A DATADRIVEN METHOD TO ESTIMATE SPACE CHARGE EFFECT FOR BEAM PARTICLES AND POTENTIAL FOR OTHER APPLICATIONS

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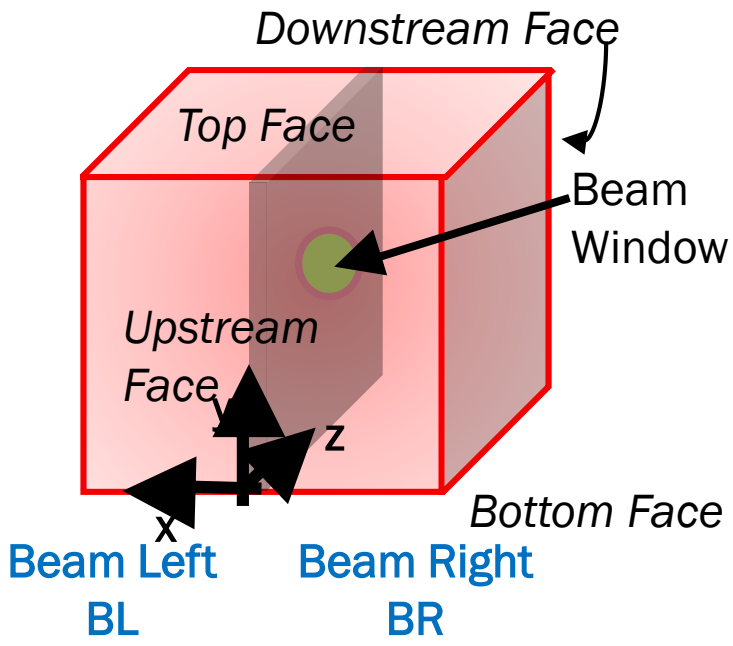
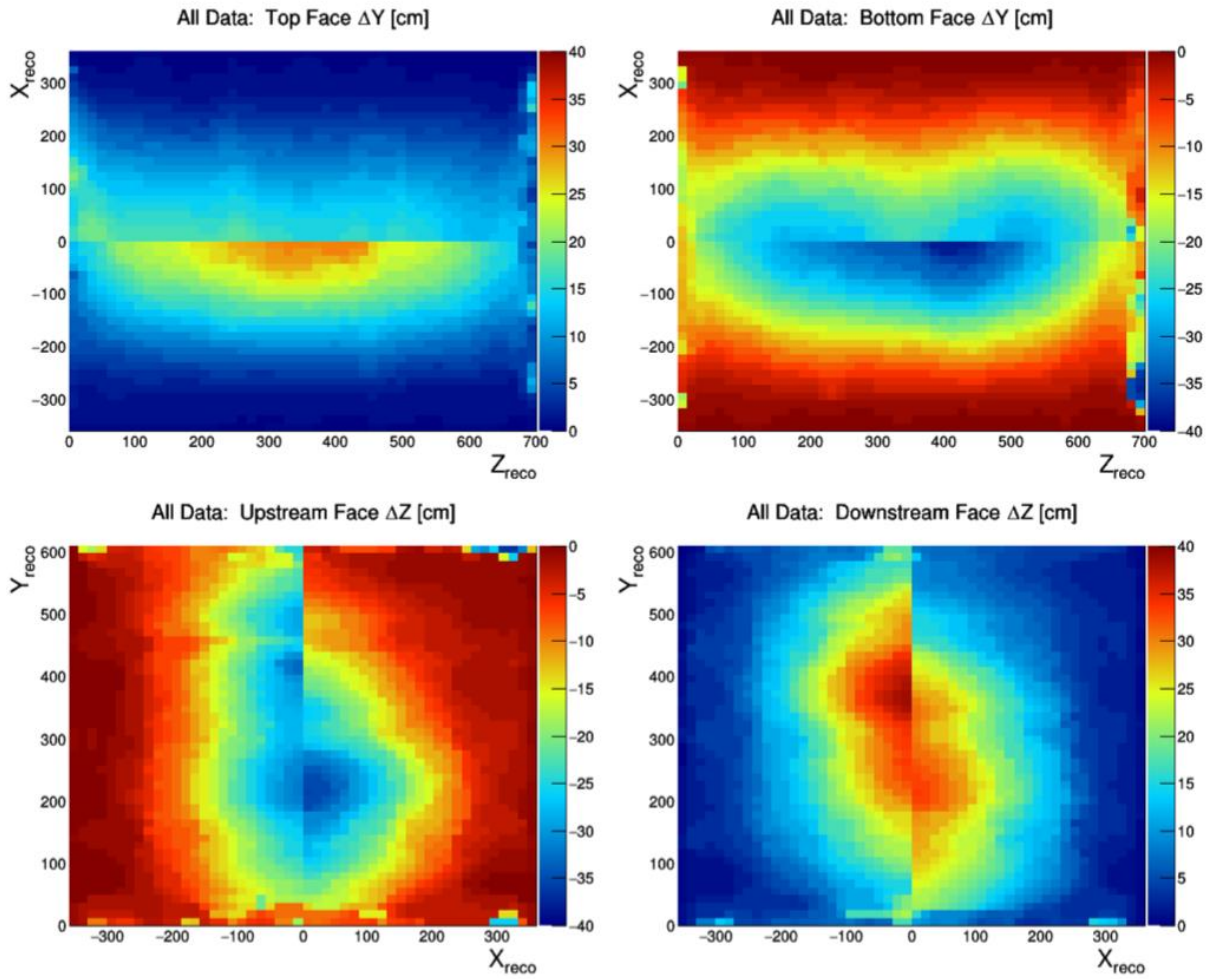
Talk Overview

- Idea & Method
- Validation of method in MC
  - *Some interesting features can be seen in MC*
- Method in data
  - *Thoughts and questions*
- Future applications

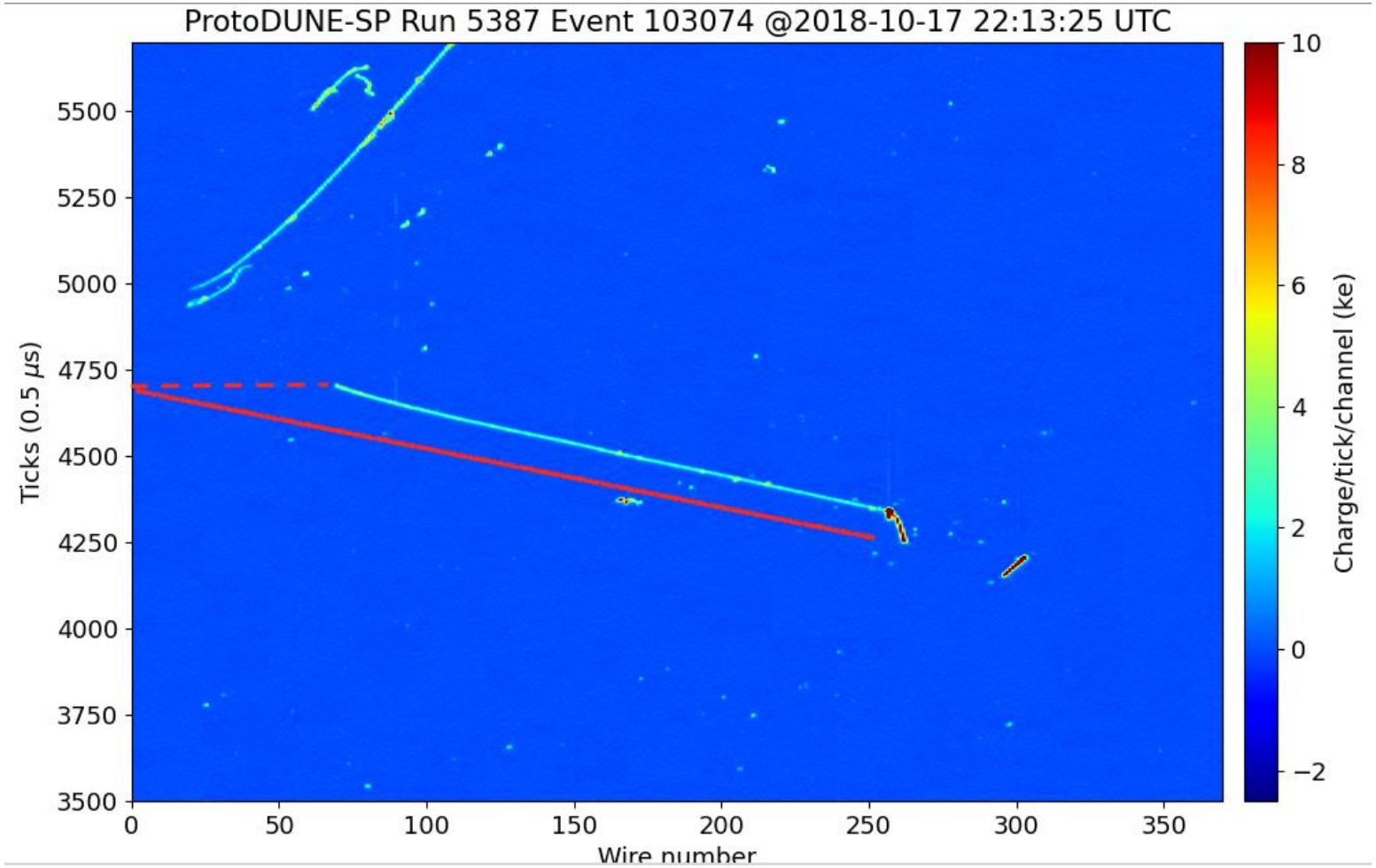


Recap SCE effect ProtoDUNE

- SCE in ProtoDUNE causes displacement in X,Y,Z
- Plots show displacement in Y and Z from the detector top, bottom, front and back faces measured with cathode crossing cosmics
- The SCE effect is modeled with these plots using interpolation between the faces
- SCE corrections are based on this work so far

