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Stereoscopic and monoscopic operation of the five IACTs in the TAIGA experiment

A.A.Grinyuk, E.B.Postnikov and P.A.Volchugov* for the TAIGA collaboration

andrei.grinyuk@gmail.com evgeny.post@gmail.com pvol4@yandex.ru*

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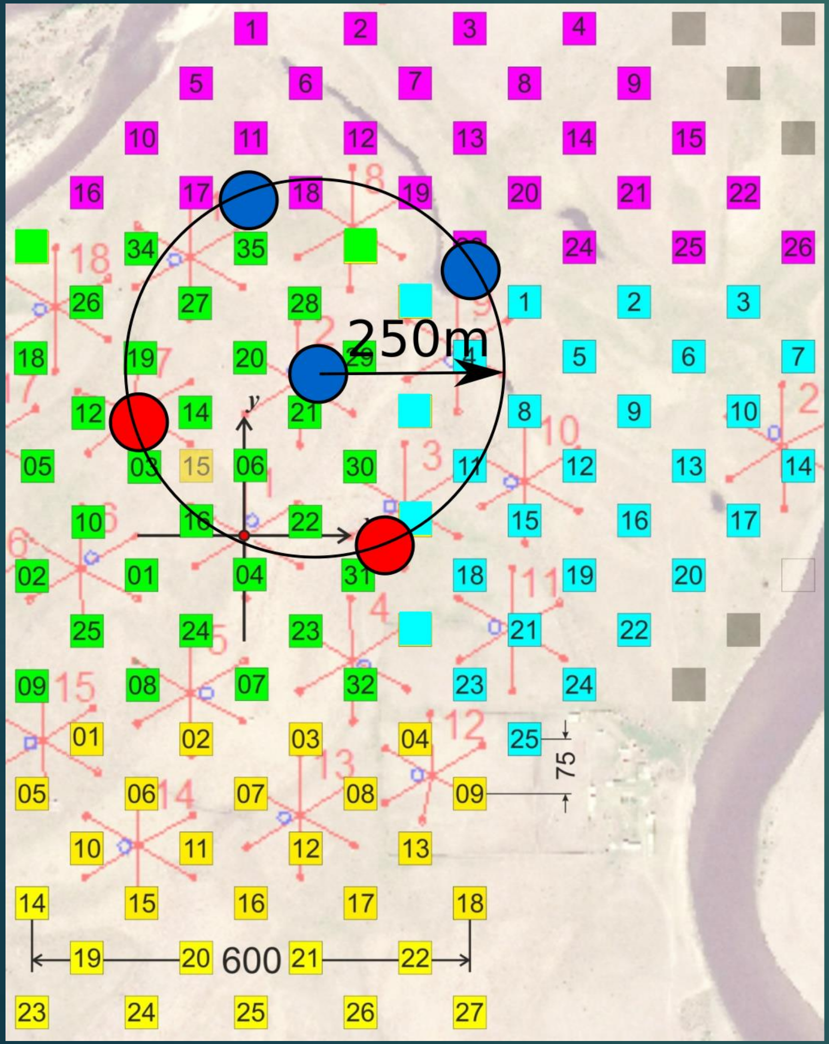
TAIGA - Tunka Advanced Instrument for cosmic ray physics and Gamma-ray Astronomy



IACT in operating

planned IACT

HiSCORE cluster#1

HiSCORE cluster#2

HiSCORE cluster#3

HiSCORE cluster#4

TAIGA-IACT – imaging atmospheric Cherenkov telescopes

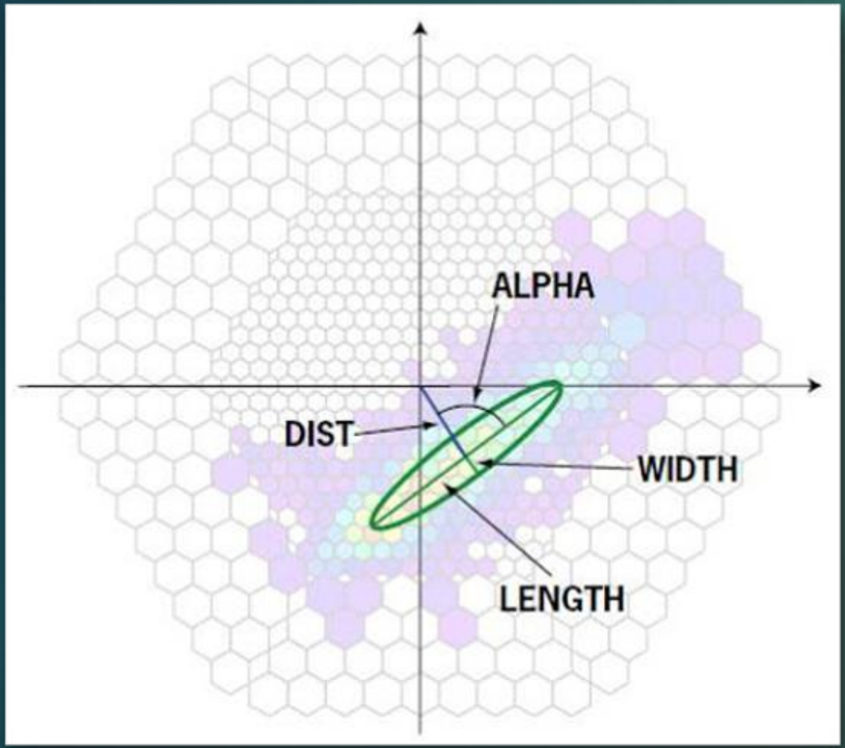
TAIGA-HiSCORE – wide-angle Cherenkov installation

TAIGA-Muon - EAS scintillation installation

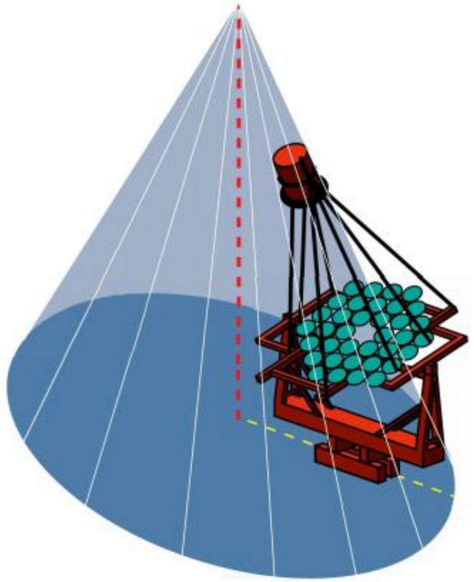
TAIGA-IACT

- focal length - 4.75 m;
- reflector diameter - 4.3 m;
- TAIGA-IACT recording cameras include XP1911 PMTs grouped into 22 clusters (560 and 600 for IACT1 and IACT2)
- each PMT is equipped with a Winston cone;
- pixel viewing angle - 0.36 °;
- camera FoV - 9.6 °;
- camera diameter ~ 110 cm;

