

Spectral and timing analysis of bright pulsars with nine years of DAMPE data

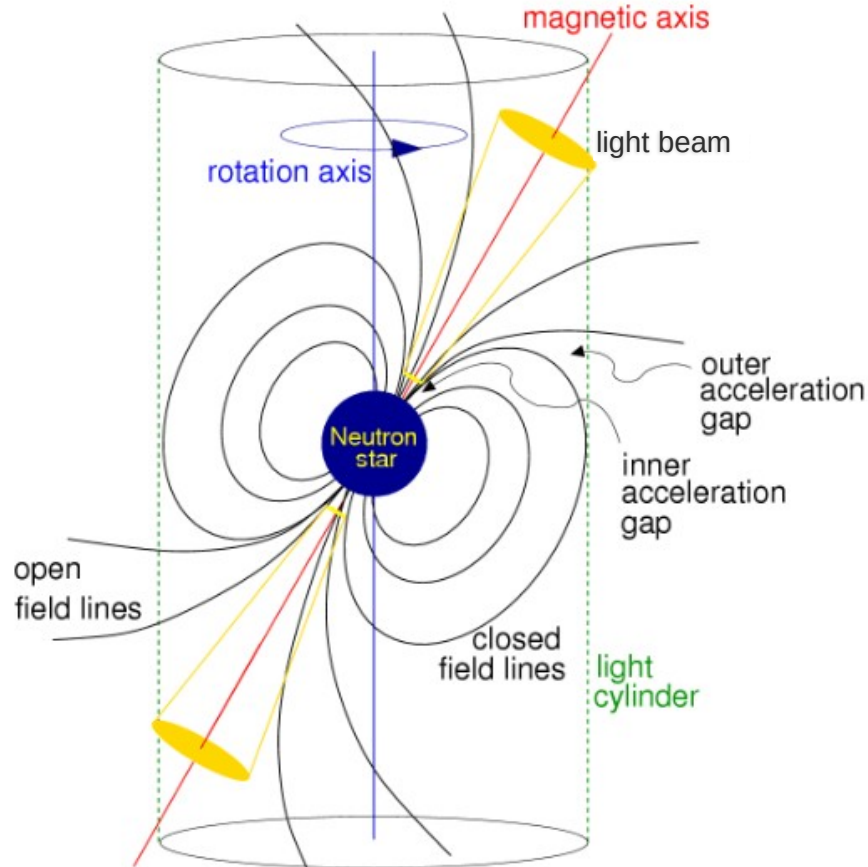
L. Lebrun, J. M. Frieden
and C. Perrina

on behalf DAMPE
collaboration

23/07/2025

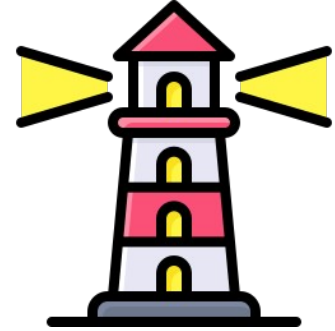


Motivation : Pulsars



Pulsars :

- Spinning neutron stars
- High magnetic field
- Electromagnetic radiation beam : periodic pulses

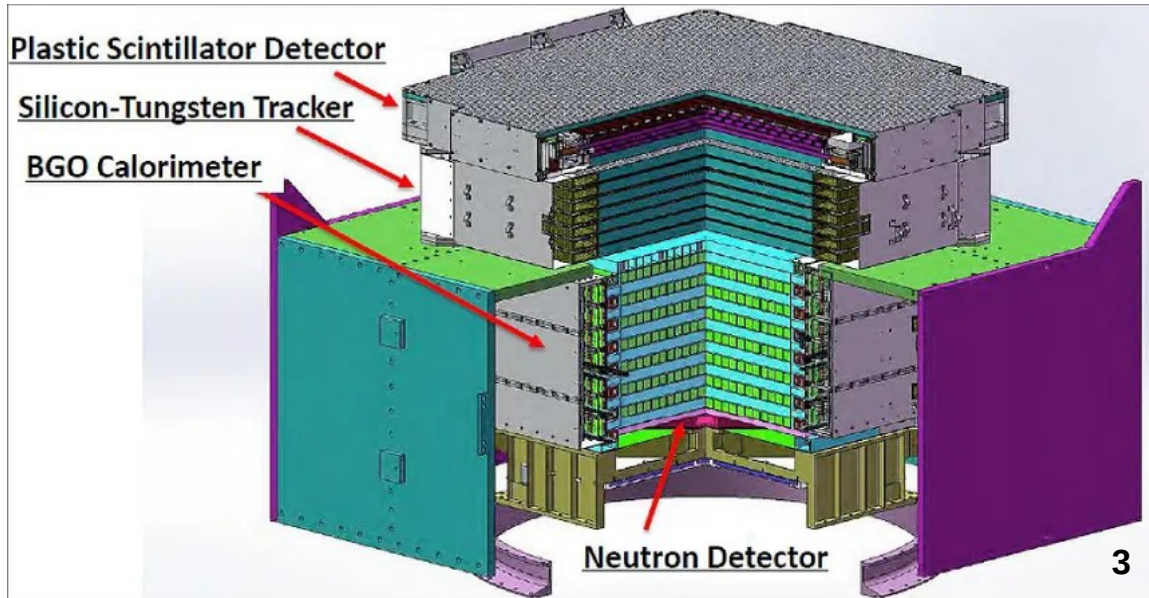
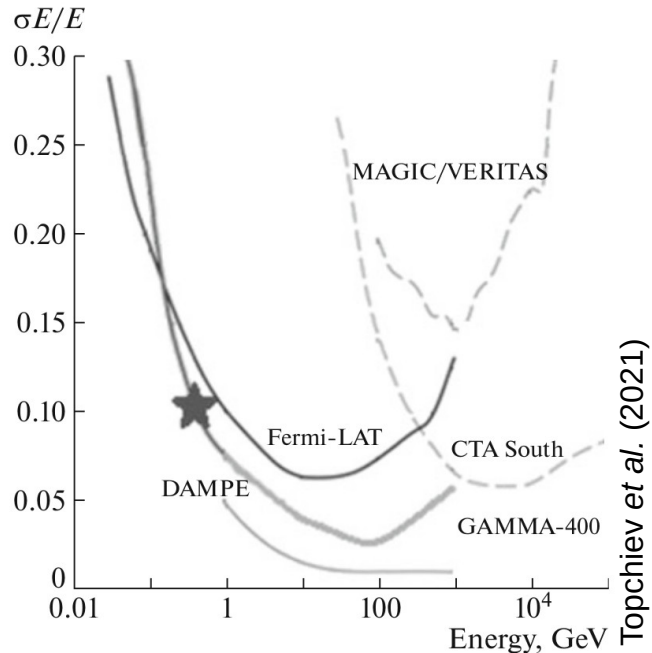


Interest for research :

