Update on CERN Activities

H. Haseroth

for the

Neutrino Factory Working Group

at CERN

What is new since February?

2.2 GeV Proton Driver

≈350 MCHF

Some parameter changes

Target for 4 MW

Tests at Grenoble in high B field

Tests at BNL

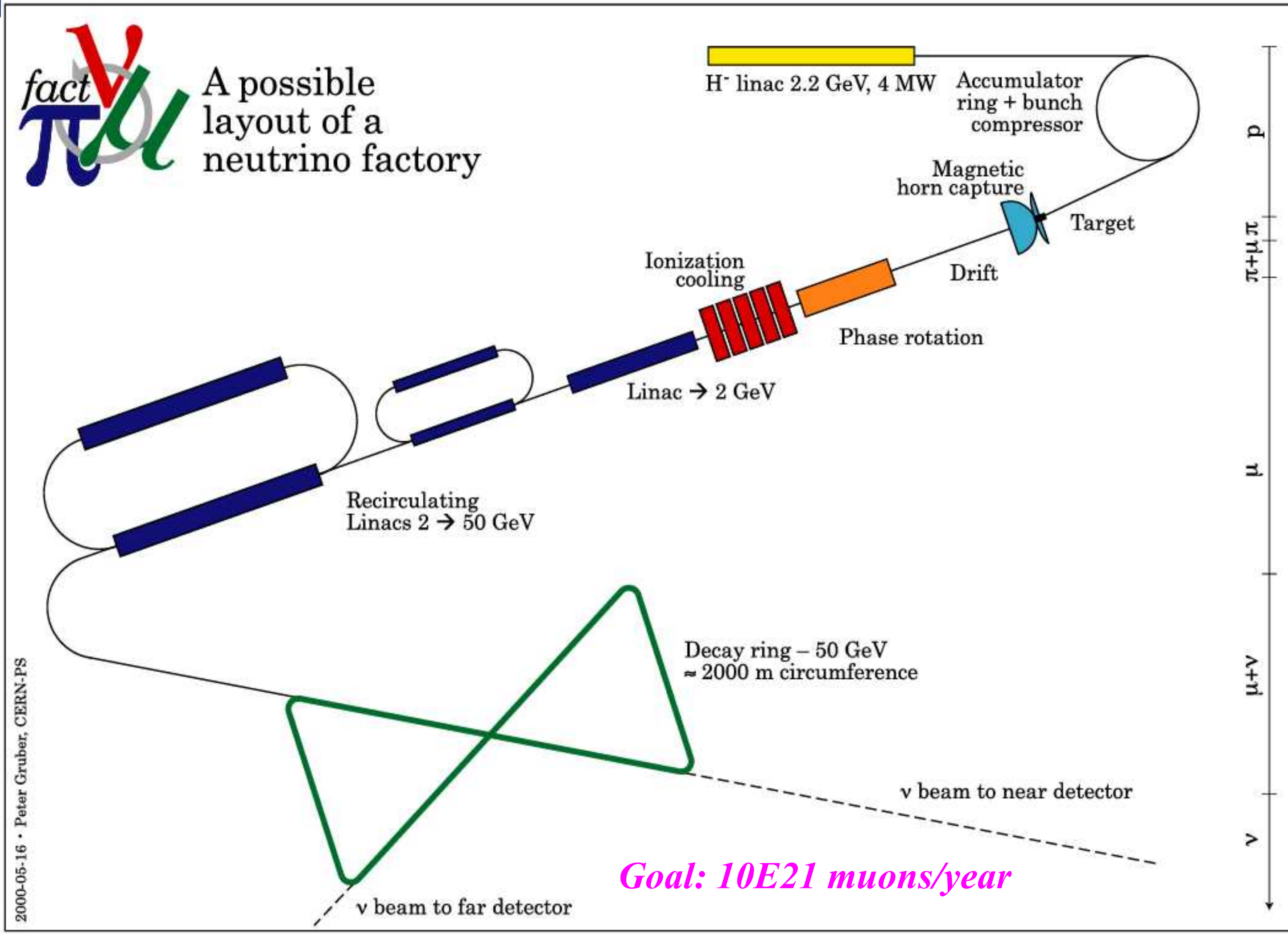
40/80 MHz capture/cooling system

Work going on for a "cooling cell"

RLAs: Some discussions about acceptances and possible use of 200 MHz cavities

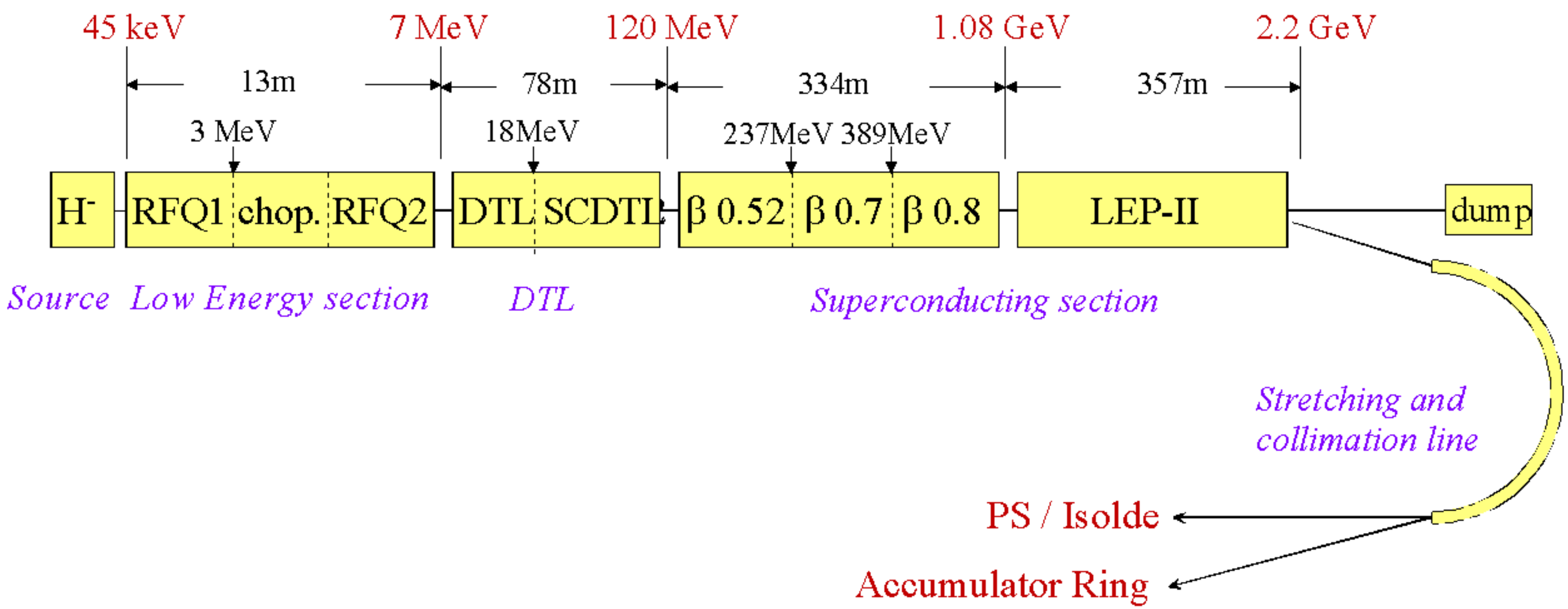
Layout on CERN site being studied

Discussions about a cooling experiment

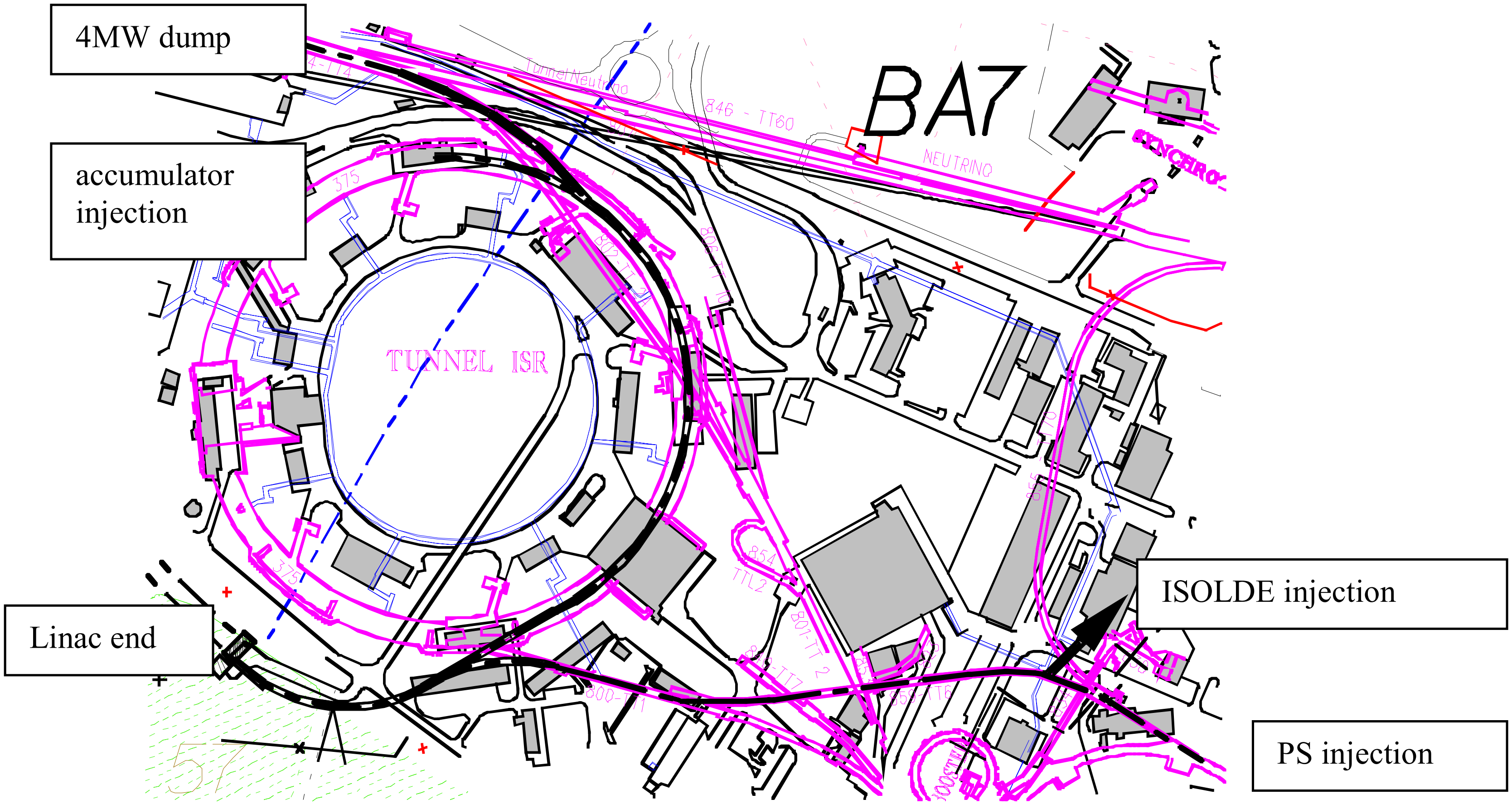


Goal: 10E21 muons/year

Schematic Layout of the SPL (4 MW of Beam Power)



Layout of the transfer line



F. Gerigk

SPL BEAM CHARACTERISTICS: CASE 3

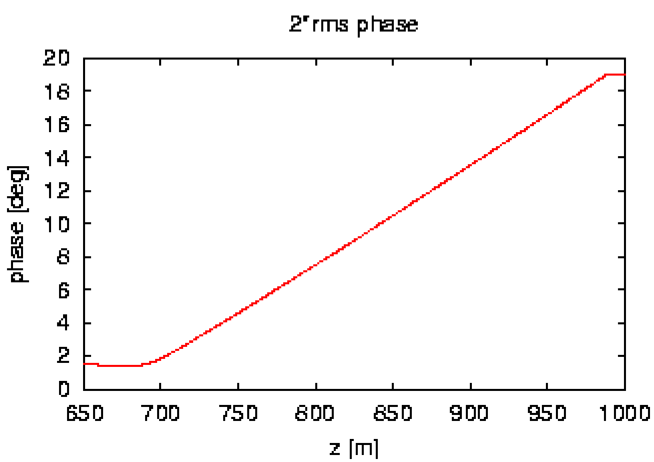
(2.2 GeV - 50 Hz - 144 bunches in the accumulator)

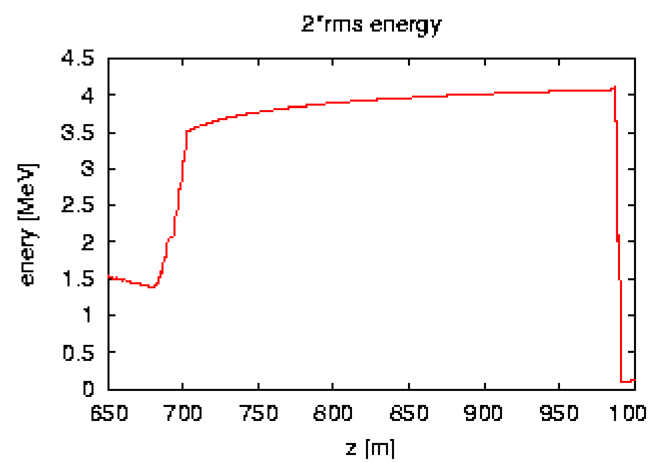
	Parameter	Value	Unit
MEAN PARAMETERS	Ion species	H-	
	Kinetic energy	2.2	GeV
	Mean current during the pulse	13	mA
	Duty cycle [mean beam power]	14 [4]	% [MW]
	Pulse frequency	50	Hz
	Pulse duration [number of H- per pulse]	2.8 [2.27 E 14]	ms [H^-/pulse]
FINE TIME STRUCTURE	Bunch frequency [minimum distance 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]	144 [146-2]	
	Maximum bunch current [maximum number of charges per bunch]	22 [3.85 E 8]	mA [H^-/bunch]
BUNCH CHARACTERISTICS	Bunch length (total)	0.5	ns
	Energy spread (total) [relative momentum spread (total)]	0.5 [~ 0.175 E-3]	MeV
	Normalised horizontal emittance (1σ)	0.6	µm
	Normalised vertical emittance (1σ)	0.6	µm
	Energy jitter during the beam pulse	< +- 0.2	MeV
	Energy jitter between beam pulses	< +- 2	MeV