Observation methods

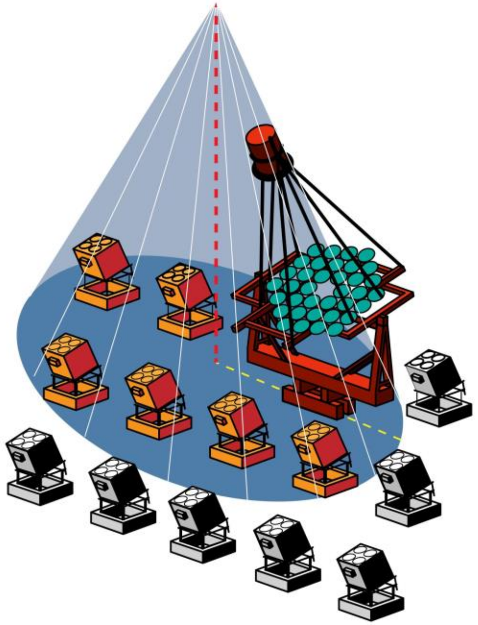


In any observation mode, IACTs form images that can be parameterized. These parameters are the basis for further data analysis.



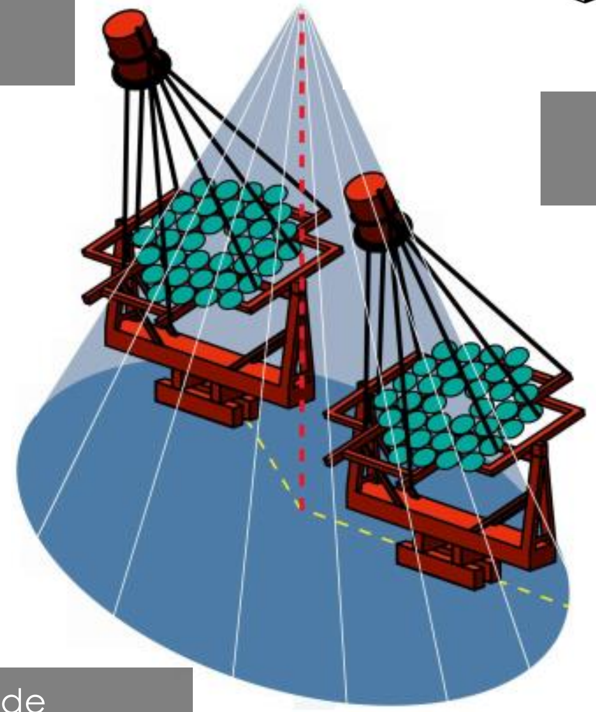
Mono mode

E > 2 ТэВ



Hybrid mode

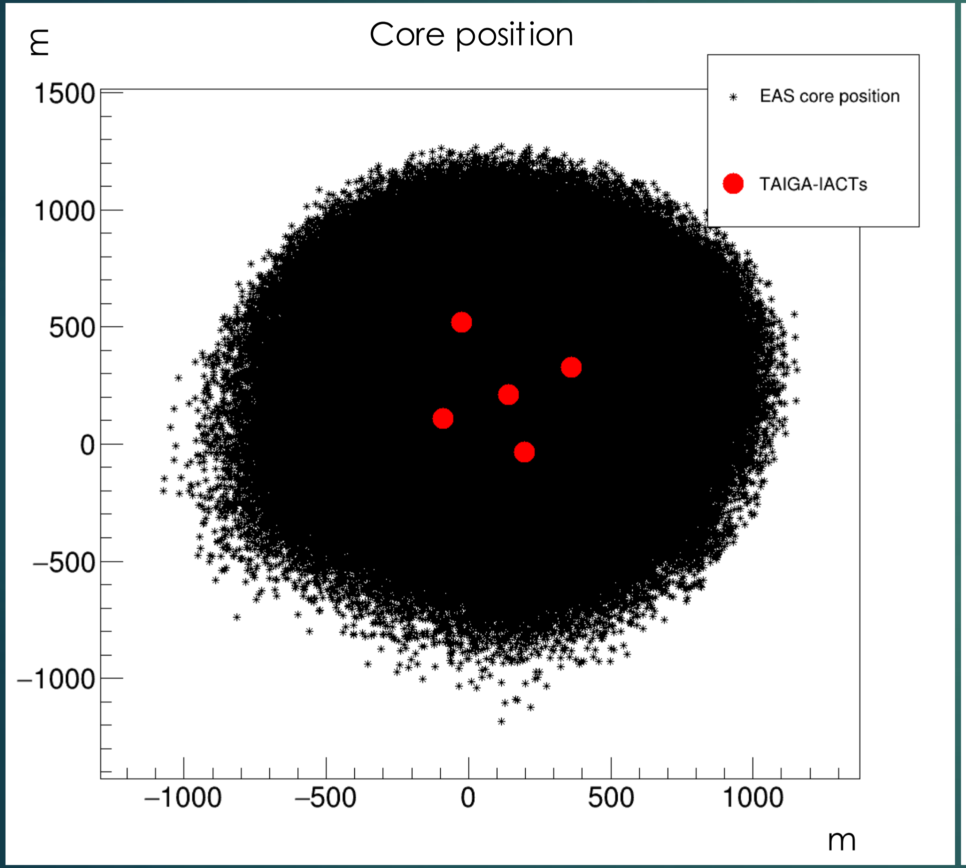
E > 40 ТэВ



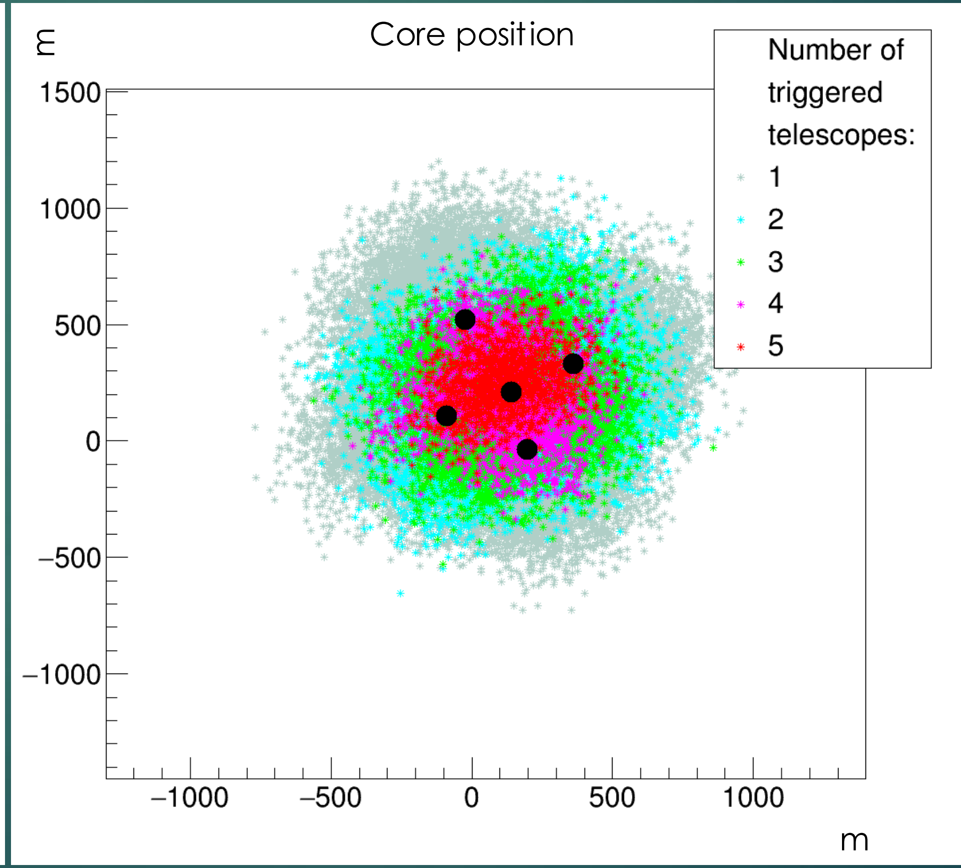
