VARIABILITY STUDY OF THE CRAB PULSAR ABOVE FEW TENS OF GeV WITH MAGIC

Giovanni Ceribella
Max-Planck-Institut für Physik

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

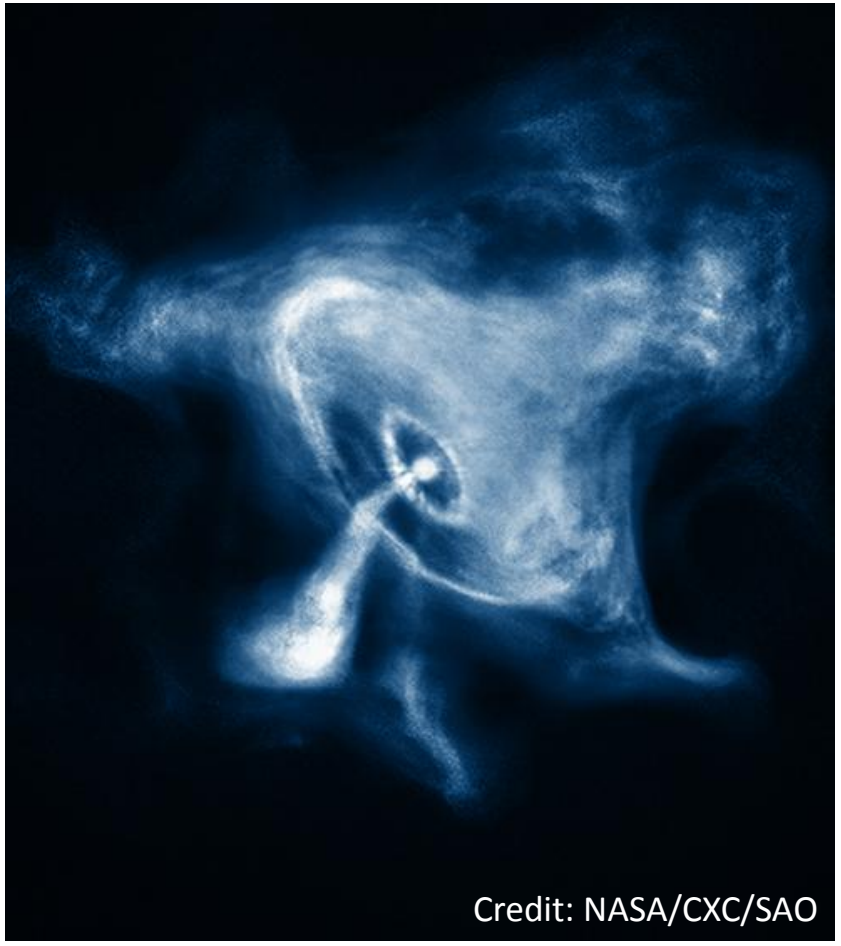
MAGIC

SUMMARY

1. **The Crab nebula and pulsar:**
   Physical case of the nebula flares.
2. **Analog Sum-Trigger II for MAGIC:**
   Review of the lower energy trigger;
3. **Preliminary results and future plans.**

