Report of the International Working Group on Muon Beamlines

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- Introduction
- Beam requirements - the cooling experiment
- Single particle muon beams
- High intensity proton beams ~ the "blast" test
- Comparison
- Conclusions

Charge to the IWG

(1) Survey existing muon beams

(2) Determine the requirements for muon beams

(3) Check if existing beams satisfy these

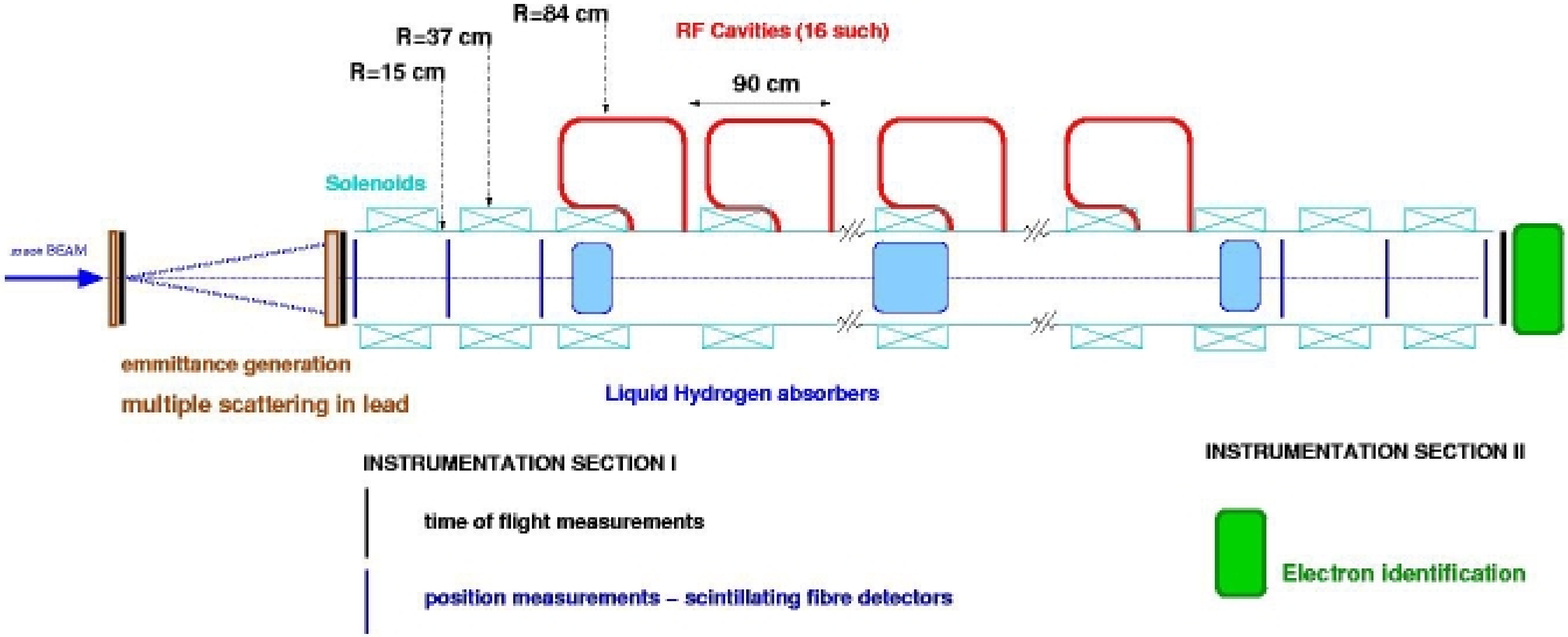
(4) If not, find plans for new beams

(5) Submit a report by NuFACT'01

There has been a lot of progress on (2) $\Rightarrow$ Cooling experiment

Thus, (1), (3) and (4) have been combined and will be compared against (2).

A Cooling Experiment



- 10% reduction in (large) 6-d emittance using prototype components

Aims:
- Measure the (small) equilibrium transverse emittance
- Measure evolution of angular momentum

Requirements for the beam

- Muons with a range of parameters for emittance studies:
  - Emittance: 1π mm.rad to 50π mm.rad
  - Momentum: 200 to 450 MeV/c
  - Momentum spread: “zero” to 20%
- Beam diagnostics of x, P_x, y, P_y, z or t, P_z

$\Rightarrow$ Single particle muon beam

  - To measure a 10% change, need ~ 1% precision $\Rightarrow$ ~ 10k muons

- Test cooling components under high radiation

$\Rightarrow$ Blast test with protons

- Some advantage to doing single particle and blast test in the same place

Infrastructure Requirements

Experiment is:

