# Measurement of π-N interaction PIAνO-Harpsichord

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for
PIAνO-Harpsichord Duet collaboration

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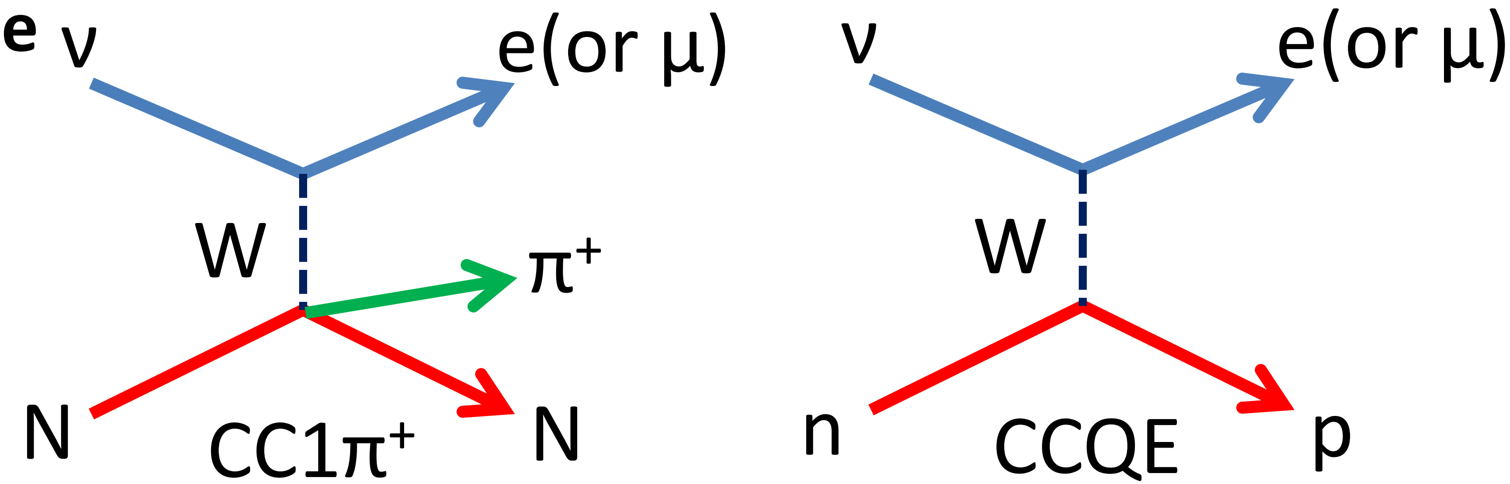
**PIAnO-Harpsichord** member:
Japan :Kyoto, ICRR, Tokyo
Canada: TRIUMF, UBC, Regina, Toronto, Alberta
In total about 20 people.

# Importance of Pion interaction

- For neutrino beam with E<1GeV (like T2K), pion production probability through delta resonance is relatively high.
- Understanding of interactions of those secondary pions with nuclei is key to reduce systematics.

**Example**




If pion is absorbed, CC1π looks like CCQE
We need to know how often this can happen

# What we measure

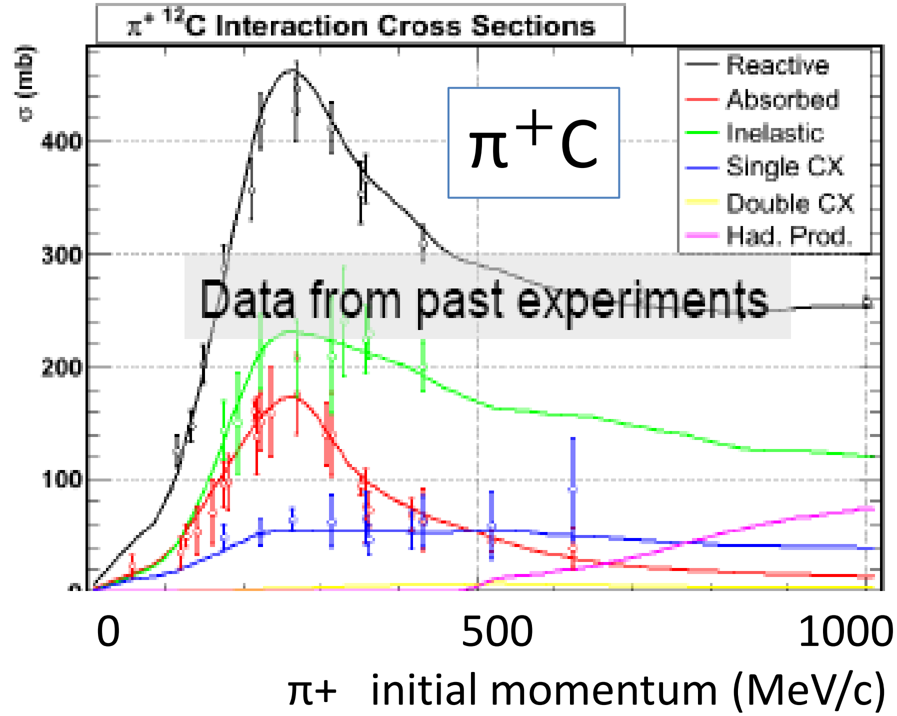
Data from past experiments have 20-30% uncertainty for absorption cross section.

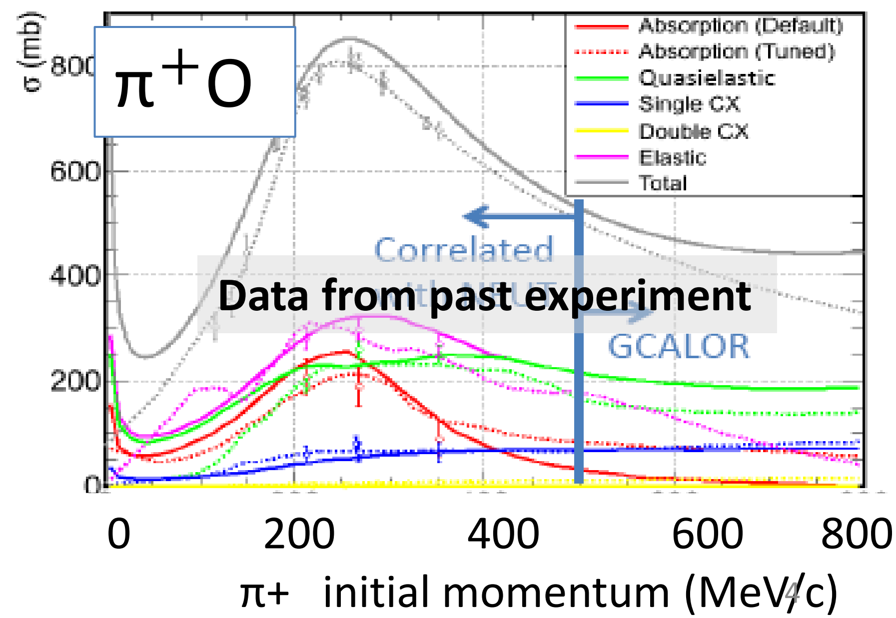
Our goal:

Measure Cross section

- **π absorption**
- **π charge exchange (CX)**

using scintillator tracker detectors with 10% sys. uncertainty.



# Impact to T2K

Our results:

>Will improve ν.int. calculation uncertainty

(Final state interaction).

- Now, the contribution to T2K $\nu_e$ event expectation error is 10% .

  We plan to improve this to 5%.

>Will improve understanding of π propagation in detector material.

→ Improve both Near and Far detector sys for T2K experiment.

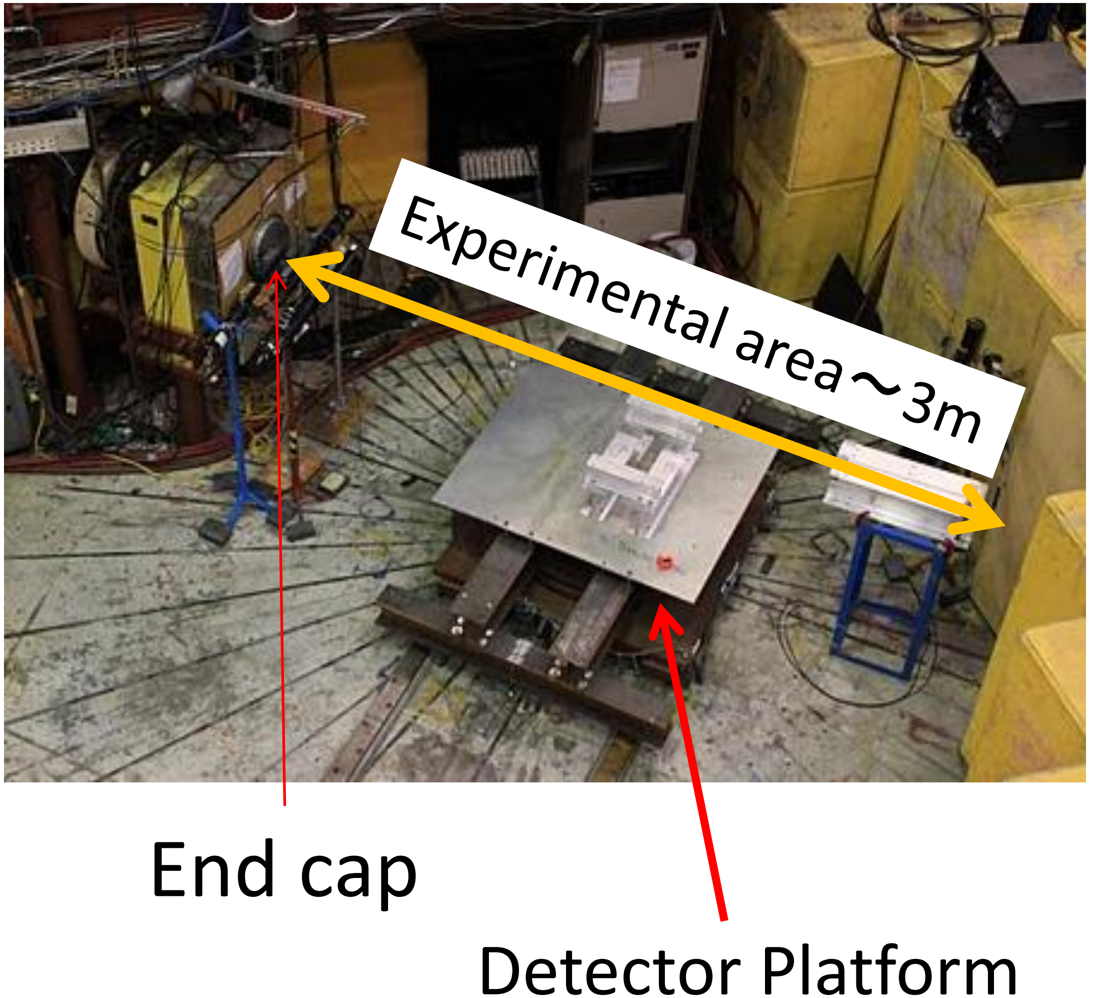
T2K Sys . for number of expected $\nu_e$ events at SK

| Error Source | For $\sin^2 2\theta_{13}=0$ |
|---|---|
| Beam flux | ±8.5% |
| Final State Int. | ±10.1% |
| ν int. X sec. (except FSI) | ±9.7% |
| Near Det | +5.6% -5.2% |
| Far det. | ±14.7% |
| Near Det. stat. | ±2.7% |
| Total | +22.8% -22.7% |

