Cooling Test Experiment

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- Introduction
- Definition of emittance
- Cooling experiment
- Beams
- Instrumentation
- Cooling box
- Cost and timescale

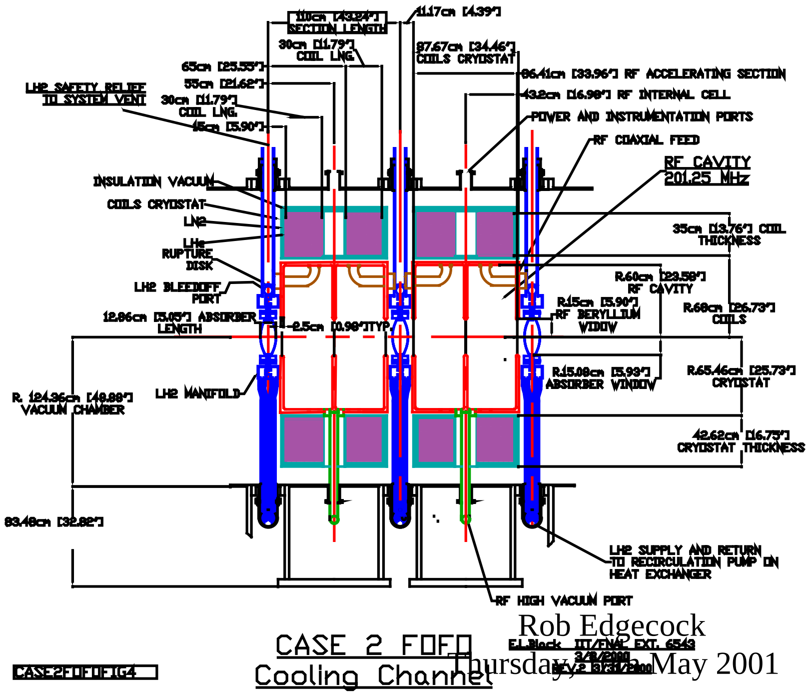
Cooling Experiment

Why is a cooling experiment necessary?

- Cooling is very important for a neutrino factory: factor ~16 in intensity
- Delicate balance between energy loss and scattering

$$\frac{d\varepsilon_{\perp,\mathrm{N}}}{dz} = -\frac{\varepsilon_{\mathrm{N}}}{\beta^2 E}\frac{dE}{dz} + \frac{\beta_\chi (13.6\mathrm{MeV/c})^2}{2\beta^3 E m_\mu L_R}$$

- Cooling channel is complex



Test is essential!

Cooling Experiment

What does it have to do?

- Demonstrate a cooling channel is feasible
- Measure a 10% reduction in emittance
- Allow an investigation of the channel performance as a function of
  - Emittance: 1πmm.mrad to 50 πmm.mrad
  - Energy: 100 to 400 MeV
  - Energy spread: “zero” to 20%
  - Phase, B-field, etc?
- Use a single particle beam

Emittance

- If z is the beam direction, at a given z, each particle is characterised by

$$v = (x, x', y, y', t, t'), \text{ where } x' = p_x/p_z,\ y' = p_y/p_z,\ t' = E/p_z$$

- Emittance determined from covariance matrix $V(z)$:

$$V_{ij} = \left\langle \left(v_i - \bar{v}_i\right)\left(v_j - \bar{v}_j\right) \right\rangle \qquad \text{e.g.} \quad V_{11} = \sigma_x{}^2$$

$$\varepsilon(z) = \{\text{Det } V(z)\}^{1/2}$$

6D: (x, x', y, y', t, t')

4D: (x, x', y, y')

Emittance

Interested in: $(\varepsilon^{out} / \varepsilon^{in}) < 90\%$

- $\sigma_{statistics} < 1\% \Rightarrow$ # of events < 10000 (Patrick Janot)
- Detector resolution: "corrections" < 1% (Alain Blondel)