- ~ 30 m long by 3 m across
- Pulsed at 50 Hz with 100 μs per pulse

Pulsed rf ⇒ Beam should be pulsed

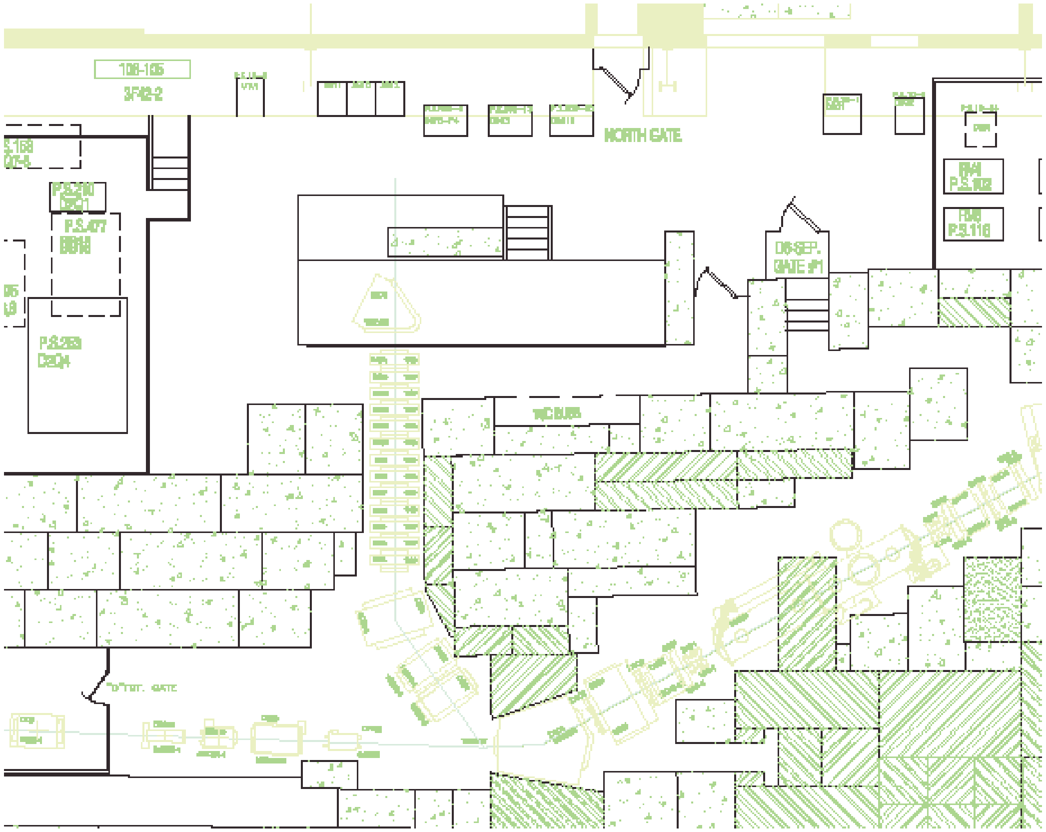
- Ex: Pulsed at 50 Hz with 100 μs per pulse

Power amplifiers for rf require:

- 1-2 MW of power
- 50-100 m^3/hr of cooling water
- ~ 28 by 19 m^2 of space

D2 at BNL

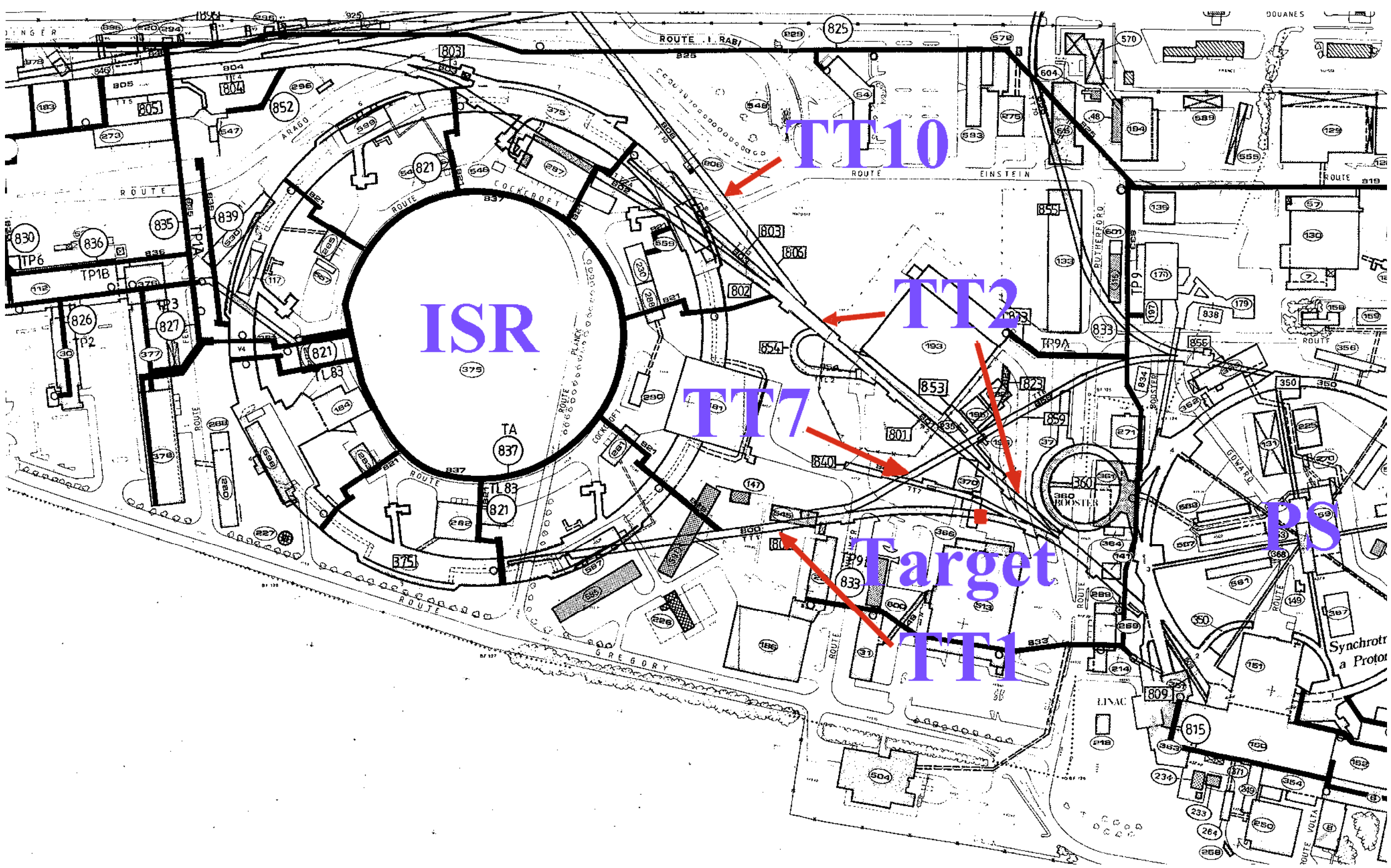
- Beam exists, but rarely used
- Designed for 300 MeV/c pions
- Currently limited to 184 MeV/c muons by final dipole
- Space limited < 5 m (unless D4 line removed)
- Either slow spill, or 12 fast bunches
- $\mu/p \sim 10^{-6}$



