

# Alma 9 Validation

## Dark Photon Samples

January 26, 2025

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# Introduction

- Validate Alma9 version of Calypso for the track variables
- For the Dark-Photon Samples
- Specifically to understand the difference in two track reconstruction when they are close by

# Data Description

- We want to look at Dark Photon decays to two tracks.
- 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 gives a total of 60k events.
- Justification for chaining given diff mass/couplings?

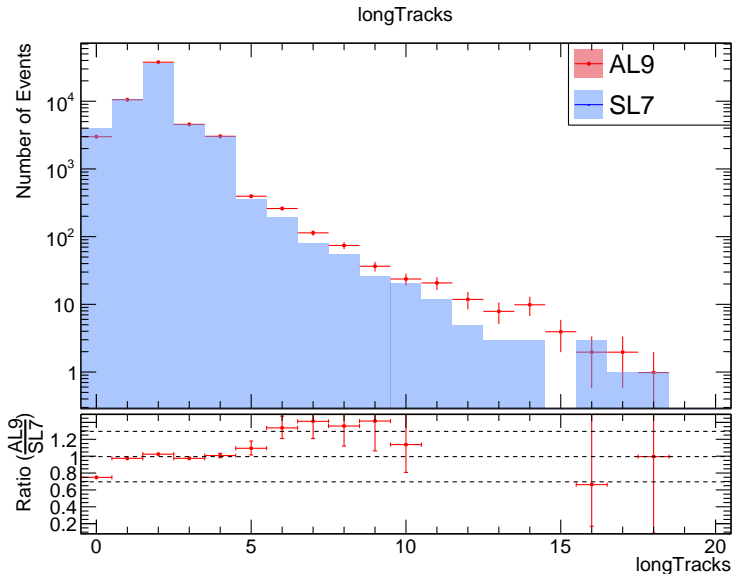
# Overview of Validation

- Begin with a sanity check by looking at the TrackParameters
  - longTracks
  - Track Chi2 / Track Chi2/DoF
  - Track nDoF
  - Track Charge
  - ...
- Quantify separation between tracks
- Compare track reconstruction as a function of above
- Definition of Efficiency?
- Residues?

