Influence of the geomagnetic field on gamma/hadron separation in Cherenkov telescopes

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VERITAS
DESY

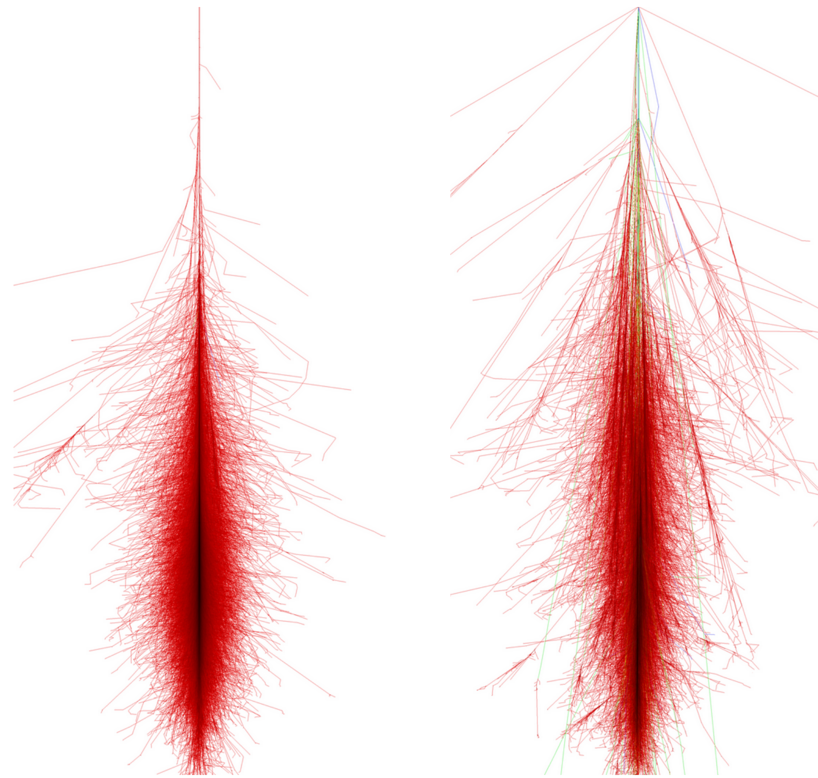
Background

VERITAS

- 4 ground based Cherenkov telescopes in Arizona (US)
- Maximum sensitivity: 100 GeV – 10 TeV
- For this project:
  - Background sample: VERITAS data
  - Signal sample: simulations

Gamma-ray and hadron showers

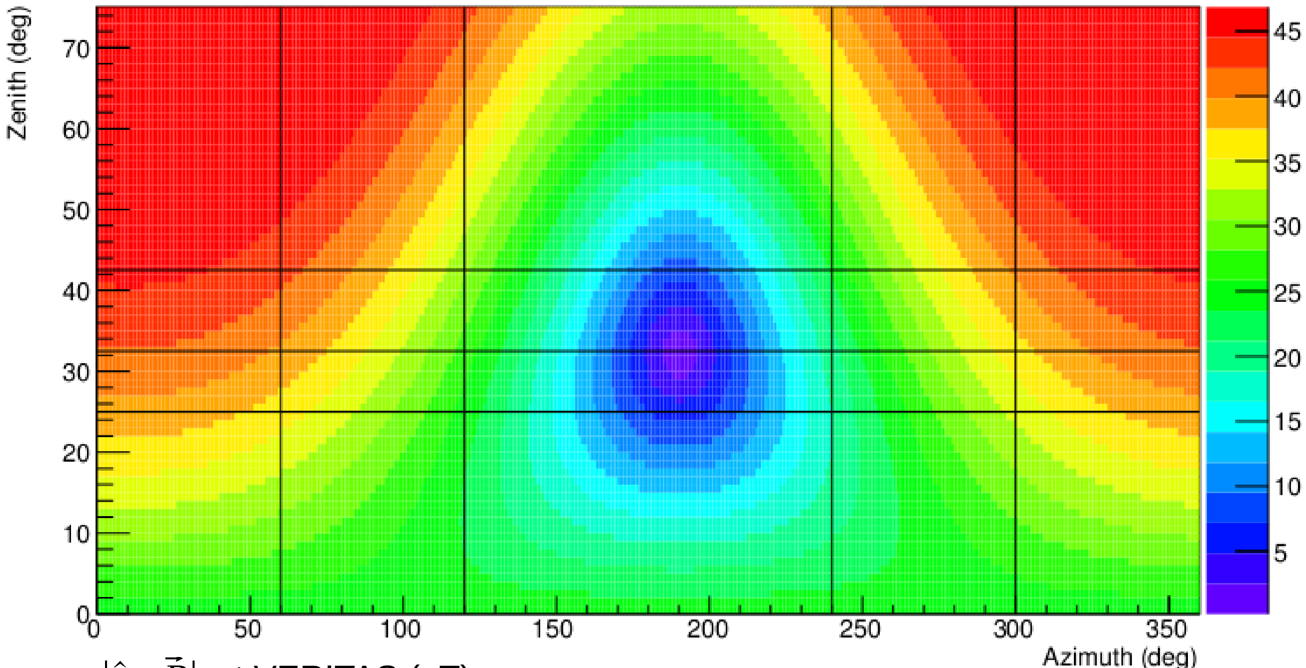
- Gamma rays produce an electromagnetic cascade: extensive air shower
- Gamma-ray showers are different from proton showers
- The geomagnetic field influences the shape of the showers



