K2K実験
SciBar前置ニュートリノ検出器
読み出しシステムと時間情報の較正

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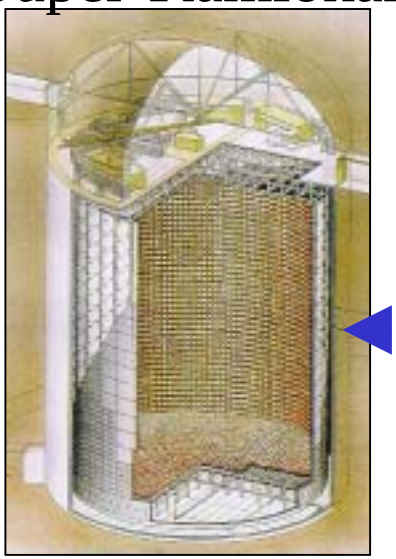
Contents

- K2K experiment
- SciBar detector & readout system
- Cosmic ray trigger system
- Timing calibration
- Conclusion

K2K Experiment

Super-Kamiokande

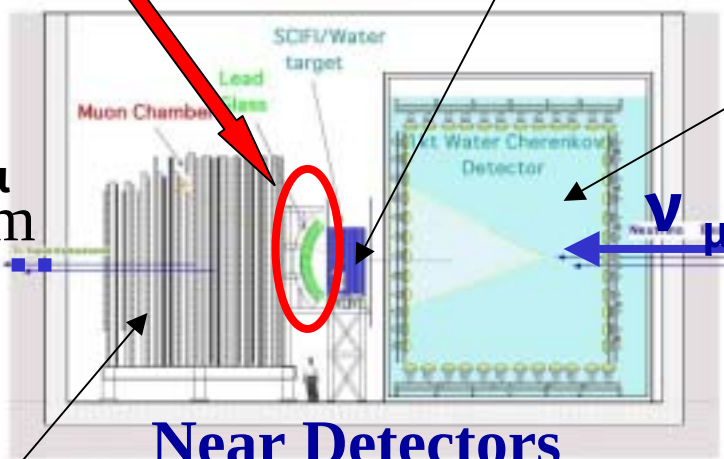


SciBar detector

SciFi detector

1kt water cherenkov detector

Pure ν_μ
L = 250km



Near Detectors

MRD(Muon Range Detector)

KEK 12GeV PS

K2K experiment uses neutrinos made by the accelerator

Pure ν_μ beam whose Flux and energy are well known, can be obtained .

Neutrino Oscillation

Square mass difference(eV^2) Flight length (km)

$$\text{Oscillation Probability} = \sin^2 2\theta \cdot \sin^2\left(\frac{1.27\Delta m^2 L}{E_\nu}\right)$$

Neutrino energy (GeV)

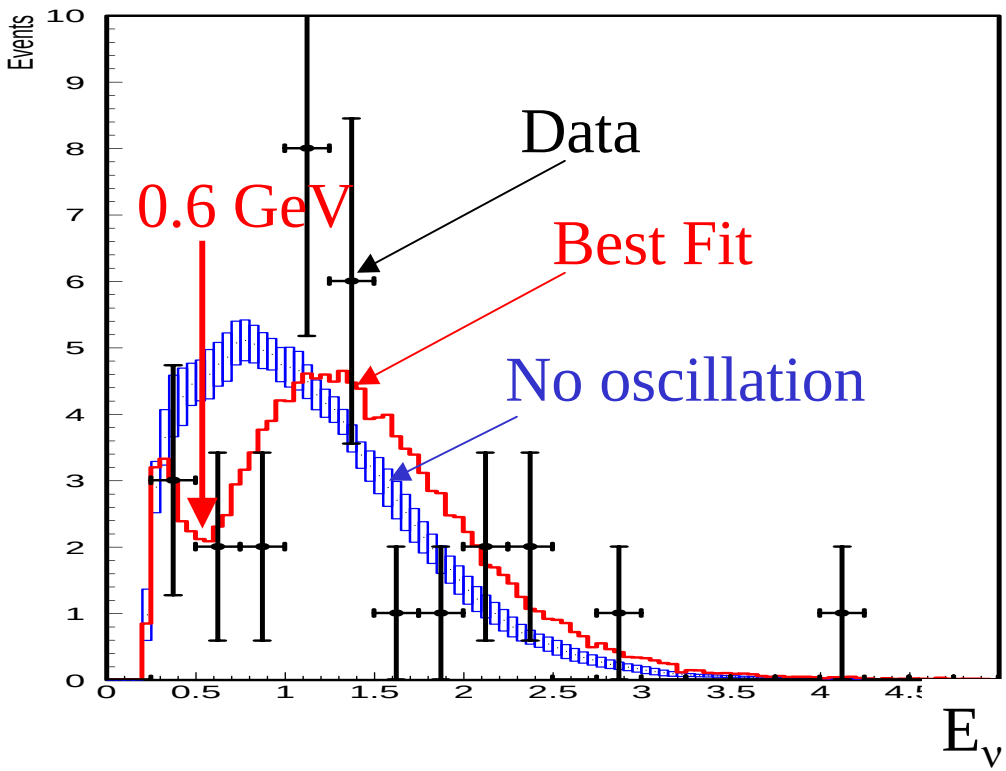
Mixing angle

K2K current status

Best fit

$\Delta m2 = 2.8 \times 10^{-3} (eV^2)$

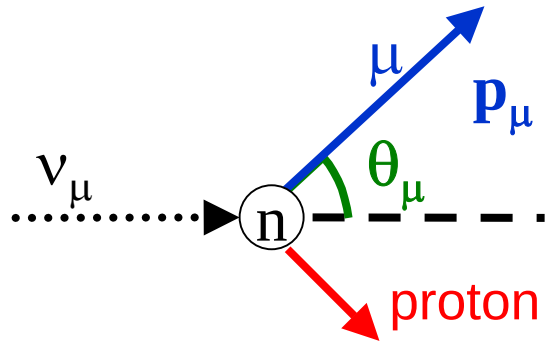
$\sin^2 2\Theta = 1.0$



Neutrino interaction

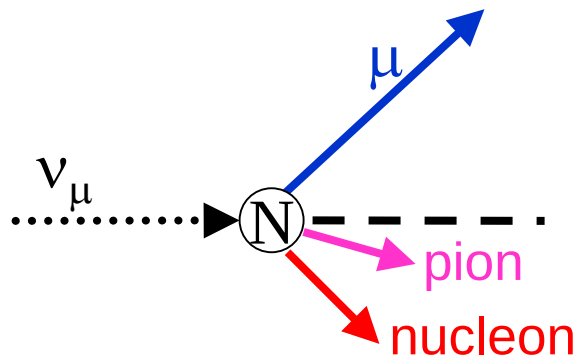
- Assuming Charged Current Quasi-Elastic interaction
  - Dominant process around 1GeV neutrinos.
- Oscillation maximum ~0.6GeV
- Non-QE interactions are backgrounds for E_ν measurement

CC-QE Interaction



$$E_\nu^{rec} = \frac{m_n E_\mu - m_\mu^2/2}{m_n - E_\mu + P_\mu \cos\theta_\mu}$$

CC-nonQE Interaction



SciBar detector

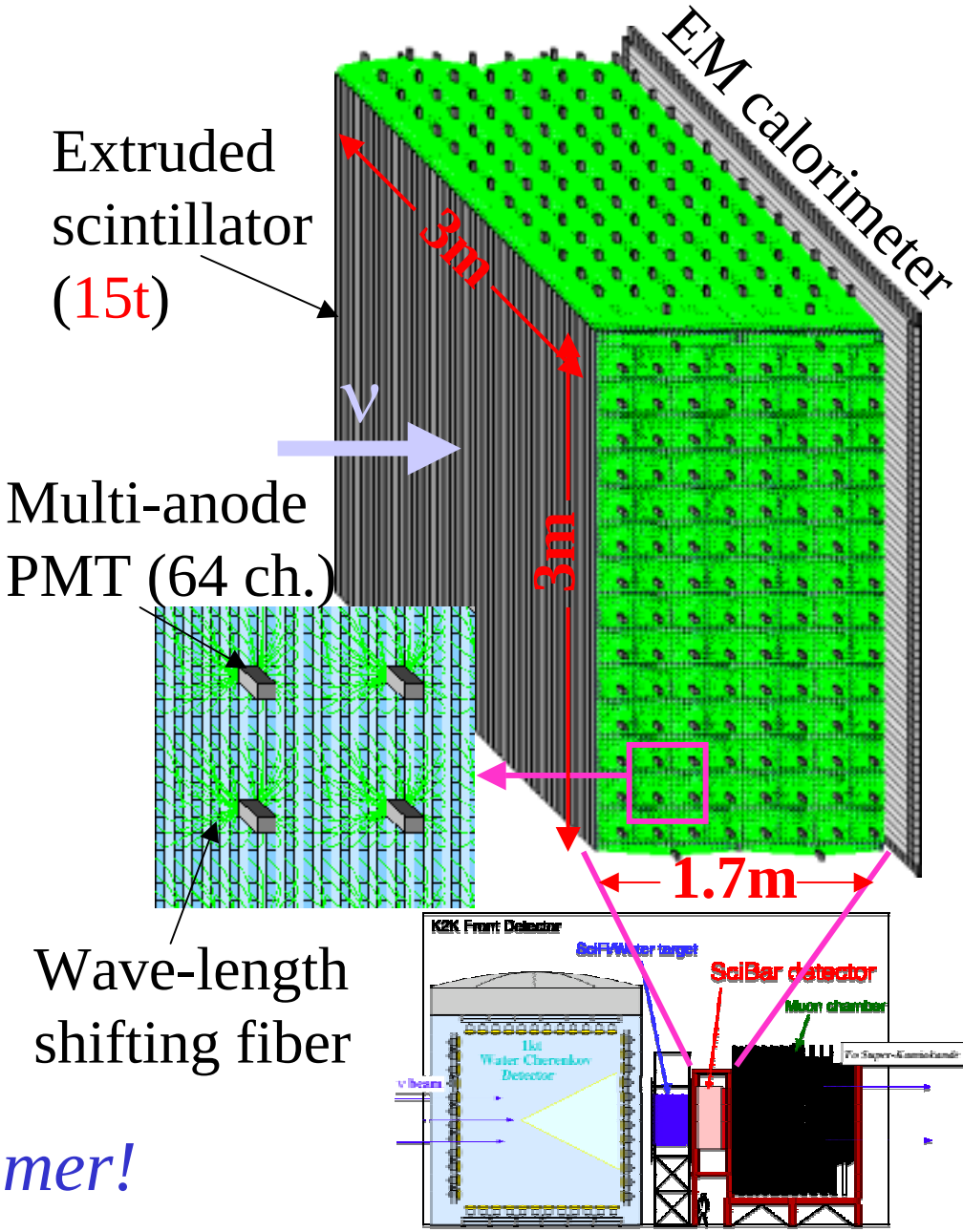
- Extruded scintillator with WLS fiber readout
- Neutrino target is scintillator itself
- 2.5 x 1.3 x 300 cm^3 cell
- ~15000 channels
- Light yield

  7~20p.e./MIP/cm (2 MeV)
- Detect 10 cm track
- Distinguish proton from pion by using dE/dx

