GE DETECTOR CALIBRATION WITH IMPROVED FIT FUNCTION AND COMPARISON OF CALIBRATION CONSTANT FROM DIFFERENT DAYS

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OLD VERSION OF FIT FUNCTION DESCRIBING TAIL DISTRIBUTION

- GERDA fit function has:
  - Gaussian peak distribution described as: $$g(E) = \frac{n}{\sqrt{2\pi}\sigma} \exp\left[-\frac{(E-\mu)^2}{2\sigma^2}\right]$$
  - Low energy tail distribution described as: $$h(E) = \frac{c}{2\beta} \exp\left(\frac{E-\mu}{\beta} + \frac{\sigma^2}{2\beta^2}\right) \operatorname{erfc}\left(\frac{E-\mu}{\sqrt{2}\sigma} + \frac{\sigma}{\sqrt{2}\beta}\right)$$
  - Number of parameters that describe these two distributions are 4: n (amplitude of gaussian peak), σ (width of gaussian peak), c (amplitude of tail), β (width of tail) (in total 8 parameters)
  - We need to express number of events in tail portion as a fraction of total events in the peak
  - Typo in GERDA paper[1] found

$$h(E) = \frac{c}{2\beta} \exp\left(\frac{E-\mu}{\beta} + \frac{\sigma^2}{2\beta^2}\right) \operatorname{erfc}\left(\frac{E-\mu}{\sqrt{2}\sigma} + \frac{\sigma}{\sqrt{2}\beta}\right), \quad (5)$$

where β and c are the height and slope of the tail, respectively. An example of the FEP peak fit is shown in the inset of Fig. 1.

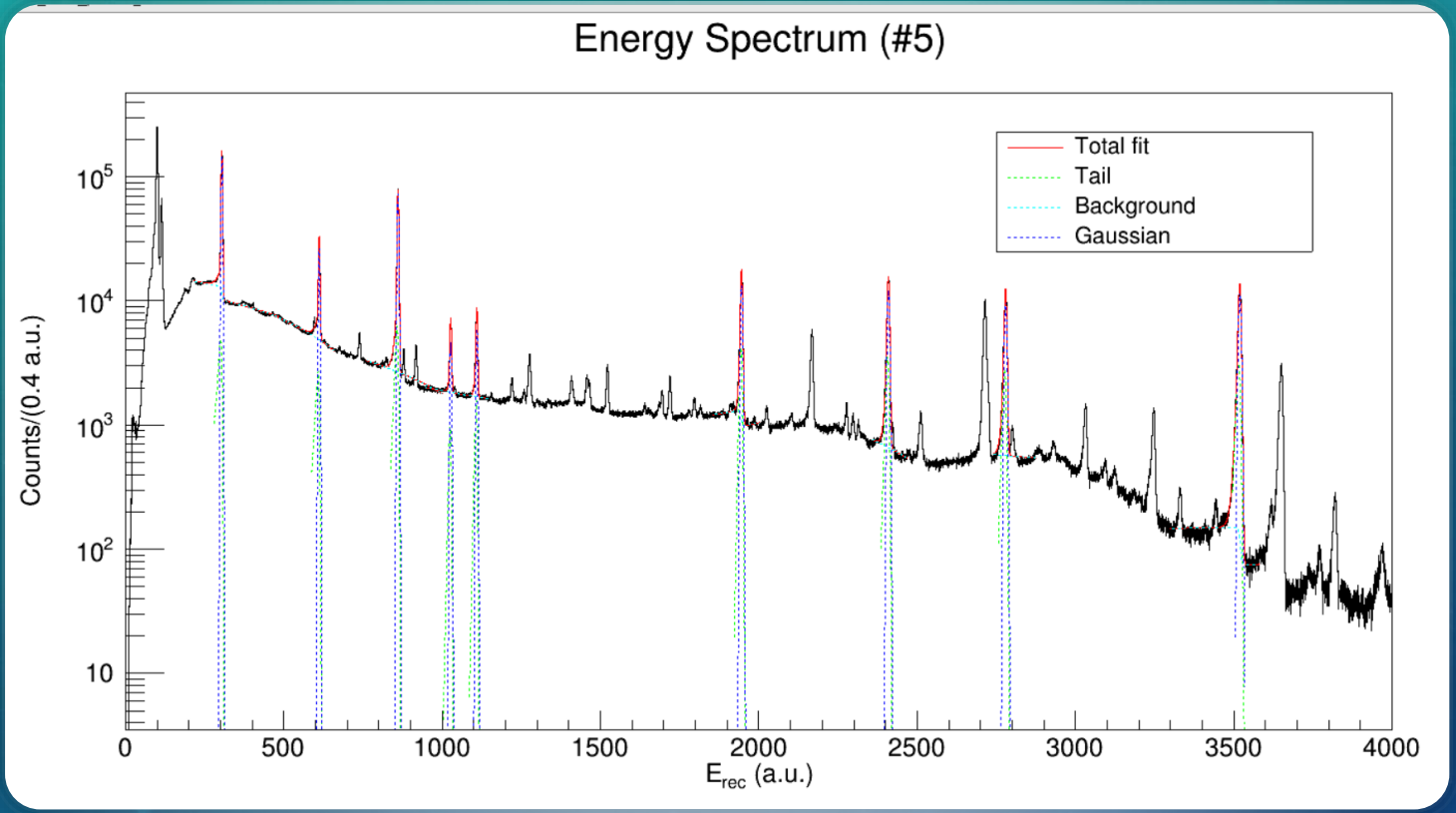
[1]Agostini, M., et al., *Calibration of the GERDA experiment*. arXiv preprint arXiv:2103.13777, 2021)

NEW VERSION OF FIT FUNCTION DESCRIBING TAIL DISTRIBUTION

- Amplitude of gaussian peak expressed as a fraction (f) of total peak count (N) and peak width σ_{gaus}
    - N.f. Gaussian
- Amplitude of low energy tail restricted to fraction (1-f) of total peak count (N)and peak width σ_{tail}
    - N.(1-f). Gaus*Erfc
- Number of parameters remain same in both cases (8) as N, f, σ_{gaus} and σ_{tail} replace the 4 variables : n, σ, c and β
- Method already used by MAJORANA collaboration [2]
- Parameter limits on ‘f’ float between 0.7-1, restricting the tail contribution to 30% of the total peak
- For now, unable to find any theoretical motivation for this fraction

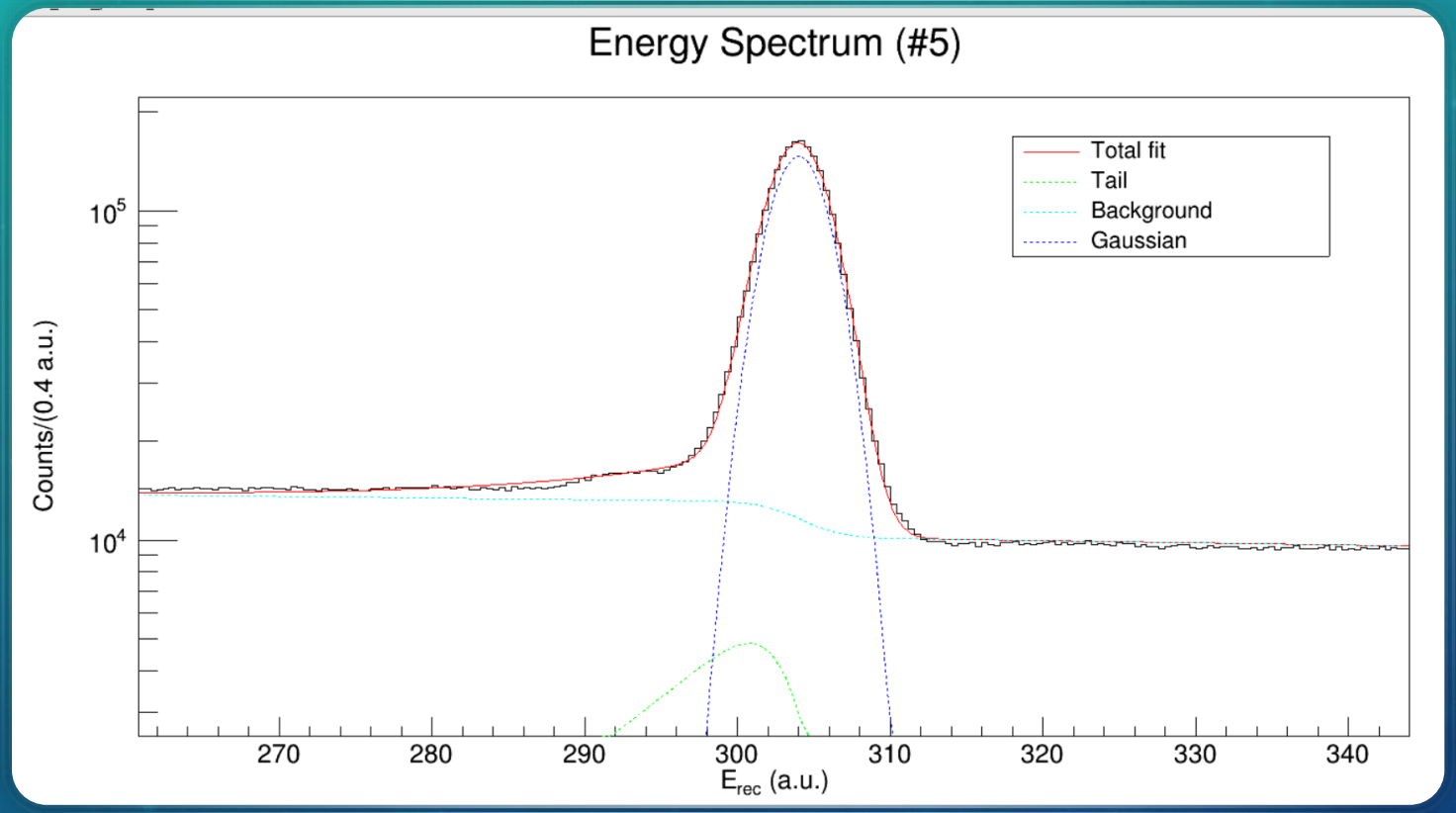
[2] Abgrall, N., et al. "The MAJORANA DEMONSTRATOR calibration system.“ arxiv:1702.02466

