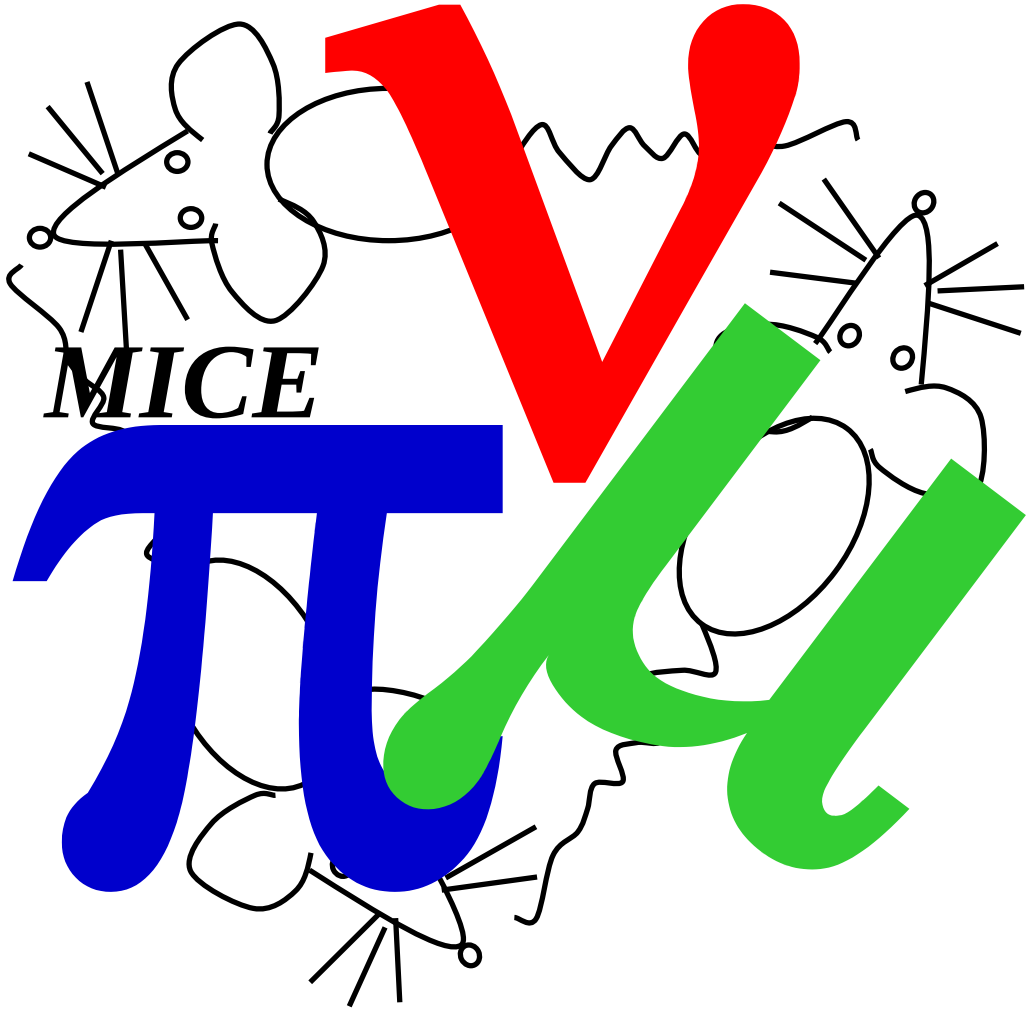
International
Muon Ionization Cooling Experiment



1. Why MICE?
2. Measurement
3. Prototyping
4. MICE at RAL
5. schedule

for more information → http://hep04.phys.iit.edu/cooldemo/

Why MICE?

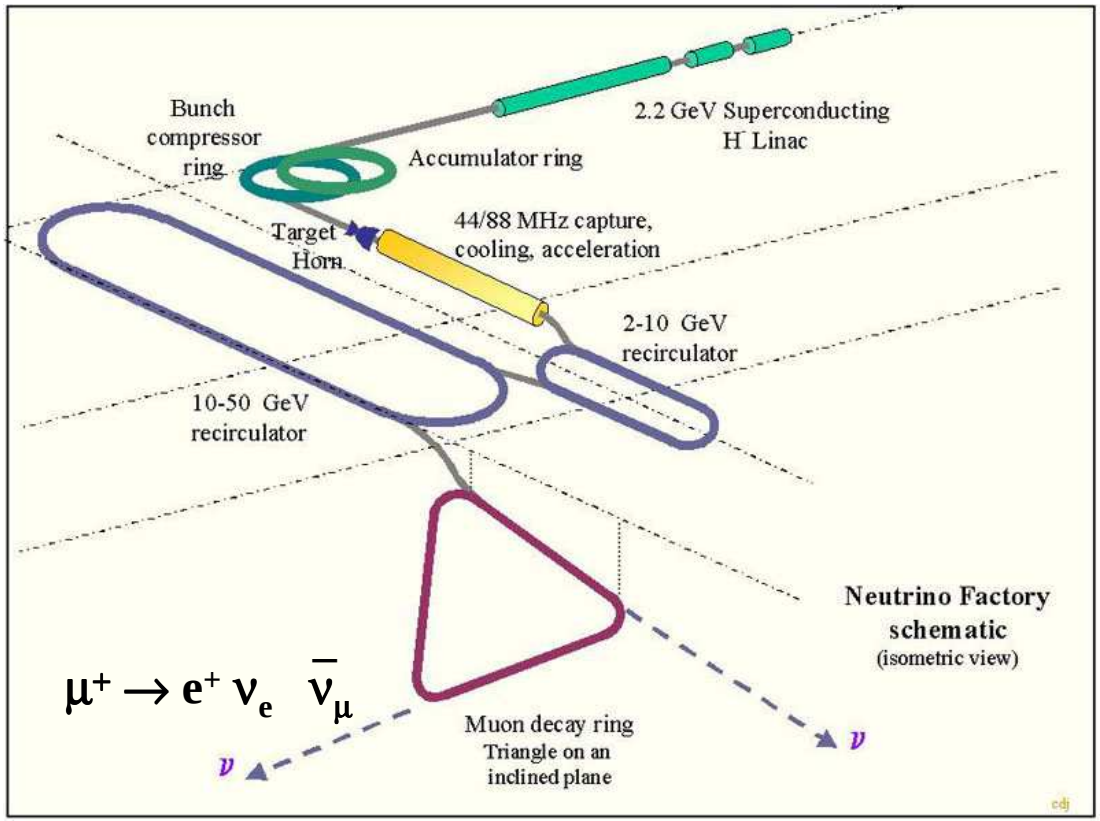
Based on Muon collider ideas and development (Palmer et al, 92->), the Neutrino Factory concept (Geer, 1998) resonated in 1998 with the final demonstration of Atmospheric Neutrino Oscillations by the SuperK Collaboration.

International workshops:

NUFACT 99 (Lyon, France)
NUFACT 00 (Montery, California)
NUFACT 01 (Tsukuba, Japan)
NUFACT 02 (London, UK)
NUFACT 03 (Columbia,NY,USA)
NUFACT 04 (Osaka, Japan)
NUFACT 05 (Frascati,Italy)

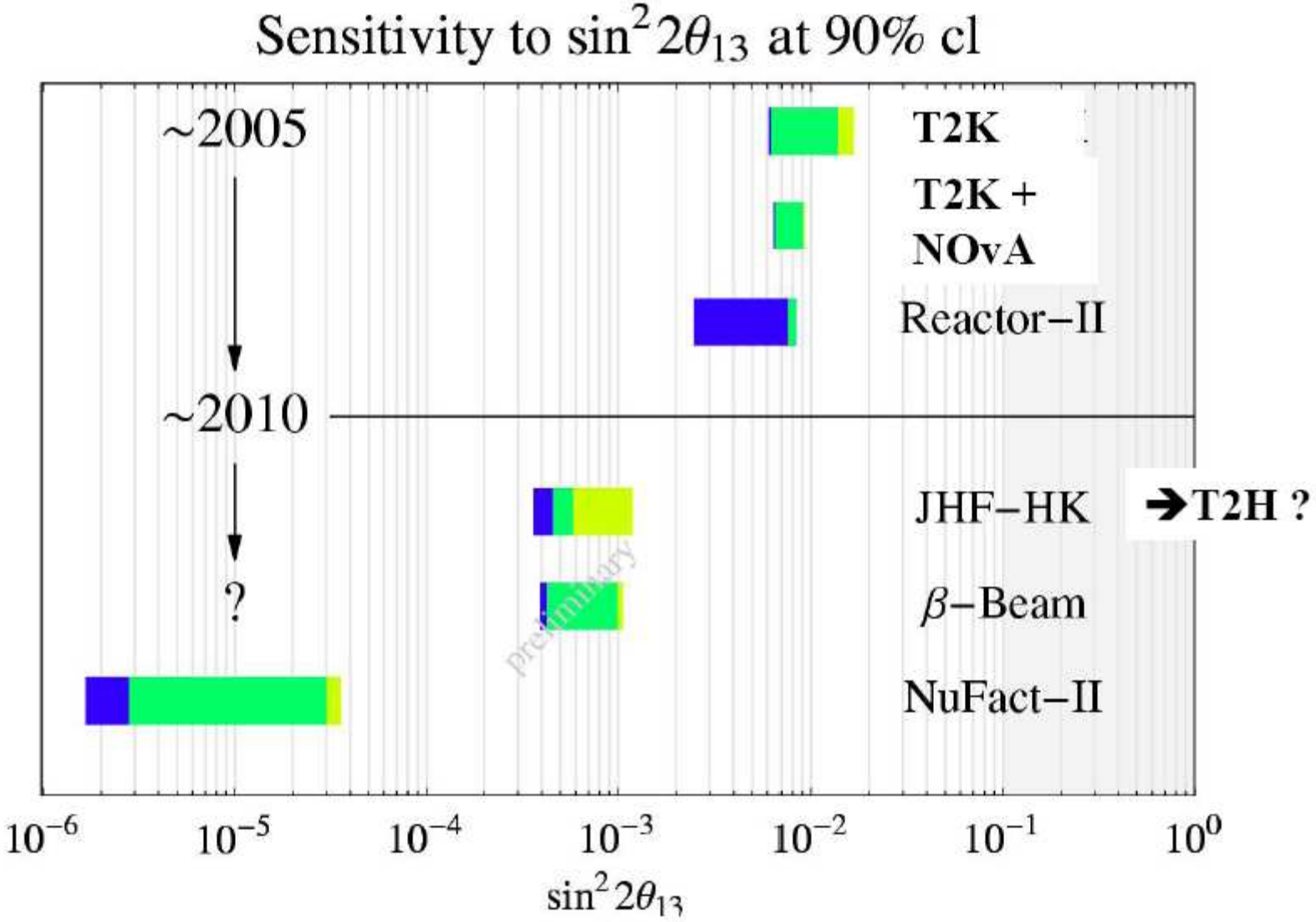
⇒ Neutrino Factory is the ultimate tool for study of Neutrino Oscillations

-- 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


Sensitivity to $\sin^2 2\theta_{13}$ at 90% cl
~2005
~2010
?
T2K
T2K +
NOvA
Reactor–II
JHF–HK
➔T2H ?
β–Beam
NuFact–II
Preliminary
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
$\sin^2 2\theta_{13}$

Neutrino factory physics conclusions

(my concluding slide at SPSC in sept 2004)

1. The Neutrino Factory remains the most powerful tool imagined so far to study neutrino oscillations

Unique: High energy $\nu_e \rightarrow \nu_\mu$ *and* $\nu_e \rightarrow \nu_\tau$ transitions
at large θ_{13} has the precision
at small θ_{13} has the sensitivity

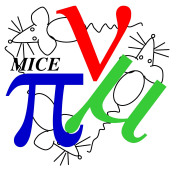
2. The complex offers many other possibilities

3. It is a step towards muon colliders

4. There are good hopes to reduce the cost significantly thus making it an excellent option for CERN in the years 2011-2020

5. Regional and International R&D on components and R&D experiments are being performed by an enthusiastic and motivated community
(rate of progress is seriously funding limited, however)

6. Opportunities exist in Europe:
HI proton driver, (SPL@CERN)
Target experiment @ CERN
Collector development @LAL-CERN
MICE @ RAL



ECFA recommendations (September 2001:)

4) an improved educational programme in the field of accelerator physics and increased support for accelerator R&D activity in European universities, national facilities and CERN.

For the long-term:

5) a co-ordinated collaborative R&D effort to determine the feasibility and practical design of a neutrino factory based on a high-intensity muon storage ring;

MUTAC (14-15 jan 2003)(US)
The committee remains convinced that this experiment, which is absolutely required to validate the concept of ionization cooling, and the R&D leading to it should be the highest priority of the muon collaboration. Planning and design for the experiment have advanced dramatically(…)

EMCOG: (6 feb 2003) (Europe)
(…)EMCOG was impressed by the quality of the experiment, which has been well studied, is well organized and well structured. The issue of ionization cooling is critical and this justifies the important effort that the experiment represents.
EMCOG recommends very strongly a timely realization of MICE.

MUTAC: Muon Technical Advisory Committee (Helen Edwards, et al) (US)
EMCOG: European Muon Coordination and Oversight Group (C. Wyss et al)

John Dainton
Villars 2004
October 7th 2004
CERN seminar

SPSC

2010

.. Future neutrino facilities offer great promise for fundamental discoveries (such as CP violation) in neutrino physics, and a post-LHC construction window may exist for a facility to be sited at CERN.

..CERN should arrange a budget and personnel to enhance its participation in further developing the physics case and the technologies necessary for the realization of such facilities. This would allow CERN to play a significant role in such projects wherever they are sited.

..A high-power proton driver is a main building block of future projects, and is therefore required.

..A direct superbeam from a 2.2 GeV SPL does not appear to be the most attractive option for a future CERN neutrino experiment as it does not produce a significant advance on T2K.

..We welcome the effort, partly funded by the EU, concerned with the conceptual design of a β-beam. At the same time CERN should support the European neutrino factory initiative in its conceptual design.

encouraging signs from CERN…
report from Scientific Policy Committee to council

Recommendations

- CERN should make every reasonable effort to deliver the approved p.o.t. to CNGS.
- Future neutrino facilities offer great promise for fundamental discoveries. CERN should join the world effort in developing technologies for new facilities : Beta beams, Neutrino Factory…wherever they are sited.
- Focus now on enabling CERN to do the best choice by 2010 on future physics programme.
- Explore further synergies with EURISOL

Particle physicist:
Q: Can a Neutrino Factory be built?

Accelerator physisicst:
A: YES! *(US Study II, CERN)*

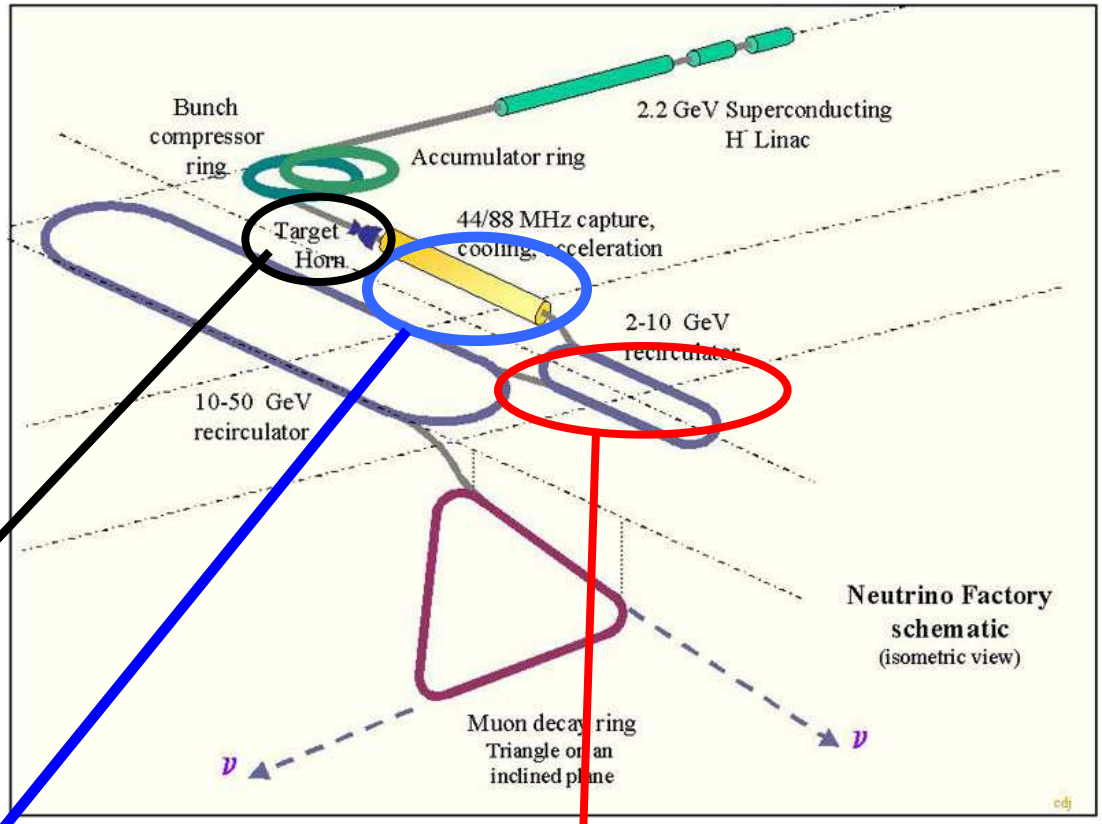
but… it is expensive,
and many ingredients
have never been demonstrated!

