MICE project board IV
response to charge and MPB questions

Please respond to the recommendations MPB-3 (March 8 2012), which were:

1. *Look further at the temperature margin on the Coupling Coils and make a decision as soon as possible on the copper-to-superconductor ratio for the production MICE coils, and buy sufficient conductor to make three coils.*

2. *Wind three identical Coupling Coils, in order to have a spare coil.*

These questions have been answered by S. Gourlay
and reproduced in the written document

3. *Assemble an operational support plan, that includes the resources required and types of resources needed for operation of MICE, both in the near term for Step 4 and also in the long term for Step 6, and present at the next MPB.*

See plan description in the report.

It should be stressed that this requires 4 new people

-- a resident MICE Operations Mannager (r-MOM)
This could be support for someone already paid elsewhere or term contract employment.

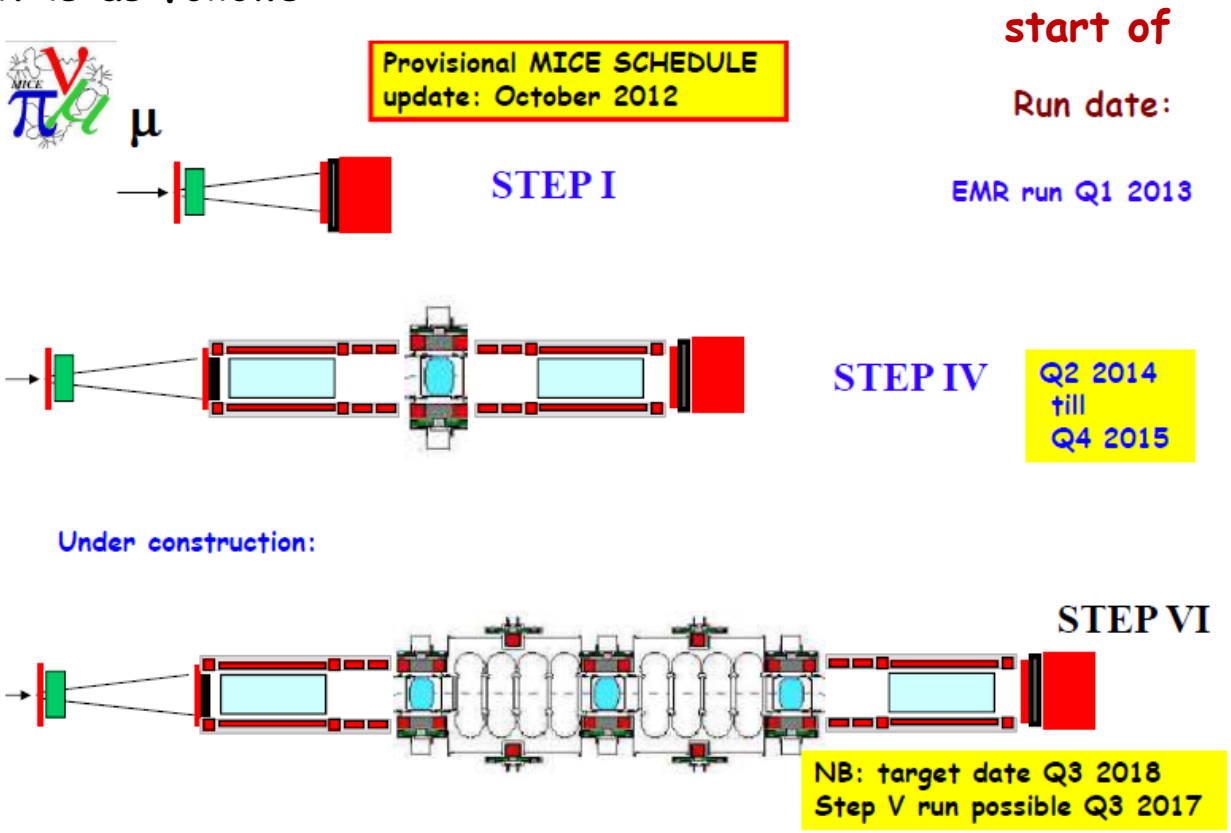
-- three people with engineering profile who are able to cover for the
-- liquid hydrogen
-- cryogenics
-- superconducting and conventional magnets and their controls

at present there is no explicit means of support

4. Make a single integrated resource loaded schedule for the production, assembly, installation and commissioning of all components, and present at the next MPB. Link this schedule with the available budget.

