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CALETによる陽子，ヘリウムの
エネルギースペクトルの観測の最新結果

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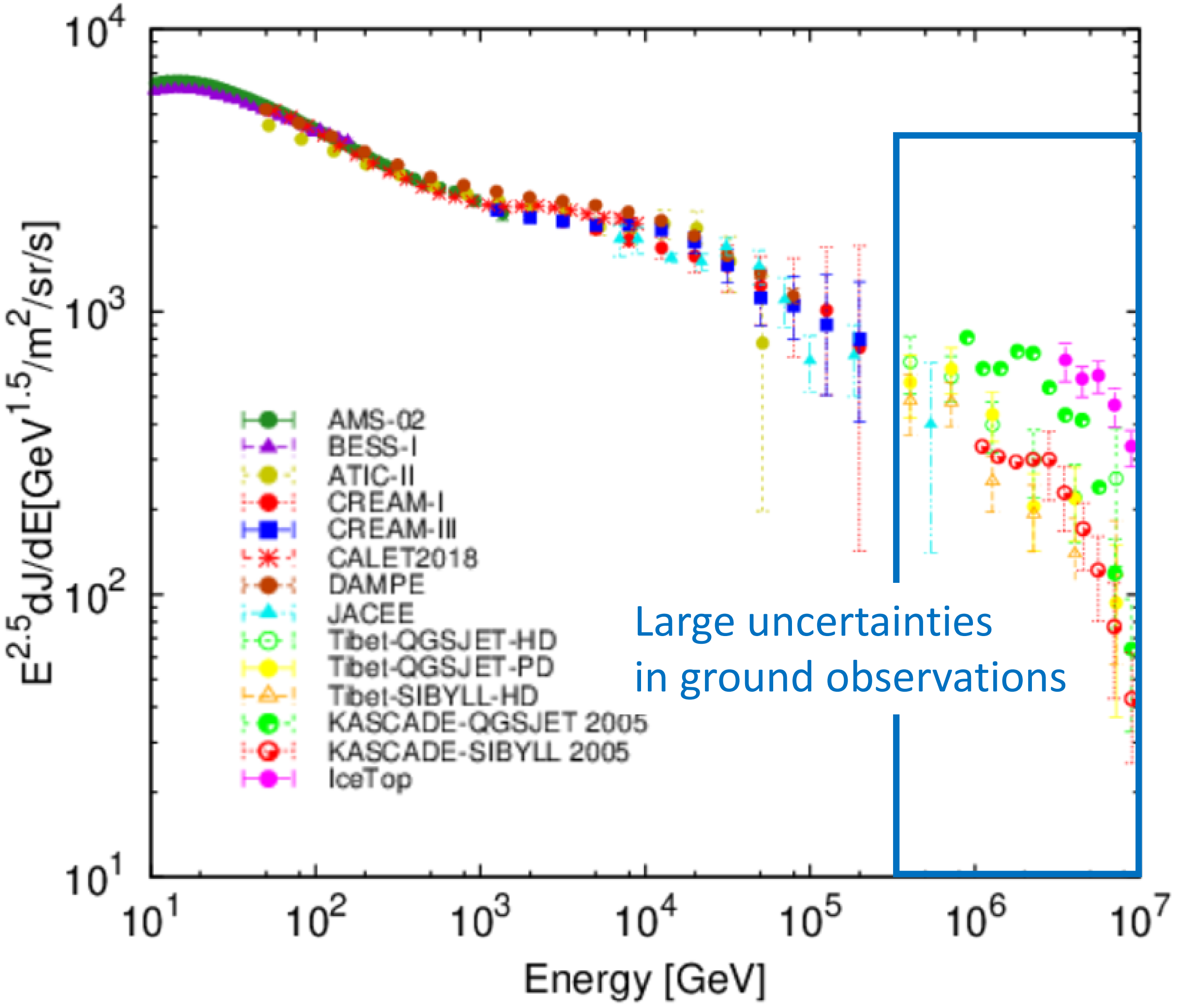
Motivation

- Proton flux hardening has been observed around a few 100GeV region. Also softening was observed by CALET, DAMPE and Balloon Experiments around 10TeV. It is important to determine spectrum hardening and softening parameters in order to understand cosmic ray source, acceleration mechanism, and propagation effects.
- It is also important to determine the flux up to hundreds of TeV by the direct measurements. That would also give a normalization of flux, for ground observations, and help an understanding of the origin of the KNEE in all-particle energy spectrum
- What is the different to the helium?

