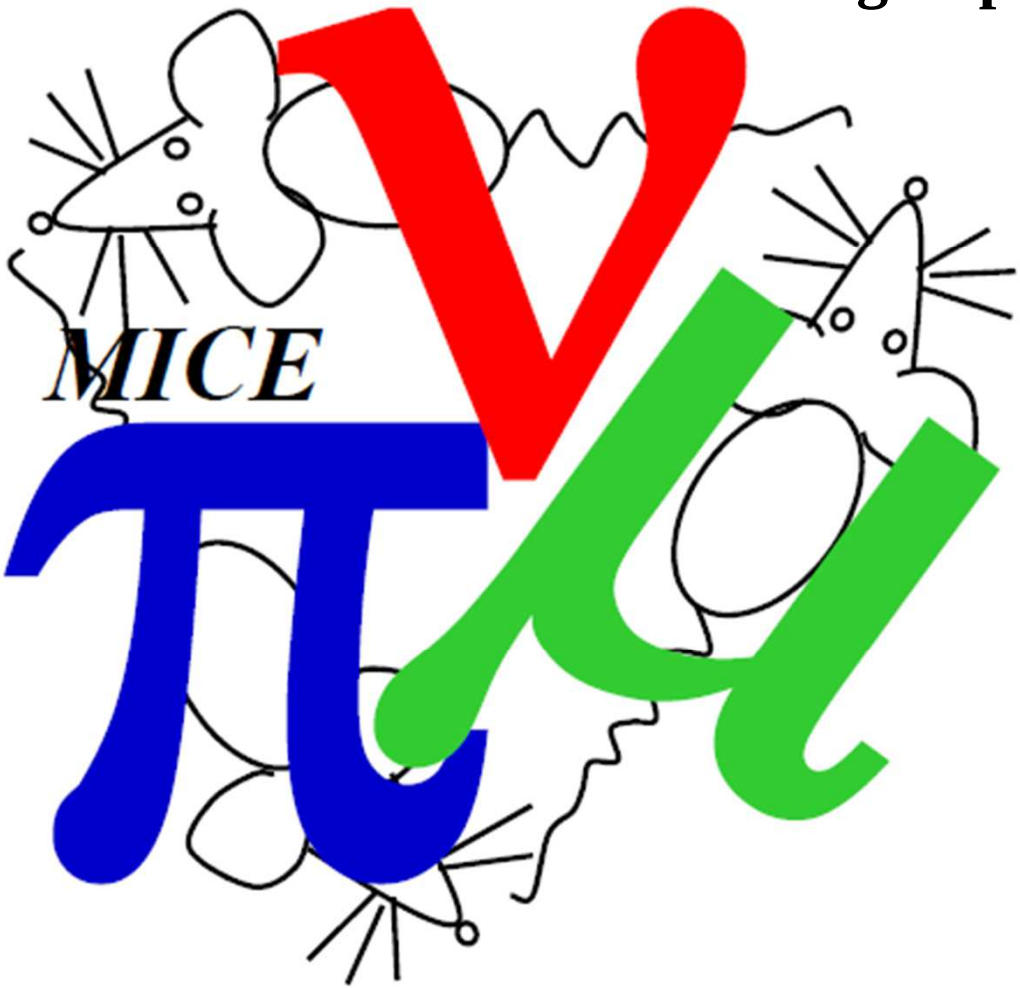
MICE at STFC-RAL

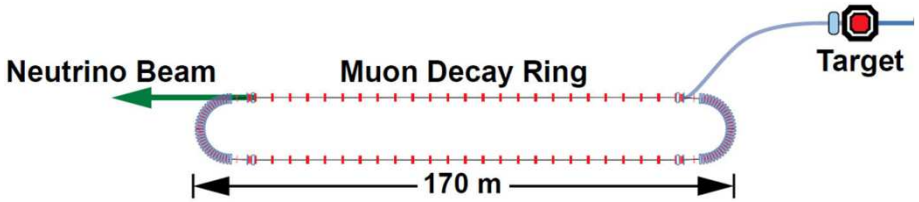
The International Muon Ionization Cooling Experiment

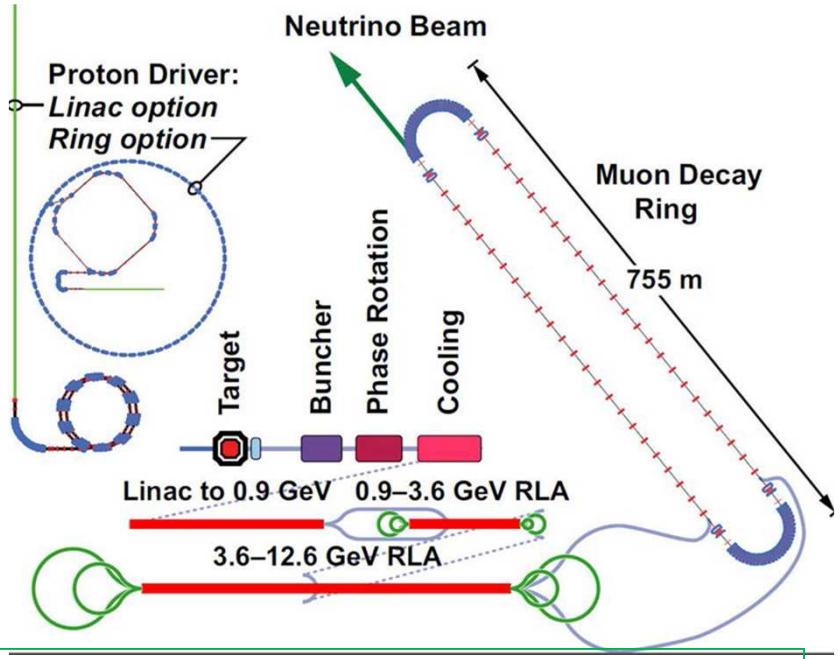


-- Design, engineer and build a section of cooling channel capable of giving the desired performance for a Neutrino Factory;

