

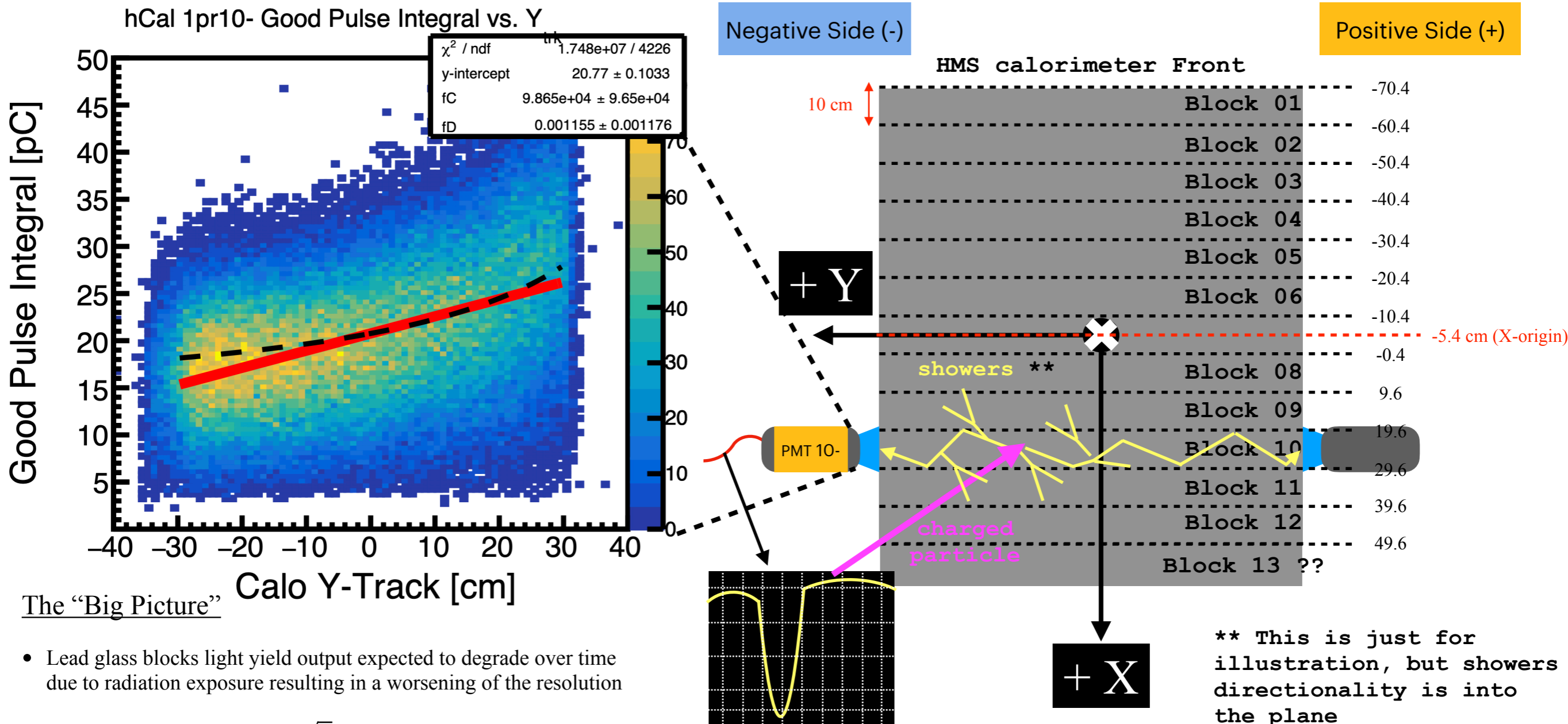
Fit Residuals

2nd Supplemental Plots for 1st Generation of Fit Studies
(using electrons)

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May 13, 2021

HMS Calorimeter Coordinate Definition / Overview of this Study (The “Big Picture”)



The “Big Picture”

- Lead glass blocks light yield output expected to degrade over time due to radiation exposure resulting in a worsening of the resolution
 - Expected resolution : $\sim 5\% / \sqrt{E}$ obtained from width of gaussian fit to e- peak over various experiments
 - Main drivers for resolution: # of p.e. collected, non-uniformities in lead glass, small dead layers between blocks, etc.
 - HCANA has hard-coded (per layer) parameters applied as a Y-coordinate correction factor (Ycor) to the total track energy
- Questions:**
1. How well does HCANA fit works on recent (12 GeV era) data ?
 2. How well does HCANA fit to data compare to our fit using (per pmt) optimized parameters ?
 3. Are the difference observed between HCANA and our fits significant enough to apply a PMT-basis correction ?
 4. By how much would a PMT-basis correction improve the resolution?
- We have focused on fitting only the Layers A and B (2-sided PMTs). We are currently working on Layers C and D (1-sided PMTs)

Original FIT Function

A : Vertical Offset
 C, D : Additional Parameters
 y : Y-Track Position [cm]

Fit Function:
(Norm. Light Yield)

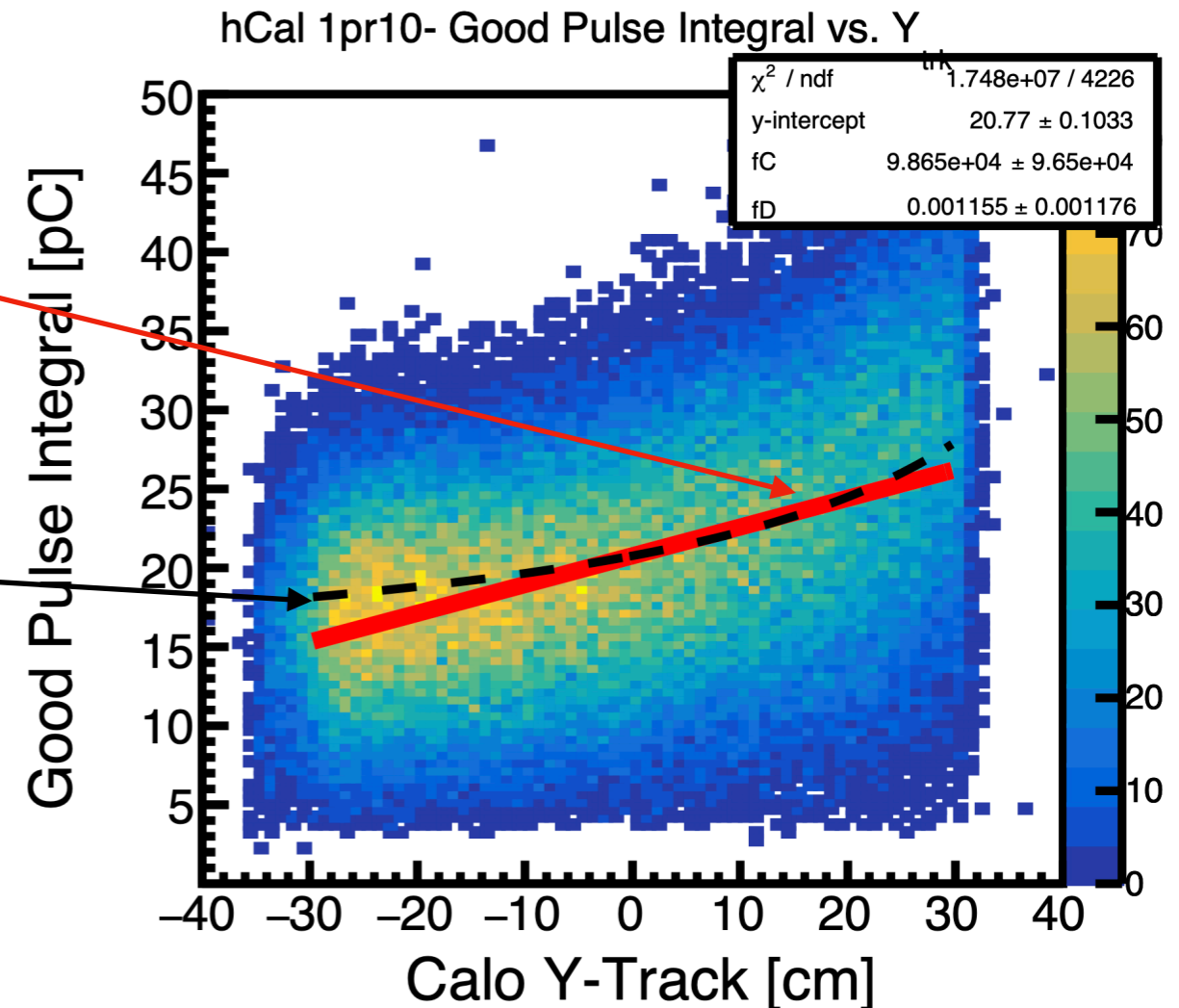
$$f = A \cdot \frac{C \pm y/D}{C \pm y}$$

Data Fit:

- An initial guess of the fit parameters is made: $A = 15$ pC, $C = 64.36$ cm, $D = 1.66$
- The initial guess of C & D is EXACTLY the current parameters hardcoded in HCANA

HCANA "Model":

- Uses the inverse of the Fit Function (above) with hardcoded parameters: $C = 64.36$ cm, $D = 1.66$
- For the offset parameter, I used the final offset determined from the **Data Fit**



The **Data Fit** uses the hardcoded parameters as an initial guess, and the ROOT Minuit Algorithm determines the “best” set of parameters to describe the 2D correlation. The same Fit Function used in HCANA is also plotted to make a comparison.

NEW FIT Function

Fit Function:
(Norm. Yield)

$$f = A \cdot \frac{1 \pm y/E}{1 \pm y/C}$$

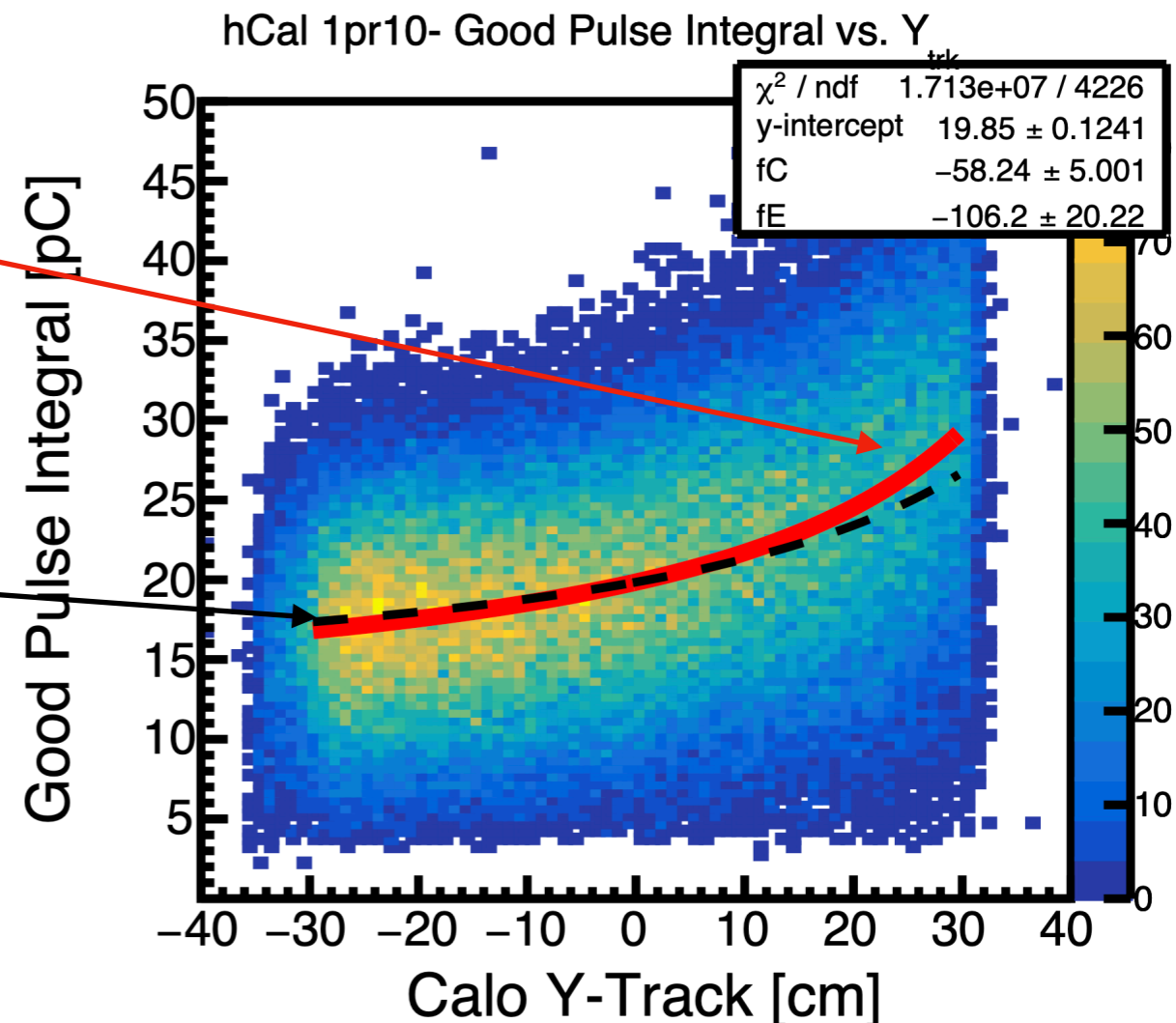
A : Vertical Offset
 C, E : Additional Parameters
 y : Y-Track Position [cm]