ENERGY SPECTRUM



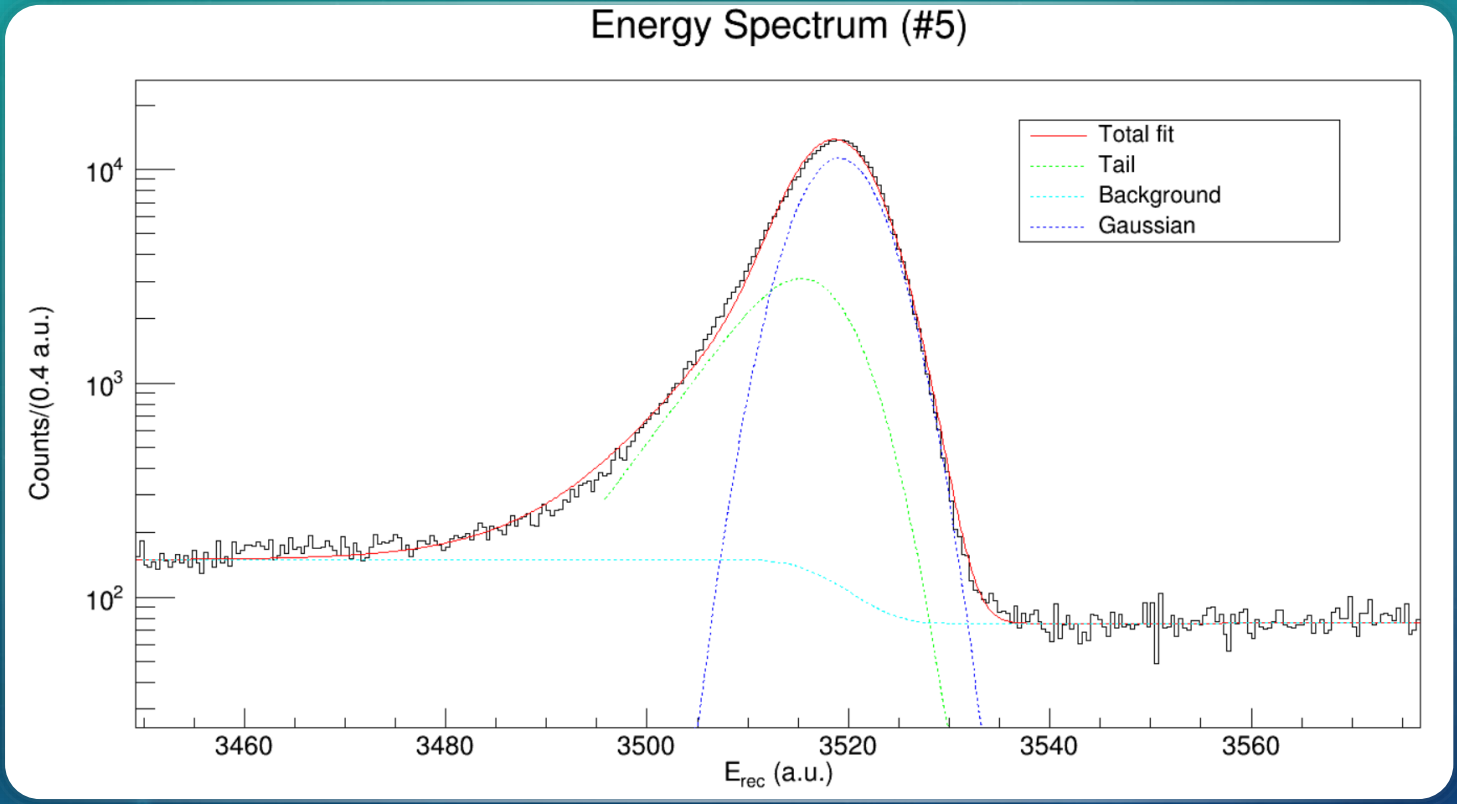
- After implementing the new fit function, 9 out of 12 peaks were fitted
- Using MIGRAD algorithm, status “converged” and Error Matrix was “accurate”

