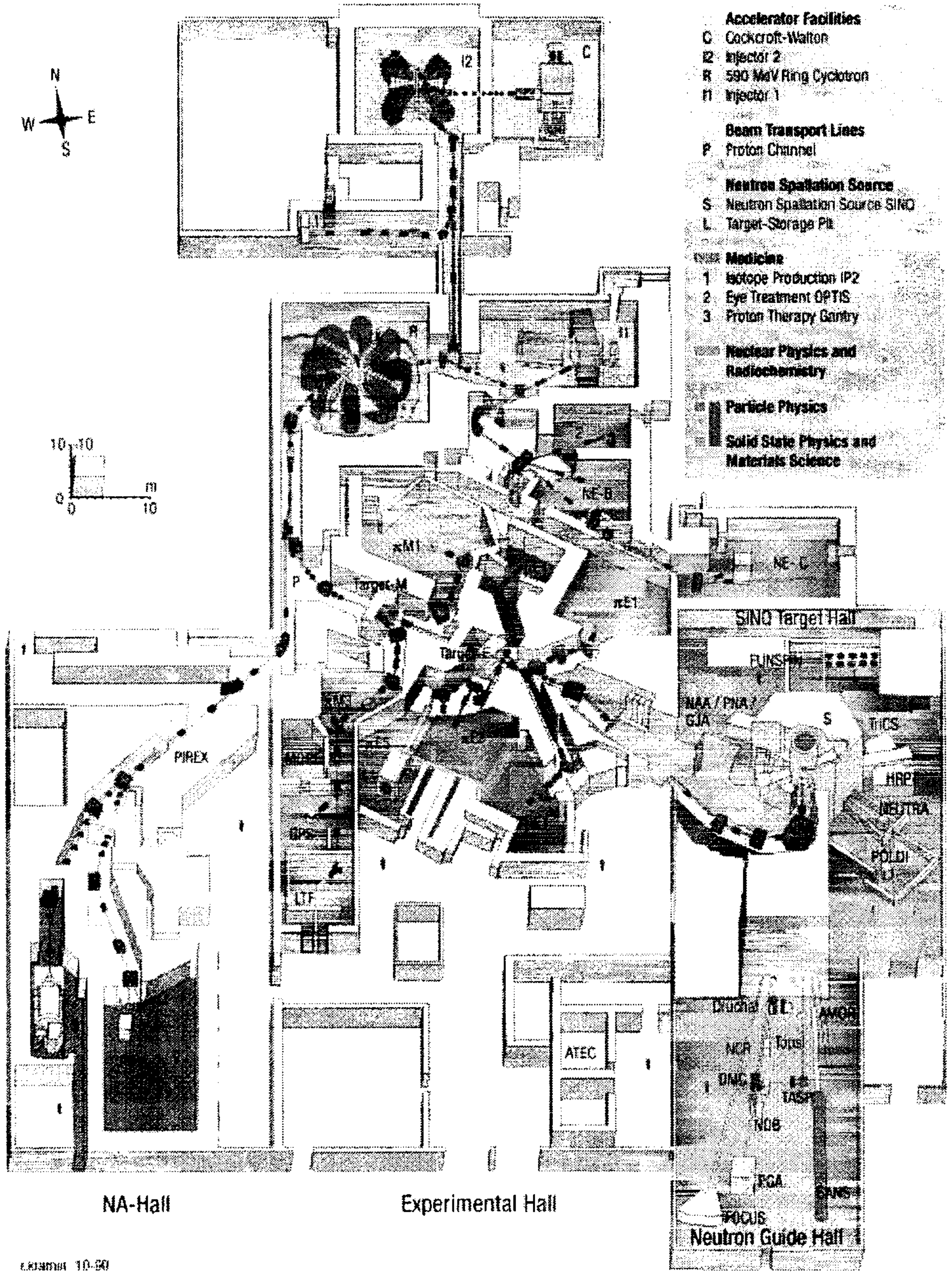
A and B gives transverse coordinates, C (together with the fieldmap of the bending magnet) the longitudinal coordinates. Needs measurements which work in the specific environment and are "transparent"…
Note: They are not in rf or solenoidal fields!

Conclusion at the Workshop on Instrumentation for Muon Cooling Studies at the Imperial College, London:

1) Abandon the idea of multiparticle measurements

2) Concentrate on what can work for single particles in the neighborhood of rf, solenoidal fields and some other radiation…

Make it sufficiently transparent!


Accelerator Facilities
C Cockcroft-Walton
I2 Injector 2
R 590 MeV Ring Cyclotron
I1 Injector 1
Beam Transport Lines
P Proton Channel
Neutron Spallation Source
S Neutron Spallation Source SINQ
L Target-Storage Pit
Medicine
1 Isotope Production IP2
2 Eye Treatment OPTIS
3 Proton Therapy Gantry
Nuclear Physics and Radiochemistry
Particle Physics
Solid State Physics and Materials Science
N
W
E
S
NE-B
NE-C
SINQ Target Hall
PIREX
ATEC
NA-Hall
Experimental Hall
Neutron Guide Hall

SPL

SPL STUDY GROUP MEMBERS:

B. Autin, K. Bongardt (FZ-Juelich - D), R. Cappi, F. Caspers, E. Chiaveri, R. Garoby, F. Gerigk, H. Haseroth, C. Hill, A. Krusche, D. Kuchler, M. Lindroos, A. Lombardi, R. Losito, H. Ravn, R. Ryne (Los Alamos), R. Scrivens, M. Silari, M. Vretenar, J. Tuckmantel, M. Paoluzzi, M. Poehler, J. Pedersen

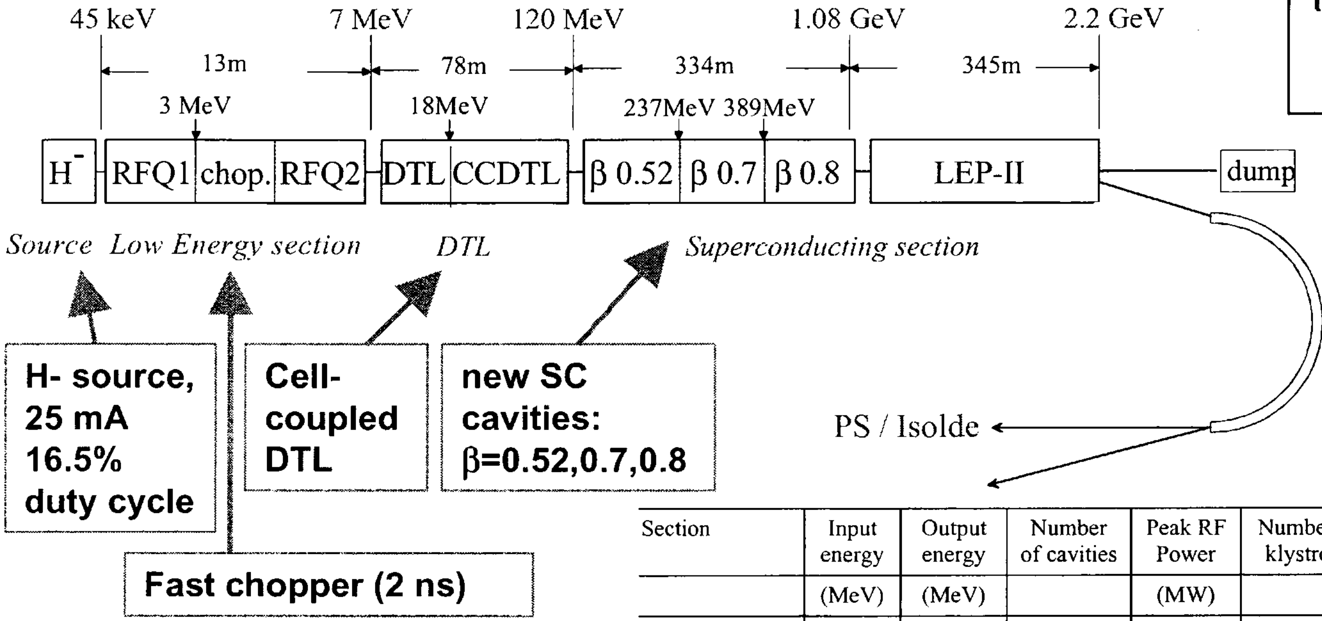
COLLABORATION:

CEA (DAPNIA @ Saclay) - CNRS (IN2P3 @ Orsay & Grenoble)

SPL beam specifications

	Parameter	Value	Unit
MEAN PARAMETERS	Ion species	H-	
	Kinetic energy	2.2	GeV
	Mean current during the pulse	11	mA
	Duty cycle [mean beam power]	16.5 [4]	% [MW]
	Pulse frequency	75	Hz
	Pulse duration [number of H- per pulse]	2.2 [1.51 E 14]	ms [H^-/pulse]
FINE TIME STRUCTURE	Bunch frequency [minimum distance between bunches]	352.2 [2.84]	MHz [ns]
	Duty cycle during the beam pulse [number of successive bunches/number of buckets]	61.6 [5/8]	%
	Number of bunches in the accumulator [total number of buckets – empty buckets]	140 [146-6]	
	Maximum bunch current [maximum number of charges per bunch]	19 [3.3 E 8]	mA [H^-/bunch]
BUNCH CHARACTERISTICS	Bunch length (total)	~ 0.2	ns
	Energy spread (total) [relative momentum spread (total)]	~ 0.5 [~ 0.2 E-3]	MeV
	Normalized horizontal emittance (1σ)	0.6	µm
	Normalized vertical emittance (1σ)	0.6	µm
	Energy jitter during the beam pulse	Within +- 0.2	MeV
	Energy jitter between beam pulses	Within +- 2	MeV

Detailled in the SPL Conceptual Design Report (CERN 2000-012)

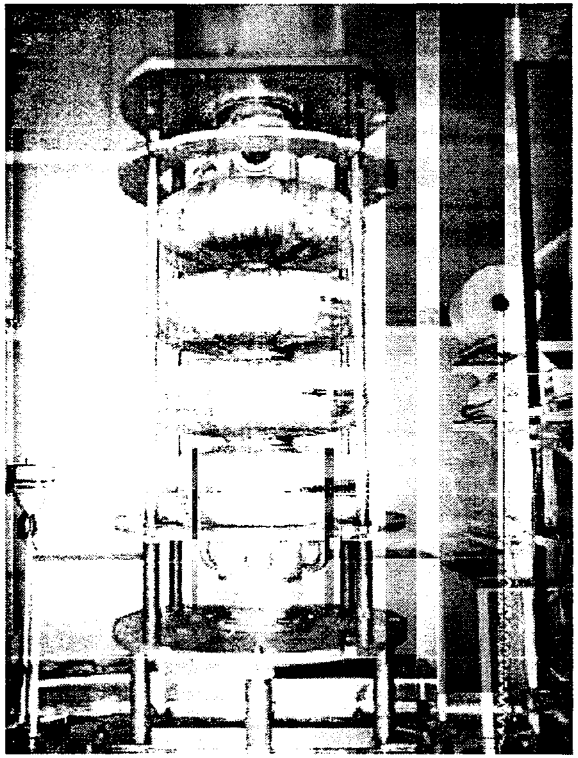


RF system:
- **freq.: 352 MHz**
- **ampli.: tetrodes and LEP klystrons**

Careful beam dynamics design, large apertures to avoid halo formation and beam losses (50 M particles + mismatch ⇒ OK)

