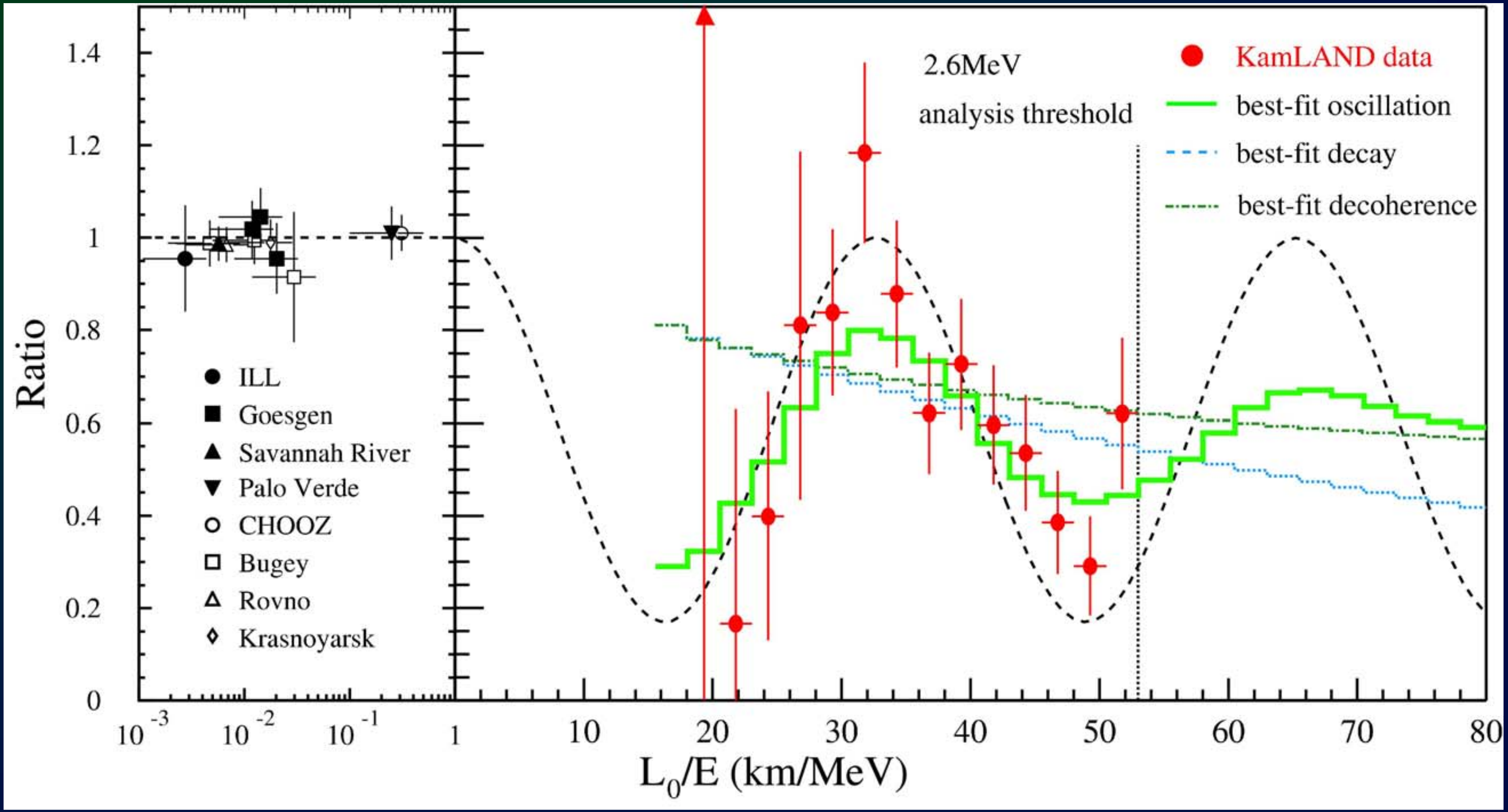
Introduction:

Contents

- Motivation

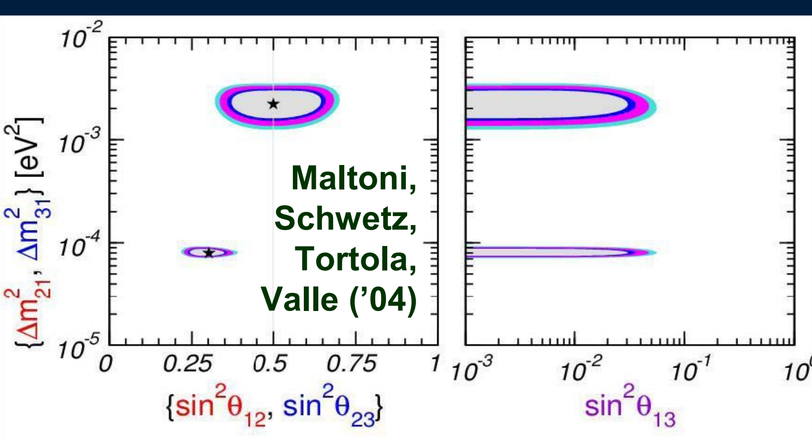
Motivation: neutrinos oscillate

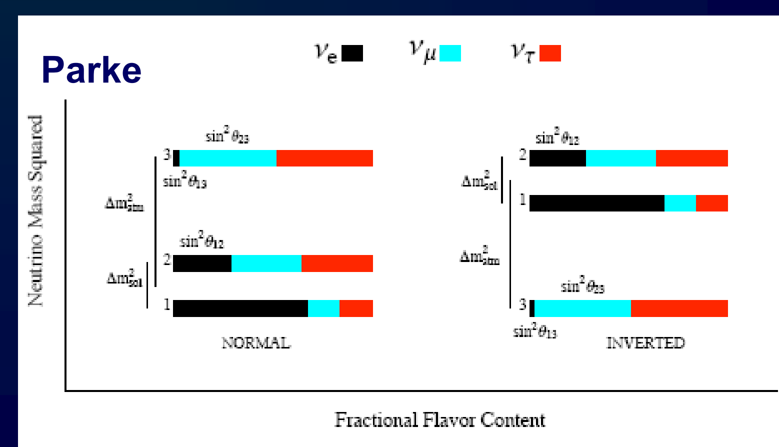


Fundamental breakthrough?

- Neutrino oscillations indicate Standard Model (SM) is incomplete, but, is this a fundamental breakthrough?
  - Can accommodate neutrino oscillations in SM:

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13}e^{i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{-i\delta} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$