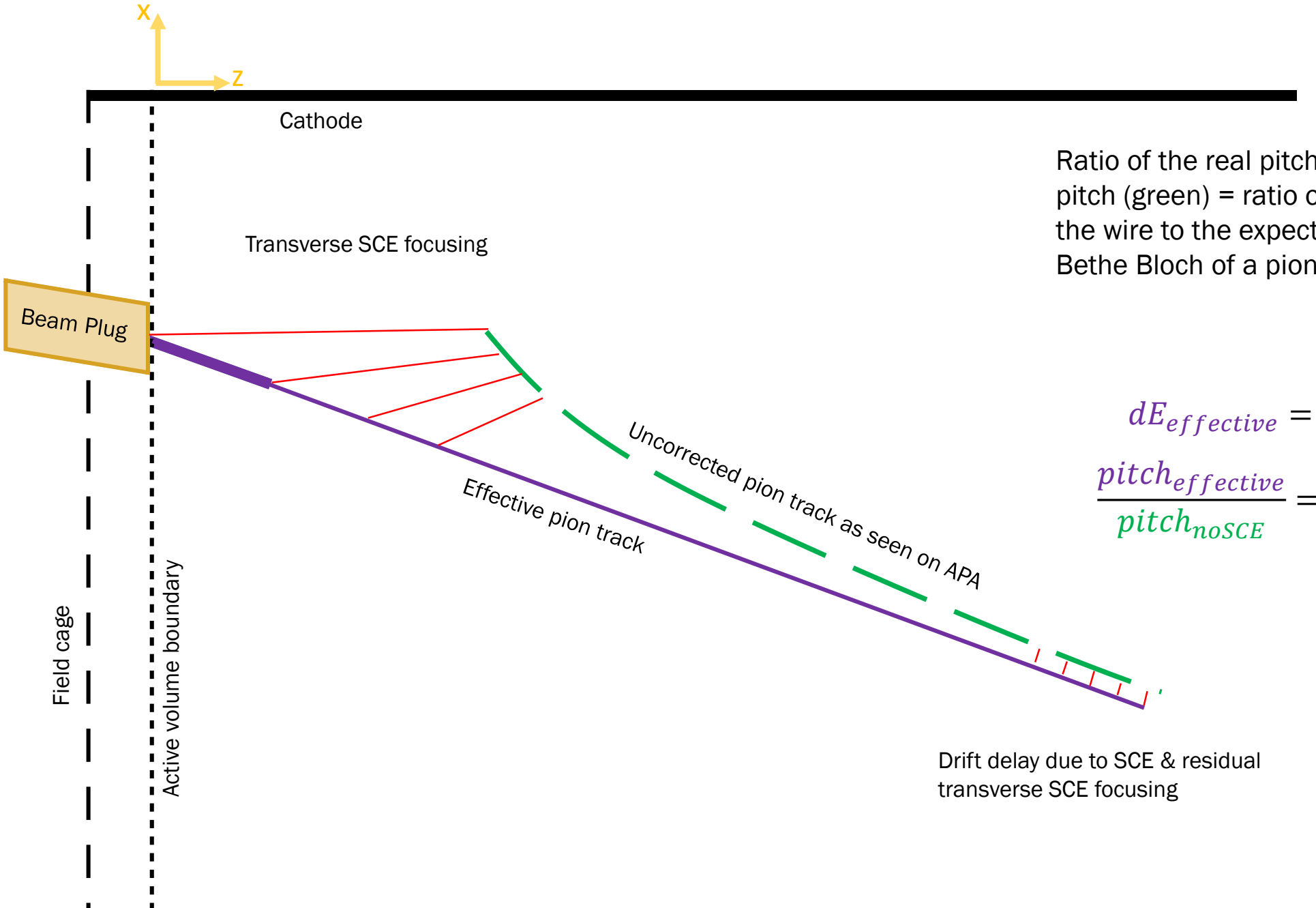


Test SCE correction with model independent approach for beam particles



- Using data a point by point correction can be found for beam particles

Idea of the method



Ratio of the real pitch (purple) to the apparent pitch (green) = ratio of dEdx (MPV) recorded on the wire to the expected dEdx (MPV) from Bethe Bloch of a pion at given kinetic energy

$$dE_{effective} = dE_{noSCE+lifetime}$$

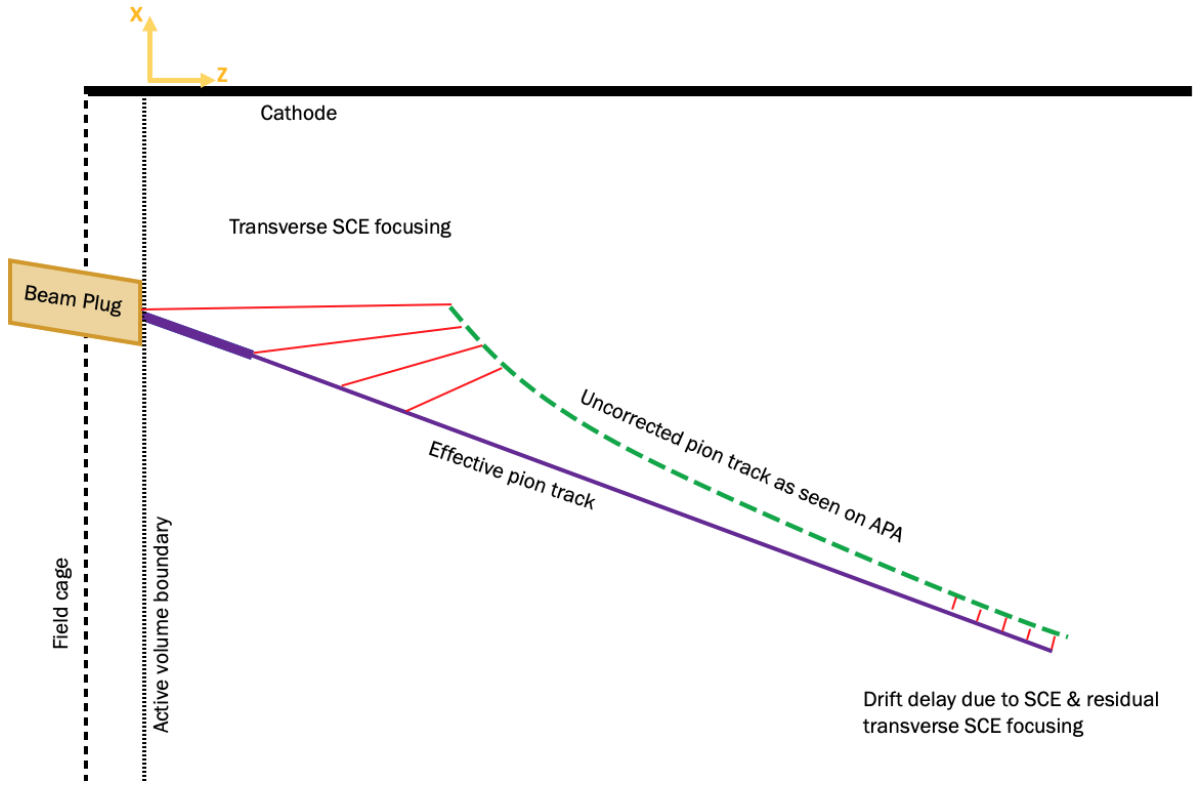
$$\frac{pitch_{effective}}{pitch_{noSCE}} = \frac{dEdx_{noSCE+lifetime}}{dEdx_{expected}}$$

Strategy

- Retrieve $pitch_{effective}$ for each wire using $pitch_{noSCE}$, $dEdx_{noSCE + lifetime}$, $dEdx_{expected}$ → from MPV BetheBloch

- $pitch_{noSCE}$ → **pandoracalonosce** Object
- $dEdx_{noSCE}$ → **pandoracalonosce** Object, add manual lifetime correction on wire by wire basis → $dEdx_{noSCE + lifetime}$

- $dEdx_{expected}$ →BetheBloch MPV for pion/muon



$$dE_{effective} = dE_{noSCE+lifetime}$$

$$\frac{pitch_{effective}}{pitch_{noSCE}} = \frac{dEdx_{noSCE+lifetime}}{dEdx_{expected}}$$

Validation of Method

If transverse focusing in □□ is small enough then the sum of the two pitches should differ by a ΔL corresponding ~ to the transverse initial shift (wire 68*0.48cm = 32.5cm) at Z = 350cm

In order to access region where transverse focusing is smallest (symmetry axis in Z of detector) allow beam particles to traverse APA 3 – 2 gap

$$L = \sum pitch * \cos\theta$$

$$\Delta L = L_{effective} - L_{noSCE+lifetime}$$

$$= \sum pitch_{effective} * \cos\theta - \sum pitch_{noSCE+lifetime} * \cos\theta$$

$$= 32.5\text{cm}$$

Validation of Method / Expected result

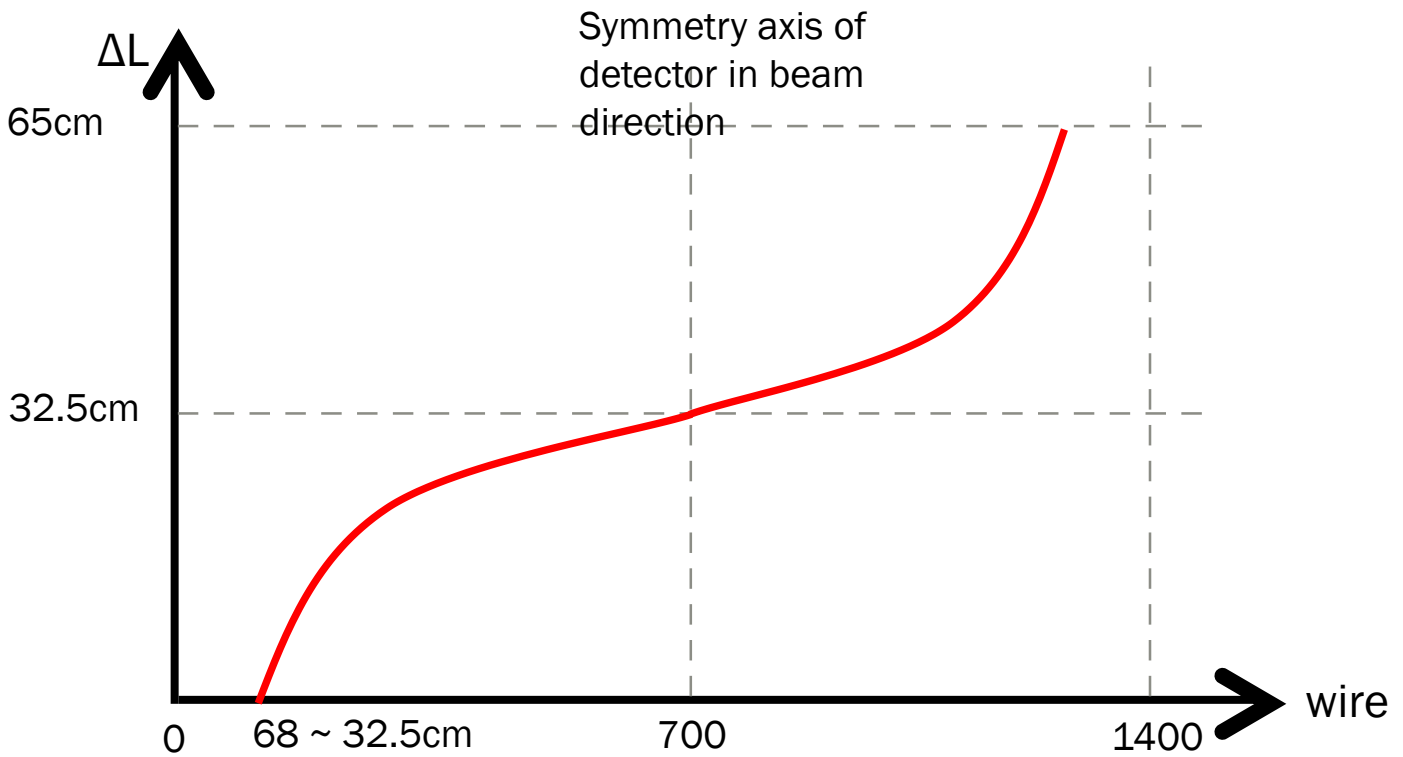
$$L = \sum pitch * \cos\theta$$

$$\Delta L = L_{effective} - L_{noSCE+lifetime}$$

$$= \sum pitch_{effective} * \cos\theta - \sum pitch_{noSCE+lifetime} * \cos\theta$$

$$= 32.5\text{cm}$$

- Plotting the evolution ΔL against the wire should asymptotically reach the 32.5 cm in the middle of the detector where the SCE effect in Z is negligible



Data / MC Sets & Cuts

- Run 5387, 1 GeV, Production 4, protodune-sp_runset_5387_reco_v09_09_01_v0
  - *20ms lifetime*
- MC 1 GeV PDSPProd4_MC_1GeV_reco1_sce_datadriven_v1
  - *35ms lifetime*
- Selection
  - *Is beam particle*
  - *Passes beam window cut*

➢ Sample of **beam pions and muons** that cover APA3 and partially APA2 up to wire ~730 good statistics

➢ This is a very localized sample within the TPC, this method is only applicable for beam particles as we know their exact location

Pandora Objects used

- **Pandoracalonosce** – Objects (NO SCE calibrations)
  - *Added a lifetime correction myself for these objects on a wire by wire base*
  - ➢ *Pandoracalonosce + lifetime*
- dEdx from BetheBloch MPV
  - *Bethe Bloch MPV calculated for pions / muons at initial beam Momentum*
  - *Density effect included*
  - *Energy loss included as particle propagates through LAr*

$$\Delta_p = \xi \left[\ln \frac{2mc^2\beta^2\gamma^2}{I} + \ln \frac{\xi}{I} + j - \beta^2 - \delta(\beta\gamma) \right]$$

