# *Electron Neutrino Analysis At Near Detector ND280*

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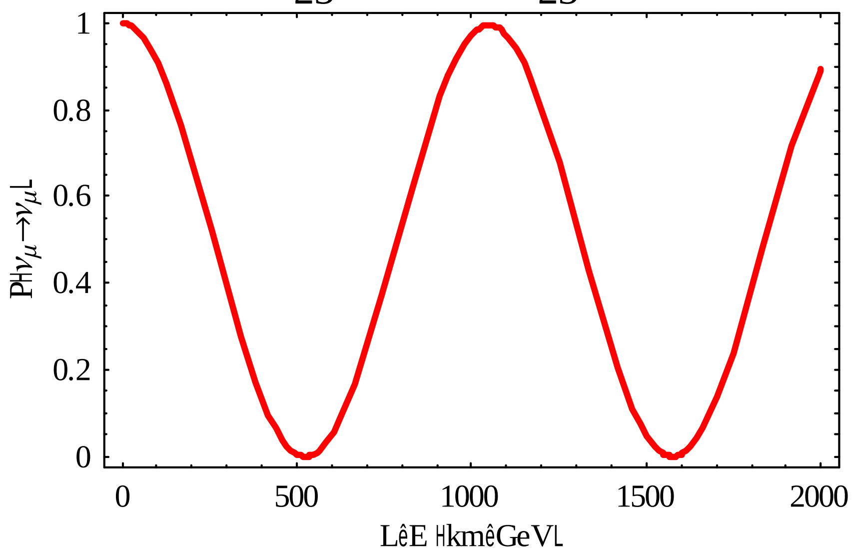
# Outline

- **Physics motivation**
  - **Neutrino oscillations**
  - **T2K overview**
- **Electron neutrino analysis at ND280**
  - **Preliminary study to separate the signal from the background**

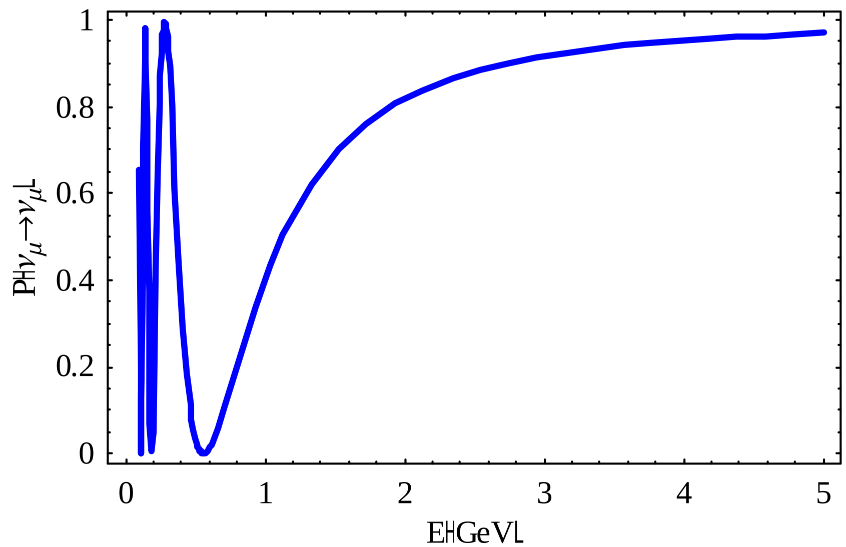
# Neutrino Oscillations: Muon Neutrino Disappearance

$$P(\nu_\mu \rightarrow \nu_\mu) = 1 - \sin^2 2\theta_{23} \sin^2\left(1.27\Delta m^2_{23} \frac{L}{E_\nu}\right)$$

