NOνA Analysis at Argonne

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For the Argonne Neutrino Group
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Overview

- This talk will cover Argonne's involvement in NOvA offline software development, calibration and analysis work

- Our major projects include
  - Development of offline software and calibration tools
  - Validation and on-going development of beam and cosmic Monte Carlo
  - Study of far detector backgrounds
  - Development of electron PID

Offline Software Development and Calibration

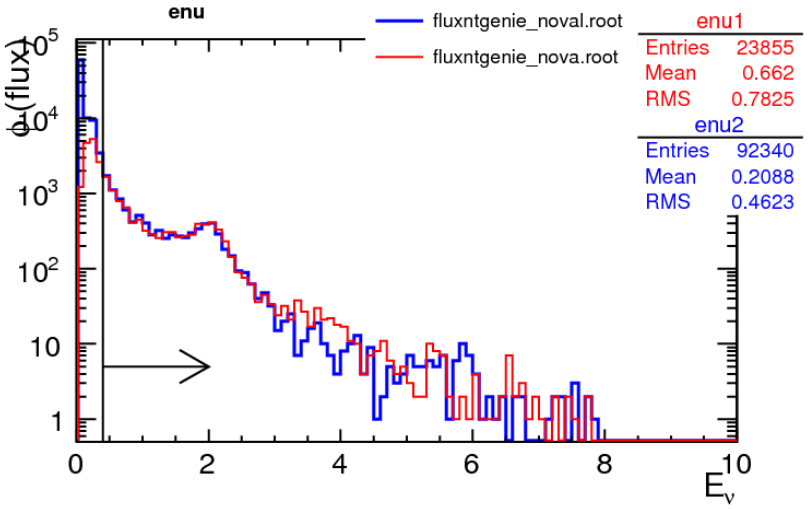
- Mayly Sanchez (joint appointment with Iowa State) is a convener of the offline software group
- Sarah Phan-Budd and Zelimir Djurcic work on NOνA beam (NUMI and Booster) simulation and cosmic Monte Carlo
- Jon Paley works on core offline software development and software implementation at Argonne
- Steve Magill works on true event reconstruction and developing methods to compare purity and efficiency of algorithms using Monte Carlo truth information
  - Used to study acceptance for various near detector configurations
- Xiaobo Huang works on the MEU/Stopping Muon calibration and the timing calibration
- Various students work with Paul Bloom (North Central College) and Sarah Phan-Budd on hand scanning events

NuMI Beam and Cosmic Simulation

- Beam simulation:
  - Neutrino simulation was prohibitively slow for the NDOS off-axis location because of many low-flux off axis events
  - Argonne helped develop methods to speed up event generation

- Cosmic simulation:
  - Validating distributions and timing for NDOS cosmic simulation

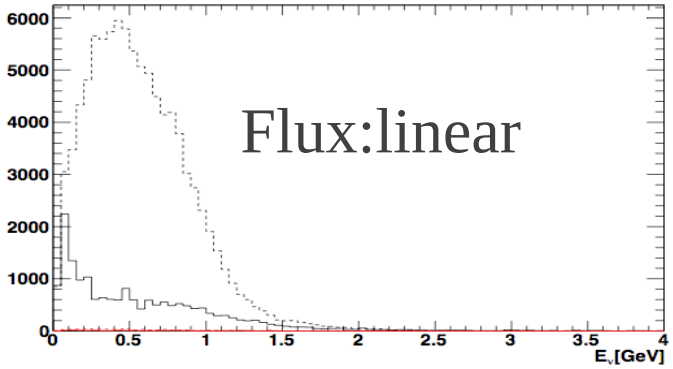
NuMI beam simulation

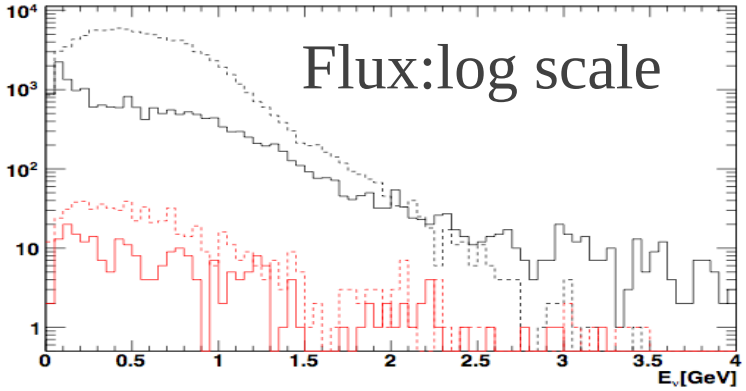


Booster Flux

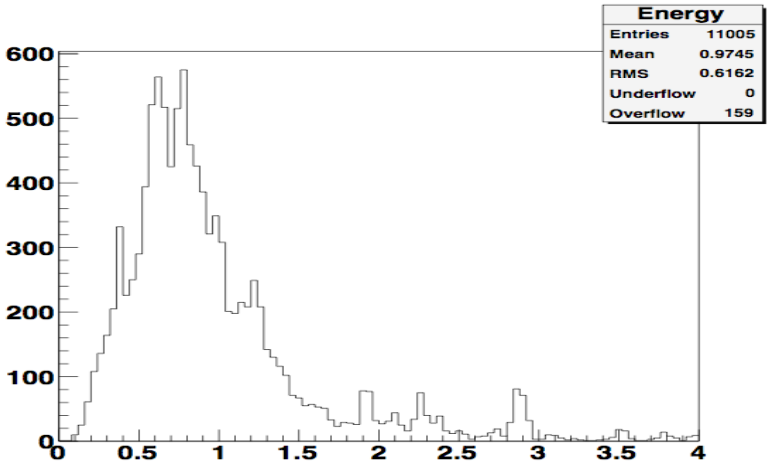
-Legacy of the MiniBooNE Collaboration

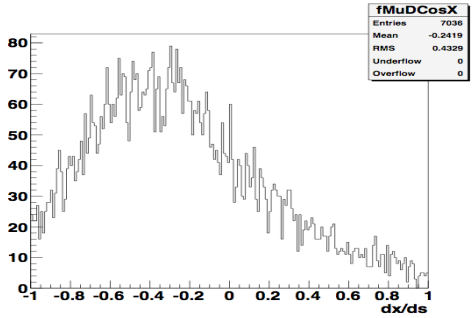
-Converted booster beam files (hbook) to NuMI flux file format (genie).



