The Geminga pulsar with the LST-1

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Outline

1. γ-ray pulsars
2. Geminga
3. LST-1 observations and results

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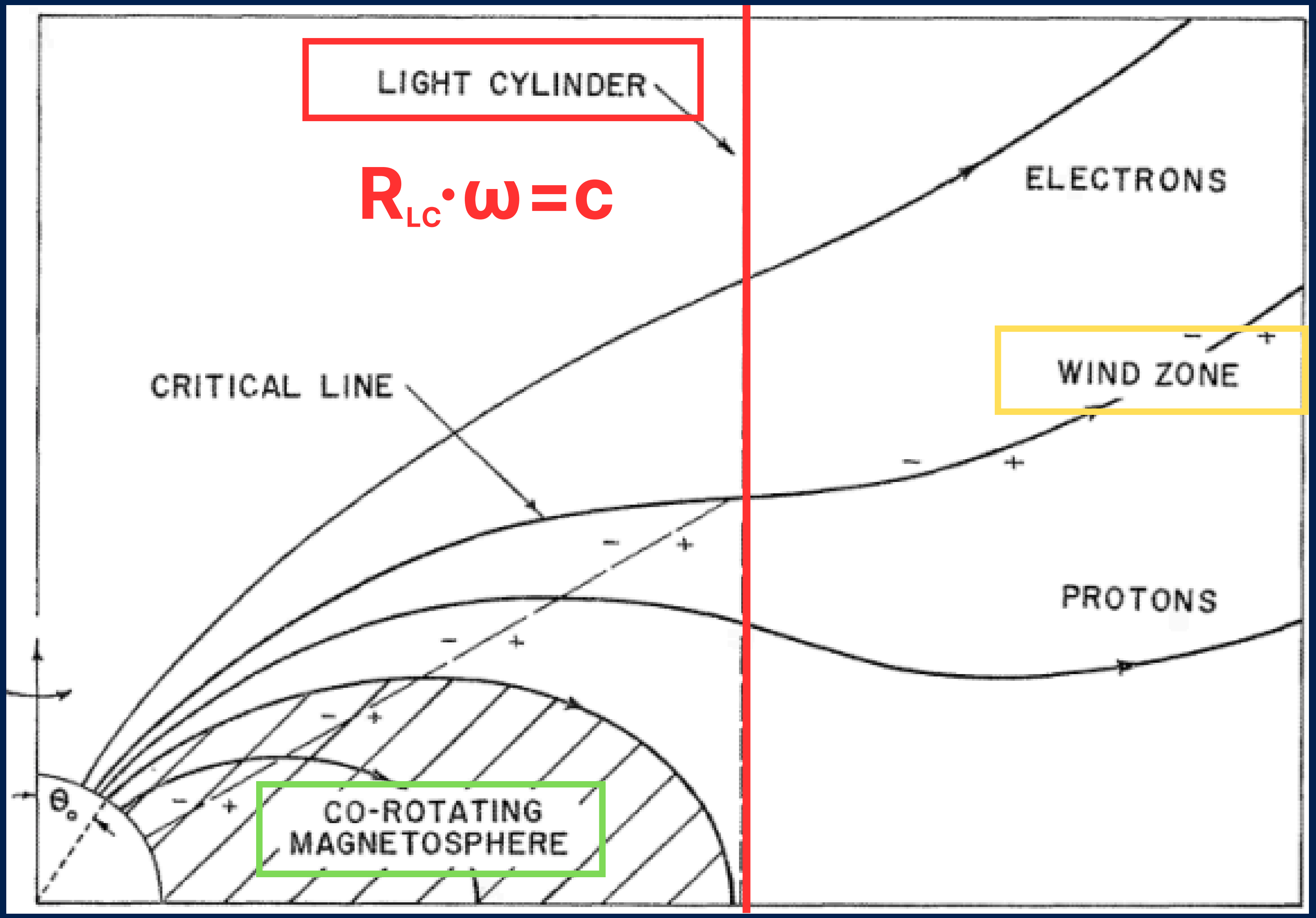
LST-1 observations and results

The magnetosphere

Lines crossing the LC are open → particles can escape



Credit: P. Golreich & W. H. Julian, "Pulsar Electrodynamics"

Region dominated by the pulsar wind

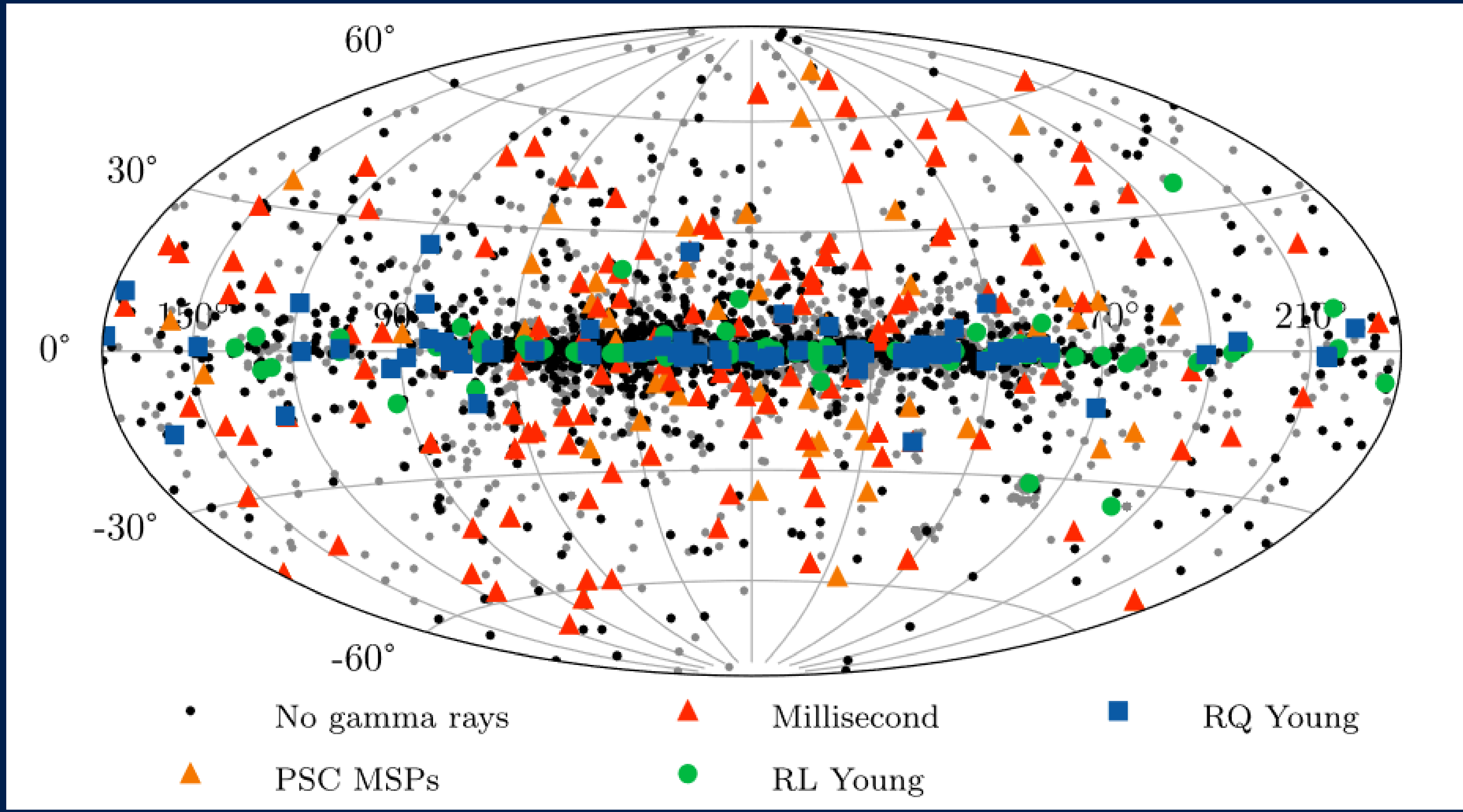
The magnetic field lines rigidly rotate with the NS

