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@ NBI2002

# *Secondary beam monitoring at K2K experiment*

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For K2K collaboration & KEK-PS beam channel group

- 1. Introduction (K2K beam)*
- 2. Pion Monitor*
- 3. Muon Monitor*
- 4. Front n detectors (Neutrino monitor)*
- 5. Summary*

# 1. Introduction (K2K beam)

- **1.1 msec** spill/2.2 sec
- GPS alignment < **0.01mrad**.
- Civil construction < **0.1 mrad**.

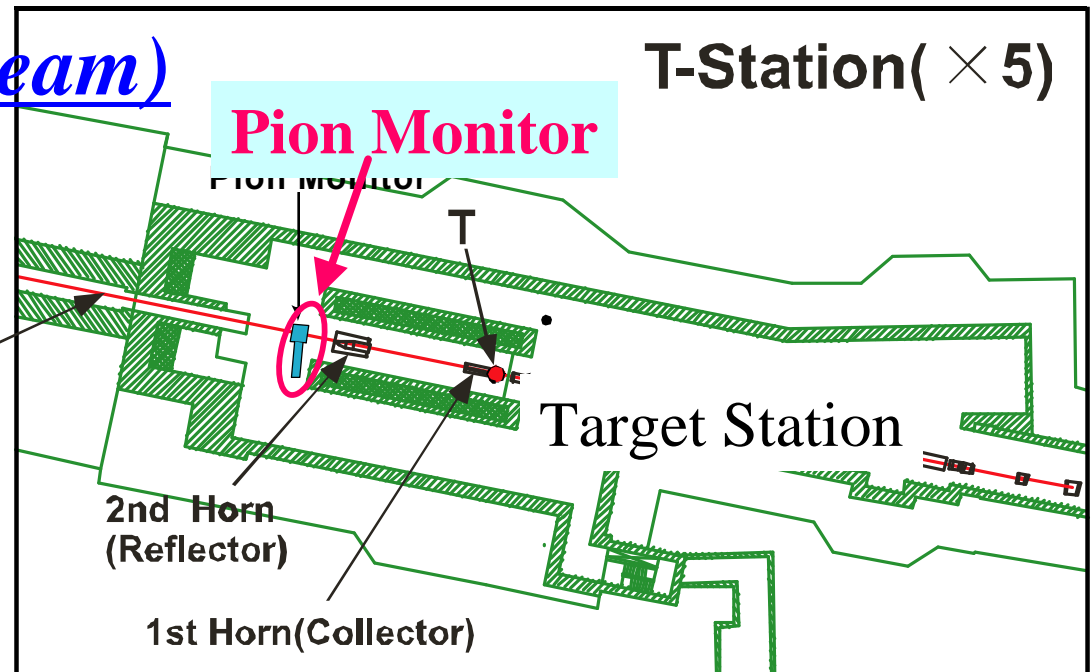
**Front Detector  
(Neutrino Monitor)**

To SK



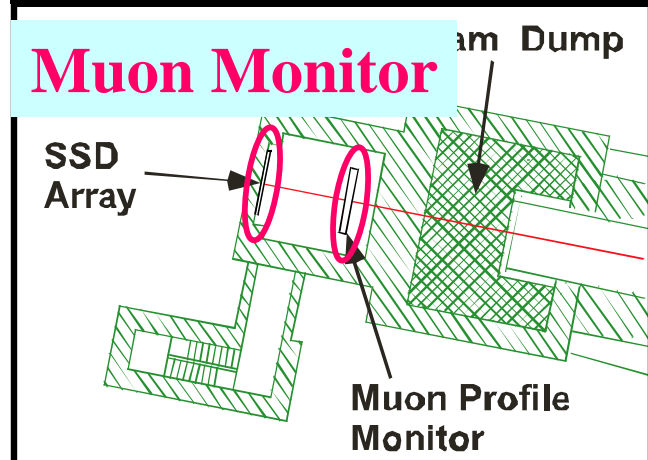
Decay  
tunnel

200m



**Muon Pit( × 10)**

**Muon Monitor**



12-GeV Proton Beam

**12GeV protons**

0 200 m



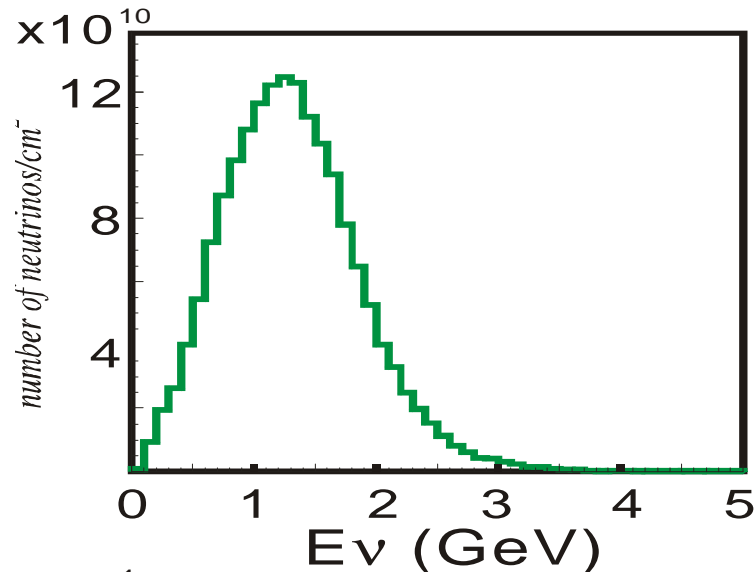
# *Monitoring Items at K2K*

## **Goal:**

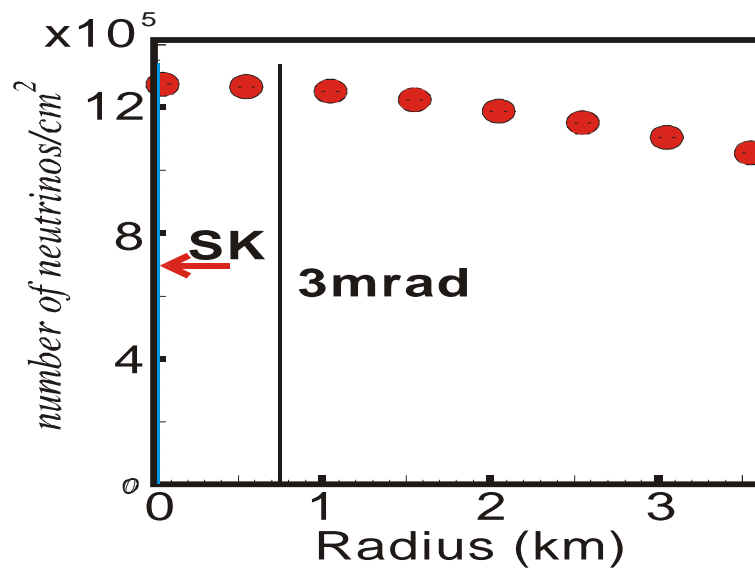
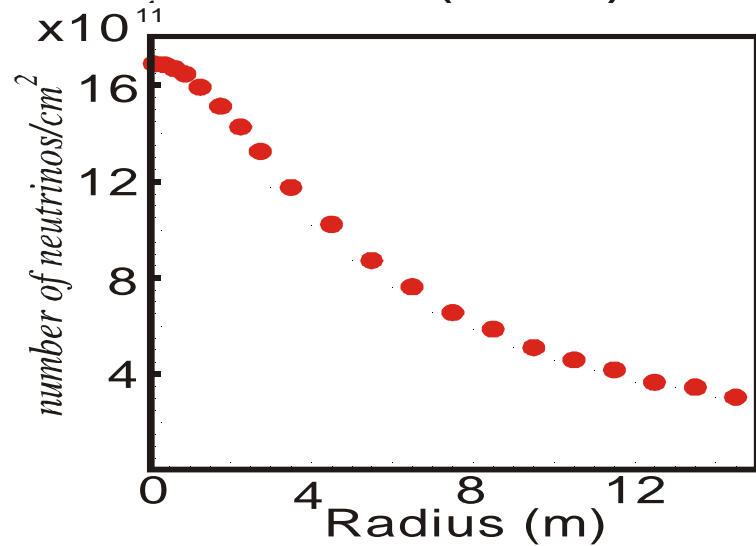
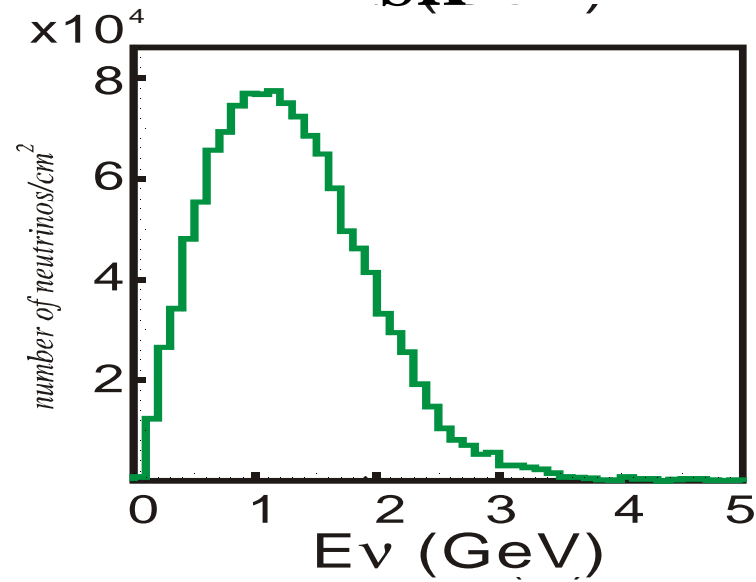
- Guarantee the neutrino beam pointing to the far detector (Super Kamiokande) at 250km away within 1 mrad accuracy.
  - Expect the neutrino flux and the spectrum at Super Kamiokande to study the neutrino oscillation phenomena.
- 
- **Direction** (spill by spill online, day by day)
    - **m**, n
  - **Profile** (spill by spill online, day by day)
    - **m**, n
  - **Spectrum** (including the stability)
    - **p**, n (→ Require the study of  $\nu$  interaction.)
  - **Flux** (including the stability)
    - n (→ Require the study of  $\nu$  interaction.)