PEAK AT 121 keV

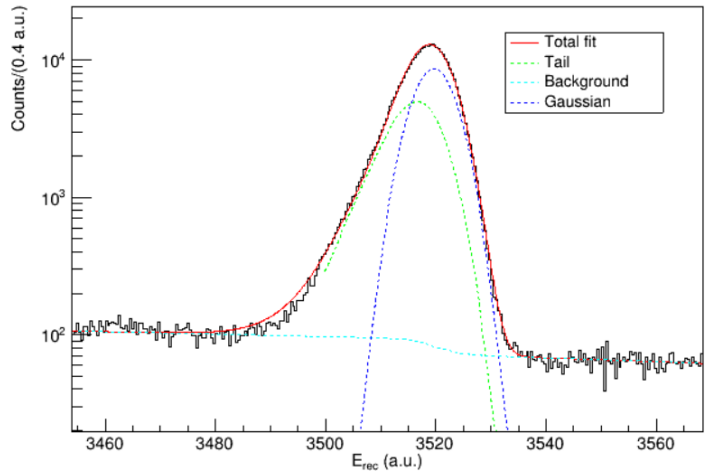


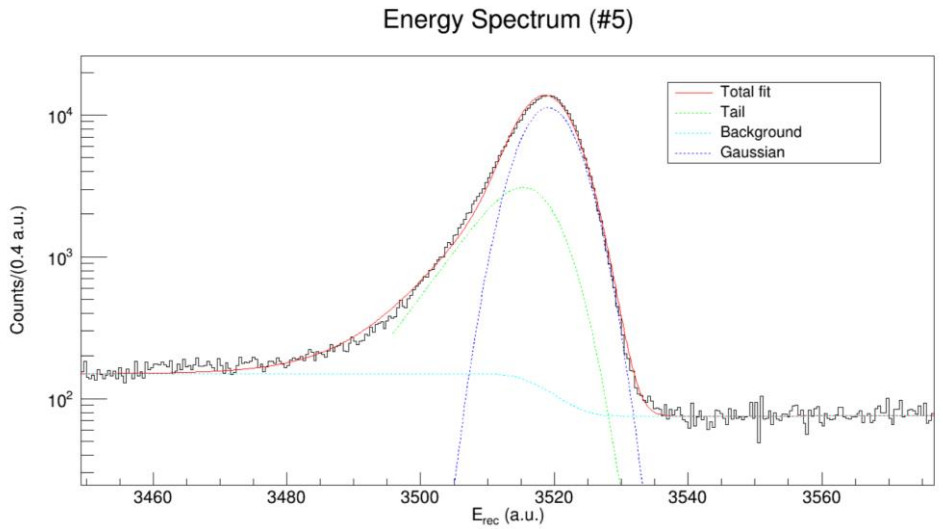
- Shows fit of highest intensity peak

PEAK AT 1408 keV



Before restricting

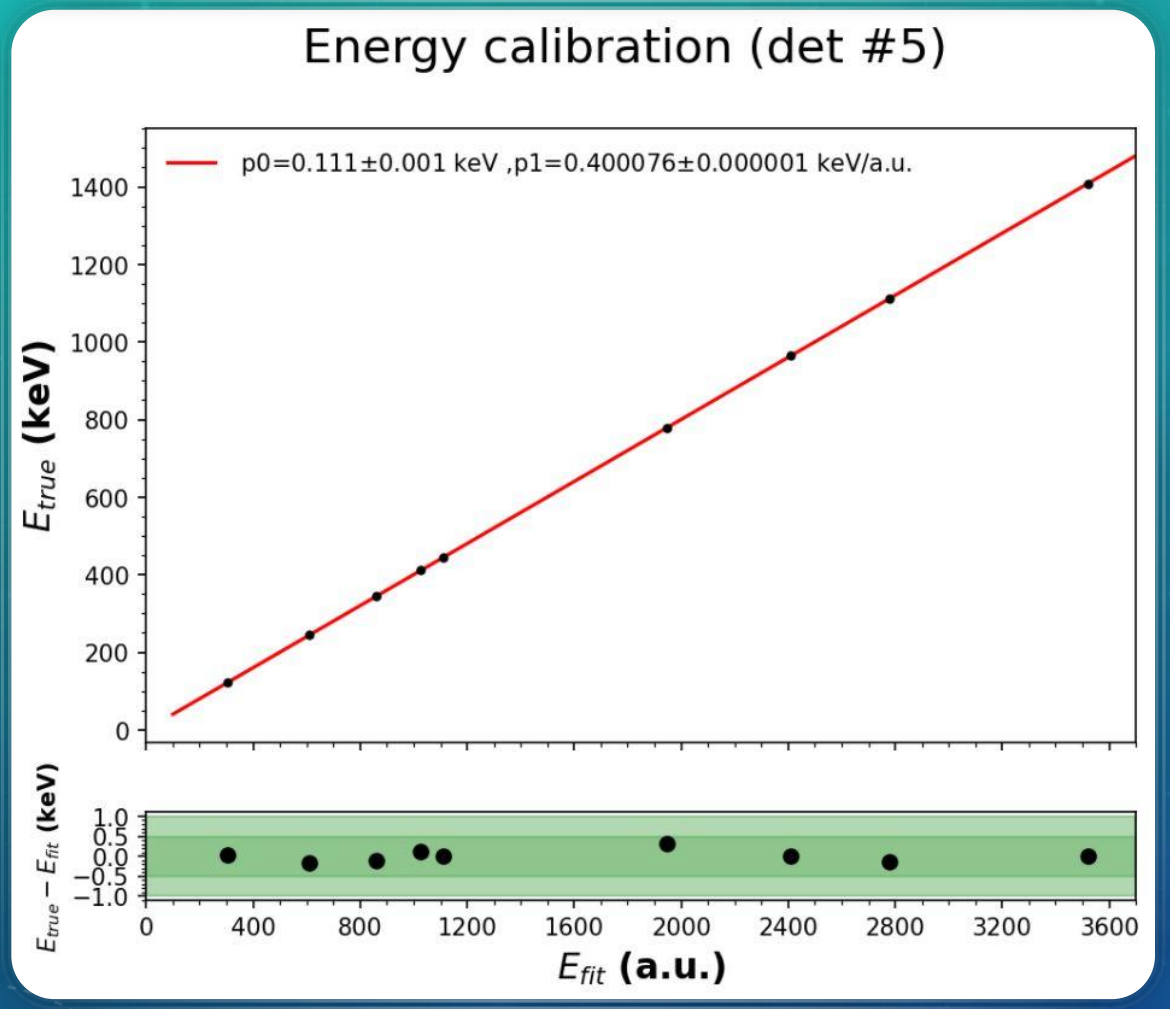




After restricting

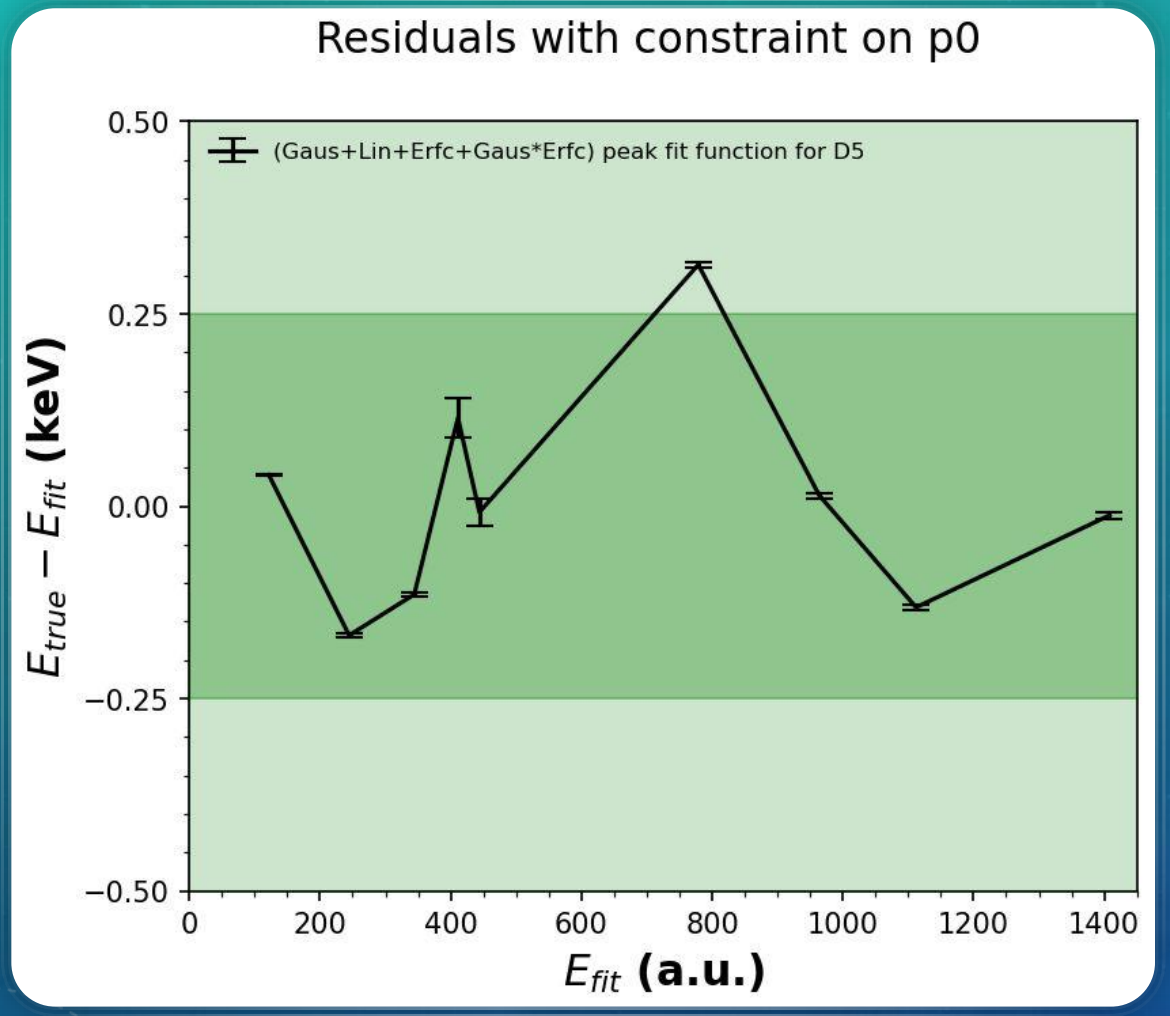
PEAK AT 1408 keV

- We can clearly see the difference in peak of function describing tail portion before and after the peak fraction of tail is restricted to 30% to total peak count