1 TeV gamma ray 1 TeV proton

The geomagnetic field

Lorentz force: $\vec{F} = q(\vec{v} \times \vec{B})$



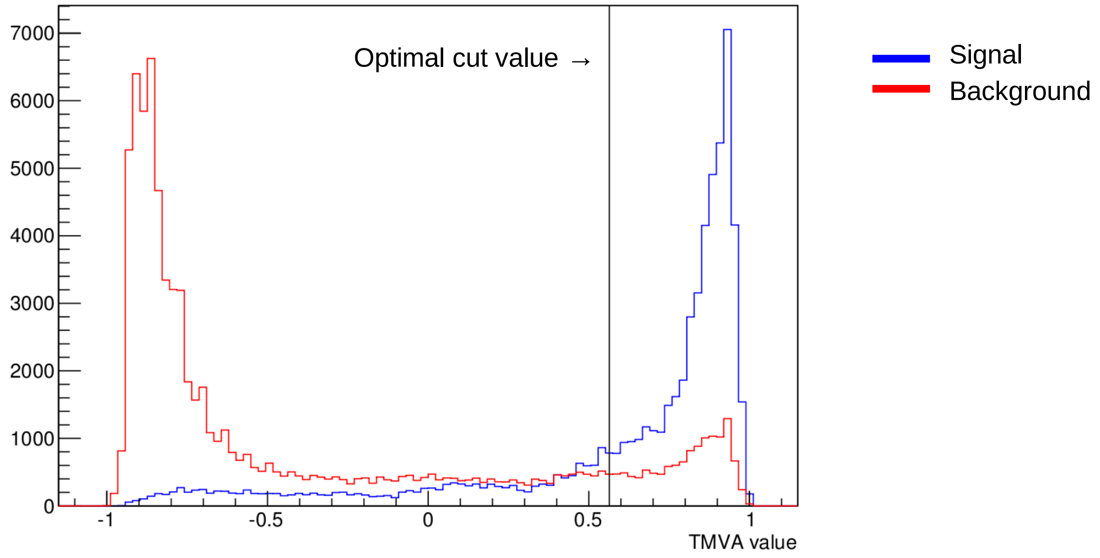
$|\hat{r} \times \vec{B}|$ at VERITAS (nT)

Project:

- Does this influence the separation of gamma-ray and proton showers?
- Can we improve gamma/hadron separation by taking it into account?

