UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES
Département de physique nucléaire et corpusculaire

The DArk Matter Particle Explorer (DAMPE)

- and the High Energy Radiation Detection facility (HERD)

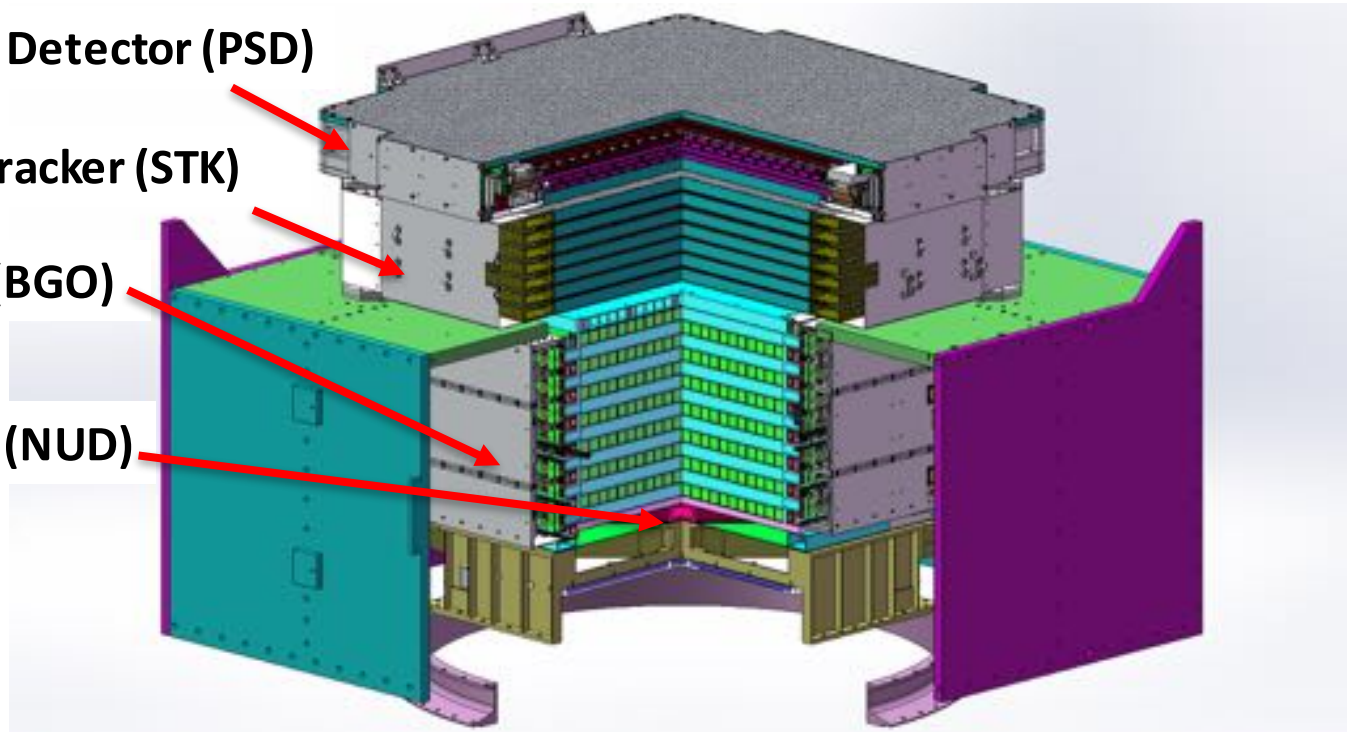
Xin Wu

DPNC, University of Geneva, Switzerland

Science Data Center Meeting

29 September 2016, ISDC, Geneva, Switzerland

The DAMPE detector



- ✓ Thick imaging calorimeter (BGO of 32 X_0)
- ✓ Precise tracking with Si strip detectors (STK)
- ✓ Tungsten photon converters in tracker (STK)
- ✓ Charge measurements with PSD and STK
- ✓ Extra hadron rejection with NUD

→ high energy electron, γ-ray, and cosmic ray telescope

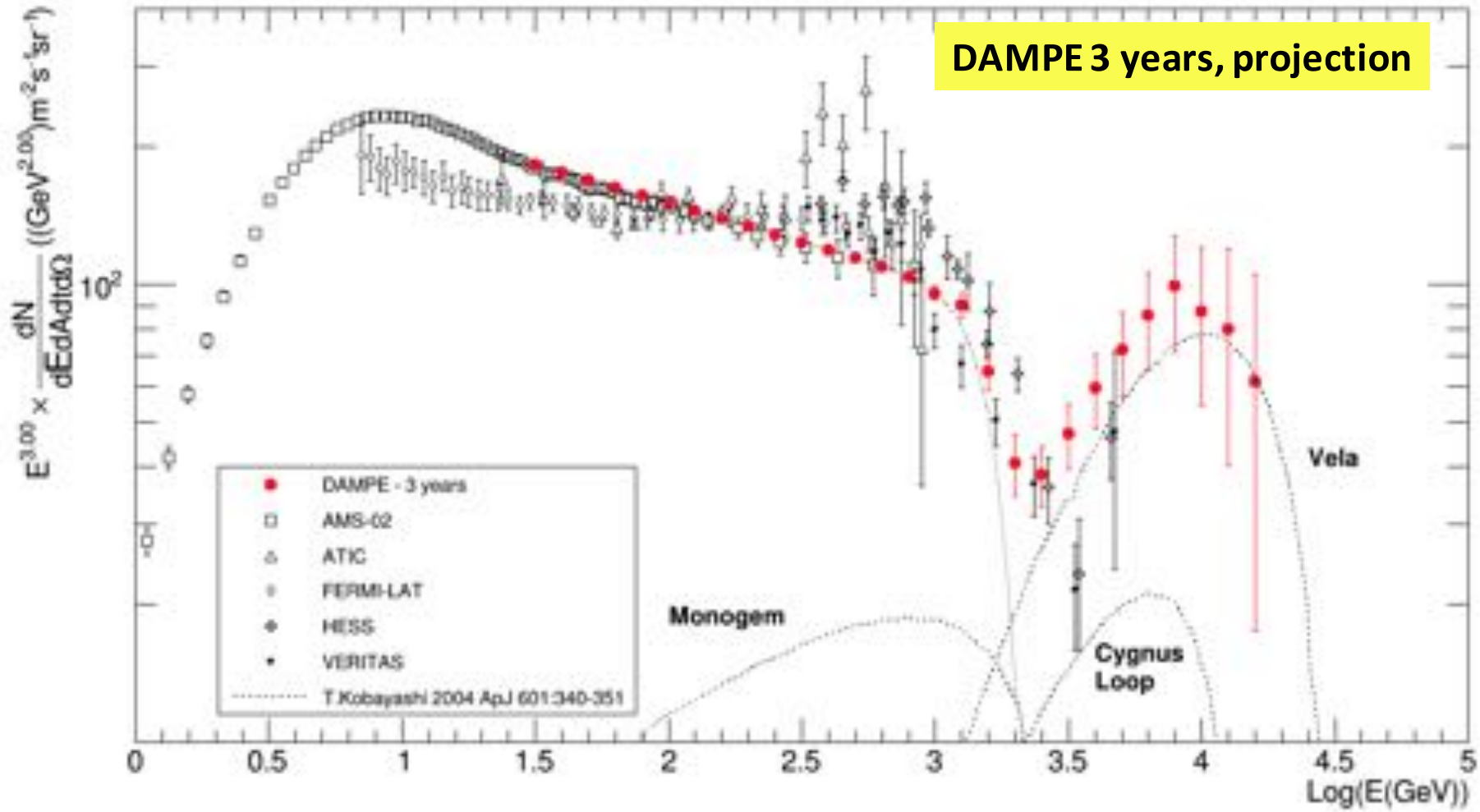
First time 3 in 1!

Scientific objectives of DAMPE

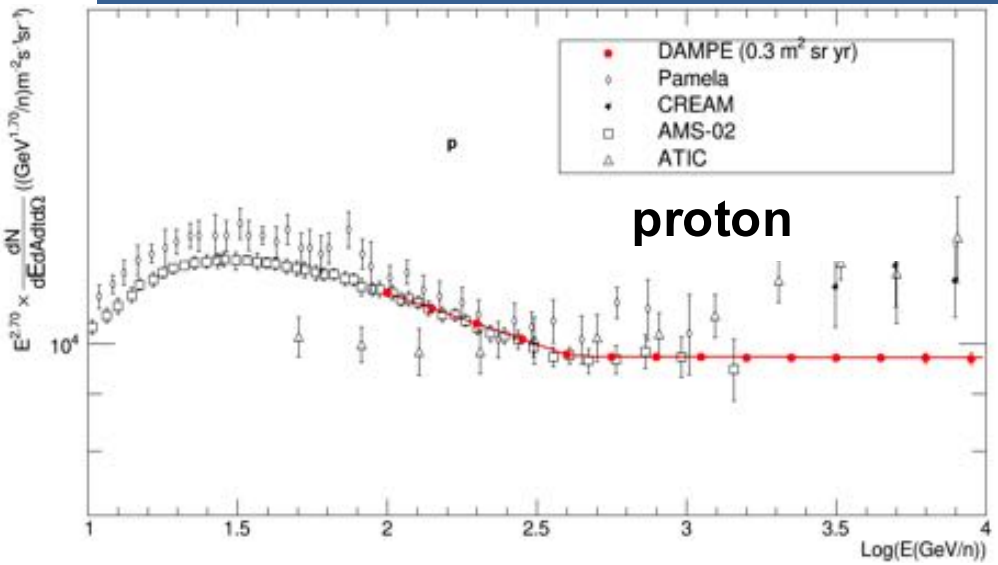
- High energy particle detection in space
  - Measure the high energy cosmic electron and gamma spectra and search for Dark Matter signatures
  - Study of cosmic ray spectrum and composition
  - High energy gamma ray astronomy

