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TRIUMF
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NP01 at KEK

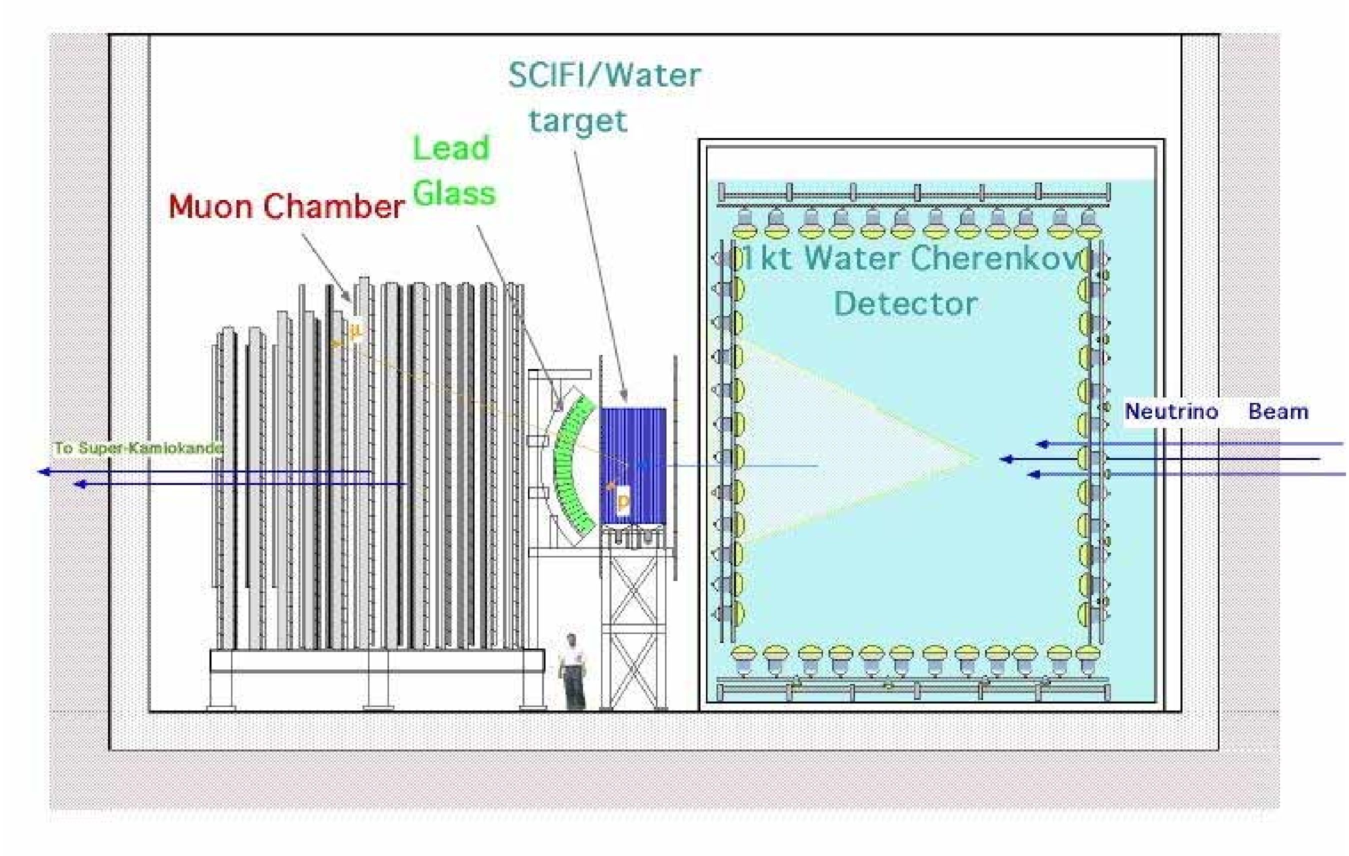
Near detector requirements and design

Prediction of reconstructed neutrino spectrum in far detector

1. ν_μ disappearance
   - **Signal:** ν_μ QE (quasi-elastic)
   - **Background:** ν_μ inelastic $\sim 3\%$
2. ν_e appearance
   - **Signal:** ν_e QE
   - **Background:** ν_e contamination, ν_μ NC $\sim 0.3\%$ each

