DAMPE space mission: first data

Fabio Gargano – INFN Bari

on behalf the DAMPE collaboration

INFN Istituto Nazionale di Fisica Nucleare Sezione di Bari

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
  - **Exotica** and "**unexpected**", e.g. GW e.m. counterpart in the FoV

Detection of
10 GeV - 10 TeV e/γ
50 GeV - 500 TeV protons and nuclei
with excellent energy resolution, tracking precision and particle identification capabilities

The collaboration

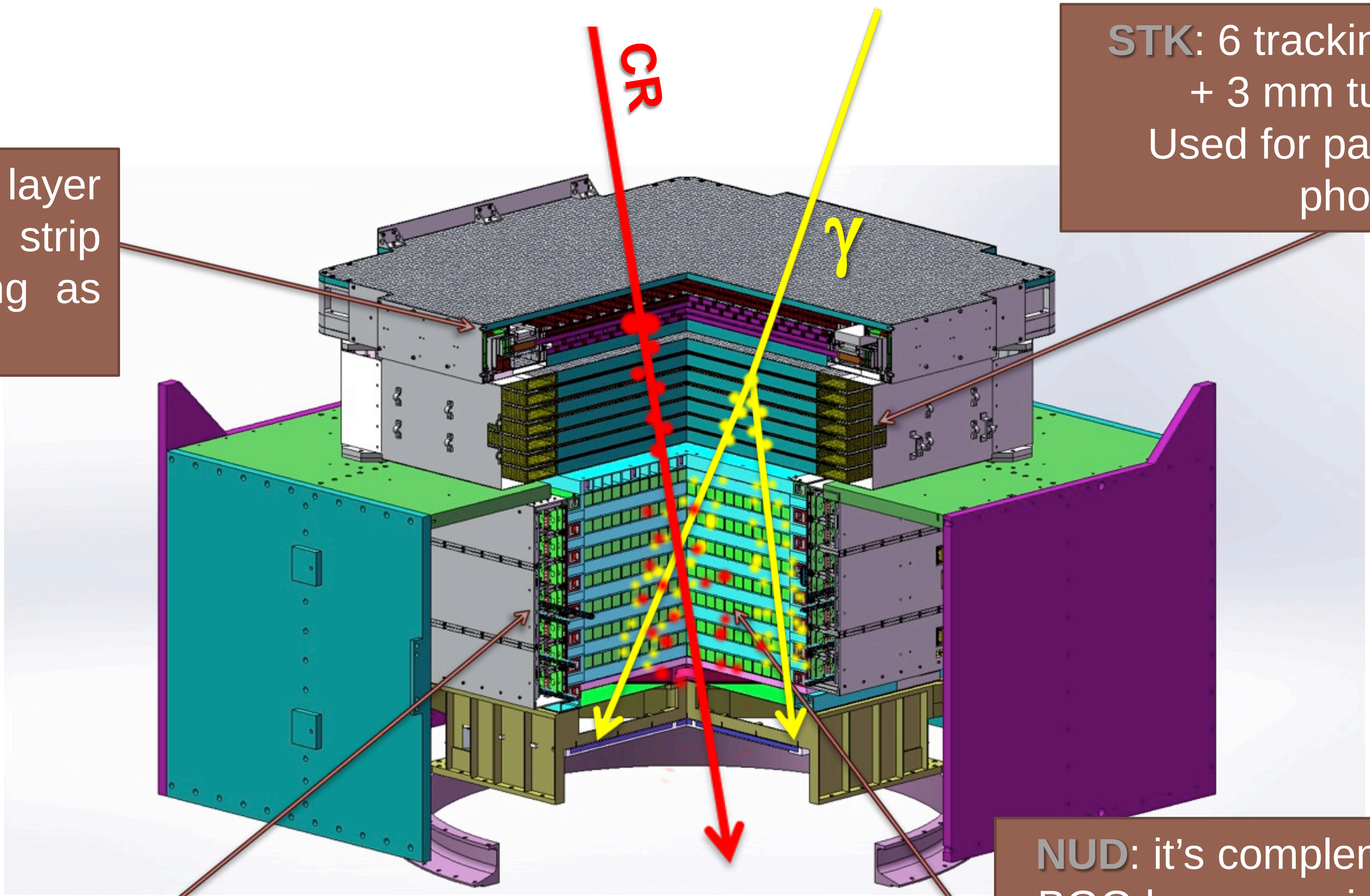
- **CHINA**
  - **Purple Mountain Observatory, CAS, Nanjing**
    - Prof. Jin Chang (Principal Investigator)
  - **Institute of High Energy Physics, CAS, Beijing**
  - **National Space Science Center, CAS, Beijing**
  - **University of Science and Technology of China, Hefei**
  - **Institute of Modern 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

PSD: double layer of scintillating strip detector acting as ACD

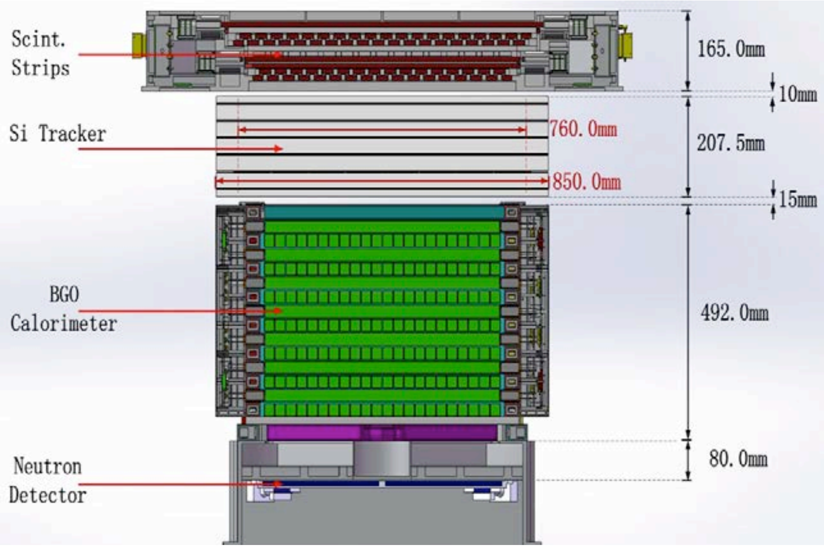


STK: 6 tracking double layer + 3 mm tungsten plates. Used for particle track and photon conversion

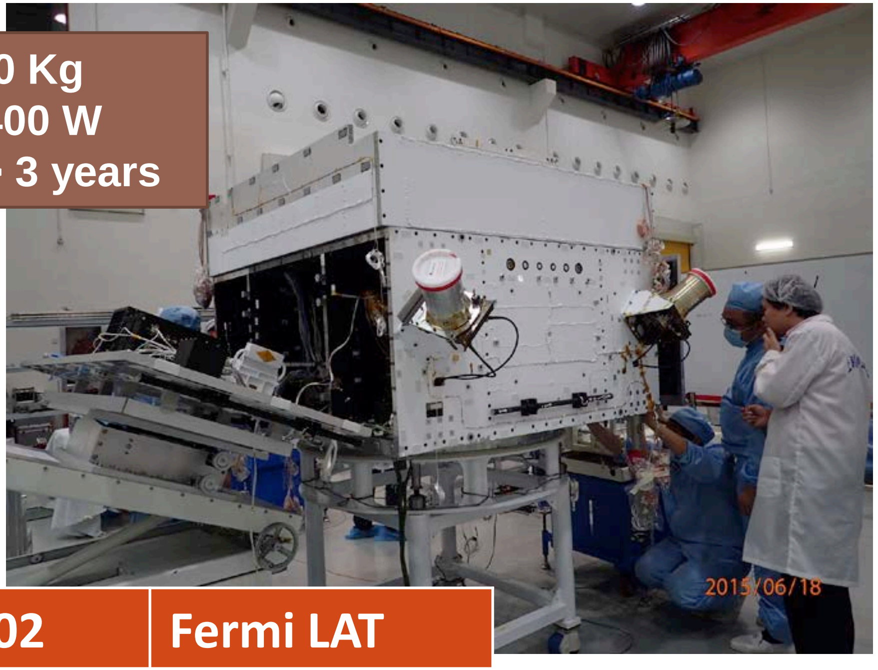
BGO: the calorimeter made of 308 BGO bars in hodoscopic arrangement (~31 radiation length). Performs both energy measurements and trigger

NUD: it's complementary to the BGO by measuring the thermal neutron shower activity. Made up of boron-doped plastic scintillator

Comparison with AMS-02 and FERMI



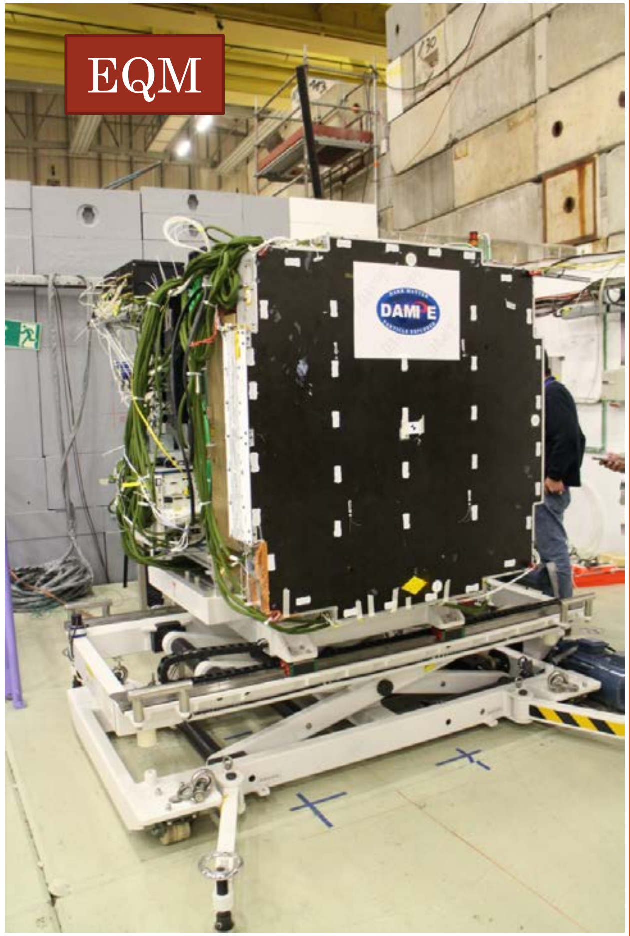
Mass: 1400 Kg
Power: ~ 400 W
Lifetime: > 3 years



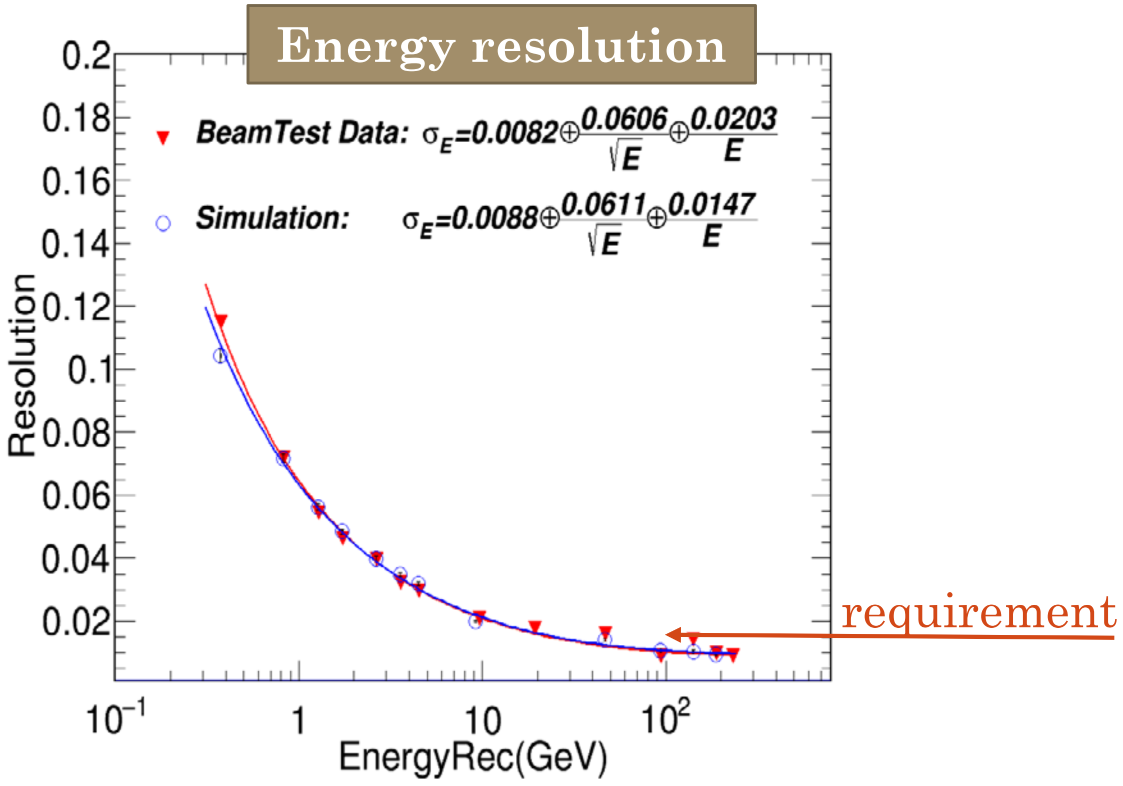
	DAMPE	AMS-02	Fermi LAT
e/γ Energy res.@100 GeV (%)	**1.5**	3	10
e/γ Angular res.@100 GeV (deg.)	0.1	0.3	0.1
e/p discrimination	10^5	10^5 - 10^6	10^3
Calorimeter thickness (X_0)	**32**	17	8.6
Geometrical accep. (m^2sr)	**0.29**	0.09	1

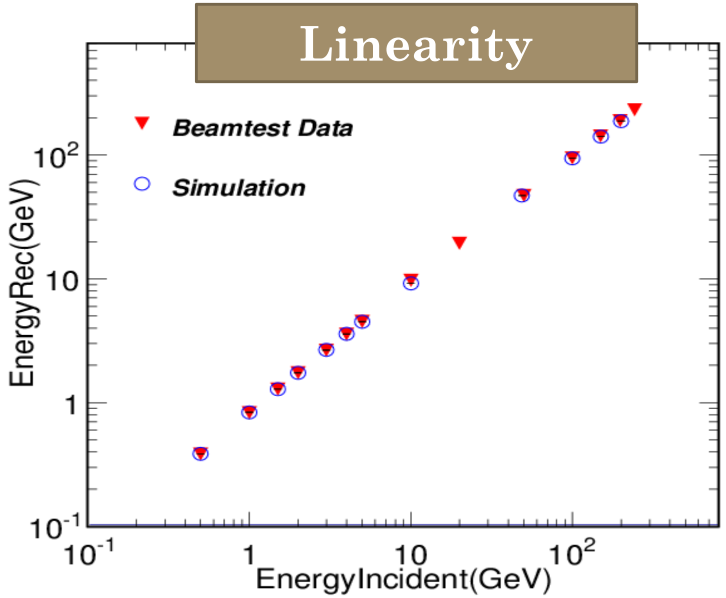
Test beam activity @ CERN

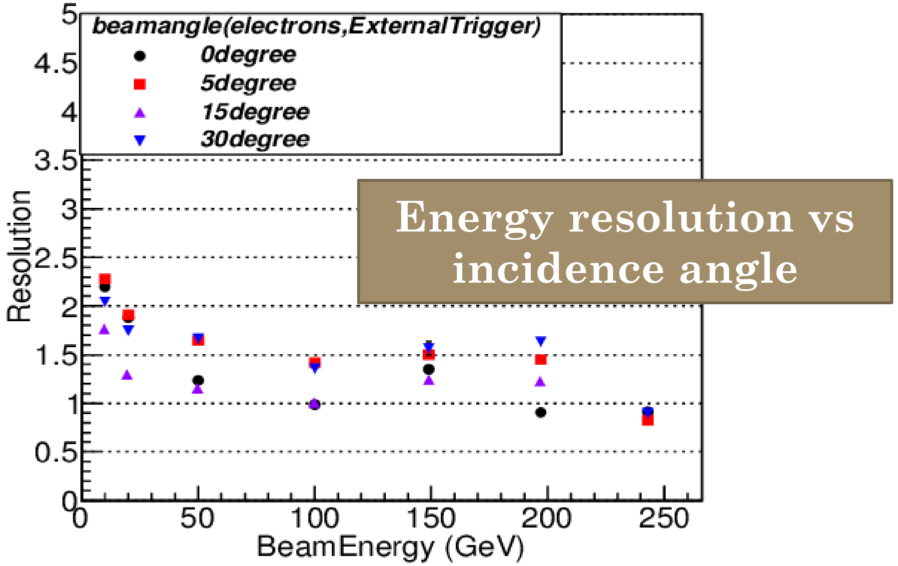
- **14days@PS，29/10-11/11 2014**
  - e @ 0.5GeV/c, 1GeV/c, 2GeV/c, 3GeV/c, 4GeV/c, 5GeV/c
  - p @ 3.5GeV/c, 4GeV/c, 5GeV/c, 6GeV/c, 8GeV/c, 10GeV/c
  - π-@ 3GeV/c, 10GeV/c
  - γ @ 0.5-3GeV/c
- **8days@SPS，12/11-19/11 2014**
  - e @ 5GeV/c, 10GeV/c, 20GeV/c, 50GeV/c, 100GeV/c, 150GeV/c, 200GeV/c, 250GeV/c
  - 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
- **6days@SPS, 20/11-25/11 2015**
  - Pb 30 AGeV/c (and fragments)



