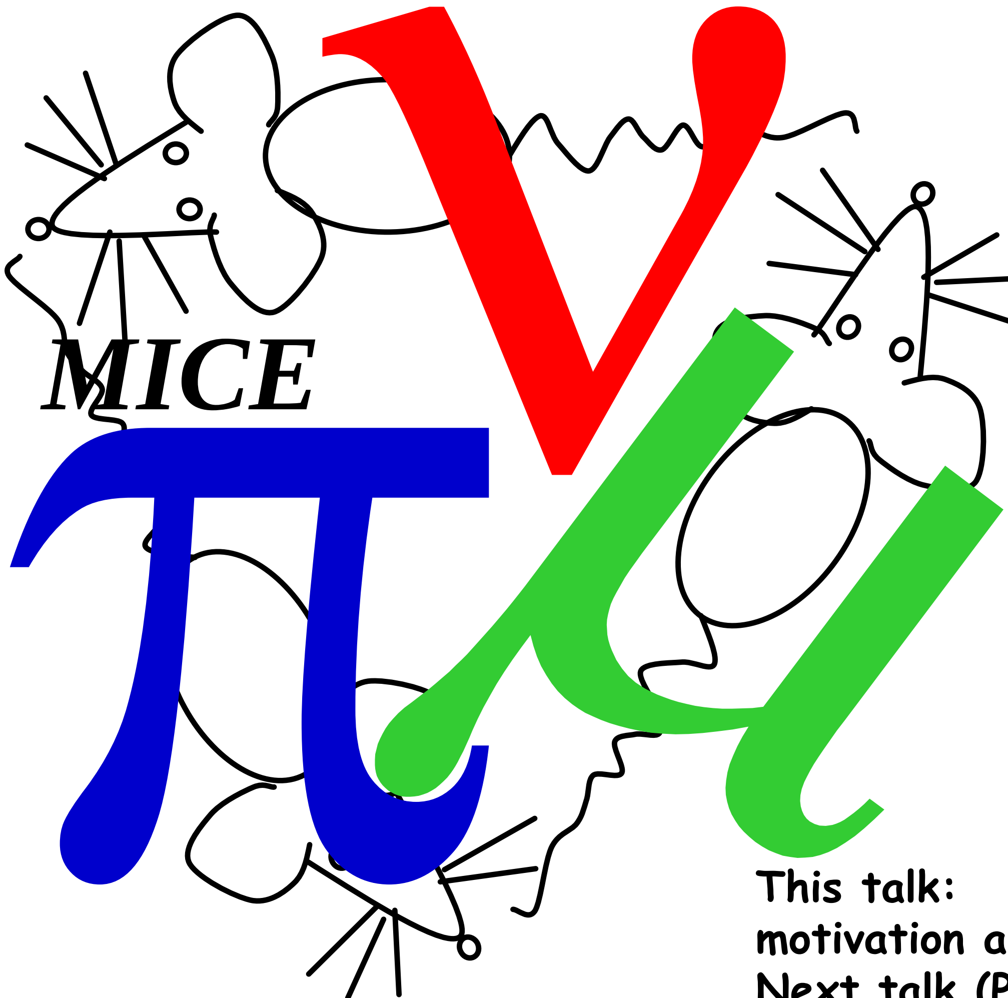
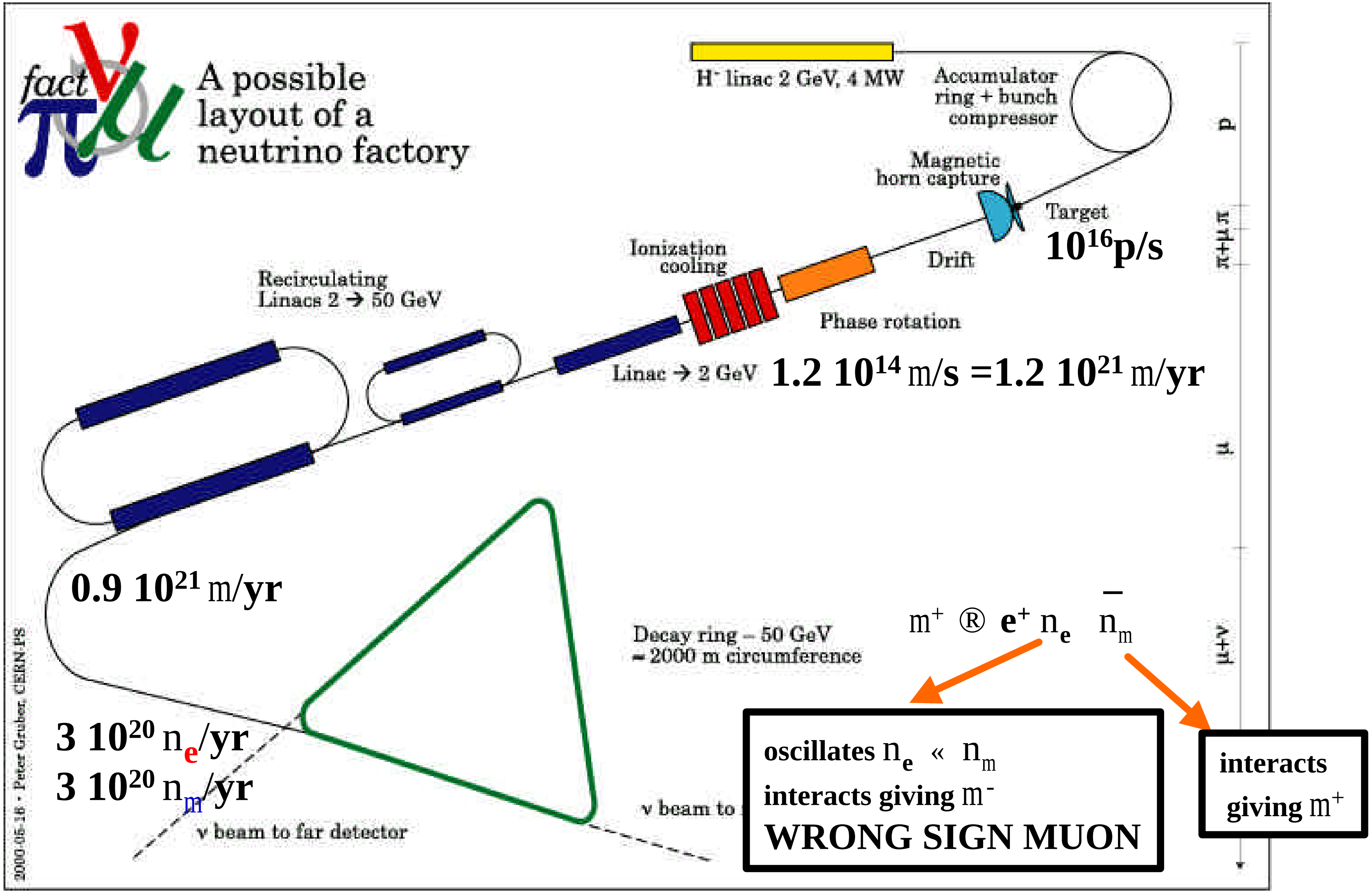
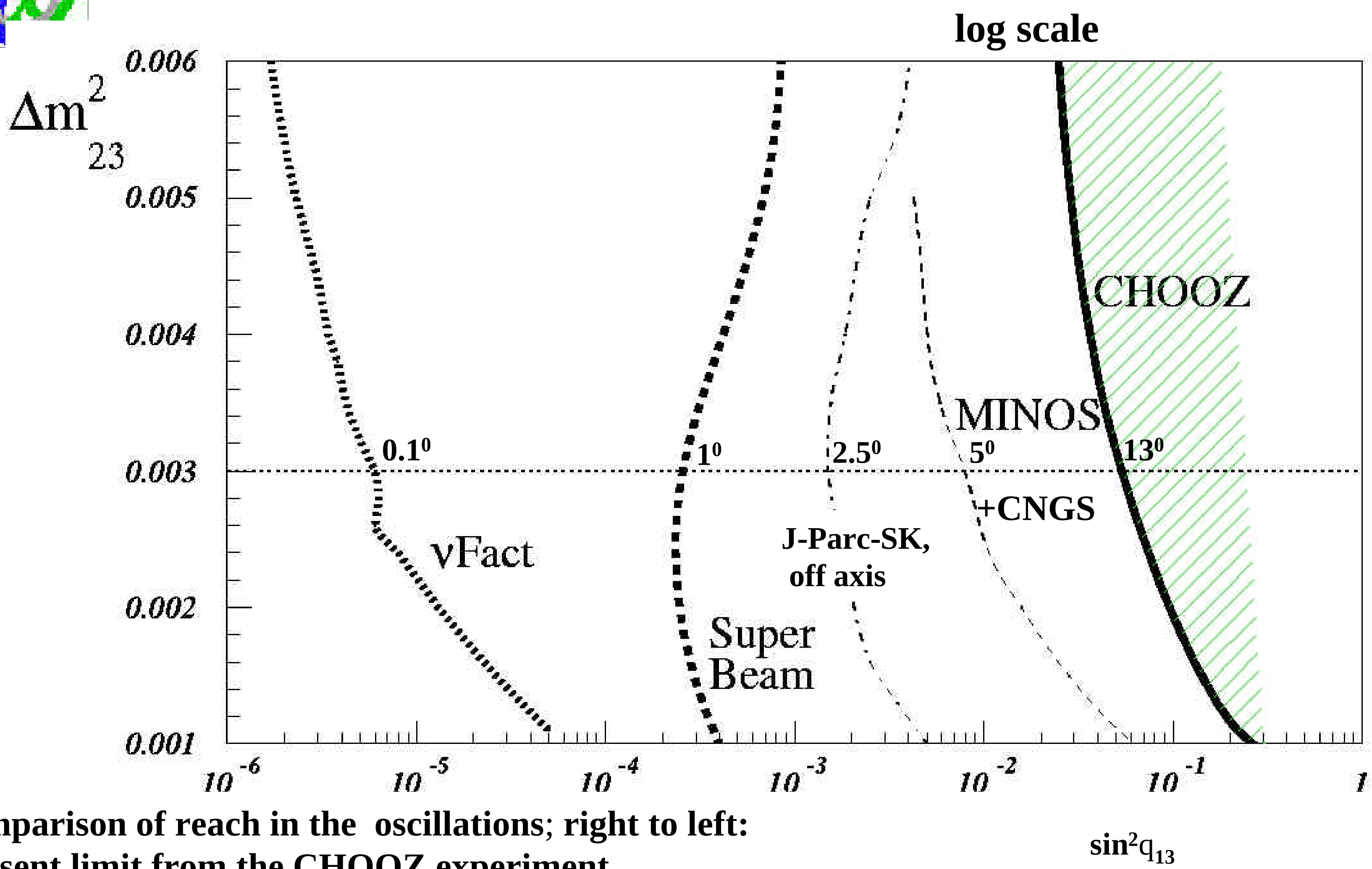
International Muon Ionization Cooling Experiment



This talk:
motivation and measuring technique
Next talk (Paul Drumm):
Beam, power sources,
installation at RAL, safety.

-- Neutrino Factory -- CERN layout



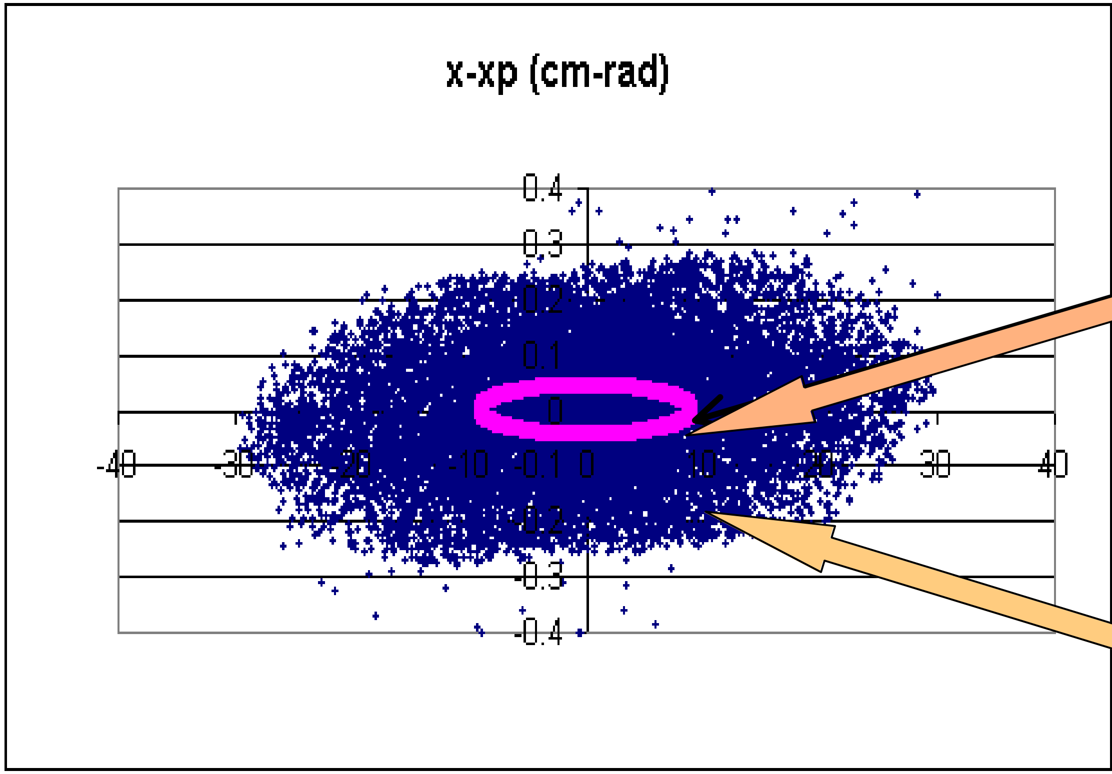


comparison of reach in the oscillations; right to left:
present limit from the CHOOZ experiment,
expected sensitivity from the MINOS experiment, (and CNGS expts)
0.75 MW J-Parc to super Kamiokande with an off-axis narrow-band beam,
Superbeam: 4 MW CERN-SPL to a 400 kton water Cerenkov in Fréjus or J-Parc
from a Neutrino Factory with 40 kton large magnetic detector. INCLUDING SYSTEMATICS

NUFACT R&D; Cooling

⌘ Problem: $\mu \rightarrow$ Beam pipe radius of accelerator & storage ring

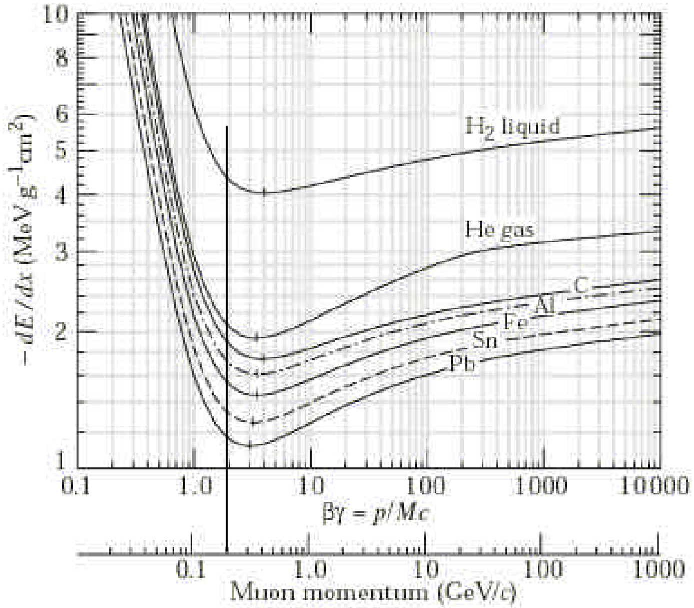
$P_\perp$ or x' and x reduction needed: COOLING



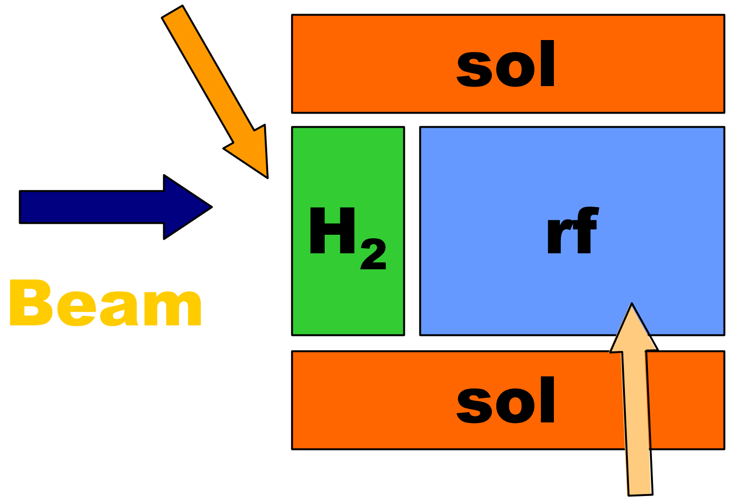
Accelerator acceptance
R ≈ 10 cm, x' ≈ 0.05 rad
rescaled @ 200 MeV

π and μ after focusing

Ionization Cooling : the principle



Liquid H_2: dE/dx



RF restores only $P_{//}$

What muon cooling buys , and costs…..

