Alma 9 Validation

Dark Photon Samples

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Introduction

- Validate ALMA9 version of Calypso for the track variables
- Sinead already looked at single muon samples
- Ansh looked at the A' analysis cutflow
- We want to look at the "two track reconstruction" as a function of separation between them

Data Description

- We will to look at Dark-Photon decays to electron pairs
- Data samples used are /eos/experiment/faser/data0/sim/mc24/foresee/1100{33,38,51}/
  - 110033 : Mass = 10 MeV, epsilon = 1E-5
  - 110038 : Mass = 100 MeV, epsilon = 1E-5
  - 110051 : Mass = 10 MeV, epsilon = 1E-4
- ALMA 9 samples : ./phy/s0008-dev/
- CENTOS 7 samples: ./phy/s0008-r0019/
- Chaining them together for better statistics [total 60k events]
- Can separate based on mass/couplings if interested

Overview of Validation

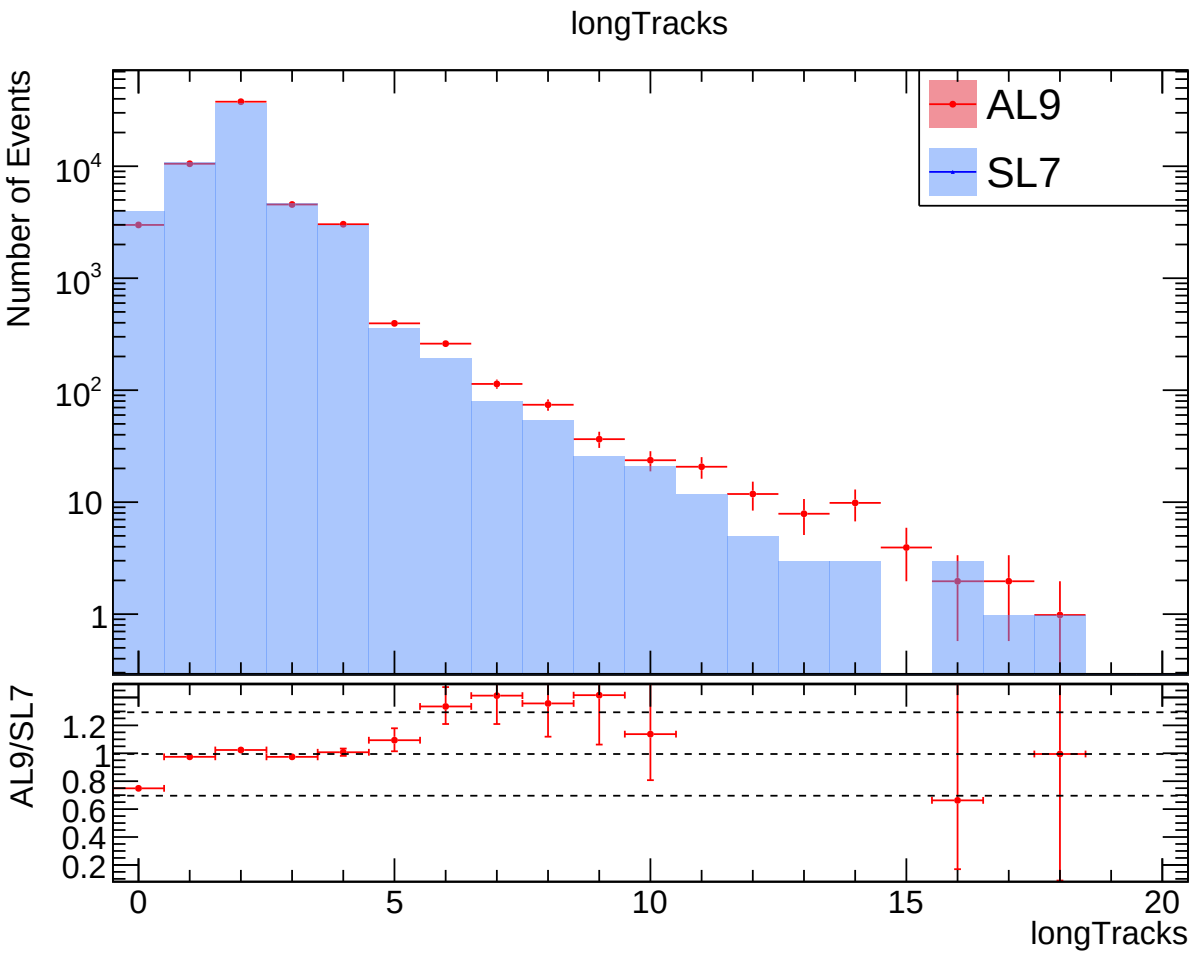
Objective: To Quantify two track reconstruction efficiency as a function of separation between the tracks

- Quantify separation between tracks
- Compare generic track reconstruction as a function of above
- Define an "Efficiency" and compare
- Residues?

Distribution of Track Parameters

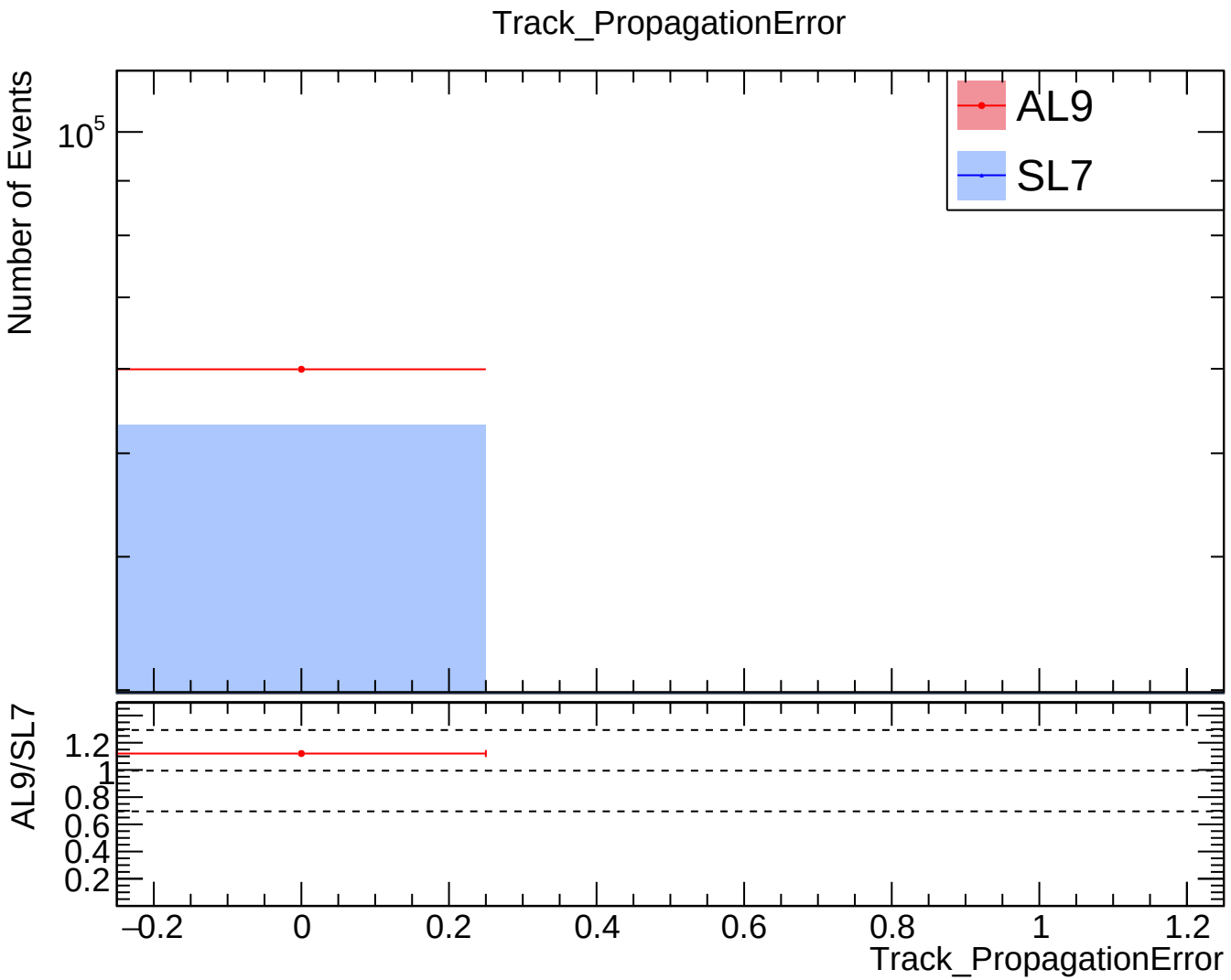
- longTracks
- Track Propagation Error
- Track Chi2
- Track Chi2perDoF
- Track nDoF
- Track charge
- Track nLayers

Distribution of longTracks



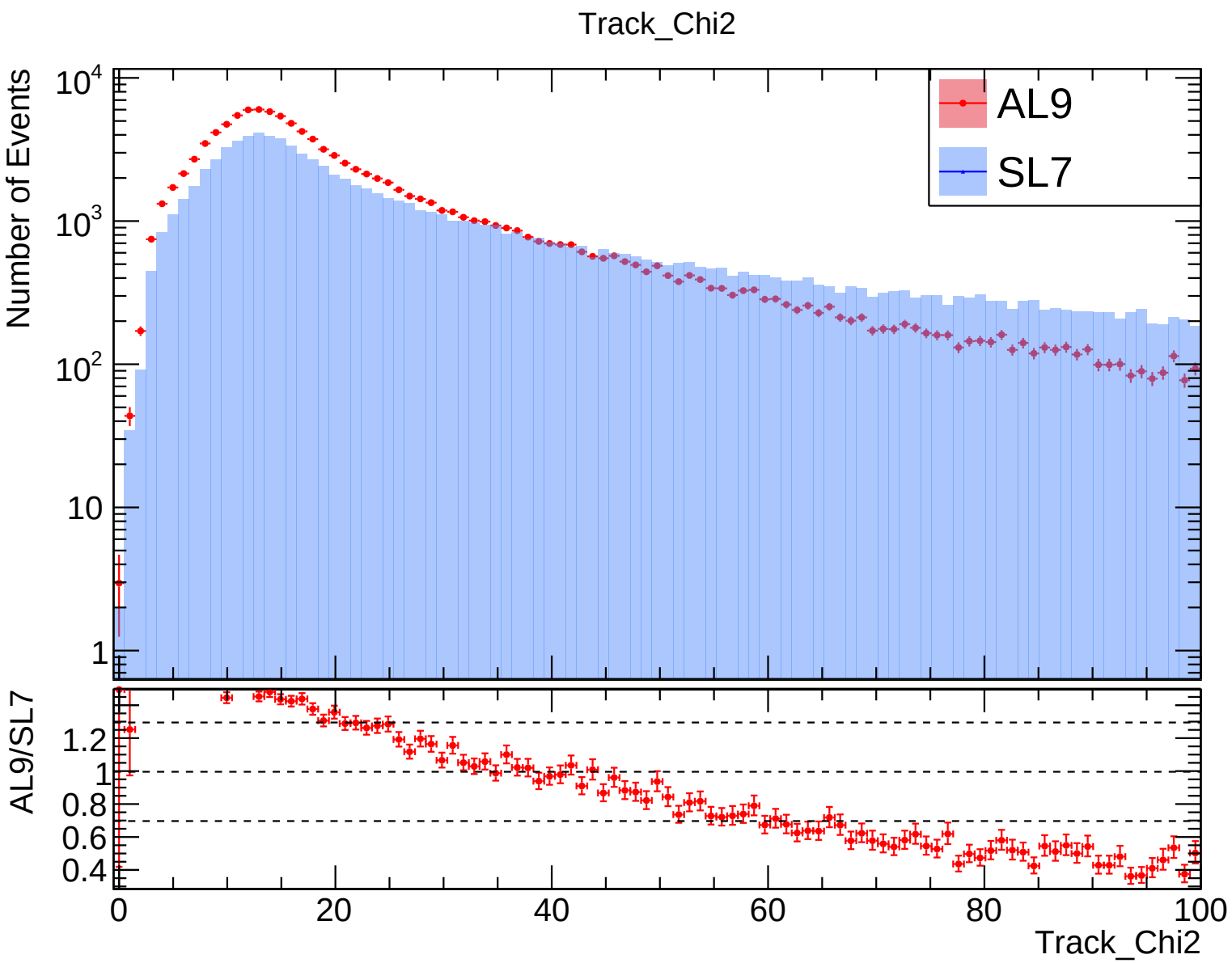
- Overall agreement is good in early bins
- Bin 0 has a drop in AL9
- longTracks 5 shows more discrepancy, Concerning?

Distribution of TrackPropagationError [SKIP]

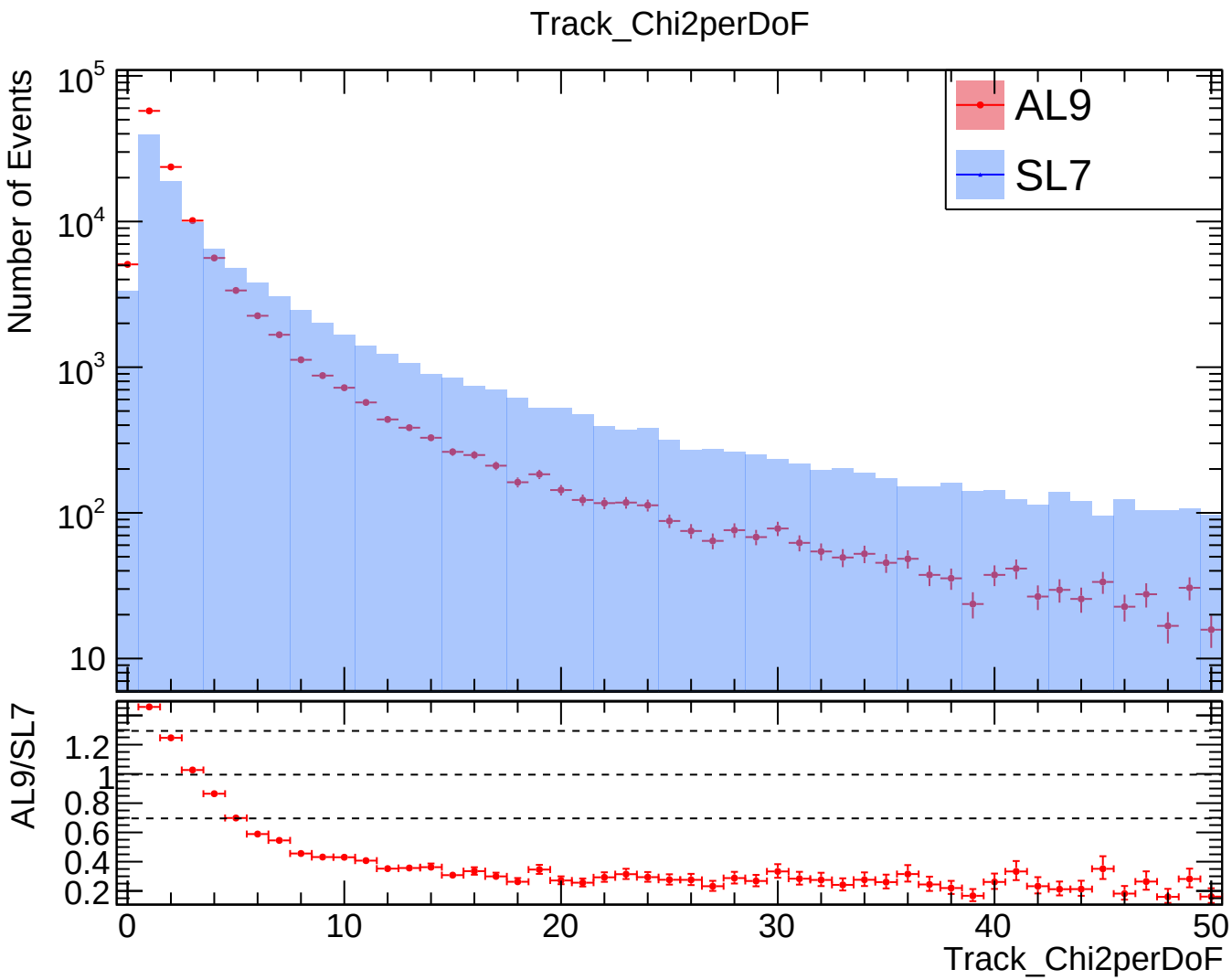


- More TrackPropagationErrors in CENTOS7.

