

THE FINE GRAINED DETECTORS FOR THE T2K EXPERIMENT

CAP Congress

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On behalf of the T2K FGD group

UBC, Kyoto University, University of Regina, TRIUMF,
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T2K Experiment

See talks by
Mark Hartz
And
Kendall Mahn

- 2nd generation long baseline neutrino oscillation experiment
- Precision measurement of ν_μ disappearance $\rightarrow \theta_{23}$ and Δm_{23}^2
- Search for ν_μ to ν_e appearance \rightarrow first measurement of θ_{13}

Super-Kamiokande

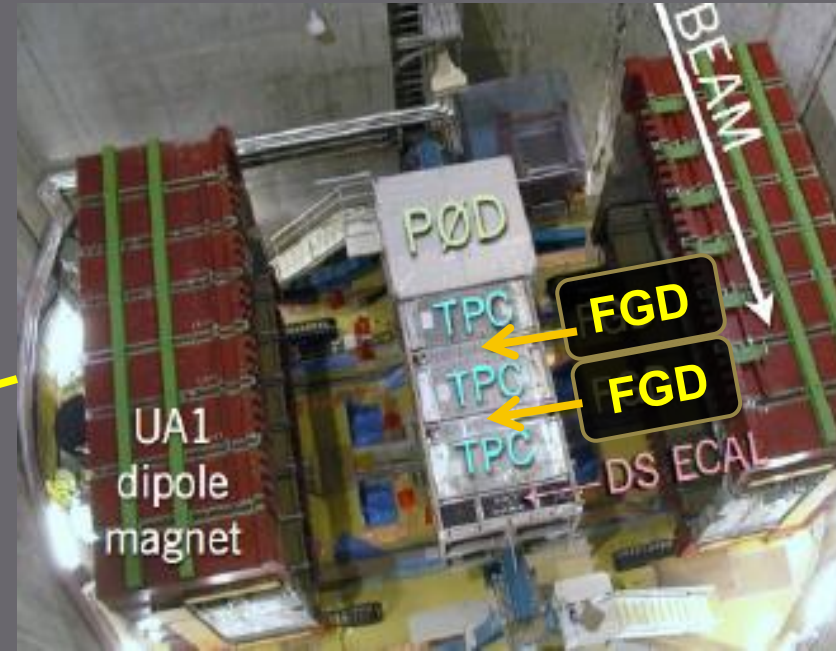
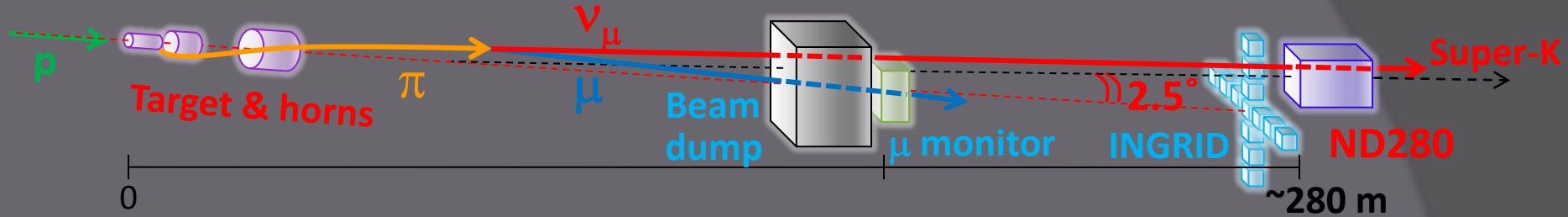
- 50kt Water Cerenkov Detector
- Post-Oscillation Measurement

Japan Proton Accelerator Research Complex (JPARC)

- 30 GeV Proton Synchrotron
- Near Detector \rightarrow Pre-Oscillation Measurement



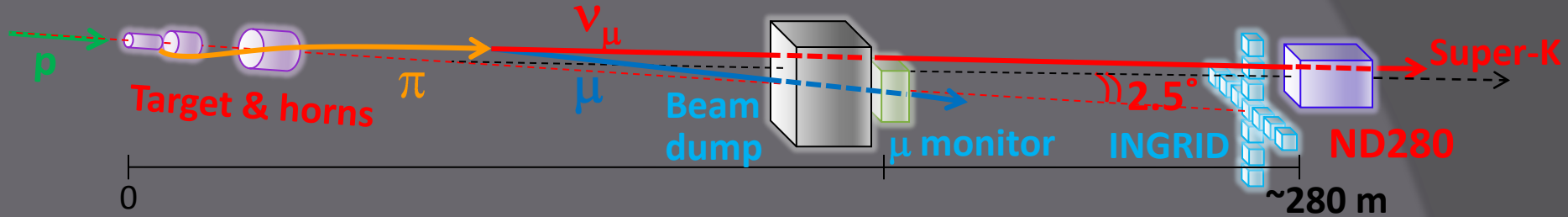
ND280



- Near Detector 280m from target
- Off Axis 2.5 degrees
- Measure Neutrino Beam before oscillation
 - Energy Spectrum of neutrino beam
 - Gives backgrounds for :
 - ν_e appearance
 - ν_{μ} disappearance

See Andre
 Gaudin's talk
 on TPCs

ND280

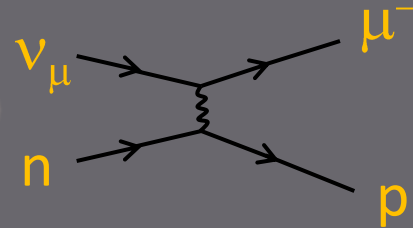


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Fine Grained Detectors (FGDs)

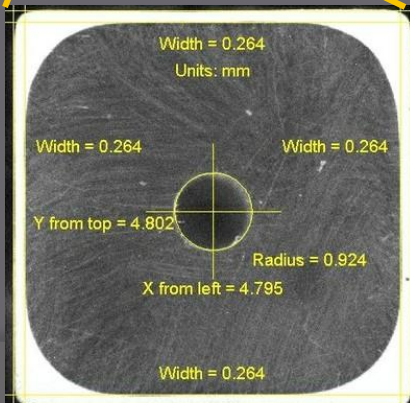
- Active target mass of ND280
- Finely grained for vertex resolution
- Reconstruct and identify short tracks



Key channel for oscillation analysis:
Charged Current
Quasi Elastic (CCQE)



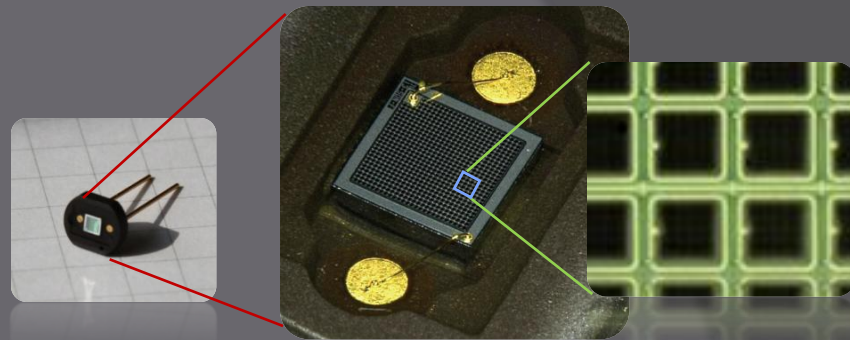
- Scintillator Bars: 9.6mm x 9.6mm x 1843mm
- FGD1: 15 modules (30 layers)
- FGD2: 7 modules (14 layers) + 6 water panels
- 8448 channels in total
- Each is ~1.1 ton



- Light from scintillator bars collected by Wavelength Shifting (WLS) fibers
- Propagates down fibers to Multi Pixel Photon Counters (MPPCs)



FGD Calibration



➤ **MPPC+Fiber Calibration:**

- Determine single photon-electron (p.e.) from dark noise
- Various effects accounted for:
 - MPPC saturation
 - Bar to Bar: Fiber-MPPC coupling and scintillator non-uniformity
 - Light Attenuation
 - Second Order Effects:
 - Crosstalk, photon detection efficiency, afterpulsing
- Can predict single p.e. pulseheight as temperature and operating voltage vary
 - Based on parameters from voltage scans