Section	Input energy	Output energy	Number of cavities	Peak RF Power	Number of klystrons	Number of tetrodes	Length
	(MeV)	(MeV)		(MW)			(m)
Source, LEBT	–	0.045	–	–	–	–	3
RFQ1	0.045	2	1	0.3	1	–	2
Chopper line	2	2	2	–	–	2	6
RFQ2	2	7	1	0.5	1	–	5
DTL	7	120	100	8.7	11	–	78
SC – reduced β	120	1080	122	10.6	12	74	334
SC – LEP	1080	2200	108	12.3	18	–	345
Debunching	2200	2200	8	–	1	–	26
TOTAL			334	32.4	44	76	799

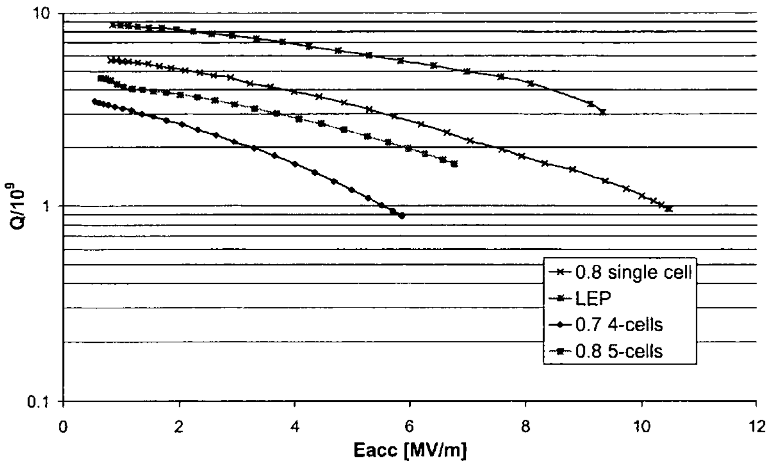
Superconducting cavities



The β=0.7 4-cell prototype

☆ CERN technique of Nb/Cu sputtering for β=0.7, β=0.8 cavities (352 MHz):

- ⇨ excellent thermal and mechanical stability
- ⇨ (very important for pulsed systems)
- ⇨ lower material cost, large apertures, released
- ⇨ tolerances, 4.5 °K operation with $Q = 10^9$



☆ Bulk Nb or mixed technique for β=0.52 (one 100 kW tetrode per cavity)

RF and Superconducting cavities Parameters

Section	design beta	Gradient [MeV/m]	N. of cells/cavity	Cryostat length [m]	Input Energy [MeV]	Output Energy [MeV]	N.of cavities	N.of cryostats	N.of tubes	RF Power [MW]	Length [m]
1	0.52	3.5	4	5.76	120	237	42	14	42 T	1.3	101
2	0.70	5	4	8.46	237	388	32	8	32 T	1.7	80
3	0.80	9	5	11.29	388	1085	48	12	12 K	7.7	153
4	1	7.5	4	11.29	1085	2240	108	27	18 K	12.7	357
TOTAL							272	68	30 K + 74 T	23.4	691

NOTES:

- distance between cryostats (for focusing doublets) is 1.49 m all along the linac
- sections 1 and 2: power tetrodes are preferred to help the operation of field regulation loops and improve beam stability
- section 3: 4 cavities/klystron
- section 4: 6 cavities/klystron

Ongoing activities

ITEM	MAIN THEMES
H- source	Studies in collaboration
Chopper (Los Alamos / CEA-Saclay)	Test structure and prototype driver
RFQ(s) (CEA-Saclay / INFN Leganro)	Stay informed
RT Linac [DTL (CEA-Saclay) etc…]	- Test prototype components for DTL structures - Analyse extension to 240 MeV
SC cavities	- High power & pulsed test of multi-cell beta=1, 0.8 & 0.7 - Test fabrication techniques for mono-cell beta=0.52
Klystrons and power converters	Test of pulsed operation
Servo-systems for pulsed operation of SC cavities	Continue the study, using the results from the pulsed tests
Beam dynamics (CEA / Los Alamos / KFZ-Juelich)	Refine the design / analyse alternative solutions
Coordination with users – Refinement of specs.	- Neutrino Factory - New users (Conventional "super neutrino beams", Physics with stopped muons,…) - Plan for upgrade of high intensity proton beams at CERN - ISOLDE / EURISOL

Budget for 2001

South Hall test place (100 kW @ 352 MHz)	50 kCHF
DTL structures prototyping	100 kCHF
Chopper development	50 kCHF
Test of LEP klystron in pulsed mode	50 kCHF
Development of reduced beta Superconducting cavities	300 kCHF
TOTAL	550 kCHF

STATUS AND PLANS FOR THE NUFACT TARGET WORK
DRAFT 03/04/01

PION PRODUCTION TARGET.

PION COLLECTOR HORN.

SPENT BEAM ABSORBER.

CERN WORKING GROUP

INTERNATIONAL CONTACTS

PLANS FOR 2000/2001

BUDGET FOR 2000-

CERN WORKING GROUP

AUTIN, Bruno. PS/PP, Pulsed target

BALL, A. EP, Horn design

BERNADON, Audrey. PS/PP, Technical student on Hg-Jet

BRUNO, Luca. SL/BT ,Target calculations

FABICH, Adrian. PS/PP, Thesis student on Hg-jet target

GRAWER, Gregor. PS/PP

GILHARDONI, Simone. PS/PP, Horn and pion collection

HAUVILLER, Claude. LHC/CRI ,Beam dumps. Back 1 august 2000

KURTYKA, Tadeusz. EST/ME

LETTRY, J. PS/HP, Target construction and tests

JOHNSON, C., PS/HP Member of steering group

MAUGAIN, Jean-Marie. EP/EOS, NGS Horn design

PERAIRE S. SL/BT NGS, target

RAVN, Helge. EP/IS, Targetry

SGOBBA, S. ST/SM, Metallurgist

SILARI, Marco. TIS/RP, Shielding calculations

SIEVERS, Peter. LHC/MTA, Target calculations

STEVENSON, G. TIS/RP

VASSILOUPOULOS, N. EP/HL, Pion production and collection

VLACHOUDIS, V. SL

VOELKER, F. PS/PO, Target and horn power supplies

INTERNATIONAL CONTACTS

The following European laboratories have agreed to be potential partners:

RAL. Mechanical design and stress calculations in solid targets. Paul Drumm.

PSI. Consultancy on liquid Mercury technology and metallurgical analysis. G. Bauer.

LCMI Grenoble. Injection of molten metal into a high magnetic field. Walter Joss.

MOL. Interested in participation in molten metal target technology. Petre Kupschus.

Grenoble, Pi Production calculations Johan Collot

University of Munich. Simulations of Laser induced pion production. Dieter Habs.

GSI Darmstadt. Potential partner for developing molten Li target technology since they have to acquire it for their future HI fragmentation projects. Hans Geissel.

GANIL Caen. Potential partner for developing molten Li target technology since they have to acquire it for their future HI fragmentation projects. Antonio Carlos C. Villari.

INFN Legnaro. Potential partner for developing molten Li target technology since they may have to acquire it for their fission product accelerator. Luigi Tecchio.

CRS4 Center of Advanced Studies Calgary. Numerical methods Georgio Foti.

BINP Novosibirsk, Molten metal jet formation, Seliverstov G.,?

Technicatome, Consultancy on liq. metal handling, Thomas, Sala

PION PRODUCTION TARGET.

TARGET CONCEPTS STUDIED OUTSIDE CERN

1. Solid radiation cooled Tantalum or Tungsten metal is being theoretically studied at RAL.
   Very large circumference.
   Question of lifetime limitations due to radiation damage?.
   Radioactivity control problematic?
   New technology?

2. Solid radiation cooled Graphite is being studied theoretically and experimentally in the US.
   Graphite evaporation rate and proton pulse induced stress may limit the target power absorption to 300 kW?

TARGET CONCEPTS STUDIED AT CERN

3. Liquid metal-jet targets simulated with Mercury are being studied theoretically and experimentally at CERN and BNL.
   Jet formation and stability?
   Cooling power capability determined by jet speed (>10 m/s) and diameter (2 – 20 mm)?
   The hydro-dynamic interaction of the jet with a proton beam pulse and a magnetic field?

4. Molten metal target working like a Li-lens with a current pulse for pion collection.
   Large additional ohmic power deposition in the target?
   Questions around the electrical contacts to the jet?

5. Water or liquid metal cooled target consisting of a (fluidised) bed of 2mm Ta spheres presently under theoretical study at CERN.
   Power density in windows?
   Mechanical and chemical corrosion?
   Heat transfer calculations?

PION COLLECTOR HORN.

Theoretical beam optical studies at CERN of the best shape of a horn which can be adapted to the target dimensions and the following accelerator parts is in progress.
Collaboration with the NGS horn group has started on design and construction of a suitable test horn, its power supply as well as use and refurbishing of their test laboratory.
Diameter of the inner conductor and the accommodation of the target and its plumbing?
Cooling on the inner conductor of the horn?
Stress limit due to 50 Hz repetition rate?
Spent beam exit?

SPENT BEAM ABSORBER.

Not much work done yet but it seems to be easier to accommodate it with a horn than with a solenoid?

Schedule of the CERN of 1st quarter 2001 Hg-jet experimental tests

January	Off-line tests of the Hg pump and jet
January	Delivery and test of the endoscope and camera
February	Commissioning of a Hg-jet in a 1.5 T CERN magnet
February	Test of a Hg-jet in a 13T magnet at Grenoble
February	**Planning and request of a Hg-jet test in a 20 T Grenoble magnet**
February	**Final design of the chamber for the Hg-trough test**
April?	**Hg-trough installation and feasibility test at ISOLDE**
April?	**Hg-trough tests at ISOLDE**

Plans for Year 2001/2002

1. Make a plan for which parameters of solid and liquid metal targets should be experimentally determined, what equipment is needed for their measurement.
2. Identify and do the hydrodynamic calculations the experimental results should be compared to.
3. Start planning the in-beam tests of the Hg-jet in the ISOLDE target area.
4. Design the vacuum vessels and support including Hg circulation and on-line distillation needed for the in-beam tests at ISOLDE.
5. Building and off-line testing of the in-beam set up.
6. Request and perform on-line tests of the Hg jet in the ISOLDE proton beam.
7. Set up a horn test laboratory (power supplies)
8. Design and construct a horn prototype.
9. Start planning of a dedicated NuFACT test area at CERN.
10. Start designing a prototype target and its connection to the neutrino collector.

