SciBar and future K2K physics

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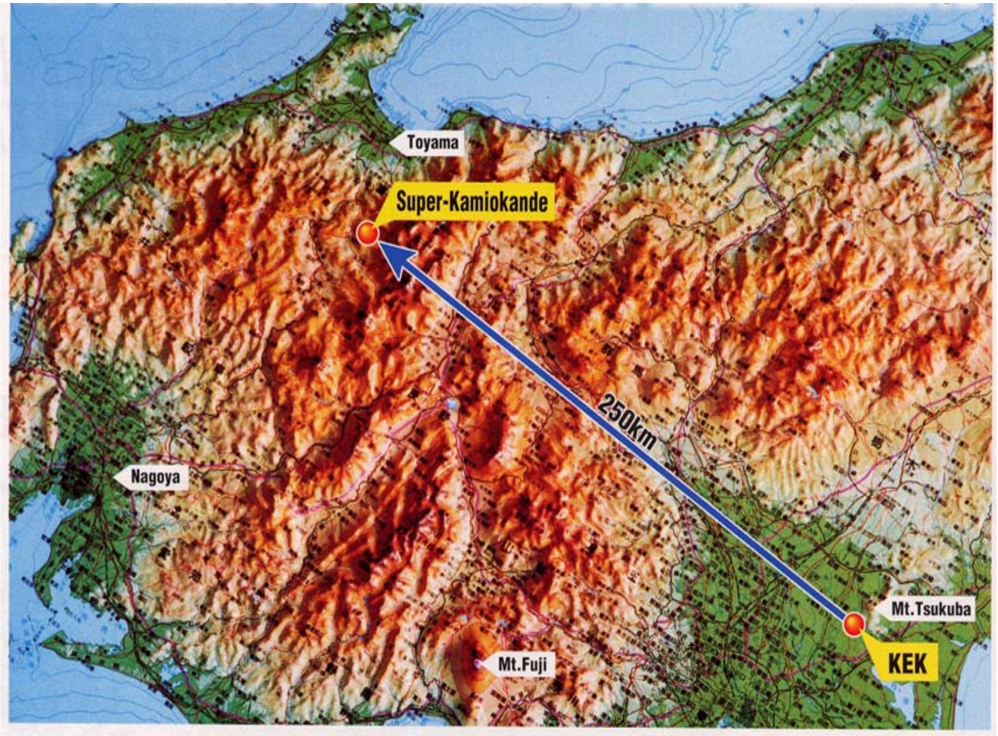
Outline

- Introduction: K2K
- SciBar detector:
  - Physics goals
  - Design
  - Electron catcher
  - Installation & Commisioning status
- Prospects & concluding remarks

K2K

Search for neutrino oscillations using accelerator-produced neutrinos

- neutrino beam
  - Conventional ν_μ
  - Average energy ~1.3GeV
  - Produced at the 12 GeV PS proton accelerator at KEK.
- Far Detector (Super-Kamiokande)
  - Detect neutrino signal after possible oscillation.
  - 250 km distance from KEK
- Near Detectors at KEK
  - Measure neutrino flux and spectrum at the production point.
  - Study neutrino interactions.
  - 200 m downstream the production target

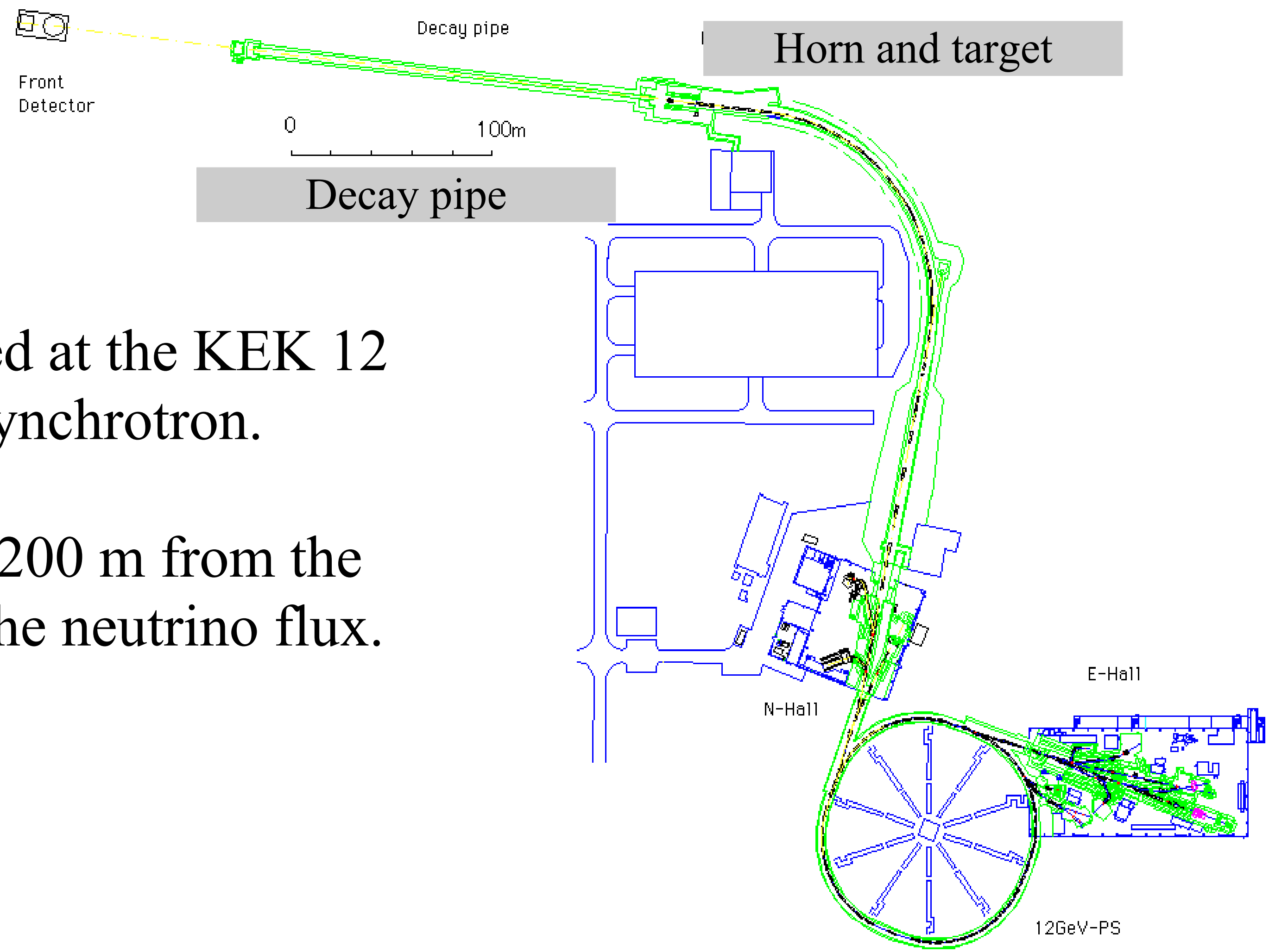


K2K

Protons interact with Al target and produce π.

π's are foused by a magnetic horn.

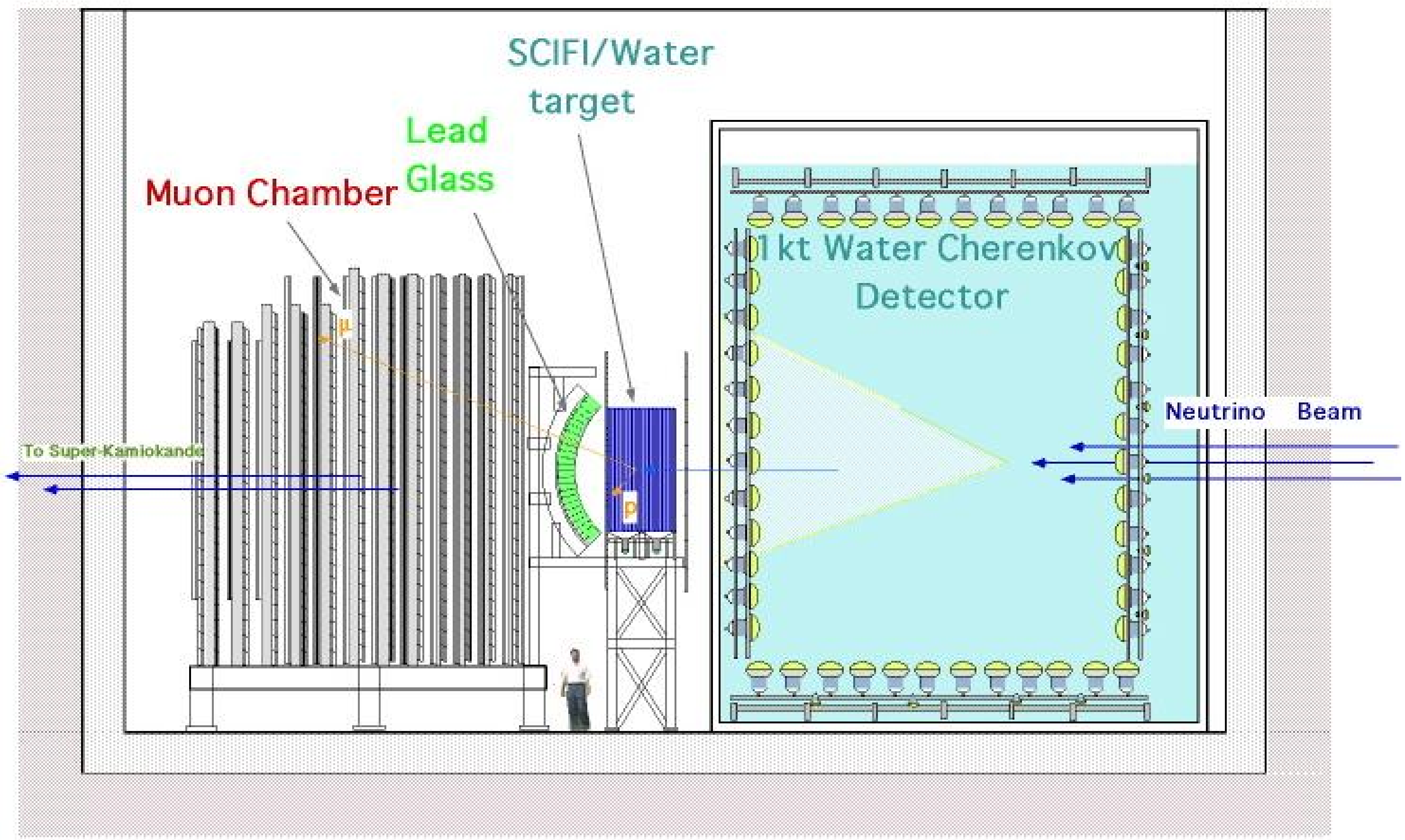
π's decay at a long decay pipe producing ν_{μ}



Neutrinos are produced at the KEK 12 GeV PS proton synchrotron.

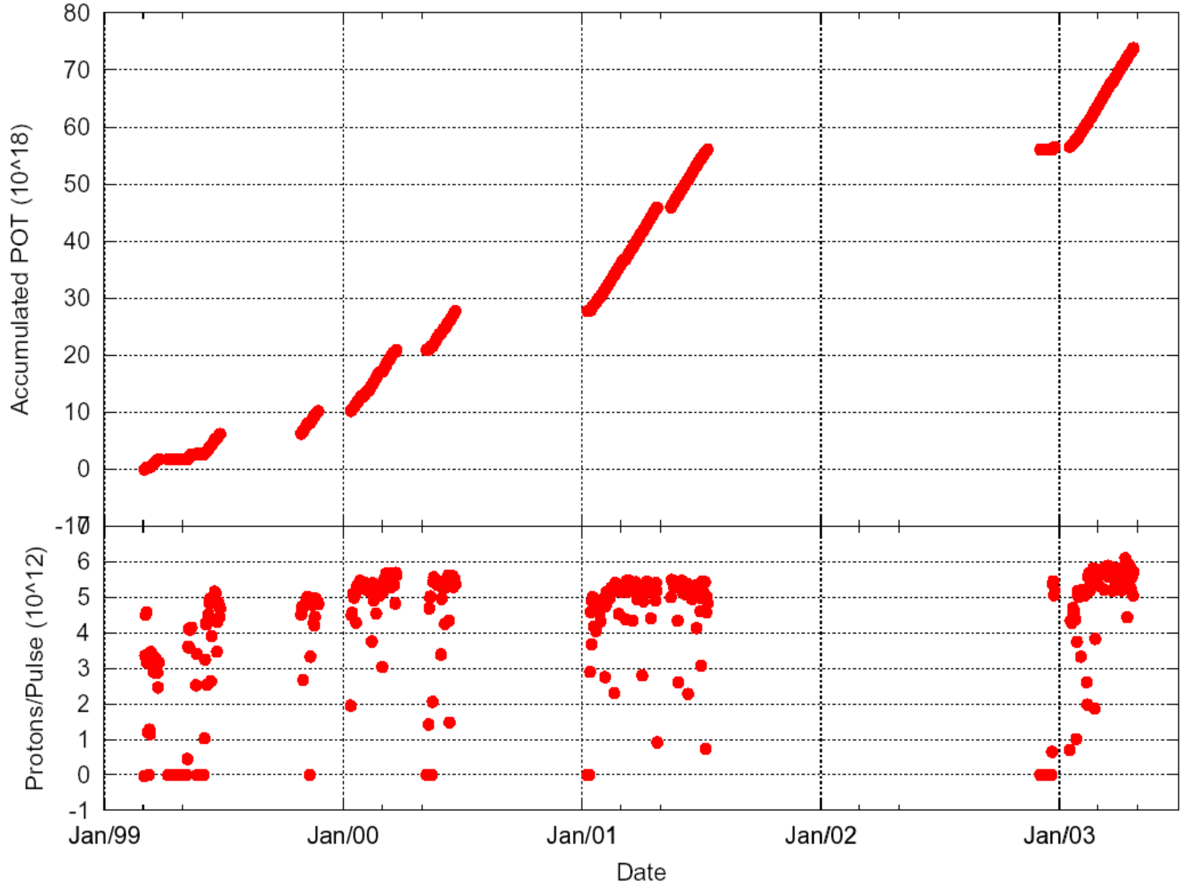
A detector located at 200 m from the production measures the neutrino flux.

K2K near detector
(1999-2001)



1 Kton water Čerenkov detector water target 25 ton fiducial.

Scintillating fiber tracker water target 6 ton fiducial.
Lead glass detector
Muon range detector Fe target 330 ton fidual.



K2K-II

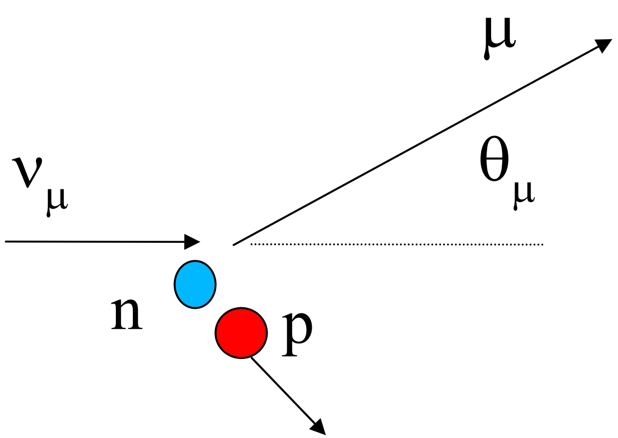
Succesful restarting after SK accident.

- K2K-I : $56.06 \cdot 10^{18}$ PoT,
- K2K-II: $24.91 \cdot 10^{18}$ until June 2003.

- K2K-I : 56 events for 80.1 expected
- K2K-II (Apr. '03, $15.22 \cdot 10^{18}$ PoT):16 events 28.3 ± 0.13 expected

Charged Current Quasi elastic

Charged Current Quasi Elastic interaction



Optimal neutrino energy reconstruction at low energies.

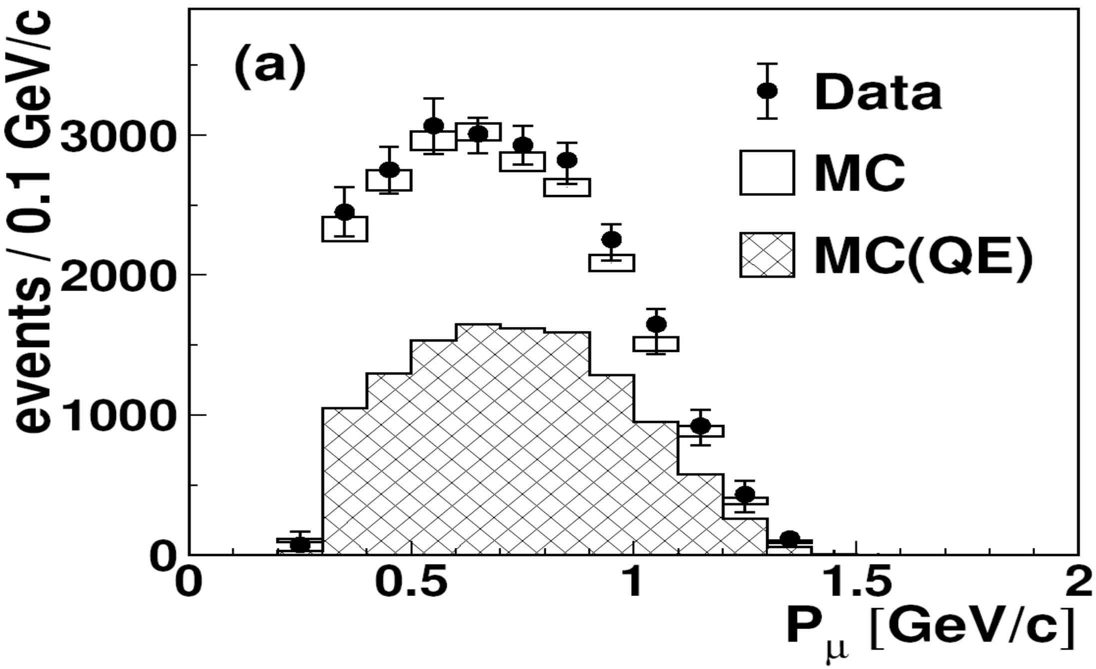
Neutrino energy is reconstructed assuming the neutron at rest and neglecting proton

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

The only information needed is the momentum and angle to the neutrino direction.

Main problem is the background of fake QE events → proton tagging.

K2K near detector
(1999-2001)



1 Kton detector

Muon momentum distribution at 1kt water Čerenkov detector.

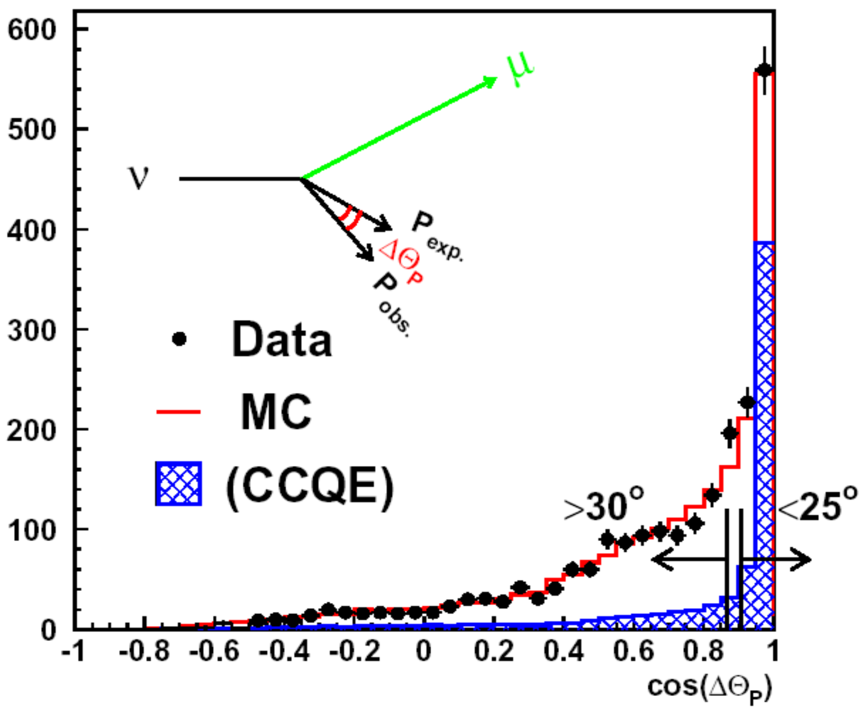
Fraction of CC quasi-elastic events (νn->pμ) ~ 50%.

