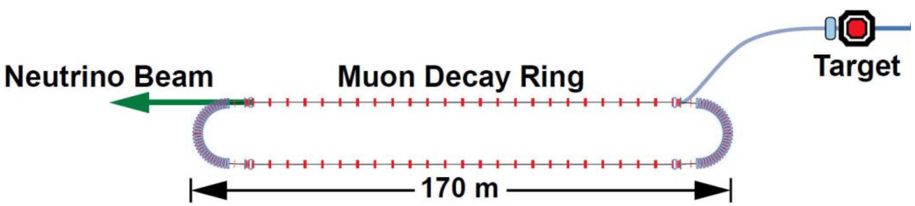
MICE at STFC-RAL

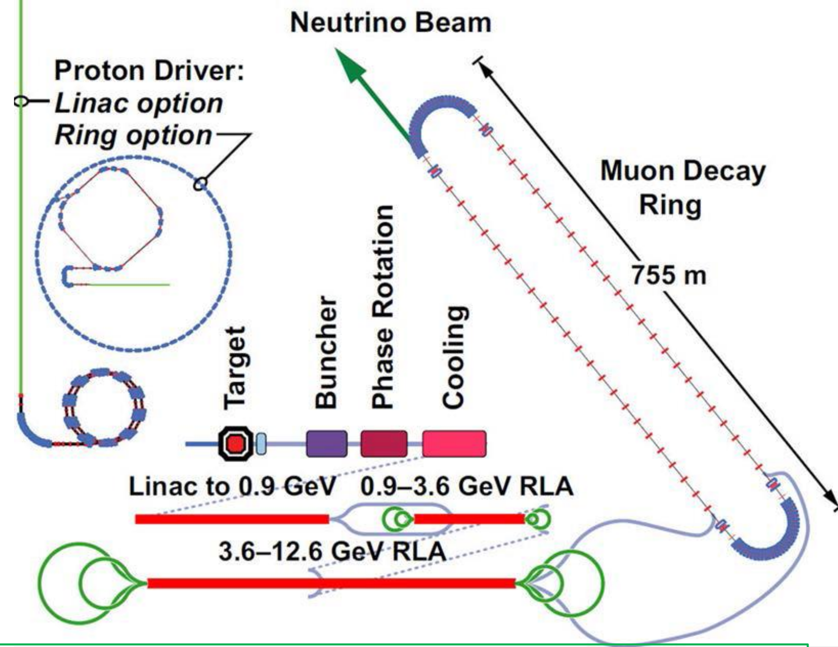
The International Muon Ionization Cooling Experiment

-- Design, engineer and build a section of cooling channel capable of giving the desired performance for a Neutrino Factory;

-- Place it in a muon beam and measure its performance in various modes of operation and beam conditions, thereby investigating the limits and practicality of cooling.

