Beta-Beams from the HERA facility @ DESY ?

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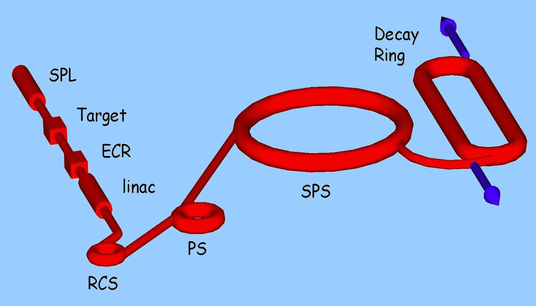
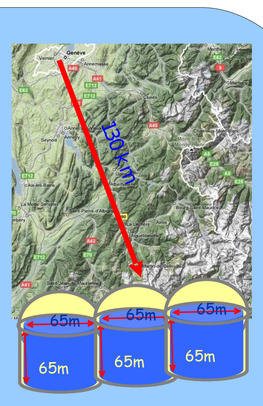
Beta-Beam

$^{6}He \rightarrow \beta^{-} \rightarrow \upsilon_e$
$t_{½} = 807$ ms
$Q = 3.5$ MeV

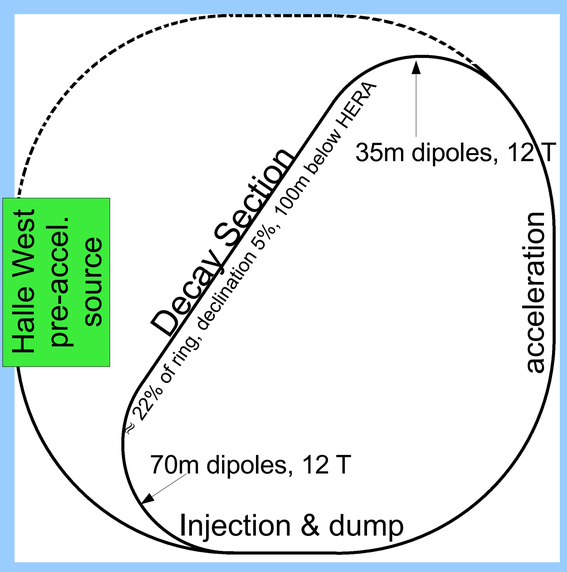
$^{18}Ne \rightarrow \beta^{+} \rightarrow \upsilon_e$
$t_{½} = 1.7$ s
$Q = 3.4$ MeV



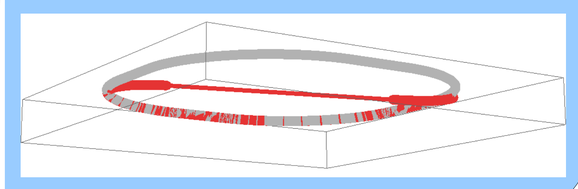


Conceptual Layout of the Beta-Beam facility studied within the EU design study EURISOL. The facility is located at CERN. It uses existing accelerators where ever possible. The neutrinos stem from the decay of He-6 and Li-8 ions in the decaz ring. The ions source was part of the EURISOL project. The neutrino beam is directed a detector in the Frejus laboratory 130 km away from CERN.

Beta-Beam @ HERA

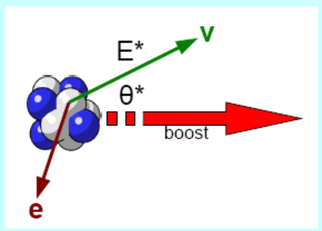


- simple source based on 40 MeV deuteron beam (see separate poster)
- linac and/or RCS to β=0.8 (4.7 GeV)
- build RCL from HERA arcs, 2 ¼ turns to 110 GeV injection energy
- decay ring partially in the HERA tunnel. Sharp turns into a new decay section.



