Analysis Result of the High-Energy Cosmic-Ray Proton Spectrum from the ISS-CREAM Experiment

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On behalf of the ISS-CREAM Collaboration

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ISS-CREAM Collaboration

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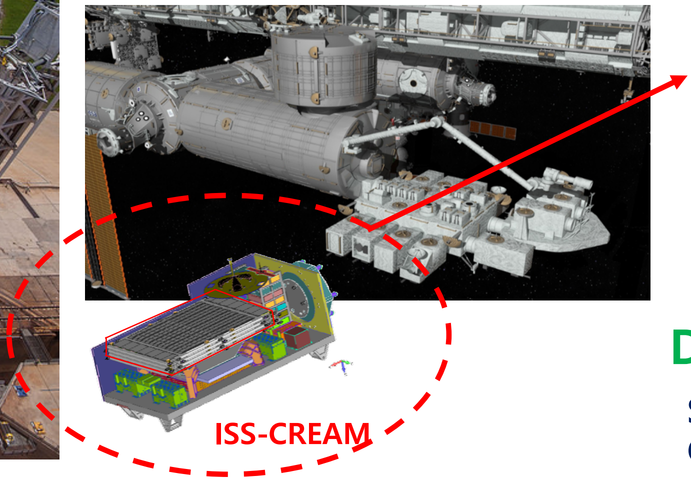
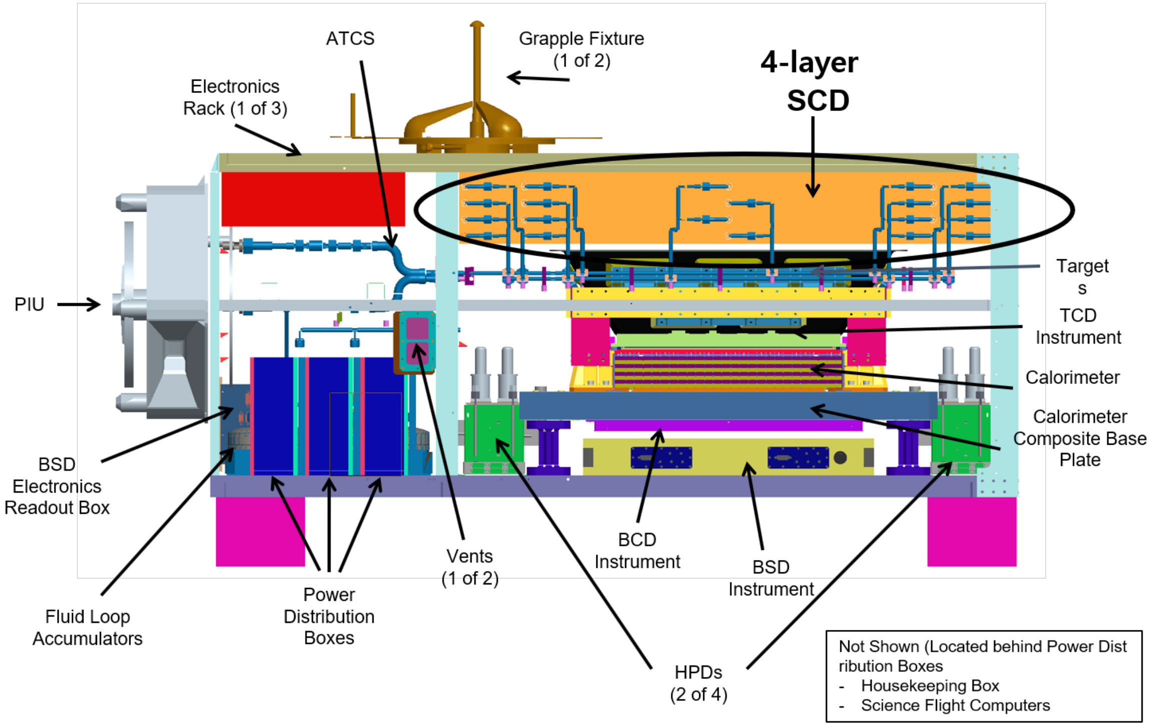
Description of the ISS-CREAM payload

E.S. Seo et al., Cosmic Ray Energetics And Mass for the International Space Station (ISS-CREAM), Adv. in Space Res.,53/10,1451, 2014;





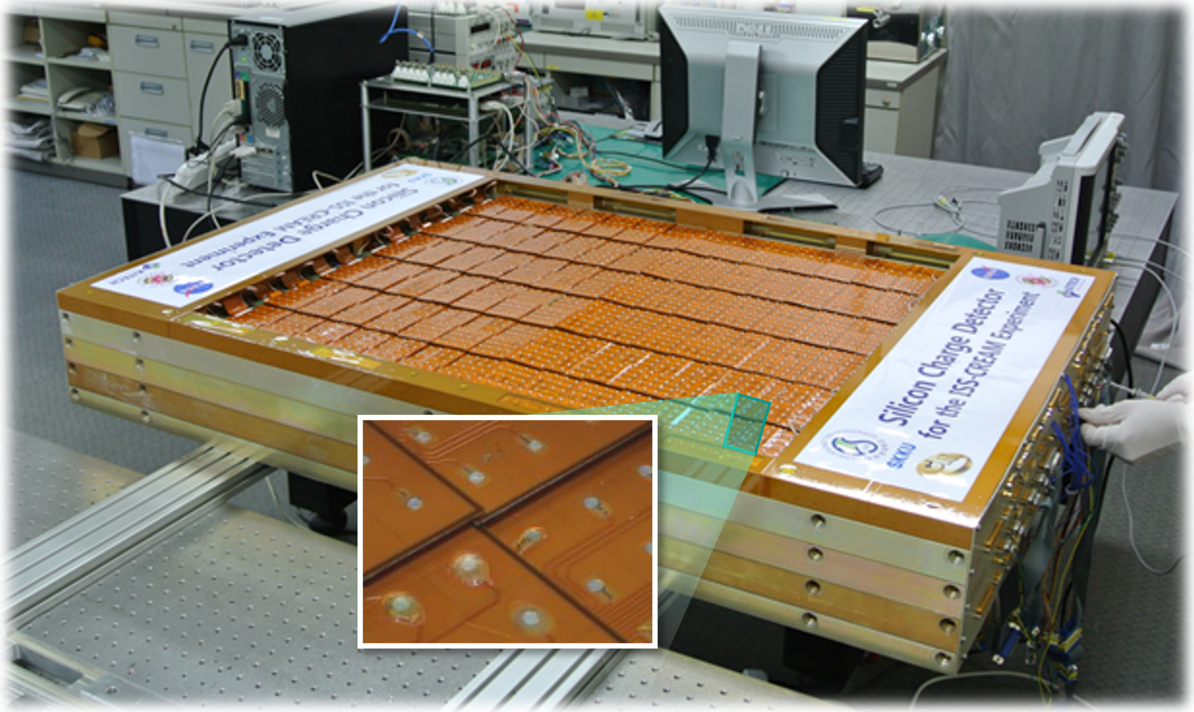
Direct measurement (TeV – PeV)