Muon storage rings

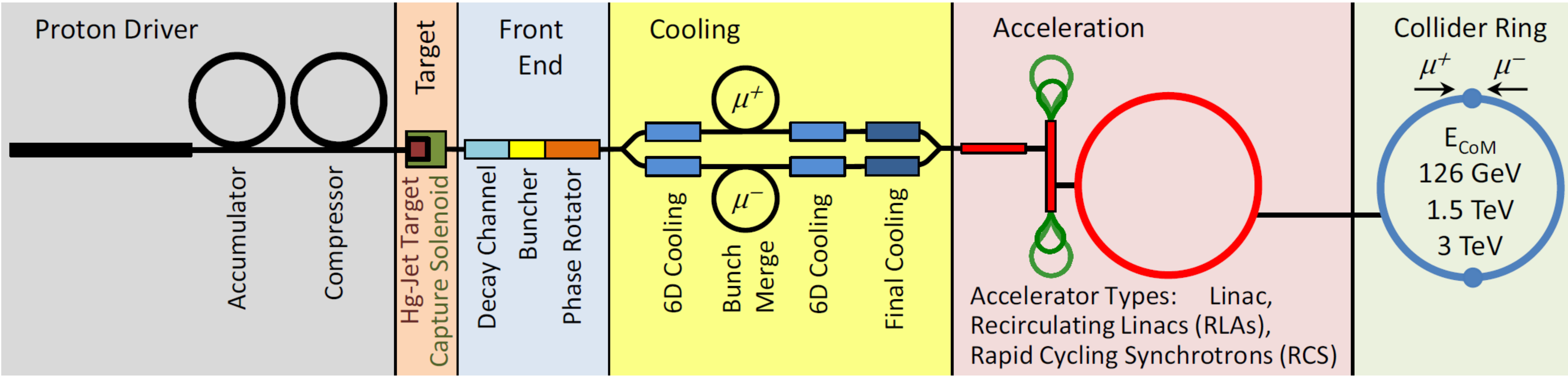




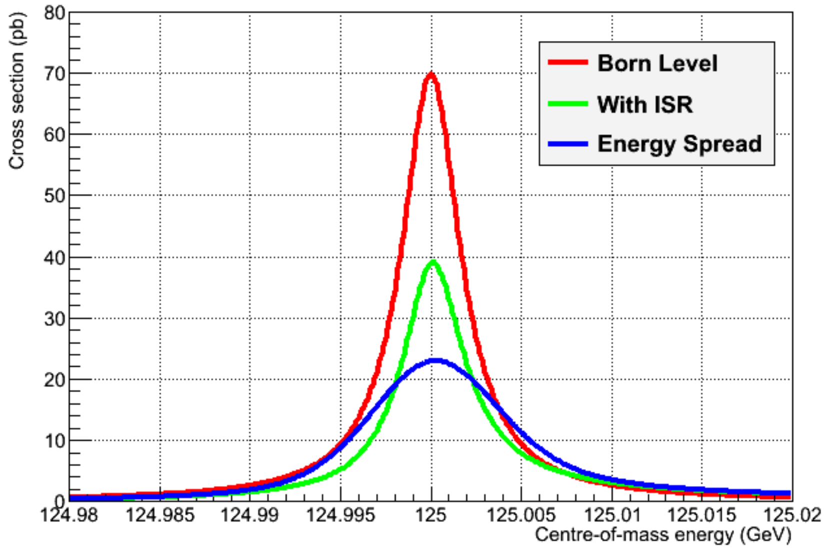
nuSTORM: 10^{11} μ/s storage ring:
(<1%) $\nu_e\ \nu_\mu\ \bar{\nu}_e\ \bar{\nu}_\mu$ x-sections and $\nu_{sterile}$ search

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

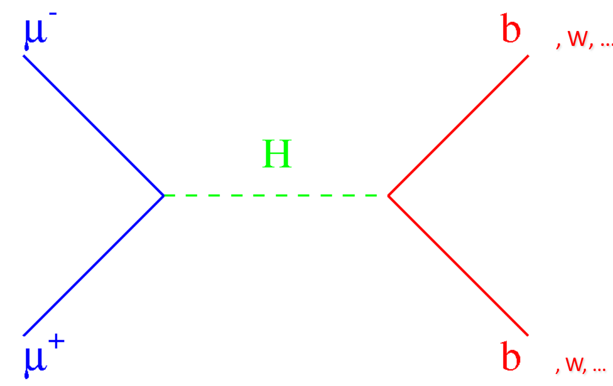
Precision muon collider Higgs factory studies of H(126), H/A system
ultra-precise measurements of any new particles in 50-1000 GeV range
High energy muon collider most powerful energy frontier machine



$\mu^+ \mu^-$ Higgs factory



$\sigma E/E$ = 0.003% (σE ~ 3.6 MeV, Γ_H ~ 4 MeV)

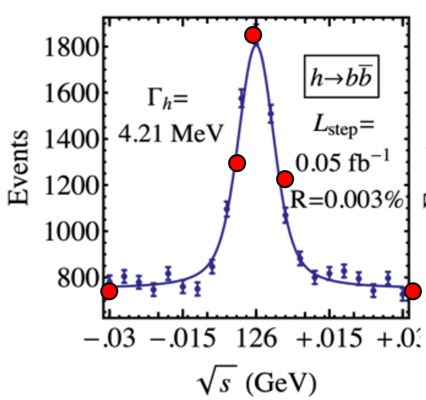


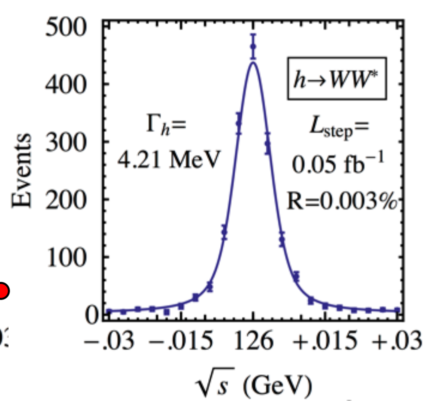
Unique: s-channel production

Can 'see' the Higgs width and identify if it is a single resonance.

Exquisite energy and energy spread measurement from muon g-2 precession

Requires $\sigma E/E$ ~ 0.003%
Longitudinal cooling!

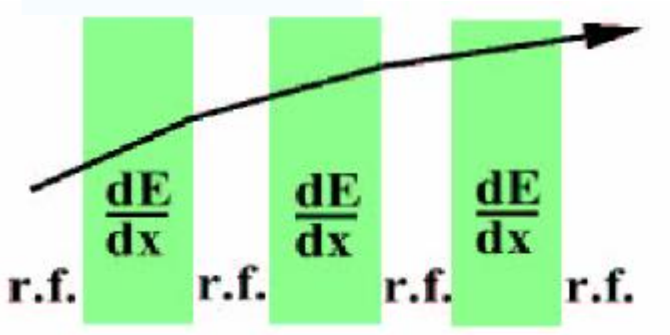




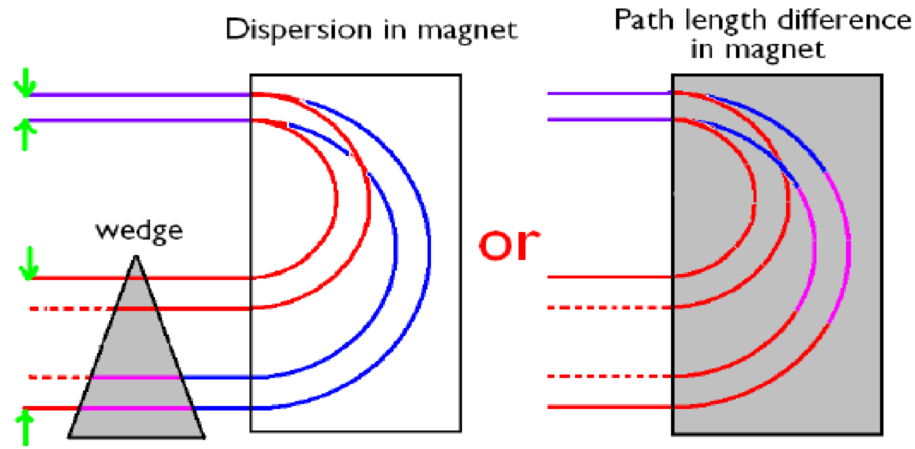
Performance similar to e+e- colliders…
feasibility and cost?

