DAMPE and its first year in Orbit

S. Zimmer, University of Geneva
(on behalf the DAMPE collaboration)
Outline

• Intro: Launch, Detector design & Expected Performance

• On-orbit Performance

• Results
  • first light with $\gamma$-rays
  • p/He spectrum measured with DAMPE

In case you need to go (I hope you can stay):
• DAMPE works well & provides new instrument for GeV-TeV $\gamma/e/p/ions$
• 1$^{st}$ year data confirms results from several different experiments
1. Introduction: 
Launch, Design &
Expected Performance
China’s first Astronomical Satellite

- **Launch**: December 17th 2015 CZ-2D rocket
  - scientific payload: ~1400 kg, 400 W
- **Lifetime**: > 3 years (nominal mission time)

- **Altitude**: 500 km
- **Inclination**: 97.4065°
- **Period**: 95 minutes
- **Orbit**: sun-synchronous
- **16 GB/day** downlink

Wukong “Monkey King”
DARK MATTER PARTICLE EXPLORER

Particle Dark Matter ID

CR Acceleration & Propagation

Gamma Ray Astrophysics

DAMPE Coll. [arXiv:1706.08453]
Instrument Design

Silicon TracKer converter (STK)
6 double layers of single sided-silicon strips interleaved with 3 mm of tungsten used for tracking & photon conversion

Plastic Scintillator Detector (PSD)
double layers of scintillating strips acting as top ACD

Bismuth-Germanium Oxide (BGO)
calorimeter
308 hodoscopically arranged bars (~32 $X_0$)
particle identification
energy measurement
direction reconstruction
trigger
$\Delta E/E (>10 \text{ GeV}) \approx 1.5\% (e/\gamma)$

NeUtron Detector (NUD)
boron-doped plastic scintillator aids particle ID by measuring delayed neutrons from proton-induced showers
## Expected Performance

**The DArk Matter Particle Explorer mission**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy range of gamma-rays/electrons</td>
<td>5 GeV to 10 TeV</td>
</tr>
<tr>
<td>Energy resolution (electron and gamma)</td>
<td>&lt;1.5% at 800 GeV</td>
</tr>
<tr>
<td>Energy range of protons/heavy nuclei</td>
<td>50 GeV to 100 TeV</td>
</tr>
<tr>
<td>Energy resolution of protons</td>
<td>&lt;40% at 800 GeV</td>
</tr>
<tr>
<td>Eff. area at normal incidence (gamma)</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</td>
<td>&lt;0.2 degree at 100 GeV</td>
</tr>
<tr>
<td>Field of View</td>
<td>1.0 sr</td>
</tr>
</tbody>
</table>

2. On-Orbit Performance
• Acquisition rate up to 200 Hz (50 Hz for HE trigger, pre-scaled during calibration & for LE trigger)

• live-time: 18.4 hours / day (incl. SAA), 3 ms dead time after each event

• 100 GB/day orbit data (observation & calibration runs); calibration run at b +20 deg
Acceptance Estimates

- \( \sim 0.3 \text{ m}^2\text{sr} \)
- \( \sim 0.2 \text{ m}^2\text{sr} \)
- \( \sim 0.04 \text{ m}^2\text{sr} \)
- \( \sim 0.03 \text{ m}^2\text{sr} \)
3. Results
Gamma Rays: First Light

roughly: ~200 γ/day
full sky coverage ~few times per year
highly non-uniform (limited all-sky monitoring capabilities)
(Re)discovering the $\gamma$-Ray Sky

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Bright Pulsars & Timing

- Vela X (T~89 ms)
- PSR J0007+7303 (T~316 ms)
- Geminga (T~237 ms)

[Xu et al. / Lei et al. / Muñoz-Salinas et al. (DAMPE), ICRC 2017]
Protons & Ions

445 GeV < E < 560 GeV

Geant4 MC simulations
QGSP_BERT & FTFP_BERT with similar results investigating scaling cross sections at highest energies

PRELIMINARY

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Proton Flux Measurement

~16M events

hardening ~200 GeV

- template fits to account for He background
- main uncertainty trigger efficiency

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Charge ID - Flight Data

Flight measurement - PSD

(1 year) PRELIMINARY

Charge Res.: \( \sim 0.13e \) for H and \( 0.32e \) for Fe

Flight measurement - STK (~0.5 year)

