Status of the long baseline neutrino experiment from KEK to Super-Kamiokande (K2K)

H. Sobel

Feb. 24, 1999

Participating institutions

- KEK, High Energy Accelerator Research Organization
- ICRR, University of Tokyo
- Kobe University
- Niigata University
- Okayama University
- Tohoku University
- Chonnam National University
- Dongshin University
- Korea University
- Seoul National University
- Boston University
- Los Alamos National Laboratory
- State University of New York, Stony Brook
- University of California, Irvine
- University of Hawaii
- University of Washington

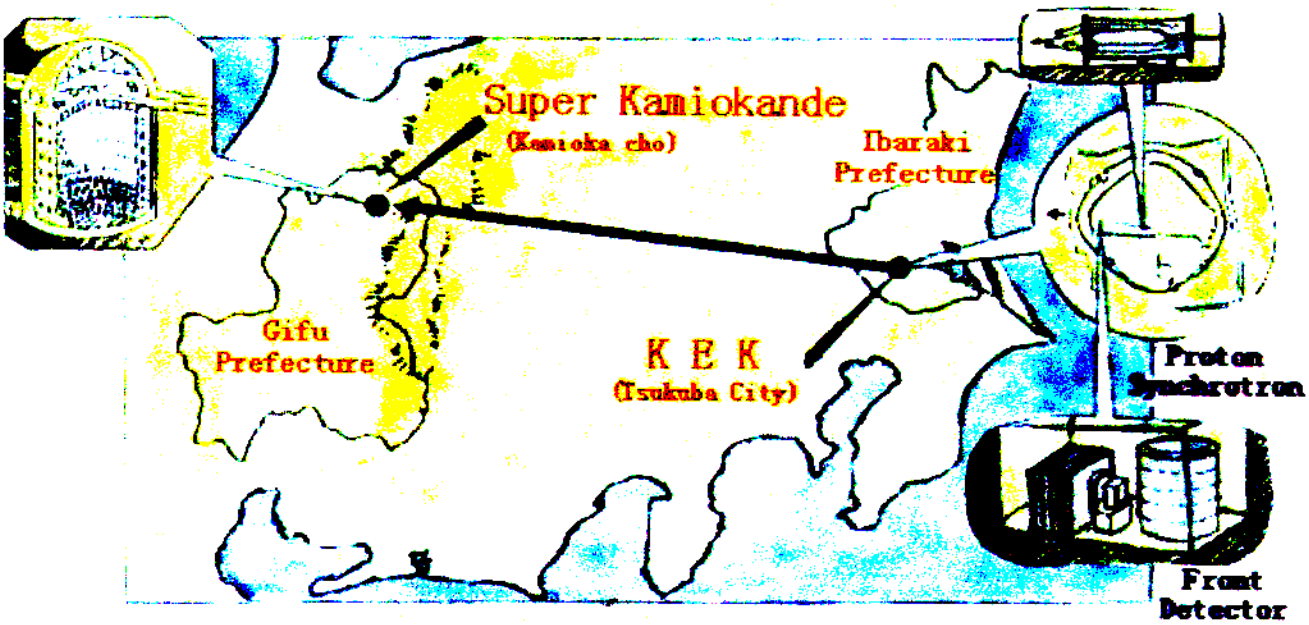
$i = 16$

Experimental goals

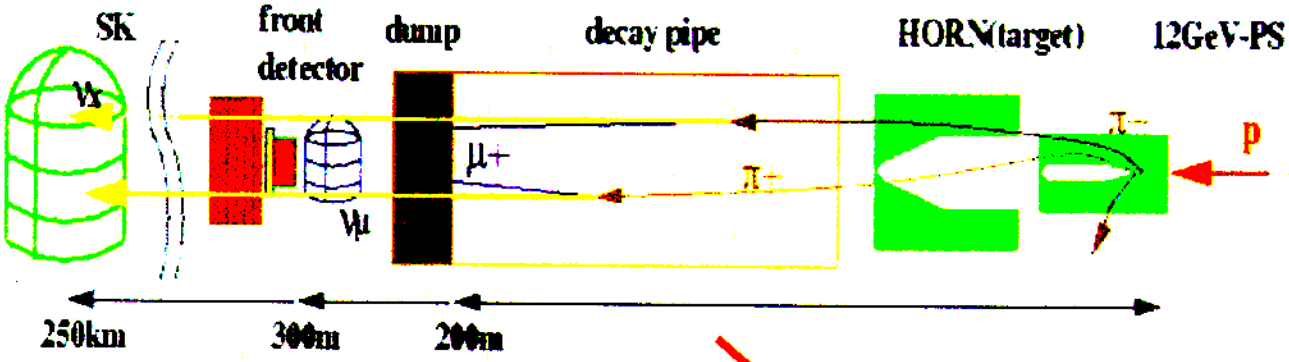
- Confirmation of $\nu_\mu \rightarrow \nu_x$ oscillations observed by SK for atmospheric neutrinos. @ KEK, absolute flux ≤ 10%
  flavor $\nu_\mu \sim 95\%$, $\bar{\nu}_\mu \sim 4\%$, $\nu_e \sim 1\%$
- If oscillations are observed - determine δm^2 from observed distortion of spectrum of neutrinos interacting in SK.
- Check possibility of $\nu_\mu \rightarrow \nu_e$ by searching for ν_e appearance. But, CHOOZ already more sensitive here
- High statistics study of ν_μ interactions in water in 1 GeV energy range.