$\sin^2 2\theta_{23} = 1, \Delta m^2_{23} = 0.0024$

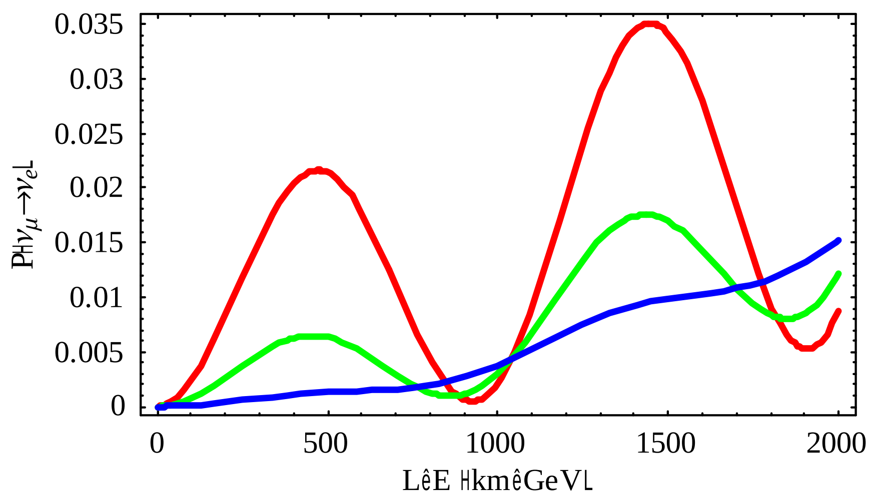


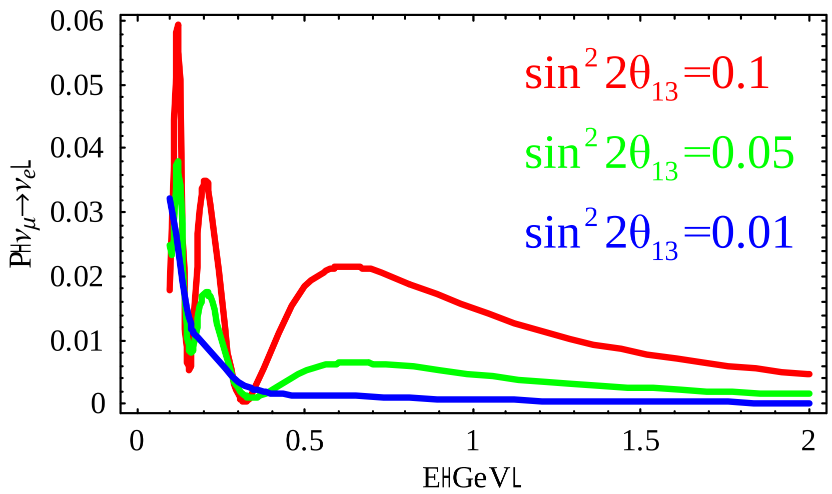

$\sin^2 2\theta_{23} = 1, \Delta m^2_{23} = 0.0024, L = 295\text{km}$



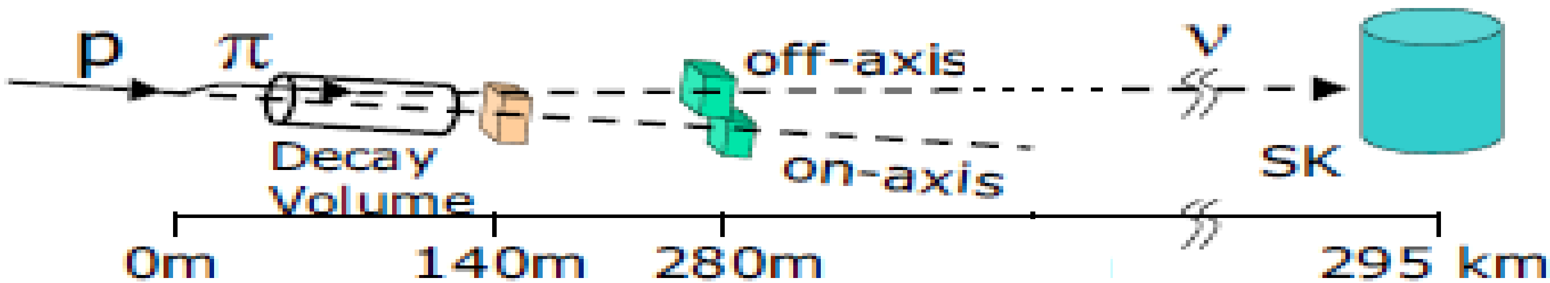
# Neutrino Oscillations: Electron Neutrino Appearance

