Track Extrapolation in the g-2 experiment

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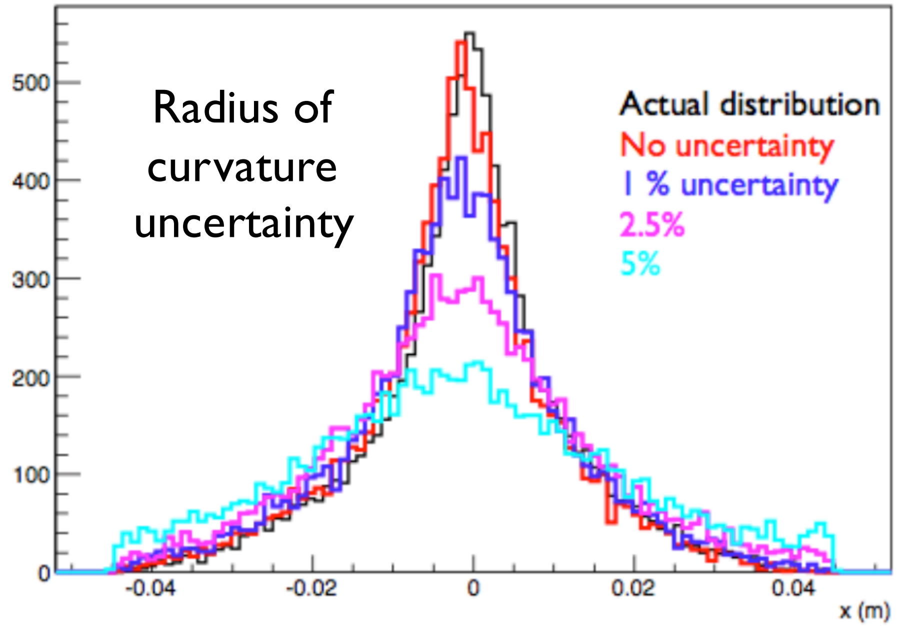
Introduction

- Reminder of tracking requirements in g-2
- Track extrapolation overview
- Identifying the decay vertex position
- True – reconstructed position distributions
- Optimising the extrapolation
- Results from simulation

Tracking Requirements - reminder

- Trackers required for 3 main reasons:
  - Measure beam profile as a function of time at multiple locations around the ring
  - Understand systematic uncertainties on the ω_a measurement e.g. pileup (multiple e+ hitting calorimeter within a short time window), calorimeter gain and muon loss by providing an independent measurement of the momentum of the incident particle
  - Measure any vertical tilt in muon precession plane → EDM signal

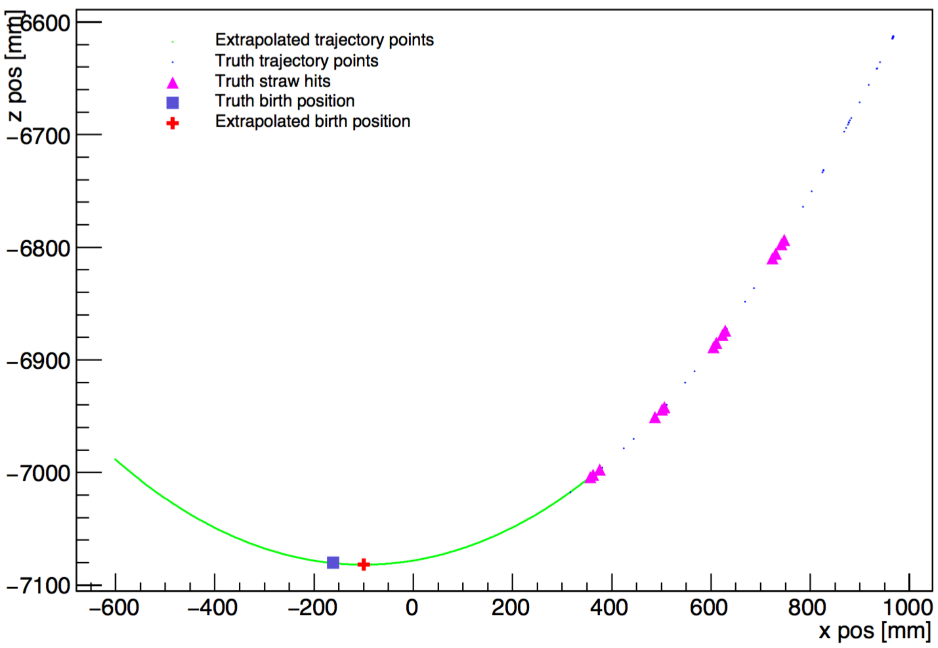
- Requirements:
  - <1% momentum resolution
  - mm-level position resolution



Track Extrapolation - overview

Fitted decay positron tracks are extrapolated back to the muon decay vertex location using a 4th order Runge-Kutta algorithm