TT1 at CERN (for LHC beam)

- 72 bunches, each 1 ns long, separated by 25 ns; each bunch makes 5-10 turns
- Assume 1 μ / turn (on average) ⇒ 720 μ / 25 μs, every 14.4 s
- Pion/muon production using a target in TT1 line; experiment also in TT1
  ⇒ transverse space limited
- Blast test possible
- Limited space for rf
- Doesn't exist:

  Cost:
  4MCHF

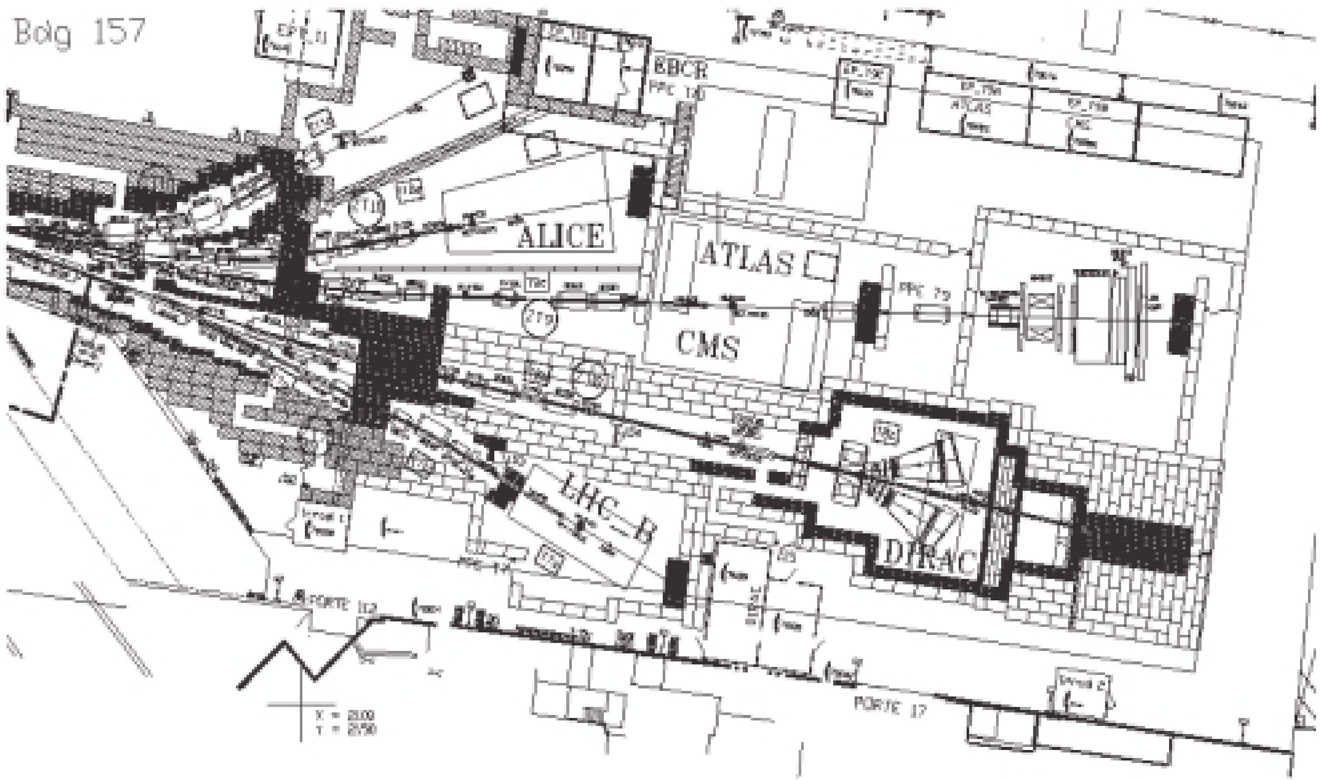


East Hall at CERN

- For East Hall, use slow extraction: 4 bunches, making >10000 turns
- 1 μ/ bunch / turn ⇒ >40000/14.4s, separated by 450ns
- Plenty of space (in principle), including for rf power

High intensity blast test may also be possible, e.g. DIRAC

Cost: Unknown



Linac Test Facility at FNAL

- At the end of the FNAL linac
- Produces 400 MeV H^- ions
- 15kW beam power
- Pulses 50μs long with bunches 0.2ns long
- 1.6×10^9 particles/bunch
- Designed for "blast" test of cooling components
- Construction expected to start spring 2002

