DEEP UNDERGROUND NEUTRINO EXPERIMENT

13/01/22

Secondary stopping kaon analysis

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IFIC-VALENCIA

Update

- The event selection has been optimized and tested with all 6 GeV data (reco2 production).
  - It provides enough statistics and purity for a significant dEdx measurement.
- Firsts dEdx vs Residual Range plots are ready.
  - They could be used as a control sample for a systematic error.
- Starting to think about a XS measurement.

Previous talks: September CM, 22/07/2021, 16/06/2021, 26/05/2021

Event selection optimization

- The selection has been optimized by **maximizing the product Efficiency*Purity**.
- The optimization process has simplified the selection.
- The optimization has allowed to avoid cutting on the kaon CNNs, which could have biased the dEdx measurement.

- All plots that are being shown use all 6 GeV data (reco2 production) and all 6 GeV MC (PDSPProd4a_MC_6GeV_gen_datadriven_reco1_sce_datadriven_v1_0i)

Preselection in a nutshell

- Secondary kaons are produced in hadronic reactions generated by the beam particle → beam PDG = 211, 321 or 2212.

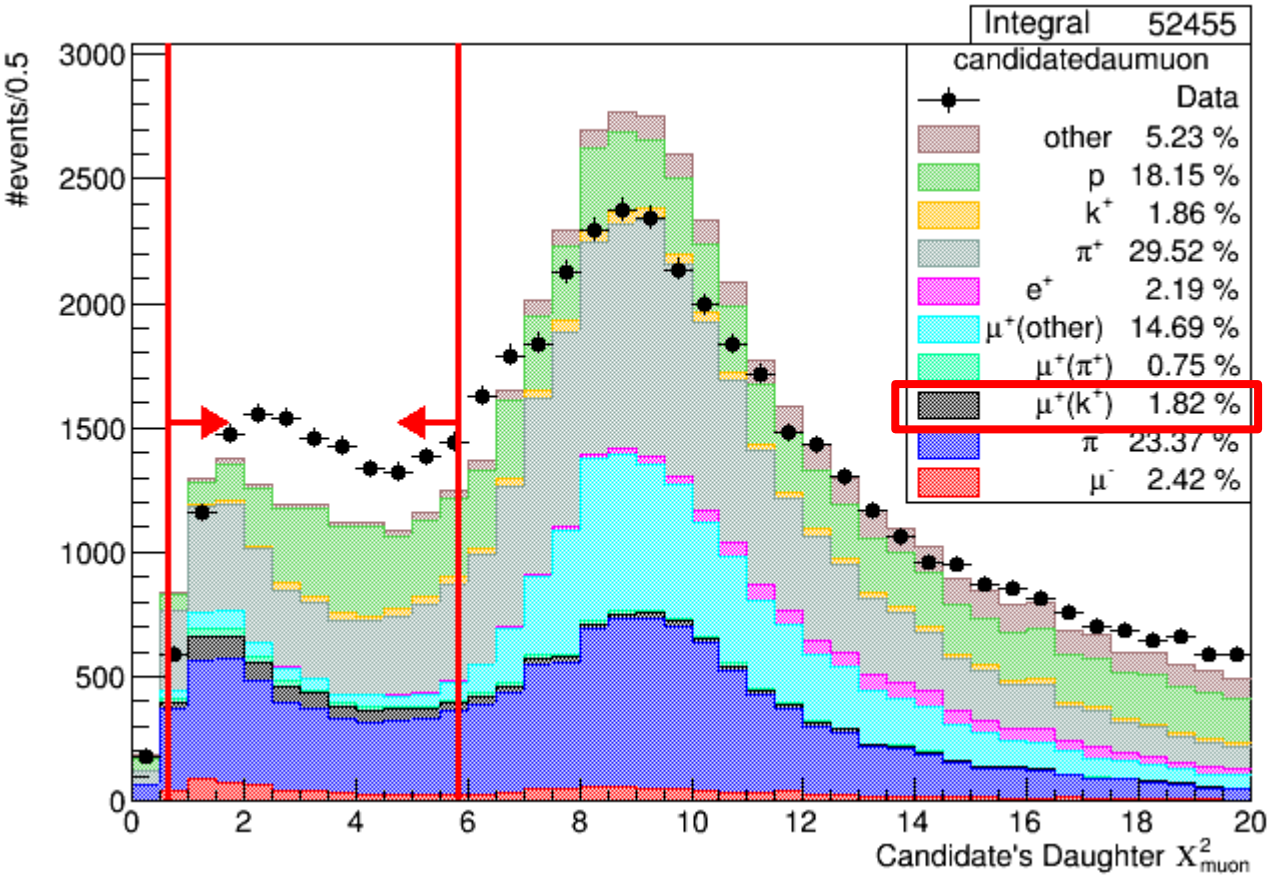
- Kaon main decay channel (63%) **2-body decay!** $K^+ \rightarrow \mu^+ \nu_\mu$ provides a way of identifying decaying kaons: they must have a single reconstructed daughter (track-like).

- Muon (daughter) kinematics can be used to identify the decaying kaon.

- **Preselection summary**: we are looking for **non-primary particles with a single daughter (track-like) in beam hadron events**.

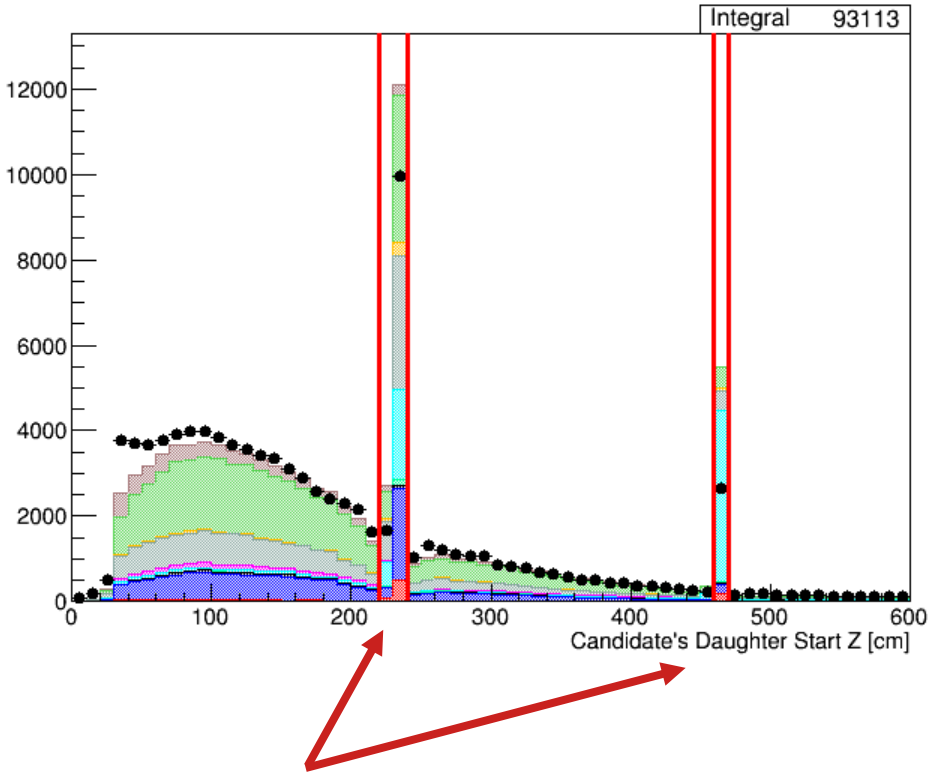
Daughter Chi² cut

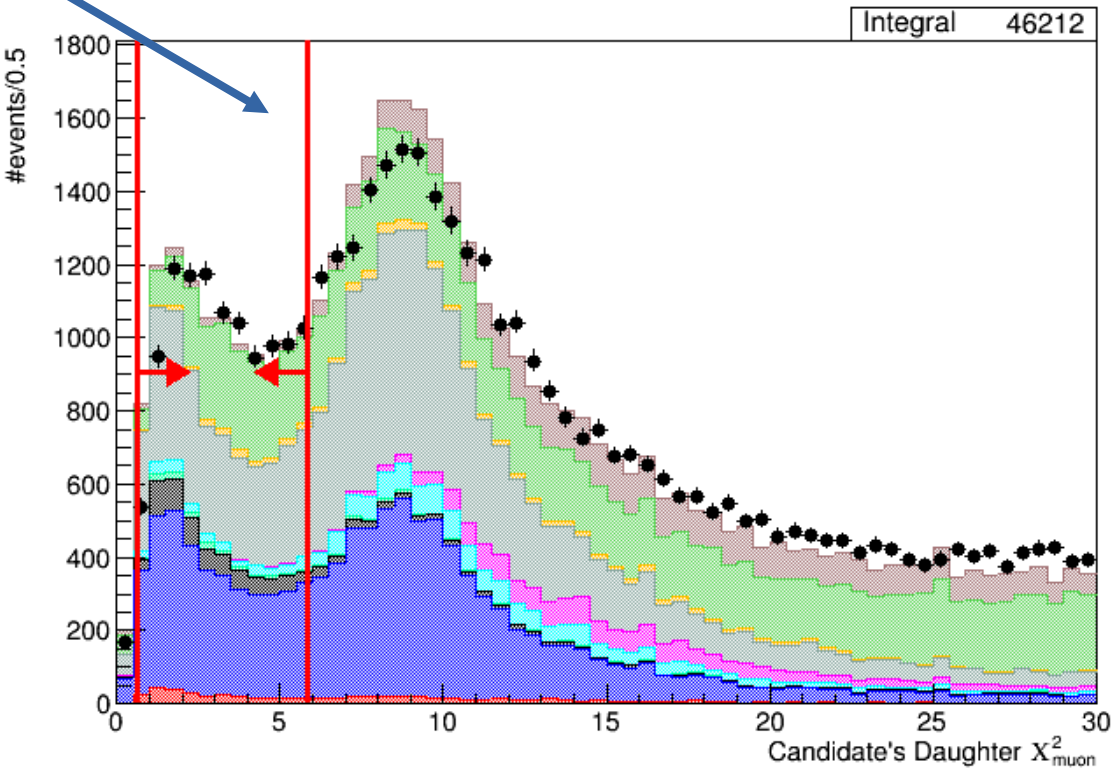
- Decaying kaon's daughter should be a muon and this is reflected on the Chi² (muon hypothesis distribution).
- More restrictive cut than before.
- The discrepancies data-MC are due to broken tracks on APAs (see next slide)



Daughter Chi² cut

Excluding tracks starting/ending around APAs border we can see a better agreement data-MC

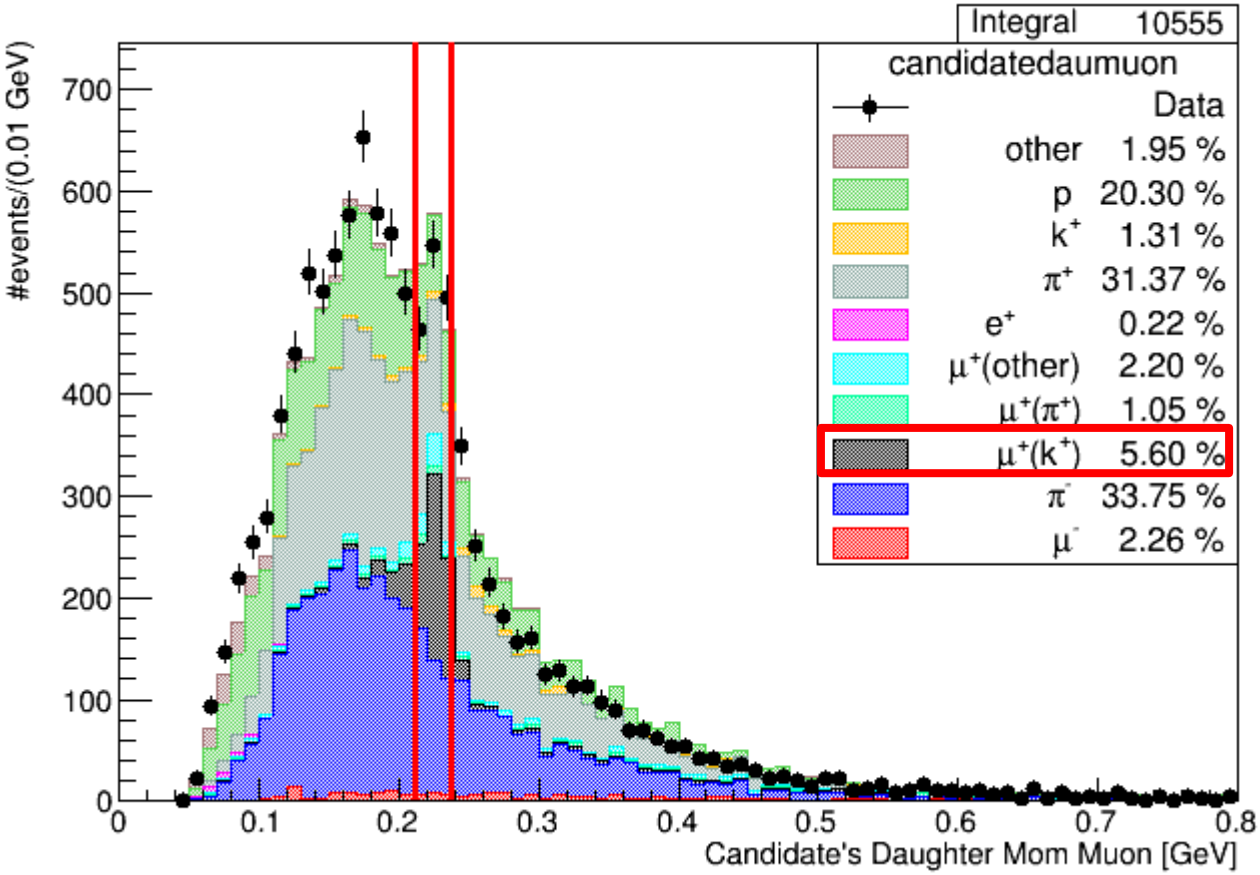




Exclude this tracks from the selection for the moment. It should be possible to fix this difference with a weight systematic.

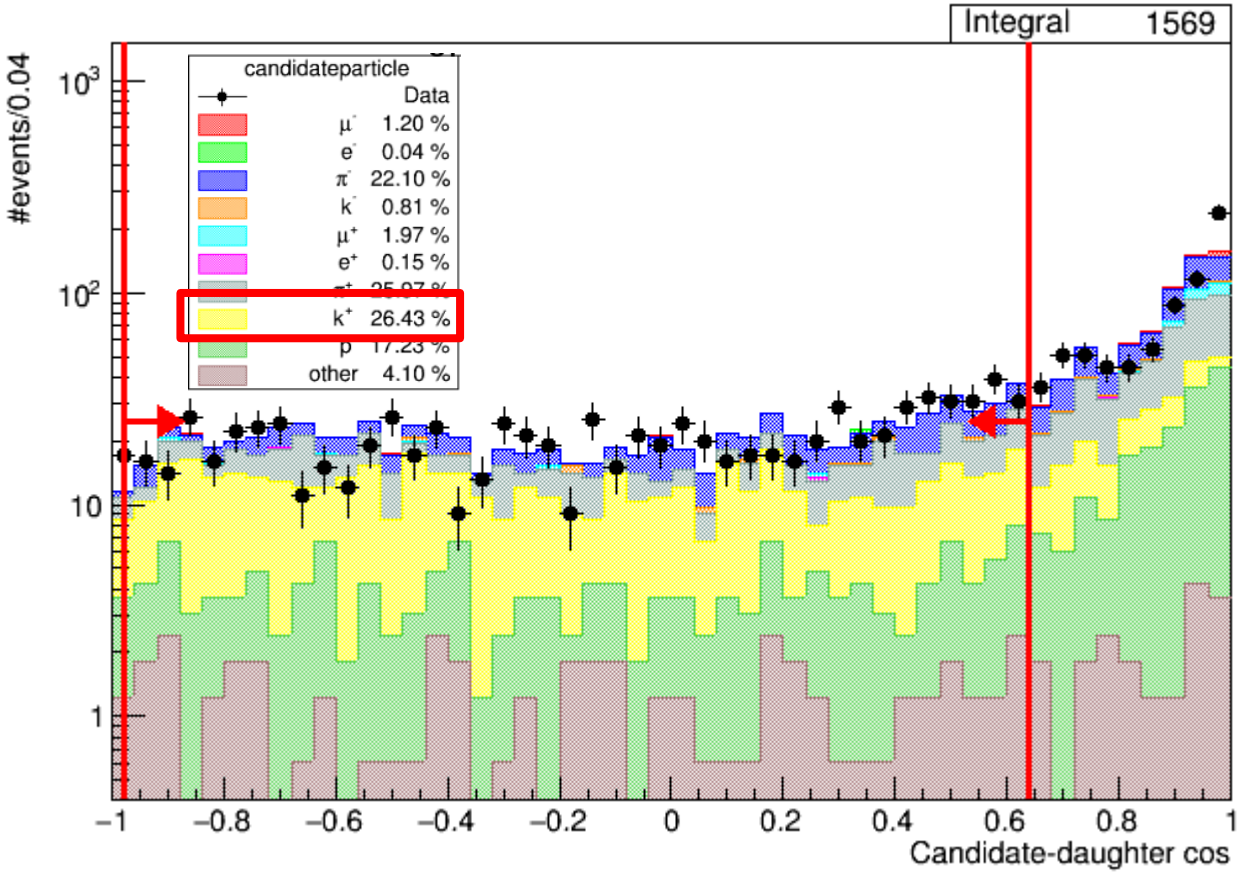
Daughter mom by range

- Kaon decay is a two-body decay so muon momentum is very well defined.
- Very good agreement data-MC.