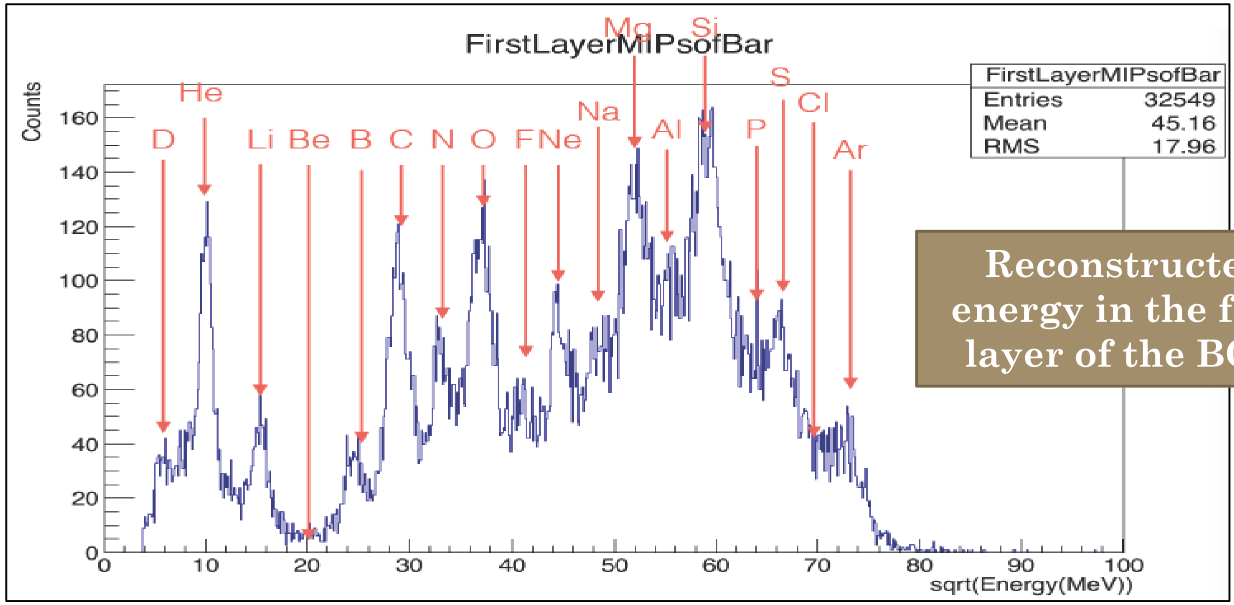
BGO Test beam preliminary results: electrons





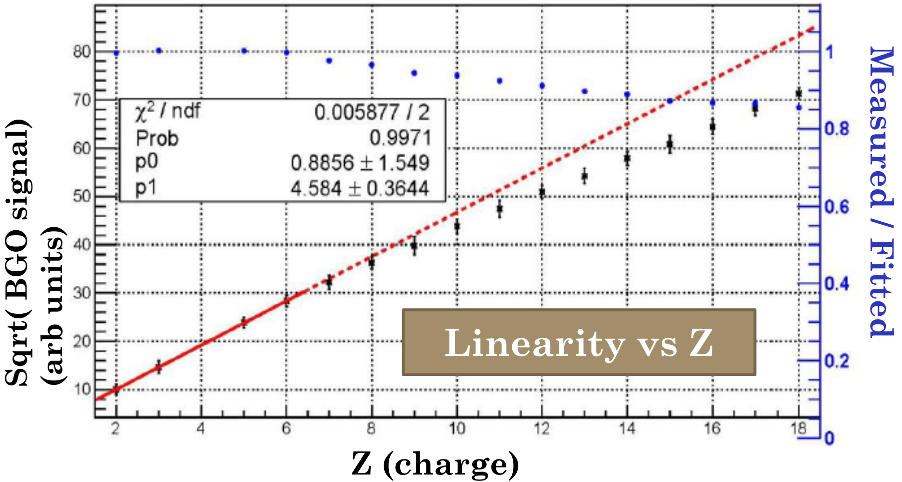


BGO Test beam preliminary results: ions



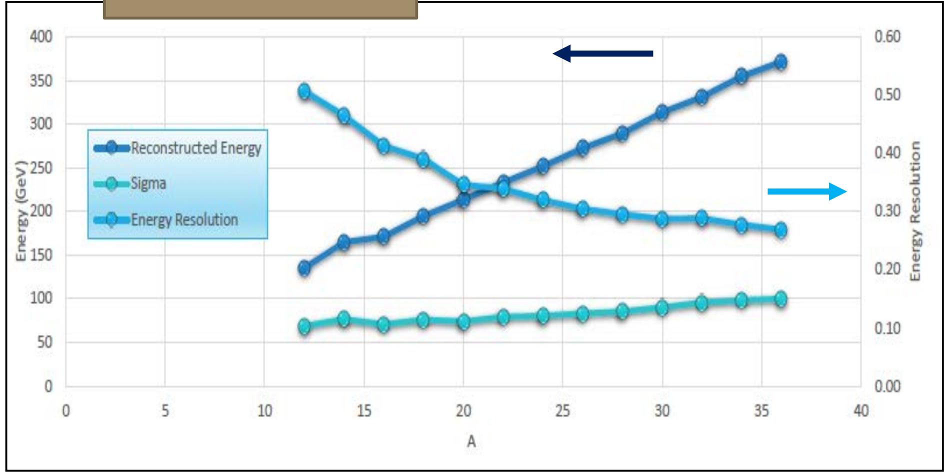
Reconstructed energy in the first layer of the BGO

Beam: Ar @ 40 GeV/n



Linearity vs Z

Simulation



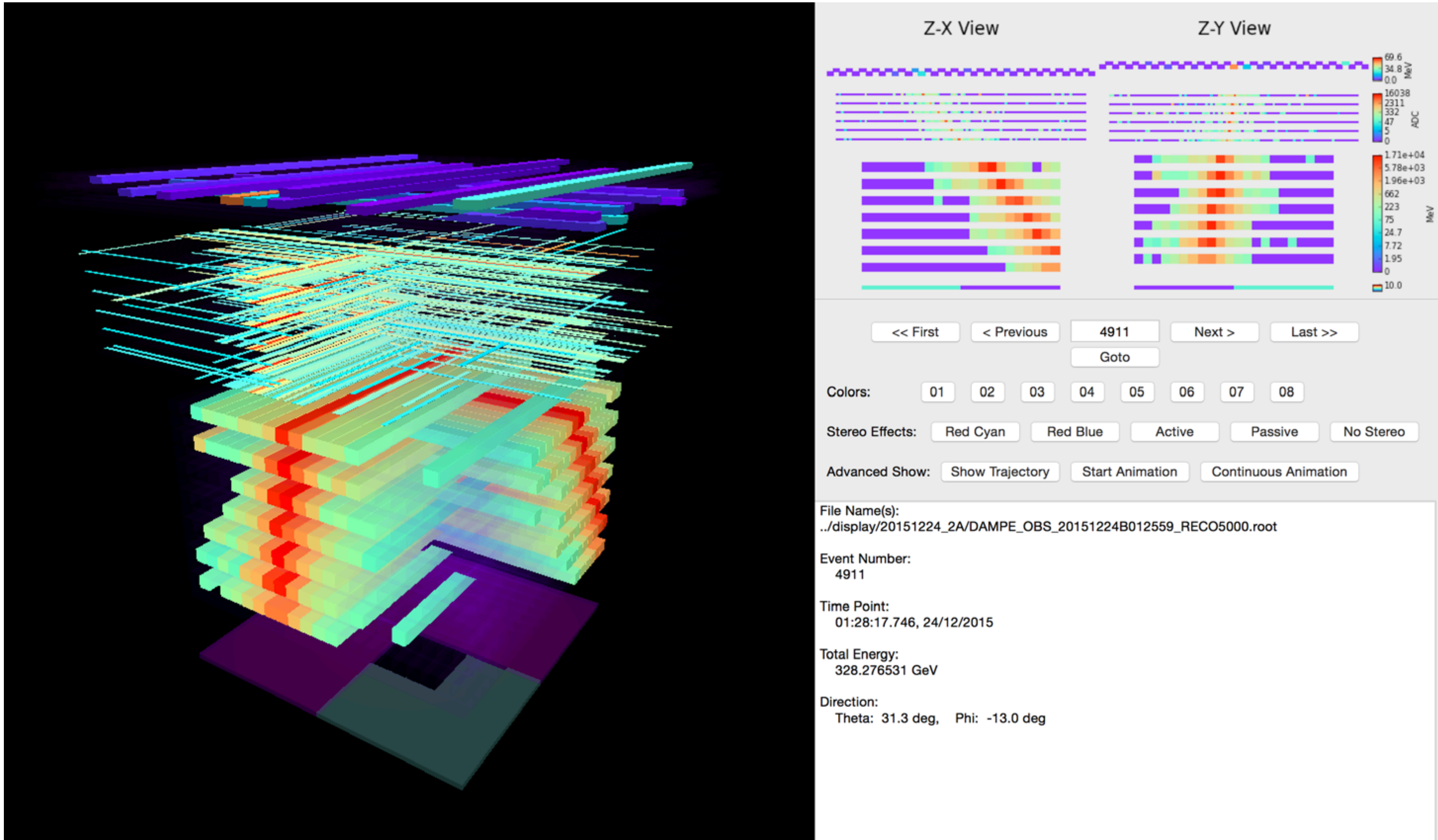
The launch: Dec 17th 2015, 0:12 UTC

Jiuquan Satellite Launch Center
Gobi desert

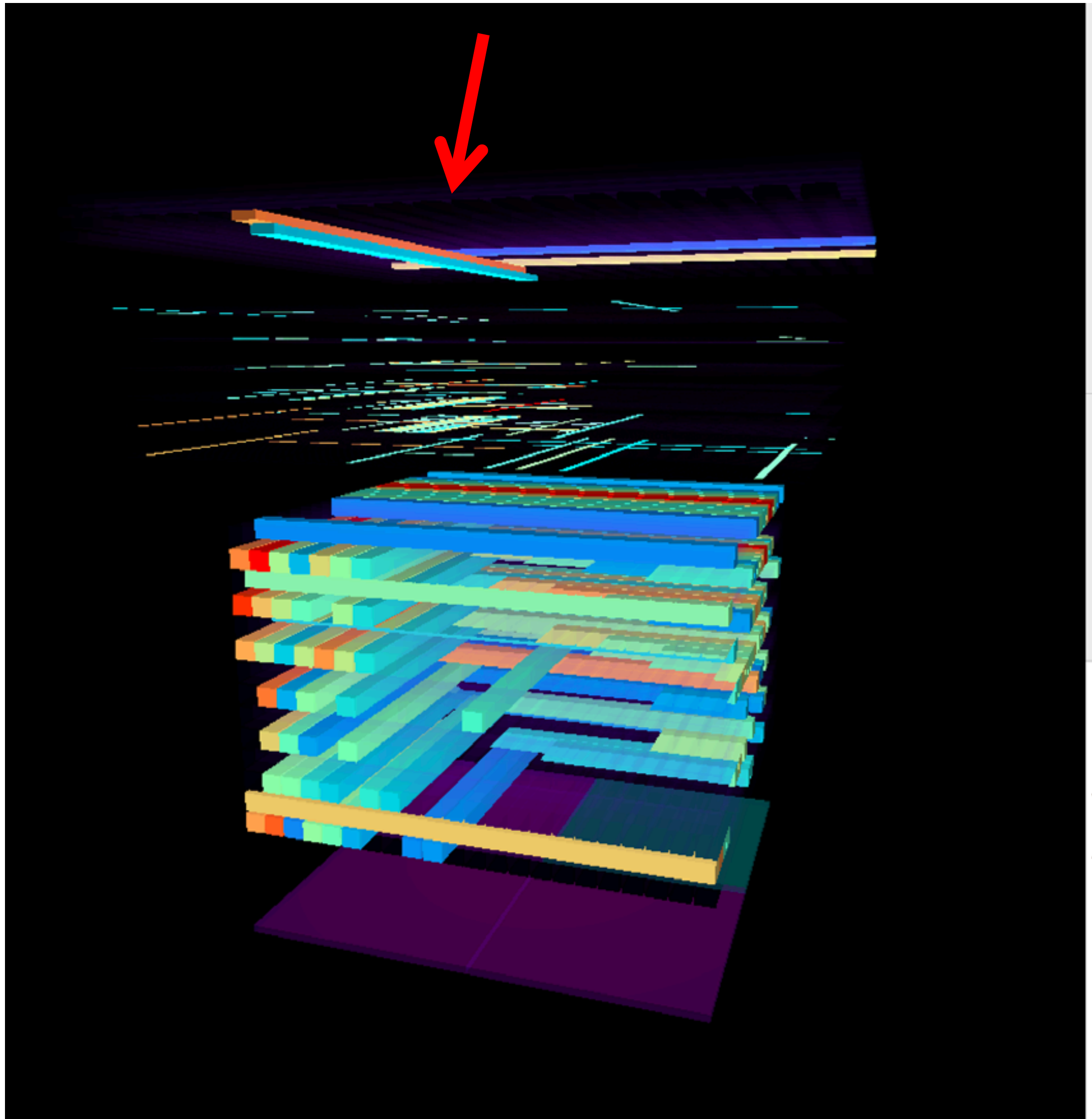
Orbit: sun synchronous, 500km

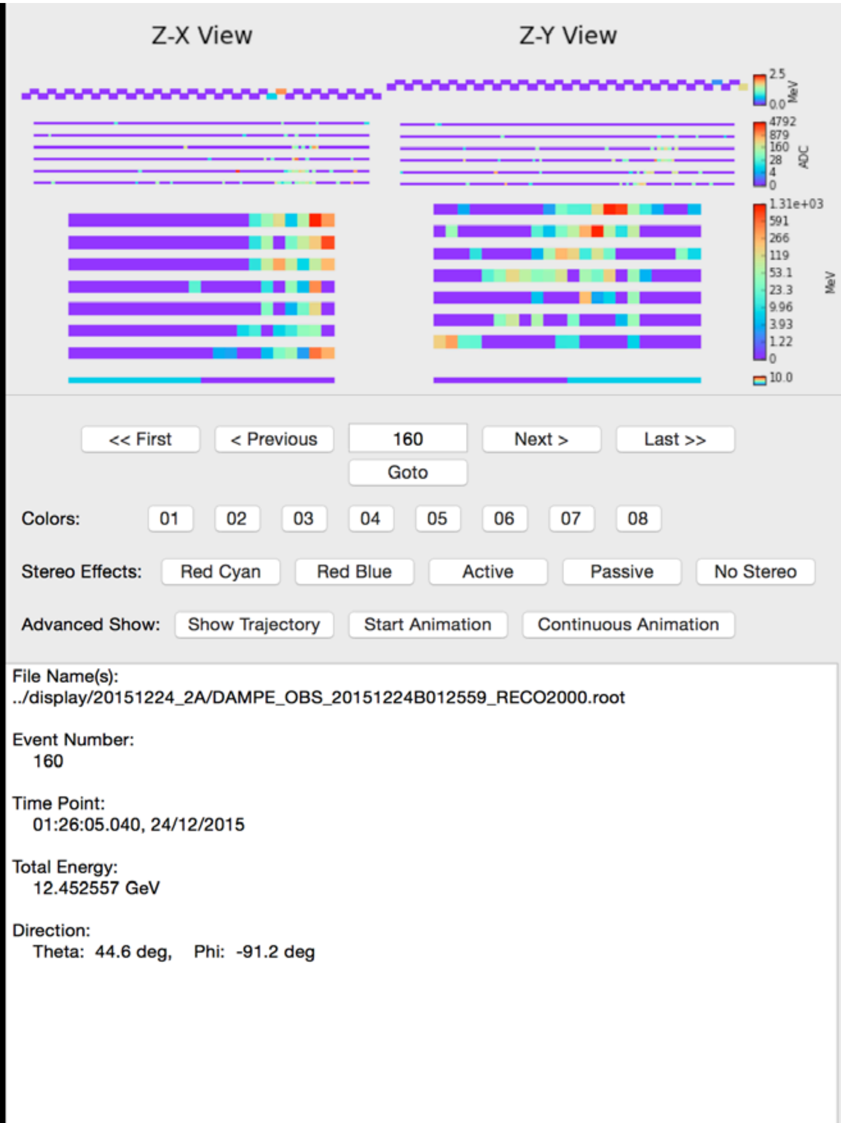
DAMPE → 悟空 (Wukong)

