A Brand new neutrino detector 「SciBar」(2)

- Readout Electronics -

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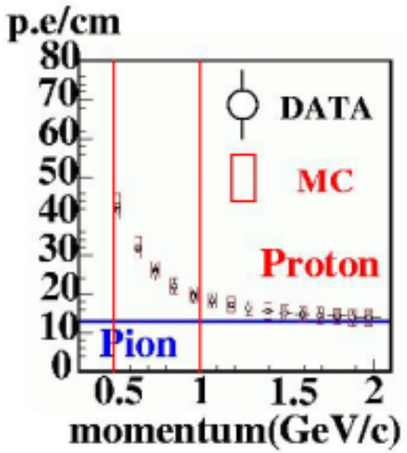
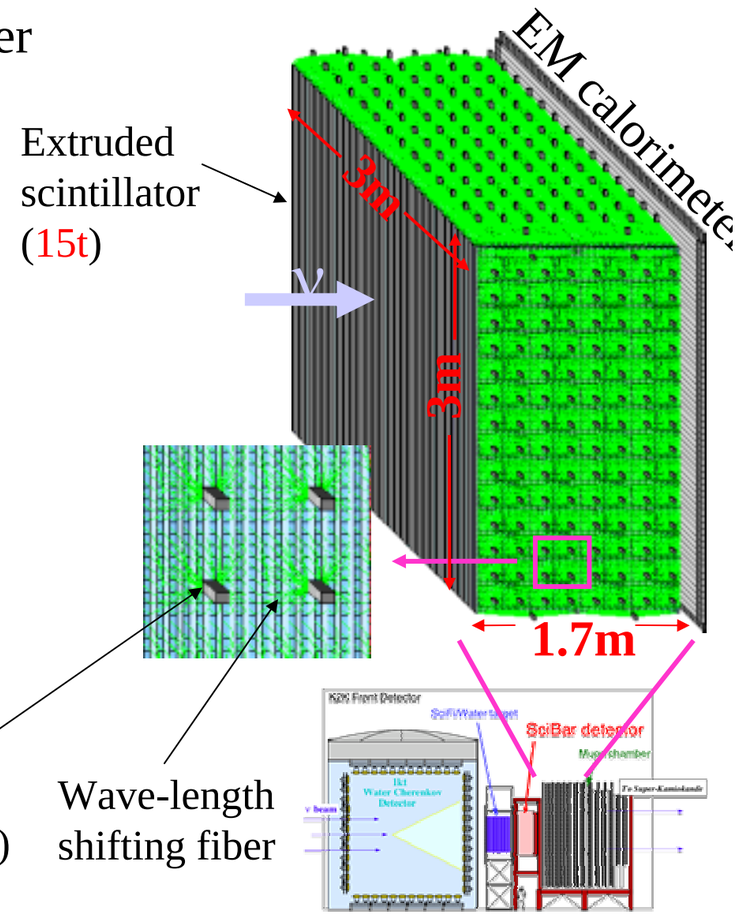
- Introduction
- Readout electronics
- Cosmic ray trigger modules
- Conclusion

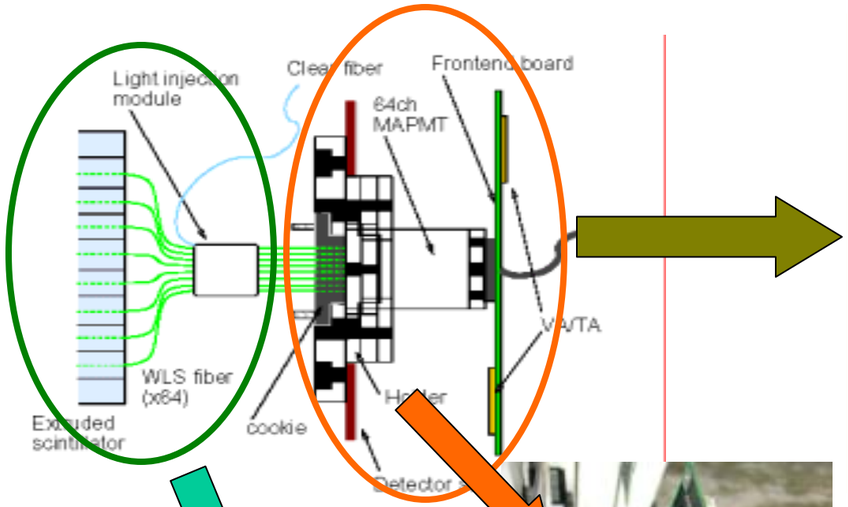
SciBar detector

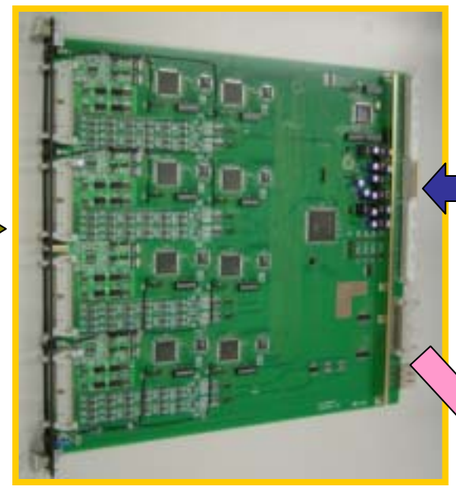
- 2.5 x 1.3 x 300 cm^3 scintillator strips
- Extruded scintillator with WLS fiber readout
- ~15000 channels
- Light yield
  7~20p.e./MIP/cm (2 MeV)
- Requirement for p/π separation
  Dynamic range>10.6MIP(286p.e.)
  Stopping π





Detector Components

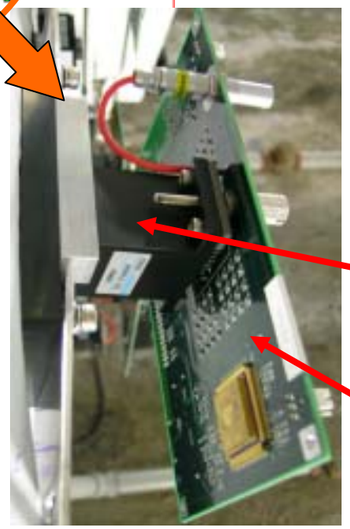




DAQ board

Timing distributor

Trigger board
AMT



64ch MAPMT

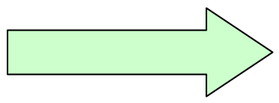
Front-end board

Requirement to readout electronics

- ➢ Large number of channel (~15,000)
  - compact photo-detector and circuit
- ➢ High sensitivity (MIP : 7 ~ 20 p.e./1strip)
  - Noise level < l p.e. (0.08 pC)

