

Particle Energy Calibration of Timepix Detector

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NASA Active Radiation Sensor Requirements

- Timepix selected to be the main technology used for future exploration missions' radiation monitoring (NASA dedicated to use technology next 10 – 20 years)
- Accurate, reliable dosimetry of energetic electrons, protons, and higher-Z ions
- Accurate, reliable measurement of energetic particle flux
- Accurate, reliable measurement of LET spectra (dE/dx)
 - Requires accurate measurement of both dE and dx

NASA/JSC Team and Efforts Using Timepix Technology

- REM TEAM

Quite a strong team – 4 HW developers (S. Wheeler), 5 SW developers (N. Townsend), mechanical, thermal engineers

Science team - T. Campbell-Ricketts, A. Empl, A. Firan, D. Fry, R. Gaza, S. George, M. Kroupa, L. Pinsky, R. Rios, E. Semones, N. Stoffle

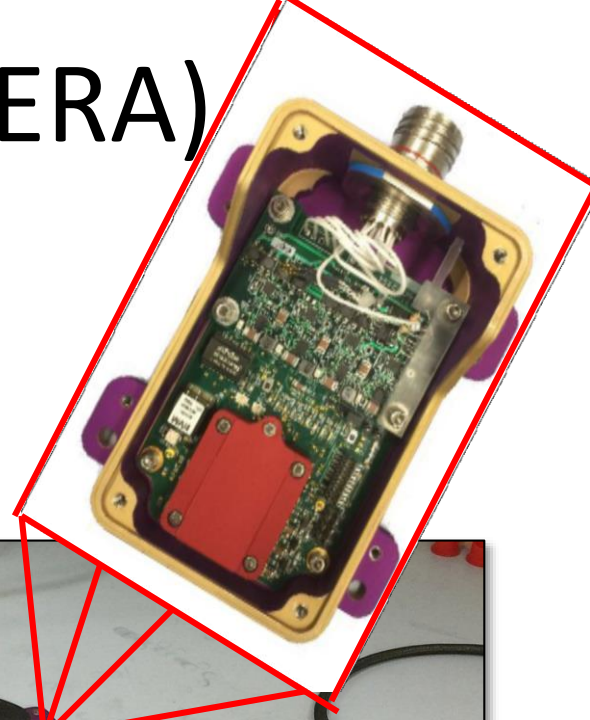
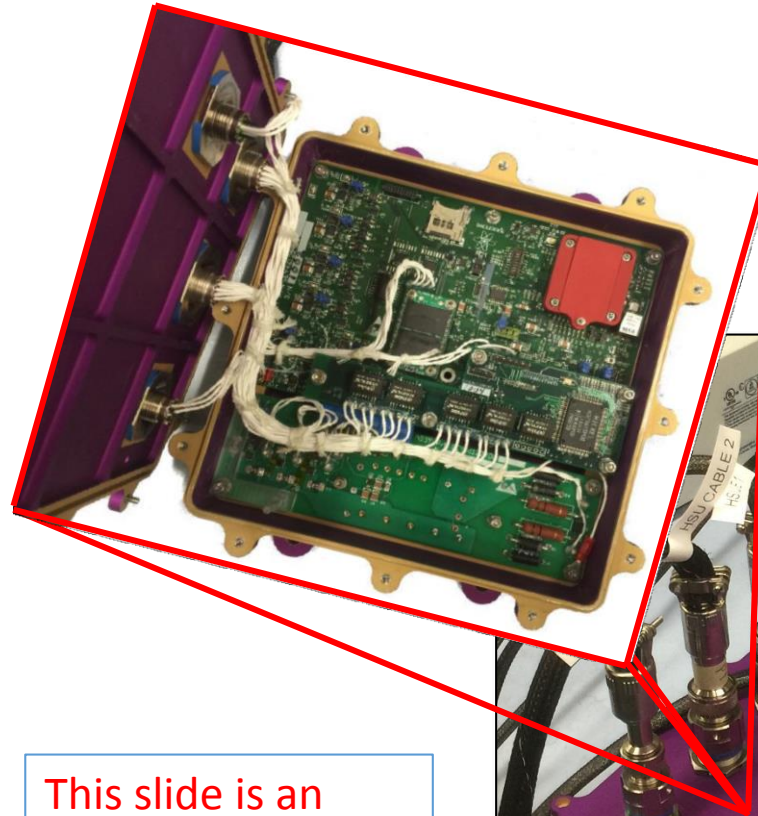
- Development Efforts

- REM
 - BIRD
 - HERA
 - MPT
- Fast prototyping with off-shell products, following by own development
 - Incremental capability

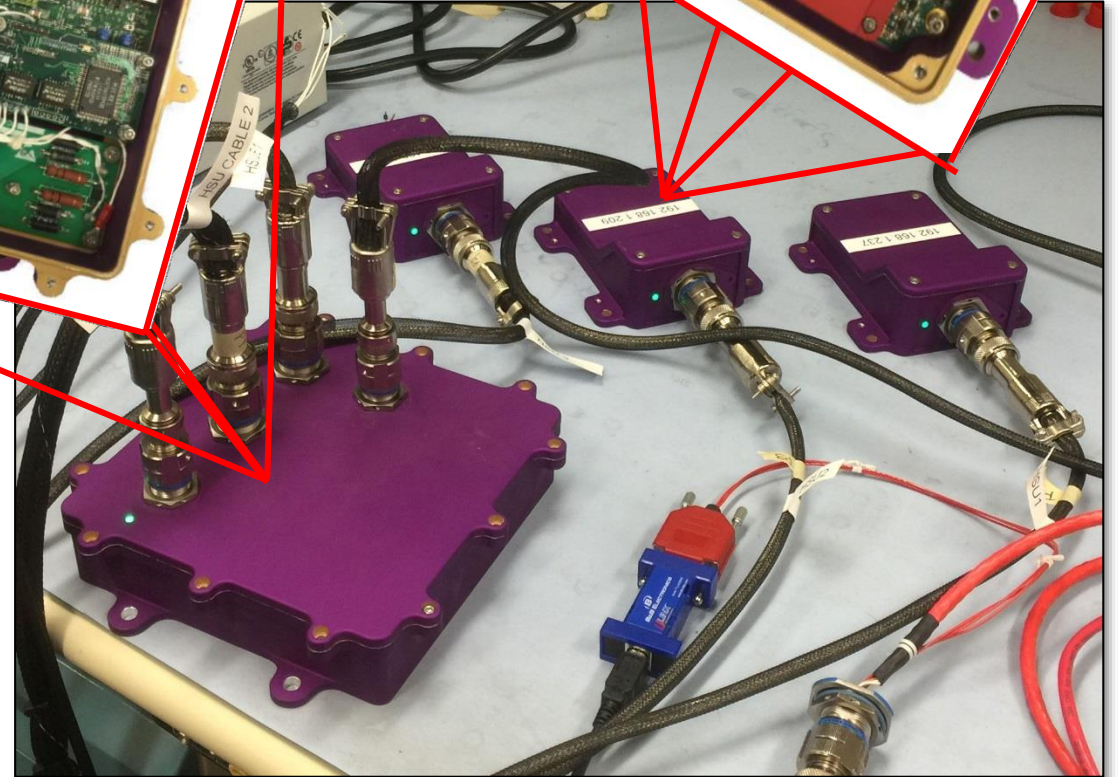


Hybrid Electronic Radiation Assessor (HERA)