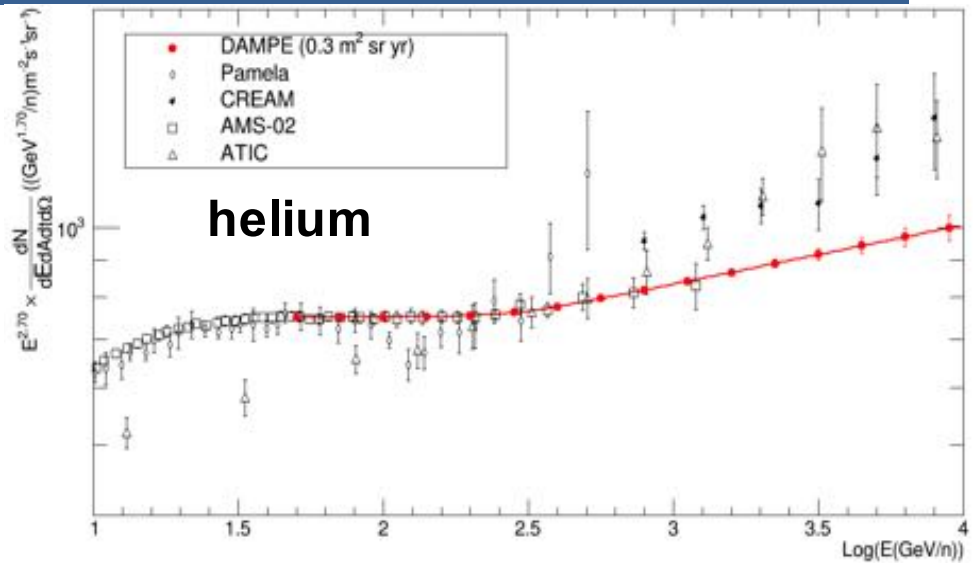
Detection of 1 GeV - 10 TeV e/γ, 100 GeV - 100 TeV cosmic rays with excellent energy resolution, direction reconstruction (γ) and charge measurement

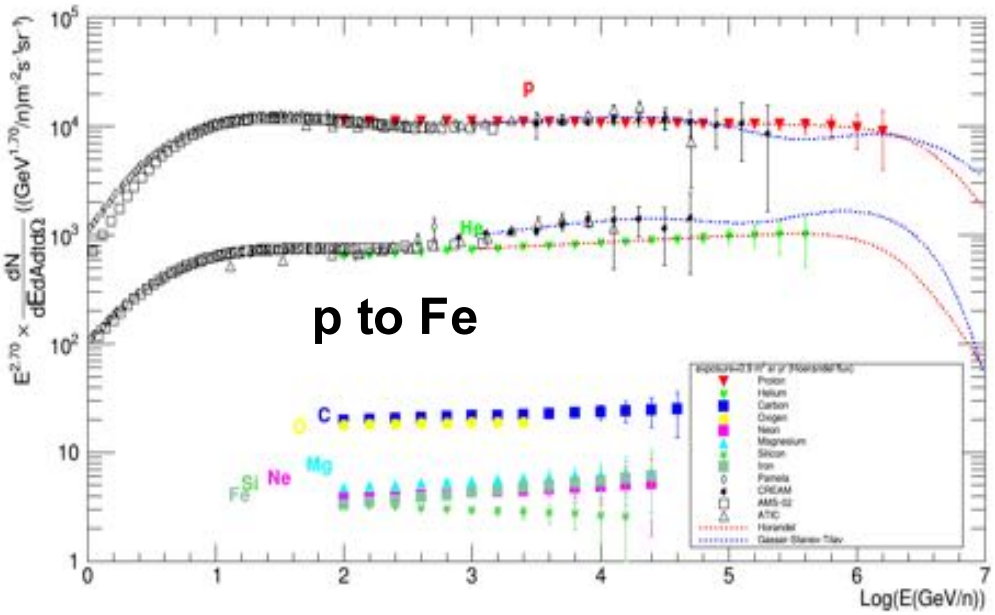
Electron flux

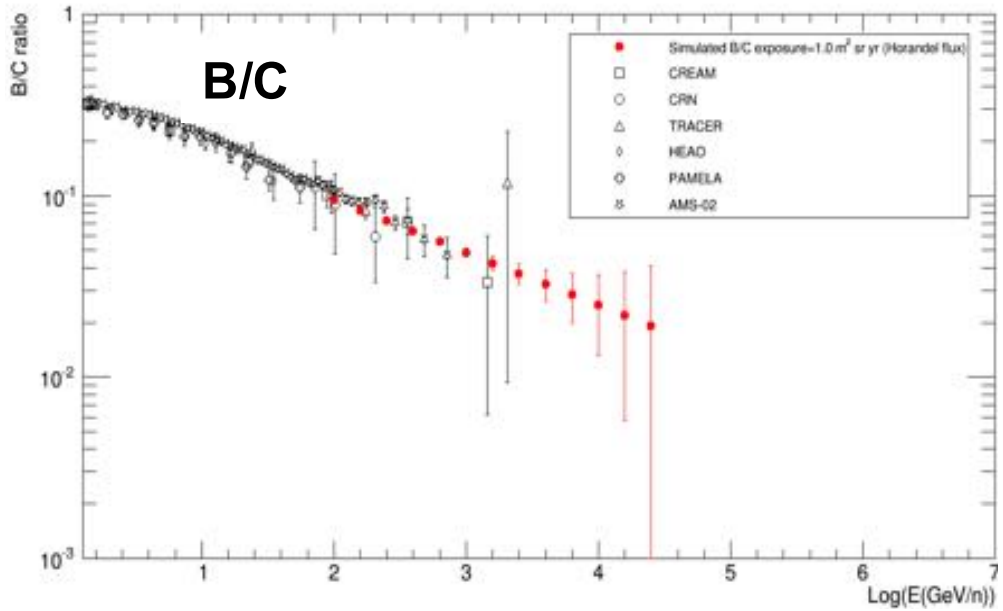


Protons and nuclei: DAMPE 3 years



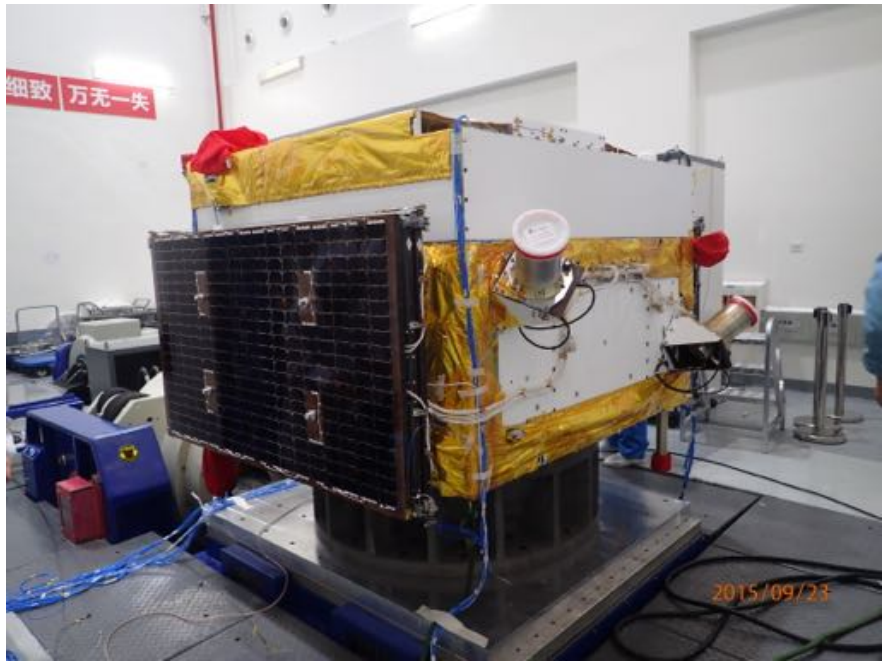






The DAMPE detector in real

EQM, Oct. 2014, CERN



Integrated satellite, Sept. 2015, Shanghai

Weight : 1450/1850 kg (payload/satellite)
Power: 300/500 W (payload/satellite)
Readout channels: 75,916 (STK 73,728)
Size: 1.2m x 1.2 m x 1.0 m
Data rate: 16 GB/day