Revised parameters are in red

General layout and principle

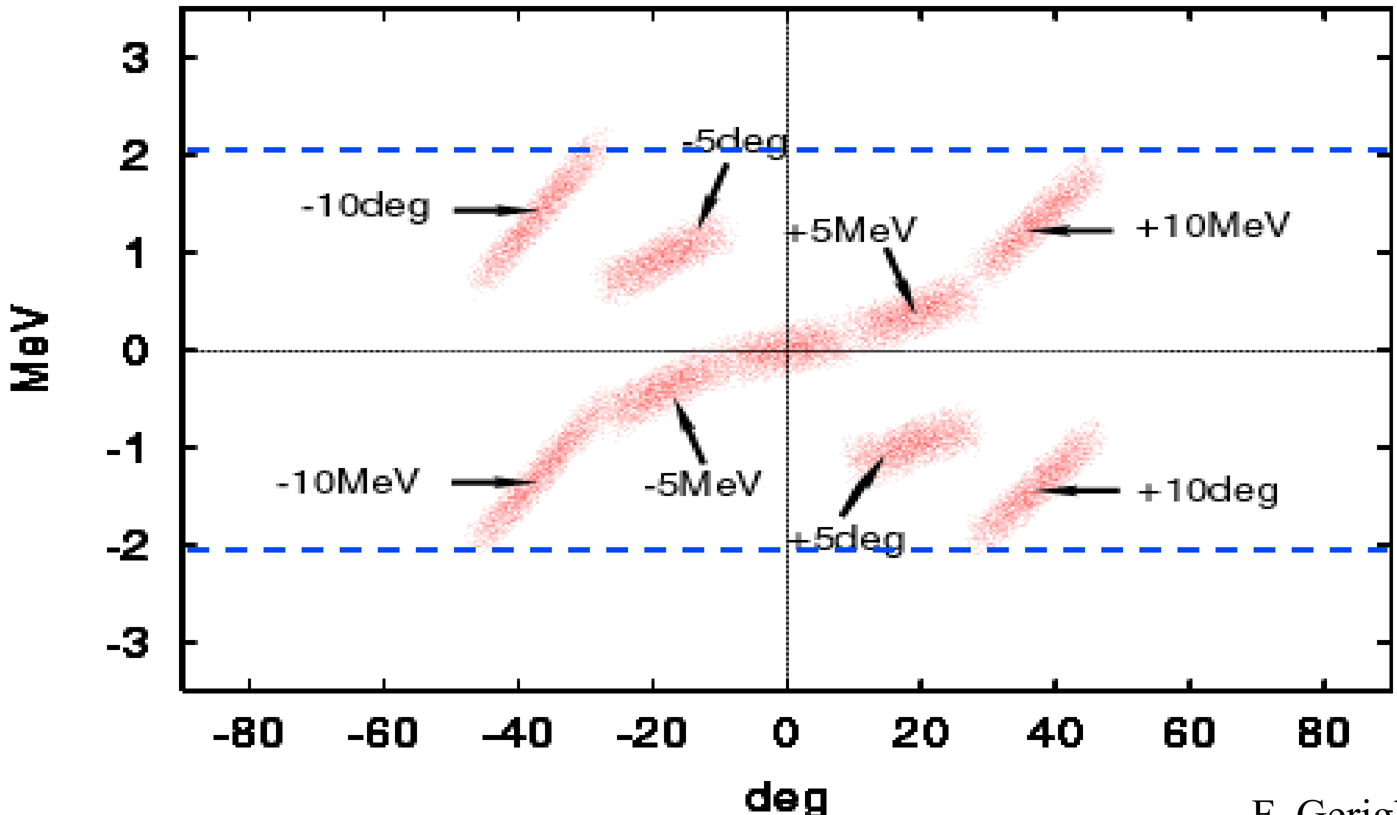
4 debunching cavities → 230 m drift → 4 bunching cavities





small Δt
large ΔE
→
large Δt
small ΔE

debuncher + 230m drift + buncher
(180ps bunch length, matched beam)



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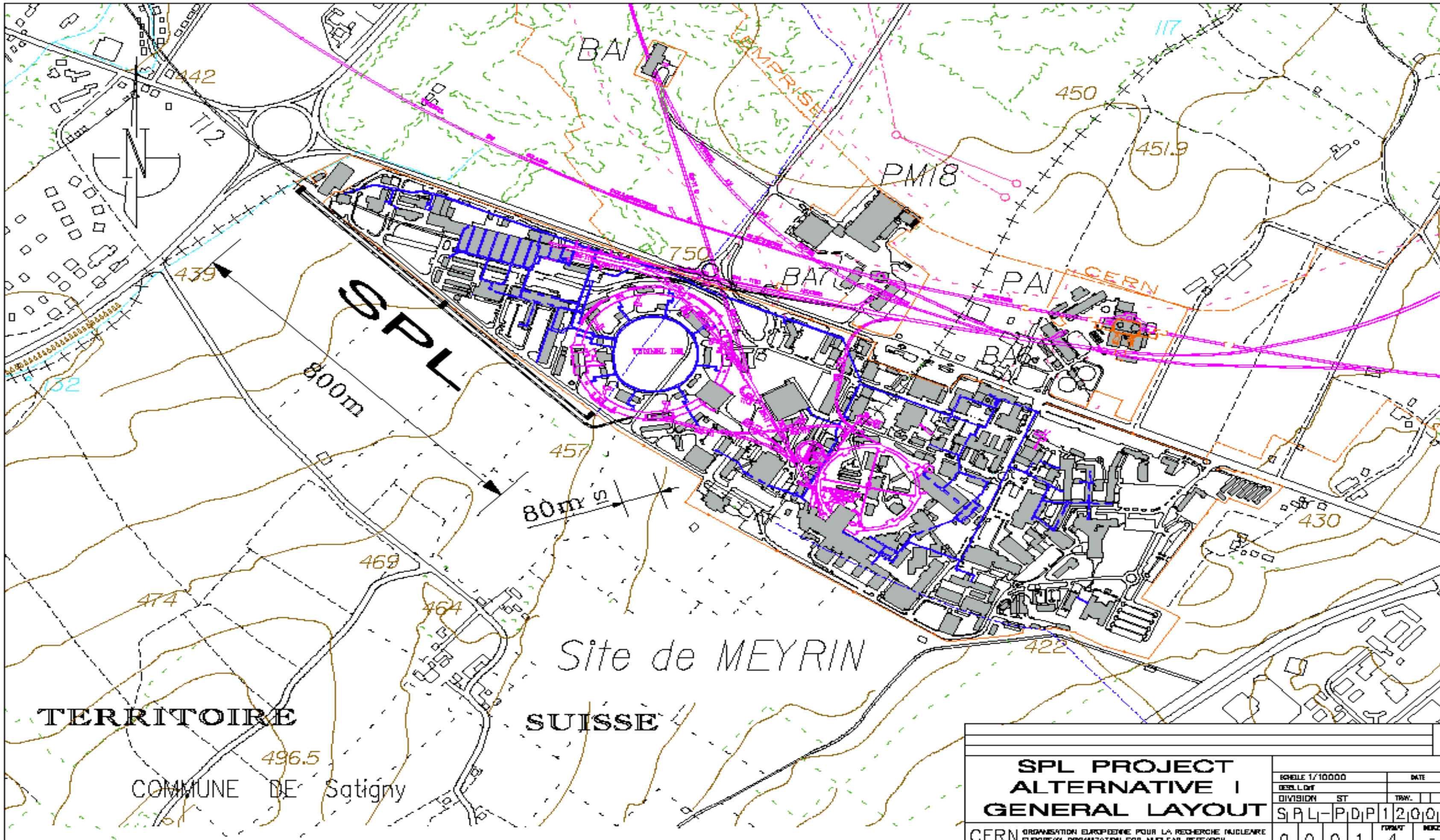
The SPL on the CERN site



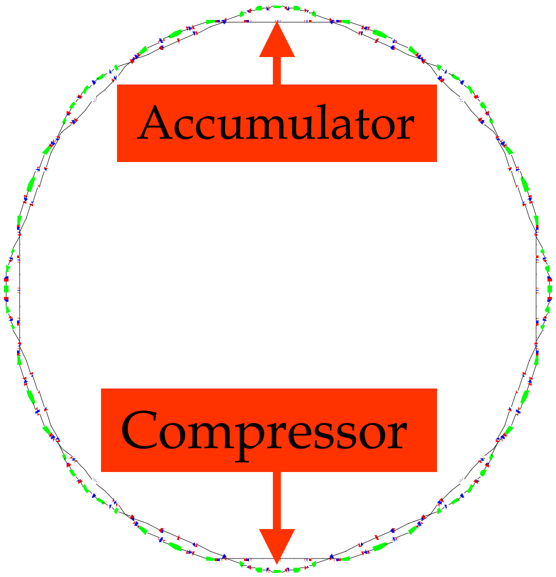
SPL TOTAL COST ESTIMATE

Last update: 22/11/2000
R. Garoby for the SPL study group

ITEM	COST ESTIMATES (MCHF)
H- Source	0.6
RFQs & LEBT	6
Chopper with high & low power electronics	3.5
DTL	9
Quads with power supplies	10
Tetrode amplifiers (+ spares)	20
Klystron amplifiers (+10 new klystrons)	25
Cavities servos and beam phase monitoring	3
Reduced beta SC cavities (+ spares)	55
Beta=1 SC cavities	5
Beam instrumentation	6.3
Controls	6
Civil engineering	75.7
Cooling & Ventilation	10
Controlled access & Alarm	1.3
Electricity	14.6
Cryogeny	40
Vacuum	8
Transfer lines (vacuum, magnets, power supplies)	4
Dumps (2 + 1.5 spare)	1.8
Radiation monitoring	0.5
Injection in the PS	4
Injection in ISOLDE	0.5
Land acquisition	1.5
Cavities cold test (3 bunkers + 5 years duration)	10
Contingencies	28.7
TOTAL	**350**

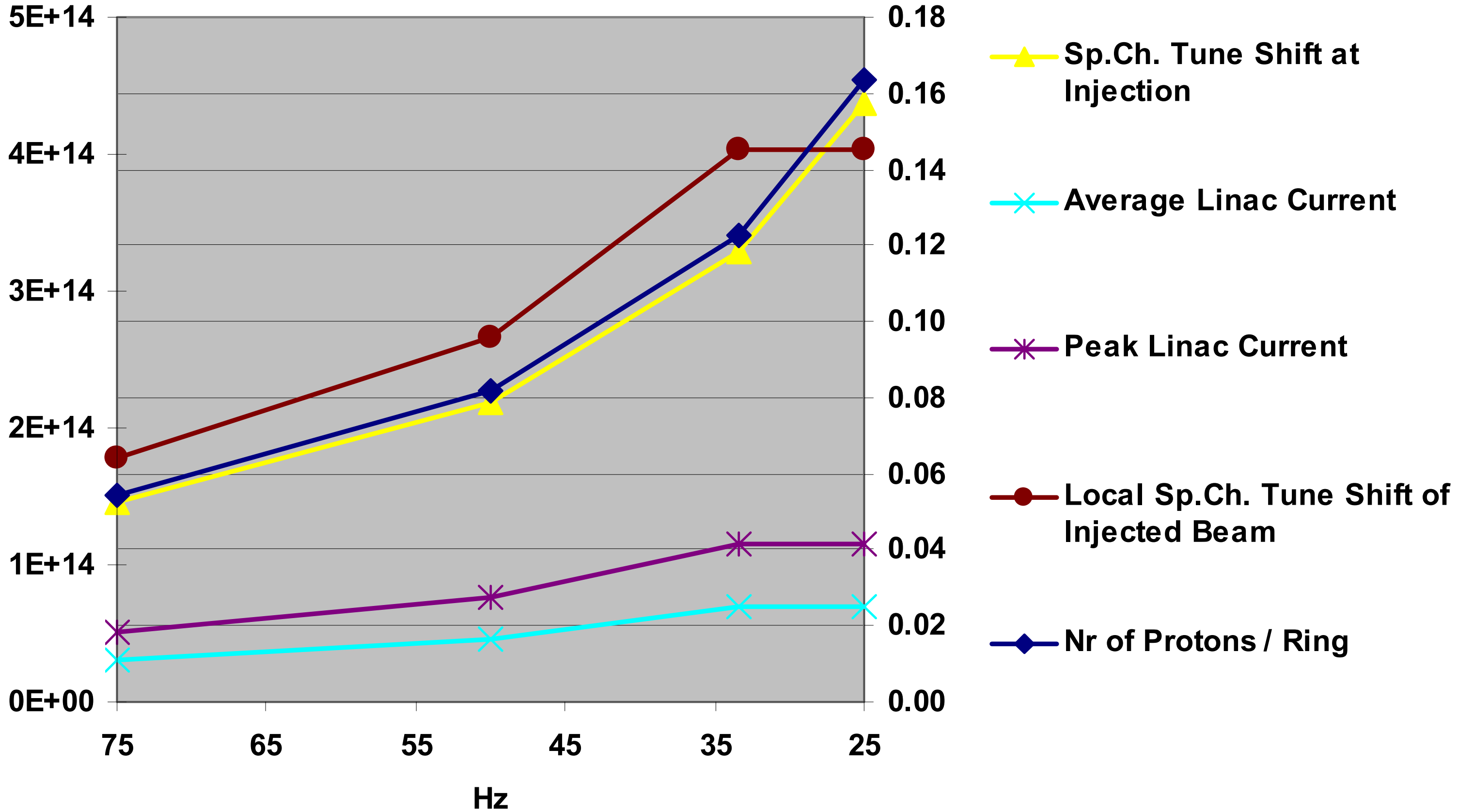
RAL Accumulator & CERN Compressor (2)

Accumulator & Compressor



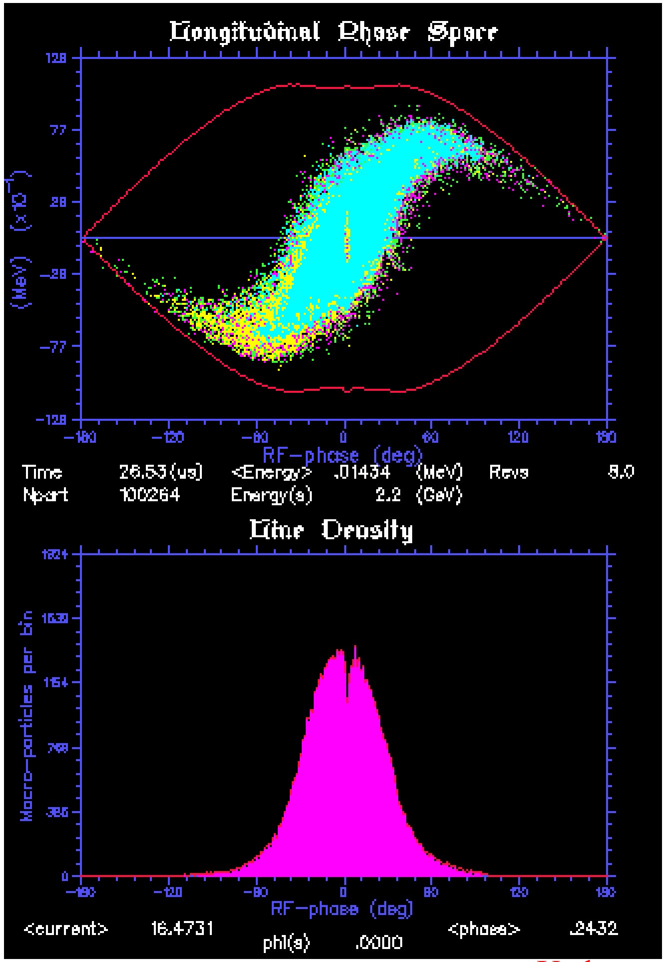
in ISR Tunnel

PDAC2 Operation at Reduced Repetition Rate
(max. I_{linac}= 42 mA)

