DAMPE: first data from space

Ivan De Mitri
Università del Salento and INFN, Lecce, Italy
(on behalf of DAMPE collaboration)

6th Roma International Conference on AstroParticle physics
June 22-24, 2016, Frascati (Rome)
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

Detection of

- 10 GeV - 10 TeV e/$\gamma$
- 50 GeV - 500 TeV protons and nuclei

with excellent energy resolution, tracking precision and particle identification capabilities

- Exotica and “unexpected”, e.g. GW e.m. counterpart in the FoV
The 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

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

- Plastic Scintillator Detector (PSD)
- Silicon-Tungsten Tracker (STK)
- BGO Calorimeter (CALO)
- Neutron Detector (NUD)

- Charge measurement (dE/dx in PSD, STK and BGO)
- Tungsten converter (pair production)
- Precise tracking (silicon strips)
- Thick calorimeter (BGO bars)
- Hadron rejection (neutron detector)

high energy γ-ray, electron and cosmic ray telescope
The Silicon TracKer (STK)

- 768 silicon sensors
- Silicon detectors
- 192 ladders
- VA140 (front end chip)
- 1152 ASICs
- 73728 channels

- 48 µm wide Si strips with 121 µm pitch
- (95 × 95 × 0.32 mm³) Silicon Strip Detectors (SSD) with 768 strips
- One ladder composed by 4 Silicon Strip Detectors (SSD)
- 16 Ladders per layer (76 cm × 76 cm)
- 12 layers (6x + 6y)

Analog Readout of each second strip:
384 channels / SSD- Ladder
Charge sharing
The Silicon TracKer (STK) - 2
The CALOrimeter

- 14 layers of 22 BGO bars
  - Dimension of BGO bar: 2.5 × 2.5 × 60 cm³
  - 14 hodoscopic stacking alternating orthogonal layers
  - depth ~32X₀
- Two PMTs coupled with each BGO crystal bar in two ends
- Electronics boards attached to each side of module

308 bars
616 PMTs
The CALOrimeter -2

- Carbon Fiber Structure
- BGO crystal installation
- PMT installation
- Cable arranging
- Cable connector
- BGO Cal
The PSD and the NUD

**PSD**

- 1.0 cm thick, 2.8 cm wide and 82.0 cm long scintillator strips
- Staggered by 0.8 cm in a layer
- 82 cm × 82 cm layers
- 2 layers (x and y)

**NUD**

- 4 large area boron-doped plastic scintillators (30 cm × 30 cm × 1 cm)

\[ n + ^{10}B \rightarrow \alpha + ^7Li + \gamma \]
Comparison with AMS-02 and FERMI

<table>
<thead>
<tr>
<th>Comparison</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>1.5</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>e/γ Angular res.@100 GeV (°)</td>
<td>0.1</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td>e/p discrimination</td>
<td>$10^5$</td>
<td>$10^5 - 10^6$</td>
<td>$10^3$</td>
</tr>
<tr>
<td>Calorimeter thickness ($X_0$)</td>
<td>32</td>
<td>17</td>
<td>8.6</td>
</tr>
<tr>
<td>Geometrical accep. ($m^2sr$)</td>
<td>0.29</td>
<td>0.09</td>
<td>1</td>
</tr>
</tbody>
</table>

Mass: 1400 Kg
Power: ~ 400 W
Livetime: > 3 years
Test beam activity at CERN

- **14days@PS, 29/10-11/11 2014**
  - e @ 0.5GeV/c, 1GeV/c, 2GeV/c, 3GeV/c, 4GeV/c, 5GeV/c
  - p @ 3.5GeV/c, 4GeV/c, 5GeV/c, 6GeV/c, 8GeV/c, 10GeV/c
  - \( \pi^- \) @ 3GeV/c, 10GeV/c
  - \( \gamma \) @ 0.5-3GeV/c
- **8days@SPS, 12/11-19/11 2014**
  - e @ 5GeV/c, 10GeV/c, 20GeV/c, 50GeV/c, 100GeV/c, 150GeV/c, 200GeV/c, 250GeV/c
  - p @ 400GeV/c (SPS primary beam)
  - \( \gamma \) @ 3-20GeV/c
  - \( \mu \) @ 150GeV/c
- **17days@SPS, 16/3-1/4 2015**
  - Fragments: 66.67-88.89-166.67GeV/c
  - Argon: 30A-40A-75AGeV/c
  - Proton: 30GeV/c, 40GeV/c
- **21days@SPS, 10/6-1/7 2015**
  - Primary Proton: 400GeV/c
  - Electrons @ 20, 100, 150 GeV/c
  - \( \gamma \) @ 50, 75, 150 GeV/c
  - \( \mu \) @ 150 GeV/c
  - \( \pi^+ \) @ 10, 20, 50, 100 GeV/c
- **10days@SPS, 11/11-20/11 2015**
  - Pb 30AGeV/c (and fragments) (HERD)
- **6days@SPS, 20/11-25/11 2015**
  - Pb 030 AGeV/c (and fragments)
Test beam activity at CERN: electrons