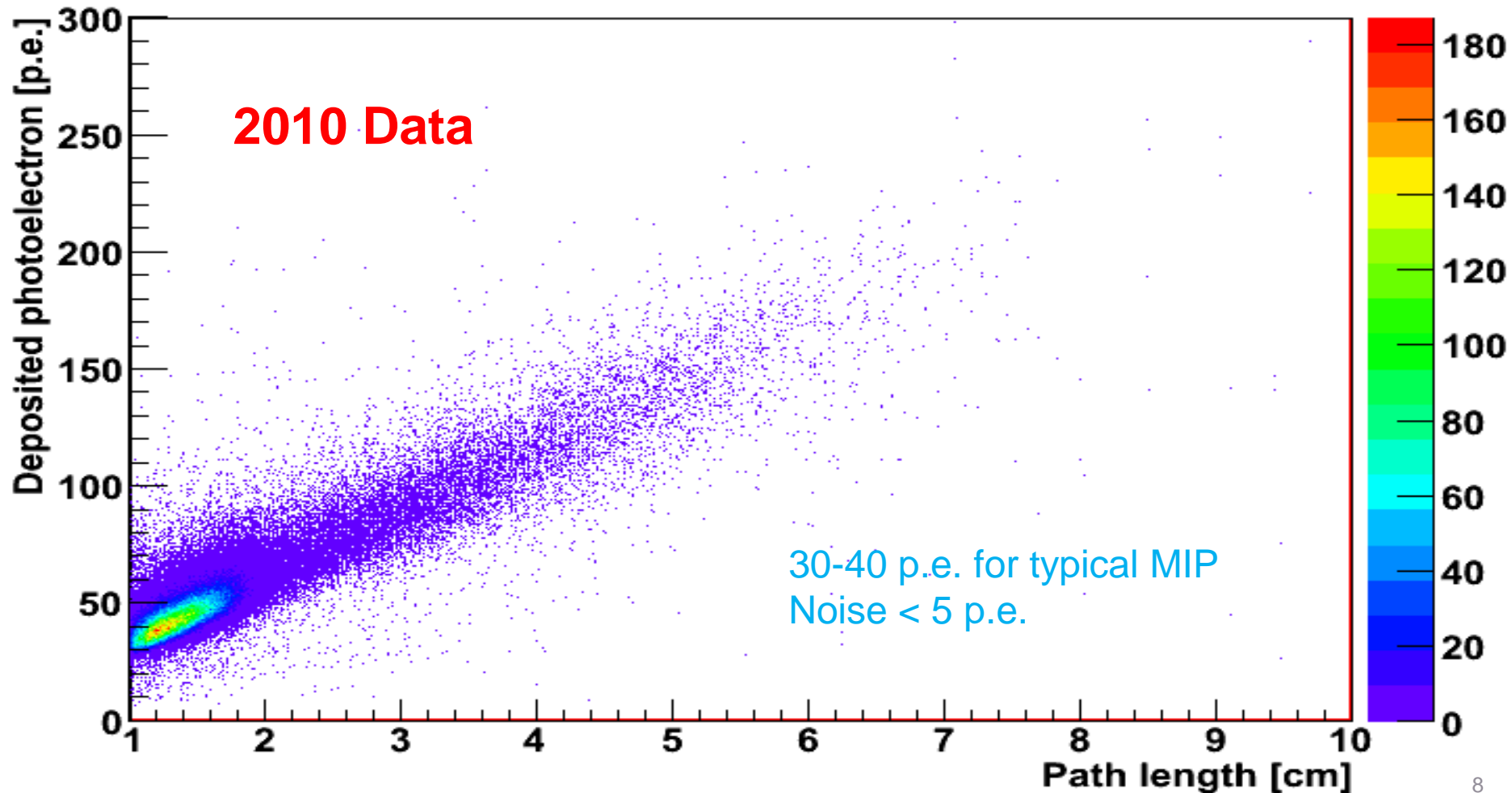
➤ **Particle Identification:**

- Clear separation of protons from pions/muons using energy deposition per unit length of track

Cosmics

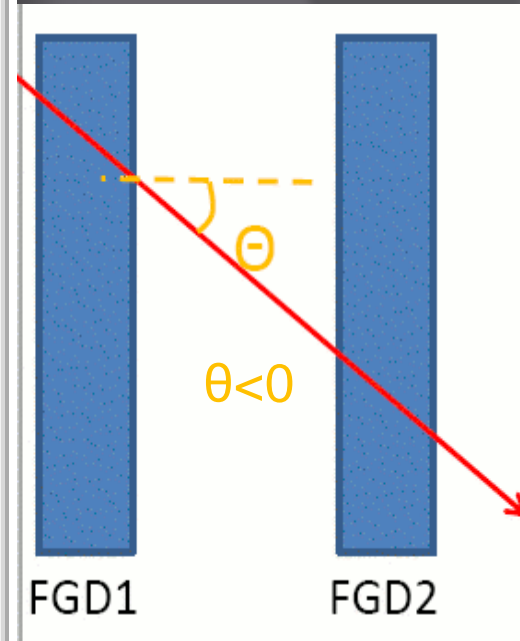
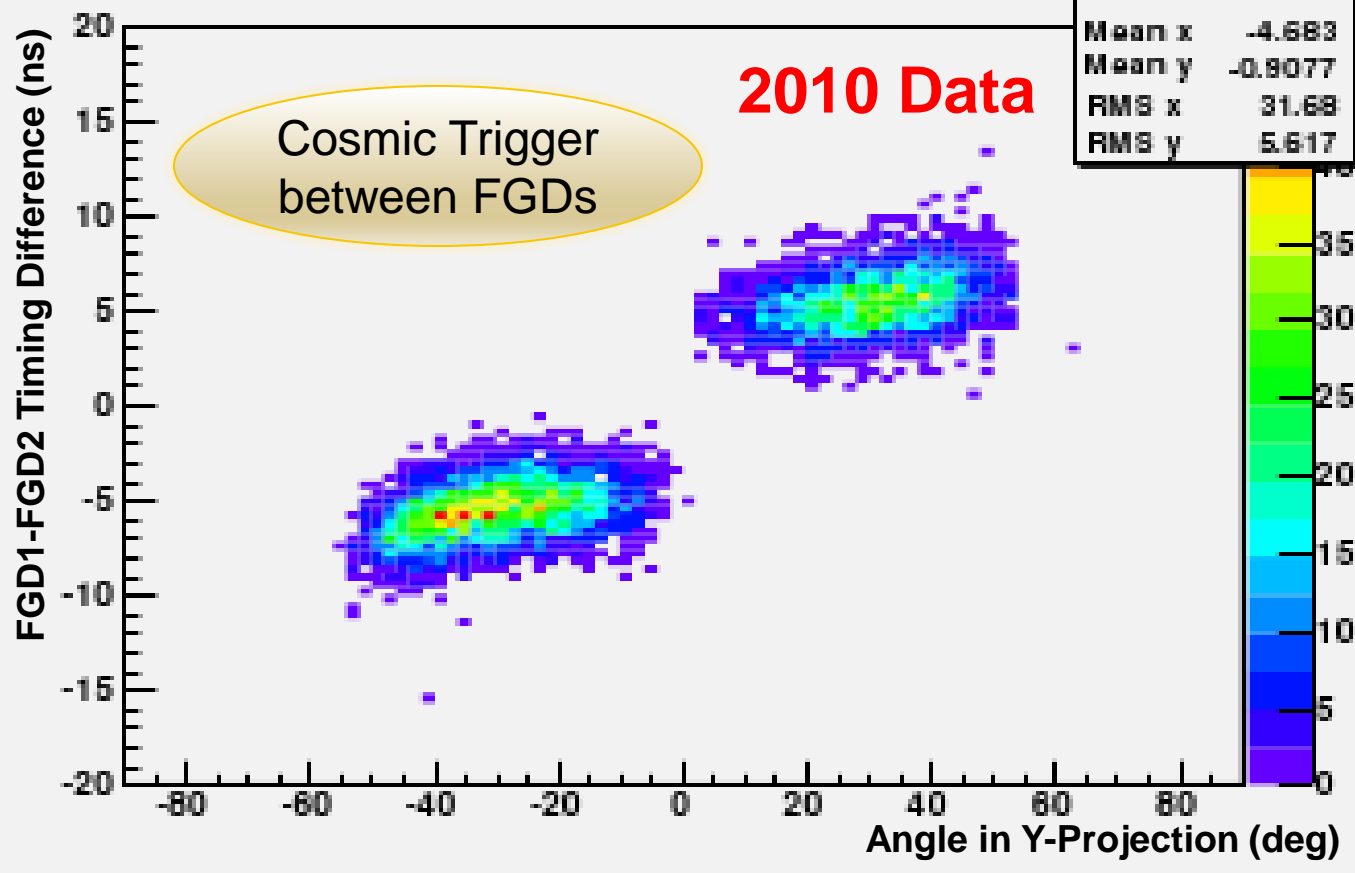
FGD can self trigger based on coincidences of analog sums of pulse heights

