MICE Introduction

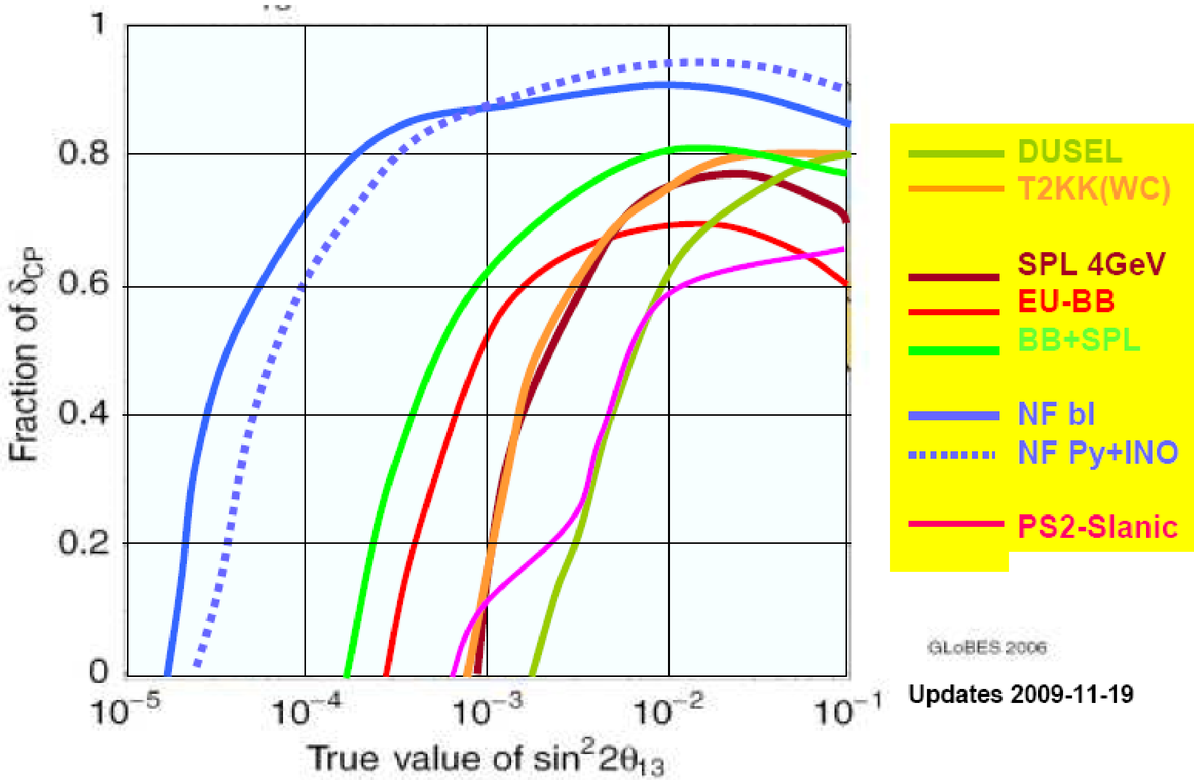


Figure 2 A representative compilation of sensitivities of some future long baseline projects. Here the fraction of δ_{CP} where CP violation can be observed at 3 standard deviations is plotted as a function of θ_{13}.

T2KK: *T2K 1.66 MW beam to 270 kton fid volume Water Cherenkov detectors in Japan*

DUSEL

SPL 4

NF bl

NF Py *... inland*

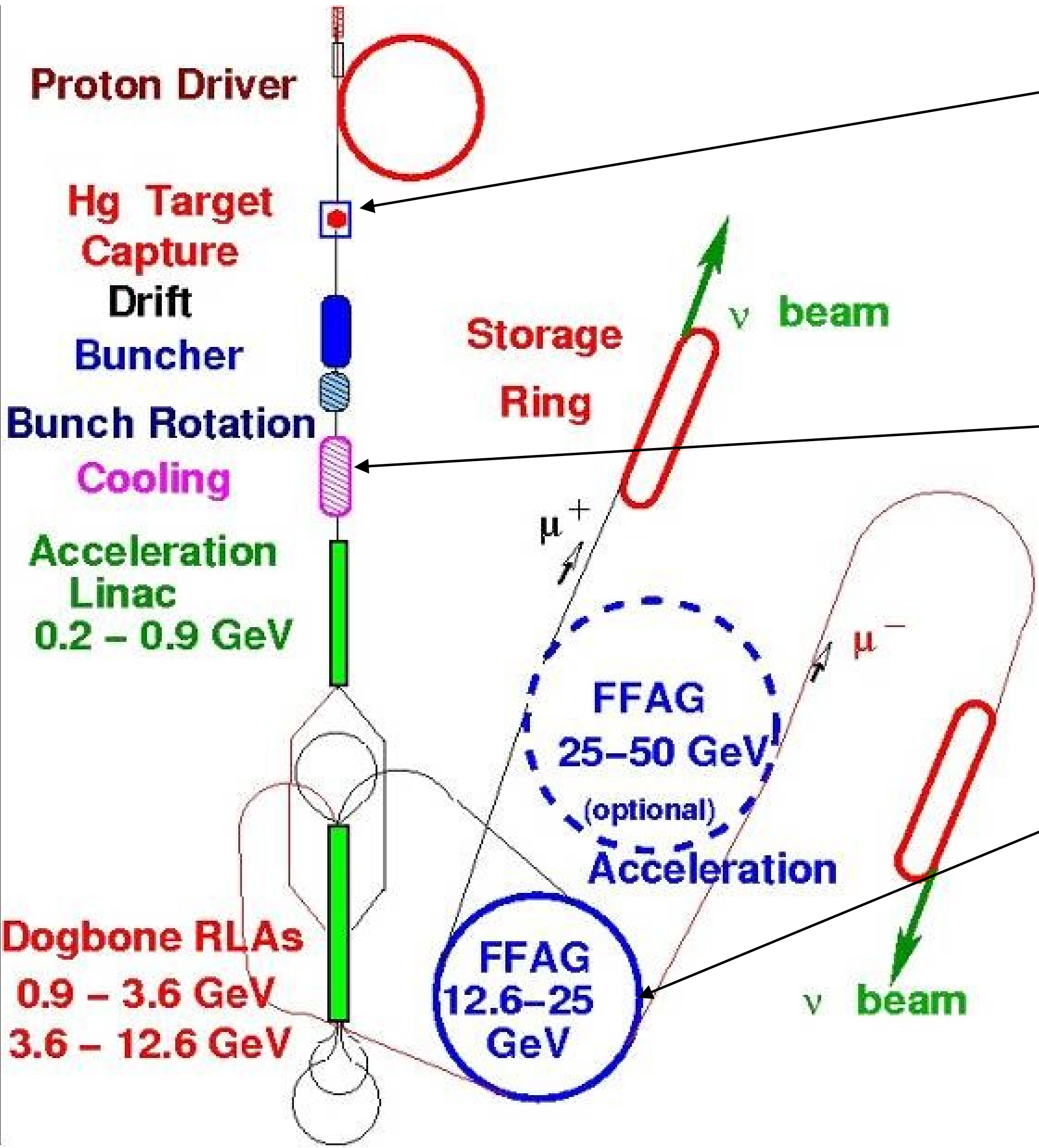
(2285

PS2-S *... PS2 to*

1.66M

NEUTRINO FACTORY
IS ULTIMATE NEUTRINO FACILITY
FOR STUDY OF 3X3 OSCILLATIONS
-- AND BEYOND --

Major challenges tackled by R&D expts



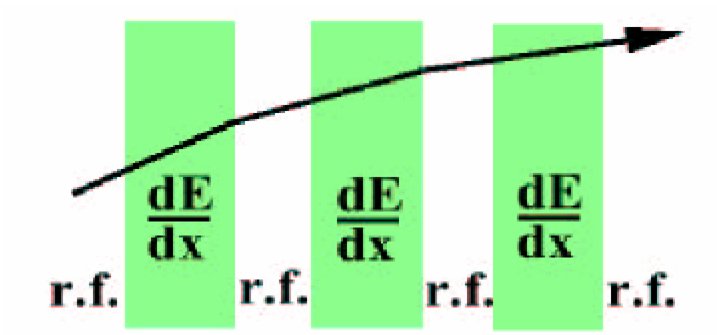
High-power target
. 4MW
. good transmission
MERIT experiment (CERN)