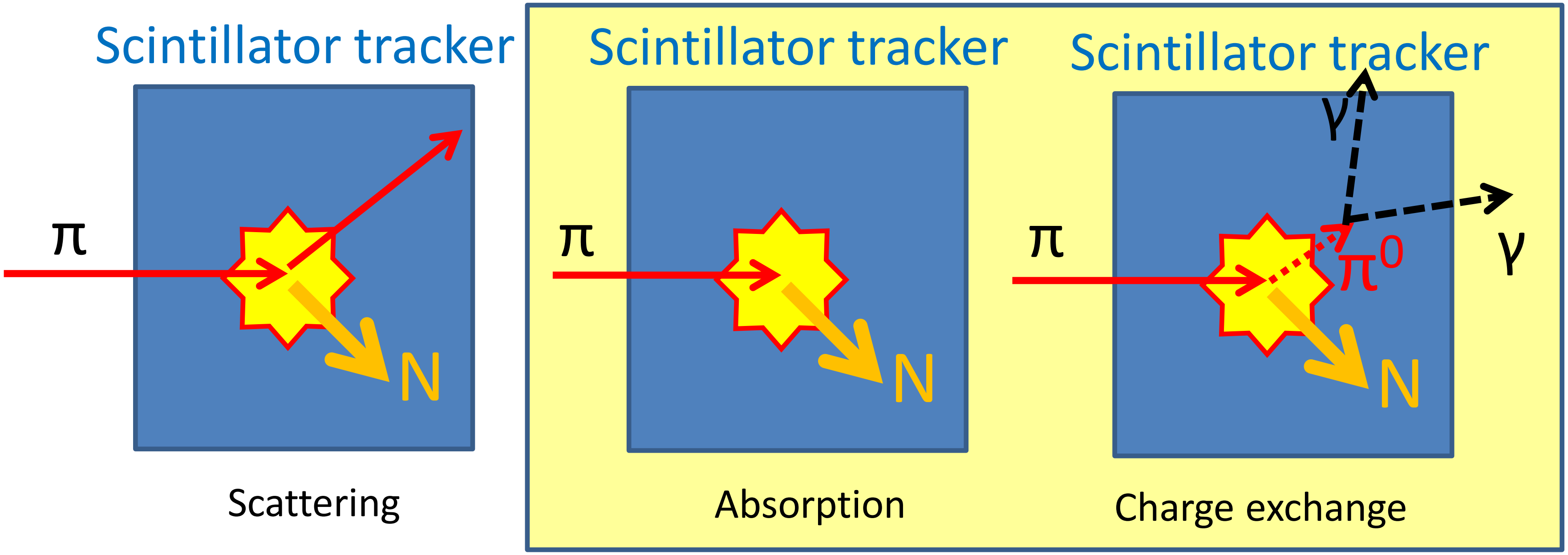
# Overview of experiment

- TRIUMF@Vancouver：
  M11 beam-line
- Secondary π beam
  - includes e, μ and p
- π Momentum：
  - 150MeV/c~375MeV/c
    （in step of 25MeV/c）
- Trigger rate
  - 30Hz
- Data taking in last year
  - 2010/10 ~2010/12
- Target material
  - Scintillator
    (-CH2CH(C6H5)-)

M11 Experimental area before the experiment

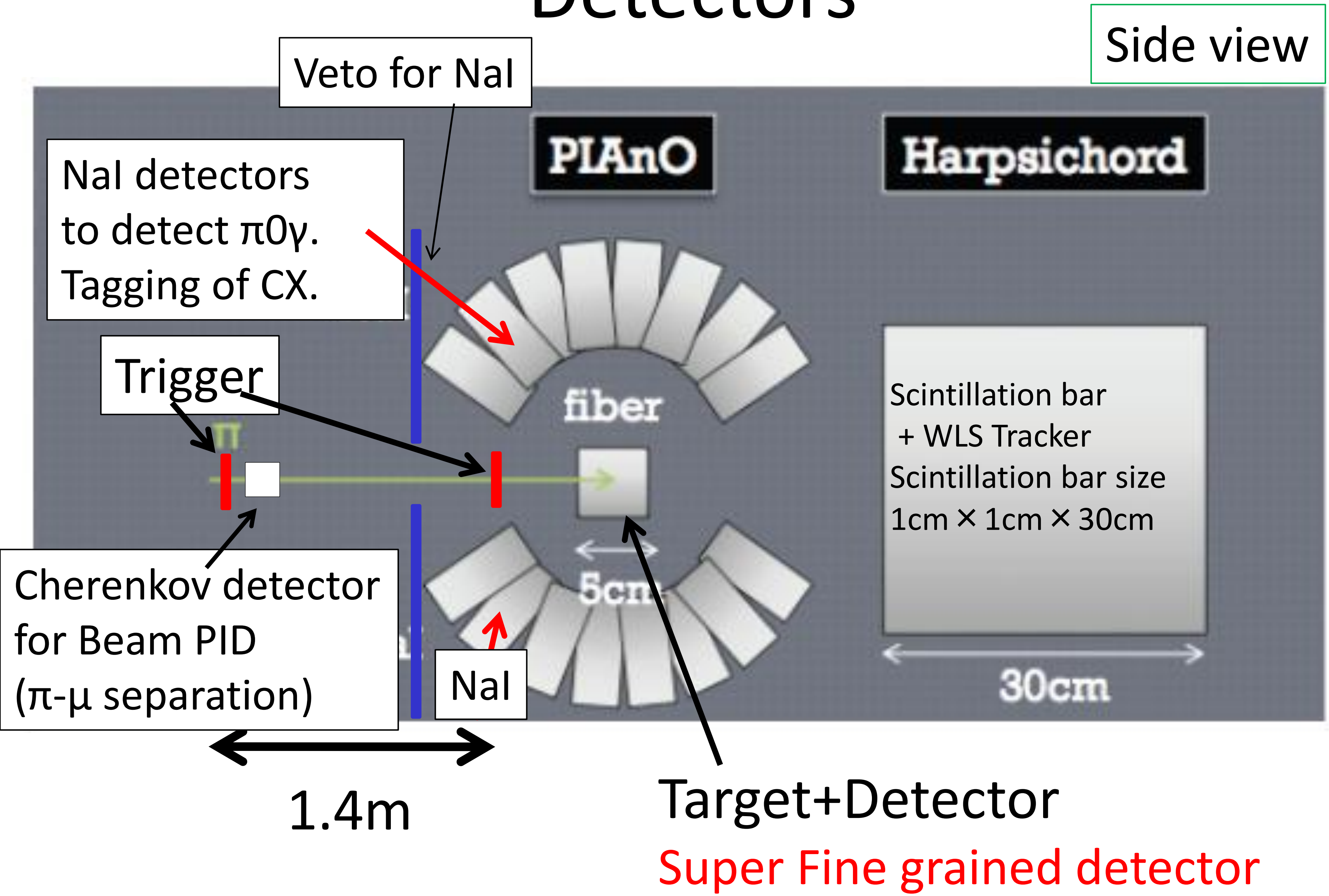


# Interaction of Pions



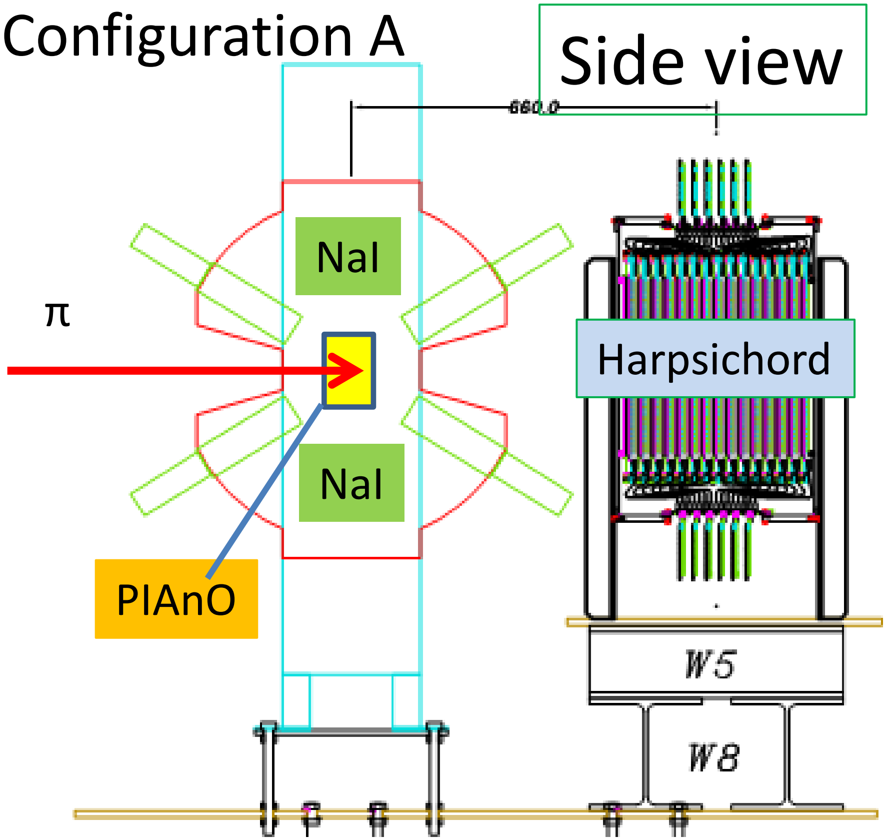

1. Detect secondary particles to separate absorption/cx from scatt.
   → Full active "super" fine grained scintillator tracker
2. With only scintillator tracker, absorption and charge exchange can not be separated.
   → We put gamma detectors around the tracker

