cherenkov telescope array

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Physics Performance of the Large-Sized Telescope prototype of the Cherenkov Telescope Array

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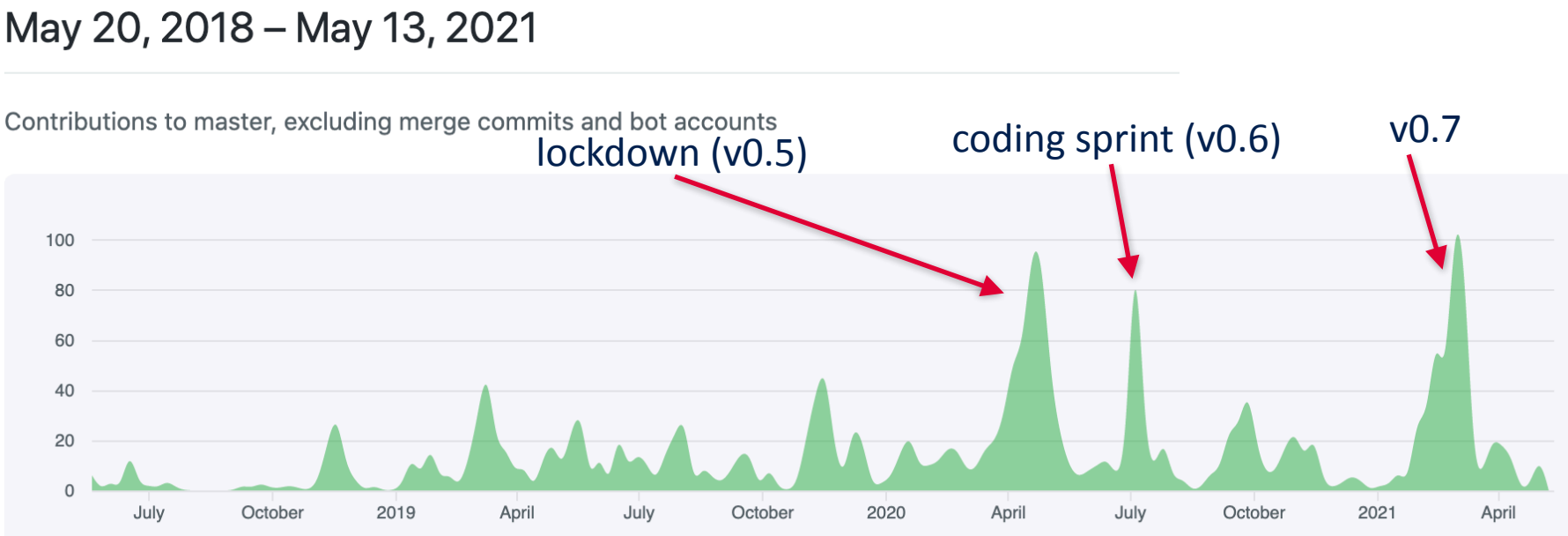
The Large-Sized Telescope

- Largest telescope of the Cherenkov Telescope Array
  - Camera comprises 1855 Photomultiplier Tubes
  - Focal length of 28 m
  - Mirror area 400 m^2
- Trigger threshold down to **~20 GeV**
- First prototype already built and taking sky data since November 2019.
- See General LST talk of D. Mazin for details.

LST-1 data analysis framework

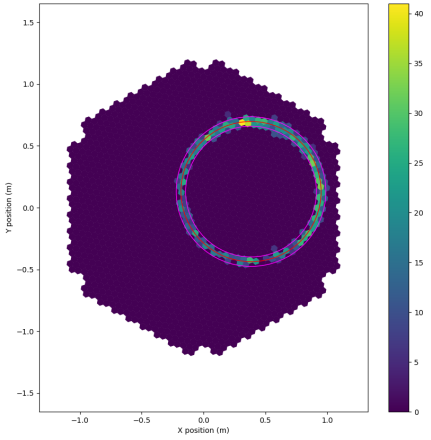
- Python-based analysis framework: ***cta-lstchain***, heavily dependent on ***ctapipe***. Using the **ctapipe_io_lst** plugin to read data.