⇒ R&D is needed. (est. 5yrs)
to
1. ascertain performance
2. reduce costs

among critical items:

Target

*** COOLING ***

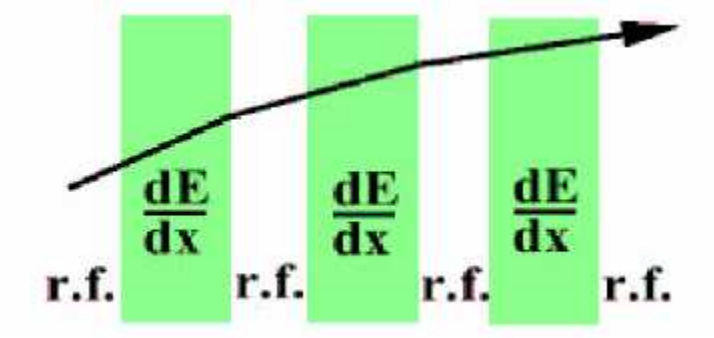


*** Acceleration ***

Cooling component development programme+ 'blast test':
MUCOOL collabration (US-Japan-UK)

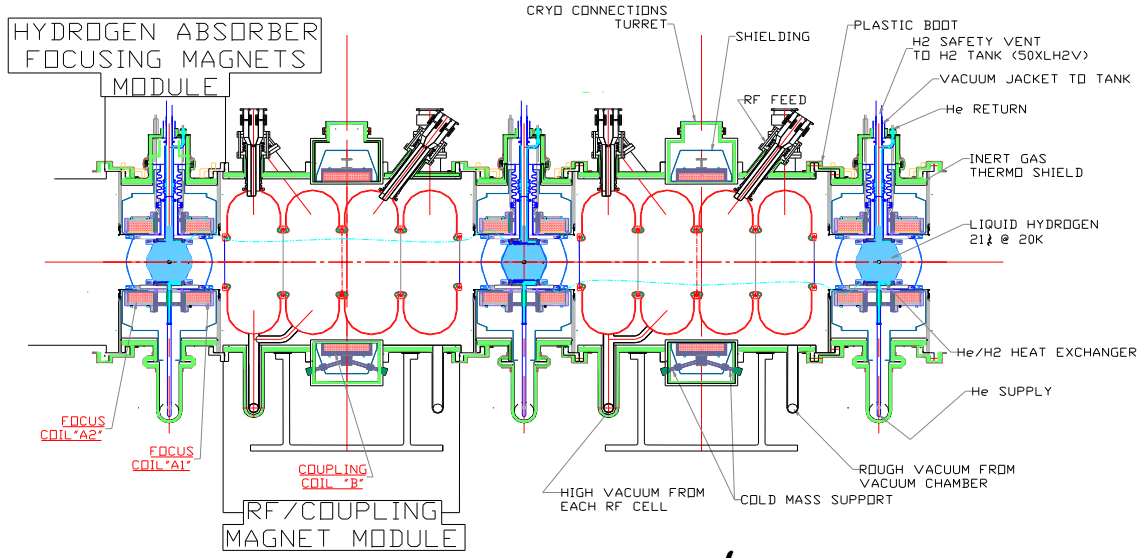
IONIZATION COOLING

principle:



this will surely work..!

reality (simplified)



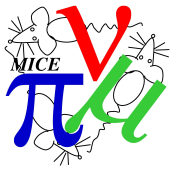
….maybe…

A delicate technology and integration problem
Need to build a realistic prototype and verify that it works (i.e. cools a beam)
Difficulties lay in particular in
⇒ operating RF cavities in Mag. Field,
⇒ interface with SC magnets and LH2 absorbers
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.

⇒RF Noise!!



An International Muon Ionization Cooling Experiment (MICE)

Summary

The aims of the international Muon Ionization Cooling Experiment are:

To show that it is possible to design, engineer and build a section of cooling channel capable of giving the desired performance for a Neutrino Factory;
To place it in a muon beam and measure its performance in a variety of modes of operation and beam conditions.

The beam never lies

The MICE collaboration has designed an experiment where a section of an ionisation cooling channel is exposed to a muon beam and reduces its transverse emittance by 10% for muon momenta between 140 and 240 MeV/c.

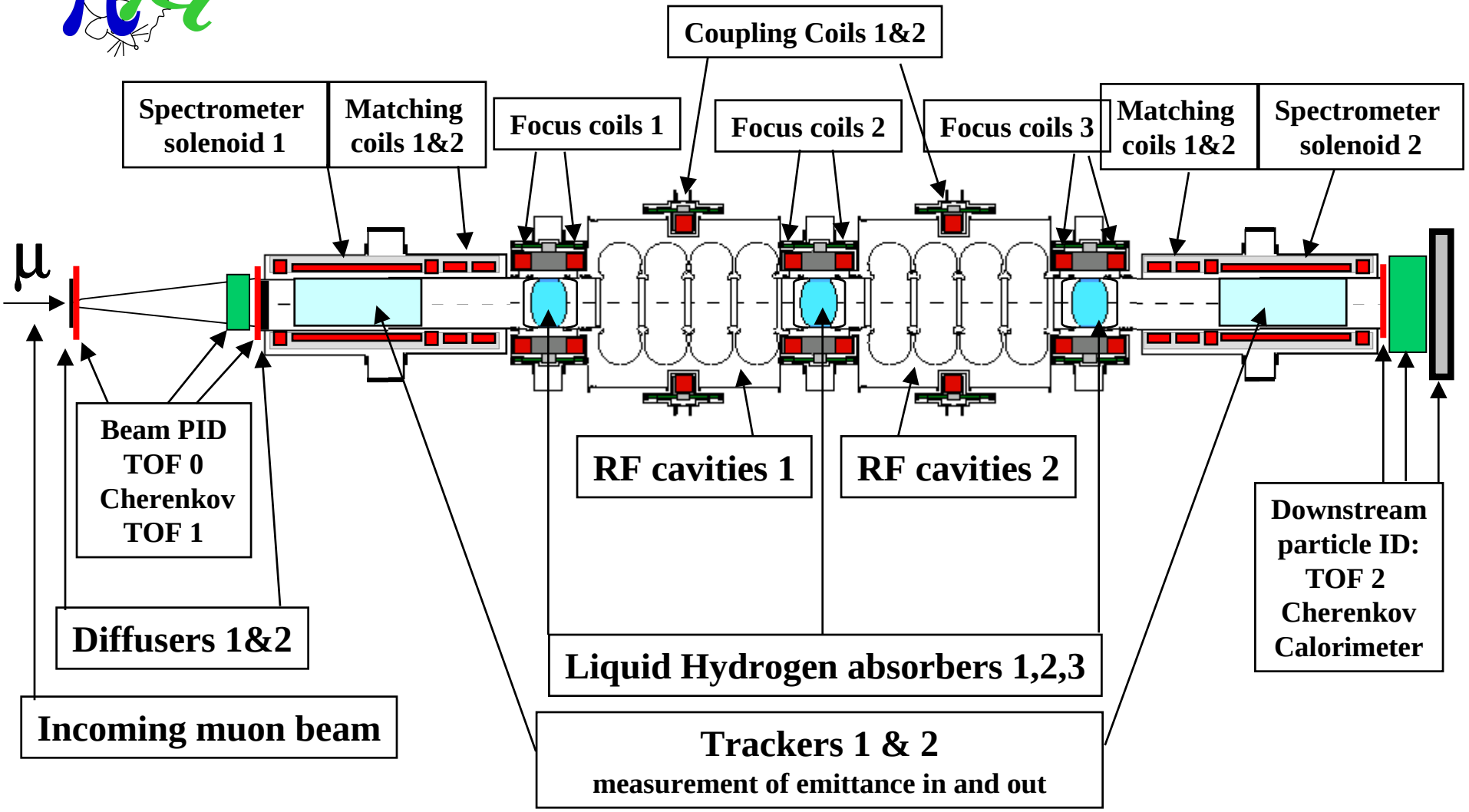
The experiment has been called for, recommended and APPROVED….

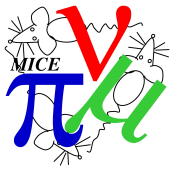
10% cooling of 200 MeV/c muons requires ~ 20 MV of RF

single particle measurements =>

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

never done before either….





Some challenges of MICE:

1. Operate RF cavities of relatively low frequency (200 MHz) at high gradient (16 MV/m) in highly inhomogeneous magnetic fields (1-3 T)
   dark currents (can heat up LH_2), breakdowns

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

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

And…

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

Universite Catholique de Louvain Belgium

INFN Bari, INFN Laboratori Nazionali di Frascati INFN Genova
INFN, Laboratori Nazionali di Legnaro INFN Milano INFN Napoli INFN Padova
INFN Roma III ROMA TRE University INFN, Trieste Italy

KEK Osaka University Japan

NIKHEF The Netherlands

CERN
Geneva Paul Scherrer Institut Switzerland

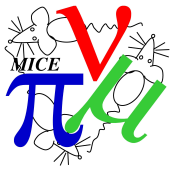
Brunel University Edinburgh Glasgow Liverpool ICL London Oxford Darsbury RAL Sheffield UK

Argonne National Laboratory
Brookhaven National Laboratory
Fairfield University
University of Chicago Enrico Fermi Institute
Fermilab
Illinois Institute of Technology
Jefferson Lab
Lawrence Berkeley National Laboratory
UCLA Physics Department
Northern Illinois University
University of Iowa
University of Mississippi
University of California, Riverside
University of Illinois at Urbana-Champaign USA

THE MICE COLLABORATION
140 collaborators
60 of which attended
the MICE collaboration
meeting at LBNL last week

MICE is an international effort from the start.

NUFACT00	Re-activated the recognized need for muon cooling expt
2000-2001	Workshops on Muon Cooling Experiment (CERN, Chicago, London)
NUFACT01 7:30 am	Steering group formed
Sept. 2001	Workshop at CERN where final experiment took shape.
November 2001	Letter of Intent (LOI) submitted to PSI and RAL
January 2002	PSI cannot host experiment, will collaborate (beam solenoid)
June 2002	RAL IPRP Review Panel encouraged submission of a proposal
January 2003	Proposal submitted
July 2003	Recommendation by International Peer Review Panel
October 2003	'Scientific approval' letter by RAL CEO JohnWood
	Project Manager appointed (P. Drumm, RAL)
	RAL CM: collaboration charter approved
December 2003	Gateway 1 review
June 2004	Gateway 1 passed on 'amber'
20 December 2004	Gateway 2/3 passed 10 green + 4 amber (MICE PHASE I)
22-25 February 2005	Release of funding remains to be approved by PPARC and CCLRC end of february 2005 9.7 M£



at that point MICE (PhaseI) should be an approved and funded project in 5 countries

-- UK: 9.7M£

-- USA: 1.2 M$ approved for next three years (NSF+DOE)
(+RF source + MRI proposal + ?)

-- Japan: US-Japan ~$100k/yr, UK-Japan (travel funds)
(+ 500k$ requested)

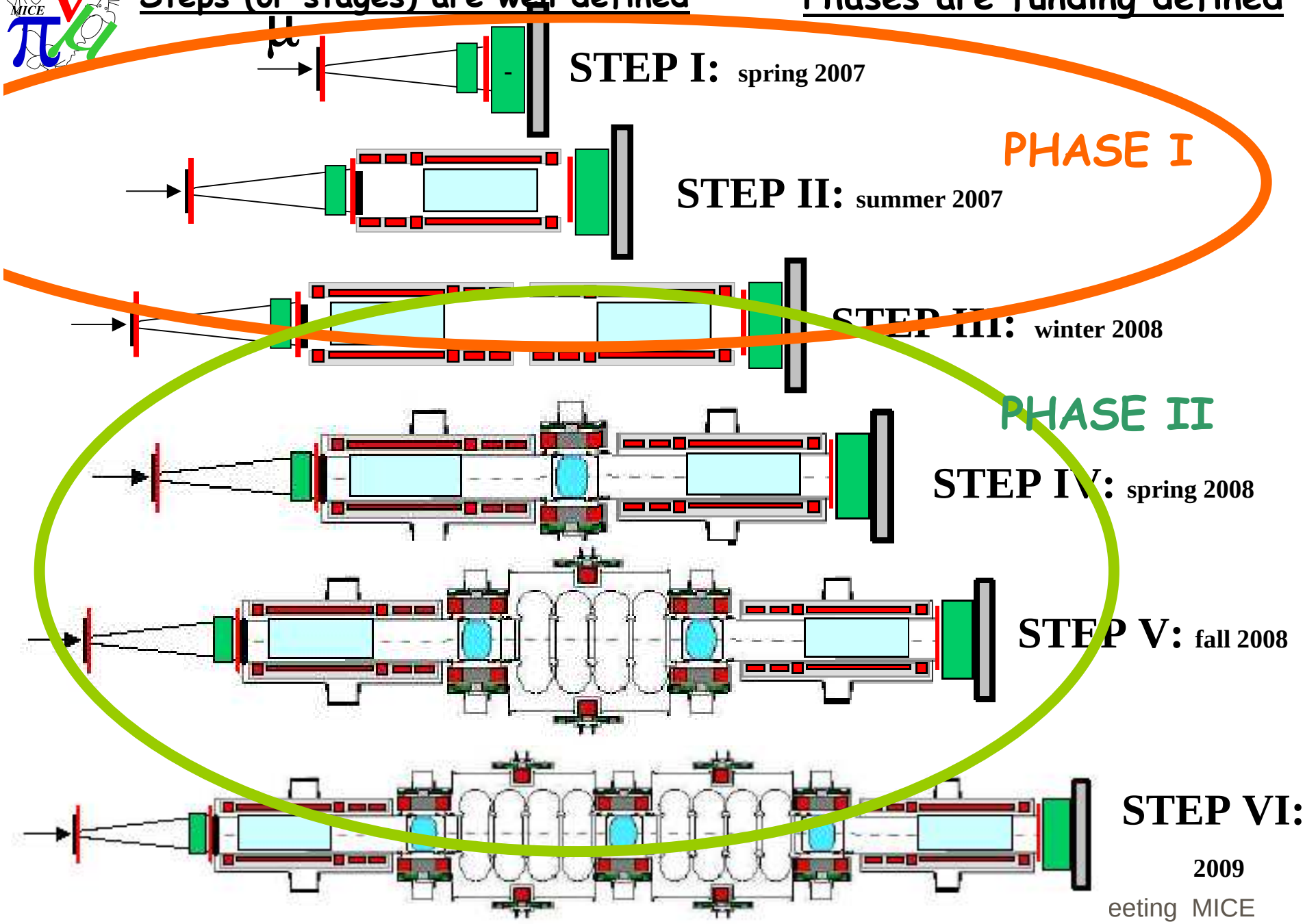
-- Switzerland: PSI solenoid + Uni-Geneva-NSwissF (80KCHF/yr)+ 1 PDA+1PhDS

-- Netherlands: Mag probes + 1 PhDS

+ Proposal invited in Italy and submitted in Belgium,
EU funding proposal being put together.