➢ Large dynamic range (1 p.e. ~ 300 p.e.)
for proton energy reconstruction

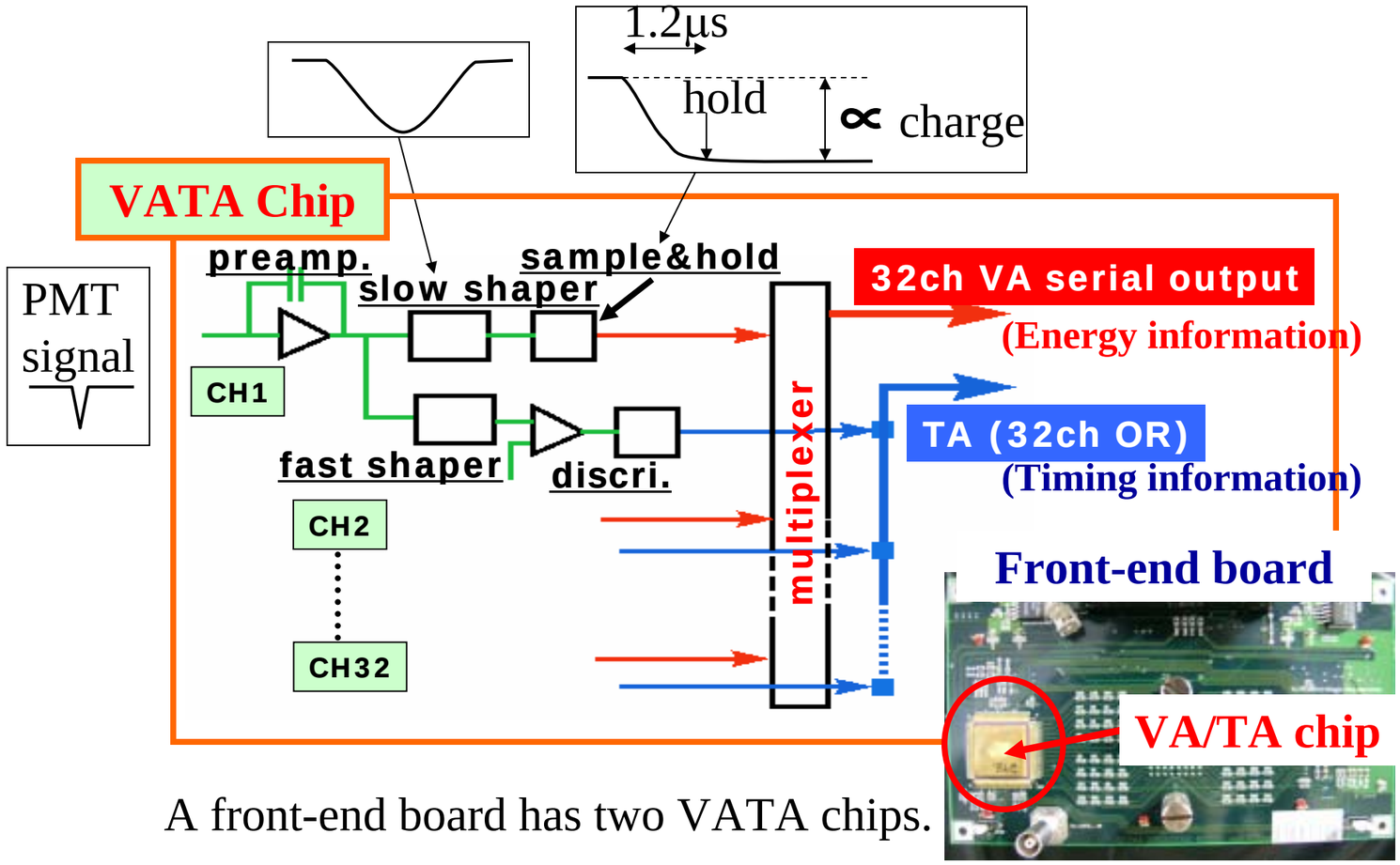
➢ Fast trigger (Bunch identification)



- VA/TA front-end electronics
- DAQ board (VME)
- AMT, Timing distributor

Readout Electronics

VATA is used for MAPMT for the first time.

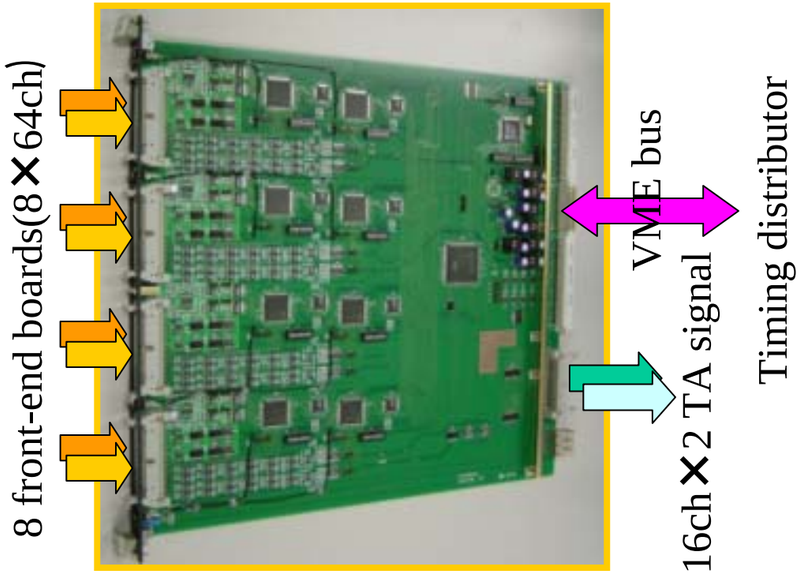


A front-end board has two VATA chips.

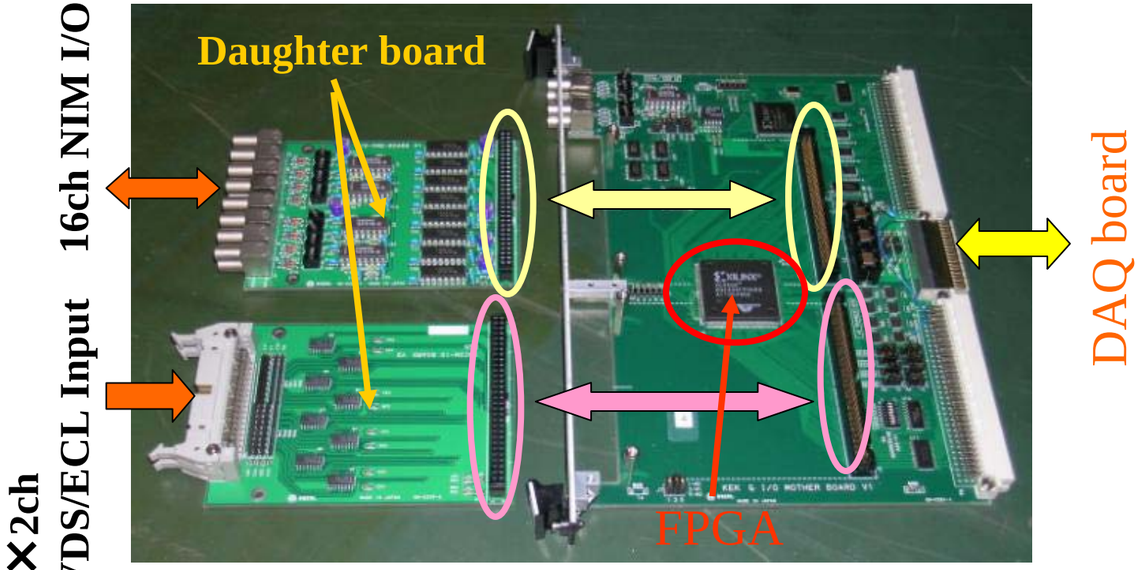
DAQ board

- DAQ board is custom module for SciBar readout.
- Control of VA readout sequence
- Setting of VA trigger threshold
- VA serial output is digitized by FADC (dynamic range ~300 p.e.)
- 8 front-end board (512 ch) are connected to one DAQ board.

→ **All channels (~15,000) are read by only 28 DAQ boards.**



Timing Distributor



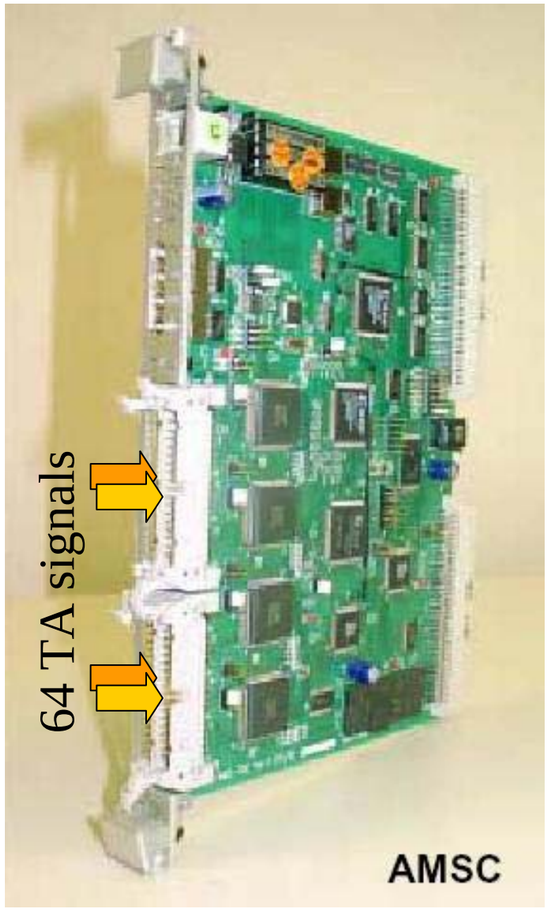
- VME 6U module that distributes timing signals to DAQ boards through the bus.
- 4ch NIM I/O on main board + 2 daughter boards

  Daughter board

  16×2 ch LVDS/ECL Input

  16ch NIM I/O
- Flexible data processing is realized using FPGA.