Data Fit:

- An initial guess of the fit parameters is made: $A = 15$ pC, $C = 64.36$ cm, $E = 106.83$ cm
- The initial guess of C is EXACTLY the current parameters hardcoded in HCANA
And $E = CD$ (product of two hardcoded HCANA params)

HCANA "Model":

- Used the Fit Function (see above) with hardcoded parameters: $C = 64.36$ cm, $E = 106.83$ cm
- For the offset parameter, I used the final offset determined from the **Data Fit**

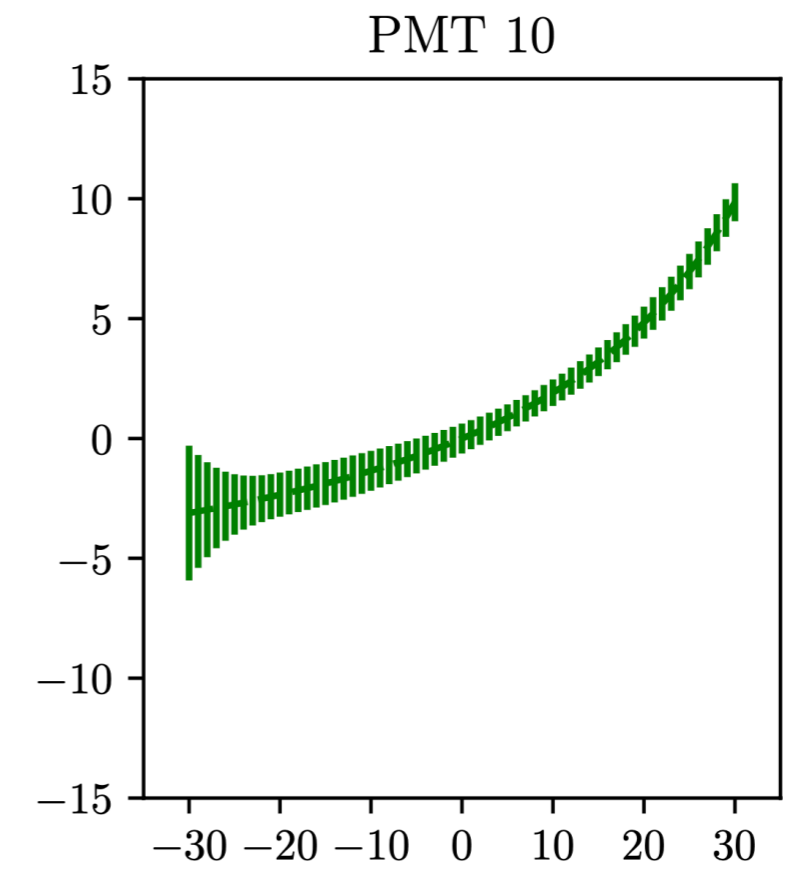
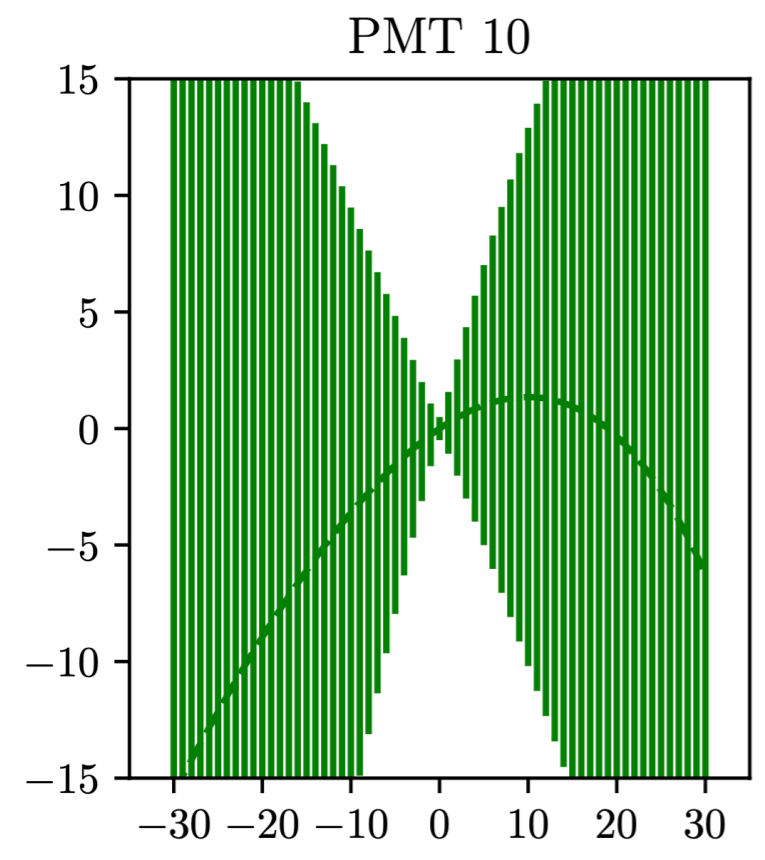
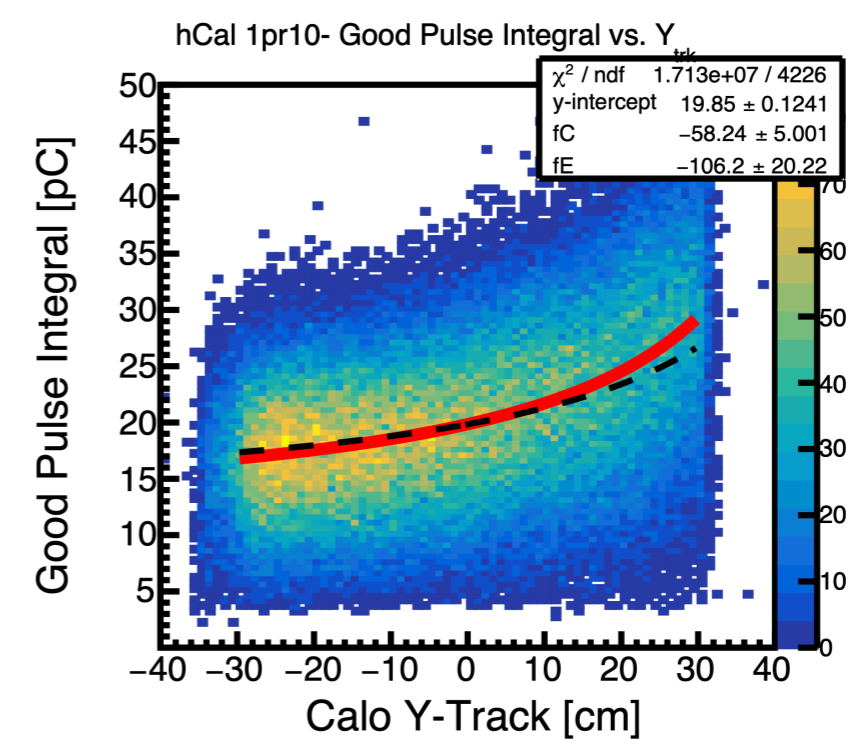
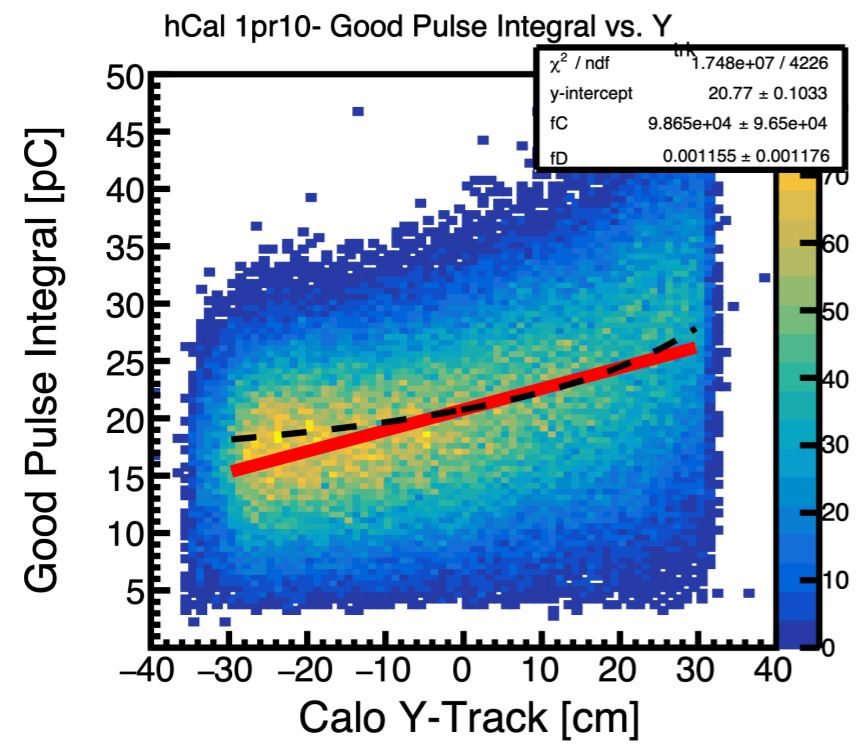


The **Data Fit** uses the hardcoded parameters as an initial guess, and the ROOT Minuit Algorithm determines the "best" set of parameters to describe the 2D correlation. The same Fit Function used in HCANA is also plotted to make a comparison.