TARGET DEVELOPMENT RESOURCES FOR 2001/2002.

The personel is in addition to those presently working. Personel and material is planned to be committed in 2001 with payment extending well into 2002.

Budget personel

	Sfr	
1 FTE Designer engineer	12*8000	96000
1 FTE Technical draughtsman(service contract)	12*5000	60000
1 FTE Physicist post doc. for calculations on target materials in general.	12*6000	72000
1 FTE Physicist post doc. for experimental work on solid targets.	12*6000	72000
1 FTE Mechanics (service contract)	12*5000	60000
0.5 FTE Technical student	6*3600	21600
0.5 FTE Electro mechanical mounting of horn power supplies (service contract)		45000

Budget materials

Stores		10000
Transport		2000
Travels	5*3*2000	30000
Microphone system		10000
Fiberoptic strain gauges		20000
3PC's Jet control system or for the personel mentioned above	3*3000	9000
Construction of horn for test		160000
On-line Hg-jet chamber and pumping system.		
Chamber and stand may also be used for other target concepts.		100000
Total		**757600**

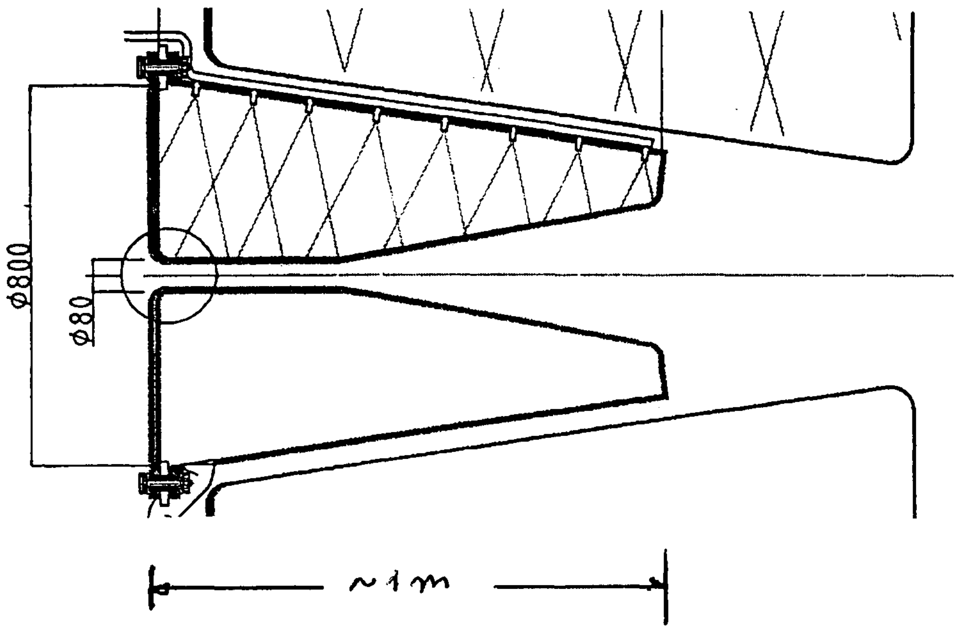
30 March, 2001, F.Völker

POWER SUPPLY
FOR
HORN

1.Horn

The study of the horn is still under way.

We refer here to the so-called 40/400 Horn (40 mm waist and 400 mm max. radius)



The electrical parameters of this Horn are

Impedance: R ≈ 0.5 mΩ and L ≈ 0.7 μH
(connection lines included)

Peak current: I_{peak} = 300 kA

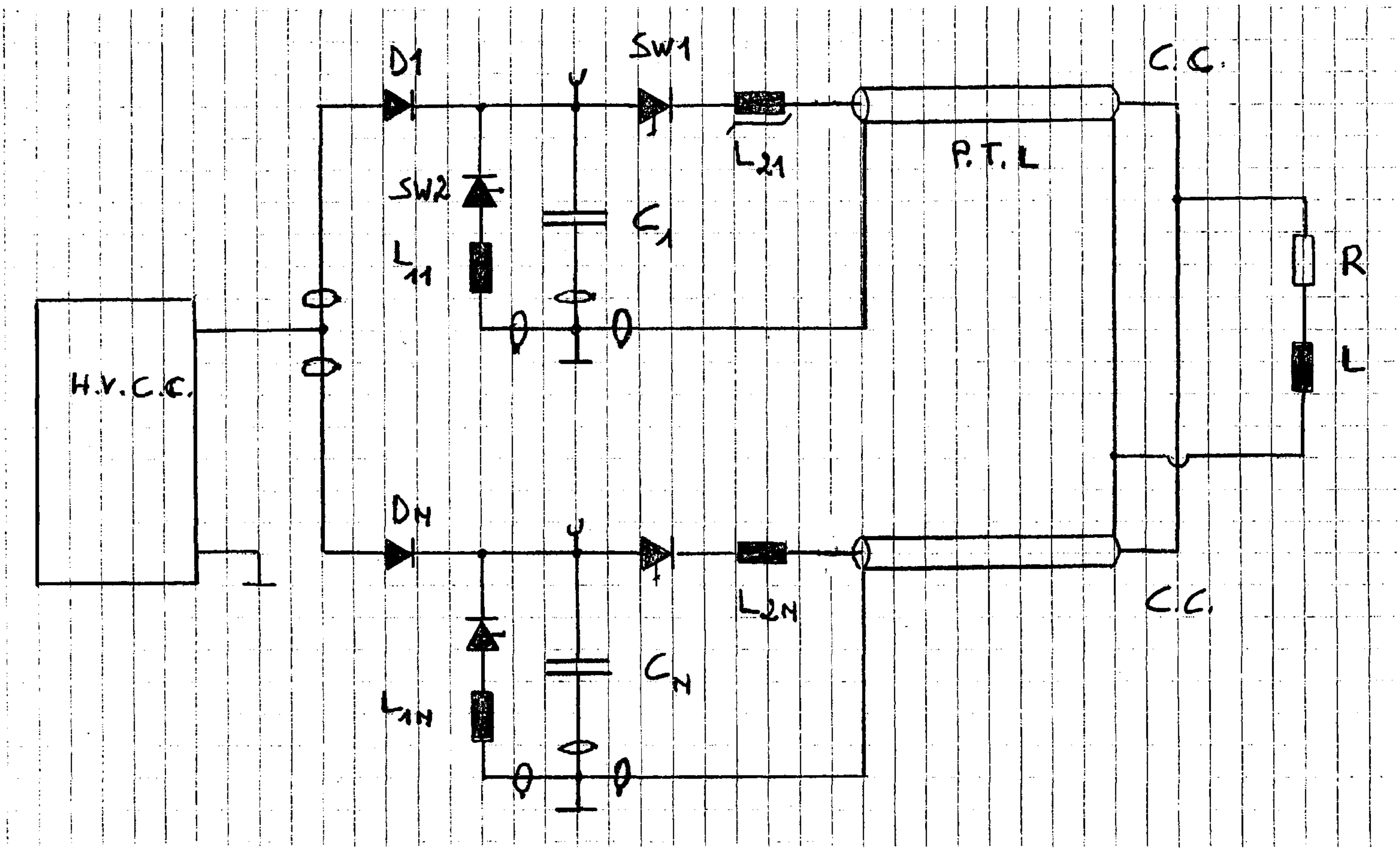
Half-sinus pulse duration: T_{pulse} ≤ 100 μs

