29° International Symposium on Lepton Photon interactions at High Energies

TeV Particle direct detection in space – Recent Results from the DAMPE mission

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• Introduction
• DAMPE mission & detector
• On-orbit performance
• Physics Results
• Summary
Satellite-borne particle detector, project of the Strategic Pioneer Program on Space Science, promoted by the Chinese Academy of Sciences (CAS).

- Study of Cosmic Rays composition, origin and propagation
- Search for Dark Matter signatures in lepton and photon spectra
  - High Energy Gamma-Ray Astronomy

ALTITUDE: 500 km
PERIOD: 95 minutes
ORBIT: Sun-synchronous

- Purple Mountain Observatory
- University of Science and Technology
- Institute of High Energy Physics
- Institute of Modern Physics
- National Space Science Center
- INFN Lecce and University of Salento
- INFN Bari and University of Bari
- INFN Perugia and University of Perugia
- INFN LNGS and Gran Sasso Science Institute
- Geneva University
Cosmic Rays

3 Major Scientific goals

- Precision measurements of cosmic ray spectra: cosmic ray origin, acceleration, and propagation
- The spectra above TeV are not well measured due to limited statistics of direct detection experiments
Table 1: Summary of DAMPE instrument parameters and Expected performance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Energy range of γ−rays/electrons</td>
<td>5 GeV–10 TeV</td>
</tr>
<tr>
<td>Energy resolution of γ−rays/electrons</td>
<td>≤ 1.5% at 800 GeV</td>
</tr>
<tr>
<td>Energy range of protons/heavy nuclei</td>
<td>50 GeV–100 TeV</td>
</tr>
<tr>
<td>Energy resolution of protons</td>
<td>≤ 40% at 800 GeV</td>
</tr>
<tr>
<td>Effective area at normal incidence (γ−rays)</td>
<td>1100 cm$^2$ at 100 GeV</td>
</tr>
<tr>
<td>Geometric factor for electrons</td>
<td>0.3 m$^2$ sr above 30 GeV</td>
</tr>
<tr>
<td>Photon angular resolution$^a$</td>
<td>≤ 0.2° at 100 GeV</td>
</tr>
<tr>
<td>Field of View (FoV)</td>
<td>$\sim$1.0 sr</td>
</tr>
</tbody>
</table>

Note: a. For the 68% containment radius.
**DAMPE detector**

| PSD | 2 planes with double layer configuration  
|     | 82 bars of plastic scintillator  
|     | **CHARGE MEASUREMENT (Z<28, Z\sqrt{E})**  
|     | **γ-RAYS VETO**  
| STK | 6 planes with 2 single-sided silicon layers  
|     | 3 thin tungsten layers (for γ conversion in e^+/e^-)  
|     | **TRACK RECONSTRUCTION**  
|     | spatial resolution <70 μm for CR (θ_{inc} < 60°)  
|     | angular resolution ~0.2° for γ at 10 GeV  
|     | **CHARGE MEASUREMENT ( Z = \sqrt{ADC} )**  
| BGO | 14 layers, each one with 22 bars of Bi_3Ge_4O_{12} ,~32 Χ_0  
|     | **ENERGY MEASUREMENT**  
|     | 1 GeV - 10 TeV for electrons and γ  
|     | 50 GeV - 100 TeV for nuclei  
| NUD | 1 layer, 4 boron-doped plastic scintillator  
|     | detection of neutrons generated in the BGO for hadron/e.m. showers discrimination  

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Giovanni Marsella for DAMPE – LP2019, August 6th 2019, Toronto, Canada
Observation Overview

DAMPE 3.5 year counts map

7 full scans of the sky

5M events/day
6.5 billion in total

DAMPE DAQ Statistic

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Detector Stability

PSD pedestal < 0.5%

STK pedestal < 0.7%

BGO pedestal < 0.9%

NUD pedestal < 0.6%
**High Energy Trigger (HET)**

- **HET rate**: ~50 Hz
- **~4 M events recorded/day**
- **~12 GB/day transferred to ground**

**EXPOSURE TIME**: $7.86 \times 10^7$ s

**Exposure time affected by:**

- **South Atlantic Anomaly (SAA) region**
  
  (~ 4.5% of the operation time)

- **on-orbit calibration data-taking**
  
  (~ 1.5% of the operation time)

- **instrumental dead time**
  
  (~18.5% of the operation time)

$E_{\text{dep}} > 10$ MIPs in first three BGO layers

$E_{\text{dep}} > 2$ MIPs in 4th BGO layer

(1 MIP$_{\text{BGO}}$ = 23 MeV)

**Lower rates:**

- Events excluded due to Intense Solar flare
- Events excluded due to High Voltage reset
- Data acquisition suspended for calibrations, monitoring, …

**DATA Taking**: January 1st, 2016 to March 31th, 2019

**Very Stable Since Jan. 1st, 2016**
We use the lateral (\textit{SumRMS}) and longitudinal (energy ratio in last layer) developments of the showers to discriminate electrons from protons.

For 90\% electron efficiency, proton background is $\sim 2\%$ @ TeV, $\sim 5\%$ @ 2 TeV, $\sim 10\%$ @ 5 TeV.
• Physics Results
Gamma-Ray Sky Map

DAMPE 3 years
E > 2 GeV

Preliminary
Gamma-Ray point sources

- 143 sources with TS > 20
- Most are pulsars and AGNs
PSD Charge Measurements

Species | Res.
---|---
P | 0.07
He | 0.12
Li | 0.14
Be | 0.21
B | 0.17
C | 0.18
N | 0.21
O | 0.21
Three different PID methods give very consistent results on event-by-event level.

Direct detection of a spectral break at $\sim 1$ TeV with $6.6\sigma$ confidence level.

Analysis with new data is on-going.

Nature, 552, 63 (2017)
- Confirms the hundreds GeV hardening

- Detecting a softening at ~13 TeV with high significance
Preliminary Helium flux per nucleon compared with results obtained by previous experiments.

An unfolding method has been adopted in order to reconstruct the primary energy of Helium nuclei.

The grey band represents the total systematic uncertainty:

More studies on systematic uncertainties (hadronic model, unfolding, etc..) are in progress.
A spectral hardening can be observed below 1 TeV (Energy/nucleus)

The full evaluation of systematic uncertainties, for the extension of the measurement up to about 100 TeV, is ongoing.
The DAMPE detector is in a stable data-taking at 500 km of altitude since Dec. 17, 2015

Preliminary Photon Maps are available

Very precise measurements of the $e^+e^-$ spectrum from 25 GeV to 4.6 TeV have been obtained, showing a spectral break at $\sim$TeV energies and possible new spectral features

Proton and Helium preliminary results have been presented

More results are coming...