# Detectors

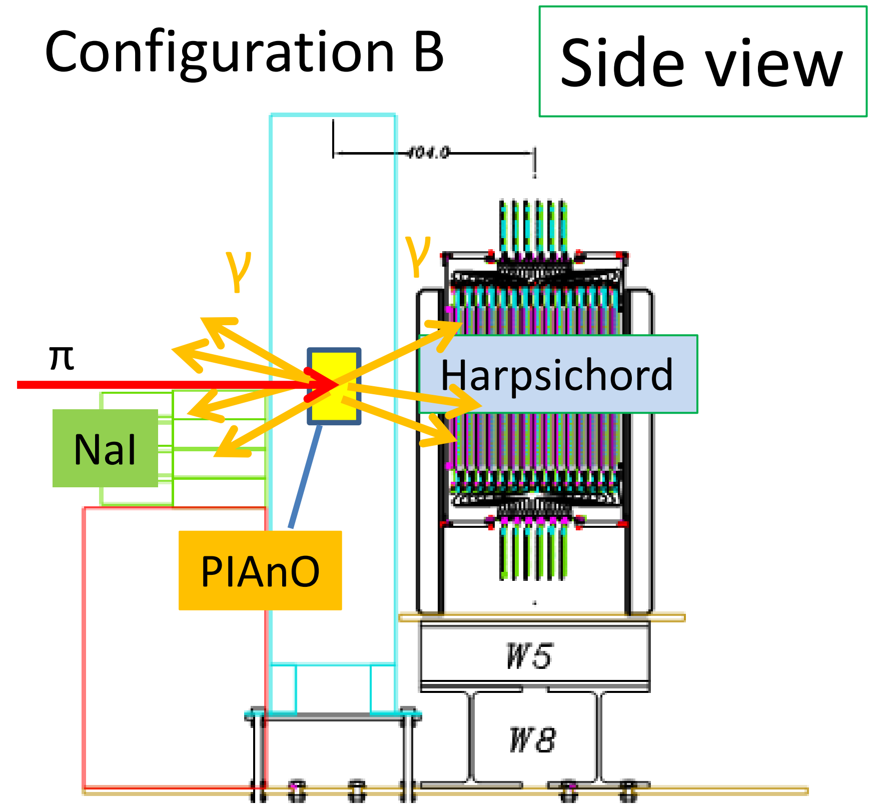

Side view
Veto for NaI
NaI detectors
to detect π0γ.
Tagging of CX.
PIAnO
Harpsichord
Trigger
π
fiber
Scintillation bar
+ WLS Tracker
Scintillation bar size
1cm × 1cm × 30cm
5cm
30cm
Cherenkov detector
for Beam PID
(π-μ separation)
NaI
1.4m
Target+Detector
Super Fine grained detector

# Data taking with 2 configurations

Configuration A




Configuration B




First, measure angular distribution of $\pi^0$ decay γs

γs are mostly emitted to forward and backward direction in calculation.

Then, check the distribution with different configuration. We can get more statistics, with larger solid angle

# PIAnO detector

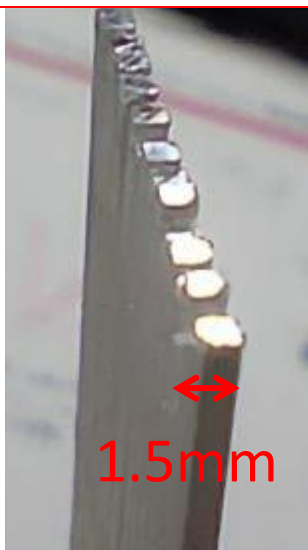
Consist of 1024 Scintillation fibers

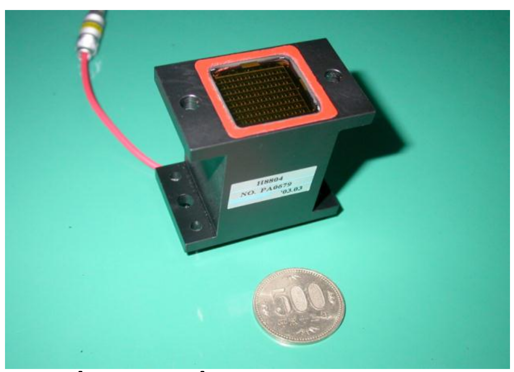
- 1.5 mm square fiber.
- 32 fibers for one layer.
- 32 layers in total.

→5cm × 5cm × 5cm Detector volume

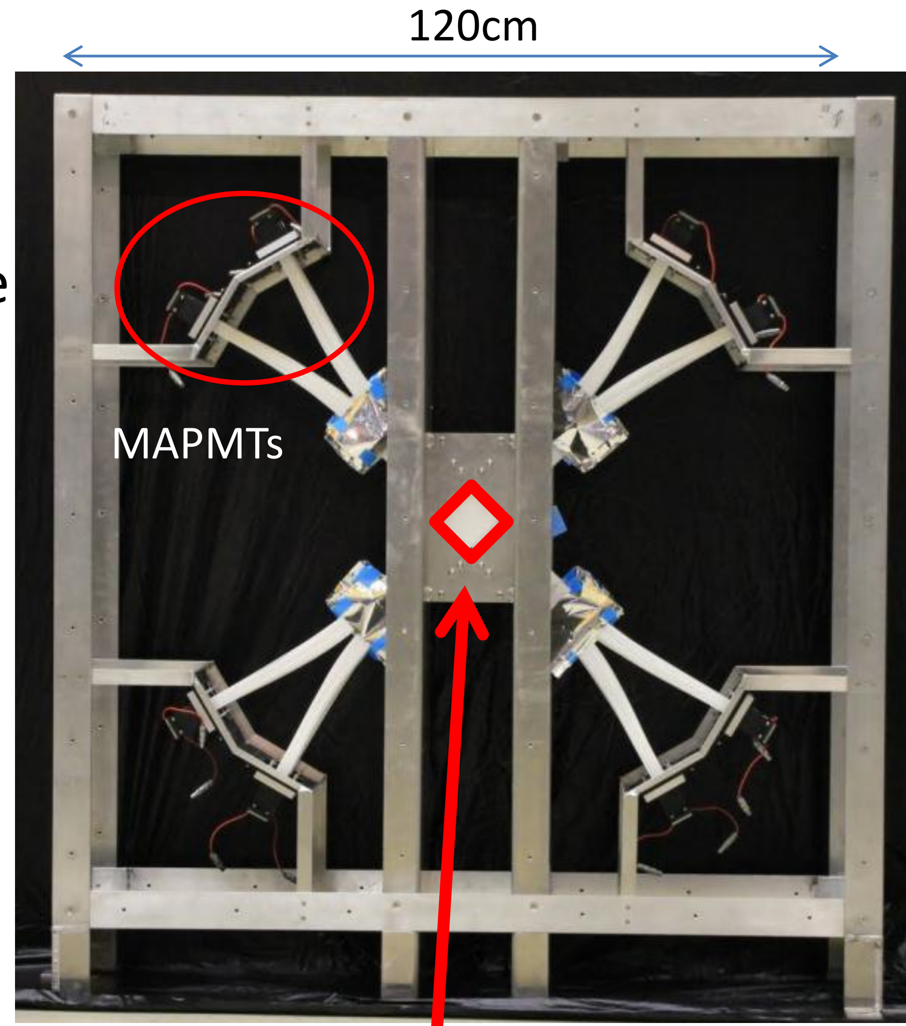
MAPMT and Read out elec.
are from SciBooNE/SciBar.

Scintillation fibers are coated by reflector and aluminized.



