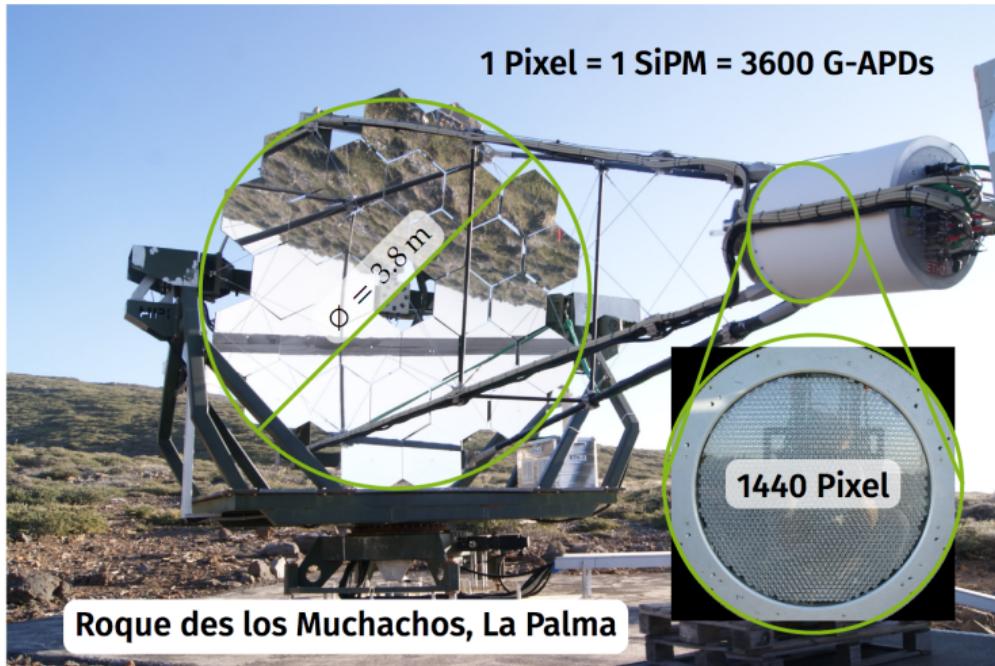

Analysis Of The Crab Nebula Using FACT's Photon Stream Data

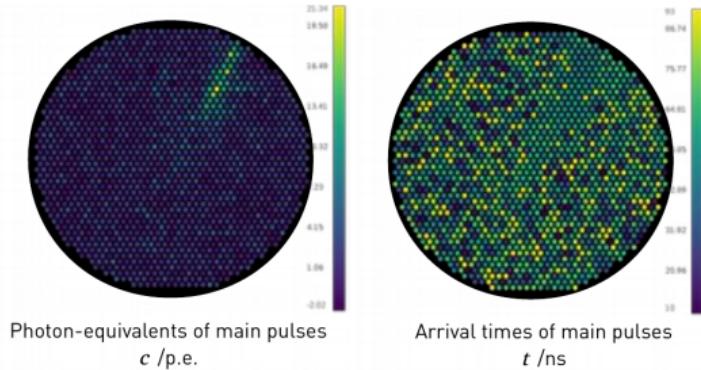
Kevin Sedlaczek, Maximilian Nöthe for the FACT-Collaboration
DPG-Frühjahrstagung 2018 Würzburg

The First G-APD Cherenkov Telescope



The Photon Stream Data

Main-Pulse Event Representation



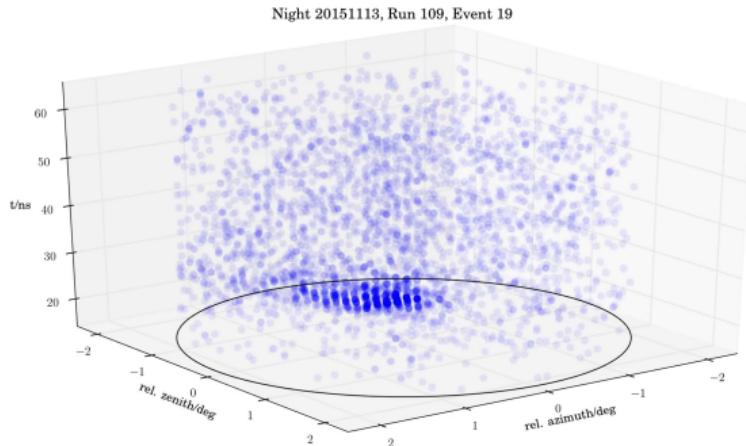
- FACT records data in format close to readout hardware
- superposition of multiple photon signals
- not intended as physics format
→ **Photon Stream**
- list of individual photons (arrival times)