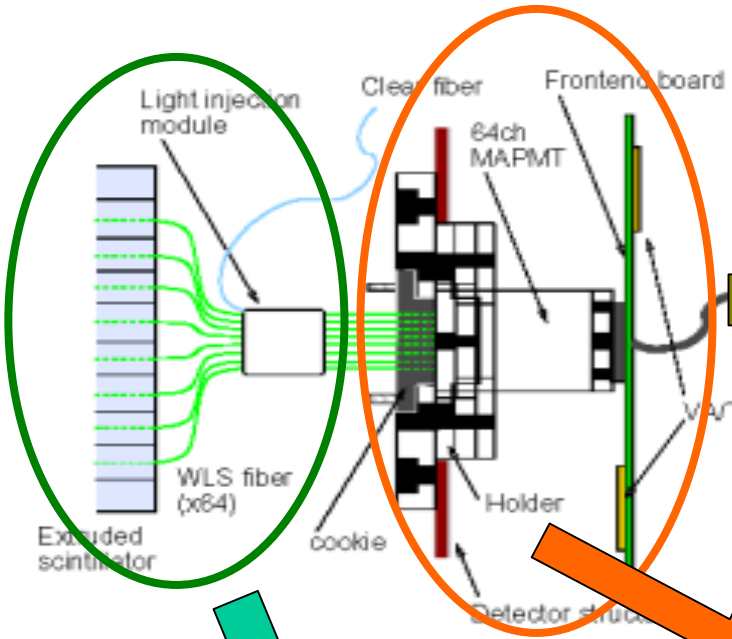
➔High 2-track CC-QE efficiency

➔Low non-QE backgrounds

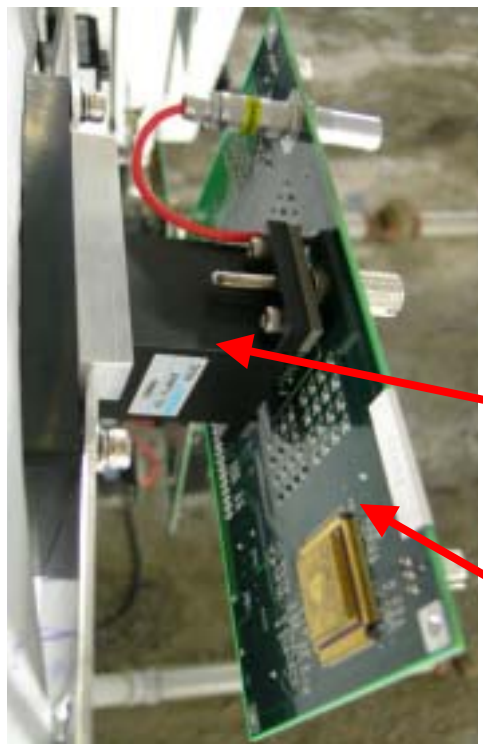
Just constructed in this summer!



Detector Components



DAQ board



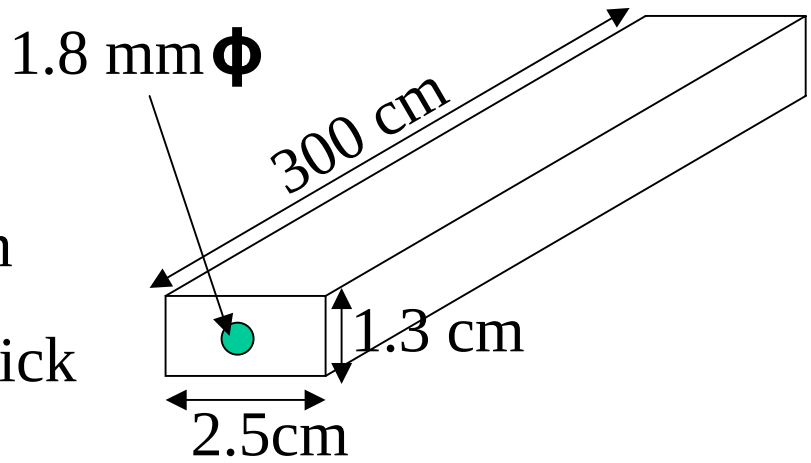
64ch MAPMT

Front-end board

Scintillator & WLS Fiber

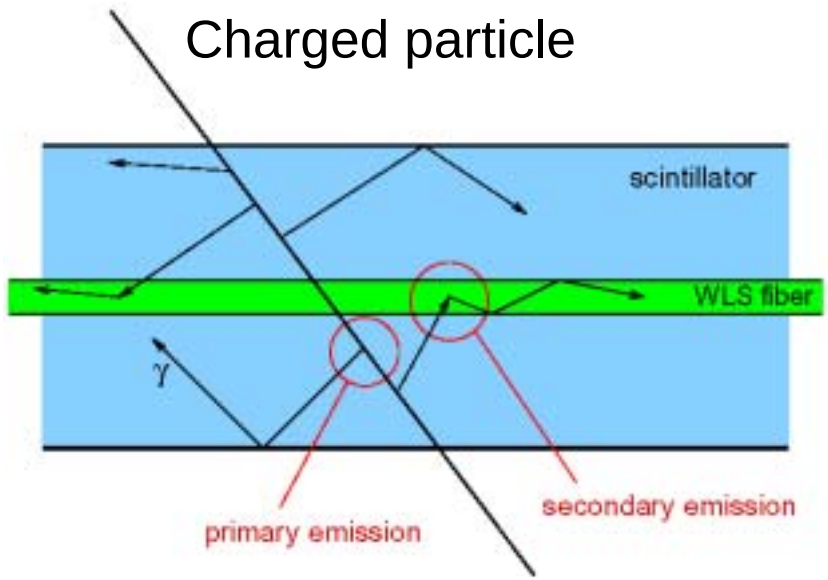
Scintillator

- Size : 1.3✕2.5✕300 cm^3
- Peak of emission spectrum : 420 nm
- TiO2 reflector (white) : 0.25 mm thick



Wave-length Shifting Fiber

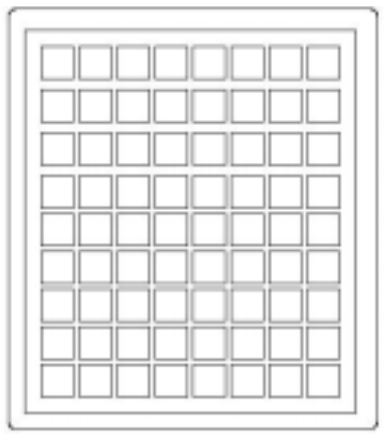
- Kuraray
  - Y11(200)MS 1.5mmϕ
  - Multi-clad
- Attenuation length ~3.6m
- Absorption peak ~430nm
- Emission peak ~476nm

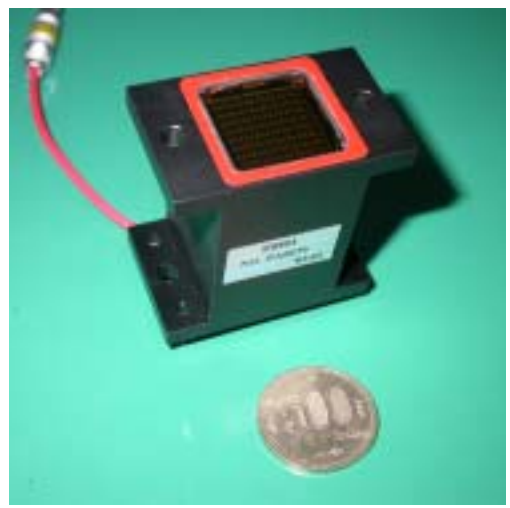


Multi-anode PMT

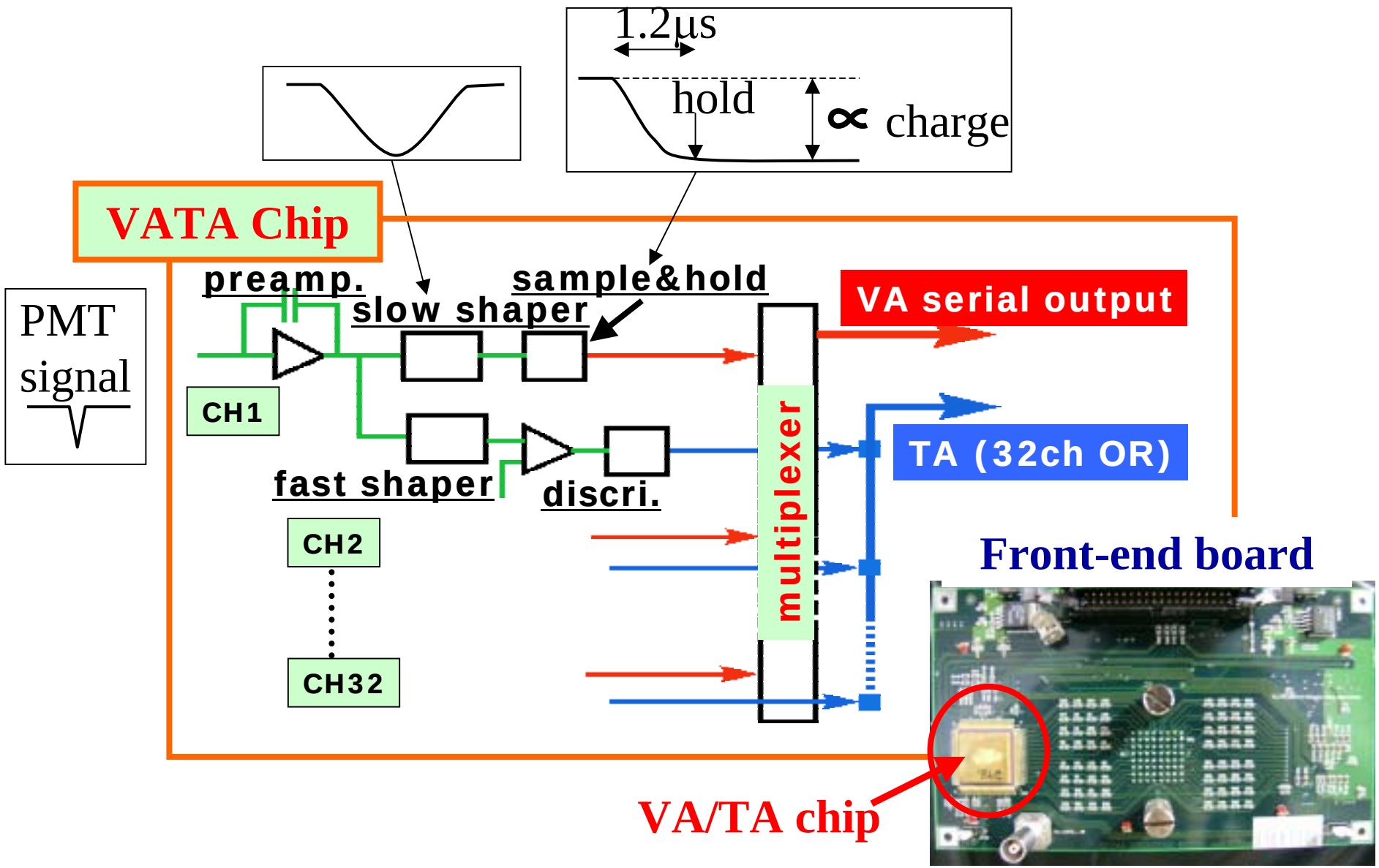
- Hamamatsu H7546 type 64-channel PMT
  - 2 x 2 mm^2 pixel
  - Bialkali photo-cathode
  - Compact
  - Low power : < 1000V, < 0.5mA
  - Typical gain : 6 x 10^5
  - Cross talk : ~3%
  - Gain uniformity : ~20% (RMS)
  - Linearity : ~200 p.e. @ 6 x 10^5

