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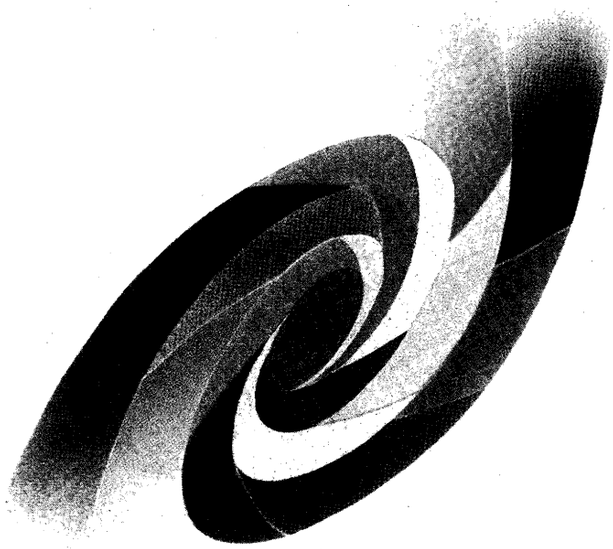

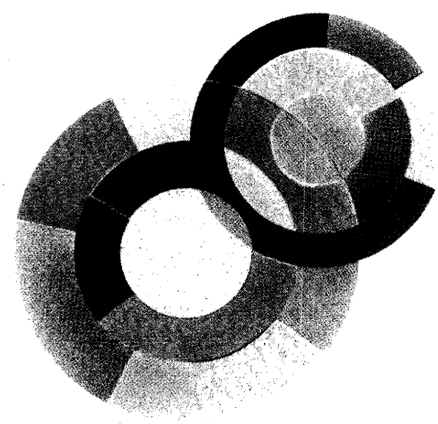

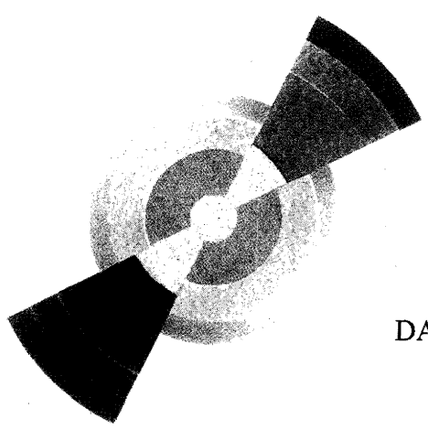

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Beta-beams from CERN to the Fréjus site

L. Mosca

Talk given at the 8th International Workshop on Topics in Astroparticle and Underground Physics (TAUP-2003), Seattle (U.S.A.), September 05-09, 2003

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Beta-beams from CERN to the Fréjus site

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Abstract

The Beta-beam concept, a beautiful and fruitful idea proposed by Piero Zucchelli and actively developed at CERN, is based on the production of very intense ν_e and anti-ν_e beams from the decay of relativistic radioactive ions. The recent progresses of this approach are emphasized. The expected performances for the determination of the neutrino mixing matrix parameters θ_{13} and the CP violating phase δ, by using as a detector a megaton water Cerenkov installed in the Fréjus underground site, are excellent, especially if the Beta-beam will be coupled with a ν_μ(anti-ν_μ) Super-beam.

1. PHYSICS MOTIVATIONS

In the Neutrino Mixing Matrix two elements remain unknown : the mixing angle θ_{13} and the CP-violating phase δ . We only know, from the Chooz experiment, that θ_{13} is smaller than 10 degrees. Both these parameters govern the ν_μ - ν_e oscillation at the atmospheric frequency ($\Delta m_{23}^2 \approx 2.5\ 10^{-3}$ eV^2). So the best way to measure θ_{13} and δ is to study the ν_μ - ν_e oscillation around their first maximum. For that two solutions have been successively considered as discussed below.

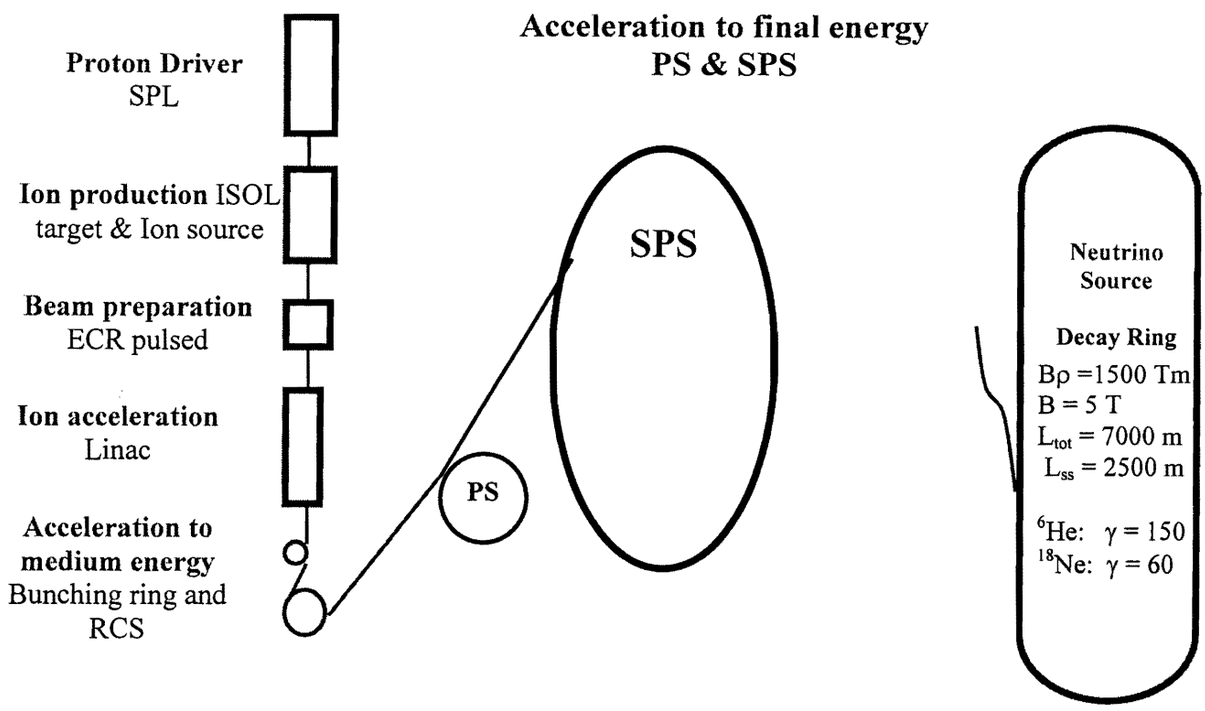
2. THE ENVISAGED NEUTRINO BEAM STRATEGIES

