Neutrino Input to CERN Strategy Review
&
Summary of Town Meeting

+ With apologies to Alain Blondel

+ Everybody who was there should feel free to interrupt and comment at any time!

+ Ditto with questions

Framework for Input

- **Strategy review will look at the long term**
- **Focus will be on the next 5-6 years**
- **2006 Strategy said:**

Studies of the scientific case for future neutrino facilities and the R&D into associated technologies are required to be in a position to define the optimal neutrino programme based on the information available in around 2012

- **As Alain said, if we propose nothing, that's what we'll get!**
- **Reminder:**
  - **this was our motivation**
  - **we've done more studies than anybody else in EU!**
- **Alain's plan: 3-4 page summary document as input**

European strategy for future accelerator-based neutrino physics

1. ~~Physics case~~
2. Next steps: a neutrino road map
3. Community and global context
4. Opportunity in Europe for the next step
5. ~~Short baseline neutrino beam and sterile neutrino search~~
6. Preparing for longer term, precision experiments

Also left out comments added after Town meeting.
Mainly for LBNO.

2. NEXT STEPS – a neutrino road map

The recent measurement of $\sin^2 2\theta_{13} \sim 0.097 \pm 0.012$ clarifies the next steps to follow. The large value of this parameter will allow a clear-cut determination of the mass hierarchy of neutrinos, and may render observation of CP violation accessible, though not easily, with conventional neutrino beams, within the next 10-20 years depending on the value of parameters

Observation and study of CP violation require accelerator-based neutrino beams

**A precise study of CP violation, a full verification of the 3x3 mixing of active neutrinos and the search for physics beyond this framework,
will require precise determination of all possible flavour transitions of neutrinos for which new, better defined neutrino beams will become necessary
(beta beam or neutrino factory)**

The search for neutrino Majorana mass terms will require $0\nu\beta\beta$ experiments which cannot be done at accelerators

The search for sterile neutrinos is an extremely broad field as their masses are not constrained between few meV to 10^9 GeV, and can be pursued in a great variety of means.
A good starting point is the clarification of the possible anomalies in nuclear reactor and short baseline experiments, using nuclear sources and short baseline acclerator experiments

3. COMMUNITY AND GLOBAL CONTEXT

The neutrino oscillation community involved in running experiments in Europe is not small (600-900)

OPERA (~180) ICARUS(~60) DChooz(~170) T2K(~250) MINOS (~25)
BOREXINO (100), ANTARES(153), ICECUBE (125)
There is a strong accelerator group at CERN (CNGS) – but no physics group

This community has acquired the necessary competence and will be able to support a leading edge neutrino project with a conventional neutrino beam.

The European physicists are playing a leading role in R&D and studies towards future accelerators and detectors (MERIT, MICE, Beta beam, IDS-NF, EUROnu AIDA and LAGUNA) and in the ancillary experiments necessary for the precision of accelerator-based experiments worldwide (NA61/SHINE).

The presently running experiments in the US (MINOS+, NOVA) and in Japan (T2K) will improve the measurements of oscillation parameters considerably, but will most probably not be able to carry out the determination of MH and discovery of CPV in a definitive way.

Further experiments (DUSEL, T2HK) are being discussed but their exact scope and time scale is not clear yet. The projects are largely complementary and the importance of the subject justifies a competitive approach.

4 OPPORTUNITY IN EUROPE FOR THE NEXT STEP

The next step should be an experiment which is feasible in a reasonable time (less than ~10 years), maintains the community healthy, with **a real chance of discovery** and long term upgrade possibilities.

The existence of a possible long baseline in Europe
CERN → Pyhasalmi = 2300 km is unique in this regard.

Building on the experience with CNGS and on the pioneering competence in Liquid Argon TPCs, European physicists are in the position to propose a realistic next step: a conventional neutrino beam in **CERN north area neutrino facility** aiming at 20kton of fine grain detector (Larg) followed by a magnetized iron detector (MIND) at Pyhasalmi. It should be supported by extensive hadroproduction measurements in an upgraded SHINE/NA61.