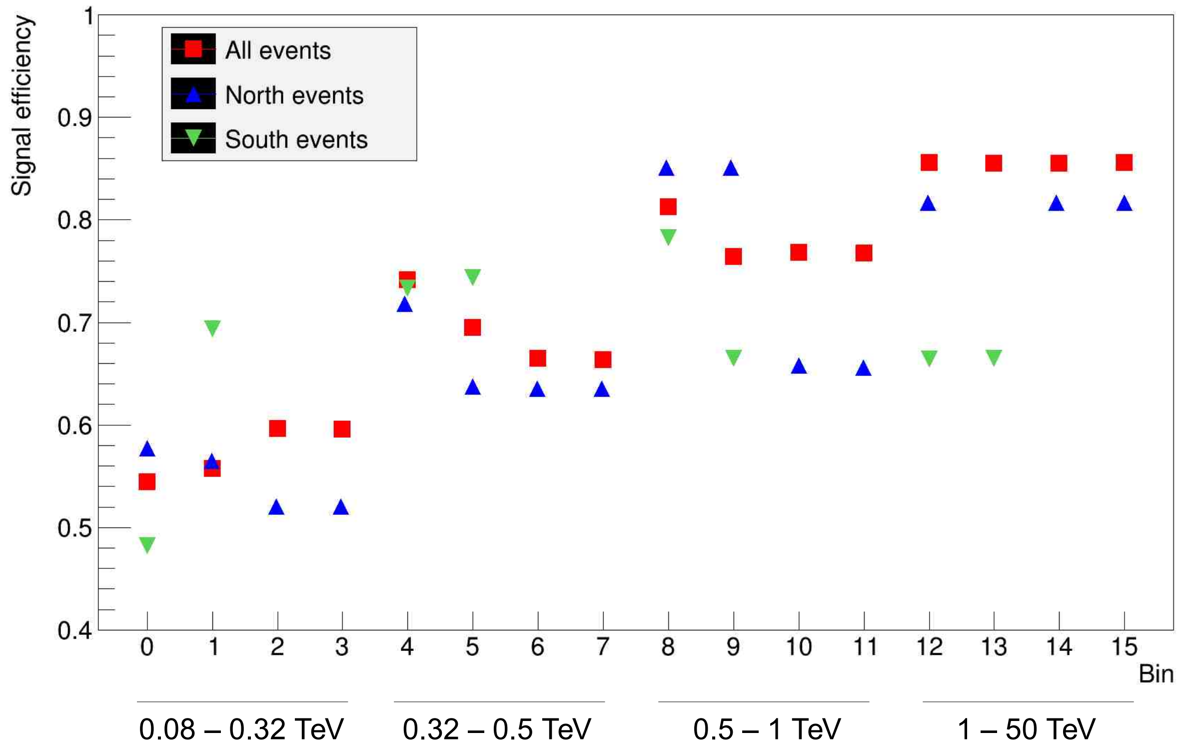
Boosted Decision Trees (BDTs)

- Multivariate analysis technique
- Built (trained) and tested with a sample of known signal and background events
- Each event → value from -1 to 1
- Best cut value: highest significance
- To compare performance of BDT: signal and background efficiency



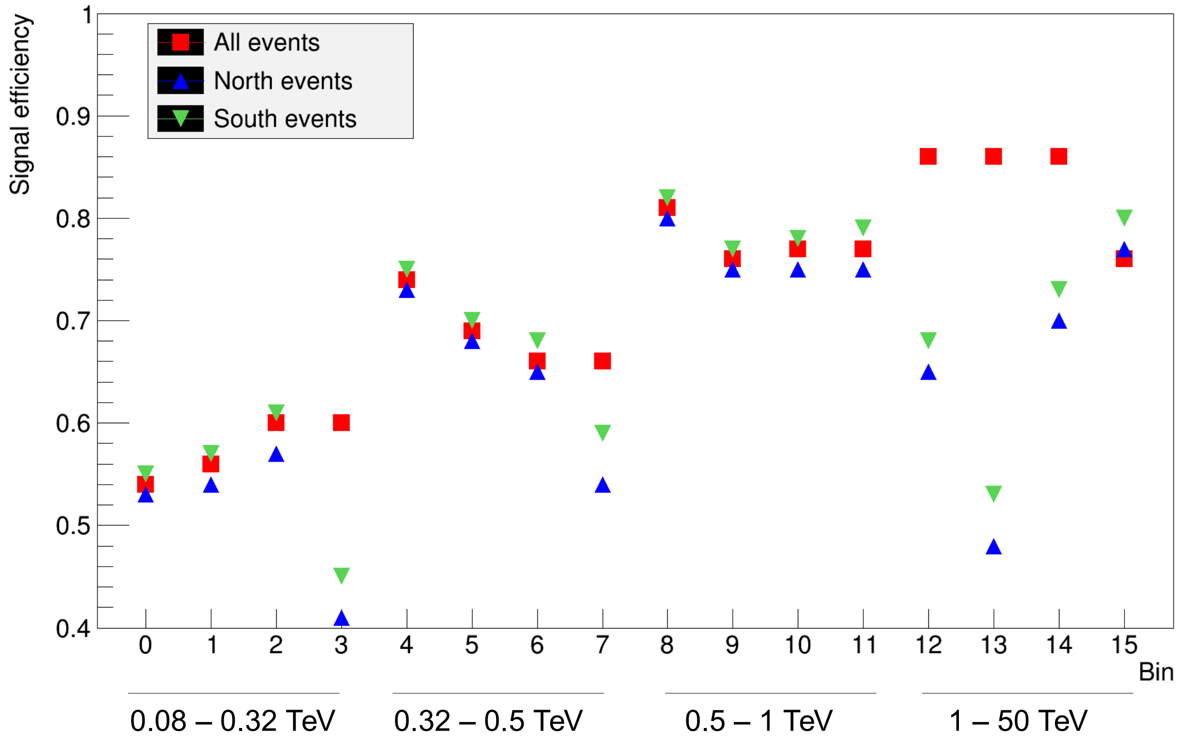
BDT training for north and south

- Two sets of BDTs trained with only N and S events (separately)
- Differences in signal efficiencies → direction influences training
- Not conclusive