# Neutrino energy spectrum and the profile

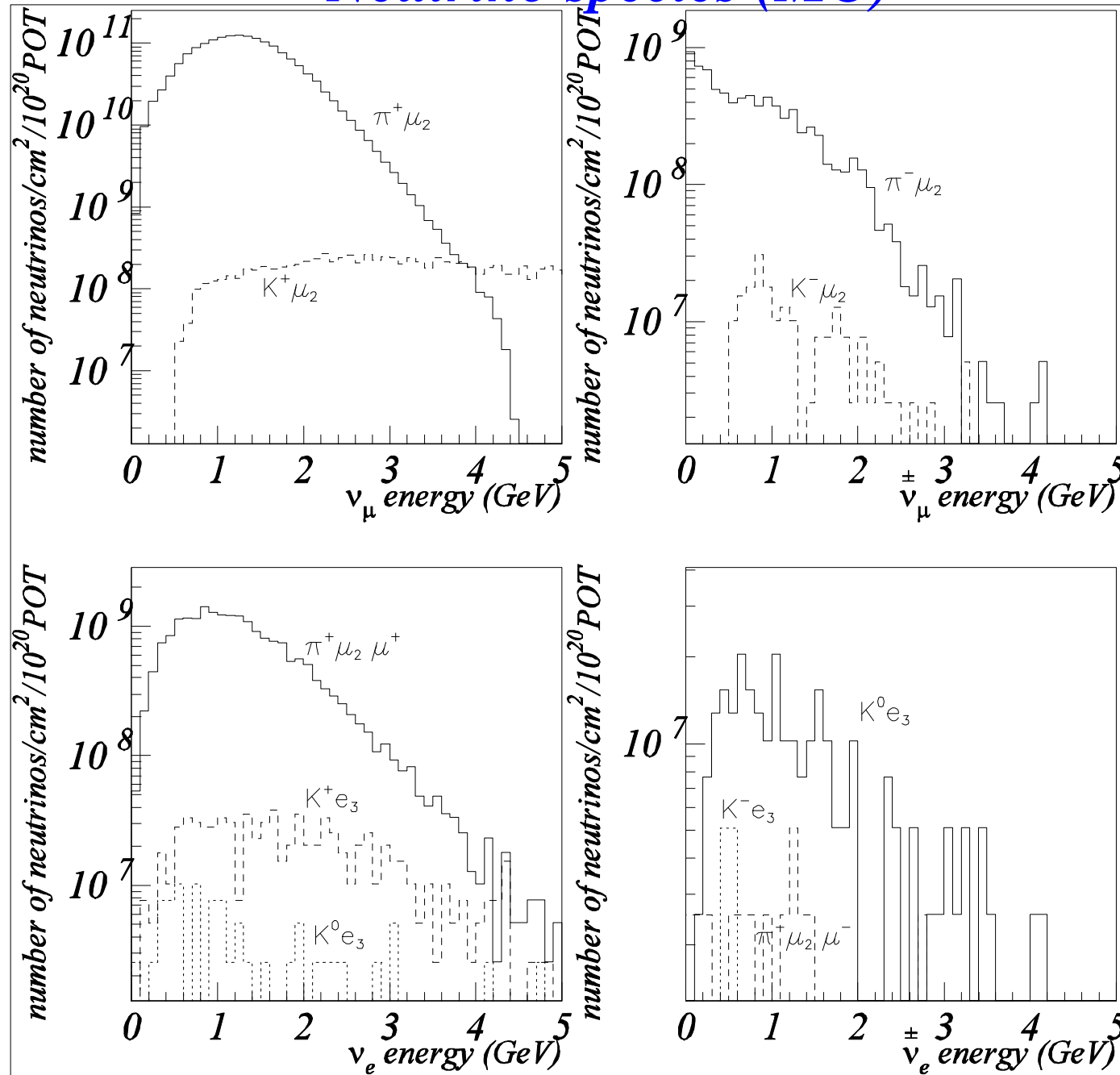
**KEK**



**SK**



# Neutrino species (MC)

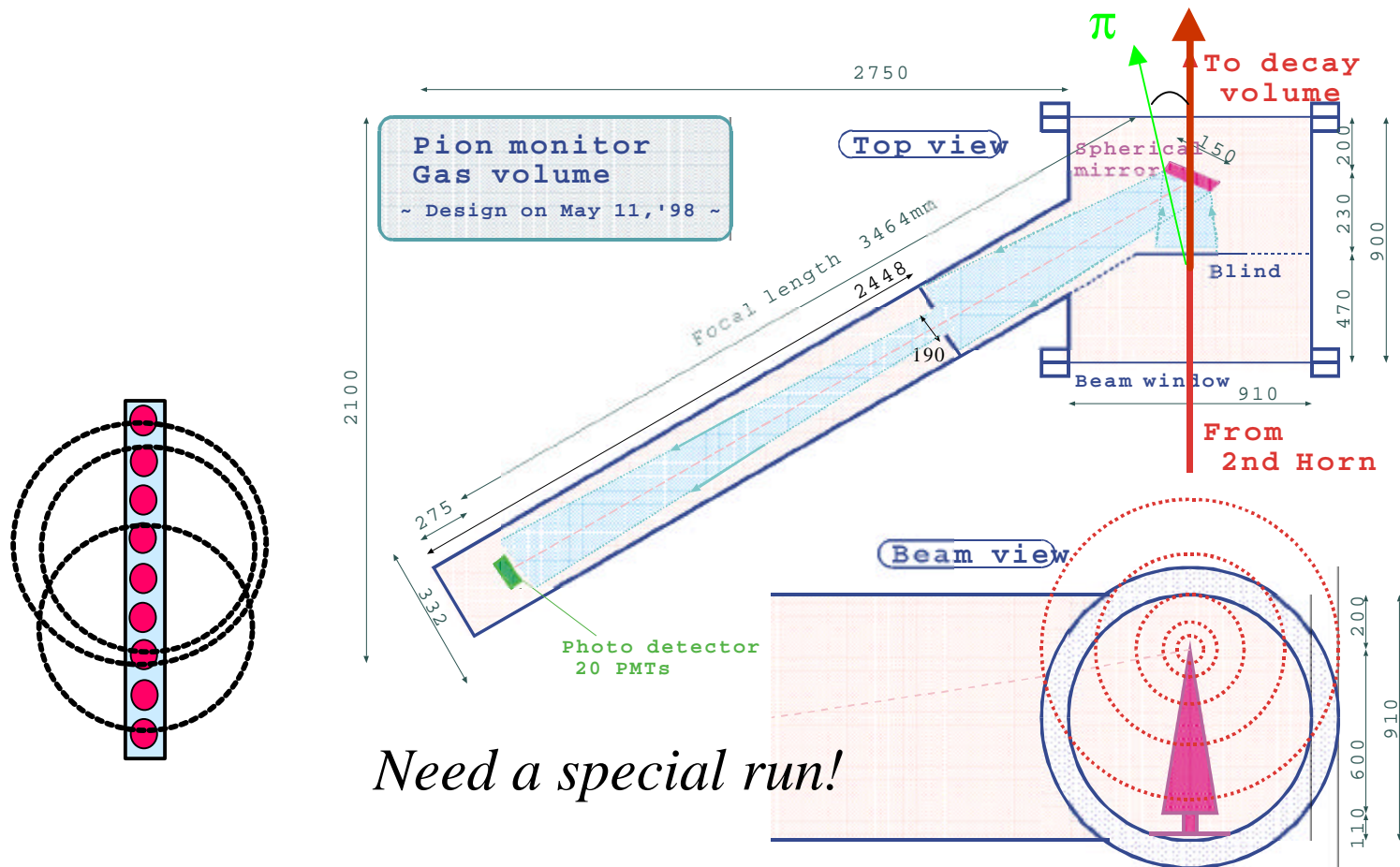


## 2. Pion Monitor

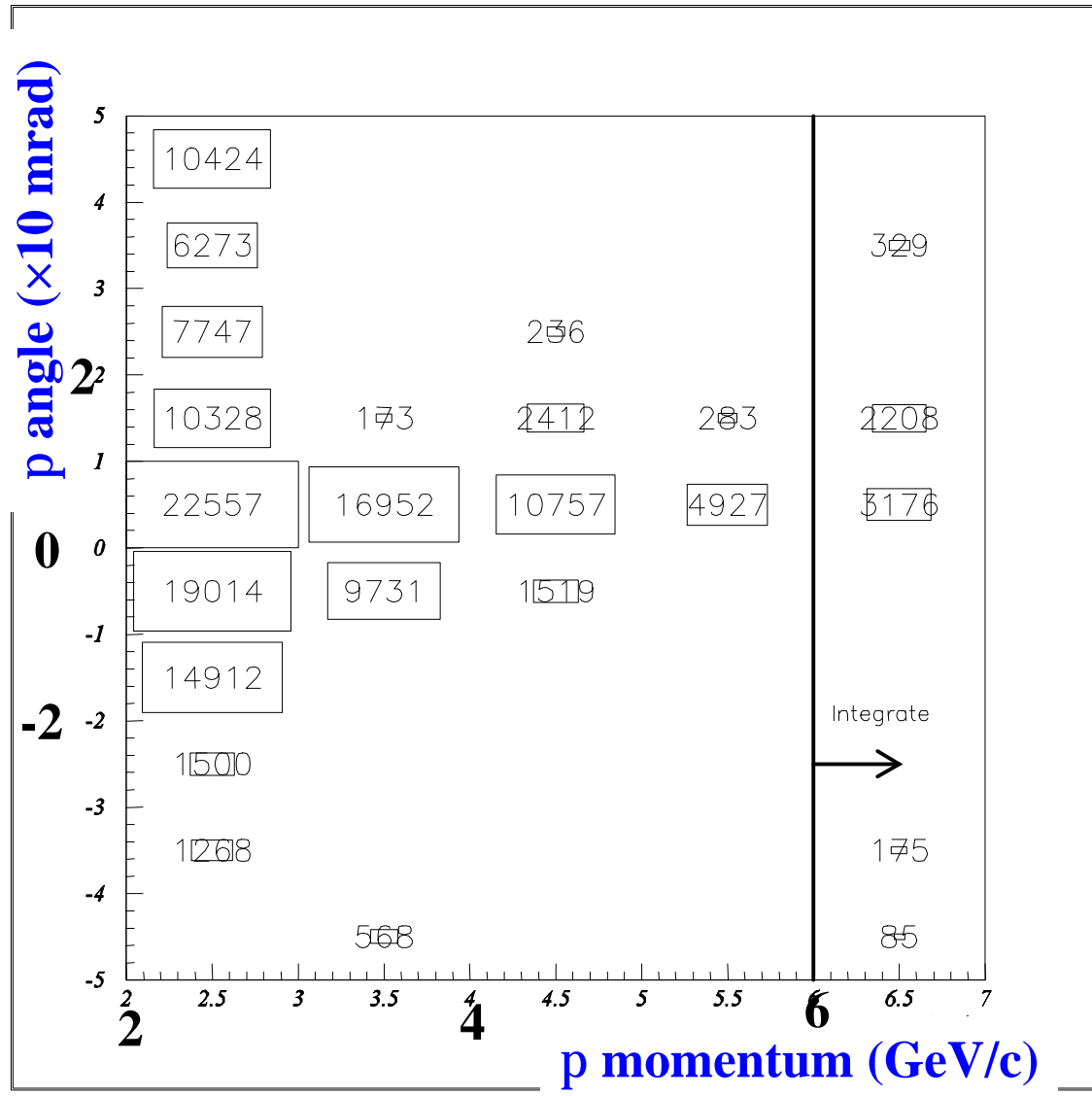
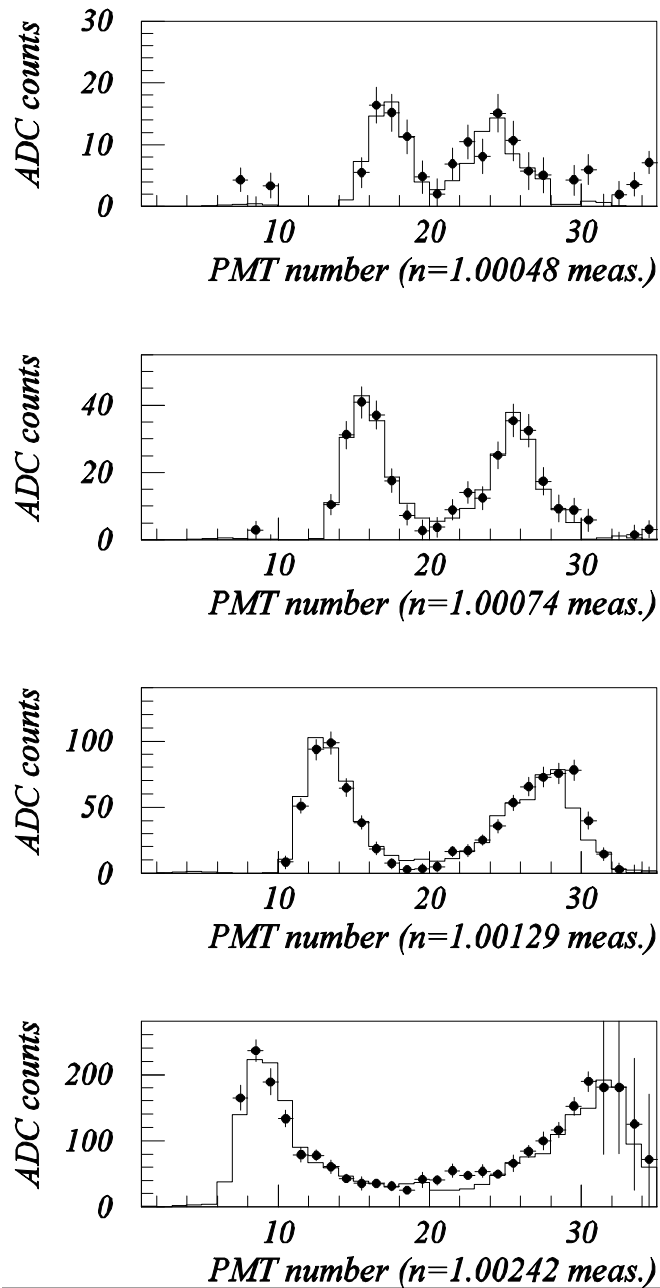
Gas Cherenkov detector: (insensitive to primary protons)

Measure momentum and angular distribution of pions,

$N(p_\pi, \theta_\pi)$  just after the target/horns system.



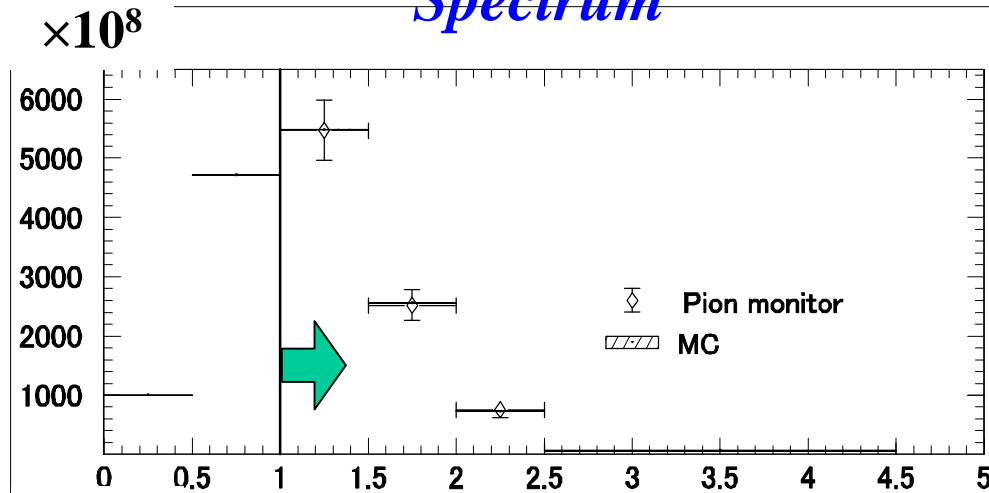
# Fitting (November)



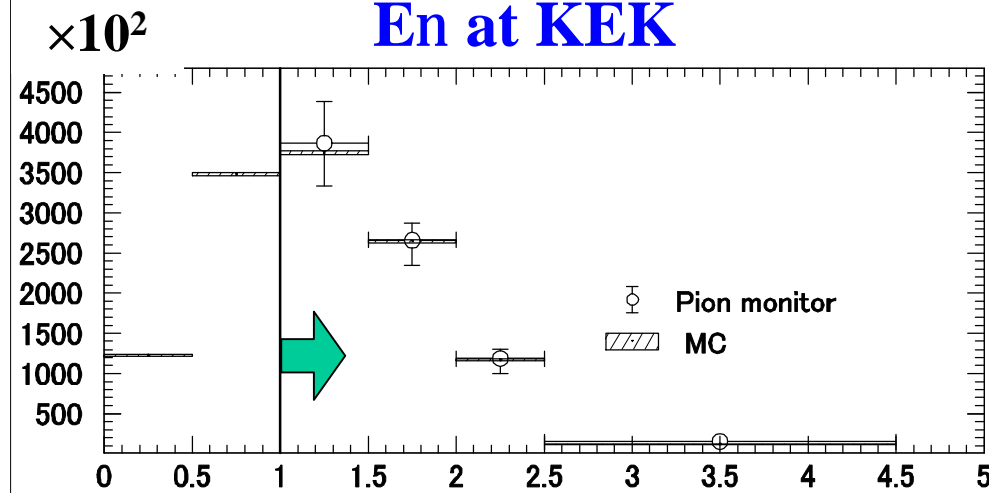


- $N(\mathbf{p}_p, \mathbf{q}_p)$ :
  - with the simple two decay kinematics
  - with the well-defined decay volume geometry
- **Predict the neutrino spectrum shape at both near and far sites and the so-called “far/near ratio”.**
  - Because of the severe 12 GeV primary proton background, the cherenkov threshold was set to 2GeV for  $\pi$  ( $\sim 1$ GeV for  $\nu$ ).

