technische universität dortmund

FACT
First G-APD Cherenkov Telescope

SFB 876 Providing Information by Resource-Constrained Data Analysis

lehrstuhl exp. physik 5

FACT Open Data

Maximilian Nöthe, Kai Brügge for the FACT-Collaboration

HAP Workshop – Big Data Science in Astroparticle Research – 2018

technische universität dortmund

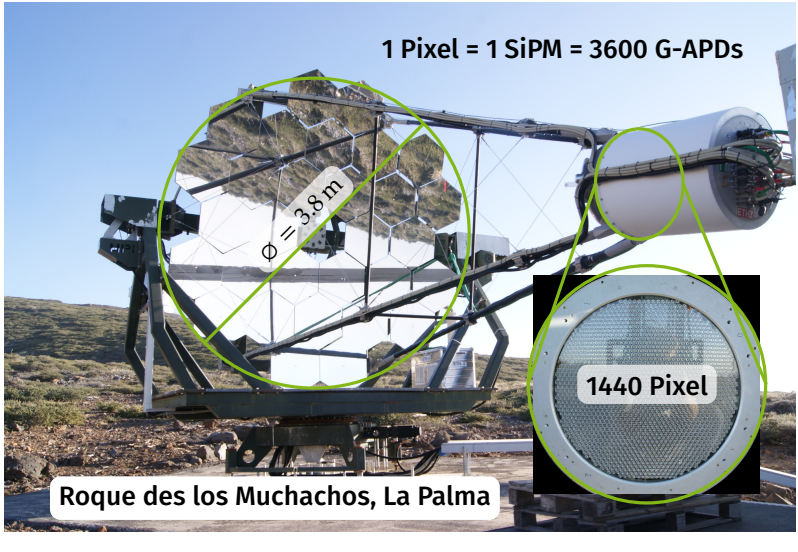
ETH zürich

ISDC
DATA CENTRE FOR ASTROPHYSICS

Julius-Maximilians-
UNIVERSITÄT
WÜRZBURG

Overview

[Miguel Claro]


1 Pixel = 1 SiPM = 3600 G-APDs
$\phi = 3.8\,m$
1440 Pixel
Roque des los Muchachos, La Palma

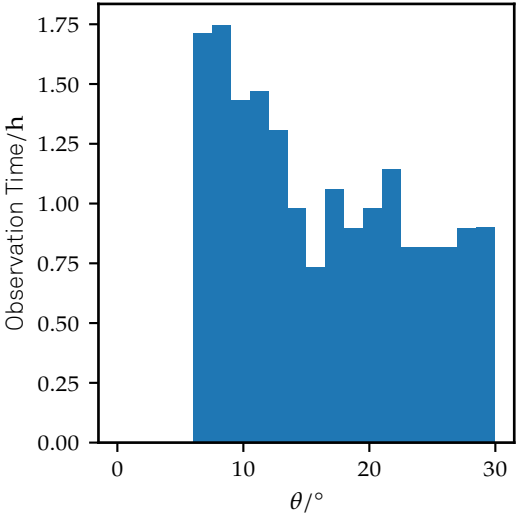
The Dataset

- Crab Observations from November 2013
- Point-source gamma-ray simulations
- Diffuse gamma-ray simulations
- Diffuse proton simulations
- Available in different formats and multiple analysis stages

https://fact-project.org/data

Observations

- 17.7 hours of Crab Nebula observations
- Good environmental conditions
- Zenith distance between 6° and 30°



Simulations

- CORSIKA for air shower simulations
- CERES for FACT detector response simulations

Gammas

Energy Range	200 GeV − 50 TeV
Spectral Slope	−2.7
Max. Impact	270 m
Zenith Distance	0° − 30°
CORSIKA Events	12 000 000
Triggered Events	1 914 812

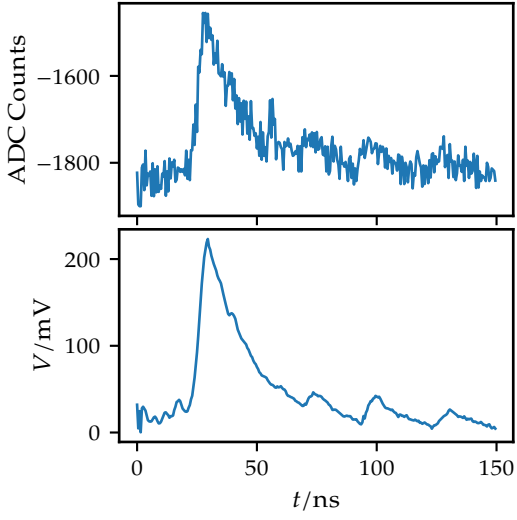
Protons

Energy Range	100 GeV − 200 TeV
Spectral Slope	−2.7
Max. Impact	400 m
Zenith Distance	0° − 30°
CORSIKA Events	780 046 520
Triggered Events	509 652

