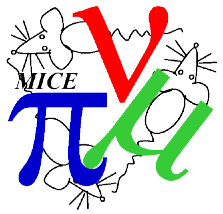
Imperial College London



High Energy Physics 1st Year PhD Student Talks

The Neutrino Factory and MICE

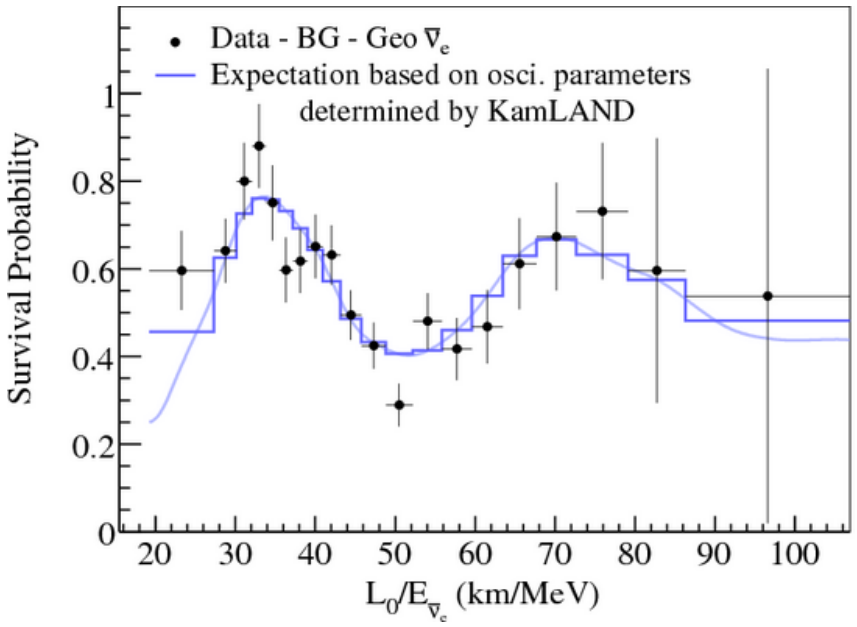
6th March 2008

Adam Dobbs

Motivation: Neutrino Oscillations

- As early as 1960s a deficit in the expected number of neutrinos from Sun observed – “Solar neutrino problem”
- Neutrino disappearance further confirmed by Super Kamiokande and SNO in 1990s, looking at atmospheric and solar neutrinos
- Neutrino oscillations proposed as solution: neutrino *flavour* eigenstates are not equal to the *mass* eigenstates but rather are coherent sum of them

- Observed conclusively at KamLAND reactor experiment



- Oscillations formulated in analogous way to mixing in the quark sector:

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = U_{PMNS} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$