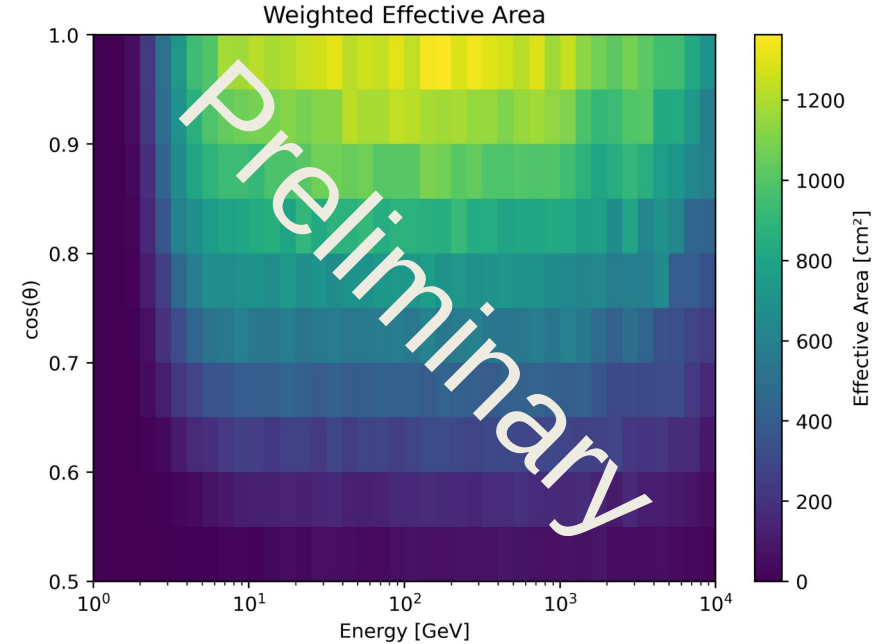
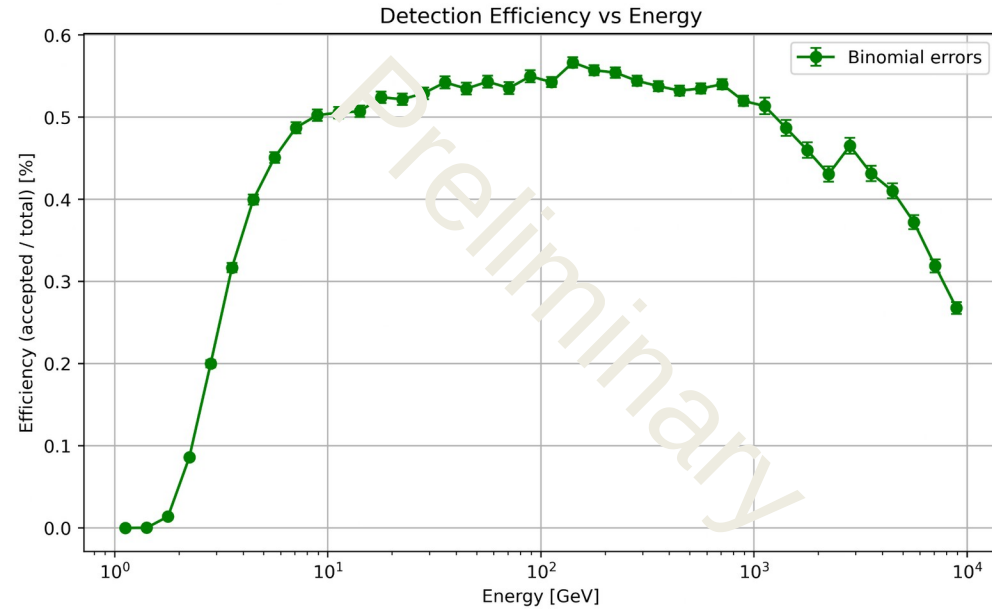
- Pulsar timing : accurate clocks
- Probes of interstellar medium
- Detection of GW background : [NANOGrav 2023](#)

DAMPE Experiment

- Space-based astroparticle detector: 500 km SSO
- Excellent energy resolution in the 1 – 100 GeV energy range
- New gamma-ray selection algorithm

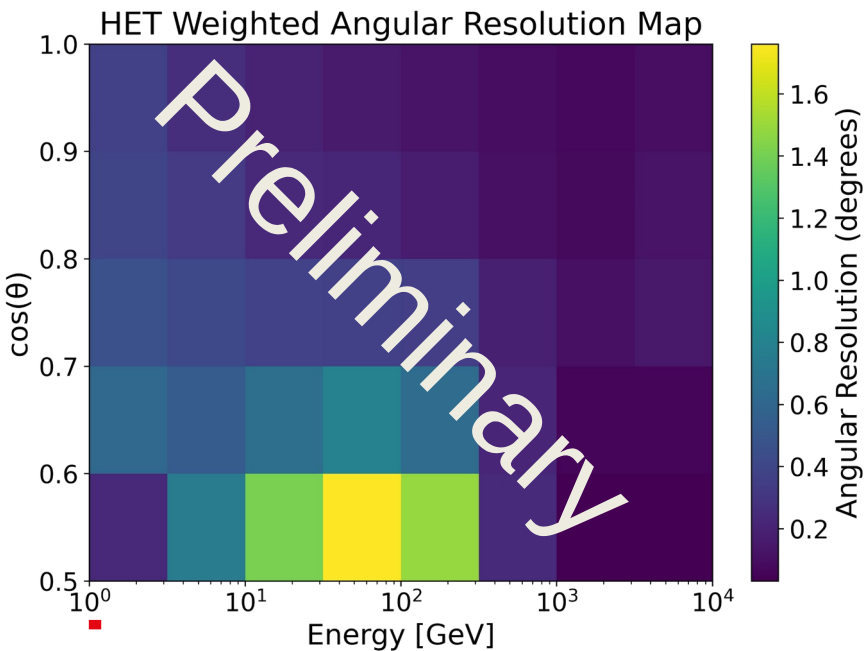


Instrument Response Functions : Efficiency / Effective Area

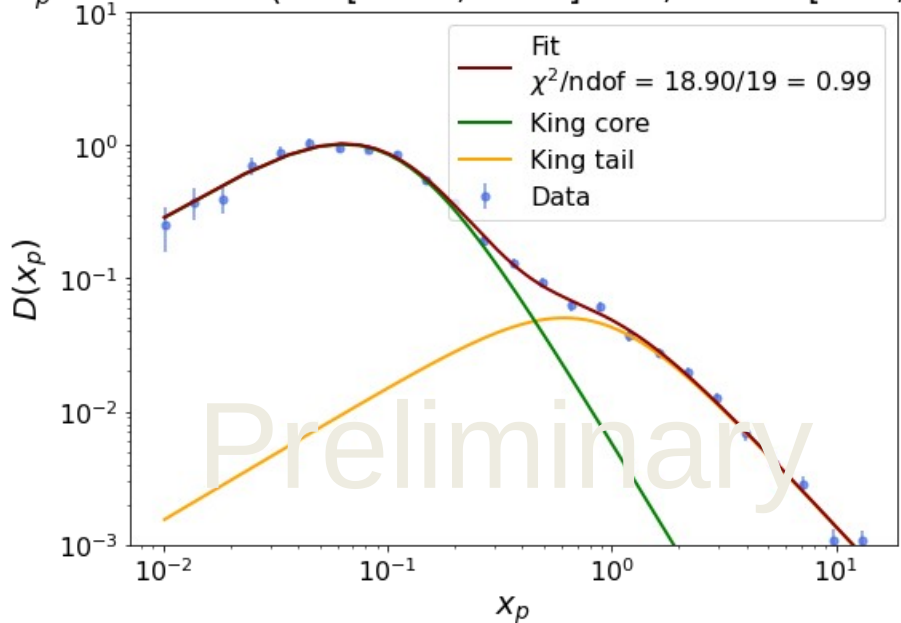


Instrument Response Functions : Point Spread Function

$$K(x_p; \sigma, \gamma) = \frac{1}{2\pi\sigma^2} \left(1 - \frac{1}{\gamma}\right) \left[1 + \frac{x_p^2}{2\gamma\sigma^2}\right]^{-\gamma}$$

