The DAMPE silicon tungsten tracker

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Contents

- DAMPE
- The STK construction
- The STK qualification
- The STK test beam
- Performances on orbit:
  - STK Noise
  - Temperature evolution
  - Alignment
  - Tracking efficiency
  - Charge calibration

Launched the 17th December 2015
DAMPE (DArk Matter Particle Explorer)

- Scientific satellite project of Chinese Academy of Sciences (CAS)
- Collaboration: UniGE, Perugia, Bari, Lecce, IHEP, PMO, USTC, IMP, NSSC
- CERN recognized experiment since March 2014

- Thick imaging calorimeter (BGO of ~ 32 X₀)
- Precise tracking with Si strip detectors (STK)
- Photon conversion thanks to Tungsten plates in STK
- Charge measurements with PSD and STK
- Extra hadron rejection with NUD

High Energy gamma-ray, electron and Cosmic Ray Telescope

Detection of 5 GeV - 10 TeV e/γ
100 GeV - 100 TeV Cosmic Ray
The Silicon TracKer (STK)

- 7 support trays made of a carbon fiber sheet with Al honeycomb core
- Trays 2, 3 and 4 equipped with 1 mm thick Tungsten plates (~ 1 $X_0$)
- 768 Silicon detectors -> 192 ladders -> 12 layers: Silicon surface ~ 7 m$^2$
- 8 readout boards on the 4 sides
Silicon detectors

- Single-sided Silicon strip detectors produced by Hamamatsu
  - 9.5x9.5 cm$^2$ 768 strips 121 um pitch (AGILE geometry)
  - 320 um thick (AGILE 410 um)
  - Resistivity 5-8 k$\Omega$, $V_{fd}$ 10-80 V
  - Total strip capacitance 2.1 pF/cm
- 865 for FM
  - Excellent quality
  - $I_{\text{leak}} \sim 120$ nA @ 150 V
  - $V_{fd} < 60$ V
  - Few bad channels
  - Cut precision: ~ few um
STK Readout Electronics

- Readout every other strip - readout pitch 242 um
- ASIC: VA140 from IDEAS - updated version VA64hdf (AMS-02)
  - Low power (0.3 mW/channel) and large dynamic range (200 fC)
  - Analog readout: Charge measurement and Better position resolution
- Tracker Front-end Hybrid (THF)
  - Thin bias circuit integrated with PCB housing 6 ASICs with integrated readout cable
  - Support structure for the SSDs
  - Vias and copper bands for heat transfer
STK Silicon ladders

- Precise jigs to assemble (align, glue and bond) 4 sensors to form a ladder
  - requirement 20 um alignment -> achieved < 10 um for more than 97%
STK Tracker planes

- 16 ladders glued on both faces (in X/Y direction) of the supporting trays (except last and first plane)

- The assembled planes are measured with the metrology machine, flatness ~100um
- The excellent quality of the SSD maintained during the assembly
- Low leakage current of 192 ladders after plane assembly at 80 V
STK FM assembly

• The flight model assembly has been completed in April 2015
• Tested with cosmic rays before delivered to China
STK Qualification

• An EQM (Engineering and Qualification Model) and a Flight Model have been assembled
• The EQM equipped with 26 ladders and the rest with mechanical sensors
• The EQM passed a series of space environmental qualification tests: vibration, acceleration, shock, thermal cycling, thermal vacuum
The ladders were installed on a rotation stage in the middle of a beam telescope made of 6 HV-CMOS pixel detectors ~5um resolution - Good data/MC (SPICE/GEANT4) agreement for all the angles - Spatial resolution lower than 60 um for incidence angle within the STK acceptance (< 60°)

Details in: ICRC2015 HSTD10
DAMPE Satellite

- Launch: December 17th 2015, CZ-2D rocket
  - Total weight ~1900 kg
  - Power consumption ~640 W
- Scientific payload ~1300 kg, ~400 W
  - Lifetime > 3 years

- Altitude: 500 km
- Inclination: 97.4065°
- Period: 95 minutes
- Orbit: sun-synchronous
- 12 GB/day downlink
73728 readout STK channels

- Bulk of the noise ~ 2.8 and lower respect to ground thanks to the lower operation temperature in flight
- Less than 0.3% of noisy channels
Temperature Evolution