- **Pandoracalinoxyzt** – Objects with SCE correction AND lifetime correction

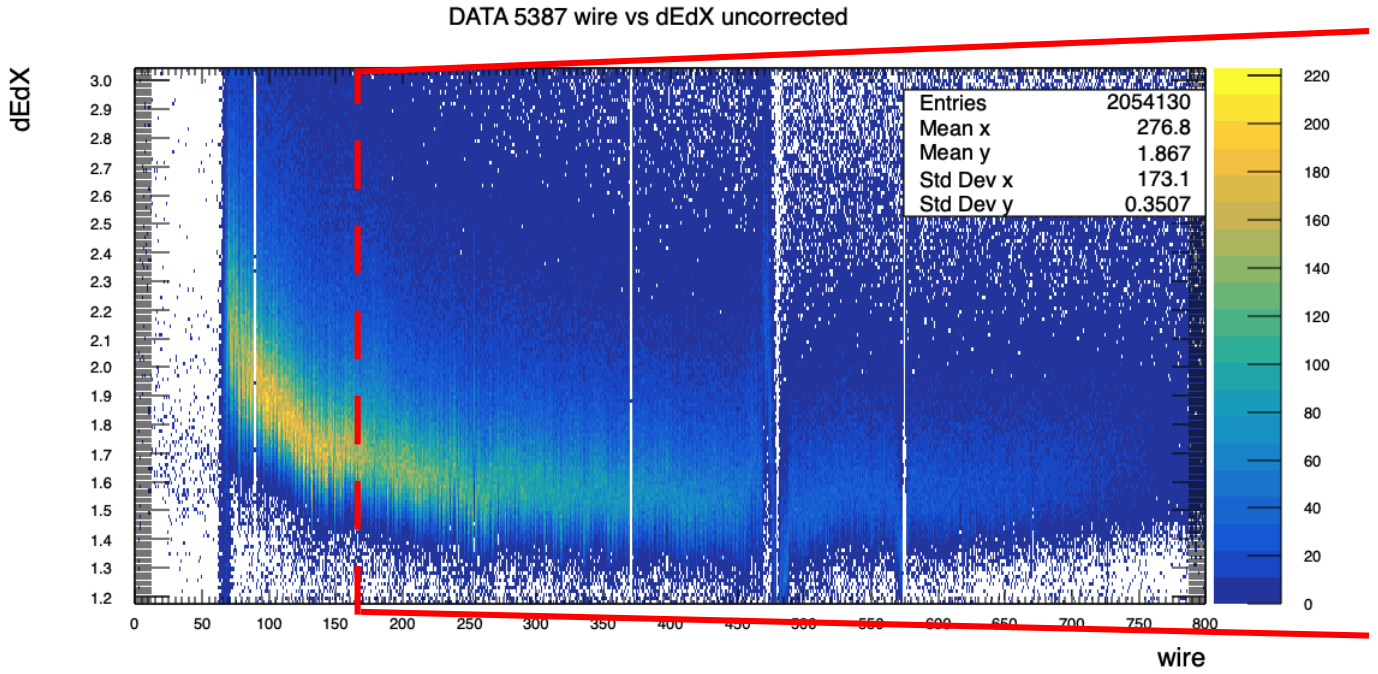
➢ Difference between pandoracalonosce + lifetime and pandoracalinoxyzt is ONLY the SCE correction

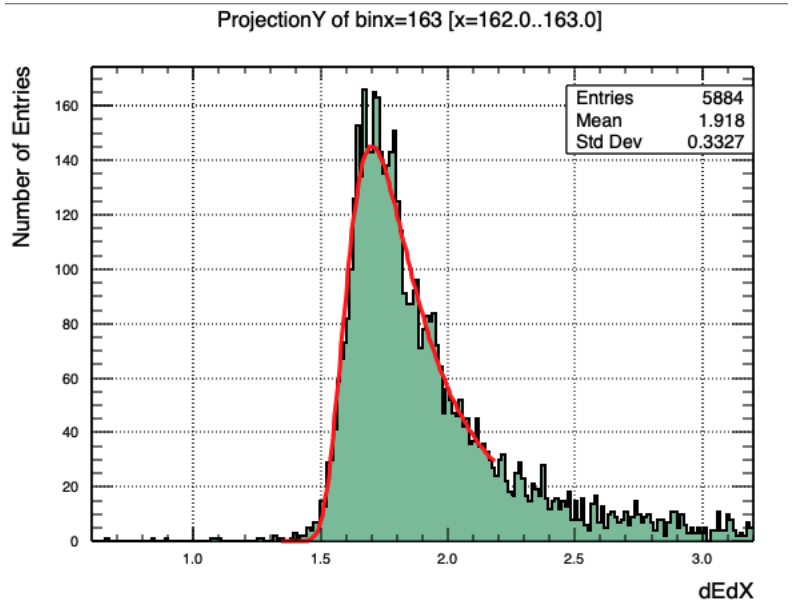
➢ can compare datadriven $pitch_{effective}$ and pandoracalinoxyzt Objects

❖ **NOTE, $pitch_{effective}$ is the pitch that has been corrected by data for SCE**

Validation of method

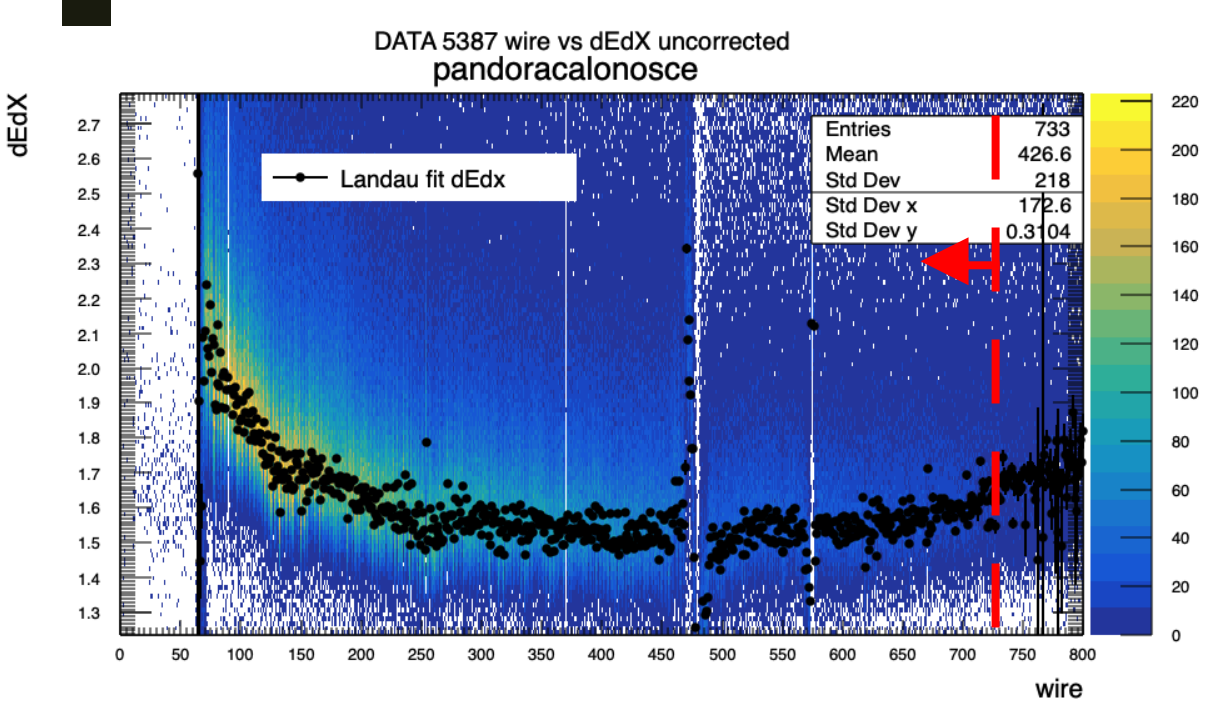
- $dEdx_{noSCE}$ is retrieved by fitting h2 (dEdX vs wire) with a landau for every wire and extracting the MPV
- $pitch_{noSCE}$ is retrieved by fitting h2 (trackPitch vs wire) with a gaussian for every wire
- $dEdx_{noSCE + lifetime}$ is obtained by adding the lifetime (20ms in data) correction to $dEdx_{noSCE}$

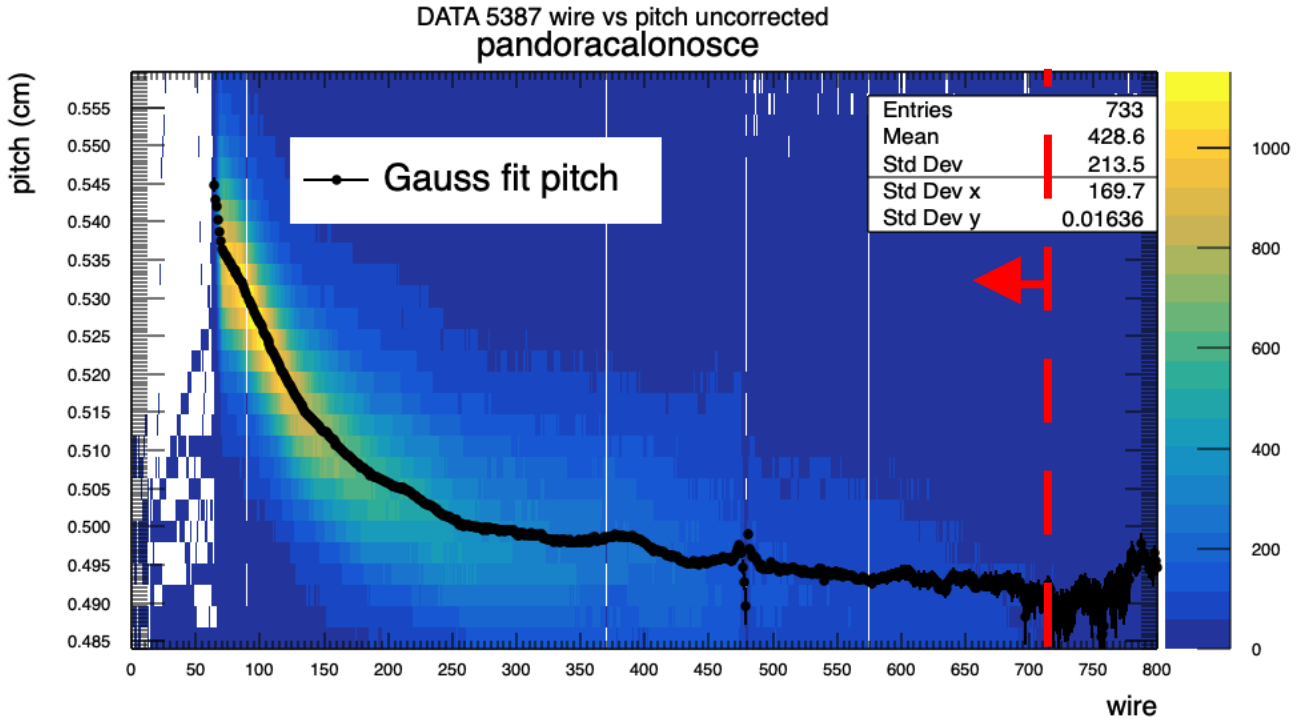




OK. Now Data. Run 5387, lifetime 20ms

- Lifetime correction for 20ms as function of Z
- dEdx Data goes up and down, statistical fluctuation? Also this wire-by-wire effect that I looked into 2 months ago

