Proposal for a Fermilab-Beijing Long Baseline Neutrino Experiment

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Introduction

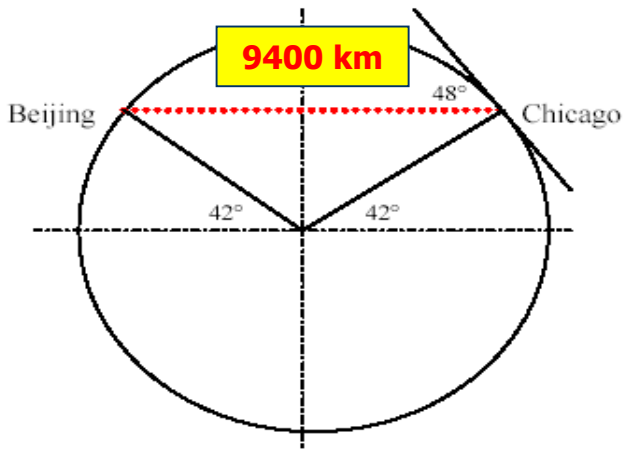
- The Institute for High Energy Physics (IHEP) in Beijing is the major HEP laboratory in China. It is the site of the Beijing Electron-Positron Collider (BEPC).
- There have been discussions between the IHEP and KEK for a long baseline between JPARC/Tokai and Beijing (~2100 km). The IHEP is considering to build a large underground detector to receive neutrino beams from JPARC (a 0.75 MW, 50 GeV proton source).
- At an ICFA meeting last February in Paris, Prof. Chen, Director of the IHEP, expressed interest in a long baseline neutrino experiment between Fermilab and Beijing (~9400 km). The Beijing detector could also receive neutrino beams from the Fermilab Proton Driver (a 2 MW, 120 GeV proton source).
- A group of physicists have started to investigate this possibility. It seems there are good reasons to pursue this "9400 km + 2100 km" 2-baseline option.

JPARC/Tokai–Beijing Long Baseline

Fermilab–Beijing Long Baseline

Fermilab Proton Driver: 120 GeV protons (2 MW) → ν to Beijing

	Latitude	Longitude
Chicago	41:50:13 N	87:41:06 W
Beijing	39:55:00 N	116:23:00 E
Tokyo	35:41:00 N	139:44:00 E

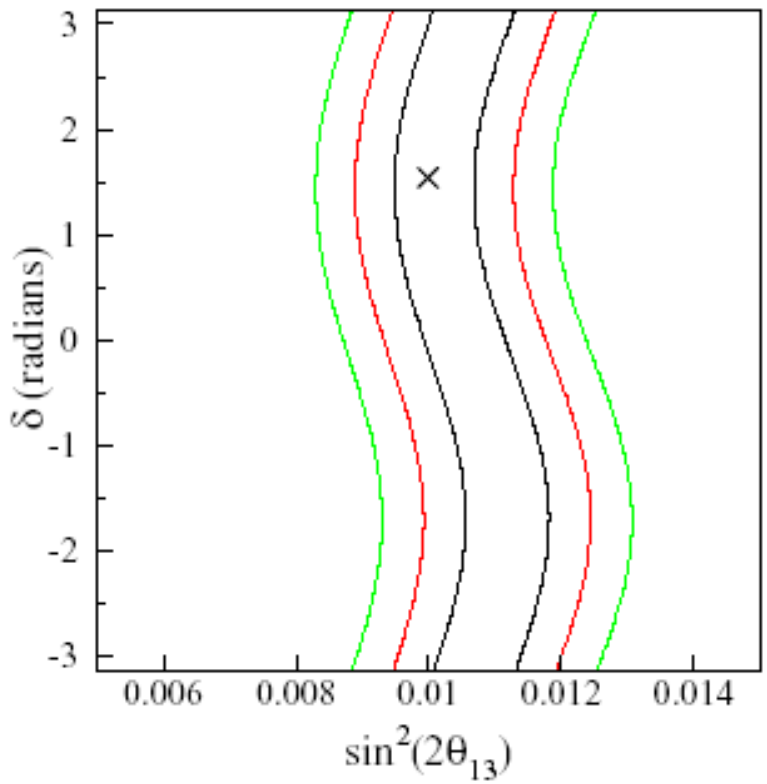


Physics of 9400 km Baseline Experiments

- Fermilab-Beijing:
  - Disappearance experiment:
    - First oscillation minimum at 17 GeV.
      - 'High energy' beam called for. Good for the event rates
      - Good energy resolution. Relatively free of the systematic uncertainties
        ➔ precise determination of the Δm^2_{23}
    - Second minimum at 5 GeV: spectacular oscillation pattern well visible.
    - Full oscillation observed ➔ decoupling of Δm^2_{23} and mixing angle determination ➔ precise determination of $\sin^2(2\theta_{23})$
  - Appearance experiment(s):
    - $\nu(\mu) \rightarrow \nu(\tau)$: systematic similar to CNGS, but the signal 40 $\times$ higher (at the oscillation maximum!)
    - $\nu(\mu) \rightarrow \nu(e)$: matter enhancement, clean determination of the mass hierarchy, relative insensitivity to CP violation

