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

Implementation of a Dedicated Workflow in the `autoMAGIC` Project

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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
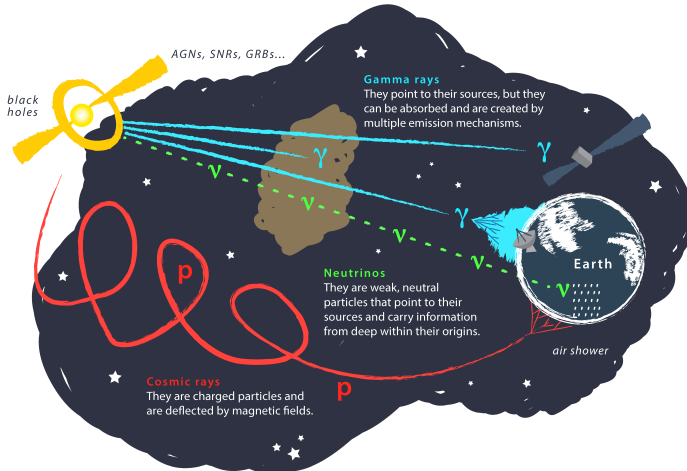
Gamma Astronomy Basics

Overview Astroparticle Physics

AGNs, SNRs, GRBs...

black holes

Gamma rays
They point to their sources, but they can be absorbed and are created by multiple emission mechanisms.

γ

γ

γ

Neutrinos
They are weak, neutral particles that point to their sources and carry information from deep within their origins.

p

Earth

air shower

Cosmic rays
They are charged particles and are deflected by magnetic fields.

p

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

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

https://www.mpi-hd.mpg.de/hfm/CosmicRay/Showers.html
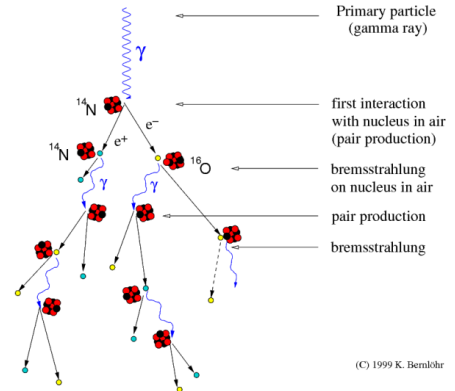
Cherenkov Radiation

- Charged particle faster than the speed of light in the medium
  →elementary dipoles align
  →constructive interference
  →Cherenkov radiation

- Emission in a Cherenkov cone

- Cherenkov photons can cause ejection of electrons in photomultiplier tubes
  →Current can be measured
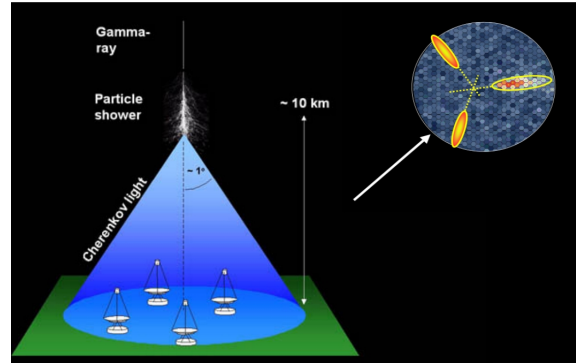
http://www.ung.si/media/storage/cms/images/2015/02/13/15/47/33/02_stereoscopic_technique.jpg

The MAGIC-Telescopes

- **M**ajor **A**tmospheric **G**amma-Ray **I**maging **C**herenkov 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**: **M**AGIC **A**nalysis and **R**econstruction **S**oftware

- Analysis steps are performed by individual executables

- Data types required for the analysis:
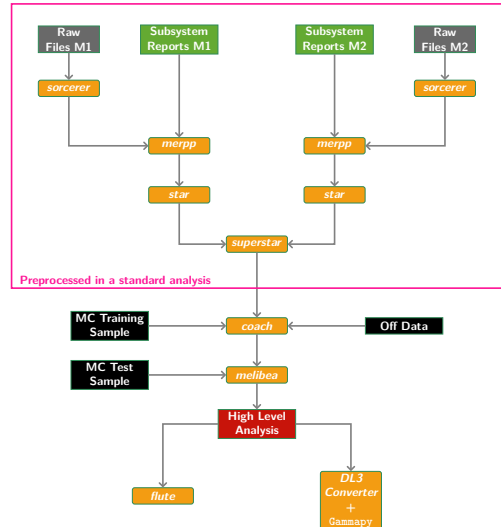 →On data
  →Off data
  →Monte Carlo (MC) data

