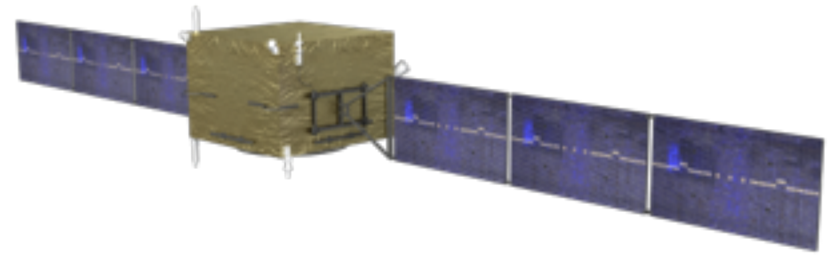

Reconstruction Software of the Silicon Tracker of DAMPE

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University of Geneva

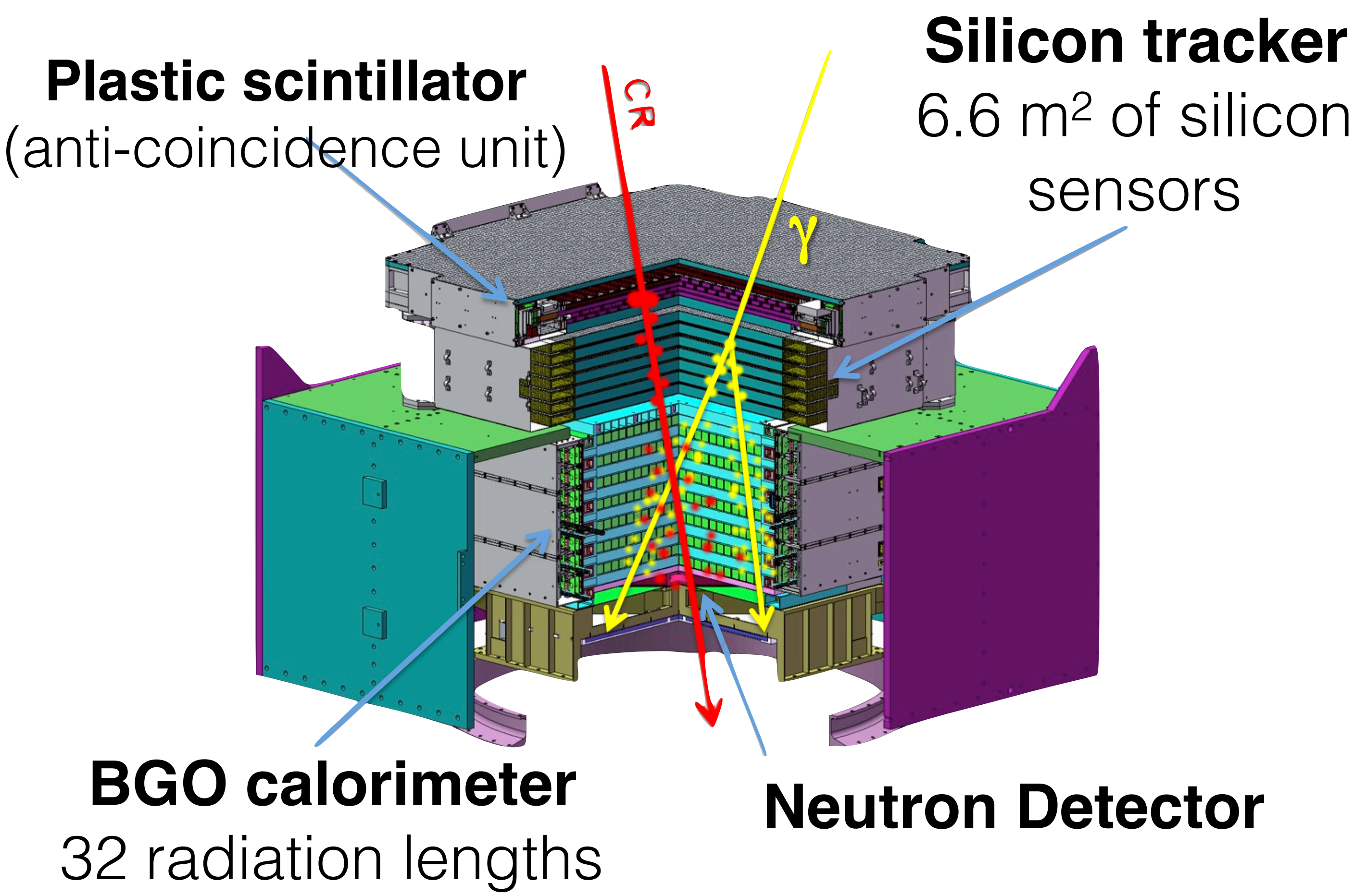
CHEP2016, San-Francisco,10-14 October 2016

Outline

- Introduction: DAMPE mission
- Track reconstruction software: combined-2D vs 3D
- Implementation of detector geometry: CAD-2-GDML
- Alignment of tracker: method of *varying*-χ^2

DAMPE mission

DAMPE is designed to detect
5 GeV to 10 TeV e/γ
50 GeV -100 TeV protons and nuclei
with excellent energy resolution, tracking precision and particle identification capabilities



DAMPE successfully launched on December 17, 2015

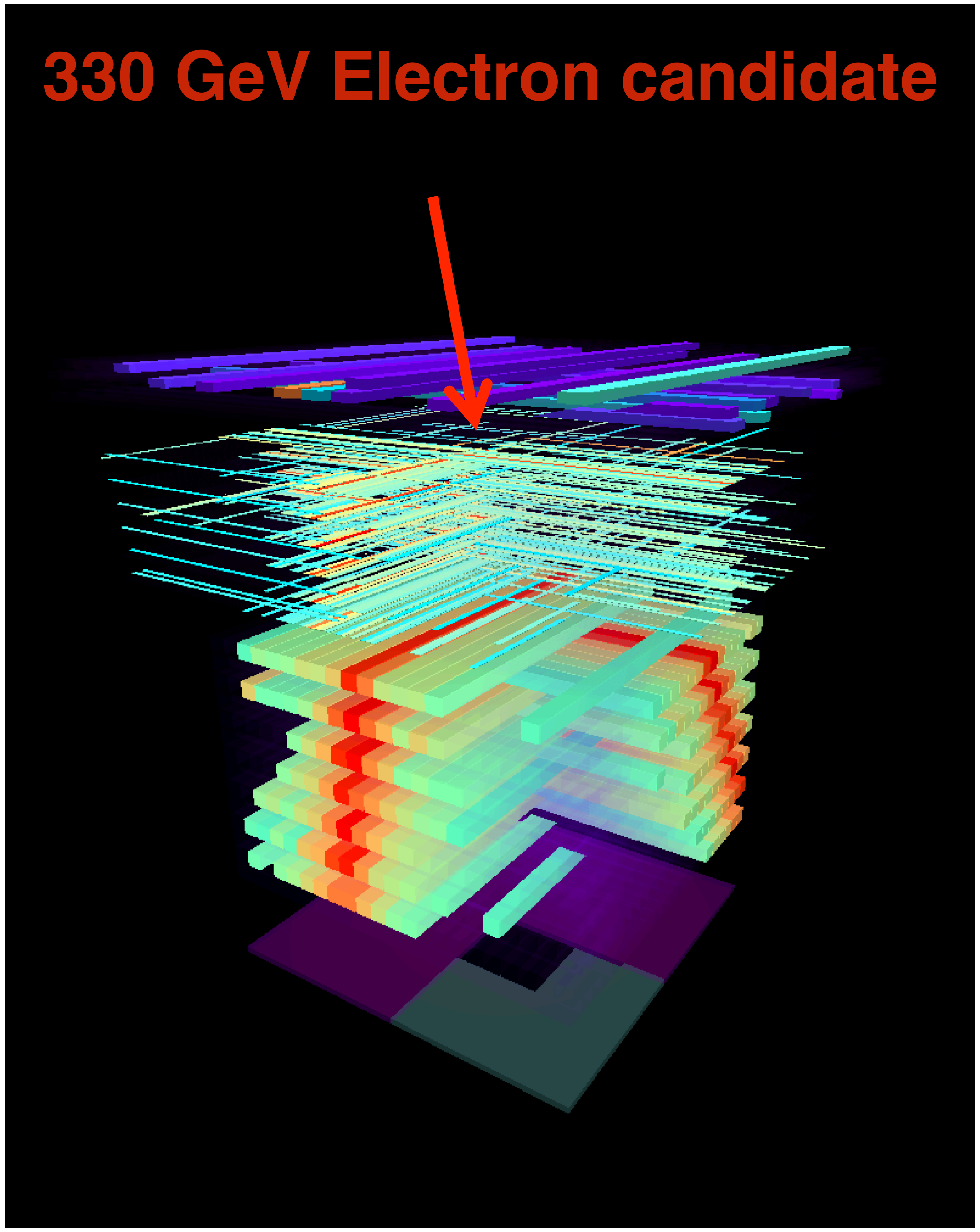
DAMPE → WUKONG

Jiuquan Satellite Launch Center
Gobi desert, China

Particle track reconstruction in DAMPE

Steps of the track reconstruction

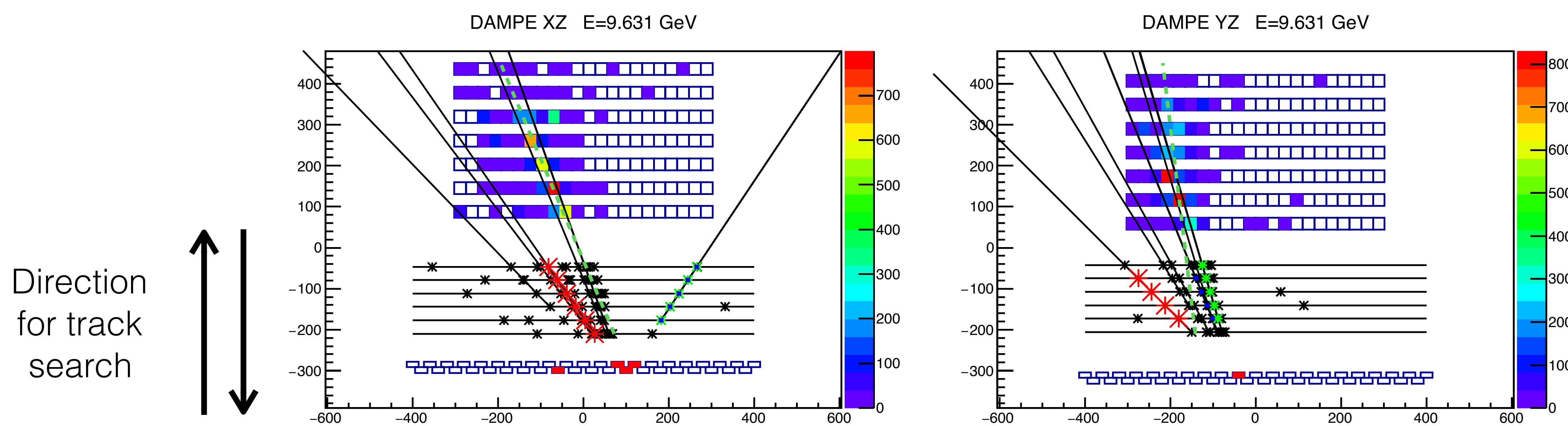
- Seeding
- Propagation (Kalman filter)
- Removal of ghost and duplicates