Steps (or stages) are well defined

Phases are funding defined



Thanks to the outstanding work of all MICE
with special congratulations to UK colleagues
(Paul Drumm, Ken Long and our godfather K.Peach!)
for getting experiment through gateways:

MICE is getting REAL!

First beam 1st April 2007

**** 365*2+46= 774 days to data taking !!!

Meanwhile….

MICE is being

designed

simulated

reviewed

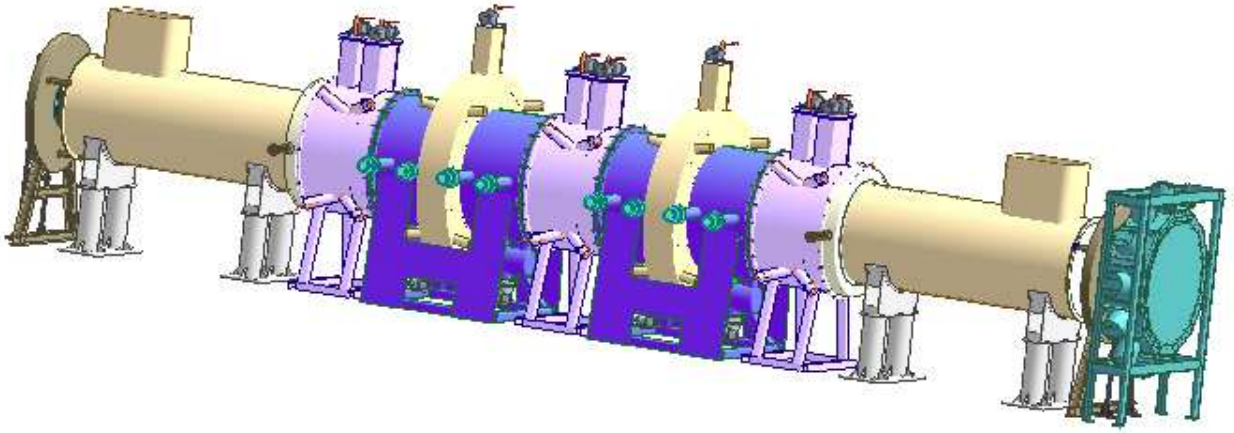
MOU'ed

dug

and prototyped!


Presenting a
VERY SPECIAL DANCE
IN YOUR HONOR!
Ladies & Gentlemen
The Cooling Channel strip show
GO!
Wing Lau and Stephanie Wang

Comp.	TOF0	Chev 2	TOF 1&2	Magnetic Shield	Detector Module	Radiation Shield	AFC modules 1 & 3	Coupling Modules 1 & 2
visible	□	□	□	□	□	□	□	□



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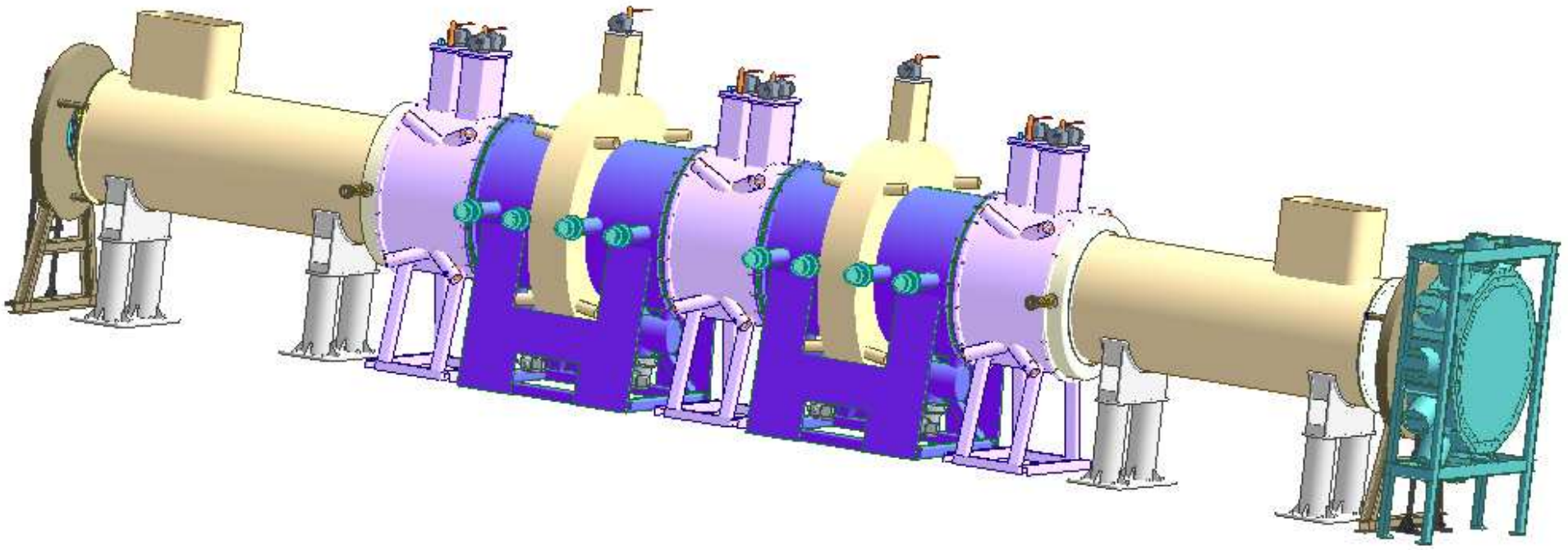

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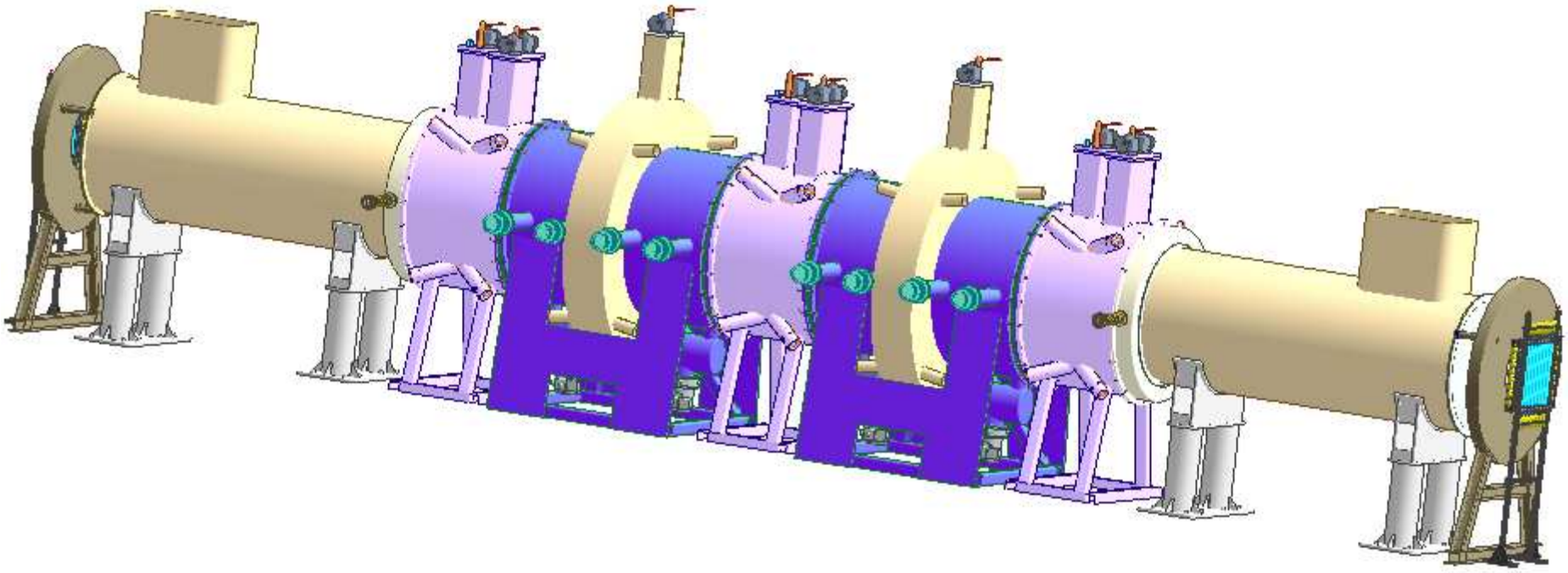
visible			□	□	□	□	□	□



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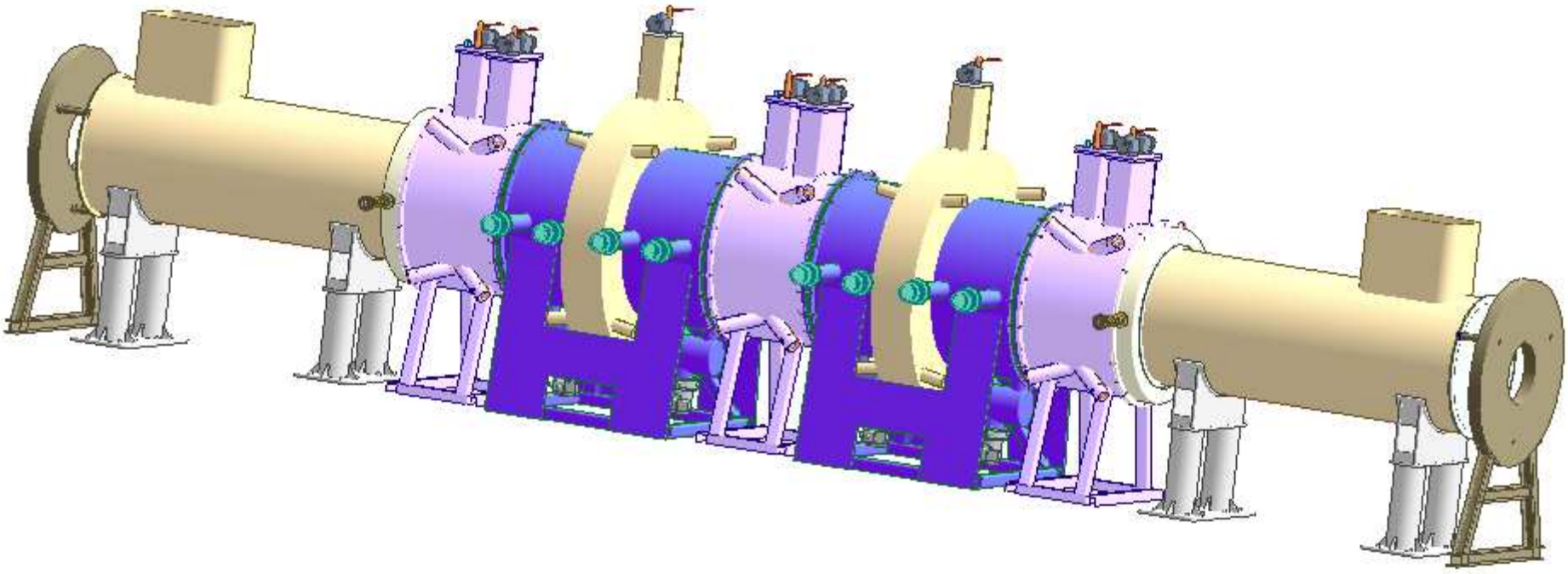
visible				□	□	□	□	□



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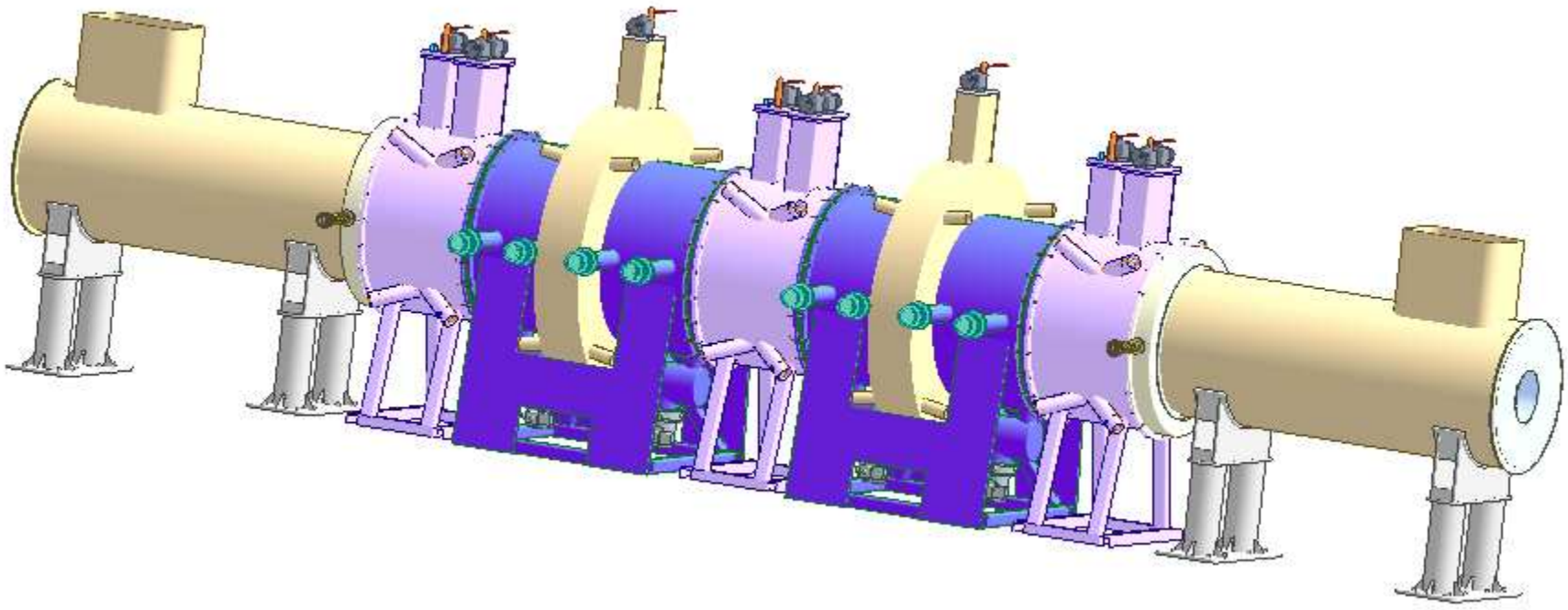
visible					□	□	□	□



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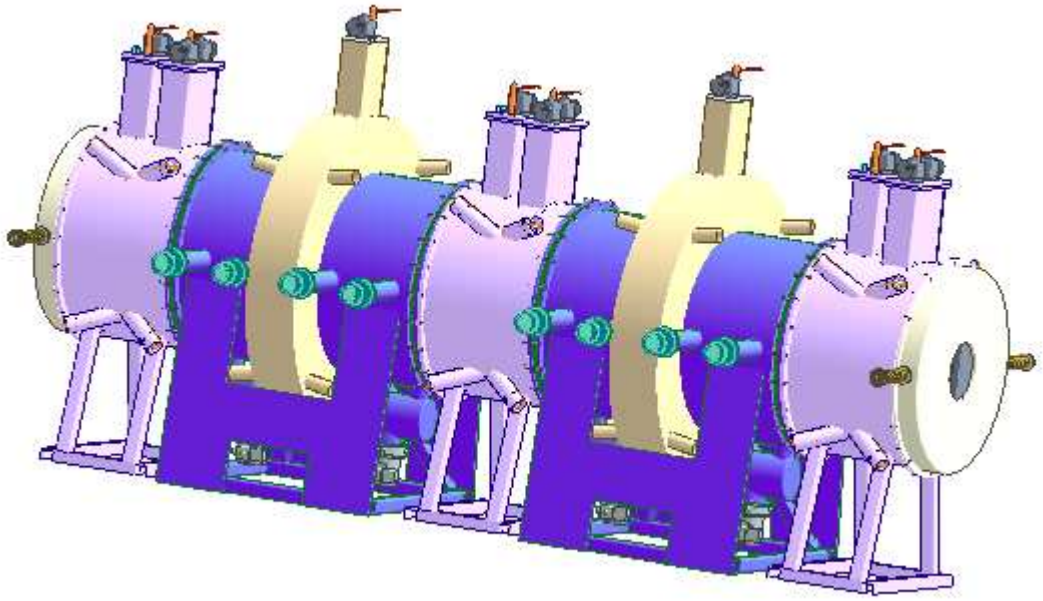
visible						□	□	□