Proton flux in PRL2019 compared to other direct and ground measurements



Proton spectrum (50GeV<E<60TeV)

proton

$$\Phi(E) = \frac{N(E)}{S\Omega T \Delta E \varepsilon(E)}$$

$\Phi(E)$: proton flux
$N(E)$: number of events in ΔE bin (after background subtraction)
$S\Omega$: geometrical acceptance ($510 cm^2 sr$)
T: livetime
ΔE: energy bin width
$\varepsilon(E)$: detection efficiency

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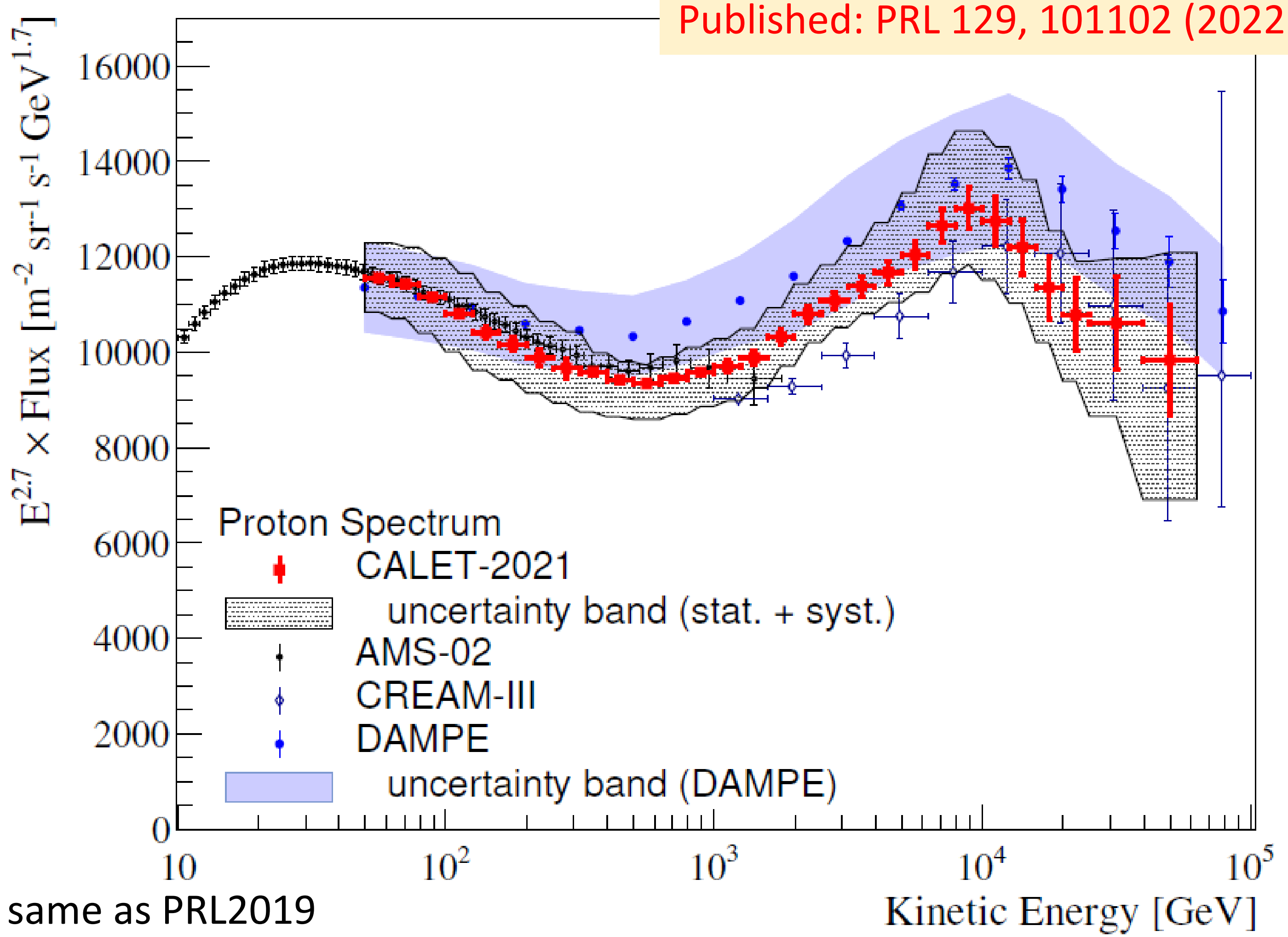
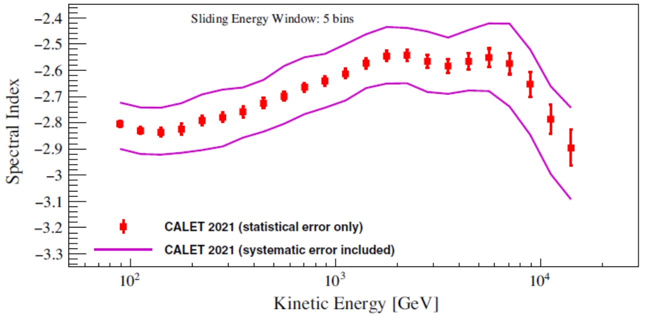
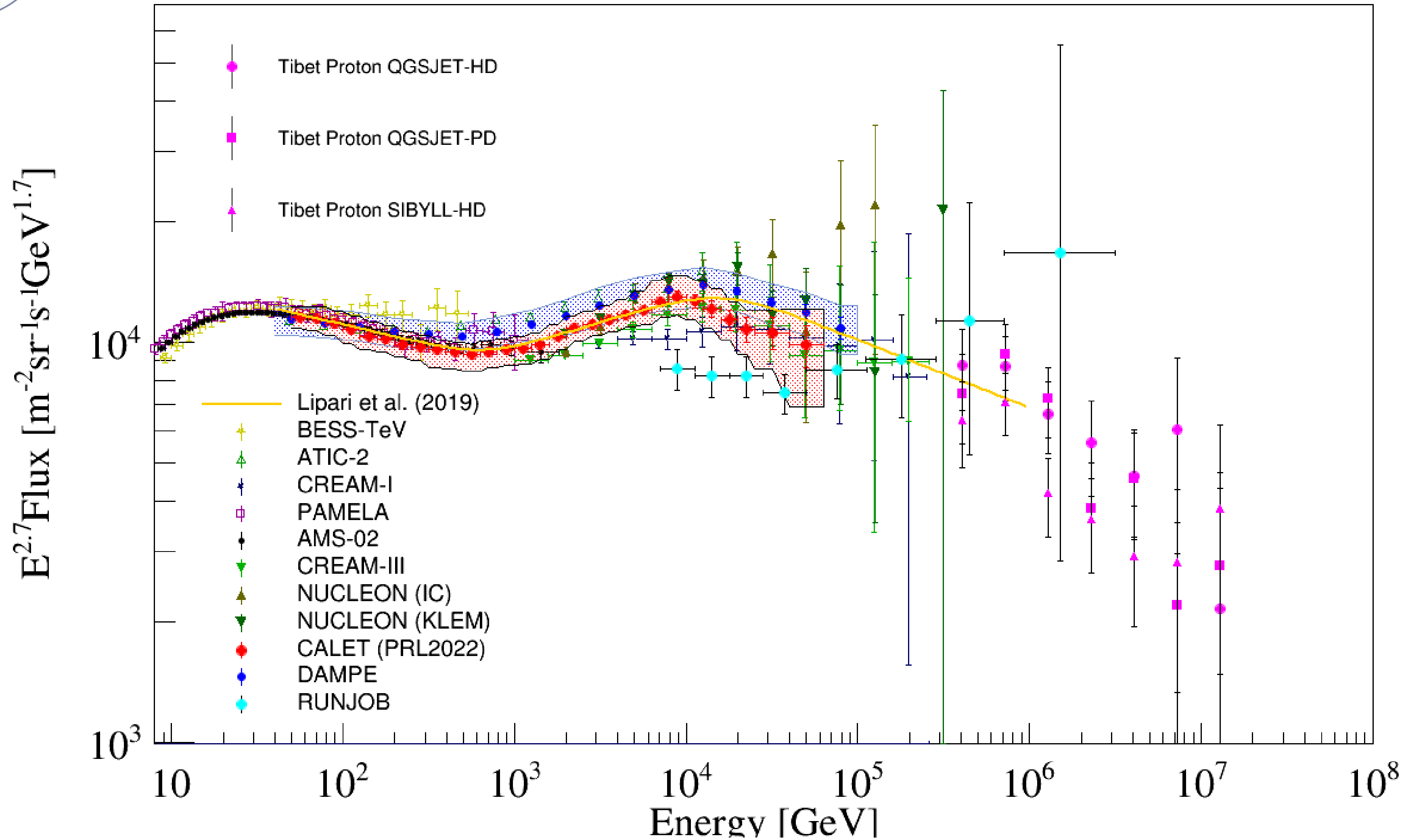