MAGIC Standard Analysis

- **sorcerer**: Calibration

- **merpp**: Merge subsystem reports and *sorcerer* output

- **star**: Image cleaning and image parameterization

- **superstar**: Stereo reconstruction
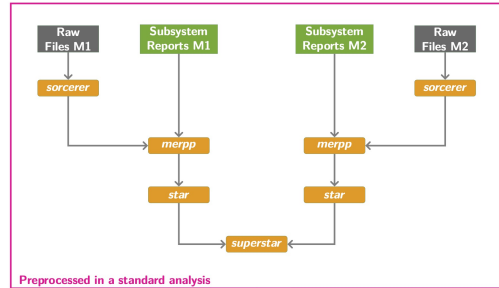
MAGIC Standard Analysis

- **coach**: Train models for the event reconstruction

- **melibea**: Apply the trained models to the data

- **flute**: Compute lightcurve
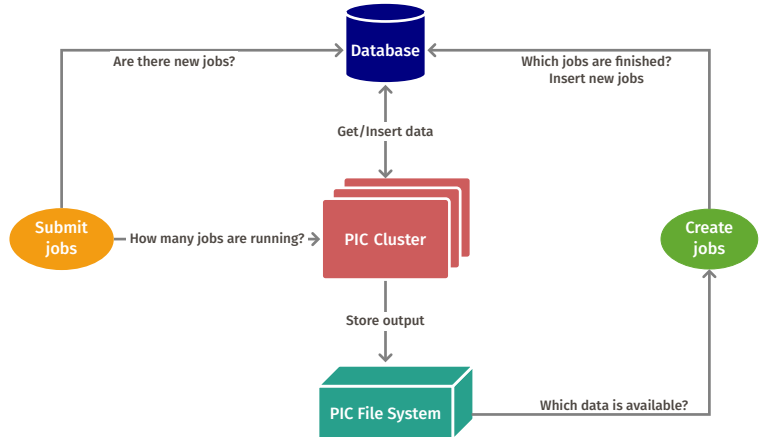
- **DL3 Converter**: Compute DL3 Data

`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

- Analysis-related information is organized in a database

- Wrappers for each needed executable

- Create jobs and submit them to cluster

- Automatic analysis after specification of input parameters

Database

Are there new jobs? →

Which jobs are finished?
Insert new jobs ←

Get/Insert data

Submit jobs — How many jobs are running? → **PIC Cluster**

Create jobs

Store output

PIC File System — Which data is available?

autoMAGIC - A Little Impression of the Database

Sum-Trigger-II

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
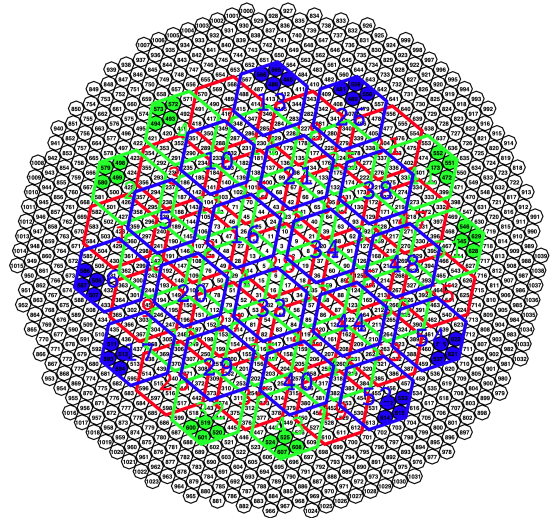

arXiv:1404.4219v1

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:
  →Special image cleaning
 →Removal of bright stars in field of view
  →Adaptions of thresholds