Particle track reconstruction in DAMPE

- **Track seeds**:
  1. Direction from calorimeter (Calorimeter-seed) - baseline
  2. Blind seeds (on-ground tests only)

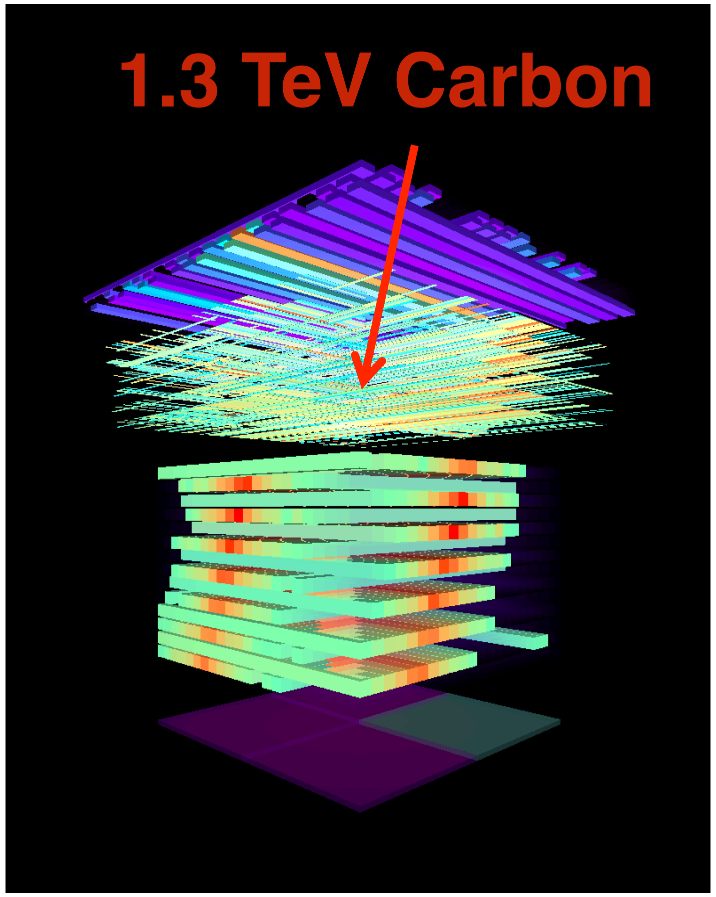
- **Calorimeter seed**:
  - *x* and *y* track candidates are reconstructed separately (Kalman filter)
  - Combined *xy* tracks are refitted again with Kalman algorithm

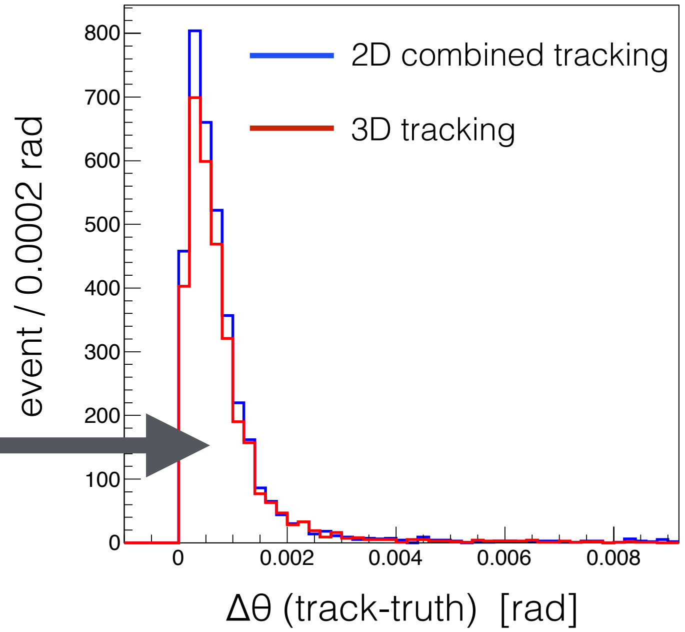


Particle track reconstruction in DAMPE

- Iterative track reconstruction:
  - If a good track is found - first hit in is removed from “seeding points”
  - Track-finding repeated until all seeding points are exhausted
- Reconstructing tracks in XZ and YZ is **O(100) faster** than 3D reconstruction
  - Allows to remove per-event limit of maximum number of iterations

10 % higher efficiency in finding the best possible track in event





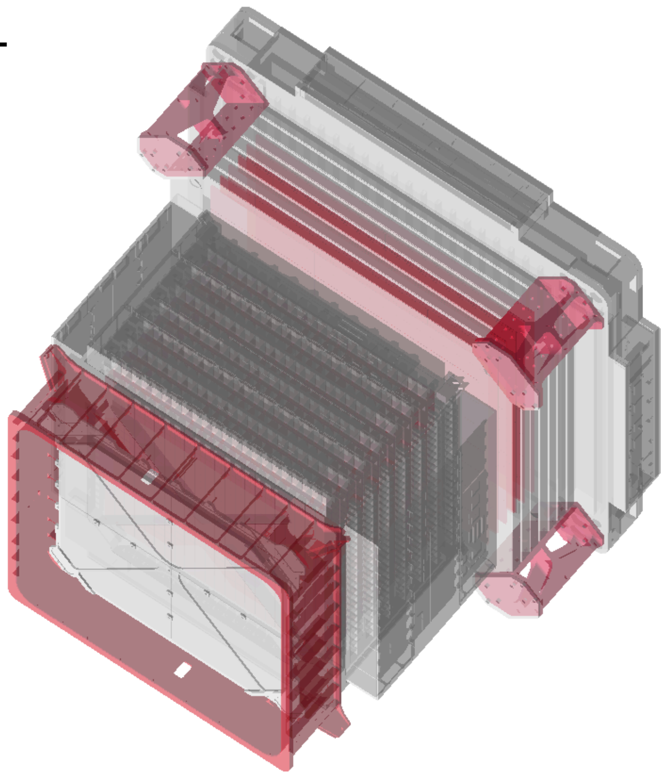
DAMPE geometry implementation: CAD-2-GDML

- GEANT4 geometry model of DAMPE is obtained as GDML from CAD drawings using an in-house conversion tool:

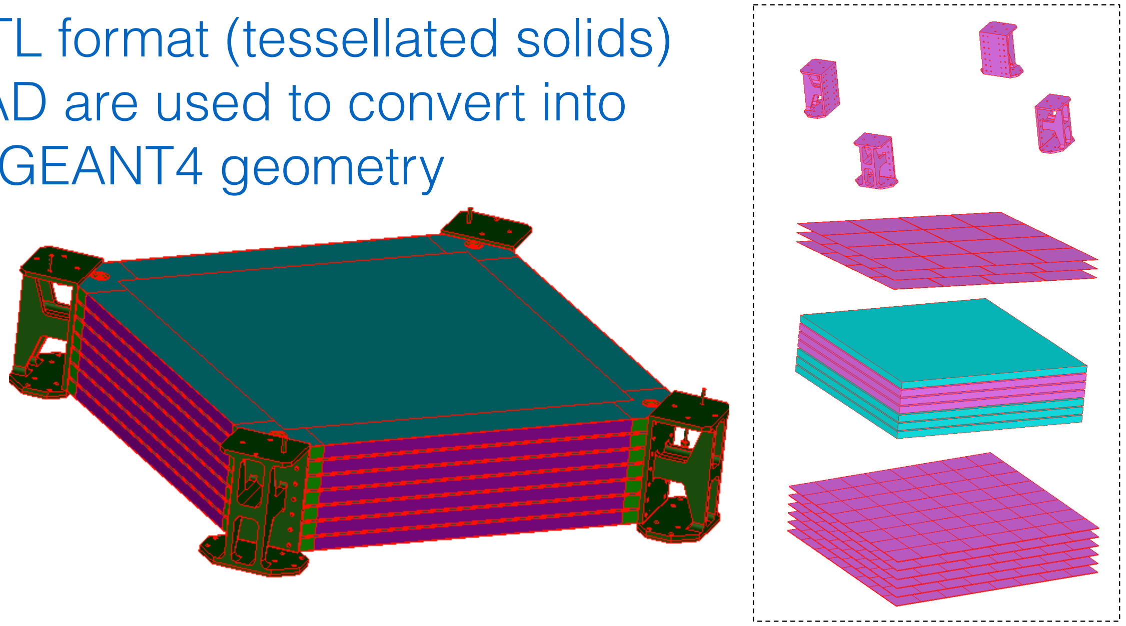
  https://github.com/tihonav/cad-to-geant4-converter

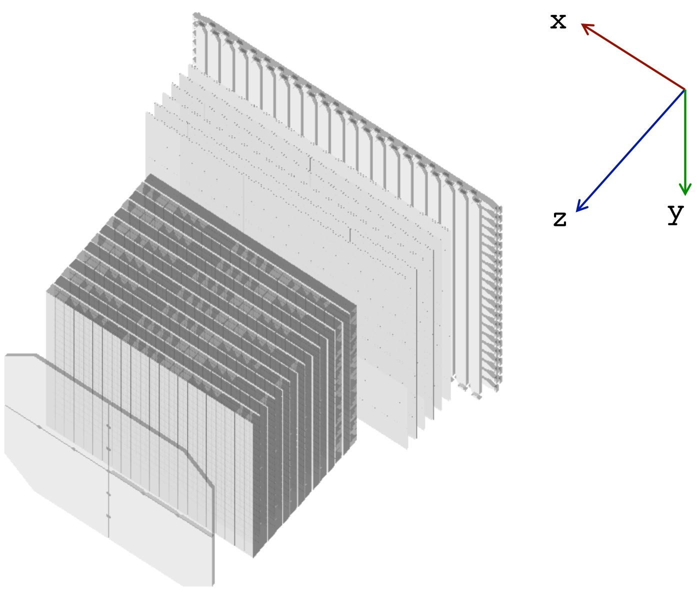
- The same GDML geometry is used in the reconstruction

- Supporting structures are included



Files in STL format (tessellated solids) from CAD are used to convert into GEANT4 geometry