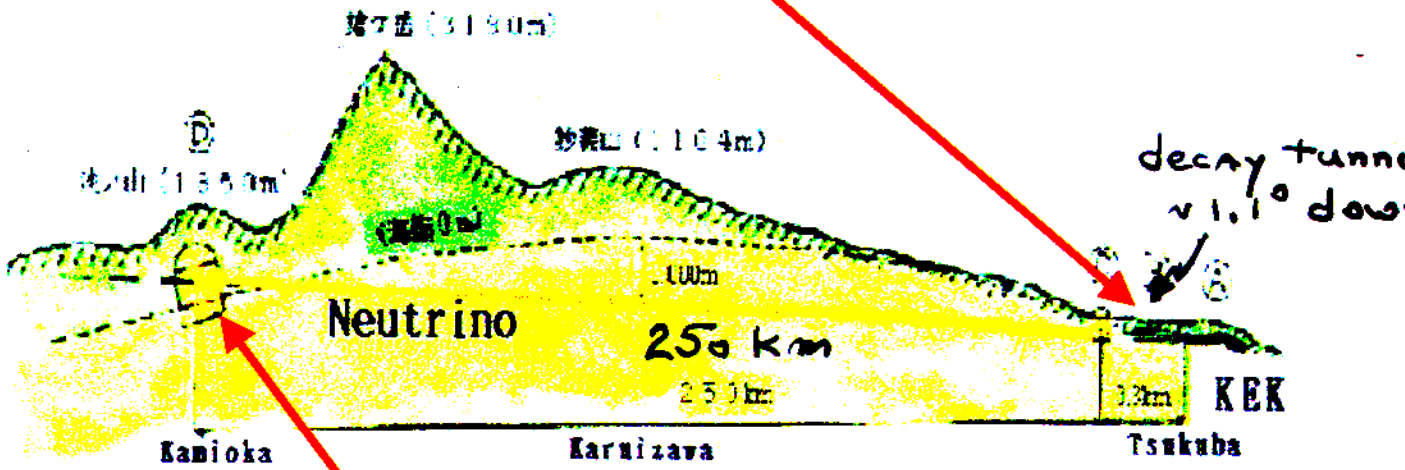
also $\pi^0/CC\mu \rightarrow$ Super K

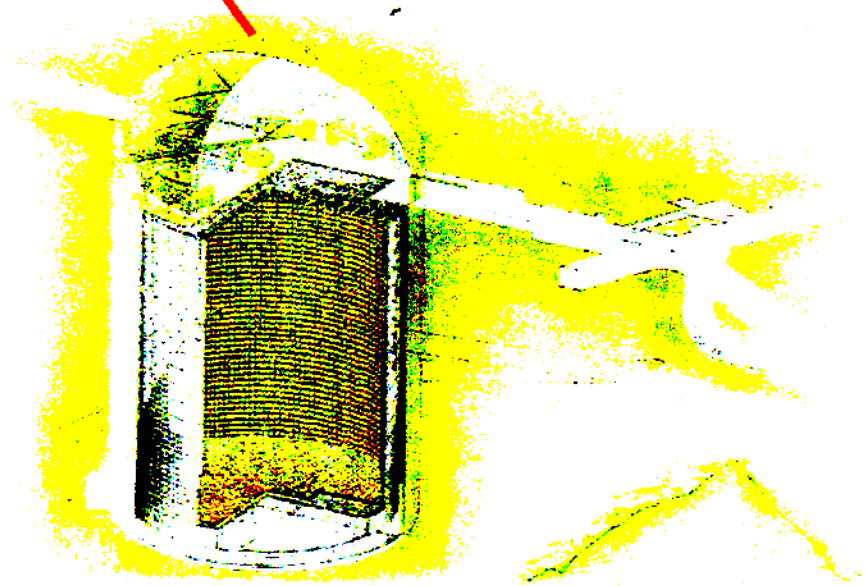
ν Beam to SuperK



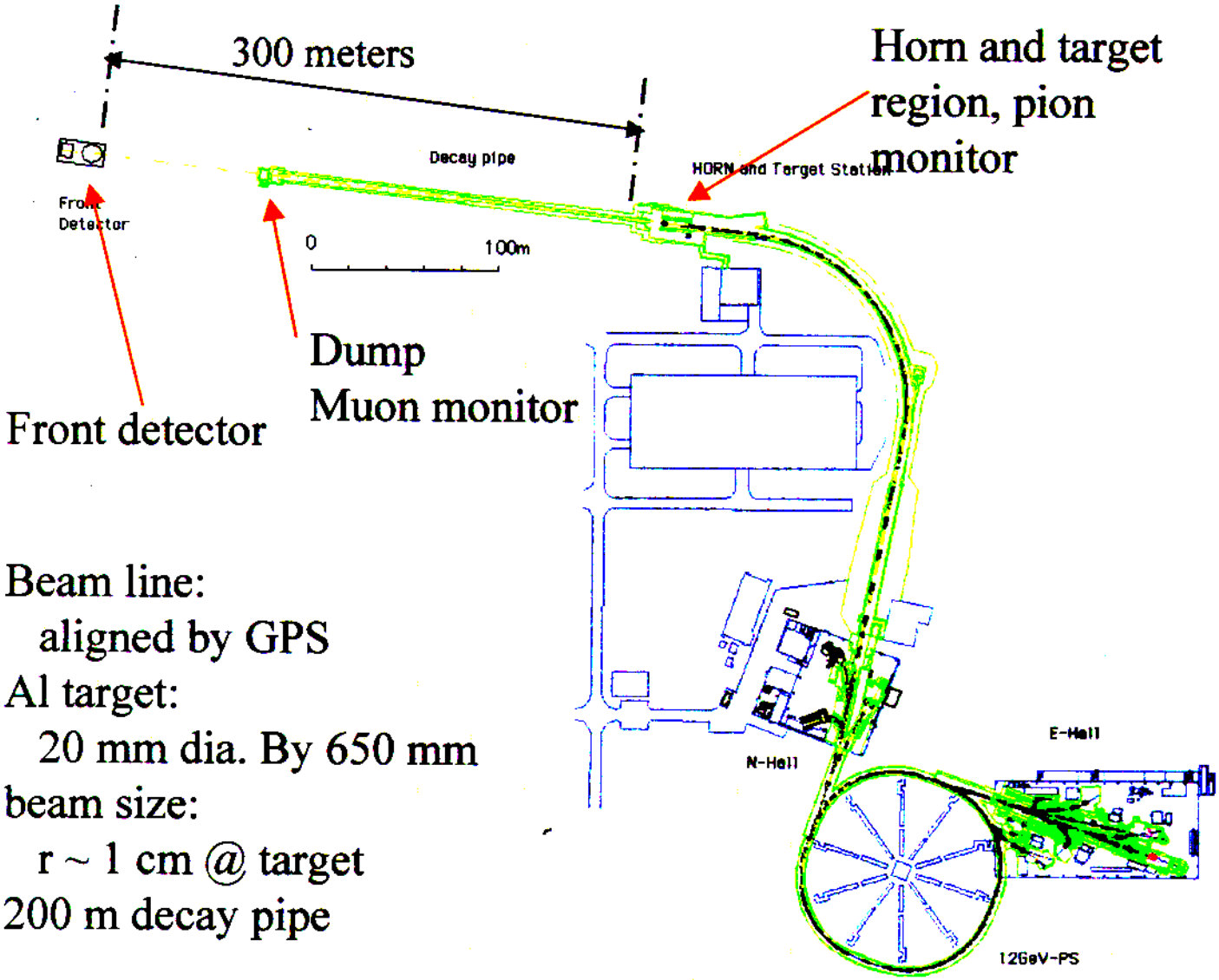
Experimental layout







Beam line

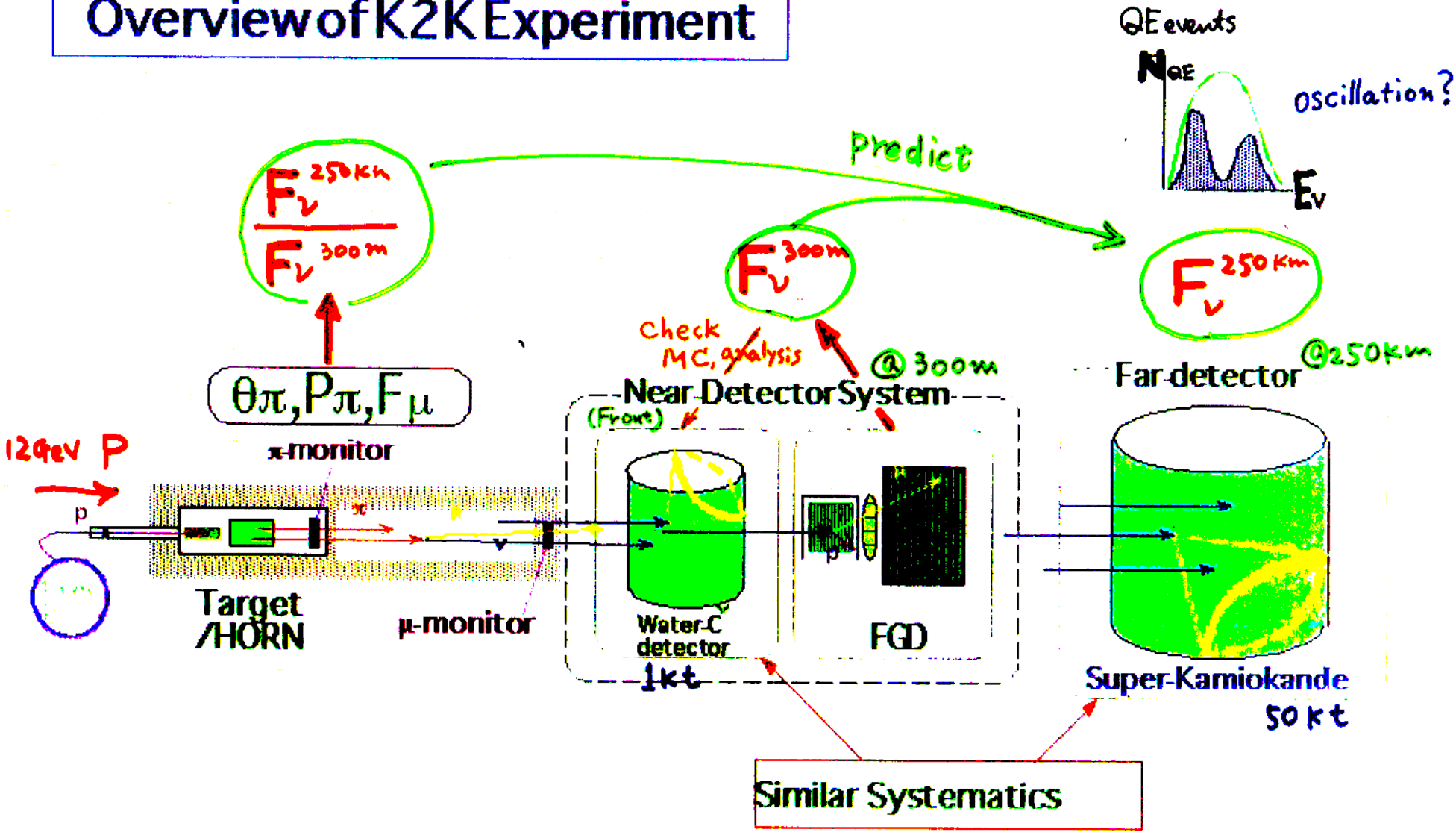


Beam line:
aligned by GPS
Al target:
20 mm dia. By 650 mm
beam size:
r ~ 1 cm @ target
200 m decay pipe

4 months x 3 years
➡ 10^{20} p.o.t.

12 GeV PS
1 pulse/2.2 sec
1 μs spill
6 x 10^{12} protons/pulse

Overview of K2K Experiment



Beam monitors

- Incident proton beam monitors
  - proton flux and profile
- Pion Cherenkov monitor
  - P_π , θ_π distribution
  - Δ (far/near flux ratio) < 5%
- Inocopter
  - ϕ symmetry of secondary beam around beam axis
- Muon monitor
  - beam center and intensity
- 1 kt water Cherenkov detector
  - Similar event definition as SK
  - Cherenkov ring counting, P.I.D.

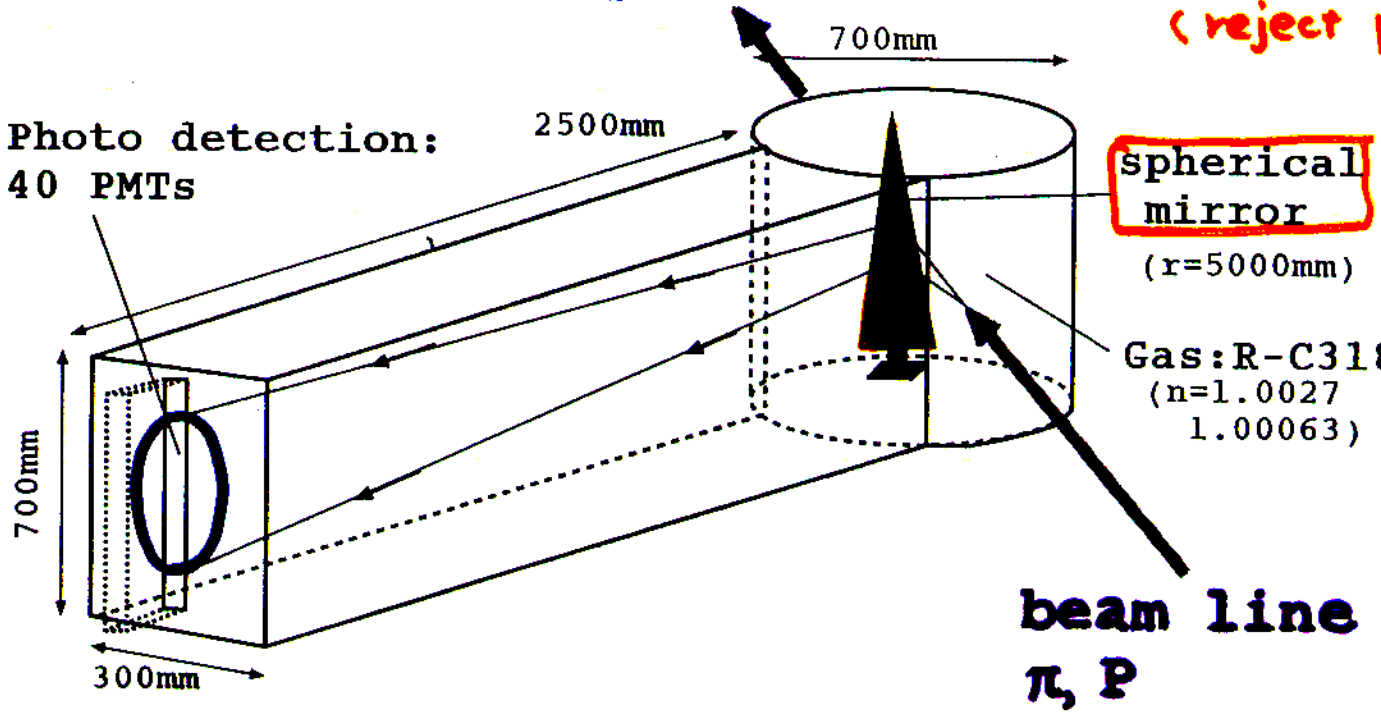
Predict neutrino energy distribution at SuperK

Pion monitor :

measures $\frac{F_\nu^{250km}}{F_\nu^{300m}}$ to Decay volume

Gas Cherenkov detector

→ only sensitive for pions (reject protons)

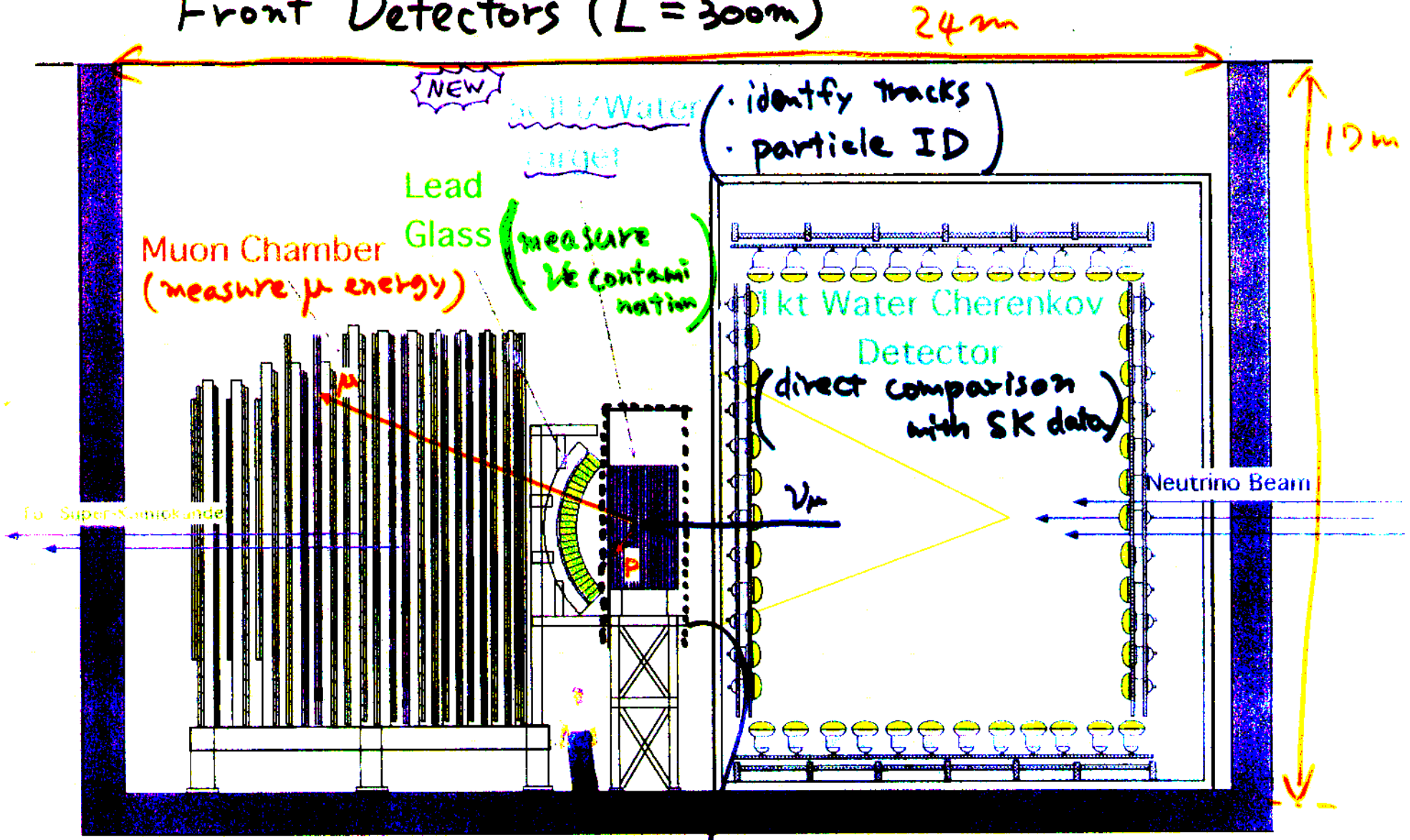


Čerenkov ring

radius → P_π

position → θ_π

Front Detectors (L = 300m)



1kt ← E261A

Fine Grain Detector
- LG ← TOPAZ
- MUC ← VENUS
- TRIG ← TOPAZ, VENUS
- SCIFI is NEW

Trigger counter
(· measure event timing
· reject cosmic-ray μ background)

Establish F_J^{300m}

Fine-grained detector –

- **Water / Scintillating fibers**

  2.4 × 2.4 × 1.2 m Layers

  Sci-fi Layers every 9 cm 2x, 2y

  $\sigma_x \cong 250\,\mu m$

  Fiber → IIT → lens → CCD

  4×4 pixels/fiber

- **lead glass**

  600 blocks, 10cm × 10cm, ~20 r.l.