$\Rightarrow$ Important to understand tails in the distributions

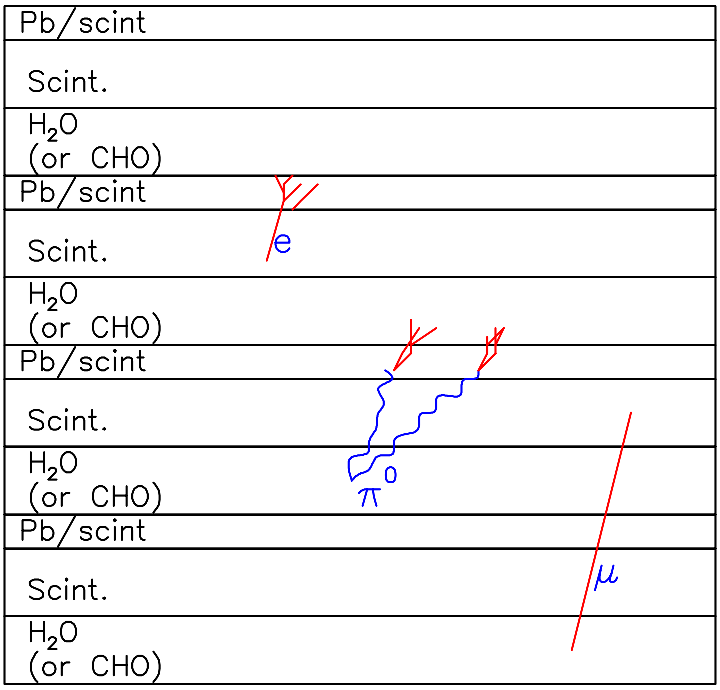
Candidate near detectors



- **Water Čerenkov detector**
  Good for detecting particles below 1GeV
  Similar systematics as the far detector
  Miss low velocity particles (low energy π and p
- **Fine grained detector**
  Good PID and vertex reconstruction
  Water/CH_2 cross section comparison required
- **Fe(magnetized)/scintillator/chamber detector**
  Good for high energy μ detection

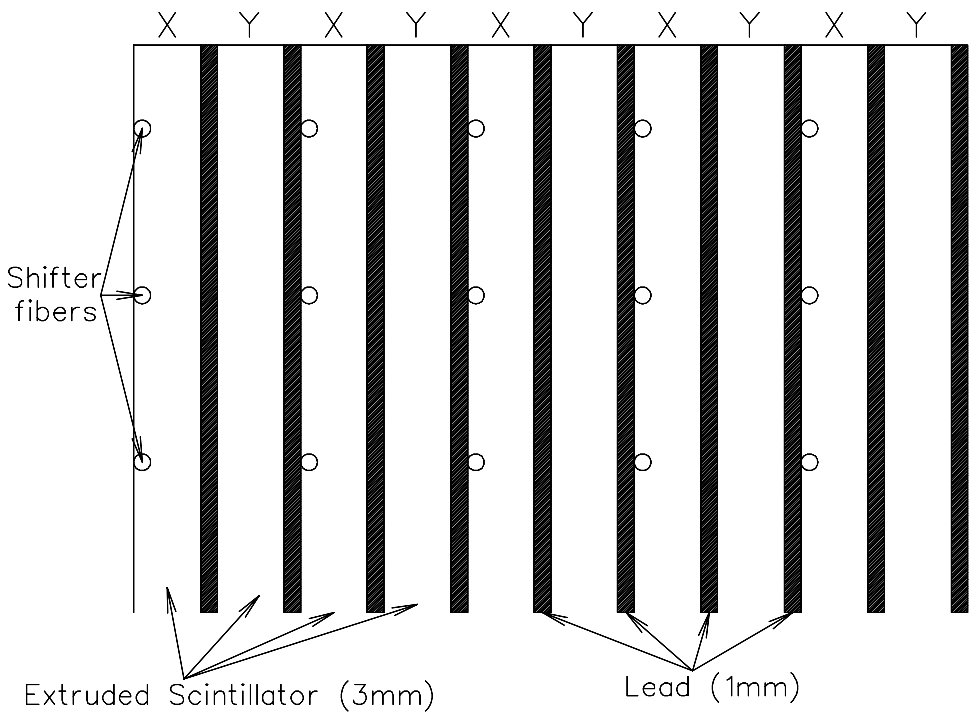
Neutrino interaction points spread in space
$\Rightarrow$ homogeneous detector instead of separate function

