IFAE Institut de Física d'Altes Energies

Establishing the MAGIC data legacy

adopting standardised data formats and open-source analysis tools

C. Nigro *on behalf of the MAGIC Collaboration*

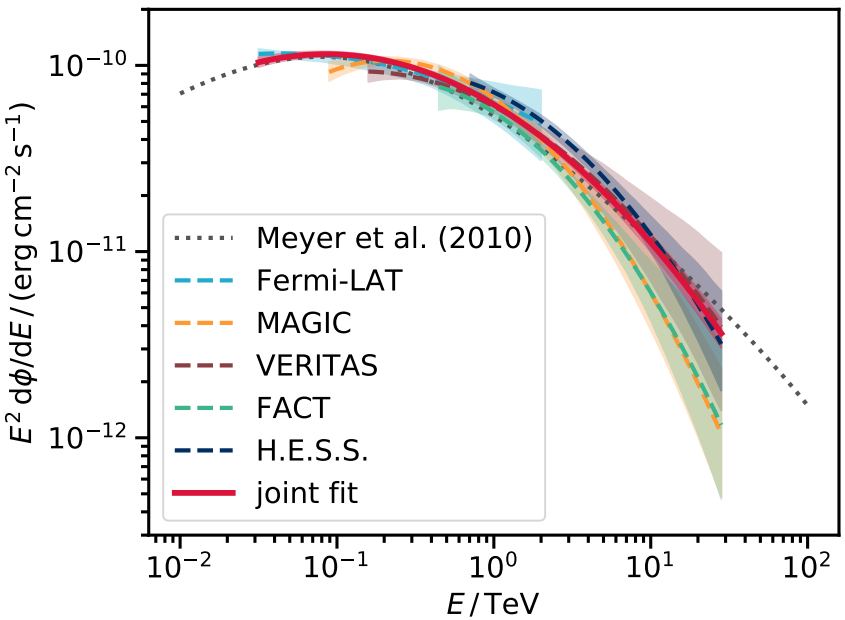
Introduction

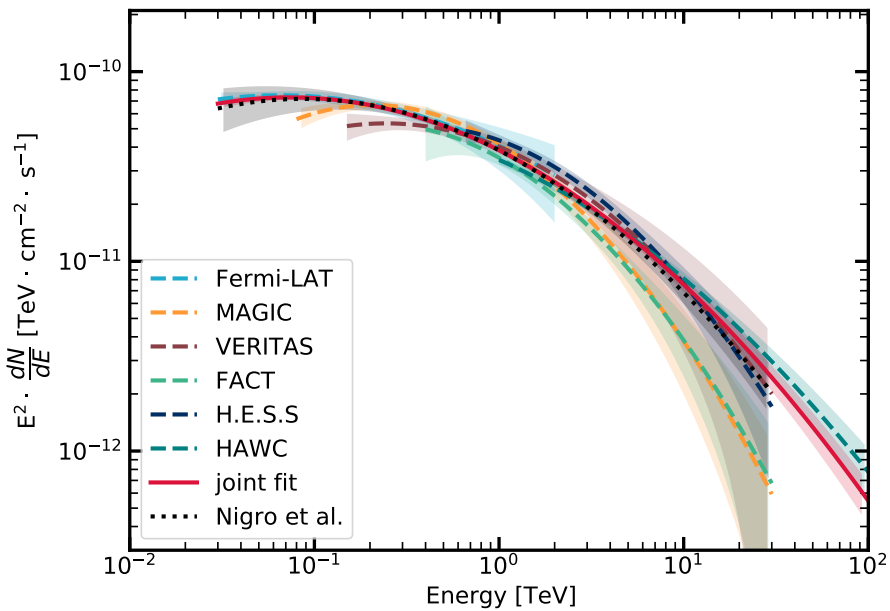
Why standardised data and open-source analysis tools?

- Current generation of IACTs: proprietary data and closed-source analysis tools;
- standardised data:
  - → preserve and make publicly available current IACT data beyond their lifetime,
  - → initiative providing specs for standardised *high-level* gamma-ray data: Data formats for gamma-ray astronomy (GADF);
- open-source analysis tools:
  - → data legacy usable by the scientific community,
  - → `Gammapy`;
- next generation of gamma-ray observatories will face the same issues (dissemination of data and analysis tools to the public).

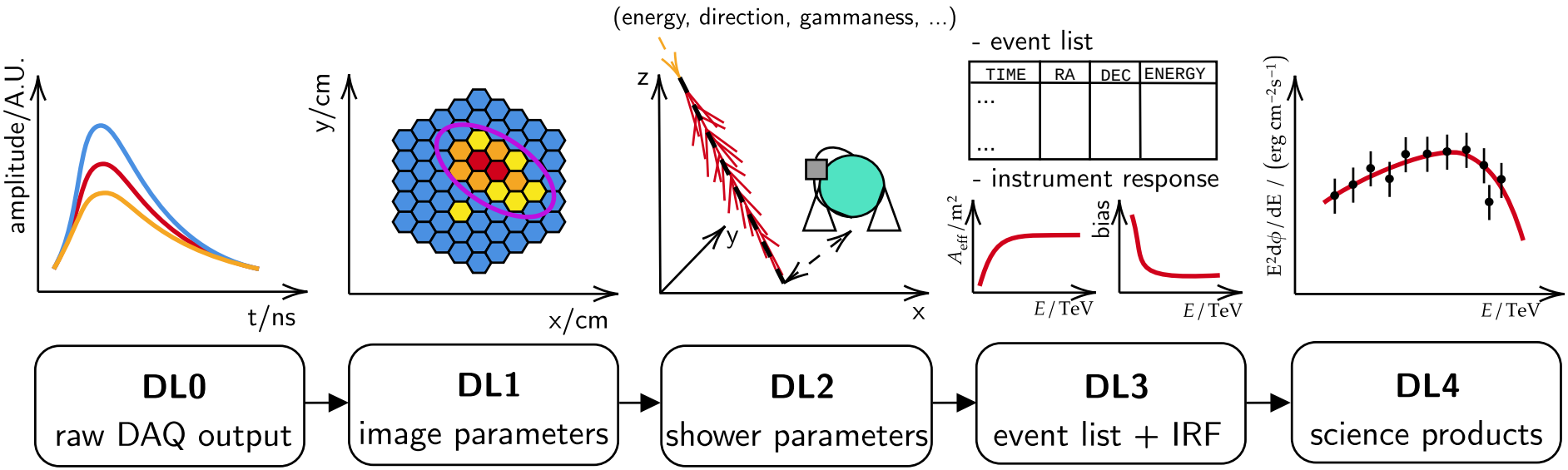
Why standardised data and open-source analysis tools?