- Active dosimetry system built for NASA Multi-Purpose Crew Vehicle, based on semiconductor pixel detector technology (Timepix)
- Modular structure
- Completely stand alone capability, all data processing on board, including alarms, etc.
- Measures dose rates at up to four positions
- Gives estimate of the radiation environment
- dE/dx measurement, directionality measurement

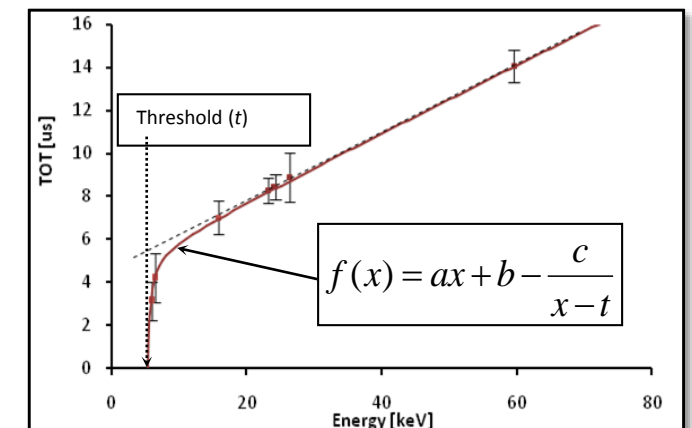
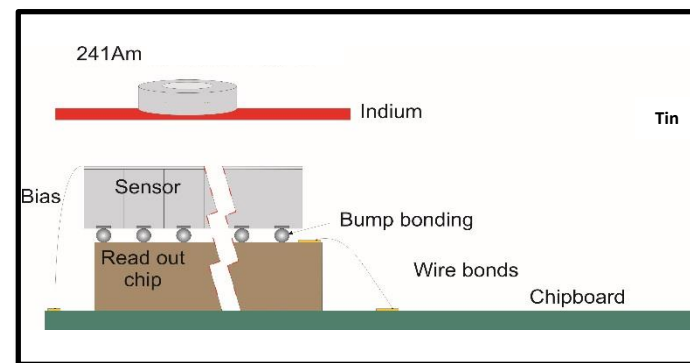
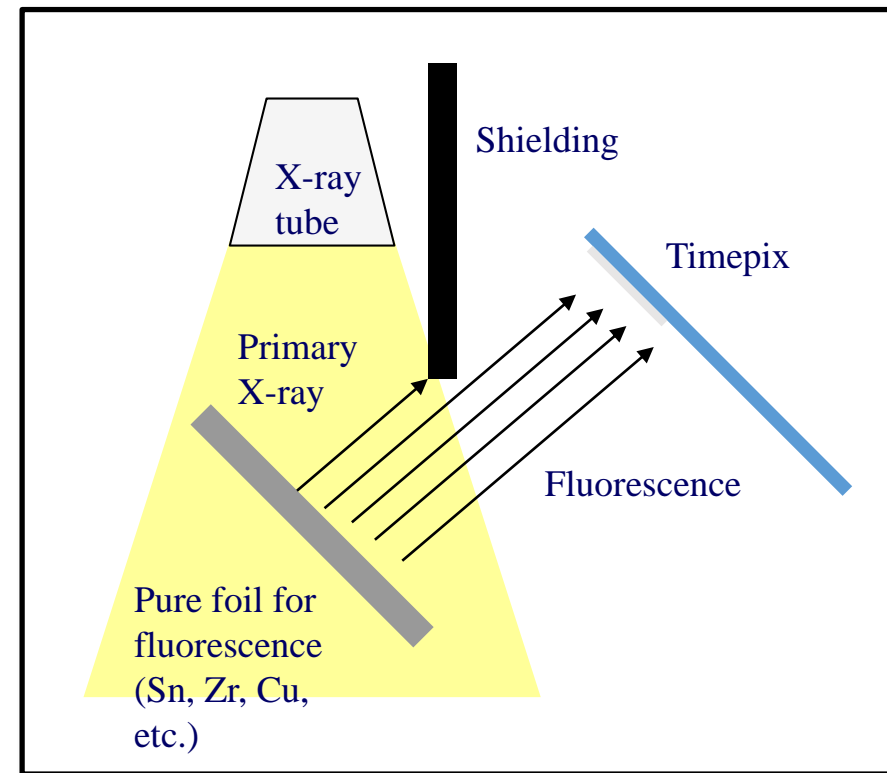


This slide is an example of the latest and greatest...