[Gallo et al. (DAMPE), VERTEX 2016]
Helium Flux

- p & Li contamination negligible
- systematic uncertainty ~21% (dominated by trigger efficiency)

PRELIMINARY

~4.4M events

hardening at ~200 GeV

Gallo et al. (DAMPE), ICRC 2017

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Summary

• DAMPE has been successfully launched and has been in orbit since Dec 2015

• after very short turn-on phase, DAMPE has been in nominal science operations since January 2016

• unique experiment with largest deployed calorimeter in space to-date (32 $X_0$)

• DAMPE covers large scientific exploration program:
  • gamma-rays: comprehensive study of GeV-TeV sources, bridge between GeV-scale instruments (Fermi-LAT & Agile) and IACTs: detected bright sources (pulsars, AGN)
  • protons & He: largely in line with existing experiments, confirm behavior towards lower energies
  • expect to see CRE results soon

Thank you for your attention!
[CRD153] The first results from DAMPE
[DM030] In-orbit Performance of the Silicon-Tungsten Tracker of the DAMPE Mission
[CRD051] Measurement of absolute energy scale of ECAL of DAMPE with geomagnetic rigidity cutoff
[CRD082] Studies on cosmic-ray proton flux with DAMPE
[CRD096] Studies on Helium flux with DAMPE
[CRD097] Measurement of cosmic ray charge with DAMPE Silicon-Tungsten Tracker
[CRD098] PSD performance and charge reconstruction with DAMPE
[CRD117] The On-orbit Performance of DAMPE Trigger System
[CRD124] Determination of the South Atlantic Anomaly from DAMPE data
[DM032] Readout Electronics of DAMPE BGO Calorimeter and the Status during the First Year In Orbit
[DM041] Study of E/P separation for the DAMPE experiment with the TMVA BDT method
[DM042] Validation of GEANT4 Monte Carlo Models with a three dimensional BGO Calorimeter of DAMPE
[DM043] Acceptance research and electron/proton characteristic investigation in the DAMPE experiment
[DM044] Energy calibration of DAMPE in space
[DM045] The Performance of a 3D Imaging Calorimeter of DAMPE for Cosmic Ray Physics in Orbit
[GA183] First observations of Pulsars with the DArk Matter Particle Explorer
[GA184] Gamma-ray selection of DAMPE
[GA204] The variable sky of DAMPE
[GA206] Gamma-ray Astronomy with DAMPE
[GA248] The performance of DAMPE for gamma-ray detection
[GA268] Calibration of the point-spread function of DAMPE with bright pulsars and AGNs
[GA271] Bright gamma-ray sources observed by DArk Matter Particle Explorer
[GA282] A Machine Learning classifier for photon selection with the DAMPE detector
EXTRA
DAMPE Integral Sensitivity

[Zhang et al., arXiv:1407.4866]
Charge ID - Beamtest*

*Argon beam at CERN SPS
A new instrument to find lines & spectral features

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DAMPE Coll. [arXiv:1706.08453]
Good Angular Resolution for HE $\gamma$-rays

DAMPE Coll. [arXiv:1706.08453]
The DAMPE collaboration

PI: Prof. Jin Chang (PMO)

- Purple Mountain Observatory, CAS, Nanjing
- 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
- INFN Perugia & University of Perugia
- INFN Bari & University of Bari
- INFN Lecce & University of Salento
- University of Geneva

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Absolute Energy Scale

- use LE spectral cut-off of CRE to test absolute energy scale ($1 < L < 1.14$ & $8 \text{ GeV} < E < 100 \text{ GeV}$)
- direct comparison between back-tracing code (IGRF12) and data
- 2.15B triggered events between Jan 2016 and Feb 2017, after selection ~40M events left

C data/C tracer = 1.0125 ± 0.0174 (stat.) ± 0.0134 (sys.)

[Zang et al. (DAMPE), ICRC 2017]
Particle Identification

Distinctly different signature in BGO

PSD  STK  BGO  NUD

Z-X View  Z-Y View

electron  gamma  proton
Bright Sources

PRELIMINARY

[Liang et al. (DAMPE), ICRC 2017]

PRELIMINARY

[Liang et al. (DAMPE), ICRC 2017]
## Comparison with AMS-02 & Fermi-LAT

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<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>
</tr>
<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 acceptance (m^2 sr)</td>
<td>0.3</td>
<td>0.09</td>
<td>1</td>
</tr>
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</table>