Top view



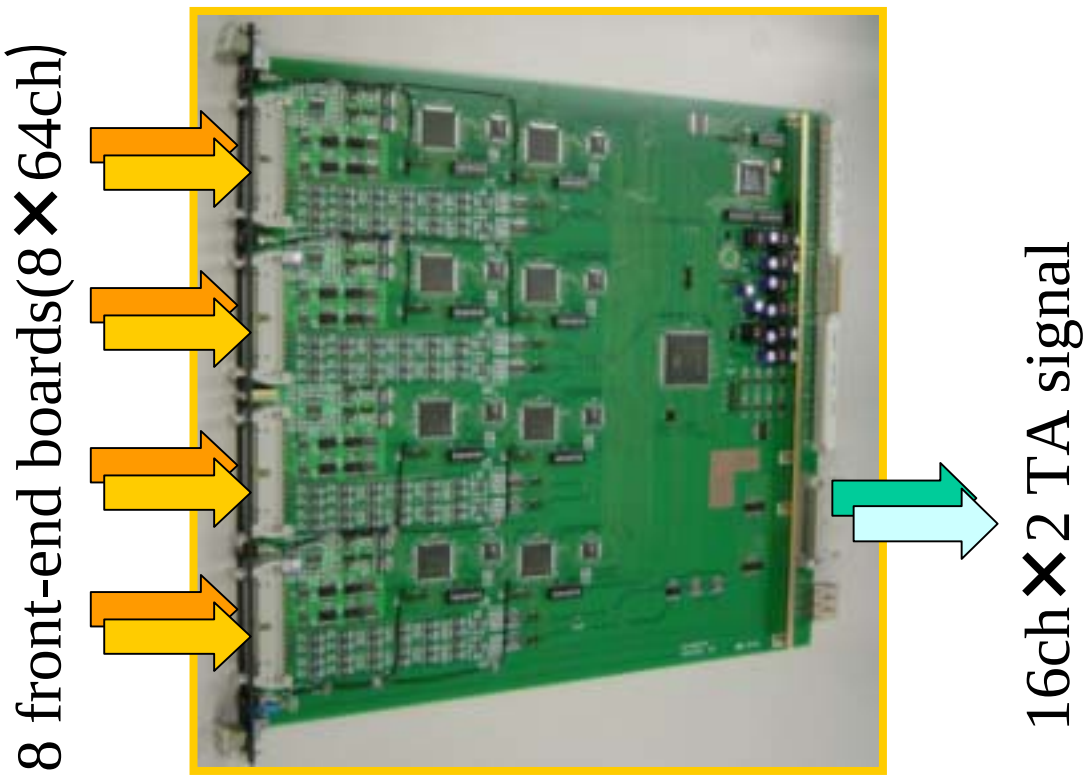


Readout Electronics



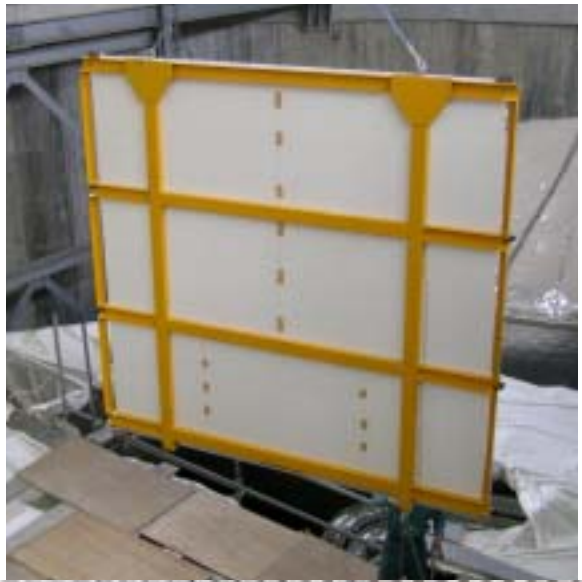
DAQ board

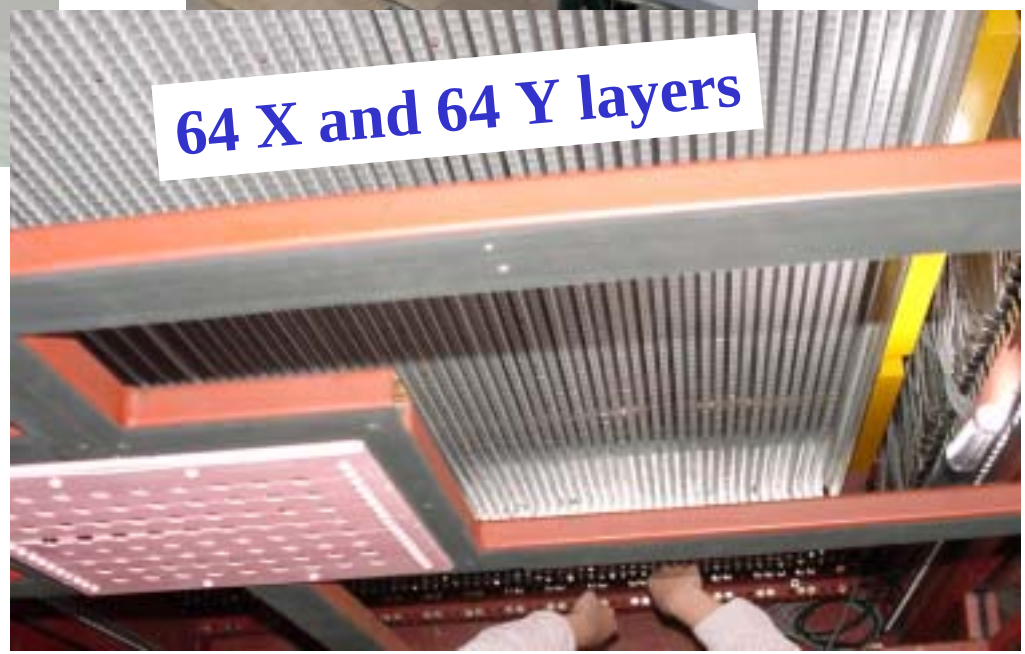
- Control of VA readout sequence
- Setting of VA trigger threshold
- A/D conversion of VA serial output by FADC
- 8 front-end board (8 MAPMT) are connected to one DAQ board.