Fermi-LAT γ-ray pulsars

~340 γ-ray pulsars in the 3PC

Common features of the γ-ray emission:

- **Double-peaked** phaseogram
- **Cutoff** in the spectrum at ~10s of GeV

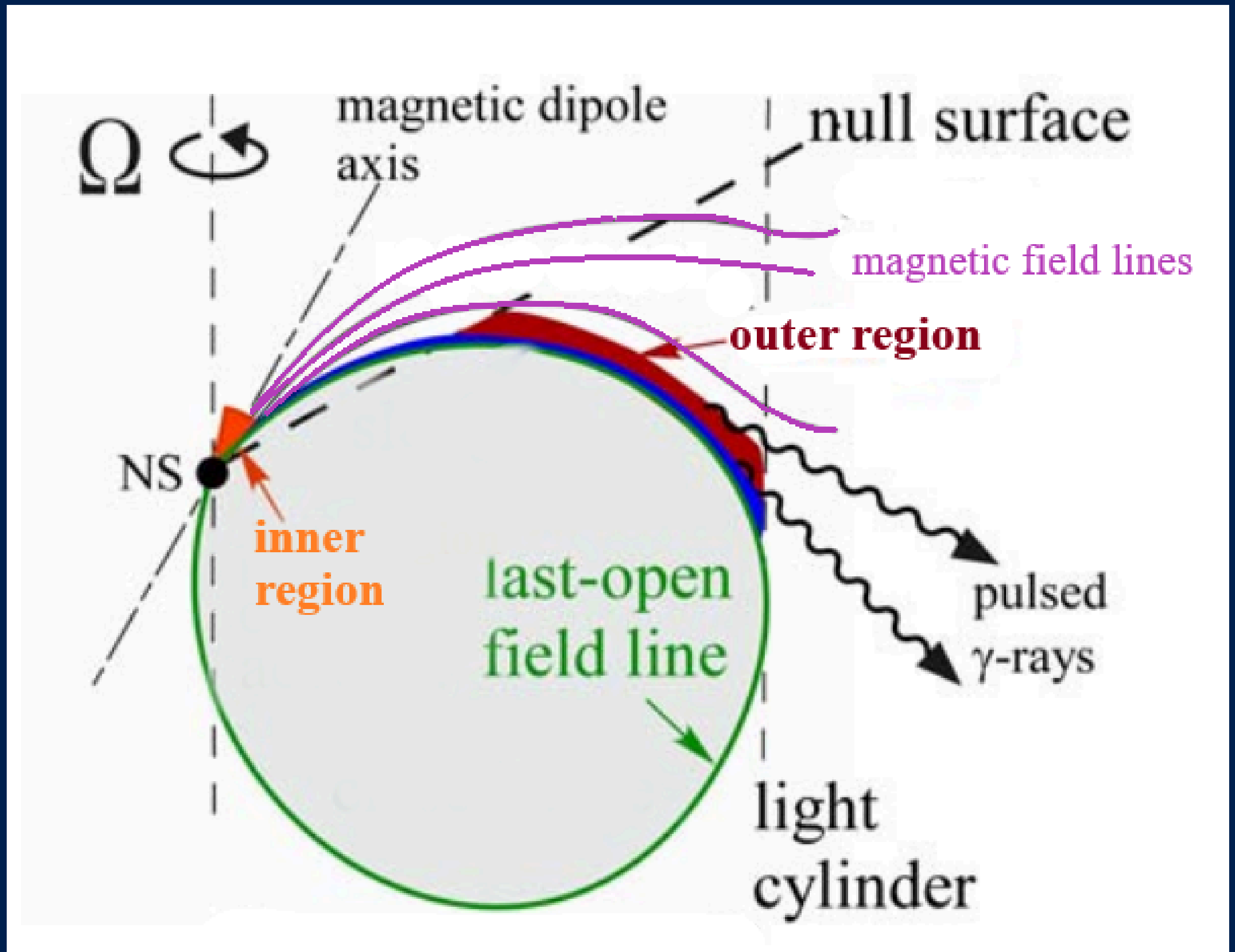


Credit: D. A. Smith et al, "The Third Fermi Large Area Telescope Catalog of Gamma-Ray Pulsars"

