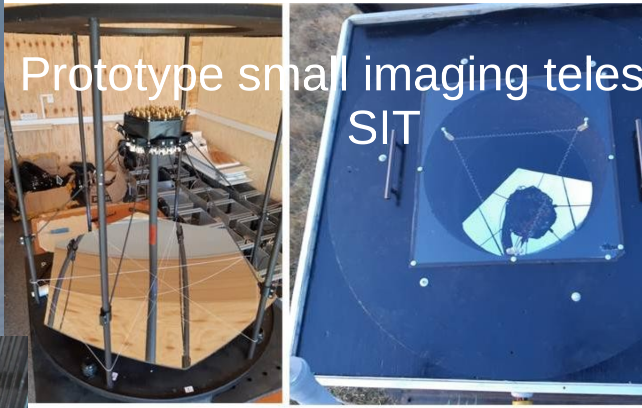
TAIGA Status and Results

Martin Tluczykont
For the TAIGA Collaboration
https://taiga-experiment.info

ISCRA, Moscow, June 2021

Tunka observatory site



- Very high energy Astrophysics under extreme conditions
- Proximity to BAIKAL ν Experiment
- Tunka valley, Republic Buryatia

Air Cherenkov arrays

Particle detectors

Optical Astronomy

(Radio air shower detection)

TAIGA

Tunka Advanced Instrument for cosmic ray and Gamma Ray Astronomy

Russia
MSU (SINP), Moscow
ISU (API), Irkutsk
INR RAS, Moscow
JINR, Dubna
MEPhI, Moscow
IZMIRAN, Moscow
BINR SB RAS, Novosibirsk
NSU, Novosibirsk
ASU, Barnaul

Germany
MPI, Munich
University of Hamburg (Iexp), Hamburg
DESY, Zeuthen

Italy
Torino University, Torino

Romania
ISS, Bucharest

The hybrid TAIGA Experiment

TAIGA-HiSCORE

Integrating air Cherenkov
Timing array
2020: 89 stations
2021: 120 stations

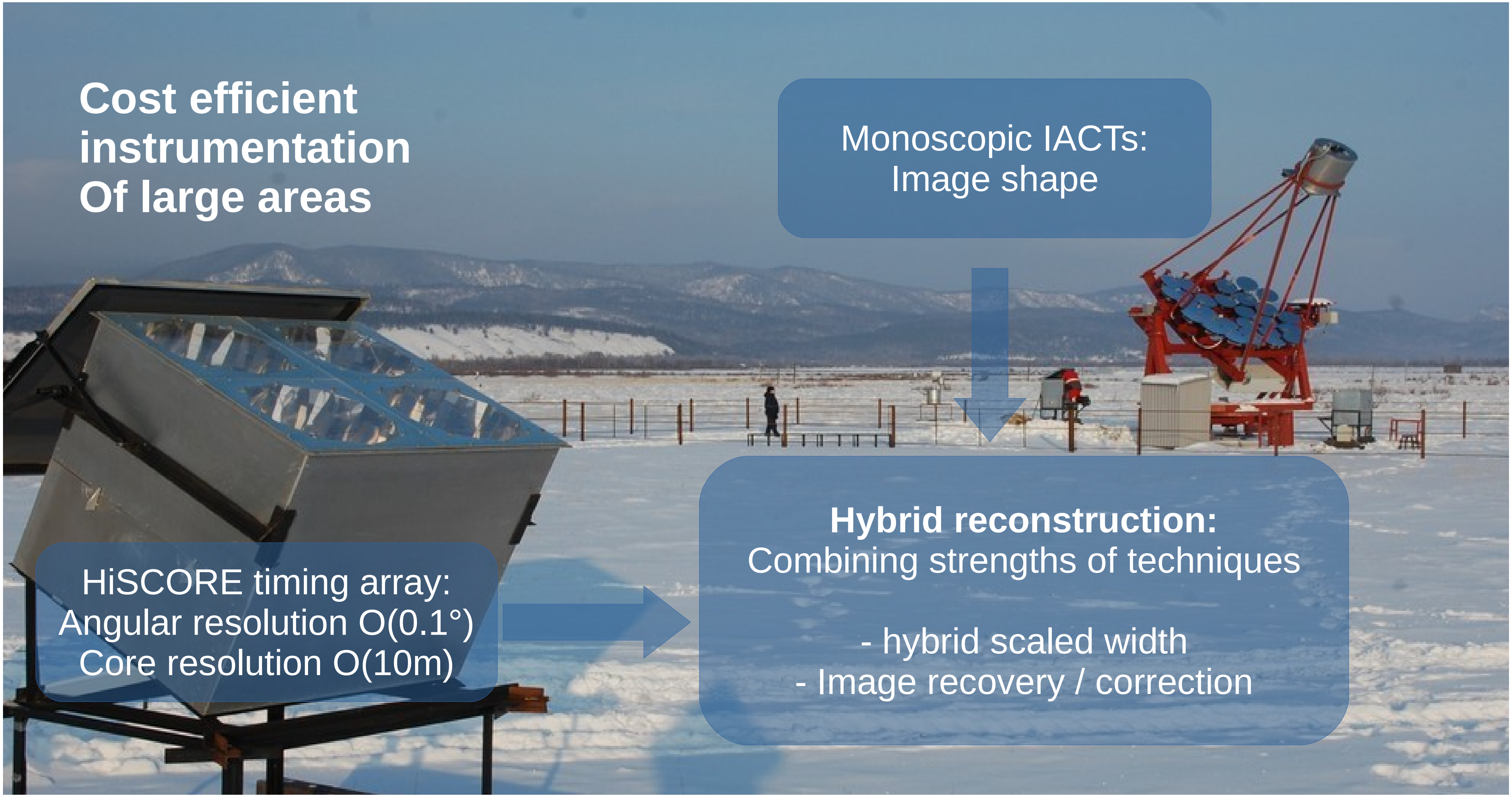
TAIGA-IACT

IACT-1: first results available
IACT-2: data taking started
IACT-3: in consturction

TAIGA-Muon

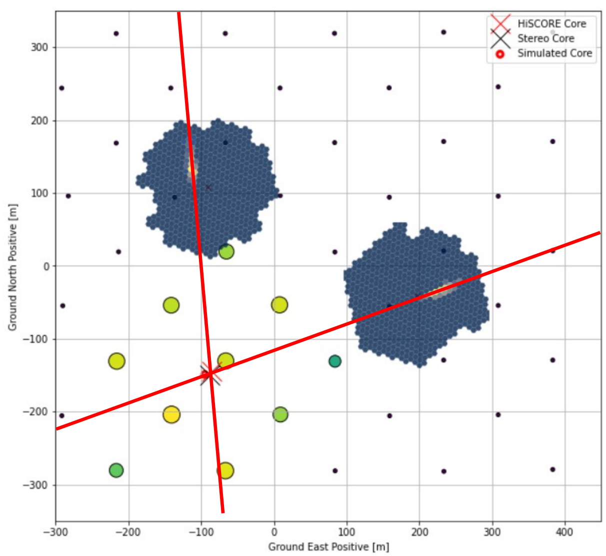
240 m² surface and
underground particle
detectors

Hybrid air Cherenkov approach

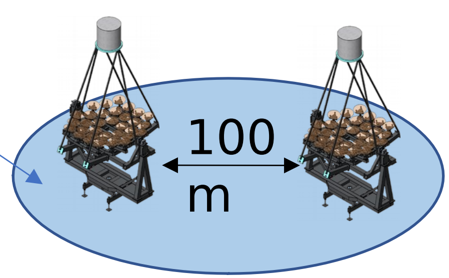


Hbrid reconstruction

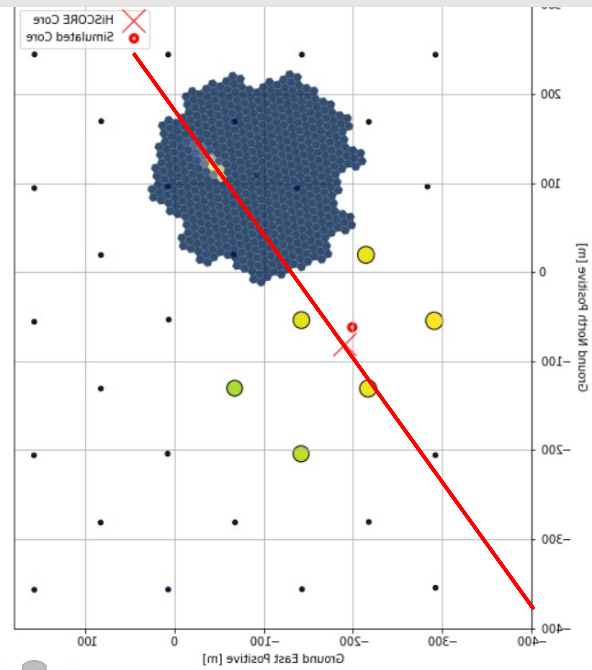
Stereo

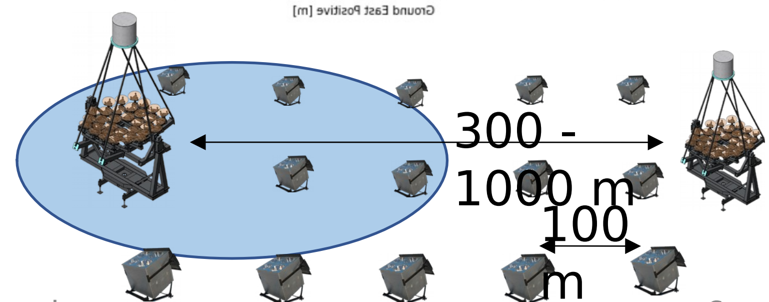


Light Pool



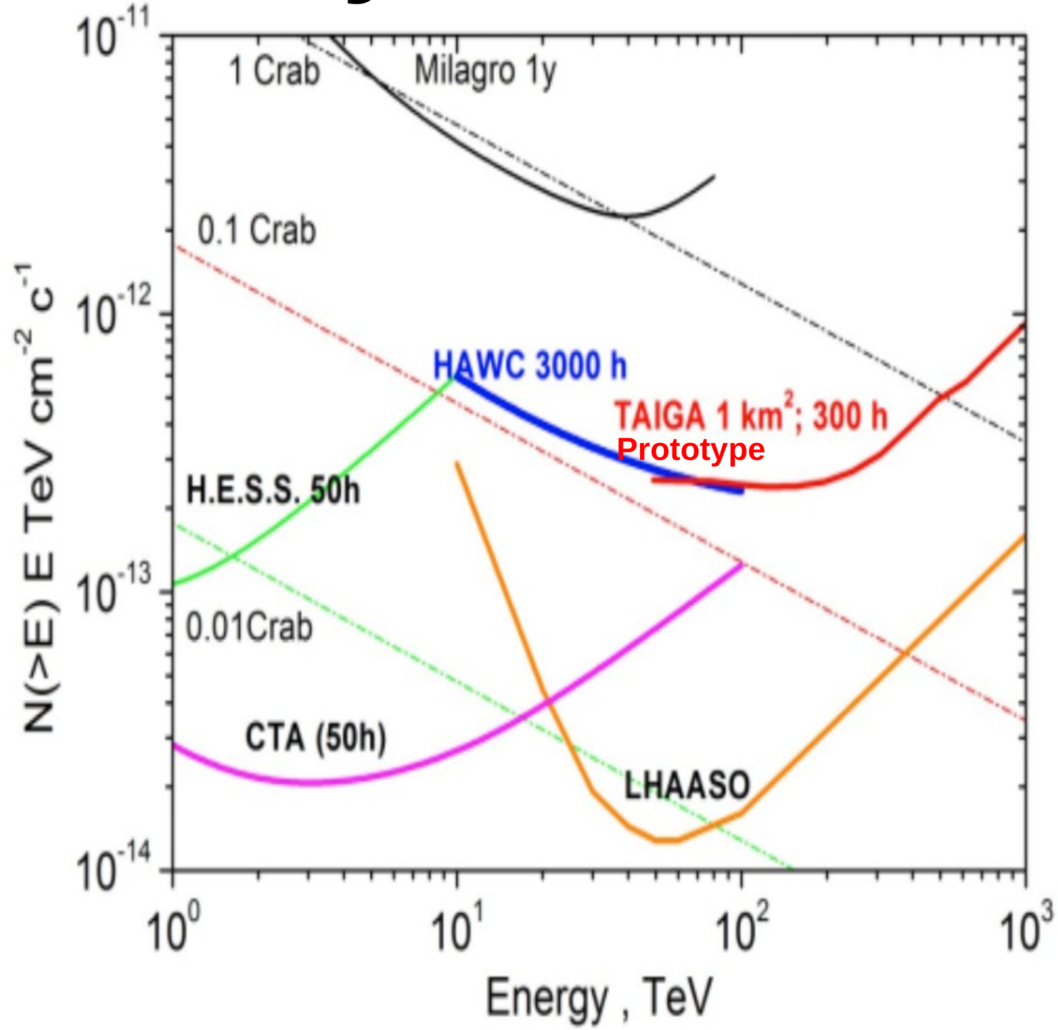
Hybrid imaging+timing





TAIGA Pilot complex Sensitivity

- Hybrid sensitivity estimate
  - 1km² HiSCORE
  - 3 IACTs
- Different FoV
  - HiSCORE ~60° diameter
  - IACTs ~9° diameter
- Key to **source identification morphology spectroscopy**:
  - Δθ 0.15° @O(TeV)
  - ΔE/E 15% @O(TeV)



