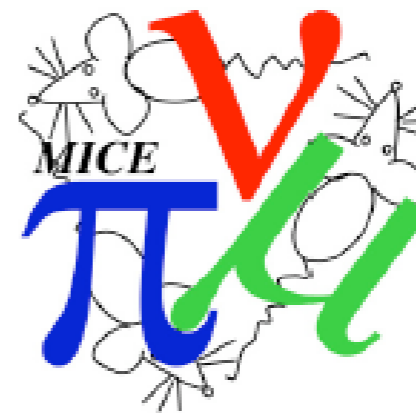


Status of MICE

Daniel M. Kaplan



MAP Meeting
Jefferson Lab
28 Feb. 2011

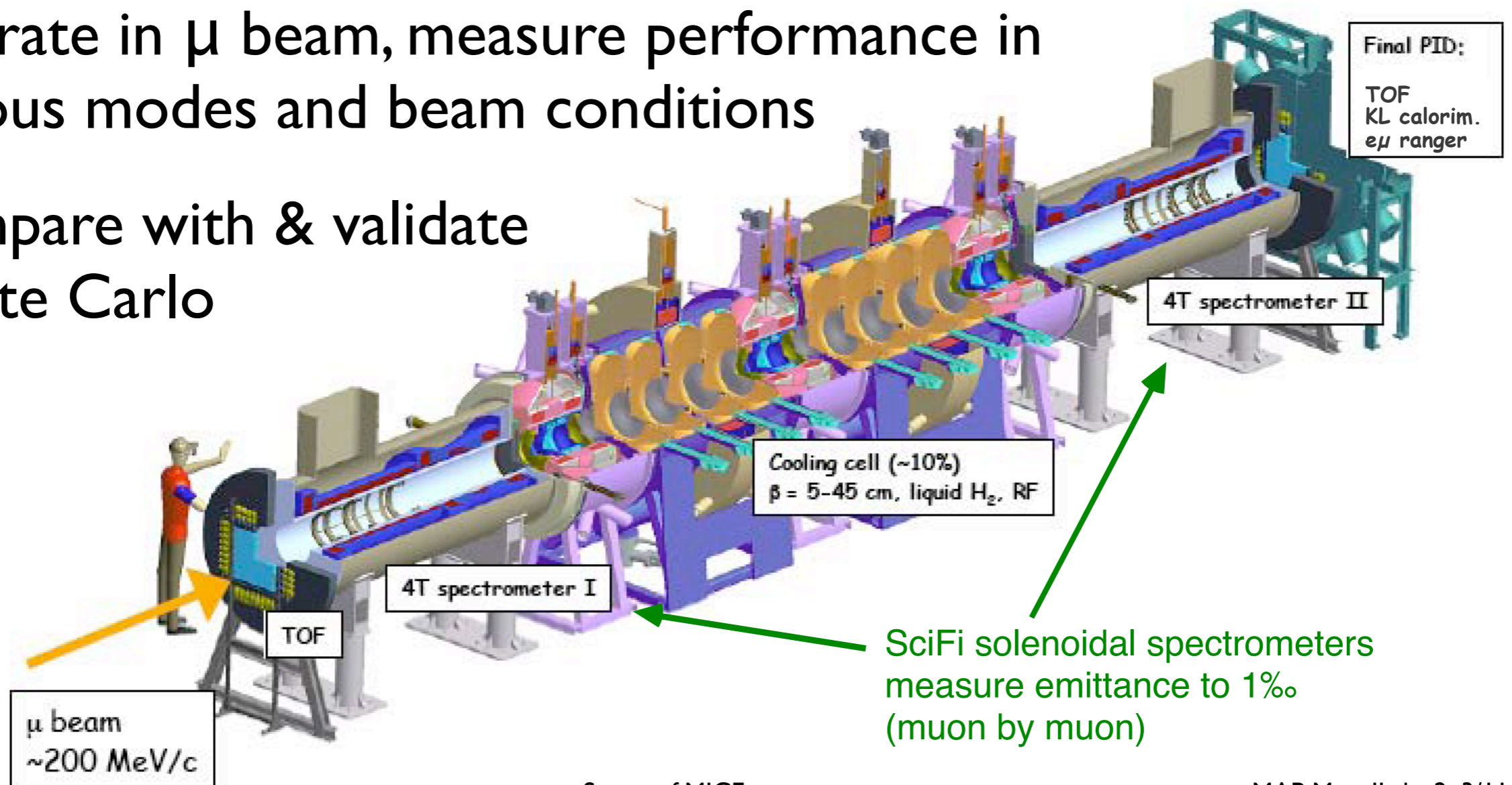
Outline

- MICE Overview
- Beam & Target
- Particle ID
- Emittance Measurement
- Tracking
- Cooling Cell
- Software
- Outlook

Muon Ionization Cooling Expt

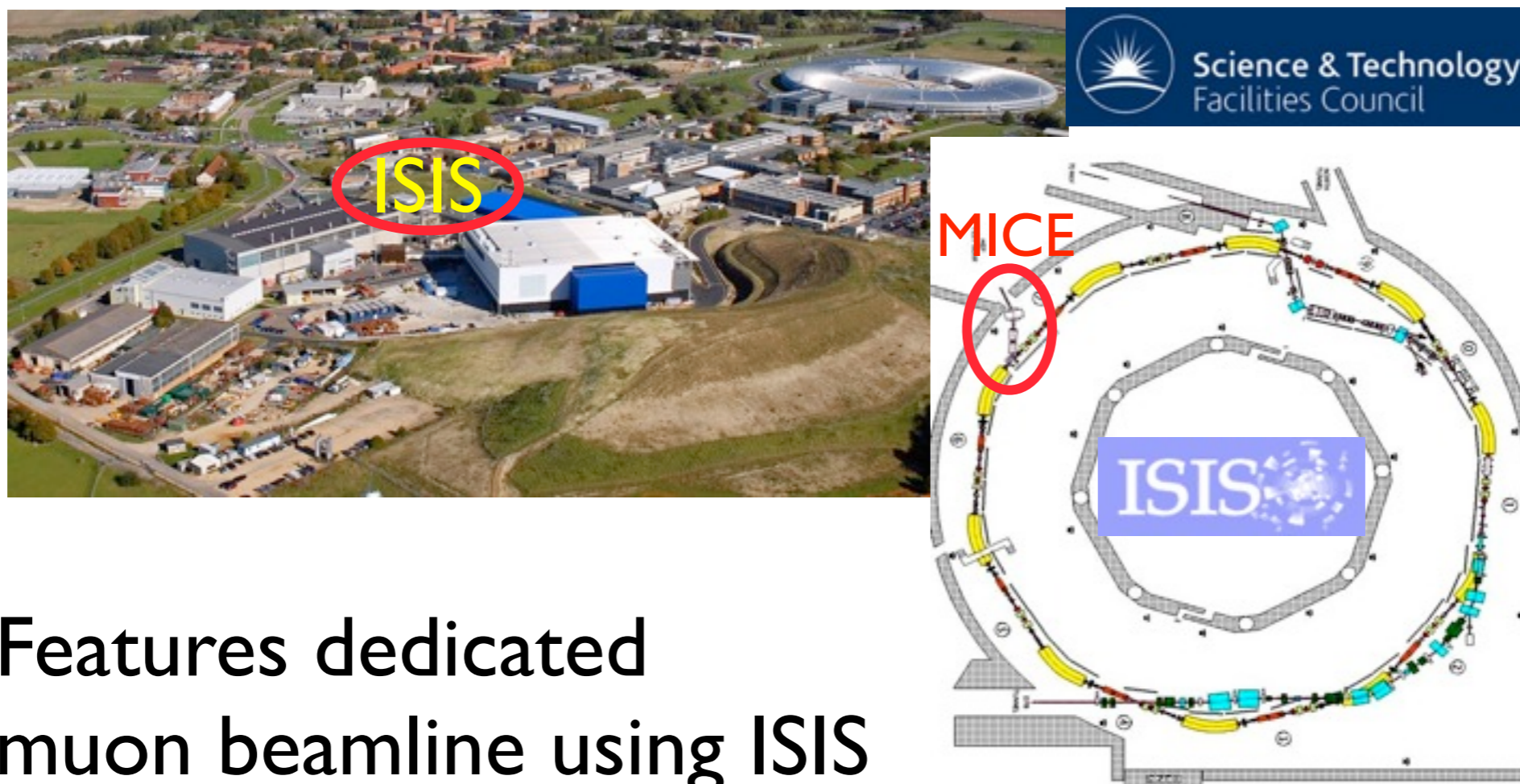
Goals of MICE:

- Build section of cooling channel giving desired performance for a Neutrino Factory
- Operate in μ beam, measure performance in various modes and beam conditions
- Compare with & validate Monte Carlo



Muon Ionization Cooling Expt

- Located at Rutherford Appleton Lab (Chilton, Didcot, Oxon, UK)



- Features dedicated muon beamline using ISIS 800-MeV proton synchrotron

MICE Collaboration



The MICE Collaboration

(listed alphabetically in country.town order)

- M. Bogomilov, Y. Karadzhov, D. Kolev, I. Russinov, R. Tsenov
[Department of Atomic Physics](#), St. Kliment Ohridski University of Sofia, 5 James Bourchier Boulevard, BG-1164 Sofia, Bulgaria
- R. Bertoni, M. Bonesini, S. Terzo
[INFN Milano](#), Dipartimento di Fisica G. Occhialini Piazza Scienza 3, 20126 Milano, Italy
- V. Palladino
[INFN Napoli](#) e Università Federico II, Napoli, Italy
- G. Cecchet, A. de Bari
[INFN Pavia](#), Italy
- D. Orestano, F. Pastore, L. Tortora
[INFN Roma III](#) and Physics Department of [ROMA TRE University](#), Via della Vasca Navale 84, I-00146 Roma, Italy
- P. Chimenti, G. Giannini
University of Trieste and [INFN Trieste](#), Italy
- S. Ishimoto, S. Suzuki, K. Yoshimura
[High Energy Accelerator Research Organization \(KEK\)](#), Institute of Particle and Nuclear Studies, Tsukuba, Ibaraki, Japan
- Y. Mori
[Kyoto University Research Reactor Institute](#), Kumatori-cho Sennan-gun, Osaka 590-0494, Japan
- Y. Kuno, H. Sakamoto, A. Sato, T. Yano, M. Yoshida
[Osaka University](#), Graduate School of Science, Department of Physics, Toyonaka, Osaka, Japan
- L. Wang, F. Y. Xu, S. X. Zheng
Institute of Cryogenics and Superconductivity Technology, [Harbin Institute of Technology](#), Harbin, 150001, PR China
- F. Filthaut
[NIKHEF](#), Amsterdam, The Netherlands
- N. Mezentsev, A. N. Skrinsky
Budker Institute of Nuclear Physics, Novosibirsk, Russian Federation
- R. Garoby, H. Haseroth, F. Sauli
[CERN](#), Geneva, Switzerland
- A. Blondel, J.-S. Graulich, V. Verguilo
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- R. Seviour
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- M. Ellis, P. Kyberd, H. Nebrensky
[Brunel University](#), Uxbridge, Middlesex UB8 3PH, United Kingdom
- D. Forrest, F. J. P. Soler
[Department of Physics and Astronomy](#), Kelvin Building, The University of Glasgow, Glasgow, G12 8QQ, UK
- P. Cooke, R. Gamet
[Department of Physics](#), University of Liverpool, Oxford St, Liverpool L69 7ZE, UK
- G. Barber, A. Dobbs, P. Dornan, A. Fish, R. Hare, A. Jamdagni, V. Kasey, M. Khaleeq, K. Long, H. Sakamoto, T. Sashalmi, K. Walaron
[Imperial College of Science, Technology and Medicine](#), Prince Consort Road, London SW7 2BW, UK
- W. W. M. Allison, M. Apollonio, G. Barr, J. Cobb, S. Cooper, S. Holmes, H. Jones, W. Lau, H. Witte, S. Yang
[Department of Physics](#), University of Oxford, Denys Wilkinson Building, Keble Road, Oxford OX1 3RH, UK
- J. Alexander, G. Charnley, S. Griffiths, B. Martlew, A. Moss, I. Mullacrane, A. Oats, S. York
[CCLRC Daresbury Laboratory](#), Daresbury, Warrington, Cheshire, WA4 4AD, UK
- R. Apsimon, P. Barclay, D. E. Baynham, T. W. Bradshaw, M. Courthold, R. Edgecock, P. Flower, T. Hayler, M. Hills, T. Jones, N. McNubbin, W. J. Murray, C. Nelson, A. Nicholls, P. R. Norton, C. Prior, J. H. Rochford, C. Rogers, W. Spensley, K. Tilley
[CCLRC Rutherford Appleton Laboratory](#), Chilton, Didcot, Oxfordshire, OX11 0QX, UK
- C. N. Booth, P. Hodgson, M. Mohammad, R. Nicholson, P. Smith
[Department of Physics and Astronomy](#), University of Sheffield, Sheffield S3 7RH, UK
- J. Norem
[Argonne National Laboratory](#), 9700 S. Cass Avenue, Argonne, IL 60439, USA
- A. D. Bross, S. Geer, D. Neuffer, A. Moretti, M. Popovic, R. Raja, R. Stefanski, Z. Qian
[Fermilab](#), P.O. Box 500, Batavia, IL 60510-0500, USA
- T. J. Roberts
[Muons Inc.](#), Batavia, IL 60510, USA
- A. DeMello, M. A. Green, D. Li, A. M. Sessler, S. Virostek, M. S. Zisman
[Lawrence Berkeley National Laboratory](#), Berkeley, CA 94720, USA
- B. Freemire, P. Hanlet, D. Huang, D. M. Kaplan, Y. Torun
[Illinois Institute of Technology](#), 3101 S. Dearborn St., Chicago, IL 60616, USA
- M. A. C. Cummings
[Northern Illinois University](#), DeKalb, IL 60115, USA
- U. Bravar
[University of New Hampshire](#), Durham, NH 03824, USA
- Y. Onel
[University of Iowa](#), Iowa City, IA52242, USA
- D. Cline, K. Lee, Y. Fukui, X. Yang
[UCLA Physics Department](#), Los Angeles, CA 90024, USA
- R. A. Rimmer
[Jefferson Lab](#), 12000 Jefferson Avenue, Newport News, VA 23606, USA
- S. B. Bracker, L. M. Cremaldi, R. Godang, G. Gregoire^o, T. Hart, D. J. Summers
[University of Mississippi](#), Oxford, MS 38677, USA
- L. Coney, G. G. Hanson, P. Snopok
[University of California, Riverside](#), Riverside, CA 92521-0413 USA
- R. B. Palmer, R. Fernow, S. Kahn, J. Gallardo, H. Kirk
[Brookhaven National Laboratory](#), Upton, NY 11973-5000, USA