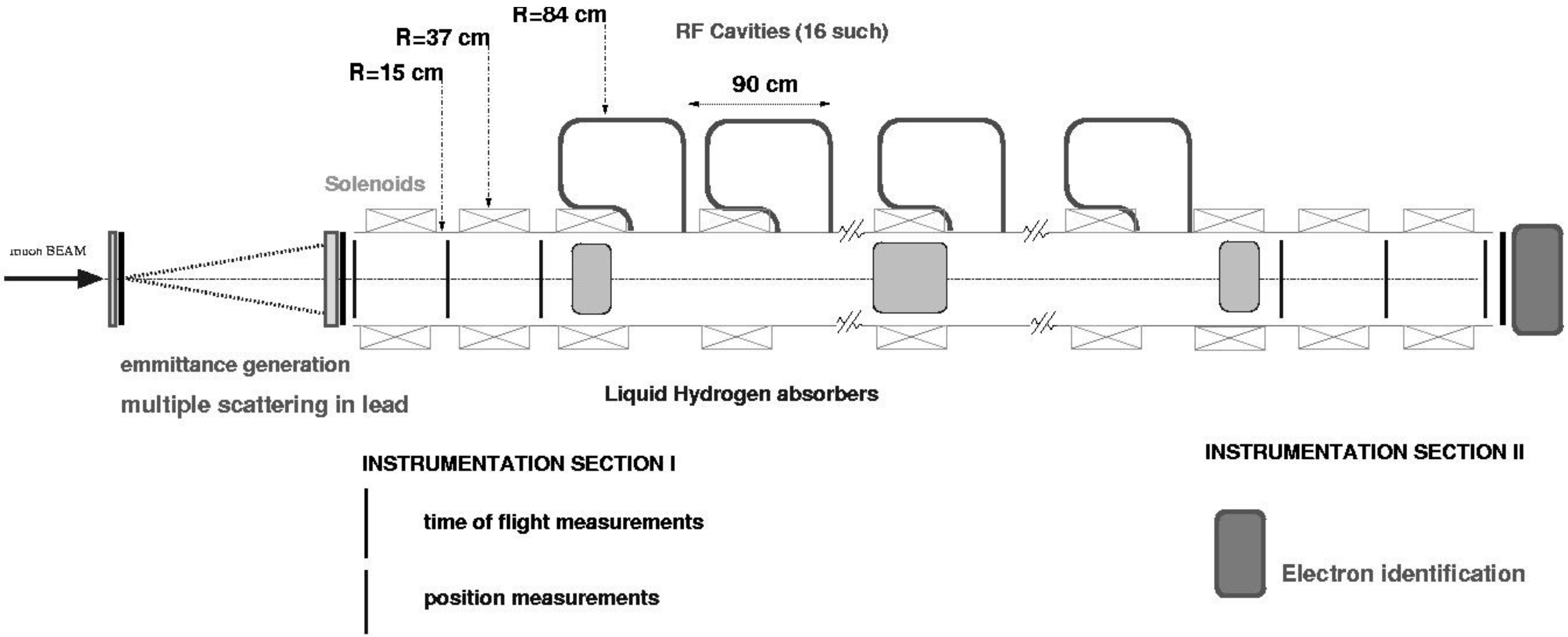
$$\Rightarrow \sigma^2_{measured} = \sigma^2_{true} + \sigma^2_{tracker} = \sigma^2_{true}\,(1 + x)$$

$$x \leq 1\% \Rightarrow \sigma_{tracker} \leq 1/7\ \sigma_{true} \quad \text{(say 1/10)}$$

- Typical values:

$\sigma_{x,y}$	~3-5cm
$\sigma_{x',y'}$	~50mrad
σ_t	~2ns
σ_E/E	±10%

Experiment



NB: rf pulsed at 50Hz, with 100µs per pulse

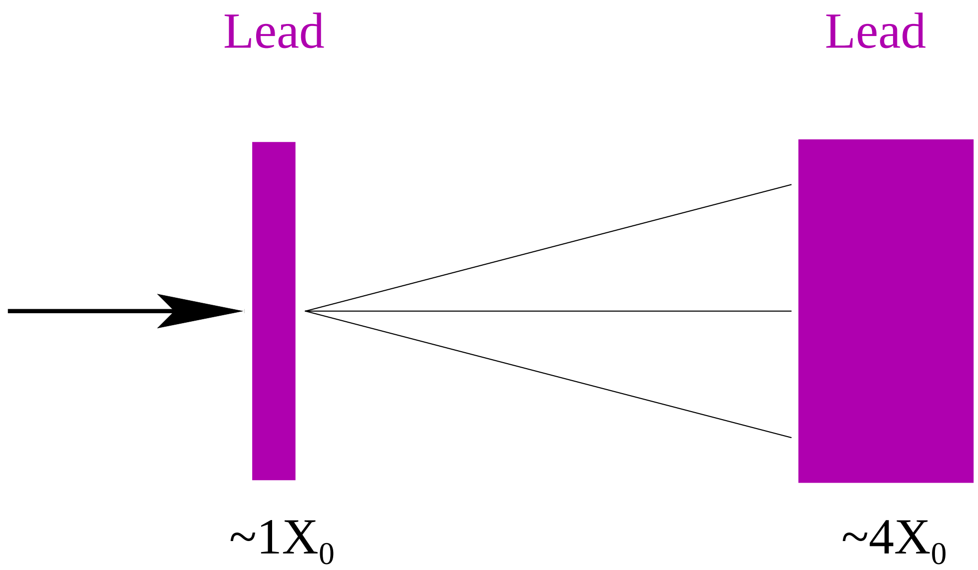
Muon Beams

Remember:

- Emittance: 1πmm.mrad to 50πmm.mrad
- Energy: 100 to 400 MeV
- Energy spread: “zero” to 20%

Candidate beams in Europe:

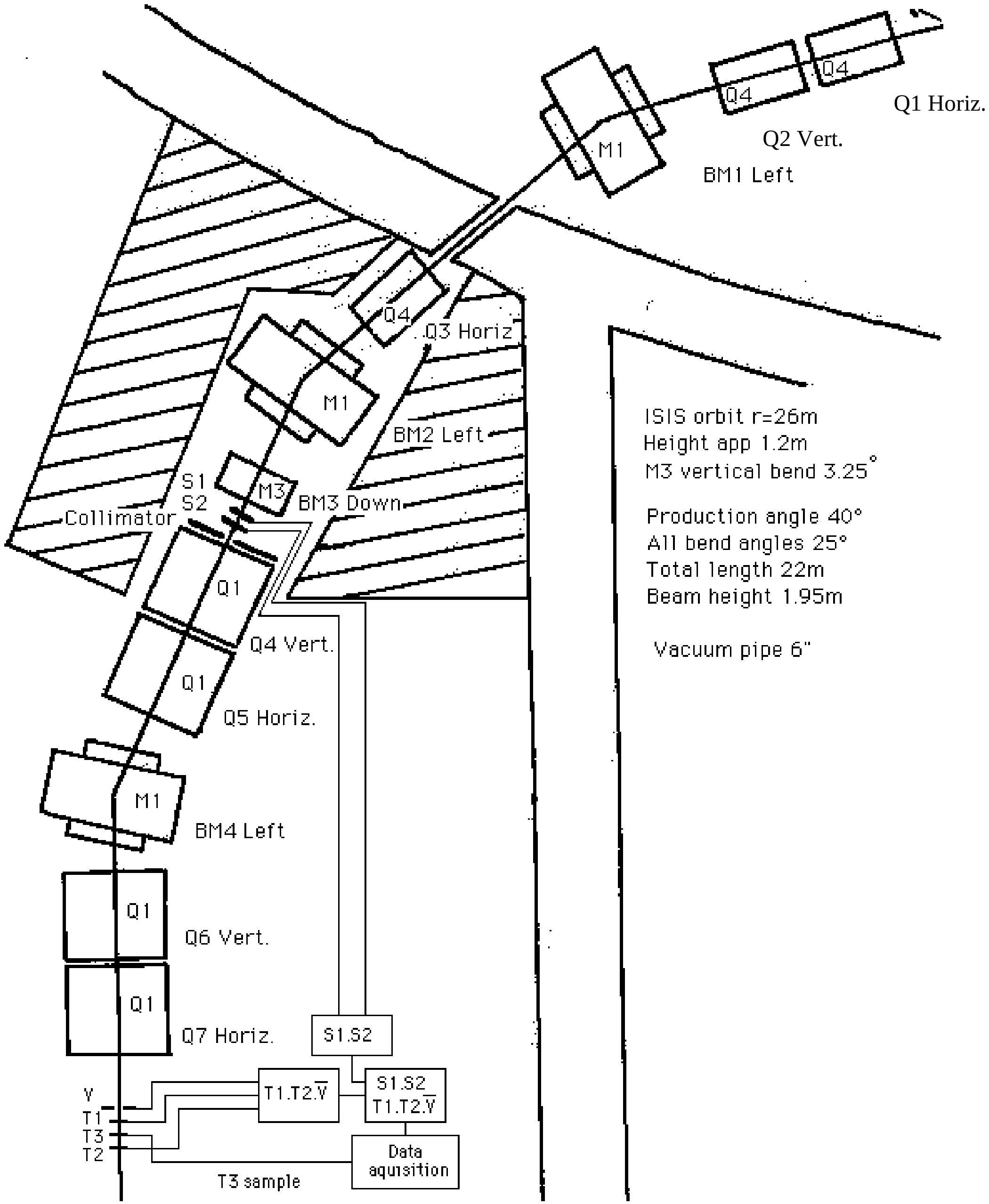
- ISIS at RAL
- μE1 at PSI
- PS at CERN