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}

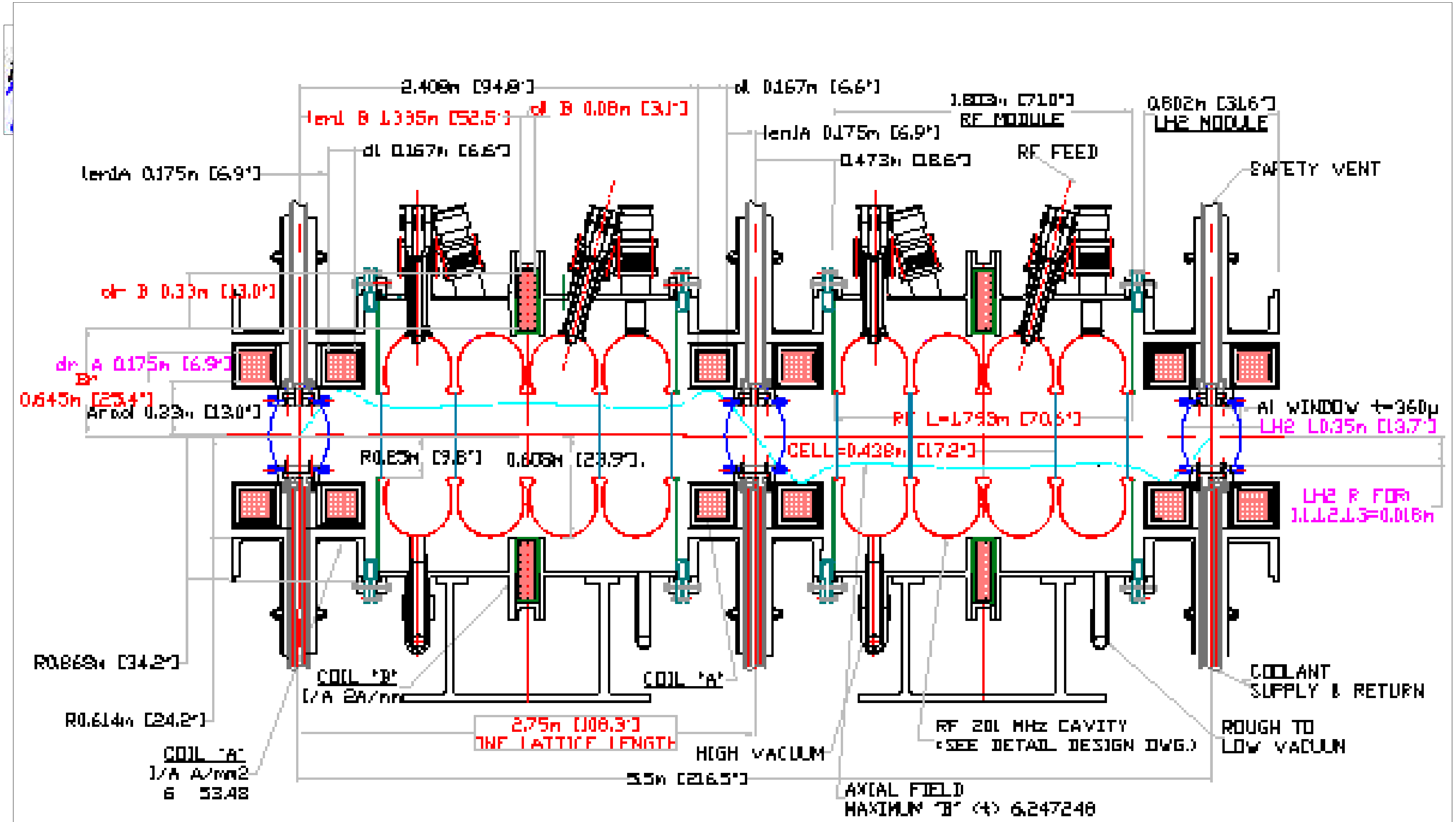
K. Hanke, CERN scheme

exact gain depends on relative amount of phase rotation (mono-chromatization vs cooling trade off)
'only a factor of 3-4 in US Study II'

Study II cost:

System	Total
Proton Driver	184.4
Target Systems	100.8
Decay Channel	5.1
Induction Linacs	351.0
Bunching	75.5
Cooling Channel	**348.7**
Pre-accel. Linac	207.8
RLA	391.0
Storage Ring	118.1
Site Utilities	139.6
TOTAL	**1922.0**

1. Quality of cooling impacts on downstream systems (accelerator)
2. Major hope for reduction in cost in better cooling…



studyII cooling channel – many challenges:

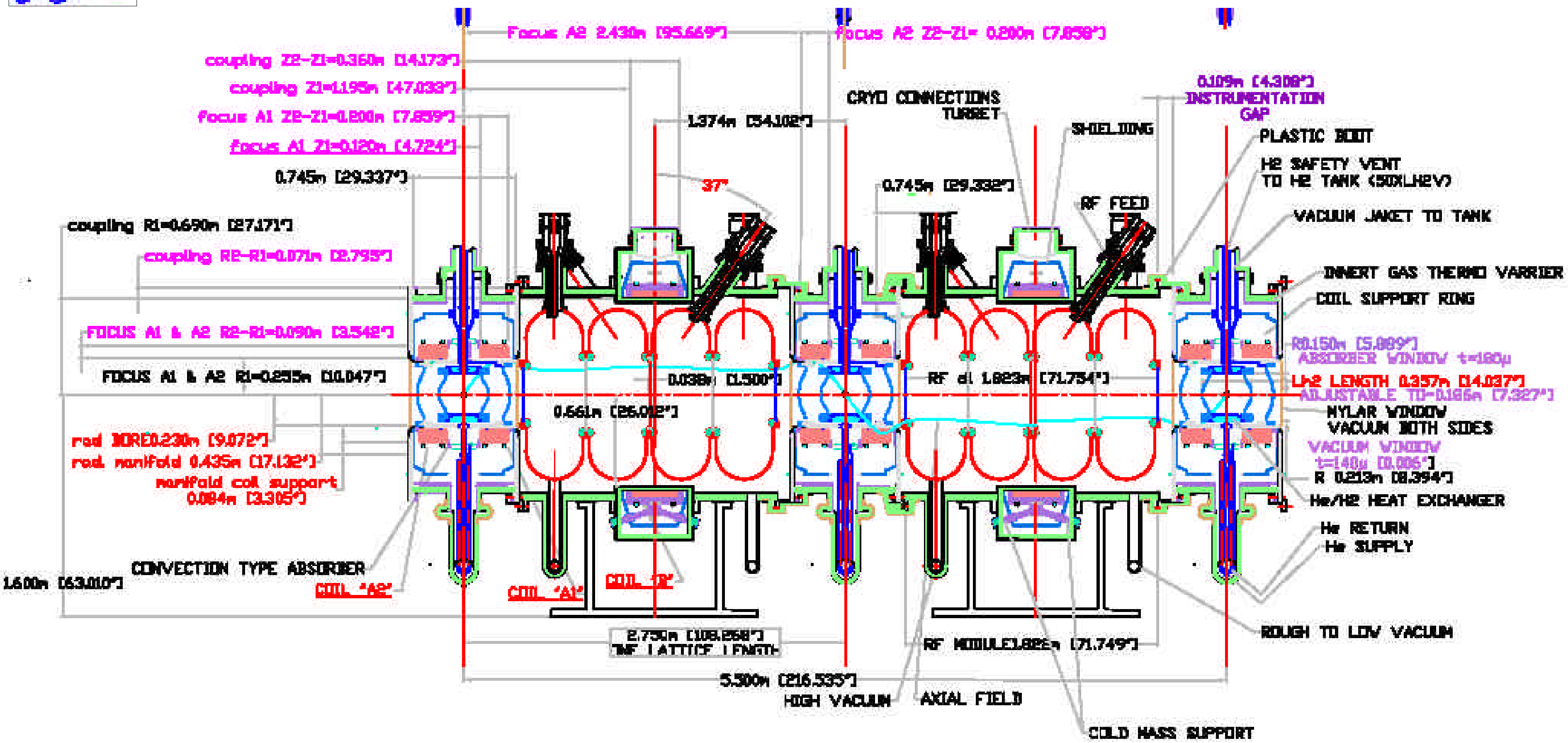
Thin H2 windows,

Clean high gradient RF (risk to boil hydrogen or dammage windows)

High mag. fields

Large aperture RF pill box => Beryllium windows

Realism

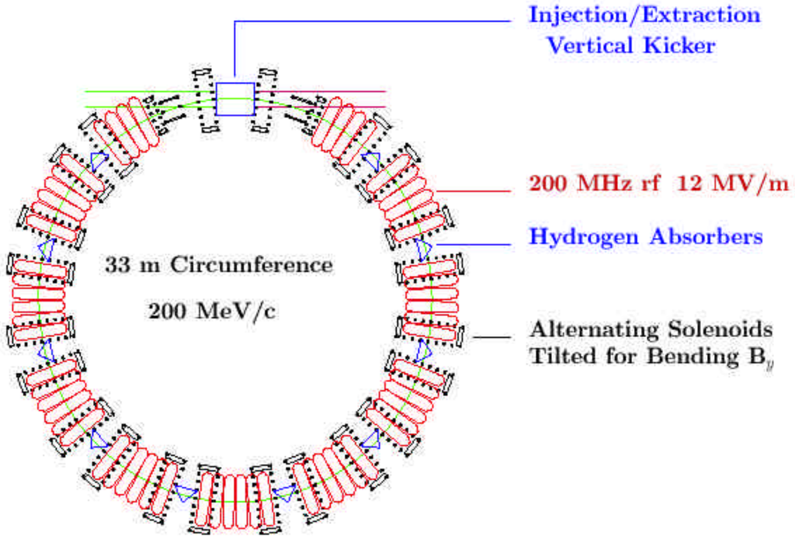


MICE cooling channel: magnets have been reduced in size (cost saving) while keeping same aperture

windows and a argon gas jacket have been added for safety.

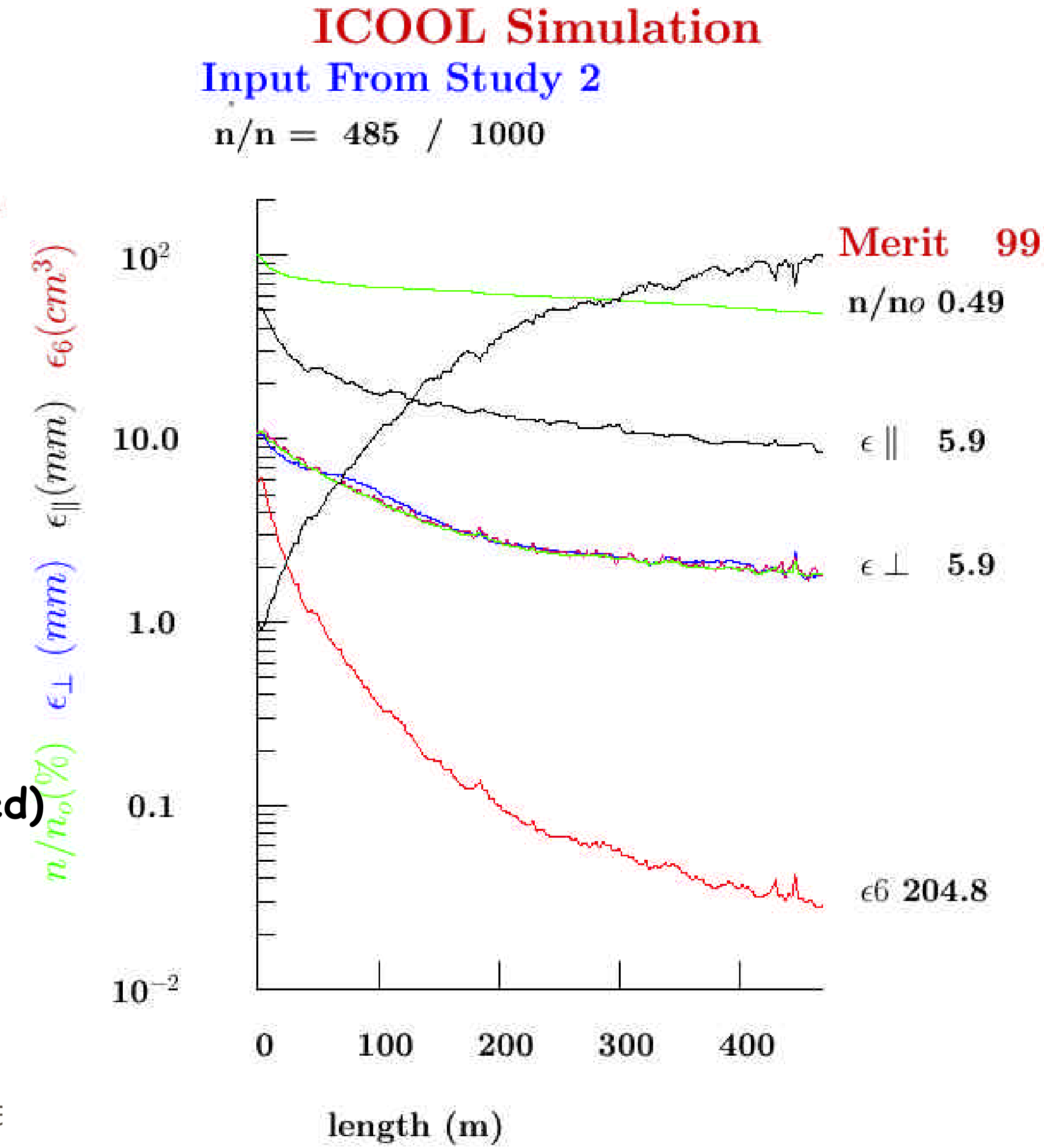
COOLING RINGS

Two goals: 1) Reduce hardware expense on cooling channel
2) Combine with energy spread reduction (longitudinal and transverse cooling) potentially saving on accelerator …



Simple but Sinful:

- Rf in dispersive location



same cooling components as MICE (Solenoids and LH2 windows are tilted)

major problem: Kickers

(Same problem occurs in Japanese acceleration scheme with FFAG)

the MICE mission

The aims of the international Muon Ionization Cooling Experiment are:

To show that it is possible to design, engineer and build a section of cooling channel capable of giving the desired performance for a Neutrino Factory;

To place it in a muon beam and measure its performance in a variety of modes of operation and beam conditions, thereby investigating the limits and practicality of cooling.

in other words:

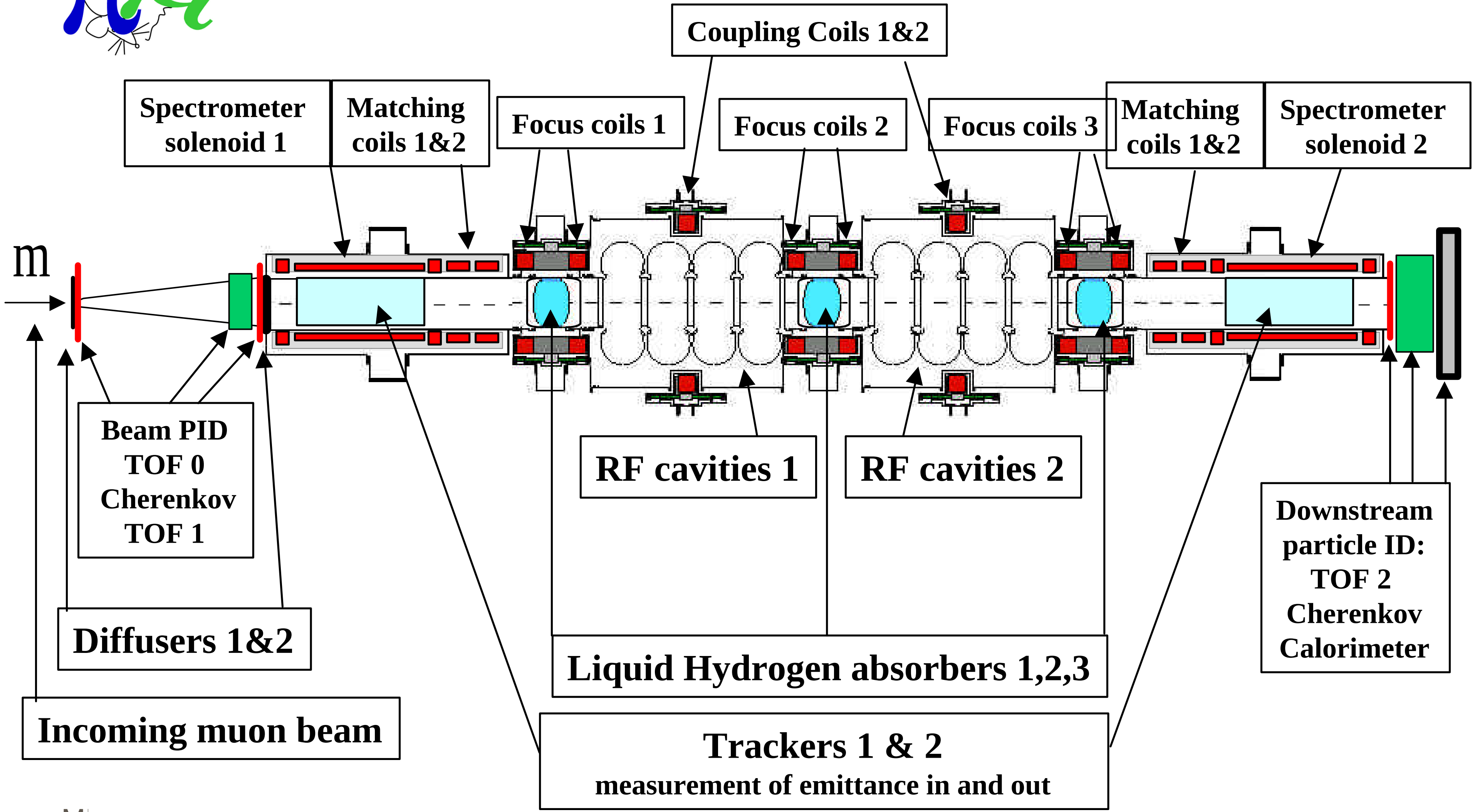
The first challenge for MICE is to turn a new concept, which on paper surely works, into an apparatus that works in practice, supported by a community of experienced people capable of operating it, maintaining it and improving it.

The next challenge is to do this in a significant way, from the combined points of view of precision, realism and relevance.

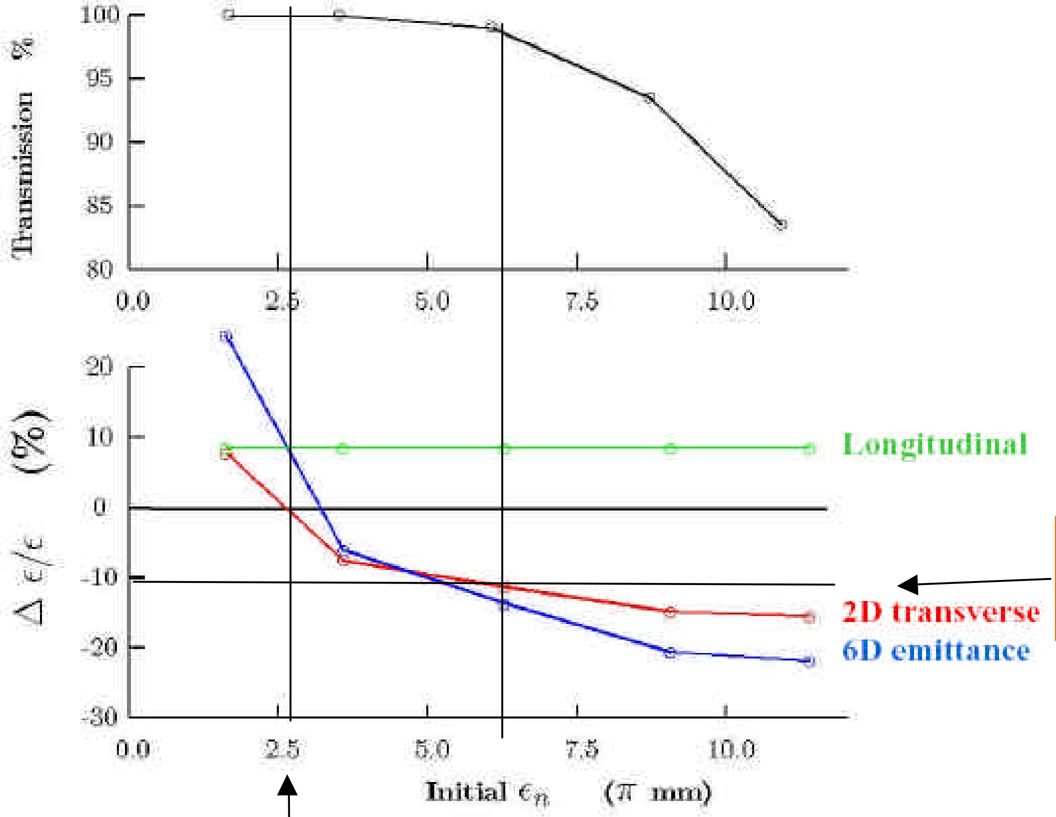
(A muon will go more than 100 time through cooling cells, in which errors accumulate.)

10% cooling of 200 MeV muons requires ~ 20 MV of RF
single particle measurements =>

measurement precision can be as good as $D (e_{out}/e_{in}) = 10^{-3}$
never done before either….



Quantities to be measured in a cooling experiment

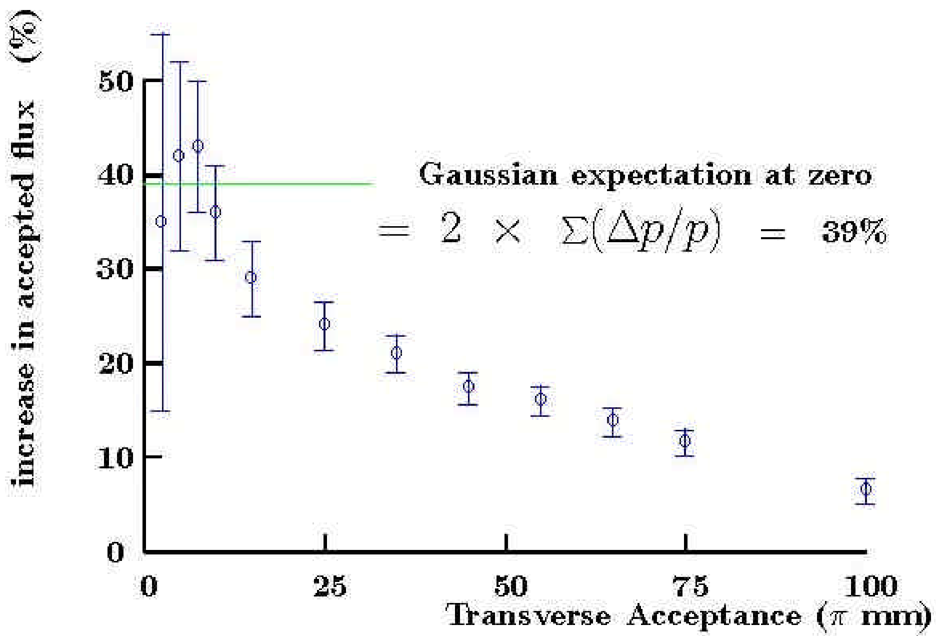


cooling effect at nominal input emittance ~10%

equilibrium emittance

curves for 23 MV, 3 full absorbers, particles on crest

Quantities to be measured in a cooling experiment (ctd)



number of particles inside acceptance of subsequent accelerator
(nominal is 15 mm rad)

Need to count muons coming in within an acceptance box and muons coming out.

It is difficult to count very precisely particles of a given type in a bunch
and to measure emittance very precisely. => single particle experiment

Emittance measurement

Each spectrometer measures 6 parameters per particle

x y t

$x' = dx/dz = P_x/P_z$ $y' = dy/dz = P_y/P_z$ $t' = dt/dz = E/P_z$

Determines, for an ensemble (sample) of N particles, the moments:

Averages <x> <y> etc…

Second moments: variance(x) $s_x^2 = < x^2 - <x>^2 >$ etc…

covariance(x) $s_{xy} = < x.y - <x><y> >$

Covariance matrix

$$M = \begin{pmatrix} s_x^2 & s_{xy} & s_{xt} & s_{xx'} & s_{xy'} & s_{xt'} \\ \cdots & s_y^2 & \cdots & \cdots & \cdots & s_{yt'} \\ \cdots & \cdots & s_t^2 & \cdots & \cdots & s_{tt'} \\ \cdots & \cdots & \cdots & s_{x'}^2 & \cdots & s_{x't'} \\ \cdots & \cdots & \cdots & \cdots & s_{y'}^2 & s_{y't'} \\ \cdots & \cdots & \cdots & \cdots & \cdots & s_{t'}^2 \end{pmatrix}$$

Getting at e.g. $s_{x't'}$ is essentially impossible with multiparticle bunch measurements

Evaluate emittance with:

$$e^{6D} = \sqrt{\det(M_{xytx'y't'})}$$

$$e^{4D} = \sqrt{\det(M_{xyx'y'})} = e^2_{\wedge}$$

Compare e^{in} with e^{out}

requirements on spectrometer system:

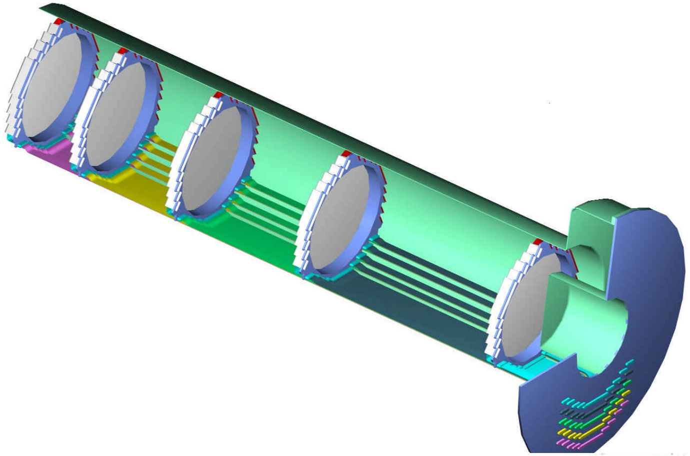
1. must be sure particles considered are muons throughout
   - 1.a reject incoming e, p, p
     - => TOF 2 stations 10 m flight with 70 ps resolution
   - 1.b reject outgoing e => Cerenkov + Calorimeter

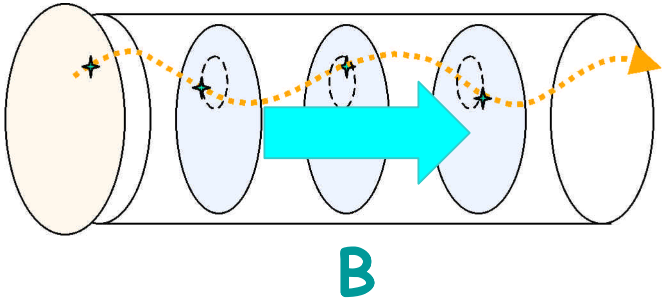
2. measure 6 particle parameters
   i.e. x,y,t, p_x/p_z , p_y/p_z , E/p_z

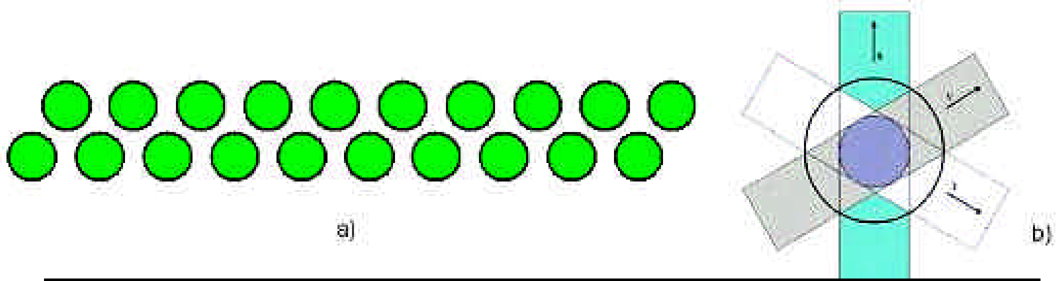
3. measure widths and correlations
   resolution in all parameters must be better than 10% of width
   at equilibrium emittance (correction less than 1%)

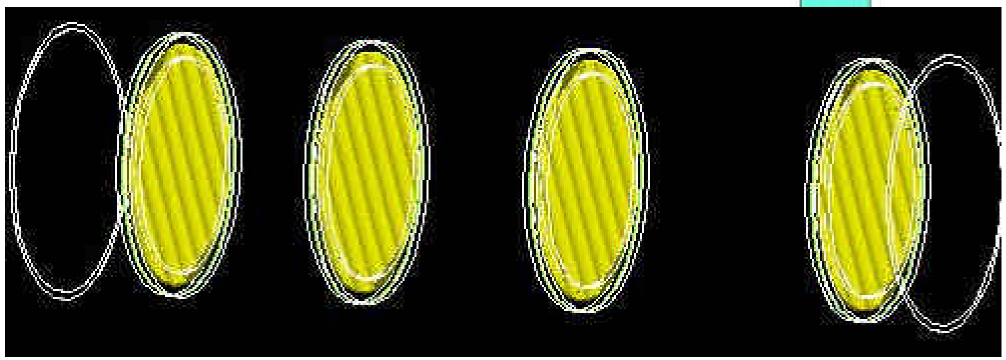
4. robust against noise from RF cavities

tracking in a solenoid:









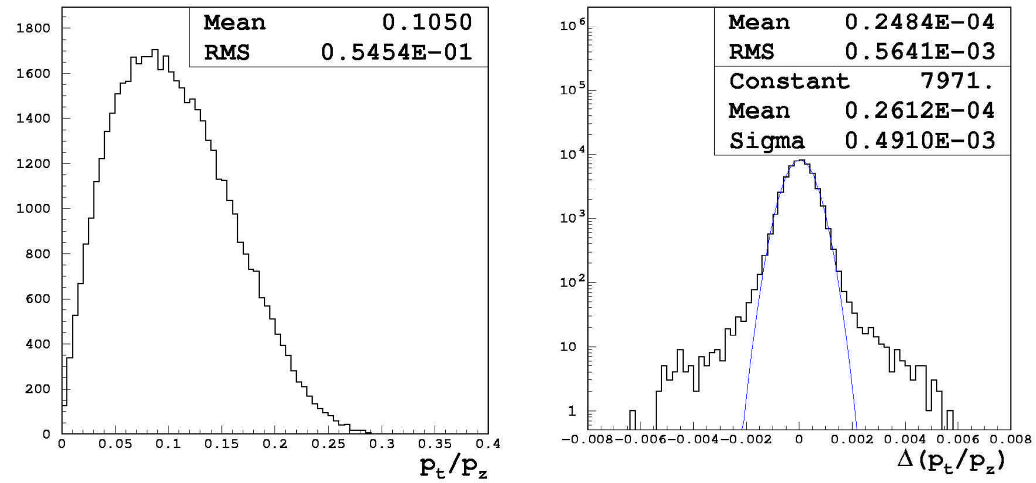
SIMULATIONS:

LOI: DWARF4.0 by P.Janot: a fast simulation including dE/dx & MS (ad-hoc)

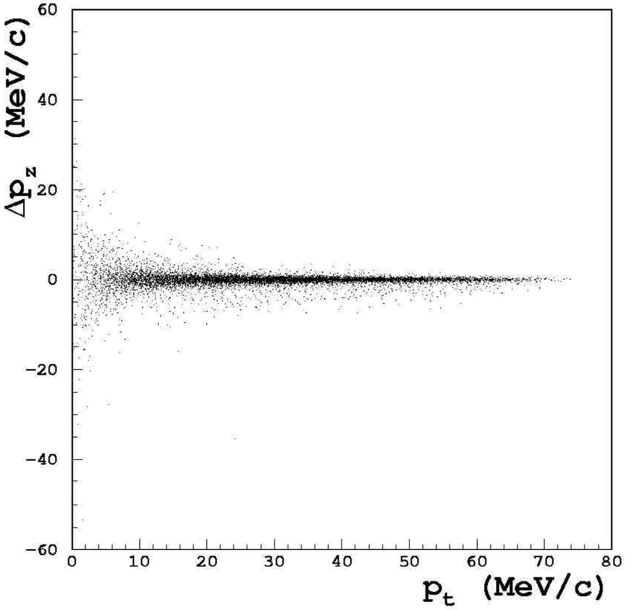
Proposal: G4MICE: Geant 4 application including everything including noise (long term FOUNDATION FOR MICE software)

RESULTS

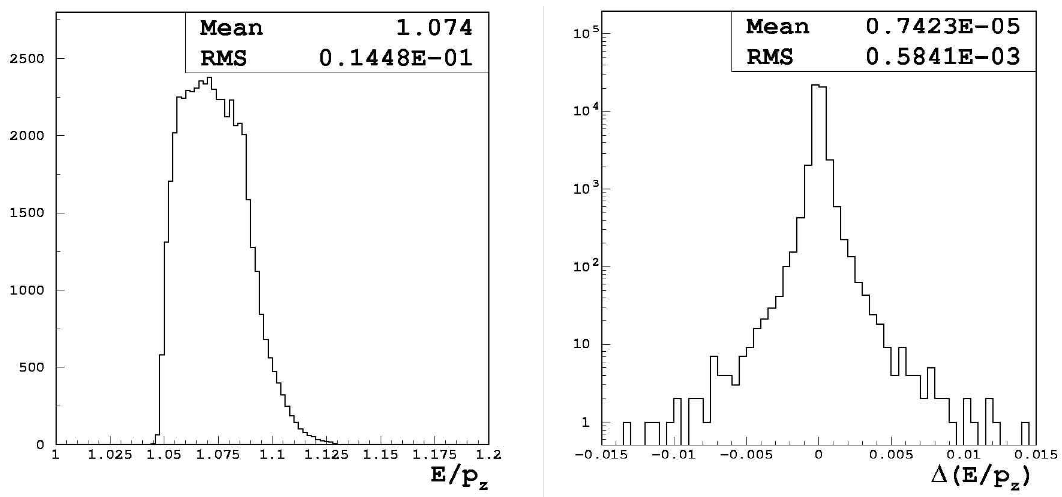
TRANSVERSE MOMENTUM RESOLUTION S_{pt} = 110 keV



P_z resolution degrades at low p_t :

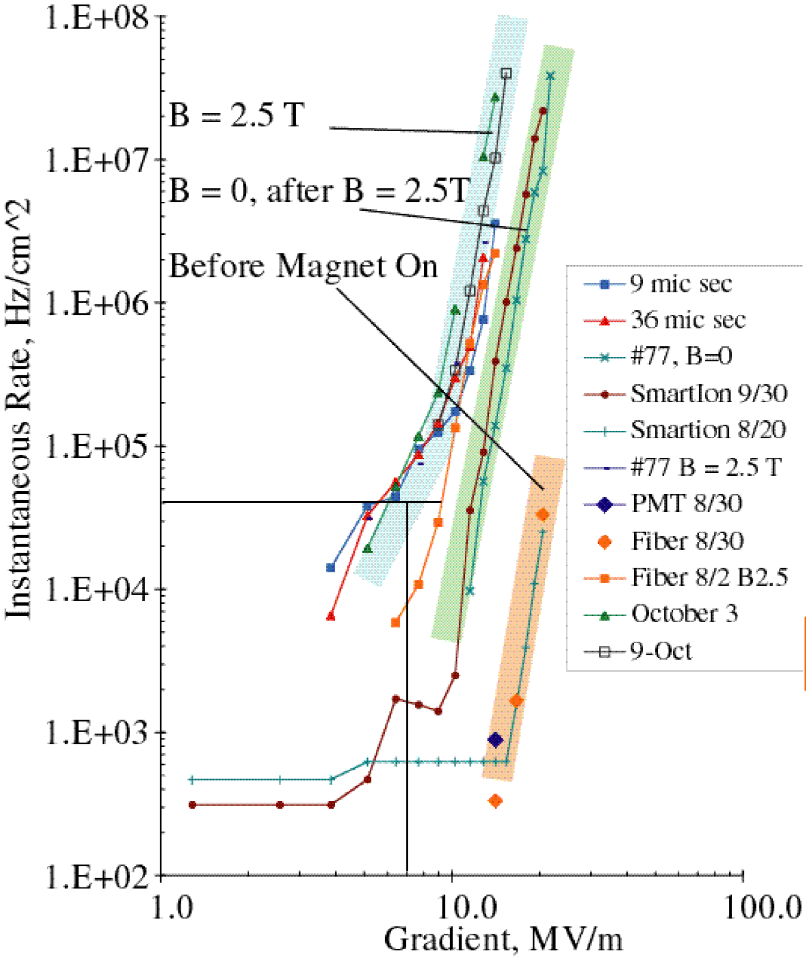


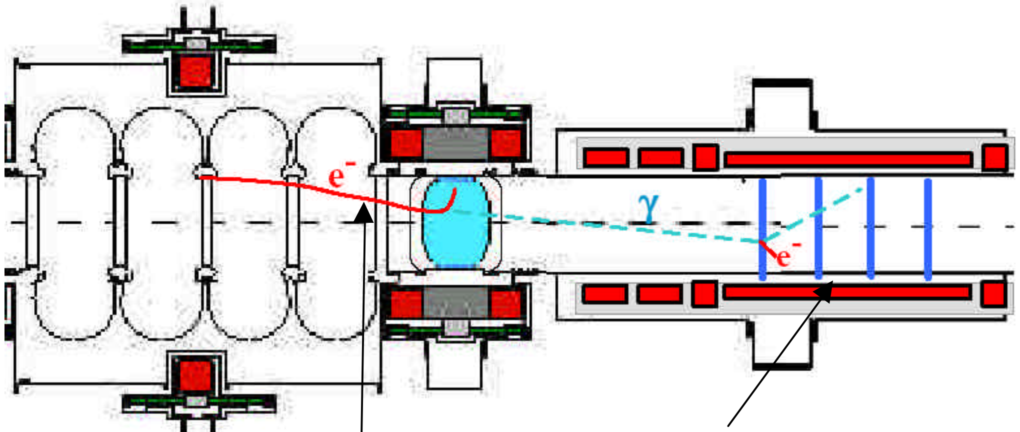
resolution in E/P_z is much better behaved



measurement rms is 4% of beam rms

Backgrounds





Dark current backgrounds measured on a 805 MHz cavity in magnetic field with a 1mm scintillating fiber at d=O(1m)

Extrapolation to MICE (201 MHz):
scale rates as (area.energy) X 100
and apply above reduction factor 2 10^{-4}

4 10^4 Hz/cm^2 @ 8 MV/m @805 MHz
$\Rightarrow$0.8 kHz/cm^2 per sci-fi
$\Rightarrow$ 500 kHz/plane
! within ± one order of magnitude !

=> **6.70 MV/m**

=> **4.65 MV/m**

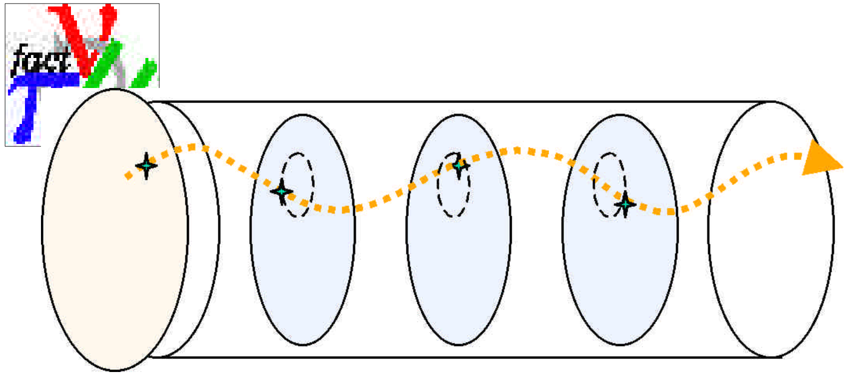
Available power supplies	Voltage from one 4-cell cavity	Voltage from two 4-cell cavities
1 X 4 MW	11.5 MV on crest 5.7 MV at 30°	16 MV on crest 8 MV at 30°
2 X 4 MW	16 MV on crest 8 MV at 30°	23 MV on crest 11.5 MV at 30°
8 X 4 MW		46 MV on crest 23 MV at 30°

Table VII.1: Achievable muon acceleration for various configurations of number of cavities and available RF power.

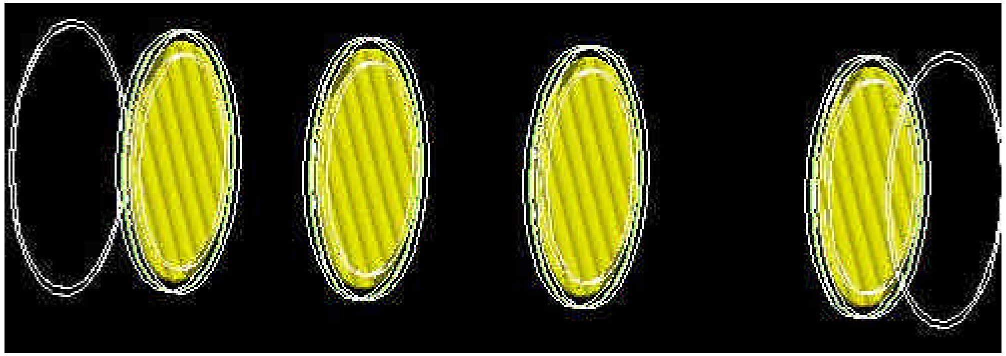
.43 X 4 cells = 1.7 m Þ 11.5 MV for 1X 4 = 6.70 MV/m

16 MV for 2X4 = 4.65 MV/m

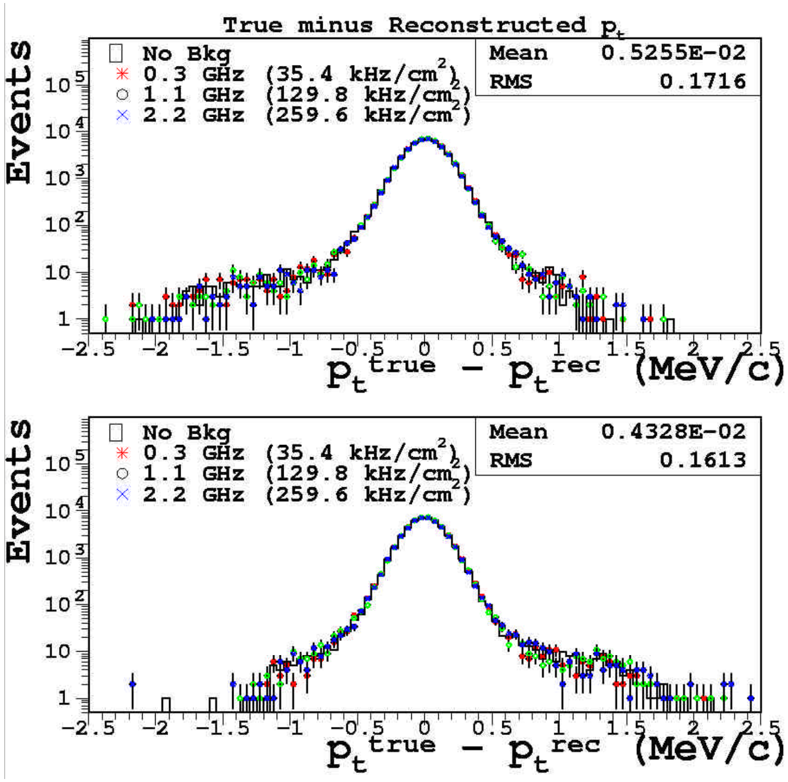
16 MV for 1X4 = 9.3 MV/m



concept



G4MICE



background simulated at level 1000 times that extrapolated from measurements does NOT degrade resolution seriously (No multiplexing here!)

further improvements from the RF cavity will be seeked (TiN coating) etc…

looks good.
if this is confirmed, one could envisage running with higher gradients.
This is possible if
--8 MW power to one 4-cavity unit
-- LN2 operation

Tracker

Baseline Option:

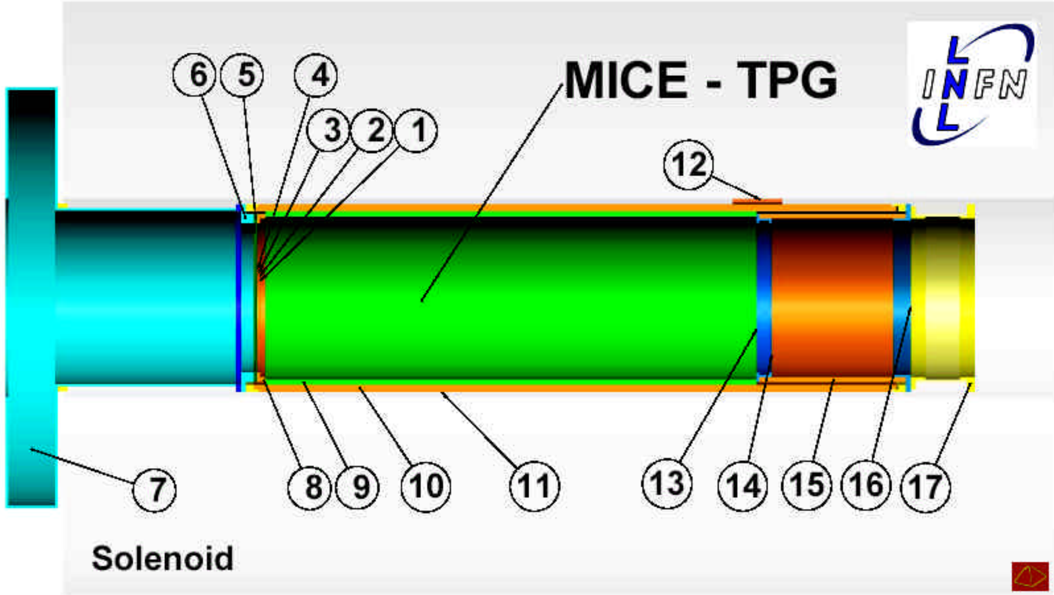
scintillating fibre tracker – 5 stations with 3 crossing double planes of 350 μm fibres readout by VLPC (High Q.E. and high gain) as in D0.