- Make possible multi-instrument and reproducible analyses!
- demonstrated with the `joint-crab` project in 2019:
  - → combined prototypical GADF-compliant *Fermi-LAT* and IACTs data, analysed them with `Gammapy`;
  - → in 2022, HAWC extended the example presenting its GADF-compliant data!





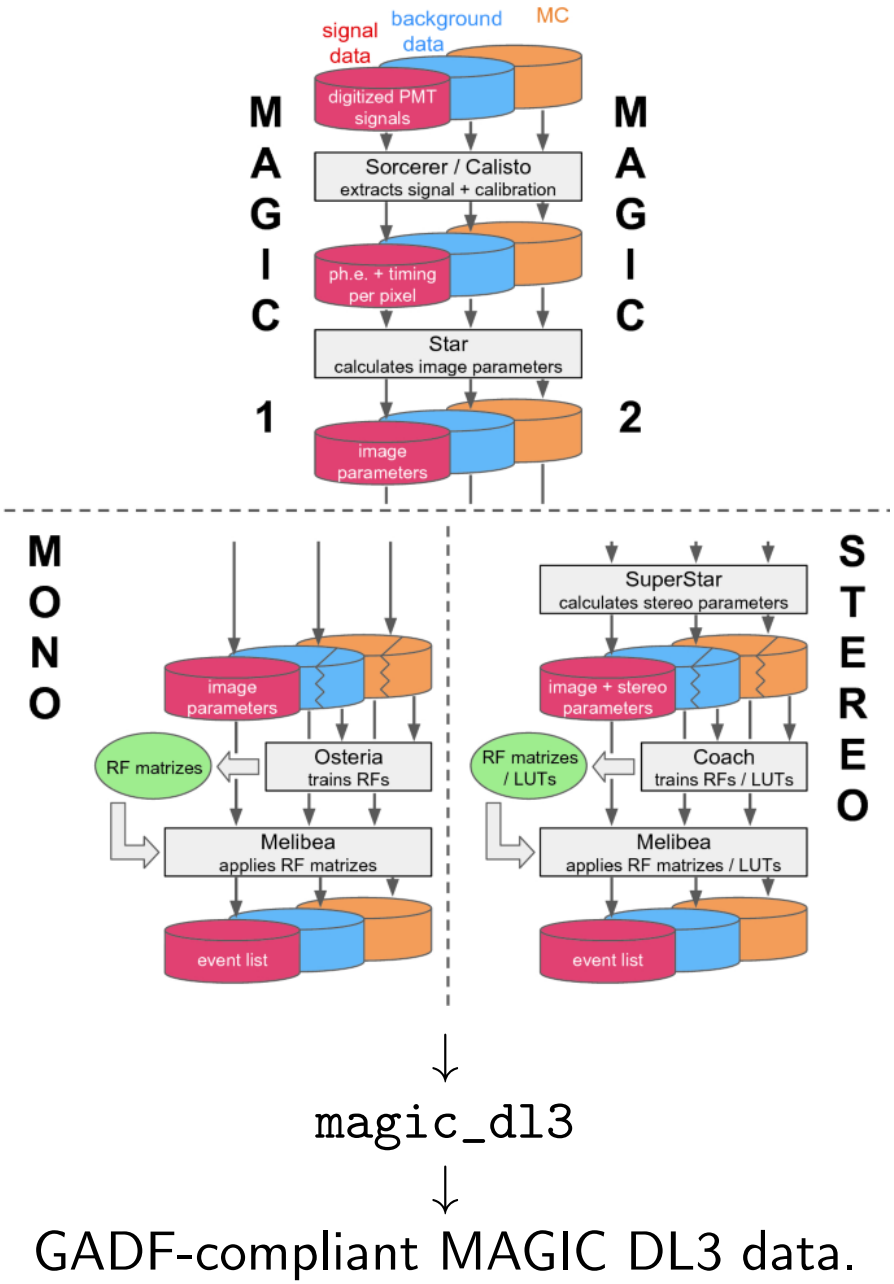
Which data level is standardised?



- Information stored in data level 3 independent of detection, calibration and analysis technique;
- GADF-compliant DL3 data regularly produced by IACT and WCD, some data sets public (H.E.S.S. DL3 DR1, joint-crab dataset).

