Coordinated Neutrino Physics R&D in Europe – Status and Roadmap

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Abstract

EUROnu is a European Commission Framework Programme 7 project undertaking a Design Study of possible future neutrino oscillation facilities for Europe. The three main candidates being studied are a CERN to Fréjus Superbeam, a Neutrino Factory and a Beta Beam. This contribution will introduce EUROnu, outline the contributions it is making to the field and explain how it is contributing to the CERN strategy for future facilities.

1 Introduction

A complete understanding of the implications of neutrino oscillations needs precise measurements of the parameters governing the oscillations. This will require a new high intensity beam-based neutrino oscillation facility in which neutrino beams are generated using new and highly challenging concepts. The EUROnu Design Study will review all three of the currently accepted methods of realizing this facility: the neutrino Superbeams, Beta Beams and Neutrino Factories. It includes a detailed study of the key technical challenges of the accelerator facilities and of the detector options necessary to measure the neutrino oscillation parameters and a comparison of the physics reach of these facilities.

The objectives of the Design Study follow the recommendations of the European Strategy for Particle Physics approved by CERN Council in Lisbon on 14th July 2006 and which is the reference for Particle Physics Research Infrastructures in the ESFRI Roadmap (the neutrino facility being an Emerging Proposal). Further, EUROnu will be a significant step towards solving a problem noted by the OECD: the lack of a formal framework for global collaboration in this area.

In addition to a physics performance evaluation, the design study will also perform a cost, safety and risk assessment. These will be reported to the CERN Council via the CERN Strategy Group secretariat. This will permit the European research authorities to make a timely decision on the lay-out and construction of a future European neutrino oscillation facility.

2 Structure of EUROnu

EUROnu started on 1st September 2008 and will run for 4 years. It consists of 15 partners from 9 countries in Europe, as shown in table 1. In the usual FP7 style, a partner means different things in different countries. Taking into account the cases for which a partner is more than one institute, there are a total of 24 in the consortium. In addition to these, EUROnu has 15 associate partners, from institutes around the world, who have not signed the project Grant Agreement but are nevertheless contributing to work in this area. Limited funds are available in EUROnu to enable members of these institutes to travel to EUROnu meetings.

The work of the Design Study is organized into the 6 work packages (WP) shown in table 2, each with both a coordinator and a deputy coordinator. There are separate WPs for each of the three facilities, plus a WP to look at the performance and cost of the baseline neutrino detectors and another to provide an independent assessment of the physics reach of the facilities and detectors. WP 1 is responsible for the overall management of the project and reporting the outcome to the CERN Council.

A brief description of each of the three facilities is given in the next section. More detail can be found in other contributions to this report. The last section will expand on the international collaboration of EUROnu and role it is taking in the future neutrino strategy at CERN and elsewhere.

Table 1: Partners in the EUROnu consortium

Participant number	Participant name	Country
1	STFC	UK
2	CEA	France
3	CERN	Switzerland
4	University of Glasgow	UK
5	Imperial College	UK
6	CSIC	Spain
7	CNRS	France
8	Cracow University of Technology	Poland
9	University of Durham	UK
10	INFN	Italy
11	MPG	Germany
12	University of Oxford	UK
13	University of Sofia	Bulgaria
14	University of Warwick	UK
15	UCL	Belgium

Table 2: EUROnu Work Packages

WP number	WP name	Coordinator	Deputy
1	Management	R.Edgecock (STFC)	
2	Superbeam	M.Zito (CEA)	C.Densham (STFC)
3	Neutrino Factory	J.Pozimski (Imperial)	M.Martini (CERN)
4	Beta beam	E.Wildner (CERN)	C.Hansen (CERN)
5	Detector performance	P.Soler (Glasgow)	A.Cervera (Valencia)
6	Physics reach	P.Hernandez (Valencia)	A.Donini (Madrid)

3 Facilities being studied in EUROnu

3.1 CERN to Fréjus Superbeam

Superbeam here means a conventional neutrino beam created by the decay of pions, but using a proton driver with a beam power of around 4MW and a Mton water Cherenkov detector or equivalent. The layout of the CERN to Fréjus Superbeam is shown in figure 1. It will use a high power version of the proposed Superconducting Proton Linac (HP-SPL) at CERN to accelerate a 4MW proton beam to 2-5GeV. The proton bunches from the linac will be combined into around 100 bunches of 3μs duration in an accumulator ring and then impinged on to a target. The pions produced will be focussed using a magnetic horn to produce a low energy neutrino beam. This will be directed at the Modane Laboratory in the Fréjus tunnel under the Alps. The baseline detector will be a Mton scale water Cherenkov.