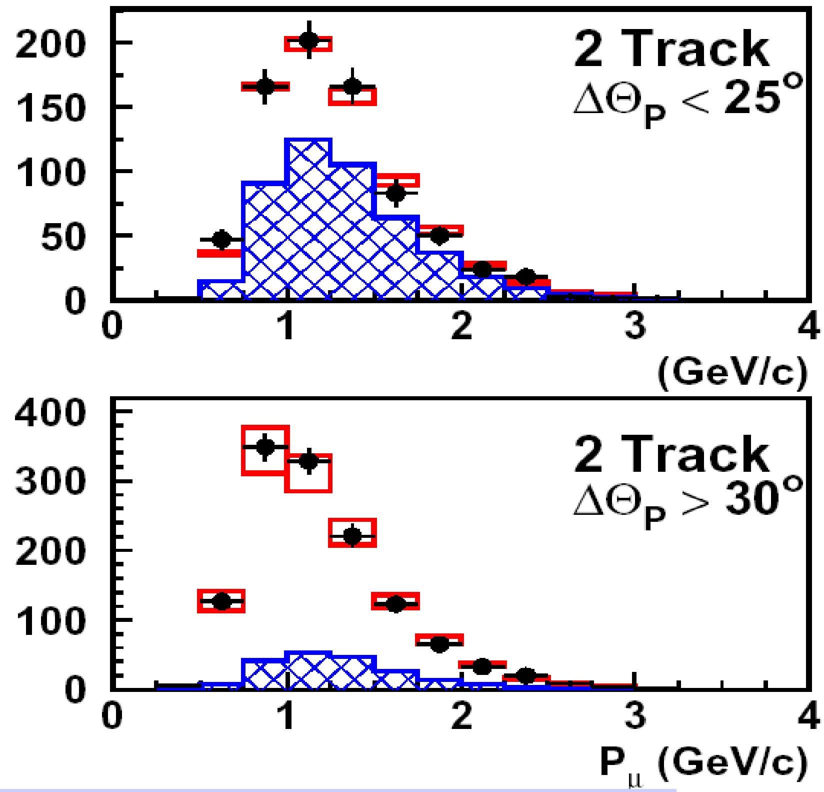
Threshold for proton ~ 1.2 GeV.

K2K near detector

(1999-2001)

SciFi detector





Fraction of QE can be enhanced looking at the angle between the expected proton direction and the observed one.

Problems: large threshold $p_p > 0.5$ GeV (water target thickness) and low efficiency for muons (lead glass). No p/π separation capabilities.

SciBar detector

- The oscillation maximum predicted by SK has shifted to lower values:

  for 250km base line $E_\nu \sim 0.6$ GeV

  We have to be able to look at rather low

energy neutrino interactions (<1GeV).

- Better understanding of backgrounds in near and far detectors: single π production, (NC and CC) π^0 production and Nπ production and CC-QE.

SciBar detector

- Requirements of a new detector:
  - Low energy proton tag.
  - $\mu/\pi/p$ separation capabilities.
  - Electron id. and energy measurement.
  - π^0 id. and momentum reconstruction.
- Main physic requirement is to measure the neutrino spectrum with CC-QE interactions.

SciBar detector

Full active Scintillator Bar detector SciBar

- **Large Volume**
  - *(300 × 300 × 180) cm^3 ~15tons*
- **Fine segmentation**
  - *2.5 × 1.3 × 300 cm^3 (~15000 detector channels).*
- **Large Light Yield**
  - *7~20 photo-electrons/cm for MIP*
  - *Particle ID with dE/dx and range*
  - *Proton Momentum reconstruction by dE/dx and range*
  - *Large hit efficiency*

SciBar detector: Electron Catcher

To improve the π^0 and electron reconstruction capabilities.

Physics capabilities

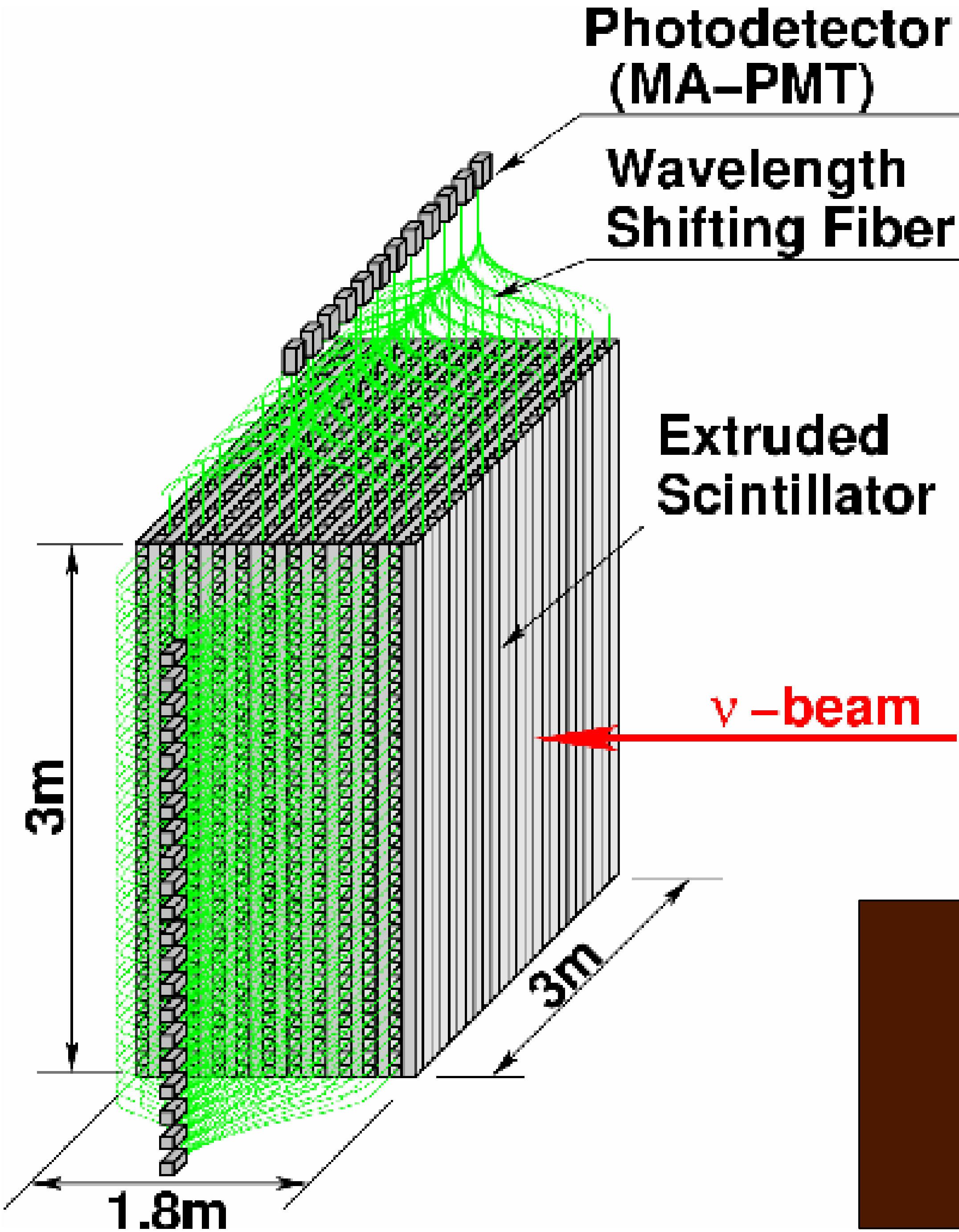
Longitudinal containment (85% at 3GeV)

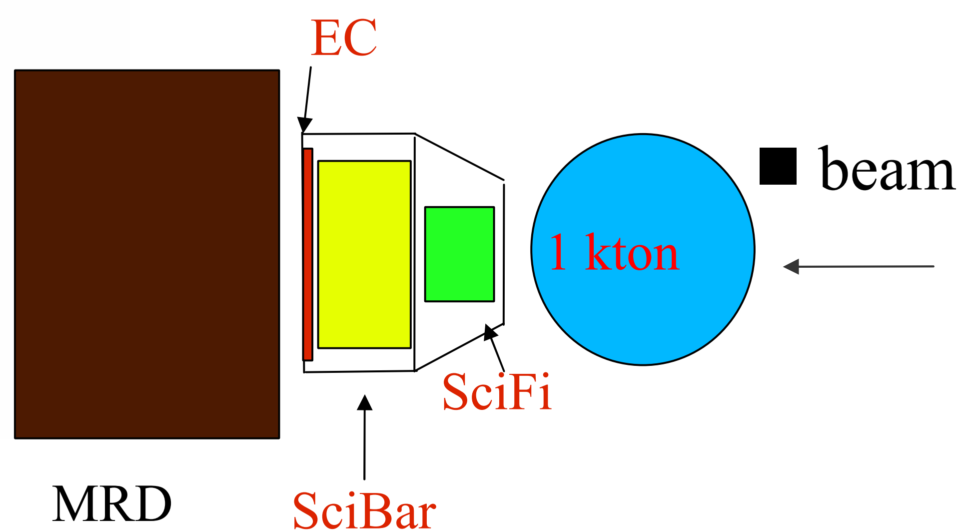
Energy reconstruction (14%/$\sqrt{E}$)

electron vs (muon or pion) ID

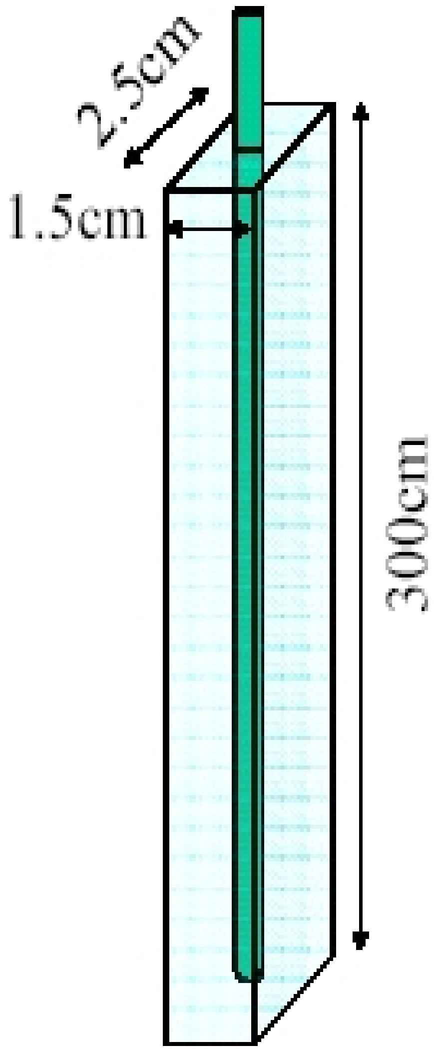
π^o reconstruction

SciBar detector





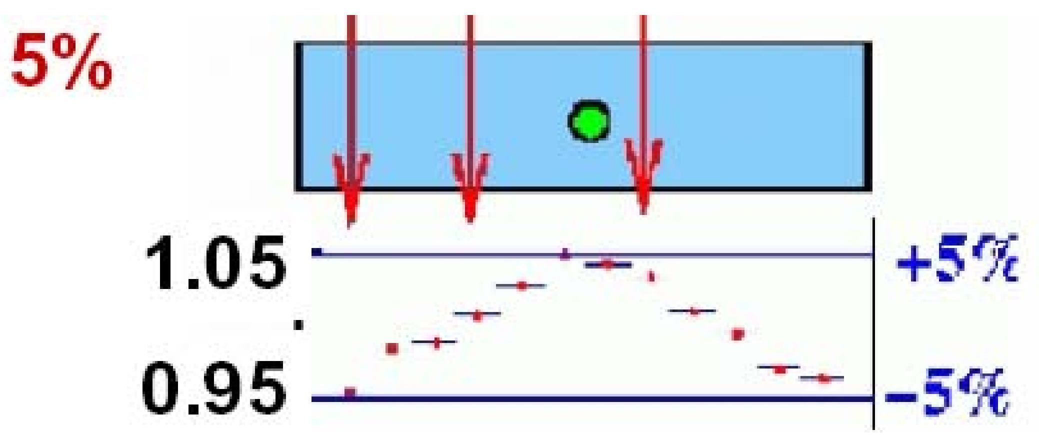
SciBar detector



Scintillator 2.5x1.3x300cm3 made
by Fermi-Lab.

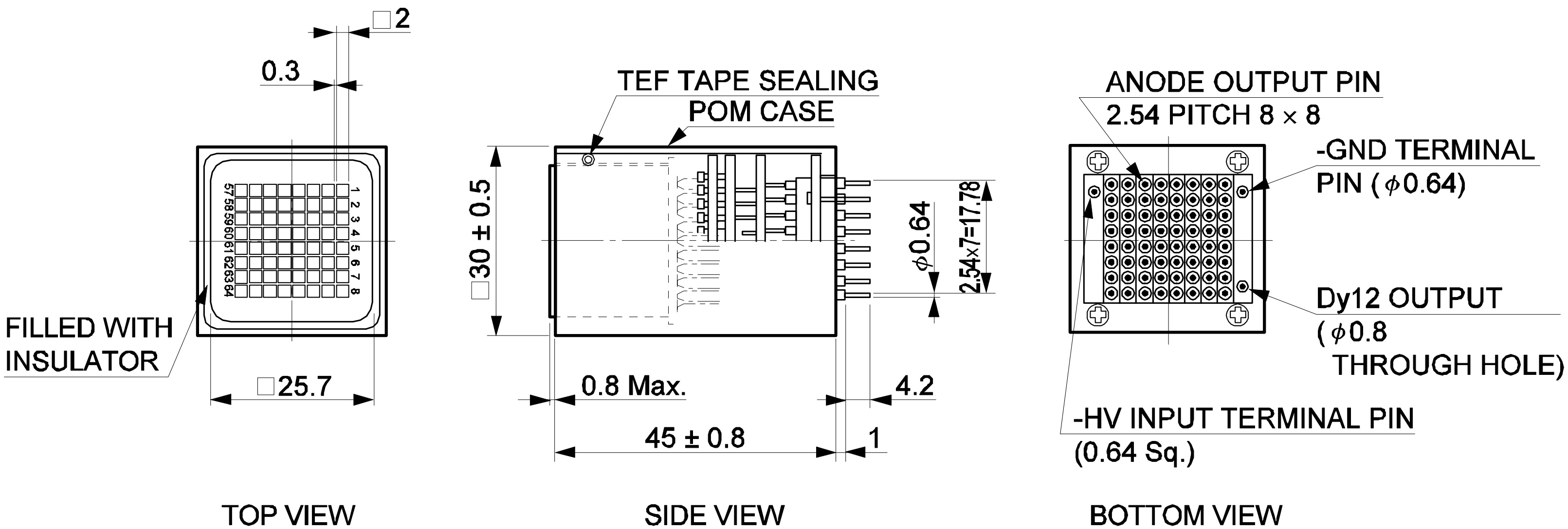
Wave length shifting fiber
1.5mm ϕ x 360cm Kurare Y11
attenuation length ~3m

Photon collection uniformity better than 5%

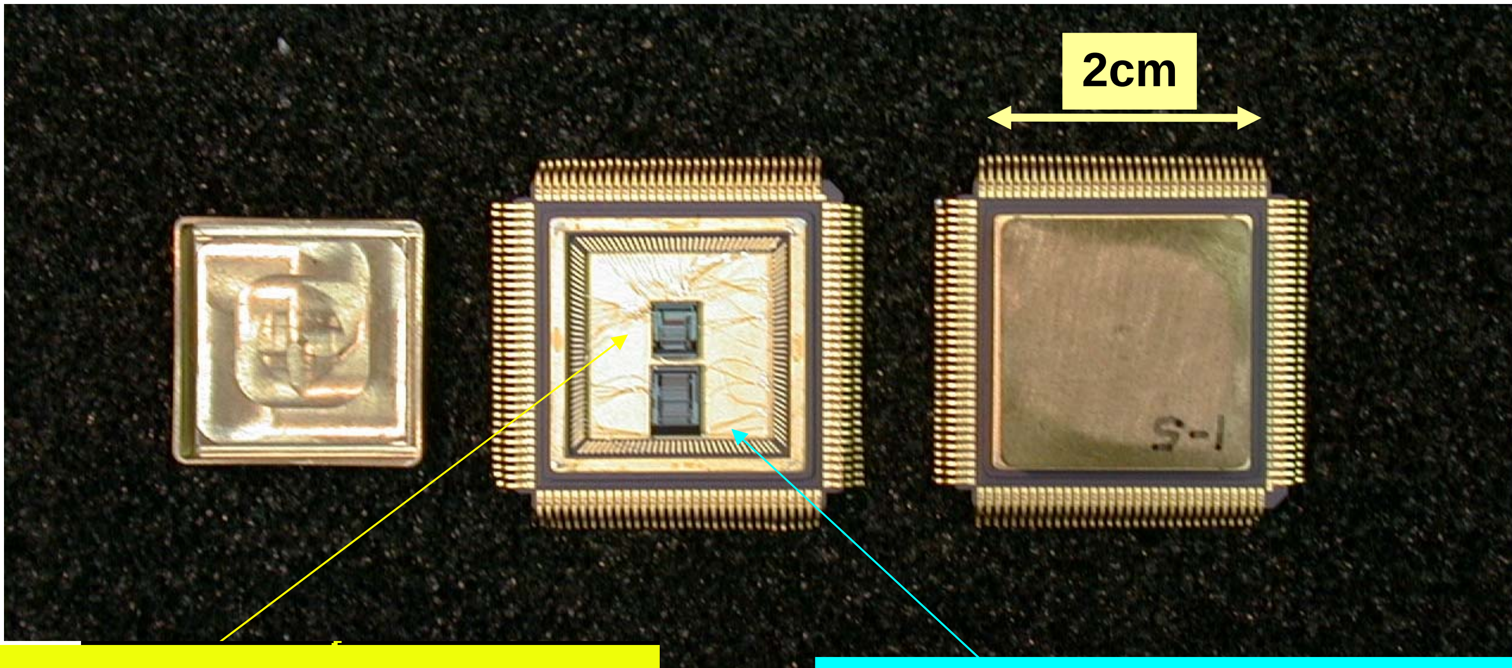


SciBar detector

- Fiber readout done with a Hamamatsu multianode (64) PMT.



SciBar detector



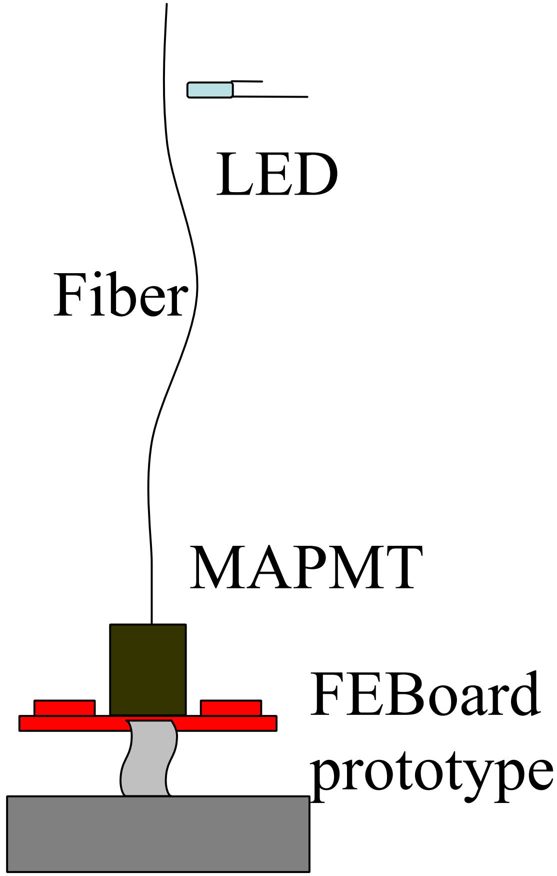
VA
- 32ch input
- Slow shaper (peaking time: 0.8 – 1.2 μsec)
- Gain : 36μA / pC
- Dynamic range : -35pC - +25pC
- Noise < 1fC

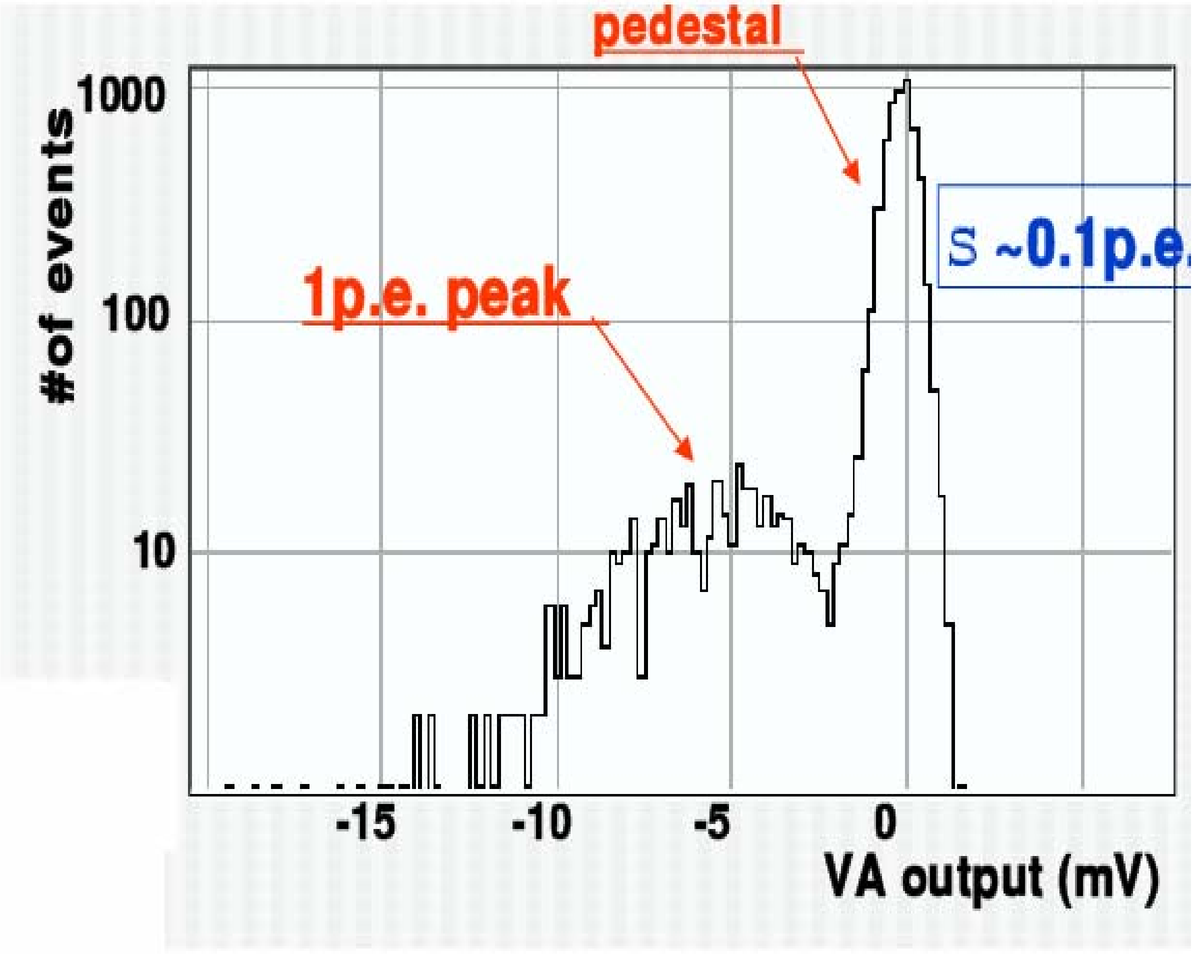
TA
- Optional gain-stage (<10x)
- Fast shaper (peaking time ~75ns)
- Level-sensitive discriminator
- 32ch ORed trigger output