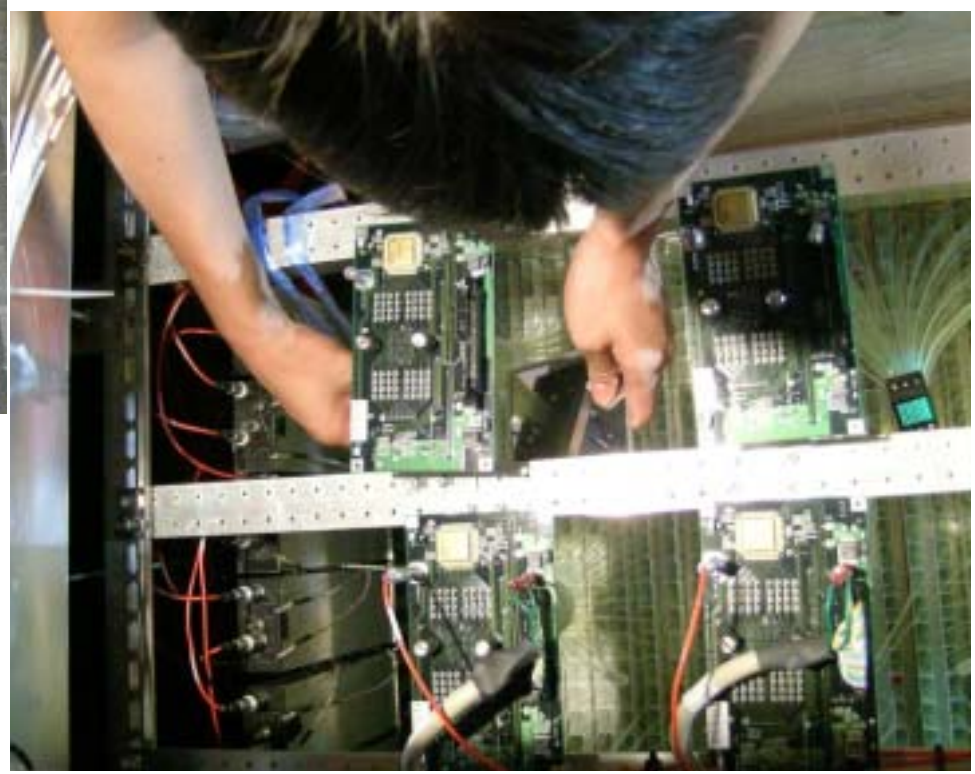
Scintillator Installation

X and Y planes were glued

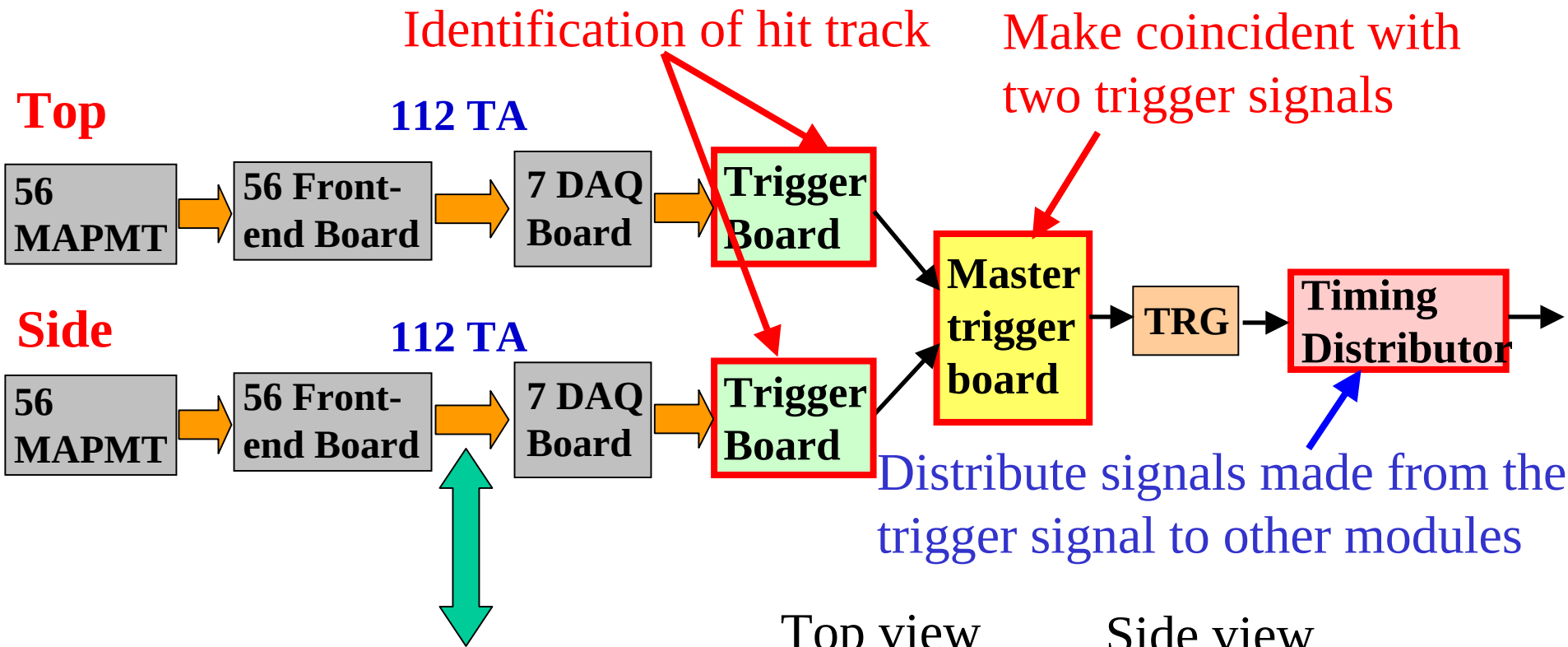




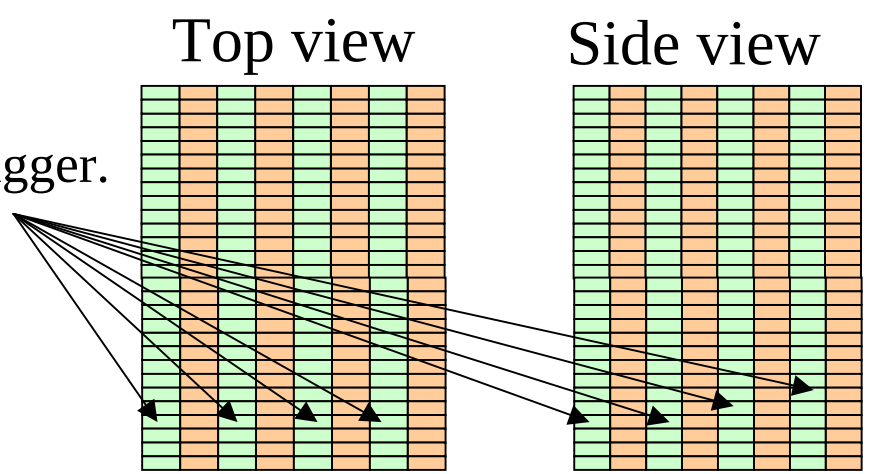
WLS Fiber and PMT installation



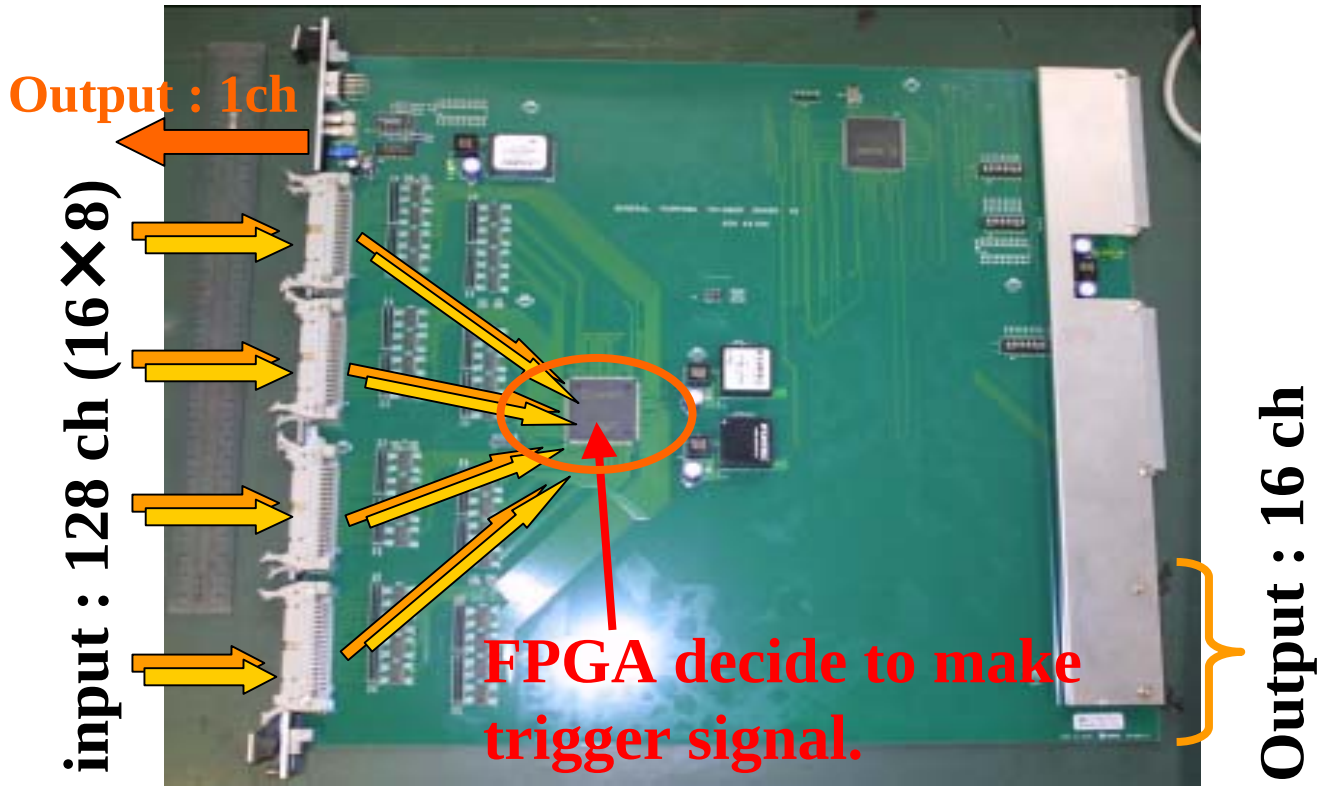
Logic Diagram for Cosmic Ray Trigger



We use half of the TA channels (224ch/448ch) for cosmic ray trigger.

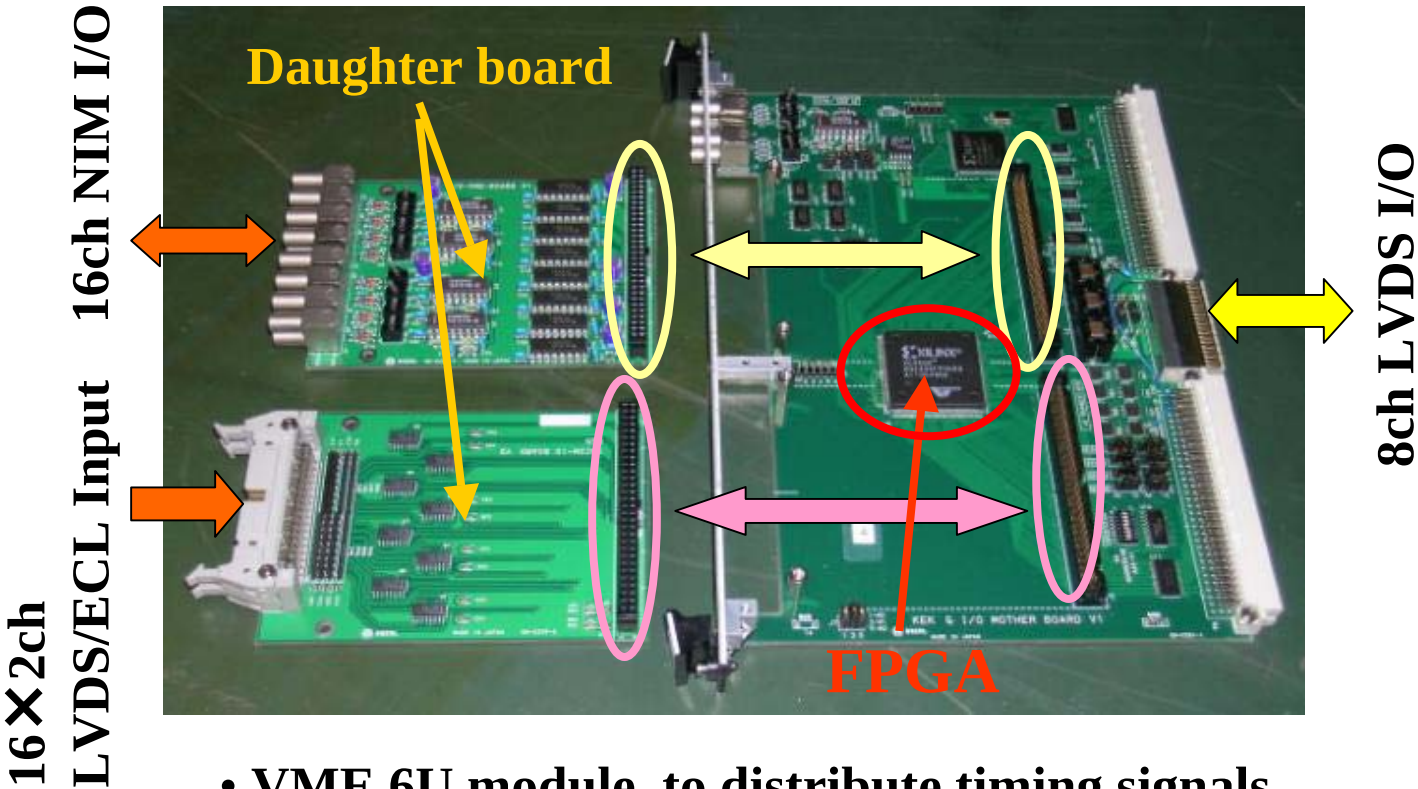


Trigger Board



- **VME 9U module**
- **Front panel : input 128 (16×8) ch LVDS/ECL**
- **Back plane : output 16ch LVDS/ECL**
- **Using FPGA, trigger logic can be easily implemented for any combinations of 128 inputs.**

Timing Distributor



- **VME 6U module to distribute timing signals made by trigger system to DAQ backend boards**
- **4ch NIM I/O on main board + 2 daughter boards**

Daughter board

16×2 ch LVDS/ECL Input
16ch NIM I/O

- **Flexible data processing is realized using FPGA.**

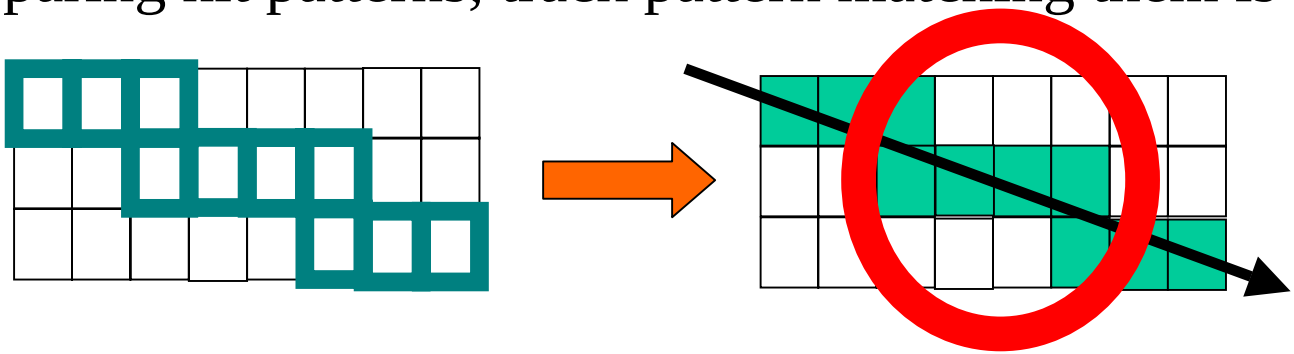
Requirement for Cosmic Ray Trigger

- Horizontally through-going muons are taken for calibration effectively.
- Distribution of cosmic ray hits is uniform.
- Decision time is less than 100 ns (due to the cable length of electron catcher)
- 32ch OR'ed signals from TA[*1] (fast-triggering ASIC) are trigger board input signals.