Structure of a fine grained calorimeter



- $\nu_\mu n \rightarrow \mu^- p$ (QE) measurement
  Cross section (Q^2 dependence), $\nu_m u$ energy distribution
  - Full reconstruction (p-tag) in the fine grained scint.
  - Comparison between H_2O and CH_2
- $\nu_e n \rightarrow e^- p$ (QE) measurement
  Study ν_e contamination
- $\nu_\mu N \rightarrow \nu_\mu \pi^0$ (NC) measurement
  Study π^0 background
- Cross section and E_ν spectrum studies for $\bar{\nu}$
  Study for CP and CPT measurements

A fine grained calorimeter

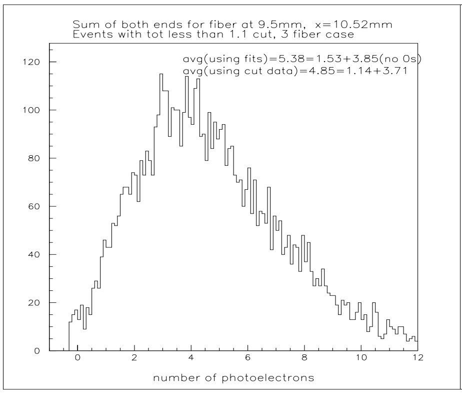


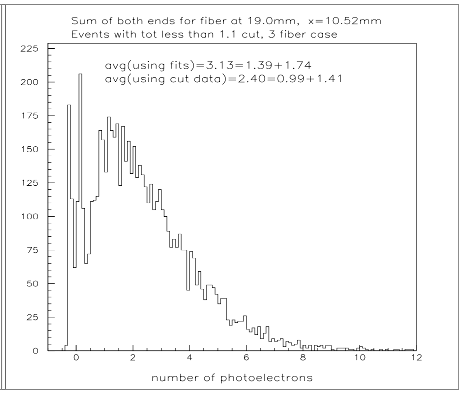
- Position measurement by reading each fiber ($\sigma \sim 2\ mm$)
- Timing ($\sigma_t \sim 1 nsec$)
- Energy measurement (12p.e./MeV, $\sigma_E/E \sim 3-5\%/\sqrt{E}$)
- Range measurement $\rightarrow$ dE/dx measurement

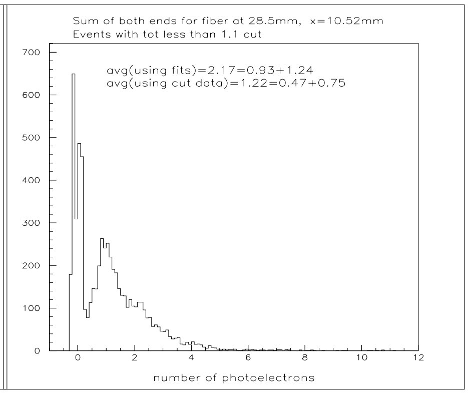
Prototype result (3 fibers)