## Spectrum

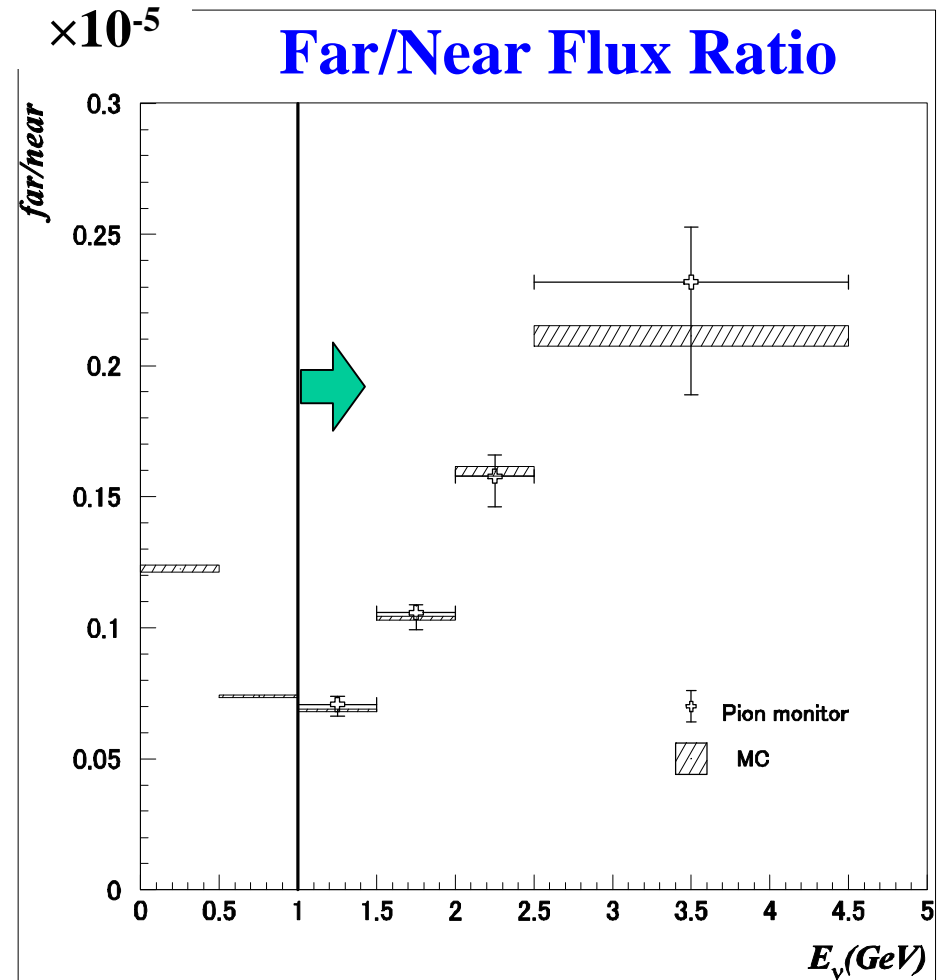


## En at KEK



## En at Kamioka $E_\nu$ (GeV)

## Far/Near Flux Ratio

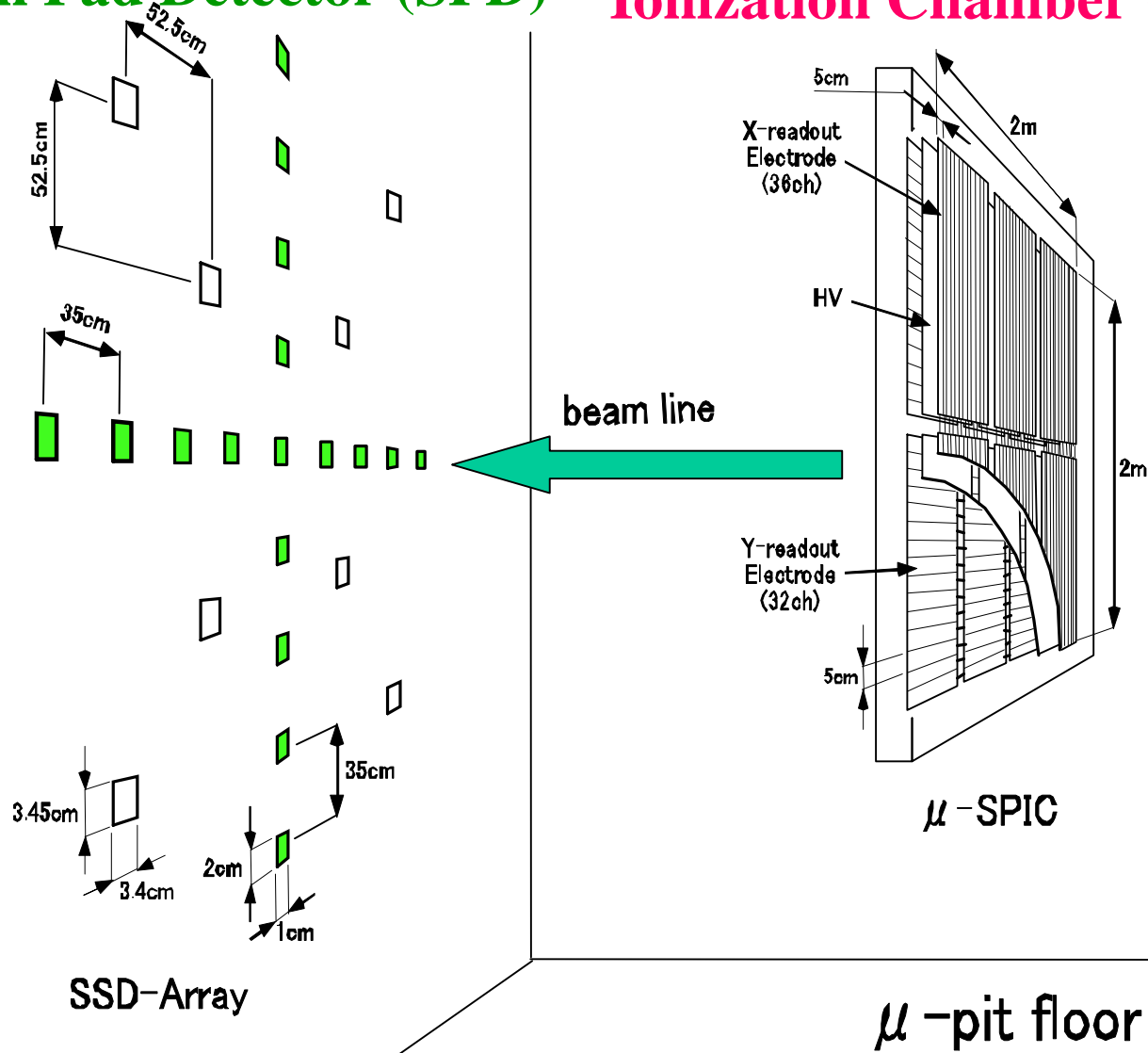


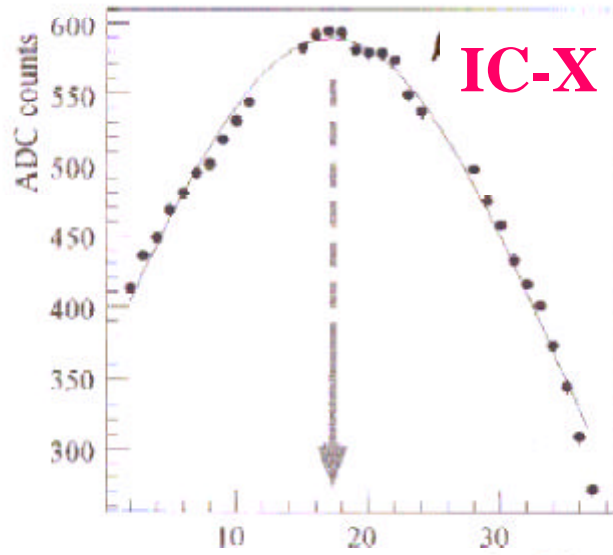
The error on the number of events estimate = **+5.7 -7.4 %**<sub>10</sub>

### 3. Muon monitor

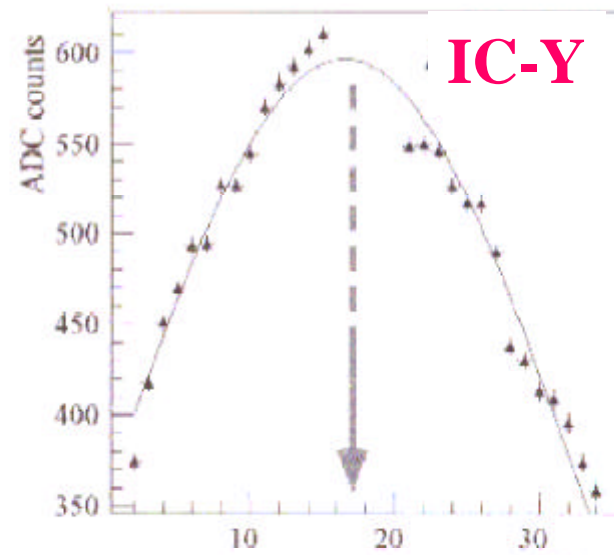
Silicon Pad Detector (SPD)

Ionization Chamber (IC)