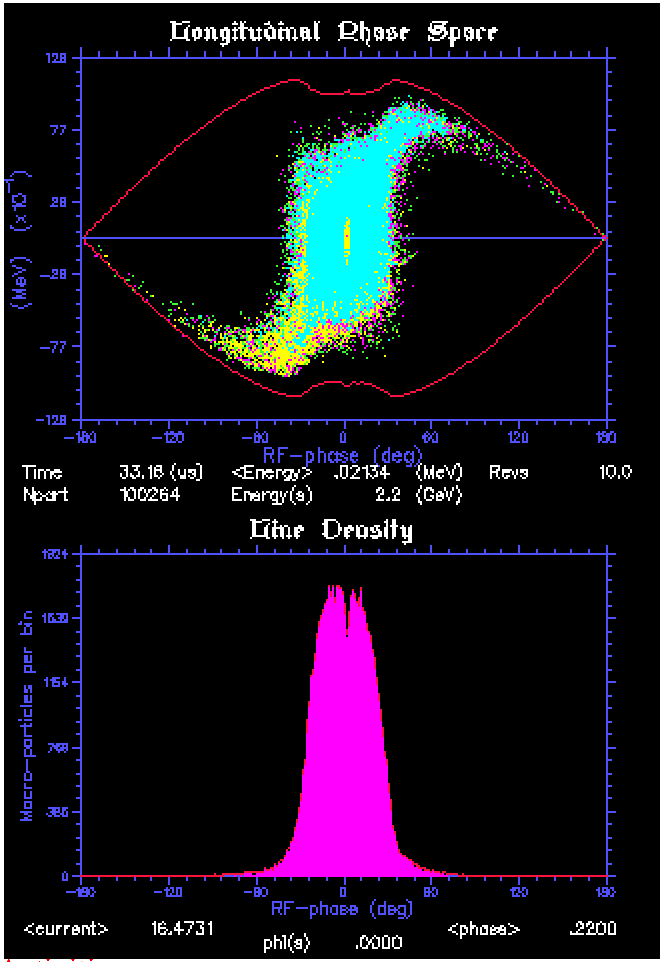


33 Hz Operation with 3.41 10^{14} p/p :
End of Compression (Phase painting +/- 90 deg)

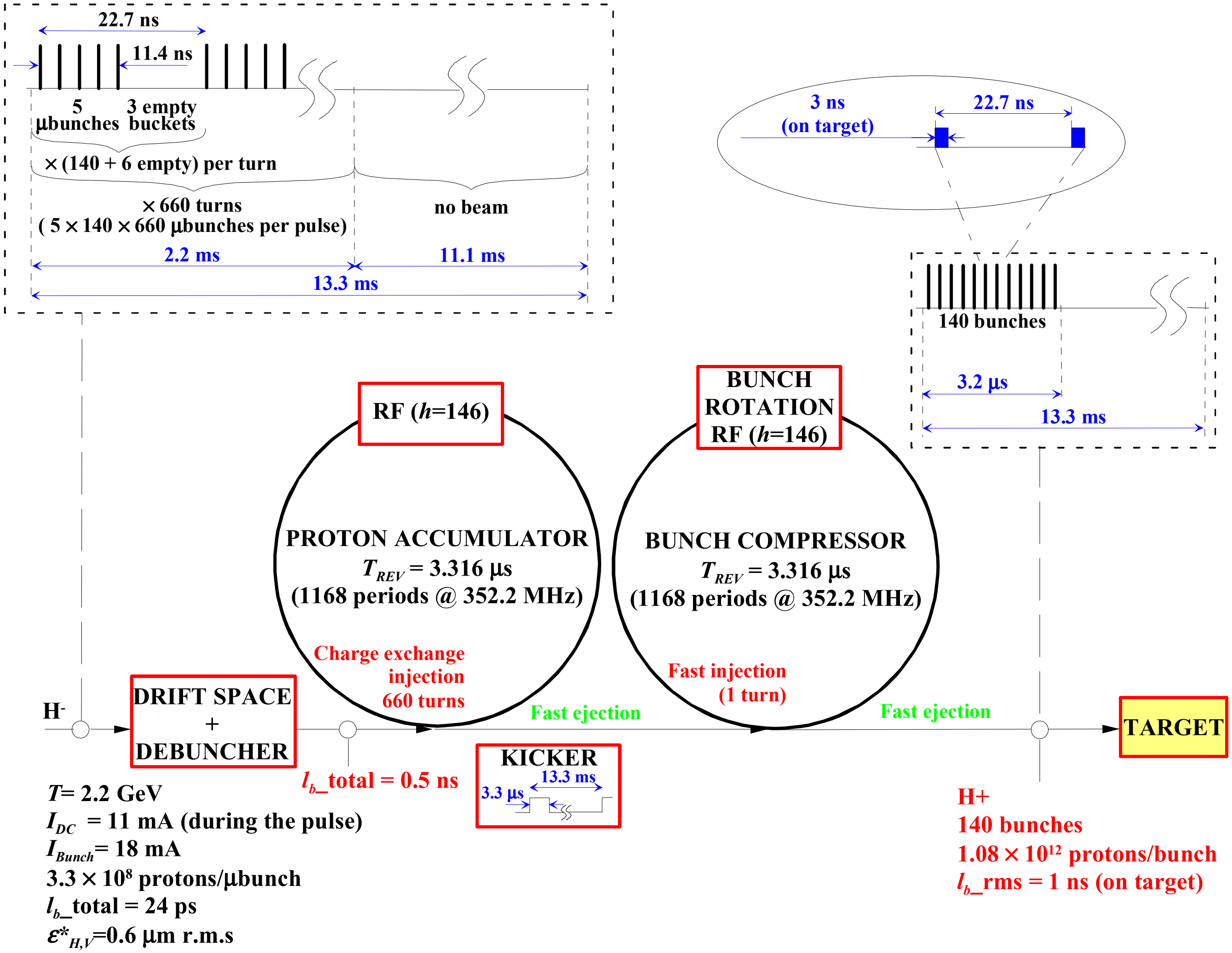
8 turns



10 turns



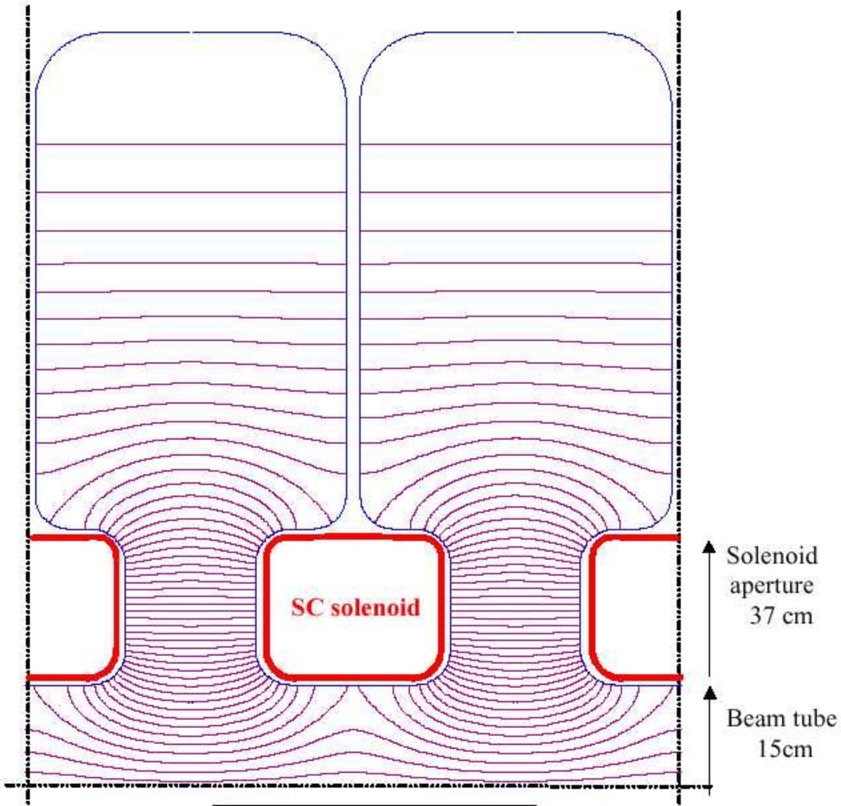
Accumulator-Compressor scheme for a Neutrino Factory



Old scheme for 44 / 88 MHz cooling and acceleration

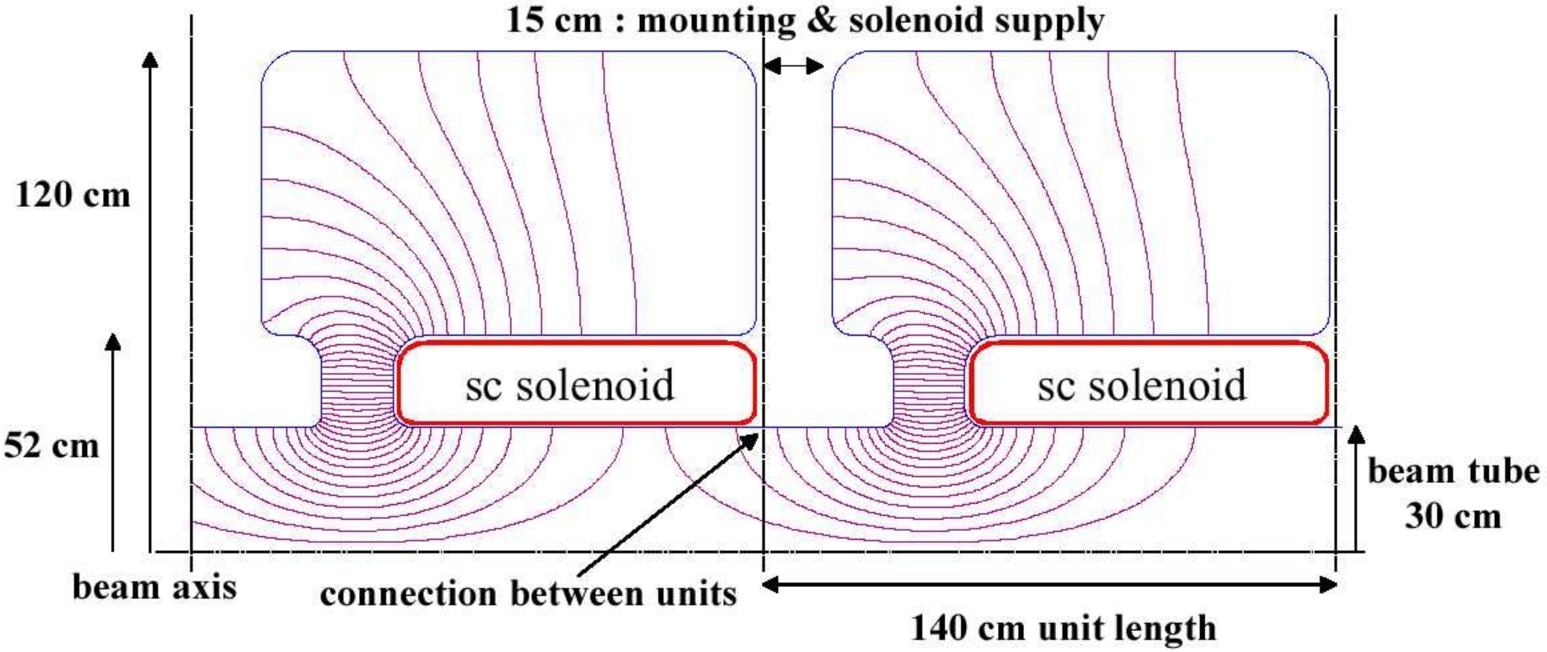
- Huge diameter: 3.3 m / 2.1 m,
- complicated construction,
- no access to solenoids,
- lousy efficiency.

E_0T	= 4 MV/m
Z_{TT}	= 10.8 MΩ/m
P_{PEAK}	= 0.74 MW/cavity
R/Q	= 60 Ω
T_{FILL}	= 164 µs
f_{REP}	= 75 Hz
P_{MEAN}	= 54 kW/m
Kilpatrick: 1.2	