COOLING -- Principle is straightforward…

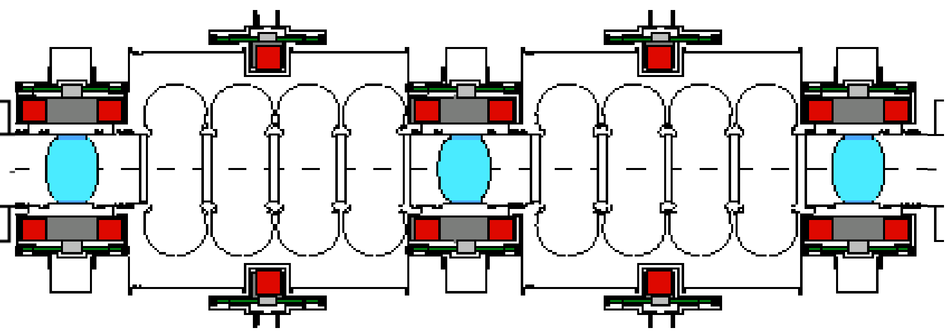
Transverse:



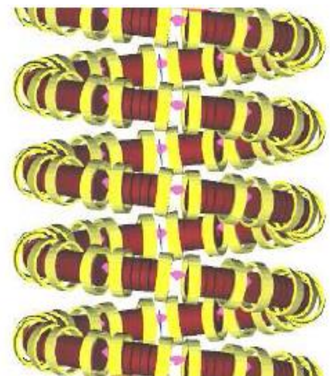
Longitudinal:



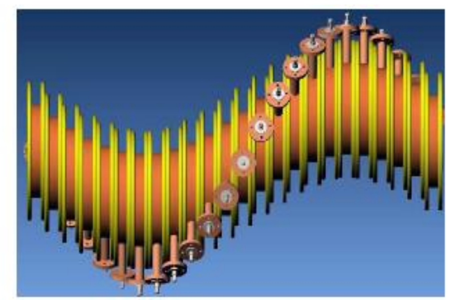
Practical realization is not!



MICE cooling channel (4D cooling)

