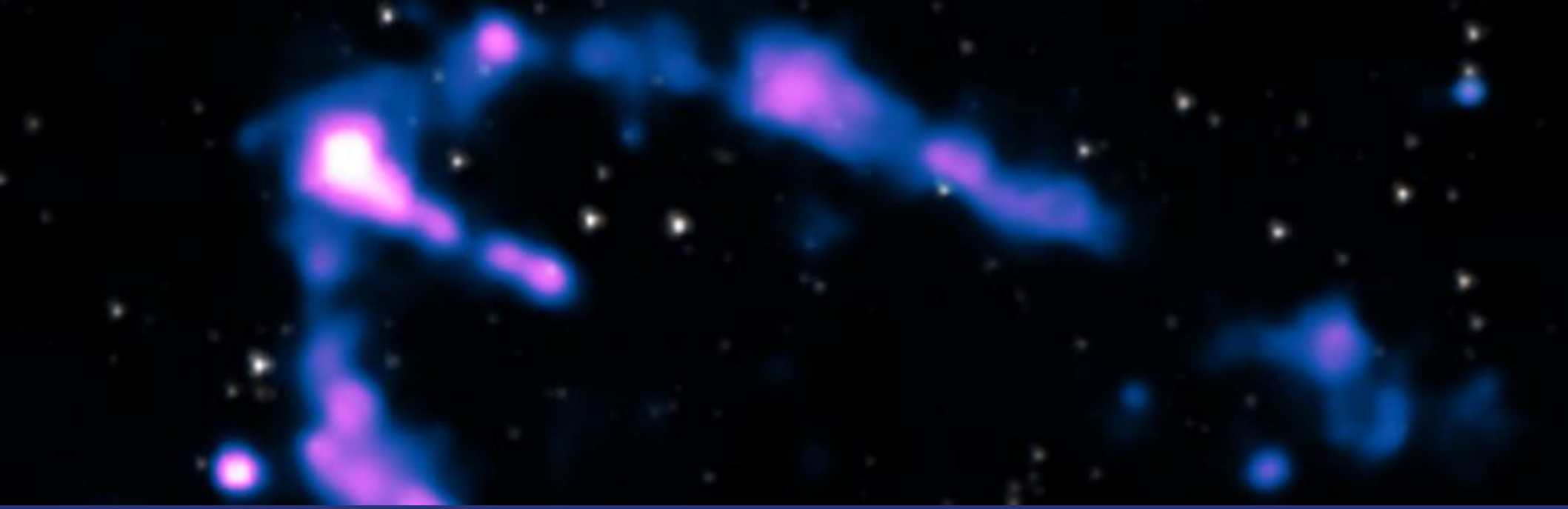


MAGIC DETECTION OF GEMINGA PULSAR AT THE VERY HIGH ENERGIES

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

Giovanni Ceribella

Marcos López, Francesco Dazzi, Thomas Schweizer,…

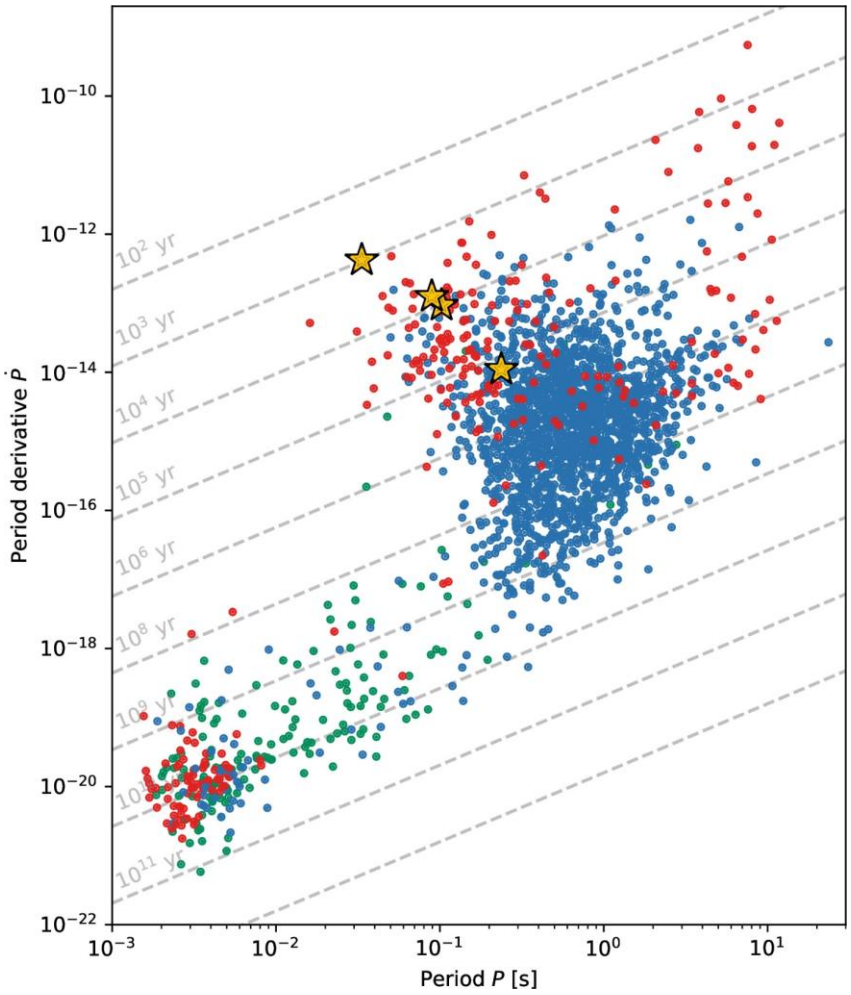
for the MAGIC Collaboration

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

MAGIC

VHE PULSARS & GEMINGA

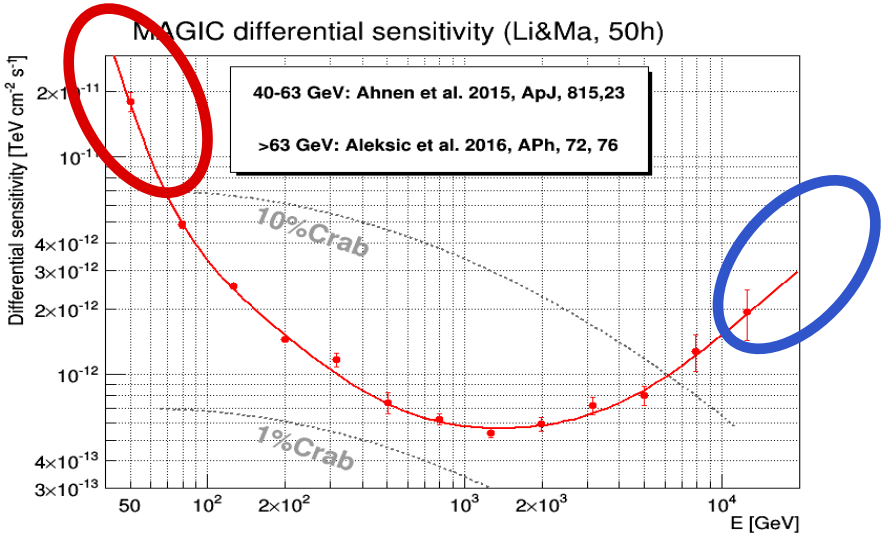
- **Few pulsars** known to emit at **VHE energies**
- **Geminga** (PSR J0633+1746):
  - **Radio-quiet** gamma-ray pulsar
  - Middle-aged: **~3·10^5 yr**
  - Distance: **250 pc**