Silicon Charge Detector (SCD) : Charge measurement, tracking
C-Target & Calorimeter (CAL) : Energy measurement, tracking, trigger
Top/Bottom Counting Detector (TCD & BCD) : e/p separation, trigger
Boronated Scintillator Detector (BSD) : e/p separation by neutron detection

- Launch : Aug. 14, 2017
- Data taken period : Aug. 22, 2017 ~ Feb. 12, 2019 (~ 539 days)
- Design to direct measurement of high-energy cosmic rays

ISS-CREAM – Silicon Charge Detector (SCD)

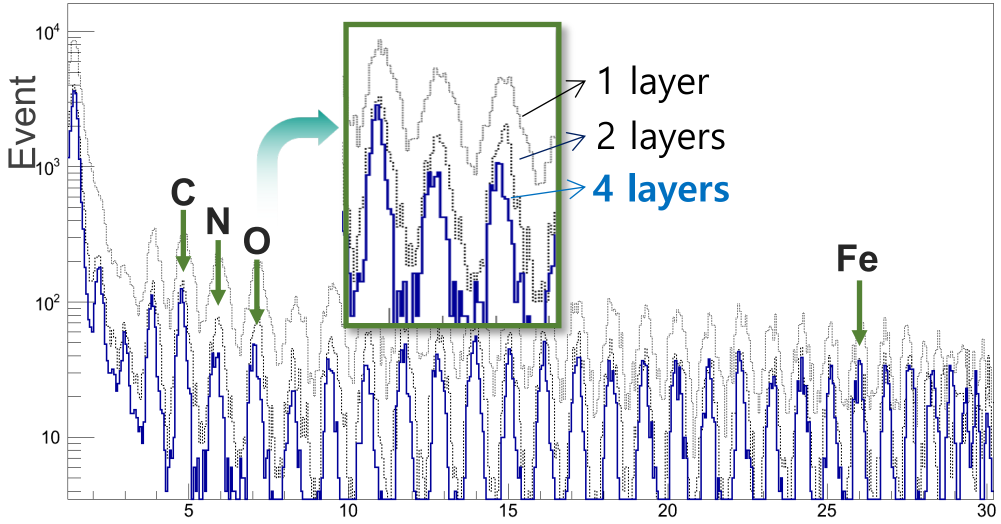
SungKyunKwan University (SKKU)



J. Lee et al., The ISS-CREAM Silicon Charge Detector for identification of the charge of cosmic rays up to Z = 26: design, fabrication and ground-test performance, Astroparticle Physics 112 (2019) 8–15.

Direct measurement of the charge

CERN Beam test results with our 4-layer silicon charge detector



	Charge resolution		
	1 layer	2 layers	4 layers
C	0.21	0.17	0.11
N	0.26	0.21	0.16
O	0.27	0.19	0.15
Average	**0.24**	**0.19**	**0.14**

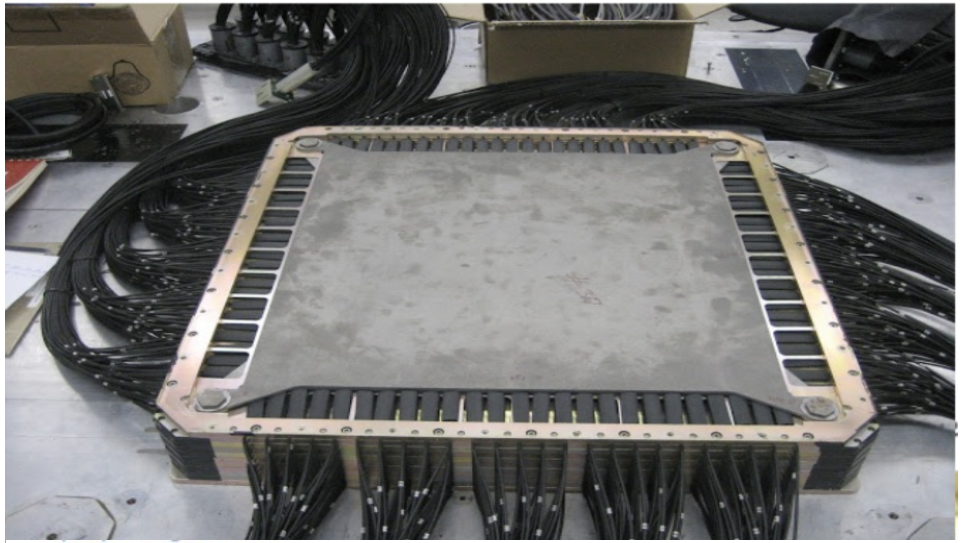
- $dE/dx \propto Z^2$
- Consist four layers with total 10,752 silicon pixels
  (finely segmented ; minimize backscatter effect)
- Silicon pixel size : 1.37 x 1.57 x 0.05 cm^3
- Particle identification : H ~ Fe (Z = 1 ~ 26)