  $\Delta E_e/E_e \sim 8\%/\sqrt{E_e}$

- **Muon ranger**

  900 drift chambers

  12 Iron plates 7.6m × 7.6m

  0.1 – 0.2 m thick

  $\Delta E_\mu/E_\mu \sim 8-10\%$

Typical Charged Current QE events

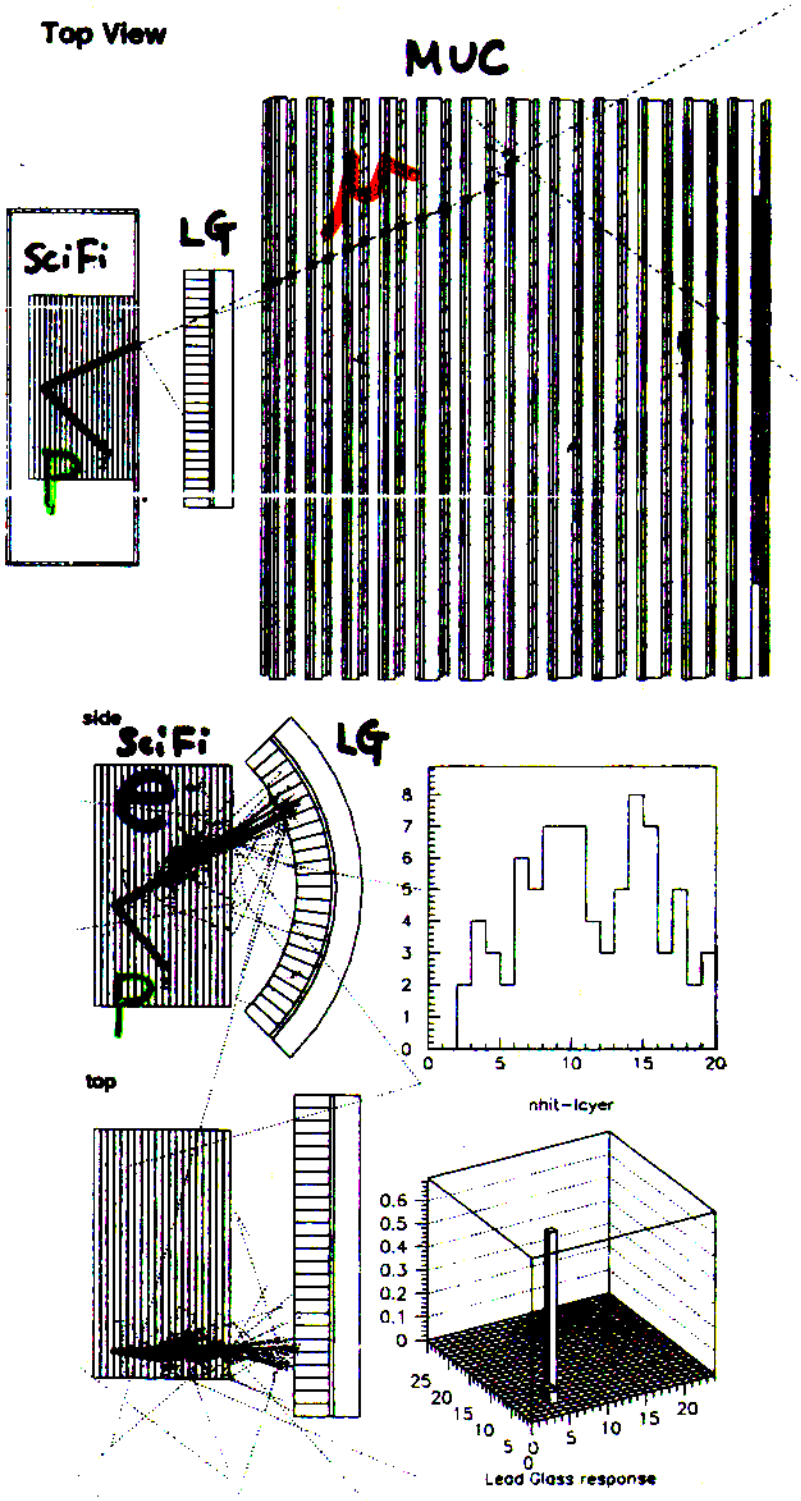


Fig. 4. Typical CCQE event generated by GEANT. (i):muon (ii):electron.

Event Selection & Reconstruction

$\nu_\mu n \to \mu^- p$

Fiducial volume cut 2m x 2m x 1m
Muon chamber hit
Number of tracks 1 or 2
$\theta_\mu \leq 50^\circ$
$\alpha(\mu, p) \leq 20^\circ$ from expected

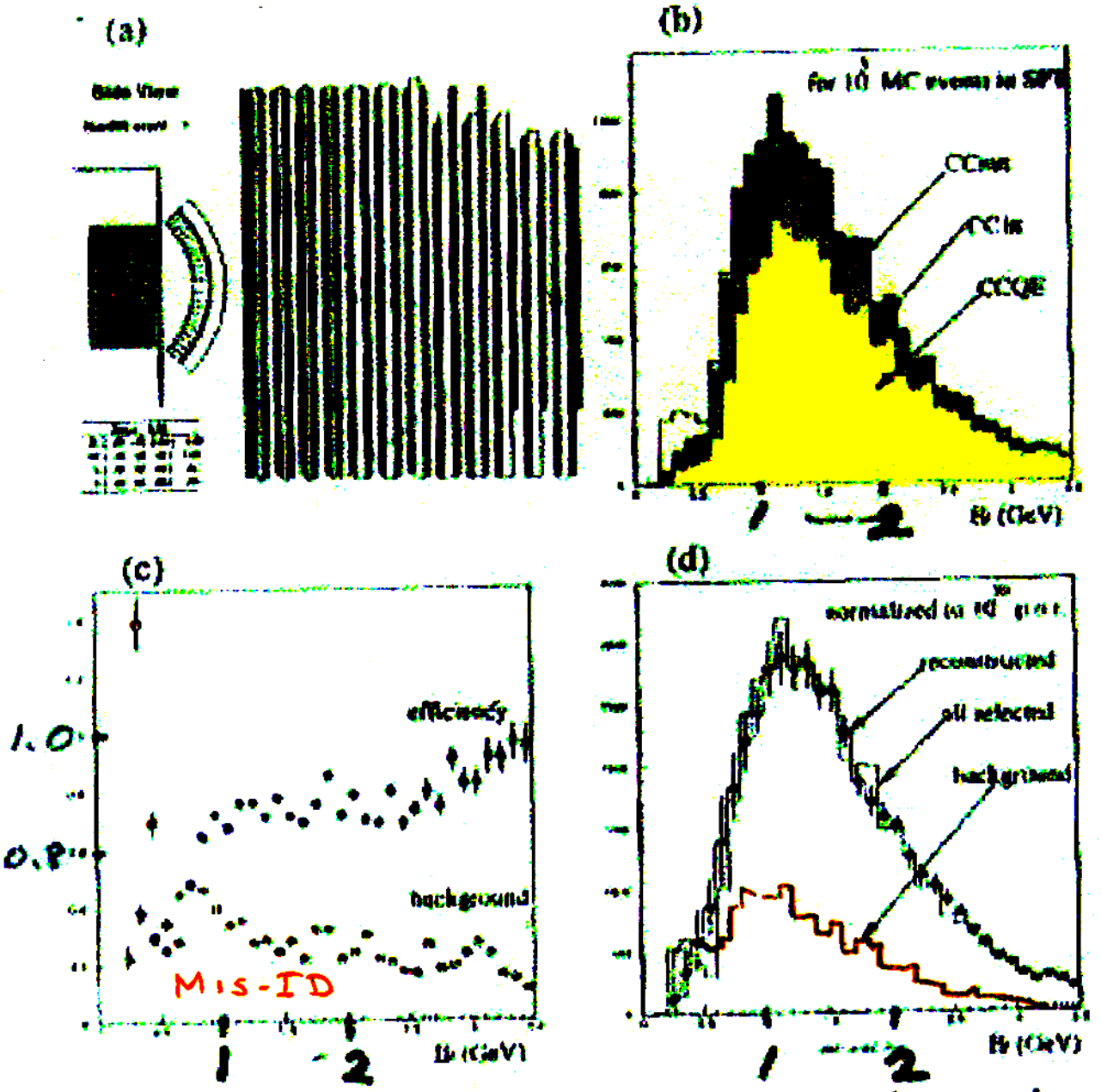
$\nu_e n \to e^- p$

Fiducial volume
No muon chamber
1 or 2 tracks
$E_e \geq 1$ GeV (Sci-fi + LG)
$\alpha(e, p) \leq 20^\circ$ from expected

$E_\mu, \theta_\mu \Rightarrow E_\nu$

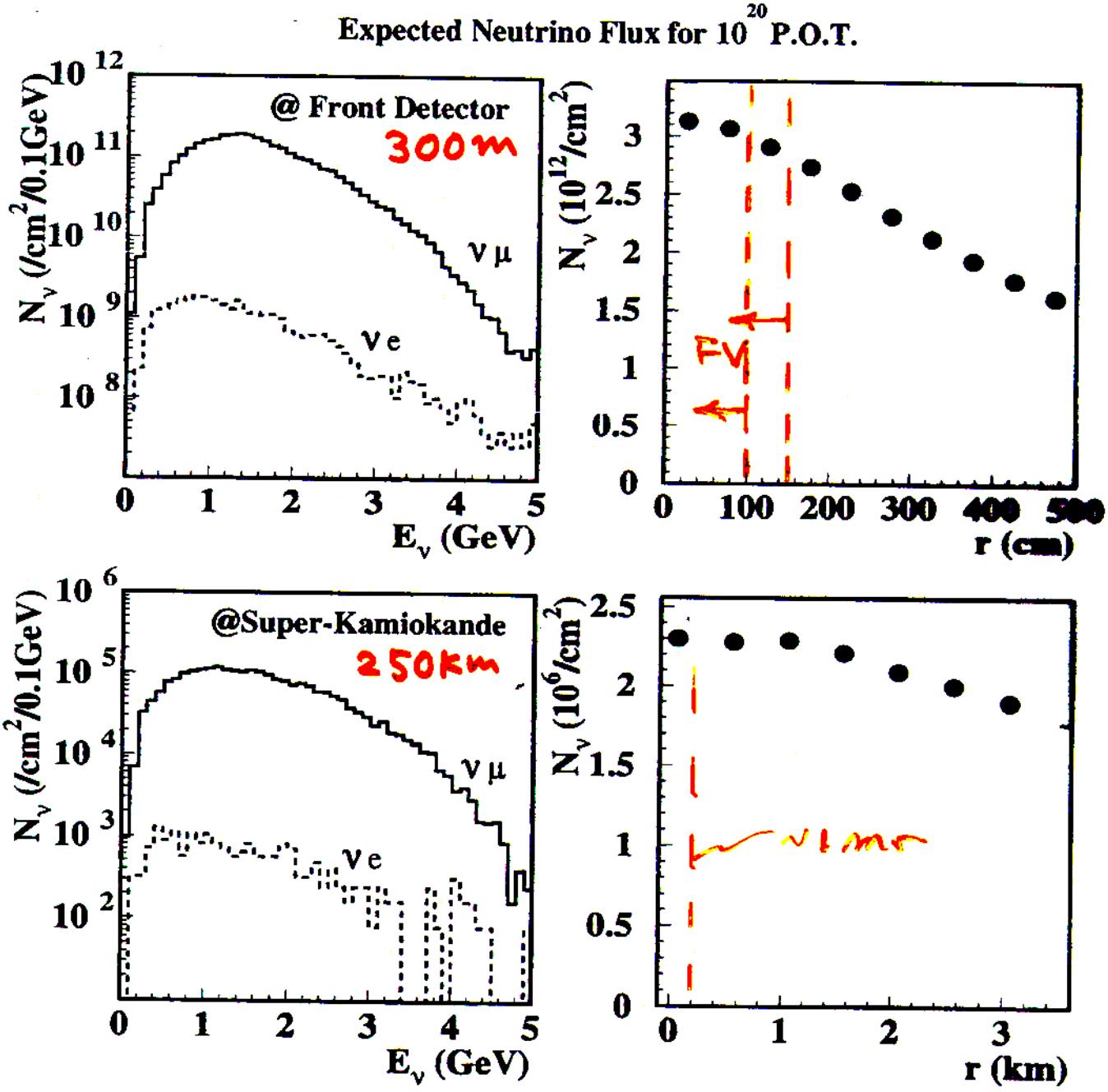
Background - non QE processes
$\nu_\mu N \to \mu^- N (n\pi)$