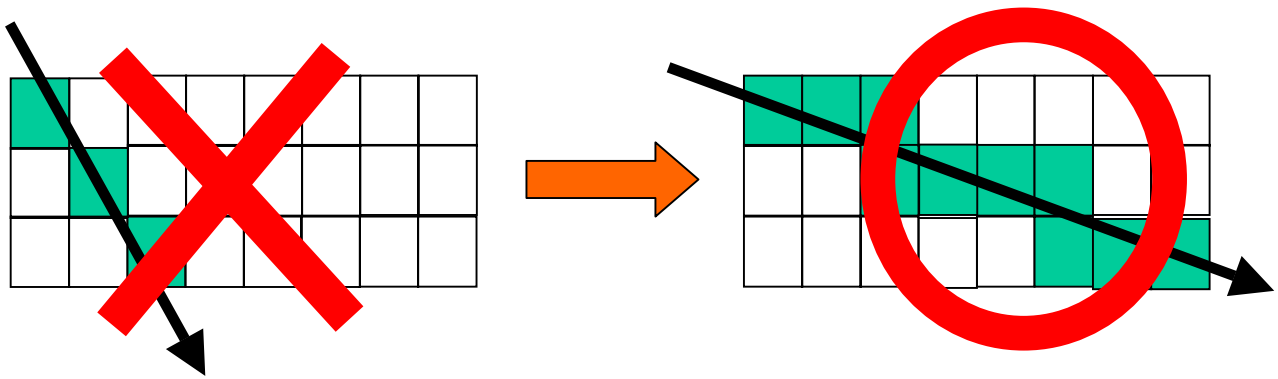
Trigger Design

- **Trigger is generated, based on the hit pattern identification.**

  Preparing hit patterns, track pattern matching them is selected.



- **Track which is less than 45 degree of zenith angle is taken.**



Zenith angle > 45 degree Zenith angle < 45 degree

- **Pre-scale factor can be set on the hit pattern to make hit distribution uniformly.**

Achieved Performance & Current Status

Achieved performance

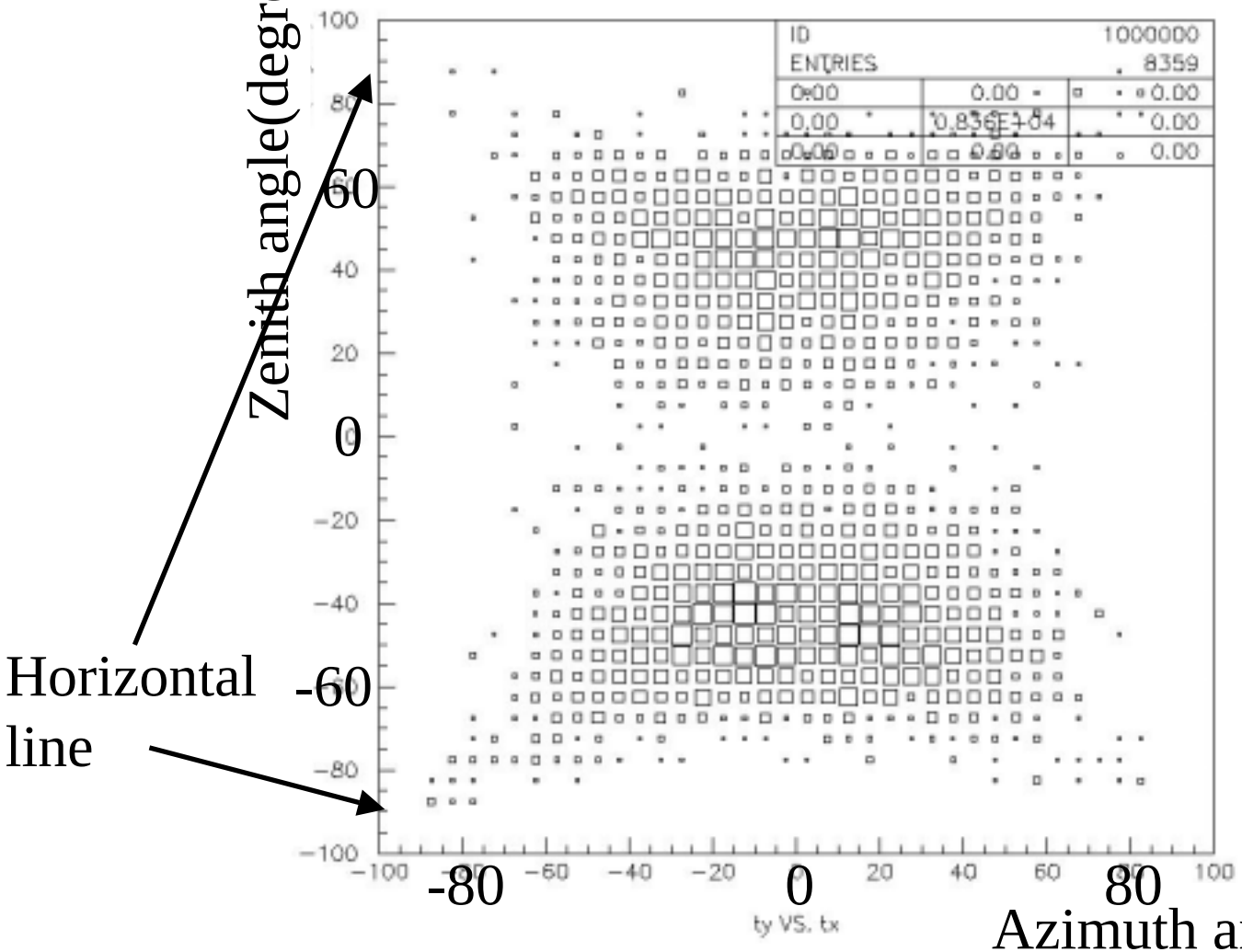
- **Decision time is 100 nsec.**
- **Single rate of one TA is about 100 Hz.**
- **Trigger rate is about 100 Hz.**
- **Data acquisition rate is about 20 Hz.**

Current Status

We now use a trigger logic for the commissioning. We make "or" signals of every other layer, and make coincident with those of the top and side separately. We make "and" signal of the top and side.