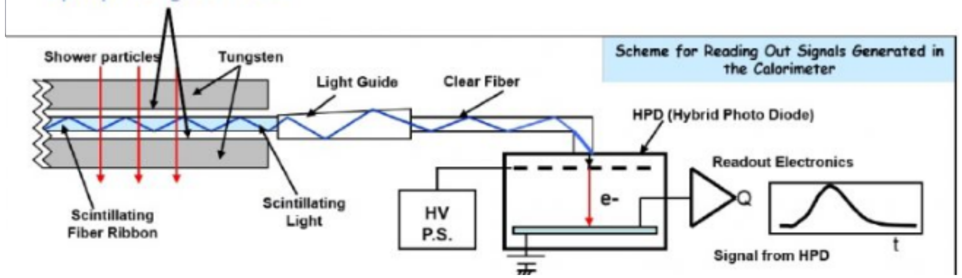
ISS-CREAM - Calorimeter (CAL)

H. S. Ahn et al., The Cosmic Ray Energetics And Mass (CREAM) instrument
Nucl. Instrum. Methods A, 579, 1034, 2007

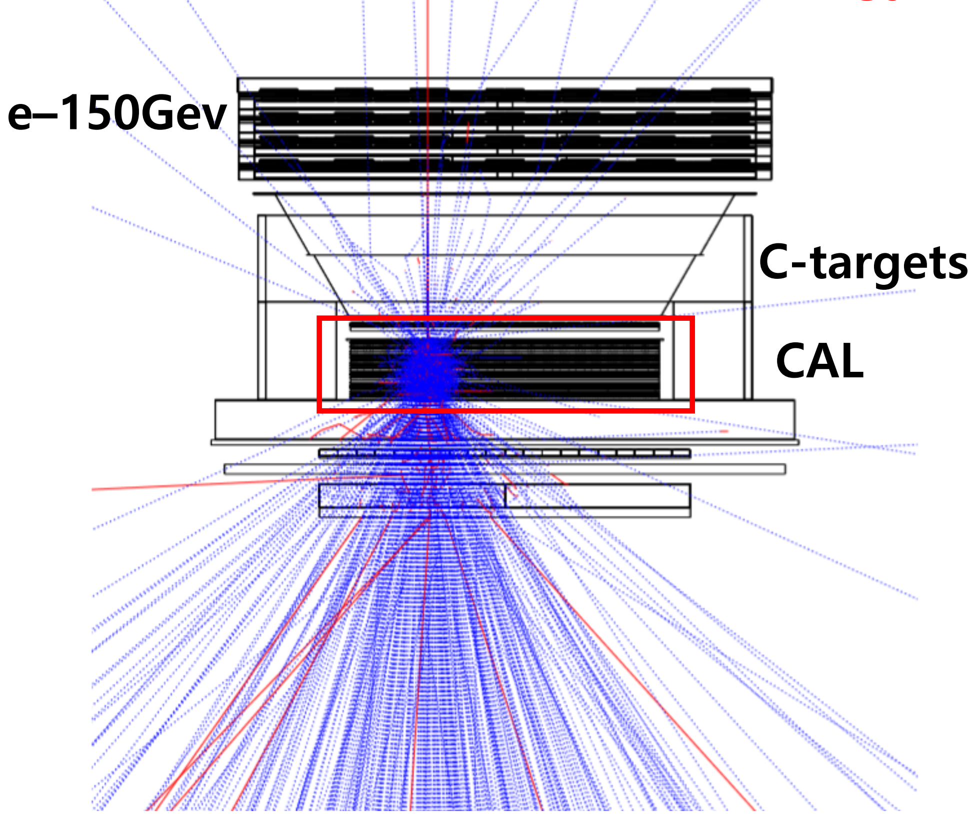
E.S. Seo et al., Result from the Cosmic Ray Energetics And Mass for the International Space Station (ISS-CREAM) experiment, PoS(ICRC2021)095

University of Maryland (UMD)





Direct measurement of the energy



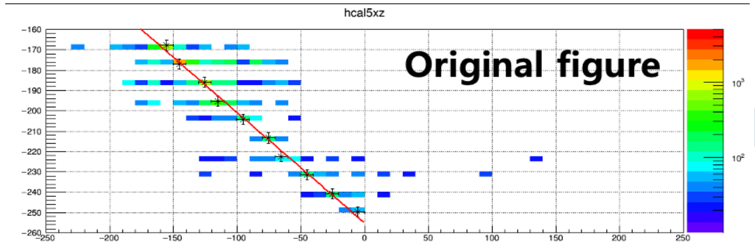
- Carbon targets : induce hadronic interactions -> Showers develop in the CAL
- CAL : 20 layers of alternating tungsten plates and scintillating fibers.
- Determines energy & Provides tracking and trigger

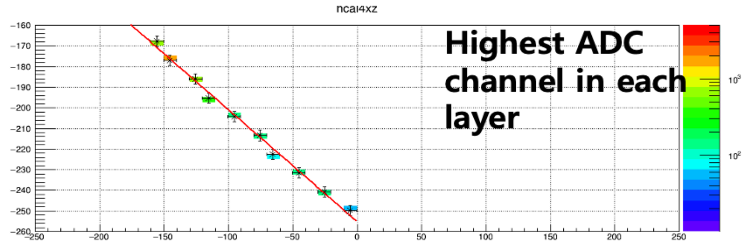
Cosmic-ray tracking (CAL)

With any of physics trigger (6-consecutive layers have hit above threshold as 360 MeV in the CAL)
Satisfied at least 1 channel (CAL ribbon) has over 20 MeV in the CAL (tracking threshold)
Using deposited energy in the CAL