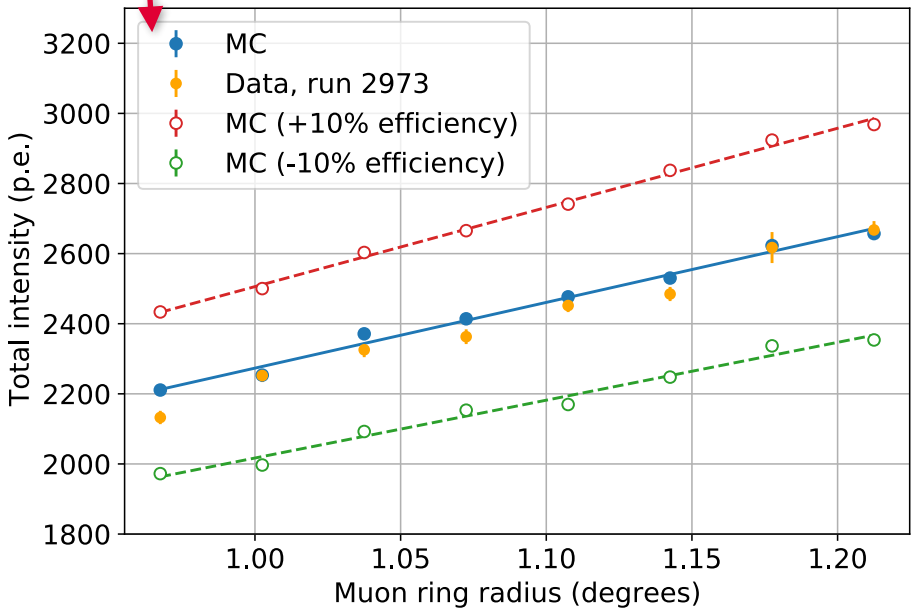
- cta-lstchain current version is v0.7.3 → Released April 2021

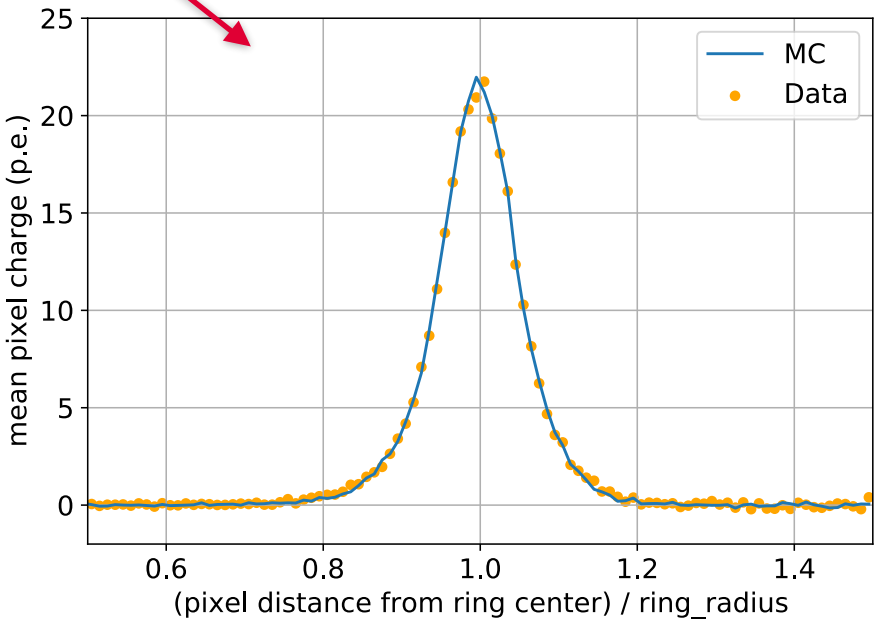


Data/MC adjustments

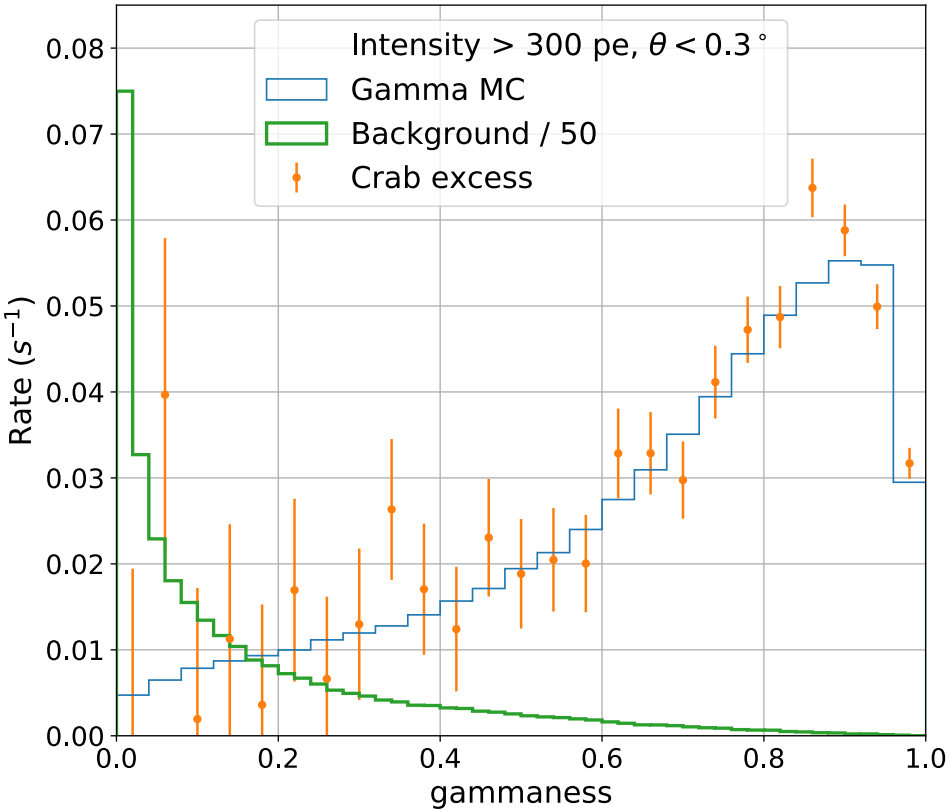
- Calculated using measured muon rings
  - measured optical efficiency based on muon rings compared to that of the MC
  - Data/MC radial profile also adjusted to reproduce real PSF of the instrument