Fast muon cooling
MICE experiment (RAL)

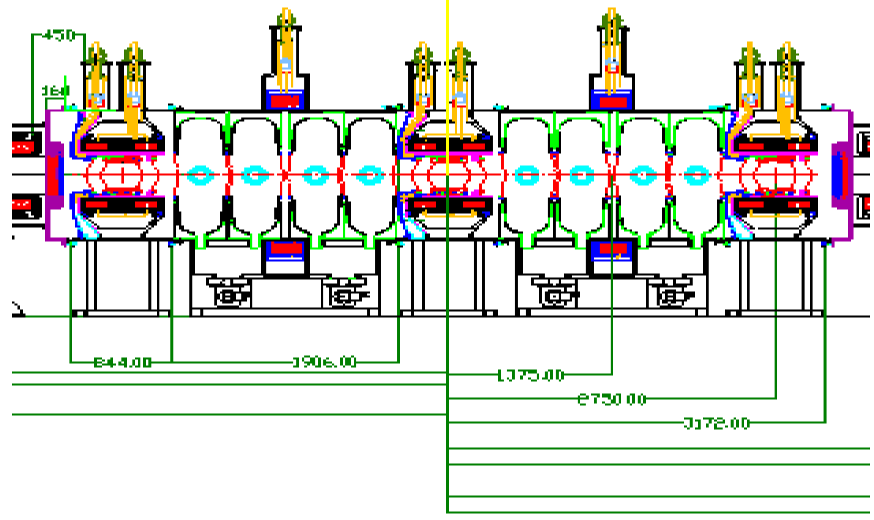
Fast, large aperture accelerator (FFAG)
EMMA (Daresbury)

IONIZATION COOLING

principle: **reality (simplified)**



this will surely work..!



....maybe...

A delicate technology and integration problem
Need to build a realistic prototype and verify that it works (i.e. cools a beam)

Can it be built? What performance can one get?

Difficulty: affordable prototype of cooling section only cools beam by 10%, while standard emittance measurements barely achieve this precision.
Solution: measure the beam particle-by-particle

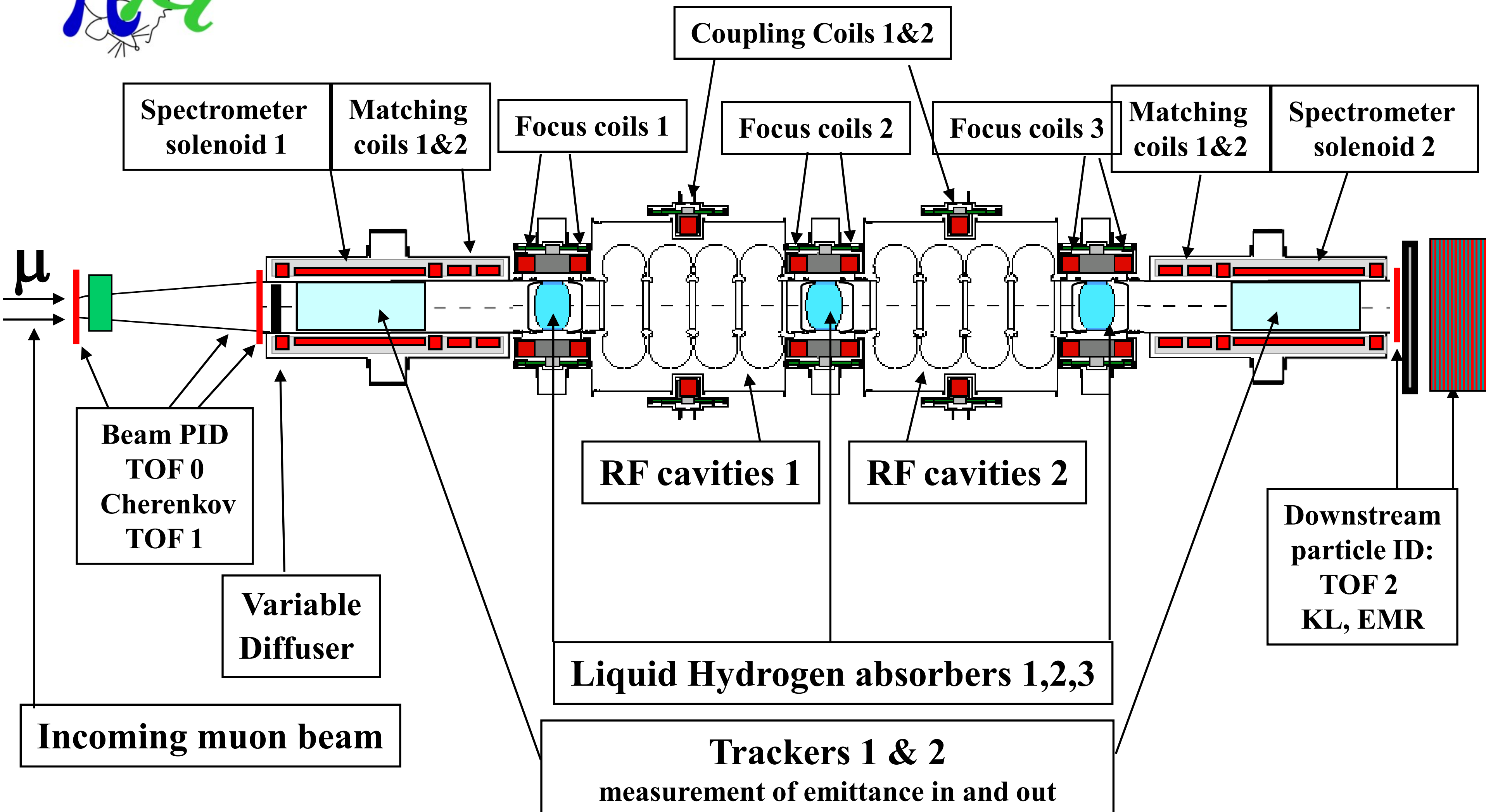
state-of-the-art particle physics instrumentation will test state-of-the-art accelerator technology.