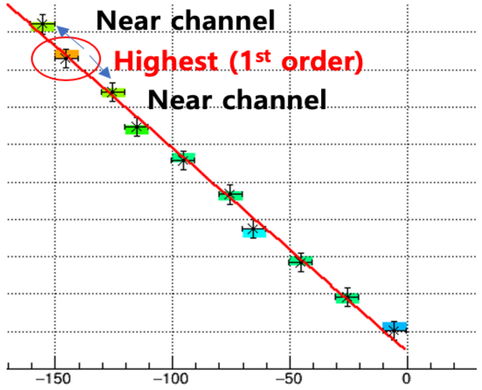
Tracking algorithm

1. Finding highest ADC value channel for each layer

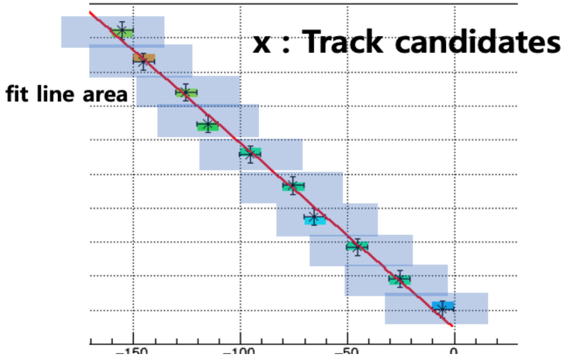




2. Finding highest ADC value for "1" and selecting near two channels

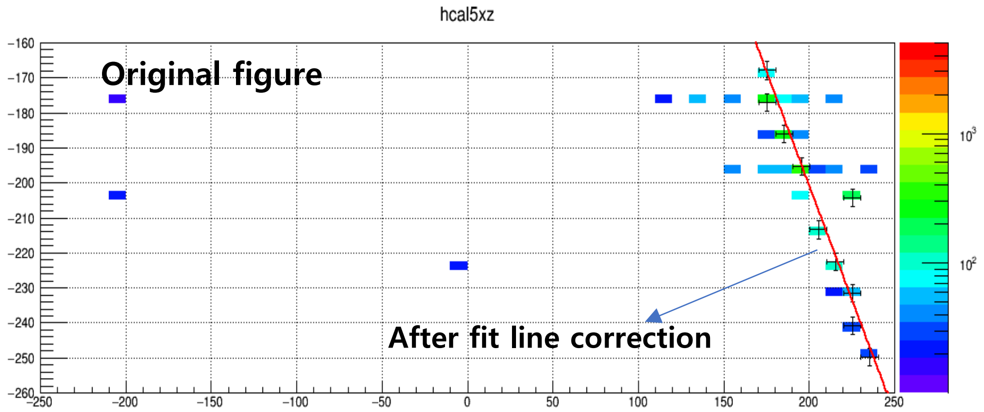


3. Fitting – using 3 channels
=> If highest ADC value channels exist within fit line area (width 3 channels then the channel are selected and fitting.

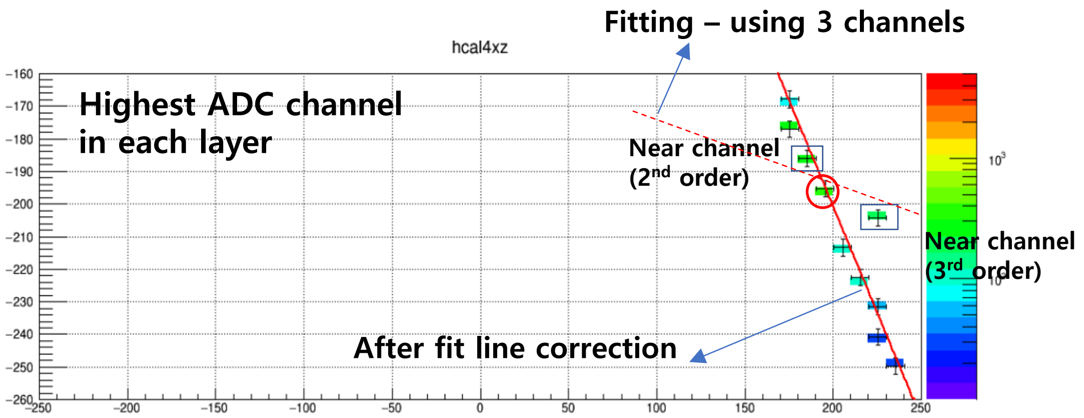


4. **Fit line correction & Noise filtering**

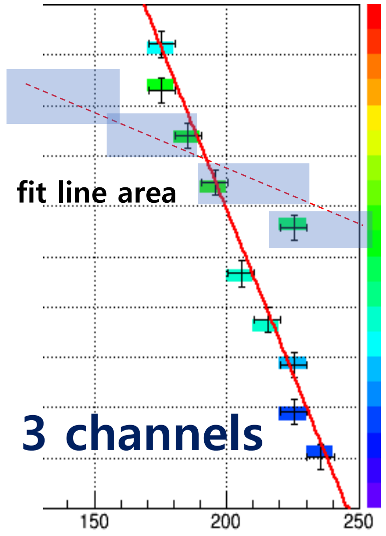
- Using two channels fitting (2nd & 3rd order channels (4))



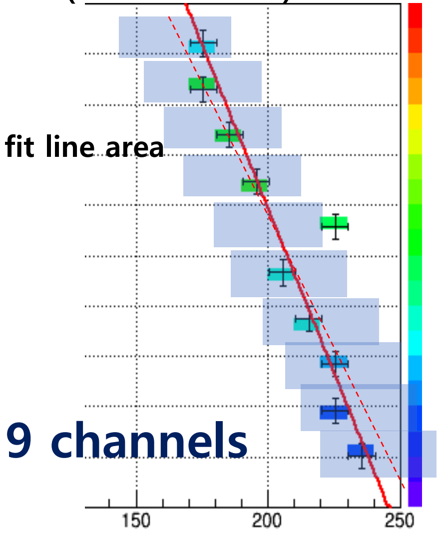
Previous step



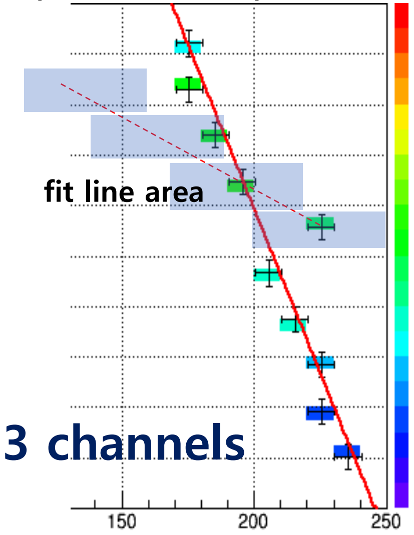
Selected channels using 3 channels within fit line area (1)



Selected channels using 2 channels (1st & 2nd order) within fit line area (2)