The Photon Stream Data

```
uint8
+---+---+---+---+
0 |   A | B | C | 255 | <- Pixel CHID=0, 3 photons, arrival slices A, B, and C.
+---+---+---+---+
1 | XXX | XXX | 255 |
+---+---+---+
2 |   C | 255 | <- Pixel CHID=2, 1 photons, arriving in slice C.
+---+---+---+
3 | XXX | XXX | XXX | XXX | 255 |
+---+---+---+
4 | XXX | 255 |
+---+---+---+
5 | XXX | 255 |
+---+---+
6 | 255 | <- Pixel CHID=6, 0 photons, empty.
+---+---+
7 | XXX | XXX | 255 |
+---+---+
.
.
.
1437 | XXX | 255 |
+---+---+
1438 | XXX | XXX | XXX | XXX | 255 |
+---+---+
1439 | D | E | 255 | <- last pixel CHID=1439, 2 photons at slices D and E.
+---+---+
Pixel
CHID
```

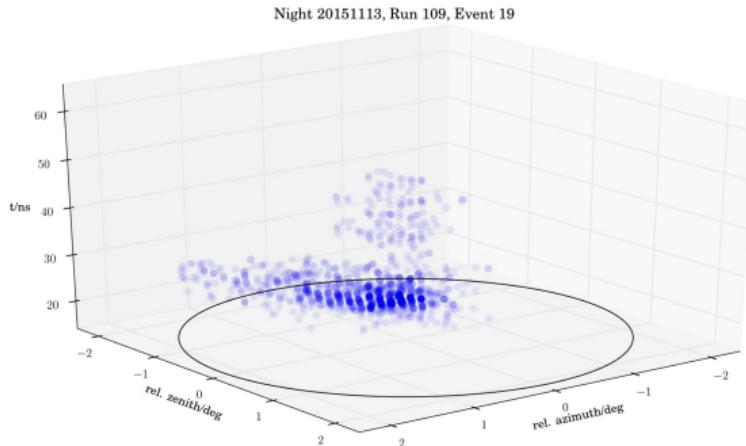
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The Photon Stream Data



- smaller file size: possible to compress all FACT data to fit on one 10TB drive
- simplify *exchange* and *analysis*, gain timing knowledge
- DBSCAN: cluster based image cleaning
- exptected improvement for cleaning

The Photon Stream Data



- smaller file size: possible to compress all FACT data to fit on one 10TB drive
- simplify *exchange* and *analysis*, gain timing knowledge
- DBSCAN: cluster based image cleaning
- expected improvement for cleaning

The Data set: FACT open data crab sample



- <https://fact-project.org/data>
- Crab Nebula observations from November 2013
- including gamma-ray and proton simulations
- 17.7 hours of observations