MICE Collaboration

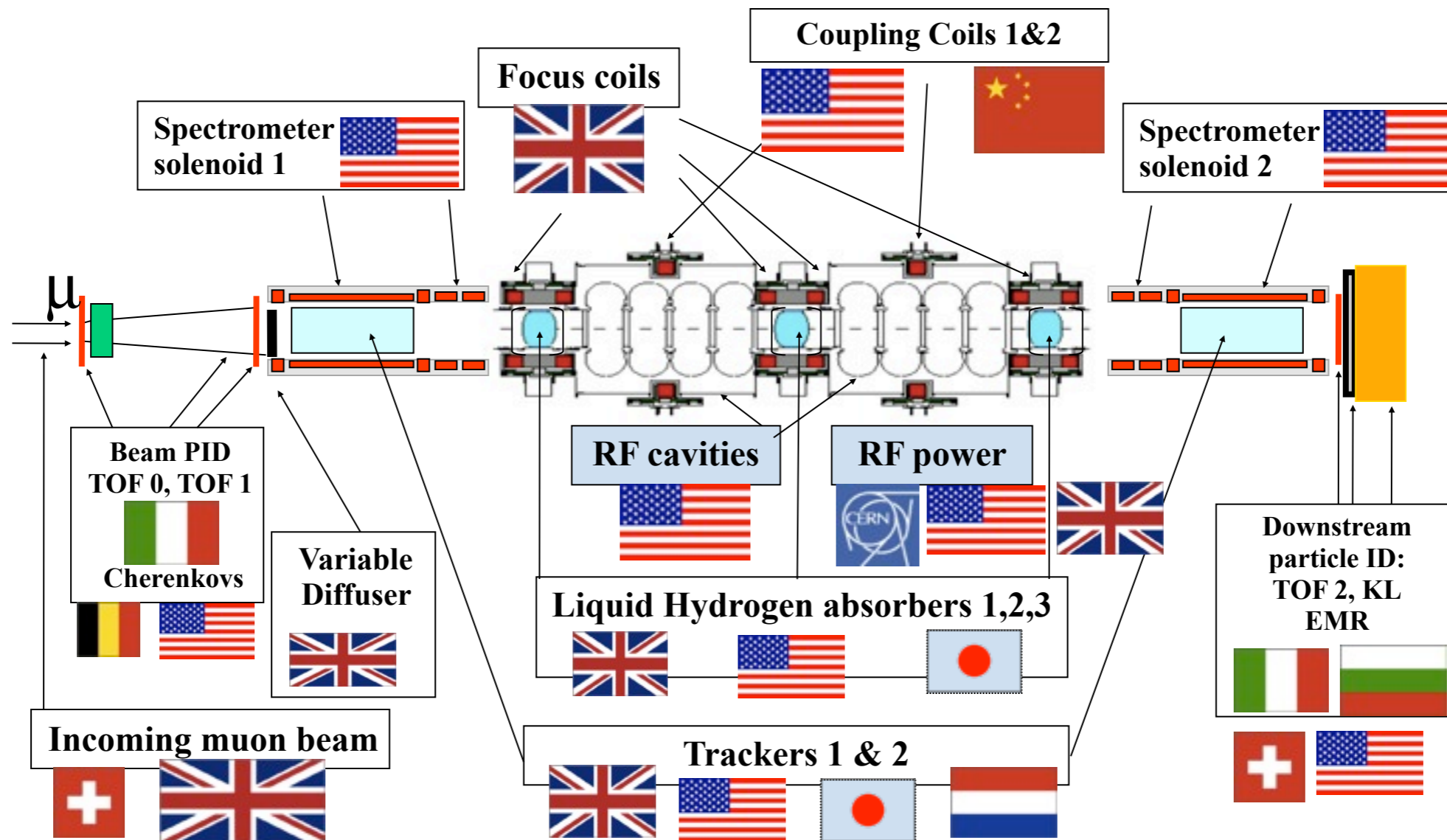


(listed alphabetically)

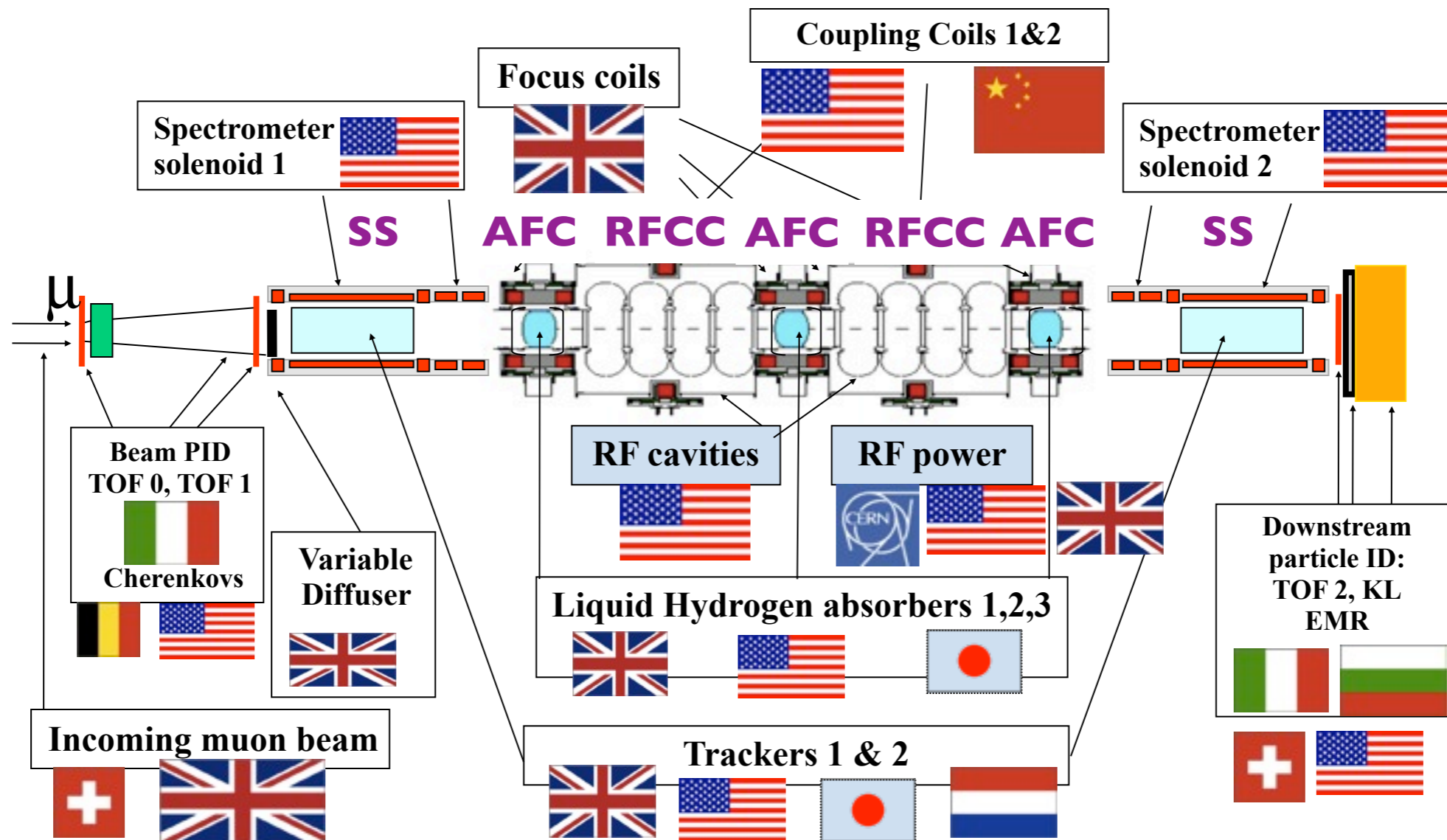
- M. Bogomil
[Department](#)
Boulevard,
- R. Bertoni,
[INFN Milan](#)
- V. Palladino,
[INFN Napoli](#)
- G. Cecchet,
[INFN Pavia](#)
- D. Orestano,
[INFN Roma](#)
84, I-00146
- P. Chimenti,
Universitv c



MICE Collaboration



MICE Collaboration



MICE Module Types:

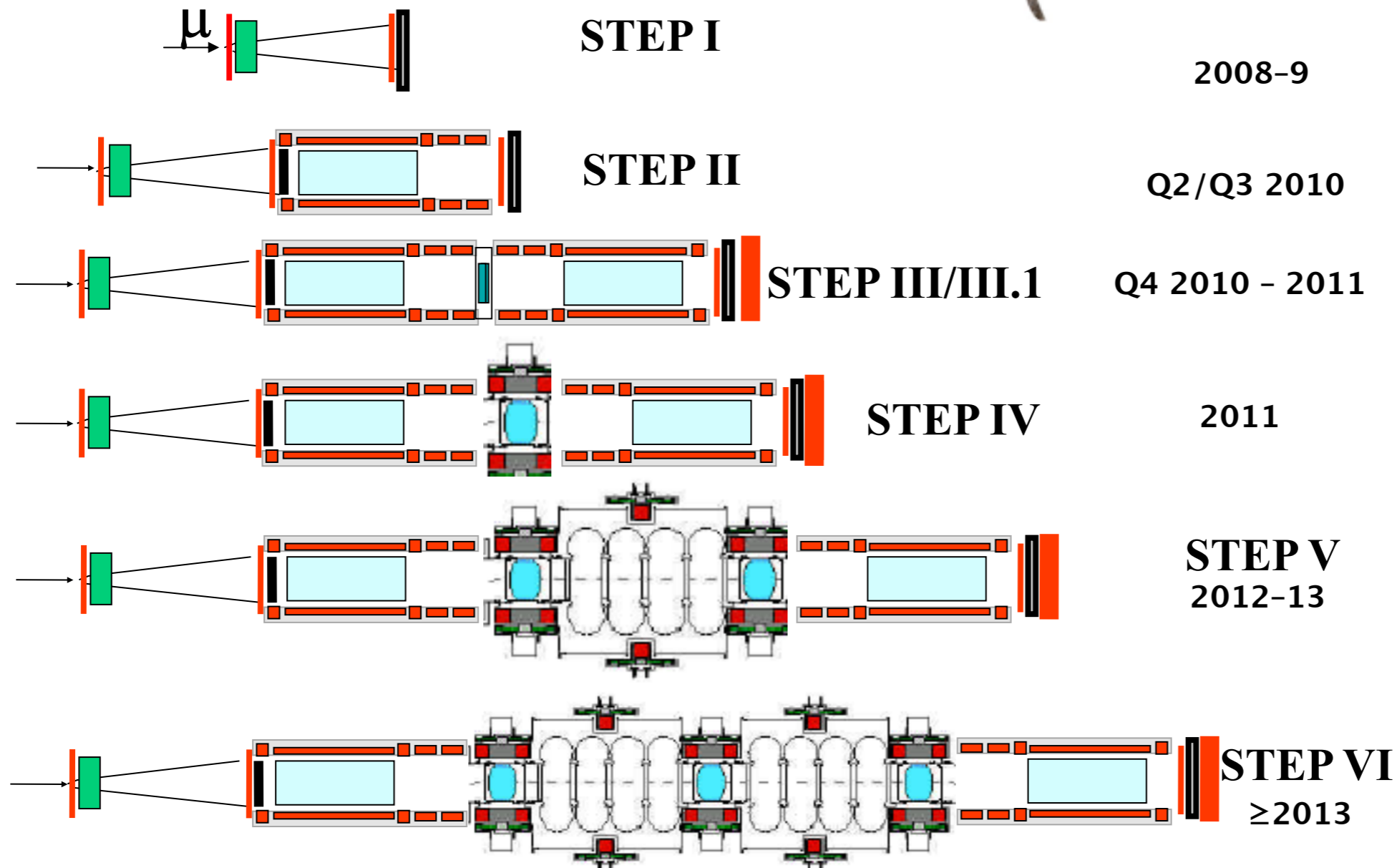
- **S**pectrometer **S**olenoid
- **A**bsorber-**F**ocus **C**oil
- **RF**-**C**oupling **C**oil