β source on top of fiber 1

Fiber 1 | Fiber 2 | Fiber 3

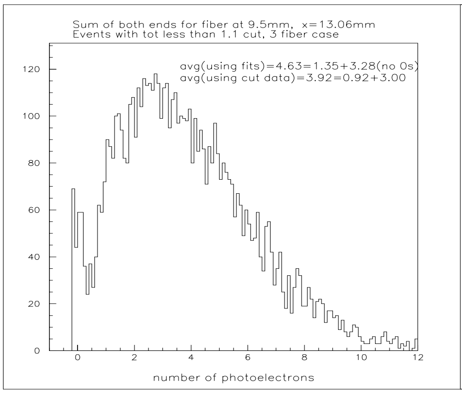


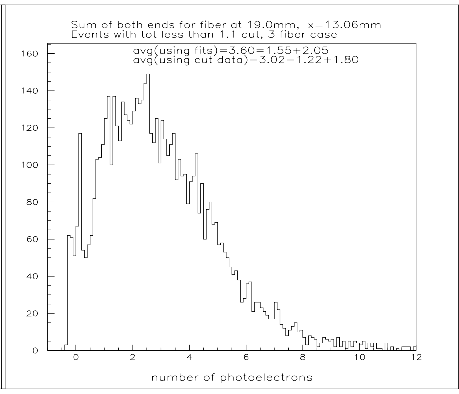


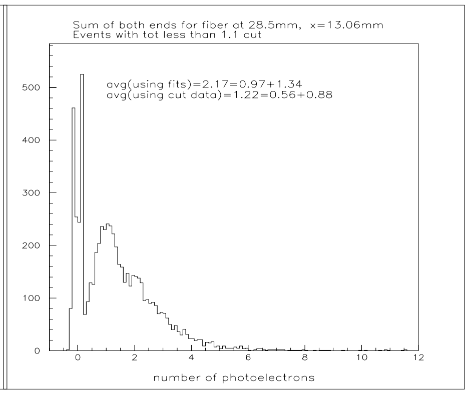


β source between fiber 1 and fiber 2

Fiber 1 | Fiber 2 | Fiber 3

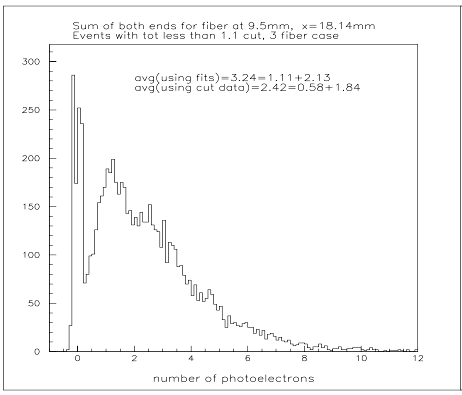


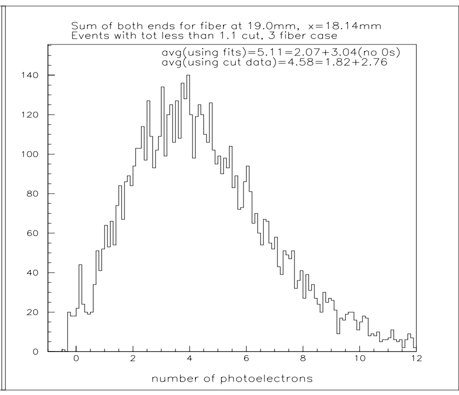