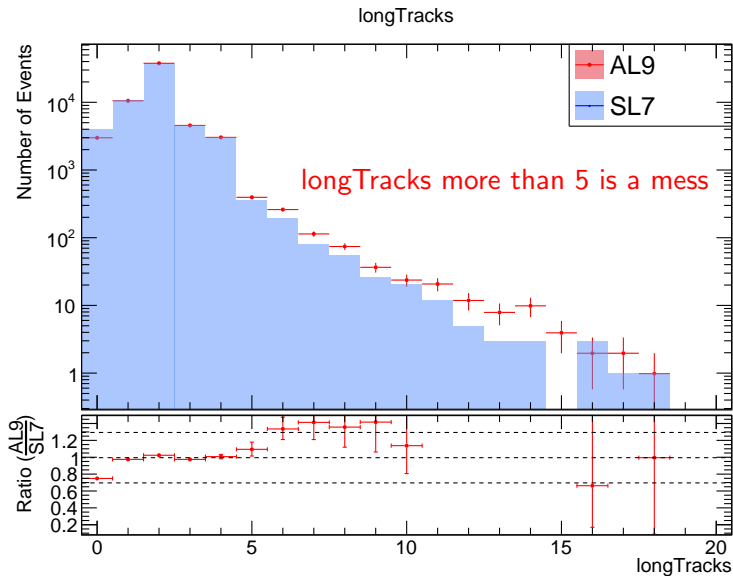
# Distribution of Track Parameters

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

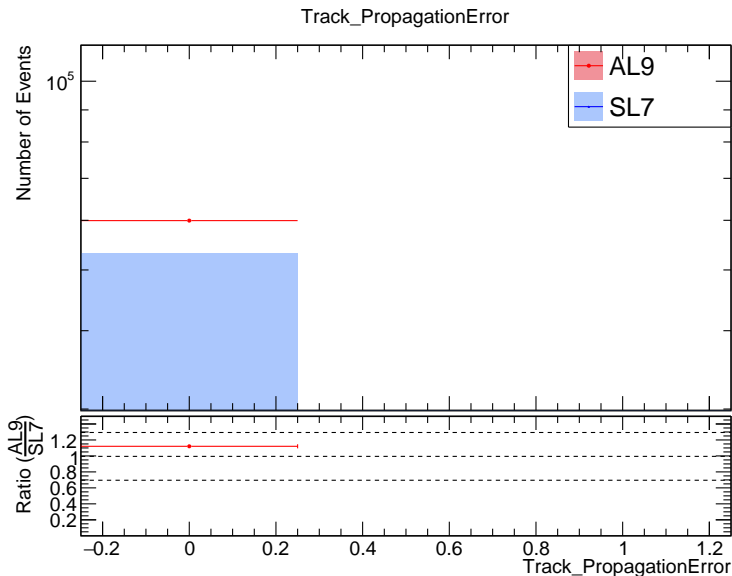
# Distribution of longTracks



# Distribution of longTracks

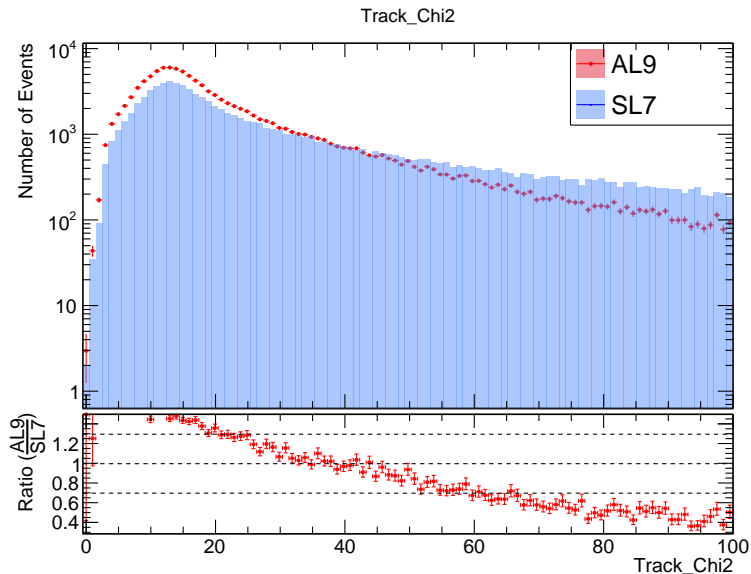


# Distribution of TrackPropagationError [SKIP]

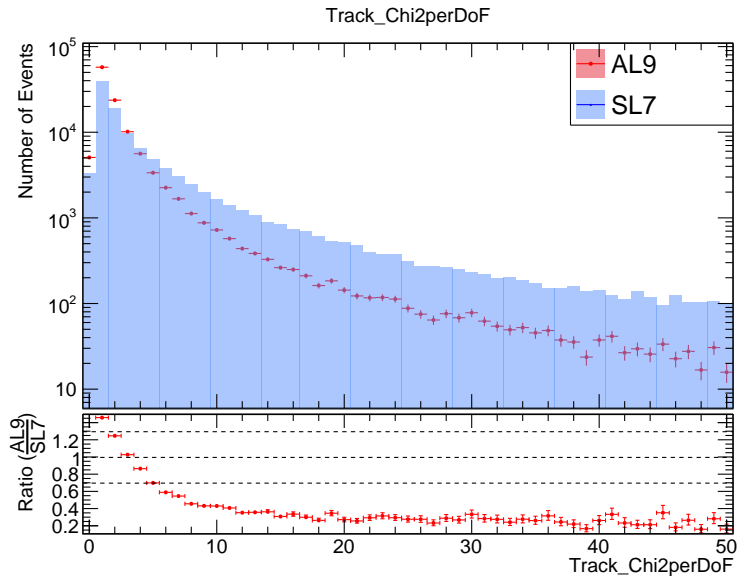




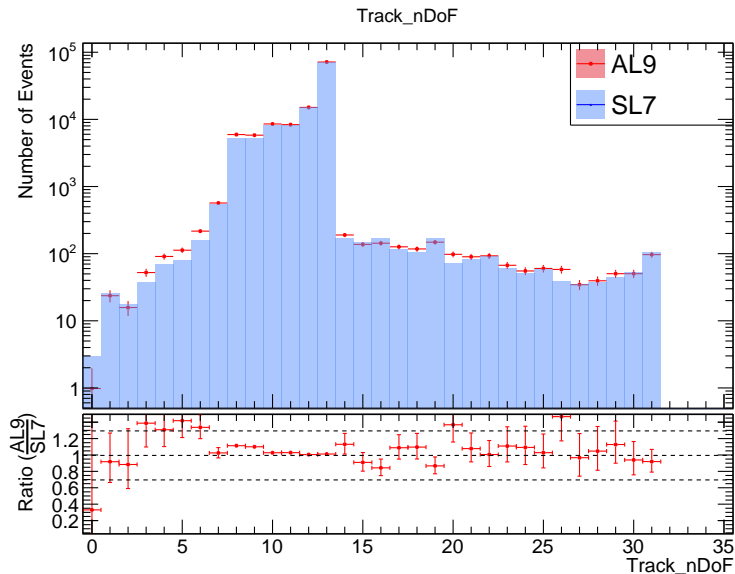
# Distribution of TrackChi2



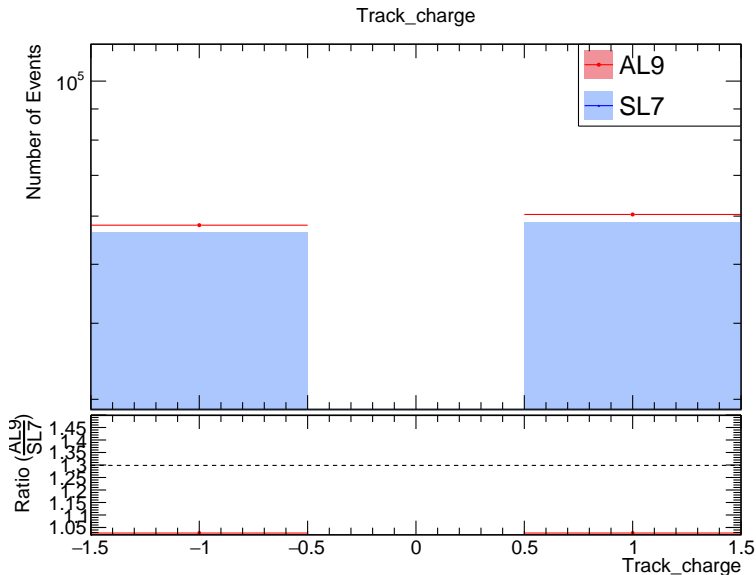
# Distribution of TrackChi2perDoF



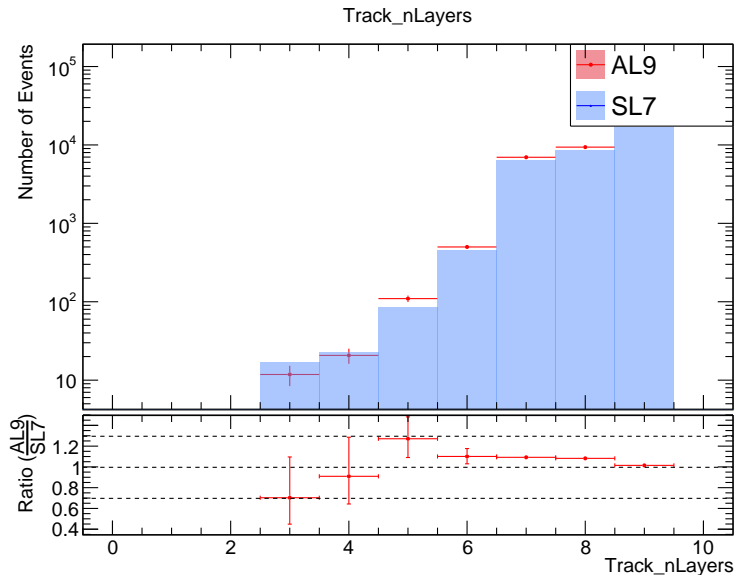
# Distribution of TrackNDoF



# Distribution of Track Charge



# Distribution of Track nLayers



# Comments on Track Parameters

- longTracks 5 is a mess, But not particularly useful
- Track Propagation Error is a easily interpretable function
- Track Chi2 changed a lot, much higher peak and lower tail in AL9, which is good.