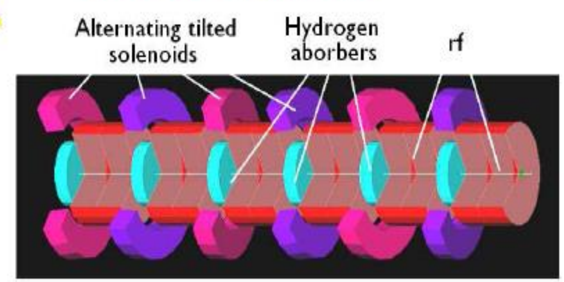


Guggenheim



Helical Cooling Channel

Snake



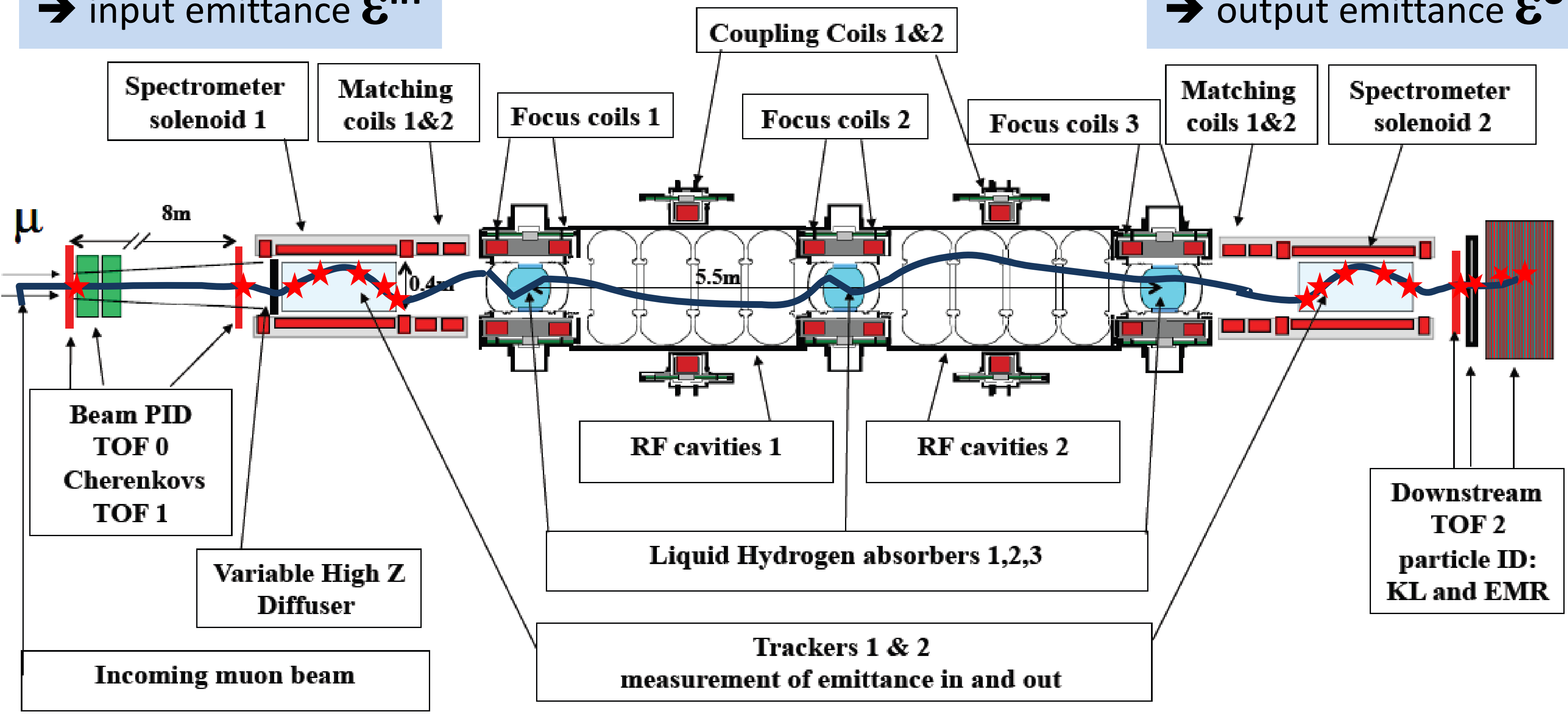
6D candidate cooling lattices

MICE the Muon Ionization Cooling Experiment

Measure input particle
x,x',y,y', t, t'=E/Pz
➔ input emittance ε^{in}

➔ COOLING CHANNEL ➔

Measure output particle
x,x',y,y', t, t'=E/Pz
➔ output emittance ε^{out}



Particle by particle measurement, then accumulate few 10^5 muons
➔ $\Delta[(\varepsilon^{in} - \varepsilon^{out})/\varepsilon^{in}] = 10^{-3}$

MICE STEPS

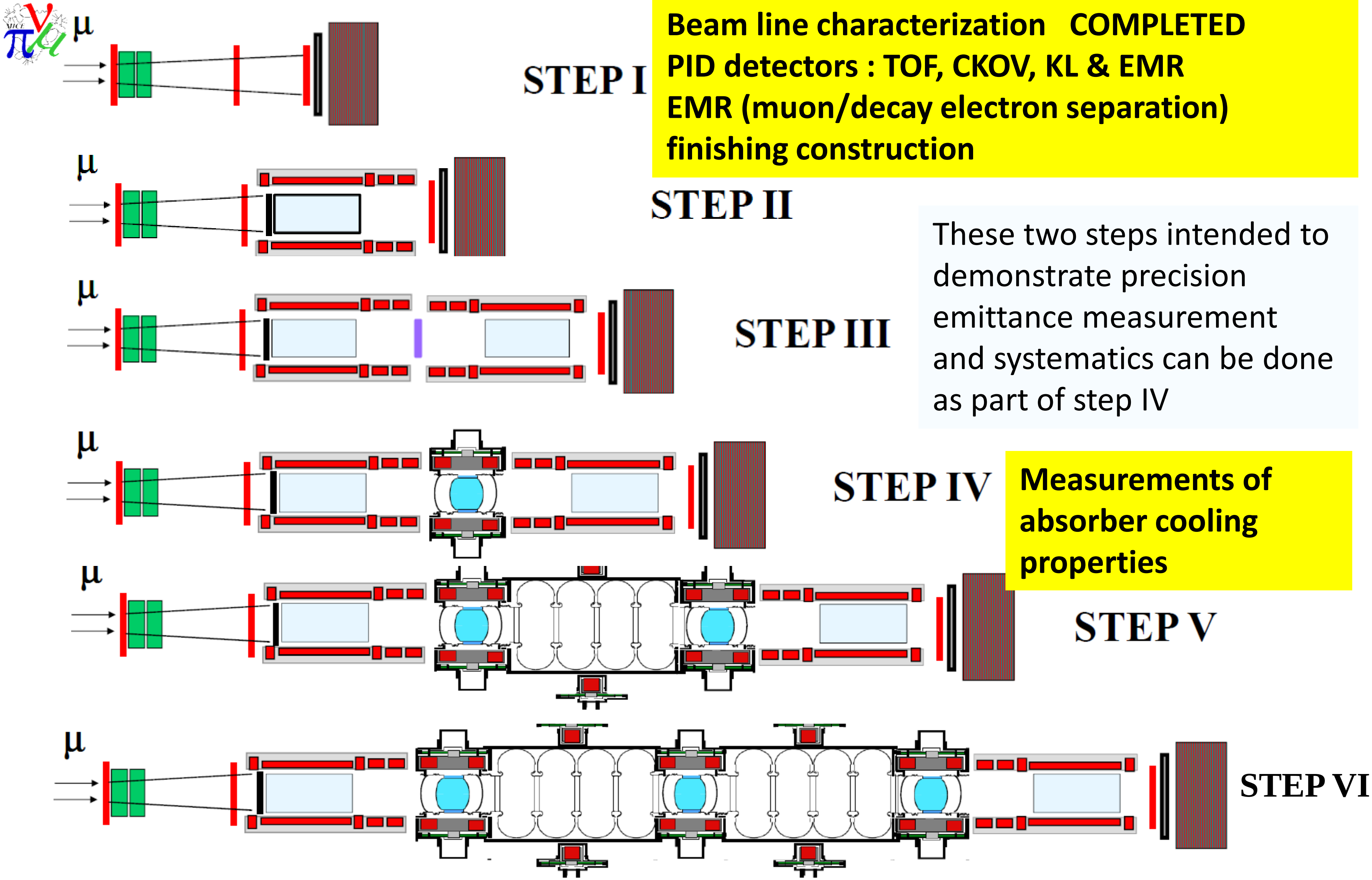
For Neutrino Factories and muon colliders the high intensity muons beams are generated and prepared in a powerful magnetic 'bottle', from the target solenoid all the way to the last stages of cooling. This magnetic 'bottle' consists of continuous magnetic field lines generated by a string of axial coils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

