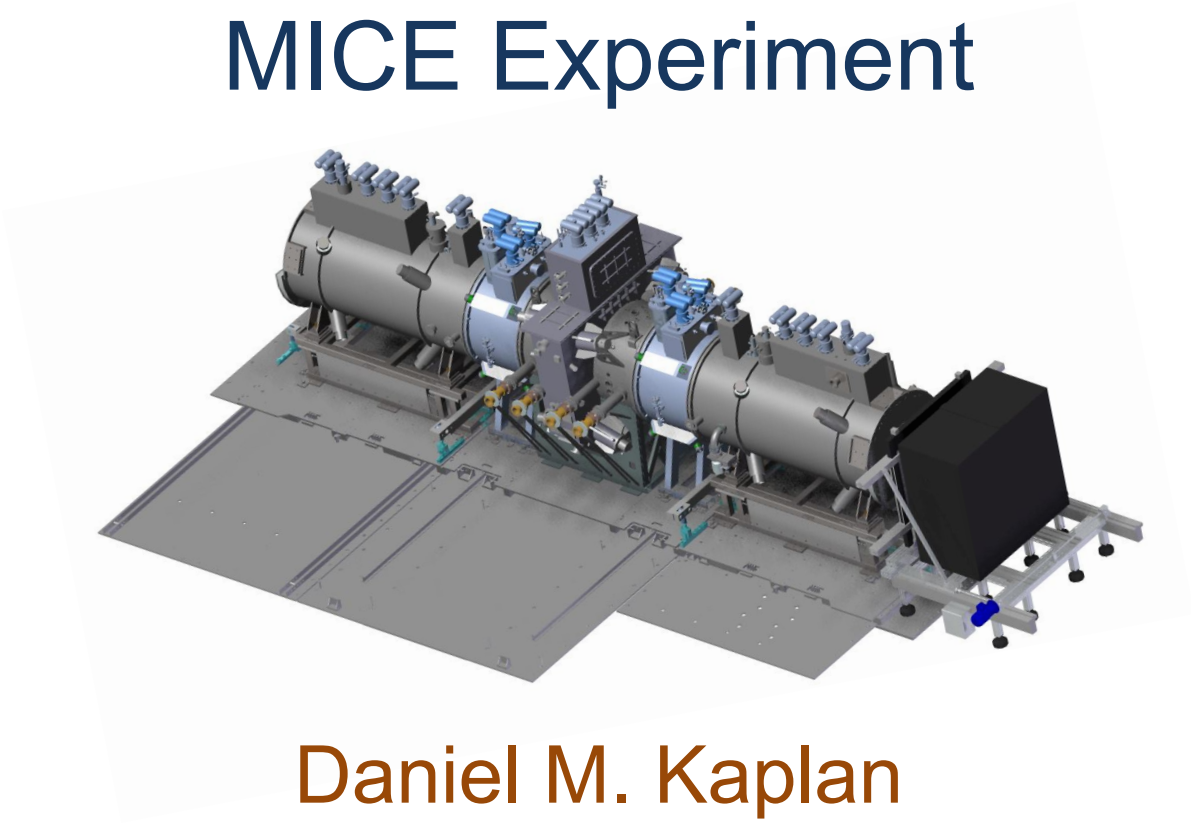
MICE Experiment



Daniel M. Kaplan

ILLINOIS INSTITUTE OF TECHNOLOGY

May 28, 2014

Outline

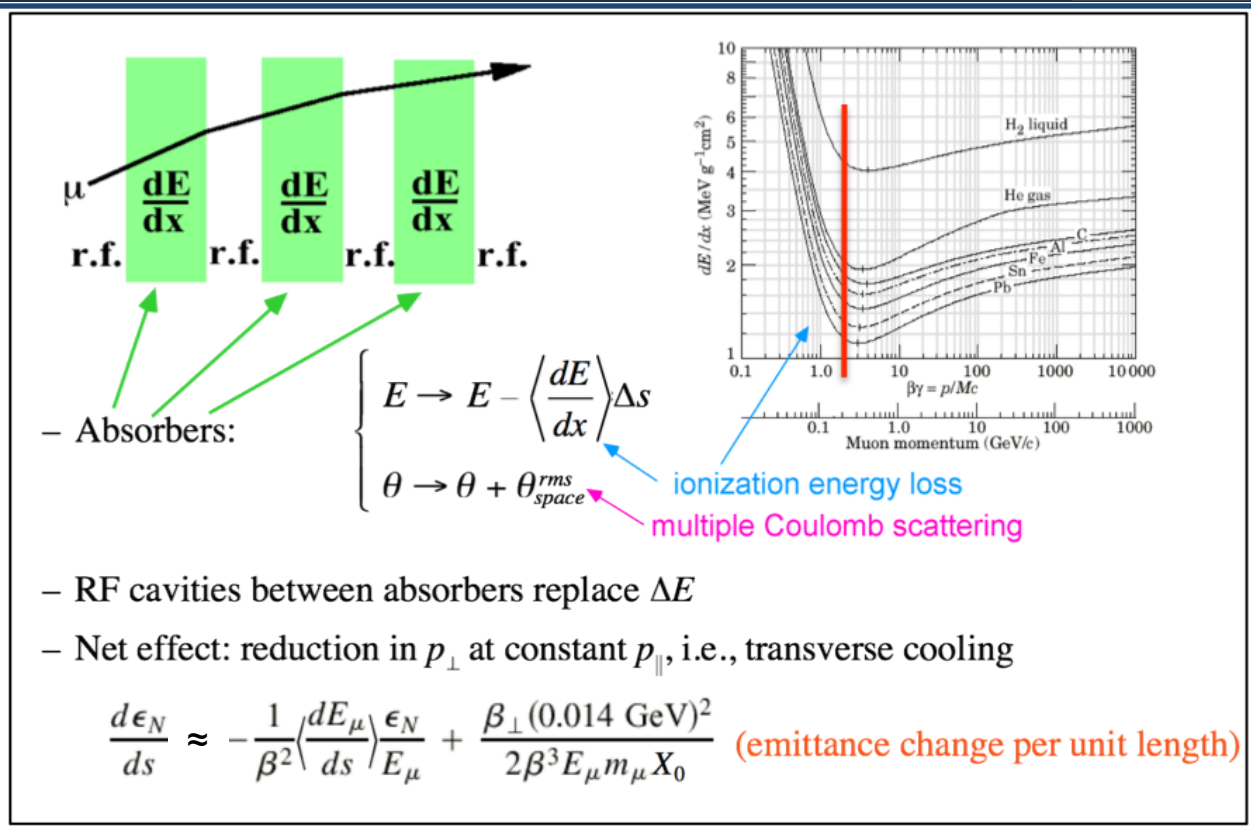
- MICE Overview
- Goals & Status
- Recent Progress
- Personnel & Activities
- Budgets & Funding
- Schedule
- Conclusions

MICE Overview

- Muon ionization cooling (μIC) yet to be demonstrated experimentally
  - But crucial to feasibility and performance of muon colliders and neutrino factories
    - Both NF and high-$\mathcal{L}$ MC require more than an order of magnitude of 6D-emittance reduction
- Purpose of MICE: demonstrate μIC feasibility & validate its simulations
- Approach: build short piece of realistic ionization cooling channel and operate it in a muon beam instrumented with precision diagnostics
