Charge Loss Correction in the Silicon-Tungsten Tracker-Converter for Proton-Helium Charge Identification in the DAMPE Detector

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(on behalf of the DAMPE collaboration)

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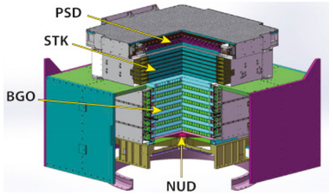
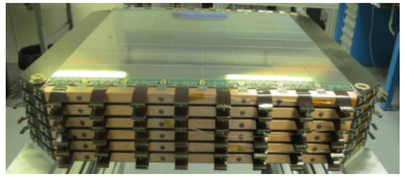
DArk Matter Particle Explorer (DAMPE)

- A satellite-borne experiment, in operation since 2015
- The detection energy range for cosmic rays goes from 10 GeV to >100 TeV
- Four sub-detector modules ▼
  - plastic scintillator detector (PSD) for charge measurements
  - silicon-tungsten tracker-converter (STK) for trajectory measurement
  - bismuth-germanium-oxide (BGO) electromagnetic calorimeter for energy measurement
  - neutron detector (NUD) for electron-hadron discrimination

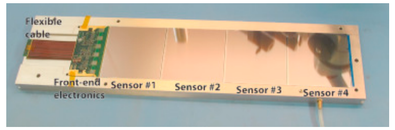


Silicon-Tungsten Tracker Converter (STK)

- 6 double-sided layers ▶
- Each layer consisting of silicon micro-strip detectors (SSDs)
- Orthogonal layers give information on X and Y coordinates to reconstruct particle track
- Layers 2, 3 and 4 have tungsten plates inserted between them for photon conversion



- One silicon sensor module (called a ladder) is made of 4 SSDs ▶
- There are 768 strips on each ladder read out with 6 VA140 ASIC chips
- Read out is done only for every other strip



Charge Measurement in the STK

- For every ladder, signal is recorded only on the 384 read-out strips
- Pre-built algorithm finds clusters of signals which are then associated with tracks
- Clusters give information on charge in units of ADC counts
- Average energy loss of a particle $\langle dE/dx \rangle$ is proportional to its squared charge (z^2) — Bethe-Bloche equation
- However, calibration of the STK ladders an important step required before charge measurement
- Charge loss correction — One such calibration method is to correct for the cluster amplitude's dependance on the impact point and inclination of the incident particle with respect to the sensor

Charge Loss Correction

a) In order to distinguish between signals generated by particles impinging on the read-out and floating strips of the STK ladder, the η variable is introduced and defined as

$$\eta = \frac{S_1}{S_1 + S_2}$$

where S_1 and S_2 are signals from two adjacent channels with S_1 being the highest and S_2 being the next highest signals.
b) The loss of charge is evident as the impact position varies (which is quantified by η) for both, proton and helium candidates.
c) For 1-strip clusters, the charge is not shared between strips and η = 1, so a correction is not required. Therefore, the energy of 1-strip clusters is used as the target energy for the correction.
The correction procedure is as follows:

- STK cluster energy histograms for pre-selected helium candidates are built in bins of number of strips, $\theta_{x,y}$ and η. For a given bin in η, these histograms are fitted with a Moyal distribution and a linear background. The peaks of the fits (MPVs) in each η bin are obtained. (d)
- For each combination of bins in $\theta_{x,y}$ and number of strips, a 2D distribution of the dependance of the STK energy on η is obtained (figure 10) where the MPVs of the previous fits in slices of η are marked in black dots. (e)
- These points are fitted using a quadratic function whose the quadratic coefficient a fixed at 200.

$$f(\theta_{x,y}, n_{\text{strips}}) = a\eta^2 + b\eta + c$$

The linear and constant terms, b and c, of these functions are determined from their dependance on $\theta_{x,y}$ in bins of number of strips.