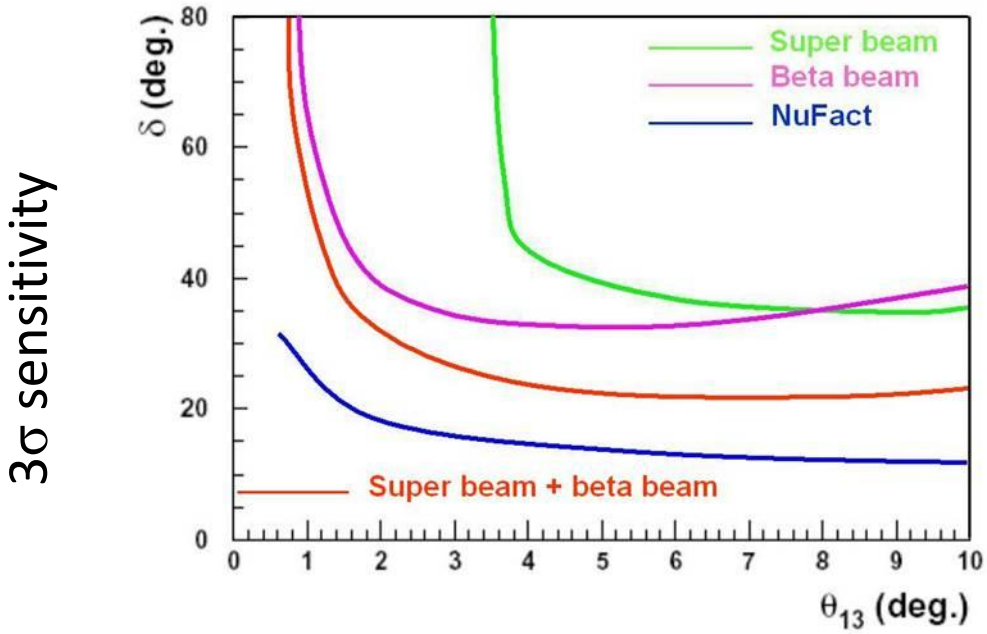
$$U_{PMNS} = \begin{pmatrix} c_{12}c_{13} & s_{12}c_{13} & s_{13}e^{-i\delta} \\ -s_{12}c_{23} - c_{12}s_{23}e^{-i\delta} & c_{12}c_{23} - s_{12}s_{23}s_{13}e^{-i\delta} & s_{23}c_{13} \\ s_{12}s_{23} - c_{12}c_{23}s_{13}e^{-i\delta} & -c_{12}s_{23} - s_{12}c_{23}s_{13}e^{-i\delta} & c_{23}c_{13} \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & e^{-i\frac{\alpha}{2}} & 0 \\ 0 & 0 & e^{-i\frac{\beta}{2}} \end{pmatrix}$$