The DAMPE Collaboration

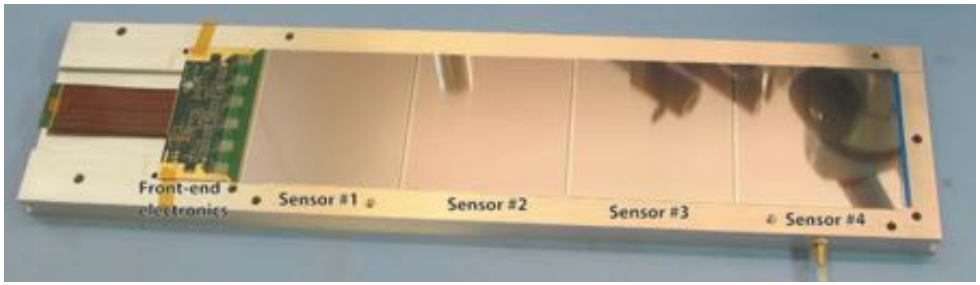
- China
  - Purple Mountain Observatory, CAS, Nanjing
  - University of Science and Technology of China, Hefei
  - Institute of High Energy Physics, CAS, Beijing
  - Institute of Modern Physics, CAS, Lanzhou
  - National Space Science Center, CAS, Beijing

- Switzerland
  - DPNC, University of Geneva, Switzerland

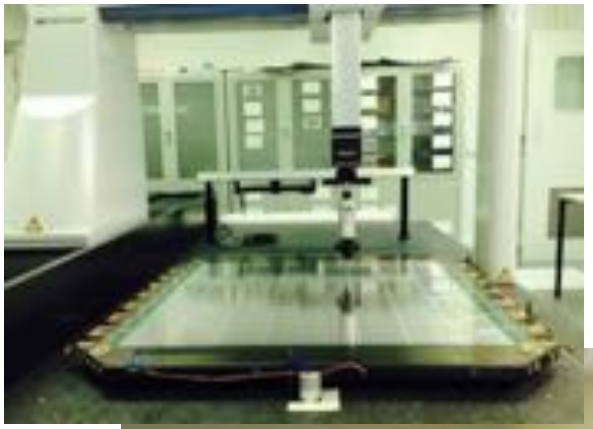
- Italy
  - INFN Perugia and University of Perugia
  - INFN Bari and University of Bari
  - INFN Lecce and University of Salento

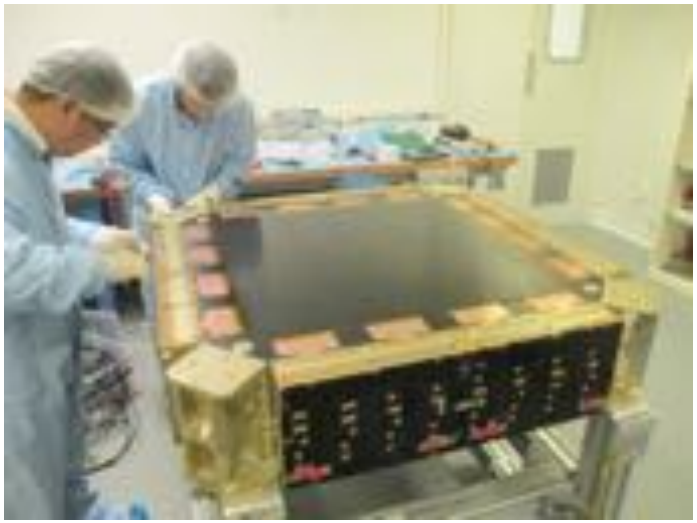
First launch of the 5 approved scientific satellites of the Chinese Academy of Sciences

STK: DPNC responsibility



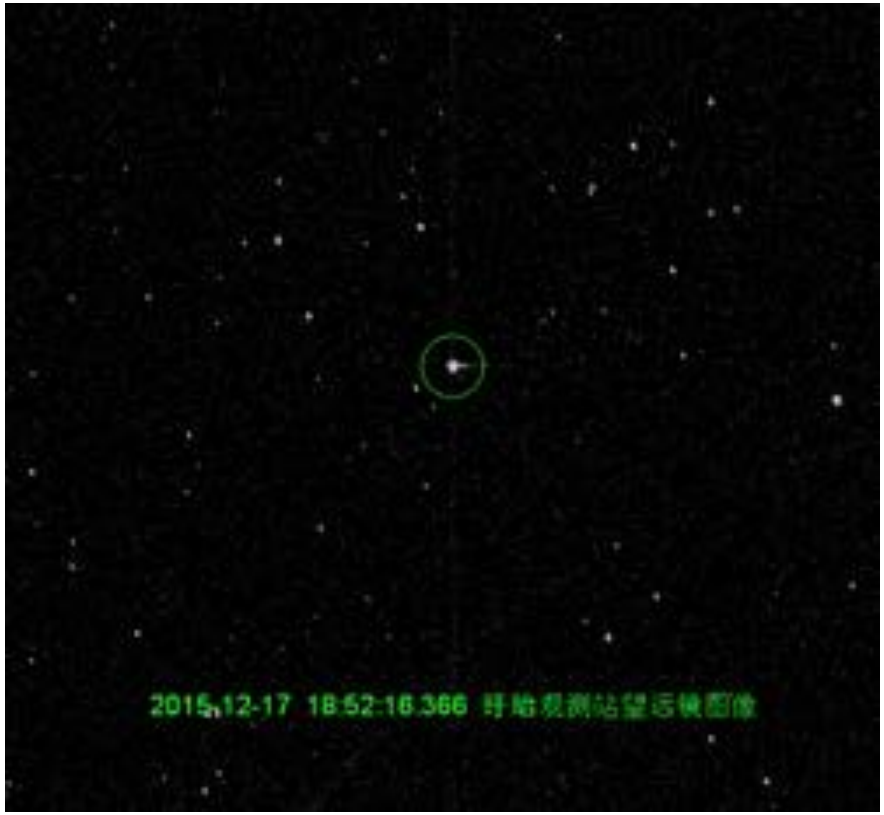
DPNC is the leading house of the silicon-tungsten tracker project, in collaboration with INFN Perugia and IHEP, Beijing

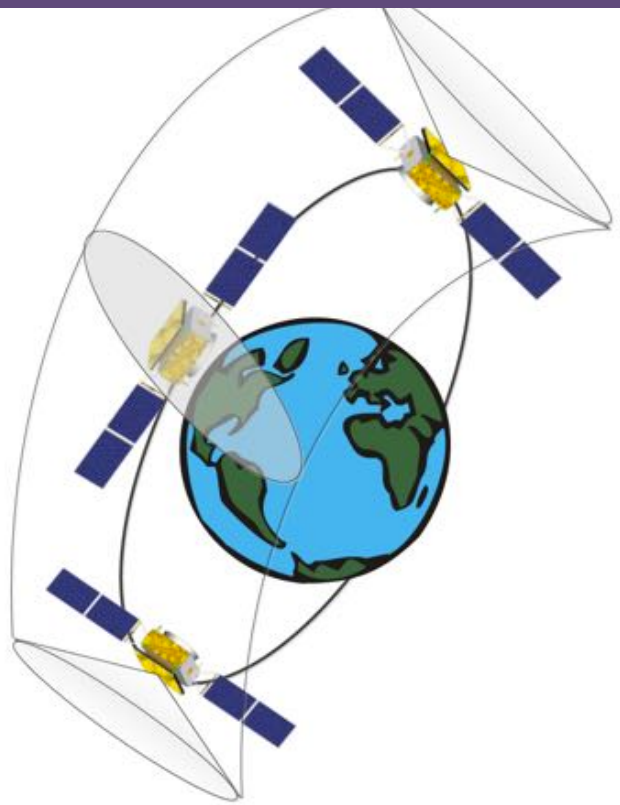




Successfully launched on Dec. 17 2015!

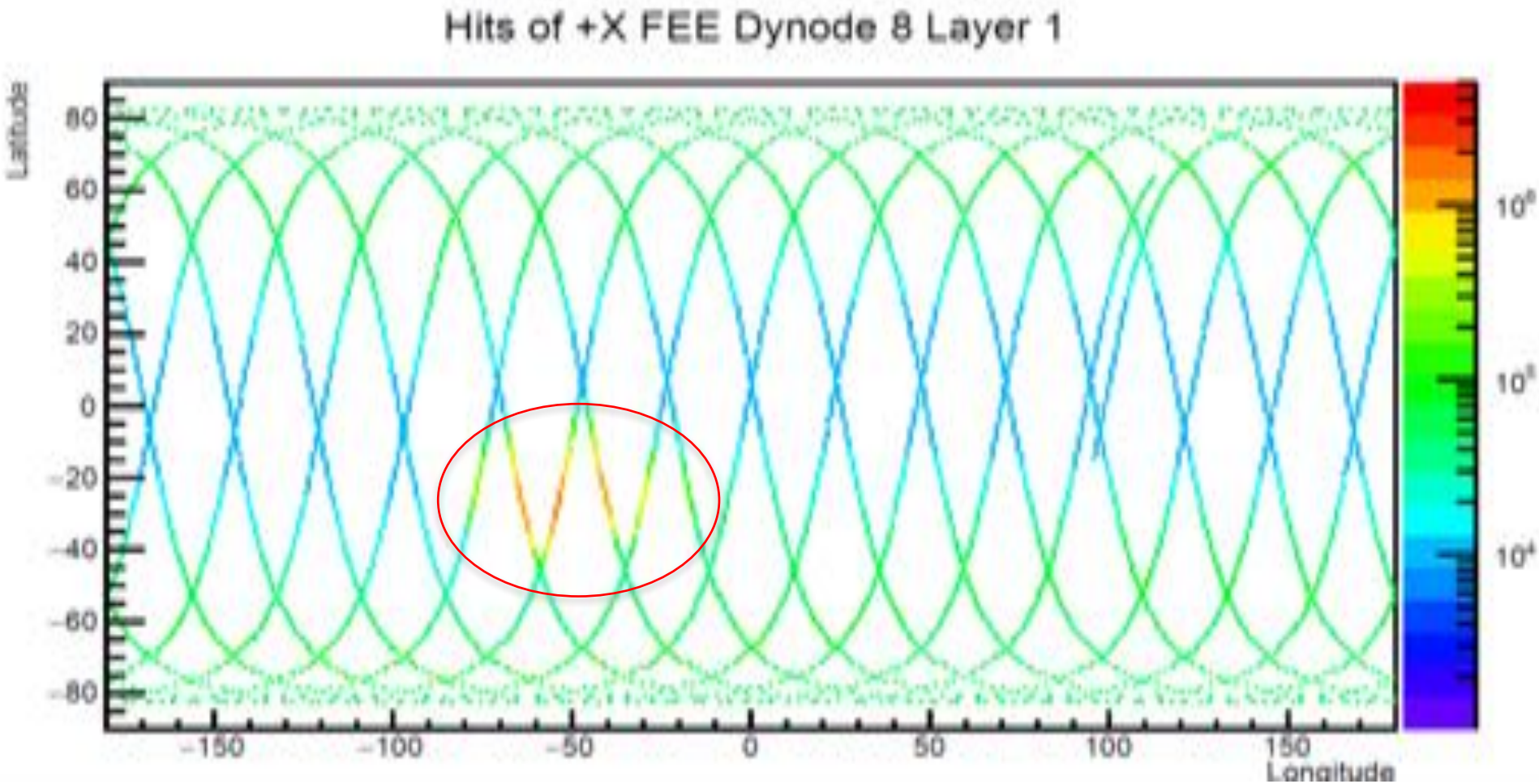
- Altitude: 500 km
- Inclination: 97.4065°
- Period: 95 minutes
- Orbit: sun-synchronous
- Pointing precision 0.005°