This has been an joined effort by the UK and US project teams. The result was discussed by A. Nichols, K. Long and M. Palmer. Great progress for the project.

The main result is as follows



Comments

Step IV

The breakdown of delays with respect to the previous (MPB3) schedule is as follows:

+ 4 months for warmups and retrainings of SS1 following the mishaps.
+ 2 months for full implementation of controls, monitoring and alarms
+ 2 months for surface shipping
+ 3x5 weeks for re-training the magnets at RAL

Which totals up to ~12 months

Most of this is the consequence of learning how the magnet behaves.

Some recovery can be envisaged

-- careful planning of shipping could recover part of 2 months

-- running the end-coils at their operating current (rather than solenoid current) will possibly save time and helium on the trainings (trim Power Supply)

-- considering if magnetic field measurements in situ may be postponed (risk?)

But -- any new incident would cost at least 2 months

-- magnetic field mitigation is not home-free yet

Step VI to run in second half of 2018

Analysis of the longer time estimate with respect to MPB3 is as follows:
-- the test of the first cold mass has been delayed by 6 months.
-- the preparation of fabrication drawings for the cryostats is almost one year later.
-- the construction time for the cryostats is longer (9 months instead of 6)
-- the integration time is also longer (15 months instead of 12)
Spectrometer solenoid 'incidents' have had an impact.

Time recovery possibilities for step VI involve

-- use of MUCOOL magnet as MICE CC 2 . This requires
  -- MUCOOL program to be completed in 18 Months
  -- MUCOOL magnet to be operational with cryocoolers.
  -- could save O(6 months) and a lot of resources

-- new collaborator performs e.g. integration task for the MICE magnets
  -- discussion has started with the CERN ATLAS magnet group,
  -- careful planning and job description needed

Step V could be assembled to run in the second half of 2017

Please make use of the "single integrated resource loaded schedule" of recommendation 4 (wherever possible), to respond to the following questions:

A) Define the "project success" scope for MICE. Describe an alternative "off-ramp" definition of success at Stage V, as well as a punch list of potential achievements at Step VI.

Progress success scope for MICE

Facilities based on muon storage rings have been advocated for several physics applications of great interest with discovery potential

A. nuSTORM: 10^{11} μ/s storage ring: (<1%) ν_e ν_μ $\bar{\nu}_e$ $\bar{\nu}_\mu$ x-sections and $\nu_{sterile}$ search

B. neutrino factory: 10^{14} μ/s storage ring precision study of CPviolation, unitarity

C. Precision muon collider Higgs factory studies of X(125.5), H/A system (if there) ultra-precise measurements of any new particles in 50-1000 GeV range

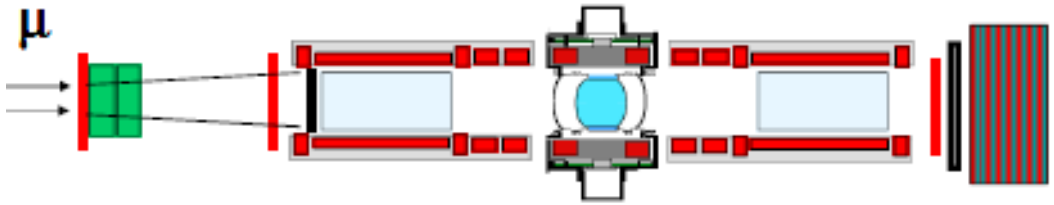
D. High energy muon collider: the most powerful envisaged machine to search the high energy frontier

For B C D the high intensity muons beams are generated and prepared in a powerful magnetic 'bottle', from the target solenoid all the way to the last stages of cooling. This magnetic 'bottle' consists of continuous magnetic field lines generated by a string of axial coils and solenoids.