VA32hdr11+TA32cg

SciBar detector

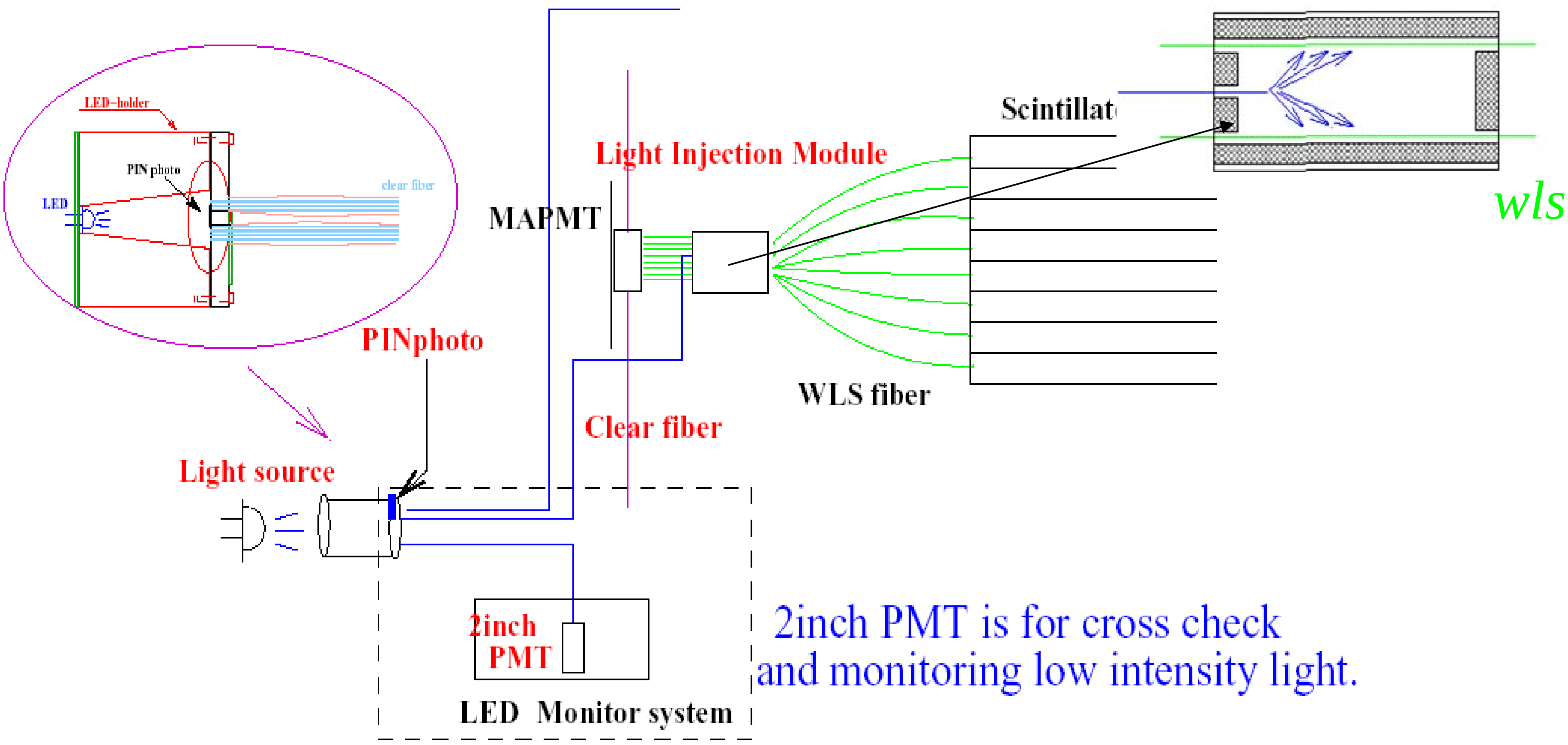
Test bench results shows we are sensitive to 1 p.e.





SciBar detector

Stability of the PMT gain is monitored online

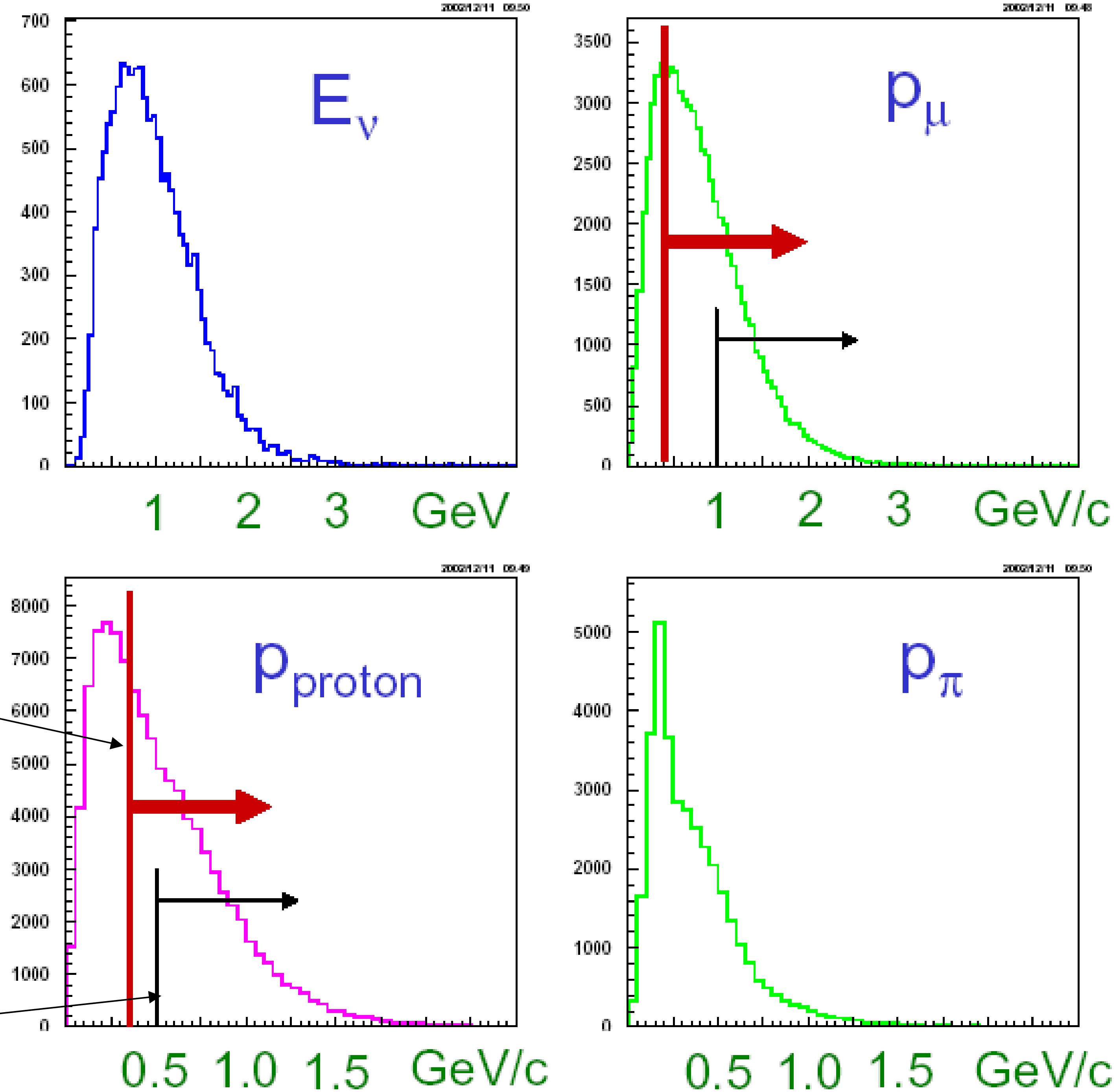


2inch PMT is for cross check and monitoring low intensity light.

A cosmic muon trigger is also implemented to monitor and calibrate the performance of the detector.

SciBar detector

Energy spectra of ν, μ, p and π in SciBar (MC).



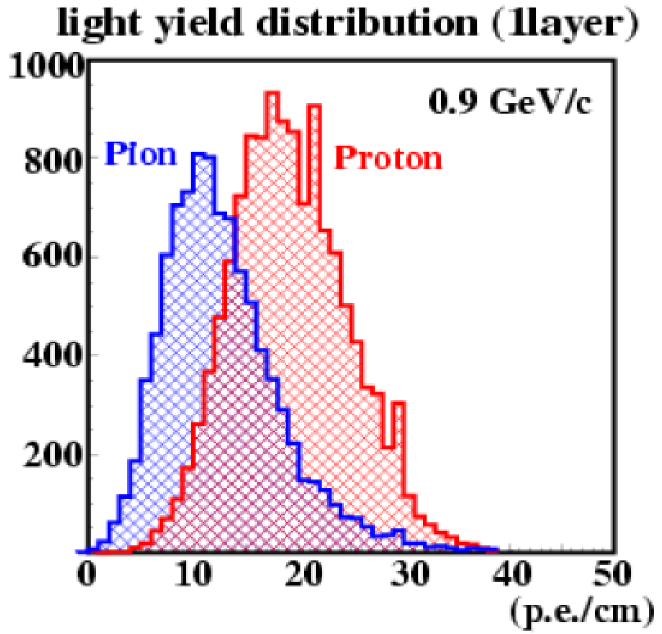
Energy threshold for protons in tracking mode.

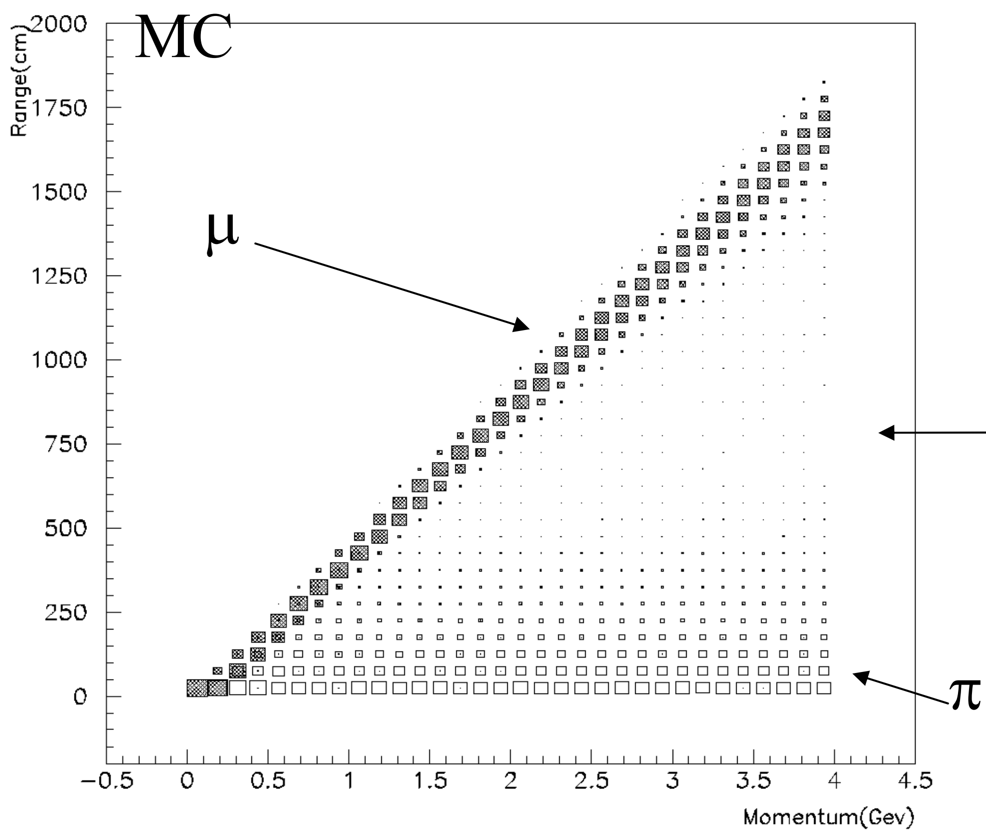
SciFi limit

SciBar detector

p/π separation based on dE/dx

Test Beam results for a fixed energy proton/π



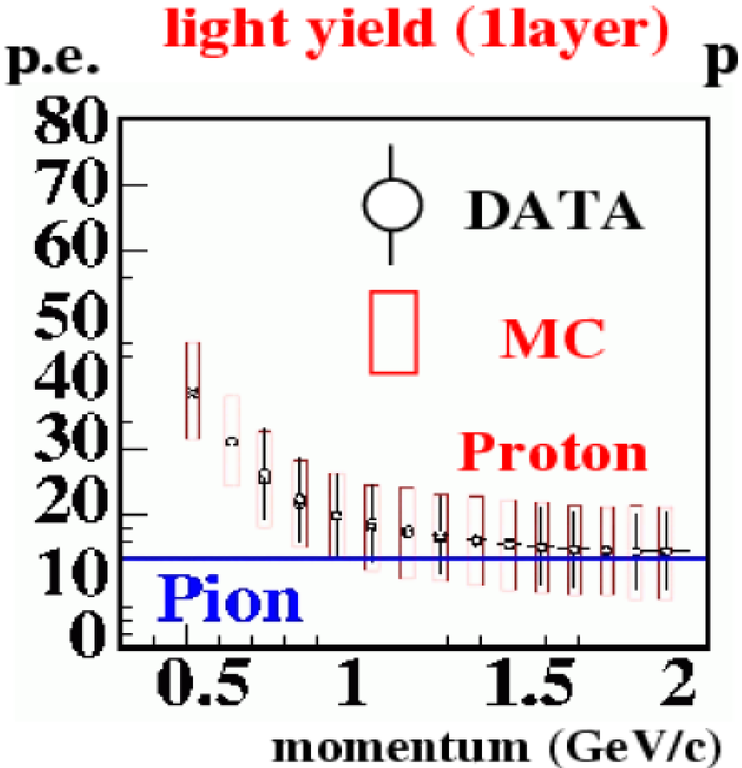


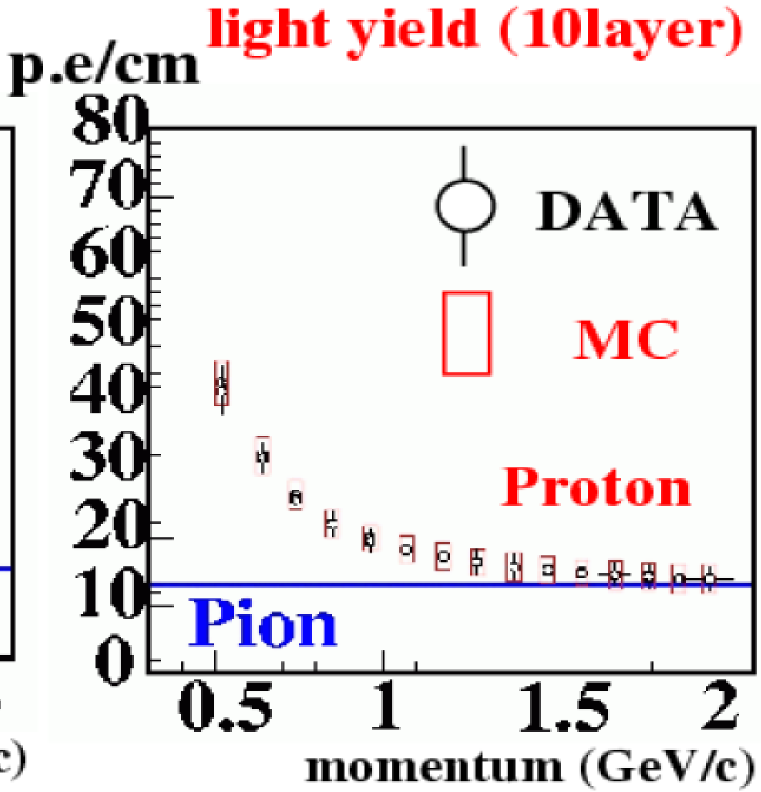
π/μ separation based on range

We want to calibrate the method in a Test Beam in Spring 2004.

SciBar detector

p/π separation based on dE/dx



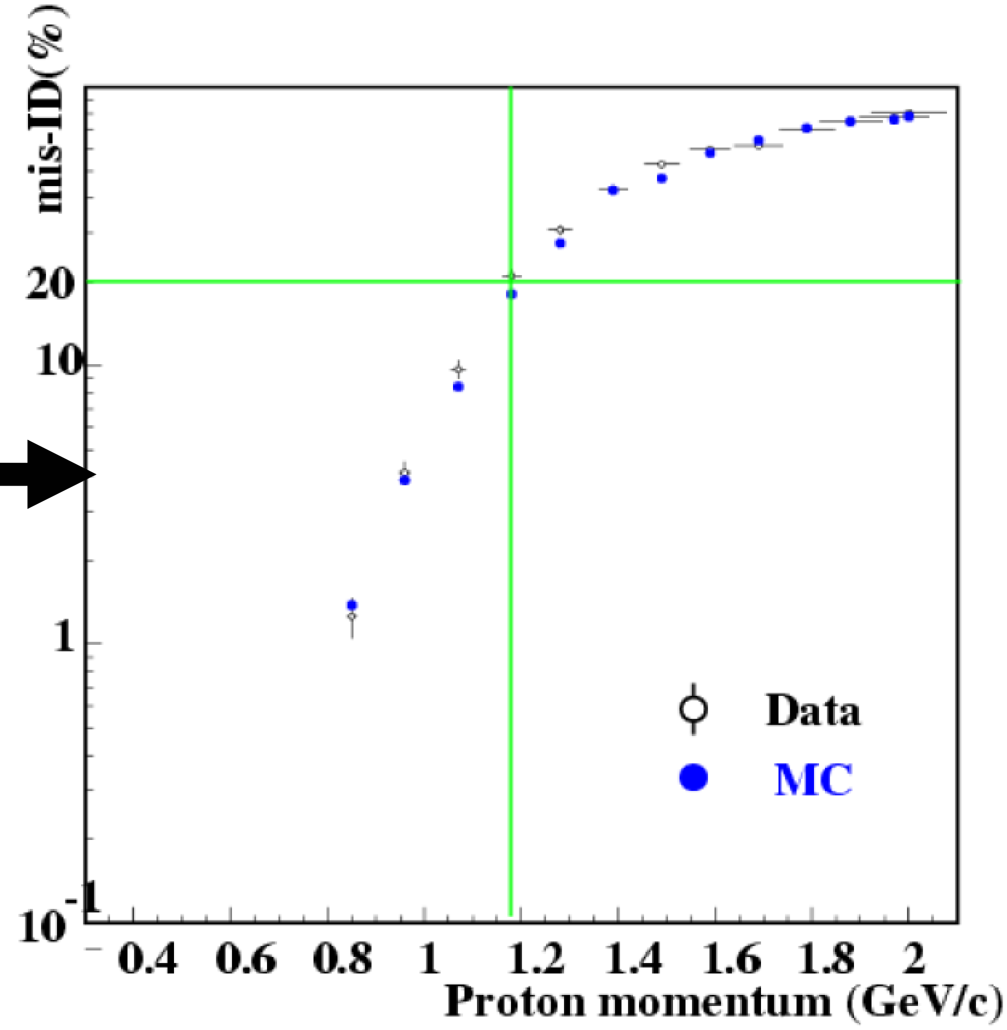


Good p/π separation up to 1 GeV.