AMT

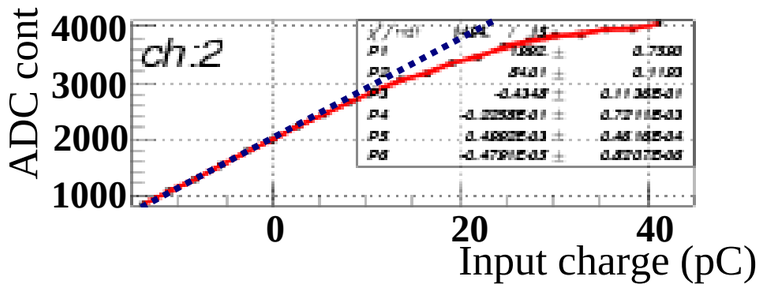


- Develop as Atlas Muon TDC(AMT)
- VME 6U module
- Multi-hit TDC
- 64 channel in a module
- 100 usec full scale
- 0.78 nsec/count

All TA signals (448 ch) are read by 8 AMTs

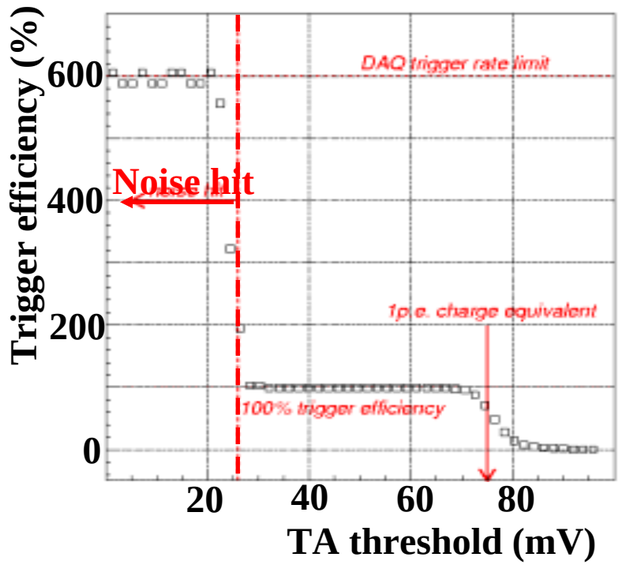
Basic performance of VATA readout

Gain linearity



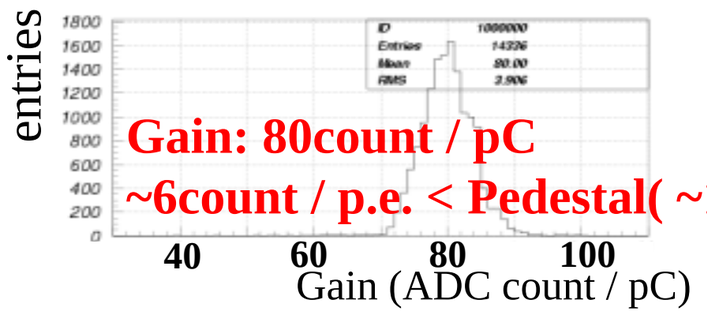
5% non-linearity < 24pC(300p.e.)

TA threshold curve



TA threshold canbe set ~0.4 p.e. without noise hit.

Gain distribution (all channels)



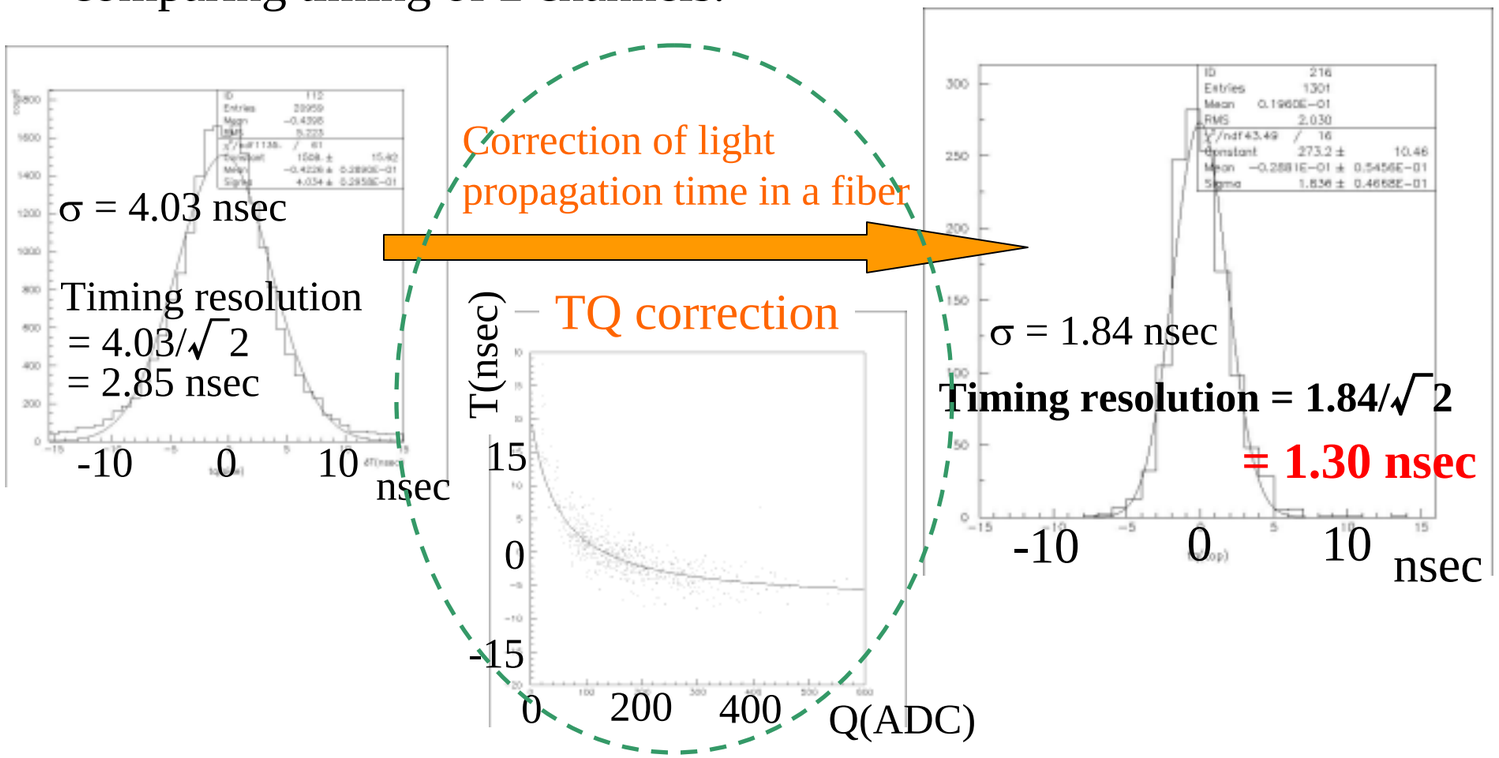
Gain: 80count / pC

~6count / p.e. < Pedestal(~1.5count)

Timing resolution

Cosmic ray event is used to estimate timing resolution.