Scientific goals of the TAIGA Pilot complex

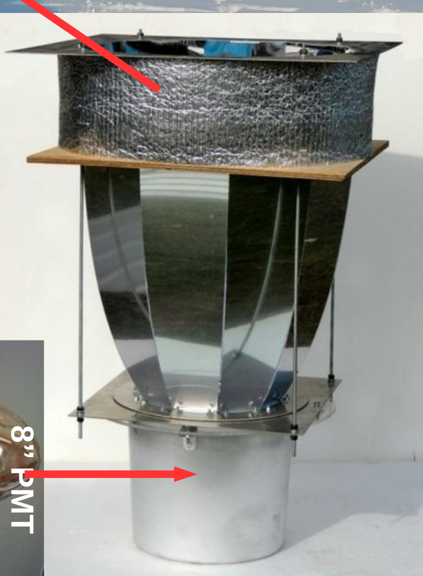
- Establish the new hybrid imaging and timing approach for gamma-ray and cosmic ray astrophysics
- **TeV-PeV gamma-ray spectroscopy**
  - Extend gamma ray spectra into 100 TeV range
  - Search for Galactic Pevatrons
    spectroscopy (15% resolution) of cutoff energy range
    morphological studies (0.1° angular resolution)
- Monitoring of bright extragalactic sources
- Fundamental physics
  - Heavy dark matter, axion search
  - Lorentz invariance violation

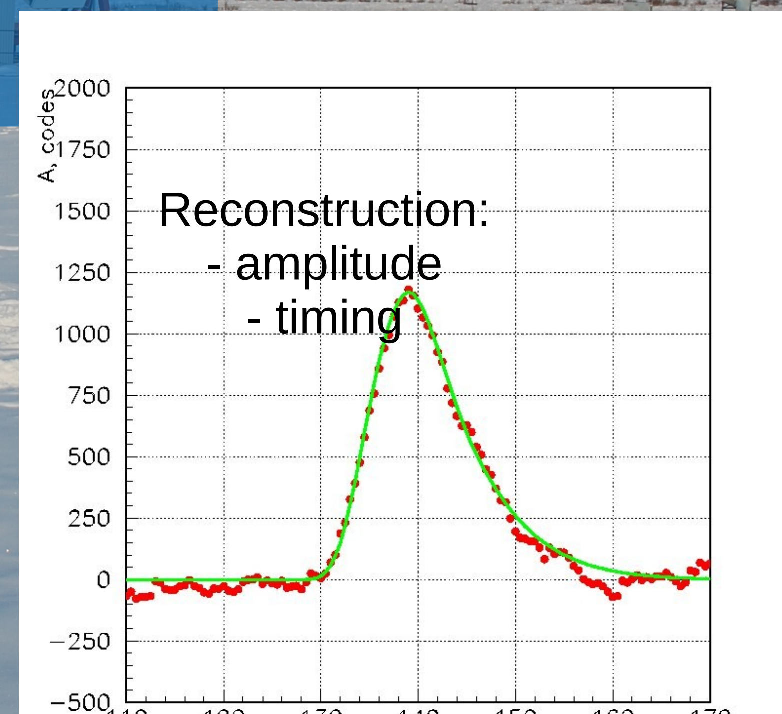
TAIGA-HiSCORE timing array

Also see A. Panov, this conference

TAIGA timing stations

- 0.5 m² light collection, FoV ~0.6 sr
- “Tilting” for extension of sky coverage
- **Sub-ns** array-wide time synchronization





0.5ns sampling, DRS4

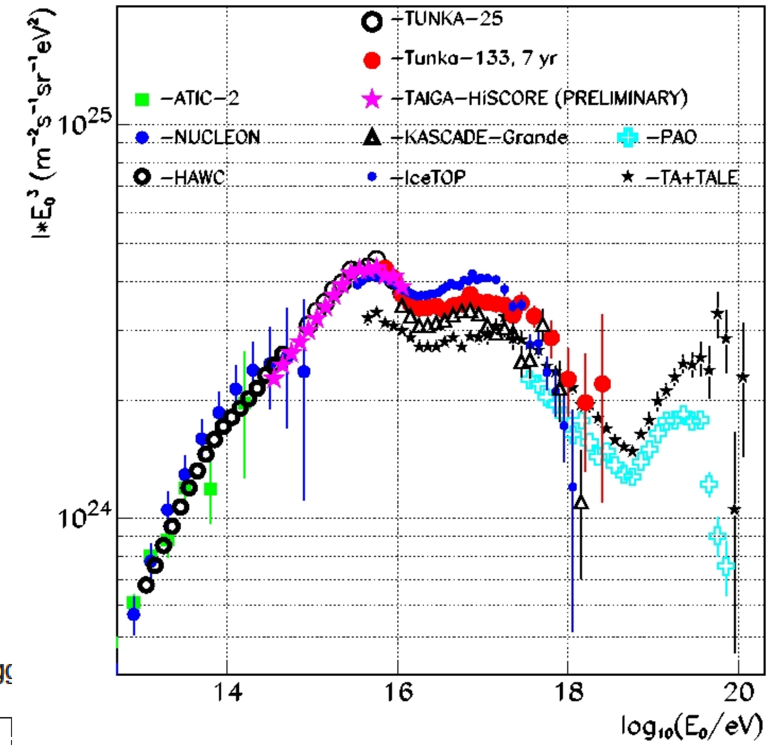
HiSCORE results

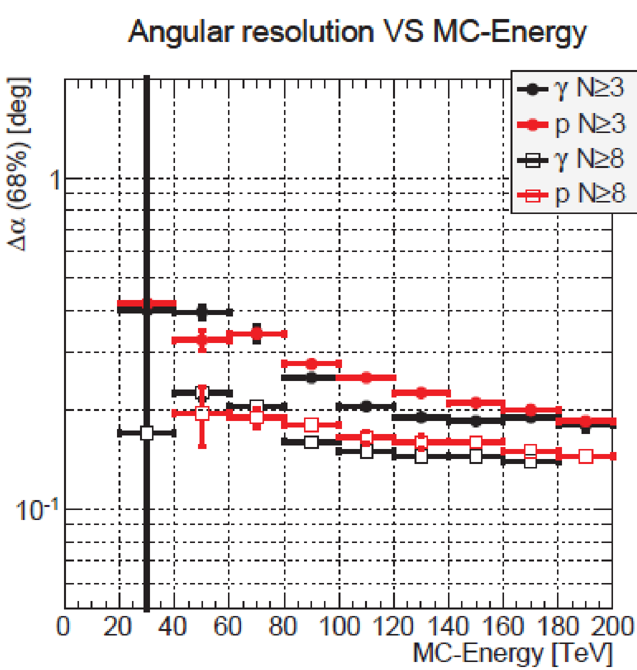
Cosmic ray energy spectrum

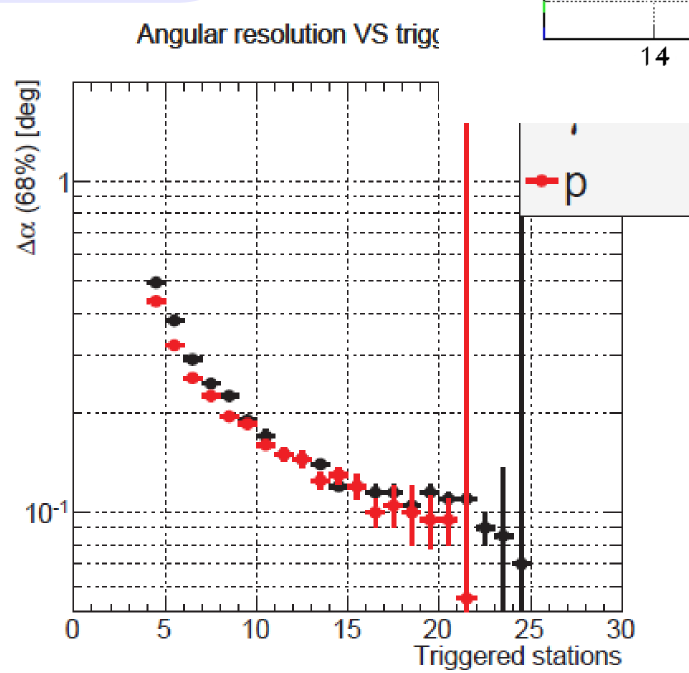
Angular resolution from MC
Verified with data (chessboard)

Single station trigger rates
Reproduced (Ethr ~ 50TeV)