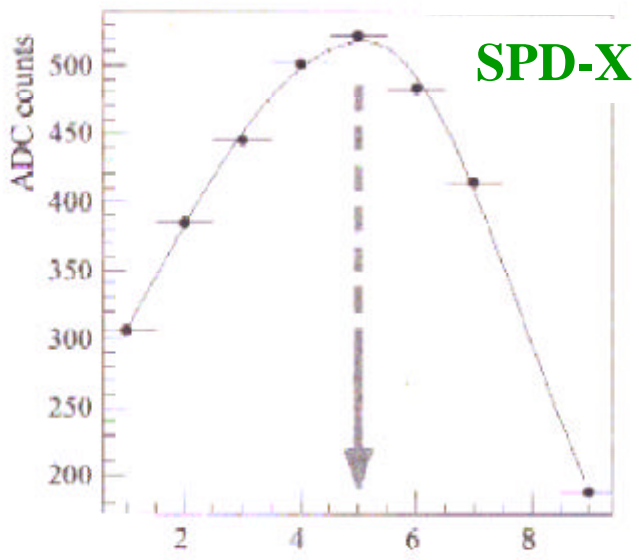




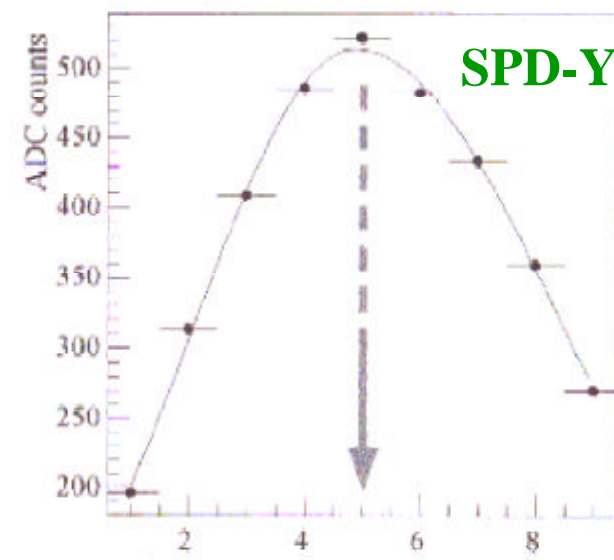
5cm/ch



5cm/ch

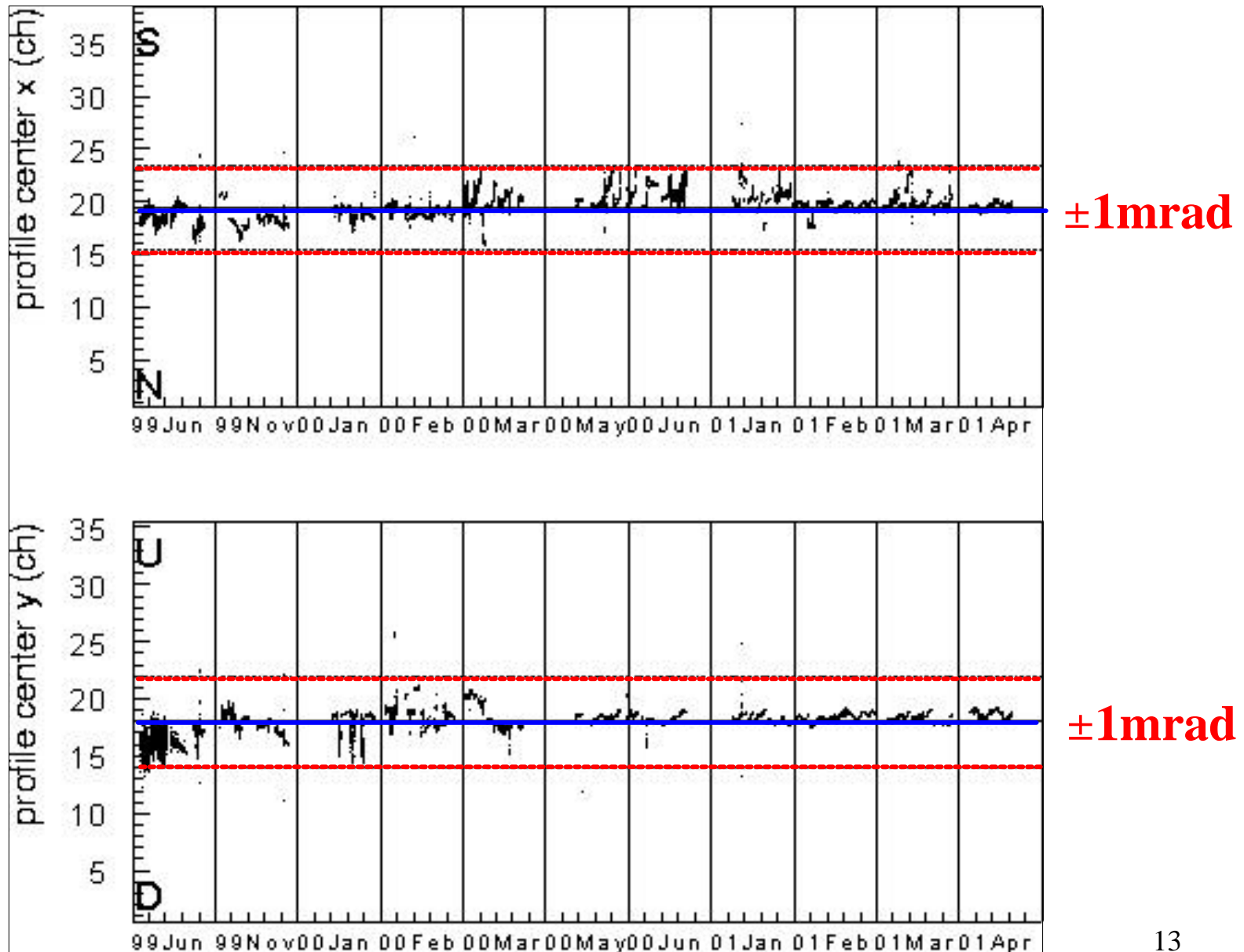


35cm/ch



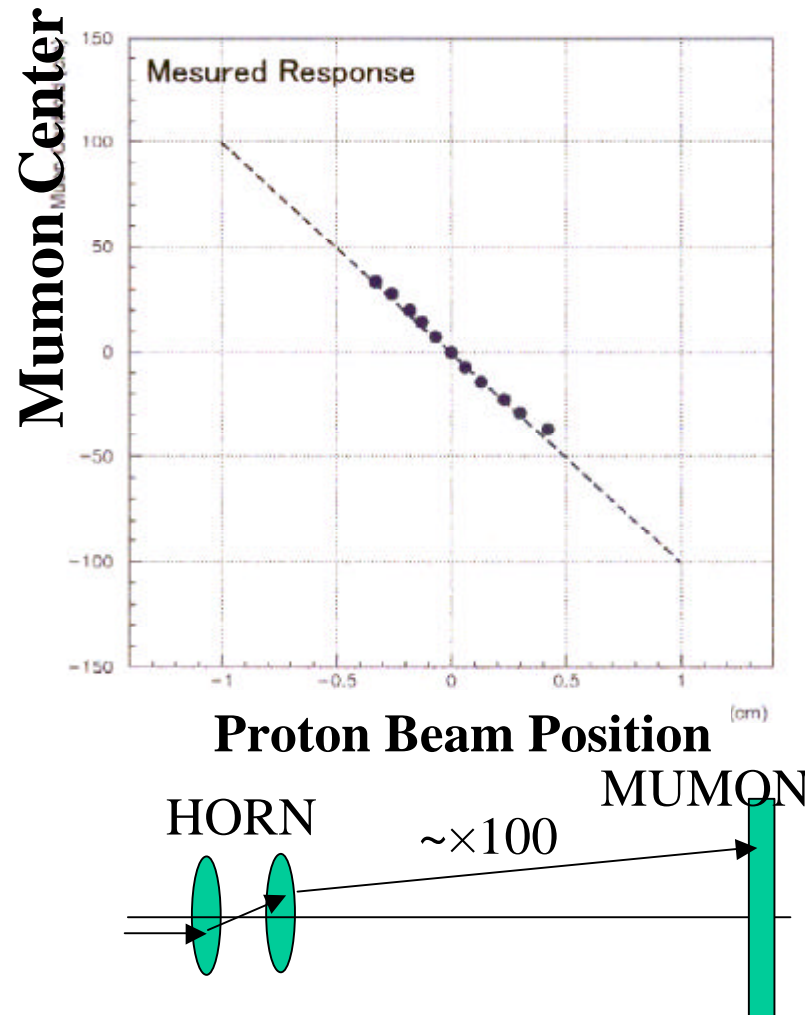
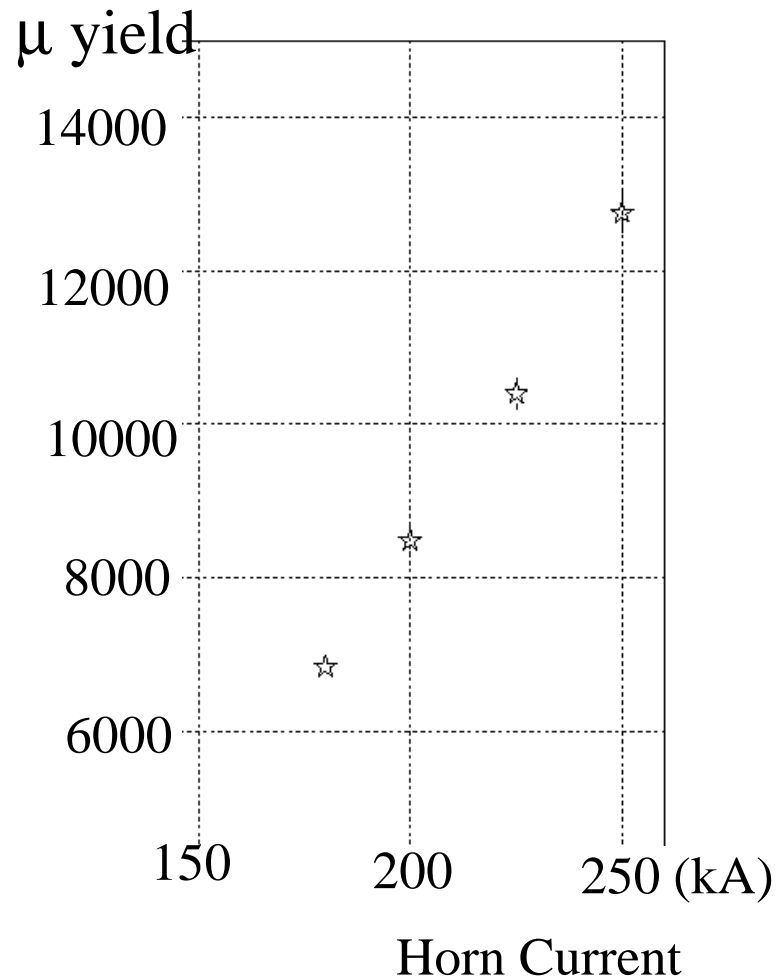
35cm/ch

Monitor the profile center of muons spill by spill.



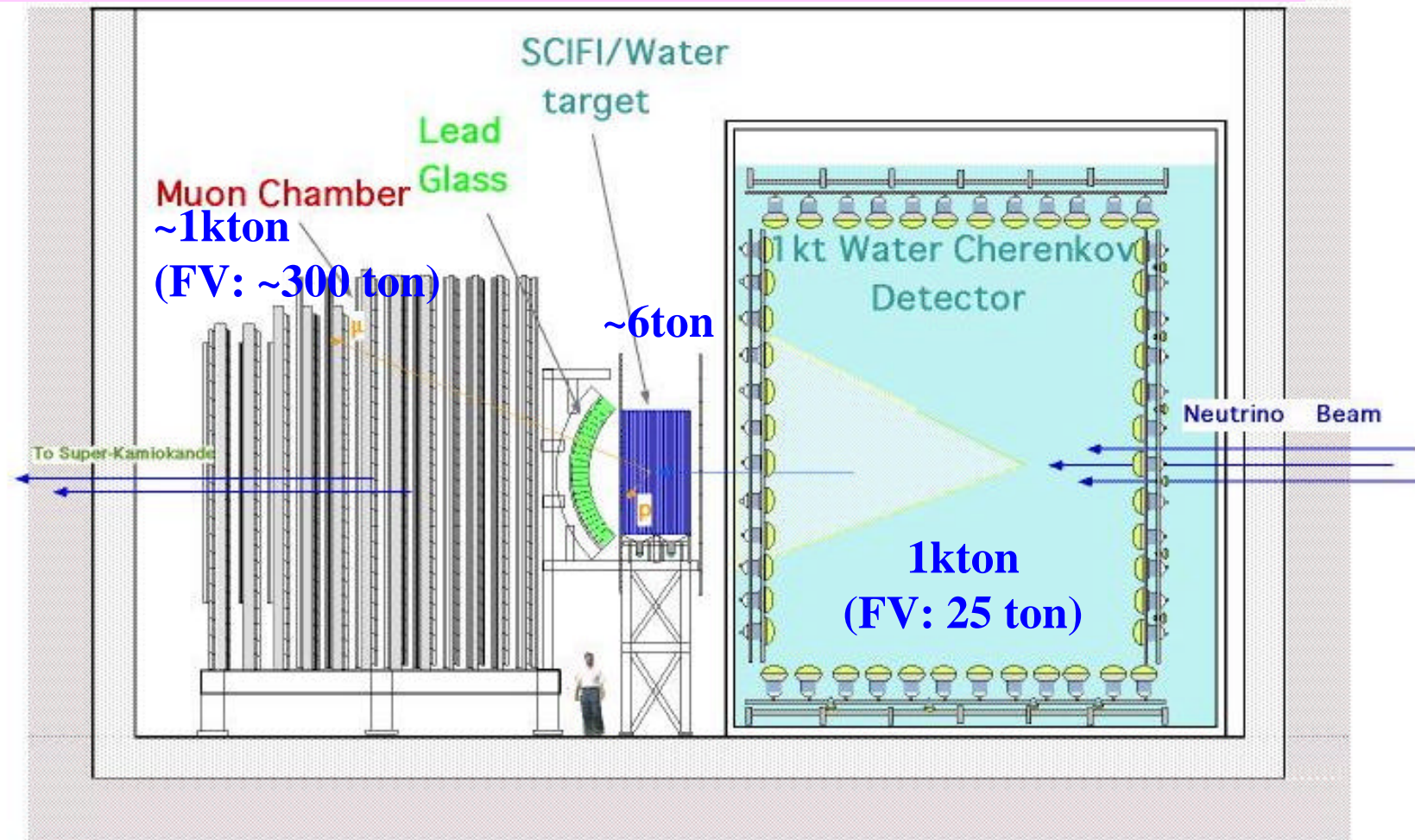
Each data point has a better than 0.1 mrad accuracy

- Sensitive to the muons w/  $\geq 5.5 \text{ GeV}/c$  ( $\sim E\nu > 2.5 \text{ GeV}$ ).
- Sensitive to the secondary pions direction, and also to the targeting efficiency (by charge information from the detectors).



## 4. Front n Detectors (Neutrino Monitor)

At KEK: 1kt Water Cherenkov, Scinti. fiber tracker,  
Lead Glass, Muon Range Detector (MRD)



