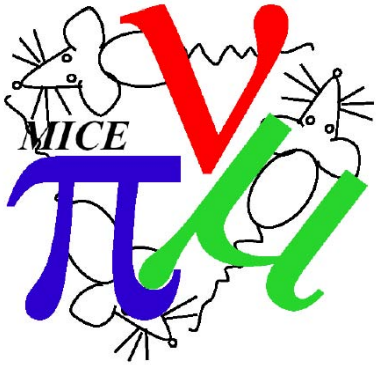
Muon Collaboration

MICE-US: Status and Plans

Daniel M. Kaplan

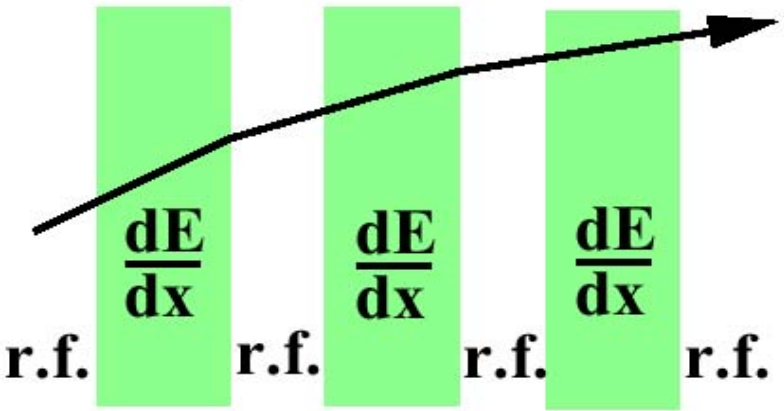


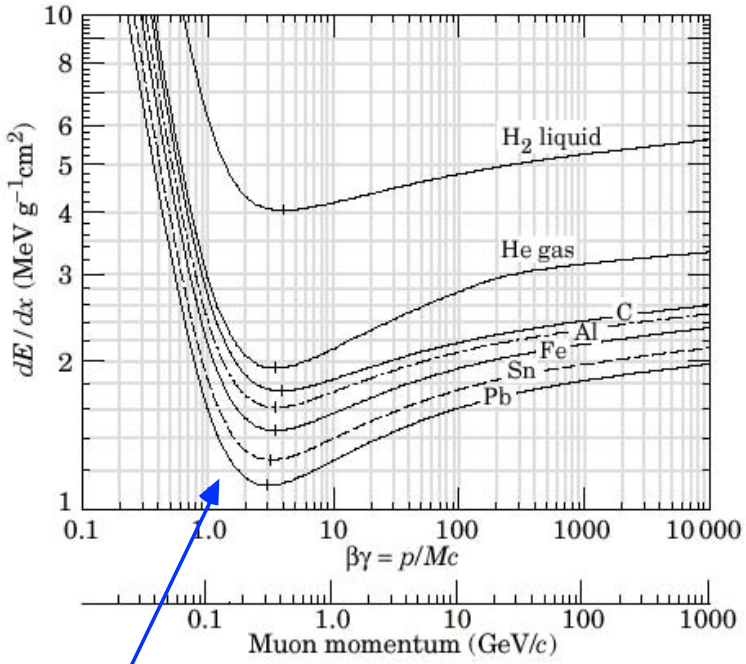
MUTAC Review
Lawrence Berkeley National Laboratory
April 25, 2005

Outline:

1. MICE
2. US Contributions to MICE
3. Funding
4. Summary

Ionization Cooling: Background





- Absorbers:

$$\begin{cases} E \rightarrow E - \left\langle \frac{dE}{dx} \right\rangle \Delta s \\ \theta \rightarrow \theta + \theta_{space}^{rms} \end{cases}$$

ionization energy loss

multiple Coulomb scattering

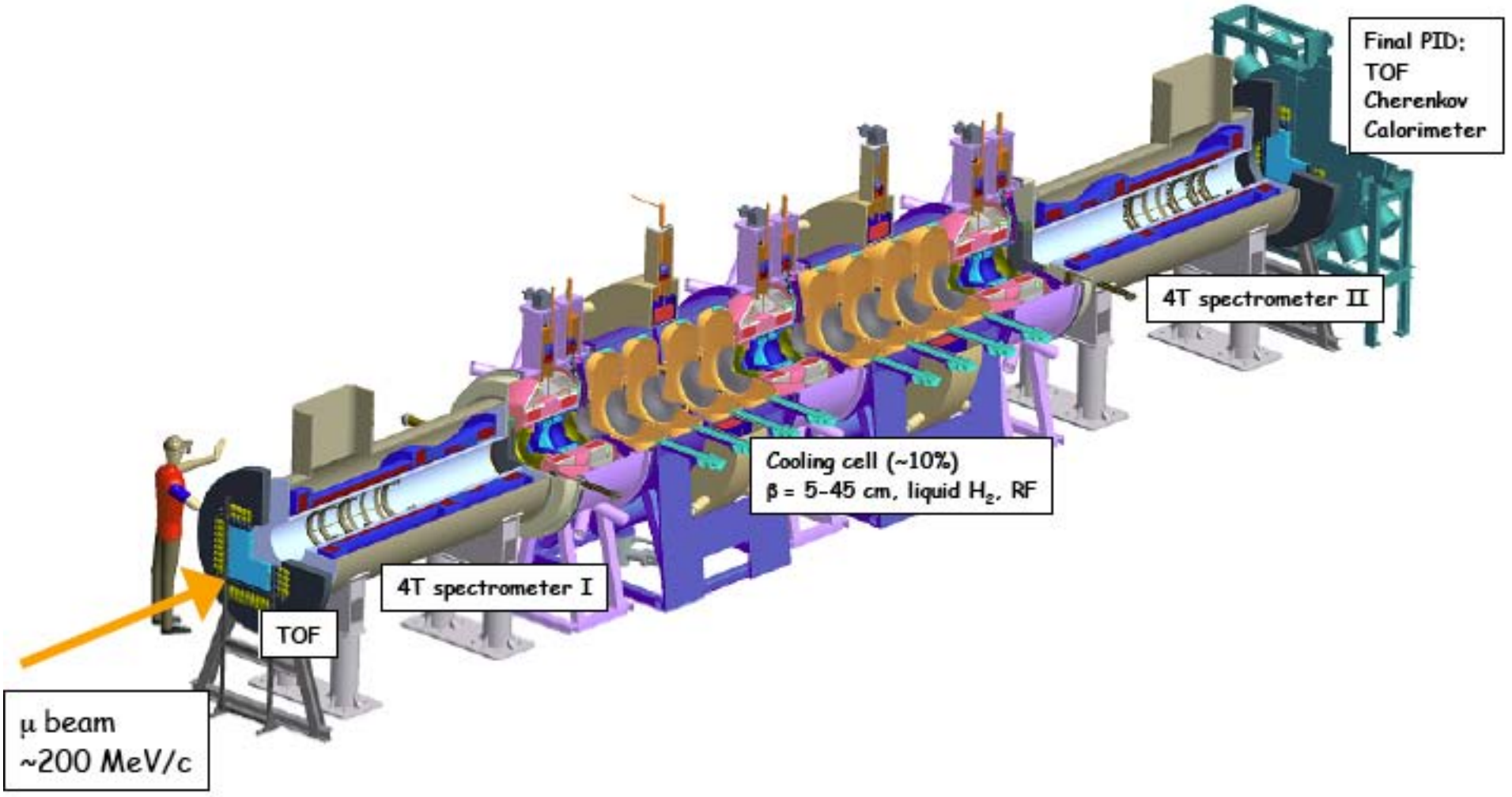
- RF cavities between absorbers replace ΔE
- Net effect: reduction in $p_\perp$ w.r.t. $p_\parallel$, i.e., transverse cooling

Note: The **physics** is not in doubt

$\Rightarrow$ in principle, ionization cooling **has** to work!

... but in practice it is subtle and complicated so a test is important

MICE



Goals of MICE:

- 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.

Current Status:

24 Oct '03: MICE approved!

- CCLRC (letter from John Wood, Chief Exec., Council for the Central Laboratory of the Research Councils)

  "...accepts the strong endorsement of the proposal by the Astbury panel and consequently considers the proposal to have full scientific approval."

  "...approves the project subject to satisfactory passage through Gateway."

20–21 Dec '04: Gateway 2/3 Review (prerequisite to funding – passed)

21 Mar '05: MICE (Phase 1) funded!

- UK Science and Innovation Minister, Lord Sainsbury:

  "It is a testament to the UK's world class science and facilities that leading experimental physicists from across the globe have supported conducting a project of this calibre in the UK. The Government's investment in this experiment will provide a unique showcase of UK scientific and engineering technology..."