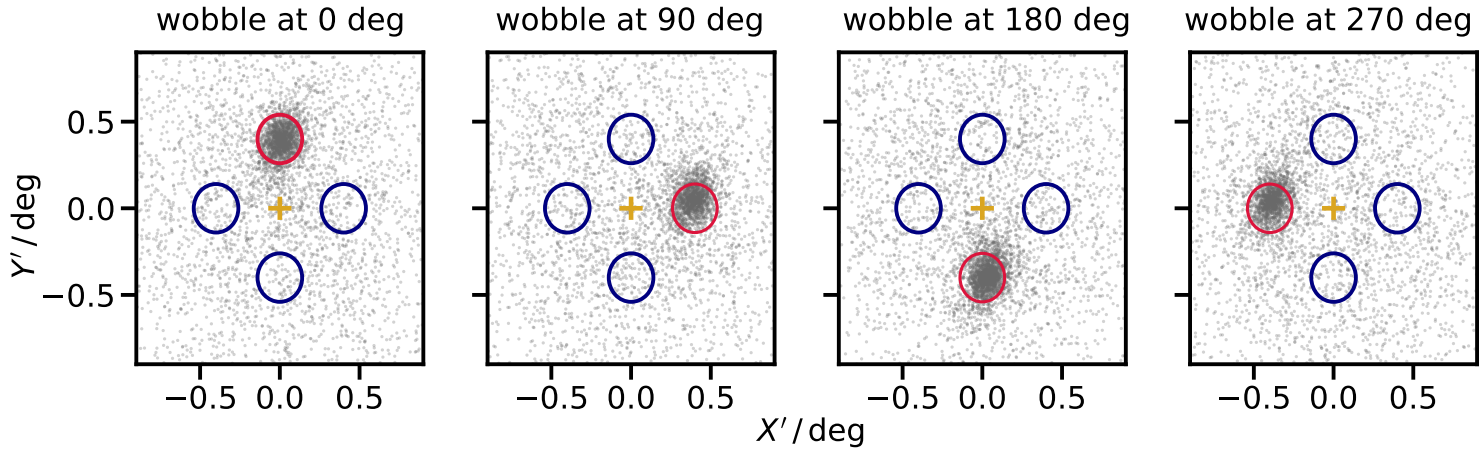
MAGIC production of DL3 data

MAGIC DL3 data production



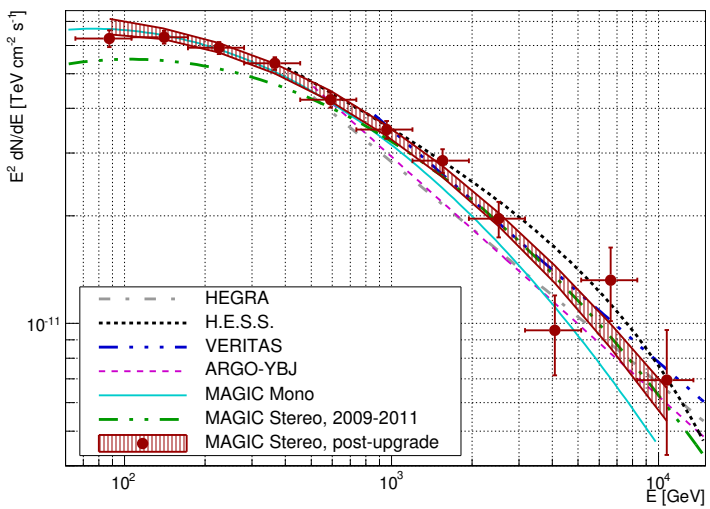
- MAGIC DL3 conversion:
  - → standard `MARS` data reduction down to DL2 (melibea),
  - → observations used for the event list, MCs for the IRF computation,
  - → `MARS`-based `C++` library generating GADF-compliant `FITS` files;
- only conversion of stereo data available at the moment;
- small DL3 samples used for validation (this talk);
- major DL3 productions ($\sim$ years observational periods) initiated.

Validation of the point-like analysis

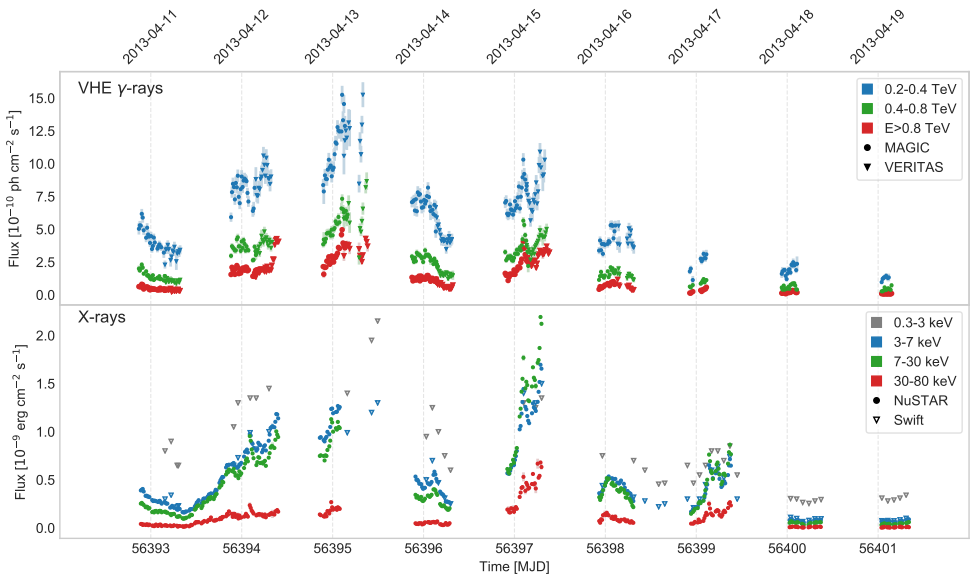


Point-like analysis validation

- Most MAGIC science cases are point sources, can be worked out with a 1D (point-like) analysis;
- ON and OFF region sizes (θ cut) can be energy-dependent: accounts for improvement of direction reconstruction;
- implemented handling of energy-dependent θ cuts in `Gammapy`;
- objective: reproduce `MARS` point-like analysis with DL3 data and `Gammapy`;
- two data sets chosen for validation:

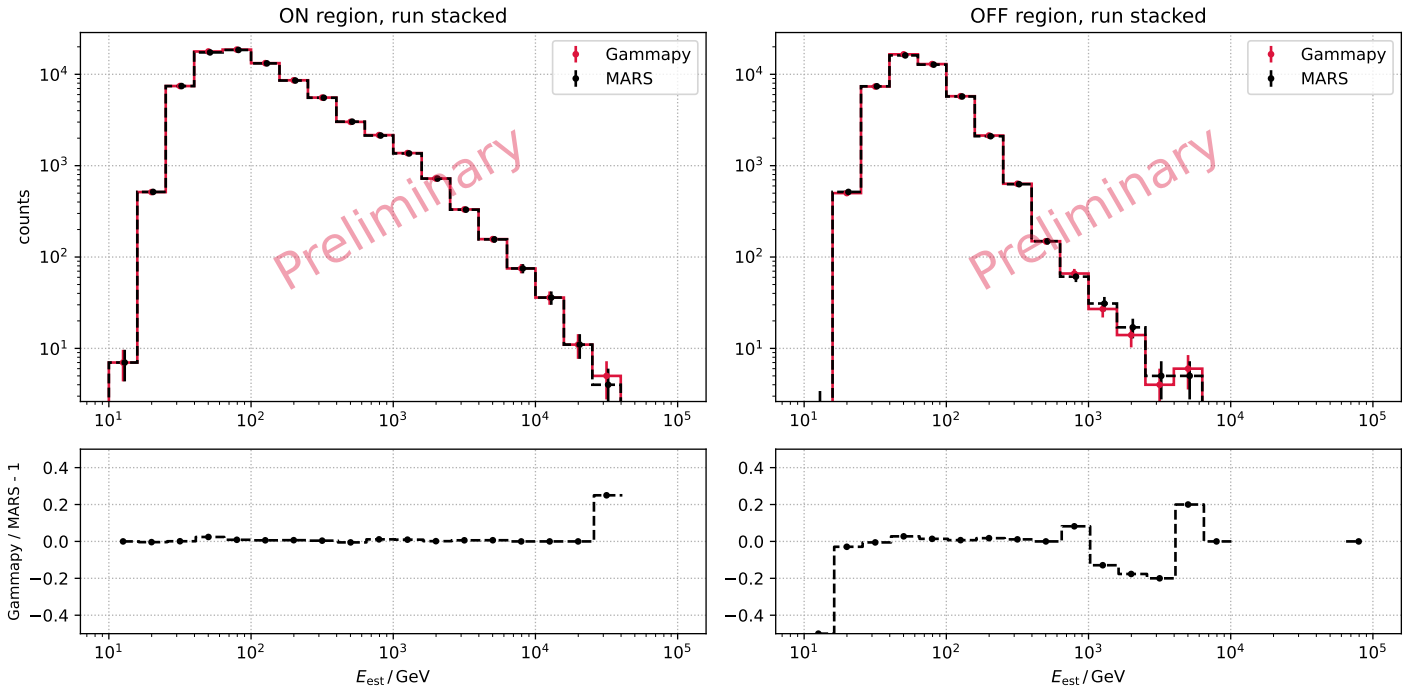


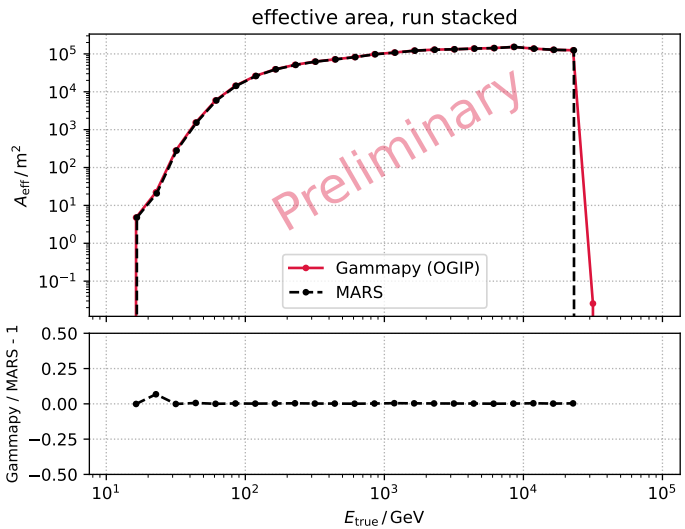
Crab Nebula, $\sim 50\,\mathrm{h}$ of single- and multi-offset obs. (performance and SkyPrism papers);



Mrk421, $42\,\mathrm{h}$ obs. April 2013 flare.