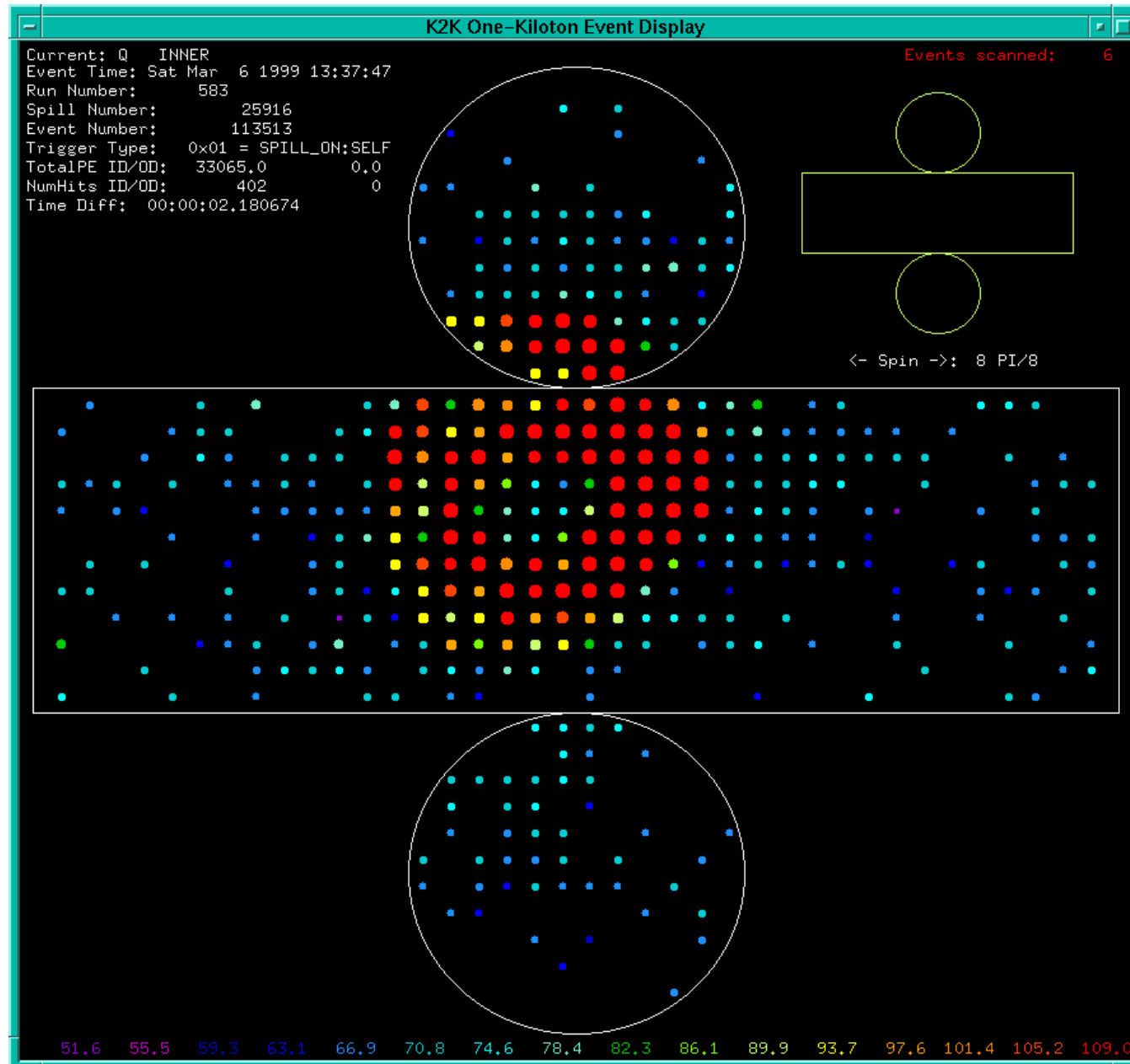


## *n detectors*

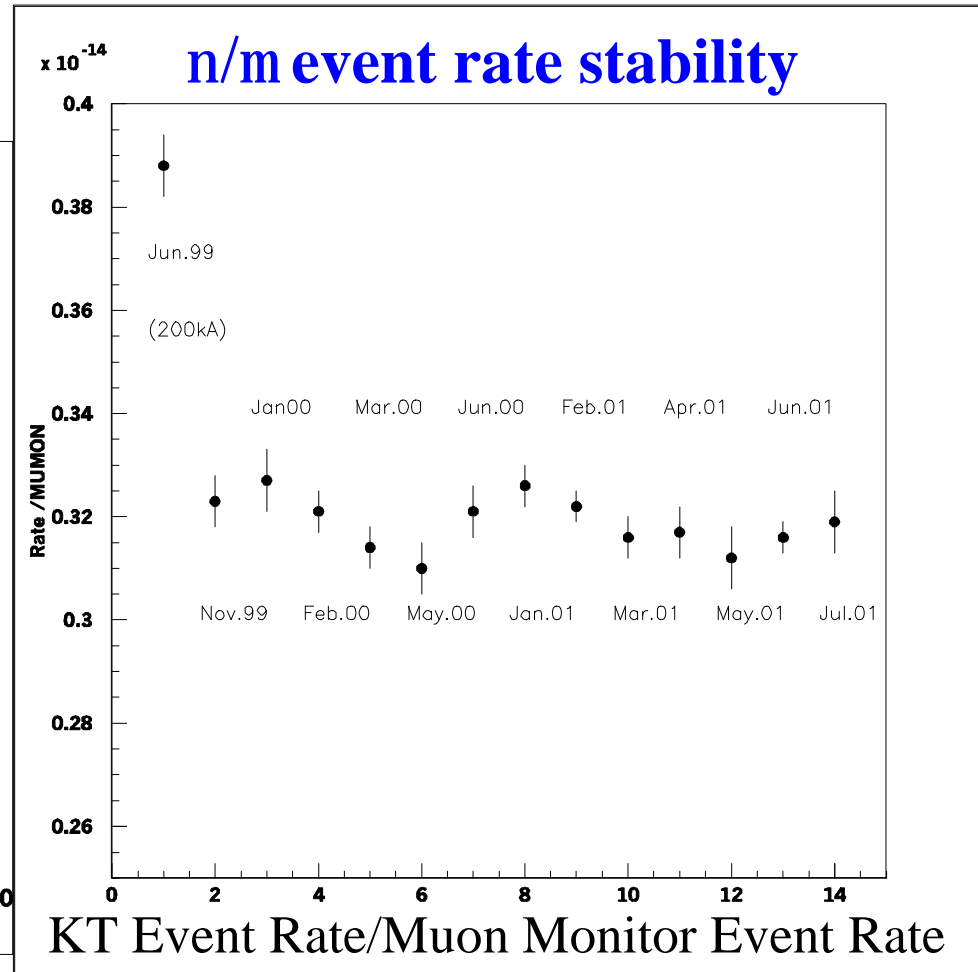
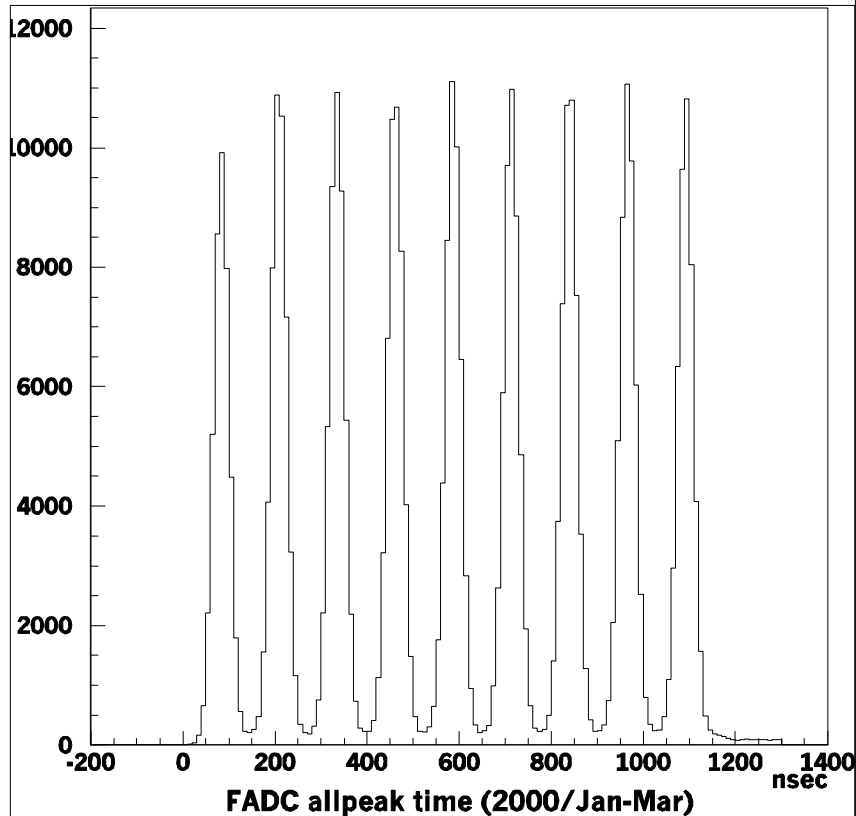
- 1KT Water Cherenkov Detector
  - Event Rate, Spectrum,  $\nu$  interaction, the stability
- MRD (Muon Range Detector)
  - Direction of  $\nu$ , Stability of Event Rate and Spectrum
- SciFi (Scintillation Fiber/Water Target Sandwich Detector)
  - Event Rate, Spectrum,  $\nu$  interaction
- Lead Glass
  - $\nu_e$  measurement
- (Full Active Scintillator Tracker) – 2003
  - Spectrum,  $\nu$  interaction



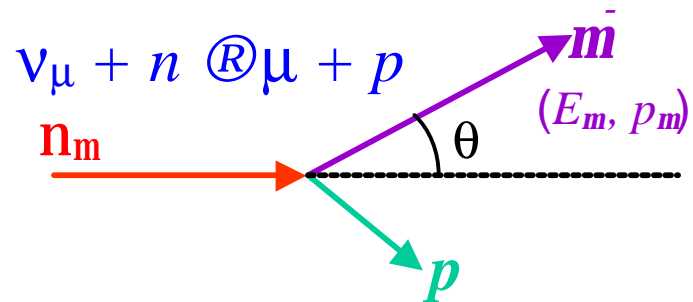
# *1kt Water Cherenkov detector*



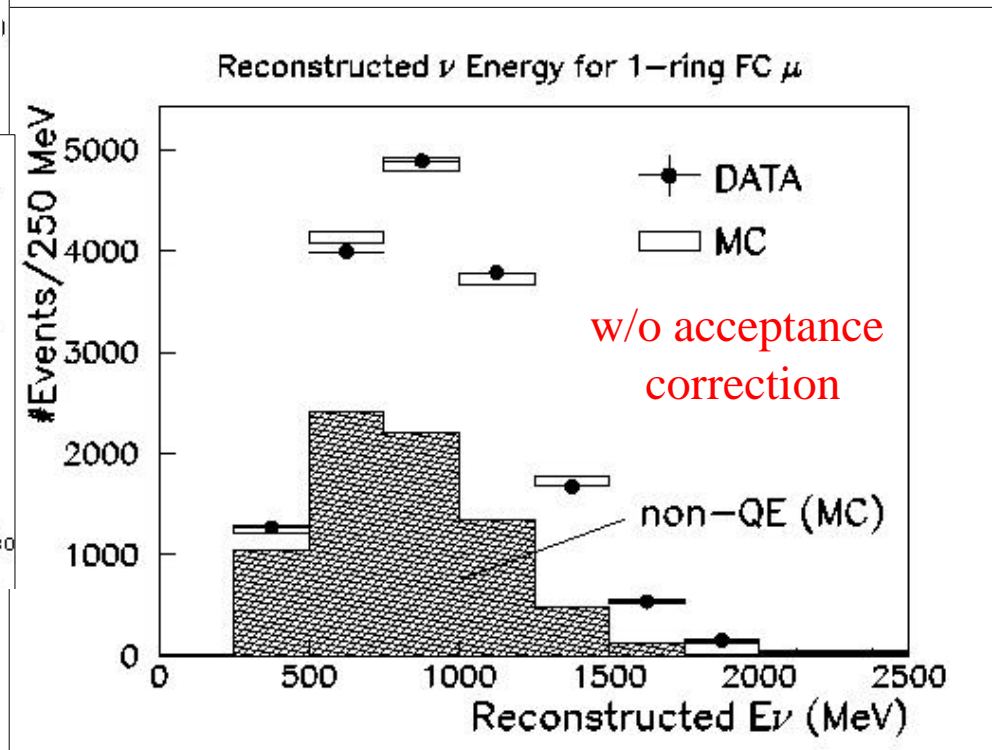
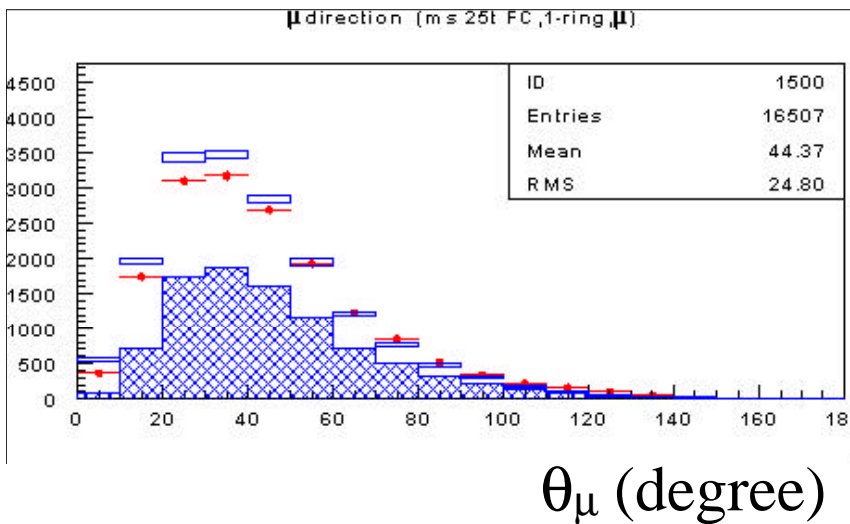
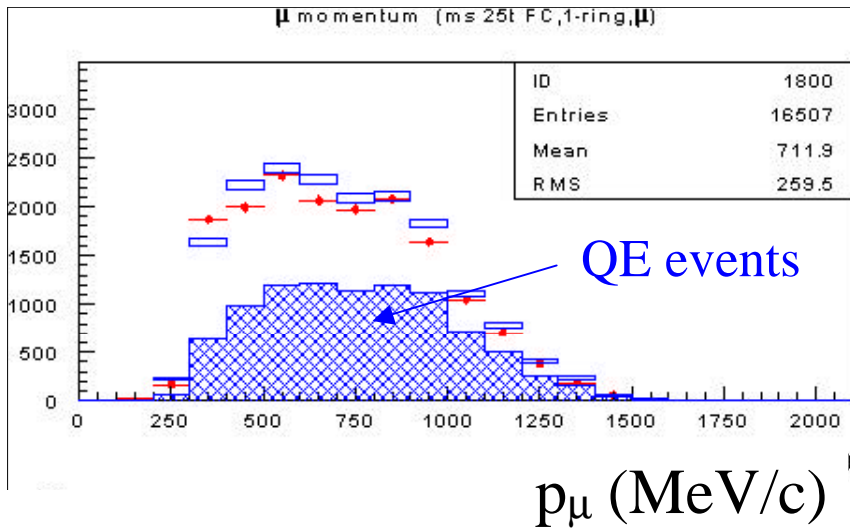
## Beam structure (9 bunches in one spill)