-- 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

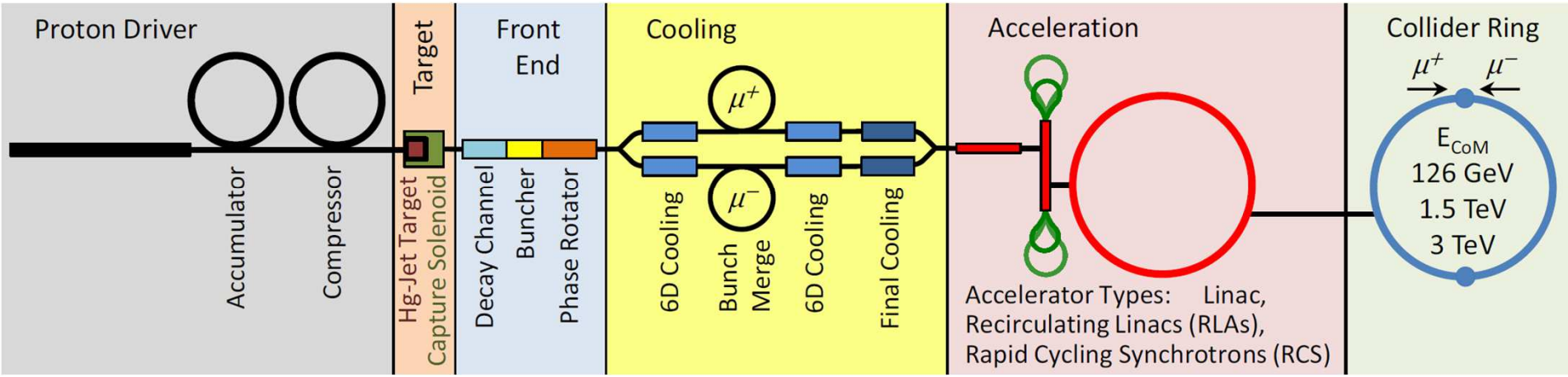




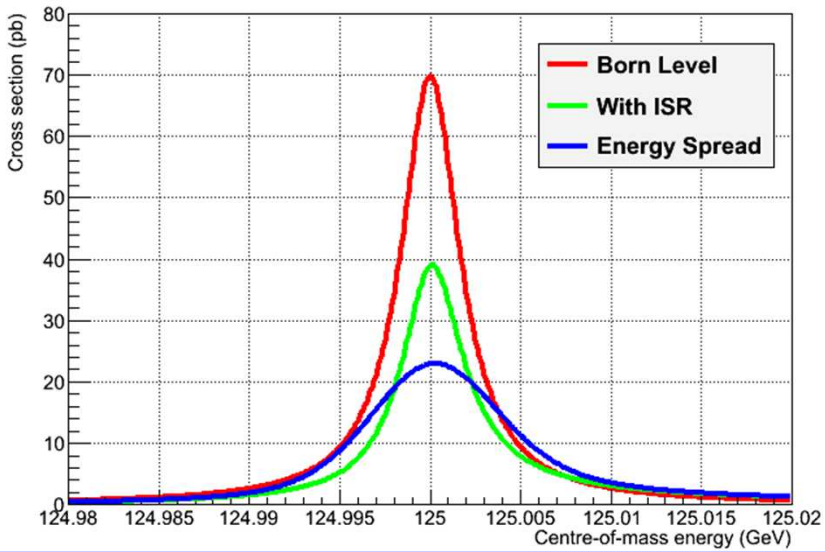
nuSTORM: 10^{11} μ/s storage ring:
(<1%) ν_e ν_μ $\bar{\nu}_e$ $\bar{\nu}_\mu$ x-sections and $\nu_{sterile}$ search

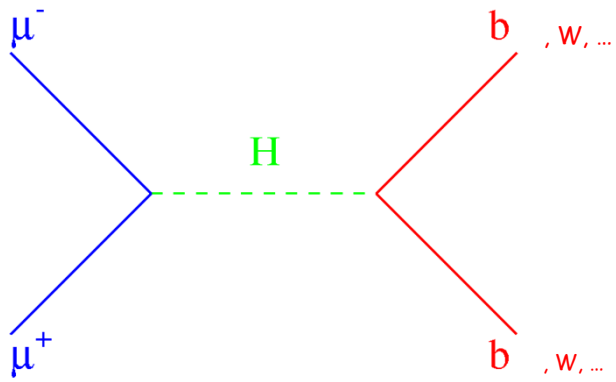
neutrino factory: 10^{14} μ/s storage ring
precision study of CPviolation, unitarity

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

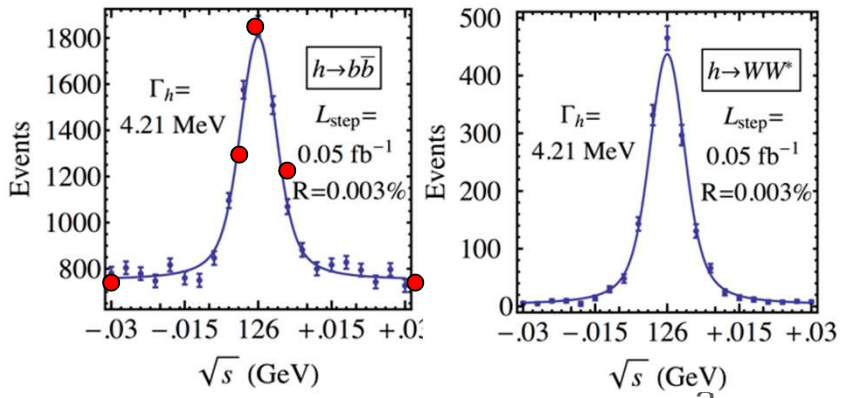


$\mu^+ \mu^-$ Higgs factory





$\sigma E/E$ = 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.