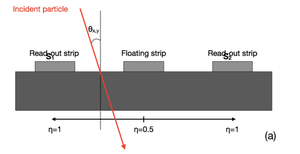
- The correction parameter for a given bin in η is then given by

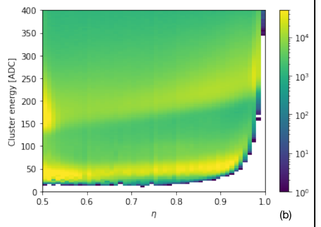
$$\text{Correction param.}(\eta) = \frac{E_{\text{He, 1-strip}}}{f(\theta_{x,y}, n_{\text{strips}})}$$

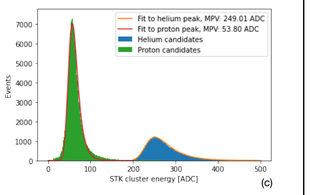
where $E_{\text{He, 1-strip}}$ is the target value of the cluster charge and the denominator is the analytical function for evaluated for a given η.

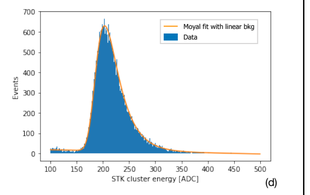
- The correction is applied to the STK cluster charge for every STK ladder in the following way:

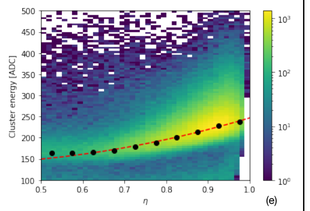
$$E_{\text{corr}} = E \times \text{Correction param.}(\eta)$$





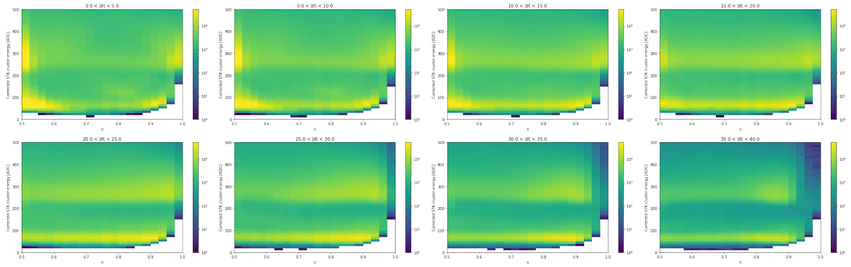






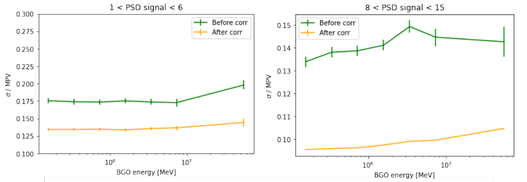
Results

- A charge loss correction, or eta correction, that includes the dependance of the STK cluster energy on the number of strips that make up a charge cluster, was developed and deployed.
- The correction was succesfully applied to carbon nuclei and work is currently underway to adapt it for saturation effects in heavier nulcei.

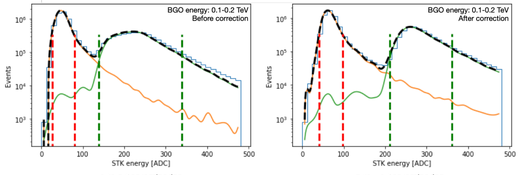


- Corrected STK cluster charge distributions in bins of increasing angles of incidence $\theta_{x,y}$ ▲

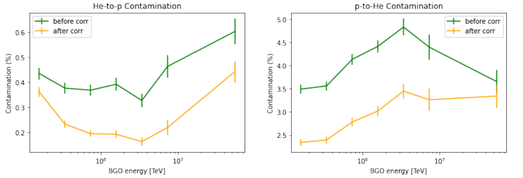
- σ/MPV ratios for proton (left) and helium (right) candidates reduced after correction. ▶



- Template fits made to MC data in bins of BGO energy before (left) and after (right) correction. ▶



- Helium background in proton signal region (left) is reduced. Proton background for helium identification (right) is reduced by a factor of 1.5 for MIP tracks. ▶



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