10% cooling of 200 MeV/c muons requires ~ 20 MV of RF

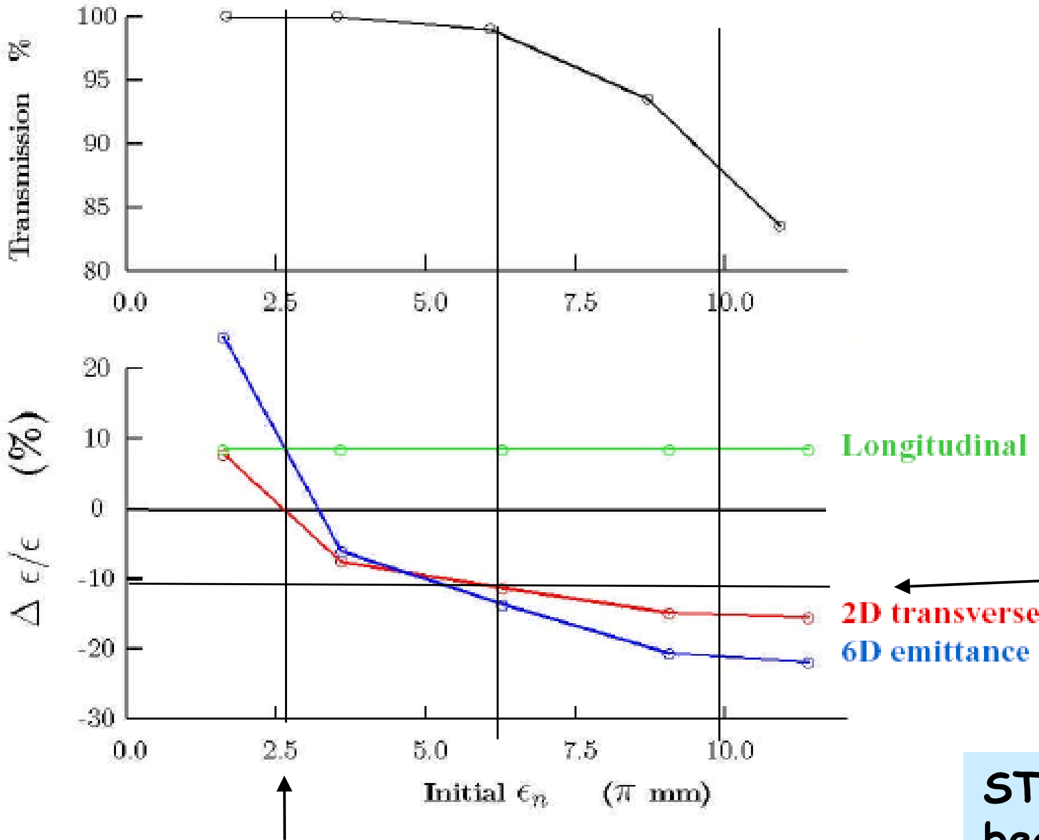
single particle measurements =>

measurement precision can be as good as $\Delta(\varepsilon_{out}/\varepsilon_{in}) = 10^{-3}$

never done before either…



Quantities to be measured in a cooling experiment



Measurements of

TRANSMISSION
EMITTANCE REDUCTION
EQUILIBRIUM EMITTANCE

for the standard Study II optics

are the main deliverables

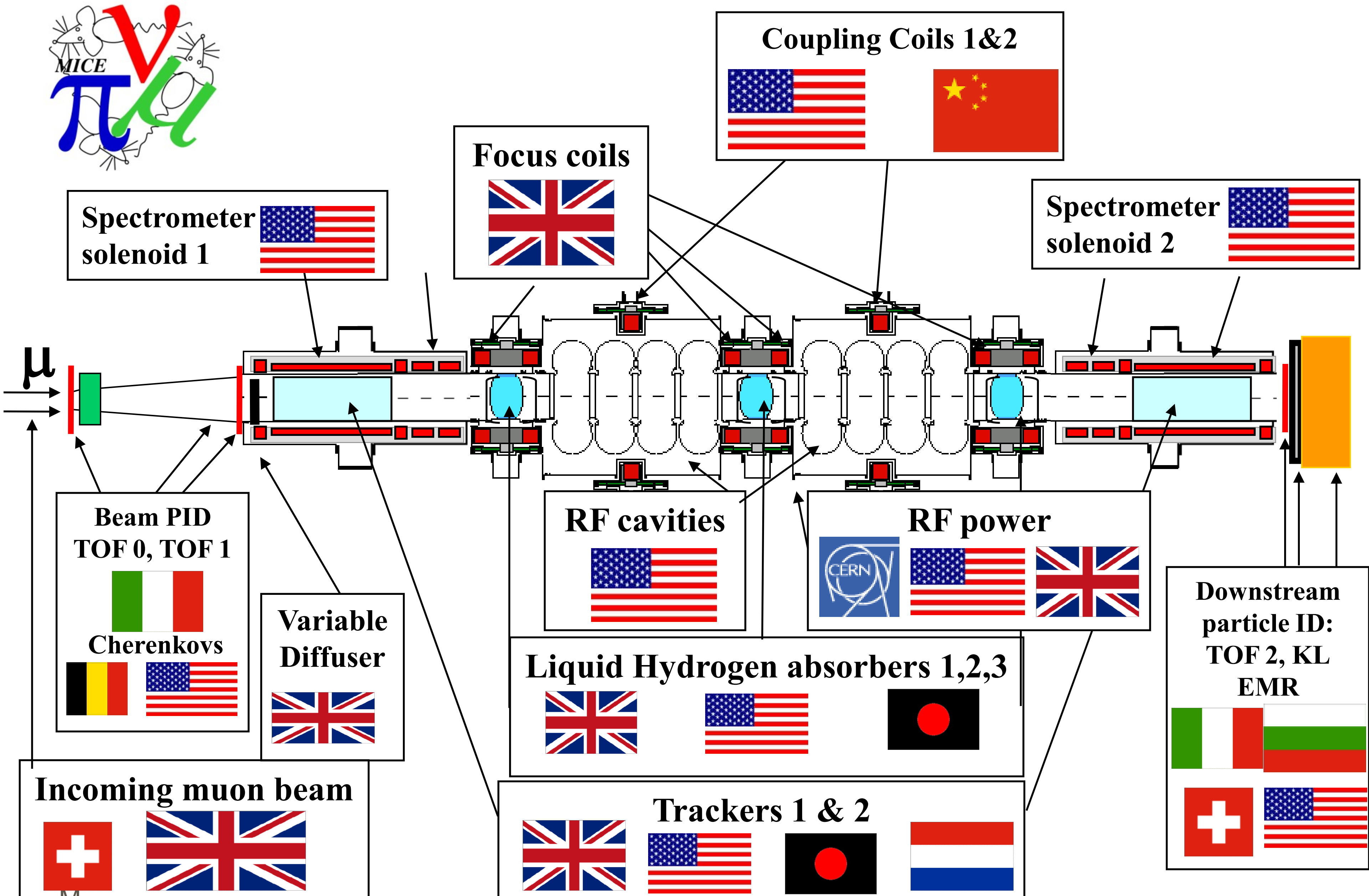
cooling effect at nominal input emittance ~10%