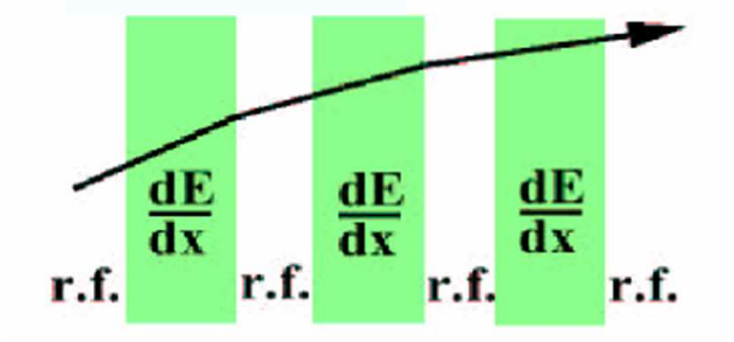
Exquisite energy and energy spread measurement from muon g-2 precession

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

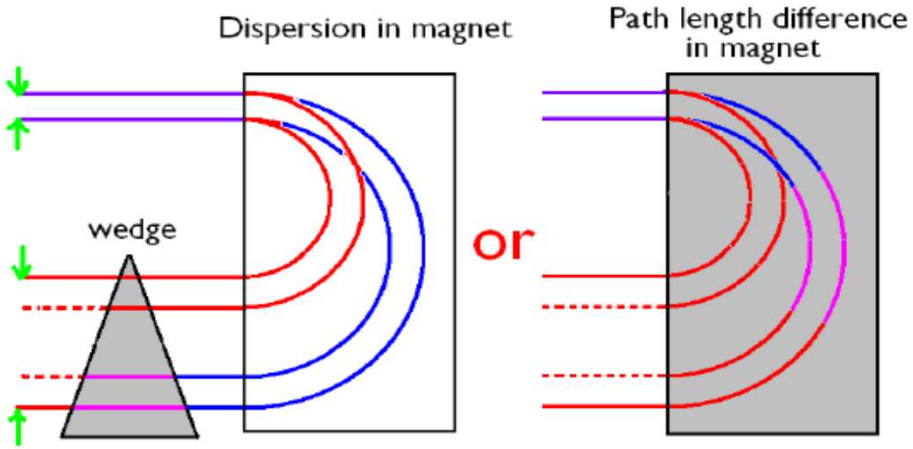
Performance similar to e+e- colliders…
feasibility and cost?

COOLING -- Principle is straightforward…

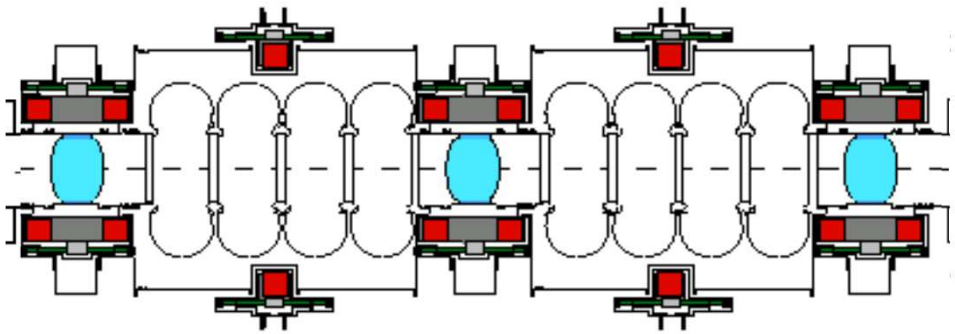
Transverse:



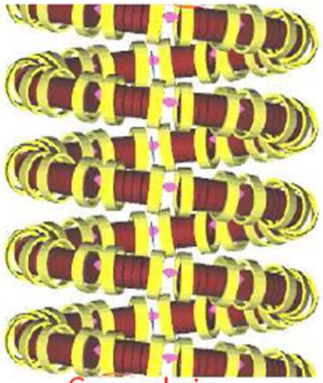
Longitudinal:



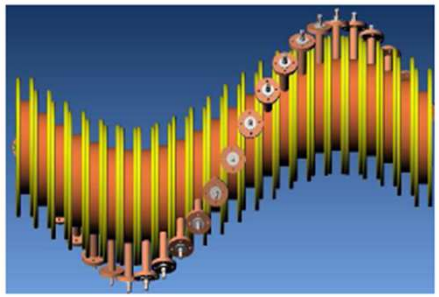
Practical realization is not!



MICE cooling channel (4D cooling)

