Super-Kamiokande as a Far Detector

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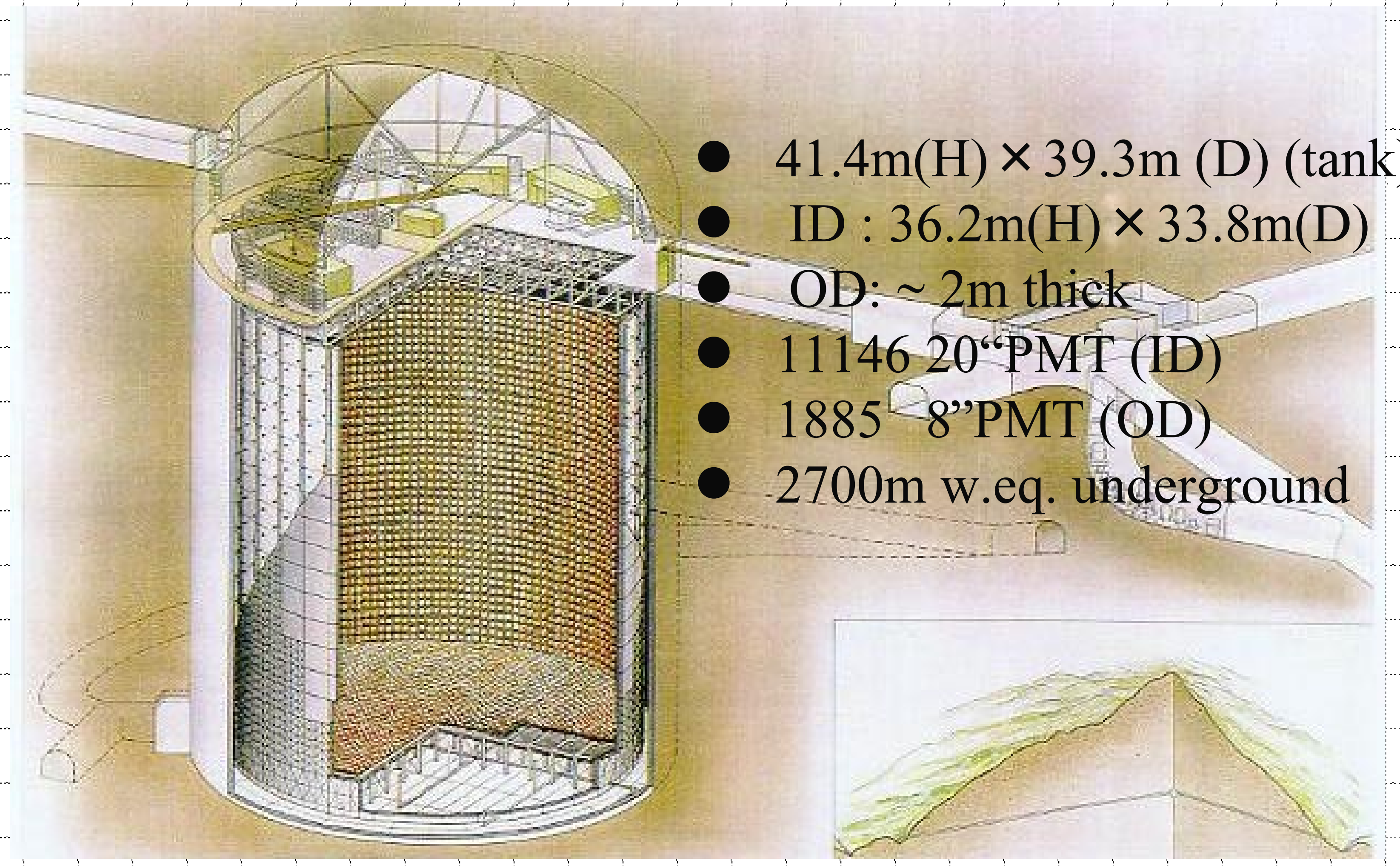
Super-Kamiokande



- 41.4m(H) × 39.3m (D) (tank)
- ID : 36.2m(H) × 33.8m(D)
- OD: ~ 2m thick
- 11146 20“PMT (ID)
- 1885 8”PMT (OD)
- 2700m w.eq. underground