Models for γ-ray emission

Classical models are based on **curvature radiation**

Acceleration in the **inner magnetosphere** (Polar Cap models): **excluded by *Fermi*-LAT**

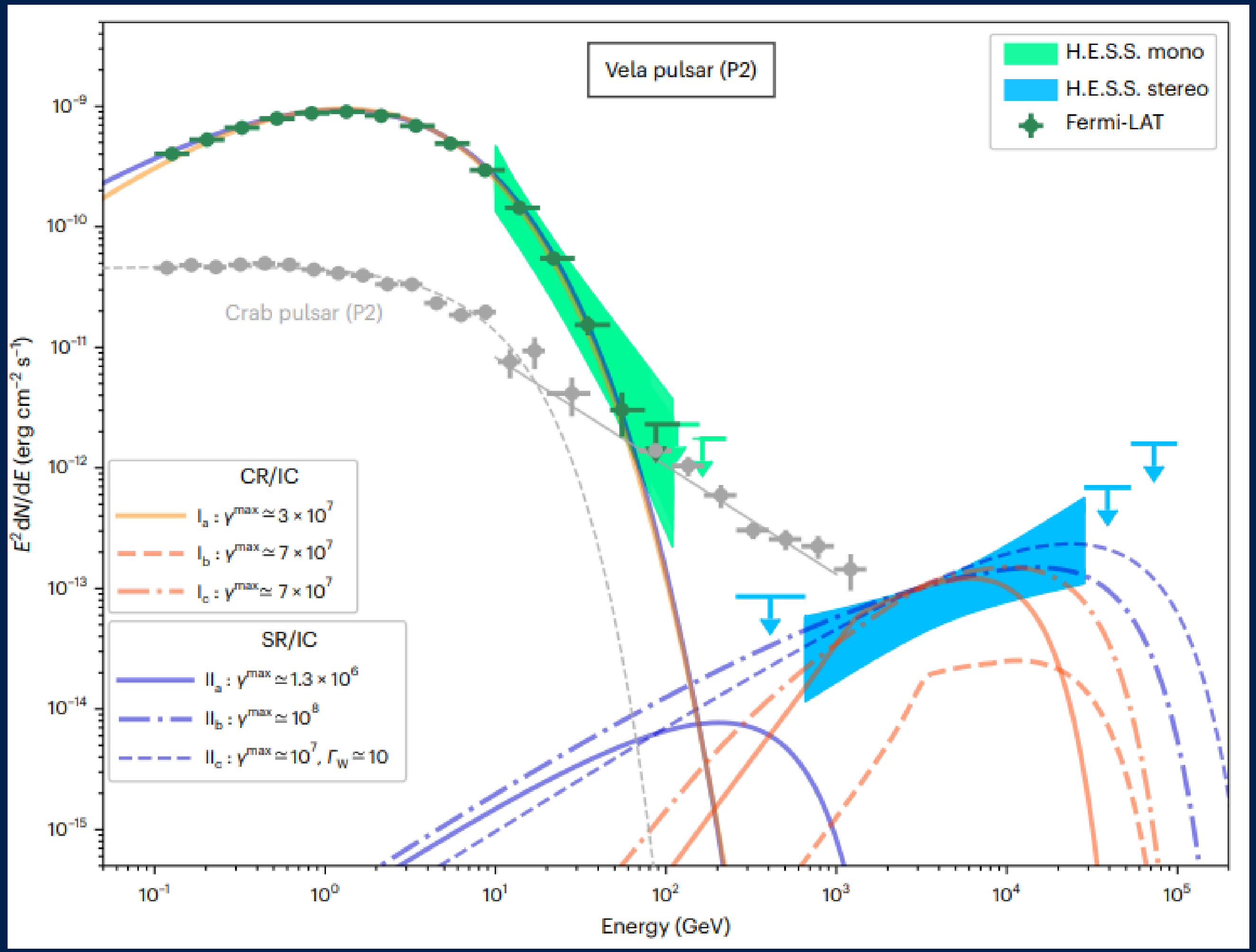


Adapted from: K. Hirotani, "High Energy Emission from Rotation-Powered Pulsars: Outer-gap vs. Slot-gap Models"

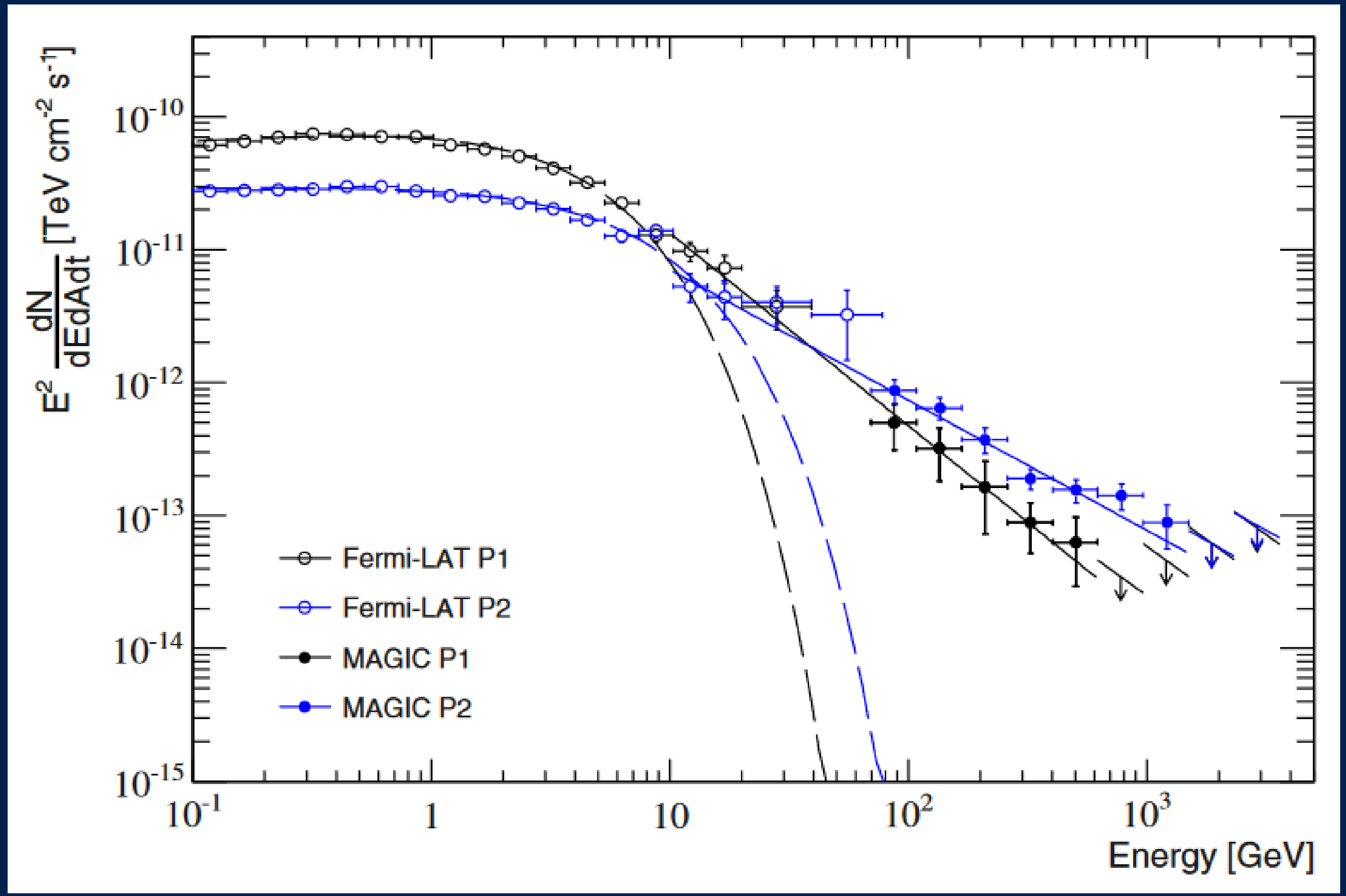
Acceleration in the **outer magnetosphere** (Outer Gap models)

