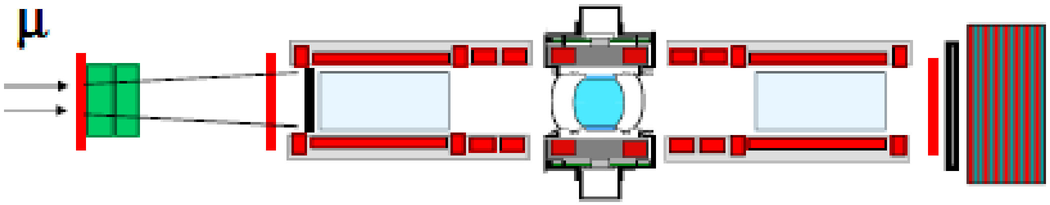
« STEP IV operations : Physics »

(one of the) Request from MPB

- Establish a set of criteria for the demonstration of the successful conclusion of Step IV for the autumn. *(NB these are acceptance criteria of the constructed apparatus)*
  Blondel + Analysis group

The following is a fist go at answering this question.
If possible we should be able to show simulation of some of the results

MICE note 432



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.

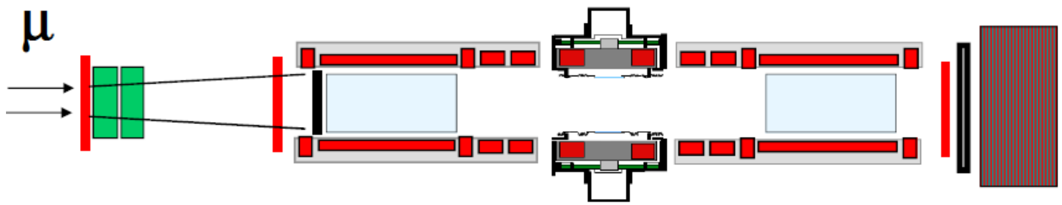
Presentation of Step IV

The MICE step IV program aims at providing important physics and methodological results:

- Engineering test of beam line made of several magnetically connected components;
- Liquid hydrogen absorber realization and safe routine operation;
- Understanding of the propagation of (imperfect) beam through the magnetic channel;
- Operate a complete particle detector system; amplitude reduction and emittance measurements to $\pm 10^{-3}$ precision with systematic errors cross-calibrated by the two spectrometers and completed by TOF and EMR range measurements.
- Measure the equilibrium emittance of a given set-up of momentum, beta-function and absorber material, by varying the input emittance.
- Explore for a set of three beta functions and three momenta
- measurement of 4D and 6D emittance change
- limited possibility to test the longitudinal cooling with the wedge absorbers
- correlated measurements of multiple scattering and energy loss straggling

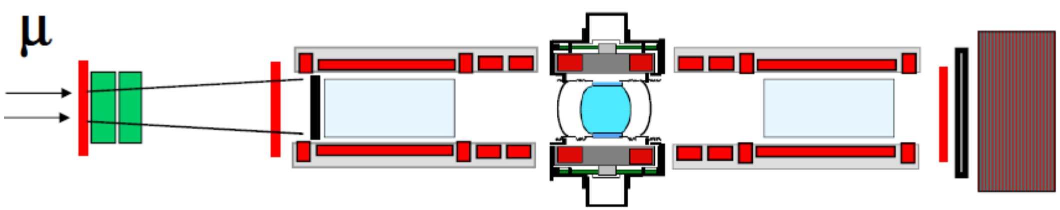
These measurements will constitute a textbook contribution to experimental particle physics, and will be essential for reliable simulation of neutrino factory and muon collider.

STEP IV EXPERIMENTS (2015-2016)