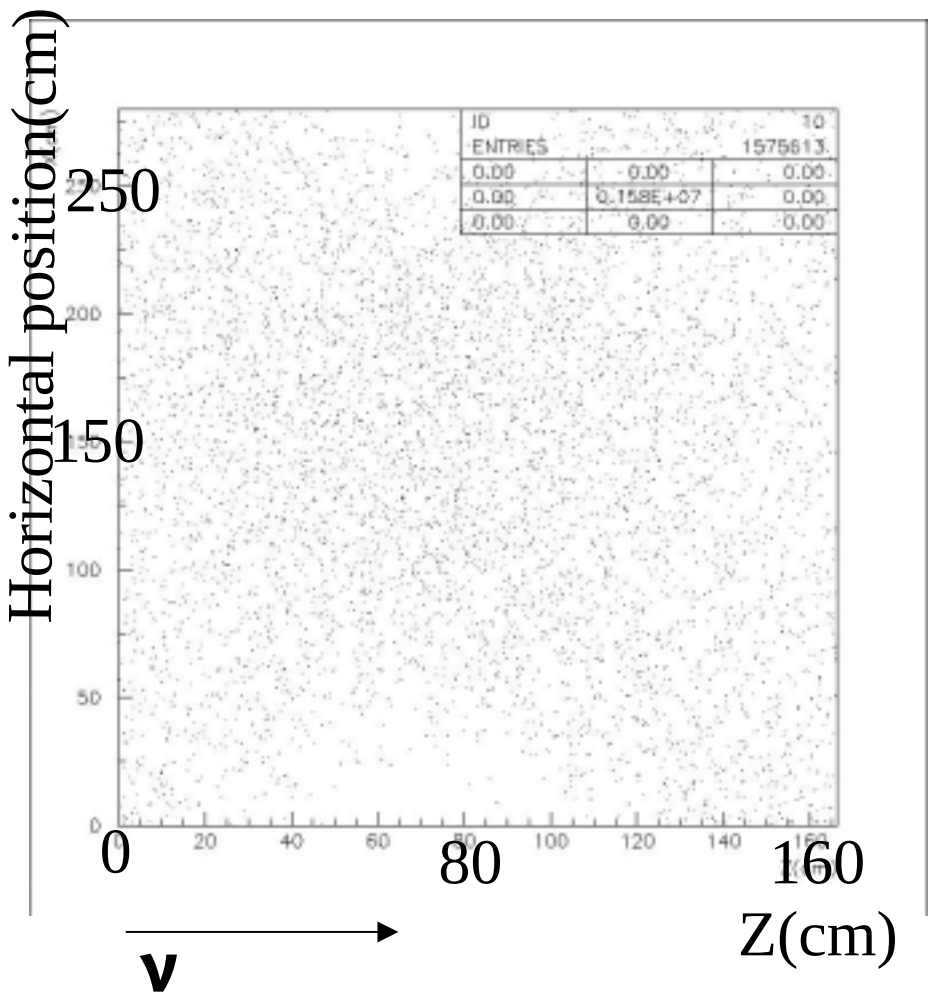
Angle distribution of cosmic ray event

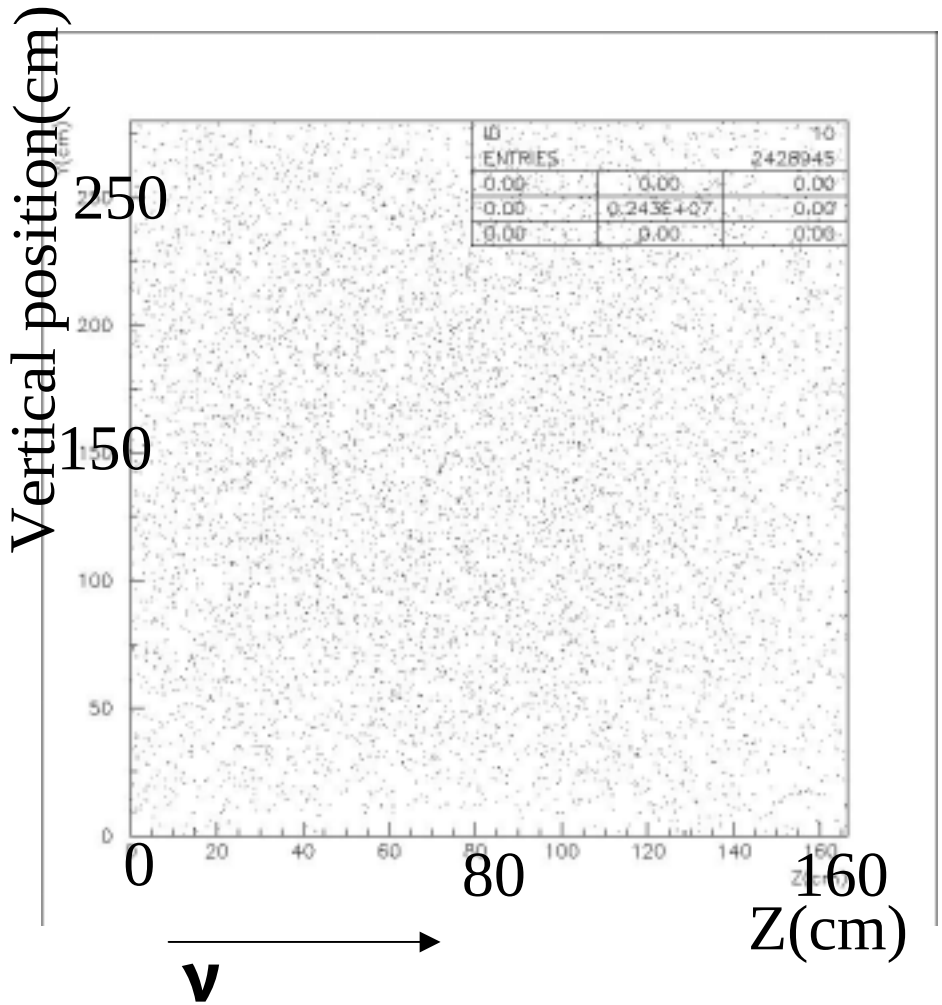
taken by commissioning trigger



Hit distribution of cosmic ray event

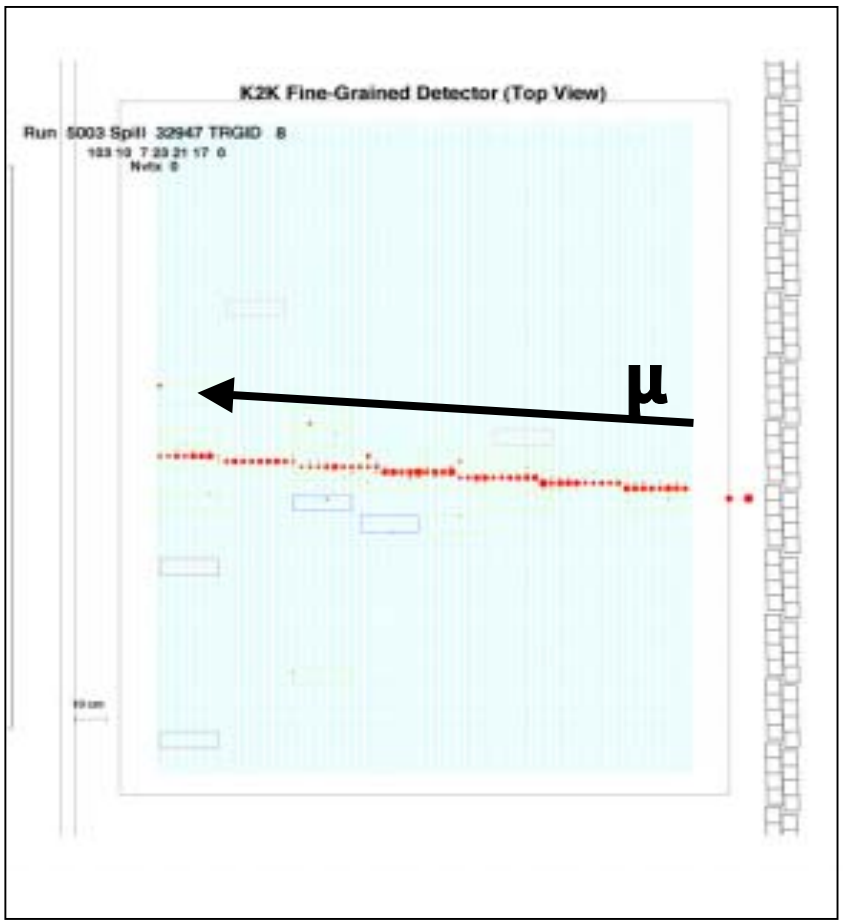
taken by commissioning trigger



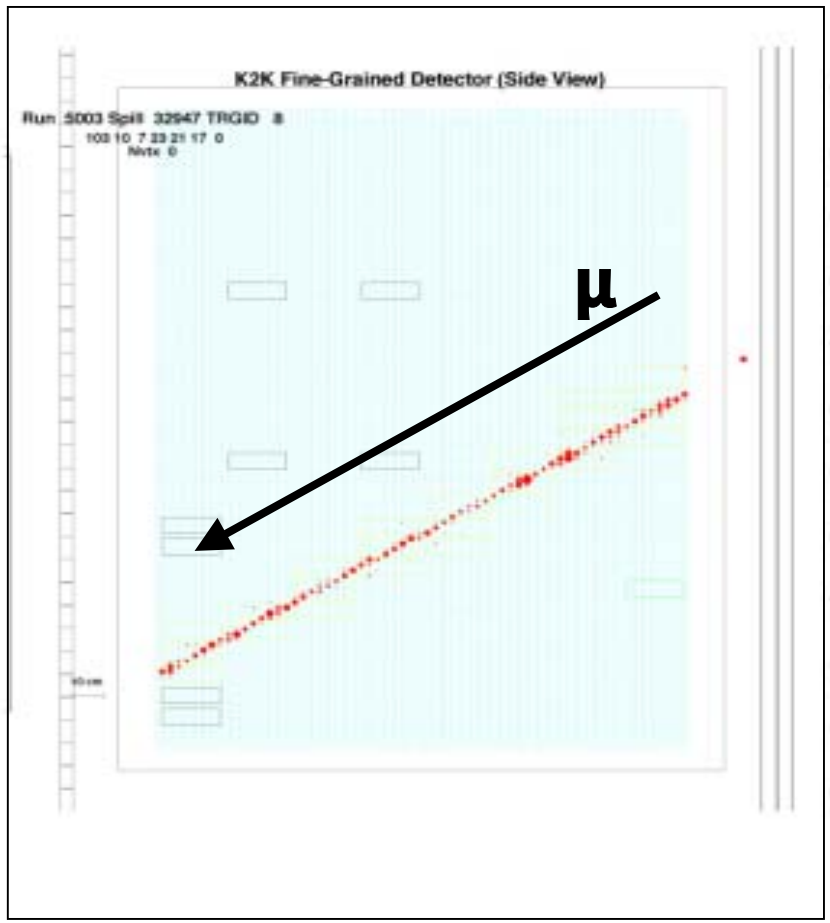


Event display of cosmic ray event

Top View



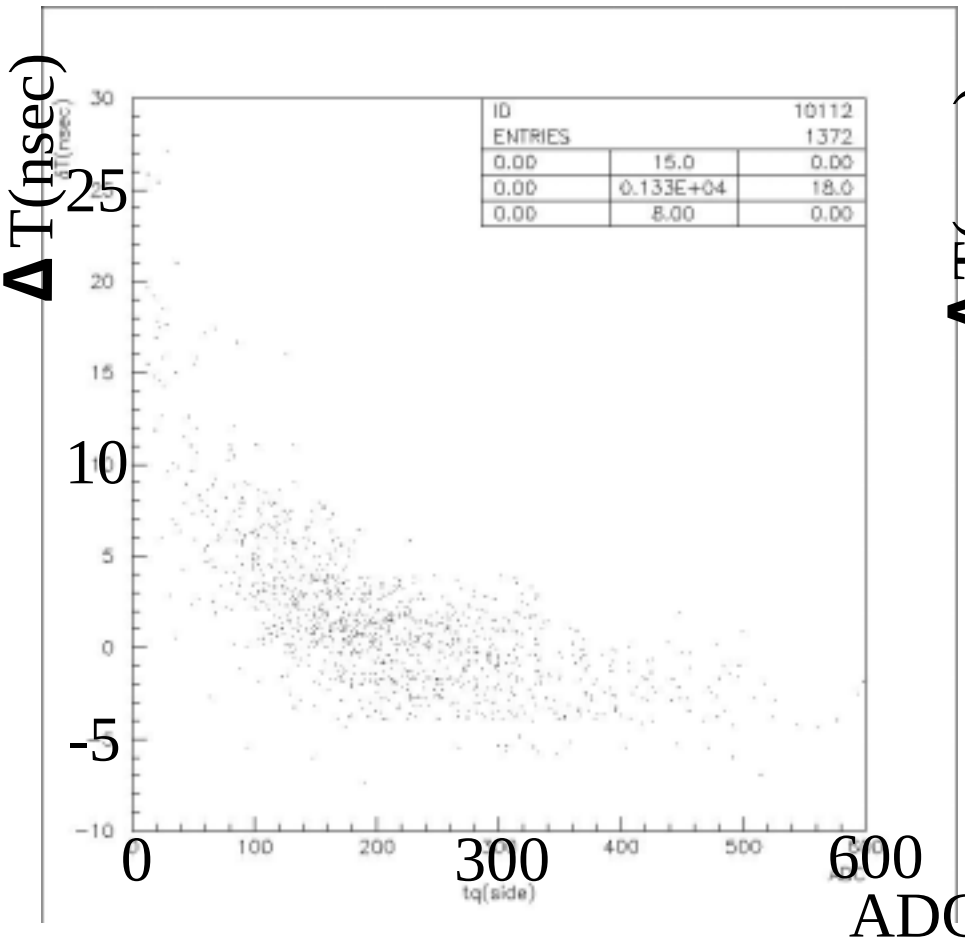
Side View

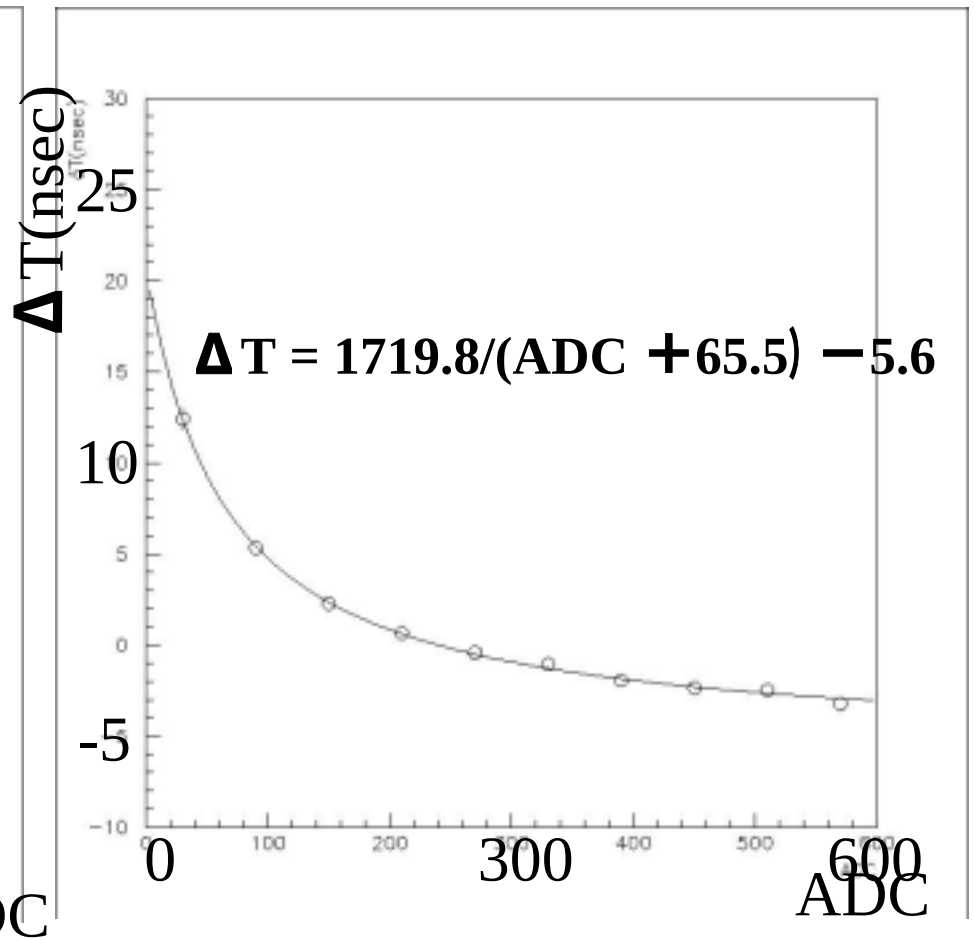


TQ Distribution

Correction function : $\Delta T = A/(ADC + B) + C$ A,B,C : const

