



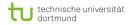
Automatization of the Reduction of MAGIC Sum-Trigger-II Data

Implementation of a Dedicated Workflow in the autoMAGIC Project

Jan Lukas Schubert

Master Talk 29. Oktober 2021

Experimentelle Physik 5b Fakultät Physik





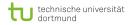
Content

- Gamma astronomy basics
- Analysis of MAGIC data →MARS: MAGIC Analysis and Reconstruction Software →autoMAGIC: Automatic analysis of MAGIC data
- Sum-Trigger-II
- Implementation of the analysis of Sum-Trigger-II data in autoMAGIC
- Test analysis of the Crab Nebula
- Conclusion and outlook





Gamma Astronomy Basics





Overview Astroparticle Physics

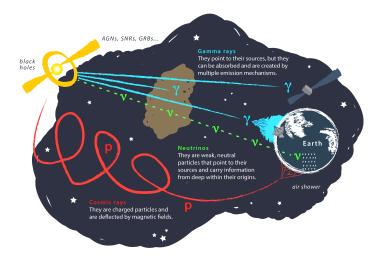
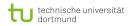


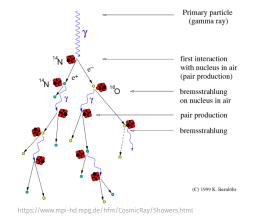
Image: Juan Antonio Aguilar and Jamie Yang. IceCube/WIPAC.



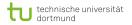
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Interactions with the Atmosphere

- Atmosphere is not transparent to gamma photons
 - \rightarrow Direct measurement with satellites or indirect measurement with Cherenkov telescopes
- Gamma photon produces extended air shower
- Charged secondary particles emit Cherenkov radiation



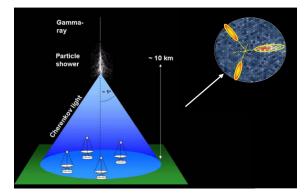
Development of gamma-ray air showers



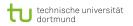


Cherenkov Radiation

- Charged particle faster than the speed of light in the medium
 - \rightarrow elementary dipoles align
 - \rightarrow constructive interference
 - \rightarrow Cherenkov radiation
- Emission in a Cherenkov cone
- Cherenkov photons can cause ejection of electrons in photomultiplier tubes →Current can be measured



http://www.ung.si/media/storage/cms/images/2015/02/13/15/47/33/02_stereoscopic_ technique.jpg





The MAGIC-Telescopes

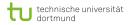
- Major Atmospheric Gamma-Ray Imaging Cherenkov Telescopes
- Two Cherenkov telescopes on La Palma
- Detection of gamma rays with energies in the GeV-/TeV range
- Data taking in the wobble mode







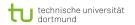
Analysis of MAGIC Data





MAGIC Standard Analysis

- MARS: MAGIC Analysis and Reconstruction Software
- Analysis steps are performed by individual executables
- Data types required for the analysis:
 - \rightarrow On data
 - \rightarrow Off data
 - \rightarrow Monte Carlo (MC) data

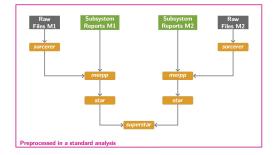


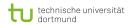


MAGIC Standard Analysis

sorcerer: Calibration

- merpp: Merge subsystem reports and sorcerer output
- **star**: Image cleaning and image parameterization
- **superstar**: Stereo reconstruction

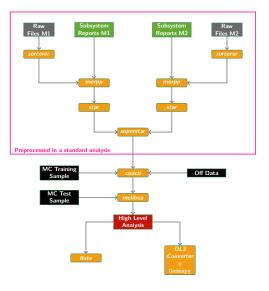


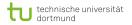




MAGIC Standard Analysis

- **coach**: Train models for the event reconstruction
- melibea: Apply the trained models to the data
- *flute*: Compute lightcurve
- DL3 Converter: Compute DL3 Data





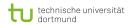


autoMAGIC - Automatized Analysis of MAGIC Data

Project initiated by Lena and Simone for their PhD theses

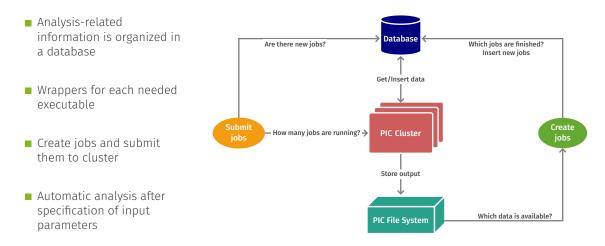
Already supports:
 →MAGIC standard analysis
 →Analysis of moon data
 →DL3