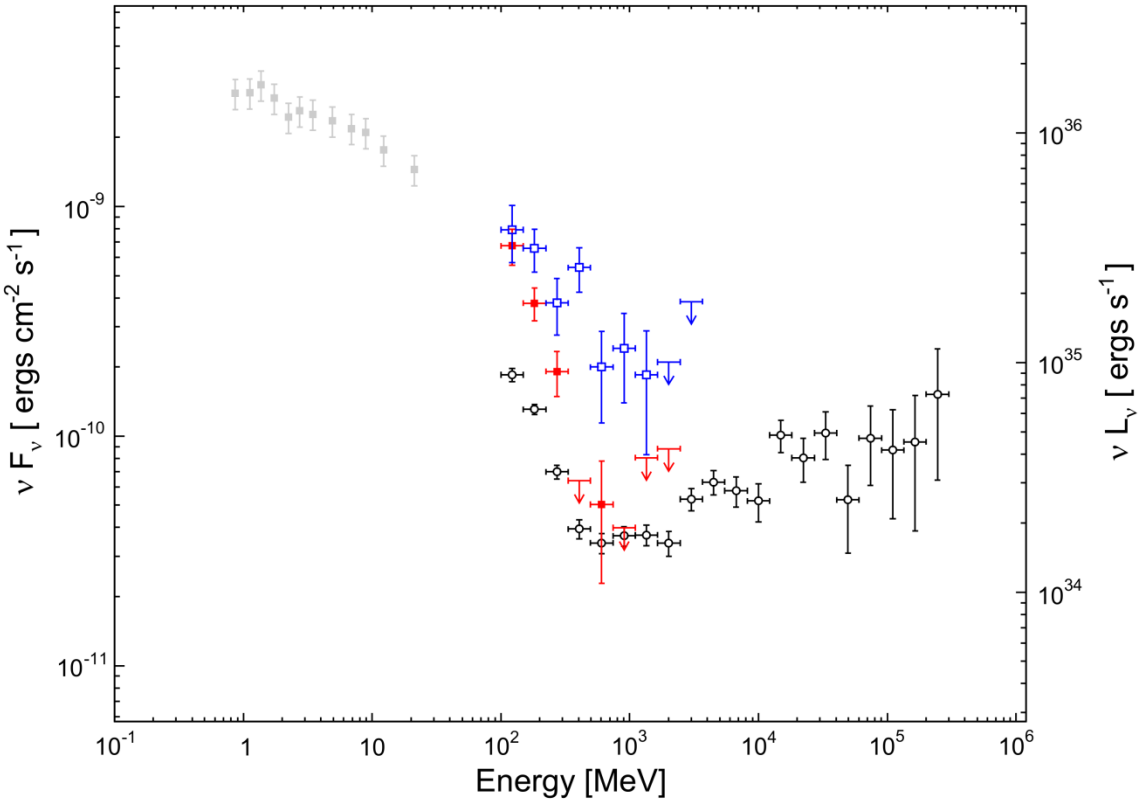
THE CRAB NEBULA

- Strongest stable VHE source of the sky and standard candle for gamma ray astronomy;
- Pulsar wind nebula powered by the young Crab pulsar;
- Synchrotron emission up to 1 GeV, Inverse compton up to tens of TeV.