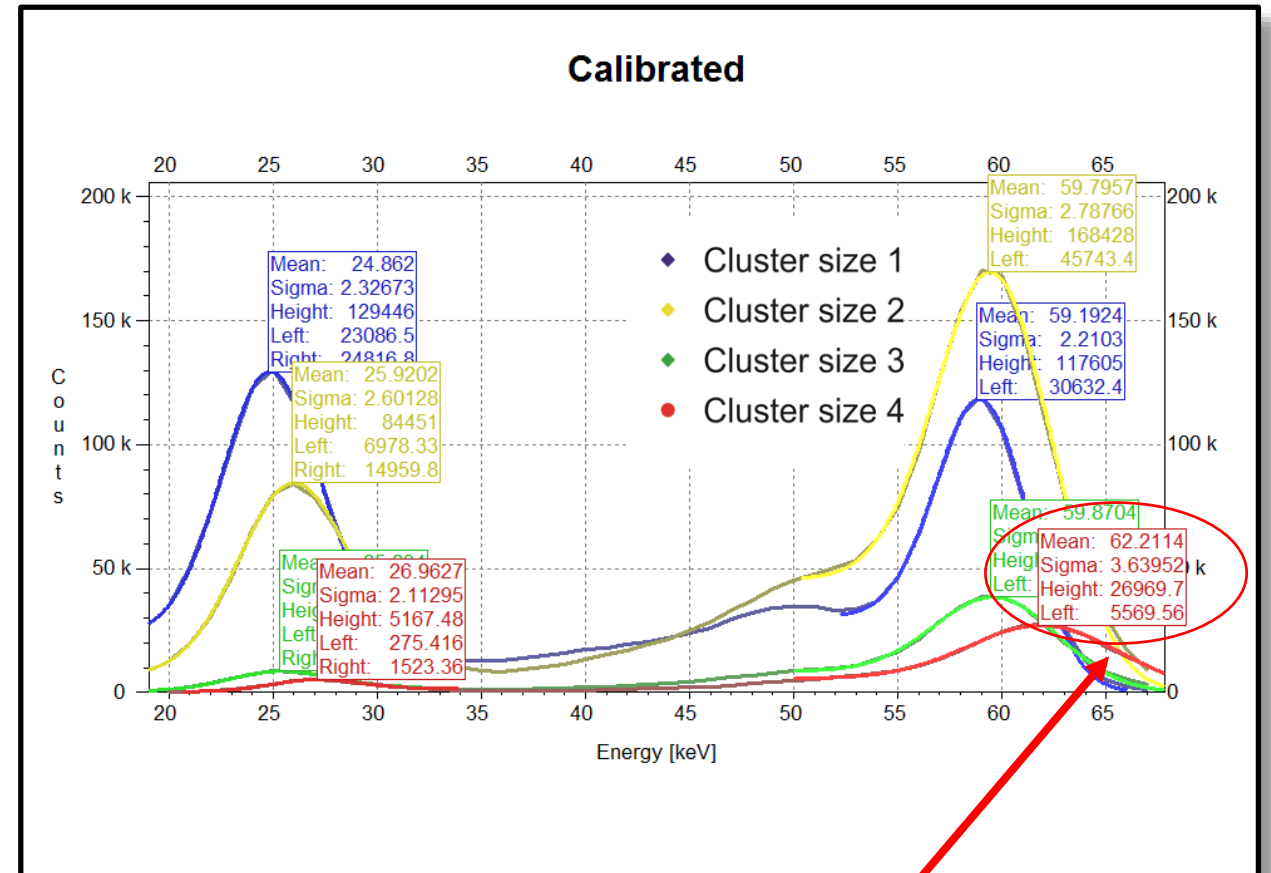
Energy Calibration

- A calibration laboratory was constructed at JSC
- The task is to calibrate more than 65k of multichannel analyzers
- Threshold set to 5 keV
- Measure spectrum in each pixel while occupancy is low → no pile up
- Measure for at least 3 points on calibration curve
 - 59.54 keV line from ^{241}Am
 - 25.27 keV fluorescence line from Sn
 - 5.99 keV from ^{55}Fe
- Note: calibration is using photons and thus not clear what a deposited energy in pixel is during calibration (charge sharing effects) → **need of advanced calibration**



Energy Calibration

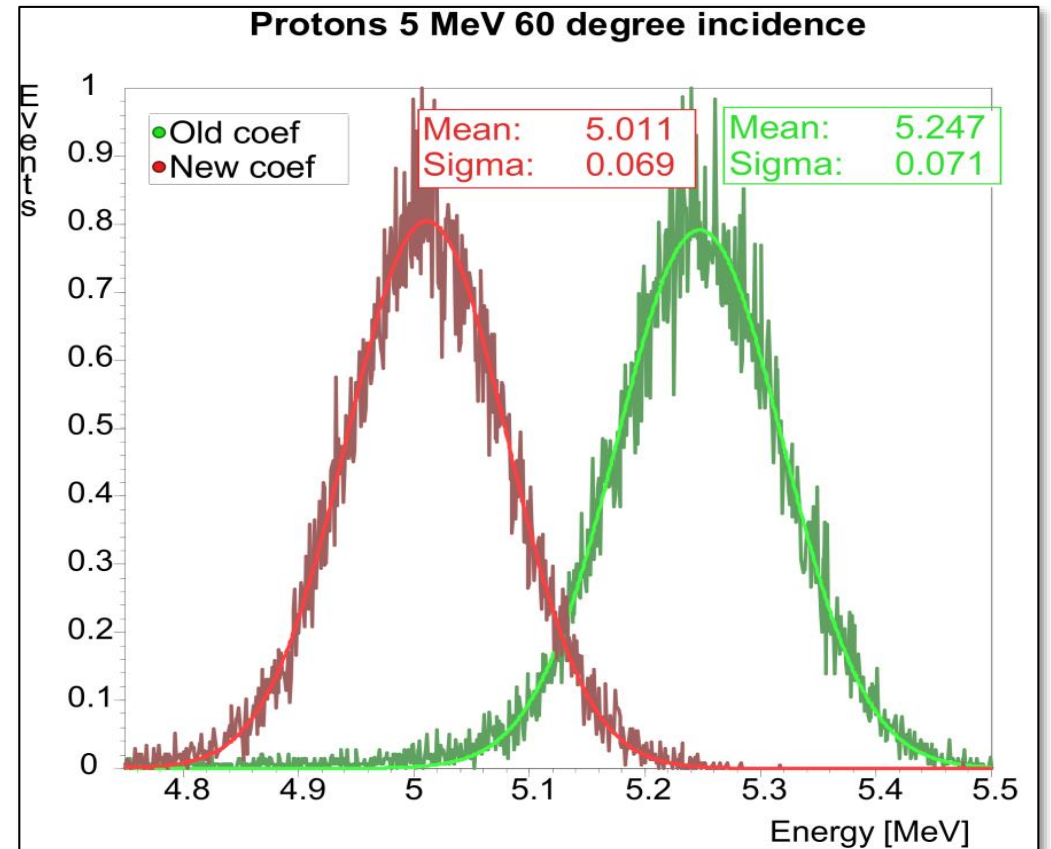
- Due to the detection processes and charge sharing effects the signal from one particle is often detected by several adjacent pixels creating a cluster
- Part of the signal might be lost under threshold
- The complete charge deposited by a particle can then be obtained by summing the signals from all pixels in a given cluster
- Regular calibration shows systematic error caused by difference between incident and measured spectra