Electrons
0.5, 1, 1.5, 2, 3, 4, 5 GeV @ PS
5, 10, 20, 50, 100, 149, 197, 243 GeV @ SPS

243 GeV Electron Longitudinal profile
Test beam activity at CERN: electrons

**BeamTest Data:**
\[
\frac{\sigma_E}{E} = \frac{0.0606}{\sqrt{E/\text{GeV}}} \oplus \frac{0.0203}{E/\text{GeV}} \oplus 0.0082
\]

**Simulation:**
\[
\frac{\sigma_E}{E} = \frac{0.0611}{\sqrt{E/\text{GeV}}} \oplus \frac{0.0147}{E/\text{GeV}} \oplus 0.0088
\]
Test beam activity at CERN: ions

@ 40 GeV/n

Preliminary
The launch: Dec 17th 2015, 0:12 UTC

Jiuquan Satellite Launch Center
Gobi desert

Orbit: sun synchronous, 500km

DAMPE → WUKONG
Dec 24th 2015: HV on 330 GeV electron
Dec 24th 2015: HV on

12 GeV proton
Dec 24th 2015: HV on

1.3 TeV carbon
Trigger rate in orbit

~50 Hz average trigger rate
→ 100GB/day on ground (about 4 M events)
Some on-orbit performance plot

**STK space resolution**

Measurements on ground

~ 40 µm resolution

**BGO “mip” peak**

RICAP 2016

I. De Mitri - DAMPE: First data from space
Electron indentification

One possible “shape parameter”

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

Rejection power > $10^5$

---

**Electrons and positrons**

**Protons and nuclei**
On-orbit energy calibration

e± rigidity cutoff with 1 month statistics

PRELIMINARY

Vertical rigidity cutoff @ h = 500 km (GV)

SAA

Trapped electron/positrons and hadron background

Counts/bin

Trigger threshold

Surface magnetic field [G]

Energy (MeV)

375.7 / 240
p0 2.654e+15 ± 8.417e+14
p1 3.102 ± 0.031
p2 1.379e+04 ± 9.279e+01
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 one TeV
- Detect structures in the spectrum due to nearby sources and/or DM induced excesses
- Detect anisotropies at high energy

Simulation assuming the AMS-02 power law spectrum + a cut-off + the contribution of nearby sources

DAMPE 3yrs
DAMPE 165 days
E > 1GeV
Counts / (0.5°)^2 pixel
σ_0 ≈ 0.2° @ 3 GeV

FERMI 5 years
E > 1GeV

Vela
Geminga
Crab
Identifying protons and nuclei

On-Orbit data (4.5 days)

Charge resolution $\sim 0.2$-$0.3$ e depending on $Z$

Charge measurement also given by STK and (with lower precision) by the BGO bars
Protons and nuclei spectra
Protons and nuclei: DAMPE 3years

Simulation assuming AMS-02 fit

Simulation assuming Horandel fluxes

Simulation assuming AMS-02 fit

Simulation assuming AMS-02 fit
Summary

The detector
- Large geometric factor instrument (0.3 m² sr for p and nuclei)
- Precision Si-W tracker (40µm, 0.2°)
- Thick calorimeter (32 X₀, σₑ/E better than 1% above 50 GeV for e/γ, ~35% for hadrons)
- “Mutiple” charge measurements (0.2-0.3 e 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
- High energy gamma ray astronomy
- Search for dark matter signatures in lepton spectra
- The “unexpected”: GW electromagnetic follow up in FoV