Physics of 9400 km Baseline Experiments (cont…)

- Strong matter effect:
  - $\times$ 20 amplification in $\nu(\mu) \rightarrow \nu(e)$ probability over max in vacuum
  - $\times$ 20 improvement in S/N
  - Signal rate is ~ 200 events/Mton-year for $\sin^2(2\theta_{13}) = 0.01$.
  - Sign of ΔM^2 unambiguously determined
- Weak dependence on δ:
  - Signal compared with that from a shorter baseline **(2100 km)** can constrain δ



Constraints (1,2,3 σ) after 2 years of running and a 1 Mton detector, input parameters marked with X.

Physics of "9400 km+2100" km 2-Baseline Experiments

- Fermilab-Beijing + JPARC-Beijing:
  - Ultimate $\nu(\mu) \rightarrow \nu(e)$ appearance experiment:
    - Different energies/baselines

      ➔ different relative contributions of matter enhancements and CP violating effects

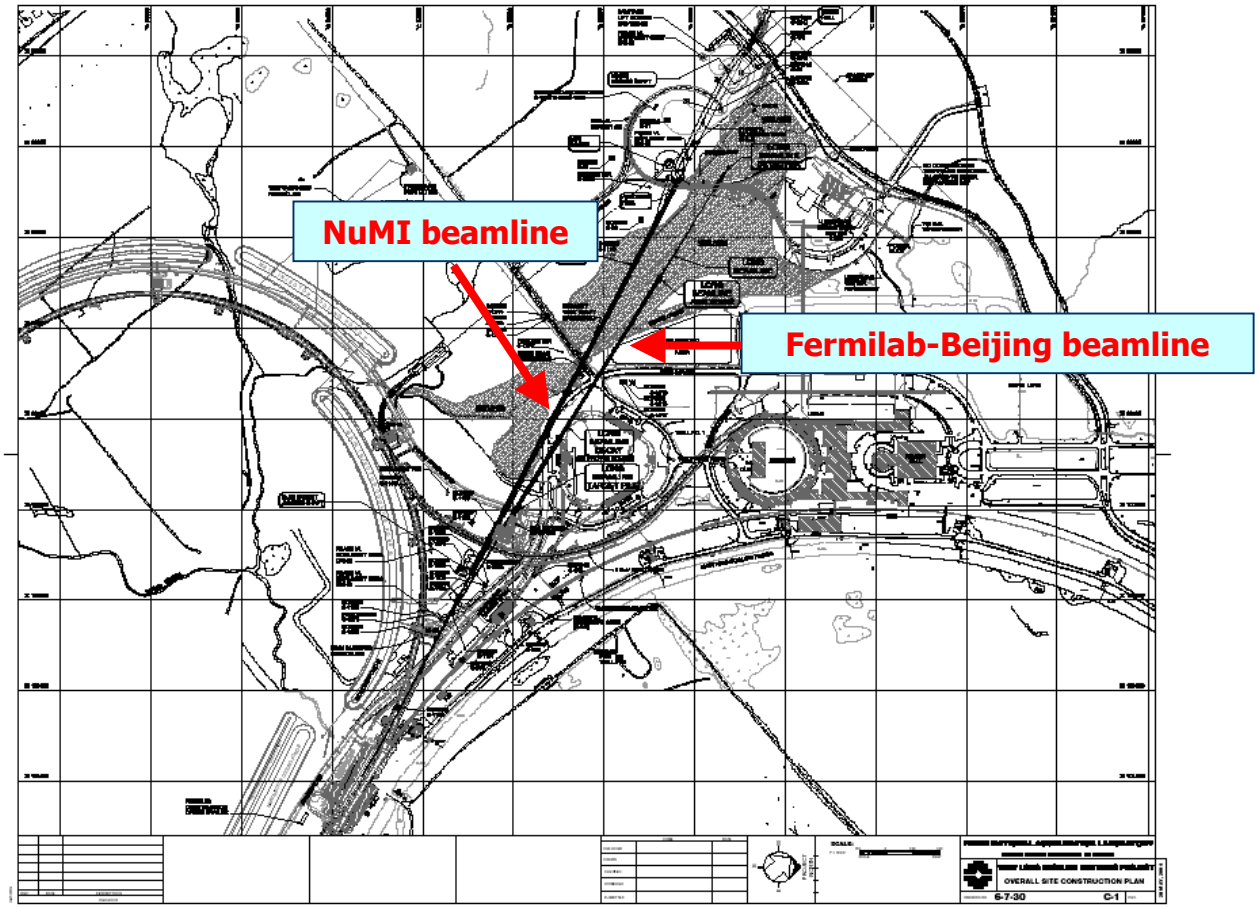
      ➔ clean determination of the neutrino oscillation parameters, breaking degeneracy of interpretation