µE1 at PSI

- CW operation, 600 MeV
- Pulse length < 1ns
- Time between pulses ~ 20ns
- Beam currently limited to 195 MeV/c
- Modifications required for 300 MeV/c and more for > 300 MeV/c
- µ/s (300 MeV/c) > 10^6
- Space available for experiment
- Blast test impossible

Cost:
Unknown

ISIS at RAL
HEP Test Beam

- ISIS: 50Hz, >100μs at maximum energy, 800 MeV

  ⇒ CW for experiment

- Two bunches, 100ns long
- Separated by 230ns
- Simulations suggest 1μ/pass; currently being measured

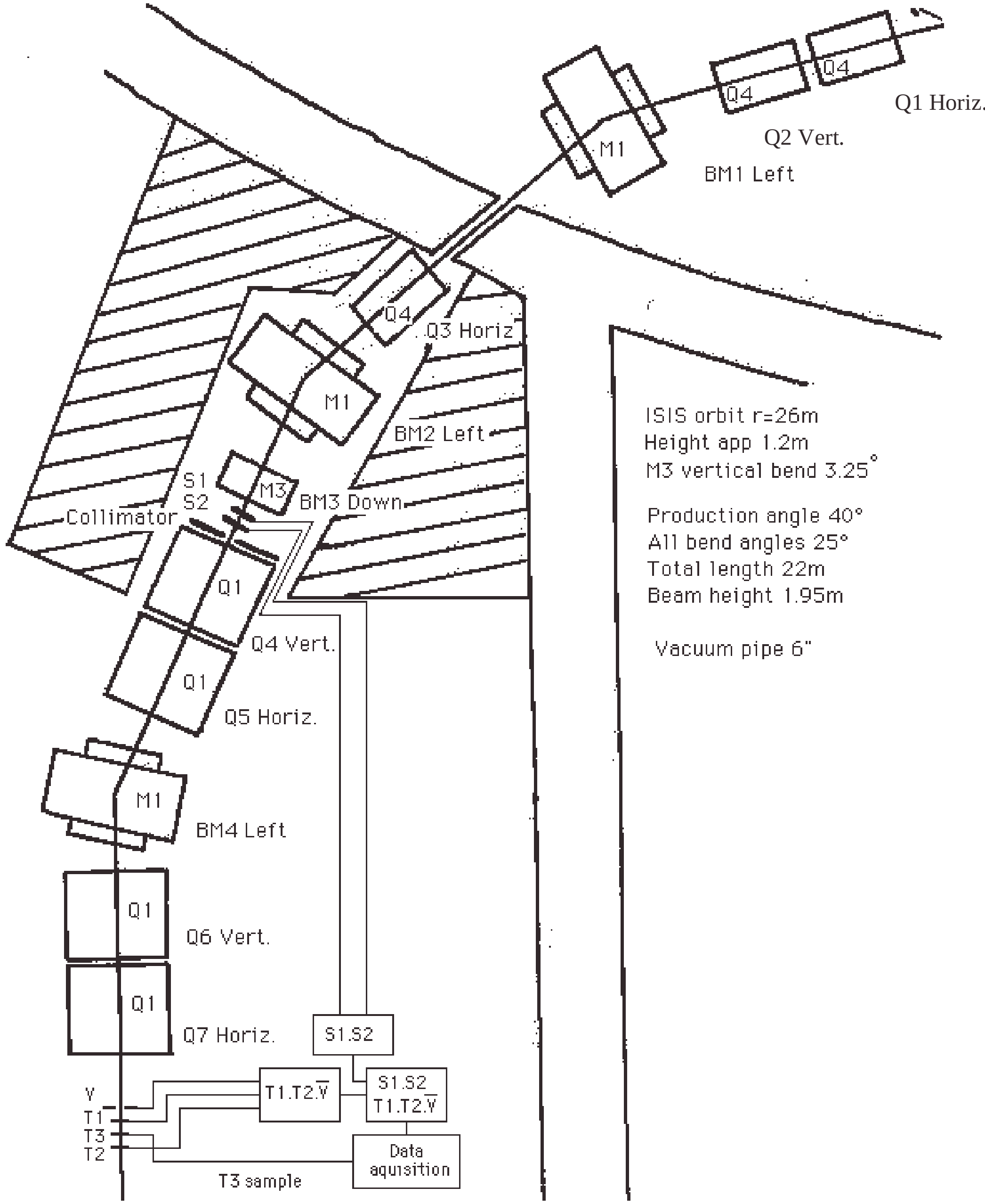
  ⇒ 20000 μ/s

- Space for experiment exists

  Cost: small

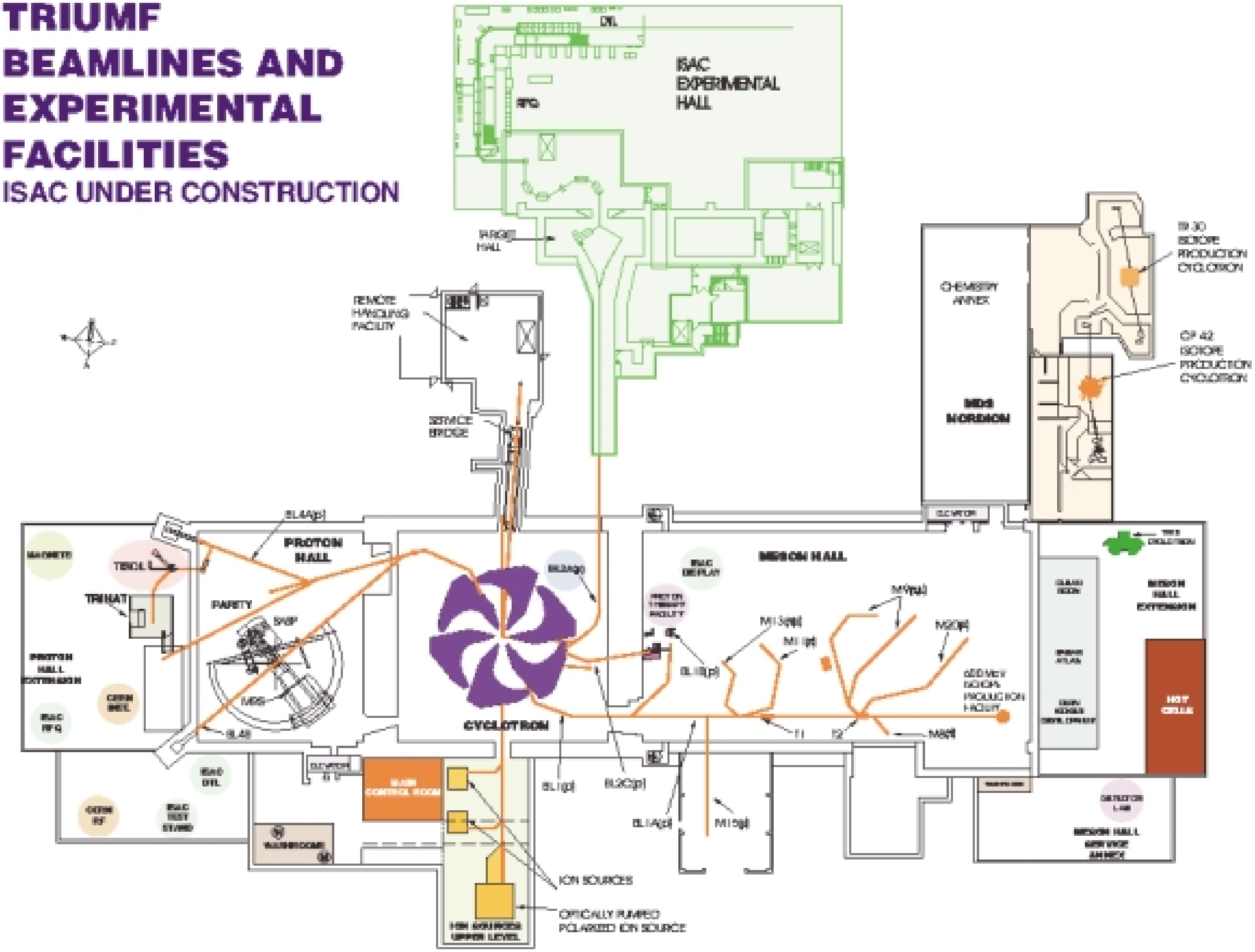
- Blast test also possible:

  Cost: possibly large!



TRIUMF BEAMLINES AND EXPERIMENTAL FACILITIES

ISAC UNDER CONSTRUCTION



TRIUMF

- CW: 1.9ns beam pulse, every 43 ns
- M11 has momentum range 100-420 MeV/c, but limited space
- M20 can have 12 m of space, but only 20-180 MeV/c
- Not clear if it is possible to increase this
- Intensity: 10^6 μ/s
- Space could be made available for rf power supplies
- Blast test not possible

Comparison between beams

Single particle muon beams:

Beam	Momentum (MeV/c)	ΔP Δ(%)	Muon Intensity (during 1 s)	Area (m^2)	Exists