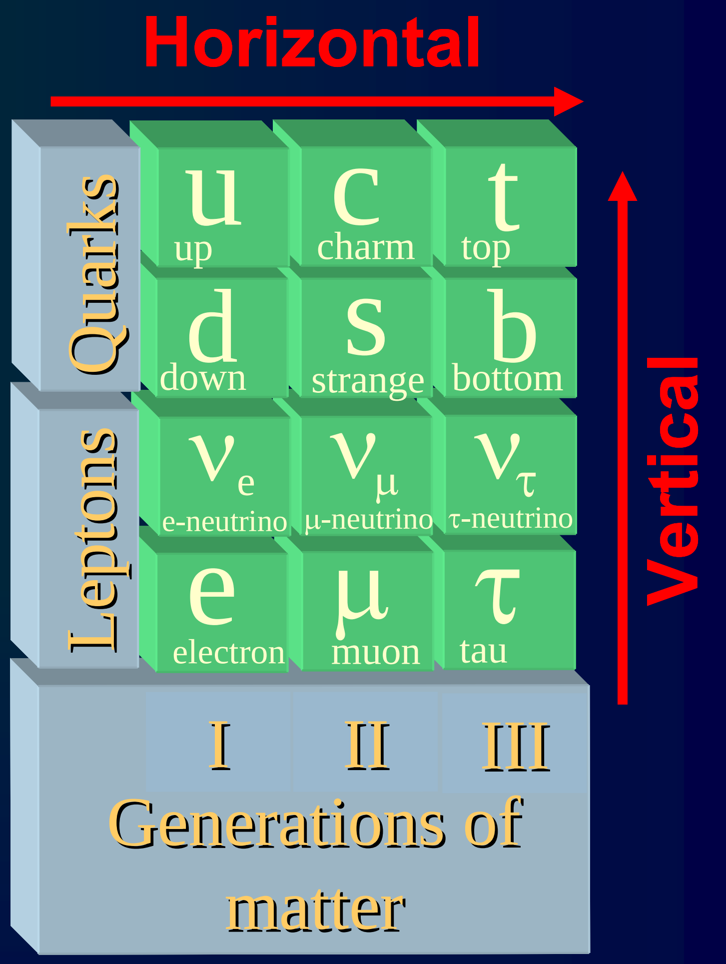


Fundamental questions:

- Origin of mass:
  - And why is neutrino mass is so small
- Why is there no antimatter:
  - And can leptonic CP violation make a decisive contribution
- Did neutrinos play a role in:
  - Inflation?
  - Galaxy formation?
- Unification of matter and force:
  - Do the differences between the quark and lepton properties hold the key?

Theoretical speculations:

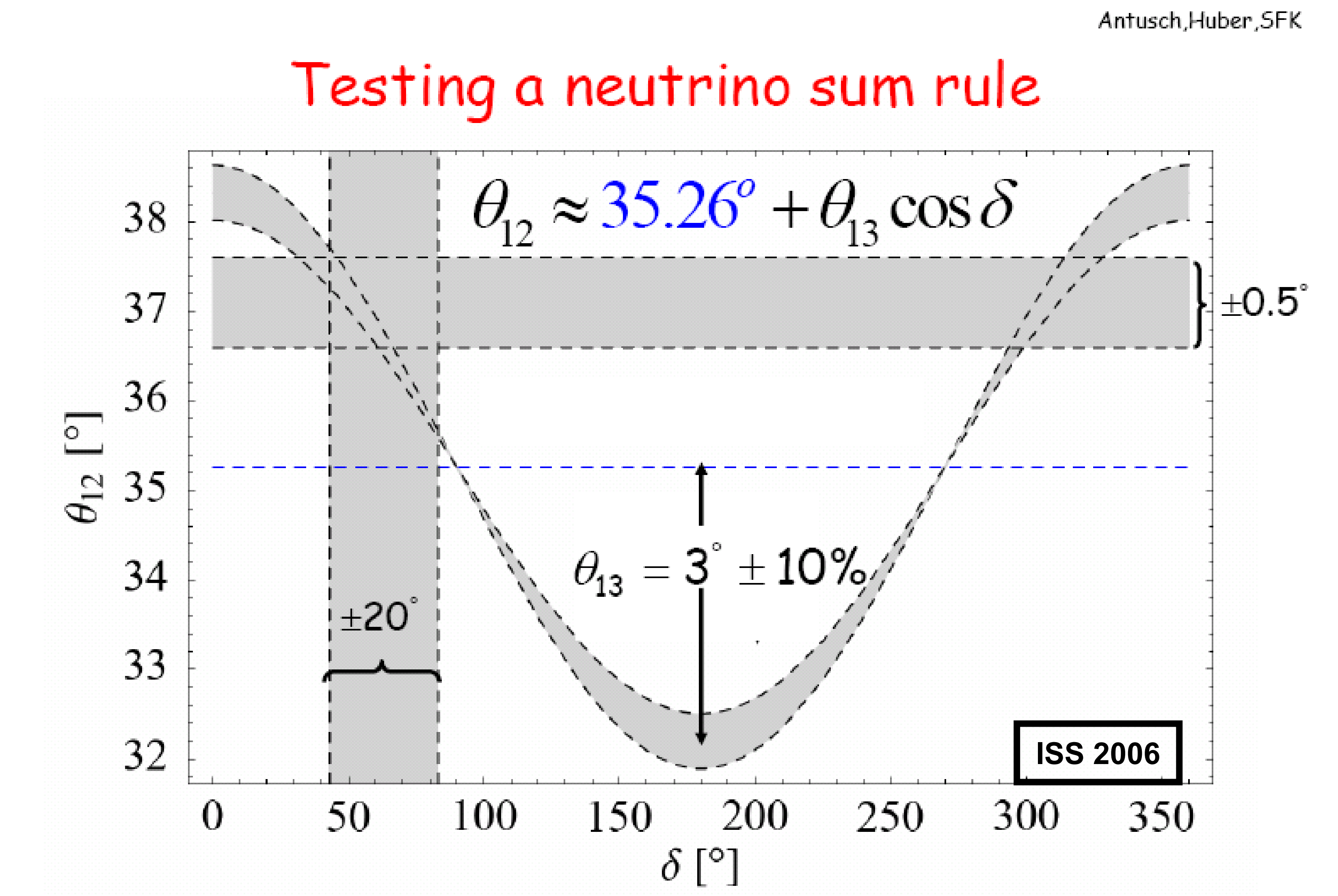
- Grand-unified (vertical) symmetry
  - Relate quarks and leptons
- Family (horizontal) symmetry
  - Relate fermions across generations
- Supersymmetry:
  - Heavy Majorana neutrinos
  - See-saw mechanism
    - Light neutrinos
    - Large neutrino mixing angles



The experimentalists' contribution:

- Search for leptonic CP violation
- Determine mass hierarchy
- Measure mixing parameters with a precision sufficient to guide theoretical speculation
  - Or, better, determine structure of theory
    - Standard Model itself established in this way
- Seek to:
  - Determine neutrino-mixing parameters with a precision approaching that of the quark-mixing parameters
    - Ultimate theory must unify quarks and leptons

Quark-lepton relationship – example:



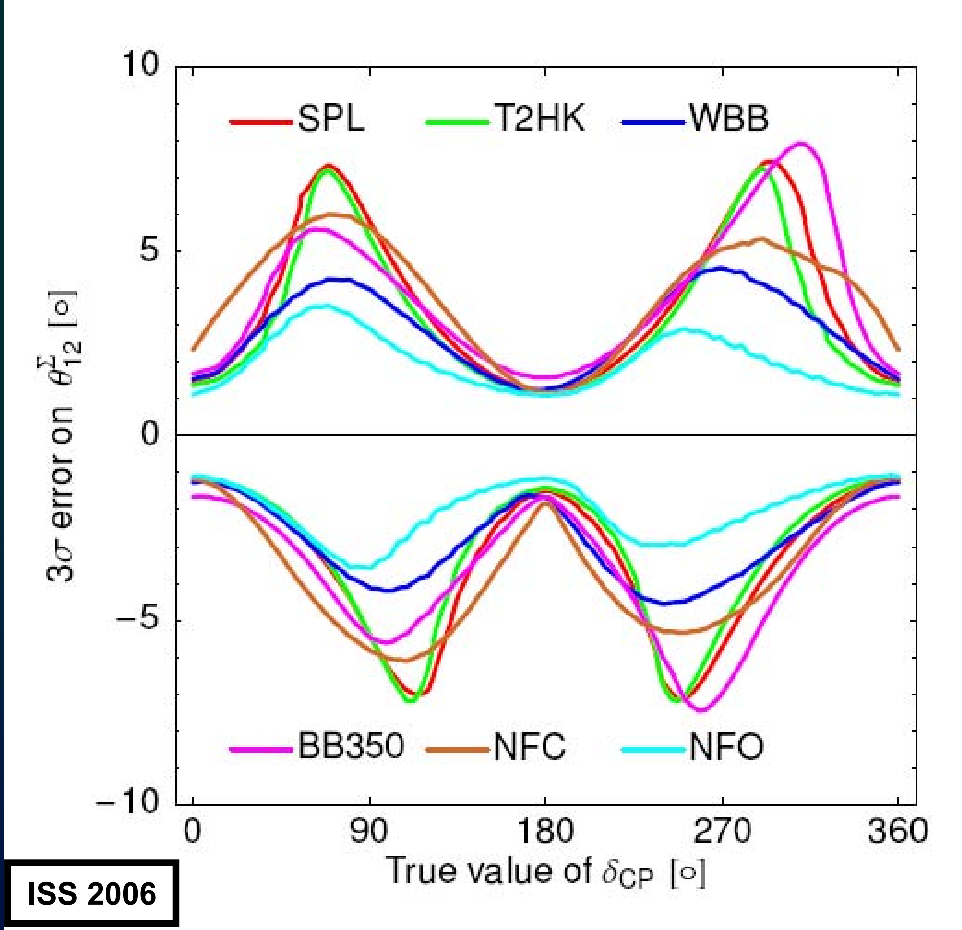
Quark-lepton relationship – example:

- **Define:**

$$\theta_{12}^{\Sigma} = \theta_{12} - \theta_{13} \cos\delta$$

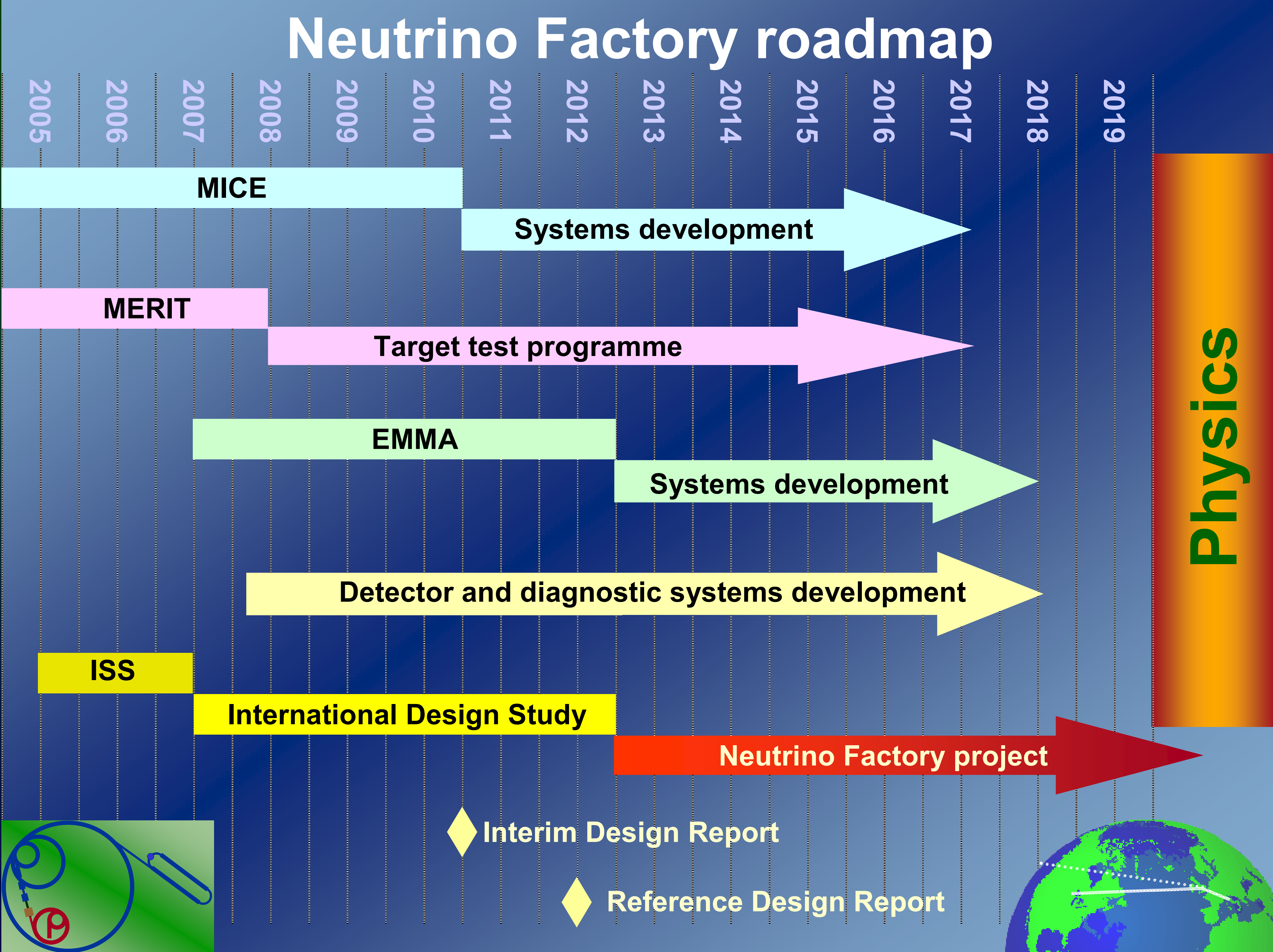
- **Precision evaluated assuming:**

$$\theta_{12} = 33.12^{\circ} \quad \theta_{13} = 9^{\circ}$$

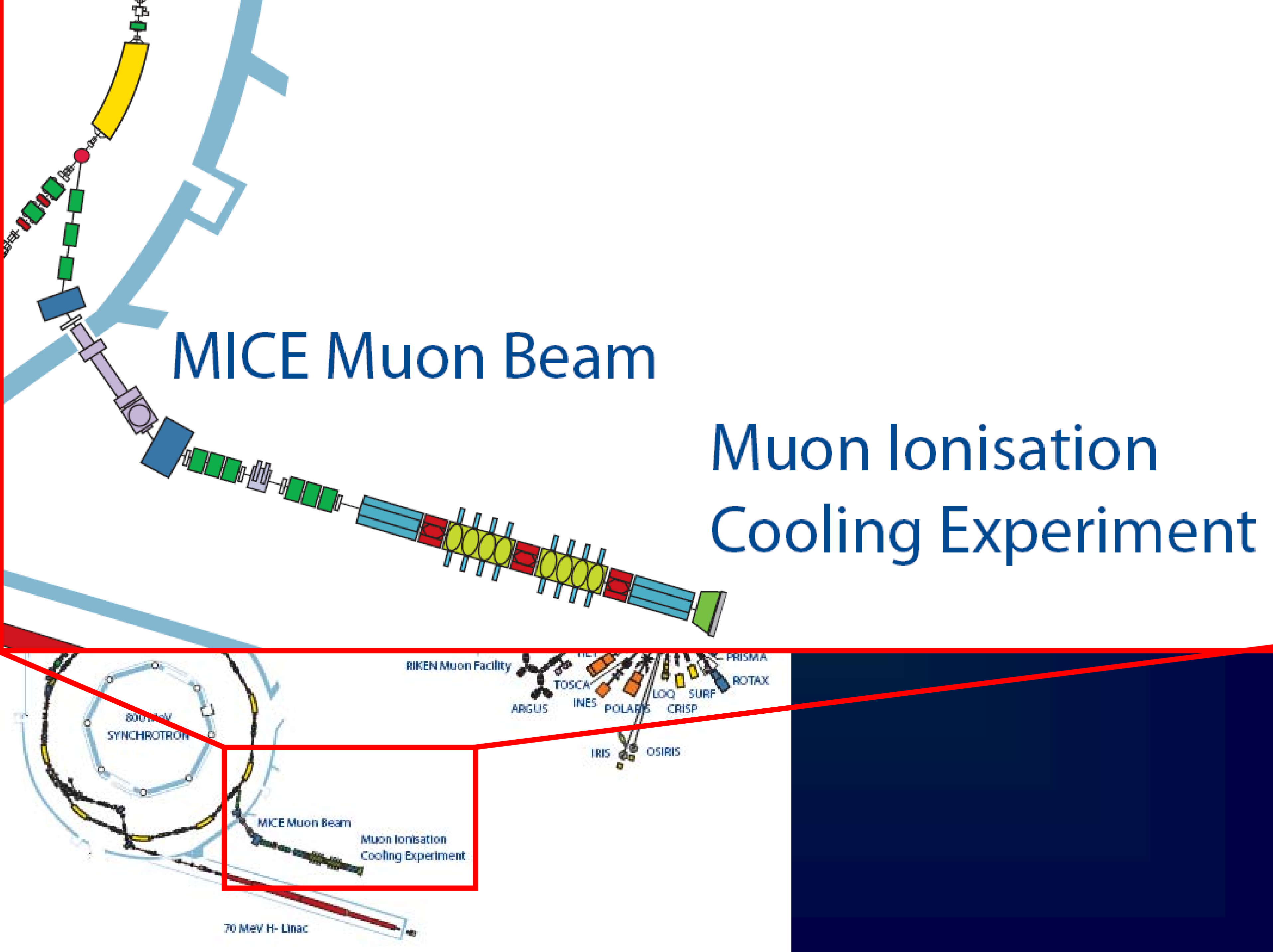


Timescale:

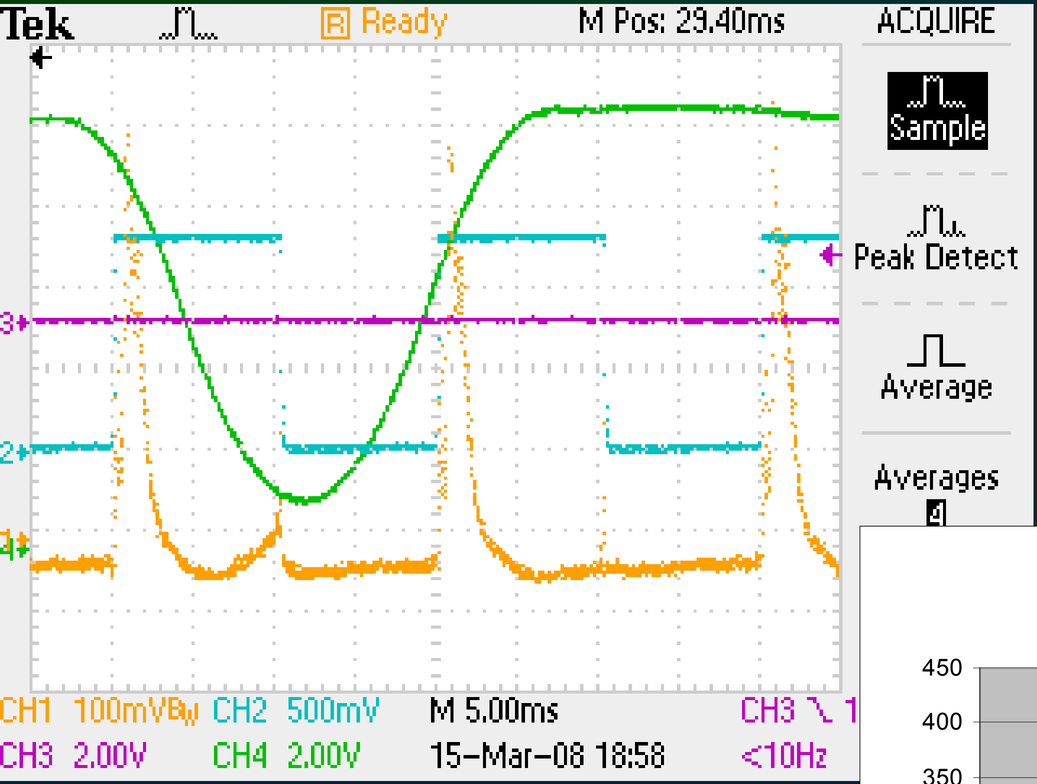
- Emerging consensus:
  - A programme of high statistics, high precision, measurements of neutrino oscillations is required to follow T2K and NOvA;
  - The decision point is likely to be around 2012:
    - Explicit in the C.E.R.N. Strategy Group statement;
    - Endorsed by EPP2010
- Not quite a consensus on what will constitute the programme:
  - Opportunity:
    - Make Neutrino Factory an option on this timescale

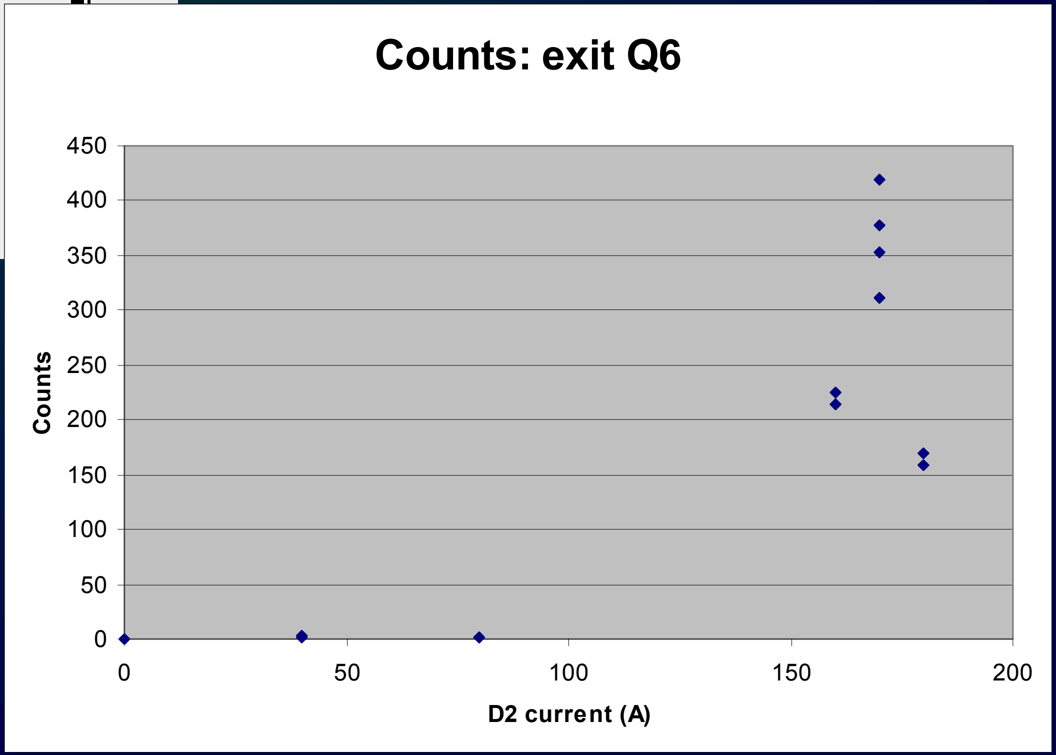


Neutrino Factory roadmap
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
MICE
Systems development
MERIT
Target test programme
EMMA
Systems development
Detector and diagnostic systems development
ISS
International Design Study
Neutrino Factory project
Physics
Interim Design Report
Reference Design Report


MICE Muon Beam
Muon Ionisation
Cooling Experiment
RIKEN Muon Facility
PRISMA
ROTAX
TOSCA
ARGUS
INES
POLARIS
LOQ
SURF
CRISP
IRIS
OSIRIS
SYNCHROTRON
MICE Muon Beam
Muon Ionisation
Cooling Experiment
70 MeV H- Linac

MICE has begun operation!