ISIS

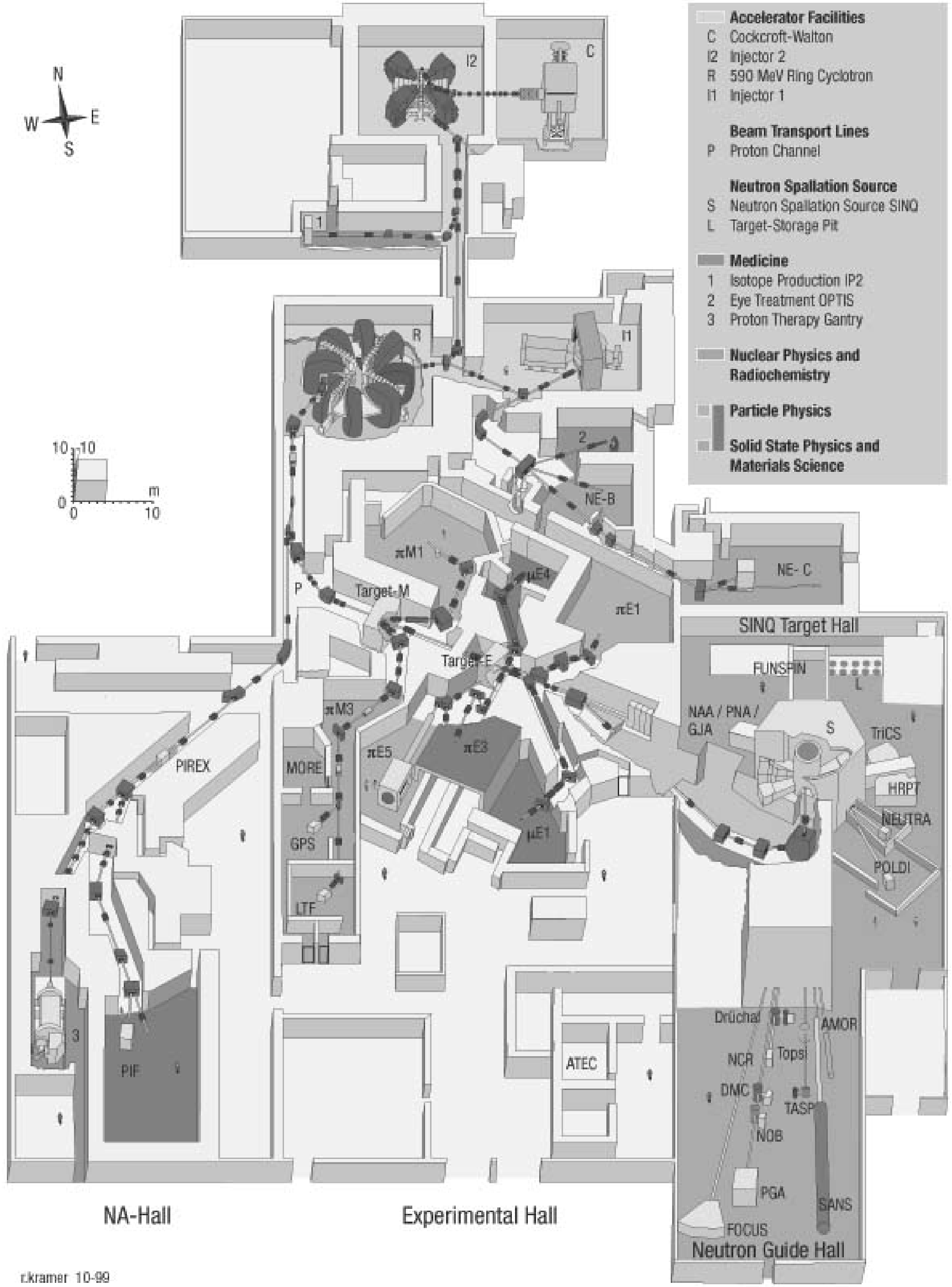
HEP Test Beam

- ISIS: 50Hz, >100μs at maximum energy, 800 MeV
  ⇒ CW for experiment
- Two bunches, 100ns long
- Separated by 230ns
- Simulations suggest 1μ/pass