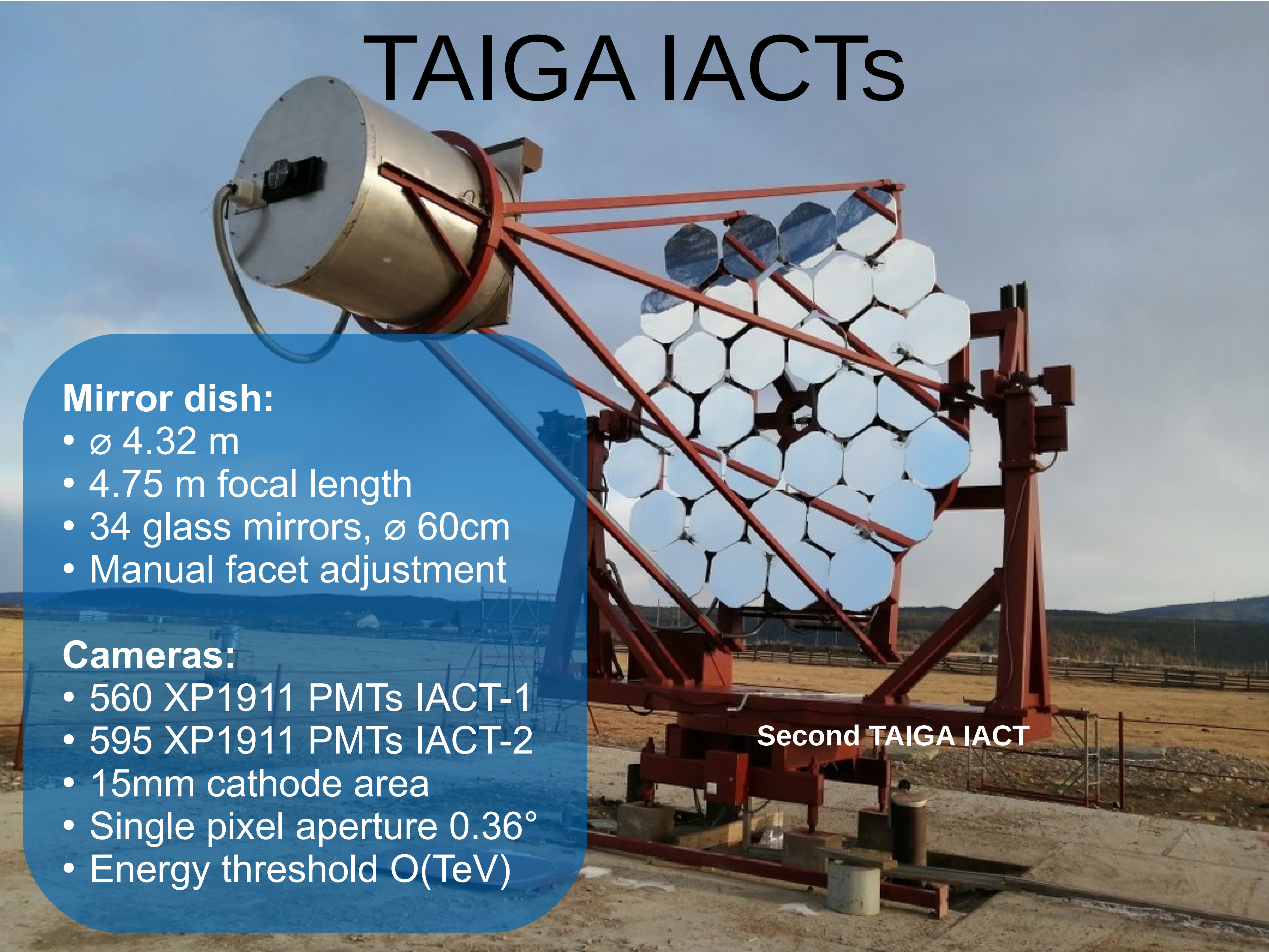
First point source: CATS Lidar







TAIGA IACTs



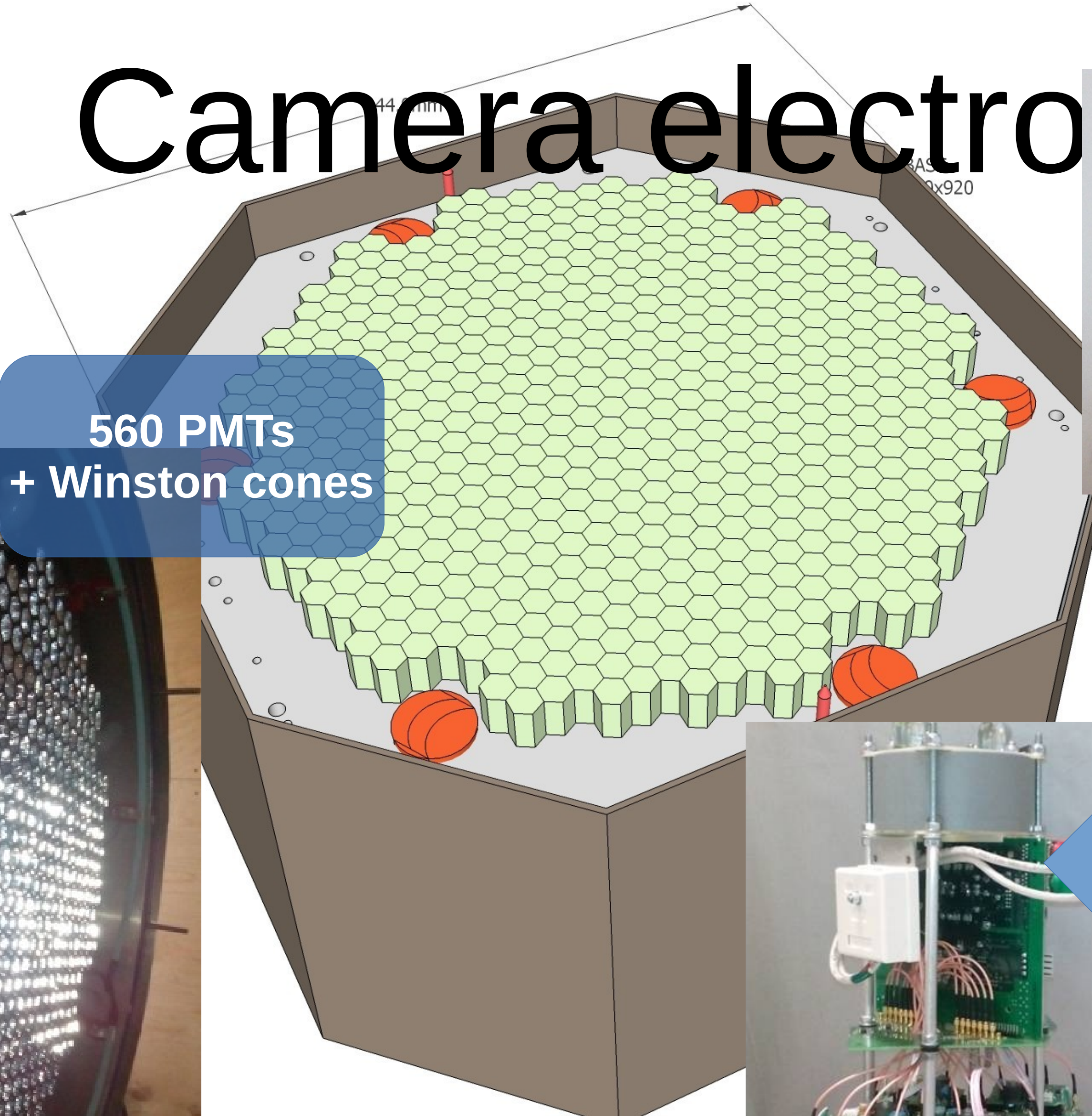
Mirror dish:

- ⌀ 4.32 m
- 4.75 m focal length
- 34 glass mirrors, ⌀ 60cm
- Manual facet adjustment

Cameras:

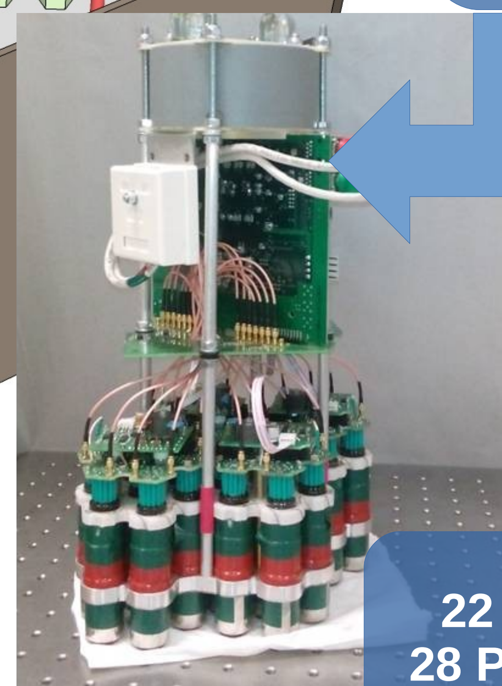
- 560 XP1911 PMTs IACT-1
- 595 XP1911 PMTs IACT-2
- 15mm cathode area
- Single pixel aperture 0.36°
- Energy threshold O(TeV)

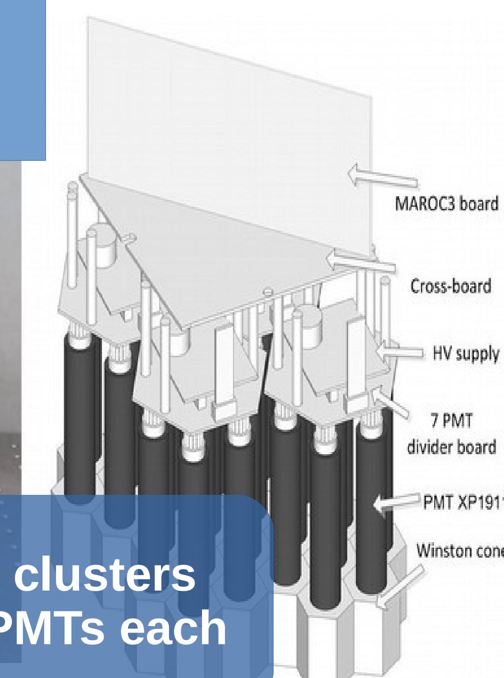
Camera electro



560 PMTs
+ Winston cones

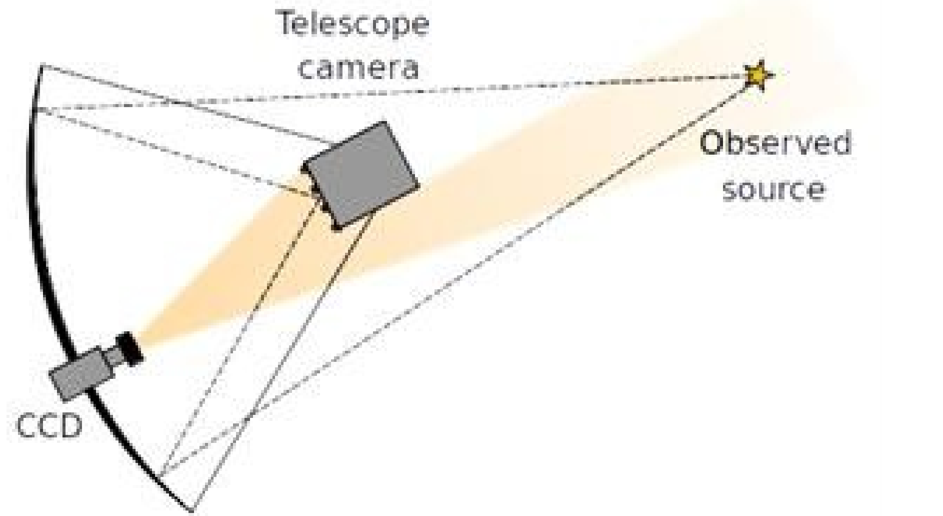
MAROC-3 board
64 channels
Trigger: fast shaper
Signal: slow shaper



