GAMMA-LIKE EVENT SELECTION AT THE TAIGA-IACT

62nd meeting of the PAC for Particle Physics

Bezyazeekov P.A., Ivanova A.D.
DLNP JINR, Dubna, Russia

Brief information

- TAIGA-IACT telescopes detect an image of Cherenkov radiation from the extensive air showers (EASs)
- Key challenge is to separate hadronic and gamma-ray-like events, as their ratio reaches the order of 10^5
- Different approaches to gamma-hadron separation at the TAIGA-IACT facility are proposed in this work

1. TAIGA-IACT telescopes

The TAIGA (Tunka Advanced Instrument for Cosmic Ray Physics and Gamma Astronomy) astrophysical complex is located in the Tunka Valley (Republic of Buryatia, Russia), 50 km from Lake Baikal at an altitude of 675 meters above sea level. It is designed for the detection of EAS initiated by cosmic rays and high-energy gamma quanta.

It includes wide-angle optical detectors Tunka-133 and TAIGA-HiSCORE, scintillation detectors Tunka-Grande and TAIGA-Muon, as well as Imaging Atmospheric Cherenkov Telescopes (IACTs) of TAIGA-IACT:

- 4 telescopes launched into operation
- Alt-azimuth mount
- Segmented mirror of Davis-Cotton design ~10m^2
- Cherenkov camera based on ~600 photomultipliers (PMTs)
- Pixel viewing angle – 0.36°
- Camera viewing angle – 9.72°
- Threshold energy 1.5 TeV

Fig.1 First telescope of the TAIGA-IACT

2. Data selection principle

- Cherenkov light from EAS is focused and creates an image on the camera (Fig.2, a)
- Analysis of the EAS image (Fig.2, b) allows the determination of the Hillas parameters (Fig. 2, c) and the type of the primary particle

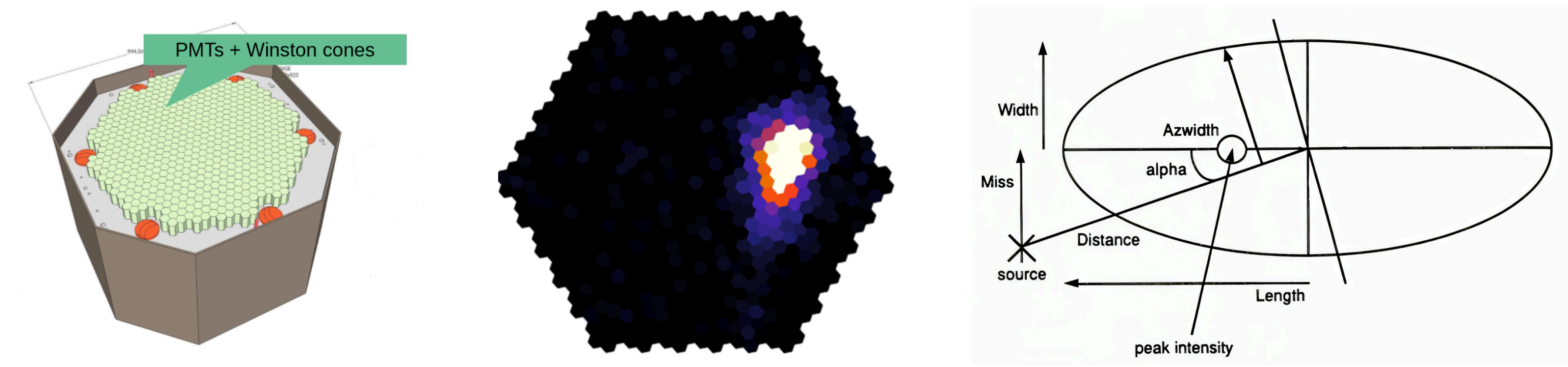


Fig. 2 Image of the Cherenkov camera with PMTs (a), example of an EAS event (b), Hillas parameters in the EAS image (c)

The main parameters include:

- Size – total number of photodiodes in the event
- Length – major axis of the ellipse
- Width – minor axis
- Azwidth – azimuthal width,
- Dist – distance between a center of the image and the source
- α1, α2 – angle between an ellipse major axis and direction to the source/anti-source
- Miss – error

3. Gamma-hadron separation methods

3.1 Distributions on Hillas parameters

Classic approach based on fixed cuts of Hillas parameters, as proposed in [1]. Tested on 2020-2022 data on the Crab Nebula from the TAIGA-IACT01. The excess is calculated as the difference between the distribution of gamma-like events at the source position and the average over 5 background positions.