SciBar detector

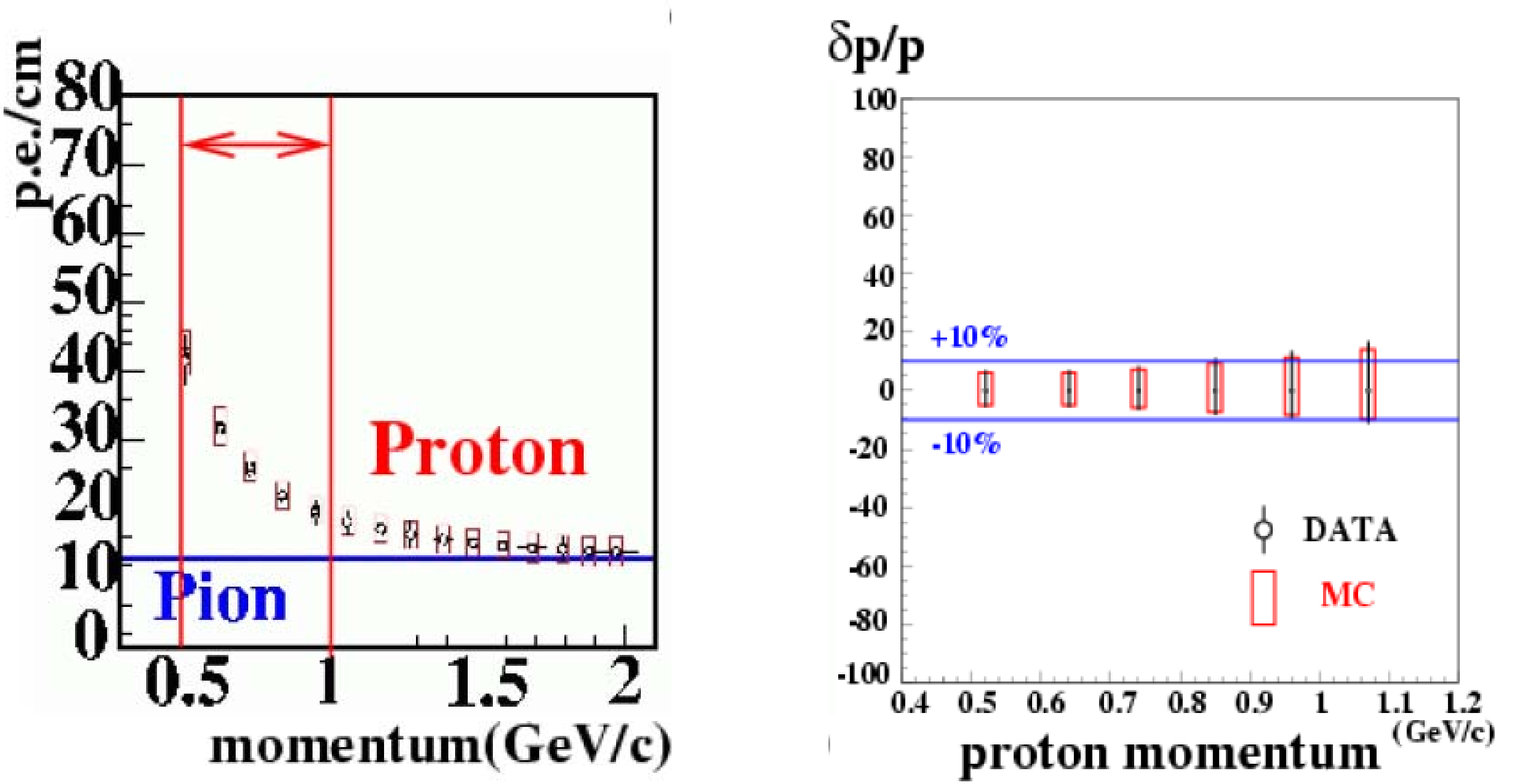
p/π separation based on dE/dx

Good p/π separation (< 20% misid) up to 1 GeV.



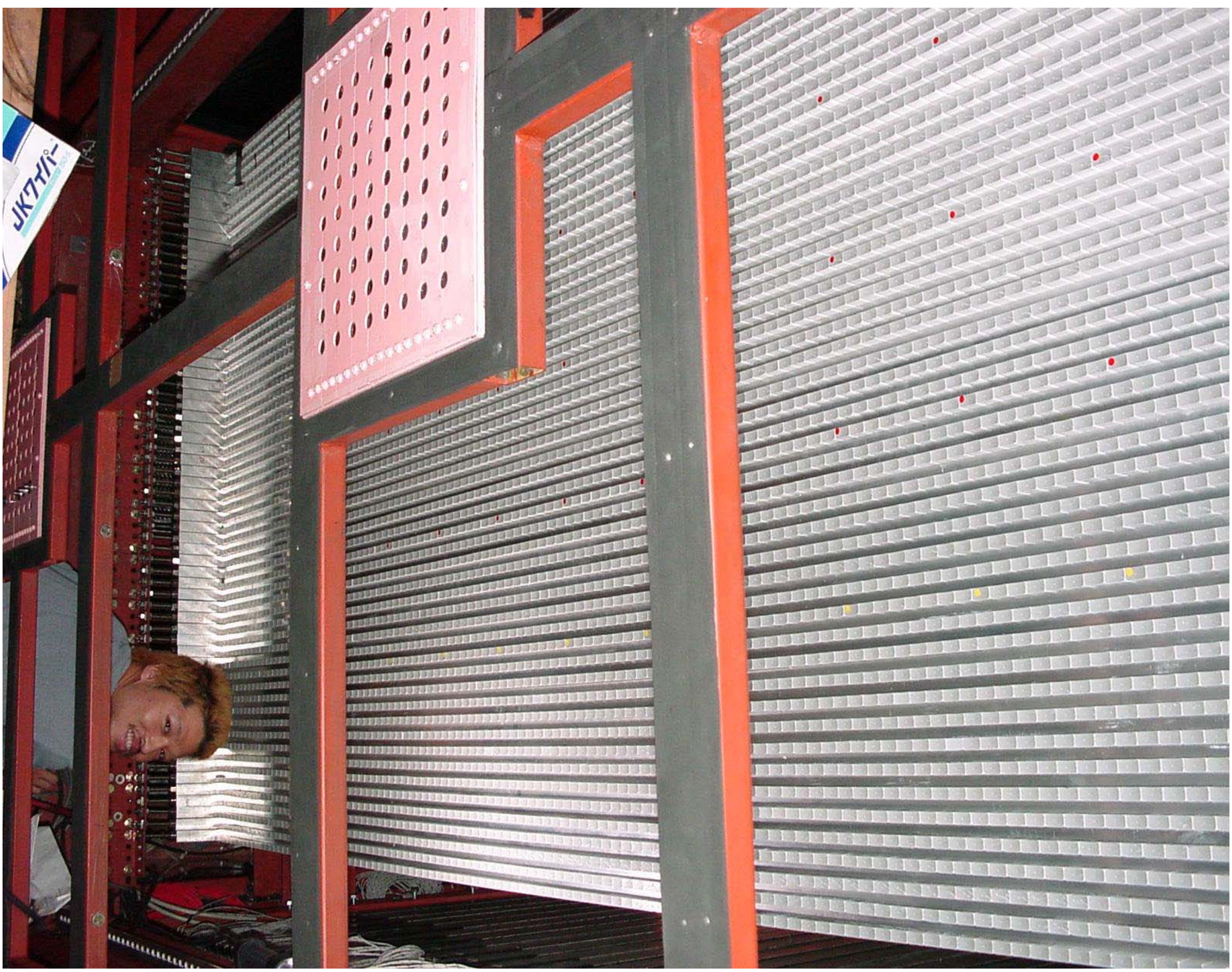
SciBar detector

Proton momentum based on dE/dx

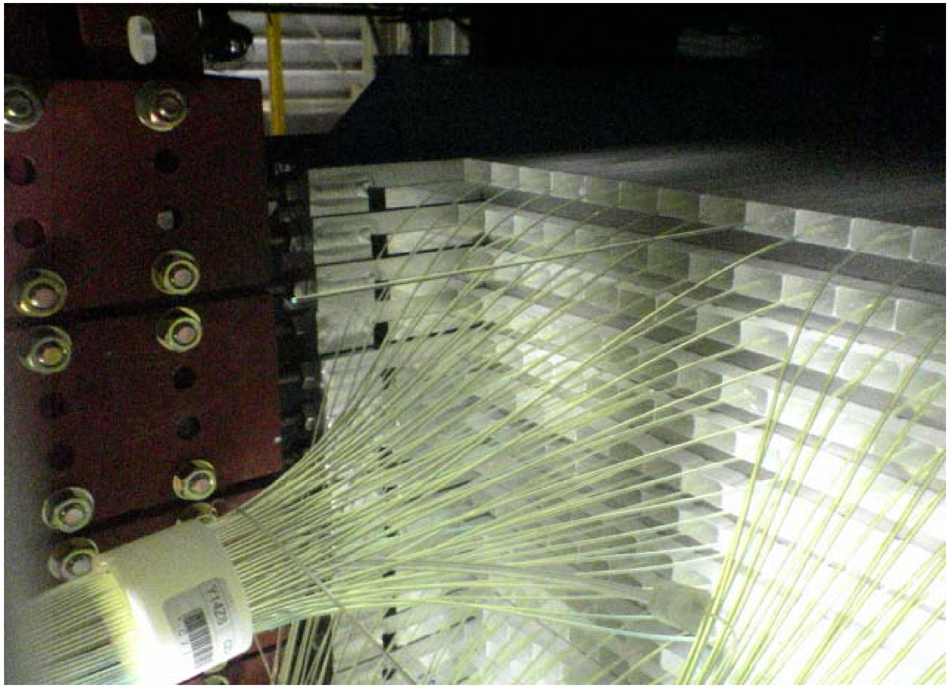


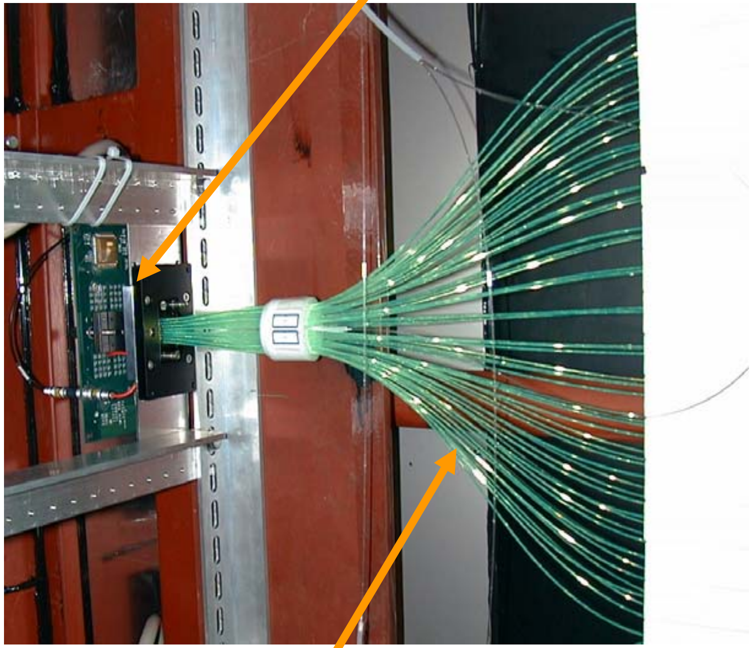
Proton energy can be reconstructed with flat 10% error
using 10 cm of particle range (> 7 layers).

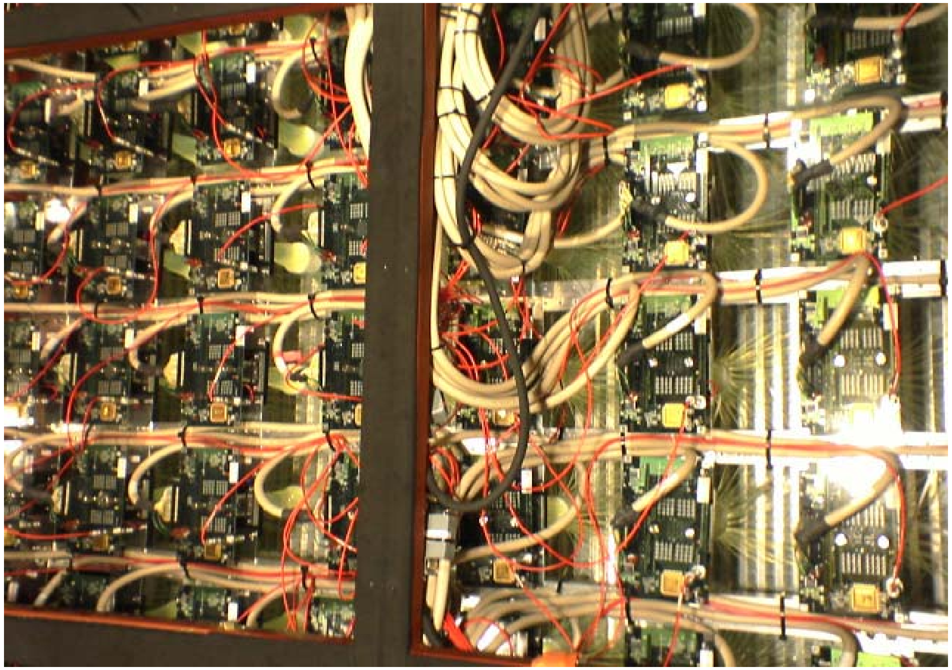
SciBar detector



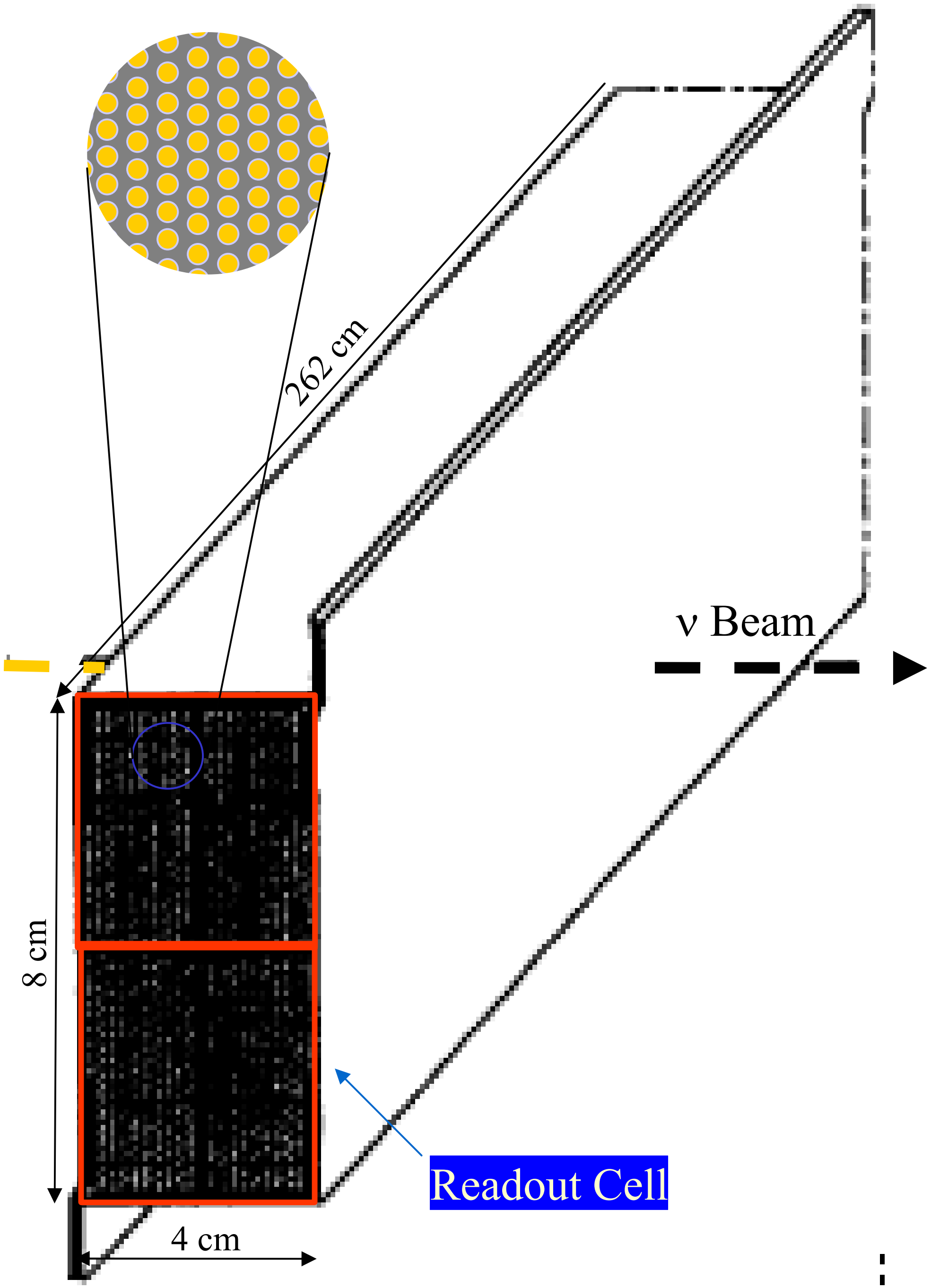
SciBar detector







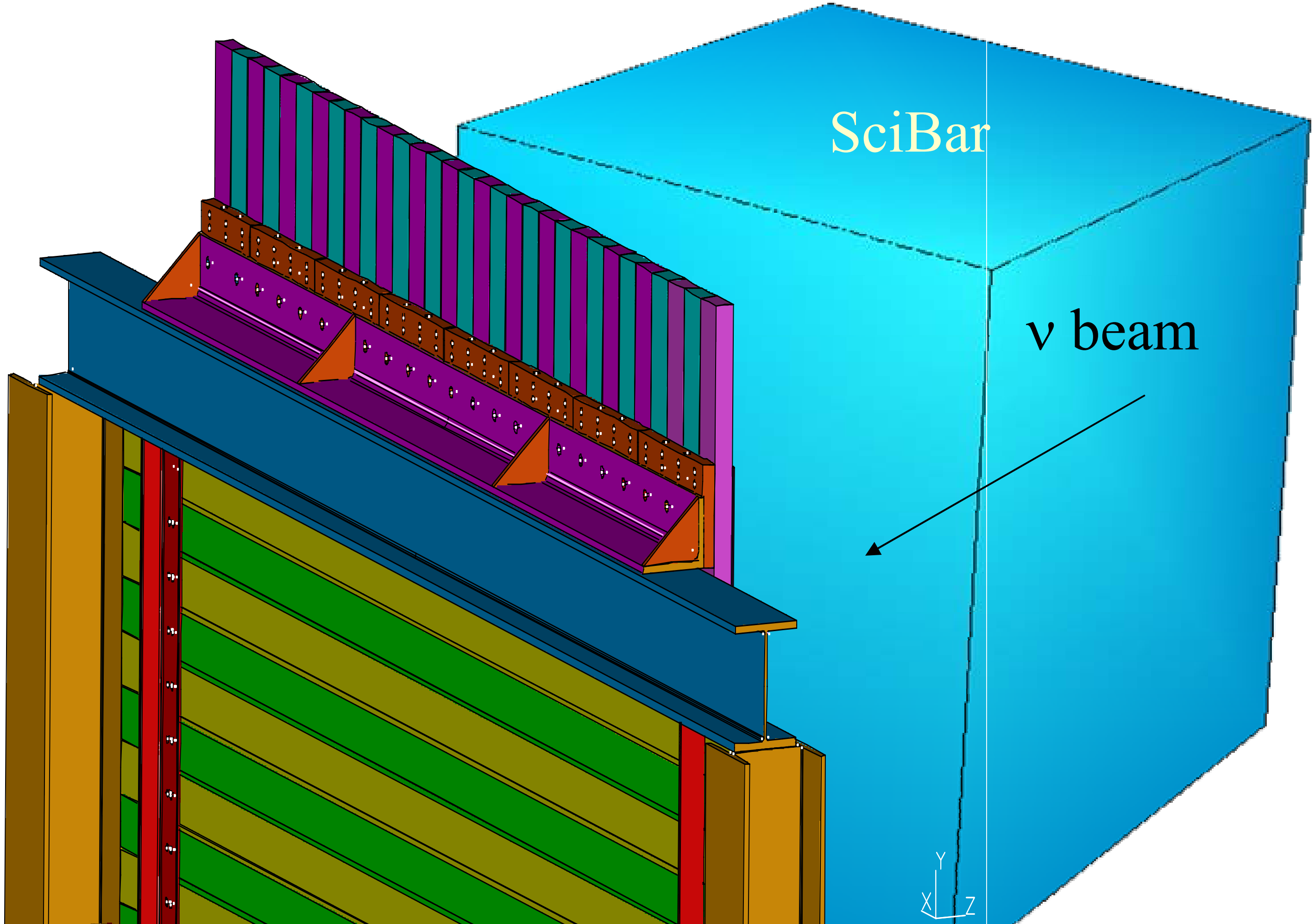
SciBar: Electron Catcher.