# Neutrino Energy Spectrum (assuming Quasi-Elastic interaction)



$$E_n = \frac{m_N E_m - m_m^2/2}{m_N - E_m + p_m \cos \theta_m}$$

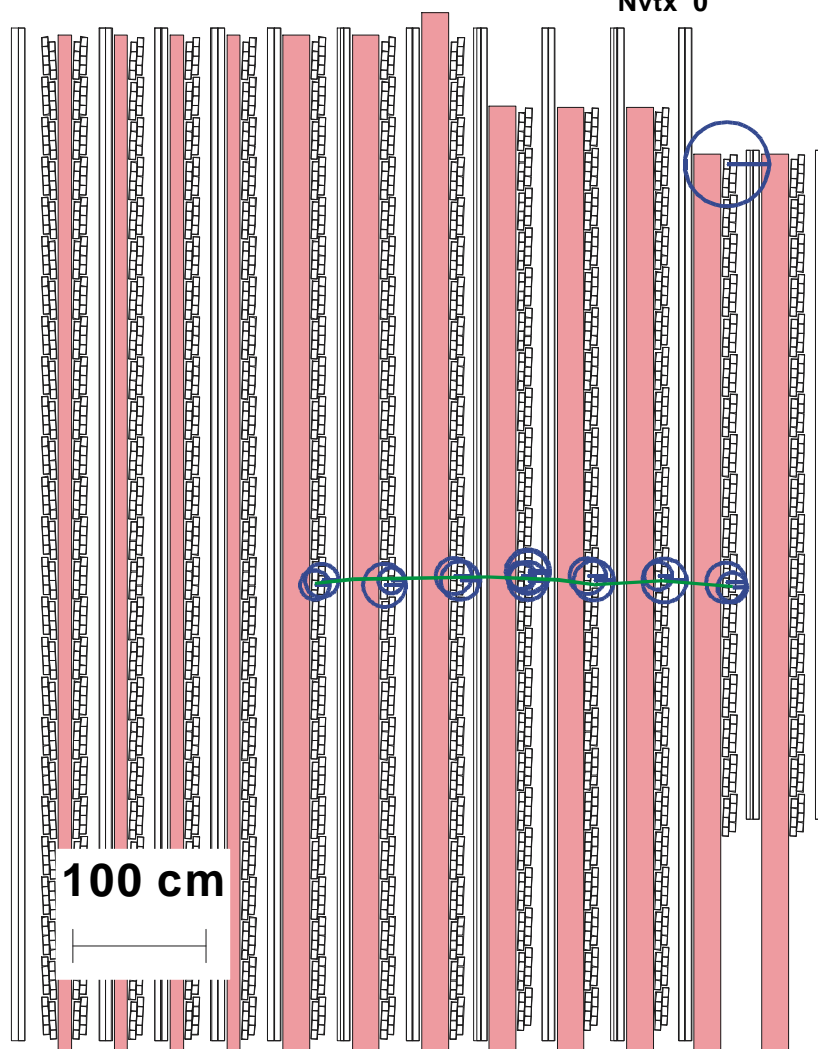
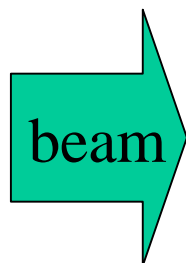


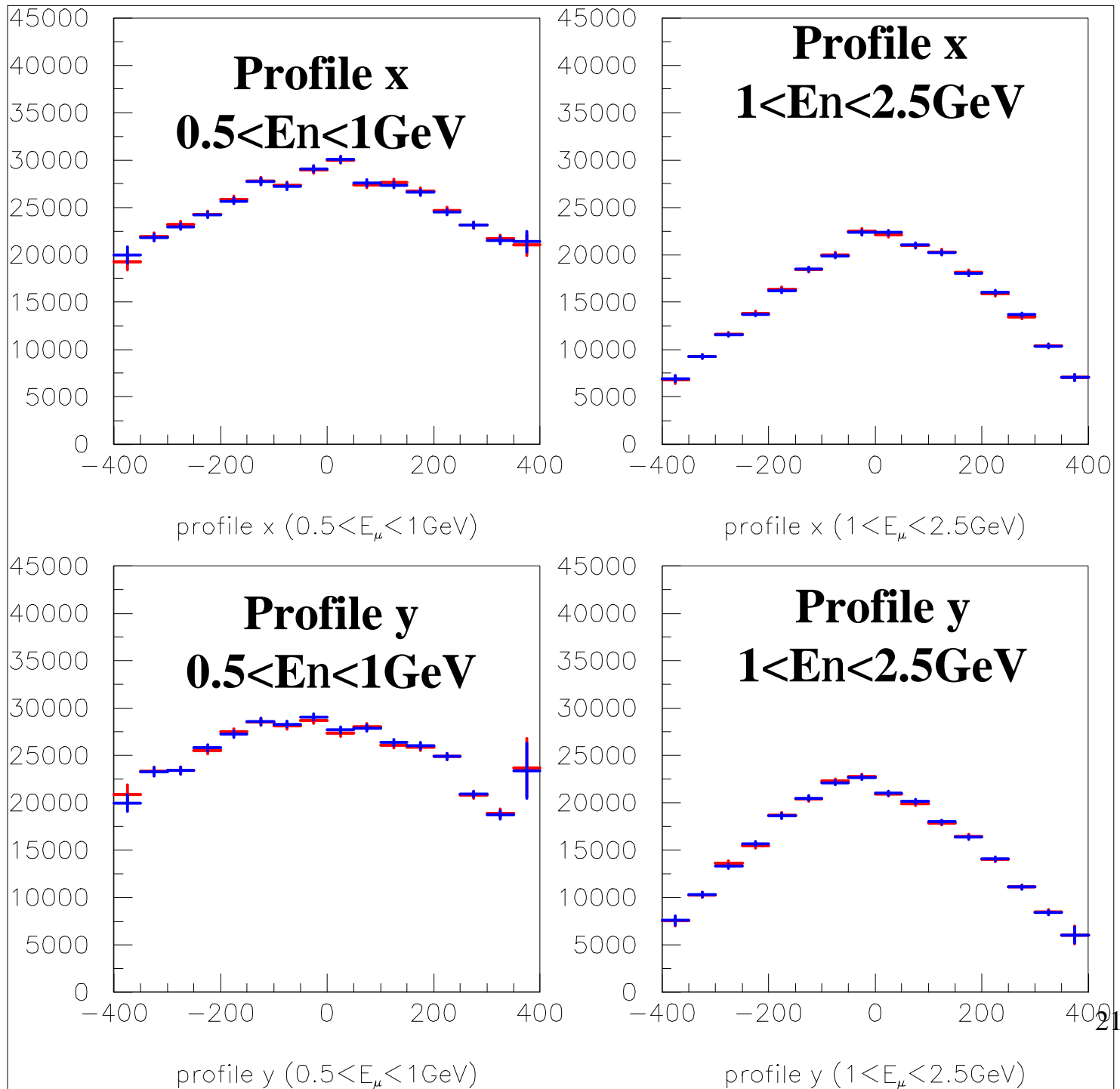
# MRD Events

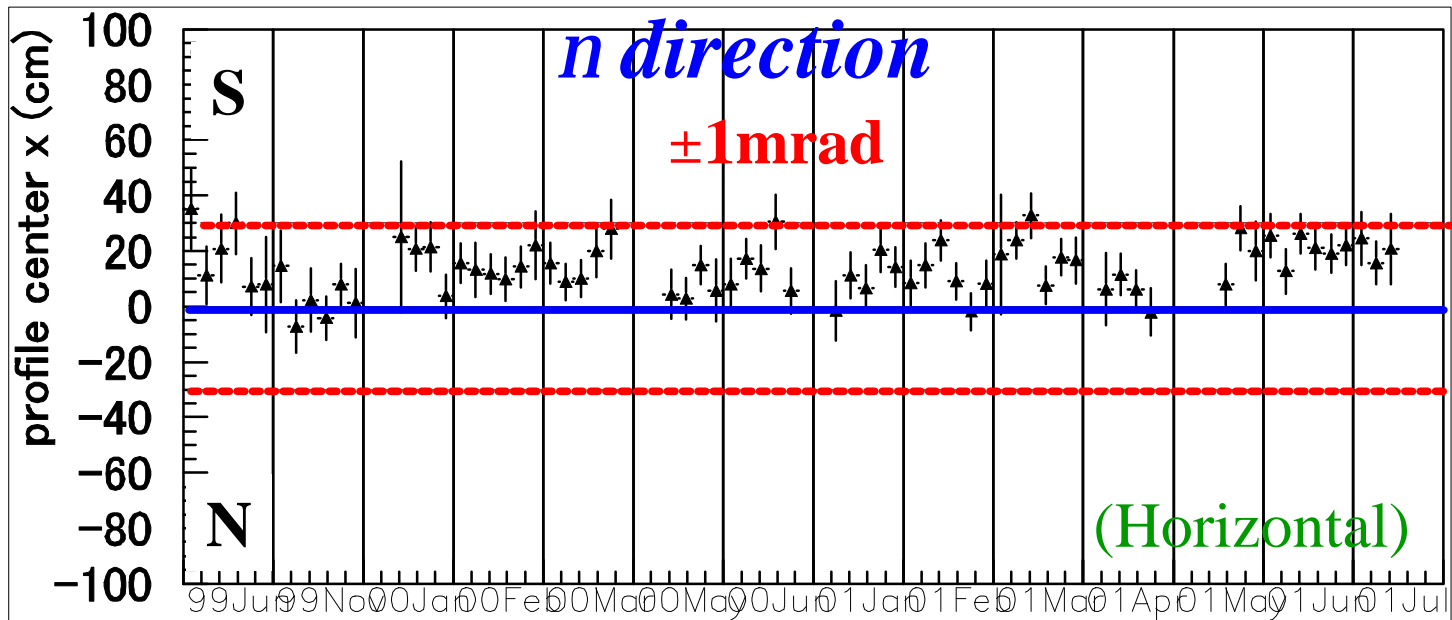
Run 1244 Spill 20799 TRGID 1

99 6 22 17 48 56 0

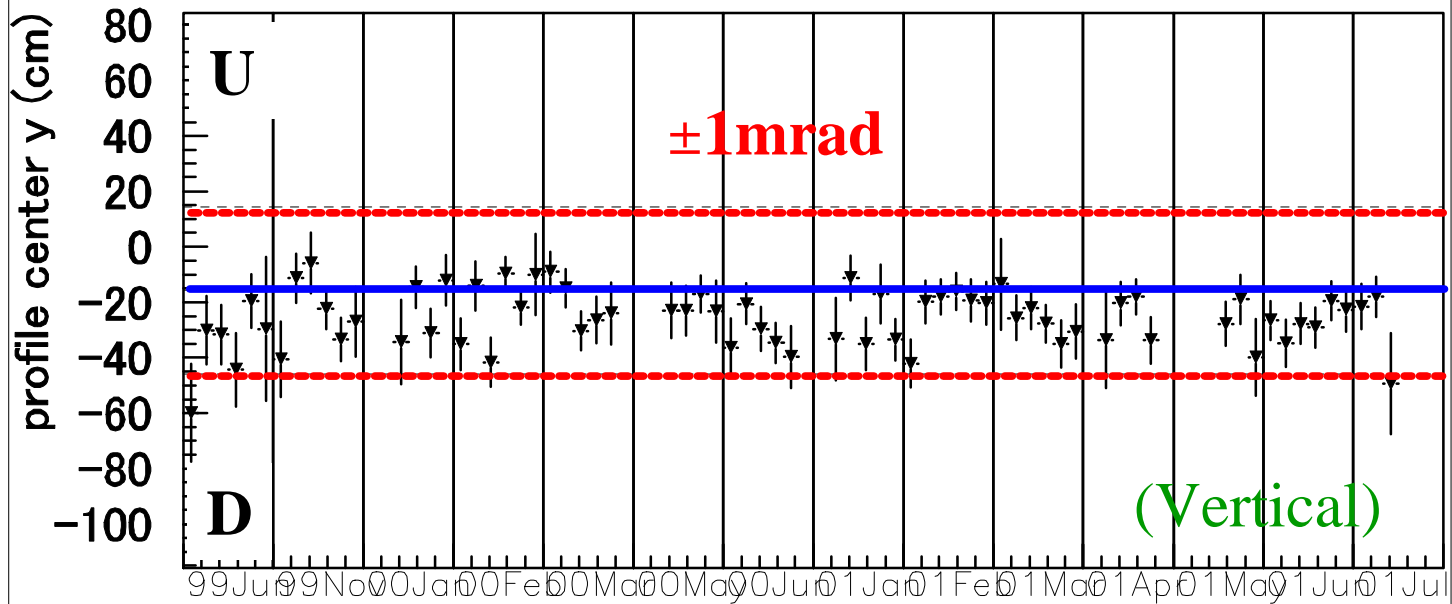
Nvtx 0





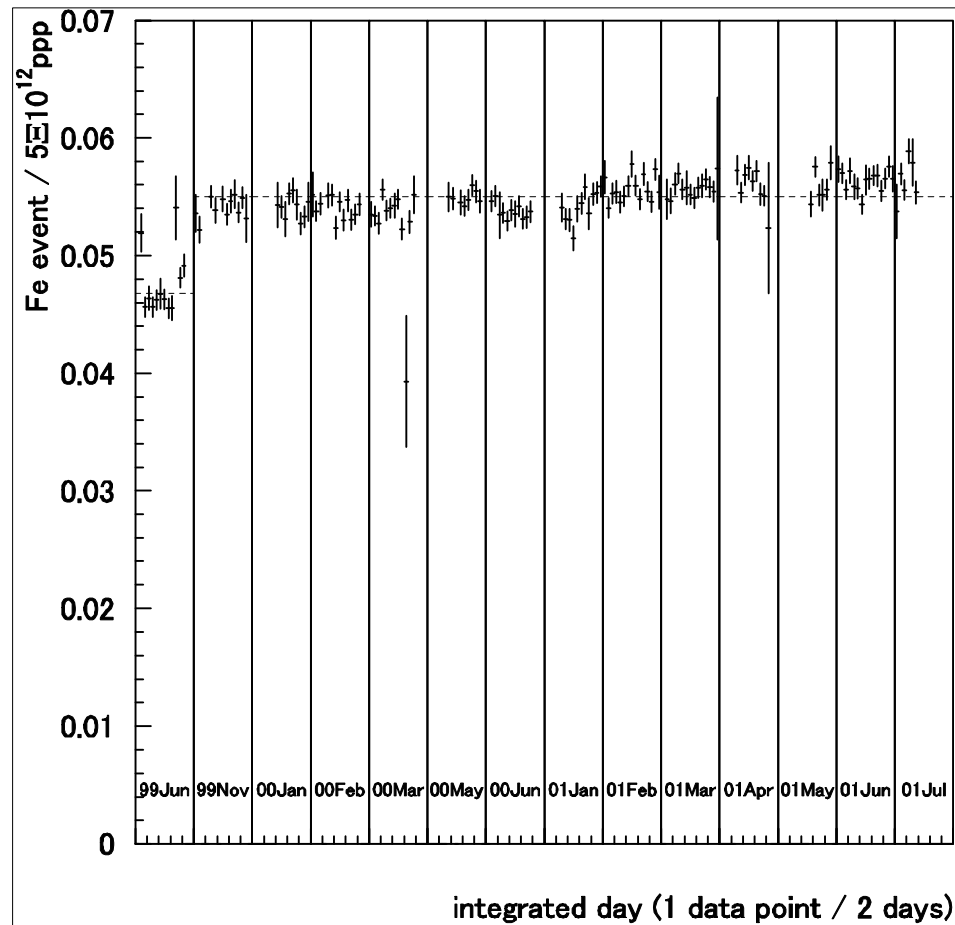


integrated day (1 data point / 5 days)