As there are already design reports for the proton driver [1], the work for this facility will focus mainly on the pion production target, the horn focussing system and the integration of these devices together and within the target station. However, the optimum parameters for the proton beam for neutrino oscillation measurements will also be determined from simulation studies.

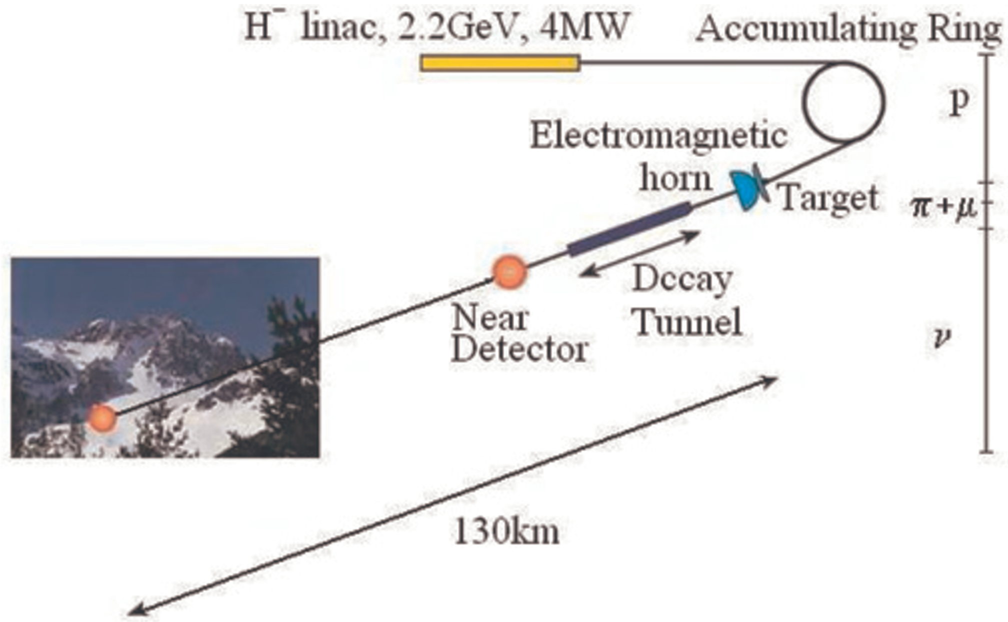

Fig. 1: The layout of the CERN to Fréjus Superbeam

3.2 Neutrino Factory

The baseline layout for the Neutrino Factory, produced by the International Scoping Study [2], is shown in figure 2. In this, a 4MW proton driver in the energy range 5-10GeV impinges a beam onto a high Z target to produce pions. As large a fraction of the pions as possible are focussed by a combined normally and super-conducting solenoid into a decay channel. The muons produced by the decay are transported into the muon front end, where they are bunched, phase rotated to reduce the energy spread and then cooled transversely. They are then accelerated to 22.5GeV by a combination of linear, recirculating linear and FFAG accelerators, before injection into one or more storage rings. The neutrino beams are produced by the muon decays in the straight sections of the storage ring and directed at one or more far neutrino detectors.

All aspects of the Neutrino Factory accelerator complex are well beyond the state of the art. However, the focus in EUROnu is on the target station, the muon front end and the muon acceleration system.