Both for funding and science reasons MICE is executed in Steps ....
Originally we had 6 Steps

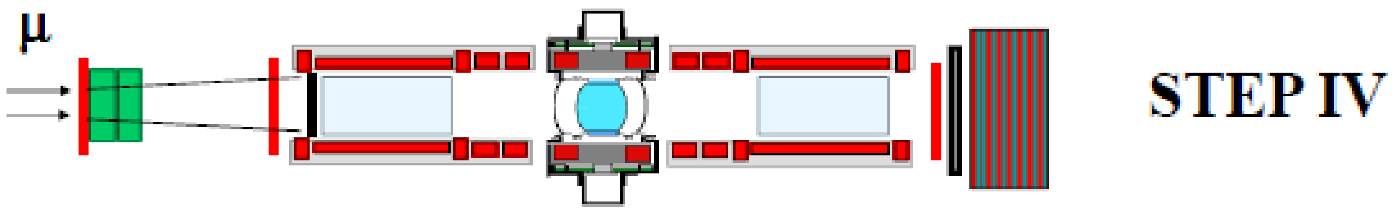


Beam line characterization COMPLETED
PID detectors : TOF, CKOV, KL & EMR
EMR (muon/decay electron separation) finishing construction

These two steps intended to demonstrate precision emittance measurement and systematics can be done as part of step IV

Measurements of absorber cooling properties

Steps V and VI feature room temp RF cavities in magnetic field (8MV/m).
Step VI is one full cooling cell , in which we can full replenish the muon energy, and test a full set of optics configurations



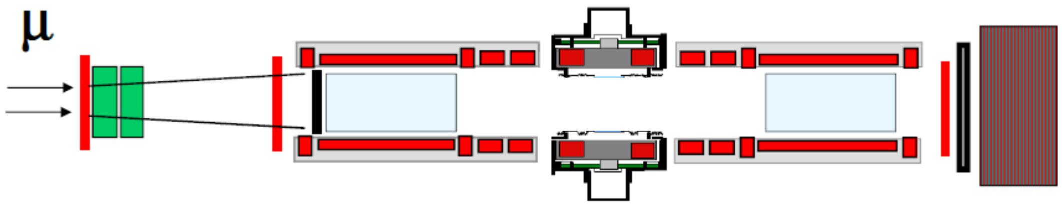
Step IV

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.

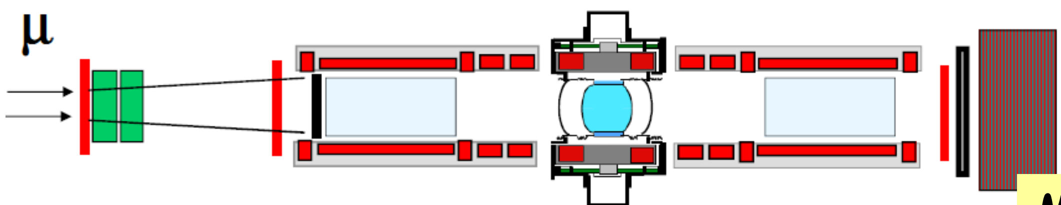
These measurements will constitute a textbook contribution to experimental particle physics, and will be essential for reliable simulation of the performance of neutrino factory and muon collider.

Within step IV:



STEP IV

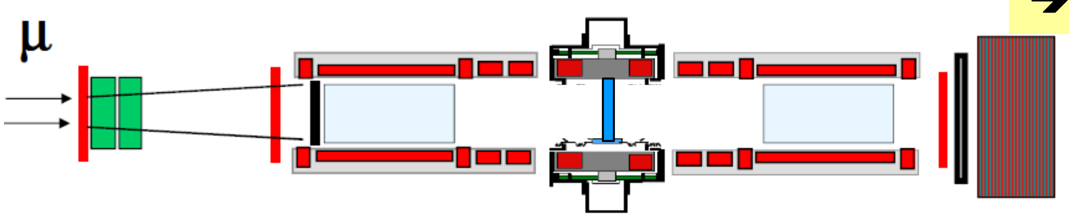
No absorber
--No magnetic field:
Alignment
--With magnetic field
optics studies



STEP IV

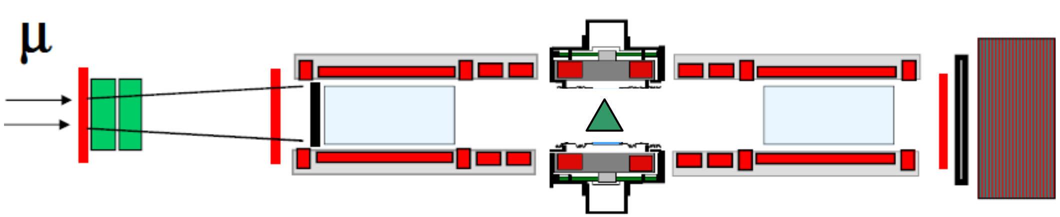
Liq H_2 absorber
(full/empty)