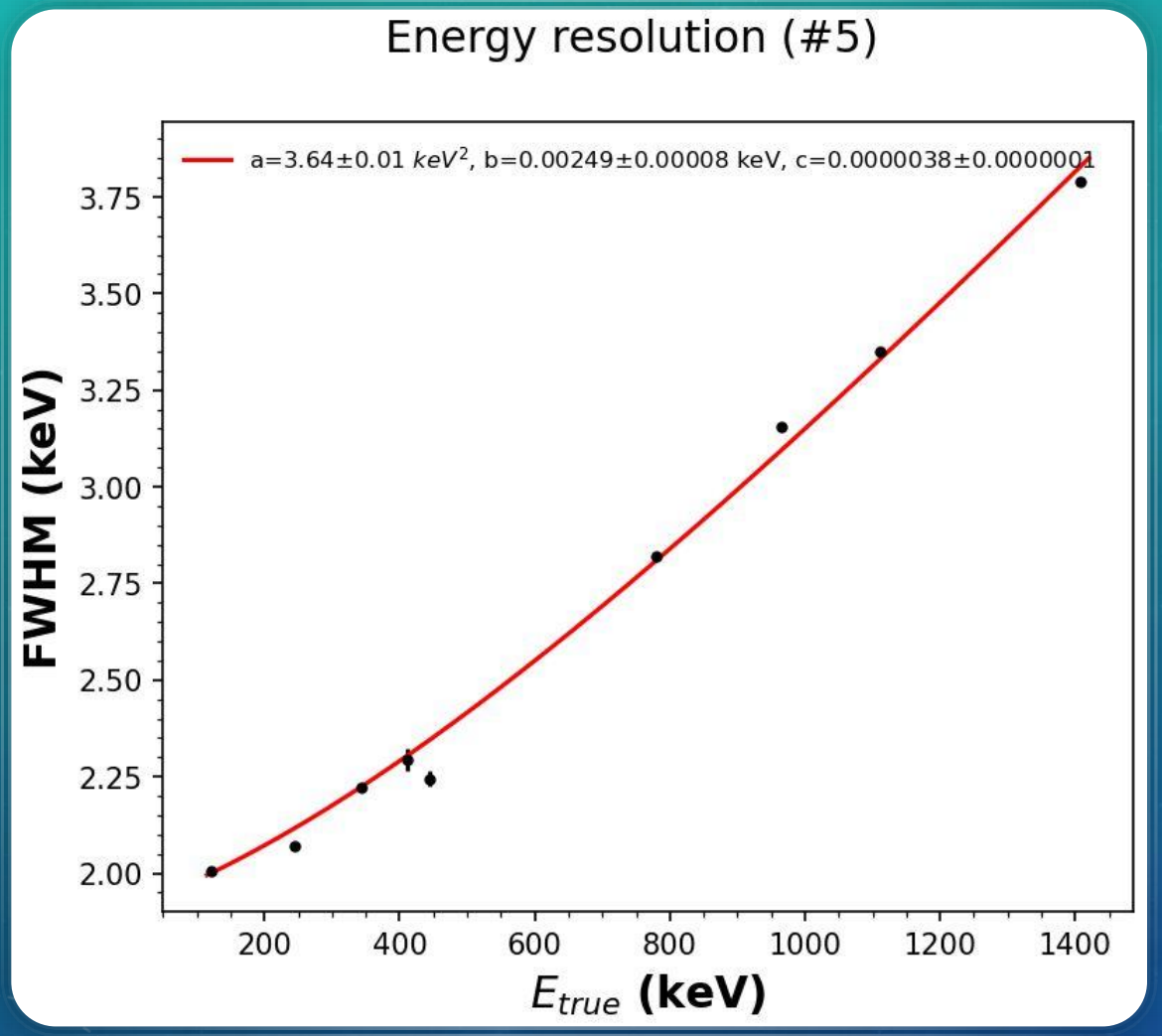
ENERGY CALIBRATION CURVE

- Slope of the fit shows a significantly small change (of the order of 1E-5)
- Intercept is significant in this case as compared to previous function where it is of the order of ~1E-11.



RESIDUALS

- With constraint on intercept, the residuals of the new peak fitting function are within -0.17 keV to +0.31 keV

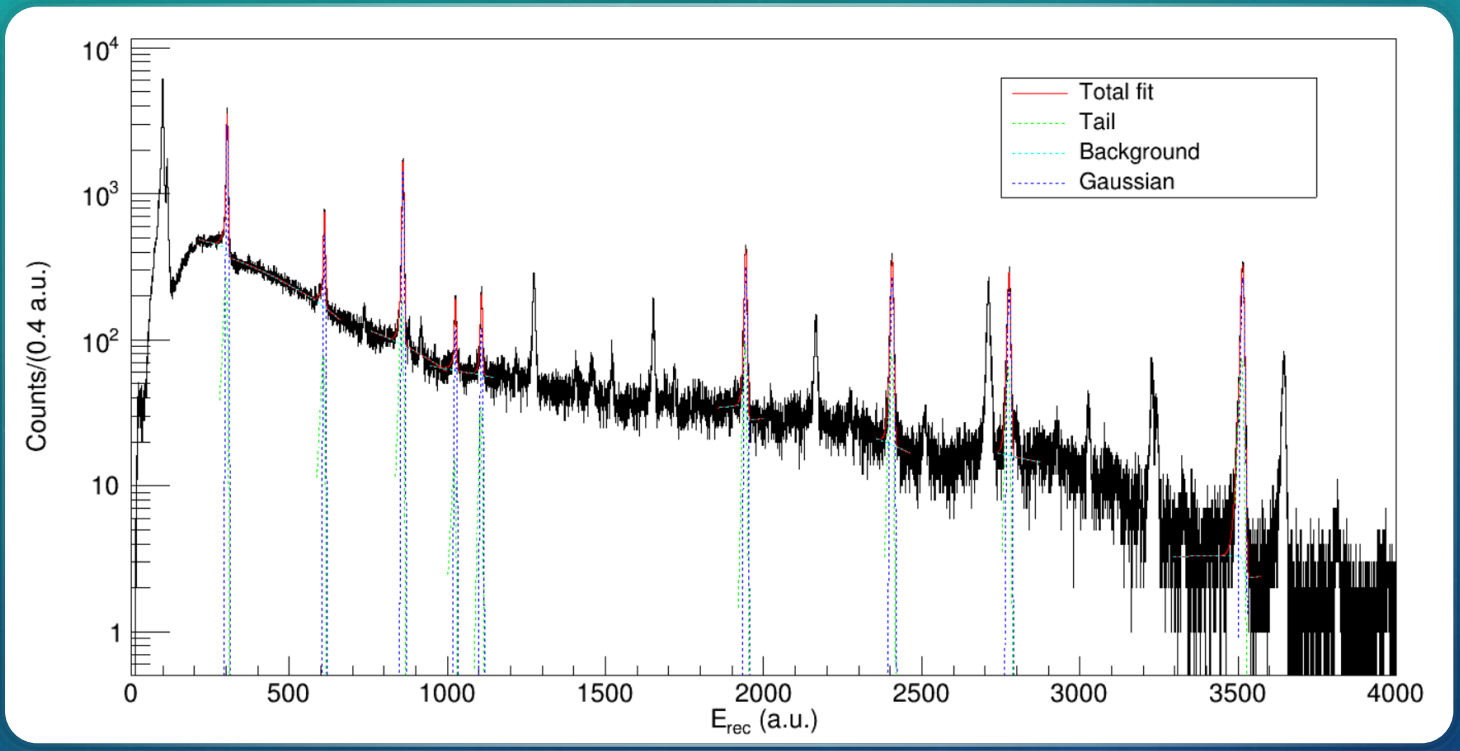


ENERGY RESOLUTION

- Introduced an E^2 term in the fit of resolution to account for charge carrier collection
  - $FWHM = 2.355 \cdot \sqrt{a + bE + cE^2}$
- Resolution is 3.7 keV at 1.33 MeV
- Resolution without including E^2 term was 3.3 keV
- Need to include systematic errors as well