Implementation of automatic analysis of Sum-Trigger-II data done in this work





autoMAGIC - Basic Structure

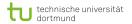






autoMAGIC - A Little Impression of the Database

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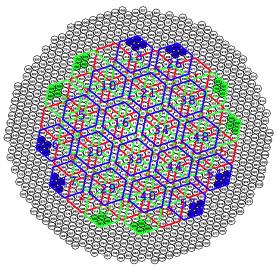


Sum-Trigger-II

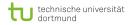
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Sum-Trigger-II - Hardware

- Aim of Sum-Trigger-II: Lower the trigger threshold
- Camera is divided into macrocells of 19 pixels each
- Three overlapping layers of macrocells
- Signal in macrocell is summed up
- Threshold is applied to summed signal of macrocells



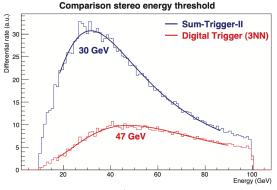
arXiv:1404.4219v1





Sum-Trigger-II - Benefits

- Improvement of signal to noise ratio
- Sensitivity for low-energy photons increased
- Threshold lowered from ~50 GeV to ~25 GeV
- Dedicated analysis required:
 - \rightarrow Special image cleaning
 - \rightarrow Removal of bright stars in field of view
 - \rightarrow Adaptions of thresholds

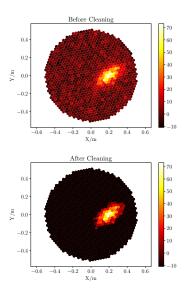


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Analysis of Sum-Trigger-II Data - Image Cleaning

- Special image cleaning ("MaTaJu Cleaning") needed
 - $\rightarrow\!\mathsf{Applied}$ during calibration
 - \rightarrow Start on raw data needed
 - $\rightarrow \text{MARS}$ executables sorcerer and merpp needed
- MaTaJu Cleaning:
 - $\rightarrow\!\mathsf{Aim}:$ Lower the threshold for the image cleaning
 - $\rightarrow \mbox{Dynamic cuts}$ for thresholds and time coincidences
- MaTaJu cleaning is very sensitive to correlated noise between pixels







Analysis of Sum-Trigger-II Data - Removal of Bright Stars

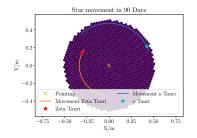
- Bright stars cause local noise which can be easily misinterpreted as showers
 - \rightarrow Exclusion of pixels around bright stars needed

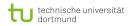
 $\rightarrow \mbox{Radius}$ of area of excluded pixels depends on brightness of star

- Removal is necessary for:
 - \rightarrow On data
 - \rightarrow Off data
 - \rightarrow MC test sample
- Removal in MC test sample necessary because otherwise mismatch in effective collection area

Stars move in the camera

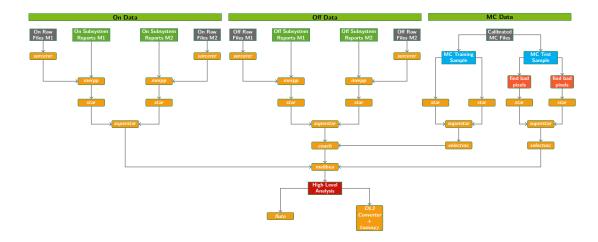
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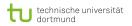
Analysis of SumTrigger-II Data - Overview







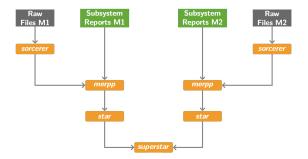
Analysis of Sum-Trigger-II data in autoMAGIC

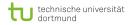




Data Analysis Chain

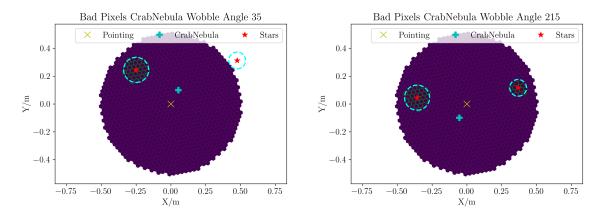
- Implement additional MARS executables (necessary due to MaTaJu cleaning)
 →sorcerer
 →merpp
- Implement changes in star and superstar →Different cuts
 - $\rightarrow \text{Exclusion}$ of pixels around bright stars

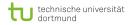




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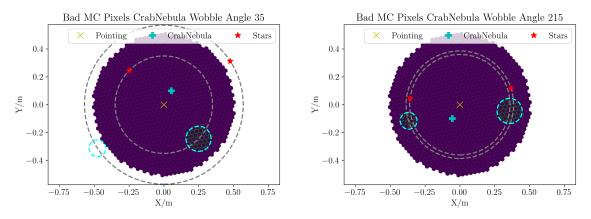
Data Analysis Chain - Exclusion of Pixels





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Monte Carlo Analysis Chain - Exclusion of Pixels



One dedicated MC set for each wobble position for each source!