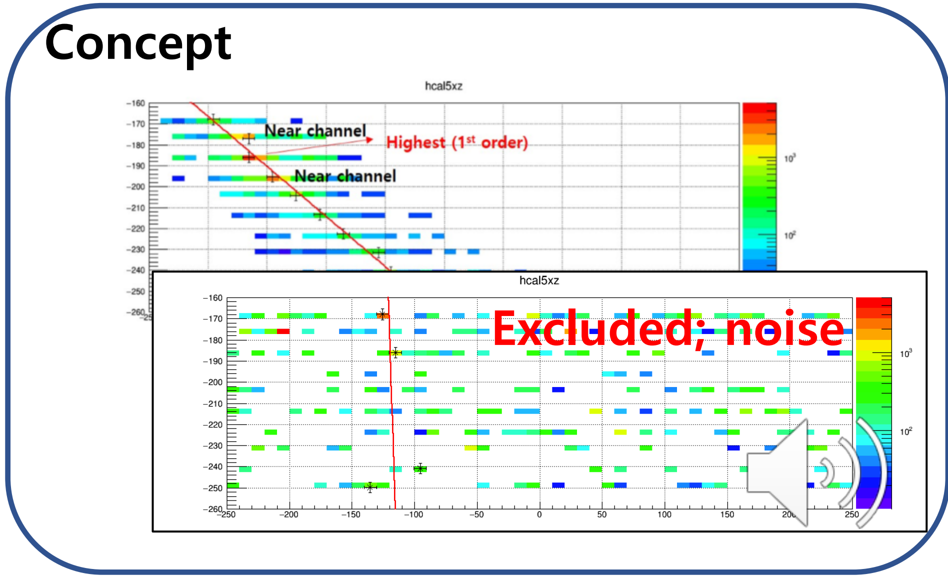


Selected channels using 2 channels (1st & 3rd order) within fit line area (3)



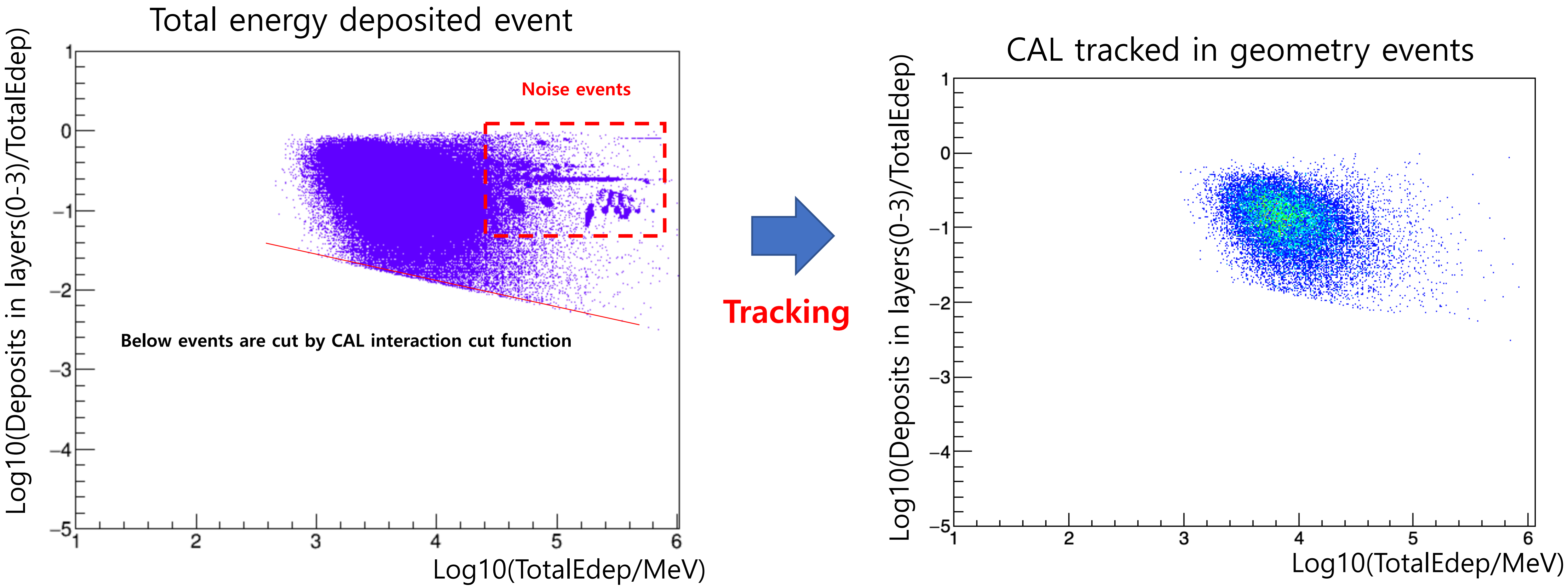
+ Slopes comparison

-> Noise event filtering



Scatter plot of CAL Energy deposit

Y.S. Yoon et al., Proton and Helium Spectra from the First Flight of the CREAM Balloon-Borne Experiment, Doctoral Thesis, University of Maryland, 2010.



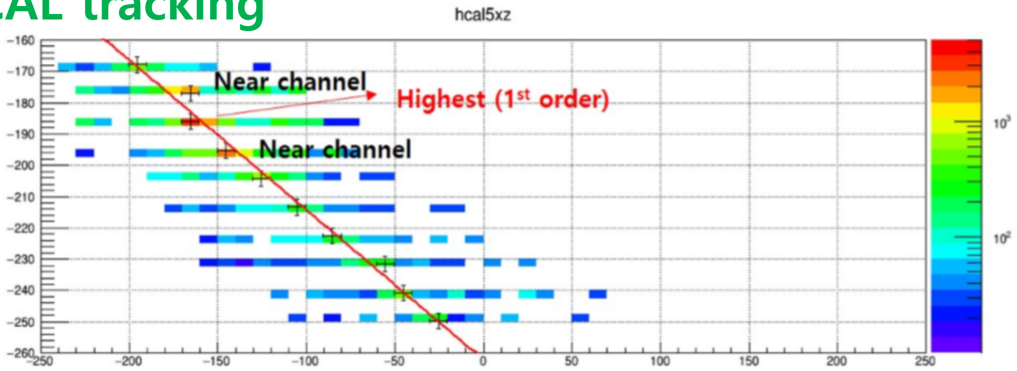
Advantages of this tracking method
- Noisy days don't need to be excluded (may not lose good events)
- Only noisy events are excluded.