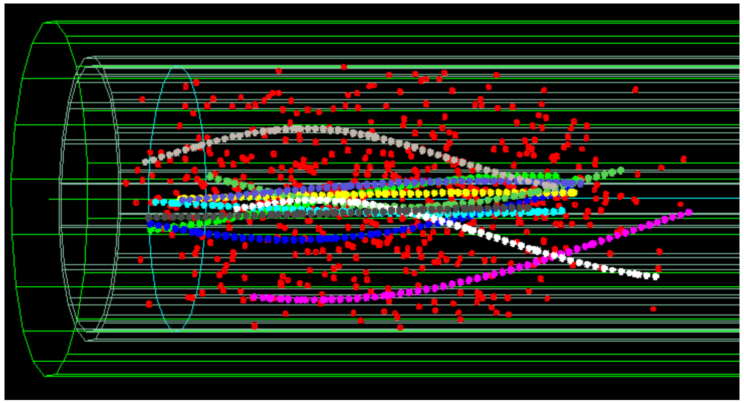
Pro: we are essentially sure that this will perform well enough for MICE.
con: 43000 channels make it quite expensive (4.1 M€)

Saving alternatives:

Option 1 **Sci-Fi -- Reduce channel count by multiplexing channels (1/7)**
-- cost reduced by factor 4.
-- it is not known if this can work in presence of Bkg and a few dead channels.

Option 2 **Use a Helium filled TPC with GEM readout ('TPG')**
pro: very low material budget (full TPG = 2 10^{-4} X0) and lots of points/track (100)
cheaper (<0.5 M€ of new money)
con: long integration time (50 μs vs 10 ns) => several muons at a time, integrate noise
effect of x-rays on GEMs themselves is unknown.

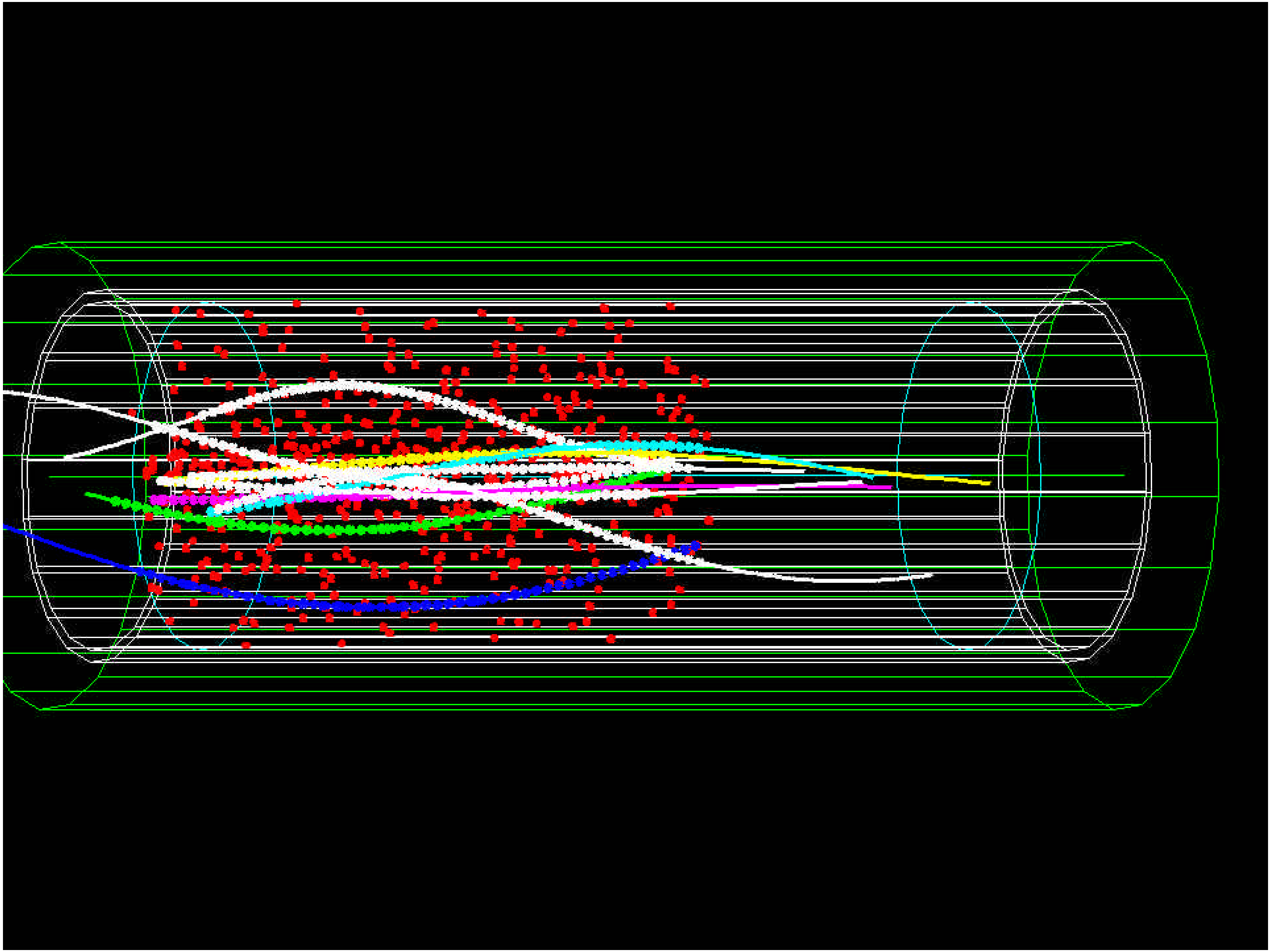




at noise rate similar to that simulated for fibers, no difficulty finding tracks and measuring them.

resolution somewhat better than sci-fi (which is good enough)

difficulty: nobody knows the effect of RF photons on the GEM themselves
tests in 2003, decision October 2003

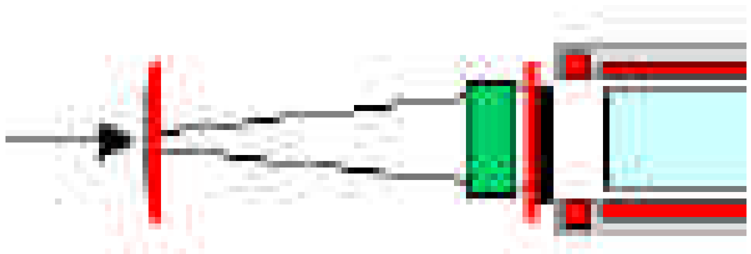


Upstream Particle Identification

Even with a solenoid decay channel, the beam is not perfect.
Entering electrons and protons have different cooling properties
and must be rejected (easy)

Pions are more of a problem since they can decay in flight with a daugther of different momentum Big bias in emittance!

requires less than one permil contamination in final sample.



TOF in the beam line with 10m flight path and 70 ps resolution provides
p/m separation better than 1% @ 300 MeV/c
Þ it is sufficient that the beam has fewer than 1 pi for 10 muons

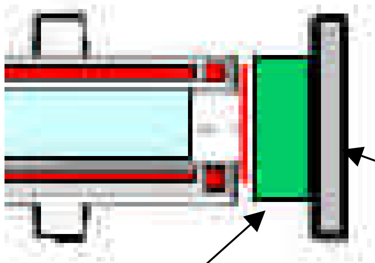
A beam Cherenkov is foresen to complete the redundancy in this system.

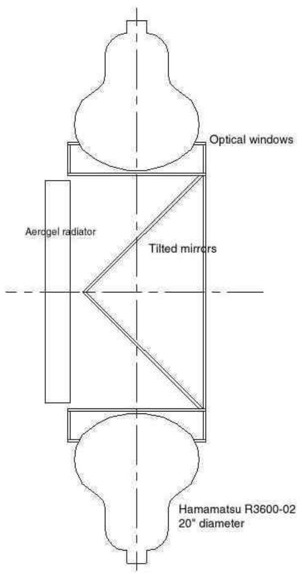
Downstream PID

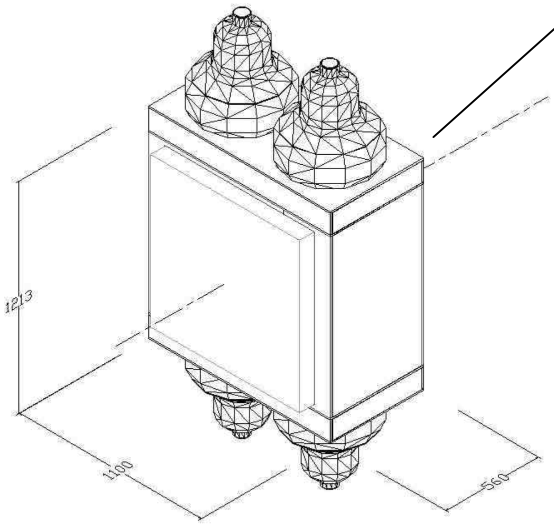
0.5% of muons decay in flight.
This leads to large bias if a forward-decay electron is confusd with a muon

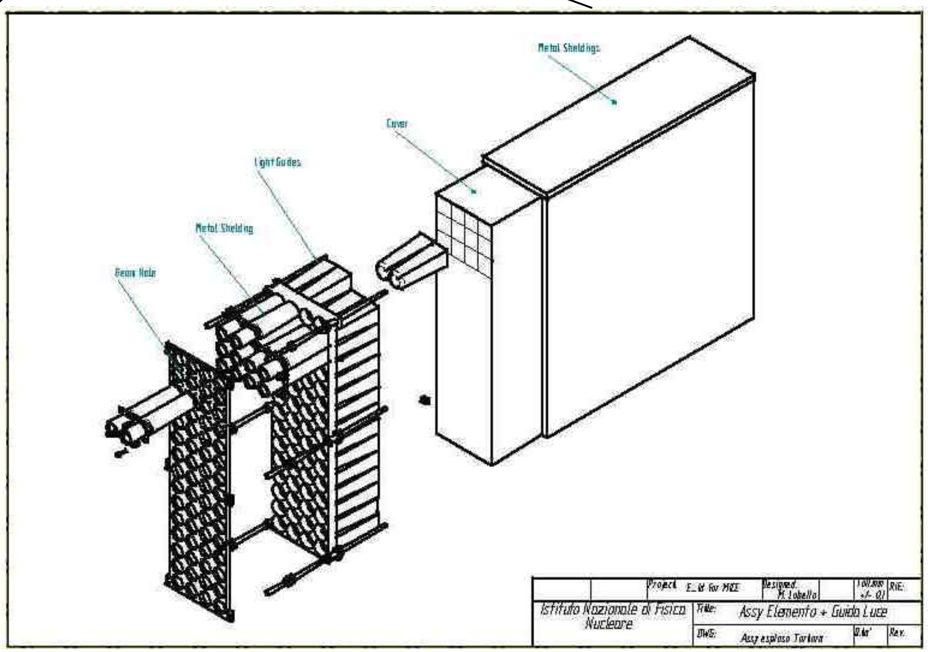
two systems are foreseen to eliminate electrons below 10^{-3} :
Aerogel Cherenkov and a calorimeter.

Positive Identification of a particle in the calorimeter consistent with a muon combined with no signal in the Cherenkov









PRECISION

1. statistical

--emittance is measured to 10^{-3} with ~10^6 muons.
-- ratio of emittances to same precision requires much fewer (10^5)
we are using the same muons and they go through little material:
statistical fluctuations largely cancel in the ratio

-- Due to RF power limitations we can run about 10^{-3} duty factor 1ms/s
-- To avoid muon pile up we want to run at ~1 muon per ISIS bunch (1/330ns)

3000/s

-- The emittance generation keeps 25% of incoming muons within acceptance
-- about 1/6 are on crest => 100 good muons per second.

A 10^{-3} measurement of emittance ratio will take less than one hour

N.B. this assumes a beam line with a solenoid to be obtained from PSI.
A quadrupole channel has more background and less rate, and would lead to a time longer by a factor ~10.

Systematics

MICE-FICTION:

. MICE measures e.g. $(\varepsilon^{out} / \varepsilon^{in})_{exp} = 0.894 \pm 0.001$ (statistical)

compares with $(\varepsilon^{out} / \varepsilon^{in})_{theory.} = 0.885$

and tries to understand the difference.

SIMULATION

A. theory systematics:
modeling of cooling cell
is not as reality

REALITY

B. experimental systematics:
modeling of spectrometers
is not as reality

MEASUREMENT

The errors of class A (Cooling Theory)

must not affect the expected 10% cooling effect by more than 10^{-3} absolute, i.e., 1% of its value.
Errors in this category include:

- **Uncertainties in the thickness or density of the liquid-hydrogen absorbers and other material in the beam**
- **Uncertainties in the value and phase of the RF fields**
- **Uncertainties in the value of the beta function at the location of the absorbers**

Misalignment of the optical elements
Uncertainty in the beam energy scale
Uncertainties in the theory (M.S. and dE/dx and correlation thereof)

All errors of type A become more important near the equilibrium emittance.

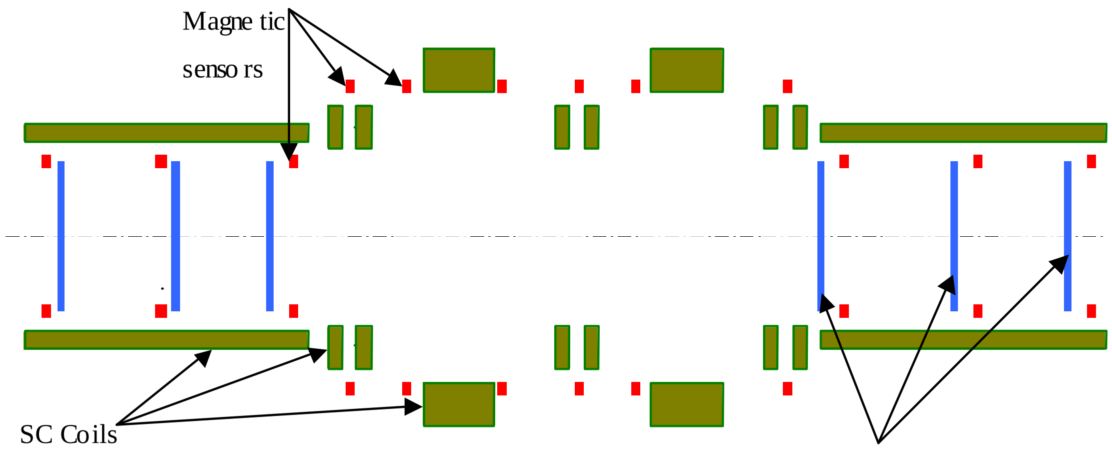
The errors of class B (Experimental):

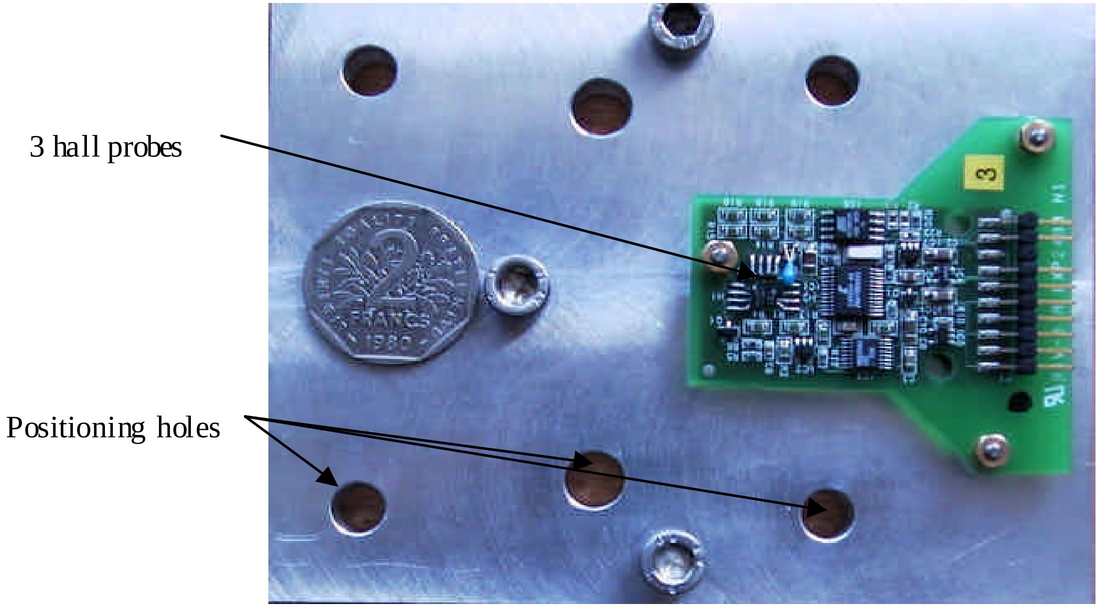
systematic differences between incoming and outgoing measurement devices.
efficiency differences
different misalignments
possible differences in the magnetic field.

