Nuclear charge measurement using the DAMPE Silicon-Tungsten Tracker

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DAMPE on the web:
http://dpnc.unige.ch/dampe/

Image credit: Hubble

1. Introduction

2. STK Calibration for $Z = 1, 2$

3. Application of calibration parameters

4. Conclusions

The DArk Matter Particle Explorer - DAMPE

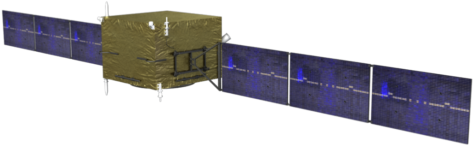
DAMPE is a high energy astroparticle satellite launched on December 17 2015 into a sun-synchronous orbit at the altitude of 500 km.

Key scientific objectives:

Dark Matter search

Indirect Dark Matter search.

- $DM + \overline{DM} \rightarrow \gamma + X$ where X $= (\gamma, Z_0, H)$ or other new neutral particle;
- DM decaying in charged particles.



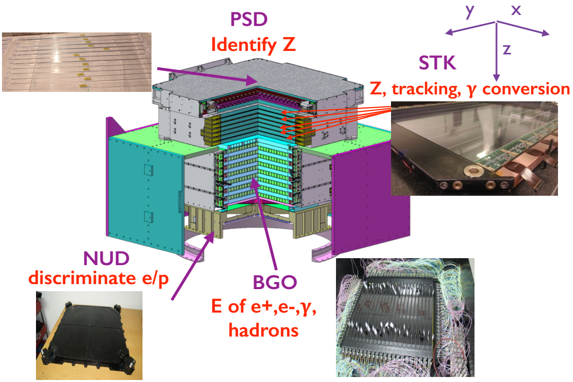
Cosmic and γ ray physics

- **Cosmic ray physics.** DAMPE can provide measurements of various nuclei fluxes to better understand the origin and the acceleration of cosmic rays.
- γ **ray physics.** DAMPE can reveal the engimatic nature of high energy γ-ray phenomena, especially violent GeV-TeV transients;

The Detector

DAMPE is composed by:

- A Plastic Scintillator strip Detector (PSD);
- A Silicon-Tungsten TracKer (STK);
- A Bismuth Germanate Oxide Calorimeter (BGO);
- A boron-doped plastic scintillator serving as a NeUtron Detector (NUD);



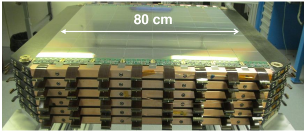
DAMPE can perform the measurement of γ rays and e from 5 GeV to 10 TeV with $\sigma_E/E \approx 1.5\%$ @ 100 GeV (TB result), and of charged cosmic nucleis up to 100 TeV.

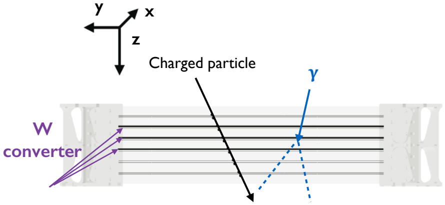
The Silicon-tungsten TracKer converter

STK has been designed to measure charged particle tracks, to convert γ into e^+, e^- pairs in order to measure the photon direction and to measure the Z of cosmic rays.

STK consist of:

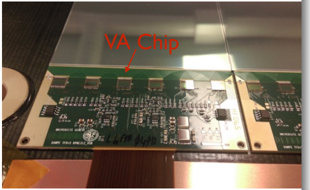
- 7 support planes, 3 with 1mm thick W inside, forming 6 tracking double layers;
- 192 *ladders*, 16 on each sensitive face (12). Each ladder is made by 4 SSD 320µm×9.5mm ×9.5mm.





Each ladder is r/o by 6 VA 140 ASIC chips.

- 1 ladder has 768 strips;
- every other strip is r/o, total 384 (6×64).



Equalize the response of the chips

The charge resolution of the tracker is degraded by a number of detector effects that need to be taken into account and corrected for.