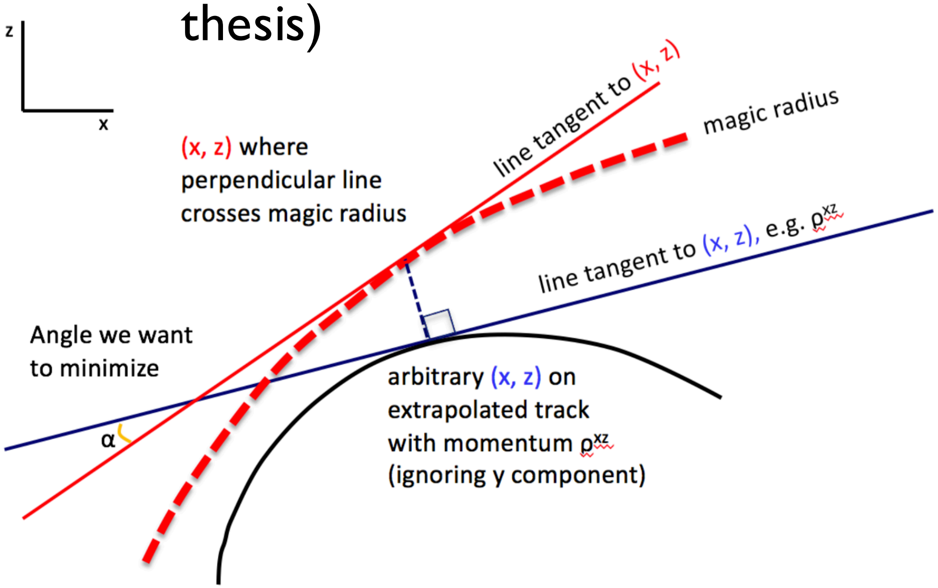
- uses Nystroem algorithm (Handbook Nat. Bur. of Standards, procedure 25.5.20) – method for solving ODEs
- Define a fixed step size and swim particle through field along the step
- Look up the magnetic field at each step
- Stop extrapolating when momentum of extrapolated track is tangential to the magic radius
- Algorithm can be optimised to use varying step size in regions where field gradient is larger

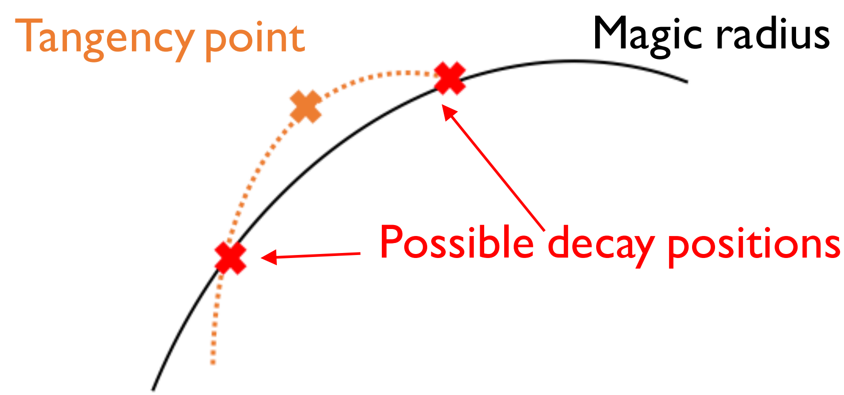


Finding the muon decay point

The decay vertex position is assumed to be the point of tangency to the 'magic radius'

- No fixed decay vertex so need to choose when to stop extrapolating
- A good first estimate of the decay point is the point where the momentum of the track is tangential to the magic radius
  - Assumes that e+ always emitted tangential to beam – need to correct for times where this is not the case. On average this is a 1mm effect (Sossong thesis)