Distribution of TrackChi2

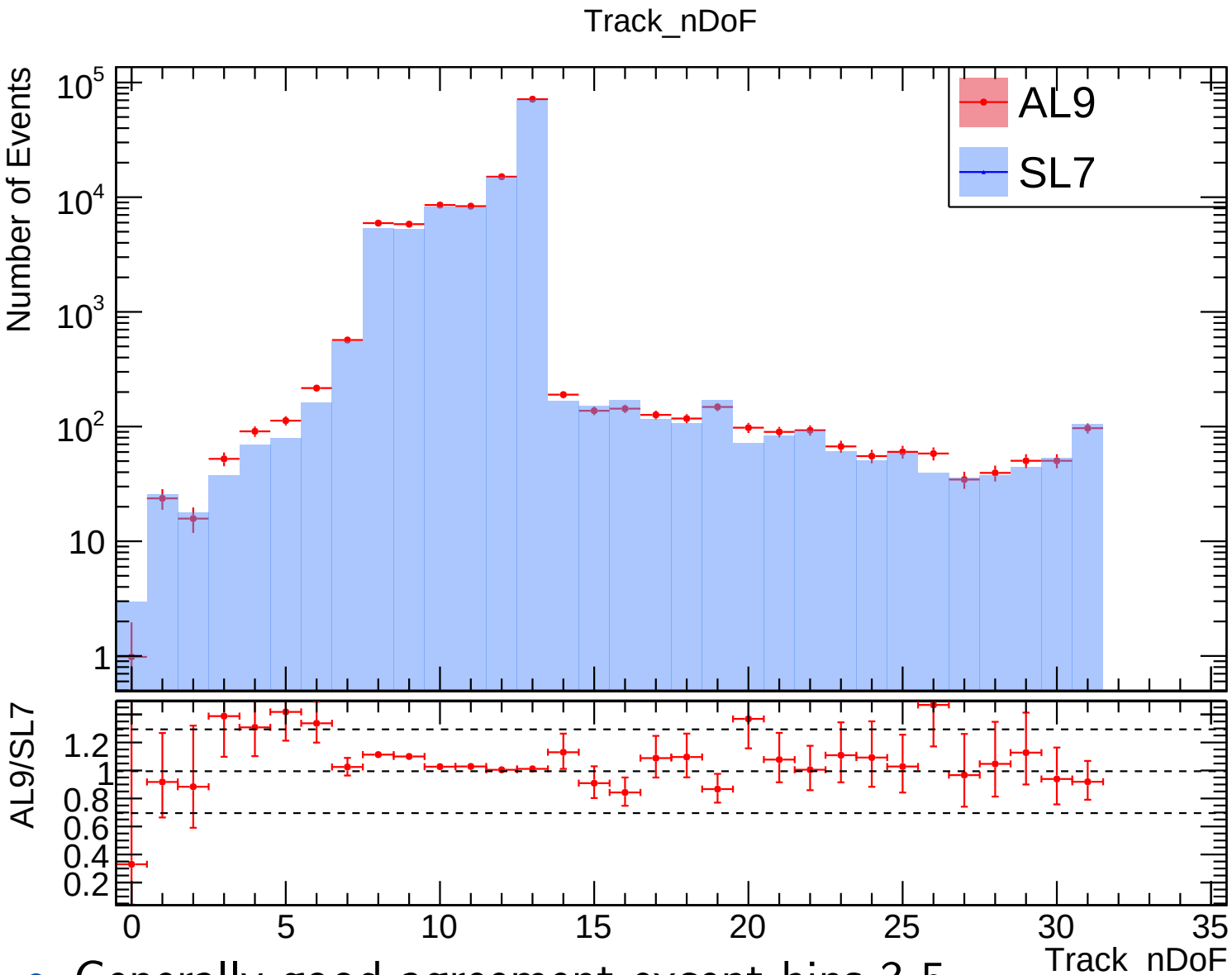


Distribution of TrackChi2perDoF



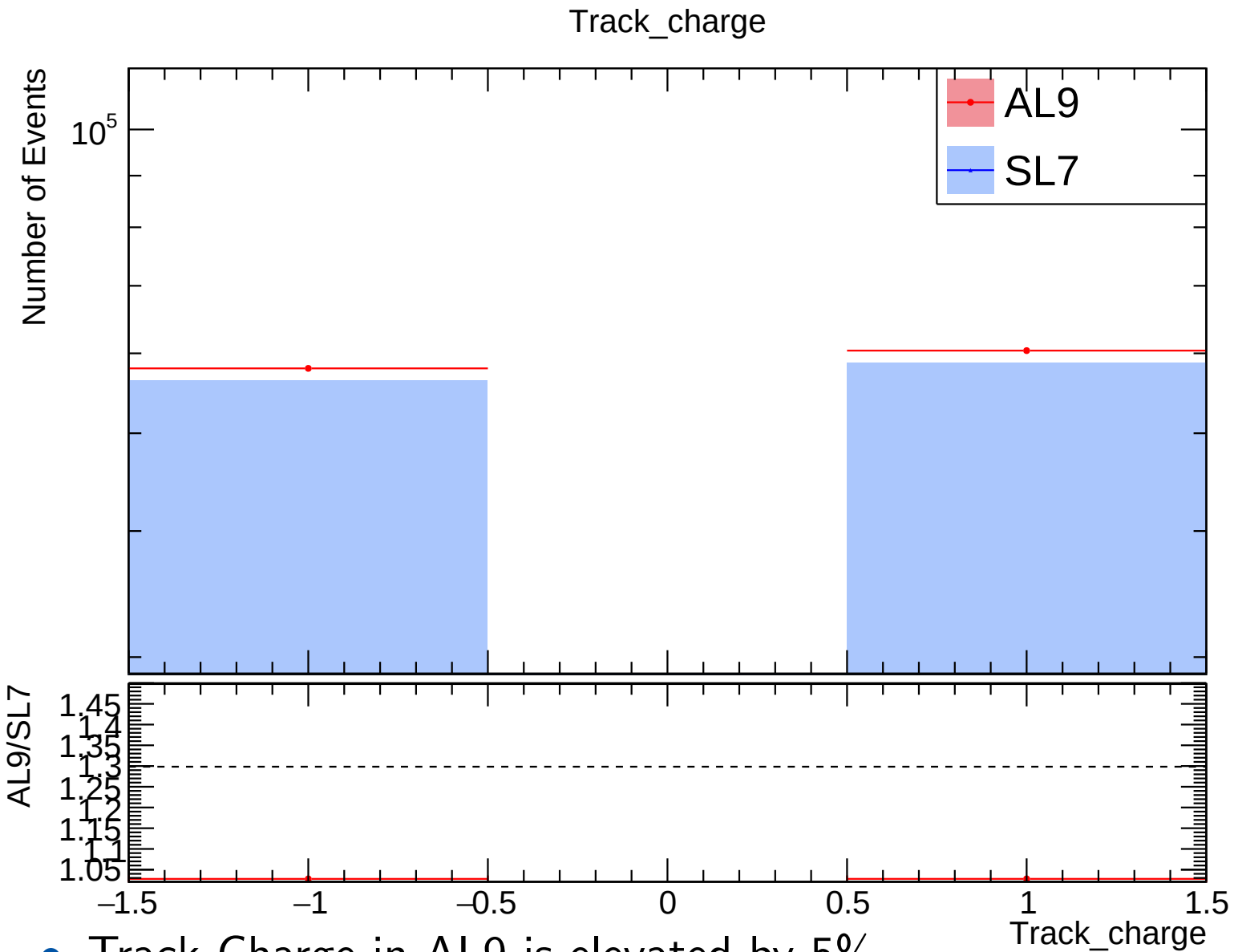
- Shows "most" improvement in ALMA9.
- More events with lower Chi2/DoF and tail is also lower.

Distribution of TrackNDoF



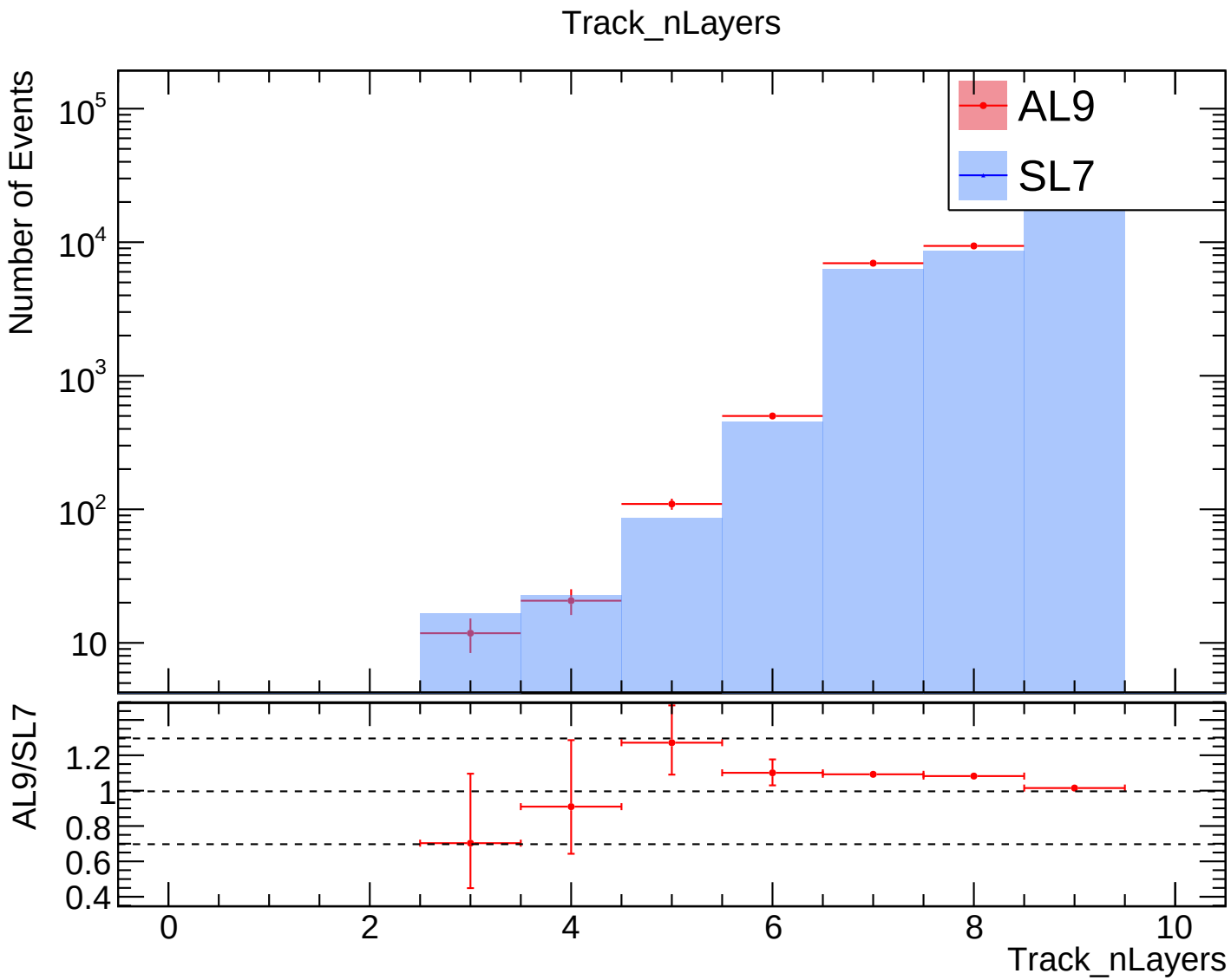
- Generally good agreement except bins 3-5

Distribution of Track Charge



- Track Charge in AL9 is elevated by 5%

Distribution of Track nLayers



- Overall we hit more layers in AL9

Quantifying Separation

Possible Track Separation Variables

- ΔR_0 : Separation between the electron and positron at the first tracking station in the x-y plane
- ΔX_0 : Same as above but only in x direction
- ΔY_0 : Same as above but only in y direction
- θ_0 : Angle between the line connection decay vertex to the two tracks at the first tracking station
- $\Delta R_P = \sqrt{\Delta\eta^2 + \Delta\phi^2}$: Momentum space separation between electron and positron