Steps of MICE:



Steps of MICE:

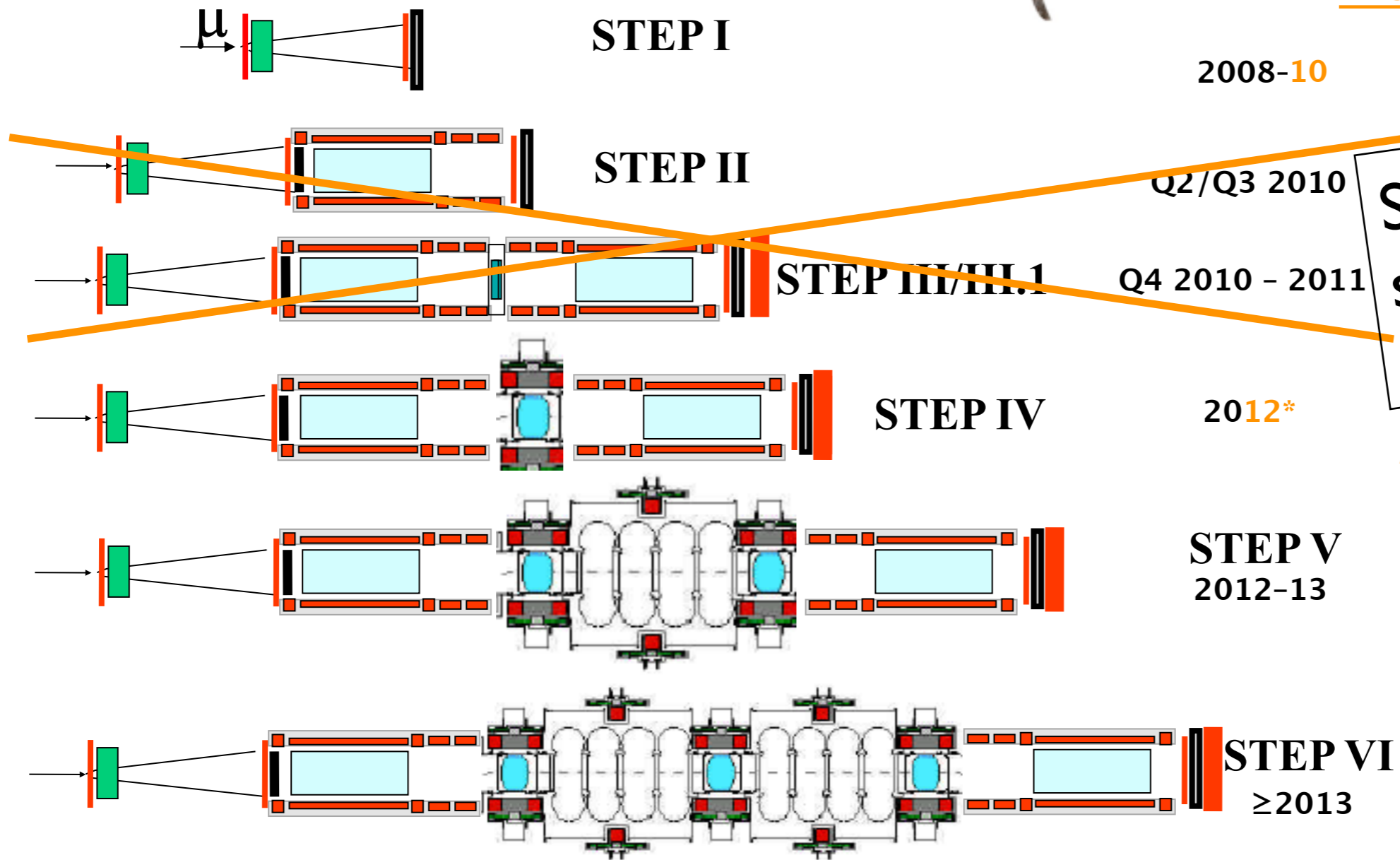
April '08 Plan:



Steps of MICE:

April '08 Plan:

As of Feb. '11:



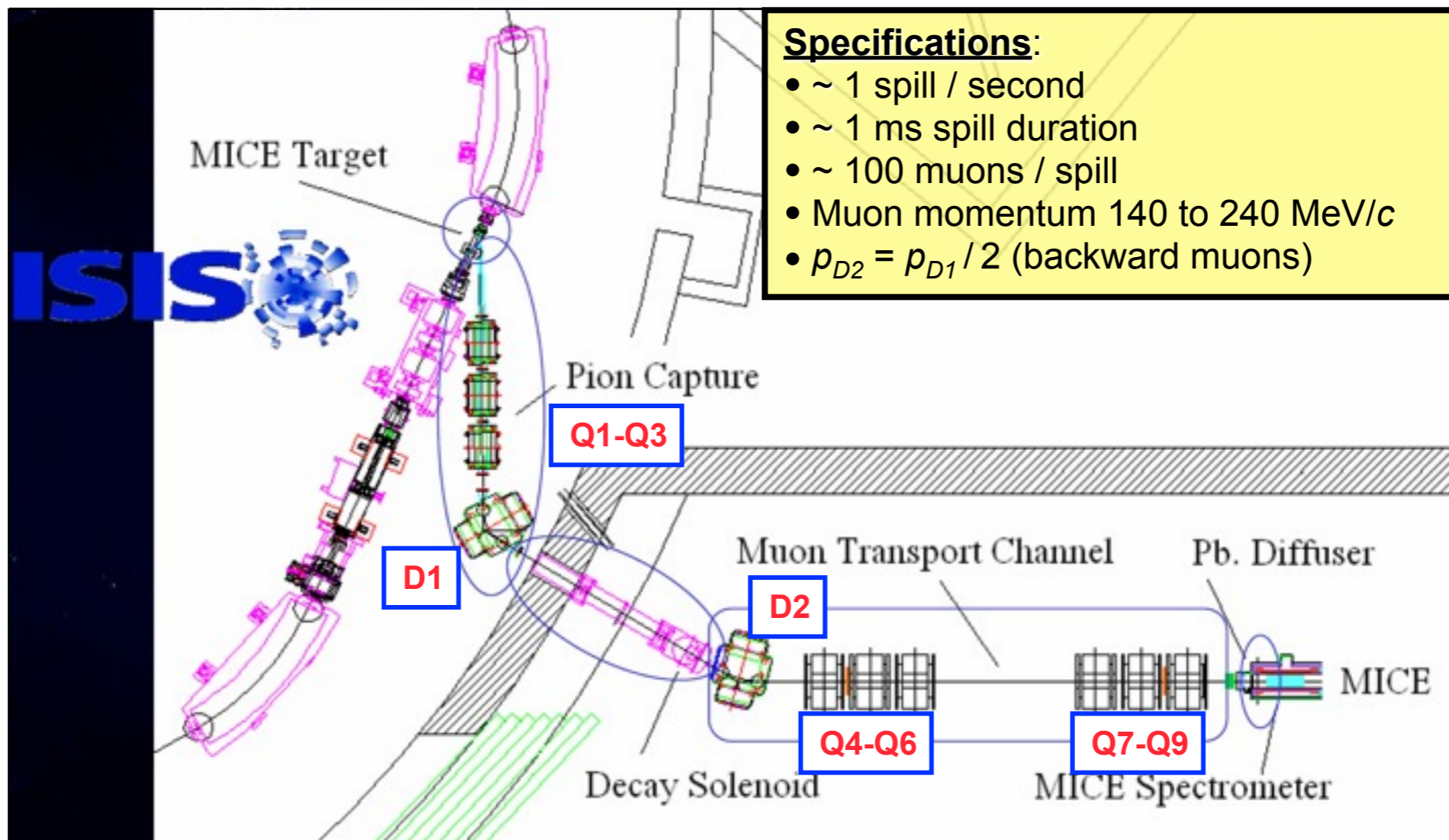
Spectrometer solenoids late!
(next talk)

*provisional

MICE Beamline

[RAL]

- Installed 2007–8

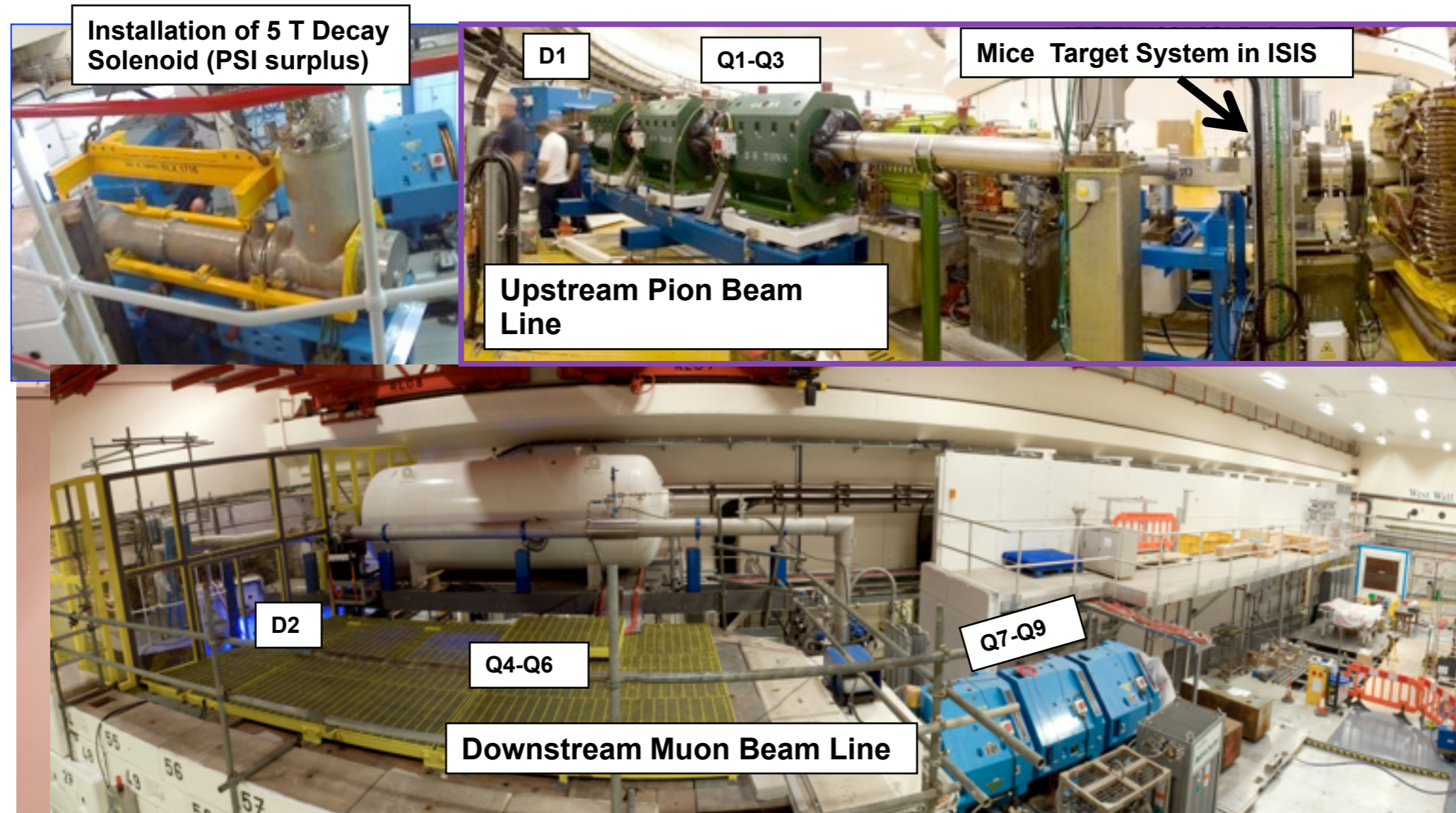


- Working well

MICE Beamline

[RAL]

