Letter of Intent: FP6 Design Study for a beta-beam facility

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Introduction

The term beta-beam has been coined for the production of a pure beam of electron neutrinos or their antiparticles through the beta decay of radioactive ions circulating in a storage ring. The neutrino source itself consists of a storage ring for the relevant energy range, with long straight sections in line with the experiment(s). The beta-beam was first proposed by Piero Zucchelli [1] at CERN and is a unique European initiative that has triggered a lot of interest both in the US and in Japan.

The radioactive ion production would only require a fraction of the proton beam delivered by a driver such as the SPL studied for a muon based neutrino factory. Consequently, the beta-beam facility could run in parallel with a Super Beam facility and ultimately, even with a muon-based neutrino factory itself. The stored ions in the decay ring would be kept in short bunches creating a bunched neutrino beam and allowing efficient background suppression in the detector. First estimates show that it should be possible to store two types of ions in the decay ring simultaneously permitting a time separated beam of both electron neutrinos and anti-neutrinos for the experiment(s).

CERN is in a rare position considering the know-how required for the beta-beam with both a long experience of radioactive ion production and a solid expertise in heavy ion acceleration to energies compatible with the beta-beam requirements. The decay ring does not exist at CERN today, nor does a high-intensity proton source for the production of the radioactive ions. Nevertheless, the existing CERN accelerator infrastructure would represent an important saving for the facility. The financially strained situation due to CERN's heavy undertaking to build LHC for the future of high energy collider physics, has so far prevented any major design work at CERN beyond a first feasibility study [2].

A first workshop on the beta-beam concept [3] was held in March 2003 and the embryo for European wide collaboration to develop this exciting concept was formed. This collaboration has asked for network money from the EU within the BENE proposal and the announced design studies within the 6th FP look ideal for finding the necessary extra resources to advance to a Technical Design Report (TDR) for a beta-beam facility.

Physics reach

The beta-beam concept was initially proposed as an intermediate step for neutrino physics while waiting for a full-scale muon based neutrino factory. It was considered essential that the facility was based on existing technology with moderate extrapolations so that it could be built without any major and time consuming R&D work. The study of the physics reach of a facility with radioactive ions accelerated to a Lorentz gamma as high as150, combined with a Super Beam, has shown that the beta-beam can successfully address CP violation for values of the mixing angle θ_{13} as small as 1 degree [4]. In conjunction with the Super-beam, the beta-beam would also allow for tests on T and CPT in the neutrino sector. Furthermore, with some improvements in target and ion source yields, the beta-beam sensitivities would become comparable to those of a muon based neutrino factory.

The detector suitable for a beta-beam is a water Cerenkov detector installed in the underground Frejus laboratory. This is a megaton detector like UNO [5] originally designed for proton decay studies and supernovae explosion observations. The important point we want to make is that such a detector is a multipurpose observatory which will address several fundamental physics issues besides neutrino oscillations.

Synergies

The beta-beam facility is fully compatible with a EURISOL facility and they could run in parallel with each other. The relevant ion production and the acceleration of the ions to 100 MeV/u have already been investigated within the 5th FP by the EURISOL study [6]. This study is likely to continue as a design study within the 6th FP. The approved major upgrade of the GSI facility [7] includes proposals for storage rings similar to the one required for the beta-beam and it is likely that major synergies will be found in the R&D for many accelerator issues. Discussions with the nuclear physics community within EURISOL and at GSI have shown that there is major interest in collaboration. In particular, the idea to carry out nuclear structure research with the neutrino beams [8] available at a beta-beam facility has evoked a lot of interest within this community. The neutrino beams required for nuclear structure research would not necessarily have to be as energetic as the beams required for the full-scale beta-beam project, a fact that opens up possibilities for a low energy facility at GSI and at GANIL (SPIRAL [9]) for example.

Outline of the design study

The design study could start with Technical Preparatory Work (TPW) on several issues, such as the required ECR ion source and the target design. Plans are already in progress at LPSC in Grenoble for R&D on the ECR source. A full-scale target module could be tested at an early stage at ISOLDE at CERN and at ISAC in Vancouver, at CERN with nominal beam energies and at ISAC with the full beam power. A feasibility study for improved target stations, the superconducting dipoles and the overall acceleration chain is needed, but that would at a later stage result in TPW proposals. The design study could deliver an intermediate Technical Design Report (TDR) based on existing technology, with a final design report integrating the progress made during the study itself.

Funding

The above-mentioned synergies with the design studies for future nuclear physics facilities will mean considerable savings concerning manpower and management. We envisage that the design study would require of the order of half (5 MEur) the maximum sum available for individual design studies in the 6th FP.

Management

The unique position of CERN having a suitable infrastructure of existing accelerators and being at the right distance from the proposed underground detector in Frejus would suggest that CERN be the hosting laboratory for the study. However, the design study could be hosted at another laboratory with the relevant know-how. Many of the existing laboratories for nuclear physics in Europe have expressed interest to participate. An important contribution could come from LPSC Grenoble with their unique expertise in ECR technology. Many of the physicists and engineers participating in the BENE beta-beam work packages have expressed interest to also work on a possible design study. In fact, the BENE network is the ideal information backbone for the design study as, if financed, it would provide a sequence of meetings and reports that should assure good information exchange between the collaborators and the evident channel to publish the results.

Conclusions

We believe that all concepts proposed for the production of intense neutrino beams need to be fully explored to permit the neutrino physics community to take the right decision for the future of the subject. The best comparison can only be made once TDRs, with a full description of the physics potential, exist for the proposed alternatives. The right umbrella organisations for the work are in our view ESGARD and EMCOG. The first issue to be dealt with is evidently the question of how to organise the different proposals for design studies and the possible synergies with other communities, in particular the nuclear physics community. We are convinced that the physics case for the beta-beam option is solid and exciting. There is today a group of physicists and engineers willing to work on a beta-beam design study, provided the right form can be found for this work.

References

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