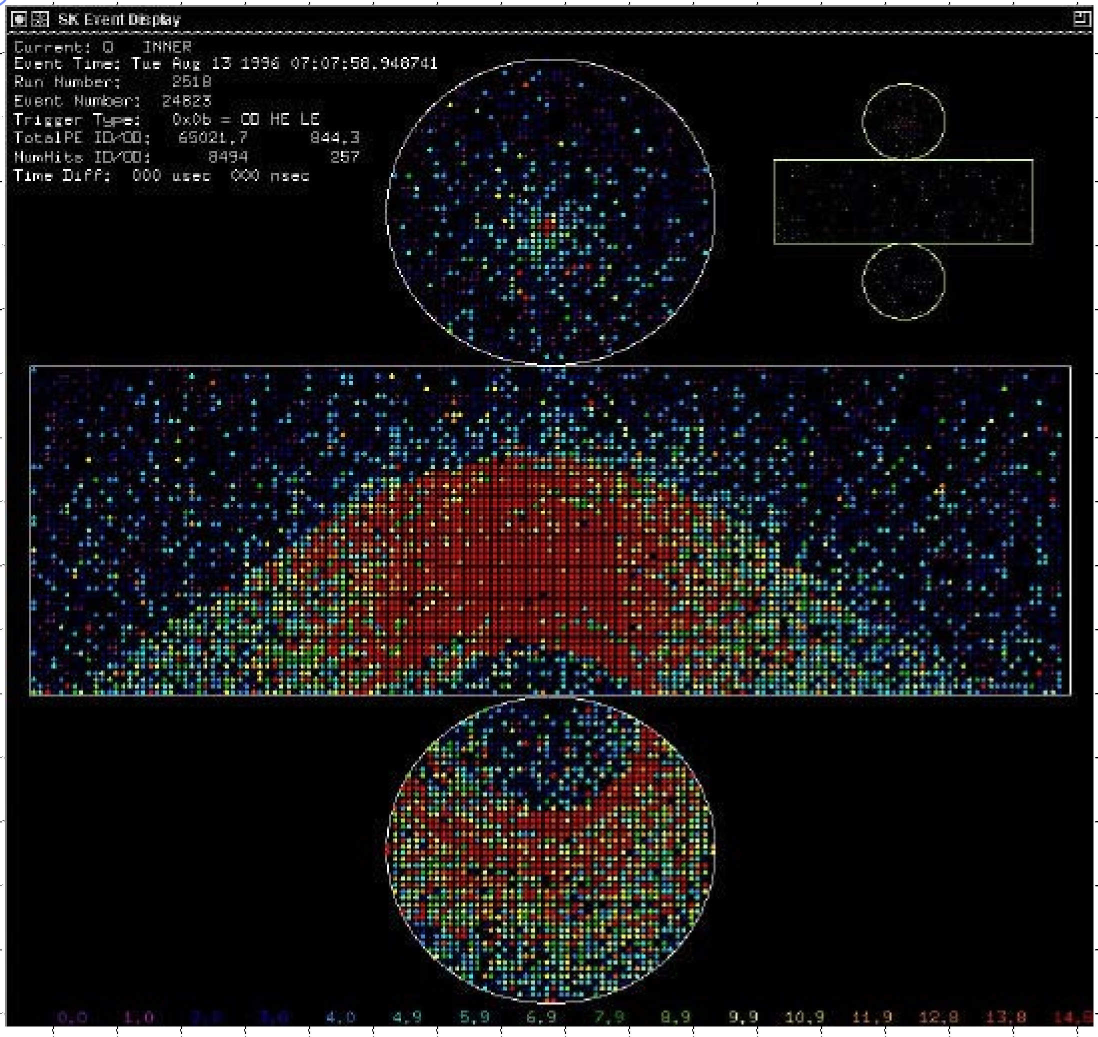
Function of far detector

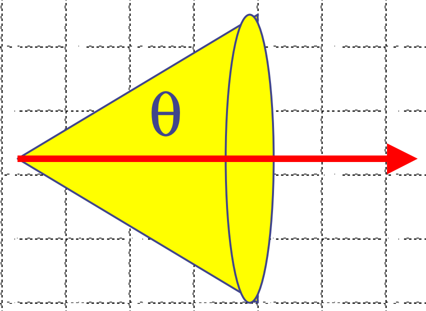
- identify ν events by beam timing
- separately identify CC and NC
- measure $E\nu$ of CC events
- separate ν_e CC from NC
- (sign of muons)

Advantage of Super-Kamiokande

- Large mass
- 4π and uniform detector
- Active imaging target
- Large energy coverage (5MeV-100GeV)
- $\mu/e/\pi^0$ separation
- Already existing
- Well-established,well-calibrated