$$f = A \cdot \frac{C \pm y/D}{C \pm y}$$

Fit Function Comparison:
(Showing Improvements)

$$f = A \cdot \frac{1 \pm y/E}{1 \pm y/C}$$



Residuals: Original FIT Function

$$R = \frac{f_{\text{dataFit}} - f_{\text{HCANA}}}{f_{\text{HCANA}}}$$

$$\delta R = \frac{\delta f_{\text{dataFit}}}{f_{\text{HCANA}}}$$

$$f_{\text{dataFit}} = A \cdot \frac{C \pm y/D}{C \pm y}$$

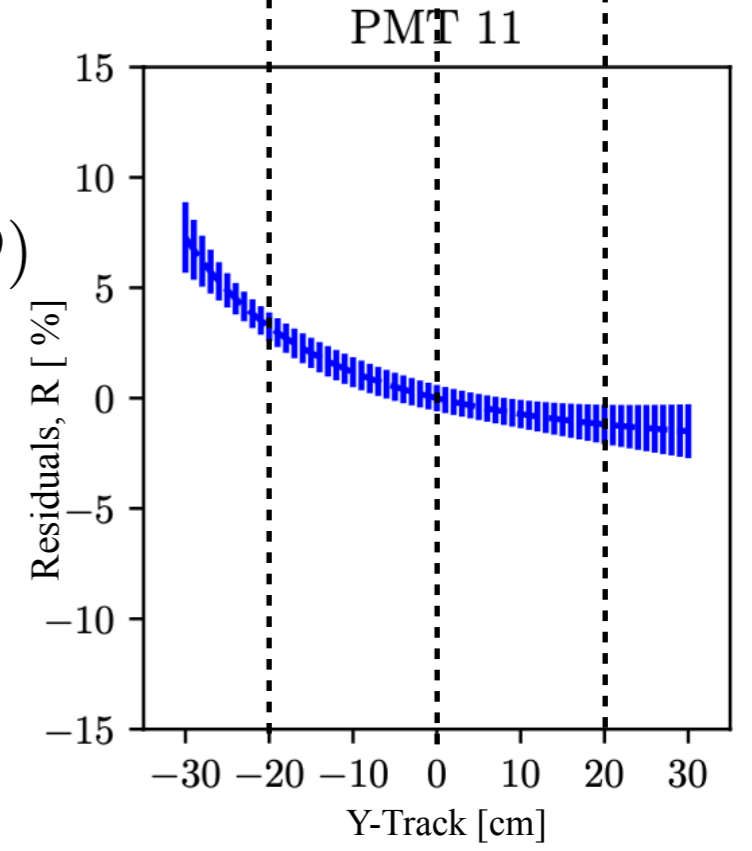
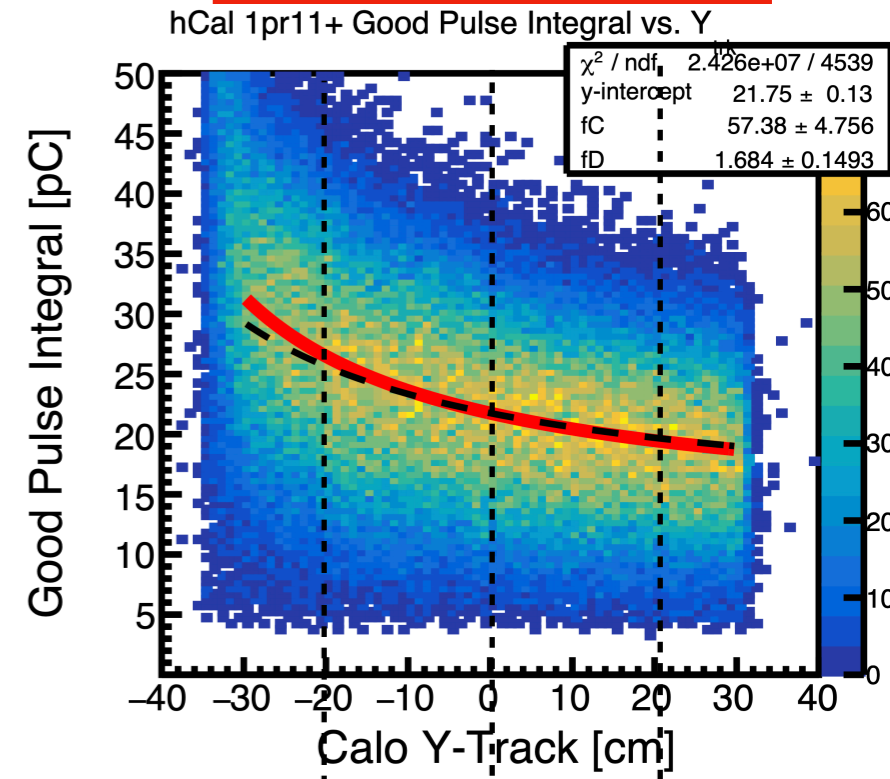
$$\delta f_{\text{dataFit}}^2 = \left(\frac{\partial f}{\partial A}\right)^2 \delta A^2 + \left(\frac{\partial f}{\partial C}\right)^2 \delta C^2 + \left(\frac{\partial f}{\partial D}\right)^2 \delta D^2 + 2 \frac{\partial^2 f}{\partial A \partial C} \text{cov}(A, C) + 2 \frac{\partial^2 f}{\partial A \partial D} \text{cov}(A, D) + 2 \frac{\partial^2 f}{\partial C \partial D} \text{cov}(C, D)$$

$$\left(\frac{\partial f}{\partial A}\right) = \frac{C + y/D}{C + y} \quad \left(\frac{\partial f}{\partial C}\right) = A \left(\frac{y(1 - 1/D)}{(C + y)^2}\right) \quad \left(\frac{\partial f}{\partial D}\right) = -\frac{Ay}{D^2(C + y)}$$

Standard Error Propagation of the Data Fit (errors in fit parameters are used)

NOTE: I dropped the subscript 'dataFit' for simplicity

Example: Layer 1pr, PMT 11+



Interpretation: In this example, there is up to ~ 7.5 % difference between our studies and HCANA on the lower one end of the block at ~ -30 cm

Residuals: NEW FIT Function

$$R = \frac{f_{\text{dataFit}} - f_{\text{HCANA}}}{f_{\text{HCANA}}}$$

$$\delta R = \frac{\delta f_{\text{dataFit}}}{f_{\text{HCANA}}}$$

$$f_{\text{dataFit}} = A \cdot \frac{1 \pm y/E}{1 \pm y/C}$$

$$\delta f_{\text{dataFit}}^2 = \left(\frac{\partial f}{\partial A} \right)^2 \delta A^2 + \left(\frac{\partial f}{\partial C} \right)^2 \delta C^2 + \left(\frac{\partial f}{\partial E} \right)^2 \delta E^2$$

$$+ 2 \frac{\partial^2 f}{\partial A \partial C} \text{cov}(A, C) + 2 \frac{\partial^2 f}{\partial A \partial E} \text{cov}(A, E) + 2 \frac{\partial^2 f}{\partial C \partial E} \text{cov}(C, E)$$

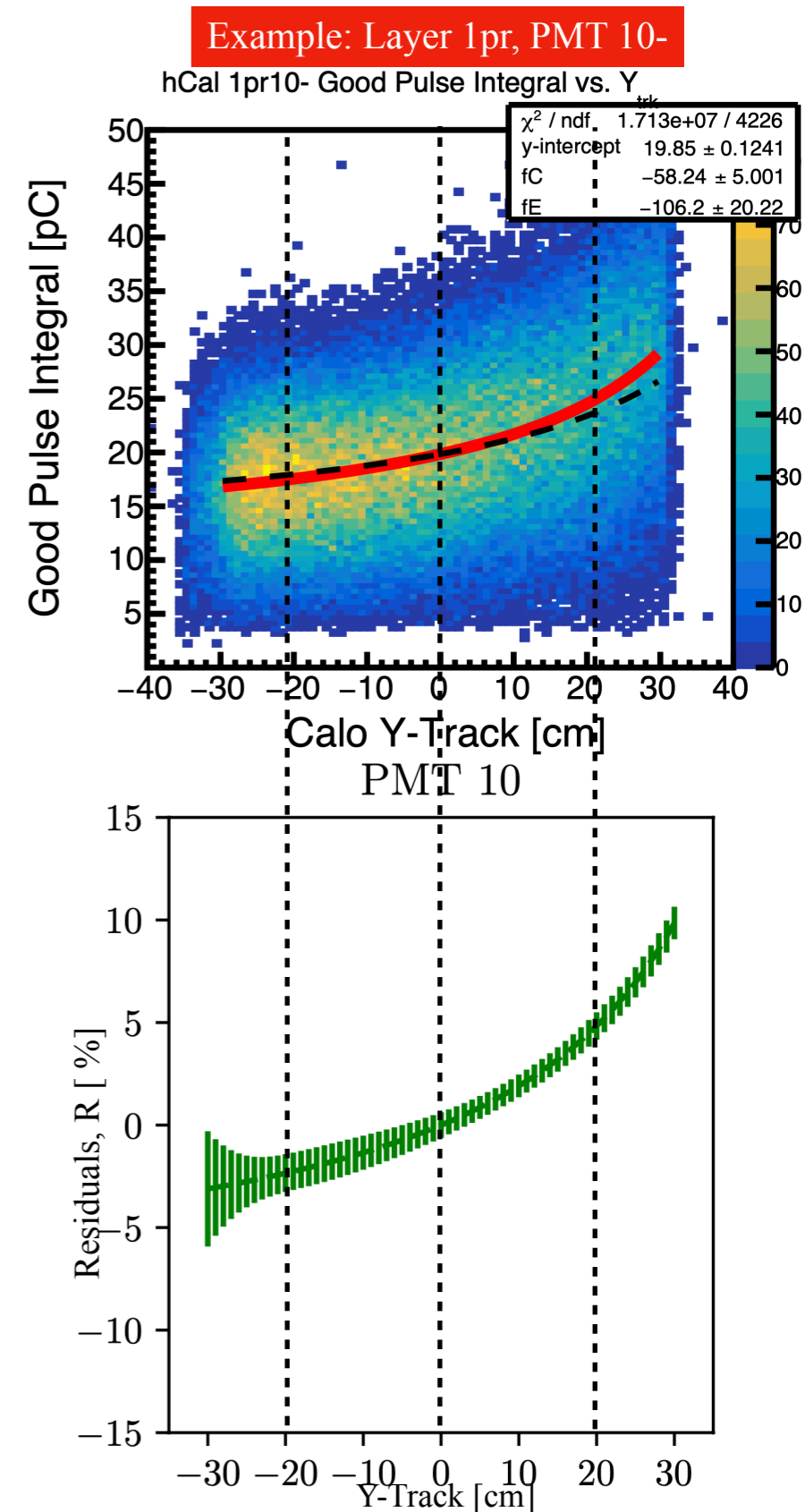
$$\left(\frac{\partial f}{\partial A} \right) = \frac{1 \pm y/E}{1 \pm y/C}$$

$$\left(\frac{\partial f}{\partial C} \right) = \pm A \cdot \frac{(1 \pm y/E)(y/C^2)}{(1 \pm y/C)^2}$$

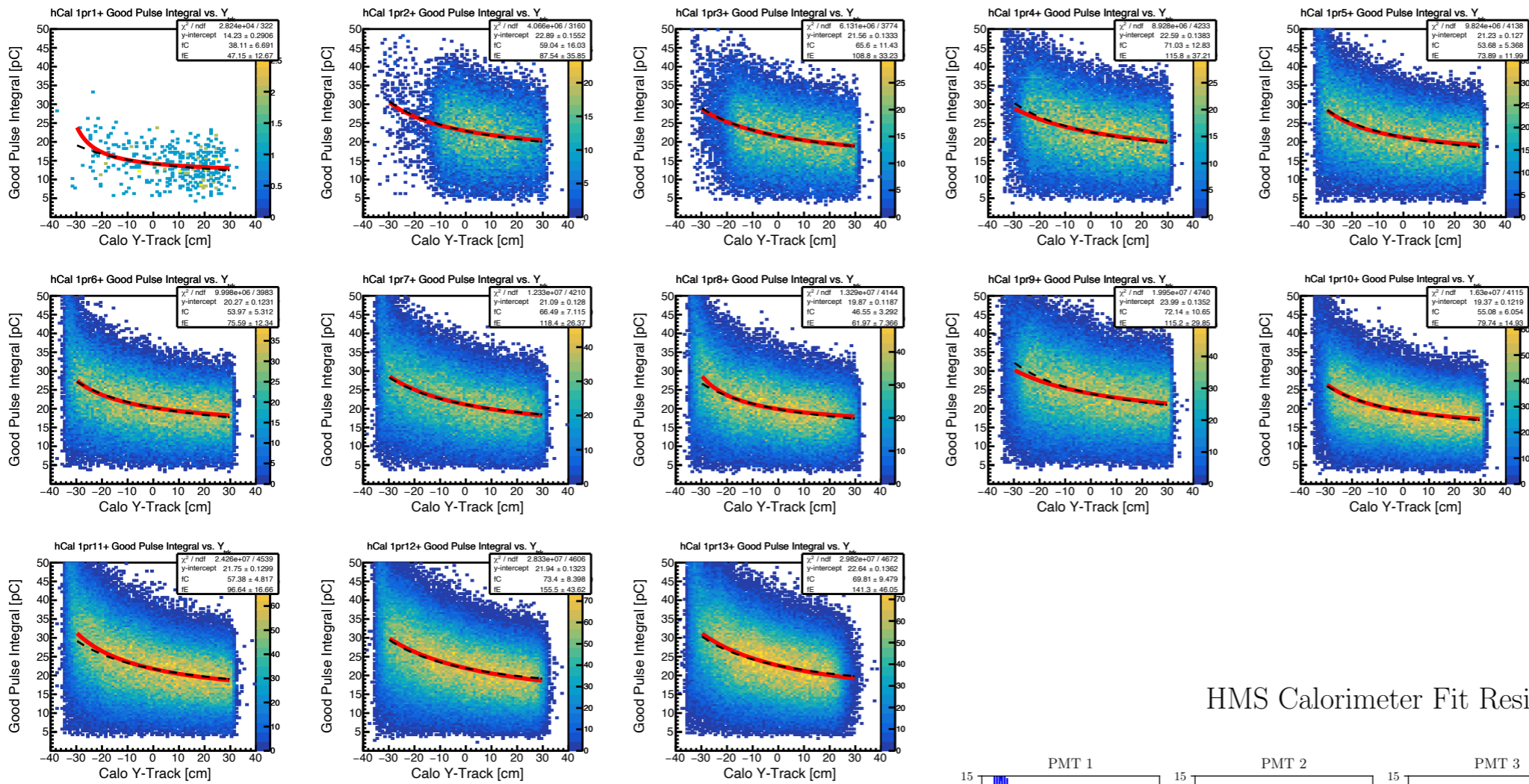
$$\left(\frac{\partial f}{\partial E} \right) = \pm A \cdot \frac{-y/E^2}{1 \pm y/C}$$

