Report of the SPC panel on Future Neutrino Facilities

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Relations between CERN and the ongoing development work regarding future neutrino facilities. I. Summary

Annex: Relations between CERN and the ongoing development work regarding future neutrino facilities. II. Supporting document

This presentation summarises the final conclusions as compared to the panel presentation at the SPC meeting in December 2009. Mostly excerts from the Summary document with some items from the Supporting document are given.

Question 1

What is the view of the SPC on the importance of precise measurements of the neutrino oscillation parameters, in particular the CP violating phase and mass hierarchy? - **UNCHANGED**

After intensively studying hadron flavour physics for many decades, engaging in a comparable effort to study lepton flavour physics and determine all the neutrino oscillation parameters as precisely as possible is the logical next step.

Neutrino properties are very likely to provide a unique window on physics beyond the Standard Model, irrespectively of the existence of new particles at the TeV scale.

Discovering either the violation of total lepton number in neutrinoless double beta decay or leptonic CP violation in neutrino oscillations would be a top-class scientific achievement.

Determining the mass hierarchy and precisely measuring the other neutrino oscillation parameters are also very important, as they could shed light on possible flavour symmetries.

Overconstraining the standard framework of unitary 3x3 mixing in the neutrino sector, as has been done for the quark sector, is also crucial. Possible deviations could be linked to new degrees of freedom near or even below the TeV scale.

To summarize:

Neutrino physics will play an important part in ongoing attempts to understand what is beyond the Standard Model

and

There is a large active European community taking this challenge

Question 2

One of the most promising techniques for such measurements is the neutrino factory and there is currently an International Design Study (IDS) to produce a conceptual design report for a neutrino factory by 2012. This is not site specific. What is the view of the SPC on the overall value of the IDS for the future of the subject? Should CERN take a more active role in enabling the study to reach its goals, irrespective of where such a facility would be sited? **- UNCHANGED**

The Neutrino Factory, associated with large magnetic detectors, constitutes the most powerful neutrino facility with potential for discovery which can currently be envisaged. It can study several elements in the neutrino mixing paradigm to an unmatched precision: the mixing angles θ_{23} and θ_{13} , the mass difference Δm^2_{13} and its sign, and the CP violating phase δ, for $\sin^2 2\,\theta_{13} > 2\ 10^{-5}$

It is unique in producing high energy $(\nu_\mu, \bar{\nu}_e), (\bar{\nu}_\mu, \nu_e)$ pairs in an identical environment, which, with suitably fine grained detectors, allow tests of unitarity by detectable transitions, including those to tau neutrinos at the near and/or far detector stations. It appears today very likely that without a Neutrino Factory several questions will remain unanswered.

