

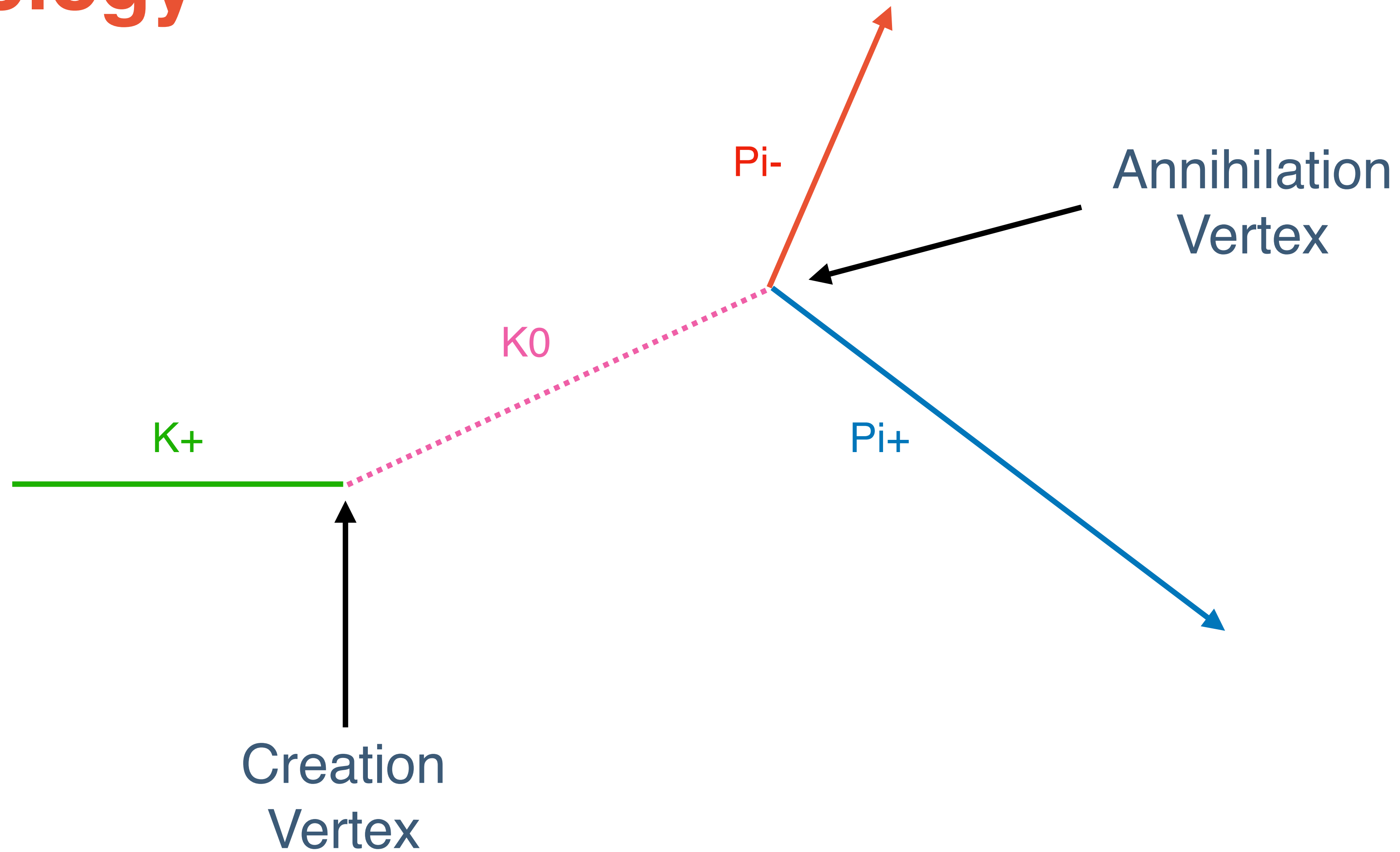
Reconstructing Pion Momenta

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Impact of pion momentum on the analysis outcome