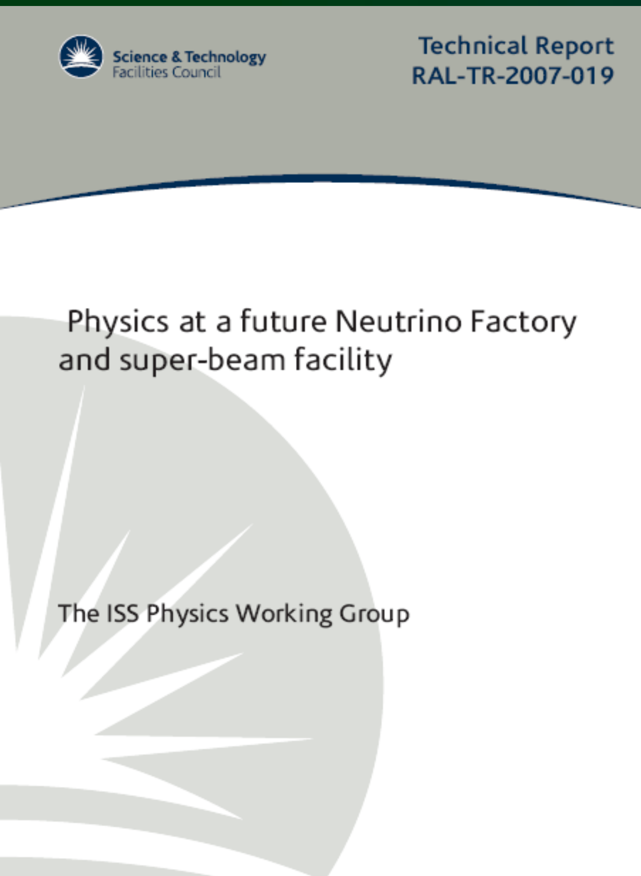


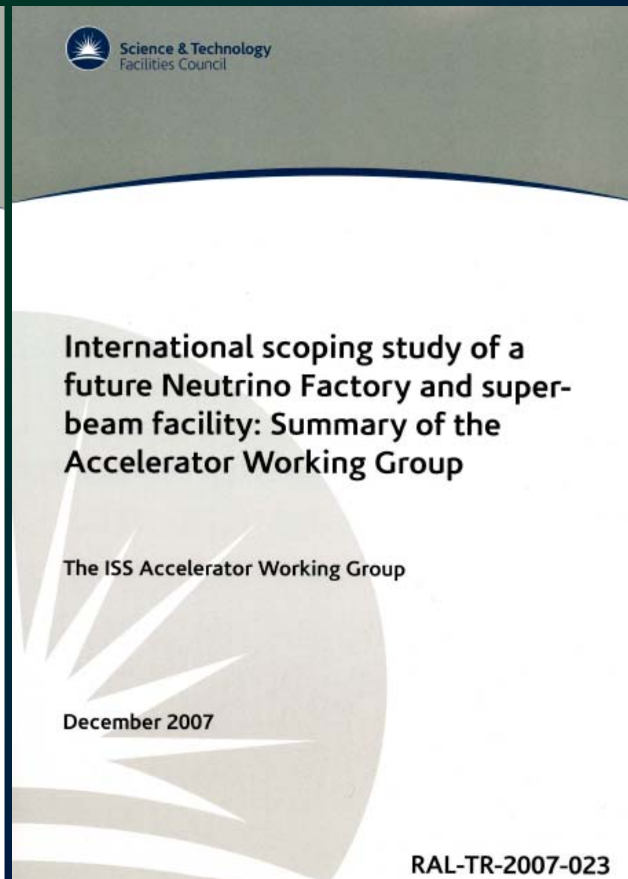


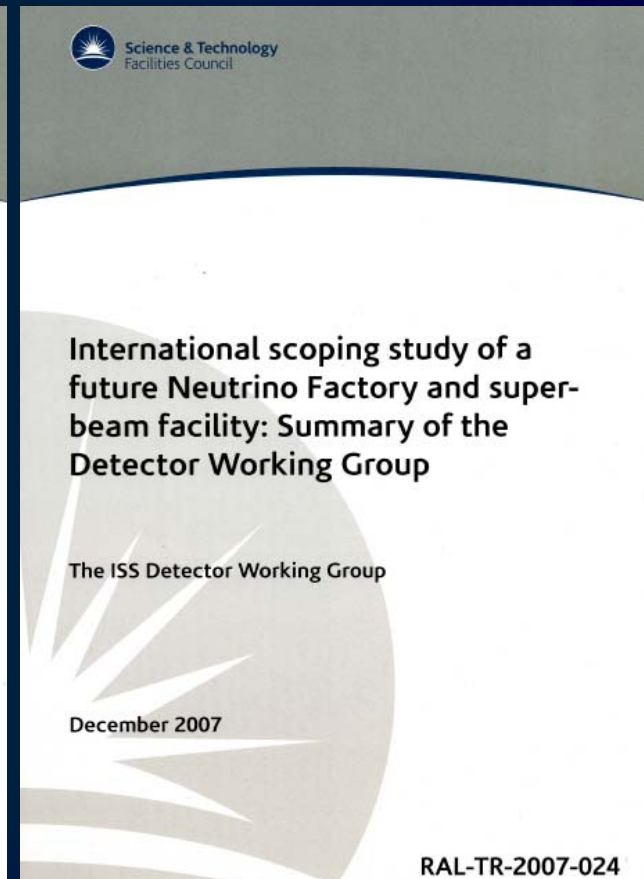
Timescale:

- Are we slipping?
- ISS conceived as a step on the way:
  - A one-year programme to lay the foundation for a more in-depth design study to follow …
- The IDS-NF:
  - Goal: to produce a ‘Reference Design Report’ for the Neutrino Factory by 2012:
    - The RDR is conceived as the document that will allow the ‘decision makers’ to consider initiating the Neutrino Factory project
  - The IDS-NF, therefore, differs from the ISS in that the emphasis will increasingly be placed on the engineering in order to:
    - Demonstrate the technical feasibility of the various systems; and
    - Evaluate the cost of the facility at the 30—50% level

Bringing the ISS to a conclusion:


Science & Technology Facilities Council
Technical Report
RAL-TR-2007-019
Physics at a future Neutrino Factory and super-beam facility
The ISS Physics Working Group


Science & Technology Facilities Council
International scoping study of a future Neutrino Factory and super-beam facility: Summary of the Accelerator Working Group
The ISS Accelerator Working Group
December 2007
RAL-TR-2007-023


Science & Technology Facilities Council
International scoping study of a future Neutrino Factory and super-beam facility: Summary of the Detector Working Group
The ISS Detector Working Group
December 2007
RAL-TR-2007-024

- Seeking to publish:
  - Physics report in Rep. Prog. Phys.
  - Accelerator and Detector reports in J.Inst
- Executive summary:
  - 10-pager: written by PJD; now in tidying-up phase

IDS-NF plenary #1: achievements:

- **Agreed first version of the IDS-NF baseline:**
  - See http://www.hep.ph.ic.ac.uk/ids/docs/IDS-NF-Baseline-2007-1.0R3-Final.pdf

- **Also, agreed work plan for period to NuFact08, Valencia, 30Jun—05Jul**
  - See (for example) http://www.cap.bnl.gov/mumu/project/IDS/workplan.html

- **IDS-NF starting (albeit a little slowly)**

IDS-NF-Baseline-2007/1.0 Revision 3 – Final 25th January 2008

Neutrino Factory: specification of baseline
for the accelerator complex and detector systems

1. Introduction

The purpose of this document is to define the baseline for the Neutrino Factory accelerator complex and the detector systems adopted by the International Design Study of the Neutrino Factory (the IDS-NF). The baseline specification will be re-issued from time to time by the IDS-NF Steering Group to reflect improvements made in the course of the IDS-NF. In this, the first definition of the IDS-NF baseline, the baseline developed through the International Scoping Study of a future Neutrino Factory and super-beam facility (the ISS) [1] is adopted. The performance of the facility defined in sections 2 and 3 below is presented in section 4.