Position Based Separation variables

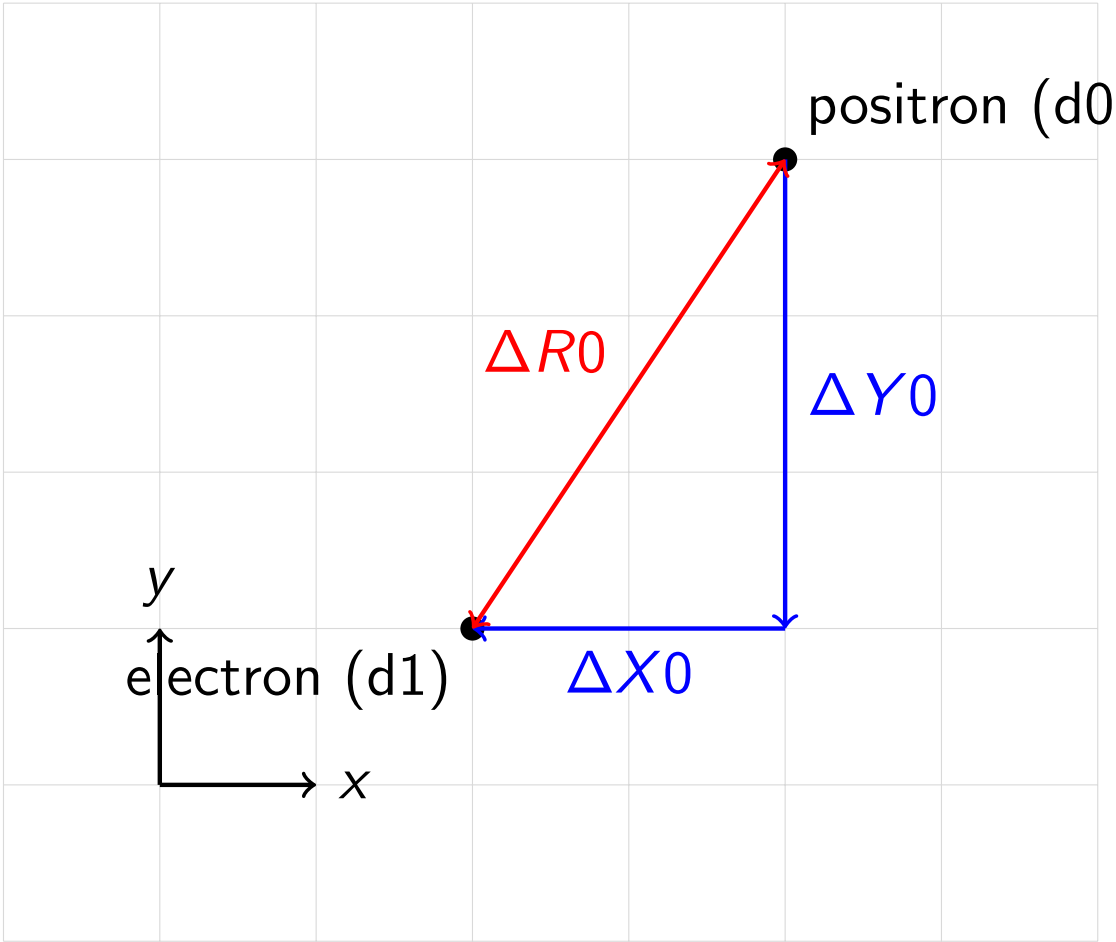


Figure: Tracking Station 1

ADD CODE SNIPPET

Track Separation in terms of Angle

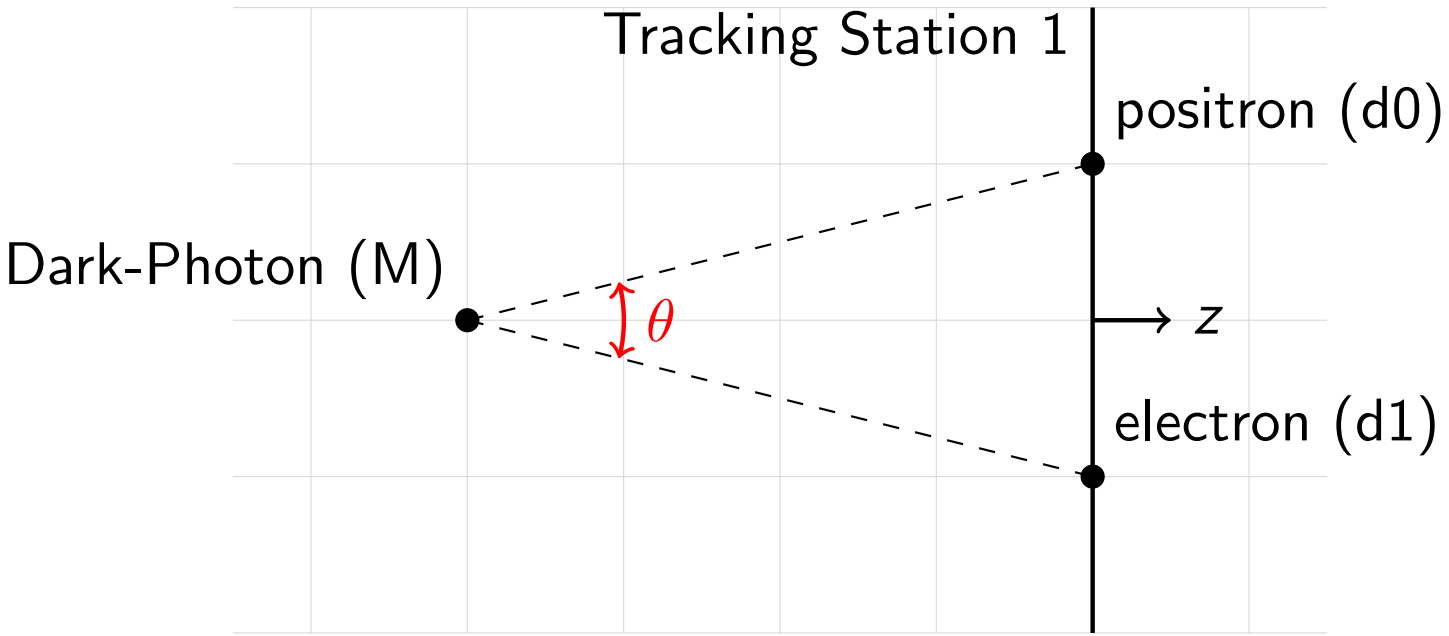


Figure: Angle between Tracks

ADD CODE SNIPPET

Track Separation in η - ϕ Space

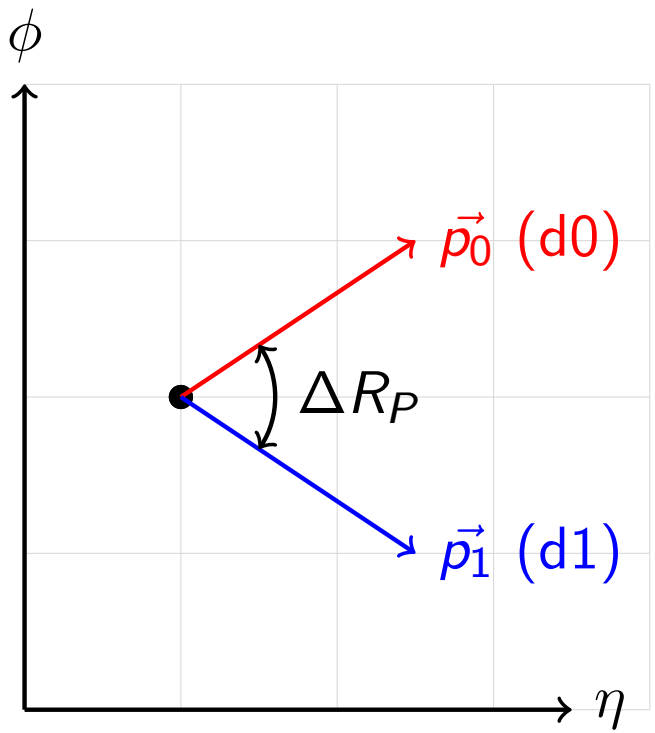
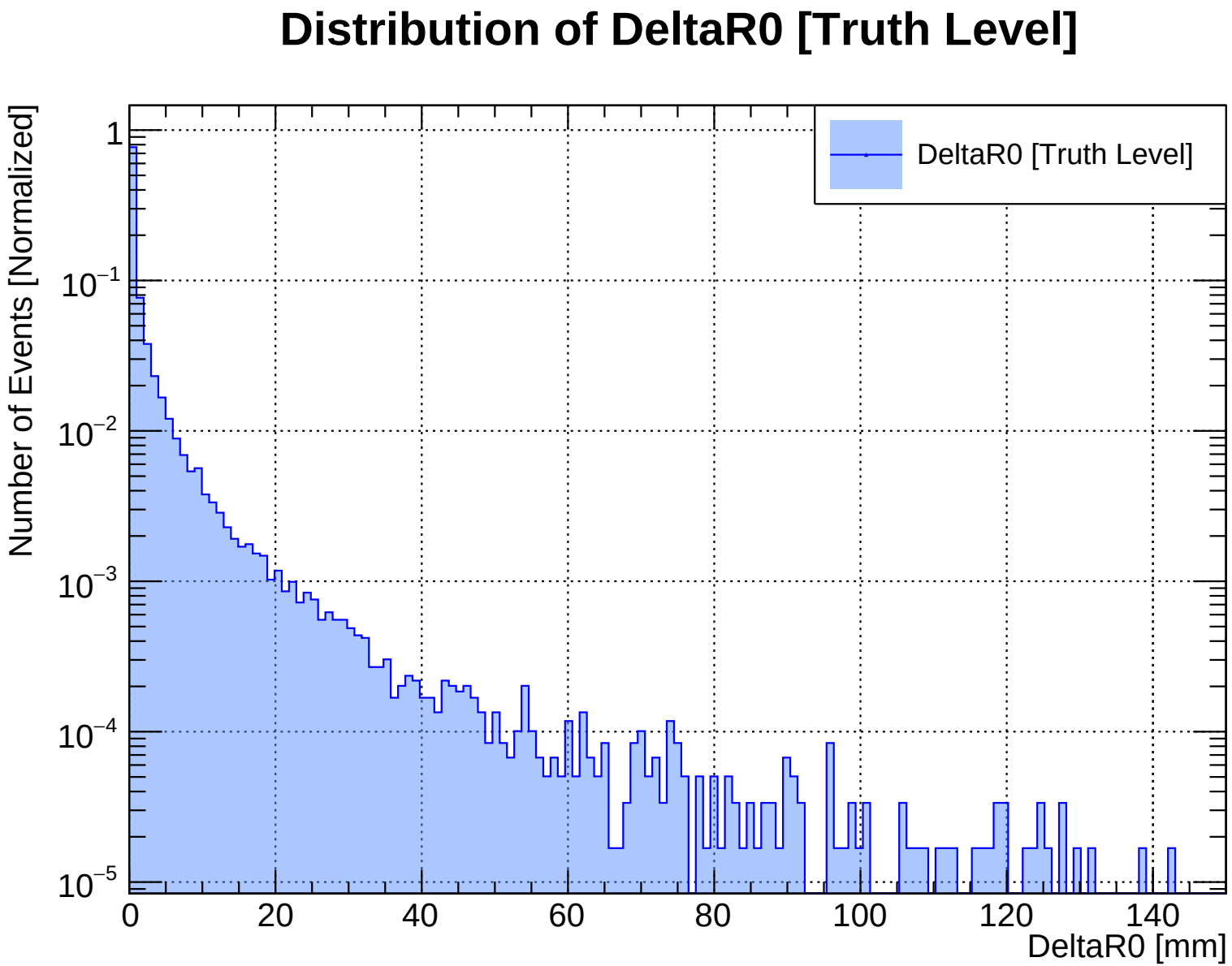


Figure: Angle between Momenta

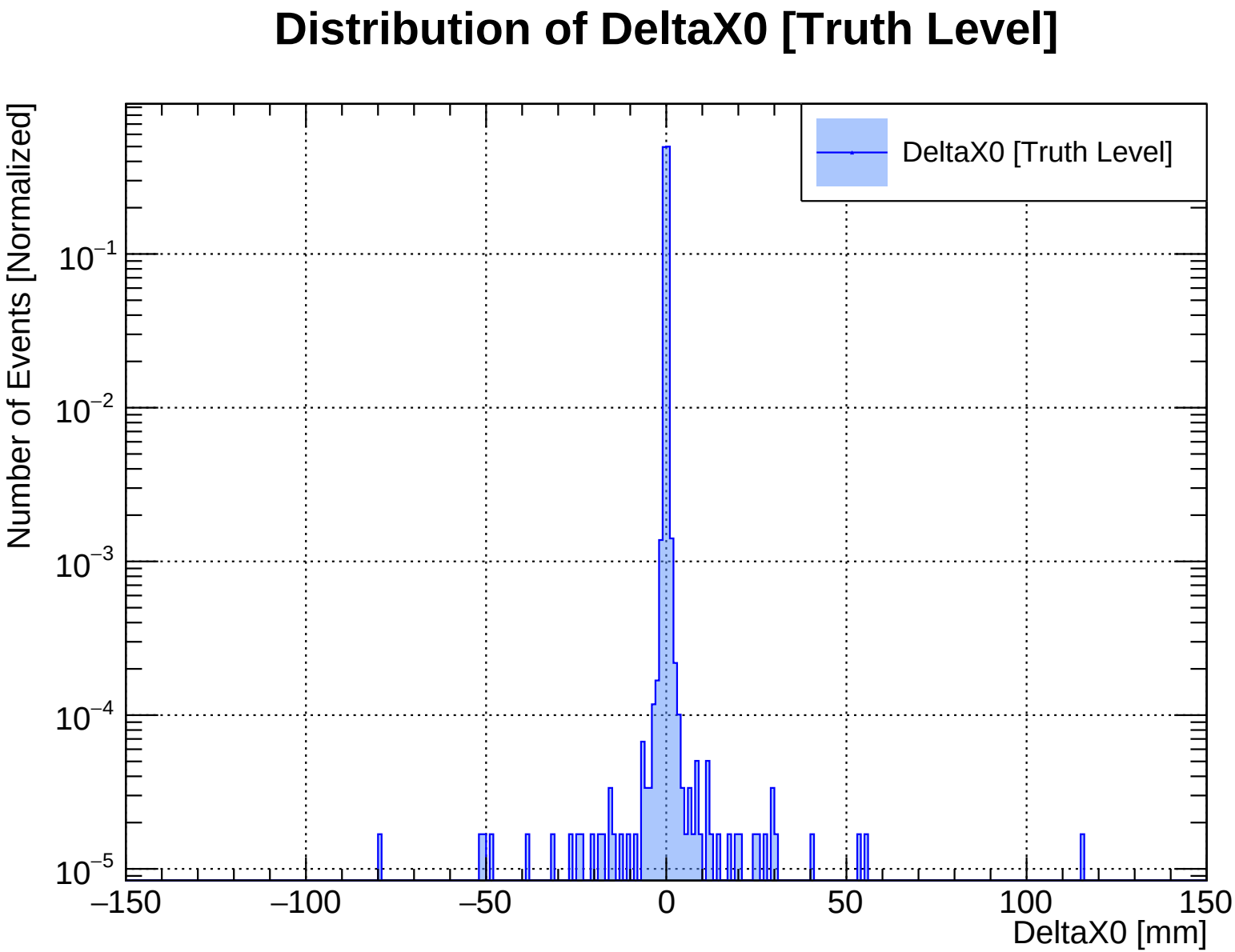
Code Sinppets

TODO: Fix listing here

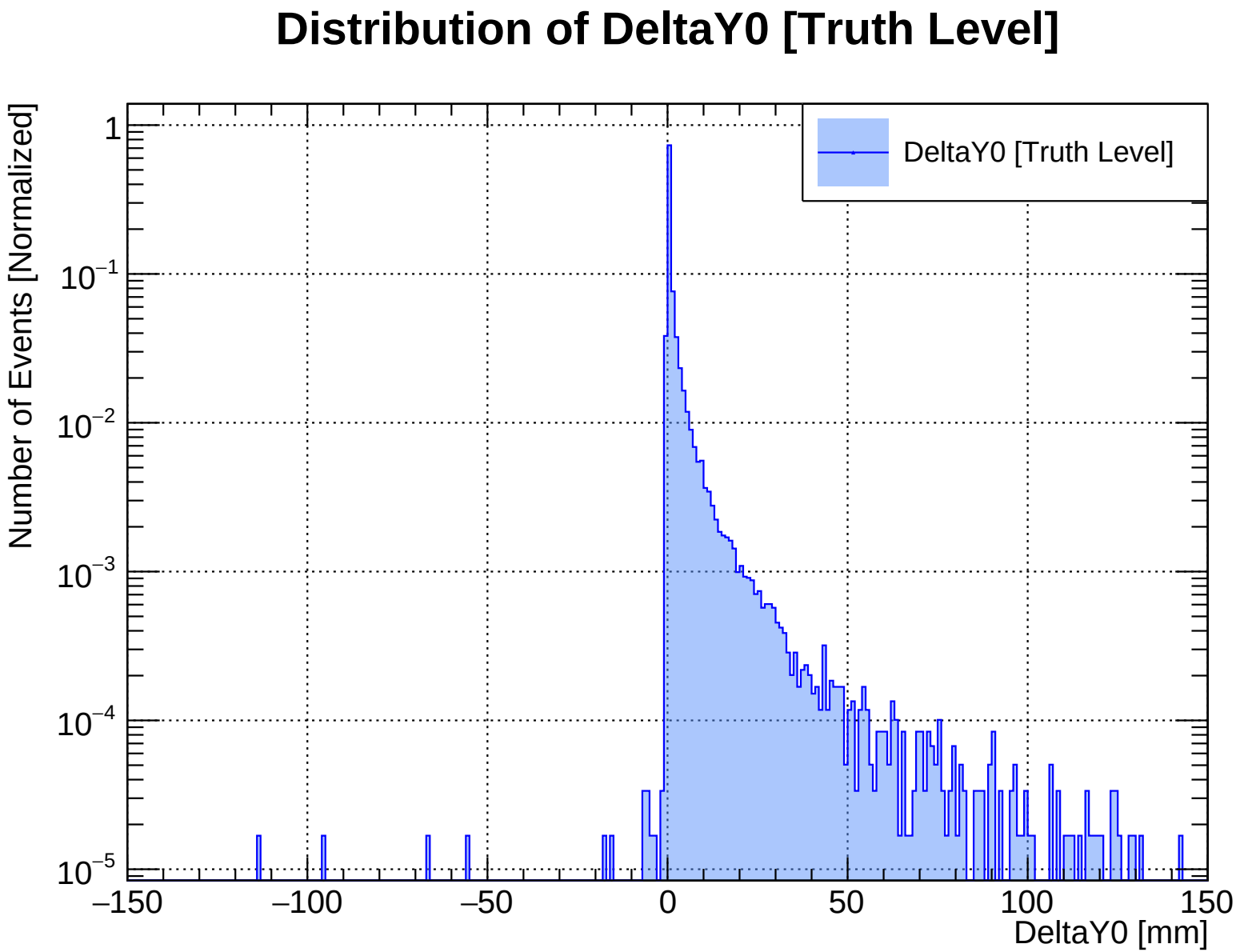
Distribution of DeltaR0



Distribution of DeltaX0



Distribution of DeltaY0



Comments on Position Based Separation

- Particle predominantly separated in the y-direction
  - Comes from the magentic field's deflection
  - Positron deflected upwards, electron downwards leading asymmetry in DeltaY0 plot
  - DeltaX0 looks symmetric
  - DeltaY0 can be approximated to DeltaR0
- In general Nevents fall off as sepration increases [characteristic of DP Decay?]
- Similar features seen in overlay plot but different in scale
- We can just look at the distributions using DeltaR0 as our primary variable for position based separation.