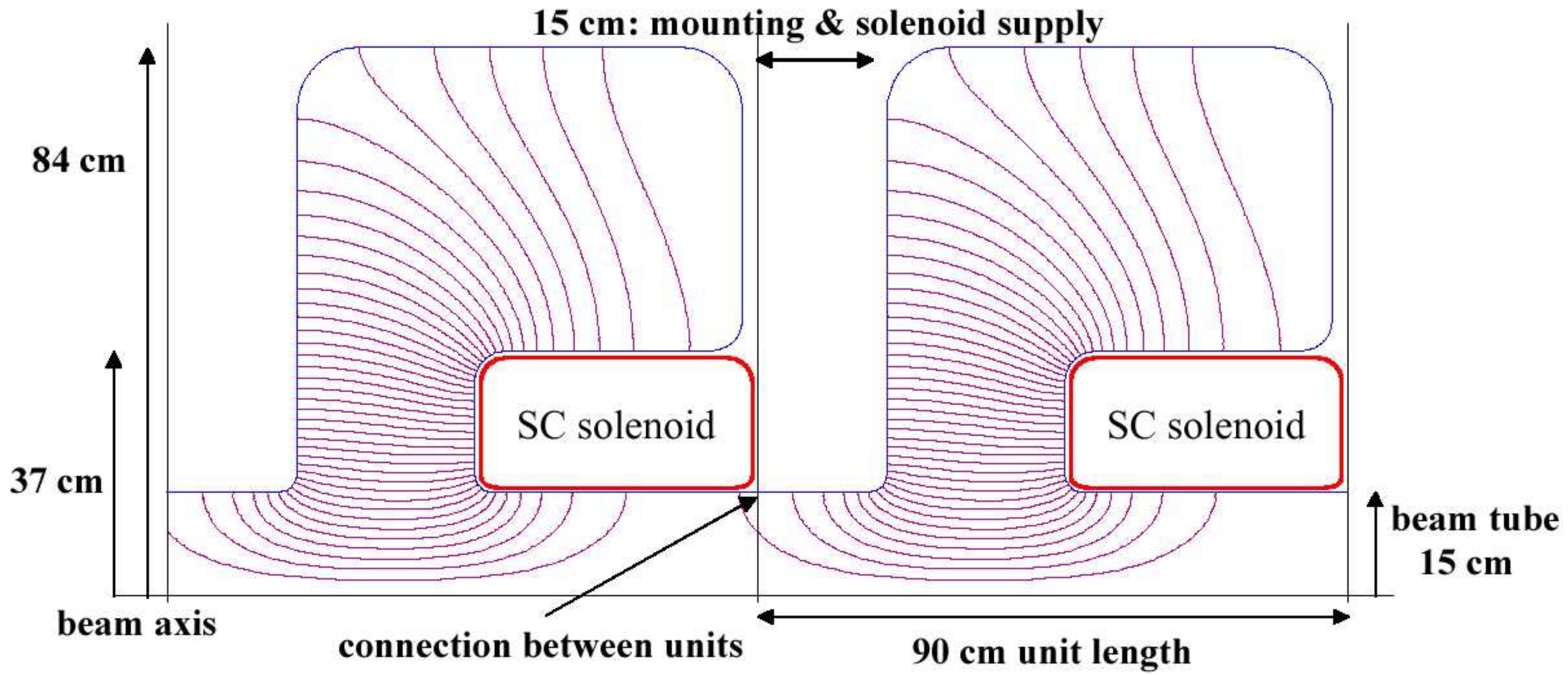
88 MHz cavity

New Asymmetric 44 MHz cavity



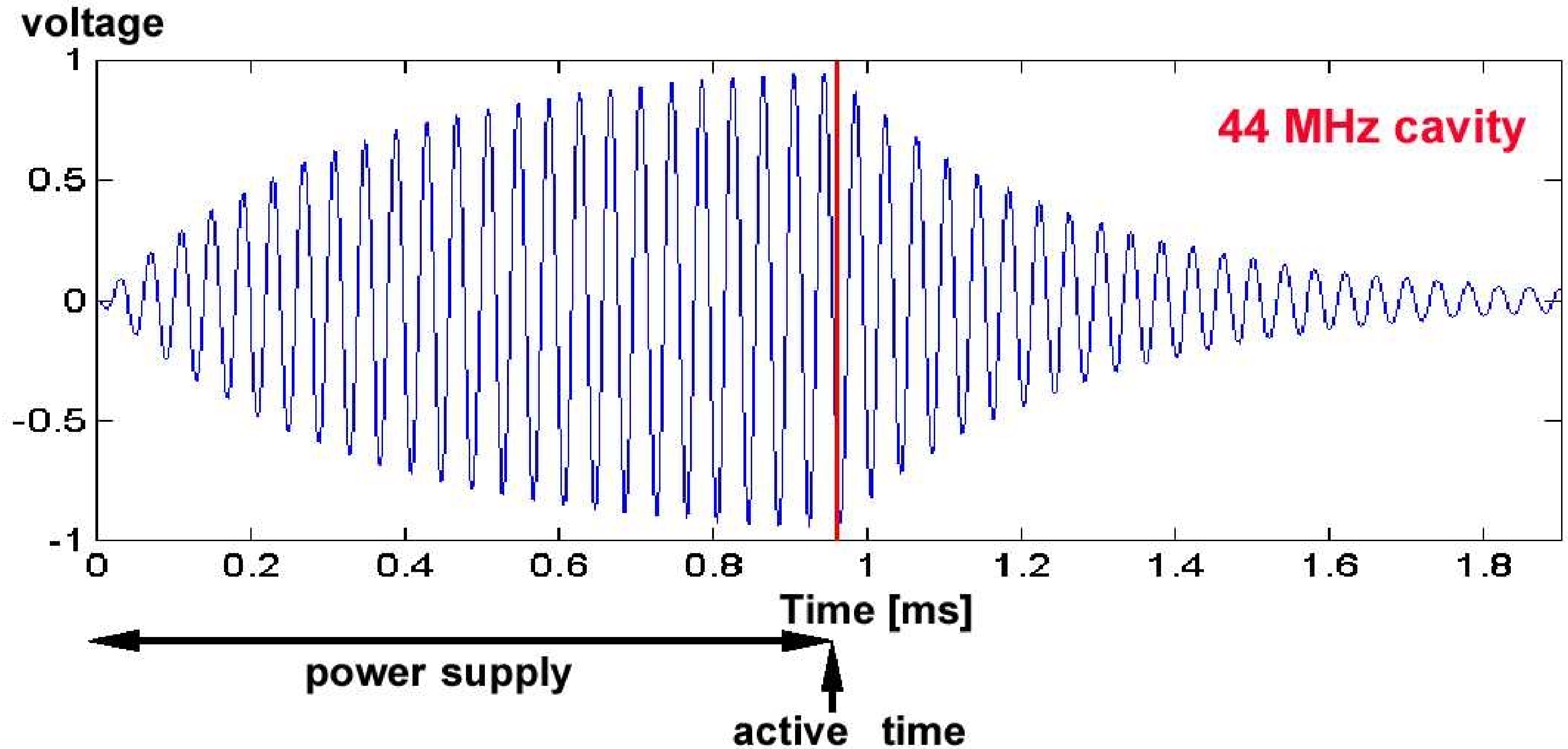
E_0T	= 2 MV/m	τ	= 318 µs	solenoid: 88 x 20 cm
Z_{TT}	= 3.6 MΩ/m	P_{PEAK}	= 1.57 MW/cavity	Kilpatrick: 2.5
R/Q	= 114 Ω	P_{MEAN}	= 80 kW/m for 75 Hz repetition rate	

Asymmetric 88 MHz cavities



E_0T	= 4 MV/m	τ	= 156 µs	solenoid: 40 x 20 cm
Z_{TT}	= 5 MΩ/m	P_{PEAK}	= 2.19 MW/cavity	Kilpatrick: 2.3
R/Q	= 137 Ω	P_{MEAN}	= 85 kW/m for 75 Hz repetition rate	

Bad Efficiency ⇒ don't wait so long (?)



99.7% of the generator power is used to heat copper

Target and Pion Capture

A number of ideas are under consideration which in principle should allow a beam power on target power of up to 4 MW.

The crucial problems are mechanical movements in high magnet fields, heat transfer, material stress, radiation damage and radioactivity confinement.

TARGET

Tests with High B Field in Grenoble High Magnetic Field Laboratory

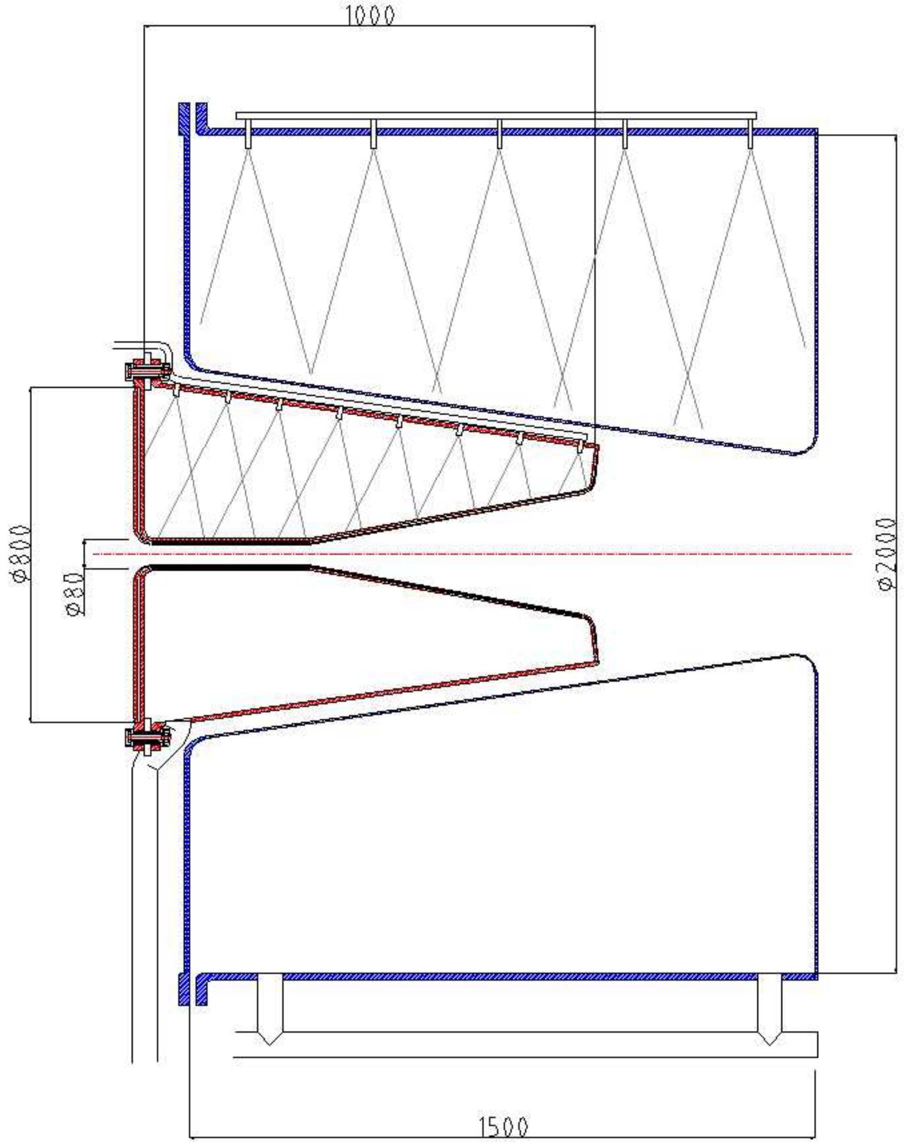
Tests with Trough at BNL
Test with Hg jet at BNL

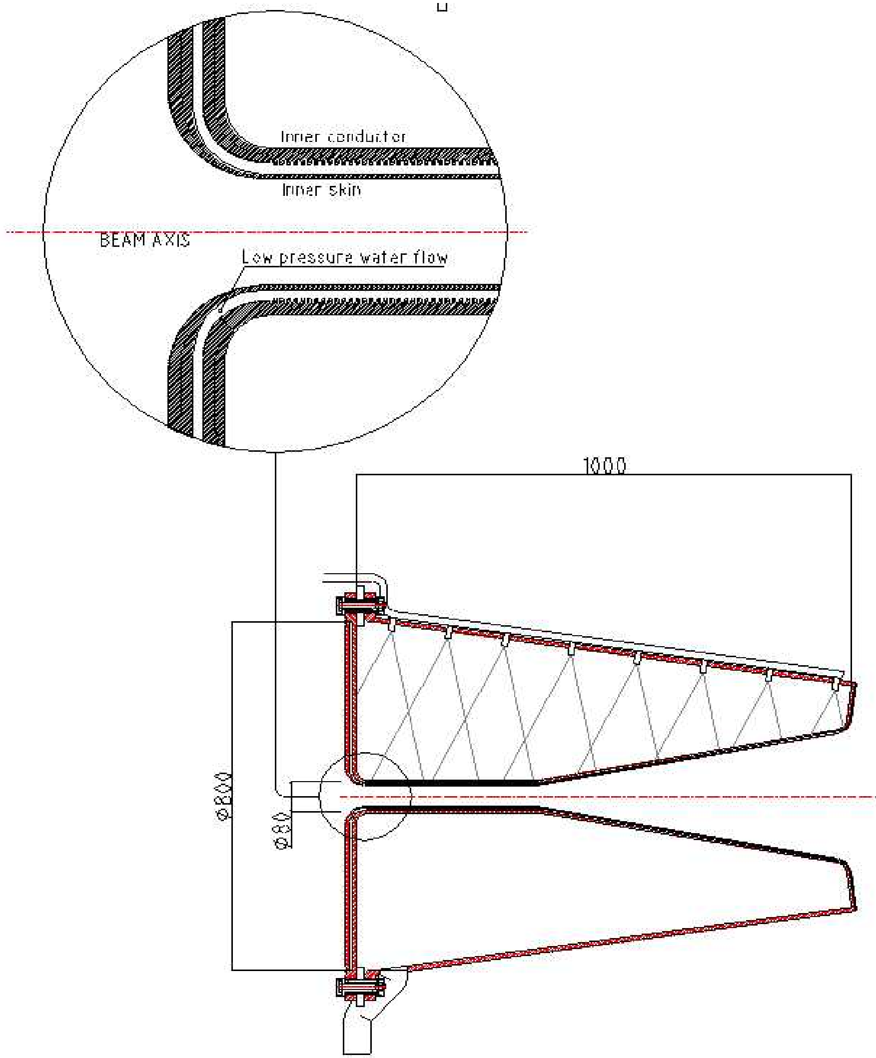
Future: Test with Trough at ISOLDE

PION collection: HORN

Since one is interested in the production of pions of only one polarity for any given proton bunch, we envisage a pion collection system based on azimuthal magnetic fields generated by a horn. A major advantage of horns is that the parts exposed to the beam are rather simple, inexpensive and can be radiation hard.

The horn will be designed to focus particles emitted at large angle, and with a momentum range of 200-400 MeV/c, from a target of typically 2-interaction lengths.