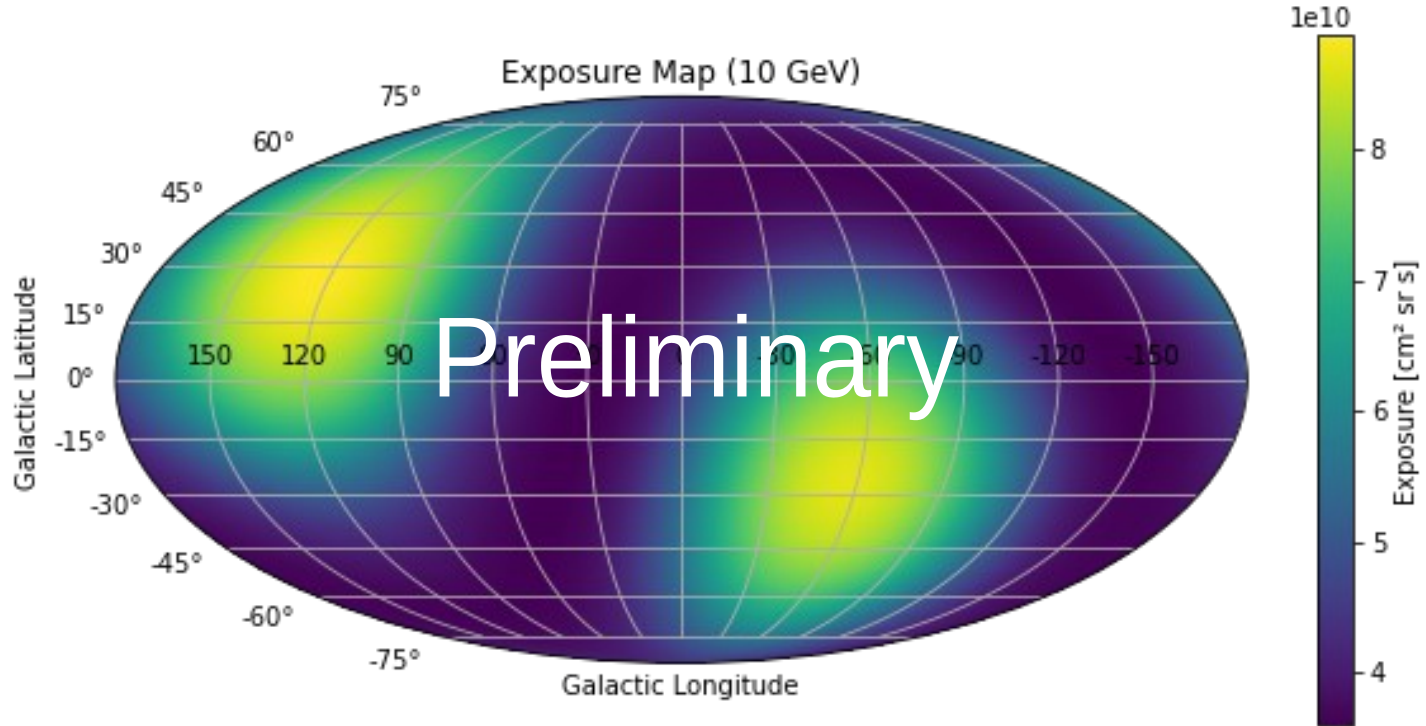


x_p Distribution ($E \in [10.00, 31.62]$ GeV, $\cos\theta \in [0.60, 0.70]$)

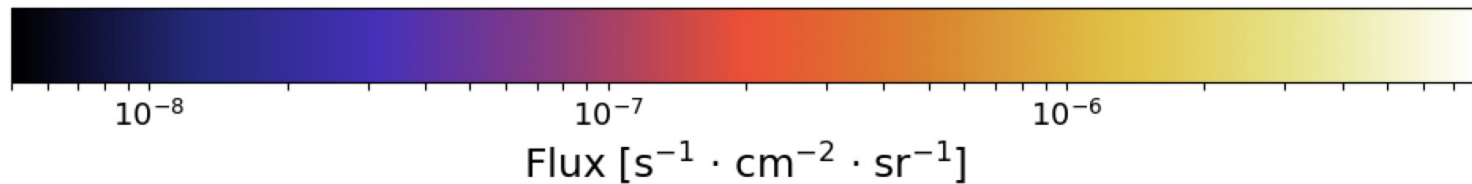
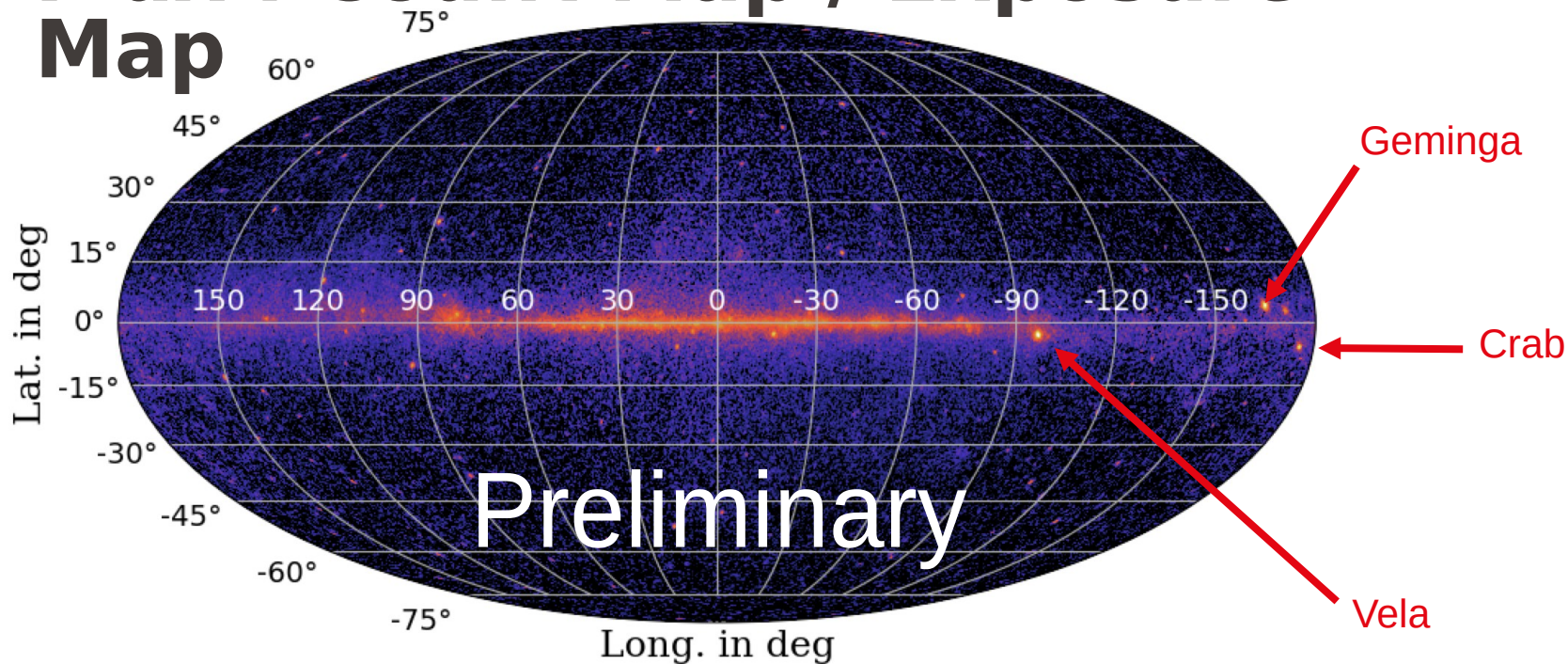


Exposure Maps

Based on HouseKeeping data : integration over effective area and FoV at each t



Flux : Count Map / Exposure Map



EPFL Timing Analysis

Compute pulsar's light curve :

- Barycenter events coordinates
 - Accounts for spacecraft and Earth orbits
 - Compensate gravitational wells
 - Earth, Sun, Jupiter
 - Incorporate pulsar's ephemerides
 - Periodicity drifts, glitches
- **Phase fold !**

If statistic allows :