The In-flight VA response equalization of the Tracker is done using the statistics accumulated over 2 months of operation.

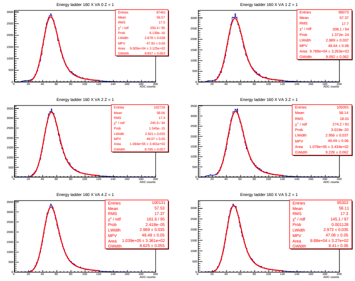


Figure: Signals of Z= 1 particles collected in the 6 VAs of a Si ladder. The fit is done using a Landau convoluted with a Gaussian noise function.

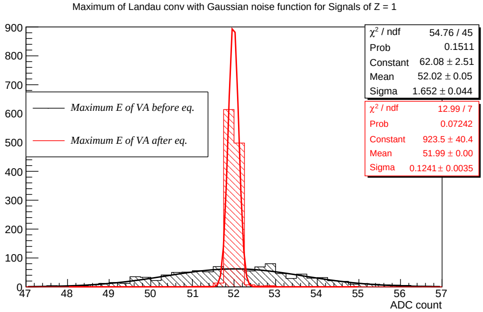


Figure: Equalization of 1152 VAs (192 ladders × 6 VAs, $\mathrm{corrVA_{factor}} = \mathrm{Eq.parameter}/\mathrm{Max_{E_{VA}}}$)

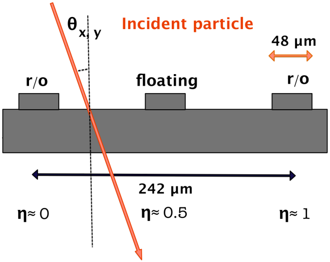
η: a variable used to know the impact position

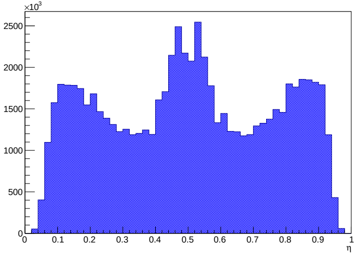
The cluster amplitude depends on the impact position of the particle on the Si sensor and on its inclination.

The variable η divides signals generated by a particle impinging on readout strips and signals generated by a particle impinging on floating strips:

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

where S_1 and S_2 are the two channels with highest signal in the *cluster*, identified by their readout channel.

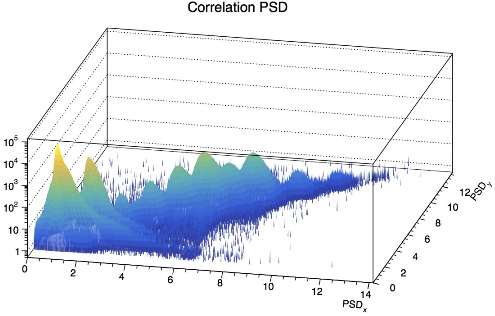




Event sample selection

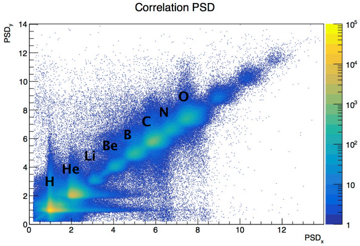
Selection

- Flight data from 27/12/15 to 30/06/2016, not in SAA;
- Not in pole region ($80^\circ < |\mathrm{geo_b}| < 90^\circ$ excluded);
- Selecting only events with E_{rec} in BGO> 10 GeV;
- Only one track in the event, at least one PSD hit, E_{rec} in PSD > 1 MeV;
- Selecting only tracks with at least 5 hits;
- Fiducial volume cut: projection of STK track on BGO [-280 mm, 280 mm];
- Geometrical acceptance of STK track on PSD [-410 mm, 410 mm];
- Match STK-PSD within 15 mm;