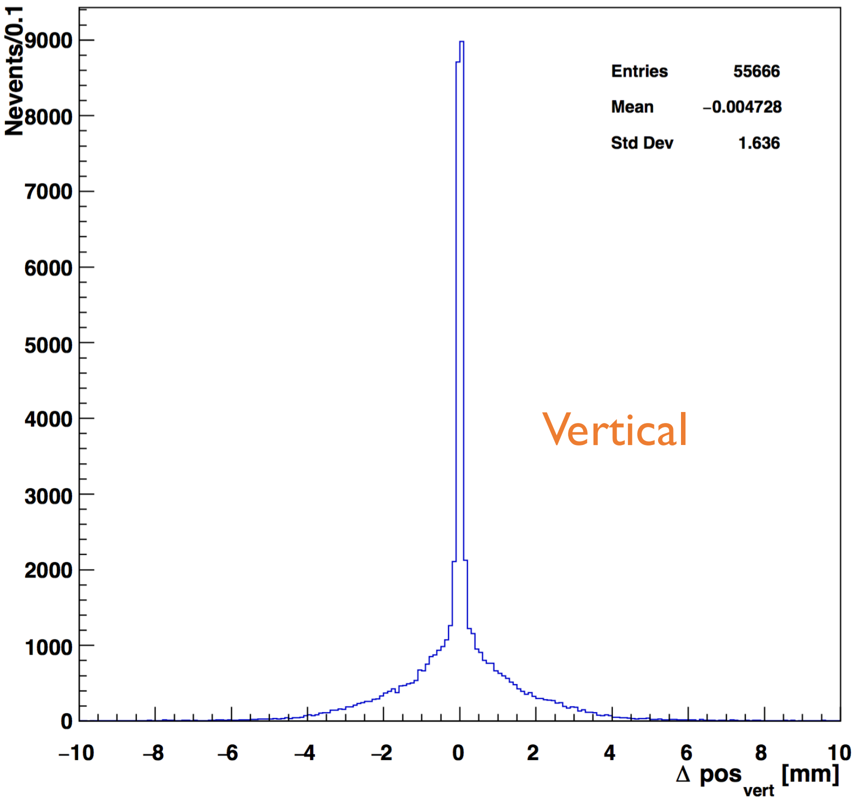


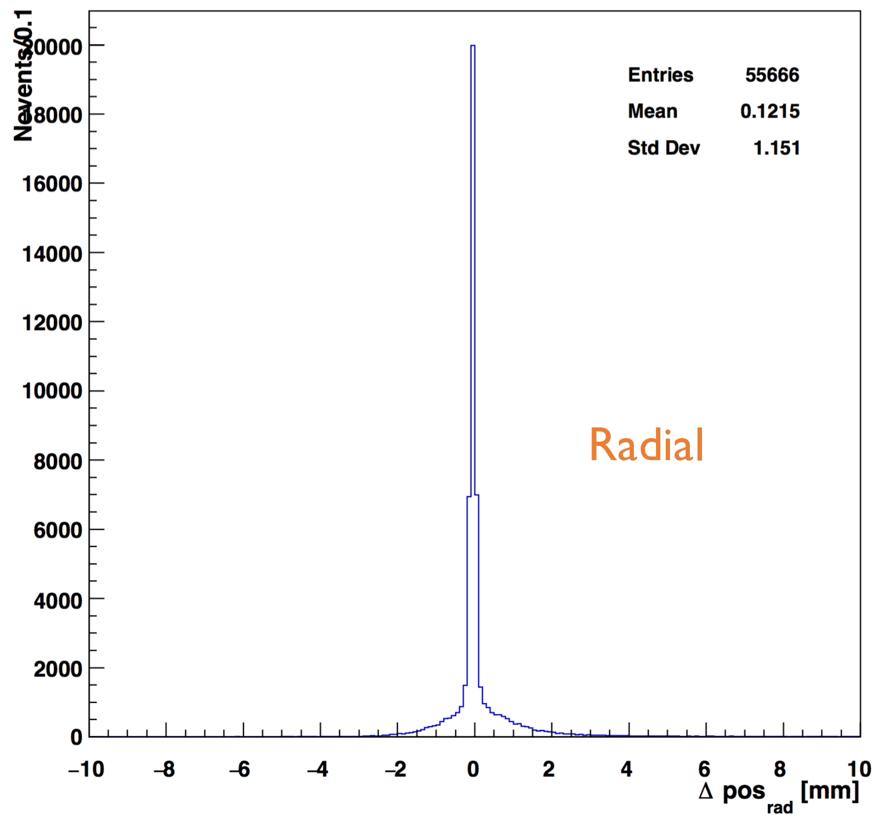
- For checking success of algorithm, also consider the DCA of the extrapolated track to the true decay position from simulation
  - Choose the three closest points to the true decay point, fit a circle to them and find the point on the circle to the true decay position

True – DCA position distributions

Plot the true – DCA radial and vertical positions, using true position and momenta as input, to gauge success of extrapolation algorithm

- Extrapolated from true positions/momenta





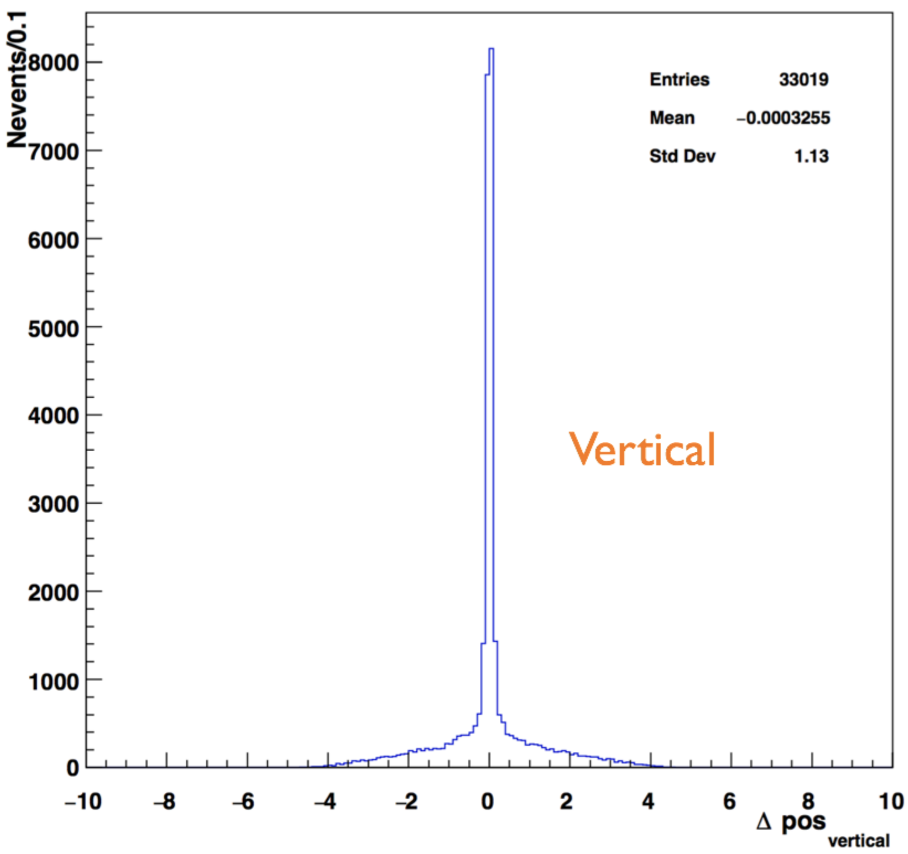
- Applying cuts could improve distributions, but limited information available