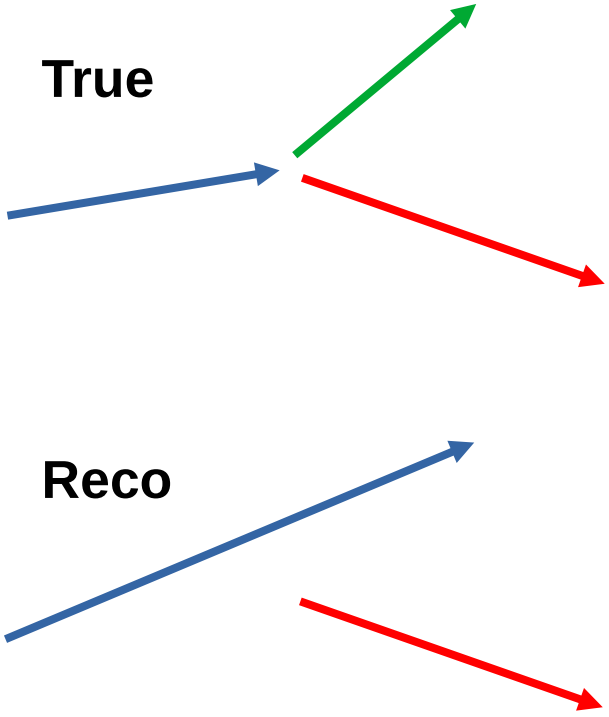
Cos(candidate-daughter)

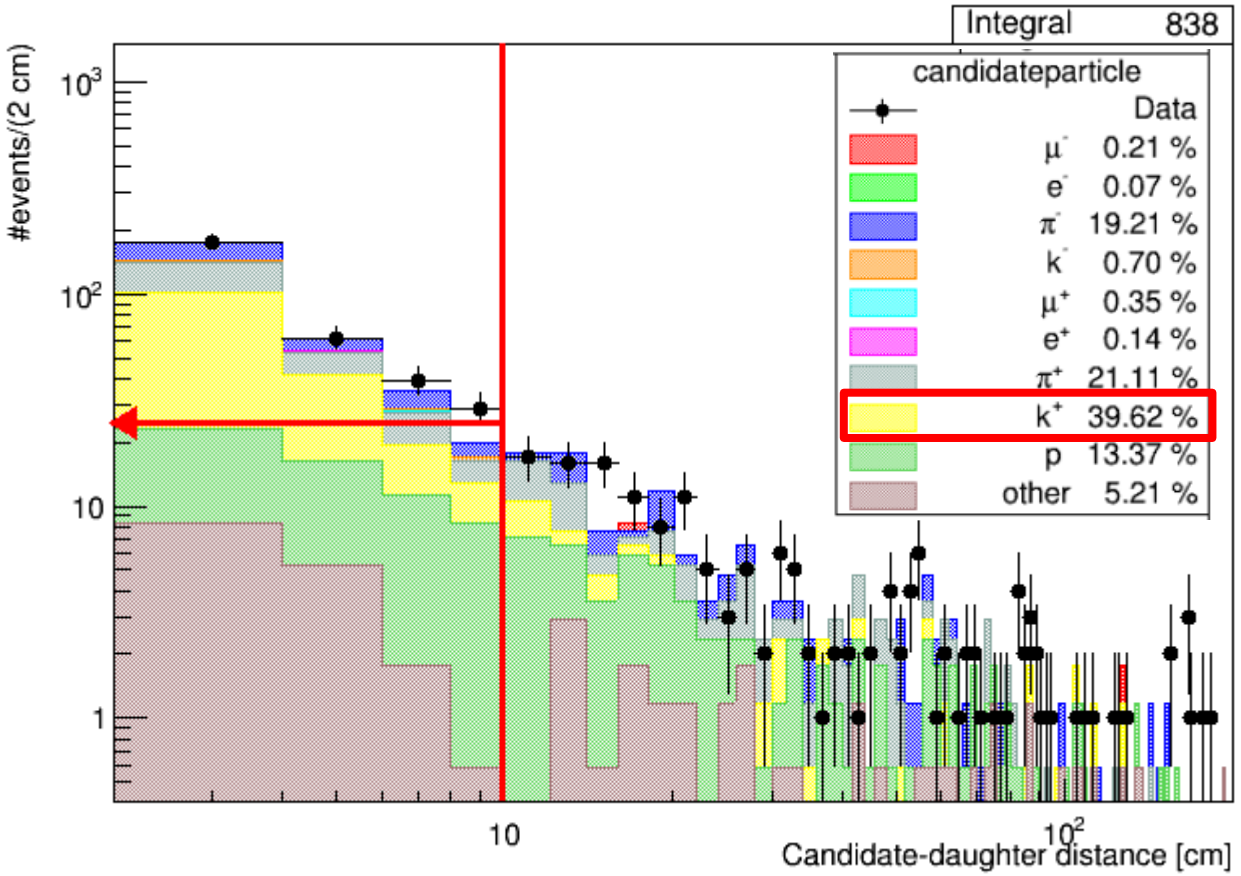
- Kaon decay is at rest so kaon-muon angle distribution should be isotropic and we can focus on the backward part.



Distance candidate-daughter

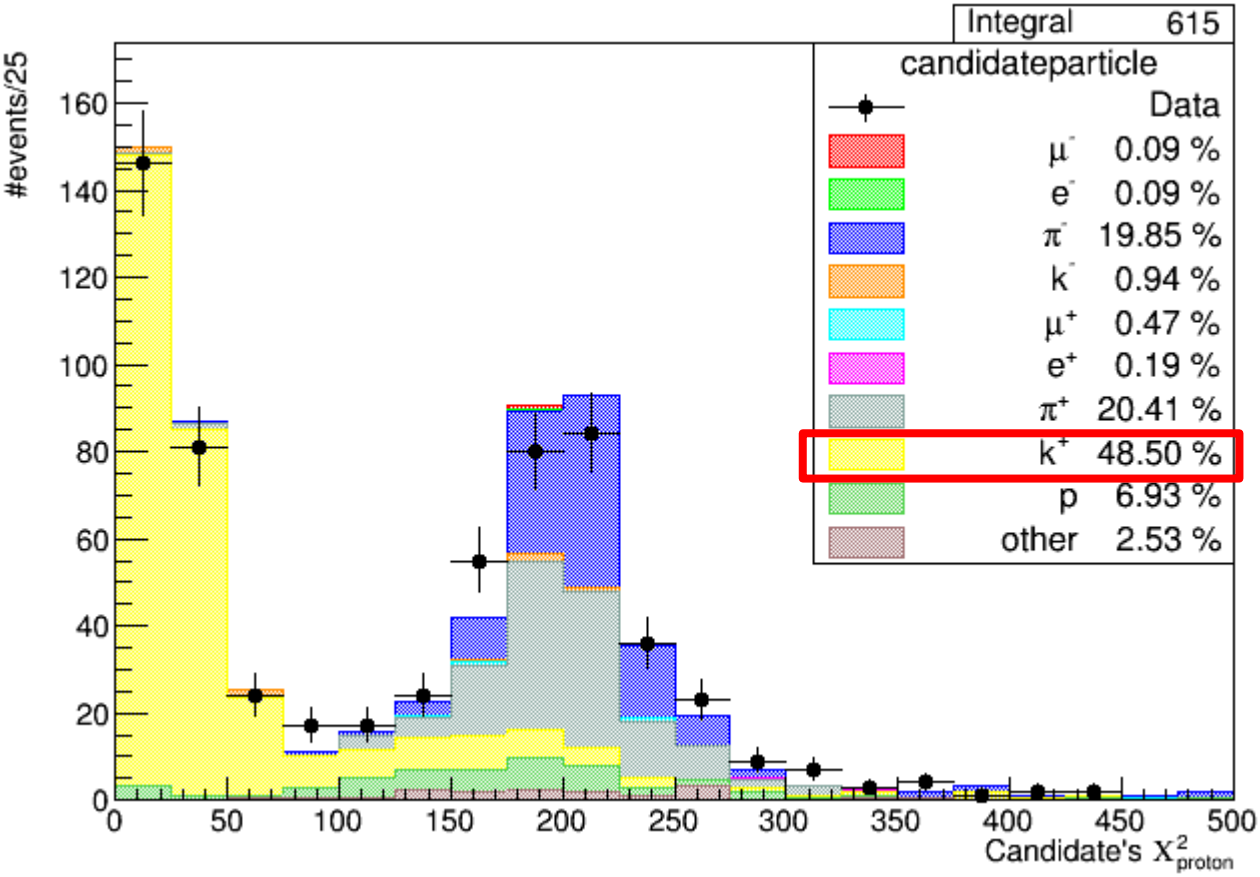
- This cut removes reconstruction errors on scattering interactions.





Event Selection result

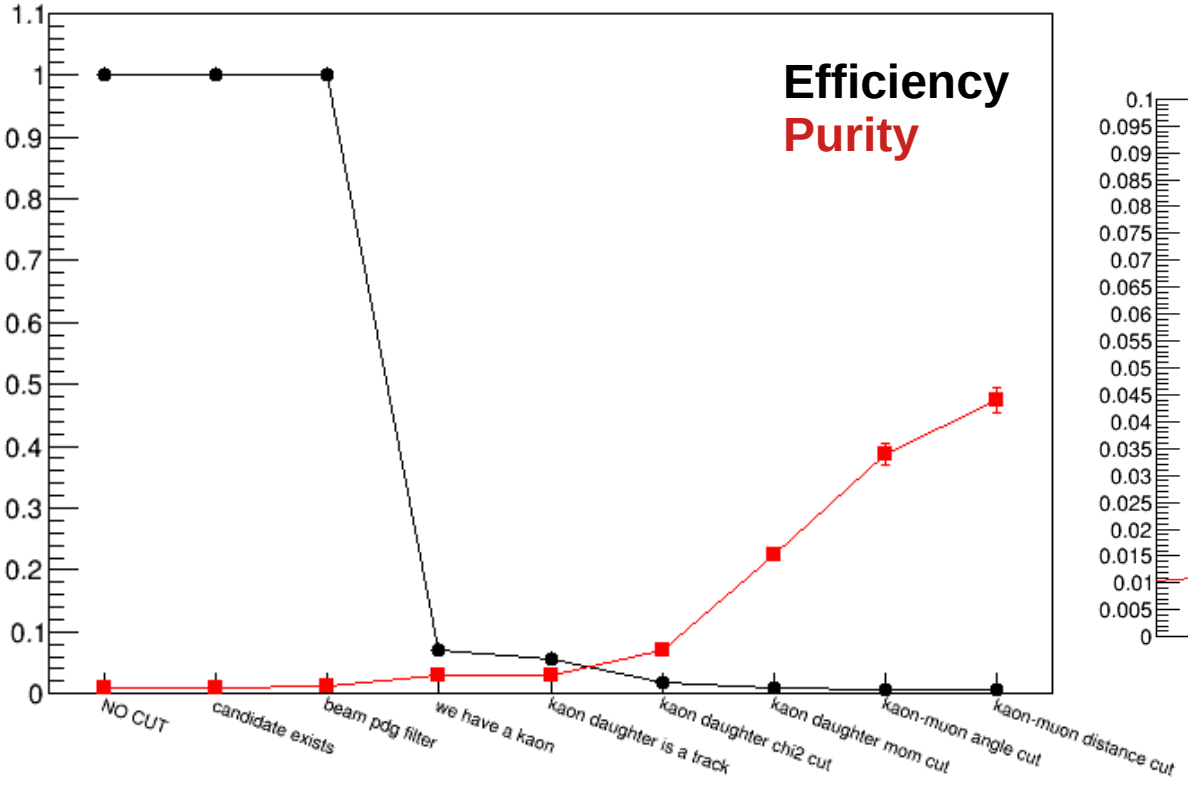
- The event selection has almost 50% purity, and both distributions (signal and background) can be clearly differentiated in data and MC.
- Good agreement data-MC.
- We have about 300 kaons, enough for a significant measurement. We still have to add 7GeV runs, so a final population of 500-600 kaons is expected.

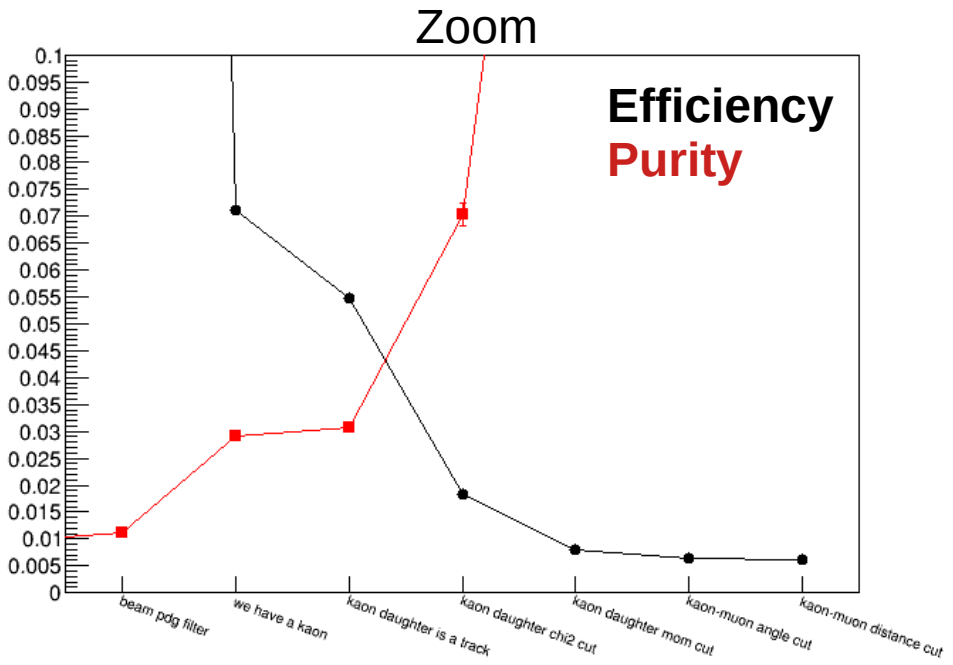


- The current selection does not cut on the CNN of the kaon candidate. In that way we avoid a potential dEdx bias.

Efficiency and Purity

Most of the decaying kaons are lost because they are not reconstructed or because they are not properly reconstructed (no daughter associated)