1.1 Baseline numbering convention

The various iterations of the IDS-NF baseline will be identified by a version number. The version number will be YYYY/P.s where: YYYY is the year in which the baseline was derived; P is the 'principal version number; and s is the subsidiary version number. A number of parameters are defined below as 'principal interface' parameters. Changes in principal interface parameters directly affect the physics performance of the facility and will trigger a change in the principal version number. Examples of principal interface parameters include the stored muon-beam energy and the fiducial mass of the detector. When the value of a parameter that affects the specification of a sub-system (the proton driver, for example) is changed without affecting any of the principal interface parameters, a change in the subsidiary version number will be triggered.

A change in the IDS-NF baseline version number requires the agreement of the IDS-NF steering group. It is anticipated that changes in the version of the baseline will be made in response to a request from one or more of the working groups. The reasons for the change and the performance implications must be fully documented. Each new version of the baseline will be documented in a baseline specification document.

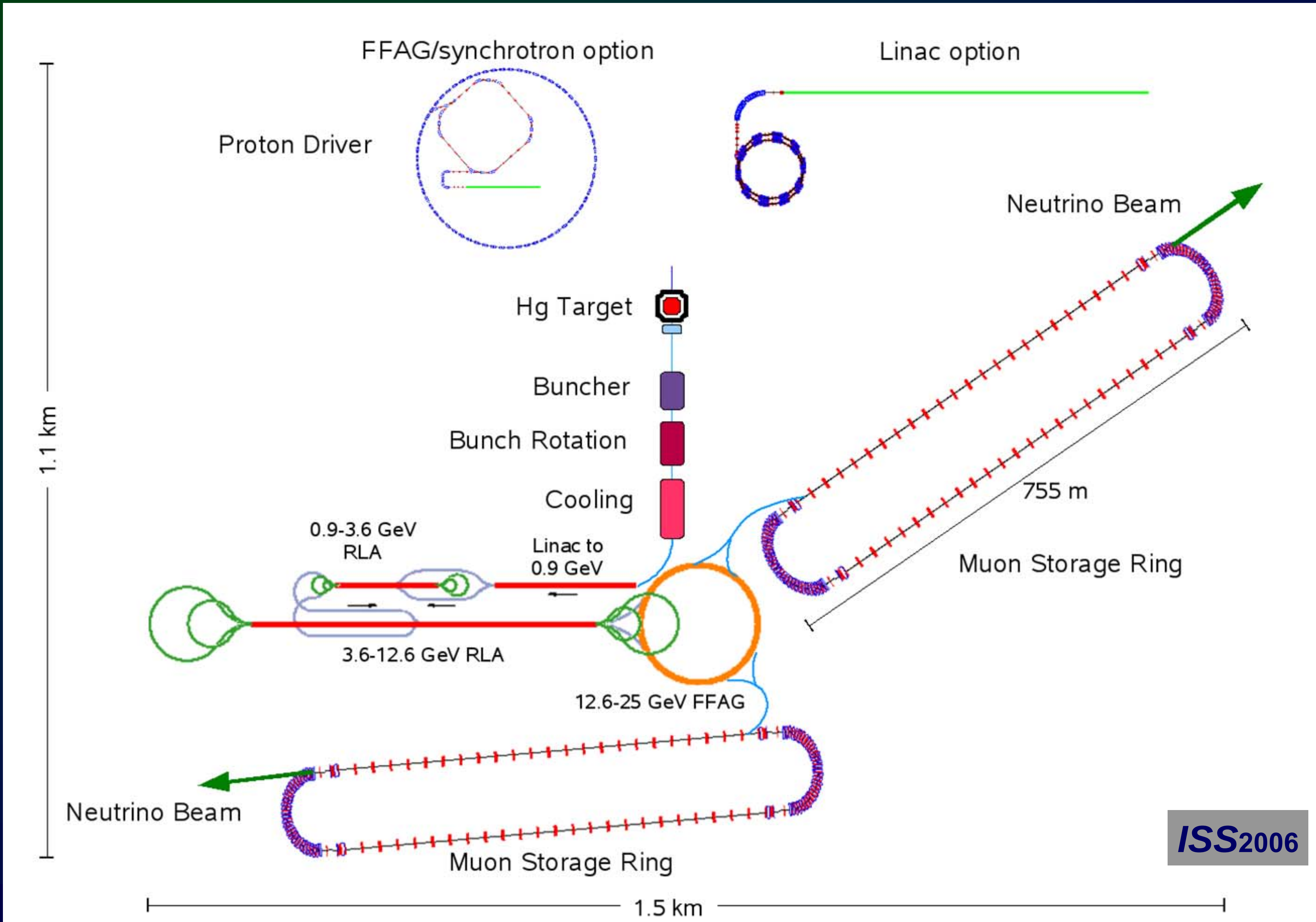
2. The Neutrino Factory accelerator complex

The specification for the accelerator systems developed by the Accelerator Working Group of the ISS is described in [2]. A schematic diagram of the ISS baseline is shown in figure 1 and the parameters of the various sub-systems are defined in table 1. The principal interface parameters are highlighted and shown in bold face. The baseline for the stored muon energy is 25 GeV and the facility will deliver a total of 10^{21} useful muon decays per year. The baseline for the storage rings is that both signs of muon are stored at the same time. Note that the neutrino-production rates will vary slighting (~±10%) depending on details of the accelerator complex. The fluxes quoted are those used in the performance evaluation in section 4.

The baseline pion-production target is based on a liquid-mercury jet. This implies a 3 proton-driver bunches per bunch train. The baseline target choice, and the consequences to the proton-driver bunch structure will be reviewed by (or at) NuFact08.