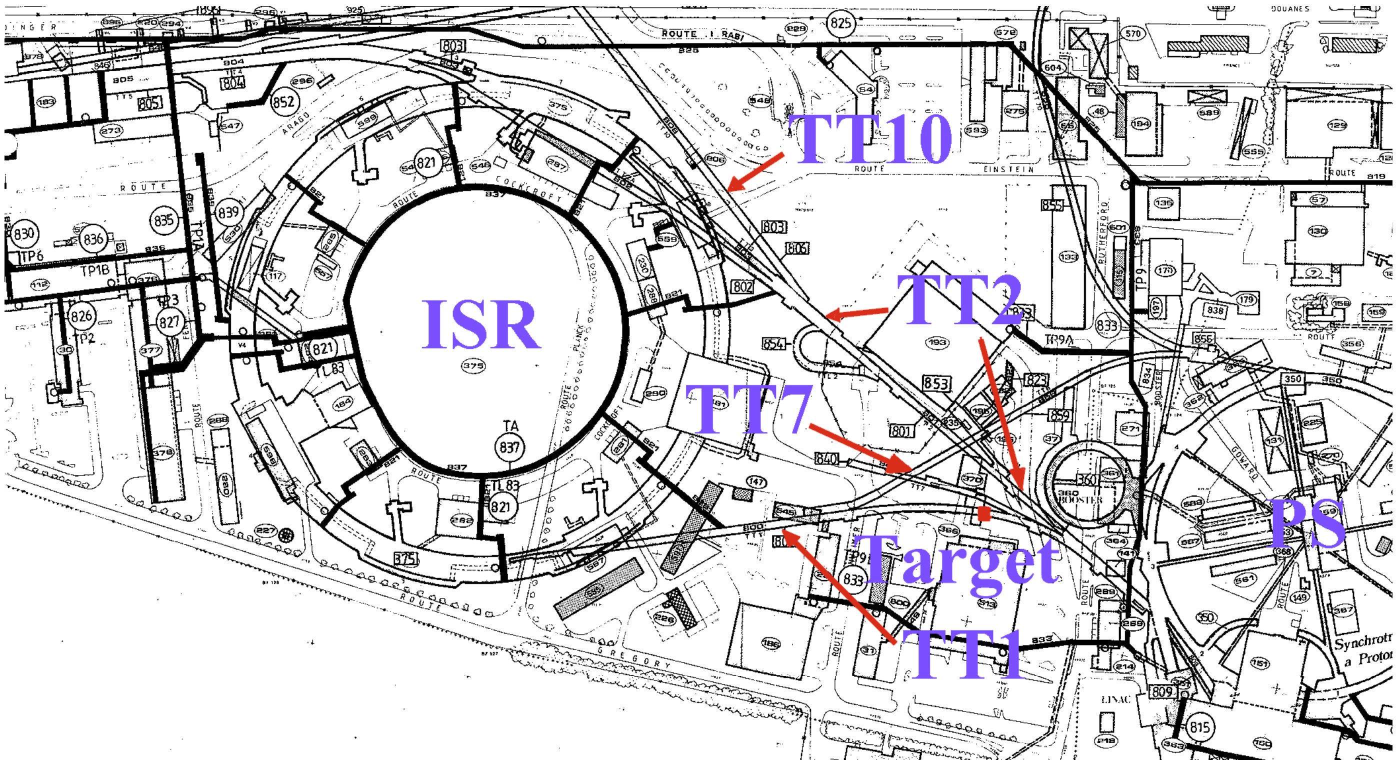
μE1 at PSI

- Pulse length ~ 0.3ns
- Time between pulses ~ 20ns
- μ/s (300 MeV/c) > 10^6
- Average μ separation < 1μs



PS at CERN (for LHC beam)

- 72 bunches, each 1ns long, separated by 25ns
- Each bunch makes 5-10 turns ⇒ 11-22μs spill
- Assume 1 μ/turn (on average) ⇒ 720 μ/14.4s
- 25 ns separation