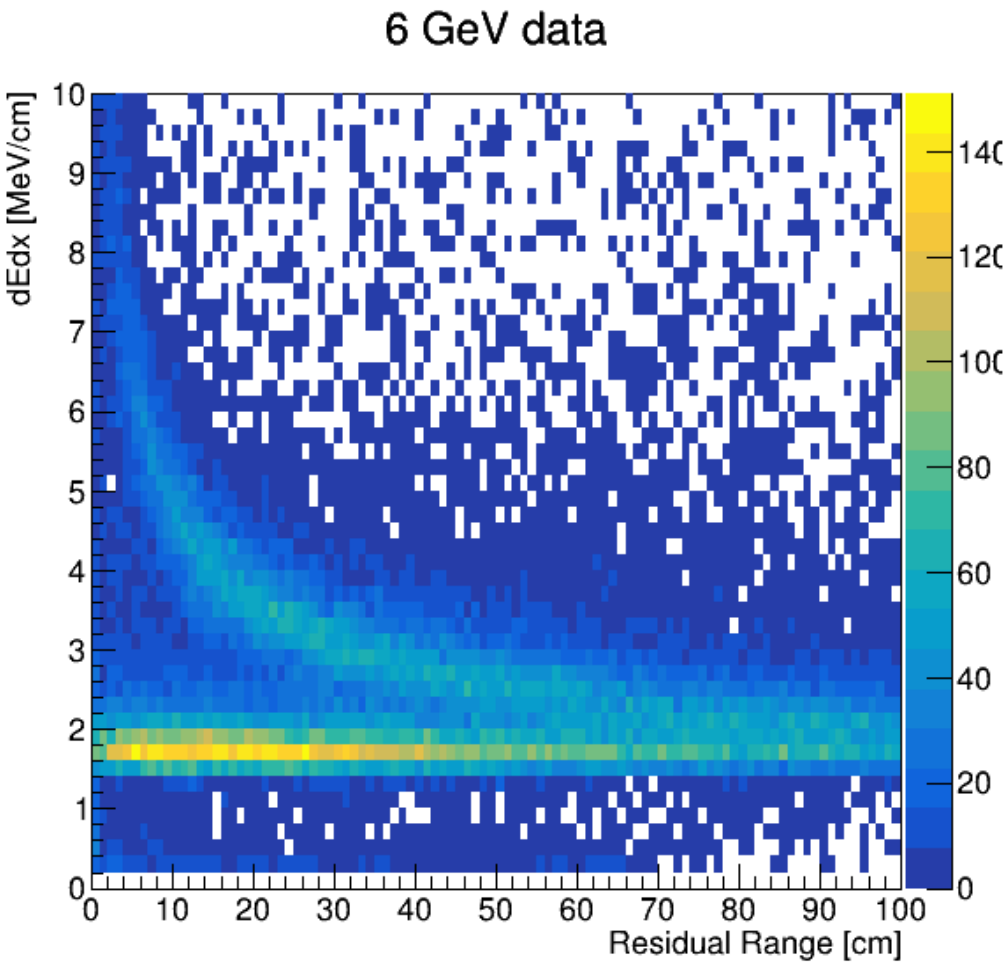


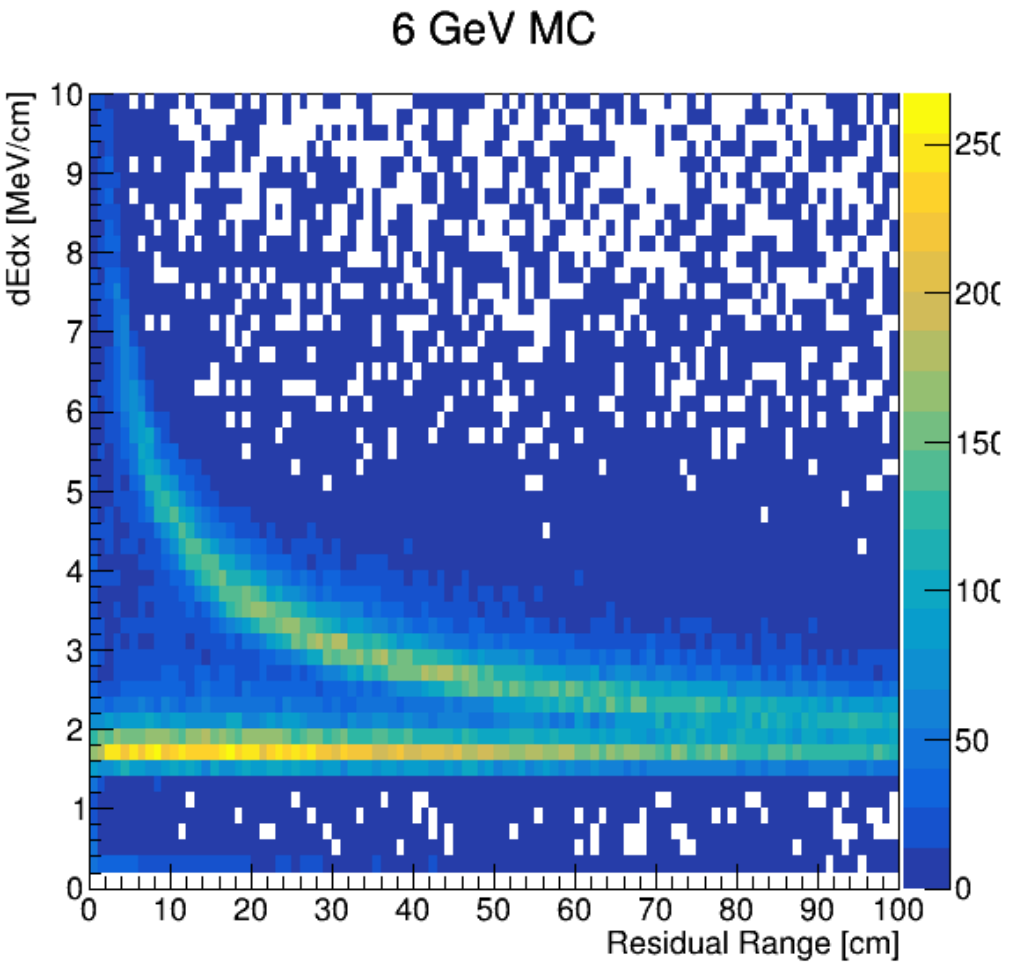


Overall efficiency below 1%
Overall purity 48.5%

Cut	True Candidates (Eff %)	Purity (%)
Beam PDG	87747	1.1%
Candidate Exists	6921 (7.9%)	2.9%
Daughter track	5297 (6.0%)	3.1%
Daughter Chi²	1705 (1.9%)	7.0%
Daughter Mom	702 (0.80%)	22.5%
Cos(daughter-mother)	567 (0.65%)	38.8%
Dis(daughter-mother)	540 (0.062%)	47.5%