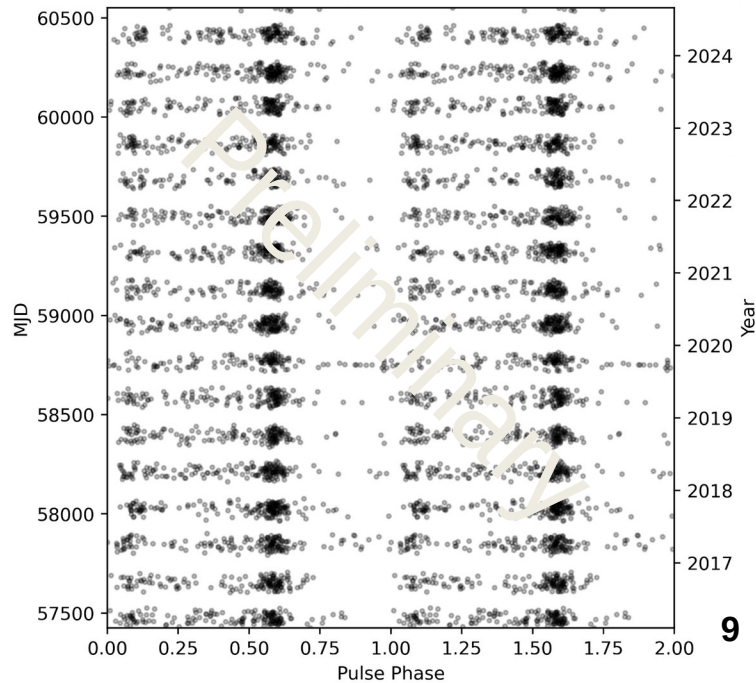
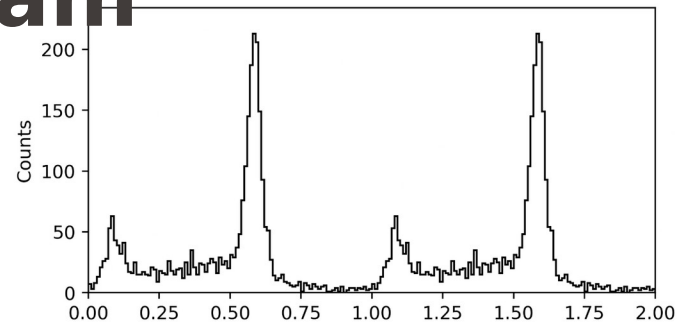
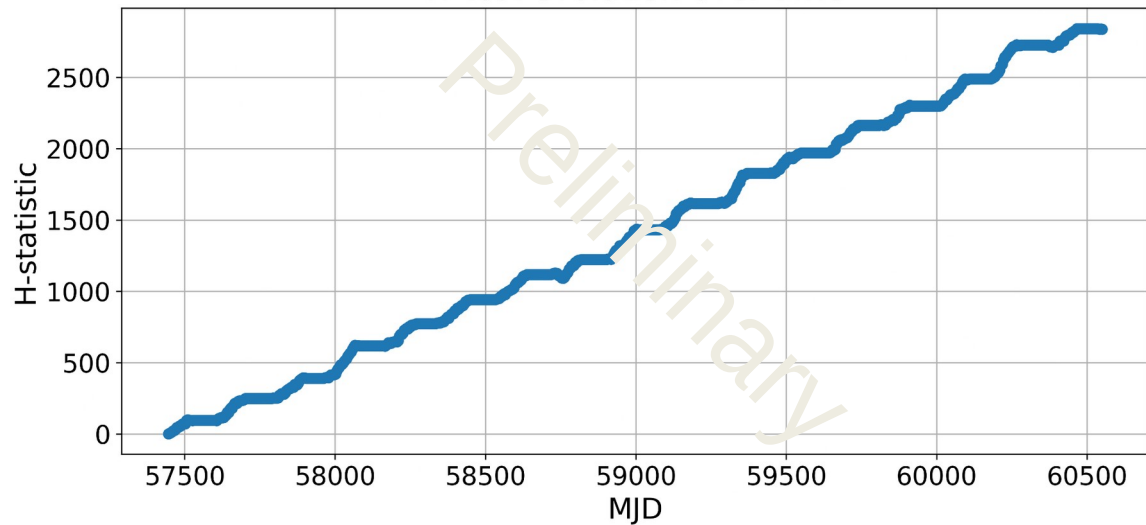
- See spectral evolution of main features (major/minor peaks ratio...)
 - Constrain the geometry of the magnetosphere
- Probe DAMPE's efficiency and energy reconstruction

The [PINT](#) software



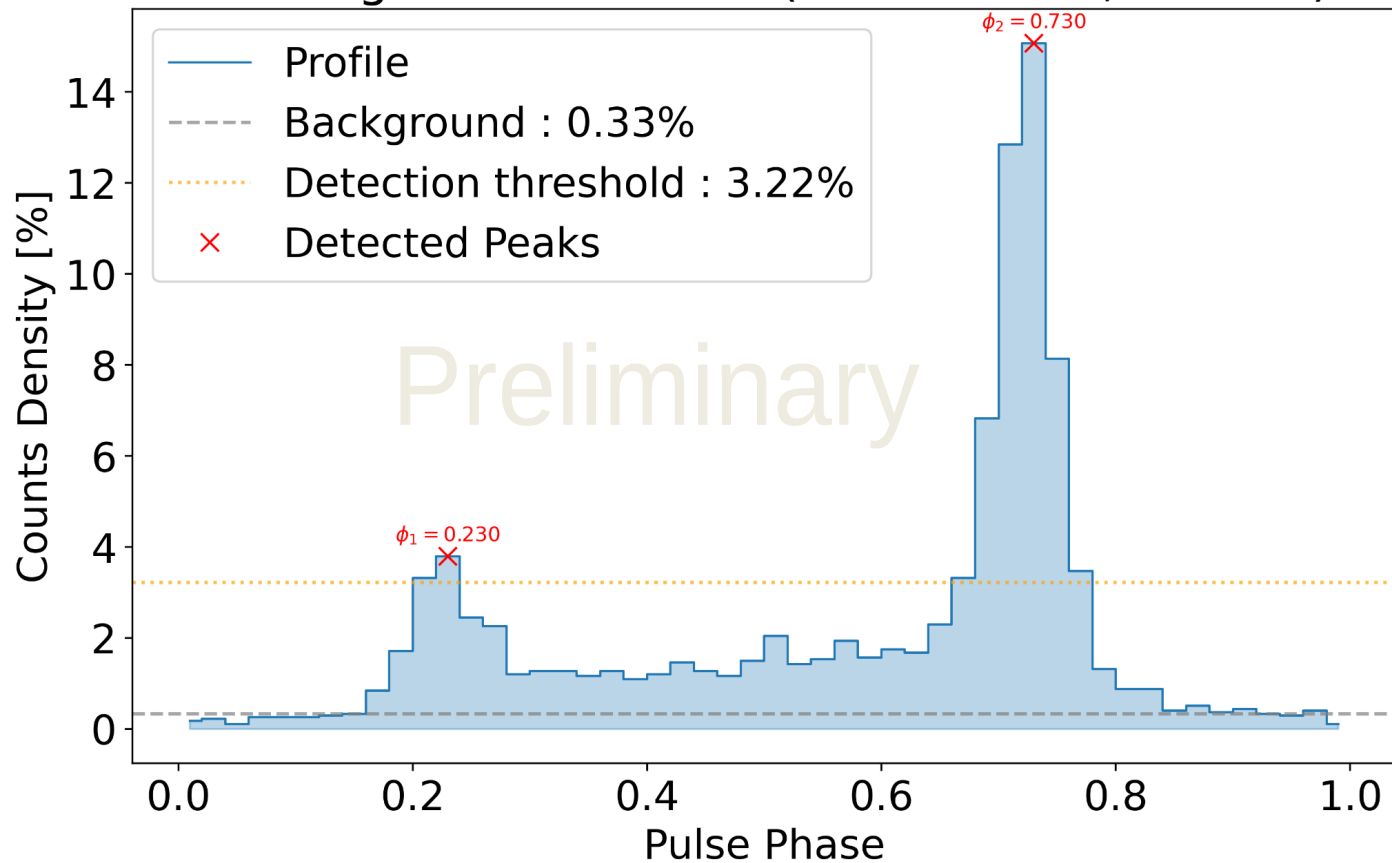
*Courtesy of Dr. Paul Ray (NRL)
and Dr. Matthew Kerr (NRL)*

