The calorimeter-seeded track reconstruction in Mu2e

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Experimental setup

• ***Production Solenoid:***

➡ Proton beam strikes target, producing mostly pions

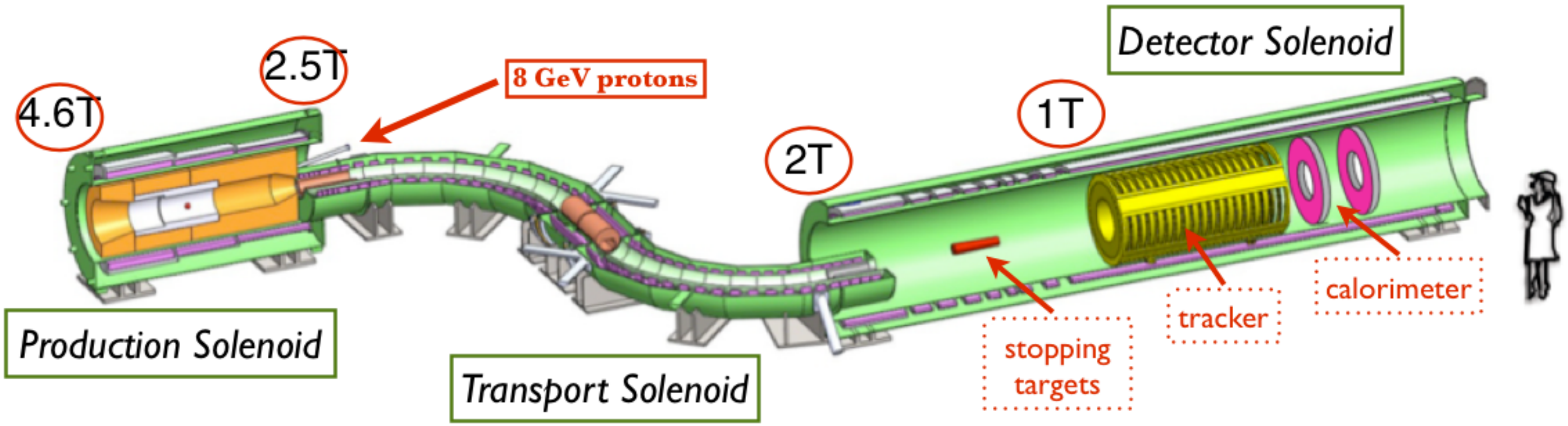
➡ Graded magnetic field contains backwards pions/muons and reflects slow forward pions/muons

• ***Detector Solenoid:***

➡ Capture muons on Al target

➡ Measure p in the tracker and E, t, x in the calorimeter

➡ Graded field increases CE detector acceptance: ~70%



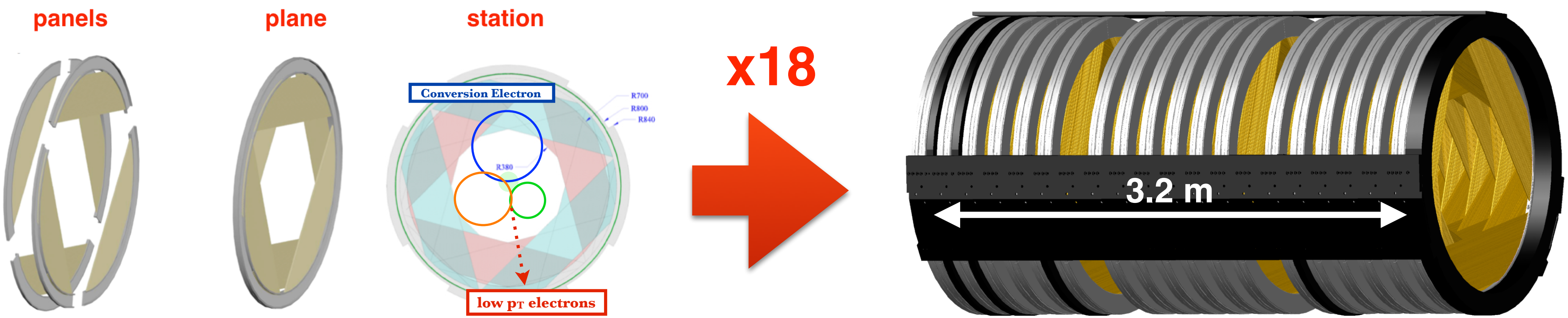
• ***Transport Solenoid:***

➡ Select low momentum, negative muons

Tracker design

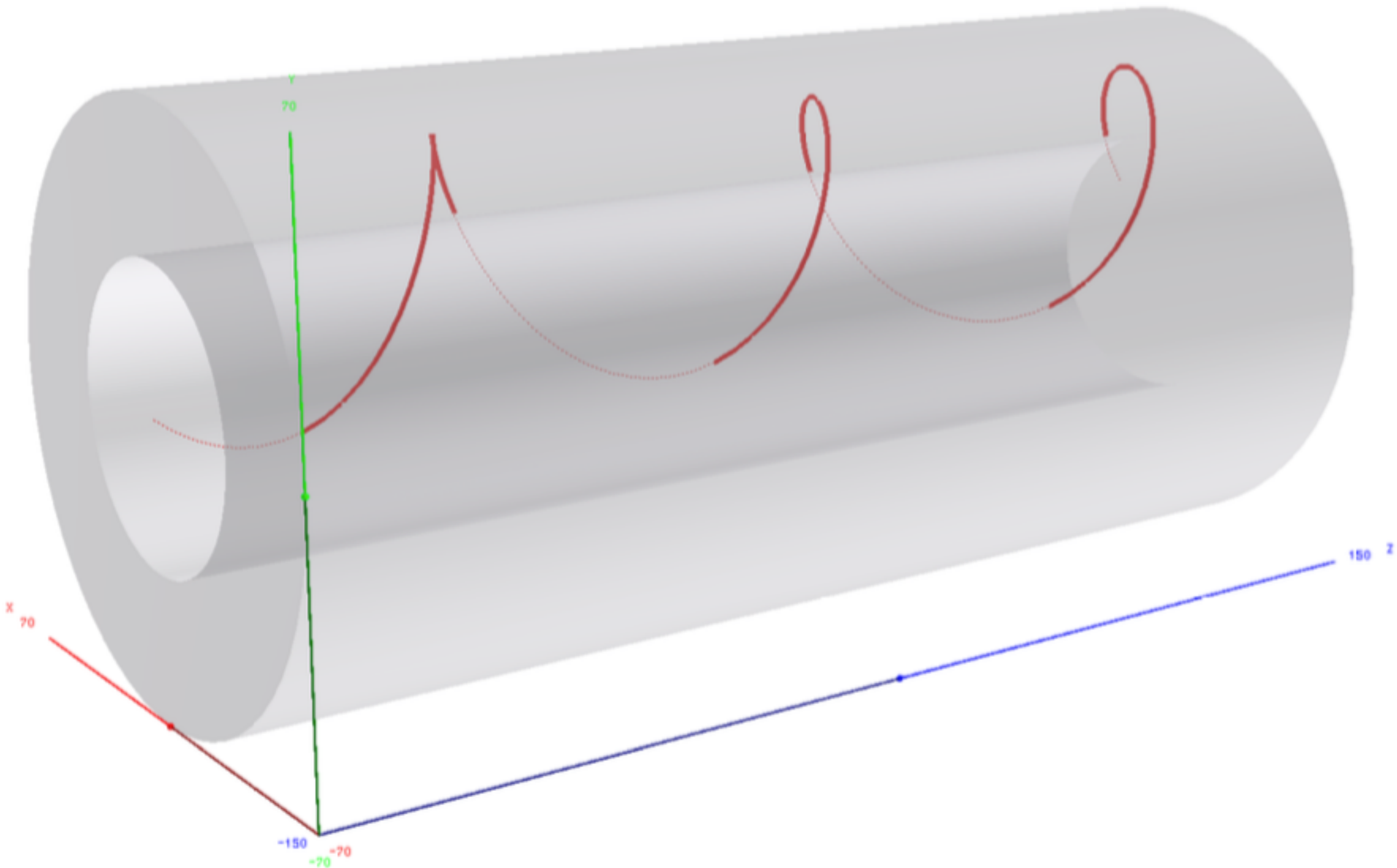
- 18 stations with straws transverse to the beam
- Straw technology employed:
  - ✓ 5 mm diameter, 15 μm Mylar walls
  - ✓ 25 μm Au-plated W sense wire
  - ✓ 80/20 Ar/CO_2 with HV ~ 1500 V
- Inner 38 cm un-instrumented:
  - ✓ blind to beam flash
  - ✓ blind to >99% of the DIO spectrum