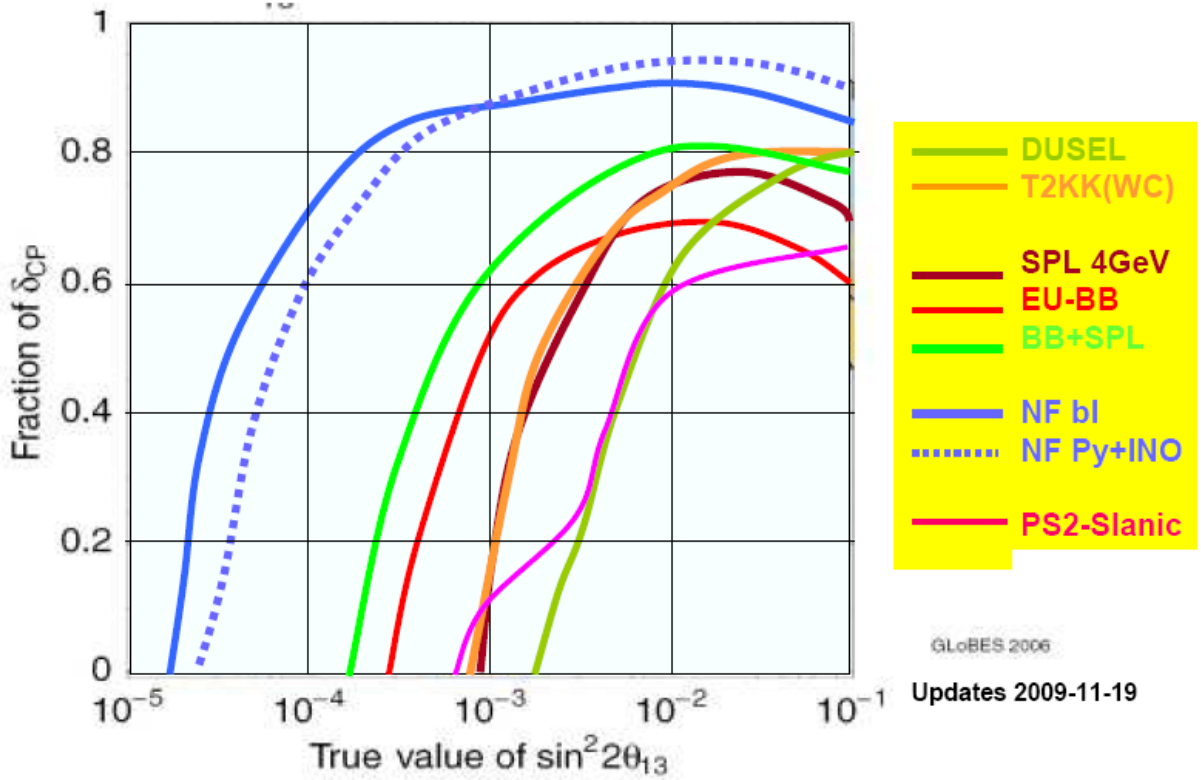


Figure 2 A representative compilation of sensitivities of some future long baseline projects. Here the fraction of δ_{CP} where CP violation can be observed at 3 standard deviations is plotted as a function of θ_{13}. T2KK: T2K 1.66 MW beam to 270 kton fid volume Water Cherenkov detectors in Japan (295km) and in Korea (1050 km); DUSEL: a WBB from Fermilab to a 300 kton WC in Dusel (1300km); SPL 4 GeV, EU-BB and BB+SPL curves stand for the CERN to Fréjus (130km) project; NF bl is the Neutrino Factory baseline (4000km and 7000km baselines) and NF Py+INO represents the concrete baseline from CERN to Pyhasalmi mine in Finland (2285 km) and to INO in India (7152 km); PS2-Slanic is a preliminary study of an experiment at 1500km based on an upgrade of PS2 to 1.66MW and a 100kton Liquid Argon TPC **(references added in footnotes)**.

The IDS-NF effort is lacking manpower in several critical areas, in particular costing and safety.

Although the study is not site specific, investigating in concrete terms the cost and feasibility of such a machine at CERN would give great credibility to the IDS-NF study. The high power version of the Superconducting Proton Linac (SPL) would be a suitable proton driver for a Neutrino Factory.

Building on the success of the CERN-NTOF11 MERIT experiment, a study of the design and safety implications of a high power target station, particularly with a mercury (or alternative liquid metal) jet, should be given high priority. The Muon Ionization Cooling Experiment (MICE) at RAL will be a crucial demonstration, to which CERN has contributed and should continue to participate.

Question 3

What other high intensity neutrino facilities are technically possible and how would they address the measurements above?

What should be the involvement of CERN in studies of these facilities, in particular with regard to the planned LHC upgrades? **- THE CHANGED PERSPECTIVE**