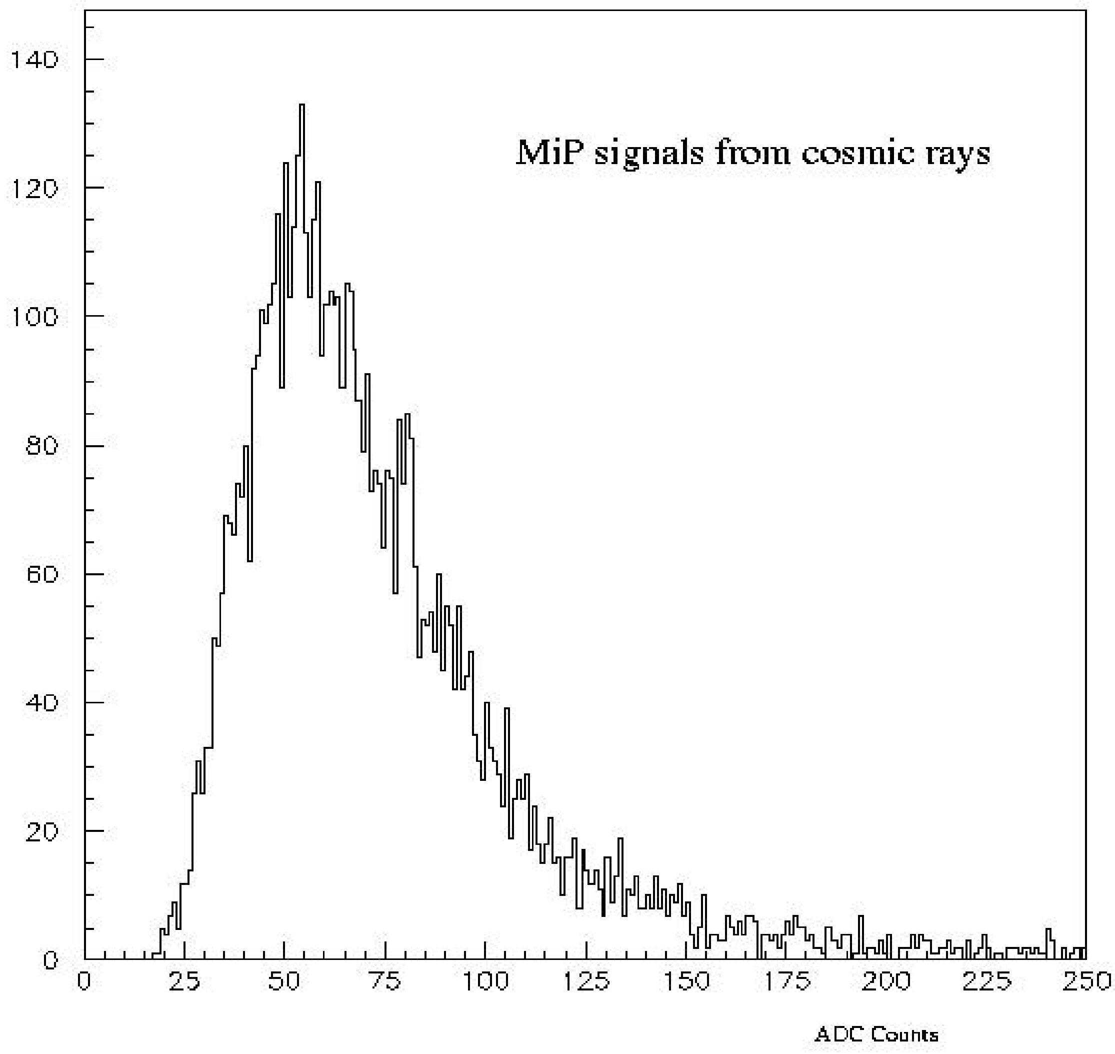
- Scintillating fibers positioned in the grooves of a stack of thin, extruded lead foils ("spaghetti" calorimeter)
  1 mm diameter fibers, 740 fibers per module
- Fine sampling lead and scintillating fibres
  Fiber/Lead 1:4 in volume, 0.3 Xo sampling
- Fibers in a 4x4cm^2 cell, are bundled and read by a 1" PMT on each side
  Hamamatsu R1355/SM PMT,   Kuraray SCS-F81 scintillating fibers, λ_{att}~500 cm
- Good energy resolution and linearity
  Resolution 14%/√E, linearity better than 10% in the range 50MeV÷1GeV
- 85% containment @ 3 GeV

SciBar: Electron Catcher.

- Two orthogonal planes just downstream of SciBar, providing energy reconstruction and cluster positions in both transverse projections (11 Xo and 0.38 λint).
- 30 horizontal modules (60 readout cells) and 32 vertical modules (64 readout cells).
- The fibers in each readout cell (4x4x265cm) are bundled both side to 248 PMTs.



SciBar: Electron Catcher.



- Each PMTs has been individually equalised and pre-calibrated with cosmic ray muons before installation.
- A MIP releases about 60 MeV in a module.
- The HV pre-setting has been done adjusting the pulse height for MIPs to about 50 ADC (5 pC).

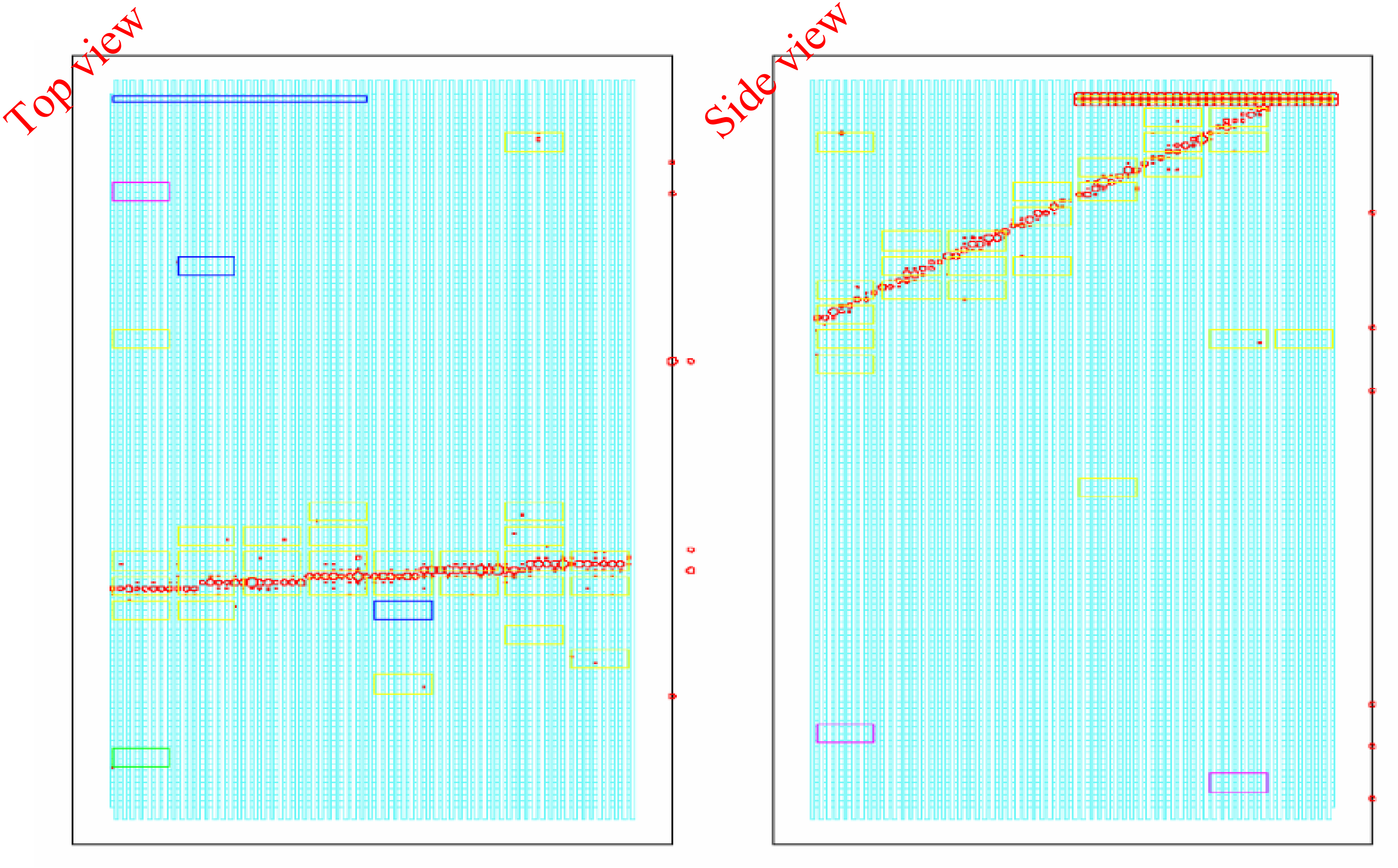
SciBar: Electron Catcher.

SciBar review

Weight	15t	~11t fiducial
Size	300x300x180 cm^3	
Segment	2.5x300x1.3 cm^3	14 000 channels
#ν interactions	45000	3 10^{19} proton on target
# ν interactions (QE)	12000	3 10^{19} proton on target
Proton threshold	> 350 Mev/c	Range ~ 3.5 cm
Proton mom. Resolution	~ 10%	500<p<1000 MeV
EC Energy Resolution	14%/√E	
ECLong.containment	85% @ 3 GeV	