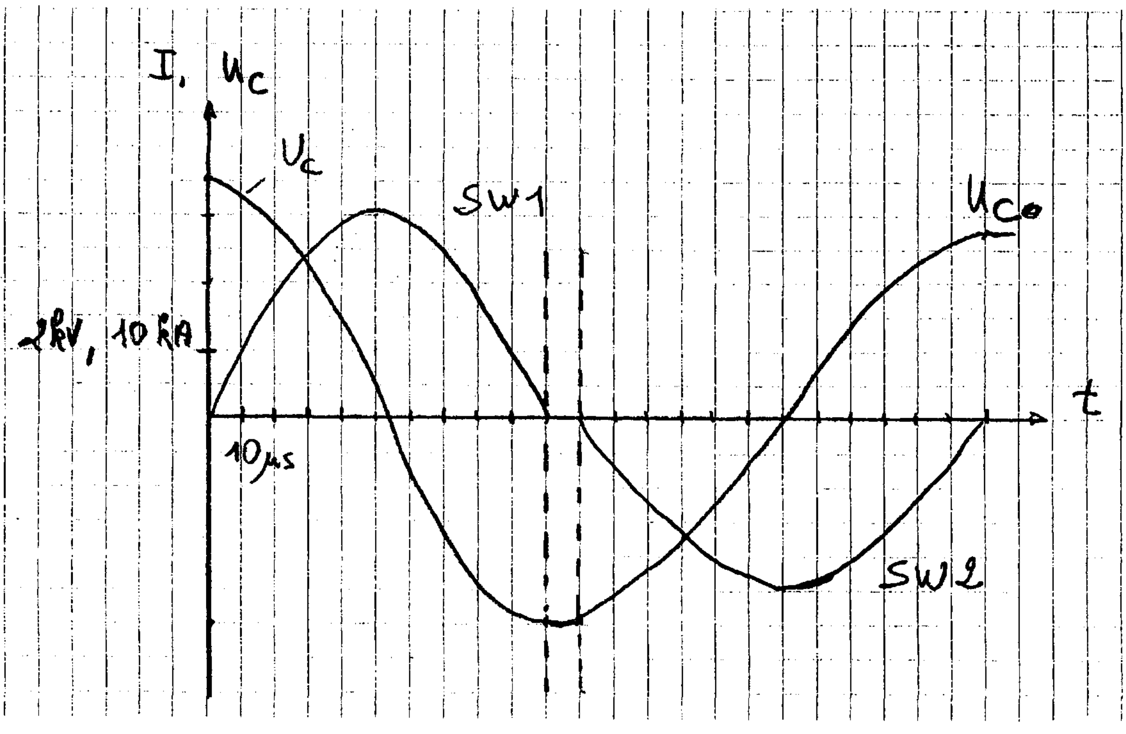
Pulse repetition frequency = 50 Hz

30 March, 2001, F.Völker

2. Horn Power Supply

2.1 Circuit layout and Operation

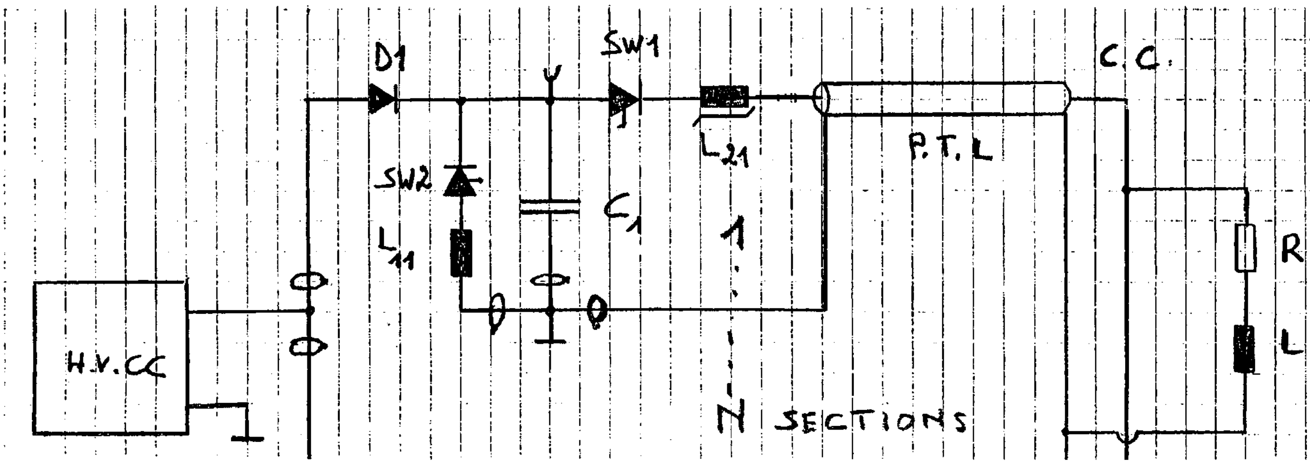




30 March, 2001, F.Völker

2.2 Composition of Power Supply

- HVCC = High-Voltage Capacitor Charger
- D_1 to D_N = Charge de-coupling Diodes
- C_1 to C_N = N Energy Storage Capacitor Banks
- SW1 = Main Thyristor Switch
- SW2 = Energy-Recovery Thyristor Switch
- Gate Drive circuits for SW1 and SW2
- Water cooling System of thyristor switches
- L_{11} to L_{1N} = Energy-Recovery Inductances
- L_{21} to L_{2N} = di/dt limiting Saturable Reactors
- P.T.L.= Pulse Transmission Lines
- C.C.= Cable Collector and Strip-Line
- Voltage and Current Sensors
- Control, Monitoring, Protection Electronics
- R, L = Horn or Dummy-Load.



2.3 Preliminary Data of Horn Power Suppy

R_{load} = 0.5 mΩ
L_{load} = 0.7 μH
$C = \Sigma C_N$ = 1440 μF

δ = 357.14 Hz [damping factor R/(2L)]
ω = 31497 Hz [frequency $(LC)^{-1/2}$]
ω_o = 31495 Hz [frequency $(\omega^2 - \delta^2)$]
T_{pulse} = 99.75 μs (pulse duration π/ω_o)
$e^{-\delta T_p/2}$ = 0.9824 (pulse damping at $T_p/2$)

U_C = 6733 V (E-storage capacitor voltage)
U_{Co} = 5500 V (estimated recovery voltage)
I_C = 120 A (charge current at f_{rep}=50 Hz)
P_C = ~850 kW (ratings of capacitor charger)

I_{peak} = 300 kA
I_{RMS} = 15 kA (213 kA during T_p)
I_{AVE} = 955 A (192 kA during T_p)
$(di/dt)_{t=0}$ = 9448 A/μs
N = 10 ÷ 12 (# of capacitor + switching sections

Critical items: Switches SW1/SW2, and charger

Thyristors are assumed to be of the "distributed -gate type" with symmetric voltage hold-off.

Each switch (SW1-SW2) consists of a number of thyristors in series (3-6) [one aims to avoid having 2 assemblies in parallel].

The selection criteria concerning
- * **number of sections N** ($N=10 \div 12$)
- * **type of thyristor,**
- * **number of thyristors in series(/parallel)**

depend on the:
- **Characteristic of capacitors (KVAr, etc.)**
- **Peak repetitive current per section (I_{peak} /N).**
- **RMS current/section [$I_{peak} \sqrt{(T_p/T_{rep})} / (\sqrt{2}\, N)$].**
- **Losses [$P_{th} = f_{rep} \int [i(t) (V_o + r_d\, i(t))]$, cooling**
- **Mean temperature θ_m and $\Delta\theta$ of junction**
- **Repetitive $\int i^2\, dt$ of thyristor [$T_p (I_{peak}/(\sqrt{2}\, N))^2$]**
- **Repetitive di/dt of thyristor ($> I_{peak}\, \omega_o /N$)**

ET CETERA

2.4 Power Supply for first Horn Tests:

I_{peak} = 300 kA, $T_p \approx$ 100 μs, $f_{rep} \approx$ 1 Hz
(higher f_{rep} for lower I_{peak} is desirable for vibration tests)

After checking and overhaul, part of following PS owned equipment can be re-used:

- **Charge power supply 12 kV/7A (OCEM)**
- **60 capacitors 12 kV/23.4 μF (~120 available)**
- ***24 capacitors 7.5 kV/64 μF***
- ***Charge supply 4.2 kV/50 A (OCEM)***
- ***48 capacitors 4.5kV/200 μF***

The switching circuits as well as the other components, which are not part of this list, must be procured in industry and/or built at CERN.

One assumes erecting the power supply in Building BA7 and co-operating with EP division as far as building up the horn supply and testing the horns concerns.

2.5 Final Horn Power Supply

I_{peak} = 300 kA $T_{pulse} \leq$ 100 µs f_{rep} = 50 Hz

The switching circuits for the test power supply will be designed keeping in mind the ratings of the final power supply.

The proposed objective would be to make available for tests in 2002/2003 1/Nth of the final power supply, i.e.

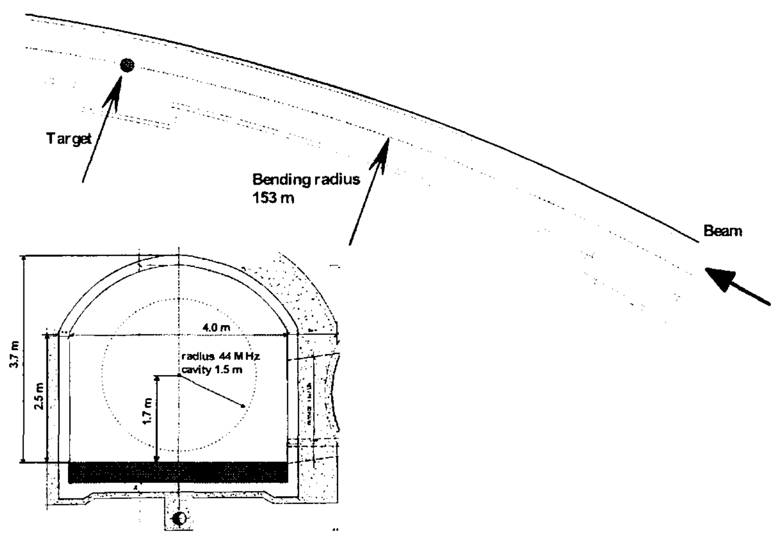
a complete prototype capacitor + switching section, and

a (< 100 kW) capacitor charger module.

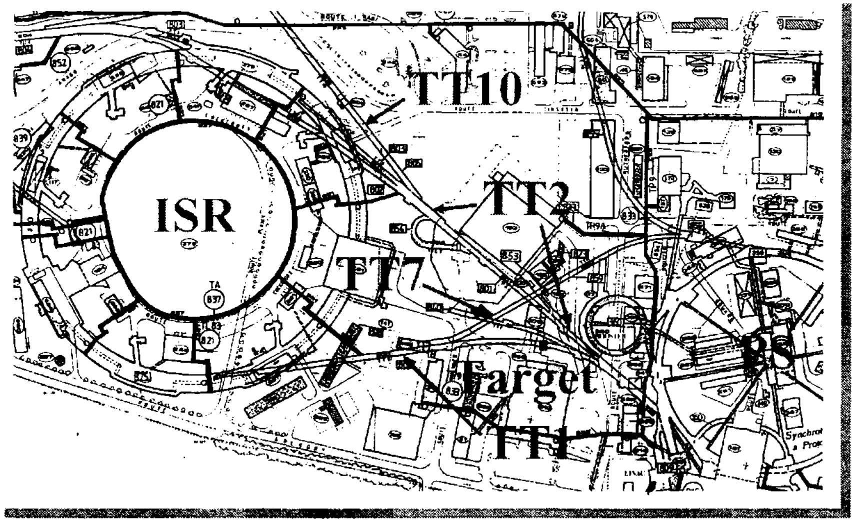
Beams and Transfer Line

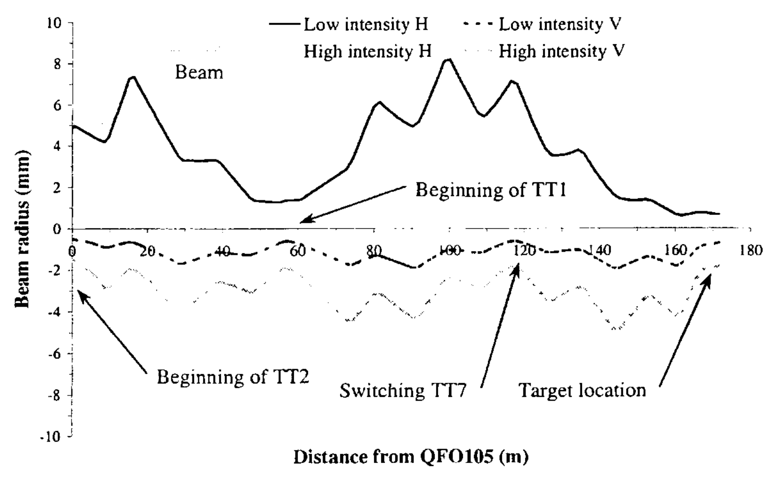
Beams

- **Standard:** $N_\mathrm{p} \approx 5 - 50 \times 10^{11}$ p/bunch, $\epsilon^*_{rms} \approx 1 - 10\ \mu\mathrm{m}$, $k_\mathrm{b} \leq 16$, $\mathrm{p_{ext}} \leq 20$ GeV/c.
- **LHC-type:** $N_\mathrm{p} \approx 1.1 \times 10^{11}$ p/bunch, $\epsilon^*_{rms} \leq 3\ \mu\mathrm{m}$, $k_\mathrm{b} \leq 72$, $\mathrm{p_{ext}} = 26$ GeV/c.
- **Extraction modes:** Fast, CT (5 turns). Longer proton pulse would be even better (single-particle measurements).