Dec 24th 2015: HV on 330 GeV electron

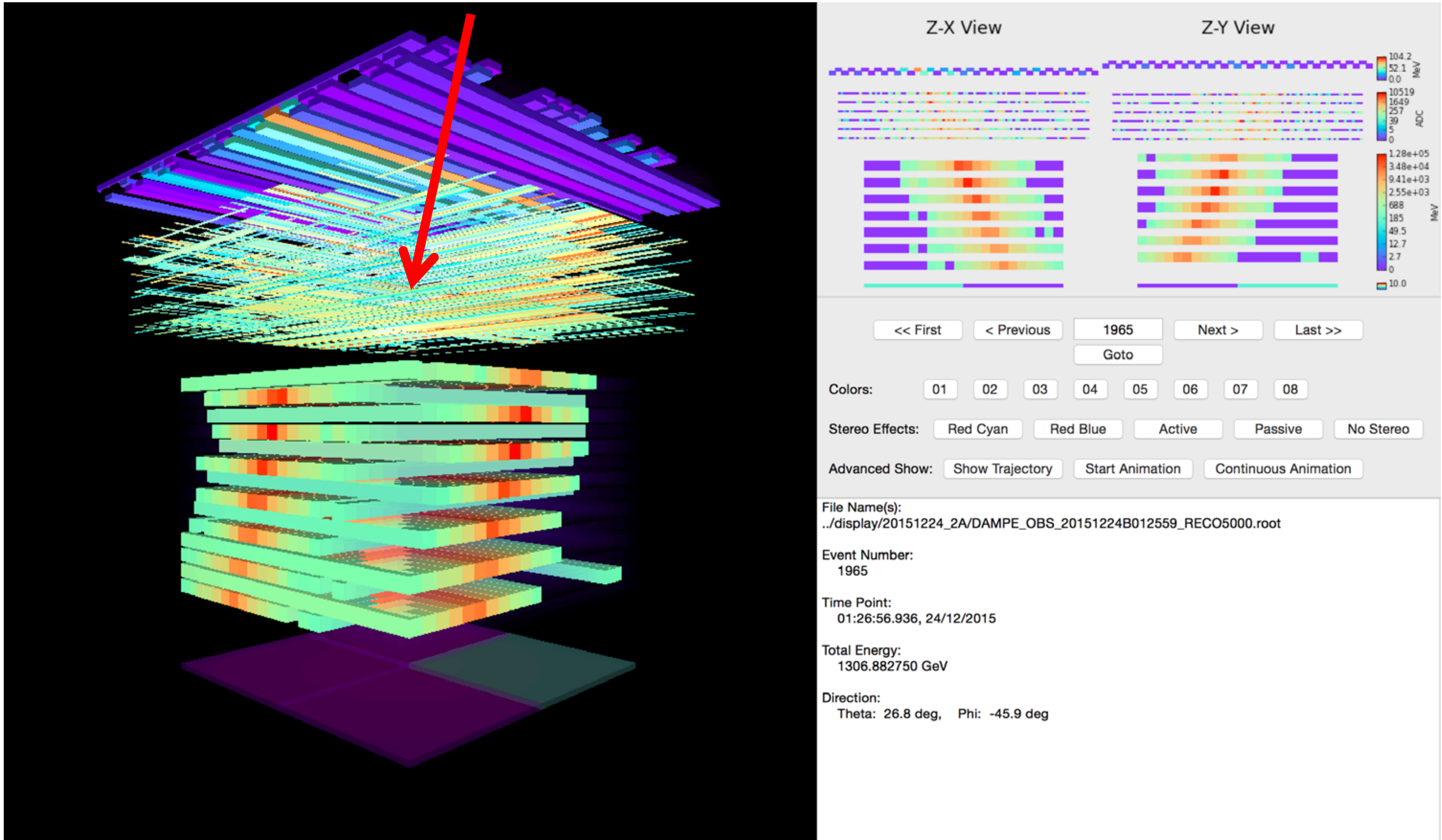


Dec 24th 2015: HV on 12 GeV proton

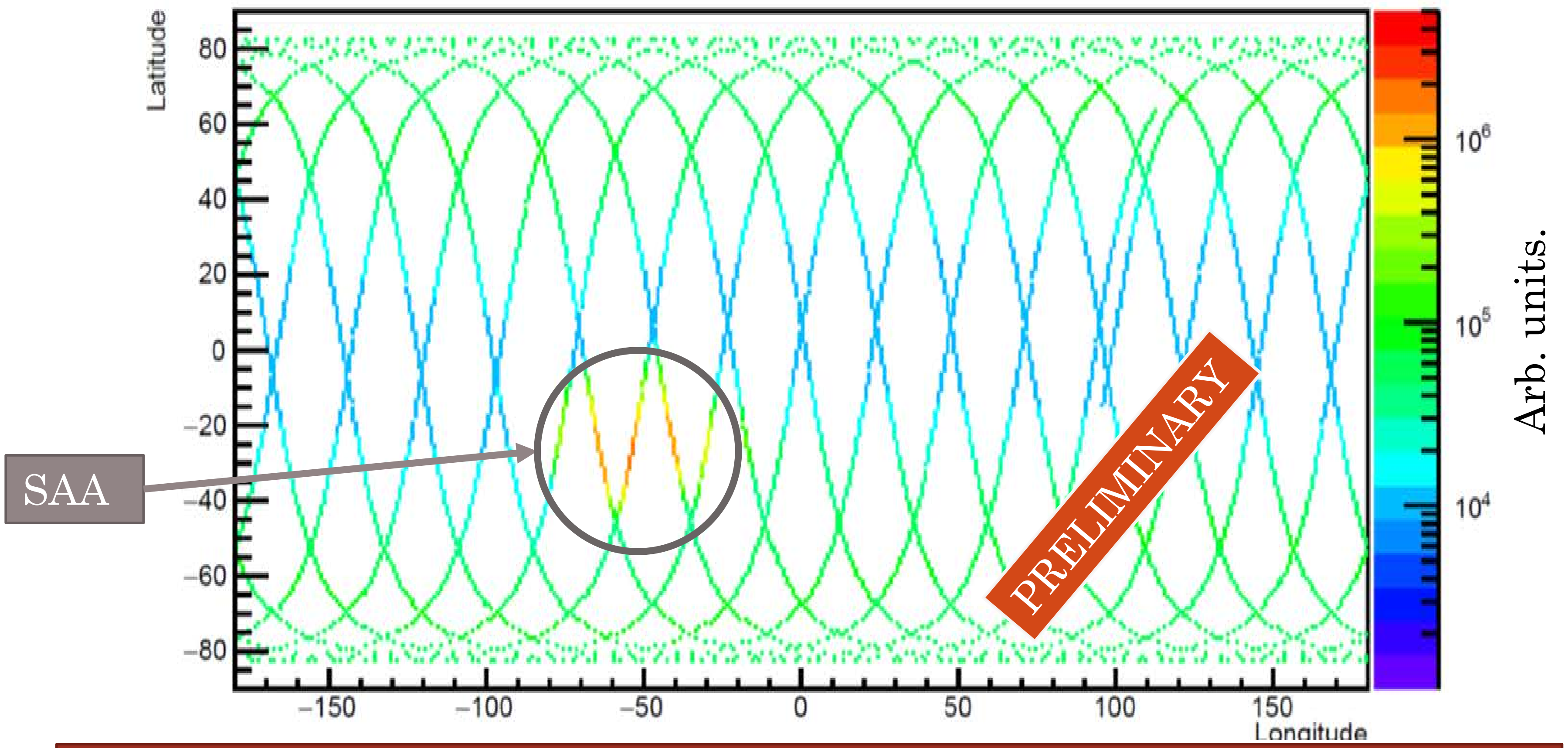




Dec 24th 2015: HV on
1.3 TeV Carbon



Trigger rate in orbit

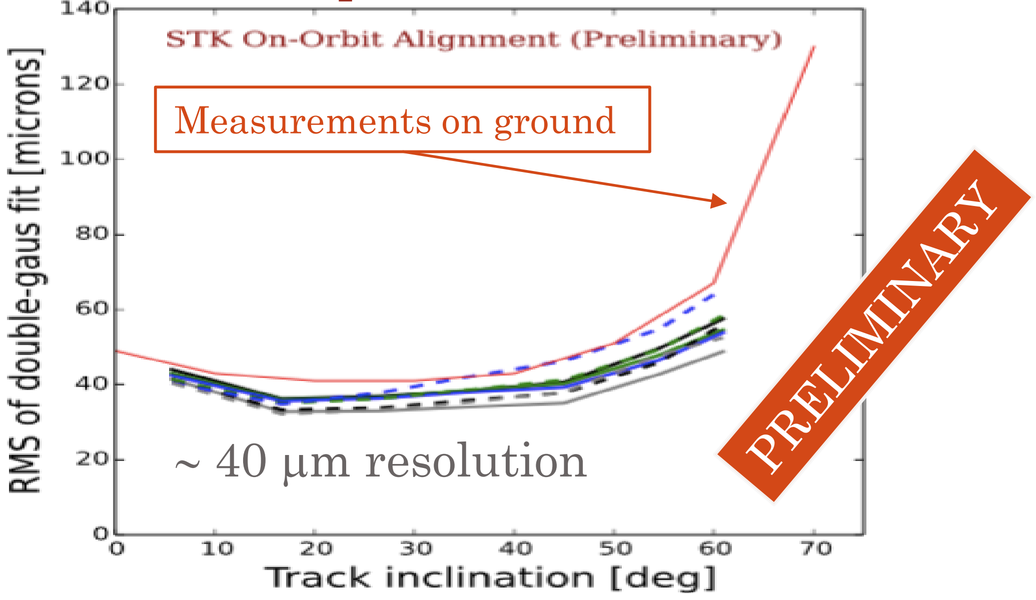


~50 Hz average trigger rate (some triggers are pre-scaled)

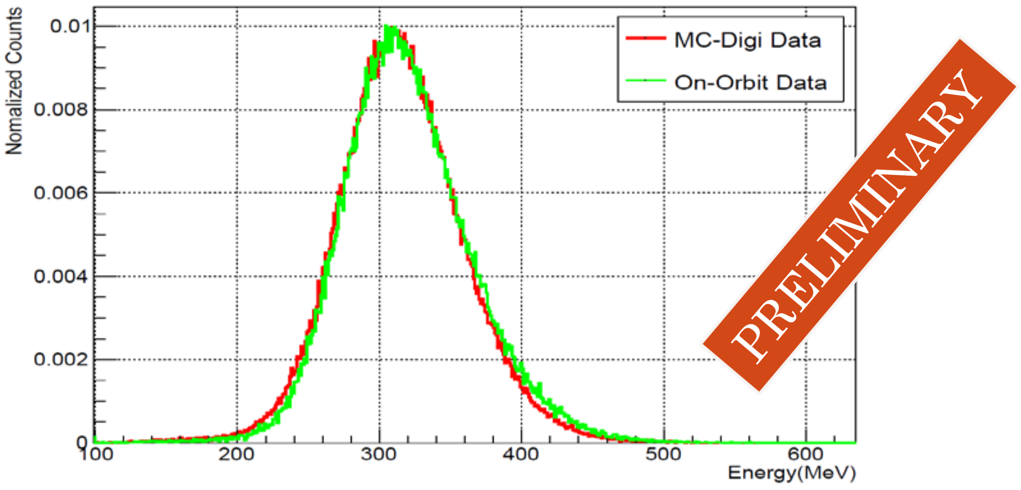
→100GB/day on ground (about 4 M events)

Some on-orbit performance plot

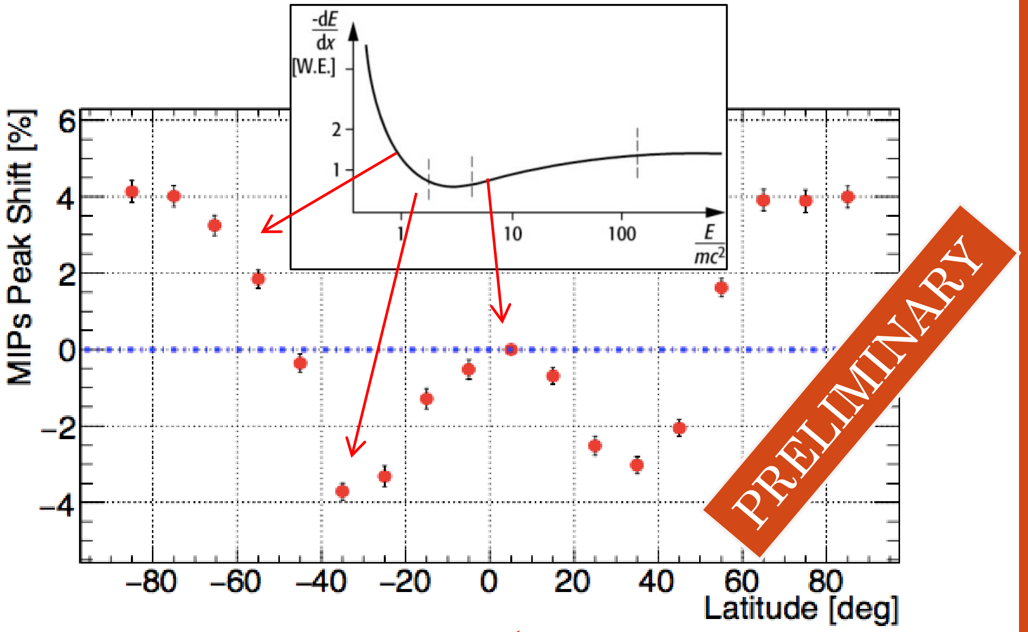
STK space resolution



BGO "mip"peak



The "mip" (i.e. not showering particle) peak shift according to the latitude due to the geo magnetic cut-off.
Very good energy resolution !

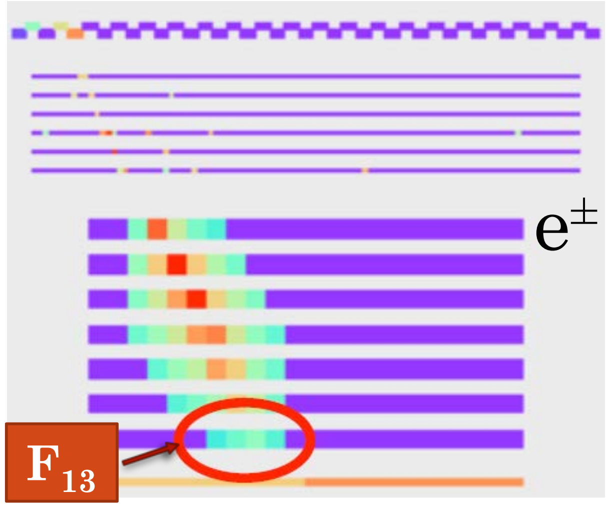


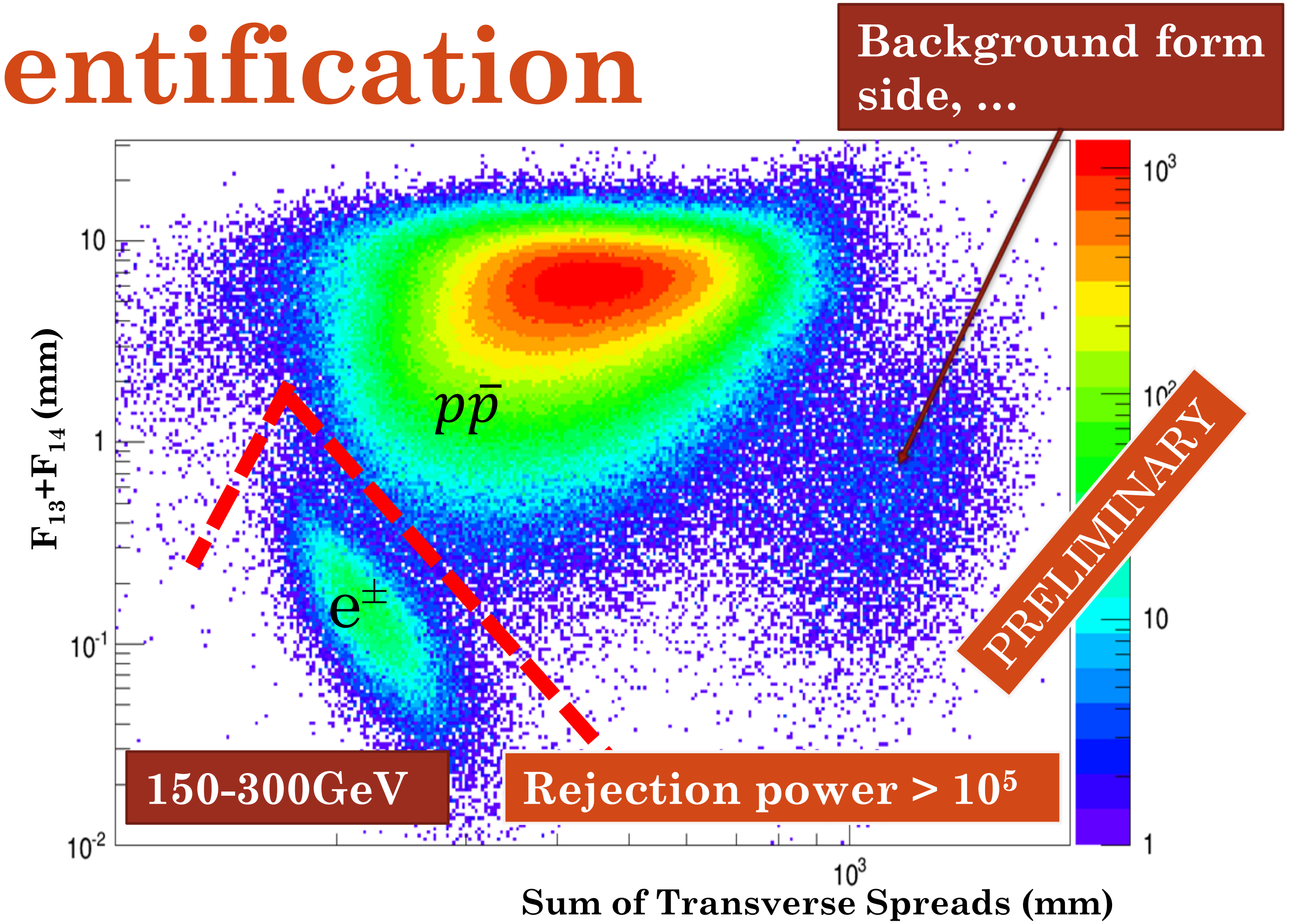
Vertical rigidity cut-off

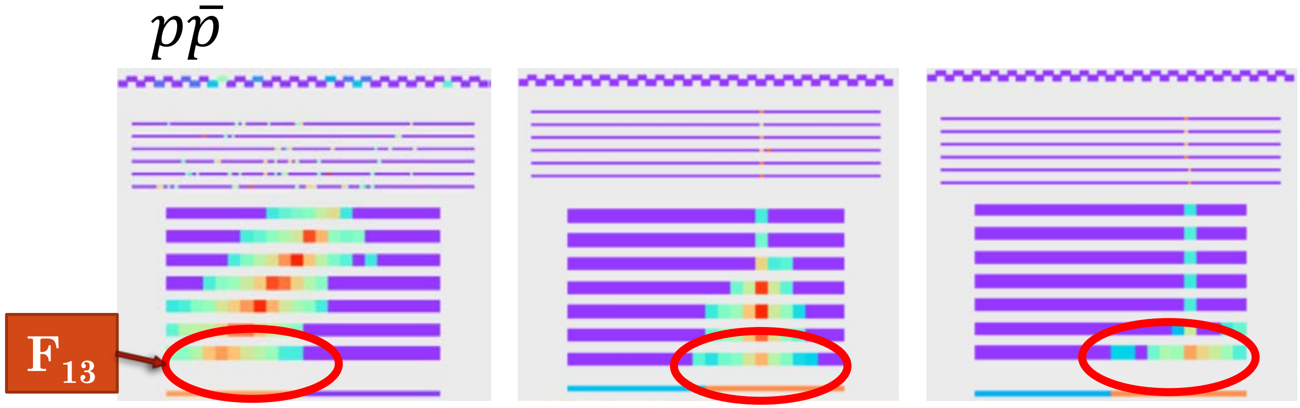
Electron identification

One possible “shape parameter”