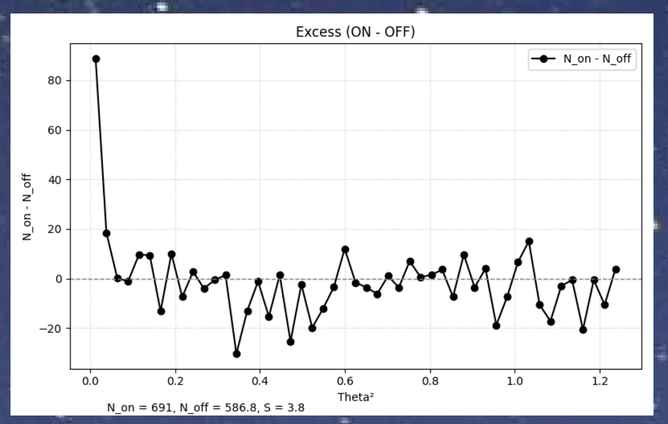
Common cuts on data quality:
- Count rate > 5 Hz
- Size > 120 p.e.
- Best weather mark
- No stars in field of view
- No border pixels flashed

Gamma selection cuts (MC tuned):
- 0.36 < dist < 1.44
- 0.024 < width < 0.068*log10(size – 0.047)
- length < 0.145*log10(size)

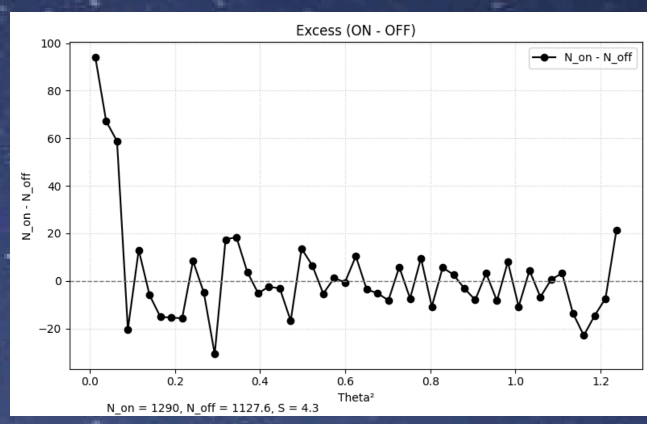
"Theta" is the distance between the gamma-source and the estimated source position.

Escess:

2020-2021



2021-2022



3.2 Random Forest (RF)

Random Forest binary classifier.

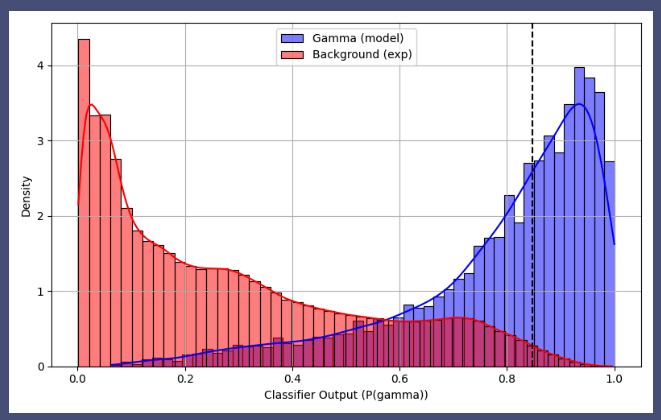
Structure:
- 100 decision trees
- 10 max depth
- threshold set to 80% survival

Selection cuts are generally the same as for classic approach, but were slightly relaxed to enlarge the training dataset:
- Size > 100
- 0.3 < dist < 1.5

Dataset:
- 8000 x2 samples size
- MC gamma events
- Experimental hadron events
- All events were processed with the standard denoising procedure based on amplitude threshold

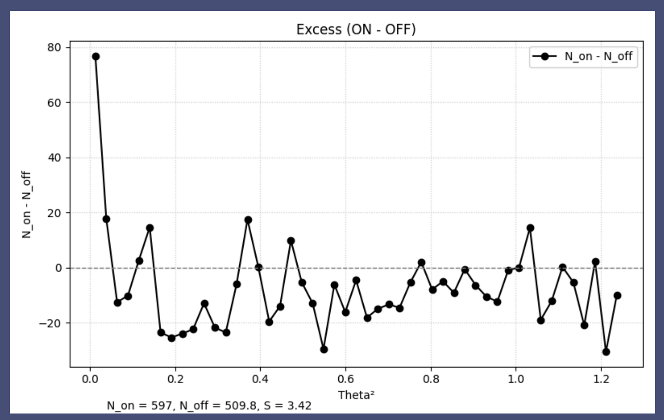
Input parameters:
- Size
- Width
- Length
- Dist
- Skewness along
- Skewness across
- Kurtosis along
- Kurtosis across