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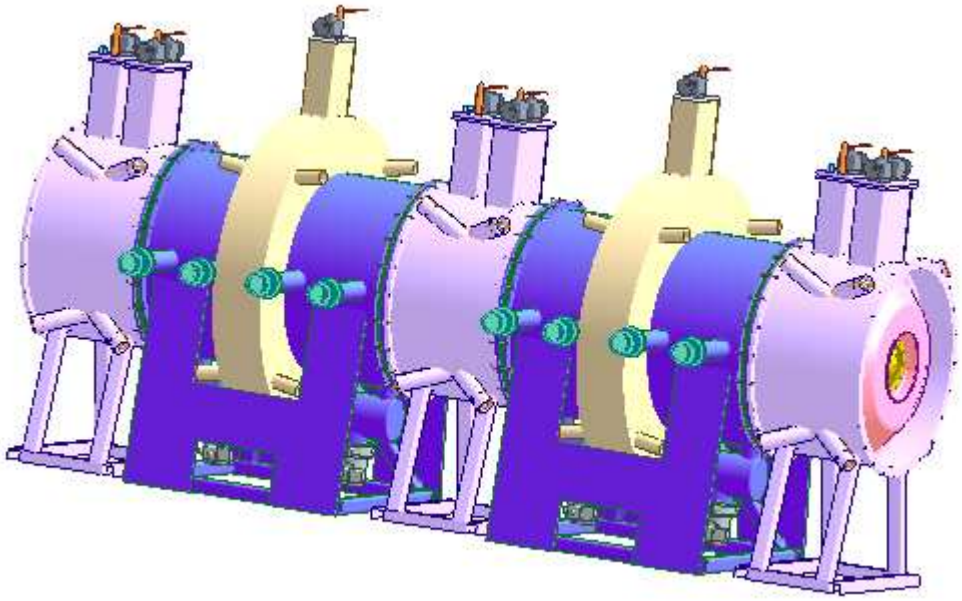

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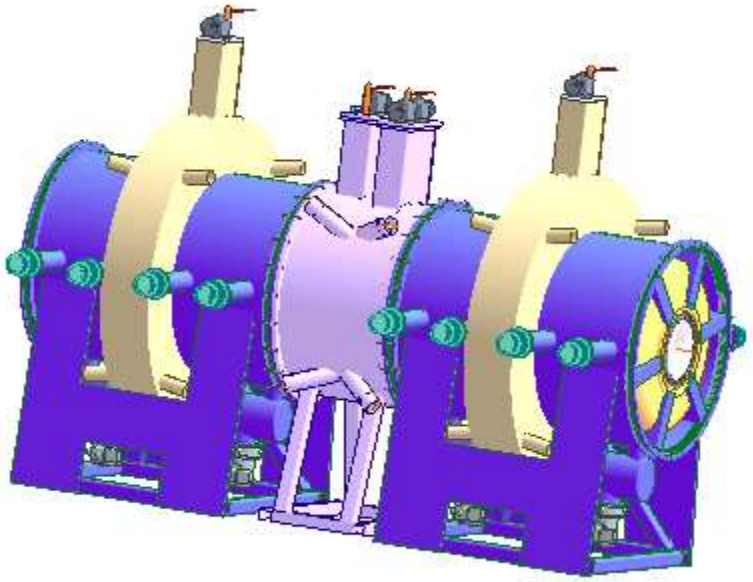

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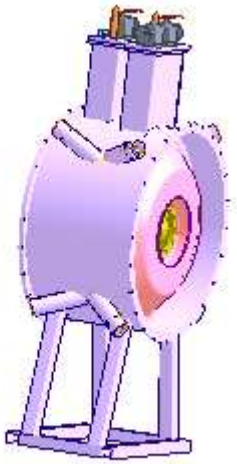
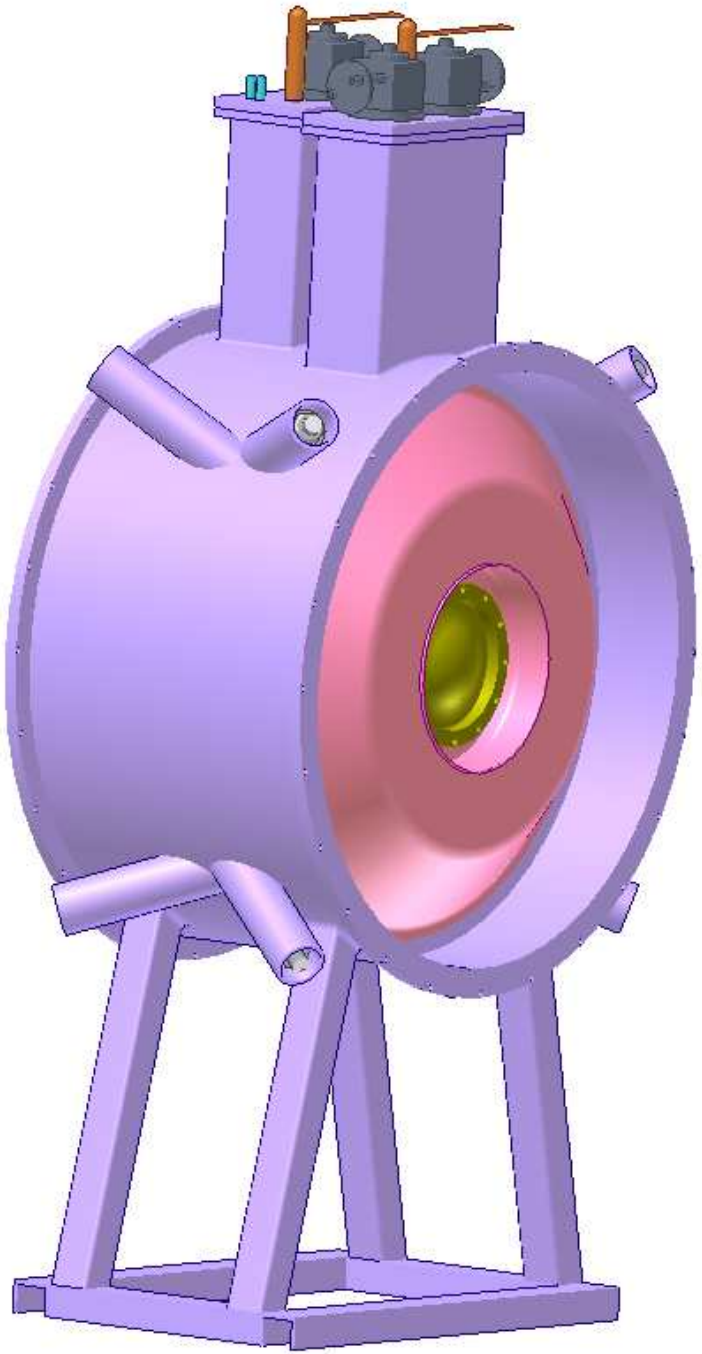
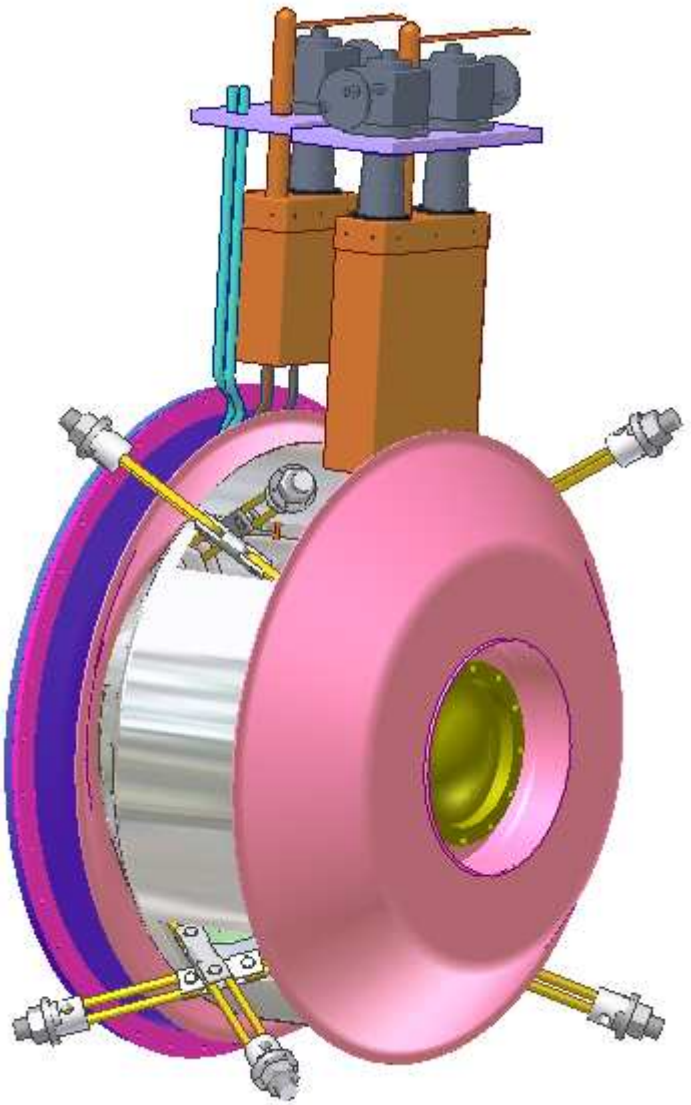
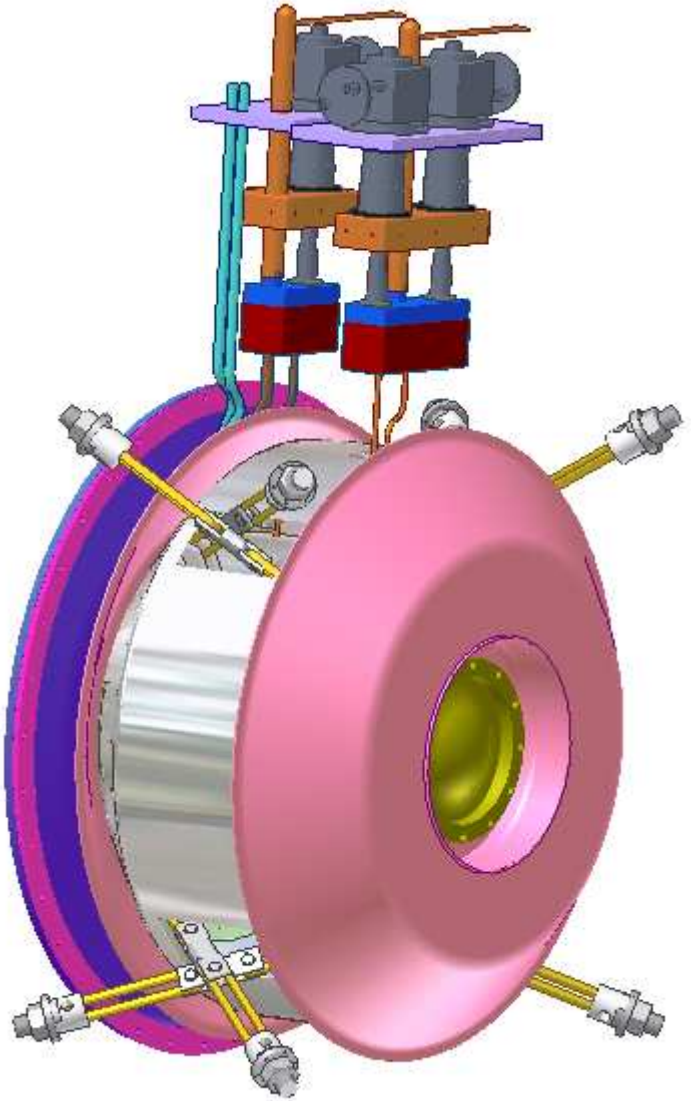
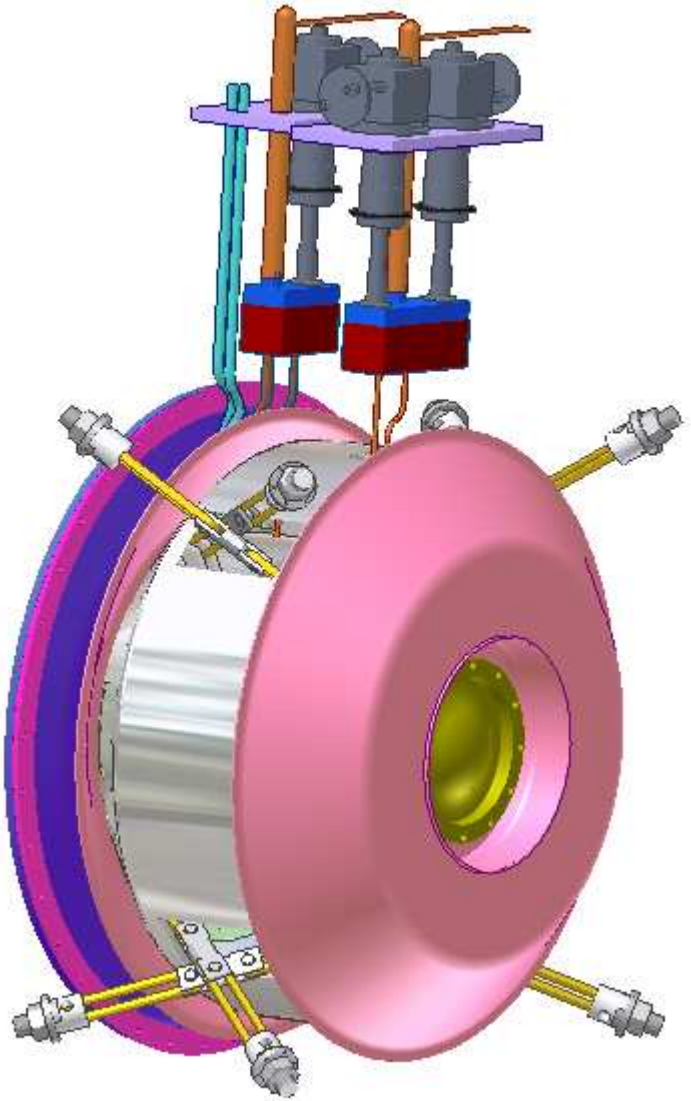
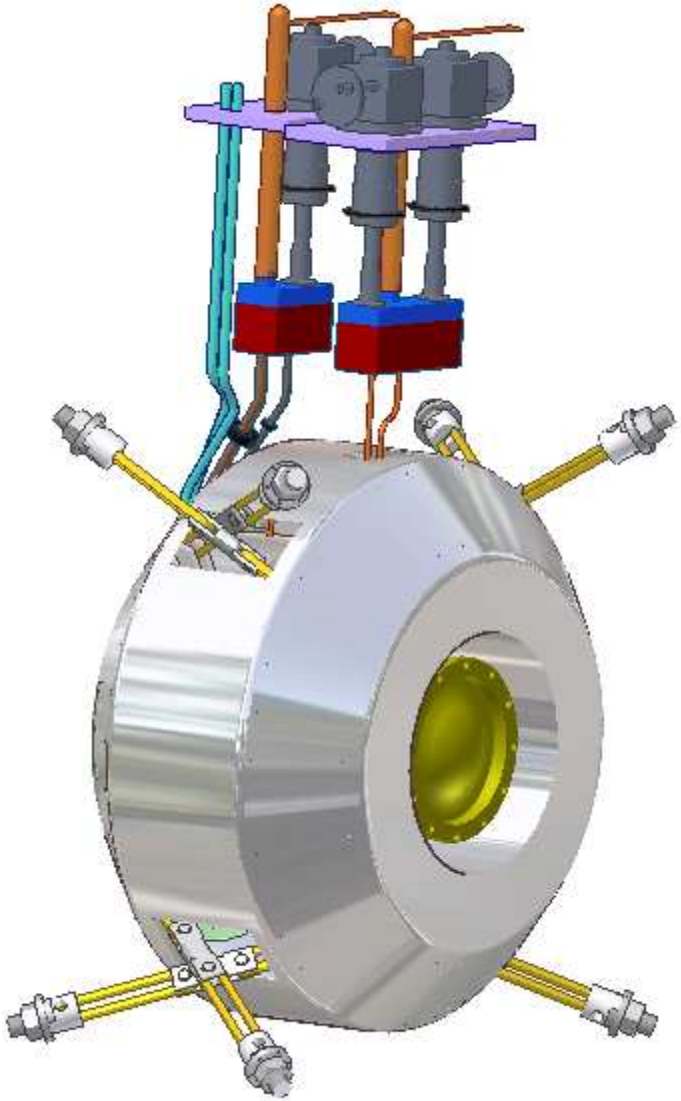