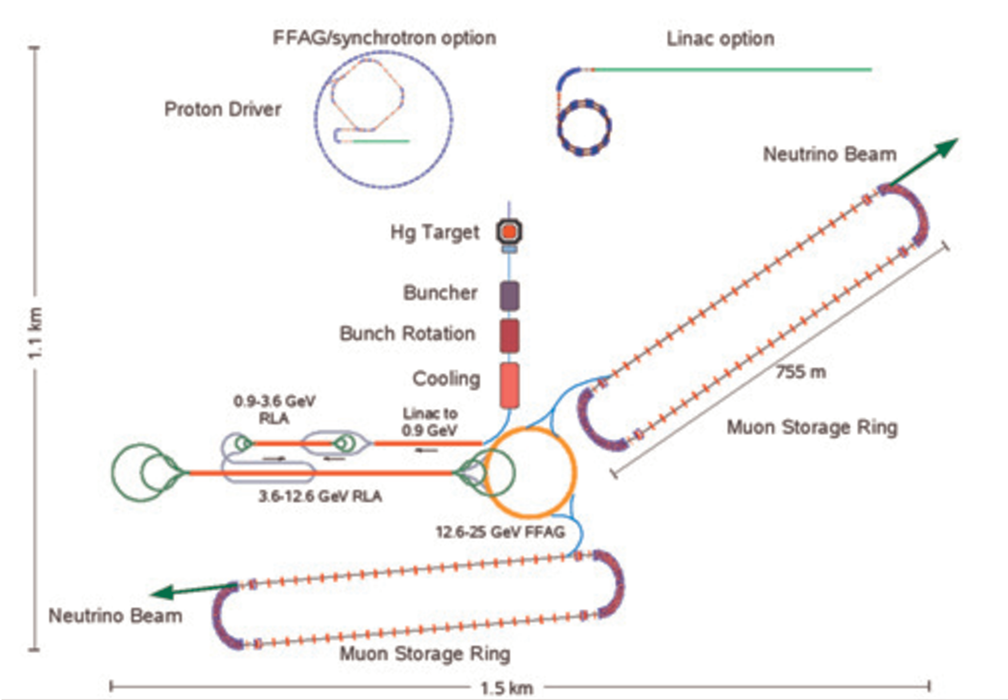

Fig. 2: The layout of the Neutrino Factory from the International Scoping Study.

3.3 Beta Beam

In a Beta Beam, pure beams of electron neutrinos and anti-neutrinos are created by the decay of beta emitting radioactive ions stored in a ring (see figure 3). The baseline version of a Beta Beam has been studied by the FP6 EURISOL Design Study [3] and uses beams of ^{6}He and ^{18}Ne. The problem is, with the standard ion production method, the flux of He achievable is about a factor of 2 smaller than required to meet the physics specifications and the flux of Ne about a factor of 25 too small. While an alternative production method for these ions, direct production [4], is being considered, EUROnu is also investigating another pair of ions, ^{8}Li and ^{8}B, created using an ion production ring.

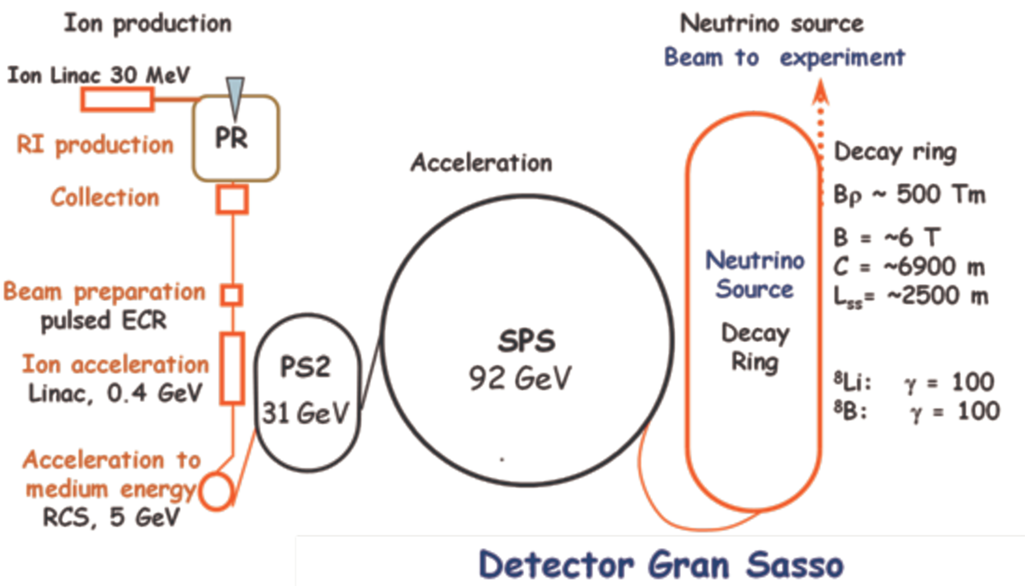

Fig. 3: The version of a Beta Beam employing an ion production ring.