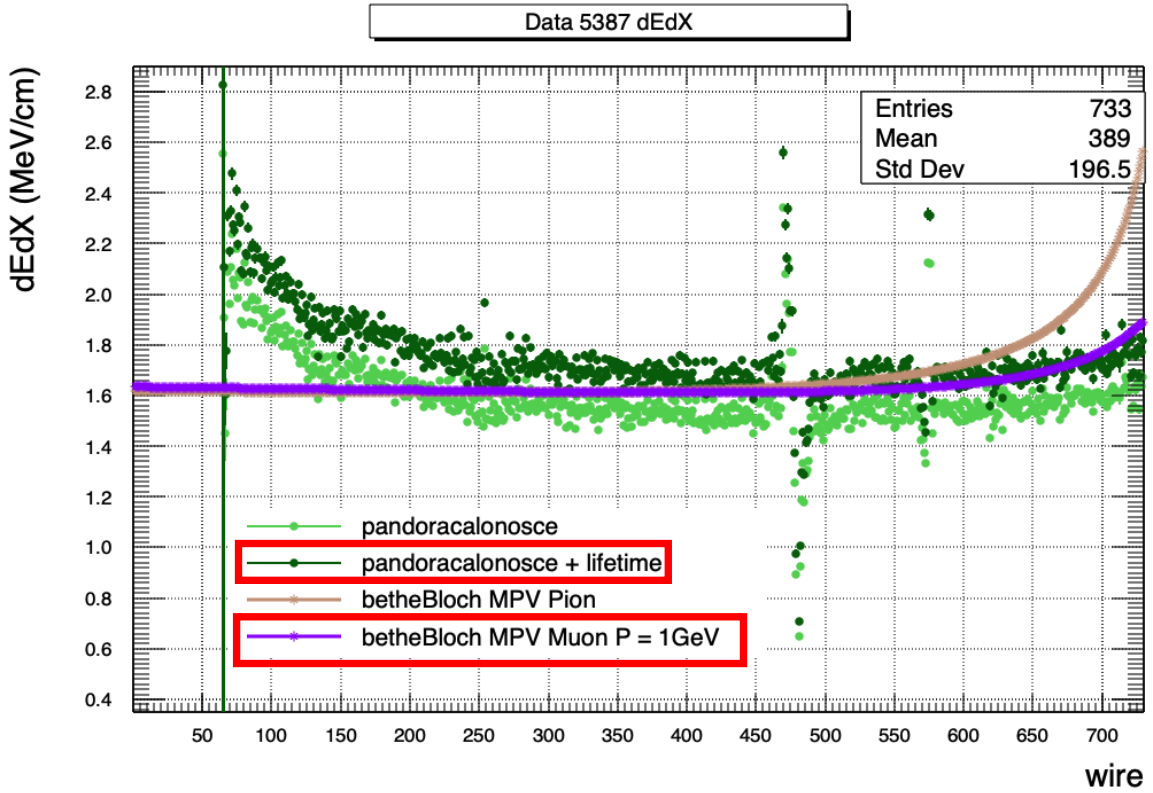


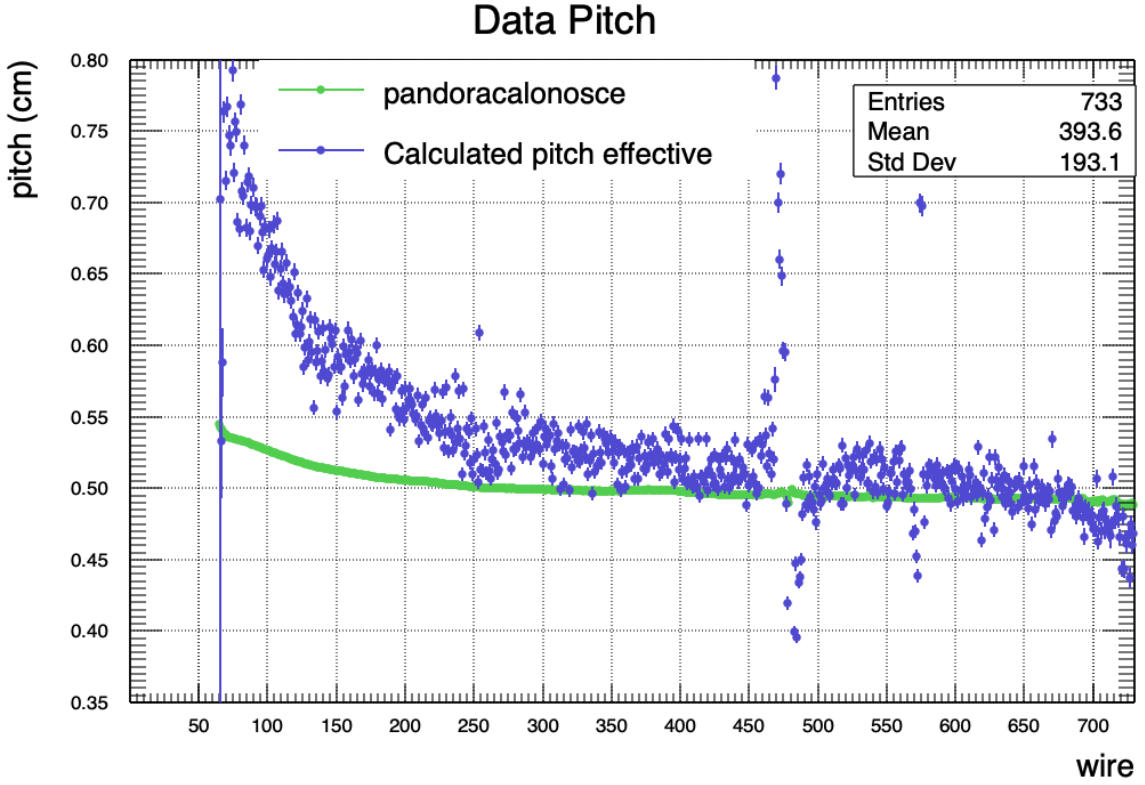


Data dEdx and pitch$_{effective}$ calculation

$$pitch_{effective} = \frac{dEdx_{noSCE+lifetime}}{dEdx_{expected}} pitch_{noSCE}$$

- For the calculation the dEdx from BetheBloch MPV of a 1GeV Muon is used
- From wire 650 on Bethe is higher than lifetime corrected dEdx that is why the pitch is smaller → suppose that Bethe should be smeared when reaching final range of muons of P = 1GeV to match better data, also due to beam spread, only muons with P > 1GeV are more likely to make it that far, would need to tune BetheBloch back there

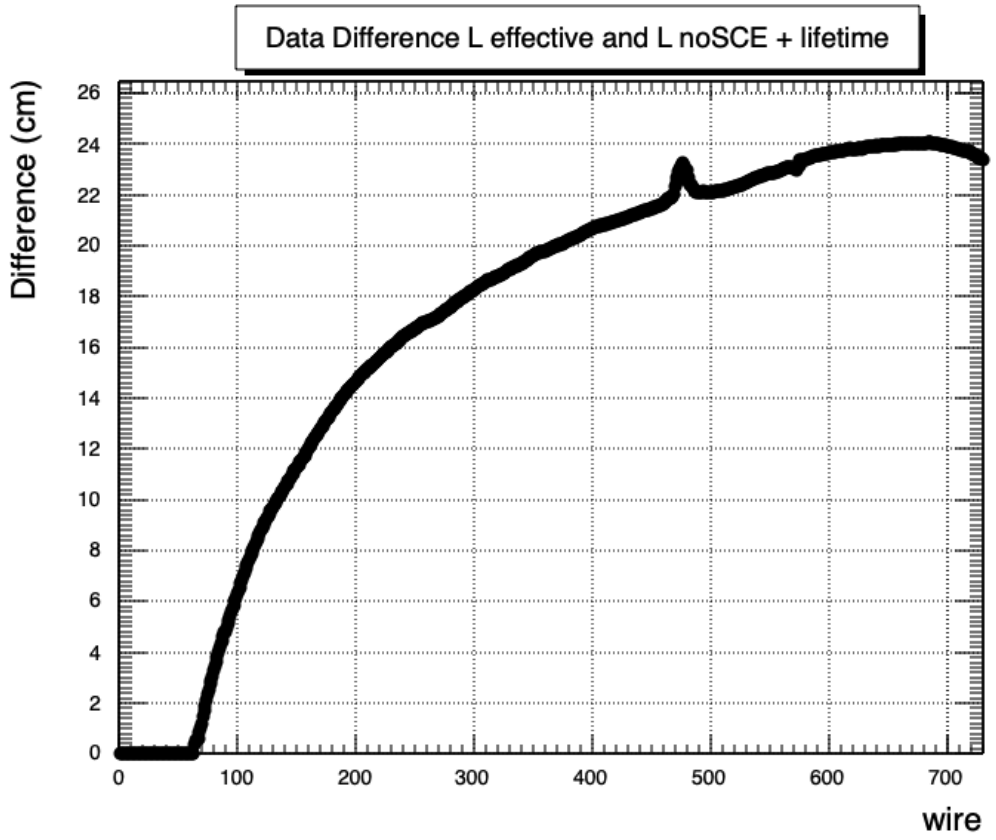




Data Difference of $L_{effective}$ and $L_{noSCE + lifetime}$

$$\Delta L = L_{effective} - L_{noSCE+lifetime}$$
$$= \sum pitch_{effective} * \cos\theta - \sum pitch_{noSCE+lifetime} * \cos\theta$$
$$= 32.5\text{cm}$$

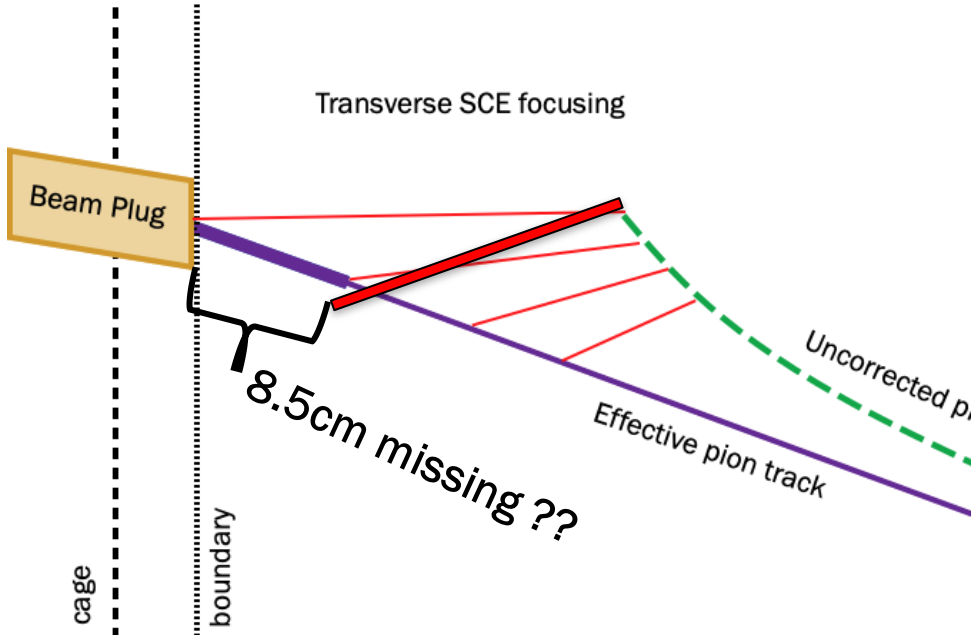
- At wire 700 → ΔL = 24cm
- We are missing 8.5cm
- Does the Method not work in data?
- Are we missing something?
- ➢ Might have an explanation