- TrackNDoF shows good agreement except between 3-5
- Track Charge in AL9 is slightly elevated, not sure why
- Track nLayers is also decent agreement except at 5-8

# Quantifying Separation

## Possible Track Separation Variables

- $\Delta R_0$  : Separation between the electron and positron at the first tracking station in the x-y plane
- $\Delta X_0$  : Same as above but only in x direction
- $\Delta Y_0$  : Same as above but only in y direction
- $\theta_0$  : 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

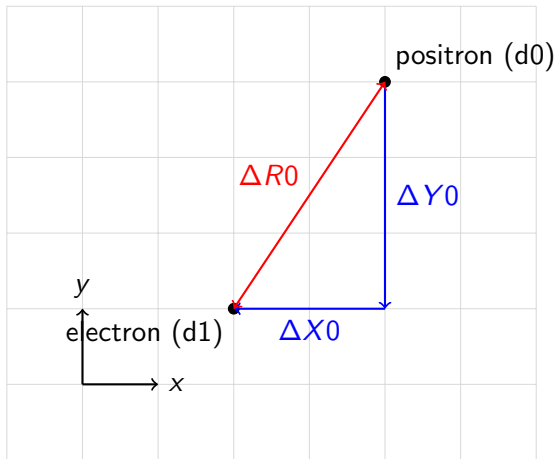


Figure: Tracking Station 1

ADD CODE SNIPPET



# Track Separation in terms of Angle

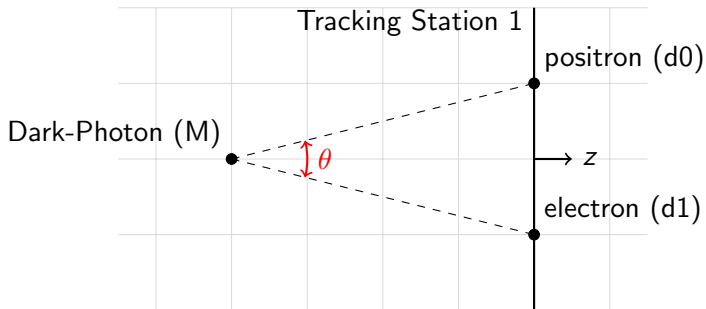


Figure: Angle between Tracks

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# Track Separation in $\eta - \phi$ Space