straw tube



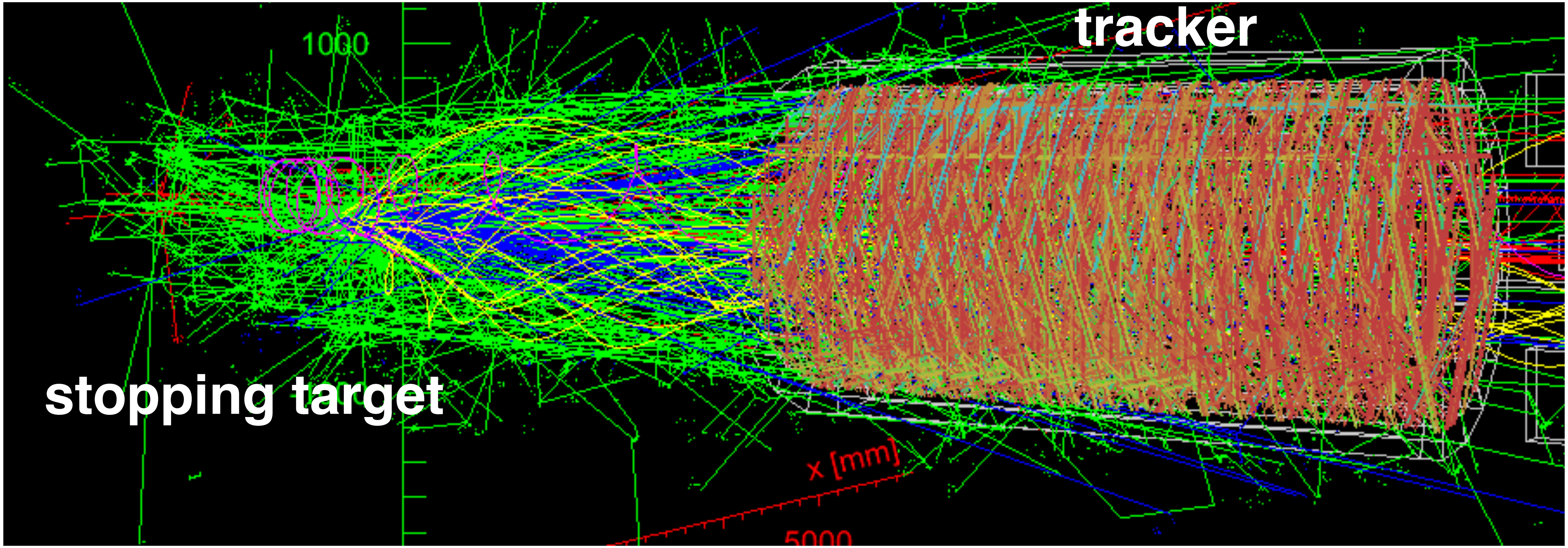
Mu2e signal - ideal case

- **Our signal:** e⁻ with p~105 <MeV/c coming from the Al target



Mu2e signal - real case

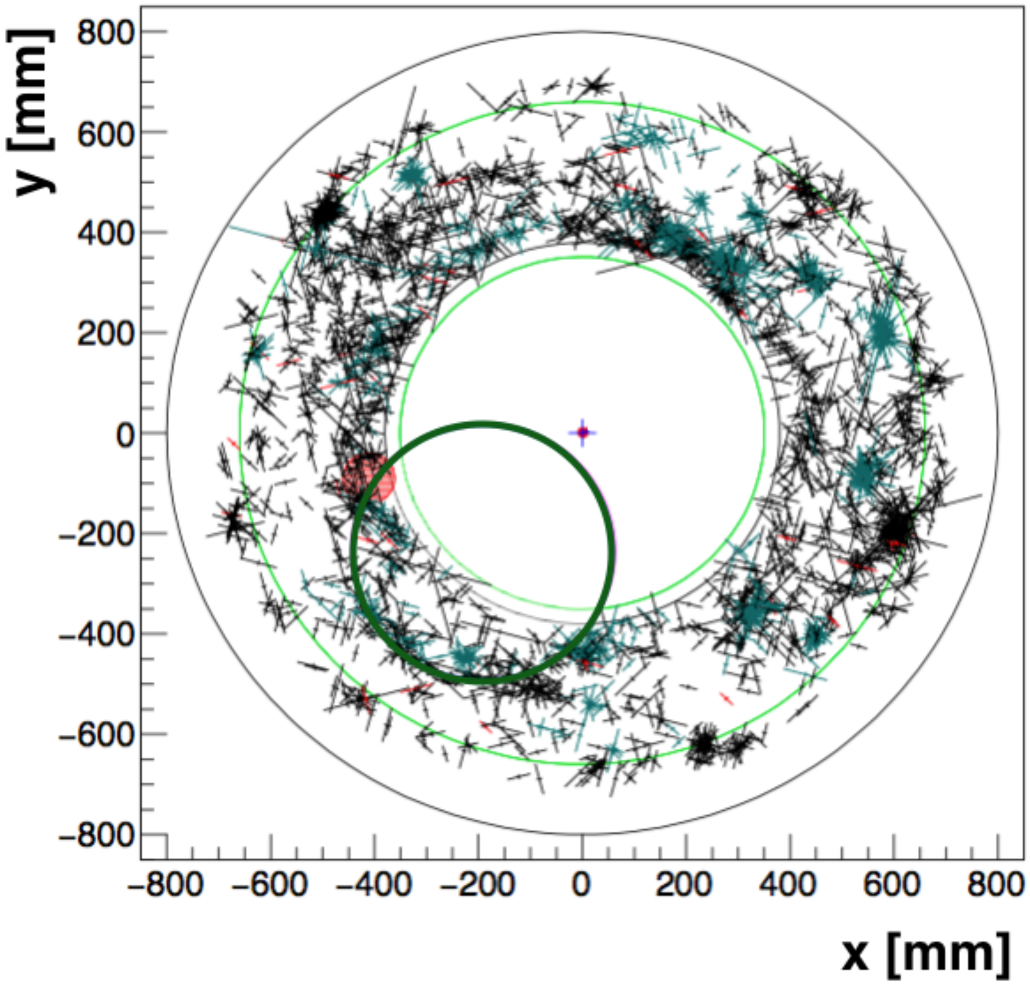
- μ- beam produces secondaries via brems, nuclear capture, etc



1 bunch event = 1.7 μs

Track search in Mu2e

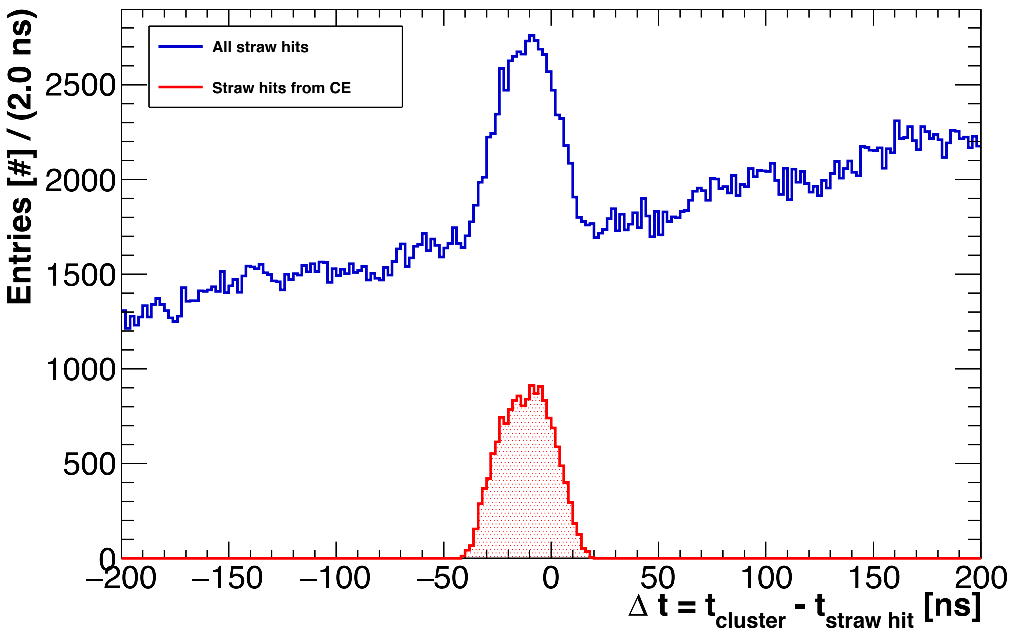
- Hits from background sources complicate the track search
- Calorimeter information helps the track search



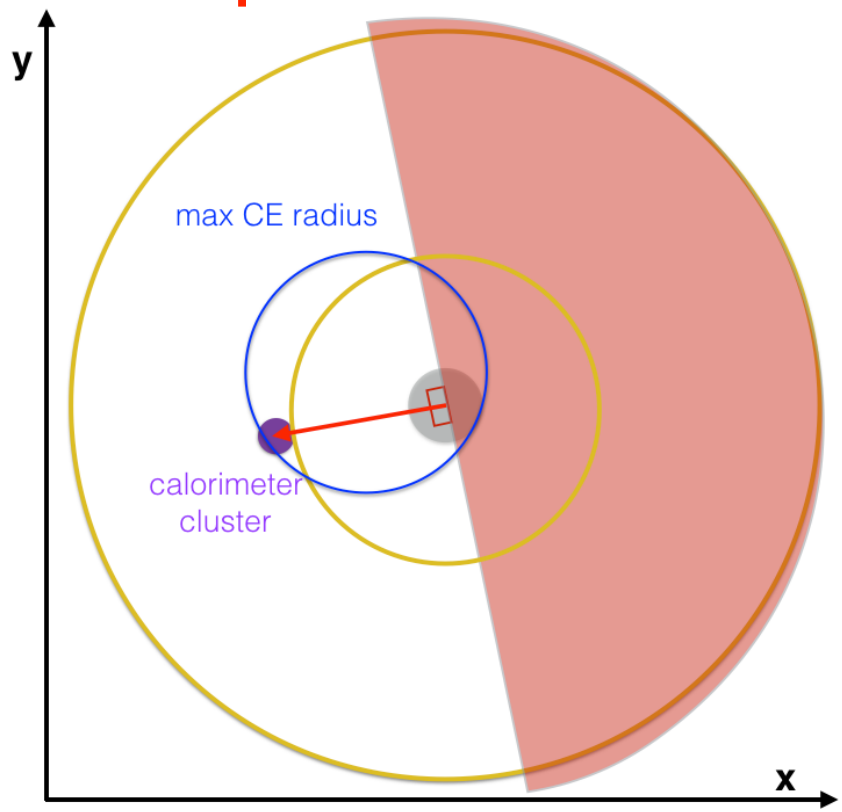
Hit pre-selection I

- Cluster time and position are used for filtering the straw hits:
  - ✓ time window of ~ 80 ns
  - ✓ spatial correlation

time window

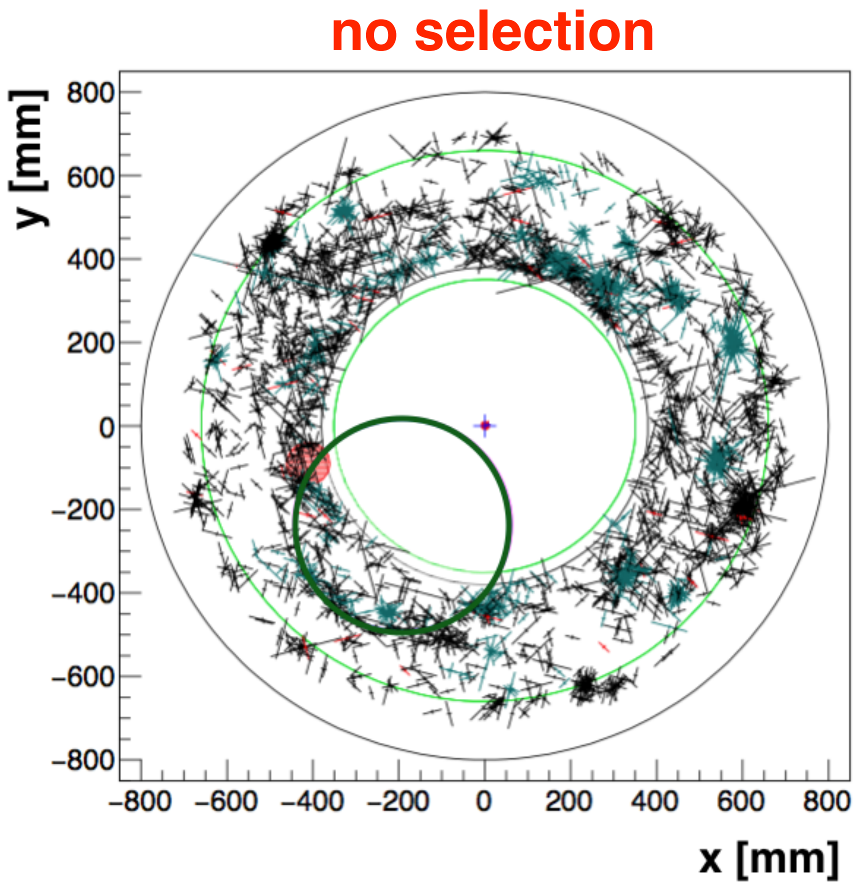


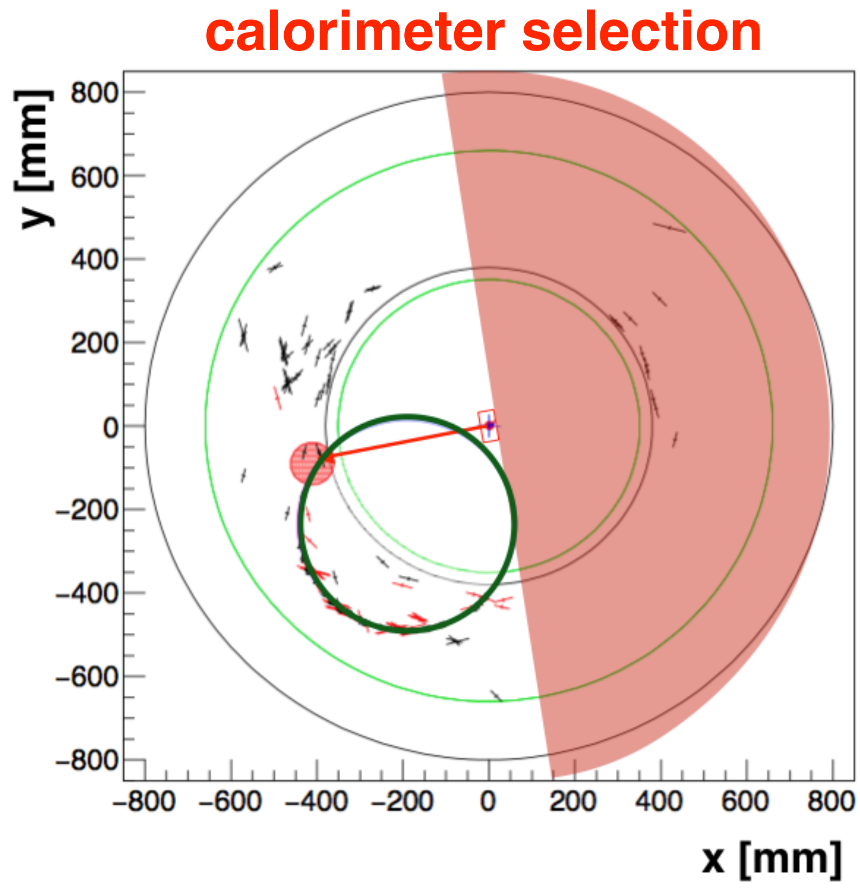
spatial correlation



Hit pre-selection 2

- Cluster time and position are used for filtering the straw hits:
  - ✓ time window of ~ 100 ns
  - ✓ spatial correlation