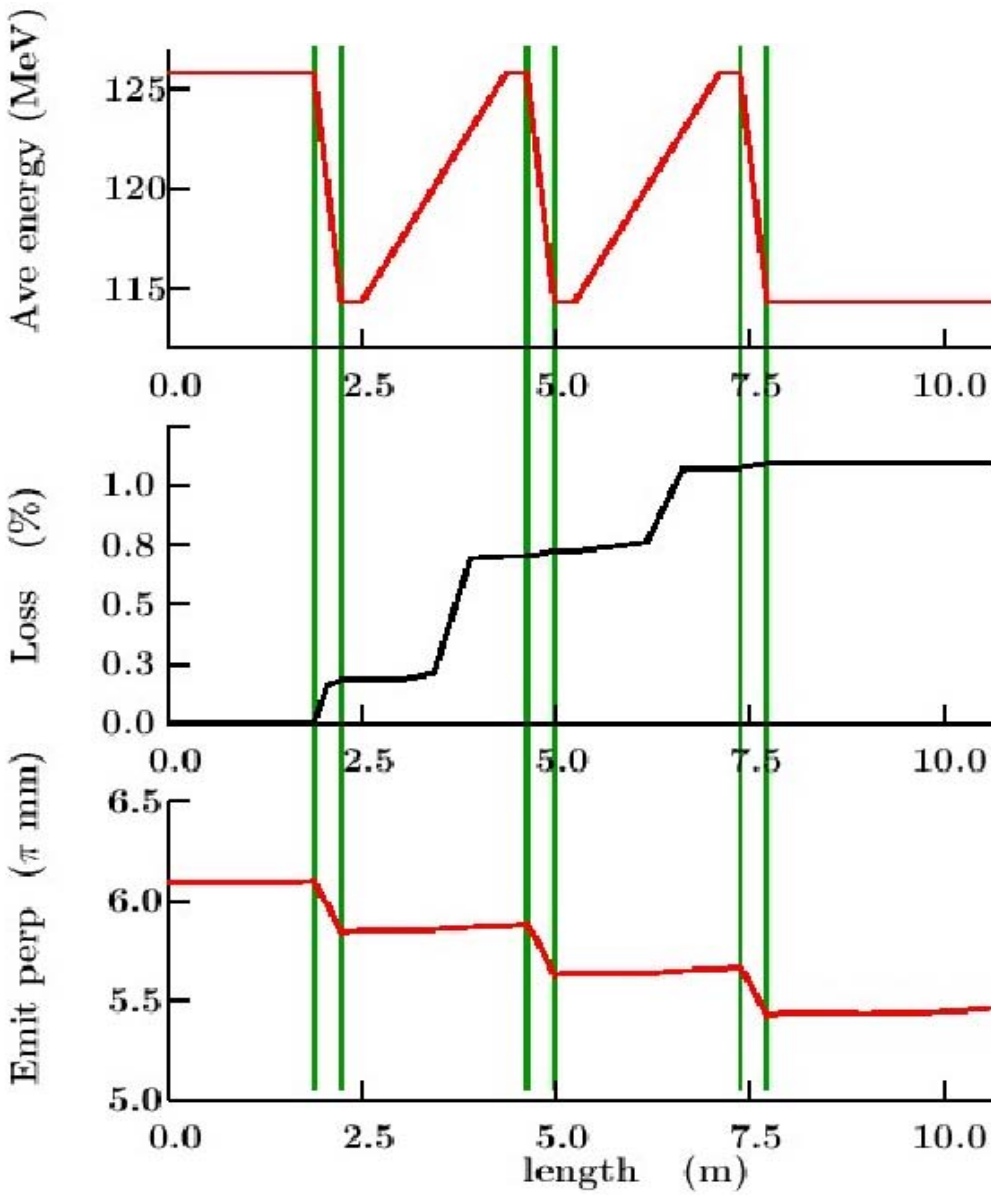
- £9.7M UK funds released ≈April '05

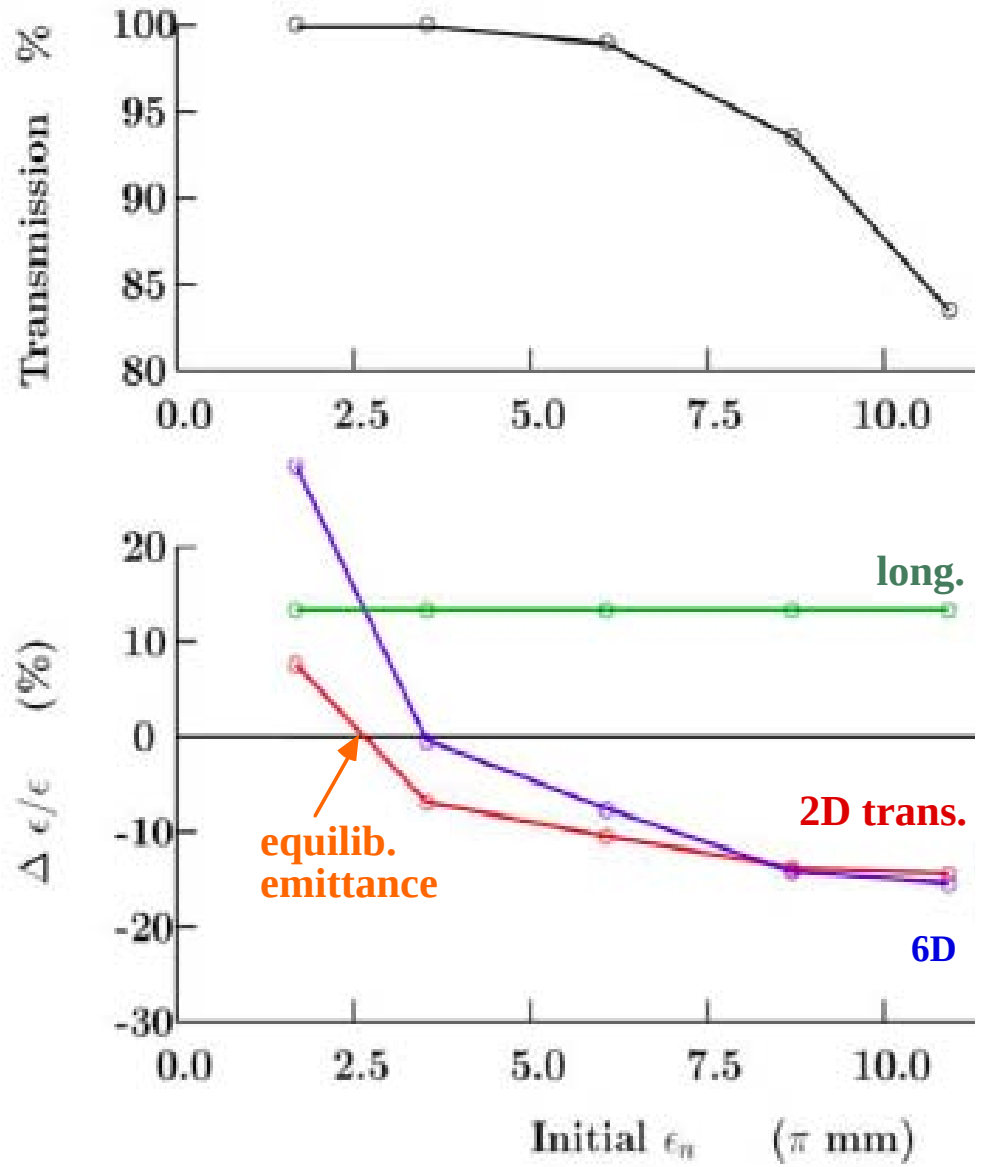
US Contributions to MICE:

- Muon Collaboration developing cooling-cell components to be tested in MICE, including
  - high-gradient 201-MHz RF cavities
  - LH_2 absorbers
- Within MICE, US collaborators responsible for
  - cooling-cell concepts and simulation (Palmer/Fernow/Gallardo, BNL)
  - beamline simulations (T. Roberts, Muons, Inc.)
  - RFCC cooling-cell modules (LBNL)
  - thin windows for LH_2 absorbers (Cummings et al., NIU/IIT/FNAL/UMiss/Oxford)
  - upstream Cherenkov counter for incoming-muon ID (UMiss)
  - VLPC readout & fiber prep for SciFi trackers (FNAL/IIT/UCLA/UCR)
  - software development (Y. Torun, IIT)
  - oversight & leadership (Zisman/Bross/Kaplan/Torun)
- Additional responsibilities we have taken on:
  - spectrometer solenoids (so far not funded by Italy, 1st one needed on “Day 1”)
  - RF power (2 surplus supplies contributed by LBNL)

Performance Simulation (nominal SFOFO mode):

(BNL ICOOL simulation)