where $s_{ij} = sin\theta_{ij}$, $c_{ij} = cos\theta_{ij}$ and α, β, δ are CP violating phases

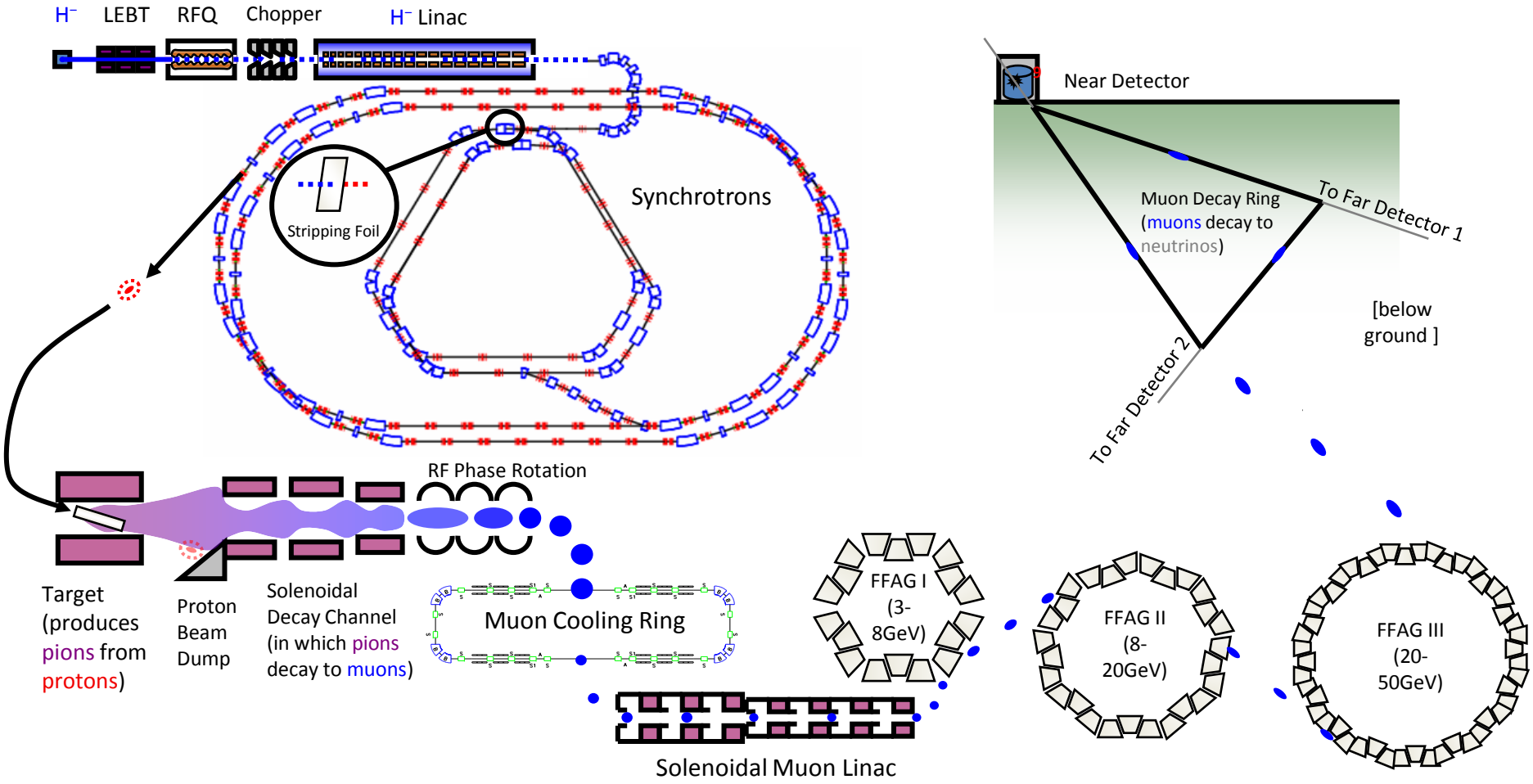
- Arguably the most important discovery in particle physics of the last decade - experimental evidence for physics beyond the standard model
- Vital for our further understanding of BSM to measure the mixing parameters accurately