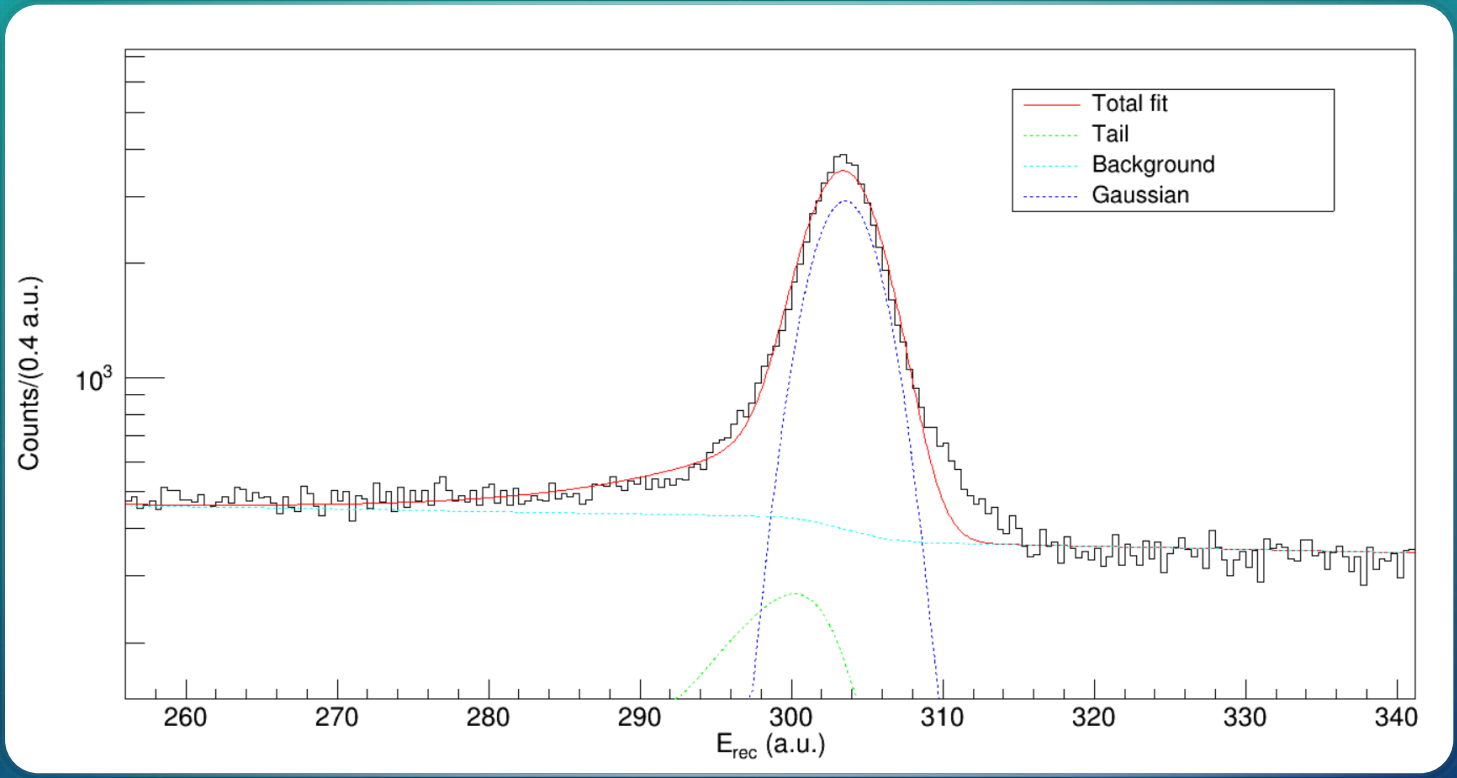
FIT FROM CALIBRATION DONE ON NOV 7

ENERGY SPECTRUM



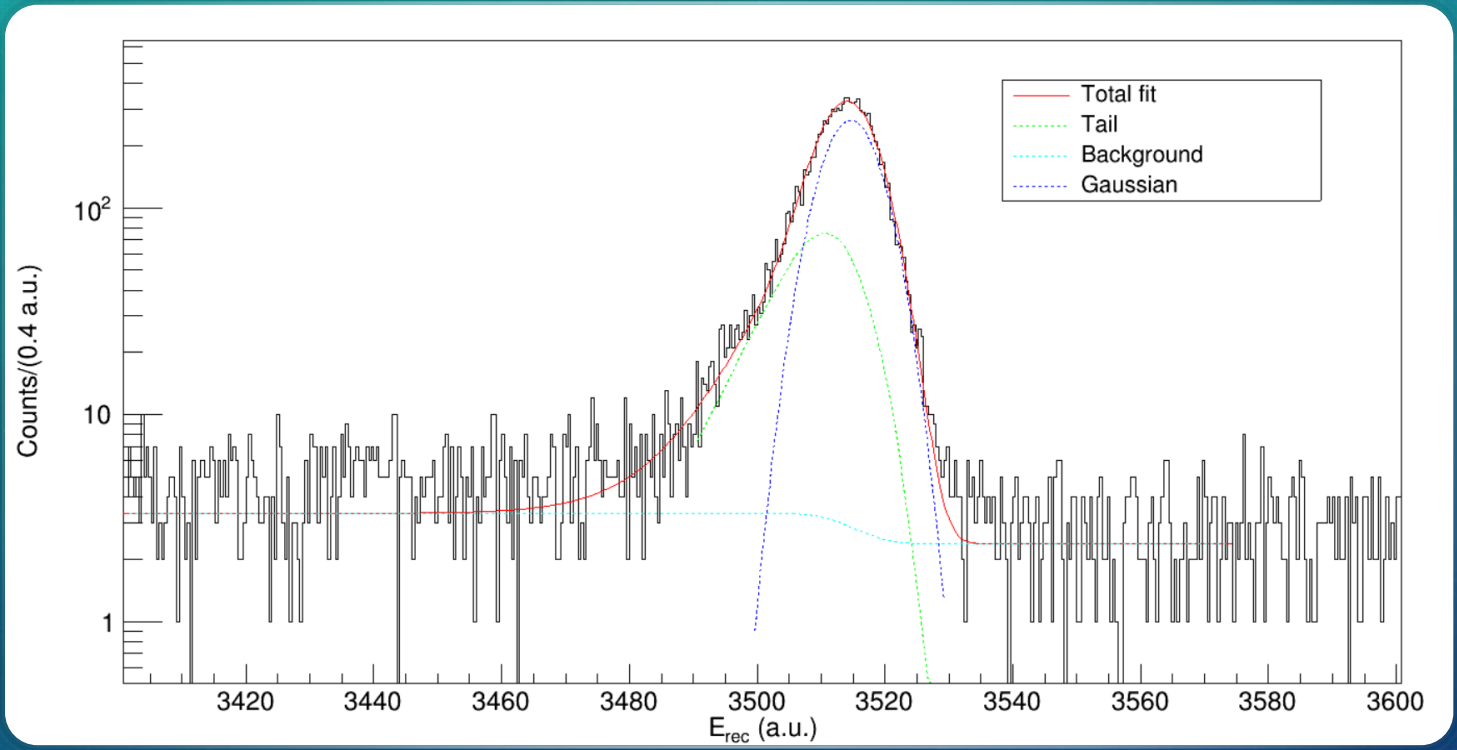
- With the new fit function, 9 out of 12 peaks were fitted
- Using MIGRAD algorithm, status “converged” and Error Matrix was “accurate”
- Statistics is low in this data, so we will add more later

PEAK AT 121 KEV



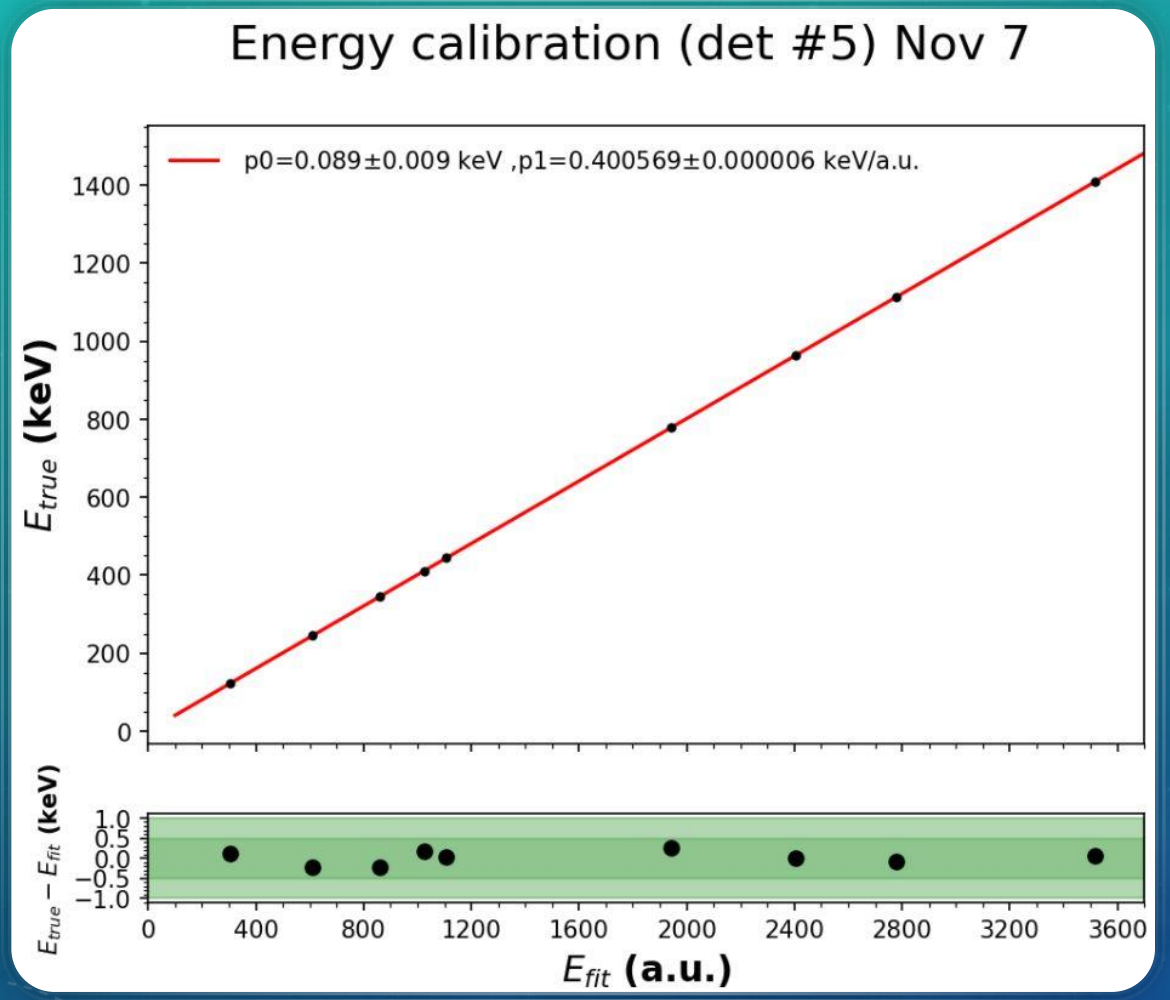
- Fitted peak from energy spectrum obtained on Nov 7