Exceptions: Vela and Crab

Clear deviation from the spectral cutoff → **new models must be tested**



Credit: The H.E.S.S. Collaboration, "Discovery of a radiation component from the Vela pulsar reaching 20 teraelectronvolts"



Credit: S. Ansoldi et al. (The MAGIC Collaboration), "Teraelectronvolt pulsed emission from the Crab Pulsar detected by MAGIC"

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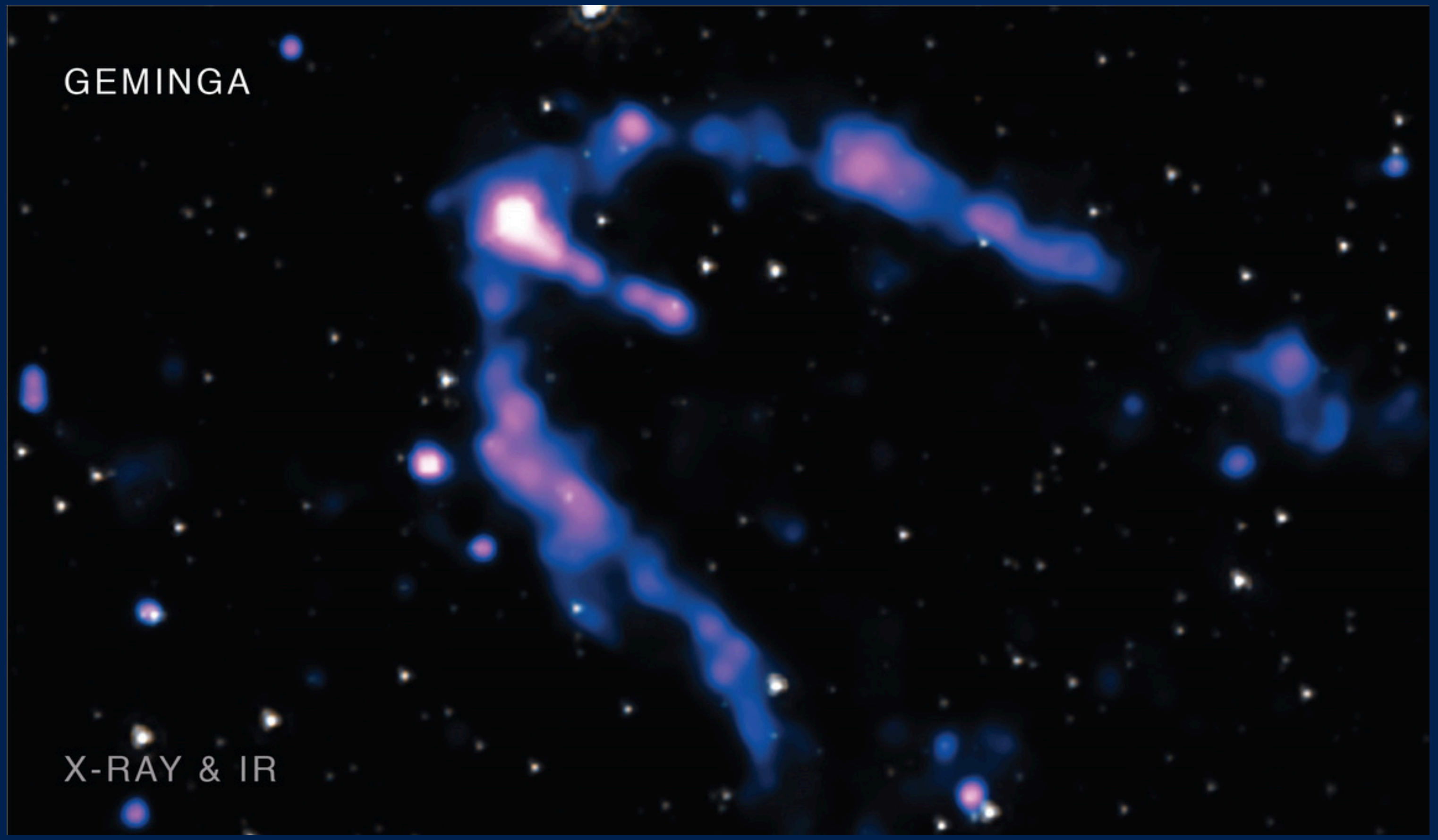
LST-1 observations and results