- Installed 2007–8

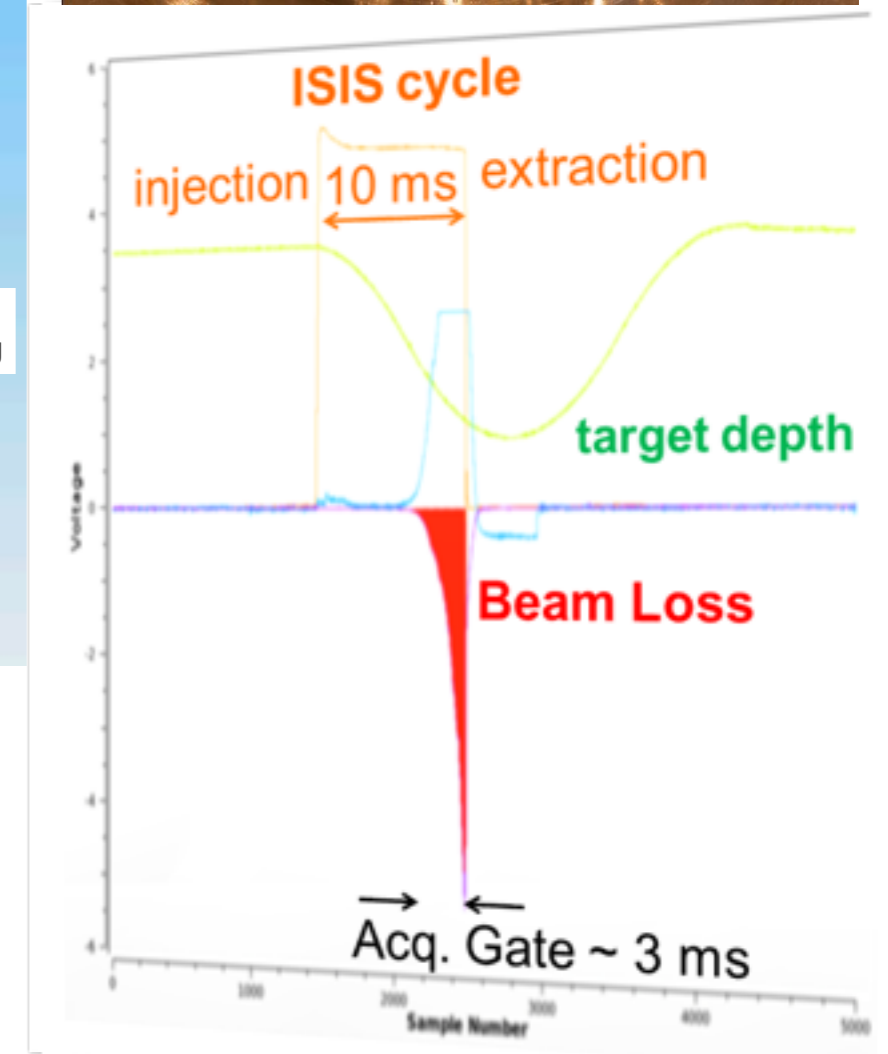
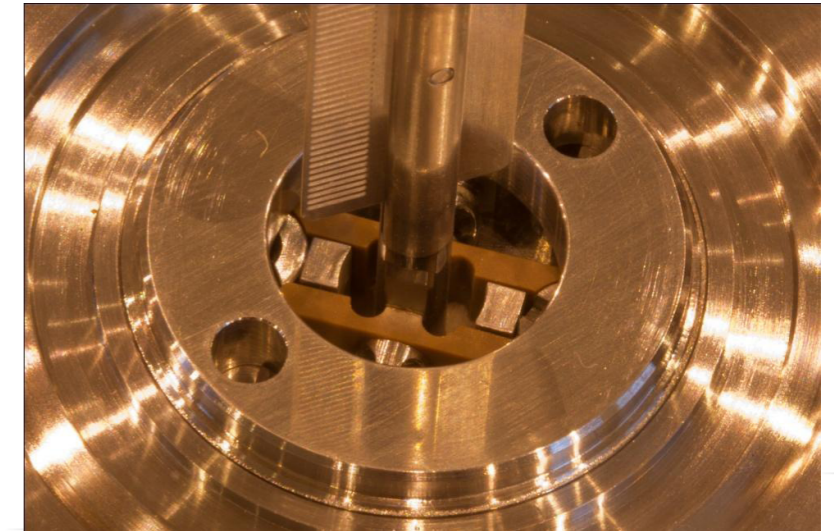
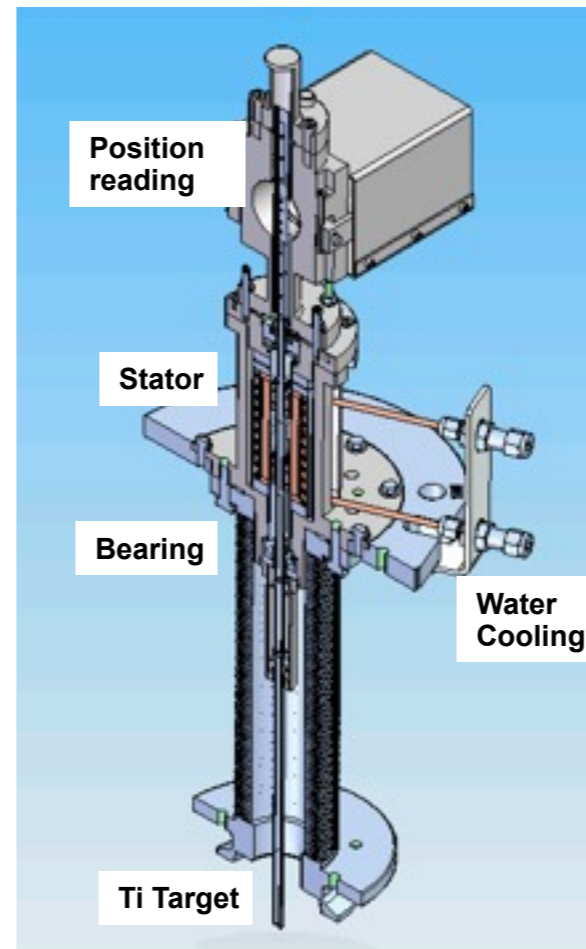


- Working well

MICE Target

[Sheffield, RAL, ICL]

- Linear electric motor drives Ti tube down into ISIS beam
- Uses 80g acceleration to get in and out within one pulse (ISIS pulses at 50 Hz)
- Demonstrator with Tefzel bearings has run for 3M cycles without dust
- Plan to even out spill via beam bump

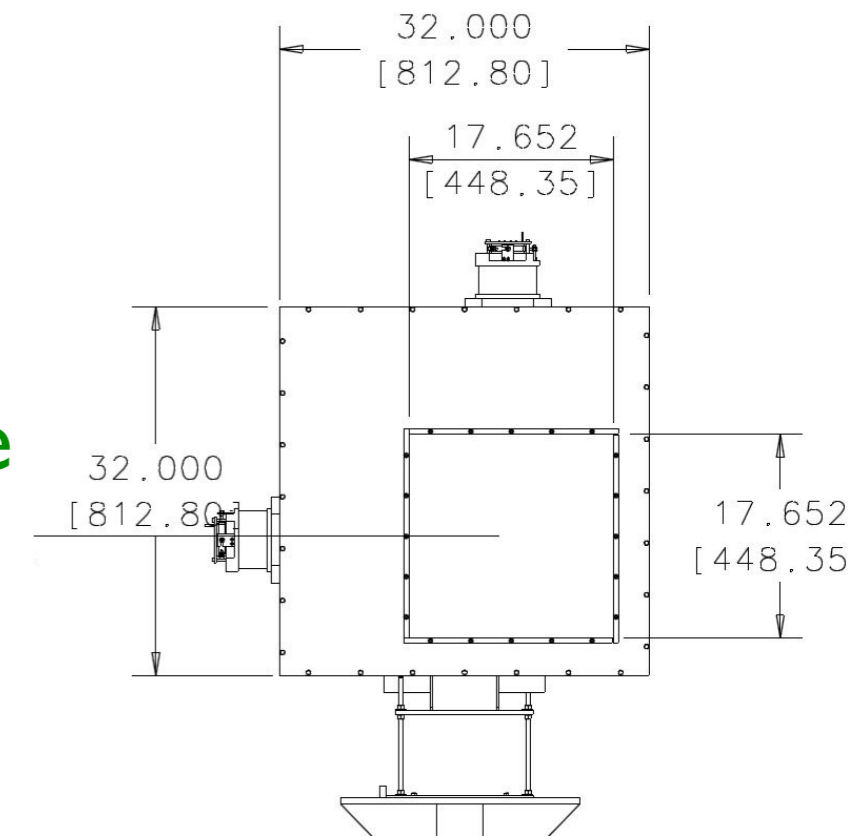
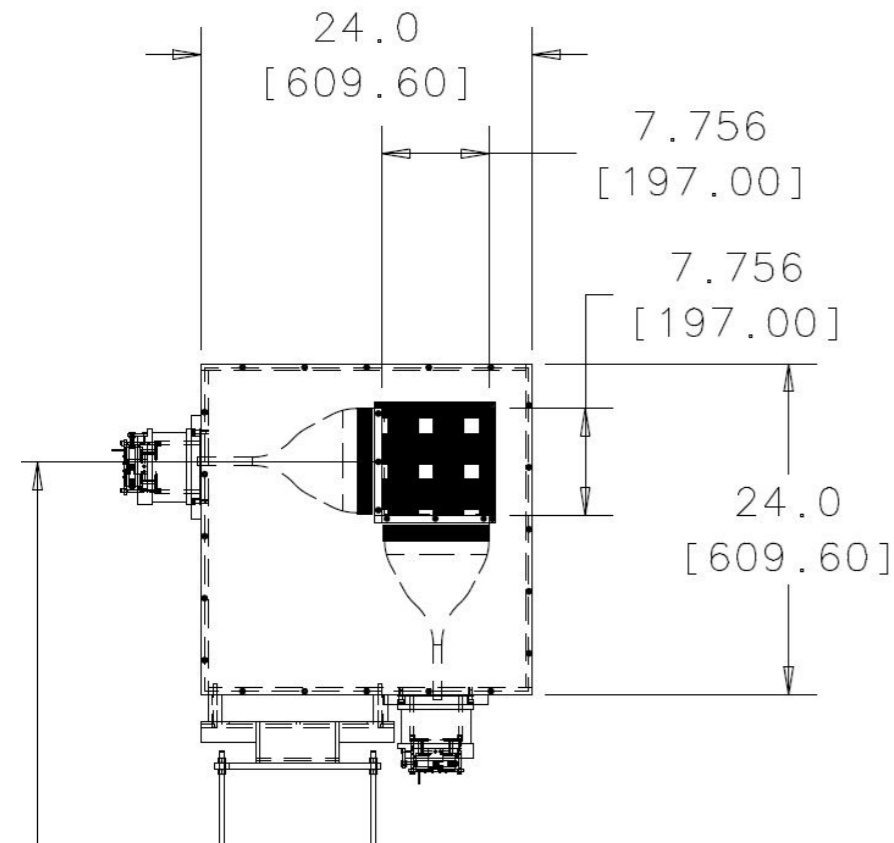


Beam Position Monitors

[FNAL]

Small

Large



- Both are installed & working
- Electronic noise now completely eliminated via improved shielding
- Each only \approx 1 mm thickness of plastic