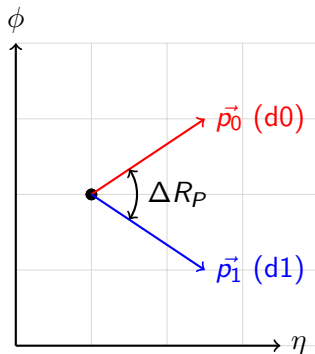
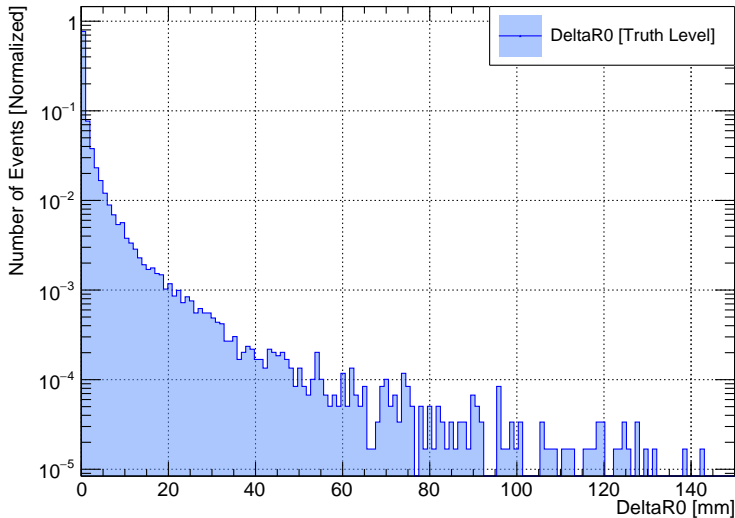


Figure: Angle between Momenta

TODO: Fix listing here

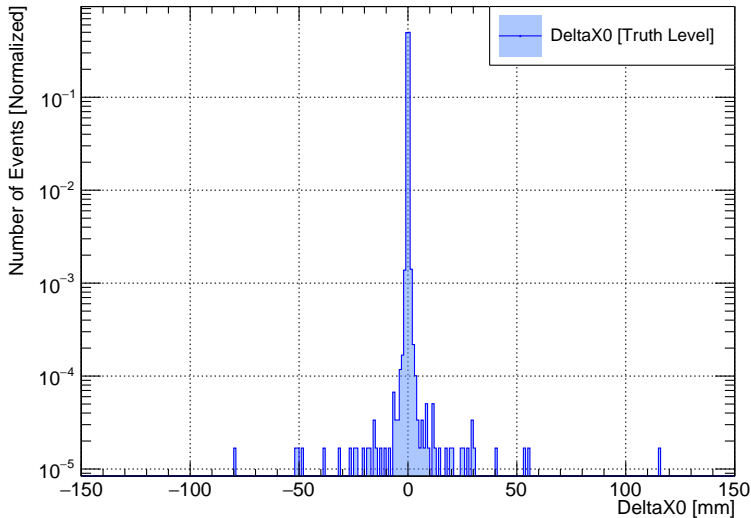
# Distribution of DeltaR0

Distribution of DeltaR0 [Truth Level]