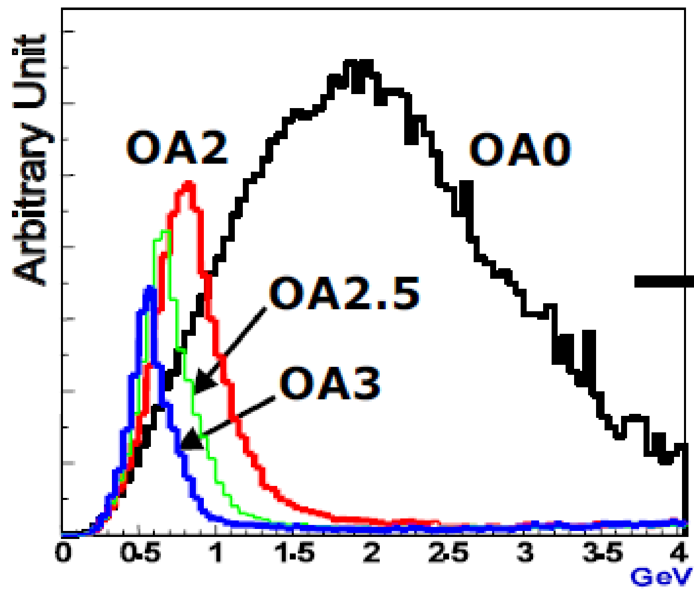
$$P(\nu_\mu \rightarrow \nu_e) = \sin^2 2\theta_{13} \sin^2\left(1.27 \Delta m^2_{23} \frac{L}{E_\nu}\right)$$



# T2K Overview

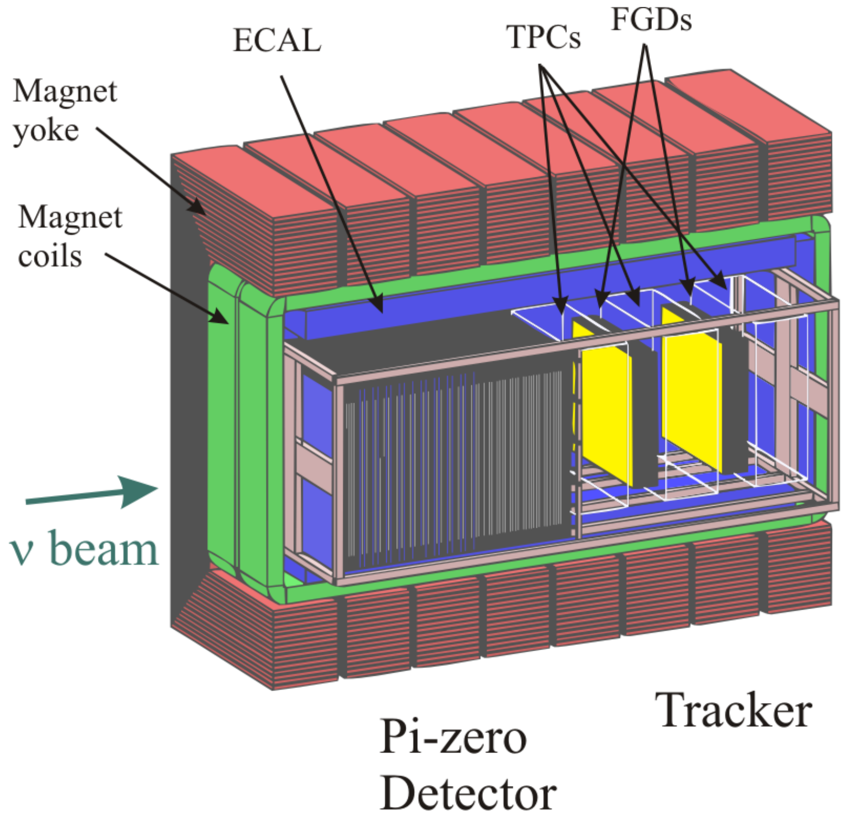



- Use the idea of the off axis angle
  - Reduce the background contamination
  - Select the angle corresponding to to oscillation maximum

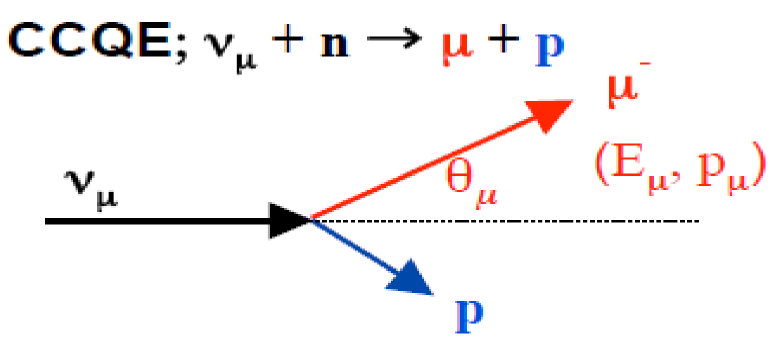
# The Near Detector – ND280

- **Measure neutrino interactions and estimate the background contaminations for Super-K**
  - **UA1 magnet provides 0.2T B field**
  - **Front optimized to measure π0 interactions**
  - **Rear optimized to measure charge current interactions**
  - **Surrounded by the calorimeter and muon detector**