- STK is constantly 10° higher than radiators
- Day to day the variation is much less than 1°
- Max monthly variation of ~2.5°
- As expected the ladder noise is correlated to the temperature change
- The noise variation is very small ~0.01 ADC per 2°
Position resolution

- Offline clustering -> CoG
- **Alignment** correction due to the displacement and rotation of SSD
- Tracks reconstruction based on Kalman algorithm
- Position resolution: residuals between the hit and the track position
- Comparison with a perfect aligned MC
- Achieved 40-50 um for most of the angles
- Good agreement with MC and test beam campaign

**PRELIMINARY**
STK Mechanical stability

- The STK stability is monitored by alignment constant
- The X-Y moment results to be negligible
- Small movement in Z which implies a correction with the temperature
- The max observed displacement is of ~ 25 μm
Alignment vs Time

- Variation of the resolution as a function of time
- The position resolution for inclined track is affected by the alignment constants
- The stability is reached when the alignment procedure is applied each month
Tracking Efficiency

- Selection of a sample of $Z = 1$ and $Z = 2$ particle using only PSD and BGO
- No showering before the first 6 layers of BGO
- Sample of proton and helium MIP events

**Track efficiency:**
- High Track efficiency > 99 %
- Stable over time
VA Equalization

- The chip response has been studied for $Z = 1$
- Each distribution has been fitted with a landau convoluted with a gaussian function
- The VA equalization factors have been calculated using 2 month of data
STK charge measurements need to be corrected for the strip floating/readout scheme.

- The charge loss in the floating region can be up to ~ 40%.
- The dependence is mainly due to the particle inclination.
- The VA saturation effects $Z > 6$ charge reconstruction.
Charge calibration

- Calibration procedure: fit of a gaussian convoluted with a landau function using: RooFFTConvPdf
- The fit is performed in $Z$, $\theta$, $\eta$ bins
- As first approximation the mean for the correction obtained from helium to carbon is used to improve the charge measurement and to identify fragmented ions along the path (W plates)
Charge calibration

- Improvement of the charge identification up to $Z = 6$
- A second calibration depending from $Z$ is also needed to improve the identification
- Methods to identify ions for $Z > 6$ are understudy together with the TB data analysis
Conclusions

- The DAMPE Silicon Tungsten tracker has been successfully built in very short time 2013->2015 profiting of the robust technology and excellent quality of the SSD and the previous experience in space experiments.

- The EMQ and FM have been qualified for space in terms of vibration, acceleration, shock, thermal cycling, thermal vacuum tests.

- The quality of STK is excellent and the specifications are kept during all the construction and qualification steps.

- The DAMPE mission has been successfully launched the 17th December 2015.

- The STK performances on-orbit are excellent and stable.

- The STK will play a crucial role for: track reconstruction, gamma ray detection and cosmic ray charge measurements.

STAY TUNED FOR NEW PHYSICS RESULTS!!!
THANK YOU!
back-up
STK Test beam

- **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
  - π- @ 3GeV/c, 10GeV/c
  - γ @ 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)
  - γ @ 3-20GeV/c
  - μ @ 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
  - γ @ 50, 75, 150 GeV/c
  - μ @ 150 GeV/c
  - π+ @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)
Charge selection using PSD:
- Two landau + 8 gaussian
- Mean +/- 2 Sigma for Z= 1 and 2
- Mean +/- 1 Sigma for Z > 2
- Li selection with PSD is difficult, therefore the STK (total ST) is used
- STK used only for Li
## Comparison with AMS-02 and FERMI

<table>
<thead>
<tr>
<th></th>
<th>DAMPE</th>
<th>AMS-02</th>
<th>Fermi LAT</th>
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<tbody>
<tr>
<td>e/γ Energy res.@100 GeV (%)</td>
<td>1.5</td>
<td>3</td>
<td>10</td>
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<tr>
<td>e/γ Angular res.@100 GeV (°)</td>
<td>0.1</td>
<td>0.3</td>
<td>0.1</td>
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<tr>
<td>e/p discrimination</td>
<td>$10^5$</td>
<td>$10^5 - 10^6$</td>
<td>$10^3$</td>
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<tr>
<td>Calorimeter thickness ($X_0$)</td>
<td>32</td>
<td>17</td>
<td>8.6</td>
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<td>Geometrical accep. (m²sr)</td>
<td>0.29</td>
<td>0.09</td>
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Mass: 1400 Kg  
Power: ~ 400 W  
Livetime: > 3 years