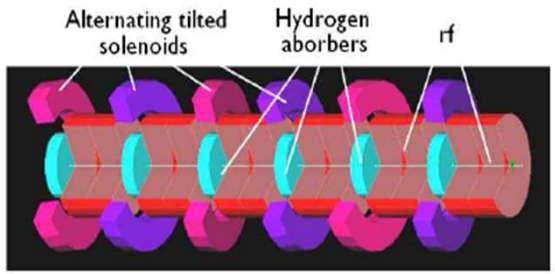


Guggenheim



Helical Cooling Channel

Snake



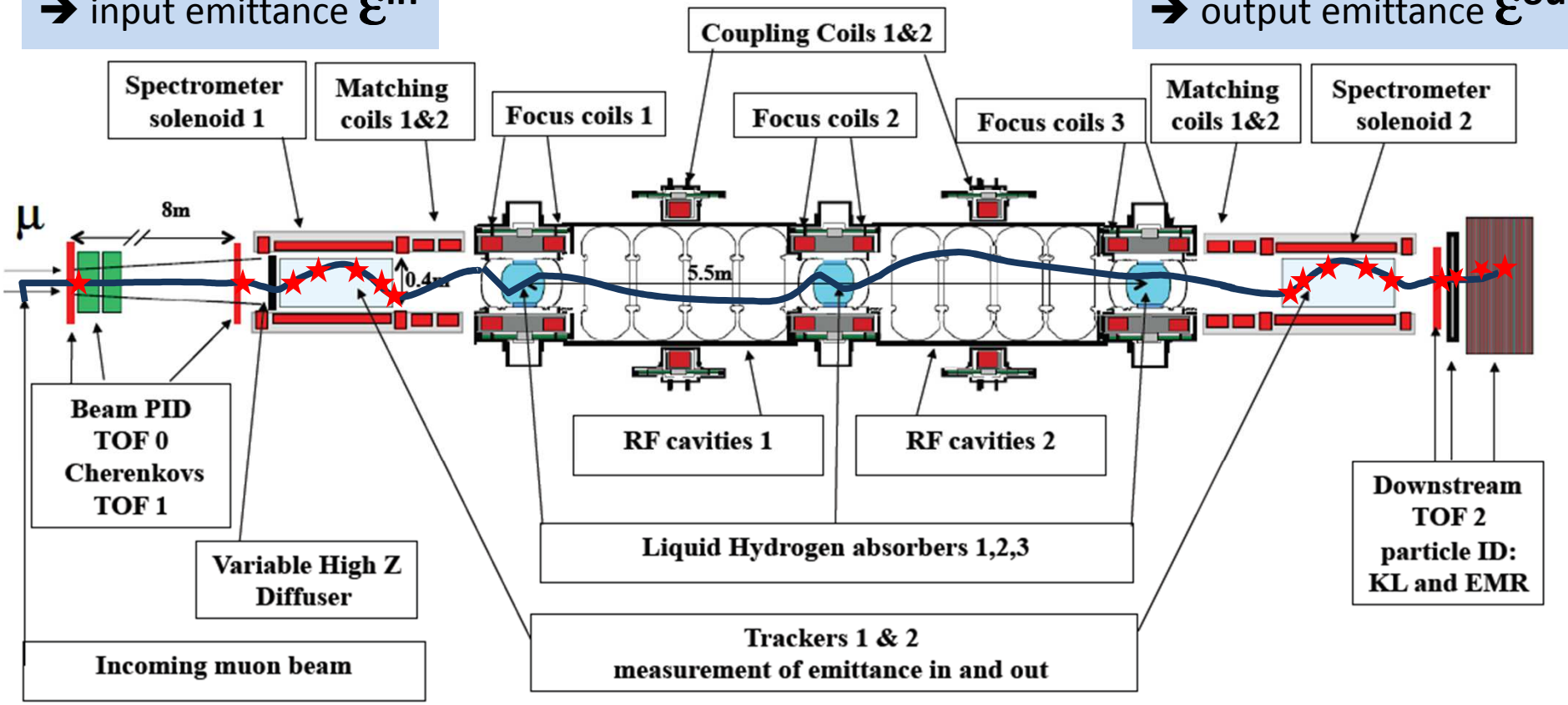
6D candidate cooling lattices

MICE the Muon Ionization Cooling Experiment

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

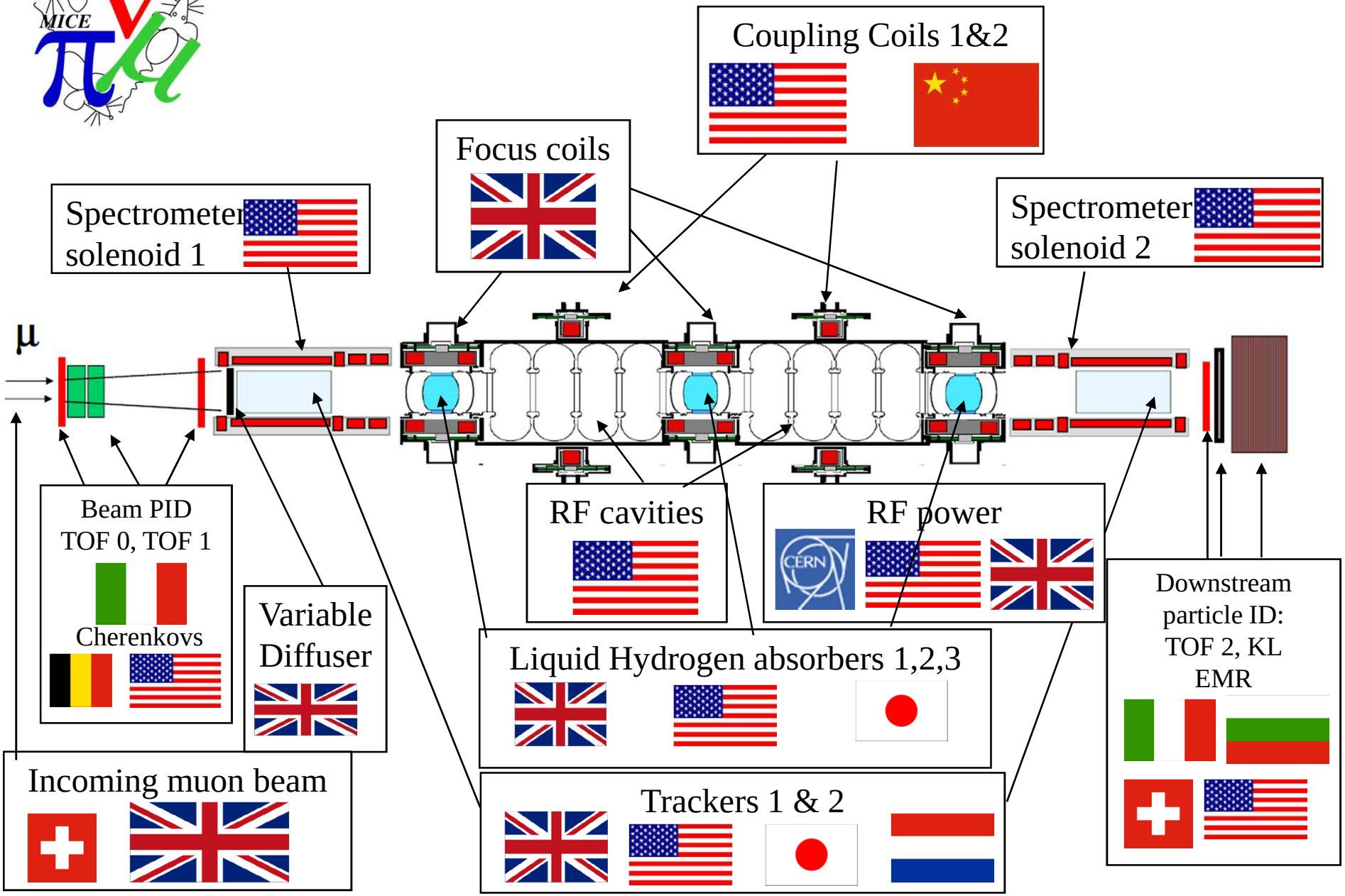
COOLING CHANNEL

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 Collaboration across the planet



International collaboration

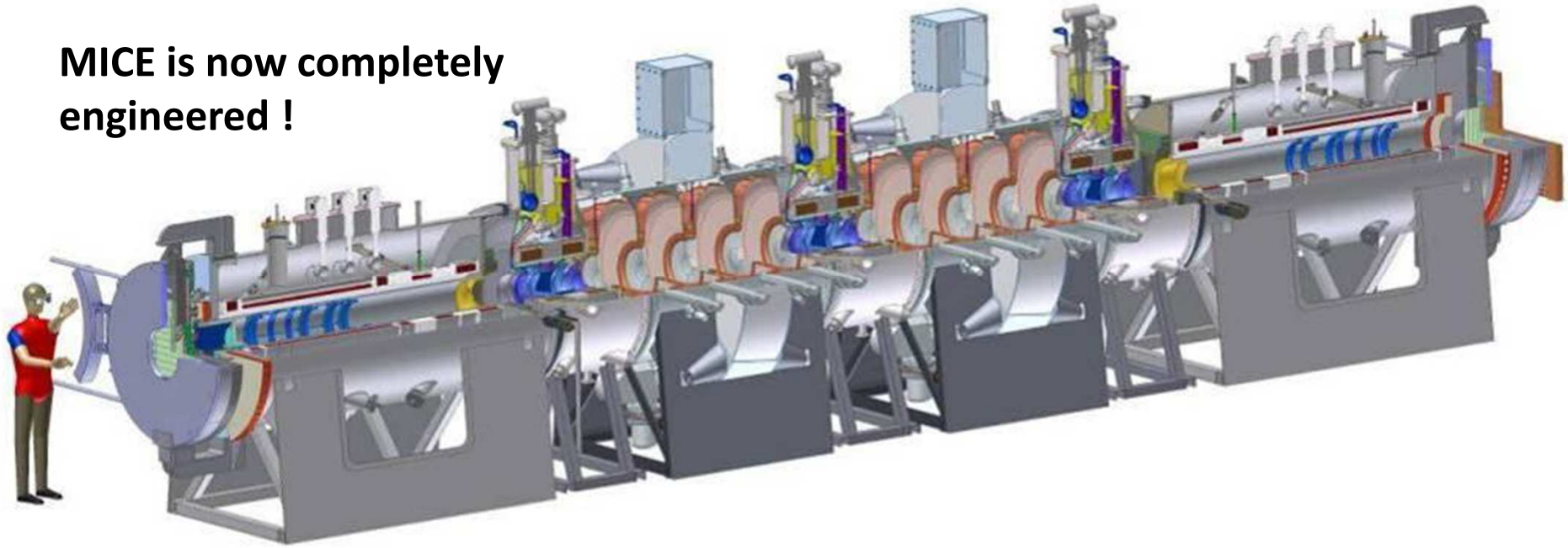
This RLSR correctly concentrates on the main partners of MICE (UK & US)

Contributions from other partners are not negligible:

-- LH2 absorbers from KEK
-- tracker as Japan/UK/US collaboration
-- TOF & KL from INFN & Bulgaria
-- EMR as INFN, UNIGE, Fermilab collaboration
-- important contributions in DAQ, software, analysis and publications
-- MOM's, shifters, operations manpower.

-- MICE is a CERN recognized experiment
-- RF amplifiers
-- e.g. CERN + UNIGE provides equipement and manpower for field mapping
-- use of CERN team accounts and purchasing services possible
-- MICE benefits from EU TransNational Access for travel and subsistance of collaborators from continental Europe

MICE is now completely engineered !