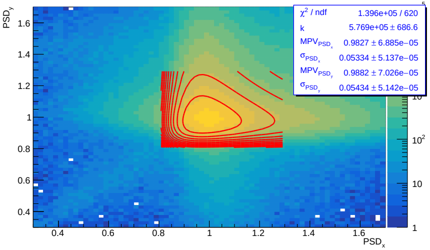


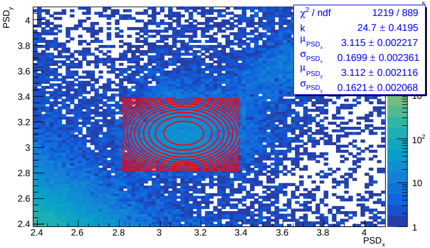
Charge sample selection

$$\mathrm{PSD_{x,y} charge} = \sqrt{\frac{E_{max} \times \cos(\theta_{azimuth})}{E_{MIP}}}$$



- Select $Z = 1, 2$ through 2D Landau: $MPV_{PSD_{x(y)}} - \sigma_{PSD_{x(y)}} < PSD_{x(y)} < MPV_{PSD_{x(y)}} + \sigma_{PSD_{x(y)}}$
- Select $Z > 2$ through 2D Gaussian: $\mu_{PSD_{x(y)}} - \sigma_{PSD_{x(y)}} < PSD_{x(y)} < \mu_{PSD_{x(y)}} + \sigma_{PSD_{x(y)}}$



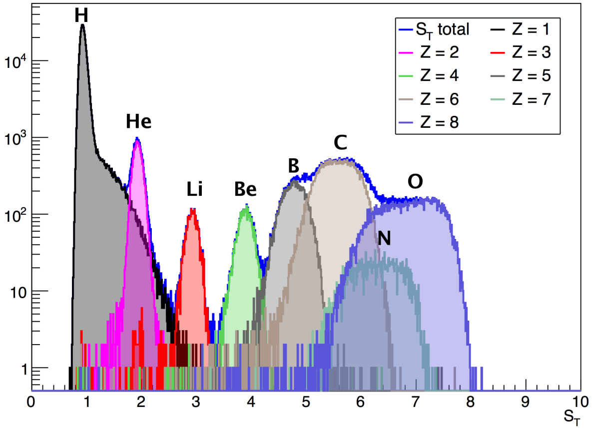


Charge measurement in STK

The parameter to identify the Z in STK is the *truncated mean* defined as:

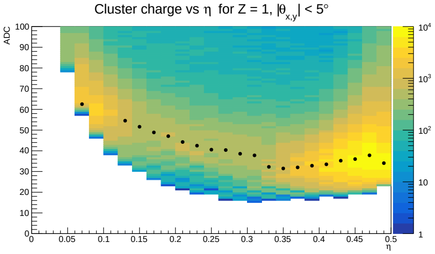
$$S_T = \sqrt{\frac{\sum_1^n S_i - S_{max}}{n-1}}$$

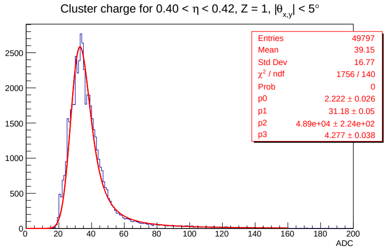
where n is the number of clusters entering the truncated mean calculation and S_i the signal of the cluster.

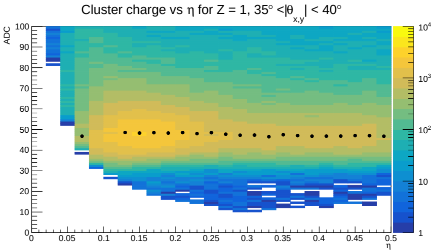


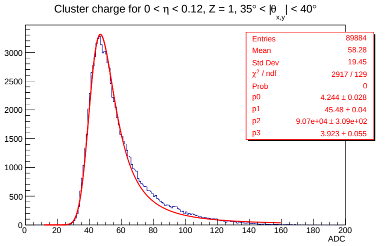
- VAs showed to have a saturation and therefore a change of gain after O ⇒ different calibration after O has to be implemented.