Solutions:
Step III or
run MICE empty with no RF or
analyse cooling vs muon phase (free)

Most critical is the control of the magnetic fields.

For this reason MICE will be equipped with a set of magnetic measurement devices that will measure the magnetic field with a precision much better than 10^{-3}.

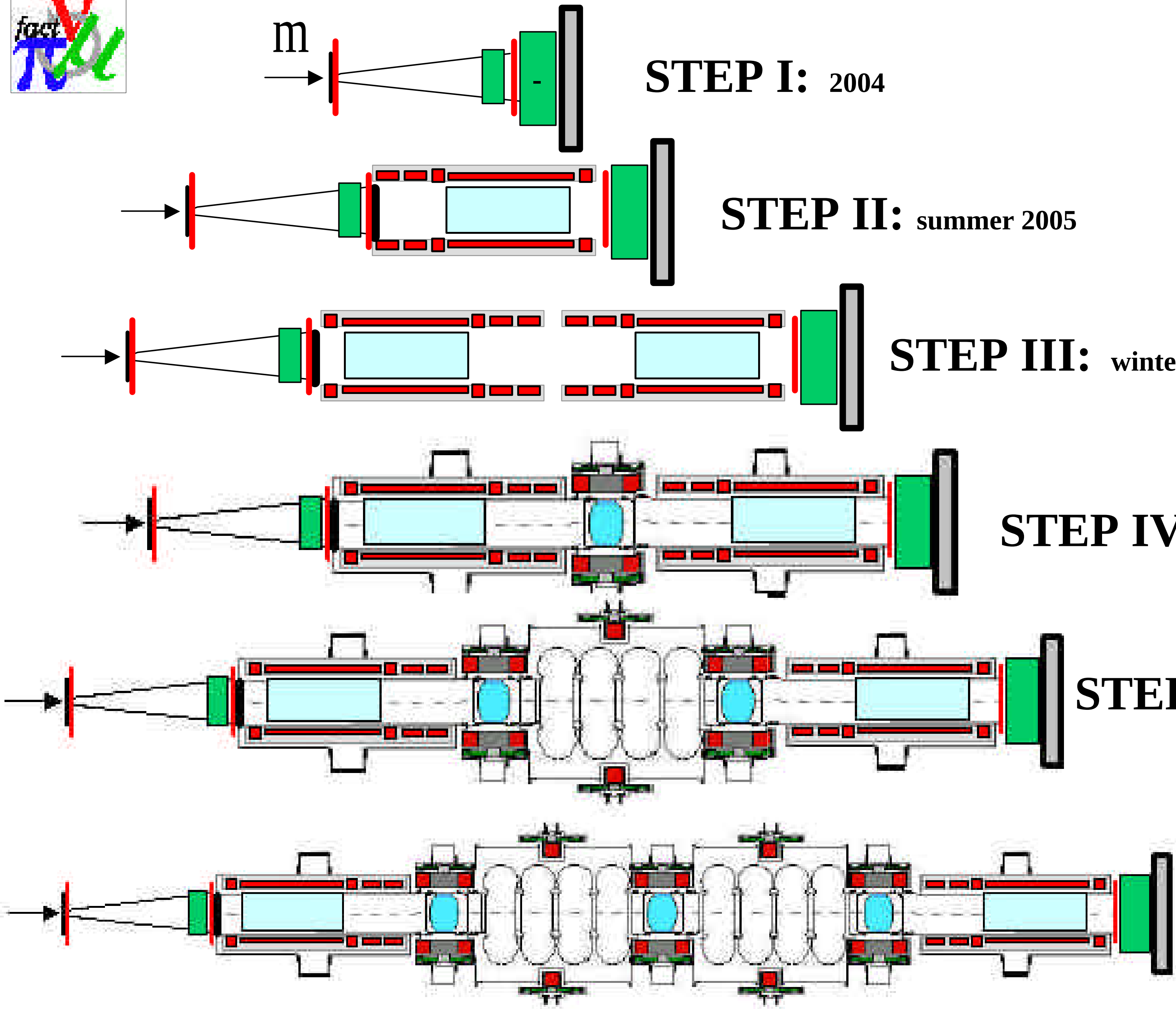




Magnetic measurements

design of system and procedures by Saclay (Rey, Chevallier)

NIKHEF will provide the probes (Linde)



STEP I: 2004

STEP II: summer 2005

STEP III: winter 2006

STEP IV: spring 2006

STEP V: fall 2006

STEP VI: 2007

The statistical precision will be very good and there will be many handles against systematics.

We believe that the systematic errors on the measurement of the ratio of emittances can be kept below 10^{-3}

This will require careful integration of the acquisition of data from the spectrometers and from the cooling cell.

A lot remains to be done in this area, admittedly, to make sure that MICE has foreseen the necessary diagnostics by the time it turns on.

Proposal to the Rutherford Appleton Laboratory
An International Muon Ionization Cooling Experiment (MICE)

Abstract (excerpts)

The aims of the international Muon Ionization Cooling Experiment are:

To show that it is possible to design, engineer and build a section of cooling channel capable of giving the desired performance for a Neutrino Factory;

To place it in a muon beam and measure its performance in a variety of modes of operation and beam conditions.

The MICE collaboration has designed an experiment where a section of an ionisation cooling channel is exposed to a muon beam and reduces its transverse emittance by 10% for muon momenta between 140 and 240 MeV/c.

Improvements in the evaluation of the background in the detectors due to radiation from the RF cavities make us confident that the desired precision can be achieved.

A scenario exists to satisfy the safety requirements related to the use of liquid hydrogen as cooling medium.

Assuming proper funding and support, ionization cooling of muons will be demonstrated by 2007

Further Explorations

We have defined a baseline MICE, which will measure the basic cooling properties of the StudyII cooling channel with high precision, for a moderate gradient of ~8 MV/m, with Liquid Hydrogen absorbers.

Many variants of the experiment can be tested.

1. other absorbers: Various fillings and thicknesses of LH2 can be envisaged
   The bolted windows design allows different absorbers to be mounted.

2. other optics and momentum: nominal is 200 MeV/c and b = 46 cm.
   Exploration of low b (down to a few cm at 140 MeV/c)
   Exploration of momentum up to 240 MeV/c
   will be possible by varying the currents.

3. the focus pairs provide a field reversal in the baseline configuration, but they have been designed to operate also in no-flip mode which could have larger acceptance both transversally and in momentum (Fanchetti et al)
   (We are not sure this can be done because of stray fields…)

4. Higher gradients can be achieved on the cavities, either by running them at liquid nitrogen temperature (the vessel is adequate for this) (gain 1.5-1.7) or by connecting to the 8 MW RF only one of the two 4-cavity units (gain 1.4)

International Muon Ionization Cooling Experiment

Organization:

Steering committee:

A. Blondel*[1] (University of Geneva) H. Haseroth (CERN**) R. Edgecock (Rutherford Appleton Laboratory)
I. Ivaniouchenkov[2] (RAL)
Y. Kuno (Osaka University)
S. Geer (FNAL), D. Kaplan [3](Illinois Institute of Technology) M. Zisman (Lawrence Berkeley Laboratory)
* convener, [1]EU spokesperson, [2]Interim Project Engineer, [3]US spokesperson, secretary

- **Conveners of technical teams:**
- **a) Concept development: R. B. Palmer (BNL), R. Edgecock (RAL/CERN)**
- **b) Experiment simulations: M. G. Catanesi (Bari), Y. Torun (IIT)**
- **c) Hydrogen absorbers: S. Ishimoto (KEK) M. A. C. Cummings (Northern Illinois)**
- **d) RF cavities, power sources: Derun Li (LBNL), R.Church (RAL), H.Haseroth (CERN)**
- **e) Magnetic system: M. A. Green (LBNL), J.-M. Rey (CEA Saclay)**
- **f) Particle detectors: V. Palladino (Napoli), A. Bross (FNAL)**
- **g) Beam line: P. Drumm (RAL)**
- **h) RF radiation: J. Norem (Argonne), E. McKigney (IC London)**
- **i) Engineering and Integration: I. Ivaniouchenkov (RAL), E. Black (IIT)**

Collaboration meetings 3X a year: US,UK,EU, etc…
S.G. phone conf. every 3 weeks
Video Conferences every 3 weeks (not easy!)

Participating institutes: (142 authors)

Belgium: Louvain La Neuve (Ghislain Gregoire)

Netherlands: NIKHEF amsterdam (Frank Linde)

INFN: Bari (M.G.Catanesi) Frascati (Michele Castellano) Genova (Pasquale Fabbriccatore)
Legnaro (Ugo Gastaldi) Milano (Maurizio Bonesini) Napoli (Giuseppe Osteria) ,
Padova (Mauro Mezetto) , Roma(Ludovico Tortora), Trieste (Marco Apollonio)

France DAPNIA, CEA Saclay (Jean-Michel Rey)

Switzerland: Geneva (Alain Blondel), ETH Zürich (André Rubbia), PSI (Claude Petitjean)

UK: Brunel (Paul Keyberd), Edimburg(Akram Khan, Glasgow (Paul Soler),
Rutherford Appleton Laboratory (Rob Edgecock), University of Oxford (Giles Barr),
Imperial College London (Ken Long), Liverpool (John Fry), Sheffield (Chris Booth)

CERN (Helmut Haseroth)

Russia Budker Institute Novosibirsk (Sasha Skrinsky) (+ Dubna, Lebedev under discussions)

Japan KEK (Shigeru Ishimoto), Osaka University(Yoshitaka Kuno)

USA Argonne National Laboratory (Jim Norem)
Brookhaven National Laboratory (Bob Palmer)
Fermi National Accelerator Laboratory (Steve Geer, Alan Bross)
Lawrence Berkeley National Laboratory (Michael Zisman)
University of Iowa (Yasar Onel), Fairfield University (David Winn)
University of California Los Angeles (David Cline)
University of Mississippi (Don Summers)
U.C. Riverside, (Gail Hanson)
University of Chicago – Enrico Fermi Institute(Marco Oreglia)
Northern Illinois University (Mary Anne Cummings)
Illinois Institute of Technology (Danial Kaplan)
Jefferson Lab (Bob Rimmer)

COST TABLE and RESPONSIBILITIES

warning: assignment of tasks will be revised when cost savings are understood (decision on tracker)

Table 11.1: Overall hardware costs for MICE in M€ (or, equivalently, M$) and effort levels in staff years. Funding assignments for the participating regions are indicated.

Item	Estimated cost (M€)	US	Japan	Europe	UK	Effort [staff-yr]
Cooling section[a]	13.9	6.3	0.3	3.7	3.6	67
Spectrometer section[b]	7.5	2.1	0.7	3.0	1.7	48.5
Ancillary items[c]	3.8	0.1	0	0.5	3.2	60.5
Total	25.2	8.5 (34%)	1.0 (4%)	7.2 (29%)	8.5 (34%)	176

possible cost savings

-- use refurbished RF from CERN: - 2500.- k€
-- use TPG or multiplex sci-fi tracker - 3000.- k€
-- use HARP electronics - 500.- k€

net cost if all savings apply: 19.2- M€ (Re: LOI 17.8 M$)

Table 11.2: Hardware cost estimate for the MICE cooling section. Cost values are in k€ (or, equivalently, k$) and effort levels in staff years.

Item	Responsible	Funding Source				Total	Effort
		US	Japan	Europe	UK		[staff·yr]
Cooling Section						13883	67
Magnets							
Focus coil pairs	UK				2491	2491	10
Coupling coils	LBNL	2560				2560	2.5
Power supplies	LBNL	135				135	0.5
Magnetic measurements	EU			100		100	0.5
RF System							
Cavities	LBNL	1686				1686	12.5
Windows	U-Miss.	855				855	2
Tuners	U-Miss.	259				259	8
Cryostat	IIT	96				96	2
System integration	IIT	235				235	5
Power distribution	UK				950	950	4
Power source + LLRF	EU			3500		3500	4
Absorbers							
Body (manifold)	Japan		349			349	3
Windows	U-Miss.	199				199	7
System integration	IIT/NIU/UK	40			17	57	2
Hydrogen safety[a]	UK	120		100	20	240	2
Diagnostics							
RF cavities	ANL/UK	22			22	44	0.5
Vacuum	EU			10		10	0.5
Cryogenics	NIU	117				117	1

[a]Paid for from 'common fund'.

Table 11.3: Hardware cost estimate for the MICE spectrometer section. Cost values are in k€ (or, equivalently, k$) and effort levels in staff years.

Item	Responsible	Funding Source US	Funding Source Japan	Funding Source Europe	Funding Source UK	Total	Effort [staff·yr]
Spectrometer Section						7540	48.5
Magnets							
Spectrometers	Genoa			2200		2200	6
Power supplies	LBNL	280				280	0.5
Magnetic measurements	NIKHEF/Saclay			50		50	0.5
Detectors							
Tracker	U.S./UK/Japan/ INFN*/Geneva	1800	500	900	900	4100	19
Cherenkov	U-Miss./Louvain	150		100		250	10
Time-of-flight	Padova/Milan	10		300		310	7.5
Calorimeter	Rome III			350		350	5

* Bari, Legnaro, Napoli, Trieste

Table 11.4: Hardware cost estimate for the MICE ancillary items. Cost values are in k€ (or, equivalently, k$) and effort levels in staff years.

Item	Responsible	Funding Source				Total	Effort
		US	Japan	Europe	UK		[staff·yr]
Ancillary Items						3757	60.5
Cryogenics							
Cooling section	UK				2480	2480	1.5
Detector electronics	UK				200	200	0.5
Vacuum							
Pumps and valves	EU			127		127	0.9
Beam spoiler	UK				20	20	0.1
Supports and Stands							
Cooling section	UK				110	110	0.6
Spectrometer section	UK				50	50	0.4
Data Acquisition	Bari	7		263		270	5
Slow Controls	UK/EU			90	90	180	
Alignment	UK				50	50	0.5
Control Room	UK				120	120	1
Consumables[a]	UK				150	150	
Travel[b]		827	100	1000	480	2407	
Exp. Supp. & Analysis[c]							50

[a] Mainly cryogenic fluids and the like.

[b] Travel costs are not included in hardware total.

[c] Post-docs.

Future

1. Proposal sent to RAL on 10 January
2. Review panel 17 february and … mid-April
3. decision expected in spring 2003
4. funding from UK optimistic * ->

UK science Budget , from the departement of trade and industry office of science and Technology.

PPARC's main strategic objectives will be to:

… … … ■ strengthen the UK's capability in accelerator science and R&D to position it to participate in the next generation of global accelerators, and, in particular, a Linear Collider and Neutrino Factory;

CLRC: (RAL) . The medium term projects currently in the roadmap, some of which secured funding in spending review 2000, include:

… … … ■ and a Muon Ionisation Cooling Device.

http://www.ost.gov.uk/research/funding/budget03-06/dti-sciencebudgetbook.pdf

Time Lines

Time lines for the various items of MICE have been explored
– procurement delays and installation –
the critical items are solenoids and RF cavities.