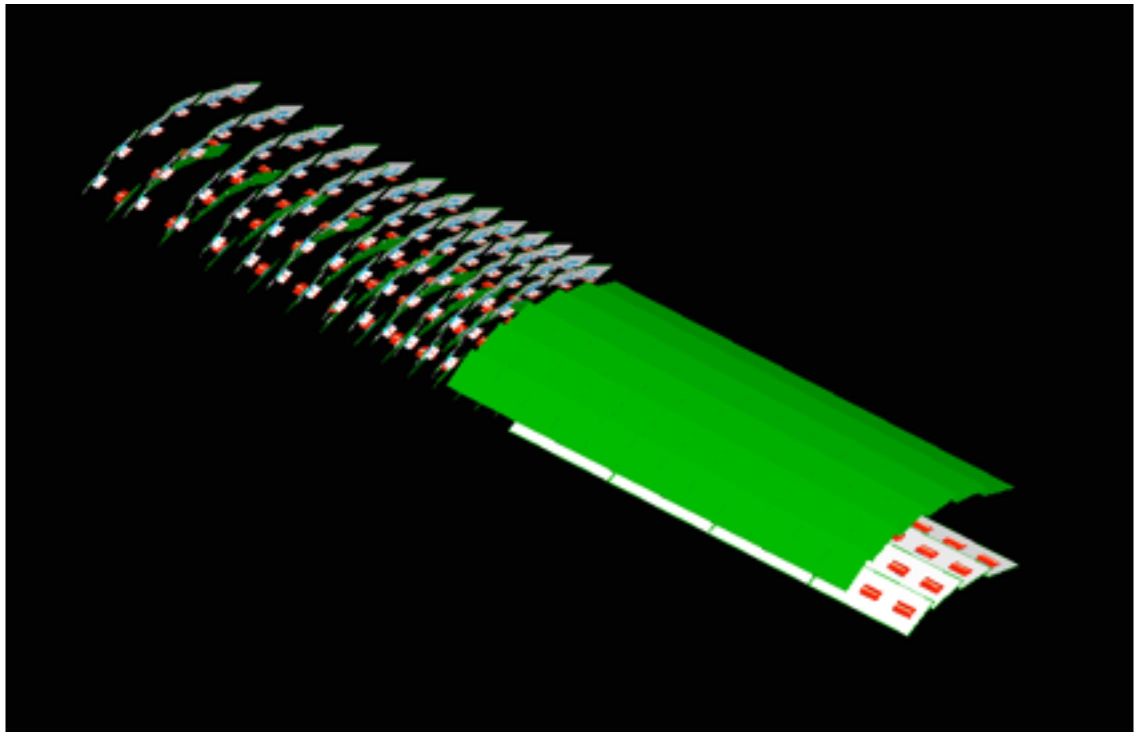




CAD-2-GDML converter

https://github.com/tihonav/cad-to-geant4-converter

- A standalone python tool
- Does not require GEANT4 or any other additional software
- Based on conversion of CAD into meshed (tessellated) objects
- Base set of materials implemented, should be easy to extend further



… possible application for ATLAS IBL is now being investigated, in particular could aid simulations used for B-tagging

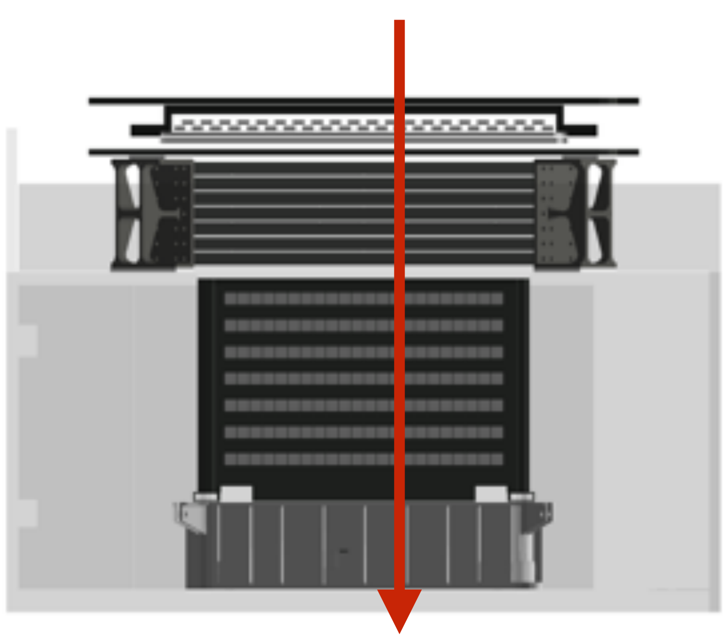
CAD-2-GDML: performance tests

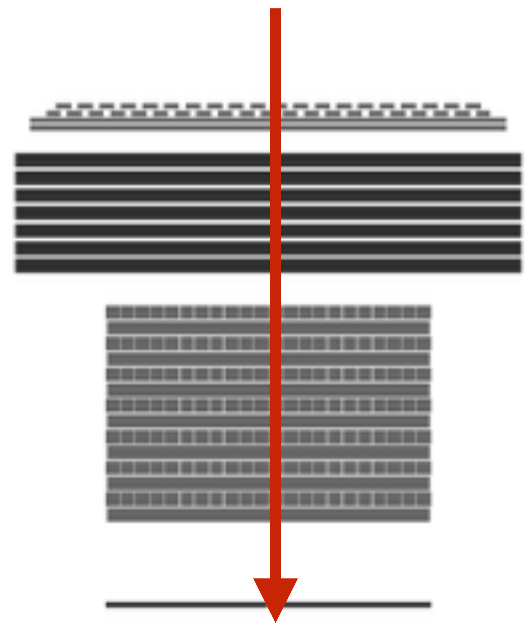
DAMPE GDML geometry:

- ~ 50 MB total
- ~ 150k vertices

	Tessellated [s/event]	Simple Geometry [s/event]	Factor
Protons:			
1-10 GeV	0.47	0.085	**5.5**
10-100 GeV	2.6	0.61	**4.2**
10-1000 GeV	24.9	4.8	**5.2**
Electrons:			
1-10 GeV	1.21	0.14	**8.7**
10-100 GeV	8.9	1.16	**7.7**
10-1000 GeV	88.9	13.22	**6.7**

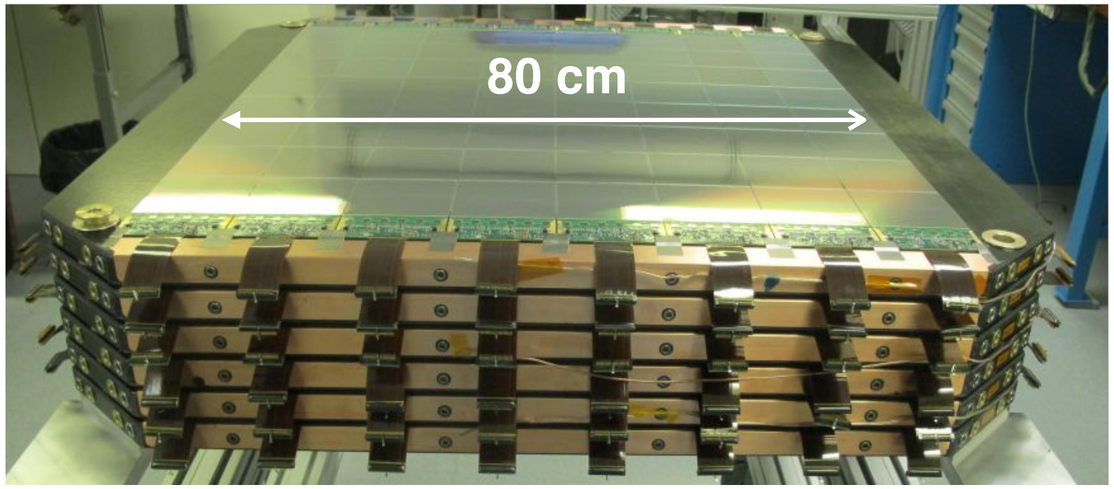
Tessellated geometry - baseline, includes supporting structures





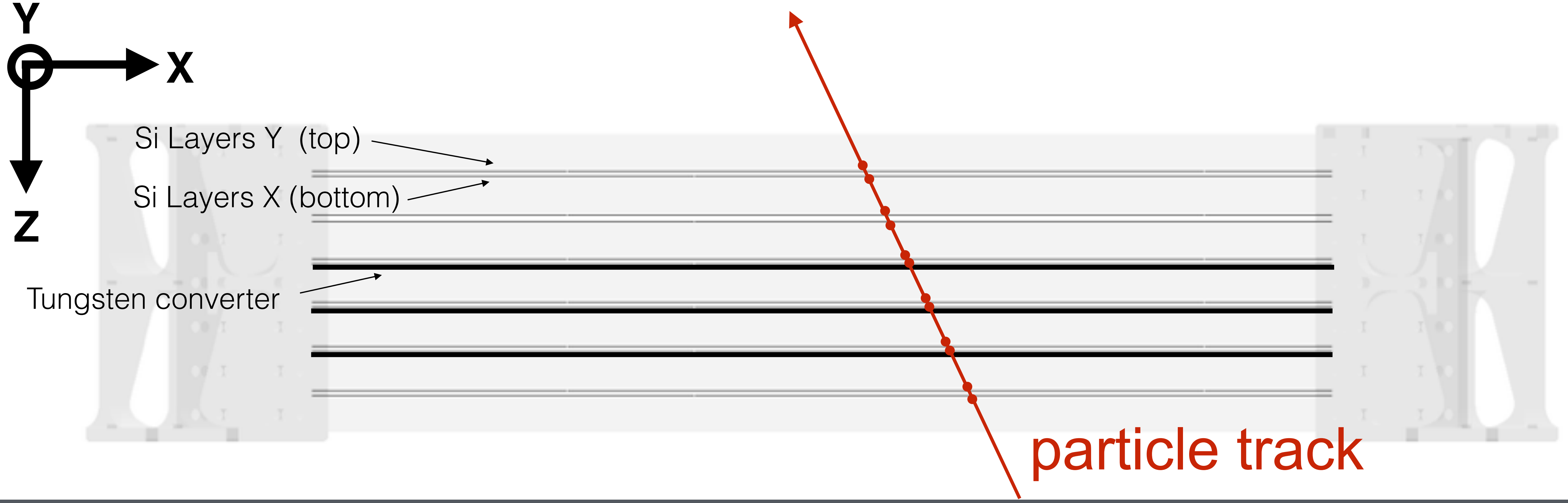
For comparison, simple geometry was used - only sensitive volumes (defined as simple boxes)