BNL D2	100 - 250	10	50,000 / 5 ms	5 x 3	Yes
CERN – TT1	200 - 450	?	720 / 0.1 ms	> 30 x 4	No
CERN – East Hall	200 - 450	?	1,000 / 0.5 ms	30 x 5	No
PSI – μE1	85 - 310	1 (?)	> 50,000 / 5 ms	30 x 5	Yes
RAL - ISIS	100 - 500	~ 2	20,000 / 5 ms	30 x 5	Yes
TRIUMF – M20	20 - 180	5	5,000 / 5 ms	12 x 4	Yes

Comparison between beams

Blast test beams:

Beam	Type	Energy (GeV)	Beam Power (kW)	P/bunch $x10^{11}$	Bunch length (ns)	Beam width (mm)
CERN -TT1	p	26	83.2*	50	14	1.8
FNAL – linac	H^-	0.402	15.7*	0.016	0.2	9
RAL - ISIS	p	0.8	32	100	7	15

*Total beam power: fraction available for tests is unclear

Summary

Six candidate beams satisfy some/all single particle requirements:

(1) BNL D2	- Area needs extending, cost ?
(2) CERN TT1	- Not yet built, cost > 4 MCHF
(3) CERN East Hall	- Not yet built, cost ?
(4) PSI μE1	- Area needs extending, cost ?
(5) RAL ISIS	- Rates low, cost small
(6) TRIUMF M20	- Space limited, energy low

There are three candidates for the blast test:

(1) CERN TT1	- As above
(2) FNAL linac	- Construction in 2002, cost ?
(3) RAL ISIS	- Extraction line required, cost large!

Only two labs can do both!