- **Fermi-LAT** detection >100 MeV energies (A. Abdo et al., 2010)
- **Searches for VHE emission:**
  - VERITAS > 100 GeV (E. Aliu et al., 2015)
  - MAGIC > 70 GeV (M. Ahnen et al., 2016)



https://www.atnf.csiro.au/research/pulsar/psrcat/

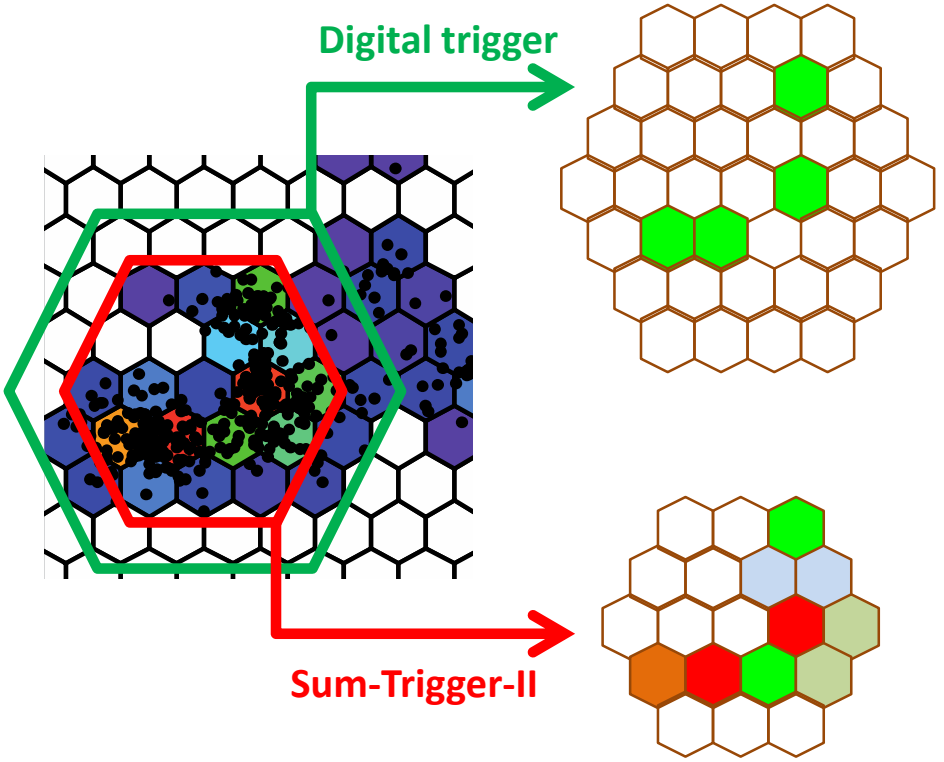
MAGIC TELESCOPES

- **Stereoscopic** system of **two IACTs** on the Canary island of La Palma (Spain)
- Diameter of **17m**
- Energy range: **~30 GeV** to **~100 TeV** (Crab-like spectrum)
- **Improvements** at the **lowest** energies: **Sum-Trigger-II**
  - Aiming at **pulsars** and soft sources, far **AGNs**, **GRBs**,…
- At the **highest** energies: **VLZA observations**



