The DAMPE experiment: 2 year in orbit (almost)

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on behalf the DAMPE collaboration
The physics goals

• **High energy particle detection in space**
  – Study of the cosmic **electron** and **photon** spectra
  – Study of cosmic ray **protons** and **nuclei**:  
    – spectrum and composition
  – High energy gamma-ray astronomy
  – Search for **dark matter** signatures in lepton spectra
  – **Exotica** and “**unexpected**”, e.g. GW e.m. counterpart in the FoV (1sr)

Detection of
  
  5 GeV - 10 TeV e/γ
  50 GeV - 100 TeV protons and nuclei

  Excellent energy resolution
  (<1.5%@100GeV e/γ; < 40% @800GeV p)

  Very good angular resolution
  (<0.2° @ 100GeV γ)
The collaboration

• **CHINA**
  – Purple Mountain Observatory, CAS, Nanjing
  – *Prof. Jin Chang*
  – Institute of High Energy Physics, CAS, Beijing
  – National Space Science Center, CAS, Beijing
  – University of Science and Technology of China, Hefei
  – Institute of Modern Physics, CAS, Lanzhou

• **ITALY**
  – INFN Perugia and University of Perugia
  – INFN Bari and University of Bari
  – INFN Lecce and University of Salento

• **SWITZERLAND**
  – University of Geneva
The detector

**PSD**: double layers of scintillating strip detector acting as ACD

**STK**: 6 tracking double layers + 3 mm tungsten plates. Used for particle track and photon conversion

**NUD**: it's complementary to the BGO by measuring the thermal neutron shower activity. Made up of boron-doped plastic scintillators

**BGO**: the calorimeter made of 308 BGO bars in hodoscopic arrangement (~32 radiation lengths). Performs both energy measurements and trigger

75k readout channels + temperature sensors
# Comparison DAMPE AMS-02 and FERMI

<table>
<thead>
<tr>
<th></th>
<th>DAMPE</th>
<th>AMS-02</th>
<th>Fermi LAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>e/γ Energy res.@100 GeV (%)</td>
<td>&lt;1.5</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>e/γ Angular res.@100 GeV (deg.)</td>
<td>&lt;0.2</td>
<td>0.3</td>
<td>0.1</td>
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<tr>
<td>e/p discrimination</td>
<td>&gt;10^5</td>
<td>10^5 - 10^6</td>
<td>10^3</td>
</tr>
<tr>
<td>Calorimeter thickness (X₀)</td>
<td>32</td>
<td>17</td>
<td>8.6</td>
</tr>
<tr>
<td>Geometrical accep. (m²sr)</td>
<td>0.3</td>
<td>0.09</td>
<td>1</td>
</tr>
</tbody>
</table>

Mass: 1400 Kg  
Power: ~ 400 W  
Lifetime: > 3 years
The launch: Dec 17th 2015, 0:12 UTC

Jiuquan Satellite Launch Center
Gobi desert

Orbit: Sun synchronous, 500km

DAMPE → 悟空 (Wukong)

Operations 24h/day, 365d/year, since the launch
Trigger rate and data transfer

- Acquisition rate up to 200Hz (50 Hz for High Energy Trigger == trigger for physics analysis)
- Data are collected 4 times per day, each time the DAMPE satellite is passing over Chinese ground stations
- 15 GB/day transmitted to ground
  - Raw Data (ROOT format 8GB) + Slow Control + Orbit Information
- 85 GB/day reconstructed data (ROOT format)
- 100 GB/day (35 TB/year) in total
Some on-orbit performance plots

On orbit STK alignment using “mips” (i.e. not showering particle). The alignment (done every two weeks) allows us to achieve a spatial resolution better than 40µm on central STK planes.