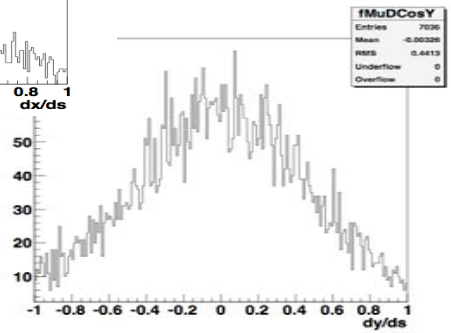


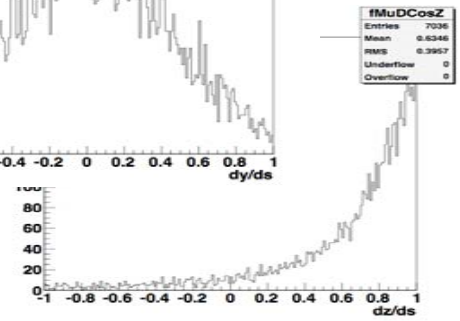
-Simulation of events in the detector



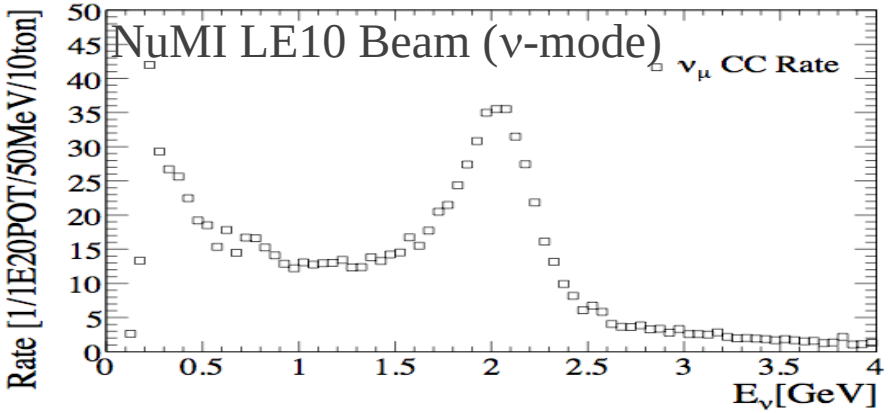


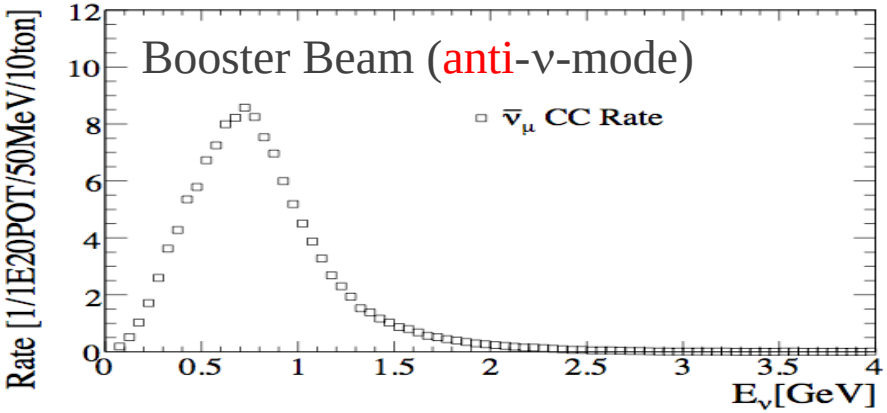
Angular Distributions





Beam and Event Rate Calculation (NuMI and Booster)

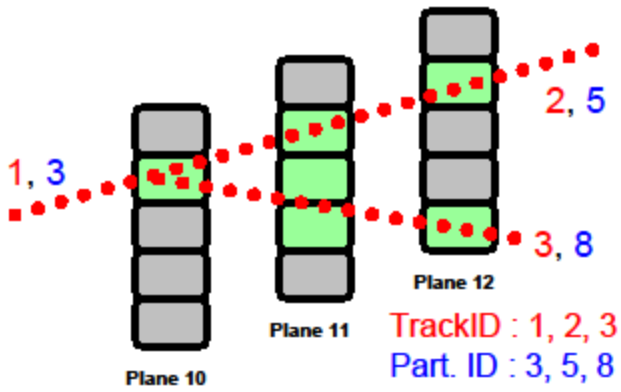




Beam line	Total Events [1/10ton/10^{20}POT]	ν-type	Total (per ν-type)	Charged Current	Neutral Current
NuMI LE10 Beam (ν-mode)	1776	ν_μ	1421	987	434
		anti-ν_μ	272	182	90
		ν_e	68	49	19
		anti-ν_e	15	10	5
Booster Beam (anti-ν-mode)	308	ν_μ	116	82	34
		anti-ν_μ	189	126	63
		ν_e	2	1.5	0.5
		anti-ν_e	1.1	0.8	0.3