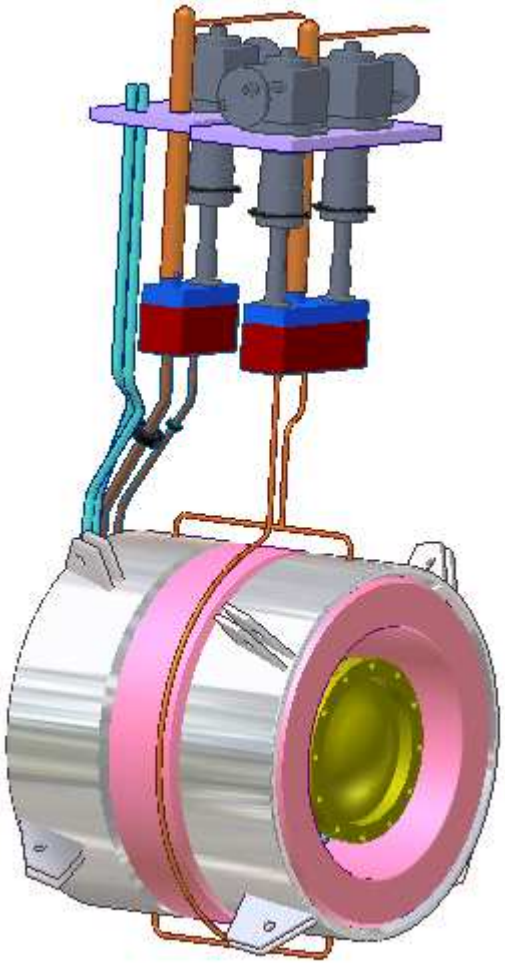


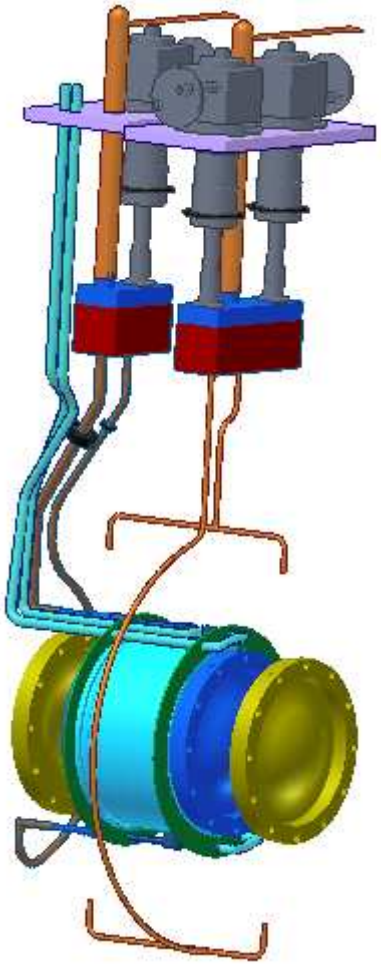


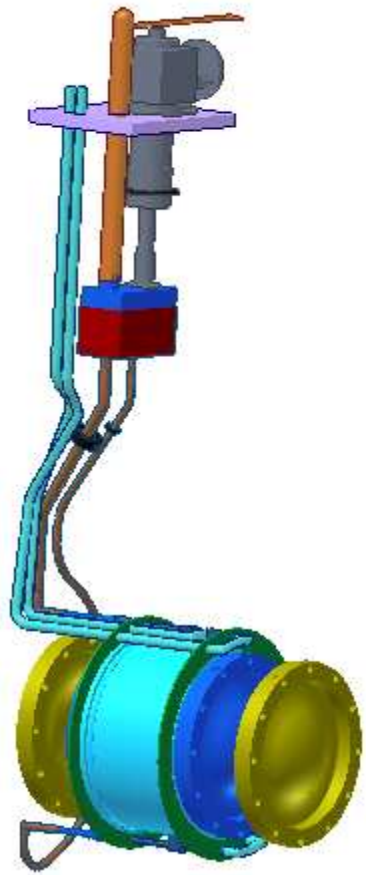


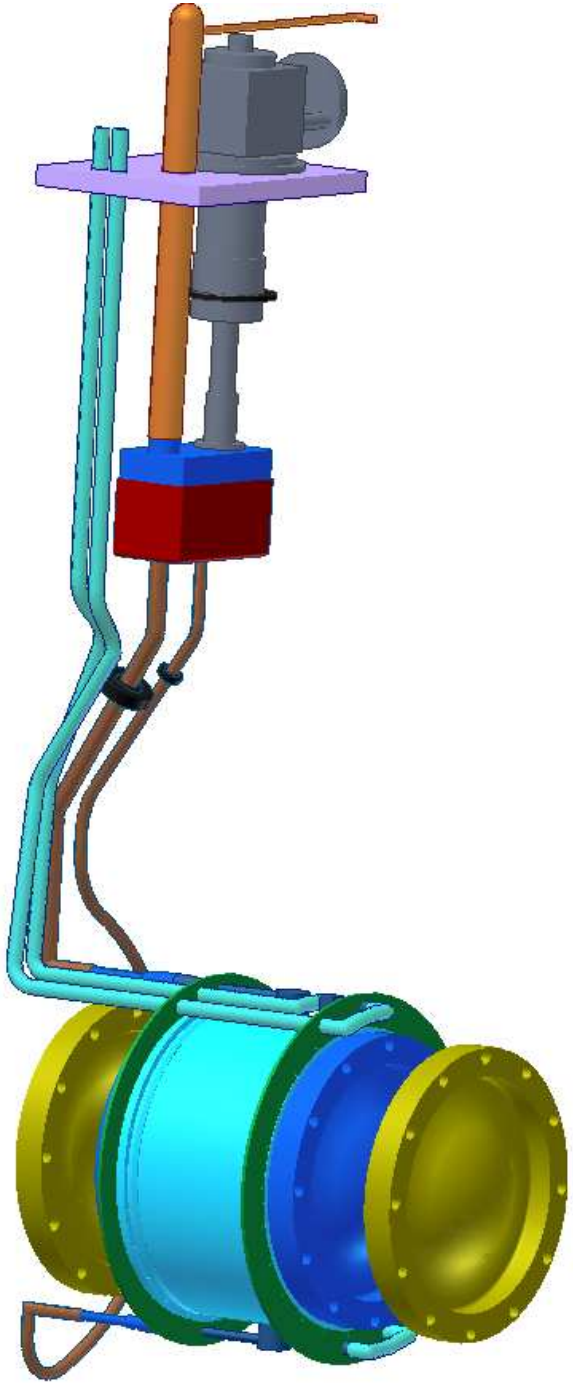


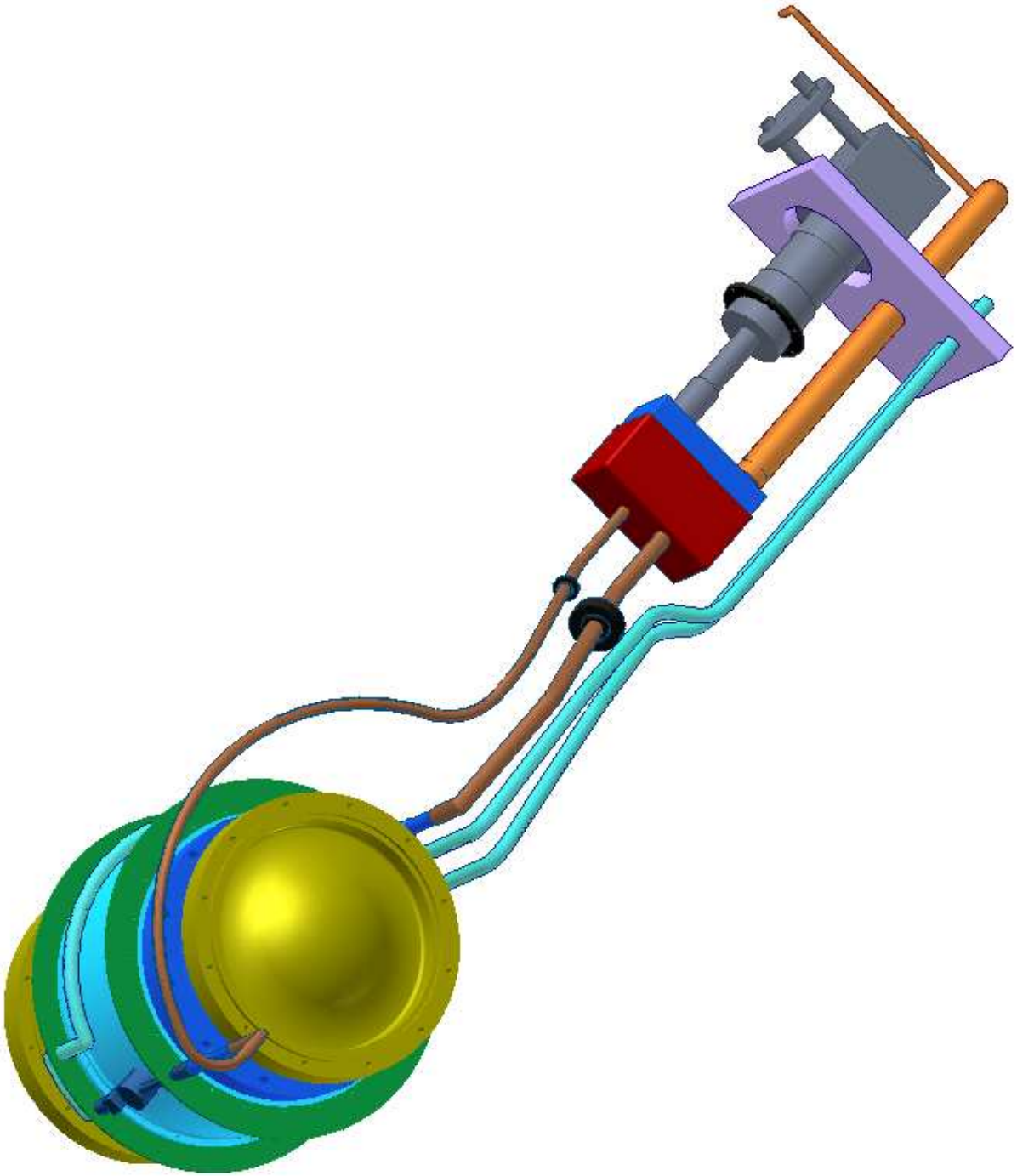


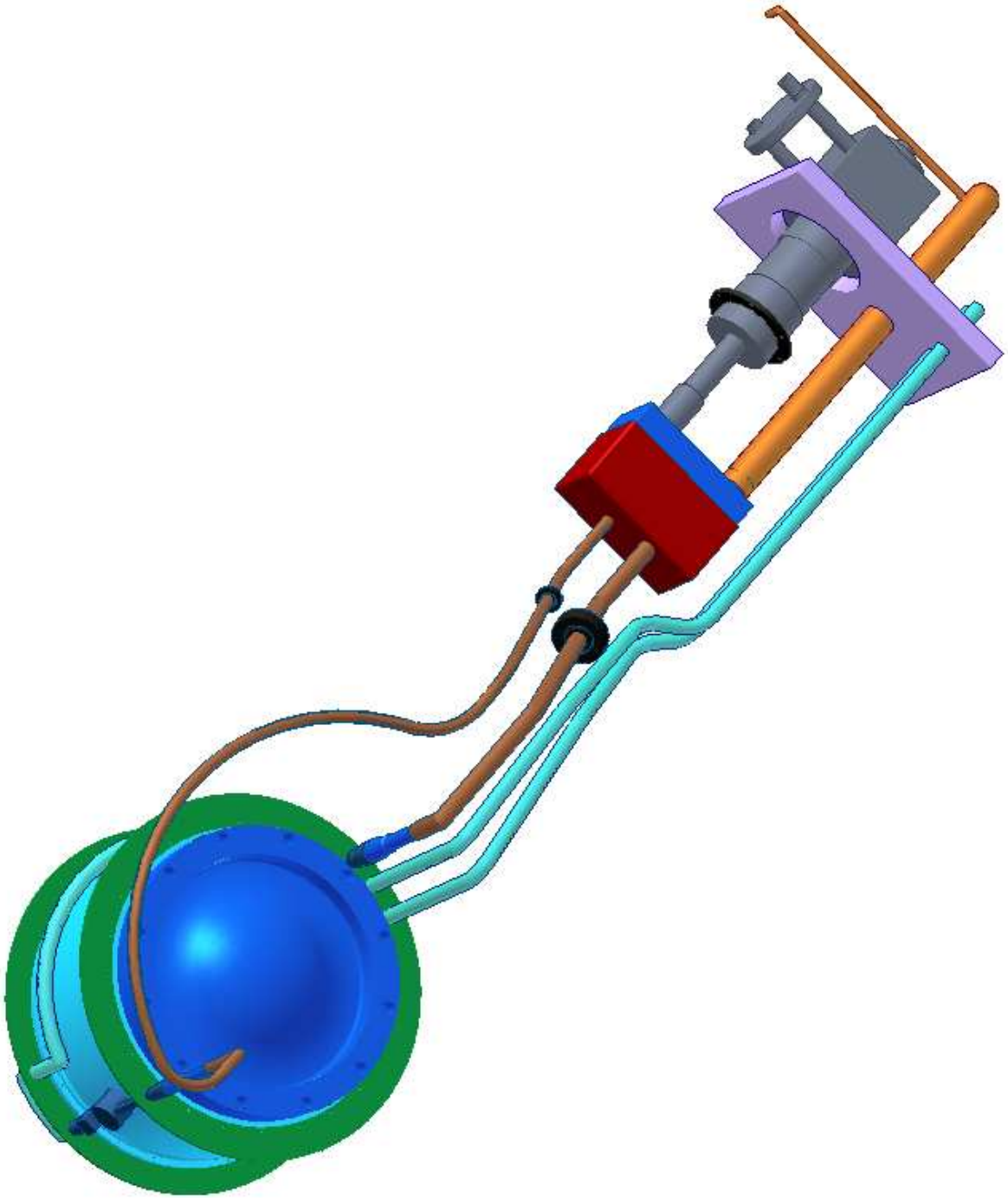


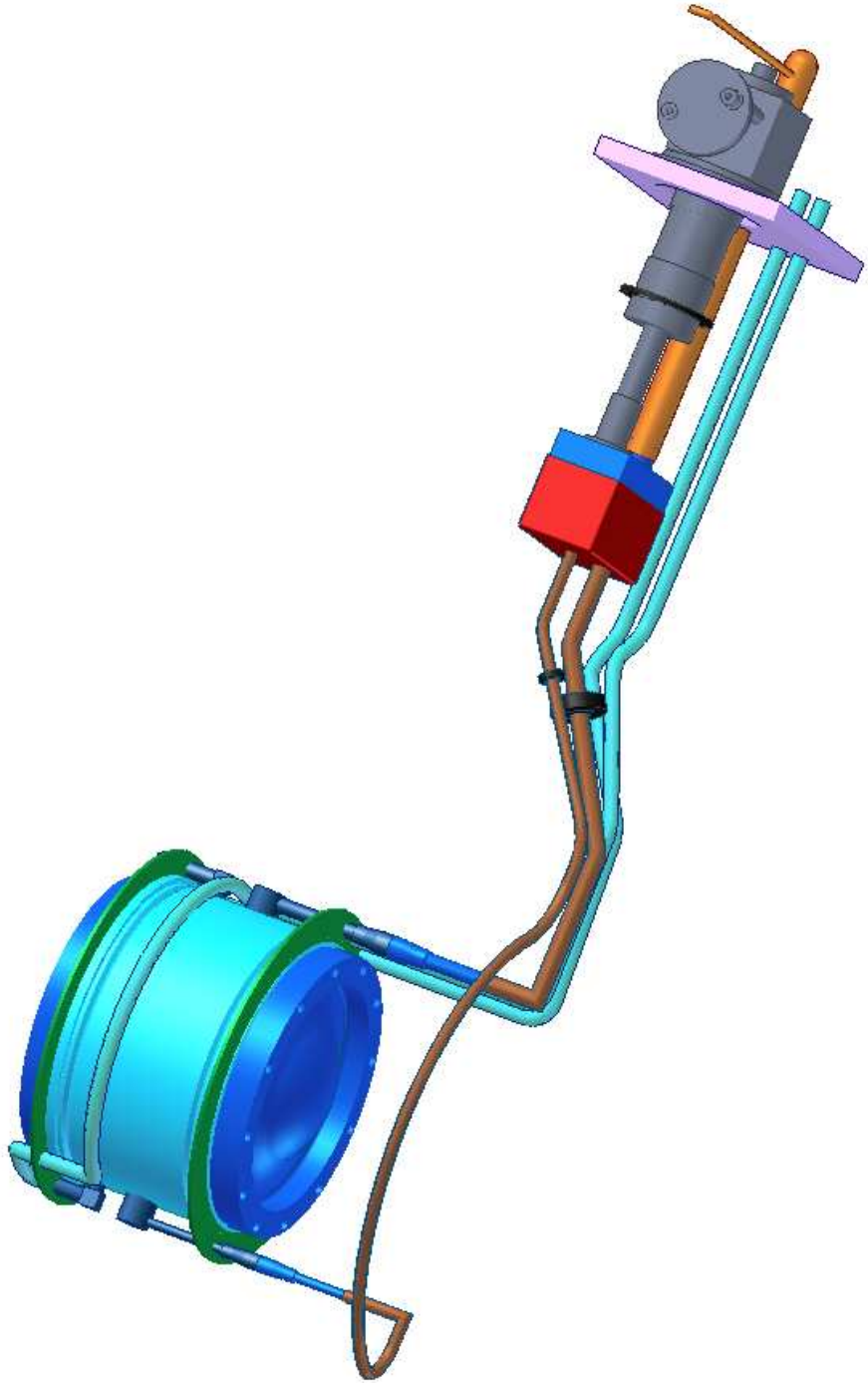










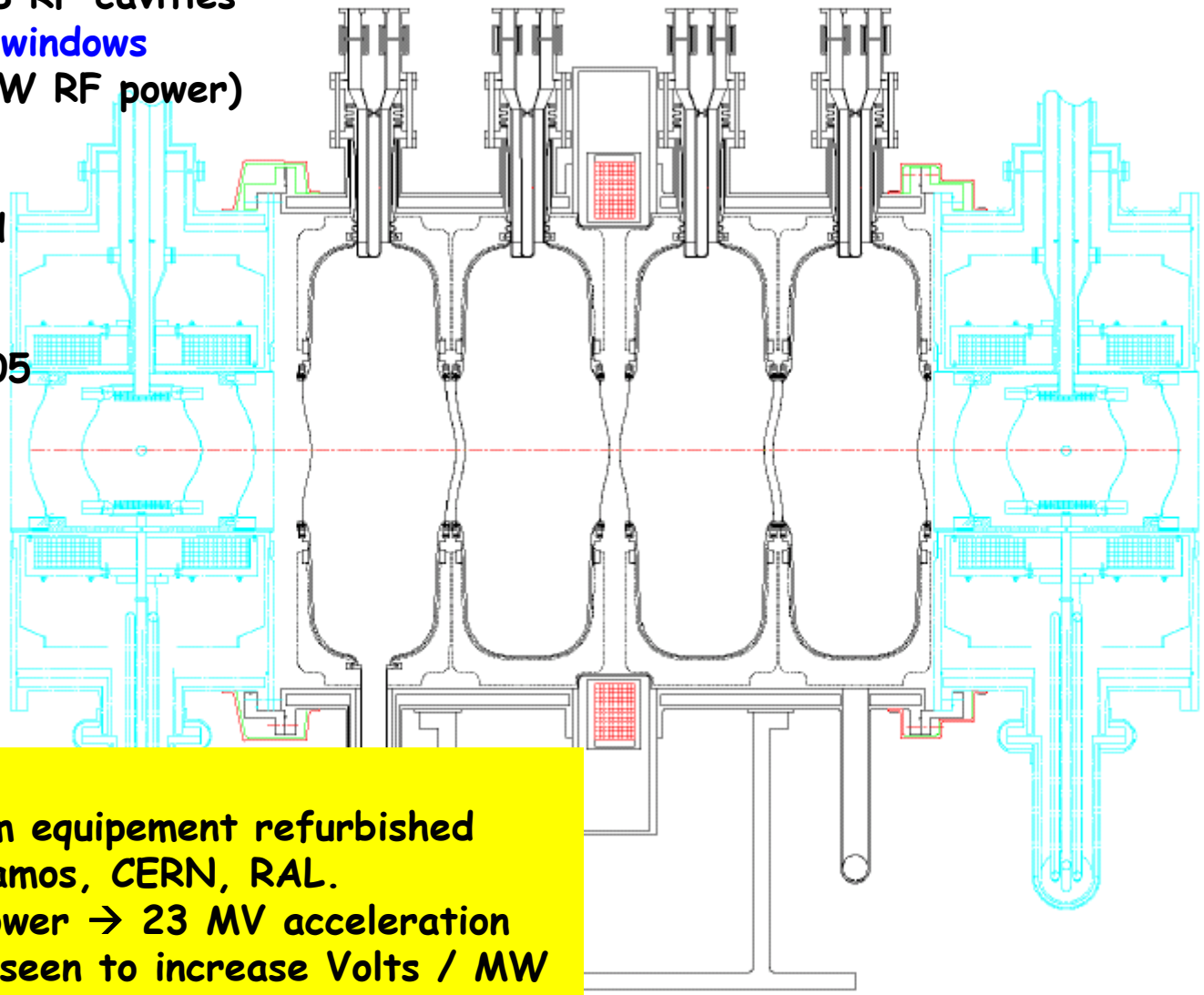


RF module

MICE is foresen with 8 RF cavities
Closed with curved Be windows
(increase gradient / MW RF power)
201 MHz

First cavity prototyped
(MUCOOL)

Completion in April 2005



RF power sources :
Will be assembled from equipement refurbished from Berkeley, Los Alamos, CERN, RAL.
Needed 8 MW peak power → 23 MV acceleration
Operation at LN2 foreseen to increase Volts / MW

SIMULATION

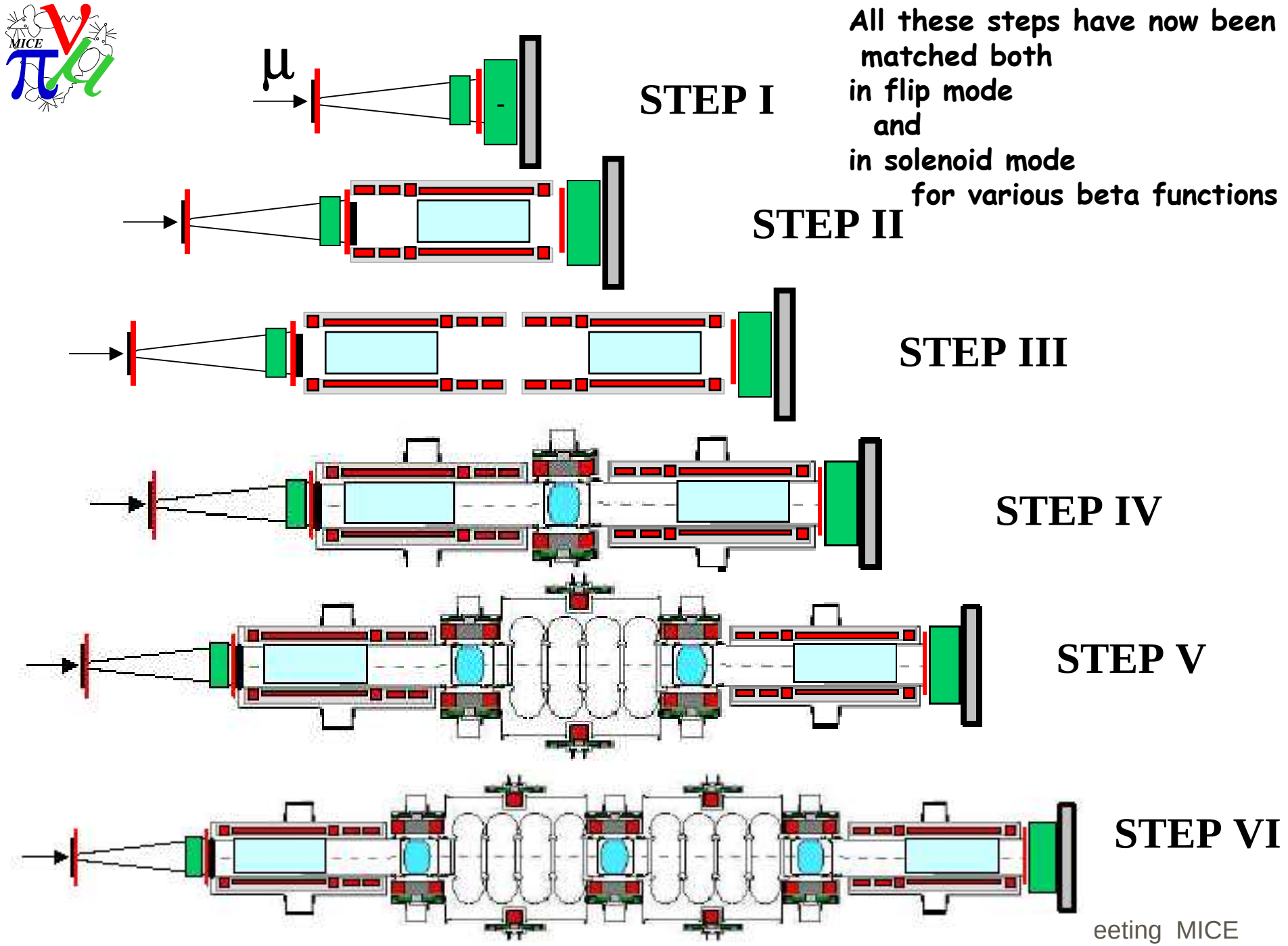
-- beam line : Turtle (Kevin Tilley) + G4beamline (Tom Roberts)
match input beam (quads and dipoles) to MICE (solenoid)