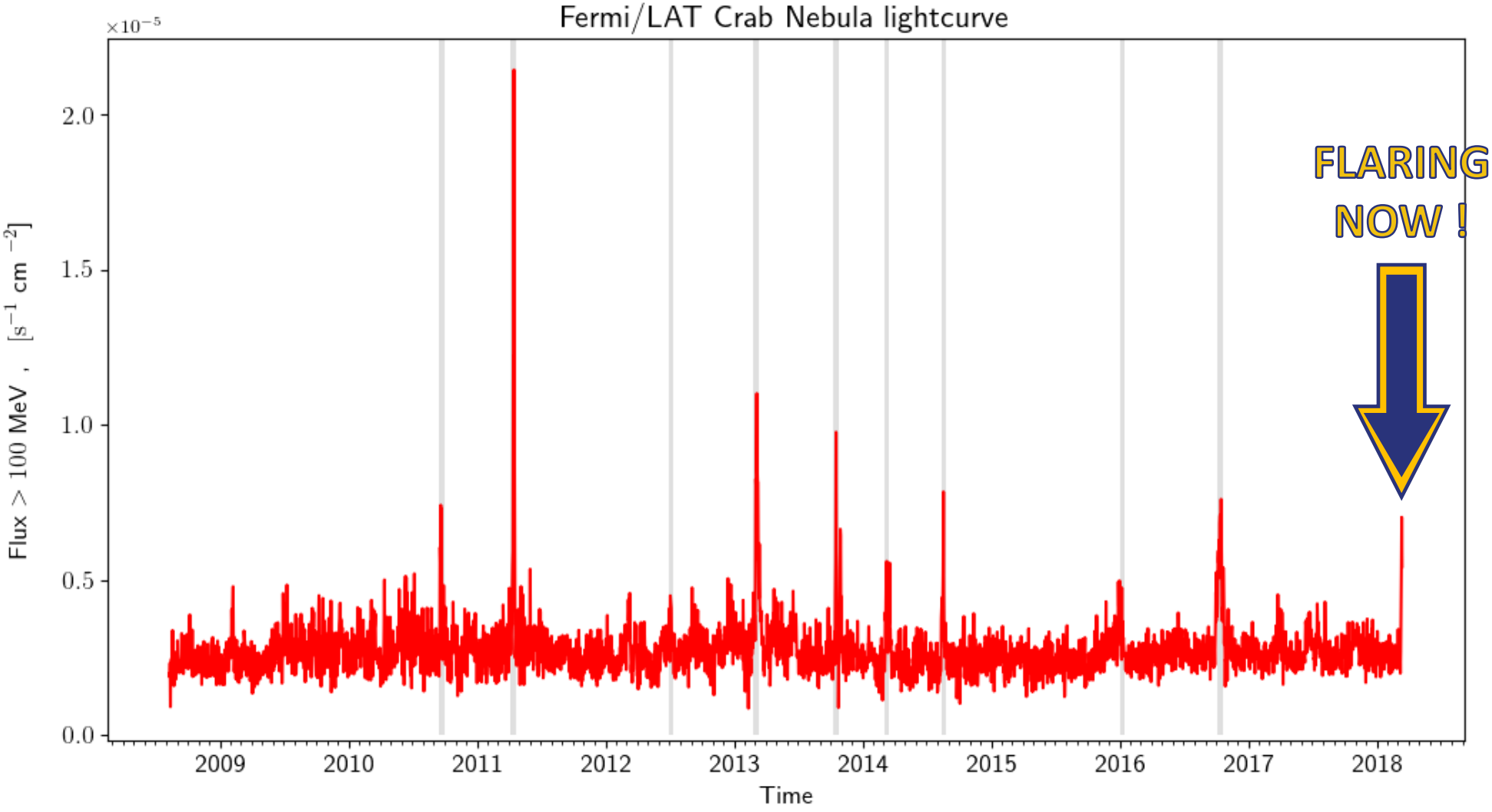
CRAB FLARES

- First detected in 2010;
- Large increase of the flux in the 100 MeV to 1 GeV energy range;
- Short timescales of days to weeks:
  - Constrains the originating phenomenon to be acting in a small region.
- Physics still debated…



Gamma spectrum of the Crab Nebula from Fermi/LAT.
Black: long term average; **Blue**/**Red** (flare state). From *[1]*.