$$F_i = Spread_i \times \frac{E_i}{E_{tot}}$$



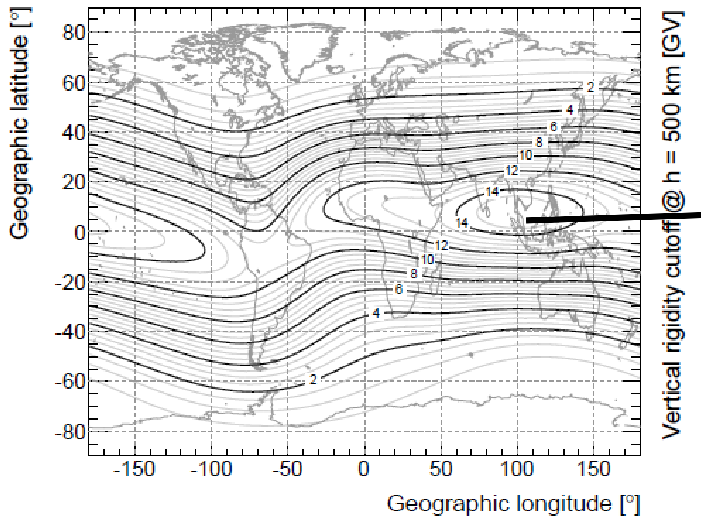


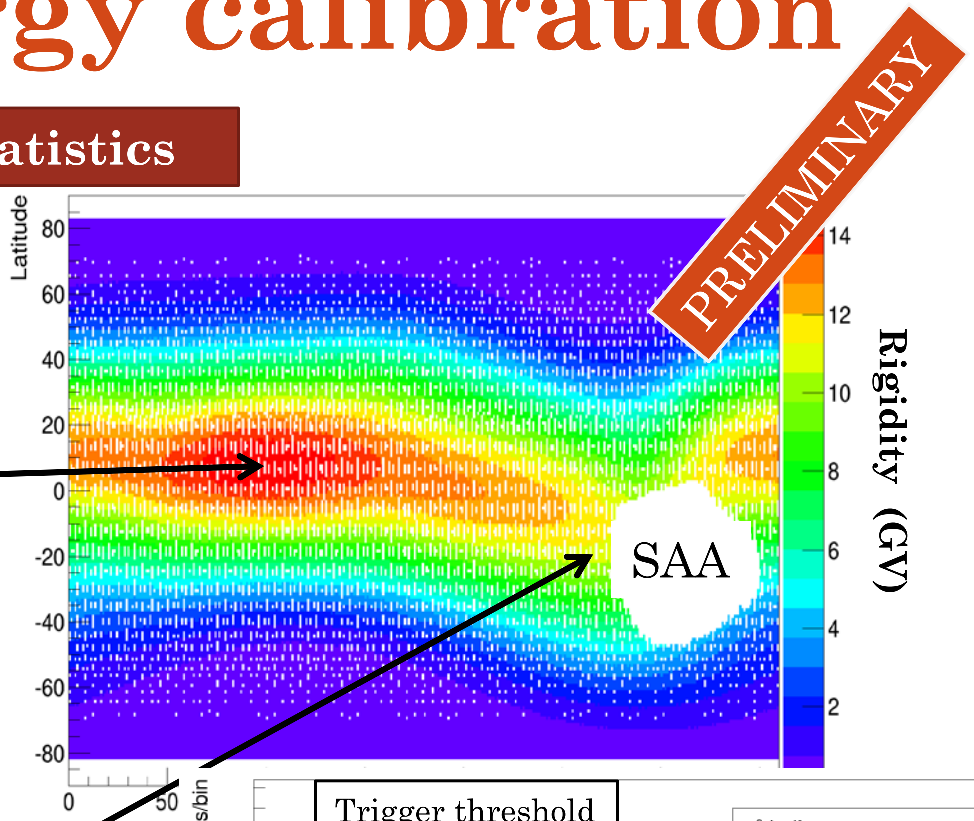


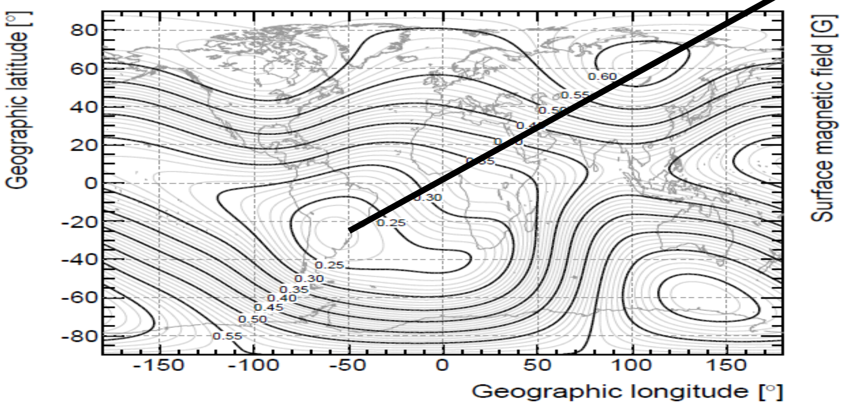
Other kind of particle identification strategies are ongoing

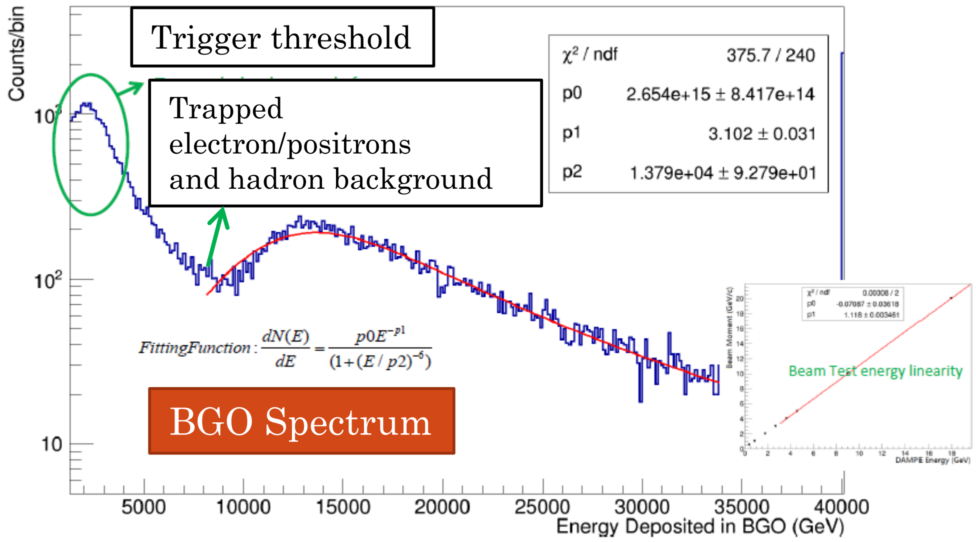
On-orbit energy calibration

e± rigidity cutoff with 1 month statistics



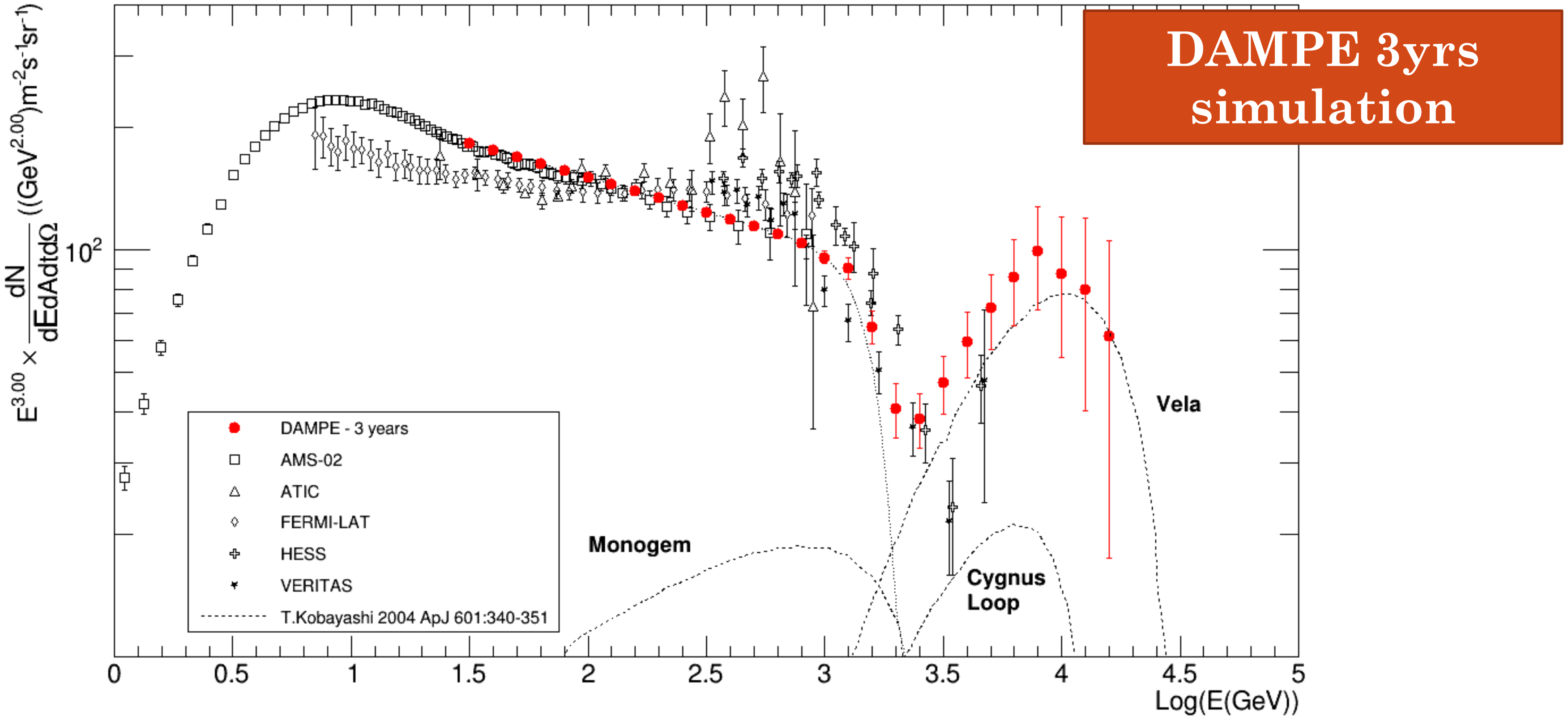






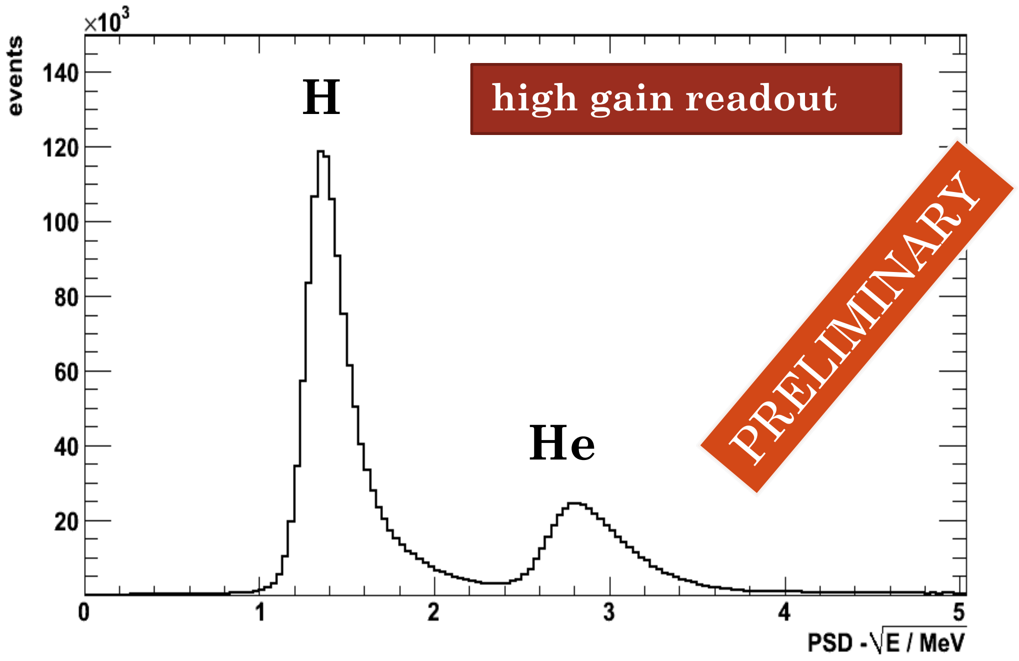
All-electron spectrum

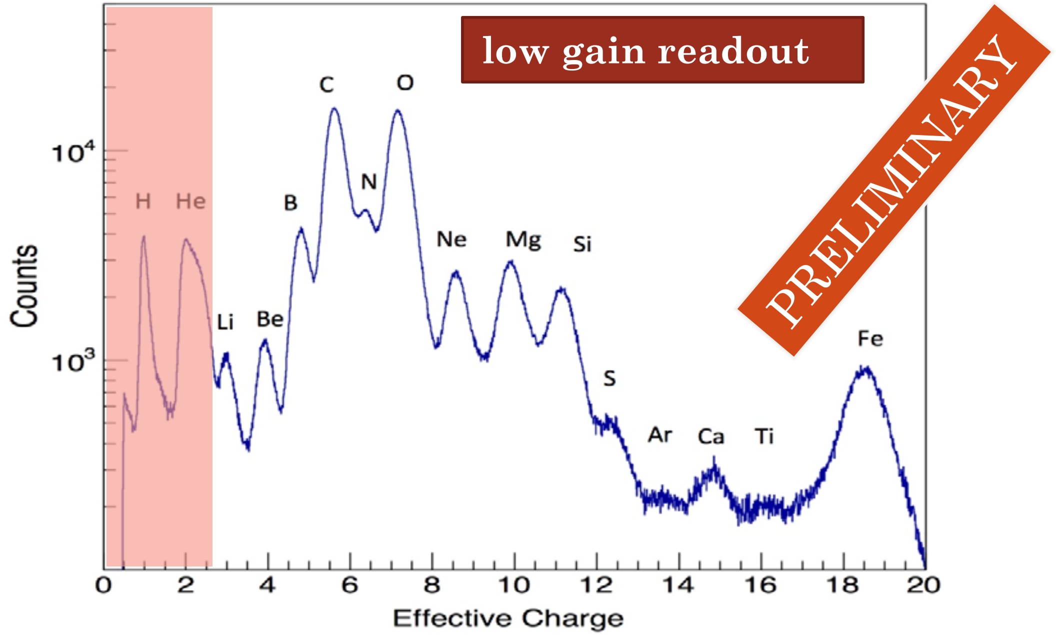
- Measure the all-electron flux up to about 10TeV
- Measure with high accuracy the sub-TeV region and the possible cut-off around one TeV
- Detect structures in the spectrum due to nearby sources and/or DM induced excesses
- Detect anisotropies at high energy



Identifying protons and nuclei with PSD

On-Orbit data (4.5 days)

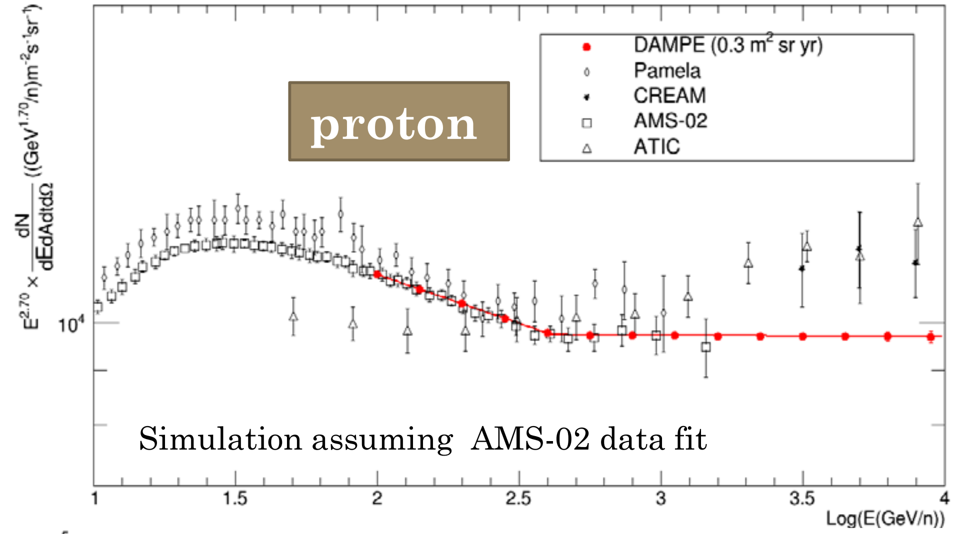


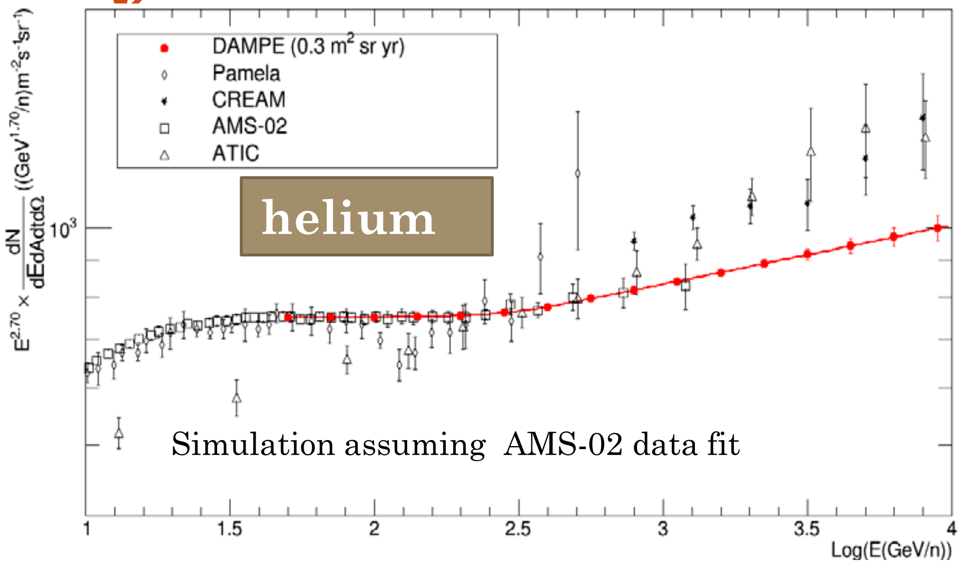


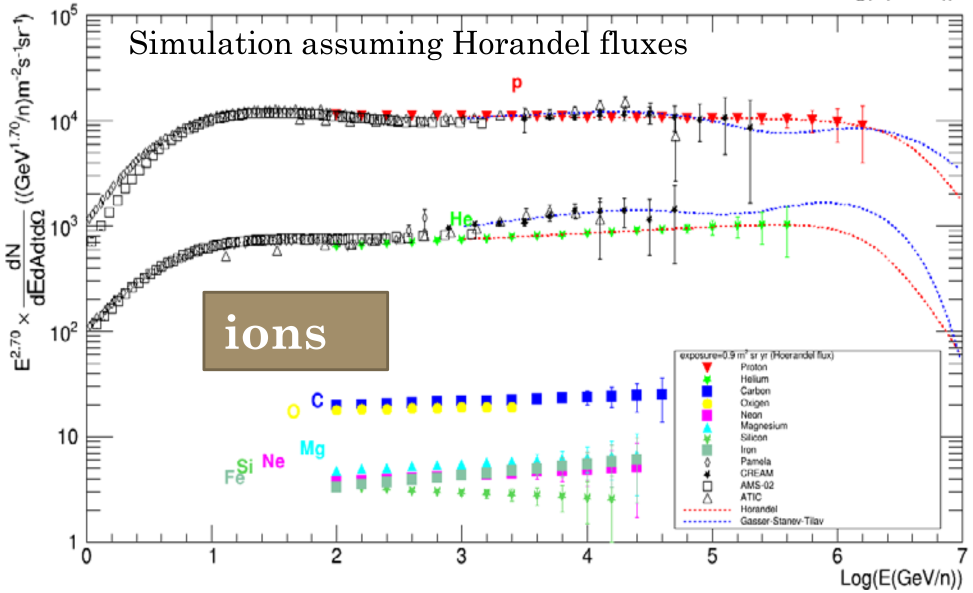
Charge measurement is also done with **STK** and (with lower precision) by the **BGO bars** (see slide 8). Analysis on going.