Overlay Plot

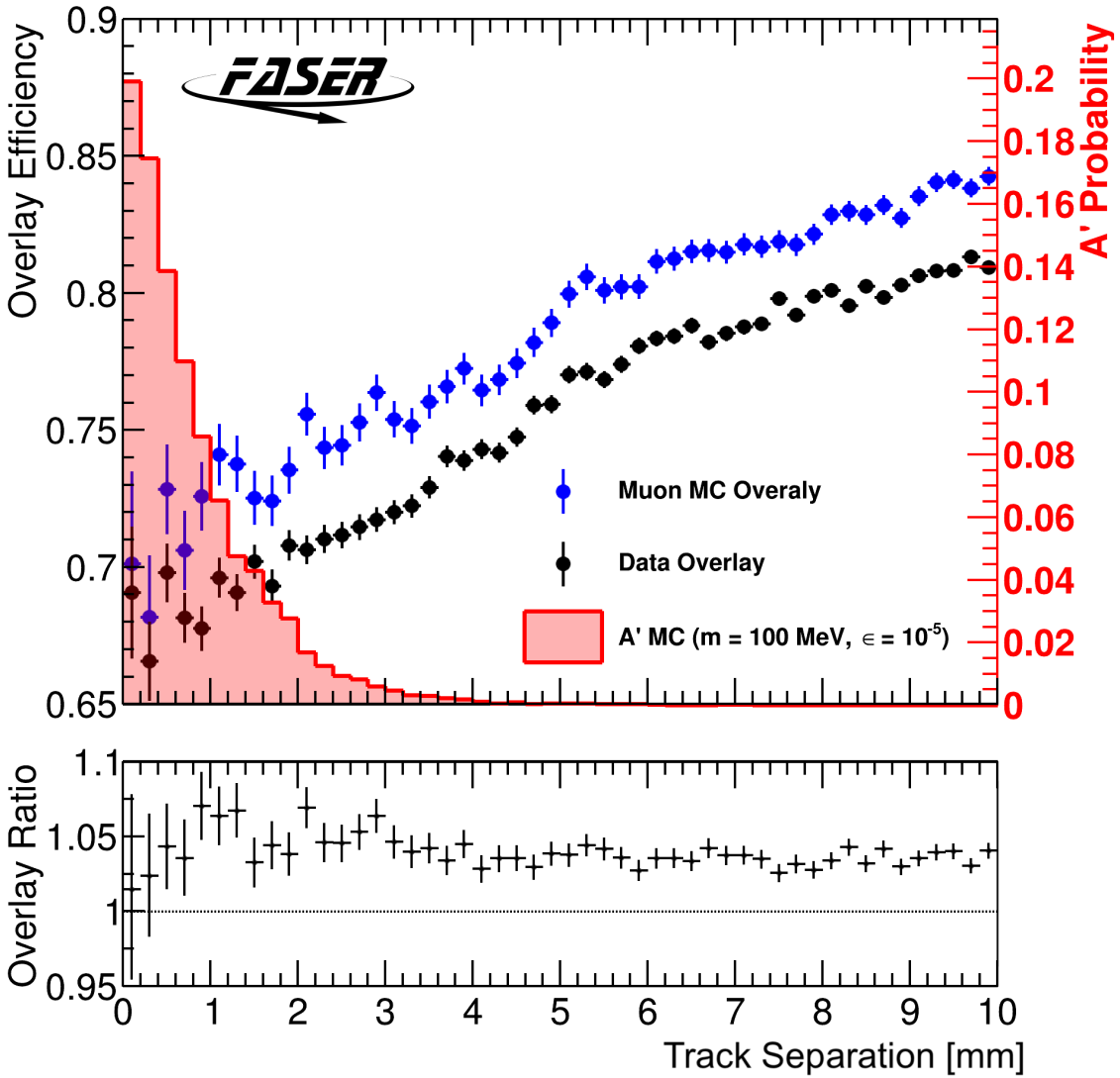
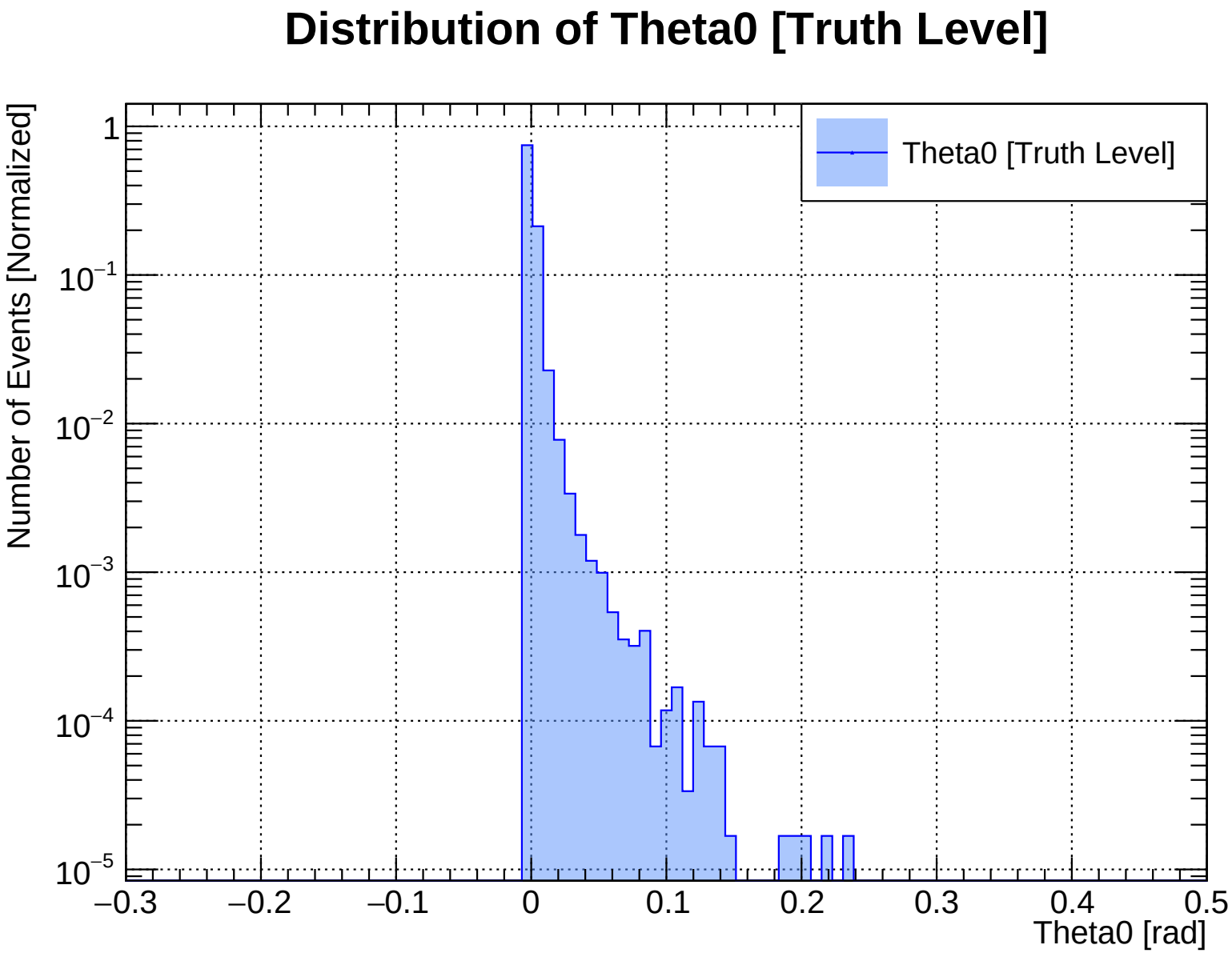
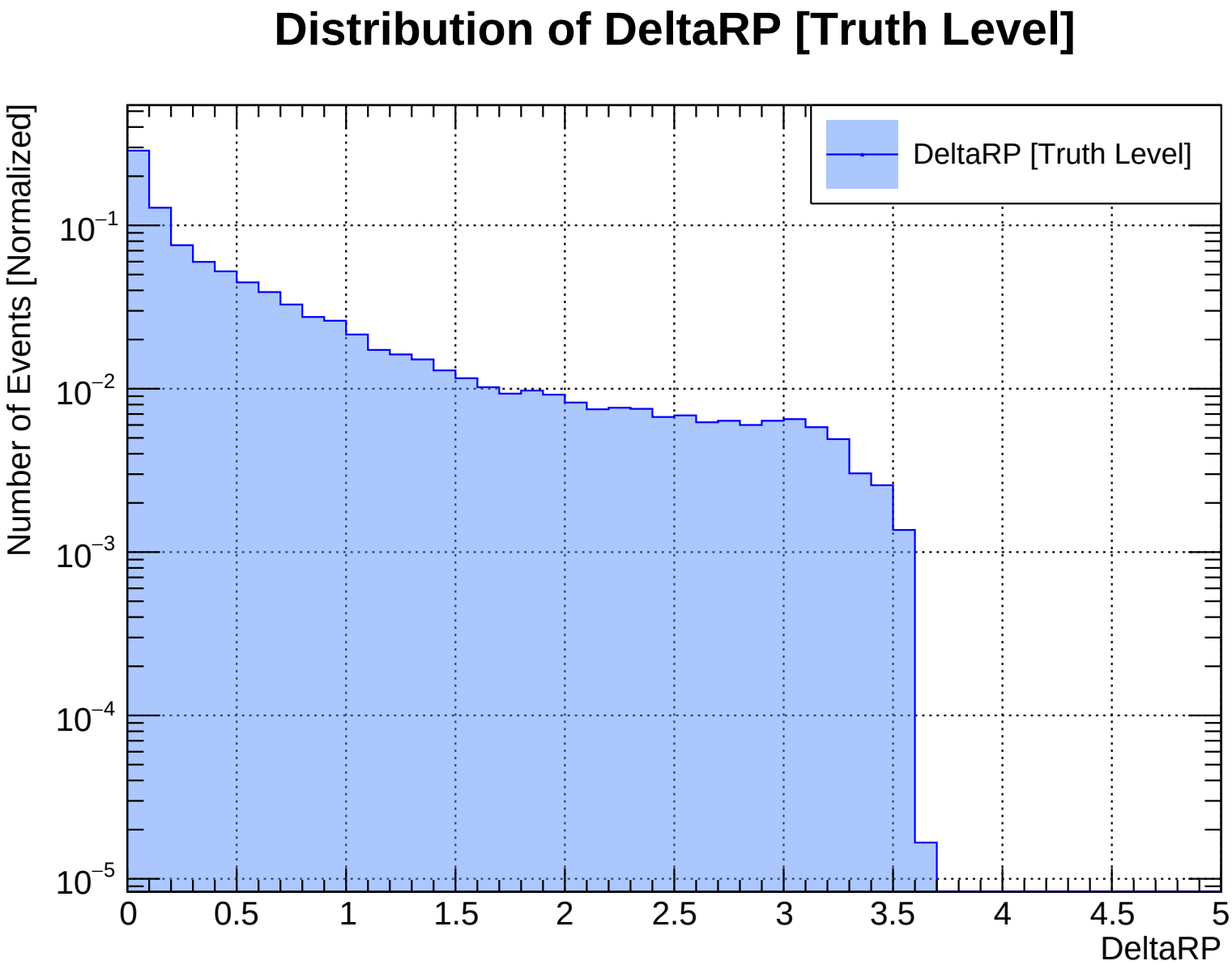


Figure: Overlay plot from Search for dark photons with the FASER detector at the LHC