LE: same as PRL2019
HE: 1925 days of live time (Oct. 2015 – Dec. 2021)

- We also observe a spectral softening starting at E~9TeV.
- Two independent analyses with different efficiencies confirm the same result.



Comparison to ground observation

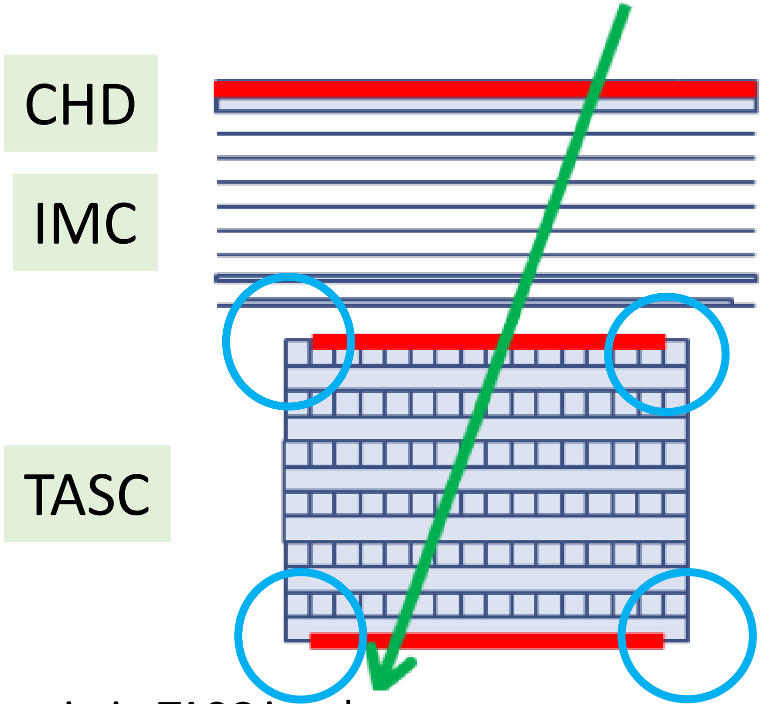


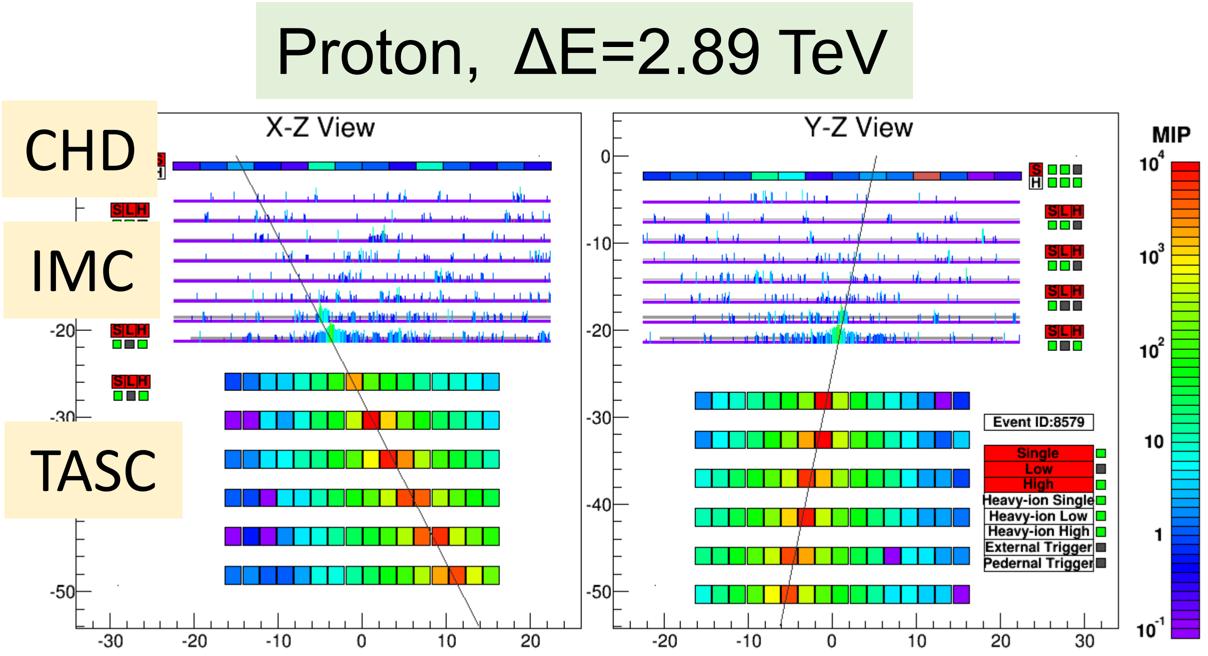
Tibet proton flux is consistent to the extrapolation from CALET data above 10TeV.

Helium event selection

selection	Brief description
1. Event trigger	HE trigger
2. Geometrical acceptance	Track going through the detector from the top to the bottom is selected (see next).
3. Track quality cut	Reliability of Kalman Filter fitting in IMC is checked.
4. Electron rejection	Electron events are rejected using the energy deposit within one Moliere radius along the track.
5. Off-acceptance cut	Residual events crossing the detector from the sides are rejected.
6. Charge identification in CHD and IMC (see later slide)	Charge identification using the energy deposit in CHD and IMC (before shower development starts) is performed to reject proton events, mainly.