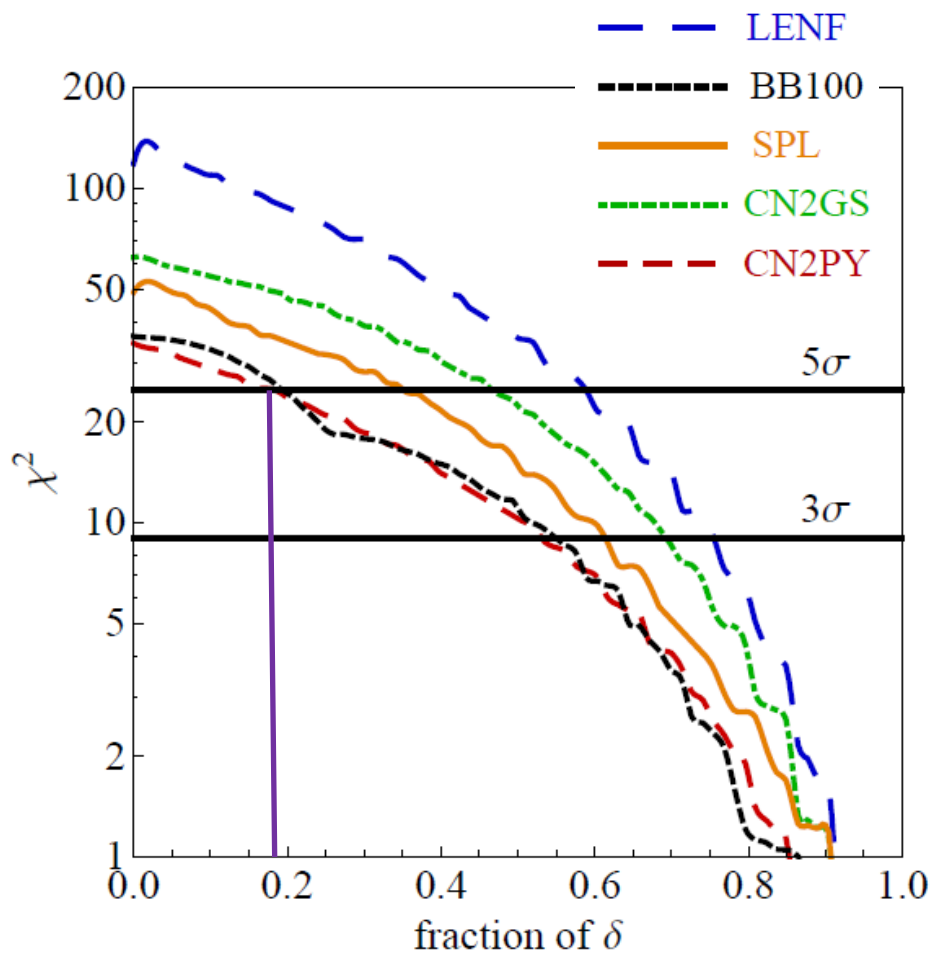
This can achieve a definitive **($\geq 3\sigma$) determination of the neutrino mass hierarchy** quite rapidly (2.5 years at present CNGS intensity) . The deep underground location allows non accelerator applications (LENA project, could also contribute to beam)

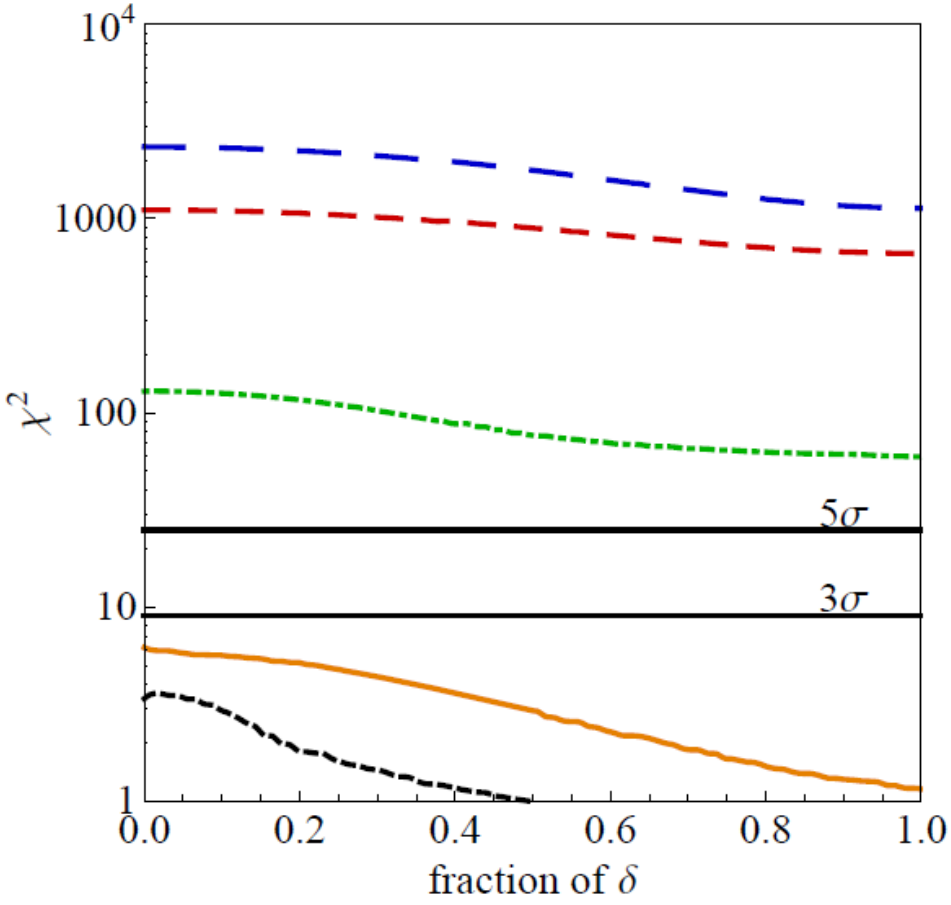
Both the local situation and the distance make it such that it can evolve into a larger detector and a more powerful beam (NF) **and thus, offers a long term vision.**