Standard Error Propagation of the Data Fit
(errors in fit parameters are used)

NOTE: I dropped the subscript 'dataFit'
for simplicity



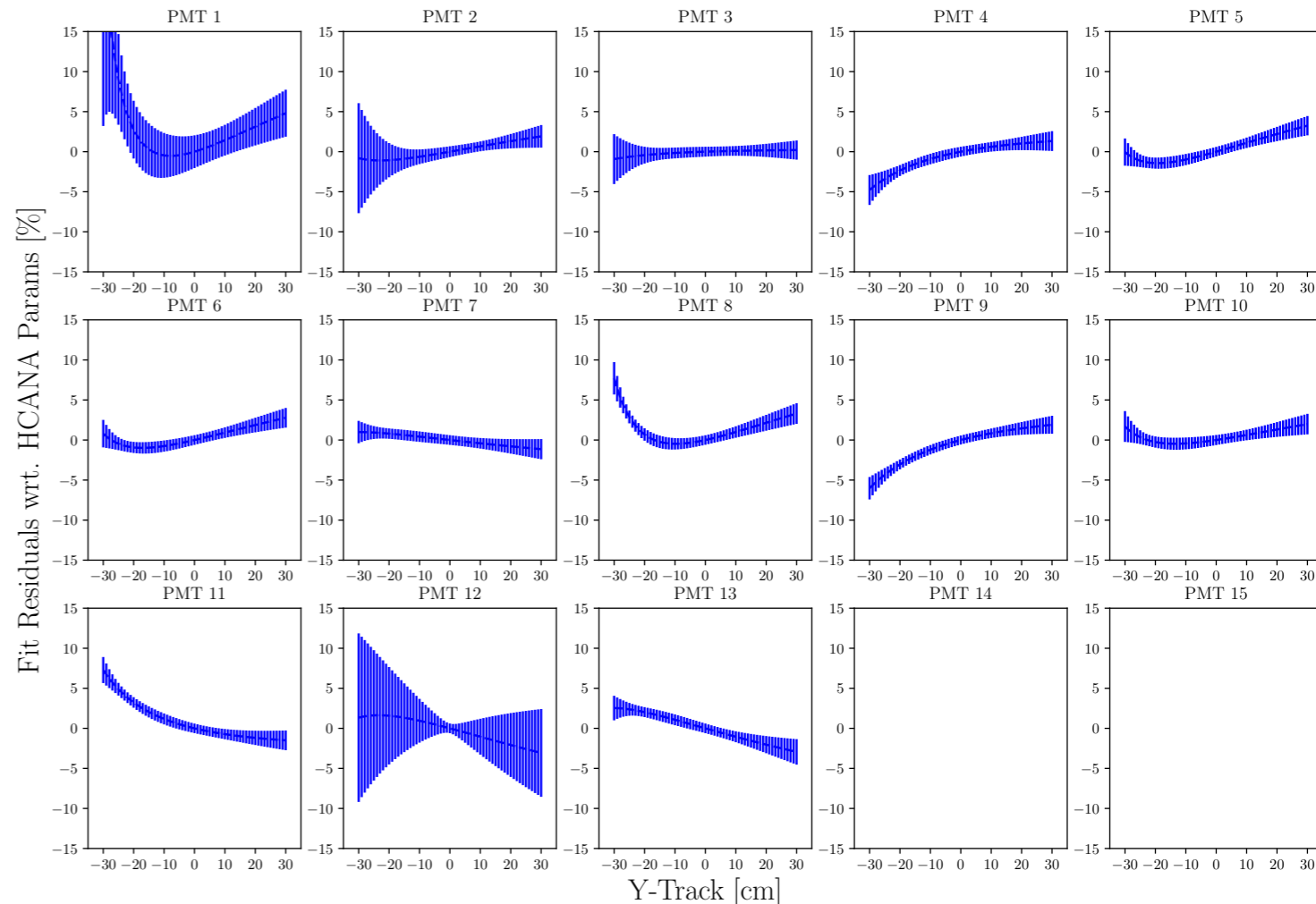
Interpretation: In this example, there is up to
~ 10 % difference between our studies and HCANA
on the upper end of the block at ~ +30 cm

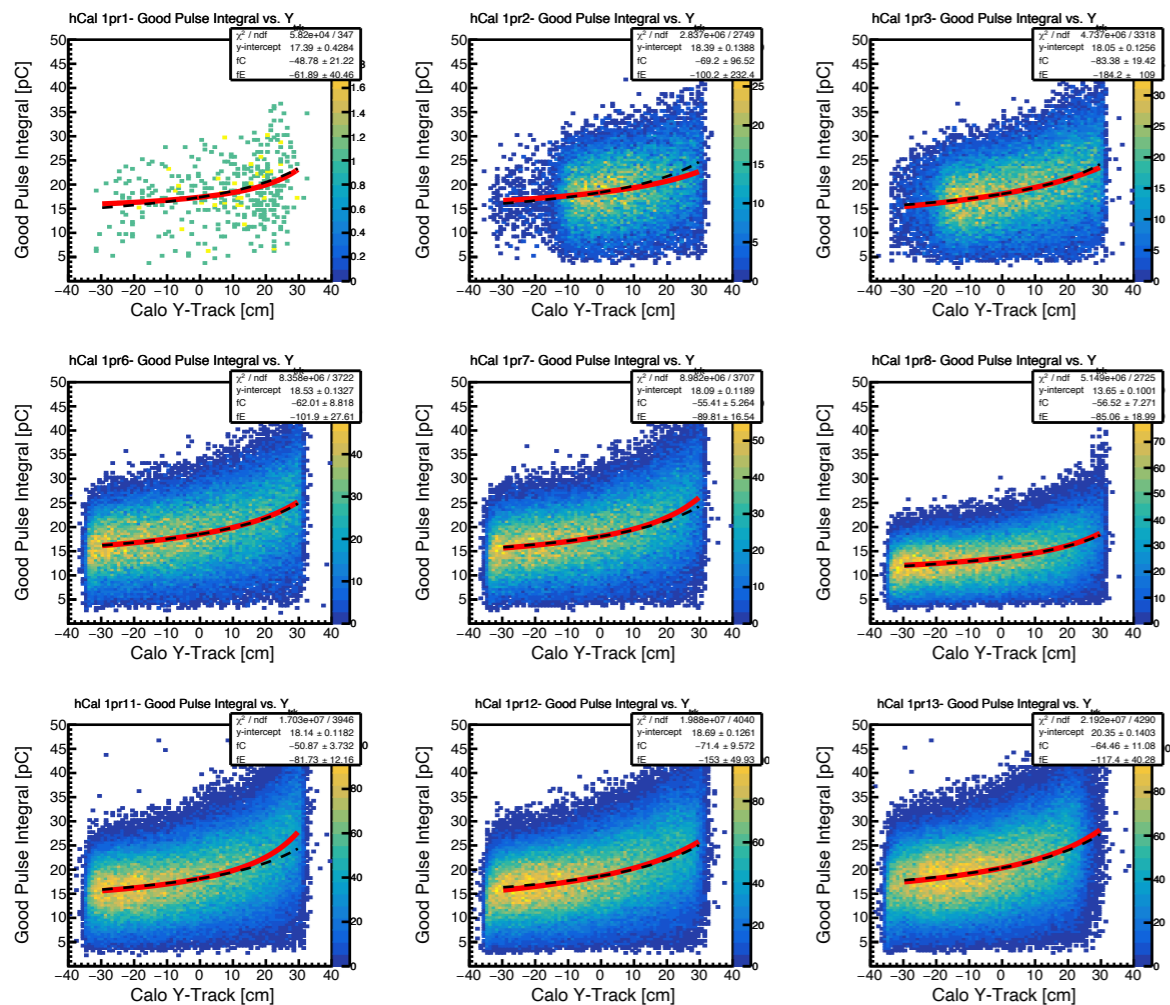


HMS Calorimeter Fit Residuals: Layer 1pr+

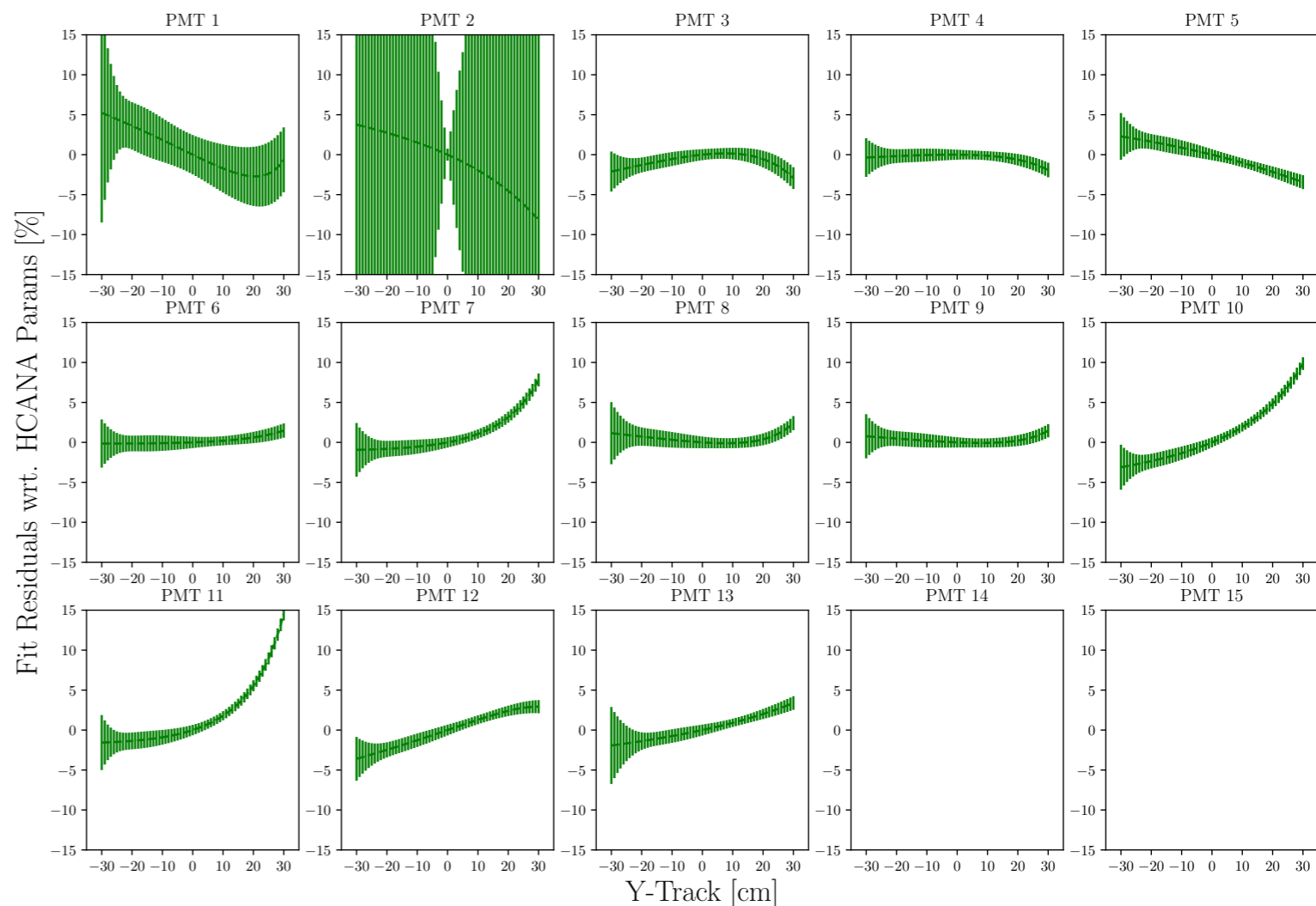
Layer 1pr +

- Correlated errors are included
- X-axis range set to (-35, 35) cm
- Y-axis range set to (-15, 15) %