The “mip” (i.e. not showering particles) peak shift with latitude due to the geomagnetic cut-off.
On-orbit absolute energy calibration

- Geomagnetic cut-off on cosmic ray electron spectrum provide a good spectral feature for absolute energy calibration
- Measure low energy CRE flux with $1 < L < 1.14$ in the energy range $8\text{GeV} < E < 100\text{GeV}$
- We made a direct comparison between flight data and MC (with back tracing in Earth magnetic field – IGRF12)

By comparing geomagnetic cut-off on cosmic ray electron and positron fluxes measured from data and MC back tracing, we found DAMPE's absolute energy scale differ from expected by $1.25\%$
Electrons: identification

One possible “shape parameter”

\[ F_i = \text{Spread}_i \times \frac{E_i}{E_{\text{tot}}} \]

> 90% detection efficiency with proton contamination varying from 2 % (< 1 TeV) to 10 % (> 5 TeV)

More PID strategies being investigated

(BoostedDecisionTree, RandomForest+ConvolutionalNeuralNetwork, …)
Electrons: performances

Acceptance for electrons and positrons

Energy resolution for E.M. showers

$0.3 \text{m}^2 \text{sr for } E > 100\text{GeV}$

$1\% \text{ for } E > 100\text{GeV}$
All-electron spectrum

- Measure the all-electron flux up to about 10 TeV
- Measure with high accuracy the sub-TeV region and the possible cut-off around 1 TeV
- Detect structures in the spectrum due to nearby sources and/or DM induced excesses
- Detect anisotropies at high energy
Protons and nuclei – Beam test

Identifying protons and nuclei with PSD and STK

Lead beam 40 GeV/n

Argon beam 40 GeV/n

Charge measurement is done with STK up to Oxygen and with PSD from protons up to Iron

Charge resolution is Z dependent and ranges from 0.2 to 0.4
Protons and nuclei – Flight data

Identifying protons and nuclei with PSD and STK

Charge resolution
H 0.13
Fe 0.32
Protons and nuclei – First spectra

• template fits to account for He background
• spectral hardening at E>200 GeV

• well in agreement with previous experiments
• currently extending analysis to higher energies
Photons: Selection

• The main background sources are protons and electrons
  - Protons: $10^5 @ E > 100\text{GeV}$
  - Electrons: $10^3 @ E > 100\text{GeV}$

• Protons
  - Are mainly rejected using the shower profile and the onboard trigger

• Electrons
  - Are mainly rejected using the PSD and 1st layer of STK
  - Main problem is back scattering at high energy
Photons: Selection

- **Proton**: PSD, BGO shower profile and NUD allow to reach a rejection $>10^7$ for hadrons.

- **Electron**: PSD and STK allow to reach a rejection of $10^3$ for electrons.

- **Gamma**: Random Forest + Convolutional Neural Network are used for PID.
Photons: Selection

- Acceptance after the selection criteria applied to reject protons and electrons

Other PID algorithm are under study to further decrease the electrons contamination at a level below the Extra Galactic Background emission
Photons: First results on timing
Pulsars and variability

Very good agreement with Fermi and Agile data
DAMPE Counts map

E > 1GeV
16 months
FERMI Counts map

E > 1GeV
16 months
Summary

- **The detector**
  - Large geometric factor (0.3 m² sr for electrons)
  - Precision Si-W tracker (40µm spatial resolution, 0.15° angular resolution)
  - Thick calorimeter (32 X₀, σ_E/E 1% above 100 GeV for e/γ, ~40% for hadrons)
  - “Multiple” charge measurements (20%-40% energy resolution)
  - e/p rejection power > 10⁵ (topology alone, plus neutron detector)

- **Launch and performances**
  - Successful launch on Dec 17, 2015
  - On orbit operation steady and with high efficiencies
  - Absolute energy calibration by using the geomagnetic cut-off
  - Absolute pointing cross check by use of the photon map

- **Physics goals**
  - Study of the cosmic electron and photon spectra
  - Study of electron anisotropy and nearby sources contribution
  - Study of cosmic ray protons and nuclei: spectrum and composition
  - Precise measurement of CR discrepant hardenings and spectral indexes
    - Preliminary results well in agreement with other experiments
  - High energy gamma ray astronomy
  - Search for dark matter signatures in lepton spectra
  - The “unexpected”: GW electromagnetic follow up in FoV and in the observable energy range

DAMPE in the sky seen from the Earth (China)