This project, called LBNO, is the first priority of the LAGUNA-LBNO consortium and is endorsed by the NF community. *It will be proposed as next step to the SPSC and the European strategy.*

Milestones - Timescale

LAGUNA Design Study funded for site studies:	**2008-2011**
Categorize the sites and down-select:	**Sept. 2010**
Start of LAGUNA-LBNO	**2011**
Submission of LBNO EoI to CERN 	**2012**
End of LAGUNA-LBNO DS: technical designs, layouts, liquids handling&storage, safety, ...	**2014**
Critical decision	**2015 ?**
Excavation-construction (incremental):	**2016-2021**
Phase 1 LBL physics start:	**2023 ?**
Phase 2 incremental step implementation:	**>2025 ?**





LENF: 1.4x10^{21} decays per year, 100 kt mass MIND at 2000 km
BB100: gamma=100, with 1.3/3.5x10^{18} decays for Ne/He, 10^{-2} atmospheric background suppression, 500 kt WC detector
SPL: 4 MW proton driver, 500 kt WC detector
CN2GS: 0.8 MW, 500 kt WC detector at Canfranc/GS (730 km)
CN2PY: 0.8 MW,100 kt LAr at 2300 km

- **10 years total running**
- **5%/10% systematics for signal/background**

Other Possible Measurements of MH?

Project	Details	MH at 5σ?	Comments	Timeline
NOvA	700kW NuMI, 810km, 15kt TASD	No	3σ is possible	Starting 2013, with 5kt; 6 years running
NOvA+T2K +GLADE	T2K to 700kW in 2019; GLADE=5kt LAr	Yes-ish, over 30%ish of δ		~2023
LBNE Phase I	(1) NuMI, 30kt LAr surface, Ash River; (2) NuMI, 15kt underground, Soudan; (3) 700kW LBNE, 10kt LAr surface, Homestake	(1) & (2) – No; (3) – Yes, over ~50% δ	Report to DOE on 1st July	~early 2020s
Daya Bay II	20kt at 60km	No	3σ after 6 years	?
PINGU	20 strings ~20m apart =20Mt!	Yes with atmospheric; yes with NuMI beam		Proposal: 2013; construction will be fast
MODULAR	10kt LAr at GS	?	Focus is on CPV	

DayaBay II	reactor 60km	20 kt LS	3 σ in 6 years	R&D on E-reso. my guess 2020	Karsten Heegner	
ICAL@INO	atmos.	50 kt MID (RPCs)	2.7 σ in 10 years	2027	Sandhya Choubey	
HyperK	atmos.	1 Mt Water Cerenkov	3 σ in 5 years 4 σ in 10 years	2027/28 2033/34	Sandhya Choubey	LoI submitted
T2HK	LBL accel. 295 km	1 Mt Water Cerenkov	0..3 σ in 10 years	2028	Masashi Yokoyama	
PINGU	atmos.	Ice (South pole)	3...11 σ in 5 years	feasibility study ongoing.	Sandhya Choubey Poster	Systematics ?
MINOS+	LBL accel. 735 km	MID 5.4 kt	no claim on mass hierarchy	---	speaker on question	
GLADE	LBL accel. 810 km	LAr 5 kt	In combination with NOνA and T2K $\leq 2\ \sigma$	Letter-of-Intent	André Rubbia, Poster	
NOνA	LBL AshRiver 810 km	TASD 14 kt	0...3 σ in 6 years depending on δ	2020	Ryan Patterson	under construction starts 2014
LBNE	LBL Homestake LBL Soudan LBL AshRiver	LAr 10 kt LAr 15 kt LAr 30 kt	1.5...7 σ in 10 y 0...3 σ in 10 y 0.5...5σ in 10 y	2030	Bob Swoboda	range gives dependence on δ
GLACIER	LBL accel. 2300 km	LAr 20 kt	> 5σ in a few y.	2025 + number of years to the decision	André Rubbia	
LENA	LBL accel. 2300 km	Liq. Scint. 50 kt	5 σ in 10 years	2028 + number of years to the decision	Lothar Oberauer	