Distribution of Theta0



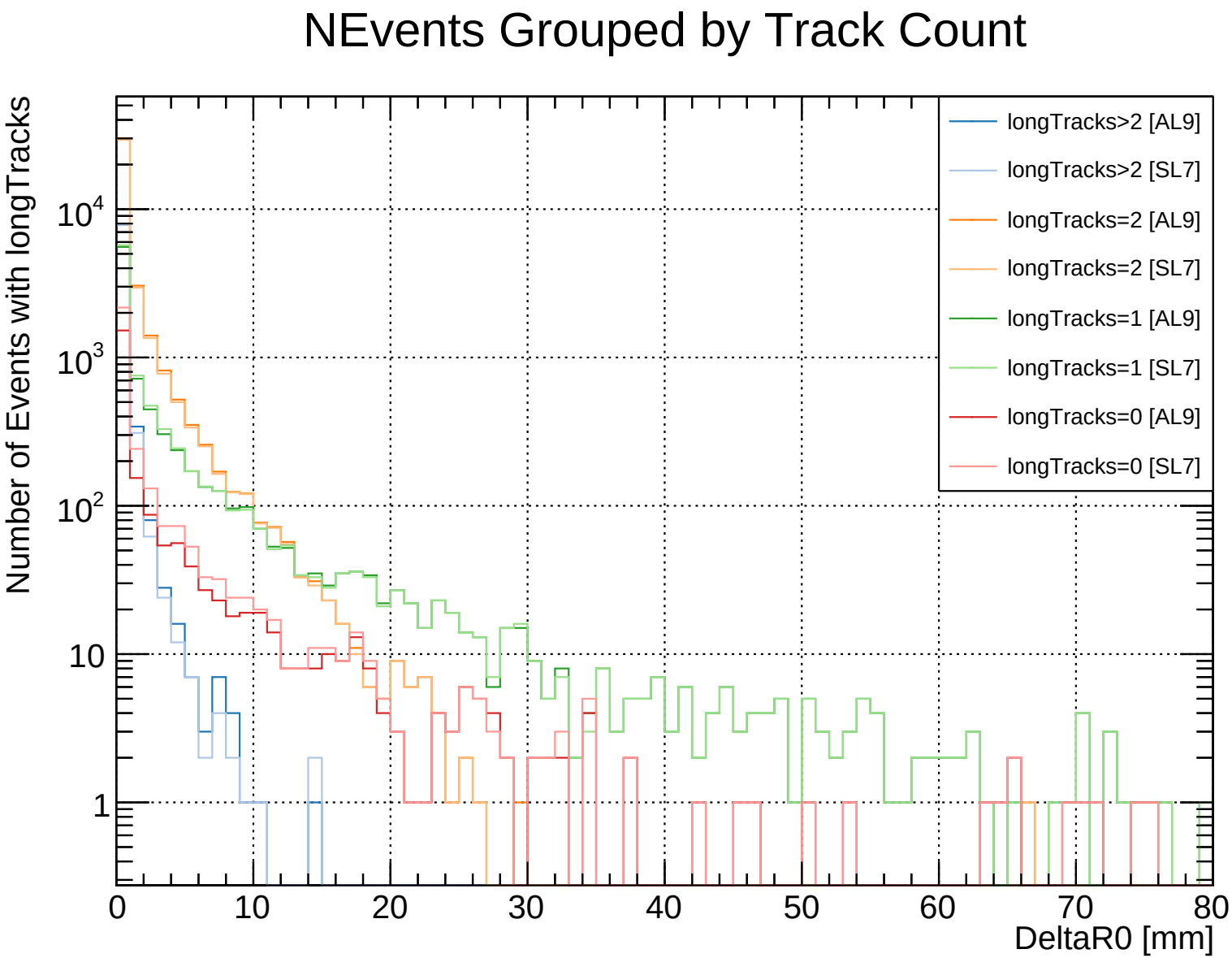
Distribution of DeltaRP



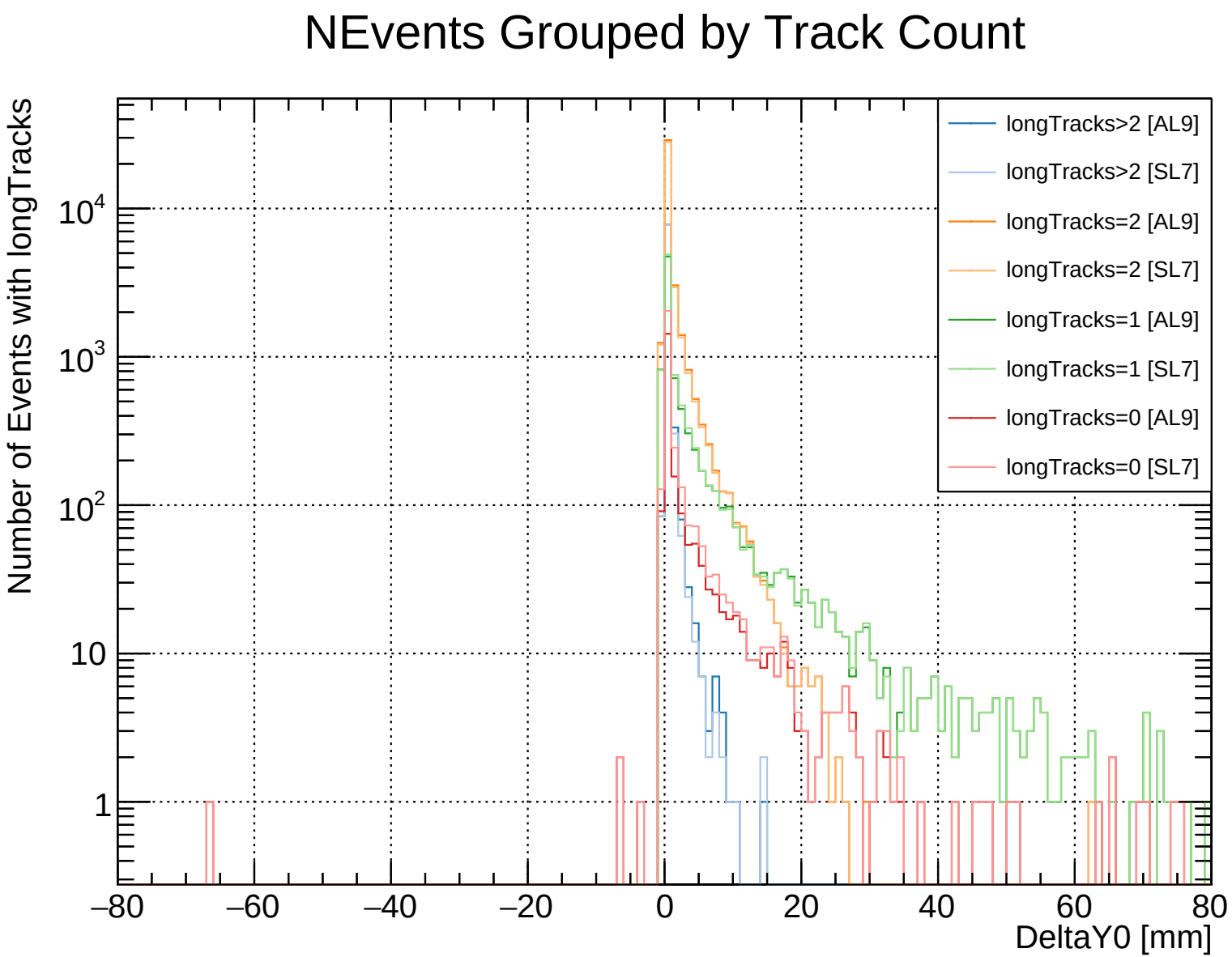
Comments on Angle Based Separation

- Theta0 is a variable to separate the tracks but falls off reapidly
- DeltaRP shows a relatively flat distribution
- To calculate the separation variables the MC level information is used
  - Same across AL9 and CENTOS7
  - More robust
  - No uncertainity from the tracking itself

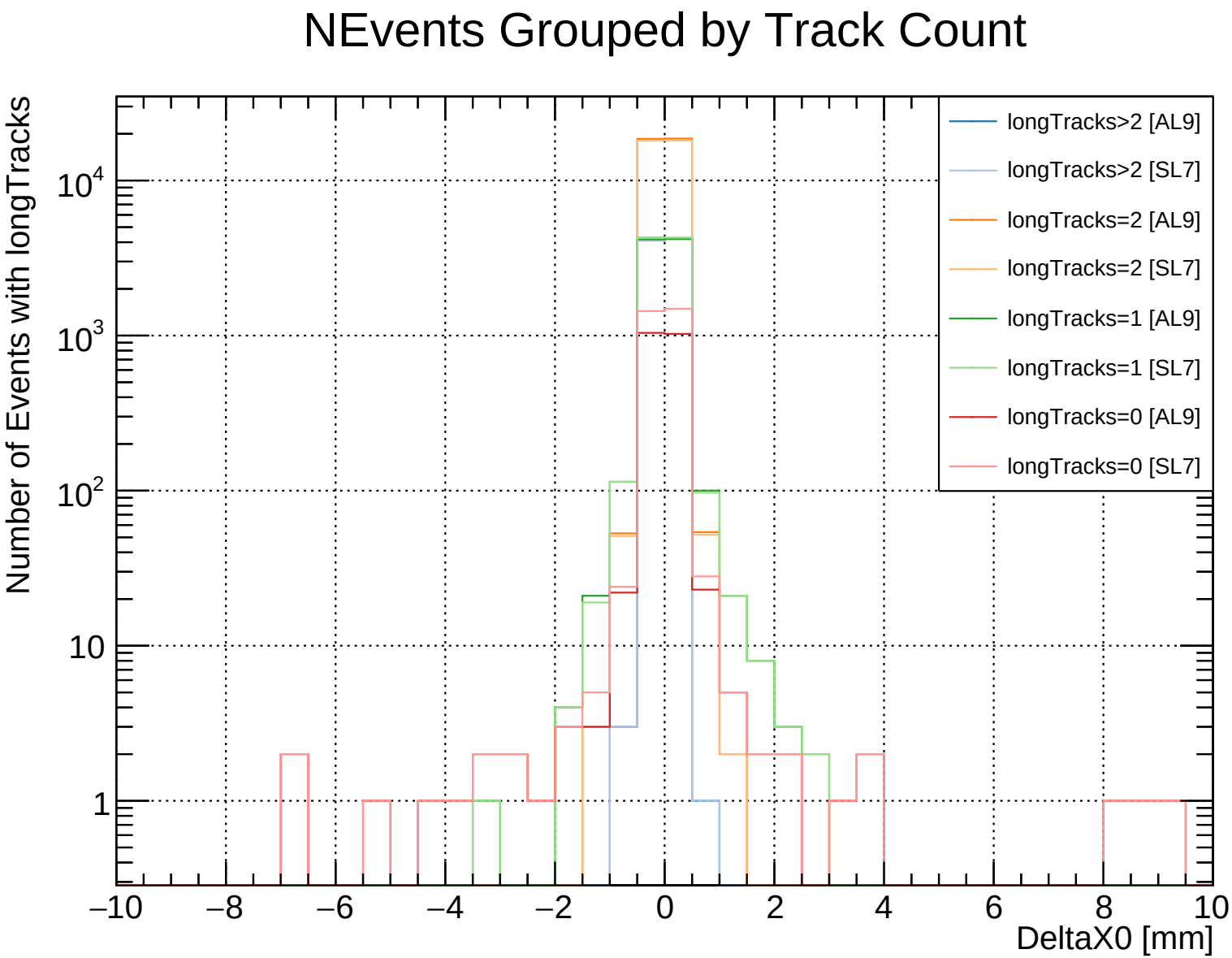
Events grouped by longTracks vs DeltaR0



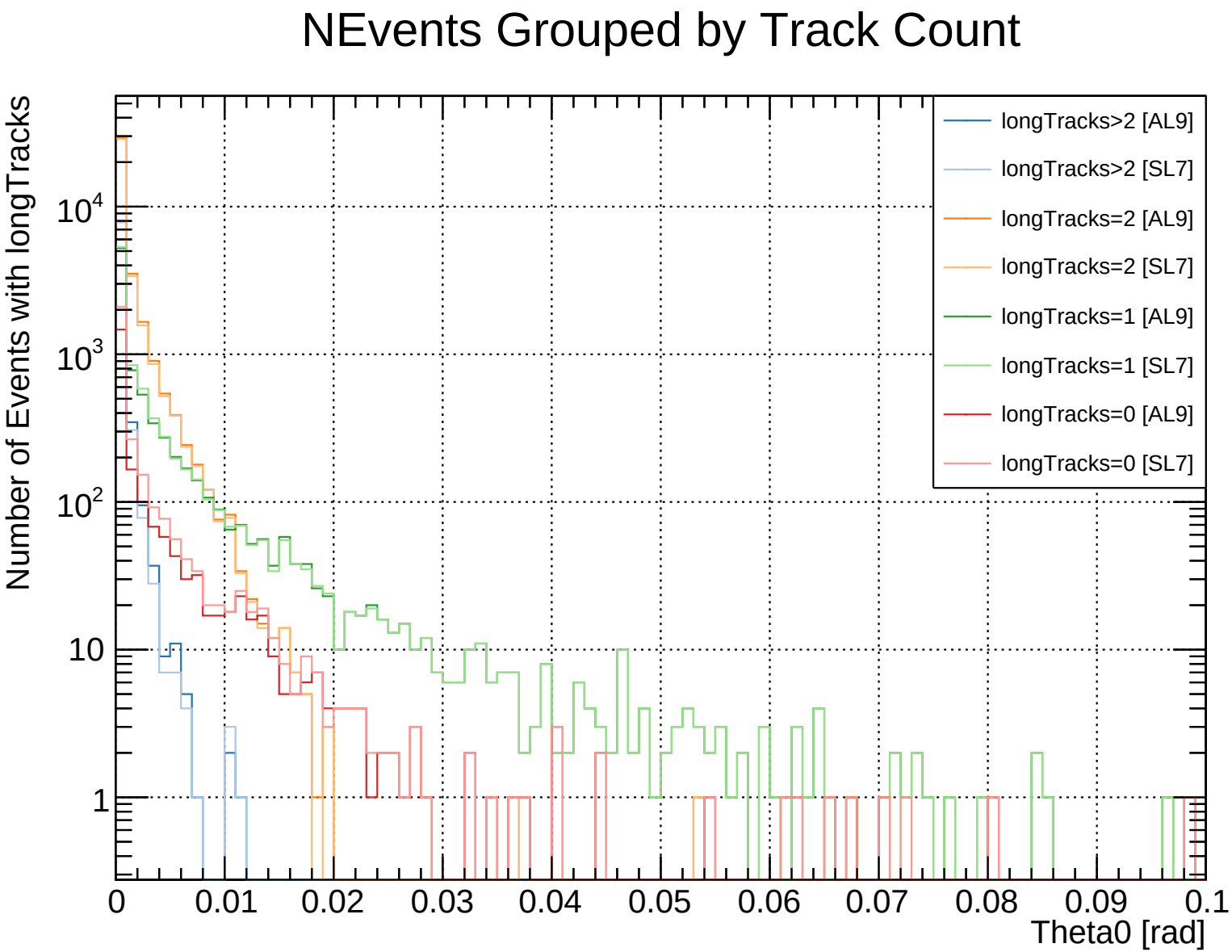
Events grouped by longTracks vs DeltaY0 [SKIP]



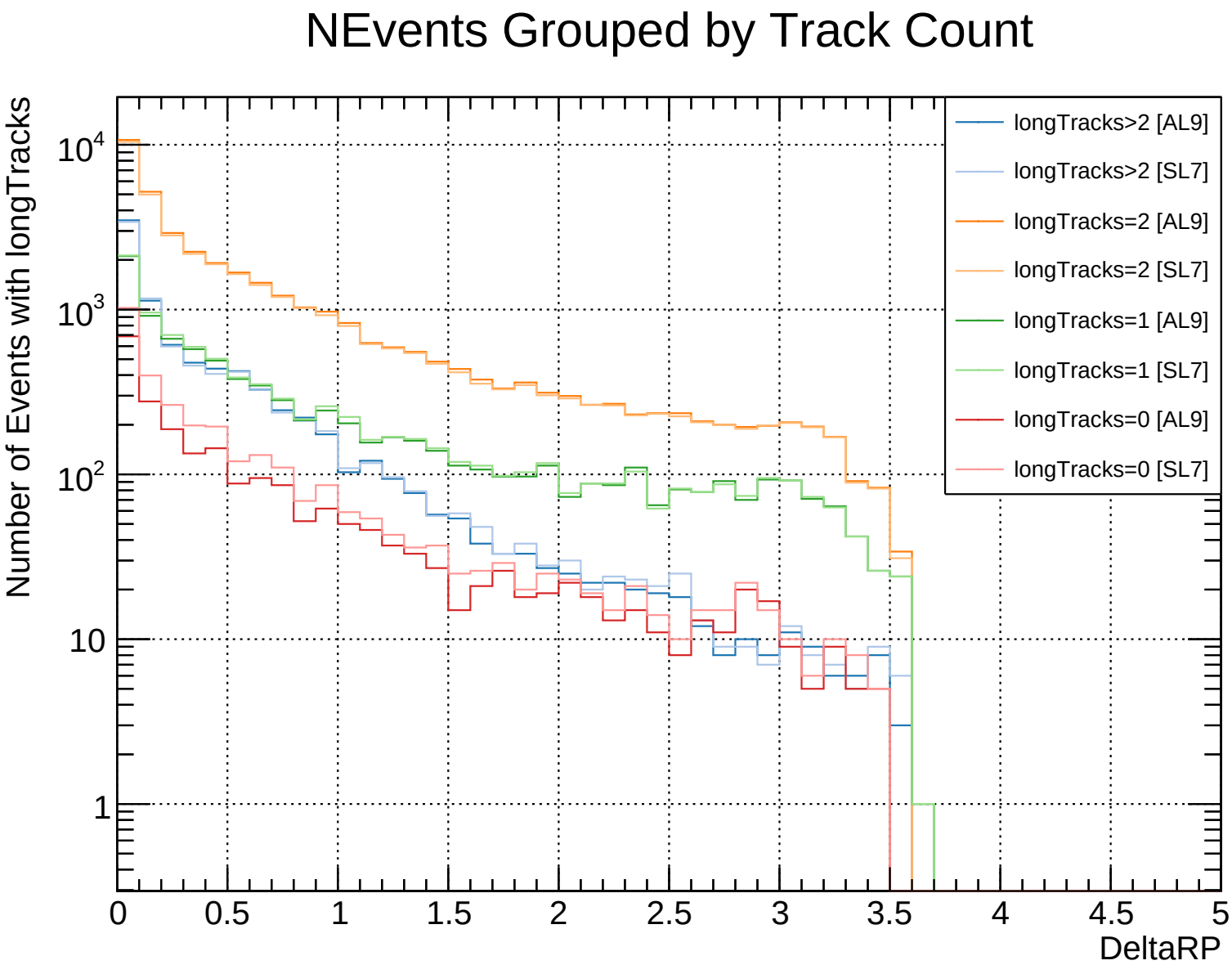
Events grouped by longTracks vs DeltaX0 [SKIP]



Events grouped by longTracks vs Theta0



Events grouped by longTracks vs DeltaRP



Comments on longTrack grouped Plots

- Good agreement between ALMA9 and CENTOS7
- Events with > 2 longTrack fall most rapidly [nothing past 10 mm]
- $= 2$ longTracks decay less rapidly [nothing past 30 mm]
- $= 1$ longTracks is relatively flat
- $= 0$ same as above - Not sure how to interpret
- In the plots where longTracks ≤ 1 AL9 performs bad at low separation
- Maybe logscale in x?