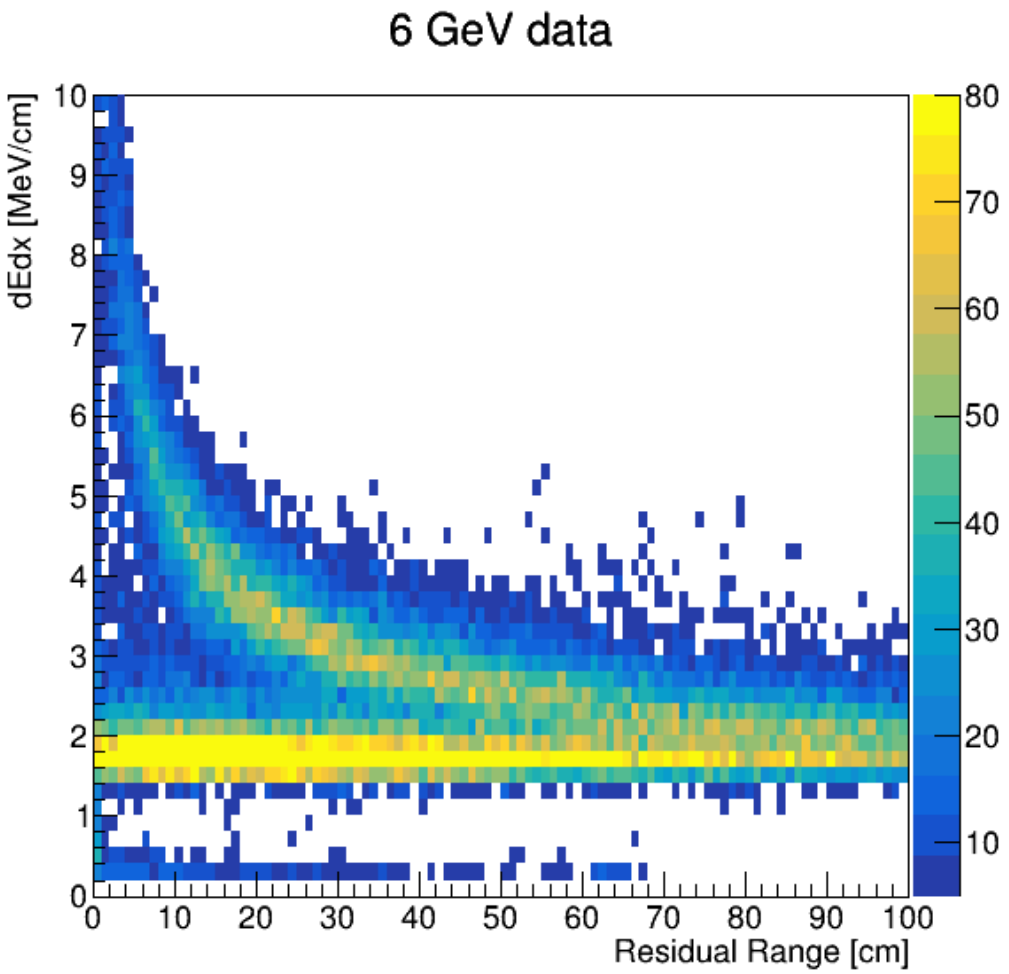
dEdx vs Residual range

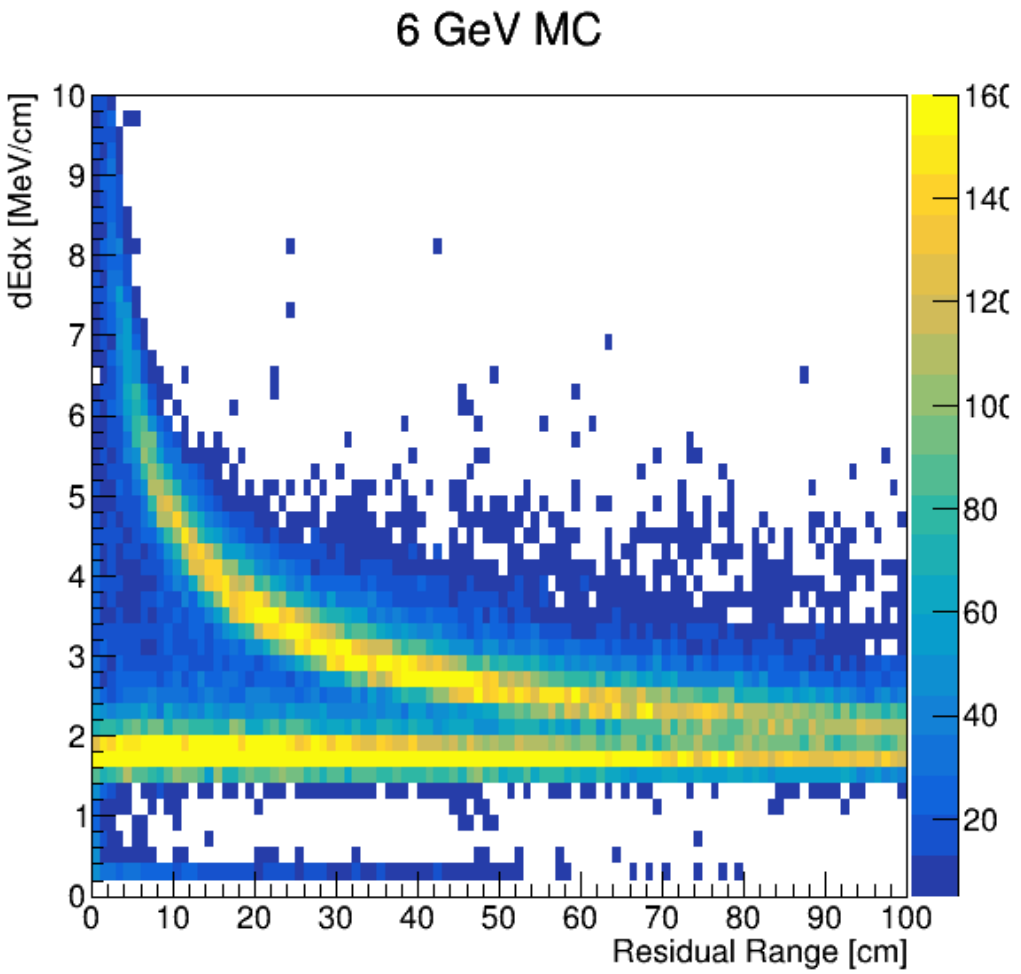




dEdx vs Residual range

Changing color range

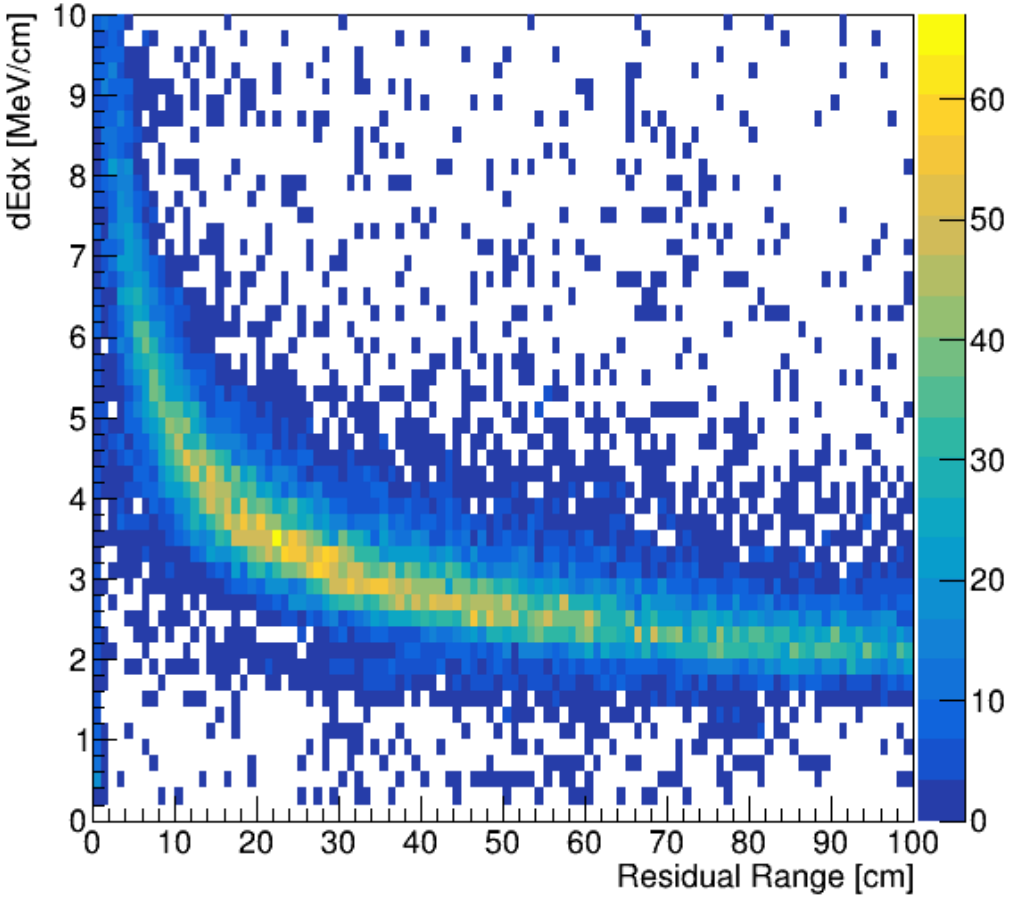




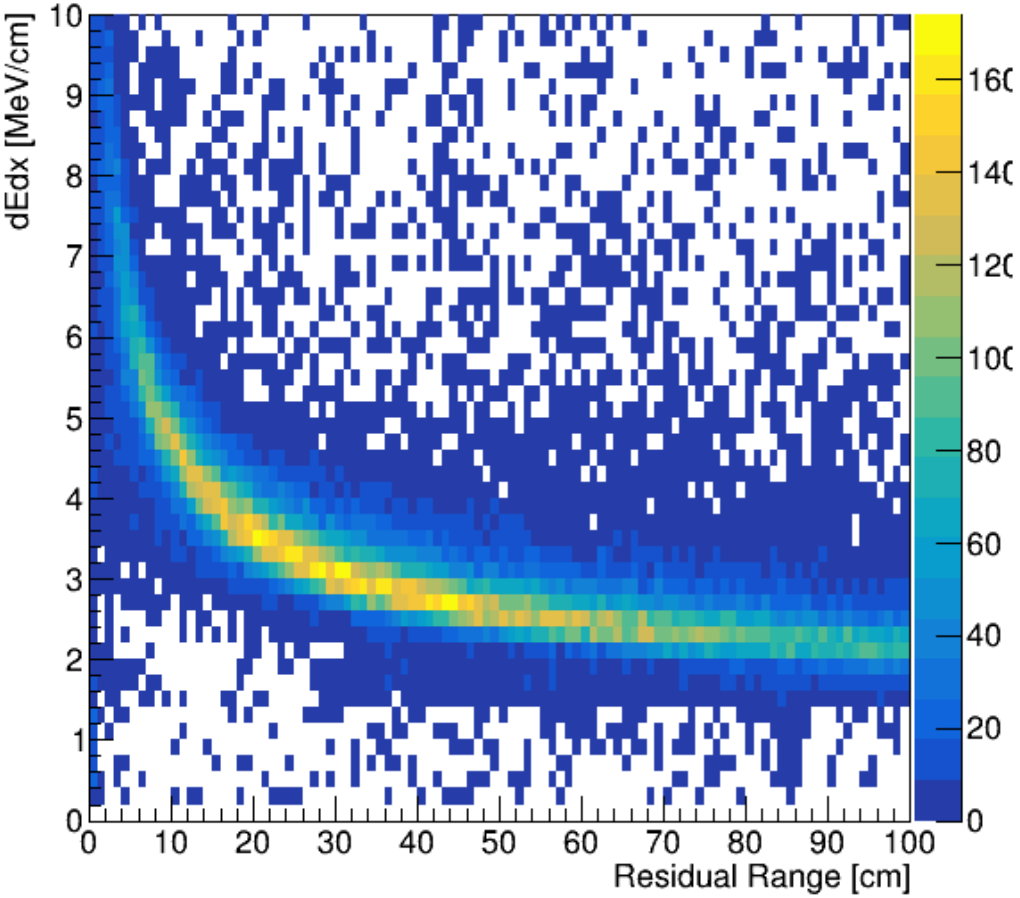
dEdx vs Residual range

Cutting on kaon Chi² < 100

6 GeV data

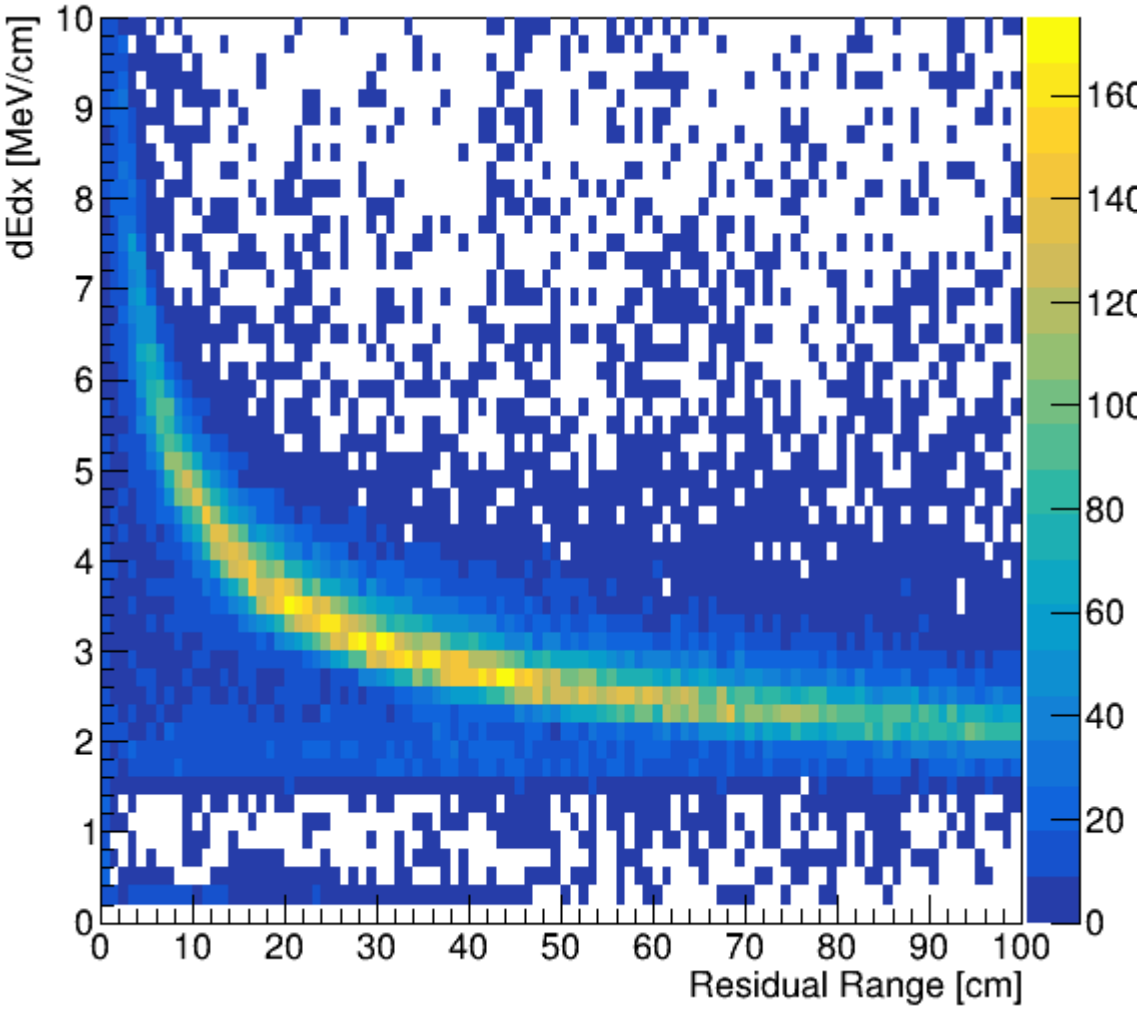


6 GeV MC

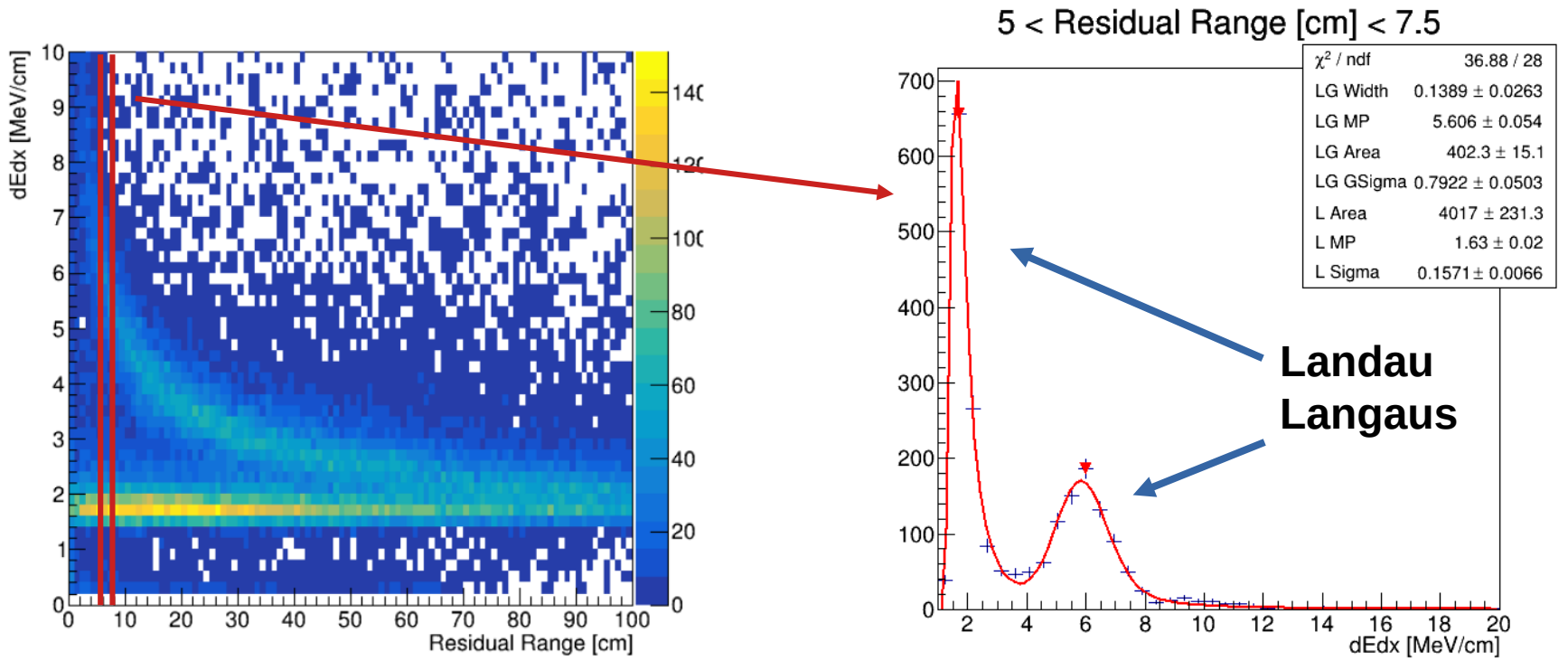


dEdx vs Residual range

True kaons



dEdx extraction

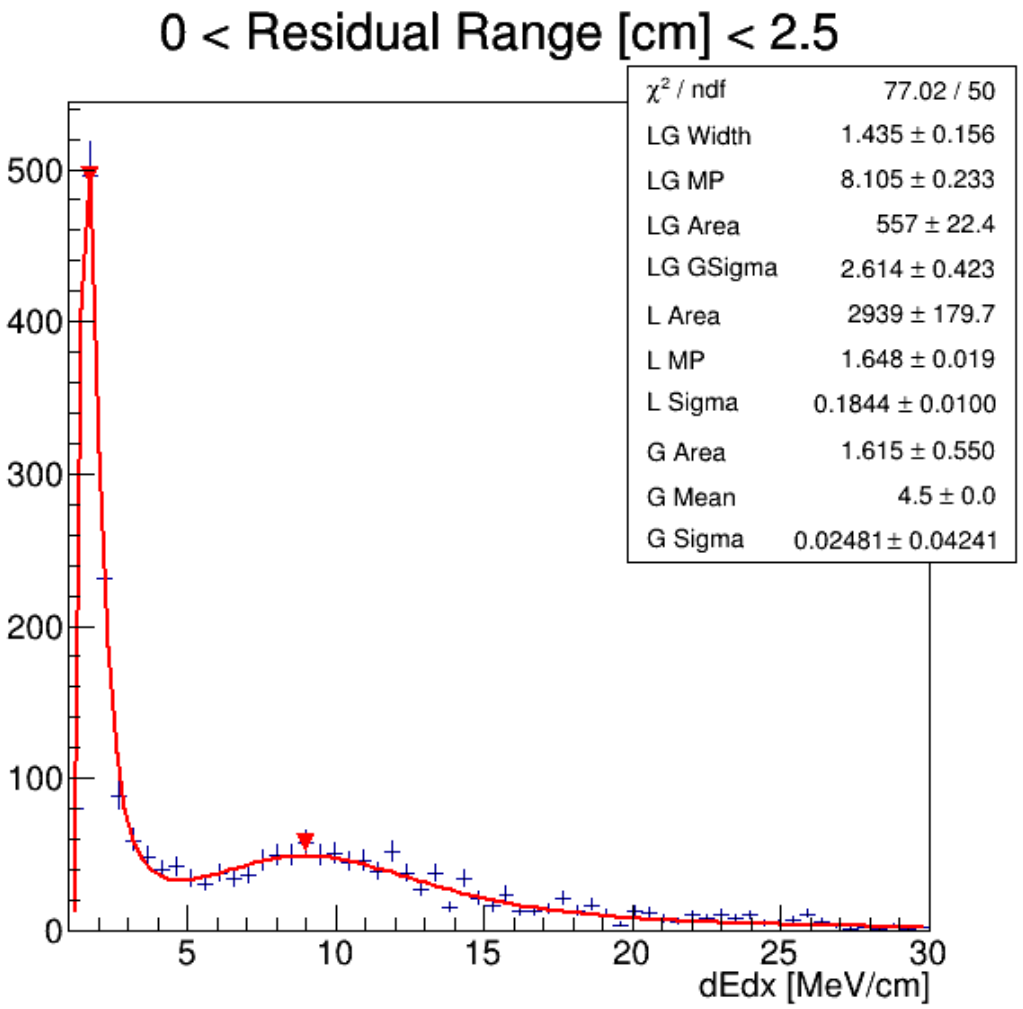


- In order to separate signal and background and present dEdx vs Residual Range measurements properly, I divided the 2D histogram in Residual range slices of 2.5 cm.
- For each slice a 1D dEdx histogram is generated, and fitted to a background+signal distribution.

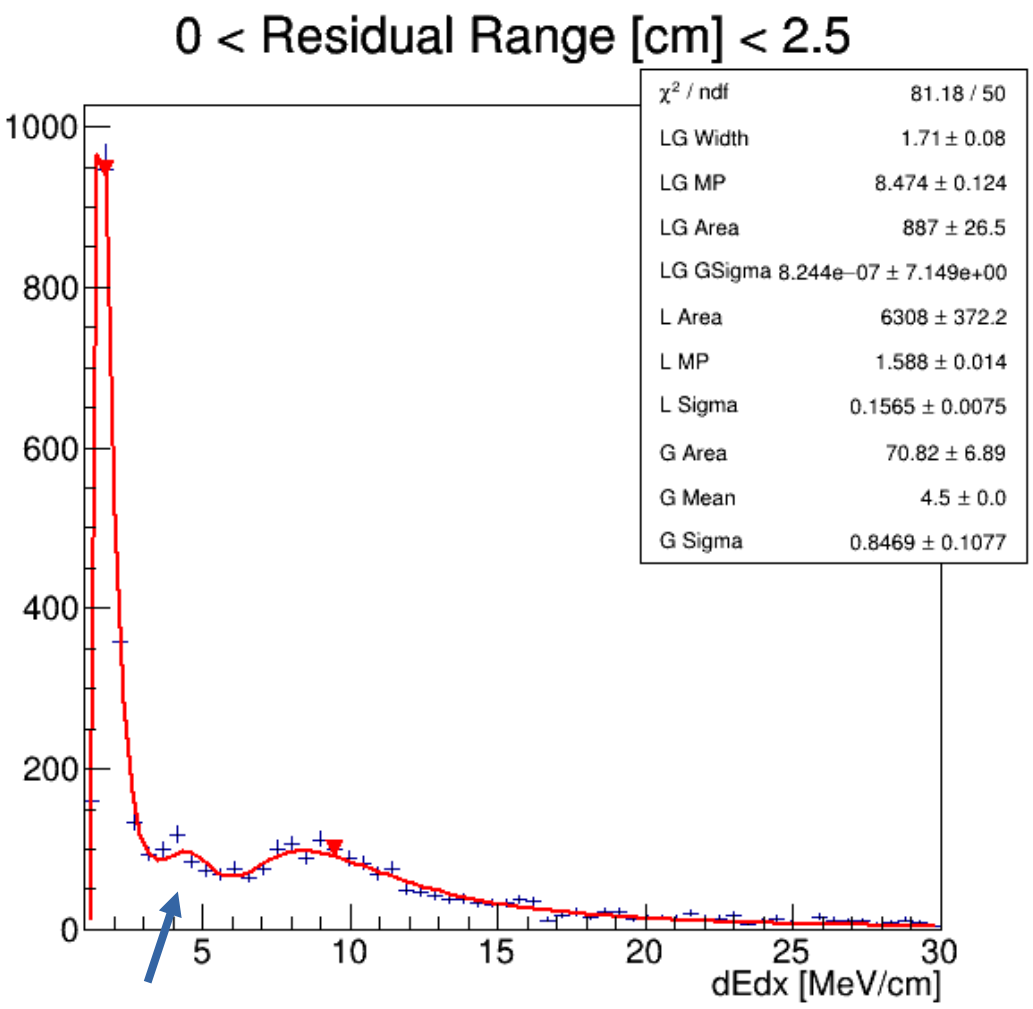
Langaus = landau-gaussian convolution

dEdx extraction

DATA



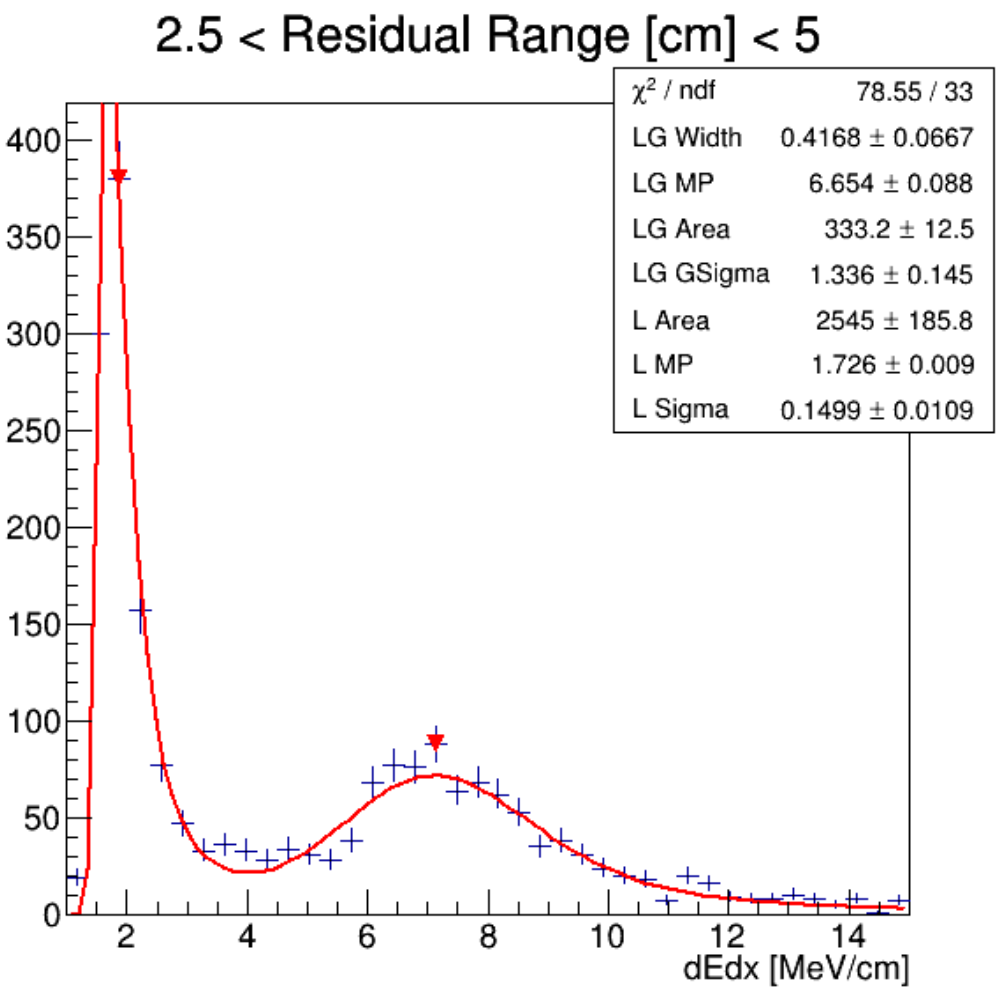
MC



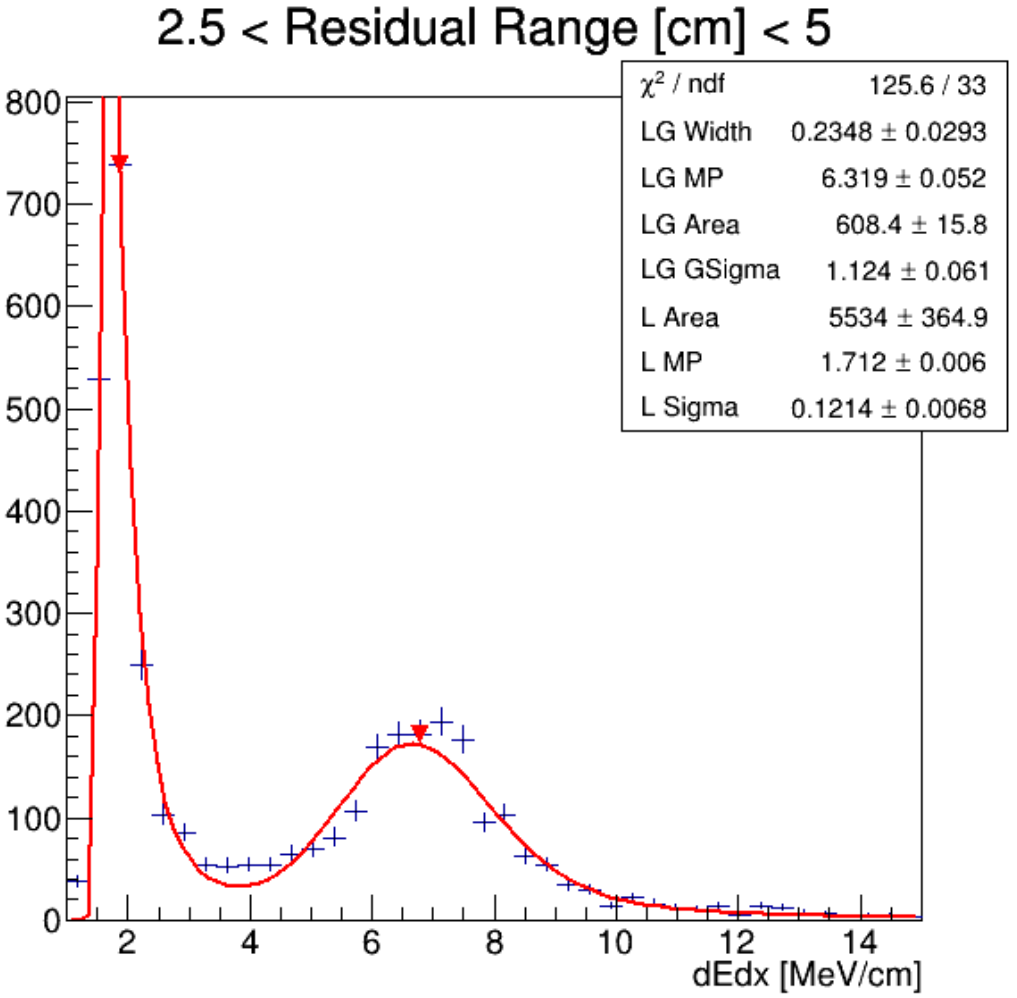
This third peak is caused by low energy kaons that interact