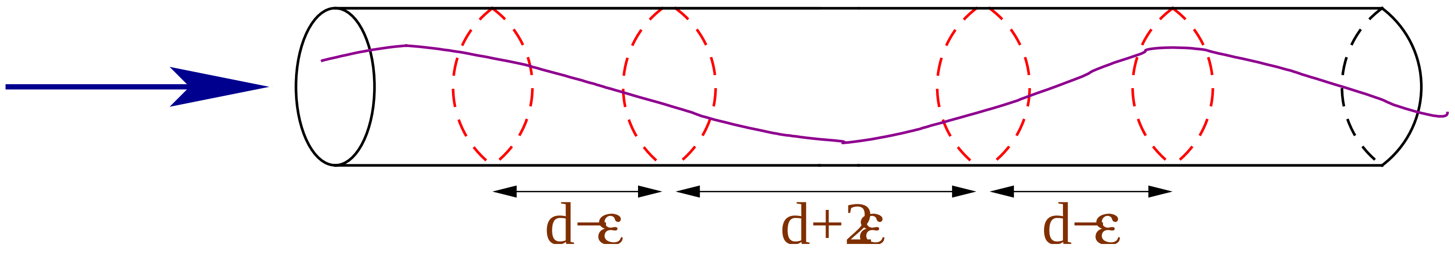


Comparison between beams

Beam	Momentum range (MeV/c)	Momentum bite (%)	Intensity (μ/s)	Space (m)	Inf.	Exists?	Blast test
ISIS	0-500	~2	20000	30x10	Yes	Yes	Yes
μE1	85-307	1(?)	>20000	30x>5	?	Yes	No
TT1	? (but must cover useful range)	?	720	Miles x3.7	Some	No	Yes