Ring Imaging Water Cherenkov pixel detector





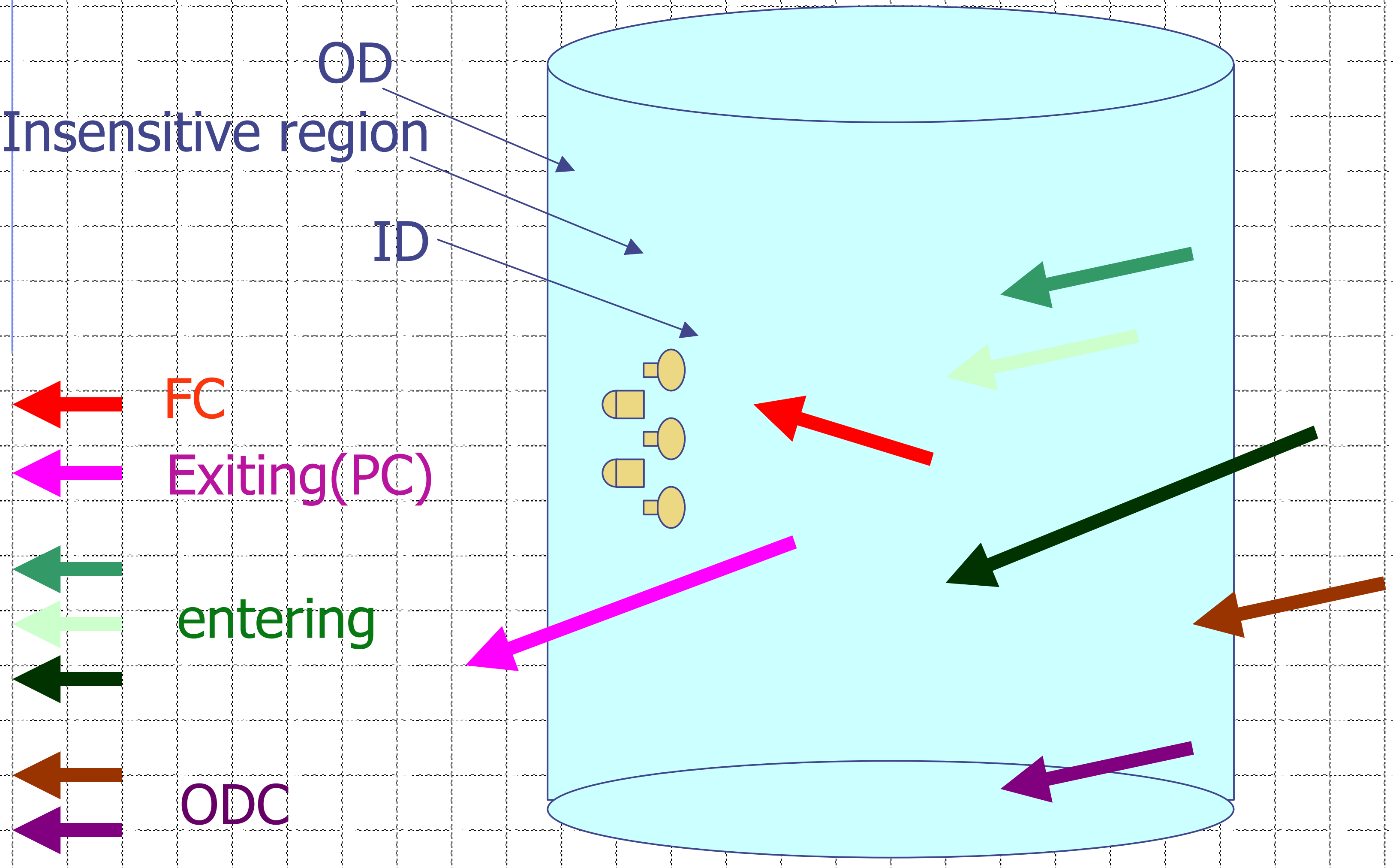
$\beta > 1/n$

$\cos\theta = 1/n\beta$

DAQ of Super-K

- Majority trigger of HITSUM
- Trigger
  - HighE (>31 ID hits 5Hz)
  - OD(>19 OD hits, 3Hz)
  - LowE(>29 ID hits=5.7MeV-e, 6Hz)
  - Super LowE(>17Hits=4.3MeV-e, 1700Hz)
  - HighE+OD invoke Split-trigger (OD-DAQ w/ GPS)
- ADC(12bit, max 250p.e.),TDC (12bit, max 1300ns)
- Double buffer of ADC/TDC -> decay electron
- (PMTSUM by flash ADC?)

Event classification



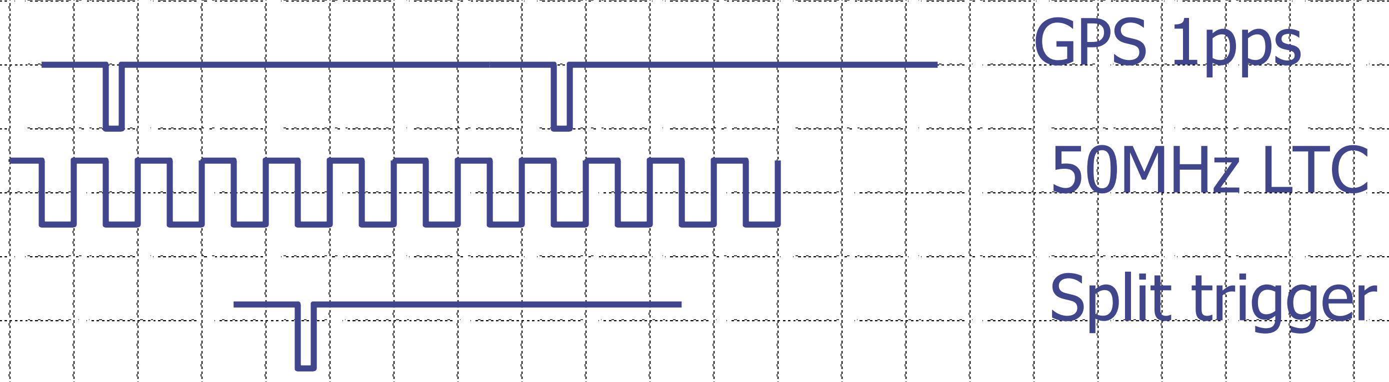
Performance of Super-K

- Fiducial volume = 22.5kt(2m from ID wall)
- Δx= ~90cm (@10MeV)
  = ~30cm (@sub-GeV)
- $\Delta\theta$ = ~26deg (@10MeV)
  = 2~3deg(sub-GeV)
- E accp. = 4.5MeV ~ 9GeV (μ),100 GeV(e)
- $\Delta E/E$= 14% @ (@10MeV)
  3%(μ) @sub-GeV
  $2.5/P^{1/2}$(GeV)+0.5)%(e)@sub-GeV
- Decay-e eff. = 80%(μ^+),63%(μ^-)
- PID(e/μ) = 99%

Event reconstruction (atm-ν)

- Pre-selection
  - ID-Q,OD-Q,pre-activity,Flasher-cut,etc..
- Vertex fit (dominant ring)
- Ring-finder
- Particle ID
- Energy determination
- Decay electron search
- MS-fit for 1-Ring event
- OD hit-cluster finding (Nhit of Highest Q cluster)

GPS time stamp



- GPS UTS of split trigger = GPS 1pps + 50MHz LTC
- 200ns accuracy
- confirmed by atomic clock