Monte Carlo Cheater

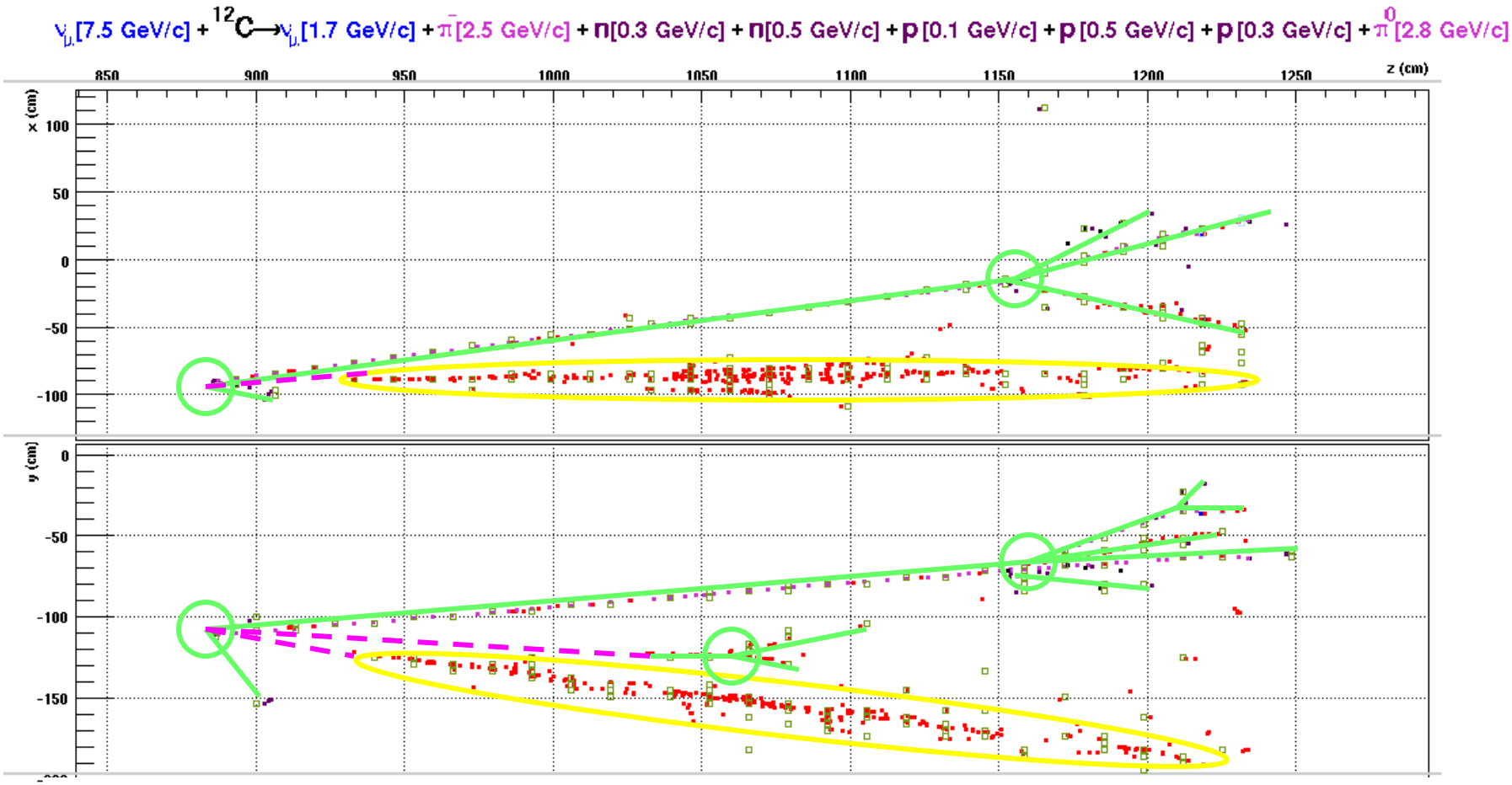
- MC Cheater
  - Set of truth objects used to study reconstruction algorithms
  - SimHits, SimTracks, SimVerticies, SimClusters



SimHits :
Plane 10, 1 hit, E = ΣFLSHit Edeps, # particles = 3
Plane 11, 3 hits, E = ΣFLSHit Edeps, # particles = 1 per hit
Plane 12, 2 hits, E = ΣFLSHit Edeps, # particles = 1 per hit

PlaneCell with FLSHit(s) -> SimHit
- Energy threshold parameter

MCCheater Objects

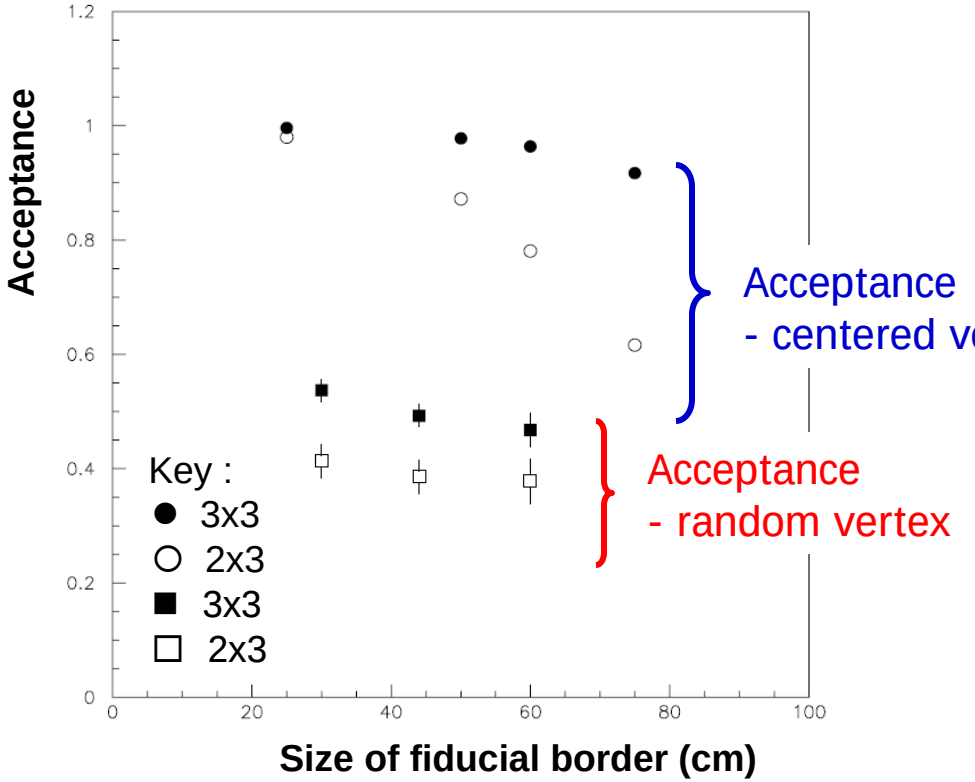


Cheated objects in an event (per interaction) :

- Vertex spacepoints (ν interactions, $\pi^{\pm}$ interactions/decays, π^0 decays, γ conversions?, etc.)
- Long-lived charged particle tracks (at least 3 planes crossed?)
- Neutral particle gaps (ν, γ, π^0, n, K_L^0, etc.)
- EM showers