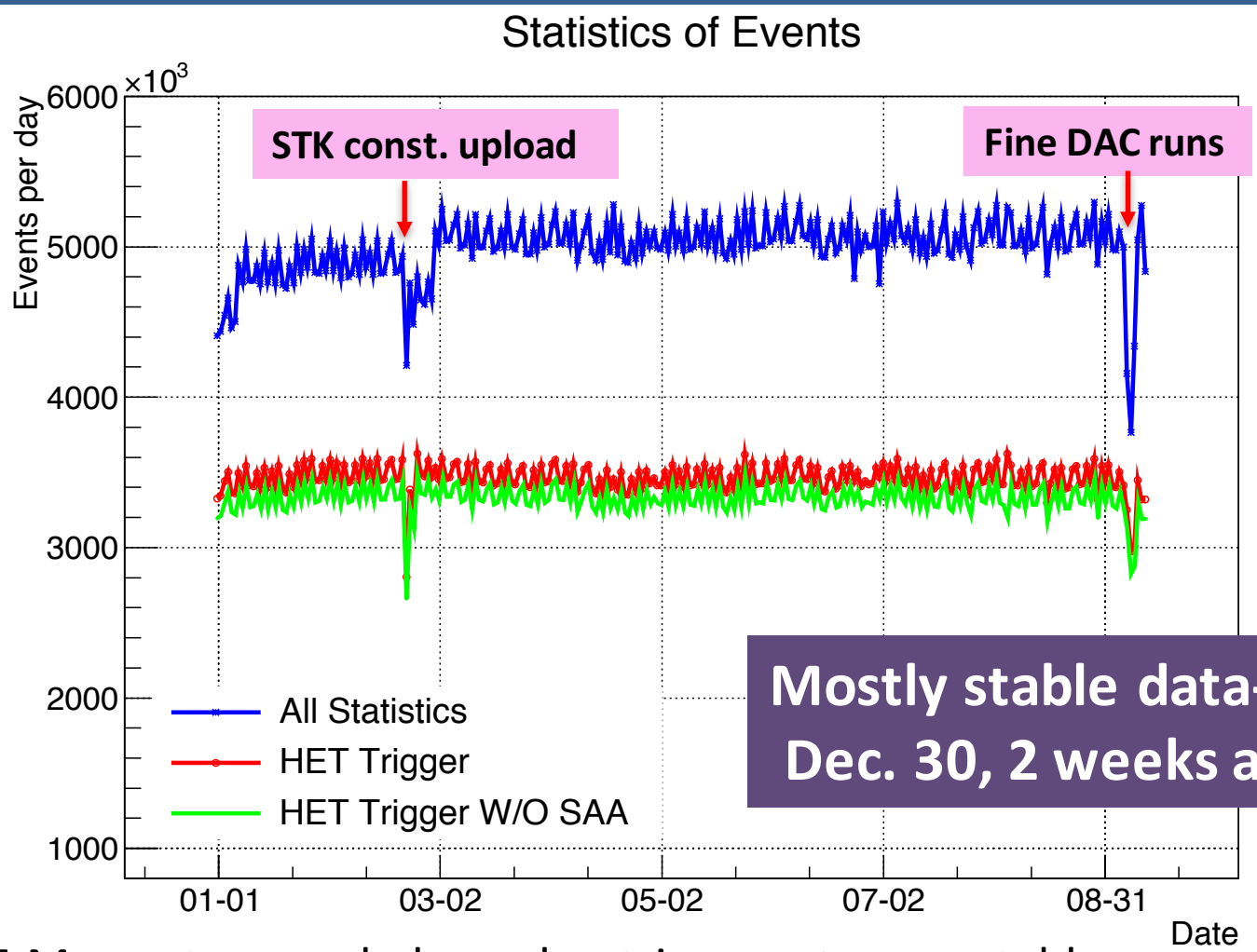
- Dec. 20: all detectors powered on, except the HV for PMTs
- Dec. 24: HV on!
- Dec. 30: stable trigger condition
- Smooth operation since!

Particle hit counts vs orbit



- 15 orbits/day
- ~50 Hz average trigger rate
  - Main high energy trigger and prescaled low energy and MIP triggers

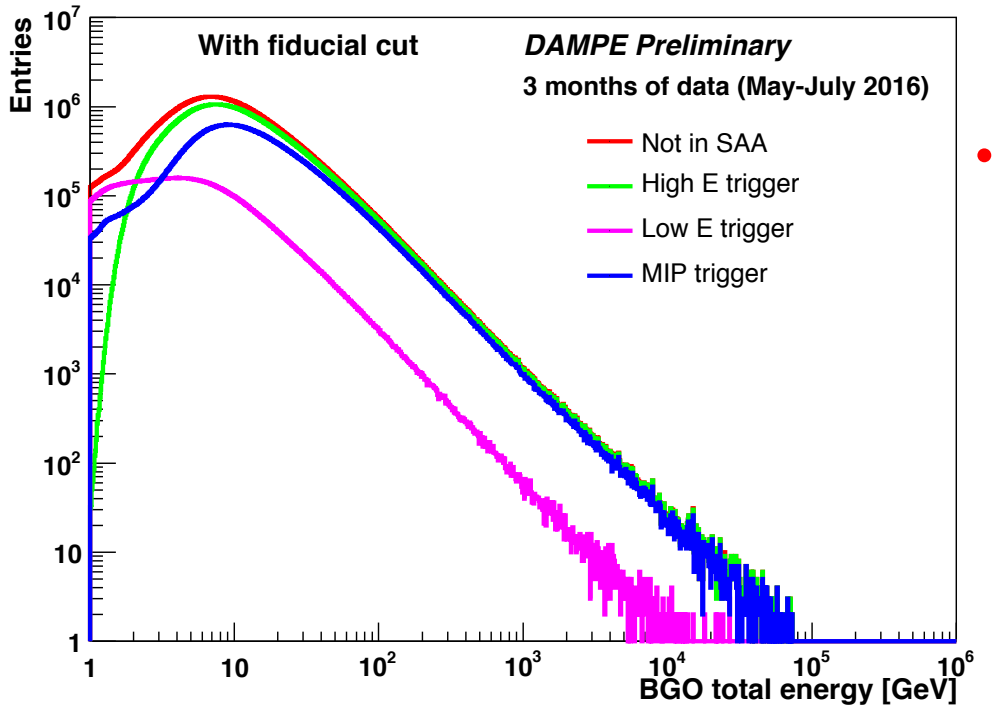
Number of events recorded per day



Mostly stable data-taking since Dec. 30, 2 weeks after launch!