Comparison stereo energy threshold

Sum-Trigger-II
Digital Trigger (3NN)

30 GeV

47 GeV

arXiv:1404.4219v1
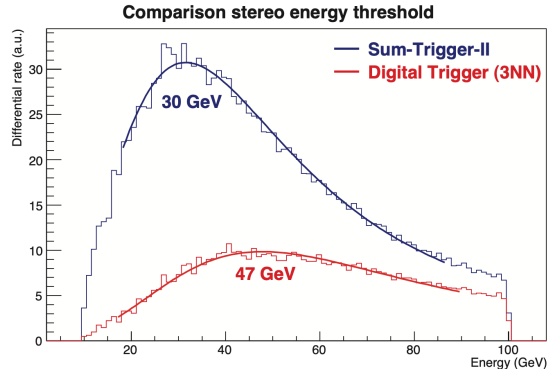
Analysis of Sum-Trigger-II Data - Image Cleaning

- Special image cleaning ("MaTaJu Cleaning") needed
  →Applied during calibration
  →Start on raw data needed
  →MARS executables *sorcerer* and *merpp* needed

- MaTaJu Cleaning:
  →Aim: Lower the threshold for the image cleaning
  →Dynamic cuts for thresholds and time coincidences

- MaTaJu cleaning is very sensitive to correlated noise between pixels

Before Cleaning

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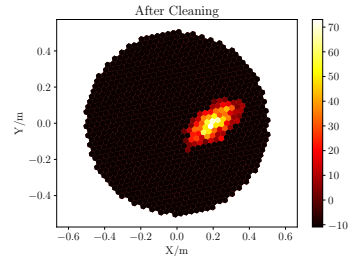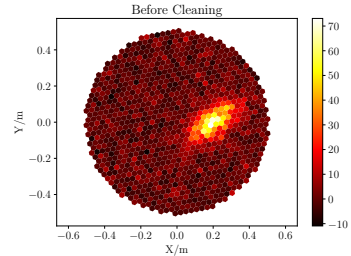
Analysis of Sum-Trigger-II Data - Removal of Bright Stars

- Bright stars cause local noise which can be easily misinterpreted as showers
  →Exclusion of pixels around bright stars needed
  →Radius of area of excluded pixels depends on brightness of star

- Removal is necessary for:
  →On data
  →Off data
  →MC test sample

- Removal in MC test sample necessary because otherwise mismatch in effective collection area
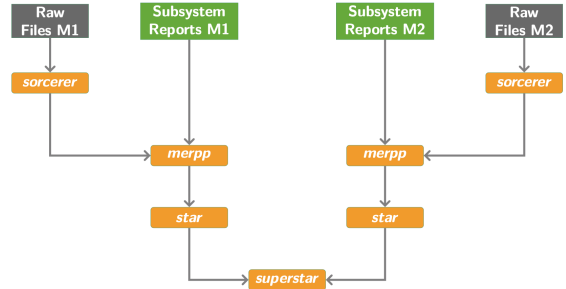
- Stars move in the camera