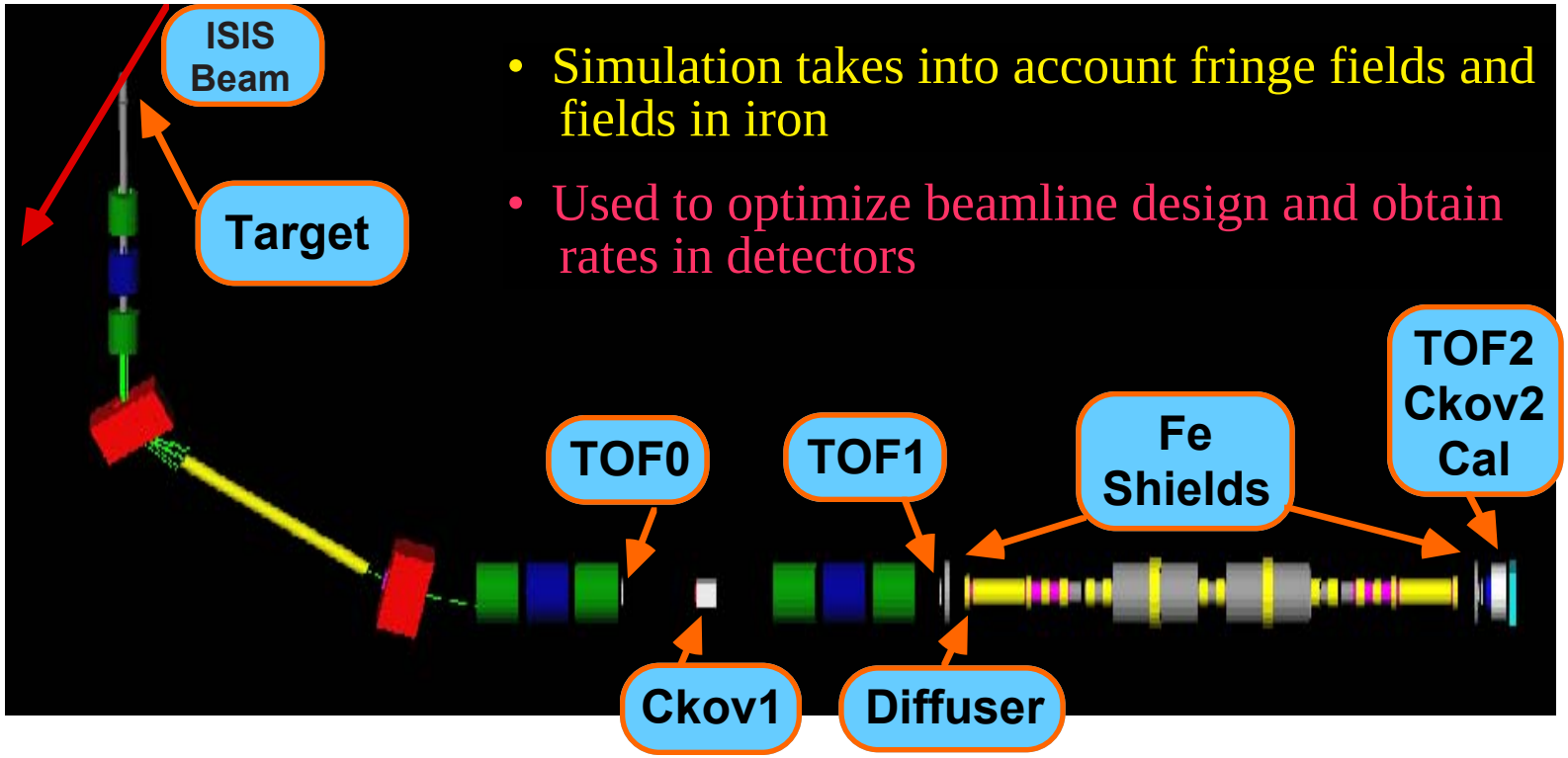


→ ≈10% transverse emittance reduction, measurable to 0.1% (abs.) given precise spectrometer, clean beam, and efficient, redundant particle ID

Beamline Simulation

(T. Roberts, Muons, Inc.)

- While at IIT, T. Roberts developed "g4beamline" to simulate MICE beam:



- Optimized beam rates per "target-in" ms (occuring once per s):

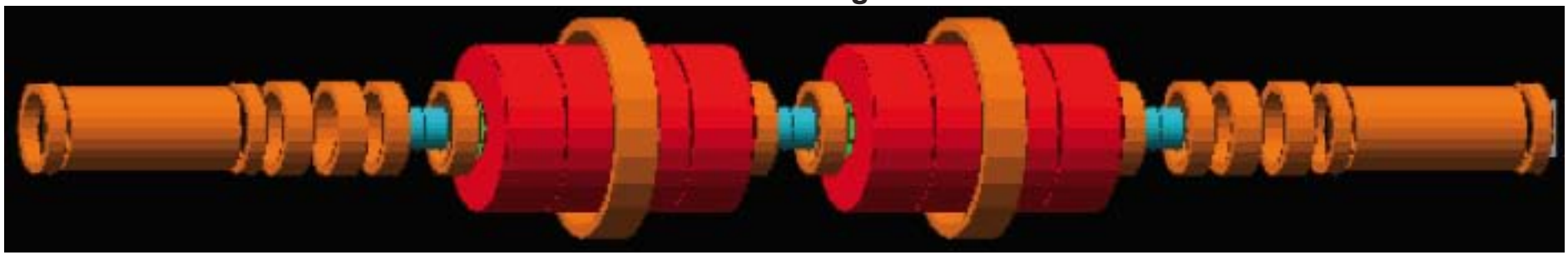
Description	LAHET	Geant4	MARS
1mm x 100mm, 10m from target			33,400
TOF0	2355	2693	2834
TOF1	462	529	557
Tracker1	422	482	507
Tracker2	284	324	342
TOF2	281	321	338
Good μ^+	277	316	333

G4MICE Experiment Simulation

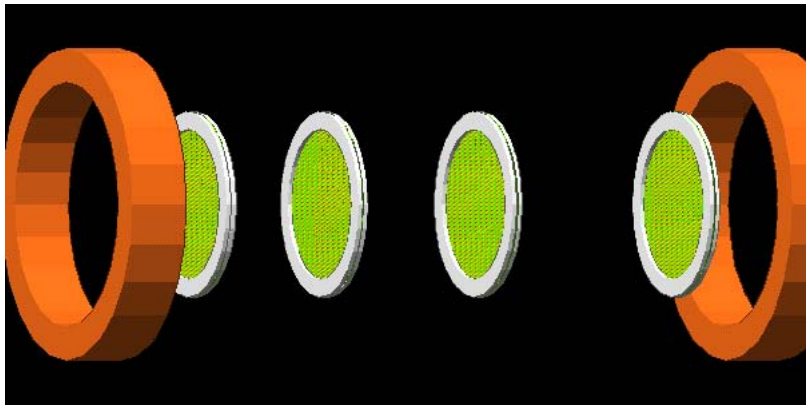
(IIT / BNL / Geneva / ICL / UCR et al.)

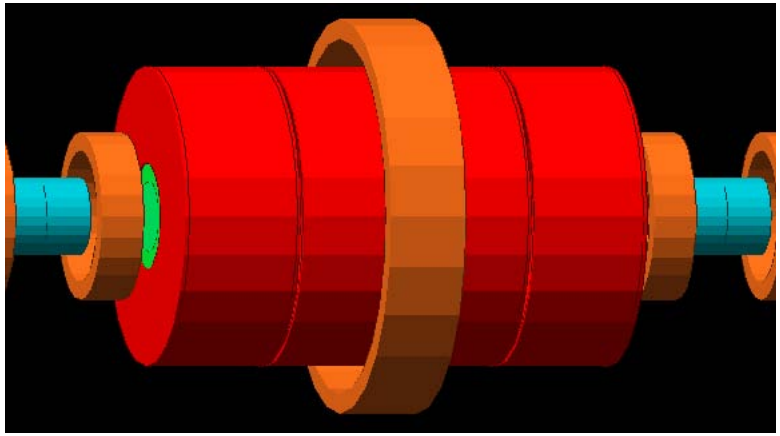
- Under development by international team under leadership of Y. Torun

Screen shot of the magnetic lattice:



View with the solenoid removed showing scintillating-fiber tracking stations:





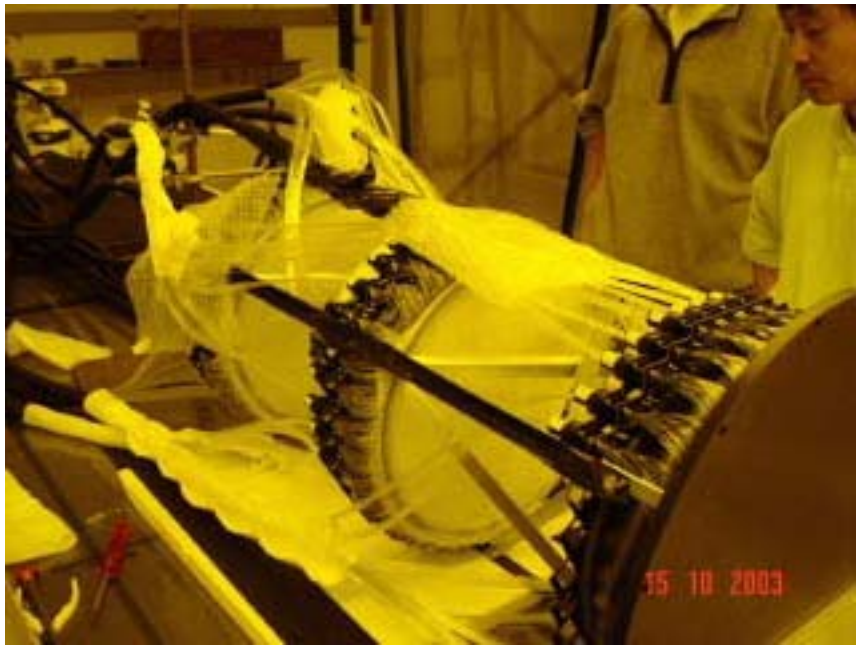
Cooling 1/2-cell: two absorbers (blue), three coils (brown), two focusing and one coupling, and four rf cavities (red)