STEP I demonstrated that
beam line can deliver 3,,6,,10 mm
other values can be reached by
offline culling or reweighting

equilibrium emittance = 2.5 mm

curves for 23 MV, 3 full absorbers, particles on crest

MICE Collaboration across the planet



THE MICE COLLABORATION -130 collaborators-

University of Sofia, Bulgaria

The Harbin Institute for Super Conducting Technologies PR China

INFN Milano, INFN Napoli, INFN Pavia, INFN Roma III, INFN Trieste, Italy

KEK, Kyoto University, Osaka University, Japan

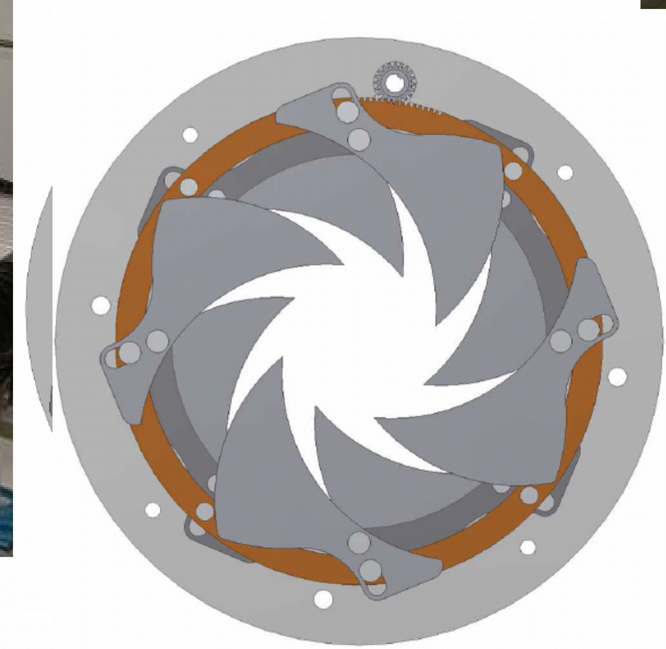
NIKHEF, The Netherlands

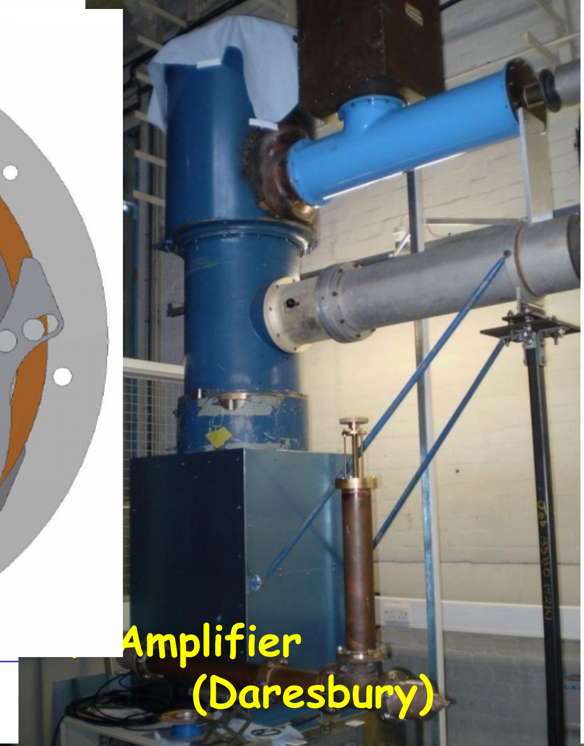
CERN

Geneva University, Paul Scherrer Institut Switzerland

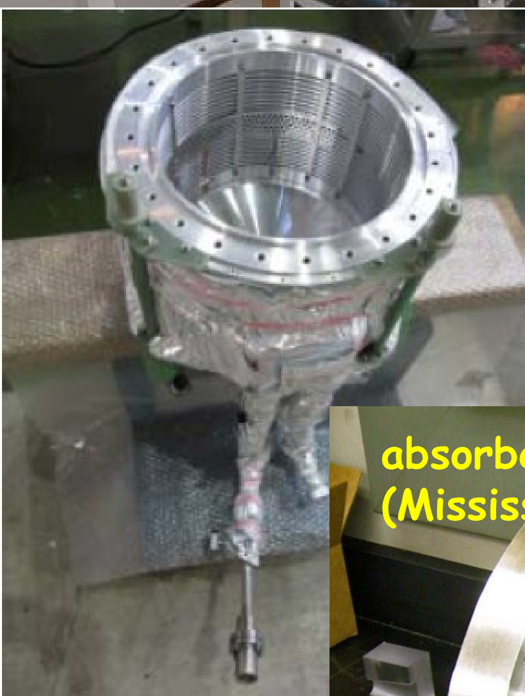
Brunel, Cockcroft/Lancaster, Glasgow, Liverpool, ICL London, Oxford, Darsbury, RAL, Sheffield, Warwick UK

Argonne National Laboratory, Brookhaven National Laboratory,
University of Chicago Enrico Fermi Institute, Fermilab, Illinois Institute of Technology,
Jefferson Lab, Lawrence Berkeley National Laboratory, UCLA, Northern Illinois University, University of Iowa, University of Mississippi, UC Riverside,
Muons Inc. USA





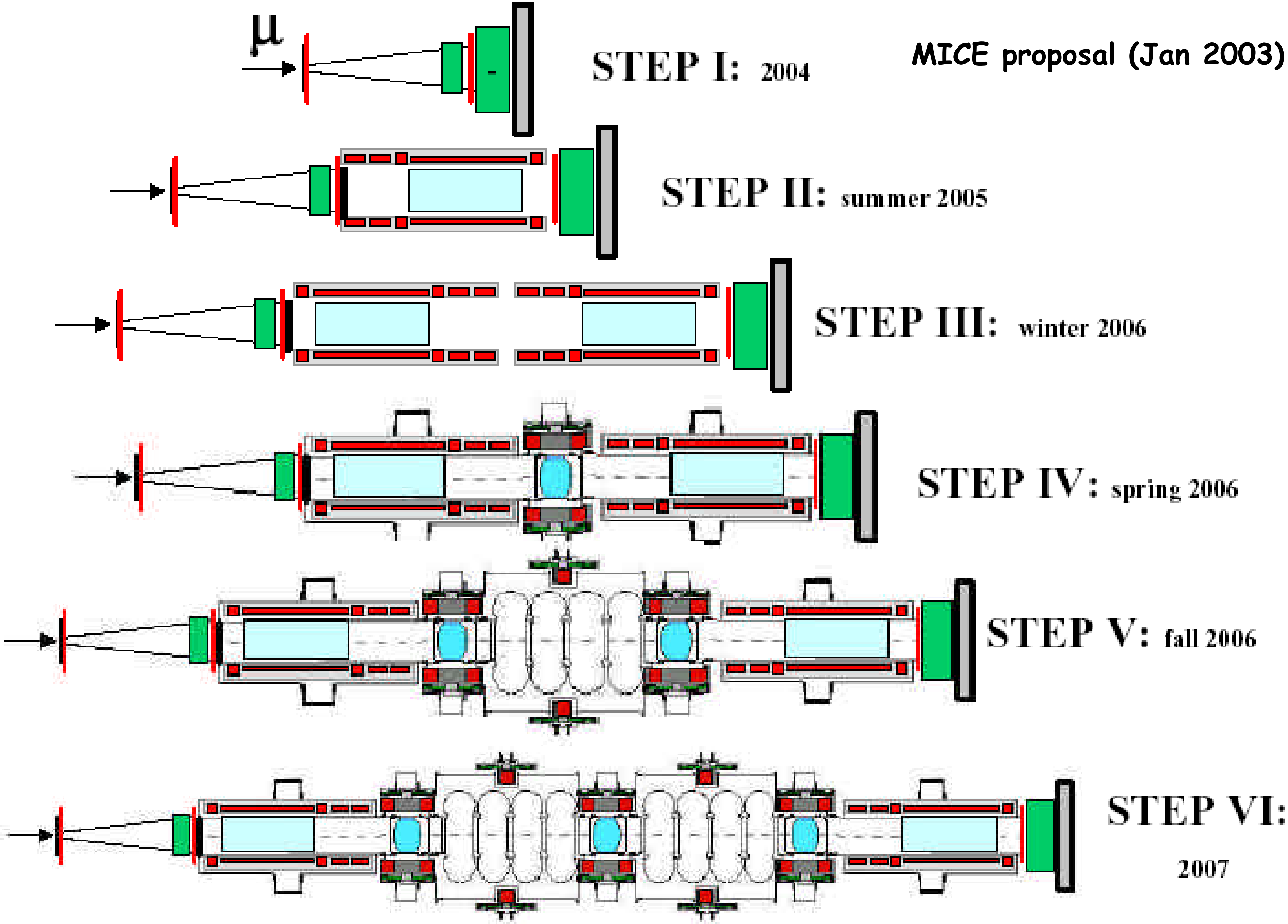
MICE is a fantastic world-wide team effort!