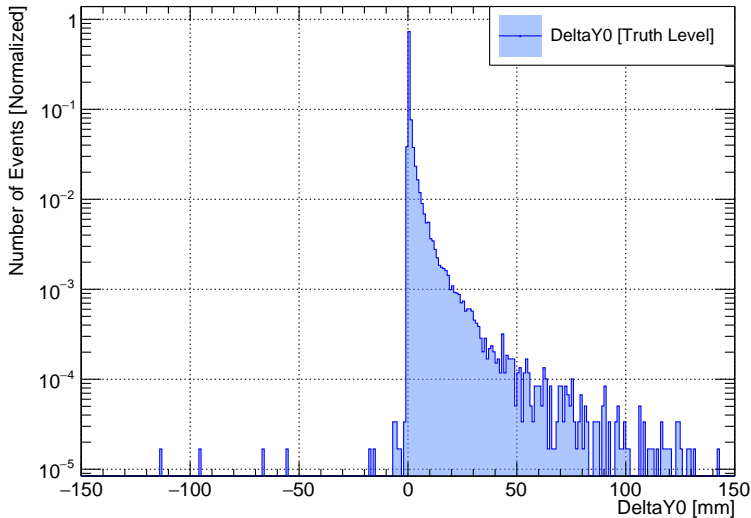
# Distribution of DeltaX0

**Distribution of DeltaX0 [Truth Level]**



# Distribution of DeltaY0

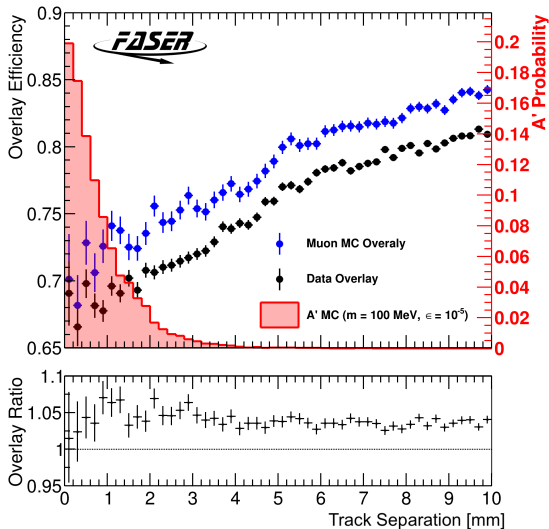
**Distribution of DeltaY0 [Truth Level]**



# Comments on Position Based Separation

- Particle predominantly separated in the y-direction
  - Comes from the magnetic field's deflection
  - Positron deflected upwards, electron downwards leading asymmetry in  $\Delta Y_0$  plot
  - $\Delta X_0$  looks symmetric
  - $\Delta Y_0$  can be approximated to  $\Delta R_0$
- In general Nevents fall off as separation increases [characteristic of DP Decay?]
- Similar features seen in overlay plot but different in scale
- We can just look at the distributions using  $\Delta R_0$  as our primary variable for position based separation.

# Overlay Plot

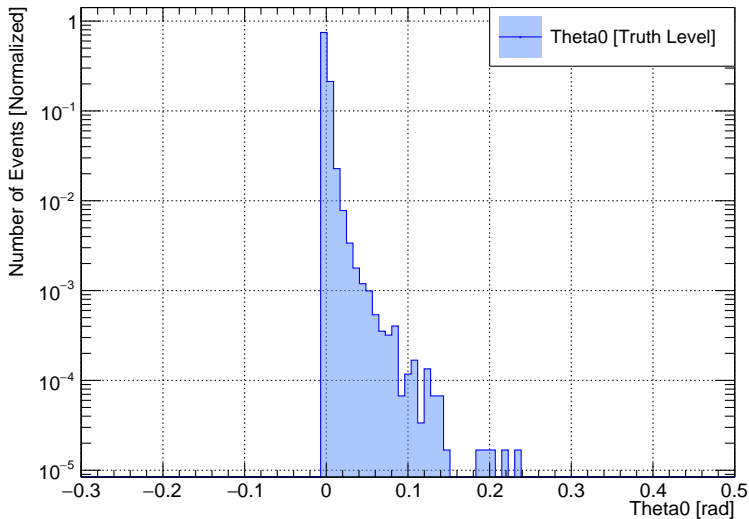


**Figure:** Overlay plot from Search for dark photons with the FASER detector at the LHC



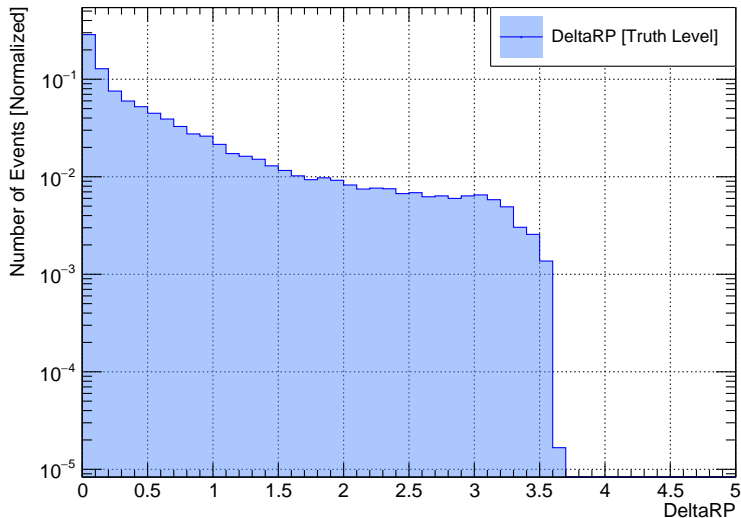
# Distribution of Theta0

Distribution of Theta0 [Truth Level]



# Distribution of DeltaRP

## Distribution of DeltaRP [Truth Level]

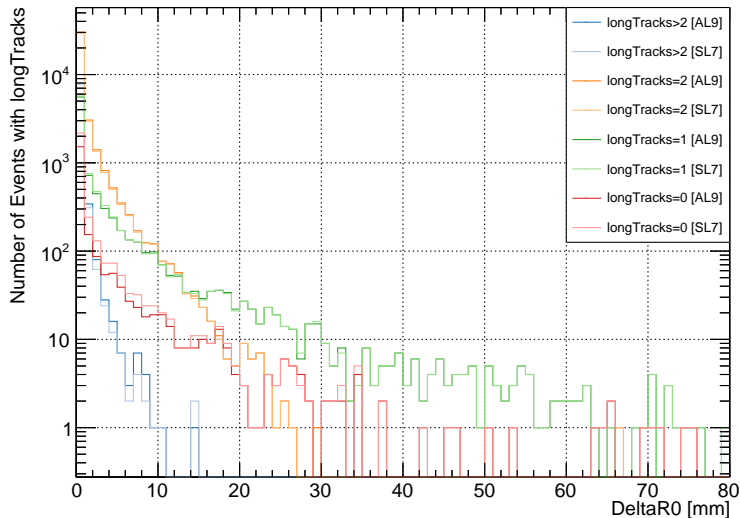


# Comments on Angle Based Separation

- 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 uncertainty from the tracking itself