  - Understand performance well enough to reliably extrapolate cost of muon cooling for MC or NF
    - Measurement of ≈10% emittance reduction to 1% relative precision, i.e., 10^{-3} emittance resolution
    - Requires single-particle measurements in low-intensity beam

Ionization Cooling

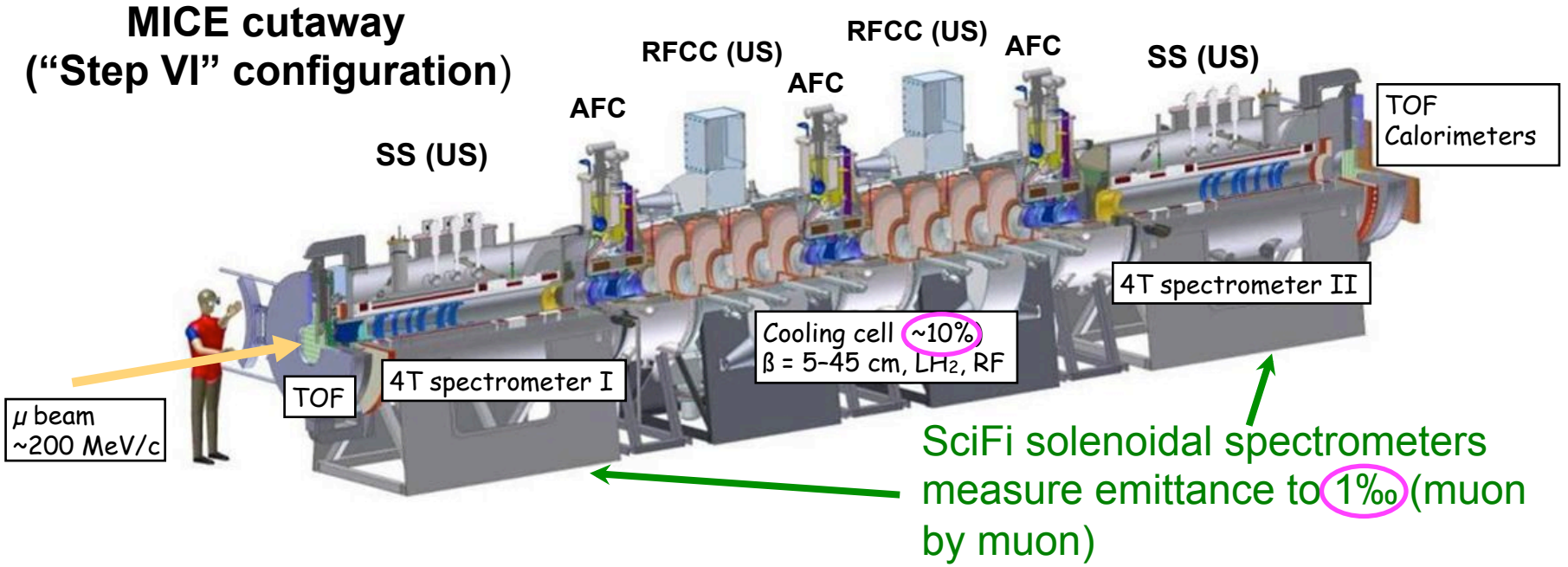
- Recall cooling principle: good cooling requires
  - Low-Z absorber
  - Low $\beta_\perp$ at absorber
    - Achievable via high magnetic field or field gradient, and with or without field flips*
    - Non-flip lattice more economical of superconductor
  - Plan to measure emittance change vs input emittance, momentum, and $\beta_\perp$ in both flip & non-flip approaches