The Contenders

- Superbeam: pion decay to neutrinos ("super" → driven by multi MW proton beam)
- Betabeam: radioactive ion decay in a storage ring to neutrinos
- Neutrino Factory: muon decay in a storage ring



Design

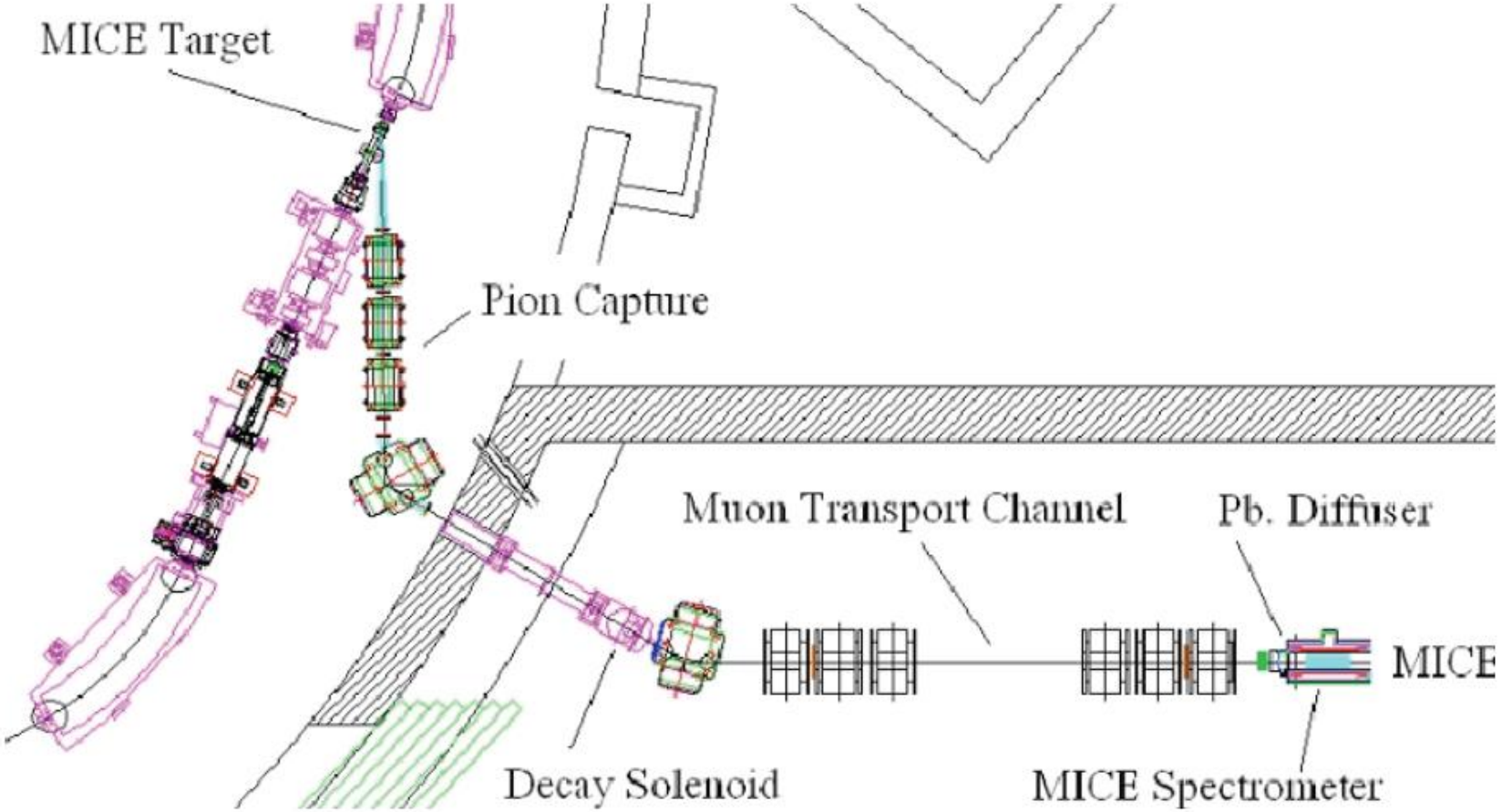

H⁻
LEBT
RFQ
Chopper
H⁻ Linac
Stripping Foil
Synchrotrons
RF Phase Rotation
Target (produces pions from protons)
Proton Beam Dump
Solenoidal Decay Channel (in which pions decay to muons)
Muon Cooling Ring
FFAG I (3-8GeV)
FFAG II (8-20GeV)
FFAG III (20-50GeV)
Solenoidal Muon Linac
Near Detector
Muon Decay Ring (muons decay to neutrinos)
To Far Detector 1
To Far Detector 2
[below ground]