This is the key to high intensity muon beams

MICE is such a magnetic 'bottle', from the diffuser to the end of the experiment. Cooling is the aim of the experiment but the lessons learned extend beyond that. (all the front end of the neutrino factory and muon collider)

MICE was designed to test the concept in stages with important results at each step



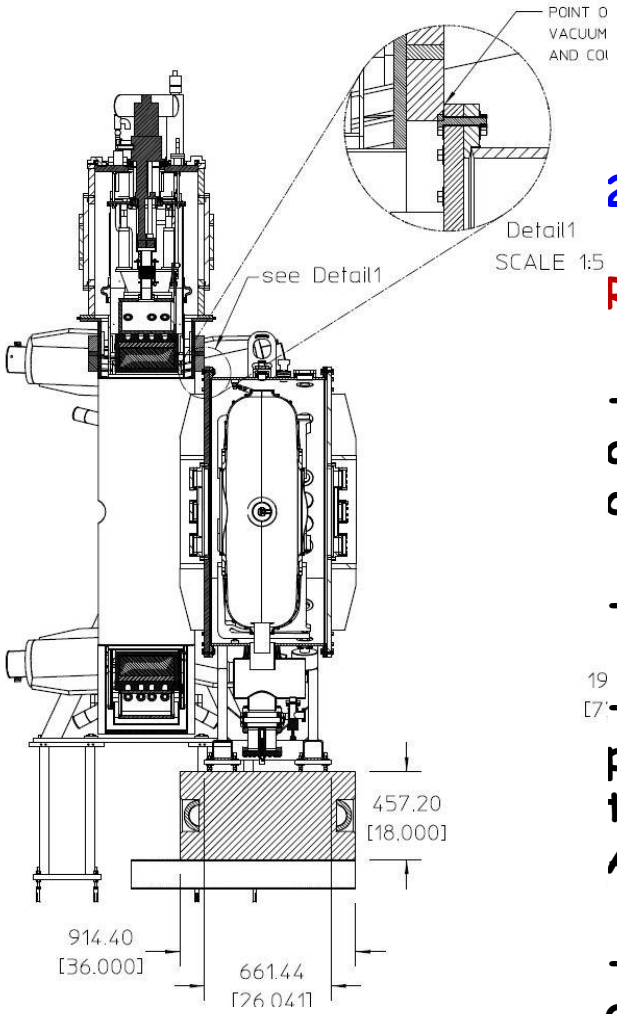
STEP IV

Step IV

1. The MICE step IV program will provide a number of important physics and methodological results:

-- Liquid hydrogen absorber realisation and safe routine operation
-- engineering test of beamline made of several magnetically connected components
-- understanding of propagation of (imperfect) beam through the magnetic bottle
-- complete particle detector system; calibrations of emittance measurement to $\pm 10^{-3}$
-- measurement of 6D emittance change (observation of normalized emittance cooling)
-- validation of simulation codes
-- limited possibility to test the longitudinal cooling with the wedge absorbers
-- correlated precision measurements of multiple scattering and energy loss straggling.

These measurements will constitute a textbook contribution to experimental particle physics, and will be essential for reliable simulation of the performance of neutrino factory and muon collider.



2. The MUCOOL program at Fermilab

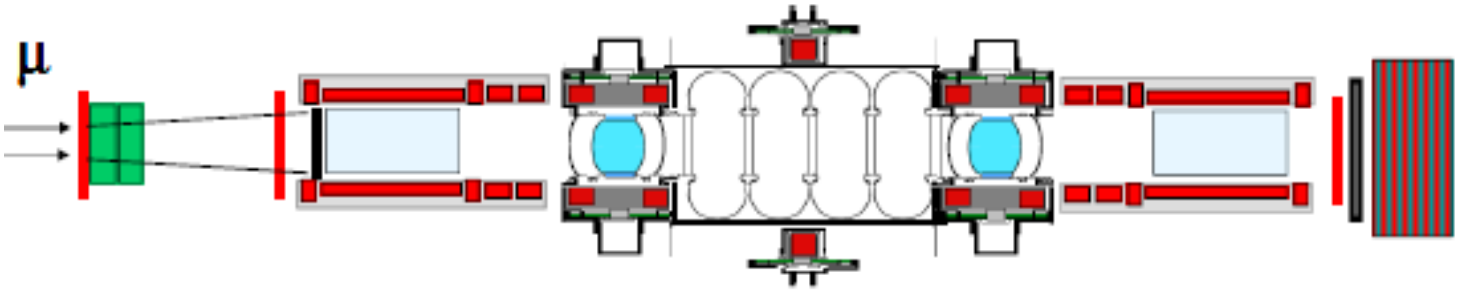
RF in magnetic field

-- will provide demonstration of the combined magnet and RF hardware that are required for a realistic cooling channel.