Geometrical acceptance and event example

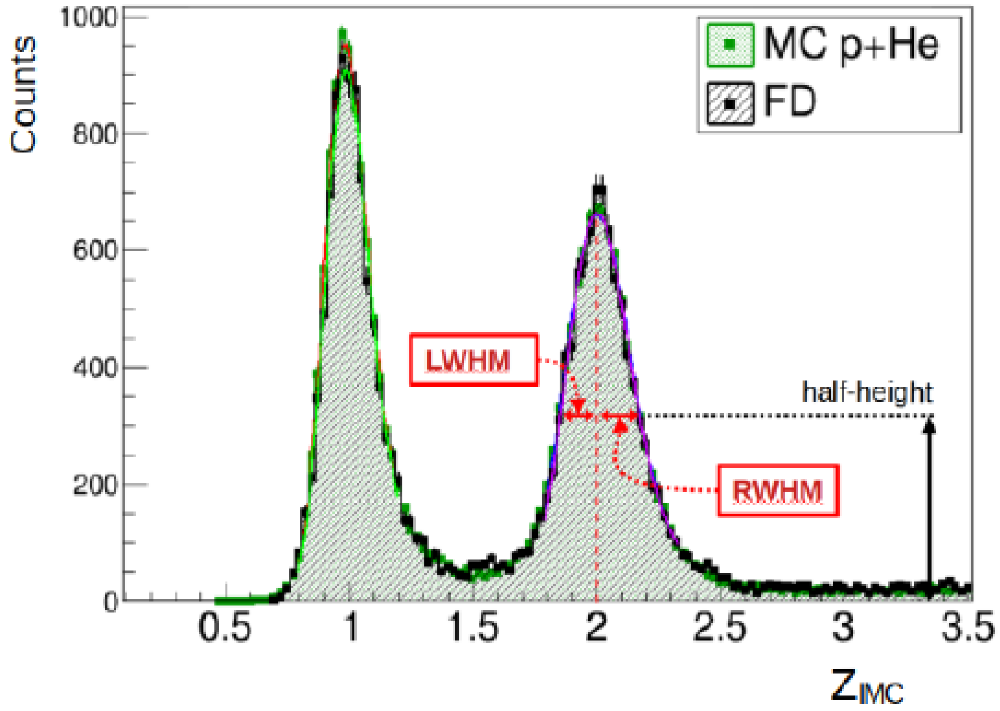


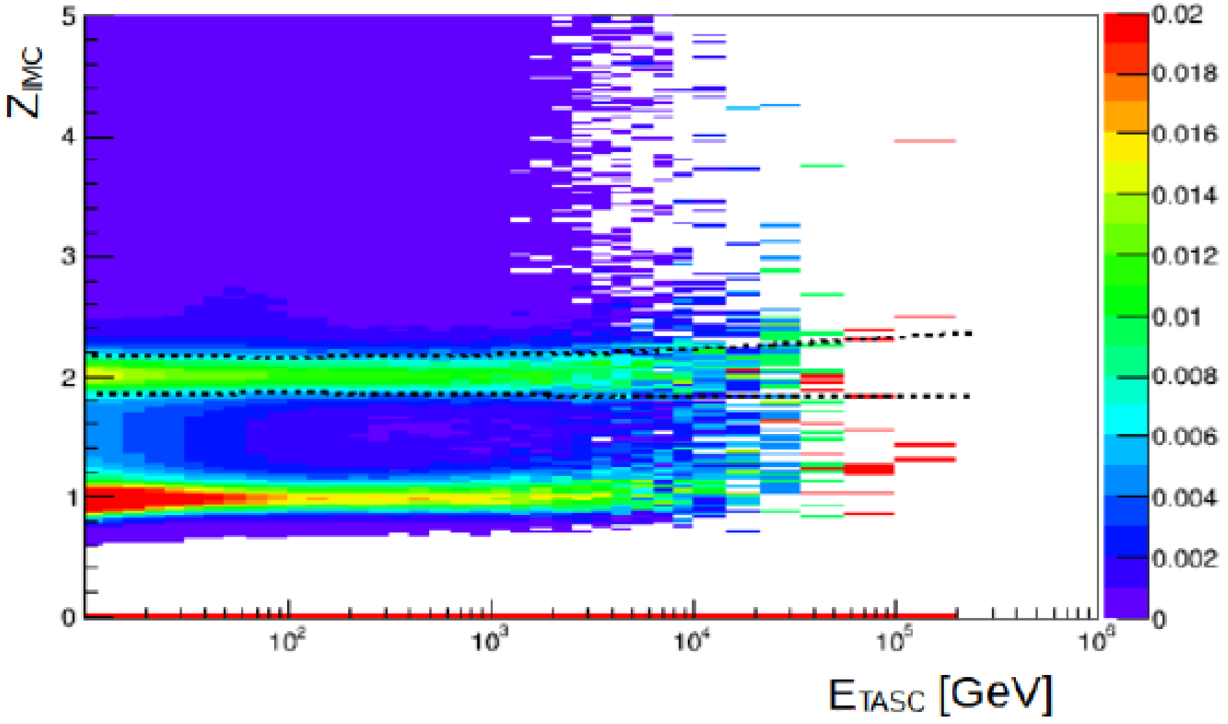


2cm margin in TASC is taken.

- The reconstructed track is required to cross the CHD and TASC from top to bottom.