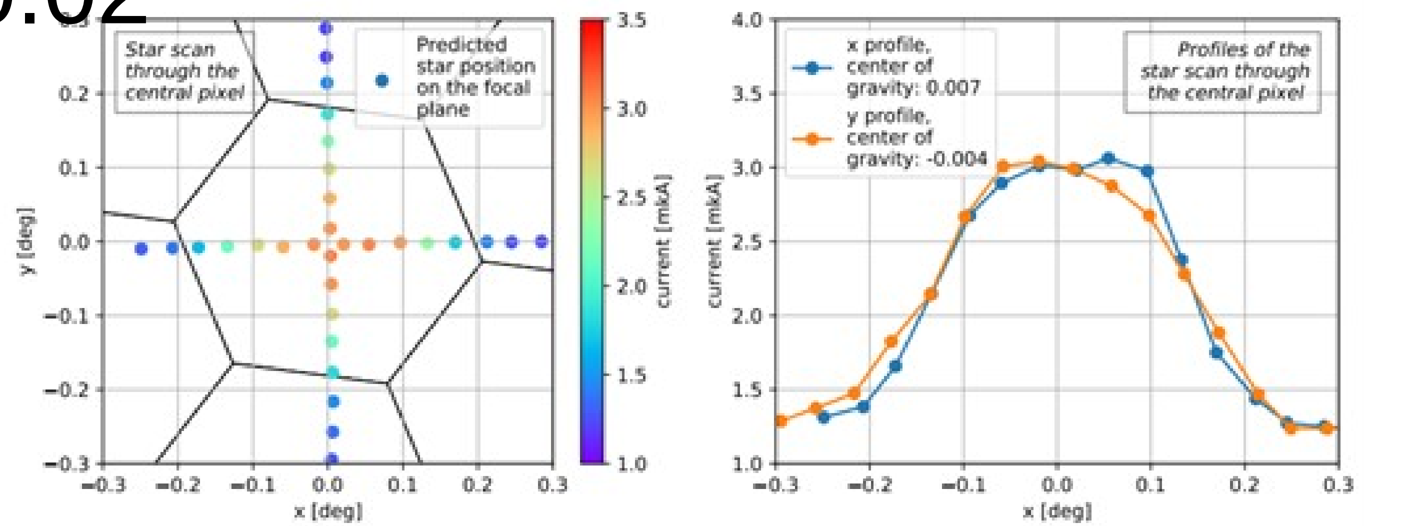


22 clusters
28 PMTs each

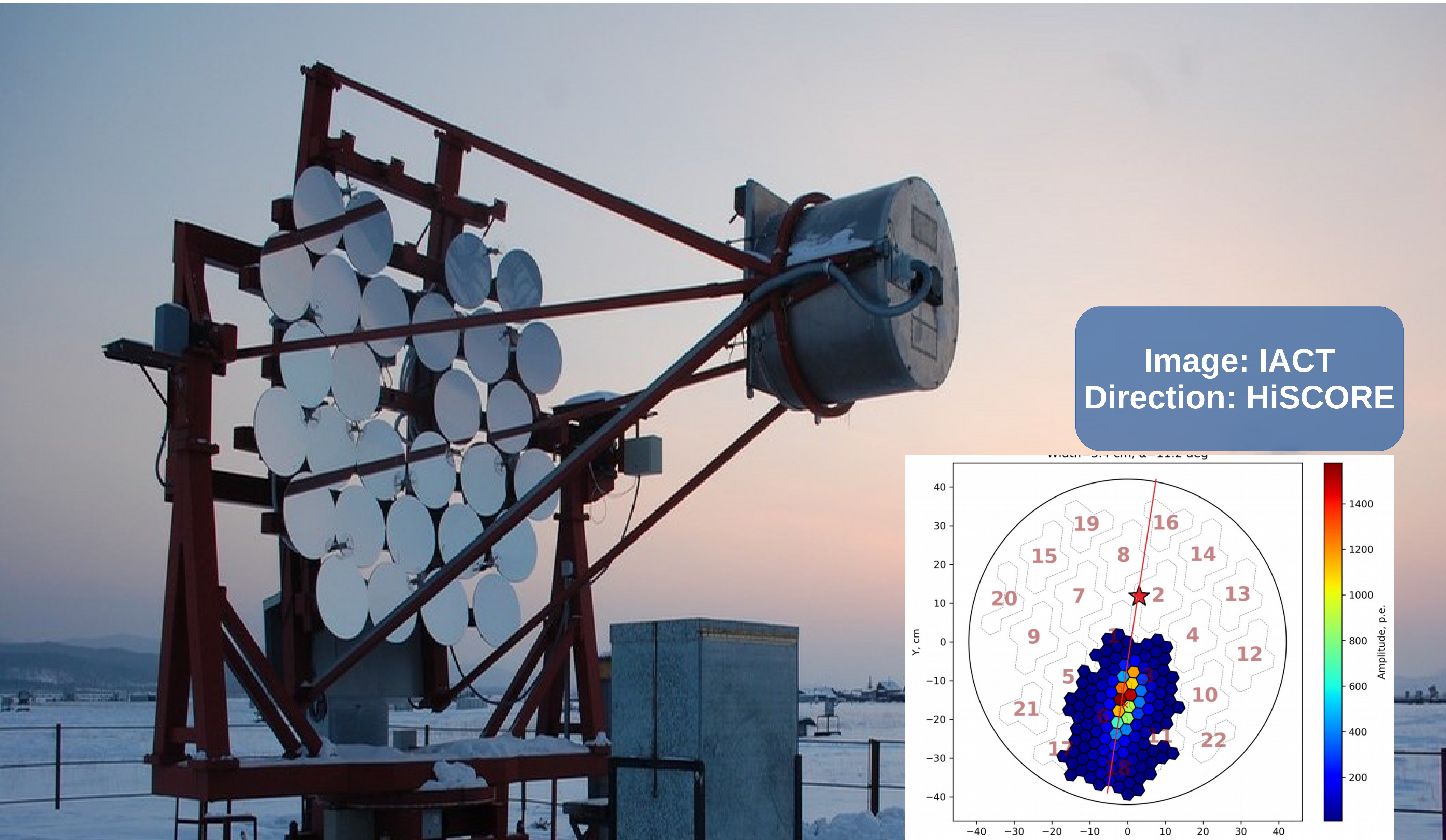
Pointing correction



- Pointing
- Shaft encoders on IACT axes
- CCD camera: calibration using bright stars
- Accuracy ~0.02°