SUM-TRIGGER-II

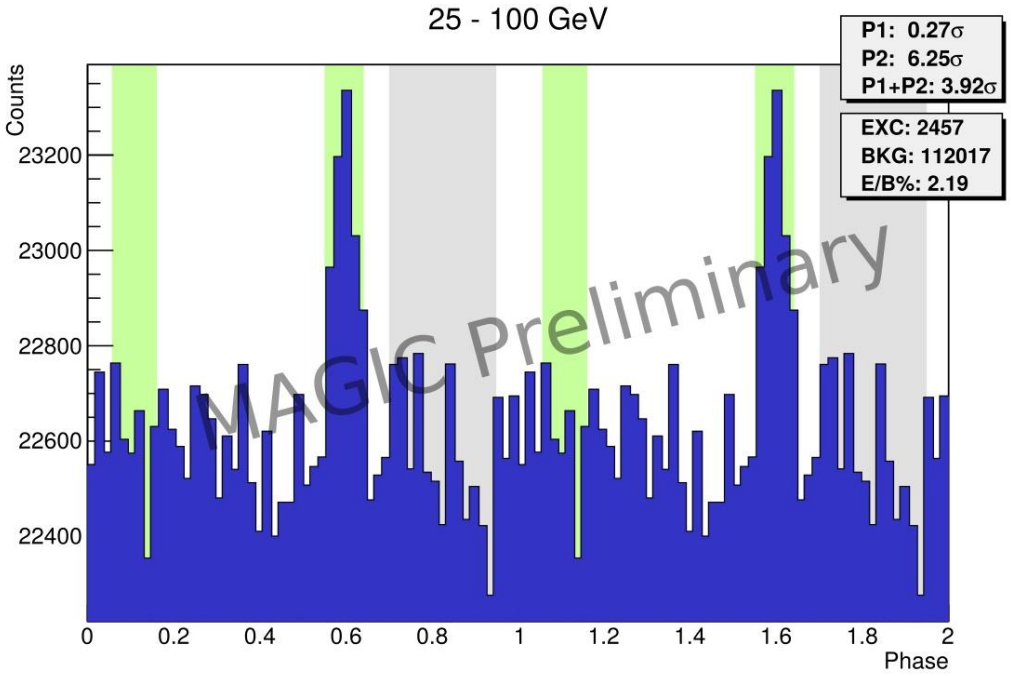
- **Stereoscopic analogue trigger** for low-energy air showers
- **Stacking signals** of neighboring pixels
- Improved **threshold** at lower energies: **15 GeV**
- **80 hours** on **Geminga**, ranging from 2017 to 2019

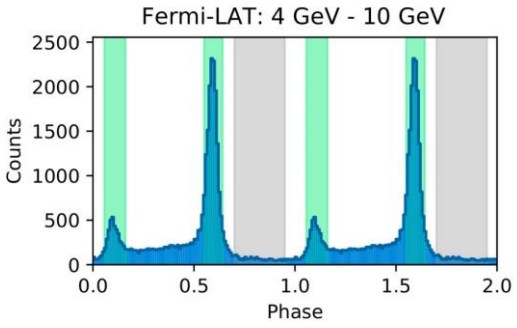


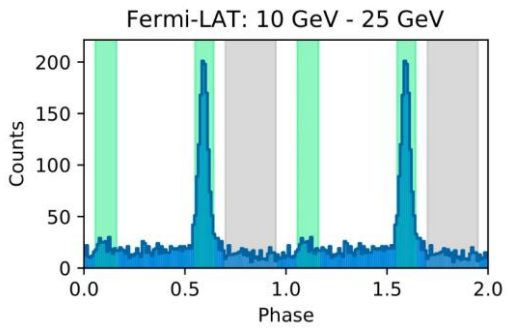
Scheme of the MAGIC Sum-Trigger-II principle. Adapted from *F. Dazzi, 2012*.

RESULTS: PHASE DIAGRAMS

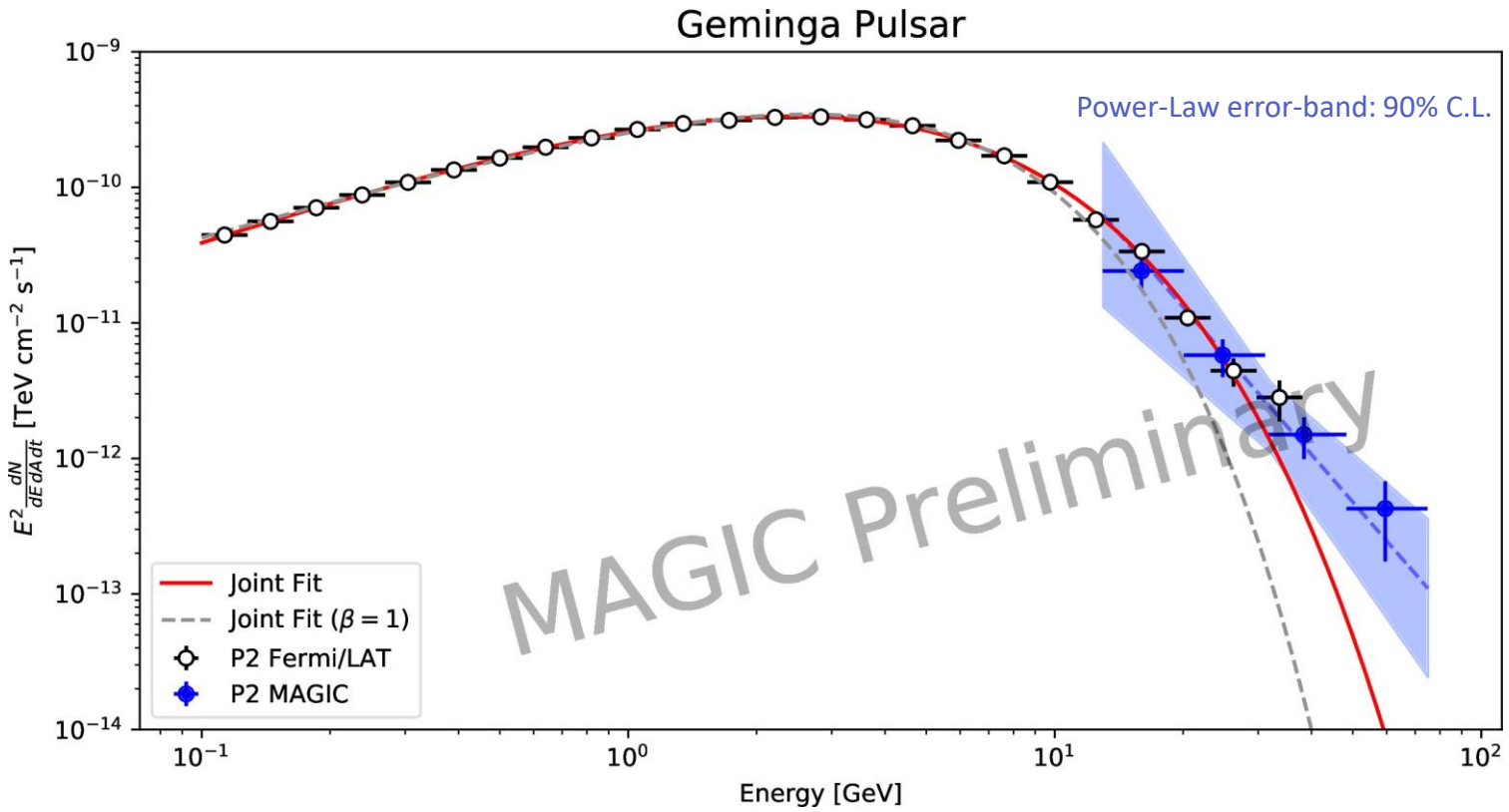
- **Rotational parameters** from **Fermi-LAT** data
- Unbiased determination of the **signal regions**
- **Estimated energy** range: 25 – 100 GeV
- **P2 detection: 6.25σ**
- **No detection** of **P1**:
  - …expected from Fermi-LAT