BDT training for all directions

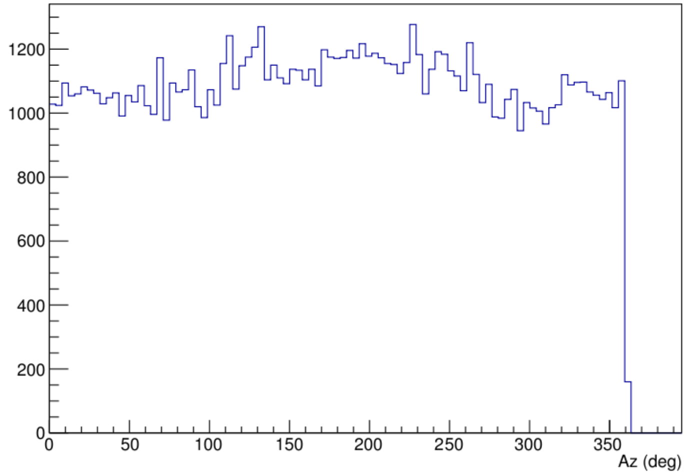
- BDTs trained with events from all directions
- Question: are events from a certain direction more accurately classified?
- Comparison of efficiency when looking only at N or S events
- South signal efficiency higher for all bins → agreement with initial expectations



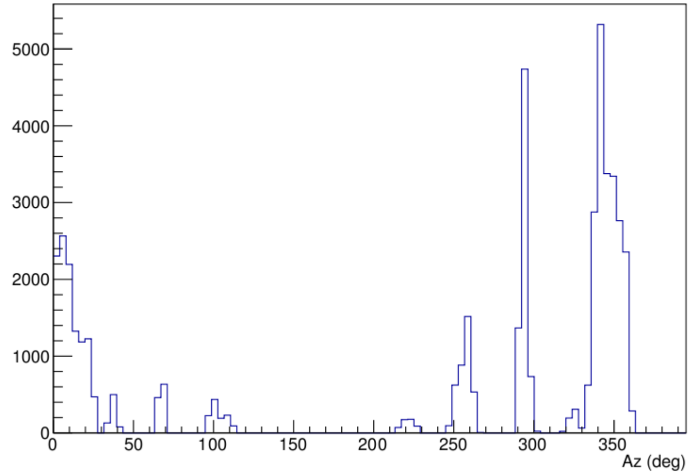
BDT training for all directions – Azimuth distribution

Surprise: background sample used for training is not evenly distributed (specially S).

- Limit in analysis
- Focus on N-trained BDTs



(a) All signal events



(b) All background events

E = 0.5 - 1 TeV, Ze = 25 - 32.5º

Check with data

- Analysis of a northern gamma ray source: binary system LSI +61 303
- 3 different methods:
  - Box cuts
  - Conventional BDTs
  - N-trained BDTs
- No improvement of significance for N-trained BDTs

Method	N_{on}	N_{off}	σ
Box cuts	1006	518	17.2
BDT cuts	792	336	19.1
North-trained BDT cuts	788	339	18.8

Conclusions

- **The direction of the showers influences their classification in BDT → the geomagnetic field affects BDT performance**
- In a conventional BDT, southern showers are better classified (as expected)
- Still unclear if training for different directions could improve BDT performance

Further studies:

- Training for N and S with larger and evenly distributed background sample
- Study of southern source with S-trained BDTs (improvement more likely)

Thank you for your attention!