*but canonical angular momentum cancellation requires at least occasional field flips

MICE Apparatus

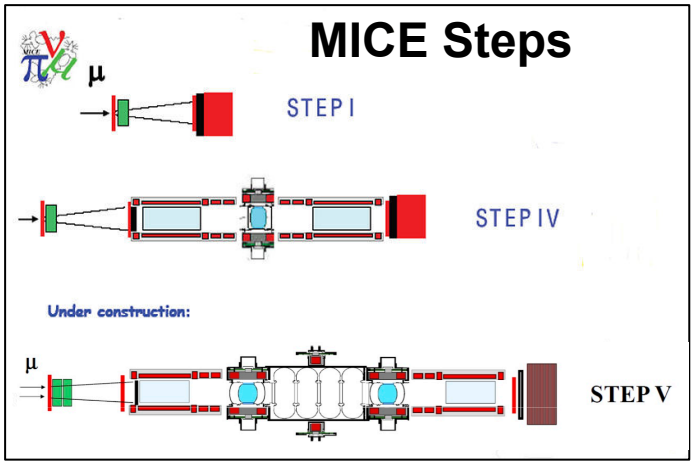
- Construction status/schedule of US components just covered
  - in sum, all components* needed for next MICE step have been built & successfully tested



* Except for wedge absorbers & partial return yolk, which are on order

Phase I and Phase II Goals

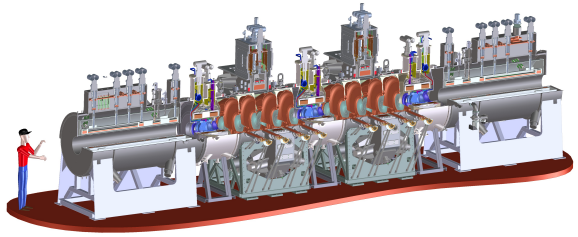
- Step "IV" Goals:
  - 1st demonstration of ⊥ cooling, but without reacceleration
  - Precisely characterize effects of low-*Z* absorber materials on muon beam
    - Validate Monte Carlo models
      - Better than in Step VI since shorter track extrapolation and simpler optics
  - Demonstrate emittance exchange (principle of 6D cooling) using wedge absorber



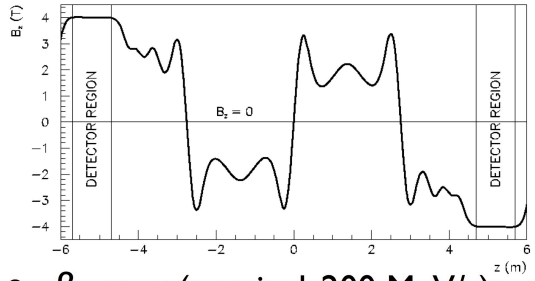
- Step "~~VI~~" "V" Goals:
  - Demonstrate "sustainable" cooling
    - Energy loss and replacement via absorbers surrounding short RF linac
  - Test performance in a variety of optics configurations
    - Thorough validation of simulation codes

Principles of MICE (Step VI)

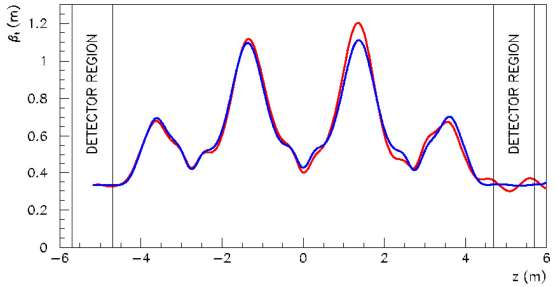
(Not yet updated for Step V)



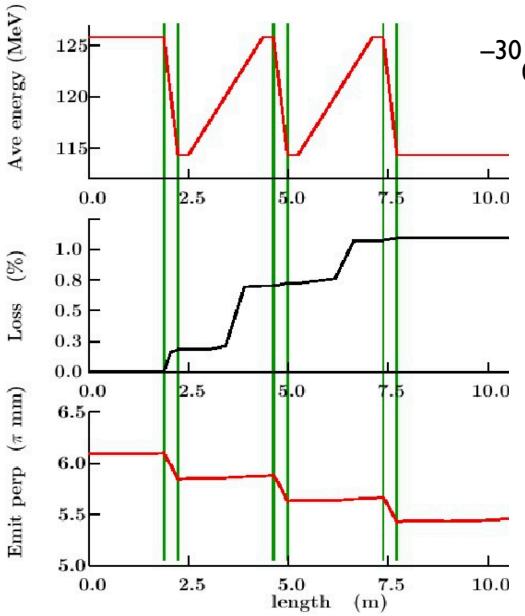
- B_z vs. z (nominal, 200 MeV/c):