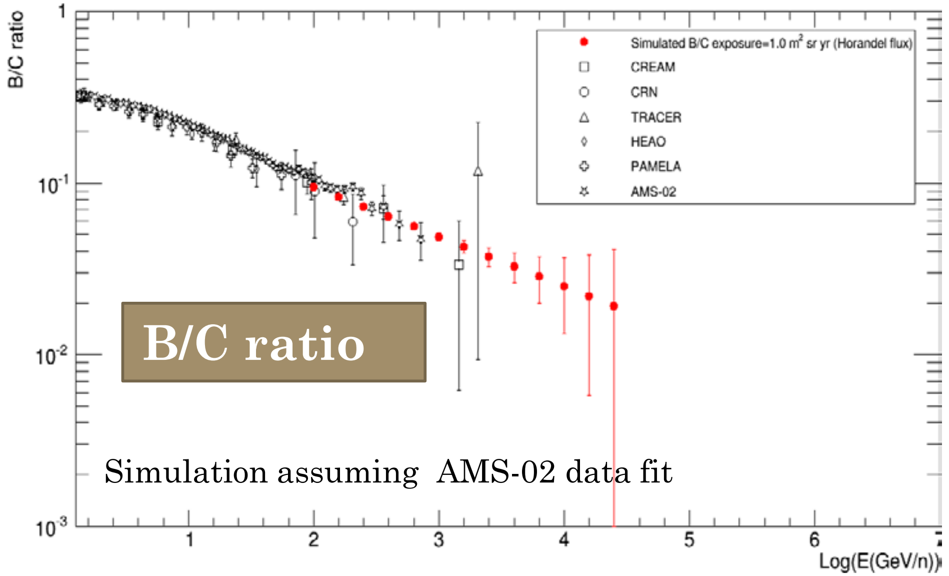
Charge resolution is Z dependent and ranges from 0.2 to 0.4

Protons and nuclei: DAMPE expected flux in 3 years

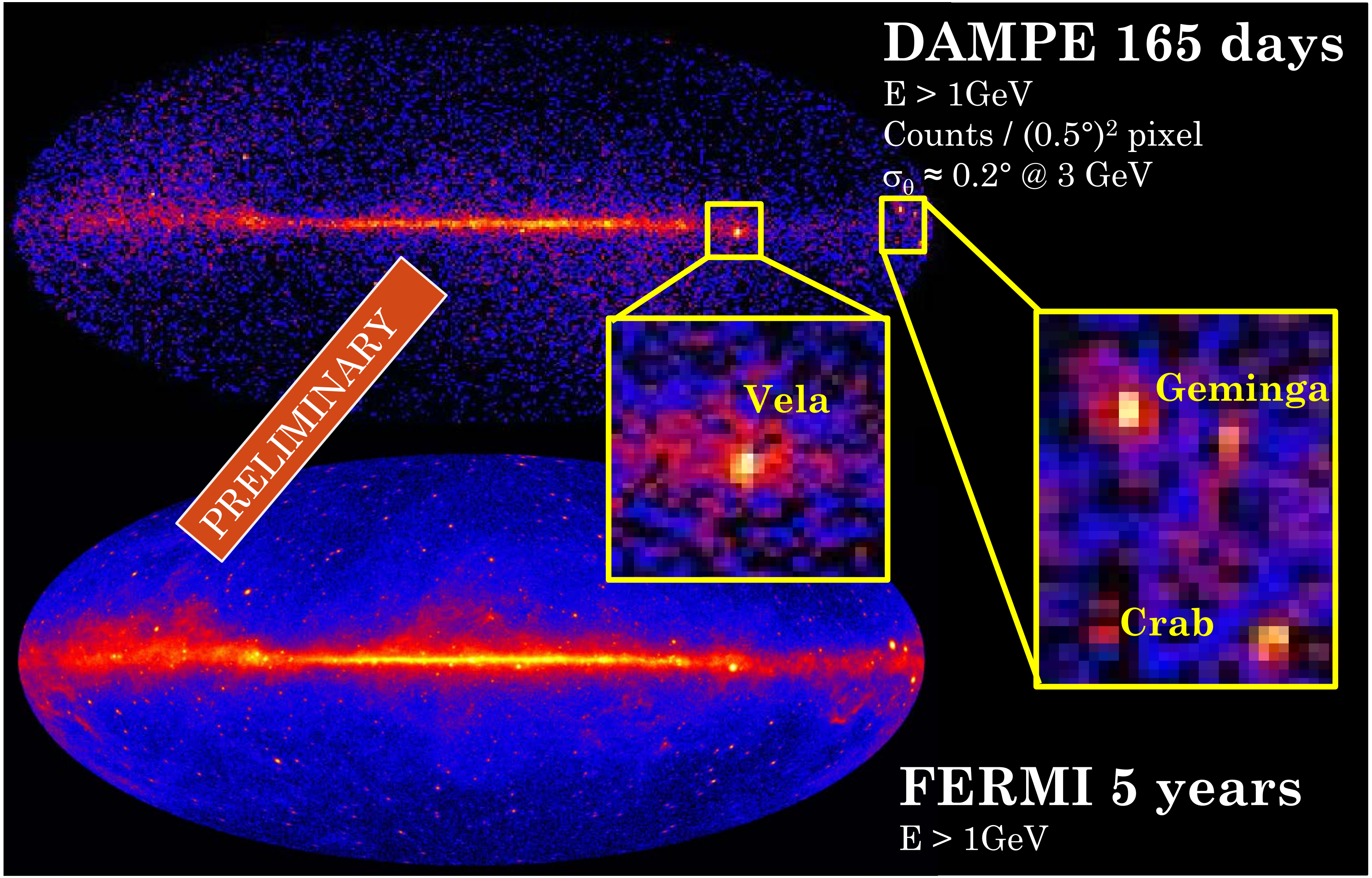






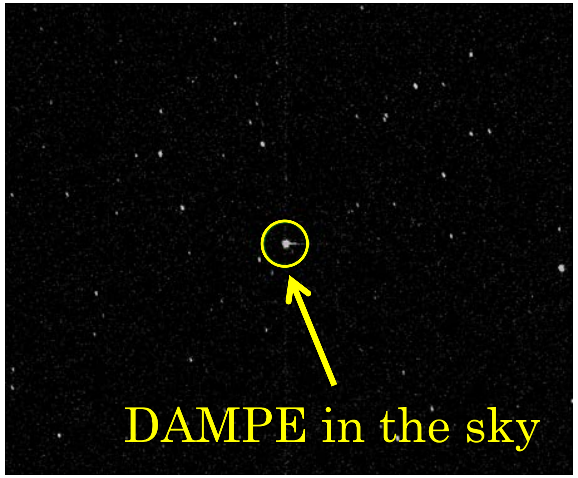


Photons


DAMPE 165 days
E > 1GeV
Counts / (0.5°)² pixel
σθ ≈ 0.2° @ 3 GeV
PRELIMINARY
Vela
Geminga
Crab
FERMI 5 years
E > 1GeV

Summary

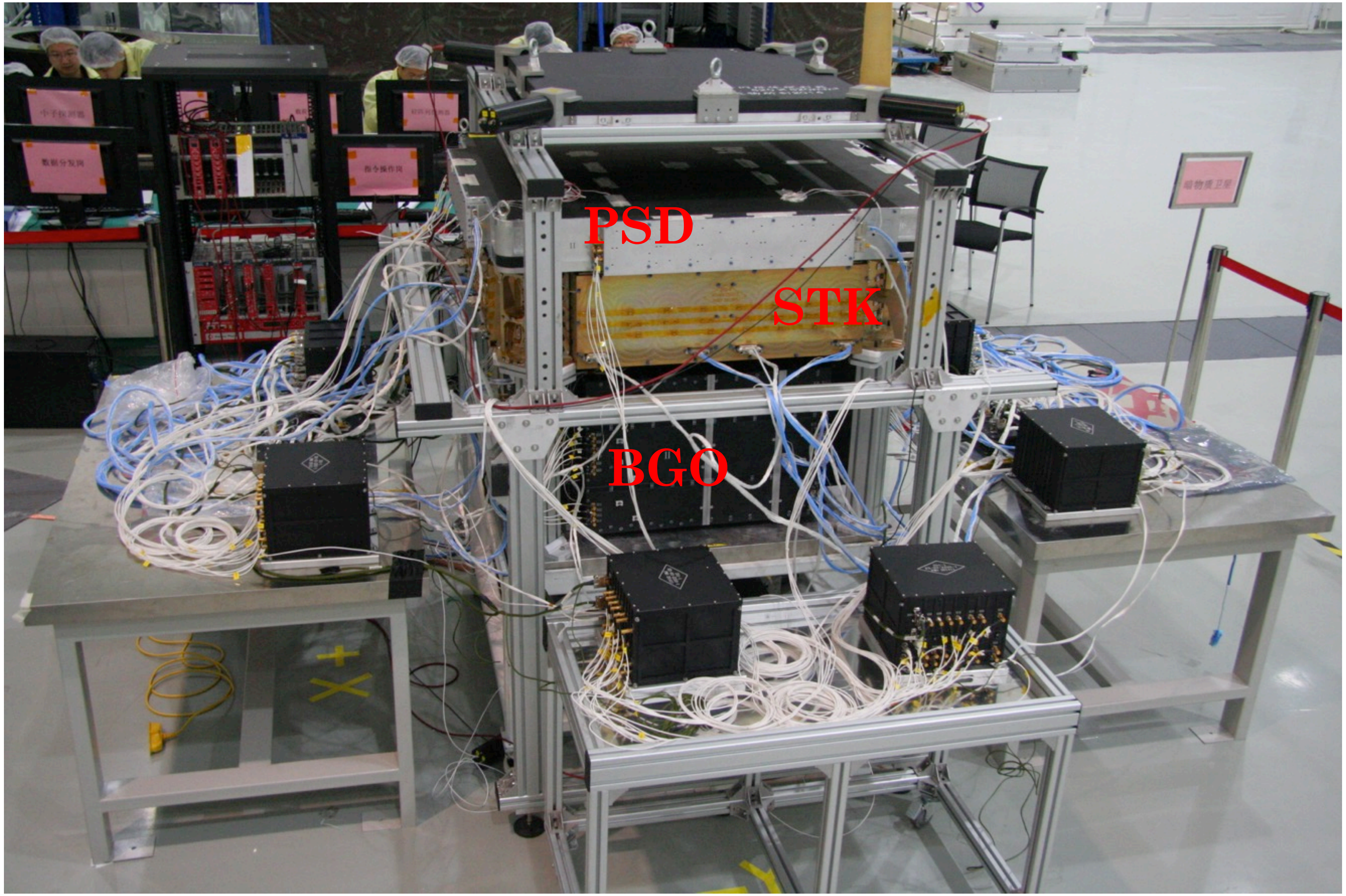
- **The detector**
  - Large geometric factor instrument (0.3 m^2 sr for p and nuclei)
  - Precision Si-W tracker (40μm spatial resolution, 0.2° angular resolution)
  - Thick calorimeter (32 X_0 , σ_E/E better than 1% above 50 GeV for e/γ , ~35% for hadrons)
  - "Multiple" charge measurements (0.2-0.4 energy resolution)
  - e/p rejection power > 10^5 (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



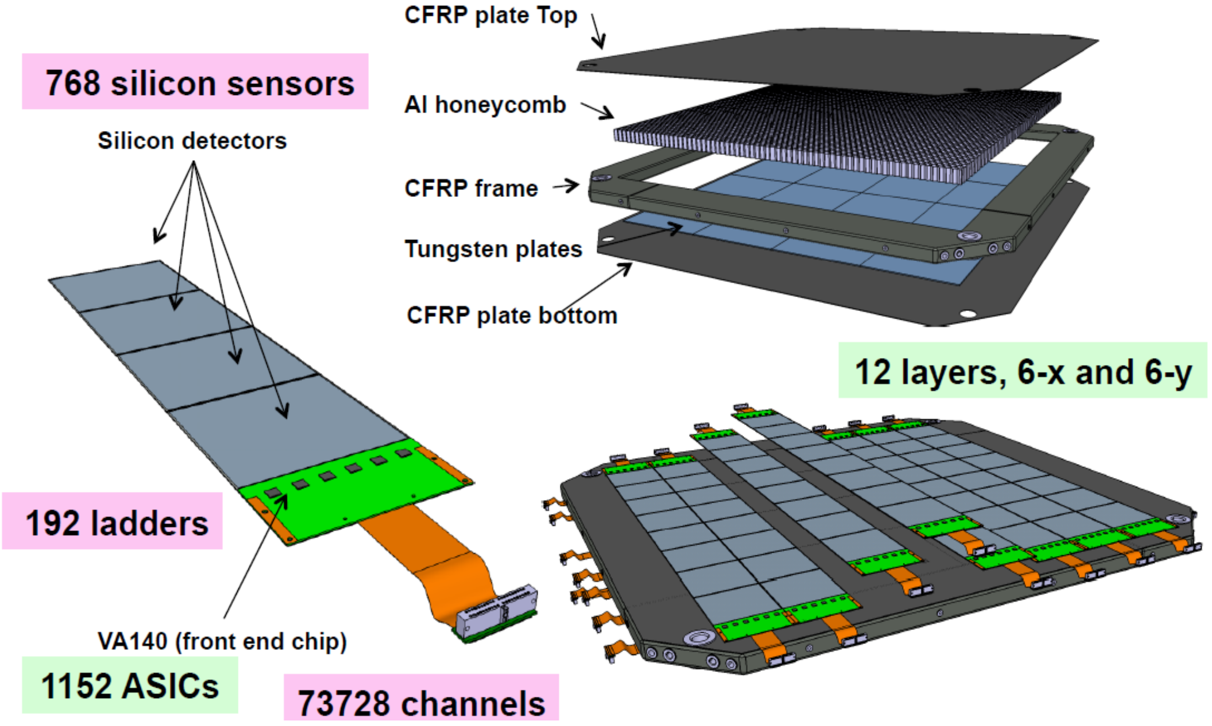
- **Physics goals**
  - Study of the cosmic electron and photon spectra
  - Study of electron anisotropy and nearby sources contribution
  - Study of cosmic ray protons and nuclei: spectrum and composition
  - Precise measurement of CR discrepant hardenings and spectral indexes
  - High energy gamma ray astronomy
  - Search for dark matter signatures in lepton spectra
  - The "unexpected": GW electromagnetic follow up in FoV

Back up slides

FM final integration (06/2015)



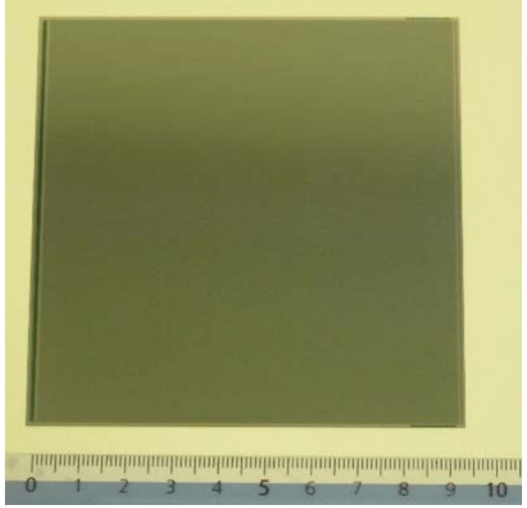
The Silicon Tracker (STK)



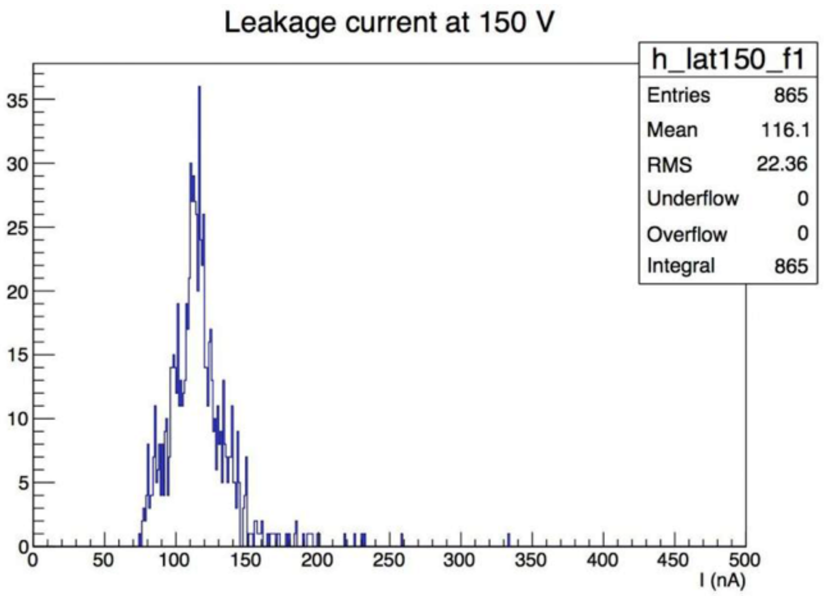
- 48 µm wide Si strips with 121 µm pitch
- (95 × 95 × 0.32 mm³) Silicon Strip Detectors (SSD) with 768 strips
- One ladder composed by 4 Silicon Strip Detectors (SSD)
- 16 Ladders per layer (76 cm × 76 cm)
- 12 layers (6x + 6y)
- Analog Readout of each second strip:
  - 384 channels / SSD- Ladder

STK Silicon Sensors

- Single-sided Silicon strip detectors produced by Hamamatsu
  - 9.5 x 9.5 cm^2, 768 strips, 121 μm pitch (AGILE geometry)
  - 320 μm thick (AGILE: 410 μm)
  - Resistivity 5-8 kΩ, V_{fd} 10-80 V
  - Total strip capacitance 2.1 pF/cm