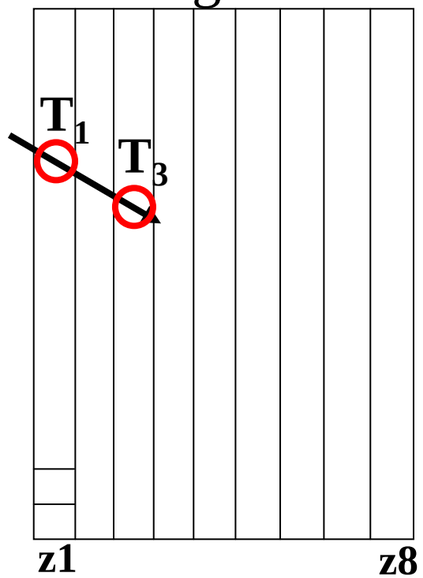
Timing resolution is estimated by comparing timing of 2 channels.

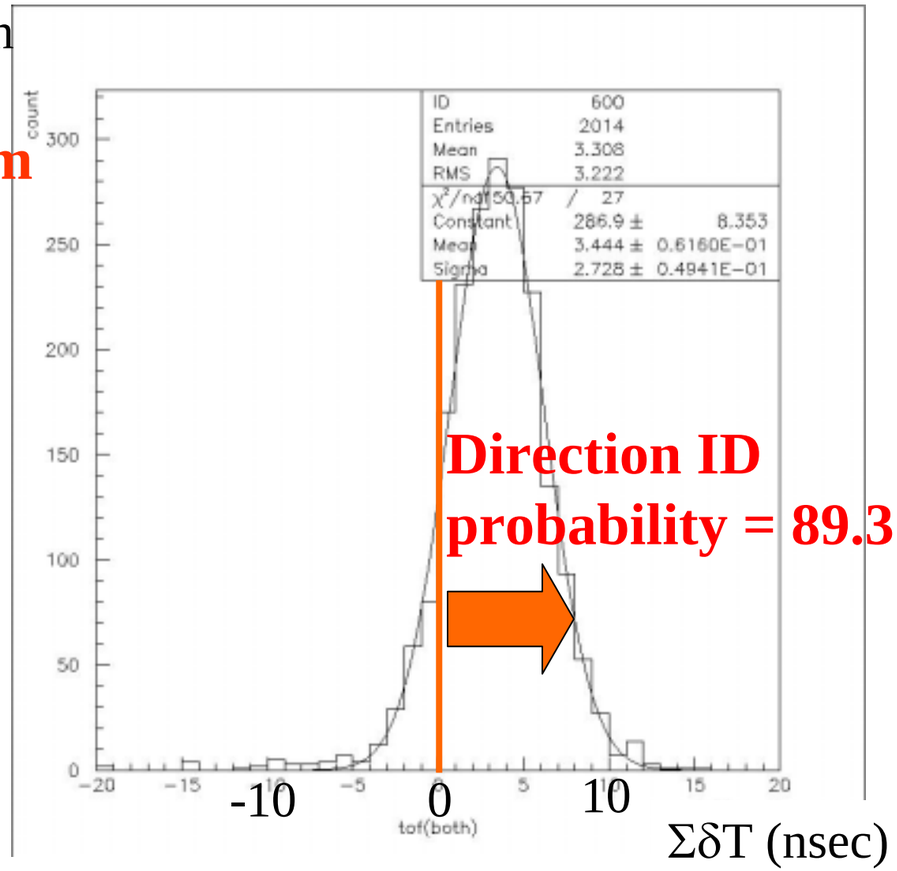


Track direction ID by TOF

3 super-layer penetration

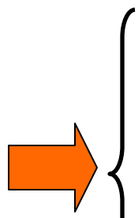
Track length = **50.5 cm**





Achieved performance

- 5 % non-linearity at 300p.e.
- Noise level < 1 p.e.
- σ_T = 1.3 nsec

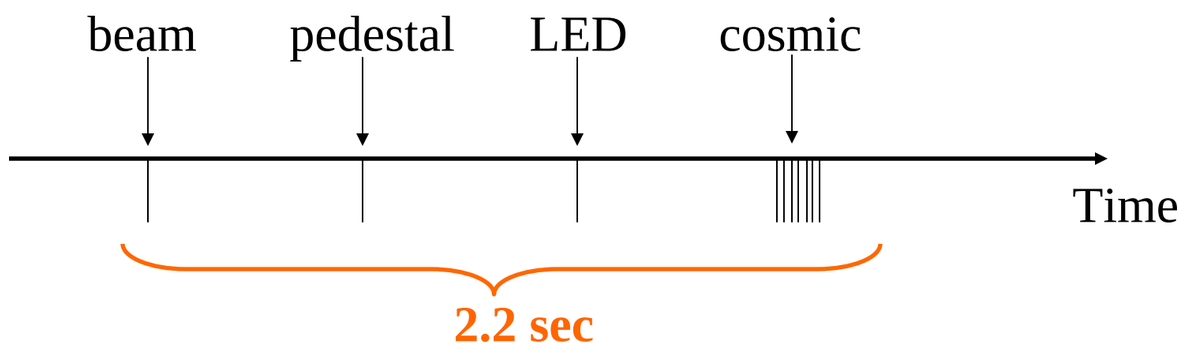


- p/π separation, momentum reconstruction
- Uniform hit efficiency
- Additional information for tracking
- Neutrino event identification from neutron B.G.