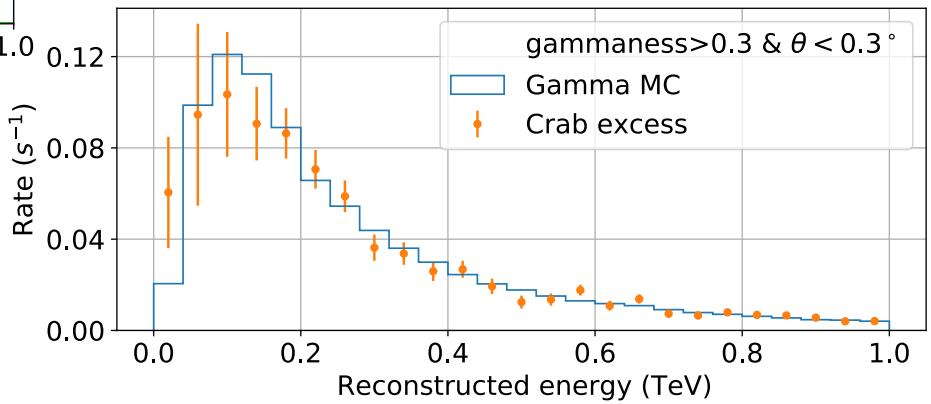




Data/ gamma MC comparisons

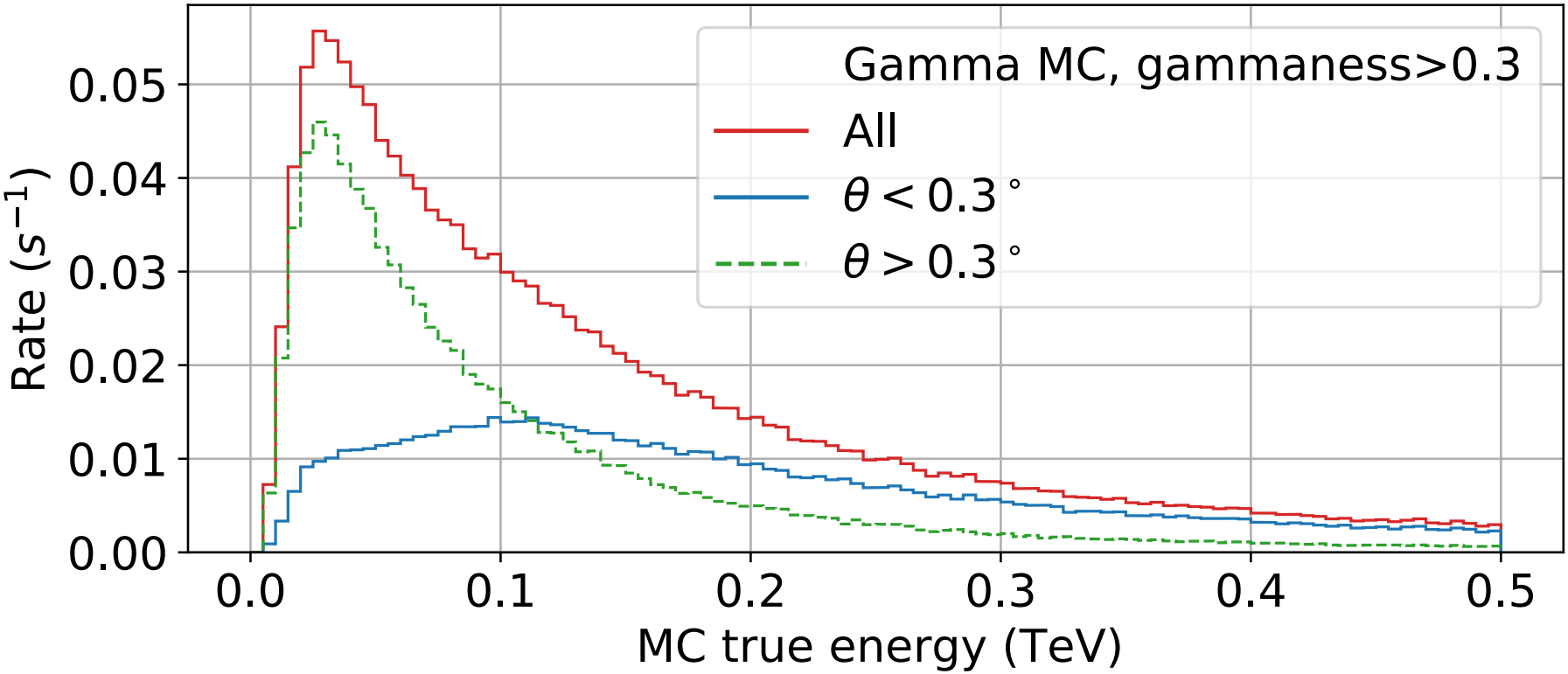


- MC normalized to Crab Nebula spectrum
- Crab excess follows the gammaness distribution from MC
  - Spectrum will be reliable with loose or more constraining cuts
- Gamma Rate vs energy also matching expectations