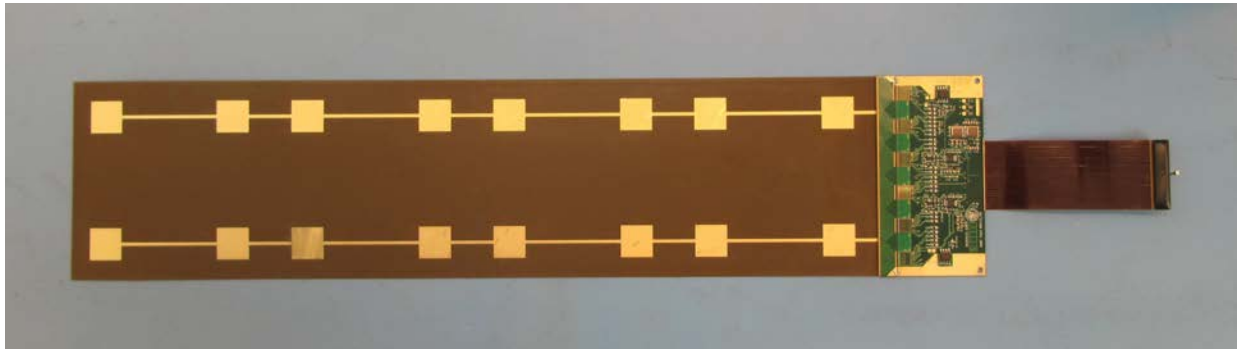


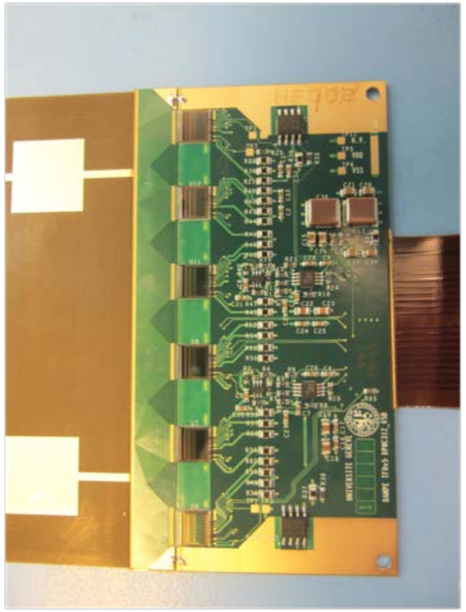
- 150 SSDs for EQM (Engineering and Qualification Model)
- 865 SSDs for FM (Flight Model)
  - Excellent quality
  - $<I_{leak}>$ ~120 nA @150V (spec: <900 nA)
  - $V_{fd} < 50$ V
  - Very few bad channels
  - Cut precision: ~ few μm



STK Readout Electronics

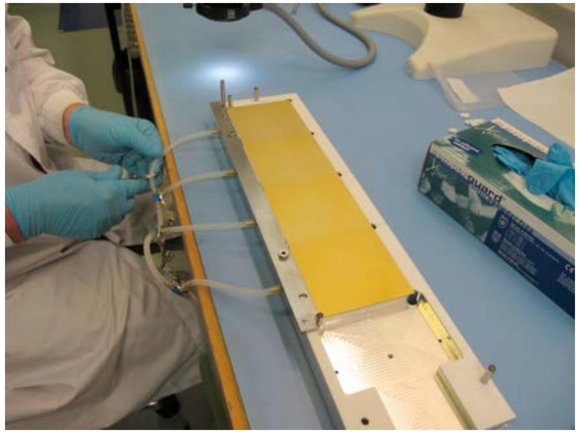
- Readout every other strip, readout pitch 242 μm
- ASIC: VA140 from IDEAS, updated version of VA64hdr of AMS-02
  - Low power (0.3 mW/channel) and large dynamic range (200 fC)
  - Analog readout
    - Charge measurement
    - Better position resolution with charge sharing
- Tracker Front-end Hybrid (TFH)
  - Thin bias circuit integrated with a PCB housing 6 ASICs, and a readout cable ("pigtail")
  - Support structure for the SSDs
  - Vias and copper bands for heat transfer

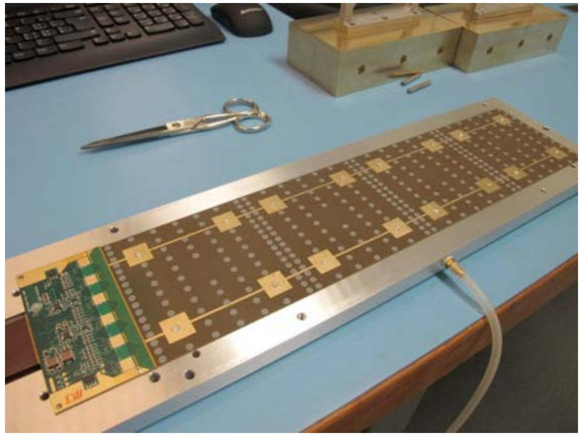


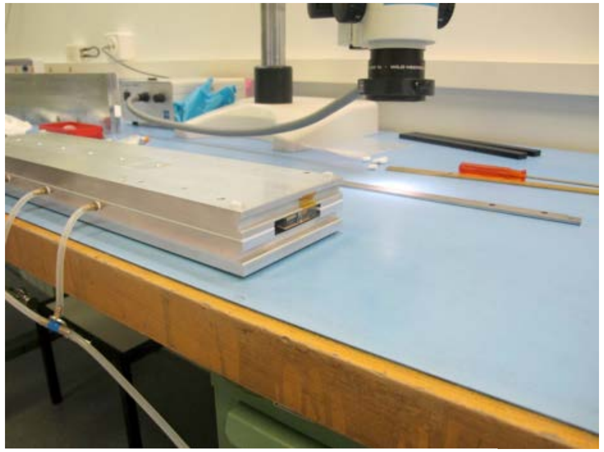


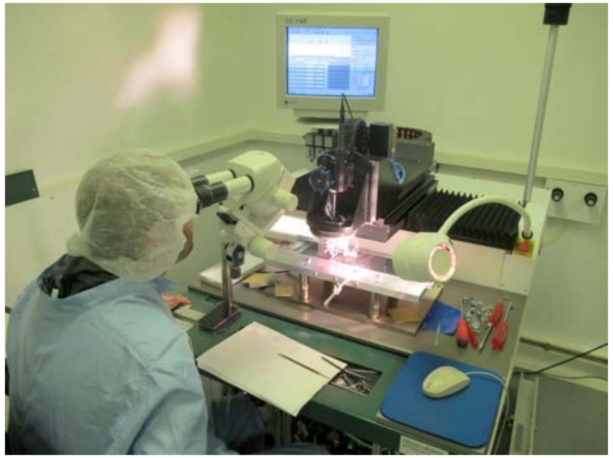
STK Silicon ladders

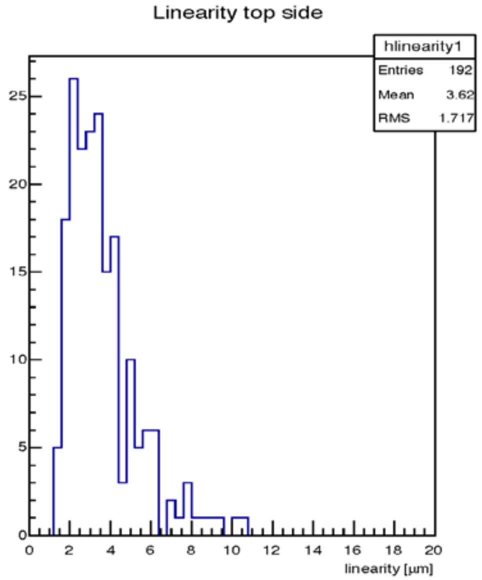
- Precise jigs to assemble (align, glue and bond) 4 sensors to form a ladder
  - require 20 μm alignment precision ⟹ achieved, most (~97%) <10 μm

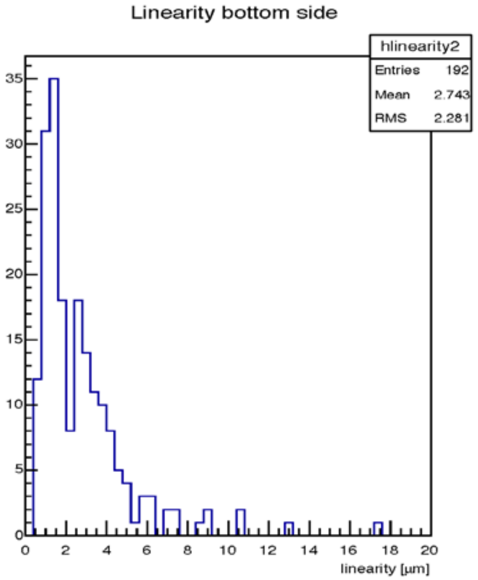






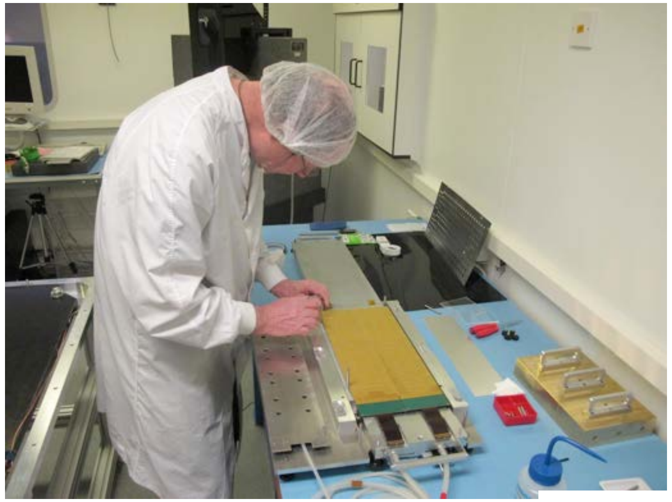


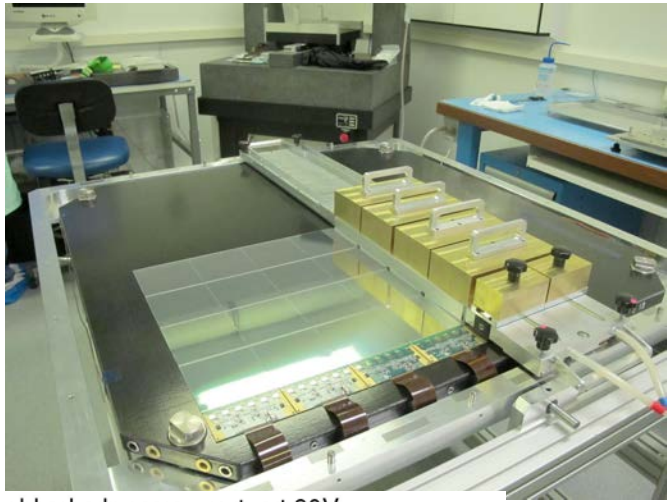


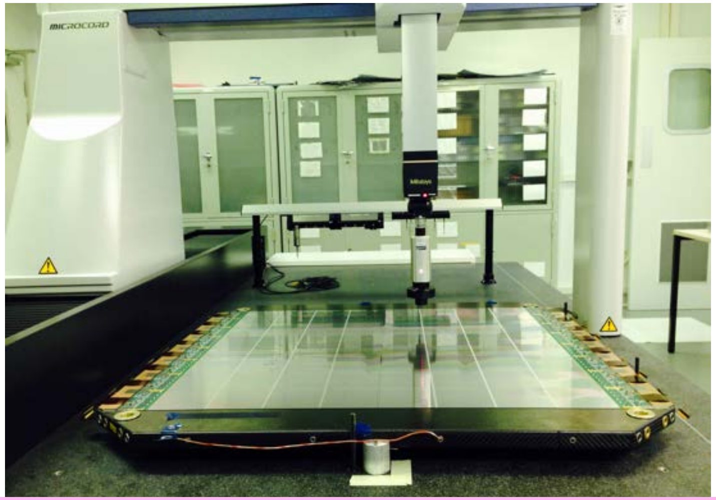


STK Tracker planes

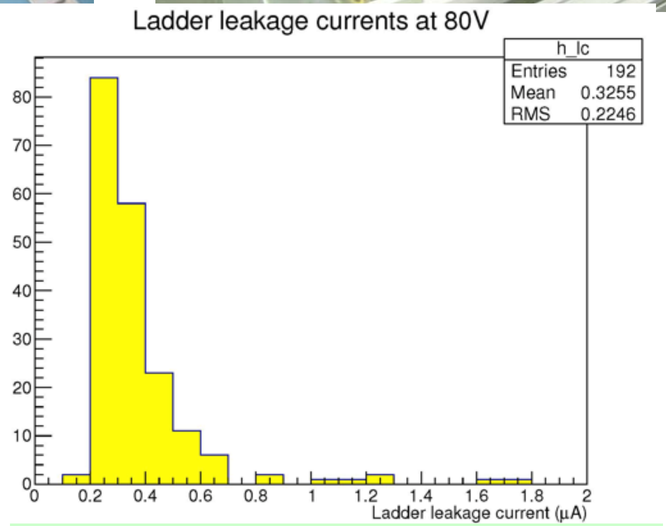
- 16 ladders glued to each surface of the support trays (except top and bottom)







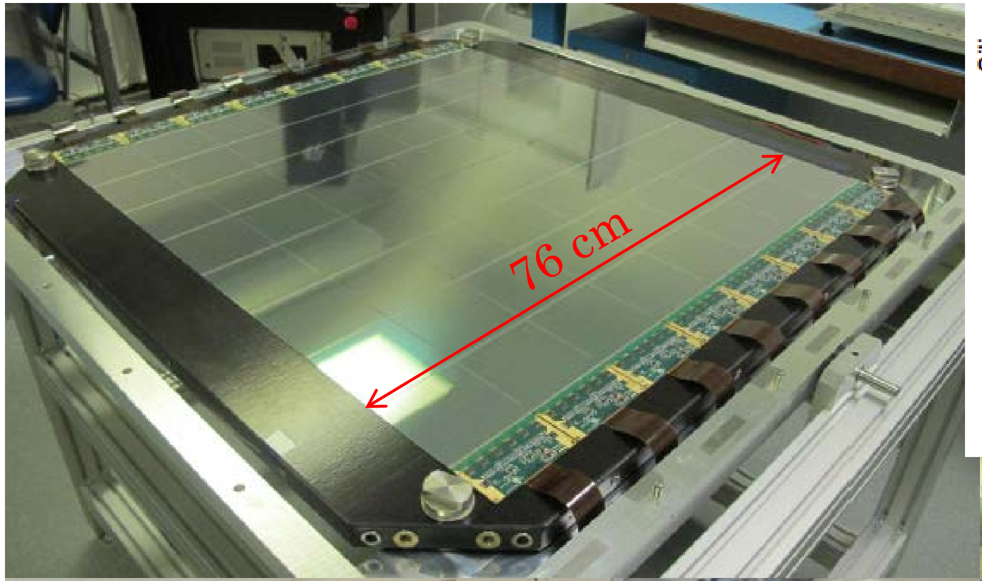
Assembled planed are measured with metrology machine, flatness ~100 μm

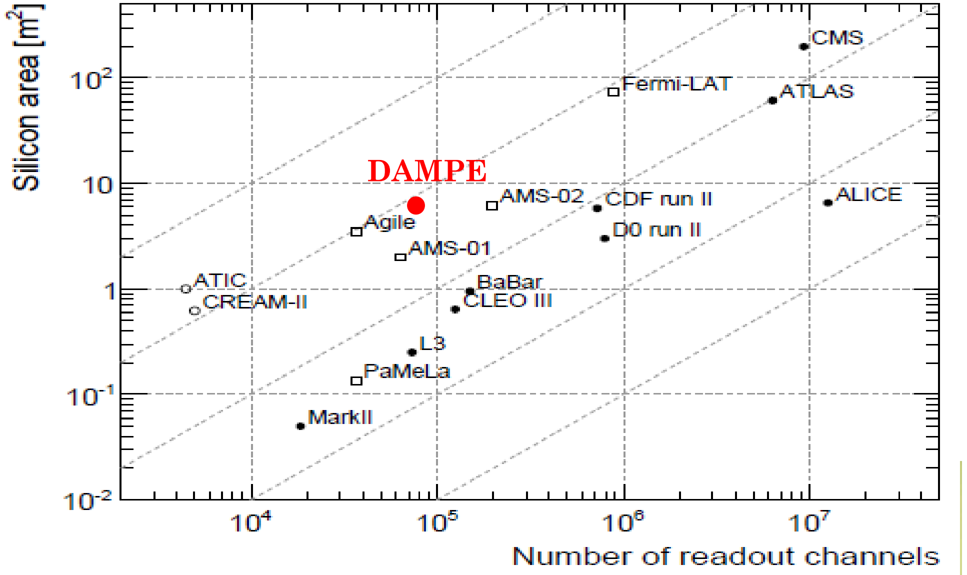


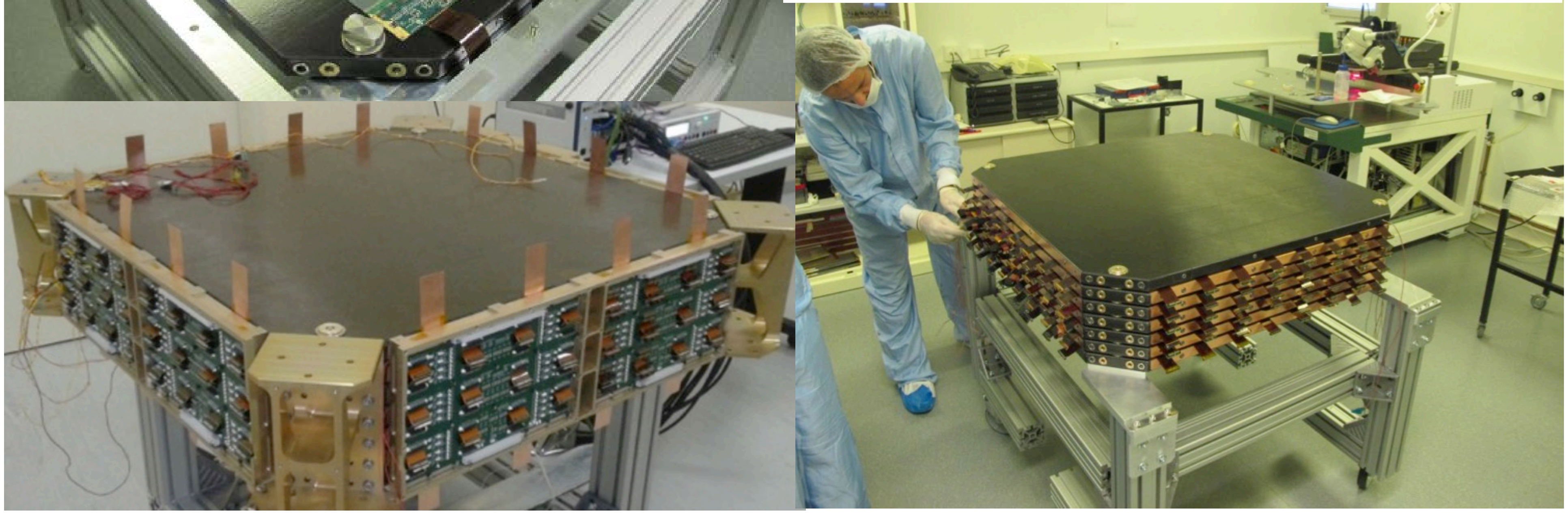
Leakage current of 192 ladders after plane assembly at 80 V

The excellent quality of the silicon sensors maintained through the ladder production and plane assembly processes!