Analysis

aim proof of concept: generate preliminary physics results

Crab Nebula well measured source of cosmic gamma rays → standard candle analysis

Standard Analysis chain

calibration identifying large pulses

image cleaning

parametrization Hillas

separation

reconstruction

Photon Stream Analysis chain

calibration extracting single photons

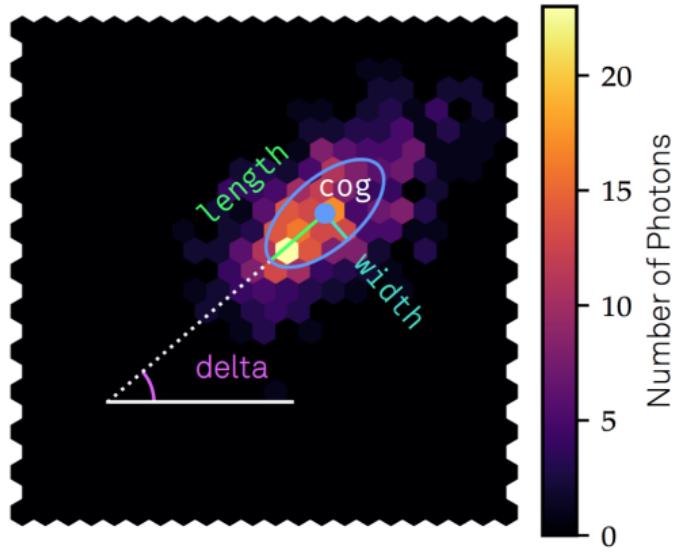
image cleaning DBSCAN

parametrization Hillas

separation

reconstruction

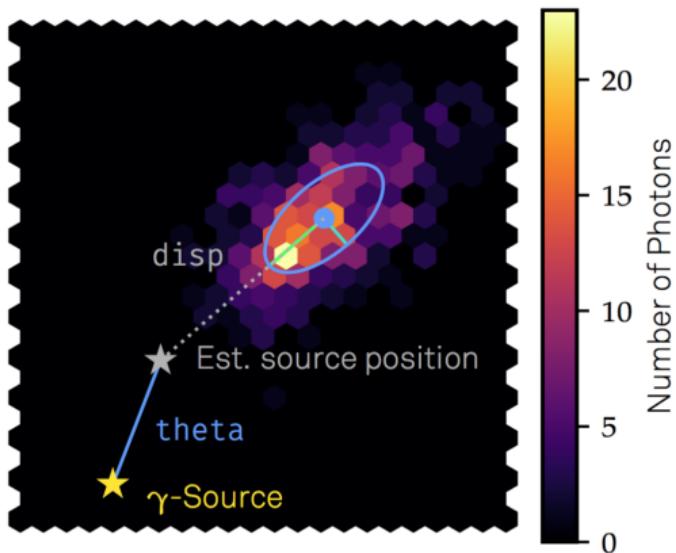
Parameterization



Hillas parameters (projected back to 2D):

- **size**: number of photons in cluster
- **length**: std. dev. along long half-axis
- **width**: std. dev. along short half-axis
- **delta**: angle between length and disp
- **skewness/ kurtosis**: higher order statistical moments along half-axes in cluster system

Parameterization



Source position reconstruction via disp-method:

- **|displ|**: distance from centre of gravity to target
- **sgn(displ)**: Head/Tail-Disambiguation
- **theta**: distance between reconstructed and true origin

Tools

Machine learning with FACT classifier-tools, using 5-fold cross validation

<https://github.com/fact-project/classifier-tools>

Energy estimation:

- random forest regressor (30 estimators)

Gamma-hadron-separation:

- random forest classifier (50 estimators)

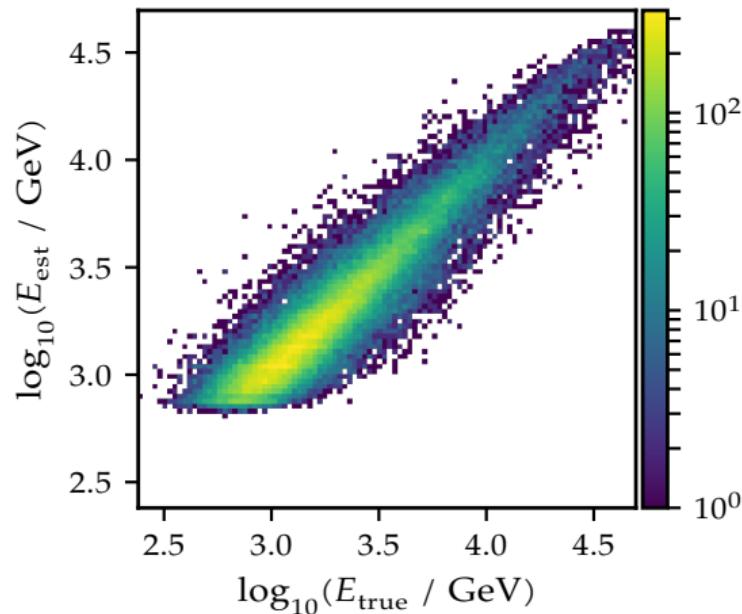
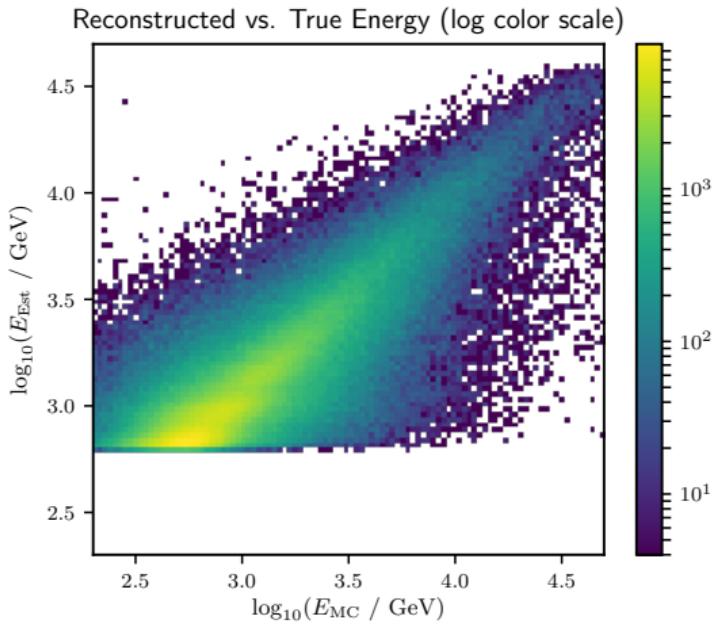
Origin reconstruction:

