CONVENTIONAL NEUTRINO BEAMS & SUPERBEAMS

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DHEP

Plan of Talk

- A short animation film
- Neutrino Beam-a little analysis
- Classification and characteristics
- Super beams
- Experiments
- References

NEUTRINO BEAM PRODUCTION

CERN neutrinos to Gran Sasso (LBL expt.):

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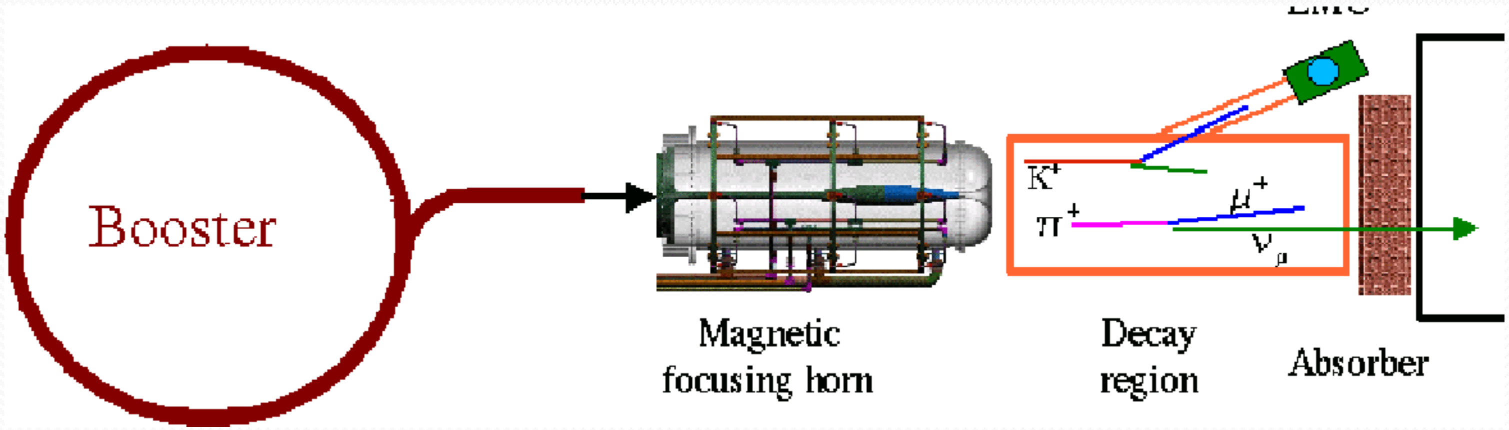
Accelerator-Based Neutrinos



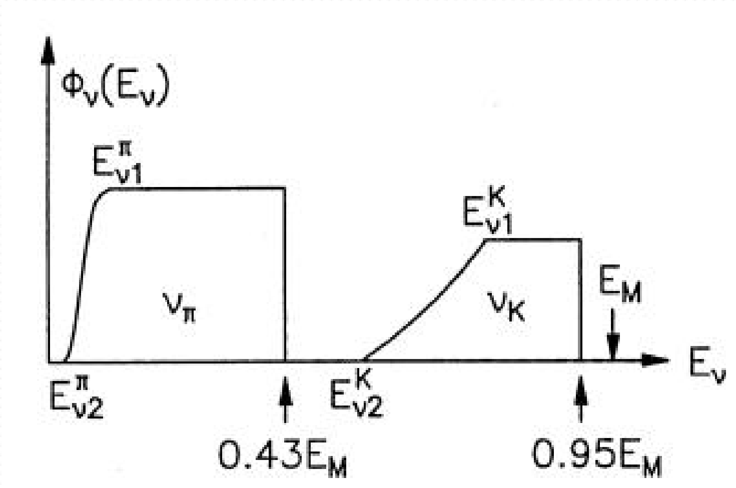
- Beam of protons + a target material = mesons (π, K)
- Mesons decay into the neutrino beam seen by a detector
  - $K^+ / \pi^+ \rightarrow \mu^+ + \nu_\mu$
    - $\mu^+ \rightarrow e^+ + \nu_\mu + \nu_e$
    - $K^+ \rightarrow \pi^0 + e^+ + \nu_e$; $K^- \rightarrow \pi^0 + e^- +$ anti-ν_e
  - Create neutrinos via meson <u>Decay at Rest</u>, <u>Decay in Flight</u>