LiqH2 absorber (KEK)

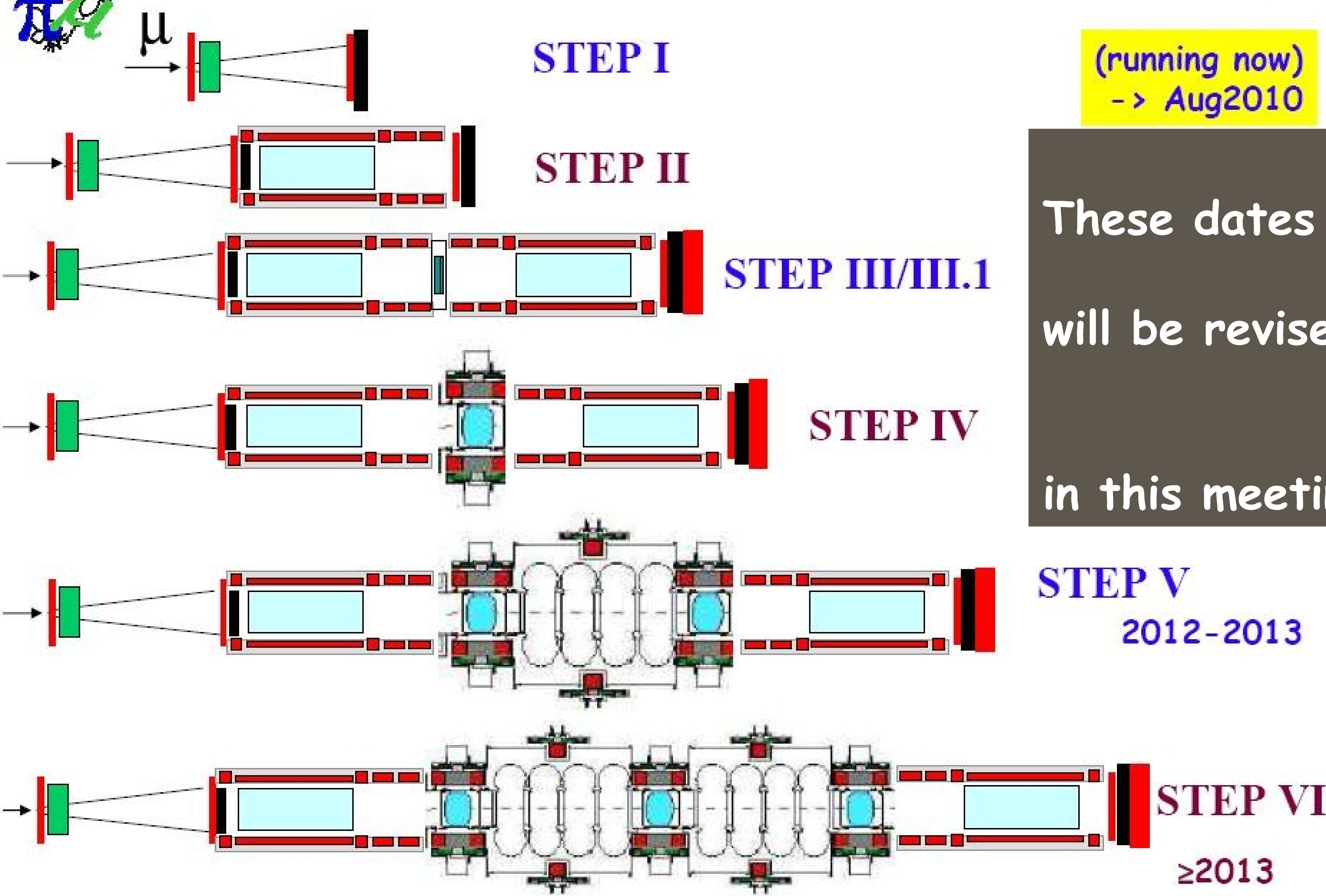
RF cavities (Berkeley)

MICE proposal (Jan 2003)



MICE Schedule as of March 2010

Run date:



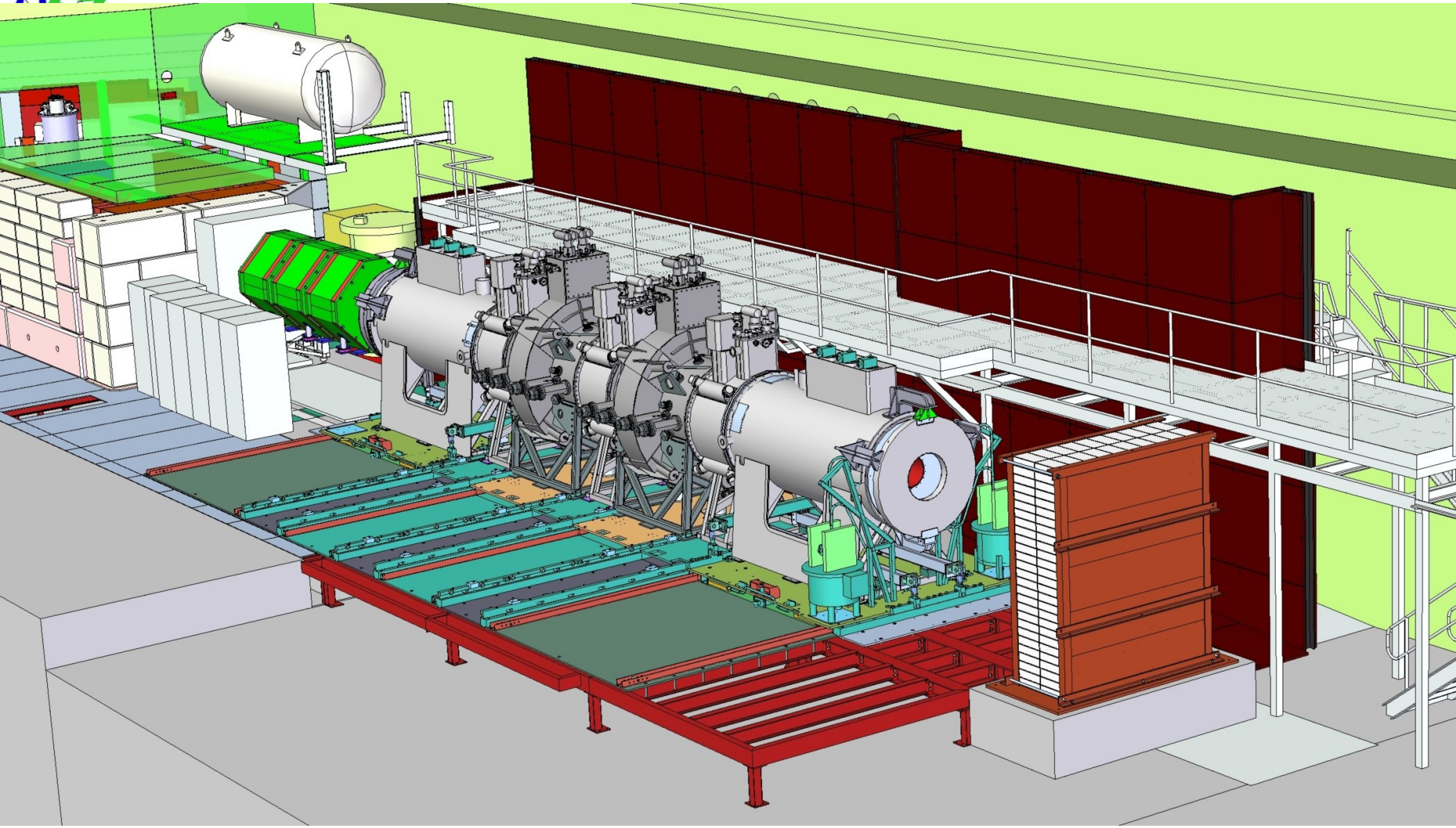
(running now) -> Aug2010

These dates will be revised in this meeting

2012-2013

≥2013

see Andy Nichols talk



MICE Step VI (detectors, cables, couplers, etc… are not shown)

Comments on steps:

STEPS were designed as a means to explicit
-- the logical scientific steps to achieve the scientific goals
-- a possible staging and assembly scenario, which
at the time of the proposal
made sense so that funding approval could be granted in phases.