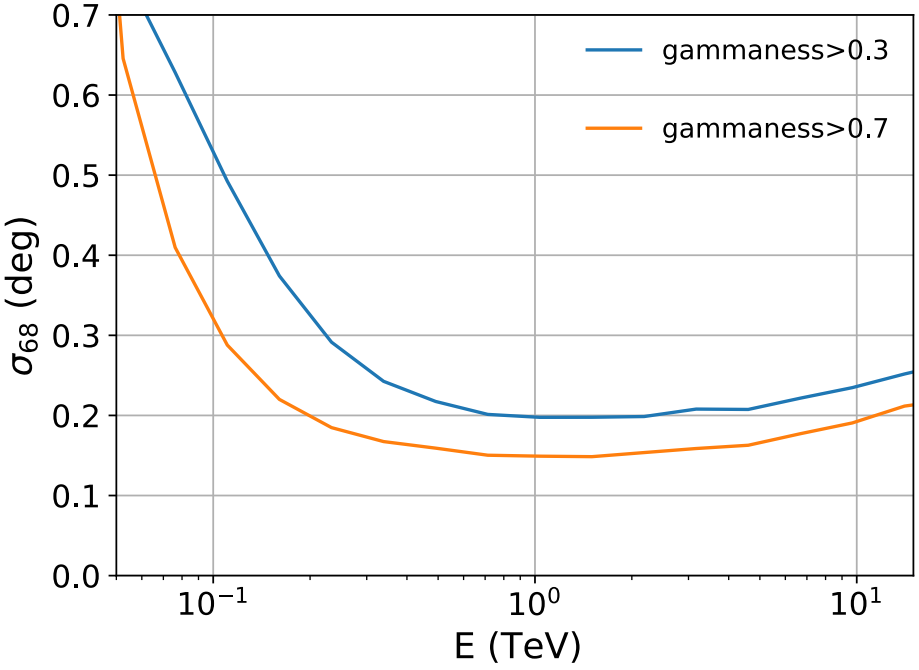
Energy threshold

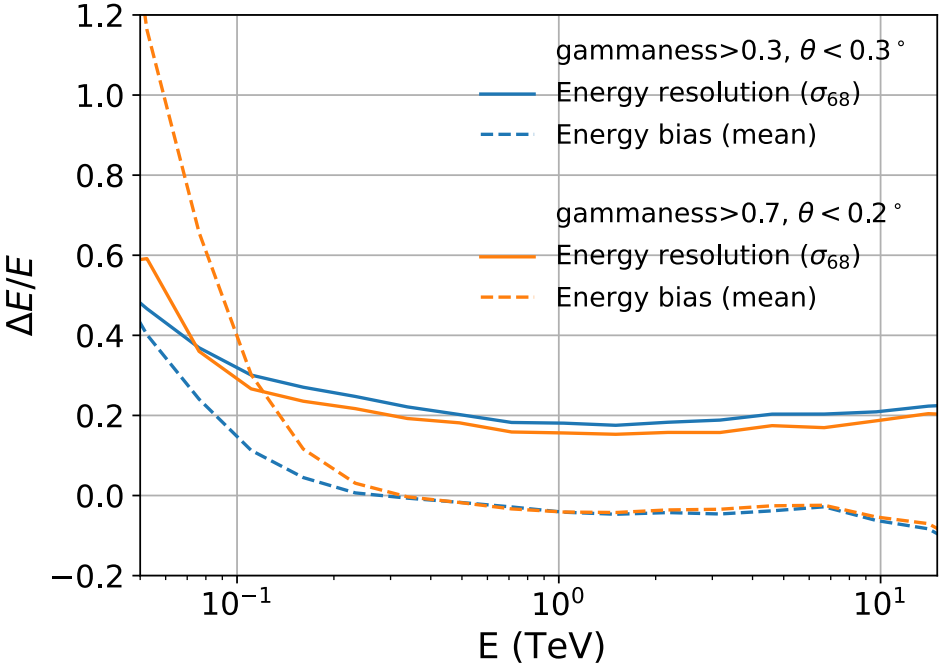
- Low-energy events lost at different stages
  - Most of them lost in the direction reconstruction
    - will be solved when more telescopes are available in the array and stereo reconstruction can be performed