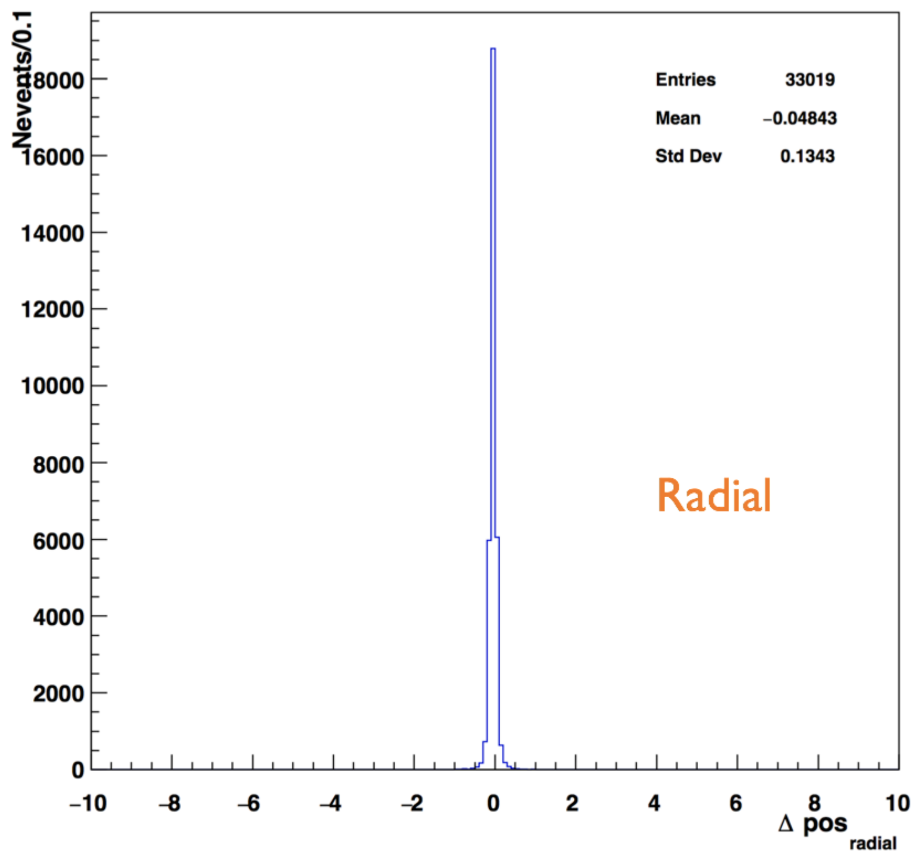
→ Use the geometry in the simulation to find out if an extrapolated track has hit any material

True – DCA position distributions

Considering only events that do not hit any material improves the true – reco resolution significantly