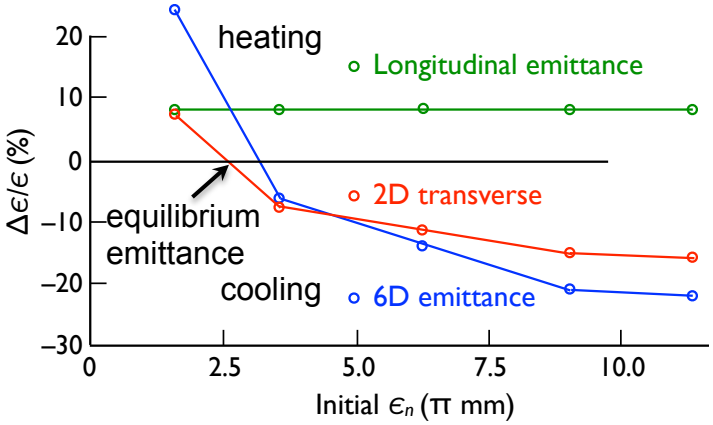
- $\beta_\perp$ vs. z (nominal, 200 MeV/c):



- Beam behavior vs. z:



- **Cooling vs. input emittance (200 MeV/c):**

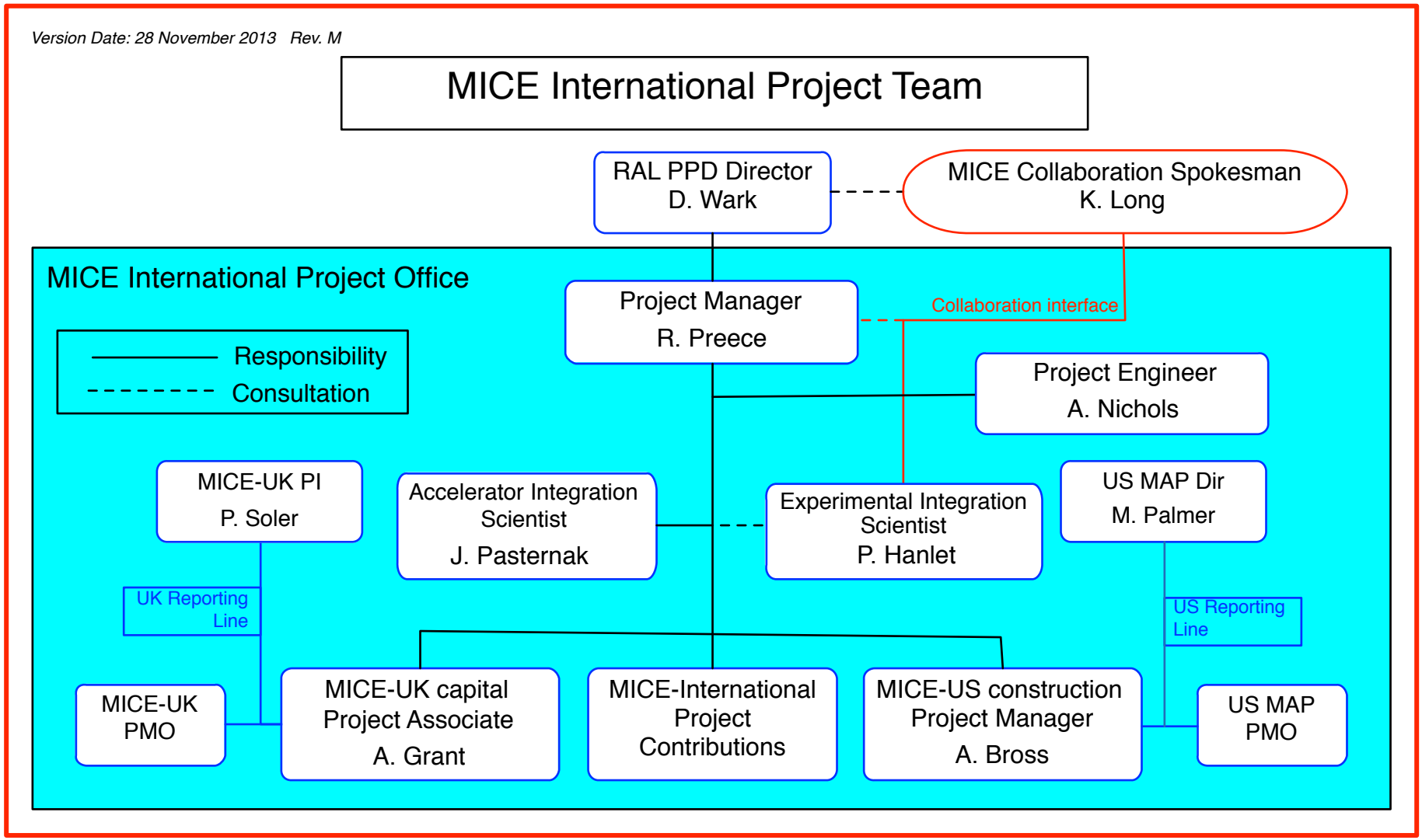


- **Emittance-momentum matrix:**