dEdx extraction

DATA

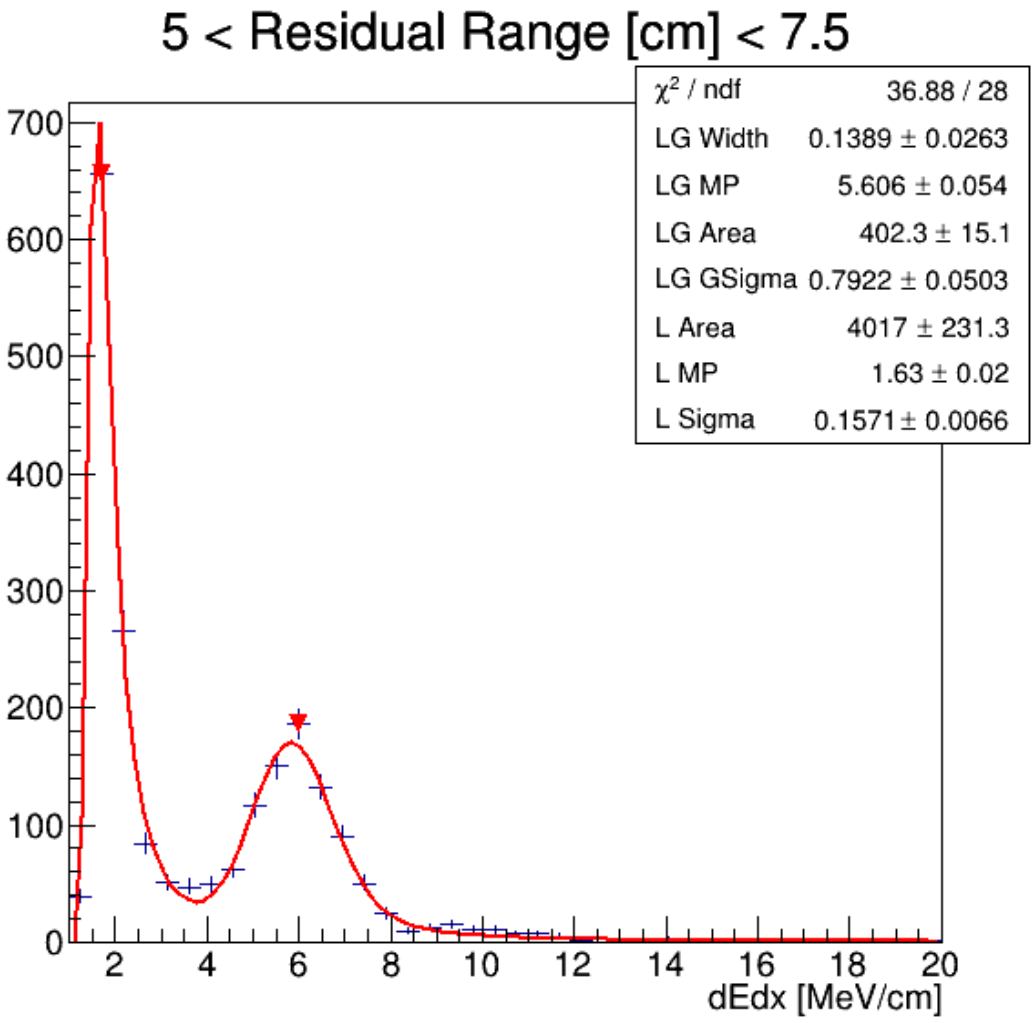


MC

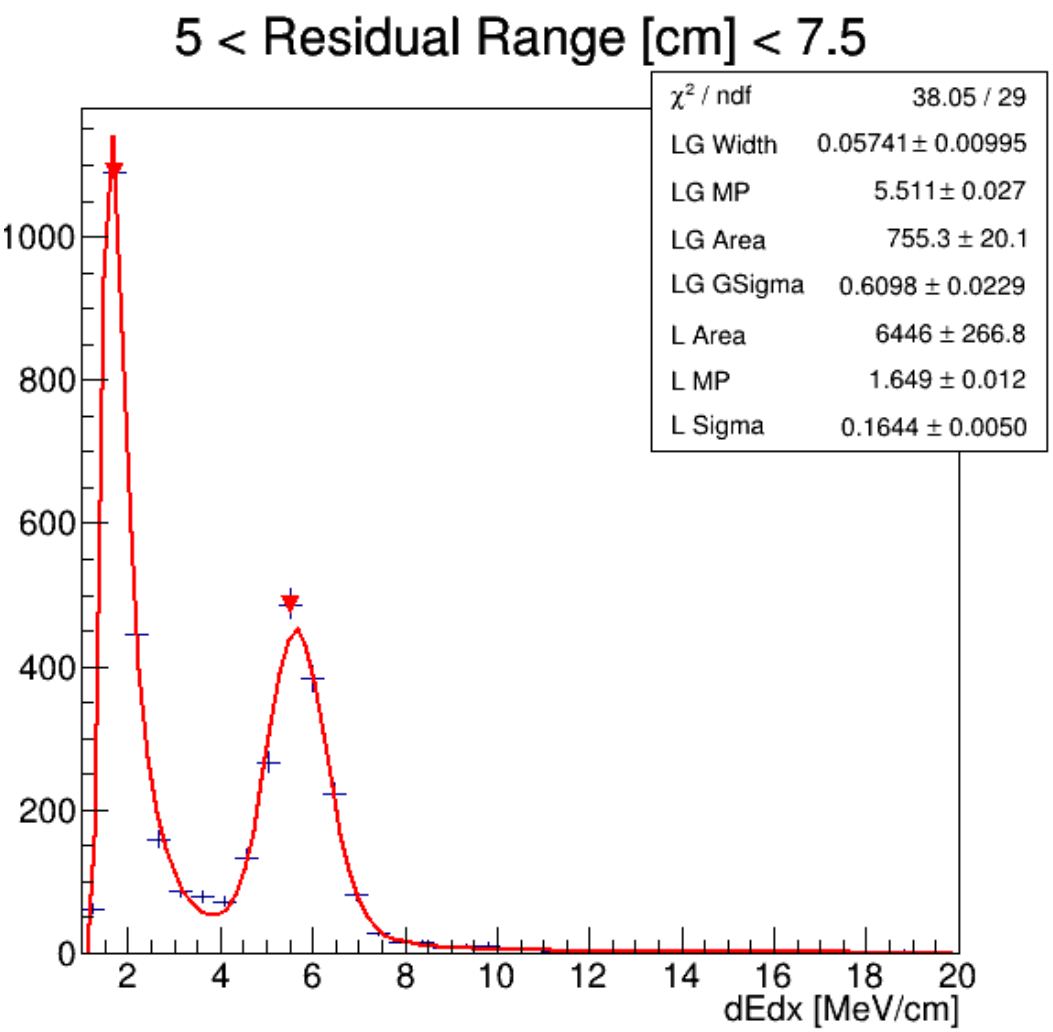


dEdx extraction

DATA



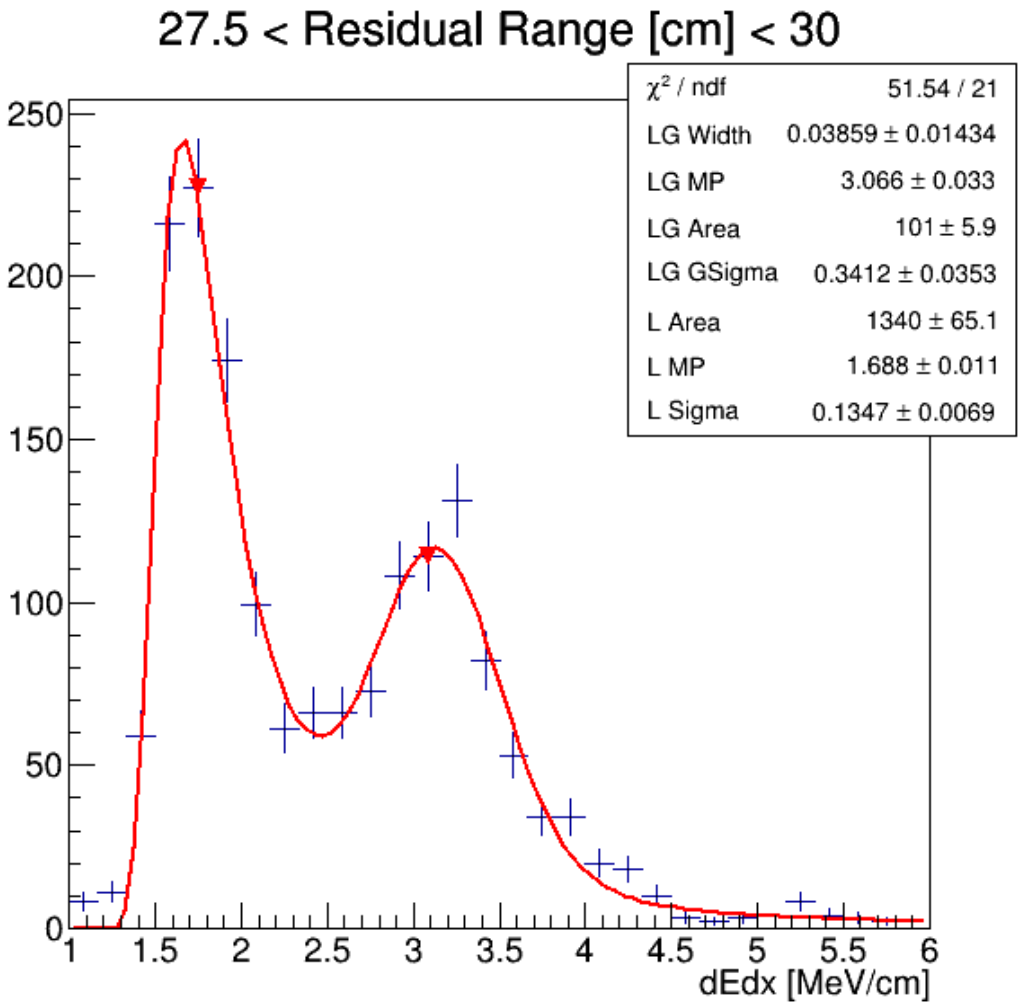
MC



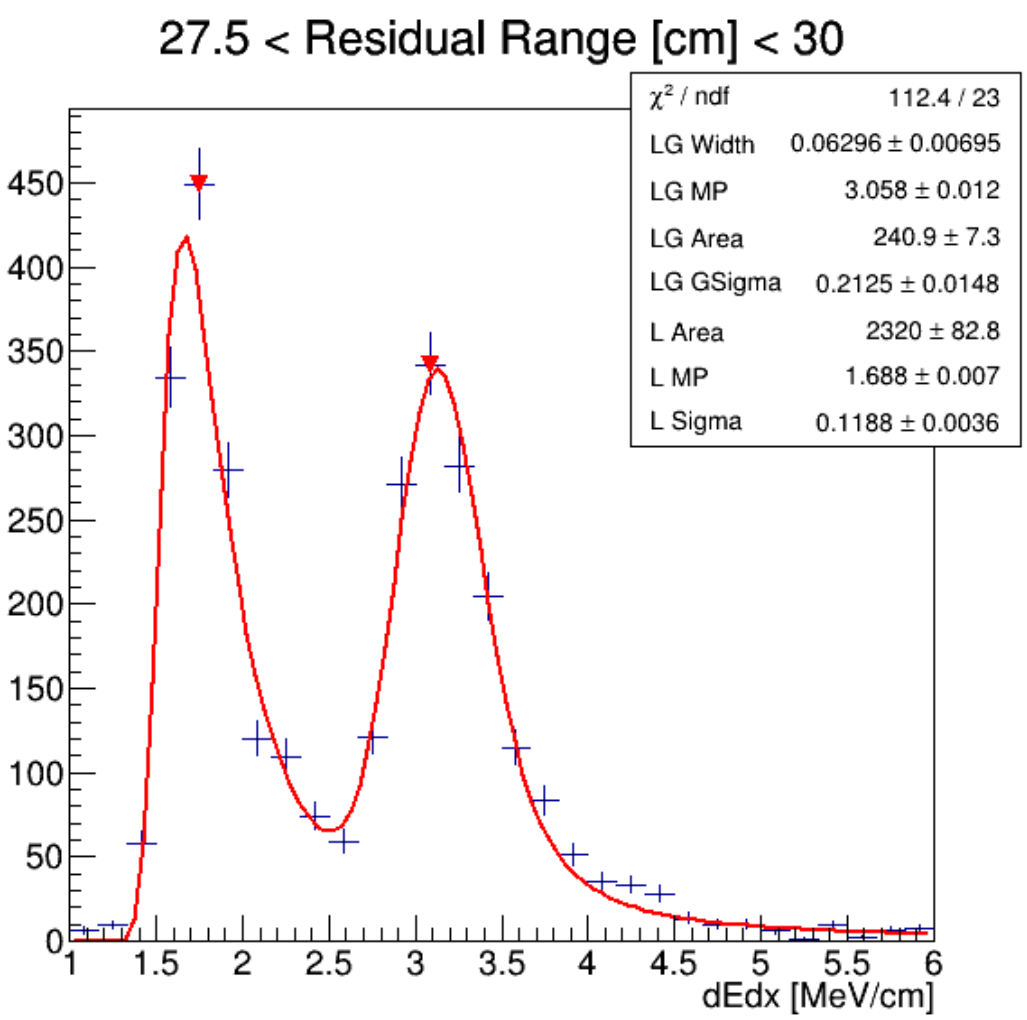
Distribution is wider for data than for MC