Using the Cheater:
Comparing Near Detector Configurations

ν_e CC Event acceptance results



Optimal acceptance > 90% for 3x3, << 90% for 2x3 with fiducial volume defined by borders > 50 cm

For random-vertex events, acceptance is determined more by event shape - ~25-30% increase for 3x3 over 2x3 models

The acceptance ratio for centered vertex events in the 3x3 ND compared to the 2x3 is dominated by the geometrical factor – for a 60 cm border, the acceptance ratio is 1.23

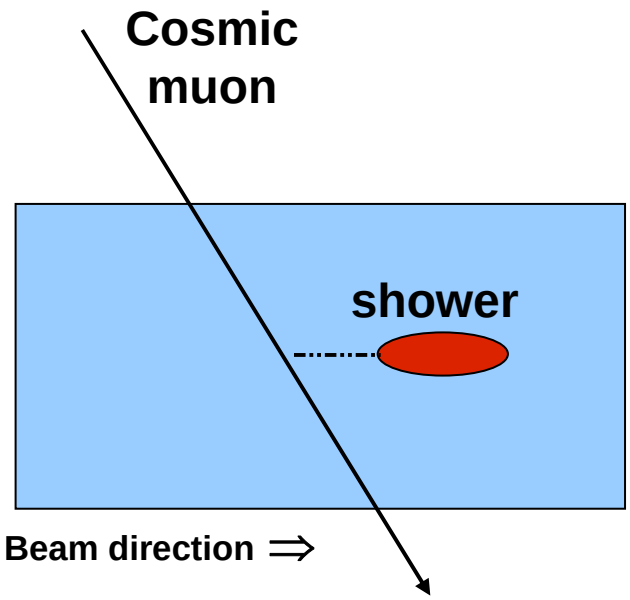
For random-centered events :

-> with a 60 cm border, the acceptance ratio is 1.24

-> with a 44 cm border, the acceptance ratio is 1.28

-> with a 30 cm border, the acceptance ratio is 1.30

Cosmic Ray Background



Xiaobo Huang and Maury Goodman are studying the cosmic ray background in the near detector on the surface and far detector

In the NOνA experiment, hits of real data will come from both the beam event and the cosmic event.

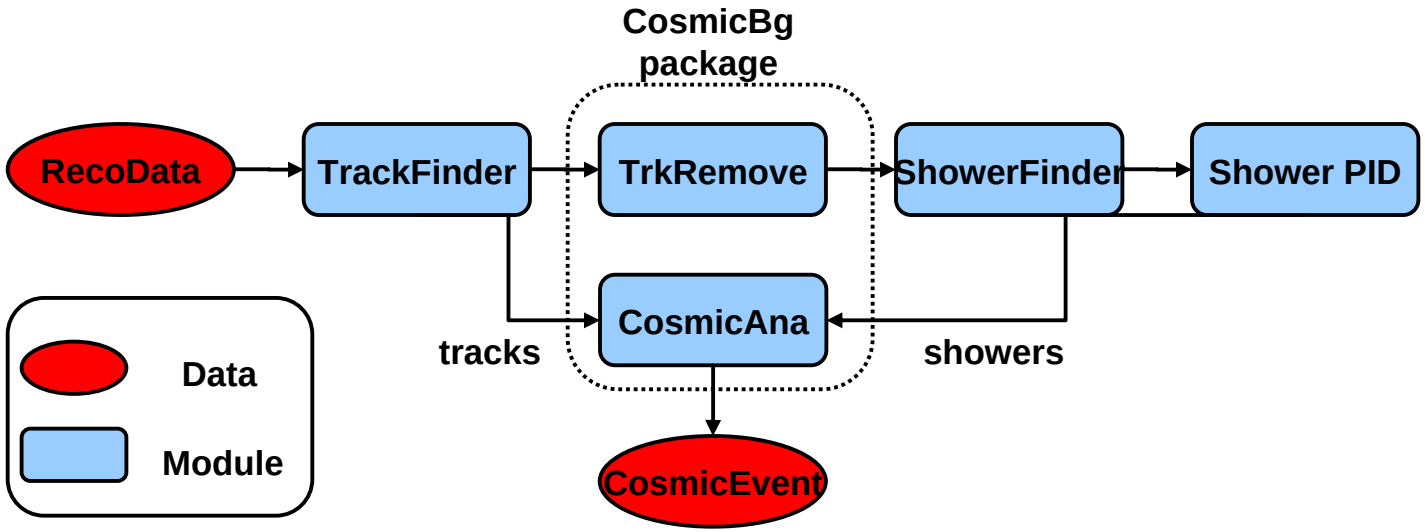
Contained short cosmic muon track having direction close to the beam direction.
- Use fiducial volume cut and zenith angle cut to estimate this background.

Cosmic tracks (visible or invisible) accompanied by showers (EM or hadronic) are a more dangerous smoking gun.
- Remove hits from cosmic tracks, then run shower finder on the remnants of the event. Apply shower PID to tell if it is a EM shower.

Work in Progress at ANL

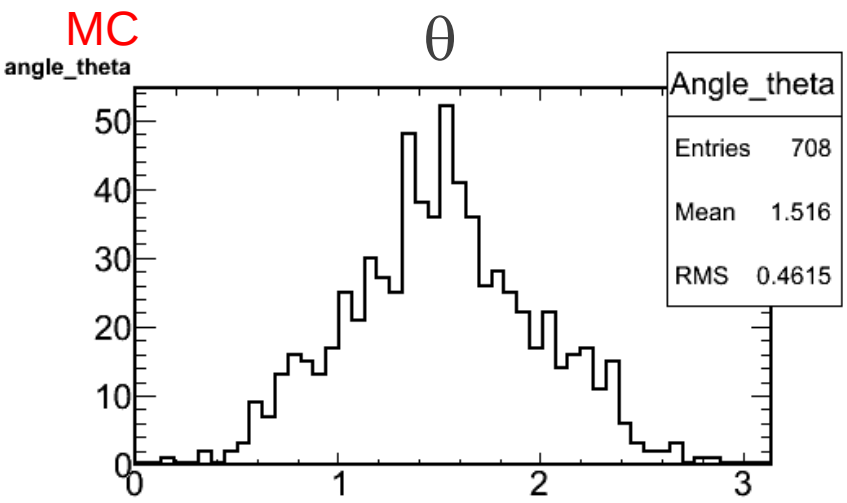
CosmicBg Package

Estimate cosmic track rate, track efficiency, track purity.
Estimate the rate of contained cosmic track with big zenith angle.
Remove hits coming from cosmic track.
Use shower finder to finder shower in the track-removed remnants.
Use shower PID to find EM shower.