1000
φ800
φ80
φ2000
1500

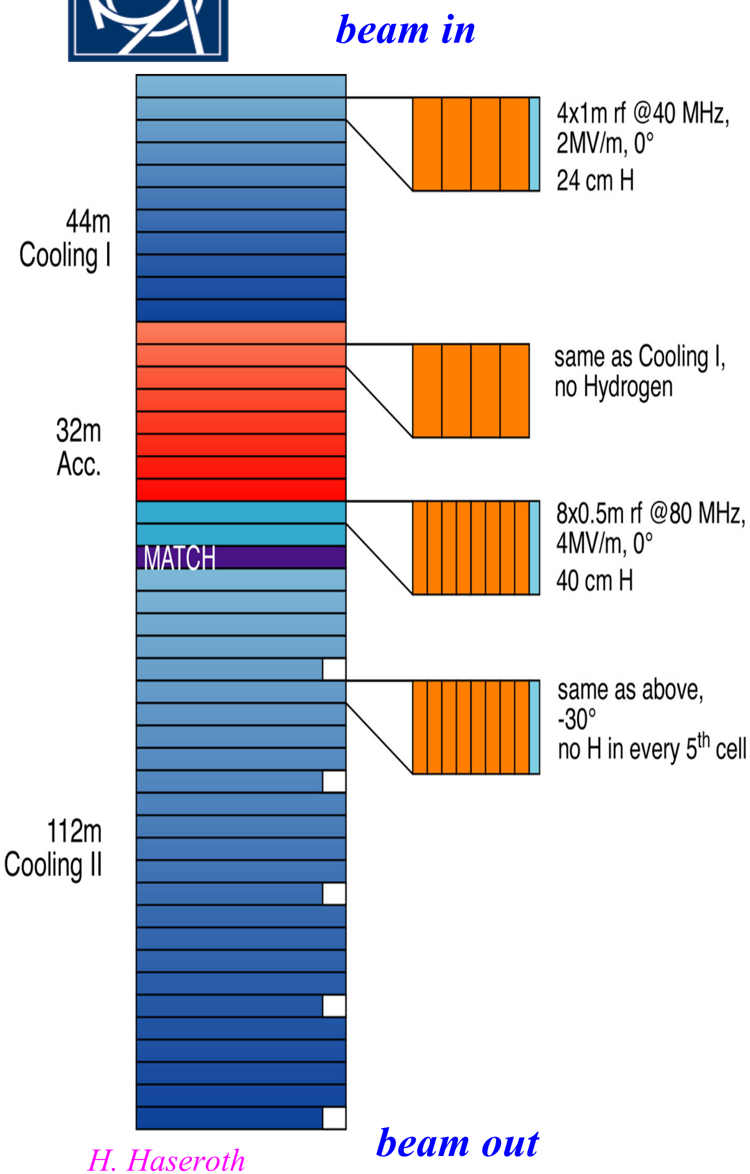


NEUTRINO FACTORY HORN 1 - PROTOTYPE IV Dimensions in mm

S. Rangod 14/03/2001

Update on CERN Activities

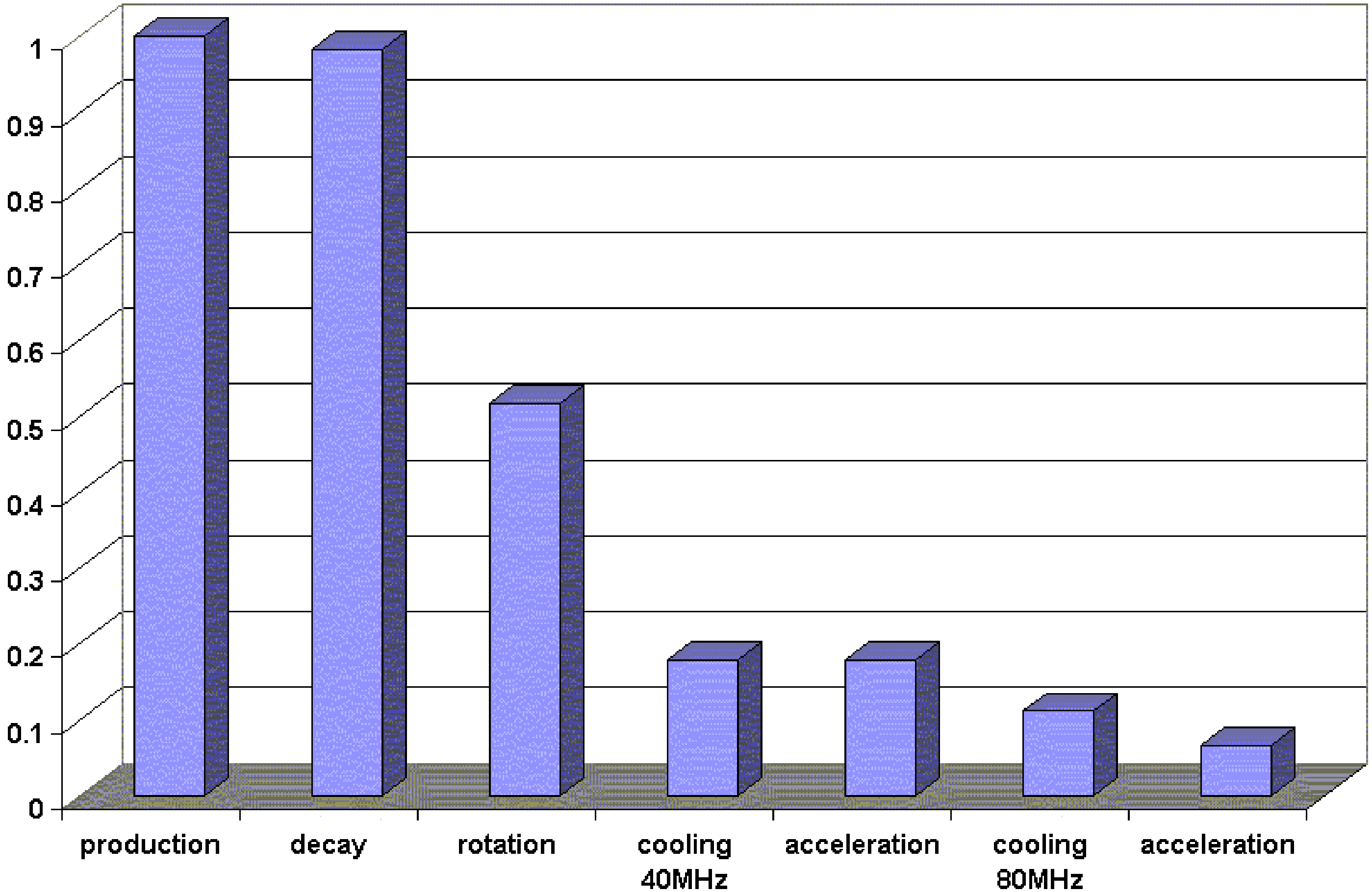
Layout of 40/80 MHz Cooling Channel



	Decay	Rotation	Cooling-I	Acceleration	Cooling-II	Acceleration
Length, m	30	30	46	32	112	≈450
Diameter, mm	600	600	600	600	300	200
Solenoid field, T	1.8	1.8	2.0	2.0	2.6	2.6
Frequency, MHz		44	44	44	88	88-176
Gradient, MV/m		2	2	2	4	4-10
Energy, MeV		200		280	300	2000

Table 3 Main parameters of the capture, phase rotation, cooling and acceleration section

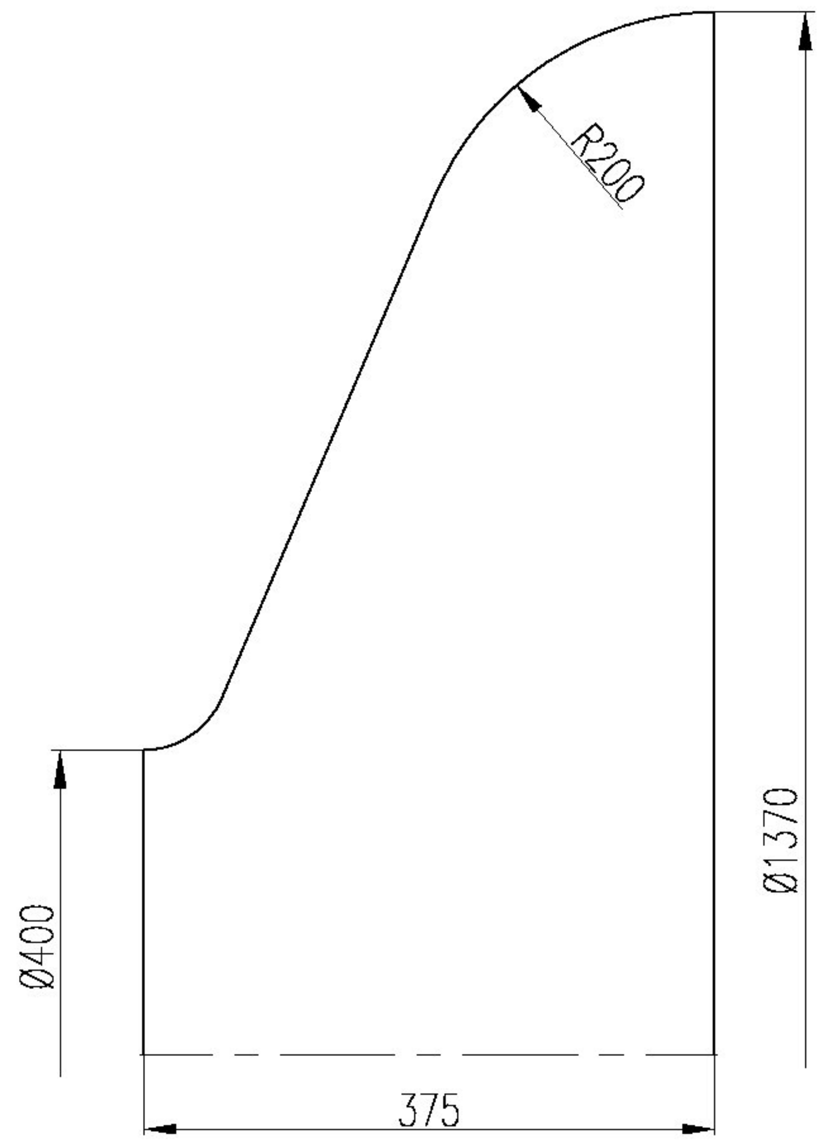
Pion/Muon Budget with Cooling

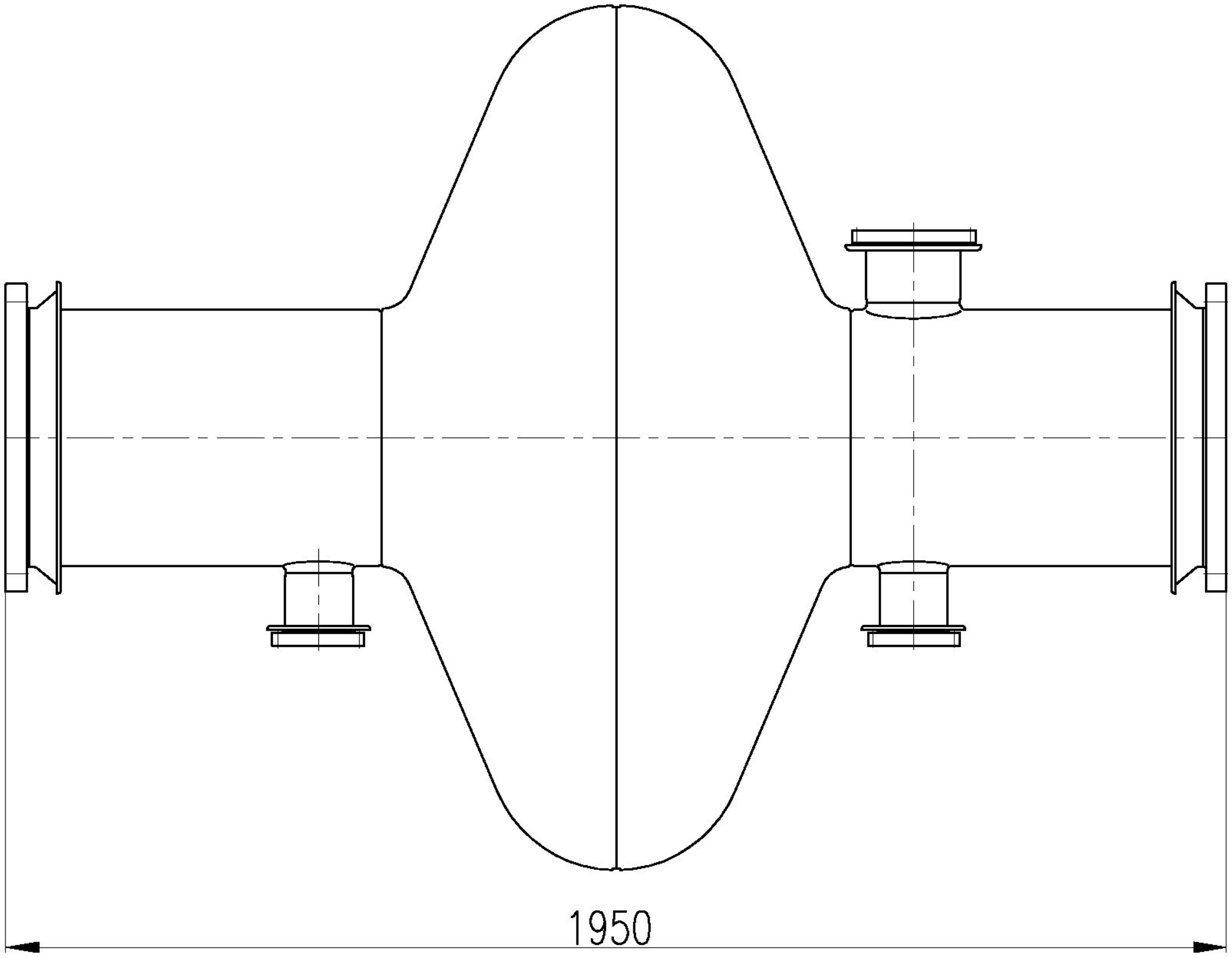


MUON Yield without and with Cooling

	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!


R200
Ø1370
Ø400
375


1950

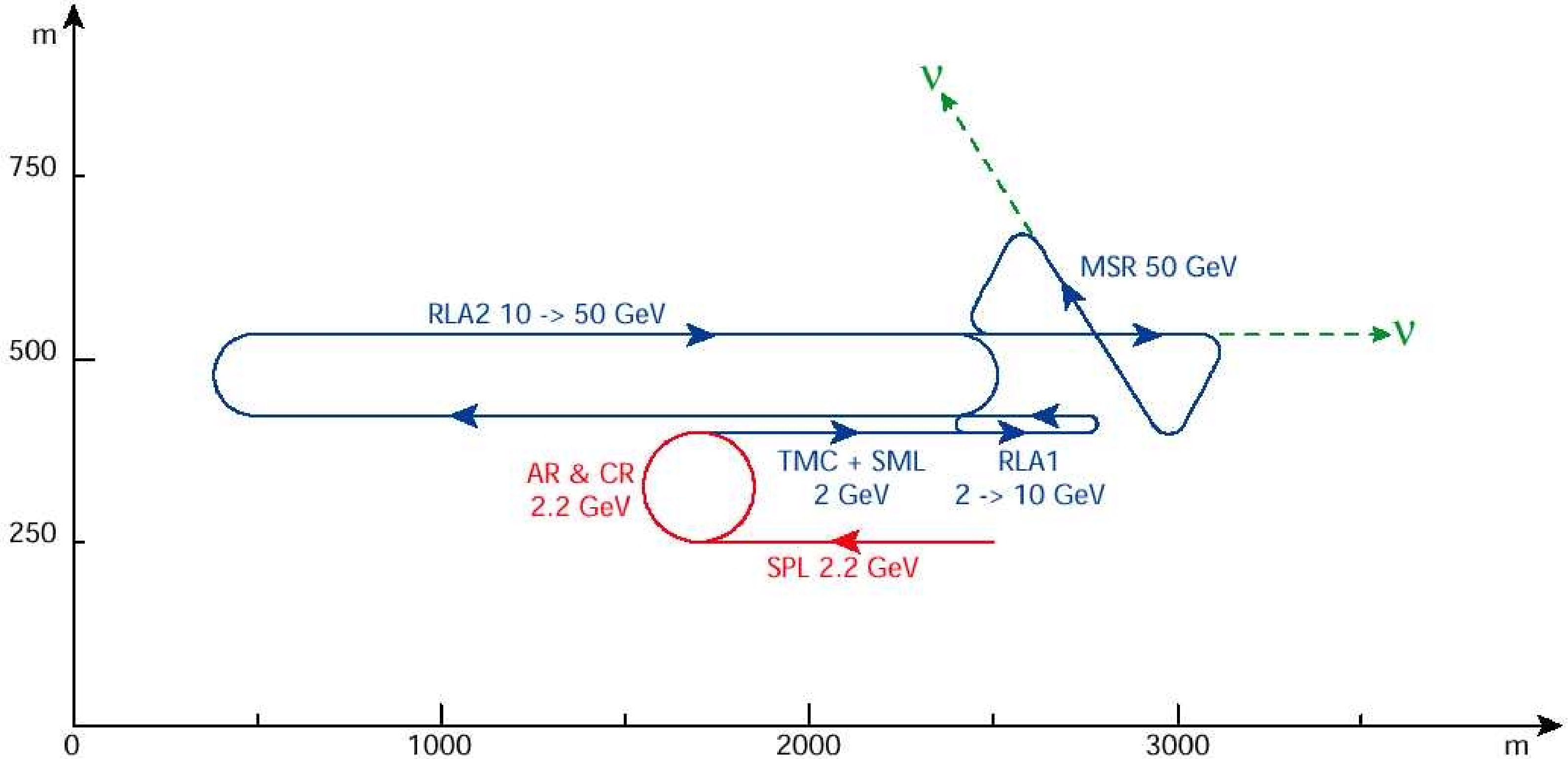
Parameters of Recirculating Linacs (RLAs)