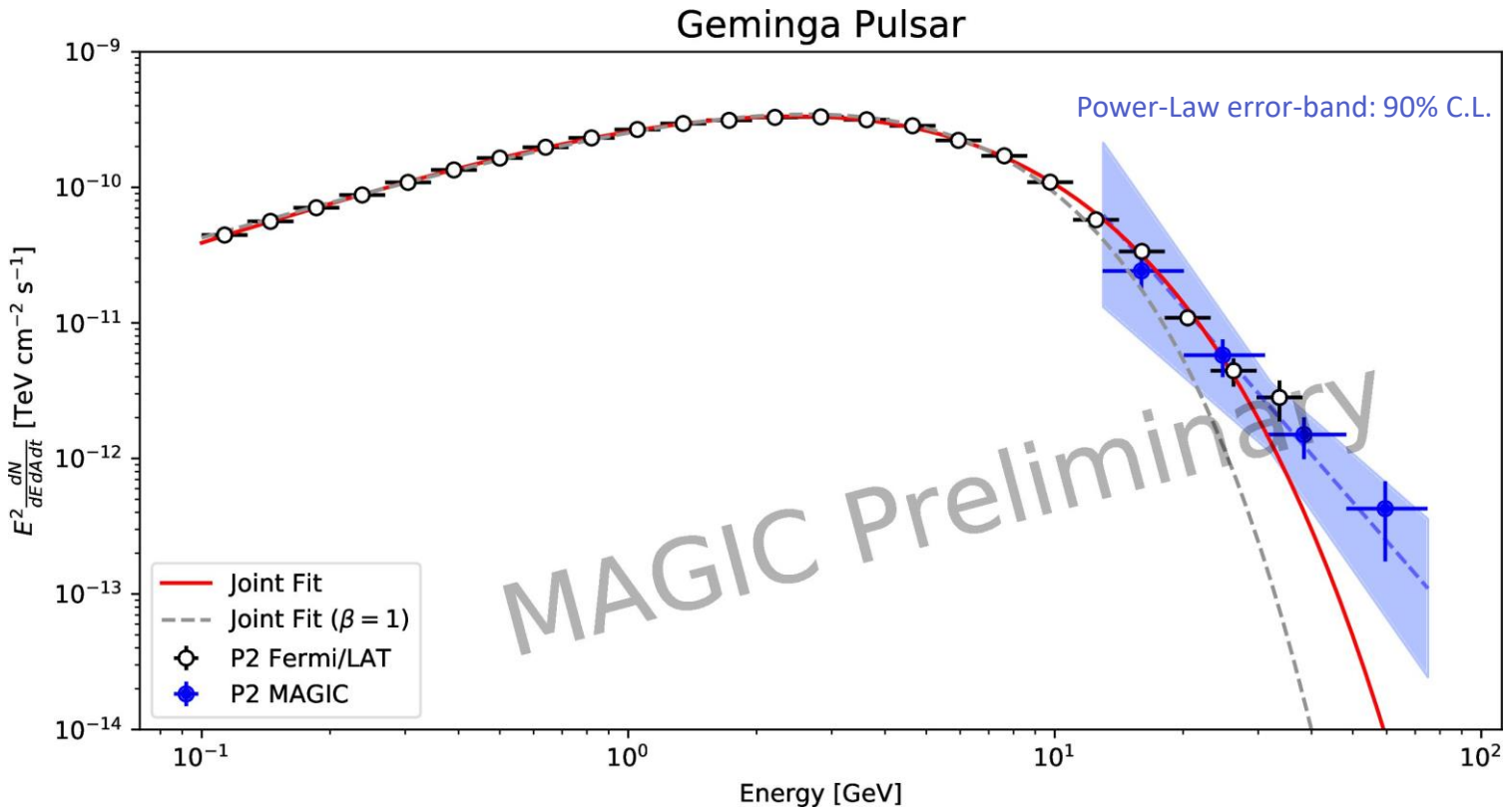


RESULTS: SPECTRUM



- **MAGIC** spectrum extending **13 GeV – 80 GeV** (after unfolding)
- **Power-law** with index **Γ = 5.6 ± 0.5**

