Performance of the DAMPE silicon-tungsten tracker-converter during the first 5 years of in-orbit operations

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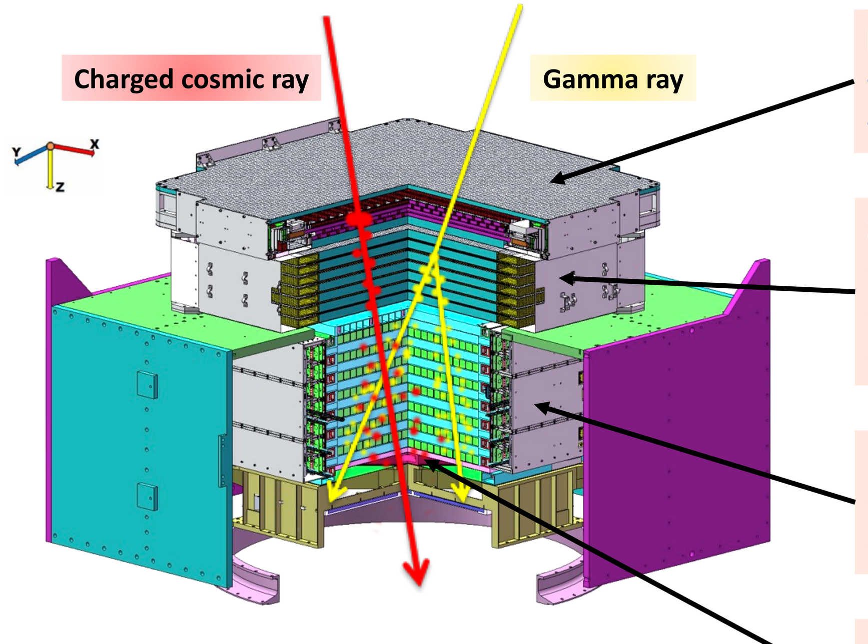
The DAMPE experiment

The DArk Matter Particle Explorer (DAMPE) is a satellite-based experiment for the detection of charged cosmic rays and gamma rays.



PSD: Plastic Scintillator Detector
- Charge measurement (|Z|)
- Anti-coincidence charged/neutral particles

STK: Silicon-Tungsten tracKer-converter
- Track reconstruction
- Photon conversion ($\gamma \rightarrow e^+ e^-$)
- Charge measurement (|Z|)

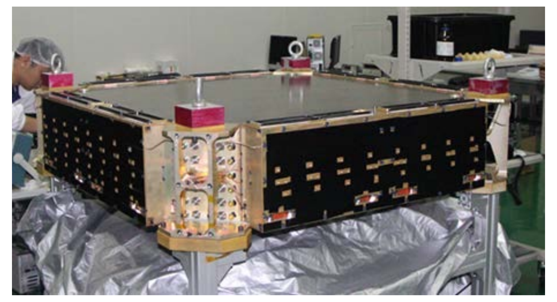
BGO: Bismuth Germanium Oxide calorimeter
- Energy measurement
- Electron/proton separation

NUD: NeUtron Detector
- Delayed neutrons coming from the hadronic interactions
- Electron/proton separation

e/γ Energy range	GeV – 100 TeV
p Energy range	10 GeV – 100 TeV
e/γ Energy resolution at 100 GeV	< 1.5 %
e/γ Angular resolution at 100 GeV	< 0.2°
e/p separation	> 10^5
Calorimeter thickness	32 X_0
Geometrical acceptance	0.3 m² sr

Launch	December 17, 2015
Orbit	Sun-synchronous
Altitude / Inclination / Period	500 km / 97° / 95 minutes
Mass / Power / Download	1'400 kg / 400 W / 12 GB/day

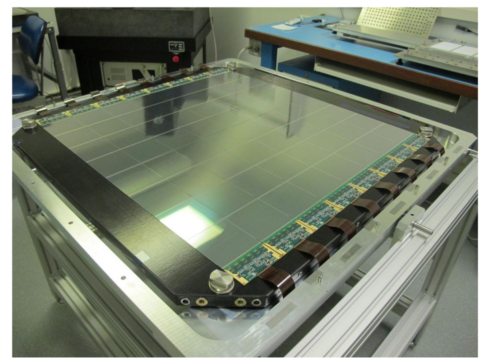
The Silicon-Tungsten tracKer-converter (STK)



Outer envelope	1.12 m × 1.12 m × 25.2 cm
Detection area	76 cm × 76 cm
Mass / Power	155 kg / 90 W

- 12 tracking layers (6x, 6y) of single-sided Si strip detectors mounted on 7 support trays.
  - Tray: two carbon fibre sheets with Al honeycomb core
- 1 tungsten layer (1 mm thick) integrated in the 2nd, 3rd and 4th tray from the top.
  - Total thickness: 0.85 X_0 for photon conversion