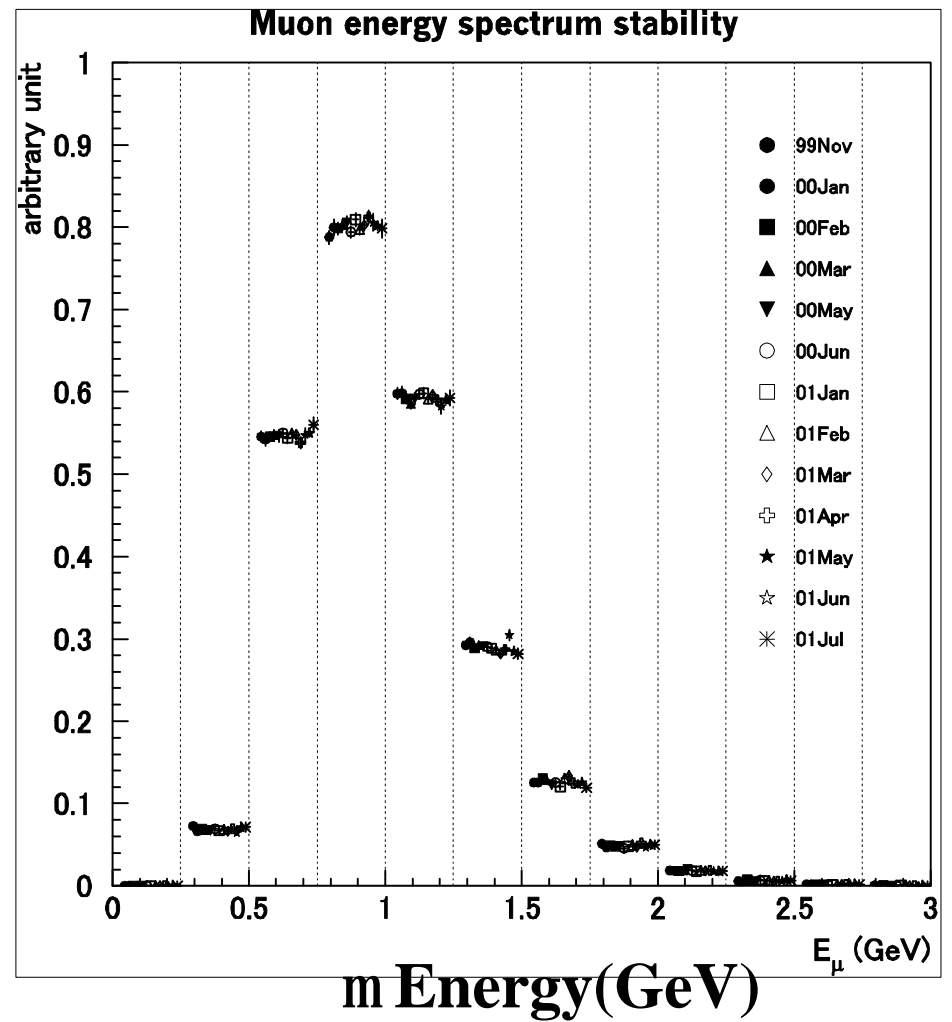


integrated day (1 data point / 5 days)

## Event Rate stability



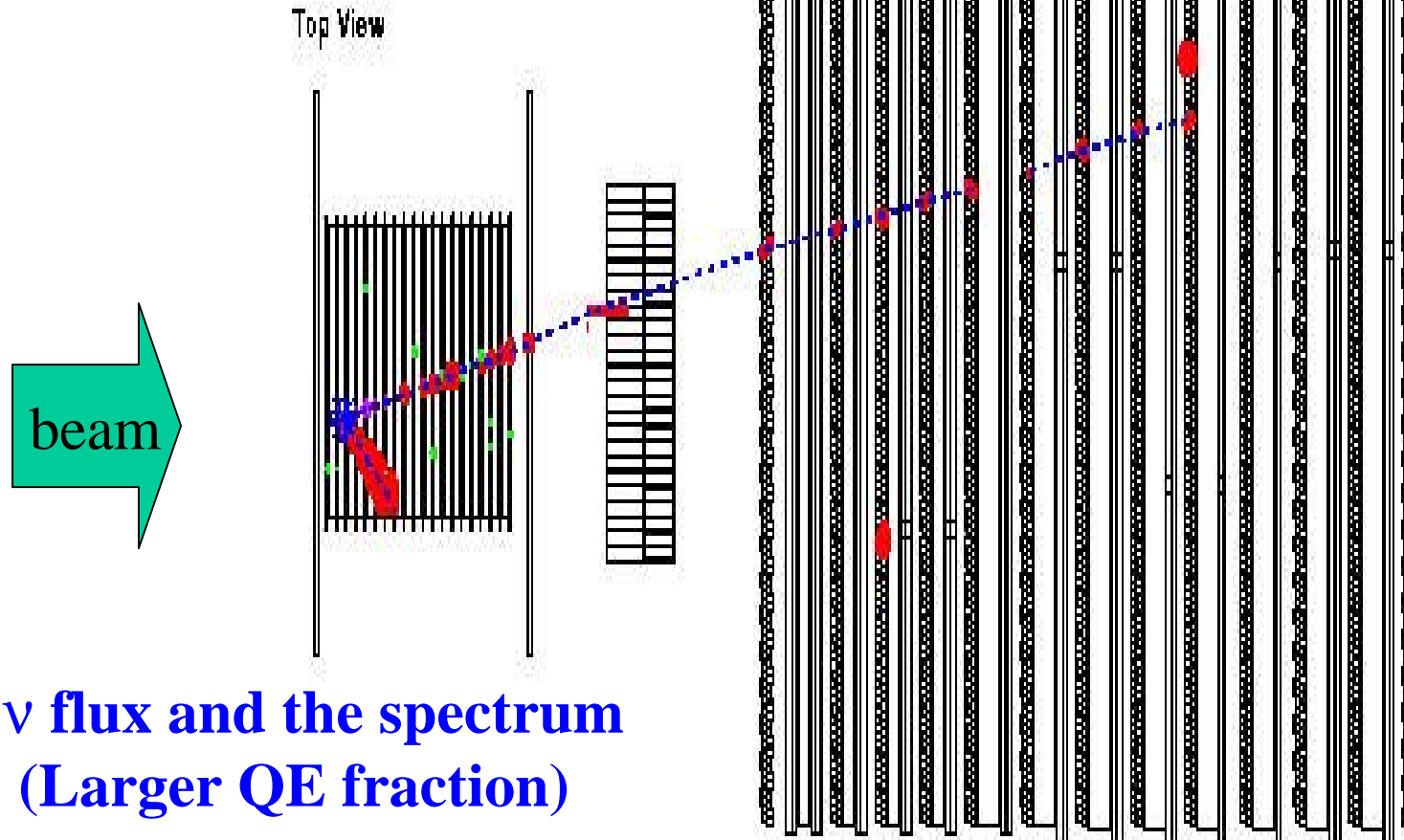
## n spectrum stability



# SciFi Events

Sun 2279 Spill 18568 TRGID 1

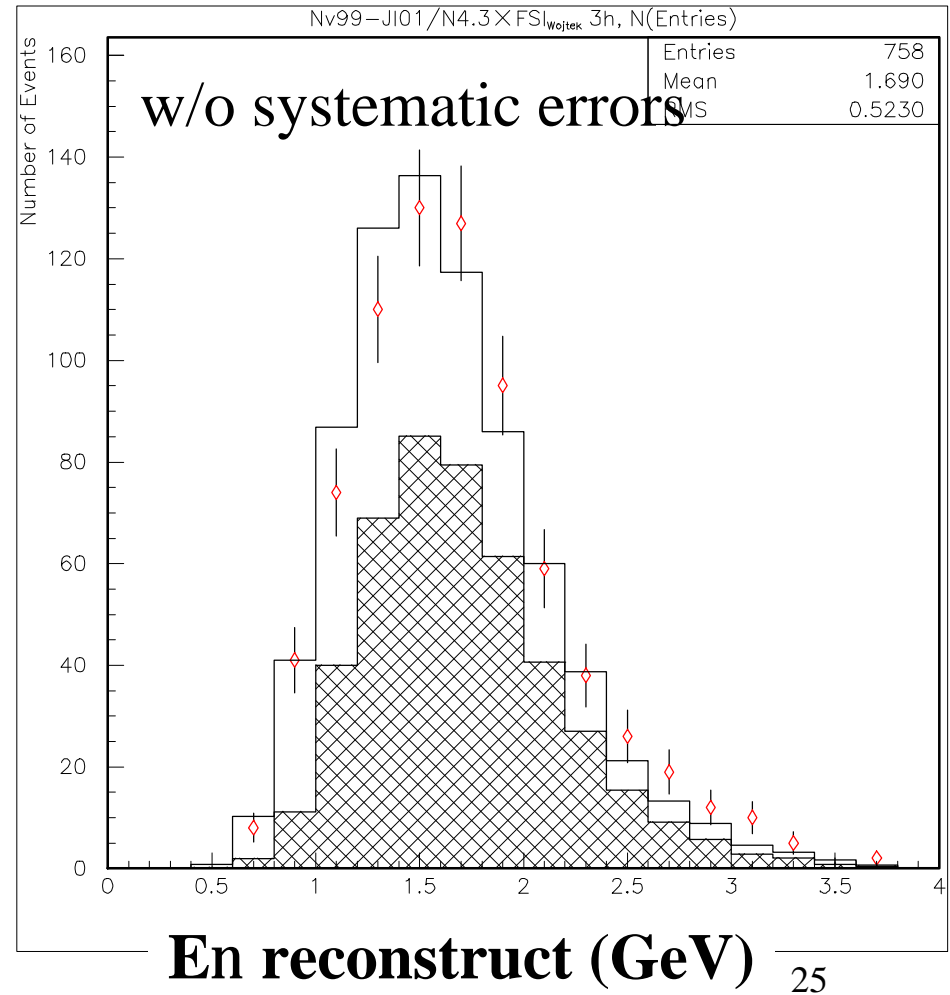
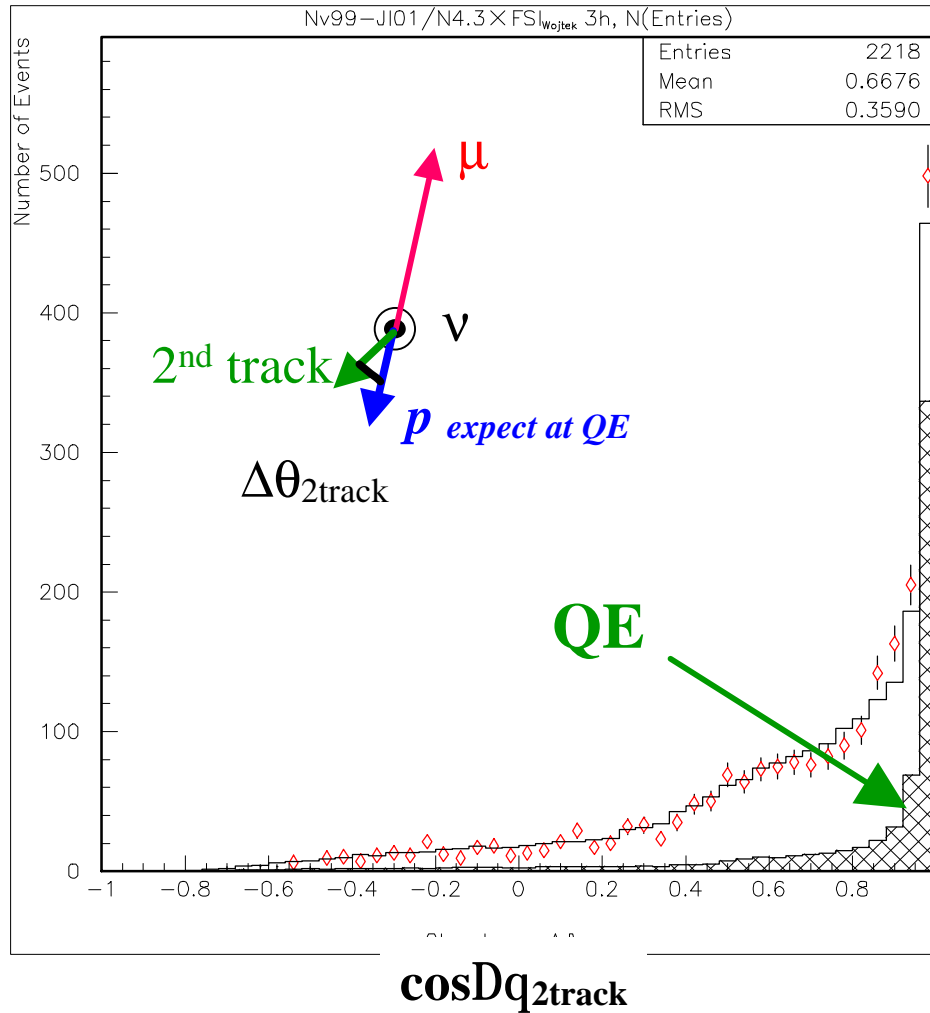
100 1 24 14 21 23 0  
Nvtx 0