A FACT Analysis

Classical IACT Analysis Chain

1. Raw Data Calibration
2. Removal of electronic artifacts
3. Extraction of number of photons and mean arrival times for each pixel
4. Image parameterization
5. Reconstruction of particle properties
   - Energy
   - Origin
   - Particle type (γ, p, μ)



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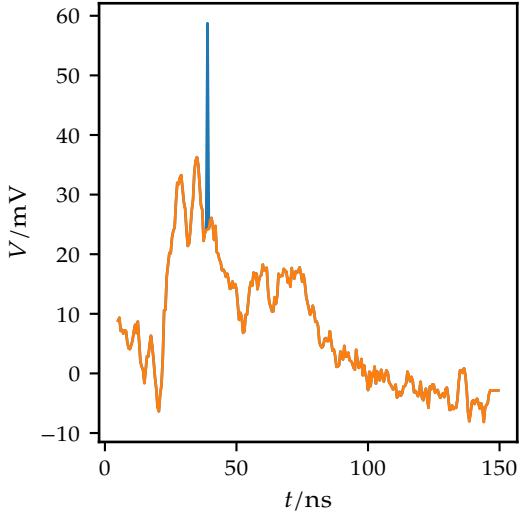

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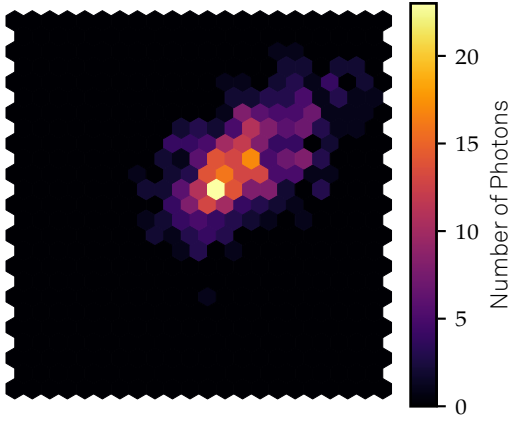

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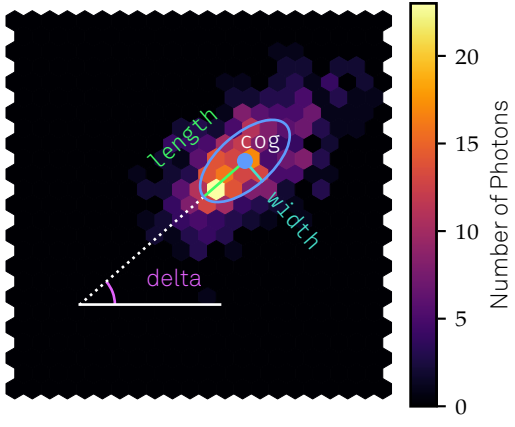
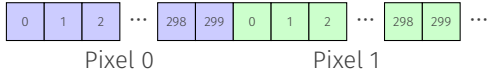


Raw Data

- FACT observations are stored in custom compressed FITS Files called `zfits`
- Readers are available for

  Python `https://github.com/fact-project/zfits`
  Java `https://github.com/fact-project/fact-tools`
  C++ (ROOT) `https://trac.fact-project.org/browser/trunk/Mars`
- FACT-Tools can be easily used to convert `zfits` to standard FITS
- Simulations are stored in standard, gzipped FITS Files
- Raw Data consists of a single array of length 1440×300 ($N_{\text{Pixels}} \times N_{\text{Slices}}$)



0.9 TB observations, 1.1 TB simulations

See: Max Ludwig Ahnen et al. “Data compression for the first G-APD Cherenkov Telescope”. In: *Astronomy and Computing* 12 (2015), pp. 191–199

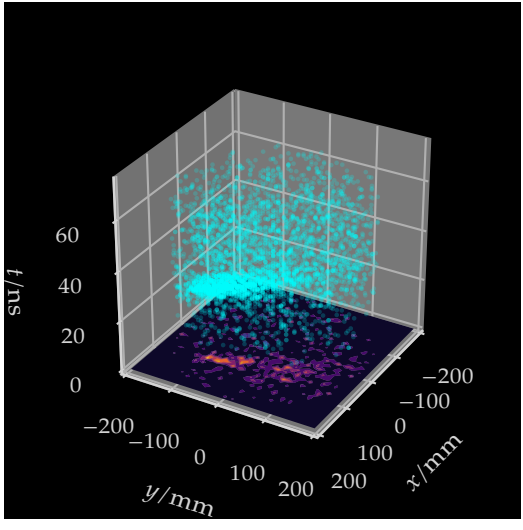
Photon Stream

- The FACT Camera has single photon resolution
- Each photon produces a known pulse shape
- Multiple photons just superimpose