Stereo mode

E > 8 ТэВ

Simulation of gamma rays for 5 telescopes



Before IACT trigger condition



After IACT trigger condition

Circle radius:
1 km

Total generated in MC:
4×10^5 events

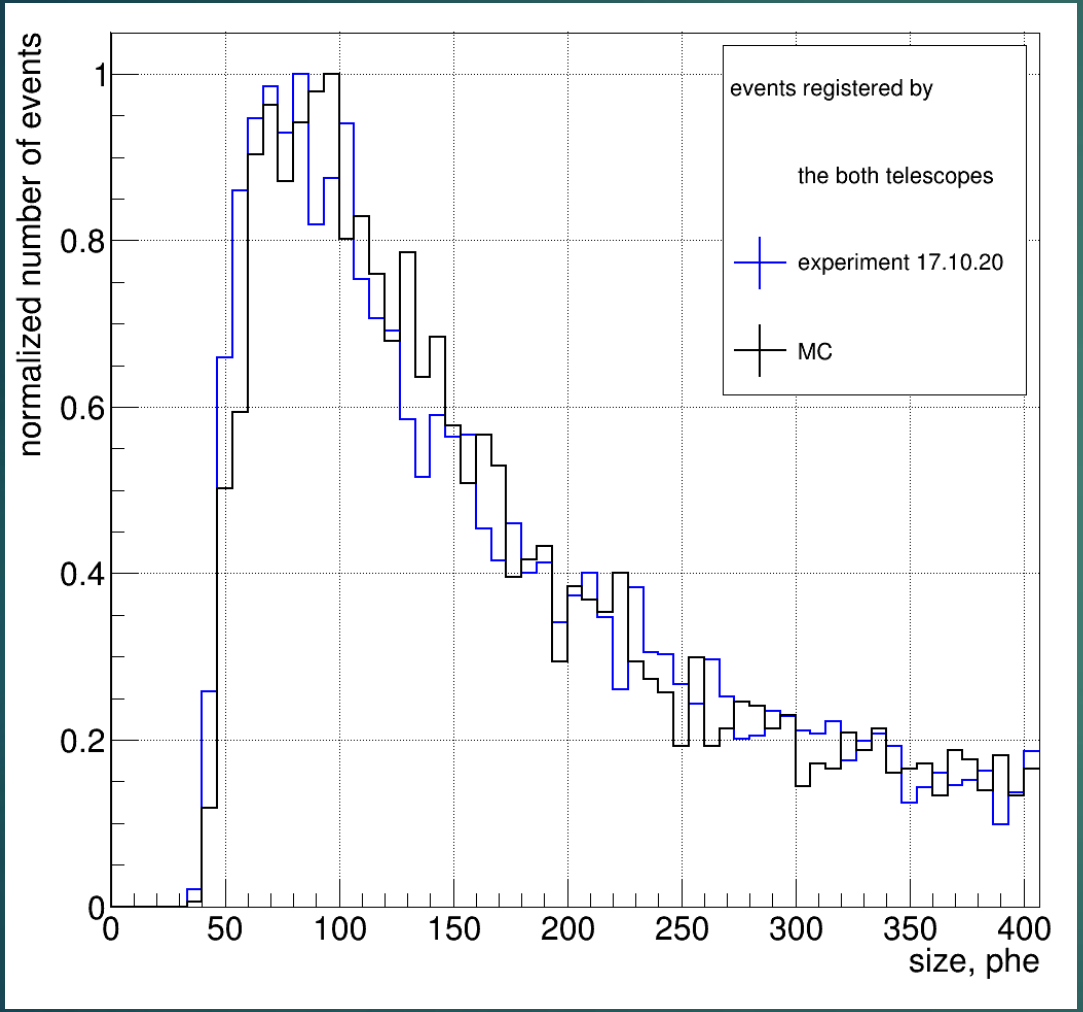
Energy range:
2 - 50 TeV

The trigger condition requires an amplitude exceeding 10 photoelectrons in two neighbouring pixels within a 15 ns window.