- Extrapolated from true positions/momenta



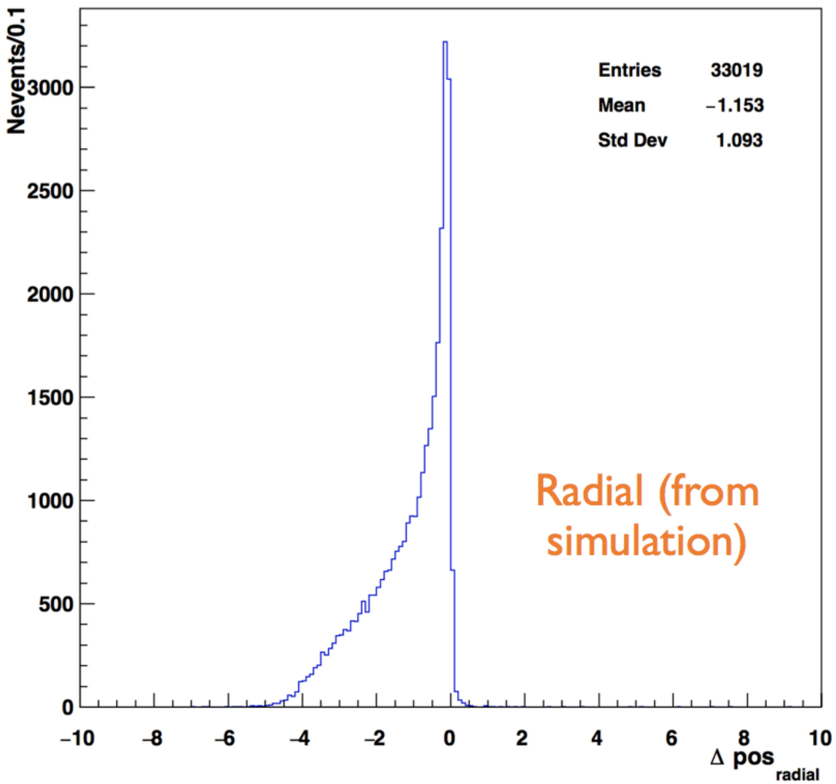


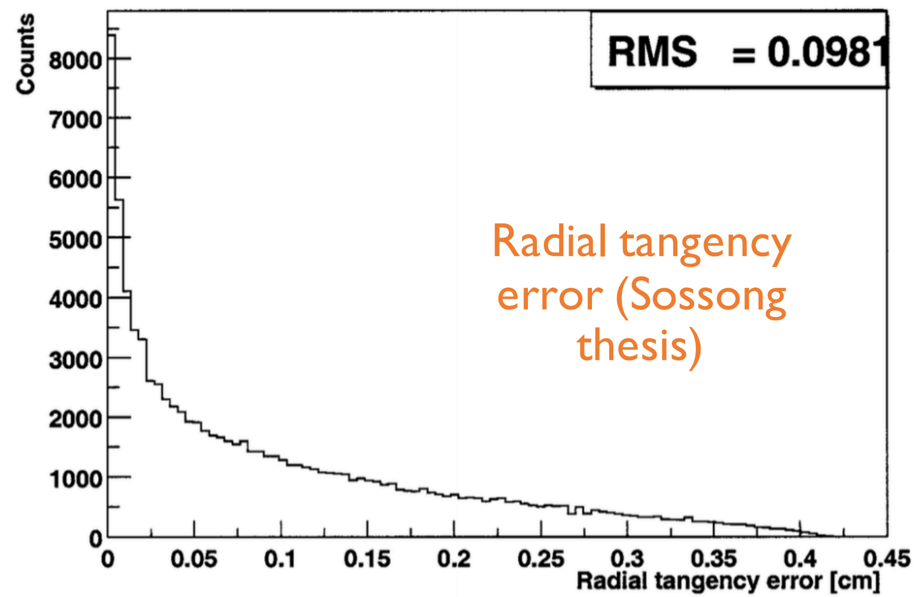
- Improvement is better for radial resolution than vertical resolution

True – tangency point position distributions

True – tangency point radial position is similar to the expected distribution before any corrections are applied