PEAK AT 1408 keV

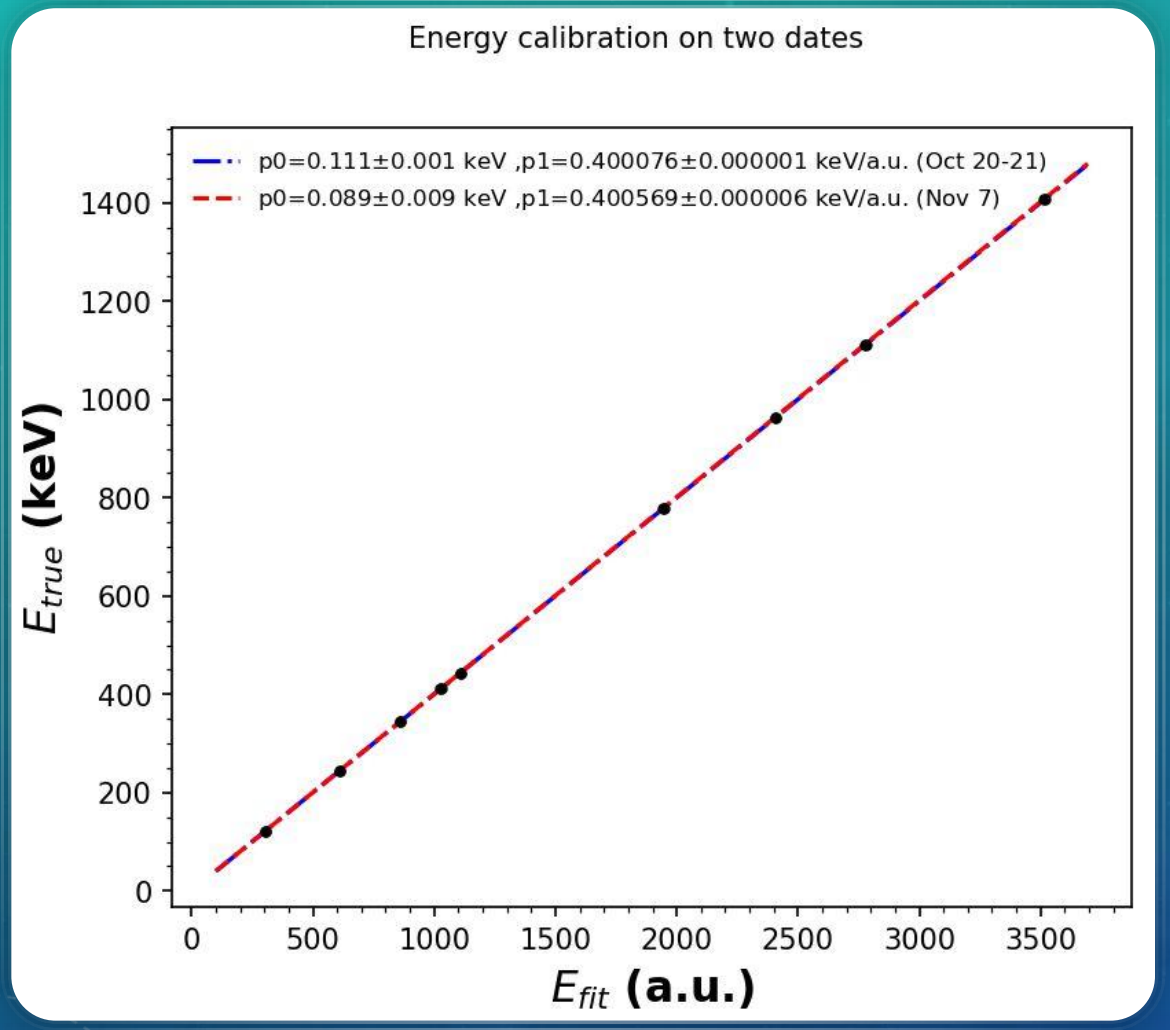


- Fitted peak from energy spectrum obtained on Nov 7

ENERGY CALIBRATION CURVE (NOV 7)

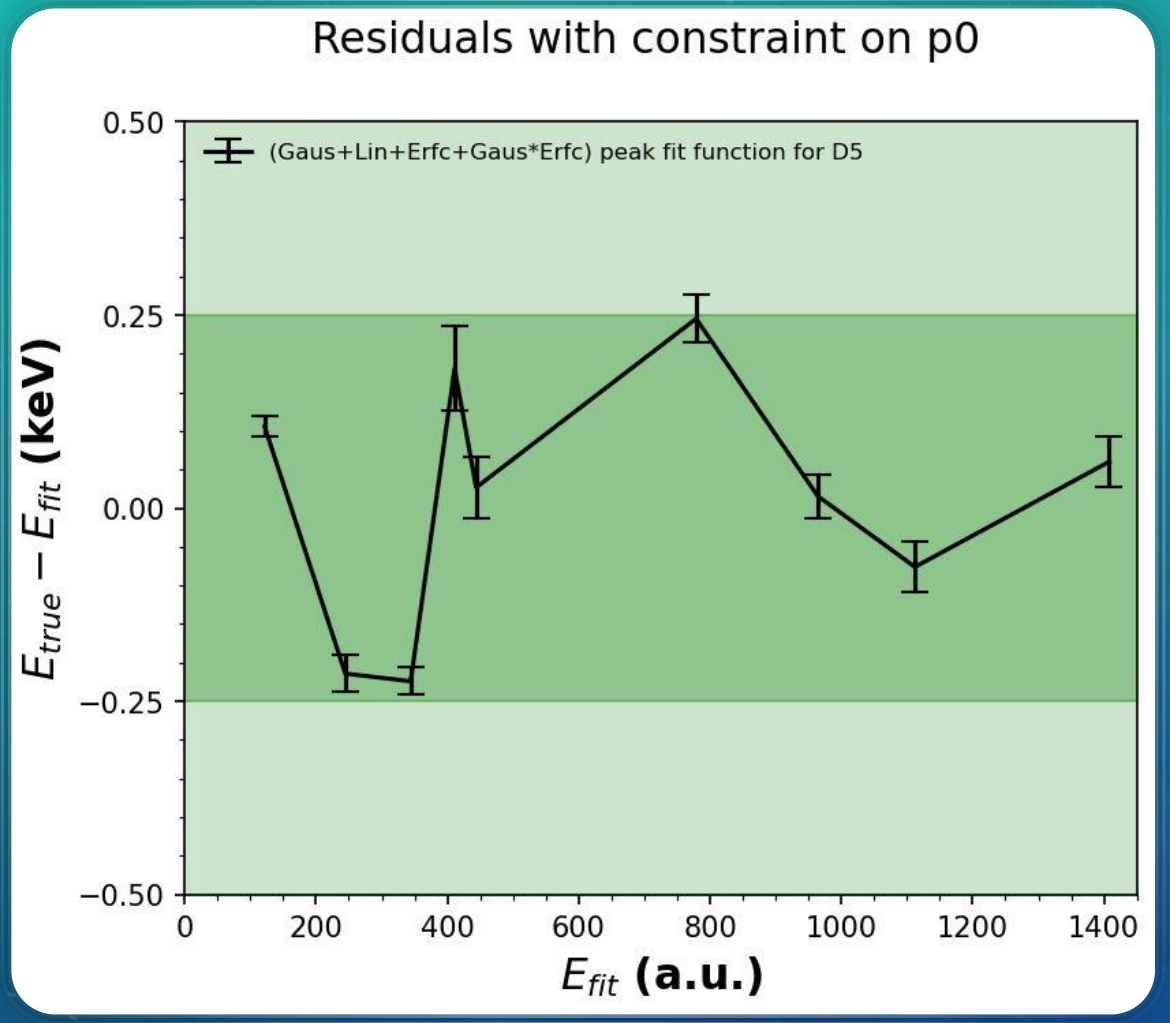


- There is a statistically significant change in values of slope and intercept
- Change in intercept is of the order of 1E-4