H-test evolution over time



Geminga : Light Curve

Geminga Folded Profile (2740 counts, 50 bins)

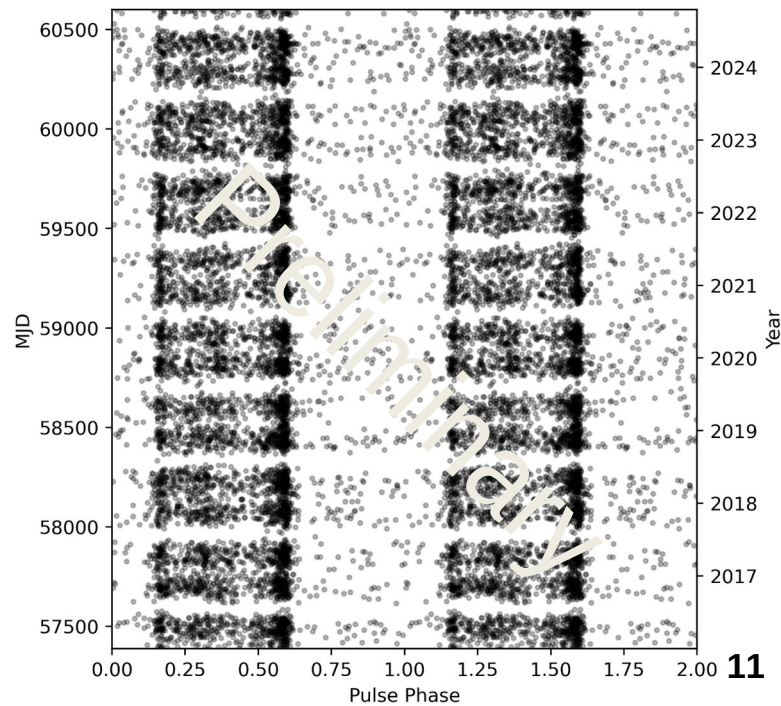
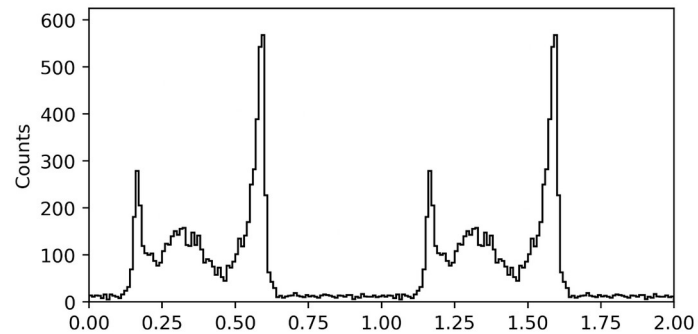
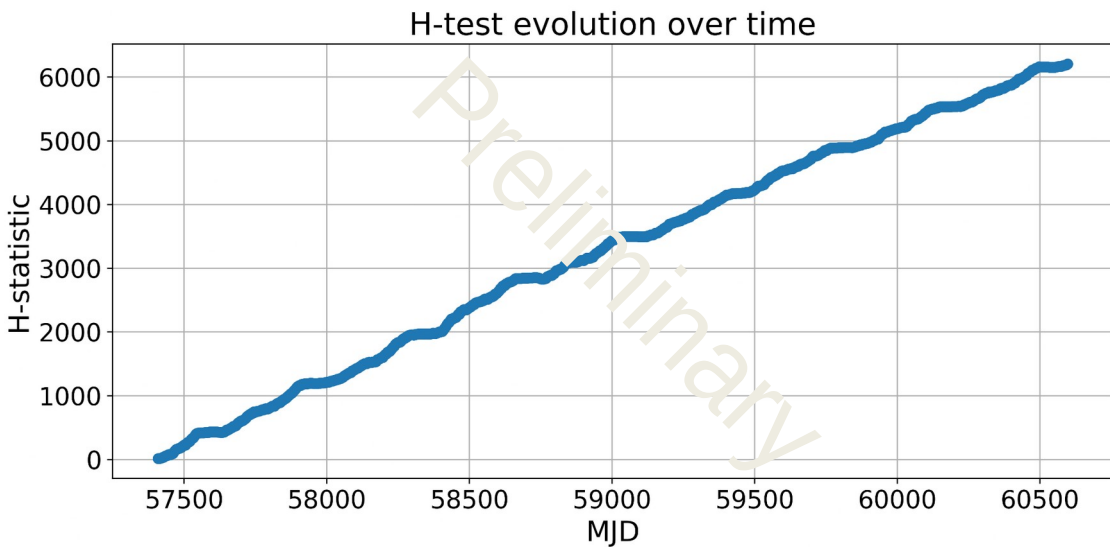


**Broadband
(1 GeV - 10 TeV):**

$$\Delta\phi = 0.50 \pm 0.02$$

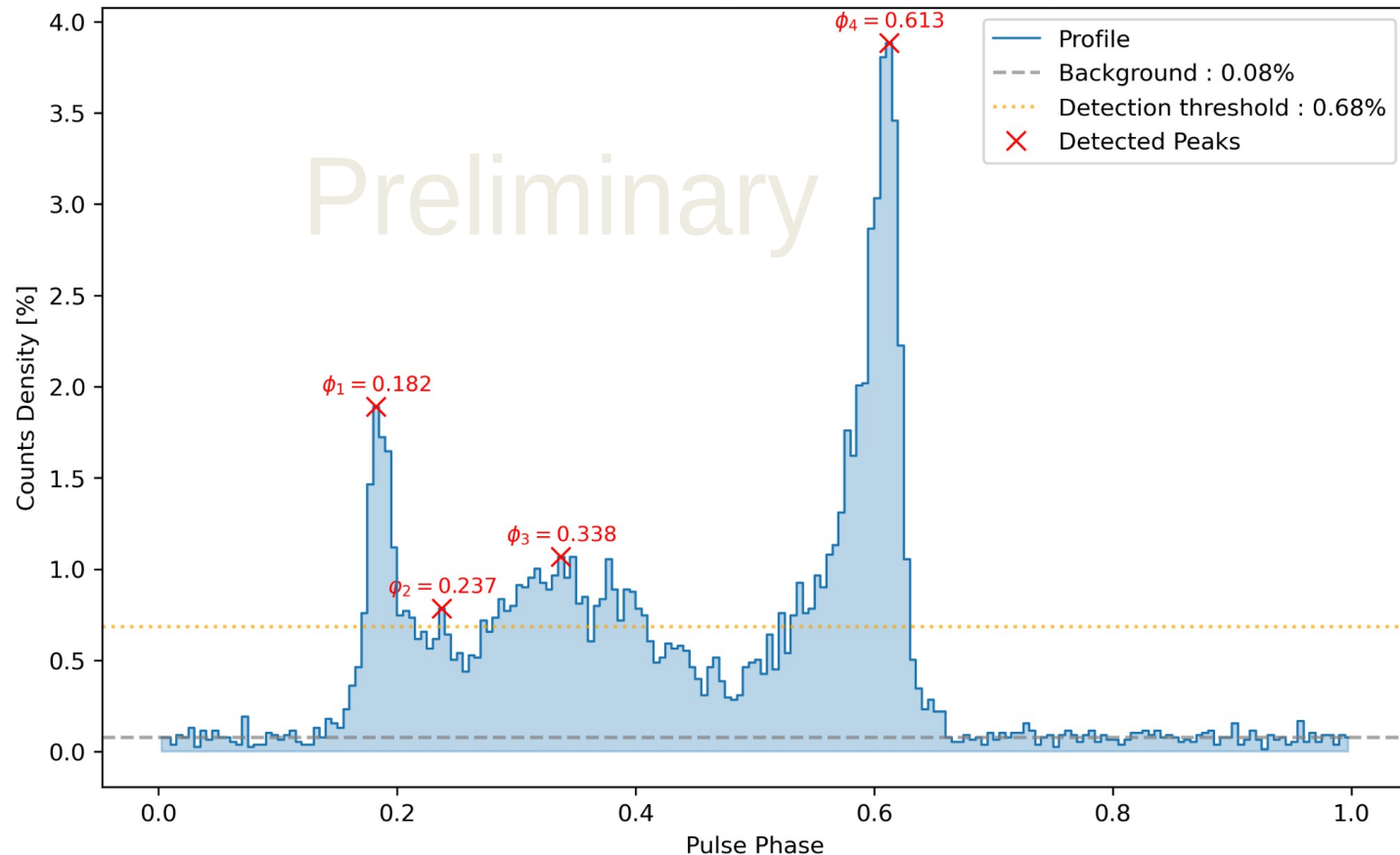
$$Y1/Y2 = 0.3 \pm 0.1$$

EPFL Vela : phaseogram



EPFL Vela : Broadband Light Curve

Vela Folded Profile (7780 counts, 200 bins)