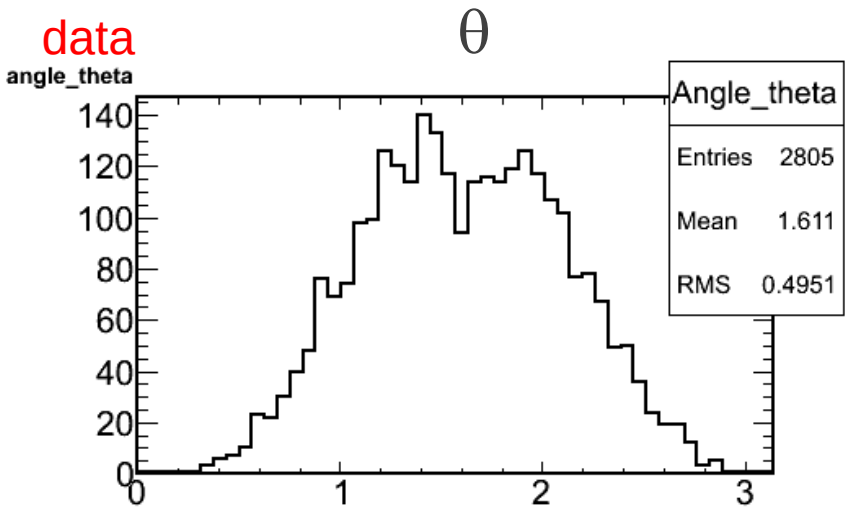


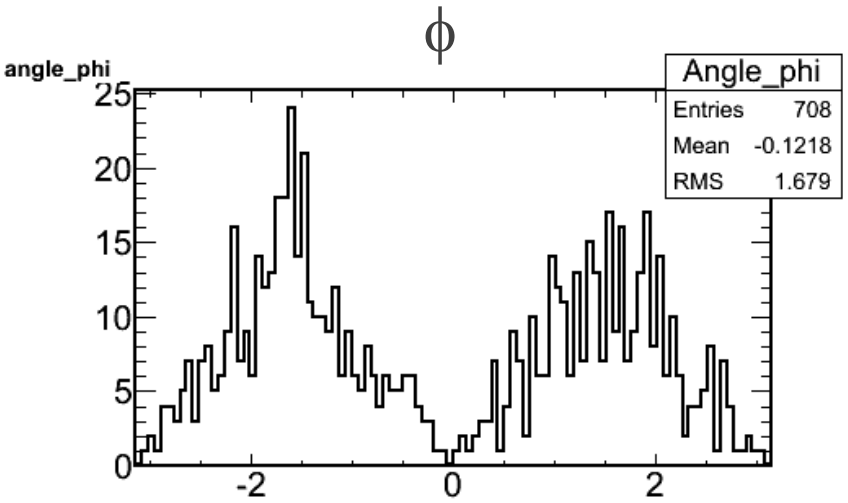
NDOS Cosmic MC/data comparisons

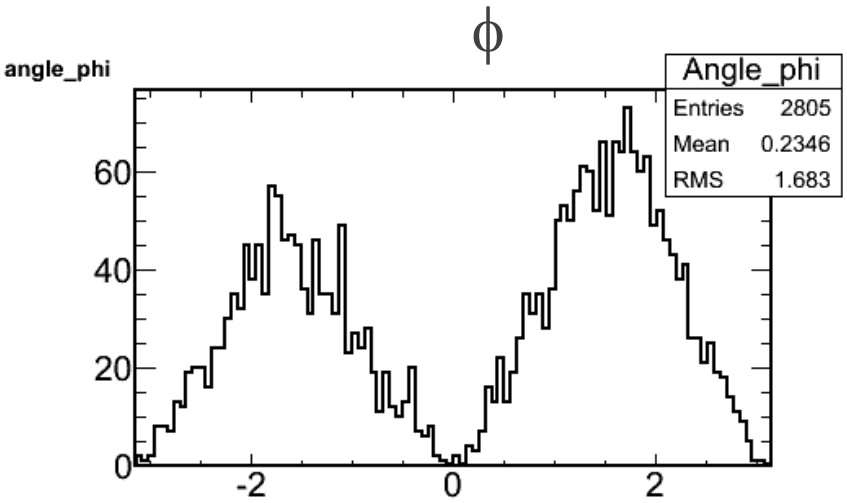
MC



data







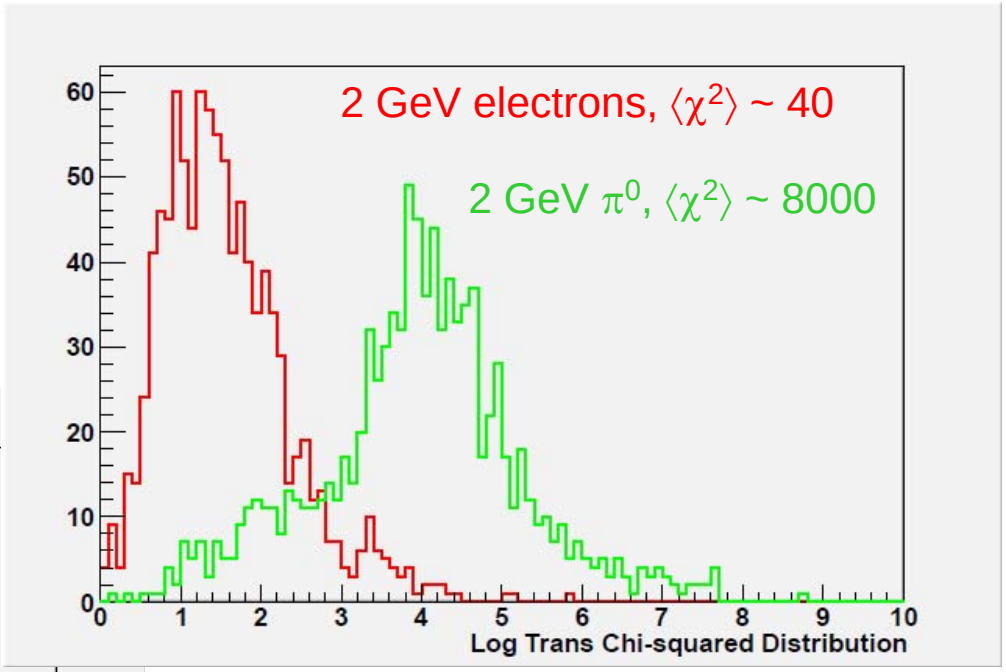
NDOS MC (5000 events) and NDOS data (Run 11301, 4142 events) are compared.