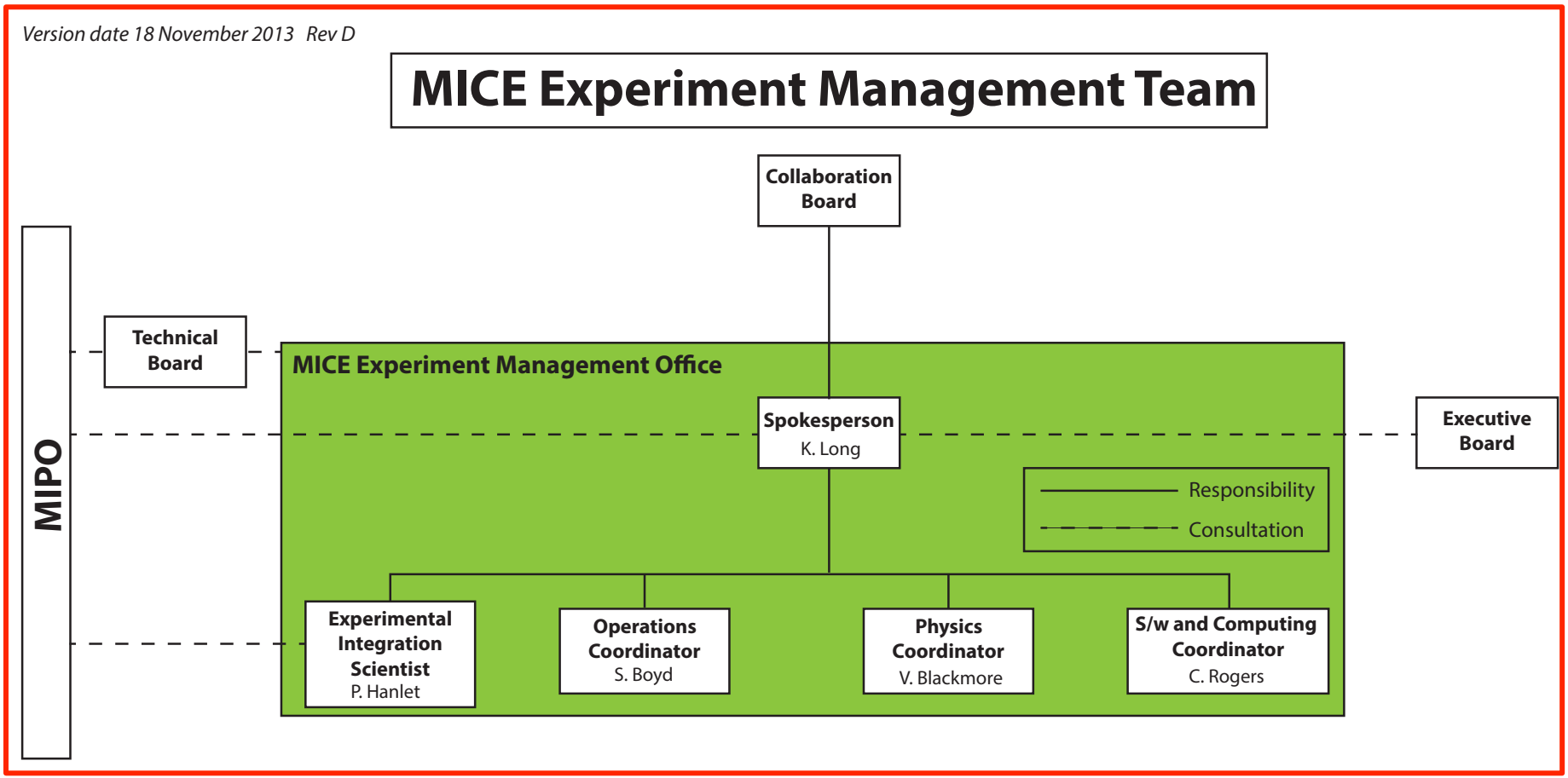
(3-140)	(3-200)	(3-240)
(6-140)	(6-200)	(6-240)
(10-140)	(10-200)	(10-240)

- **Plan to study both flip and non-flip modes, multiple absorber materials & configs**
  - need ~10^6 events for each case