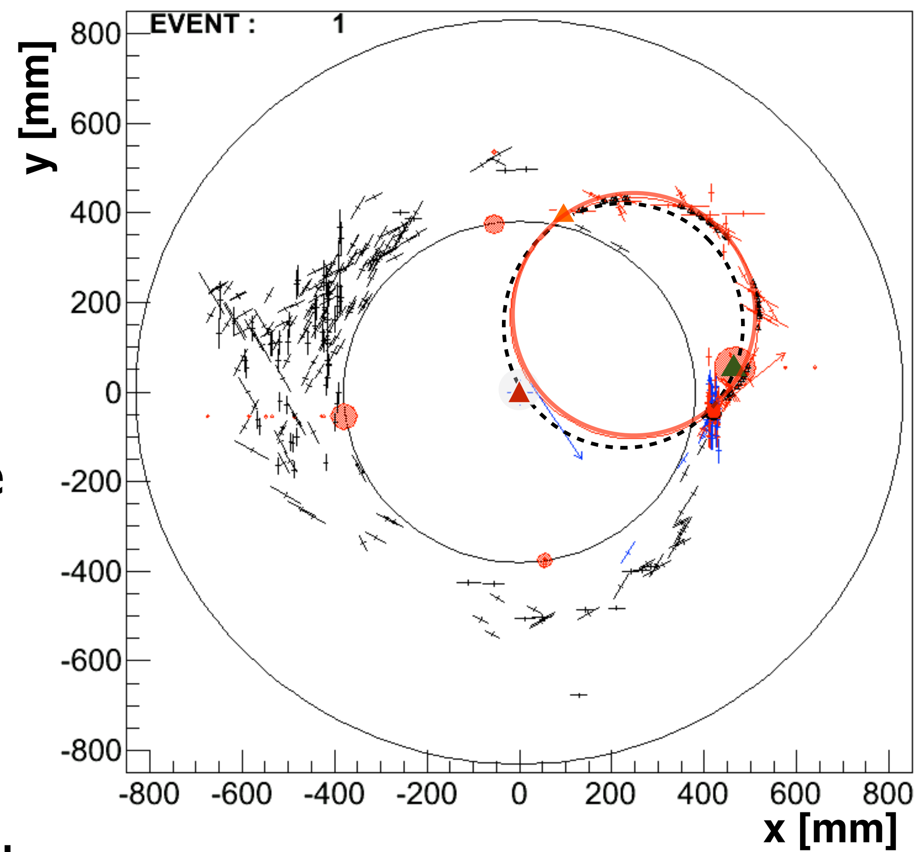


- **black crosses** = straw hits, **red circle** = calorimeter cluster, **green line** = CE track

Helix search - scheme

To identify the right pattern of hit we apply the following procedure:

1. Select a triplet with the calo cluster position, one tracker hit and the solenoid center
2. calculate helix parameters (dashed line is the reco circle, red one is the true trajectory)
3. loop over all the hits and includes those which are close to the helix
4. As soon as the second straw hit is found, the solenoid center is dropped in step 1 and the procedure re-starts.
5. adjust the helix parameters as the search progresses



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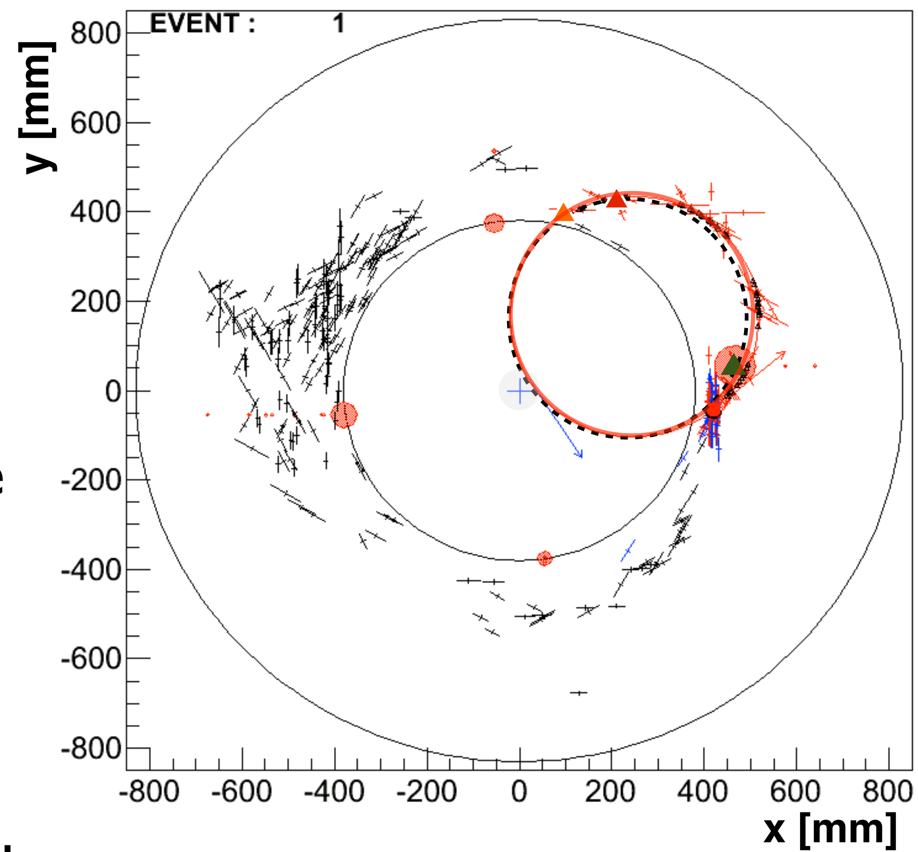
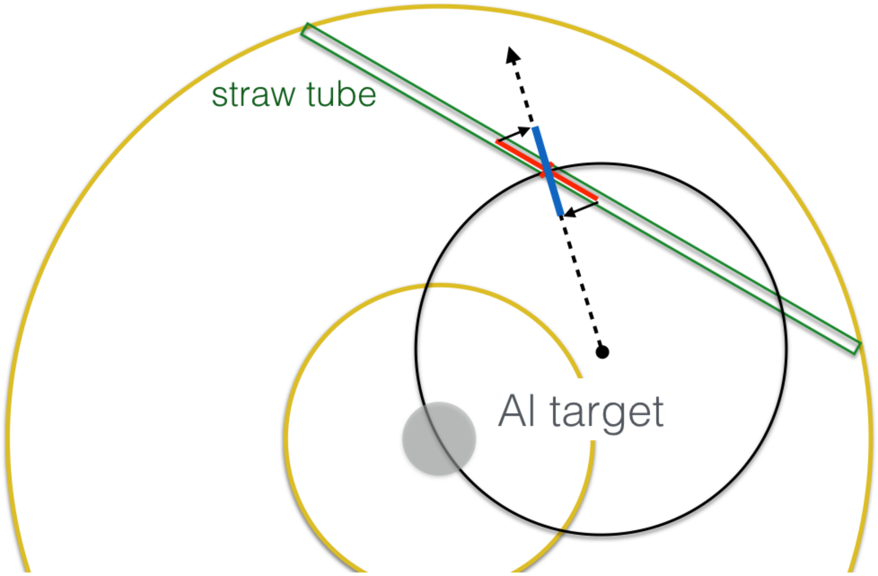
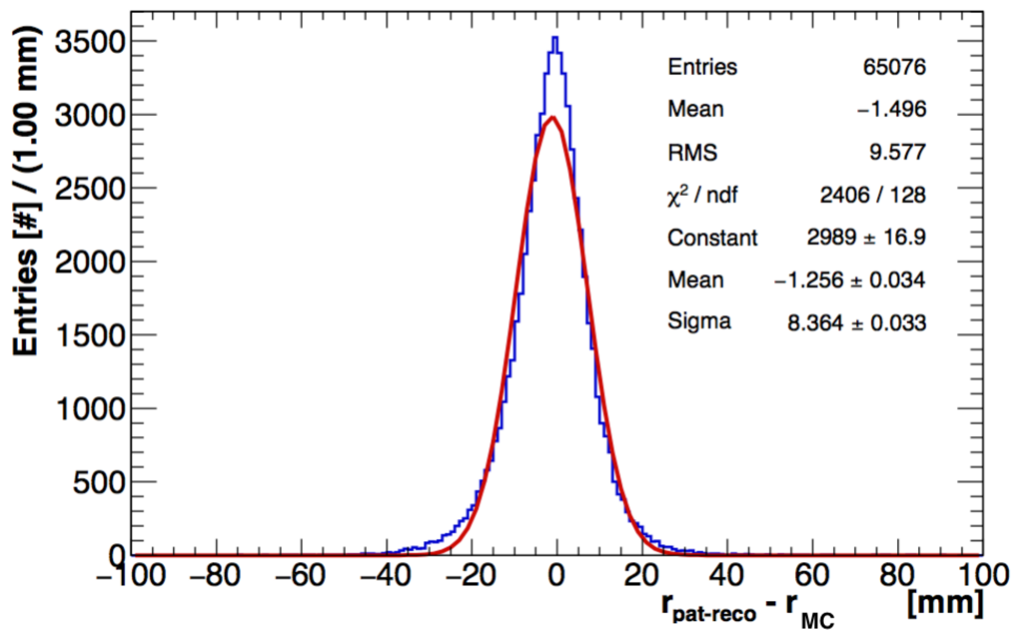


- At the end the helix with the largest number of hits is selected

Δr fit result

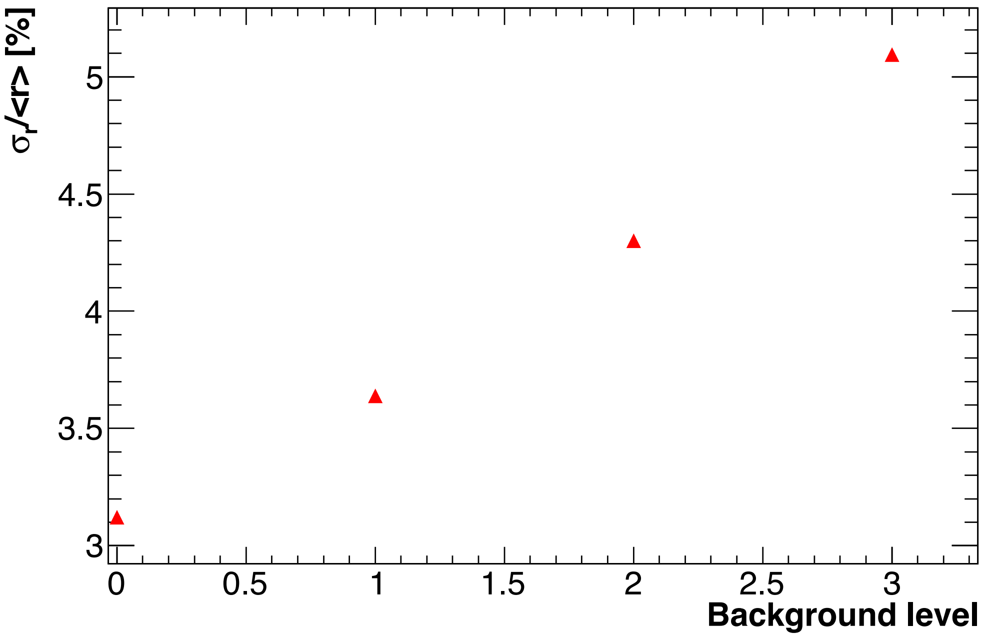
- Reduced Least Square Method for performing the circle fit
- Errors are projected along the radial direction of the trajectory