dEdx extraction

DATA

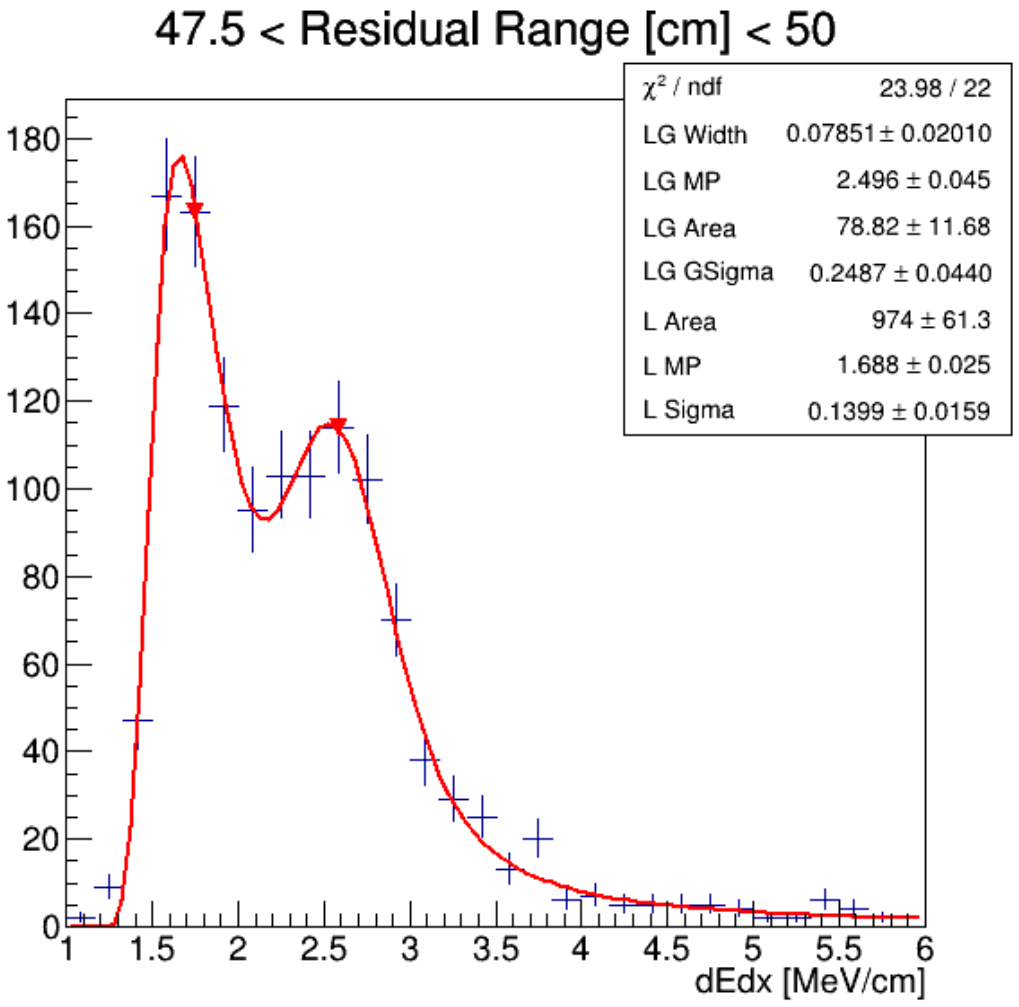


MC

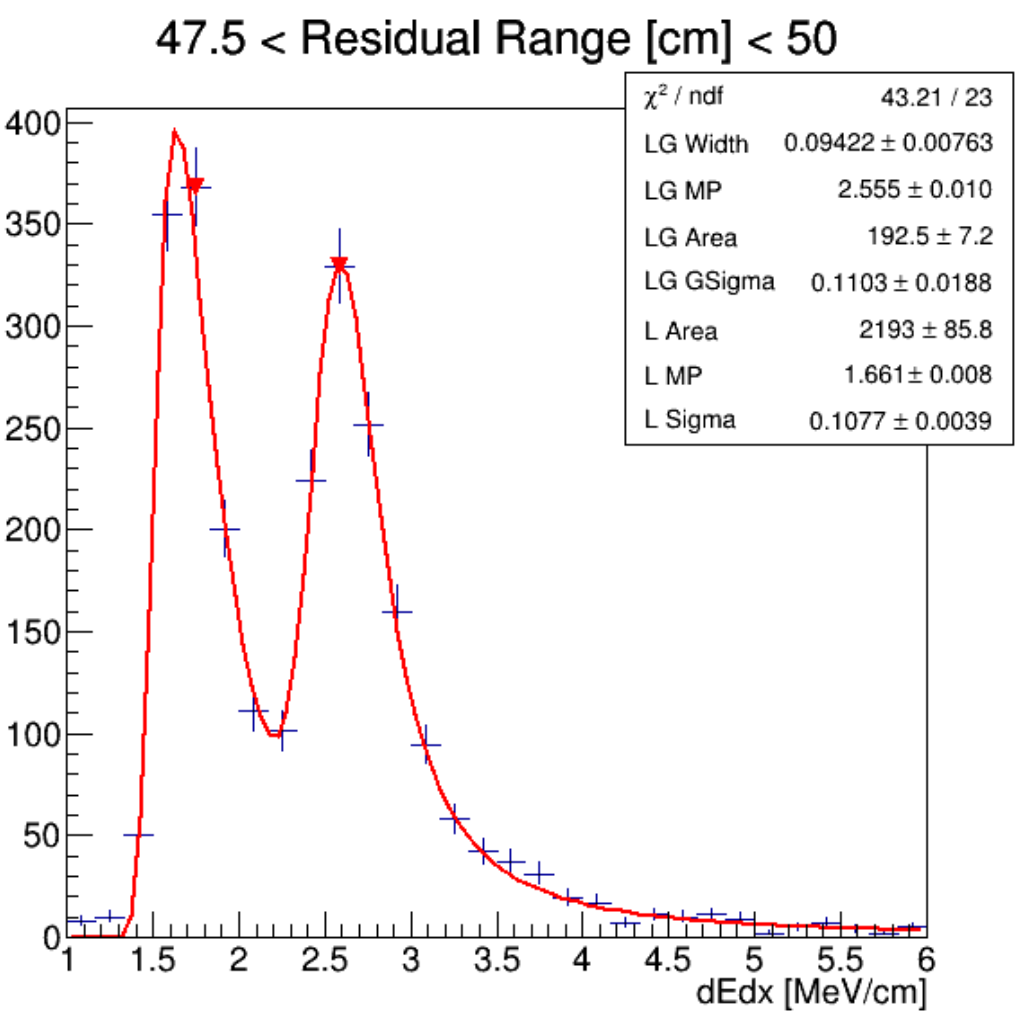


dEdx extraction

DATA



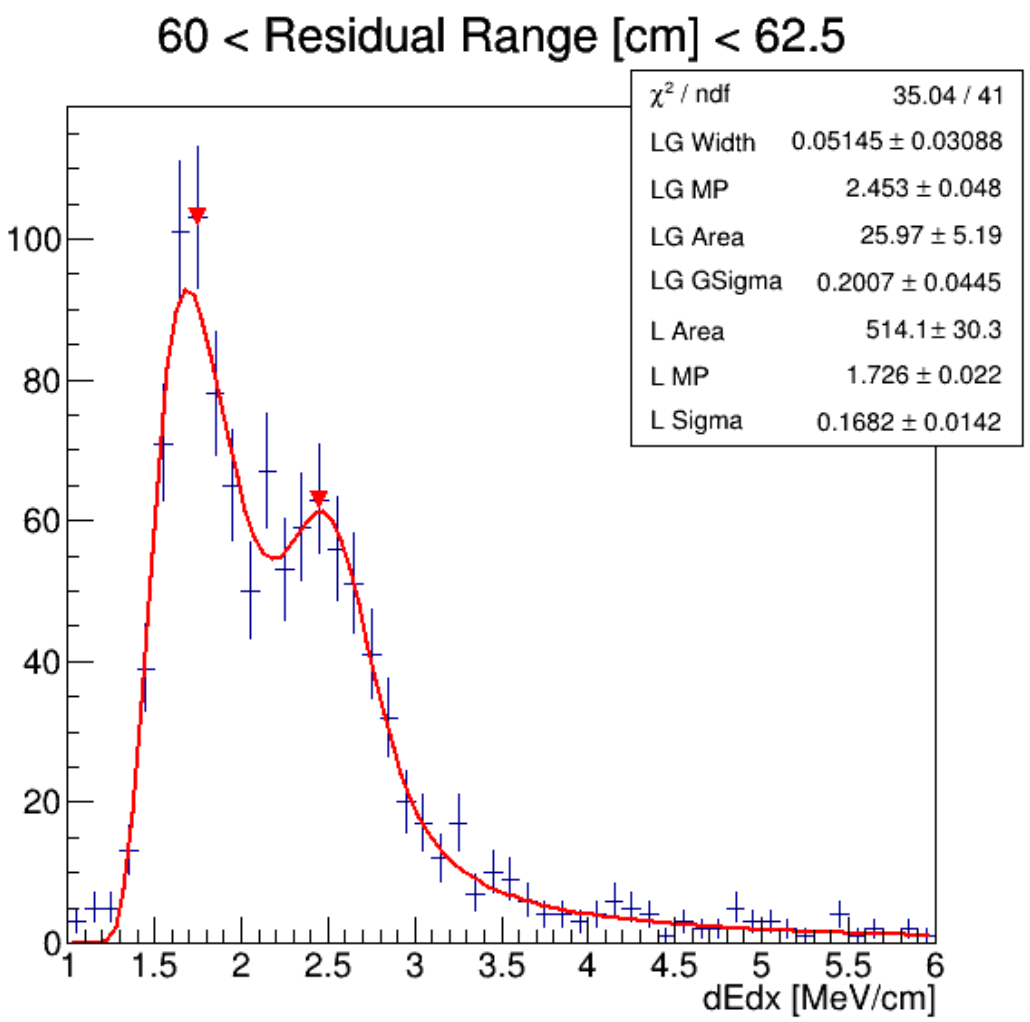
MC



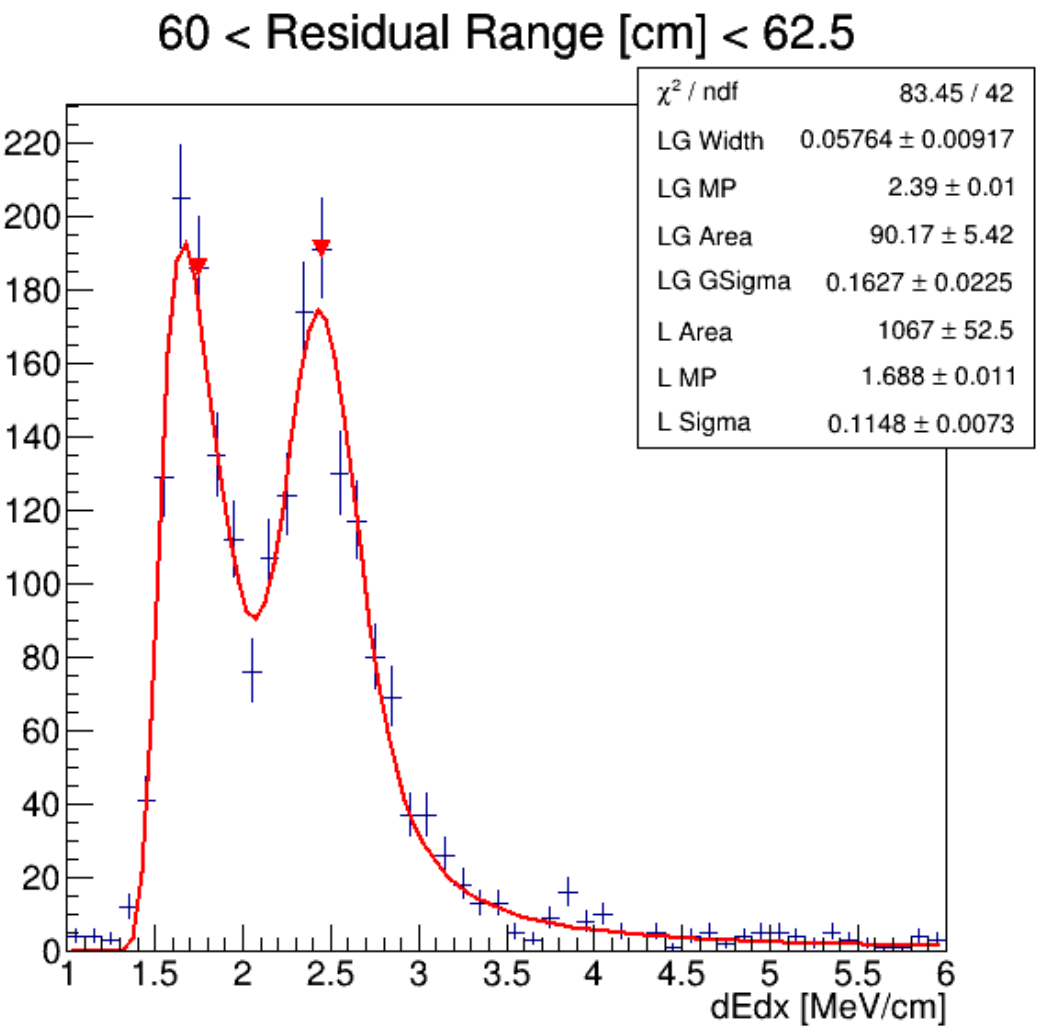
For larger residual ranges peaks are more diffused in data than in MC