Deposited photoelectron per layer vs. pathlength



Timing Difference between FGDs

time difference vs thy

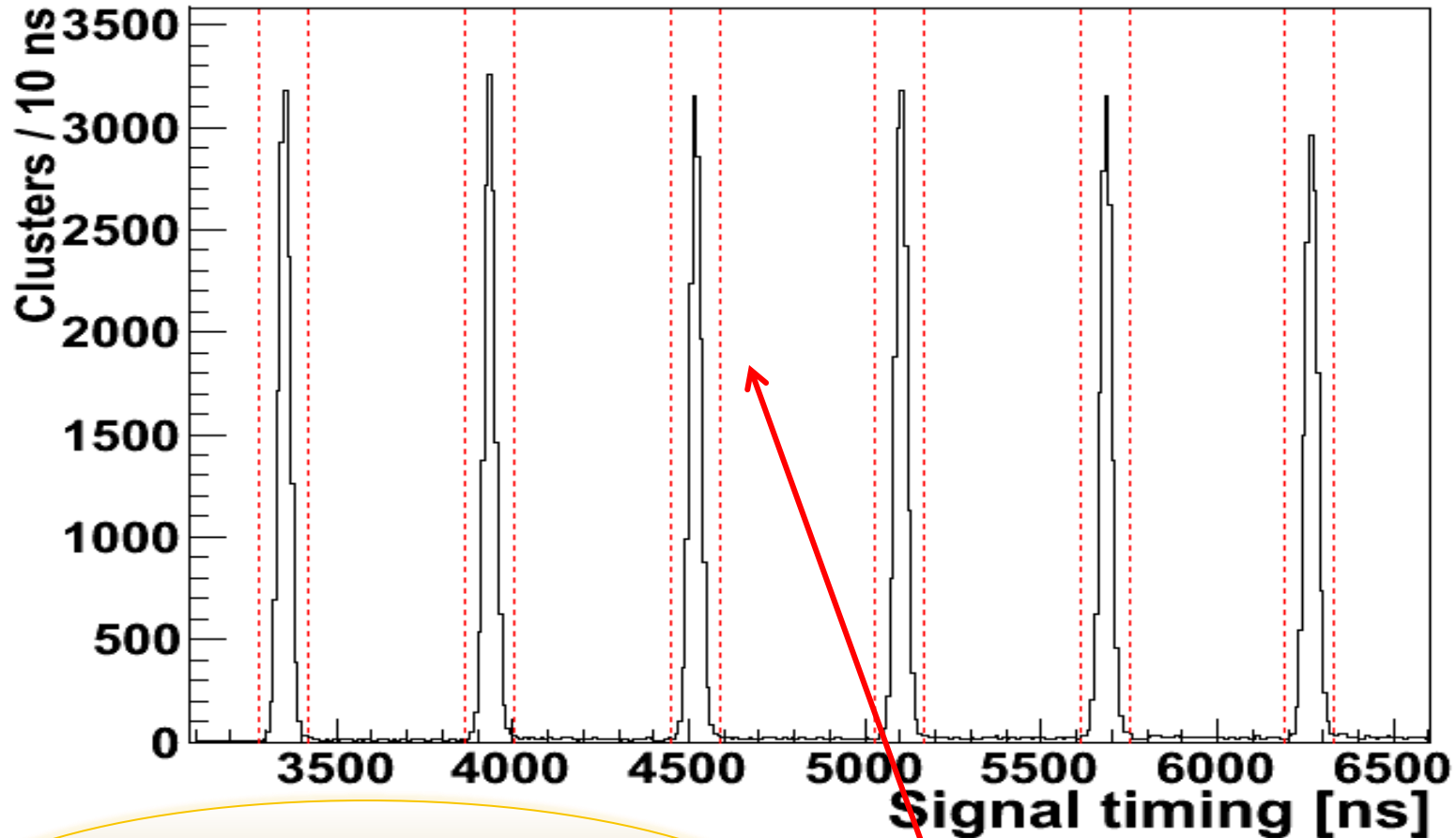


Can distinguish direction of track based on timing
➤ Identify backward going tracks