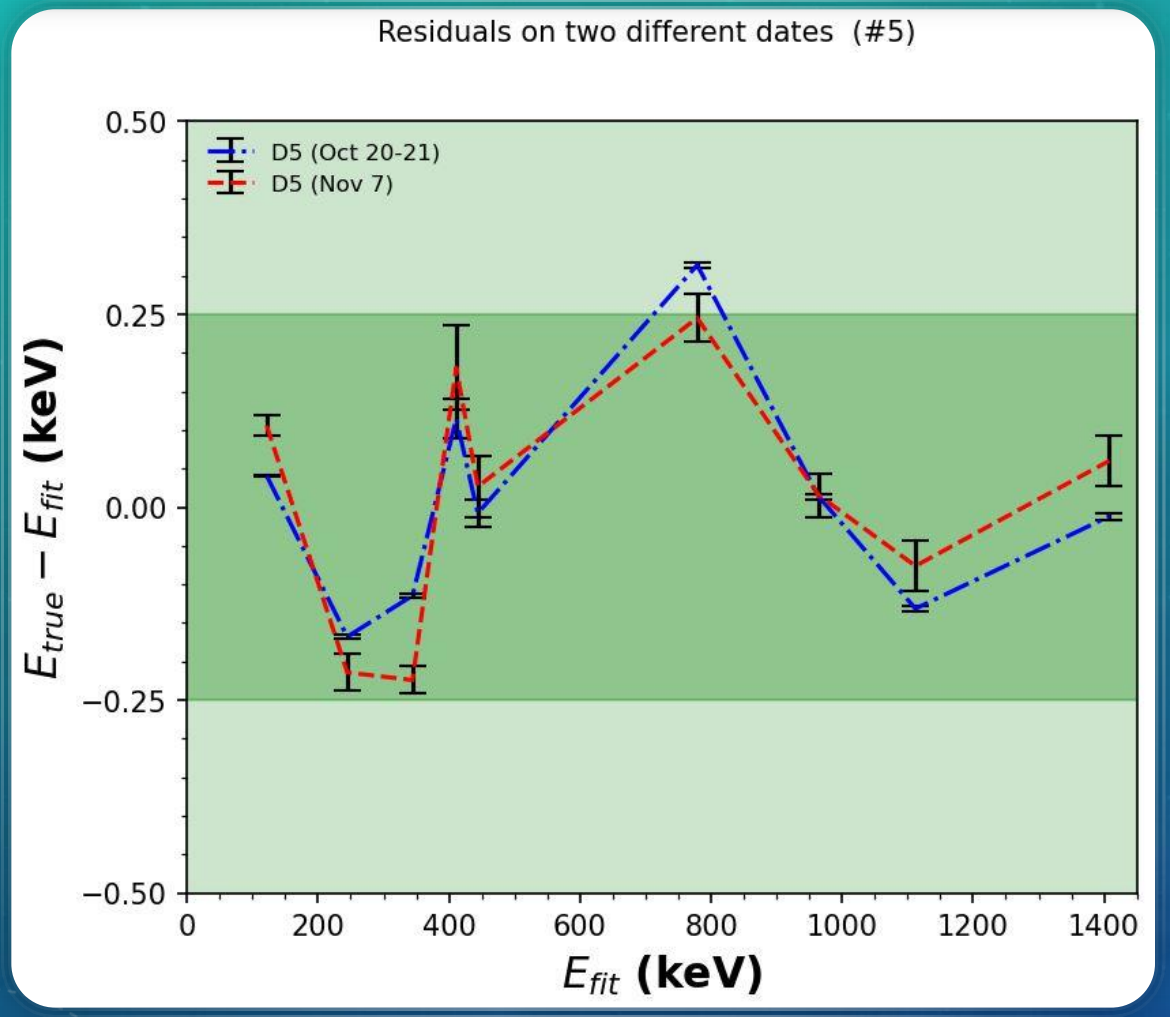
ENERGY CALIBRATION COMPARISON

- There is a statistically significant change in values of slope and intercept (change is of the order of 1E-4)
- Blue is Oct 20-21 data
- Dashed Red is Nov 7 data
- Both fit superimposed, unable to distinguish



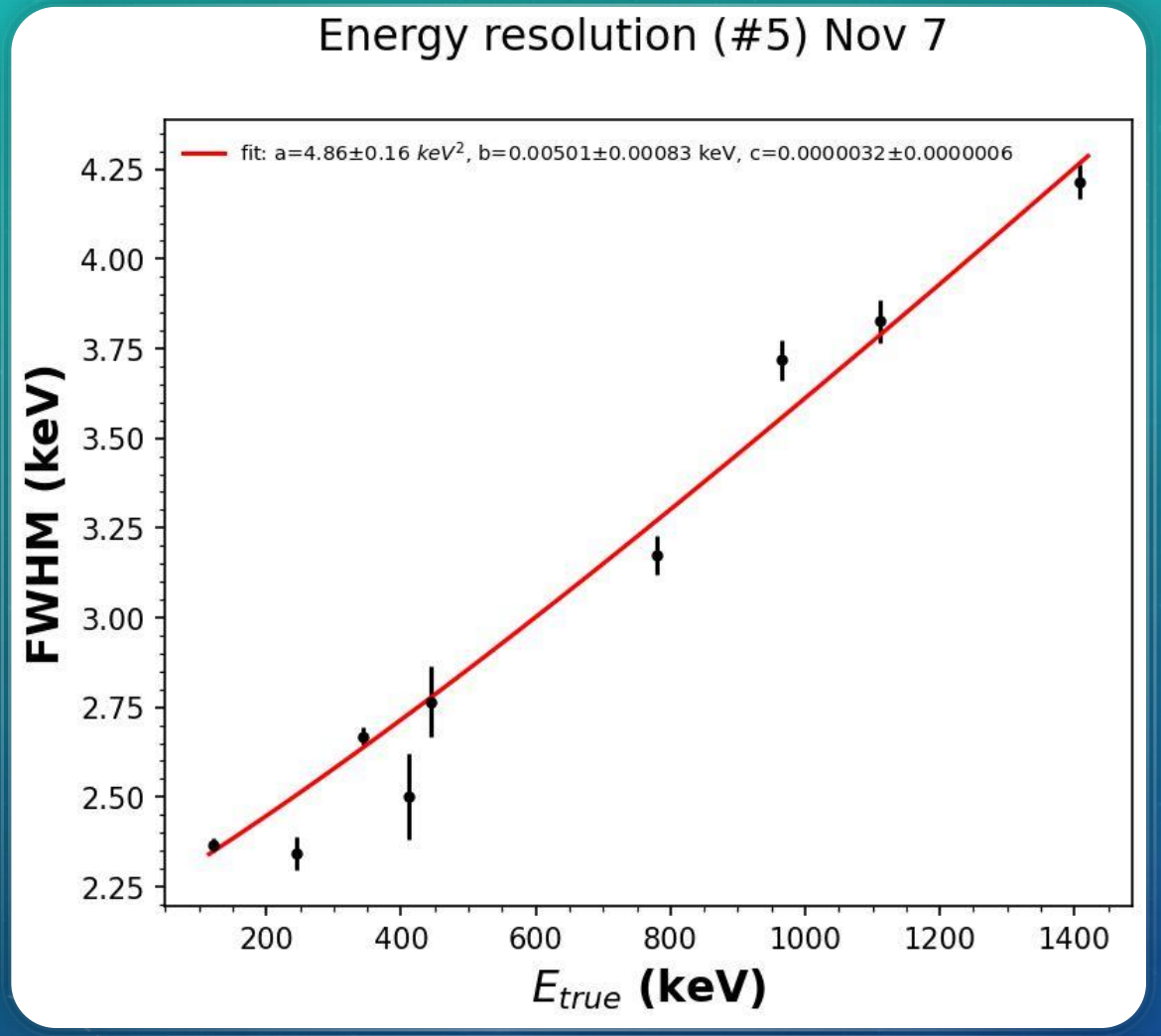
RESIDUALS (NOV 7)

- With constraint on intercept, the residuals of the new peak fitting function are within -0.22 keV to +0.25 keV