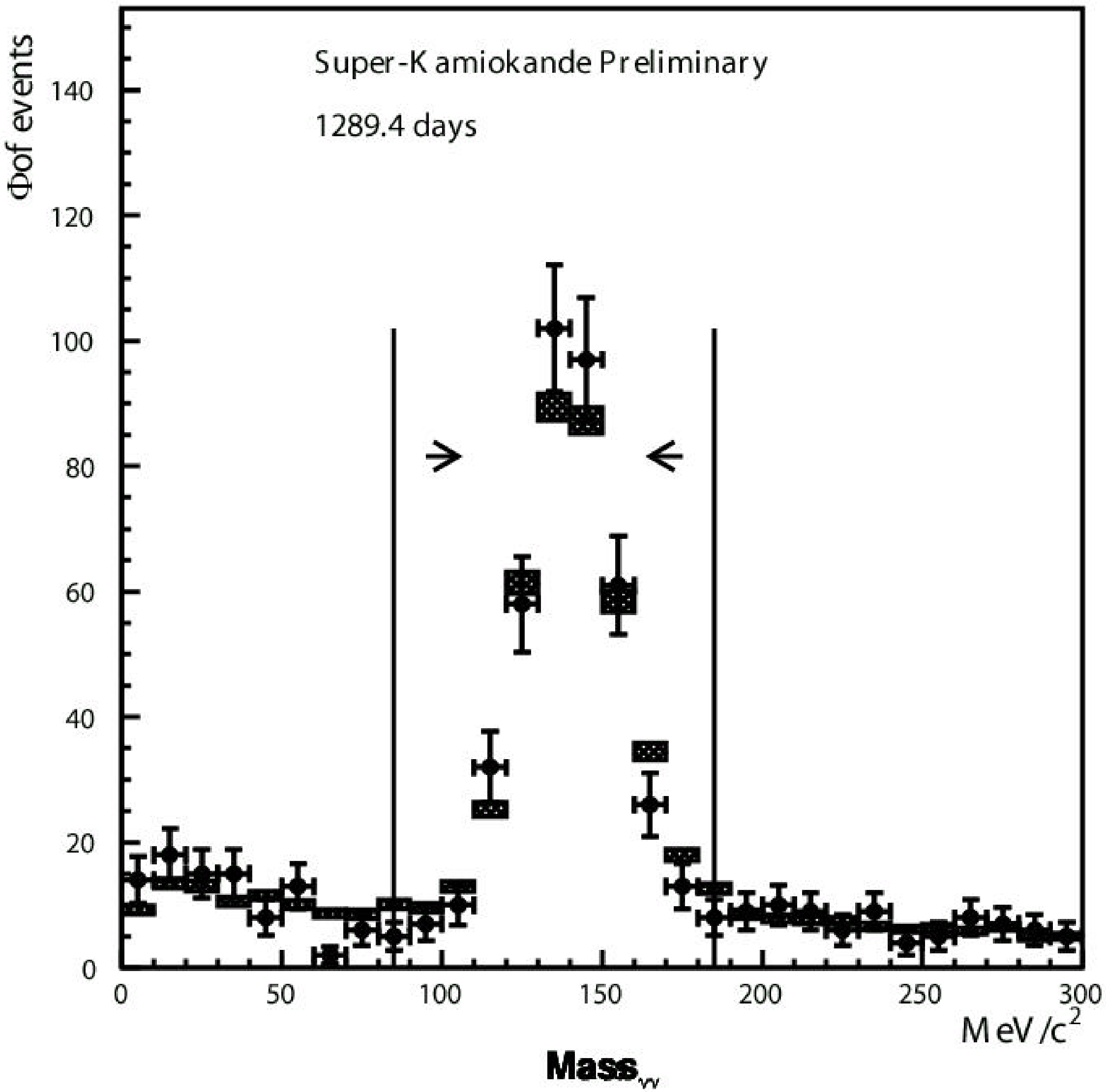
Accidental BG rate for beam events

- True signal (0.3Hz, 5micro/spill)
  - Total 2.6e-3/spill (WBB), 2.9e-4/spill(NBB)
  - Nuclear γ = total * 3% (7e-5/spill for WBB)
- BG contents
  - Cosmic ray μ = 3Hz (1e-5/spill)
  - Atmospheric ν = 10/day (1e-10/spill)
  - Decay electron = 0.01Hz (1e-8/spill)
  - LowE γ (5–20MeV) = 0.3 Hz (3e-7/spill)

Eν reconstruction

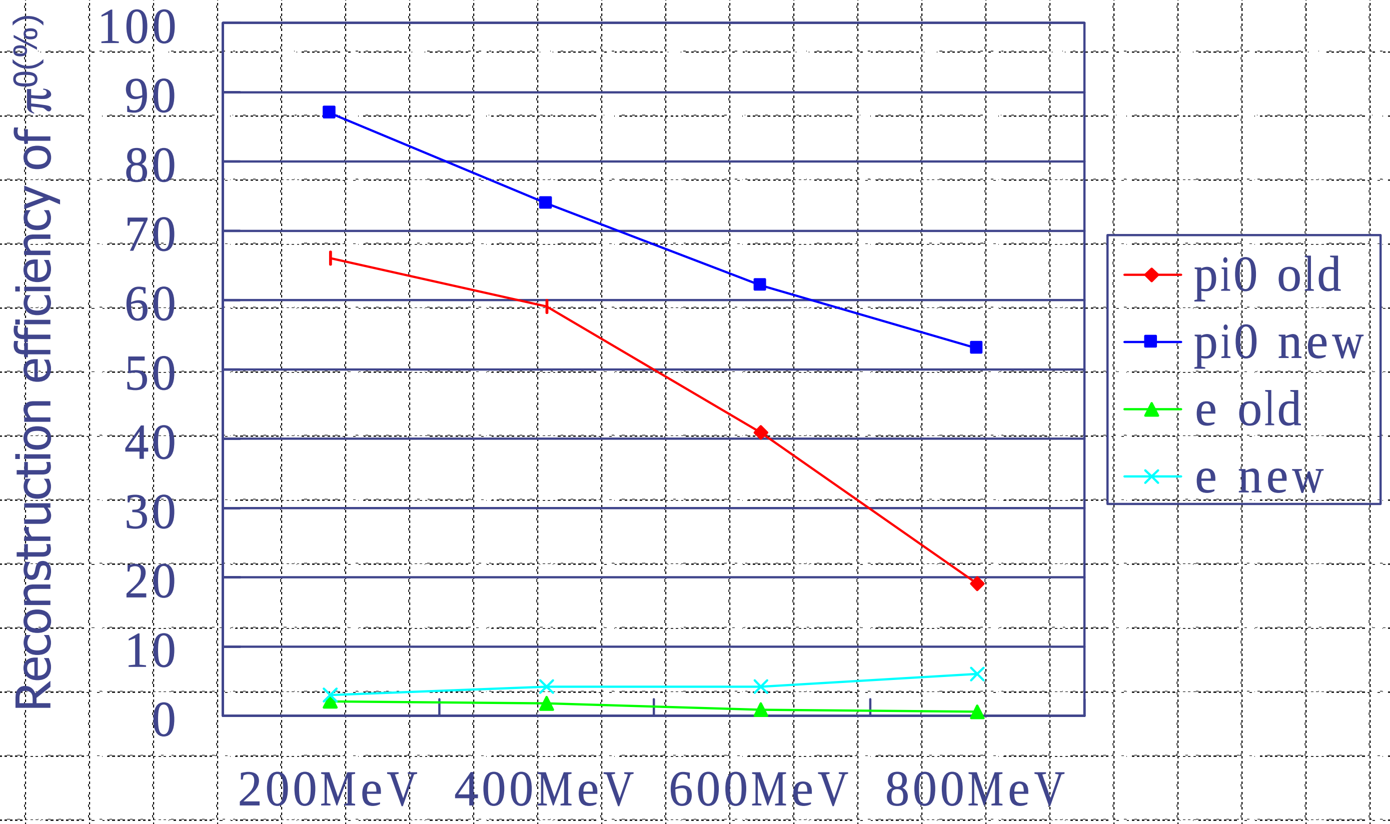
- 1-ring FC
- Momentum sum of rings
- Total visible energy
- Energy flow