STEP IV

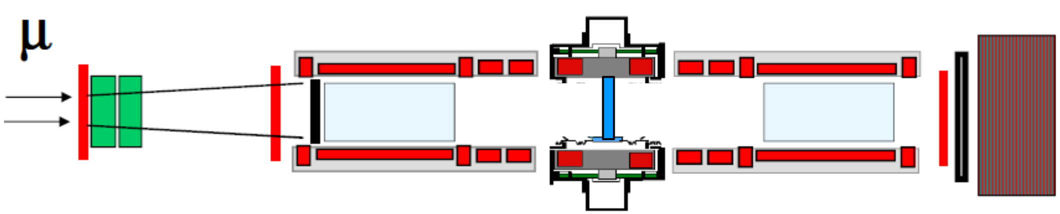
No absorber
Alignment
Optics studies



STEP IV

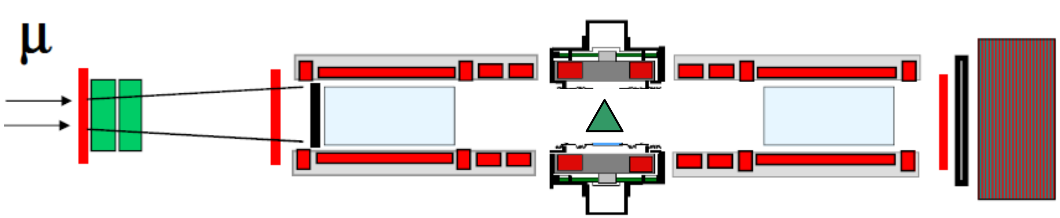
Liq H_2 absorber
(full/empty)