Measuring 62 keV for 59.5 keV incident photon

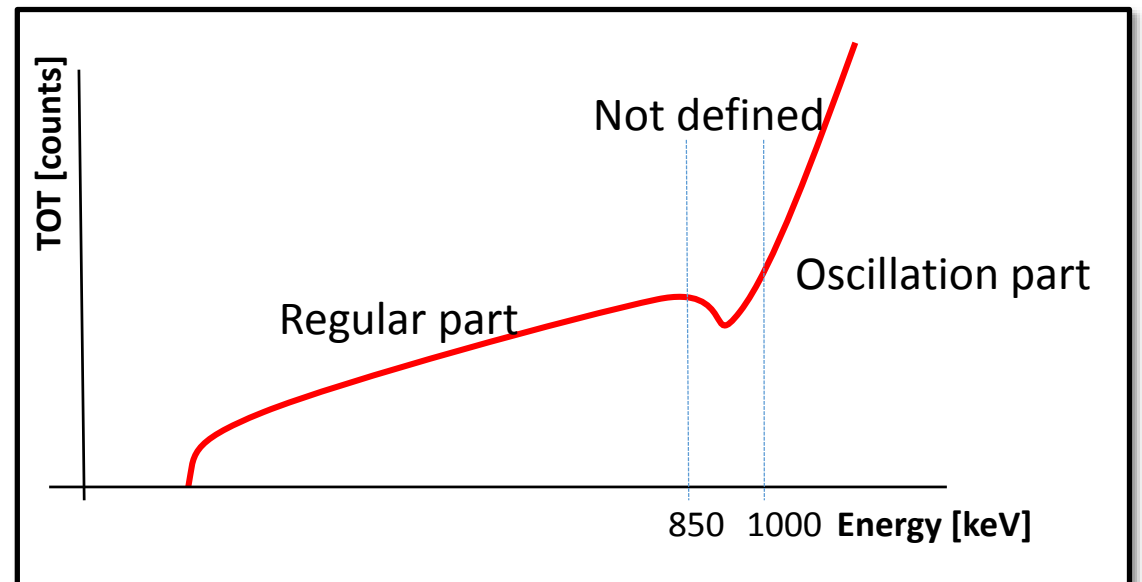
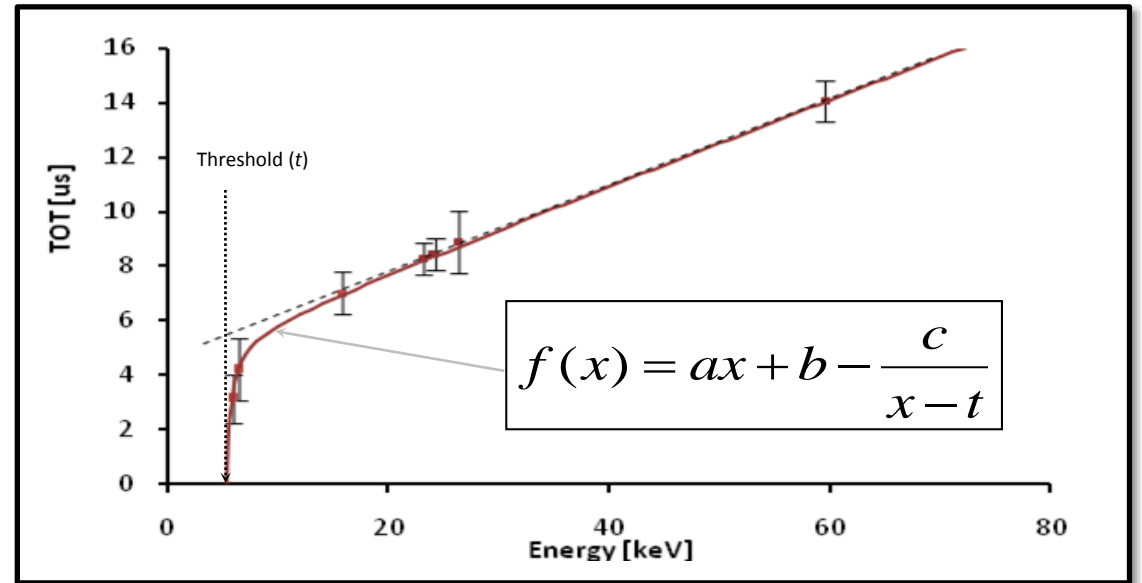
dE

- Using data from TDVG, we were able to correct for charge sharing and verify if our estimated energy deposition from calibration was correct (guess method and simulation)
- New energies for calibration (Fe – 5.998 keV -> 5.58 keV, Sn – 25.27 keV -> 23.56, 59.54 keV -> 56.71 keV) – 500 μm sensor
- Verified by TDVG data where we know exact energy deposited