dEdx extraction

DATA

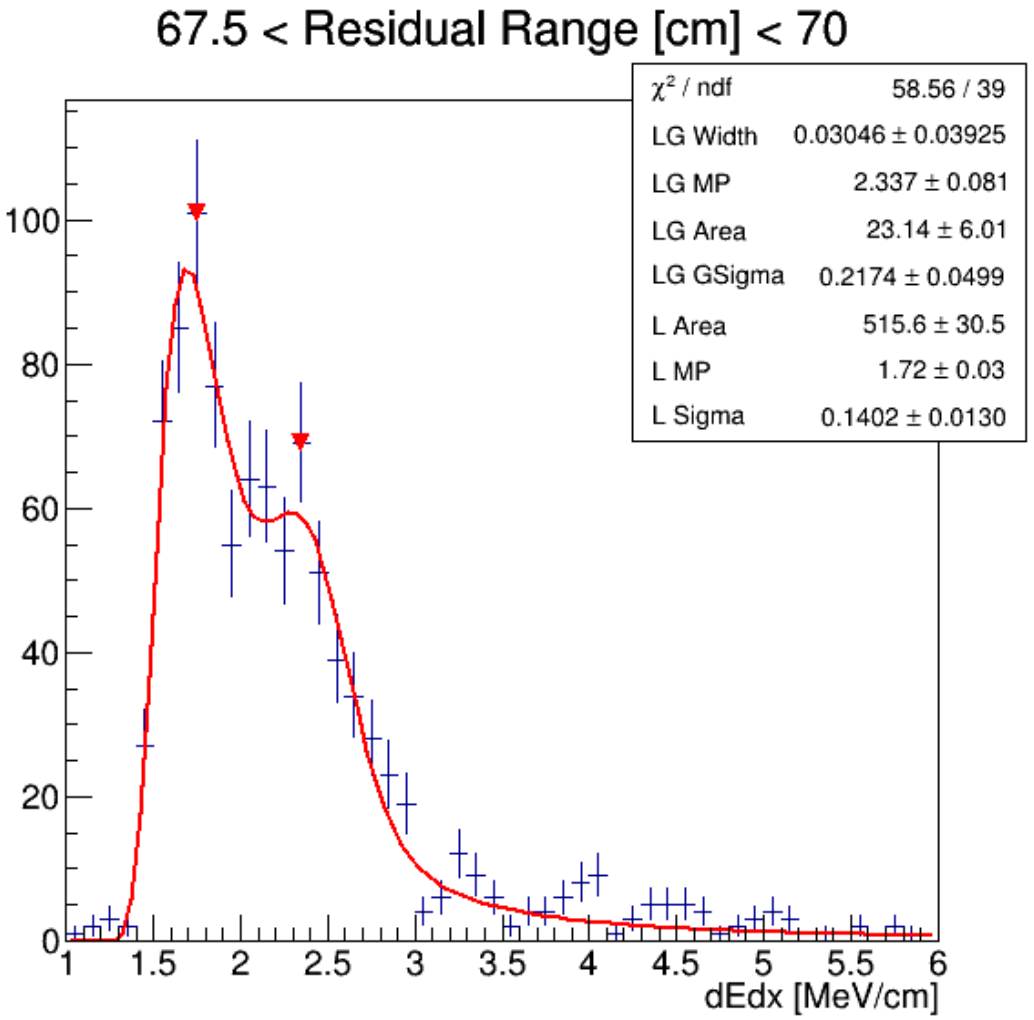


MC

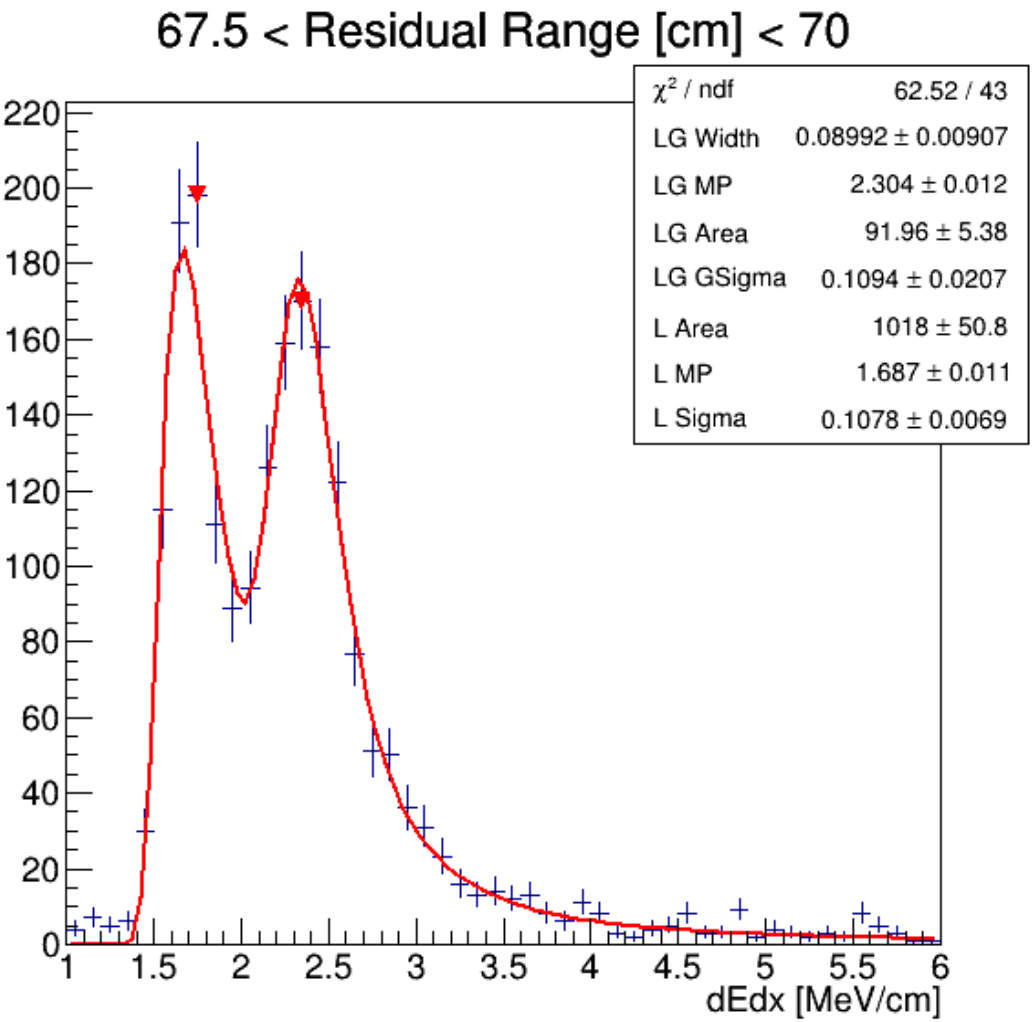


dEdx extraction

DATA

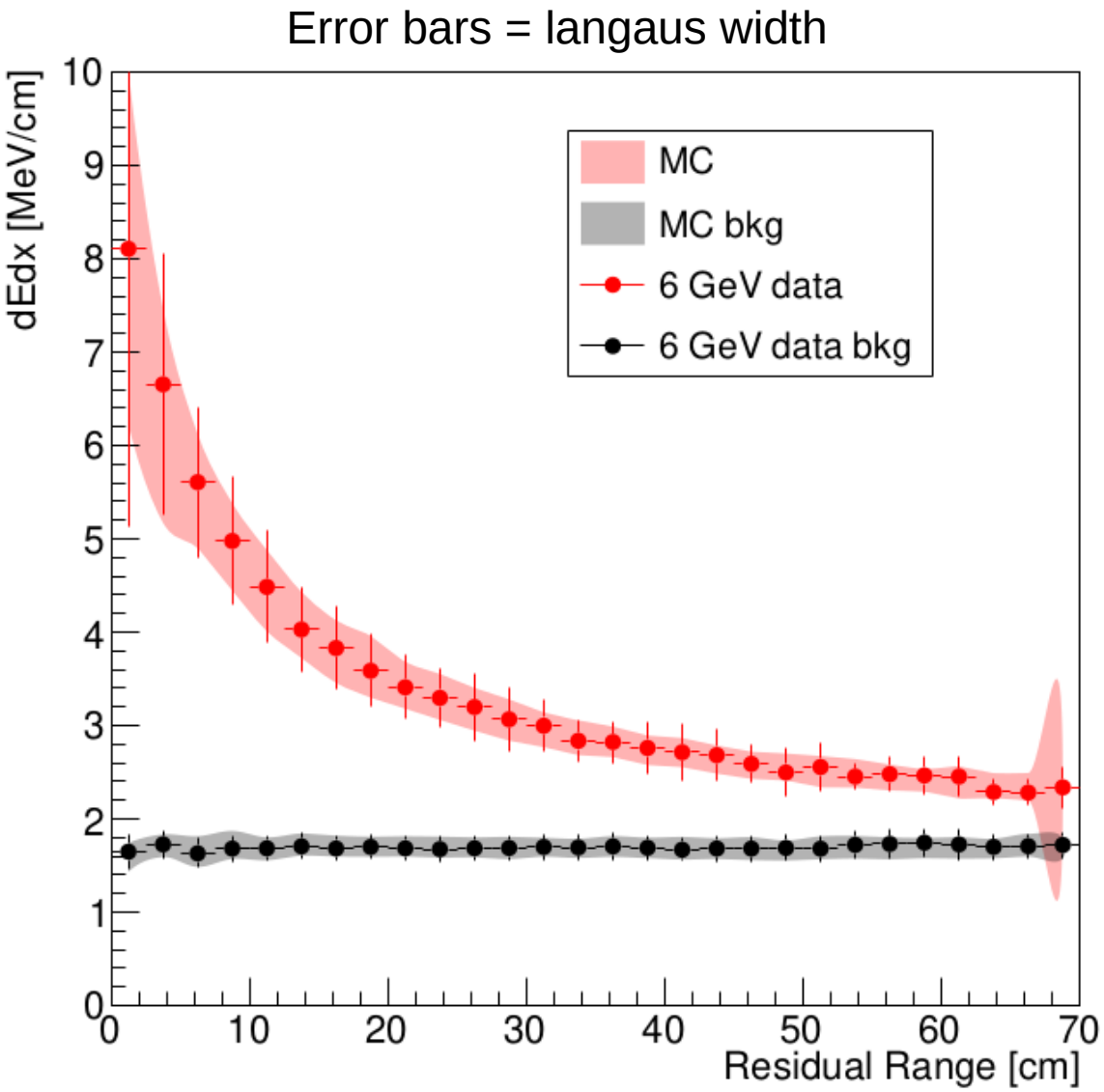


MC



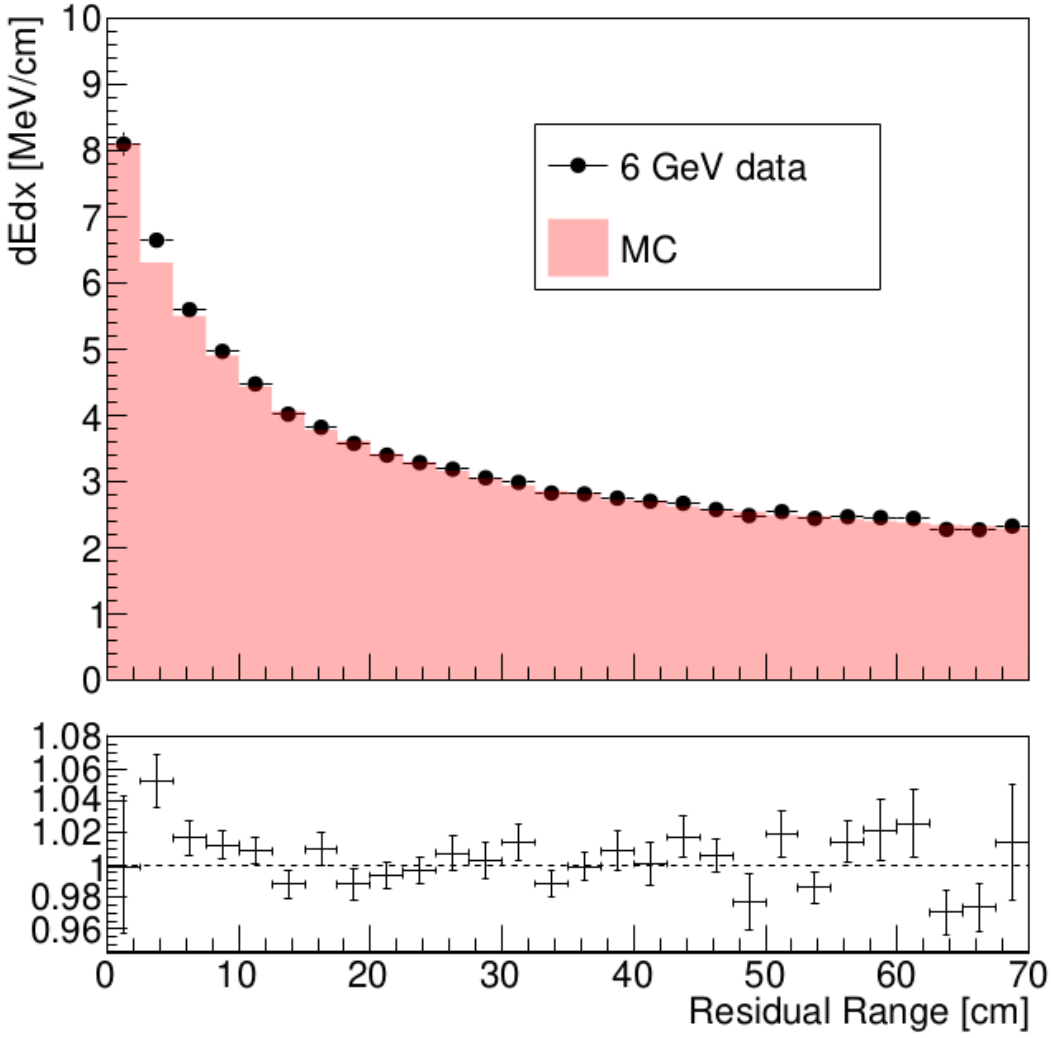
dEdx extraction

- There is good agreement between data and MC. However, the error in data (width of the distribution) is larger than in MC.

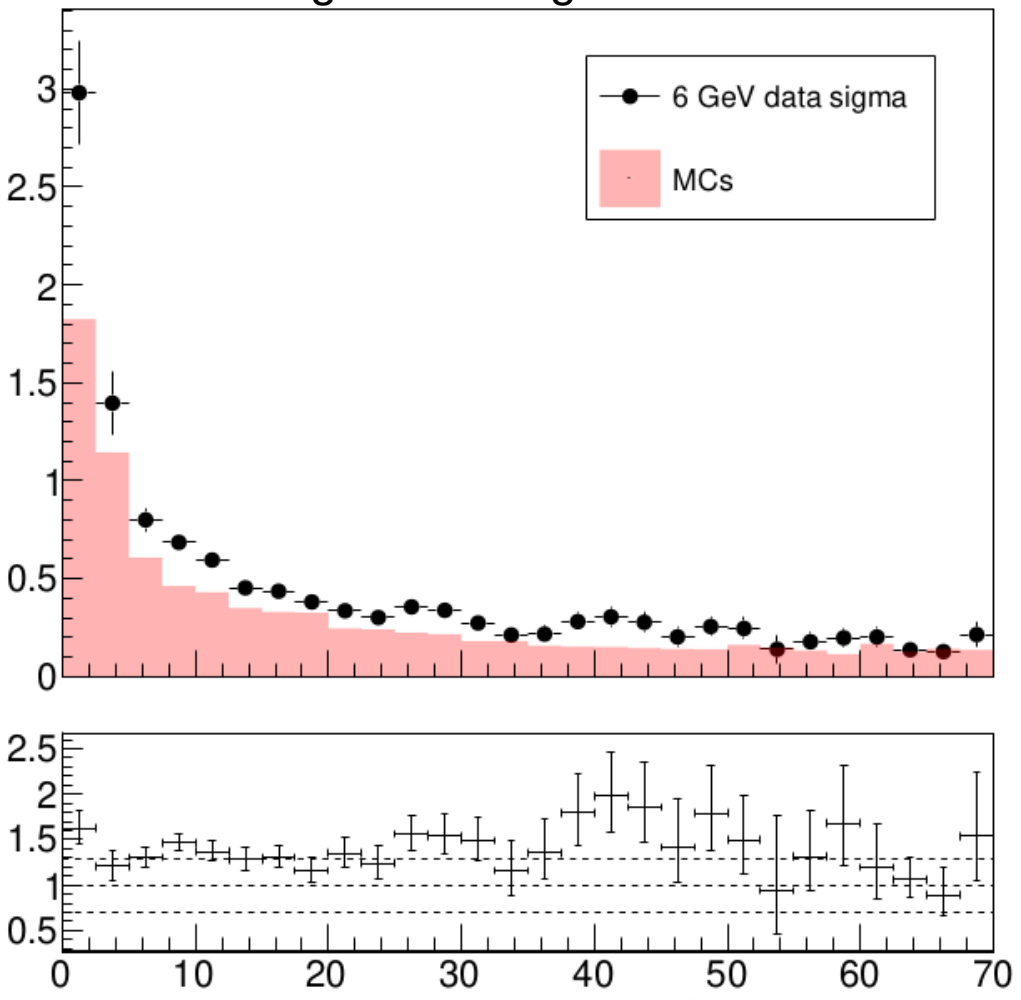


dEdx extraction

dEdx with mean error



Sigma with sigma error

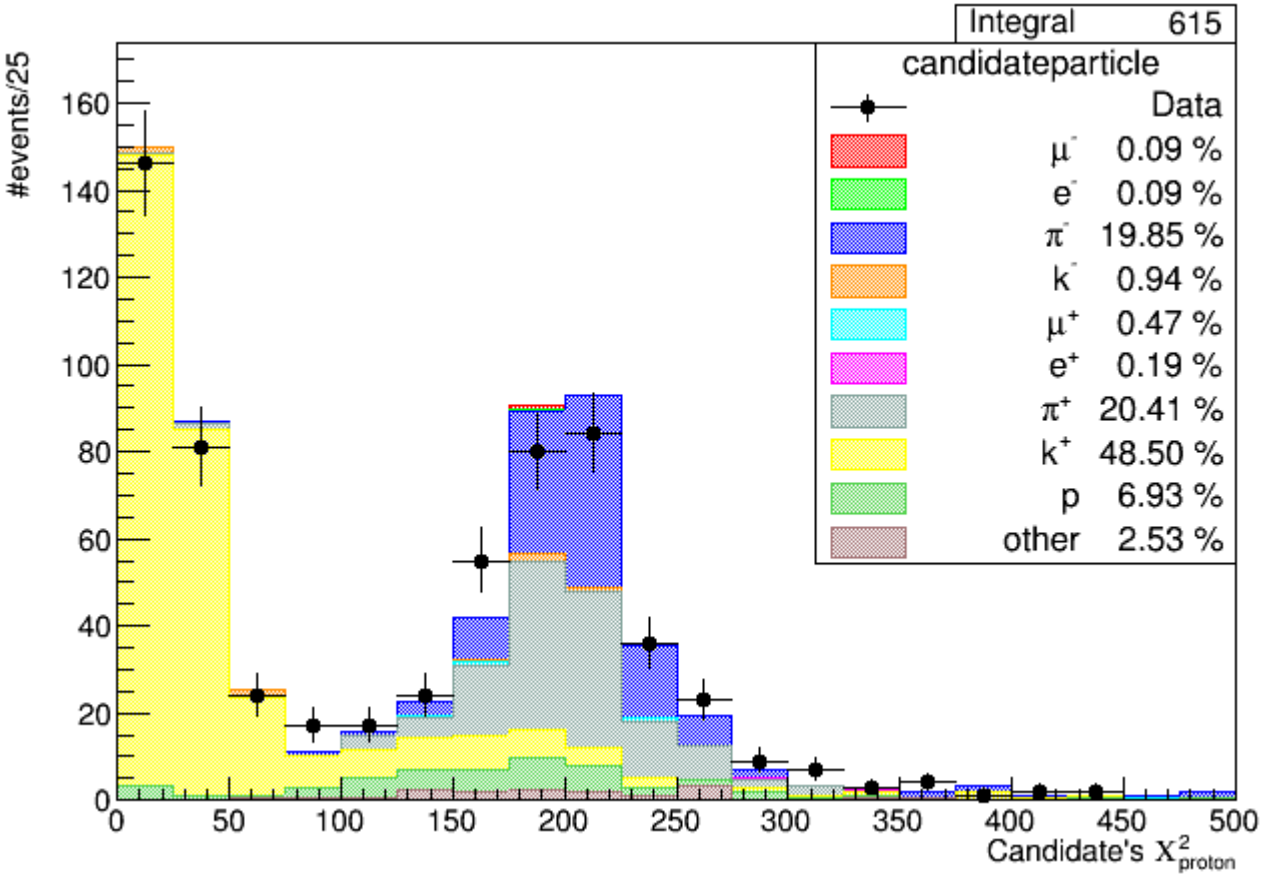


Clear difference data-MC!

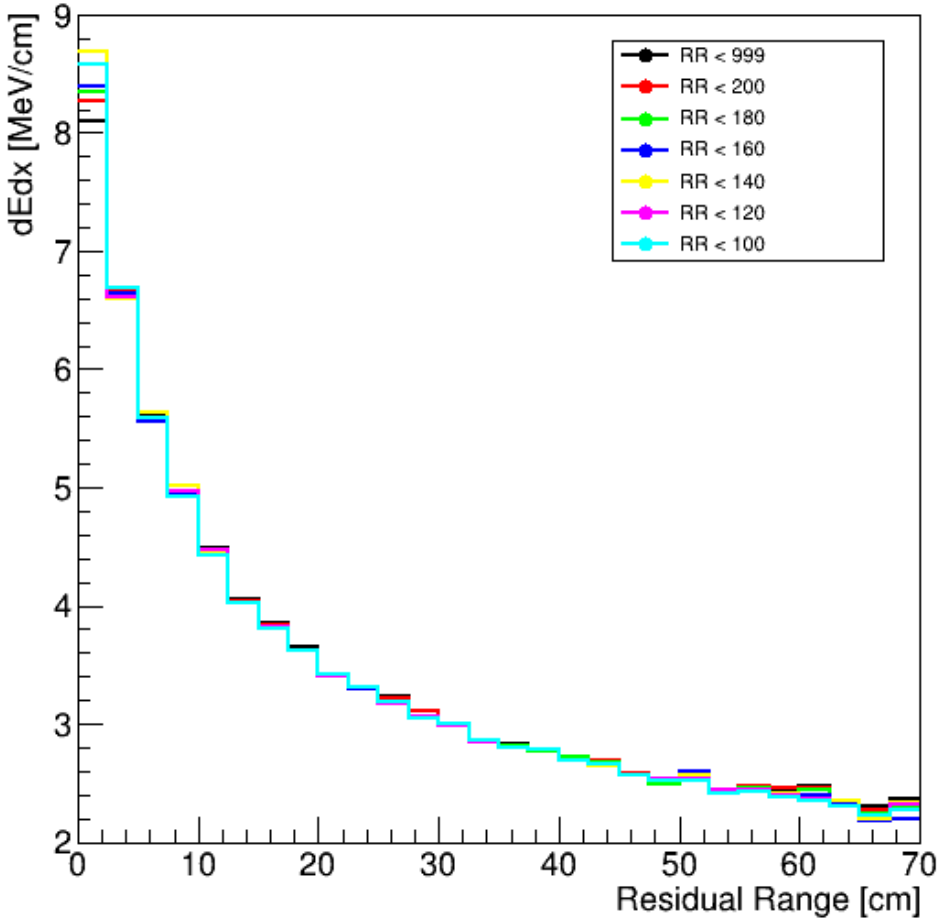
To Do: where is this difference coming from?

dEdx dependence on Chi2 cut

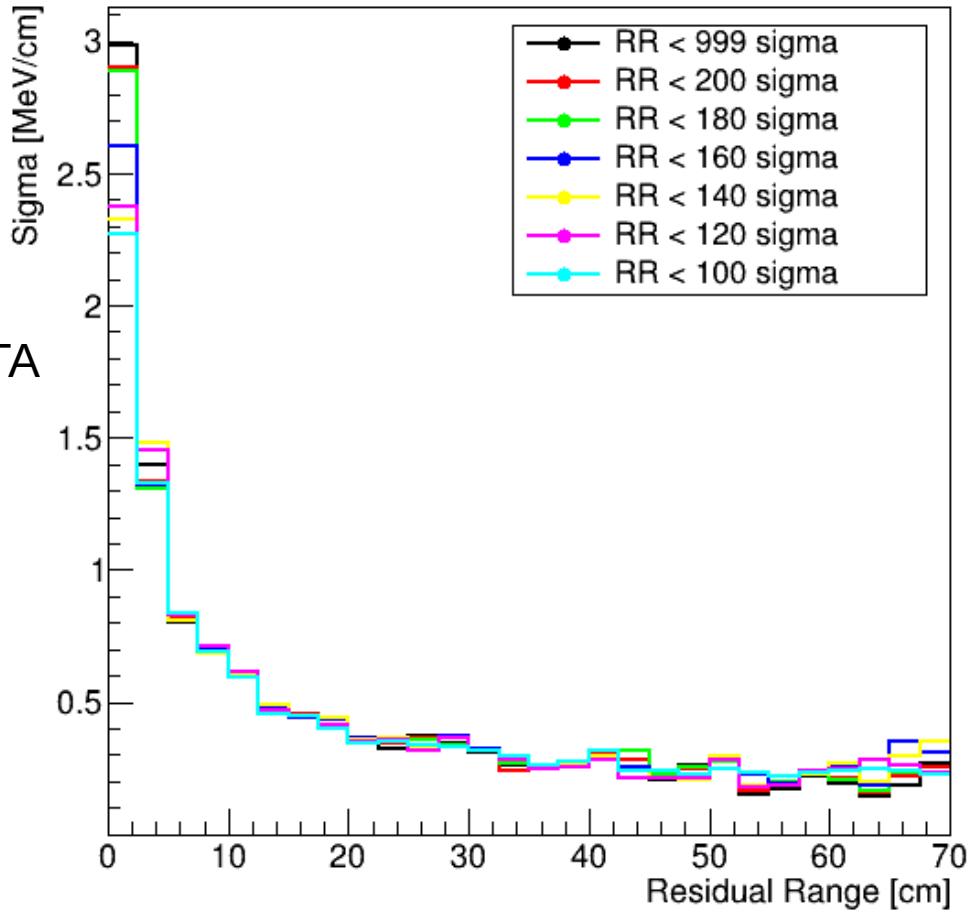
- Cutting on Chi² distribution could remove easily backgrounds.
- How much is the measurement biased by this?