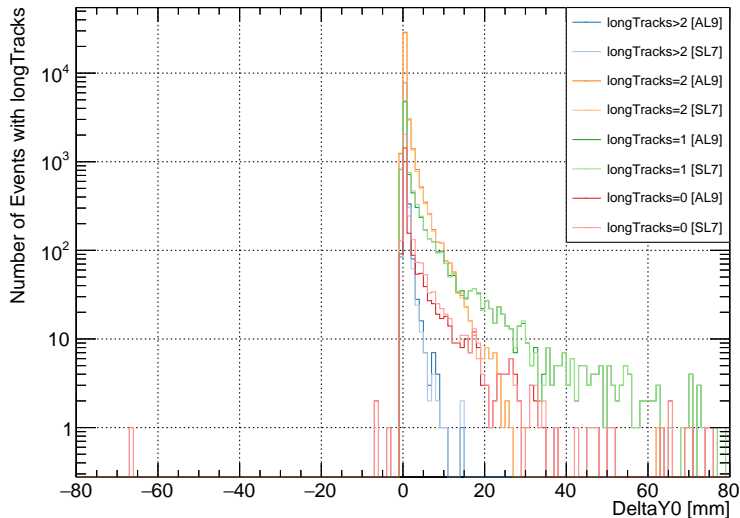
# Events grouped by longTracks vs DeltaR0

NEvents Grouped by Track Count



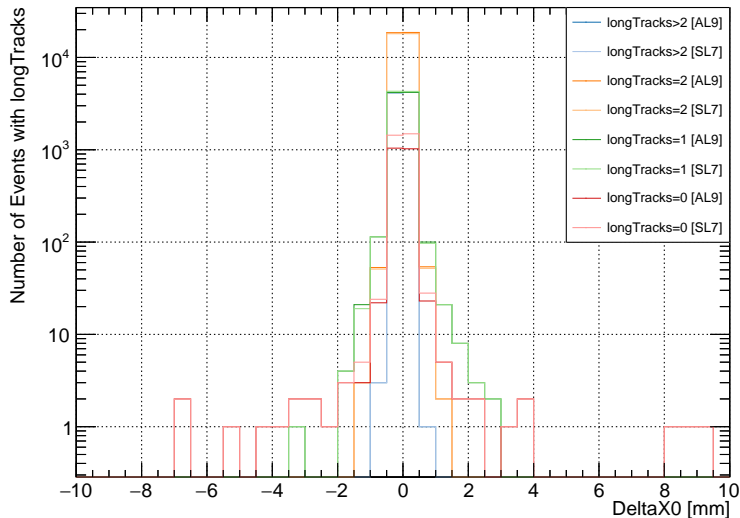
# Events grouped by longTracks vs DeltaY0 [SKIP]

NEvents Grouped by Track Count



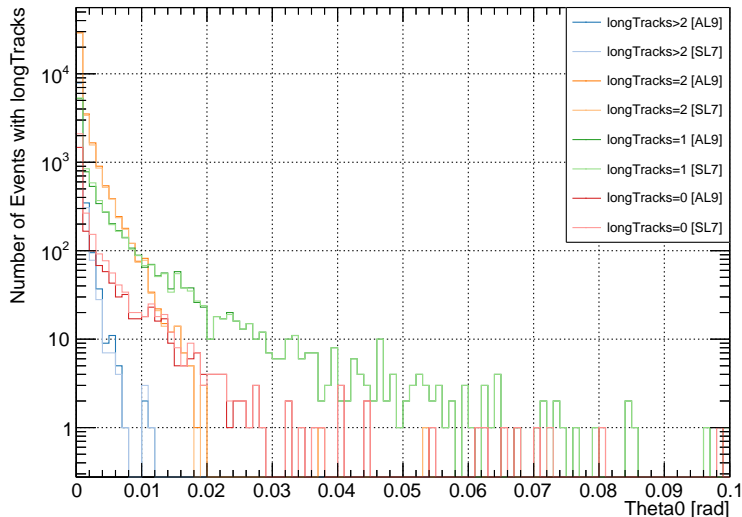
# Events grouped by longTracks vs DeltaX0 [SKIP]