π^0 reconstruction



π^0/e separation

- 2-R e-like tag (old ring-finder)
- π^0 fitter (improved ring-finder)



By T.Barszczak

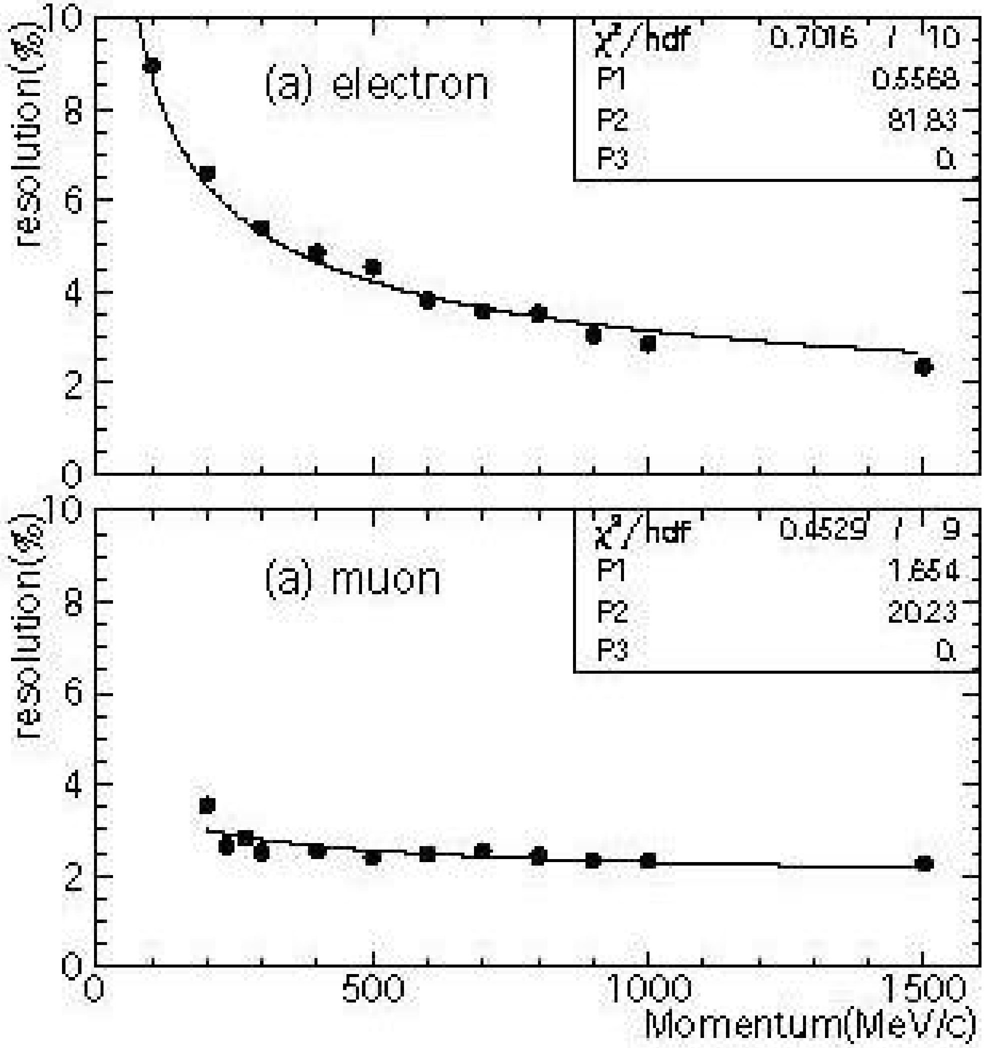
Comparison to the other far detectors

- MINOS
  - 5kt magnetized iron+scintillator hodoscope
- OPERA
  - 1kt ECC type (emulsion + iron)
- ICARUS
  - 5? kt lq. Ar TPC (+ MUC ?)