Silicon Tracker of DAMPE



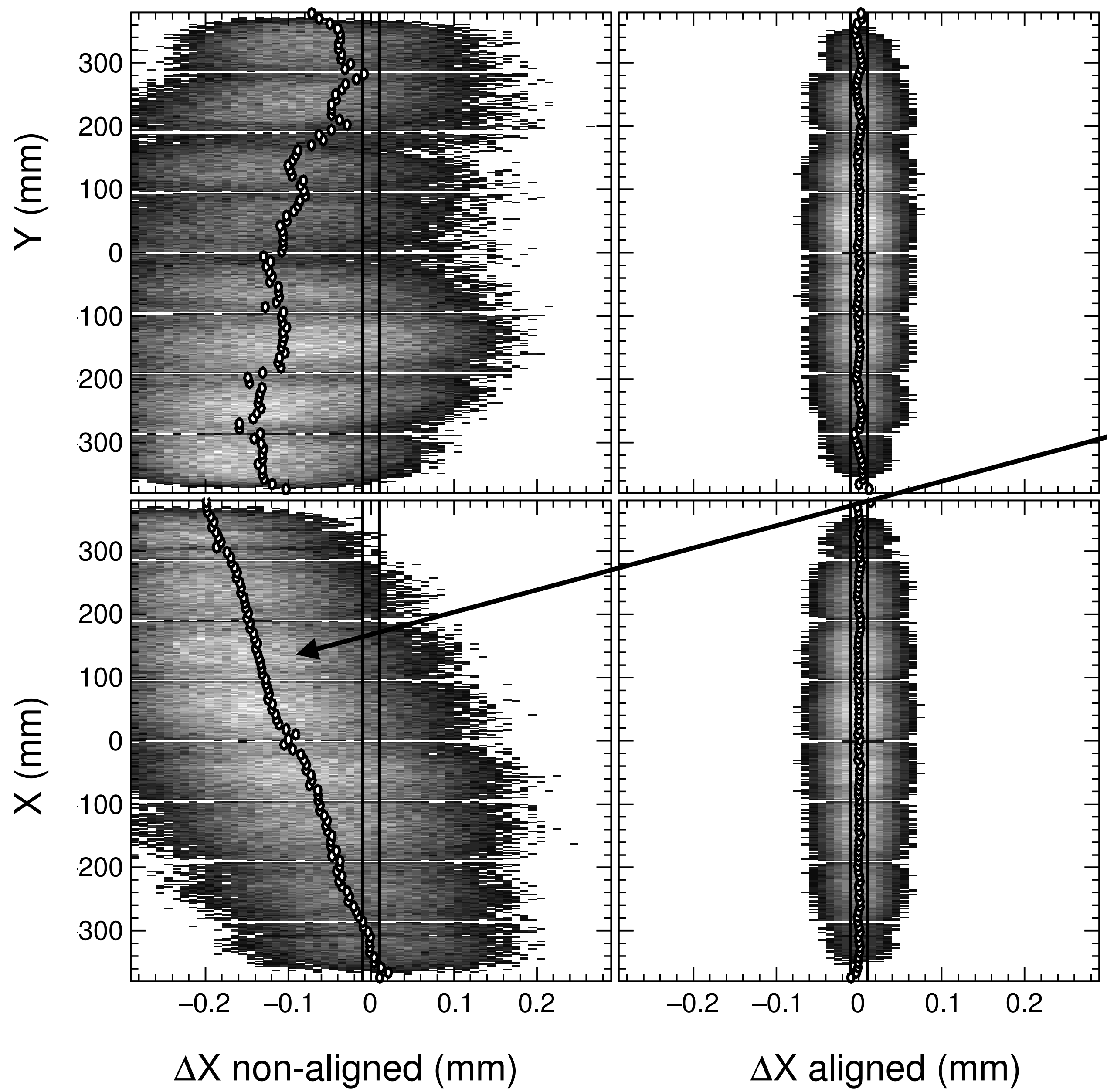
Tracker:

- 6 tracking double layers (x and y measurement)
- 768 total silicon sensors (SSD), 9.5 x 9.5 cm
- 121 μm silicon-strip pitch
- Every 2nd strip is read-out
- Total active area ~ 6.6 m^2
- **Excepted position resolution: ~40 micron**



Alignment of DAMPE Silicon Tracker

Track-hit residue VS track coordinate for one of the STK layers:



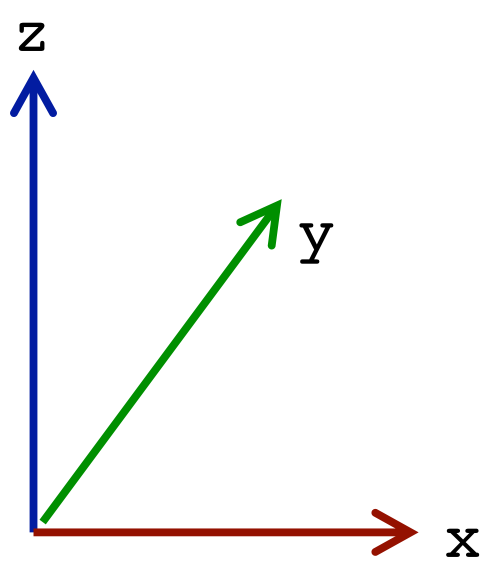
Position resolution of silicon sensors ~ 40 μm

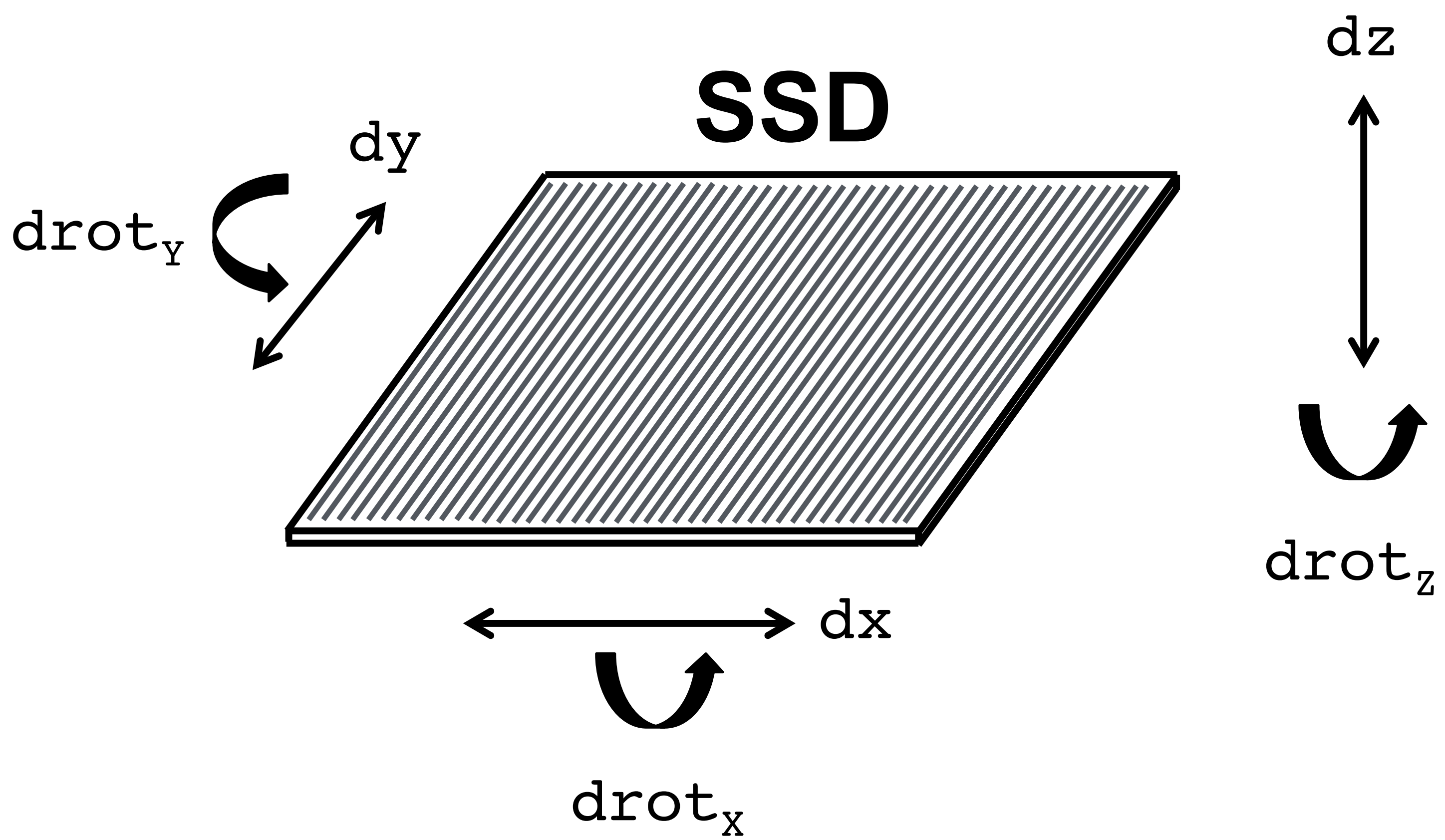
Assembly precision ~ 100 μm

Precise alignment is crucial in order to fully exploit angular resolution of the instrument

Alignment of DAMPE Silicon Tracker: method

- 5 (2 offsets, 3 rotations) alignment parameters assigned to each silicon sensor = 768 * 5 = <u>3840 alignment parameters</u>





Alignment of DAMPE Silicon Tracker: method

Aligned track coordinates *Non-aligned track coordinates*

$$x_a = x + \underline{\Delta x} - y \cdot \underline{\theta_z}$$

$$y_a = y + \underline{\Delta y} + x \cdot \underline{\theta_z}$$

$$z_a = z + \underline{\Delta z} - x \cdot \underline{\theta_y} + y \cdot \underline{\theta_x}$$

Alignment parameters

Alignment is based on minimisation of χ^2 of tracks in the alignment data sample:

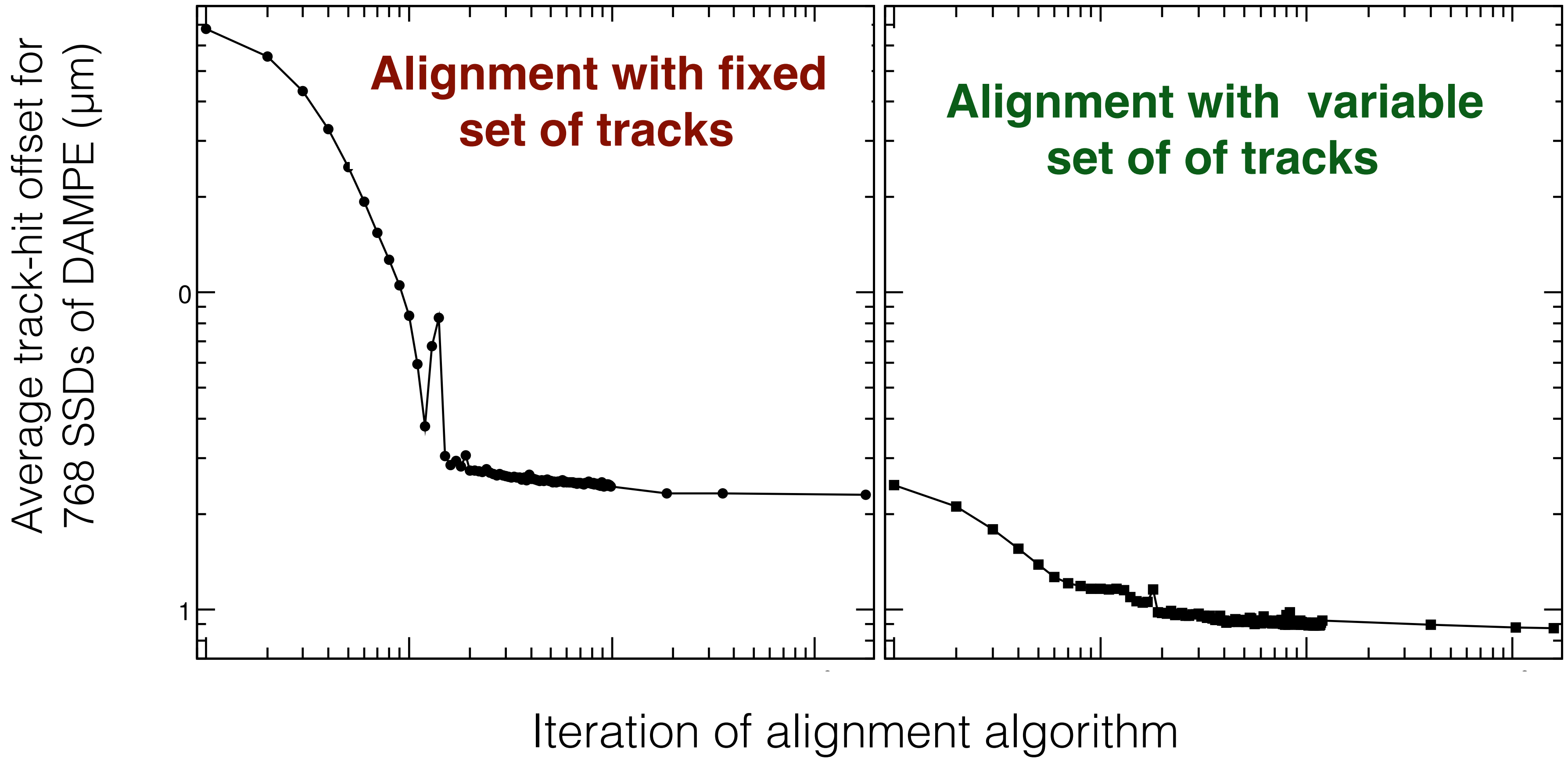
$$\chi^2 = \sum_{t \in \{tracks\}} \left(\sum_{p \in \{points\}} \frac{\left(x_{t,p}^{fit} - x_{t,p}^{hit}\right)^2}{N_{xtracks,s}} + \sum_{p \in \{points\}} \frac{\left(y_{t,p}^{fit} - y_{t,p}^{hit}\right)^2}{N_{ytracks,s}} \right),$$