CCQE (ν_μ) selection



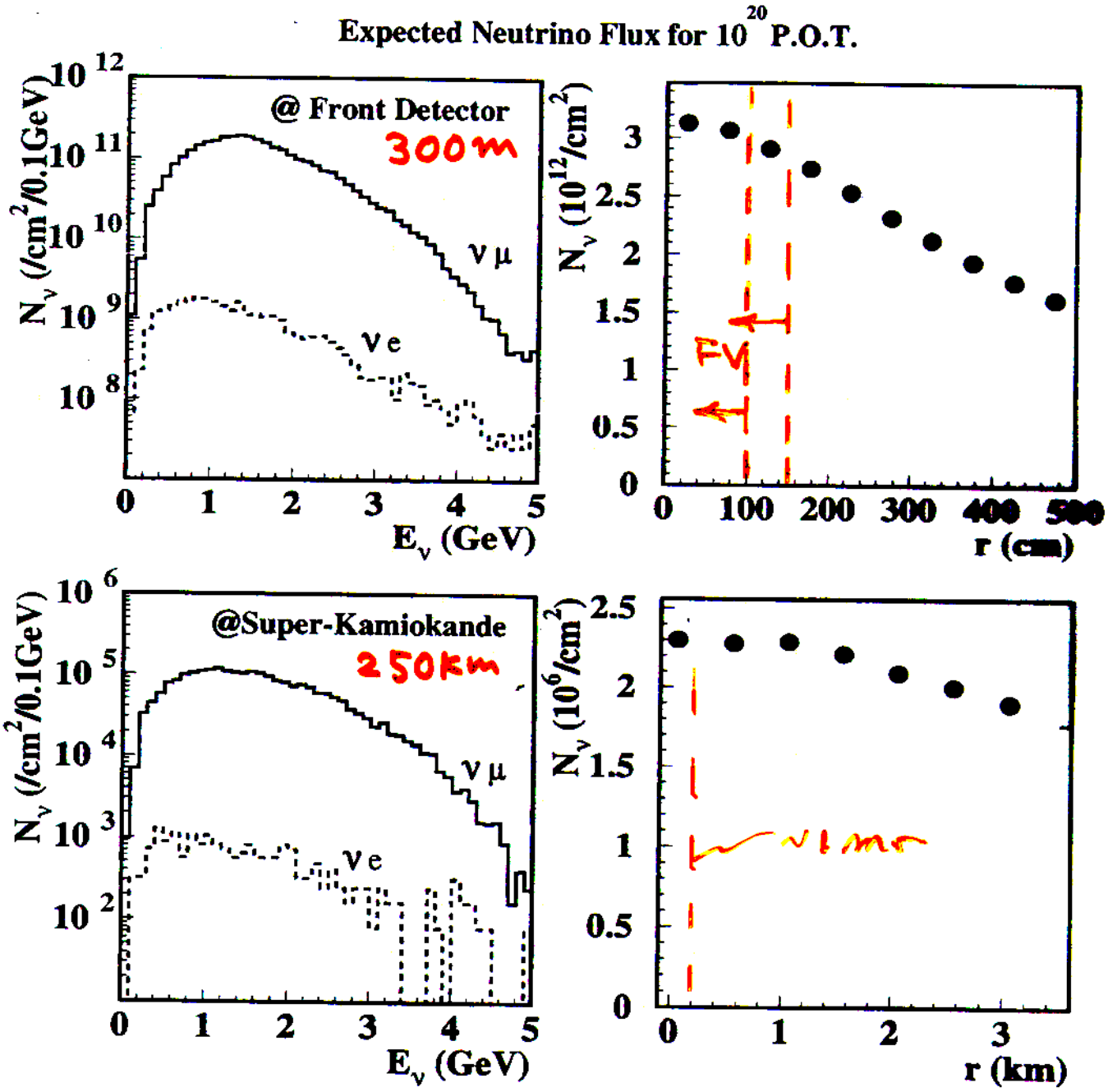
Reconstructed neutrino spectrum

Expected neutrino flux and radial distribution



Pointing accuracy of 1 m or fine —

Expected neutrino flux and RADIAL distribution

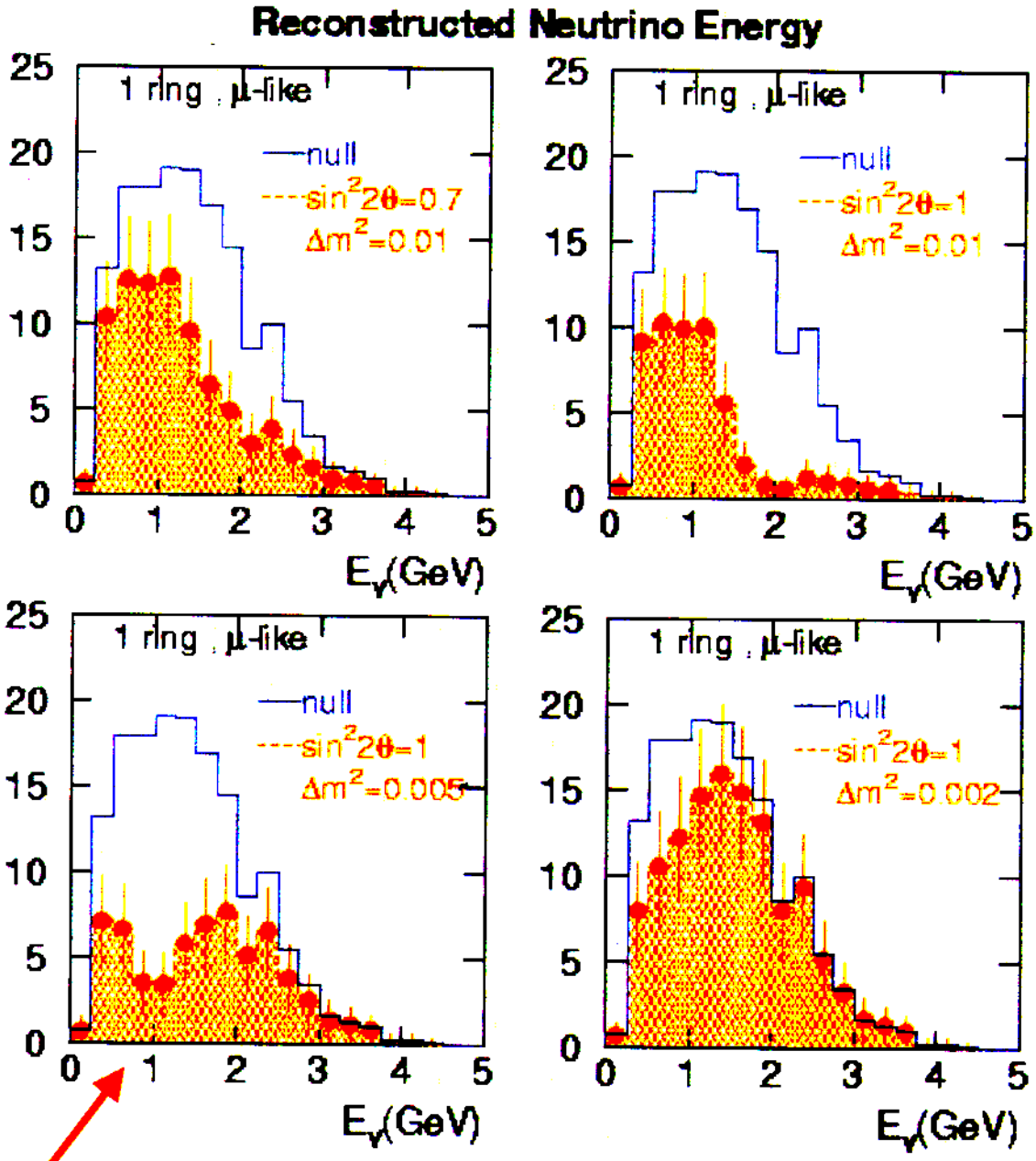


Pointing accuracy of 1mr fine —

Neutrino interaction rate (no oscillations) 10^{20} POT

Detector (fid. Vol.)	Fine-grain 4 t water	1 kt 21 t water	Superk 22.5 kt water
Flux (cm^{-2})	2.6×10^{12}	2.4×10^{12}	1.8×10^{6}
ν_μ CC	63208	325526	281
Quasi-elastic	21969	114216	93
single- π	18812	97283	79
multi- π	21031	106784	103
ν_μ NC	22530	116226	99
singe- π^0	4642	24006	20
ν_μ total	85744	441710	381
ν_e total	884	4549	4
quasi-elastic	230	1190	1
$\bar{\nu}_\mu$ total	482	2252	2
$\bar{\nu}_e$ total	8	44	0.2

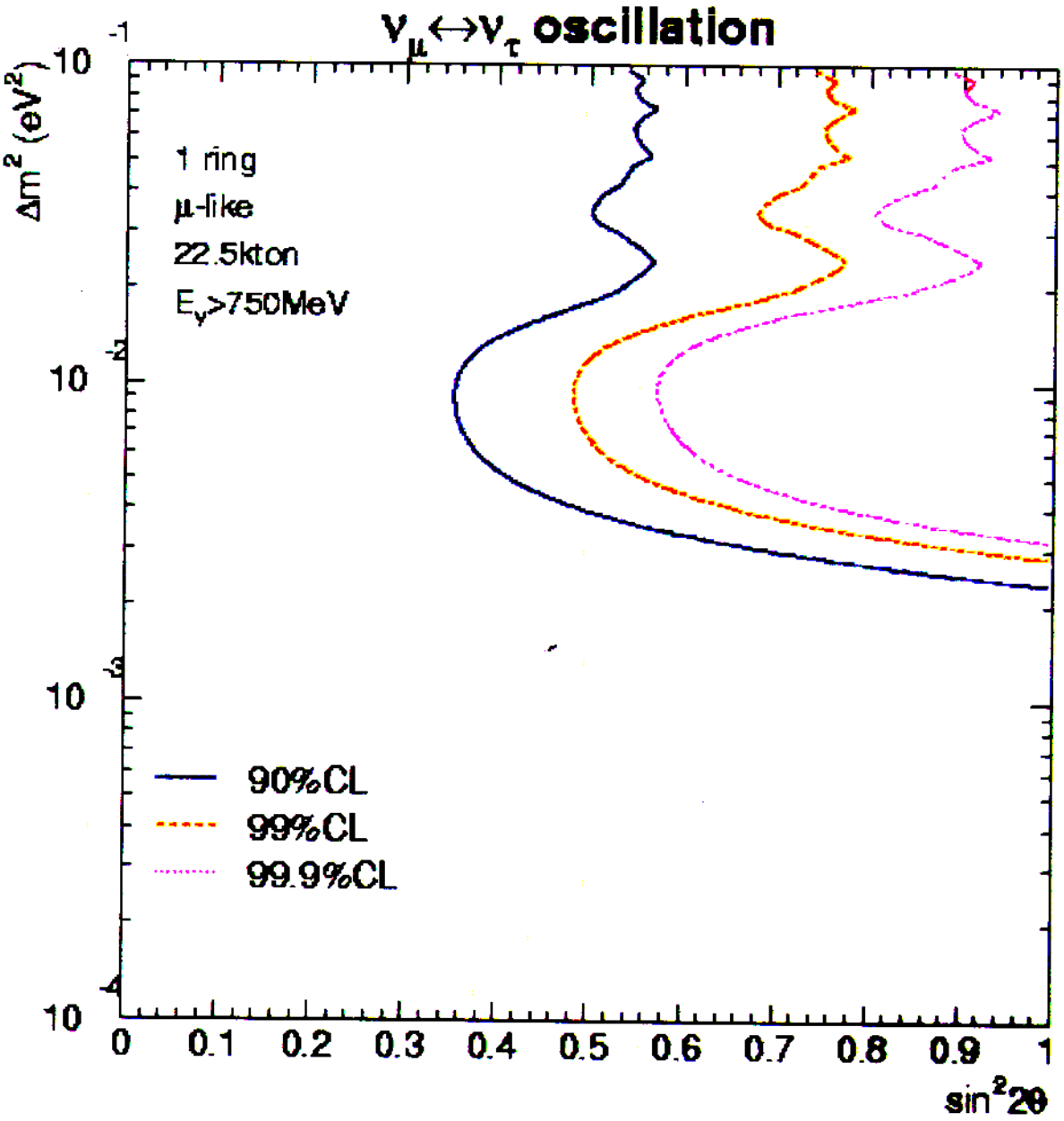
Observed energy distribution for ν_μ disappearance