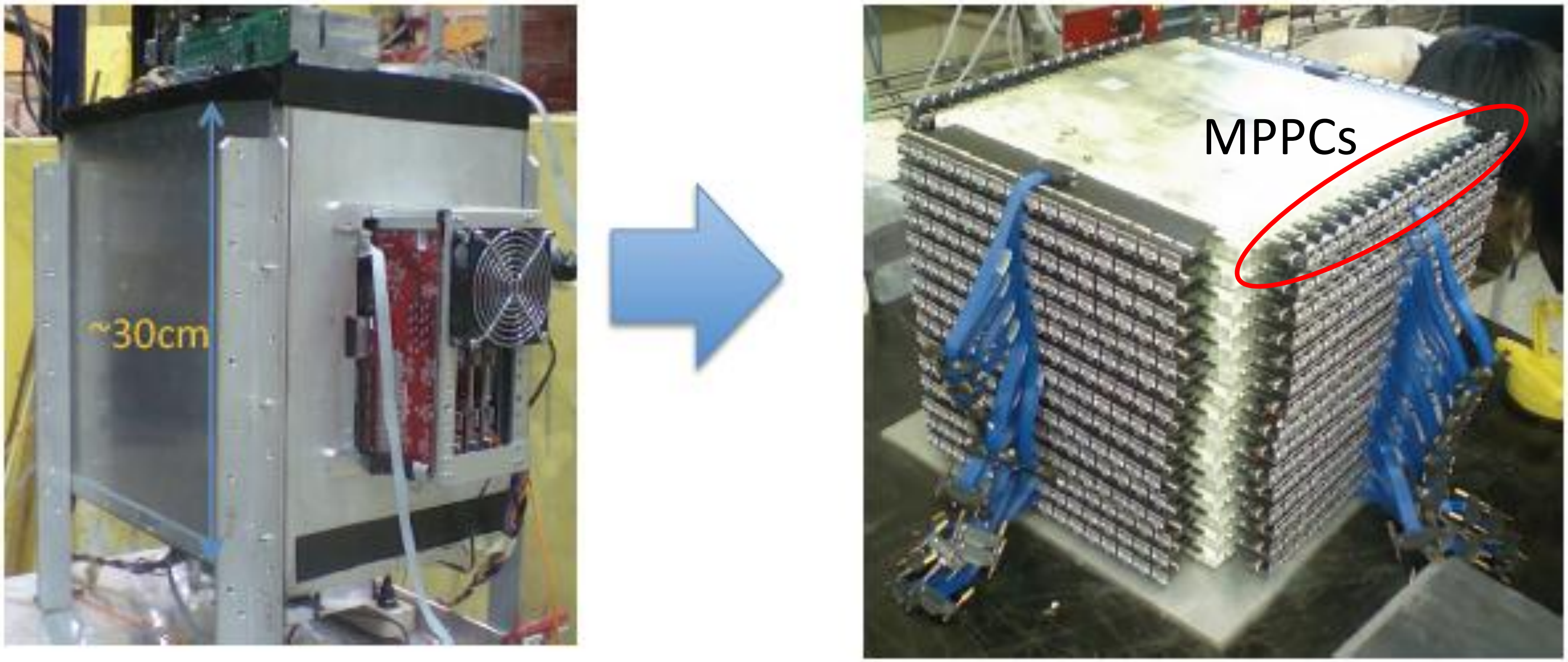



64channel
Multi Anode PMT (MAPMT)
15 MAPMTs in total




Detector volume
5cm × 5cm × 5cm

# HARPSICHORD

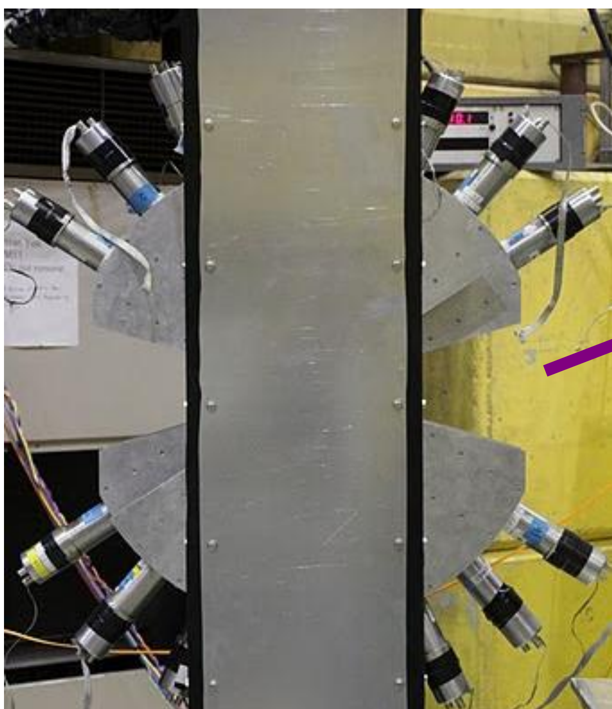


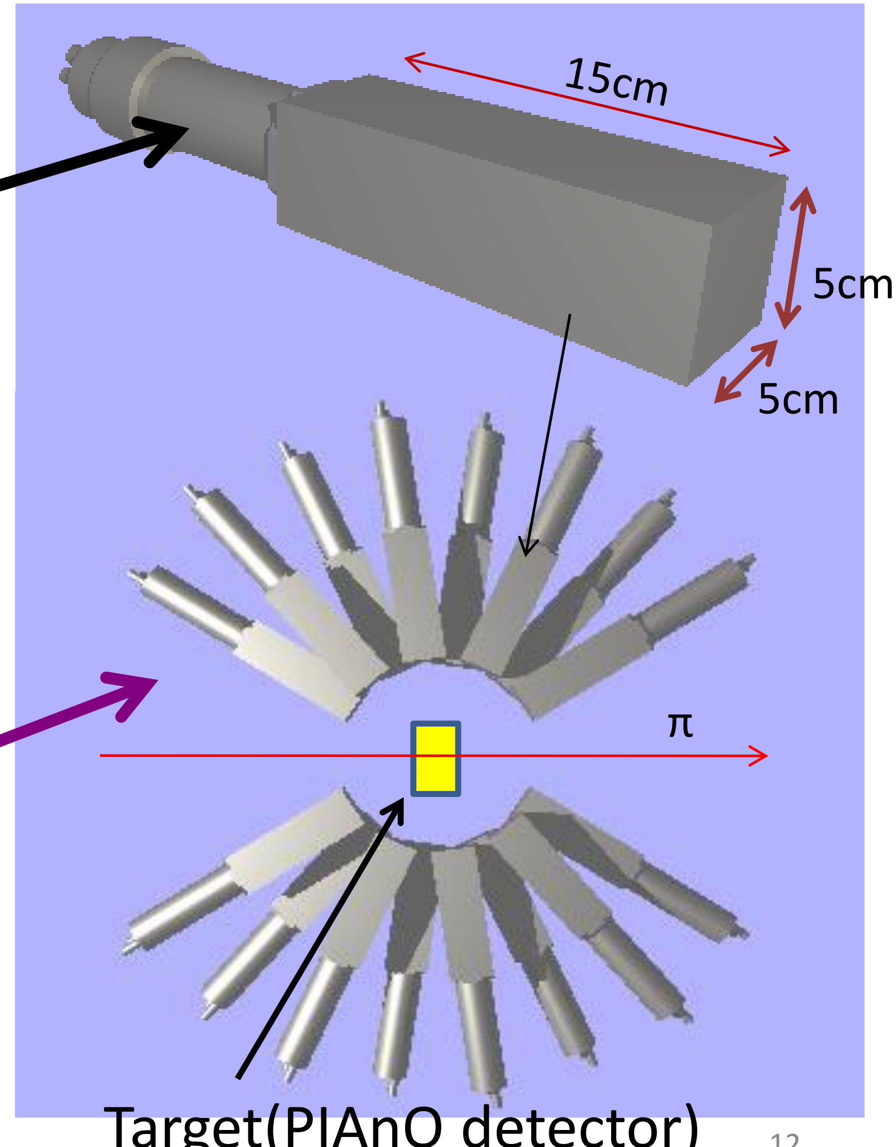

Consists of 1cm square scintillator with WLS fiber
coupled to Multi Pixel Photon Counter (MPPC).
15layers of 32(x) × 32(y) channels.
Removable lead plates (1.5mm) are installed between each layers
during configuration B to get more sensitivity to π0 gamma.

# NaI Detectors

- Size of crystal

  5cm × 5cm × 15cm
- PMT : HAMAMATSU R580
- For tagging of $\pi^0$ from charge exchange





# Beam particle identification

We use 2 detectors to identify beam particle.