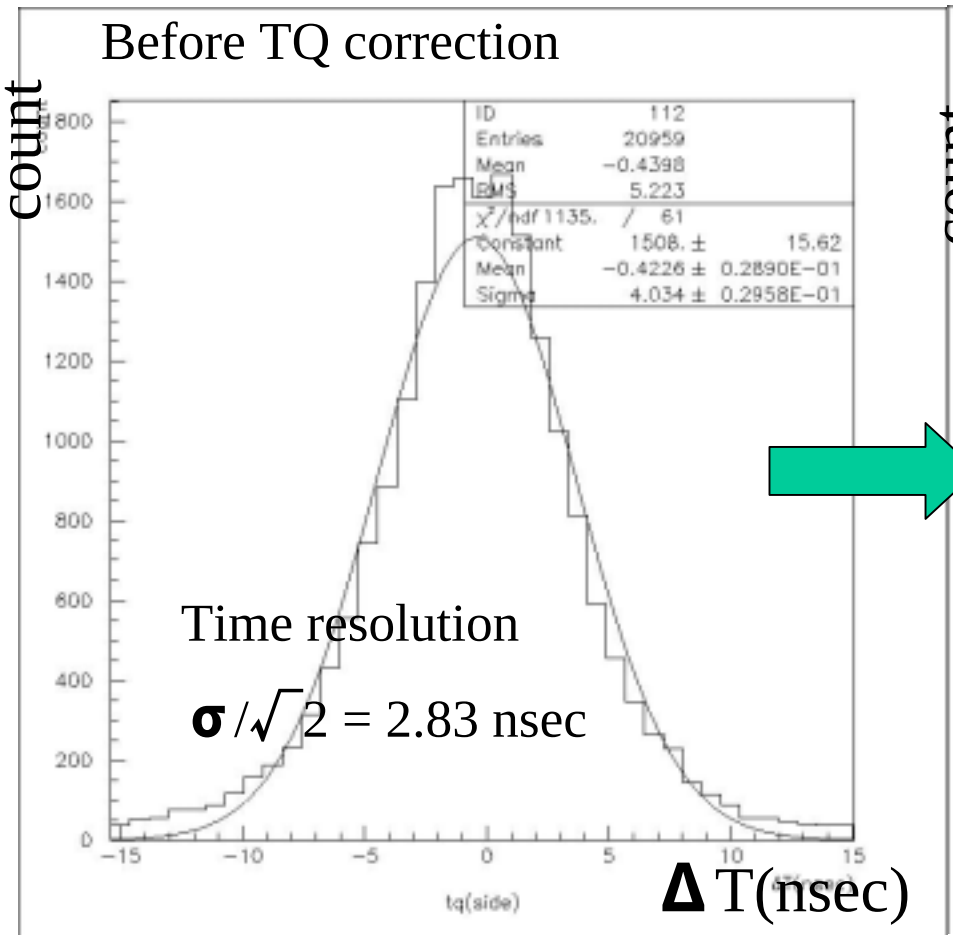
$\Delta T = T(X12Z1) - T(X12Z2)$

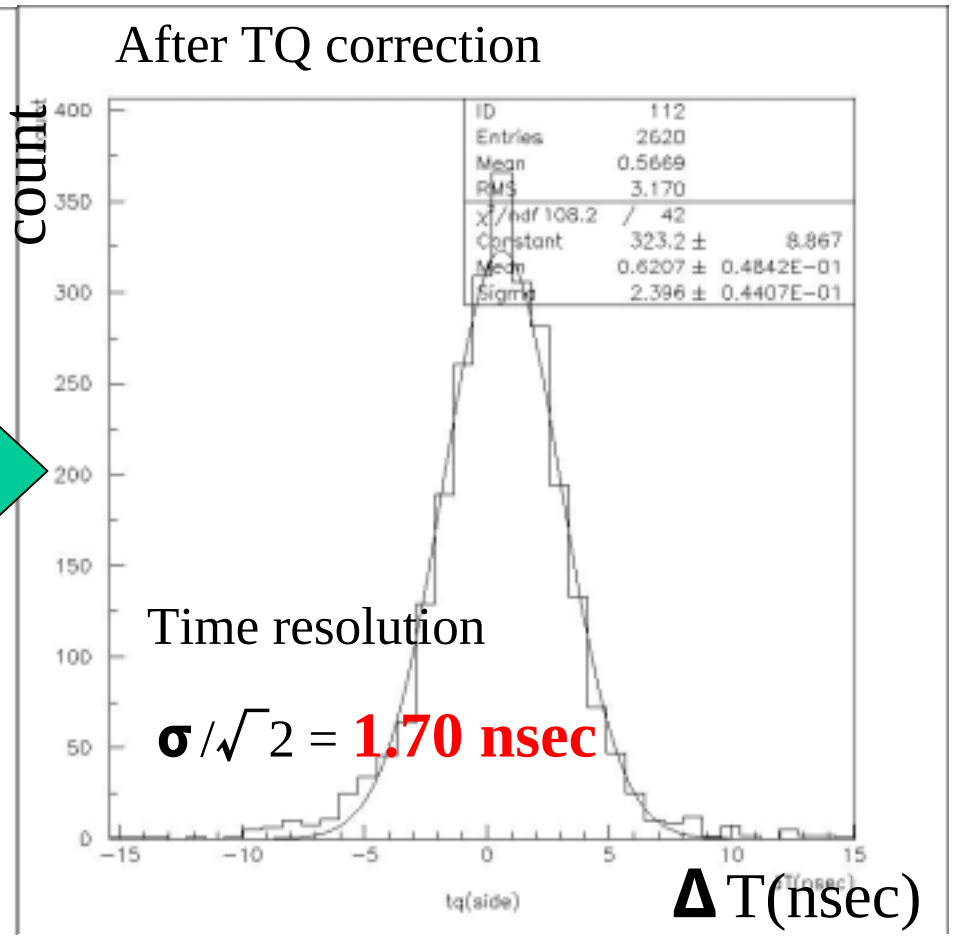




Time Resolution

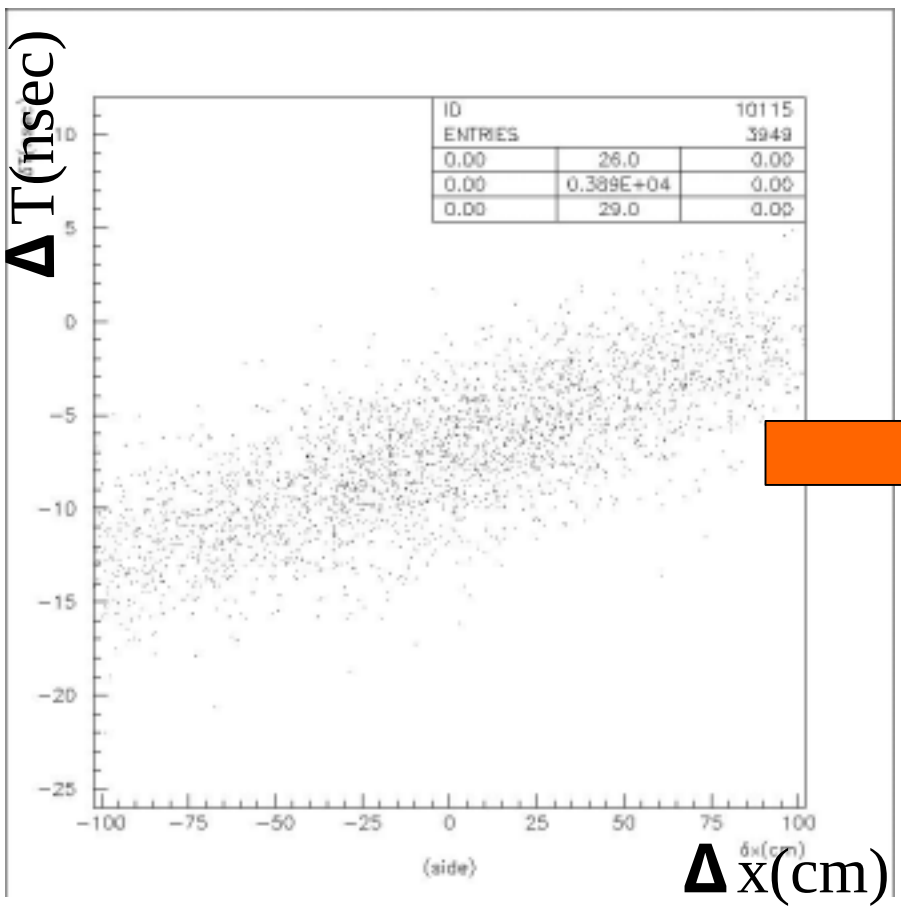
$\Delta T = T(X12Z1) - T(X12Z2)$

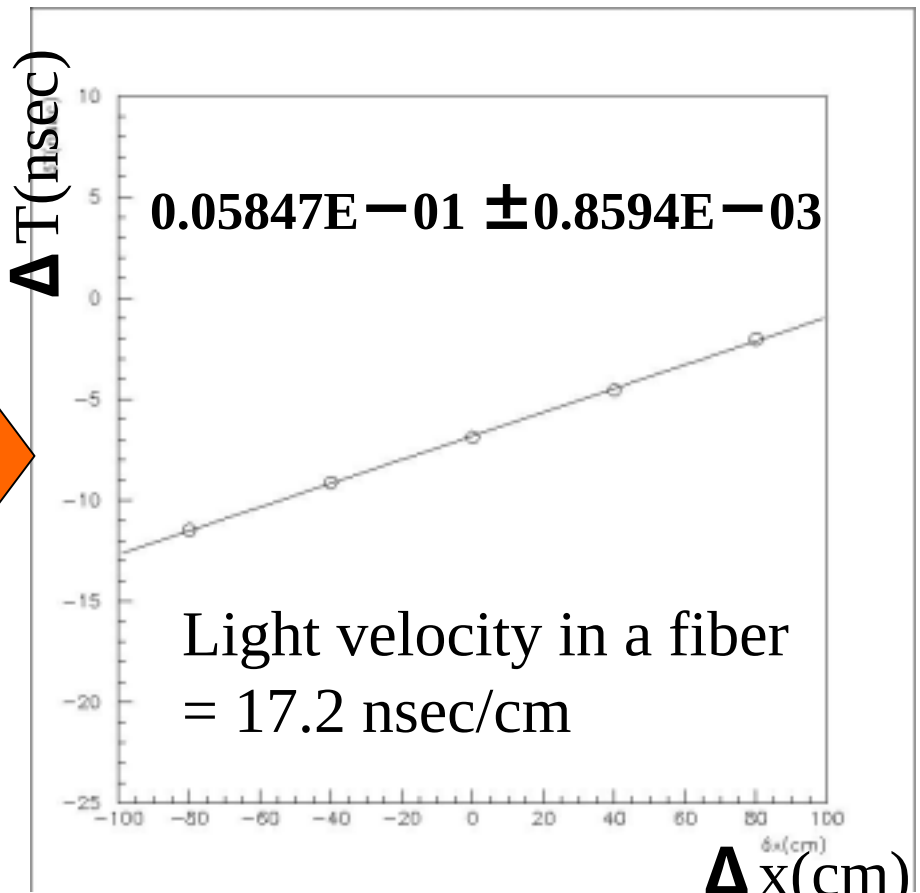




Light velocity in the fiber

y15z8





Conclusion & Next step

- Cosmic ray data is taken by commissioning trigger and useful for timing and energy calibration, and so on.
- Timing correction was done by cosmic ray data.
    - Timing resolution is 1.70 nsec.
    - Light velocity in a fiber is 17.2 nsec.