Prepared by the IDS-NF Steering Group

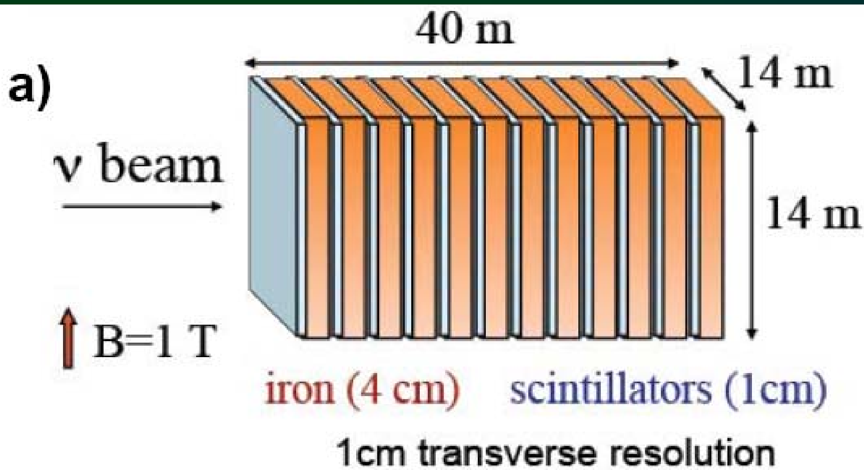
Accelerator baseline:

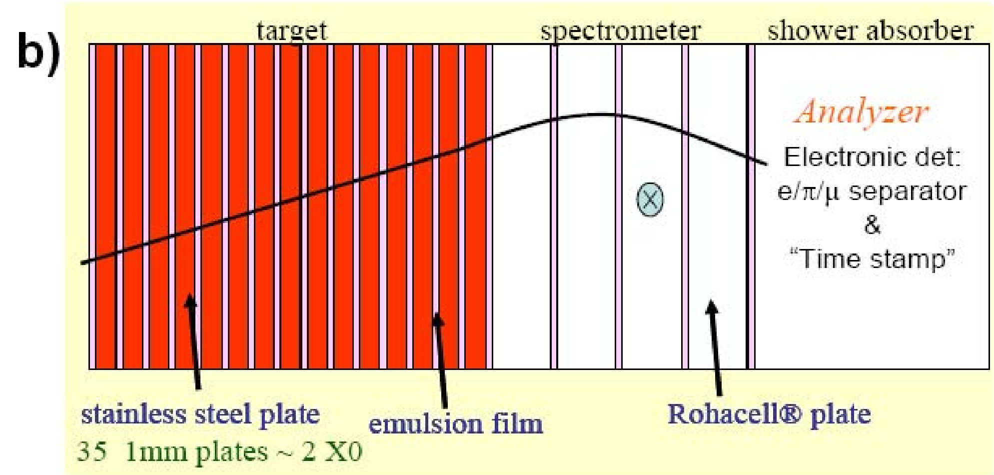


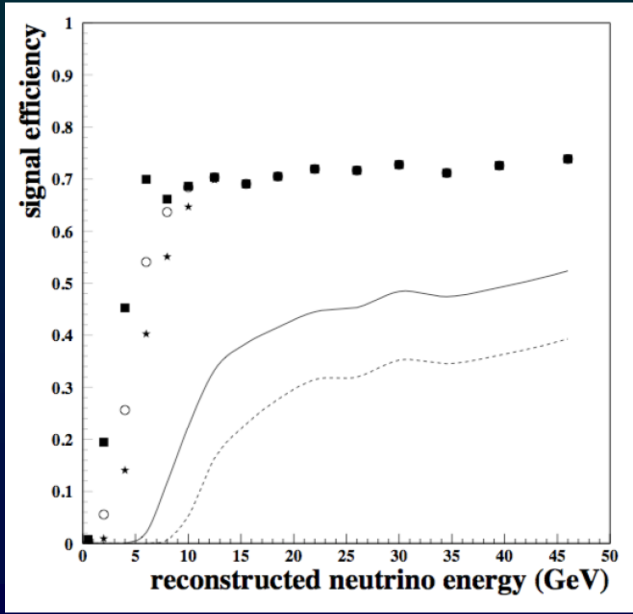
Accelerator baseline

Baseline specification for the Neutrino Factory accelerator complex			Version
Sub-system	**Parameter**	**Value**	**2007/1.0**
Proton driver	Average beam power (MW)	4	
	Pulse repetition frequency (Hz)	50	
	Proton kinetic energy (GeV)	10 ± 5	
	Proton rms bunch length (ns)	2 ± 1	
	Number of proton bunches per pulse	3	
	Sequential extraction delay (μs)	≥ 17	
	Pulse duration, liquid-Hg target (μs)	≤ 40	
Target: liquid-mercury jet	Jet diameter (cm)	1	
	Jet velocity (m/s)	20	
	Solenoidal field at interaction point (T)	20	
Pion collection			
Tapered solenoidal channel	Length (m)	12	
	Field at target (T)	20	
	Diameter at target (cm)	15	
	Field at exit (T)`	1.75	
	Diameter at exit (cm)	25	
Decay channel	Length (m)	100	
Adiabatic buncher	Length (m)	50	
Phase rotator	Length (m)	50	
	Energy spread at exit (%)	10.5	
Ionisation cooling channel	Length (m)	80	
	RF frequency (MHz)	201.25	
	Absorber material	LiH	
	Absorber thickness (cm)	1	
	Input emittance (mm rad)	17	
	Output emittance (mm rad)	7.4	
	Central momentum (MeV/c)	220	
	Solenoidal focussing field (T)	2.8	
Acceleration system	Total energy at input (MeV)	244	
	Total energy at end of acceleration (GeV)	25	
	Input transverse acceptance (mm rad)	30	
	Input longitudinal acceptance (mm rad)	150	
Pre-acceleration linac	Final total energy (GeV)	0.9	
RLA(1)	Final total energy (GeV)	3.6	
RLA(2)	Final total energy (GeV)	12.6	
NFFAG	Final total energy (GeV)	25	
Decay rings	Ring type	Race track	
	Straight-section length (m)	600.2	
	Race-track circumference (m)	1,608.80	
	Number of rings (number of baselines)	**2**	
	Stored muon energy (total energy, GeV)	**25**	
	Beam divergence in production straight (γ^{-1})	**0.1**	
	Bunch spacing (ns)	**≥ 100**	
	Number of $\mu^{\pm}$ decays per year per baseline	**5×10^{20}**	