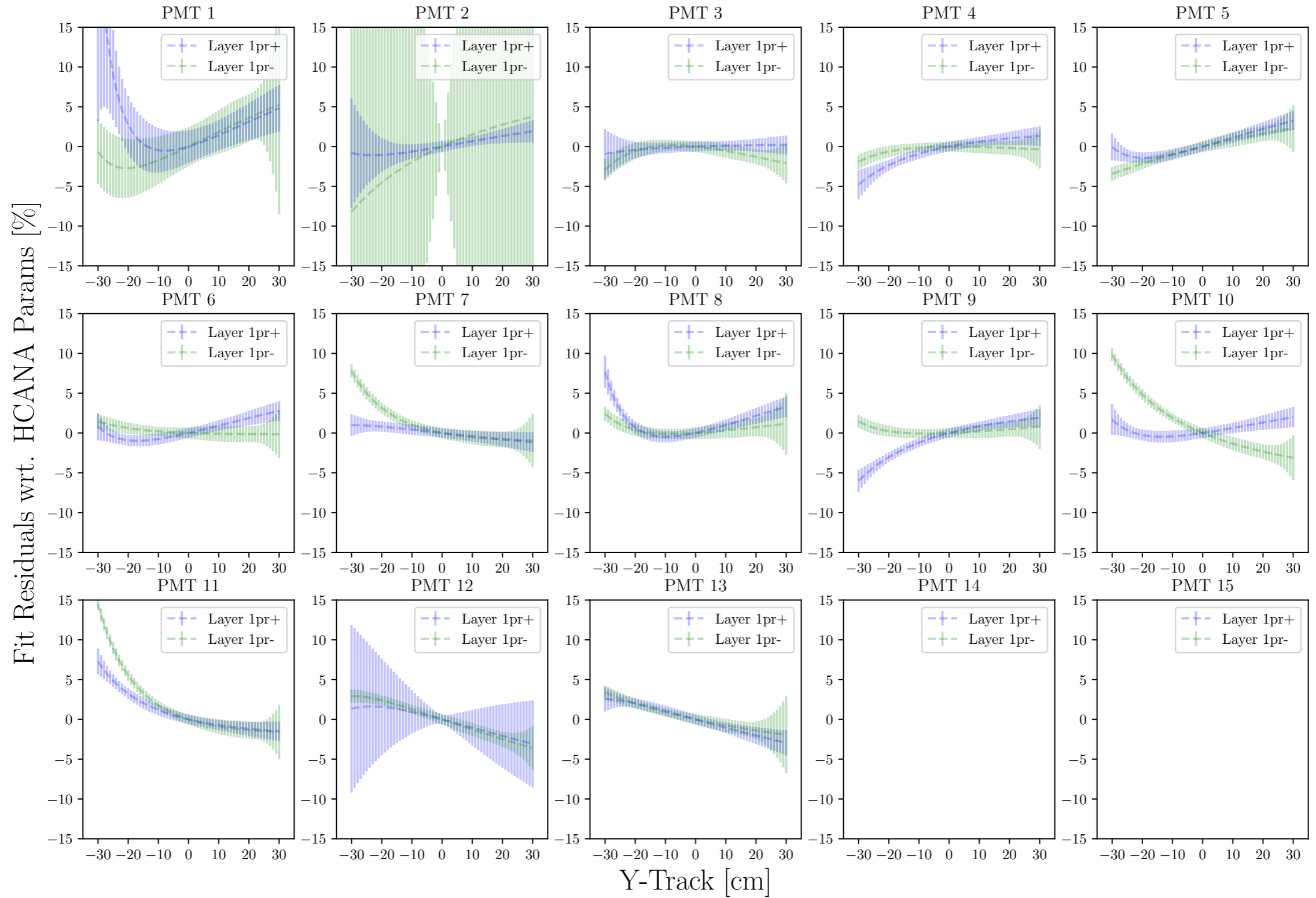
HMS Calorimeter Fit Residuals: Layer 1pr-



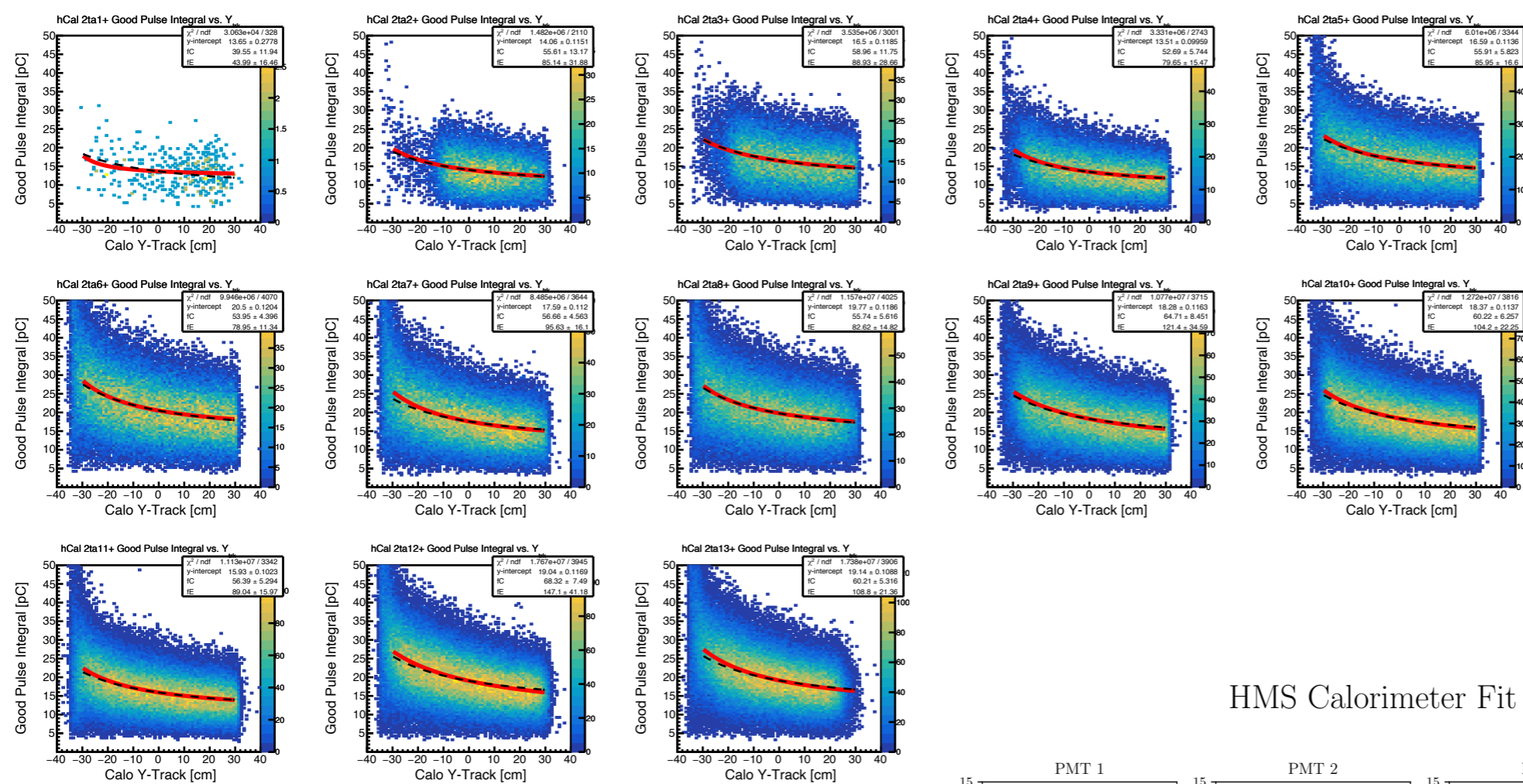
Layer 1pr -

- Correlated errors are included
- X-axis range set to (-35, 35) cm
- Y-axis range set to (-15, 15) %

HMS Calorimeter Fit Residuals Overlay: Layer 1pr



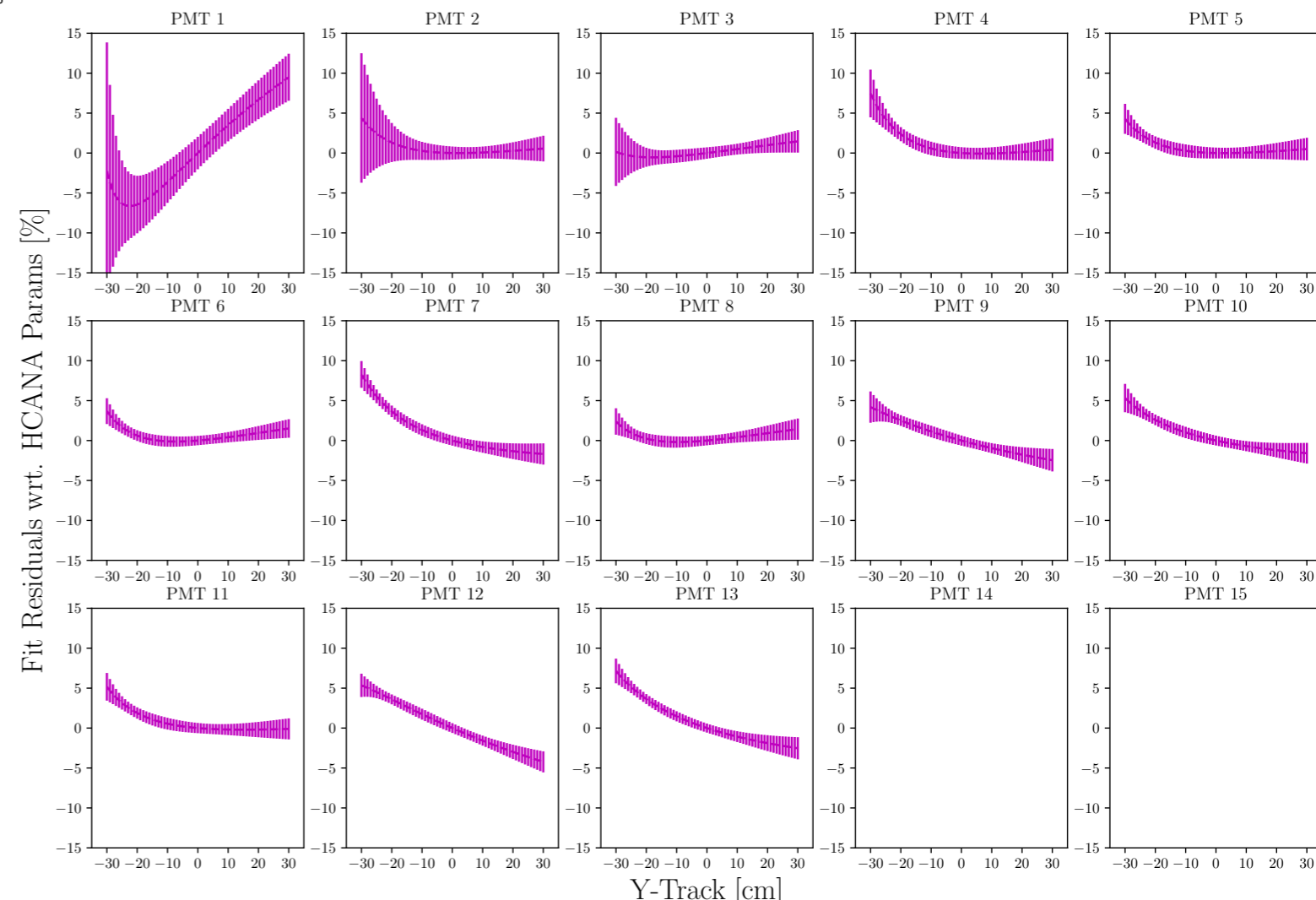
- Fit Residuals for Layer 1pr- have been reversed wrt. x-axis for a direct comparison of between both sides of the layer