Definition of Efficiency Metrics

In General

- One Track Event $\Longrightarrow$ NOT reconstructed
- Two Track event + Opposite charges $\Longrightarrow$ reconstructed
- More than two track $\Longrightarrow$ complicated

Some Possible Eff. Metrics

- Number of Events with ≥ 2 longTracks [good proxy]
- (Can add charge identification to above but not necessary)
- MC Based Effi. [matching reconstructed to truth level data]

Definition of Fiducial

Before we define the efficiency we need to account for the detector acceptance by requiring the particle to be Fiducial.

Based on reconstructed data [Adapted from Sinead]

- Requires $longTracks == 2$
- $Track_r_atMaxRadius < 100$
- $t_st\{1,2,3\}_r < 100$

Based on truth level data

- $truthd0_r[\{1,2,3\}] < 100$
- $truthd1_r[\{1,2,3\}] < 100$
- Does not need the 2track cut while maintaining that particles of interest were Fiducial, While also being independent of ALMA9 or CENTOS7

Note:

- Where are NaNs coming from at the truth-level?

How do Fiducial Cuts perform?

Selection Step	Pass	All	Effi. (%)	Cum. Effi. (%)
2LongTracks	37807	60000	63.01	63.01
Opposite Charge	32427	37807	85.77	54.04
MaxRadius < 100	31489	32427	97.11	52.48
$t_st1_r < 100$	31471	31489	99.94	52.45
$t_st2_r < 100$	31458	31471	99.96	52.43
$t_st3_r < 100$	31383	31458	99.76	52.31

Table: Efficiencies and cumulative efficiencies at various selection steps. [ALMA9]

Selection Step	Pass	All	Effi. (%)	Cum. Effi. (%)
2LongTracks	36746	60000	61.24	61.24
Opposite Charge	30375	36746	82.66	50.62
MaxRadius < 100	29520	30375	97.19	49.20
$t_st1_r < 100$	29498	29520	99.93	49.16
$t_st2_r < 100$	29491	29498	99.98	49.15
$t_st3_r < 100$	29415	29491	99.74	49.03

Table: Efficiencies and cumulative efficiencies at various selection steps.[CENTOS7]

- ALMA9 performs better over most of the cuts.
- Using this fiducial cuts throws out 50% of the data.

Cuts. Contd.

Selection Step	Pass	All	Effi. (%)	Cum. Effi. (%)
truthd{0,1}_st1_r $<$ 100	59634	60000	99.39	99.39
truthd{0,1}_st2_r $<$ 100	58429	59634	97.98	97.38
truthd{0,1}_st3_r $<$ 100	56703	58429	97.05	94.50

Table: Efficiencies and cumulative efficiencies for truth-level selection steps. [same for ALMA9/CENTOS7]

truthd_st1_r =

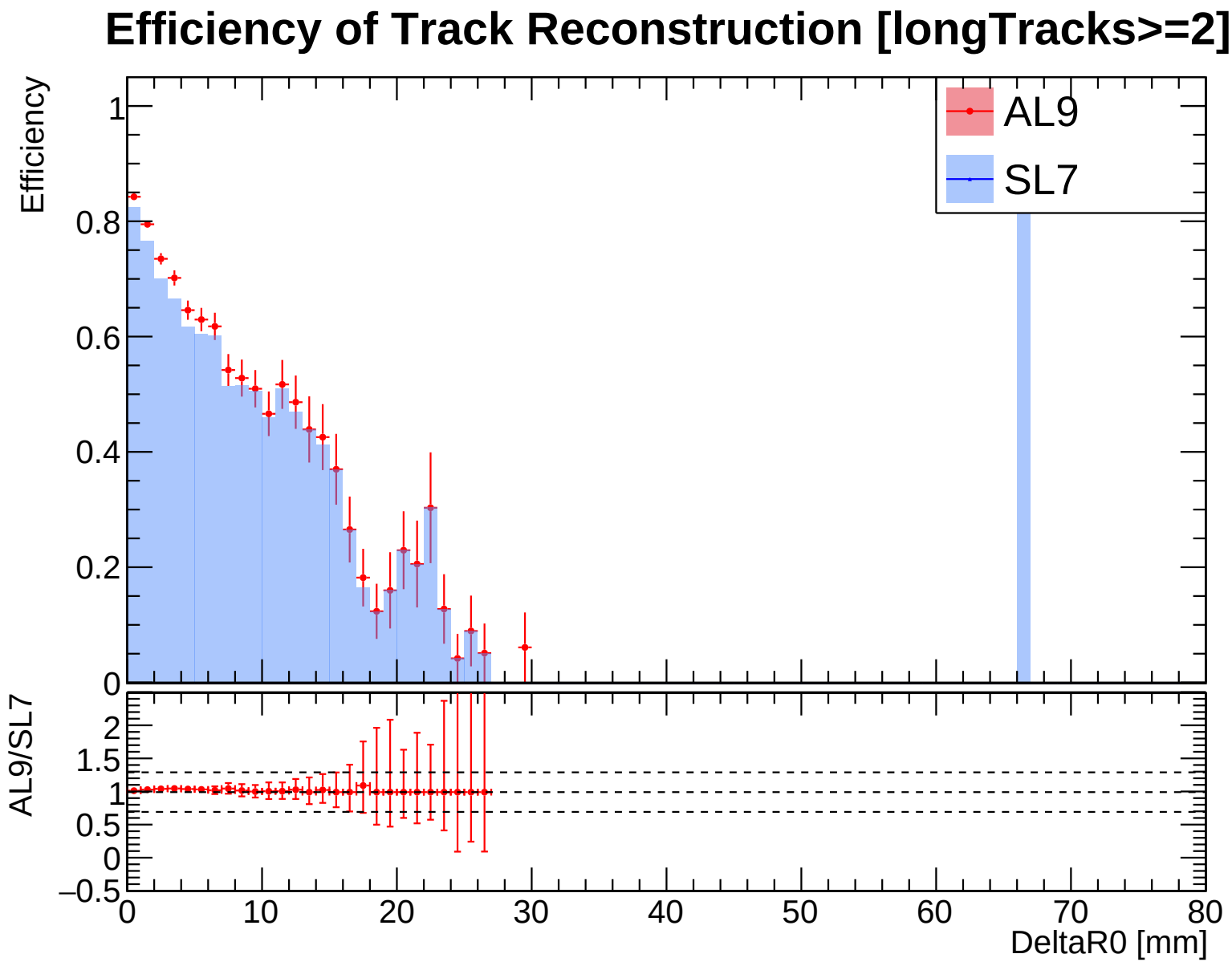
sqrt(pow(truthd0_x[1],2) + pow(truthd0_y[1],2)) $>$ 100 &&
sqrt(pow(truthd1_x[1],2) + pow(truthd1_y[1],2))

Efficiency Definition

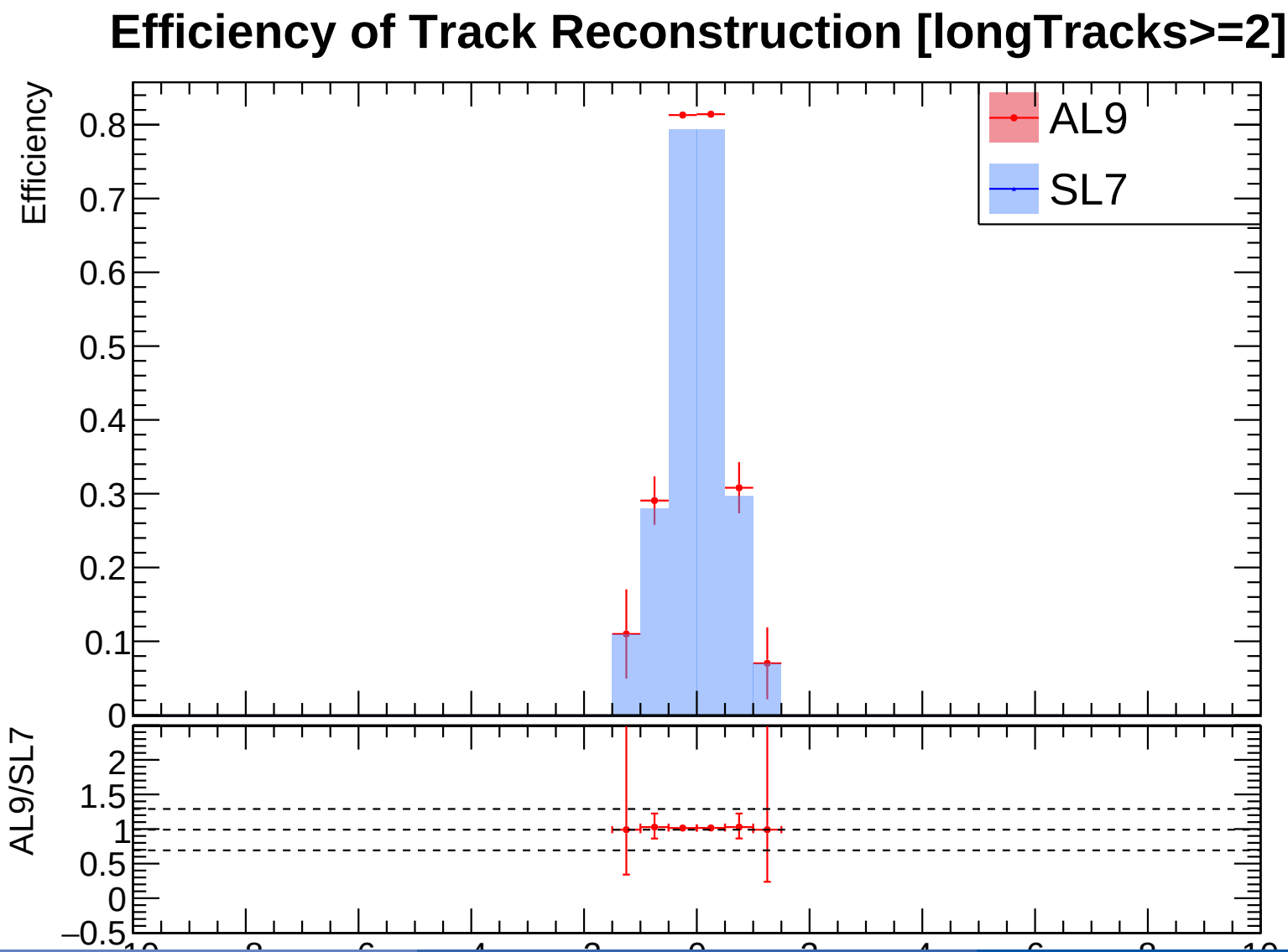
- Remove acceptance based on fiducial cuts at truth level
- Define Efficiency as the fraction of events with more than 2 reconstructed longTracks divided by the total number of events.

$$\text{Efficiency} = \frac{\text{NEvents}(\geq 2\text{longTracks})}{\text{NEvents}(\text{Total})}$$

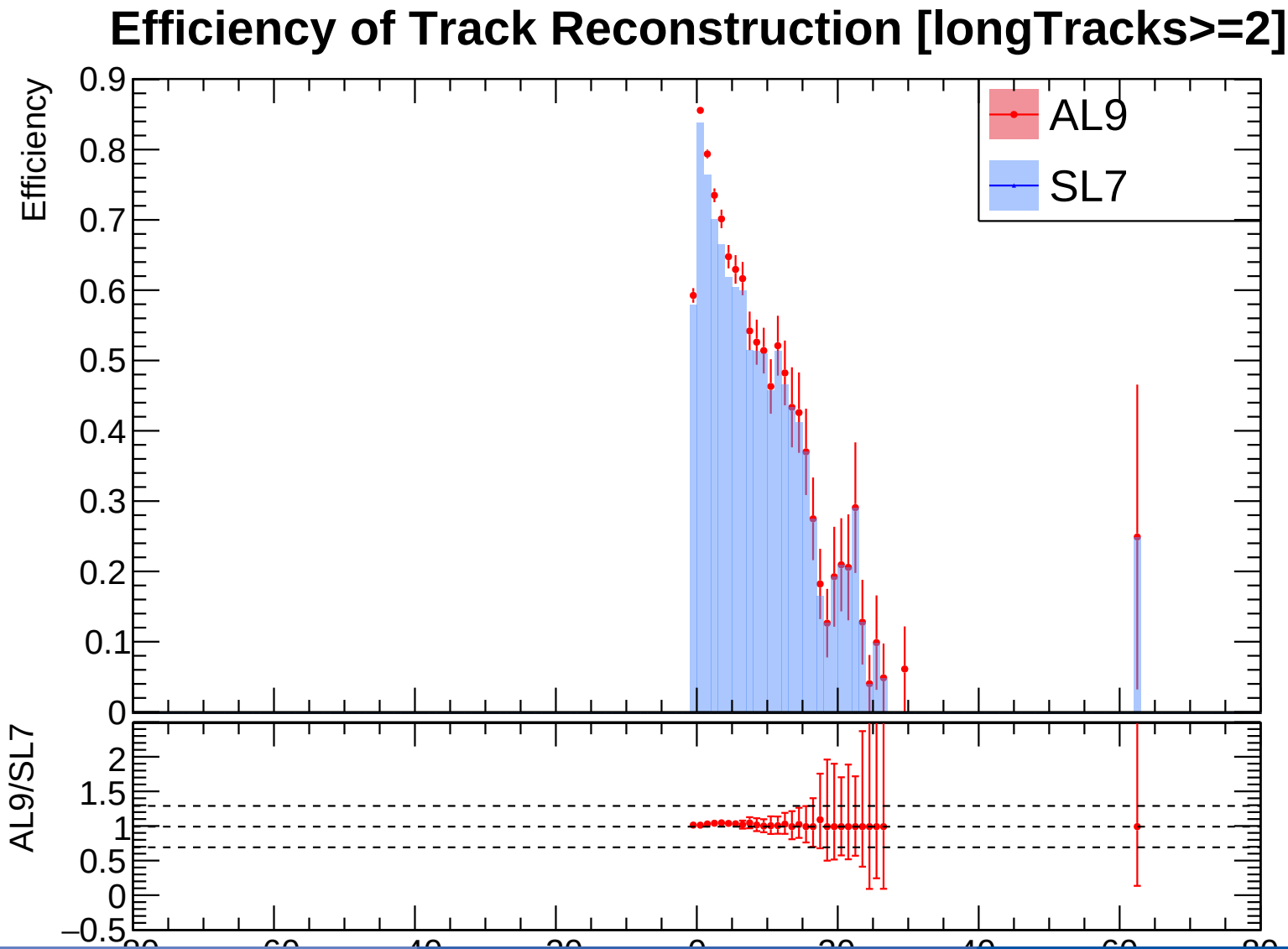
>= 2 Track Efficiency as a function of DeltaR0