Dependence of signals from impact angle and η for Z = 1

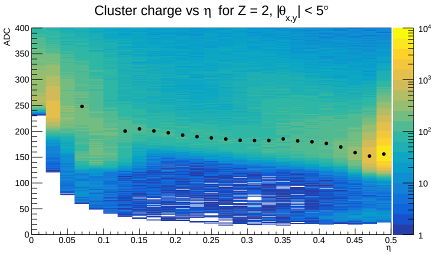


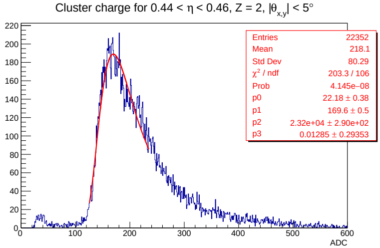


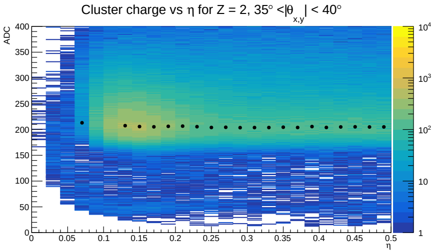


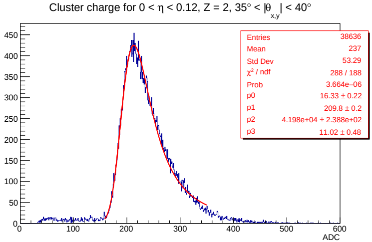


Dependence of signals from impact angle and η for Z = 2

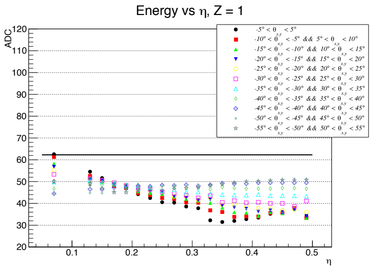


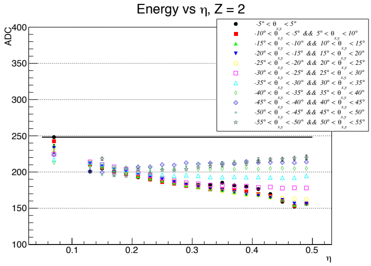




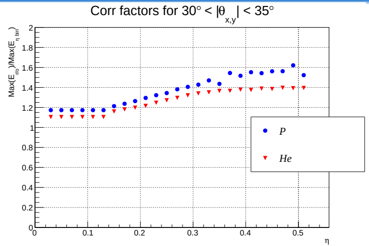


Dependence of signals from impact angle and η



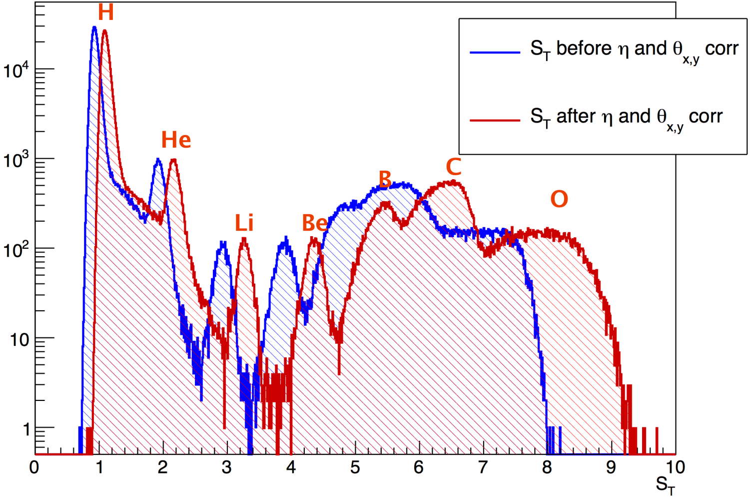


When the IP is close to the floating strip the charge is shared with the 2 neighbour strip that collect about 65% of the original released charge. If the particle hits the readout strip almost all the charge is collected.