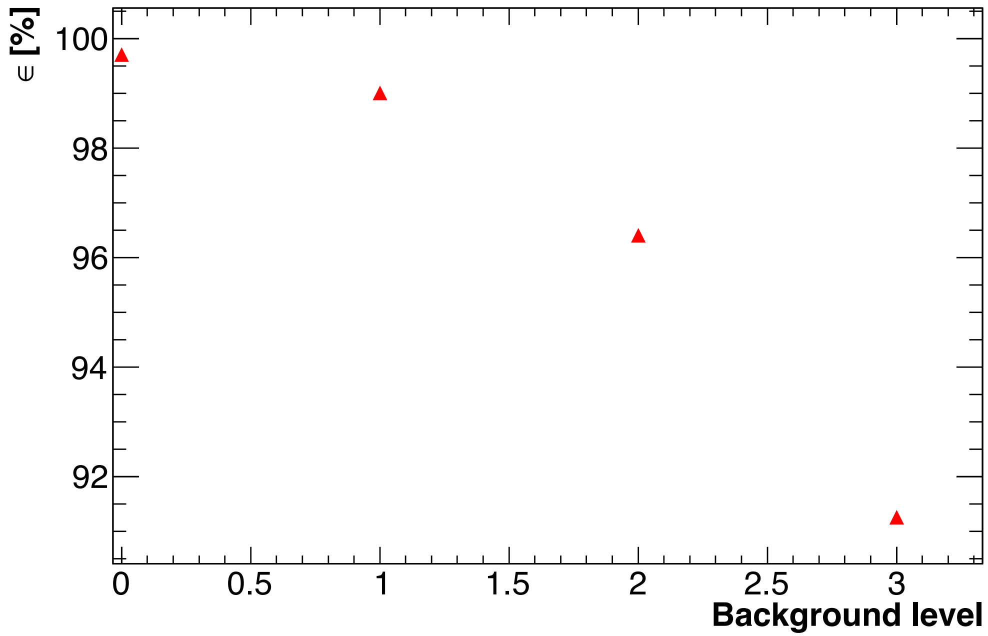




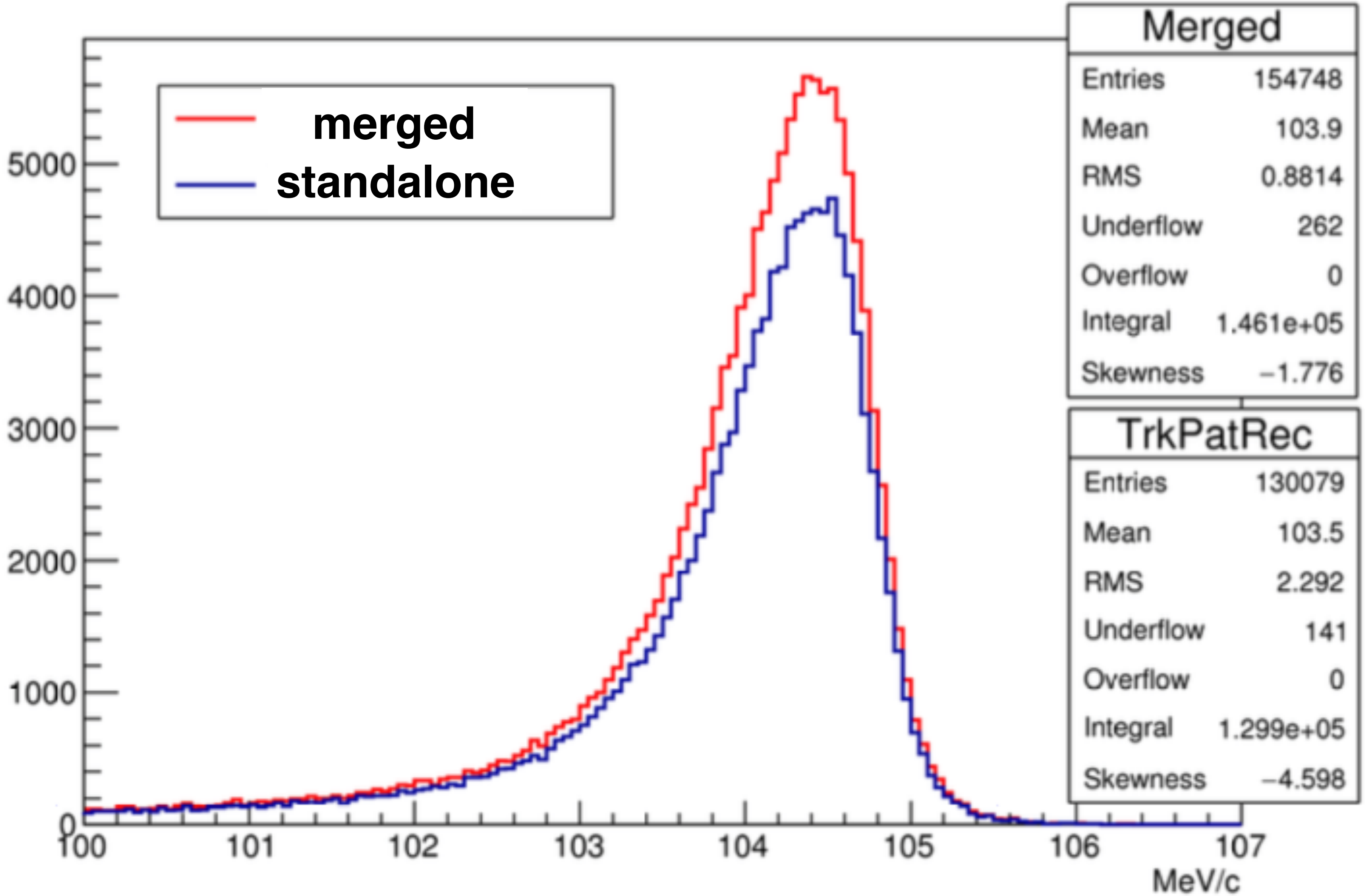
Track search: efficiency

- Resulting radius resolution $\sigma_r/<r>\sim 3.6$ % for CE
- Efficiency normalized to events with E>50 MeV & $N_{straw\text{-}hit} \geq 15$
- Resulting efficiency ~ 99%

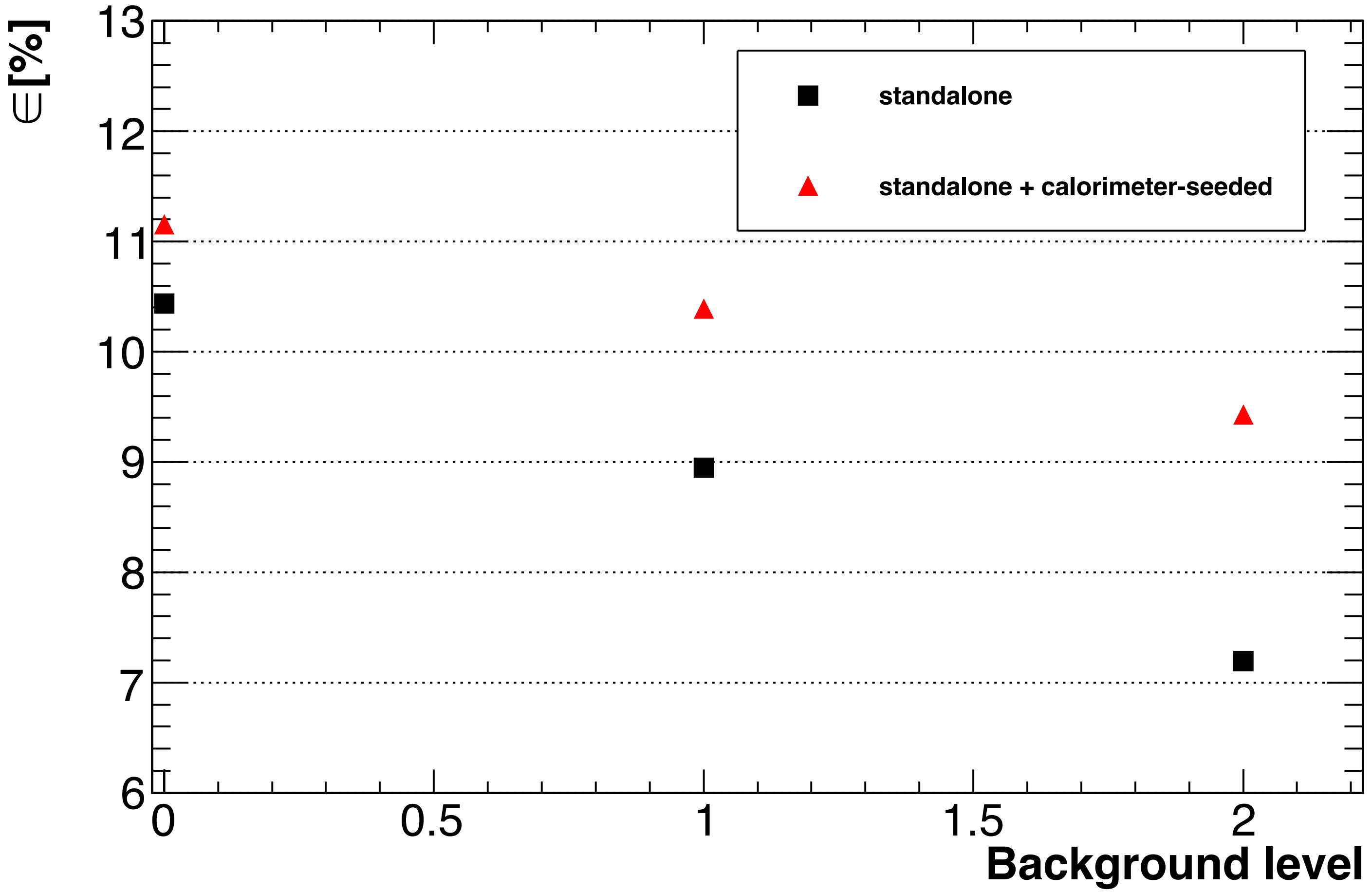




Signal momentum



CE detection efficiency



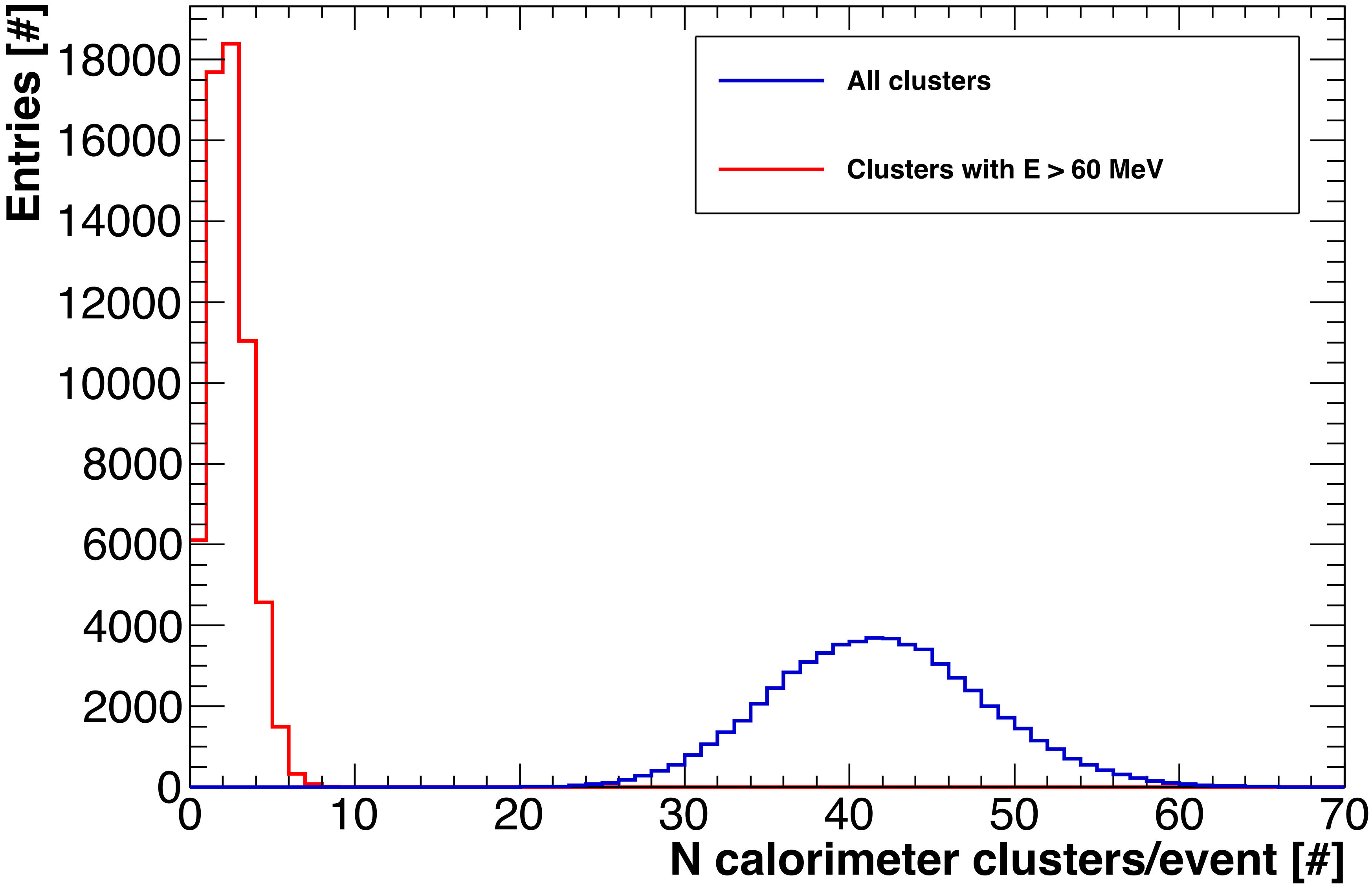
- ϵ evaluated using tracks passing quality cuts & 103.85 <p<105.1 MeV/c
- ϵ improved by ~ 15% (relative) and is more robust wrt the background
- An additional 5% (relative) by optimizing LR ambiguity algorithm