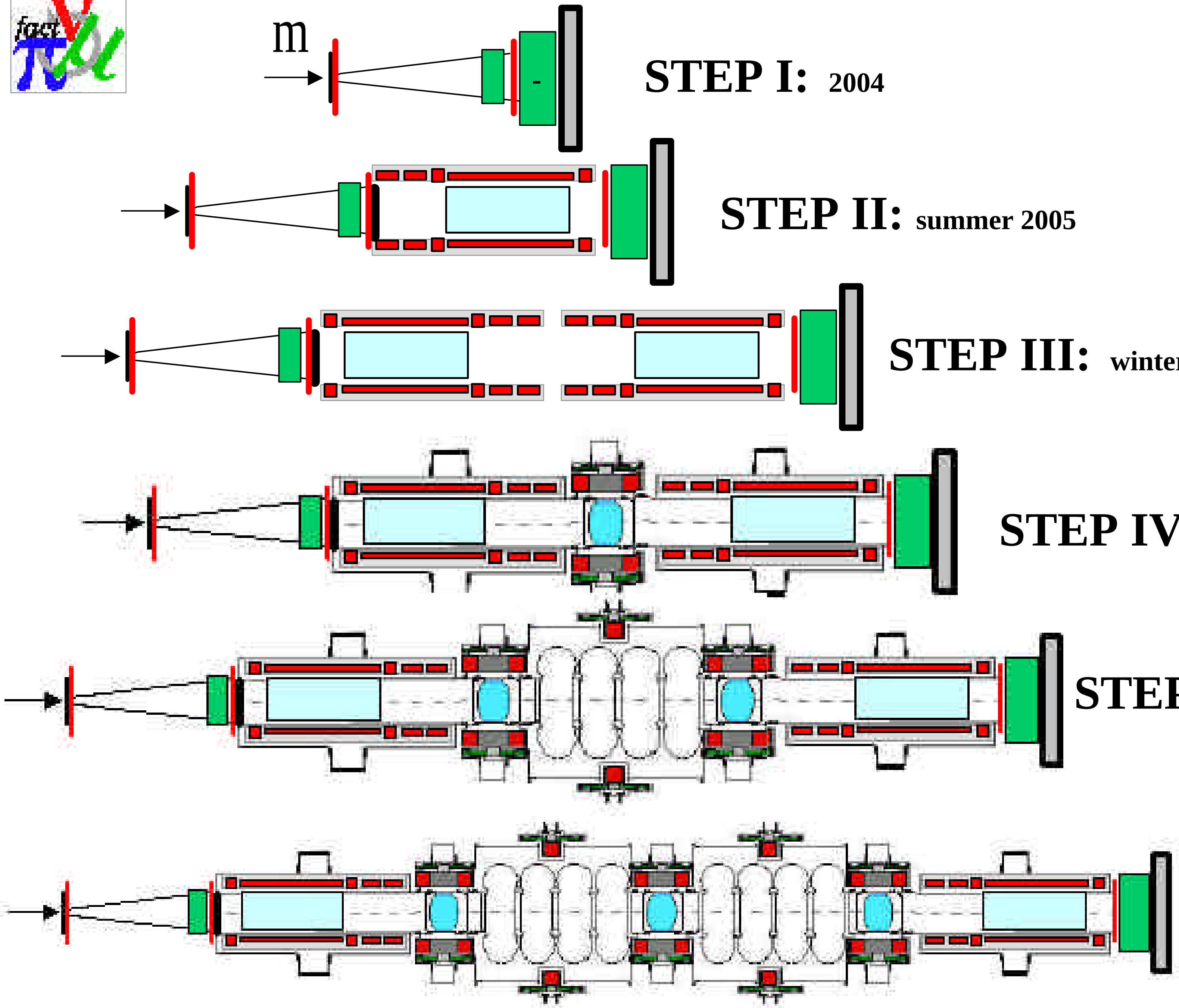
If funding is adequate, the following sequence of events can be envisaged * -> consistent with the logistics of the beam line upgrade at RAL and of the various shut downs.

Muon Ionization cooling will have been demonstrated ands measured precisely by

2007

At that time
MINOS and CNGS will have started and mesured Dm_{13}^2 more precisely
J-Parc-SK will be about to start up (Q_{13})
LHC will be about to start as well

It will be timely (…and not too soon!) to have by then a full design for a neutrino factory, with one of the main unknowns (practical feasibility of ionization cooling) removed.



STEP I: 2004

STEP II: summer 2005

STEP III: winter 2006

STEP IV: spring 2006

STEP V: fall 2006

STEP VI:

2007

Conclusions

There is no doubt that a Neutrino Factory is the ultimate tool to study neutrino oscillations and leptonic CP violation, and a first step towards muon colliders.

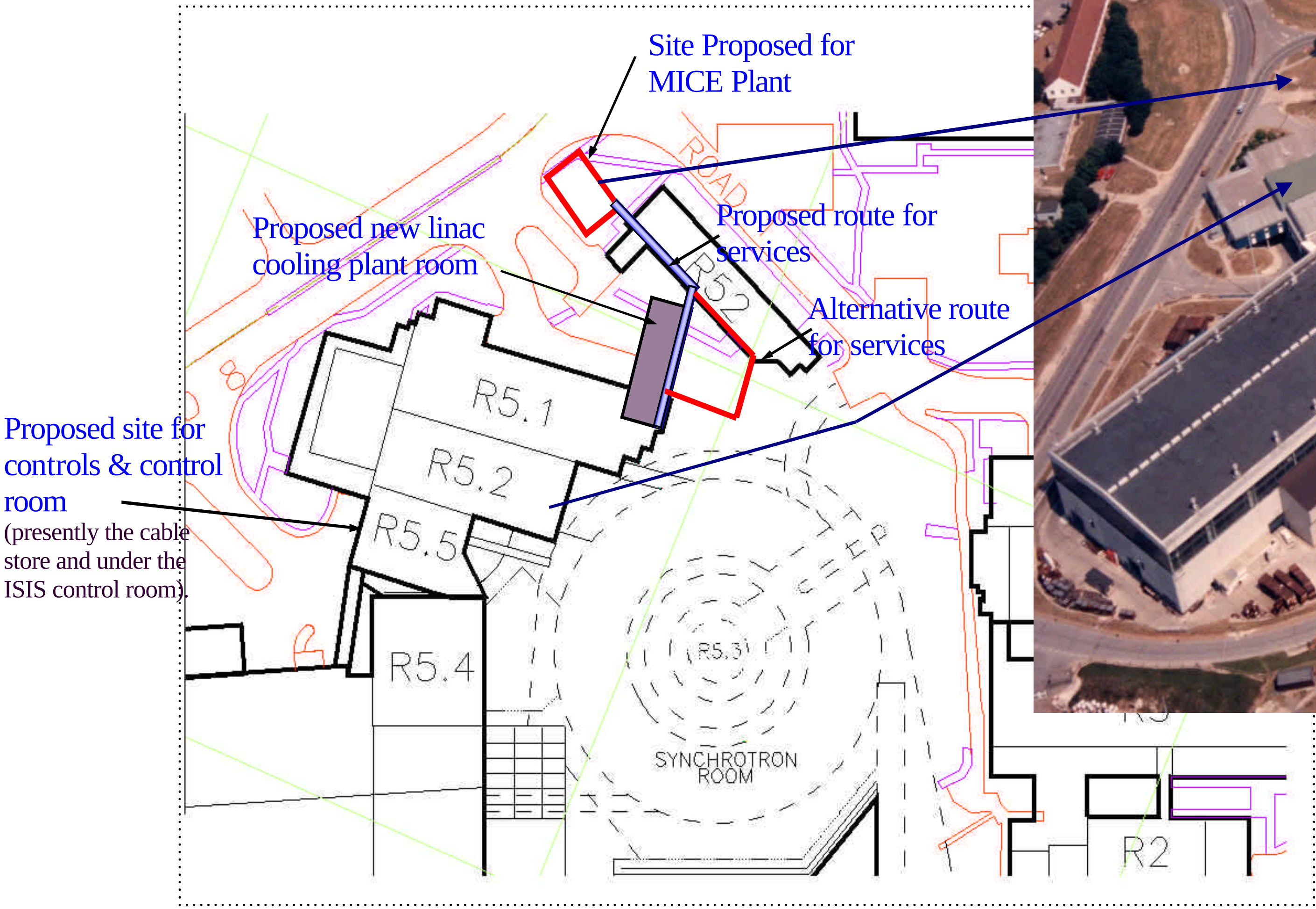
Can it be done?
Paper studies say Yes, but these are only paper studies… involving several new concepts, the newest being ionization cooling.

MICE aims at turning this new concept into an apparatus that works, with a community of people able to operate it, maintain it, improve it.

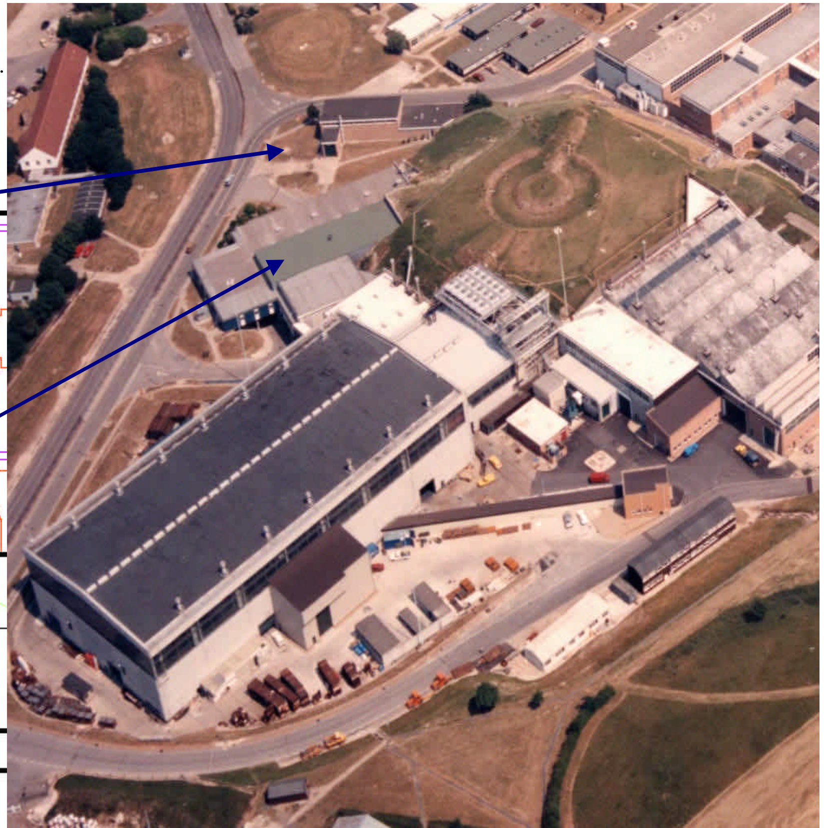
The MICE collaboration, supported by the enthusastic UK community, has designed an experiment based on a full cell of studyII and a set of spectrometers to measure the emittance reduction of 10% with a precision of $10^{-3.}$ It will also be capable of exploring a number of beam and optics conditions beyond the baseline.

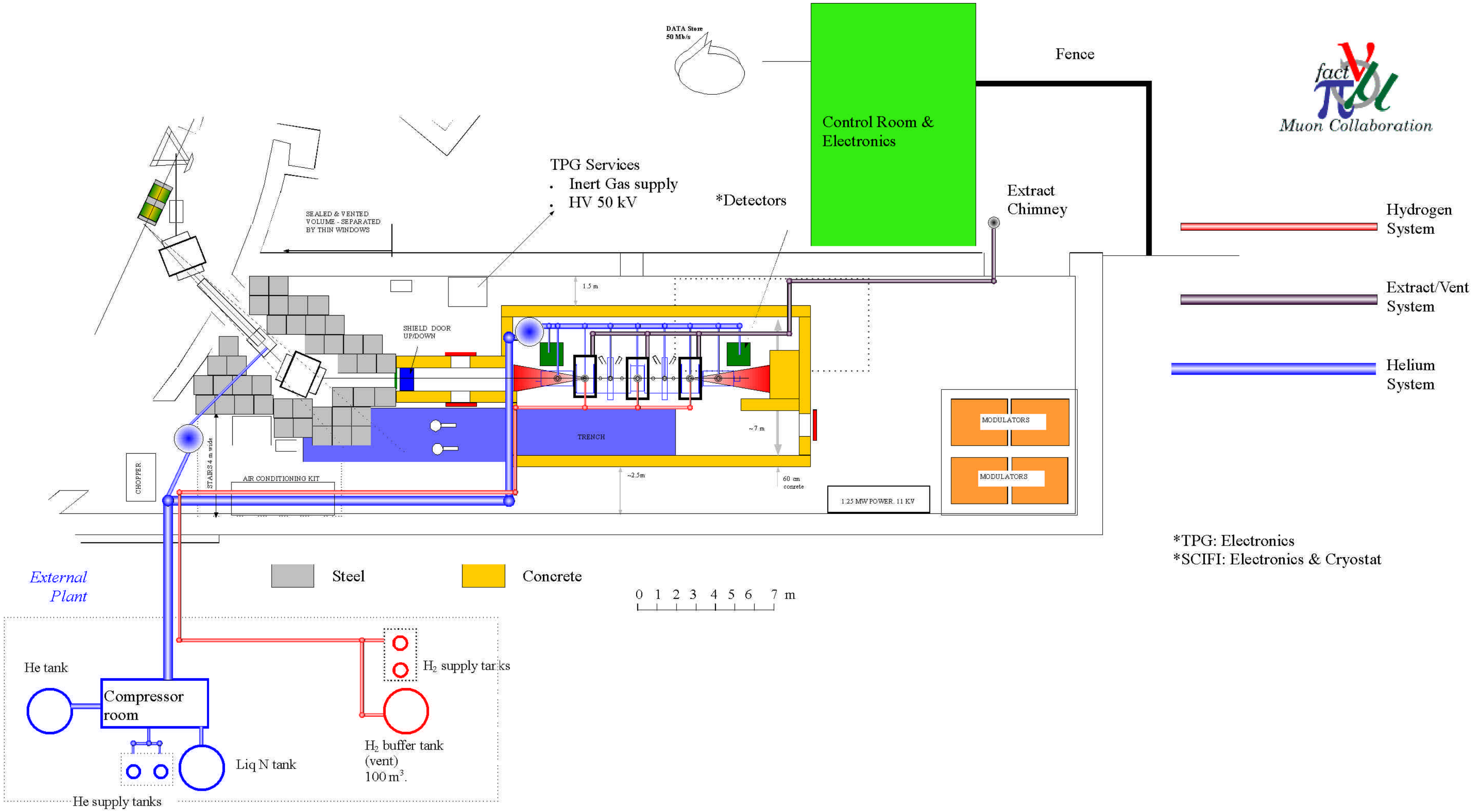
The collaboration has organised responsibilities, and determined the costs and time line of the experiment. The crucial safety issues have been addressed and a solution is proposed that should be adequate.

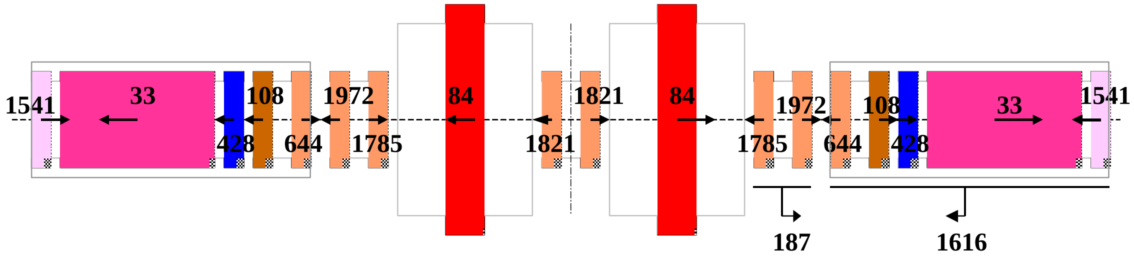
If all goes well ionization cooling will have been demonstrated in 2007. This is very timely and …… not too soon!