Geminga (PSR J0633+1746)

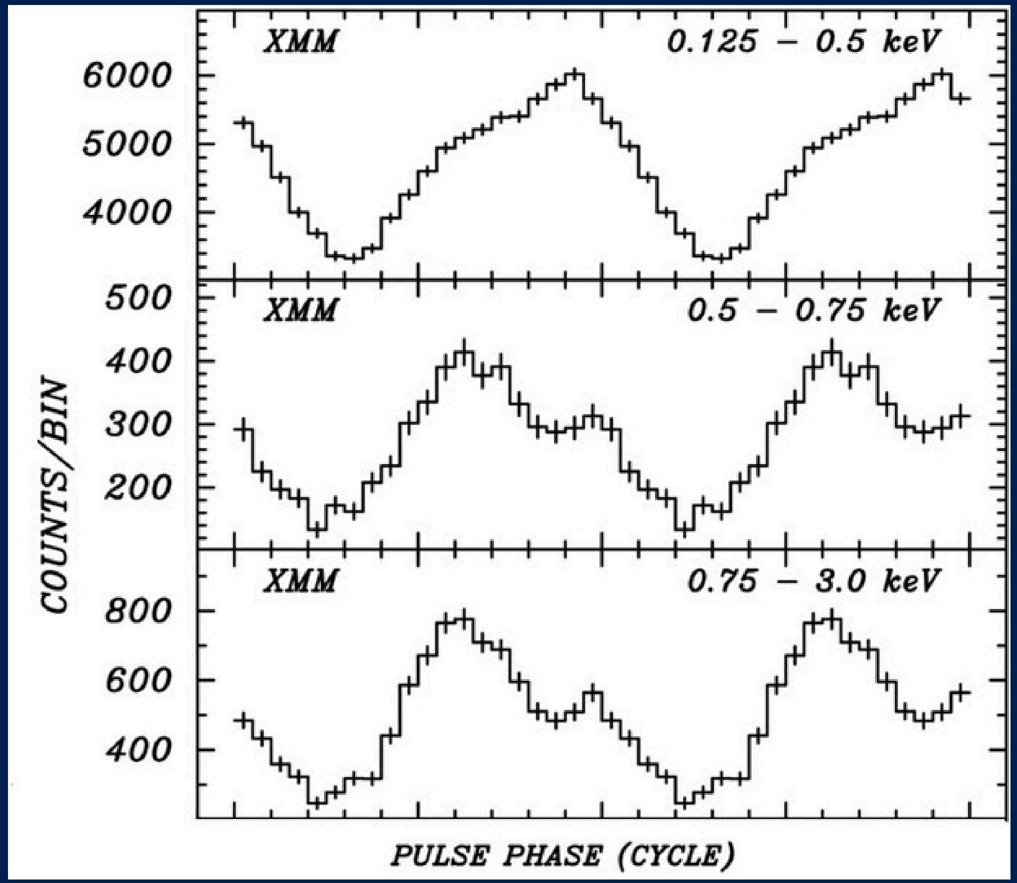
- Discovered in 1972 by SAS-2, identified as a pulsar only in 1992
- One of the closest γ-ray pulsars (d<300 pc)
- Middle-aged: t ~ 300 ky
- Characteristic parameters: P=237 ms, E_dot=3.5 · 10^{34} erg/s

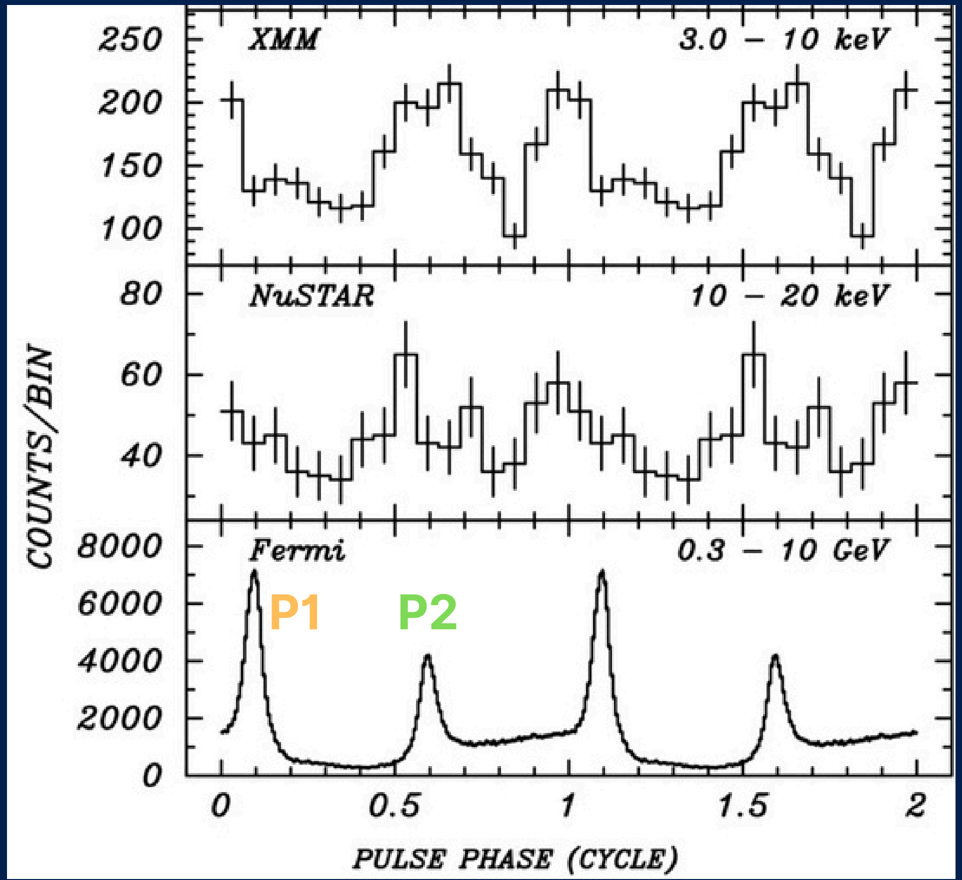


Credit: X-ray: NASA/CXC/PSU/B.Posselt et al.; Infrared: NASA/JPL-Caltech

Multi-wavelength observations

- Pulsed emission in the X-rays
- **Radio quiet**: UL~0.4-4 mJy at 111 MHz
- γ-ray lightcurve (*Fermi*-LAT): two peaks (P1, P2) separated by ΔΦ=0.5