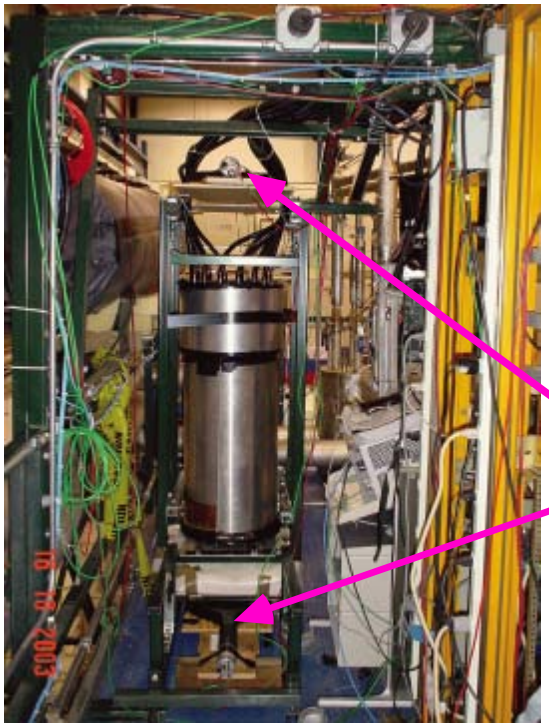
- Geant 4 simulation generates hits on detectors taking all relevant physics processes into account
- Used to study effectiveness of PID, systematics of emittance reconstruction, etc.

Tracker Progress:

(UK / FNAL / IIT / UCLA / UCR)