Transfer line





Hardware and Cost Estimate

Hardware

- Magnets: All available.
  - Dipoles (PS stock): 1 type `MCA`, 4 type `M100`, 12 type `M200`.
  - Correctors (LEP): 5 type `MCH` and 5 type `MCVA`.
  - Quadrupoles (LEP): 12 type `MQ`.
- Power converters: All available (PS stock and LEP) but one (switching dipole between TT2 and TT1).
- Beam Instrumentation: To be built.
  - 5 scintillating screens.
  - 1 beam current transformer.

Cost Estimate

- Power converters: 1 power converter (200 **kCHF**), 10 **kCHF**/p. c. (consolidation), cables (405 **kCHF**).

  Total estimated cost: 835 **kCHF**

- Beam Instrumentation: 1 beam current transformer (10 **kCHF**), 5 complete scintillating screen stations (40 **kCHF** each).

  Total estimated cost: 210 **kCHF**

- Others: Cost estimate of other items is taken from Preliminary Feasibility Study and Cost Evaluation of Neutrino Oscillations at CERN-PS (TT7) plus 50 % (contingency, safety margin).

  Total estimated cost: 2815 **kCHF**

Grand Total: 3860 **kCHF**

Muon Cooling

PS Technical Meeting 04/04/01

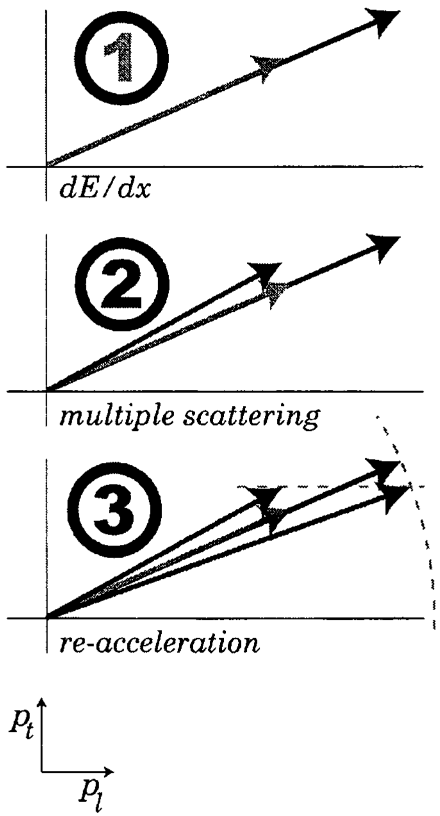
- what is (ionization) cooling?
- why do we need cooling?
- the CERN neutrino factory cooling channel
- proposed cooling experiment

K.Hanke

Ionization Cooling

Cooling := increase of normalized (transverse) phase space density

- we cannot use 'traditional' cooling techniques as in rings as the muons decay; need a *single pass* cooling scheme



1. muons loose momentum (transverse and longitudinal) in an absorber

2. multiple scattering increases the transverse momentum and works *against* cooling

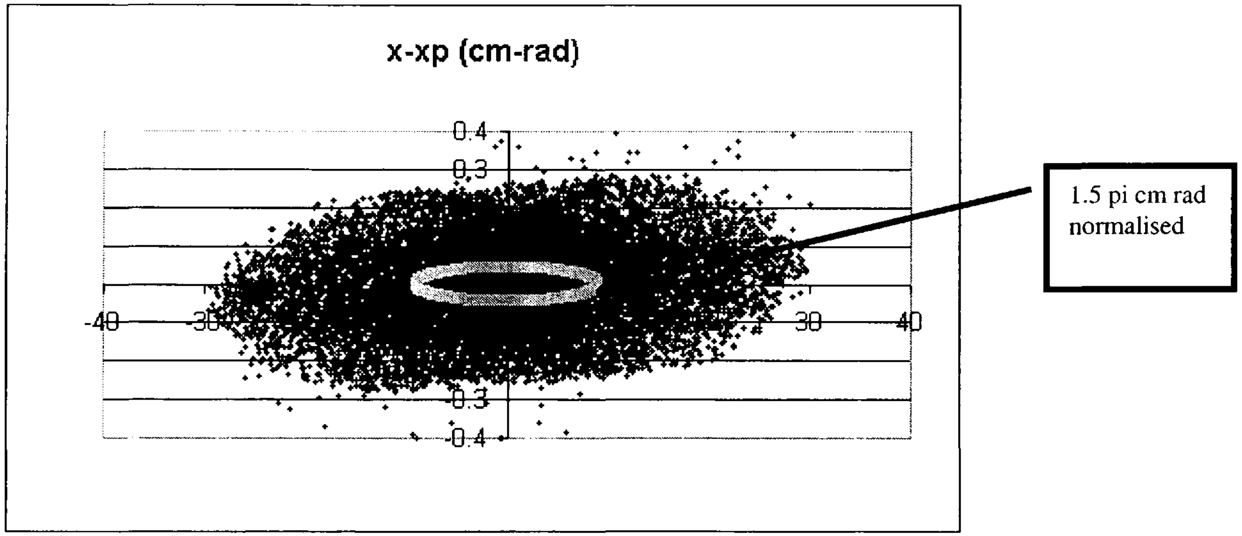
3. the longitudinal momentum is replaced by rf; the transverse momentum has decreased net effect: cooled beam

K.Hanke

Cooling for the Nufact

- required by experiments: particle divergence $< 0.1/\gamma$ and a total number of 10^21 muons/year
- muon decay ring and recirculators have a transverse acceptance of 1.5 π cm rad (normalized) + longitudinal acceptance
- need to collect as many muons as possible inside this acceptance

need about a cooling factor 20 to produce the required 10^21 muons



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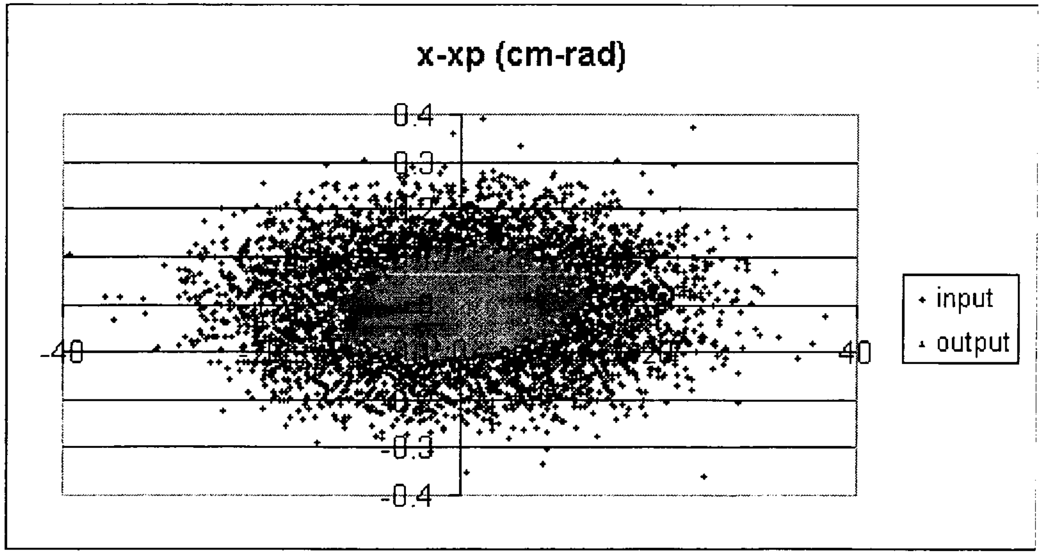
The CERN Nufact Cooling Channel

from A.Lombardi, CERN NF Note 34

	Decay	Rotation	Cooling I	Acceleration	"Cooling II"	Acceleration
Length [m]	30	30	46	32	112	≈450
Diameter [cm]	60	60	60	60	30	20
Focalisation [T]	1.8	1.8	2.0	2.0	2.6	2.6
Frequency [MHz]		40	40	40	80	80-200
Gradient [MV/m]		2	2	2	4	4-10
Kin Energy [MeV]		200		280	300	2000

- 2 cooling sections (44 and 88 MHz
- cooling factor 16 leads to 10^21 muons/year



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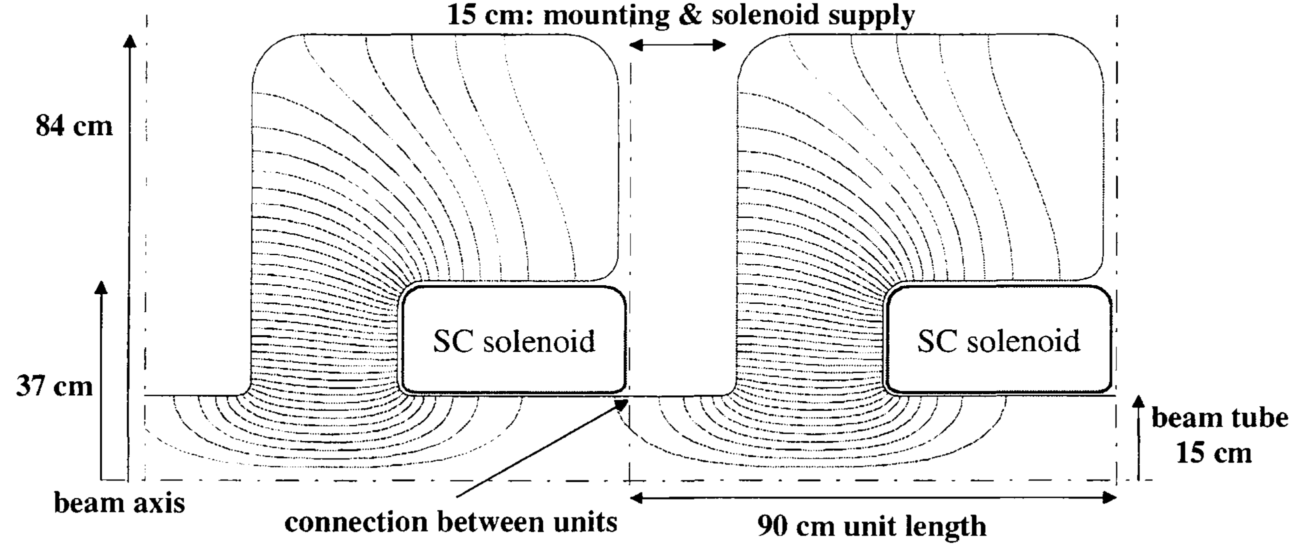
Muon Cooling Experiment