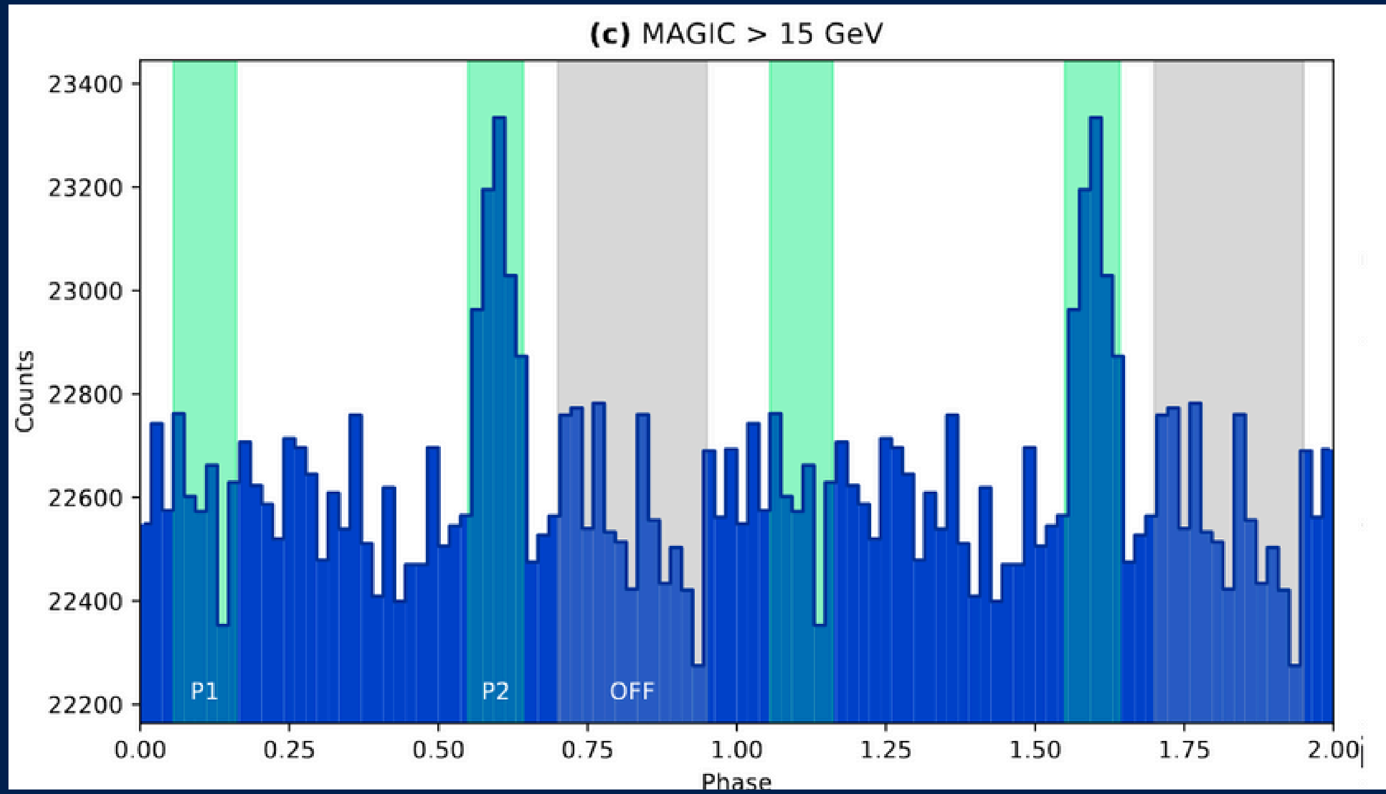


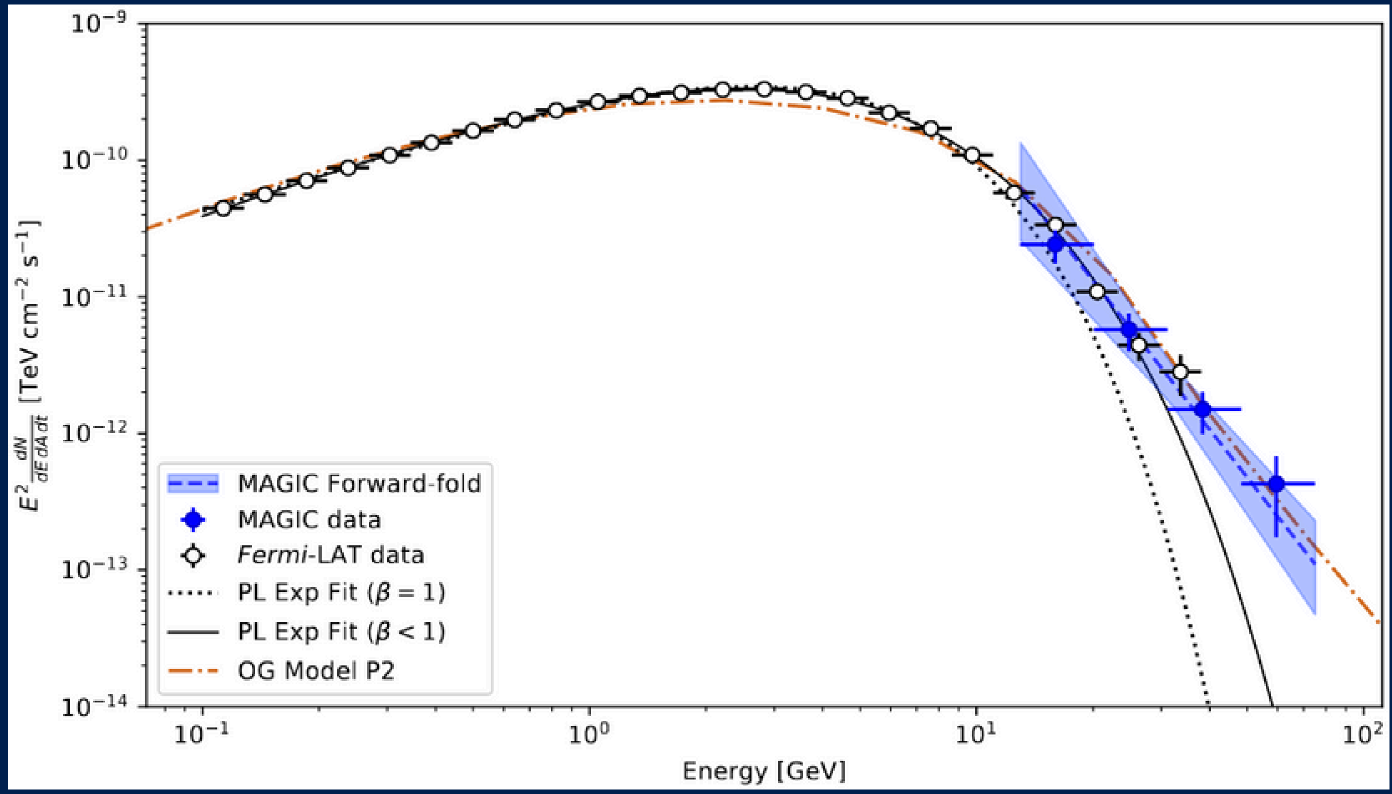
Credit: K. Mori et al, "A broadband X-ray study of the Geminga pulsar with NuSTAR and XMM-Newton"