Angular and spectral resolution

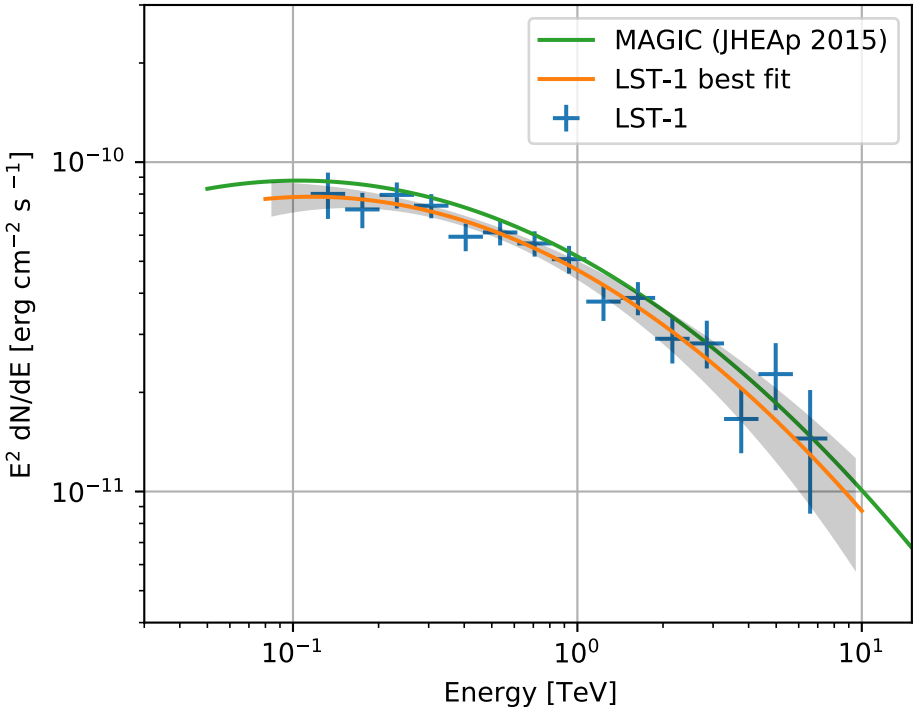
- Energy and direction reconstructed using a Random Forest.
- Angular resolution for single telescope ranging between ~0.7 deg (for tens of GeV) and ~0.2 deg for TeV energies
  - Pretty much dependent on the gamma selection cuts
- Energy resolution at 20 % level for E > hundreds of GeV with almost no bias





Crab Nebula - source-independent analysis

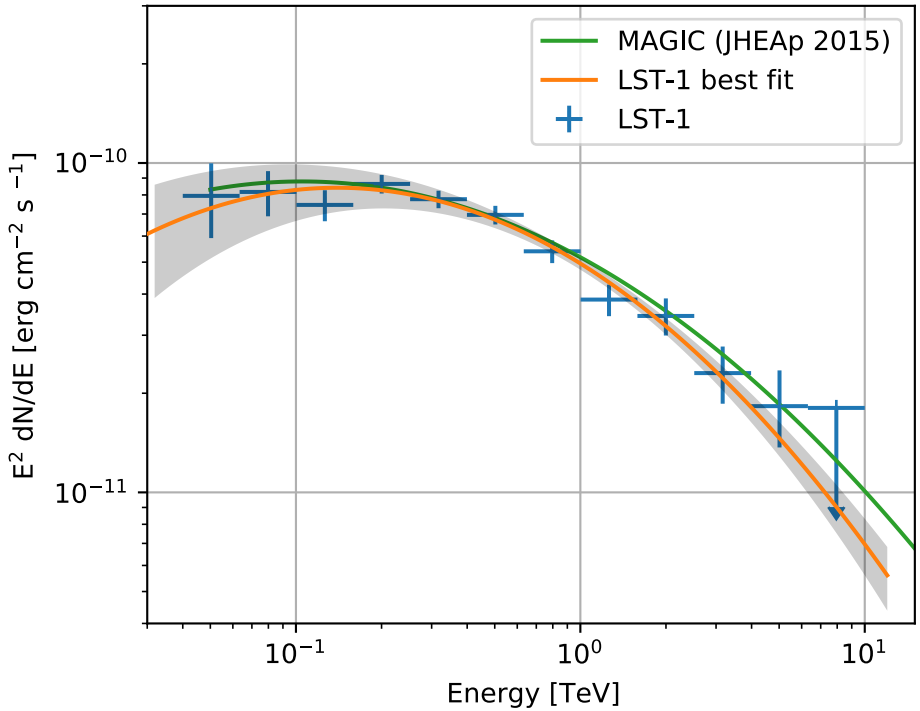
- Producing standard DL3 files in **astropy** FITS format using **ctapipe** Tools in **lstchain**
  - DL3 files contain the list of candidate gamma-ray events in the standard open gamma-ray data format.
- Usage of **pyirf** for generating IRFs with fixed gammaness and theta cut.