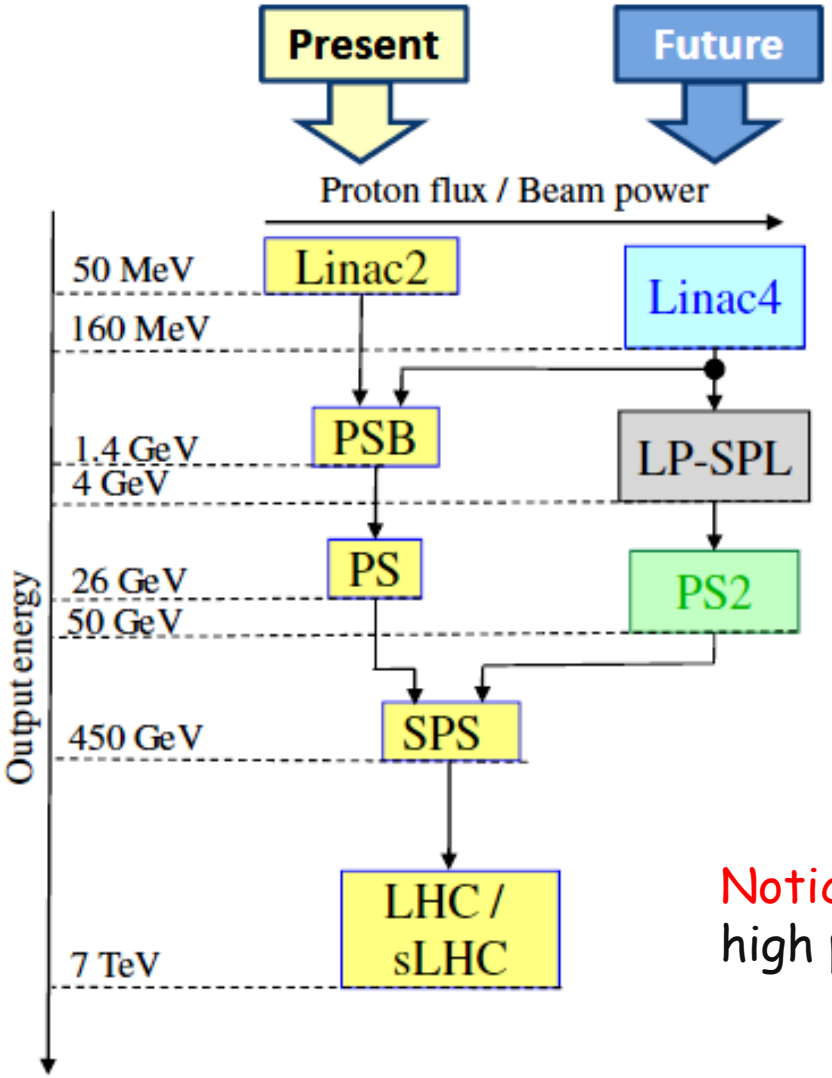
Two other techniques considered feasible for the determination of the CP phase, the mass hierarchy and precise measurement of other oscillation parameters are **the Beta Beam and a high power Superbeam**.

Originally it was assumed that the discussion of the future neutrino facilities should be related to the planned upgrade of the LHC injection chain, however **the SPC is informed that the form of any LHC upgrade has yet to be decided**.

From R.Garoby talk

Description

Plans for future LHC injectors



Notice Linac4 is the only aproved future accelerator !

LP-SPL:
Low Power-Superconducting Proton Linac (4 GeV)

PS2:
High Energy PS (~ 5 to 50 GeV – 0.3 Hz)

sLHC:
"Super-luminosity" LHC (up to 10^{35} $cm^{-2}s^{-1}$)

Notice the LHC does not require high power SPL and PS2.

Should the LHC upgrade consist of the SPL & PS2 then the basic SPL would probably be adequate for the standard beta-beam, whilst the neutrino factory and superbeam would require at least upgrading the SPL to a high power (~4MW) version. A new 50 GeV PS2 would only be of interest for neutrino physics if it was of substantially higher power than the PS2 which has been envisioned for the LHC.

The most powerful options for CERN for the 2020's are a beta beam/superbeam combination or a neutrino factory and for both of these a high power proton driver is an essential.

This would have numerous other uses outside the neutrino area.

The Beta Beam concept has been studied at CERN since 2002. Radioactive ions undergoing β+ (β-) decay are accelerated in the PS and SPS and accumulated in a storage ring to produce pure ν_e ($\bar{\nu}_e$) beams. The baseline facility has been investigated in the FP6 EURISOL design study based on the SPL and much of the existing CERN infrastructure. The ions are ^{6}He and ^{18}Ne, accelerated to a γ of 100 which yields a neutrino end point under 1 GeV.

In EUROnu another procedure for the production of 8Li and 8B is being investigated. These ions have a higher Q-value and hence give rise to higher energy neutrinos for the same γ, however establishing the overall viability of a Beta Beam facility with these ions is still in its infancy.