Data Difference of $L_{effective}$ and $L_{noSCE + lifetime}$

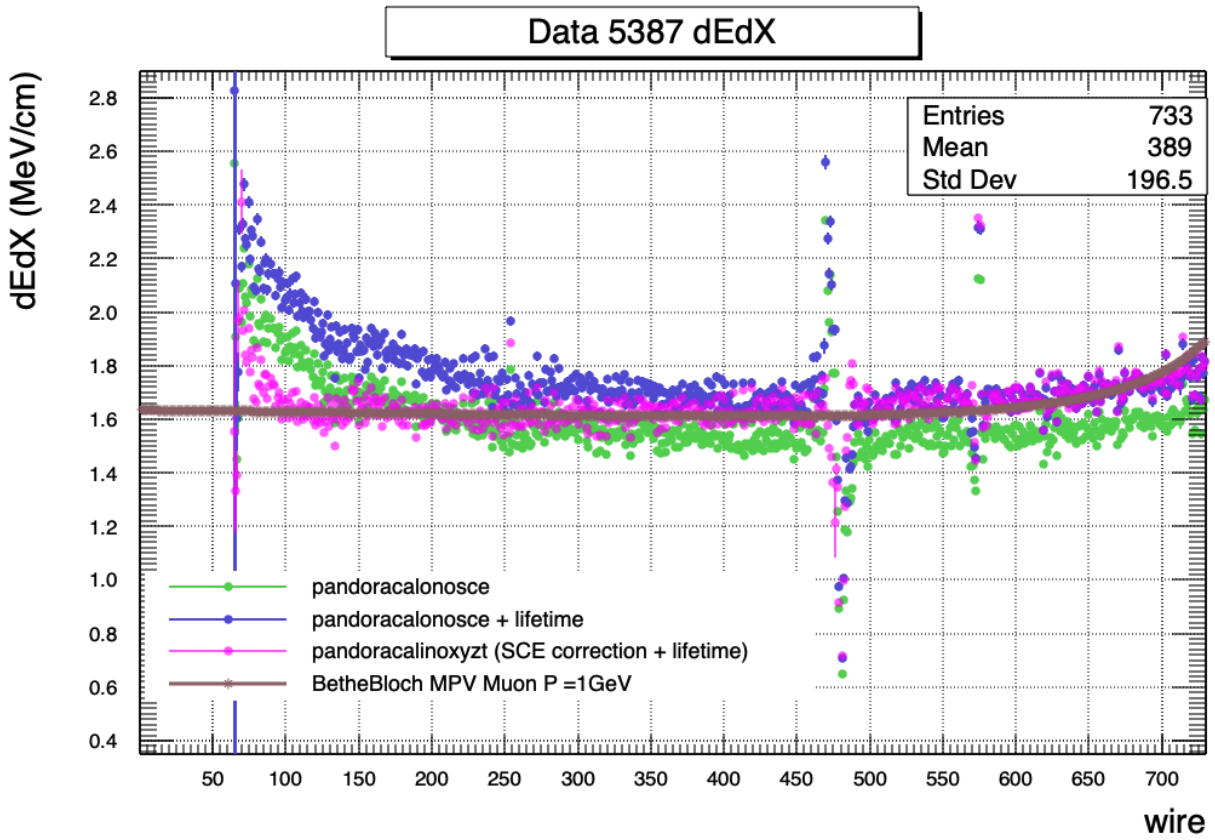
- **At wire 700 → ΔL = 24cm, Missing 8.5cm!**
- L is the sum of every pitch, so a small mis-estimation in every pitch integrates as we continue in the wires
- 8.5/32.5 → 26%
- BUT 8.5cm ≃ 2.1*8.5 = 17MeV
- We are looking at tracks traversing up to 350cm ≃ 700MeV
- 17 / 700 → **2%** uncertainty in dEdx
- **Richie Diurba gave an uncertainty of $\sigma_{dEdx\ MIP}$= 1.68 % from the calibration**
- **Could be an explanation, thoughts??**
- Of course there is more potential to better finetune things on the BetheBloch side especially in the final range region

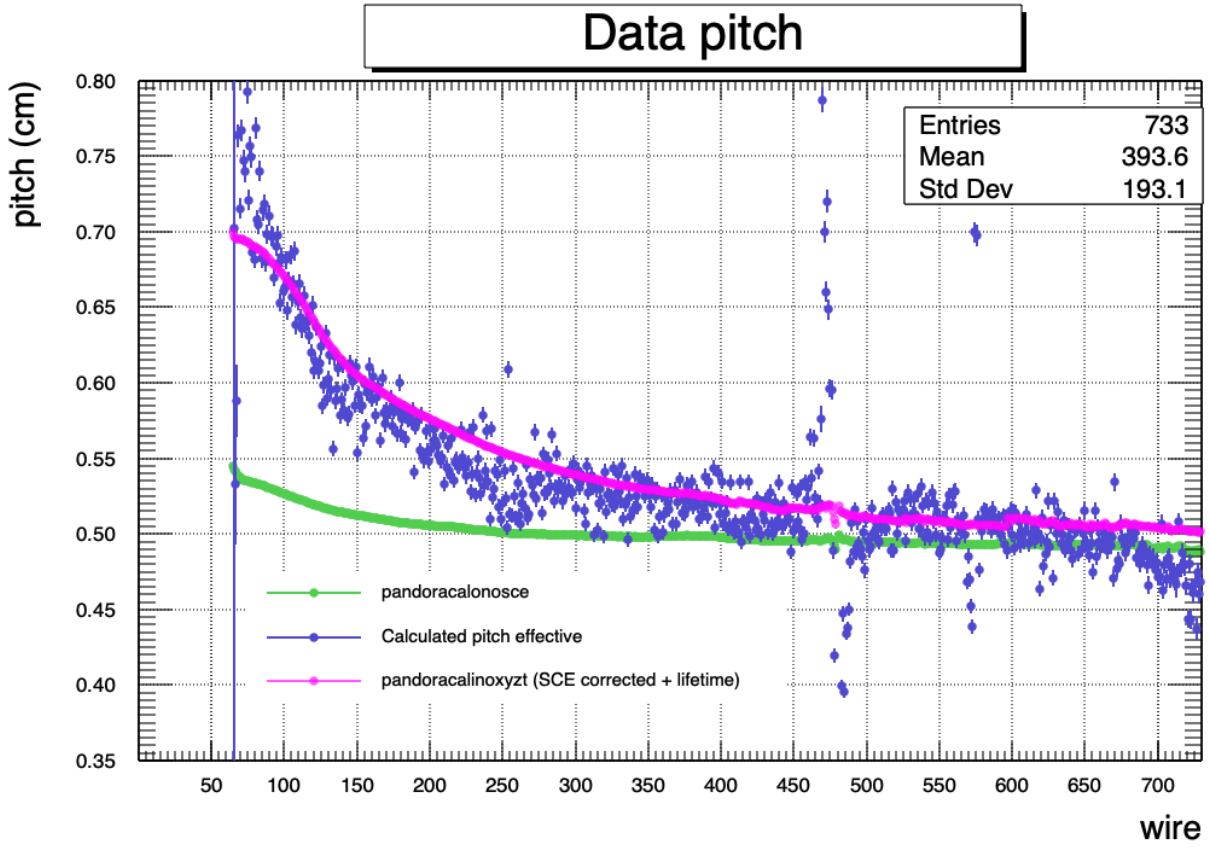
How far the correction made it



Data Compare $pitch_{effective}$ to $pitch_{SCE}$ (pandoracalinoxyzt)

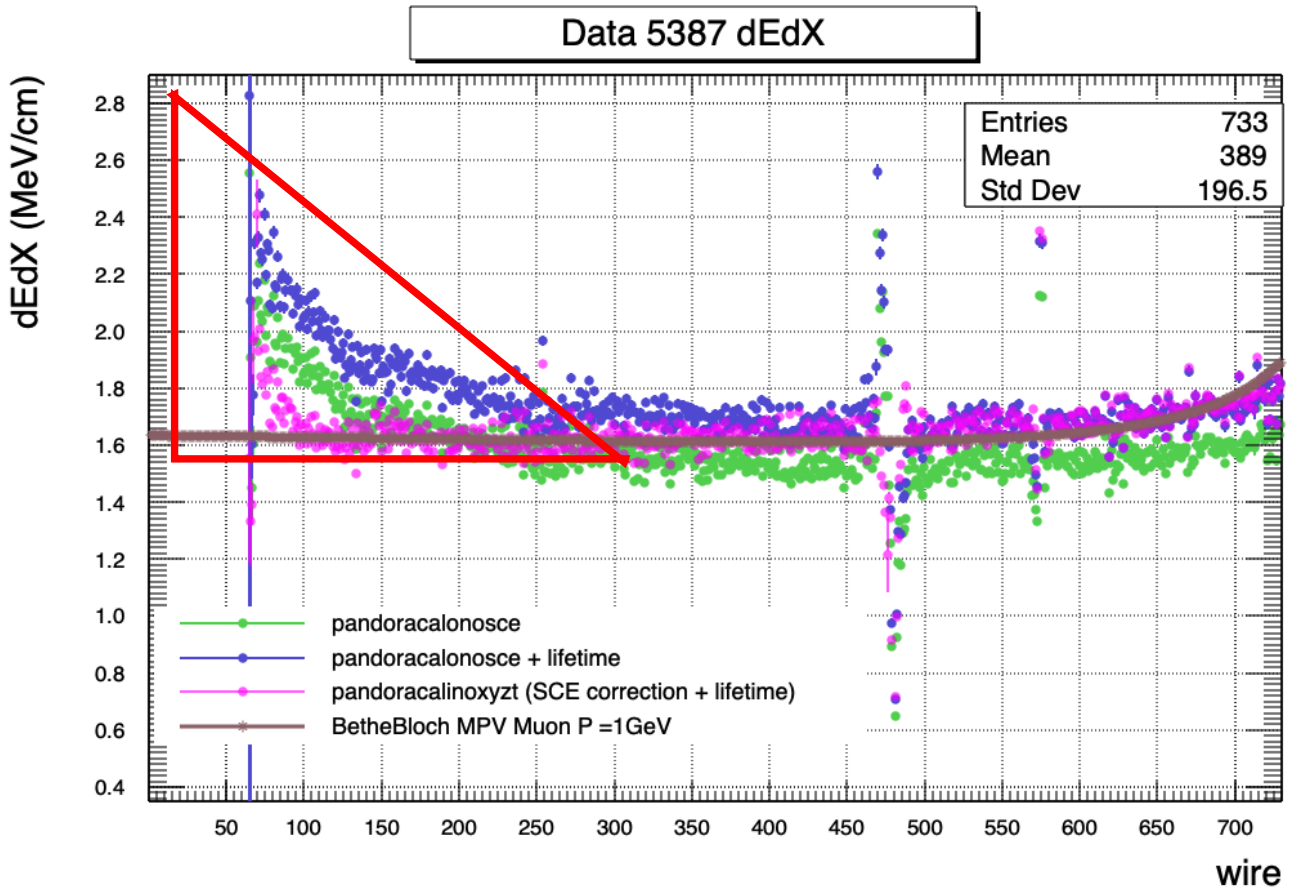
- From $pitch_{effective}$ it looks like the SCE effect is decreasing slower in the $pitch_{SCE}$
- This method provides a DIRECT datadriven way of correcting the SCE for beam particles