Trigger scheme

Cosmic ray trigger modules

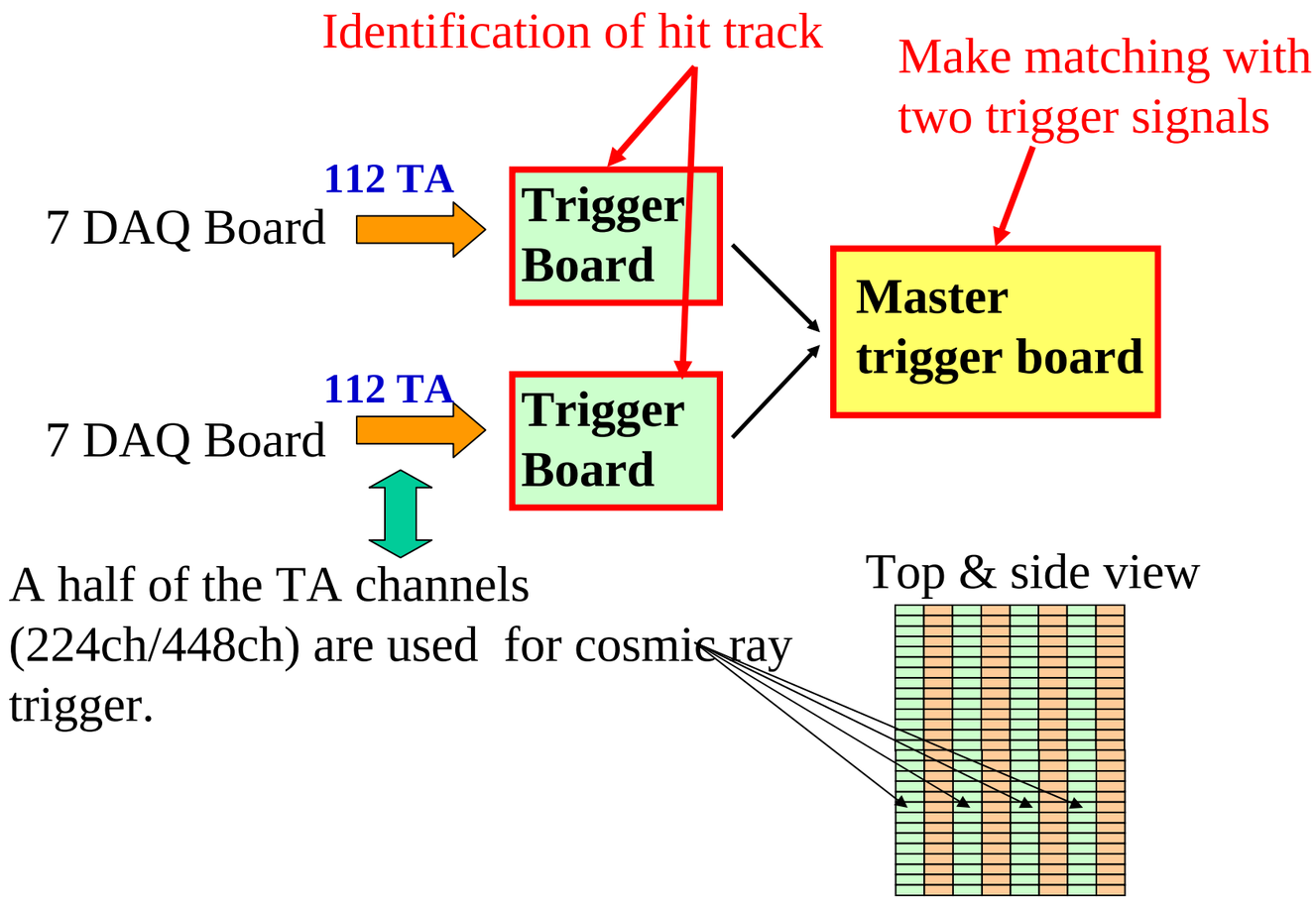
Data taking cycle



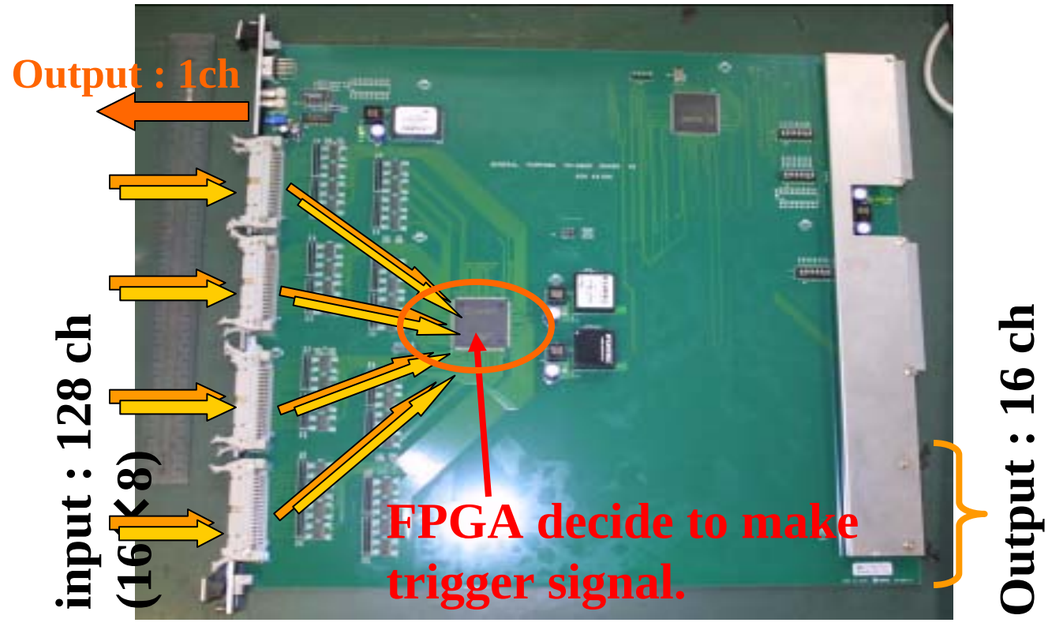
Cosmic ray data is taken for the calibration in the off-spill.

Trigger board is developed to take cosmic ray event effectively in the off-spill time

Logic for cosmic ray trigger

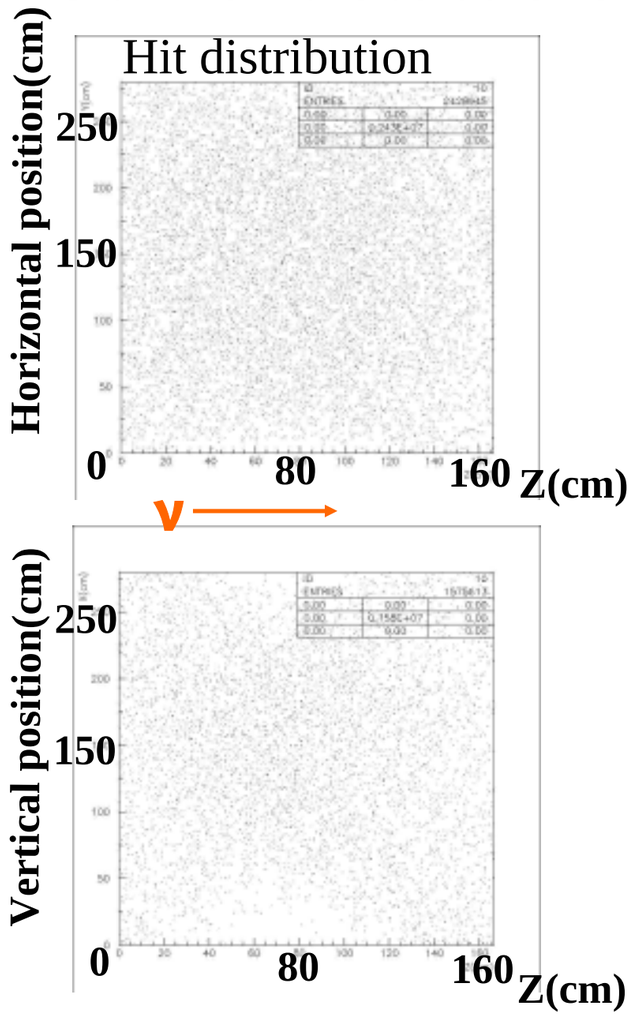


Trigger Board

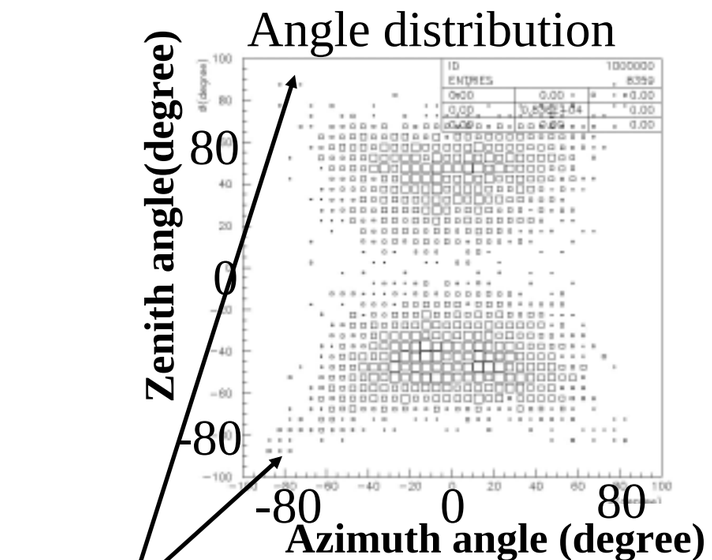


- VME 9U module
- Front panel : input 128 (16✕8) ch LVDS/ECL
- Back plane : output 16ch LVDS/ECL
- Using FPGA, trigger logic can be easily implemented for any combinations of 128 inputs.

Current status of cosmic ray event



Current cosmic ray trigger takes all though going muons



New trigger design is prepared to get horizontal events and uniform hit distribution.

Trigger Design

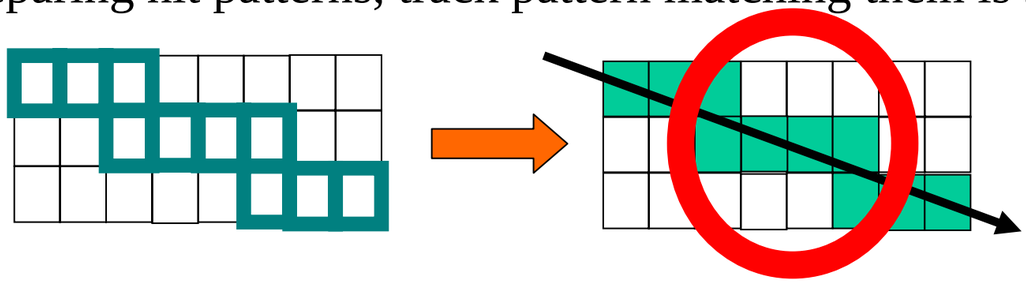
Requirement

- Horizontally through-going muons are taken for calibration effectively.
- Distribution of cosmic ray hits is uniform.
- TA signals are trigger board inputs.