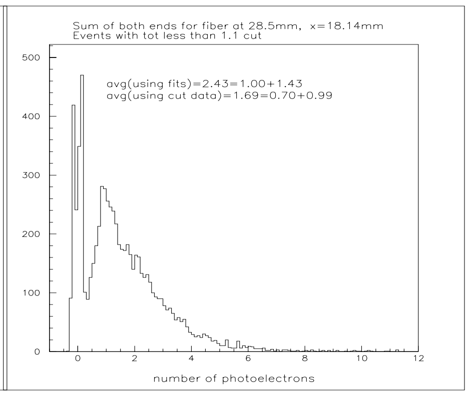


β source on top of fiber 2

Fiber 1 | Fiber 2 | Fiber 3

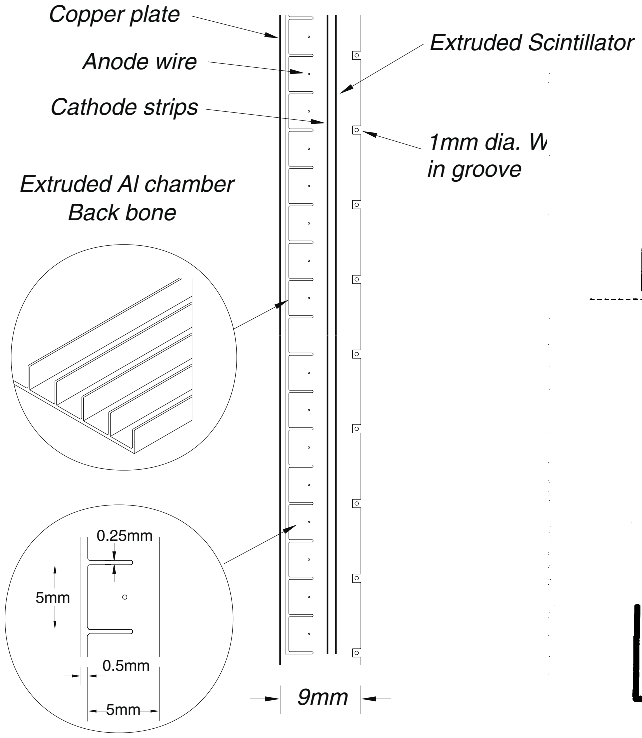




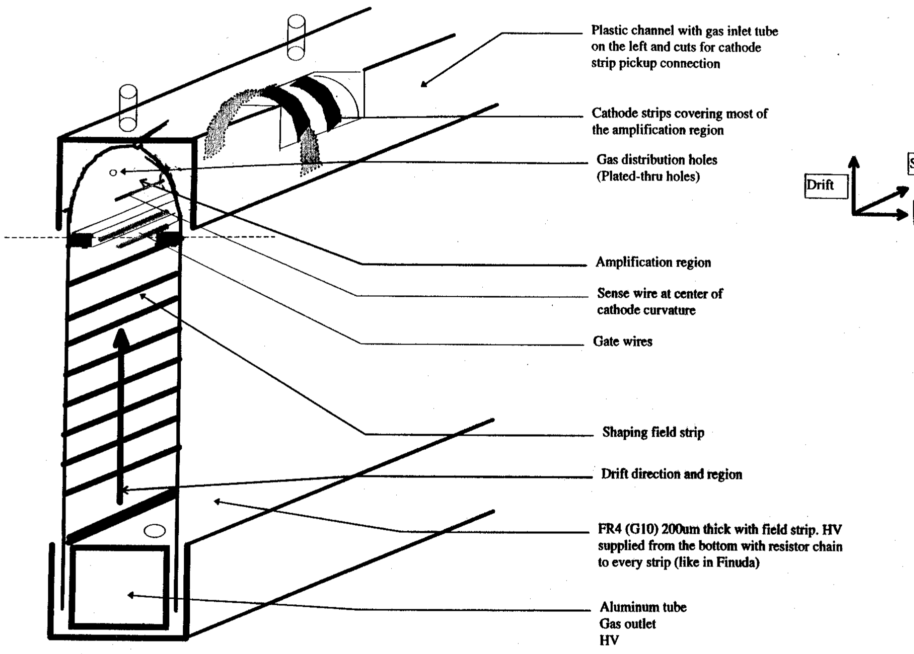


Precision tracking by adding chambers

KOPIO preradiator



TPC prototype (Bryman et.al)



- Precise charged particle tracking (E787)
- Precise γ tracking $\rightarrow \pi^0$ vertex (KOPIO)