Multiple scattering
Energy loss
➔ Cooling



STEP IV

Solid absorber(s)
LiH
Plastic
C, Al, Cu

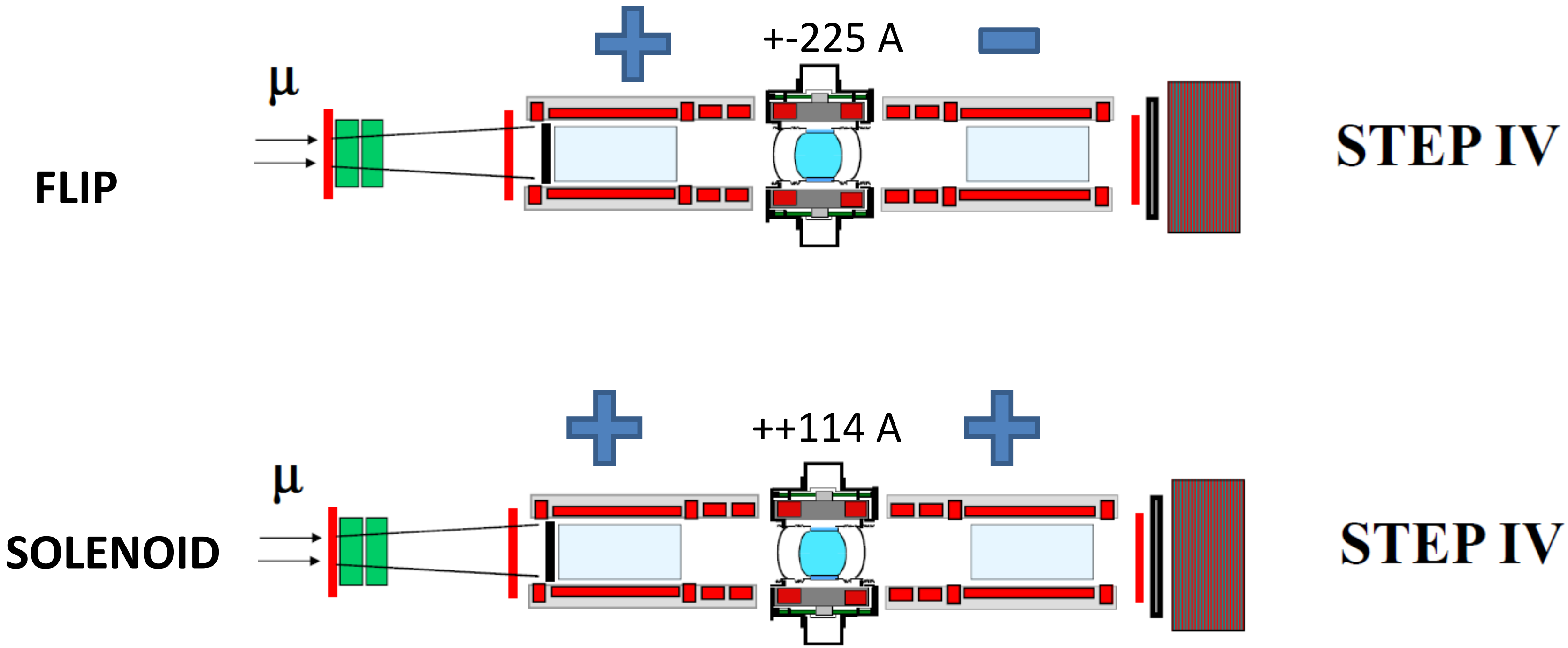


STEP IV

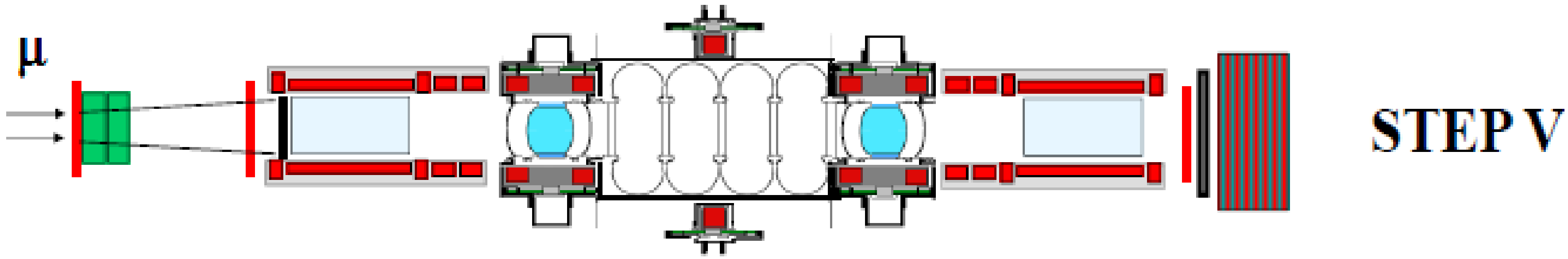
Wedge absorber(s)
LiH
Emittance exchange

Count 2 weeks to change absorbers

A running schedule unknown



We plan to run both configurations
will the AFC magnet need re-training,
and how long should we allow for this?