a) **the Super-beam solution** : The first stage of the project of a Neutrino-Factory at CERN is the the Superconducting Proton Linac (SPL) installation, driving a very intense proton beam (2 mA) of 2.2 GeV, that is with a power of 4 MW, on the target. Without waiting for the realization of the full Neutrino-Factory complex, this stage is sufficient to provide a very intense ν_μ(anti-ν_μ) beam with a typical energy of 270 MeV, for which the first maximum of the ν_μ - ν_e oscillation is at about 130 km : precisely the distance of the Fréjus site from CERN ! A water Cerenkov of total mass around 1 megaton would provide a sensitivity down to about 2 degrees for θ_{13} and the possibility to detect a maximum CP violation in the neutrino sector.

b) **the (additional) Beta-beam solution** : to do better, a new approach has been proposed by Piero Zucchelli (hep-ex/0107006 and Phys.Lett.B532(2002) 166), and then developed at CERN, consisting in the production of very intense ν_e and anti-ν_e beams from the decay of relativistic radioactive ions. Three remarkable advantages characterise this new approach : 1) a strongly focussed neutrino beam due to small Q value of beta decays, 2) a very pure flavour composition

of the beam (ν_μ contamination ~ 10^{-4}), and 3) a perfectly known neutrino energy spectrum.

A schematic layout of the Beta-beam complex is presented below: about 100 μA (only 5%) of the proton intensity from the SPL are used to produce the needed radioactive ions (^{18}Ne for ν_e and ^{6}He for anti-ν_e) with the ISOL technique, as proposed in the future EURISOL project. Then the ions are collected, fully ionised and bunched (ECR technique), pre-accelerated in a Linac, accelerated at a medium energy (300 MeV/u) and then injected in the PS+SPS already existing complex for the final acceleration at a $\Gamma \approx$ 100, before reaching the decay ring of 7 km total length and straight sections of 2.5 km, aimed at a far detector.



This baseline scenario is being studied at CERN, by Mats Lindroos and collaborators, where five new important developments have been recently performed which remarkably increase its feasibility potential :

1) pulsed ECR (Electron Cyclotron Resonance) source, which should produce very short ions bunches, allowing a multiple cycles injection in the storage-decay ring with a consequent simplification of the downstream design. (P. Sortais - Grenoble)

2) an asymmetric bunch pair merging, successfully tested in the PS (also useful for the LHC machine), and allowing a greater beam intensity by a much more efficient ions bunches injection efficiency (Benedikt, Steven Hancock and Mats Lindroos : CERN, AB Division)

3) the possibility to store at the same time ^{18}Ne and ^{6}He ions in the decay ring, which is favourable to minimize systematic effects.

4) the possibility of multi-target in ISOLDE to compensate the smaller cross section of anti-neutrinos

5) a simulation of beam losses in the

Beta-beam decay ring showing that the situation can be handled from the radio-protection point of view (Matteo Magistris, Marco Silari and Thomas Otto of CERN).

For a recent status report on the Beta-beams, see the paper :"Beta-Beams: present design and expected performances" by Jacques Bouchez, Mats Lindroos and Mauro Mezzetto, and references therein (hep-ex/0310059 30 Oct 2003).

3. PHYSICS REACH

With a UNO-like Megaton Water Cerenkov detector installed in a new Fréjus Large Underground Laboratory and 10 years running of both Super-beam and Beta beam, that is :

- 2 years of ν_μ
- 8 years of anti-ν_μ
- 10 years of ν_e
- 10 years of anti-ν_e

it would be possible to reach a sensitivity better than 1 degree for the mixing angle θ_{13} and a very competitive possibility to investigate not only the CP violation in the neutrino sector, but also the T and CPT invariance.

Moreover, the same detector would allow to address several other fundamental issues in the non-accelerator sector such as : proton decay and neutrinos from natural sources : solar, atmospheric and Supernovae neutrinos (See also my other talk: "A European Megaton Project at Fréjus" in the Nucleon Decay parallel session of this Conference).

4. CONCLUSIONS and OUTLOOK

- Beta-beams are a splendid tool to study neutrino oscillations
- Together with Super-beams, they allow to measure the mixing angle θ_{13} and the CP-violating phase δ, with a sensitivity approaching that of a Neutrino Factory
- The possibility to install in the Fréjus site a megaton detector receiving a Super-beam and a Beta-beam offers to Europe and CERN a unique opportunity of a golden fundamental physics reach.
- Moriond (March 2003) workshop has brought together two communities interested in intense radioactive beams : EURISOL and neutrino physicists.
- These two communities have agreed to coordinate their efforts on the necessary R&D.
- Moreover it has become clear at the Moriond workshop that low energy Beta-beams could also address very important issues for nuclear physics research.