1 tracking layer = 16 ladders



1 ladder = 4 single-sided AC-coupled Silicon micro-Strip Detectors (SSDs)

Front-end electronics:
- 6 VA140 ASIC chips 64 channels each
- made by IDEAS

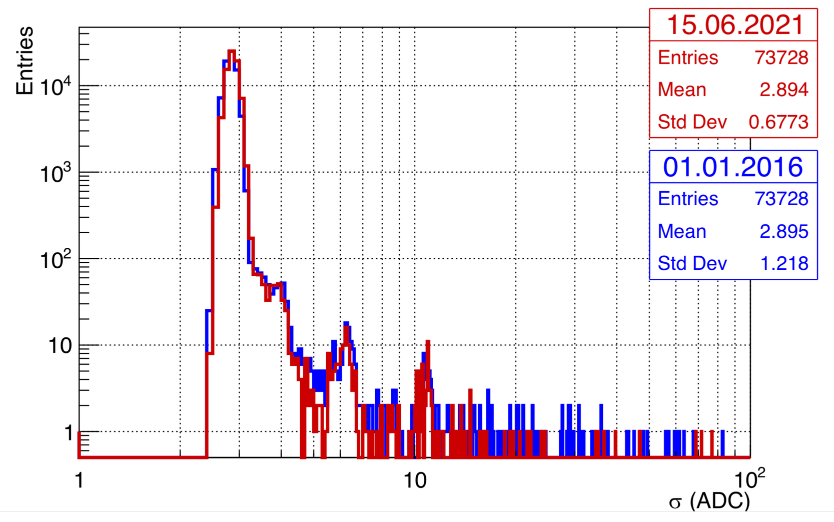
4 SSDs are daisy-chained via micro wire bonds

Producer	Hamamatsu Photonics
Detection area	9.29 cm × 9.29 cm
Si strips	768 with a pitch of 121 mm
Readout channels	384 with a pitch of 242 mm

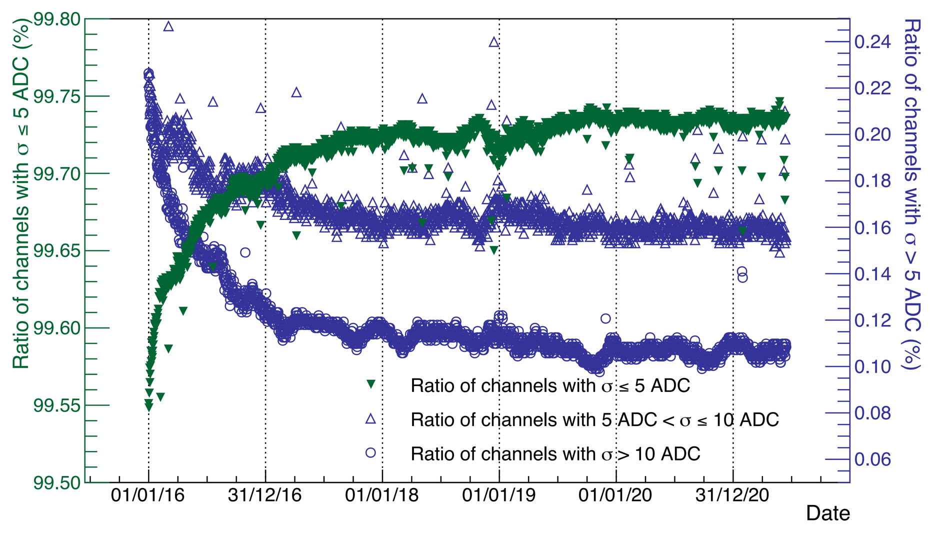
$$16\ \frac{\text{ladders}}{\text{layer}} \times 12\ \text{layers} = \mathbf{192\ ladders}$$

$$384\ \frac{\text{channels}}{\text{ladder}} \times 192\ \text{ladders} = \mathbf{73'728\ channels}$$