Step V

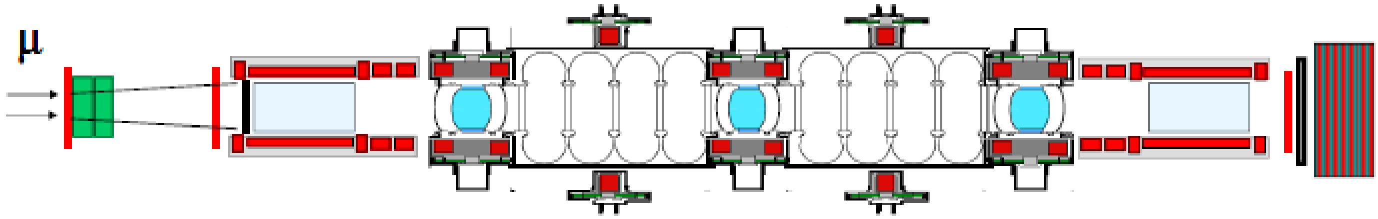
-- More difficult magnetic situation with one large 'coupling' coil

-- operation in magnetic field of 4-cavity RF module
--normally up to 8MV/m,
--on special arrangement up to 12 or 16 (risky and not designed)

-- 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

-- many things we can't do (wedge, etc..)



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.

Status of MICE (much progress -- one slide!)

1. Upstream Spectrometer Solenoid controls have been reviewed. Magnet trained and now ready for mapping.
End plates shipped, mapper re-boxed in, operation planned
Downstream magnet construction is nearly complete.

2. Focus coil has reached nominal field in solenoid mode
and is presently up at 180 A in flip mode.

3. Coupling coil cold mass leak has been repaired , now at Fermilab for testing. Cooling down.! Plan exists for construction of cryostats and assembly.

4. Considerable efforts have gone into understanding of stray magnetic fields and how to cope with them. MICE has obtained new rack room space away from magnetic field. Return yoke has been worked out.

5. EMR construction nearly finished. Testing underway.

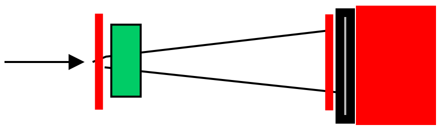
6. Careful resource loaded schedule was performed by MICE project teams UK+US.

7. MICE papers on beam particle composition and beam emittance are circulated

μ

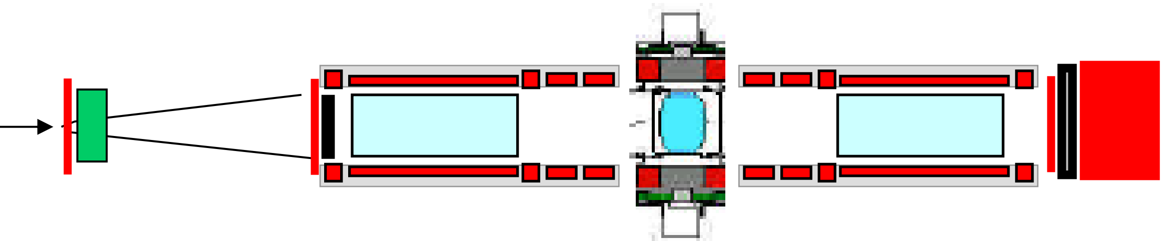
Provisional MICE SCHEDULE update: May 2013

Run date:



STEP I

EMR run July 2013

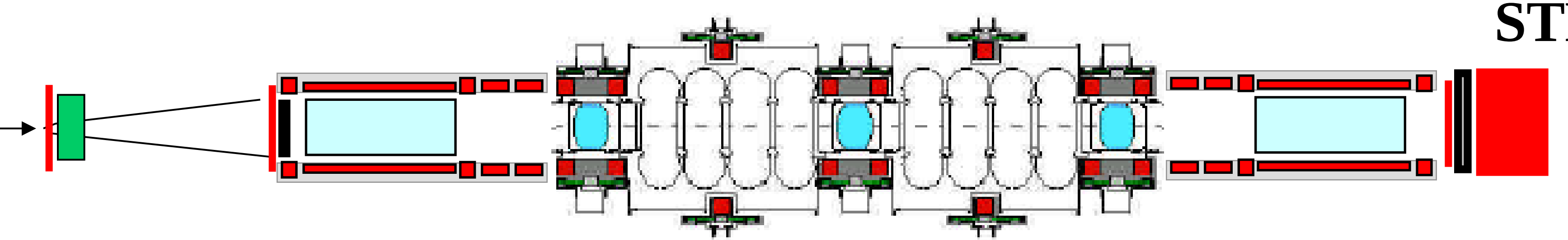


STEP IV

(Q2 2014, no field)
Q1 2015 to Q1 2016

Under construction:

STEP VI



Possible Step V run Q4 2017
Step VI 2019

MICE Resource Loaded Schedule.

In spite of MPB recommendation and MICE project efforts,
it will not be possible to run stepIV before the long ISIS shut down.

-- efforts have been made to streamline the program

-- pushing off TIARA installation, LH2 commissionning or EMR run would not save enough time and would cause considerable problems later.

-- need to include 5 weeks training of each

- -- SS2,
- -- SS1,
- -- combined system SS2+AFC1+SS2
- -- surprises are possible, better not rush it!