HOWEVER

-- the scientific steps do not require the experiment to be assembled in VI distinct physical stages.

For instance
-- the physics of step II can be achieved in any of the following steps
-- the physics of step III can be achieved in any following steps using empty absorbers and no RF acceleration etc…
➔ Should be decided by the practical considerations

➔ At the October 2010 collaboration meeting we decided that we could go directly to step IV thus skipping installation in step II and III if needed
As a consequence step IV physics program is much augmented.

➔ similar arguments could eventually be considered for step V vs stepVI

Where the experiment stands today

1. we have now essentially completed step I (beam commissioning)
   -- generated beams suited for scientific goals
   -- performed first measurement of beam emittance with HEP detectors (TOF)
   -- experiment runs well (online, offline) but perfectible!
   → need completion of target system with 1+1 target
   → explore remaining possible rate increase
   → more 'professional' controls, software, etc…

2. the detectors are all built and operational
   except for EMR
   under construction
   will constitute most beam taking activity until summer 2012.

3. experiment has been delayed in various ways since 2007
   -- decay solenoid OK now since April 2009→ June 2010
   -- target OK now since September 2009

→ step I was achieved between October 2009 and August 2010

-- Now: spectrometer solenoids

-- next? IMPORTANCE OF THIS SCHEDULE REVIEW !

Additional information
from MPB meeting of September 2010

From the MICE proposal

Given that all detectors and parts of the equipment will not be ready at the same time, one can foresee a development of the experiment in time, to allow a number of preparatory stages.

Step I The beam can be tuned and characterized using a set of TOF and particle ID detectors.
Step II the first spectrometer solenoid allows a first measurement of 6D emittance with high precision and comparison with the beam simulation. This should allow a systematic study of the tracker performance.
Step III is fundamental for the understanding of a broad class of systematic errors in MICE. The two spectrometers work together without any cooling device in between and should measure the same emittance value (up to the small predicted bias due to scattering in the spectrometer material).

Step IV, with one focusing pair between the two spectrometers, should give a first experience with the operation of the absorber and a precise understanding of energy loss and multiple scattering in it. Several experiments with varying beta-functions and momentum can be performed with observation of cooling in normalized emittance.

Starting from **Step V**, the real goal of MICE, which is to establish the performance of a realistic cooling channel, will be addressed.

Only with **Step VI** will the full power of the experiment be reached and the deliverable delivered.

Other important by products along the way

-- at step III, a spool piece allows easy insertion of slabs of solid materials to measure precisely their effect on beam emittance

-- will test materials relevant to neutrino factory
LiH, Carbon, Aluminum Titanium etc…(and simply plastic)

(this could conceivably be done in step IV – will be discussed at CM28)

-- at step IV and above, optics in FC can be explored
to allow smaller beta functions (down o 5cm at 140 MeV/c)
to test flip vs non-flip mode

-- at step IV a wedge absorber can be tested in place of a flat piece to study effect of

-- at step V and VI can test cavities with LN2 cooling to allow higher gradient (X V2) with same power

The specificities of MICE:

MICE is a collaboration of
accelerator physicists and particle physics experimenters

MICE is international

Hardware responsibilities:
collaborators pay for what they provide.

There exist collaborations for specific items:
ex: Tracker is a collaboration between UK, US, Japan
absorbers are a US-Japan collaboration
EMR is a GVA-Como-Trieste-Fermilab collaboration

There are no collaboration-wide shared expenses as could be found in large experimental collaborations and there is no common 'bank'.

Common fund is used to pay for consumables and contribution to MICE Hall personnel

A few MOU's have already been signed
-- RF sources from Berkeley
-- PSI solenoid
A more global MOU is under preparation (M. Bonesini)

The software, analysis etc… are freely shared items.

Very few changes of responsibilities since MICE proposal

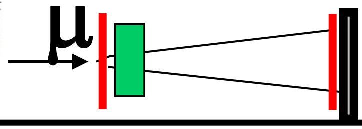
Most notable ones:

1. Spectrometer solenoids were taken up from INFN-Genoa to LBNL in fall 2005

2. EMR was taken up from INFN-Trieste to Geneva in Jan 2009

Status of MICE Steps

Color code	
	Ready and operational
	Funded, under construction and essentially under control
	Funded, but late or problems/risks involved
	funded but major technical problem
	not funded

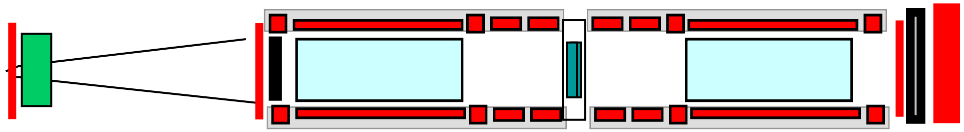


STEP I

Apr09|Sep10

data taking and analysis

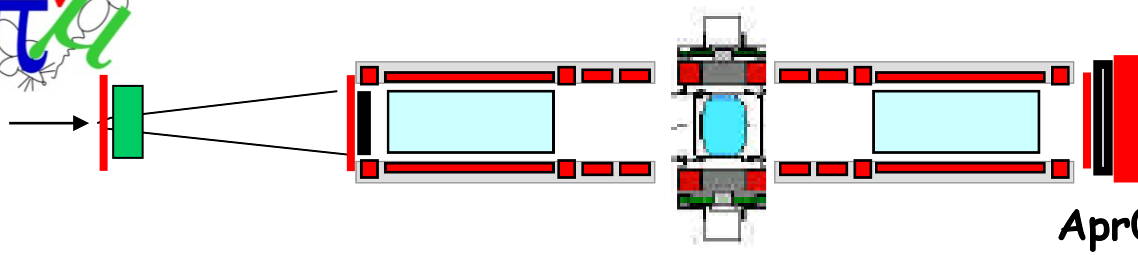
Muon beam line	responsibility			
2 dipoles 9 quads, PS, controls	RAL, DL			
Decay solenoid	PSI			
Decay solenoid cryo and PS, controls	RAL			
Target system	Sheffield, DL,RAL			Target in ISIS success! New targets under construction – not closed
Hall infra., shielding, beam stop	RAL			
detectors				
TOF0 and TOF1	MIB INFN, GVA			
CKOV A,B	Mississipi			
KL calorimeter	Roma3 INFN			
Front end electronics, DAQ, trigger	GVA, INFN			
Control room	MICE-UK			
Software	MICE collab.			
Beam monitors	FNAL, ICL, GVA			
Detector cabling and installation	RAL, DL			