Pion momentum

150 MeV/c : Pion fraction: ~50%

**TOF (~12m)**

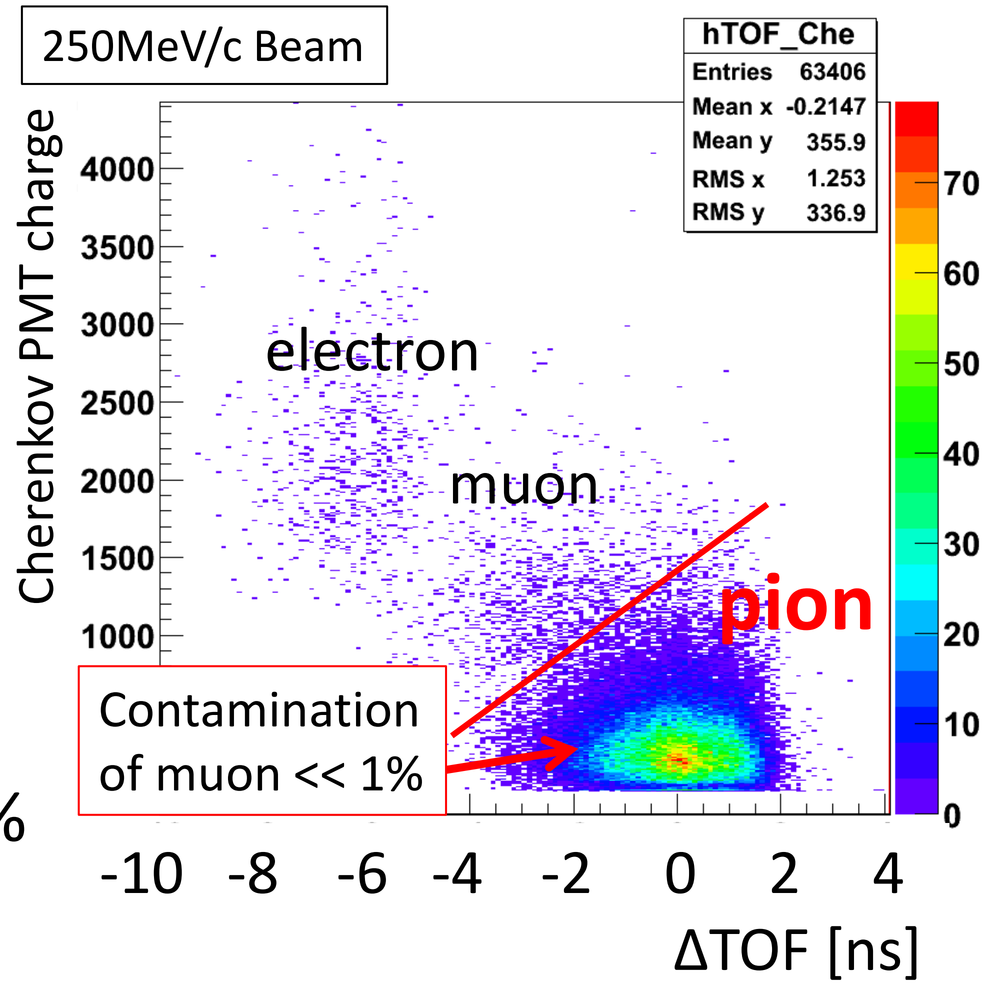
works < ~200 MeV/c

**Cherenkov + TOF**

200-300MeV/c

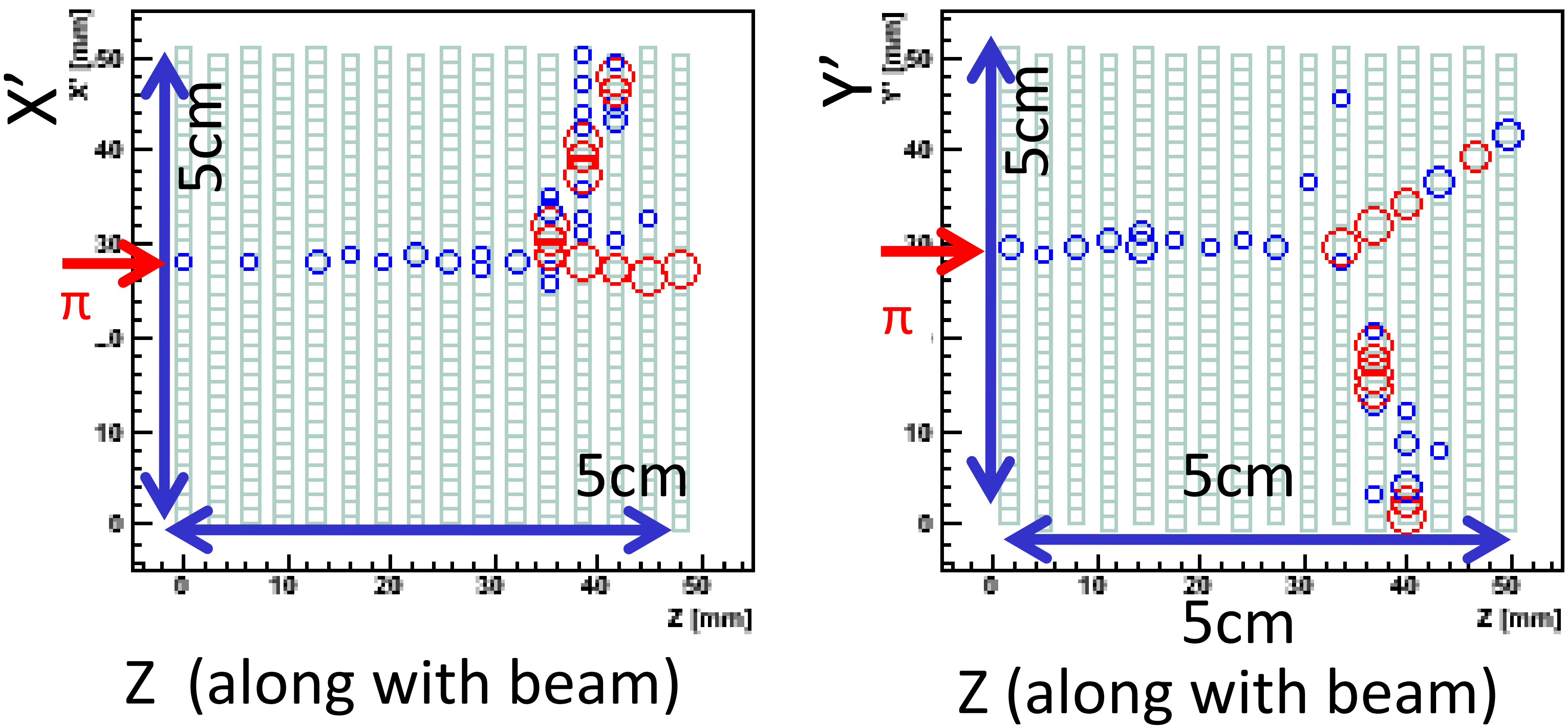
Pion momentum

300 MeV/c : Pion fraction: > ~95%



# Analysis Using PIAnO

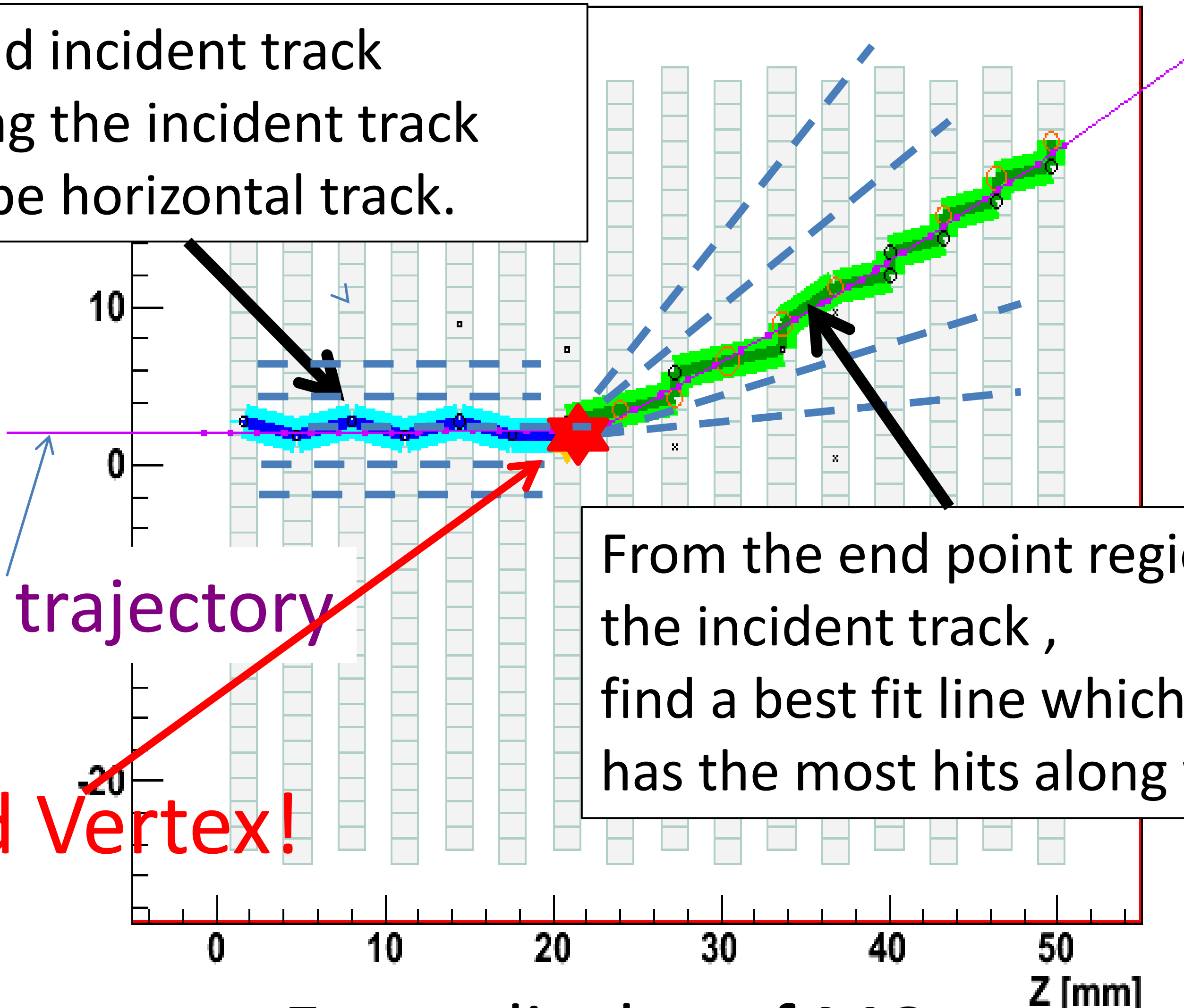
# Example of Event display (Absorption or CX like?)




Blue : Hit less than 25P.E. （π）

Red : Hit >= 25P.E. （Proton like）

# Reconstruction of Tracks




First, find incident track assuming the incident track should be horizontal track.

From the end point region of the incident track , find a best fit line which has the most hits along with it

True trajectory

Find Vertex!

Event display of MC

# Event selection

After find a vertex for a event.