Charge identification (Helium) in CHD and IMC

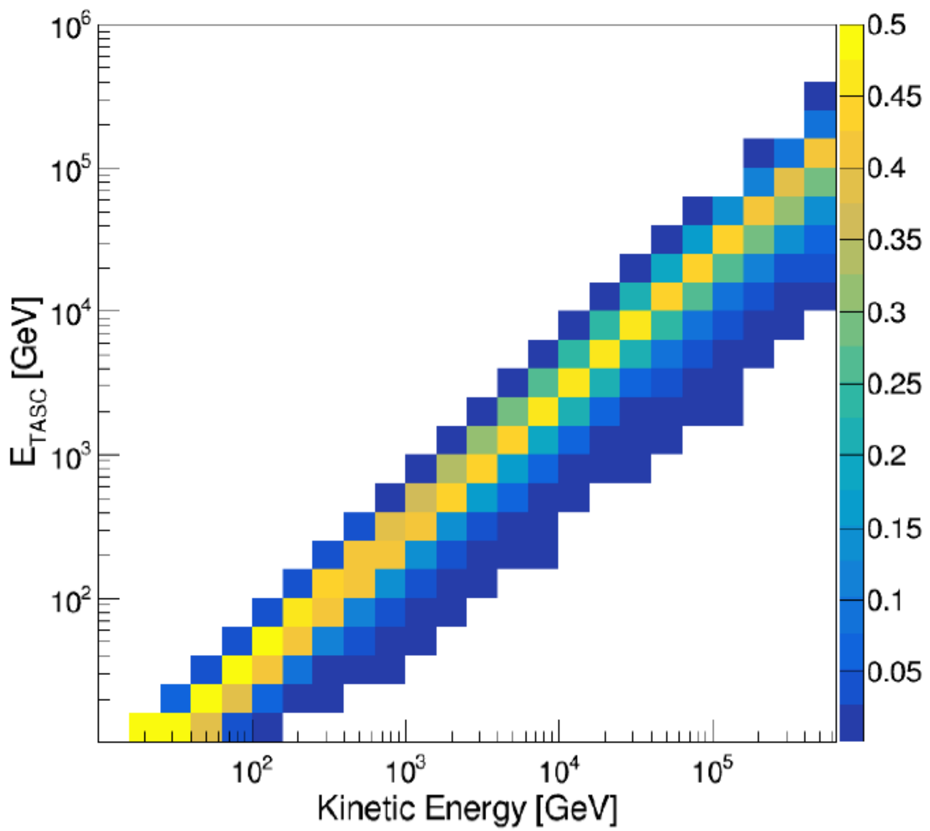




Events with 3xLWHM<Z_{IMC}<5xRWHM are selected.