The STK noise behaviour

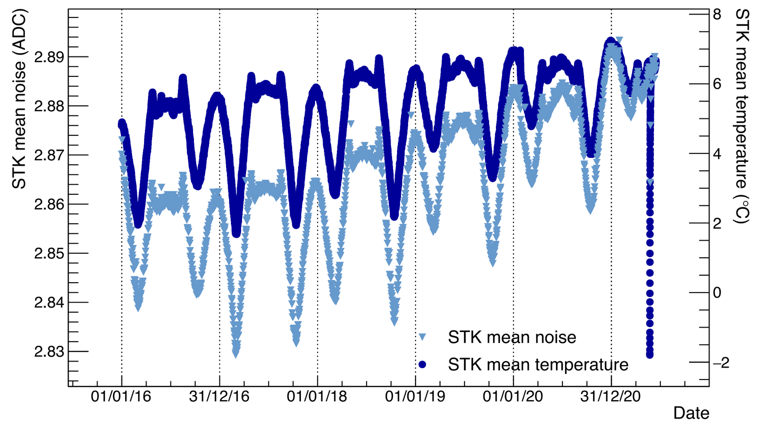


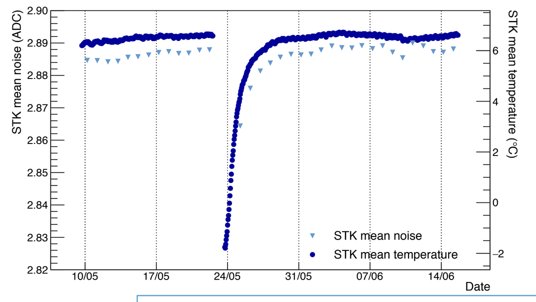
Noise distribution of the 73'728 channels at the beginning of the mission (January 1, 2016) and recently (June 15, 2021).
- Similar distribution → Excellent noise stability
- Mean < 3 ADC



Time evolution of the fraction of
1. good channels (σ ≤ 5 ADC);
2. quite good channels (5 ADC < σ ≤ 10 ADC);
3. bad channels (σ > 10 ADC).
- The fraction of good channels increased over time thanks to the stabilization in space and since two years its value is stable around 99.74%.
- Only 0.11% of the channels are "bad".

The STK noise – temperature correlation

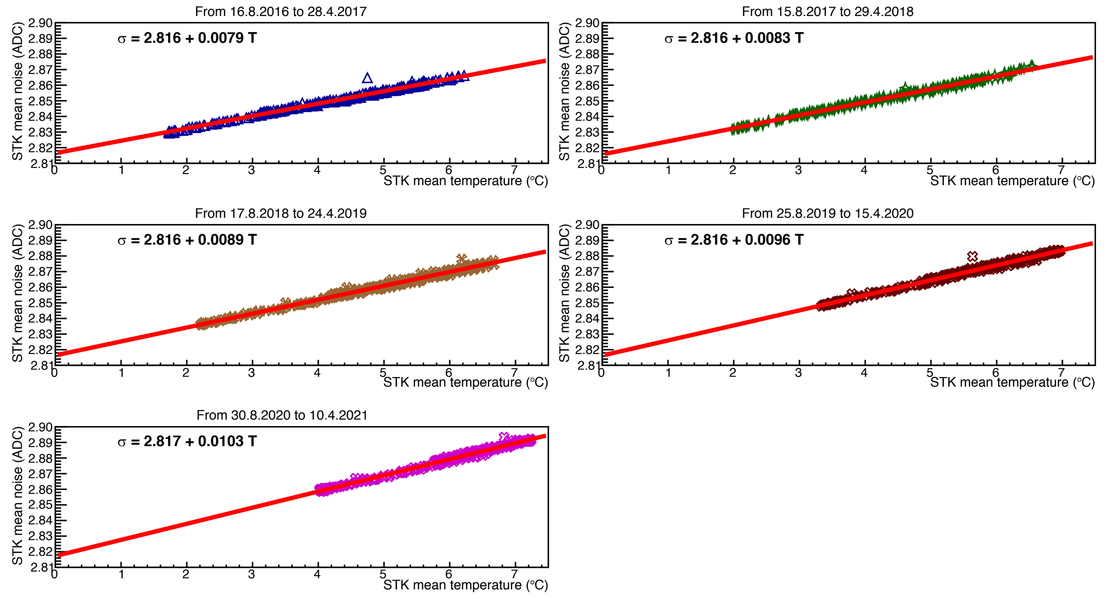




May 23 and 24, 2021: payload power off

→ after the detector was powered on again, both the noise and the temperature were back at the expected levels.