NEvents Grouped by Track Count



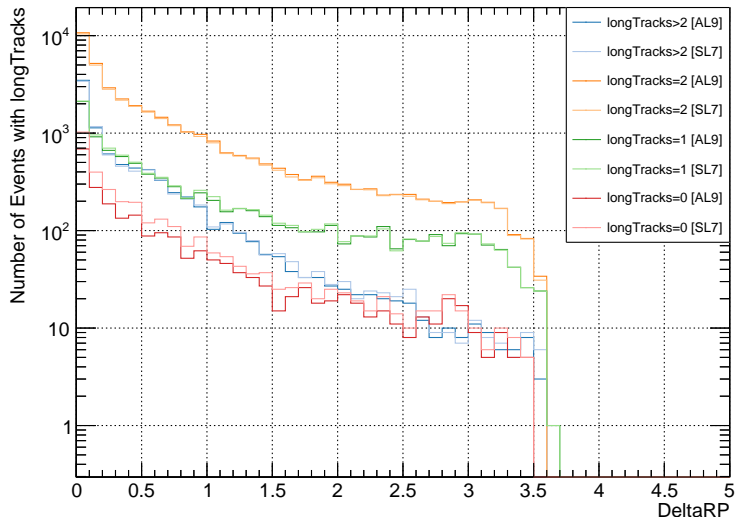
# Events grouped by longTracks vs Theta0

NEvents Grouped by Track Count



# Events grouped by longTracks vs DeltaRP

NEvents Grouped by Track Count





# 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  $\leq 1$  AL9 performs bad at low separation
- Maybe logscale in x?

# Alternative Efficiency Metrics

## In General

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

## Some Possible Eff. Metrics

- Number of Events with  $\geq 2$  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 [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

## **Notes:**

- Where are NaNs coming from at the truthlevel?

# 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.

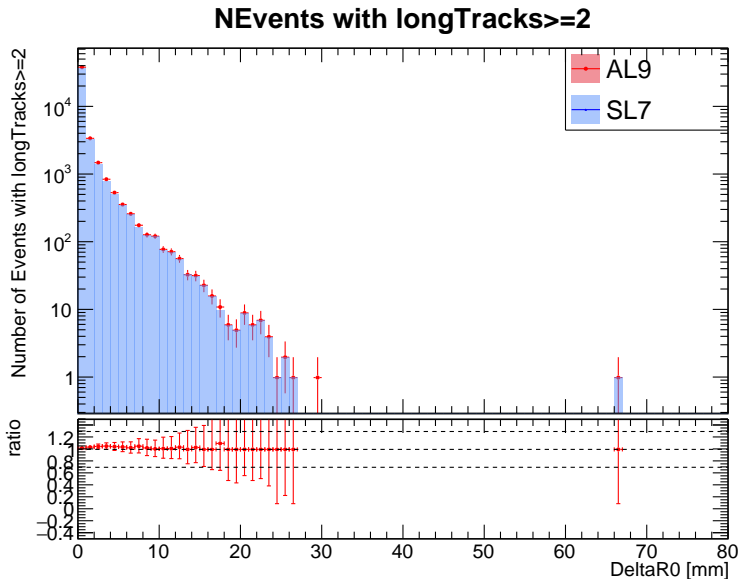
Selection Step	Pass	All	Effi. (%)	Cum. Effi. (%)
truthd0_st1_r < 100	59634	60000	99.39	99.39
truthd0_st2_r < 100	58429	59634	97.98	97.38
truthd0_st3_r < 100	56703	58429	97.05	94.50

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

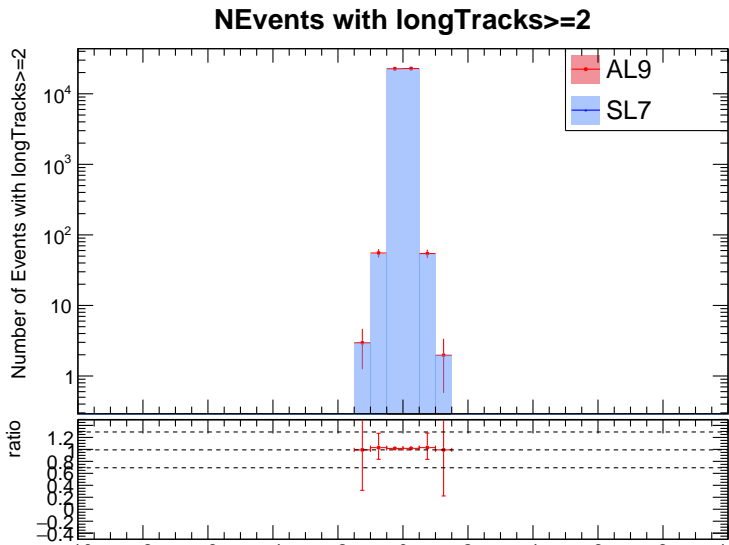
Selection Step	Pass	All	Effi. (%)	Cum. Effi. (%)
truthd0_st1_r < 100	59634	60000	99.39	99.39
truthd0_st2_r < 100	58429	59634	97.98	97.38
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**Table:** Efficiencies and cumulative efficiencies for truth-level selection steps. [CENTOS7]