STEP II/III/III.1

Apr09|Sep10 Q3-Q4 2011

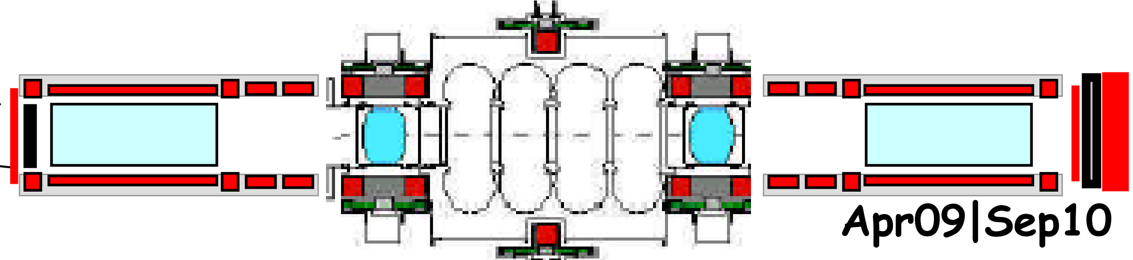
infrastructure	**RAL**			
Trackers	**UK, USA, JP**			
Spectrometer SolenoidI&II	**LBNL**			
Magnetic measurements	Fermilab or CERN-under discussion			
Magnetic probes	**NIKHEF**			
TOF2 and TOF shielding	**INFN MIB**, GVA			
Spool piece	**GVA**			
Absorbers (LiH…)	**FNAL**			
Software	**MICE**			
EMR muon ranger	**GVA**, FNAL, Trieste/Milano			prototyped, under construction
Power sub-station upgrade	**RAL, DL**			under procurement
Safety equipment	RAL, **DL**			PPS → Sept 2010



STEP IV

Apr09|Sep10

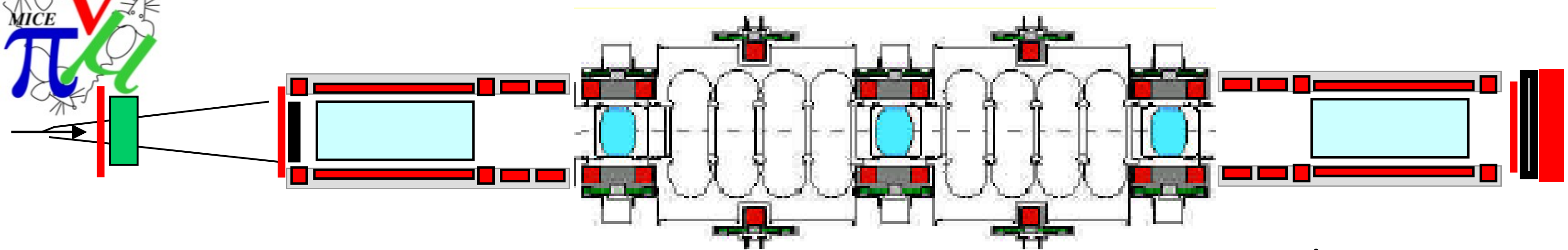
Liquid Hydrogen infrastructure and controls	RAL			
Focus coil magnet	RAL, Oxford			
FC Magnetic measurements	CERN under discussion			
Liquid hydrogen absorber and instrumentation	KEK			
Liquid Hydrogen and safety windows	Mississippi			
Software	MICE			



STEP V
2012-2013

Apr09|Sep10

		Apr09	Sep10	
RF in Mag fied R&D	MUCOOL NFMCC			delayed by CC-0
RF cavities (1+4)	LBNL			
2 Coupling coils (MUCOOL+ MICE CCI)	ICST-HIT, LBNL			solution in progress.
CCI Magnetic measurements	CERN (Discussion)			
RF Power sources parts 4+4MW	CERN, LBNL			
RF refurbishment 4+4 MW	CERN, DL			
RF infrastructure 4 cavities	DL, RAL			Layout drawn
Liquid Hydrogen infrastructure (II)	RAL			
Focus coil magnet II	RAL, Oxford			
FC Magnetic measurements	UK			
Liquid hydrogen absorber II	KEK			
Liquid Hydrogen and safety windows II	Mississippi			
RF Shield	Fermilab			construction at FNAL
Software, controls	MICE			(needs to design controls of cooling channel)



STEP VI

>2013

Apr09|Sep10

RF cavities (4)	LBNL			
Coupling coil (MICE CCII)	ICST-HIT, LBNL			
CCII Magnetic measurements	FNAL/CERN			
RF infrastructure 4 cavities	DL, RAL			
Liquid Hydrogen infrastructure (III)	RAL			
Focus coil magnet III	RAL, Oxford			
FC Magnetic measurements	UK			
Liquid hydrogen absorber III	KEK			
Liquid Hydrogen and safety windows III	Mississippi			
Software, controls				(needs to design controls of cooling chanel)

MICE Organization

Collaboration board 3
1 rep/institute
elects spokesperson
reviews EB activity
votes on decisions
prepared by EB and CF
chair: Alan Bross (FNAL)

Executive Board 12
spokesperson: A.Blondel
deputy M. Zisman (LBNL)
Project manager
software coord.
analysis coord.
reps from
UK,US,EU,JP
manages collaboration life
nominates personels
reports to CB

Technical Board 12
Project manager: A.Nichols (RAL)

management of project
and Common Fund
reports to EB
+spokesperson
+deputy
+software coord.
+level 2 WBS coordinators
enforces
design and safety reviews
change control
documents exp.design

3 collaboration meetings/yr
1 video conf/month

Editorial board ~3
Dan Kaplan IIT
controls quality of
publications
proposes publication policy

Speakers bureau ~3
V. Palladino (INFN)
solicits talks at
conferences and
proposes speakers

Analysis forum 24
Chair J.Cobb (Oxford)

MICE OPERATIONS

the MICE Operations Managers (MOM's) are experienced MICE physicists who take a continuous rota at RAL (3-4 weeks at a time) to supervise MICE operations.

delegation of safety from MICE project Manager (Andy Nichols)
delegation of physics objectives from Spokesperson (AB)

Work intensive and very demanding, during shutdowns and installation phases and even more during running phases.

System has been in place since late 2007.

For running periods:
-- two shifters in the control room
-- people in charge of relevant sub-components ensure on-call presence
-- beam line expert (BLOC) on call

Very nice results in Sept-December 2009 and June-August 2010

Challenges of MICE:

(these things have never been done before)

1. Operate RF cavities of relatively low frequency (201 MHz) at high gradient (16 MV/m) in highly inhomogeneous magnetic fields (1-3 T)
   dark currents (can heat up LH_2), breakdowns see A. Bross

2. Hydrogen safety (substantial amounts of LH_2 in vicinity of RF cavities)
   see M. Hills

3. Emittance measurement to relative precision of 10^{-3} in environment of RF bkg
   requires low mass and precise tracker
   low multiple scattering
   redundancy to fight dark-current-induced background
   excellent immunity to RF noise
   complete set of PID detectors

And…

4. Obtaining funding and resources for R&D towards a facility that is not (yet) in the plans of a major lab

FUNDING

The MICE project is approved and funded for all partners (except Bulgaria)

-- Funding is subject to proposals/approvals with finite duration
in a number of cases