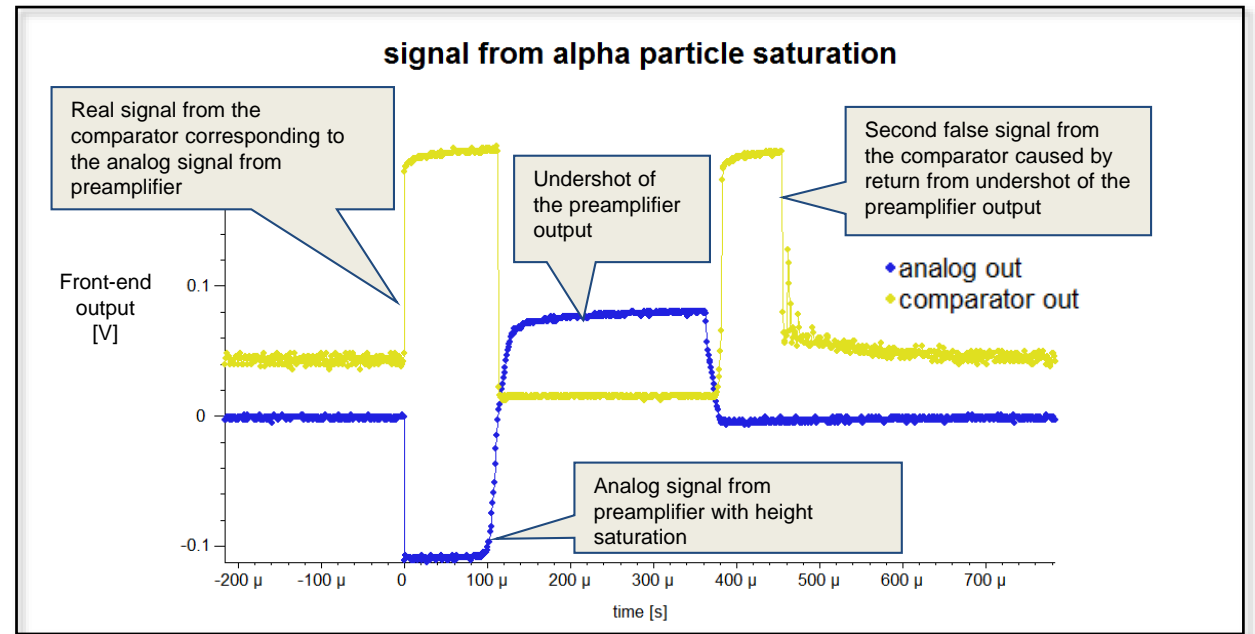
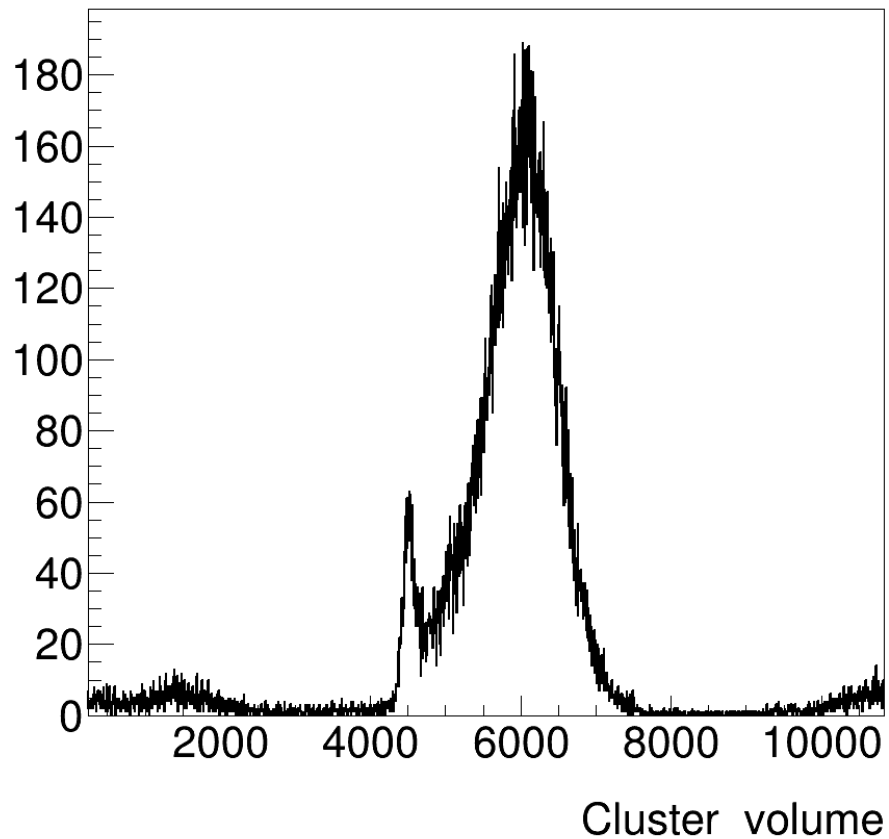
dE, (continued)

- Calibration function measured for each pixel
- Calibration curve more complex than thought
- Not defined for energies around 900 keV



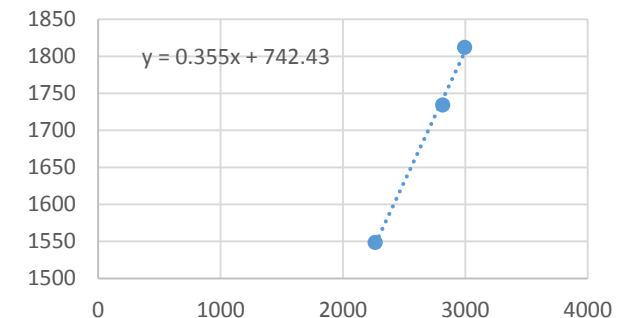
“Saturation”

5.5 MeV, 0 degree incidence, not corrected



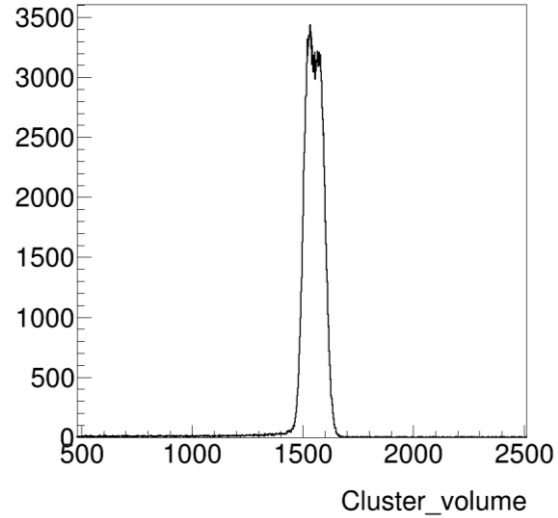
Angle	Volume	Height	Nominal	Difference	Real height
0	6180.4	2995.3	4997	1183.4	1811.9
10	6079	2816	4997	1082	1734
20	5713.3	2264.7	4997	716.3	1548.4
30					
40					
50					
60	4997	717.6	4997	0	717.6

Corrected using data from stopping particles. Results in a new calibration curve applied if the energy in pixel is higher than 850 keV.