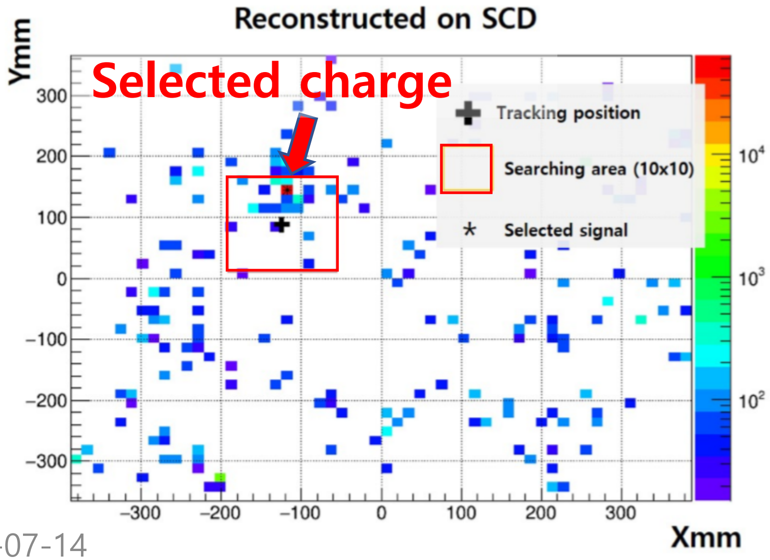
Charge determination

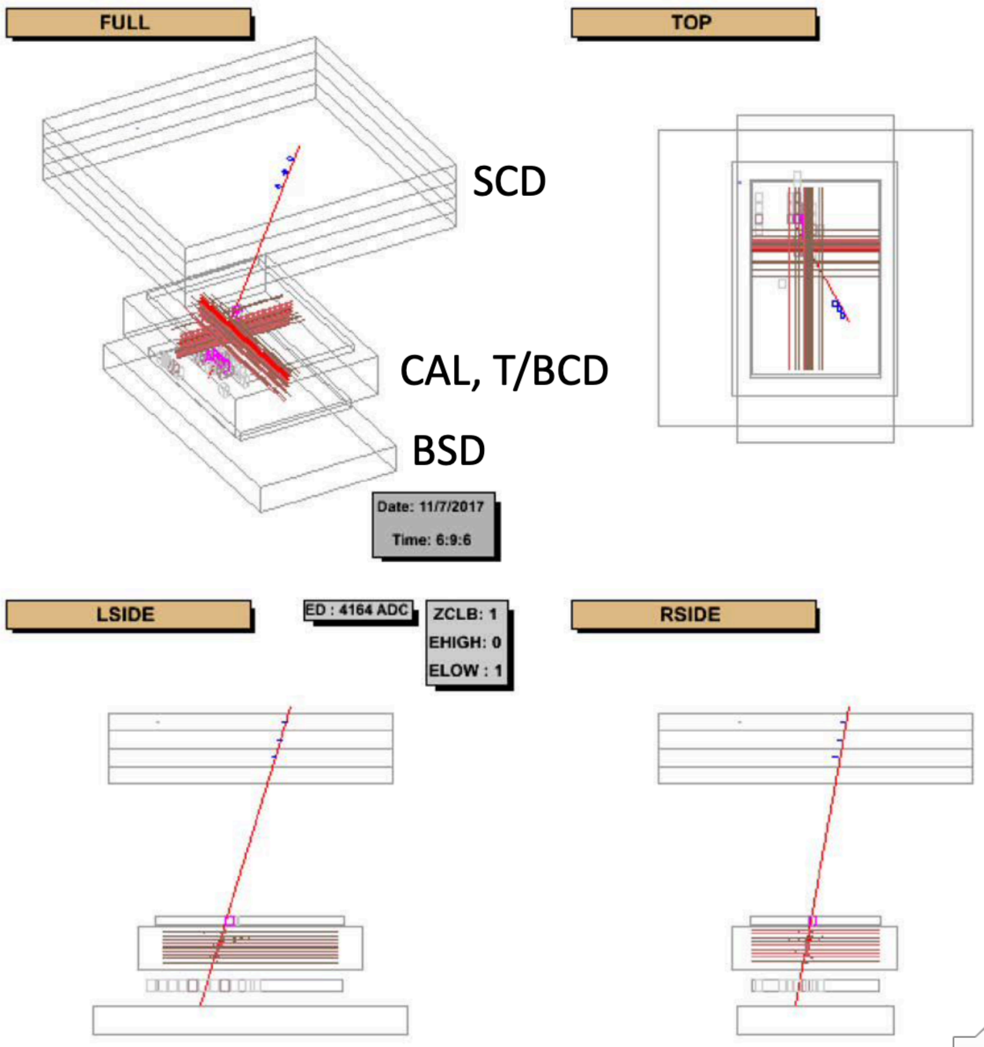
G.H. Choi et al., On-orbit performance of the ISS-CREAM SCD, PoS(ICRC2019)048
R. Takeishi et al., Cosmic-Ray Elemental Spectra Measured with ISS-CREAM, PoS(ICRC2019)140