MICE STEPS

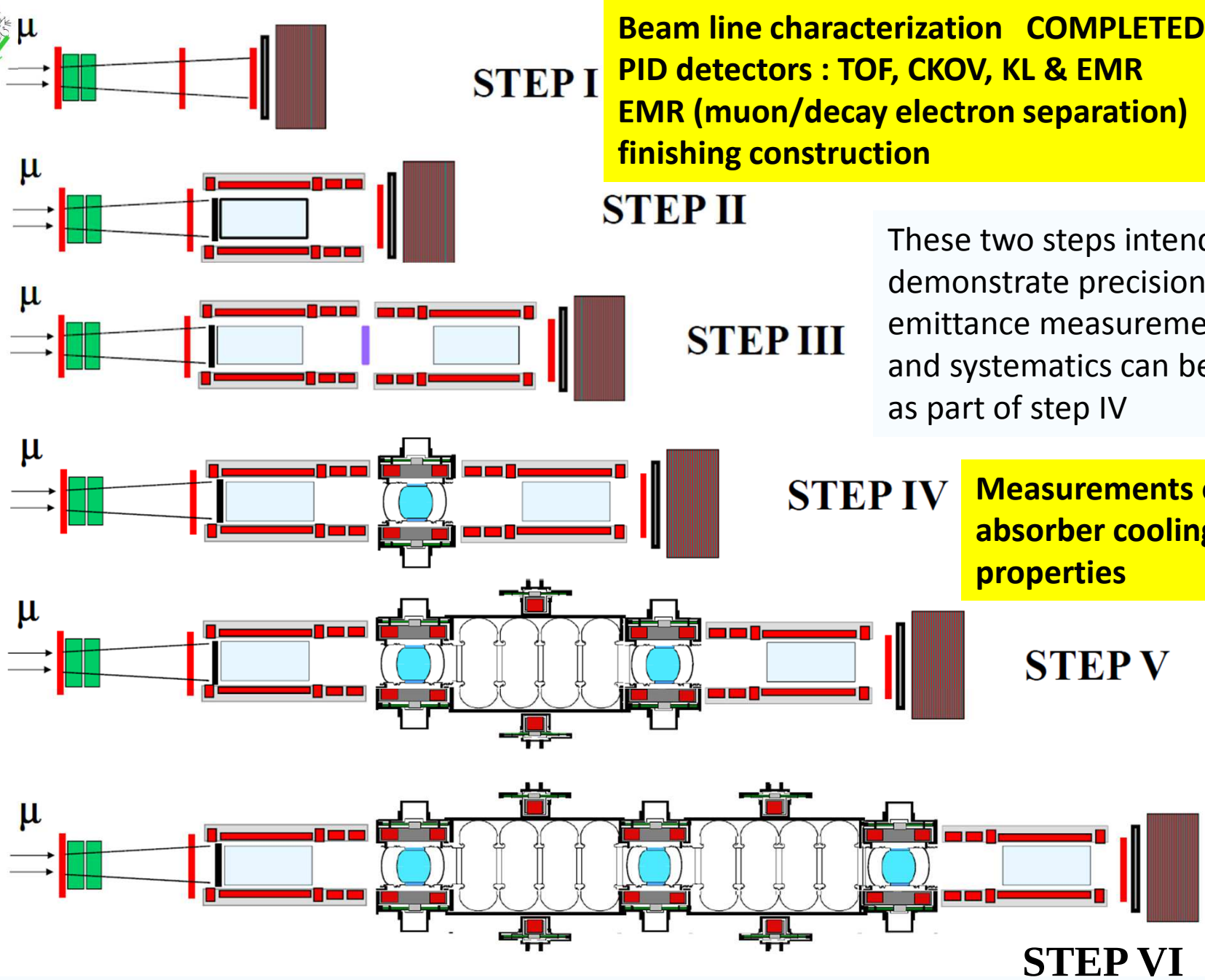
For Neutrino Factories and muon colliders the high intensity muons beams are generated and prepared in a powerful magnetic 'bottle', from the target solenoid all the way to the last stages of cooling. This magnetic 'bottle' consists of continuous magnetic field lines generated by a string of axial coils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

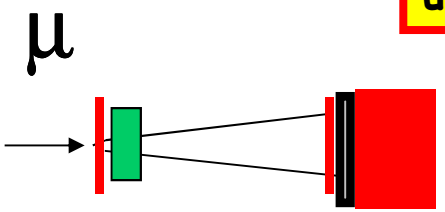
These two steps intended to demonstrate precision emittance measurement and systematics can be done as part of step IV

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

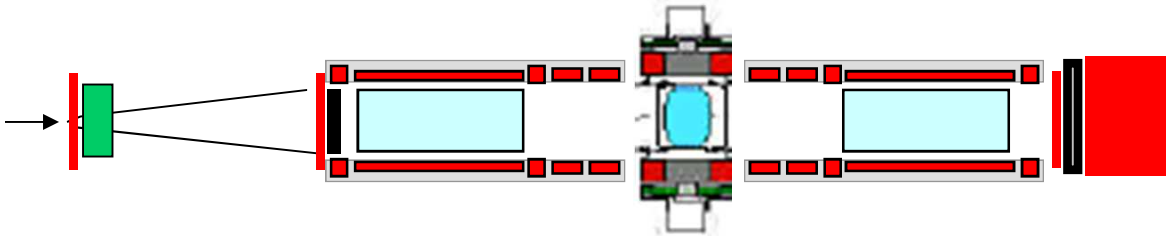
Provisional MICE SCHEDULE
update: May 2013

Run date:



STEP I

EMR run July 2013

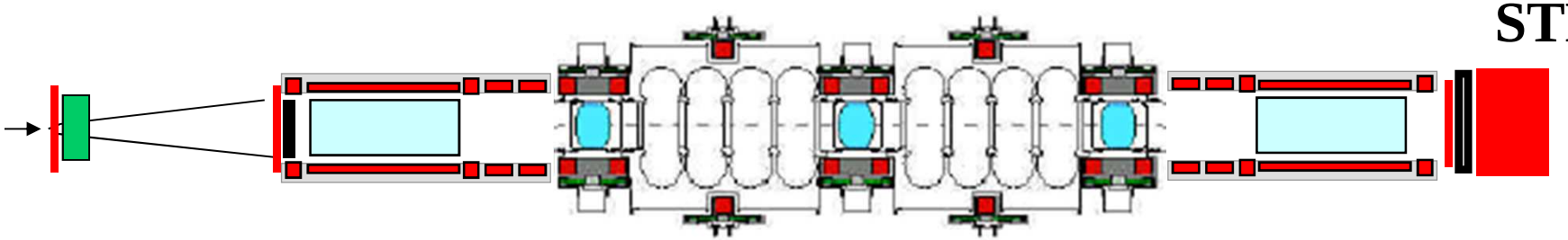


STEP IV

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

Under construction:

STEP VI



Possible Step V run Q4 2017
Step VI 2019

In spite of MPB recommendation and MICE efforts,
it is 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

-- delay with respect to previous schedule result from need to proceed to move of racks and compressors, modify MICE hall, etc..

-- new 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.

