Latest Results of the Dark Matter Particle Explorer (DAMPE) experiment

Jingjing Zang (藏京京)
Purple Mountain Observatory, CAS
(on behalf of the DAMPE collaboration)
The DAMPE collaboration

- **CHINA**
  - 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

- **ITALY**
  - INFN Perugia and University of Perugia
  - INFN Bari and University of Bari
  - INFN Lecce and University of Salento
  - INFN LNGS and Gran Sasso Science Institute

- **SWITZERLAND**
  - University of Geneva

DAMPE experiment is sponsored by Chinese Academy of Sciences and supported by many institutes from China, Italy and Switzerland.
DAMPE instrument
Dark Matter Particle Explorer (DAMPE)

Dark Matter Particle Explorer is a space-borne cosmic ray detection experiment measuring energy to over 10 TeV.

DAMPE ("Wukong") launched on Dec. 17, 2015

Three major scientific goals:
- Cosmic ray physics
- γ-ray astronomy
- Dark matter indirect detection
Instrument design

Plastic Scintillator Detector (PSD)
- $\gamma$ anticoincidence
- Z-measurement

BGO Calorimeter (BGO)
- Calorimeter ($32X_0$ & $1.6\lambda_l$)
- e/p separation
- Trigger primitives

Silicon Tungsten Tracker (STK)
- $\gamma$ convertor, particle track
- Z-measurement

Neutron Detector (NUD)
- e/p separation

More details can be found at Astropart. Phys., 95, 6 (2017)
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
Charge Res.: 0.06 for Z=1 efficiency(99.99%)
Silicon tracker

- Detection area: 76 cm x 76cm
- Total weight: ~154 kg
- Total power consumption: ~82W
- Three 1mm tungsten (0.86X0)
- Spatial resolution: 0.05mm

768 silicon sensors
95 x 95 x 0.32 mm³
1,152 ASICs
73,728 channels

192 ladders
BGO calorimeter

- Outer envelop: 100 cm x 100 cm x 50 cm
- Detection area: 60 cm x 60 cm
- Total weight: ~1052 kg
- Total power consumption: ~41.6 W
- Energy res.: 1% @ >50 GeV
NUD neutron detector

- $n + ^{10}\text{B} \rightarrow \alpha + ^{7}\text{Li} + \gamma$
- 4 plastic scintillators with boron doped
- Active area: 60 cm x 60 cm
- Total weight: ~12 kg
- Total power: ~ 0.5 W
Typical Event Show

electron

gamma

Proton & higher z particle
Over 500 configurations: $p, e^+, e^-, \pi^+, \gamma, \mu^+$, nuclear fragments with $p = 0.5\text{GV} \sim 400\text{GV}$
Test beam validation

Electrons: 0.5 - 243 GeV

Astropart. Phys., 95, 6 (2017)
On-orbit performance
STK direction measurement

Geminga

PSF calibrated with bright gamma-ray sources: ~0.5 degrees @ 5 GeV
BGO energy calibration

**MIP: minimum ionizing particle**

Counts

![Graph showing the relationship between deposited energy and counts for MIP (Minimum Ionizing Particle) events comparing On-Orbit Data and MC-Digi Data.](image)

- **Deposited Energy (MeV)**
- **Counts**

Inset graph showing the differential stopping power ($-dE/dx$) for various materials as a function of muon momentum.
BGO energy linearity

P vs. N-side

N-side Energy (GeV)

P-side Energy (GeV)
BGO energy linearity

P vs. N-side

$1.005 \pm 0.016$

$\sim 1\text{TeV}$
BGO energy linearity

Total energy vs. Max bar energy
- An energy scale higher by (1.2+/−1.3)% from the geomagnetic cutoff
- Cutoff energy is stable with time (a slight decrease due to solar modulation)
We use the lateral (SumRMS) and longitudinal (energy ratio in last layer) developments of the showers to discriminate electrons from protons.