Detector Issues

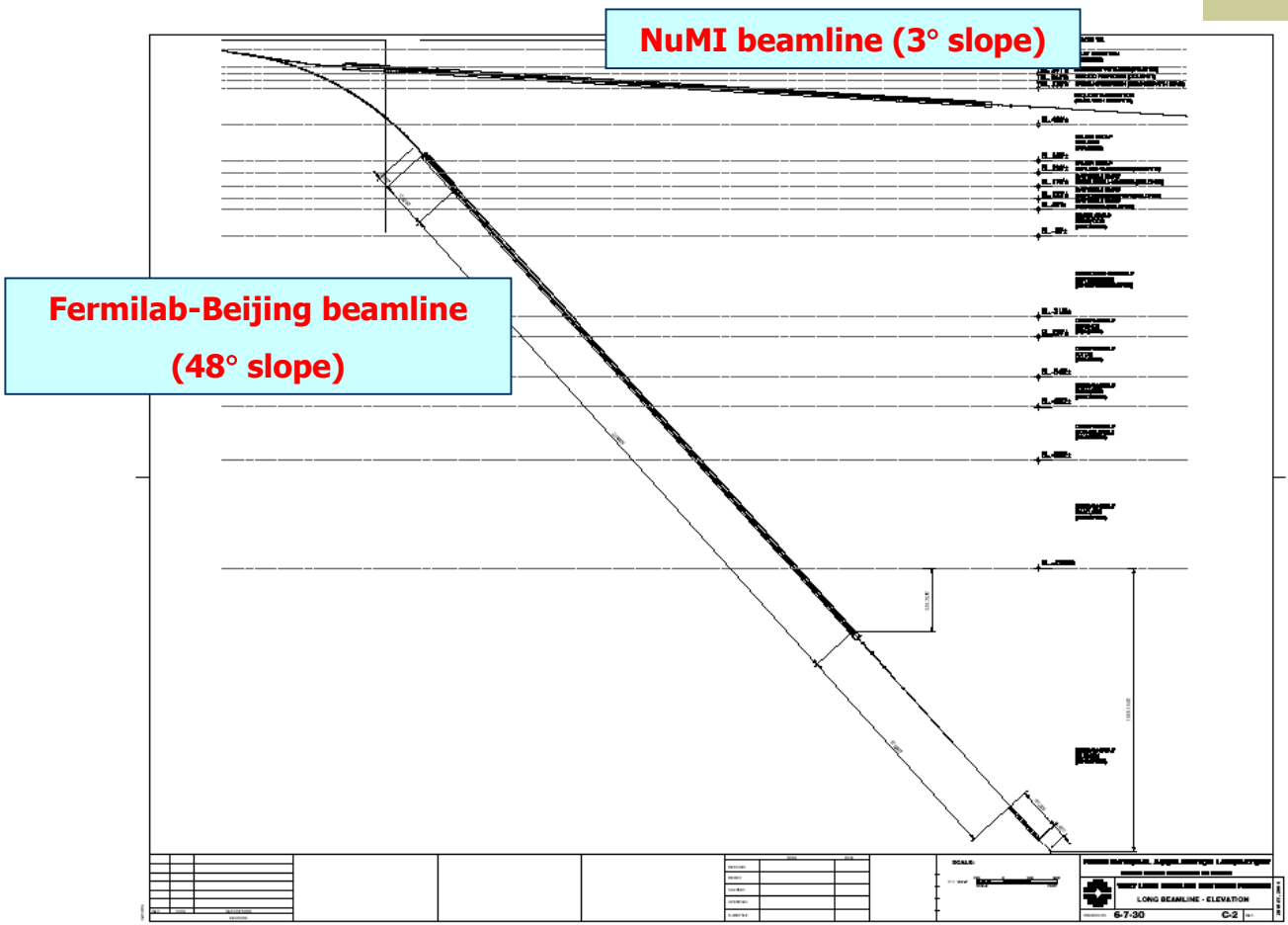
- Disappearance experiment: known beam flavor, do not need charge determination. Need
  - muon identification
  - Good energy resolution
- Appearance :
  - $\nu(\tau)$: very good granularity and high resolution (a la ICARUS)
  - $\nu(e)$:
    - good and efficient electron identification in complex inelastic events (even for the JPARC beam)
    - excellent e/π^0 separation

➔ Large Liquid Argon TPC a natural candidate ←

The "Plan View" Sketch for Fermilab-Beijing Long Baseline



The "Elevation View" Sketch for Fermilab-Beijing Long Baseline



Summary

- There is interesting neutrino physics in a "9400 km + 2100 km" 2-baseline experiment.
- A 48° tunnel is feasible, although won't be cheap.
- It is conceivable to have significant spin-offs (i.e., non-HEP) from a 9400 km long baseline experiment, e.g., earth science, mine/oil exploration, etc. (The deepest point will be 2100 km from the earth surface.)
- This study is at an early stage. There are a number of unanswered questions. It should be encouraged and continued.