Star movement in 6 Hours

Star movement in 90 Days
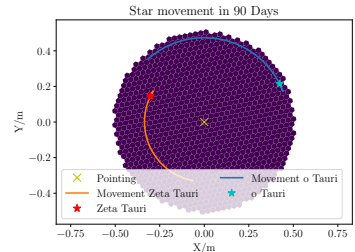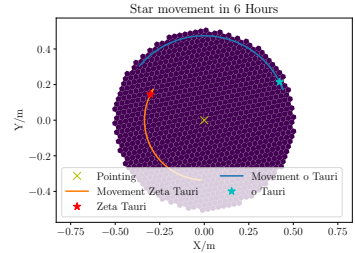
Analysis of SumTrigger-II Data - Overview
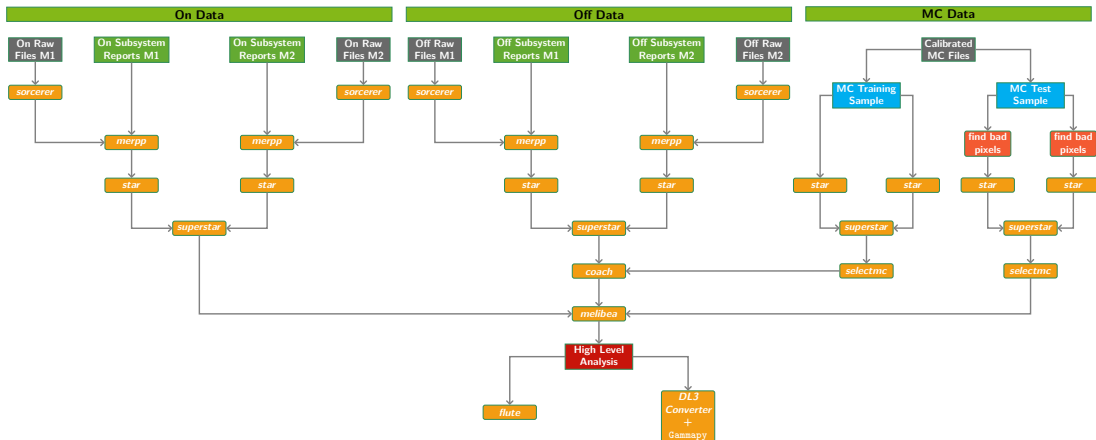
Analysis of Sum-Trigger-II data in `autoMAGIC`
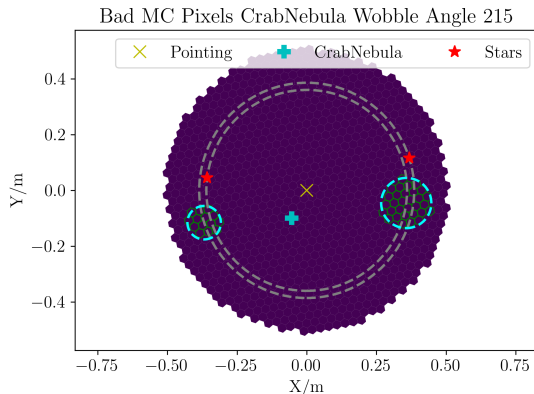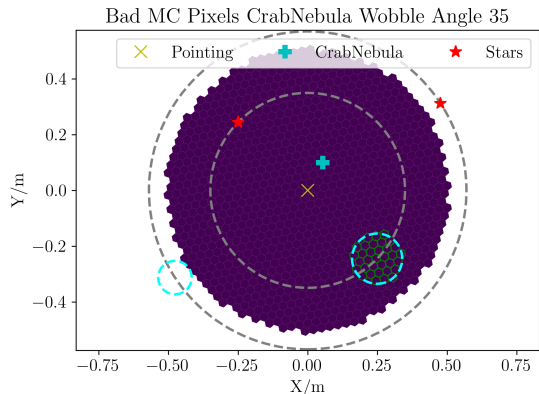
Data Analysis Chain

- Implement additional MARS executables (necessary due to MaTaJu cleaning)
  → *sorcerer*
  → *merpp*

- Implement changes in *star* and *superstar*
  → Different cuts
  → Exclusion of pixels around bright stars

Data Analysis Chain - Exclusion of Pixels

Bad Pixels CrabNebula Wobble Angle 35

Bad Pixels CrabNebula Wobble Angle 215
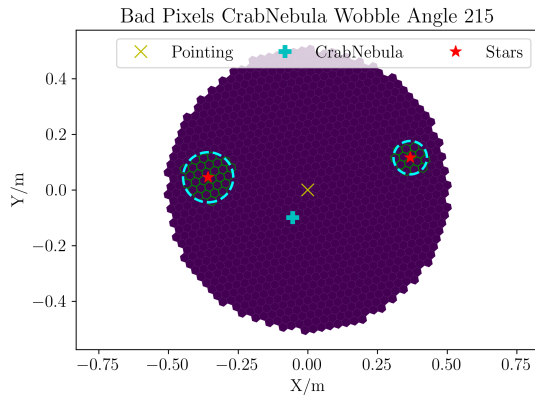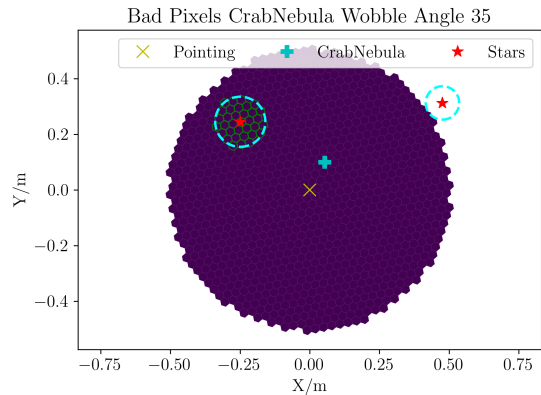
Monte Carlo Analysis Chain - Exclusion of Pixels