The information is collected from talks given at the NEUTRINO2012 conference in Kyoto in June 2012.
The following transparencies are extracted from the corresponding talks (speakers listed in the 6th column).

Observations

- No consensus reached on LBNO at Town Meeting
- LBNO will submit EoI to SPC in summer
- No commitment to develop underground lab
  - true for all EU underground labs/facilities
- Physics is MH and this may already be done
- But it may not!

6. Preparing for longer term, precision experiments

Similarly to quark flavour studies, a full investigation of the properties of neutrinos will require a longer term program of precision measurements and full coverage of all available neutrino transitions. This will require neutrino sources with excellent flux intensity and flavour control, such as beta-beam or the more powerful neutrino factory.

European physicists have acquired a leading position in often unique and international R&D experiments and studies towards future accelerator and detectors

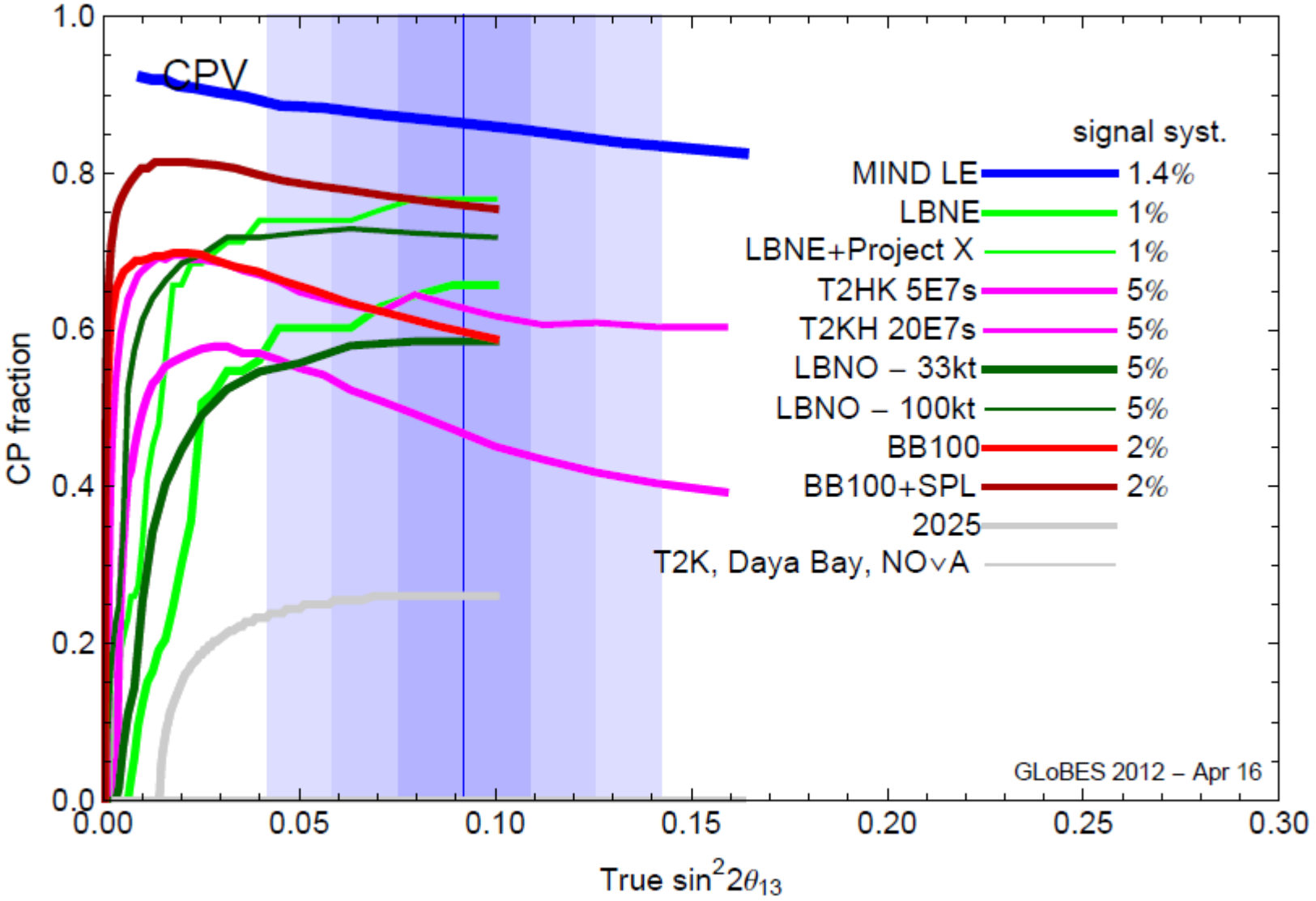
-- MERIT, MICE, Beta beam, IDS-NF, EUROnu, AIDA and LAGUNA/LBNO