Summary

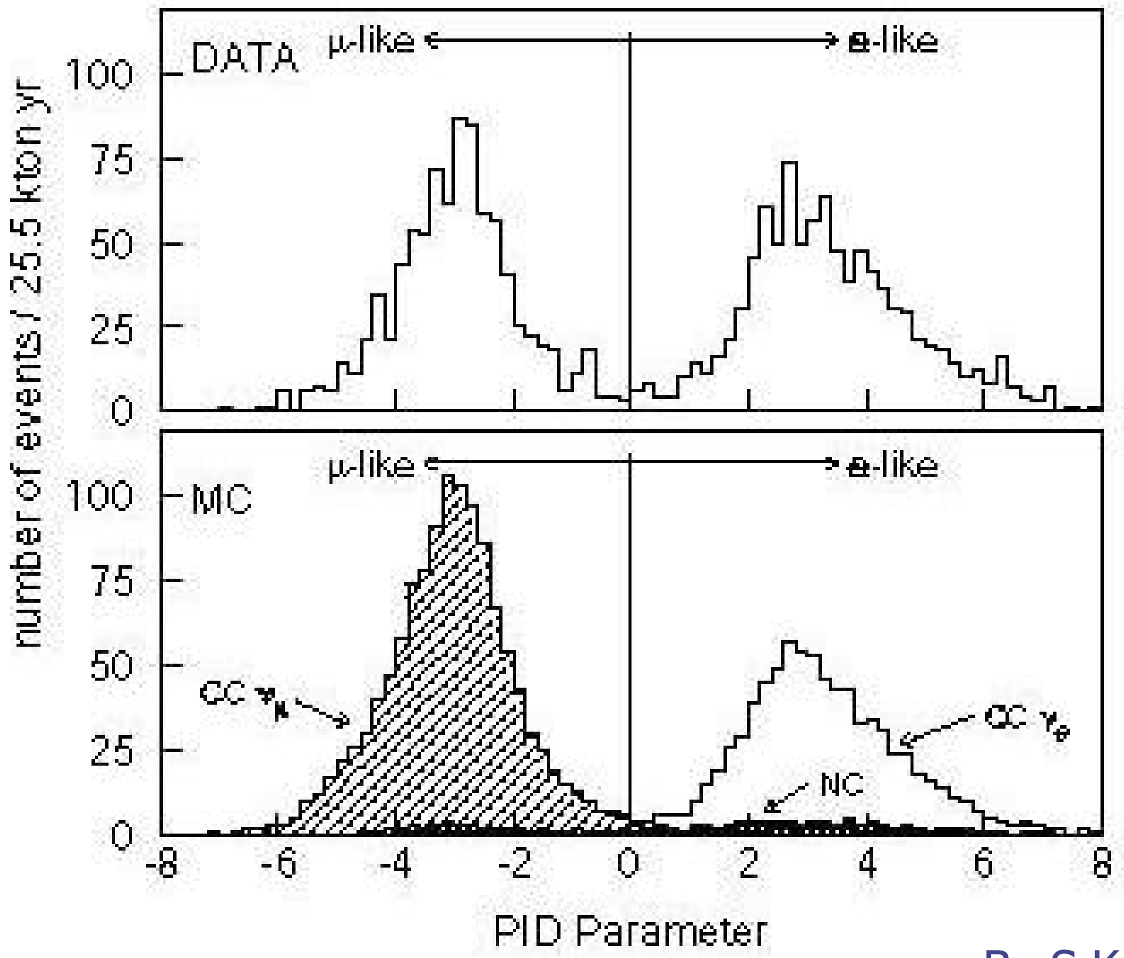
- Super-Kamiokande as a far detector
- Large mass, existing, well-understood
- Good for sub-GeV neutrinos
- Good for mu/e/NC separation
- Unique capability for a few MeV region
- Those advantage must be also same as in near detector