- Extrapolated from true positions/momenta - events that hit volumes removed



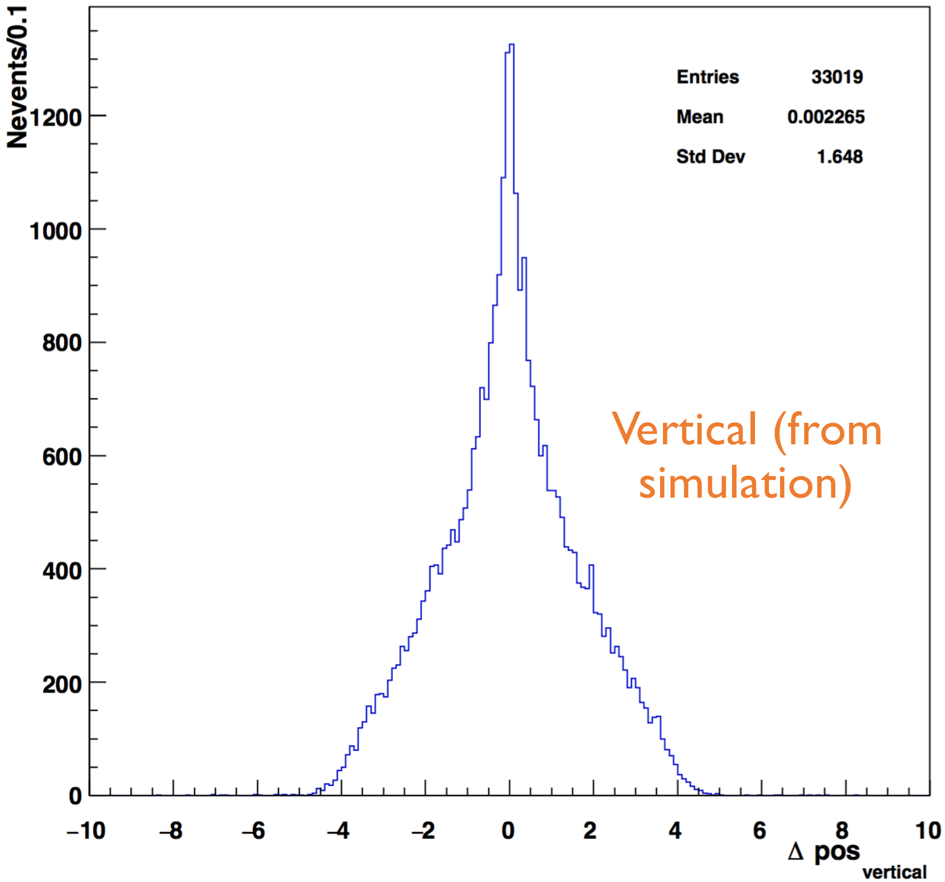


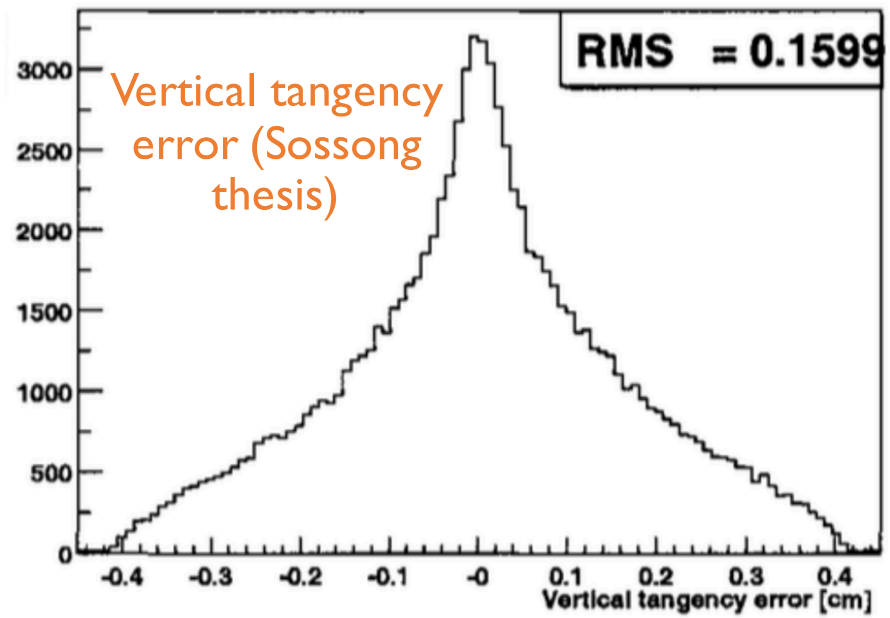
- Spread is similar to that measured in Brookhaven experiment

True – tangency point position distributions

True – tangency point vertical position is similar to the expected distribution before any corrections are applied