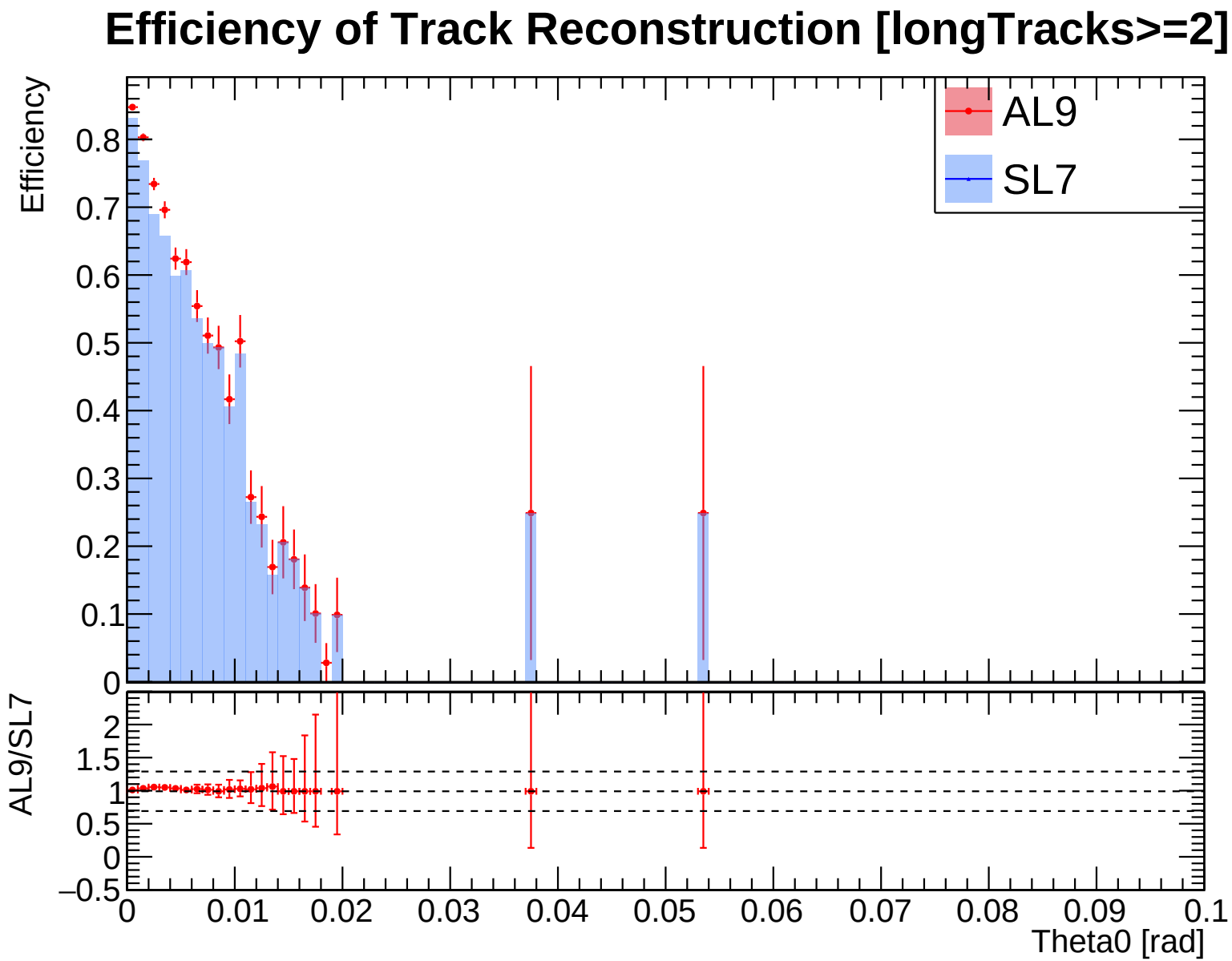
>= 2 Track Efficiency as a function of DeltaX0 [SKIP]



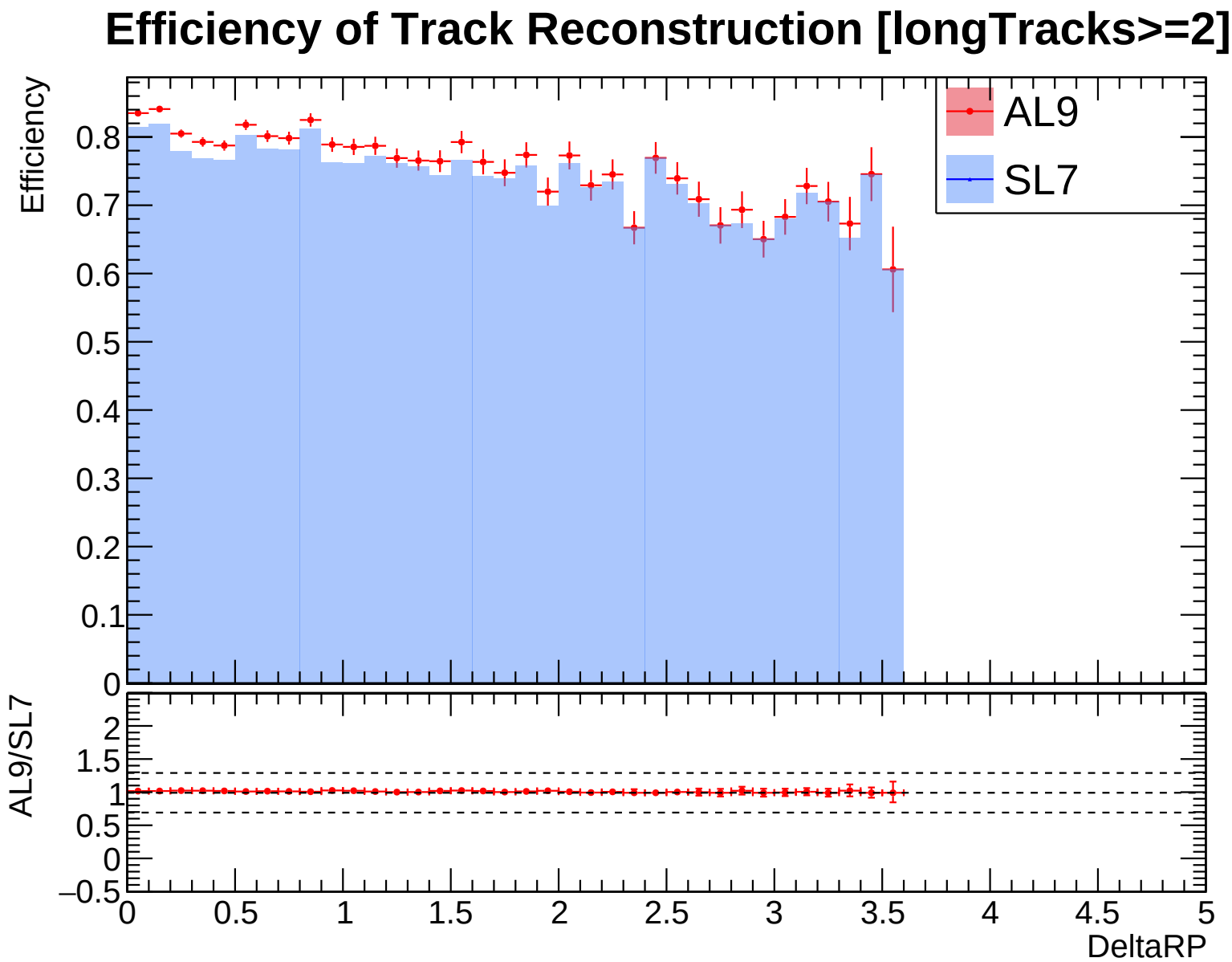
>= 2 Track Efficiency as a function of DeltaY0 [SKIP]



>= 2 Track Efficiency as a function of Theta0



>= 2 Track Efficiency as a function of DeltaRP



Comments on >2Track Efficiency

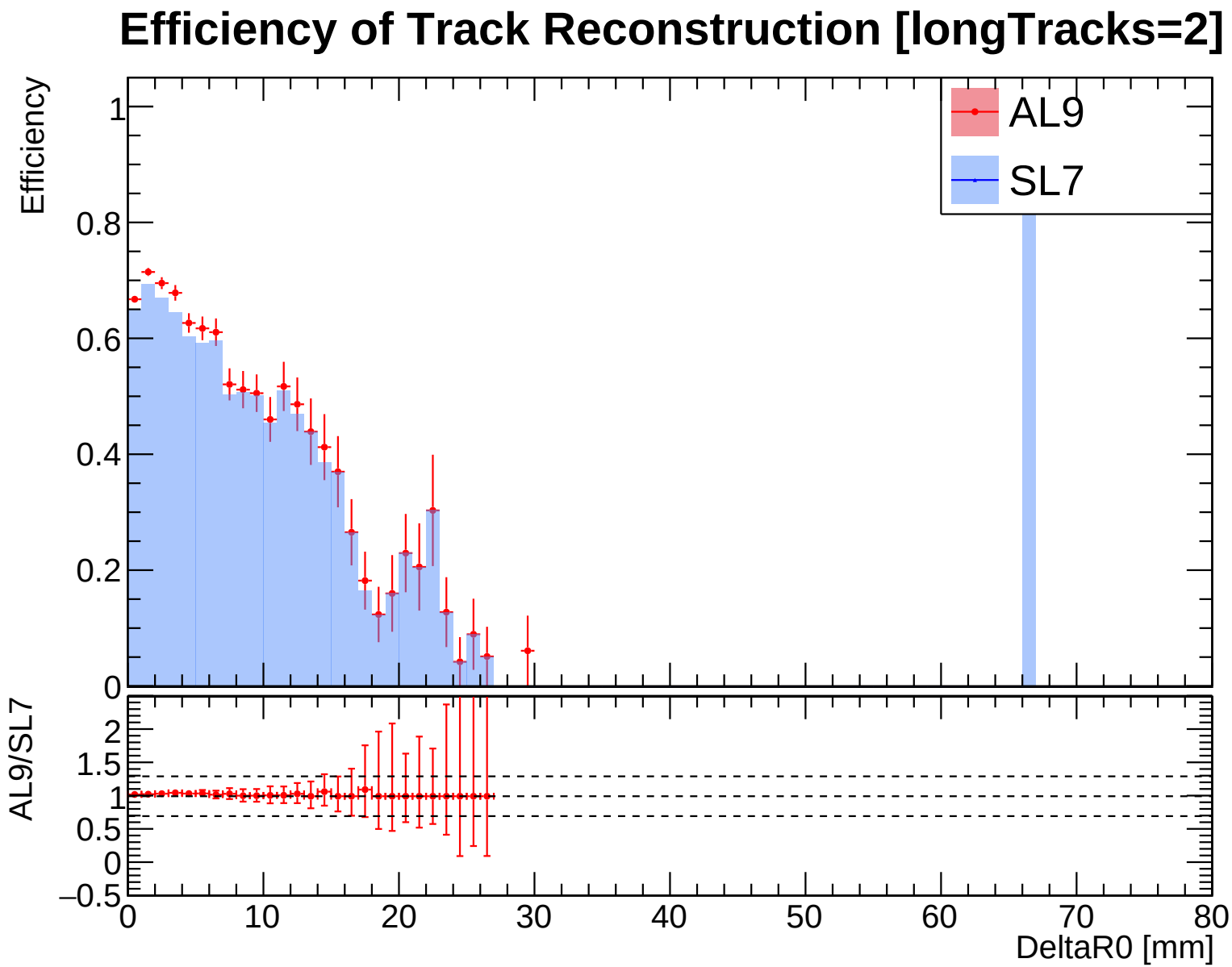
- Good agreement between ALMA9 and CENTOS7
- Minor bump at very low separation ($\approx$ 2-6 mm) for ALMA9
- Error Bars too significant to say anything about large separation

Alternate Efficiency Definition

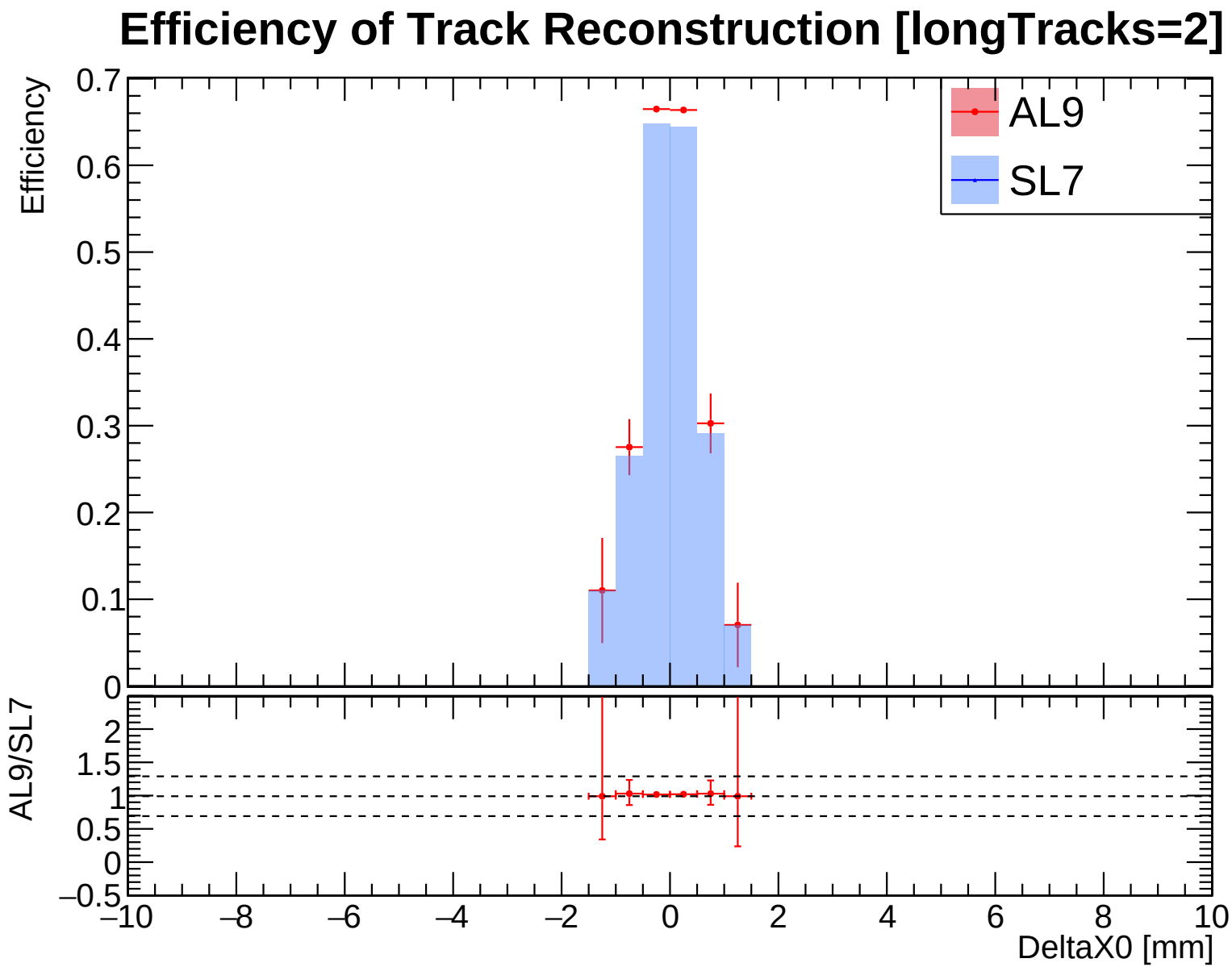
- Remove acceptance based on fiducial cuts at truth level
- Define Efficiency as the fraction of events with exactly 2 reconstructed longTracks divided by the total number of events.