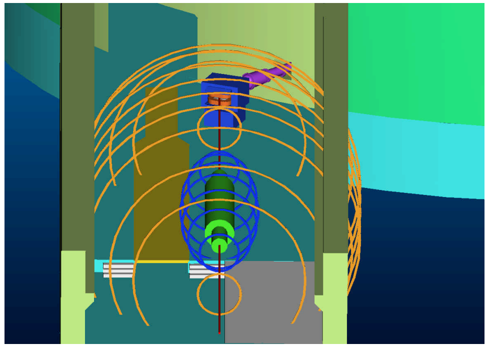


Site Proposed for
MICE Plant
Proposed new linac
cooling plant room
Proposed route for
services
Alternative route
for services
Proposed site for
controls & control
room
(presently the cable
store and under the
ISIS control room).
ROAD
R5.1
R5.2
R52
R5.5
R5.4
R5.3
SYNCHROTRON
ROOM
R2



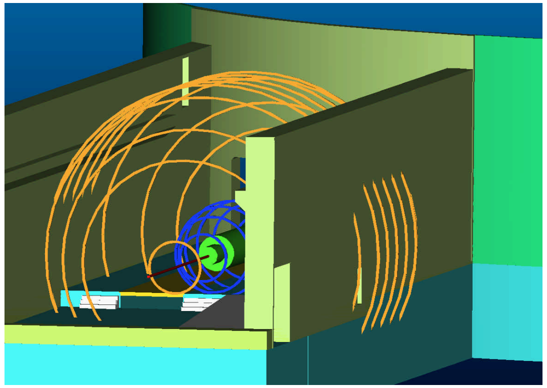

DATA Store 50 Mb/s
Control Room & Electronics
Fence
Extract Chimney
TPG Services
Inert Gas supply
HV 50 kV
*Detectors
SEALED & VENTED VOLUME - SEPARATED BY THIN WINDOWS
SHIELD DOOR UP/DOWN
TRENCH
MODULATORS
MODULATORS
1.25 MW POWER. 11 KV
AIR CONDITIONING KIT
CHOPPER
Hydrogen System
Extract/Vent System
Helium System
*TPG: Electronics
*SCIFI: Electronics & Cryostat
Steel
Concrete
0 1 2 3 4 5 6 7 m
External Plant
He tank
Compressor room
Liq N tank
He supply tanks
H_2 supply tanks
H_2 buffer tank (vent) 100 m^3.

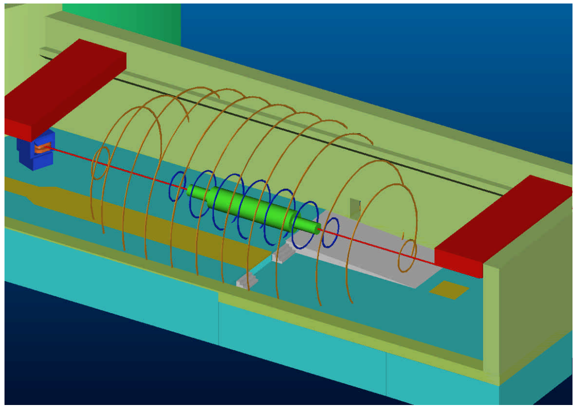


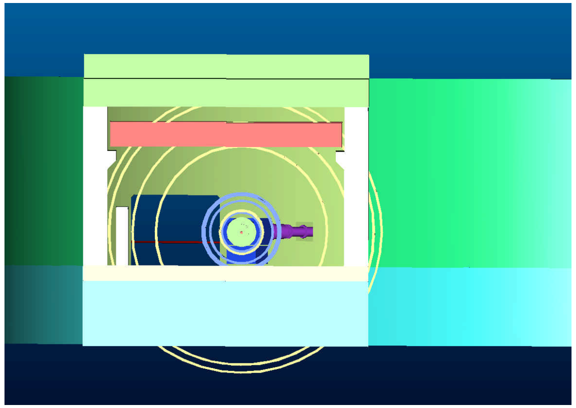


Volume in blue: 1 kGauss field

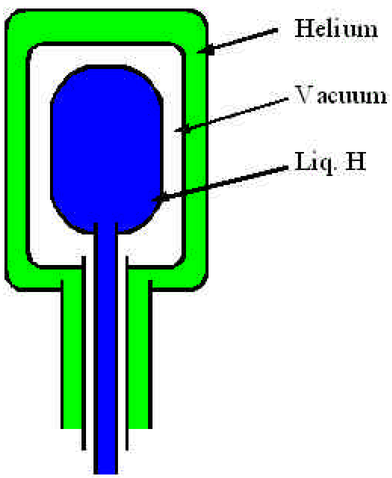
Volume in orange: 5 Gauss field

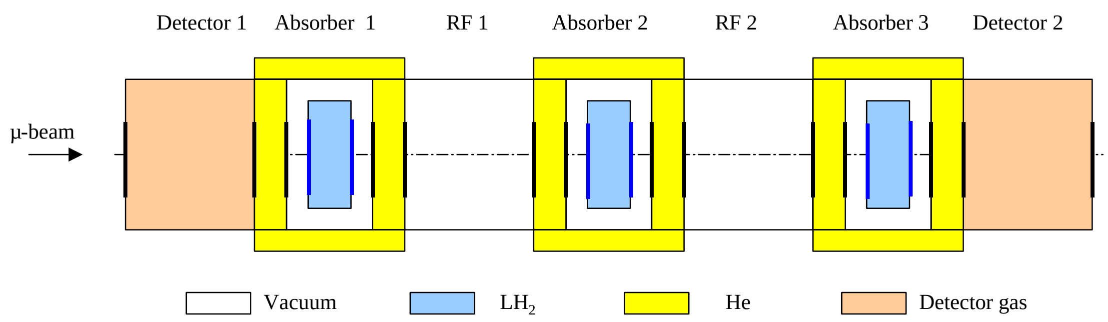






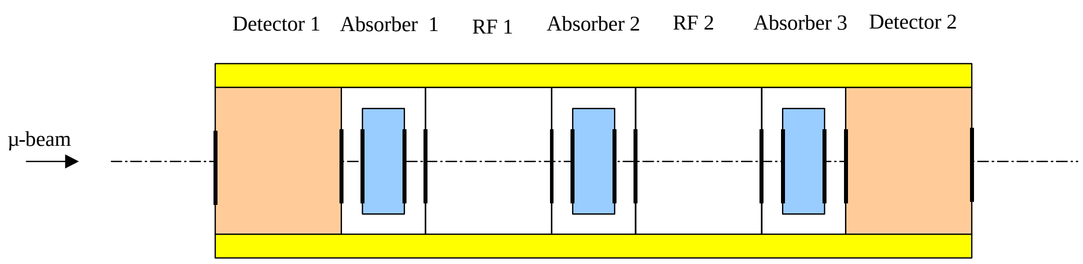
liquid hydrogen safety: liquid hydrogen must not come into contact with either oxygen or an ignition source.
Major risk involved in the cryo-pumping of air/O2 on the cold surfaces in case of a small leak. This must be shielded against. …. without increasing the amount of multiple scatterng too much!

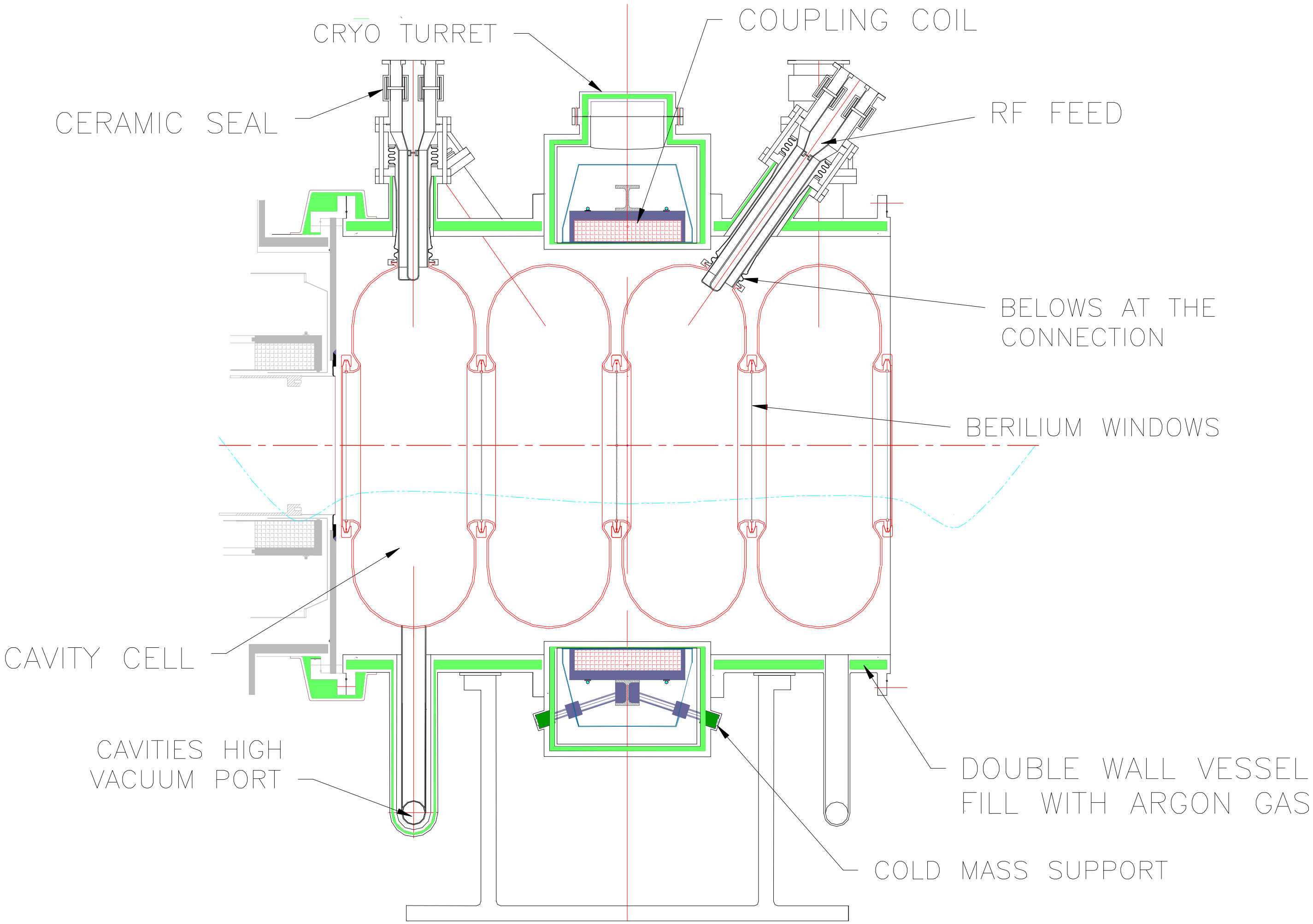




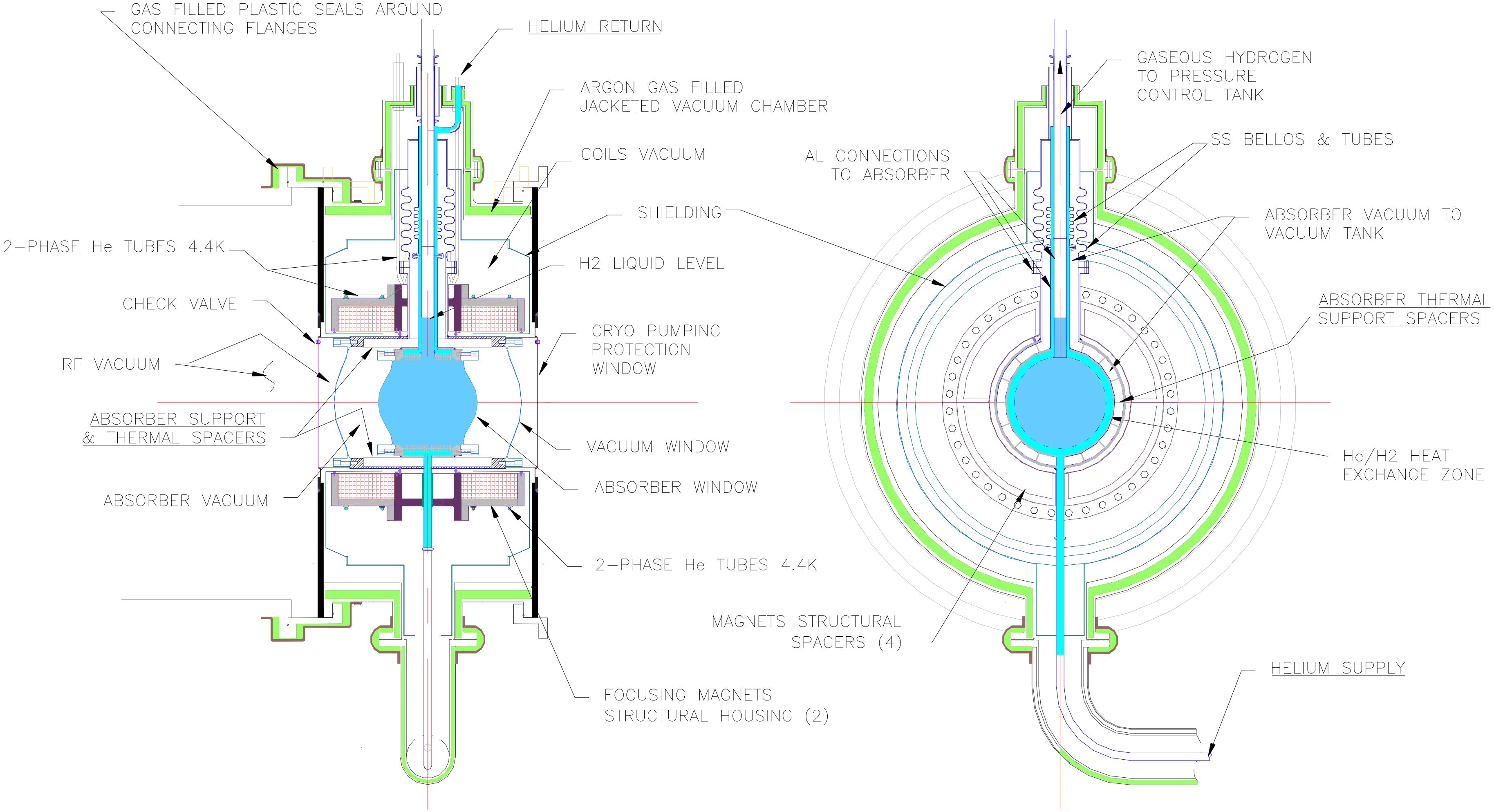
put an argon jacket around the experiment
will ensure max., safety and minimum multiple scattering.

still to pass the safety review!





CRYO TURRET
COUPLING COIL
CERAMIC SEAL
RF FEED
BELOWS AT THE
CONNECTION
BERILIUM WINDOWS
CAVITY CELL
CAVITIES HIGH
VACUUM PORT
DOUBLE WALL VESSEL
FILL WITH ARGON GAS
COLD MASS SUPPORT


GAS FILLED PLASTIC SEALS AROUND CONNECTING FLANGES
HELIUM RETURN
ARGON GAS FILLED JACKETED VACUUM CHAMBER
COILS VACUUM
SHIELDING
2-PHASE He TUBES 4.4K
H2 LIQUID LEVEL
CHECK VALVE
CRYO PUMPING PROTECTION WINDOW
RF VACUUM
ABSORBER SUPPORT & THERMAL SPACERS
VACUUM WINDOW
ABSORBER WINDOW
ABSORBER VACUUM
2-PHASE He TUBES 4.4K
FOCUSING MAGNETS STRUCTURAL HOUSING (2)
GASEOUS HYDROGEN TO PRESSURE CONTROL TANK
SS BELLOS & TUBES
AL CONNECTIONS TO ABSORBER
ABSORBER VACUUM TO VACUUM TANK
ABSORBER THERMAL SUPPORT SPACERS
He/H2 HEAT EXCHANGE ZONE
MAGNETS STRUCTURAL SPACERS (4)
HELIUM SUPPLY