Spectrum extraction

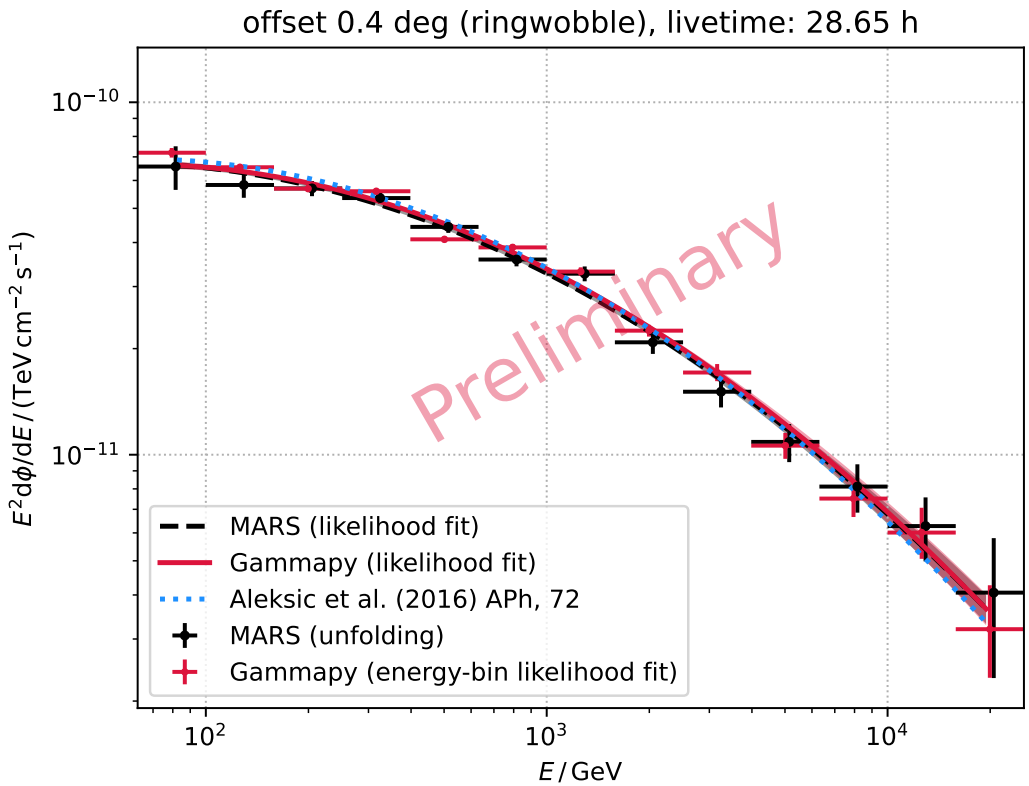




- validated spectrum extraction (signal / background estimation);
- validated correct storing of IRF components.

Crab Nebula validation

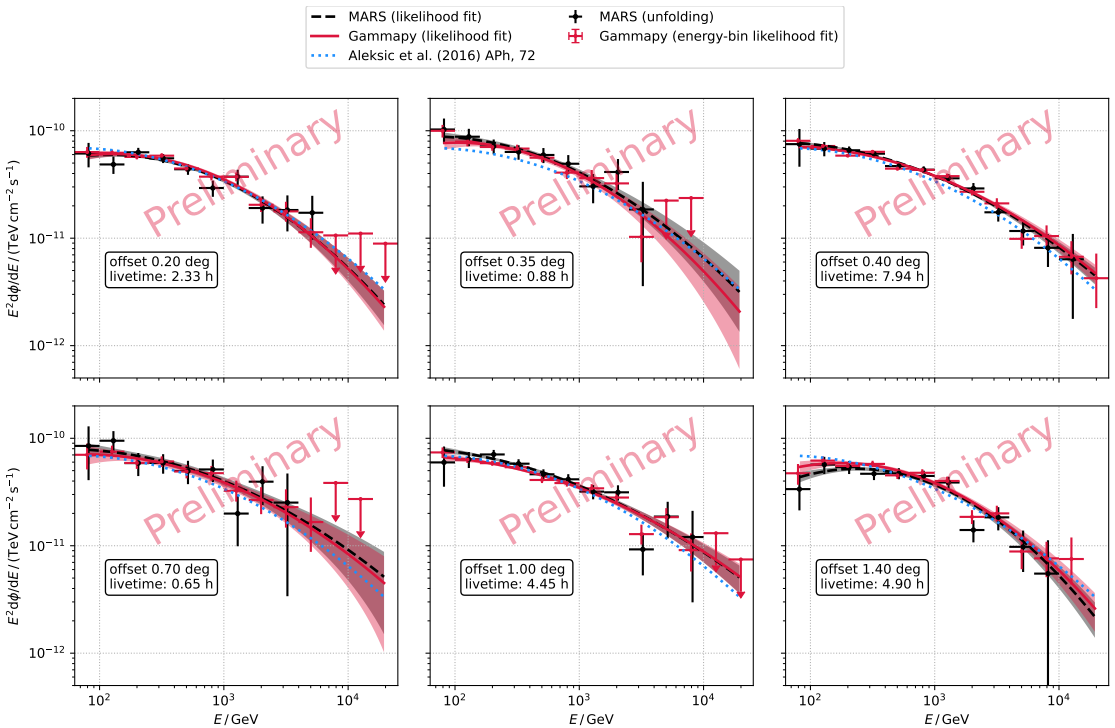
> SED of observations at 0.4° offset, standard wobbling and MCs.