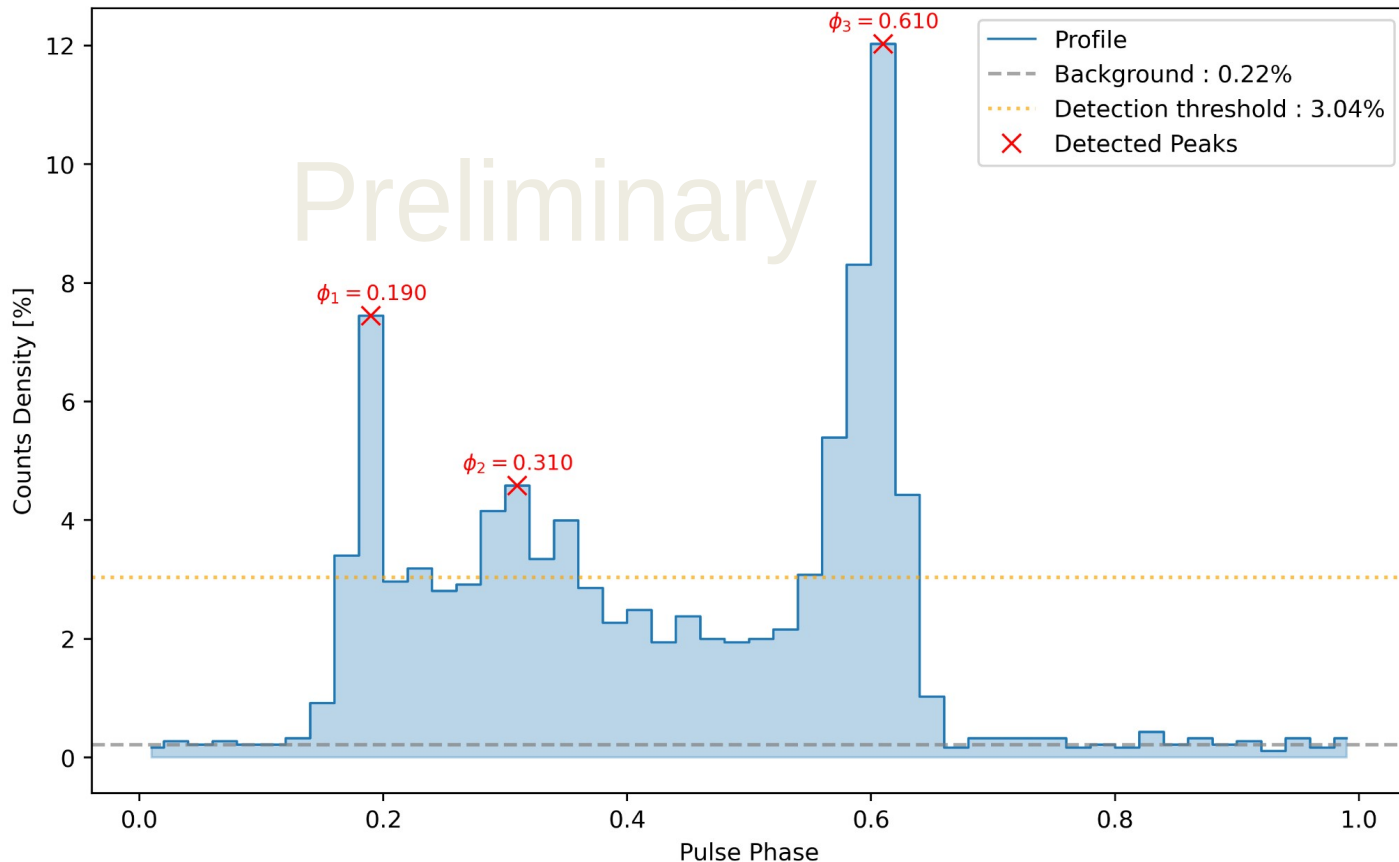
**Broadband
(1 GeV - 10 GeV):**

$$\Delta\phi = 0.43 \pm 0.01$$

$$Y1/Y2 = 0.5 \pm 0.3$$

Vela : Low-End Energy Light Curve

Vela Folded Profile (1854 counts, 50 bins)



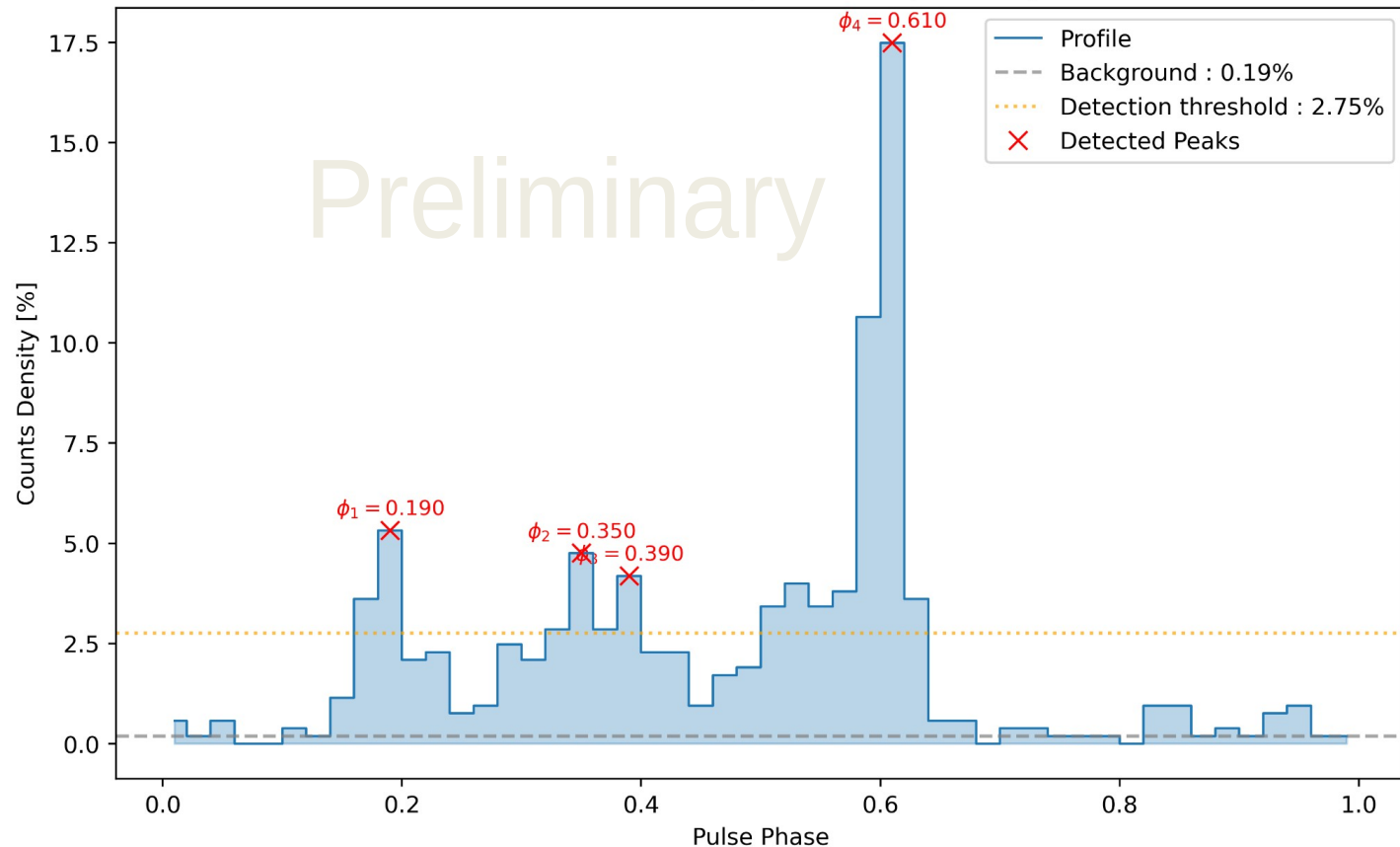
2 - 3 GeV :