For 90% electron efficiency, proton background is ~2% @ 1 TeV, ~5% @ 2 TeV, ~10% @ 5 TeV.

*Nature, 552, 63 (2017)*
Validation of e/p separation

400 GeV proton beam

243 GeV electron beam

Protons

Electrons

γ-rays
Stable Data Taking

Event rate in 2 orbits per day

DAMPE 3.5 year counts map in total

5M events/day
7.3 billion in total
Detector stability

PSD pedestal < 0.5%

STK pedestal < 0.7%

BGO pedestal < 0.9%

NUD pedestal < 0.6%
Physical results
Three different PID methods give very consistent results on event-by-event level

Direct detection of a spectral break at \(~0.9\text{TeV}\) with $6.6\sigma$ confidence level

Analysis with new data is on-going

*Nature, 552, 63 (2017)*
Errors of $e^+e^-$ spectrum

- Syst: background subtraction
- Syst: geometrical acceptance
- Syst: trigger efficiency
- Syst: $\zeta$ selection
- Statistic

Uncertainties vs. Energy (GeV)
Cooling time of TeV electrons \( \sim \) Myr, effective propagation range \( \sim \) kpc.

Assuming a total SN rate of 0.01 per year, the total number of SNRs within the effective volume and cooling time is \( O(10) \).

Implication of the spectral softening: discreteness of source distributions?

Fang et al. (2017)
Di Mauro et al. (2017)
Manconi et al. (2019)…
Spectral structures of nuclei

**PAMELA, 2011, Science**

**AMS-02, 2017, ICRC**

**CALET, 2019, PRL**


**NUCLEON, 2018, JETPL**
➤ Confirms the hundreds GeV hardening

➤ Reveals a softening at ~13 TeV with high significance

27 September 2019
Chuan Yue et al. (2019) arxiv: 1909.12857

Implications: source population (?)

Nearby source (?)

1 type

2 type

proton

Flux $\times E^{2/7}$ [m$^2$sr$^{-1}$s$^{-1}$GeV$^{-1}$]

Kinetic Energy [GeV]

nearby source
DAMPE helium spectrum

See:
Volume 358 - 36th International Cosmic Ray Conference (ICRC2019) - CRD
https://pos.sissa.it/358/058/
95% UL of dipole amplitude for 1-yr data (>~300 GeV): $6.7 \times 10^{-3}$
Summary

- DAMPE detector is working extremely well since launch

- Precise measurements of the $e^+e^-$ spectrum from 25 GeV to 4.6 TeV have been obtained, showing a spectral break at ~0.9 TeV energies

- Precise measurements of proton spectrum from 40 GeV to 100 TeV have been obtained, revealing interesting softening features at ~10 TeV

- More results are coming
Backup
Energy measurement

BGO calorimeter

308 BGO bars

616 PMTs

- Thick calorimeter ($32X_0$): high-resolution
- Two-side readouts
- Three dynode outputs enable a $>10^6$ dynamic range
e/p separation at higher energies

For 90% electron efficiency, proton background is \( \sim 2\% \) @ 1 TeV, \( \sim 5\% \) @ 2 TeV, \( \sim 10\% \) @ 5 TeV.
Raw count spectra
Laser experiment

Energy in shower max

Data 1000–1148.2 GeV

<table>
<thead>
<tr>
<th>bar</th>
<th>Entries</th>
<th>Mean x</th>
<th>Mean y</th>
<th>RMS x</th>
<th>RMS y</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14.7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Three-component $e^+e^-$ model

- Primary $e^-$ accelerated together with ions (in e.g., supernova remnants)
- Secondary $e^-$ and $e^+$ from hadronic interaction of cosmic ray nuclei
- Additional $e^-$ and $e^+$ from extra sources (e.g., pulsars, ...)

![Graph showing electron and positron spectra from AMS (2016)]

- AMS (2016) data with 16,500,000 electrons and 1,080,000 positrons
- Graph plots electron and positron fluxes against energy (GeV)