600 'good muons' per ISIS spill should be achievable
→ 10^{-3} emittance measurement in 1 hr (stat)

(work to do for diffuser, variety of optics, etc…)

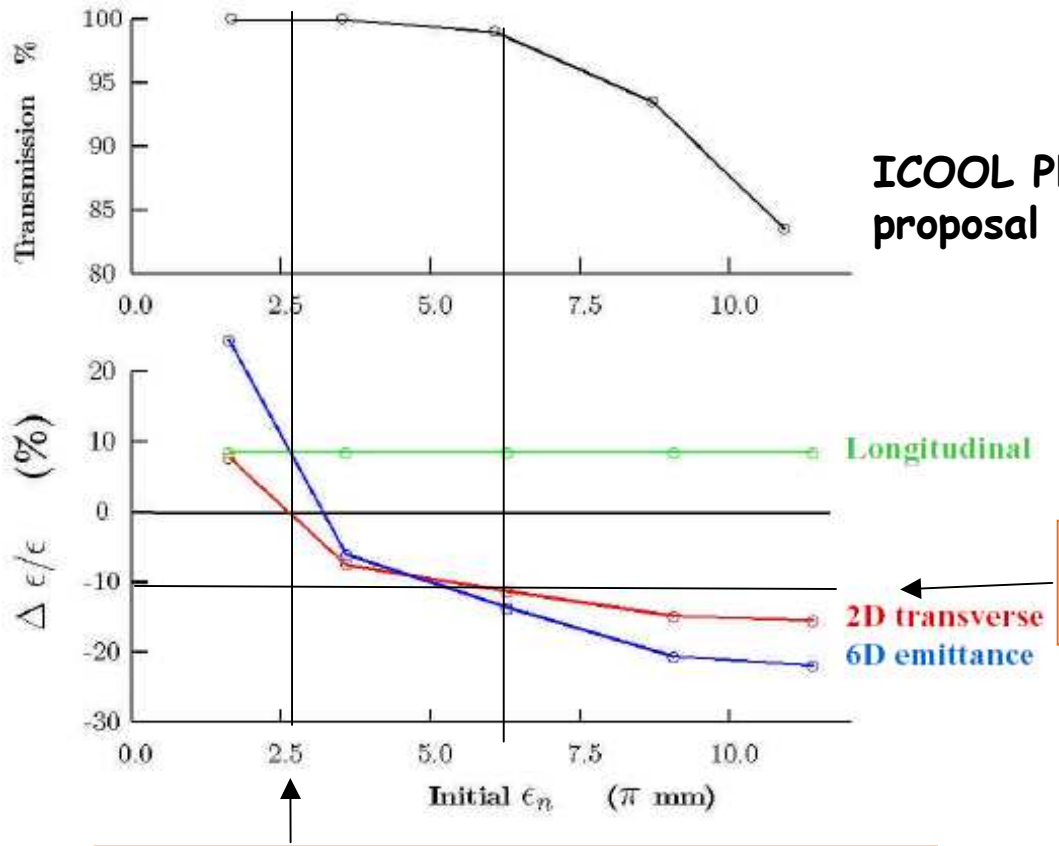
-- optics (Bob Plamer, Ulisse Bravar) ICOOL
all steps of MICE have been optically matched
(but not to the beam)
both in flip mode and solenoid mode

-- physics simulation (G4MICE, Y. Torun et al)



All these steps have now been matched both
in flip mode
and
in solenoid mode
for various beta functions

Quantities to be measured in a cooling experiment



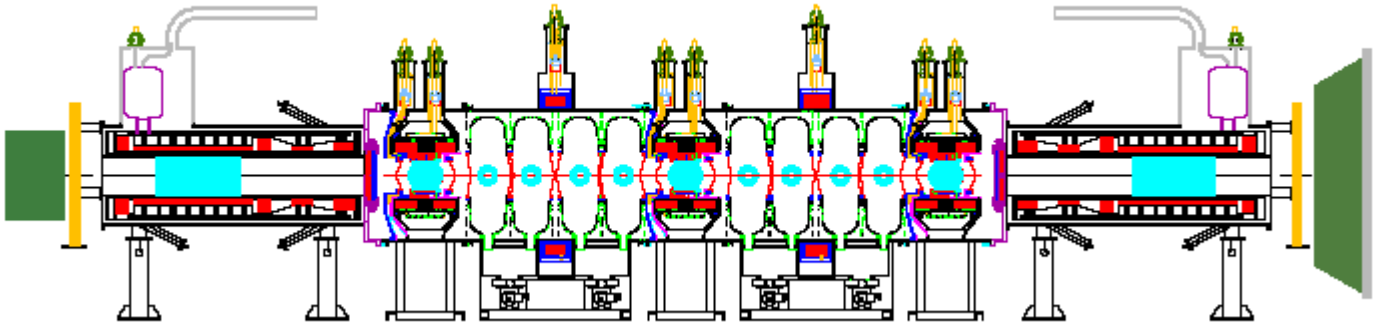
ICOOL Plot by Bob Plamer in the MICE proposal

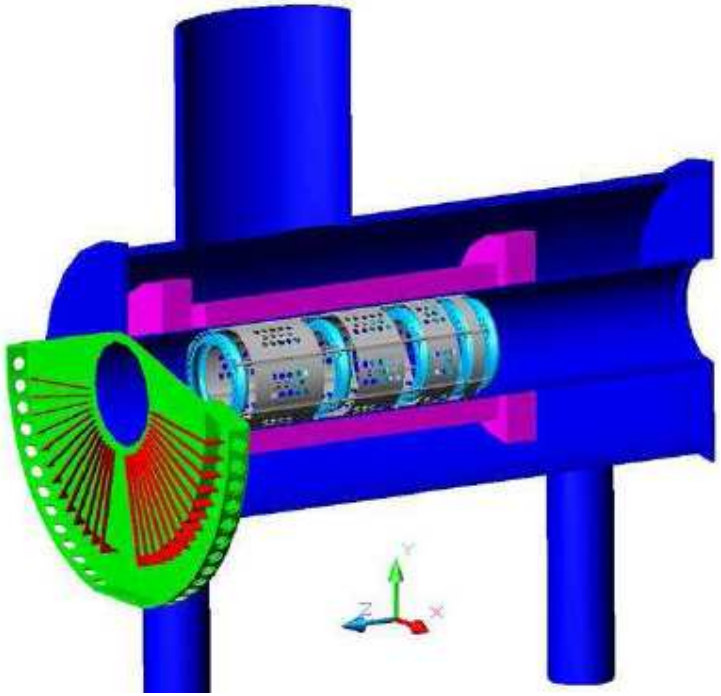
cooling effect at nominal input emittance ~10%

equilibrium emittance = 2.5 mm.radian

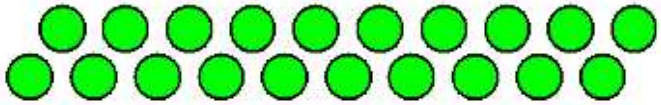
Acceptance: beam of 5cm and 120 mrad rms