- Extrapolated from true positions/momenta - events that hit volumes removed

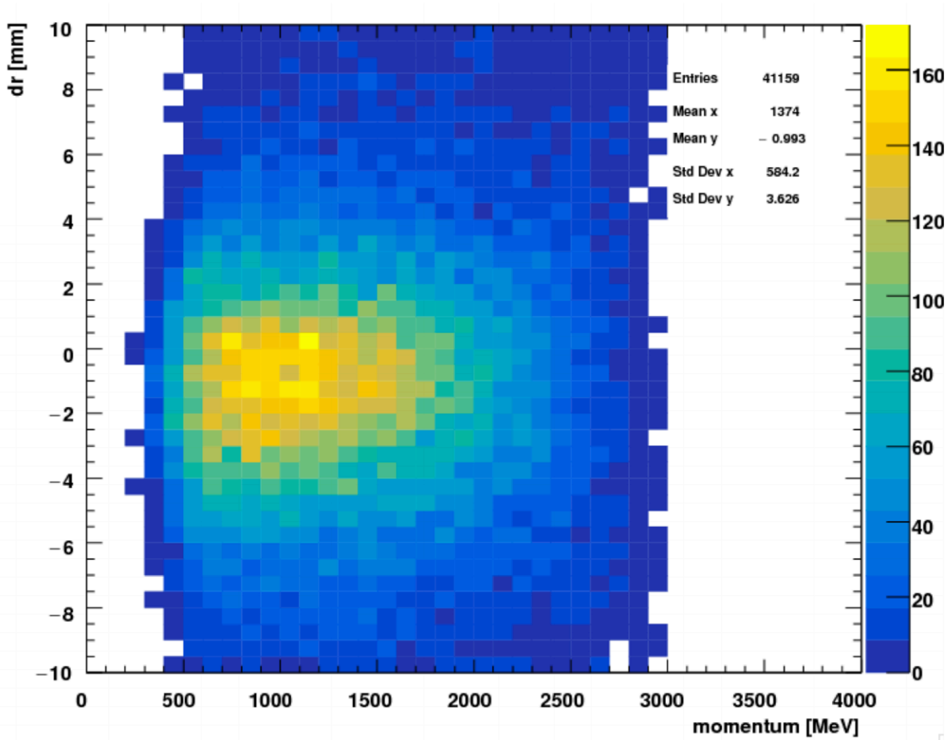


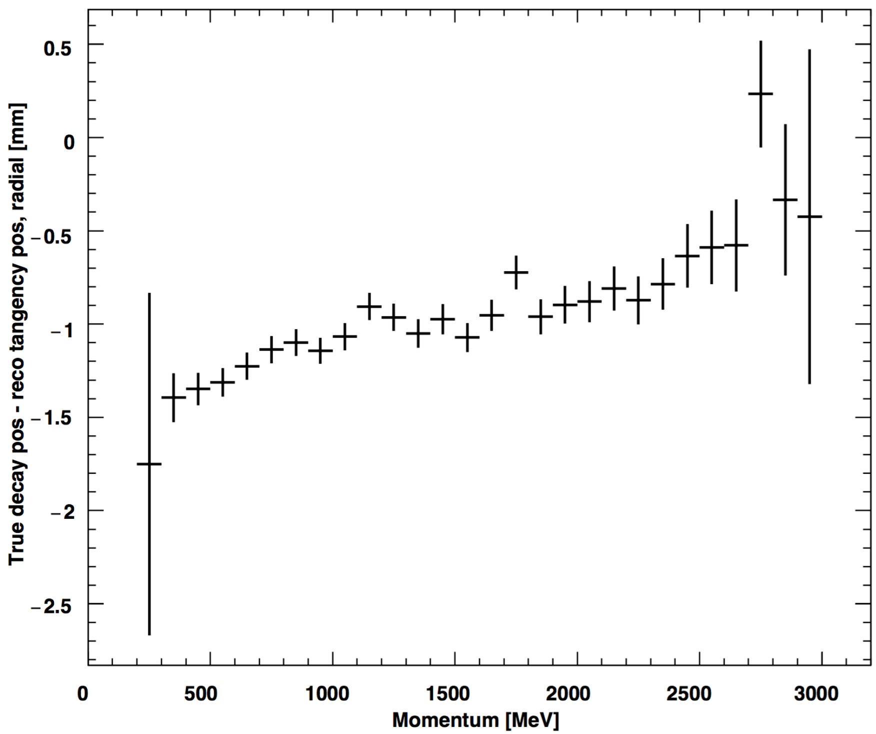


- Spread is similar to that measured in Brookhaven experiment

Reconstructed radial position

Plotting the true – tangent point position as a function of momentum shows the resolution improves with increasing momentum, as expected





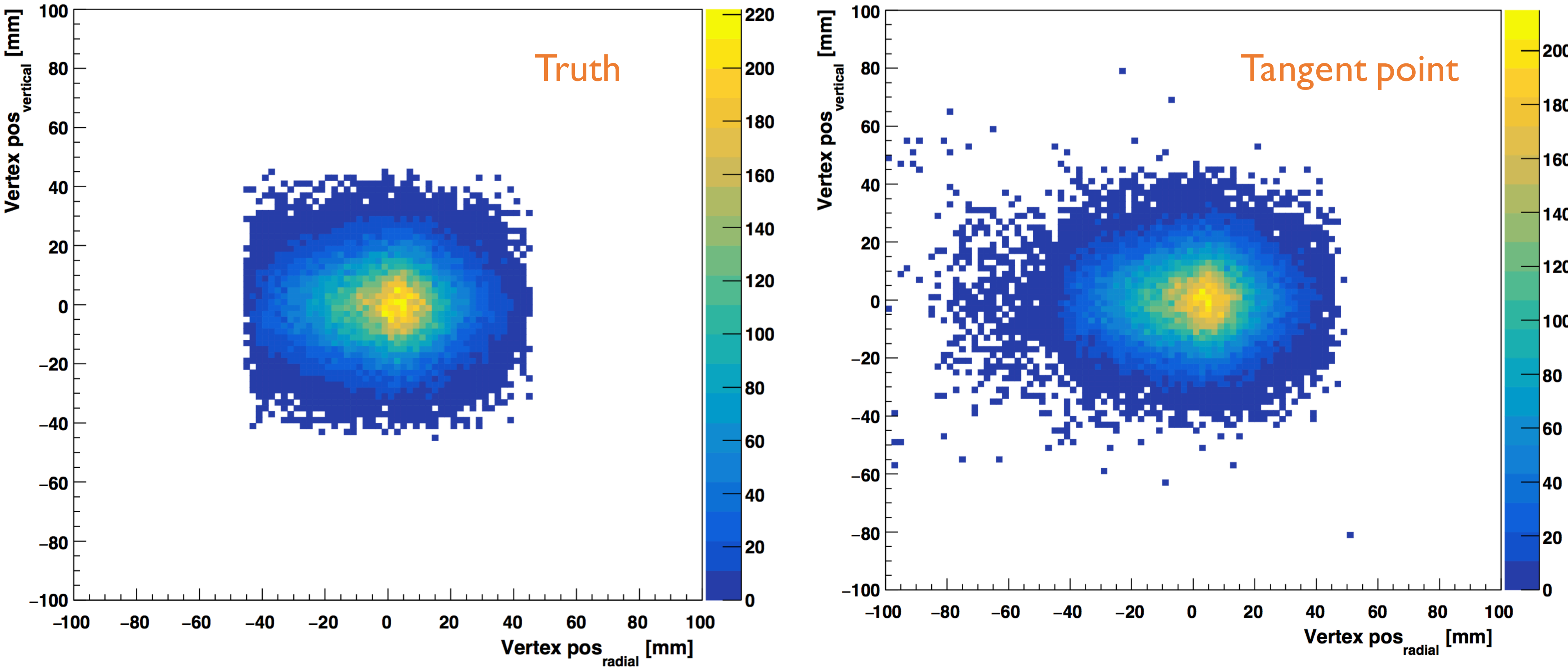
- Extrapolated from fitted tracks (GEANE)