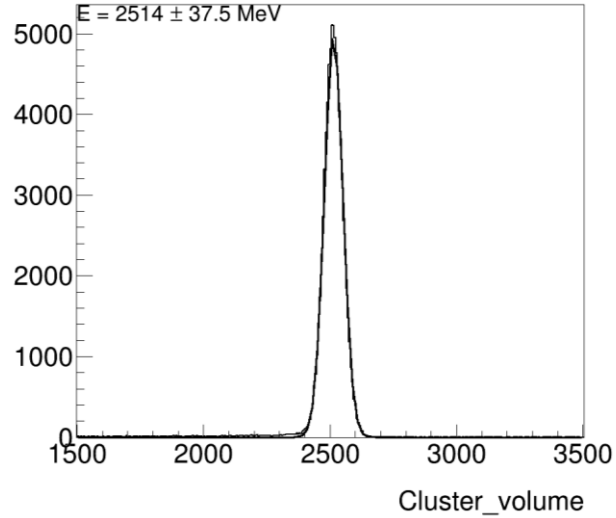


Verification of the Method

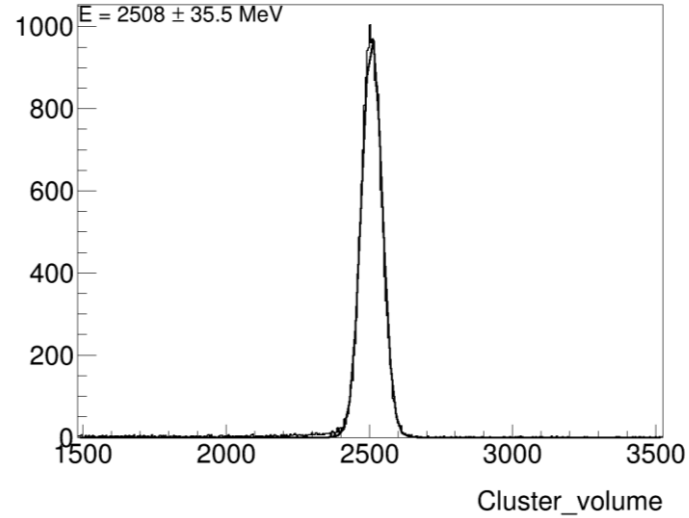
1.5 MeV, 0 degree incidence



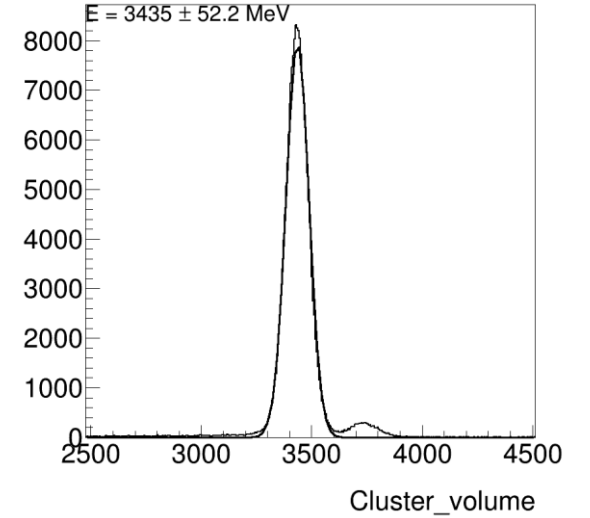
2.5 MeV, 0 degree incidence



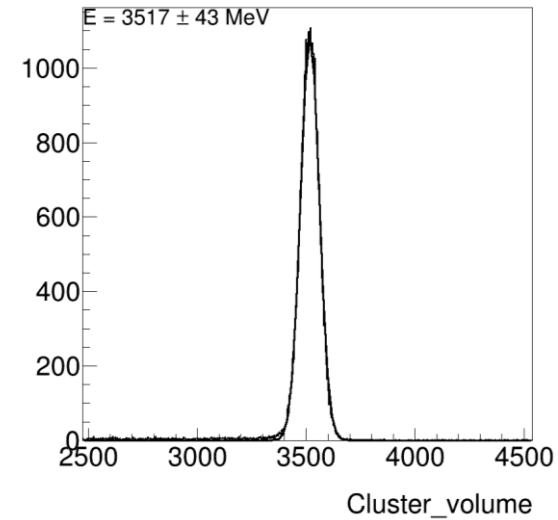
2.5 MeV, 60 degree incidence



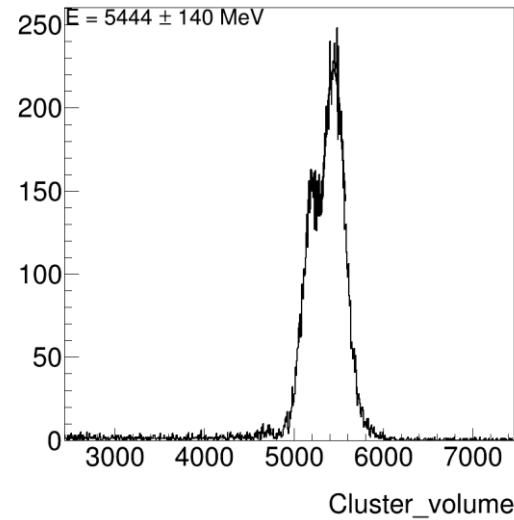
3.5 MeV, 0 degree incidence



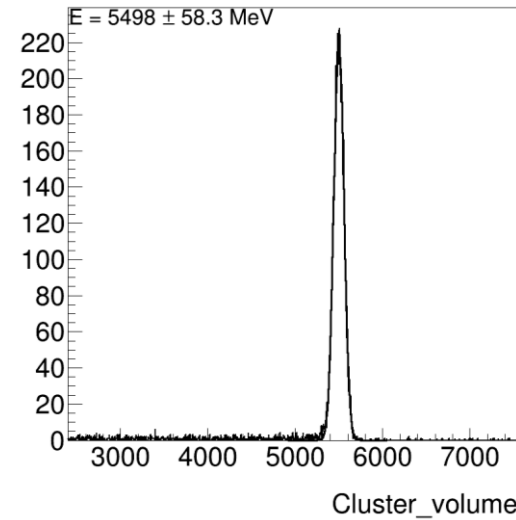
3.5 MeV, 60 degree incidence



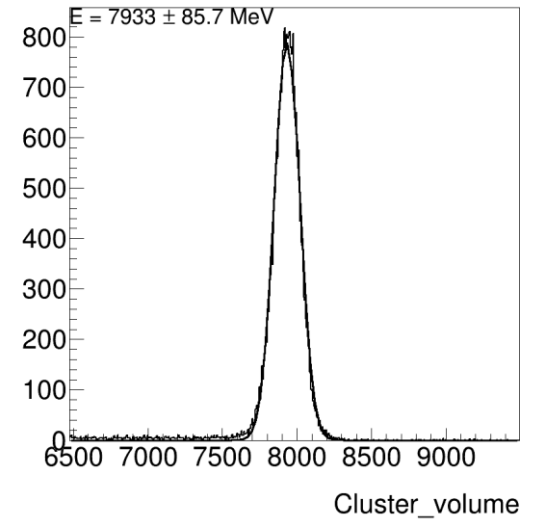
5.5 MeV, 0 degree incidence



5.5 MeV, 60 degree incidence



8 MeV, 60 degree incidence



Verification of the Method