$$s = \text{sensor}|\text{id}(t, p)$$

Alignment of DAMPE Silicon Tracker: method

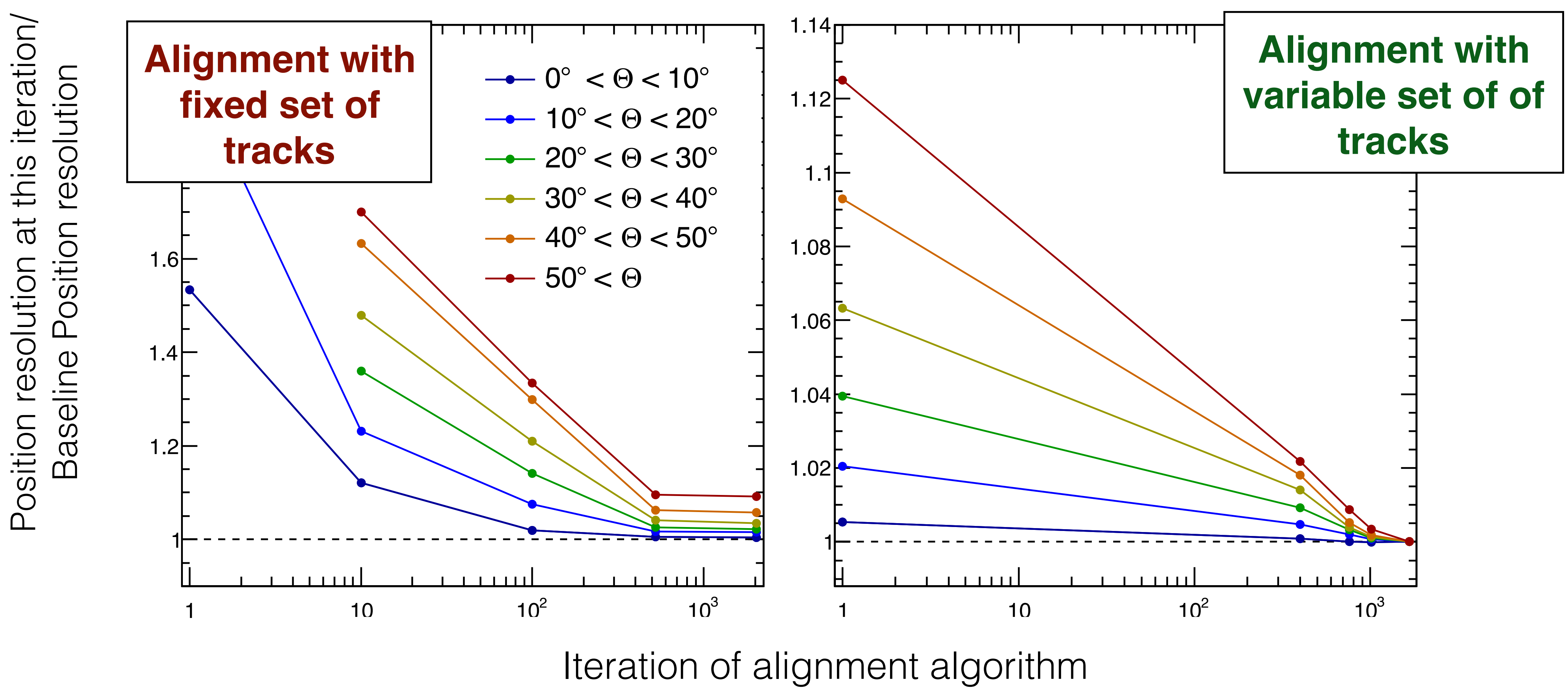
- χ^2 is affected by the noise (mis-reconstructed track hits, multiple scattering) - imposes limitations on precision of alignment

- To reduce noise contribution to χ^2, at each iteration of algorithm, we use only those tracks that pass residue cuts for the hits - this implies that χ^2 evaluation sample changes from one iteration to another



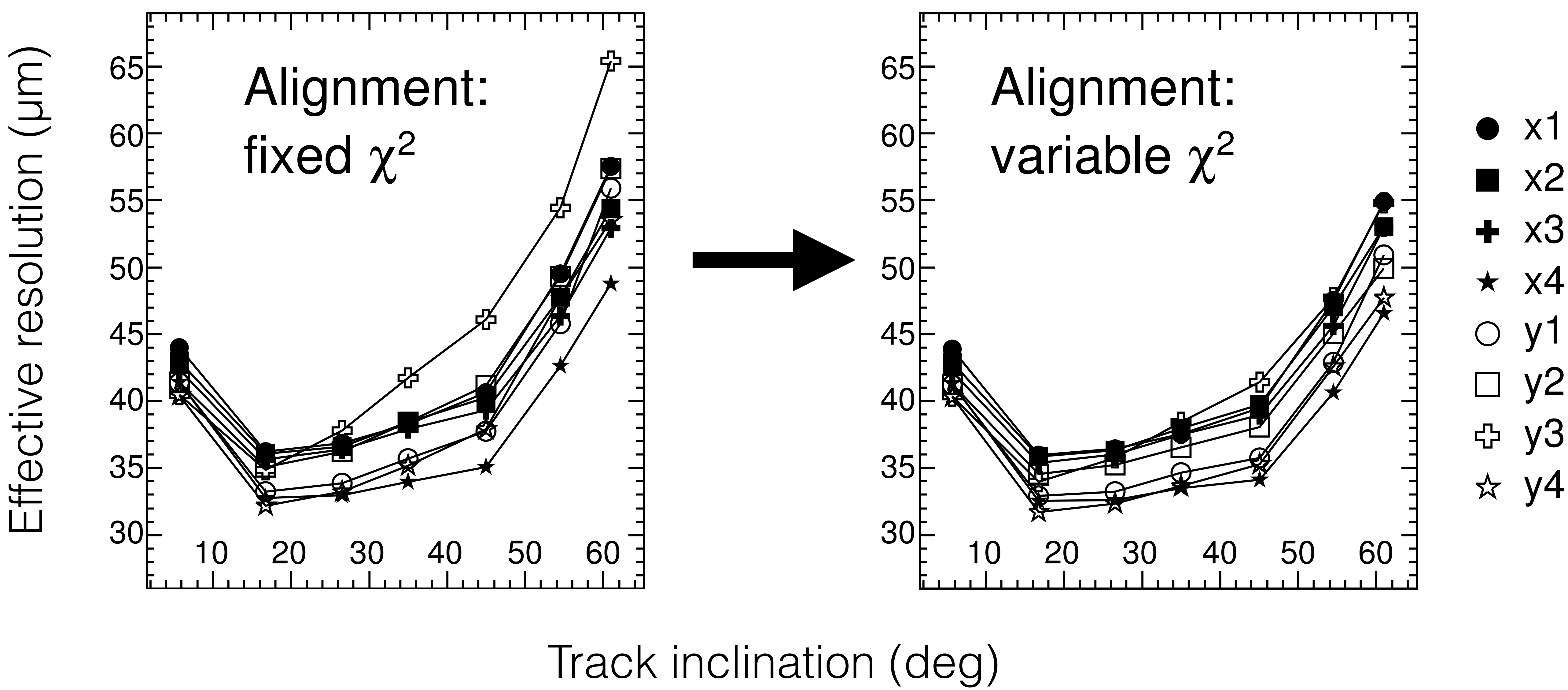
Alignment of DAMPE Silicon Tracker: method

- Optimisation of χ^2 is not a merely minimisation any more (in some iteration χ^2 can also increase)
- Instead, optimisation is performed by moving in a phase space of alignment parameters in the direction opposite to derivatives vector, until the modulus of this vector become small enough



