Response of the DAMPE BGO Calorimeter to Nuclide

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(On behalf of the DAMPE collaboration)

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Outline

- DAMPE experiment
- BGO calorimeter
- Beam test of BGO calorimeter
- Orbit performance
- Summary
DAMPE Mission

- **DArk Matter Particle Explorer (DAMPE)** is an orbit experiment for detecting high energy cosmic ray
- Launch: 17th Dec. 2015, CZ-2D rocket
- Life time > 3 years

- Orbit: sun-synchronous
- Altitudes: 500 km
- Period: 94 minutes
- 5 million events/day
- 16 GB/day downlink
## Scientific Objectives

<table>
<thead>
<tr>
<th>Science</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dark Matter</strong></td>
<td>GeV-10TeV electron&amp;gamma ray spectrum and space distribution</td>
</tr>
<tr>
<td><strong>Cosmic ray Origin &amp; propagation</strong></td>
<td>(1)0.1–100TeV nuclide spectrum (P-Fe)</td>
</tr>
<tr>
<td></td>
<td>(2)gamma ray spectrum and space distribution of SNR</td>
</tr>
<tr>
<td><strong>Gamma ray astronomy</strong></td>
<td>(1)gamma ray sources</td>
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<tr>
<td></td>
<td>(2)GRB</td>
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</tbody>
</table>

**CNINA**
- Purple Mountain Observatory, CAS, Nanjing
- National Space Science Center, CAS, Beijing
- University of Science and Technology of China, Hefei
- Institute of High Energy Physics, CAS, Beijing
- 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
DAMPE Detector

- Charge measurement (dE/dx in PSD, STK)
- Precise tracking (STK + BGO)
- Precise energy measurement (BGO)
- Particle identification (BGO + NUD)

<table>
<thead>
<tr>
<th></th>
<th>DAMPE</th>
<th>Fermi</th>
<th>AMS02</th>
<th>CALET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calorimeter thickness (X0)</td>
<td>32</td>
<td>8.6</td>
<td>17</td>
<td>28</td>
</tr>
<tr>
<td>Energy resolution</td>
<td>1.5%@800 GeV</td>
<td>&gt;8.5%@100 GeV</td>
<td>2%@100 GeV</td>
<td>2%@100 GeV</td>
</tr>
<tr>
<td>Angle resolution</td>
<td>0.1°@100 GeV</td>
<td>0.1°</td>
<td>0.1°</td>
<td>0.1°</td>
</tr>
<tr>
<td>Acceptance (m²Sr)</td>
<td>&gt;0.3</td>
<td>&gt;2</td>
<td>0.055</td>
<td>0.12</td>
</tr>
<tr>
<td>e/p discrimination</td>
<td>$10^5$</td>
<td>$10^4$~$10^5$</td>
<td>$10^5$</td>
<td>$10^5$</td>
</tr>
</tbody>
</table>
BGO Calorimeter

- 308 BGO bars (25*25*600 mm³)
- 14 layers, 22 bars per layer
- 32 radiation lengths
- 1.6 nuclear interaction lengths
- Energy range: 5GeV-10TeV (e/γ)
- Energy resolution: 1.5%@800GeV (e/γ)
- Energy range of proton/nuclide: 50GeV-100TeV
- Energy resolution of proton: <40%@800GeV

✦ Provide trigger
✦ Energy measurement
✦ e/p separation
✦ Track seed
Detection Unit of the BGO ECAL

- Energy response of one BGO bar is from 10MeV (0.5MIPs) to 2TeV (10^5MIPs)
- Two-end measurement of one BGO bar
- Multi-dynode readout of one PMT
Beam Test @ CERN

- **22 days, PS & SPS**
  - electron: 0.5 - 243 GeV
  - Proton: 3.5 - 10 GeV
  - gamma: 0.5 - 20 GeV
  - muon: 150 GeV

- **17 days, SPS**
  - Argon: 30, 40, 75 GeV/n
  - Proton: 30, 40 GeV

- **21 days, SPS**
  - Proton: 400 GeV
  - electron: 20 - 150 GeV
Electron Response in the BGO Calorimeter (Beam Test)