Important decision points

-- September 2013: installation of return yokes for step IV
why not 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

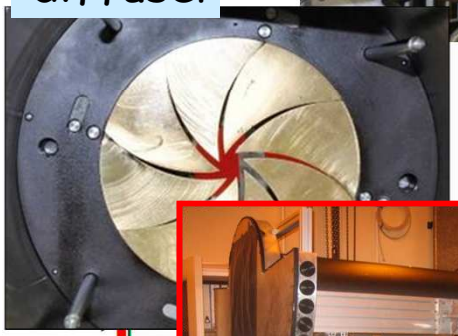
-- implementation of full return Yoke for step V/VI

STEP IV

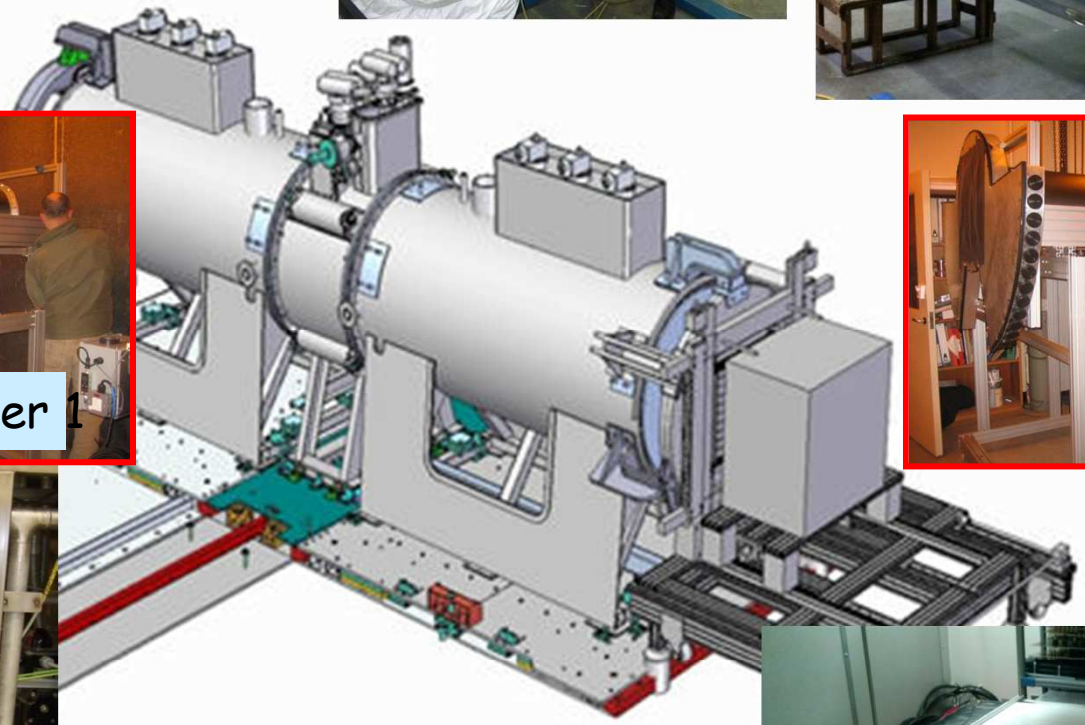

Spectrometer Solenoid 1


FOCUS COIL


Spectrometer Solenoid

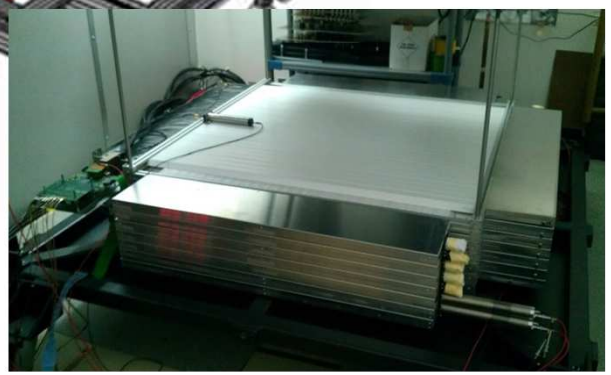

diffuser


Tracker 1

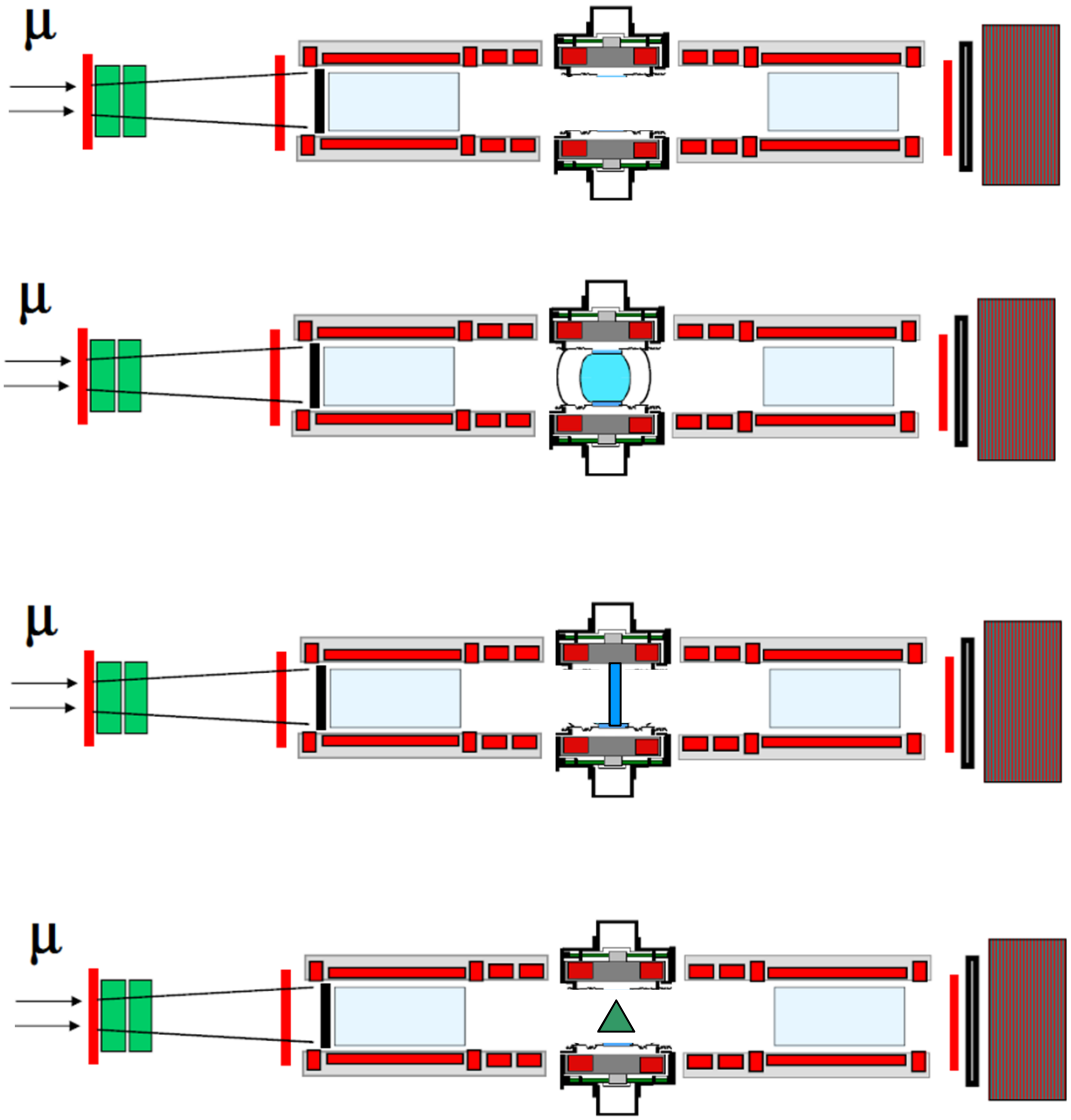



Tracker 2


LH2
system


EMR

STEP IV EXPERIMENTS (2014-16)



STEP IV