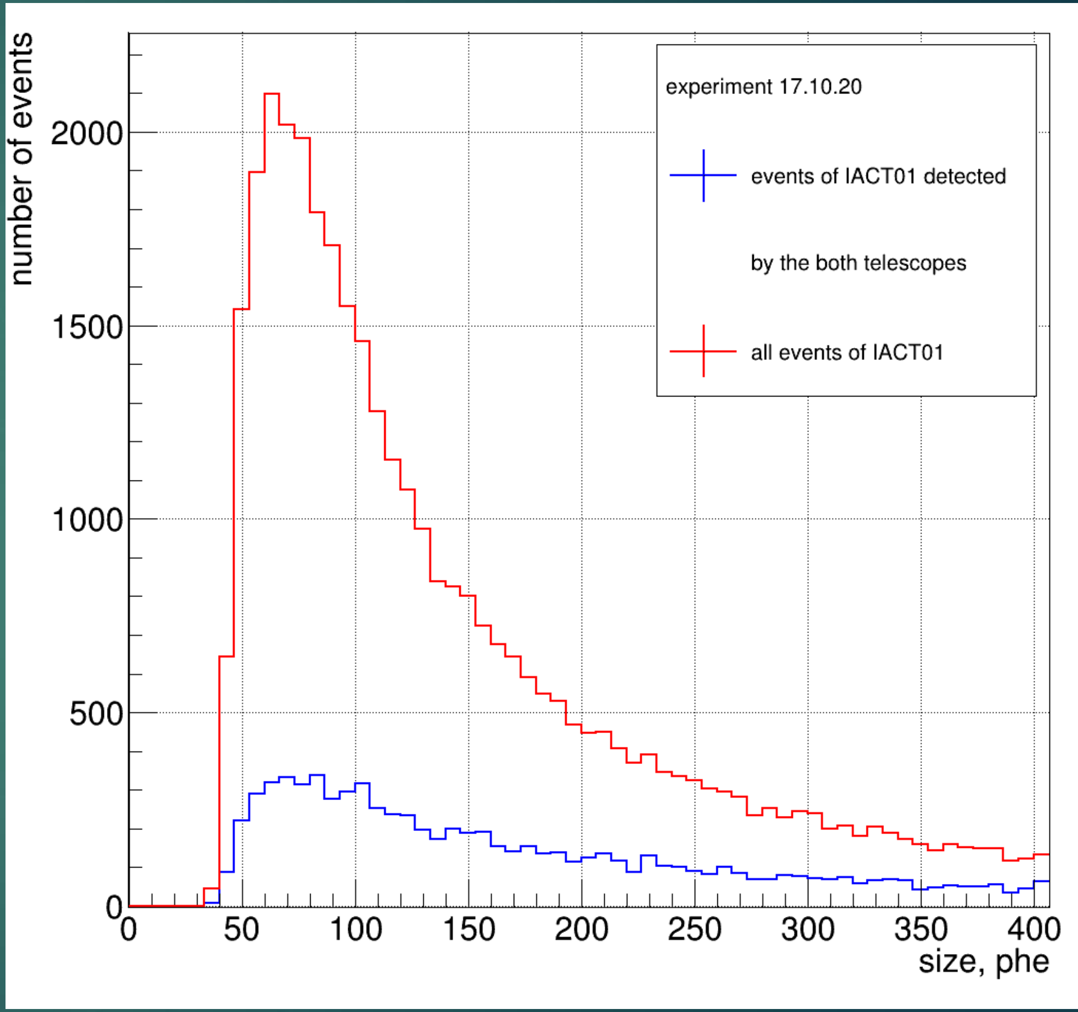
After passing the hardware trigger, the events can be analyzed in several stereo modes, such as 2+, 3+, 4+ and 5.

For example, the 2+ mode means that the analysis involves events that triggered 2 or more telescopes.

Comparison of spectra of size



experimental and MC distribution of *size* of events detected by the both telescopes of the TAIGA-IACT

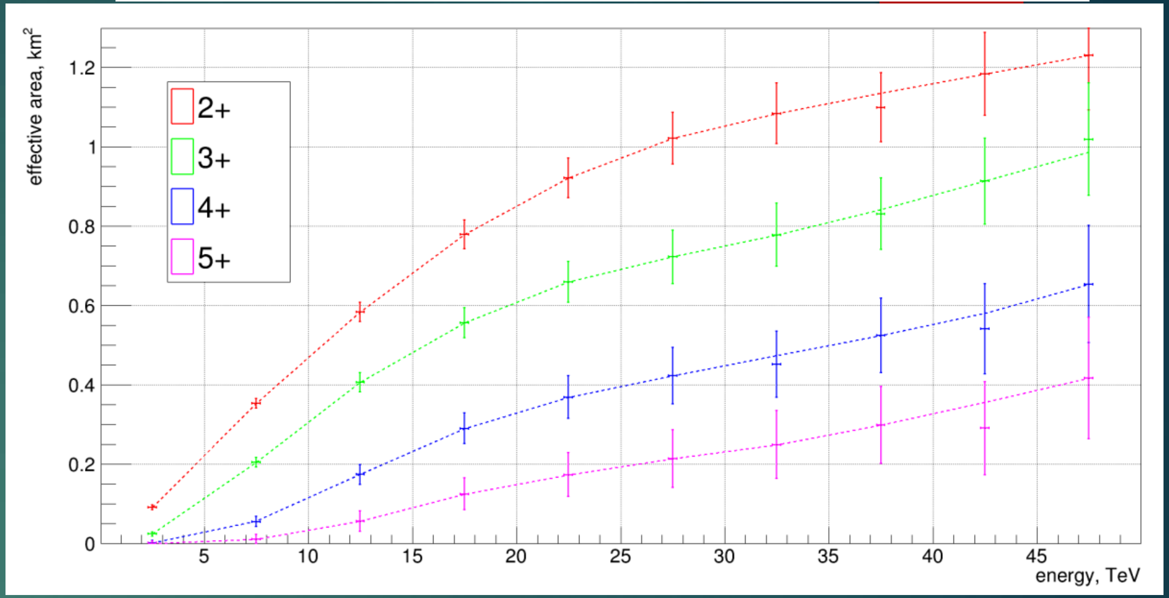


experimental distribution of *size* of all events TAIGA-IACT01 and events detected by the both telescopes

Effective area

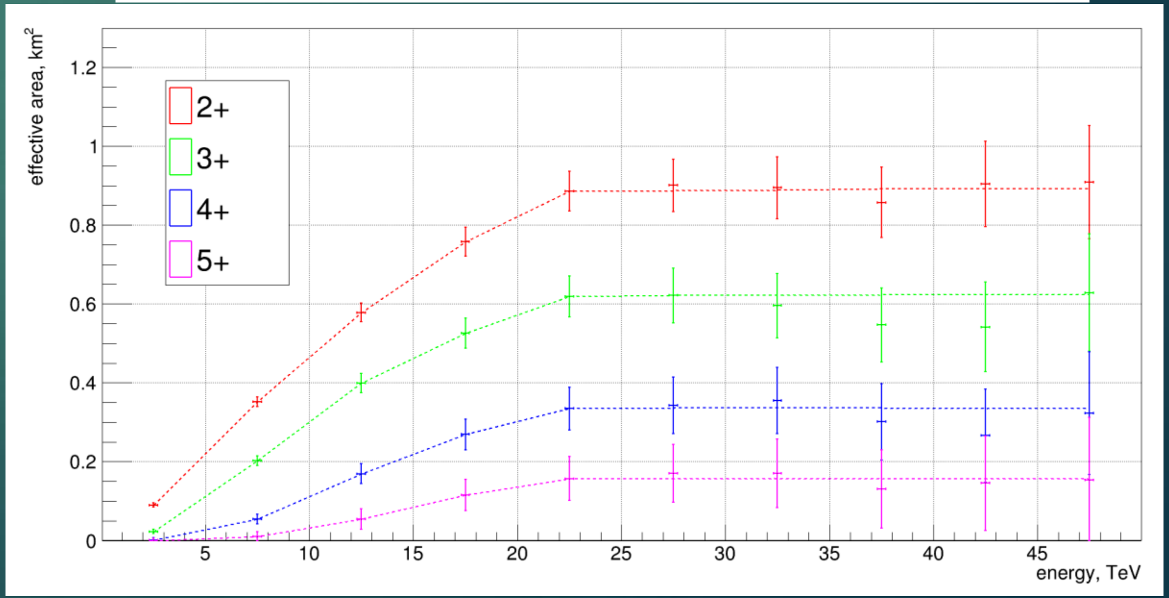
For each energy bin (5 TeV), the number of generated gamma rays was calculated. The graphs show the effective areas of the installation at different energies for different types of detected events