Other Beta Beam solutions using the He and Ne ions accelerated to a much higher γ (350) have been considered but would require, at CERN, a new 1 TeV SPS and so they are considered impractical.

Production of ^{6}He is considered straightforward by spallation from the SPL, however a means to produce ^{18}Ne ions with sufficient intensity has yet to be established.

The cost estimate of a Beta Beam facility is not available yet and will be necessary for decision making.

A future Superbeam will require a high power (2-4MW) proton driver. At CERN there would appear two Superbeam alternatives, a low energy one based on a high power SPL, and a high energy one based on a new high power 50 GeV proton synchrotron.

The former requires detectors within <~300km of CERN whilst the latter could possibly use detectors placed at much greater distances from CERN, even as far as Pyhäsalmi, 2300 km away.

Whilst the high energy version has attractions the cost and timescale for construction would appear non-competitive when related to ongoing projects elsewhere in the world. (On a foreseen time scale of 6 to 15 years, upgrades of T2K in Japan and a new beam within the framework of Project-X in the USA, will have higher power, larger detectors, longer baselines and higher neutrino energies (1-3 GeV).)

Studies of the possible upgrade of the CNGS beam have also been examined and were discussed at the May workshop. For this to be an effective long term solution the intensity would need to be increased by roughly an order of magnitude, the beam energy for a detector in Gran Sasso should ideally be less than at present and the absence of a near detector station is a weakness.

The low energy Superbeam is being studied in the framework of a EUROnu workpackage, with many issues in common with the Neutrino Factory target study. Alone it is of similar performance as other facilities planned around the world, but it offers a powerful synergy with the baseline $^{6}He/^{18}Ne$ Beta Beam; this synergy between beta beam and Superbeam could be one of the possible strengths of a future program based at CERN. At these low energies the Water Cherenkov constitutes the baseline far detector , however the interactions of low energy neutrinos are imperfectly known or understood and so, in such a scenario, particular attention must be paid to the near detector station for this information.

Superbeams and Beta Beams can be aimed at large liquid underground detectors, which could also be used in the search for proton decay and for astroparticle physics applications. This is being investigated, in particular in the framework of the LAGUNA design study. R&D and test beam studies for such detectors would be greatly helped by a support at CERN.

Question 4

What is the view of the SPC on the merit of a European strategy in this phase of neutrino experimentation and whether it should have a place on the future CERN road map? **UNCHANGED**

No global strategy exists concerning accelerator-based neutrino facilities.

In Europe, in line with the recommendations of the 2006 Strategy for Particle Physics, a number of R&D efforts have been undertaken to understand by 2012 the feasibility of the major options and their cost. Establishing an agreed R&D strategy supported by a medium-term road map and a review process, would be highly desirable. This should include specific aspects for Beta Beam and Neutrino Factory,

CERN, as the European particle physics organisation, should play an important role in the process leading to the definition and implementation of the European strategy with respect to a ν-physics programme. A targeted contribution from CERN on specific aspects related to the development of intense neutrino beams, for which CERN has unique expertise, would provide vital support to the European ν-physics community, allowing it to achieve its goals.

On the 2012/2013 timescale, new experimental results from the neutrino oscillation experiments and from the LHC, as well as the results of the design studies and R&D work, will serve as input to the definition of the long term strategy. Europe should then decide on a plan concerning the production of intense neutrino beams in its Strategy for Particle Physics, and define its contribution in the subsequent road map.

General recommendations

• CERN, as the European particle physics organisation, should play an important role in the process leading to the definition and implementation of the European strategy with respect to a neutrino physics programme. To do so CERN must create stronger links with the European neutrino community.

• Re-establishing neutrino groups in PH and BE departments would, if it is practicable, be a positive step in this direction.
However, the SPC recognizes that the desire to set up such groups has to be balanced against the many other competing demands on CERN's resources.

•The workshop on the European Strategy for Future Neutrino Physics, organized at CERN on October 1-3, was very successful. Regular meetings of this type, organized under the auspices of CERN and ECFA, could help in the integration of the European neutrino community and in increasing the role of CERN in the strategic global planning for neutrino physics.