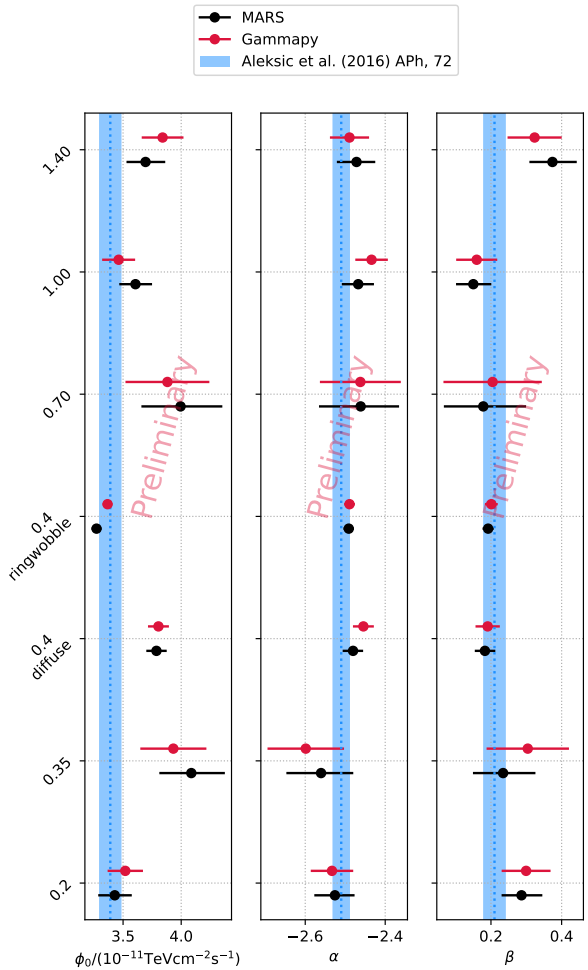


> validation of the forward-folding likelihood fit (spectral points for comparison, different methods used).

Crab Nebula validation

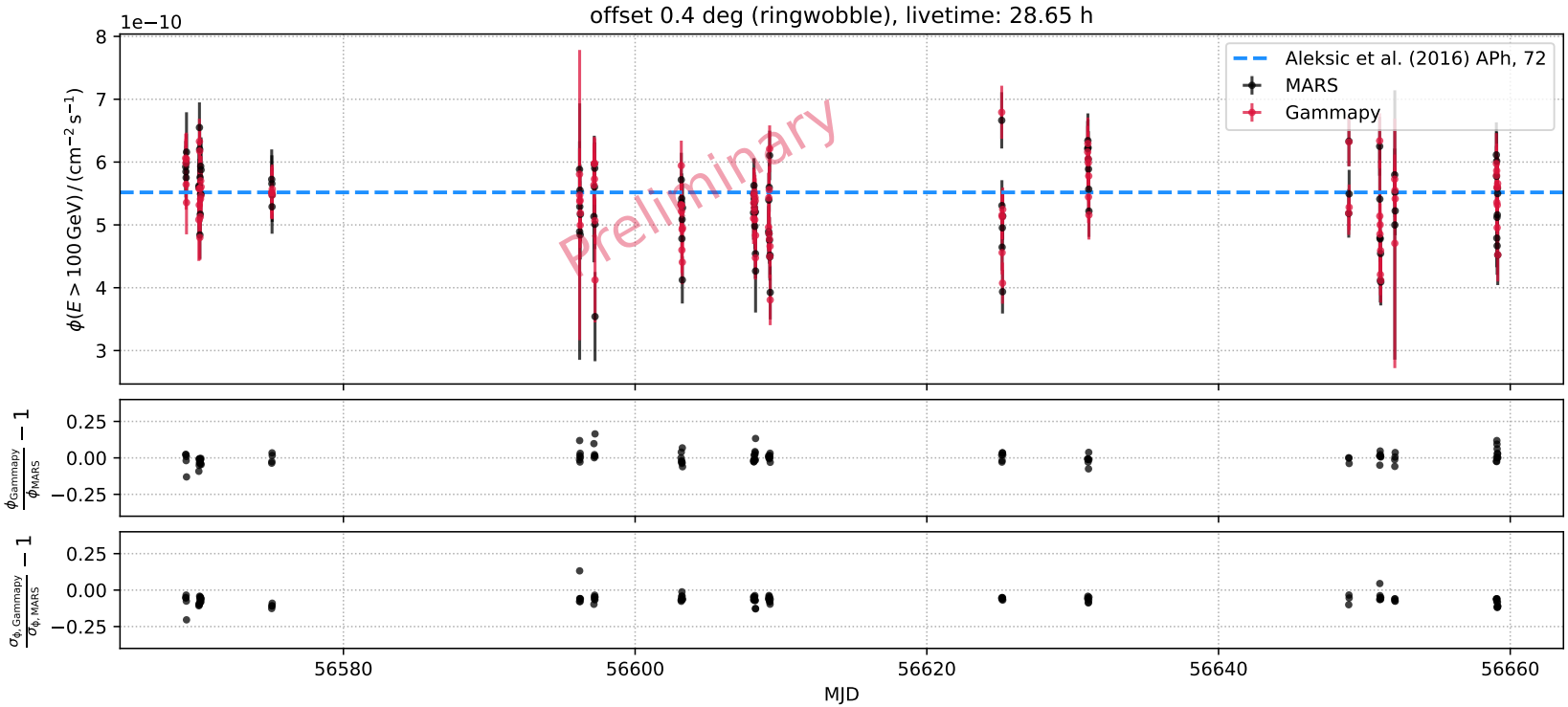
> SEDs of observations at different offsets, non-standard wobbling and MCs.