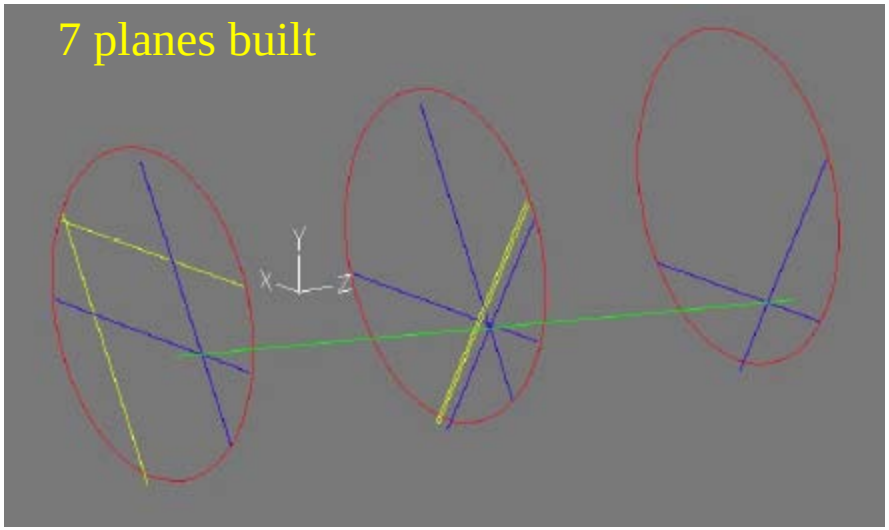
Assembly of 3-station SciFi prototype



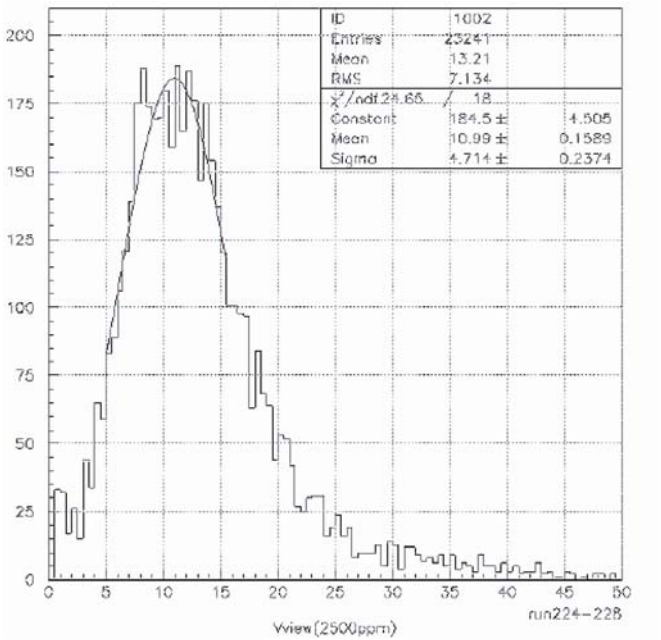


Mounted in D0 cosmic test stand

trigger scintillators



"Typical" event

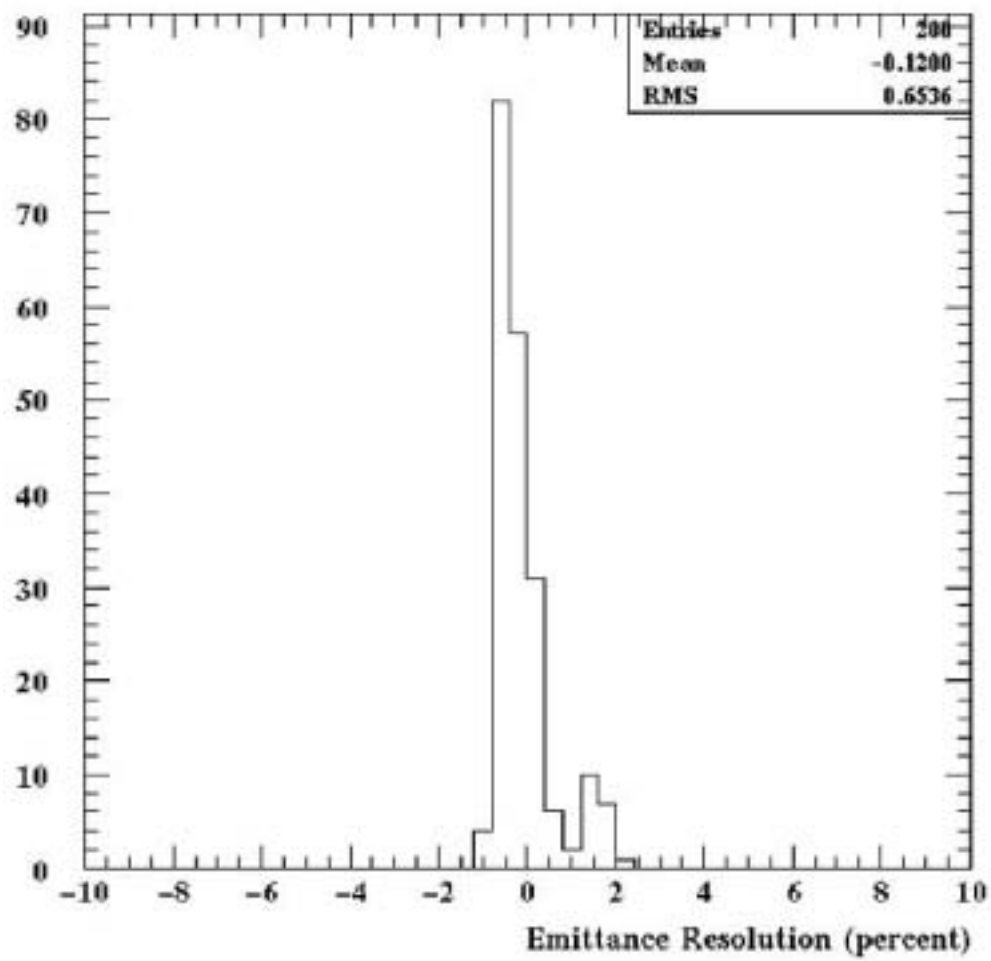


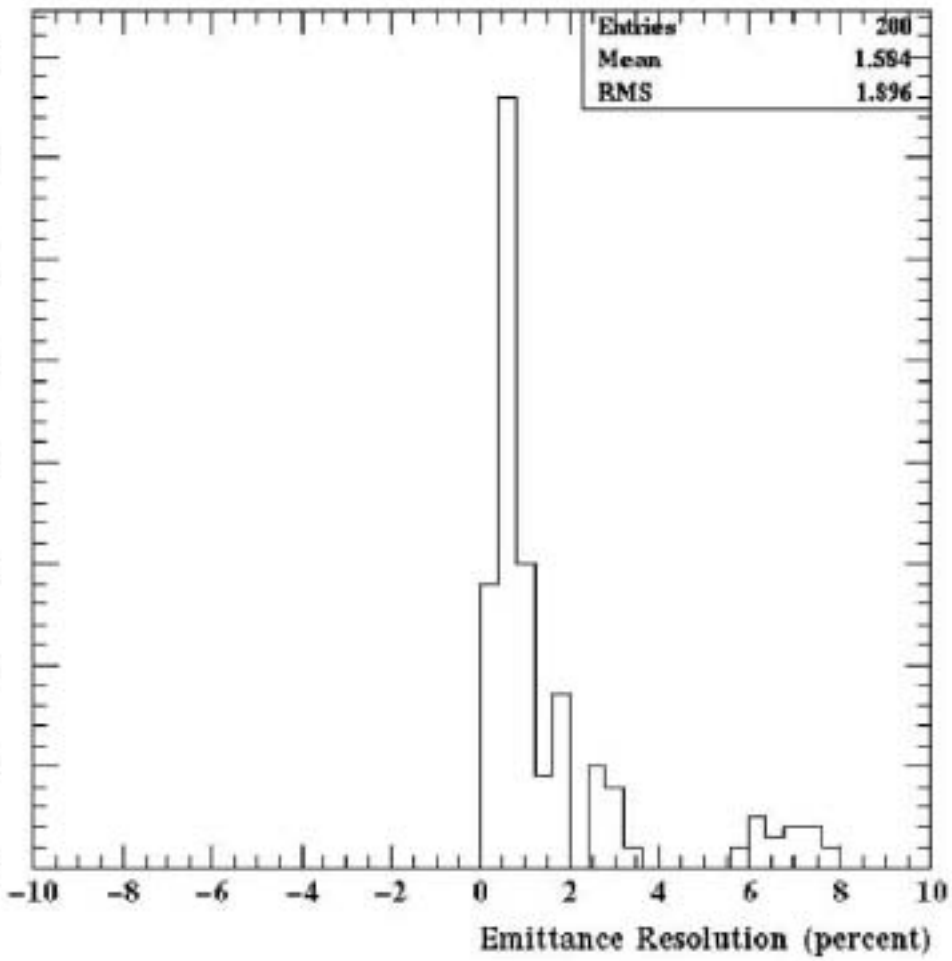
Pulse-height spectrum (mean ≈ 11 p.e.)

Tracker Performance Simulation:

(C. Rogers, ICL G4MICE simulation)

- Correctable ~1% bias due to scattering in detectors:



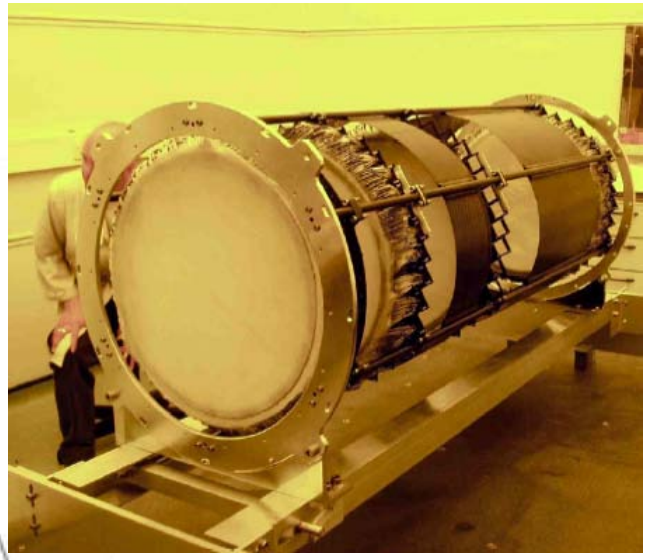


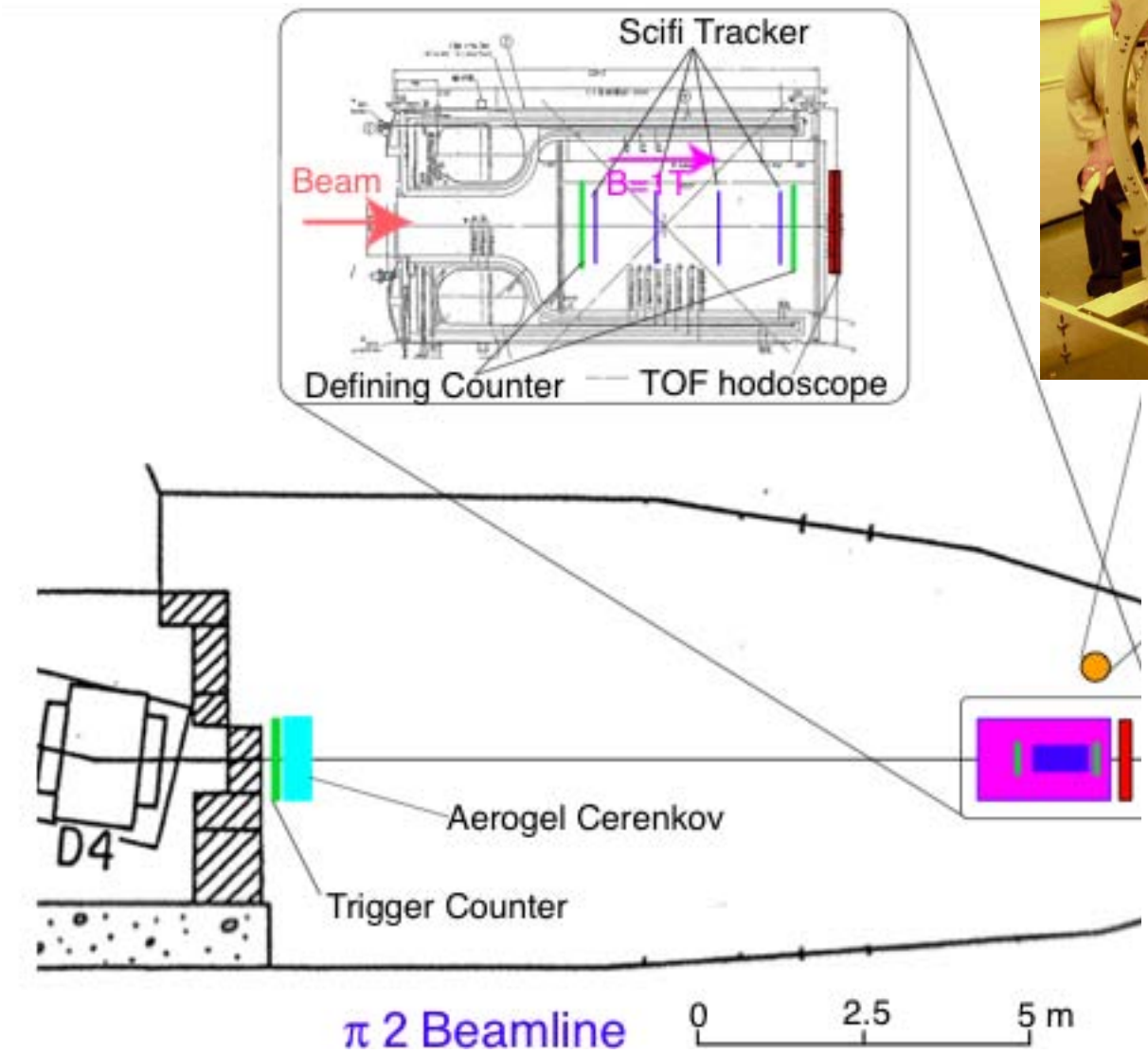
- Key physics goal of NSF MRI proposal:
  - demonstrate bias correction to <10% of itself, as needed for 0.1% emittance measurement
  - requires 2 spectrometers

SciFi Tracker Test at KEK

(KEK / UK / FNAL / IIT / UCR / Osaka)

- Assembling 4-station prototype to operate in 1T SC solenoid:



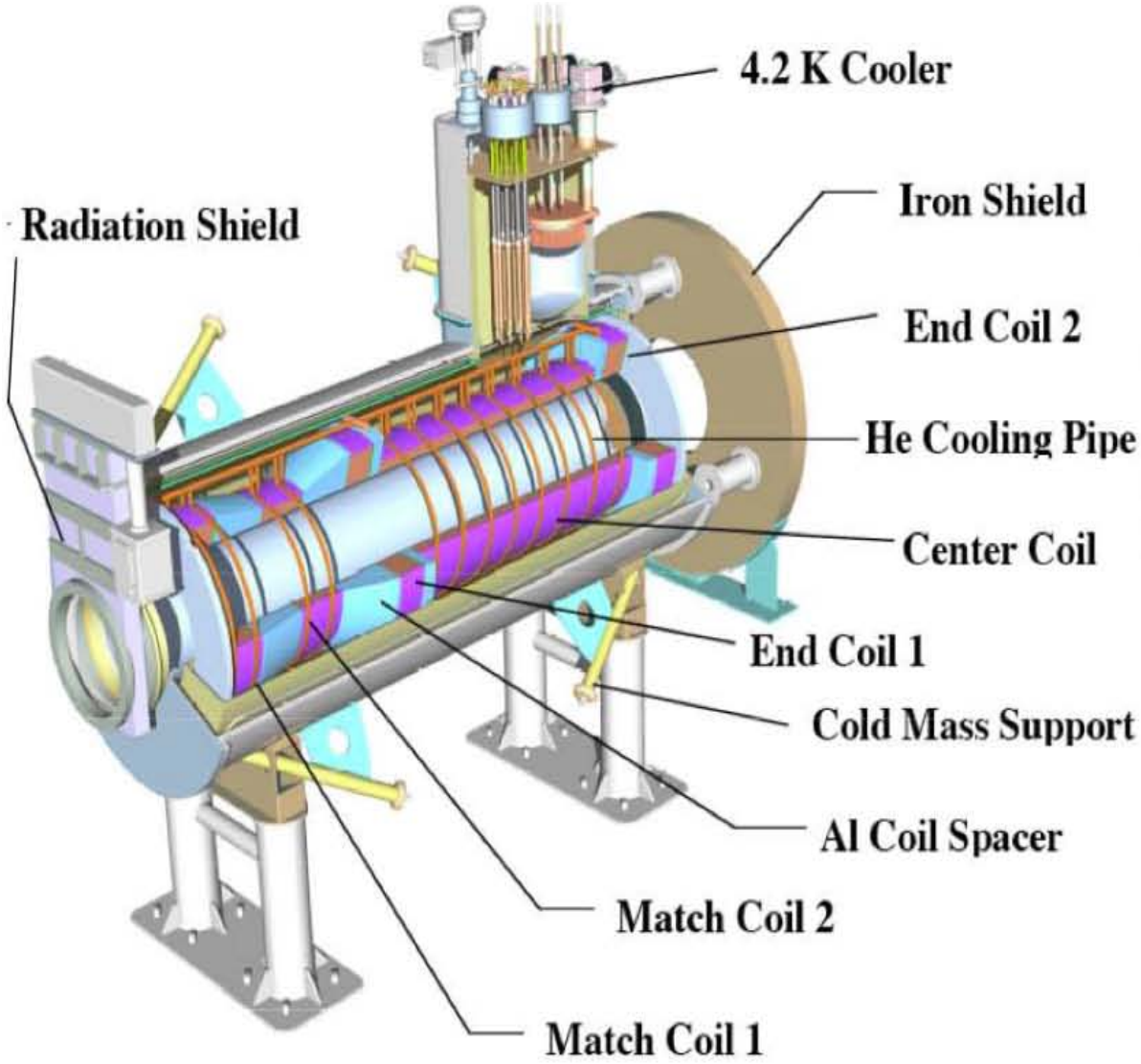


- 1st run ≈end May; 2nd run Sept. or Oct.

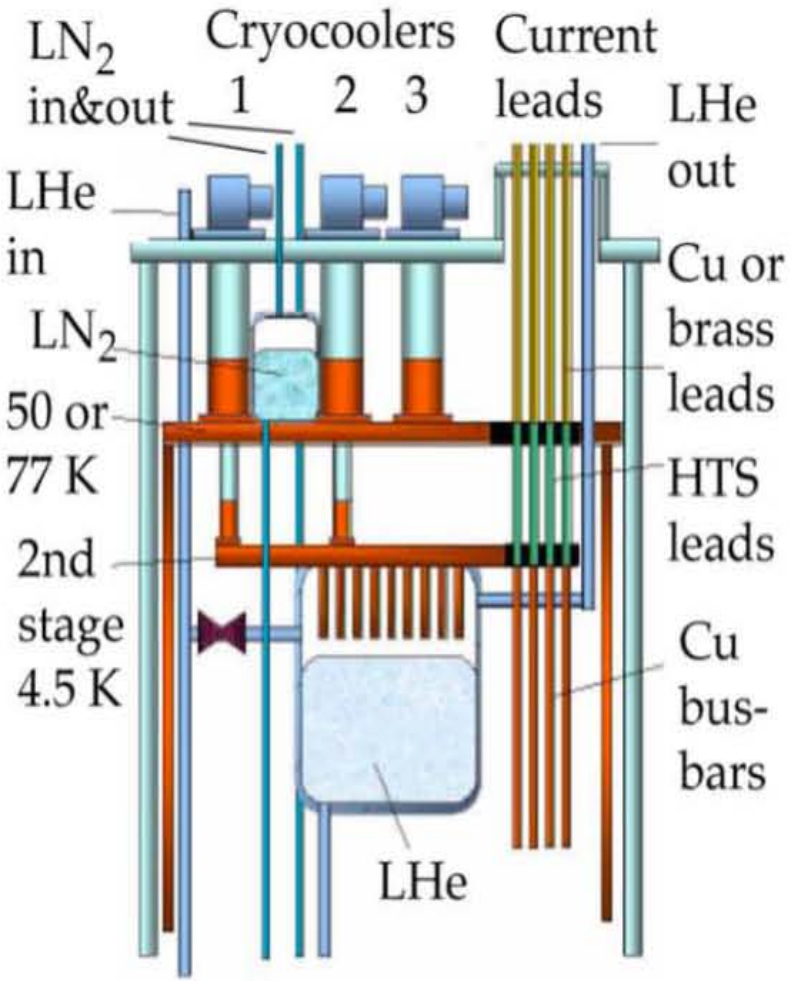
Tracker Solenoid Design

(Genoa / LBNL / Oxford)

- Cutaway 3D rendering:



- Turret detail:



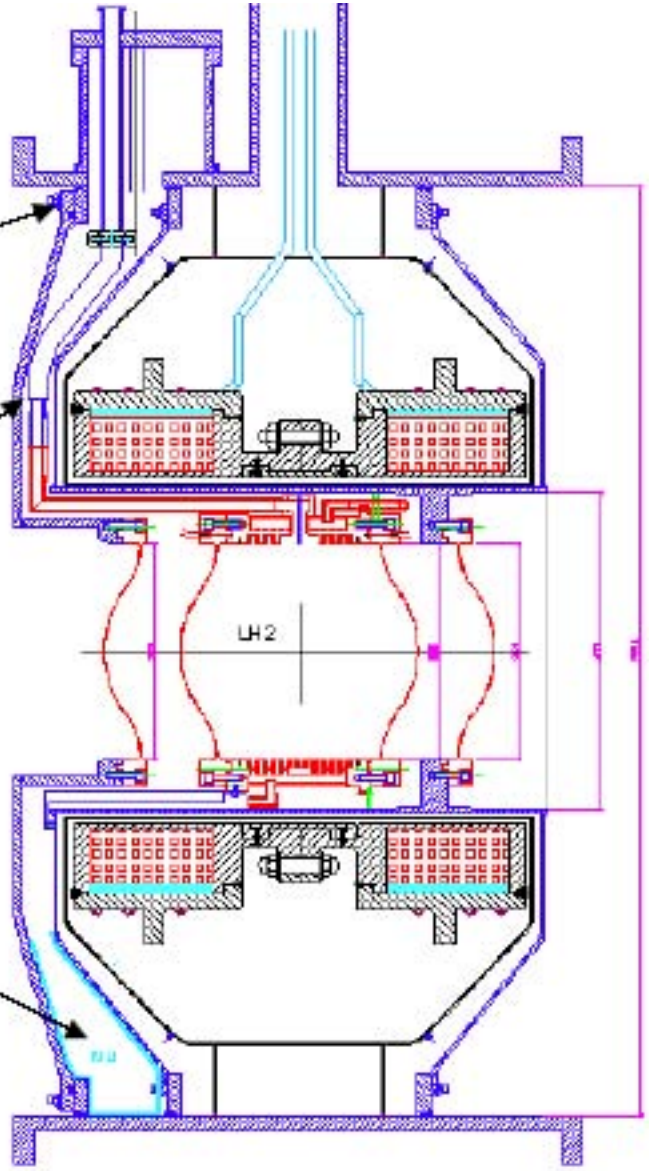
Absorber/Focus-Coil Module Engineering

(IIT / KEK / LBNL / NIU / Oxford)