Ion Beam Test Set up & Charge Measurement

Charge identification with dE/dx detectors before the BGO Calorimeter
MIP events in first layer of the BGO ECAL were utilized to identify charge.
Quenching Effect of the BGO Crystal

- Quenching effect was observed in the case of $Z>5$
- $QF = \frac{\text{Peak}_{\text{Data}}}{\text{Peak}_{\text{Simu}}}$
Energy Response to Nuclide

- A pre-selection is applied on nuclide data
  - Pass high energy trigger
  - Shower starts at the top of the BGO calorimeter
Energy Response to Nuclide (40 GeV/n)

MC: Geant4.10.1 QGSP_FTFP_BERT

Helium

Carbon

Aluminum

Argon
Energy Response to Nuclide (40 GeV/n)

Energy Fraction = Energy Deposition/Incident Energy

![Graphs showing Energy Fraction and Energy Resolution vs. Z](image)
Energy Response to Nuclide (75 GeV/n)

- Helium
- Carbon
- Sulfur
- Argon

Preliminary
Energy Response to Nuclide (75 GeV/n)

Energy Fraction = Energy Deposition/Incident Energy
Energy Fraction vs Incident Energy

**Carbon**

**Oxygen**

Data

Simu
Orbit Performance

Launched on 17th Dec. 2015
Jiuquan Satellite Launch Center, Gobi desert
Orbit Calibration with Nuclide

- No mono energy source in space
- Proton/Nuclide MIP events are utilized to do energy calibration

1 MIP $\approx 23$ MeV
MIP Events of Nuclide

Boron

\[ \chi^2 / n df = 5.908 / 4 \]
\[ \text{Prob} = 0.2062 \]
\[ \text{Constant} = 665.8 \pm 16.7 \]
\[ \text{Mean} = 544.8 \pm 0.8 \]
\[ \text{Sigma} = 36.3 \pm 0.8 \]

Carbon

\[ \chi^2 / n df = 7.067 / 5 \]
\[ \text{Prob} = 0.2157 \]
\[ \text{Constant} = 752.4 \pm 15.5 \]
\[ \text{Mean} = 785.1 \pm 1.3 \]
\[ \text{Sigma} = 59.38 \pm 1.85 \]

Oxygen

\[ \chi^2 / n df = 8.579 / 7 \]
\[ \text{Prob} = 0.2843 \]
\[ \text{Constant} = 379.6 \pm 10.6 \]
\[ \text{Mean} = 1210 \pm 1.3 \]
\[ \text{Sigma} = 51.45 \pm 1.29 \]

Iron

\[ \chi^2 / n df = 19.38 / 10 \]
\[ \text{Prob} = 0.03573 \]
\[ \text{Constant} = 76.79 \pm 4.03 \]
\[ \text{Mean} = 8690 \pm 20.8 \]
\[ \text{Sigma} = 340.9 \pm 24.1 \]
Long Time Stability

- **Boron**
- **Carbon**
- **Oxygen**
- **Iron**
Summary

- A BGO calorimeter was built for DAMPE mission
- Ion beam test was performed for the BGO ECAL
- Quenching effect of BGO crystal was observed
- More than 30% energy deposited in the BGO ECAL
- Energy resolution is better than 30%
- Nuclide MIP is good reference for energy measurement on orbit
Summary

• A BGO calorimeter was built for DAMPE mission
• Ion beam test was performed for the BGO ECAL
• Quenching effect of BGO crystal was observed
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Thank you
Backup
Energy Response to Nuclide (40 GeV/n)

- **Helium**
- **Lithium**
- **Boron**
- **Carbon**
Energy Response to Nuclide (40 GeV/n)

- **Nitrogen**
- **Oxygen**
- **Neon**
- **Magnesium**
Energy Response to Nuclide (40 GeV/n)

- **Aluminum**
- **Silicon**
- **Sulfur**
- **Argon**
Energy Response to Nuclide (75 GeV/n)

- **Helium**
- **Carbon**
- **Oxygen**
- **Neon**
Energy Response to Nuclide (75 GeV/n)

- **Magnesium**
- **Silicon**
- **Sulfur**
- **Argon**
Different MC Model (40 GeV/n)

Carbon

Counts

Energy_in_ECAL(GeV)

FTFP_BERT
QGSP_BERT
QGSP_FTPP_BERT