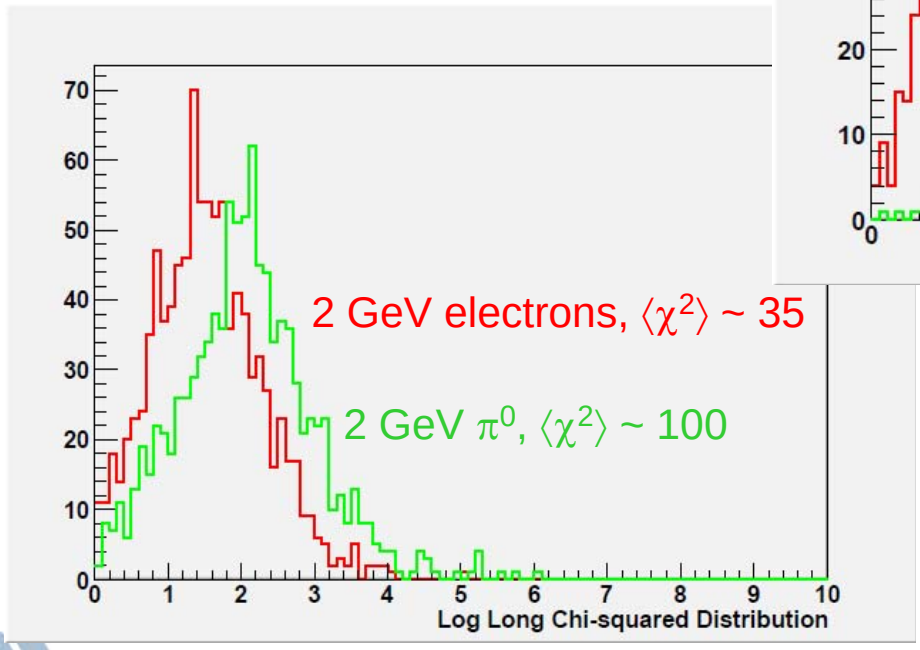
Electron Identification

- Steve Magill and Sarah Phan-Budd are working on developing an electron ID using the an ‘H-matrix’ method
- Forms a χ^2 test of the longitudinal and transverse energy distribution of a particle shower
- Used by D0 to distinguish electron showers from π^{+-}showers
- Can be used to distinguish between electrons and π^0
- Preliminary pass shows good separation between Monte Carlo electrons and pions using this technique

e, π^0 rejection with transverse H-Matrix

Separation in transverse distributions



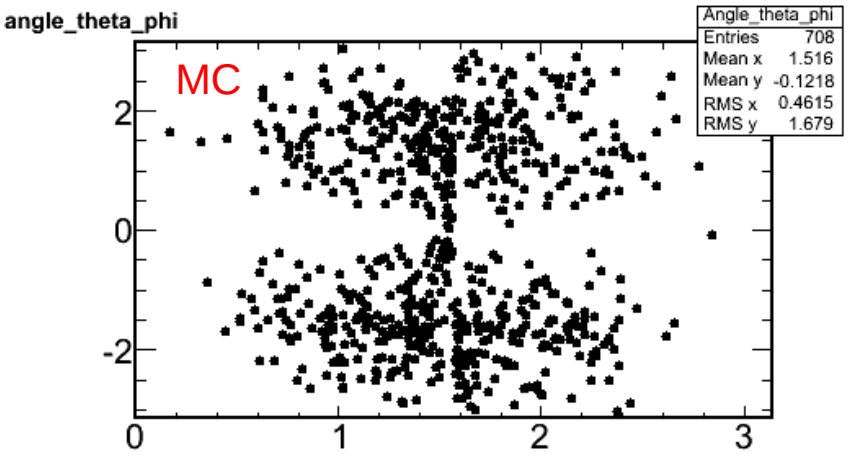


Similar longitudinal distributions*

Conclusions

- We are making significant contributions to NOvA analysis on several important fronts
- Monte Carlo development
- Calibration and offline software tool development
- Near and far detector background estimation
- Electron identification and PID

BACKUP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MC
Angle_theta_phi
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Mean y -0.1218
RMS x 0.4615
RMS y 1.679
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0
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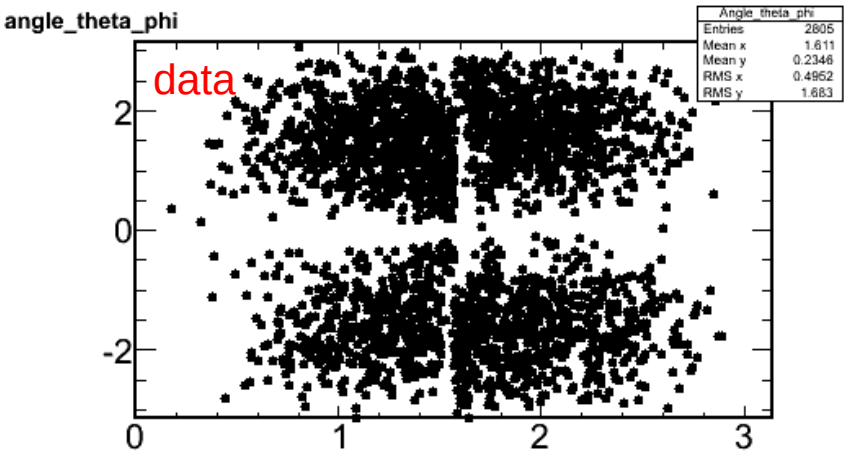
0
1
2
3