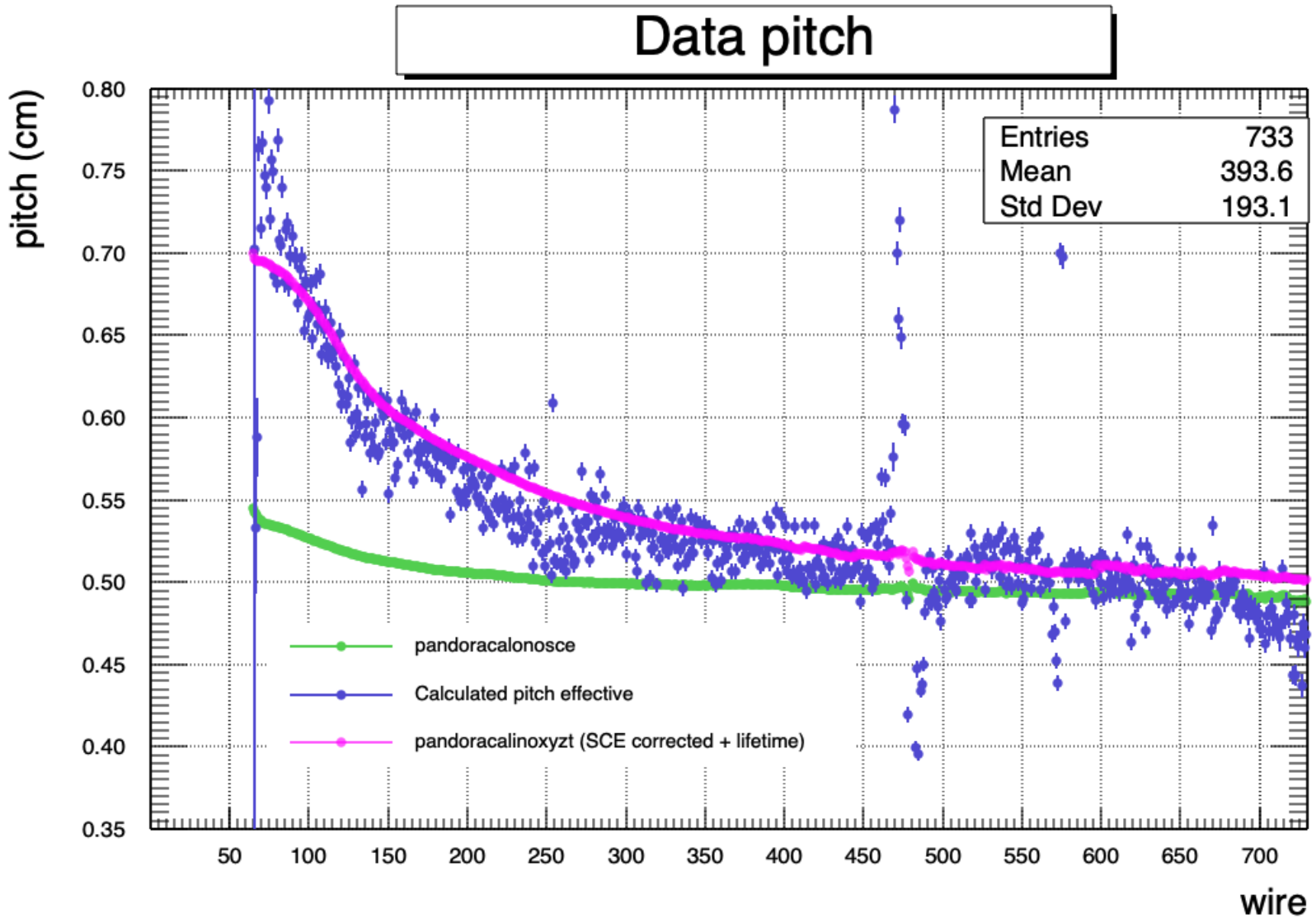
Data dEdX MPV

- dEdx MPV flattens as particles continue inside the detector. This is expected as the transversal SCE effect is becoming smaller the further we are from the beam face
- A perfect correction would spread the dEdx values in the red triangle flat until wire 0, that would be a TPC without SCE effect



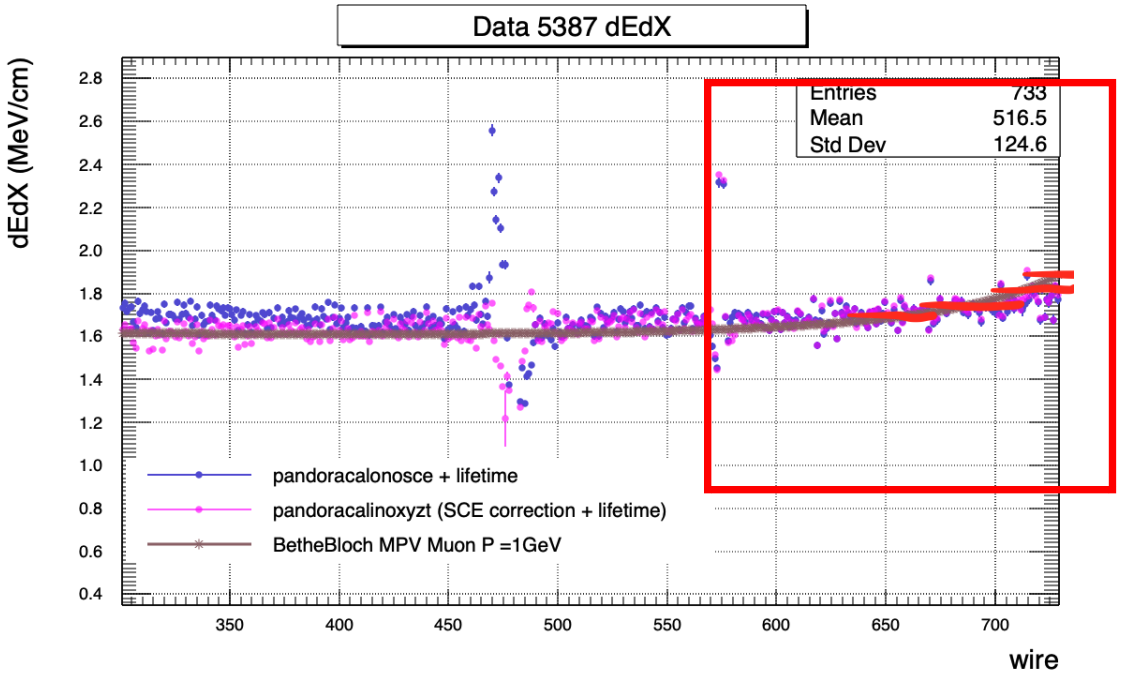
Data pitch

- It seems that the SCE c
  pitch is assuming the S
  be less sharp than wha
  from the estimation thr
  method



Summary & Outlook

- A purely data driven method was presented to correct for SCE effect for beam particles
- A few improvements can be made to the estimation of the pitch:
  - *The theoretical BetheBloch that is used for the effective pitch calculation was computed with a specific certain initial muon kinetic energy. However in the region form wire 600 onwards P= 1GeV muons start reaching final range too. We know that the beam has a spread of ~5% in momentum. In higher z regions of the detector we will have a dominance of the higher momentum beam particles which could be taken into account to make the effective pitch estimate better*
- See if beam angle can be more refined from reconstructed data
- Other thoughts and comments?



BACKUP

Validation of method with MC

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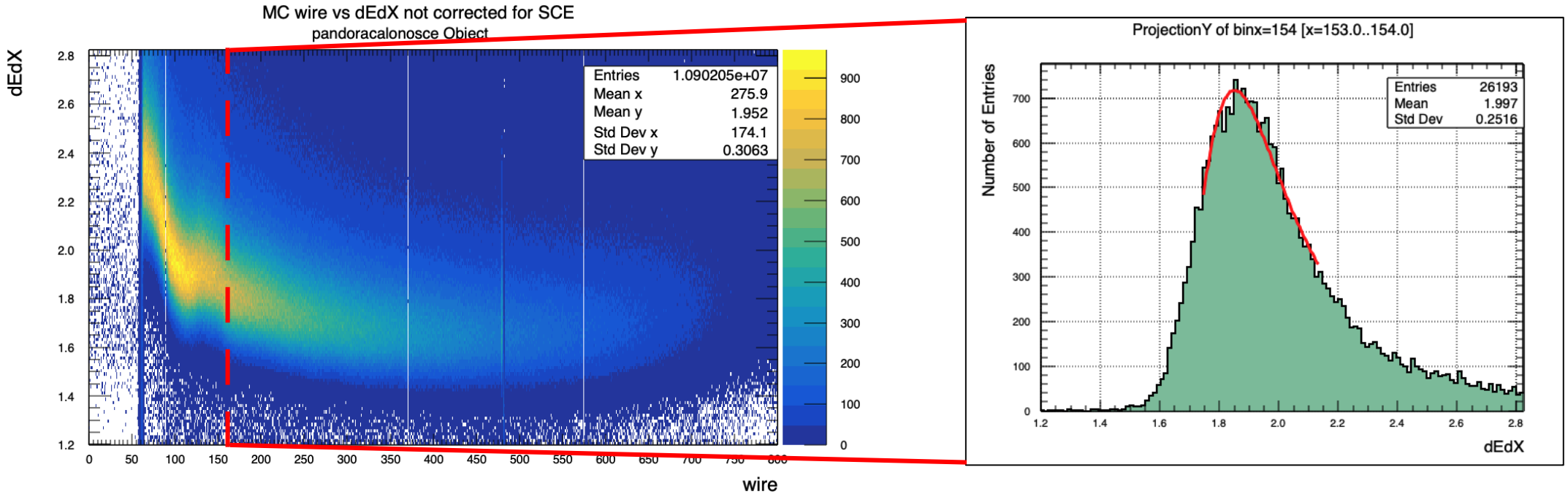
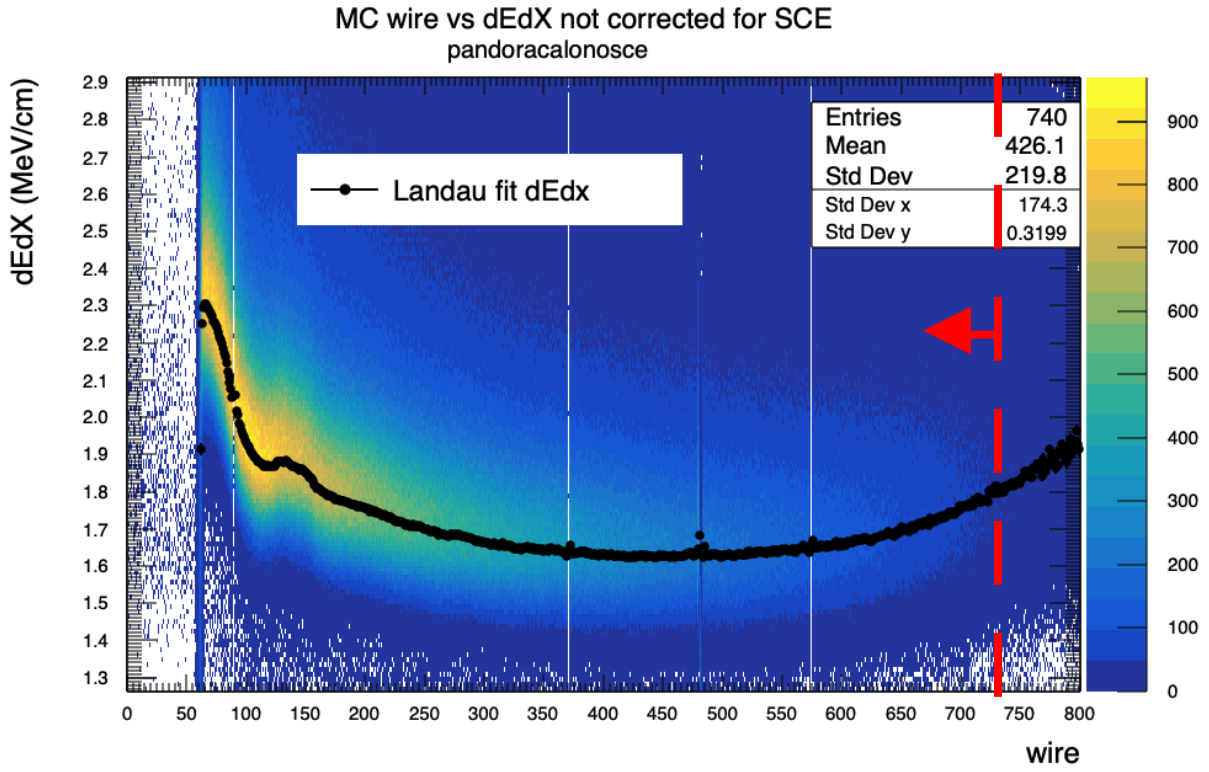
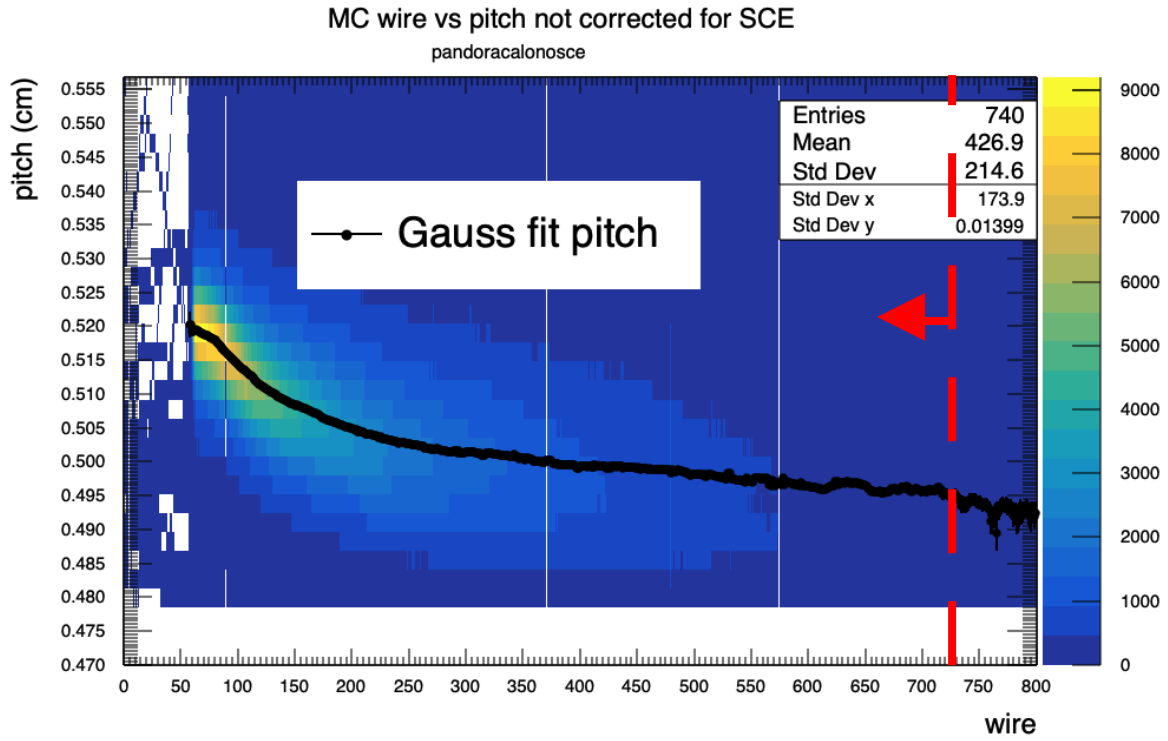