- ~5 M events recorded per day, trigger rate very stable
  - Data down-link: 16 GB/day
  - ~100 GB/day data produced on ground

Lots of high energy particles collected

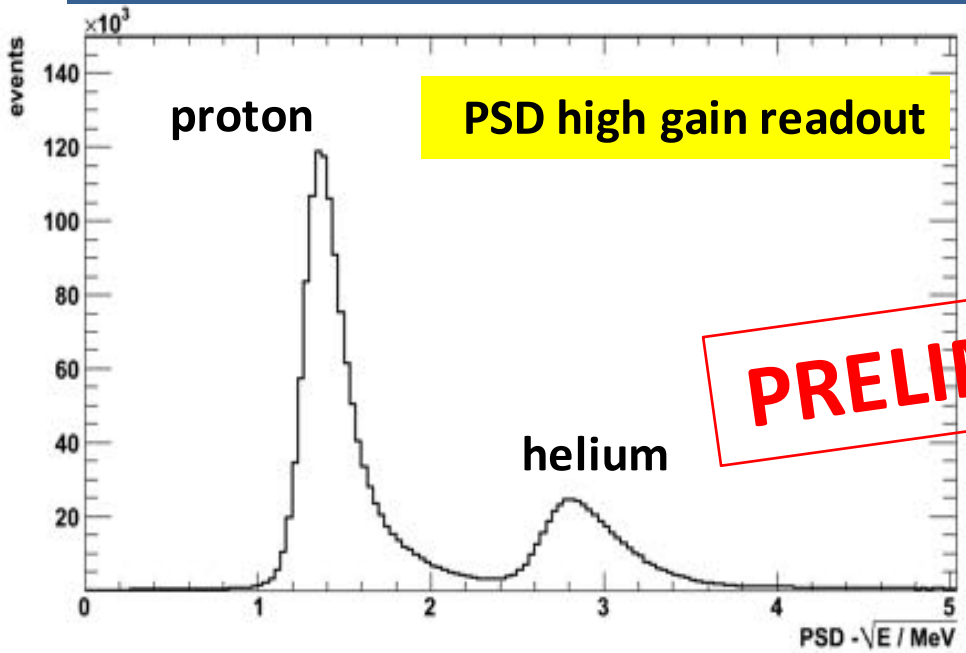


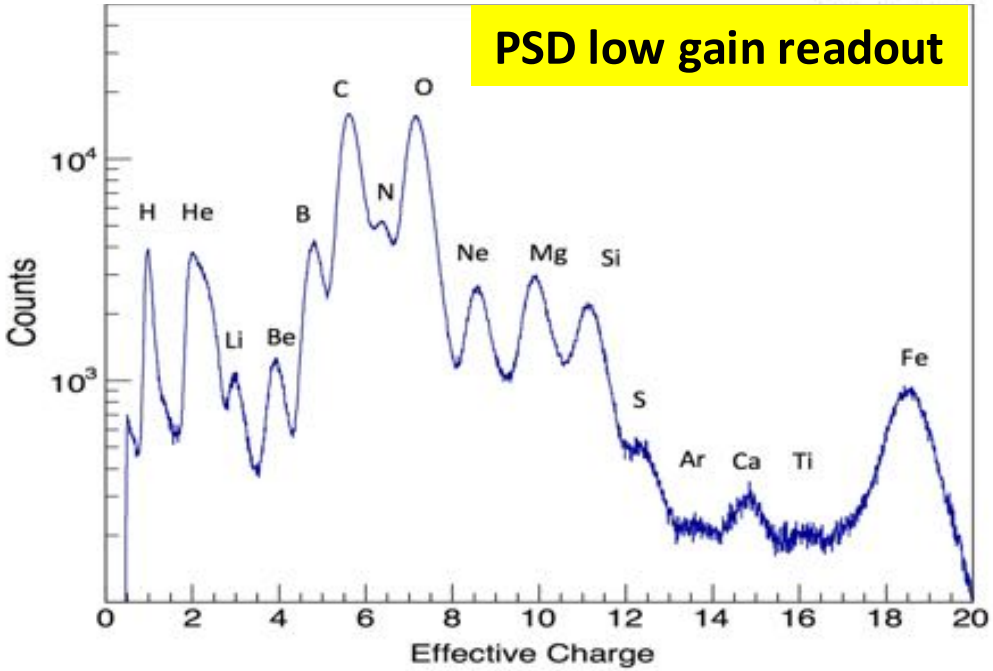
- ~465 M events collected for 3 months!
  - ~9.4% in SAA, mainly <1 GeV
  - Bulk of data collected by high E trigger, efficient for > 10 GeV
  - Also collect large amount of low E (for γ) and MIP (for calibration) data

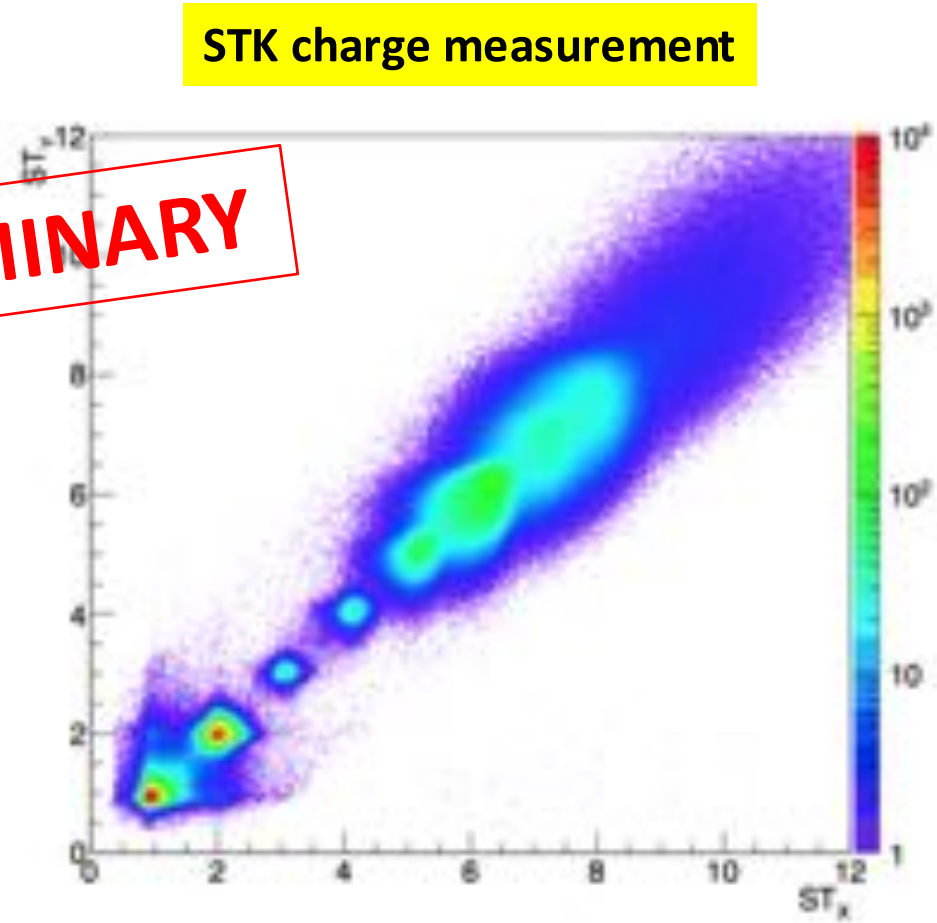
~200k TeV (raw) events/year!

Reaching few 100 TeV for high energy CR physics: connect to ground-based extended air-shower experiments