Kinematics

$$E_{lab} = \gamma \; E^{*}$$
$$\theta_{lab} = \frac{1}{\gamma} \; \frac{sin\,\theta^{*}}{1 + cos\,\theta^{*}}$$



Assume:
- fixed number of useful decays
- detector @ optimal distance

Event rate depends on γ

Opening angle $\sim 1/\gamma \Rightarrow$ flux at fixed distance $\sim \gamma^2$
$E_{lab} \sim \gamma \Rightarrow$ optimal baseline $\sim \gamma \Rightarrow$ flux at detector $\sim 1/\gamma^2$
$E_{lab} \sim \gamma \Rightarrow$ cross section $\sim \gamma \Rightarrow$ event rate $\sim \gamma$

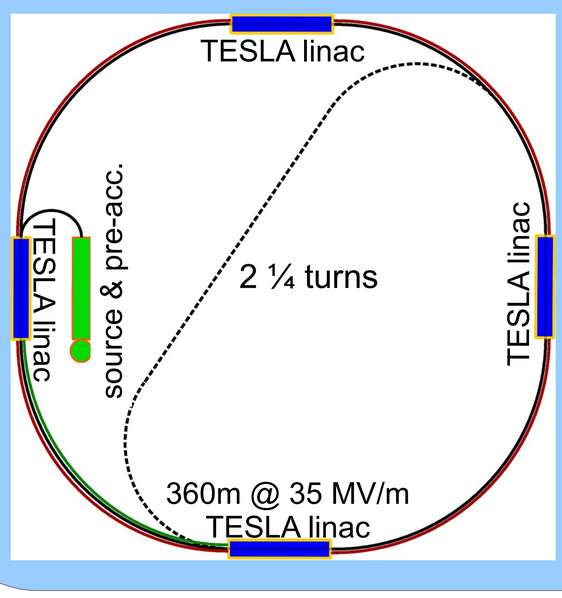
} $\sim \gamma$

Event rate depends on E^{*}

Opening angle independent of E^{*}
$E_{lab} \sim E^{*} \Rightarrow$ optimal baseline $\sim E^{*} \Rightarrow$ flux at detector $\sim 1/E^{*2}$
$E_{lab} \sim E^{*} \Rightarrow$ cross section $\sim E^{*} \Rightarrow$ event rate $\sim E^{*}$

} $\sim 1/E^{*}$

HERA as Recycling Linac



energies
pre-accel. to 4.7 GeV
14 GeV
26 GeV
38 GeV
50 GeV
62 GeV
74 GeV
86 GeV
98 GeV
110 GeV
transfer to decay ring
ramp @ 0,5 T/s to 1,4 TeV

HERA e-arcs
1 new arc
HERA p-arcs

Neutrino Oscillations

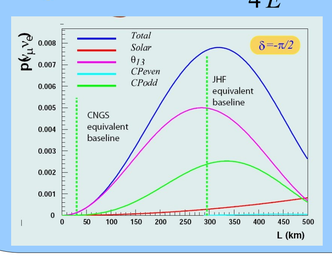
$$P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e) = 4 c_{13}^2 s_{13}^2 s_{23}^2 sin^2 \frac{\Delta m_{13}^2 L}{4E} \times \left(1 \pm \frac{2a}{\Delta m_{13}^2}\left(1 - 2 s_{13}^2\right)\right)$$ θ_{13} driven

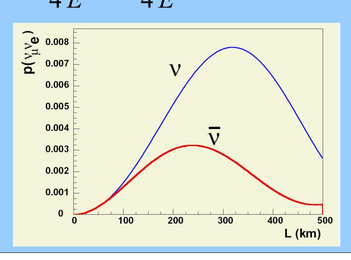
$$+ \; 8 c_{13}^2 s_{12} s_{13} s_{23} \left(c_{12} c_{23} cos\,\delta - s_{12} s_{13} s_{23}\right) cos \frac{\Delta m_{23}^2 L}{4E} \; sin \frac{\Delta m_{13}^2 L}{4E} \; sin \frac{\Delta m_{12}^2 L}{4E}$$ CP even

$$\mp \; 8 c_{13}^2 c_{12} c_{23} s_{12} s_{13} s_{23} sin\,\delta \; sin \frac{\Delta m_{23}^2 L}{4E} \; sin \frac{\Delta m_{13}^2 L}{4E} \; sin \frac{\Delta m_{12}^2 L}{4E}$$ CP odd

$$+ \; 4 s_{12}^2 c_{13}^2 \left(c_{13}^2 c_{23}^2 + s_{12}^2 s_{23}^2 s_{13}^2 - 2 c_{12} c_{23} s_{12} s_{23} s_{13} cos\,\delta\right) sin \frac{\Delta m_{12}^2 L}{4E}$$ solar driven

$$\mp \; 8 c_{12}^2 s_{13}^2 s_{23}^2 \; cos \frac{\Delta m_{23}^2 L}{4E} \; sin \frac{\Delta m_{13}^2 L}{4E} \times \frac{a L}{4E} \; \left(1 - 2 s_{13}^2\right)$$ matter effect