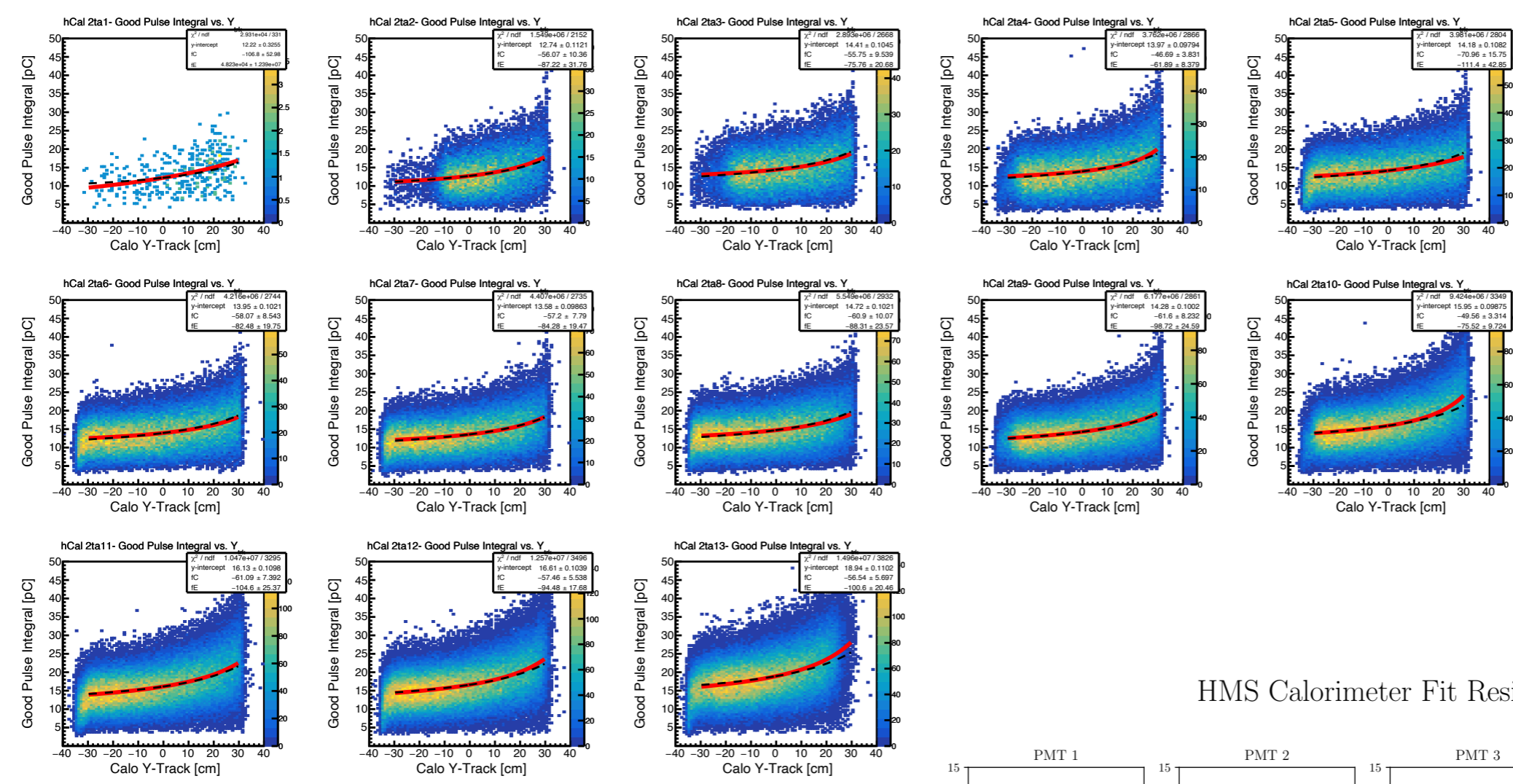


HMS Calorimeter Fit Residuals: Layer 2ta+

Layer 2ta+

- Correlated errors are included
- X-axis range set to (-35, 35) cm
- Y-axis range set to (-15, 15) %

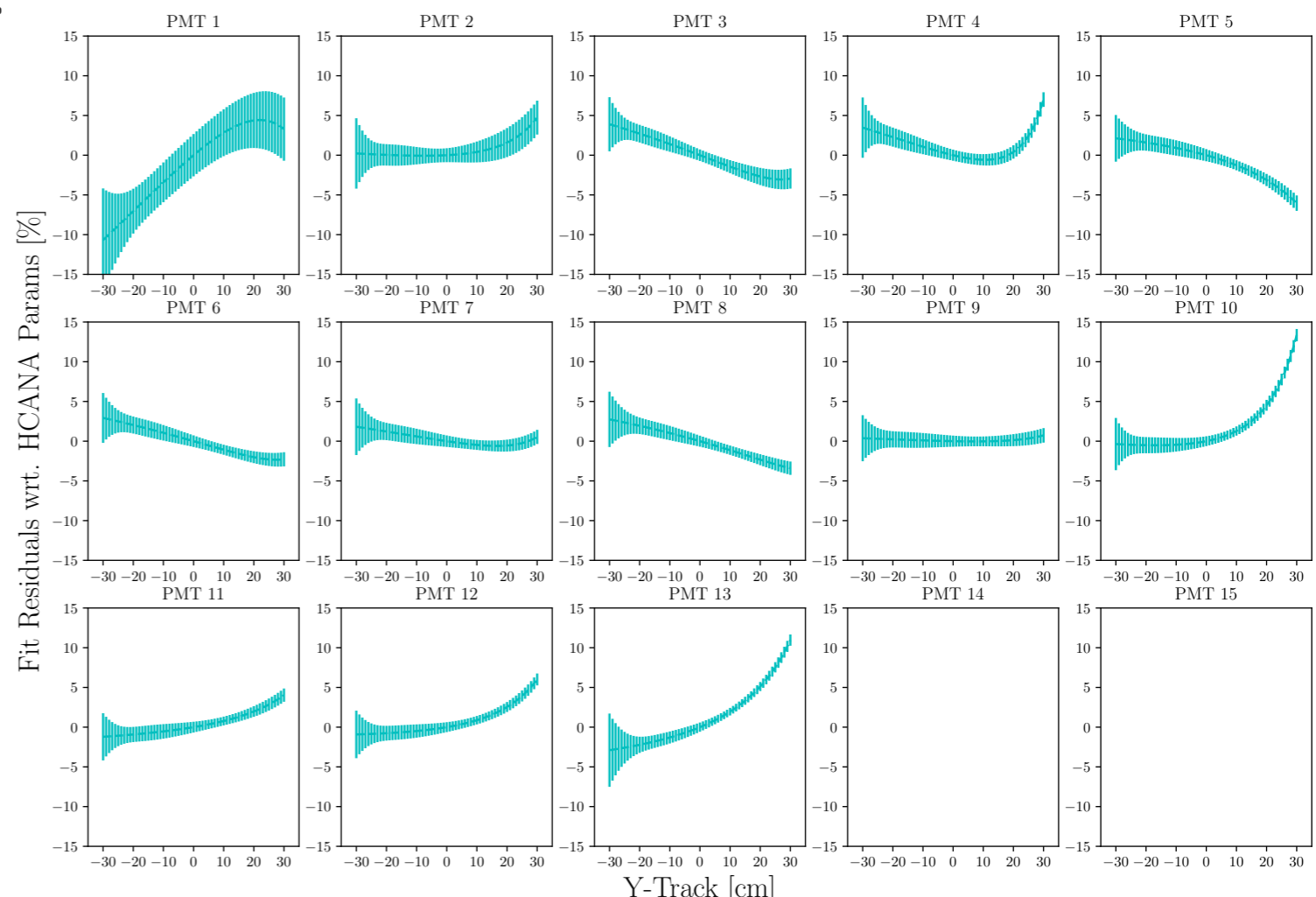




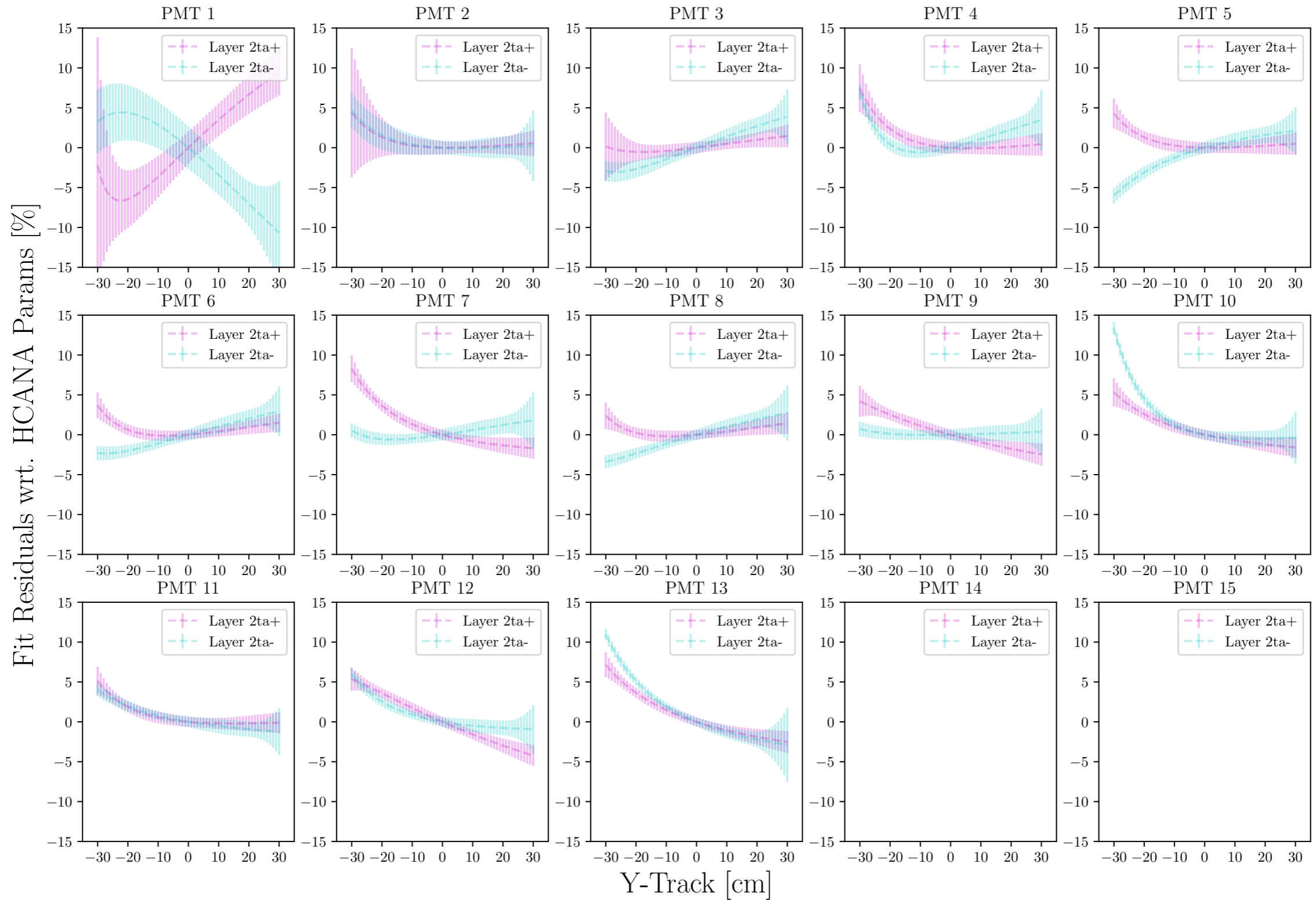
HMS Calorimeter Fit Residuals: Layer 2ta-

