The Beta-beam within EURISOL DS

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1. Introduction

The Beta-beam concept for the generation of an electron (anti-)neutrino beam was proposed in 2002 [1]. A first study [2,3] was made in 2002 exploring the possible use of existing CERN machines for the acceleration of radioactive ions to a relativistic gamma of roughly 100 for storage in a new decay ring of approximately the size of SPS. The results from this first short study were very encouraging, but as no resources could be allocated at CERN for this work, it was not continued.

In 2004 it was decided to incorporate a design study for the beta-beam within the EURISOL DS proposal. EURISOL [4] is a project name for a next-generation radioactive beam facility based on the isotope separation online method [5] for the production of intense radioactive beams for nuclear physics, astrophysics and other applications. The study is aimed at producing feasibility studies and performing technical preparatory work of the most critical parts of the future EURISOL facility. The main technical challenges and the necessary prototyping were identified during the EURISOL RTD in the 5th European framework programme [6]. This design study is part of the roadmap towards the EURISOL facility and cross-fertilization is expected between the design study and the design and construction of the so-called "mid-term" facilities. There are three possible sites identified for construction of the facility: an existing national lab, an intergovernmental lab like CERN to enable sharing of expensive infrastructure such as the driver and a green-field site in a less favored region within the European Union with support for the construction from EU structural funds. The design study officially started 1 February 2005 and will run for four years.

2. First study

The first study for a beta-beam facility (see figure 1) was made within a few months with limited manpower. The main objectives were twofold: i) to identify a possible scenario for bunching, acceleration and storage in a few very short bunches (low “duty factor”) sufficient radioactive ions for the Beta-beam; and ii) to identify possible bottlenecks in the proposed scheme.

The study proposed to use a thick ISOL target for the production of ^{6}He and ^{18}Ne as both isotopes can be produced in large quantities and are easy to handle. Neither isotope has any long-lived daughter products that could create a problem in the low-energy part of the facility. Several iterations were required for the “bunching”, but eventually a high frequency (60 GHz) ECR source was identified as a possible highly efficient tool to create sufficiently short bunches after the target for multi-turn injection into a synchrotron.

For the first stage of acceleration, it was proposed to use a 100 Mev/u linac. Further acceleration was to be done with a new rapid cycling synchrotron (RCS), the PS and finally the SPS. A new injection and stacking method was proposed to keep the duty factor in the decay ring low. The method makes use of off-momentum injection into the decay ring to approach the circulating beam without requiring ultra-fast injection elements, rotation in the longitudinal plane to bring the fresh bunches onto the central orbit and asymmetric merging to take them into the centre of the stack [7,8]. The maximum gamma that can be reached in the SPS was initially chosen for the coasting beam in the decay ring, but, taking physics reach considerations into account, it was later revised to 100 for both ion species.

The main bottlenecks in the scenario chosen in the first study were shown to be the space charge tune shifts at PS and SPS injection and the activation of the PS ring.

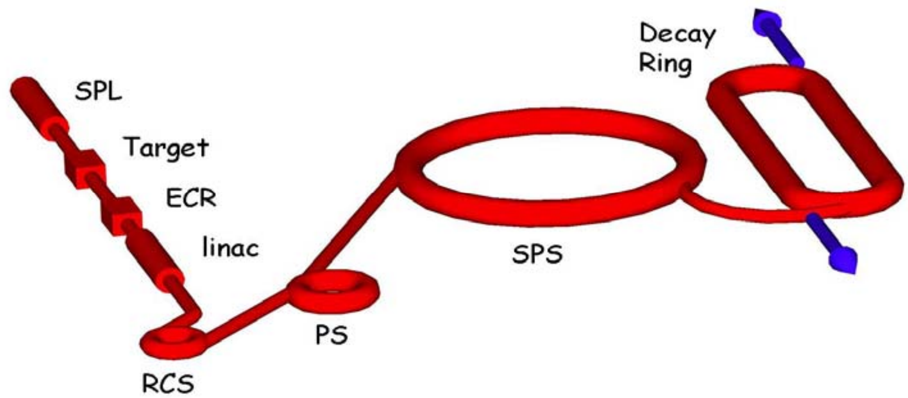

Figure 1: CERN conceptual design

3. The Beta-beam task within EURISOL

The Beta-beam task has six participating institutes and will receive close to 1 M€ over four years from the EU. Together with the contributions from the participating institutes, a total of almost 35 man-years are available for the study. The group maintains a Web site [9] with a parameter list of the EURISOL Beta-beam facility.

The facility is based on the first CERN study, with the decay ring at CERN and a megaton water Cerenkov detector at a much-extended Frejus underground laboratory [10] 130 km from CERN. A maximum of the existing CERN accelerator infrastructure is re-used, limiting the top gamma of the radioactive ions to 150 for ^{6}He and 250 for ^{18}Ne. The predicted production rate of radioactive ions is taken from the EURISOL RTD [6] and no special attempt has been made to refine and optimize a specific Beta-beam isotope production scheme.

The first revised version of the design is close to deliver the target values set by the International Scoping Study (ISS) [11] for anti-neutrinos but there is still some way to go for neutrinos. Recent progress on accumulation at low energy of radioactive ions [12] and new production methods, combined with a relaxed constraint on the decay ring duty factor puts the ISS request within reach.

4. Conclusions

The conceptual design of a beta-beam facility has taken a step further with the start of the Beta-beam task within the EURISOL design study. The first objective is to establish the annual rate of (anti-)neutrinos for a given source rate [2] using PS and

SPS for acceleration [13]. The next step, which has already started, is to optimize the machine parameters to establish the maximum achievable rate. The work done so far shows that: i) an increase at the source translates linearly into an increase of the annual rate; ii) an increase of the duty factor permits more particles to be accelerated and stored in the decay ring; iii) accumulation can potentially be a powerful tool to make better use of the ions produced; and iv) good progress is being made towards the ISS target values for the (anti-)neutrino rate.

Recently, a monochromatic beta-beam from nuclei decaying by electron capture has been proposed [14]. However, the study of such an option or even a green-field study to establish the ultimate limit of the "classical" beta-beam concept is beyond the scope of the current work. Nevertheless, it is desirable that all options are fully explored before a final decision is taken on the next generation of neutrino sources.

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