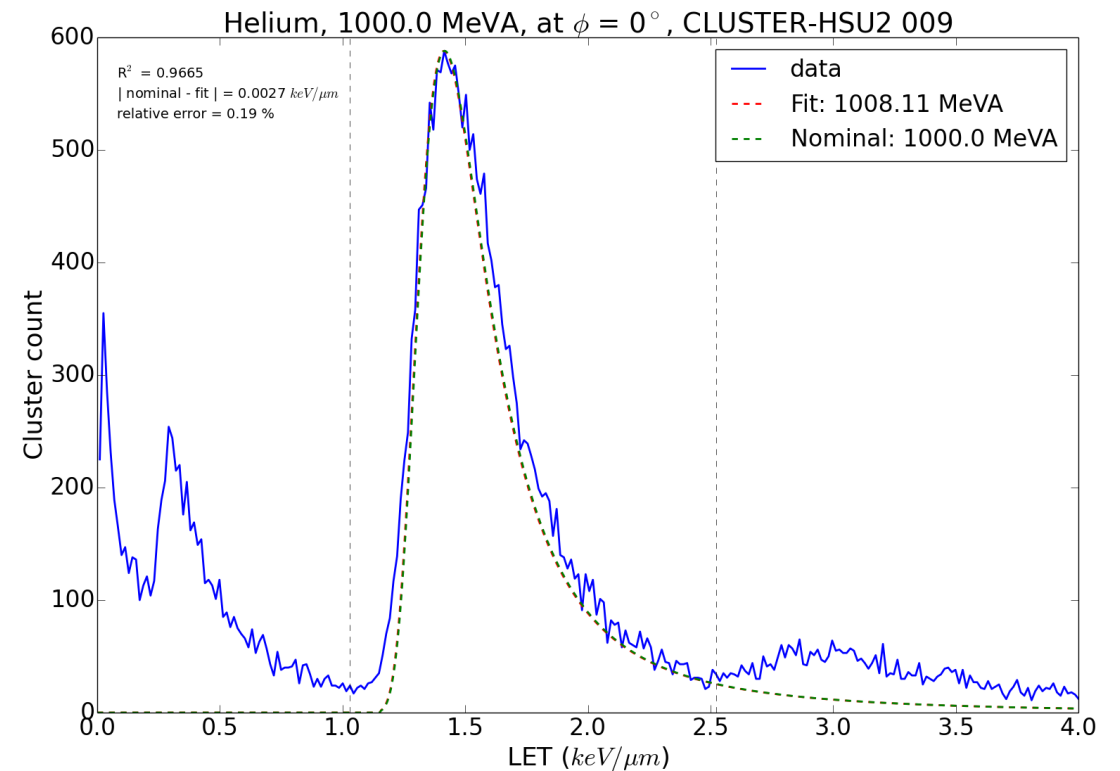
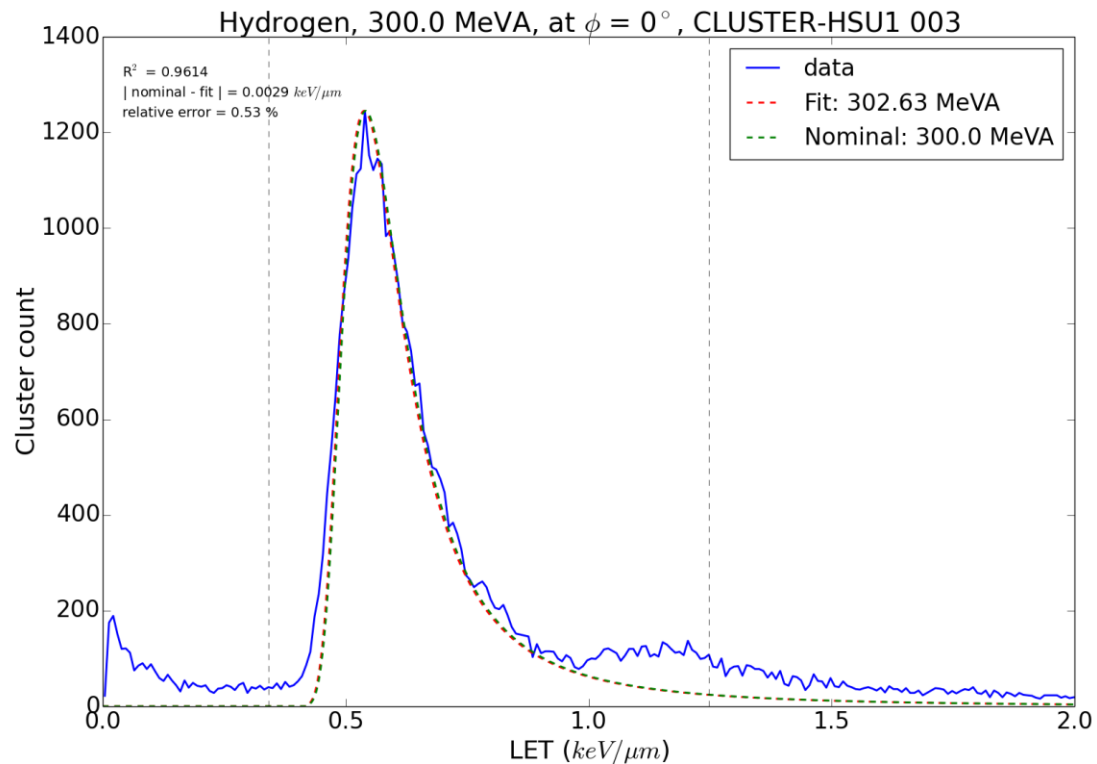
Tested on penetrating and stopping particles from protons to neon. Error reduced in some cases by 90%.

Primary	True energy (MeV/A)	Uncorrected Fit (MeVA)	Corrected Fit (MeVA)	Uncorrected Cluster Height (keV)	Error uncorrected %	Error corrected %
H	480	424.3	478.1	213	-11.6	-0.4
H	180	155.7	168.3	370	-13.5	-6.5
He	400	372.8	416.9	789	-6.8	4.2
He	207.8	197.9	207.9	846	-4.8	0.0
He	113.5	61.6	105.9	933	-45.7	-6.7
H	28	25.4	27.4	1049	-9.3	-2.1
C	180	105.2	174.3	4415	-41.6	-3.2
O	430	200.4	418.9	4500	-53.4	-2.6
Ne	498.4	225.6	543.9	4546	-54.7	9.1