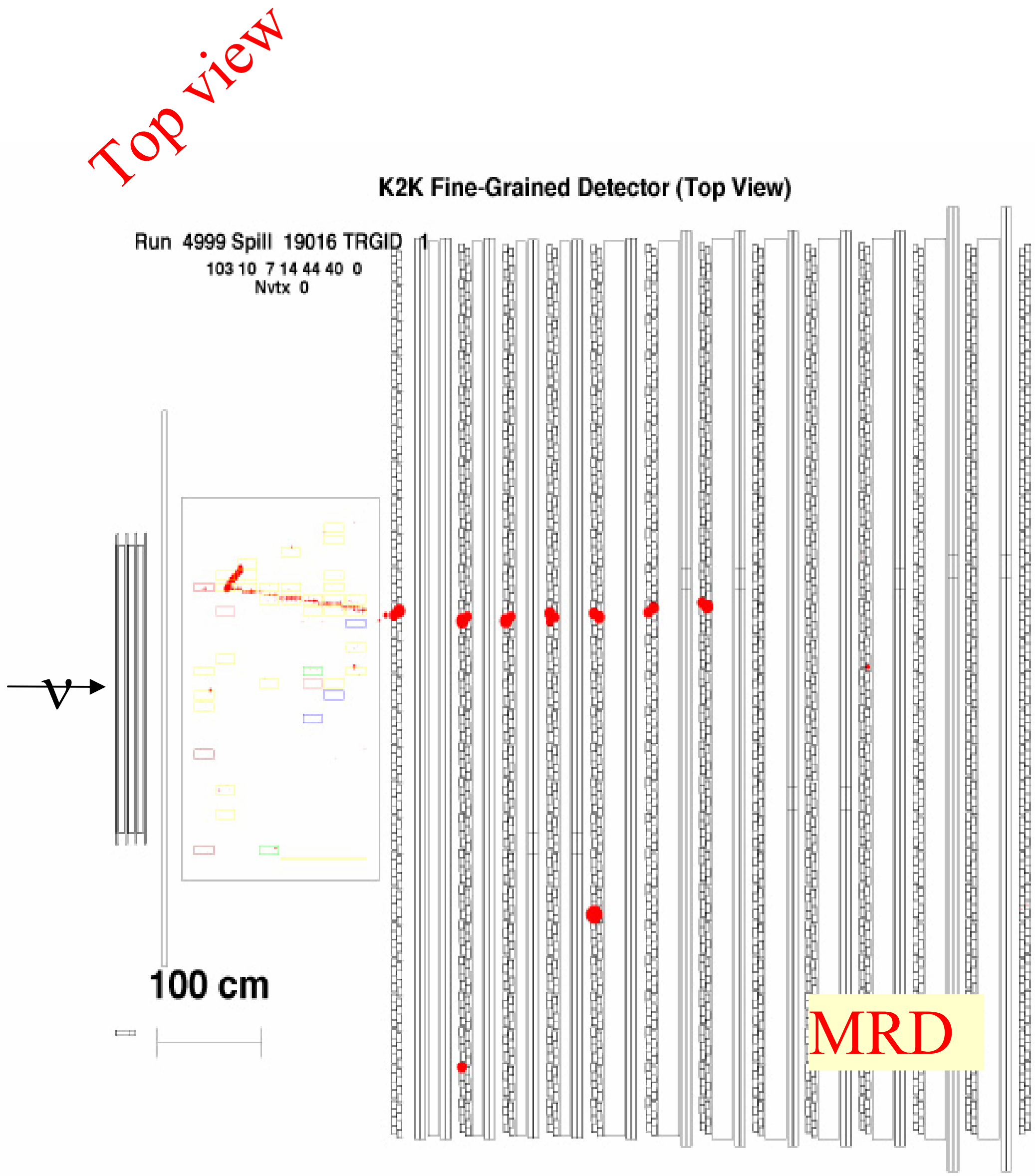
SciBar detector

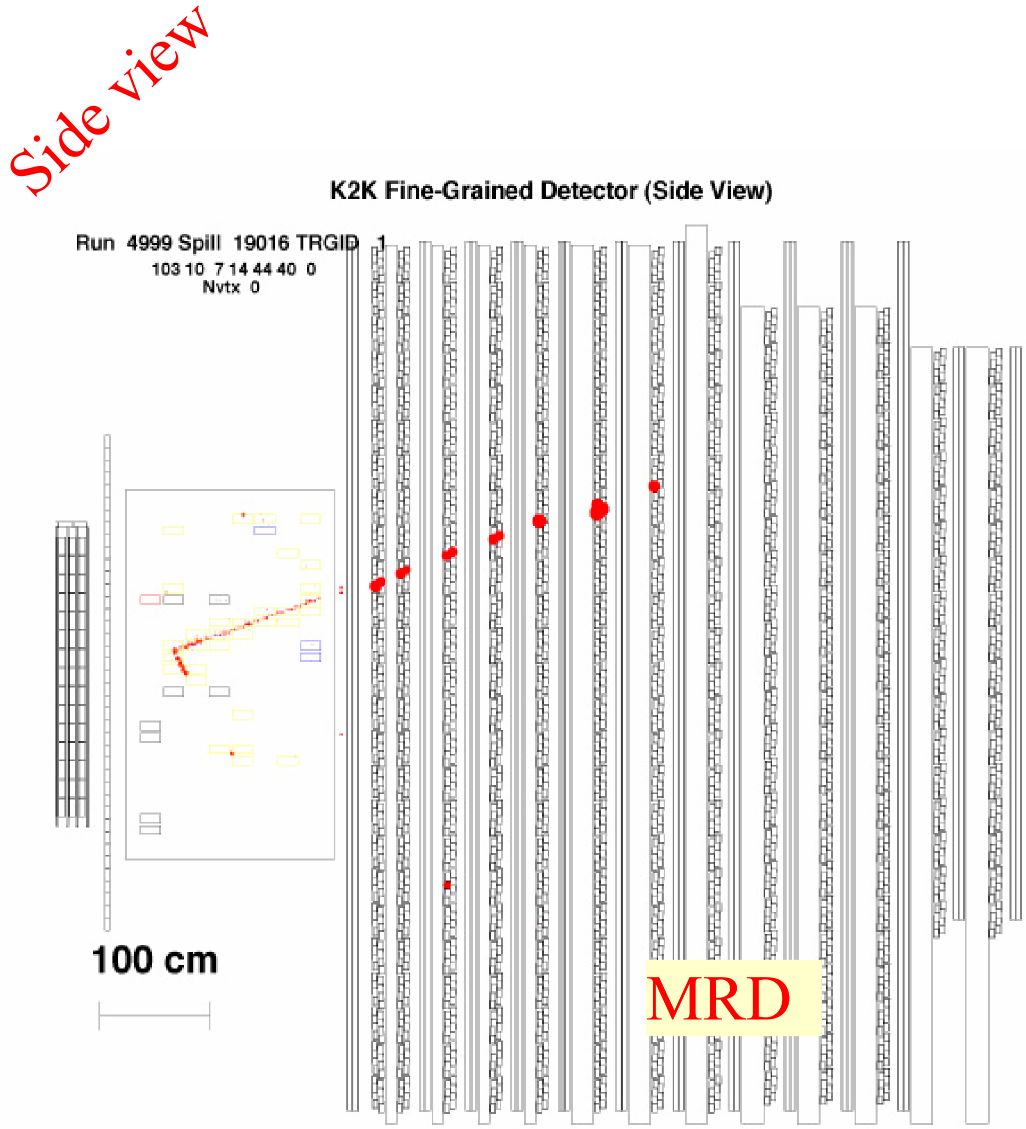
Cosmic muon



SciBar detector

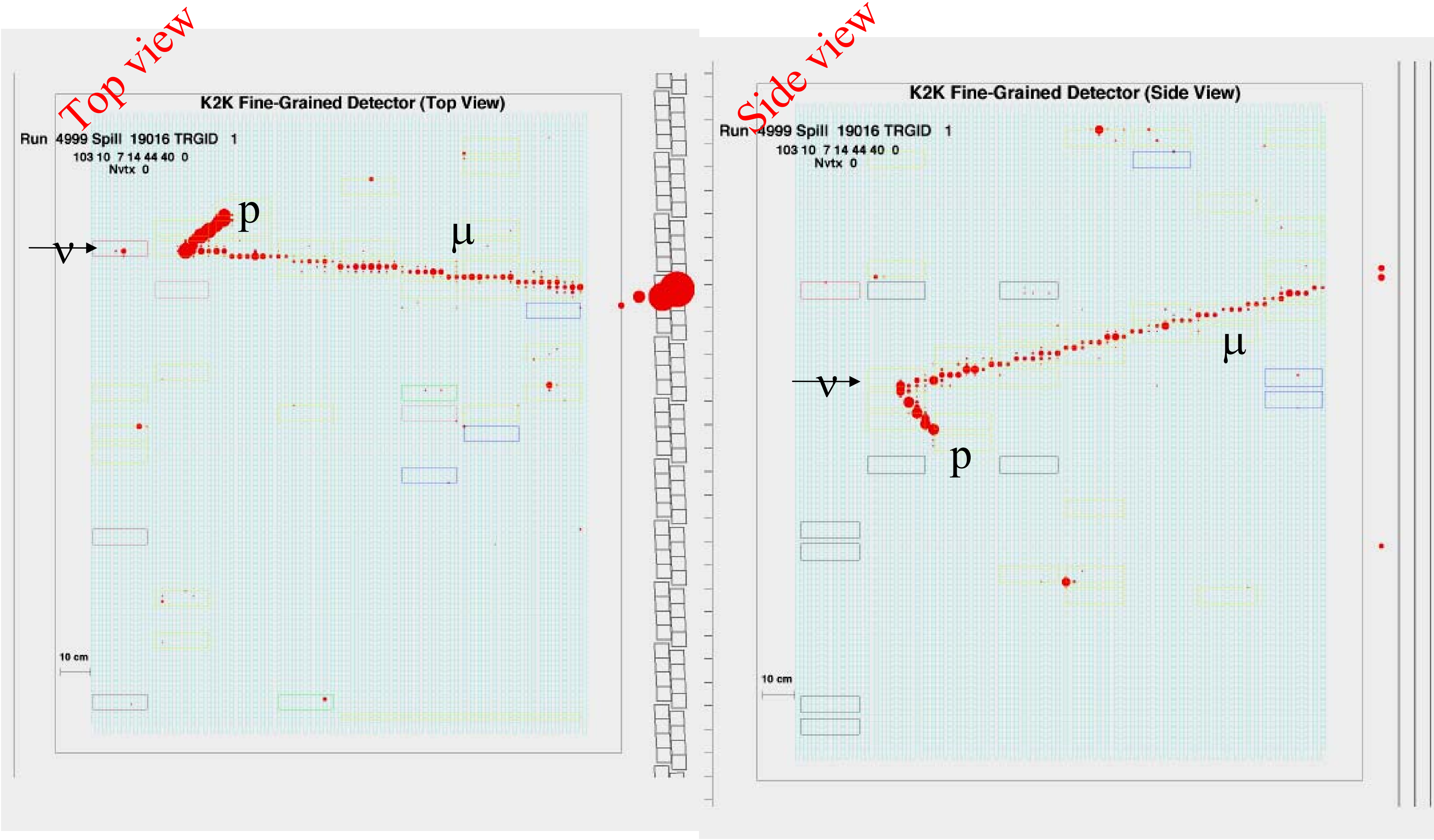
CC-QE candidate





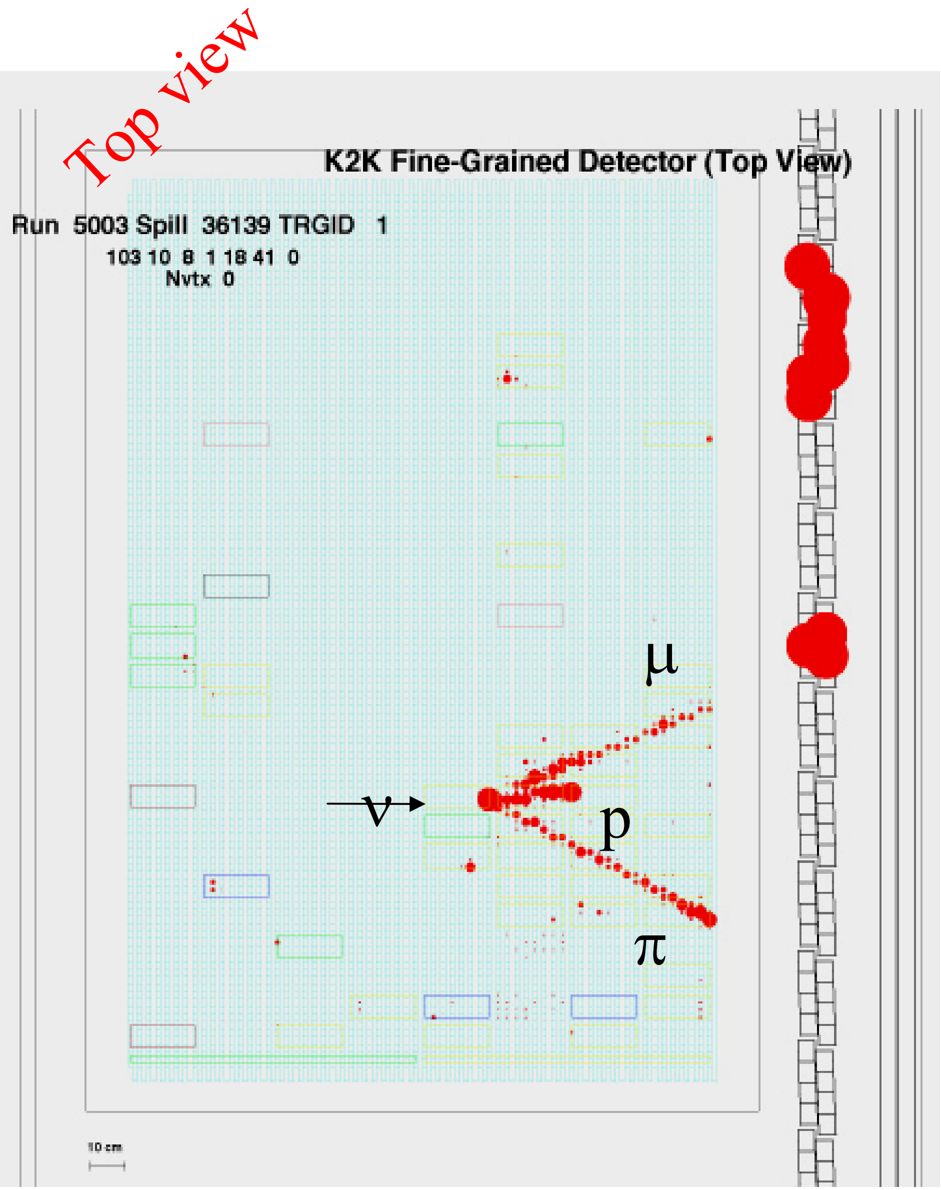
SciBar detector

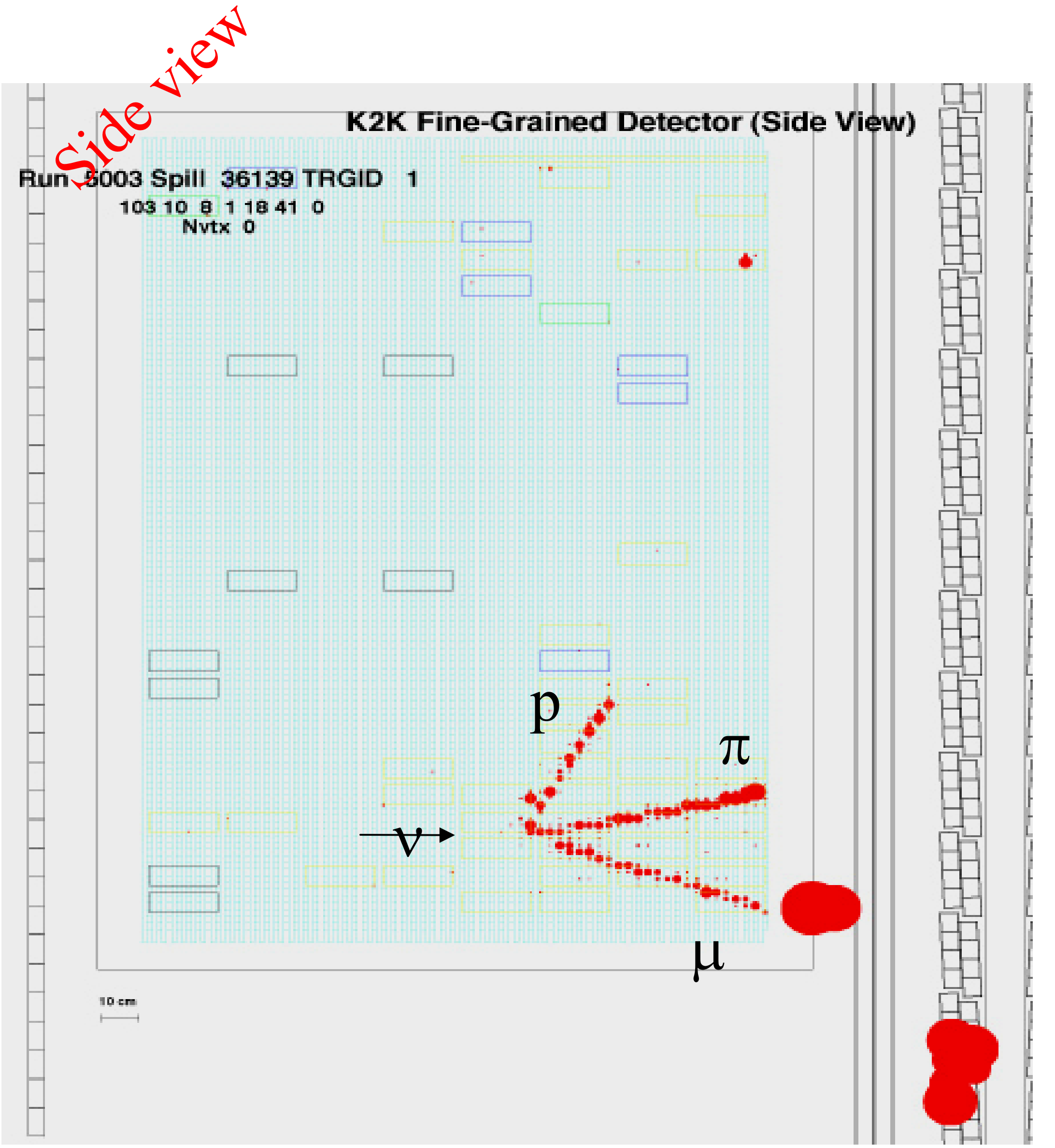
CC-QE candidate (close view)



SciBar detector

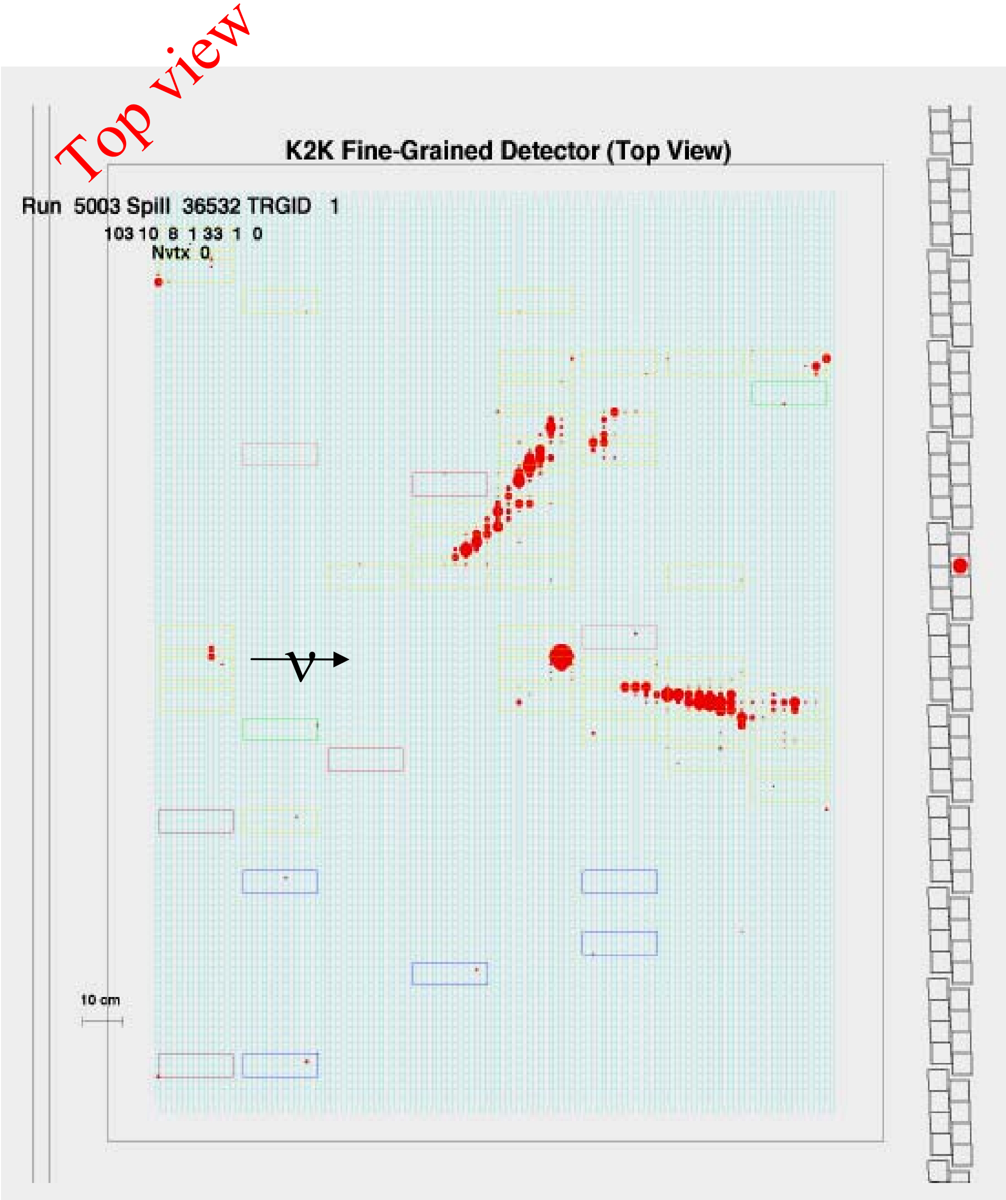
CC- pπ candidate

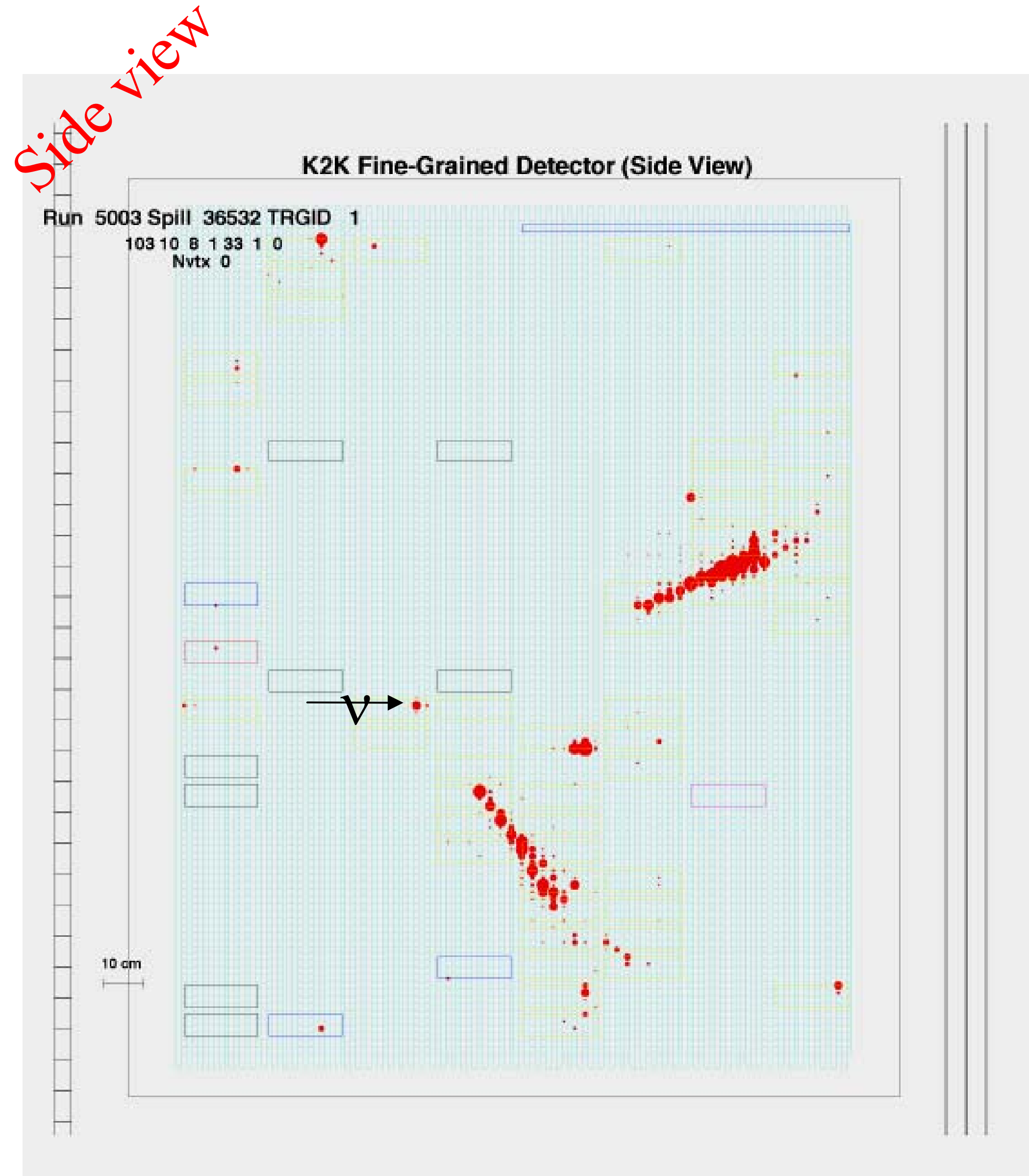




SciBar detector

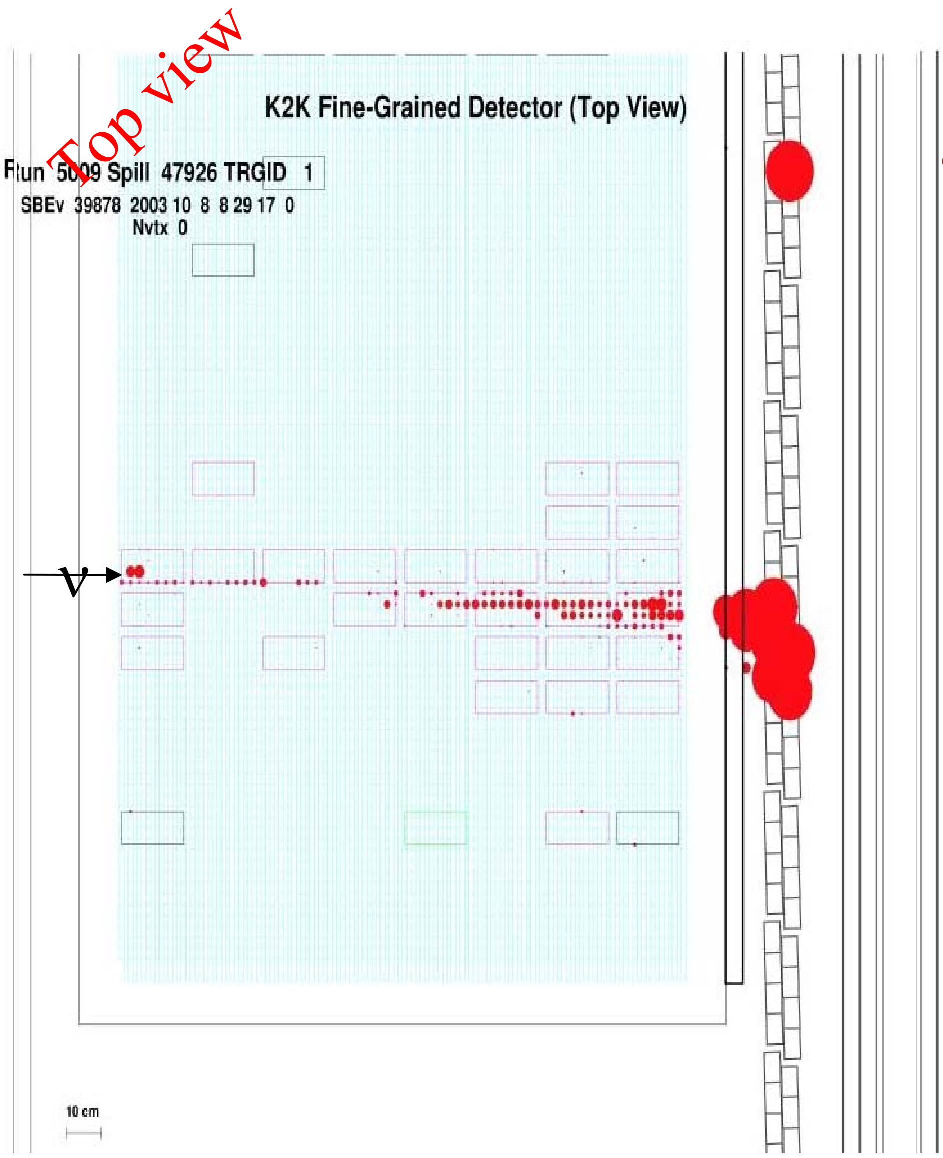
π^0 candidate

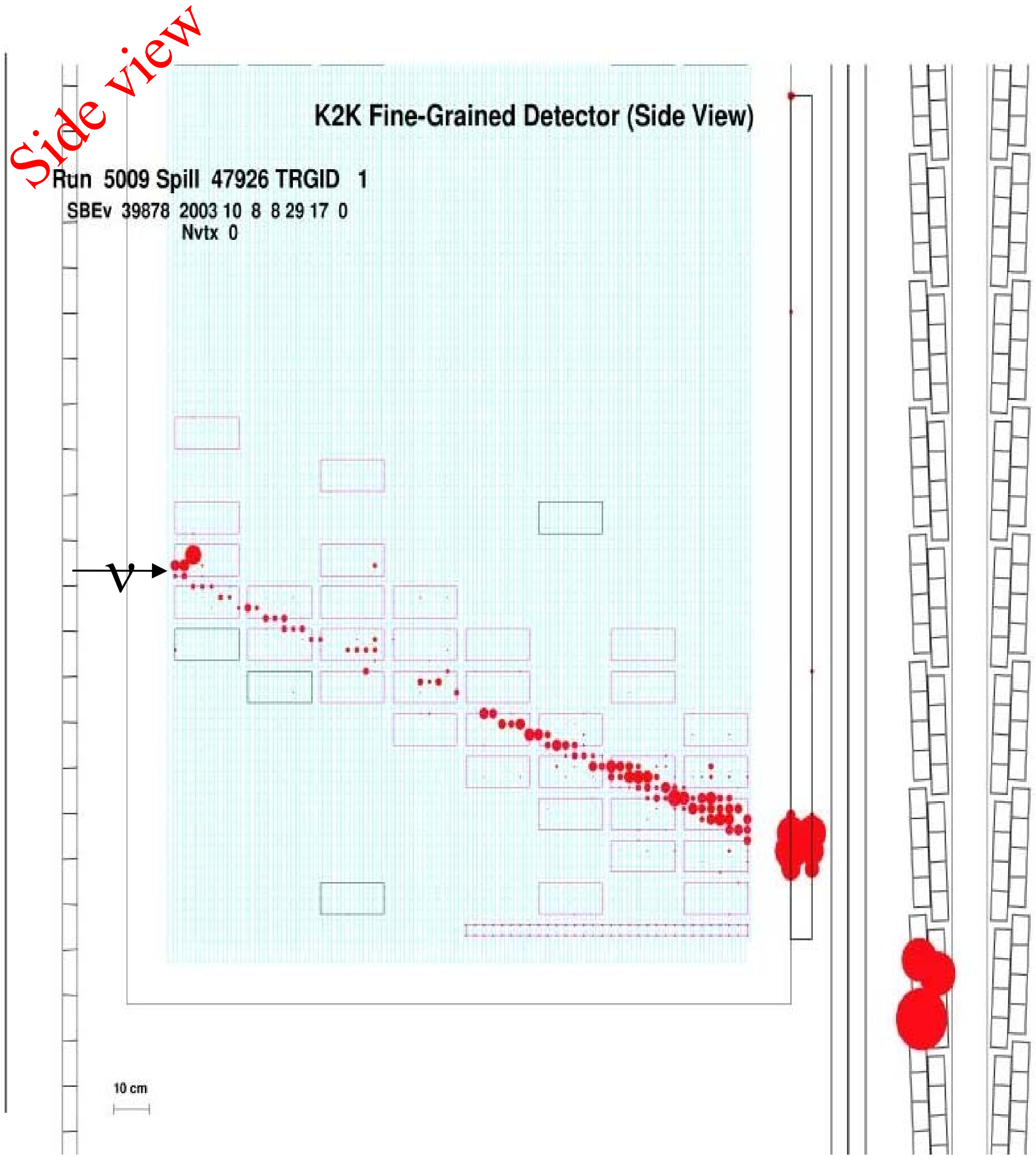




SciBar detector

ν_e CC-QE candidate





SciBar Reconstruction code

One of the critical problems of the detector is the track reconstruction.

High efficiency for short tracks.

Good association of hits to tracks for proper dE/dx measurement.

Good two track spacial separation.

Cellular Automaton track (CAT) finding

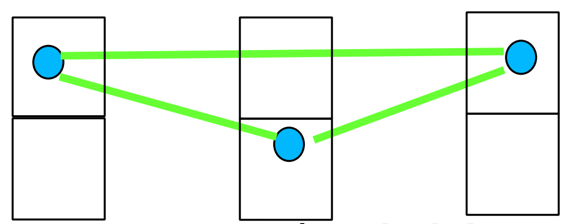
- Cellular automaton are discrete dynamical systems whose behavior is completely specified in terms of a local relation.
- Space is represented by a uniform grid, each cell containing a few bits of data; time advances in discrete steps and at each step each cell computes its new state from that of its close neighbors.
- The system's laws are local and uniform.