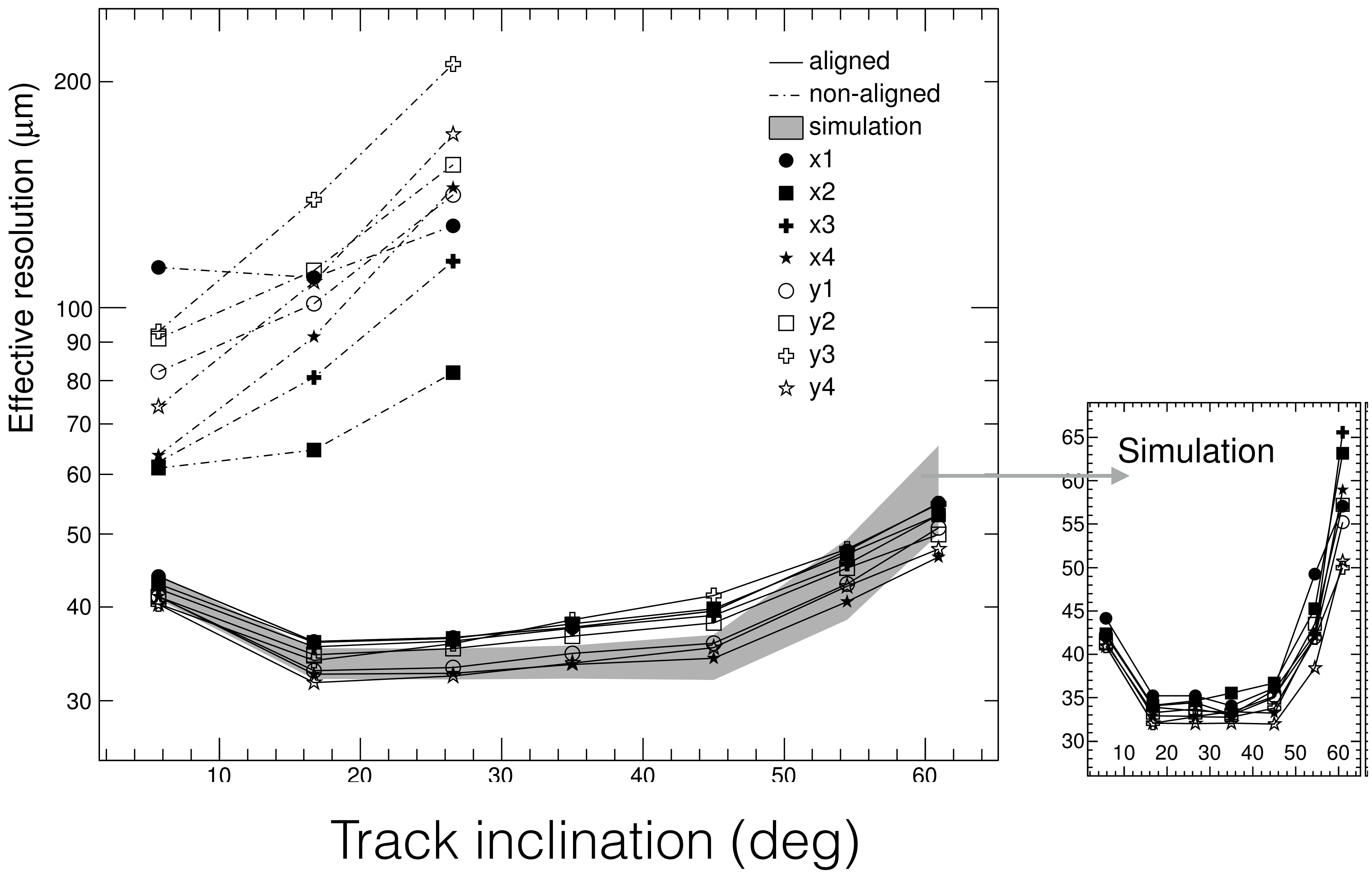
Alignment of DAMPE Silicon Tracker: results

The method of varying-χ^2 improves quality of alignment and as a result - position resolution



Alignment of DAMPE Silicon Tracker: results

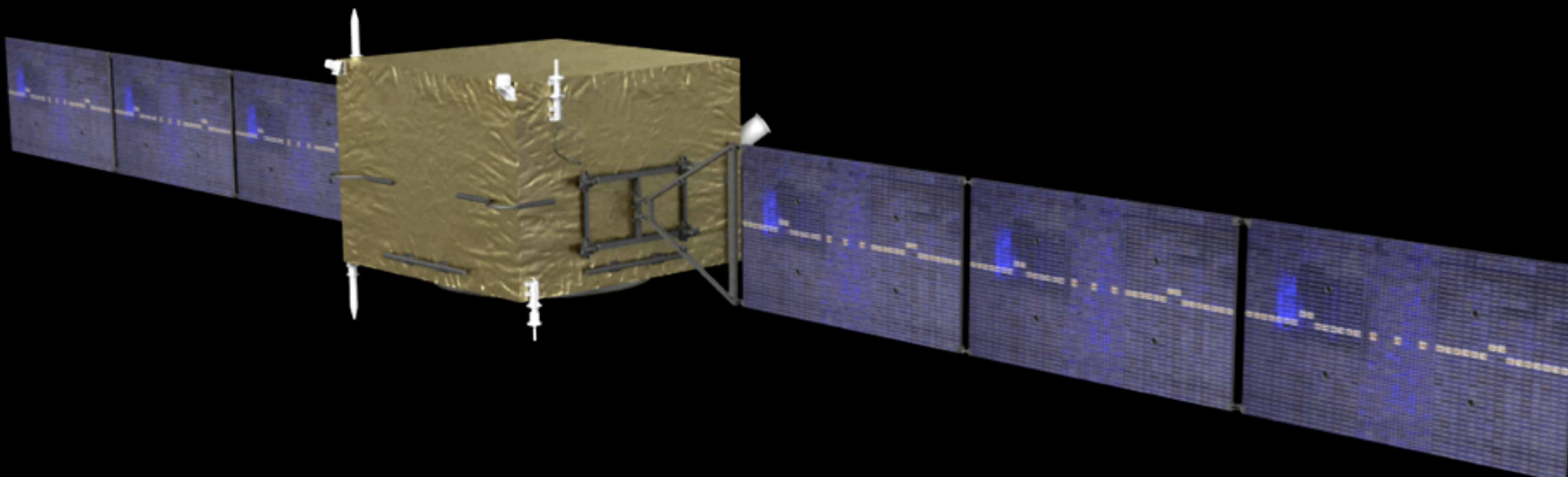
Good agreement is achieved between position resolution in the aligned and ideal (Simulation) model



Summary & Conclusions

- DAMPE is powerful high-energy particle detector satellite mission, successfully launched in the end of 2015
- Tracking detector consist of about 6.6 m^2 of silicon-strip sensors.
- Track finding is done separately in XZ and YZ with Kalman filter, then tracks are combined in 3D and Kalman-refitted again.
- Geometry of the detector is implemented through CAD-2-GDML converter; the same geometry is used in both simulation and reconstruction.
- Alignment of tracker is done using the technique which employs varying X^2 sample, outperforming the standard minimisation of X^2.

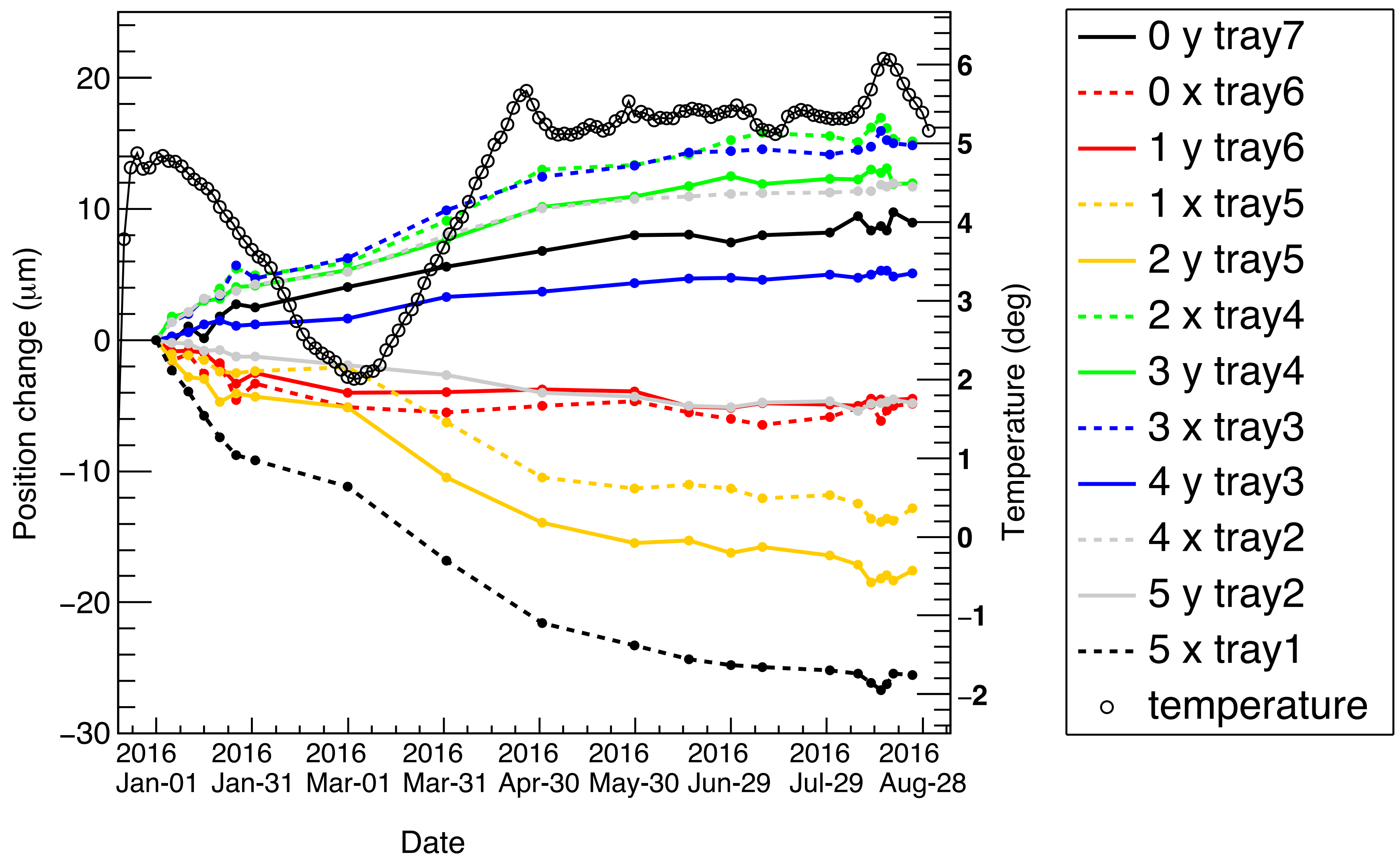
Thank you!