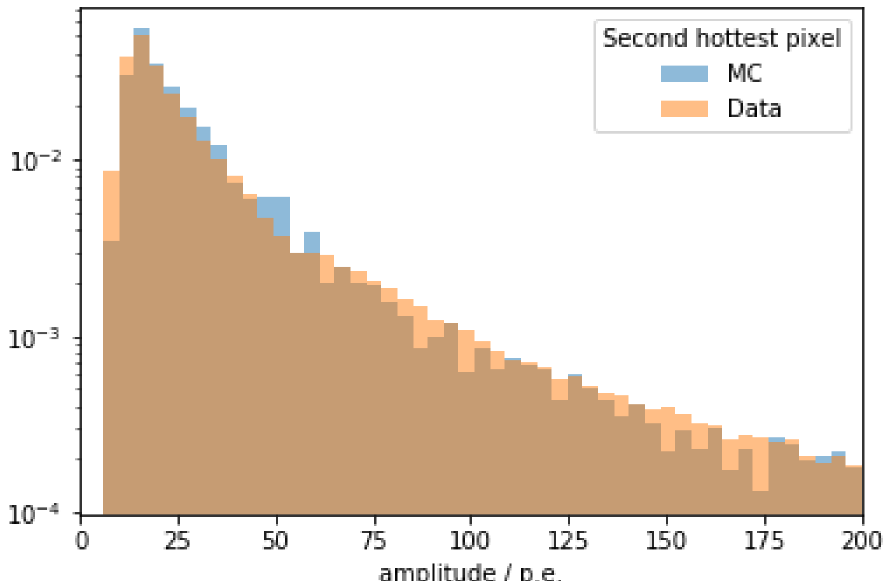


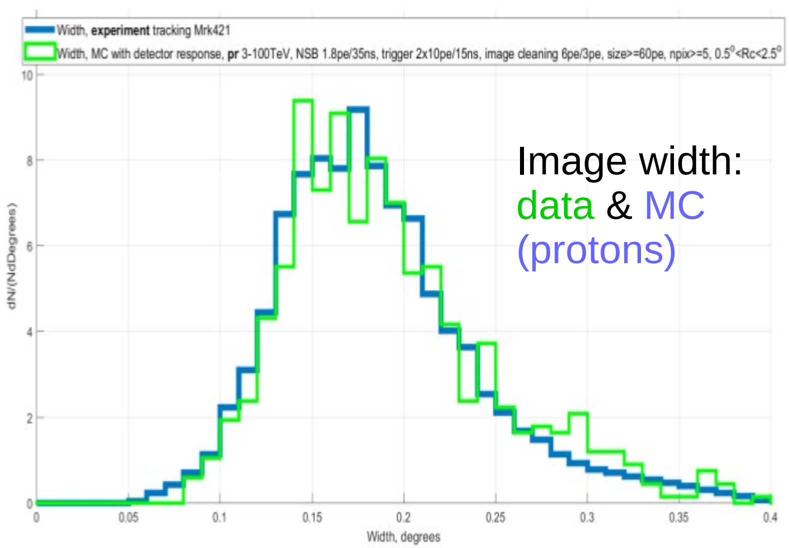
Data from 1st TAIGA-IACT

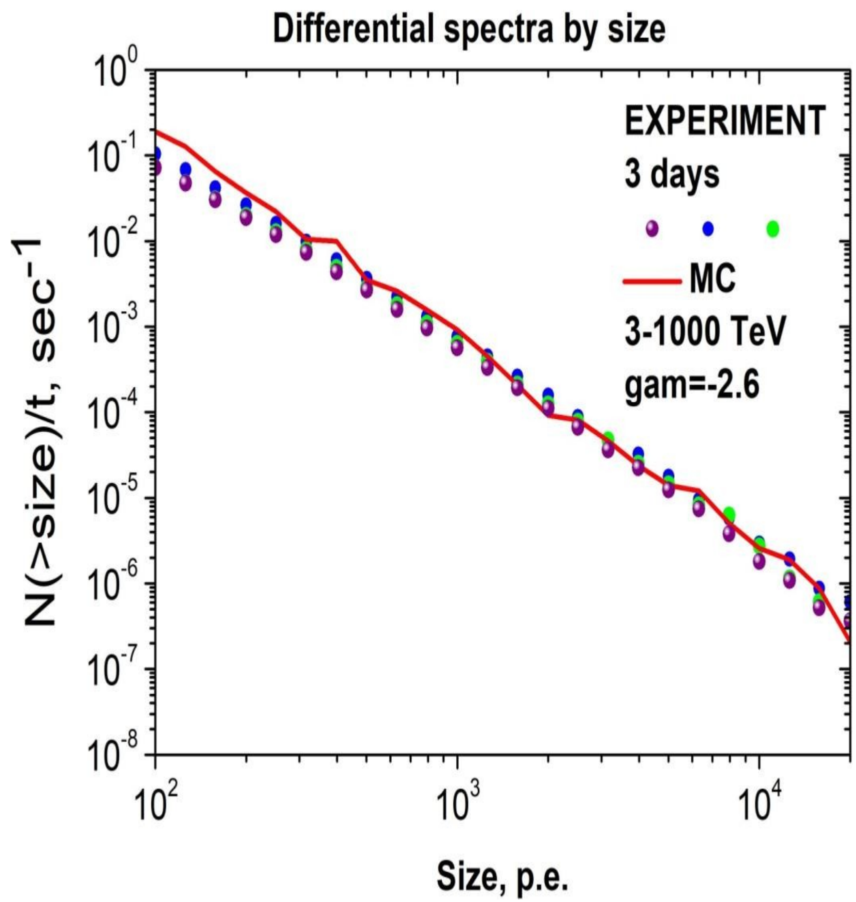


TAIGA data & MC

2 independent simulation chains







TAIGA-Muon detectors

1x1 m each detector

Wavelength shifters for scintillation light collection Fed onto PMTs

Mean cosmic muon amplitude 31 p.e. +-20%

Clear muon peak observed

Data analysis 1st IACT

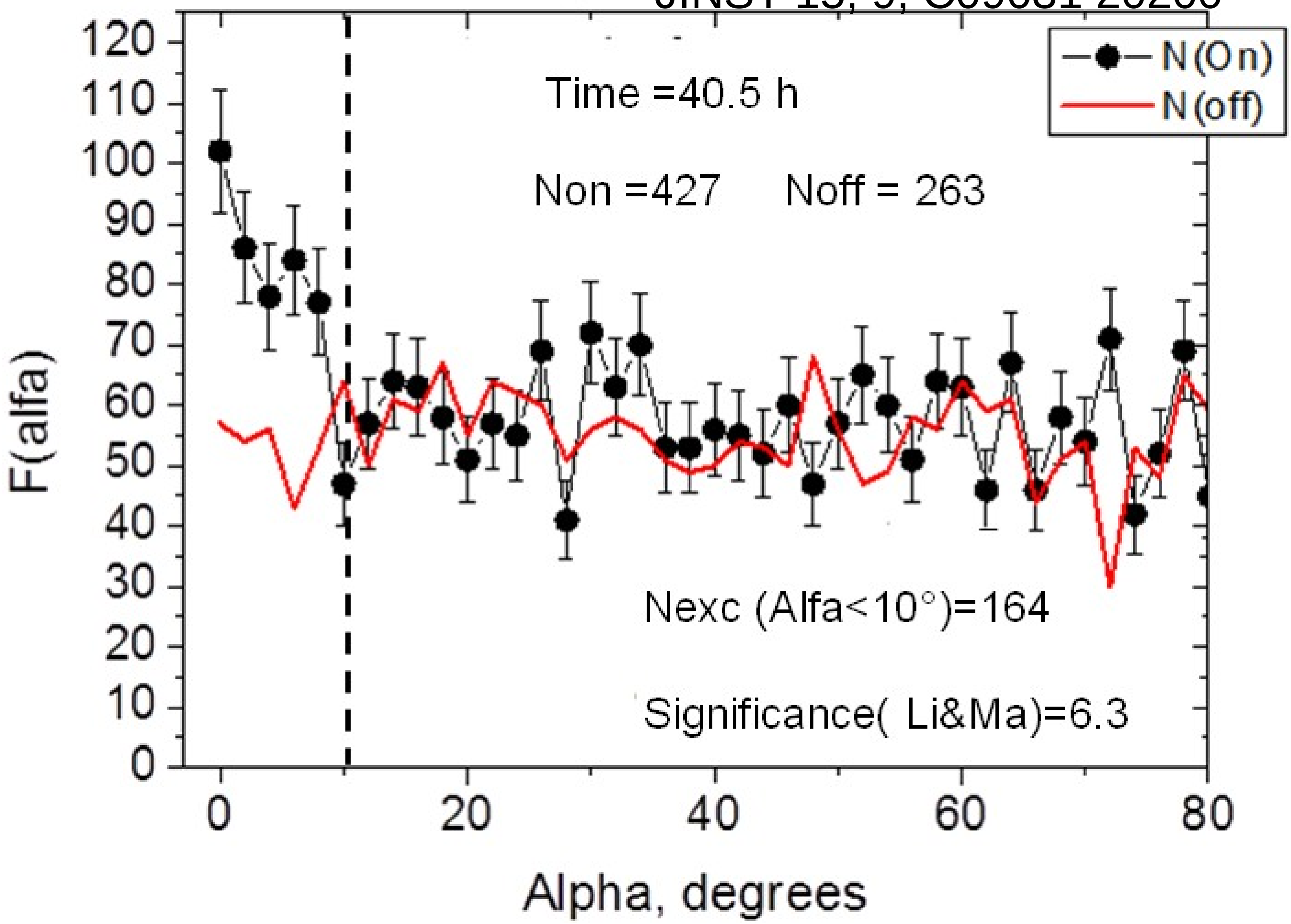
- Only 1 IACT, monoscopic, no hybrid analysis yet
- Two independent raw data reconstruction chains (from raw data to image)
- 4 groups with high level analyses
- First attempts at machine learning analyses

Observations of the Crab Nebula by IACT-1

- Culmination ~30°
- Total high quality 40.5 h
- Size > 120p.e. (~4.5TeV)
- Alpha: angle of major image axis to source position

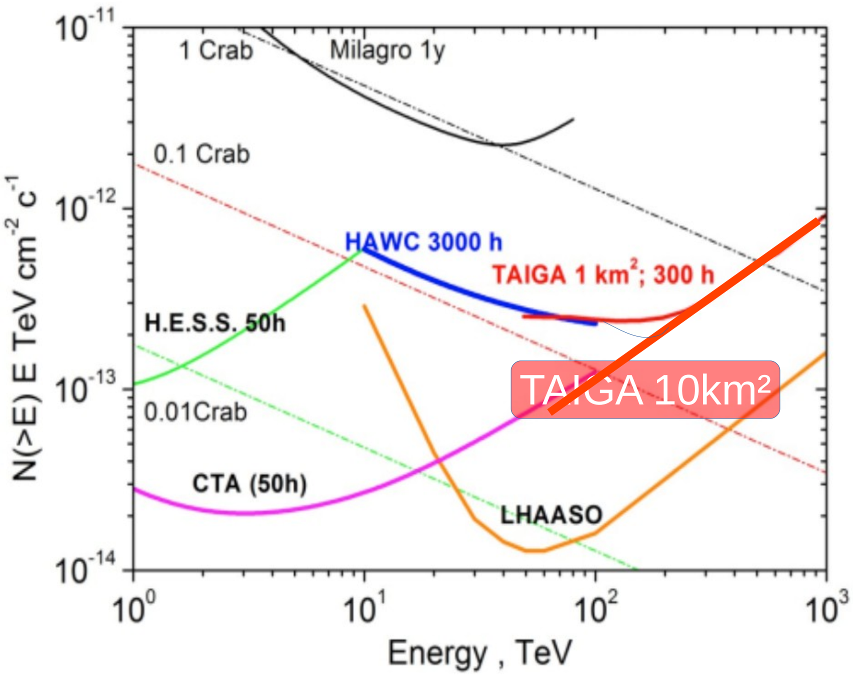
  Upcoming: journal publication

JINST 15, 9, C09031 20200



Conclusions

- **TAIGA Pilot complex, 1 km² – cost-efficient hybrid principle**
  - 89 HiSCORE stations & 2 IACTs operational
  - 120 HiSCORE stations by the end of 2021
  - 3rd IACT under construction
  - MC & Data in agreement
  - First results: Crab Nebula detected
  - Hybrid event analysis work in progress
- Improvement at high energy end using muon counters
- Future array: O(10km²)
  - 1000 wide-angle stations
  - 15 IACTs
  - $O(10^{-13})$ TeV cm^{-2} sec^{-1}



Backup slides

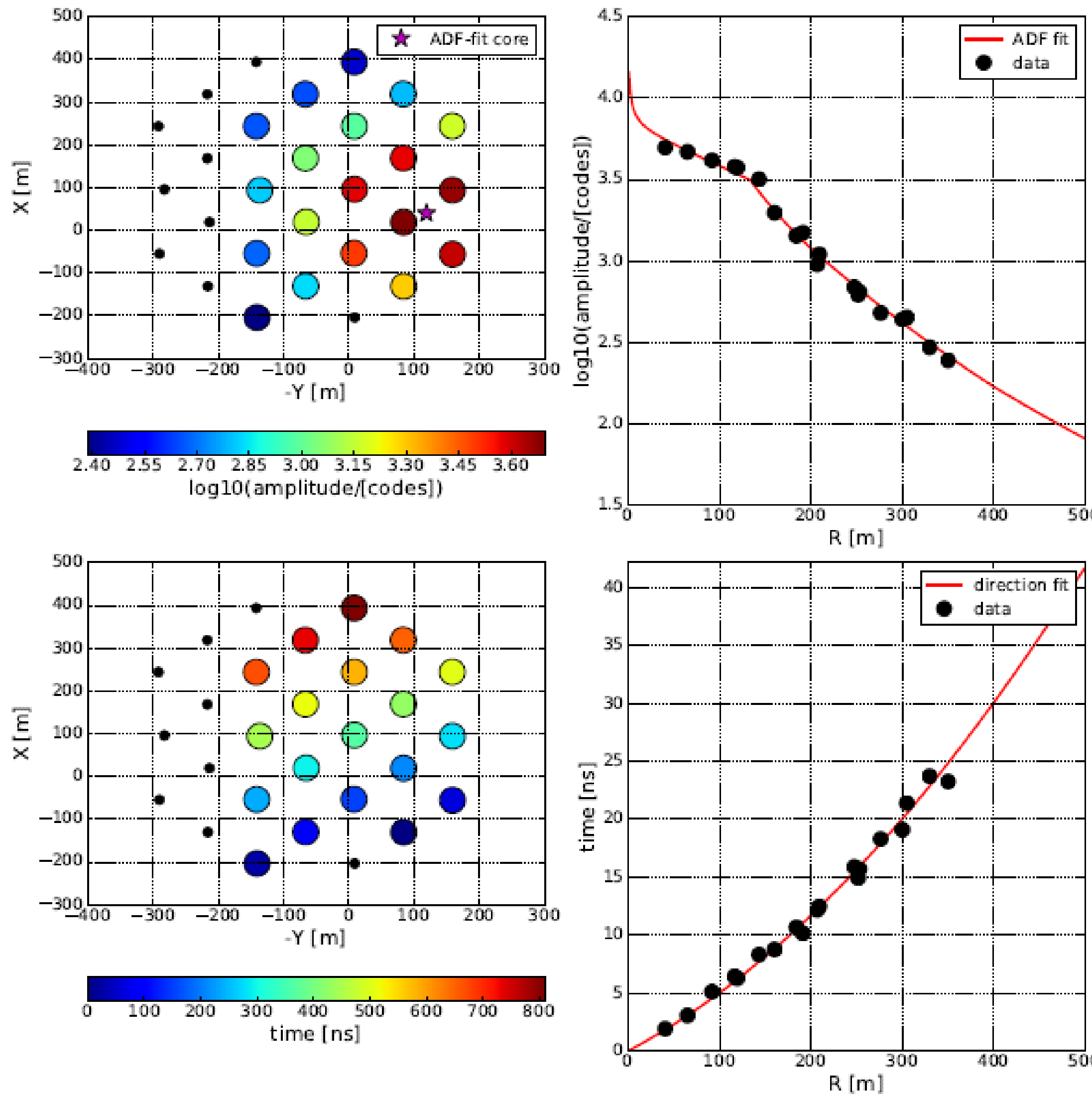
Event reconstruction

- **Station amplitudes** (LDF/ADF)