$$\text{Efficiency} = \frac{\text{NEvents}(= 2\text{longTracks})}{\text{NEvents}(\text{Total})}$$

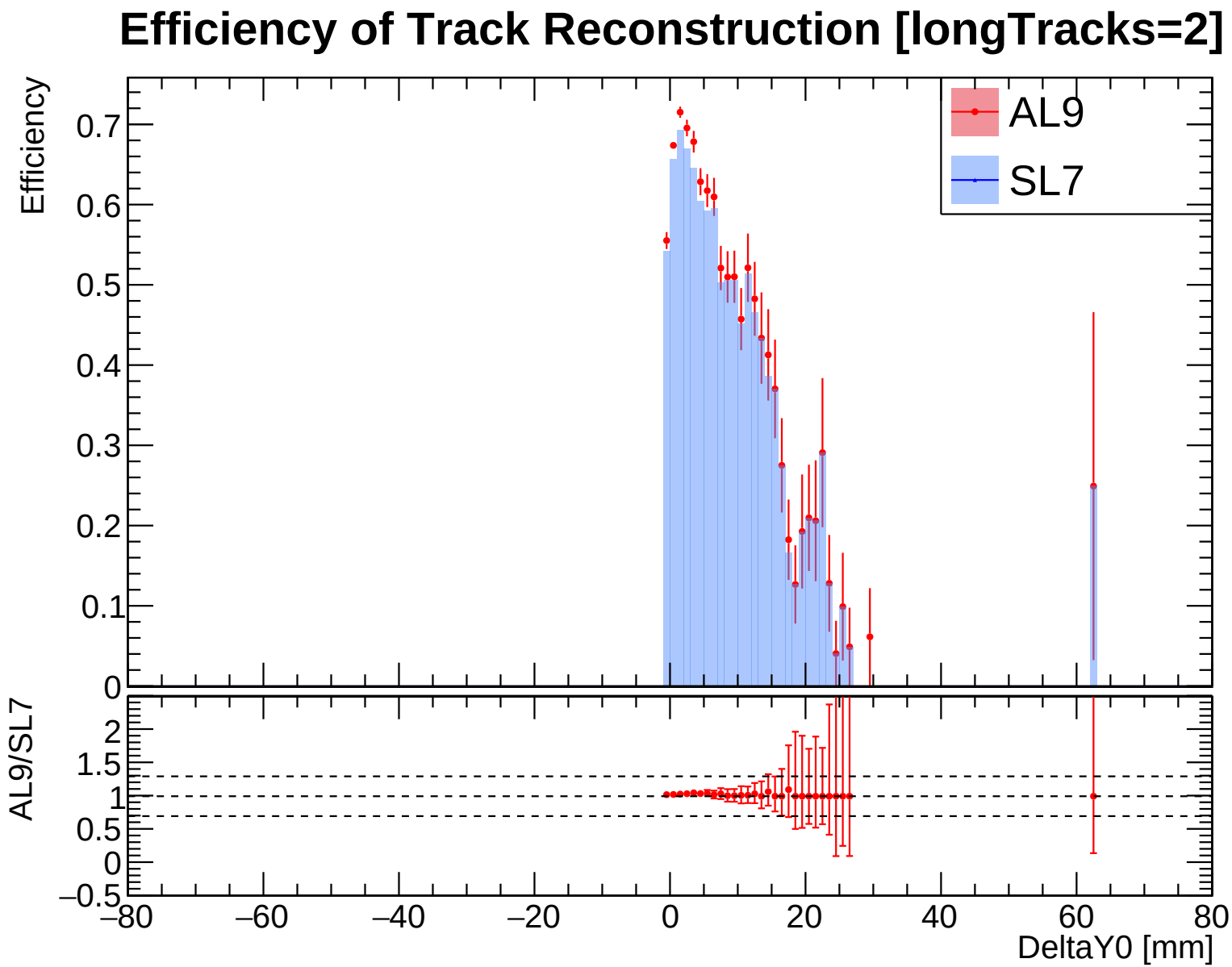
2 Track Efficiency as a function of DeltaR0



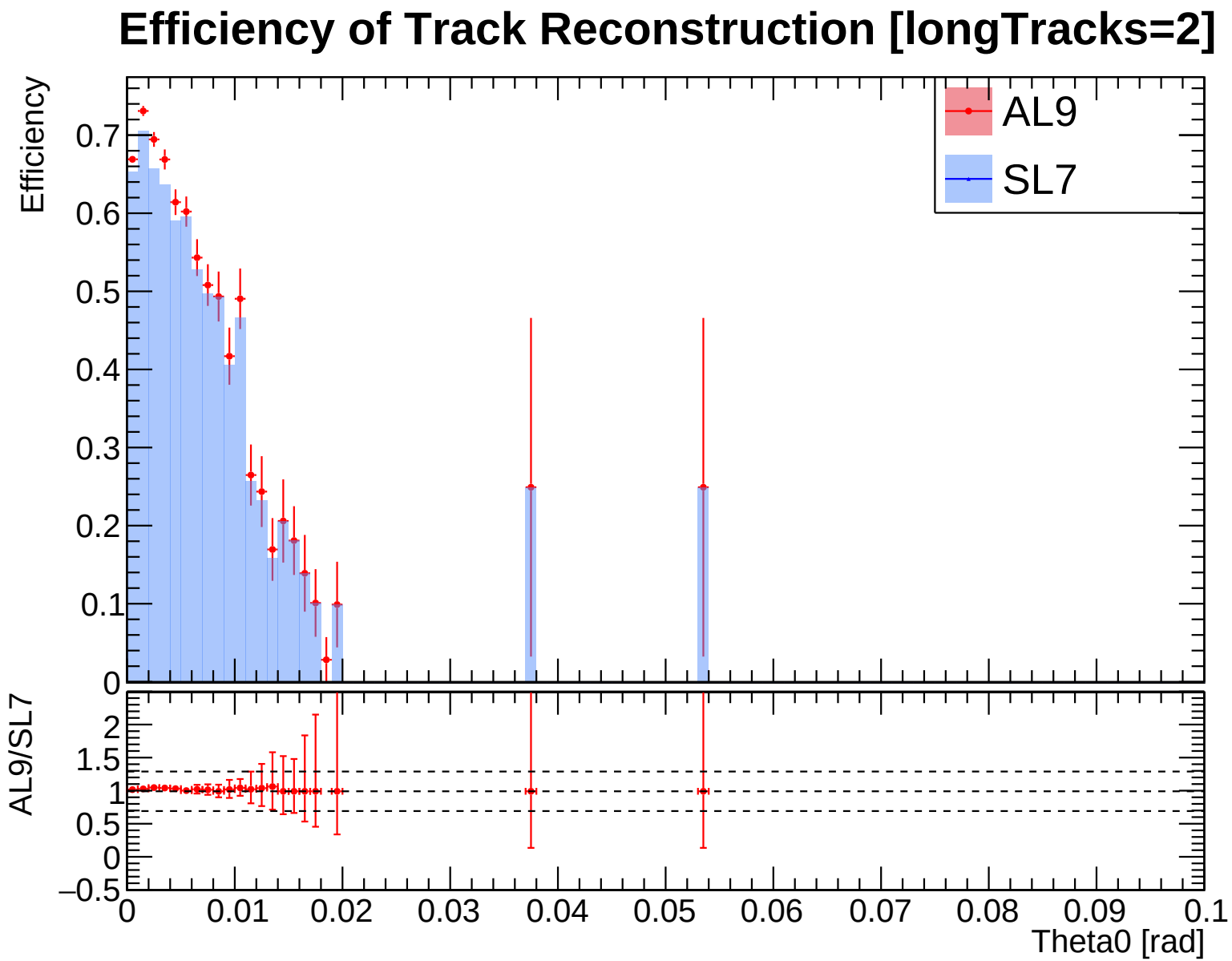
2 Track Efficiency as a function of DeltaX0 [SKIP]



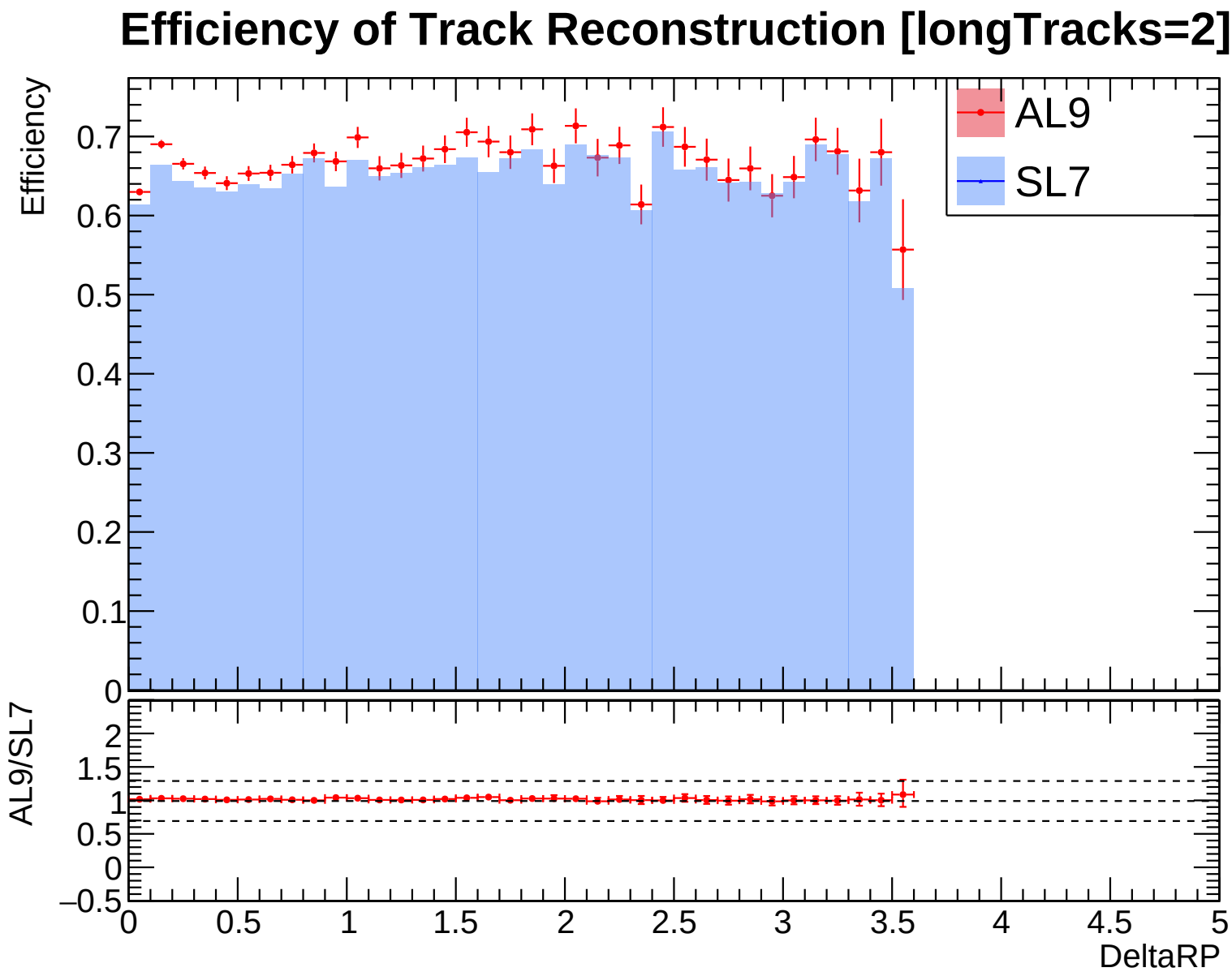
2 Track Efficiency as a function of DeltaY0 [SKIP]



2 Track Efficiency as a function of Theta0



2 Track Efficiency as a function of DeltaRP



A More Robust Efficiency Metric [MC Based]

- Our interest is only in the primary two tracks from e^+e^-
- For acceptance: Truth Position of $e^+e^- < 100$
- **Identify the two primary tracks**
  - Wanted to use t_pdg_parent ...
  - Find closest to truth (by position and momenta)...
  - not trivial what is the margin of allowed error?
  - Highest momenta tracks?
  - Best approach is to use t_truthHitRatio + PID
- Can further quantify the "goodness" of the reconstructed primary tracks

Distribution of t_pdg_parent

t_pdg_parent	AL9	SL7
-11	2	0
0	2	0
22	2610	2397
32	115877	112809

Table: Count of t_pdg_parent

All particles are daughters of the Dark Photon?

Dark Photon CutFlow from Ansh's Study [SKIP]

Sample 110038

CentOS7

Cut	# Events	Efficiency	Cum. Effs
No Cuts	20k	1	1
No Timing Saturation	19955	0.998	0.998
No VetoNu	19955	1	0.998
No Veto	19895	0.997	0.977
Timing Signal	19547	0.982	0.977
Preshower Signal	19547	1	0.977
>=1 Good Track	18281	0.935	0.914
==2 Good Track	11954	0.654	0.598
Fiducial	10874	0.91	0.544
Calo Energy	10729	0.987	0.536

Alma9

Cut	# Events	Efficiency	Cum. Effs
No Cuts	20k	1	1
No Timing Saturation	19955	0.998	0.998
No VetoNu	19955	1	0.998
No Veto	19895	0.997	0.995
Timing Signal	19546	0.982	0.977
Preshower Signal	19546	1	0.977
>=1 Good Track	18649	0.954	0.932
==2 Good Track	12530	0.671	0.627
Fiducial	11387	0.909	0.569
Calo Energy	11243	0.987	0.562

Sample 110033

CentOS7

Cut	# Events	Efficiency	Cum. Effs
No Cuts	20k	1	1
No Timing Saturation	19788	0.989	0.989
No VetoNu	19788	1	0.989
No Veto	19766	0.999	0.988
Timing Signal	19299	0.976	0.965
Preshower Signal	19295	0.999	0.965
>=1 Good Track	16593	0.86	0.83
==2 Good Track	8987	0.542	0.45
Fiducial	7685	0.855	0.385
Calo Energy	2354	0.306	0.118

Alma9

Cut	# Events	Efficiency	Cum. Effs
No Cuts	20k	1	1
No Timing Saturation	19788	0.989	0.989
No VetoNu	19788	1	0.989
No Veto	19767	0.999	0.988
Timing Signal	19300	0.976	0.965
Preshower Signal	19296	0.999	0.965
>=1 Good Track	17112	0.887	0.856
==2 Good Track	9617	0.562	0.481
Fiducial	8095	0.842	0.405
Calo Energy	2352	0.291	0.117

Sample 110051

CentOS7

Cut	# Events	Efficiency	Cum. Effs
No Cuts	20k	1	1
No Timing Saturation	19958	0.998	0.998
No VetoNu	19956	0.999	0.998
No Veto	19900	0.997	0.998
Timing Signal	19566	0.983	0.978
Preshower Signal	19566	1	0.978
>=1 Good Track	18226	0.932	0.911
==2 Good Track	12163	0.667	0.608
Fiducial	11002	0.905	0.55
Calo Energy	10849	0.986	0.542

Alma9

Cut	# Events	Efficiency	Cum. Effs
No Cuts	20k	1	1
No Timing Saturation	19958	0.998	0.998
No VetoNu	19956	0.999	0.998
No Veto	19900	0.998	0.995
Timing Signal	19566	0.983	0.978
Preshower Signal	19566	1	0.978
>=1 Good Track	18687	0.955	0.934
==2 Good Track	12837	0.687	0.642
Fiducial	11560	0.9	0.578
Calo Energy	11417	0.988	0.571

Comments on Data in NTuples [SKIP]

- Need to add newly introducted variables to twiki.
- t_st0_x, y, z are filled with NaNs, We donot use/store station0 vals?
- t_pdg_parent ???
- truthParticleMatchedTracks - What exactly is this column.?

Backup