Summary

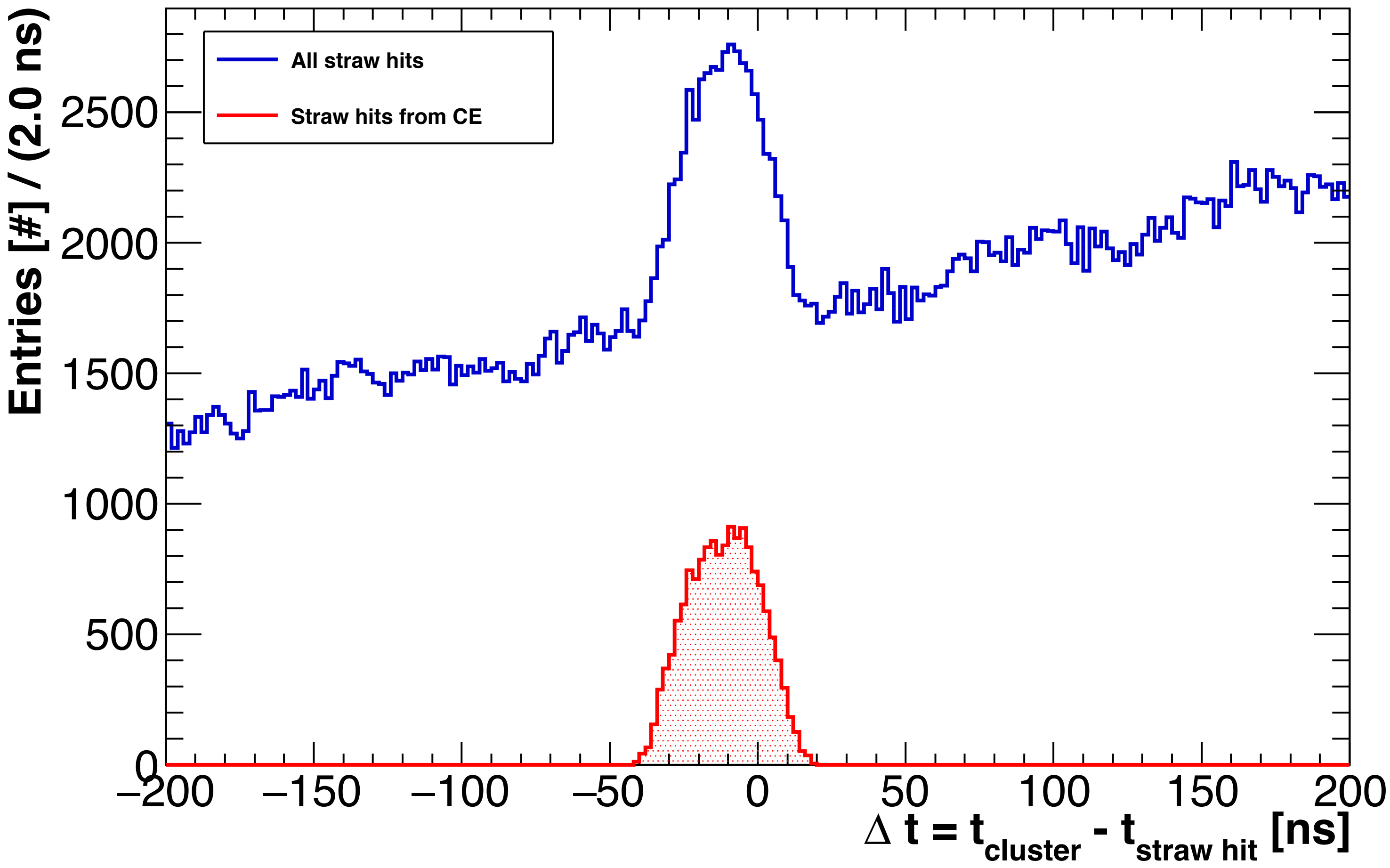
- The calorimeter improves the track reconstruction efficiency and makes it more robust
- The calo-seeded pattern recognition shows good performance at the trigger level (see Stefano Di Falco’s talk)
- The algorithm is well integrated within the Mu2e reconstruction code
- Paper under internal review
- Furthermore improvements are under discussion in the tracking group:
  - ➡ merging the standalone and calo-seeded hit pre-selection algorithms
  - ➡ including the calorimeter cluster info in the Kalman filter

backup slides

Calorimeter cluster occupancy

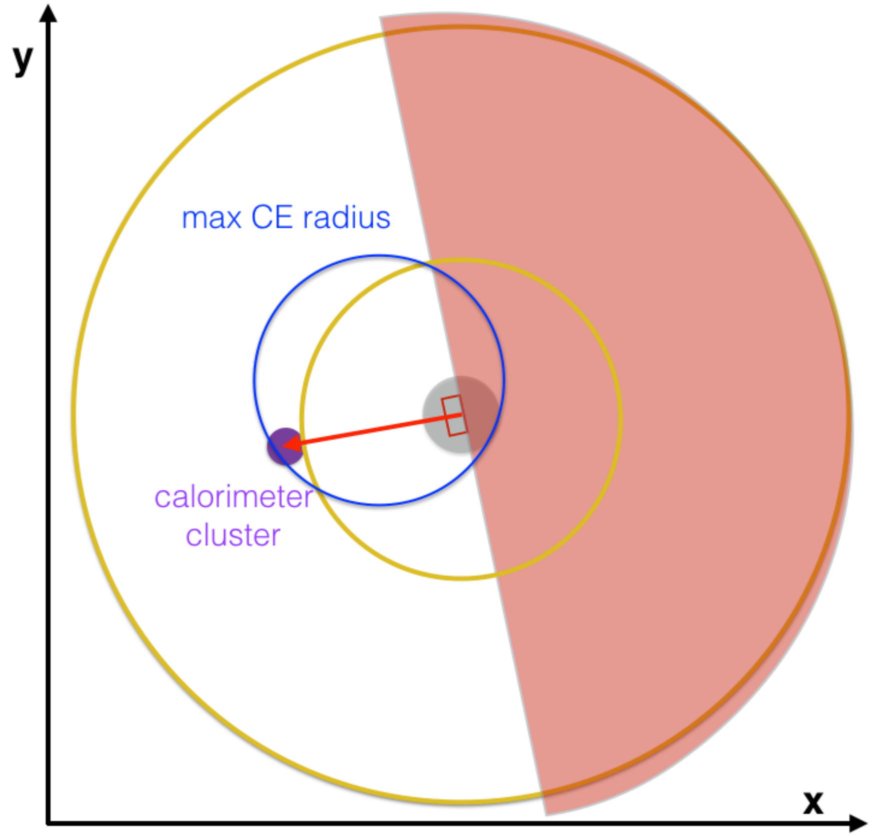


Cluster time window



- Average tof from middle of the tracker to the calorimeter ~ 8 ns
- Mean drift time ~ 20 ns
- Difference of these two numbers is consistent with the peak position

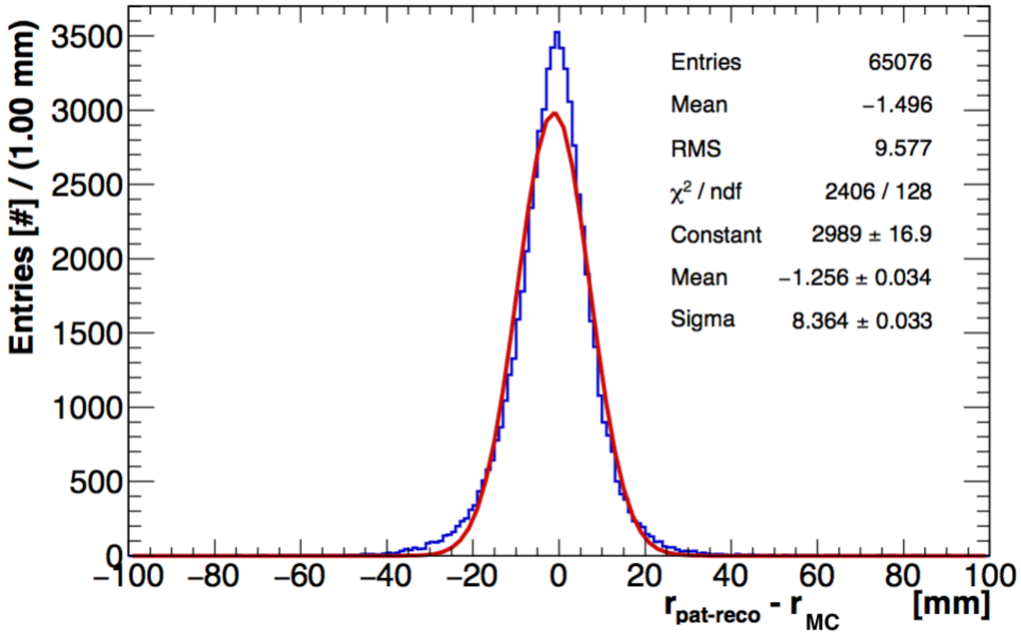
MUSE Cluster positon selection

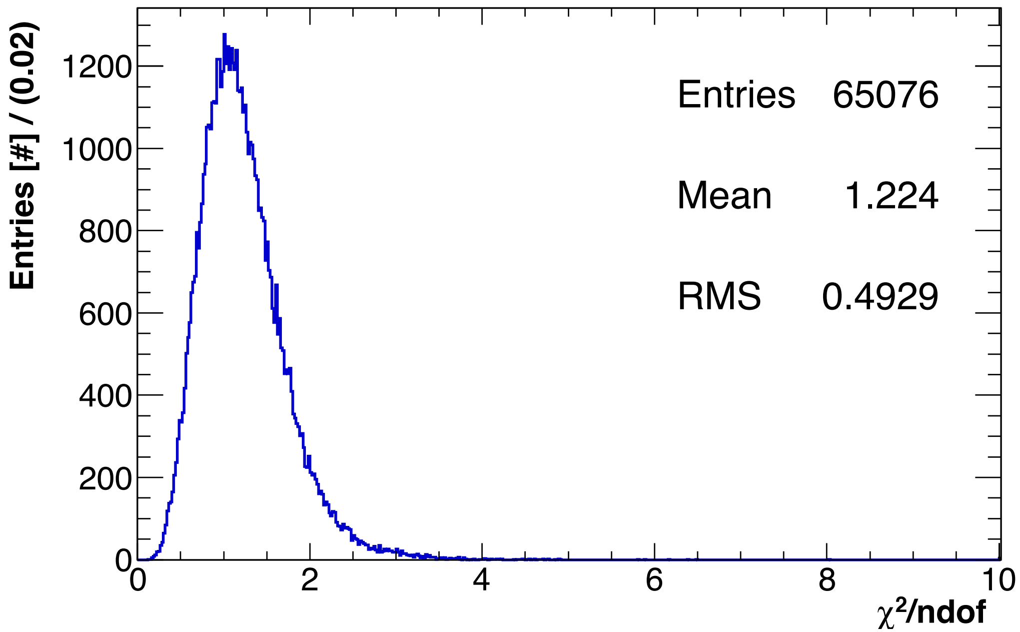


- Graded magnetic field between the stopping target and the tracker limits the CE pT
- Cluster position identifies the semi-plane where the CE track relies