- choice of frequency: 88 MHz (good cooling efficiency)
- based on new, asymmetric cavity design with total length of 90 cm and energy gain of 3.6 MeV/structure (4 MV/m)
- a system of 16 cavities allows for a total of 160 cm absorber to keep the energy constant; this should lead to an observable emittance decrease



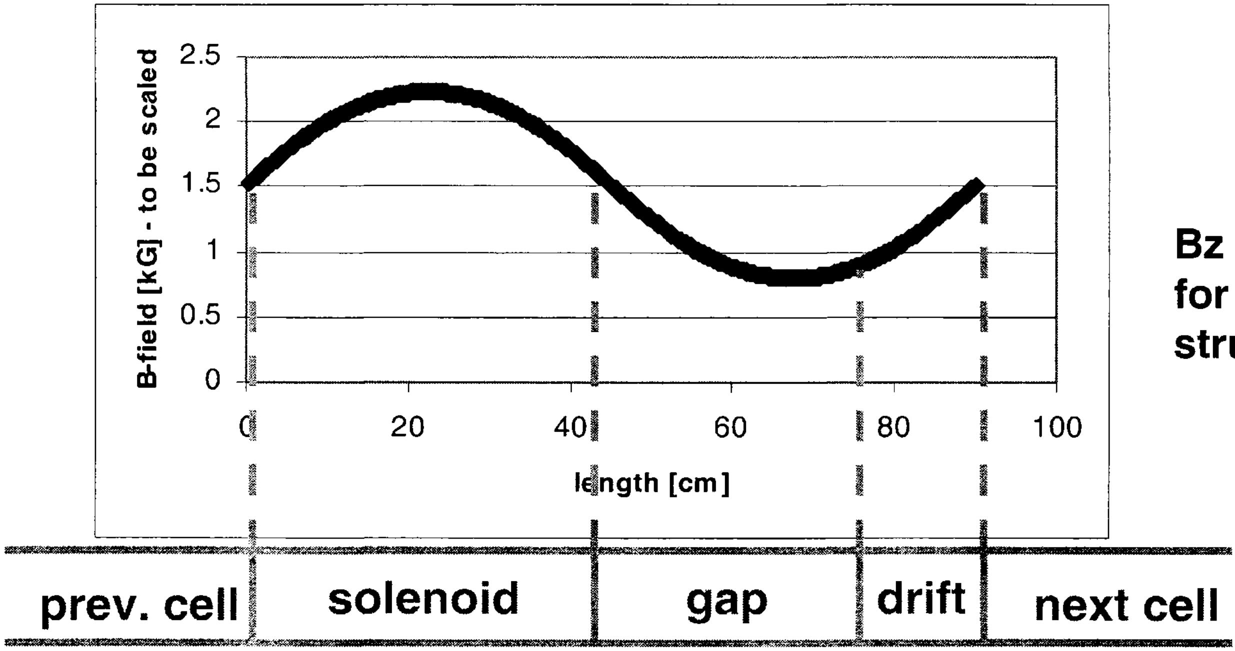
88 MHz cavities with solenoids for muon cooling channel, F.Gerigk (PS/RF)

http://www.hep.ph.ic.ac.uk/muons/f.gerigk.pdf

K.Hanke

Beam Dynamics for a Muon Cooling Experiment

- expected emittance decrease in the *per cent level*
- need to take into account all *physical effects*
- notably: go from a hard-edge model to a simulation with field maps magnetic and electric field maps have been computed with Superfish/ POISSON and included in the tracking code (PATH)



Bz along z on beam axis for one cavity/solenoid structure - to be scaled

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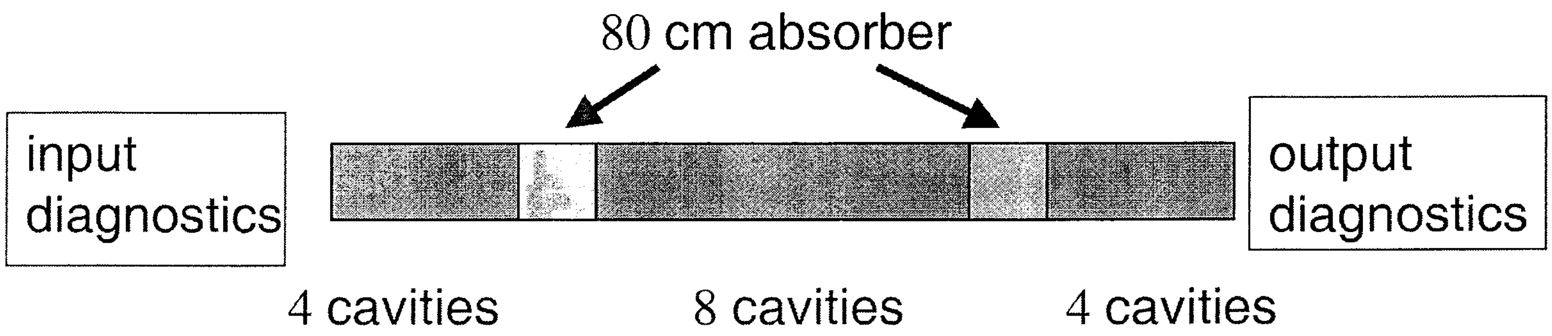
Possible Lay-Out of a Muon Cooling Experiment



- this *symmetric* arrangement is a fraction of the final cooling channel
- other arrangements are possible but limit the number of absorber walls
- we are aiming at about 10 % cooling at full transmission
- a detailed beam dynamics study *including field maps* is under way; preliminary results are promising
- solenoidal optics (matching) turns out to be a very important issue
- solenoids have to be designed with the best possible field homogenity *(POISSON)* compatible with the boundary conditions (cavity design)

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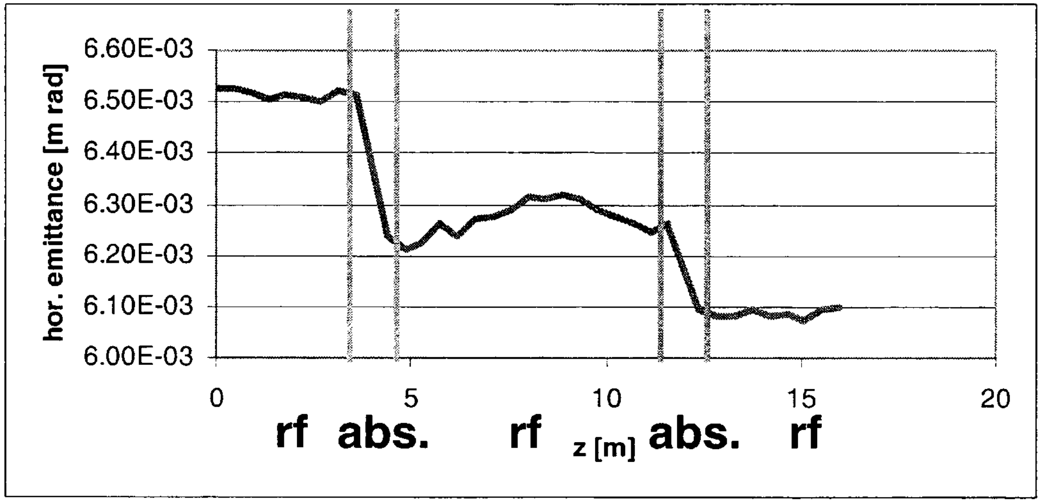
Cooling Experiment: Preliminary Results



	input r.m.s. emittance [cm mrad]	output r.m.s. emittance [cm mrad
hard-edge	652	610
field map	652	616

horizontal emittance vs z for cooling experiment

- a structure of 16 cavities and a total of 160 cm absorber gives the required emittance decrease
- very careful matching and optimization is required
- the model with field map comes close to a hard-edge model but more effort needs to be put into solenoid design