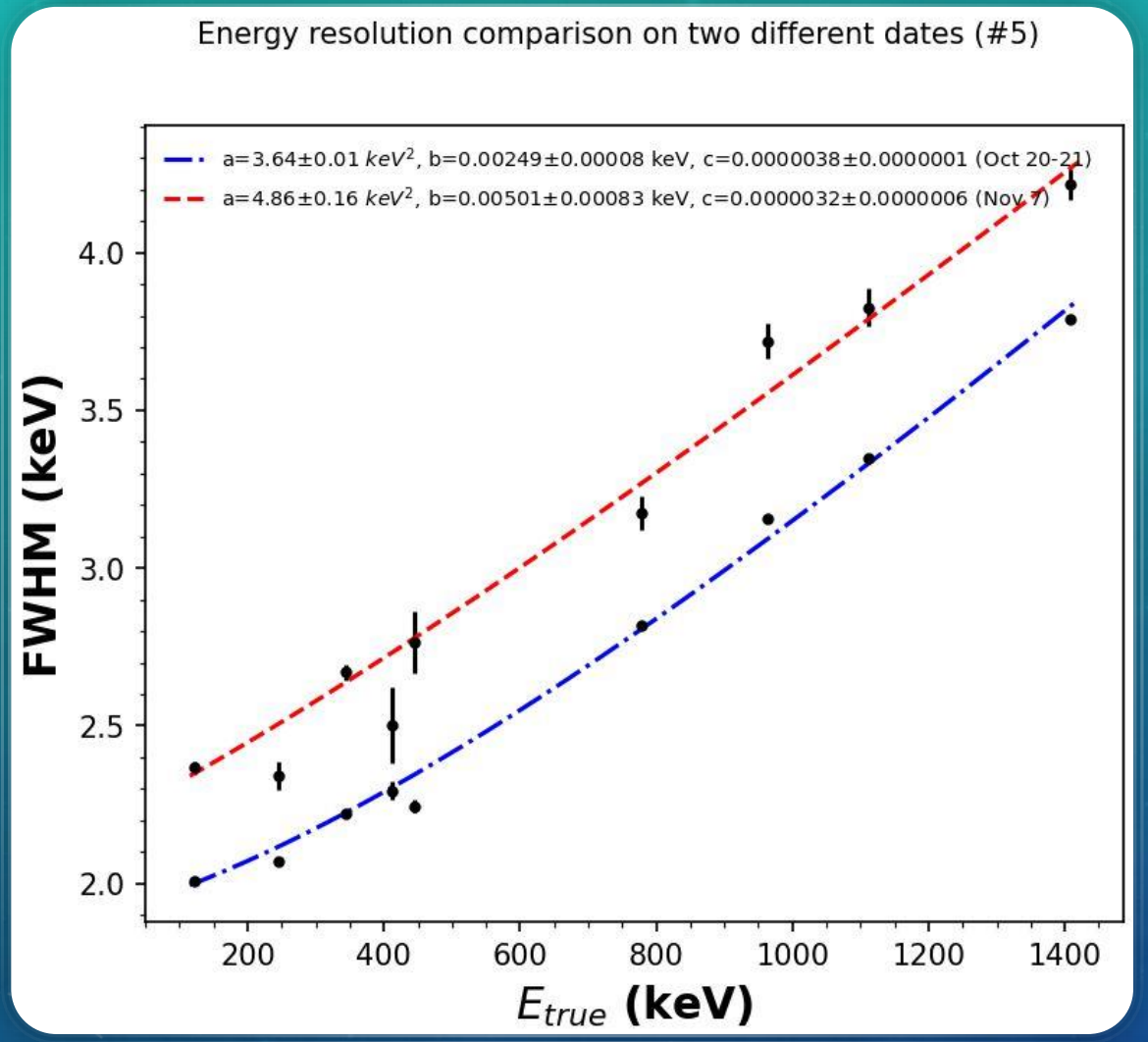
RESIDUAL COMPARISON

- Change in residuals is not significant



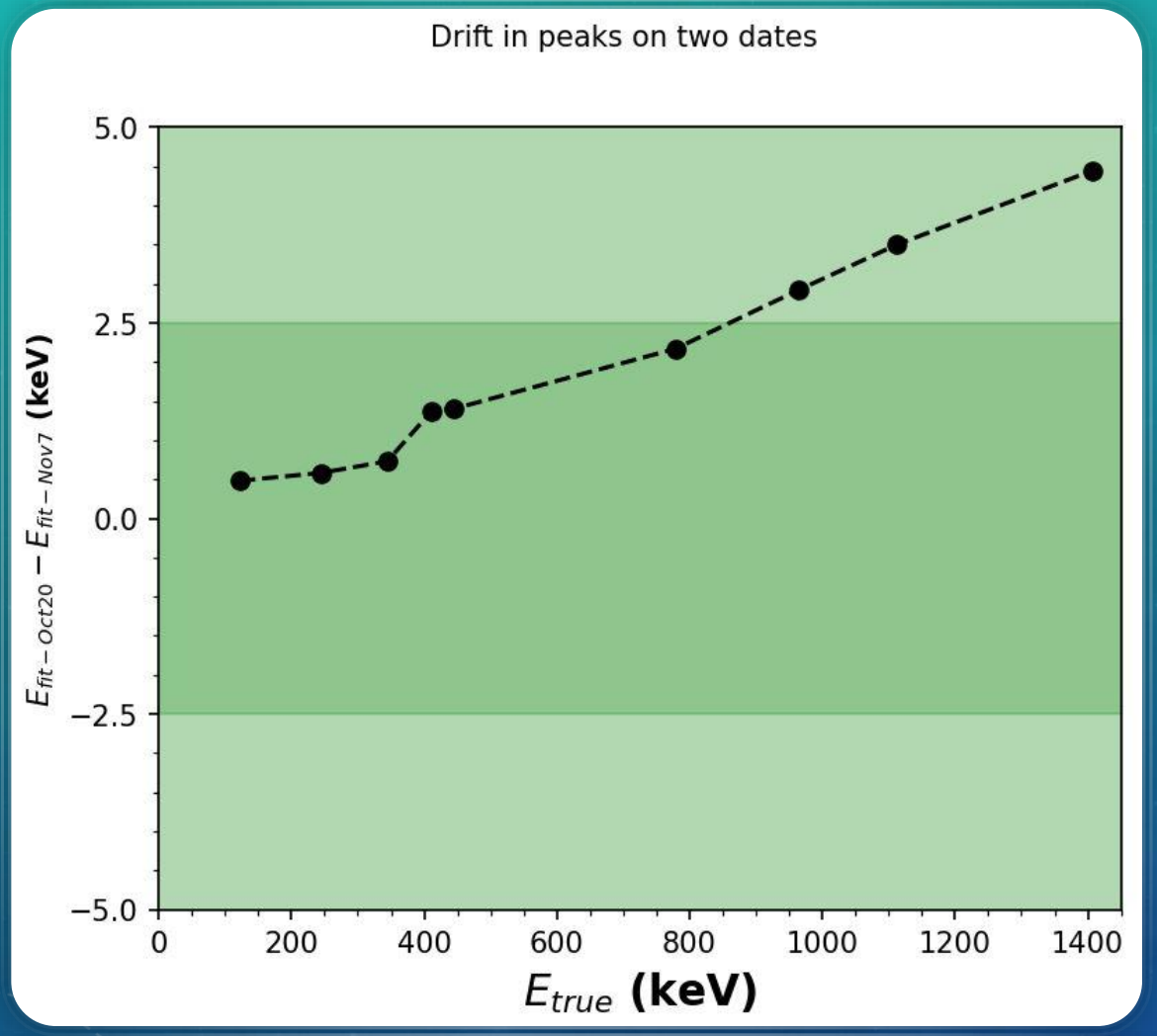
ENERGY RESOLUTION (NOV 7)

- Introduced an E^2 term in the fit of resolution to account for charge carrier collection
  - $FWHM = 2.355 \cdot \sqrt{a + bE + cE^2}$
- Resolution is 4.1 keV at 1.33 MeV
- Need to include systematic errors as well



RESOLUTION COMPARISON

- Energy resolution increased from Oct 20-21 to Nov 7
- Blue is Oct 20-21 data
- Dashed Red is Nov 7 data
- @1.33 MeV, the resolution changed from 3.7 keV to 4.1 keV



DRIFT IN PEAKS

- Drift in fitted value of peaks on two dates
- Drift = Mean value of peak from fit on Oct 20- Mean value of peak from fit on Nov 7
- Peak drift above 1200 keV is ~5 a.u., which supports our change in slope of energy calibration
- At least qualitatively, the change in calibration constant is consistent with the observed shift in peaks
- Need to analyze the shifts in more detail to understand it better

SUMMARY

- Implemented an improved fit function that restricts the counts in tail distribution to a fraction of total peak count
- Improved the fit of energy resolution by including effect of incomplete charge collection
- Comparison of calibration constant from calibration of Eu-152 done on Nov 7 with Oct 20-21 data for detector #5

NEXT STEP

- Figure out the fraction of incomplete charge collection in the peaks which should be physically meaningful
- Working on including systematic error in energy resolution
- Tried calibrating other detectors (#1 & #2) but found slope reduced by a factor of 2
- Elog entry shows changes made in the system on Oct 30th in all but detector 5, so we need to understand it, correct it and calibrate all other detectors as well