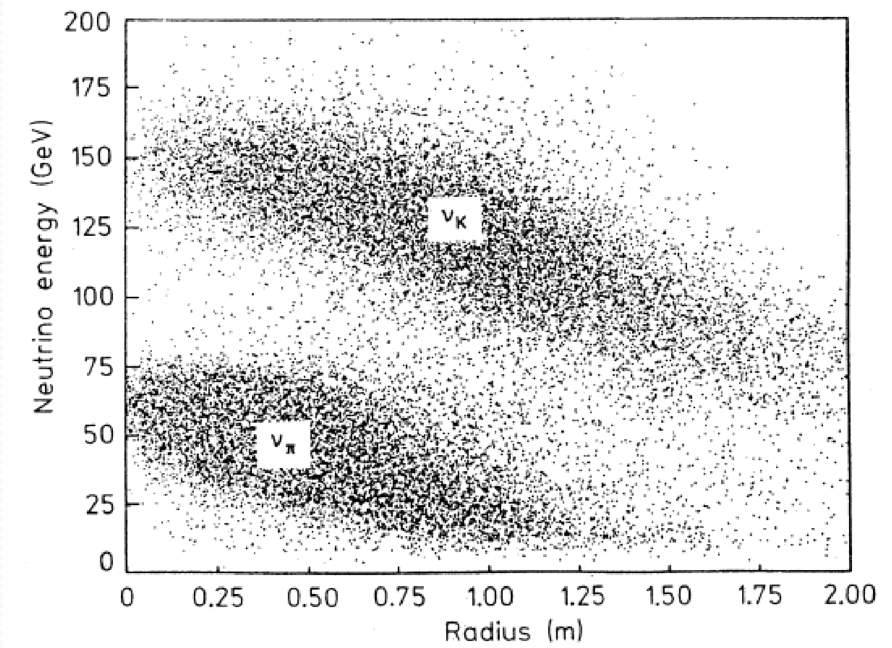
The Process

- A proton synchrotron impinges bunches of high energy protons on fixed target.
- Secondary mesons (π,K) generated.
- Mesons selected by focusing devices are channeled through decay tunnel.
- Within decay tunnel: $M^+ = \mu^+ \nu_\mu$
- Survived mesons and ‘μ’s are absorbed. The collimated ν beam aims at the experiment.

Narrow Band Beam (NBB)

- Momentum selected (π,K)s enter decay tunnel parallel.
- E_ν is related to r & L as $\theta_\nu = r/L$.
- ν beam shows dichroism.
- Flat ν_μ spectrum.
- Small intensity.
- Less ν_e contamination & NC background.





Wide Band Spectrum(WBB)

- Focusing device is a horn-like conductor pulsed with high current.
- Concentric circular magnetic field focuses particles to the beam axis.
- Calculation of $\phi(E_\nu)$ and E_ν cannot be done analytically and is simulated.
- Higher intensity and more ν_e contamination.

Beam of ν_τ

- Necessary for DONUT experiment in FNAL.
- Produced by stopping 800 GeV proton beam completely by Tungsten target.
- N-p interaction produces charmed heavy D_s meson which decay as $D_s \to \tau \, \bar{\nu}_\tau$ and $\tau \, N \to \nu_\tau \, X$
- The goal: to detect ν_τ CC reaction: $\nu_\tau \, N \to \tau^- \, X$

SUPER BEAMS

- So far: ν_μ disappearance(K2K/MINOS) or ν_τ appearance(OPERA) measurements with conventional beams.
- Idea: reduce ν_e component!
- Proposal: low energy, high intensity neutrino beams; this requires high power (2-5 MW)proton accelerator delivering more intense beam of protons on target.

T2K(Tohai to Kamioka)

- Aims to determine $\nu_\mu \rightarrow \nu_e$ oscillation (appearance experiment).
- JHF: J-PARK proton synchrotron (working @ 0.75 MW) delivers 50 GeV protons on target.
- The ν beam illuminates Super Kamiokande detector at a baseline L~295 km.
- Off-axis angle can be varied (2^0-3^0) to maximum sensitivity to θ_{13}.
- Upgraded version: T2HK (4 MW proton accelerator) and Hyper Kamiokande (1 Mton detector) may also give information about Dirac phase δ.

SPL(Super conducting Proton Linac) CERN

- 2.2 GeV intense proton beam on Hg target.
- Intense ν beam ($\phi \sim 10^{11}\ \nu_\mu/yr/m^2$) with energy E_ν=0.27 GeV.
- Detector at Modane lab in Frejus (L~130km).
- ν_e contamination from kaons suppressed to ~0.4%.
- Future Upgrade: increasing SPL energy to 3.5 GeV, ϕ_ν can be increased three-fold (more efficient focusing of secondary mesons).