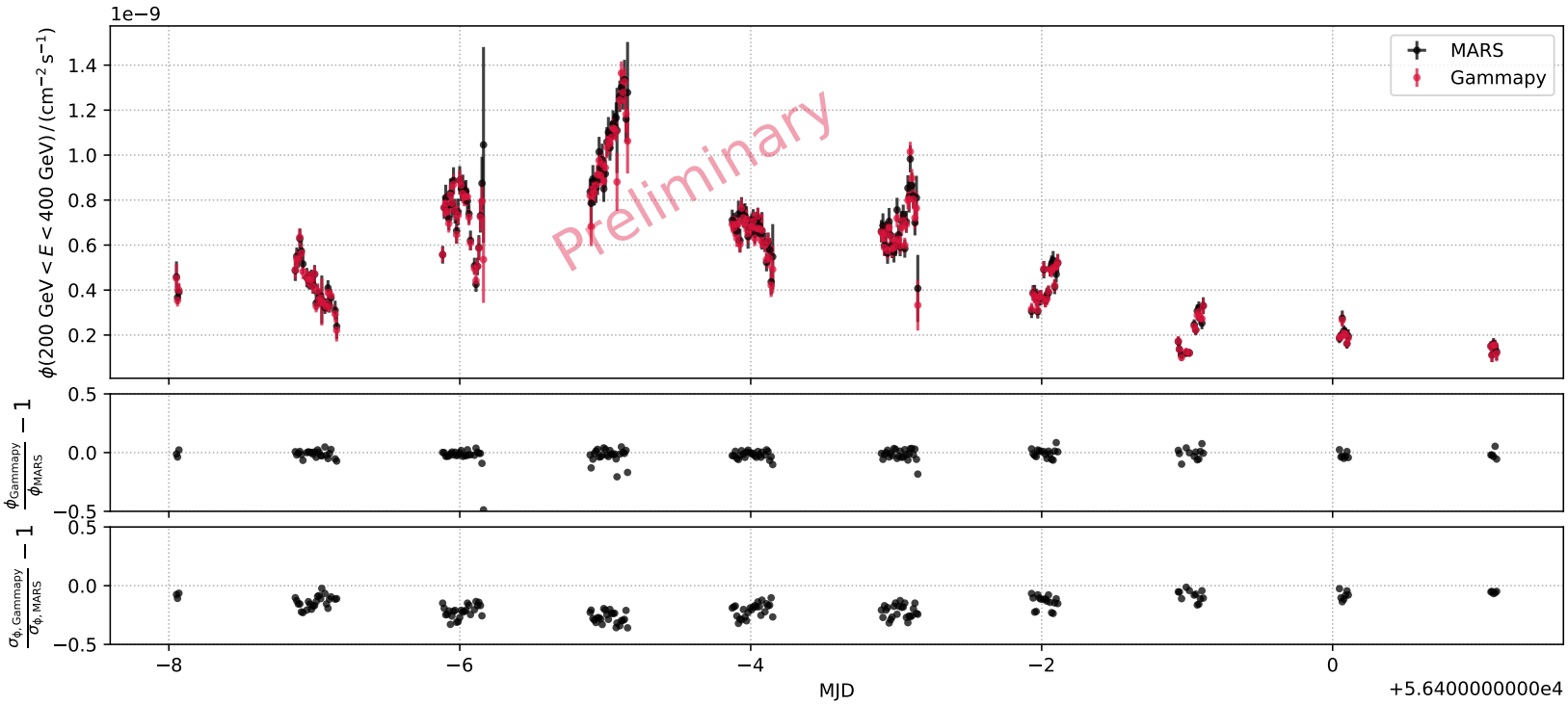
> validation of the forward-folding likelihood fit (flux points for comparison, different methods used).

Crab Nebula validation



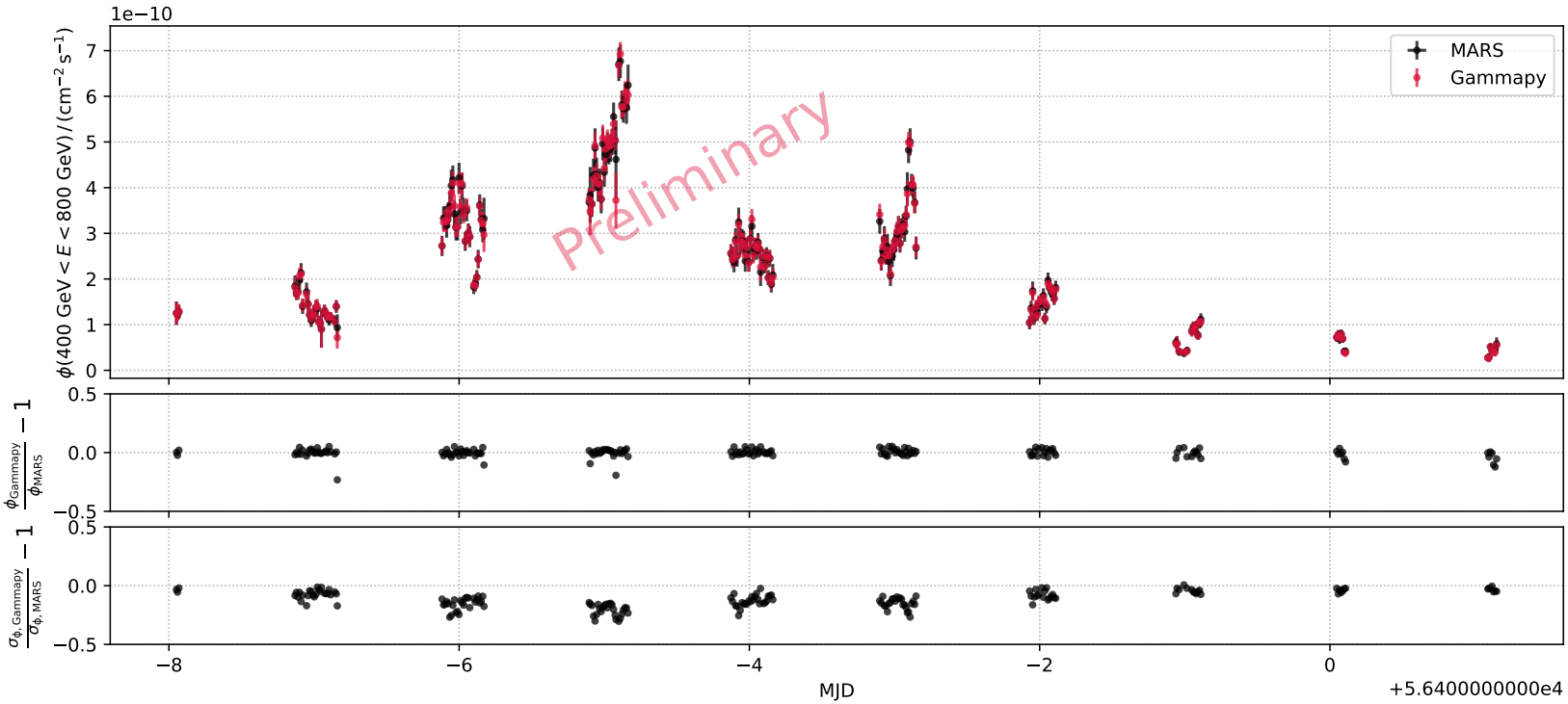
> Validation of the flux points computation for light curves: compatible results with different methods.