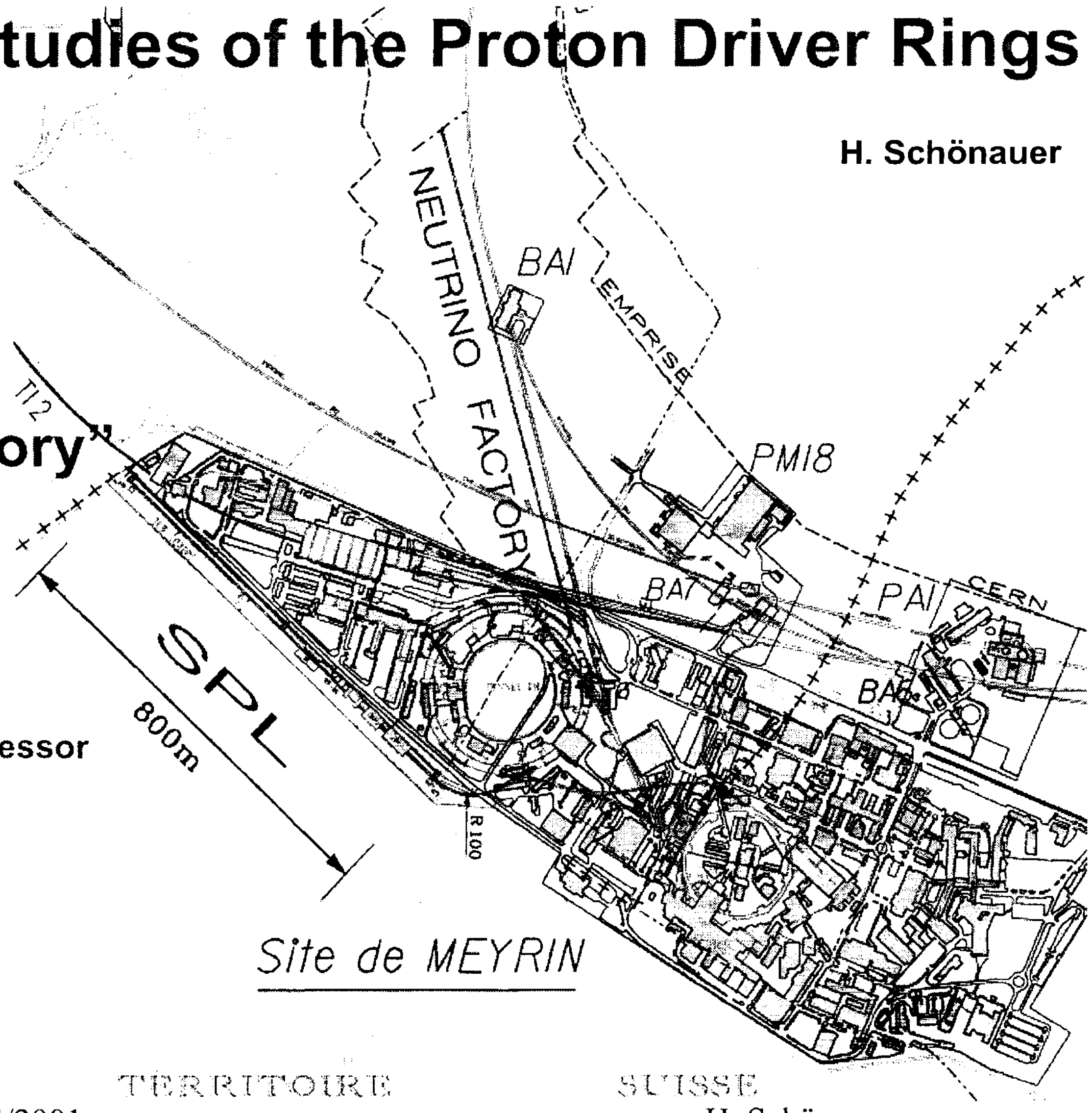
K.Hanke

Studies of the Proton Driver Rings

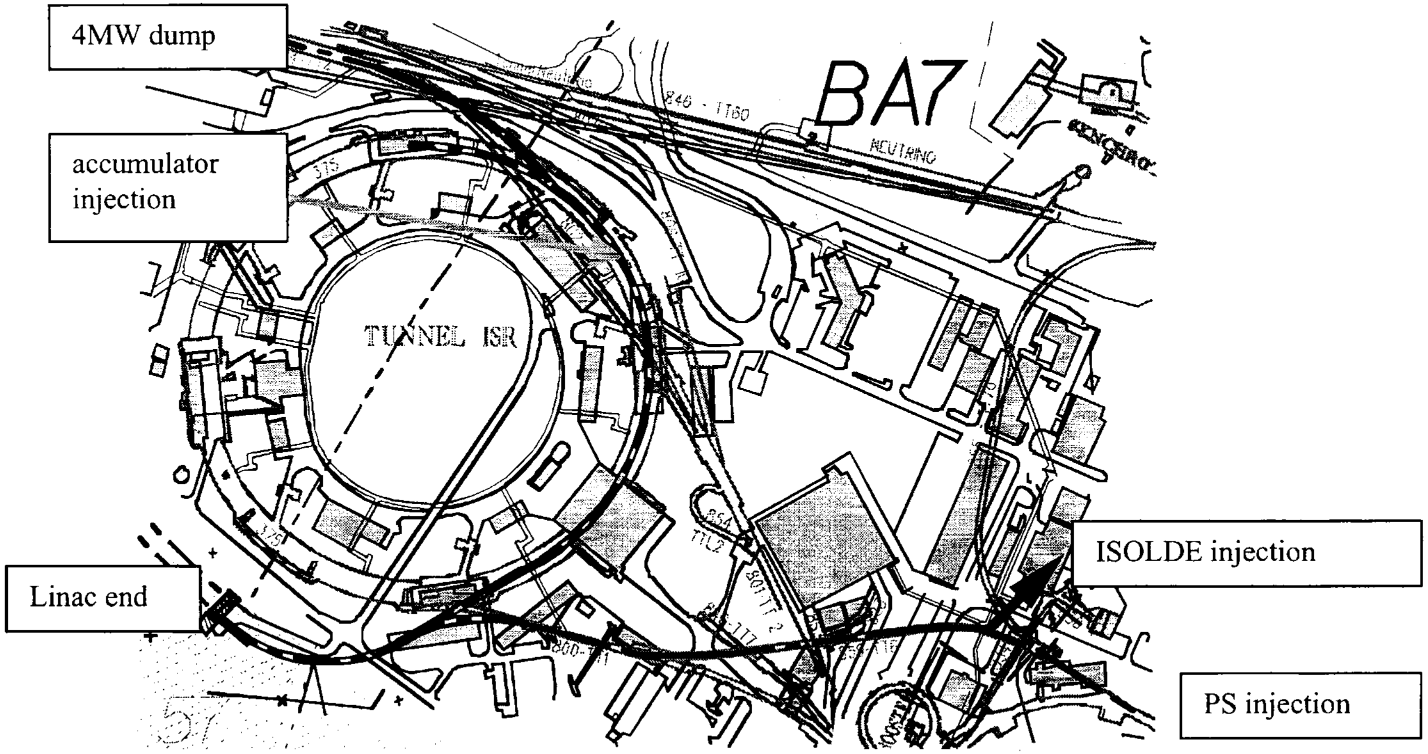
H. Schönauer

The "charted territory" of the CERN NF:

- SPL
- PDAC (Proton Driver Accumulator- Compressor in ISR tunnel)
- Extraction towards target station



Layout of the transfer line



H. Schönauer

Proton Driver Accumulator - Compressor

Evolution of the 4 MW Scenario:

0) Isochronous Rings

1) **PDAC 1: High η Accumulator & Compressor**

   2 GeV, 100 Hz, 12 bunches, H- Injection 600 turns

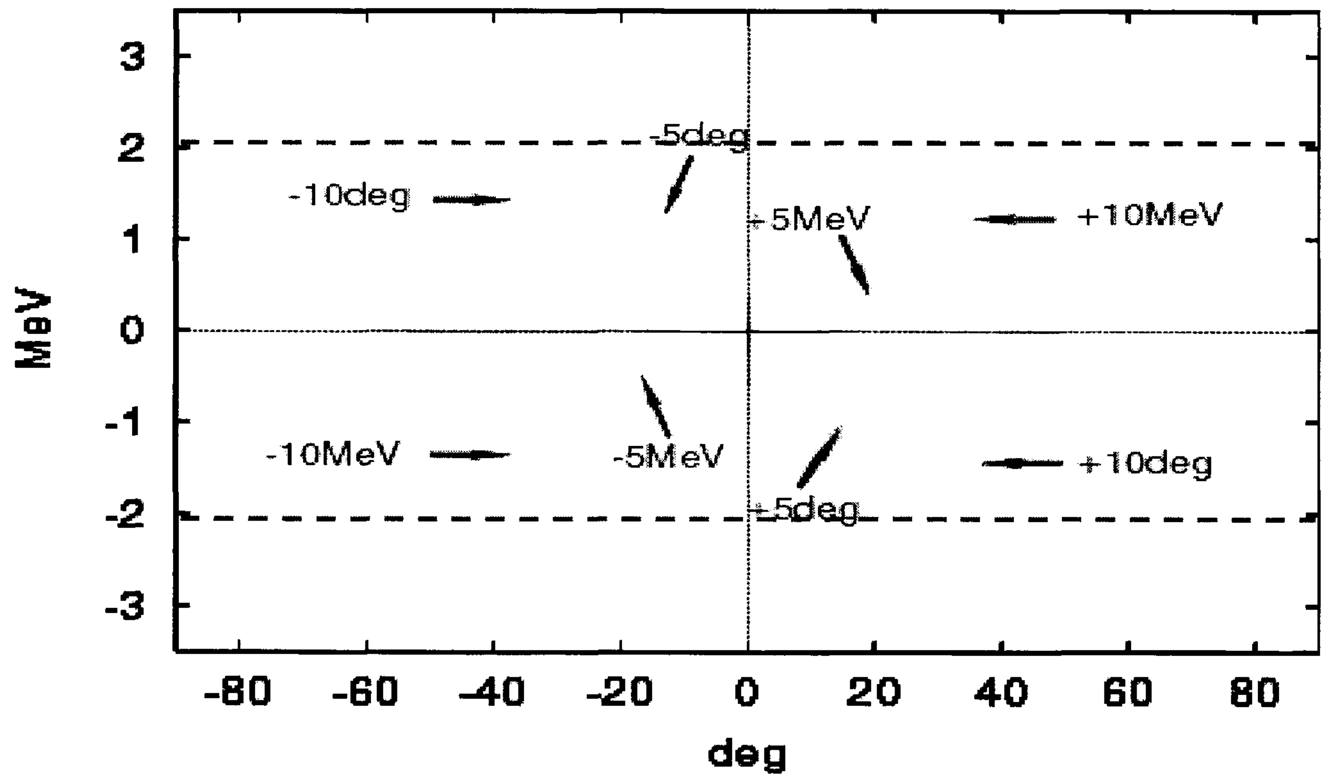
2) **PDAC 2: 2.2 GeV, 75 Hz, 140 bunches**

   RF 44 Mhz, matched to Muon Cooling Front End

3) **PDAC 2 bis: 50 Hz**

   H- Injection 840 turns (?)

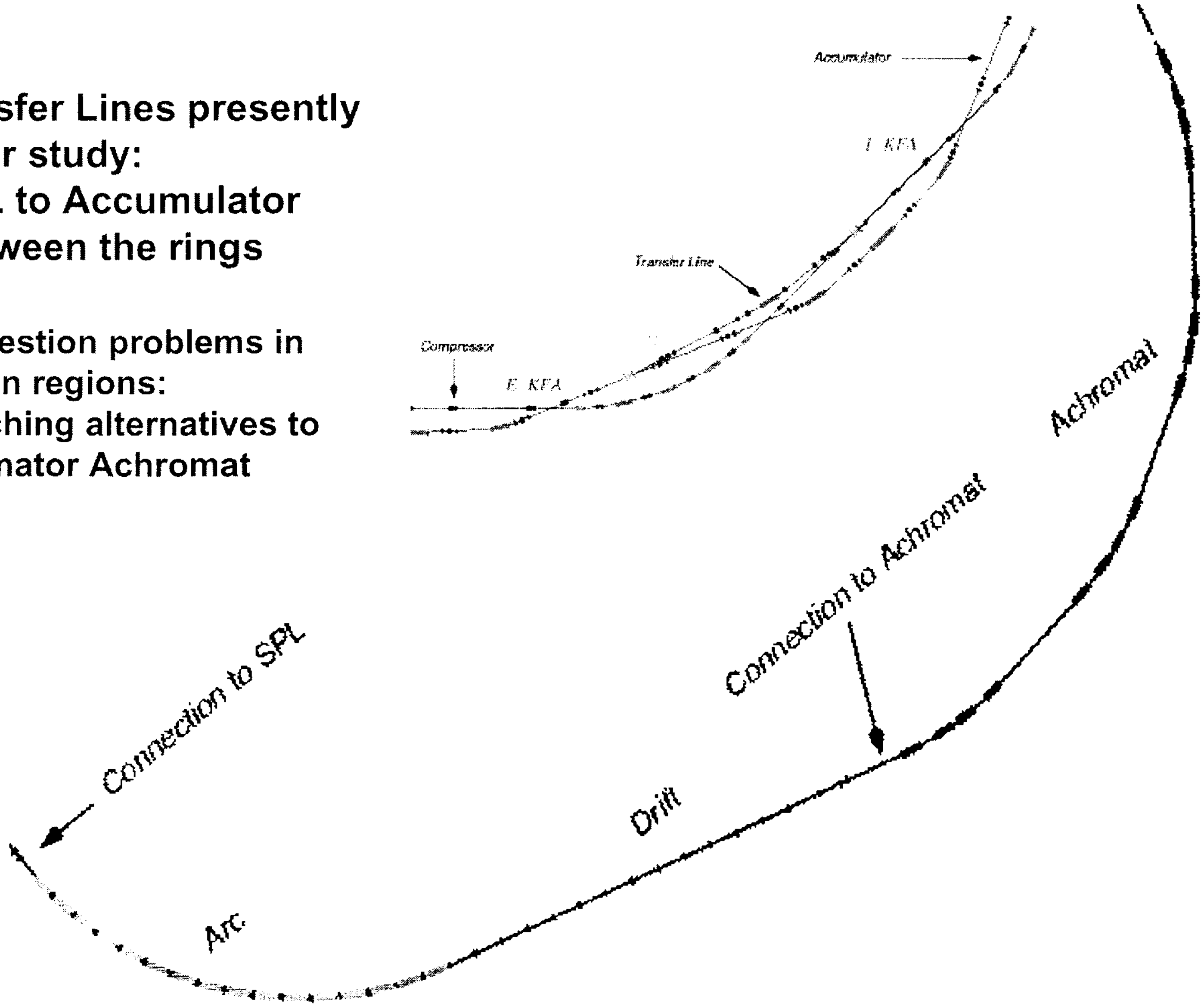
Effect of SPL Jitter AFTER debuncher + 230m drift + buncher (180ps bunch length, matched beam)