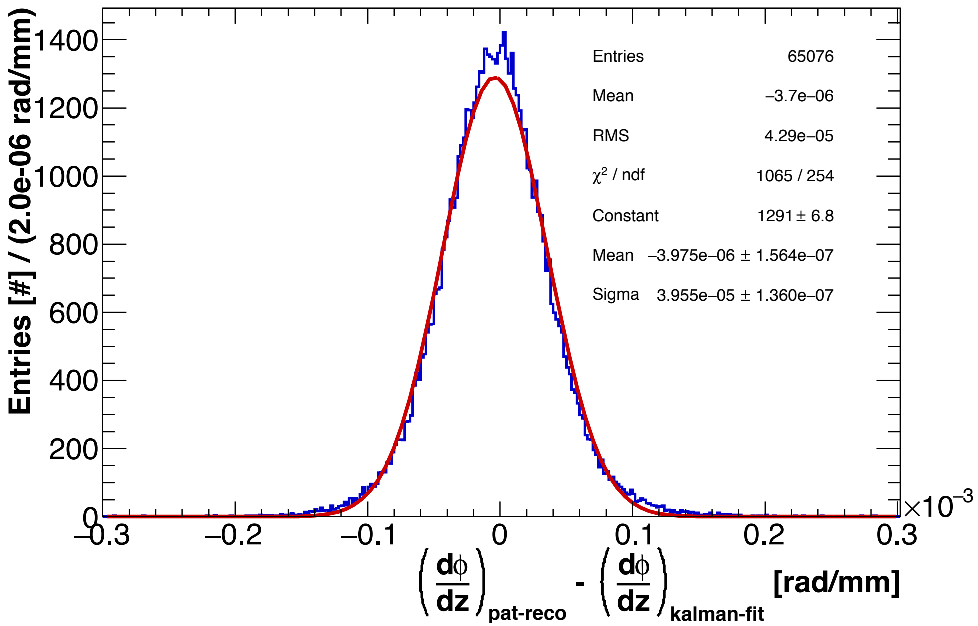
Δr fit result

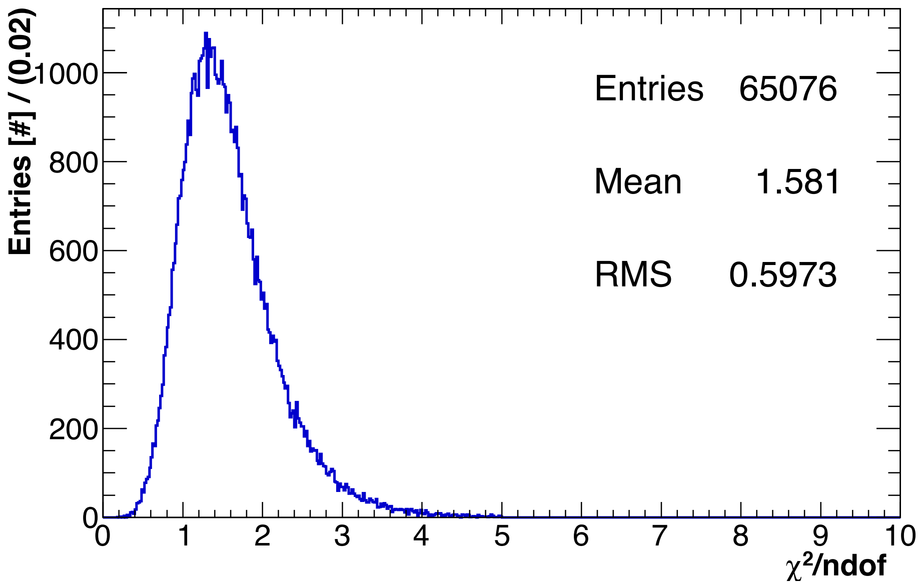
- Reduced Least Square Method for performing the circle fit
- Errors are assigned using the straw orientation wrt the helix center