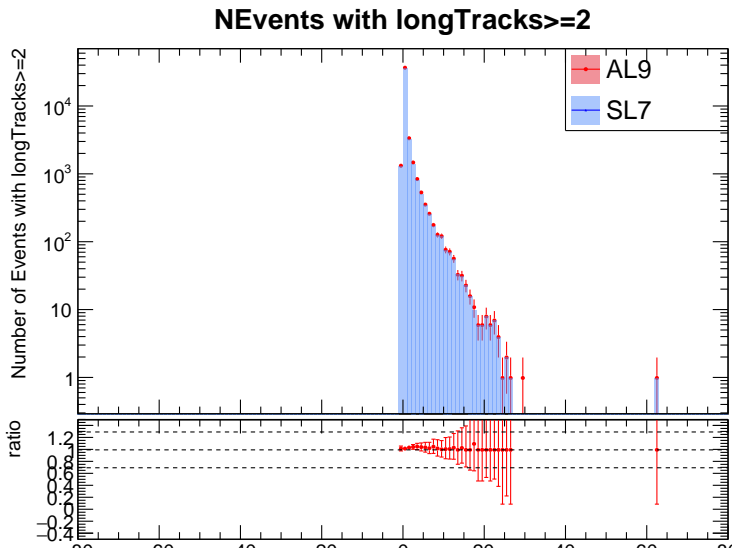
# $\geq 2$ Track Efficiency as a function of DeltaR0



# $\geq 2$ Track Efficiency as a function of DeltaX0 [SKIP]

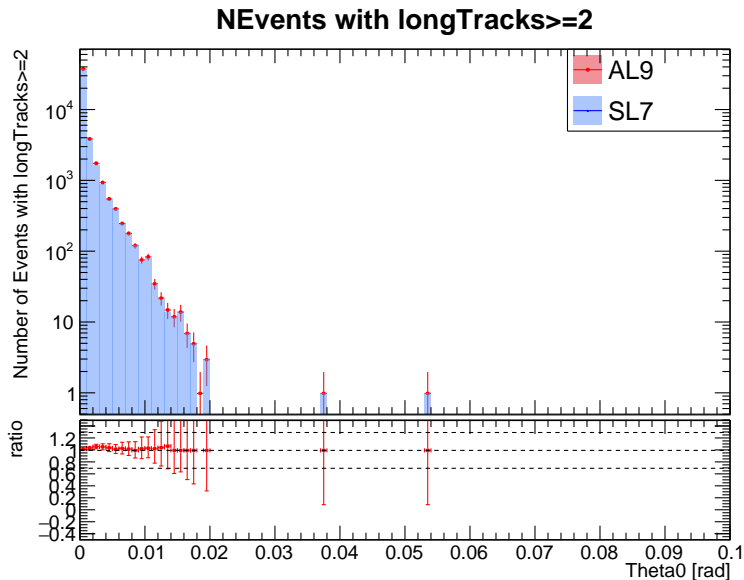


# $\geq 2$ Track Efficiency as a function of $\Delta Y_0$ [SKIP]

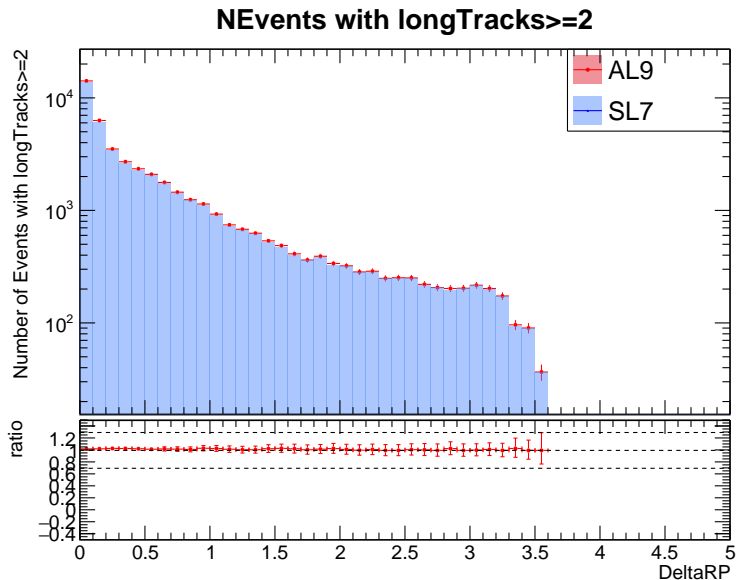




# $\geq 2$ Track Efficiency as a function of $\Theta_0$



# $\geq 2$ Track Efficiency as a function of DeltaRP



# Comments on 2Track Efficiency

- Good agreement between ALMA9 and CENTOS7
- Minor bump at very low separation ( $\approx 2\text{-}6$  mm) for ALMA9

# 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?

# Comments on Data in NTuples [SKIP]

- Need to add newly introduced 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