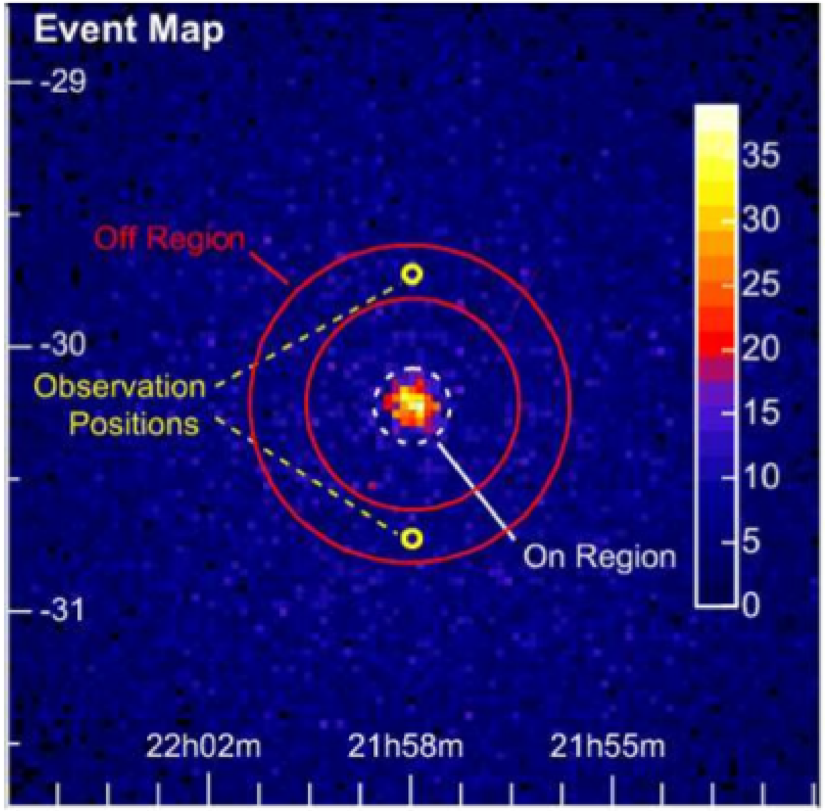
Significance

$$S = \sqrt{-2 \ln \lambda} = \sqrt{2} \left\{ N_{\mathrm{on}} \ln \left[\frac{1+\alpha}{\alpha} \left(\frac{N_{\mathrm{on}}}{N_{\mathrm{on}} + N_{\mathrm{off}}} \right) \right] + N_{\mathrm{off}} \ln \left[(1+\alpha) \left(\frac{N_{\mathrm{off}}}{N_{\mathrm{on}} + N_{\mathrm{off}}} \right) \right] \right\}^{1/2}$$

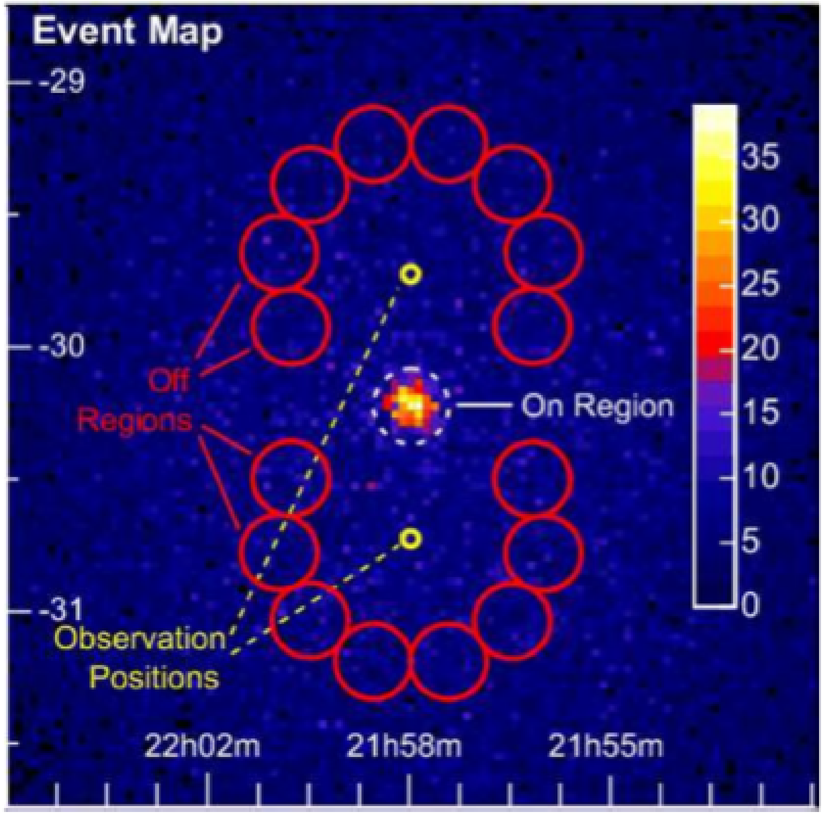
$$p = N(u = S; 0, 1)$$

Li & Ma, 1983

On and *Off* events



Ring background



Reflected region