Detector baseline





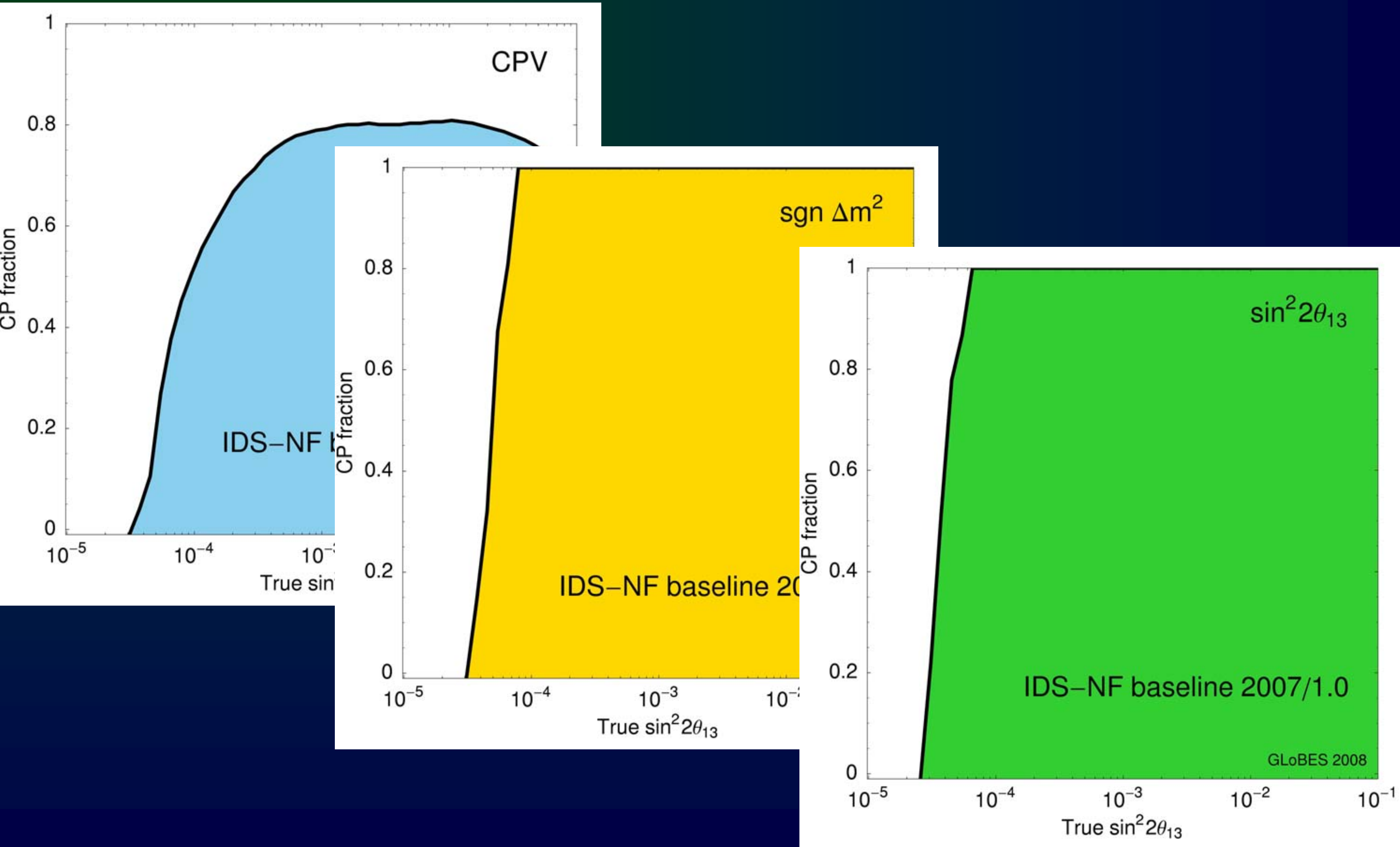


- Two baselines:
  - 3000 – 5000 km
  - 7000 – 8000 km
- Magnetised Iron Neutrino Detector (MIND) at each location
- Magnetised Emulsion Cloud Chamber at intermediate baseline for tau detection

Detector baseline

Baseline specification for the Neutrino Factory long-baseline neutrino detectors			Version
Sub-system	**Parameter**	**Value**	**2007/1.0**
Configuration	**Number of baselines**	**2**	
	Intermediate baseline (km)	3,000 to 5,000	
	Long baseline (km)	7,000 to 8,000	
	Detectors at intermediate baseline	MECC, MIND	
	Detector at long baseline	MIND	
MIND	**Fiducial mass (kTonne)**	**50**	
	Magnetic field (T)	1	
	Neutrino energy resolution ($GeV^{-0.5}$)	$55\%/E_\nu^{0.5}$	
Background fraction	Charged current (GeV^{-2})	See table 3	
	Neutral current (GeV^{-2})	See table 3	
Efficiency	ν_μ appearance: efficiency	See table 3	
	ν_μ disappearance: efficiency	0.9 (from 1 GeV)	
Systematic uncertainty	Uncertainty on number of events in signal sample	2.50%	
	Uncertainty on number of events in background sample	20%	
MECC	**Fiducial mass (kTonne)**	**10**	
	Magnetic field (T)	**1**	

Performance of baseline Neutrino Factory



UKNF/MICE-UK: the next three years

- Uncertain times!
- Have been asked to negotiate budget for next three years
  - Very good news, process has started
- Guidelines from J.Womersley:
  - JW seeks to defend accelerator R&D programme at the level of £10M/year
  - Guidelines for UKNF/MICE-UK:

Work package	Notional annual budget (£k)
MICE operations and analysis	800
MICE Phase II	1300
Neutrino Factory specific	500
Neutrino Factory generic	800

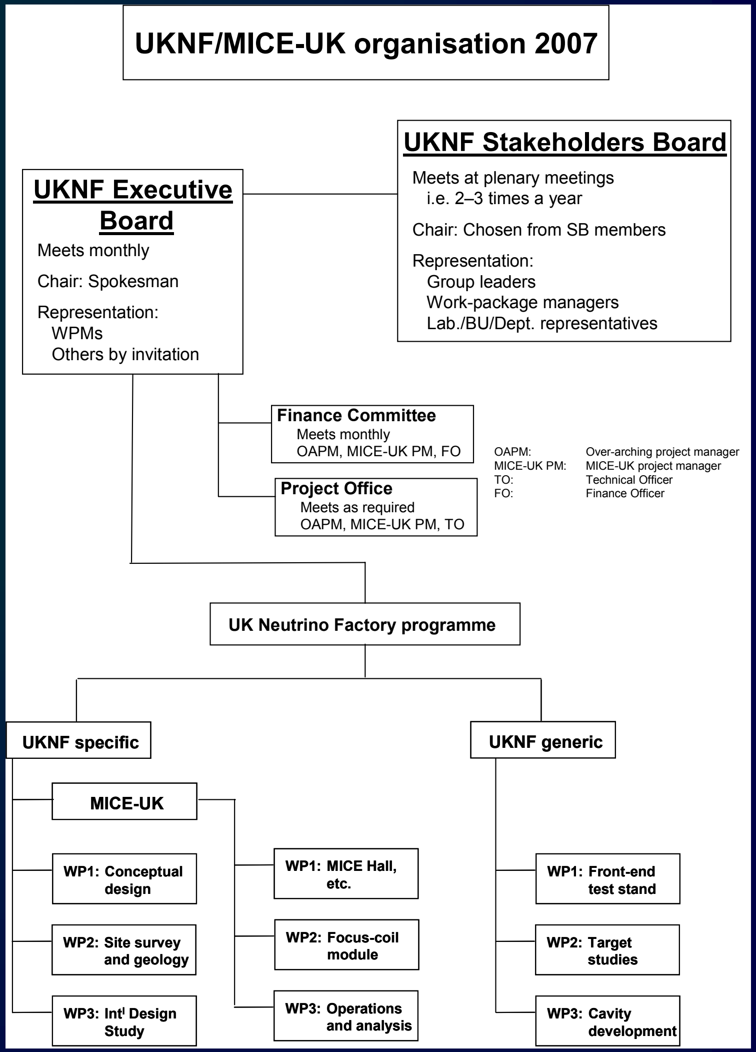
- Emerging advisory structure:
  - ‘ASTAB’:
    - Re-constituted at same ‘level’ as PPAN and PALS
      - Advisory board for accelerator-science programme
    - Reporting to Science Board
    - Close links with PPAN and PALS who will advise on science priorities

Opportunities, challenges:

- Plan UKNF/MICE-UK programme as integral part of IDS-NF:
  - EuroNu
  - DetDev
- Exploit emerging Knowledge Transfer agenda:
  - Creative proposals
- Detector development:
  - My opinion: need to present coordinated neutrino-detector R&D proposal
- Overall: opportunity to establish Neutrino Factory as a strategic priority for STFC

Organisation:

- UKNF-EB:
  - Has met ~monthly
    - http://hepunx.rl.ac.uk/uknf/Governance/UKNF-EB/
  - Need to improve link with stakeholders:
    - Propose to augment with SB chair (ex-officio)
  - Need to improve link to detector development:
    - Propose to augment with detector representative
- UKNF-SB:
  - Will meet today
- Issues:
  - OAPM: Cameron:
    - Delay in joining UKNF team:
      - Commitment to LHCb RICH
    - URGENT!
  - MICE PM early retirement:
    - Recruitment in progress
  - Effects
    - Has impacted UKNF management and IDS-NF momentum



Next meetings:

- Next UKNF plenary:
  - Agreed six-monthly cycle at last UKNF meeting
  - Propose:
    - Two days in week of 29Sep08
  - Venue?
    - Offers?
- UKNF-EB:
  - See WWW site for meeting schedule and record of meetings