At 'magic' momentum, expect decays to be perfectly tangential

→ Using tangent point as decay vertex is a better approximation at high momentum

Average beam position

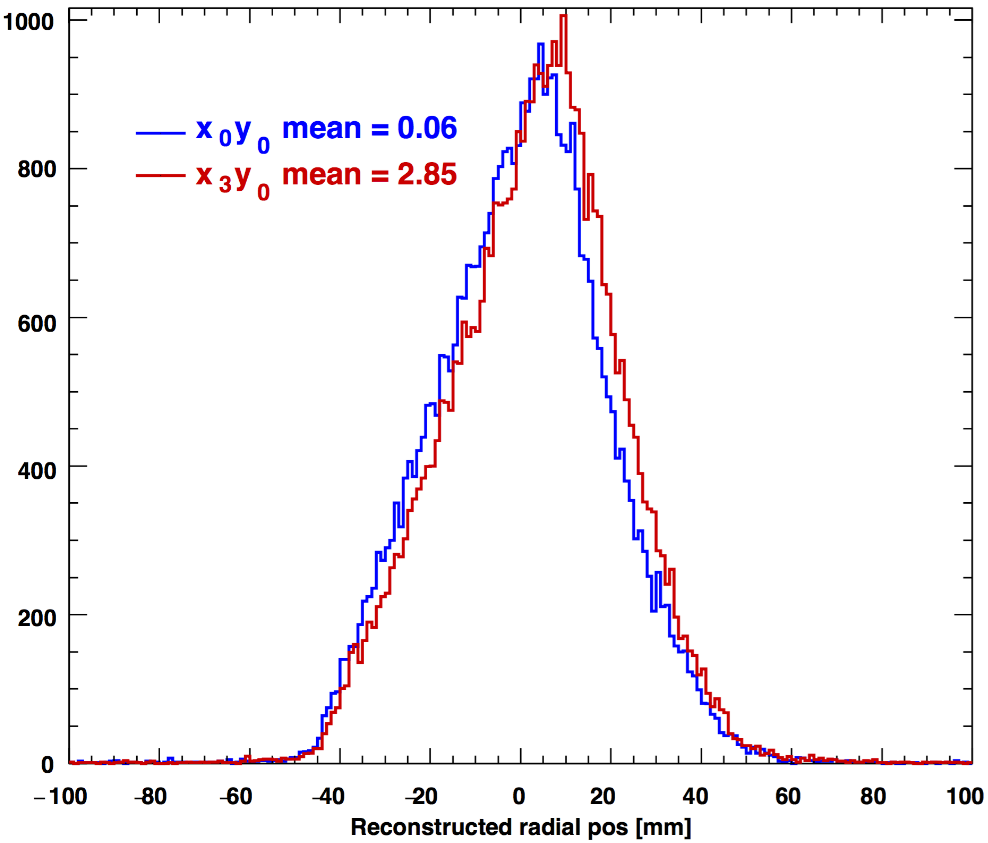
Using truth as input, the average beam position can be reconstructed with reasonable accuracy



- Extrapolated from true straw hit positions/momenta
- No cuts applied on momentum or volumes hit

Average beam position – shifted beam

Extrapolating from fitted (GEANE) tracks from two samples of muons with different beam positions - shift in mean observed as expected



- Extrapolated from fitted tracks (GEANE)
- Two samples of muons generated:
  - Beam x pos mean = 0mm
  - Beam x pos mean = 3mm
- Reconstructed beam positions from these samples:
  - Reco x pos mean = 0.06 mm
  - Reco x pos mean = 2.85 mm

Conclusions

- Track extrapolation between fitted tracks and decay vertex/calorimeters is performed using a 4th order Runge-Kutta Nystroem algorithm
- Comparison between true and DCA decay positions show algorithm is working successfully
- Cutting events that hit material improves the reconstruction
- Using the point of radial tangency to approximate the decay vertex position, the resolution on the reconstruction is sufficient to detect a shift in the average beam position