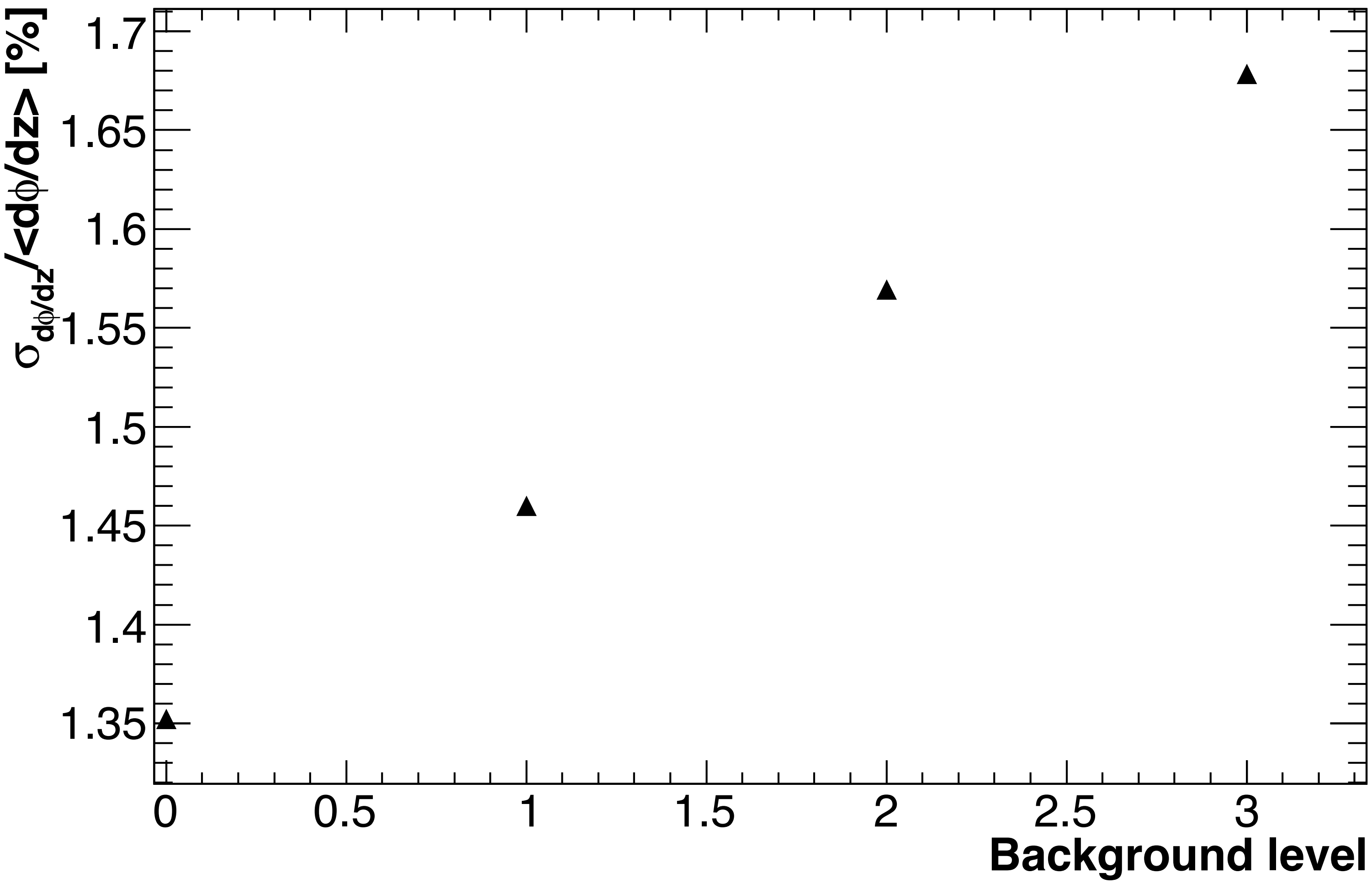


dϕ/dz fit result





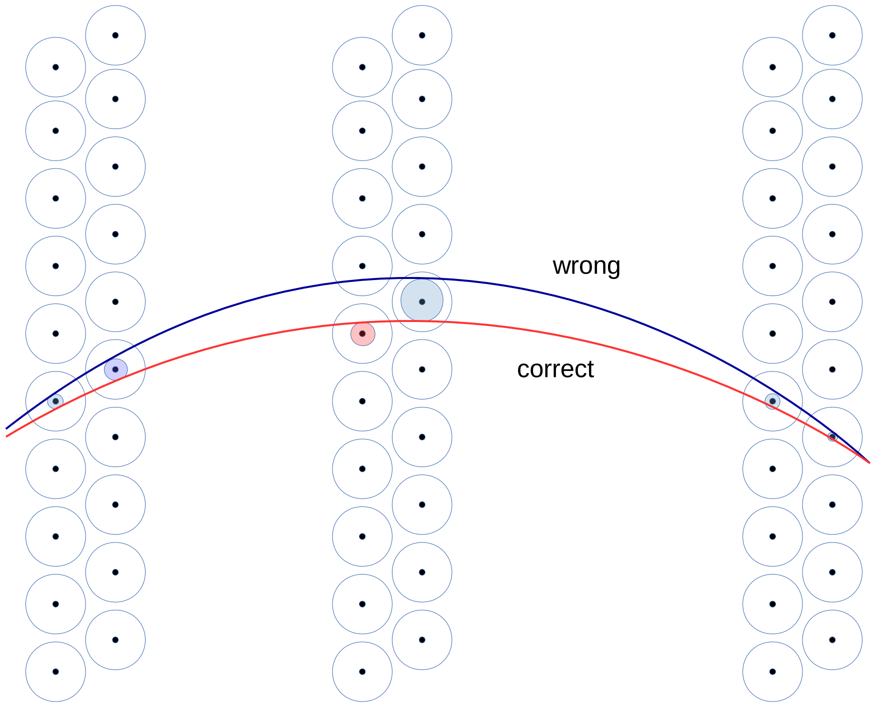
Helix search: dϕ/dz resolution

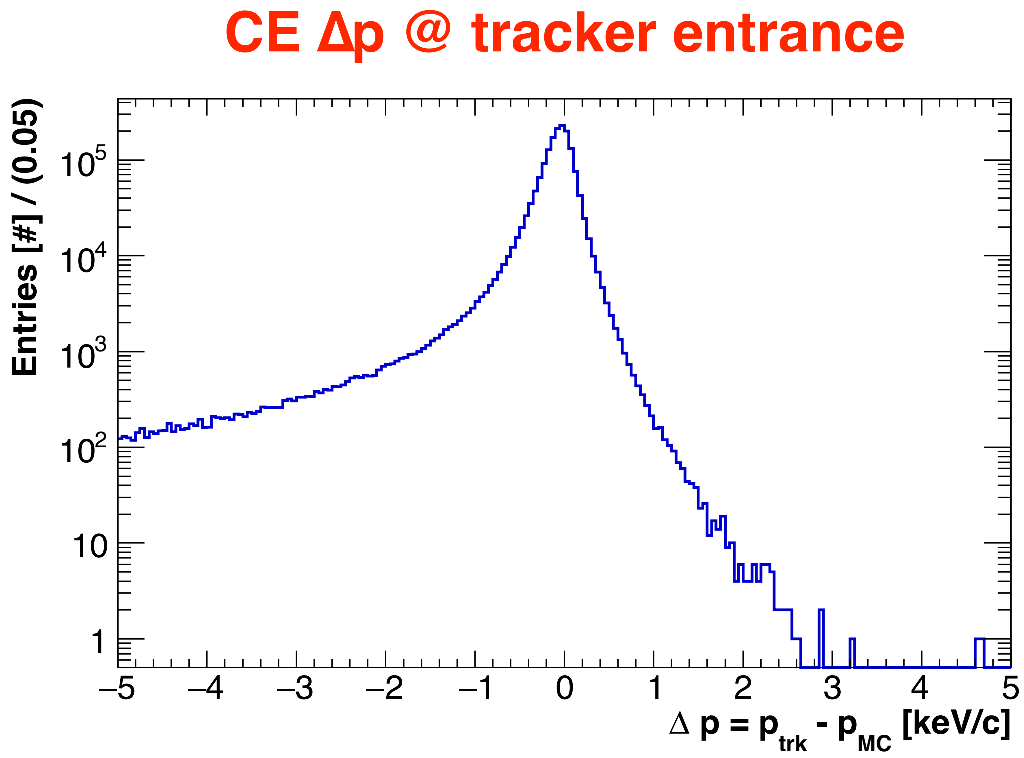


- Resulting dϕ/dz resolution $\sigma_{d\phi/dz}$/<dϕ/dz>~ 1.45 % for CE

Momentum resol tails

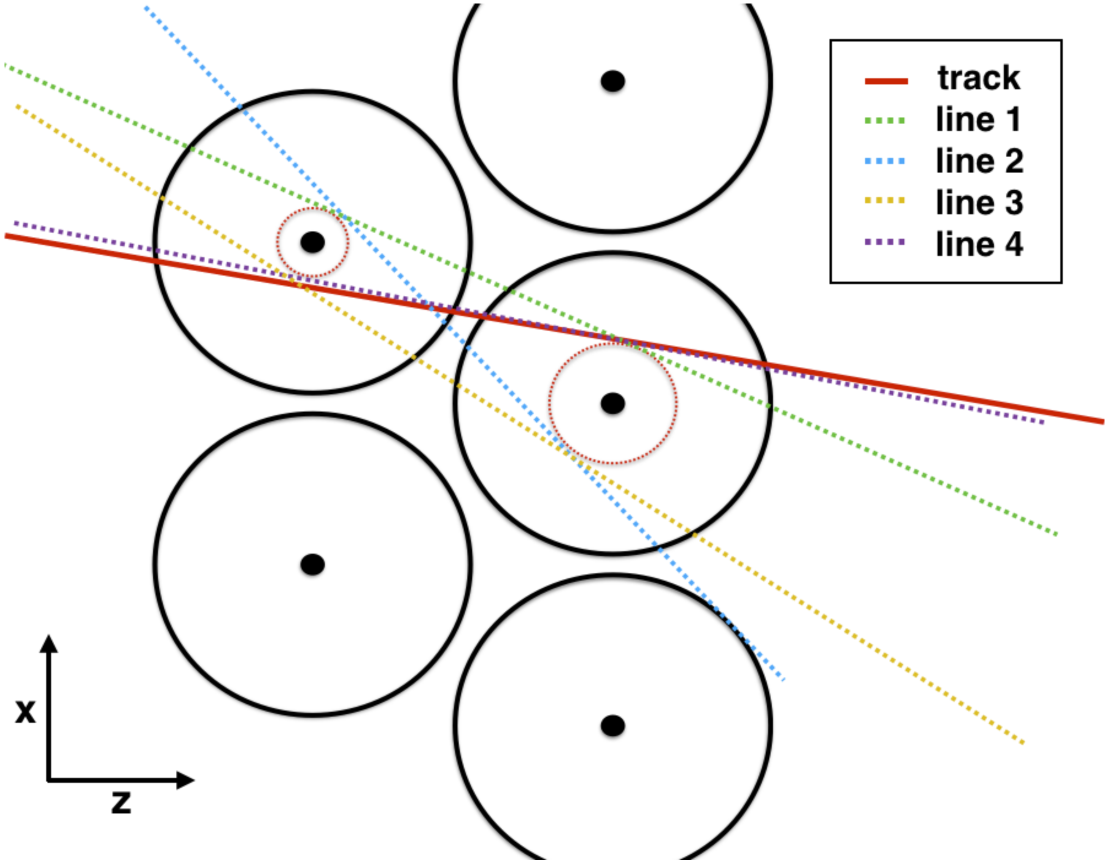
- Crucial in the final reconstruction is the "left-right" ambiguity resolution
- Drift sign mis-assignment impacts on the high-side tail



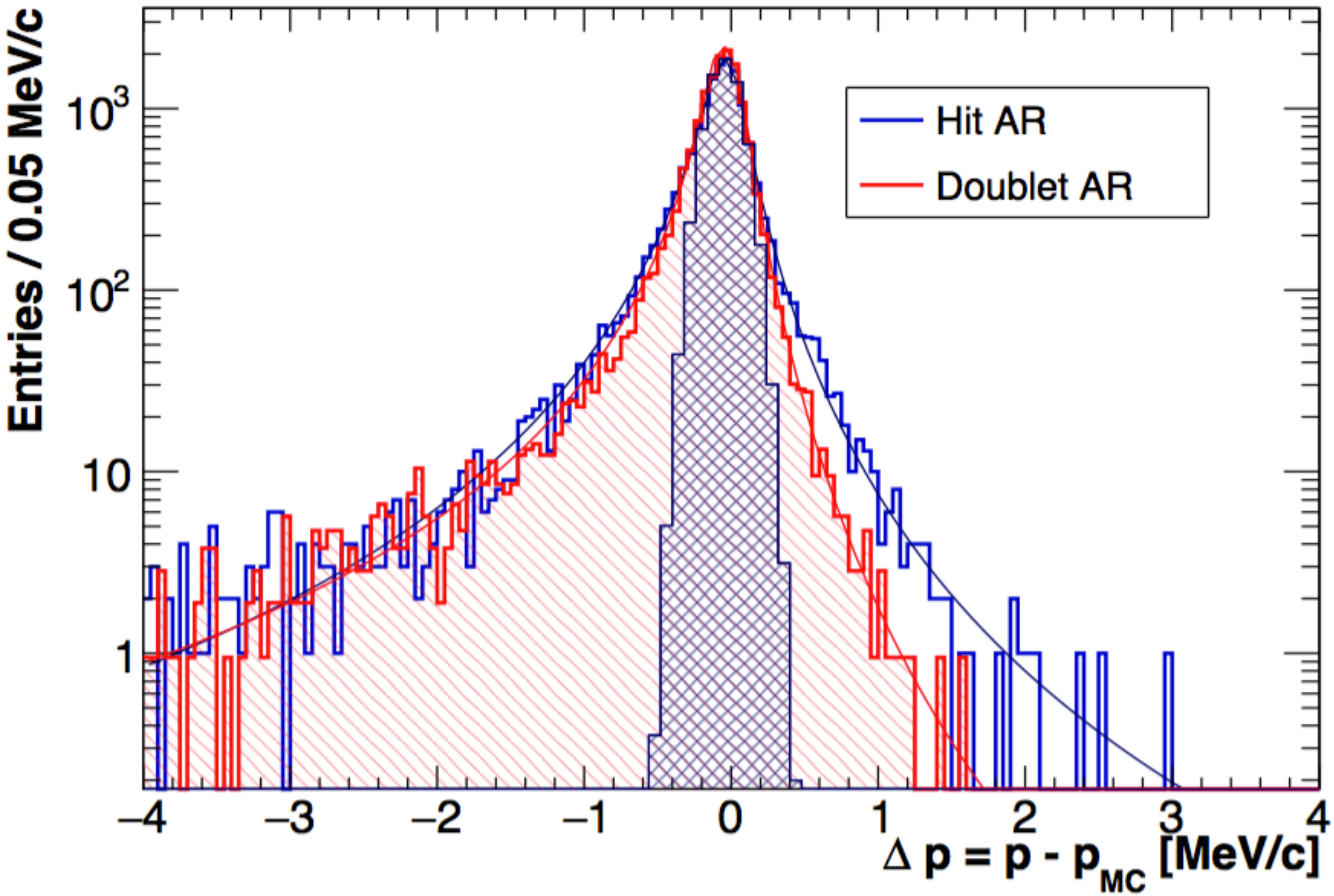


Doublet-based AR

- The tracker is composed of 2-layers panels
- With ~80% probability a track has 2 or more hits in a panel (**doublet**)
- Drift radii define 4 possible local track slopes that are used to find the correct drift directions