Mrk421 validation



> Reproduced light curve estimation in three different energy bins presented in the paper;
> small biases observed in flux estimation, under investigation.

Mrk421 validation



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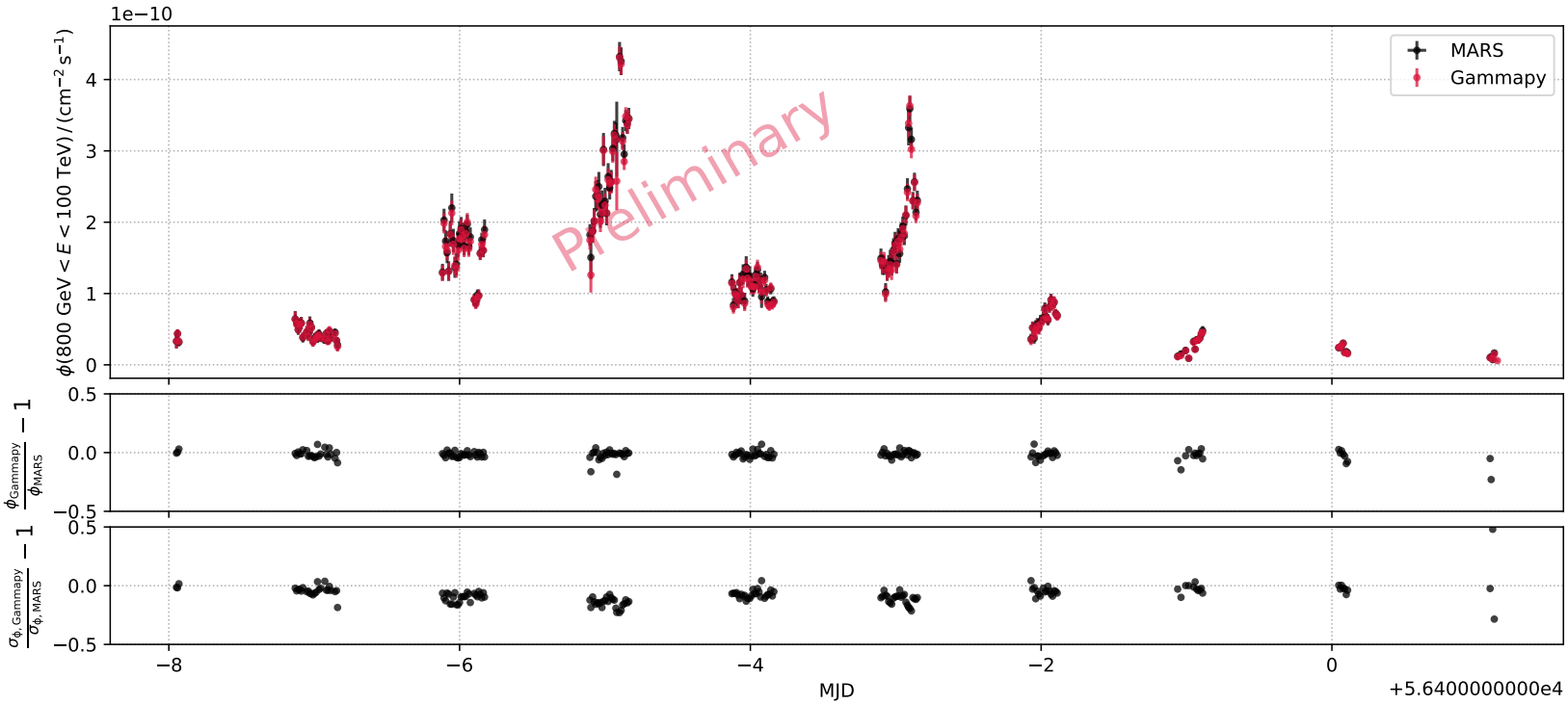
Mrk421 validation



> Reproduced light curve estimation in three different energy bins presented in the paper;
> small biases observed in flux estimation, under investigation.

Conclusion

- Validated 1D analysis of MAGIC DL3 data with `Gammapy`;
- reproduced `MARS` results for two different data sets: Crab Nebula and Mrk421:
  - → validated forward-folding likelihood fit ✔,
  - → validated flux point estimation for light curves ✔,
  - → small biases in light curve estimation for Mrk421, under investigation;
- DL3 analysis with `Gammapy` starting to be used by MAGIC analysers;
- major DL3 productions ($\sim$ years observational periods) initiated;
- milestone in the definition of MAGIC data legacy: MAGIC data can now be produced in a standardised format analysable with open-source analysis tools;
- progresses also on 3D (spectro-morphological) analysis, see Simone Mender's poster (ID 337)!