  → core impact
  → shower depth
  → primary energy

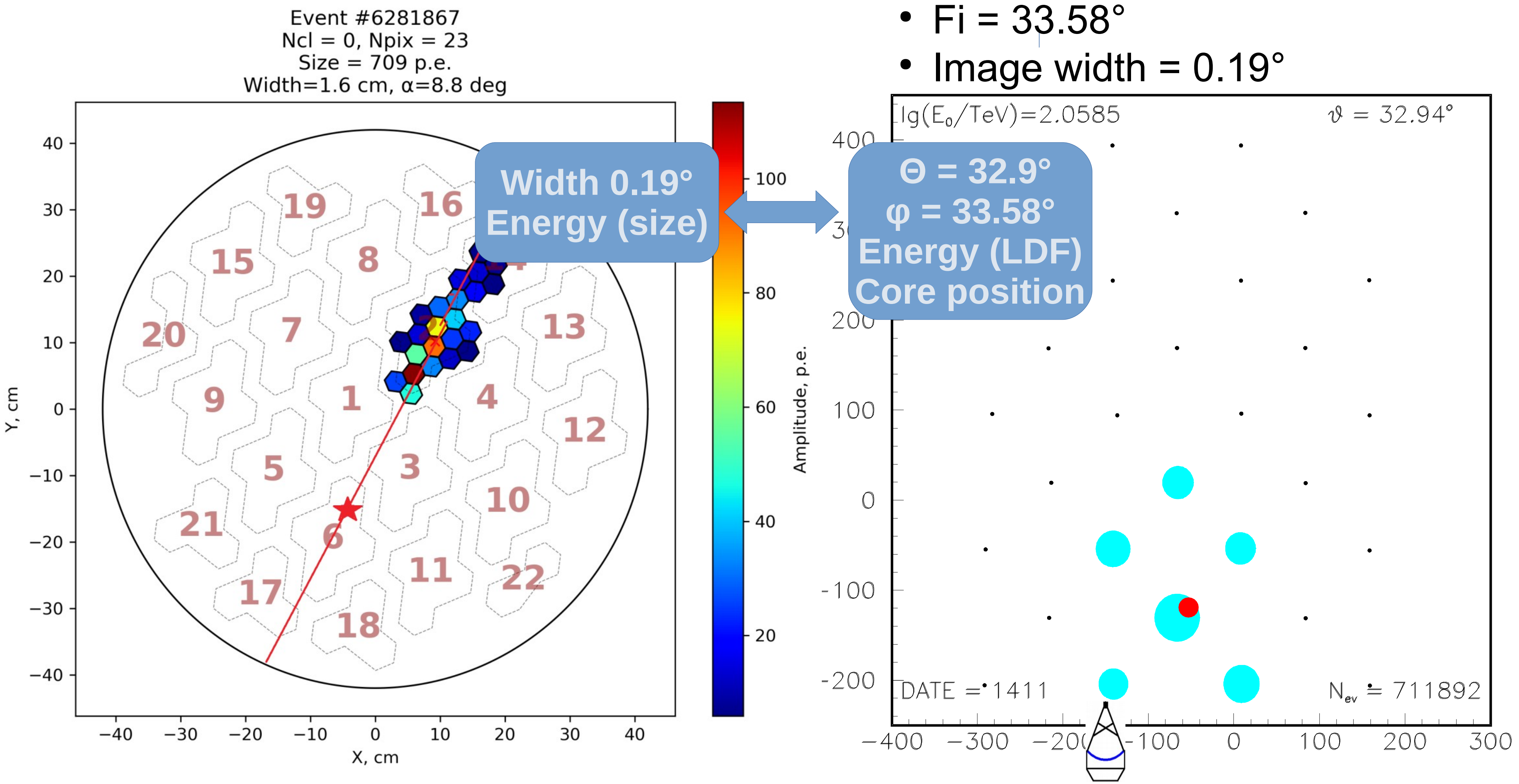
- **Station timing:** (cone fit / time-model)

  → primary direction



TAIGA IACT real data

- Tet = 32.9°
- Fi = 33.58°
- Image width = 0.19°

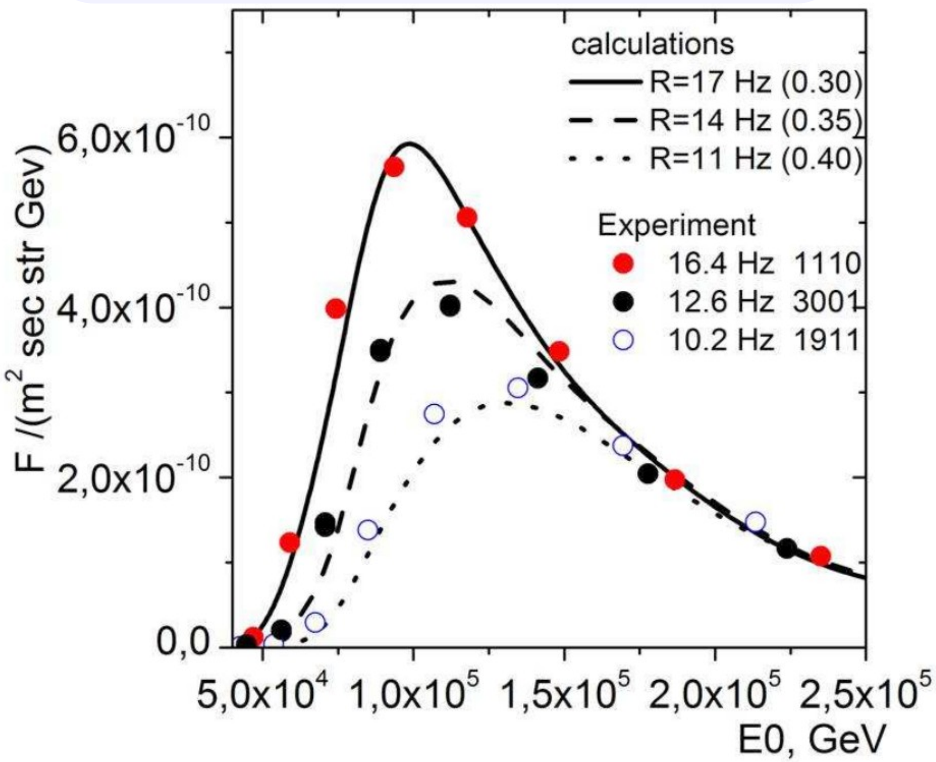


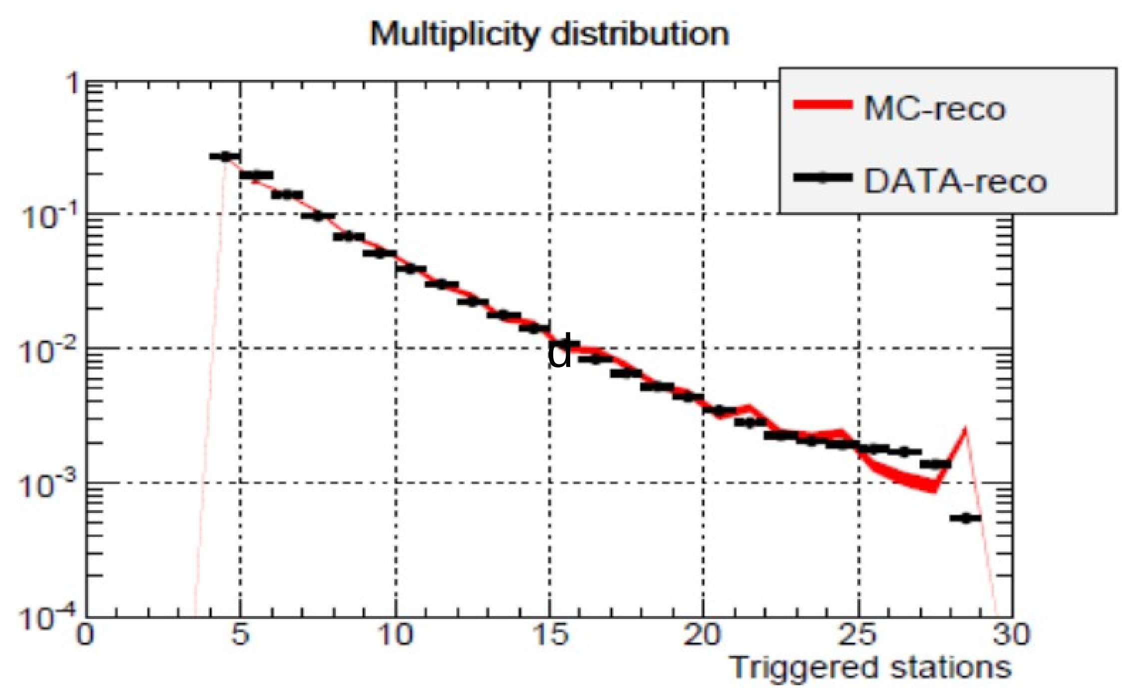
Data-MC comparison: rates

Single station trigger rates
Data reproduced with
MC-A_{thr} ~ 250 p.e.

Multiplicity

28 station array: Data / MC

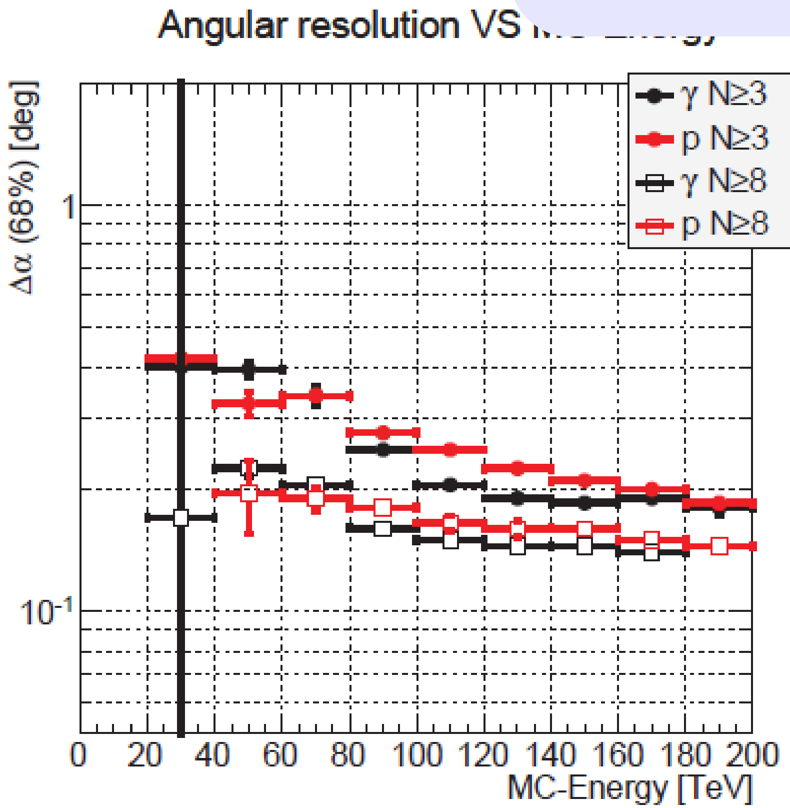


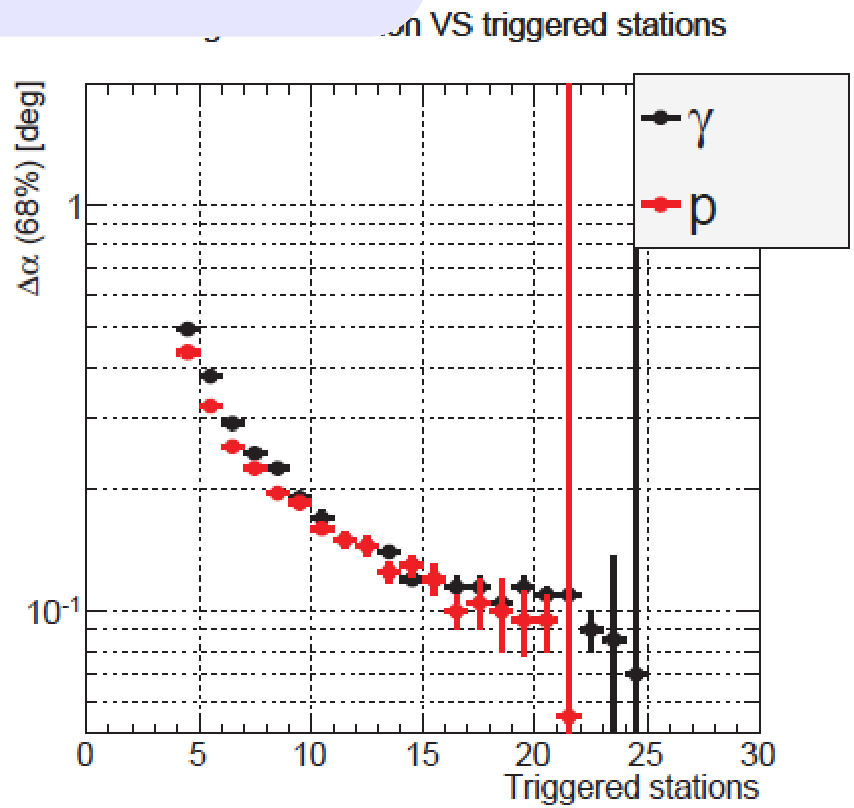


Protons: Ethr ~ 100 TeV
Gammas: Ethr ~ 50 TeV

Data-MC comparison

Angular resolution from MC
Verified with data (chessboard)