Multiple scattering
Energy loss
➔ Cooling



STEP IV

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

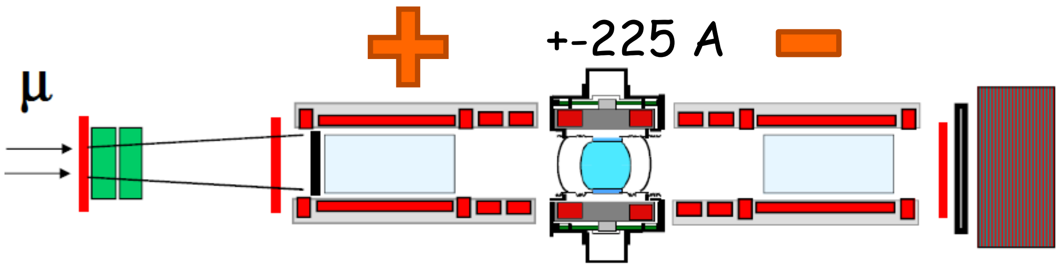


STEP IV

LiH Wedge absorber
Emittance exchange

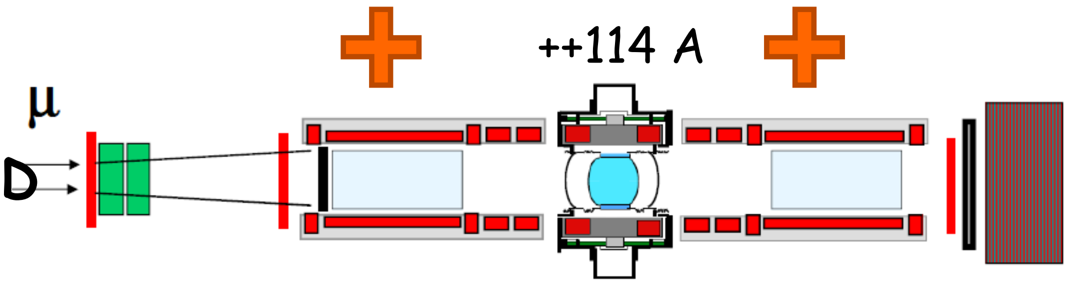
A running schedule unknown

FLIP



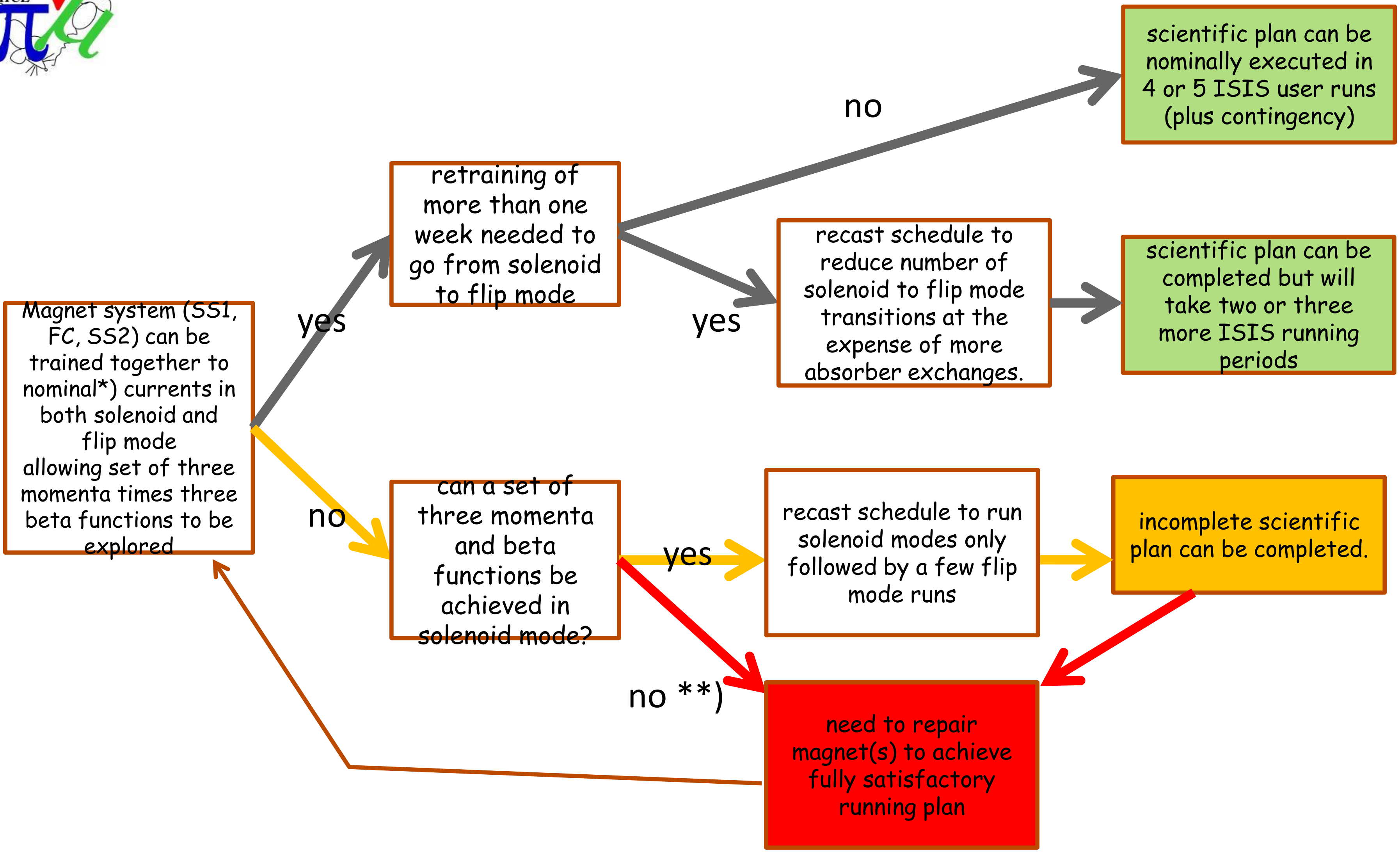
STEP IV

SOLENOID



STEP IV

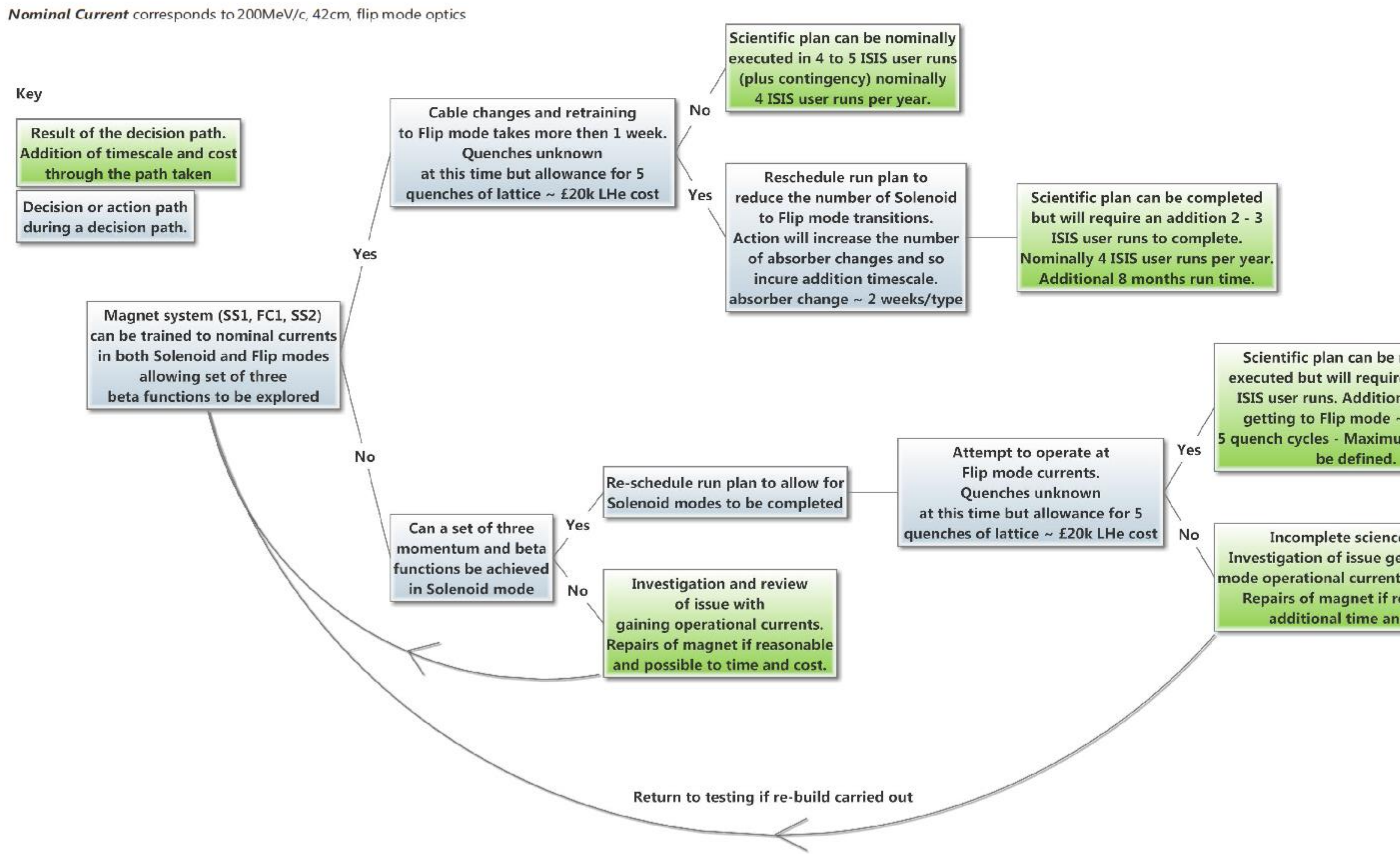
We plan to run both configurations
will the AFC magnet need re-training,
and how long should we allow for this?



*) nominal currents correspond to 200 MeV/c, 42 cm, flip mode optics

**) more precise assessment of the situation is needed before following red routes (which currents are achieved and what optics can be reached, etc..)

in the RSLR document:



MICE-Note-Gen-432
October 2013
Alain Blondel

Criteria for successful experiment at Step IV

MPB (May 2013): Establish a set of criteria for the demonstration of the successful conclusion of Step IV.

Summary:

The criteria for the demonstration of the successful conclusion of Step **IV** can be listed as follows.

- Successful operation the cooling channel and of the instrumentation, of its controls and monitoring, and of the system designed to deliver the data and to record them.
- Ability to provide before data taking: operational online reconstruction, standard calibration procedures and simulation of the experiments.
- Ability to execute a data taking campaign leading to the following results:
    - Demonstration of transmission and emittance measurements to required precision of 10^{-3}

procedures and simulation of the experiments.

- Ability to execute a data taking campaign leading to the following results:
  - Demonstration of transmission and emittance measurements to required precision of 10^{-3}
  - Demonstration of the reduction of particle amplitudes and beam emittance of a μ^+ beam, for a nominal setting of {momentum, beta function at the absorber, input emittance}, in both "flip mode" and "solenoid mode", and for one of the minimal set of absorbers: Liquid Hydrogen, LiH, plastic. (At present this nominal setting is 200 MeV/c, 42cm, 6mm emittance).
  - As a consequence, demonstrate that one can increase the number of muons within a given $\{r\text{-}p_\perp\}$ acceptance by ionisation cooling.
  - As a by-product, correlated measurements of multiple scattering and energy loss as function of momentum will be performed.
  - For each of the absorber materials the extraction of equilibrium emittance will be achieved by varying the input beam emittance.
  - Further exploration of a {3x3} matrix of momentum (up to 240 MeV/c) and beta functions (down to the minimal achievable) for each of the absorber materials.
  - If rates and time permit repeat measurements for negative beam polarity.
- Results will be published.