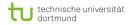
Another Quick Look at the Database

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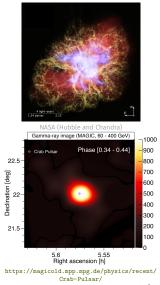
Test Analysis of the Crab Nebula

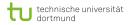




Test Analysis of the Crab Nebula

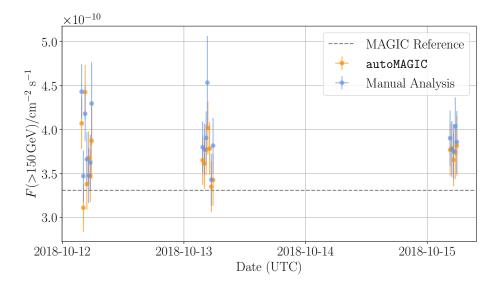
- Standard candle in the gamma astronomy
- Small data sample of the Crab Nebula from 2018-10-12 to 2018-10-15
- Off Data: B20234+28 from 2018-09-21 to 2018-10-18
- Automatic and manual analysis

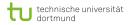






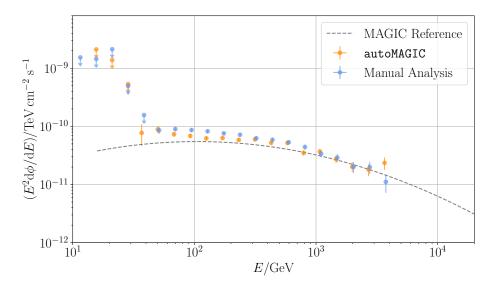
Lightcurves

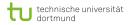






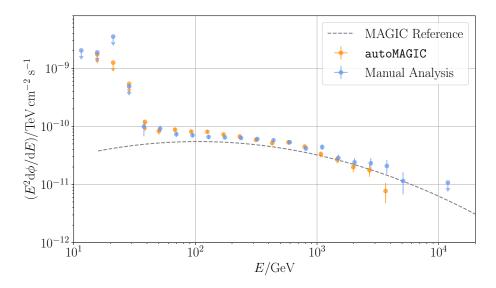
Spectral Energy Distribution W1







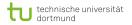
Spectral Energy Distribution W2







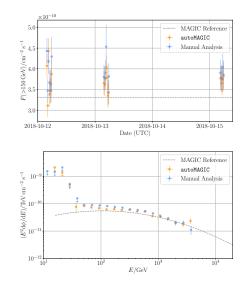
Conclusion and Outlook

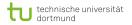




Conclusion

- Dedicated analysis chain for Sum-Trigger-II Analysis implemented in autoMAGIC →MaTaJu cleaning
 - $\rightarrow \text{Exclusion}$ of pixels around bright stars
 - \rightarrow Complex MC analysis structure
- Test Analyses of the Crab Nebula deliver comparable results
- Automatized analysis shows good performance







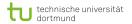
Outlook

- Optimize cleaning parameters
- MC analysis chain from raw level
- Optimize exclusion radii for bright stars
- Comparison of results of MAGIC Sum-Trigger-II and CTA LST data



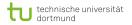


Thank You for Your Attention!





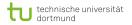
Backup





Standard Cleaning (Sum Cleaning)

- Signal of 2-4 nearest neighbors is summed up
- Threshold depends on multiplicity
- Above threshold: Take pixels as core pixels
- Search boundary pixels next to core pixels and already taken boundary pixels

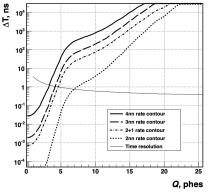


MaTaJu Cleaning

- Cuts for thresholds and time coincidences not static →Dynamical cut depends on noise of each pixel
- Image: Curves for constant accidental rates in the ΔT -Q phase space

 $\rightarrow \! \text{Values}$ above the curves are classified as noise





arXiv:1307.4939





Standard Trigger

- Three Trigger Levels: →L0: Amplitude of each pixel
 - \rightarrow L1: Groups of 2-4 nearest neighbors above threshold
 - \rightarrow L3: Stereo trigger
- For Sum-Trigger-II the L1 trigger is replaced by summing up the signal in each macrocell!