with border pixels of camera



At an energy of 22 TeV in stereo mode, the effective installation area is ~ 0.9km^2

without border pixels of camera



Reconstruction of shower geometry

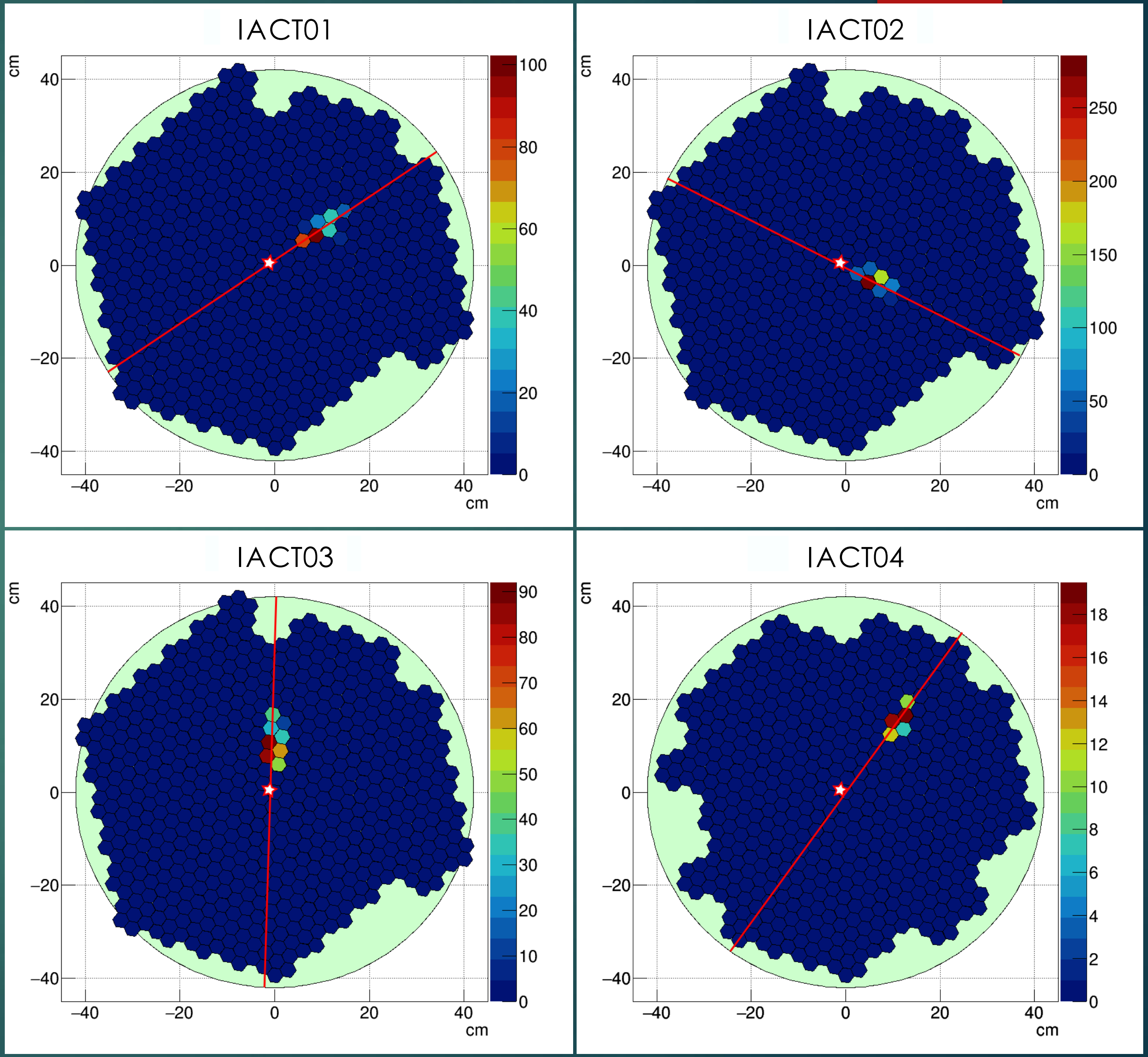
For
- 2+ triggered events,
- with *size* > 100 photoelectron
- without boundary pixels

basic suppresionn

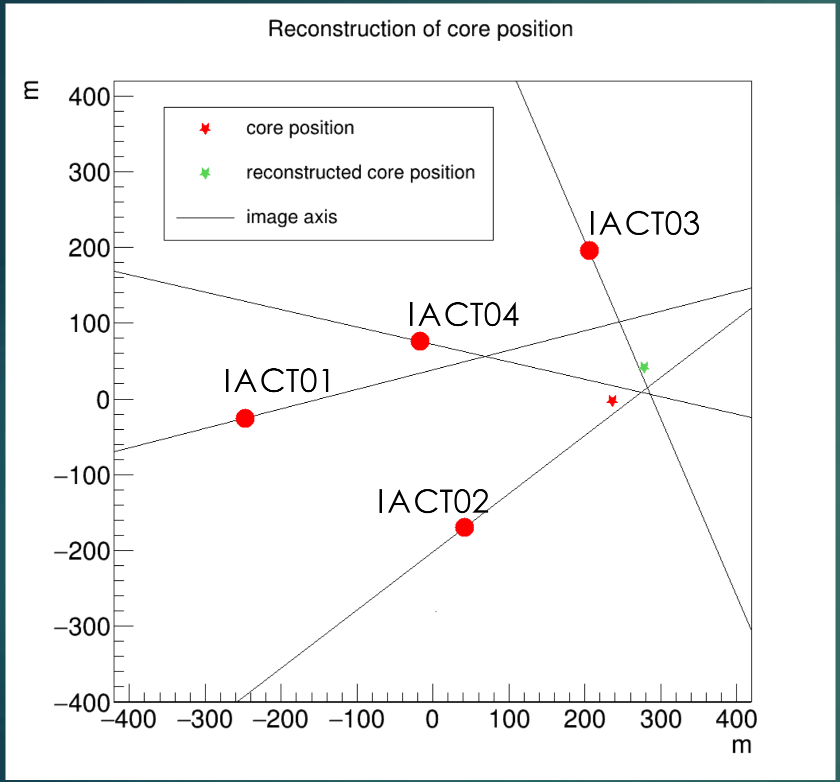
the shower geometry was reconstructed.