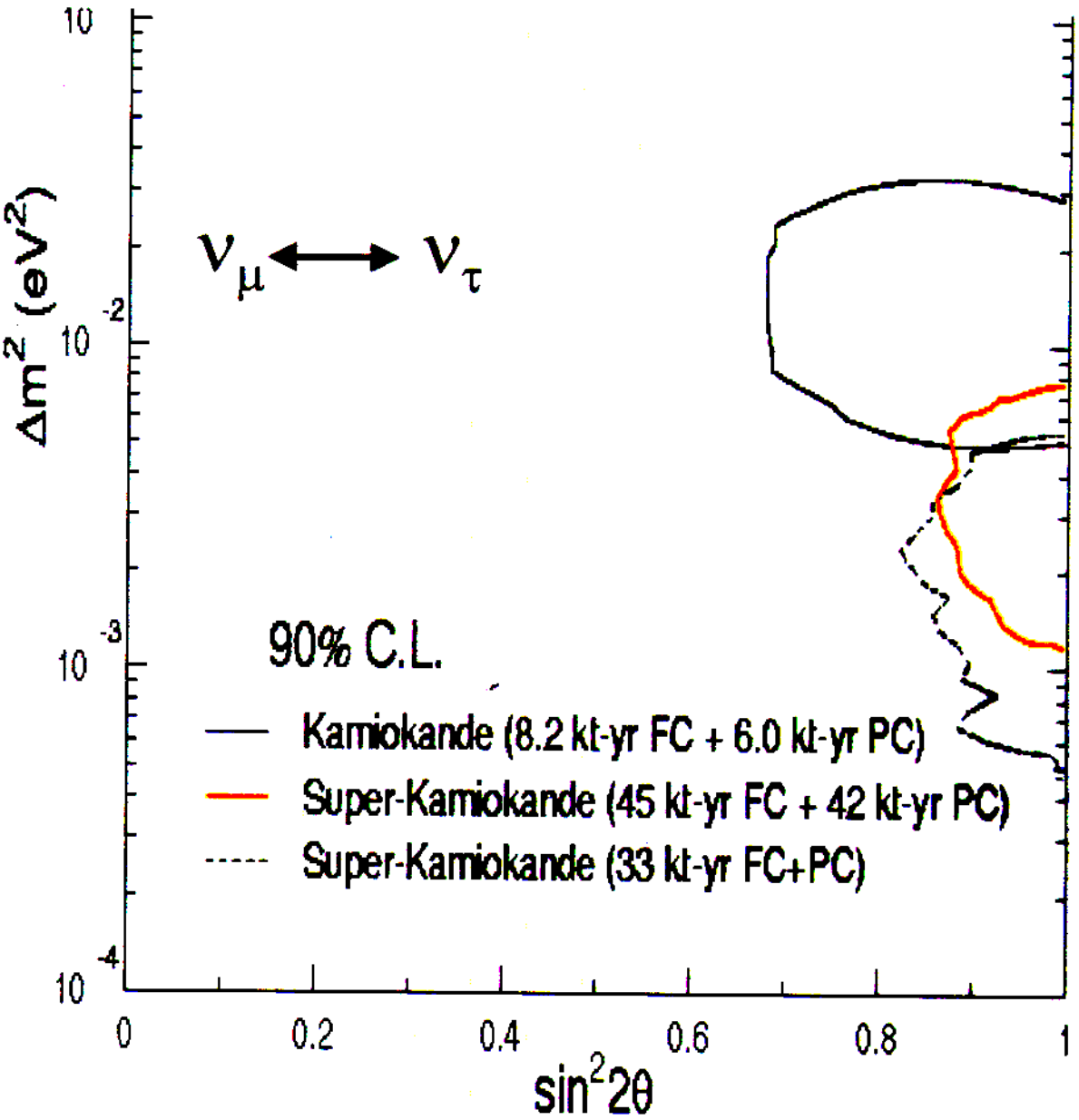
@3σ $\quad \delta m^2 = (5\ ^{+2}_{-1}) \times 10^{-3}\ eV^2$