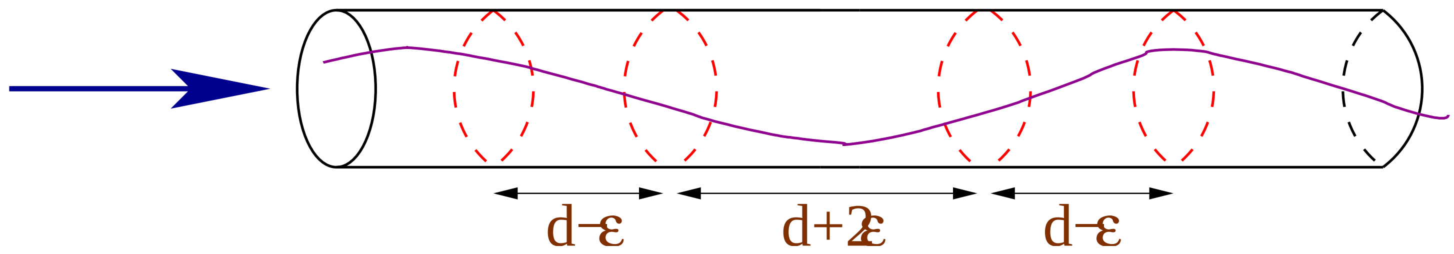
Conclusions

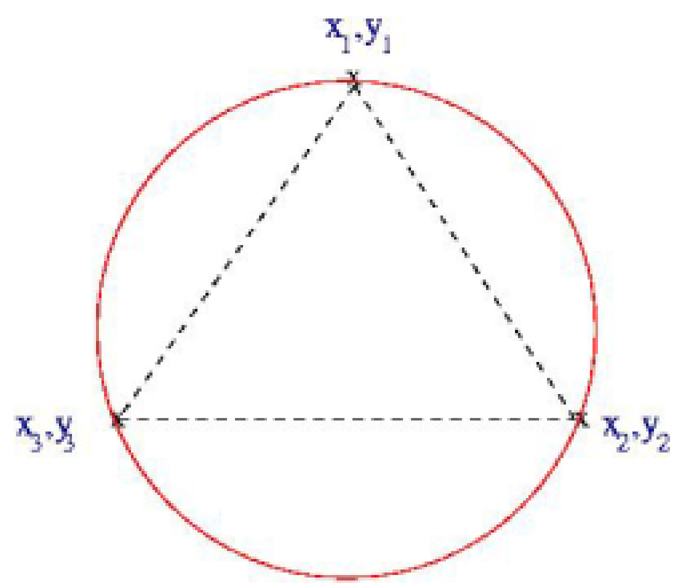
- There are candidate beams that satisfy the cooling requirements
- All require at least some work!
- The requirements have to be more clearly defined
- Once this is done, the work to be done can be costed
- The best beam(s) can then be selected

Appendix: Cooling Experiment

Instrumentation

Position, angle and momentum from four detectors in solenoids:





Muon describes a circle. Emittance Resolution depends on detector positions on path.