Cosmic ray tracking

CAL tracking





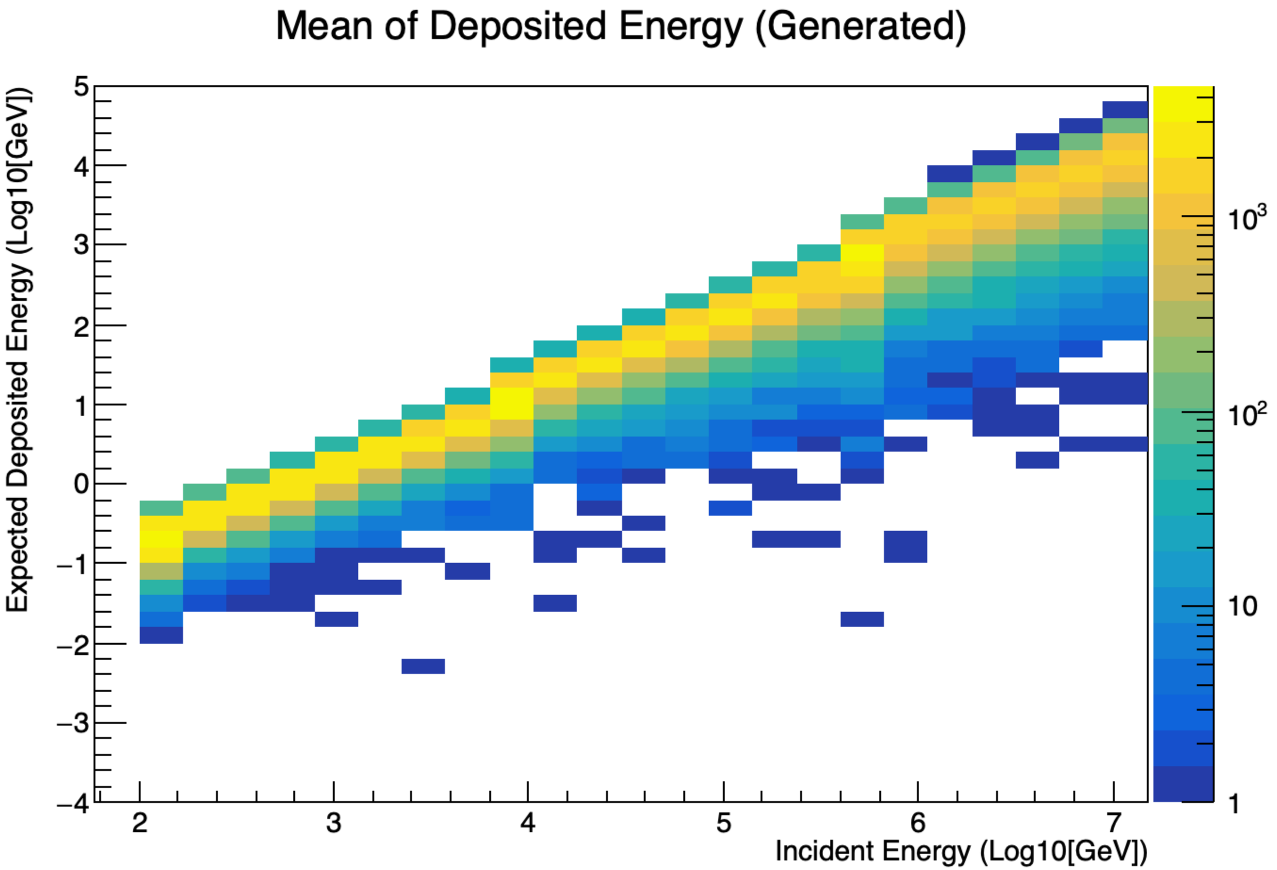


Spectral deconvolution

Y.S. Yoon et al., Proton and Helium Spectra from the First Flight of the CREAM Balloon-Borne Experiment, Doctoral Thesis, University of Maryland, 2010.
J.Wu et al., Monte Carlo Simulations of the ISS-CREAM Instrument, PoS(ICRC2019)154

$$N_{inc,\,i} = \sum_j P_{i,j} N_{dep,\,j},$$

$N_{inc,i}$, in incident energy bin i were estimated from the measured counts $N_{dep,j}$, in deposited energy bin j by the relation
$P_{i,j}$ is the probability



- Correction for the small energy dependence of the energy resolution due to shower leakage
- Deconvolution table was generated by protons MC
- Applied to flight data using Power-law weighted table.

Analysis

Y.S. Yoon et al., Proton and helium spectra from the CREAM-III flight, Astrophys. J. , 839:5, 2017

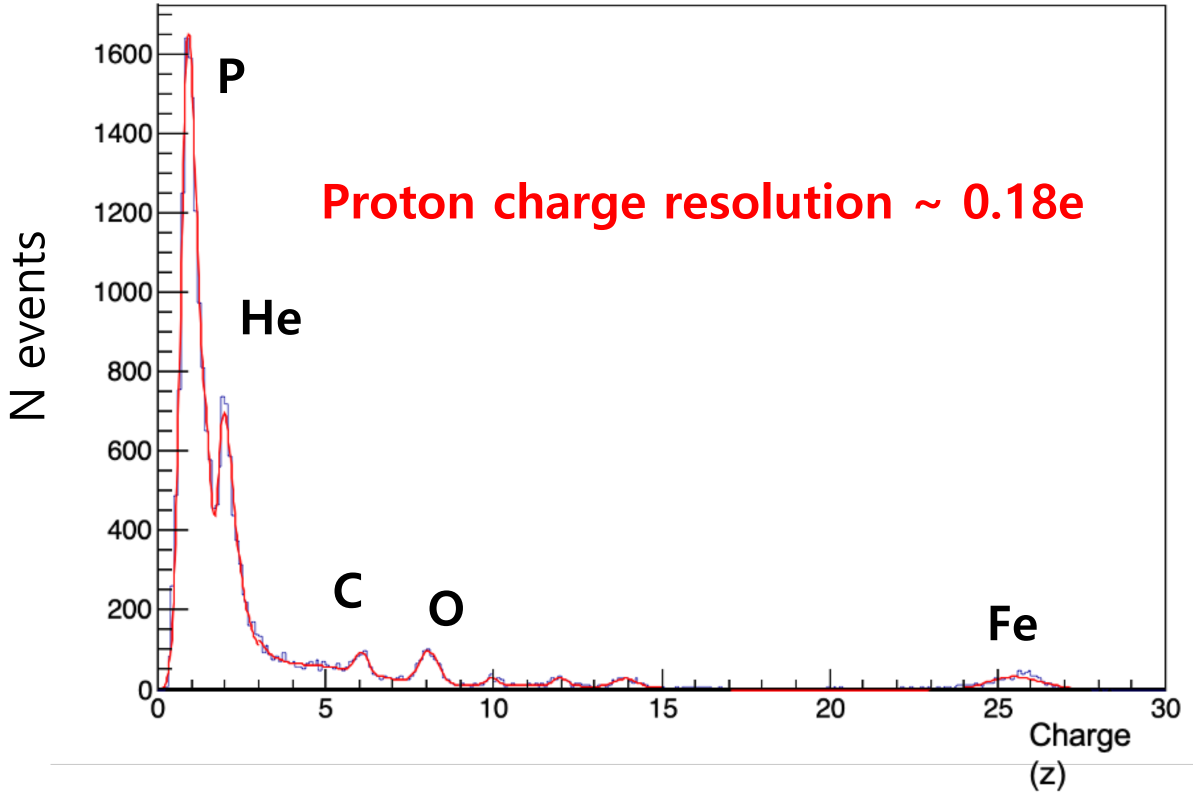
- Data period : 20170822 – 20190212 (all) – live time; ~ 228 days
- Reconstructed energy > 1TeV
- **Proton : 0.7 – 1.7e**