Fit results pandoracalonosce MC

- Stop at wire 730 ≃ 365cm (beyond middle of detector) as fits are less accurate due to less stats and smearing in energy of particles
- Special MC features visible

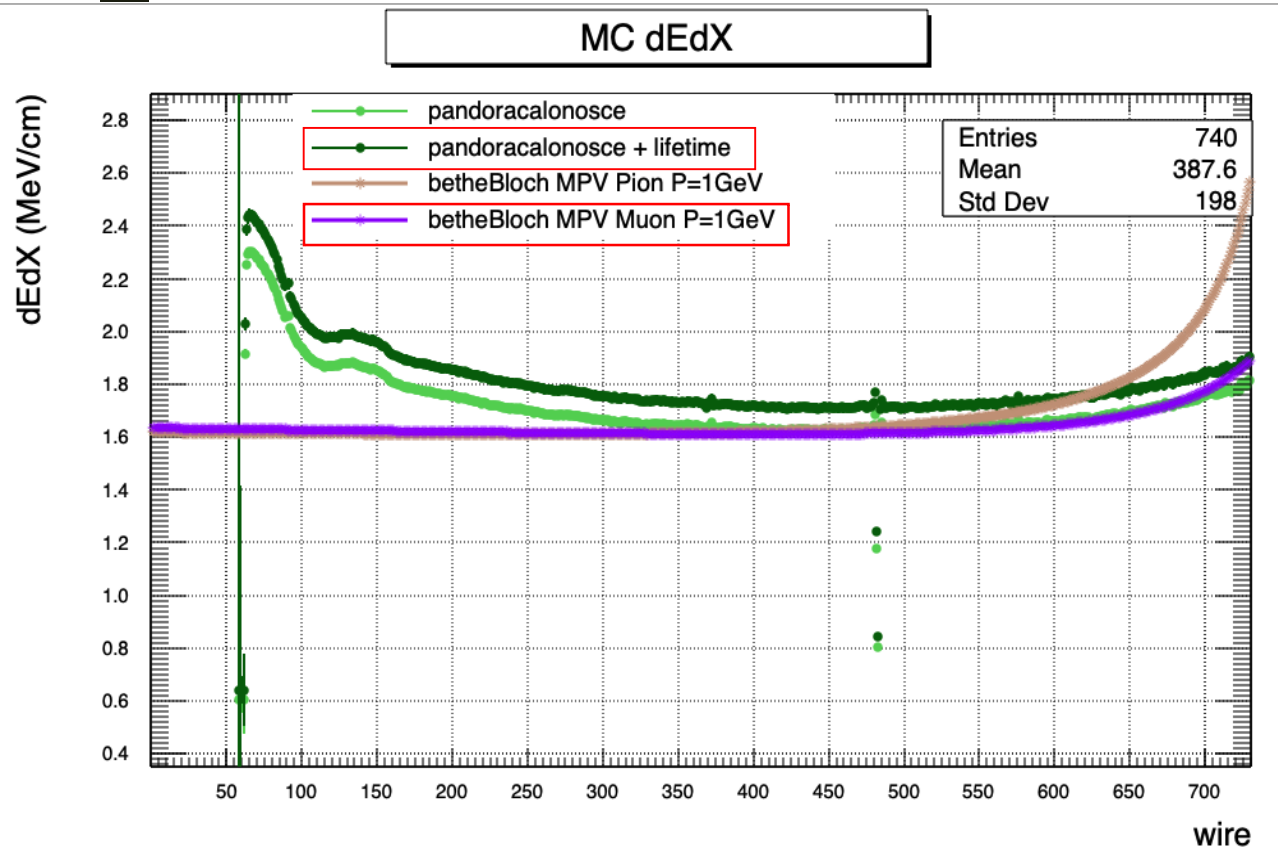


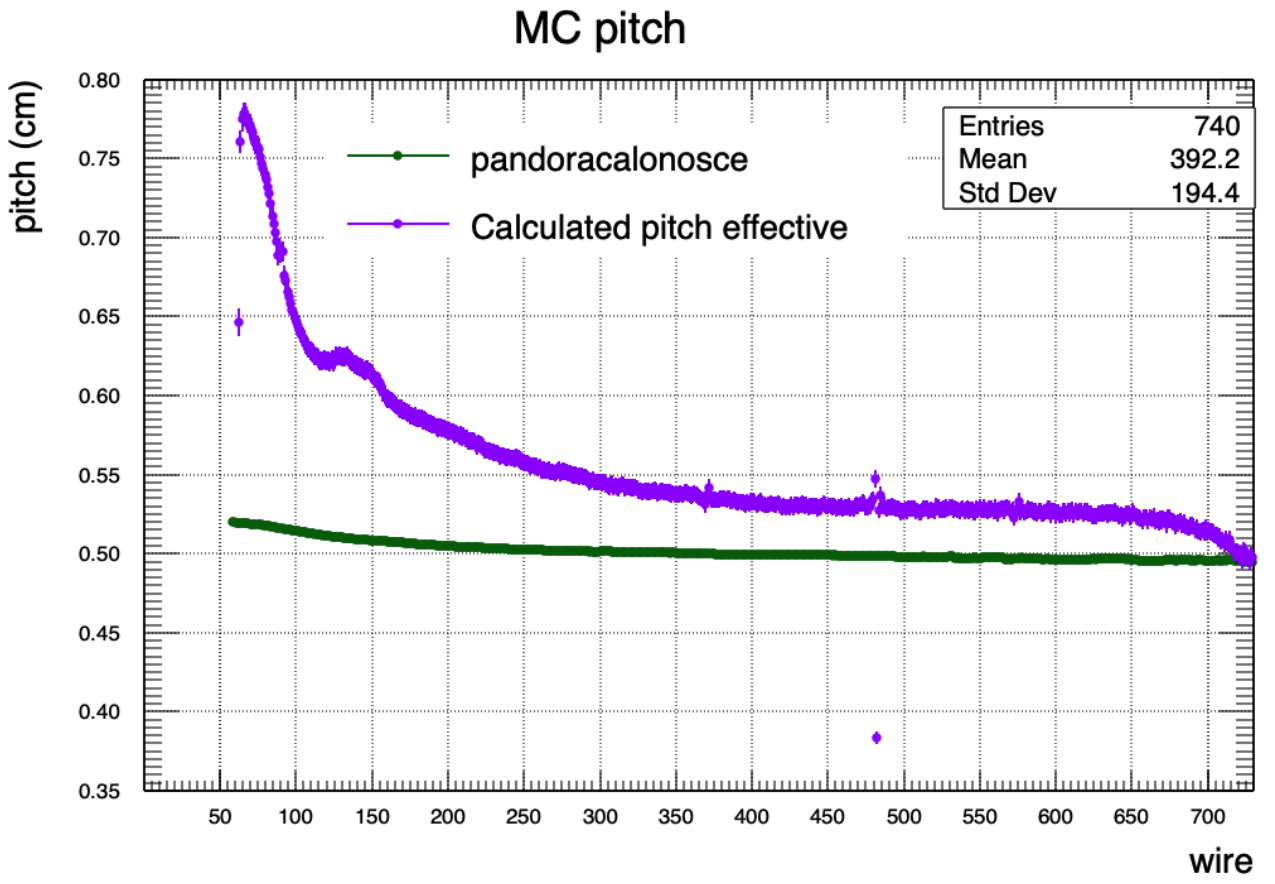


MC dEdx and pitch$_{effective}$ calculation

$$pitch_{effective} = \frac{dEdx_{noSCE+lifetime}}{dEdx_{expected}} pitch_{noSCE}$$

- For the calculation the dEdx from BetheBloch MPV of a 1GeV Muon is used as it matches dEdx better for values beyond wire 500 and is the same as the Pion for the region in APA3





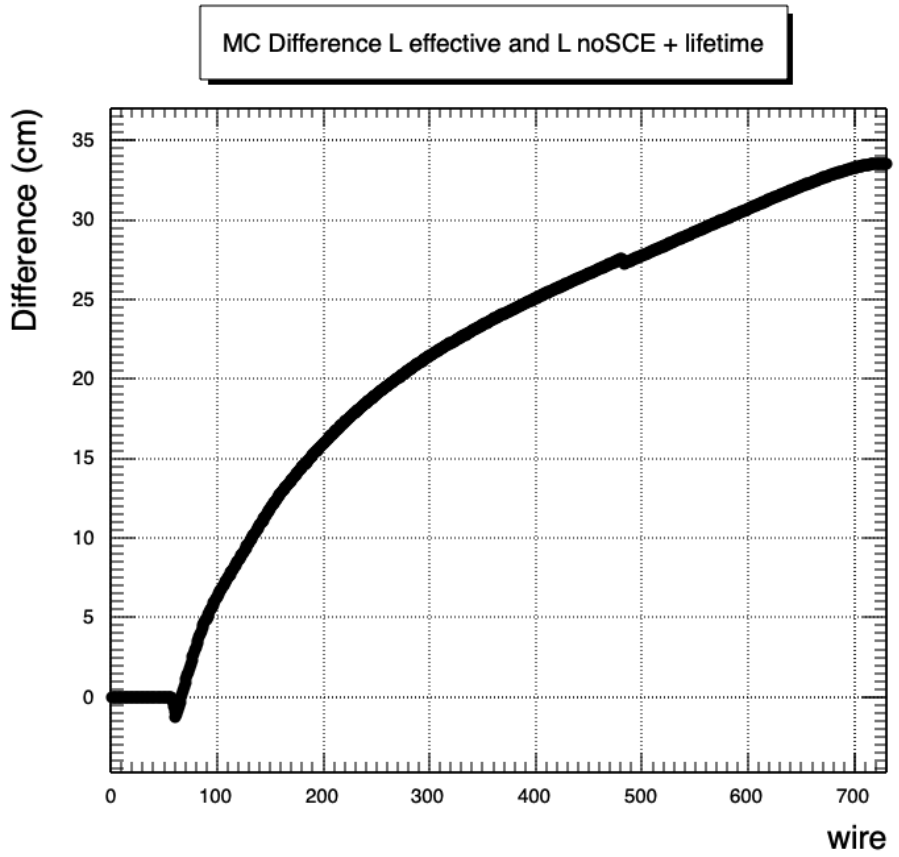
MC Validation with Difference of $L_{effective}$ and $L_{noSCE + lifetime}$