K2K sensitivity for

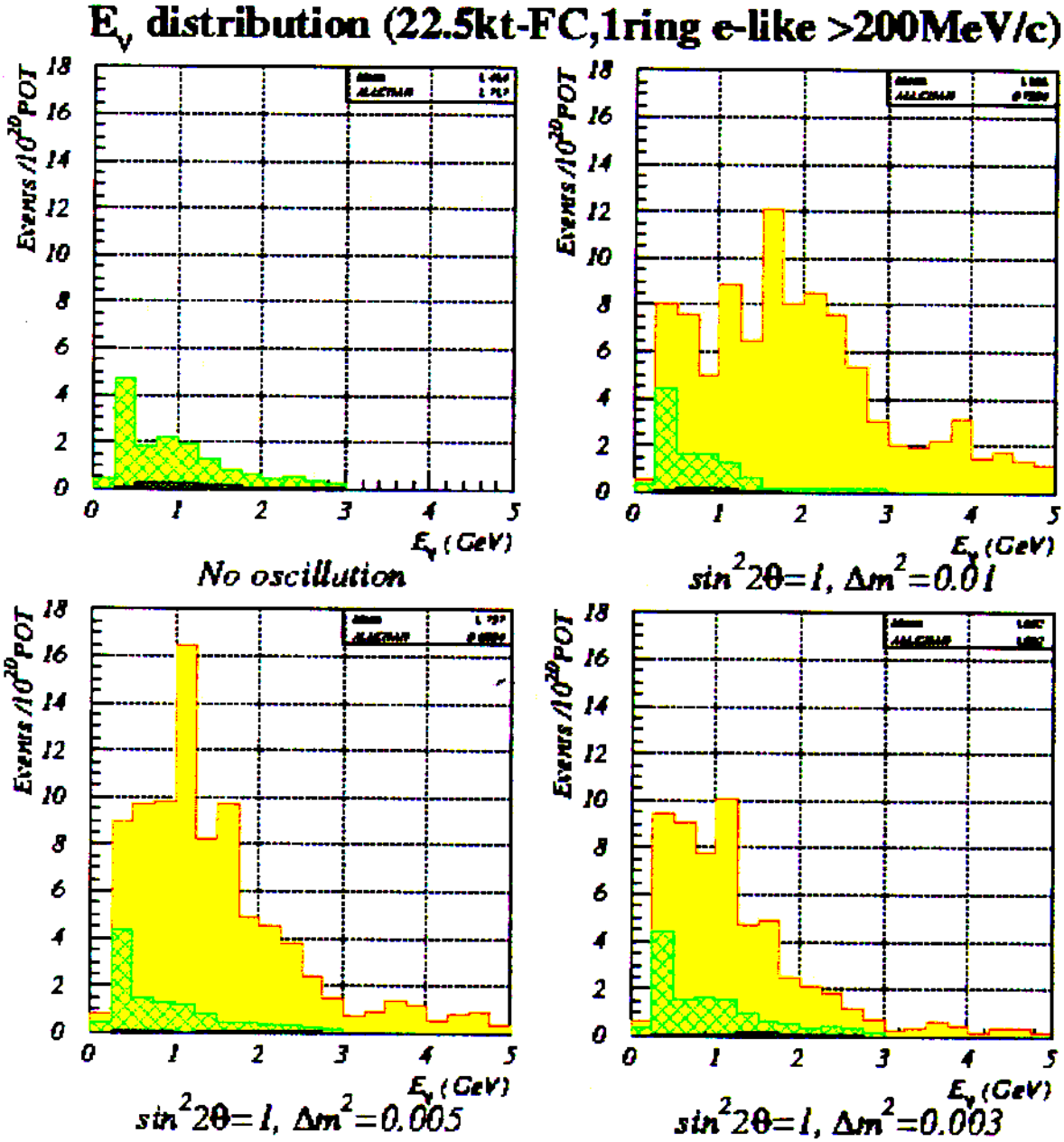
$\nu_\mu \longleftrightarrow \nu_x$



Latest SuperK

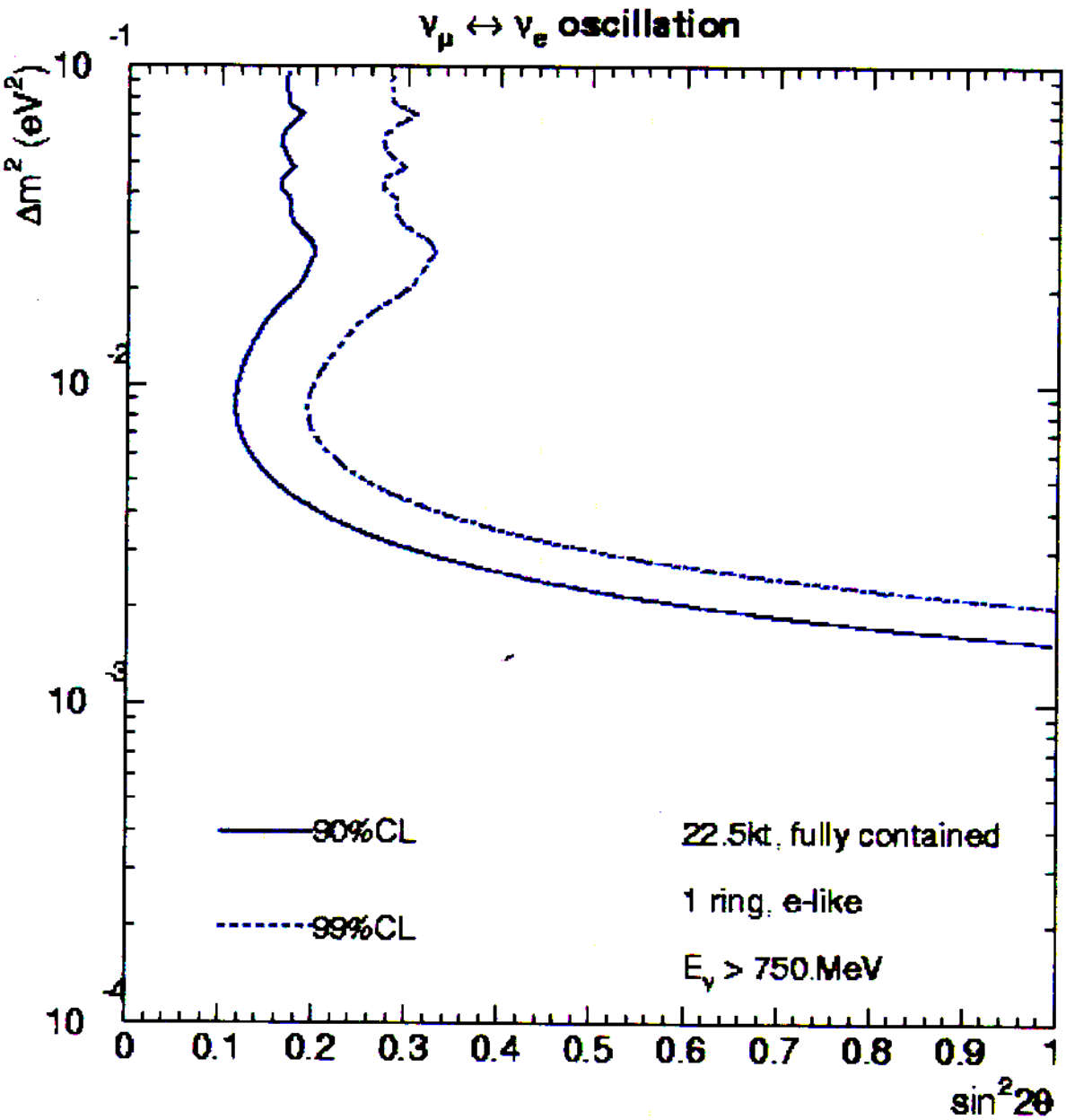


Observed energy distribution for ν_e appearance

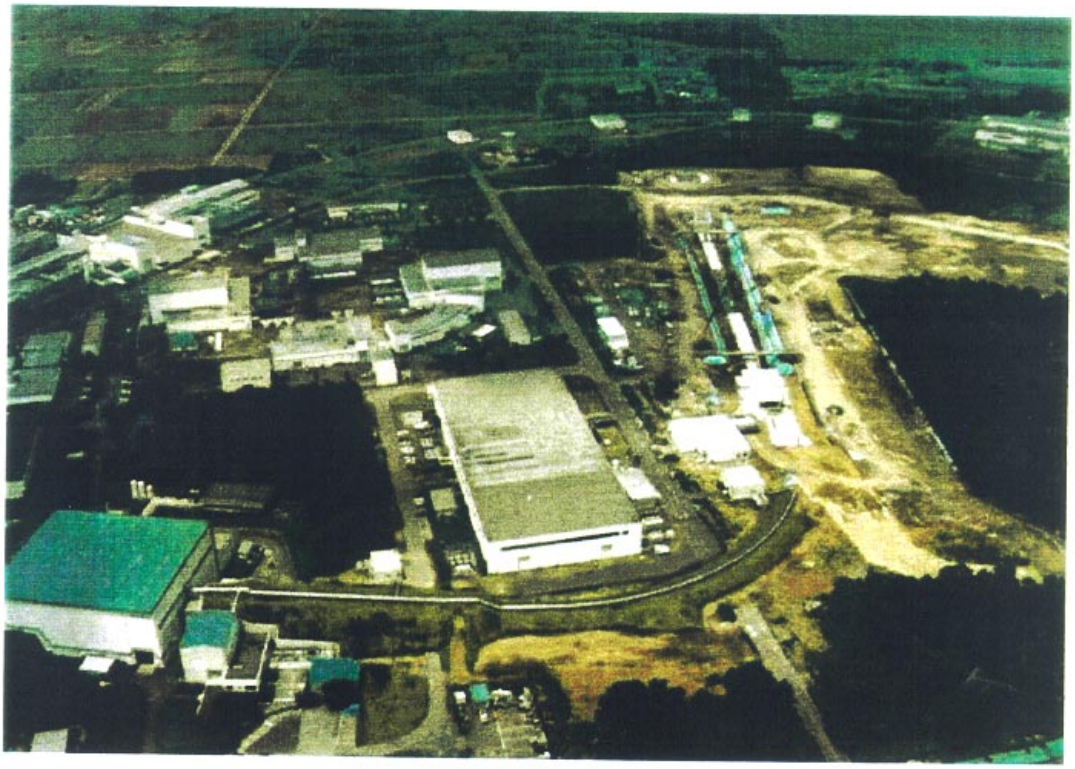


K2K sensitivity for

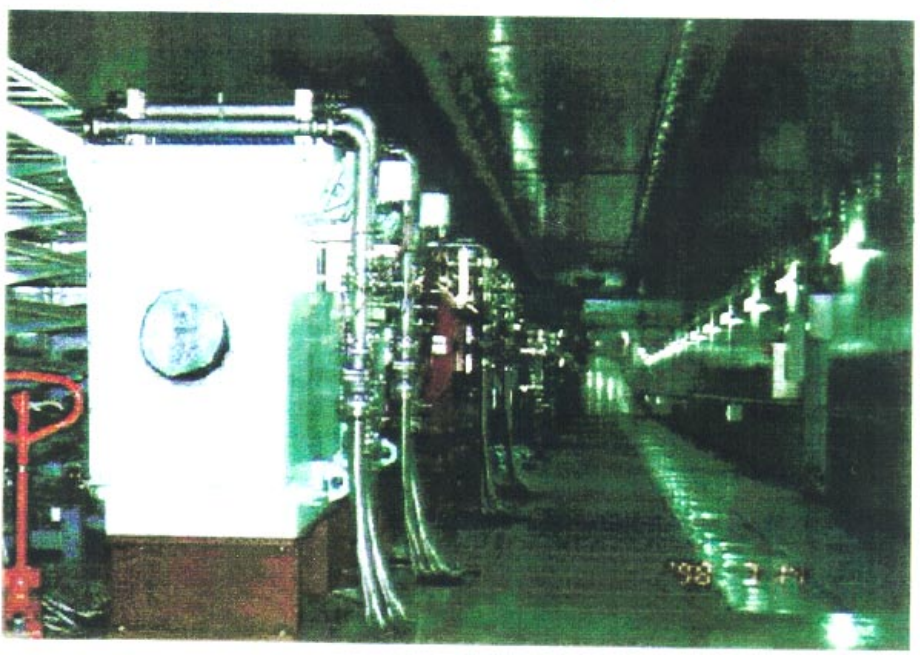
$\nu_\mu \longleftrightarrow \nu_e$



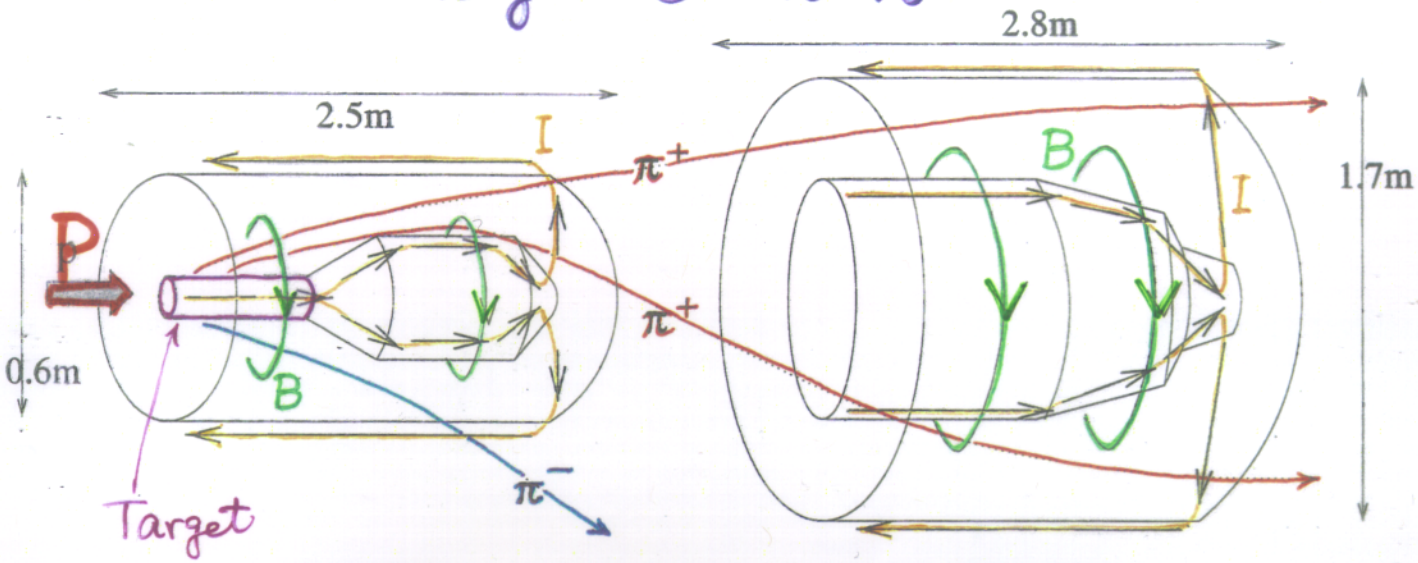
neutrino beam line



magnets for proton beam



Magnetic Horn



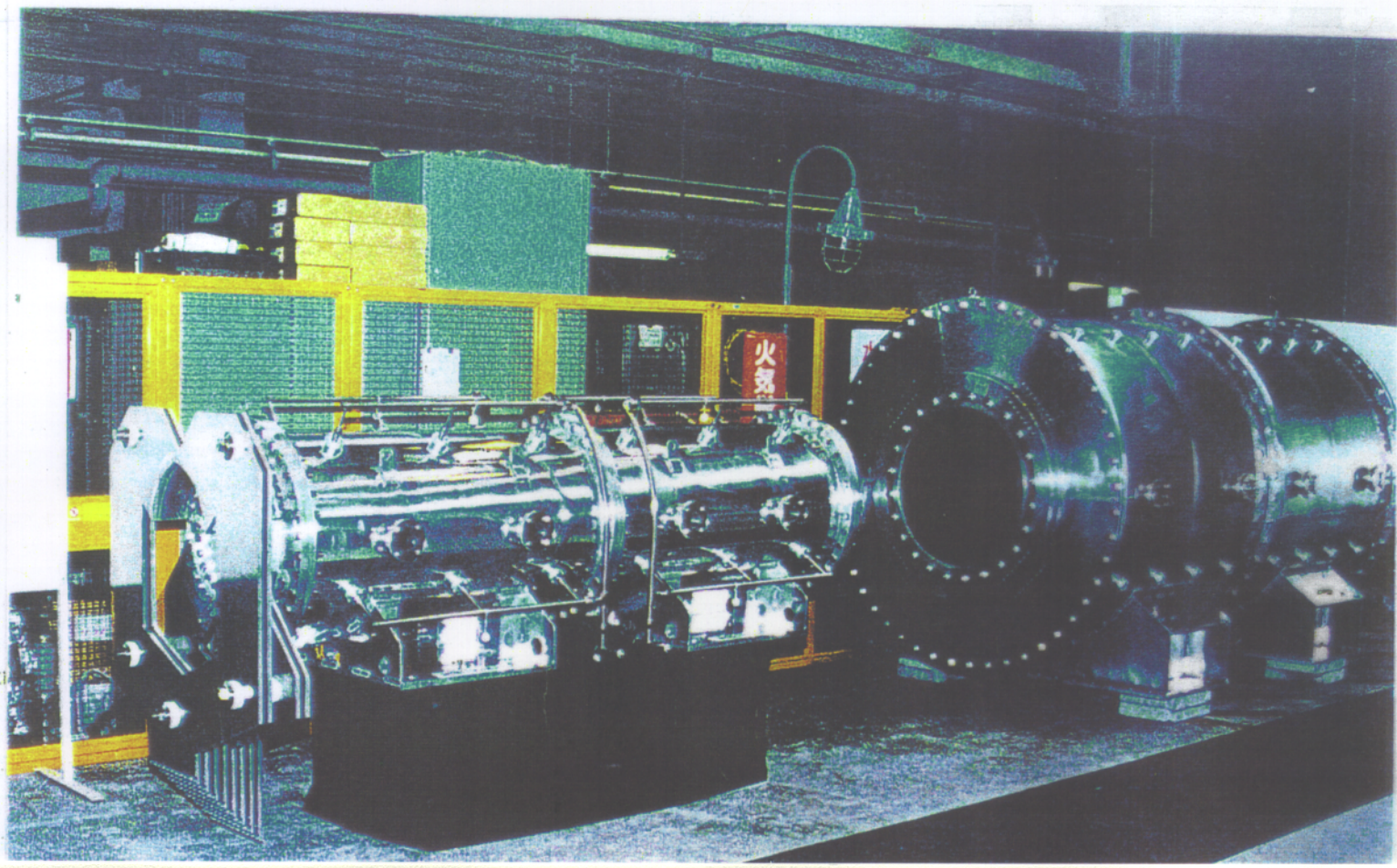
1stHORN 2ndHORN

Current 250kA/2msec pulse

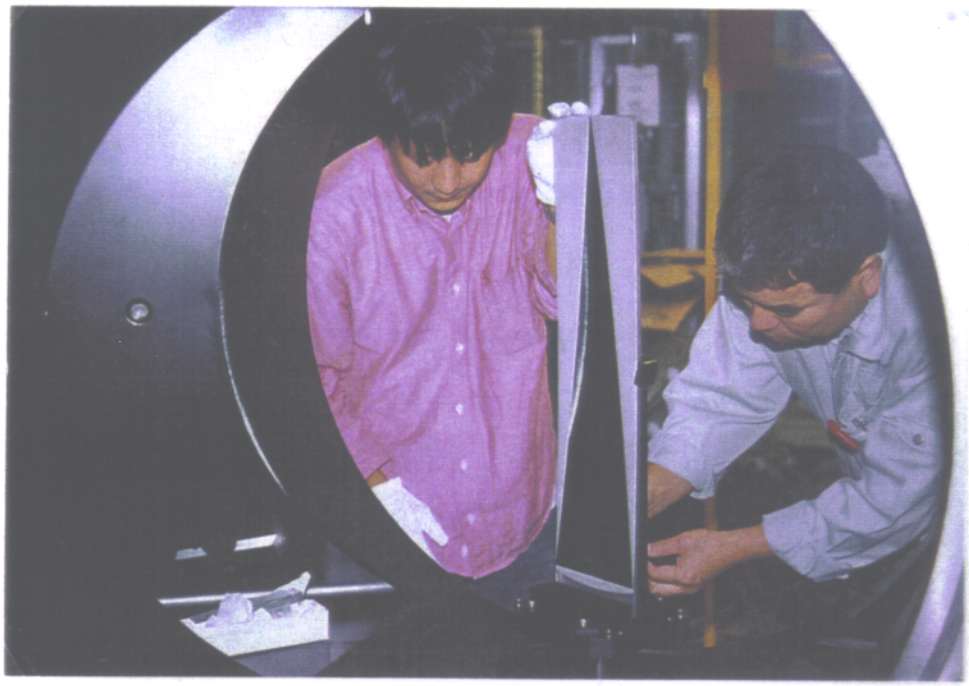
ν flux is enhanced

$$B = \frac{I}{5r} \quad [\text{kGauss}] \qquad \begin{matrix} I[\text{kA}] \\ r[\text{cm}] \end{matrix}$$