Beam Arrival Time

Timing distribution

2010 Data

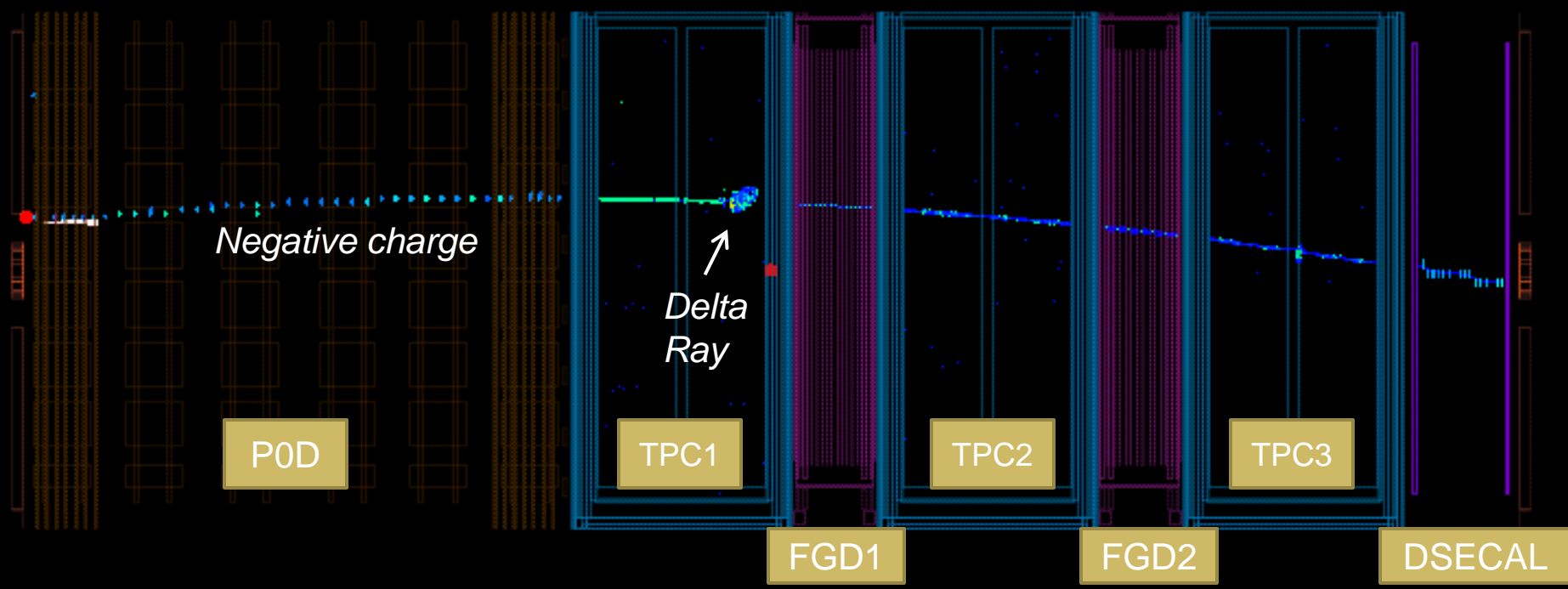


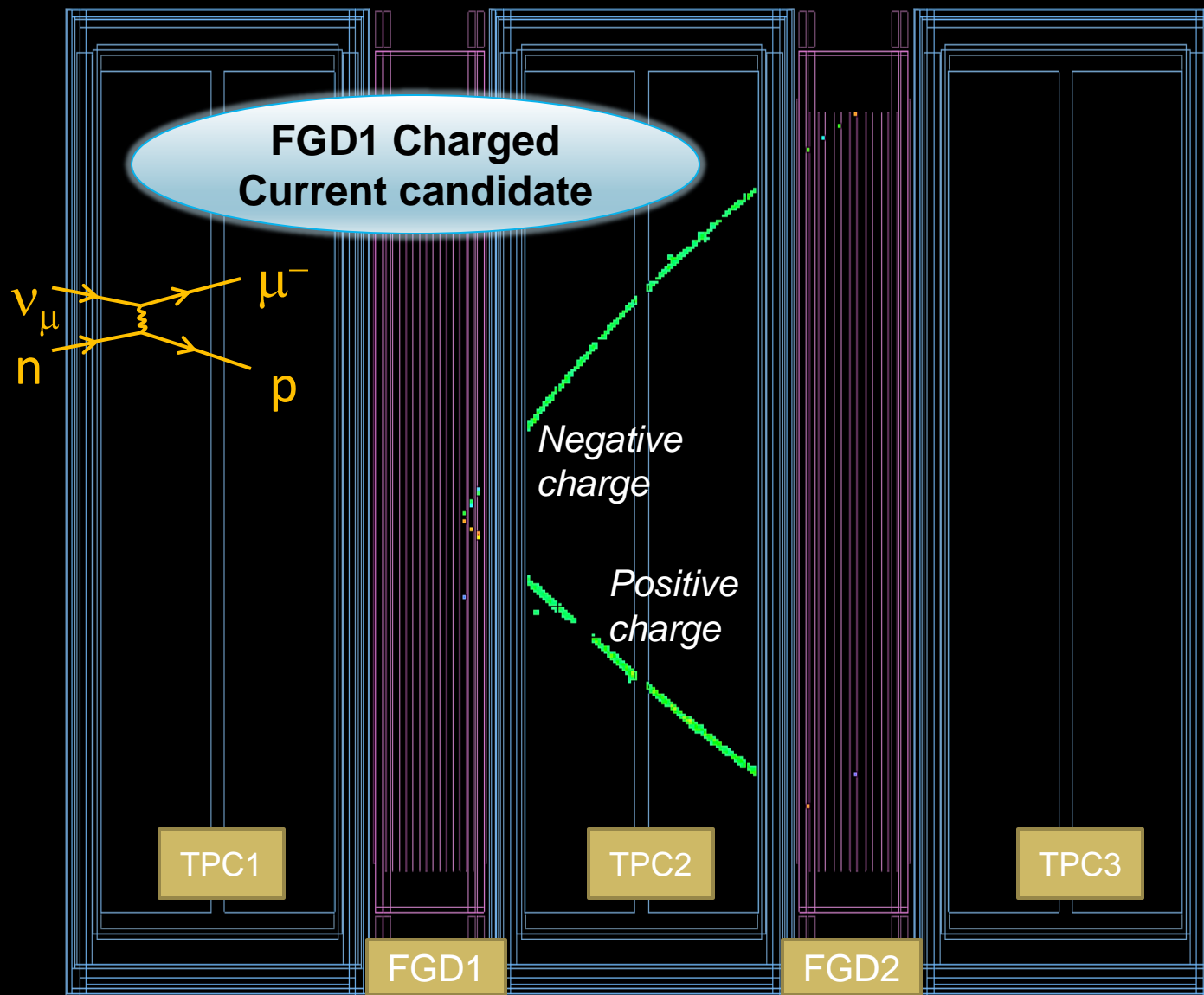
- Look at hits grouped together (time/space clustering)
- Background: Michel electrons + cosemics

Red Vertical Lines:

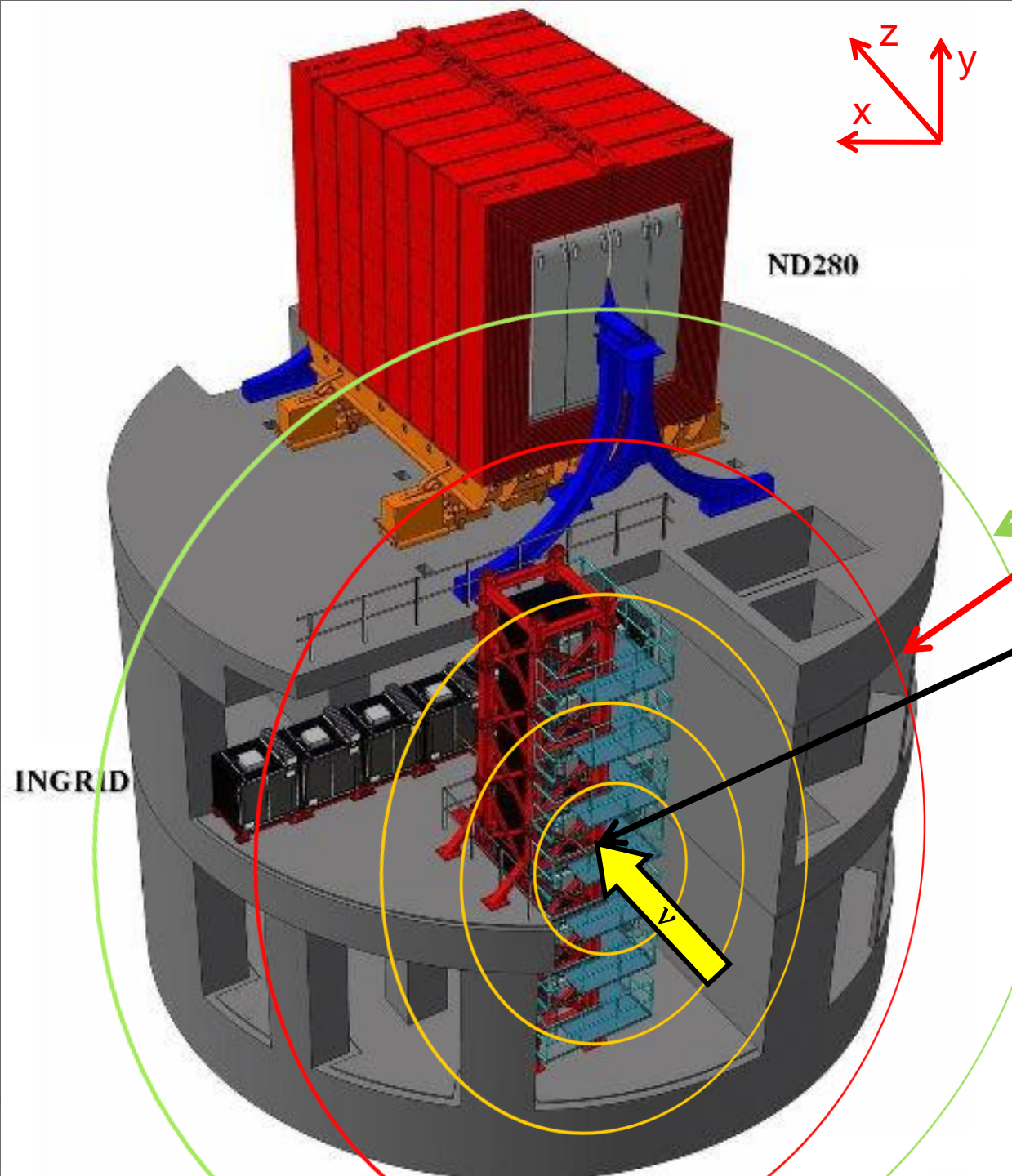
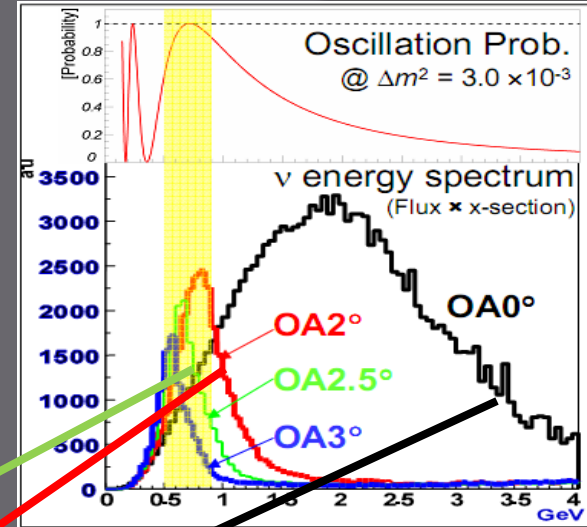
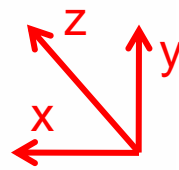
- Expected time of bunch ± 70 ns
- Based on the timing of 1st peak