Energy unfolding

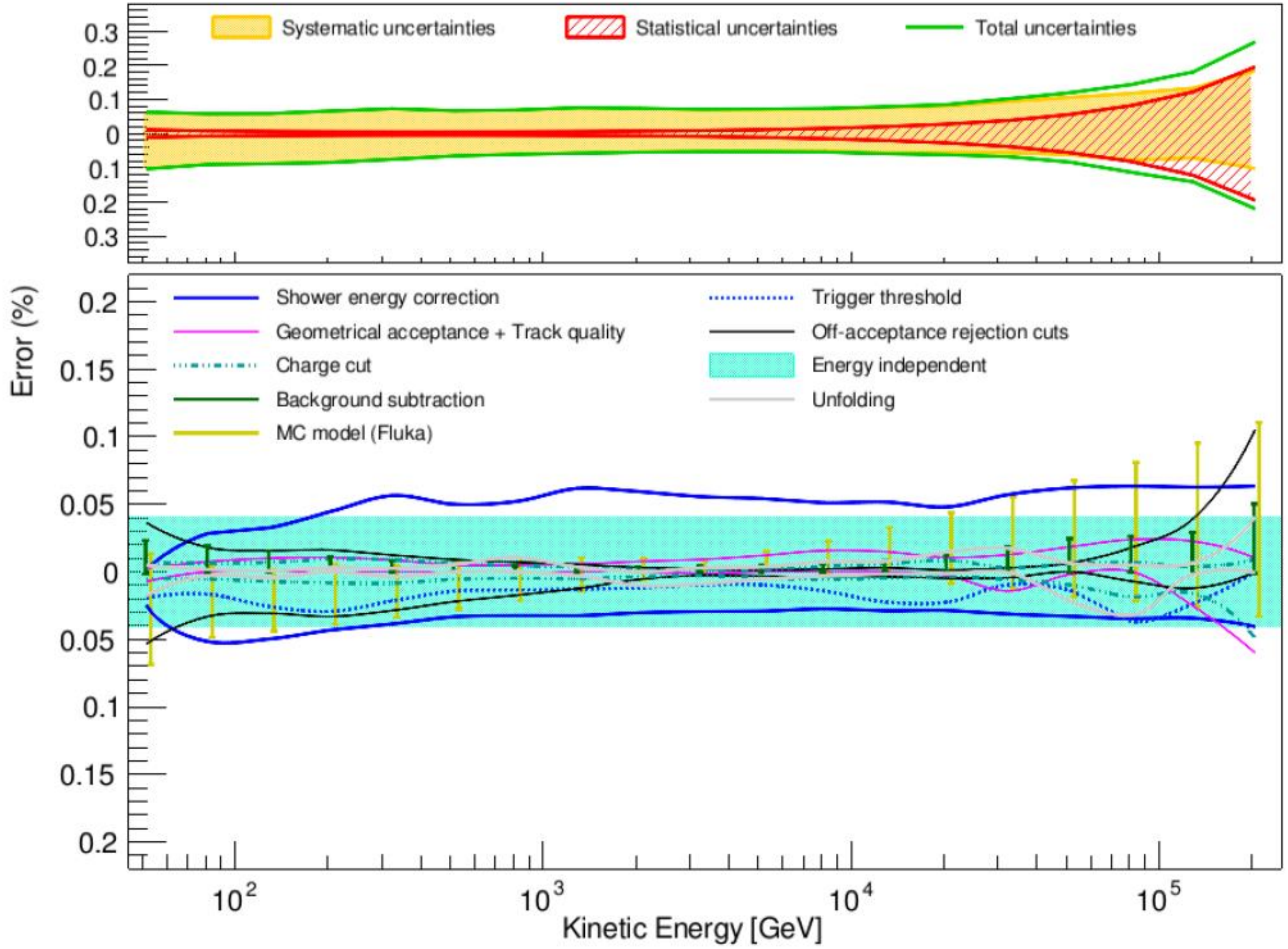
Observed/Unfolded energy spectrum



The energy resolution of helium is 30-40%. Therefore, we apply Bayes unfolding to reconstruct energy.

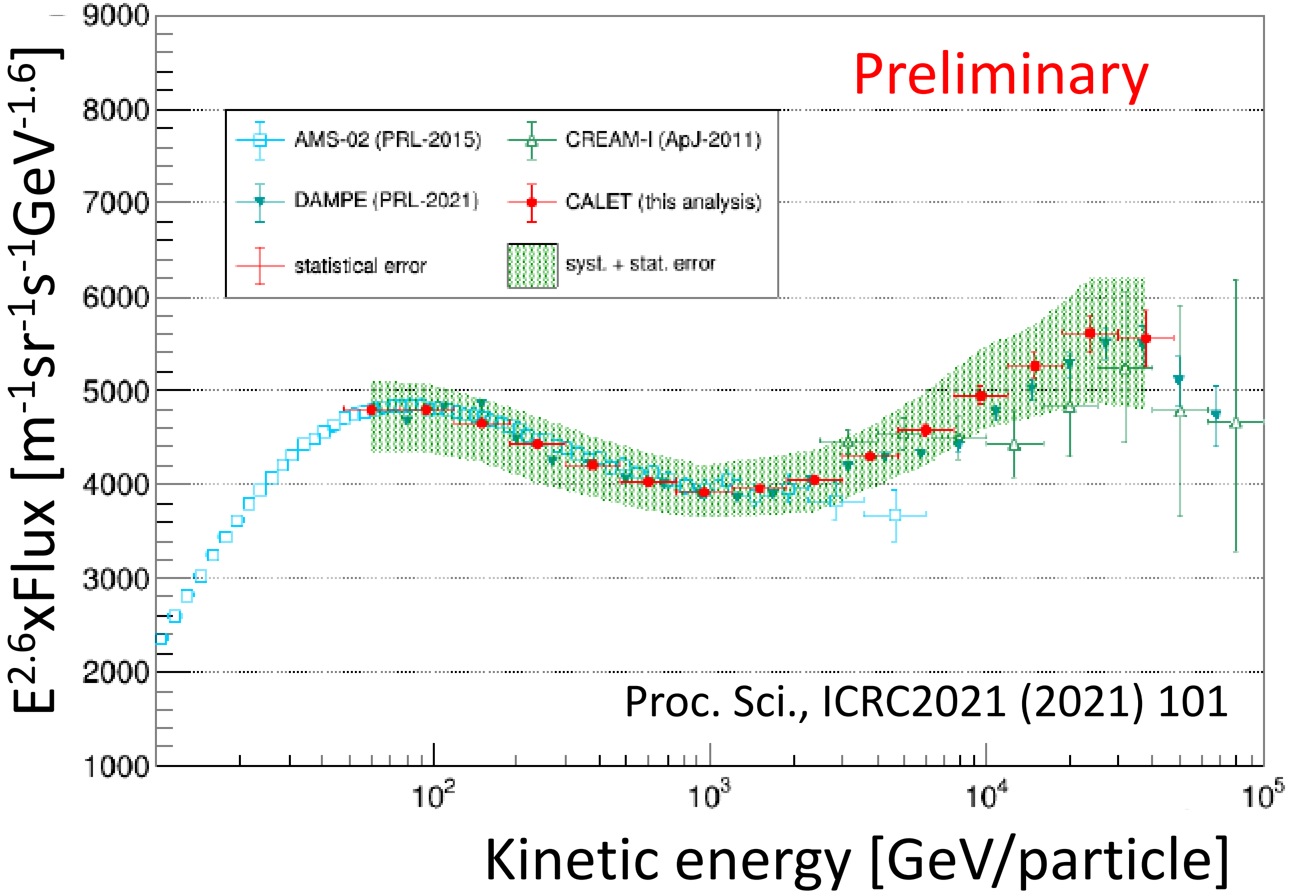
1. We build response matrix between true and observed energy spectrum using MC simulation.
2. We apply unfolding (RooUnfold) iteratively based on Bayes theorem with helium and electron background evaluation.

