Accelerator-based neutrino experiments

Towards a coherent proposal by the neutrino community

PREAMBLE

1. The European strategy process will consider the long term view, but will give guidelines for the next 5-6 years.
   Neutrino oscillation physicists should come up with a vision in European neutrino oscillations physics that encompasses a concrete short term plan.
   Are we in a position to propose such a vision and such a plan?
   Can it lead to a realistic facility with top level objectives, yet broad use and long term possibilities of development?

2, CERN is the established world leader in the high energy investigation.
   Europeans have unique strengths to offer in neutrino oscillation physics and the physics is important enough to be addressed in different ways and places.
   In this context there should be space for a meaningful accelerator-based neutrino program in Europe.

   Do we have something realistic to propose that would allow a practical realization?

The output of the workshop will be a 3-4 pages summary statement supported by a roadmap document.

The following aims to reflect the contents of the 3-4 pages summary

Suggest to note the questions for the following discussion

PREAMBLE

In 2006 the European Strategy for Particle Physics recommended:

6. 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;

We are in 2012 – What do we know, and what do we propose?

If we do not have a COHERENT answer to this question…
is it predictable that ~NOTHING will happen in Europe in the next decade

-- Scientific case
-- Status of neutrino technologies
-- A Neutrino programme

The following aims to reflect the contents of the 3-4 pages summary

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

1. PHYSICS CASE

The existence of massive neutrinos is, today, the only existing demonstration of new physics beyond the standard model of particle physics (SM)

It requires extension of the SM in a way that is yet unknown.

-- Dirac or/and Majorana masse terms
-- spectrum of masses, mixing angles and phases
-- new particles: right-handed (a.k.a. sterile) neutrinos

This opens a deep and promising field of research, with a large potential for discoveries of considerable consequences.

discoveries:

Mass hierarchy, CP violation, $0\nu\beta\beta$, sterile neutrinos, violation of unitarity, etc

consequences:

Insight in the nature of particle masses and the question of flavour
Baryon asymmetry of the Universe
Evolution of early Universe
Dark matter

Europe should place neutrino physics at highest level of priority.

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

A.

NOT PART OF THE STATEMENT

$\sin^2 2\theta_{13} \sim 0.097 \pm 0.012$ is no longer 'unknown' and is LARGE

Next: sensitivity to Mass Hierarchy (MH)
CP Violation (CPV)

This is a turning point for which we have been preparing since 1998
ECFA study groups, (+ design studies in the US)
BENE in CARE, (2004-2008)
ISS (2005-2008)
NEU2012 in EUCARD, (2009-2013)
Beta-beam in EURISOL, (2005-2009)
superbeam, beta beam and neutrino factory IDS in EURONU (2008-2012)
LAGUNA (detectors for astroparticle physics and beam experiments) (2008-2010)
LAGUNA-LBNO (focuses on beam experiments from CERN) (2011-2014)

HOW DO WE GO ABOUT IT ?

GLOBAL or EUROPEAN?

Small steps or a big step?

NOT PART OF THE STATEMENT

Global or not global ?

of course we are in a global, competitve environment.
Should we decide on facilities through a global collaborative process like ILC?
This was discussed at NUFACT11 round table
Community consensus:
there is not so much to gain here
-- host has to put down ~2/3 of investment anyway
-- there are so many aspects of neutrino physics…
and they cannot all be solved with the same technique
-- competition gives better physics/money.

ONE BIG STEP or small steps?

The neutrino oscillation community in Europe is not small (~700, some double count)
OPERA (~180) ICARUS(~60) DChooz(~170) T2K(~250) MINOS (~25)
but it has shrunk to 0 at CERN.

We need a small step to get restarted
BUT make sure steps have a small term top level result and a long term view

➔ Small steps

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.*

5 Short baseline neutrino beam and sterile neutrino search

The existence of the first large Liquid Argon TPC in the world (ICARUS) coupled with the new CERN North Area neutrino facility could allow a definitive, two-detector search for sterile neutrinos in the region, of a long-standing claim with $\Delta m^2 \sim eV^2$, with an experiment offering redundancy sensitive to several oscillation channels.

A well known neutrino flux would also allow precision measurements of neutrino cross-sections to be performed on- and off-axis.
Consistency in time and protons with the Long Baseline Neutrino Oscillation program must be ensured.

To broaden the sterile neutrino search (up to several keV), experiments with neutrino sources calibrated at the sub-% level (nuclear decays, muon storage rings, etc) will be necessary (Borexino, vSTORM, etc)

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).