# Charge Current Quasi Elastic (CCQE) Interactions

- **T2K golden interactions**
- **Easy to reconstruct the neutrino energy**




$$E_\nu = \frac{m_n E_l - {m_l^2}/{2}}{m_n - E_l + p_l \cos\theta_l}$$

# Electron Neutrino Analysis at ND280

- **Very important to characterize the electron neutrino beam contamination at near detector**
  - **Main background for the oscillation analysis at far detector**
  - **Very challenging analysis**
    - **Need very good particle separation**
    - **Need to understand the background from other sources ($\pi 0$, neutrino-electron scattering, single photon production etc) and estimate their uncertainties**
  - **Extrapolate the reconstructed electron neutrino spectrum to far detector**

# Neutrino Topology

- **Monte Carlo sample**
  - $0.15 \times 10^{20}$ POT
  - **GENIE v2.4.4 for neutrino interactions only on the FGDs**
- **Neutral Current contamination: 6670**

| | ALL | % |
|---|---|---|
| $\nu_\mu$ | 15869 | 94.49 |
| $\nu_\mu$-Bar | 606 | 3.60 |
| $\nu_e$ | 291 | 1.73 |
| $\nu_e$-Bar | 28 | 0.17 |

| $\nu_e$ | ALL | % |
|---|---|---|
| CCQE | 83 | 28.52 |
| CCRES | 111 | 38.14 |
| CCDIS | 93 | 31.96 |
| COH | 4 | 1.37 |

# Electron Neutrino Reconstruction Analysis at near detector

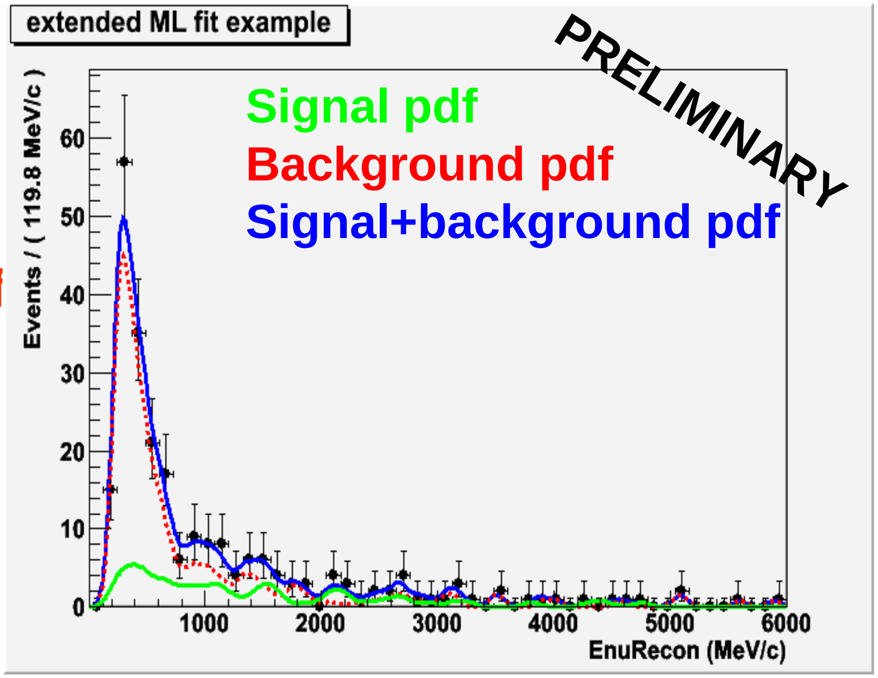
- **Use a cut chain to get a selection of reconstructed electron neutrinos in the tracker**
  - **Include also background coming from outside the tracker**
    - **For example photons created somewhere else in the detector and converged in the FGDs**
- **Try to correct and fit the selected spectrum in order to separate the signal from the background**
  - **The neutrino energy is reconstructed using always the Charge Current Quasi Elastic (CCQE) formula and then apply an energy correction in order to predict the energy spectrum for non-CCQE**