- Absolute flux

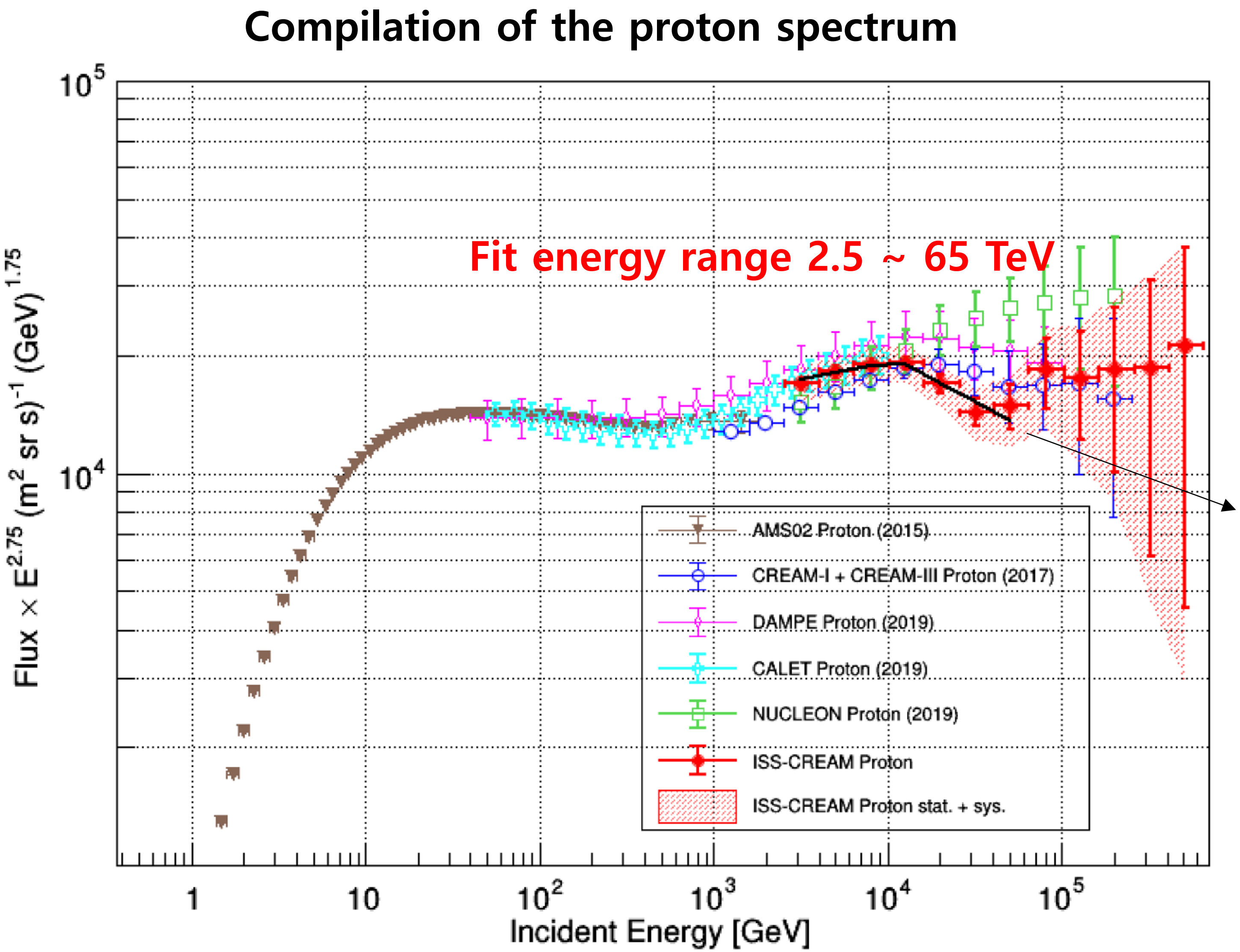
$$F = \frac{dN}{dE} \cdot \frac{(1-\delta)}{GF \cdot \varepsilon \cdot T}$$

ε : Efficiency
GF : Geometry factor
T : Live time
δ : Misidentified charge by backscattered particles

Charge distribution on the top of SCD layer



Result : Proton spectrum



Measured around 2.5 ~ 655 TeV protons data

- Consistence result with the prior CREAM experiment within systematic errors.
- CREAM, DAMPE and NUCLEON observed spectral softens ~ 10 TeV.

Spectral softening ~ 11.9 (± 5.2) TeV with significance 4.62 sigma

; 2.66 (± 0.03) with $\Delta\gamma$ = 0.33 (± 0.07)

$$\Phi(E) = \Phi_0 \left(\frac{E}{E_0}\right)^{-\gamma} \left(1 + \left(\frac{E}{E_b}\right)^{\frac{\Delta\gamma}{\beta}}\right)^{-\beta} \quad (m^2\ sr\ s\ GeV)^{-1}$$

Summary

- The ISS-CREAM experiment successfully measured the cosmic ray data during the mission period.

- The CAL tracking algorithm is excellent working in spectrum analysis.

- Observed protons energy range is 2.5 ~ 655 TeV.

- Our proton spectrum has consistence result with prior CREAM experiment.

- Spectrum softening at around 10 TeV is consistent with the bump-like structure as reported in the CREAM-I+III, DAMPE and NUCLEON.

Acknowledgement

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