Flow of selection for absorption/cx like events

Good incident track

↓

Fiducial volume

Data Result will be shown

↓

No final state pion

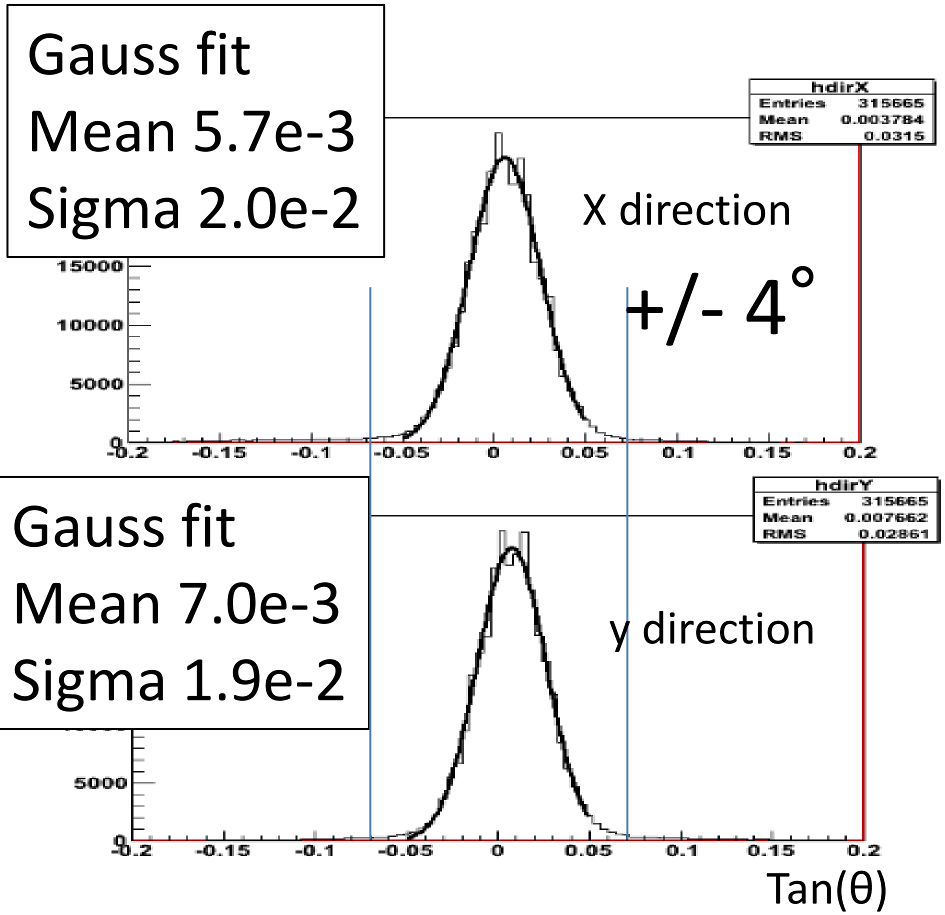
Absorption+CX

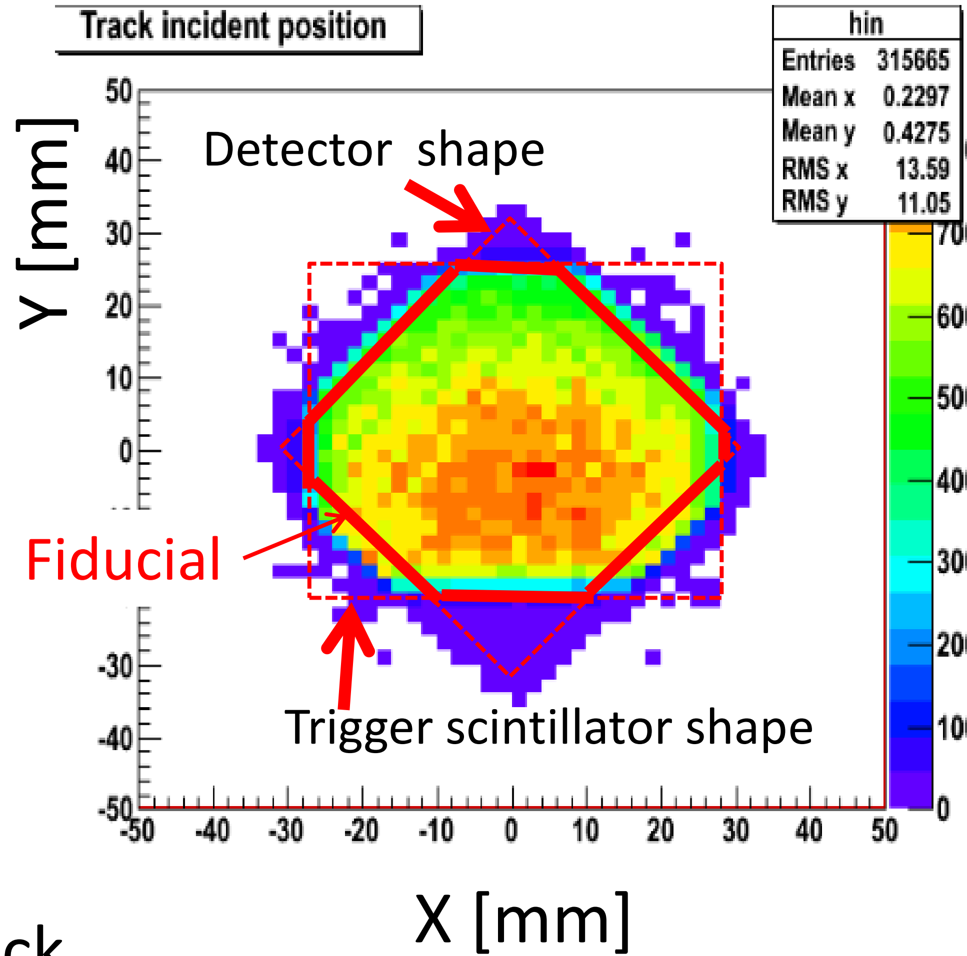
↓

Large NaI hit
or shower in Harpsichord

Charge exchange

# Good incident track (250MeV/c run)



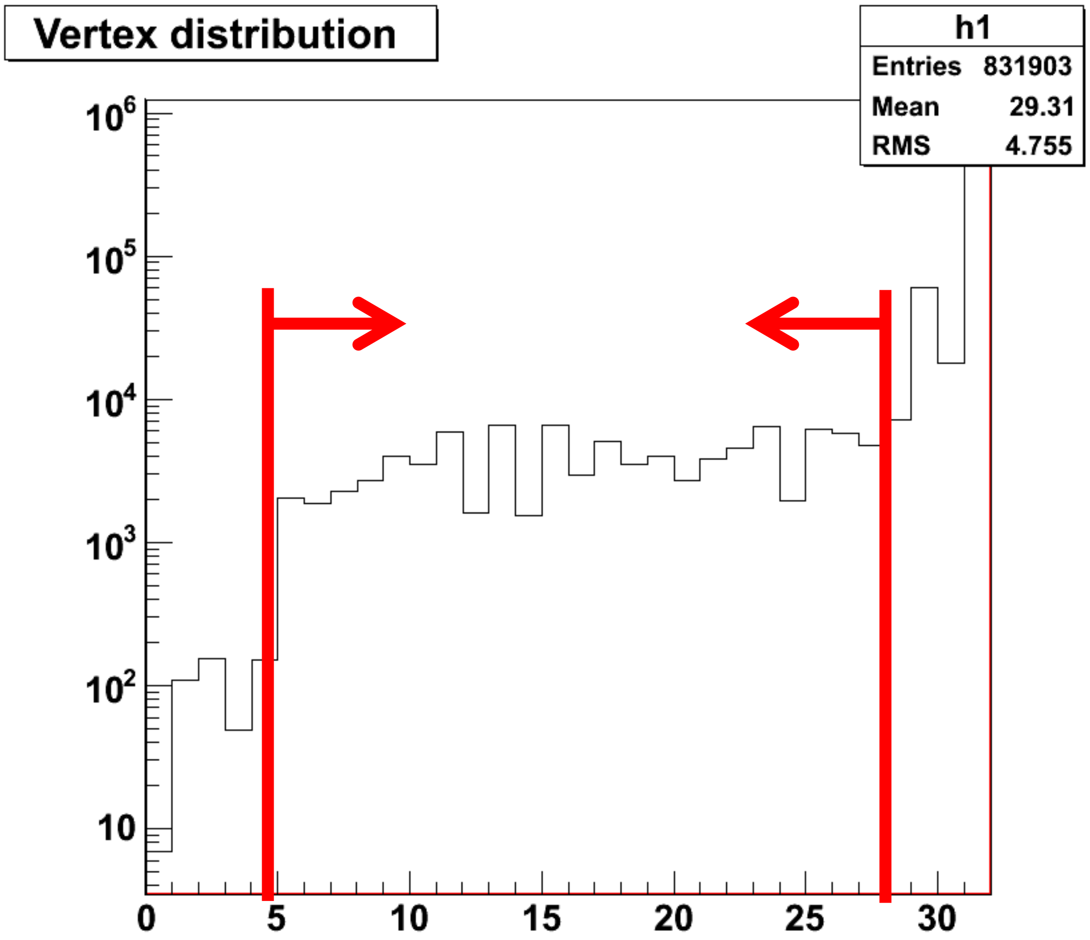




- To select good incident track, direction, incident position, and beam PID are used

# Fiducial Volume cut

Fiducial  volume cut:
X,Y positions within
Fiducial volume

Z position
 3layer from outside
4 < Z layer < 29




Vertex Z position [layer]

# Interaction rate

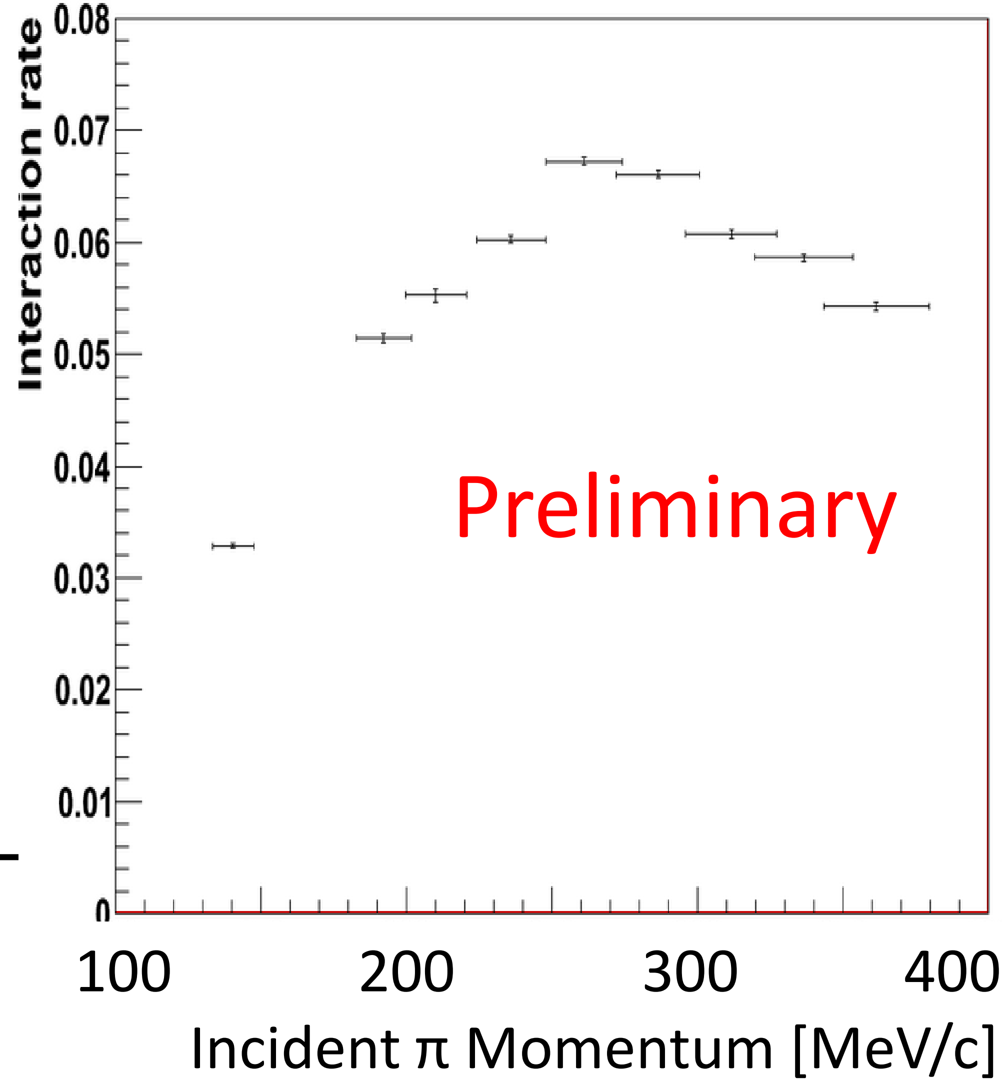
After

- Good incident track
- Fiducial volume cut

Total interaction rate is obtained.