"Sand Muon"





Off-Axis

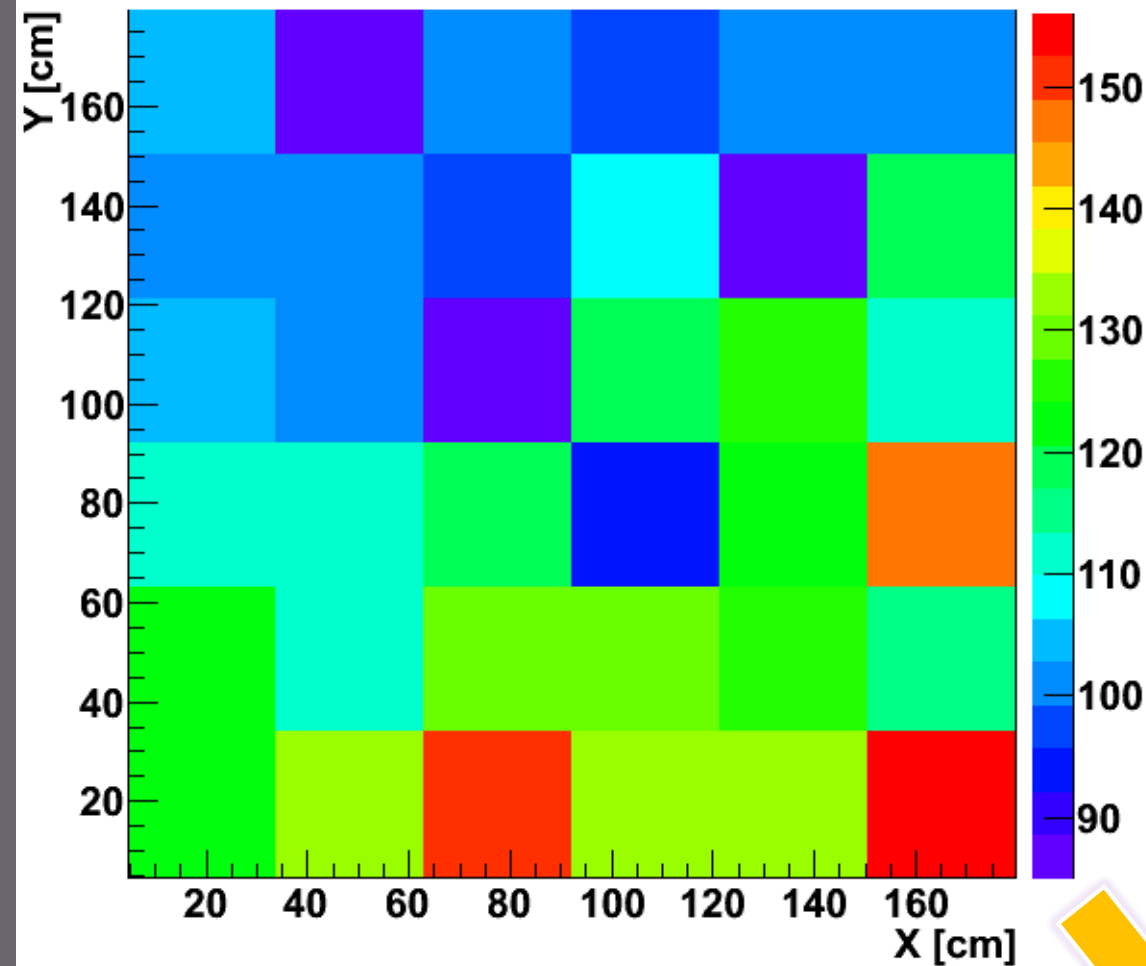


Circles are only *rough* approximations of 0.5 degree increments

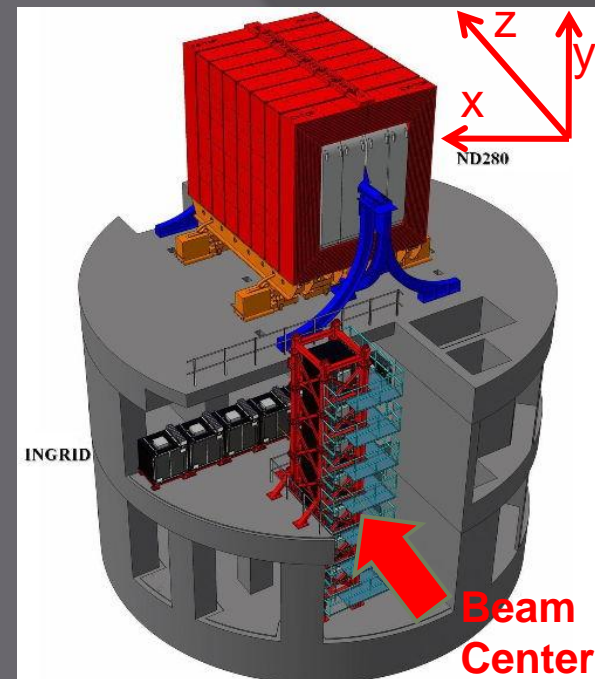
Beam Profile in FGD

Vertex 2D distribution

2010 Data



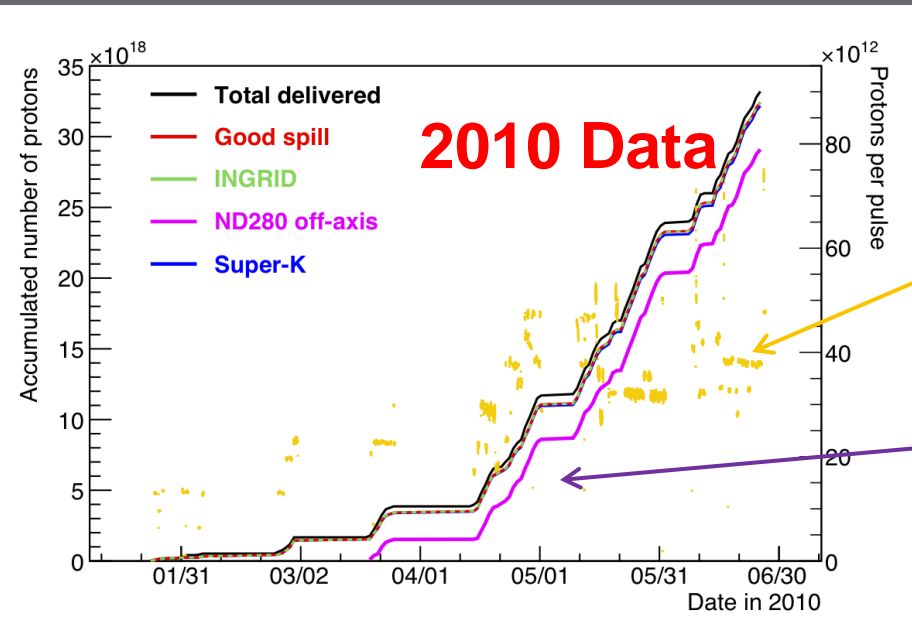
Beam Center



Cuts applied:

- Hit clustering within expected beam time
- Fiducial Volume
- Charged Current-like selection

=> See off-axis effects!