Layer 2ta-

- Correlated errors are included
- X-axis range set to (-35, 35) cm
- Y-axis range set to (-15, 15) %



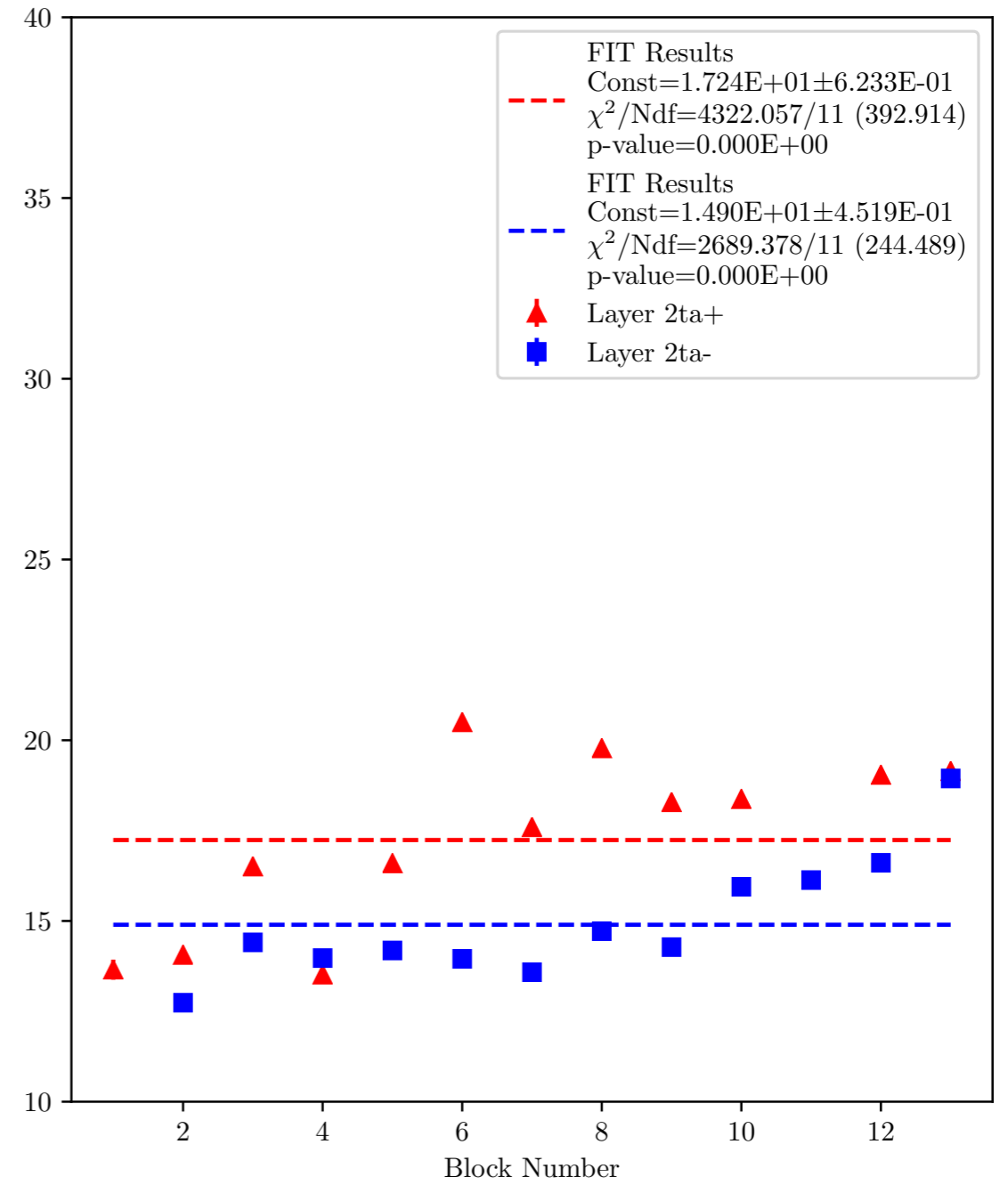
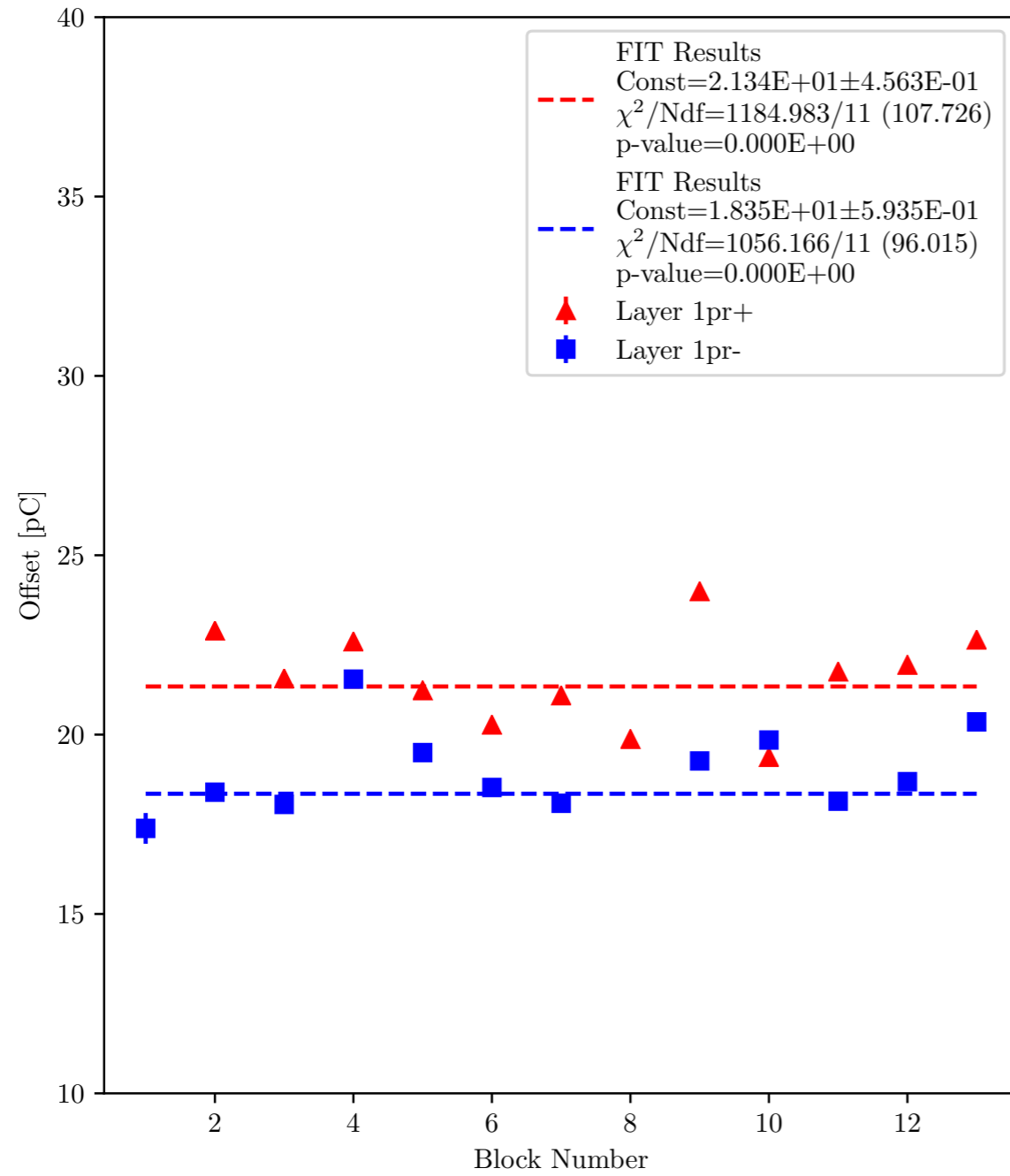
HMS Calorimeter Fit Residuals Overlay: Layer 2ta



- Fit Residuals for Layer 2ta- have been reversed wrt. x-axis for a direct comparison of between both sides of the layer