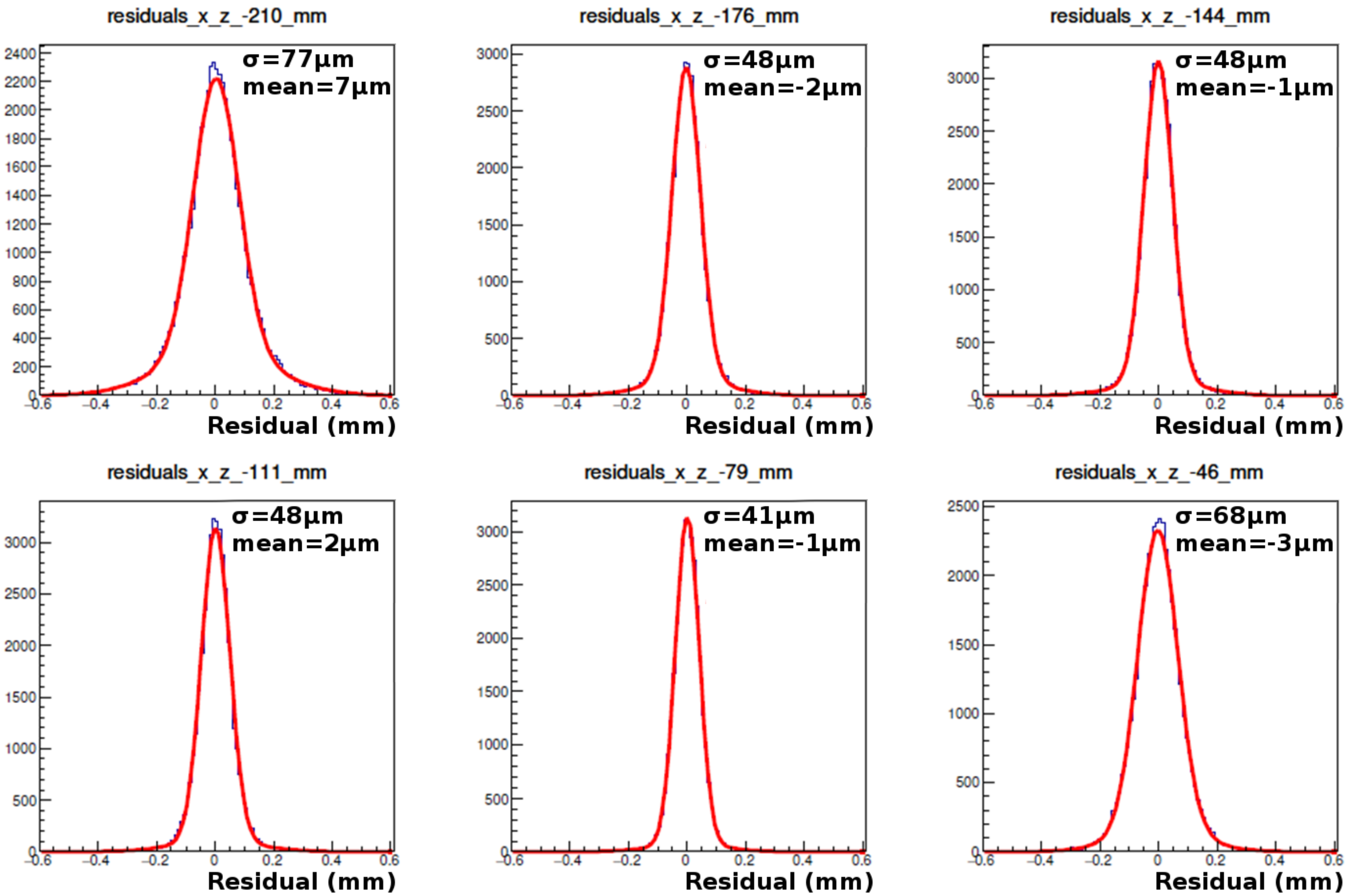
The Silicon Tracker





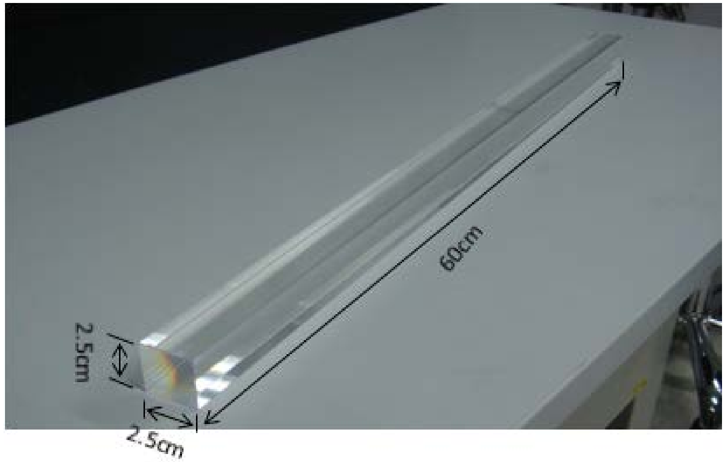


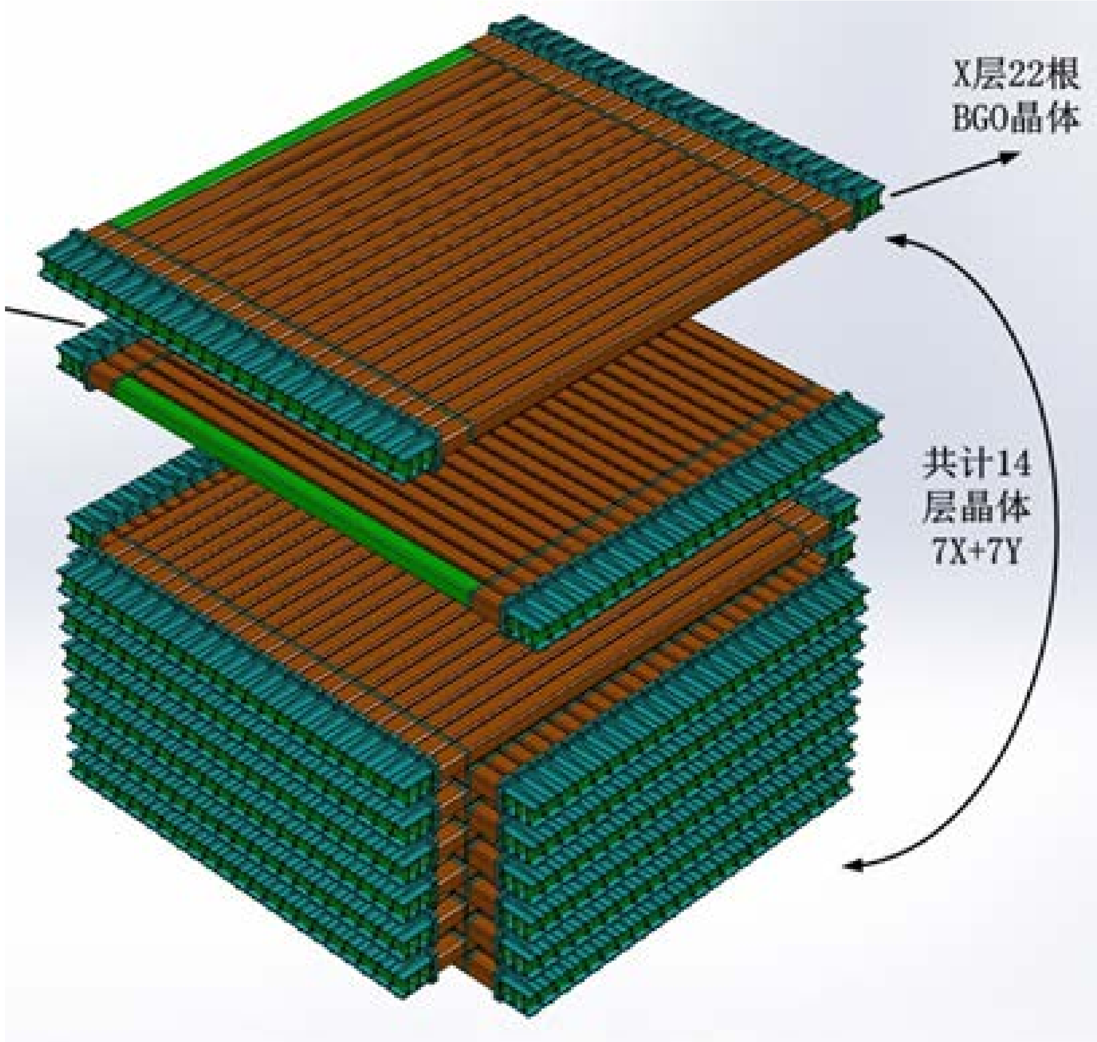
STK resolution after alignment (BT Data)



The Calorimeter

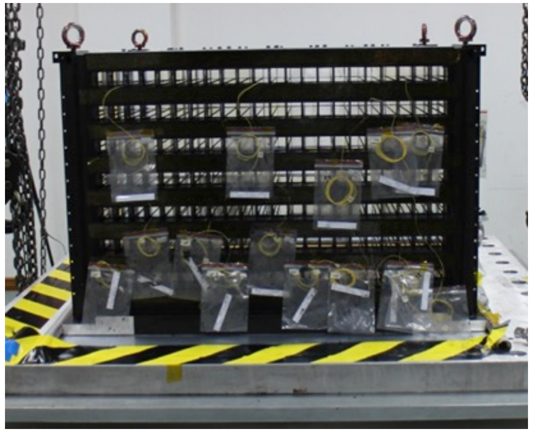
- 14 layers of 22 BGO bars
  - Dimension of BGO bar: $2.5\times2.5\times60\ cm^3$
  - 14 hodoscopic stacking alternating orthogonal layers
  - depth $\sim32X_0$
- Two PMTs coupled with each BGO crystal bar in two ends





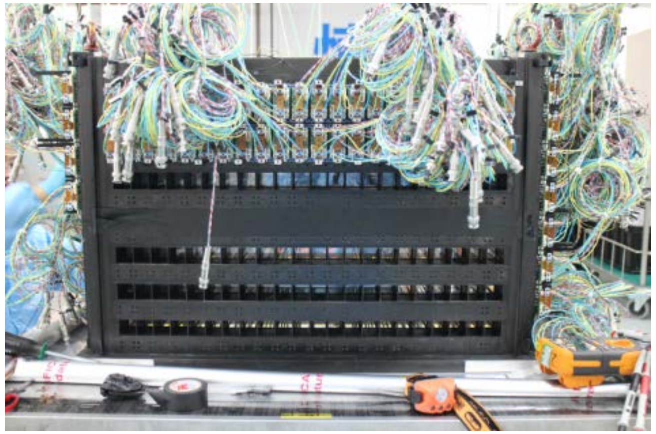
308 bars
616 PMTs

The Calorimeter -2

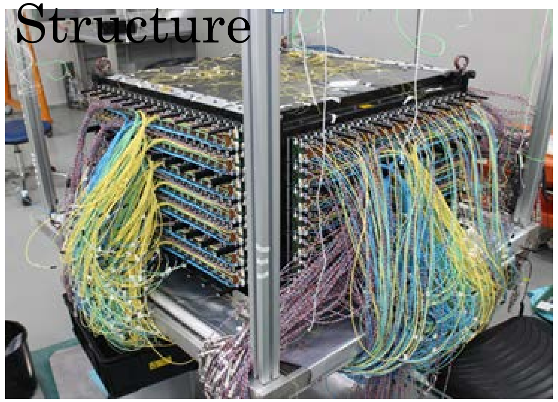


Carbon Fiber Structure

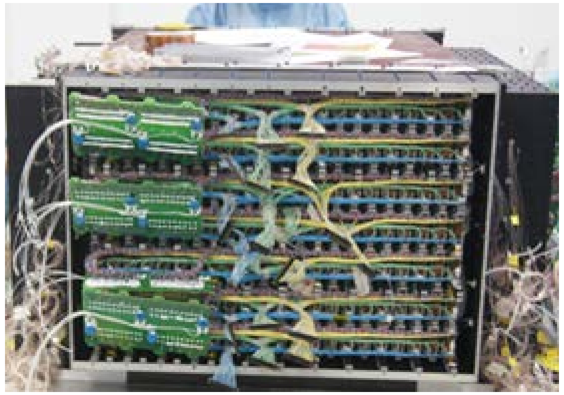
BGO crystal installation



PMT installation



Cable arranging

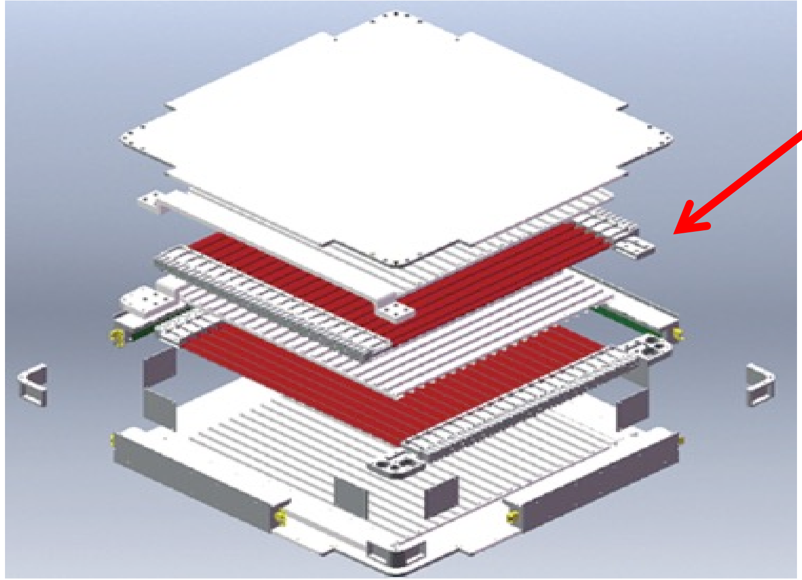


Cable connector

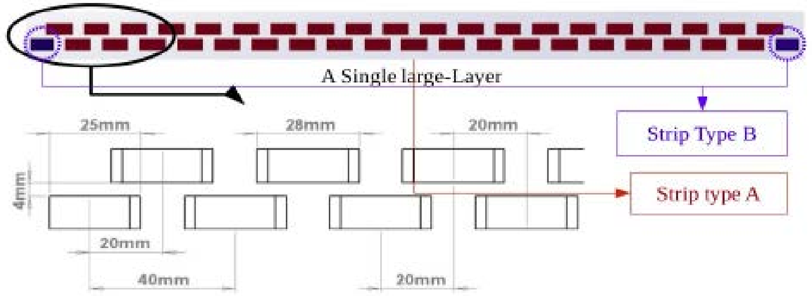
BGO Cal

The PSD and the NUD

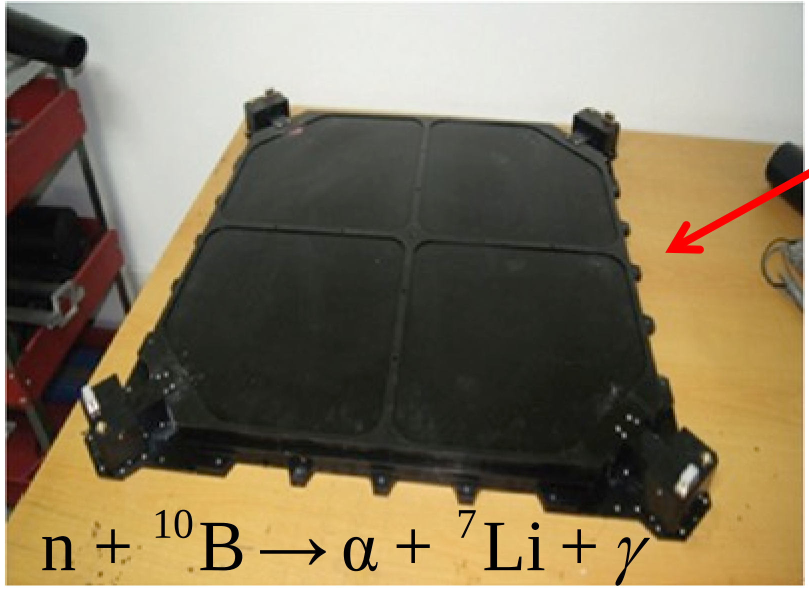
PSD



- 1.0 cm thick ,2.8cm 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)