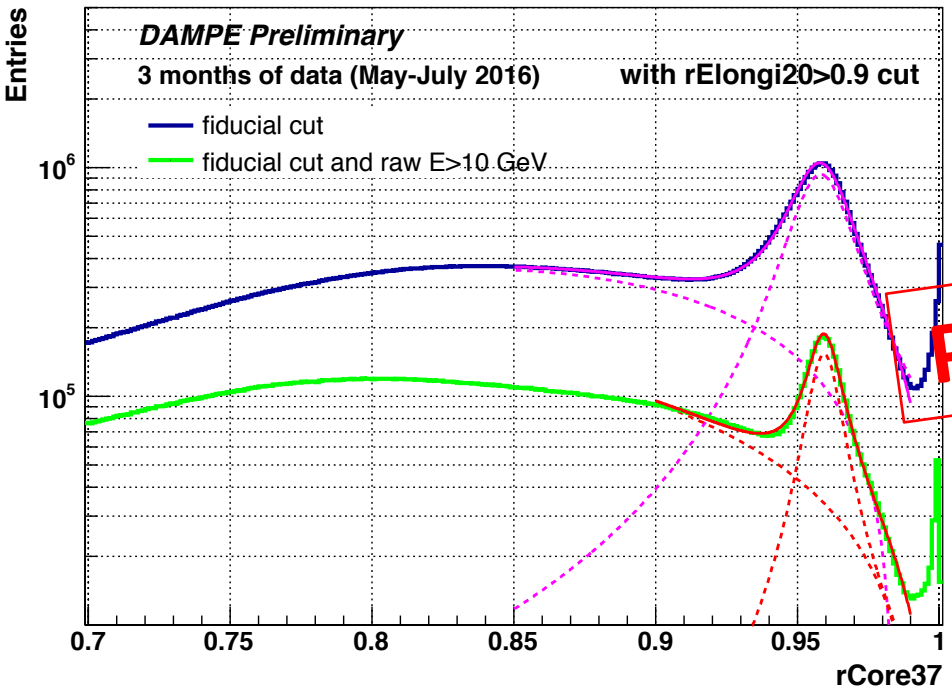
Charge measurement with PSD and STK

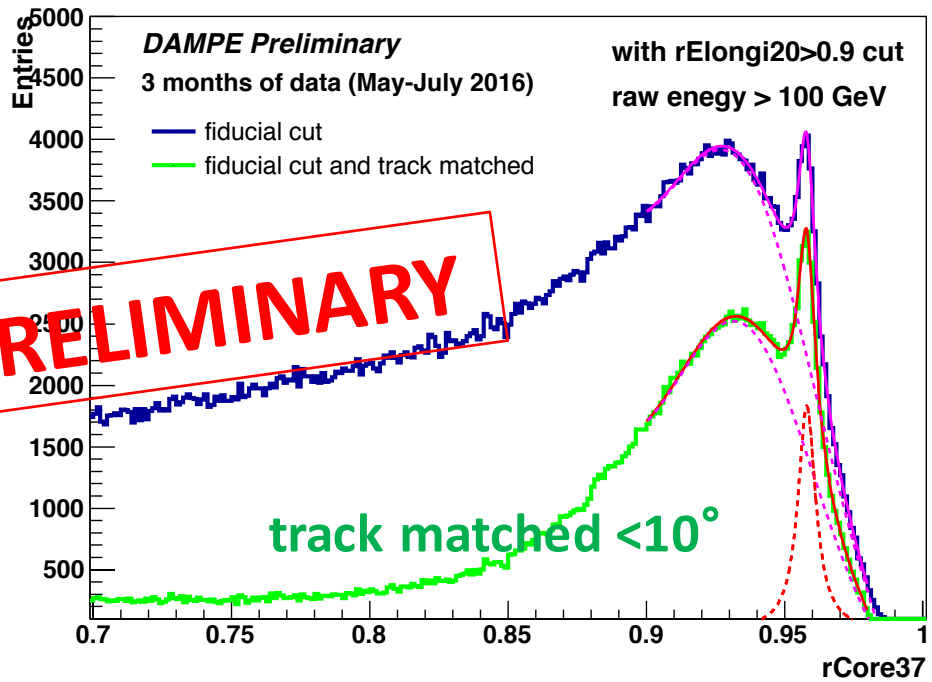






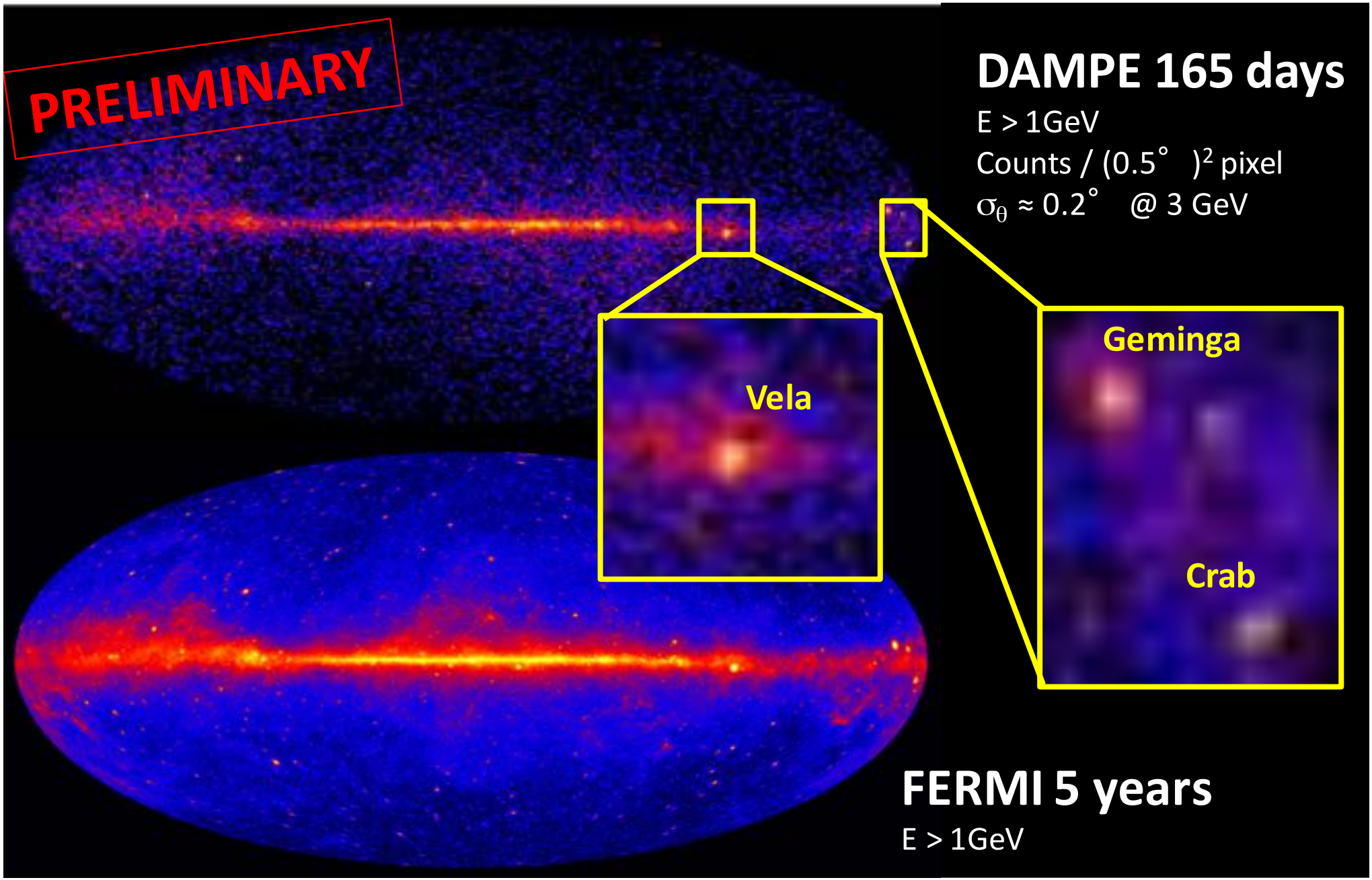
Electron and photons (3 months)





- **~24 M events in fitted signal e/γ (2σ) in full energy range**
  - **~2.2 M events in e/γ signal region above 10 GeV**
- **~15k events in fitted signal (2σ) with E>100 GeV**
  - **Signal stable with track match cut, s/b improved**

Gamma rays observed!



DAMPE Data Path

- L0: telemetry packets from the satellite received by 3 ground stations twice per day (morning and afternoon, ~16 GB/day)
  - Automatically transferred to Ground Support System (GSS) in Beijing
- L1: payload data extracted from L0, then merged, duplicated fragments removed and CRC checked
  - 1 day of data can be processed at GSS within 1 hour
  - New L1 data synchronized to Science Application System (SAS) in Nanjing
- L2/L3: unpacked and processed payload data in root format
  - Performed at SAS in Nanjing (PMO)
- L1/L2/L3 data automatically transferred from PMO to Europe (CNAF in Italy)
  - Synchronized to local cluster at DPNC