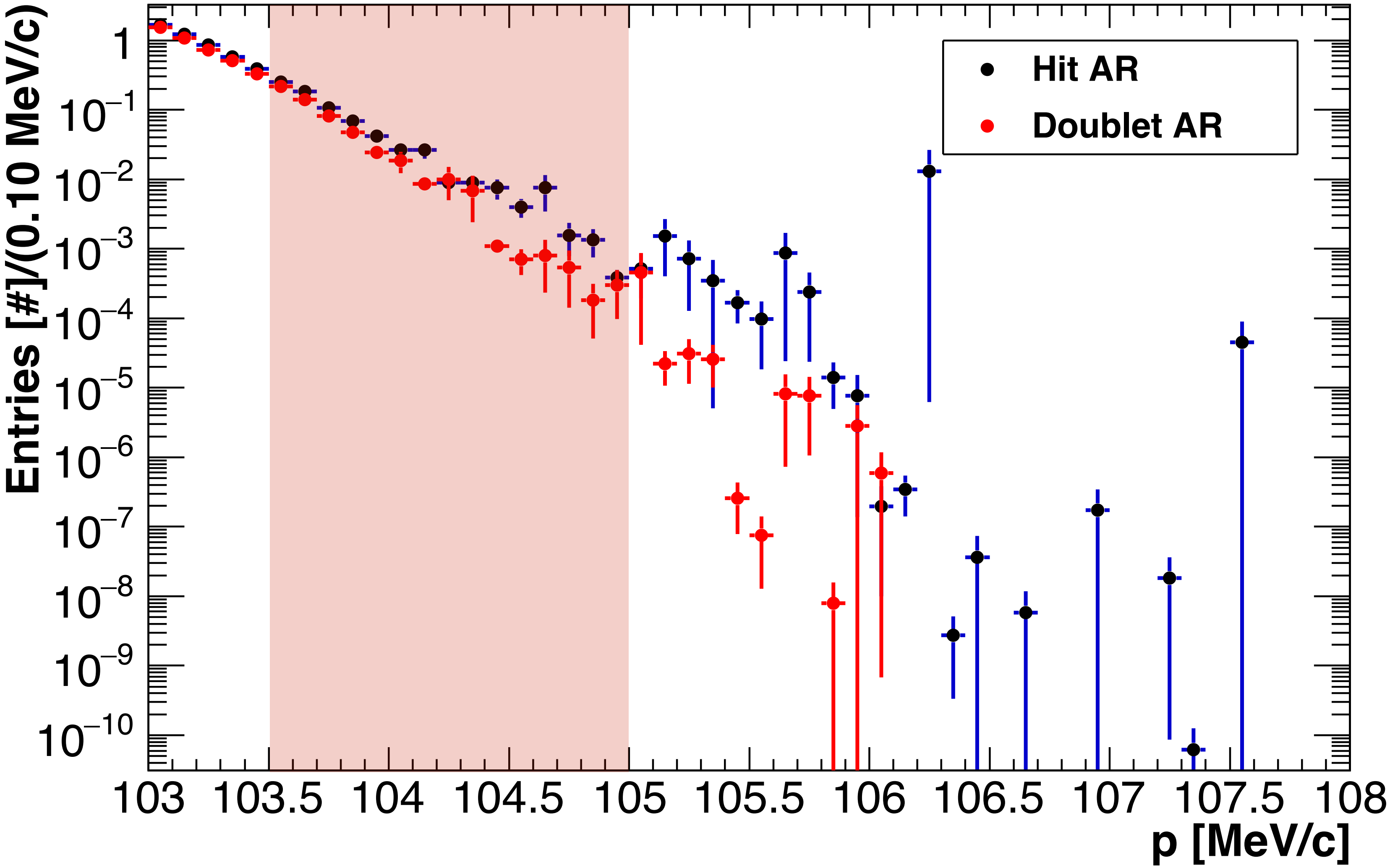


MUSE Momentum resol improvements



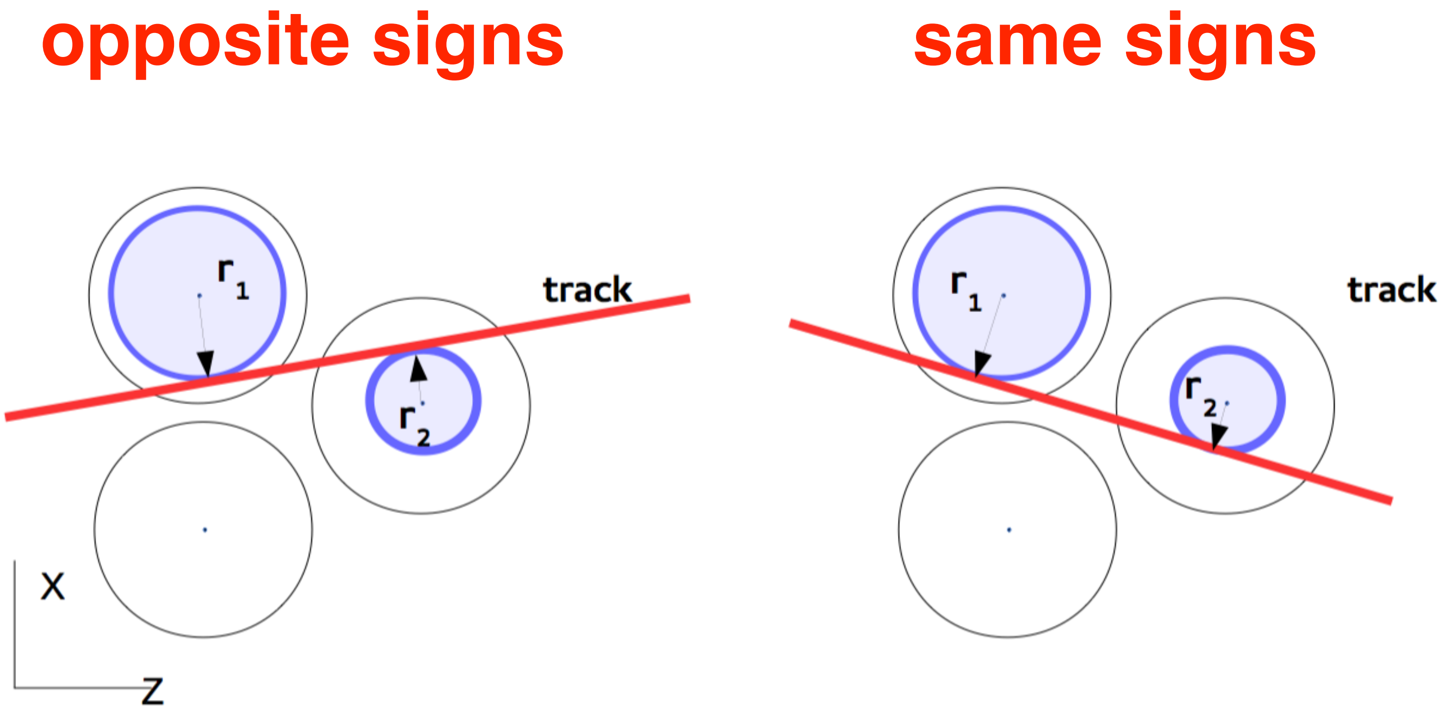
- Events with Δp>1MeV/c reduced by a factor 5

DIO suppression

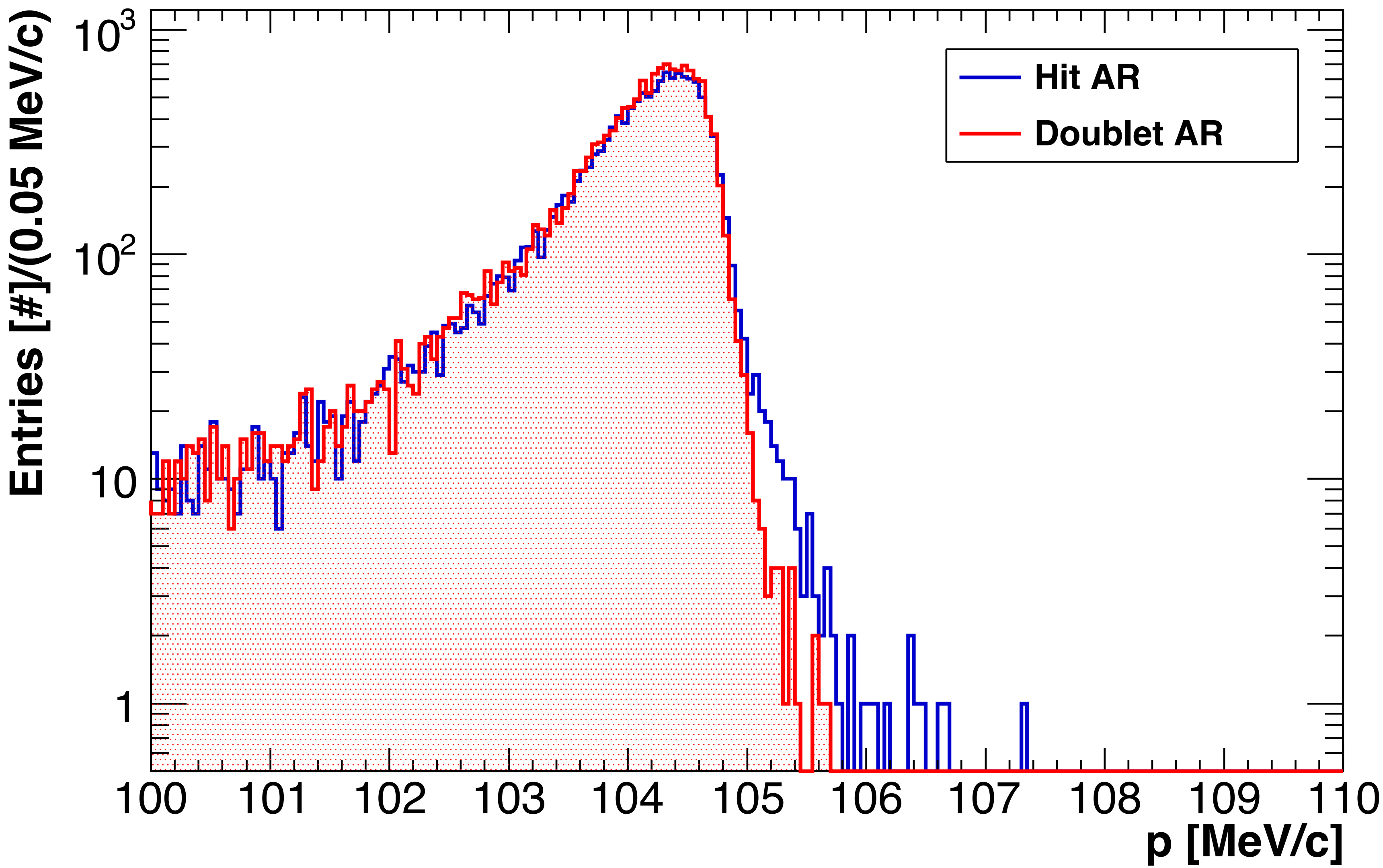


- Events with p in [103.5, 105] MeV/c reduced by factor 1.8

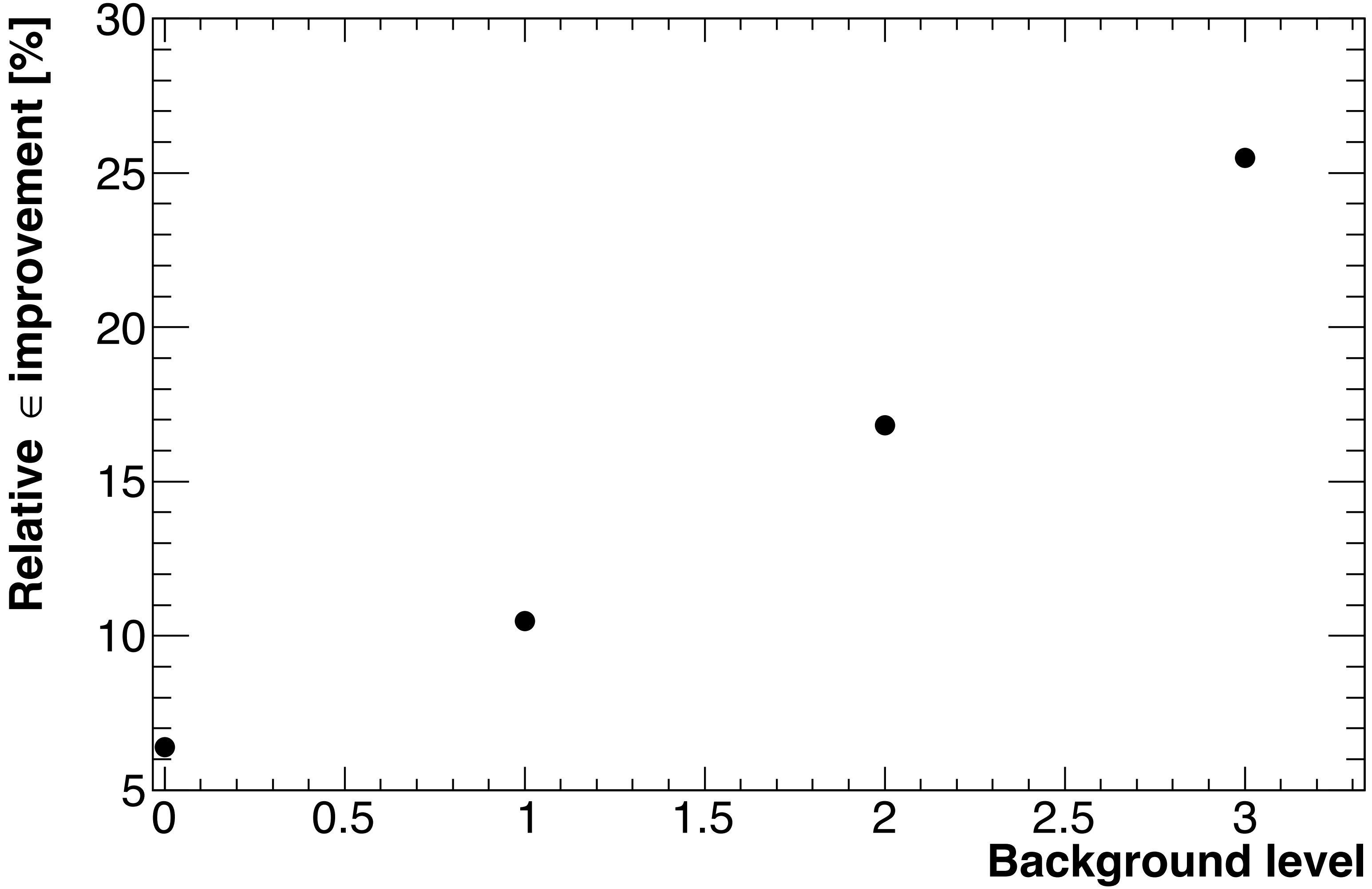
Doublet configurations



MUSE CE momentum spectrum



Impact on track-reco efficiency



MUSE Mu2e track reconstruction

The Mu2e track reconstruction has several specific features:

- a CE makes 2-3 full turns in the tracker
- **time dependence** of the track-hit position:

$$r_{\text{drift}} = v_{\text{drift}} \cdot (t_{\text{measured}} - \text{T}_0 - t_{\text{flight}})$$

The **track reconstruction** is factorized into 2 main steps:

1. **Track finding:** provides a set of straw hits consistent with a track candidate
2. **Kalman based fitter**: performs the final reconstruction

The **track finding** uses two algorithms:

A. Standalone: relies only on the tracker information
B. Calorimeter-seeded: seeds the track search using the reco cluster