With B = 5T, R = 15cm, d = 40cm optimal for p_z = 290 MeV

Detectors

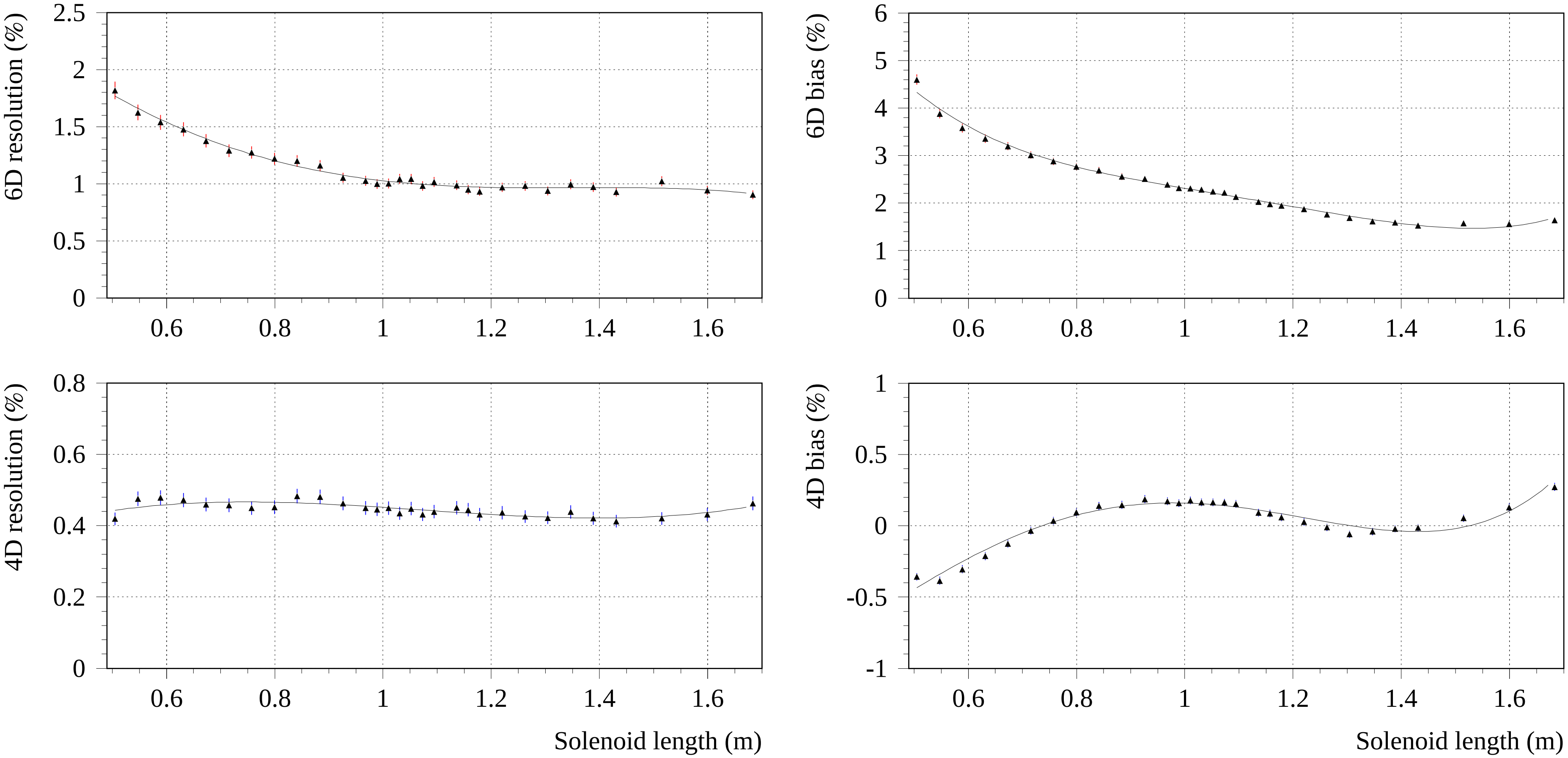
For solenoids: scintillating fibres

- Three planes of fibres
- Diameter - 0.5 to 1.0mm
- Resolution:

	Actual	Required
Position	150-290μm	5mm
Angle	<1mrad	5mrad
Time	~500ps	200ps

- Time resolution may not be good enough ⇒ tof detectors required resolution ~ 70-200ps

Emittance Resolution

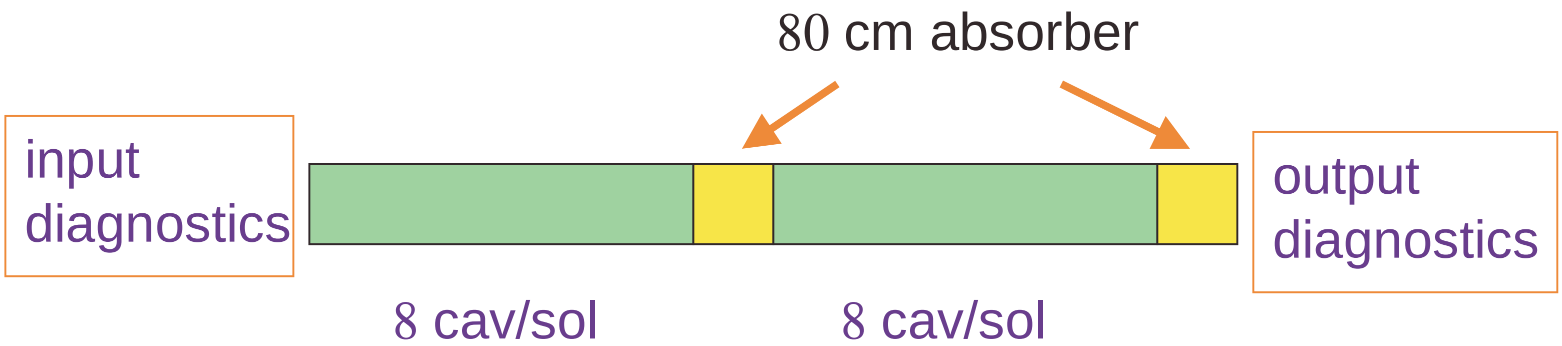


Emittance Resolution

Decays:

- μ→e : 0.2% contamination of e ⇒ 5 times worse
  Resolution and Bias
  ⇒ electron-id required
- Pion decays: similar problems
  ⇒ must be rejected (e.g by TOF)