MIPO


Version Date: 28 November 2013 Rev. M
MICE International Project Team
RAL PPD Director
D. Wark
MICE Collaboration Spokesman
K. Long
MICE International Project Office
Project Manager
R. Preece
Collaboration interface
Responsibility
Consultation
Project Engineer
A. Nichols
MICE-UK PI
P. Soler
Accelerator Integration Scientist
J. Pasternak
Experimental Integration Scientist
P. Hanlet
US MAP Dir
M. Palmer
UK Reporting Line
US Reporting Line
MICE-UK PMO
MICE-UK capital Project Associate
A. Grant
MICE-International Project Contributions
MICE-US construction Project Manager
A. Bross
US MAP PMO

MEMO


Version date 18 November 2013 Rev D
MICE Experiment Management Team
Collaboration Board
MIPO
Technical Board
MICE Experiment Management Office
Spokesperson
K. Long
Executive Board
Responsibility
Consultation
Experimental Integration Scientist
P. Hanlet
Operations Coordinator
S. Boyd
Physics Coordinator
V. Blackmore
S/w and Computing Coordinator
C. Rogers

MICE Papers

- 2 comprehensive MICE Step I papers, one recent:
  1. D. Adams et al., "Characterisation of the muon beams for the Muon Ionisation Cooling Experiment," Eur. Phys. J. C73 (2013) 2582
  2. M. Bogomilov et al., "The MICE Muon Beam on ISIS and the beam-line instrumentation of the Muon Ionization Cooling Experiment," JINST 7 (2012) P05009
- 1 more in progress:
  1. "Measurement of the pion contamination in the MICE beam"
- Plus recent technical or conference papers...

More (Recent) MICE Papers

1. The detector system of the Muon Ionization Cooling Experiment (MICE) experiment
   - Maurizio Bonesini. 2014. 3 pp.
   - Published in PoS EPS-HEP2013 (2014) 018
2. Progress towards completion of the MICE demonstration of ionisation cooling of muons
   - Y.I. Karadzhov. 2014. 3 pp.
   - Published in PoS EPS-HEP2013 (2014) 017
3. Progress Towards Completion of the MICE Demonstration of Muon Ionization Cooling
   - MICE Collaboration (Daniel M. Kaplan (IIT, Chicago) for the collaboration). Dec 5, 2013. 4 pp.
   - NuFact2013, e-Print: arXiv:1312.1626 [physics.acc-ph]
4. A totally active scintillator calorimeter for the Muon Ionization Cooling Experiment (MICE). Design and construction
   - MICE Collaboration (Ruslan Asfandiyarov for the collaboration). 2013. 6 pp.
   - Published in Nucl.Instrum.Meth. A732 (2013) 451-456
5. Muon Cooling, Muon Colliders, and the MICE Experiment
   - MICE Collaboration (Daniel M. Kaplan (IIT, Chicago) for the collaboration). Jul 15, 2013. 5 pp.
   - IIT-CAPP-13-2, MICE-CONF-GEN-415, FERMILAB-CONF-13-172-APC
   - Presented at COOL'13 Conference, e-Print: arXiv:1307.3891 [physics.acc-ph]
6. Status of the Muon Ionization Cooling Experiment (MICE)
   - Y. Torun, M. Zisman
   - Proceedings of PAC2013, Pasadena, CA USA, THPHO18

Critical Challenges

- (We do not address MICE Construction)
- Step IV Operations:
  - ISIS long shutdown Aug. 2014 – Feb. 2015
    - Must plan & execute work to be ready for Step IV data-taking as early in 2015 as possible
  - Need robust software effort in order to be ready in time
    - MAUS development progressing
    - Software effort understaffed
      - relies heavily on students, but postdocs now getting more involved
  - Common Fund (currently assessed @ £3k/yr/PhD collaborator) intended to cover operations support & cryogens
    - However, cost of "professional shifters" will exceed available Common Fund
      - LH_2, Magnet, & Cryo expert(s)
      - Controls system expert(s)
      - DAQ system expert(s)
    - Also true for cryogens

    ⇒ possible doubling of assessment
  - Need to staff these expert roles & delineate their responsibilities
  - Training & deploying sufficient shifters

Who Does What

(Both DOE- & NSF-supported)

- Fermilab: D. Adey, D. Bowring, A. Bross, M. Leonova, M. Popovic
  - Tracker
  - Beamline
- BNL: H. Witte, R. Palmer
  - Lattice design
- LBNL: D. Li, M. Zisman
  - Magnets
  - RF
- UCR: G. Hanson, C. Heidt
  - Tracker
  - Controls & Monitoring software
- IIT: M. Drews, P. Hanlet, D. Kaplan, D. Rajaram, P. Snopok, Y. Torun, M. Winter
  - Experiment integration
  - Controls & Monitoring software
  - Offline software
  - Tracker*
- U Iowa: U. Akgun, J. Nachtman, Y. Onel, R. Rahmat
  - Tracker*
- U Miss: L. Cremaldi, D. Sanders, D. Summers
  - Tracker*
  - Ckov detectors & analysis
  - RF
  - Absorber windows
- UNH: U. Bravar
  - Optics studies

*proposed

Who	MICE Admin. Role	C'tee
A. Bross	Dep. Spokes.	Exec. & Tech. Bds.
P. Hanlet	Expt. Integr. Scientist C&M Leader	Tech. Bd.
D. Kaplan	US Rep.	Exec. & Edit. Bds.
D. Rajaram	Offline Software Head	