Cellular Automaton track finding

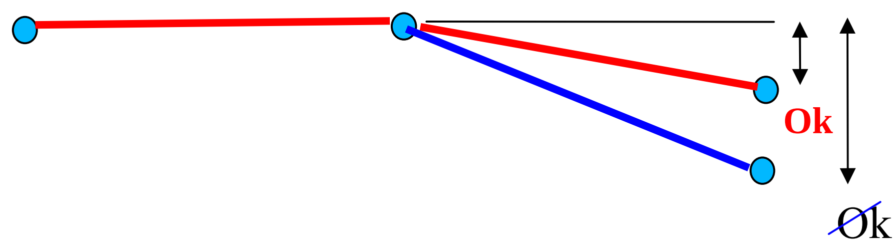
- Cellular automaton is a good representation of the evolution of a track in the detector: whatever happens to a track is a "local" phenomena.
- It is efficient to find short tracks due to the locality laws.

Cellular Automaton track finding

- Construct all segments, such that they connect hits in consecutive layers (or missing one layers to account for detector inefficiencies)



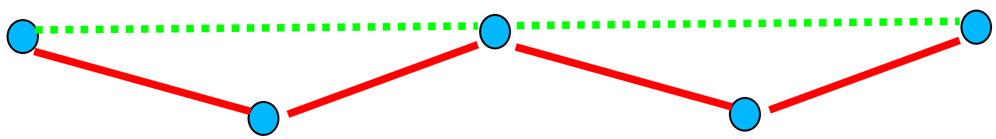
- Segments are connected (neighbor cells) if they are compatible from Multiple scattering & detector resolution



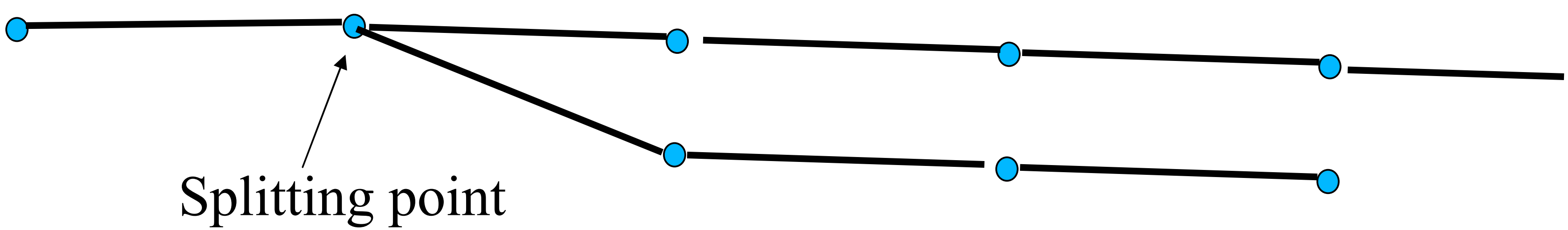
- Criteria is the χ^2 of a Least Square fit to the three hits.

Cellular Automaton track finding

- To build long tracks we find the longest connection of segments. Solid is preferred versus dashed.



- Splitting segments are identified in connection points:



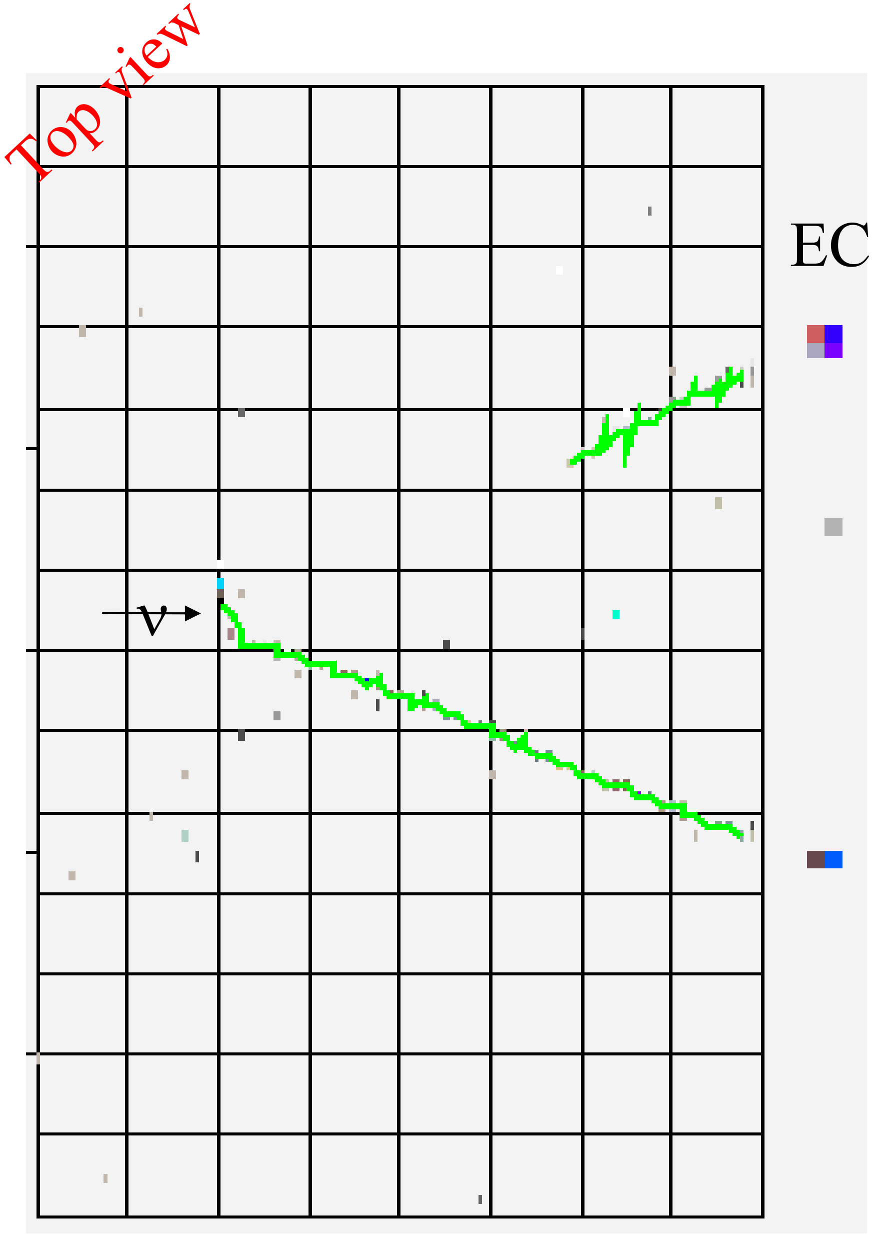
Cellular Automaton track finding

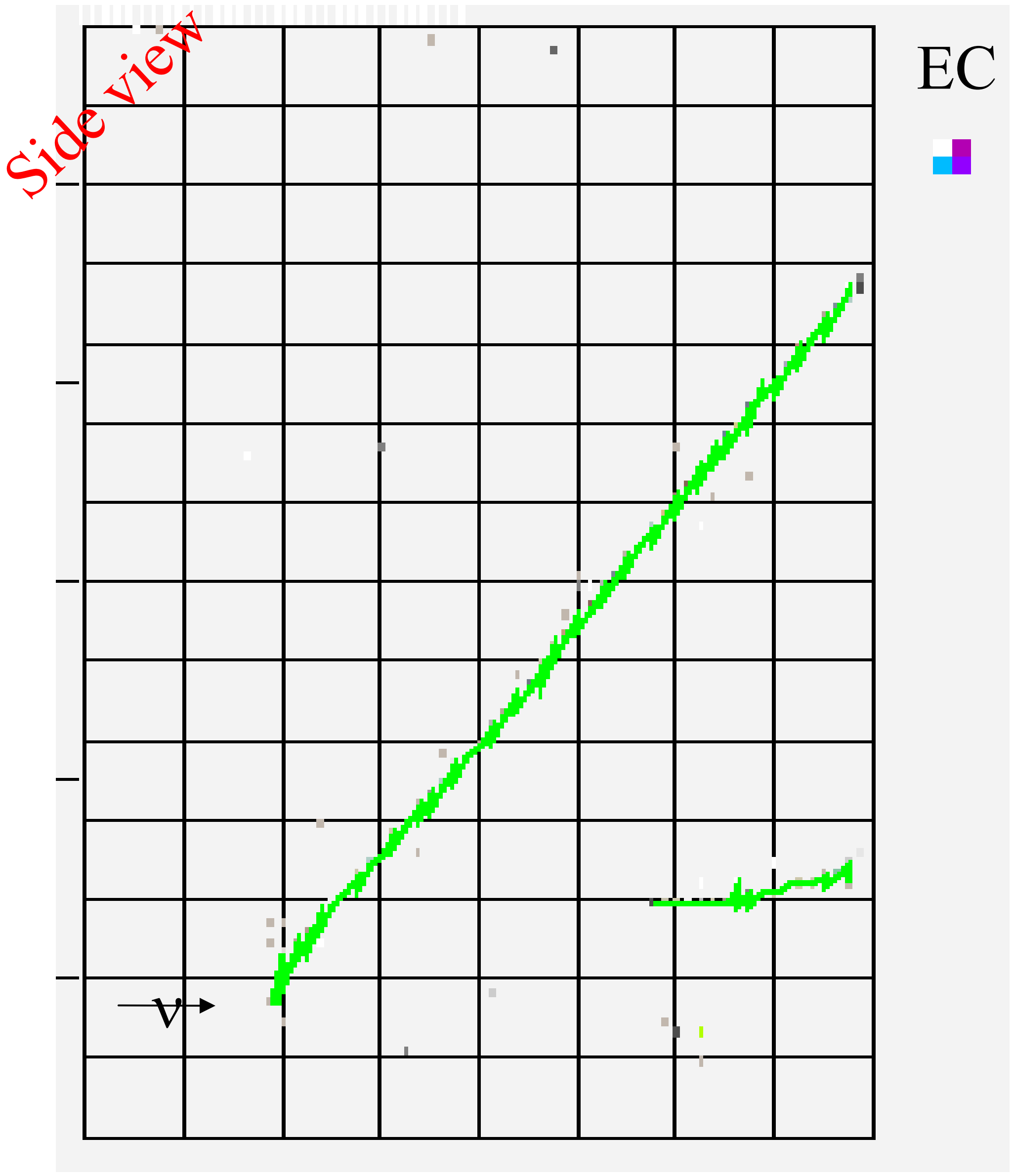
We achieve very large efficiency for tracks crossing at least three detector planes.

Fraction of common hits	Efficiency
30%	100 %
50 %	99.8 %
70%	99.1%
80%	97.6%
90%	94.0%
95%	91.3%

SciBar detector

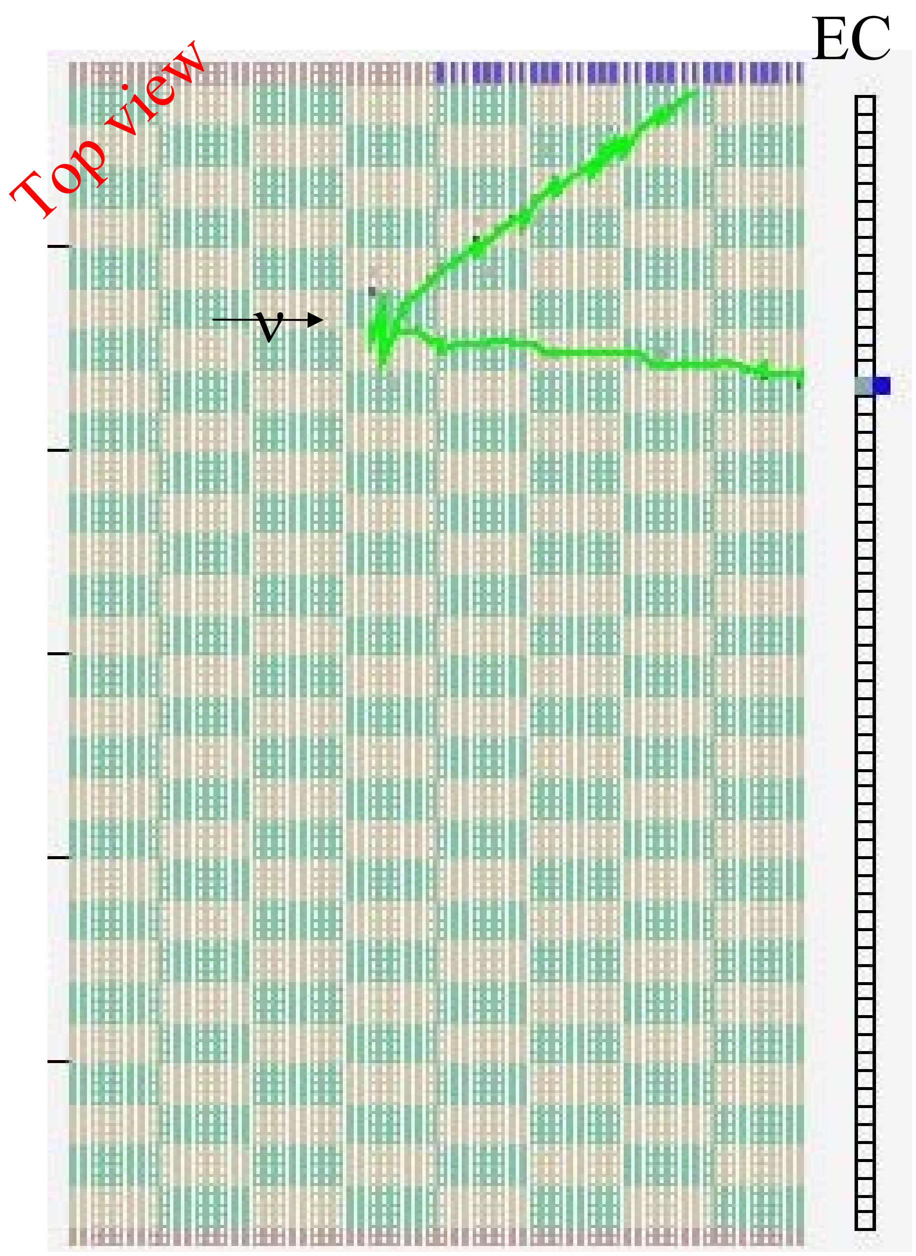
Tracking and reconstruction already running