MICE Particle ID

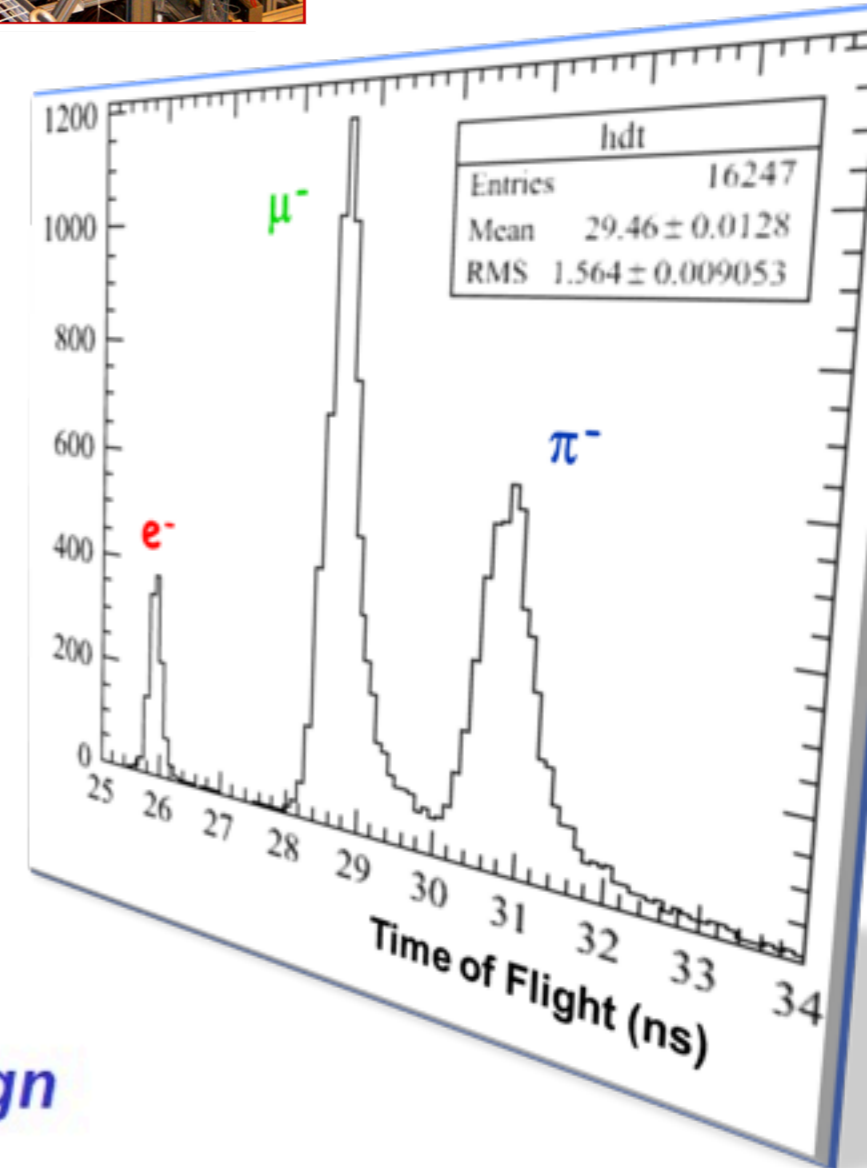
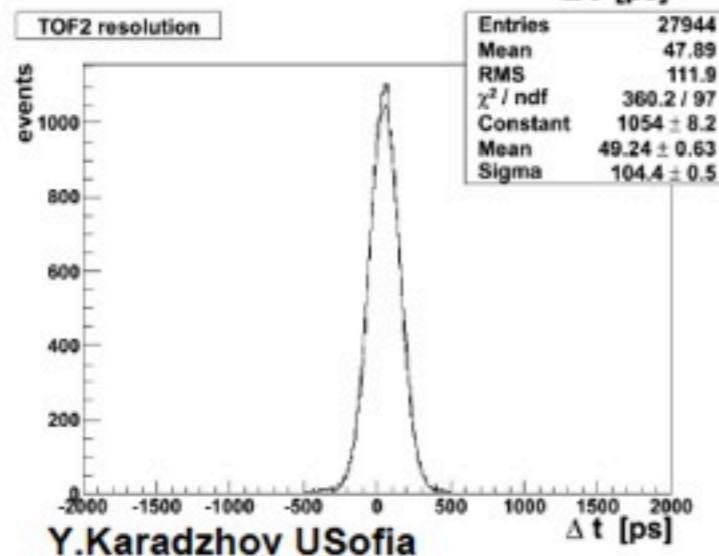
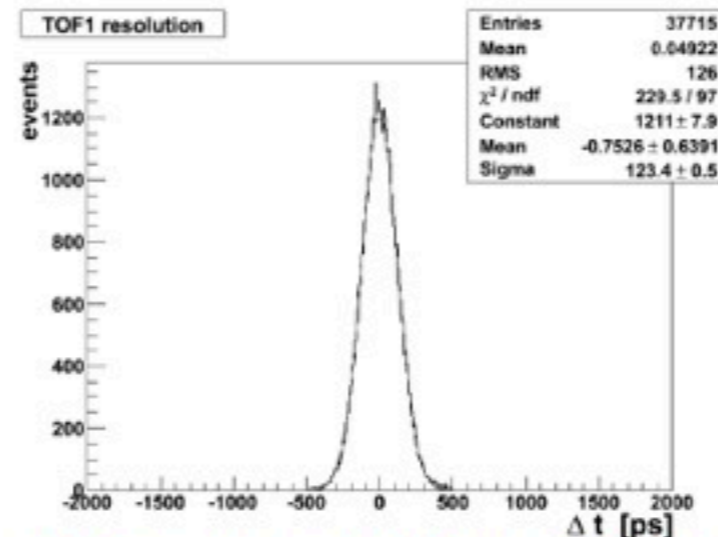
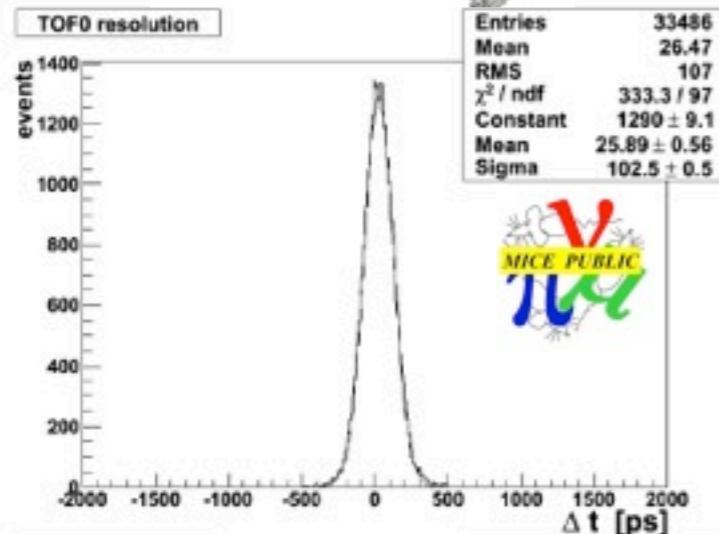
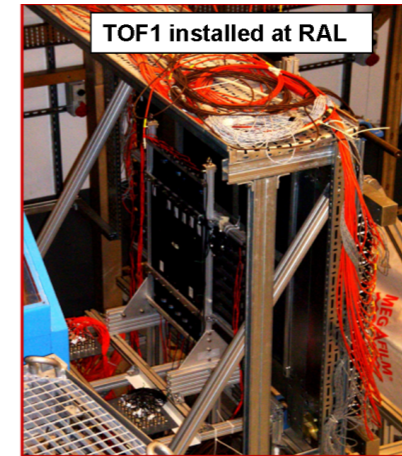
- Need to suppress (to $< 10^{-3}$ level) undecayed π in beam & decay electrons
- Performed using
 - 3 sets of TOF counters (Milan/Pavia/Geneva/Sofia),
 - 2 Cherenkov counters (U Miss/IIT/U Iowa)
 - KL sampling EM Calorimeter (Rome III), and
 - Electron-Muon Ranger (Geneva/FNAL/Trieste/Como)

MICE Particle ID

- Need to suppress (to $< 10^{-3}$ level) undecayed π in beam & decay electrons
- Performed using In and working?
 - 3 sets of TOF counters (Milan/Pavia/Geneva/Sofia), ✓
 - 2 Cherenkov counters (U Miss/IIT/U Iowa) ✓
 - KL sampling EM Calorimeter (Rome III), and ✓
 - Electron-Muon Ranger (Geneva/FNAL/Trieste/Como)

Time-of-Flight Counters

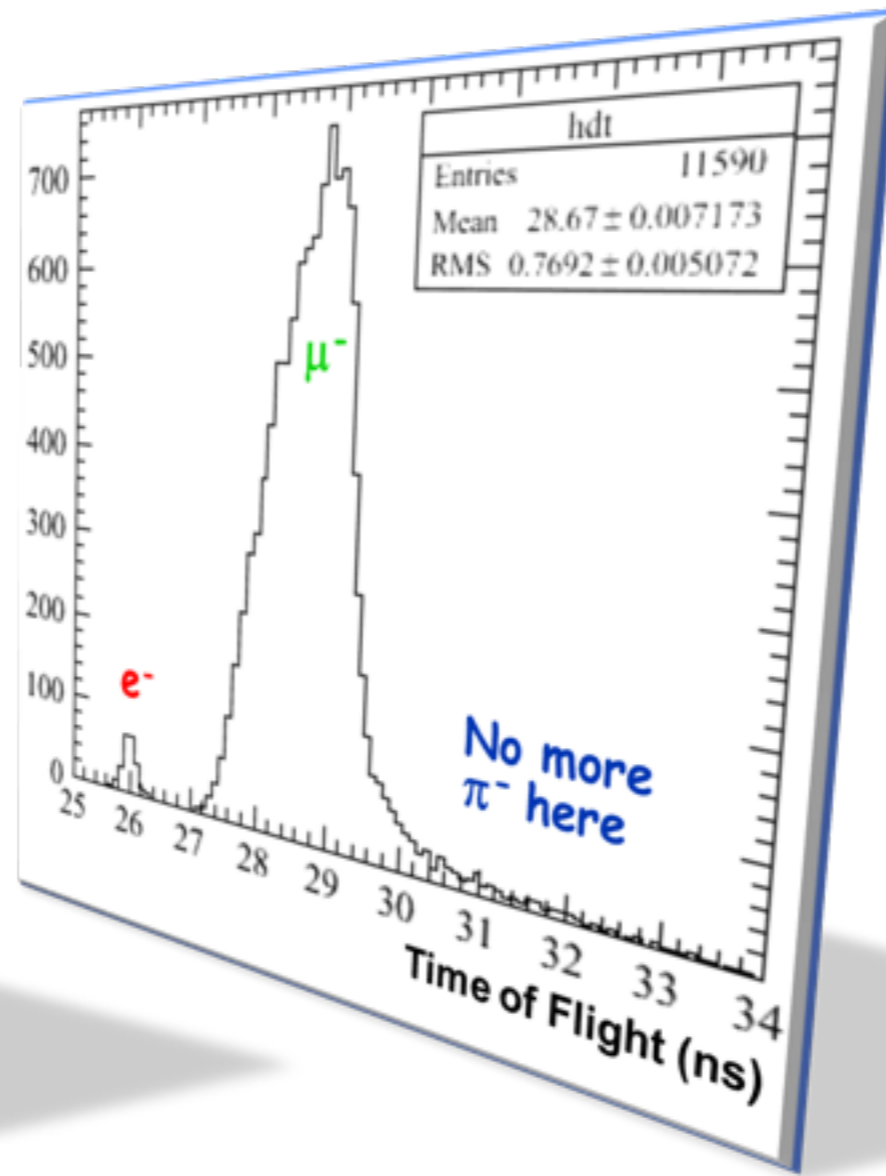
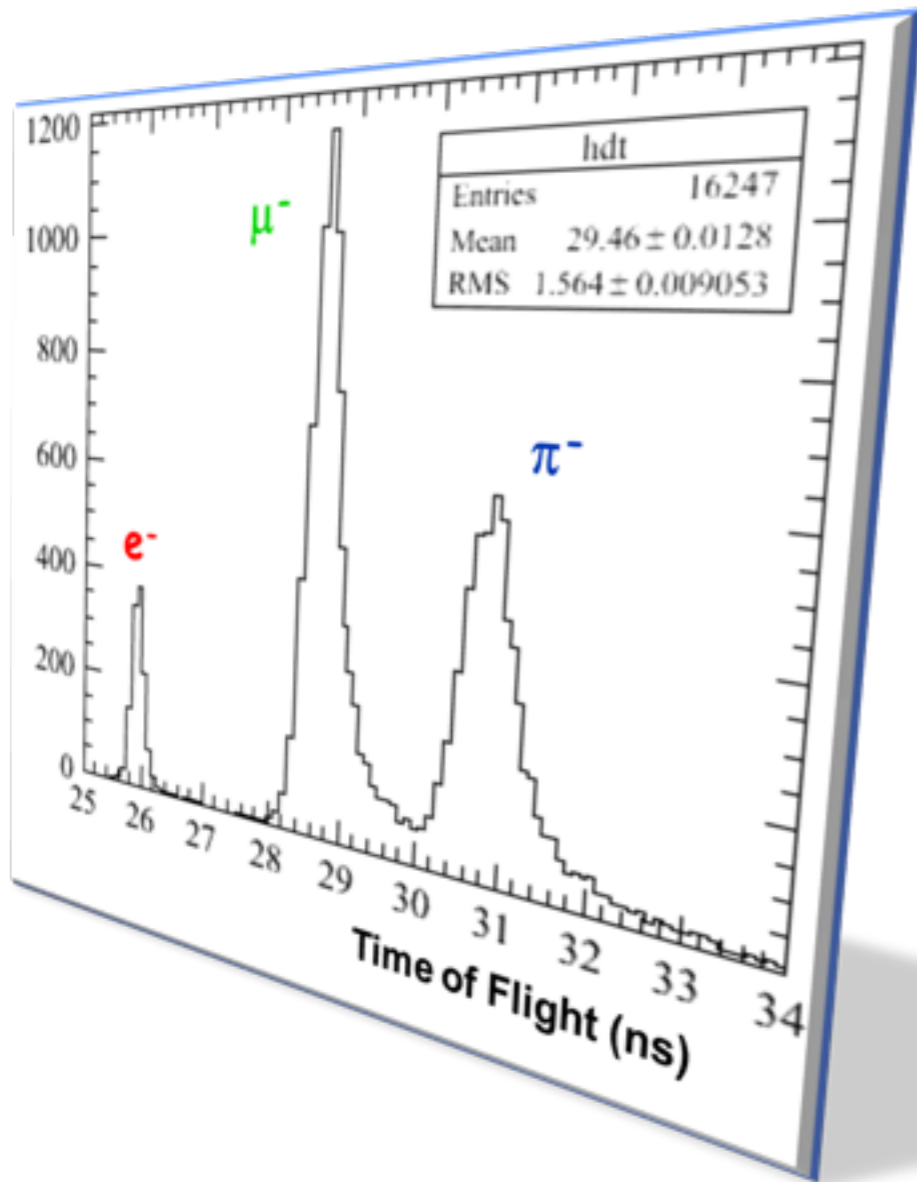
[Milan, Pavia, Geneva, Sofia]



