Study of the performances of the DAMPE silicon-tungsten tracker after five years of mission

E. Catanzani, G. Ambrosi, M. Ionica, C. Perrina, P. Azzarello, A. Tykhonov, X. Wu

enrico.catanzani@pg.infn.it
DAMPE - Scientific goals

Cosmic Rays

- Many orders of magnitude in flux and energy
- Electrons (and positrons) represent few % of the total
- The spectrum measurements above 10 TeV are challenging due to limited statistics of direct detection experiments
- $\gamma$-ray emission from galactic and extragalactic sources

Dark Matter

1. Many orders of magnitude in flux and energy
2. Electrons (and positrons) represent few % of the total
3. The spectrum measurements above 10 TeV are challenging due to limited statistics of direct detection experiments
4. $\gamma$-ray emission from galactic and extragalactic sources
DAMPE - CR spectra

All Electron spectrum, 25 GeV - 4.6 TeV

Proton spectrum, 40 GeV - 100 TeV

Helium spectrum, 70 GeV - 80 TeV
Cosmic Rays - DAMPE statistics

- Continuous data acquisition since its launch
- $\sim 10^5$ events/day
- $\sim 7$ full scans of the sky

![Image of cosmic ray sky map]

![Graph showing data statistics]
DArk Matter Particle Explorer

DAMPE (“Wukong”) launched on 17/12/2015 - 00:12 UTC

Detector description

- Sun-synchronous orbit
  - Altitude: ~ 500 Km
  - Inclination: ~97.4° quite Polar orbit
  - Period: 90 minutes

- PSD (Plastic Scintillator Detector)
  - $\gamma$/charged particle ID
  - Trigger veto
  - Particle charge measurement

- STK (Silicon Tungsten Tracker)
  - Tracking of charged particles
  - $\gamma$ conversion in $e^{\pm}$ couples
  - Particle charge measurement

- eCAL (Electromagnetic Calorimeter)
  - Energy measurement
  - Shower 3D imaging - particle ID

- NUD (Neutron Detector)
  - $e^-/n$ discrimination

Energy range $\gamma/e^{\pm}$: 5 GeV - 10 TeV
Energy range p/heavy nuclei: 50 GeV - 100 TeV
Geometric acceptance ($e^-$): $\sim 0.3$ m$^2$ sr

DAMPE mission: 2015 - 2024
- Total mass: $\sim 2 \times 10^3$ Kg
- Power consumption: 850 W
- Data transfer: 14 Gb/day
Detector description - PSD

- 2 layers (x,y) of 88.4 cm × 2.8 cm × 1 cm
- Active area: 82 cm × 82 cm
- Weight: ~103 kg
- Power: ~8.5 W
Detector description - STK

- 6 layers (x,y) of silicon detectors
- Detection area: 76 x 76 cm
- Weight: ~154 kg
- Power: ~ 82 W
- Three 1 mm tungsten planes 0.86 $X_0$
Detector description - STK

- 12 layers (6x, 6y) of single-sided Si strip detectors mounted on 7 support trays
- Tray: carbon fiber face sheet with Al honeycomb core
- Tungsten plates (1 mm thick) integrated in the 2nd, 3rd and 4th tray from the top
- Total 0.85 X₀ for photon conversion

![Diagram of STK detector](image)

\[
16 \frac{\text{ladders}}{\text{layer}} \times 12 \text{ layers} = 192 \text{ ladders}
\]

\[
\frac{768}{2} \frac{\text{channels}}{\text{ladder}} \times 192 \text{ ladders} = 73728 \text{ channels}
\]
Detector description - eCAL

- 14 layers (x,y) of BGO bars 2.5 x 2.5 x 60 cm$^3$
- Outer envelop: 100 cm x 100 cm x 50 cm
- Weight: ~1052 kg
- Power: ~42 W
- 31 radiation lengths
Detector description - NUD

\[ n + {^{10}}B \rightarrow \alpha + {^7}Li + \gamma \]

- 4 plastic scintillators
- Active area: 60 cm x 60 cm
- Weight: ~12 kg
- Power: ~ 0.5 W
STK Status

STK noise

Signal distribution

MPV = 52 ADC

Noise distribution

17th January 2016
12th August 2019
STK Status

Mean radiator and ladder temperature

- Mean radiator temperature
- Mean ladder temperature
- $T_{\text{mean, ladder}} - T_{\text{mean, rad}}$
STK Status
Mean noise and ladder temperature

[Graph showing STK mean noise and ladder temperature over time from 2016-01-17 to 2019-08-12]
STK Status

Position resolution

Internal STK layers 2-5

External STK layers 1/6

Data Aligned

Simulation

Effective resolution (μm)

Data - MC (μm)

θ_x(θ_y) (deg)
Conclusions

• After five years of missions, only 0.11% of the channels are “bad” (noise > 10 ADC)

• The number of “bad” channels is decreasing with time

• The mean STK noise was stable during the whole mission (< 3 ADC)

• The mean temperature STK is slightly increasing and so does the mean noise, from 0.008 ADC/°C to 0.01 ADC/°C in five years

• The STK performances are still excellent after five years of continuous operation in space
Backup
DAMPE Orbit
BGO shower containment

![Graph showing BGO shower containment for different energies and experiments.]

<table>
<thead>
<tr>
<th>Experiment</th>
<th>$X_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAMPE</td>
<td>31</td>
</tr>
<tr>
<td>AMS-02</td>
<td>17</td>
</tr>
<tr>
<td>PAMELA</td>
<td>15.3</td>
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<tr>
<td>FERMI</td>
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</tbody>
</table>
STK Status

Mean noise and ladder temperature
STK Status

Mean noise and ladder temperature

\[ y_i = \frac{s_i - s_0}{s_0} \]

\[ y = p_0 + p_1(x - 2016) + p_2(x - 2016)^2 \]

- from 16.08.2016 to 28.04.2017
  - \( s_0 = 0.0079 \text{ ADC/°C} \)

- from 15.08.2017 to 29.04.2018
  - \( s_1 = 0.0083 \text{ ADC/°C} \)

- from 17.08.2018 to 24.04.2019
  - \( s_2 = 0.0089 \text{ ADC/°C} \)

- from 25.08.2019 to 14.04.2020
  - \( s_3 = 0.0096 \text{ ADC/°C} \)

- from 30.08.2020 to 10.04.2021
  - \( s_4 = 0.0103 \text{ ADC/°C} \)