Example of classifier output on test dataset

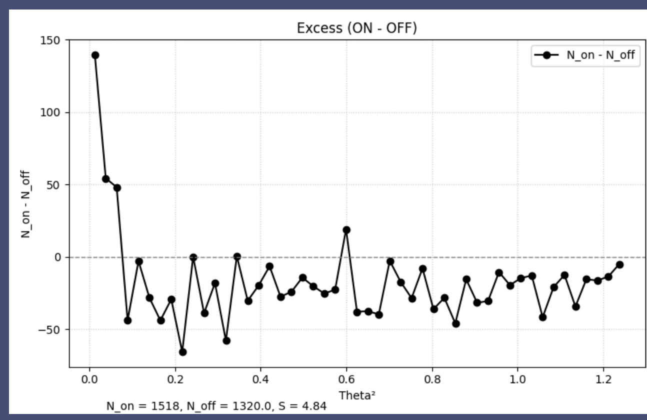


Escess:

2020-2021



2021-2022

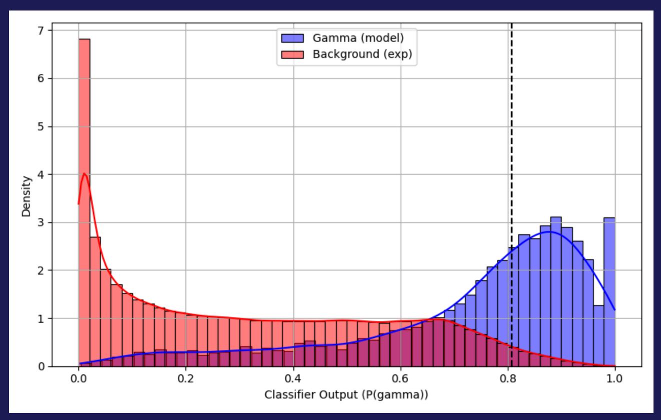


3.3 Neural network (NN)

Multi-layer fully-connected perceptron classifier.

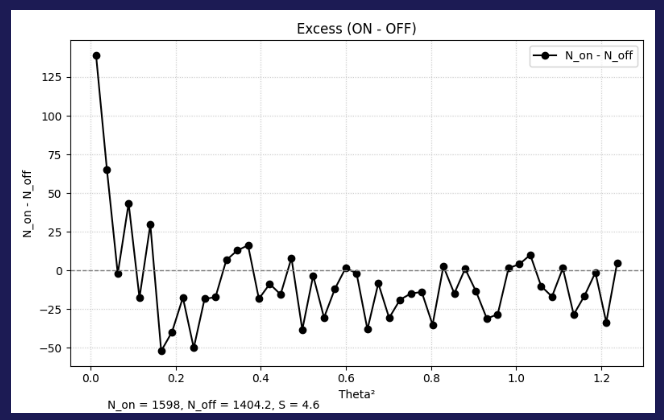
Structure:
- 8-16-8-4 neurons
- ReLU activation
- Input features normalized (StandardScaler)
- Adam optimizer

Example of classifier output on test dataset

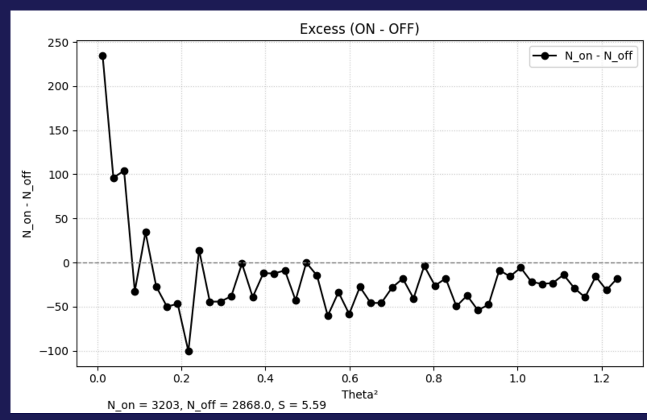


Escess:

2020-2021



2021-2022



4. Summary

The comparative analysis of various approaches for event separation based on IACT-recorded EAS images shows that NN approach gives the best significance with biggest fraction of survived events, while RF approach gives significance compared with classic one. We plan to continue our study with larger datasets and implement this approaches to full TAIGA-IACT data processing pipeline.

[1] Bull.Russ.Acad.Sci.Phys. 87 (2023) 7, 904-909 (TAIGA collaboration).