	RLA1	RLA2
Injection energy, GeV	2	10
Extraction energy, GeV	10	50
Number of turns	4	4
Length of linacs (2), m	680	3813
Rf frequency, MHz	352	352
Bending radius in arc, m	5	25
Mean arc radius, m	20	100
Circumference, m	806	4442
Peak voltage gradient per linac, MV/m	7.4	7.4
Normalised admittance, mm rad	16.47	18.80
Normalised rms emittances, mm rad	1.83	2.09

Parameters of Decay Ring

Design momentum, GeV	50
Muon fluence, s^{-1}	10^{14}
Configuration	Triangular
Normalised beam divergence in SS at σ_ε, mrad	0.1
Normalised beam emittance (σ_ε), mm rad	1.67
Aperture limit	3 σ_ε
Relative rms momentum spread	0.005
Bunch spacing, mm	851
Dipole field, T	6
Total length of straight sections, m	1500
Average radius in the arcs, m	46
Circumference, m	2075

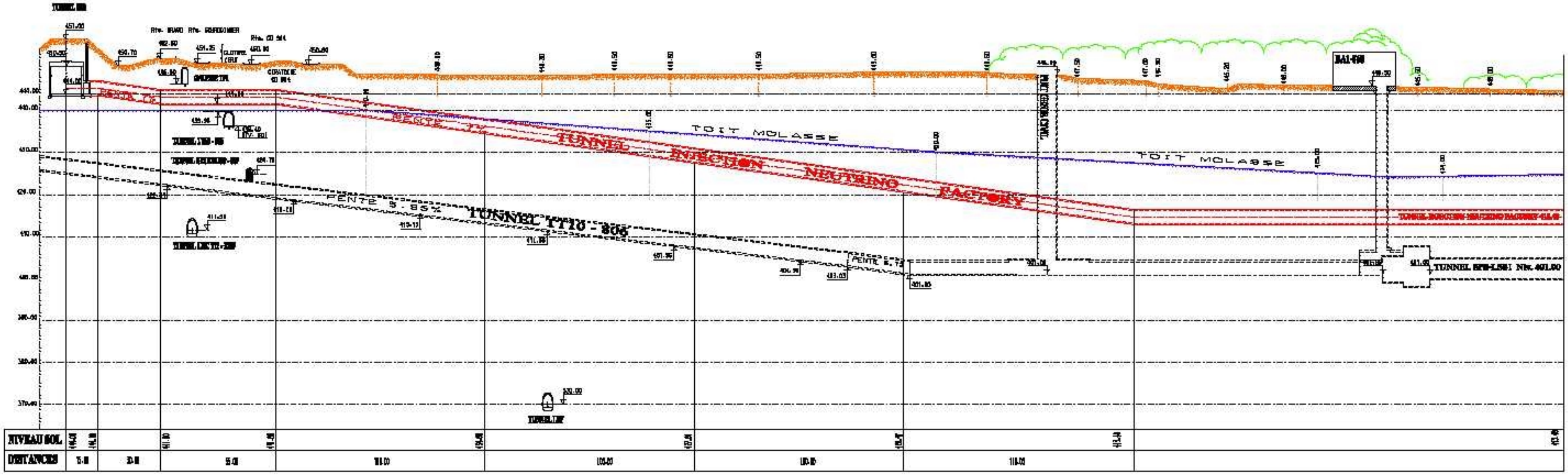
Preliminary Layout of Neutrino Factory (drawn to scale)



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

Preliminary Layout of Proton Transfer Tunnel



H = 1:2000 L = 1:1000

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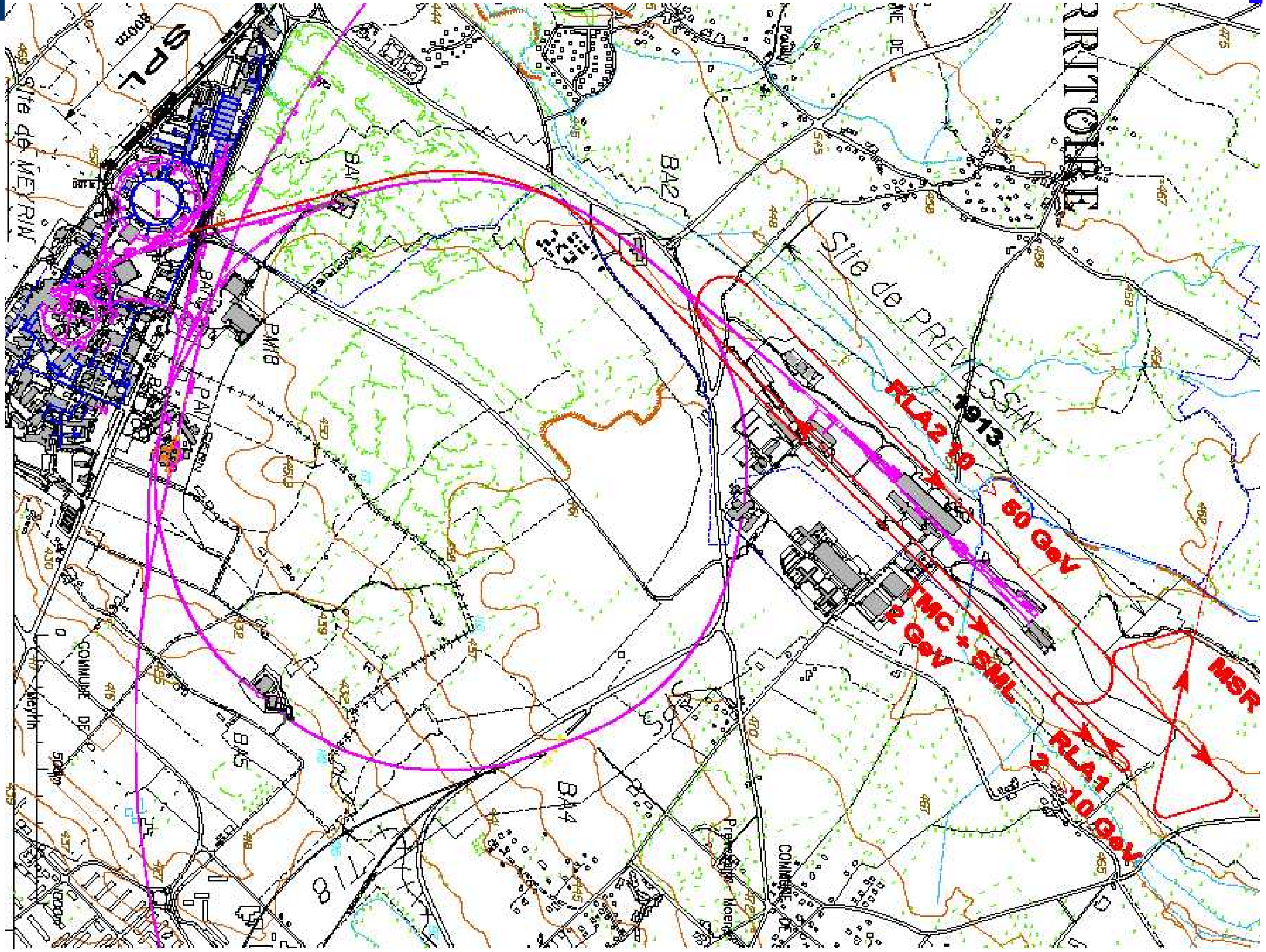
MAY 2001

Preliminary Layout of Neutrino Factory



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The neutrino factory is likely to serve experiments at the:

Gran Sasso

and a long baseline neutrino experiment at a

***new site** at a distance of some 3000 km*

Candidates: Spain, Norway, Finland

Criteria:

distance from CERN,

depth

background,

existing infrastructure

access

local community

La Palma (Canary islands), astronomical observatories, Tunnels (1 km long) under 800m of basaltic stone

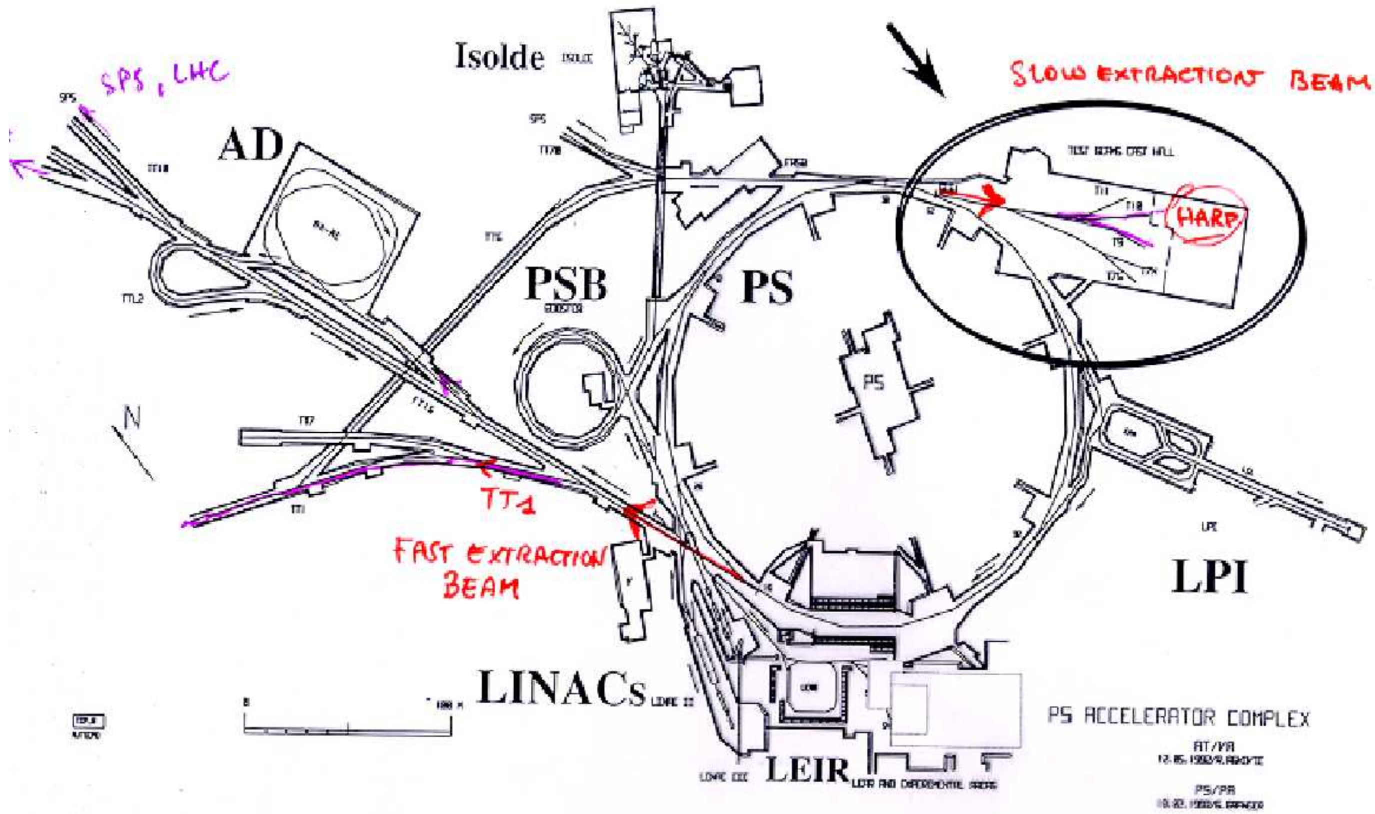
CUPP (Centre for Underground Physics **Pyhäsalmi),** Cosmic ray observatory, 960m to 1200m 2296 km from CERN

Svalbord / Spitzbergen

Michel Mayoud /Mark Jones / Aude Wiart are working on the position of the decay ring:

neutrino beam to near detector	Gran Sasso
neutrino beam to far detector	Svalbord
	La Palma
	Pyhäsalmi

The PS Accelerator Complex and possible Locations for a Muon Beam

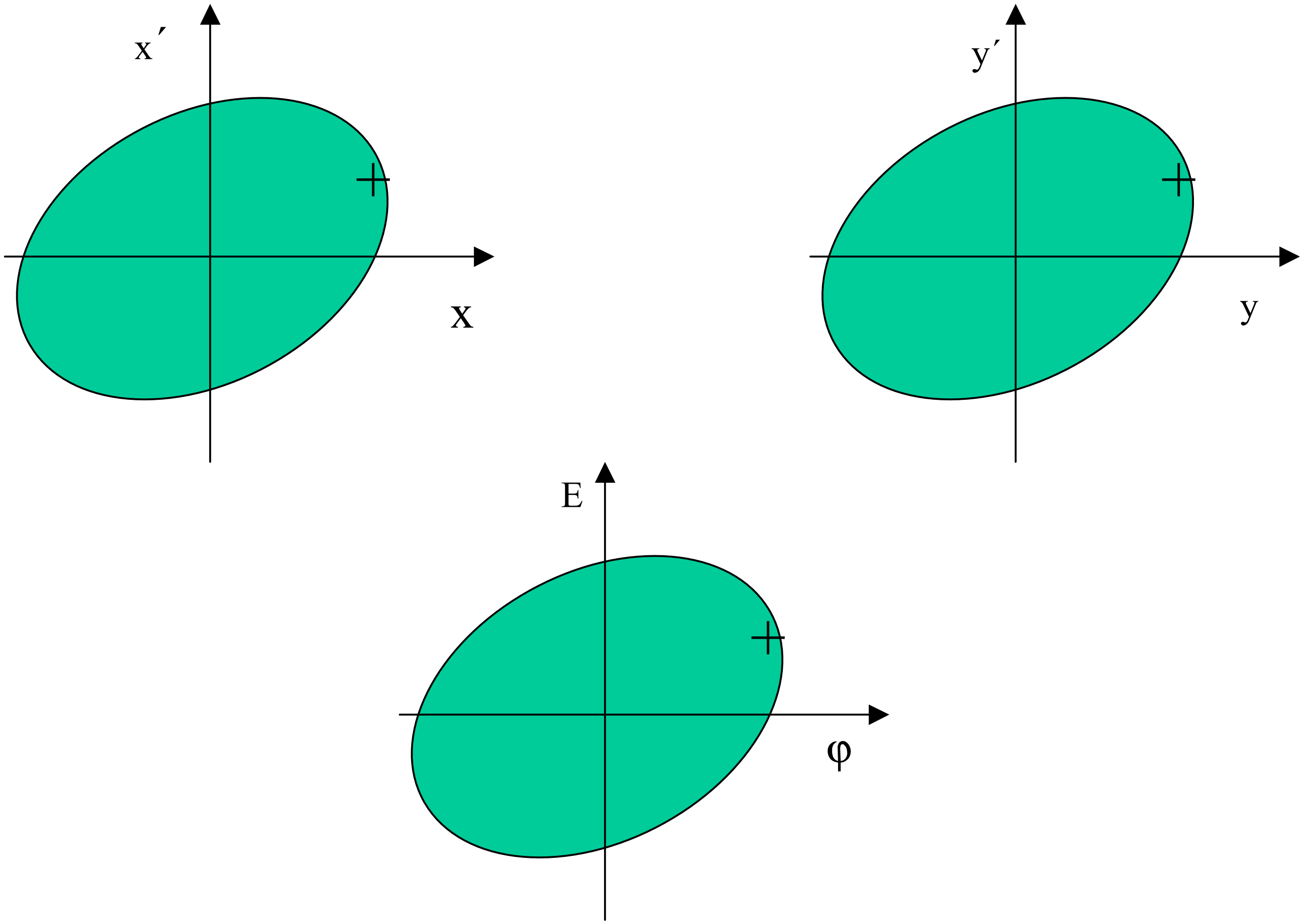


⇒ *A cooling experiment is very important to demonstrate* ⇐

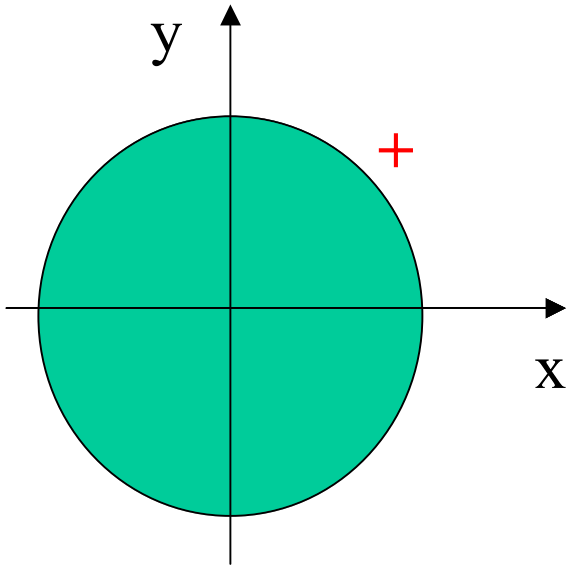
the feasibility of the technical choices made