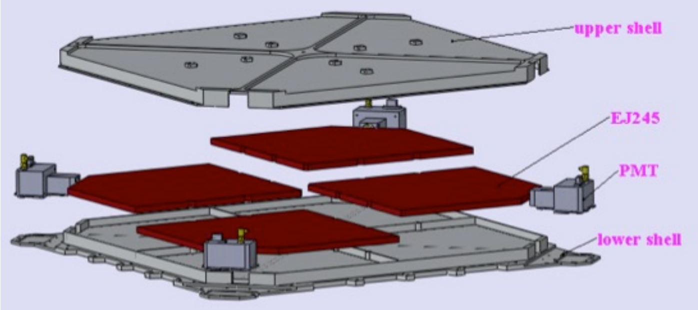


NUD

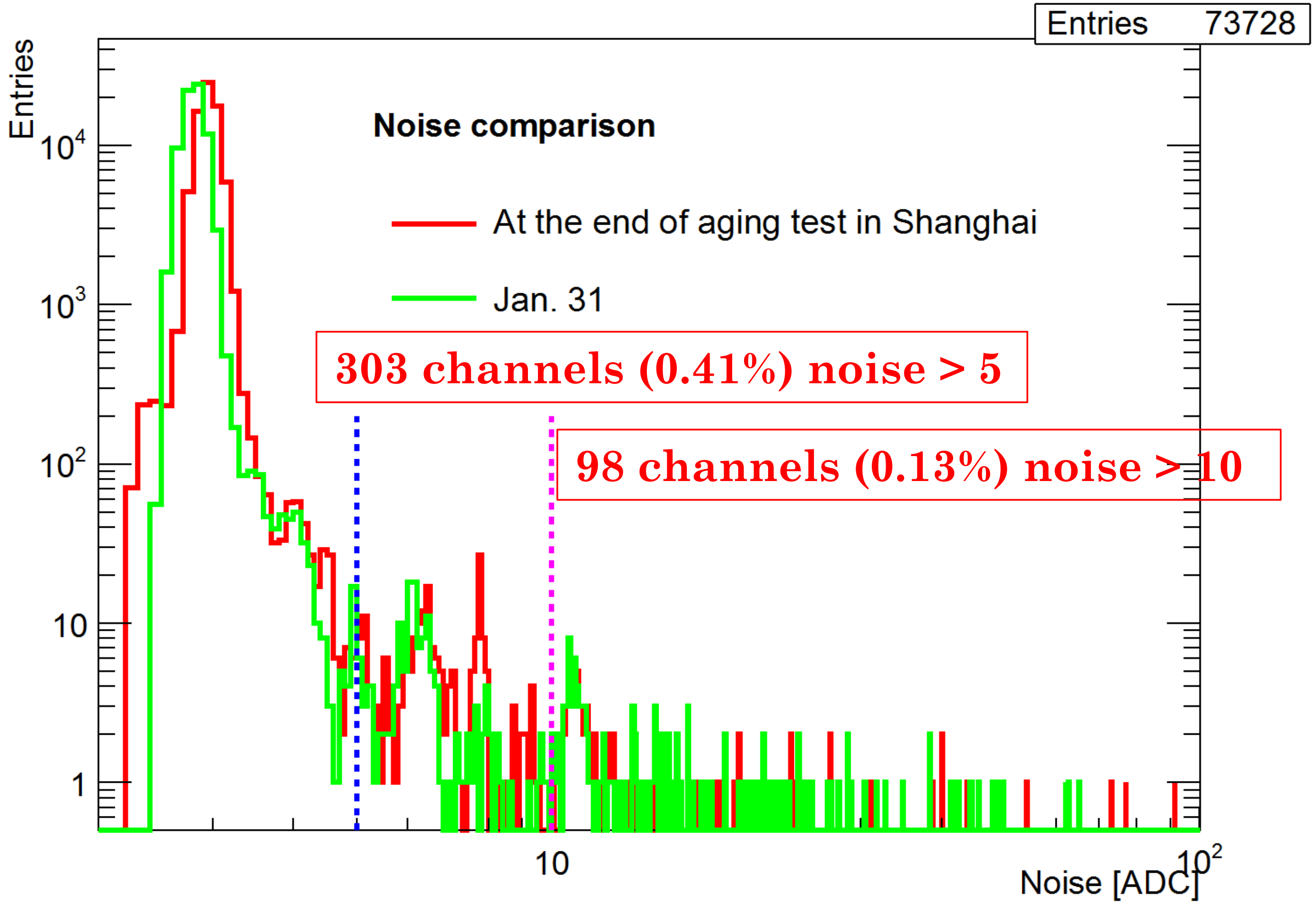


$$n + {}^{10}B \rightarrow \alpha + {}^{7}Li + \gamma$$

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

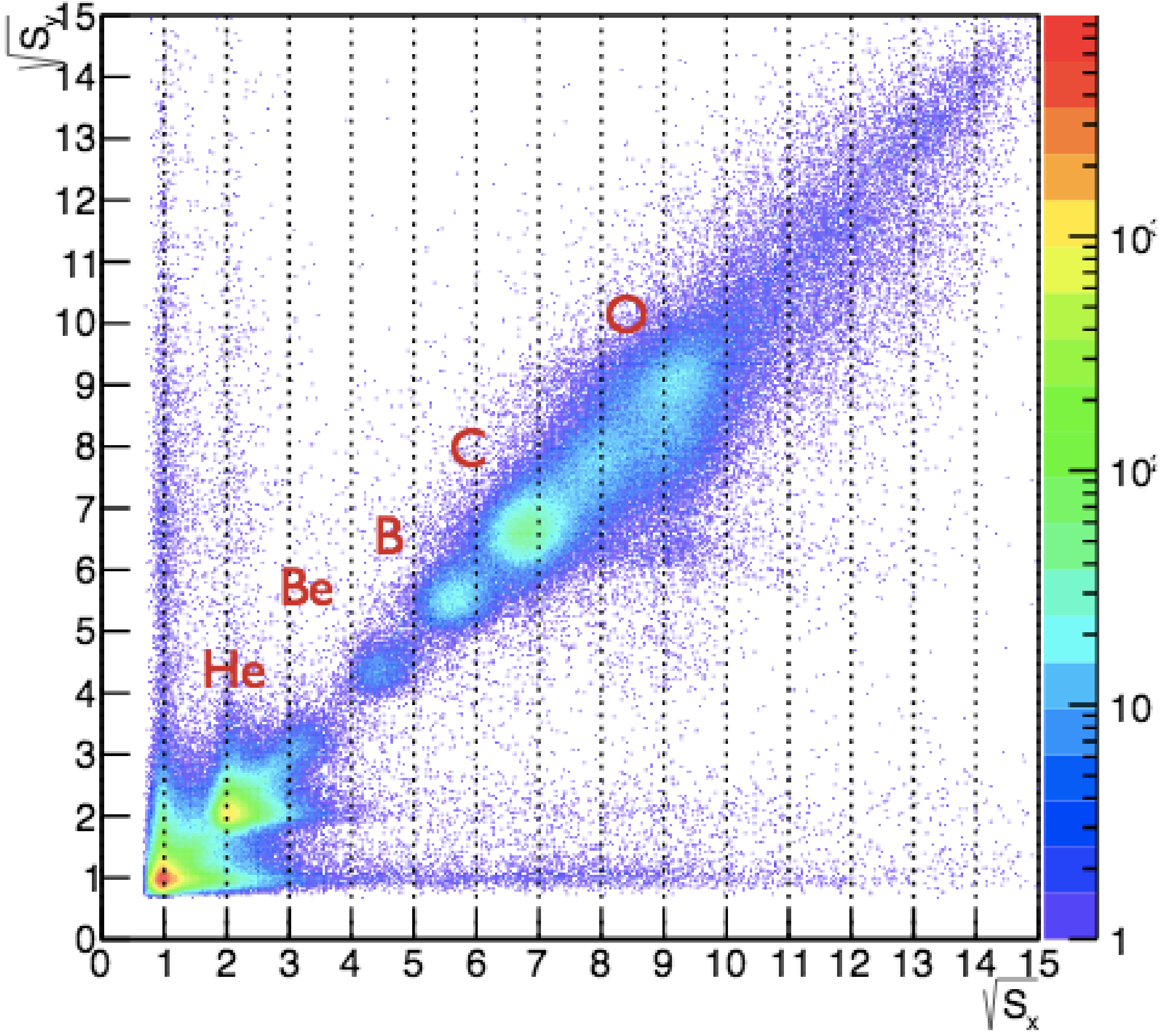


STK noise behavior in orbit

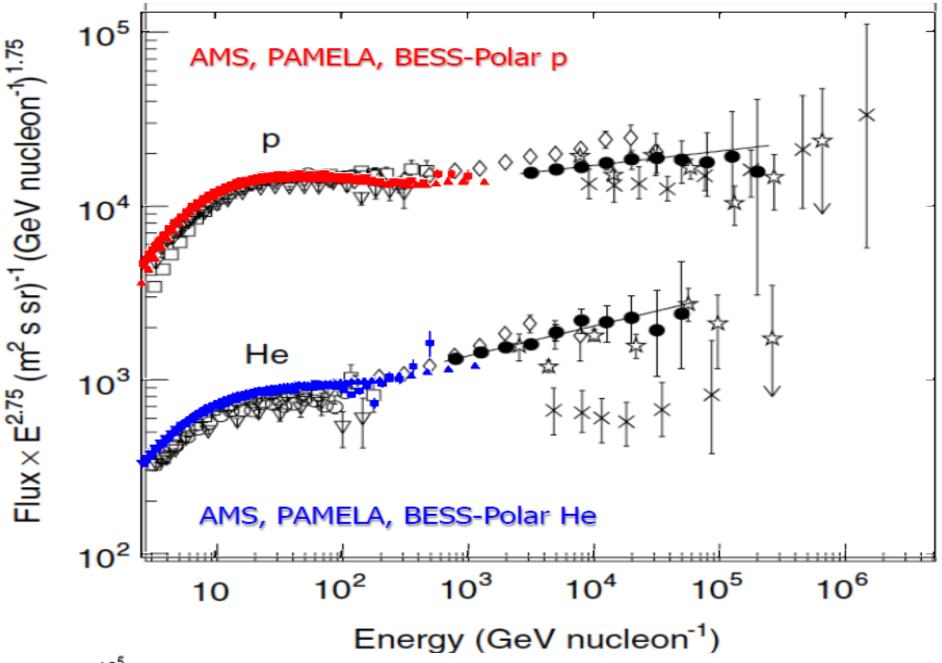


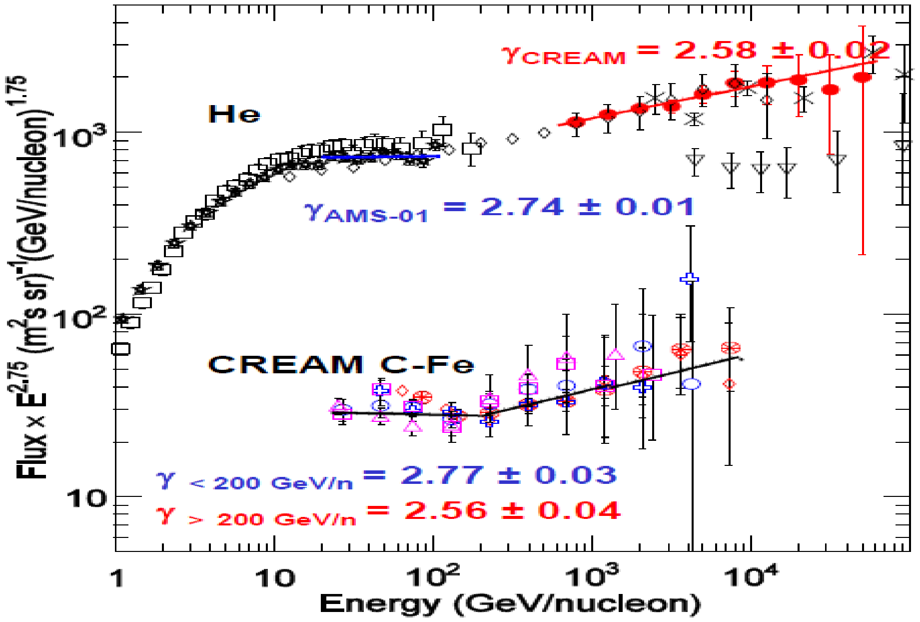
- Noise of the bulk significantly lower than on-ground

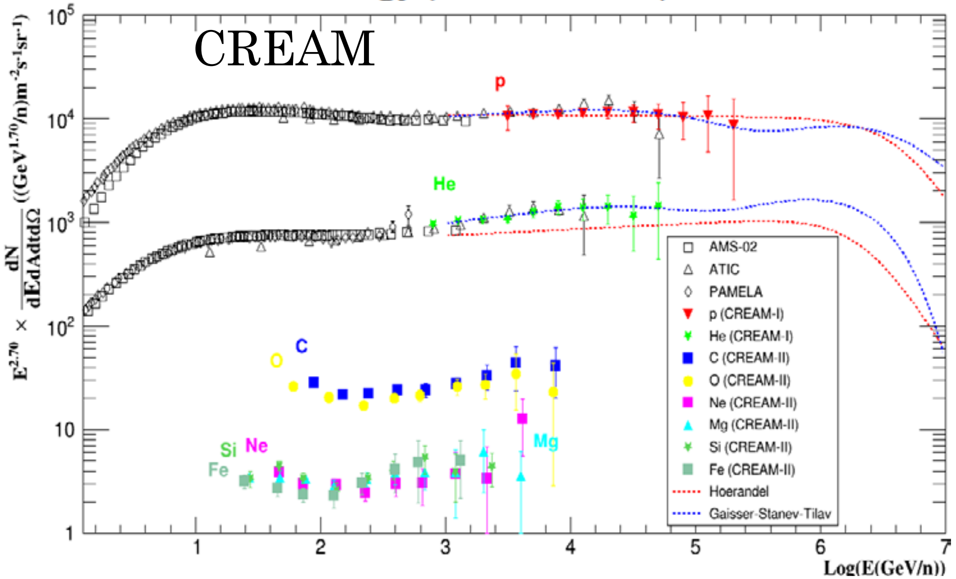
STK preliminary charge ID

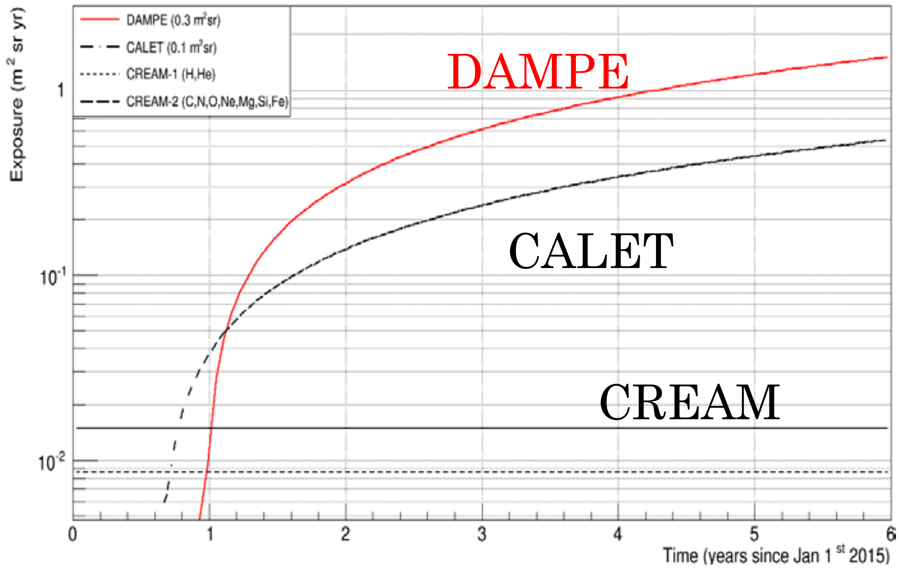


Protons and nuclei spectra

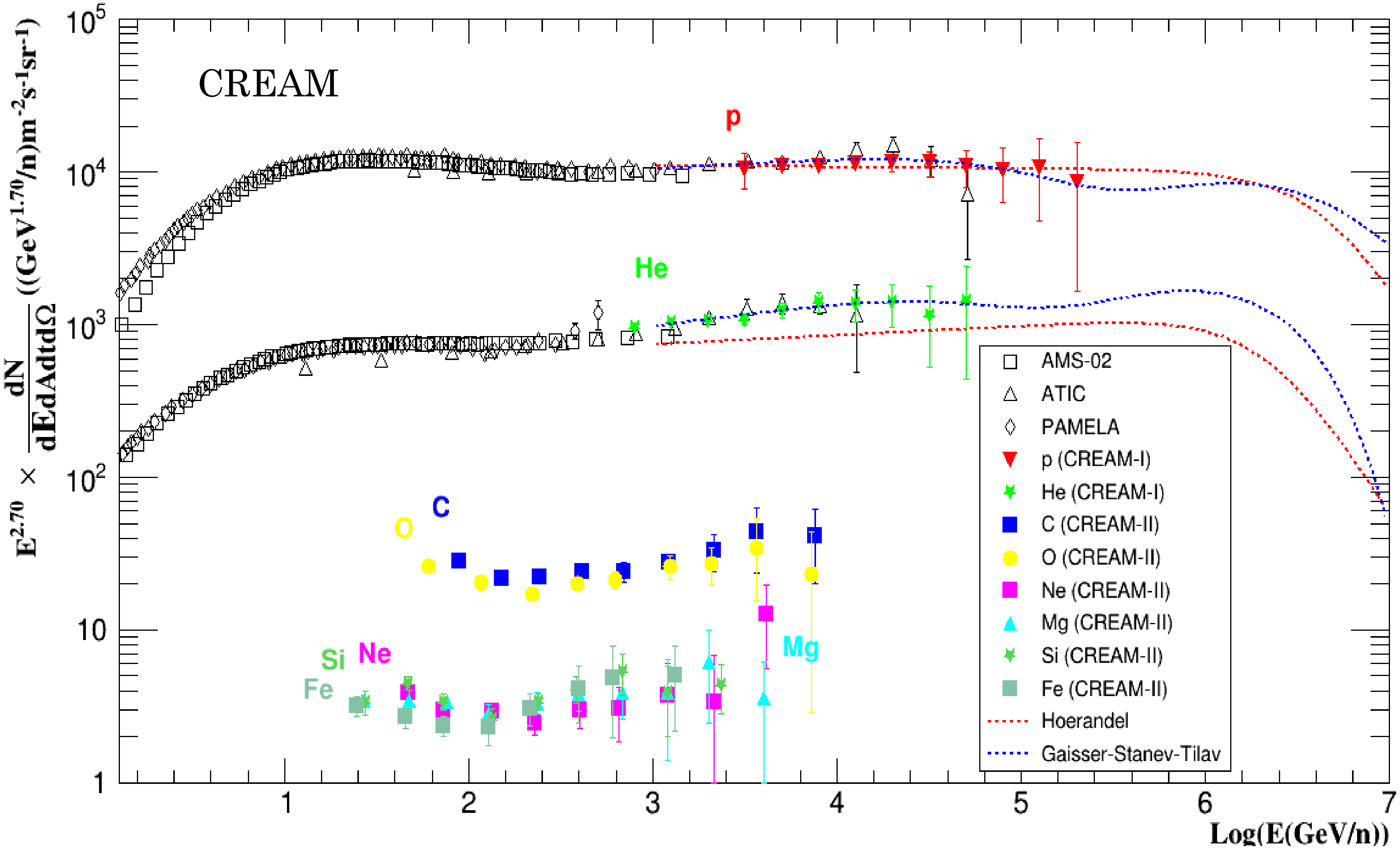








CREAM fluxes



DAMPE 3 years simulation assuming Horandel fluxes