L0

L0

L1

L1/2/3

L1/2/3

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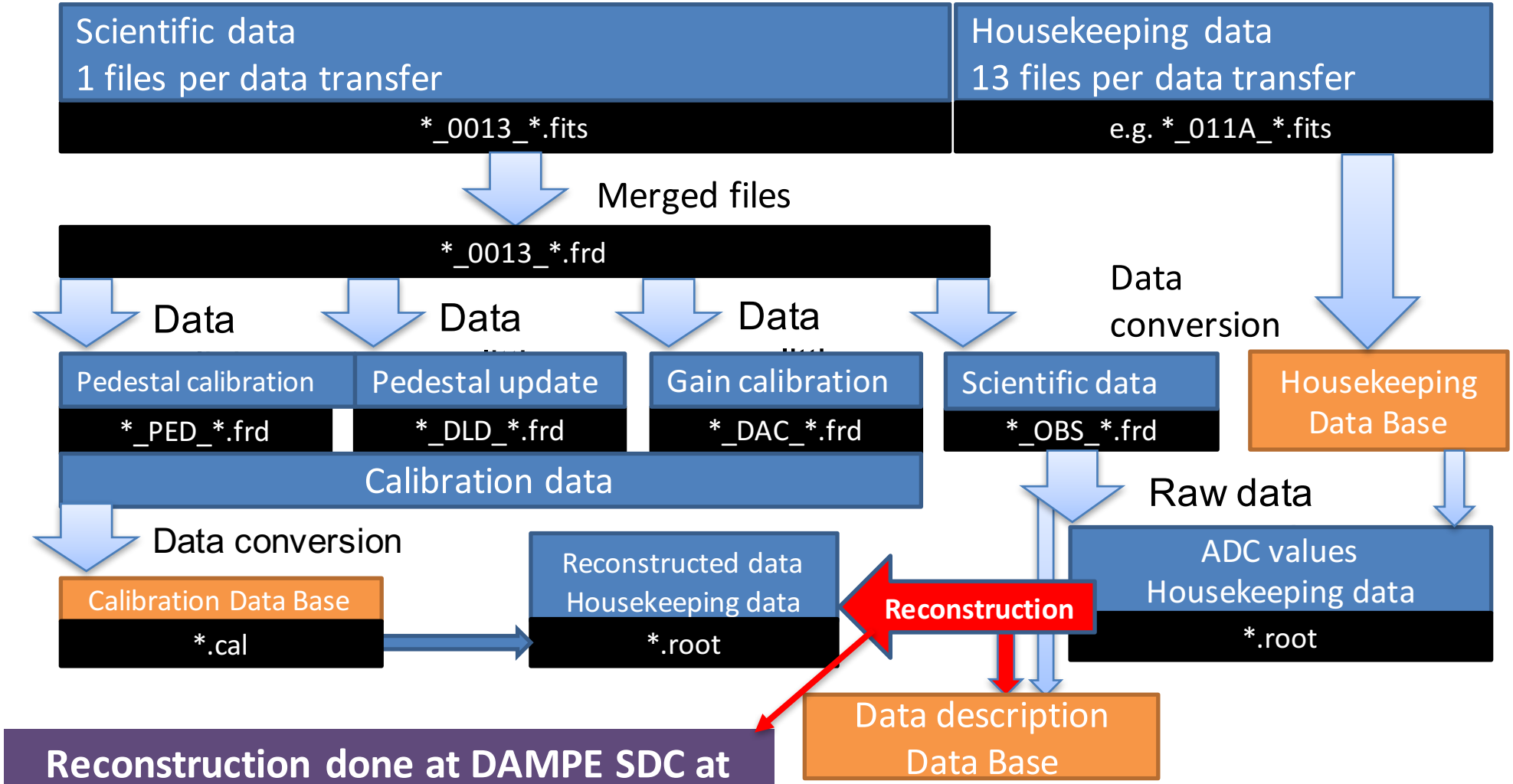
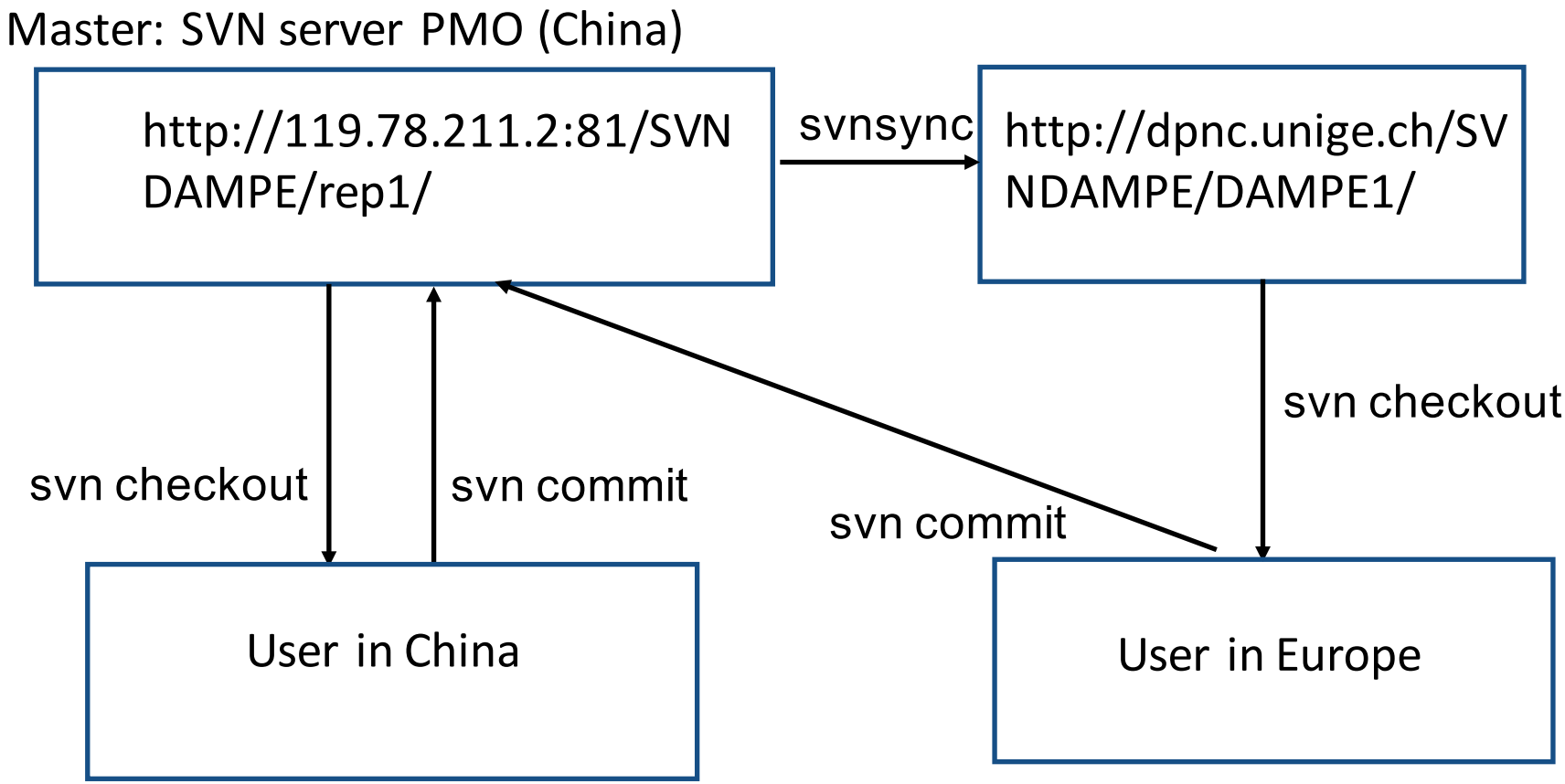
DAMPE Data Processing Pipeline



Reconstruction done at DAMPE SDC at PMO (>1400 cores, can reprocess 3 years of data in ~1 month)

Collaborative Software Development

- Base in a SVN code repository DAMPE software is stored in the SVN servers in China and Europe
  - svnsync is invoked in PMO server after each commit request
  - cron job is running in Geneva checking if servers are synchronized



Data transfer status

- PMO -> CNAF: gridftp
  - 6 gridftp processes running all the time on a dedicated server at PMO
  - Mean transfer rate ~ 6 MB/s, daily transfer: ~ 100 GB , ~110 TB transferred
    - Main L2 science data stream (2A) ~60 GB/day
  - Leased connection between PMO and the China Education and Research Network (CERNET)
    - Limited to 100 Mb/s, OK for daily transfer ~100 GB/day
    - For reprocessed data (~11 TB for 6 months of data) more efficient to transfer by hard drives!
- CNAF -> Geneva: rsync
  - 10 lsf jobs running all the time at CNAF
  - Dedicated data transfer server at DPNC
  - 70-80 MB/s, so basically no latency
  - New data transfer scheme based on XRootD is under development

DAMPE DPNC local cluster

- Share with the ATLAS Tier 3 cluster at DPNC (also IceCube, AMS, T2K)
  - Total: ~750 (+240 soon) cores, ~360 (soon ~600) TB
  - DAMPE: ~60 TB, >200TB by the end of the year
- DAMPE data stored in XRootD and NSF disk servers
  - Main science and MC data sets in XRootD servers for intensive access
    - Need a grid certificate
  - Smaller and temporary datasets in NSF disk
- Local data activities
  - STK monitoring, calibration, alignment, track reconstruction
  - Proton and heavy ion fluxes, electron spectrum, gamma ray analysis
- MC simulation is centrally handled from Geneva
  - a custom distributed workflow submission system which interacts with various computing resources across Europe (CNAF, INFN-Bari, DPNC)
- Two DELL servers running instances for ELOG, Doxygen, workflow submission, data catalog, database server, …

Data transfer integrity assurance

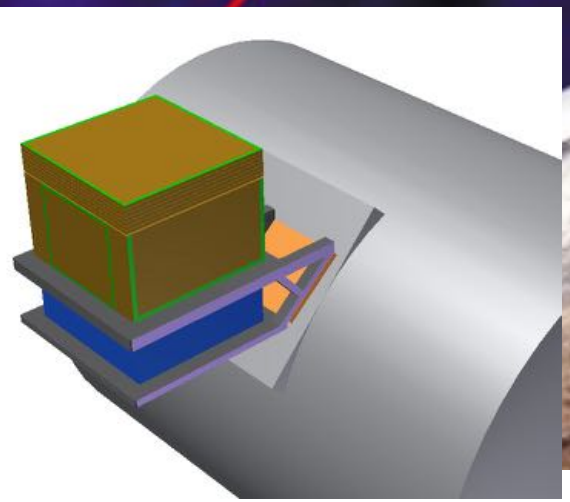
- A job running at PMO evaluates md5 checksums and pushes the results to the DPNC data server.
  - ~30 seconds per file, ~30 files per day's data
- On the DPNC rsync server, "agents"
  - Evaluates md5 sums of local files;
  - Marks as "good" files having matched md5 sum with PMO
  - Checks if "good" files in XRootD server with the same checksum
    - If file doesn't exist (or has different checksum), it is uploaded (re-uploaded) to XRootD
- Check independently each file on XRootD has the same md5 sum as in PMO
- A loop is done through the files in PMO, to ensure that each of them was copied to Geneva.
- In addition, every file on XROOTD is open with ROOT by a "crawler", and basic trees are checked, to see if file is not corrupted.

HERD: High Energy Radiation Detection facility

- **Next generation high energy particle detector on board the Chinese Space Station**
  - Similar to DAMPE, but with larger acceptance
  - 5-side sensitive!
    - Advance the frontiers of DM search, cosmic-ray physics and γ-ray astronomy
  - **Payload ~2000 kg, launch ~2025, lifetime ~10 years**
- **International proto-collaboration formed: China, Switzerland, Italy, Sweden**
  - X. Wu is the Tracker Working Group co-leader
  - R. Walter (ISDC) is the Gamma-ray Astronomy Working Group co-leader

Bigger, better, longer!