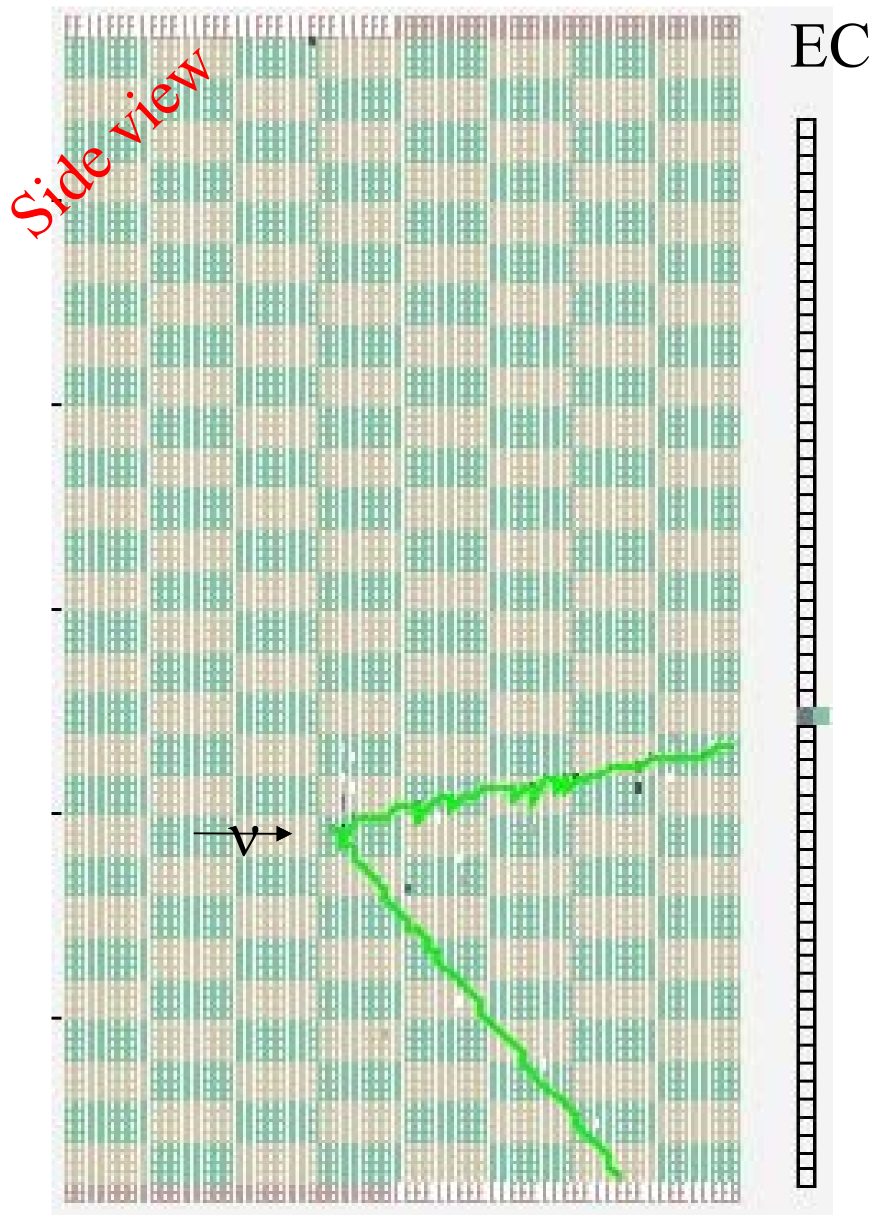




SciBar detector

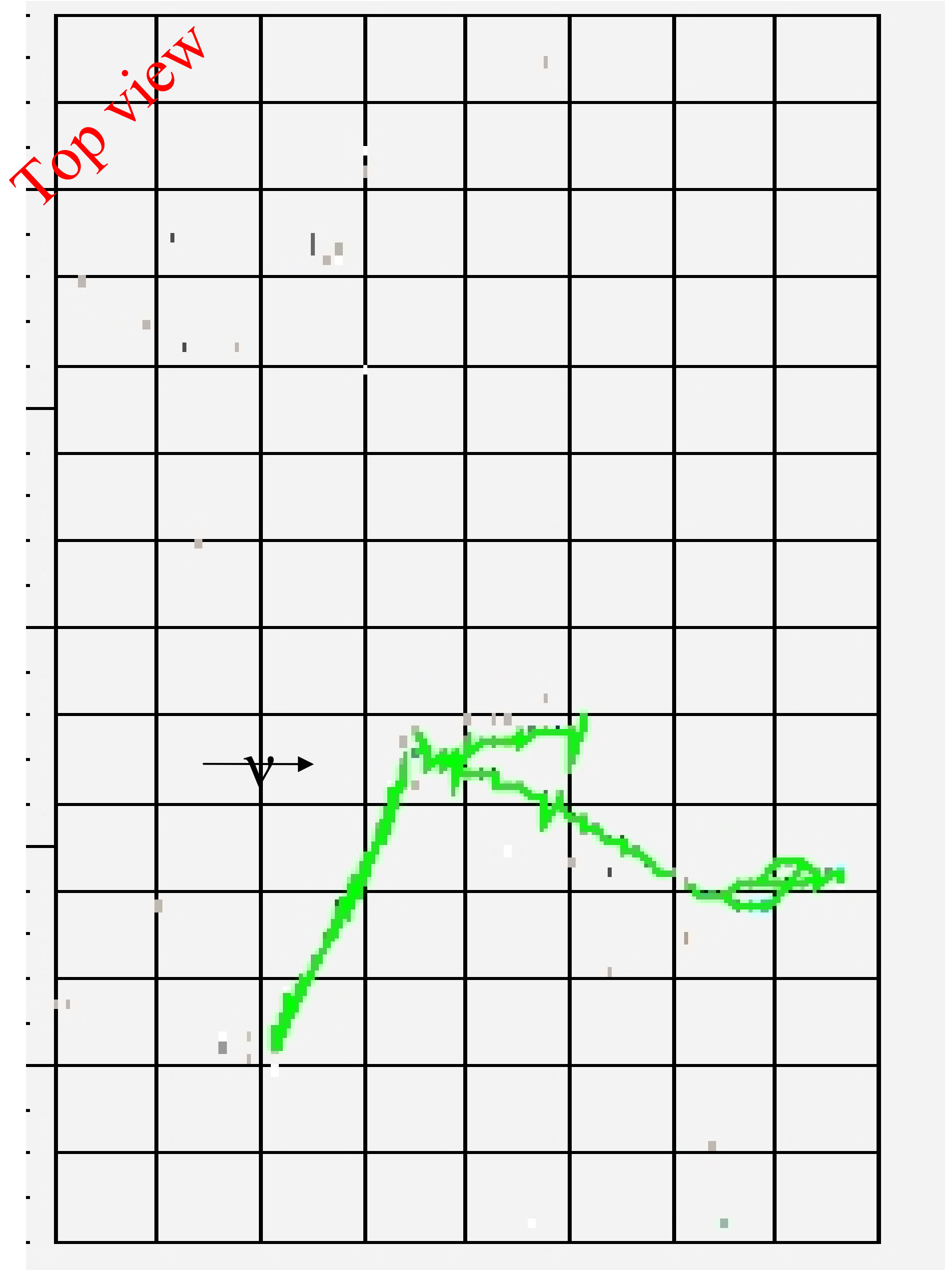
Tracking with 2 track events

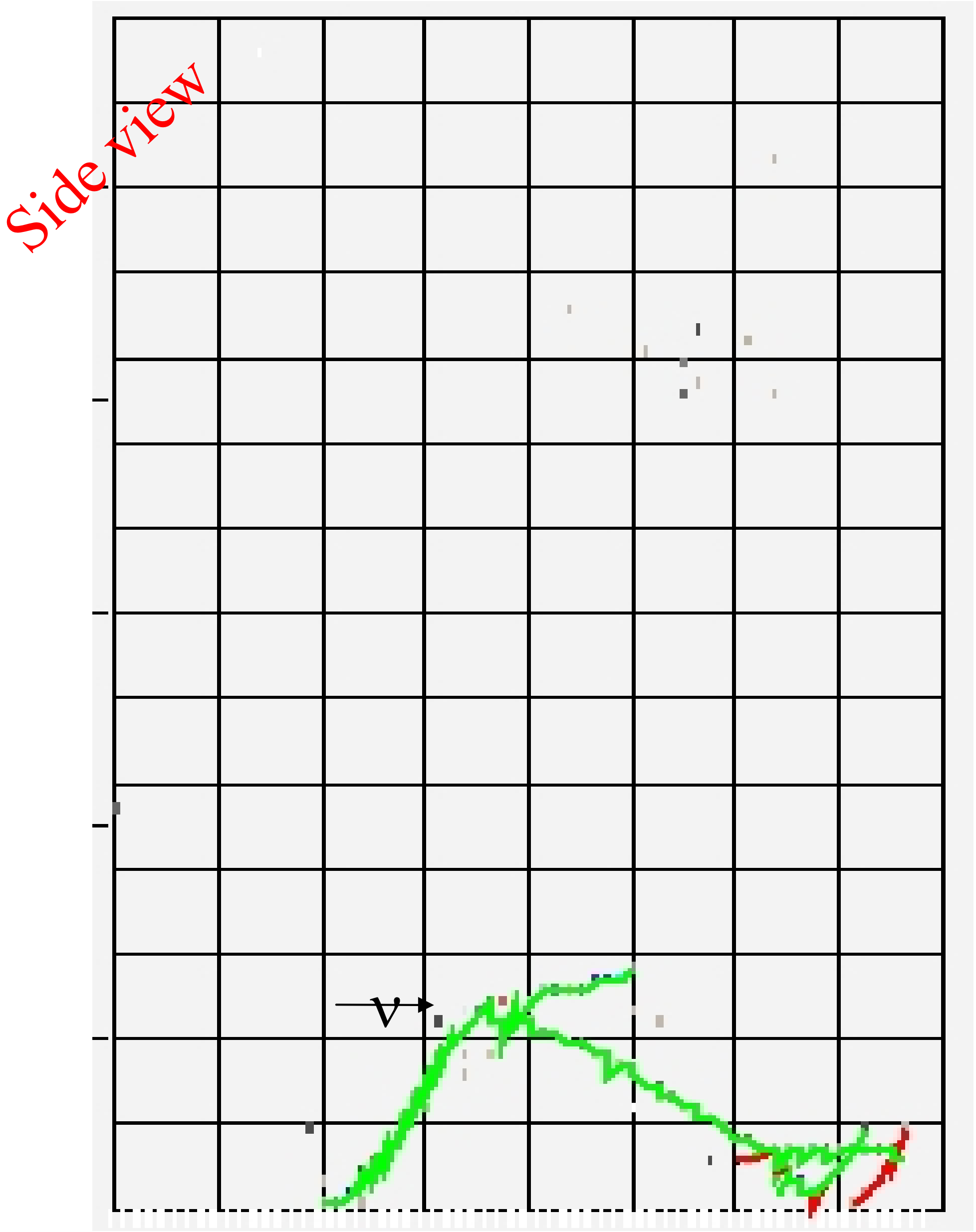




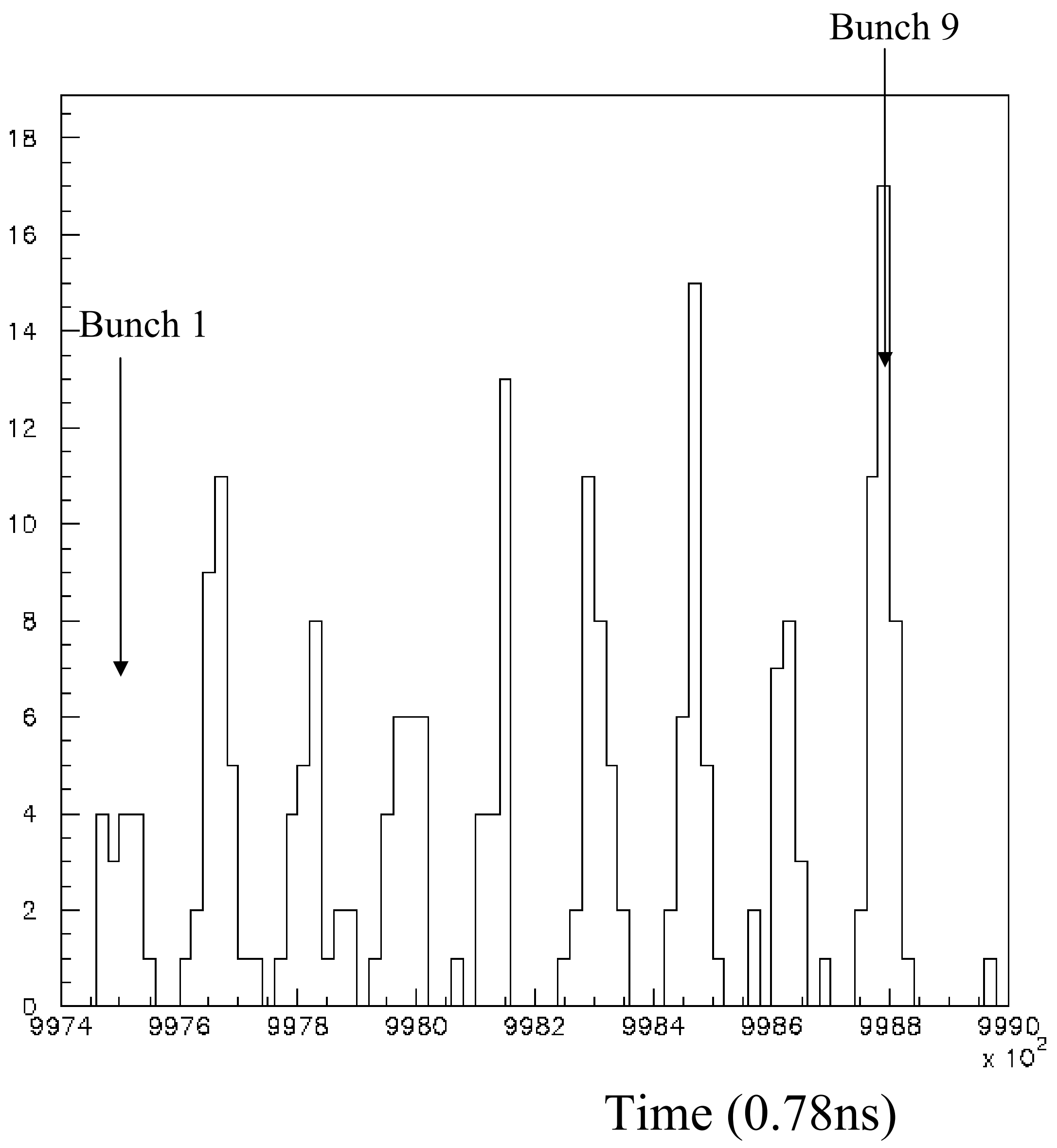
SciBar detector

Tracking with 3 track events



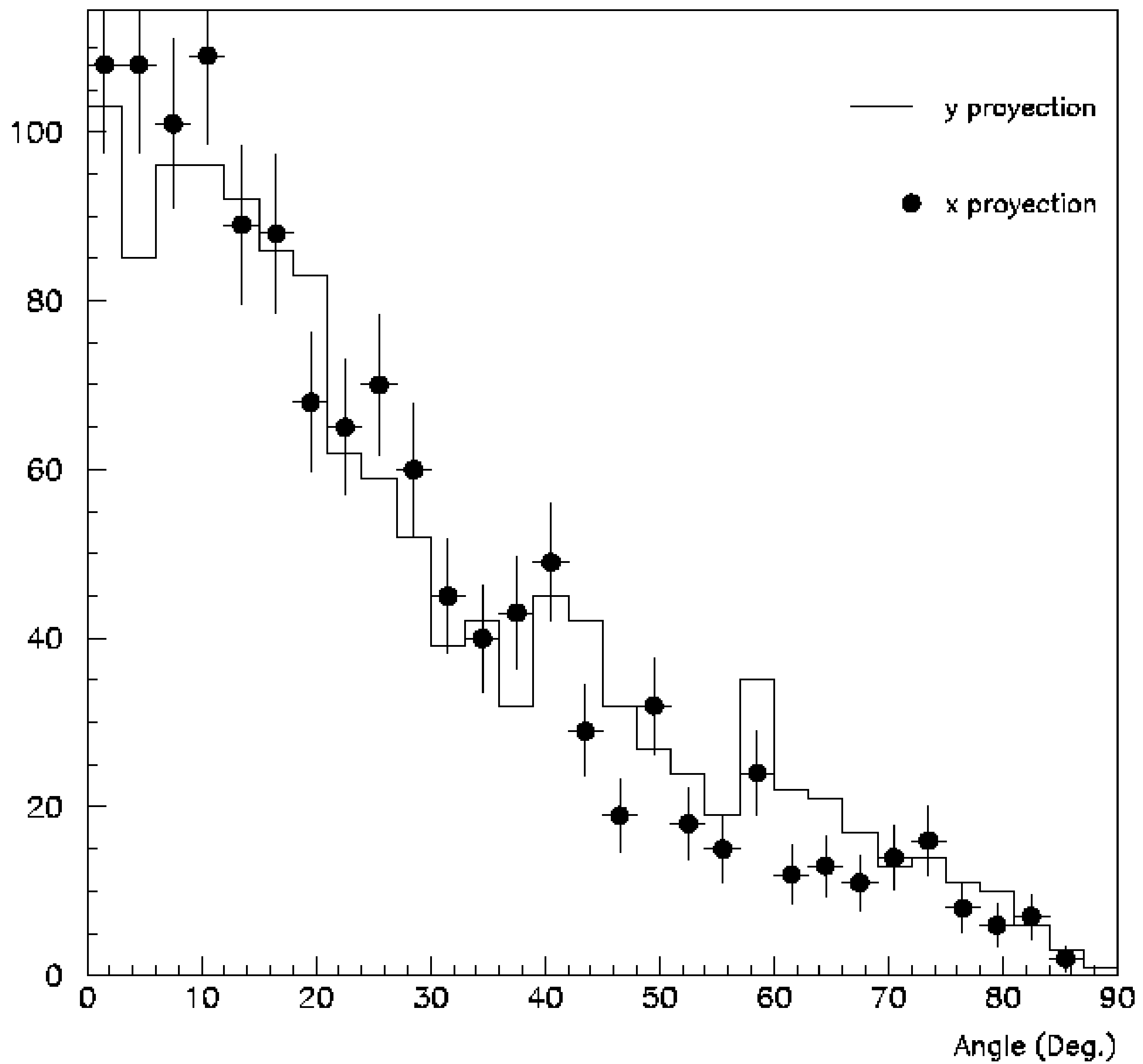


SciBar detector

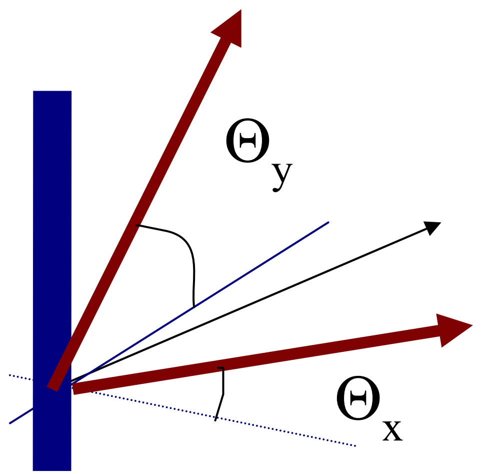


Beam time structure of 9 bunches /spill is clearly visible

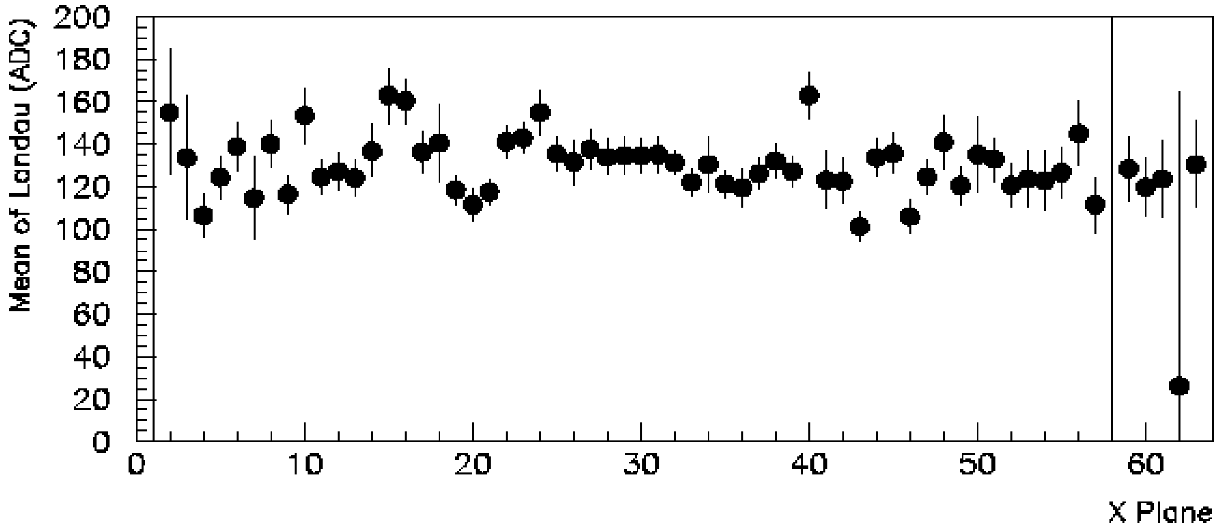
SciBar detector

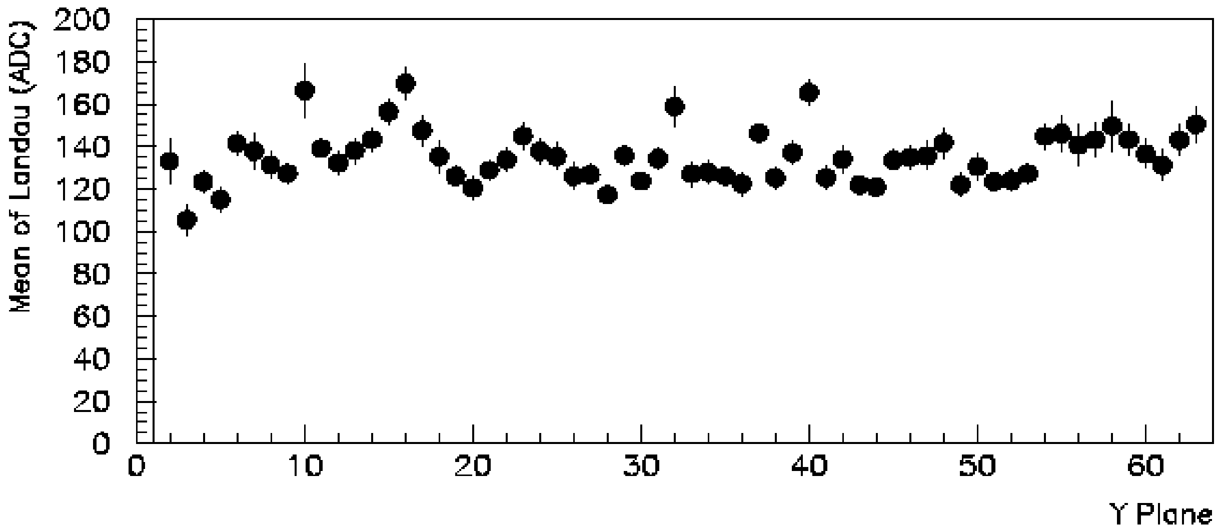


Angular distribution of the longest track in the 2 pojections for neutrino events.



SciBar detector





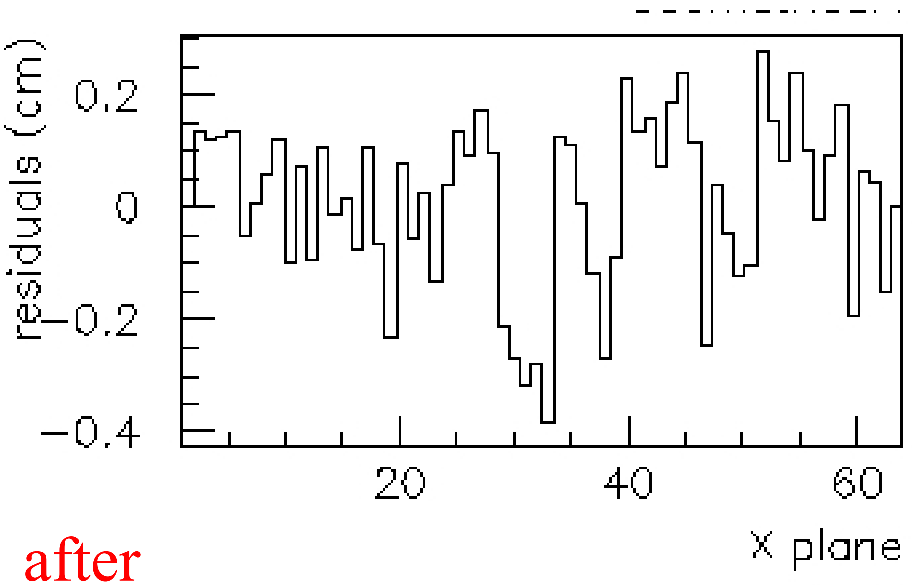
Plane number (1-64)

Detector calibration has started based on cosmic ray muons.

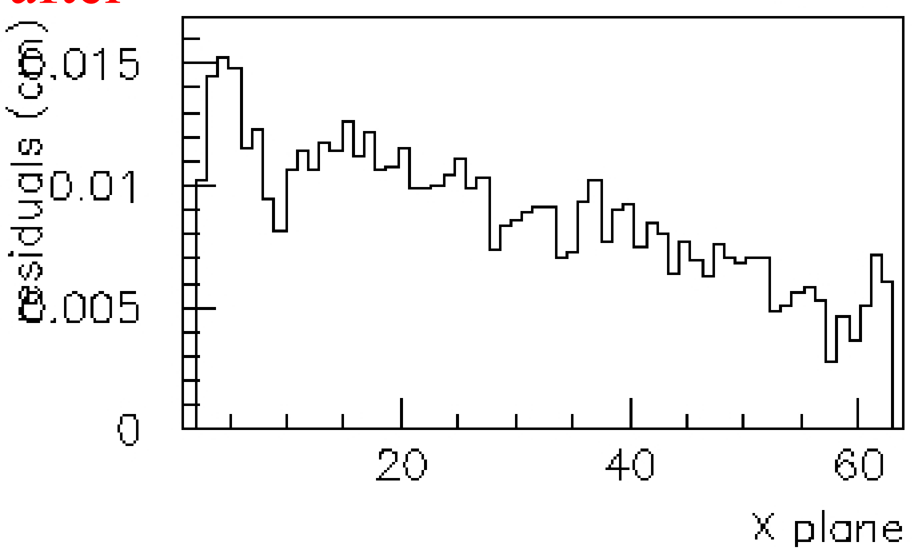
Good equalization from precalibration made prior to installation

SciBar detector

before



after



Plane number (1-64)

Detector alignment has started based on cosmic ray muons.

Plane alignment ~ 0.1 mm

Prospects & final remarks

A new detector has been installed at the near detector location of the K2K experiment at KEK.

Large detector mass (15 tons), expecting ~ 40000 neutrino/year.

Detector with capabilities for low energy proton reconstruction, π^0 and charged π detection capabilities.

First neutrino interactions the 7th of October 2003.

We are commisioning of detector... first results are very promissing.

Several event topologies have been shown.

Detailed physics analysis is just started !!!!.

Prospects & final remarks

Help in understanding neutrino interactions at low energies. Input to CC-QE studies and background characterization for K2K and SK.

Interesting physics studies beyond oscillation analysis.

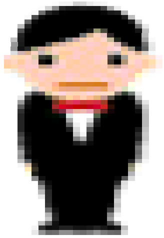
Good test bench for the JPARC fine grained detector technology.

Good input to understand background levels in K2K and future JPARC-nu experiments.

Thanks!

I want to thank Kajita-san and ICCR for offering me the opportunity to stay at KEK during the installation and commissioning period of the SciBar.

I'm looking forward for fruitful collaborations in K2K and JPARC-nu experiments in the future.



Bckup transparencies

Horn system

Magnetic Horn system

(for Long Baseline Neutrino Oscillation Experiment)