STFC approval/commitment to step VI but yearly review/atributions
DOE 5 years plan + yearly attribution
NSF: three year approval
CH: 2 years proposals
INFN review yearly

main worry/difficulty across the project is shortage of manpower

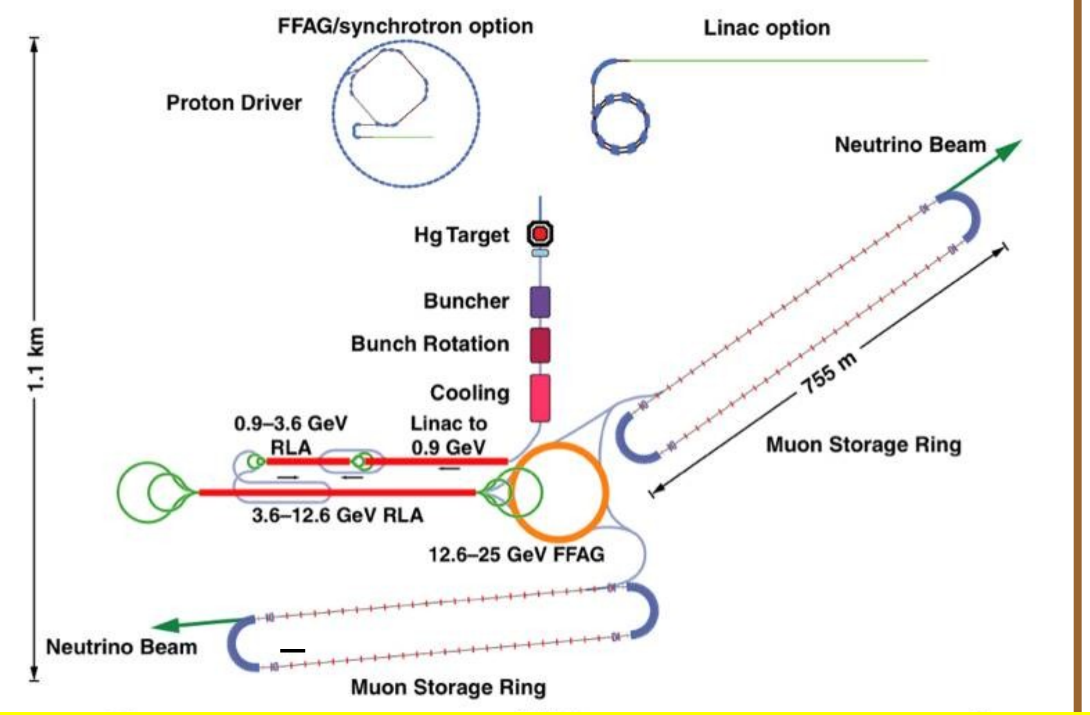
-- magnet expertise
-- control room experts
-- scientific/analysis manpower

not helped by technical delays

Why MICE?

Based on Muon collider ideas and development (Palmer et al, 92->), the Neutrino Factory concept (Geer, 1998) resonated in 1998 with the final demonstration of Atmospheric Neutrino Oscillations by the SuperK Collaboration.

International workshops:
NUFACT 99 (Lyon, France)
NUFACT 00 (Montery, California)
NUFACT 01 (Tsukuba, Japan)
NUFACT 02 (London, UK)
NUFACT 03 (Columbia,NY,USA)
....
NUFACT10 (Mumbai,India) 20Oct10



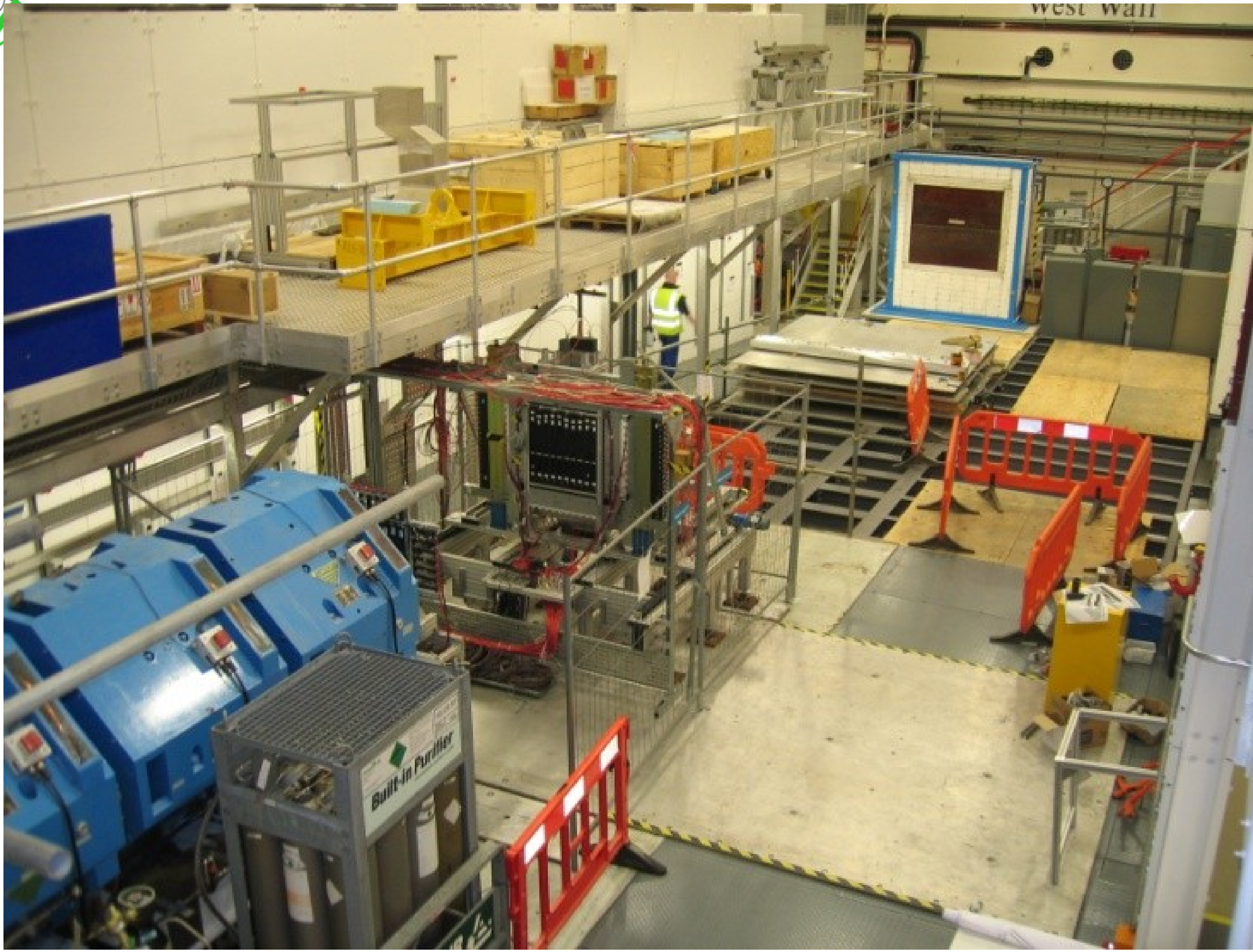
$\mu^+ \rightarrow e^+ \nu_e \ \ \bar{\nu}_\mu$ unique source of high-E ν_e's

$\Rightarrow$ Neutrino Factory is the ultimate tool for study of Neutrino Oscillations

-- unique source of high energy ν_e
--reach/sensitivity better by order(s) of magnitude wrt other techniques (e.g. super-beams) for

* θ_{13} *
** matter effects **
*** leptonic CP violation ***
**** $\nu_e \rightarrow \nu_\mu$ and ν_τ ****

NB : leptonic CP violation is a key ingredient in the leading explanations for the mystery of the baryon-antibaryon asymmetry in our universe



MICE step I in the MICE hall

MICE HALL is all ready for step II-III