-- can operate up to 20MV/m

-- The U.S. effort presently has a major emphasis on preparing a prototype coupling coil magnet which can be tested with a 201 MHz RF cavity in the MuCool Test Area at Fermilab.

-- Upon successful completion of that test, it is anticipated that production hardware can be completed for the MICE beamline. (modified if necessary)



STEP V

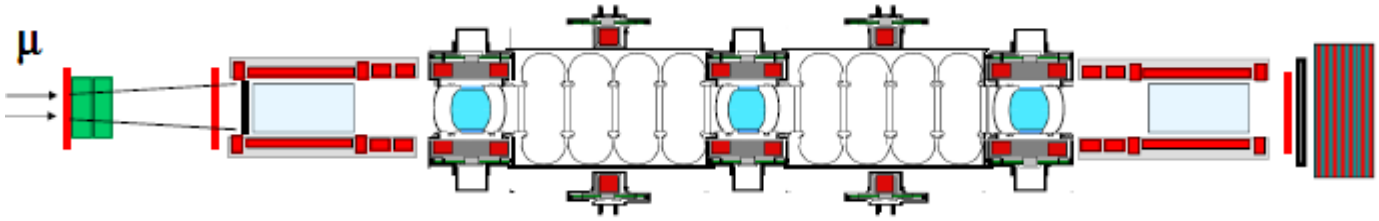
Step V

-- More difficult magnetic situation with one large 'coupling' coil

-- operation in magnetic field of 4-cavity RF module
(normally up to 8MV/m, on special arrangement up to 12 or 16)

-- verification of understanding of energy loss and RF acceleration
for particles up to large amplitudes and over all phases

-- First measurement of usable ionization cooling



STEP VI

-- operation of channel with all magnetic couplings in place.

-- full cooling cell allowing all optics configurations: flip, non-flip etc…

-- exact replenishment of energy possible

-- significant and measurable longitudinal heating

-- precise measurement of equilibrium emittance of various configurations

-- detailed and precise verification of simulation codes

The relative risks (and associated expenses) of step VI wrt Step V have been considered minor wrt to the extra time needed (18 months delay to step VI) and we have agreed (with MPB support) that the baseline option is to skip step V

MICE legacy

MICE will have achieved the first demonstration of ioniztion cooling and tested essential concepts for production of intense muon beams

It will have generated experience and know-how, bridging sometimes painfully a significant gap between the neutrino factory and muon collider dreams … and reality.
This will set future developments on firmer ground.

Once step VI is complete a powerful Cooling Test Facility is in place with

-- a quality muon beam
-- 8MW of 200 MHz RF power
-- 23MV of acceleration
-- infrastructure for 70 litres of liquid Hydrogen absorbers
-- instrumentation for precision 6D emittance measurements
-- a number of available magnets and associated infrastructure
-- and… a number of people who have made (most of) the mistakes already

a formidable asset that could be used for e.g. a 6D cooling experiment

Define the required timeliness of MICE results in co-ordination with "external" muon activities, including (but not only) the MAP R&D phase.

We have given the view point of MAP and of the European Neutrino community

MAP:
The U.S. program views the availability of MICE Step IV results, tests of MICE RF cavity operation in magnetic fields, and construction of a prototype MICE Coupling Coil magnet as high priority deliverables for Phase I of the feasibility assessment.

Commissioning of the first cooling channel by the conclusion of Phase II in late 2018 will be a critical contribution to the overall feasibility assessment for a future neutrino factory or muon collider.

It would be advantageous if a more aggressive MICE schedule could be achieved, but that appears completely unrealistic if the funding profiles remain as anticipated.