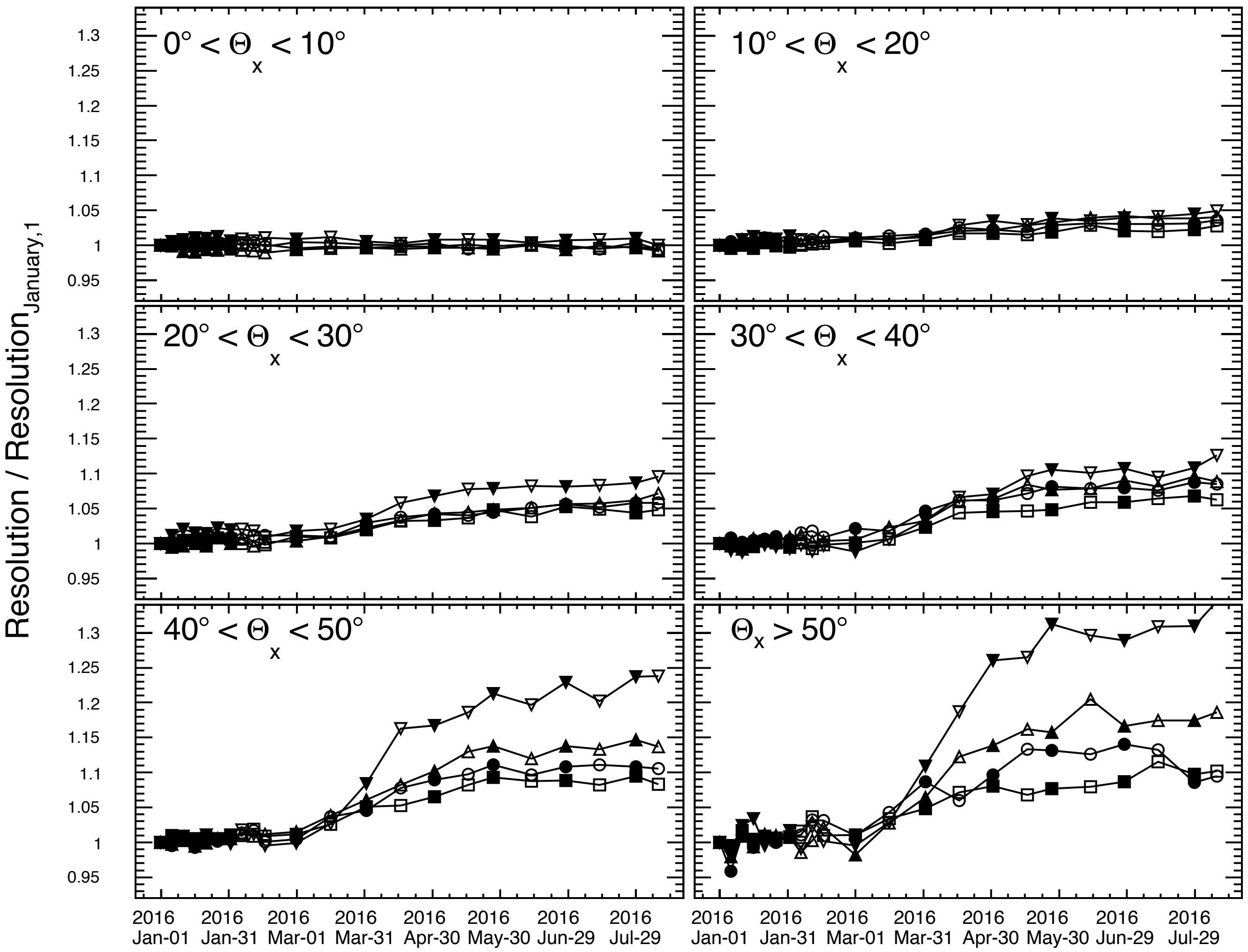
email: andrii.tykhonov@cern.ch

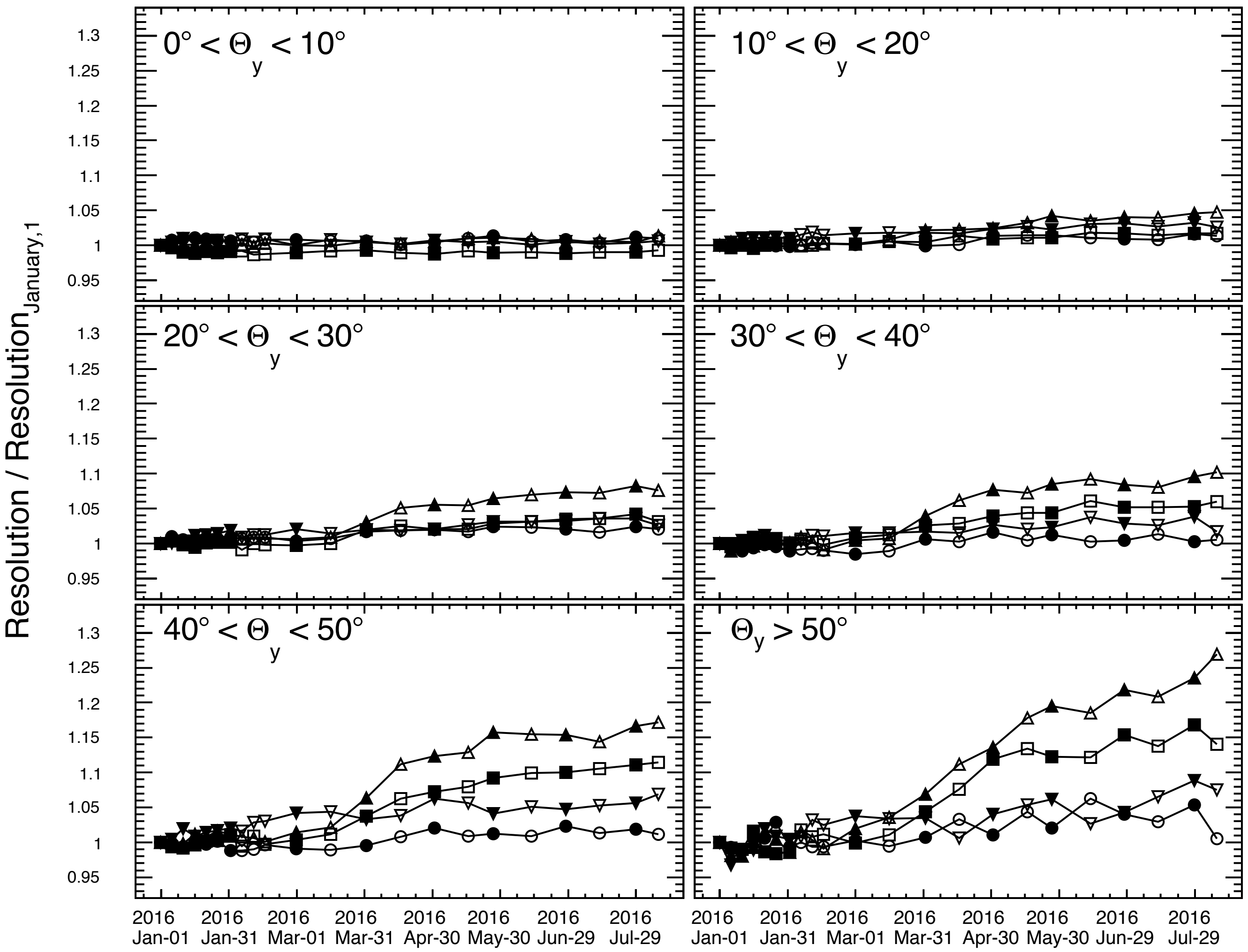
Spare slides

Alignment as a function of time

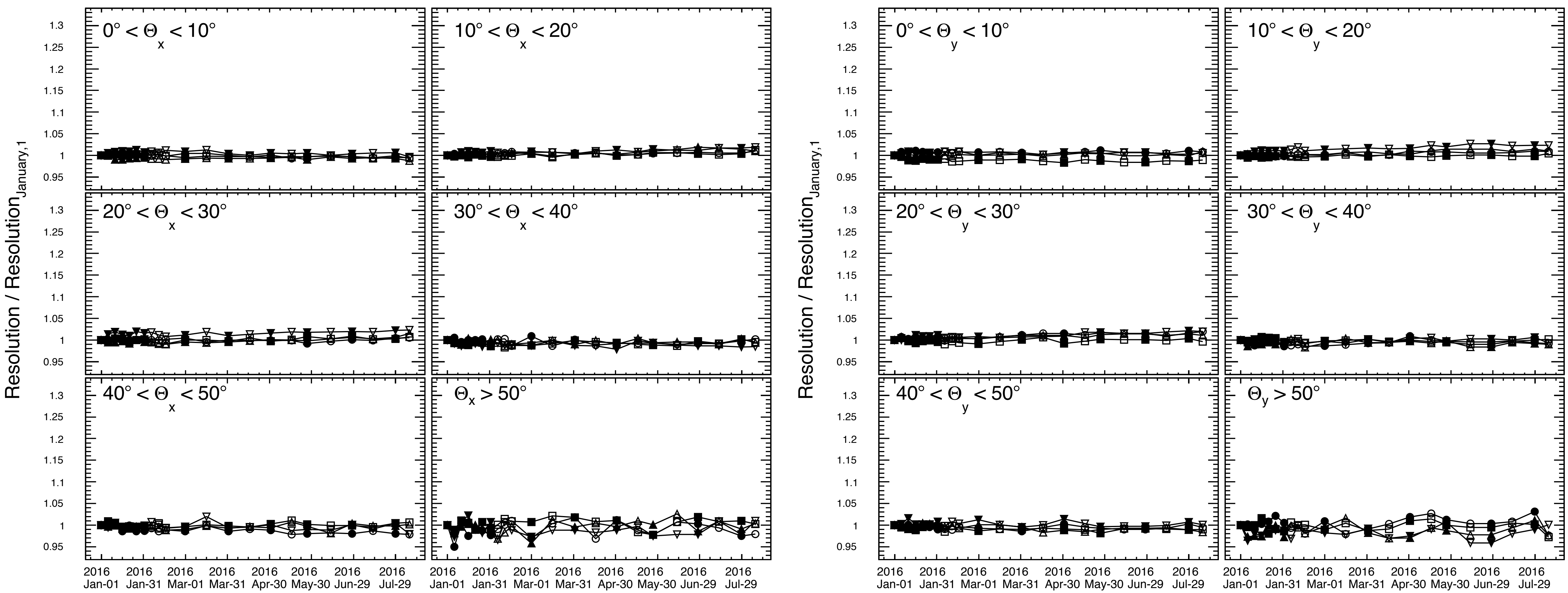


Change of position resolution (**fixed alignment**)