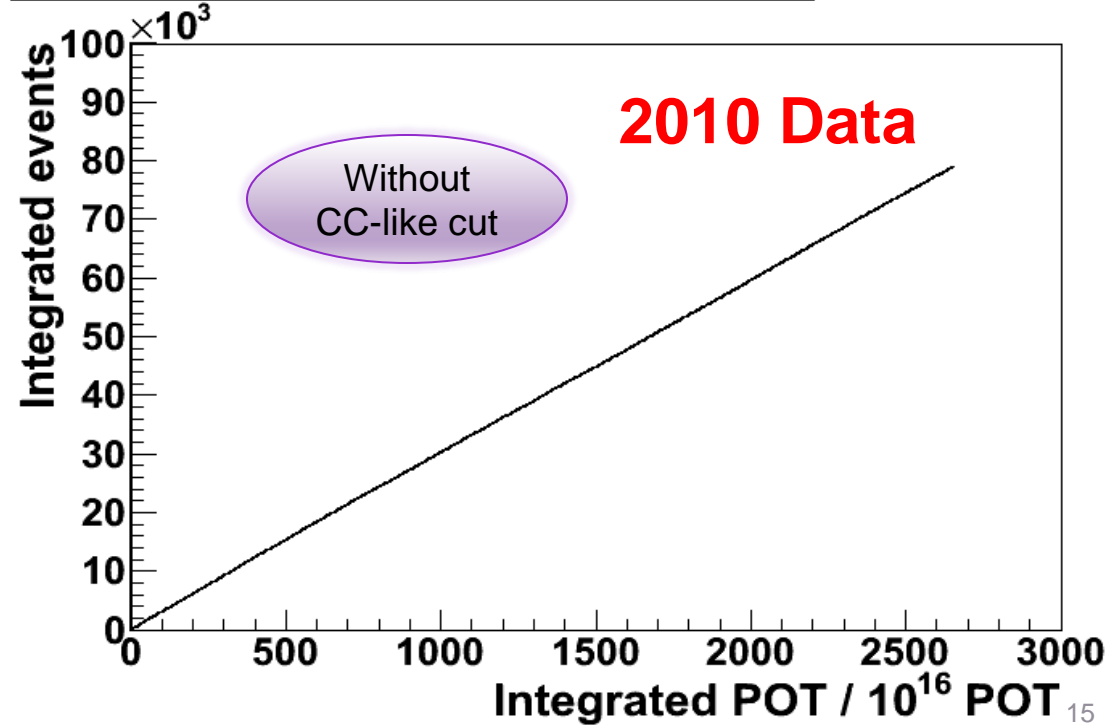
Increasing Beam Power (Protons Per Pulse)

ND280 Data

FGD Linear Response to Beam

- Apply all previous cuts (except Charged Current-like selection)
- Good spills only (based on beam data quality selections)
- The number of events is proportional to total protons on target (POT) => FGD stable!

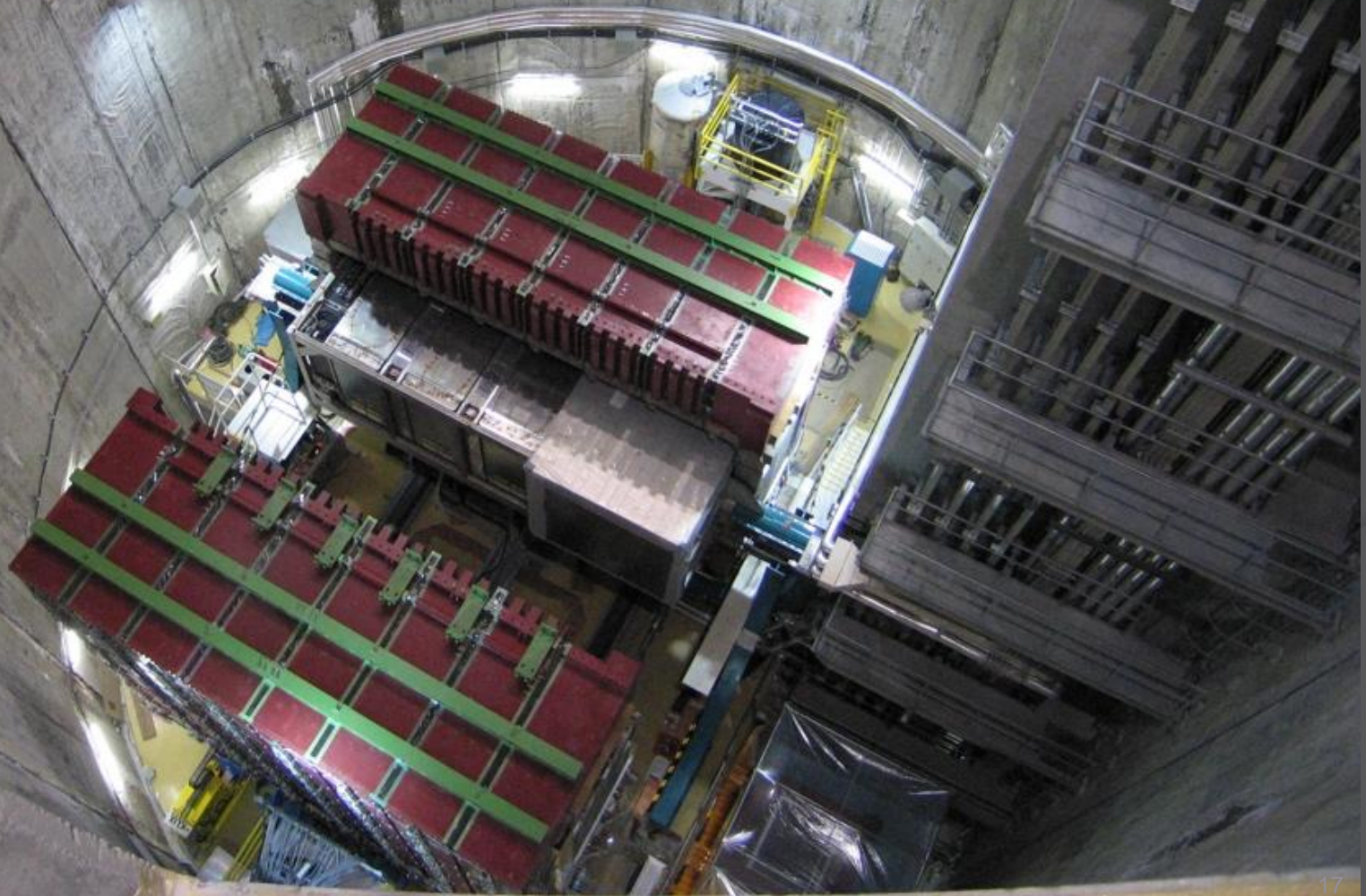
Integrated events vs. Integrated POT (Run 31~34)