$$\Delta\phi = 0.42 \pm 0.02$$

$$Y1/Y2 = 0.7 \pm 0.3$$

Vela : High-End Energy Light Curve

Vela Folded Profile (526 counts, 50 bins)



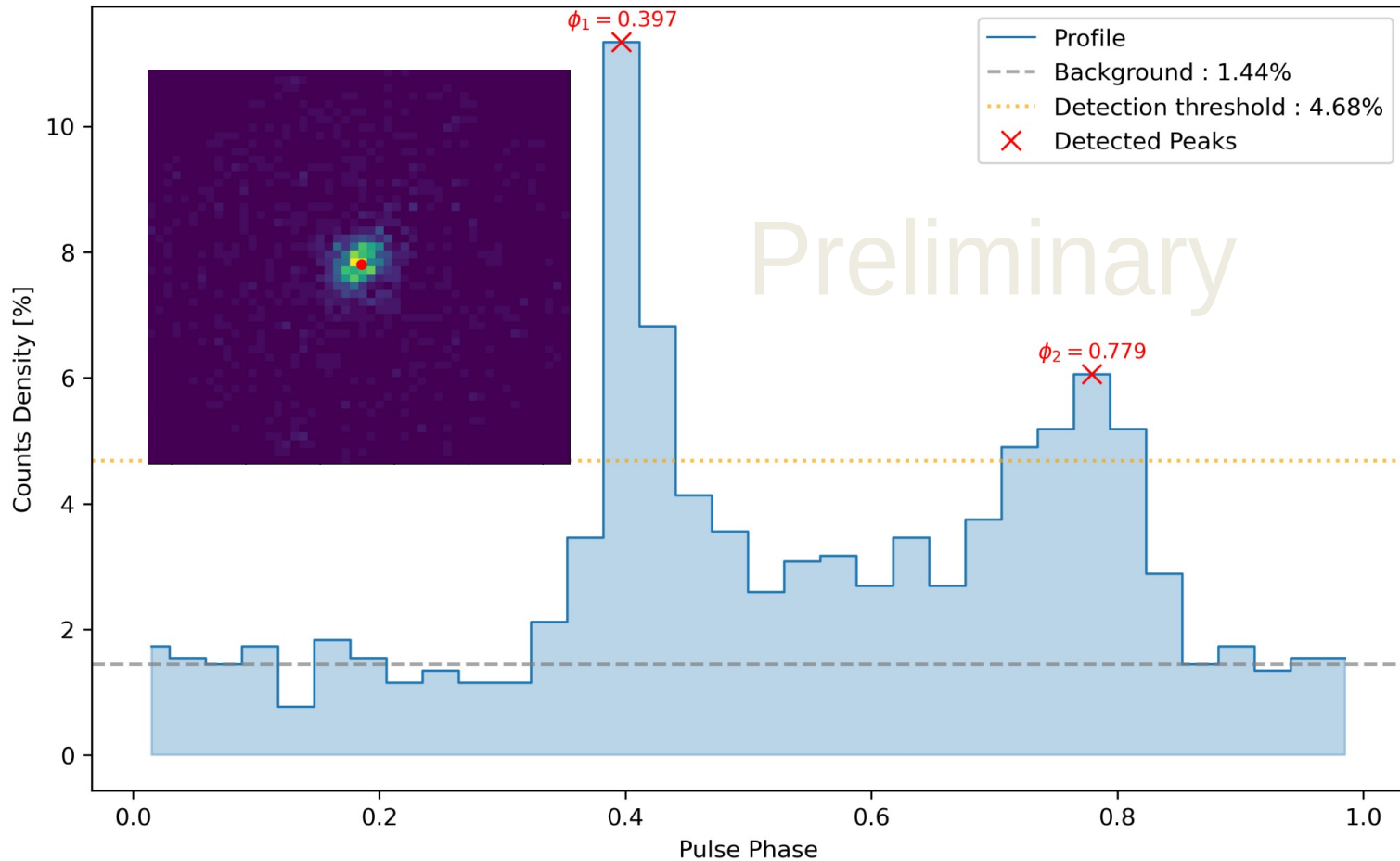
7.5 - 10 GeV :