- Usage of **gammapy** to analyze the DL3 files

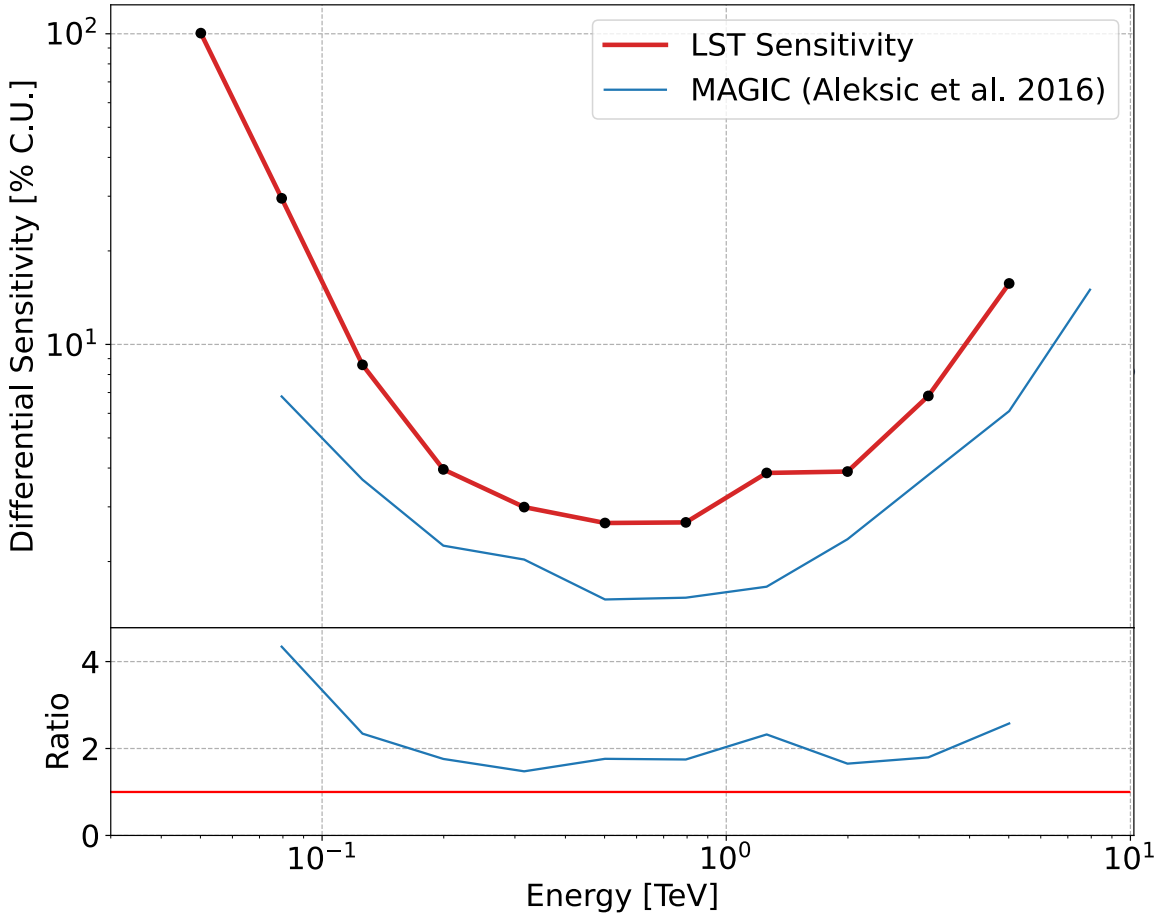
Crab Nebula - source-dependent analysis

- Usage of source-dependent parameters to train RFs and apply them to the data.
- Analysis performed using **lstchain** and **gammapy.**
- Spectrum reaches lower energies thanks to the improved performance of the source-dependent analysis.