Some thoughts are going on about a Muon Ionisation Cooling Experiment (MICE)

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



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



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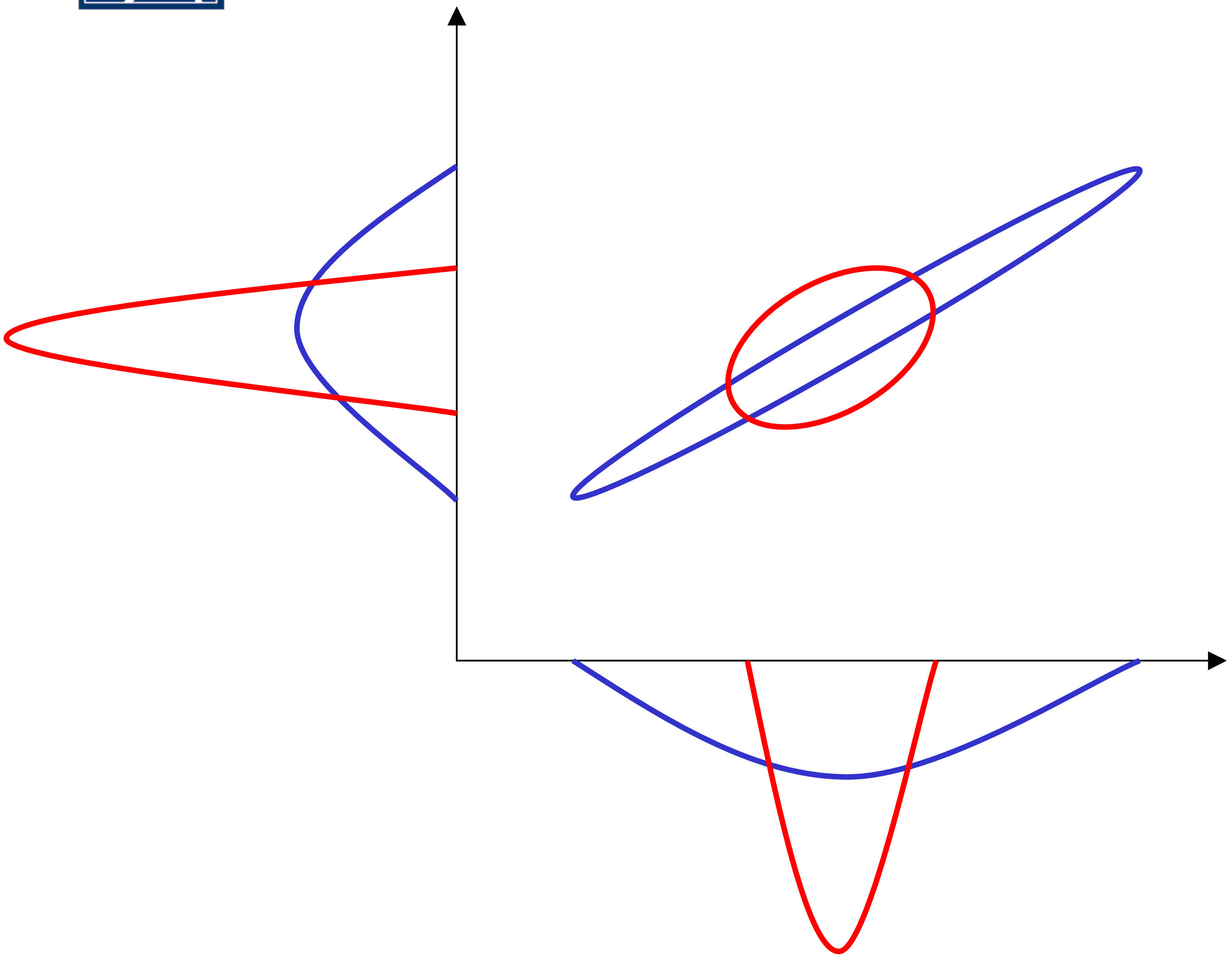
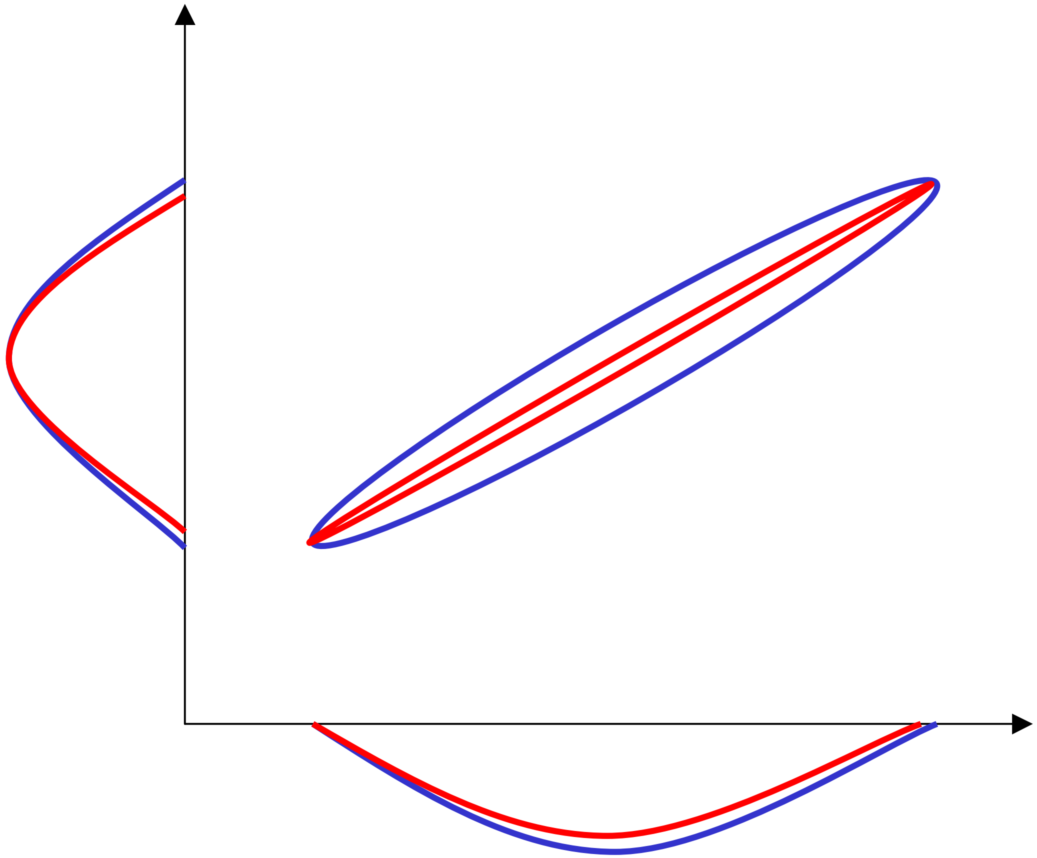
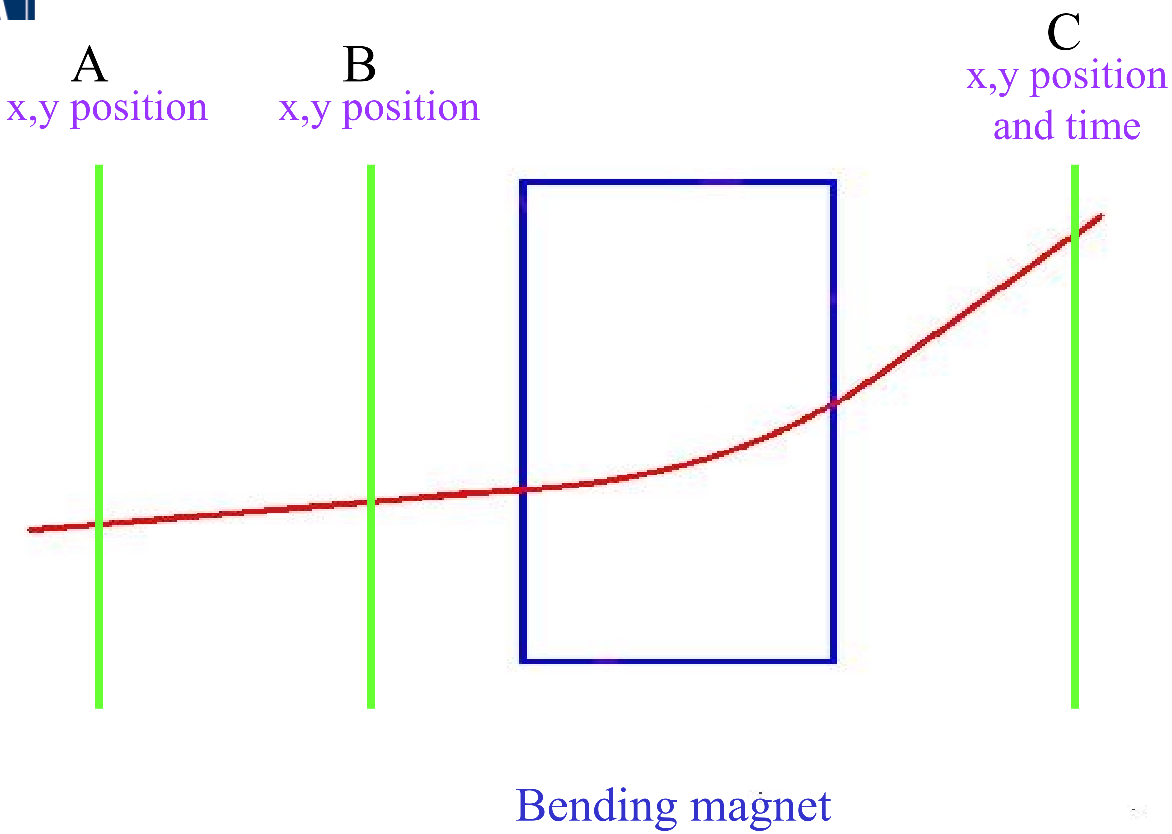
Example in a 2D case:
Do not claim the red ellipse is "cooled"!



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"…

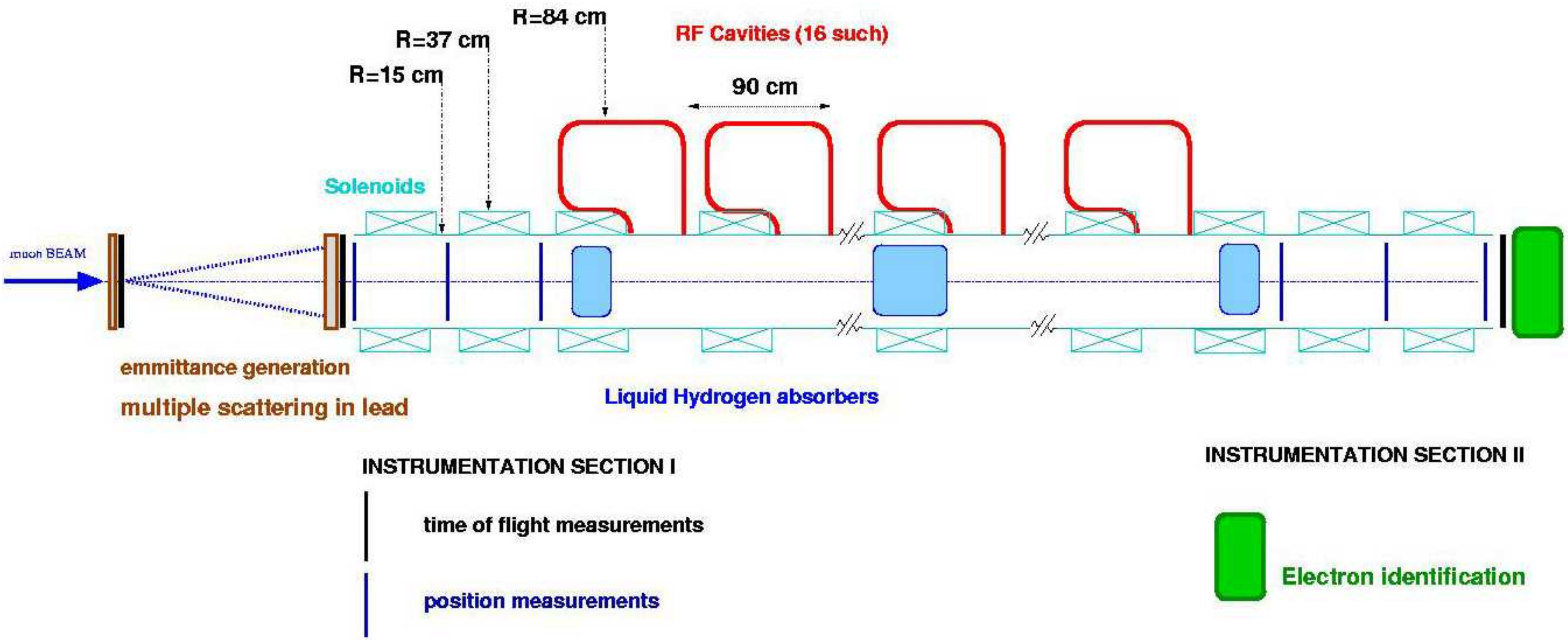
Note: They are not in rf or solenoidal fields!