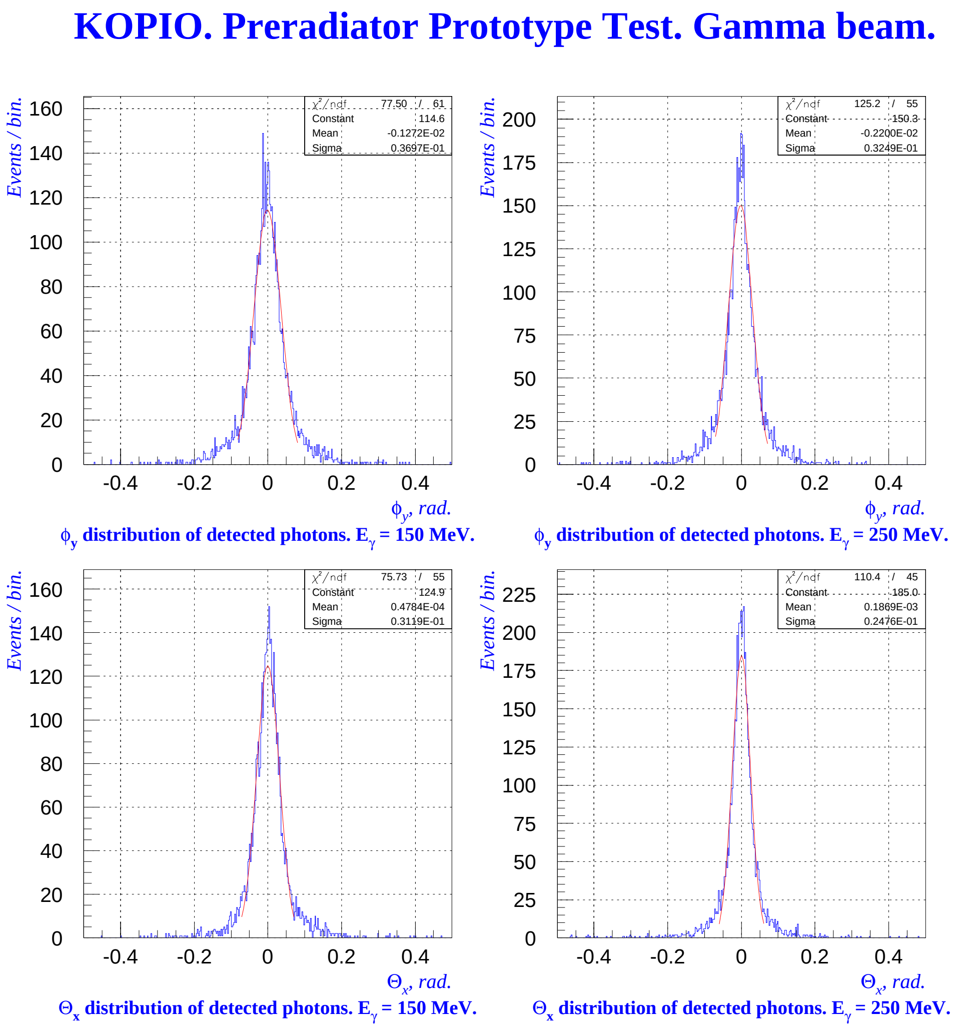
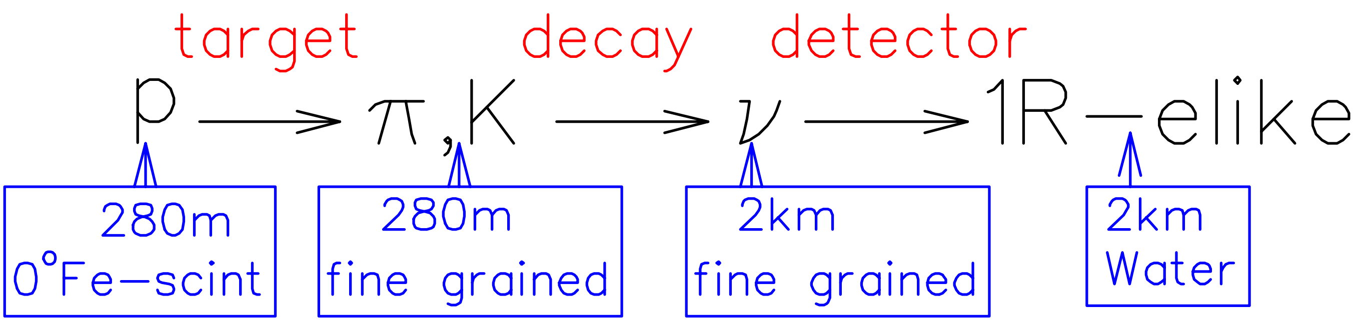


Figure: The measured angular distribution of photons for incident angle $\theta \simeq 0^\circ$ ($\phi \simeq 0^\circ$). The upper histogram for wire readout, the lower histogram is for strip readout. Left histograms are for photons in the energy range $100 \div 200$ MeV, right for $200 \div 300$ MeV.