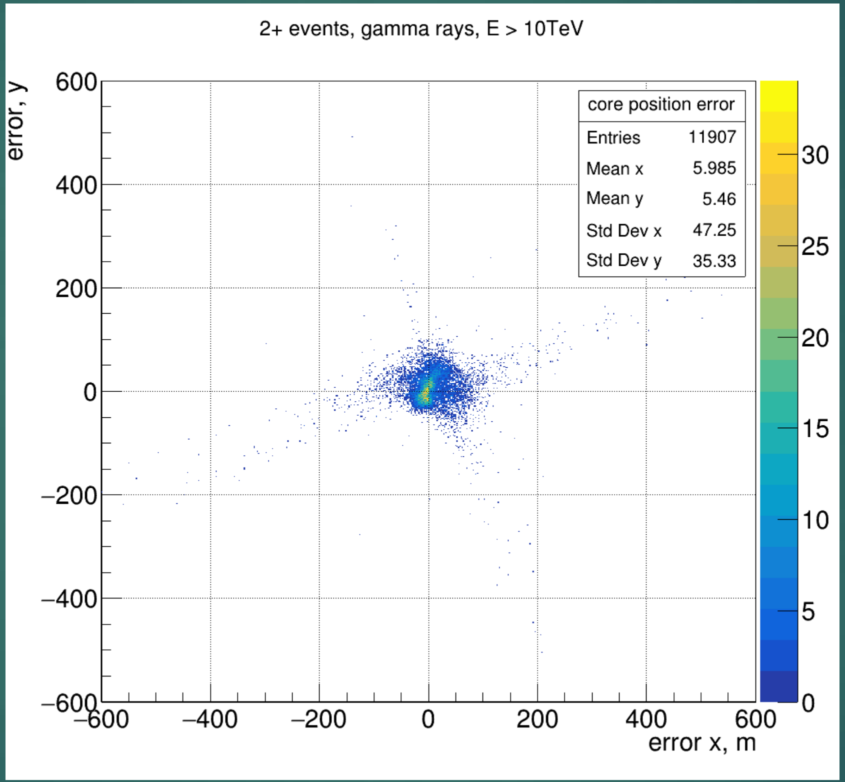
In particular, reconstruction of the core position of the EAS and the arrival direction of EAS in the FoV of the telescope can be performed.

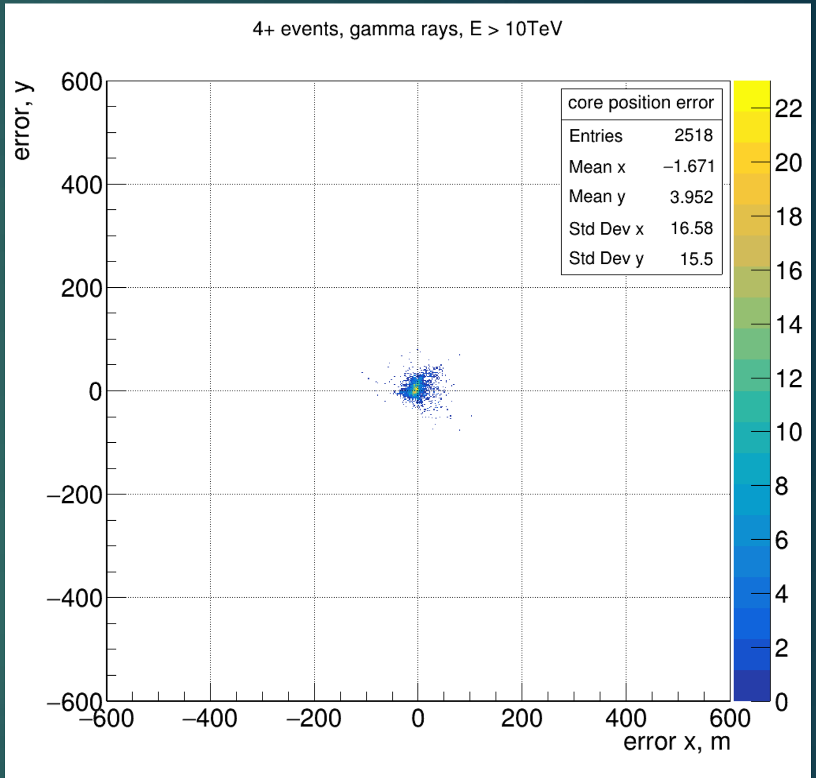
Example of event, detected by 4 telescopes