Successful completion of engaged efforts and continuation of studies towards a longer term project are essential for the field. The aim should be to be able to propose the following step by the next iteration of strategy (i.e. 2018-20).

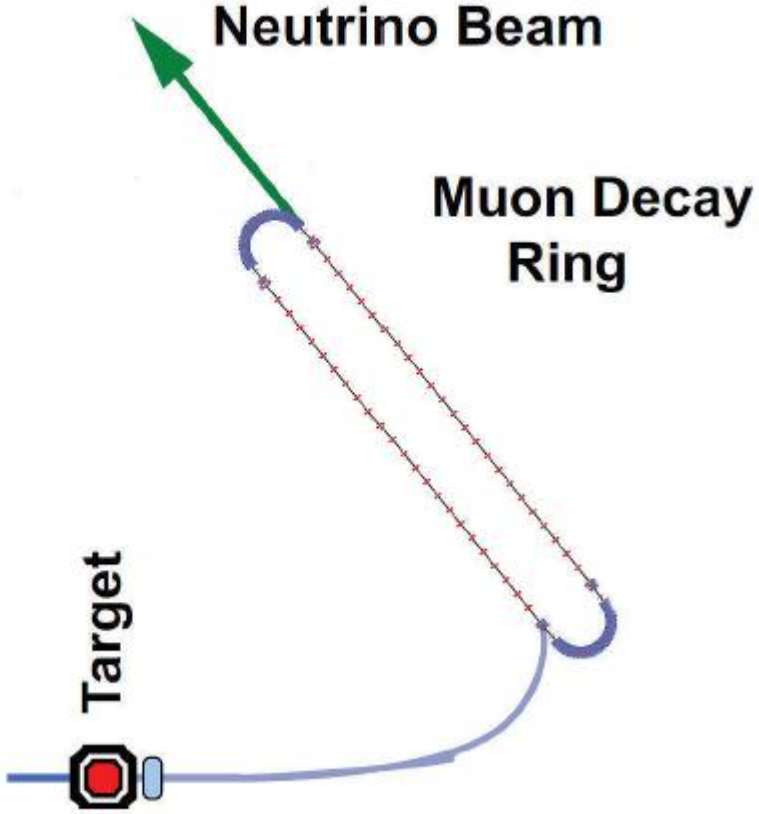
Facility for exquisite precisions

- K. Long and E. Wildner

- Daya Bay & Reno results:
  - CPV discovery conceivable; emphasizes control of systematics critical
- Scientific priorities:
  - MH; CPV; Precision measurement;
- Gamma=100, Beta beam plus SPL/Frejus super-beam:
  - Opportunity if shown to be cost effective relative to NF [EUROnu]
- Neutrino Factory
  - Offers:
    - Best discovery reach; best precision
  - Flexible, can be developed in an incremental fashion:
    - nuSTORM:
      - υ_e and υ_μ cross sections; search for sterile neutrino
    - Incremental implementation of IDS-NF baseline
      - Stage I: existing proton source; no cooling
        - CPV & MH discovery potential excellent
      - Stage II: IDS-NF 10 GeV/2000 km
        - Exquisite sensitivity and precision
- European Strategy must include European contributions to:
  - First step(s) towards high-precision, long-baseline facility:
    - nuStorm; &
    - Work required to bring forward proposal for implementation of facility over ~5 years in time for the next strategy update [implies resource]