⇒ **need two baselines to distinguish matter and genuine CP effect**
⇒ **need ν_e and ν_μ to test CP, T, and CPT**

Challenges

- RF Power for RCL

  High bunch charge, very short bunch spacing ⇒ very high peak-RF
  Use RF energy stored in cavities for short bunch trains
  ⇒ beam-dynamics in the arcs?

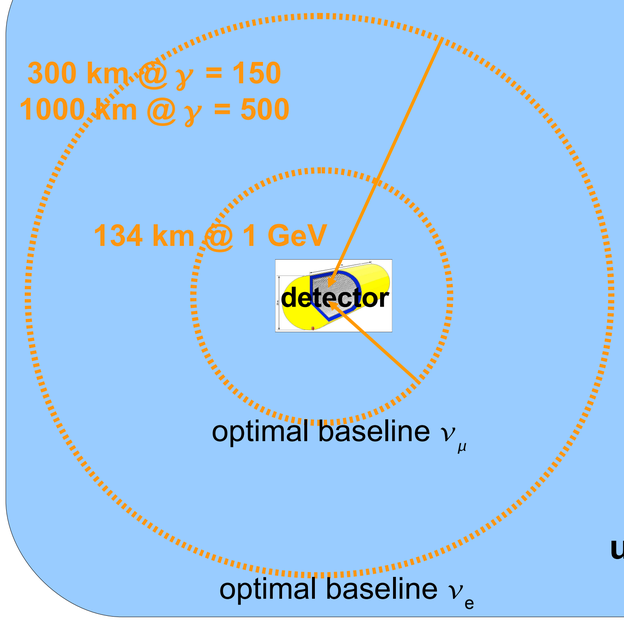
- Ion Source

  Need to accelerate ≈ 4 10^{11} ions/s (half of CERN goal because of higher γ)
  EURISOL concept too big for DESY, use deuteron-beam or production ring.

- 12 T Dipoles for Decay Ring

  Need high-field dipoles to bend beam into decay section.
  8T → decay length 850 m, 10T →1100 m, 12T → 1250 m

Why HERA?



can afford only 1 detector !

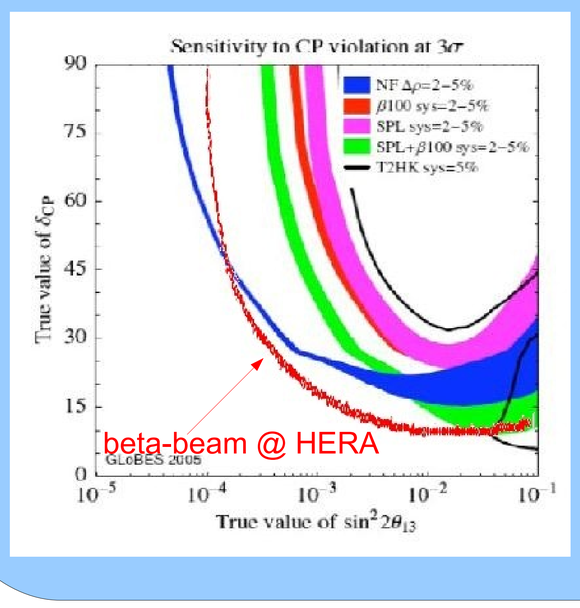
conventional ν_μ beam
from CERN SPL
L_{opt} = 134 km

beta-beam ν_e
from HERA @ DESY
$\gamma_{max} \approx 500$

CERN ↔ Frejus: 130 km
DESY ↔ Frejus: 960 km

use existing accelerator @ DESY ?

Physics Potential



Globes simulation shows statistical power to discover CP-violation as good as υ-factory (no systematics studied, yet)

precision measurement of θ_{13}

determination of mass hierarchy