Color code:
Faculty
Research Faculty
Adjunct Faculty
Scientist
Postdoc
Grad student
Undergrad

Budget Overview

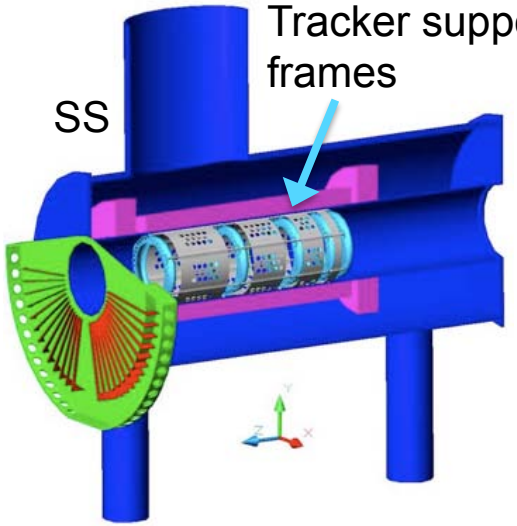
- NSF:
  - 6➔4-university consortium
    - UC Riverside (former lead institution) – G. Hanson, PI (final year of funding)
    - U Chicago – Y. K. Kim, PI (terminated)
    - IIT (now lead institution) – D. Kaplan, PI (final year of funding)
    - U Iowa – Y. Onel, PI
    - U Mississippi – D. Summers, PI
    - U New Hampshire – U. Bravar, PI
  - Previous proposal: requested $3.2M for 3 years, 2013–16
    - Renewed at "subsistence" level (IIT & UCR only, $0.2M), for 1 year
      - Advised to reapply to new Accelerator R&D program to begin in FY14
  - New proposal: $2.6M for 3 years, 2014–17 (IIT, U Iowa, U Miss, UNH)
- DOE (MAP):
  - Support for Fermilab, BNL, LBNL groups & key personnel, including
    - Alan Bross, Fermilab: Deputy Spokesperson & Construction L1 Mgr
    - Pierrick Hanlet, IIT: Expt Integration Scientist / Controls & Monitoring Head
    - Daniel Kaplan, Systems Demonstrations L1 Mgr (partial release time)
    - Durga Rajaram, IIT: Offline Software Head
  - Plus corresponding travel and Common Fund contributions

NSF Proposal Overview

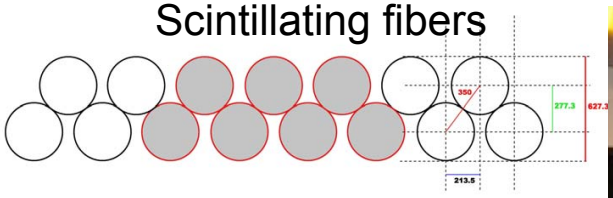
- NSF proposal – 3-year budget request:
  - IIT: 0.7M
    - Postdoc, grad student, undergrads, travel
    - Tracker DAQ support, emittance exchange studies
  - U Iowa: 0.8M
    - Postdoc, grad student, undergrads, travel
    - Tracker DAQ support, Ckov
  - U Miss: 0.6M
    - Postdoc, undergrads, travel
    - Tracker DAQ support, absorber window measurements, Ckov
  - UNH: 0.5M
    - Grad student, undergrads, travel
    - Optics simulations
  - All: operations and analysis
- Status: still under review
  - Hope to hear soon