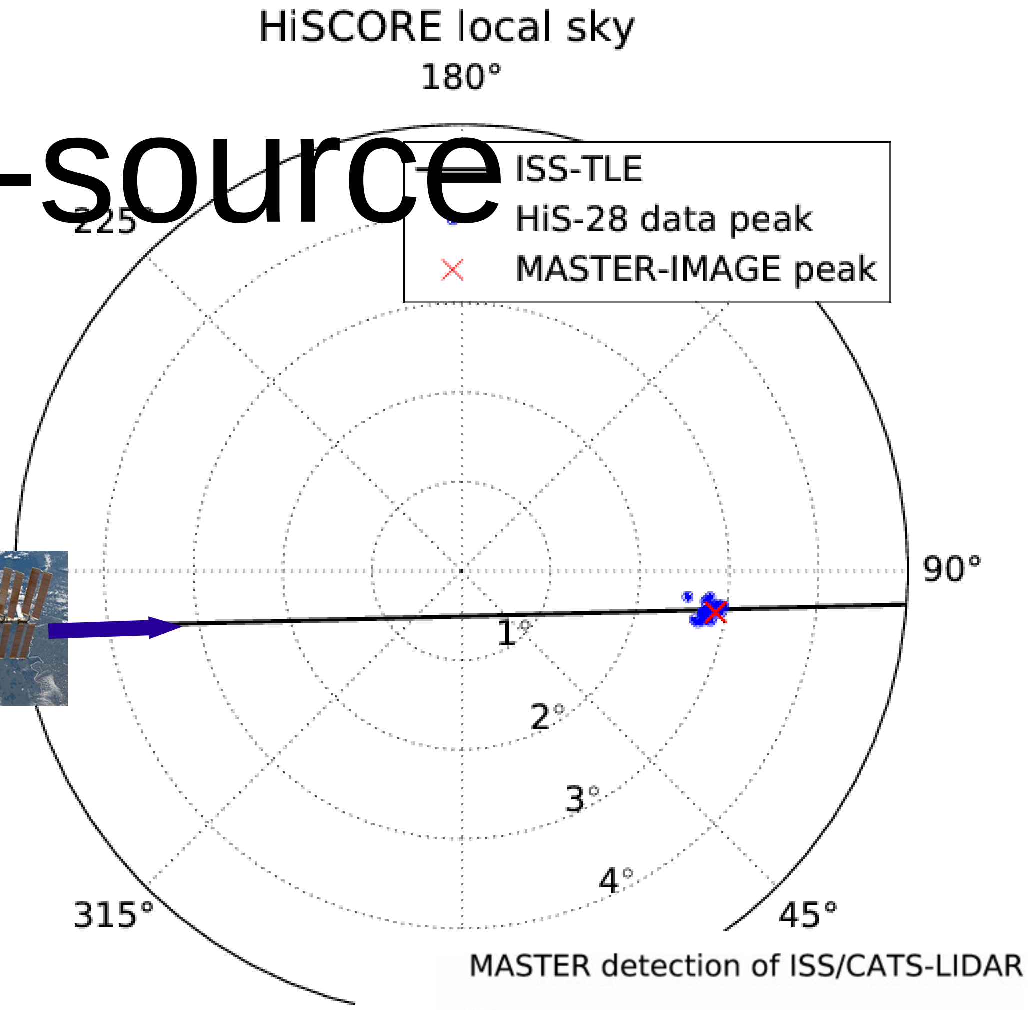


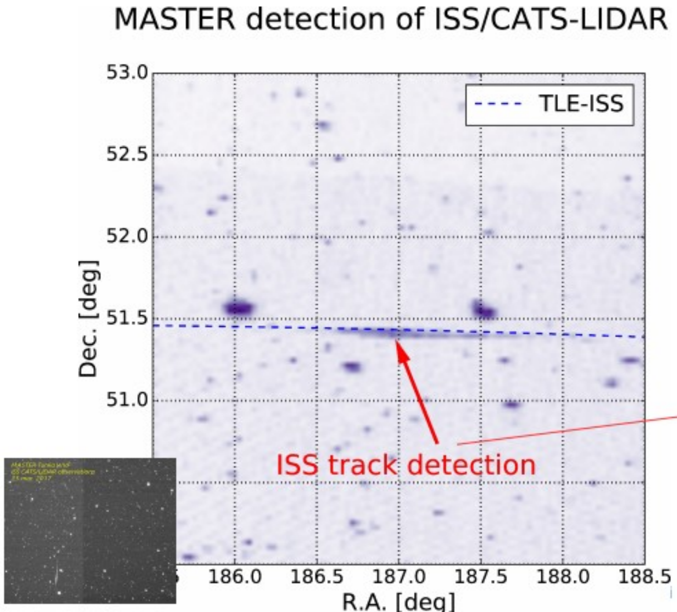


The first Point-source

In several nights:

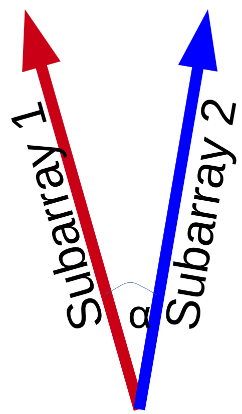
- O(s) trigger-rate “flares”, 4 kHz pulsed emission
- Point-like emission, fast moving source position
- Coincidence with ISS CATS LIDAR, 1.3mJ
- Data used for <u>absolute pointing calibration <0.1°</u>