→ Reconstruct the arrival time of each individual photon by subtracting pulses until a flat line is reached

- *Much* smaller file size compared to raw data
- All FACT Data ≈ 8 TB

See: Sebastian Achim Mueller et al. "Single Photon Extraction for FACT's SiPMs allows for Novel IACT Event Representation". In: *Proceedings of the 35th ICRC*. 2017



FACT-Tools

- Extension of the `streams`-Framework to analyze FACT data
- Developed at TU Dortmund and ETHZ
- Also performs photonstream extraction

`https://github.com/fact-project/fact-tools`

Higher-Level Analysis

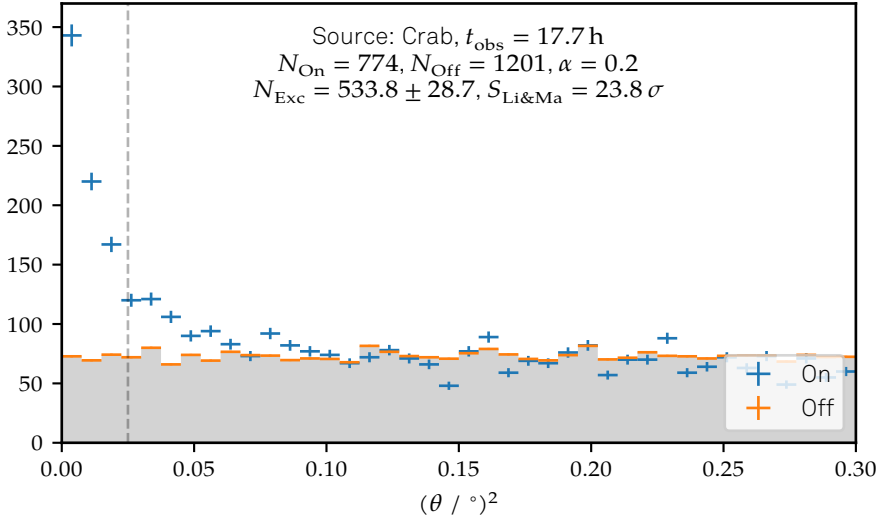
- We use the Scientific Python Stack
- `scikit-learn` models for particle classification, energy estimation and reconstruction of origin

Example analysis on the open data sample:

```
$ git clone https://github.com/fact-project/open_crab_sample_analysis
$ pip install -r requirements.txt
$ make
```

This will download the data, train models, apply them and produce a θ^2 plot for the source detection.

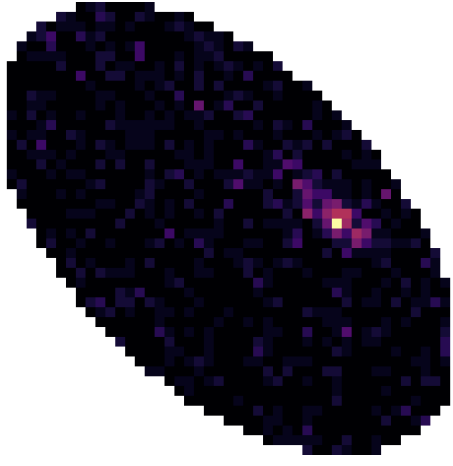
Result


Source: Crab, $t_{obs} = 17.7\,h$
$N_{On} = 774$, $N_{Off} = 1201$, $\alpha = 0.2$
$N_{Exc} = 533.8 \pm 28.7$, $S_{Li\&Ma} = 23.8\,\sigma$
On
Off
$(\theta\ /\ °)^2$

Deep Learning

- Ongoing efforts to try deep learning on this dataset
- Using photonstream representation
- Reducing the hexgrid and time domain to square images

See: `https://github.com/mackaiver/cnn_cherenkov`



Conclusions

- From the start, FACT made results of he Quick Look Analysis publicly available `https://fact-project.org/monitoring`
- In November, FACT released a dataset of Crab observations, from the raw data up.
- Accompanied by extensive simulations.
- FACT-Tools standard analysis has $23.8\,\sigma$ on this dataset
- Use it for education and outreach!
- Many possibilities including Deep Learning, Spectrum Estimation, etc.
- We are planning on releasing more data in the future.