Interaction rate is:

$$\frac{\text{\# of event in fiducial volume}}{\text{\# of event with Good incident track}}$$



# Time-line and schedule

| Year mon |
| --- |
| 2010 Apr |
| Jul |
| Oct |
| 2011 Jan |
| Apr |
| Jul |
| Oct |
| 2012 Jan |
| Apr |
| Jul |

Start Project

Detector R&D

Detector construction
20, August 2010

Run 1 Data taking @ TRIUMF

Analysis of Run1 data { Absorption Cross section.
Charge Exchange

Run 2 Data taking @ TRIUMF
: Remaining calibration.
water data taking

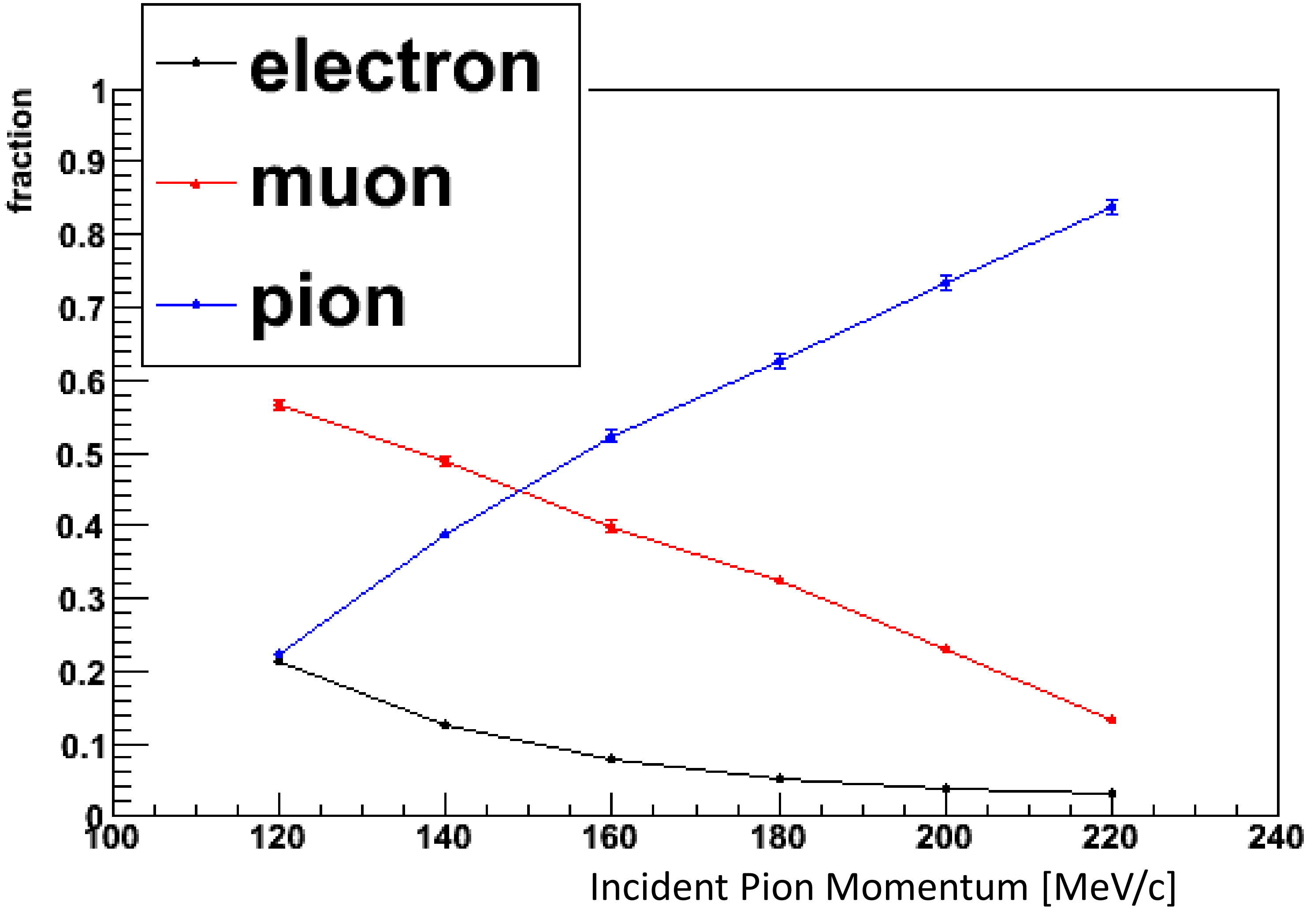
Analysis of Run2 data. Finalize results

**Feed our results to T2K analysis.**
**Update T2K systematic uncertainty**

# Summary

- Interaction of pion is important to reduce systematic uncertainty for T2K.
- Pion interaction measurement project started.
  - First target: Absorption and charge exchange cross section
- We developed 2 scintillator trackers
  - PIAnO and Harpsichord
- First data taking is done in 2010.
  - Run1 data analysis is on going
- This result will be summarized soon and used to update T2K analysis in 2012.

# Beam particles fraction



# Data taking

1momentum ~1 day
In total, we took ~1month
of data including calibration.