Differential Sensitivity - source-dependent analysis

- Cuts calculated on the full dataset and applied to the “Reference nights” (20/21 November 2020)



Definition

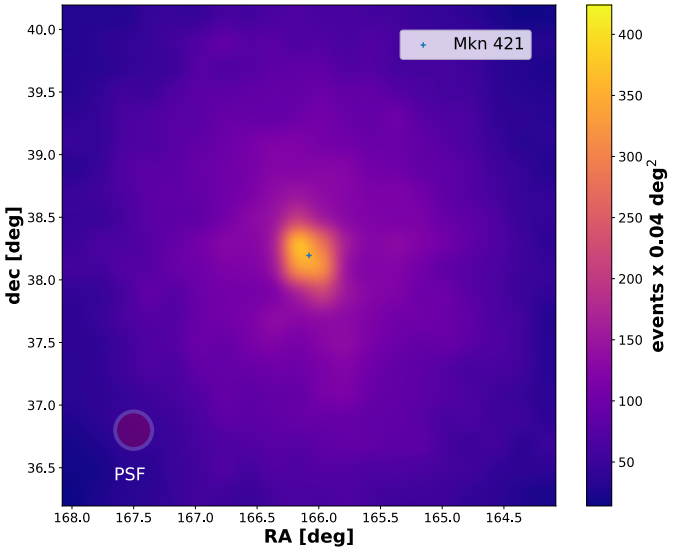
- 50 hours of observation
- Excess matching 5 sigma significance
- 5 energy bins per decade
- At least 10 gammas per bin.
- Exposure ratio ON/OFF = 0.2
- Excess > 5% Background (per energy bin)

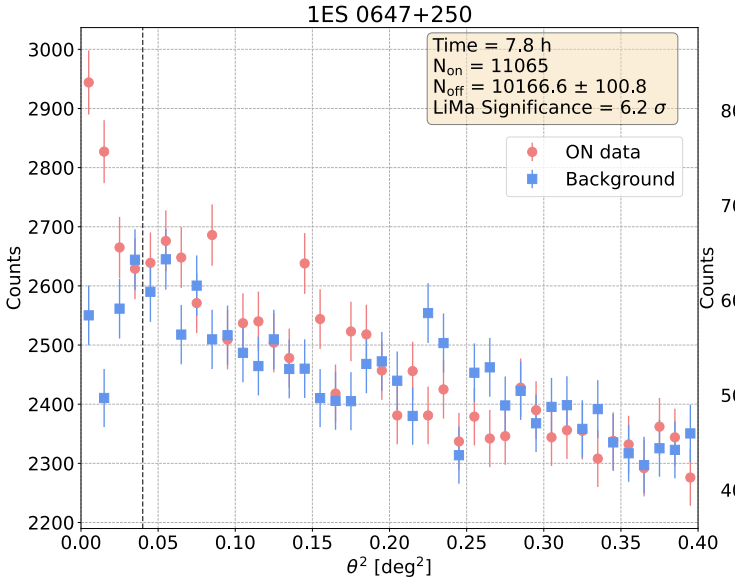
Sensitivity goes:

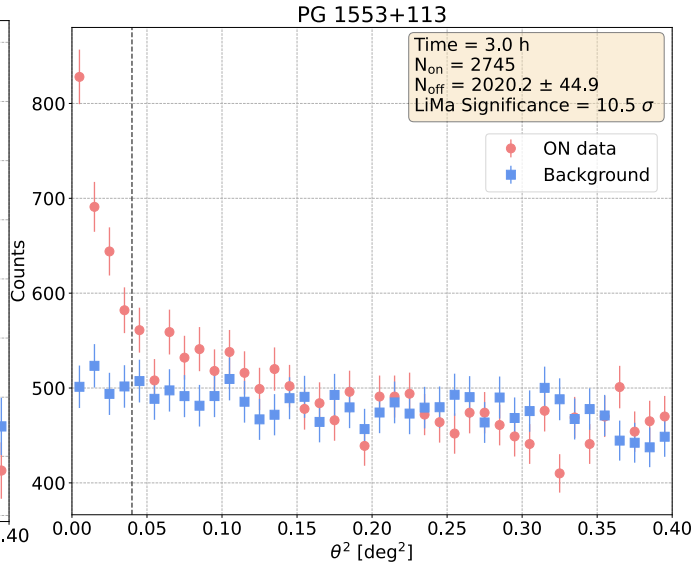
- Parallel to that of MAGIC Stereo at high energies and a factor < 2 worse
- Diverges at low energies because of the worse background rejection due to observations performed in single-telescope mode
- Improved w.r.t. that of the January/February 2020.