- One of the keys of the K_0 s analysis is to reconstruct with good accuracy and precision the momentum of the outgoing pions;
 1. The resultant momentum of the annihilation vertex will be better aligned with the reconstructed K_0 direction;
 2. The invariant mass of the K_0 will peak at the correct value and will be narrower;
- The first depends not only on the magnitude of the reconstructed momentum, but on the opening angle and on the positions of the creation/annihilation vertices;
- The second only depends on the magnitude and the opening angle;

Topology

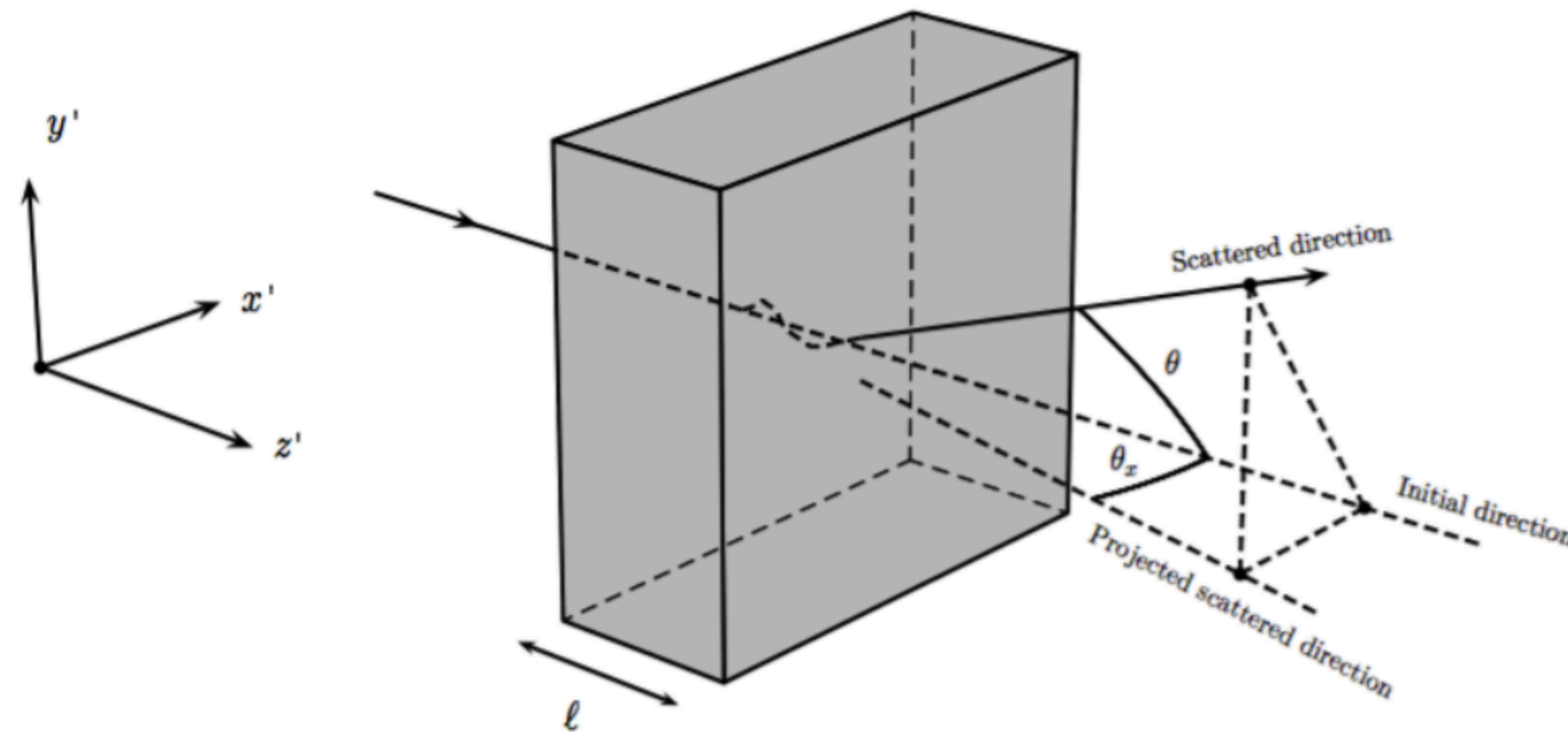


Momentum Estimation

- As far as I know, there are 3 methods to reconstruct the momentum in a non-magnetised TPC:
 1. Momentum by range: TLEFit
 2. Multiple Coulomb Scattering (MCS): (this talk)
 3. Calorimetry: Add all visible energy
- My goal is to implement the three of them, and for a single pion construct a joint likelihood from these 3 different approaches, that are complementary depending on the track properties and true momentum of the particle;

Multiple Coulomb Scattering

- MCS occurs when a charged particle traverses a medium and undergoes electromagnetic scattering off atomic nuclei;
- For a given particle momentum, the angular deflections are modelled with a Gaussian distribution centred at zero with an RMS width, σ_o^{HL} , given by the Highland formula;
- When one measures these deflections, there is the Highland-term but there is also a detector term that is not related with MCS, that needs to be determined;



$$\sigma_o^{HL} = \frac{S_2}{p\beta c} z \sqrt{\frac{\ell}{X_0}} \left[1 + \epsilon \times \ln \left(\frac{\ell}{X_0} \right) \right]$$

$$\sigma_o = \sqrt{(\sigma_o^{HL})^2 + (\sigma_o^{res})^2}$$

MCS Implementation

- MCS implementation is based on the Trajectory Points:
 - Trajectory Points are **reconstructed** objects that describe the trajectory of the reconstructed track: they have a coordinate and a direction;
 - Trajectory Points **are not physical charge deposition** (hits);
- Current MCS implementations (see this one in μ Boone: <https://arxiv.org/pdf/1703.06187>) use Trajectory Points for MCS applied to crossing muons;
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MCS Implementation