RESULTS: SPECTRUM



- **Joint MAGIC/Fermi-LAT fit:** pure **exponential cutoff** is ruled out. A **sub-exponential** cutoff fits better…
- Systematics under study

SUMMARY

- **Geminga** is the **third gamma-ray pulsar** and the **first middle-age one** detected by **IACTs.**
- **Pulsed signal** from **P2** has been observed in the **13 – 80 GeV** energy range with **6.2 σ** significance.
- **Power-law** like spectrum with spectral index **Γ ~ 5.6** .
- **Joint MAGIC/Fermi-LAT** rules out the **exponential-cutoff.**
- A **sub-exponential cutoff** fits better**:**
  - Hint of a **power-law like tail ??**
  - However **systematics** need to be accounted as well.
- Paper in preparation… **stay tuned!**

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9) Francesco Dazzi, ***A new stereoscopic "Sum-Trigger-II" for the MAGIC Telescopes***, PhD thesis 2012;

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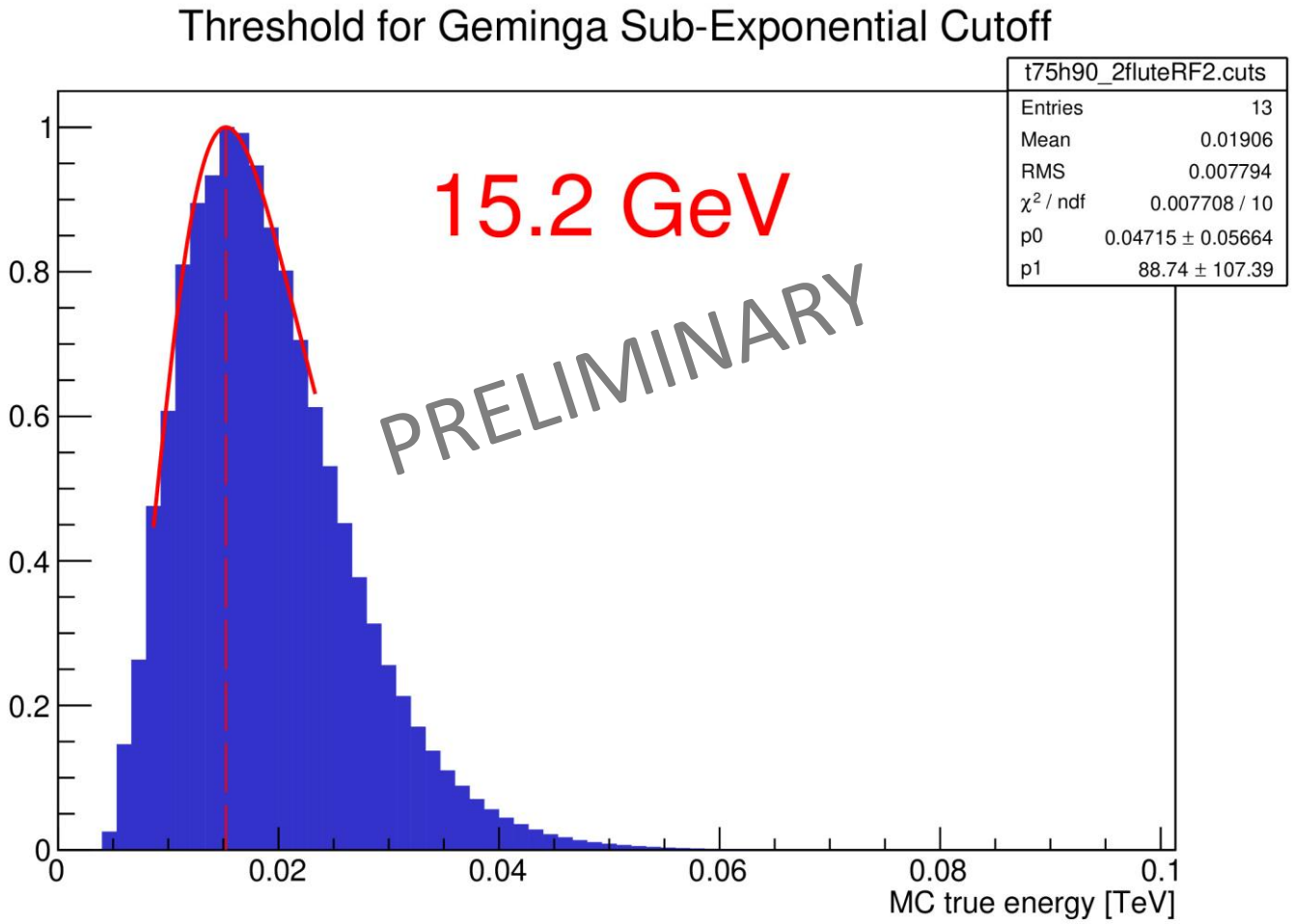
18) The VERITAS Collaboration, ***Detection of pulsed gamma rays above 100 GeV from the Crab Pulsar***, Science 2011.10;

19) The VERITAS Collaboration, ***A Search for Pulsations from Geminga above 100 GeV with VERITAS***, ApJ 2015.02;