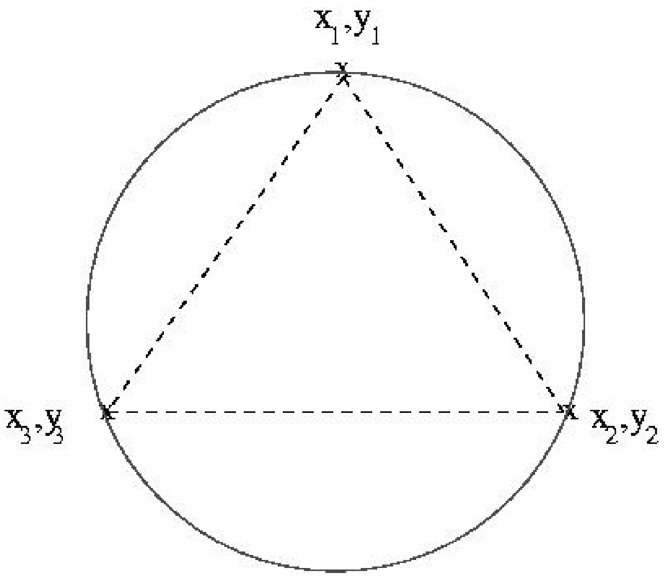
Instrumentation

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

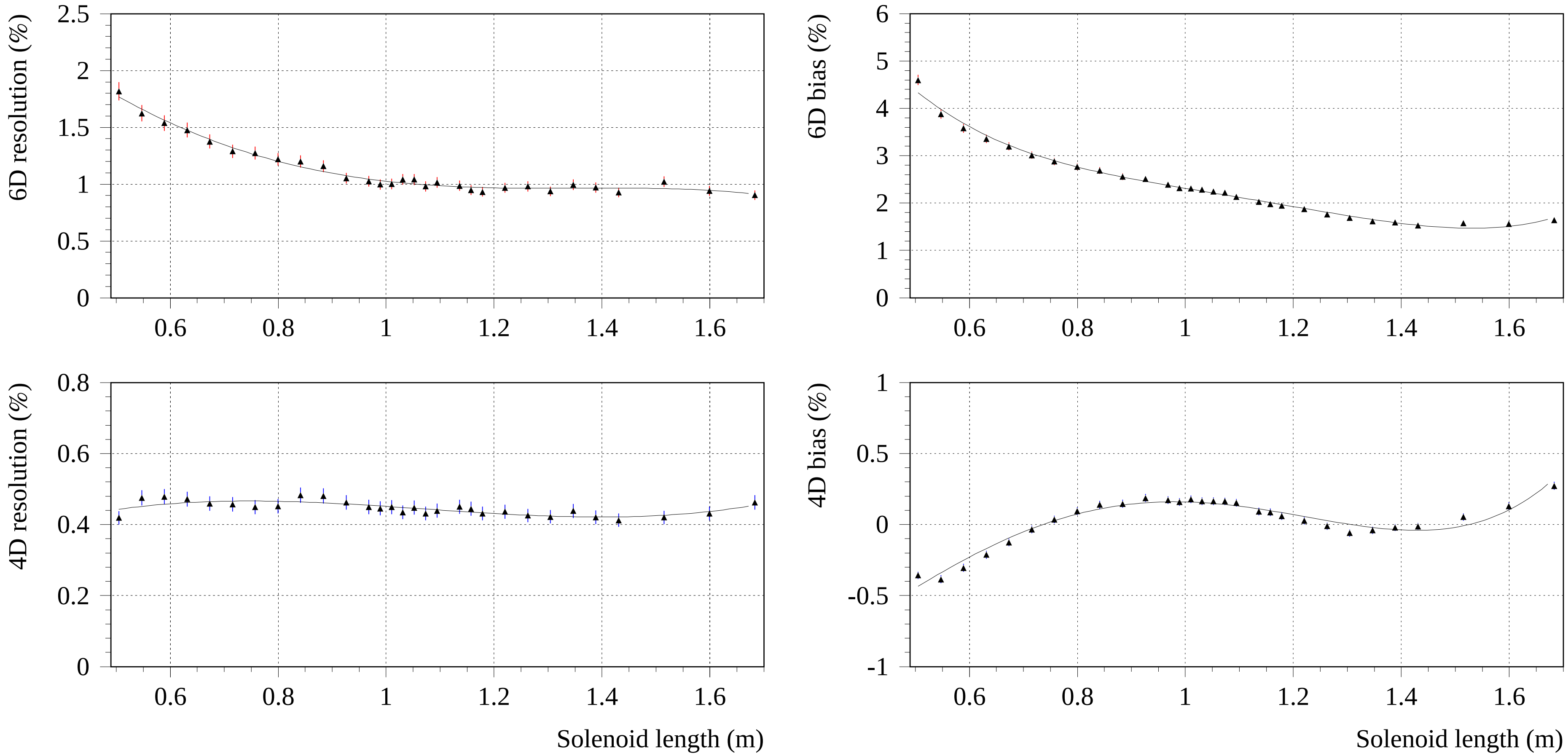
For solenoids: scintillating fibres

- 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

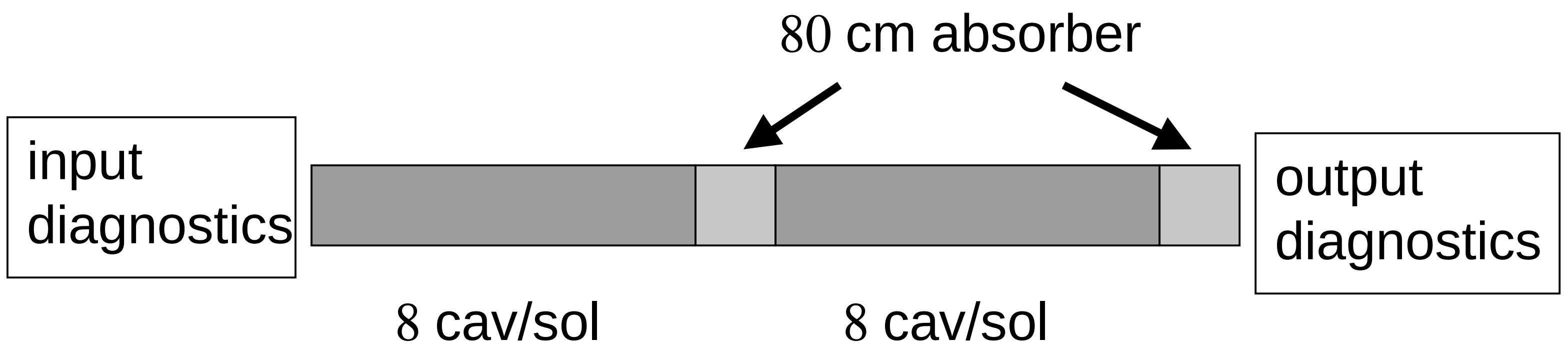


Emittance Resolution

Decays:

- $\mu \rightarrow e$: 0.2% contamination of e $\Rightarrow$ 5 times worse Resolution and Bias
  $\Rightarrow$ electron-id required
- Pion decays: similar problems
  $\Rightarrow$ must be rejected (e.g by TOF)