$$L = \sum pitch * \cos\theta$$

$$\Delta L = L_{effective} - L_{noSCE+lifetime}$$

$$= \sum pitch_{effective} * \cos\theta - \sum pitch_{noSCE+lifetime} * \cos\theta$$

$$= 32.5\text{cm}$$

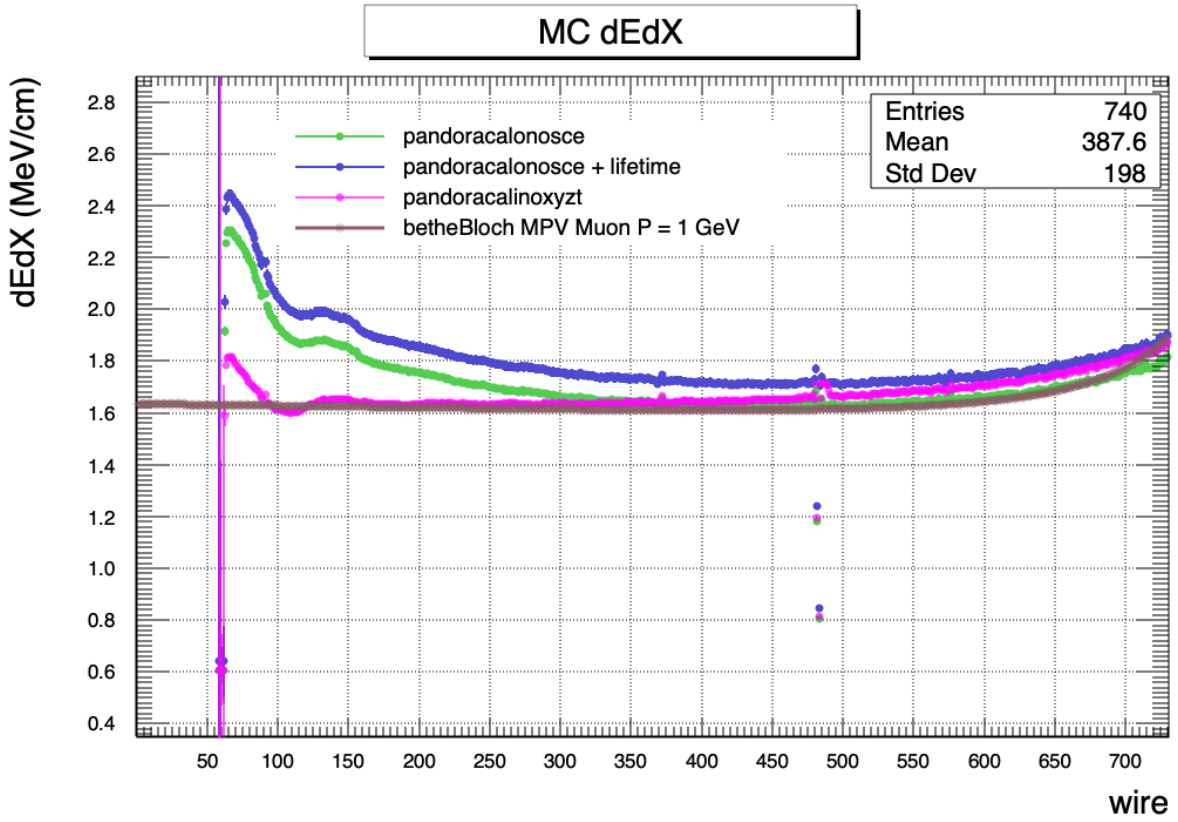


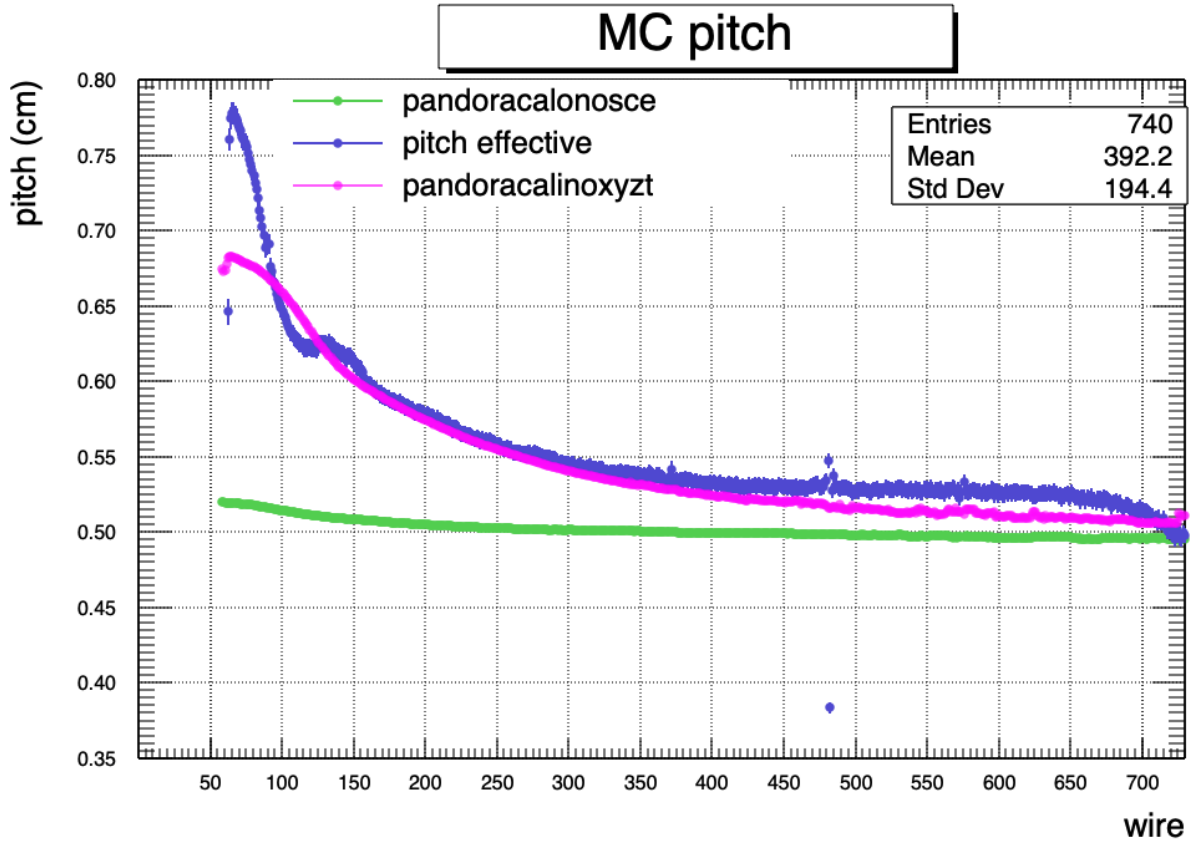
At wire 700
ΔL = 33.3cm ☺

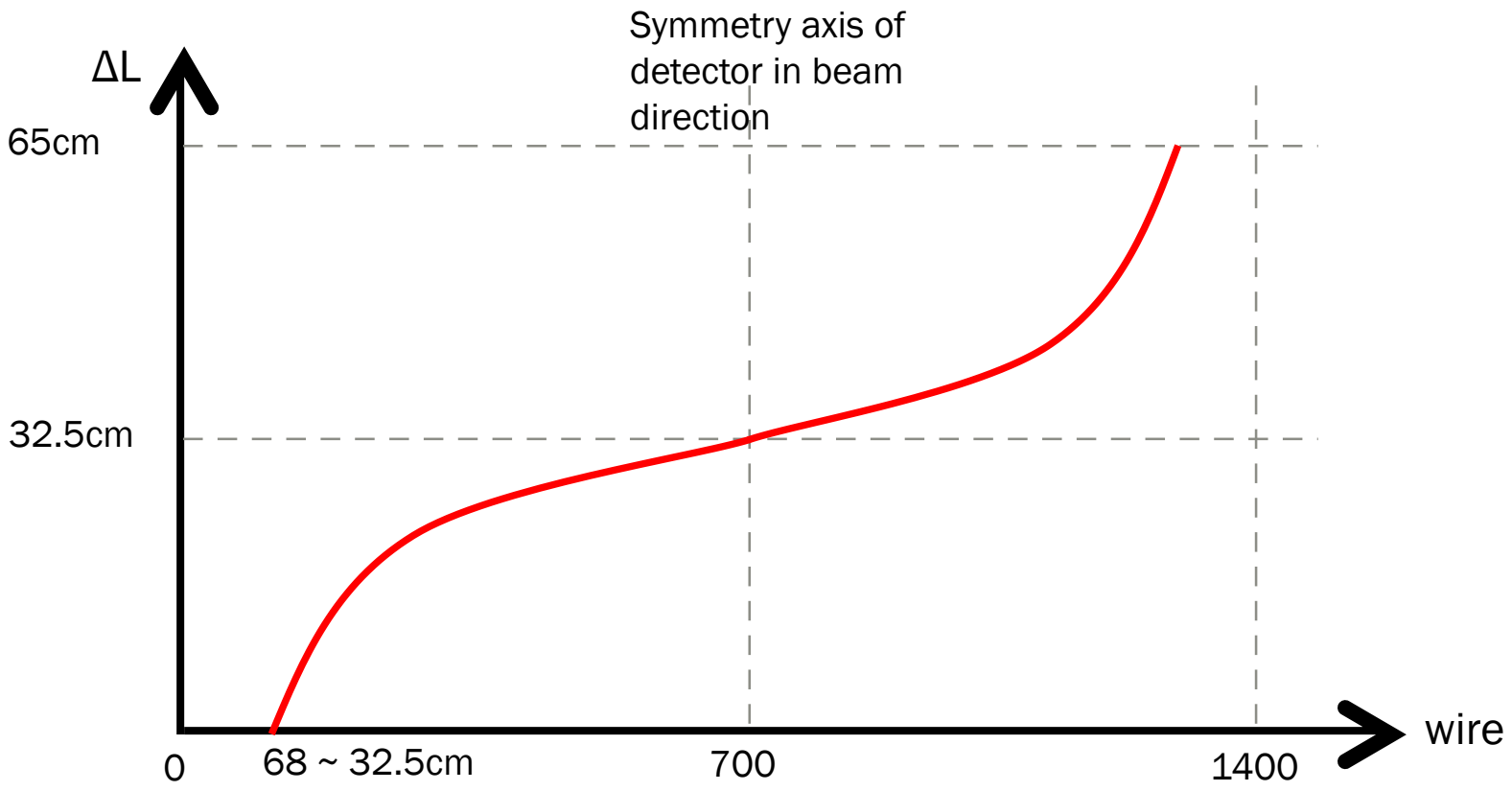
Looks like the method works!!
However effect not flattened out at 700 as we would expect (?)

MC Compare $pitch_{effective}$ to $pitch_{SCE}$ (pandoracalinoxyzt)

- We can compare the SCE correction to the calculated pitch with the method
- Inexplicable behavior for dEdx in wire 100-200 (not visible in DATA)






Symmetry axis of
detector in beam
direction
ΔL
65cm
32.5cm
0
68 ~ 32.5cm
700
1400
wire