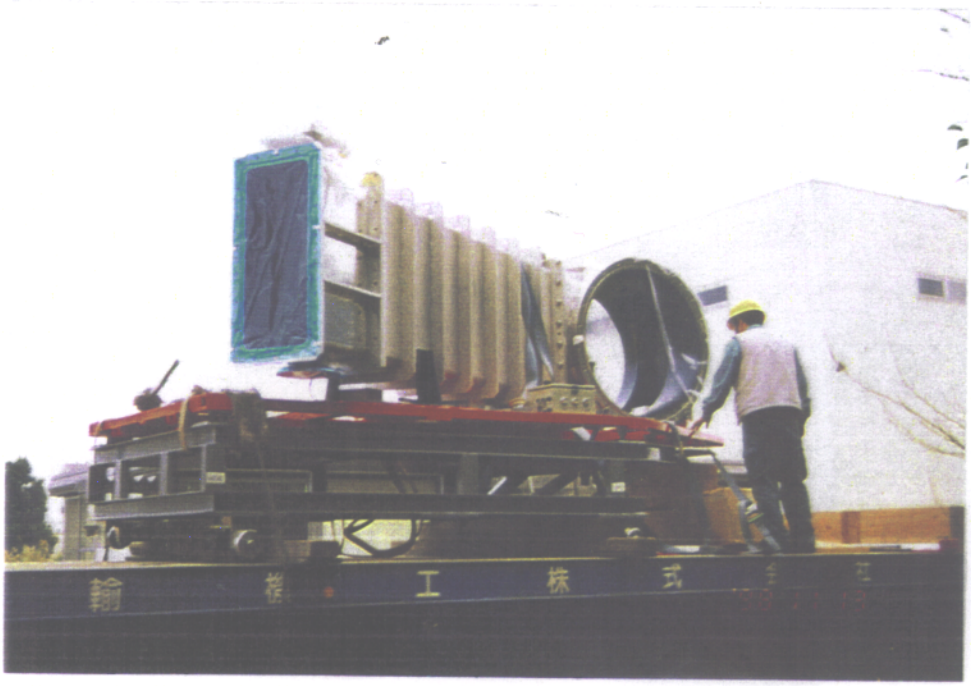
× 14



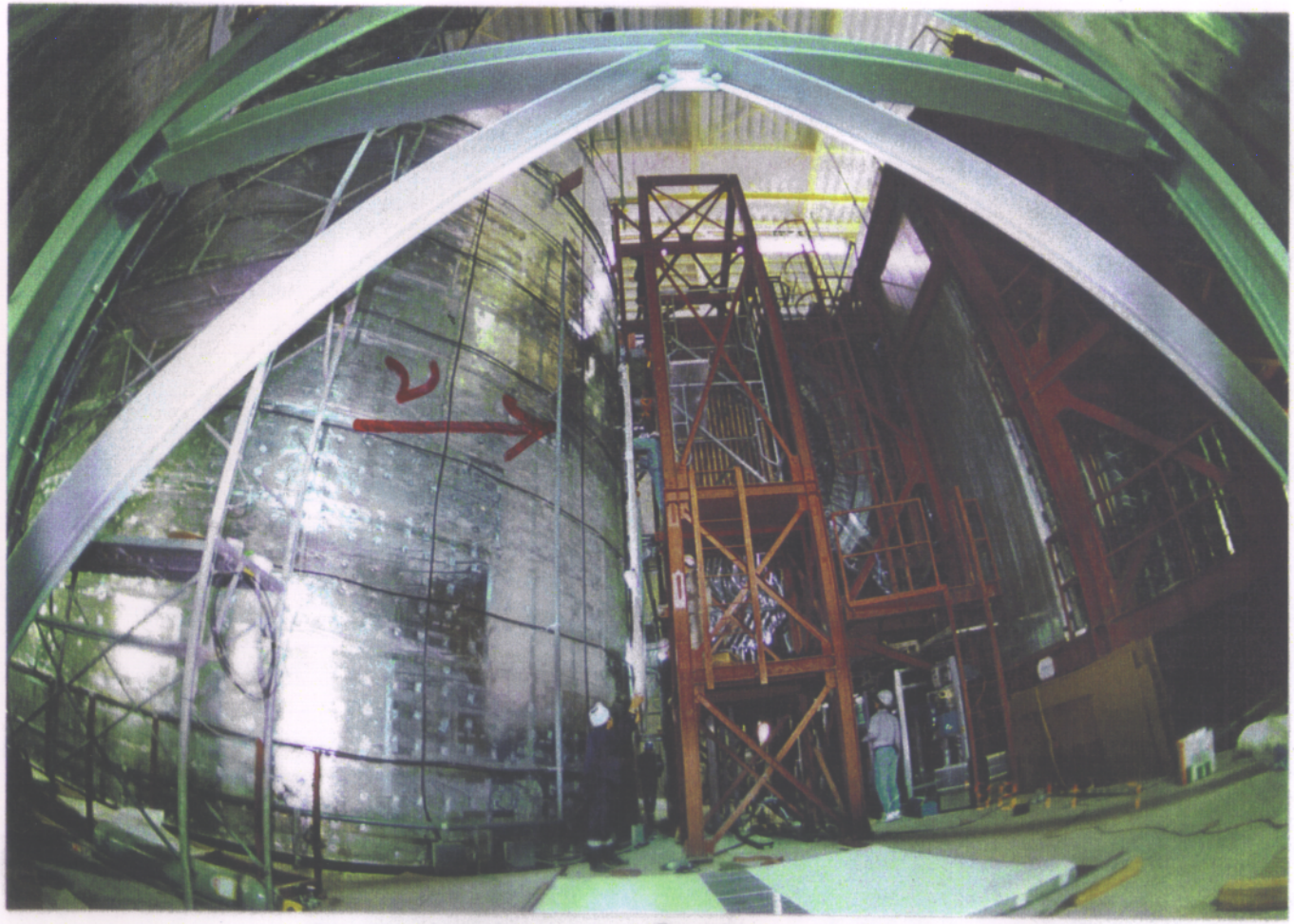
pion monitor (spherical mirror)



pion monitor

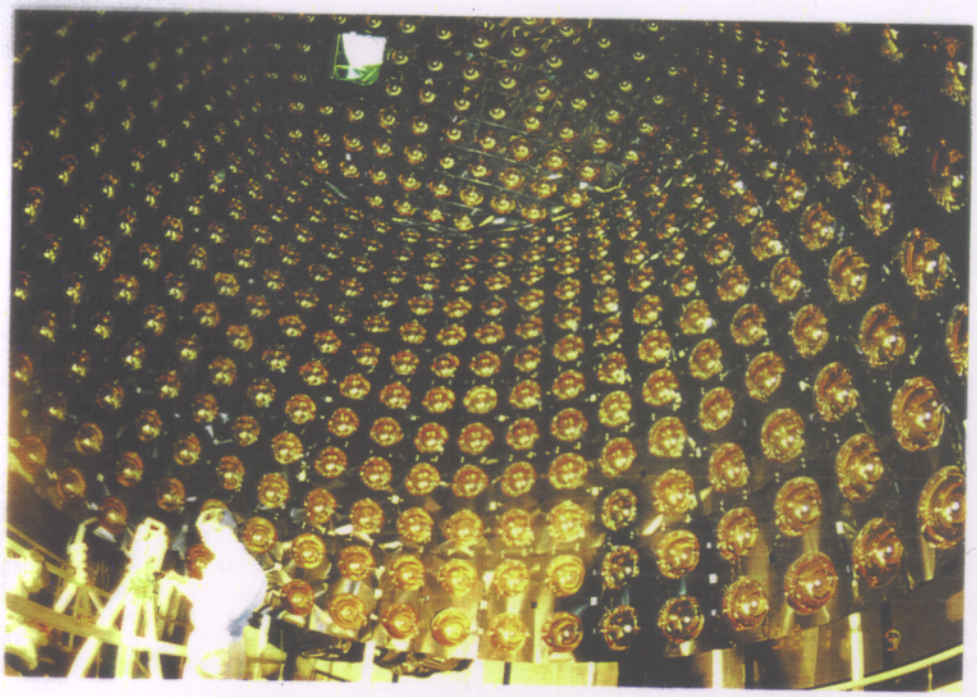


Front detectors



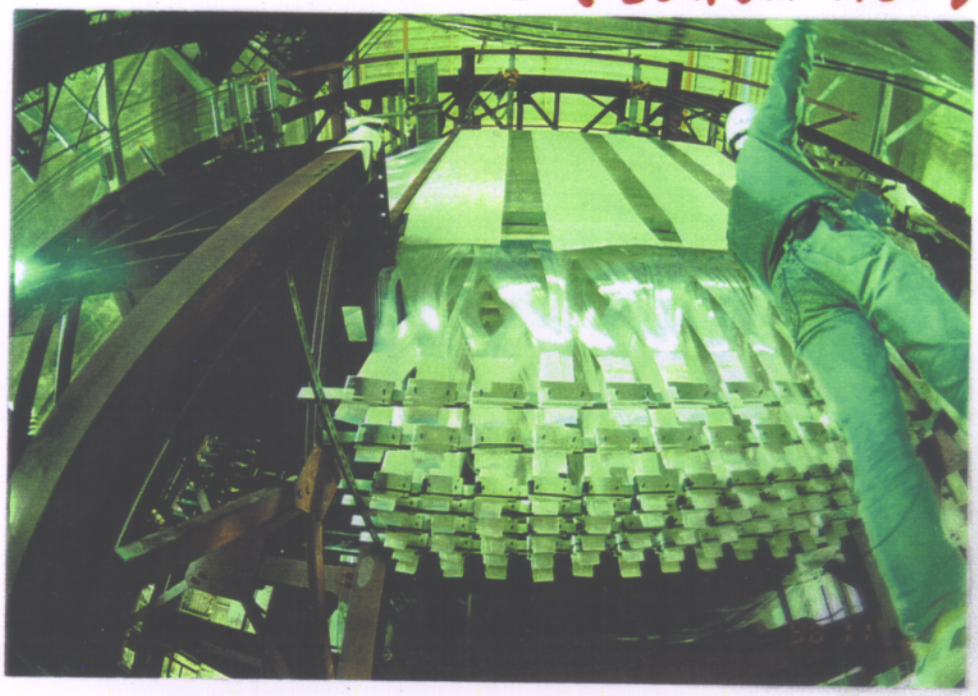
1kt SciFi LG MUC

1 kt water Cherenkov detector

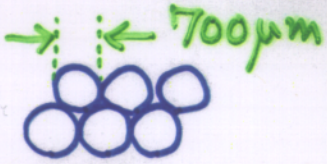


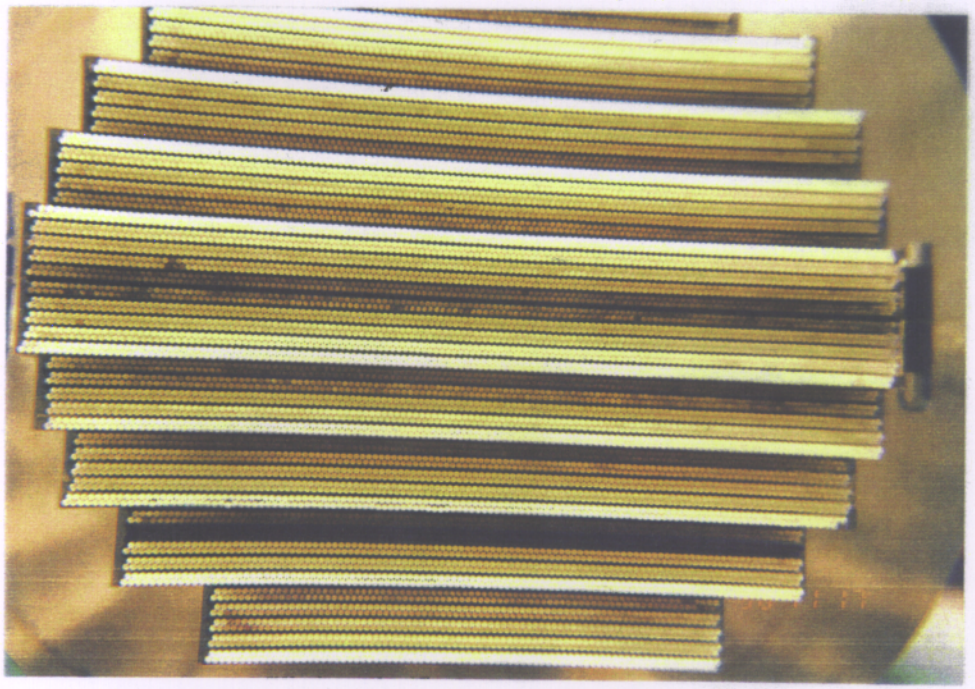
8.6m(φ) × 8.5m(h)
20"PMT × 680(inner)