momentum resolution



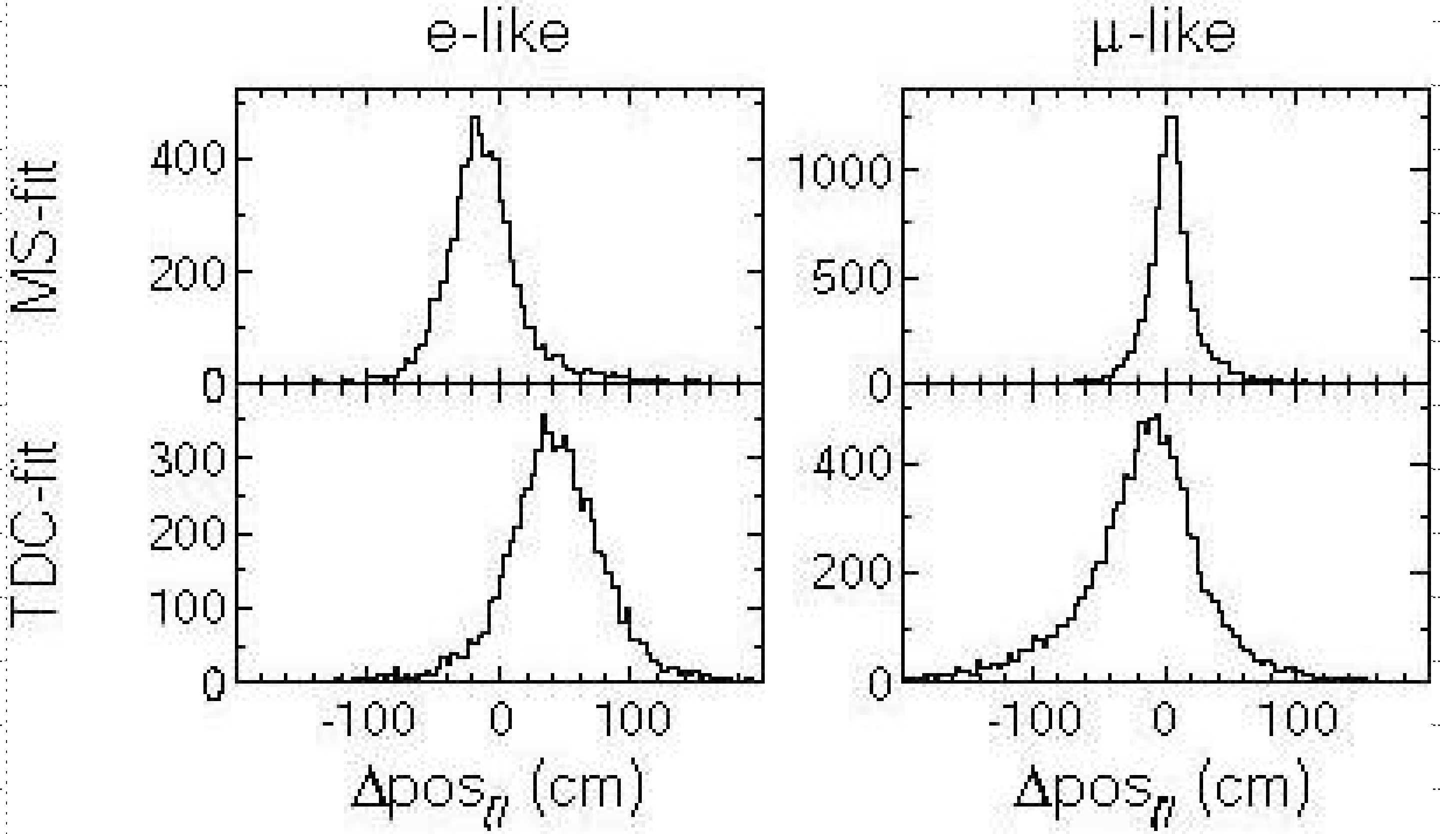
By K.Okumura

Particle identification



By S.Kasuga

Vertex reconstruction

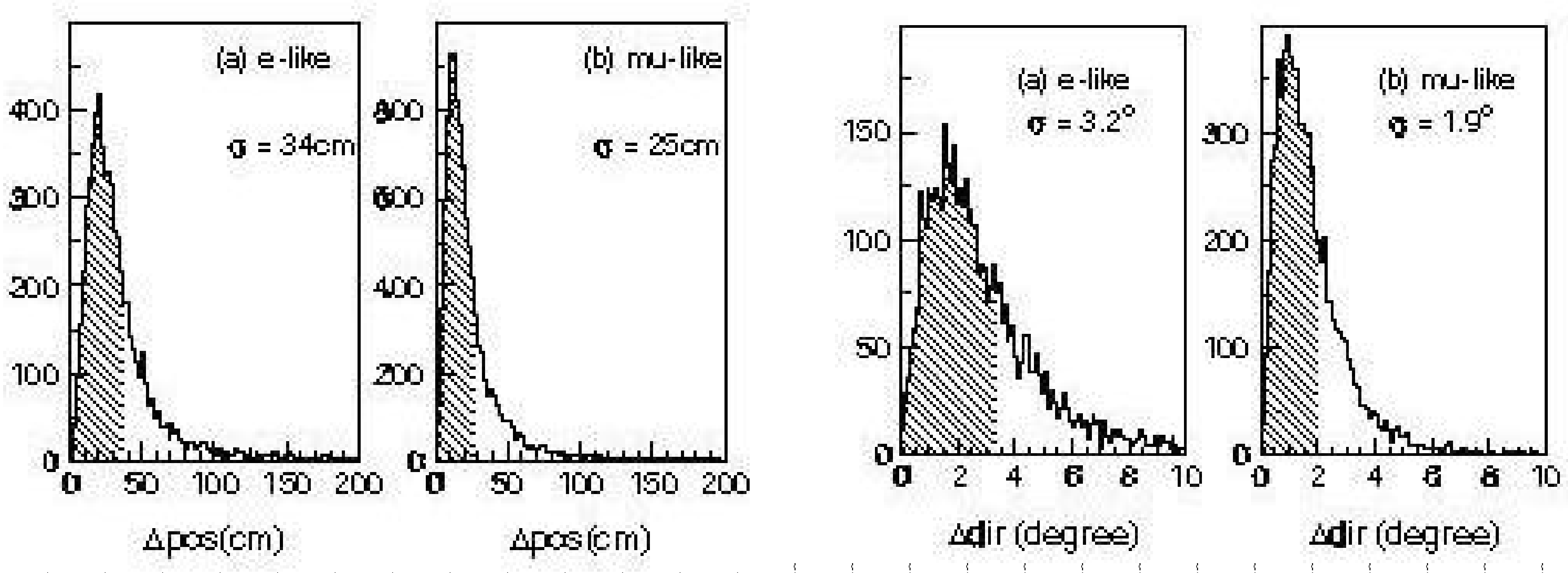


By M.Shiozawa

Vertex/angular resolution

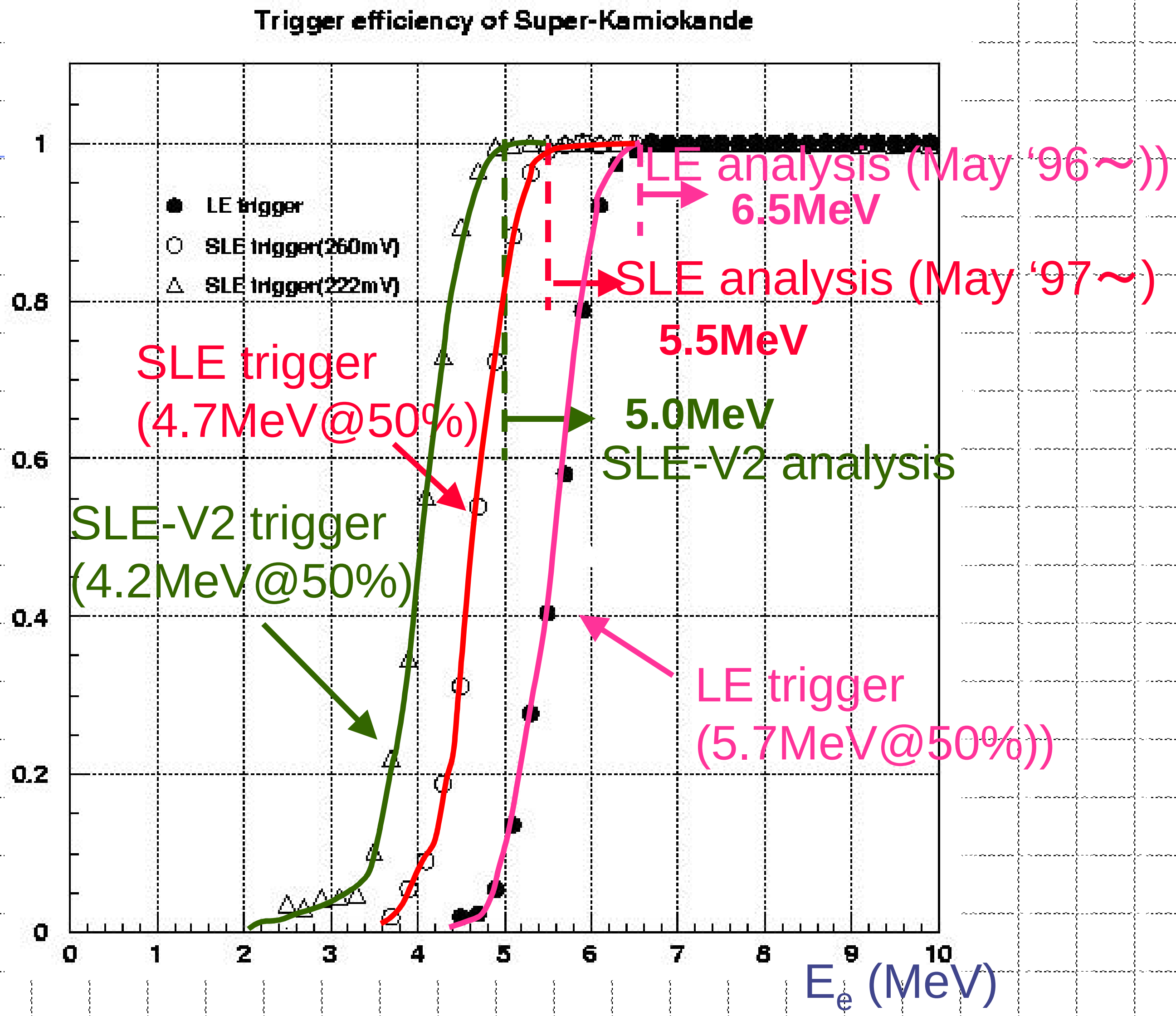
vertex

direction



By M.Shiozawa

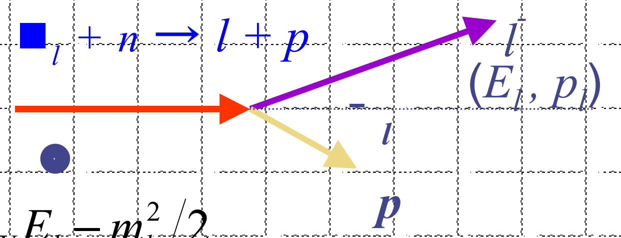