In first approximation the correction factors result similar for Z = 1 and 2. Assuming that this is true also for higher Z, the He correction factors are applied up to O.

Comparison


H
He
Li
Be
B
C
O
S_T before η and θ_x,y corr
S_T after η and θ_x,y corr
10^4
10^3
10^2
10
1
0
1
2
3
4
5
6
7
8
9
10
S_T

Conclusions

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6. More calibration methods are under study to improve the charge identification for ions heavier than Oxygen.

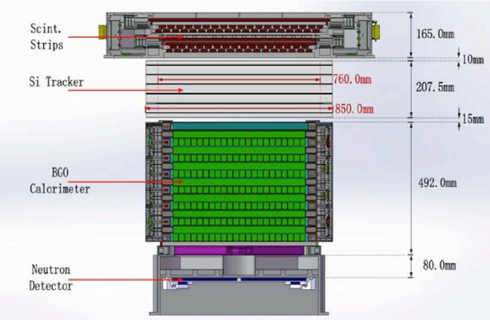
THANKS FOR THE ATTENTION

track DAMPE in real time
http://www.n2yo.com/?s=41173

backup

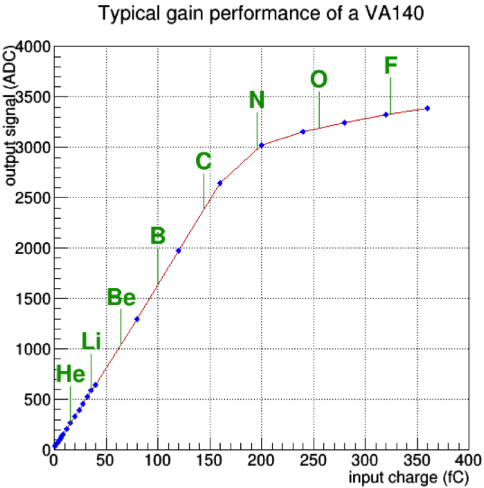
DAMPE more in detail

- The **PSD** has a double layer configuration and **82** detector modules totally; each module has a long plastic scintillator bar of 884 mm with a 28 mm $\times$ 10 mm cross-section;
- The **BGO** Calorimeter is composed of **308 BGO Crystal bars** 2.5 cm $\times$ 2.5 cm $\times$ 60 cm each;
- BGO Depth: 32 X_0, 1.6 λ;
- **NUD** 30 cm $\times$ 30 cm $\times$ 1.0 cm block of Eljen Technologies EJ-254 boron-loaded plastic scintillator.

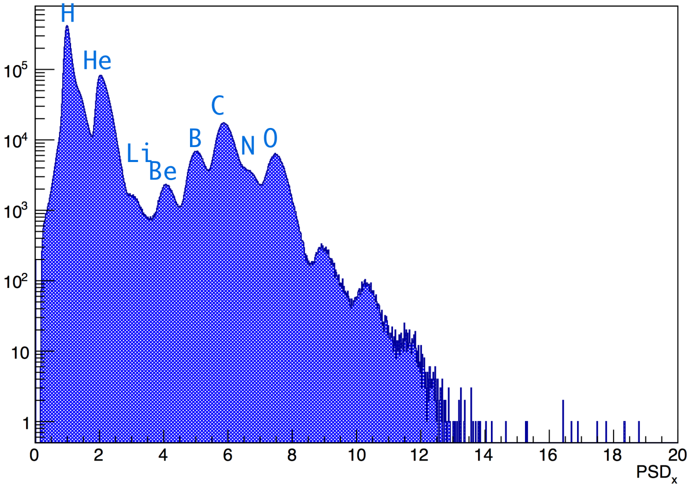


DAMPE geometrical acceptance: 0.29 m^2sr.