angle_theta_phi
data
Angle_theta_phi
Entries 2805
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Mean y 0.2346
RMS x 0.4952
RMS y 1.683
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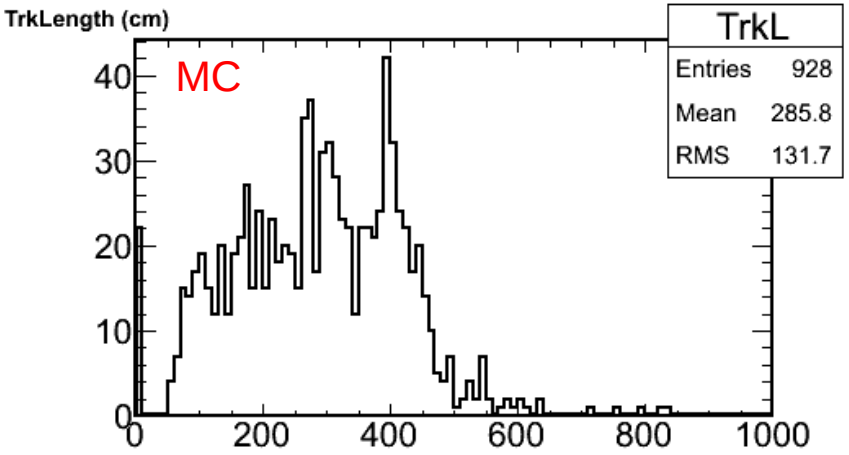
0
-2
0
1
2
3


TrkLength (cm)
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TrkL
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Mean 285.8
RMS 131.7
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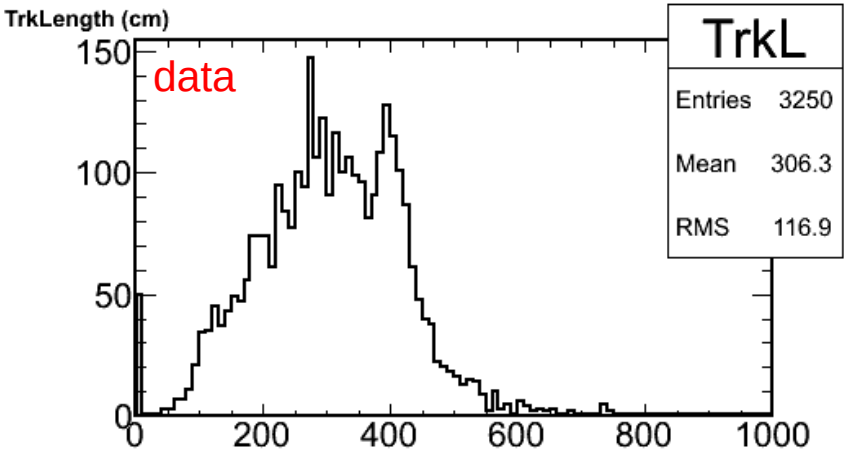
30
20
10
0
0
200
400
600
800
1000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TrkL
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RMS 116.9
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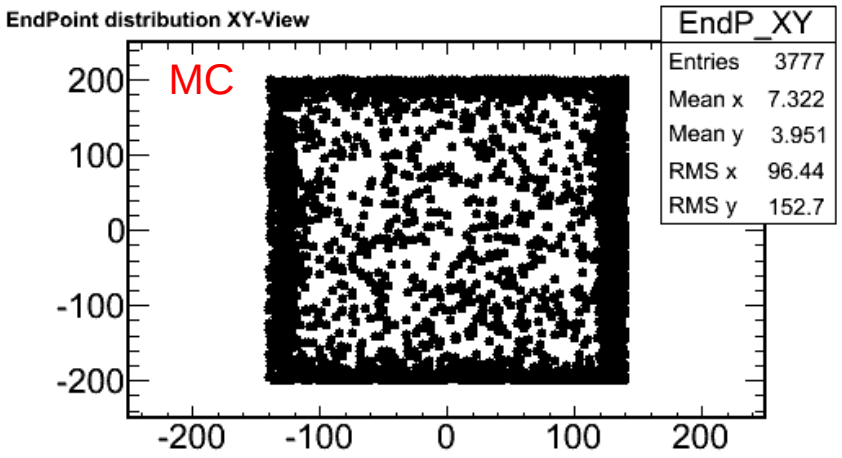
100
50
0
0
200
400
600
800
1000


EndPoint distribution XY-View
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Mean y 3.951
RMS x 96.44
RMS y 152.7
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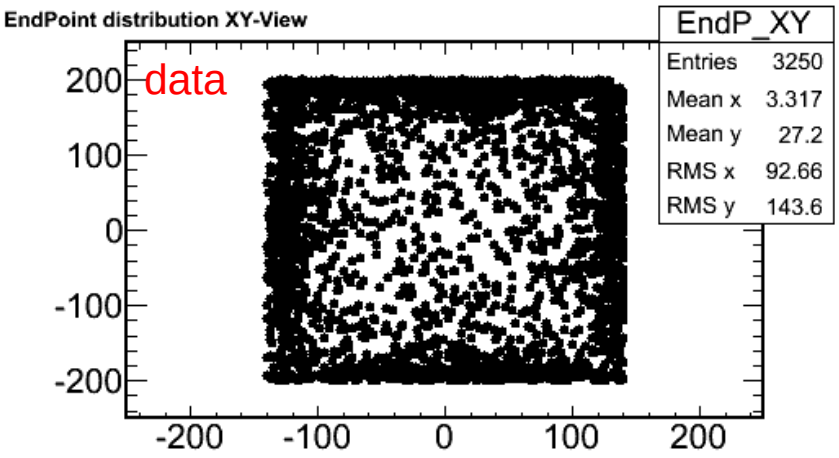
-100
-200
-200
-100
0
100
200