Sci Fi tracking detector
(bottom view)



fiber bundle

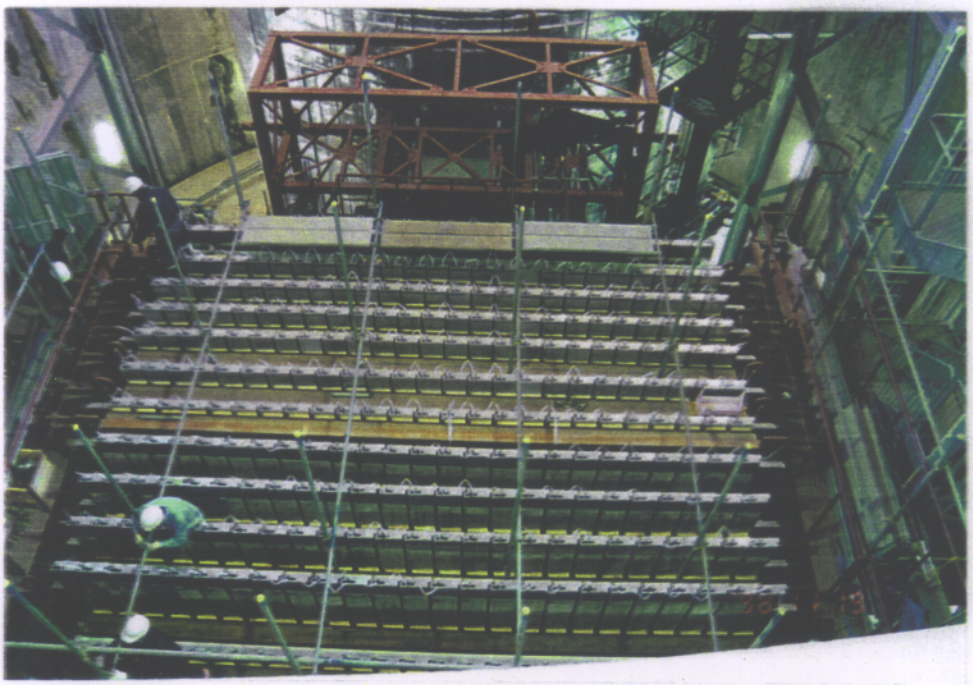




700 μm (Φ) × 3.7 m (L) × 11,420

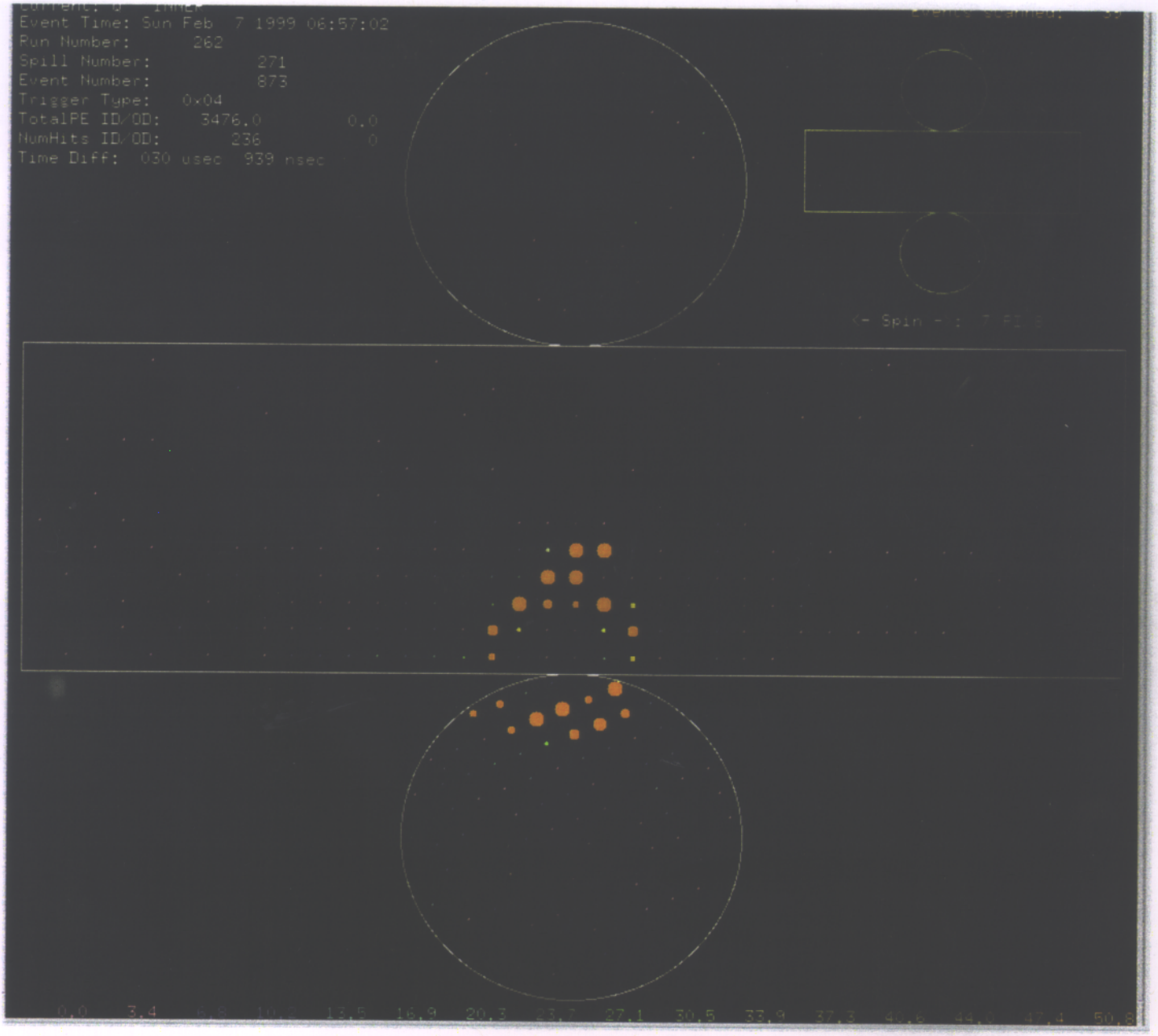
Lead glass counter

muon ranger

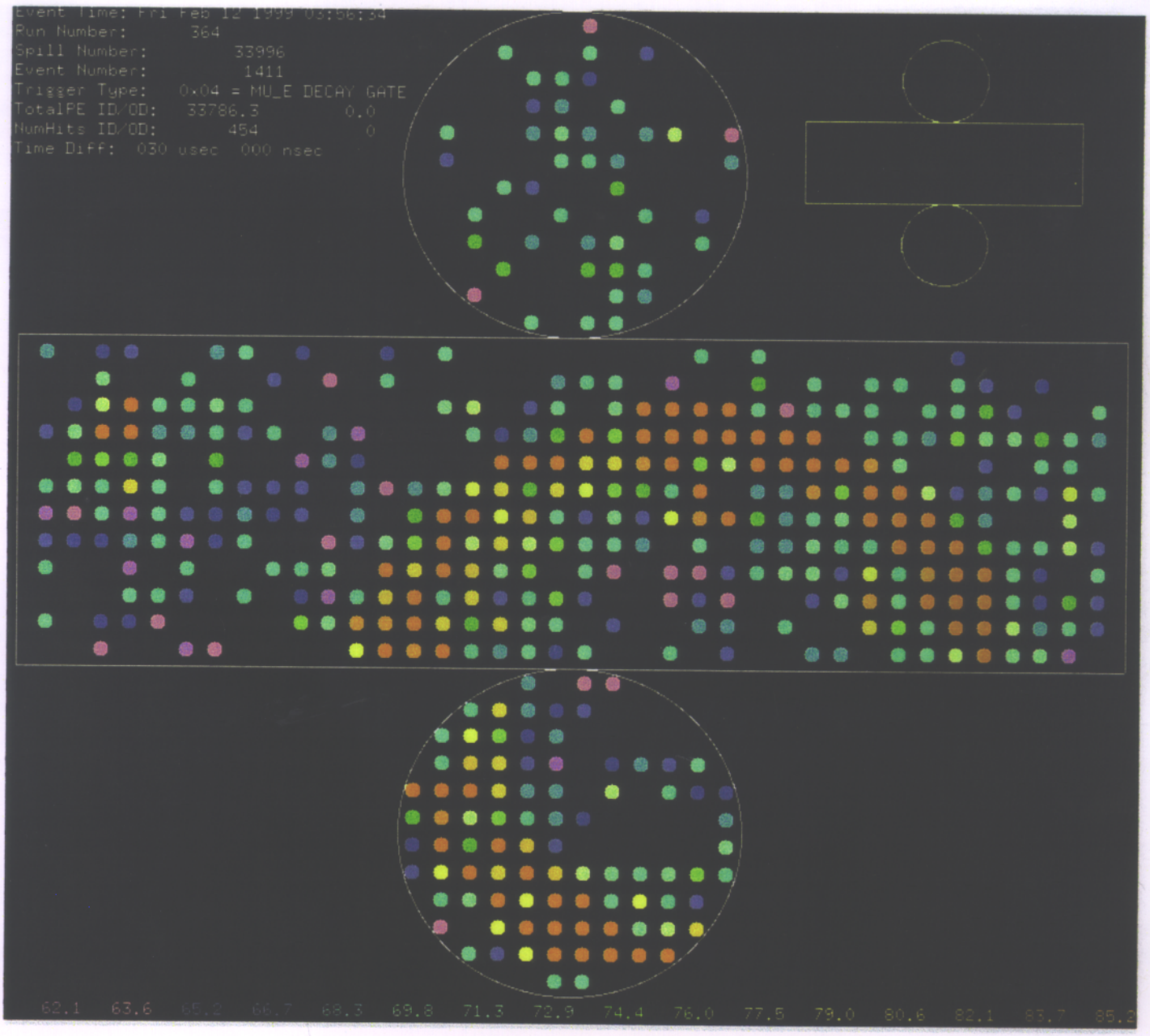


Possible ν event

(No target)



Stopping μ


Event Time: Fri Feb 12 1999 03:56:34
Run Number: 364
Spill Number: 33996
Event Number: 1411
Trigger Type: 0x04 = MUE DECAY GATE
TotalPE ID/OD: 33786.3 0.0
NumHits ID/OD: 454 0
Time Diff: 030 usec 000 nsec
62.1 63.6 65.2 66.7 68.3 69.8 71.3 72.9 74.4 76.0 77.5 79.0 80.6 82.1 83.7 85.2

K2K Status

- Beamline complete.
- Experimental hall complete.
- Horns finished and tested.
- Water system installed.
- Proton beam channel monitors running.
- Pion monitor running.
- Muon ionization chambers running.
- 1 kt detector installed and running.
- Sci-fi detector nearly complete.
- Lead glass detector running.
- Muon ranger running.
- Protons extracted - slow spill Jan. 31.
- Protons extracted - fast extraction and transported through entire beam line to target station - Feb. 3 - Feb. 15 . $I < 10^{12}$ ppp / 2.2s.
- Fast spill with maximum intensity Mar. 3 .
- Normal runs Mar. 3 -- June 21, 1999