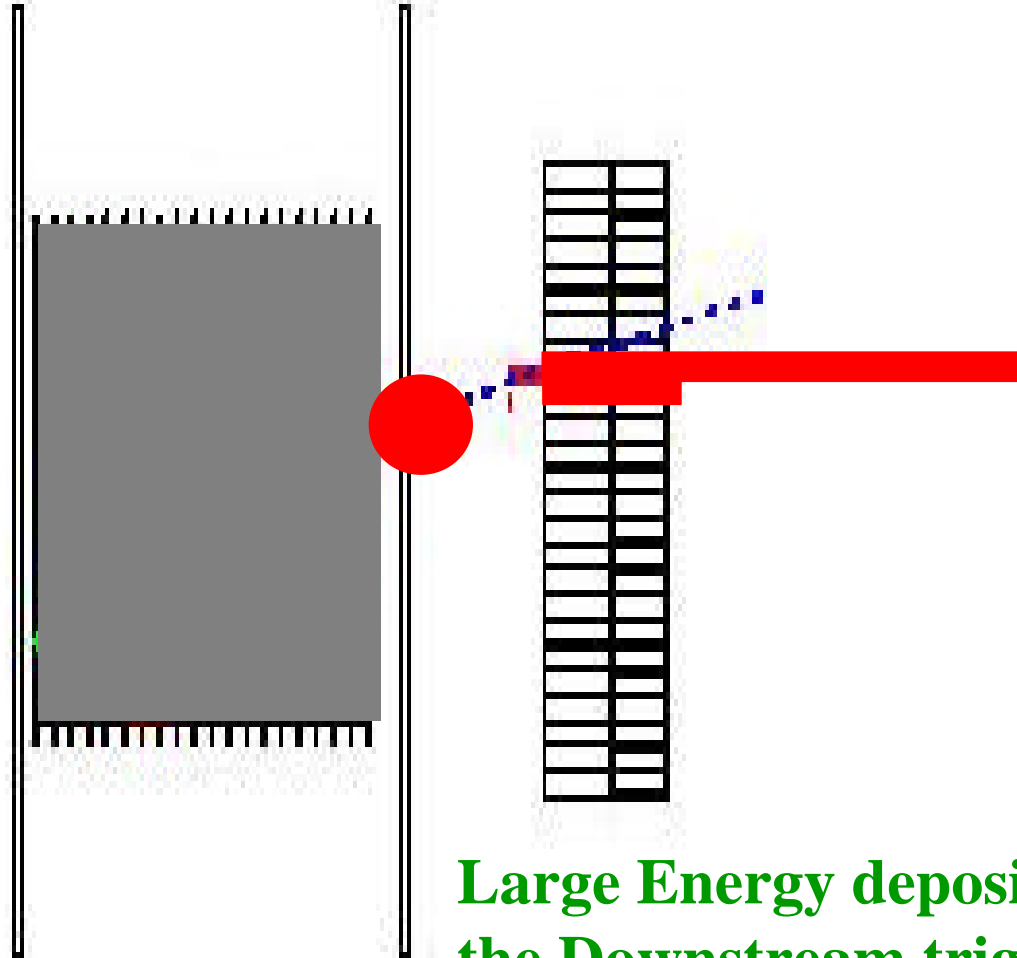


# QE Enriched Sample

$$\Delta\theta_{2\text{track}} < 25^\circ$$

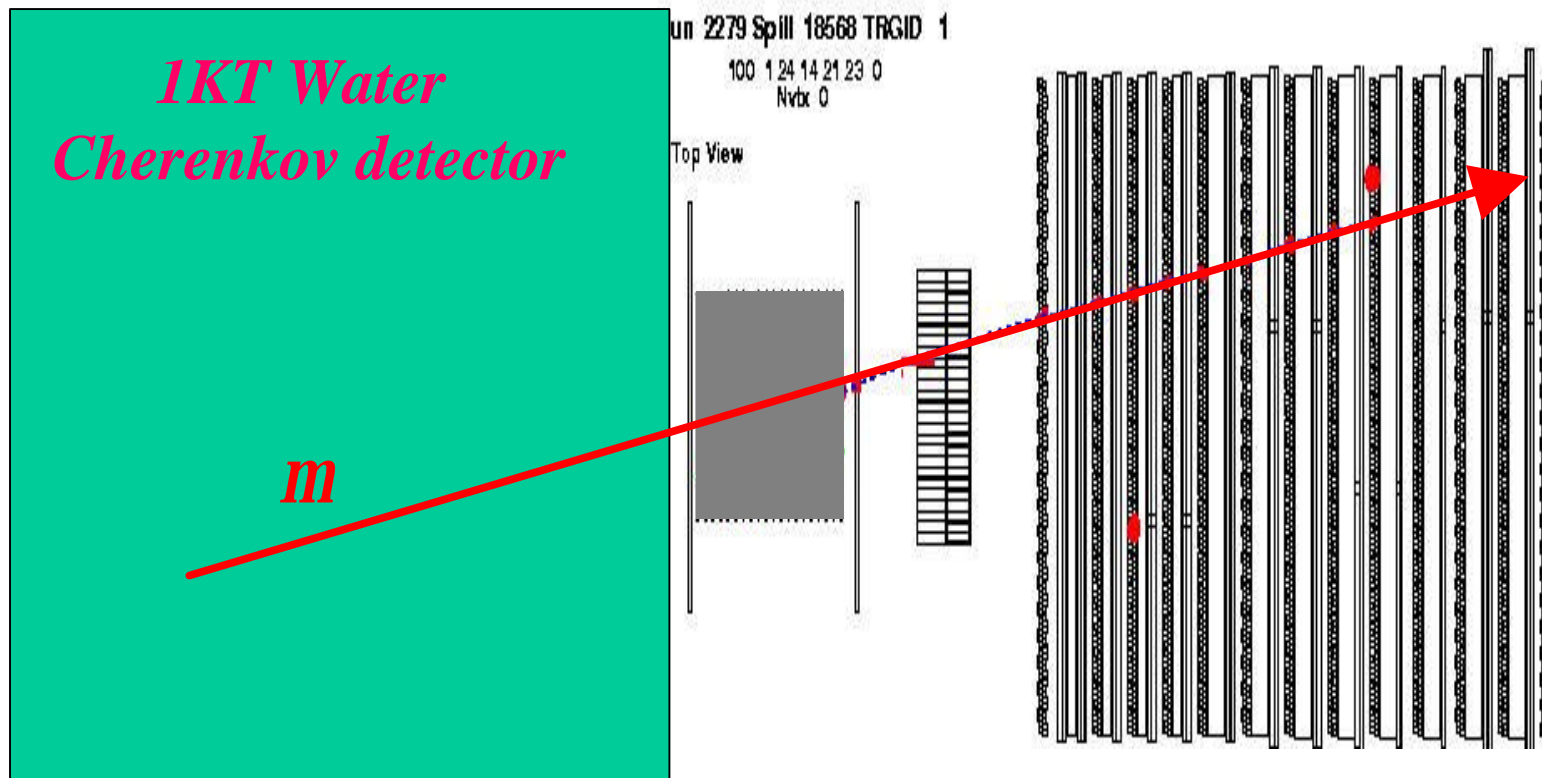


*$n_e$  measurement (under analysis)*



**Large Energy deposit on  
the Downstream trigger counter  
and Lead-Glass**

$n_m$  from  $K$  decay contribution (under analysis)



*Look for a very high energy  $m$*

# Full Active Scintillator Tracker

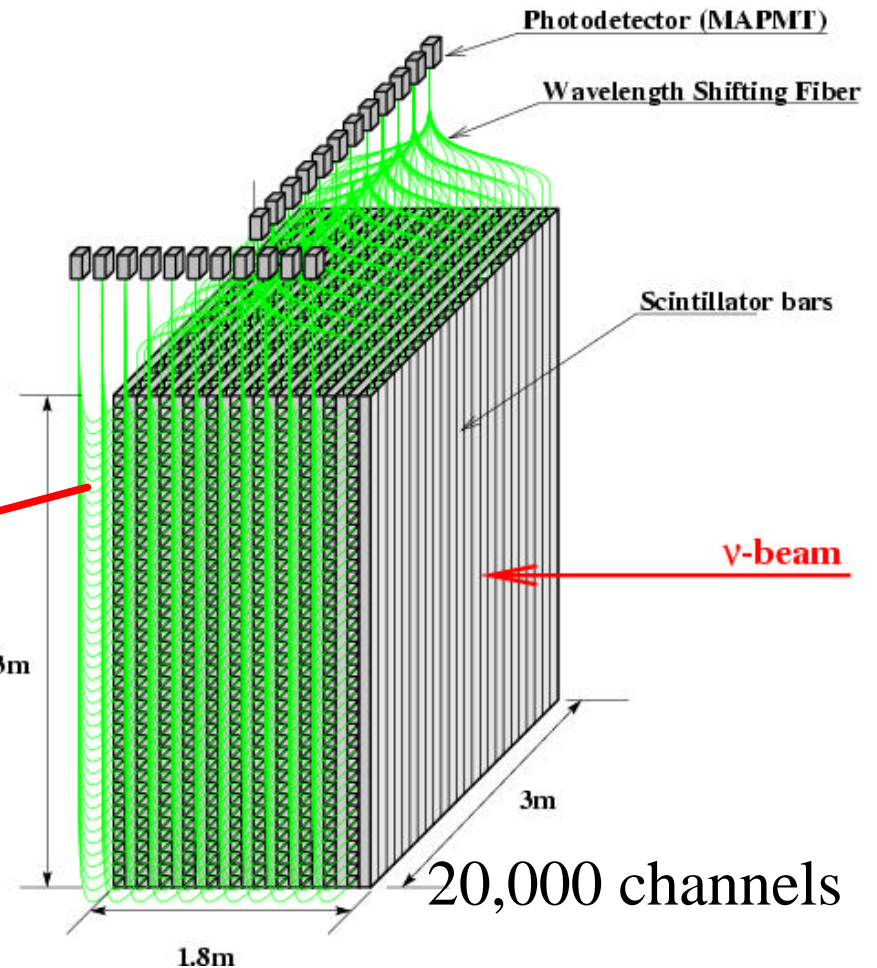
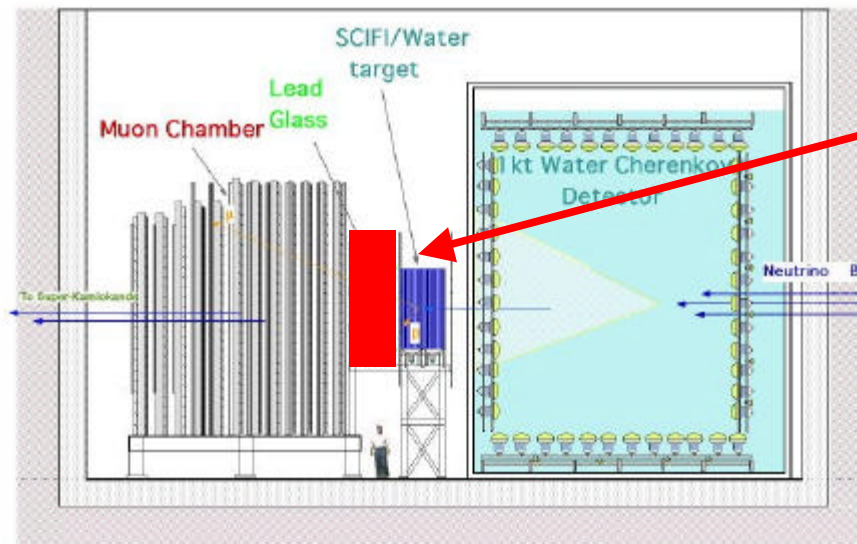
- K2K will install another brand new near detector **in summer 2003** to measure low energy neutrino flux more precisely and to study neutrino interaction in detail.

$$L=250\text{km}, Dm^2=3 \times 10^{-3}$$

$$E_\nu \sim 0.6\text{GeV}$$

## Full Active (solid) Scintillator Tracker

- High efficiency for a short (<4cm) track.
- Detect a proton down to 350 MeV/c.
- PID ( $p/\pi$ ) and the proton momentum measurement by  $dE/dx$ .
- Fine segments ( $1 \times 2 \times 300\text{cm}^3$ ).



## Summary

- K2K beam has been operated stably for more than two years.
- Pion Monitor successfully estimate the “Far/Near Ratio”.
- Muon Monitor has been watching the direction of muon for a long run period, and guarantee the direction of  $\nu$  beam and the target efficiency.
- Neutrino Detectors measure:
  - the stability of the  $\nu$  beam
  - the direction of the  $\nu$  beam
  - the Event Rate (Integrated flux)
  - the Spectrum information<sup>(\*)</sup>
  - the  $\nu$  interaction information<sup>(\*)</sup>

**(\*): for a long baseline analysis (not for the absolute measurement)**

# Supplement