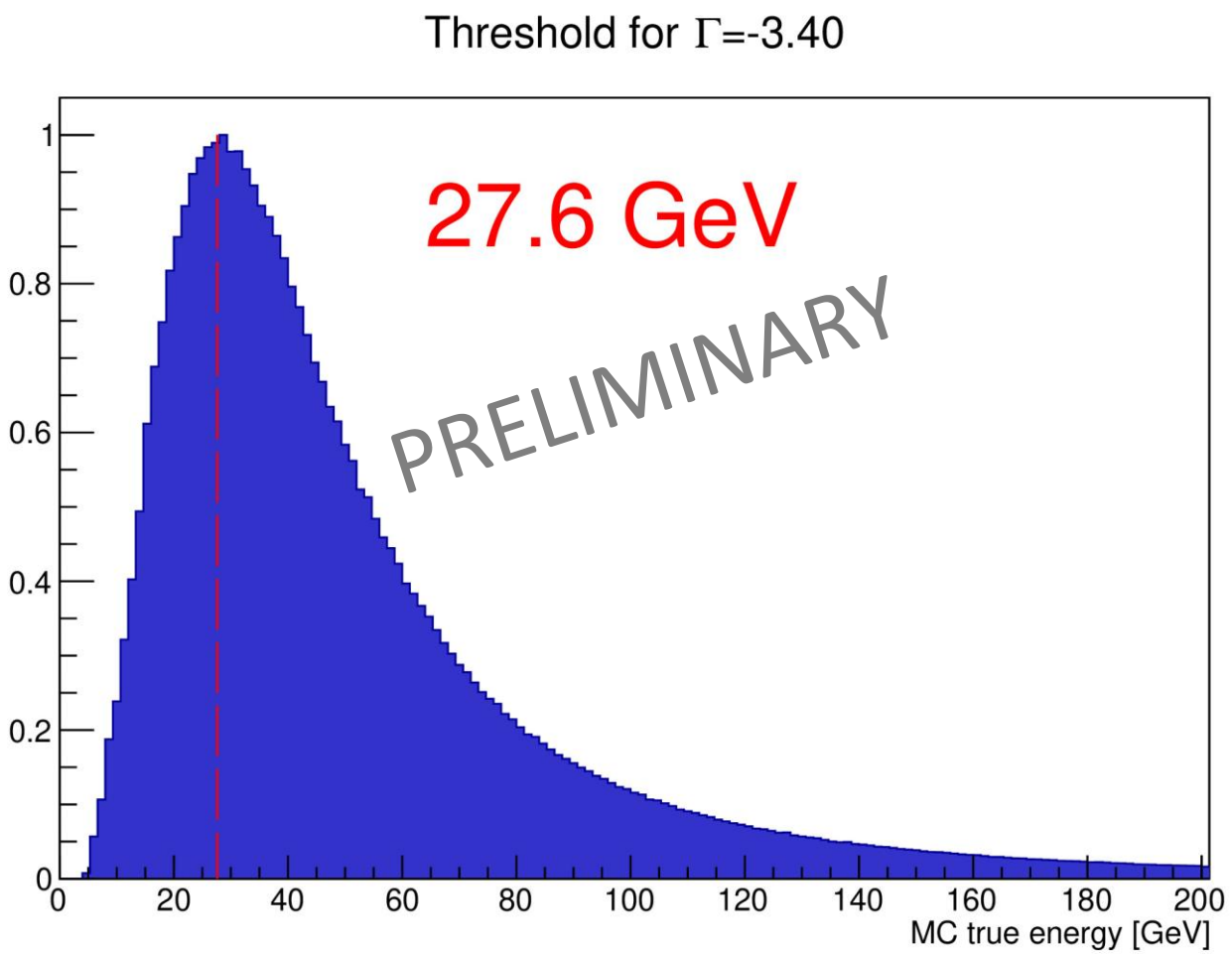
20) The H.E.S.S. Collaboration, ***First Ground-based Measurement of Sub-20 GeV to 100 GeV γ-rays from the Vela Pulsar with H.E.S.S. II***, A&A 2018.07;