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

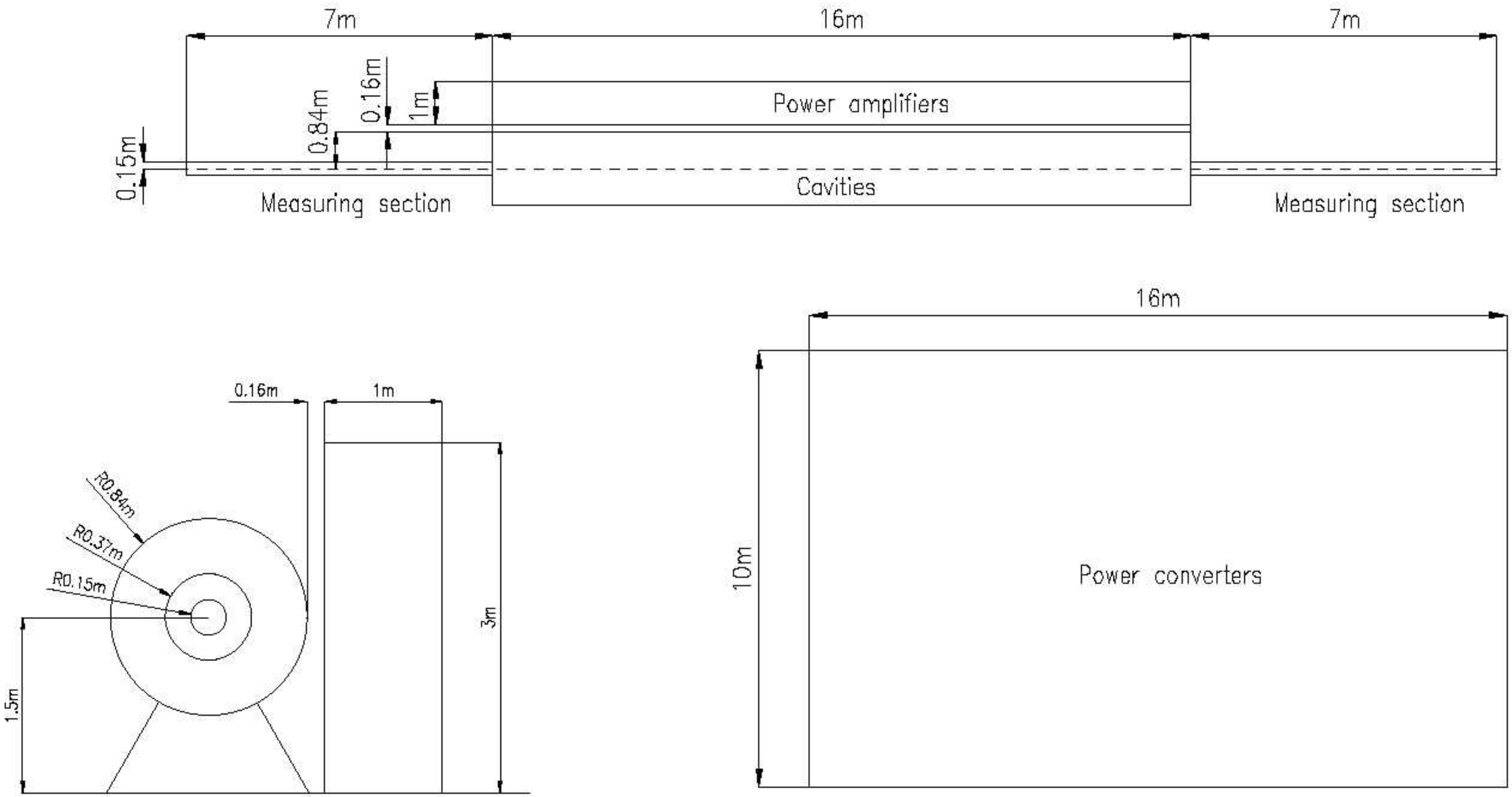
1) Abandon the idea of multiparticle measurements

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

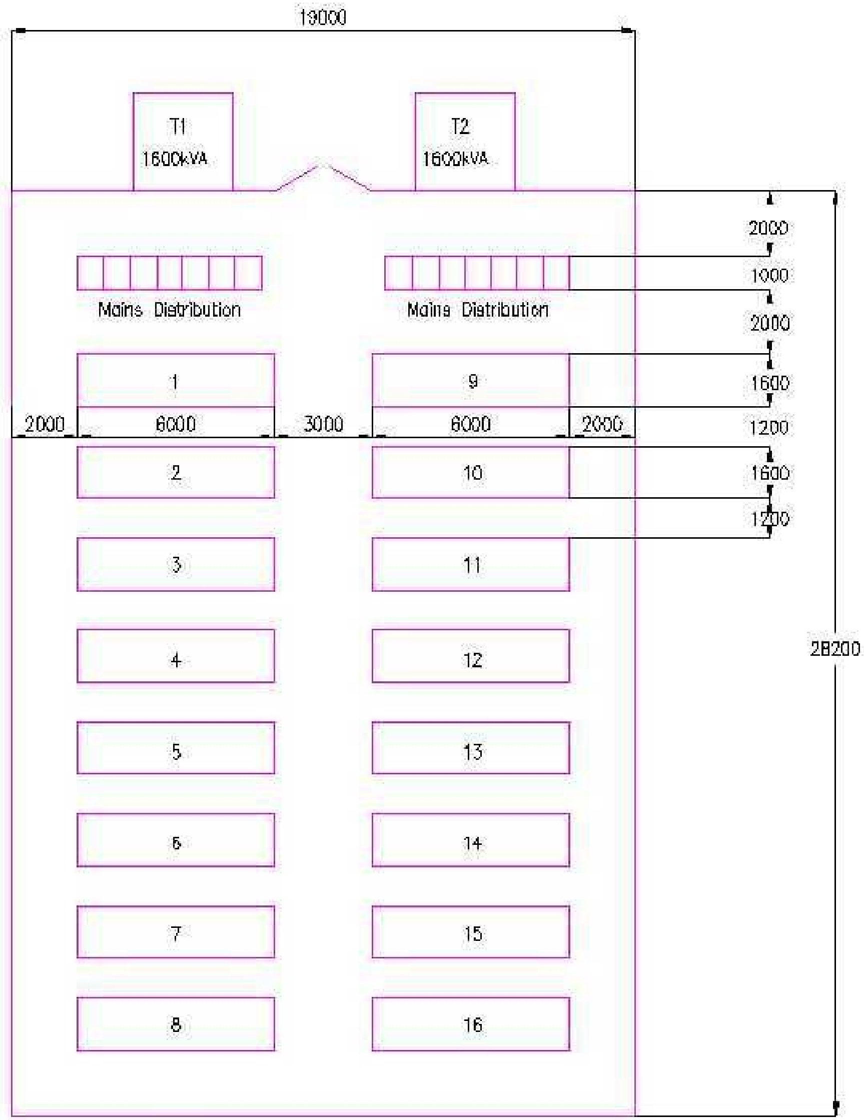
Make it sufficiently transparent!



R=84 cm
R=37 cm
R=15 cm
RF Cavities (16 such)
90 cm
Solenoids
BEAM
emmittance generation
multiple scattering in lead
Liquid Hydrogen absorbers
INSTRUMENTATION SECTION I
time of flight measurements
position measurements
INSTRUMENTATION SECTION II
Electron identification



Cavities and Amplifiers



Possible Layout of Power Converters for RF-Amplifiers
Cooling Channel Experiment

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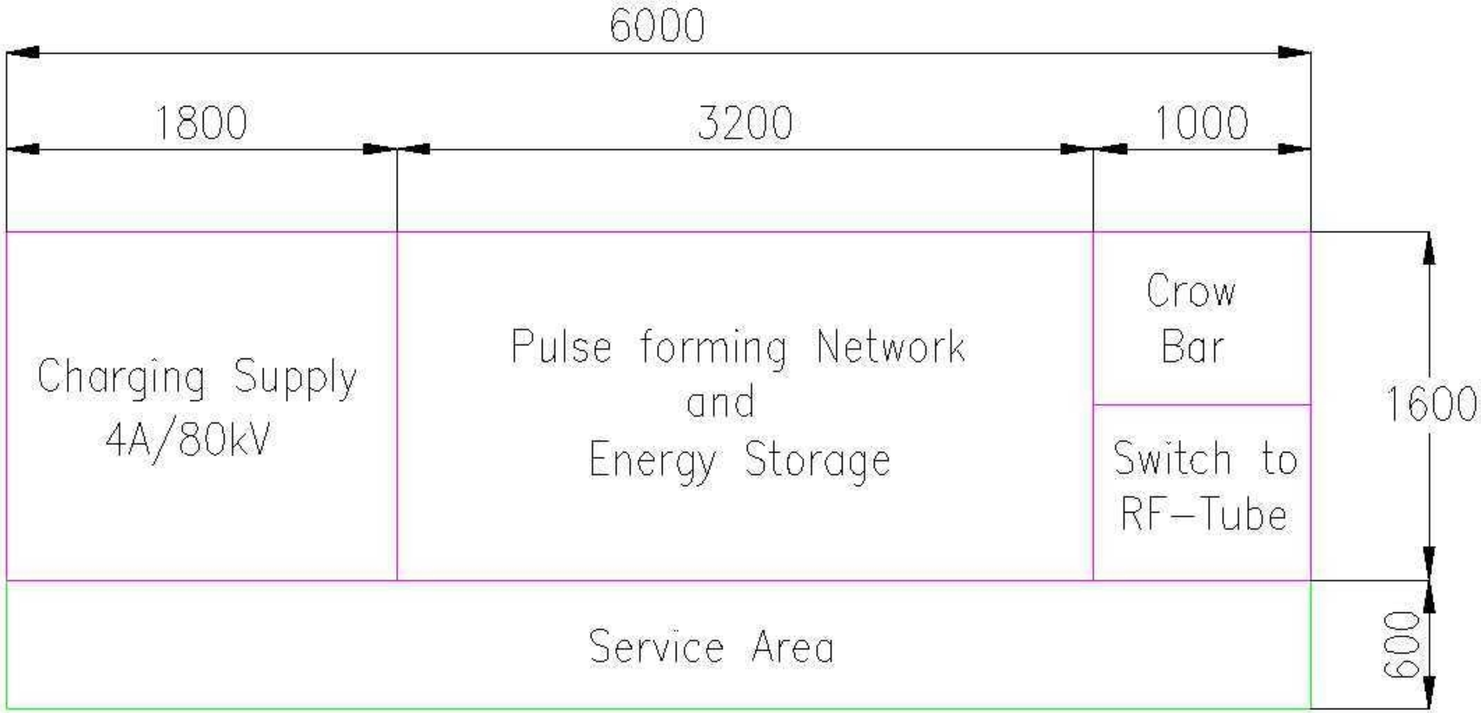
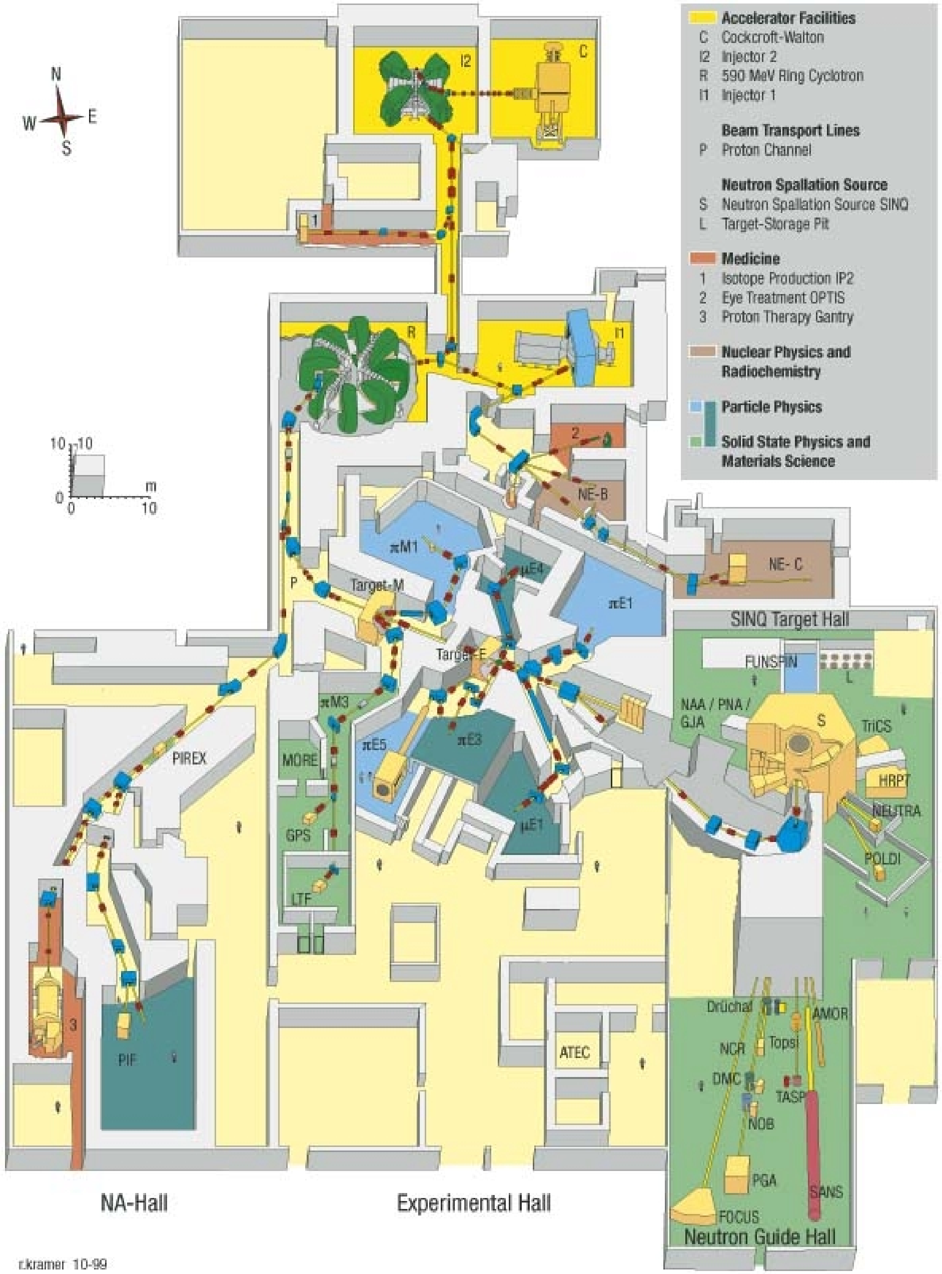
MAY 2001



Possible Layout of Single Power Converter
Cooling Channel Experiment

PSI


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
m
10
0
NE-B
NE- C
SINQ Target Hall
FUNSPIN
NAA / PNA / GJA
TriCS
HRPT
NEUTRA
POLDI
Target-M
Target-E
PIREX
MORE
GPS
LTF
PIF
ATEC
Drüchal
AMOR
NCR
Topsi
DMC
TASP
NOB
PGA
SANS
FOCUS
Neutron Guide Hall
NA-Hall
Experimental Hall
r.kramer 10-99

Acknowledgements

The work presented here is the result of the effort of the Neutrino Factory Working Group at CERN.

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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.*

- *It is intended to continue this study and to fill in the remaining gaps. 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 the end of this year may also provoke some modifications.*

- *The next steps ought to be:*
  - *the refinement of simulations, engineering designs and a*
  - *cooling experiment for which we need a strong international collaboration*