The phaseogram changes with the energy

MAGIC Collaboration results

- 80h of good-quality observations at Zd<25°: **P2 detected at 6.3σ, P1 not detected**
- Power law fit of P2: a hint of an Inverse Compton tail?





Credit: V. A. Acciari et al (The MAGIC Collaboration), "Detection of the Geminga pulsar with MAGIC hints at a power-law tail emission beyond 15 GeV"

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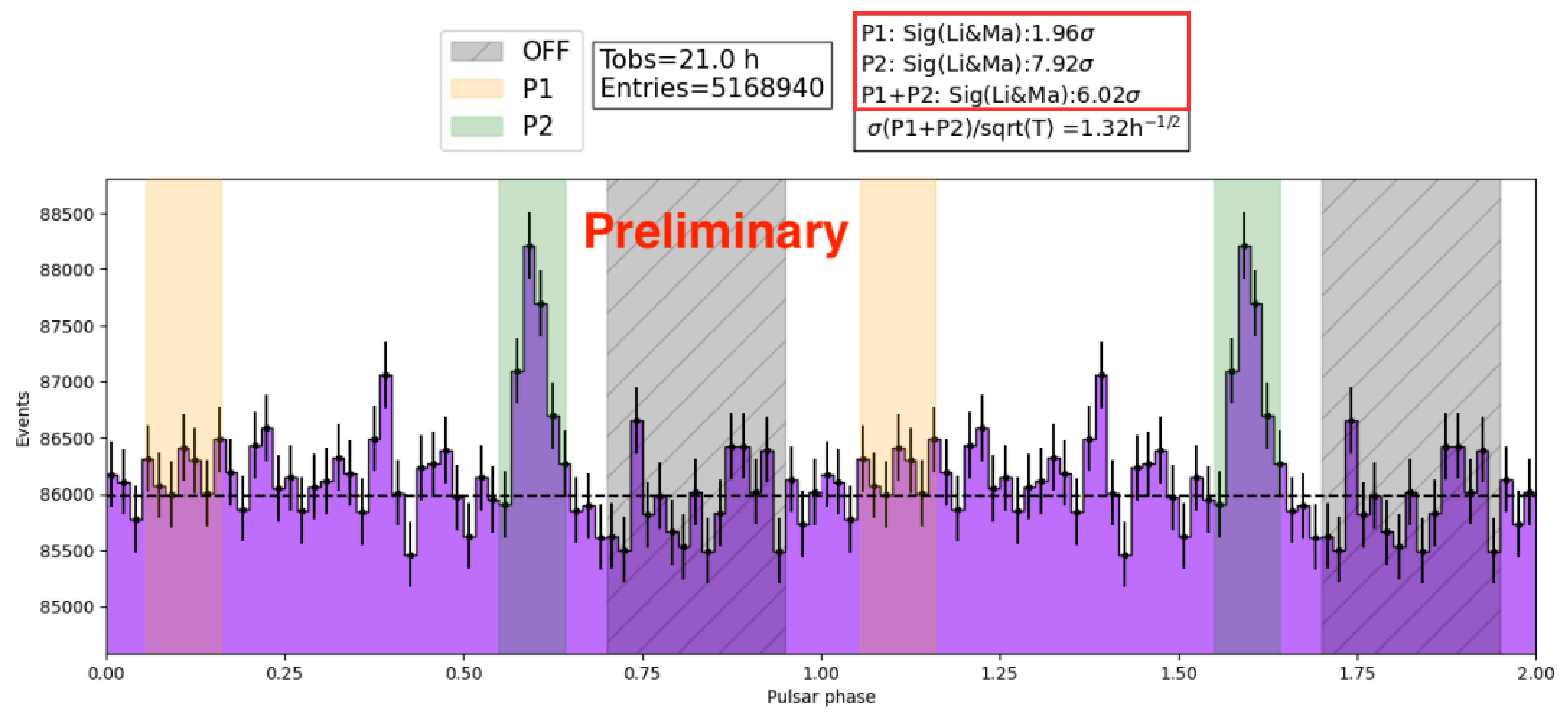
LST-1 observations and results