Recommendations for specific support from CERN to enable strategic decisions

- Costing. Support for providing comparable costing of the superbeam, beta beam and neutrino factory options is needed within the EUROnu/IDS-NF framework. In Europe the expertise required for such a comprehensive work is only available from CERN.

- Radioprotection and general safety issues. The development at CERN of a high power target facility, preferably with international collaboration from other laboratories would be a major asset, not only for the neutrino programme but also for the increasing number of areas where high power proton beams are needed.

- Completing key R&D programmes. For the Beta Beam, it is vital to demonstrate the feasibility of producing sufficient ^{18}Ne. For the Neutrino Factory continued contributions to the MICE experiment are important to demonstrate ionization cooling in a timely fashion for 2012/2013.

- R&D for future neutrino detectors. This has been taking place in Europe for some time and support from CERN, e.g. by supplying test beams, would be highly beneficial.

Long term strategy planning

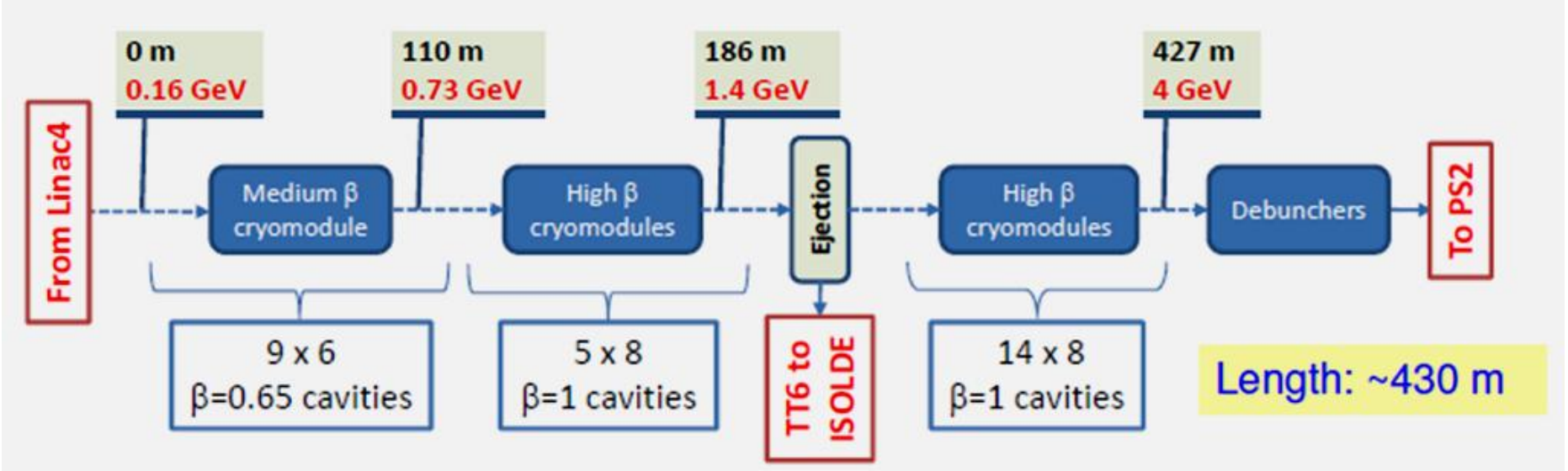
- It is unrealistic to expect to have a high intensity neutrino source of any kind in Europe before early 2020's.

- By this time it is reasonable to expect that there will be many years of operating and upgrading Superbeams in Japan and in the USA. This should be closely followed.

- Thus if Europe is to be competitive in the 2020's it should concentrate on the R&D for a new intense source, i.e. the Neutrino Factory or the Beta Beam. It would be advisable to systematically review the progress and prospects of this work.

Spare transparencies

SPL


0 m
0.16 GeV
110 m
0.73 GeV
186 m
1.4 GeV
427 m
4 GeV
From Linac4
Medium β cryomodule
High β cryomodules
Ejection
High β cryomodules
Debunchers
To PS2
9 x 6
β=0.65 cavities
5 x 8
β=1 cavities
TT6 to ISOLDE
14 x 8
β=1 cavities
Length: ~430 m