MICE

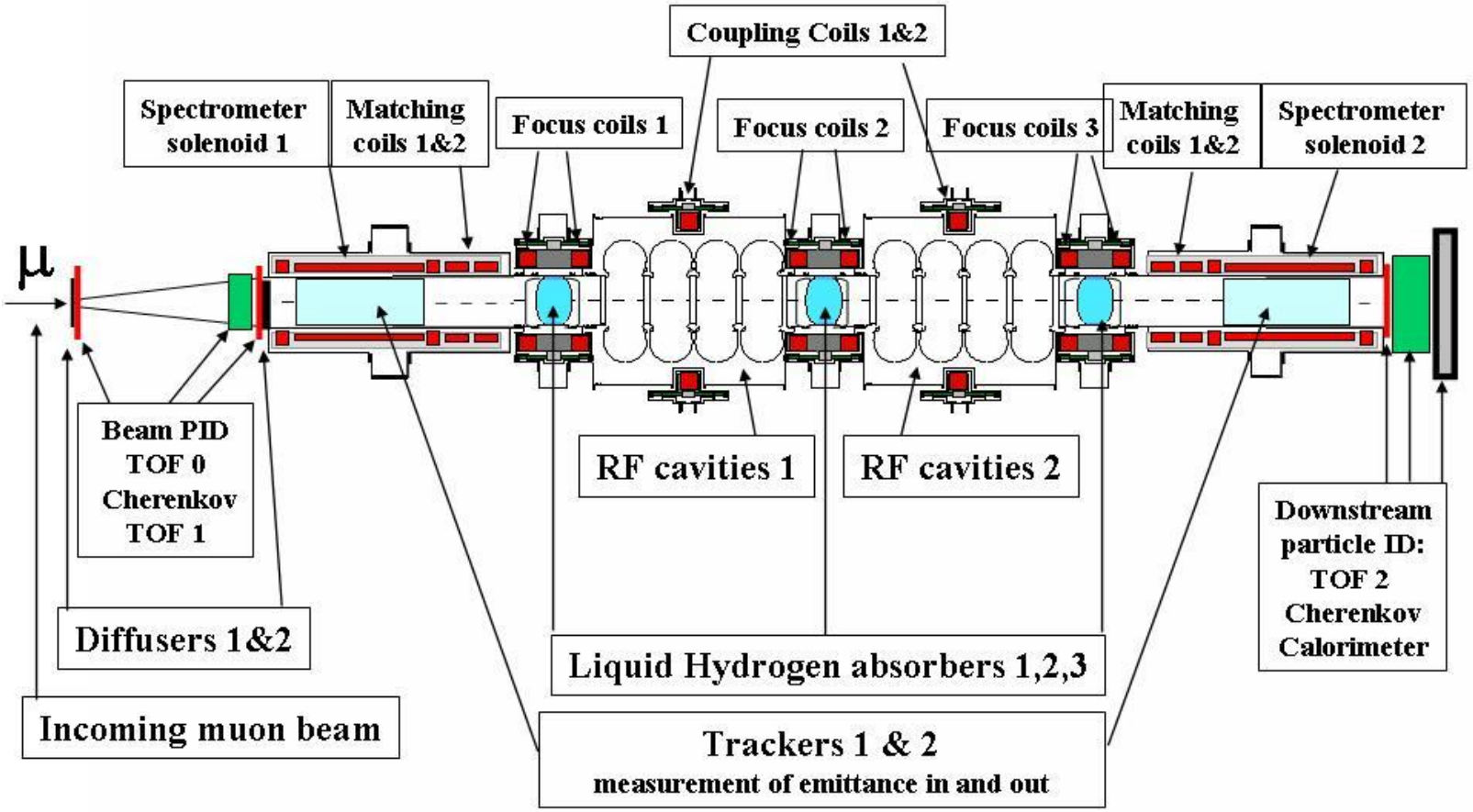
Muon Ionisation Cooling Experiment

- Cooling necessary for muon beam to be successfully accelerated to desired energies further downstream
- Represents one of the major cost and performance factors of a neutrino factory
- MICE: prototype of a single cooling channel for a neutrino factory or muon collider, designed to demonstrate required levels of cooling can be achieved
- Employs *ionisation cooling* of the muon beam
- Under construction at the Rutherford Appleton laboratory – about to receive first continuous beam