In Europe

"The European Strategy for Particle Physics must therefore provide for European participation in the programme required for a Neutrino Factory proposal to be prepared in time for the next update of the European Strategy. (i.e. 2018)

This programme must encompass:
-- The completion of the necessary hardware and system R&D including the MICE experiment;

Contributions of

EUROnu (European Design Study of future neutrino facilities
and
NEU2012 (Network of European accelerator based neutrino physicists)

to the European Neutrino Strategy for Particle Physis (KraKow meeting)

All converges to a timeliness date of 2018

Define a realistic flat-funding cost scenario, within the single integrated plan. Define a realistic end date for Step VI based on flat-funding. Define a date on which Step V would be achieved, if it were not to be skipped. Discuss the possibilities of additional sources of future funding that would affect the "scope and timeliness" issues.

As was discussed earlier, with flat flat funding and within the stated assumptions

STEP VI could start data taking in second half of 2018
STEP V could start in second half of 2017

We see possible ways to bring this forward (e.g. using MUCOOL magnet as MICE CC2) and risk that any incident will cause further delay because of lack of resources for mitigation.

Additional resources?
We have been in contact with the CERN ATLAS team who has supervised and commissioned a large system of coupled coils, the ATLAS barrel and endcap toroids. This would enrich the collaboration both in terms of the potential financial and manpower contribution but also in terms of experience. The exact terms of the collaboration need to be defined and discussed in agreement between MAP or DOE and the CERN management. We have just started.

Identify and quantify the main risks associated with the integrated plan

0. Very stretched funding: any technical incident ⇔ delay

1. Manpower issues

danger of attrition of the project if it lengthens
- **-- lose expertise of people moving on**
- **-- have to re-learn and this leads to a) time loss and b) mistakes**
- **-- lose enthusiasm of volunteer institutes**

2. controls monitoring, alarms (C&M) as an acute example of point 1,
C&M = last protection against damaging very expensive MICE equipment, setbacks and delays.

➔ each component of MICE should have one clearly identified person responsible for controls, monitoring and alarms (and not only for providing the hardware for it). At this moment the responsibility rests on one person only for the whole of MICE

3. MICE magnet system The transition from single magnets to full magnet system may be painful and associated with a number of 'glitches' and quenches.
We have added 5 weeks for retraining of the magnets, but we are anxious to see whether it happens at each time we have to change the magnetic configuration, such as (and in particular) the change from flip to non-flip mode

4. Magnetic field mitigation

-- Step IV baseline global shielding (GS) to relocate the sensitive equipment along the west hall (downstream of MICE) or behind the north shielding wall (where the RF should eventually go). ➔ risk to overlook some equipment that would turn out to be critical.

-- 'return yoke' solution is not engineered yet and could lead to significant expenses – and needed for step VI

-- recommended to obtain from ISIS usage of the ' plant room' next to the MICE hall is less risky.

5. Helium availability

6. RF project:

-- T116 availability remains a threat

-- expertise in the high power part of the amplifiers is scarce. It is important to establish a network of relations with ISIS and CERN to allow for occasional consultancy

-- RF in magnetic field is not a solved problem and could still cause a bad surprise either in the cavities themselves or in the couplers etc…

→ mitigation, operation of MICE RF cavity in the fringe field of MTA (2013) and MUCOOL testing program with full size magnet in 2015

7. Lack of staff on project for operations, as discussed earlier particularly with requisite accelerator operations experience for operation of the cooling channel, magnets and RF cavities. The operation-dedicated staff is at this moment not funded.

Conclusions

1. There is great progress all over MICE (LH2, DAQ, FC,…)

2. We have had a serious setback in the schedule with the Spectrometer solenoid – yet SS1 has reached full field (but is not operational yet)

3. MICE (UK+US) have produced a resource loaded schedule to step VI. This is big progress!

4. This places Step VI at the limit of timeliness in 2018.
Still step VI and its experimental richness and thourough testing abilities is the goal of the experiment. We could consider having a stop-over at stepV – but only if we absolutely have to – now is *not* the moment to decide.

5. There are a few ideas on how to improve the schedule within the envelope.

6. There are many risks to the schedule most of which related to the lack of manpower and resources. Any glitch leads to delays.

7. The most efficient solution remains application of appropriate and well targeted influx of manpower: highly beneficial and we believe economical in the long run.

8. The MICE team remains proudly dedicated to achieving the first demonstration of ionization cooling.