- **Time resolution after calibration:**
- **TOF0 – 51ps**
- **TOF1 – 62ps**
- **TOF2 – 52ps**
- **Resolution meets design goals for TOFs**

Time-of-Flight Counters

[Milan, Geneva, Sofia]



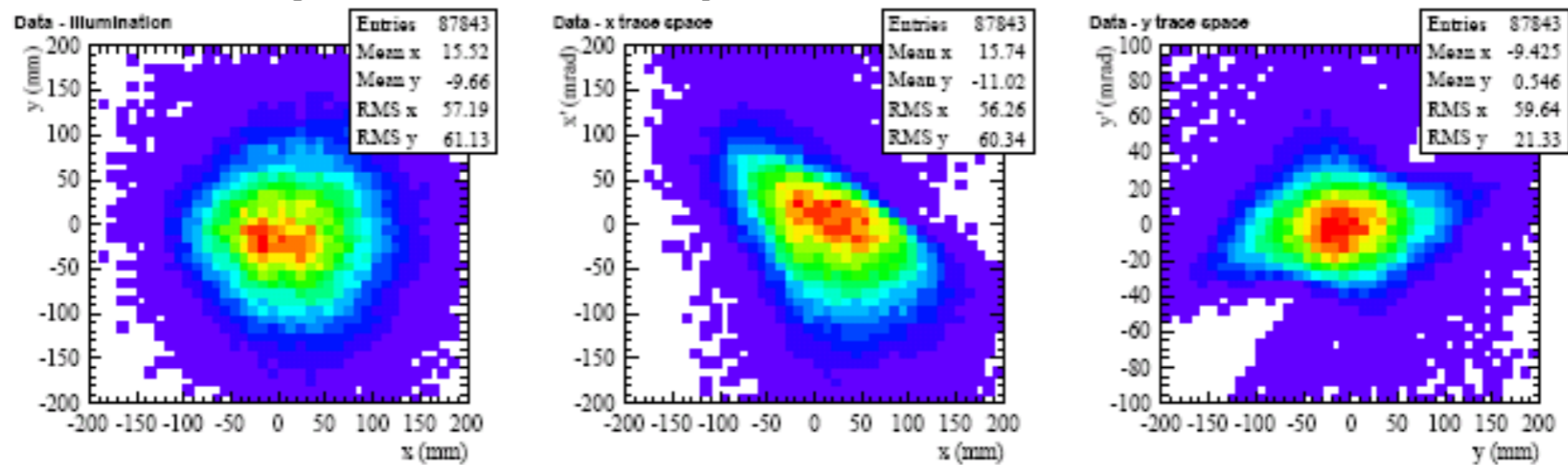
- Select μ with $p_{D1} = 2 p_{D2}$

TOF Emittance Analysis

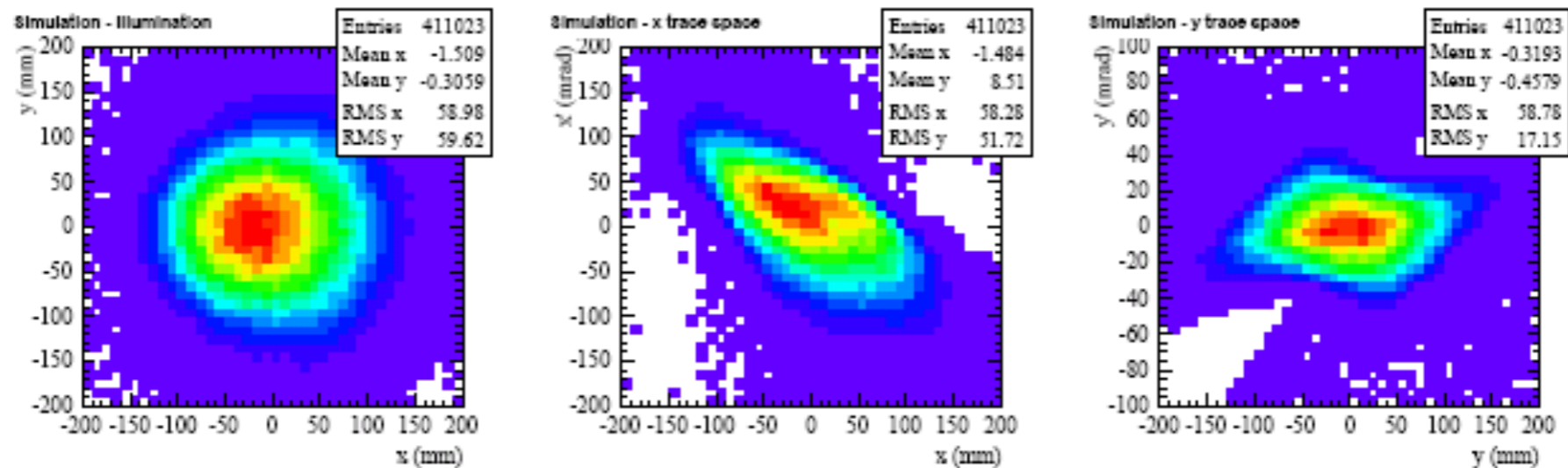
[M Rayner, U Oxford]

- Emittance analysis *without* spectrometers:

Data:



MC:

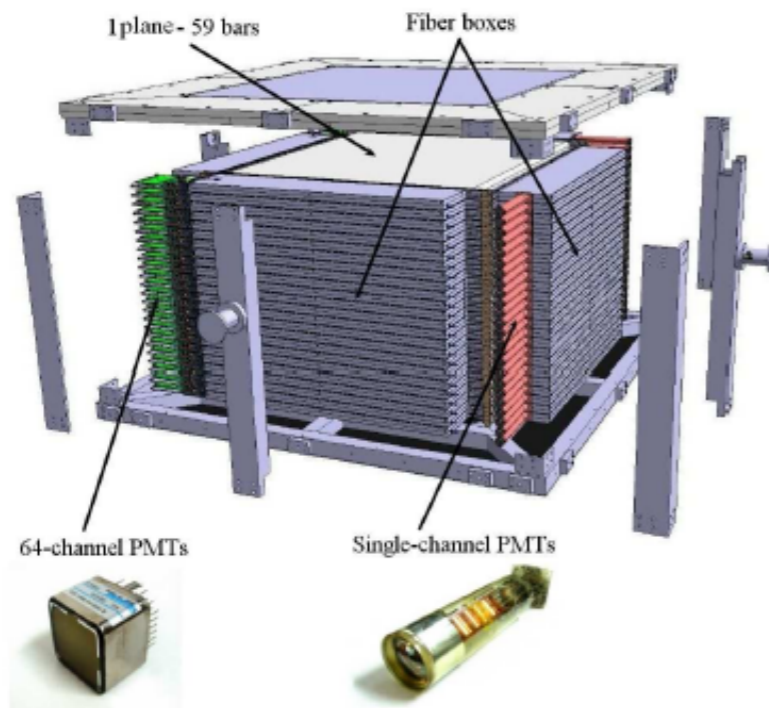


- PMTs at each end allow interpolation to ≈ 1 cm
- TOFs measure x' to 18 mrad, y' to 5 mrad, momentum to $\approx 2\%$

EMR

[Geneva, FNAL, Trieste/Como]

Characteristics Horizontal View

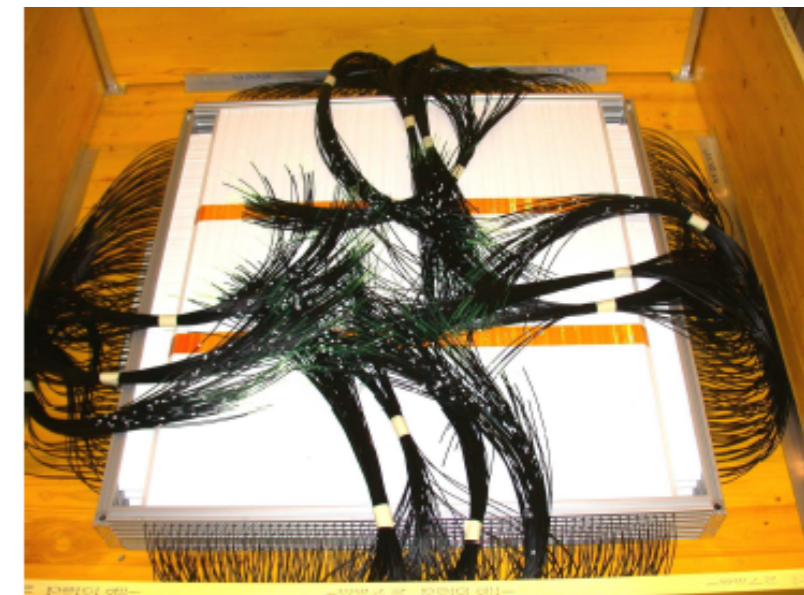
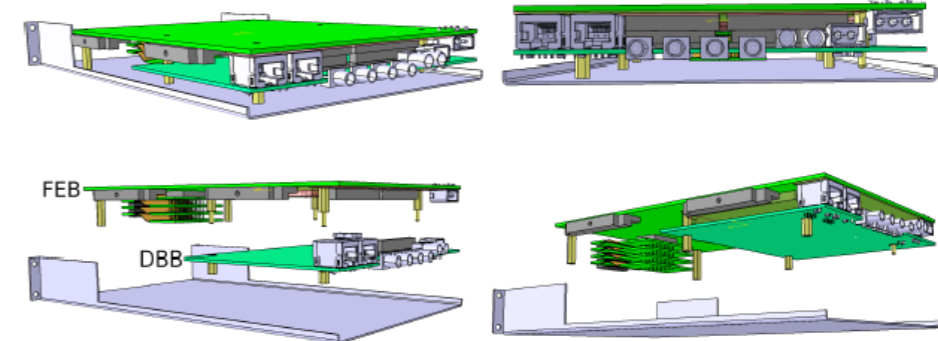


Characteristics

- 24 modules (X-Y planes)
- 48 planes
- 59 bars per plane
- 2832 bars
- 3m WLS fibers per bar
- 8.5 km WLS fibers
- single and 64-channel PMTs per plane
- 3072 + 48 channels

New Electronic Boards for 64-channel PMT

A new Front-End-Board (FEB) and Digitizer-Buffer-Board (DBB) were developed in order to read 64-channel PMT and store data during the MICE spill and subsequently transfer it to a dedicated VME board.