Systematic uncertainty (Helium)



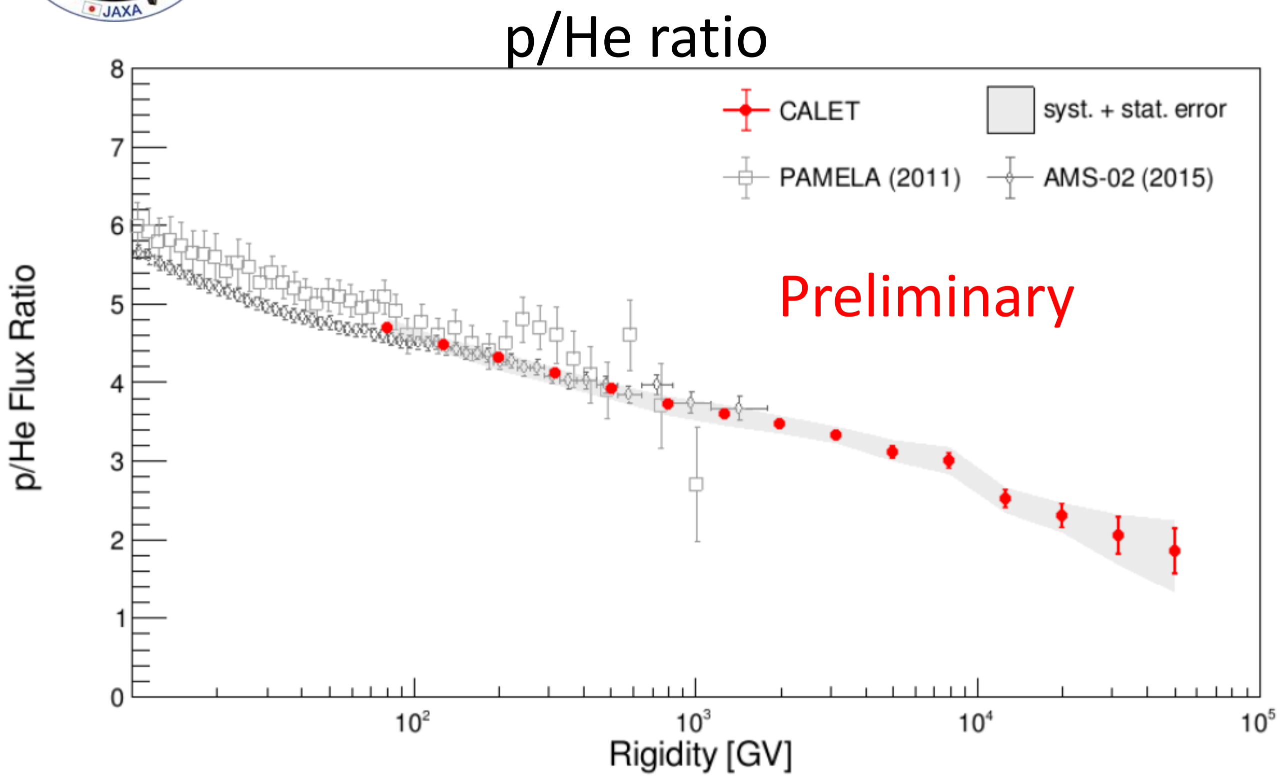
- Systematic uncertainty in E<100TeV is less than 10%.
- The uncertainty in E>100TeV comes from the MC model dependence and off-acceptance rejection cuts, mainly.

Helium spectrum



- We observe the spectral hardening starting at 1.3±0.3TeV. This is consistent with DAMPE result (PRL 2021).

Proton/He ratio



- We are now finalizing the analysis of helium flux.
- Energies/Z starting spectral hardening are consistent between proton and helium.
- Preliminary p/He ratio in 60GV/n<E<60TV/n is consistent to previous measurements.

Spectral shape comparison (energy/Z)		
	proton	helium
spectral hardening	(584^{+61}_{-58}) GeV	(650^{+150}_{-150}) GeV

Summary

- CALET data taking is stably running without any serious problem more than 7 years. We have summarized the helium analysis.
- Helium energy spectrum have a similar shape to proton. The energy/Z starting spectral hardening is consistent to proton. The helium paper will be published soon.
- p/He ratio in 60GV/n<E<60TV/n is consistent to previous measurements.