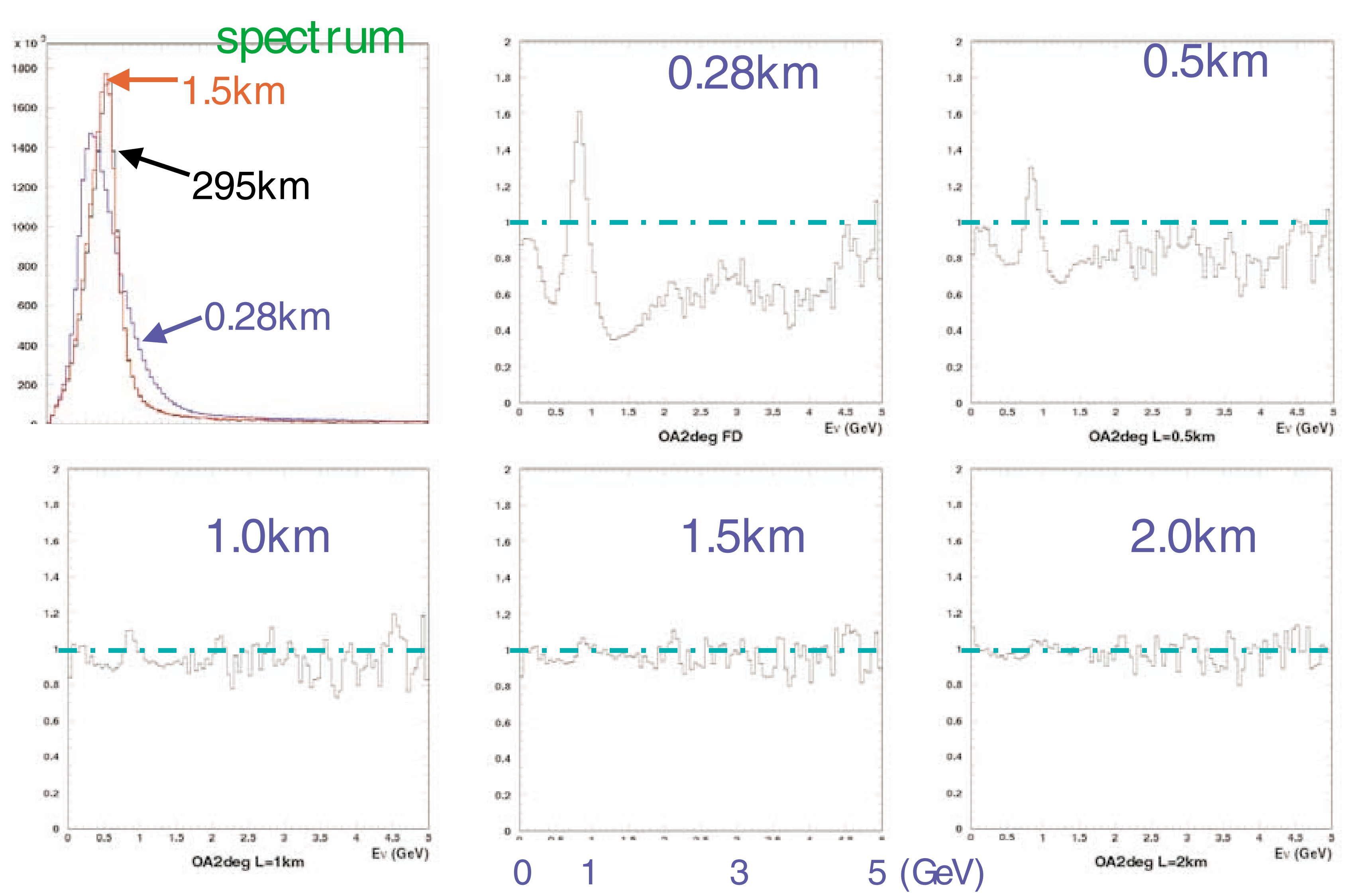
Four independent studies of the neutrino flux

1. Fe-scint beam monitor at 280m (stat=×10000)
   flux, cross-section, reconst. eff. from Monte Carlo
2. Fine grained calorimeter at 280m (stat=×5000)
   flux and cross-section measurement ⇒ far/near ratio
   reconst. eff. from Monte Carlo
3. Fine grained calorimeter at 2km (stat=×100)
   flux×cross-section measurement
   reconst. eff. from Monte Carlo
4. Water Čerenkov at 2km (stat=×100)
   flux×cross-section×reconst.eff. measurement



- Understand sources of systematics at each stages
  ⇒ reduction of systematic uncertainties
- Reliable estimates of systematics
- Essential for discovering the ν_e appearance signal

Far/ near ratio (OA 2deg)



Matrix approach on far/near ratio

M.Szleper and A.Para, hep-ex/0110001

Matrix expansion in far/near ratio

- $\Phi^{far} = R\Phi^{near}$
- $\Phi^{far}(E_i) = R_i\Phi^{near}(E_i)$
- $\Phi^{far}(E_i) = M_{ij}\Phi^{near}(E_j)$ (1st energy moment)
  $\Phi^{near}(E_j) \to E_\pi \to \Phi^{far}(E_i)$
- $\Phi^{far}(E_i) = M_{ijk}\Phi^{near}(E_j, r_k)$ (1st energy/angle moment)
  $\Phi^{near}(E_j, r_k) \to E_\pi \& \theta_\pi \to \Phi^{far}(E_i)$

Systematic error in $\Phi^{far}(E_i)$ is reduced in MINOS by M_{ij}:

* 2-3% for the main part of the flux

* 5-10% for the tail of the flux