Summary

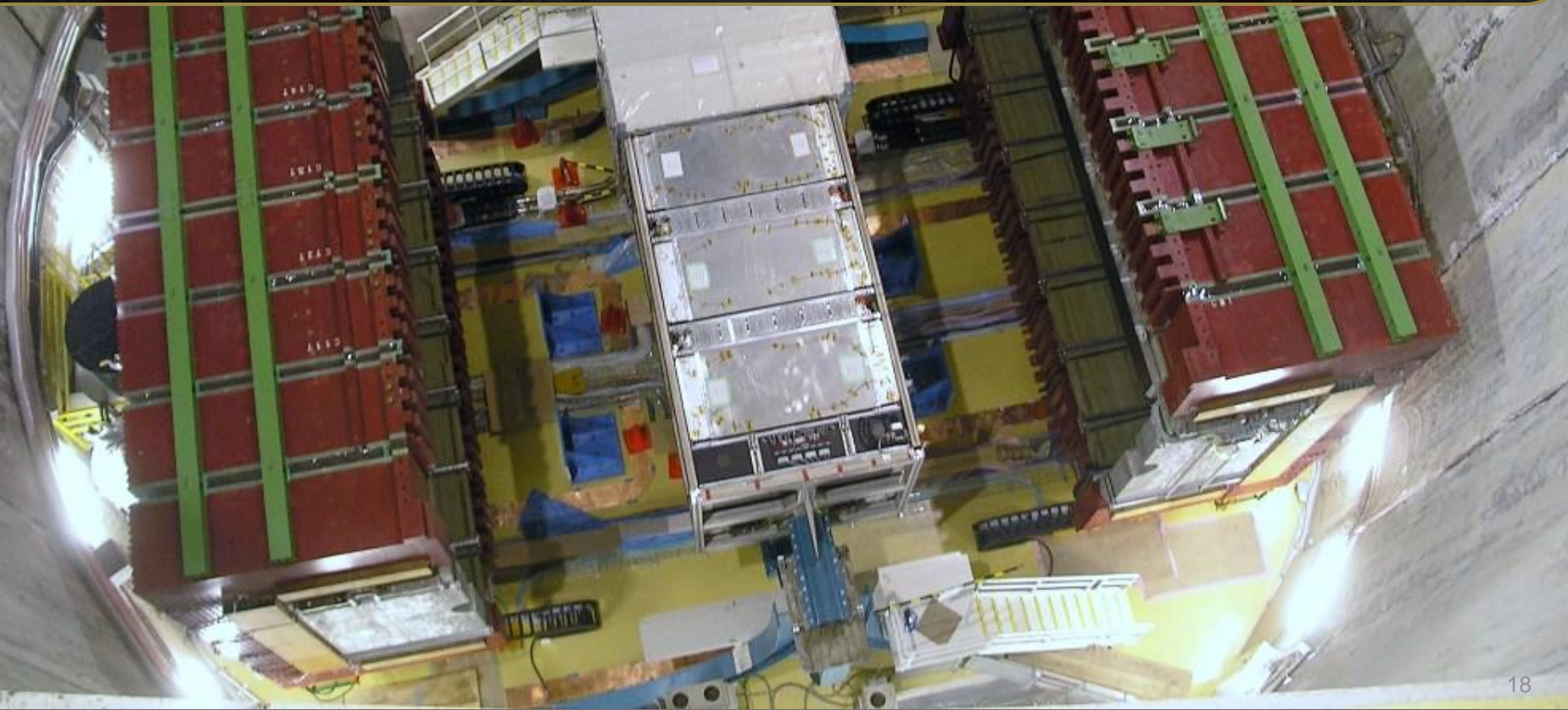
- Completed 9 months of quality data taking!
 - 1.43×10^{20} POT
- Capable of distinguishing backwards going tracks
- Beam structure seen without using accelerator data (timing, profile)
- FGD has stable event rate/POT
- For more details, see (NEW!) T2K NIM paper:
 - arXiv:1106.1238

Backup Slides



FGD Status

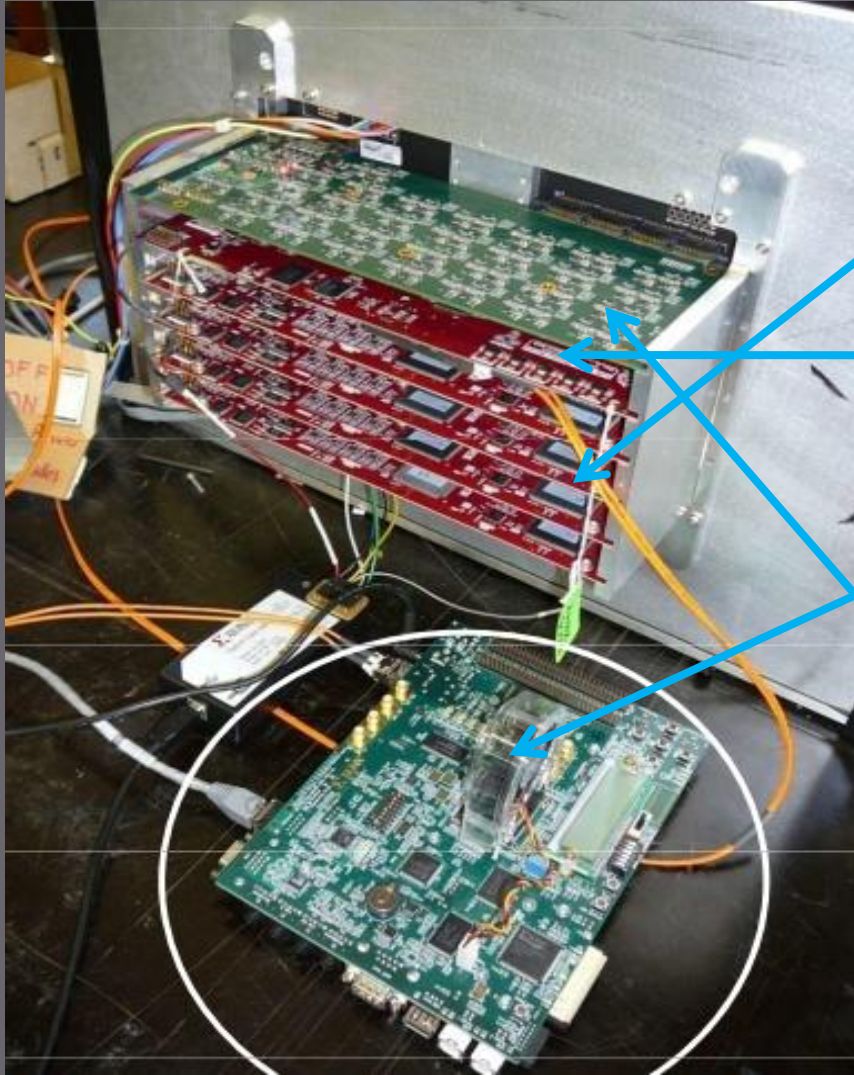
- Tsunami did not affect JPARC site (very fortunate!)
- No injuries to personnel
- Post-earthquake recovery efforts progressing well



Other FGD Progress

- **Evolving 2D to 3D track matching algorithms**
- **Alignment**
- **Preliminary studies comparing FGD to TPC energy loss**

Electronics



Front-End Boards (FEBs):

- Digitize waveform
- Split into high/low attenuation

Crate Master Board (CMB):

- Transmit data from FEBs to Data Concentrator Board
- Pass along triggers

Data Concentrator Board (DCC):

- Gather data and pass to computers

Light Pulser Board (LPB):

- Flash LED at far end of fiber
- Integrity of fiber/MPPC

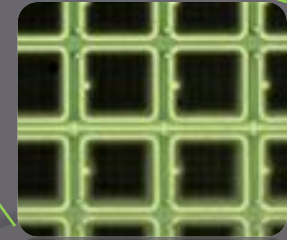
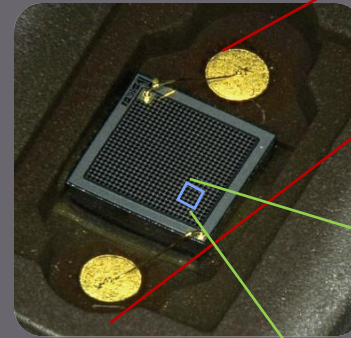
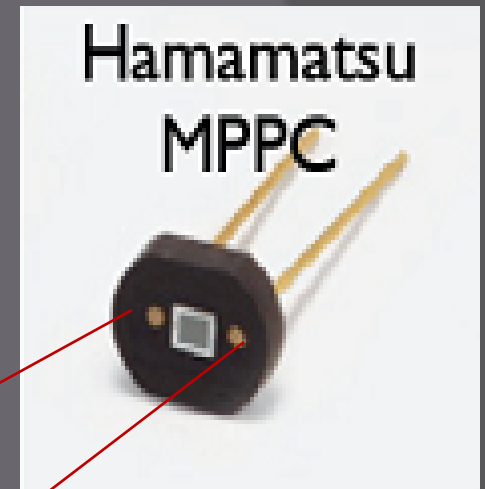
Slow control readout on all boards
(temperature, power, etc.)