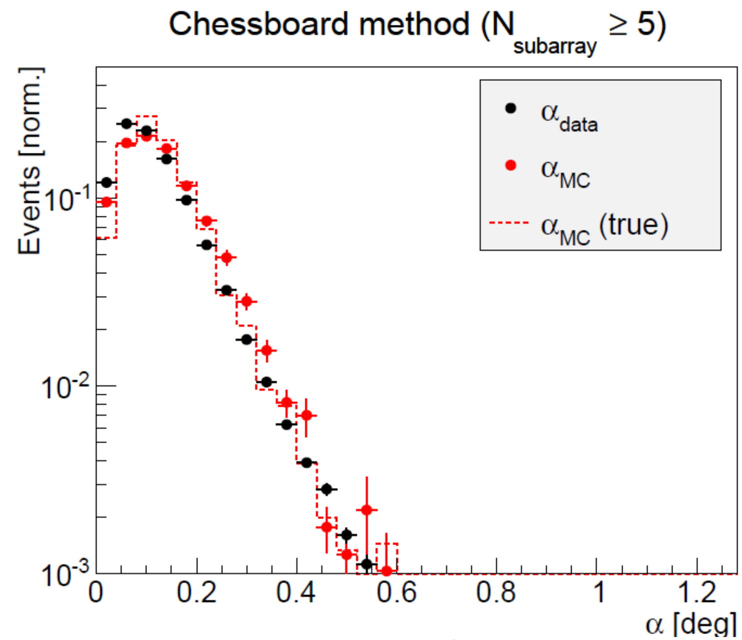


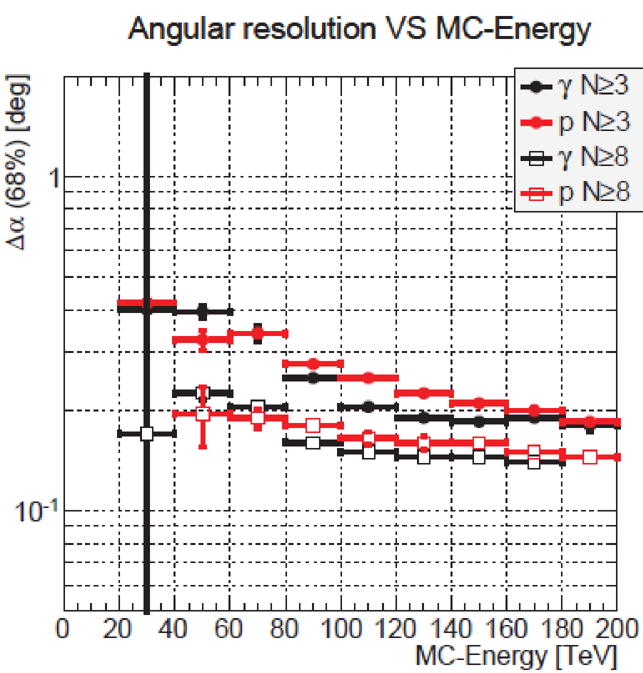


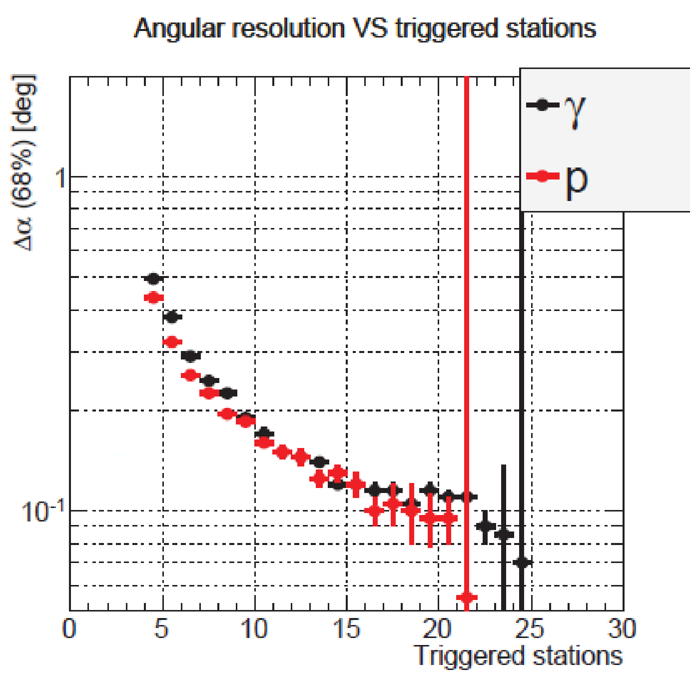
Chessboard method

Reconstruction using two different subarrays





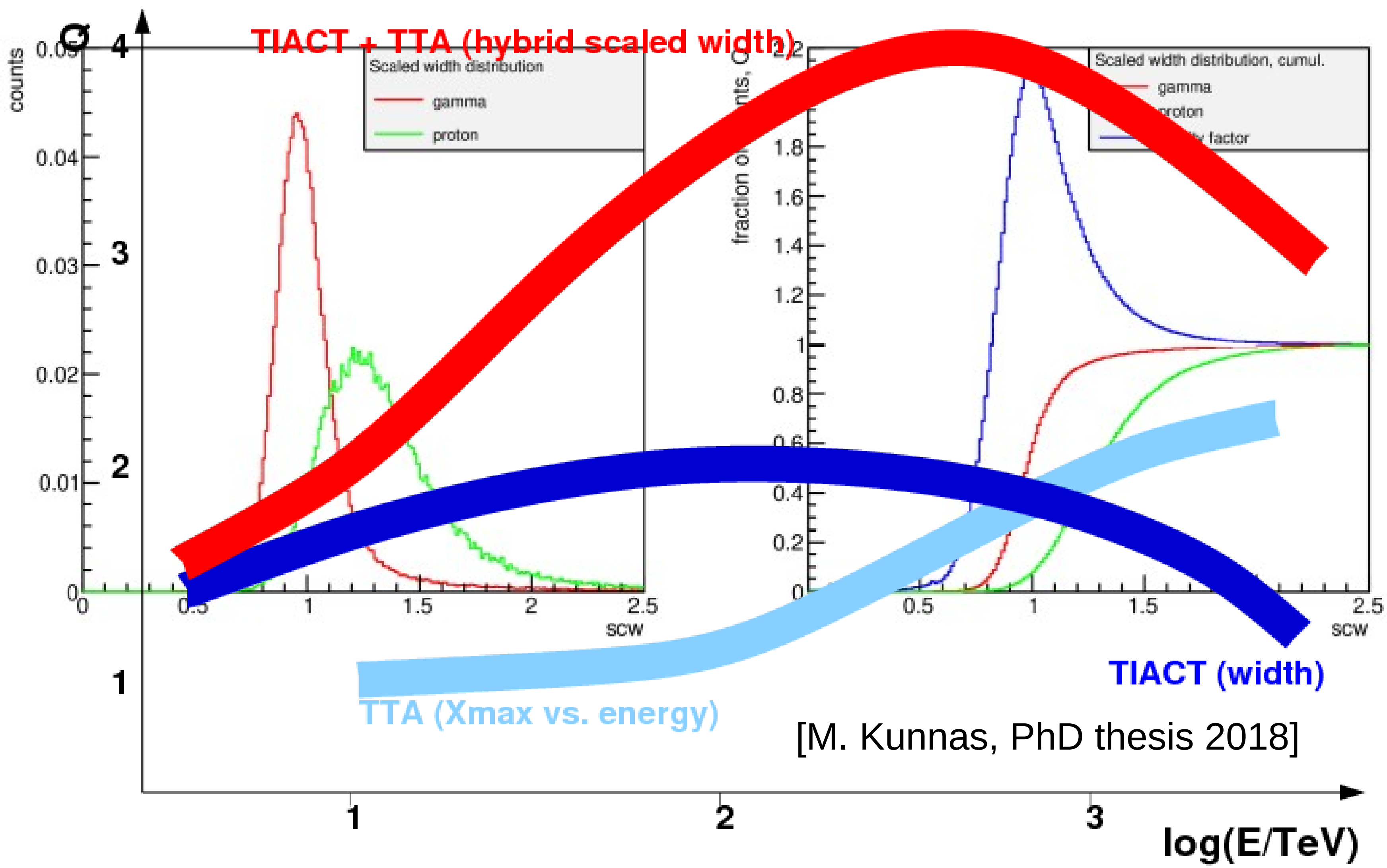




Verification of MC

g/h separation

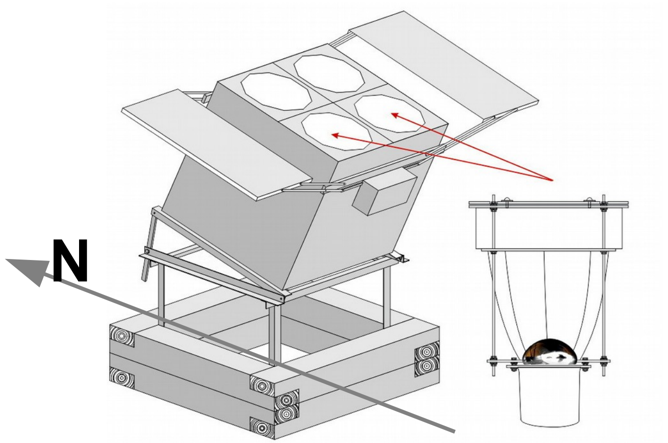
Hybrid scaled width (HSCW)



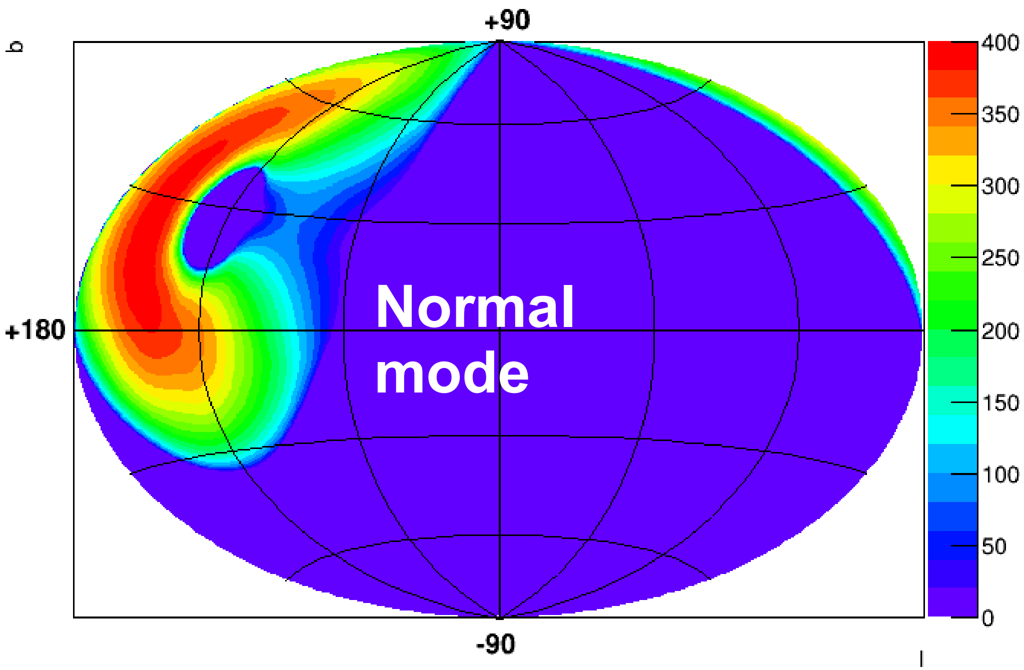
[M. Kunnas, PhD thesis 2018]

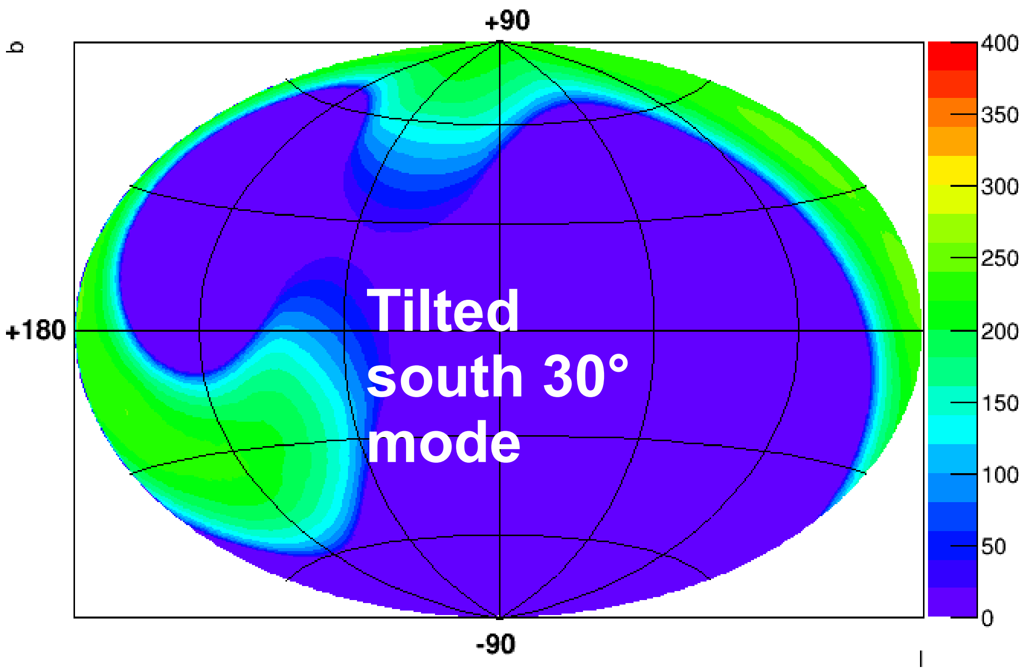
Sky coverage

Tilted mode: inclined along the north-south axis.
coverage of different parts of the sky.



Tilted south mode: 110 h on the Crab Nebula,
after weather corrections.

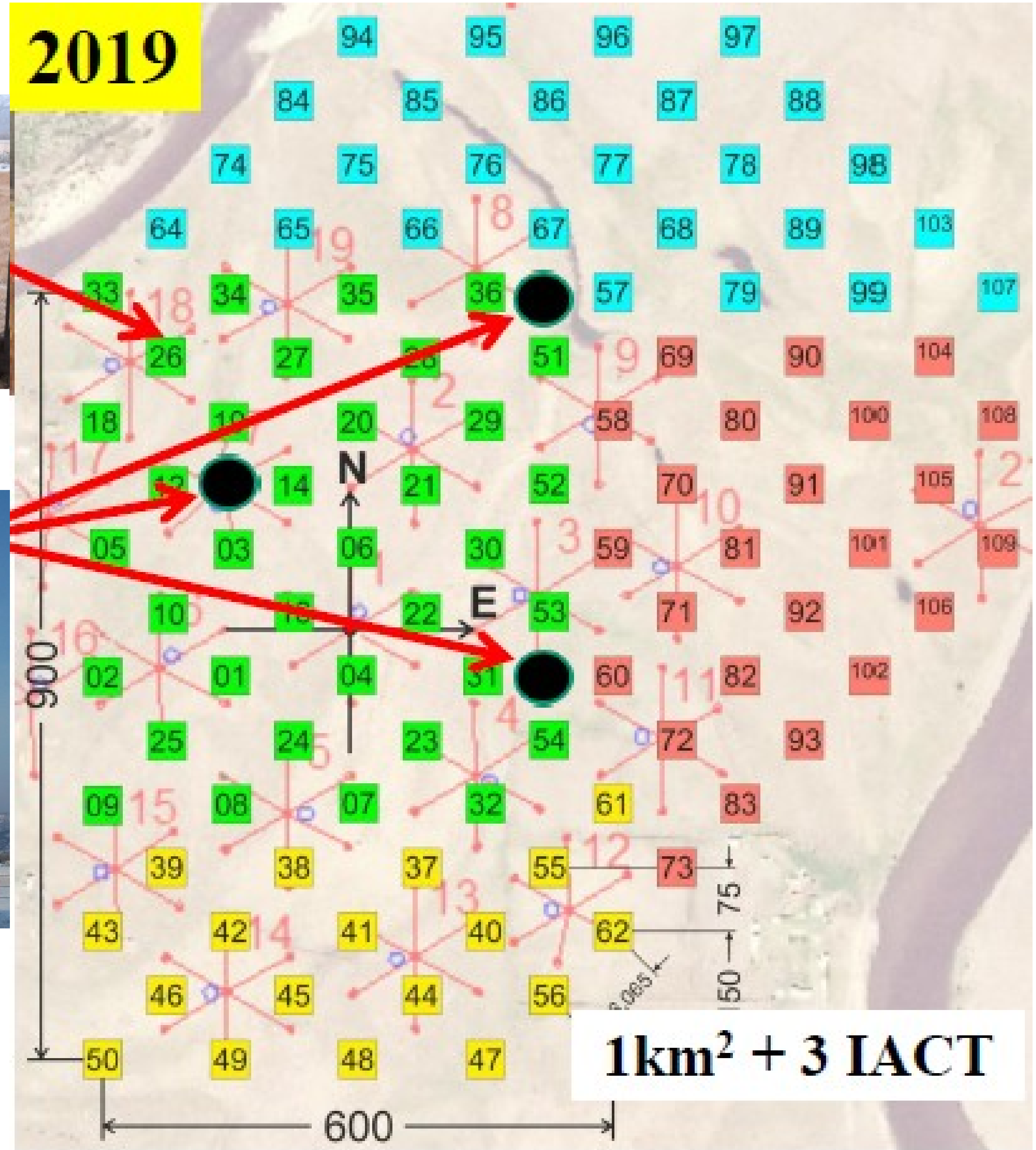




TAIGA array

120 stations

3 IACTs



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600 m
Image © 2021 CNES / Airbus
497 m

HiSCORE Reconstruction

IACT Reconstruction

Data MC convergence HiSCORE

Data MC convergence IACTs

HiSCORE verification

ISS CATS Lidar

IACT verification

Crab Nebula

Hybrid reconstruction

Cosmic ray energy spectrum

TAIGA HiSCORE preliminary

- Energy
  from light density @200m
  from shower core
  resolution ~15%
- results compatible
  with other experiments
- See presentation by
  L. Kumzmichov, this conference