NOνA (Fermilab)

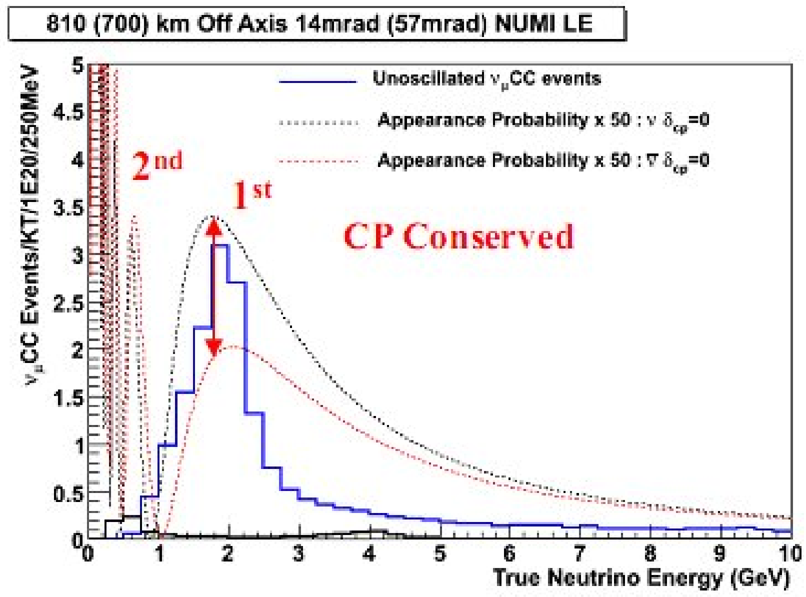
- Aims at appearance of ν_e from ν_μ through oscillation.
- 6.5×10^{20} pot/yr with (120 MeV/c momentum) on NuMI target.
- NuMI off-axis beam with E_ν=2 GeV and ν_e contamination < 0.5%.
- Near and Far end Liquid Scintillation detector.
- Baseline L=810 km with detector sited 12 km off-axis (14 mrad).
- Will achieve sensitivity to $\sin^2\theta_{13}$ comparable to that by T2K.

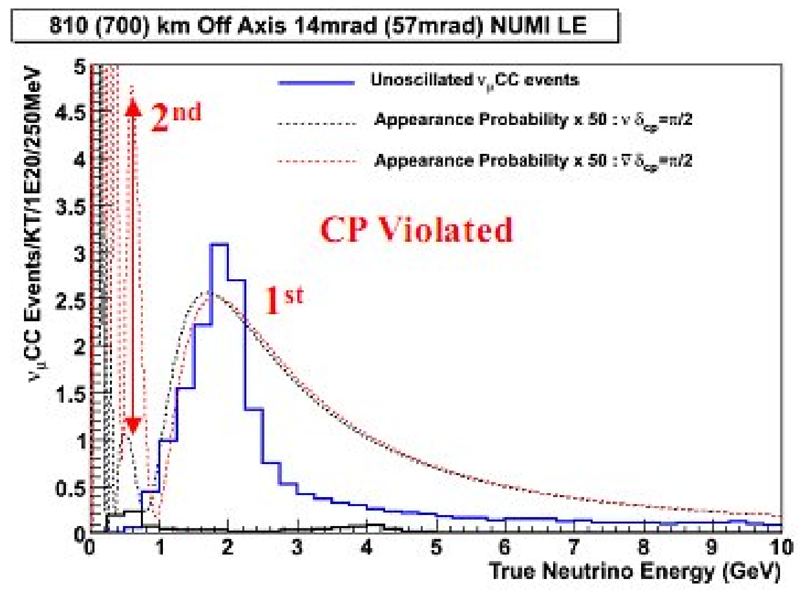
Physics with Superbeams

- Reconstructing interesting physics from type and number of neutrino interaction;E and L.
- 1st oscillation maximum exhibits a difference between neutrino-antineutrino oscillation probabilities due to matter effects, even when CP is conserved (fake CP violation).
- The 2nd oscillation maximum exhibits difference in neutrino antineutrino oscillation probabilities only when CP is violated(matter effects do not play a significant role).
- Study of 2nd maximum gives information about Dirac phase δ and mass hierarchy.

NUMI OFF-AXIS NBB

- Black dotted line: neutrino
- Red dotted line: anti-neutrino





References

- Neutrino Physics by Kai Zuber
- An Off-axis Neutrino beam-Kirt Mcdonald
- Future Possibilities with Fermilab Neutrino Beams-Niki Saoulidou
- Neutrino Factory and Super beam Facility-ISS Physics working group.