Transfer Lines presently under study:

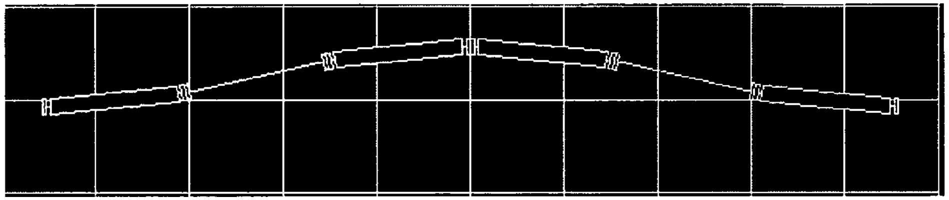
- SPL to Accumulator
- Between the rings

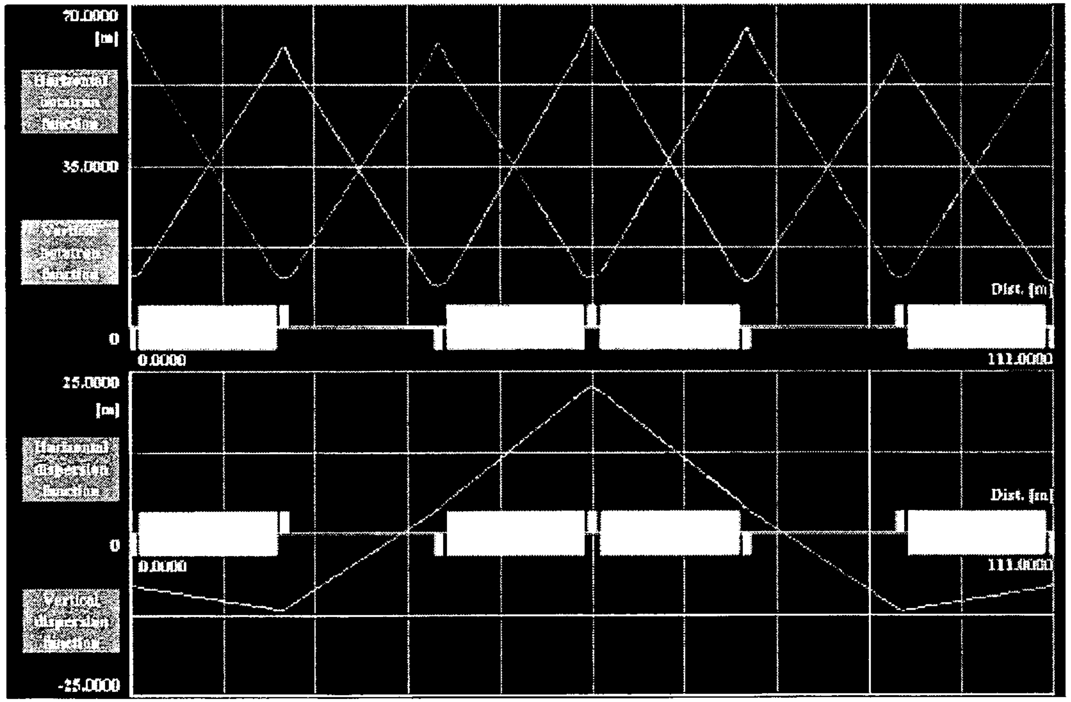
Congestion problems in certain regions:
Searching alternatives to Collimator Achromat



Wiggler Section for Microbunch Stretching

NF Note 069, Autin, Giovannozzi, Martini, Royer

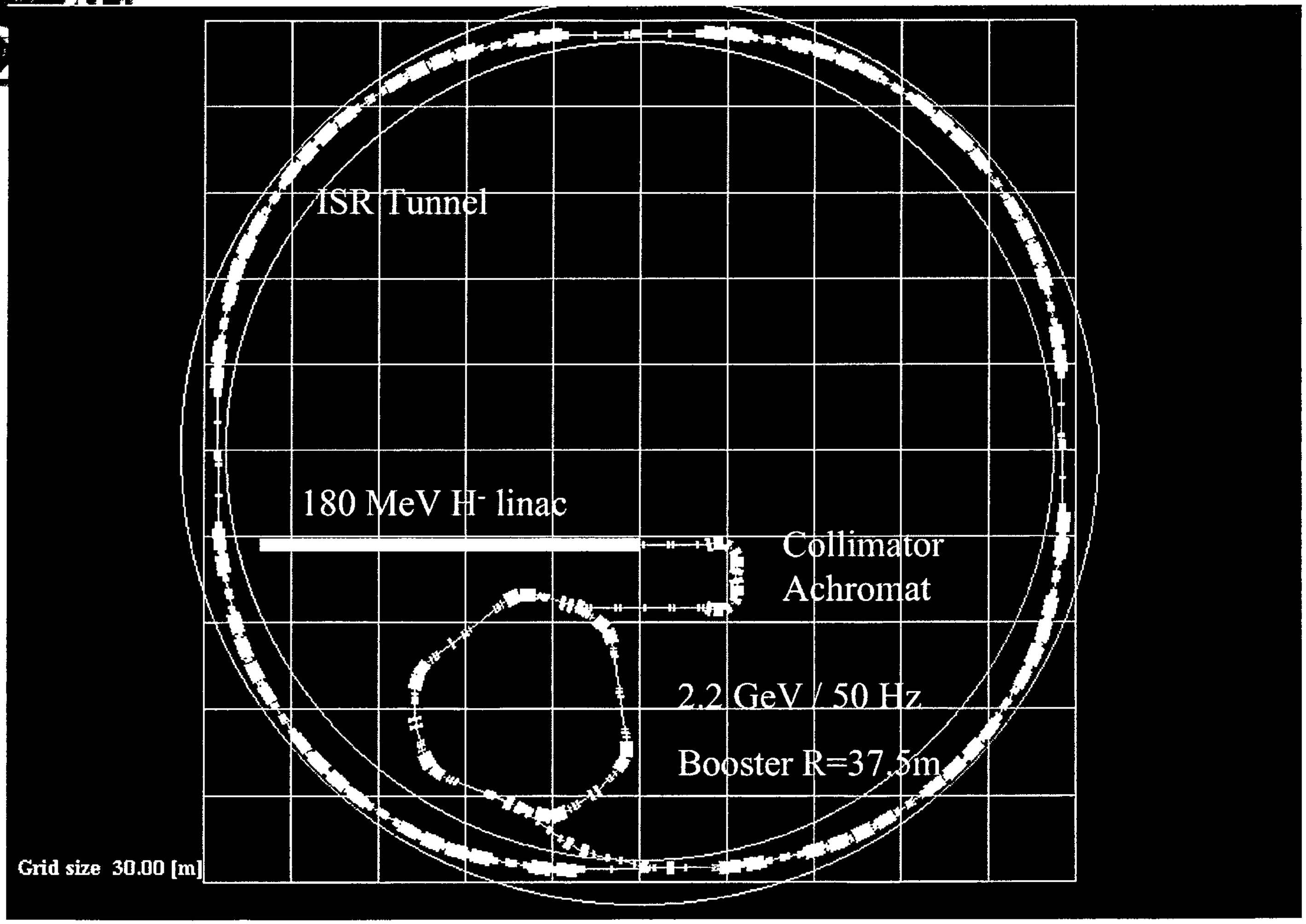




Doubles the bunch stretching w.r.t. free drift:
-> 130 ps

Provides Dispersion Bump D~20m
-> Replacement of Collimator Achromat in the SPL to ISR tunnel ?

Alternative Scenario:
CERN 4 MW 30 GeV / 8 Hz Proton Driver



PD Rings Contributors:

In bold: major contribution in 2001

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Proton Driver Rings Report

DRAFT Index

1. Introduction
2. Evolution, Description of the Configuration
3. Injection line and Achromatic Momentum Collimation Arc
4. Accumulator
    - 4.1. Lattice
    - 4.2. H- Injection
        - 4.2.1. Layout Injection Section, Bumps
        - 4.2.2. H^0, H^- evacuation
        - 4.2.3. e^- collection
        - 4.2.4. Foil heating
    - 4.3. Accumulation : Tracking Studies
        - 4.3.1. LONG1D (RF Program, Injection jitter)
        - 4.3.2. ACCSIM (Painting, Halo, Collimation?)
    - 4.4. Collective Effects
    - 4.5. RF Cavities
    - 4.6. Extraction
5. Transfer line to Compressor
6. Compressor
    - 6.1. Lattice
    - 6.2. Injection and Extraction layout
    - 6.3. Bunch Rotation (incl. Tracking)
        - 6.3.1. Envelope Formalism with Space Charge
        - 6.3.2. ESME
        - 6.3.3. LONG1D
    - 6.4. RF Cavities
    - 6.5. Collimation (ACCSIM tracking)
7. Transfer Line to Target Station
8. Shielding
9. Parameter List
10. Alternative Scenario : 25 GeV RCS

PS Technical Meeting 04/04/2001

H. Schönauer