# $\nu_e$ Selection At ND280

| | Signal | Background |
|---|---|---|
| Negative TPC Track | 218 | 64603 |
| Reconstructed vertex in fiducial FGD volume | 147 | 14734 |
| TPC PID | 100 | 2724 |
| P > 200 MeV | 80 | 553 |
| No other E-Like Tracks | 62 | 184 |

# Predict the NuE spectrum

- Fit the neutrino spectrum with the non-parametric KEYS pdf
- Apply an event weight in order to predict the signal and the background pdf
- Fit the expected number of signal and background events
- For the signal events apply another weight in order to correct the neutrino energy for the non-CCQE interactions



# Extract the $\nu_e$ signal

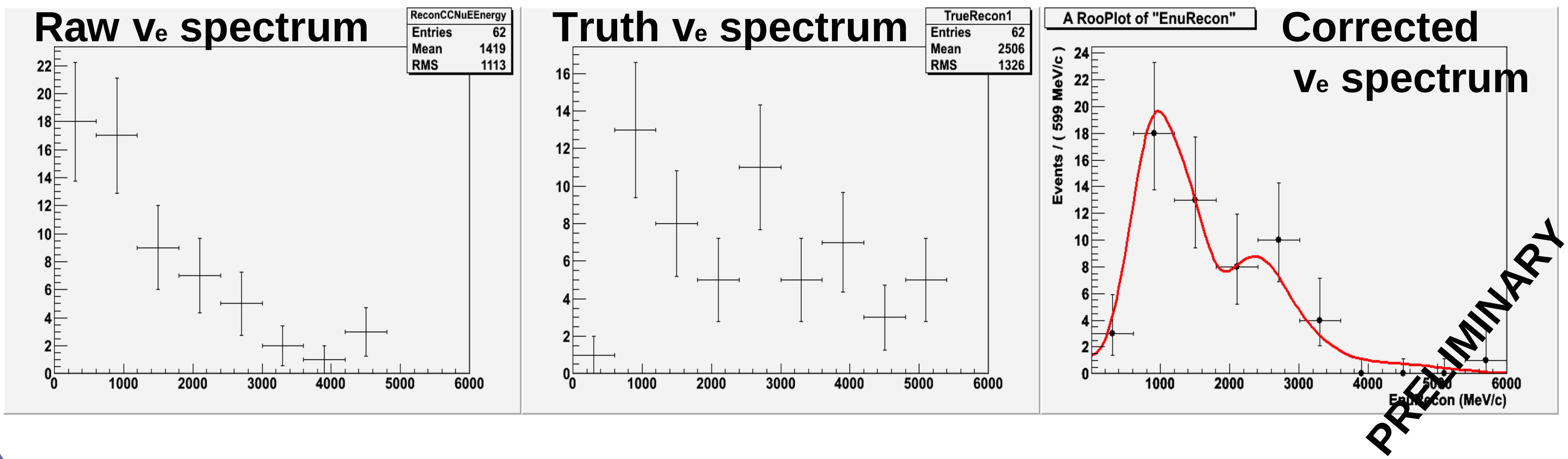
- **Fit the expected number of events**
  - **Fit both signal and background events**
    - **Signal : 57.31 +/- 15.27**
    - **Background : 180.69 +/- 18.98**
- **Errors are quite large**
  - **Weighted events**
  - **Low statistics**
  - **KEYS pdf construction bandwidth effect**
- **Use the $1/r^2$ approximation to estimate the expected number at far detector: 0.3586 +/- 0.096**

# Correct the neutrino energy

- Two methods can be used
  - Energy response matrix
  - Apply an additional bin-by-bin weight by comparing the signal true and reconstructed distributions
- Build another pdf and generate the expected corrected events from this pdf
- Compare with the true neutrino distribution