R.Asfandiyarov (U.Genève), Status of EMR Project

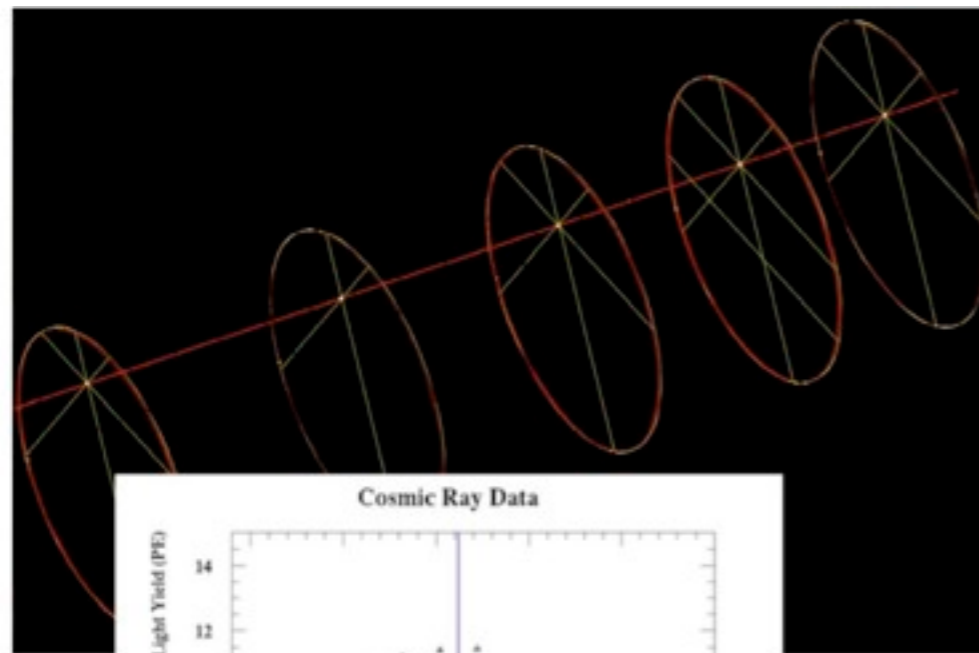
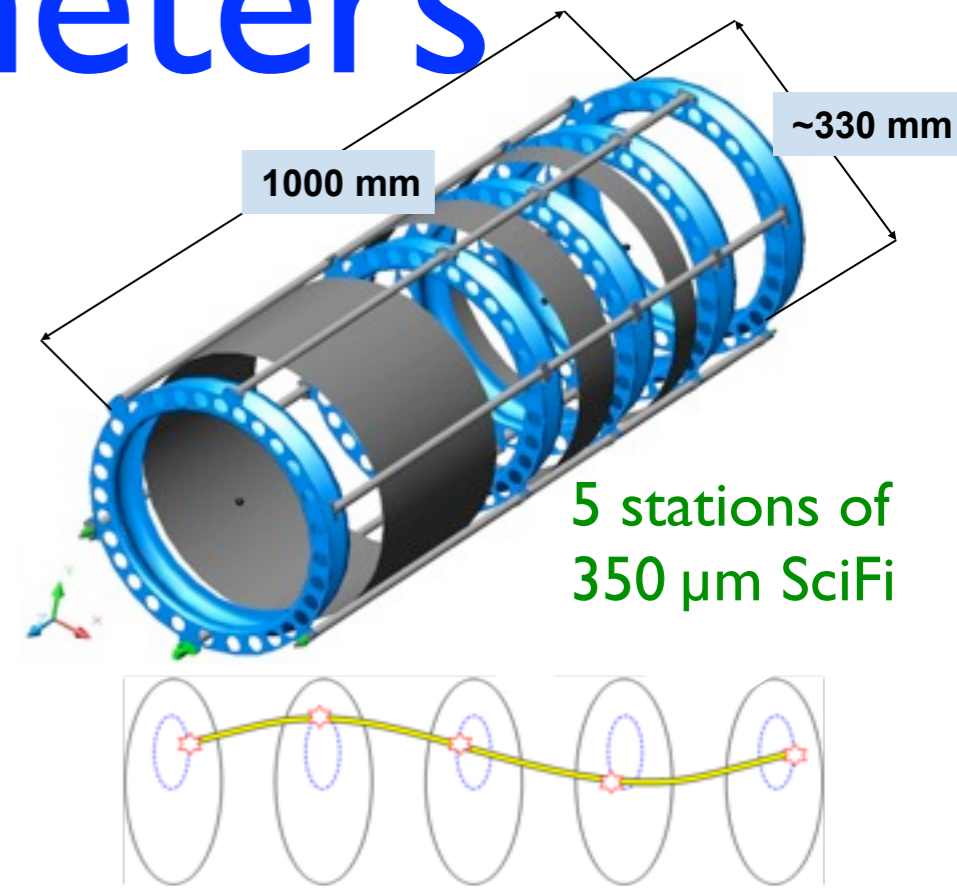
MICE Collaboration Meeting 29, February 15-18, 2011 2/27

- Under construction at U Geneva
- Prototype to be tested at MICE this summer

SciFi Spectrometers

[US / UK / Japan]

- Trackers complete & tested with cosmic rays
- Awaiting delivery of spectrometer solenoids



← Typical cosmic track

← Light yield ≈ 10 p.e.



Cosmic test setup

Spectrometer Solenoids

[LBNL]

- Build at Wang NMR (CA) to LBNL specification
- Design field = 4 T
- Training quenches revealed design flaws (excessive boil-off, HTS, LTS lead burnouts)

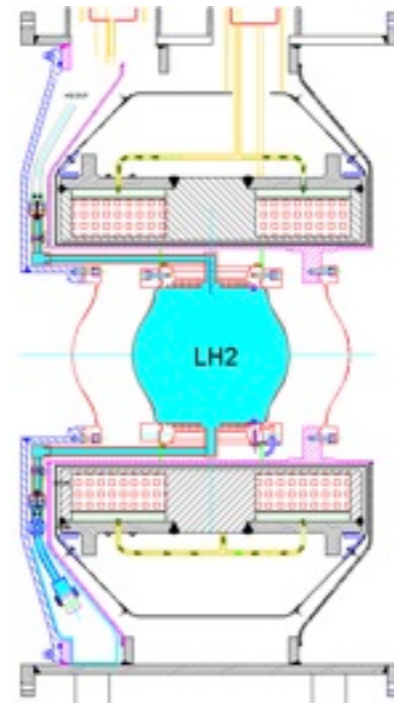


- Repair in progress

See next talk...

AFC Modules

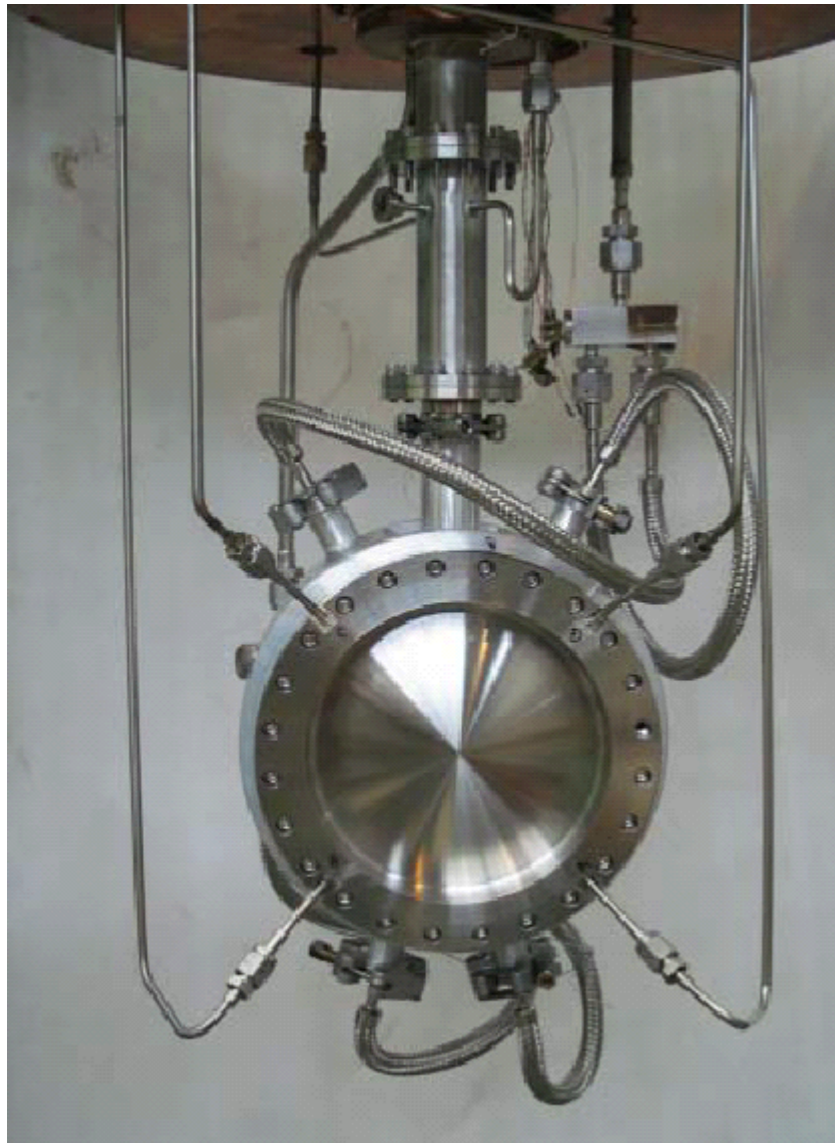
[U Oxford, RAL]



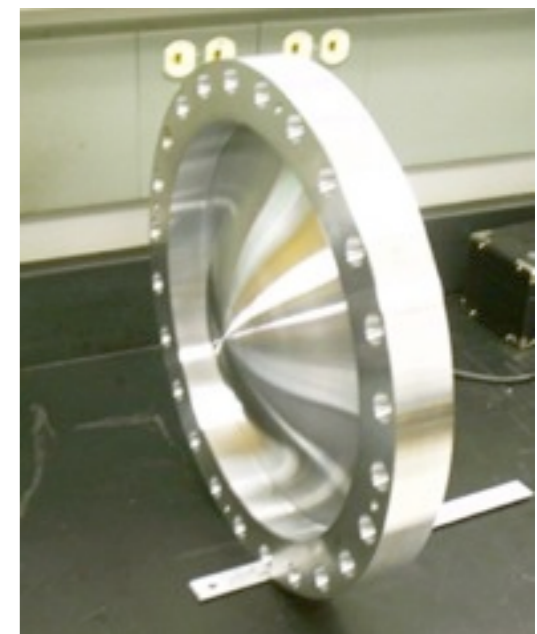
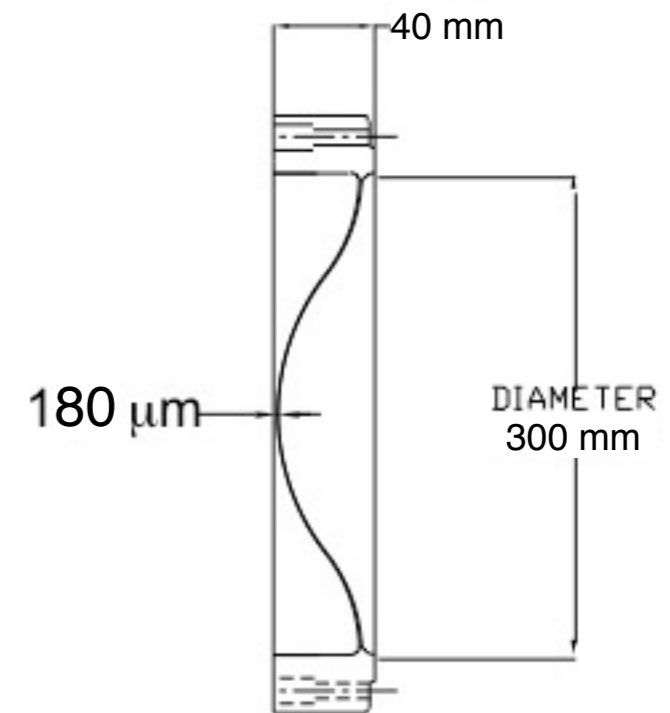
- Fabrication in progress at Tesla Eng. Ltd. (UK)
- Delivery expected this summer

LH₂ Absorbers

[KEK]