BACKUP

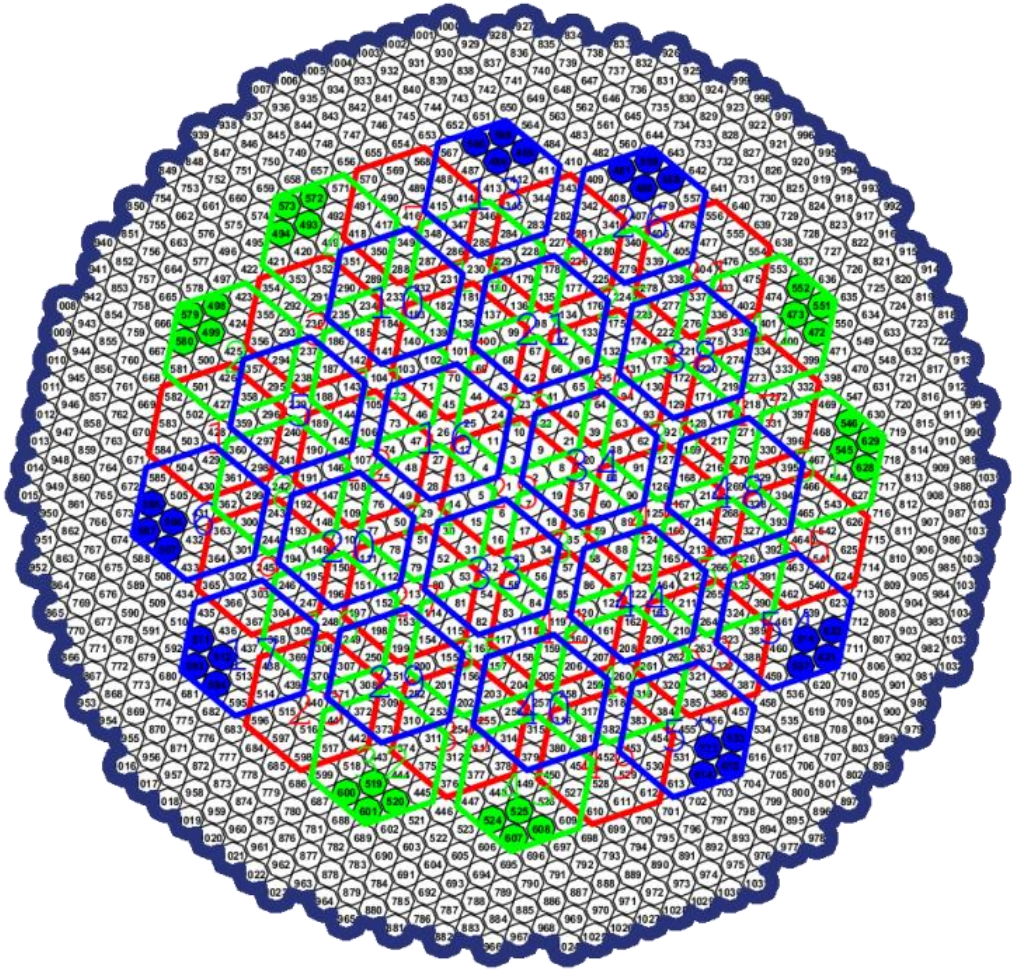
SUM-TRIGGER-II THRESHOLD



SUM-TRIGGER-II THRESHOLD



SUM-TRIGGER-II macrocell layout

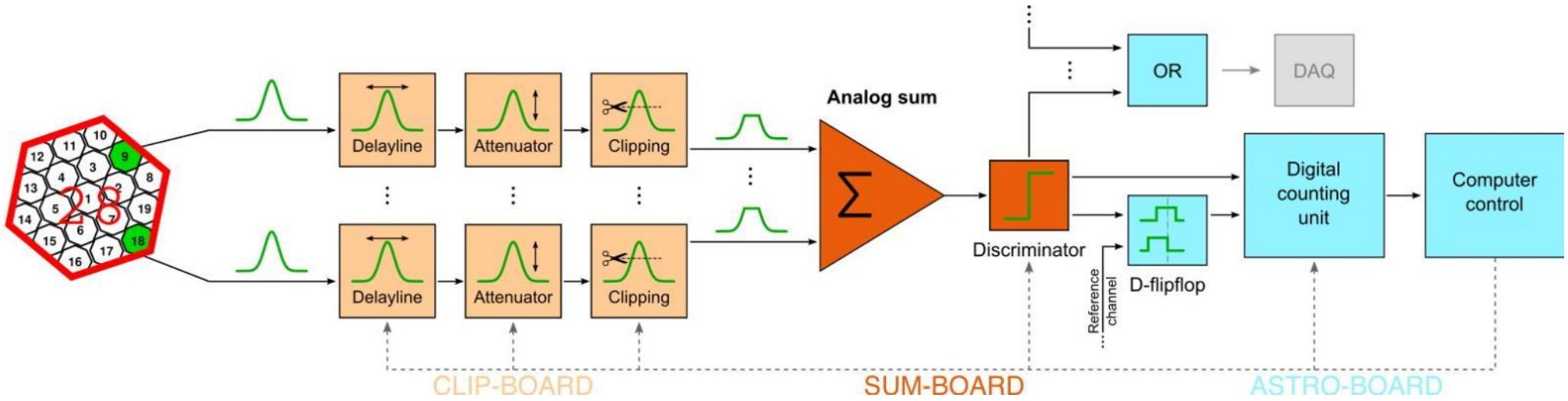


SUM-TRIGGER-II: HOW DOES IT WORK?