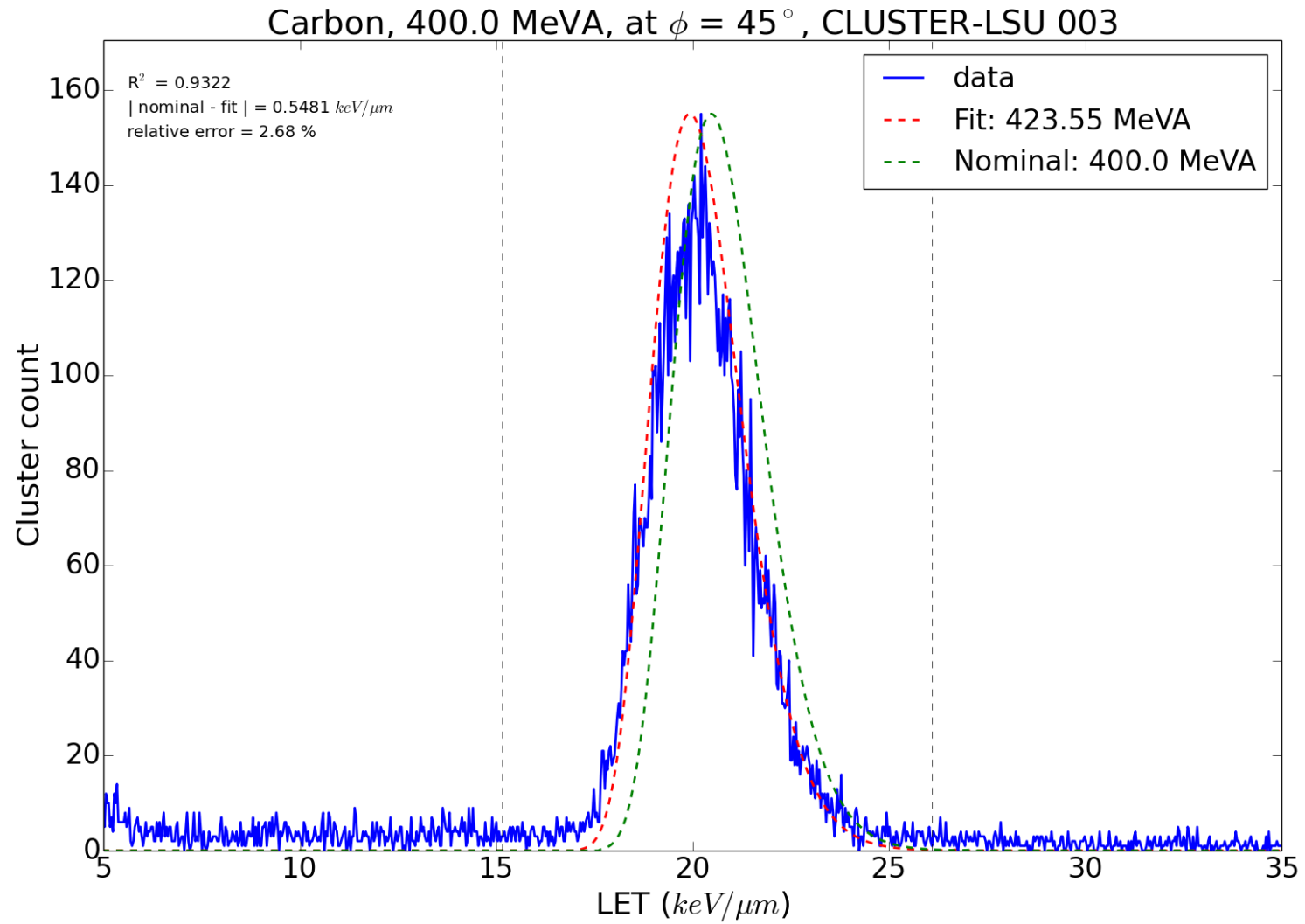
Primary	True energy (MeV/A)	Uncorrected Fit (MeVA)	Corrected Fit (MeVA)	Uncorrected Cluster Height (keV)	Error uncorrected %	Error corrected %
H	5	5.2	5.0	2272	4.0	0.0
Li	10	12	9.7	2683	20.0	-3.0
Li	12	15.6	11.8	3125	30.0	-1.7

dx

- Using fuzzy logic to calculate polar angle and track length, which corresponds to dx
- Found some issues for parallel tracks – resolved, going to more complex algorithm

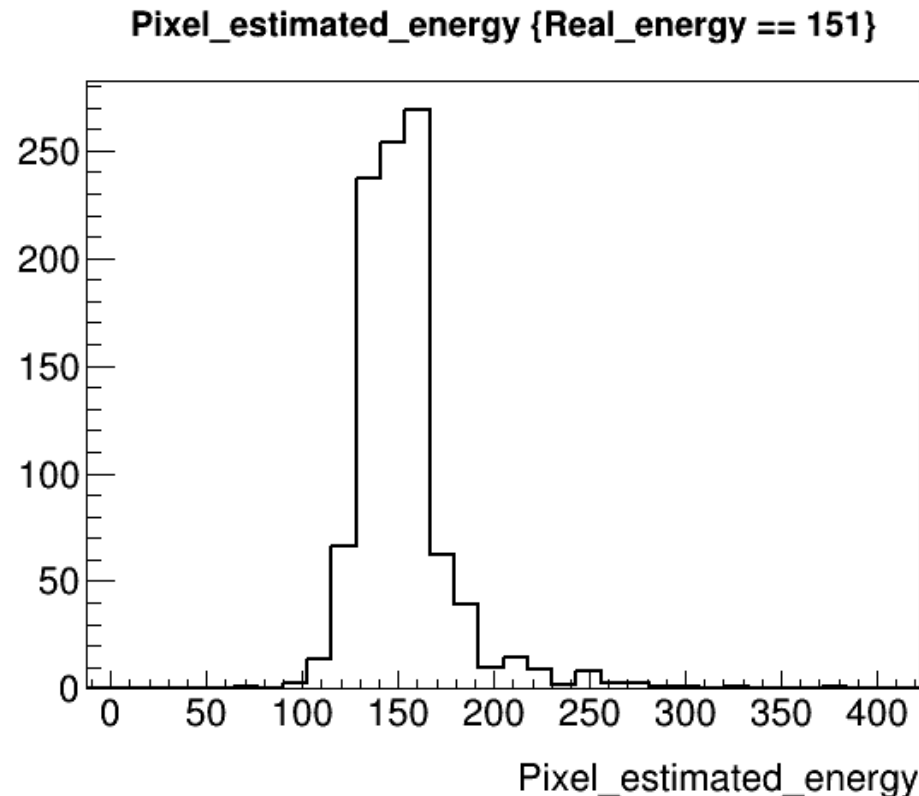


dx



Real Utility: Energy Reconstruction

- Want to use dE/dx measurements for particle ID and energy reconstruction
- Ongoing effort; first results will be published soon



Conclusions

- NASA has very well defined application for Timepix, will continue to work with it
- We are interested in the new chip development, improvements on front-end, TOA, low-power mode
- We plan to continue work on energy calibration (volcano effect) and evaluation procedures (thermal studies), simulations (Fluka and Geant4 models), eager to see TPX2
- We publish results of our work and plan to present more on MPX meeting (TPX3 study, advanced calibration, etc.)