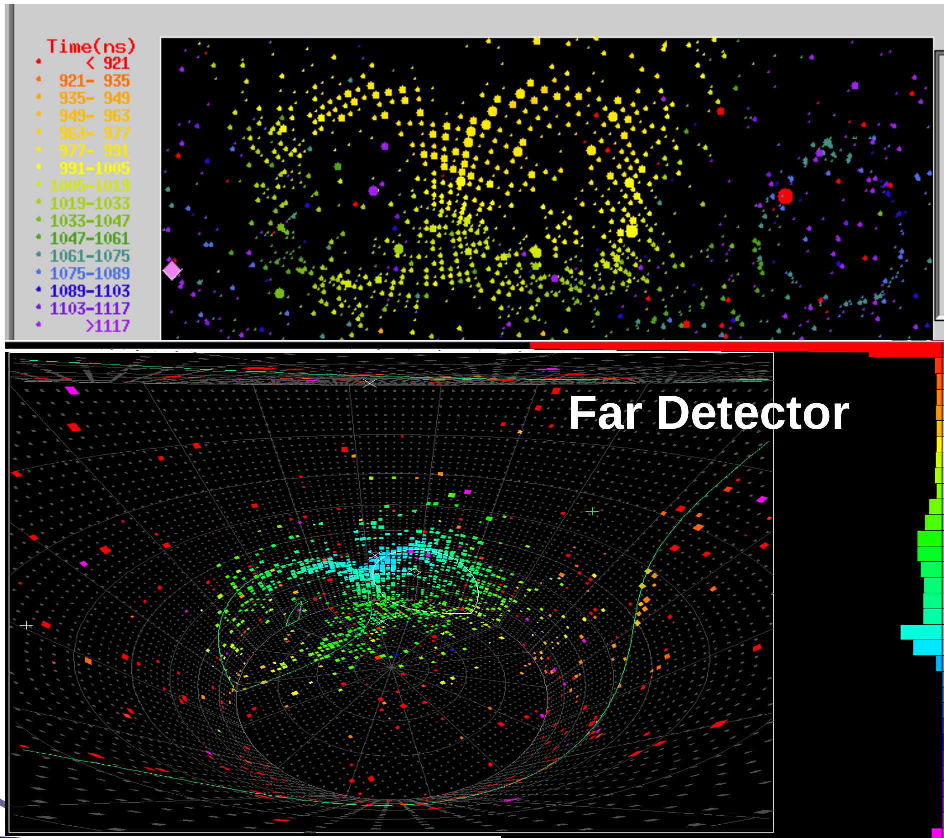
# Energy response matrix weight for correcting the $\nu_e$ energy

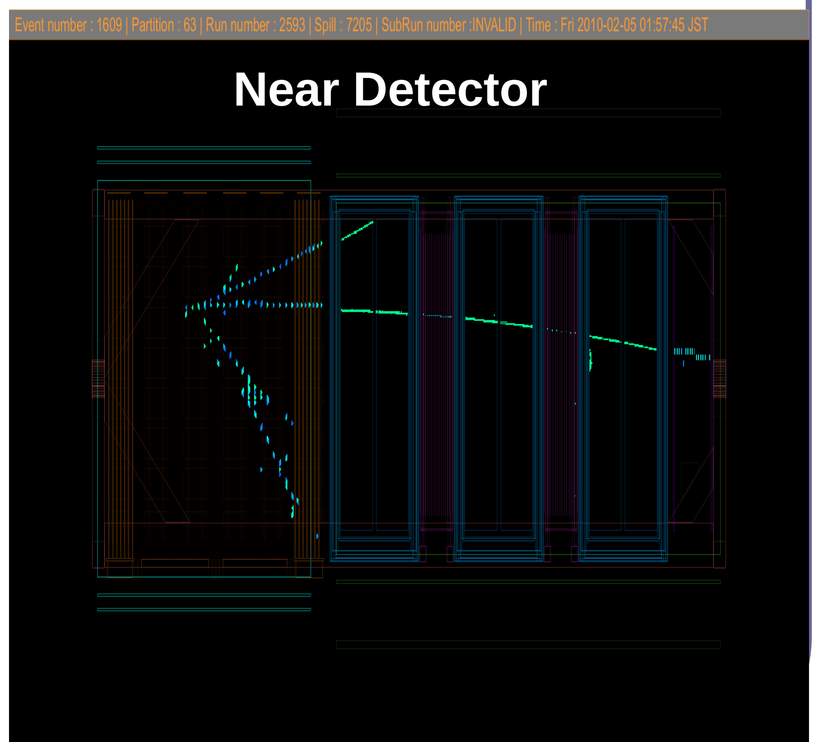
- **As a first approximation the method works well at energies below ~3.5 GeV**
  - **Need a more proper look at higher energies**



# Conclusions

- **T2K era is just beginning…**



# Backup Slides

# Energy Response matrix