P.Huber, IDS-NF, Glasgow



vStorm

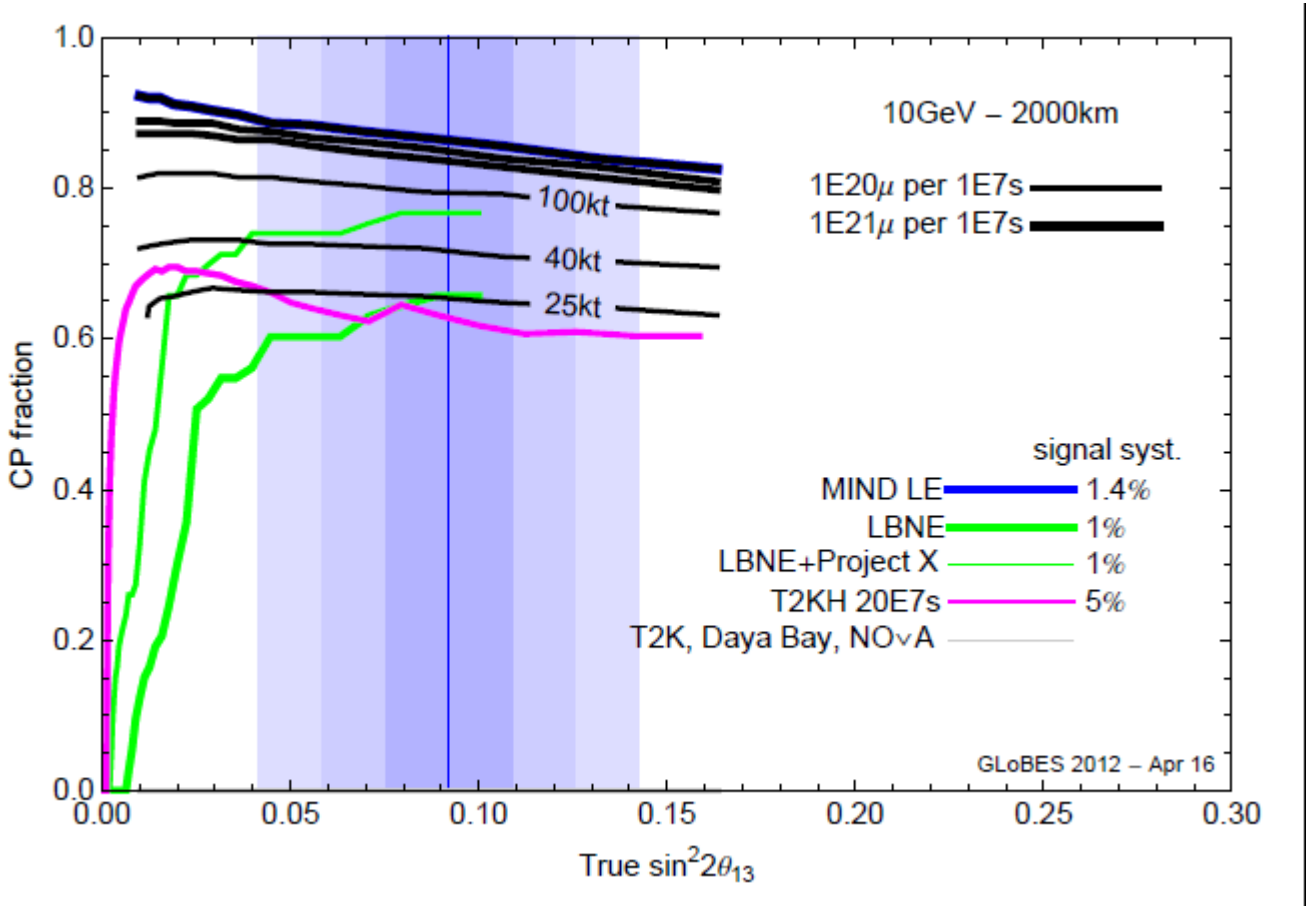
- sterile neutrinos
- cross-section measurements:

$$\nu_e \,\&\, \bar{\nu}_e$$

- NF prototype
- ν-beams for detector studies

See Kyberd et al,
arXiv:1206.0294v1

Stage I



- 700 kW protons, 10 GeV
- 20kt MIND
- No cooling

Observations

- Requires us to choose now/soon
- Physics is "known"
- Choice based on cost (+ safety + risk)?
- Input to SR:
  - R&D required to deliver proposal in 2017
  - Proposal for vStorm?
- Costs and timescales very important