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

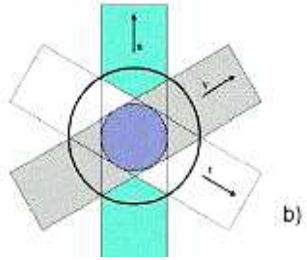




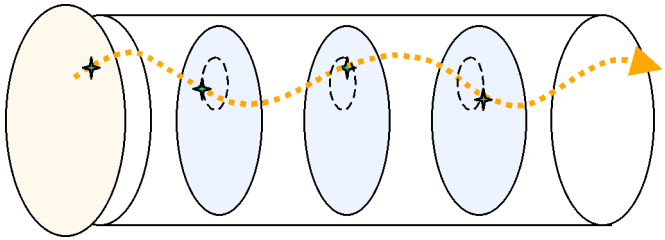
5 stations of scintillating fibers
3 coordinates each
two layers each 350 microns diameter
VLPC readout (' à la D0 ')



a)



b)

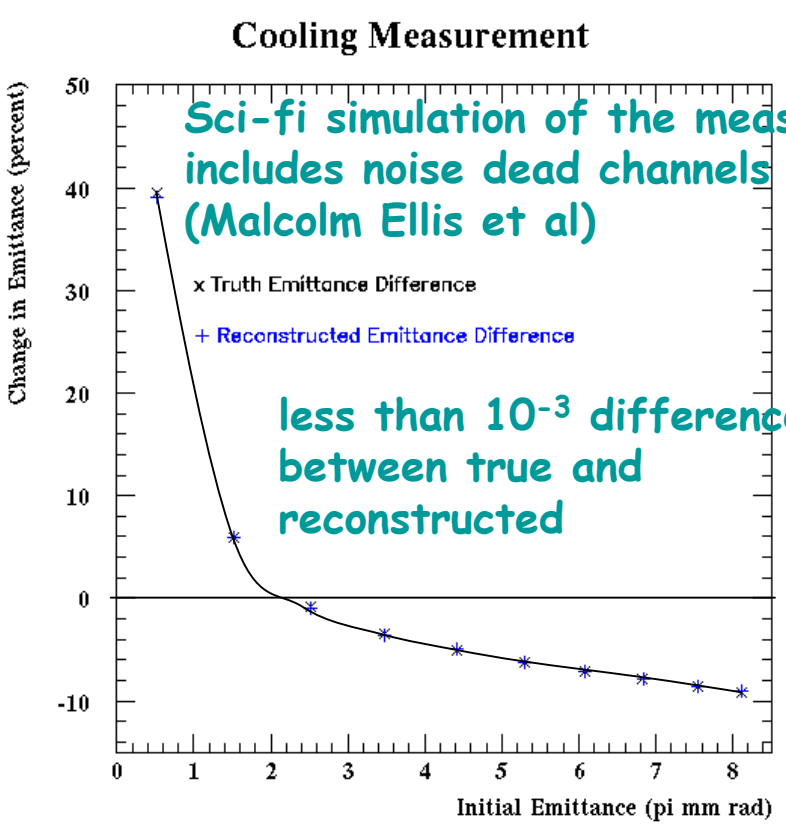


simulation shows that
DPt= 1.5 MeV/c DPz = 3 MeV/c
for individual muons at 200 MeV/c
at equilibrium emittance. TRACKER CHOICE WAS VALIDATED at THIS MEETING

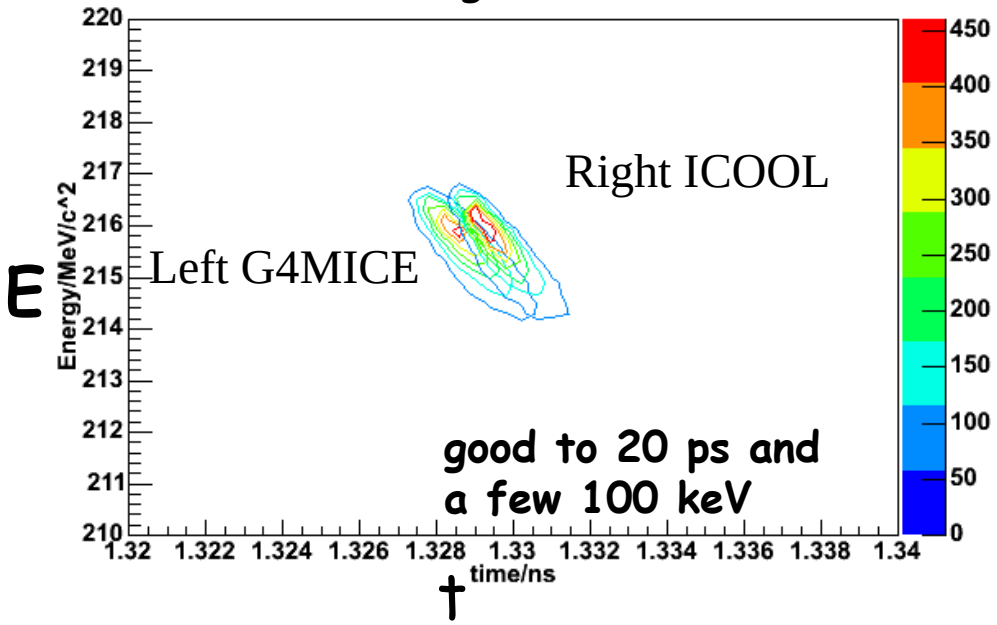
SIMULATION and software.

'Simple things should be easy and complicated things should be possible'

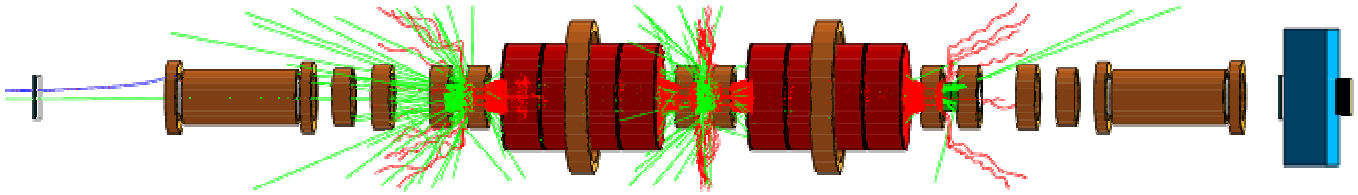
'Students are taking over the project'



G4MICE-ICOOL comparison
Chris Rogers



RF emission of X-rays (Rikard Sandstrom)

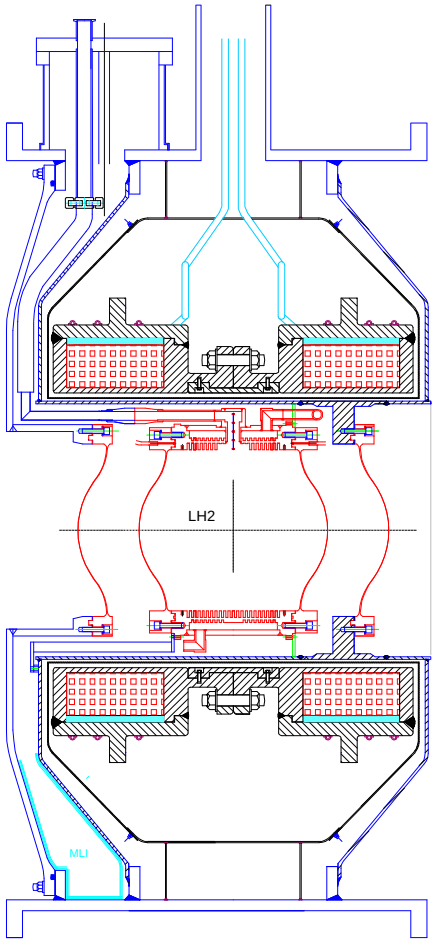


Hydrogen Safety

Safety Review process under way

Internal **review organized in Berkeley in Dec. 2003**
Reviewers:
D. Allspach (FNAL), G. Benincasa (CERN), M. Seely (Jlab), L. Starritt (NASA), J. Weisend (SLAC), J. Wells (RAL)

The committee was impressed by the amount of thought and effort expended on the safety aspects of this project. The MICE collaboration clearly understands the seriousness of the hazards involved and has done a laudable job of designing safety into the system from the start. The early consideration of quality control issues and formal failure mode analysis is particularly valuable. We believe that the MICE collaboration is ready to proceed to detailed engineering design and eventual review by the RAL External Safety Committee. We did not see any significant safety issues that were omitted nor do we find any technical show stoppers. There are 3 issues that we believe need additional development.



Evacuated buffer tank needed?	**NO**
Burst valves and relief valves?	**YES**
Separate vents for vacuum and hydrogen?	**YES**

Detailed answers issued. Proceeding now to *full* safety revue (toward end of 2005)

Design and safety working group

nominated to ensure that

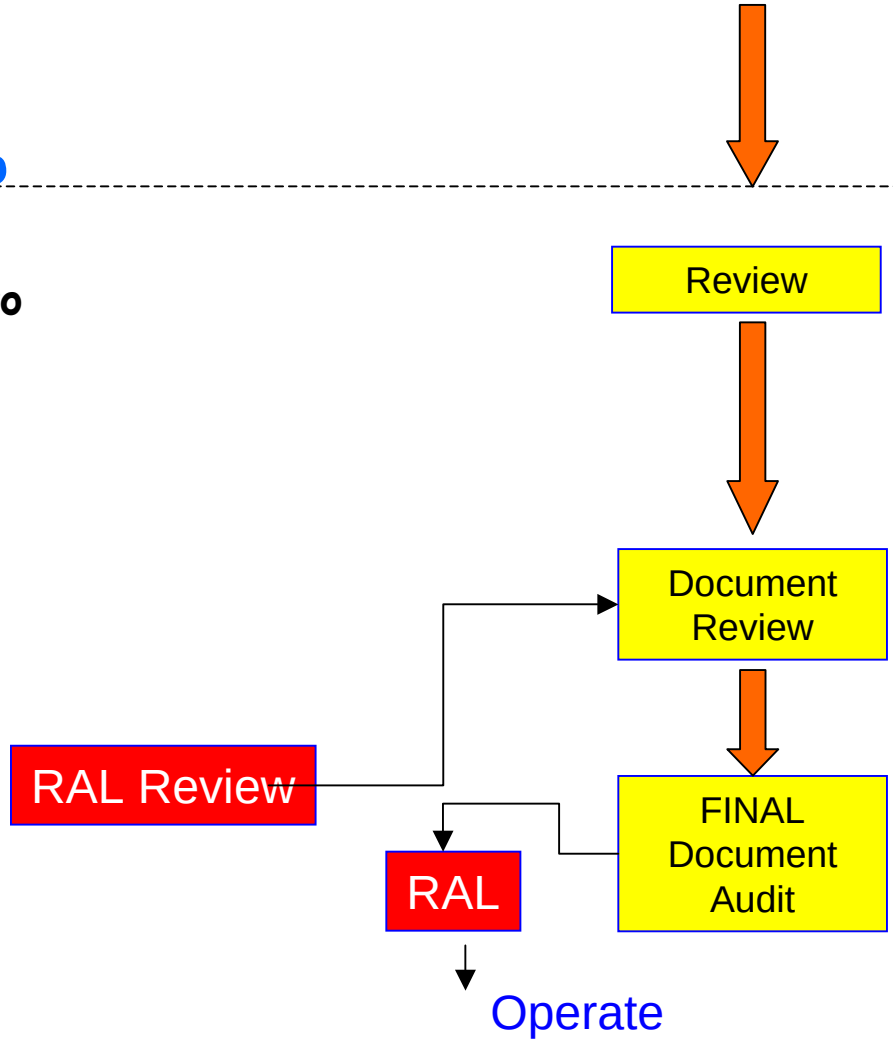
MICE is designed and built according to appropriate and safe engineering and according to RAL safety rules.

This will happen with 3 successive milestones

internal audit

external review (production readiness)

external review (OK to operate)



my impression:
ALL production reviews pertinent to PHASE I will have to be passed
before end 2005
...!

Advertisement:

we are starting a DAQ, controls and monitoring working group

aims

understand what instrumentation is needed and what data are needed at which frequency (per spill, per muon, independently)

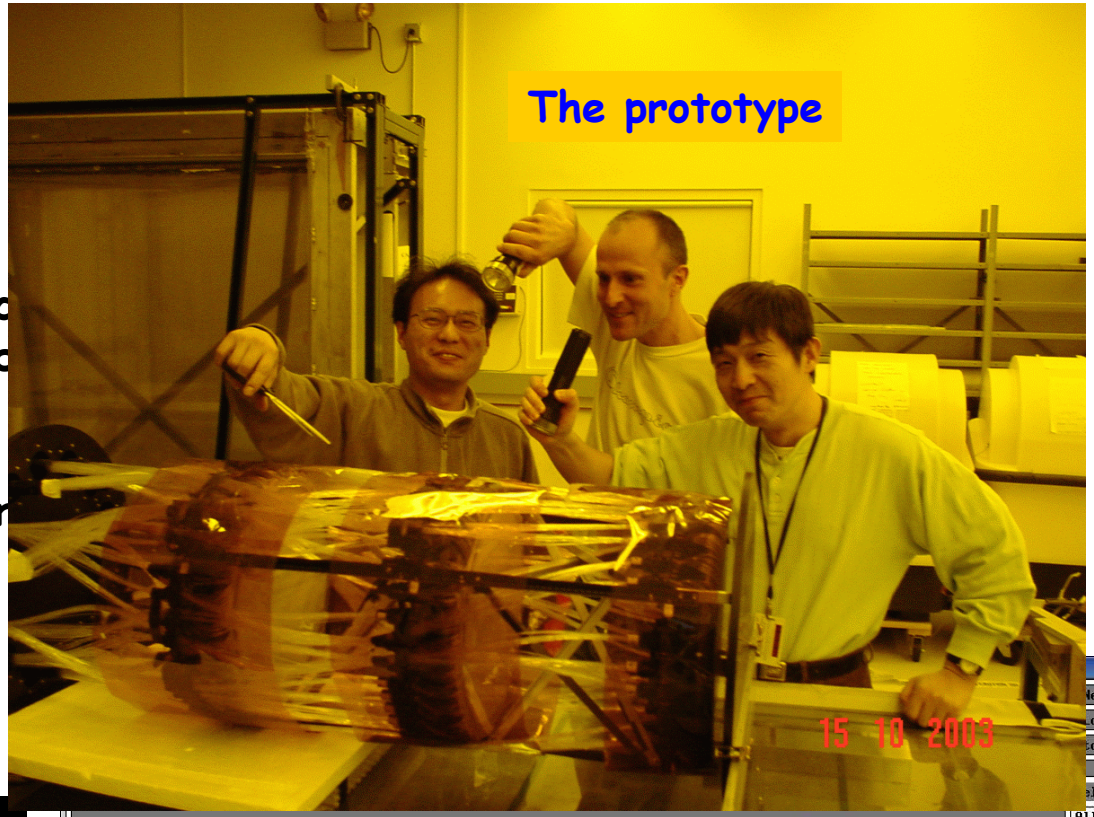
in order to perform comparison of data with simulation at the level of 10^{-3}

volunteers welcome

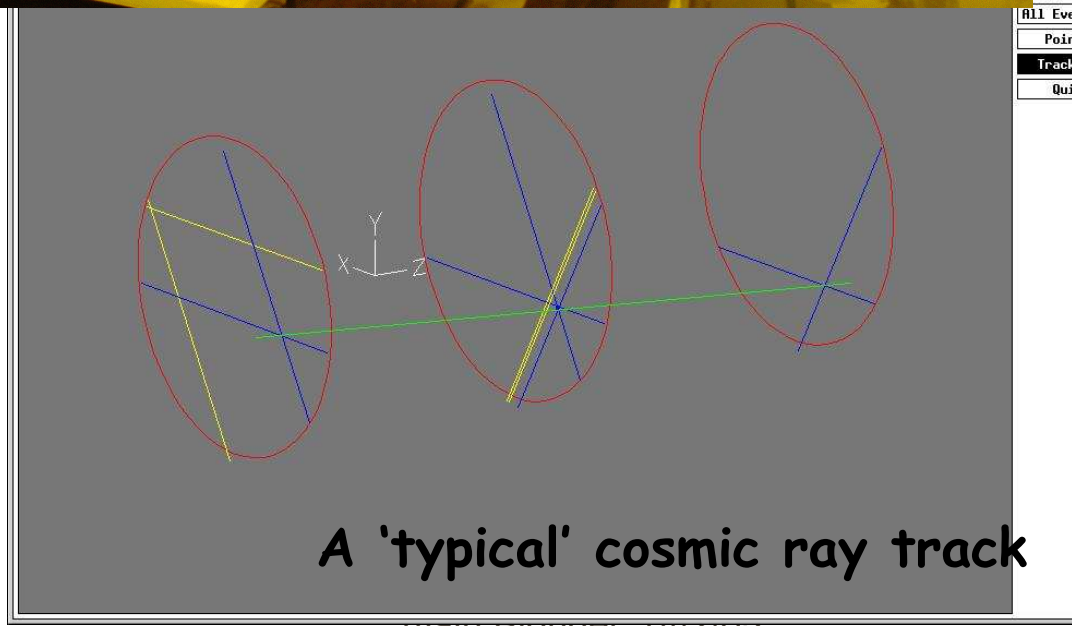
Tracker R&D

Sci-fi: a prototype of 3
out of 5 stations (3 double planes eac
was built and tested at D0 test stanc