LST-1 observations - AGNs

- AGNs
  - Follow-up observations of flaring sources
  - Already detected Mrk 421, Mrk 501, 1ES 1959+650,
    - also the further away ones 1ES 0647+250, PG 1553+113 (LST's most distant source)



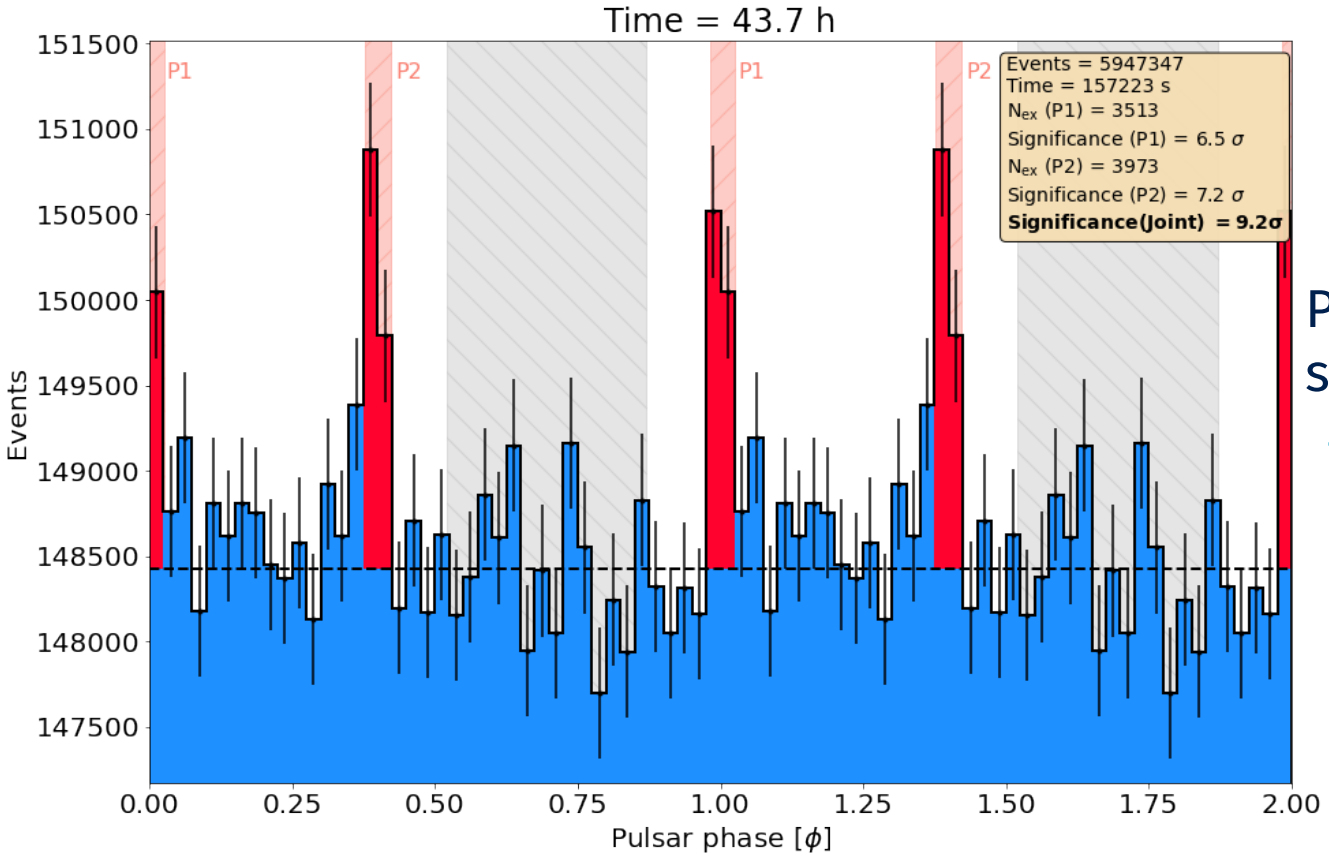




Crab pulsar: analysis details

- Observations
  - 13.6 hours taken in January/February 2020 in ON/OFF mode
  - 30.1 hours taken from November 2020 - March 2021 in Wobble mode (0.4 deg offset)
- Phase calculation using **PINT**
  - Tested on data from other IACTs with similar results to TEMPO2 software
- Data selection:
  - Ruled out runs with:
    - Bad weather or technical problems
    - Moon or Zd > 35 deg
- Analysis characteristics
  - **Source-Dependent** analysis to improve the performance at the lowest energies.
  - ON/OFF region defined by the Aleksic et al. 2012:
    - P1: [0.983, 0.026]
    - P2: [0.377, 0.422]
    - OFF: [0.520, 0.870]
  - Loose cuts to keep low-energy photons.
    - gammaness > 0.3
    - alpha < 12
    - No cut in E_reco

Crab pulsar



P1 and P2 with similar significance

- => energy threshold in the tens of GeV energy range.

Conclusion

- LST1 gradually approaching expectations in terms of performance
  - Data/MC matching approaching an optimal level.
  - Big leap in analysis thanks to all the implementations of lstchain v0.7
    - Sensitivity improved at the medium energies

- Crab Nebula, pulsar and AGNs already detected:
  - Crab spectrum reproduced using source-independent and source-dependent analysis.
  - With the improved analysis we clearly detect the two peaks of the Crab pulsar => energy threshold in the tens of GeV energy range.

Thanks!