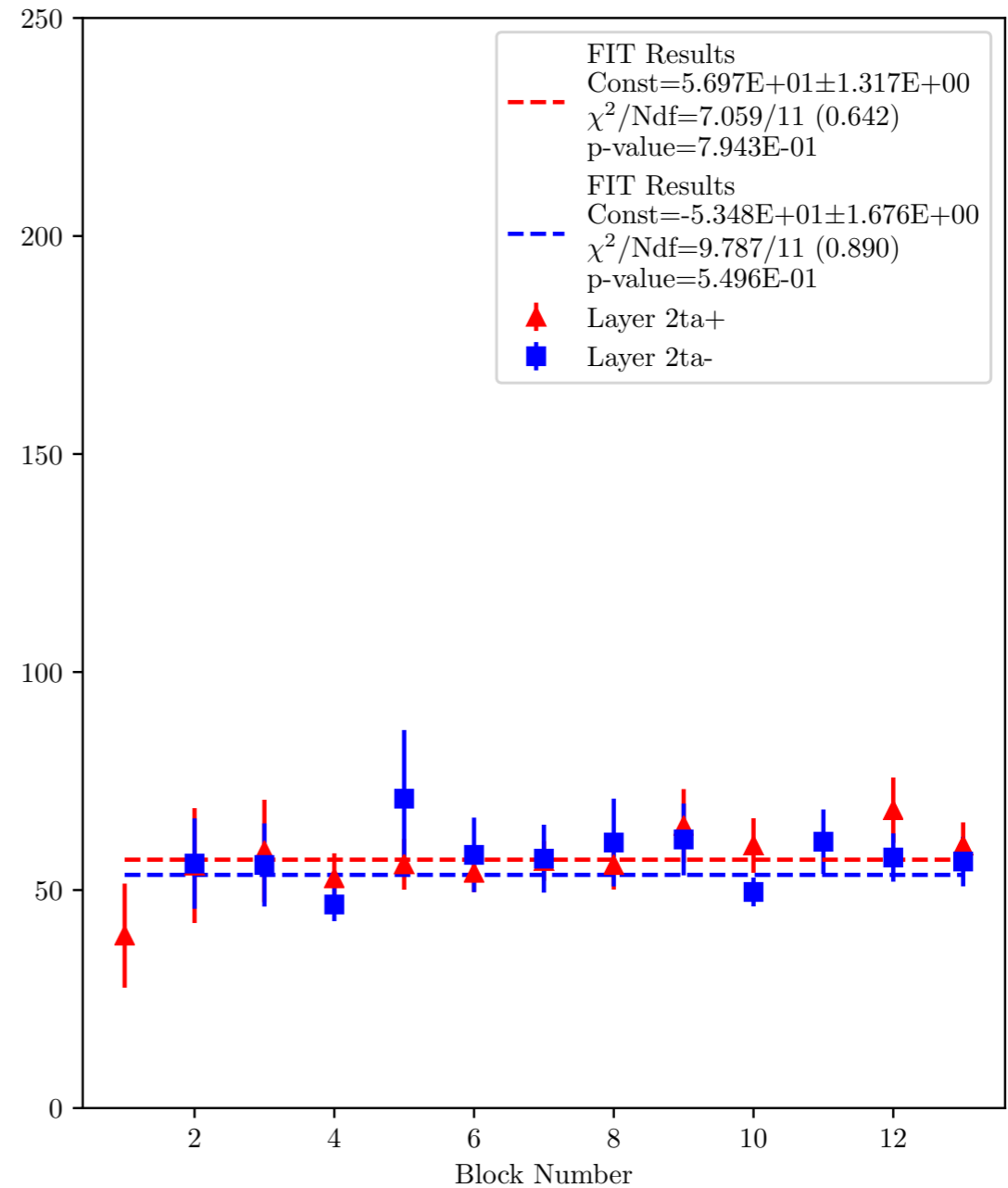
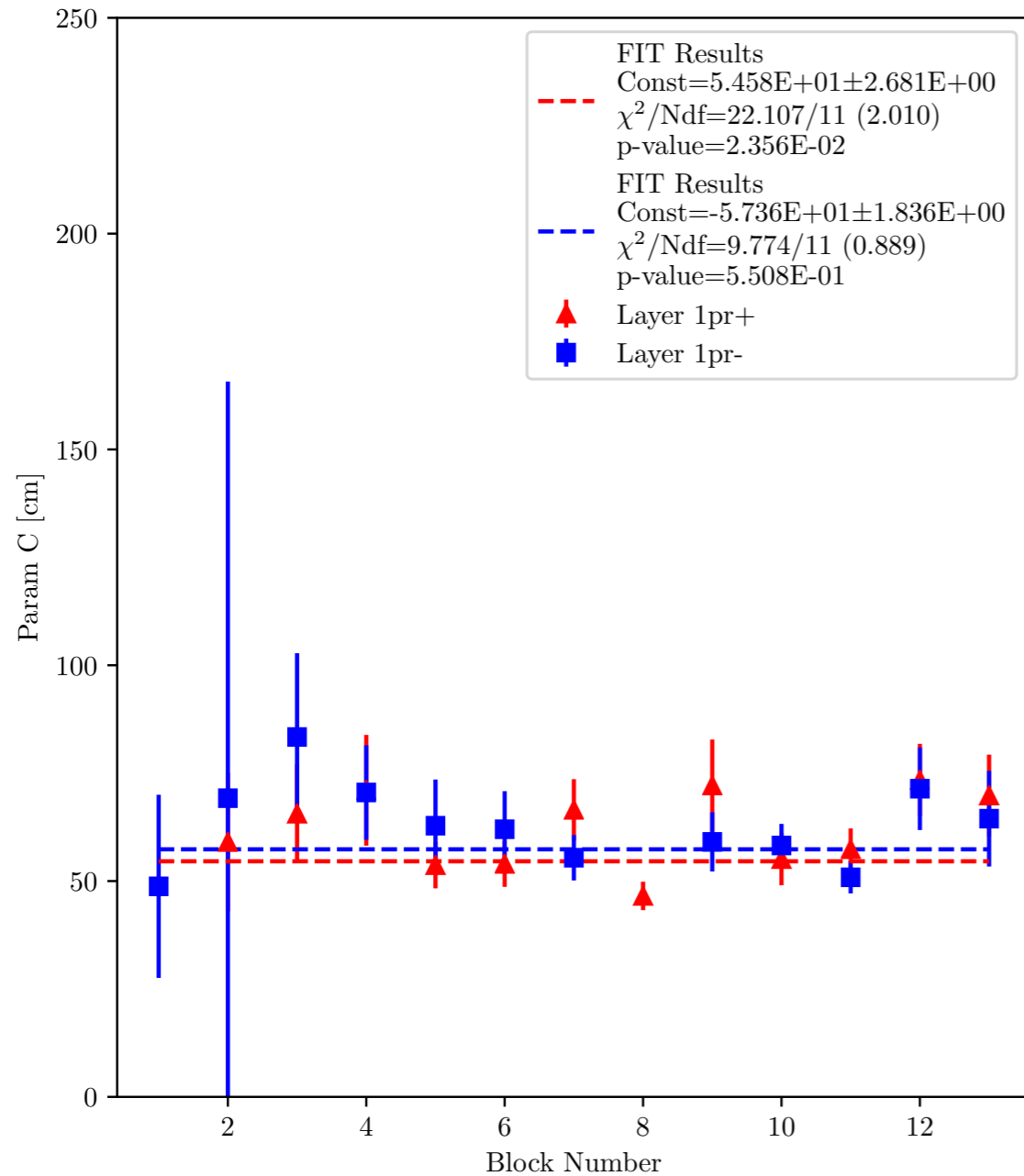
BACK-UP SLIDES

Good Pulse Integral vs. Y track: Offset Param Fit Results



○ First FIT Iteration (using new function)

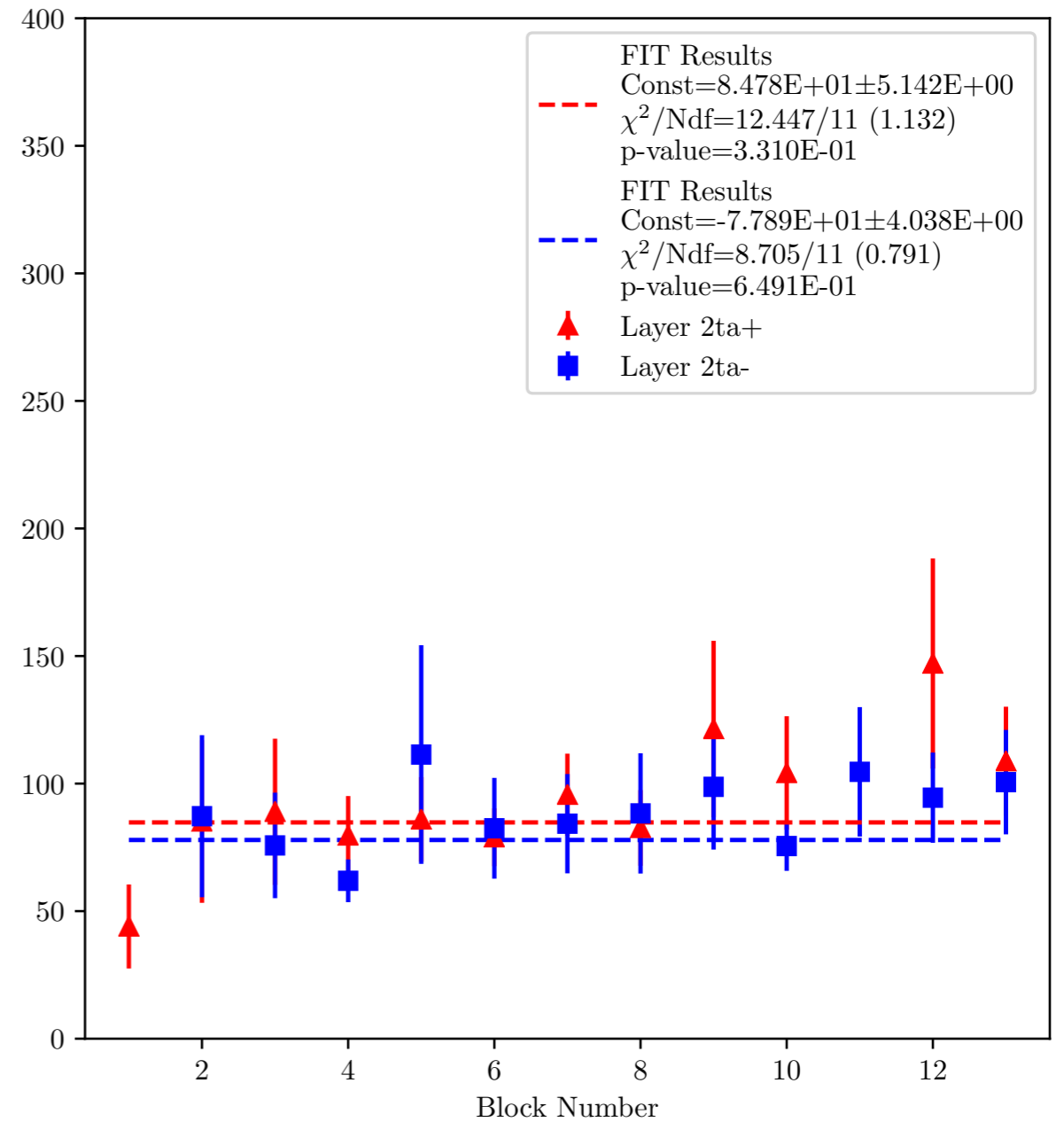
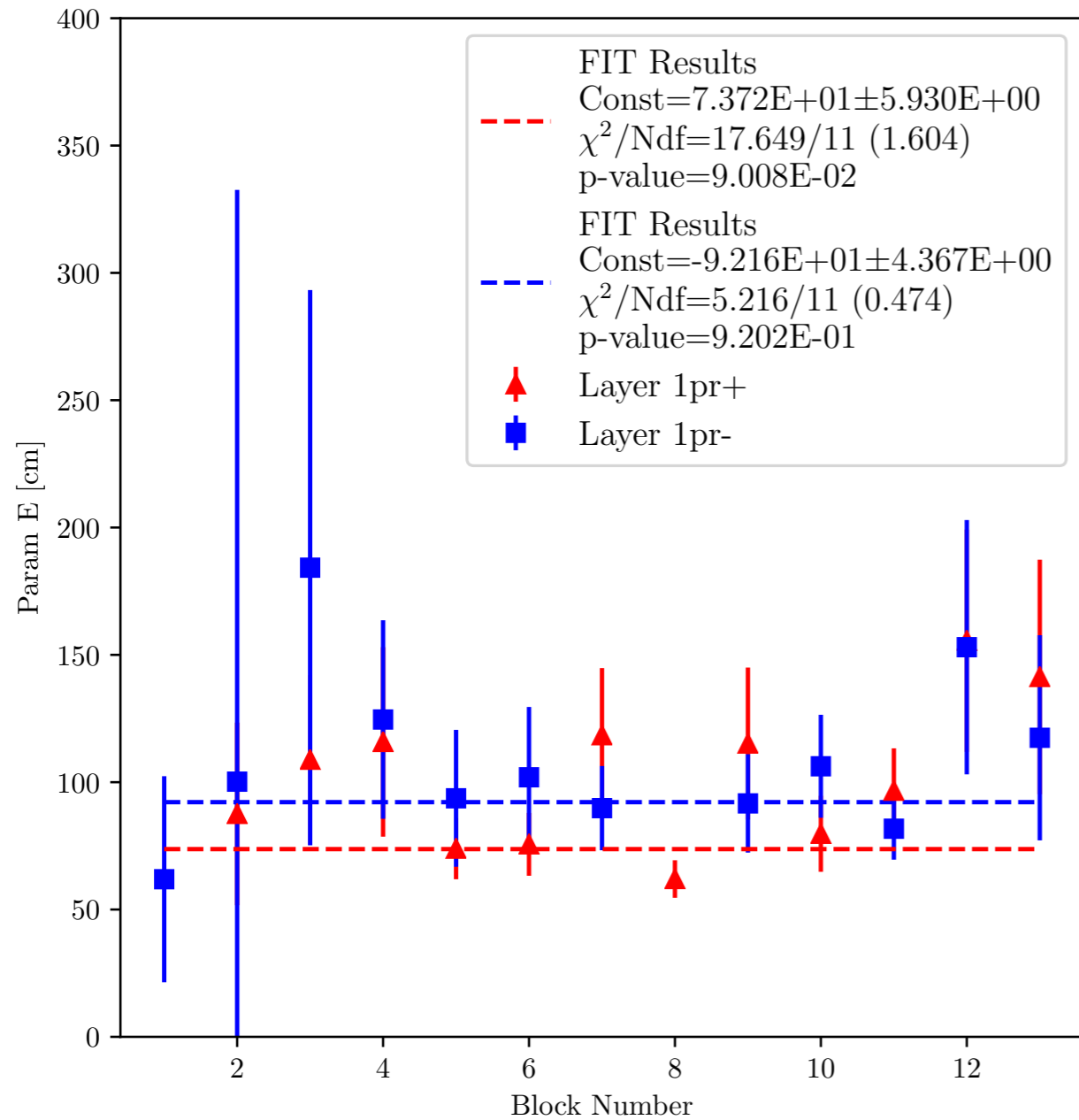
Good Pulse Integral vs. Y track: Param C Fit Results



○ First FIT Iteration (using new function)

◆ (negative layer sign is flipped for ease of comparison)

Good Pulse Integral vs. Y track: Param E Fit Results



○ First FIT Iteration (using new function)

◆ (negative layer sign is flipped for ease of comparison)