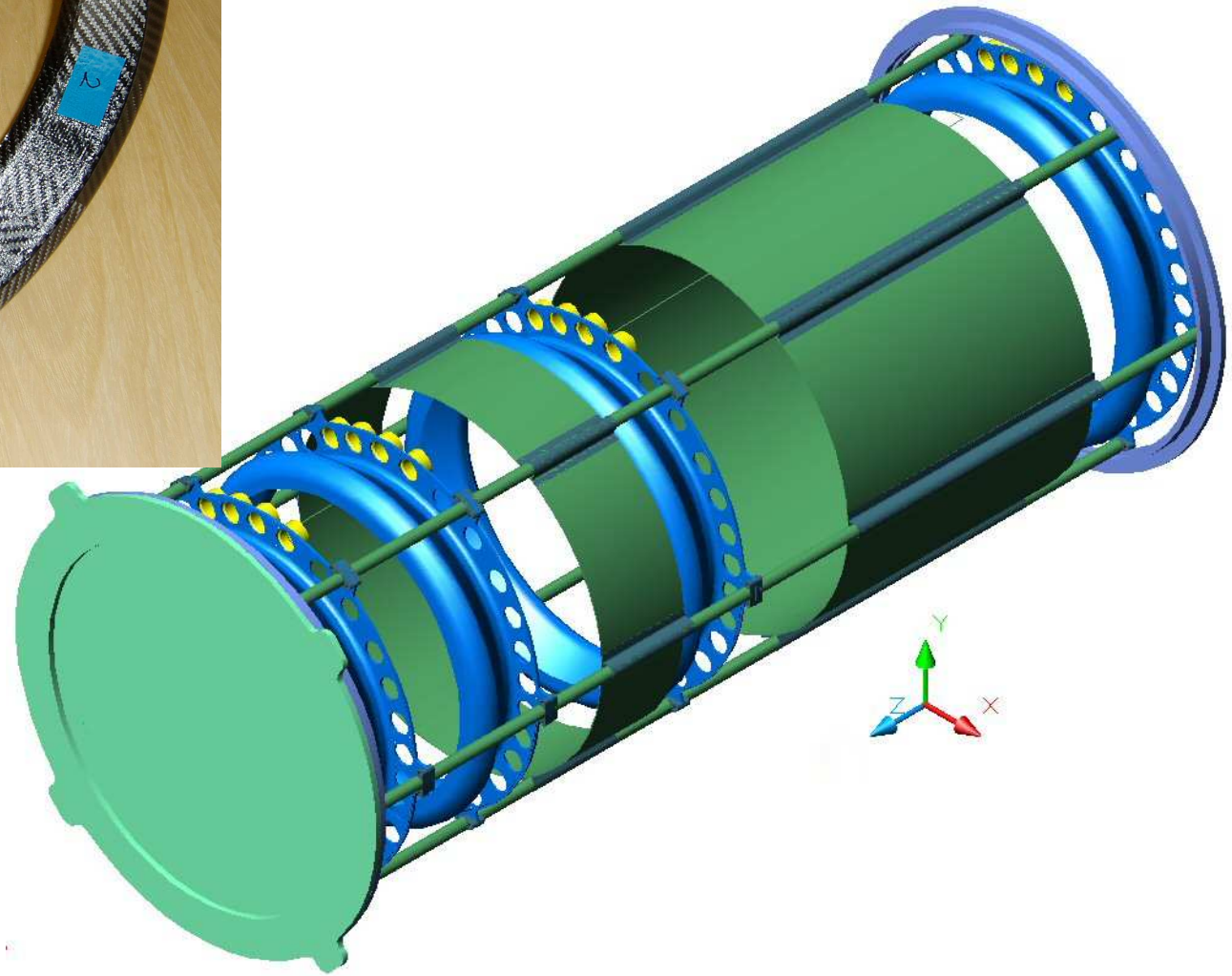
a 4 station prototype will be tested
in a beam at KEK in May and October



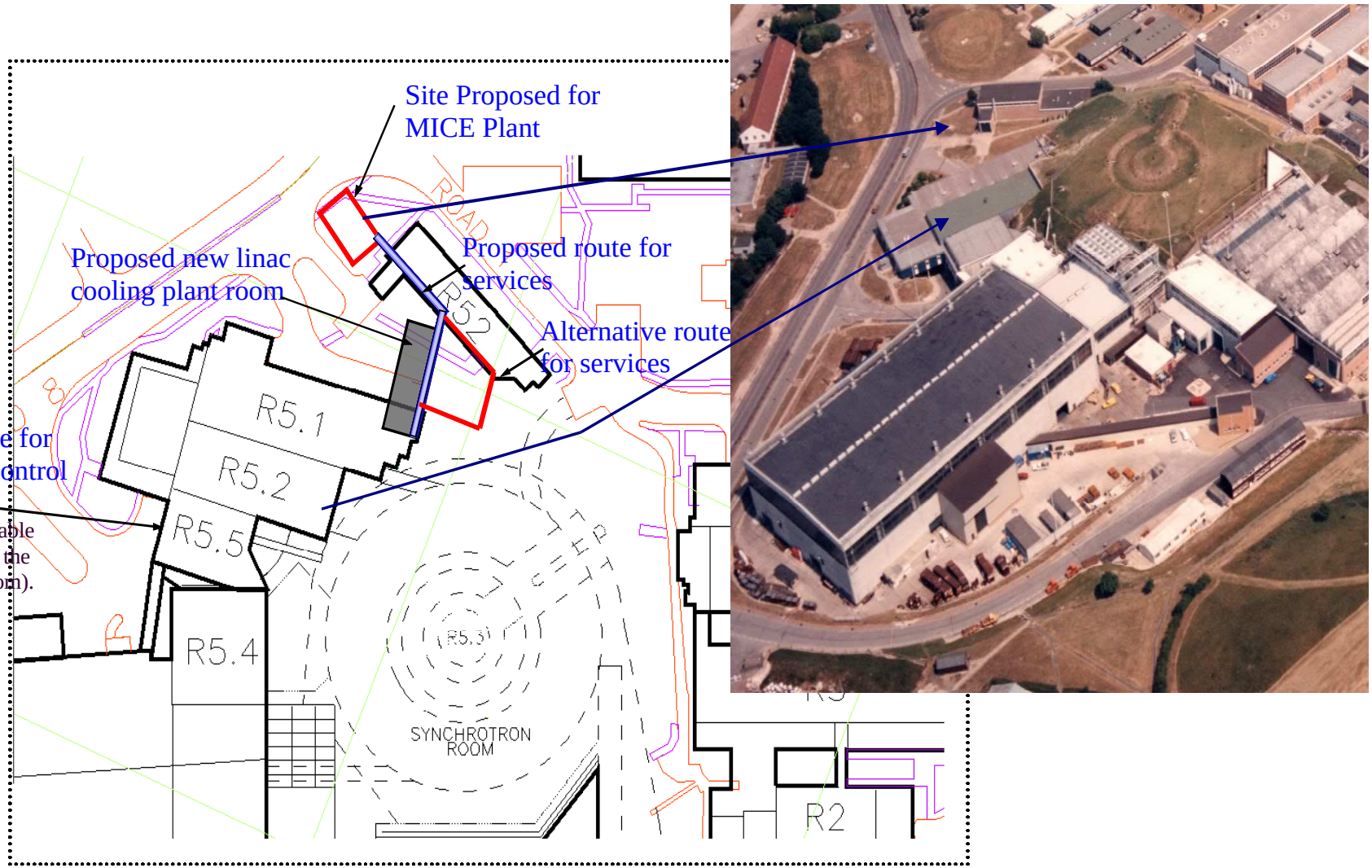
Fiber feed-throughs



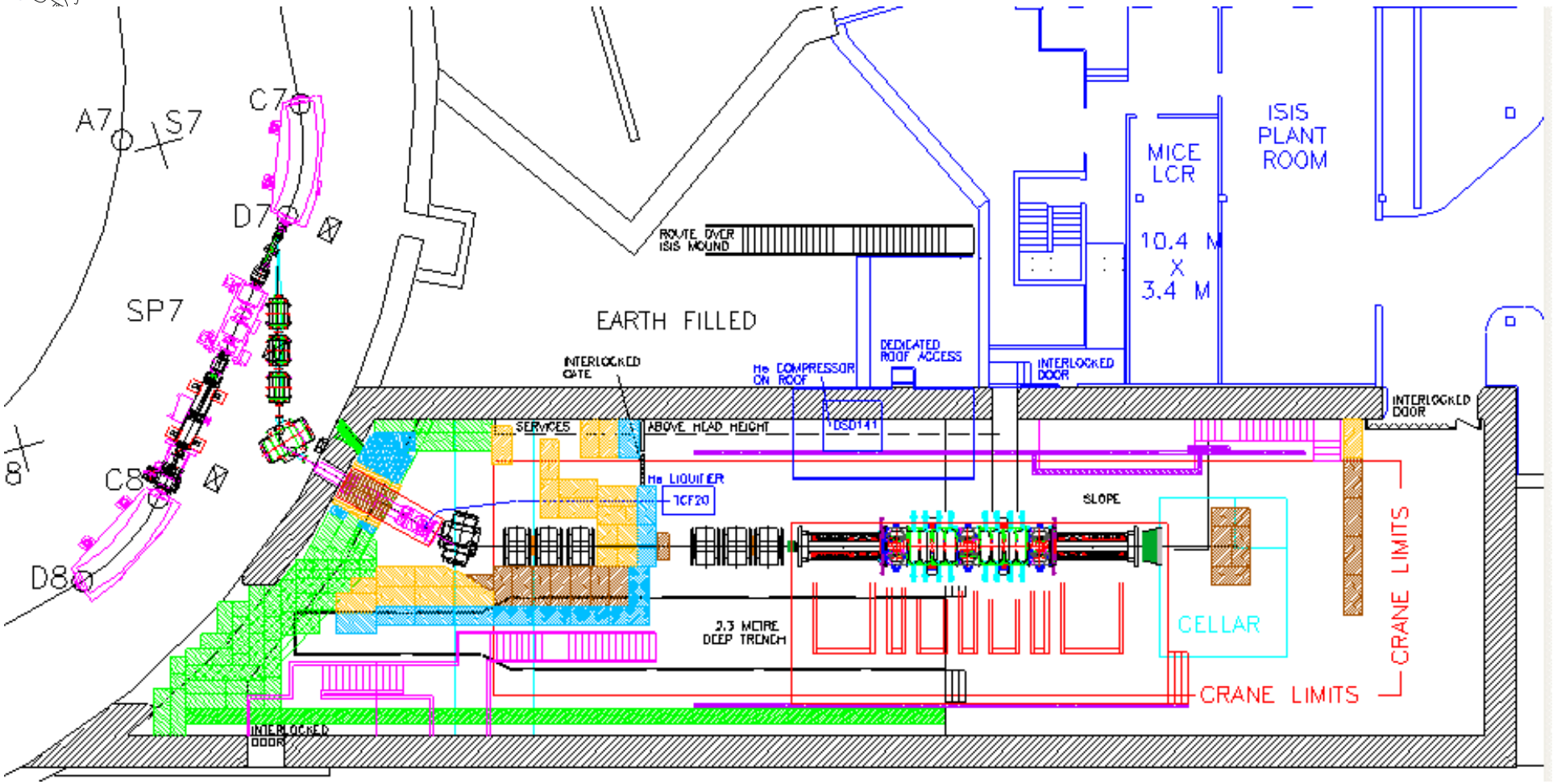
A 'typical' cosmic ray track


Y
Z
X

INSTALLATION OF MICE at RAL



MICE Muon Beam

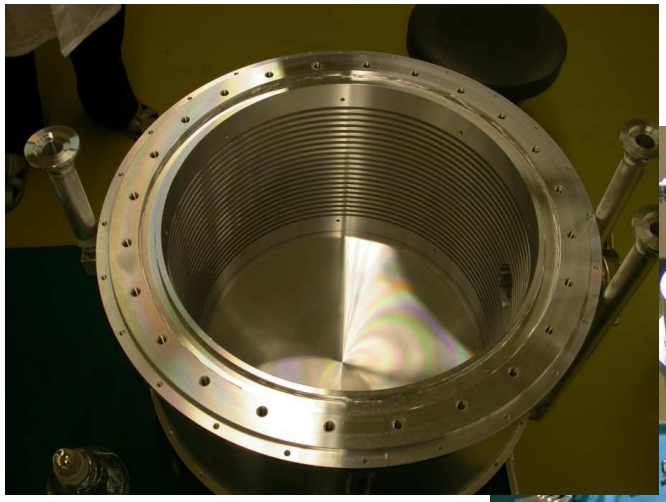


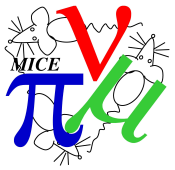
- Design integration:
  - Beam line and shielding, cryogenics
  - MICE:
    - Support systems, RF, services, …

MICE Hall preparations

Absorber II

Absorber body built at KEK, with cryostat





An important credit:

The US developed the first credible concepts for both the muon collider and the neutrino factory through the pioneering work, in particular, of David Neuffer, Robert Palmer and Steve Geer, as well as through two detailed feasibility studies.

The concept of the MICE cooling cells is based upon the US Study II, and the actual magnetic layout of the experiment is the result of Robert Palmer's ideas.

US groups have provided the lion's share of the R&D work for the cooling channel modules so far, and have also been actively involved in developing the beam line optics, the overall simulation of the experiment, and the tracker prototype. In particular, the construction of the first MICE-compatible 201-MHz RF cavity prototype is now nearly completed.

In addition, our US colleagues have already shipped to RAL parts for two 201-MHz RF power sources that should, after refurbishment, provide half of the RF needs of the experiment.

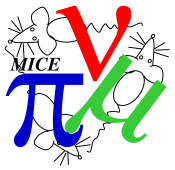
Time Line

If all goes well and funding is adequate, Muon Ionization cooling will have been demonstrated and measured precisely by

2008/9

At that time:
MINOS and CNGS will have started and measured Δm_{13}^2 more precisely
J-Parc-SK (and reactor expt?) will be about to start (θ_{13} measurement)
LHC will be starting as well

It will be timely (…and not too soon!) to have by then
a full design for a cost-optimized neutrino factory,
with no questions about
practical feasibility of ionization cooling



MICE is getting REAL!

First beam 1st April 2007

****** 365*2+44= 774 days to data taking ******

we have a lot to do…soon!