The ion production ring [5], shown in figure 4, employs a gas jet target of either deuterium or ^{3}He and lithium beams to create the required ion species via the reactions

$$^{7}Li(d,p)^{8}Li$$

and

$$^{6}Li(^{3}He,n)^{8}B$$

The ions are passed around the ring and through the target many times to increase the produced ion flux. The energy lost in the target is restored using an RF cavity. With the beam energies used, 20-30MeV, and the gas jet target, it is believed that transverse blow up of the beam will be reduced via ionisation cooling and a sufficient flux of the beta emitters will be created. In addition, these ions have a higher Q-value than the baseline ions and hence will produce higher energy neutrinos.

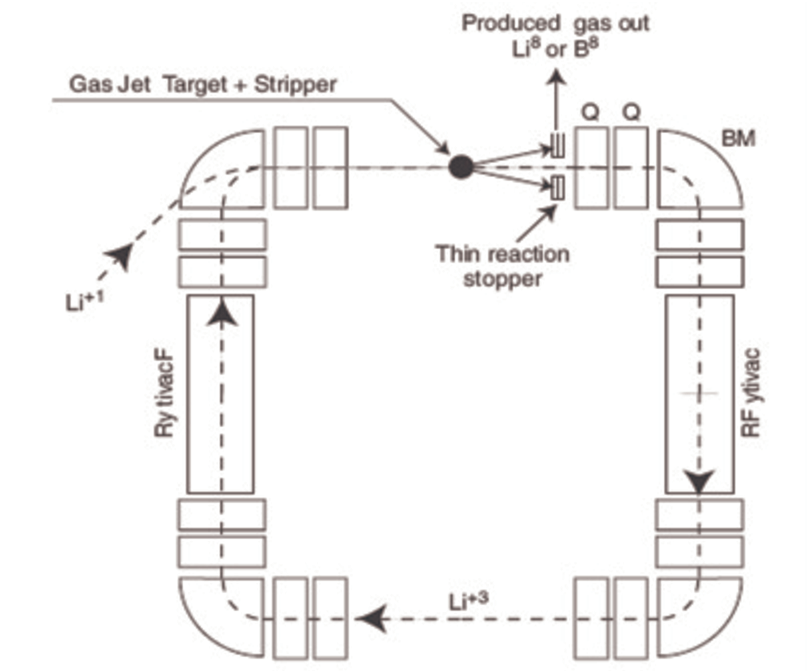

Fig. 4: The Beta Beam ion production ring.

EUROnu is studying, in particular, the direct production method for the baseline ions and these higher Q ions and the beam dynamics, design and performance of the ion ring for the latter. EUROnu will also study the collection and bunching of the higher Q ions and any necessary modifications to the rest of the complex over the baseline design in EURISOL.

4 Role of EUROnu in the future strategy for neutrino facilities

It is clear that EUROnu has a very important role in defining the future strategy for neutrino facilities in Europe and elsewhere. In addition, following a recommendation by the CERN Strategy Secretariat to the CERN Scientific Policy Committee, it has been recognised as part of the CERN Strategy. To this end, it has been the aim of the consortium to collaborate as widely as possible, both inside and outside of Europe, to ensure that any recommendations made represent the views of as wide a community as possible. There are three main manifestations of this:

- The inclusion of many associate partners, from around the world, as described in section 2. Further institutes have expressed an interest in joining the project since the current list of associates was agreed by the EUROnu Governing Board in March 2009.
- The work on the Neutrino Factory is being undertaken in close collaboration with the International Design Study for a Neutrino Factory [6].
- An International Advisory Panel has been created to oversee the work of the Design Study in an international context.

EUROnu will be reporting the results of the Design Study to CERN Council at the end of 2012, as required by the CERN Strategy Group report. It should be noted that the next step after a Design Study, as seen defined by the Research Infrastructures secretariat of the European Commission, is a Construction of New Infrastructure – Preparatory Phase project. It is our hope to be in a position to undertake such a project for a single facility, after the review of our results by Council.

Acknowledgement

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