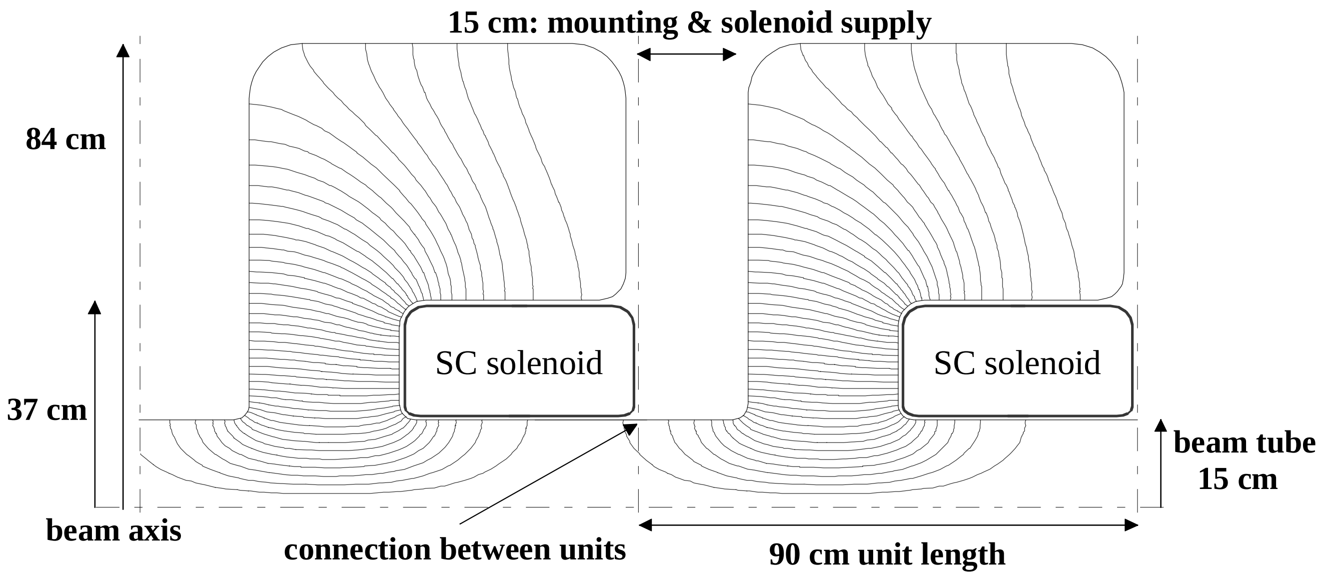
Cooling Box



- 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

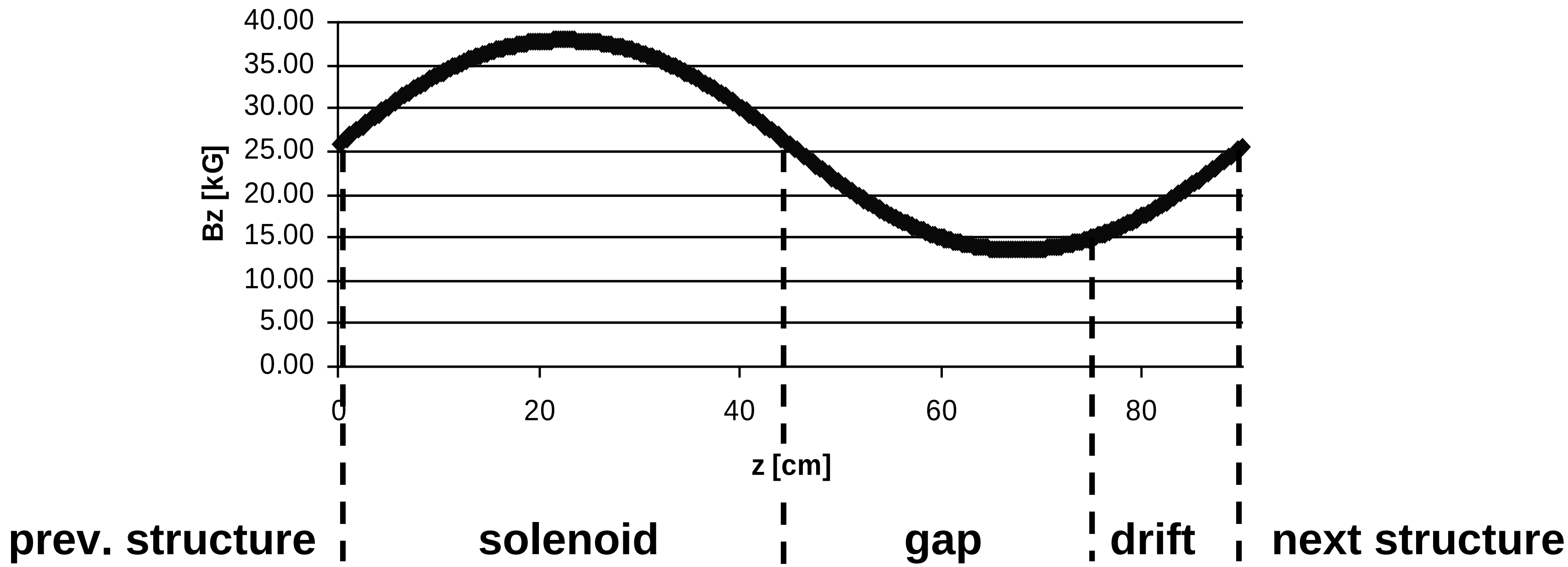
Cavity Design

- 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 → three candidates in Europe
  - Instrumentation → SciFi in solenoids + TOF
  - Cooling box → 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