Bad MC Pixels CrabNebula Wobble Angle 35

Bad MC Pixels CrabNebula Wobble Angle 215

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

Another Quick Look at the Database
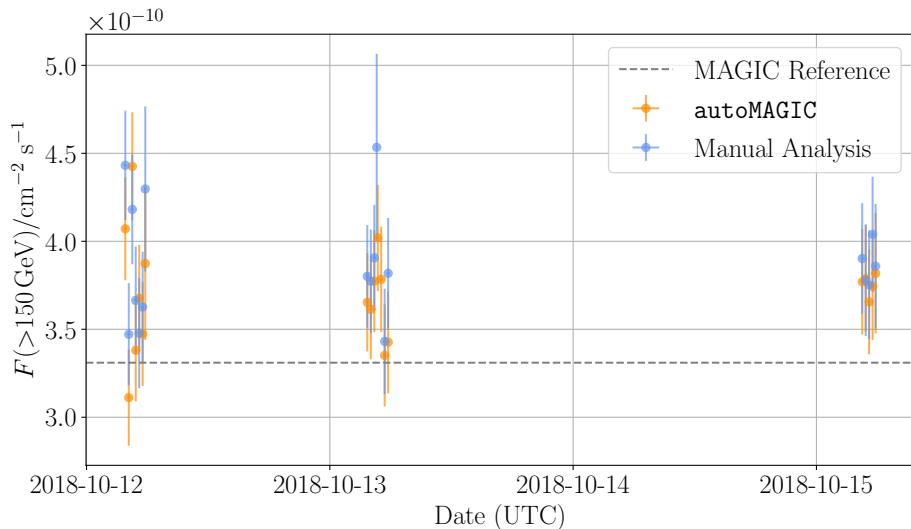
Test Analysis of the Crab Nebula