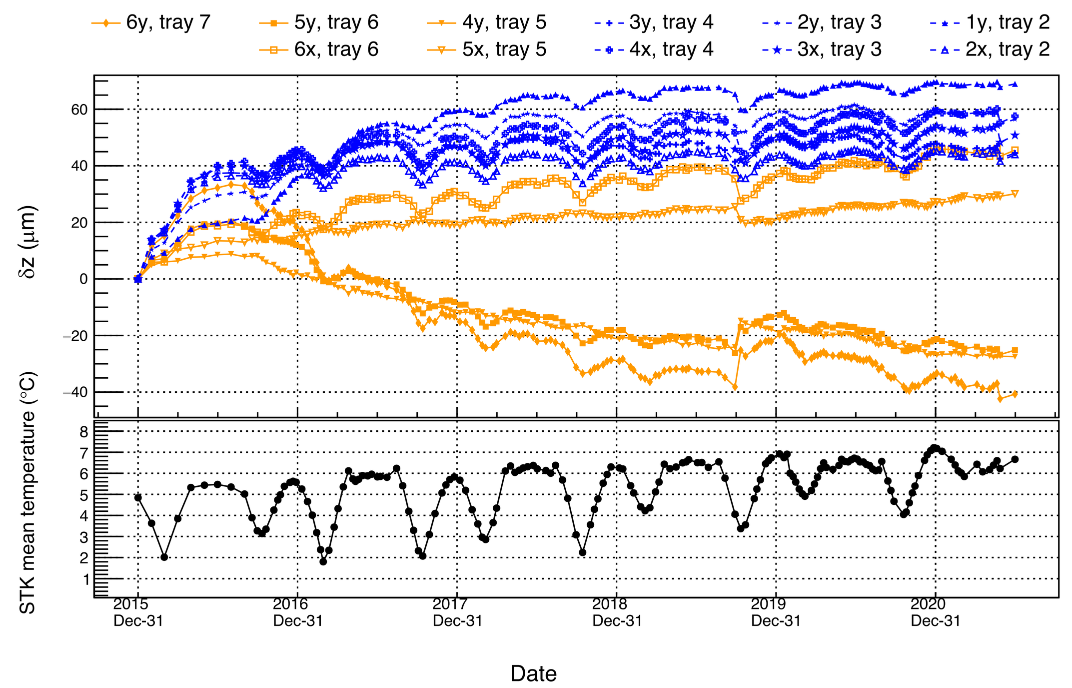
Excellent noise stability correlated to the high temperature stability, due to the robustness of the mechanical design and the Sun-synchronous orbit.



The mean STK noise is increasing slightly more than the mean STK temperature, from 0.008 ADC/°C to 0.01 ADC/°C in five years, possibly because of a still negligible radiation damage of the silicon detectors.

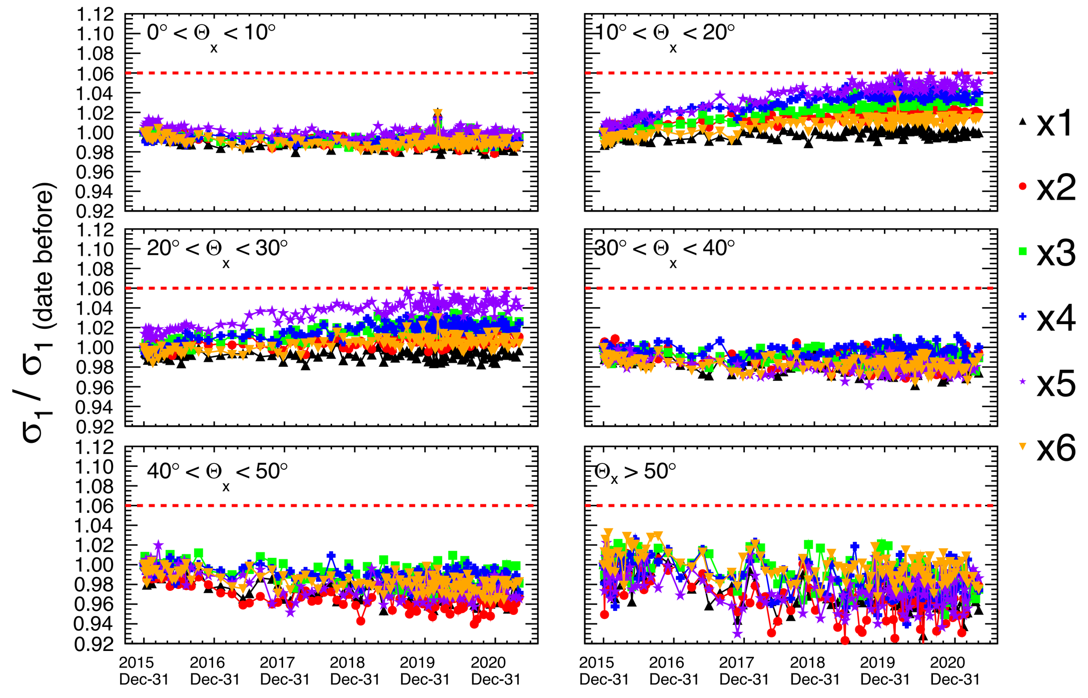
The STK alignment and position resolution

The high temperature stability also ensures a good mechanical stability. Since the mechanical assembly of the STK has a construction precision of about 100 μm larger than the position resolution of the silicon sensors (< 70 μm), an alignment procedure is needed to correct for the displacement and rotation of each sensor with respect to its nominal position, allowing the full tracker potential to be exploited.



The average z position of each STK tracking layer with respect to the first layer (1x, tray 1) is a function of the alignment parameters.

Its variation with time is due to the humidity release and temperature variation.



Thanks to the bi-weekly updates of the alignment parameters, the optimal position resolution remains stable and the deviation from the initial values is below 6% for all STK layers and particle incidence angles.

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