EndPoint distribution XY-View
data
EndP_XY
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Mean y 27.2
RMS x 92.66
RMS y 143.6
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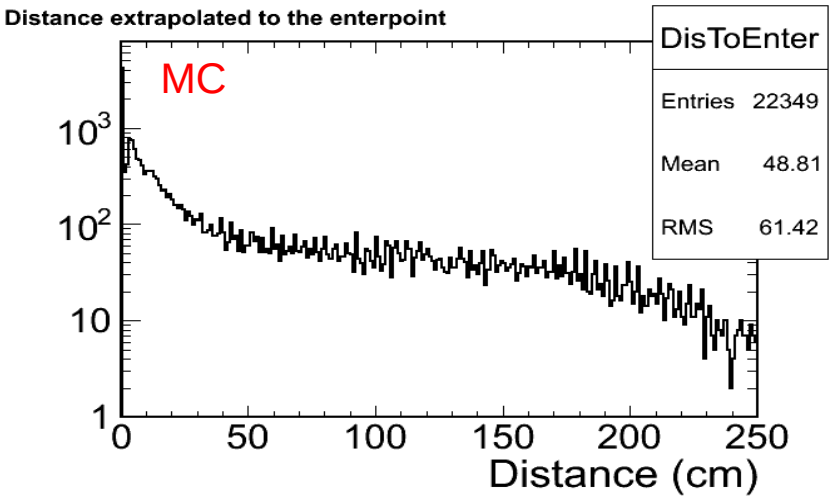
-100
-200
-200
-100
0
100
200


Distance extrapolated to the enterpoint
MC
DisToEnter
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RMS 61.42
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10^2
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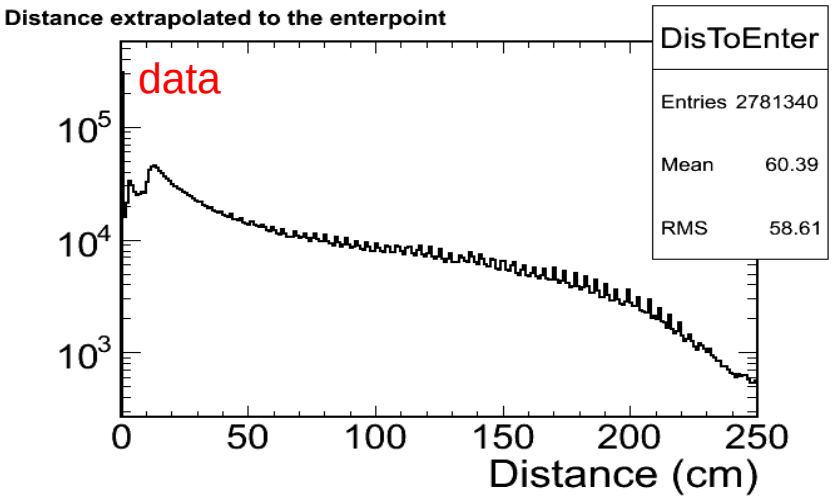
0
50
100
150
200
250
Distance (cm)


Distance extrapolated to the enterpoint
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RMS 58.61
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10^4
10^3
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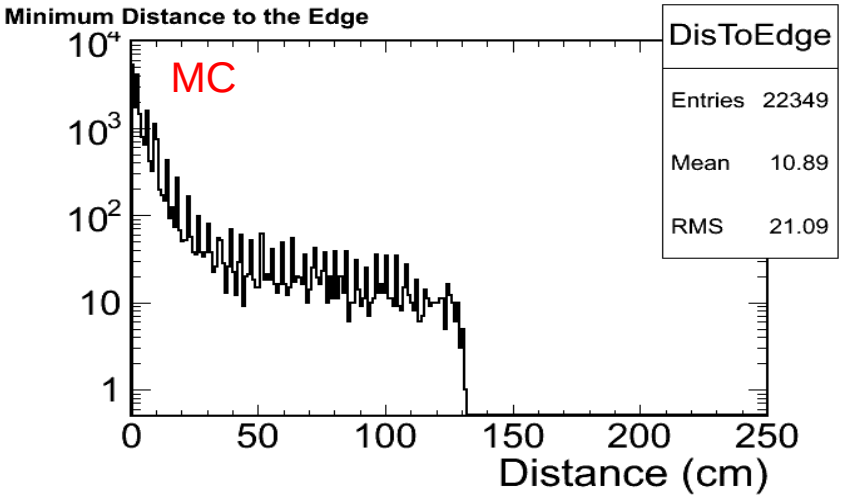
50
100
150
200
250
Distance (cm)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10^2
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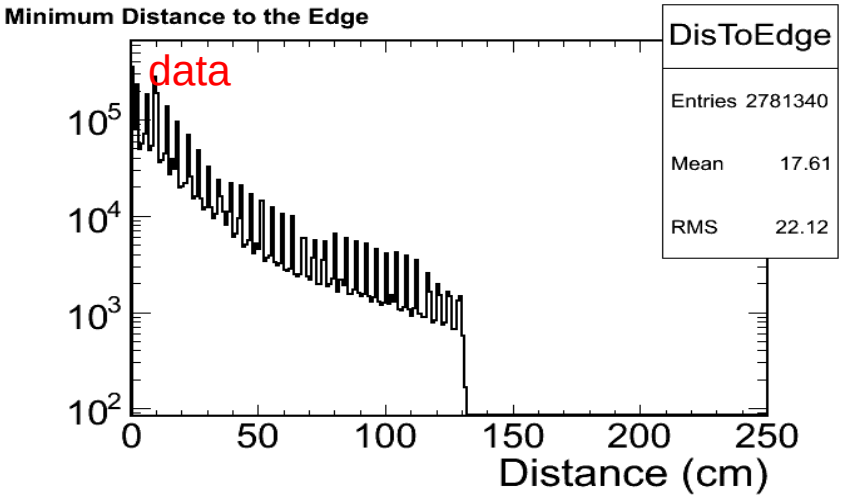
50
100
150
200
250
Distance (cm)


Minimum Distance to the Edge
data
DisToEdge
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RMS 22.12
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10^4
10^3
10^2
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100
150
200
250
Distance (cm)