- two step task: regression of $|displ|$ and classification of $\text{sgn}(\text{disp})$
- random forest regressor and classifier

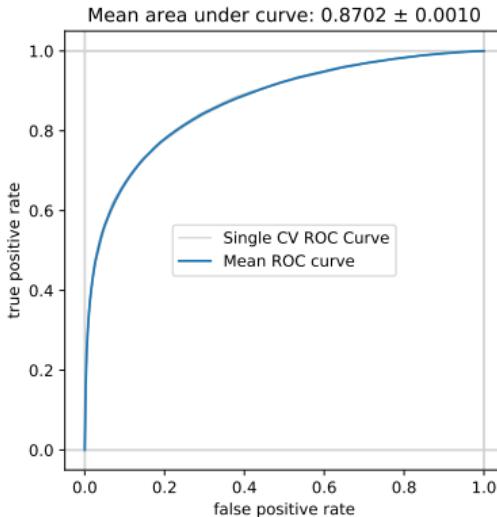
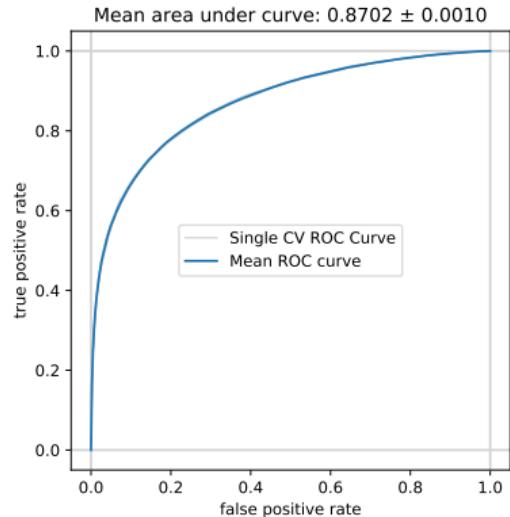
Open Crab Sample Analysis