$\Delta\phi = 0.42 \pm 0.02$

$Y1/Y2 = 0.3 \pm 0.1$

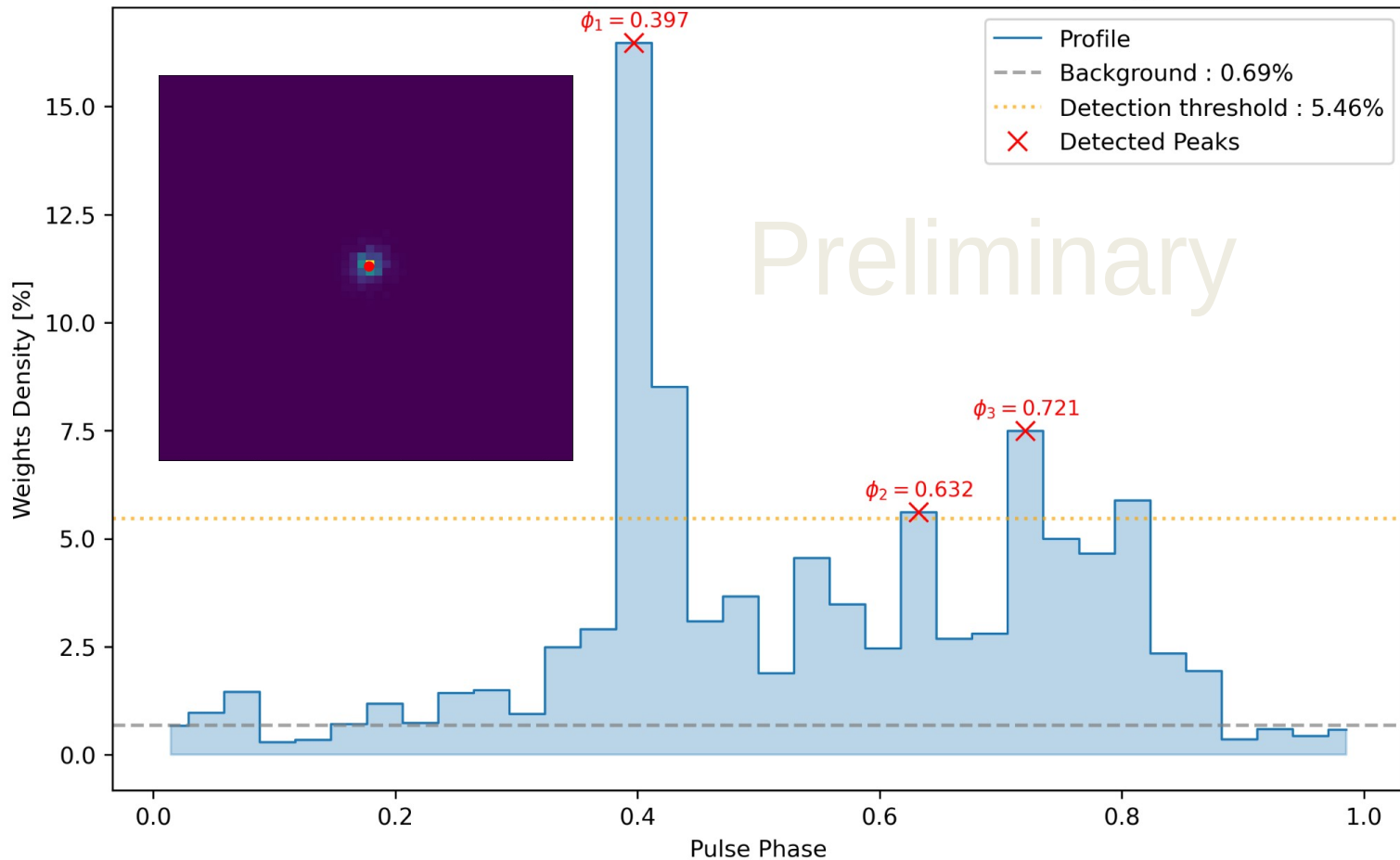
Crab : Counts Light Curve

Crab Folded Profile (1041 counts, 34 bins)



Crab : PSF-Weighted Light Curve

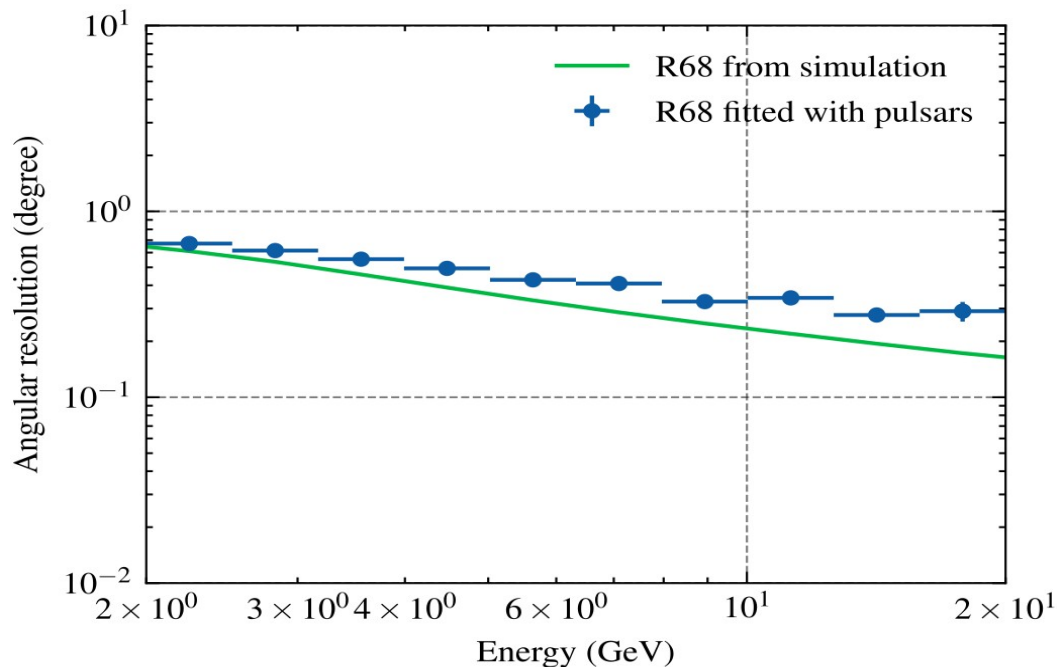
Crab PSF-Weighted Folded Profile (1041 counts, 34 bins)



Crab : the importance of weighting

- First-approach PSF-weighting efficiently reduces background
- BUT sub-optimal in presence of complex emission mechanisms (pulsar wind nebula...)
- Needs full spectral flux model for accurate weighting

IRFs calibration on pulsars



Angular resolution fitted with MC simulations and pulsars

Taken from Duan et al. 2025 : *PSF calibration of DAMPE for gamma-ray observations*

EPFL Conclusions

- Timing and spectral analyses are successfully conducted (despite the low statistics)
- Measurements consistent with previous Fermi-LAT results (Vela, Geminga, Crab)
- New pulsar catalogue from DAMPE under construction
- Qualitative study of pulsars' magnetosphere allowed

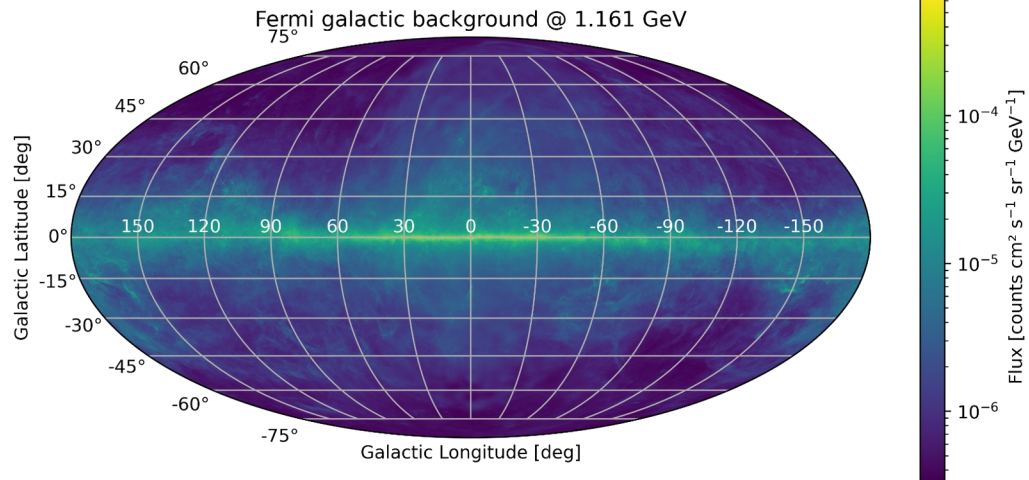
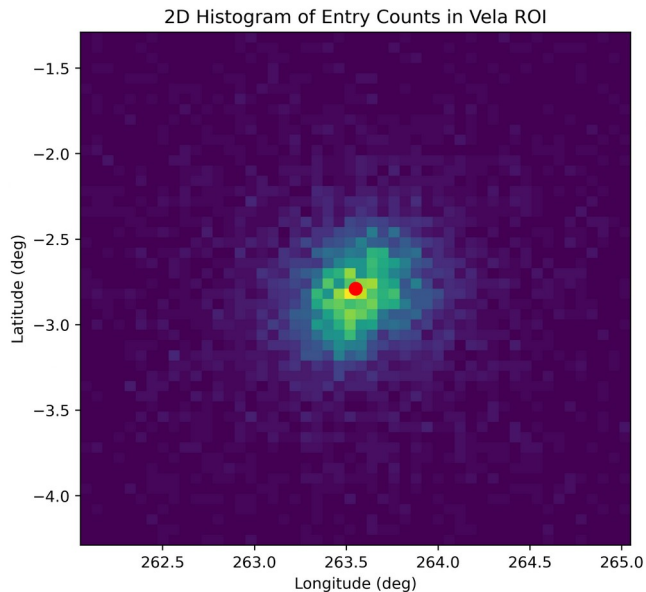
Future prospects

- Flux computation for accurate weighting of Time of Arrivals (TOAs)
- IRFs calibration using pulsars

BACKUP

Maximum Likelihood Analysis

$$F(E, \hat{p}) = F_{\text{source}}(E, \hat{p}) + F_{\text{Galactic}}(E, \hat{p}) + F_{\text{diffuse}}(E, \hat{p})$$



Fermi GIEM