LST-1 observations

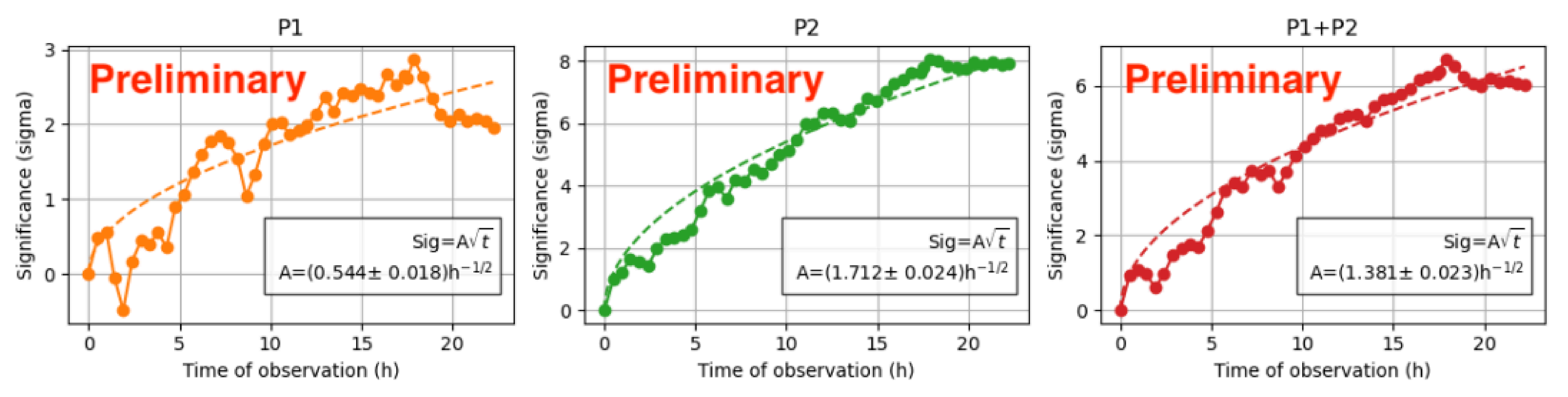
- Pulsars are good targets for the LST-1, the first observed was the Crab
- First observations of Geminga between December 2022 and March 2023: 41.5 hours in total
- Zenith cut of the analysis Zd<25° → **low energy threshold**
- After the cleaning and the selection in zenith, **21 hours survived**

Phaseogram

~8σ in only 21 hours!

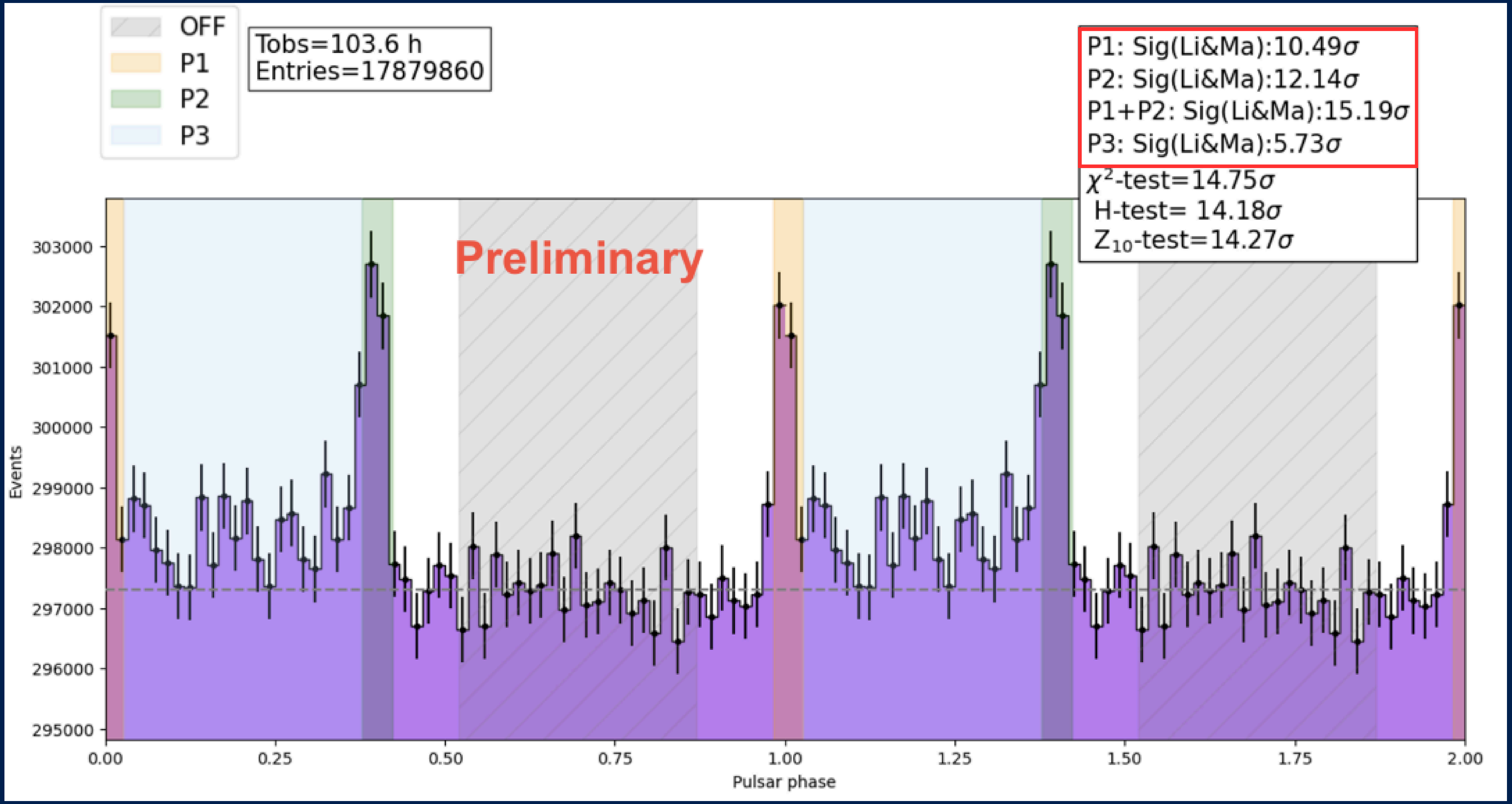


Evolution of the signal



Overall we see a **good increasing trend**

Comparison with the Crab



Both peaks detected above 10σ, the bridge at ~6σ

Conclusions

- Pulsars are fascinating sources for gamma-ray astronomy → there is still a lot to be discovered in the future
- The analysis of the LST-1 observation of Geminga is still ongoing: stay tuned for new results!
- The LST-1 has shown **excellent performance**, especially at lower energies (i.e. ~10s of GeV)