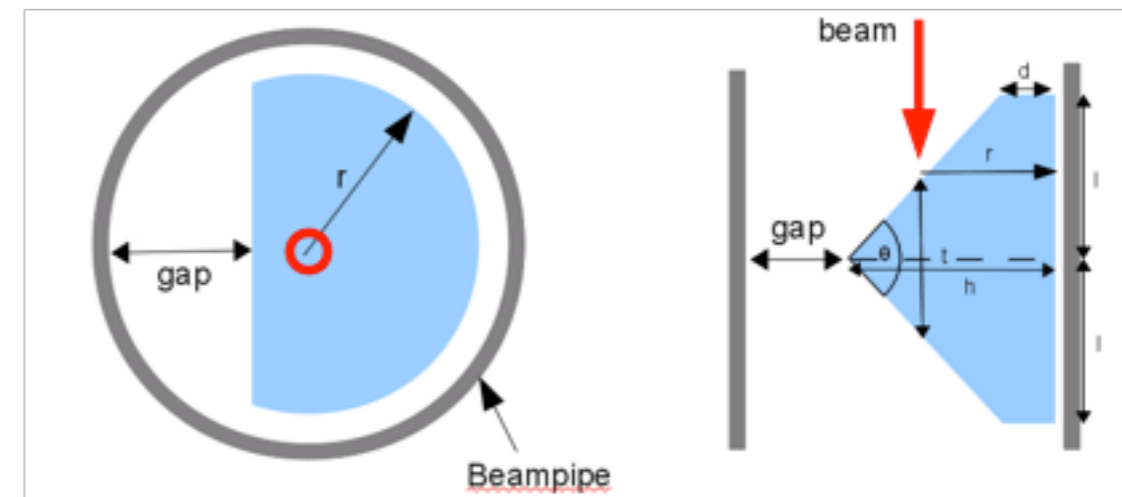
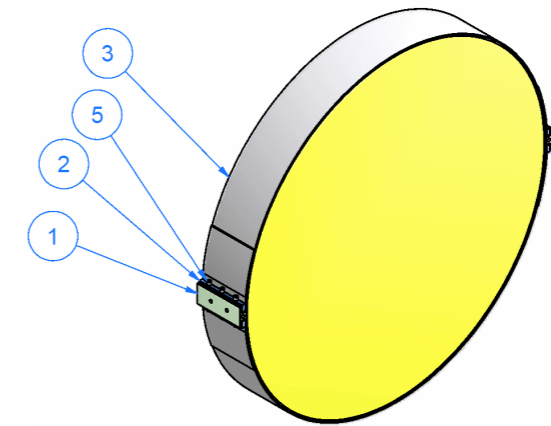
- 35 cm long x 30 cm diameter
- 3 required
 - 1 delivered so far, 2nd built
- Thin, tapered Al-alloy windows
 - designed by IIT & U Oxford
 - fabricated by U Miss
- Can also use LHe



LiH Absorbers

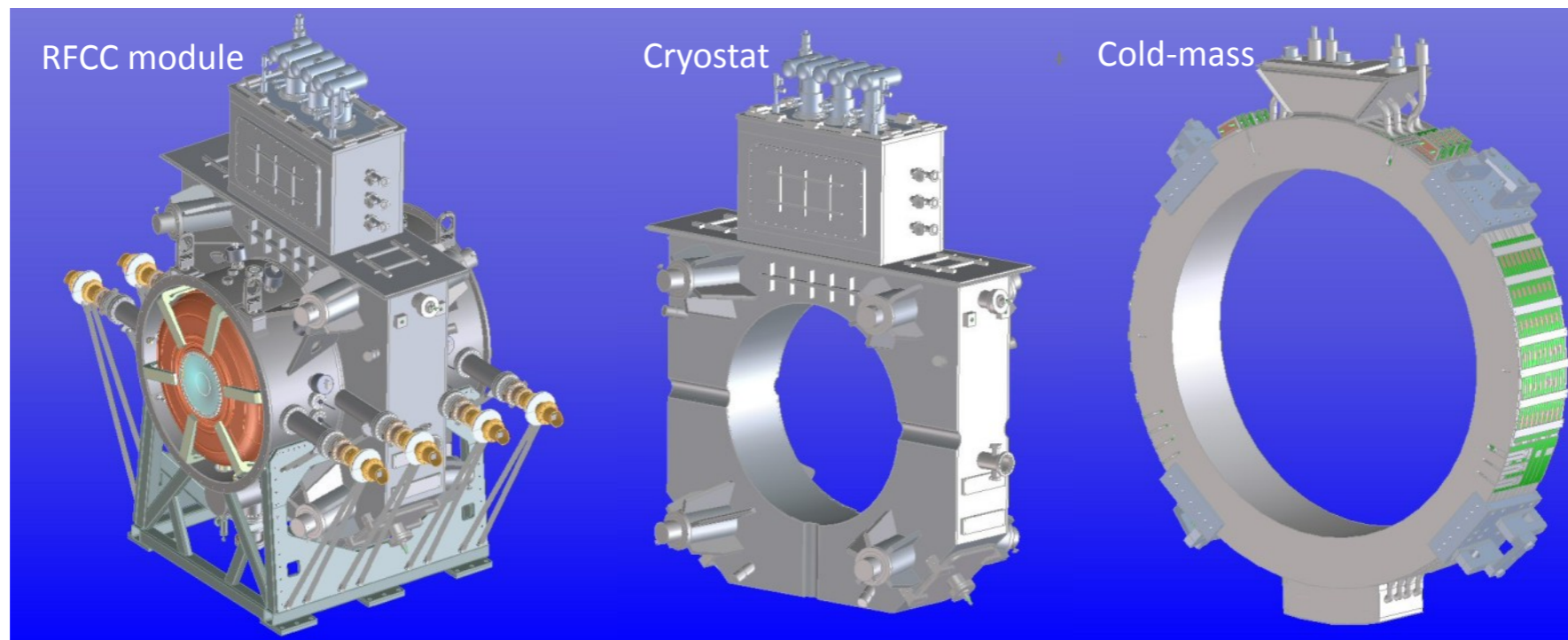
[FNAL]

- In fab at Y12 (Oak Ridge)
 - ▬ both disks and wedges ordered
 - ▬ delivery due in March
- Other solid absorbers also under consideration:
 - ▬ C, Al, polyethylene,...



RFCC Modules

[LBNL, HIT, U Miss]



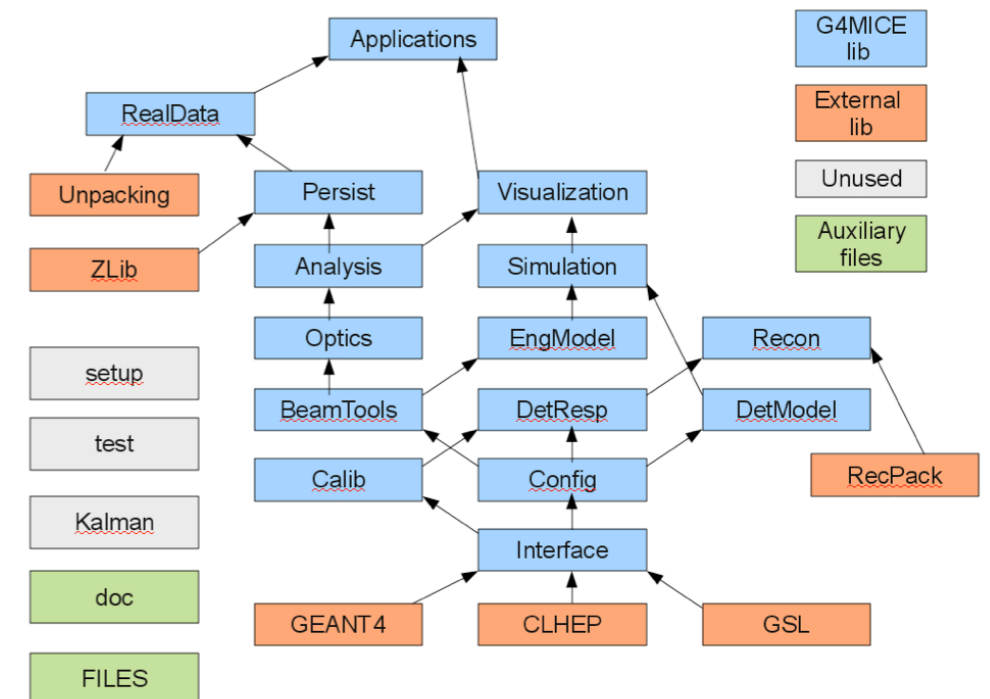
- Design done
- RF cavities built
- Coupling Coils in fab in China (HIT, Qi Huan, SINAP) under LBNL leadership

See following talks...

MICE Software

G4MICE

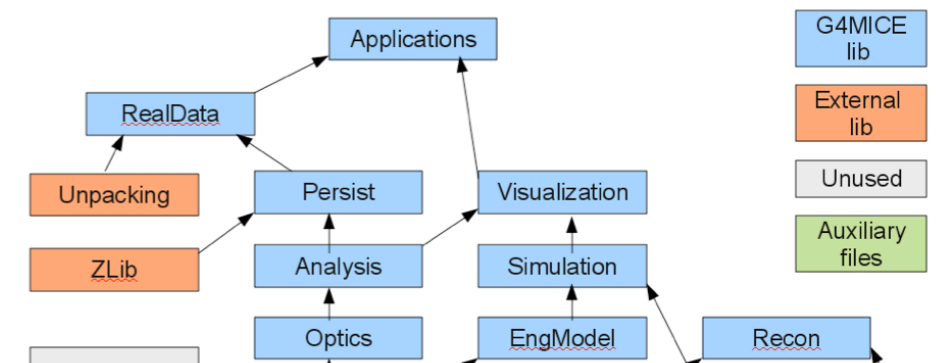
- G4MICE developed initially by Y.Torun (IIT)
- Since expanded under leadership of M. Ellis (Brunel) and C. Rogers (RAL)
- New MAUS (MICE Analysis User Software) framework by C.Tunnell (Oxford) simplifies use



MICE Software

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S	W	Job ↓	Last Success	Last Failure	Last Duration
🟢	☀️	MAUS_fedora14_32_nightly_clean	11 hr (#24)	N/A	53 min
🟢	☀️	MAUS_fedora14_64_nightly_clean	10 hr (#25)	N/A	1 hr 28 min
🟢	☀️	MAUS_nonvm_nightly_clean_gcc	12 hr (#96)	N/A	1 hr 19 min
🟢	☀️	MAUS_opensuse113_32_nightly_clean	9 hr 3 min (#20)	N/A	1 hr 40 min
🟢	☀️	MAUS_ubuntu1010_32_nightly_clean	14 hr (#19)	N/A	1 hr 37 min
🟢	☀️	MAUS_ubuntu1010_64_nightly_clean	13 hr (#27)	N/A	2 hr 4 min
🟡	☀️	MAUS_VMs_nightly	4 days 18 hr (#1)	N/A	4.3 sec

1. Test install and ~50 tests on 12 systems. I bet a cold beer it works for you with my great documentation.

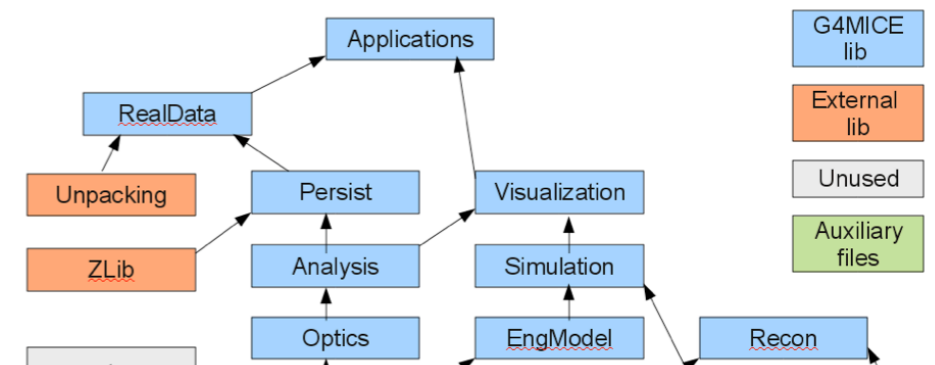
2. Tests per commit and branch.

3. Two new servers do this.

MICE Software

G4MICE

- G4MICE developed initially by Y.Torun (IIT)
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S	W	Job ↓	Last Success	Last Failure	Last Duration
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🌞	🌞	MAUS_opensuse113_32_nightly_clean	9 hr 3 min (#20)	N/A	1 hr 40 min
🌞	🌞	MAUS_ubuntu1010_32_nightly_clean	14 hr (#19)	N/A	1 hr 37 min
🌞	🌞	MAUS_ubuntu1010_64_nightly_clean	13 hr (#27)	N/A	2 hr 4 min
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1. Test install and ~50 tests on 12 systems. I bet a warm beer it works for you with my great documentation.

2. Tests per commit and branch.

3. Two new servers do this.

MICE Outlook

- Aim at complete (Step VI) study of transverse cooling within next few years
 - as well as demo of emittance exchange
- PhD theses for $\approx 1/2$ -dozen students so far, with several more in pipeline
- For more, see upcoming talks
 - and <http://mice.iit.edu/>