Trigger design

•Trigger is generated, based on the hit pattern identification.

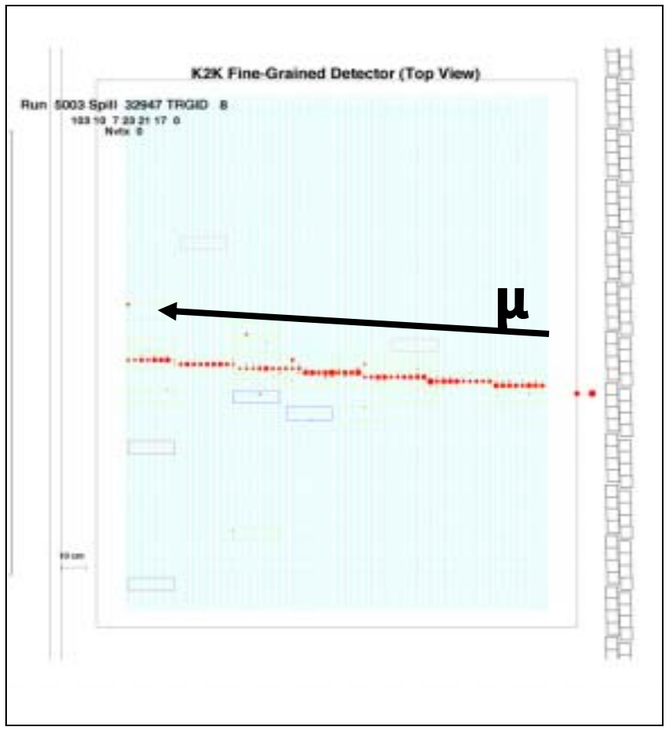
Preparing hit patterns, track pattern matching them is selected.



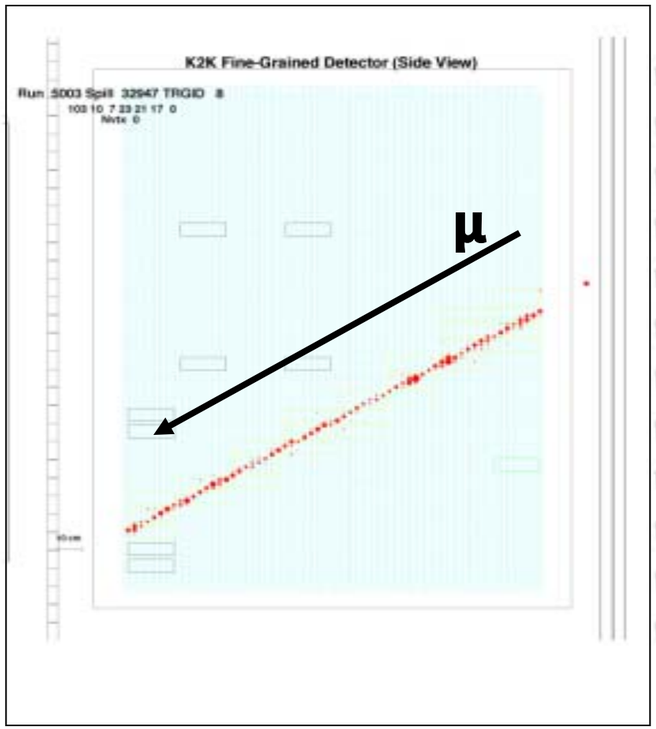
• Track with less than 45 degree of zenith angle is taken.