Trigger threshold



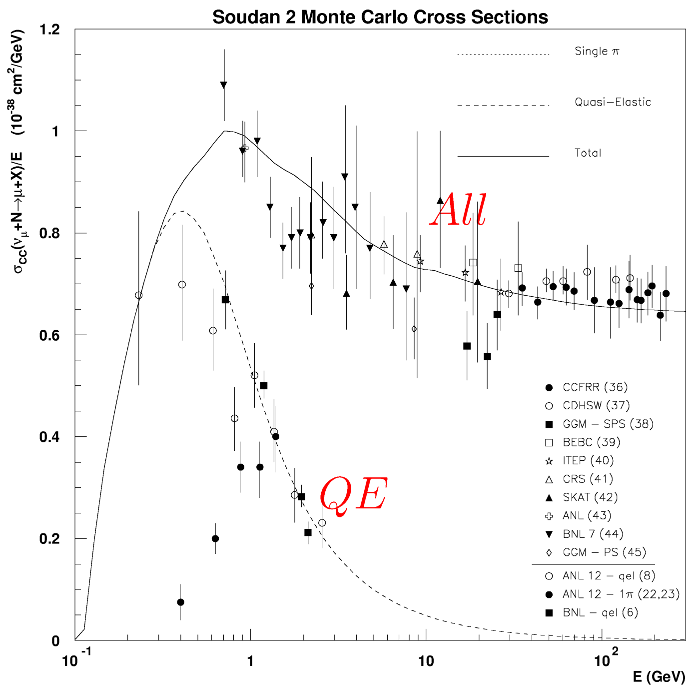
Since July 2000, further lowered by 12% (SLE-version 3).
(100 % eff. for >4.5 MeV, 3.7MeV@50%)

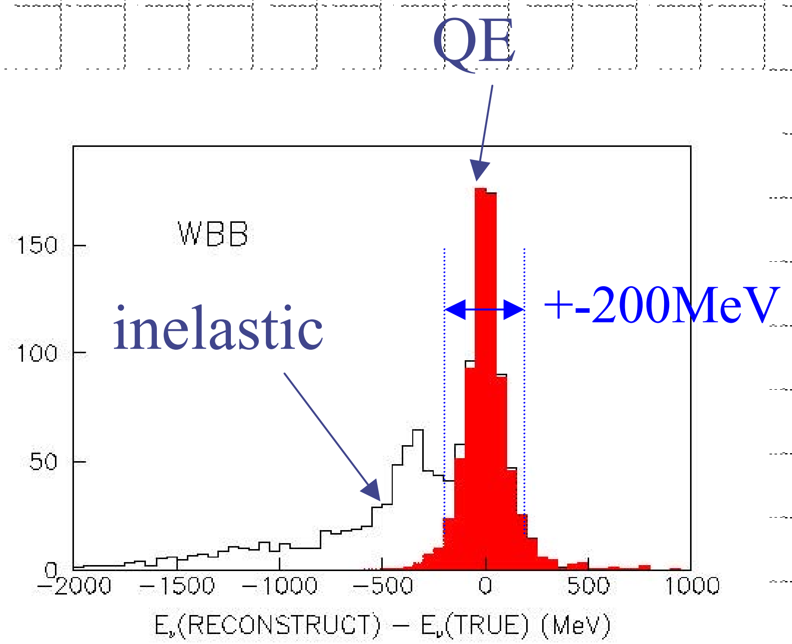
Eν Reconstruction(1R-FC)

Assume CC quasi elastic (CCQE) reaction



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





QE dominate at ~

Energy Acceptance