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

NASA (Hubble and Chandra)
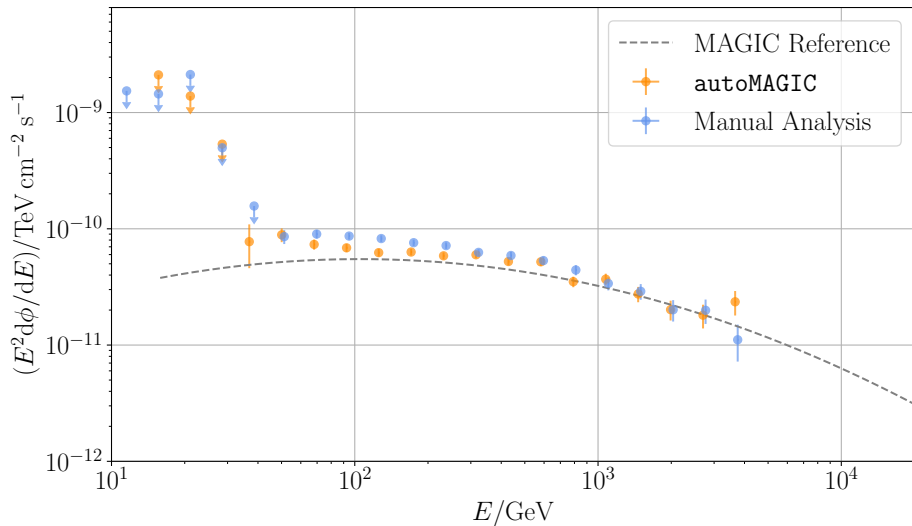

https://magicold.mpp.mpg.de/physics/recent/
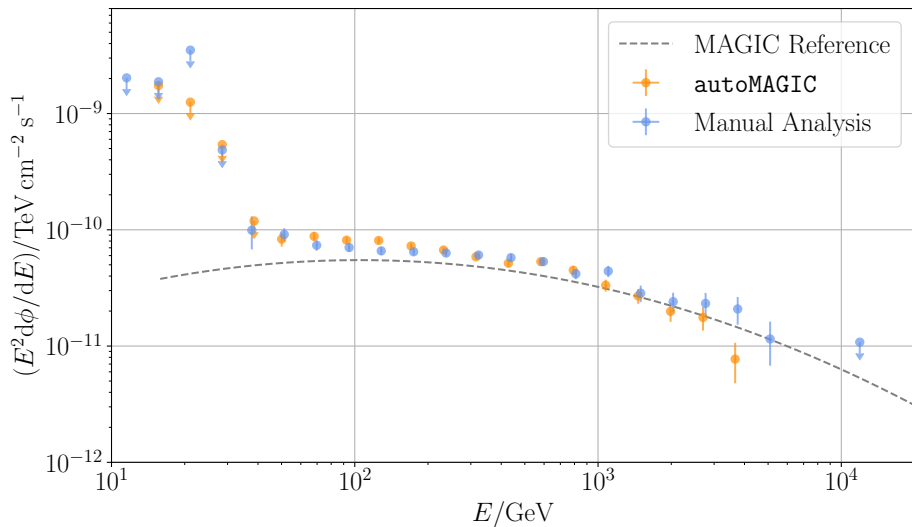Crab-Pulsar/
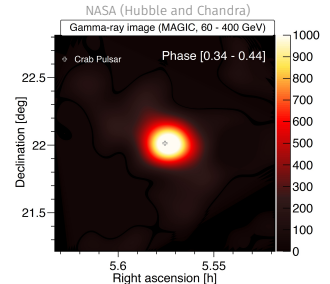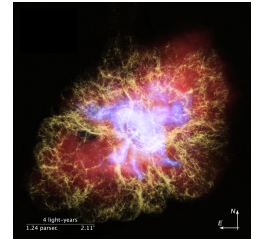
Lightcurves

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
  →Exclusion of pixels around bright stars
  →Complex MC analysis structure

- Test Analyses of the Crab Nebula deliver comparable results

- Automatized analysis shows good performance
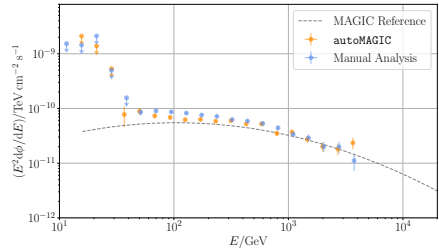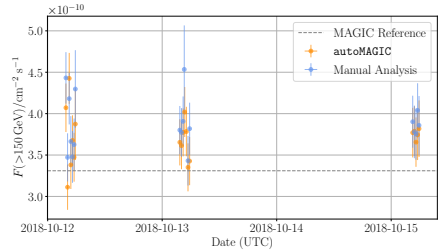
Outlook

- 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
  →Values above the curves are classified as noise
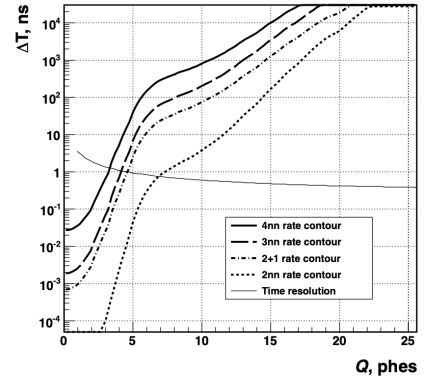
arXiv:1307.4939

Standard Trigger

- Three Trigger Levels:
    →L0: Amplitude of each pixel
    →L1: Groups of 2-4 nearest neighbors above threshold
    →L3: Stereo trigger

- For Sum-Trigger-II the L1 trigger is replaced by summing up the signal in each macrocell!