Event display of cosmic ray event

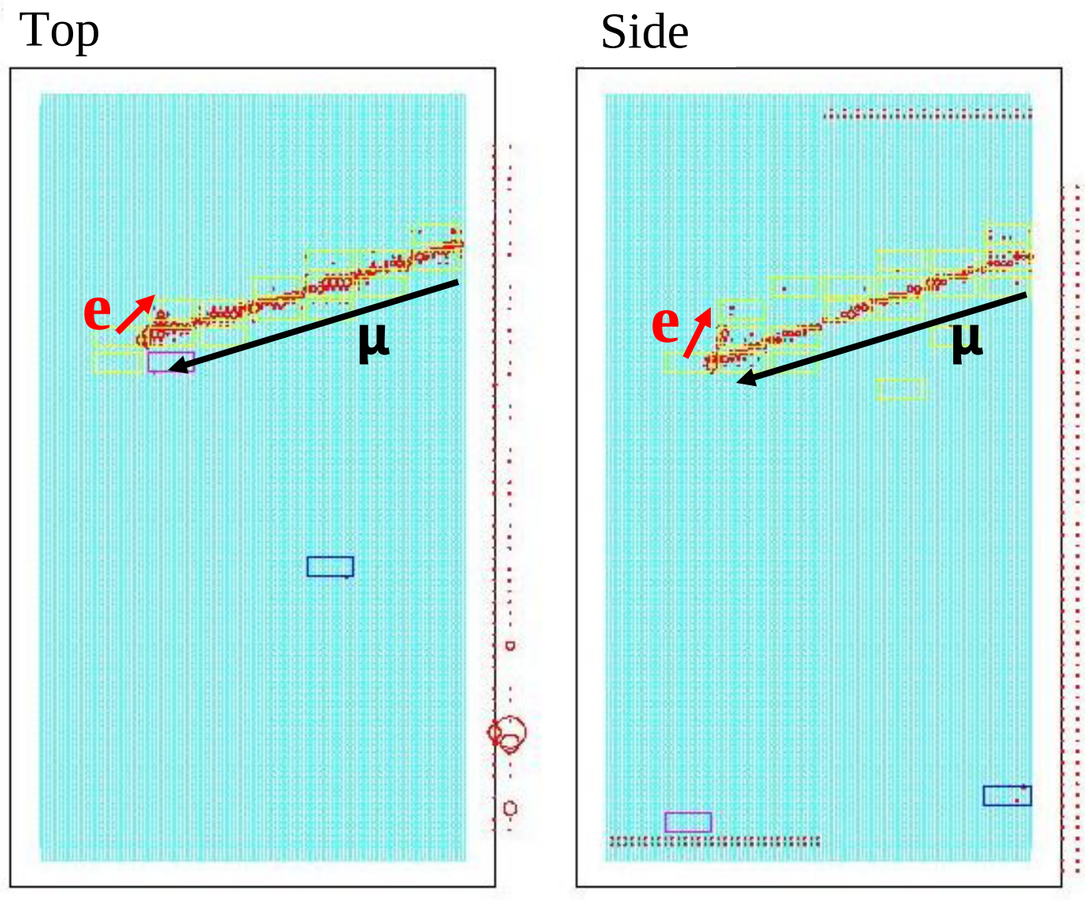
Top View



Side View



Event display of stopping μ event

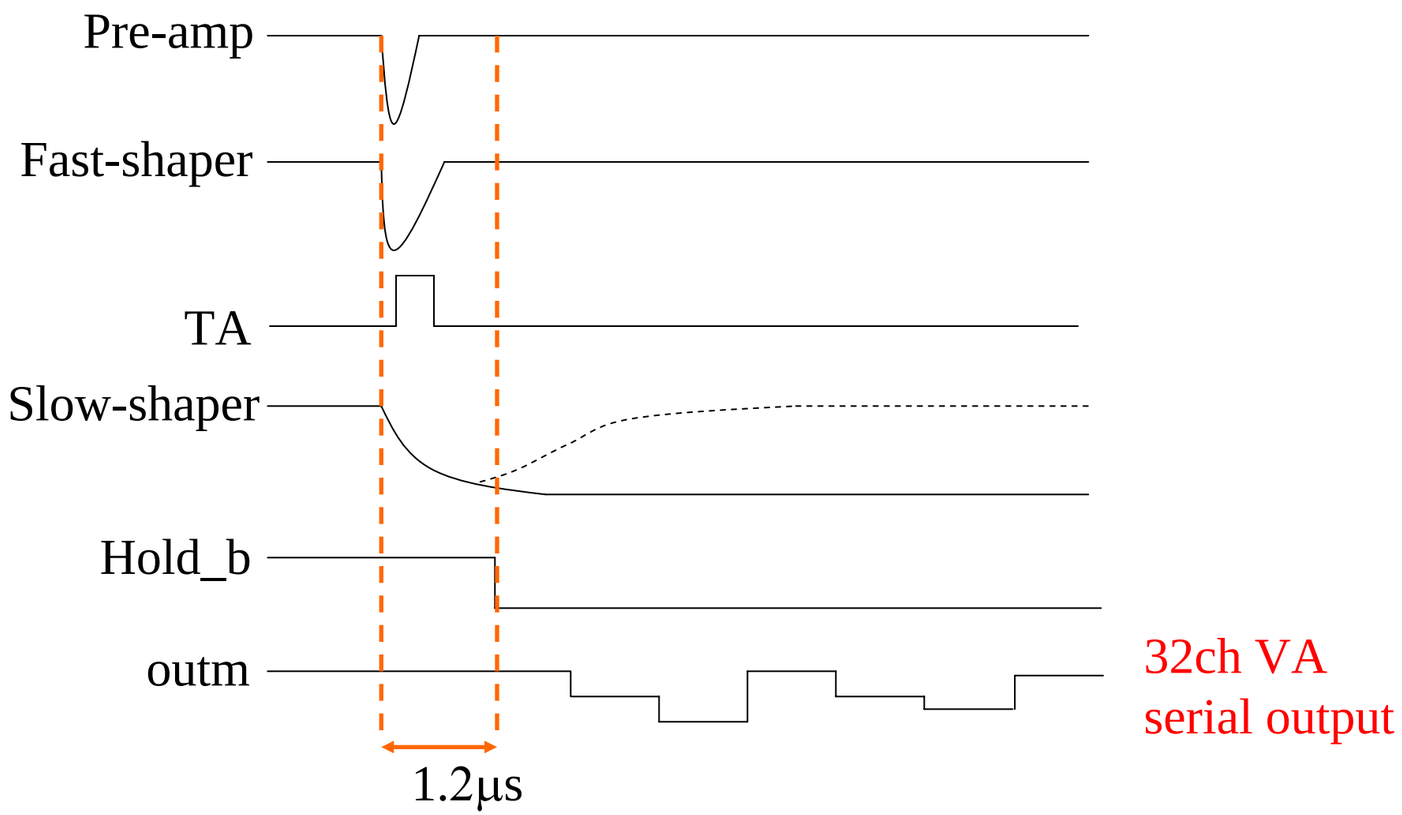


Summary

- SciBar detector uses VATA readout system.
- It has 5 % non-linearity at 300p.e., and its noise level is less than 1 p.e..That satisfies required performance.
- Trigger board is used for cosmic ray trigger, and upgrade trigger logic is prepared for effective data taking.
- All readout system is working well.

Omake

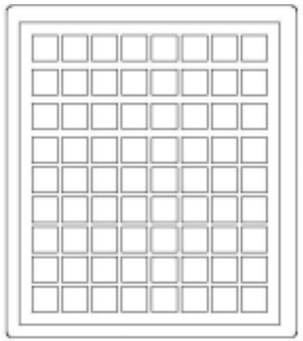
Principle of VATA readout

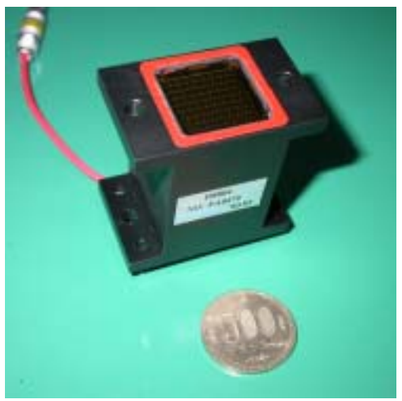


Multi-anode PMT

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

Top view

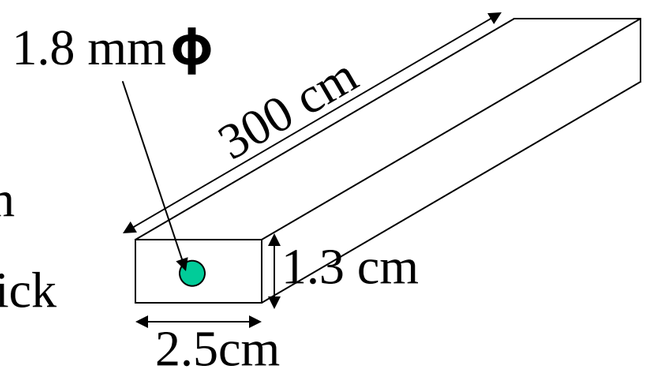




Scintillator & WLS Fiber

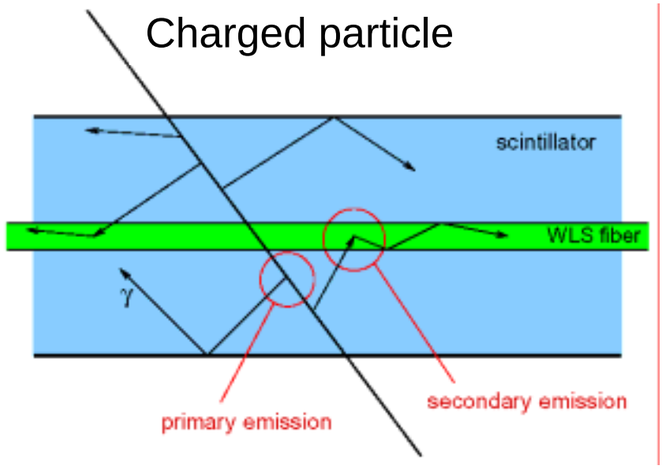
Scintillator

- Size : 1.3✕2.5✕300 cm^3
- Peak of emission spectrum : 420 nm
- TiO_2 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



Achieved Performance
& Current Status of Cosmic ray trigger

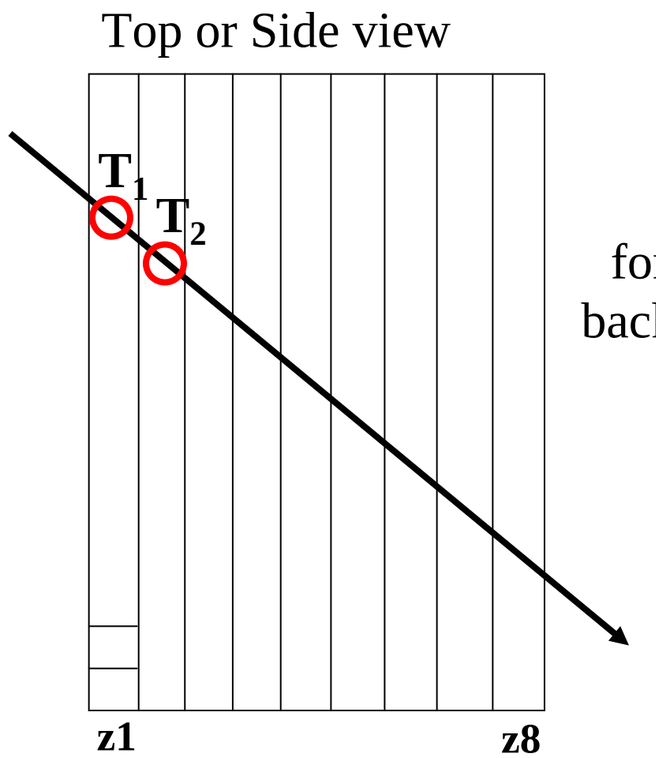
Achieved performance

- **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.**

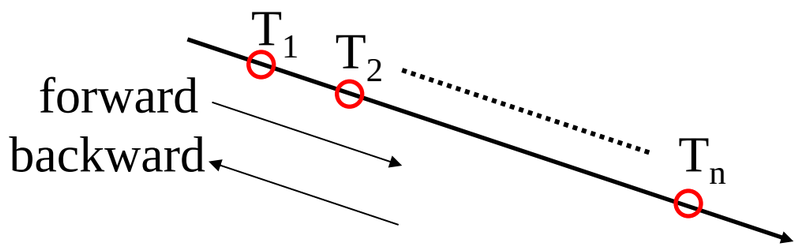
Current Status

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.