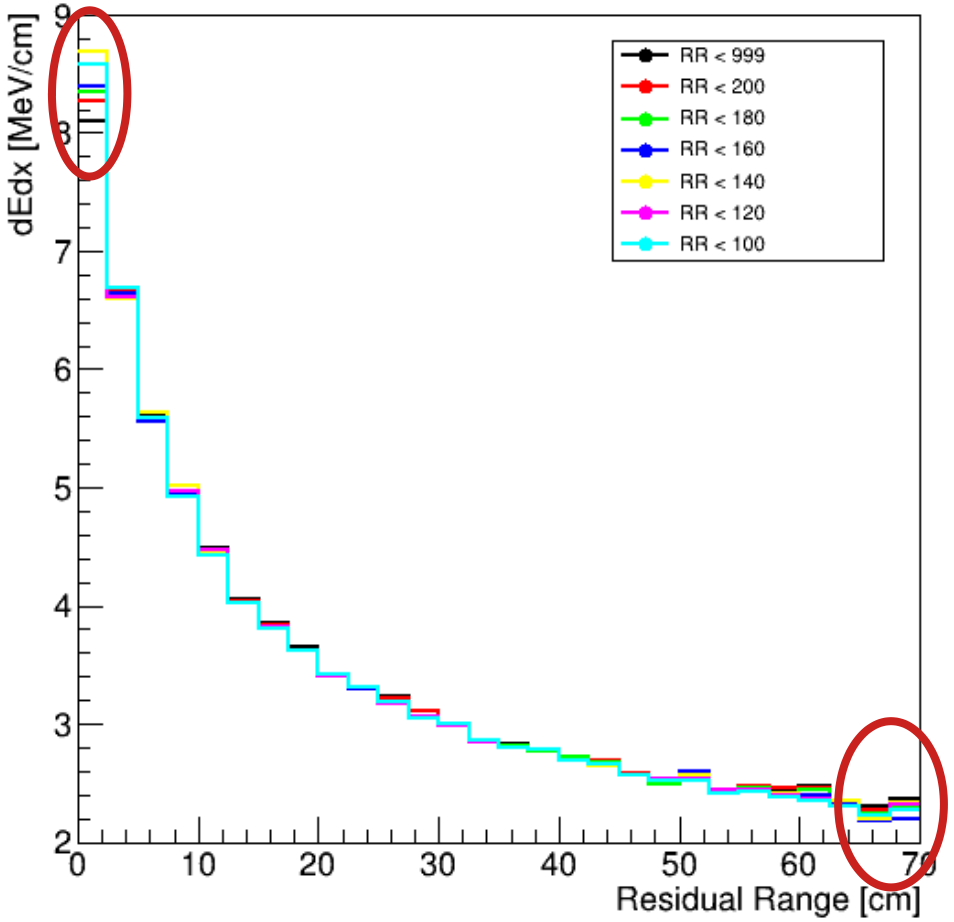
dEdx dependence on Chi2 cut



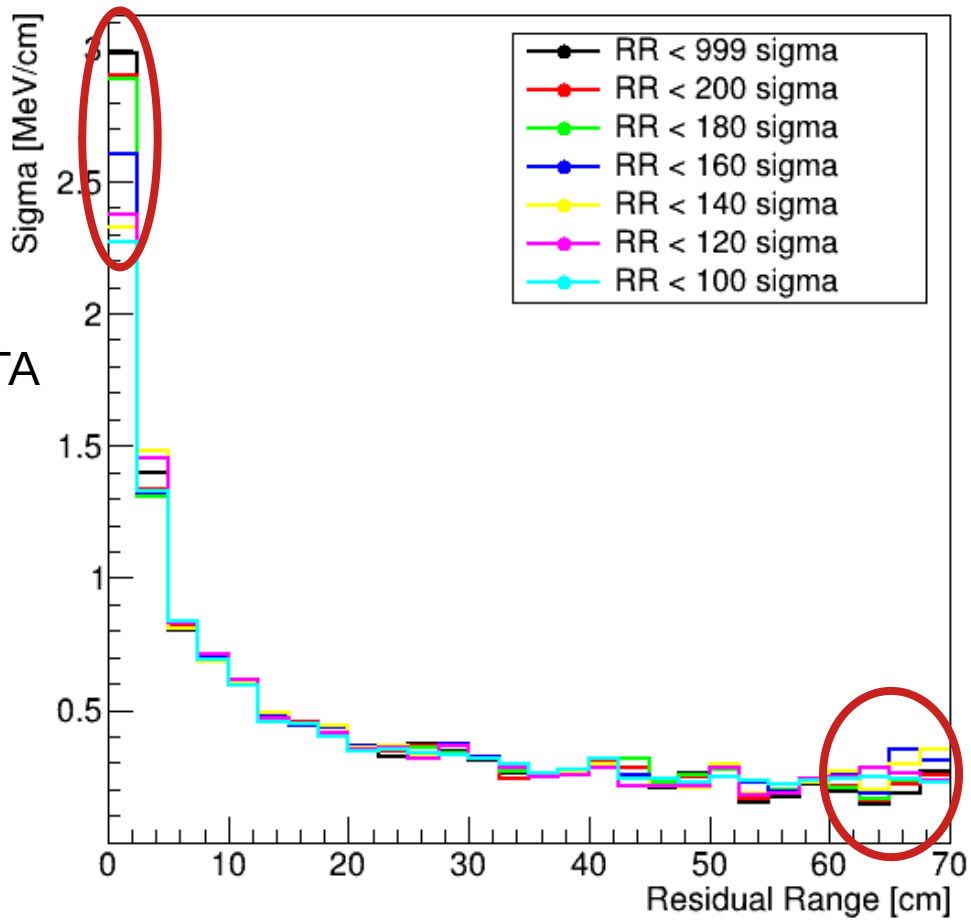
DATA



dEdx dependence on Chi2 cut



DATA

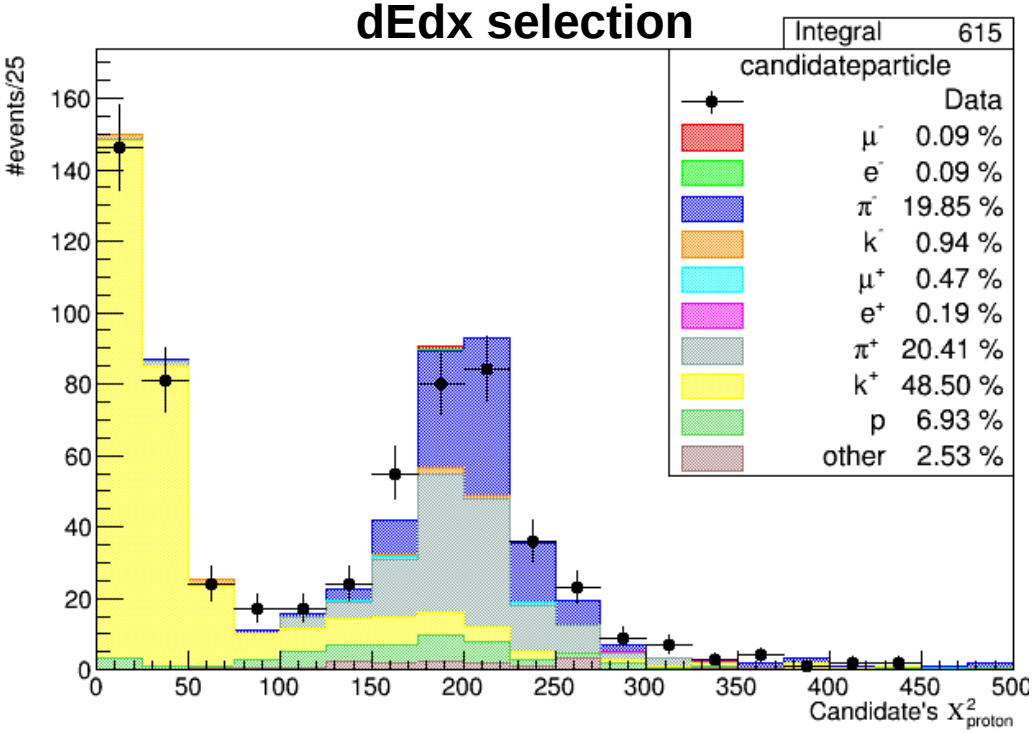


- There are only significant differences on the first and the last points, probably due to the complexity of the fit when background is present. The sigma also decreases in such points when cutting on the Chi².

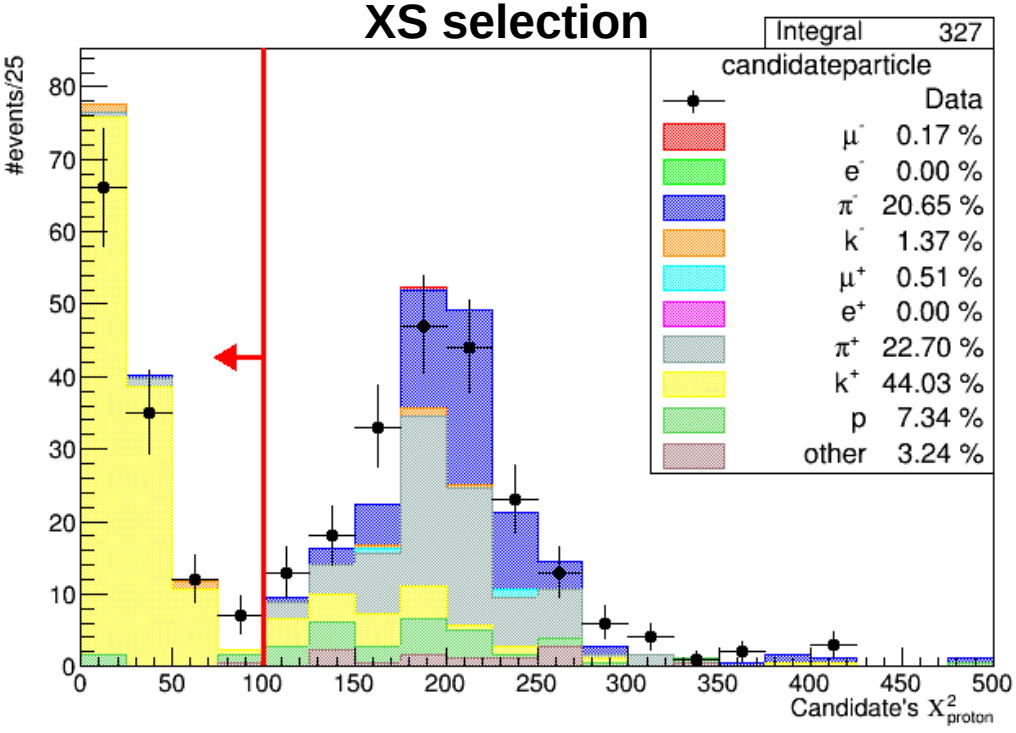
Secondary Kaon production XS

For a XS measurement the dEdx information of the Kaon could be used, which will provide a high purity on the sample. Naive example:

dEdx selection



XS selection



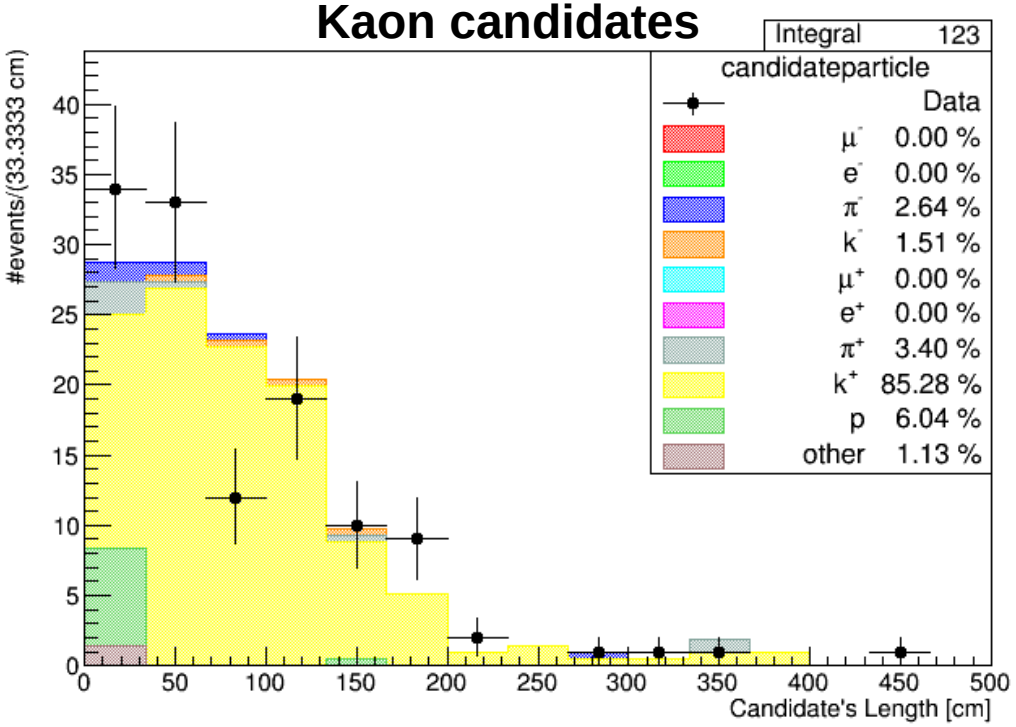
Considering only pion-like beam events and Daughters of the beam particle

Secondary Kaon production XS

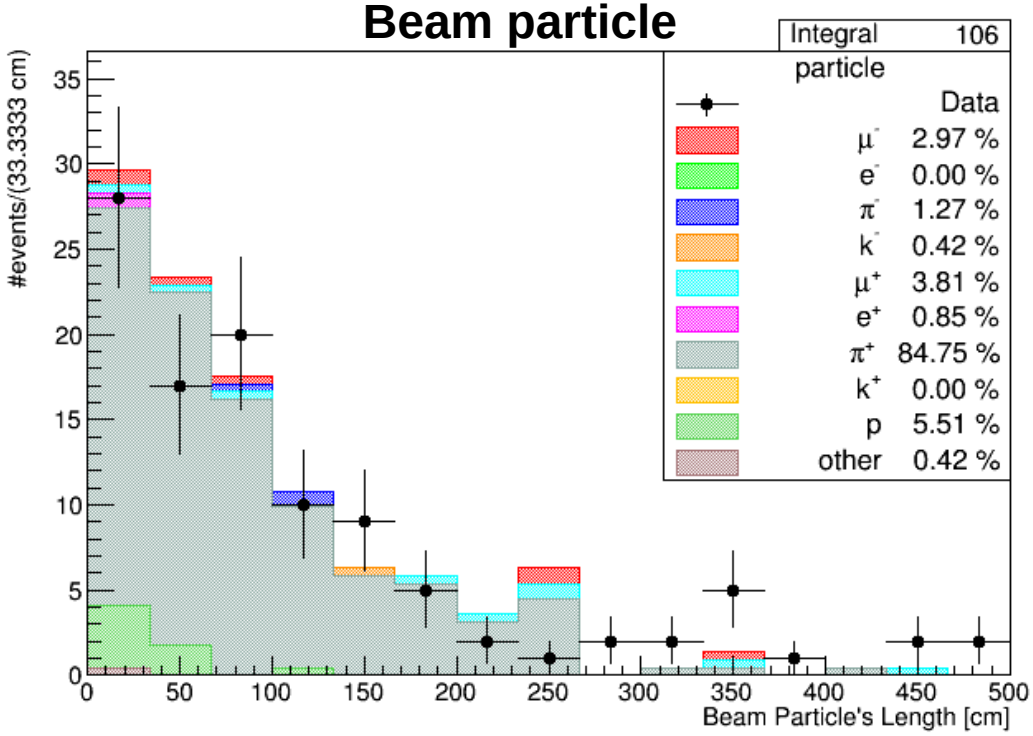
Small population (~100 events) with high purity of daughters (kaons, 85%) and beam particles (pions, ~85%).

Think about which type of measurement could be performed.

Kaon candidates



Beam particle



Summary

- The secondary kaon selection has been optimized and applied to all 6 GeV data.
  - Data and MC show good agreement.
  - The final selection has a purity of almost 50% and around 300 kaons, enough for a significant measurement.
  - 500 kaons are expected when 7 GeV data is also included on the analysis.
- dEdx vs ResidualRange plot can be extracted by slicing the 2D plot and fitting the background+signal distribution.
  - Data and MC show good agreement, although data seems to have a more wider distribution.
  - Cutting on the Chi^2 biases first and last points of the dEdx vs Residual Range plot. To be studied.
- Next steps:
  - Add 7 GeV data to the machinery.
  - Develop a selection for a secondary kaon production XS measurement.
  - Investigate the dEdx differences for data-MC and apply a systematic to the XS selection.