Error of EAS core position determination

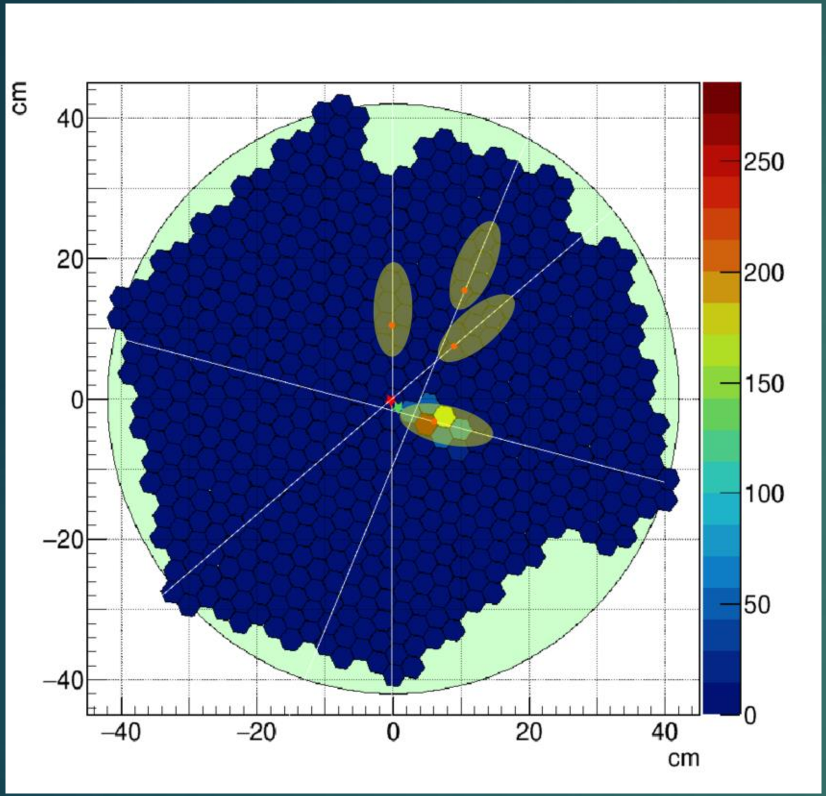


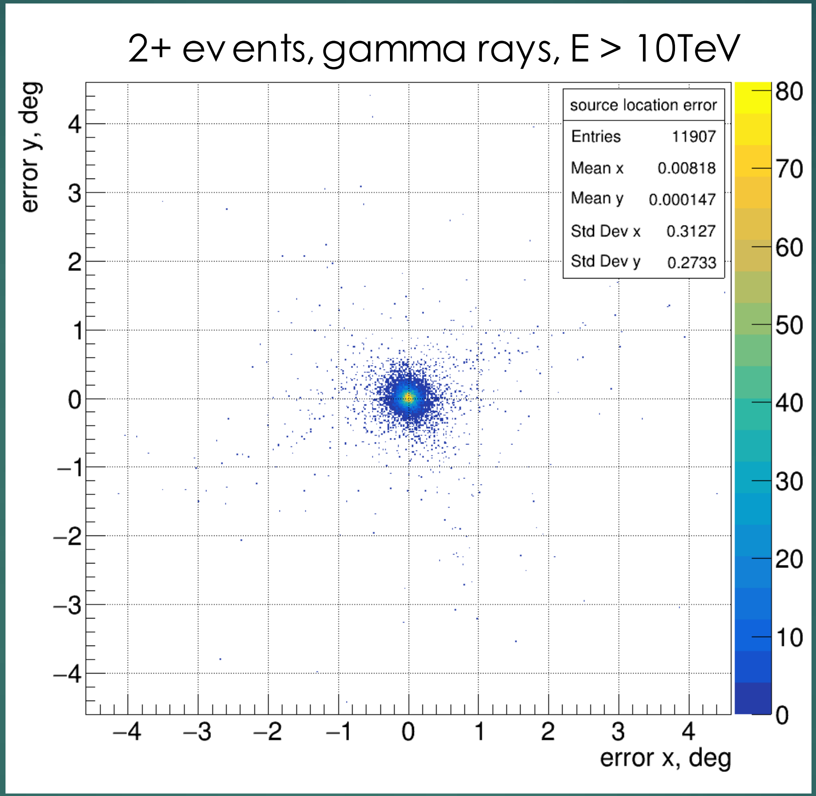


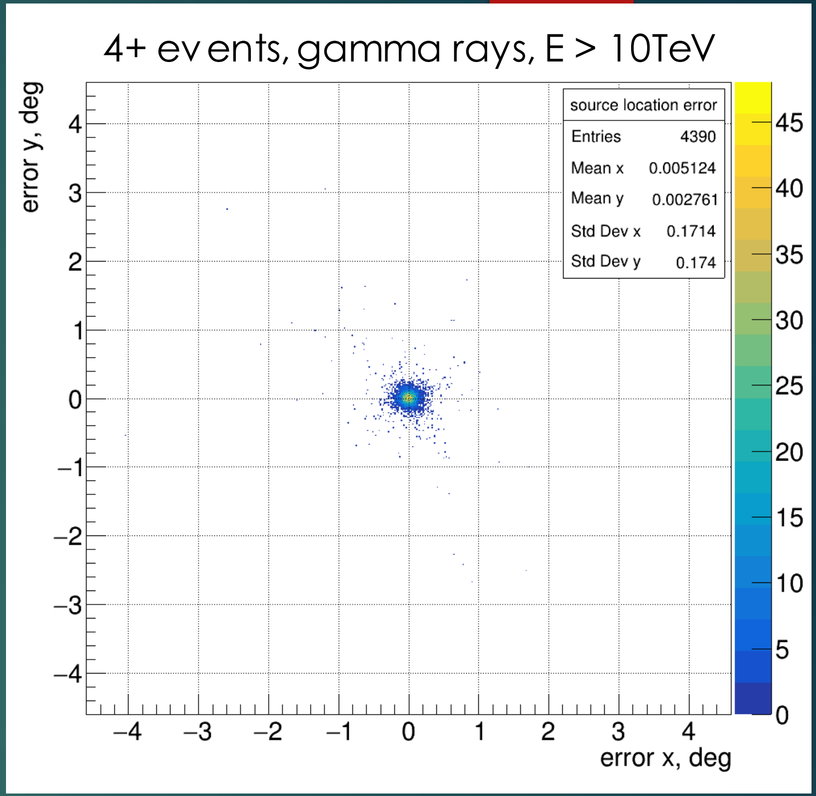


To determine the core position, the procedure for minimizing the distances to the axes connecting the image CoG and the shower arrival direction (so called *dist*) was used. In the case of triggering 4+ telescopes, the distribution RMS is ~ 16 m.