a) Windows are mounted off RT interface

b) Space for change in pipe dimension close to magnet

c) Large "bucket" at base to contain any rupture

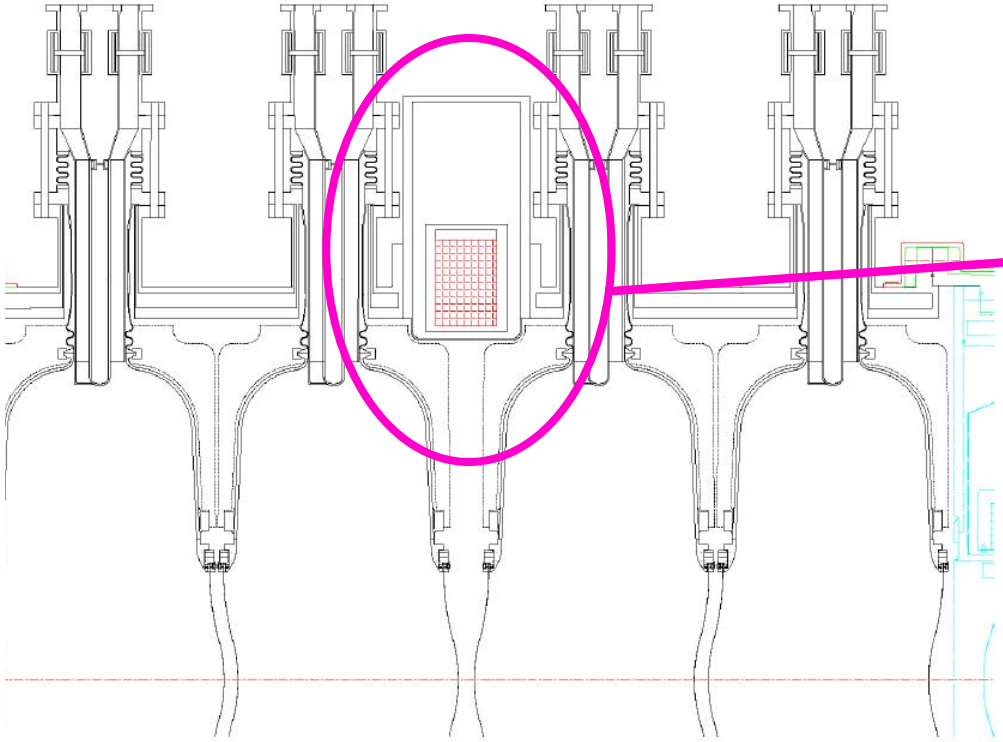


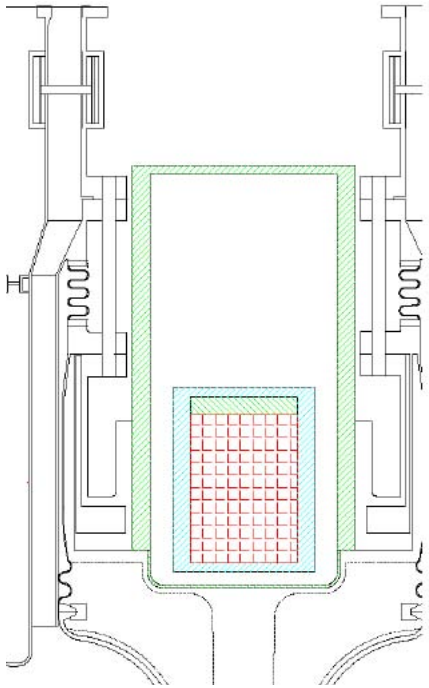
- Internal safety review passed 12/03

RF Cavity/Coupling-Coil Module

(LBNL)

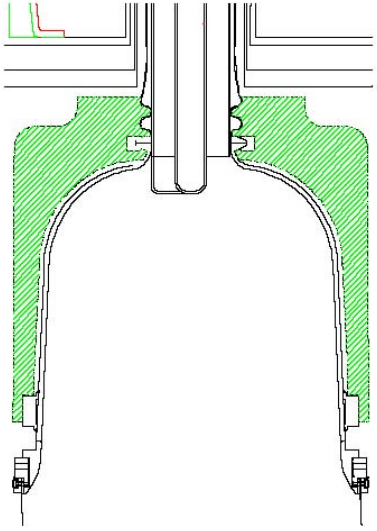
- Detailed module engineering proceeding:





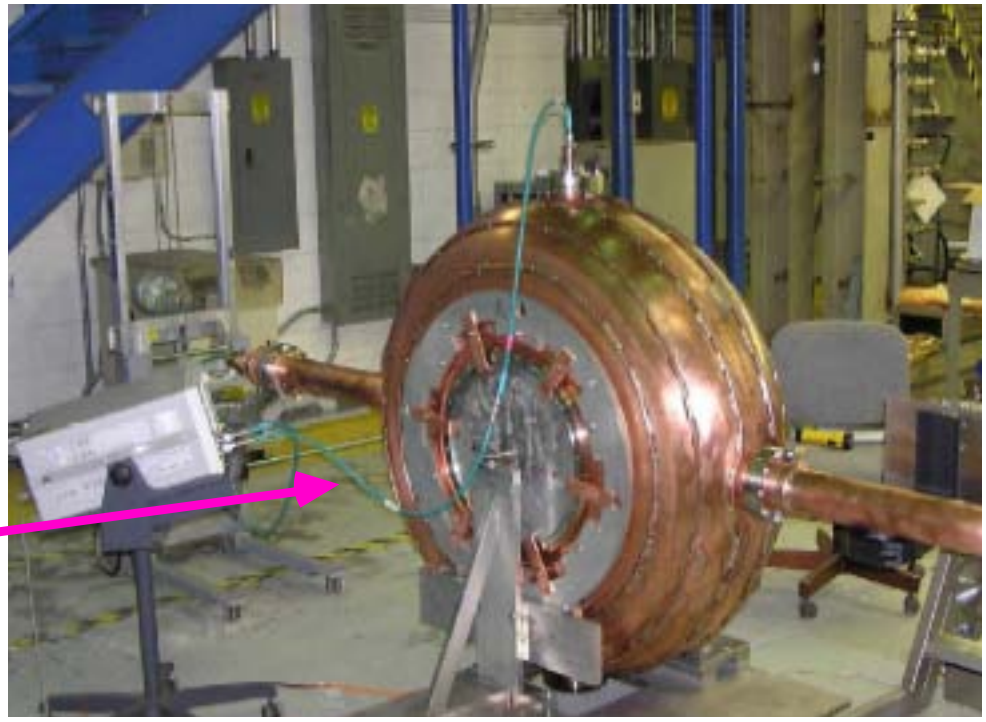
Revised coil design much narrower than previously

allows normal coupler geometry and increases interior clearance for tuners



Tuner design verified by FEA

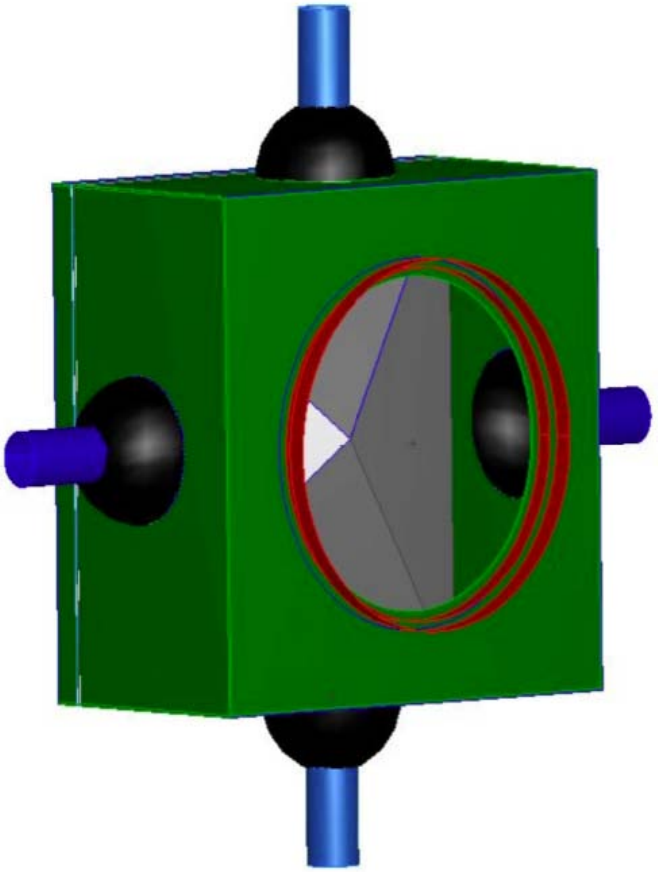
Prototype now under low-power test at JLab



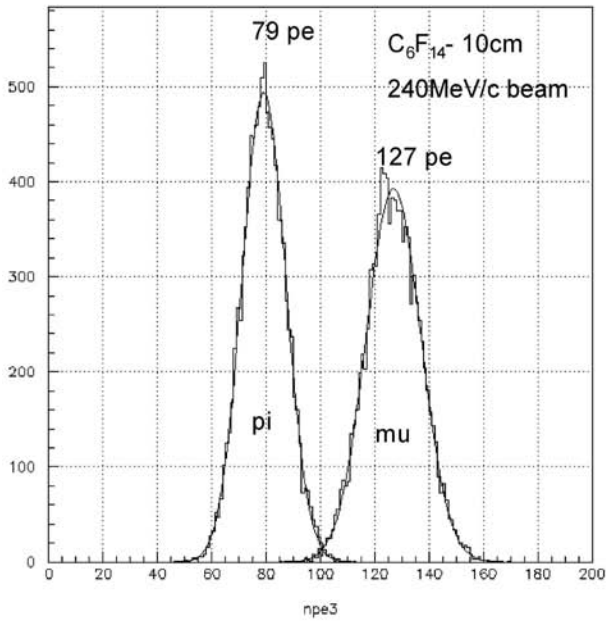
Upstream Cherenkov Detector

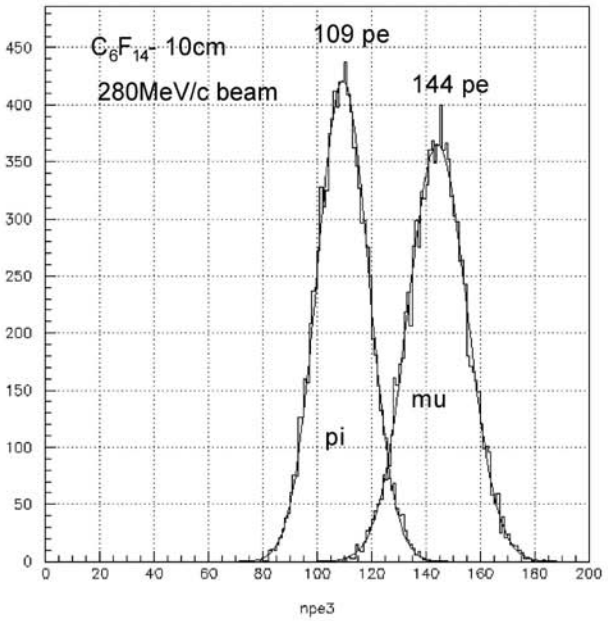
(UMiss)

- Concept: liquid radiator w/ mirrors focusing Cherenkov light on PMTs



– Simulated performance for 2 beam momenta:





- Optimization studies in progress...