Estimation of direction ID



Track direction is identified by timing information.



$$\Sigma\delta T = \sum_{\text{Top\&Side}} (T_2 - T_1)$$

If n > 2,

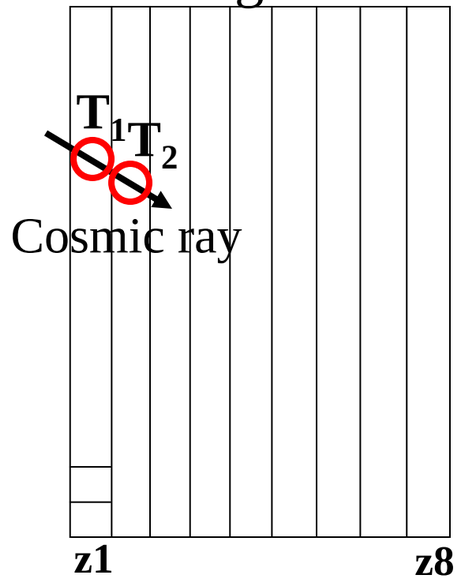
$$\Sigma\delta T = \sum_{\text{Top\&Side}} \left(-\sum_{i=0}^{n/2} T_i + \sum_{i=n/2+1}^{n} T_i\right)$$

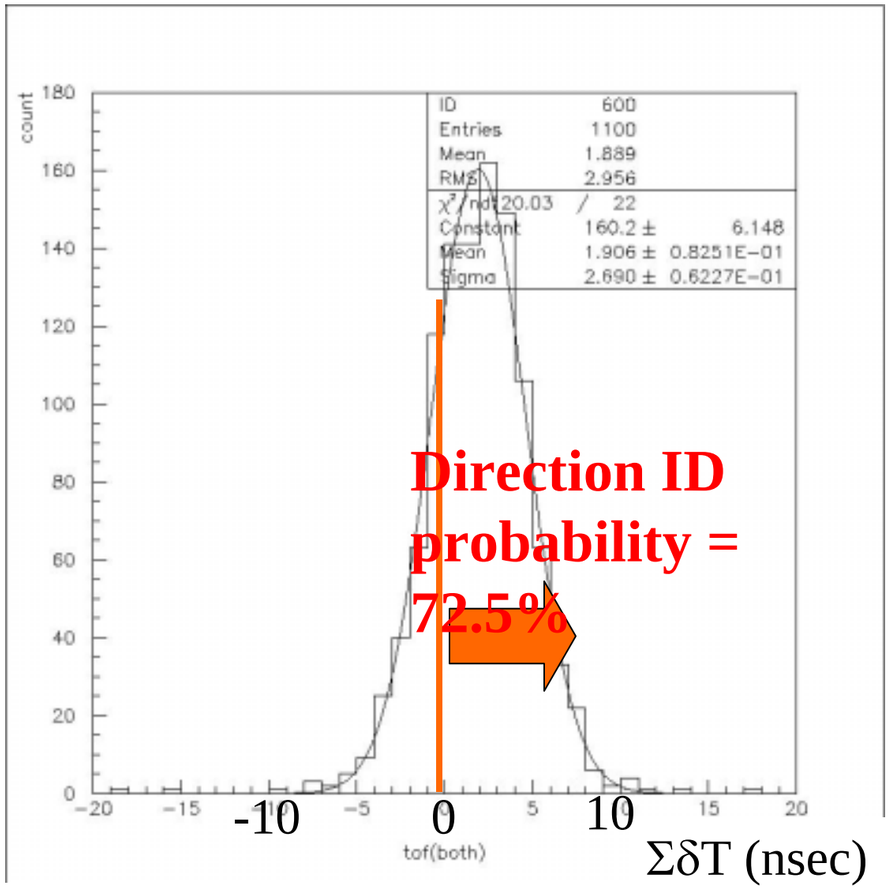
$\Sigma\delta T > 0$: forward direction

$\Sigma\delta T < 0$: backward direction

2 super-layer penetration

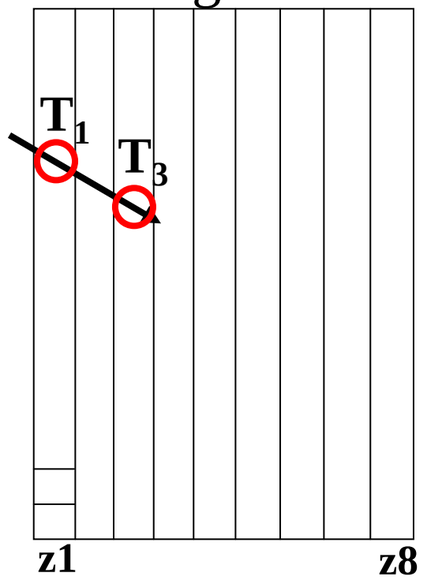
Track length = **25.2 cm**

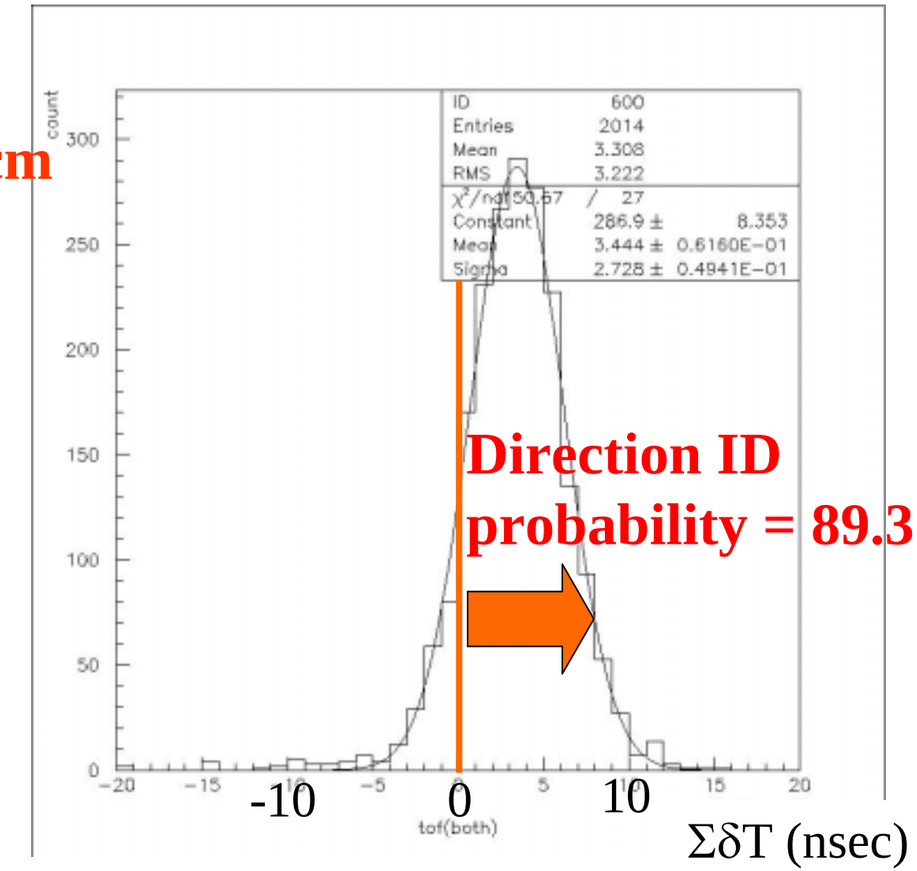




3 super-layer penetration

Track length = **50.5 cm**





Hit distribution of cosmic ray event