Reconstruction of the arrival direction of EAS



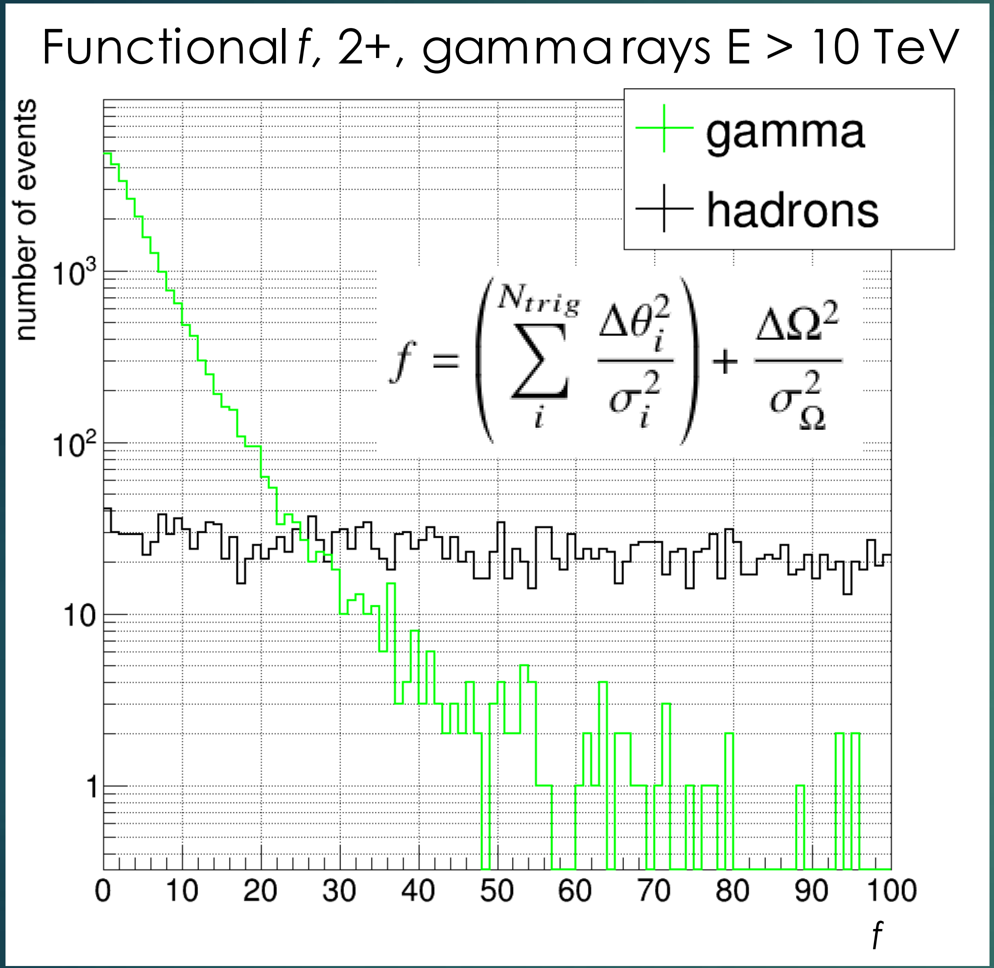


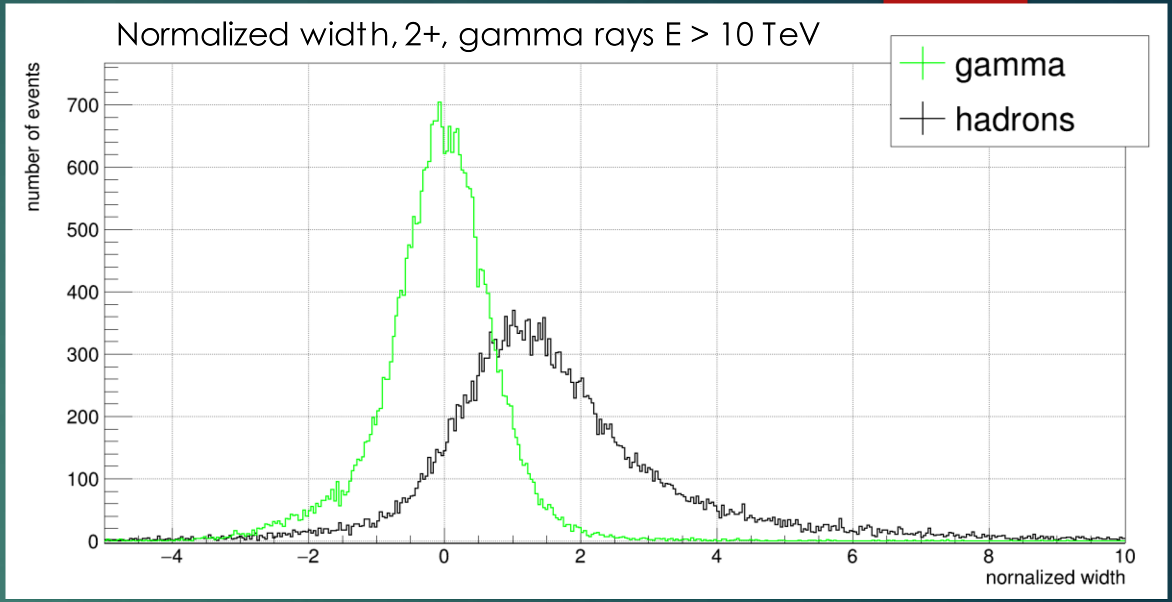


The arrival direction of particles was determined as the weighted (by image *size* and sinθ between intersection lines) average position of the points of intersection of the major axes of all ellipses.

Cut on error of arrival direction was defined as a circle with containment radius 68% of the events that passed basic suppression. The angular resolution for the 2+ events is $r_{68} = 0.2°$

Another parameters





$$w = \frac{1}{N_{\mathrm{trig}}} \times \left[\sum_{i}^{N_{\mathrm{trig}}} \frac{width_{\mathrm{i}} - w_{\mathrm{m}}(r_{\mathrm{i}}, size_{\mathrm{i}})}{w_{90}(r_{\mathrm{i}}, size_{\mathrm{i}})} \right]$$

Based on the reconstructed core positions, normalized widths were calculated.

Functional *f* minimizes error on the arrival direction of events in the telescope's FoV. This functional selects the position of the source near the intersection of the major axes of the ellipses and at small distance from the true arrival direction of events

Hadron suppresion

- Based on the considered parameters of MC events, the suppression coefficients of hadrons(2×10^{-5}) and gamma rays(2×10^{-1}) with energies above 10 TeV were obtained.

>10TeV	MC generated	hardware trigger	2+ events	exclusion of edge pixels	size > 100 phe	number of events within $r_{68} = 0.2°$	$f < 10$	$w < 0$
gamma	19627	19128	14973	14389	11907	8116	7454	3587
hadrons	215765	110354	48784	39550	29384	113	92	4

- The sensitivity of the TAIGA-IACT installation for 100 h at energy of 10 TeV is

  1.5×10^{-12} $TeV^{-1}cm^{-2}s^{-1}$

Conclusion

- A sufficiently large effective area (~1 km^2) and good angular resolution (r_{68}~0.2°) for gamma rays with energy above 10 TeV was derived from Monte Carlo simulation of 5 IACTs in TAIGA.
- Both sensitivity (~1.5×10^{-12} TeV^{-1} cm^{-2} s^{-1} for 100 h of observation) and northernmost location(51.49°N, 103.04°E) allow detailed studying energy spectra (>10 TeV) of many sources from the Crab Nebula and Mrk 501 to Dragonfly Nebula, Boomerang, ARGO J2031+4157 etc. and probably SNR CTA 1 and Tycho.
- Since fall 2021 three IACTs will be operating and available for the stereoscopic analysis. Two more IACTs are to be deployed by 2023.

Thanks for your attention