The following provides more details on the run plan and on the criteria for success.

Effect of reduced focus coil current on MICE steps IV and VI

MICE Note 434

C. T. Rogers

Abstract

During the commissioning of MICE focus coil 1, it was found that the focus coil failed to reach the specified currents. In particular, the focus coil failed to reach the current required for nominal running at 200 MeV/c, considered to be the MICE baseline. In this note, the consequences of operating the focus coil with reduced current are studied.

Momentum MeV/c	Focus coil current [A/mm^2] 102.56	113.95	136.74
140	104-332, 700-925	75-252, 456-979	32-92, 269-849
160	146-365	116-298	64-168, 469-601
180	186-407	155-342	100-229
200	224-450	192-385	136-278
220	257-493	226-425	169-319
240	356-535	306-463	215-356

Tab. 2: Range of matched β functions [mm] that can be achieved for different momenta and focus coil currents. Note that for low momentum settings there are two distinct β ranges that can be accessed.

step IV experiments:

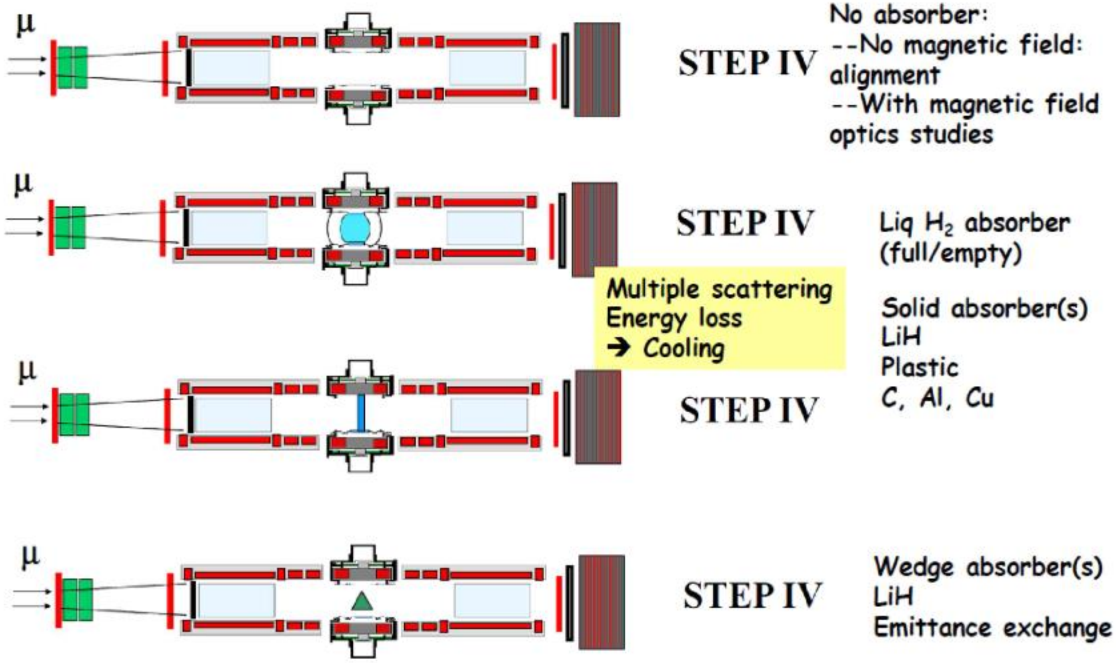


Figure 1 : MICE step IV experimental programme.

Normally, the measurements will proceed in the order described in Figure 1. This implies that the full program of measurements, including the exploration of a matrix of momenta and beta functions, and for both flip and solenoid mode, has to be performed for each absorber setting before moving to the next one. There remains an unknown in this run plan: whether the change-over from solenoid to flip mode requires a full re-training of the magnets. If this were the case, the run plan would have to be modified (and certainly lengthened) accordingly.