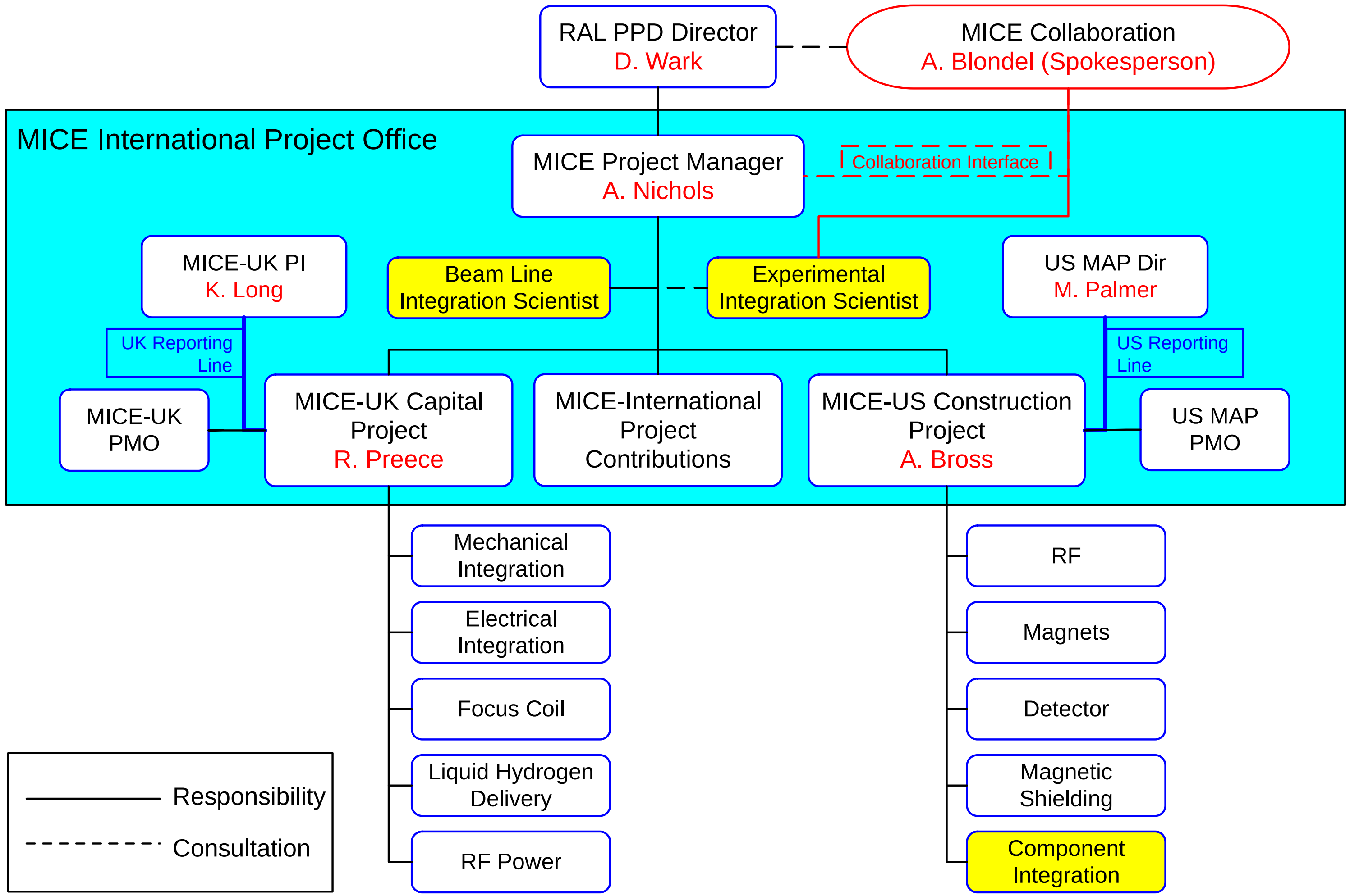
-- 2 month delay with respect to previous schedule results from need to move racks and compressors, modify MICE hall mezzanines, etc..

-- new rack and control room will be implemented

-- running MICE detectors in place with no magnetic field in Q2 2014 is an interesting possibility (integration of detectors and system, alignment). will save lots of time at later stage.

Draft: 02/2013 Rev. E

MICE International Project Team



Important decision points

-- September 2013: installation of return yokes for step IV

why not decide now?

--original motivation of baseline plan is to run step IV before Q3 2014

-- it is not certain that the tracker readout can be properly shielded (cryocooler, electronics) without return yoke

-- the cost and schedule implications of yoke implementation need to be understood

-- Around summer 2015 :

-- decision point for possible step V stop-over in 2017-2018

-- implementation of full return Yoke for step V/VI

MPB4 recommandations

Recommendations

MAGNETS

1. Ensure that instrumentation and monitoring systems are in place before re-testing the spectrometer magnet. ➔ see P. Hanlet's talk

2. Maintain the pressure to find a solution to the stray field problem – ideally one that would apply both to Step IV and to Step VI. ➔ see K. Long's talk

3. Study and resolve the best understanding possible for the HTS lead deterioration in the failures discovered in SS1, for presentation at the next MPB meeting.
➔ see S. Gourlay's talk

4. Make a full mechanical analysis of the magnet system with the new fringe field mitigation elements, covering both steady state and transient (powering, quench, etc.) operations in a realistic environment (mechanical tolerances, relief valves sizing, etc.). At least "check off" all the root causes that contributed to recent SC magnet failures in complicated systems. Present the analysis at the next MPB meeting.

Response: this will partly be included in the description of the stray field issues by Ken Long. This point will emphasized in a detailed review in August 2013 prior to final decision on step IV stray field mitigation plan

5. Initiate a small but quick QC program testing Luvata superconductor samples for the CC, as soon as possible.   DONE

6. If the first CC cryostat is assembled at Fermilab, avoid a re-learning curve by investigating different assembly solutions.   ➔ See Steve Gourlay's talk

RF

1. Present a list of requirements and a design proposal for the LLRF at the next MPB meeting.

➔ See presentation by Kevin Ronald C/O Colin Whyte