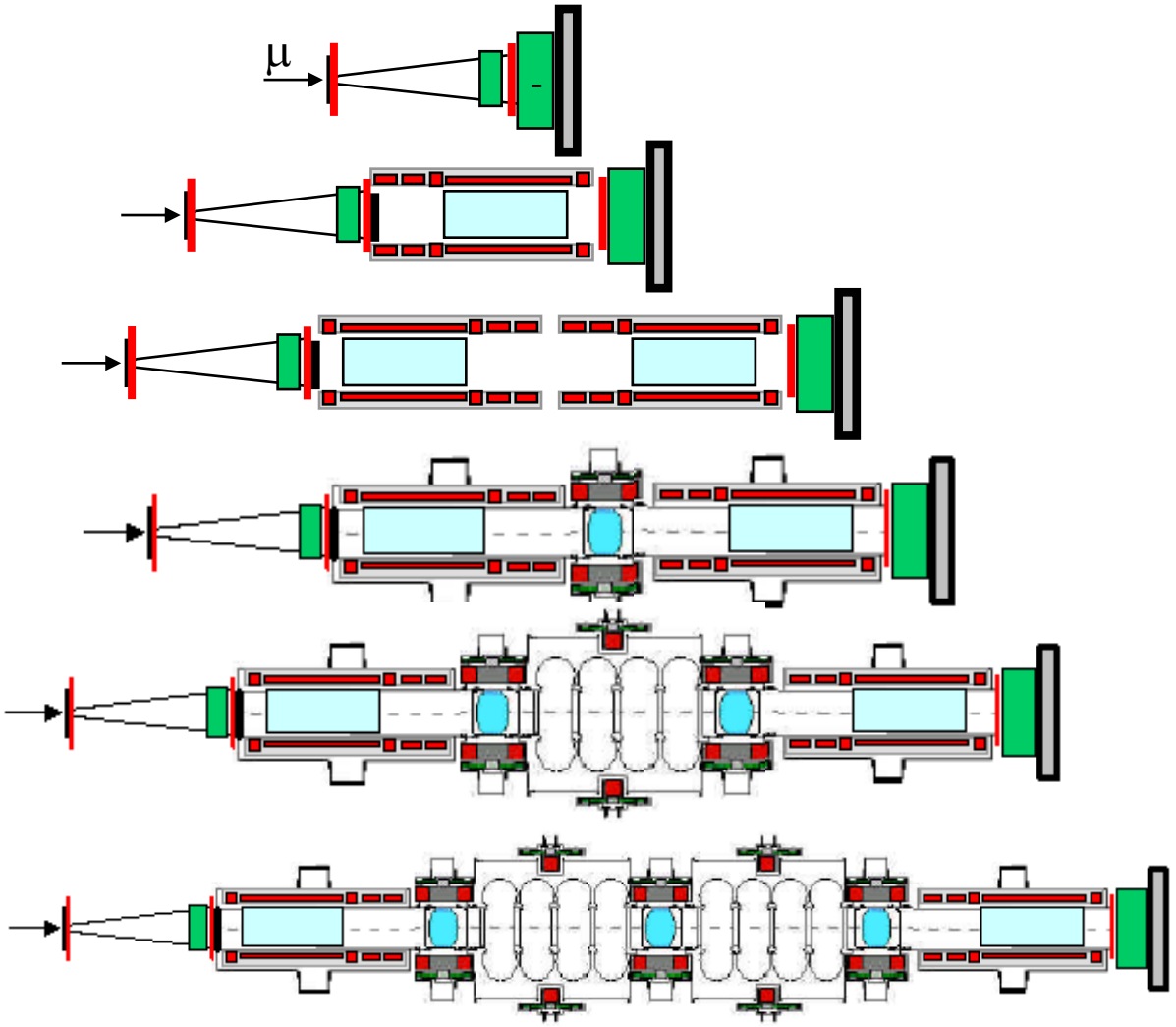
MICE beamline



MICE Schematic



MICE Schedule



Stage 1: Present

Stage 2: April 2008

Stage 3: July 2008

Stage 4: Early 2009

Stage 5: Summer 2009

Stage 6: end 2009 to 2010

The Neutrino Factory

Concept: create an intense, well understood, high energy neutrino beam from the decay of muons in a storage ring

$$\mu^- \rightarrow e^- + \nu_\mu + \overline{\nu}_e$$

$$\mu^+ \rightarrow e^+ + \overline{\nu}_\mu + \nu_e$$

Goals: beam used in long base line experiments to determine

- sign of Δm^2_{23}
- precisely measure θ_{13}
- search for non-zero δ