Continued to function for 1 hour on UPS after
Mar 11 earthquake

Other MPPC Parameters

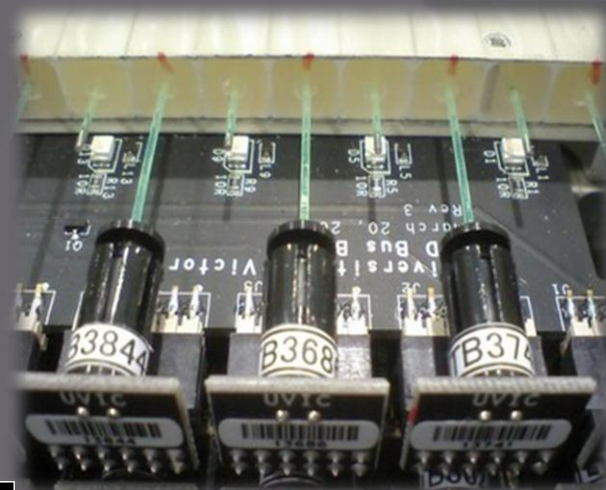
- Gain $\sim 10^6$
- Operating Voltage 68 – 71 V
- Photon Detection Efficiency (525 nm):
 - 26 – 30 %
- Pixel Size $50 \times 50 \mu\text{m}^2$
- Dark Noise Rate: $\sim \text{MHz}$

- $\sim 64,000$ produced for T2K
- Used in:
 - INGRID – 9592
 - POD – 10400
 - FGD – 8448
 - ECAL – 22336
 - SMRD – 4016

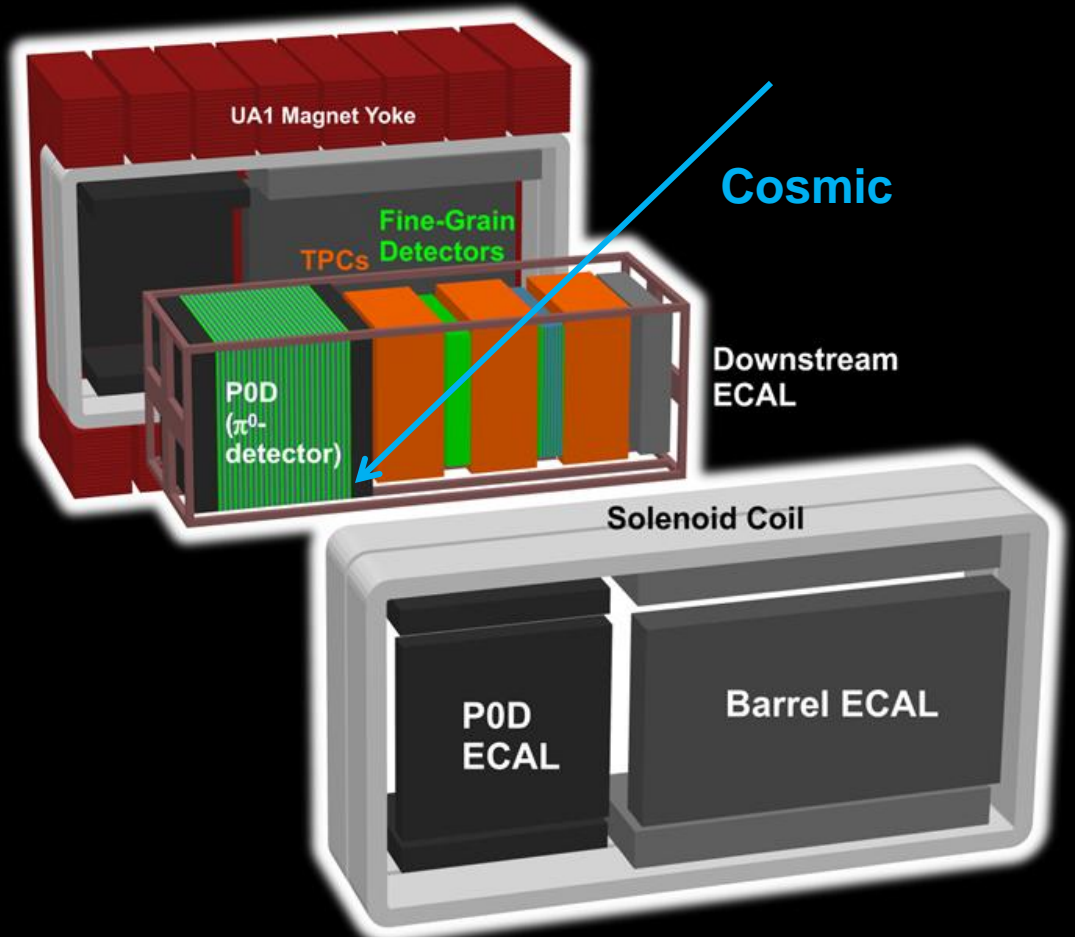


FGD Cosmic trigger:

- ASUM group: sum of pulseheight for 8 channels with own threshold
- 2 ASUM groups per busboard
- Require 1 ASUM group per projection per FGD to fire for trigger

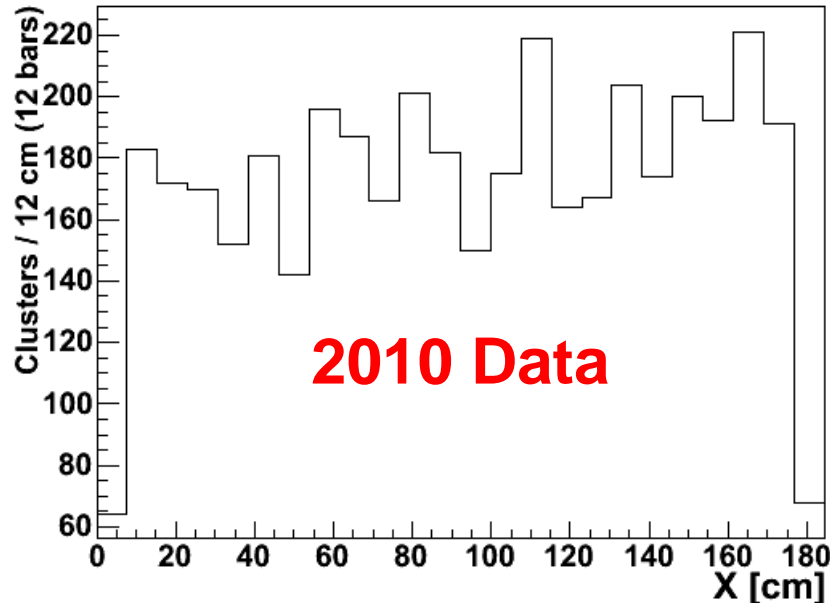


Sum 8 Channels

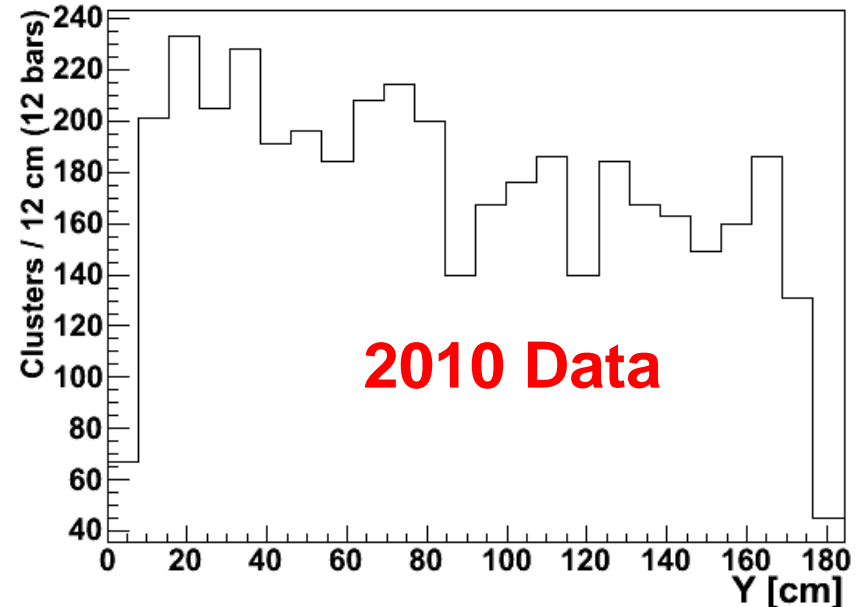


1D Beam Profile

Vertex distribution (X)



Vertex distribution (Y)



Cuts applied:

- Within expected beam time
- Remove Noise (time clustering and low p.e. removal)
- 4+ hits in cluster
- Most upstream hit inside FGD
Fiducial Volume (FV)
 - 2 layers front
 - 5 layers side
- Charged Current-like selection: 3+ continuous hits