On board the Chinese Space Station, ~2025



Conclusions

- DAMPE is a powerful space telescope for high energy electron, γ-ray, and cosmic rays, in operation!
  - Detector has been well calibrated before launch
- On-orbit commissioning has completed
  - A short commissioning period thanks to the robust detector technologies and the high quality of construction
- Smooth continues and a large amount of good quality data is being collected
- Rather robust data processing/reprocessing and data transfer schemes have been implemented
- Science data infrastructure at DPNC is in place
  - Data production and analysis are in full swing!
- Similar infrastructure is needed for HERD

DAMPE Offline Software Framework

- DAMPE offline software framework is inspired by the GAUDI philosophy (http://proj-gaudi.web.cern.ch/proj-gaudi/)
  - The core part is implemented in C++
  - Management part is done in Python
- The central component of framework is the algorithm base class
  - All algorithms are inherited from the base class, including algorithms for the conversion of binary data, simulation, and reconstructions
- Several core services:
  - algorithm manager, input-output service (based on ROOT), geometry manager, …
- Geometry manager allows for loading DAMPE read-out geometry from the XML database without using Geant4 libraries
  - Reducing significantly the overhead of initializing the reconstruction and analysis jobs

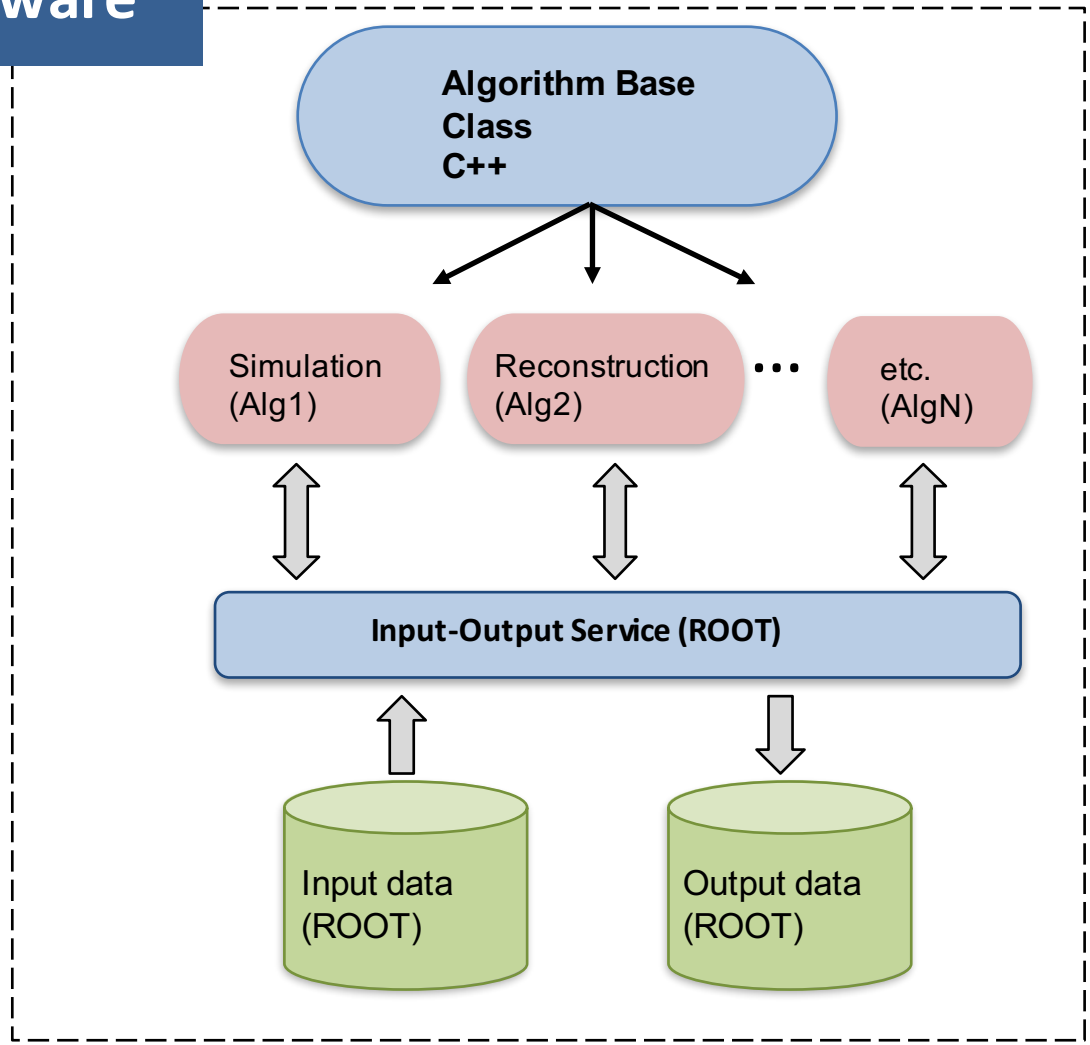
Some Software Framework Details

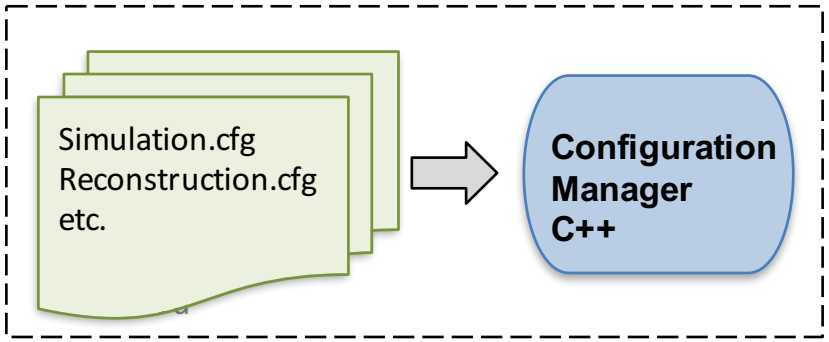
- Simulation is implemented as a dedicated algorithm, based on Geant4
- All the supporting structures of the detector are implemented in the geometry, directly from the CAD drawings, using a custom CAD-to-GDML convertor
- All DAMPE offline jobs are configured via job option files written in Python
  - Boost-python libraries are exploited for accessing the C++ code from Python
- Algorithms can be stacked together inside a job option, forming a sequence
- IO-service acts as a data buffer for communication between algorithms, and for reading (writing) the input (output) data to the ROOT files
  - IO-service is agnostic of whether data comes from the input file or as an output of preceding algorithm in a sequence
- Configuration files are used to store the configuration parameters
  - Allows for explicit versioning (tagging) of data-production campaigns

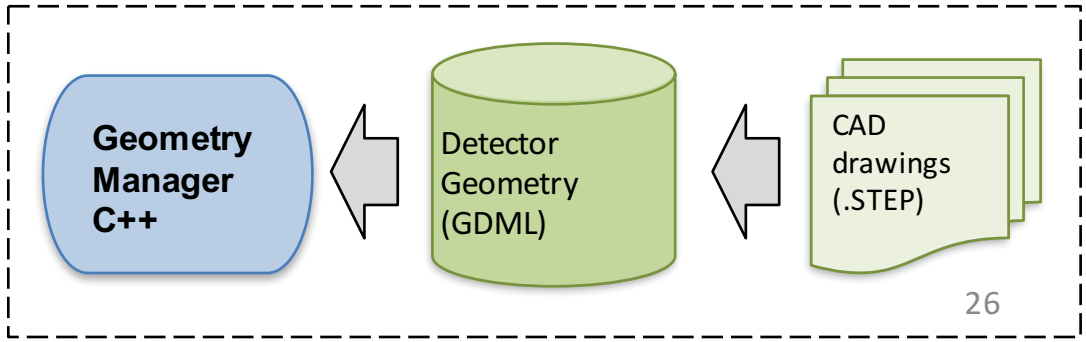
Block Diagram of DAMPE Software

Job Description Files (Python)

```python
import DampeCore as Core

#Algorithm sequence
Core.Add(Alg1)
Core.Add(Alg2)
...
Core.Add(AlgN)

#Ancillary services
Core.Add(GeometryMgr)
Core.Add(ConfigMgr)

#Code execution
Core.Initialize()
Core.RunEventLoop()
Core.Finalize()
```







#	Info	Folder	Description
1	**Single transfer data**	1AM	Test binary data
2		1E	Raw data (ADC hits, HC data). Root format
3		2Q	Reconstructed data for fast monitoring (clusters, tracks, etc.)
4		1BS	Binary data
5	**Multi transfer merged data**	1A	Binary data
6		1C	Pedestal, MIPs and Observation Science Packets
7		**1B**	**Binary data**
8		**1F**	**Raw data (ADC hits, HC data), ROOT format**
9		**2A**	**Reconstructed data (calibrated energies, hits, tracks, etc.)**
10		1D	Pedestal, MIPs and Observation Science Packets
11		1Q	BGO calibration data and plots
12	Calibration	CAL	Calibration constants
13	Configuration	Config	Job options used for data processing
14	Position information	EE	Satellite position (longitude, altitude, X, Y, Z), speed (Vx, Vy, Vz)
15		EF	Test position data
16	Orbit simulation information	OA	Orbit information 16h-00h of the previous day
17		OI	Orbit information 00h-08h of the current day
18		OL	Orbit information 00h-08h of the previous day
19	----	Productlist	Empty
20	----	Sub	Empty
21	----	TE	Satellite test data
22	----	TM	Documentation