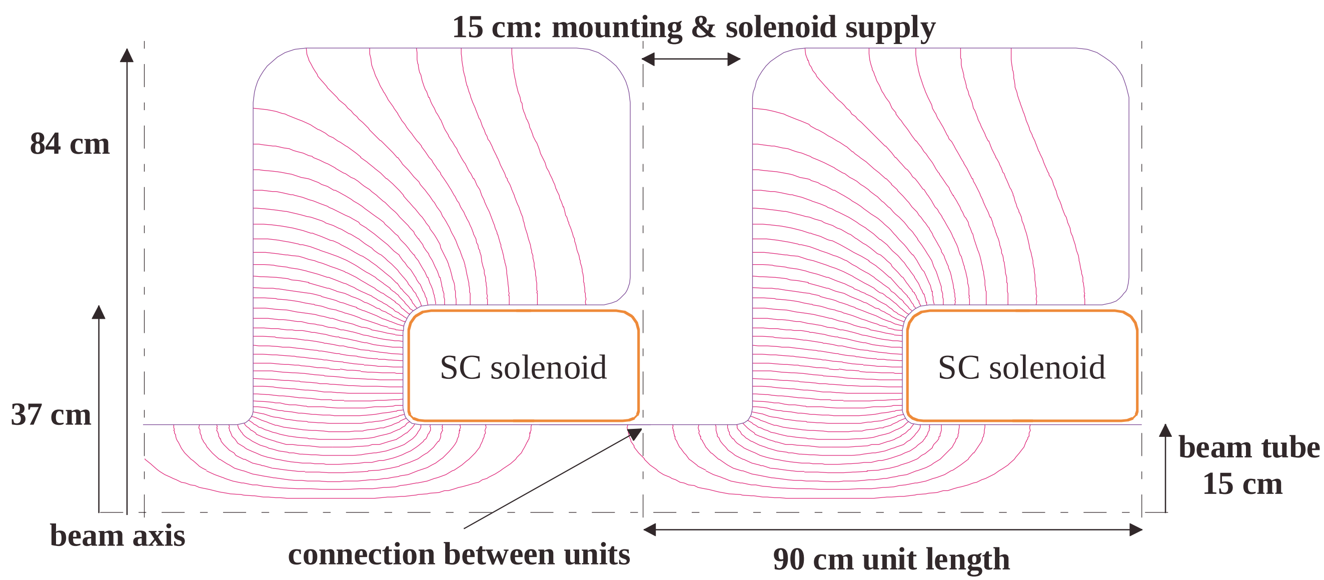
Cooling Box



- Recent simulations use solenoid field maps and E-fields for the cavities
- Looking for a loss-less channel with B < 4T
- “Matching” is crucial
- Simulated E_{kin} = 200 MeV muons

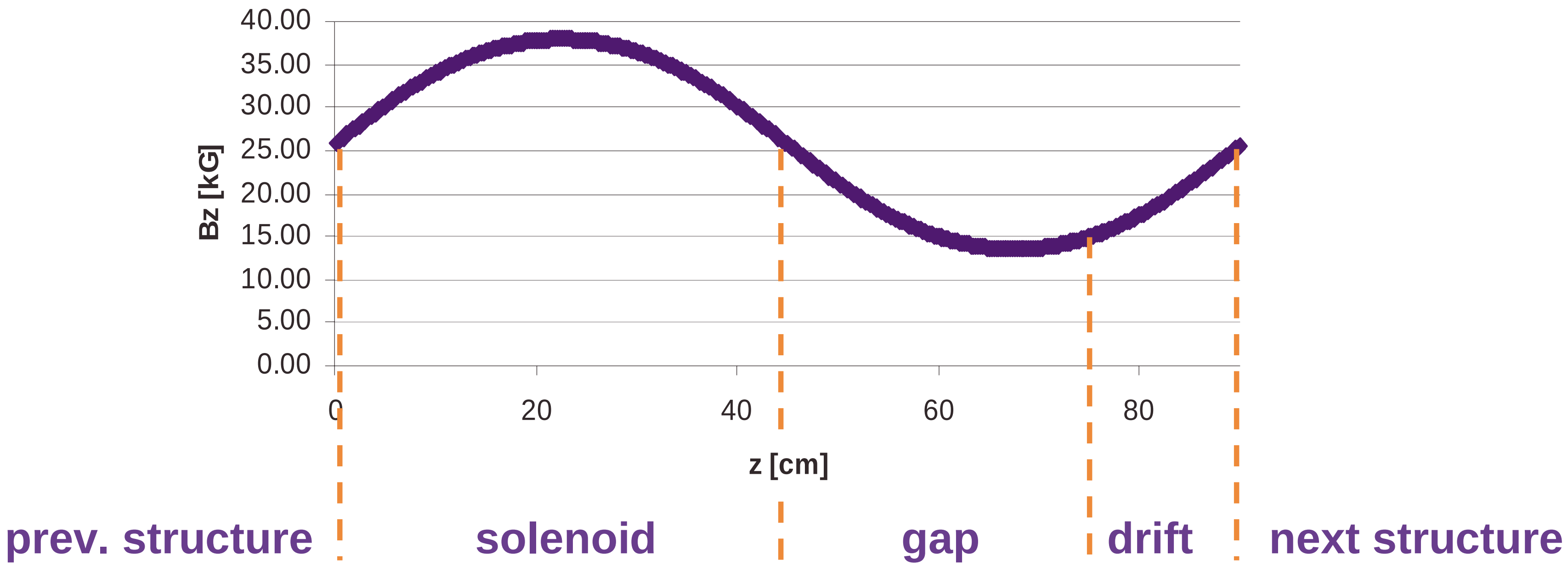
Cavity Design

- Asymmetric 88MHz cavity design by Frank Gerigk
- 90cm long with 3.6MeV energy gain per structure
- 16 cavities ⇒ 160cm of liquid hydrogen



Solenoid Design

- Cavity design leaves 45 x 20cm of space. Can use 40 x 17cm
- First rudimentary design done
- Should not exceed B = 4T



Performance

- Simulations show:

  - full transmission
  - emittance decrease from 651cmmrad to 578cmmrad
    $\Rightarrow$ 10% reduction required

- Still to be done:

  - new geometry
  - better field maps
  - beam with an energy spread
  - higher energy
  - etc.....

Cost and Schedule

Cost:

Schedule:		
	• TDR	Summer 2001?
	• Approval	2002?
	• Construction done	2004?
	• Experiment complete	2005

Conclusions

- It is essential to demonstrate a cooling channel can be built
- A cooling experiment is being developed that will do this
- This has three components:
  - Single particle muon beam $\rightarrow$ three candidates in Europe
  - Instrumentation $\rightarrow$ SciFi in solenoids + TOF
  - Cooling box $\rightarrow$ Section of 88MHz channel
- Current simulations show a 10% cooling and sufficient precision
- Setup will also allow an investigation of the cooling parameters
- Still much work to be done