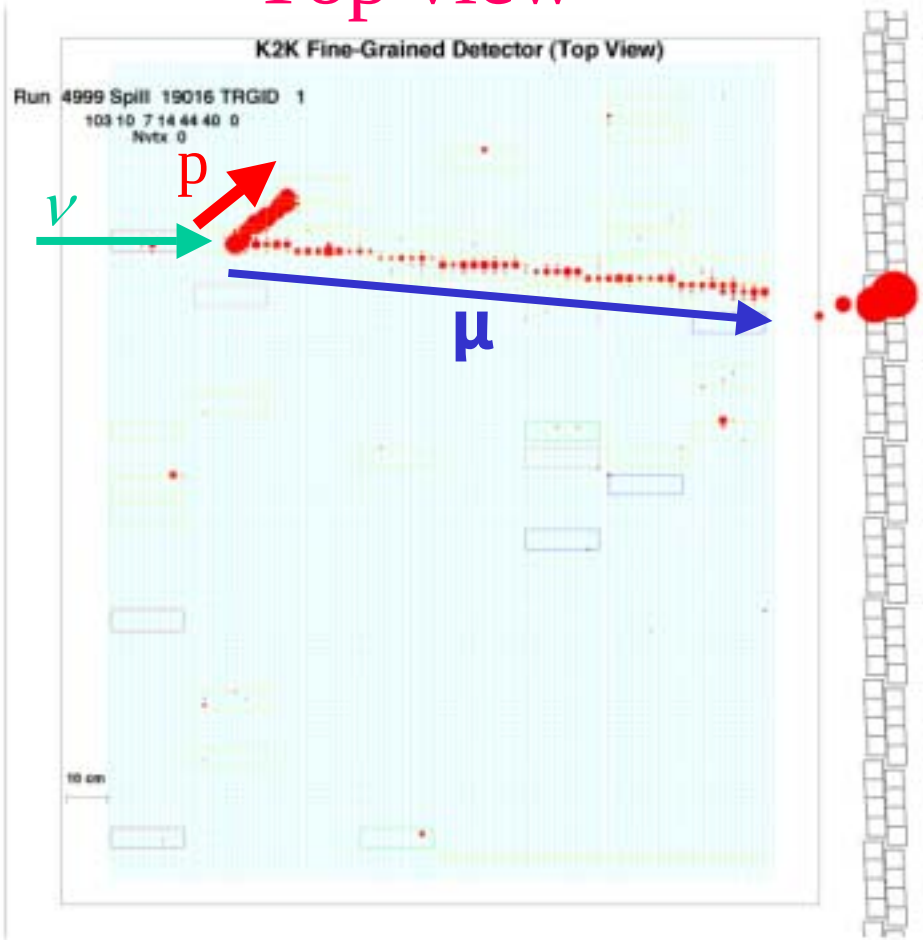
Next step

Ability of direction ID by using TOF will be estimated.

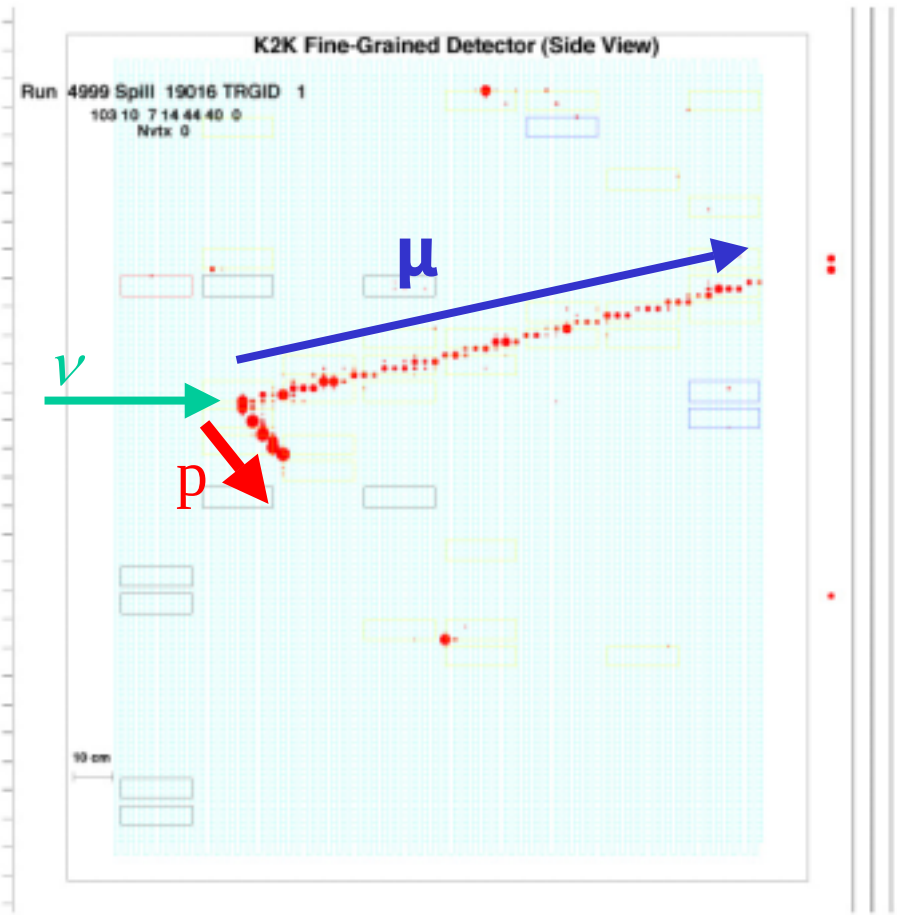
CC-QE candidate

- Area of circle is proportional to ADC
- Hits along the proton track are larger

Top view

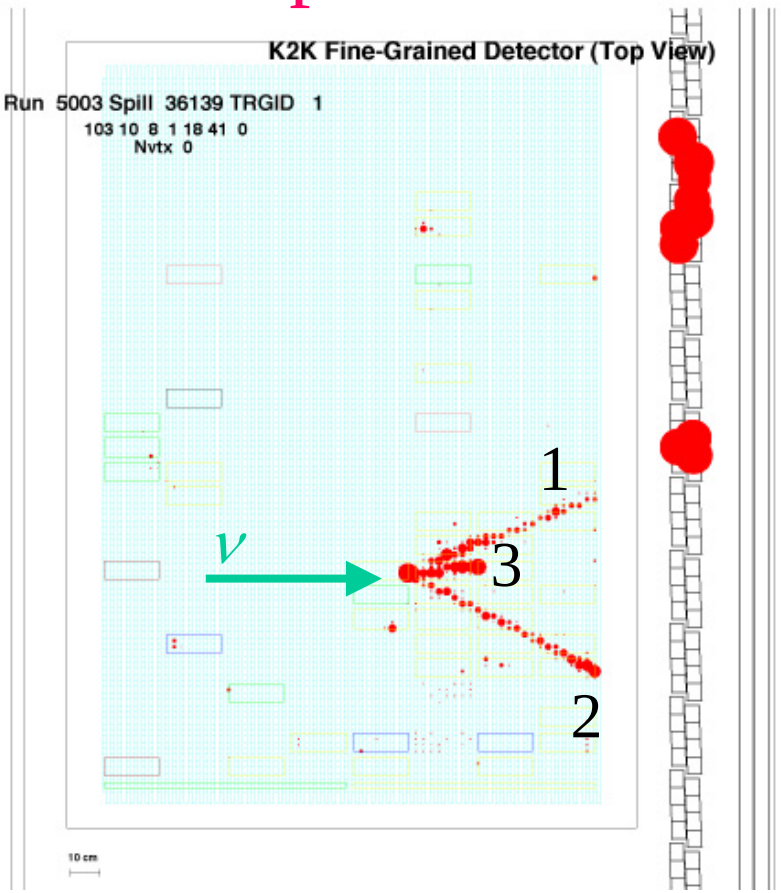


Side view

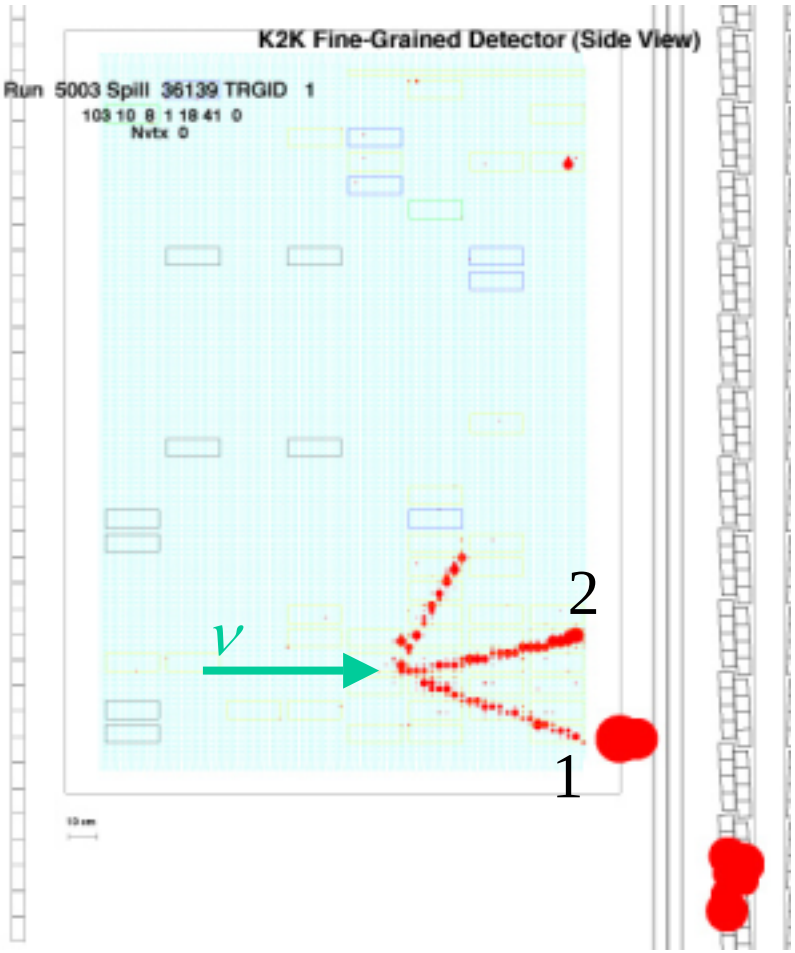


3-Track Event

Top view

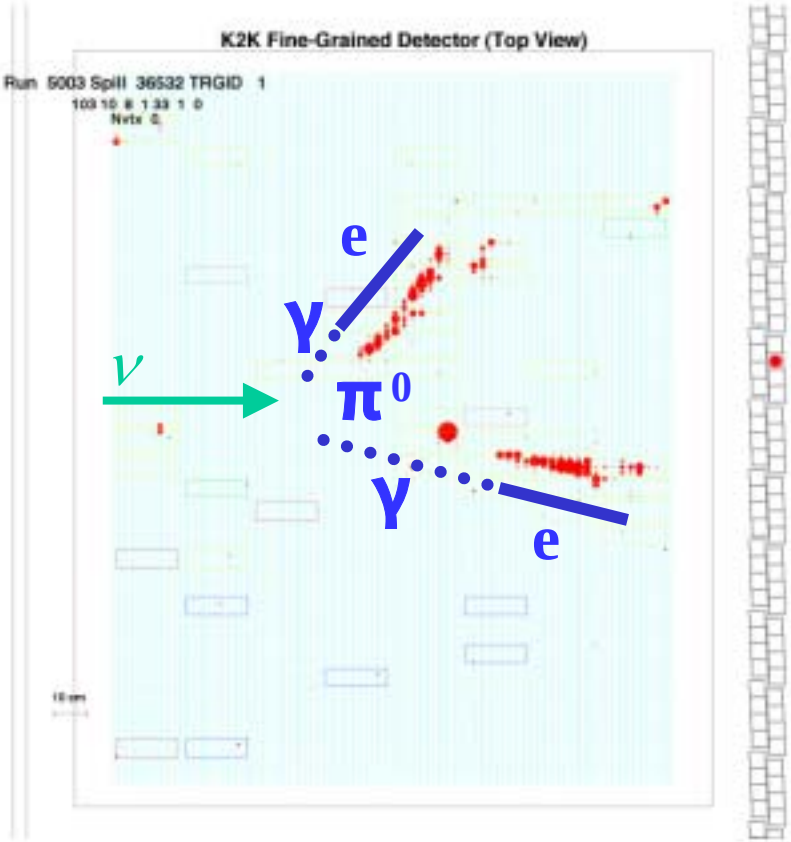


Side view



Neutral Current π_0 Candidate

Top view



Side view