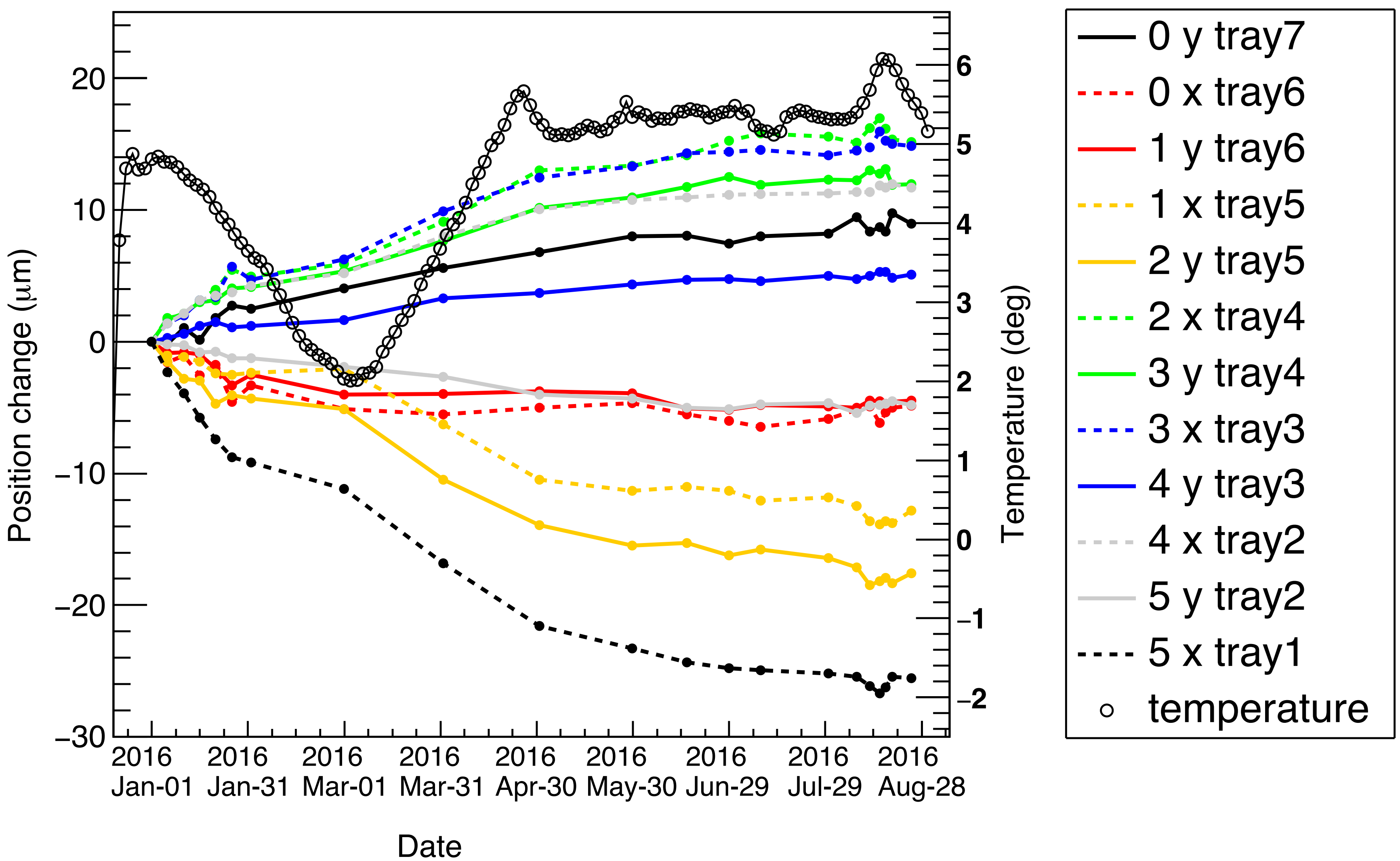




Change of position resolution (**realigned**)

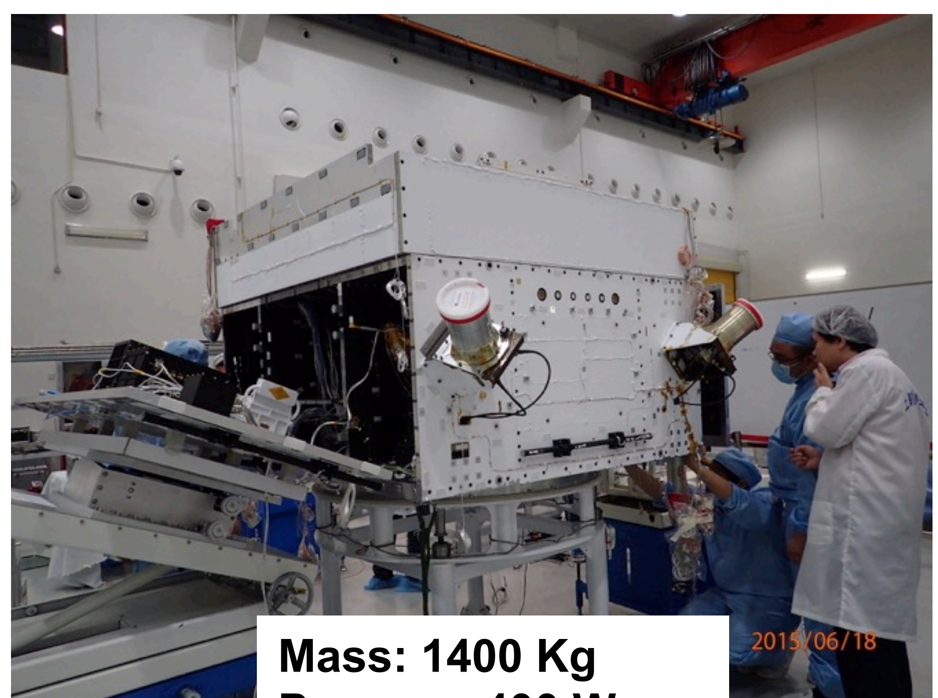


Alignment as a function of time



Comparison with AMS-02 and FERMI

	DAMPE	AMS-02	Fermi LAT
e/γ Energy res.@100 GeV (%)	**1.5**	3	10
e/γ Angular res.@100 GeV (°)	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

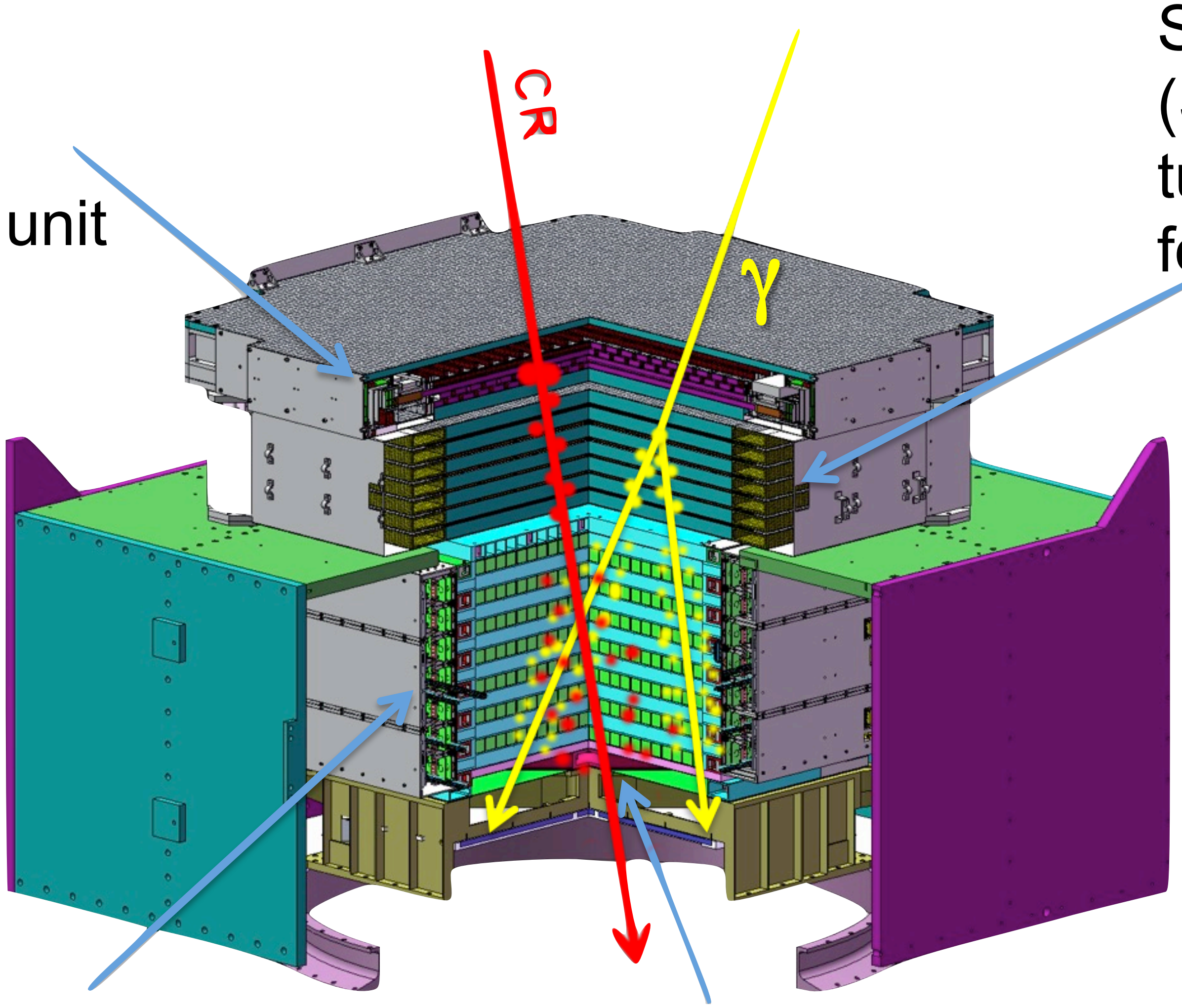


Mass: 1400 Kg
Power: ~ 400 W
Livetime: > 3 years

The DAMPE satellite

PSD: double layer of scintillating strip detector acting as anti-coincidence unit

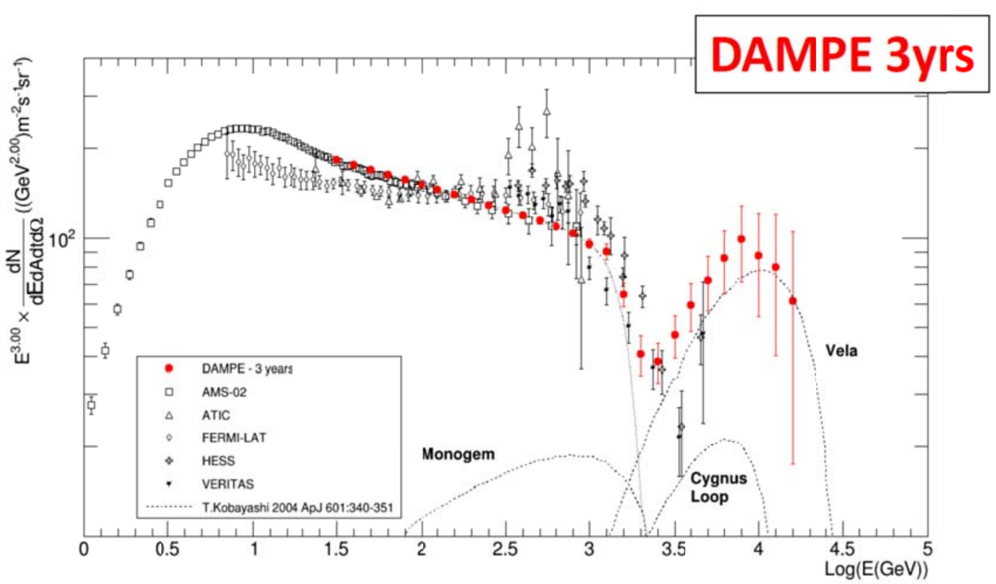
STK: 6 tracking double layers of Silicon-Strip Detectors (SSD) + 3 mm tungsten plates (used for photon conversion)



BGO: the calorimeter made of 308 Bismuth-Germanium-Oxide bars in hodoscopic arrangement (~32 radiation length). Performs both energy measurements and trigger

NUD: boron-doped plastic scintillator - complementary to the BGO by measuring the thermal neutron shower activity

The Physics Goals of the DAMPE mission



- Study of the cosmic electron and photon spectra
- Study of cosmic ray protons and nuclei: spectrum and composition
- High-energy gamma ray astronomy: AGN, Pulsars, GRBs, …
- Search for dark matter signatures in electron spectra