https://github.com/fact-project/open_crab_sample_analysis

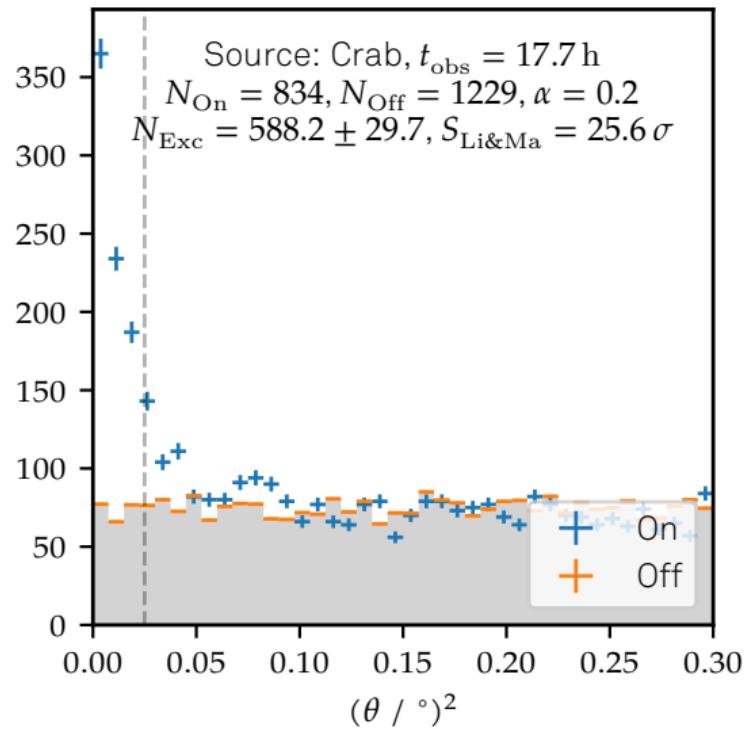
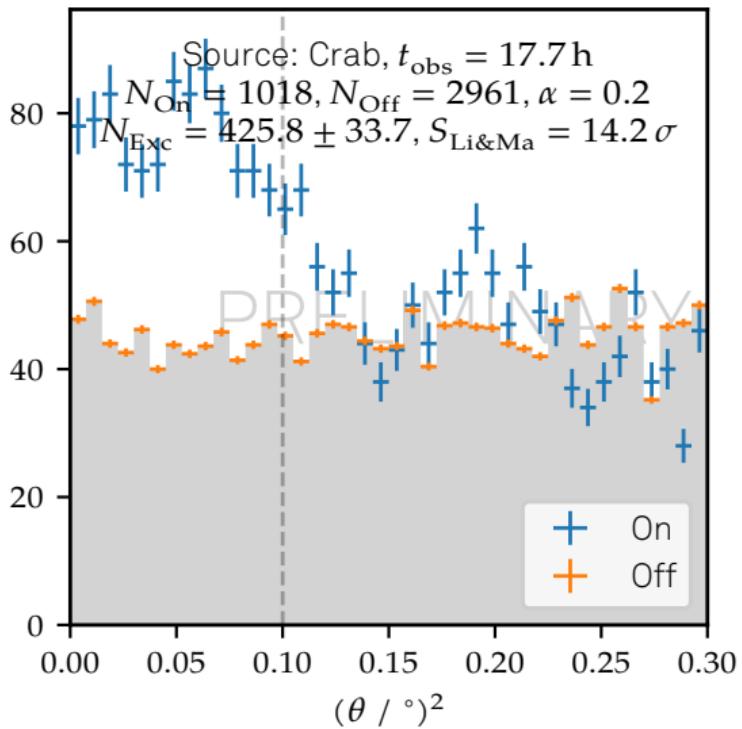
Energy estimation



Separation

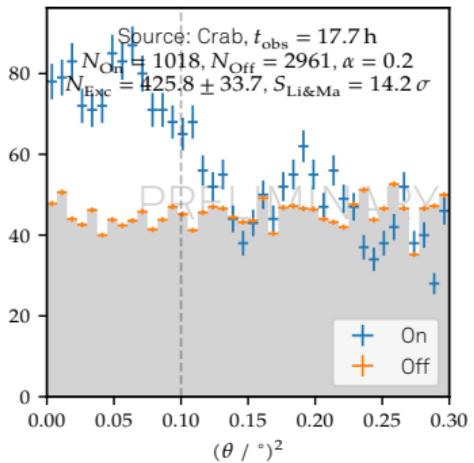
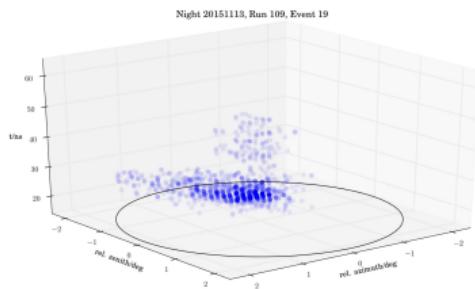


Origin reconstruction



Results

Summary



Outlook

This is just the beginning!

- improve feature selection → feature engineering
 - implement more "standard" features
 - timing information (3-dimensional point-cloud)
- improve cuts on data, hyper-parameters of classifier-tools and clustering