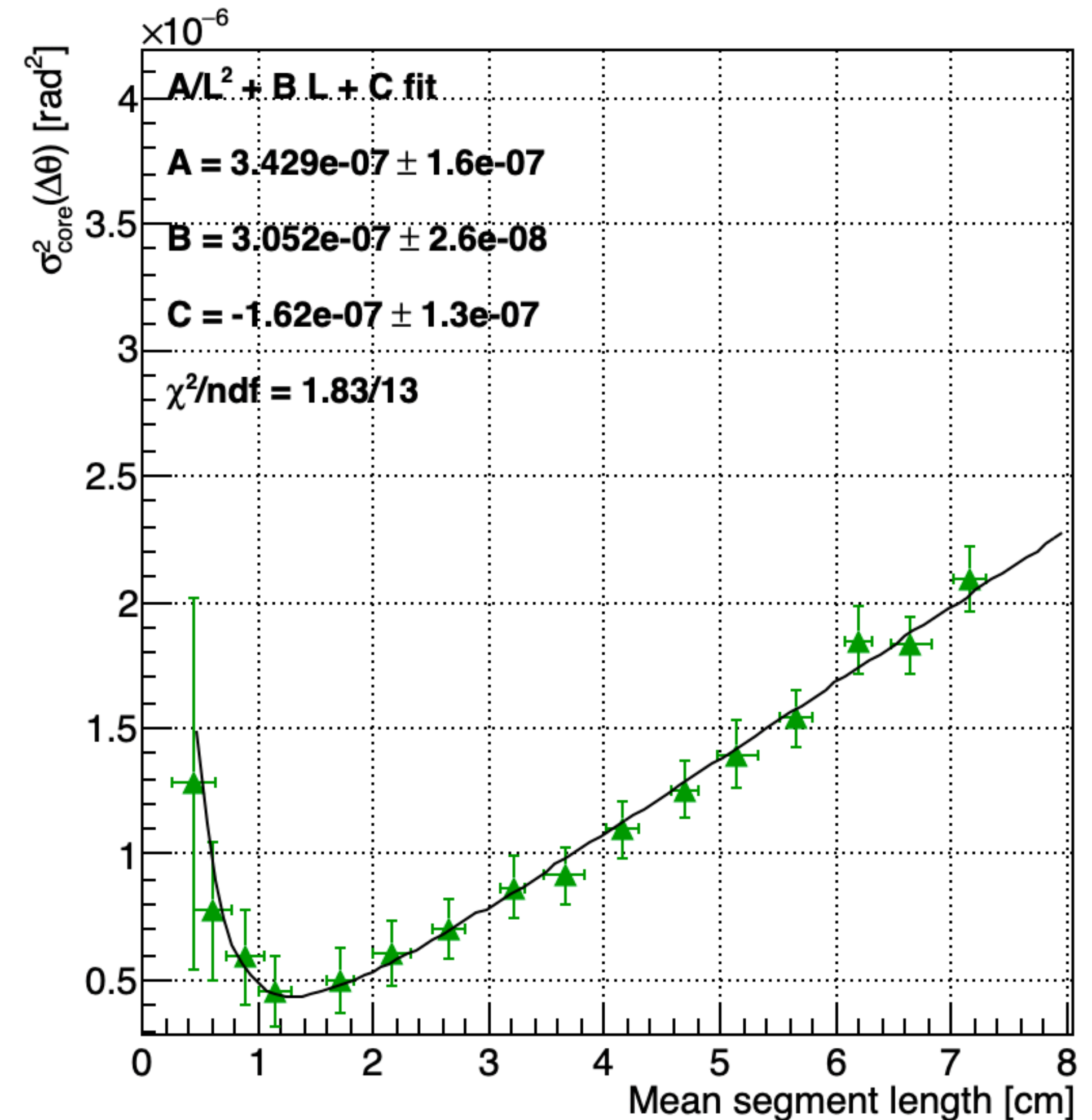
- One divides the track into segments of equal length, l , and fits a line to the Trajectory Points belonging to that segment;
 - Store the χ^2/ndf of the fit, the length of the segment, the RR of the segment, etc.
- Then, computes the angle between two consecutive segments (a segment pair $[i, i+1]$);
 - The angle is computed by re-defining the coordinate system so that the Z axis is aligned with the segment l ;
- The σ_θ of this angles (angular distribution) is related with the particle's momentum through the Highland formula;
- The dependence of the parameters S_2, ϵ on the true particle momentum can be empirically determined for the LAr case based on true information (see reference);

Results and Observations

- My goal was to determine the σ_o^{res} of the detector that includes the intrinsic detector resolution and any smearing introduced by the reconstruction;
 - I have access to beam-particle MC/data between 0.3 GeV to 7 GeV;
 - At 7 GeV, MCS becomes very small: let's use this to “isolate” the σ_o^{res} assuming that, at those high momenta, $\sigma^{res} \sim \sigma_o$
 - There might be a small HL-contribution even at those high momenta that we will model via $\sigma^{HL} \propto \sqrt{l}$;
- The detector term can be modelled as: $\sigma^{res} \propto \frac{1}{l^2}$
- The goal is to determine the best segment length given the typical momentum of my pions out of the K0 decay and their typical lengths: I scan σ_o as function of segment length at 7 GeV;

Results at 7 GeV

- To my surprise, the σ_o has a non-negligible HL-term contribution even at 7 GeV that we clearly see;
- This reveals MCS may have more power than initially thought even at high momenta;
- The detector term can be extracted from $\frac{A}{l^2} + C$



Results at other momenta

- The slope changes as a function of momentum, that is related with the momentum of the pions;