US MICE Funding:

- Proposal sent to DOE & NSF in Fall ’02 for $23.9M over 5 years
- DOE providing $300k/y for 3 years starting in FY05
- NSF providing $100k/y for 3 years starting in FY05
- MICE-US major equipment needs:

	# needed	Est. cost (k$)
RFCC modules	2	3,500
Tracker solenoids	2	2,000
Tracker electronics	8k channels	530
TOTAL		**6,000**

  - Needed equipment budget considerably reduced by 7→1 SciFi multiplexing, but increased by addition of tracker solenoids
- Also need operating funds (including several extended trips to UK)
- Approval of NSF MRI proposal ($2M) could help considerably

(Zisman’s talk tomorrow will continue this discussion)

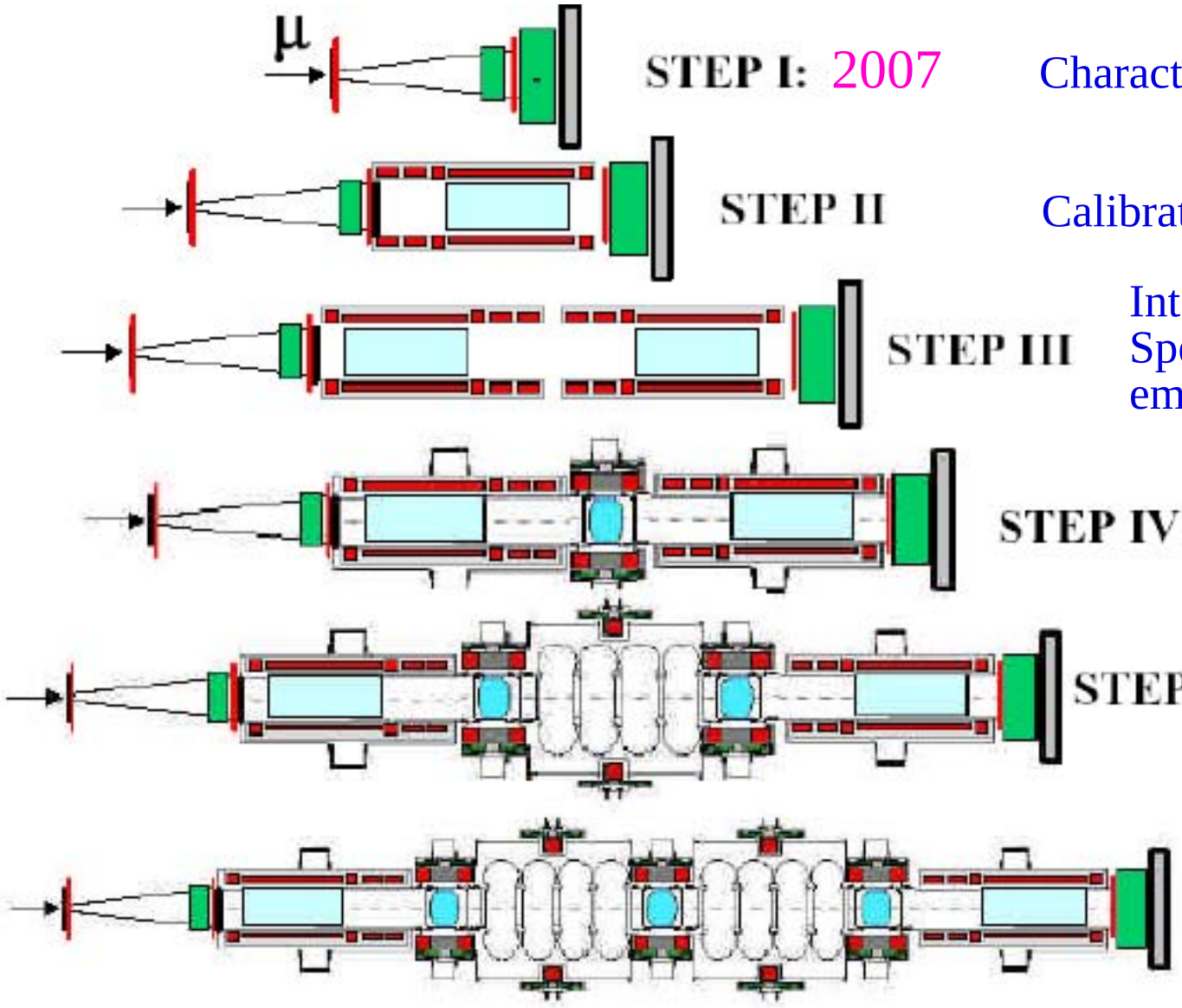
Summary

- MICE progressing well technically
- Phase 1 funded, but not a cooling demonstration *per se*
- Need to find sufficient resources for full cooling test
- Funds in hand from DOE & NSF allow some US participation
- Additional NSF funding proposed & under review
- Strong endorsement from MUTAC + international nature have been helpful

BACKUP SLIDES

Avatars of MICE

- Measurement precision relies crucially on precise calibration & thorough study of systematics:



Participating Institutes:

Louvain La Neuve
INFN Bari
INFN Legnaro
INFN Padova
INFN Roma I
INFN Roma III
NIKHEF
CERN
Paul Scherrer Institute
KEK
Brunel University
University of Glasgow
Imperial College London
University of Sheffield
Argonne National Laboratory
Fairfield University
Illinois Institute of Technology
Northern Illinois University
University of California Los Angeles
University of Chicago
University of Iowa

CEA Saclay
INFN LNF Frascati
INFN Milano
INFN Napoli
INFN Roma II
INFN Trieste
Budker Institute of Nuclear Physics
ETH Zurich
University of Geneva
Osaka University
University of Edinburgh
University of Liverpool
University of Oxford
Rutherford Appleton Laboratory
Brookhaven National Laboratory
Fermi National Accelerator Laboratory
Lawrence Berkeley National Laboratory
Thomas Jefferson Laboratory
University of California, Riverside
University of Illinois at Urbana-Champaign
University of Mississippi

Comparison with Previous Proposed Equipment Costs

(from 10/7/02 NSF proposal)

Table 3: Estimated MICE equipment-cost breakdown (in $M) for a 23-MeV cooling experiment with 8 MW of RF power; additional costs (design, testing, installation, operations, inflation, and overhead) represent a comparable contribution. Also indicated for each item are U.S. equipment-cost contribution and other main contributor.

COOLING CELLS	No. needed	Fixed cost	Unit cost	Item total	U.S. portion	Other contrib.
RF Cavities						
4-cell 201-MHz cavity	2	0.38	1.16	2.70	2.70	–
RF Power						
4-MW supply (refurbish)	2		0.20	0.40	–	EU
Magnets						
Focus pair	3	0.55	0.45	1.90	–	UK
Coupling coil	2	0.90	0.90	2.70	2.70	–
LH2 absorbers	3	0.50	0.20	1.10	0.15	Japan
H2 safety		0.30		0.30	–	UK
Total for cooling section				**9.10**	**5.55**	
SPECTROMETERS						
Solenoids	2	0.70	0.50	1.70	–	EU
Detectors						
Fiber tracking				3.75	1.88	UK
TOF				0.20	0.01	INFN
Cherenkov				0.40	0.24	Louvain
Total spectrometers				**6.05**	**2.13**	
Trigger + DAQ				0.50	0.01	INFN
Refrigeration				0.90	–	UK
SUBTOTAL				**16.55**	**7.69**	
Infrastr., extras(20%)				3.31	1.54	
TOTAL COST				**19.86**	**9.22**	

Old **New**

RFCC total:
6.5M **3.5M**

Spectrometer solenoids:
2.0M **2.0M**

SciFi readout: **0.53M**

TOTAL: **≈ 6.0M**
(+ Cherenkov cost)