Construction

All elements of MICE step IV hardware have to independently operate to specifications beforehand.

Commissionning and operations

Magnetic channel

- All magnetic configurations will be tested with complete apparatus; magnet currents well in excess of what is required for the {200 MeV/c, β=42cm} optics should be achieved, both in solenoid and in flip mode;
- magnetic field mitigation satisfactory for step IV should be in place;
- change-over from solenoid to flip mode should be tested.

Liquid Hydrogen absorber

- liquid hydrogen integrated in AFC and safe operation demonstrated;
- absorber change-over tested (from full to empty and vice versa, from liquid to solid).

Note that the change-overs of AFC&SS1 polarities as well as absorber exchanges are to be tested before data taking in order to ensure that no modification to the apparatus will be needed after the start of data taking.

Beam line, detectors, DAQ and controls

- beam line delivering a goal of 100 muons per ISIS spill at 140, 200, 240 meV/c settings and post-diffuser emittances of 3,6 10 mm (this has already largely been achieved);
- detectors and DAQ able to acquire data at or near that rate (this has not yet been achieved with tracker and EMR included);
- online reconstruction, as well as routine detector calibration procedures, tested and operational. To this effect a dry run without magnetic fields in 2014 would be highly beneficial;
- Controls and monitoring should be operational to safely and reliably control the magnets of the beamline and of MICE, the particle detectors and tracker, as well as the cooling channel elements.

Software and simulation: before going to physics runs the simulation software and analysis should be able to:

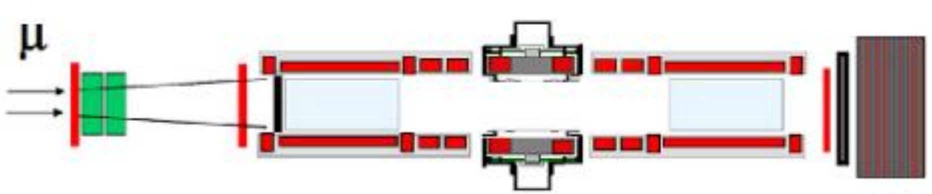
- Simulate the configurations that will be tested and provide a first prediction of the results;
- Ensure operational online reconstruction and calculation of results;
- Ensure proper archiving of data, their dissemination in the collaboration, and off-line analysis.

Data taking and physics results

The following goes through the experimental program of step IV and describes the accelerator and particle-matter interaction physics goals, whose achievements will constitute the gauge of success of MICE step IV.

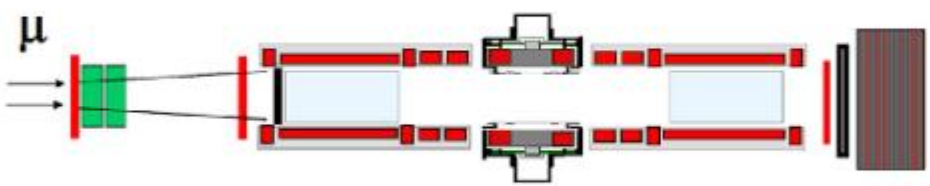
Physics run with empty diffuser and absorber and no magnetic field: (IV.0)

- successful operation of all detectors simultaneously up to a goal of 100 particles per ISIS spill
- alignment of tracker with straight particles going through to EMR
- successful global reconstruction
- verify Particle ID and particle selection