During data taking

**Beam profile**

**Trigger rate**

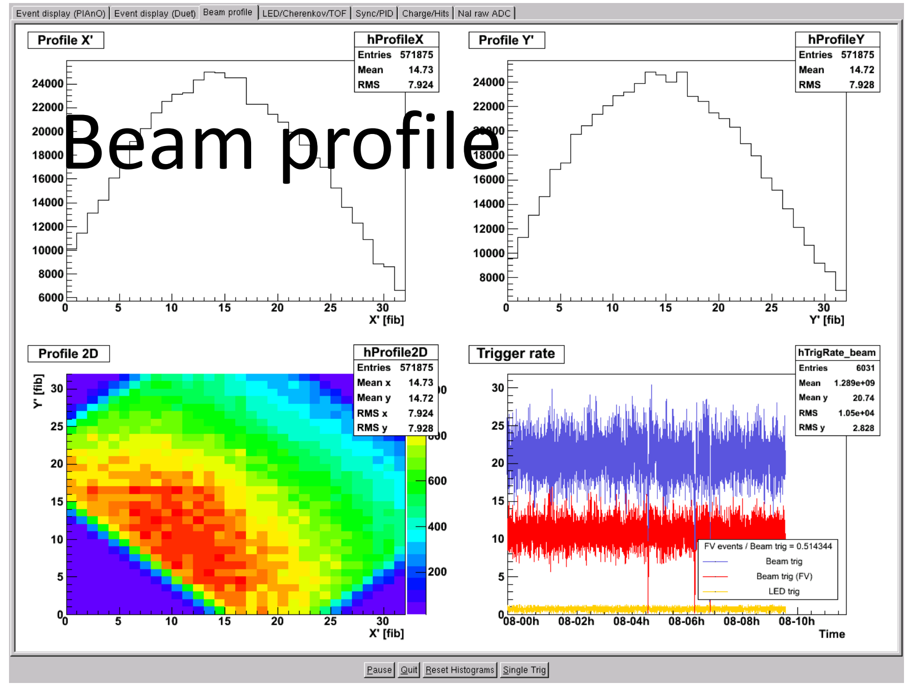
**HV values**

**Temperature**

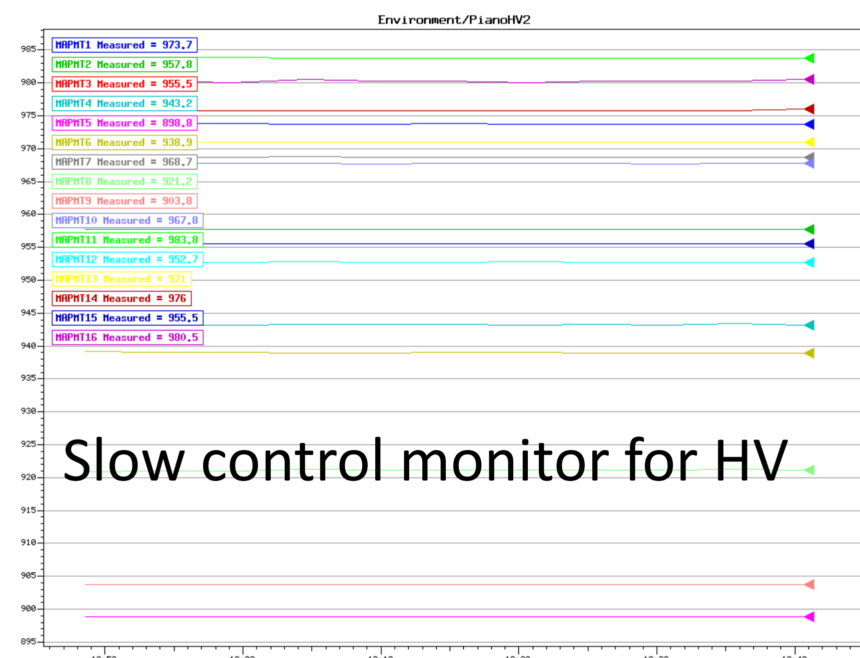
**Humidity**

**Actual Magnet strength**

Are monitored

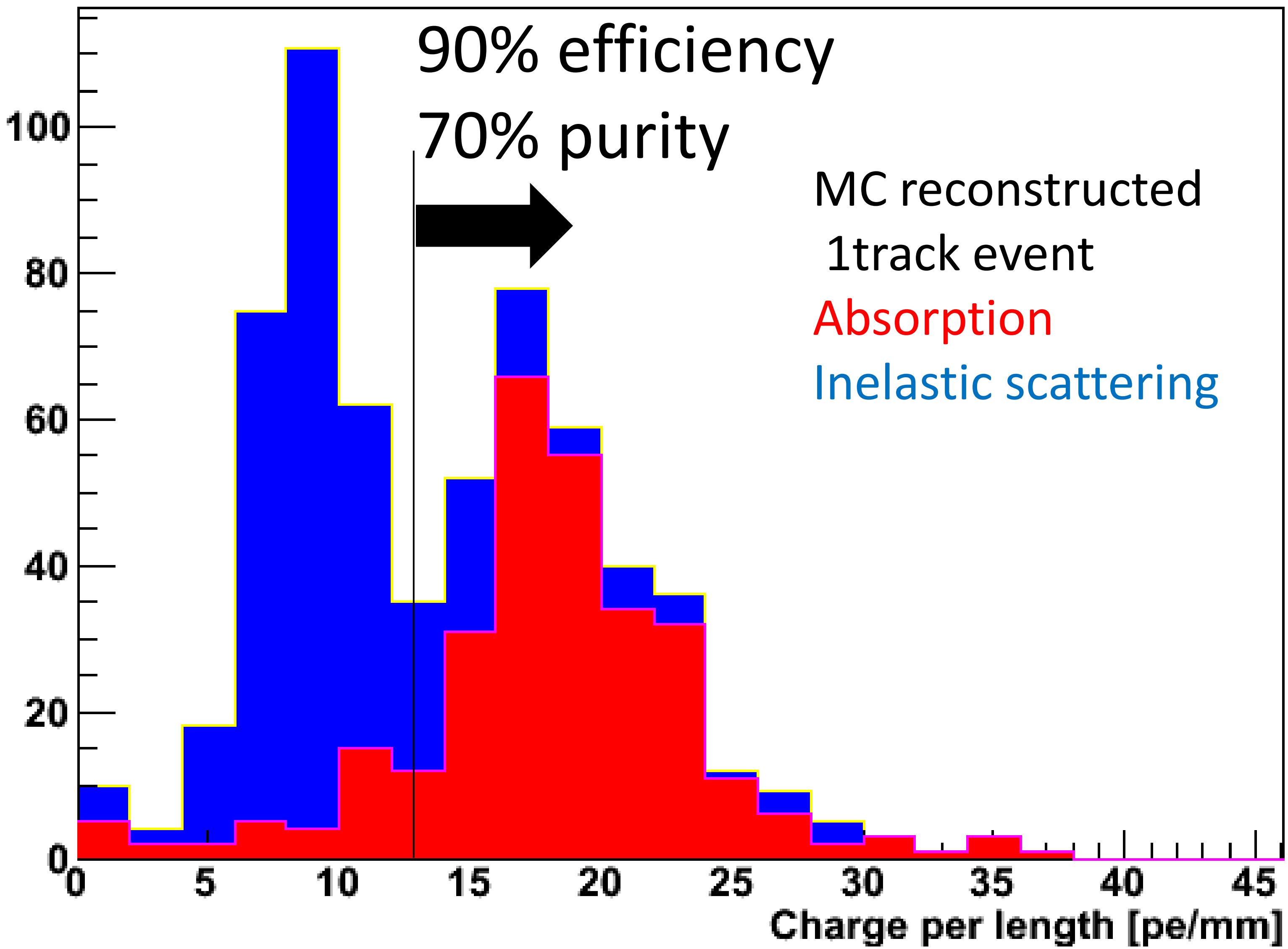



Beam profile

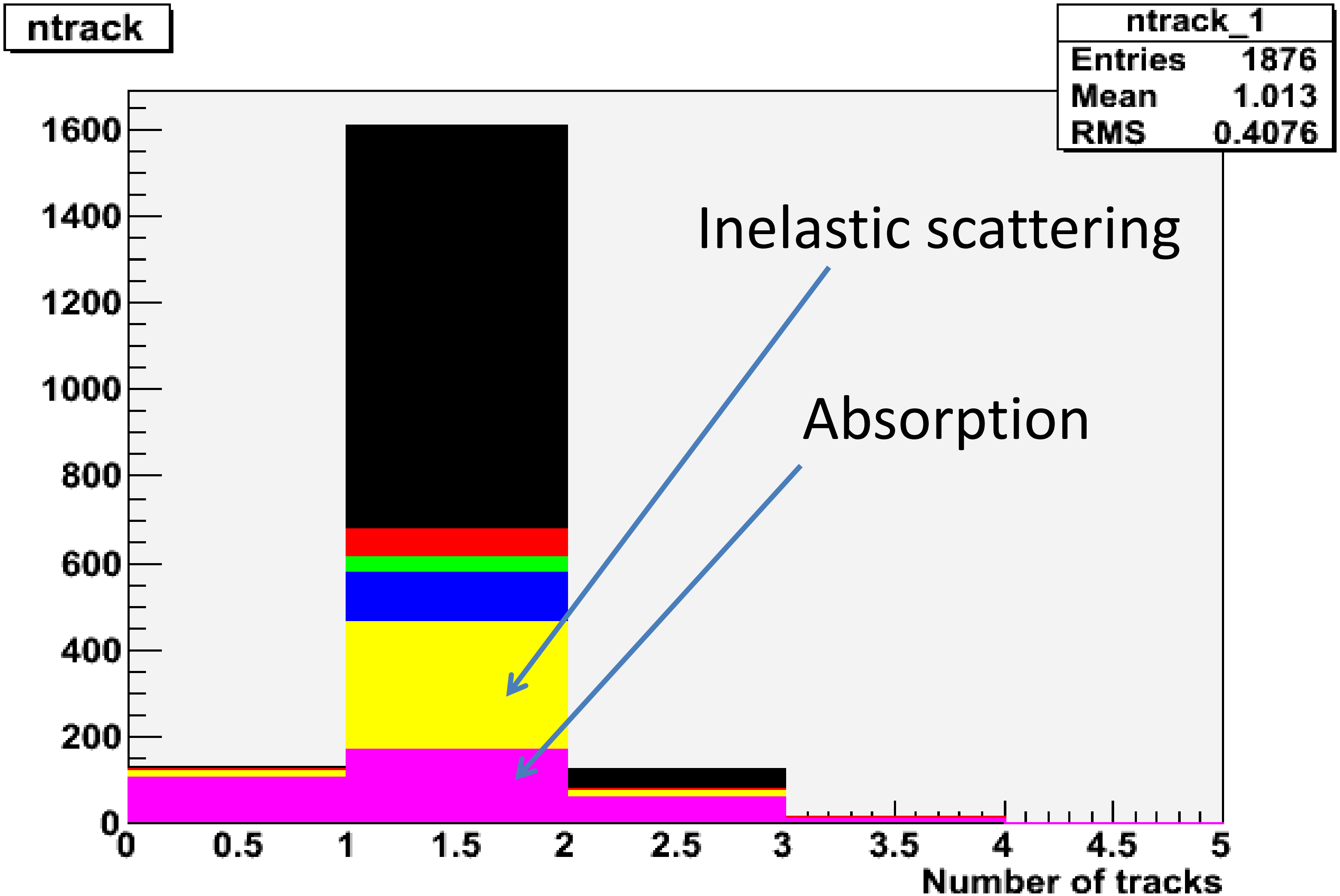



Slow control monitor for HV

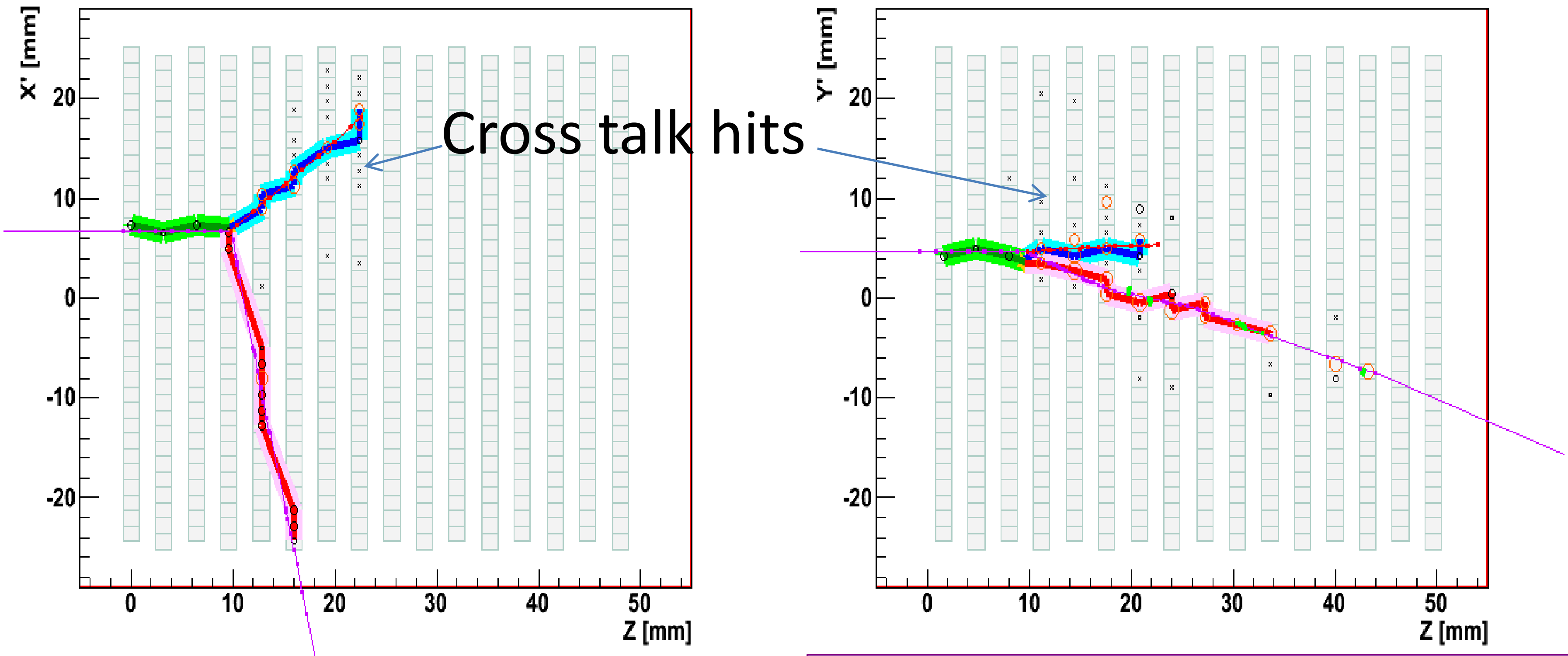
# Scattering absorption separation



# MC Number of track distribution 250MeV/c π+



# 3D matching of Tracks




True trajectory

Recon track (2D)

Recon track (3D matched)

(Same color : Same 3D track)

<u>Tracks not escaped from side:</u>
Z of both start and end points should match in X and Y view

<u>Tracks escaped from side:</u>
Only Z of start point should match

# Principle of Cherenkov detector