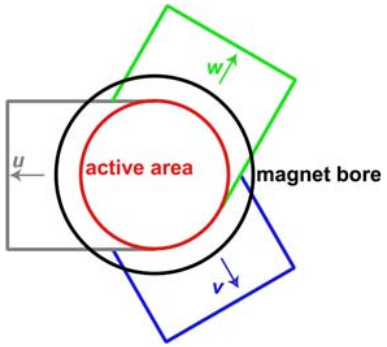
Tracker DAQ Support

- Tracker DAQ is a complex system



Scintillating fibers



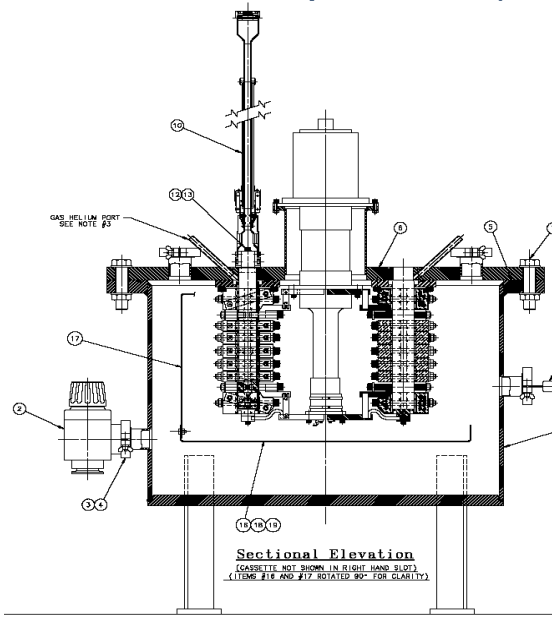


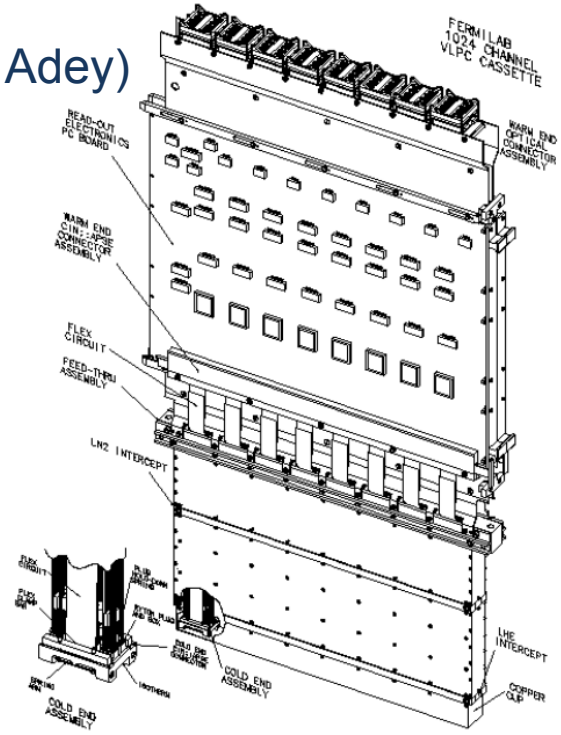
Tracker cosmic-ray test at RAL

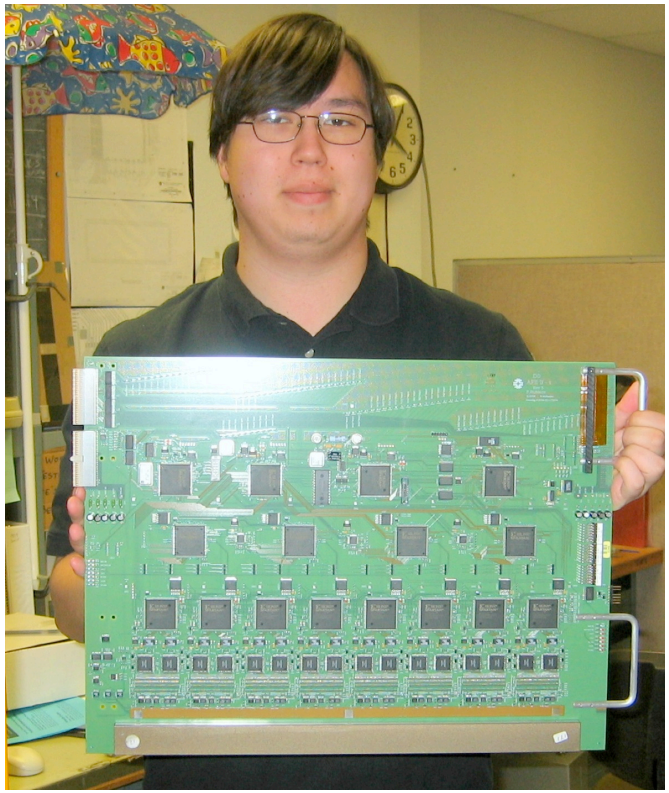
- 8k SciFi readout channels instrumented with cryogenic, VLPC photodetectors
  - Readout via DØ AFE-IIt modules, each controlled by 3 FPGAs
  - Built originally for DØ, tested with IIT MICE help (NSF MRI)
  - Its support is a US responsibility within MICE

Tracker DAQ Support

- Tracker operation entails cryogenics, calibrations, and needed μcode mods
  - Current support thin: one FNAL postdoc (D. Adey)







- NSF support for 3 postdocs requested to cover these (US) responsibilities and to provide US analysis manpower
  - Success of MICE requires full engagement by all collaborating regions
    - Appropriate US physics contribution commensurate with hardware one
  - Note UK Provides ≈ 7 FTE of tracker effort

Schedule

- Critical path driven by MICE Construction
- Anticipated schedule:
  - 1st demo of cooling (Step IV) 2015–16
  - 1st demo of sustainable cooling (Step V) 2018

Conclusions

- MICE is a program to demonstrate that ionization cooling is feasible and well understood
- Aim to demonstrate the principles of 6-dimensional cooling as well as transverse

  …and thus lay the groundwork for muon colliders and neutrino factories

  …by 2018

  – Requires some increase in support in order to accomplish needed work
    - Need few more FTE to provide adequate Tracker support and make needed progress towards Step IV readiness
    - As well as students to carry out Step IV operations and analysis
    - Hope for additional contributions from NSF!

- We are committed to seeing it through to a successful conclusion

Personal view

- In the big picture, seems a pity to spend ≈ $90M on MICE and not go the “last yard” to do the more thorough Step VI cooling validation!
  - but we can only do what we can
- Step V will be good enough