STEP IV

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



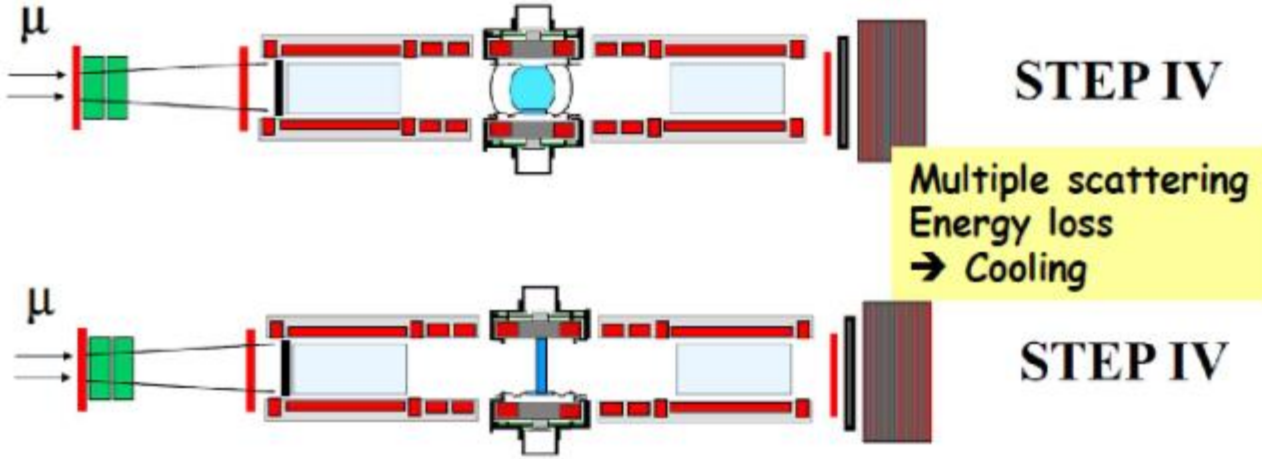
STEP IV

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

Run with diffuser and no or empty absorber and magnetic field: (IV.1)

This particular experiment reproduces the physics goals formerly assigned to 'step III'. The baseline configuration will normally be a 200 MeV/c positive muon beam with 6mm emittance generated in the diffuser, running through the channel in flip mode, 200MeV/c, 42cm optics.

- successful tracker reconstruction in magnetic field
- successful global reconstruction
- verify Particle ID and particle selection with a purity of 10^{-3}.
- comparison of tracker 1 and tracker 2 → determine detector resolutions;
- benchmark momentum scales of beam line, trackers, Time-of-flight and EMR range.
- determine properties of beam (alignments, momentum, dispersion, emittance)
- verify understanding of propagation through focus coil
- measure the transmission of the system starting from particles reconstructed in the first tracker within a given 'fiducial' acceptance.
- reconstruction of emittance 1, emittance 2 and comparison
- evaluation of systematic errors on measurement of amplitude reduction and emittance ratio
- goal: systematic errors should be below 10^{-3}
- test other diffuser and magnetic configurations



Liq H_2 absorber (full/empty)

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

Run with diffuser and LiqH2 absorber : (IV.2)

This is the nominal step IV.

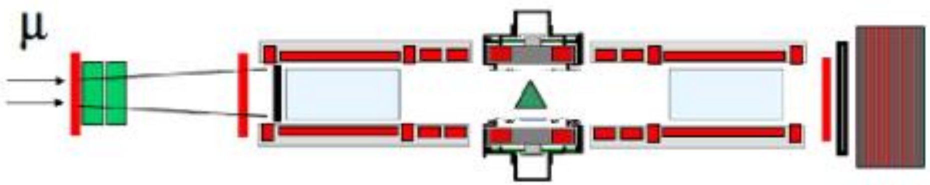
- take data with empty and full absorber
- measure transmission
- compare beam properties before and after absorber
- measure energy loss and its variance
- measure angular scattering and its variance
- measure energy-angle correlations
- measure particle amplitudes and emittance ratio
- determine equilibrium emittance by varying input beam emittance generated by diffuser
- explore results over a {3x3} matrix of momentum and beta function
- repeat for a matrix of emittances, momenta and beta functions, flip and non-flip modes.

Run with diffuser and solid absorbers : (IV.3)

same as above

Run with wedge absorber IV.4

- Requires a dedicated measurement of the beam horizontal dispersion and disposition of the wedge in such a way as to reduce it significantly.
- measure beam energy spread before and after wedge; establish 6D emittance change
- Verify the principal of emittance exchange by comparison with simulations.
- The experiment can be repeated for various optical configurations in solenoid mode.



STEP IV

Wedge absorber(s)
LiH
Emittance exchange

Conclusions and outlook

-- Criteria for success and a skeletton of run plan has been written for the Step IV running.

-- the wedge experiment needs a little more thinking because it adresses a new set of questions.

-- as all precision experiments is is paramount that the apparatus is stable during the running.

-- the plan is at the moment somewhat idealistic.

it must be backed up with

-- a set of optics

-- simulations

-- the performance of the system of magnets needs to be evaluated before one draws the final plan