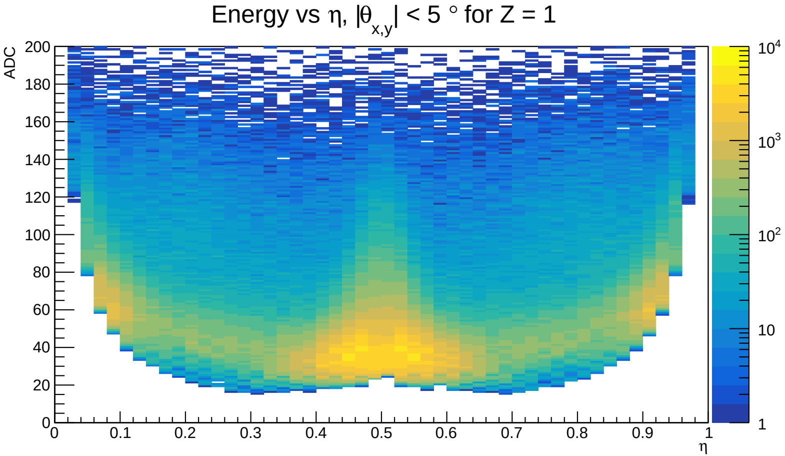
Gain of the VA



Energy distribution in PSD

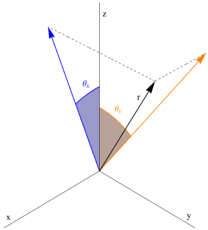


Dependence of signals from impact angle and η for Z = 1

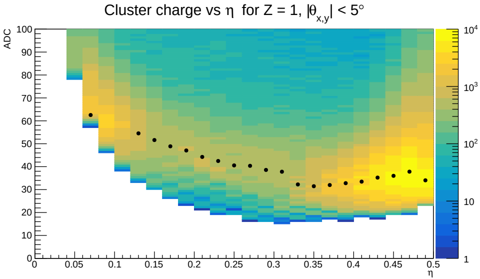


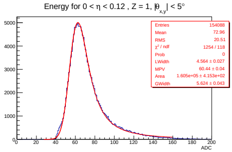
Dependence of signals from impact angle and η for Z= 1

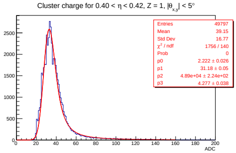
- Each track has two projections: one on the xz plane, one on the yz plane and two angles between the z coordinate: θ_x and θ_y.



Once VA equalized all the 192 ladders, we summed all them together.







- We can clearly see a different signal amplitude as a function of η and $\theta_{x,y}$.

S_T after application of η correction factor

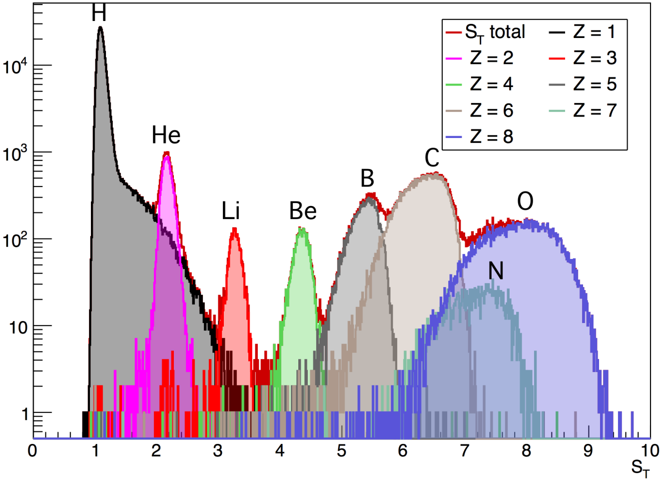


Figure: Remind: for H it was used a different set of η equalization parameters.

Number of nuclei collected with thight selection

	PSD	STK (no shower no fragmentation)
N_{H}	417361	407749
N_{He}	17675	17572
N_{Li}	2890	2785
N_{Be}	3804	3644
N_{B}	14109	11209
N_{C}	47046	22343
N_{N}	2908	716
N_{O}	22243	1050

Table: The number quoted are very rough, estimated from an integral, not from a fit.