No absorber
Alignment
Optics studies

STEP IV

Liq H_2 absorber
(full/empty)
Multiple scattering
Energy loss
➔ Cooling

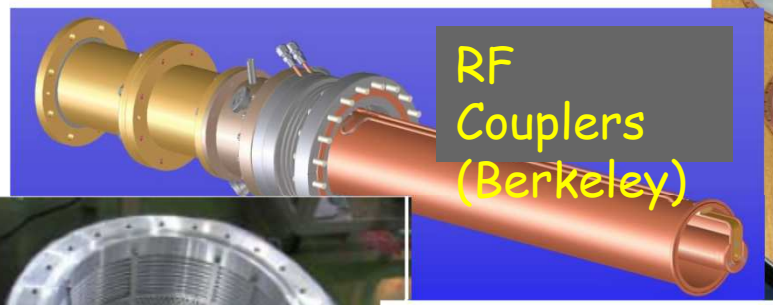
STEP IV

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

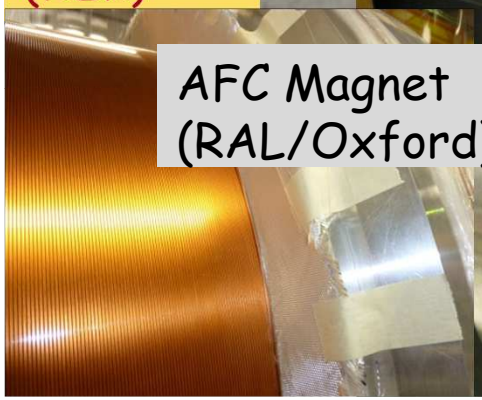
STEP IV

LiH Wedge absorbe
Emittance exchange

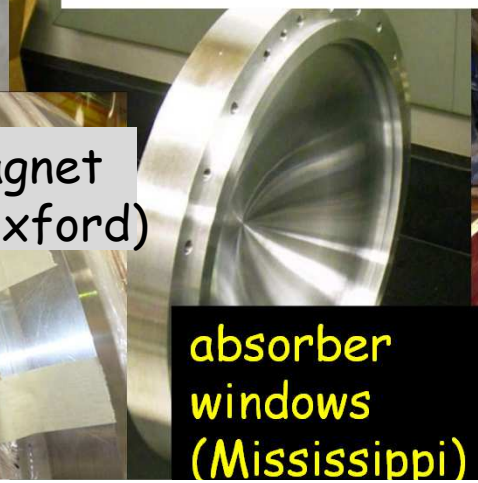
STEP VI



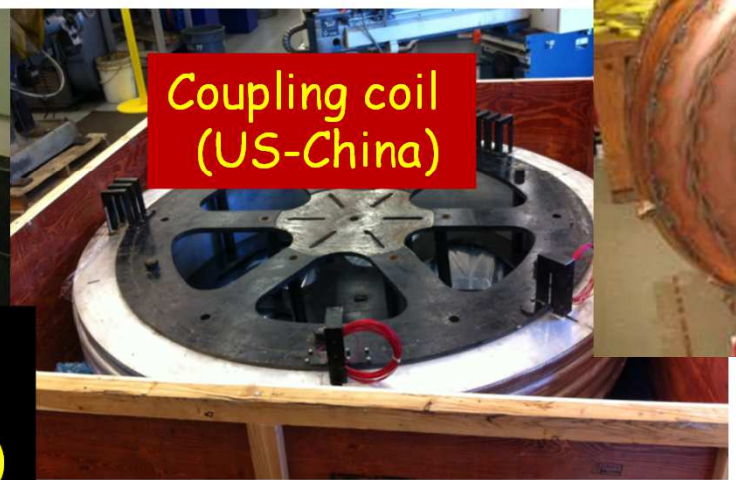
Liq H2
absorber
(KEK)



AFC Magnet
(RAL/Oxford)



absorber
windows
(Mississippi)



Coupling coil
(US-China)

RF cavities
(Berkeley)