Timing adjustment and flat-fielding

Coping with afterpulsing

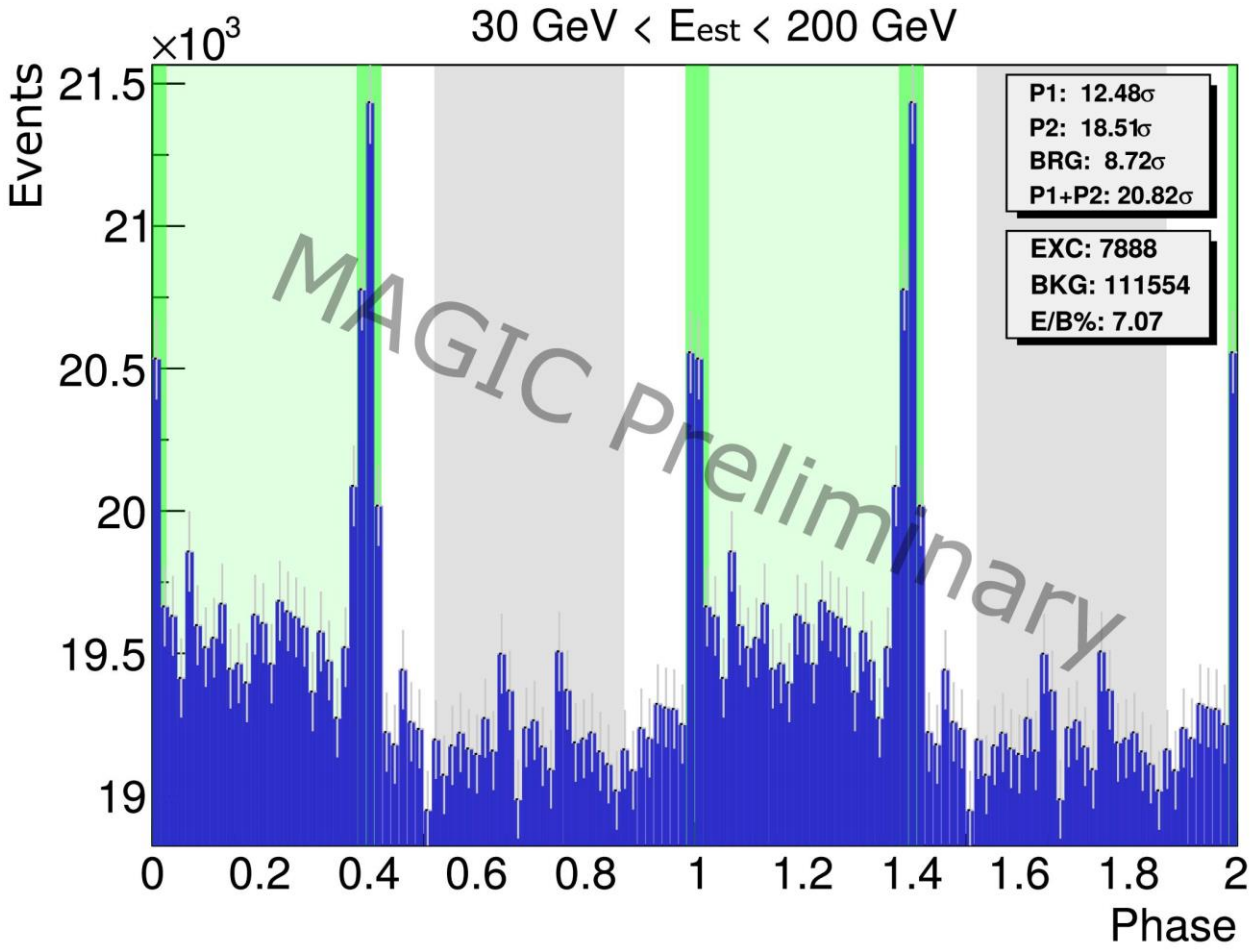
Signals sum and trigger formation



Threshold and timing controller

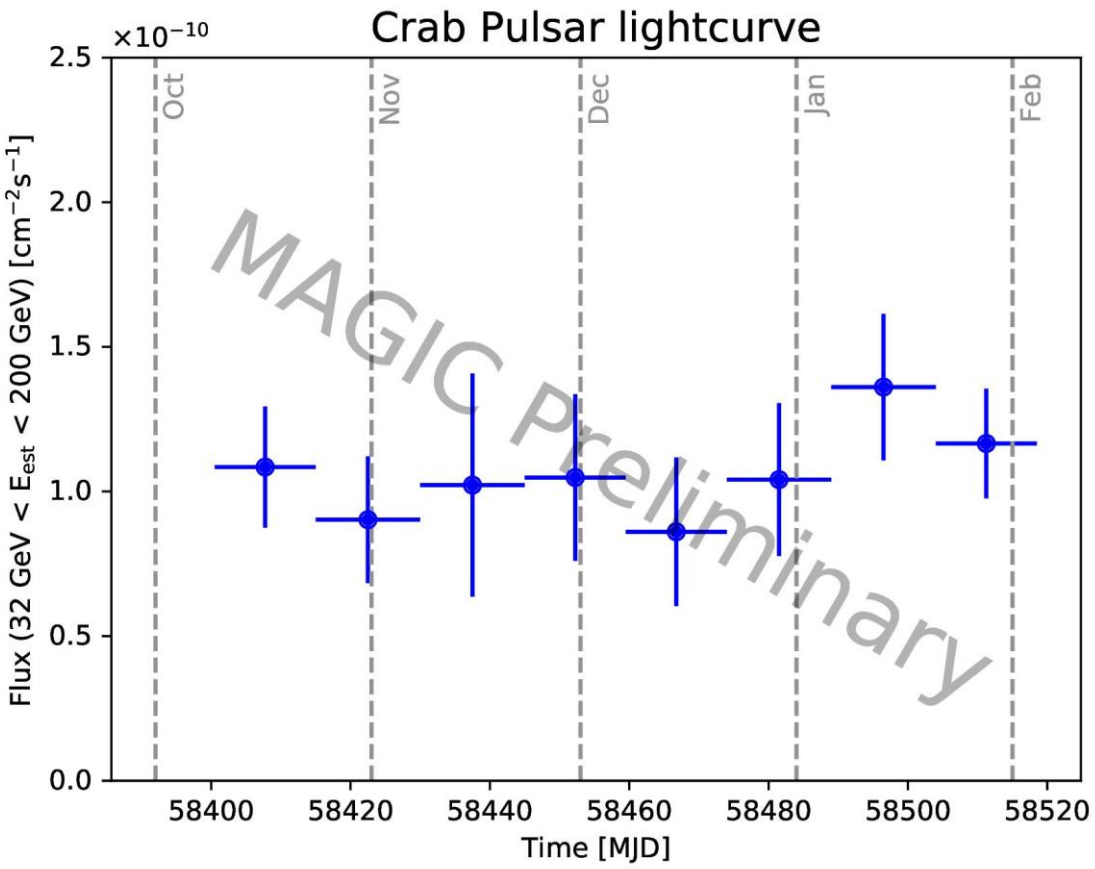
Workflow of the Sum-Trigger-II. Adapted from *F. Dazzi, 2012*.

PULSAR PHASE DIAGRAM



MAGIC can achieve a **5 sigma** detection of the pulsed signal in **~6 hours**.

CRAB PULSAR LIGHTCURVE



- Sound statistics allows to **monitor** the **pulsed emission** over time
- Crab pulsed flux over **4 months** in **2-week bins**
- **Flux** (32 – 200 GeV) consistent with **steady emission**:

$$\text{Flux} = (1.07 \pm 0.09) \times 10^{-10}\ \text{cm}^{-2}\text{s}^{-1}$$
$$\chi^2/_{\text{NDF}} = 2.9/7\ (\mathbf{0.1\sigma})$$