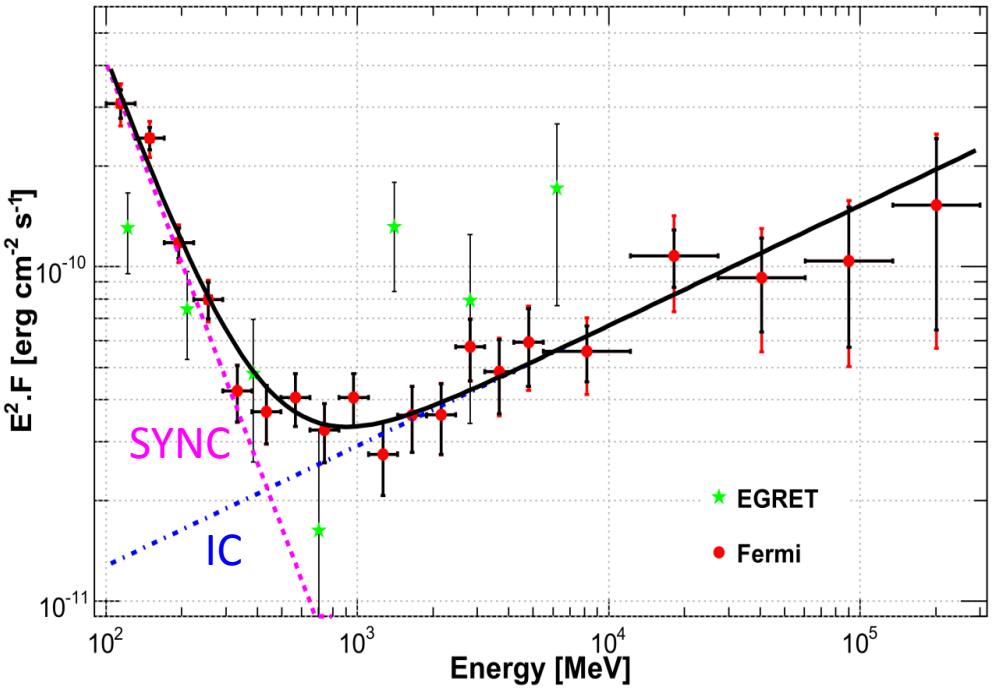
DAILY FERMI/LAT LIGHTCURVE



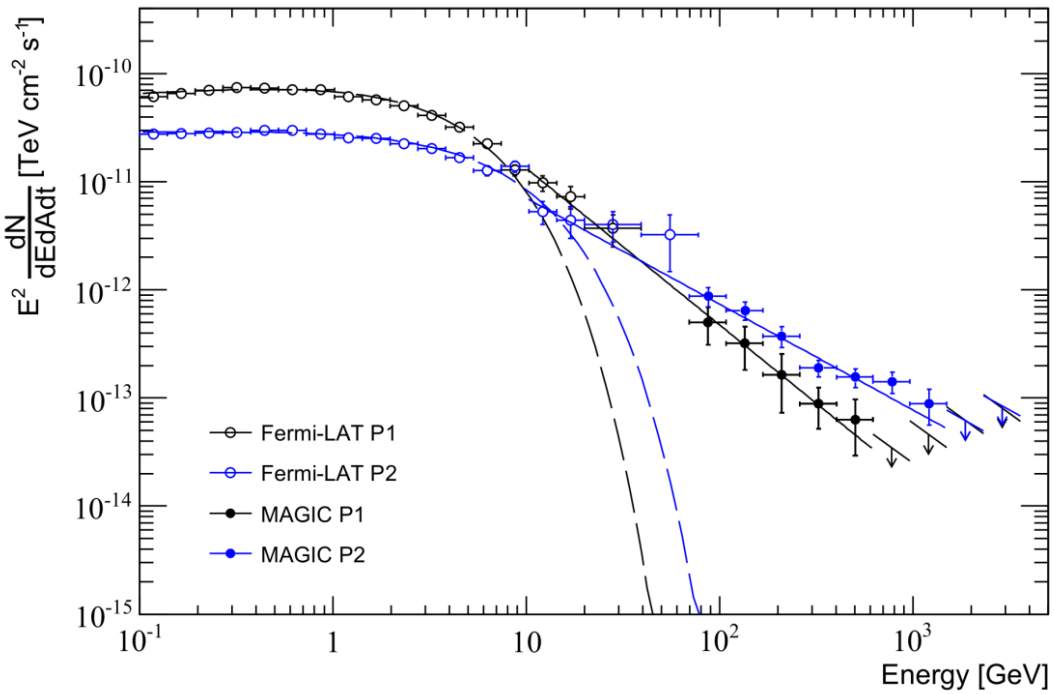
IS THE PULSAR INVOLVED?

- Pulsar: central engine of the Nebula → related to flares?
- No significant increase of pulsar flux during flares (Fermi/LAT, *[1]*).
- What about the highest energy electrons?

Fermi/LAT Crab **Nebula** spectrum, *[2]*.



MAGIC Crab **Pulsar** spectrum, *[3]*.

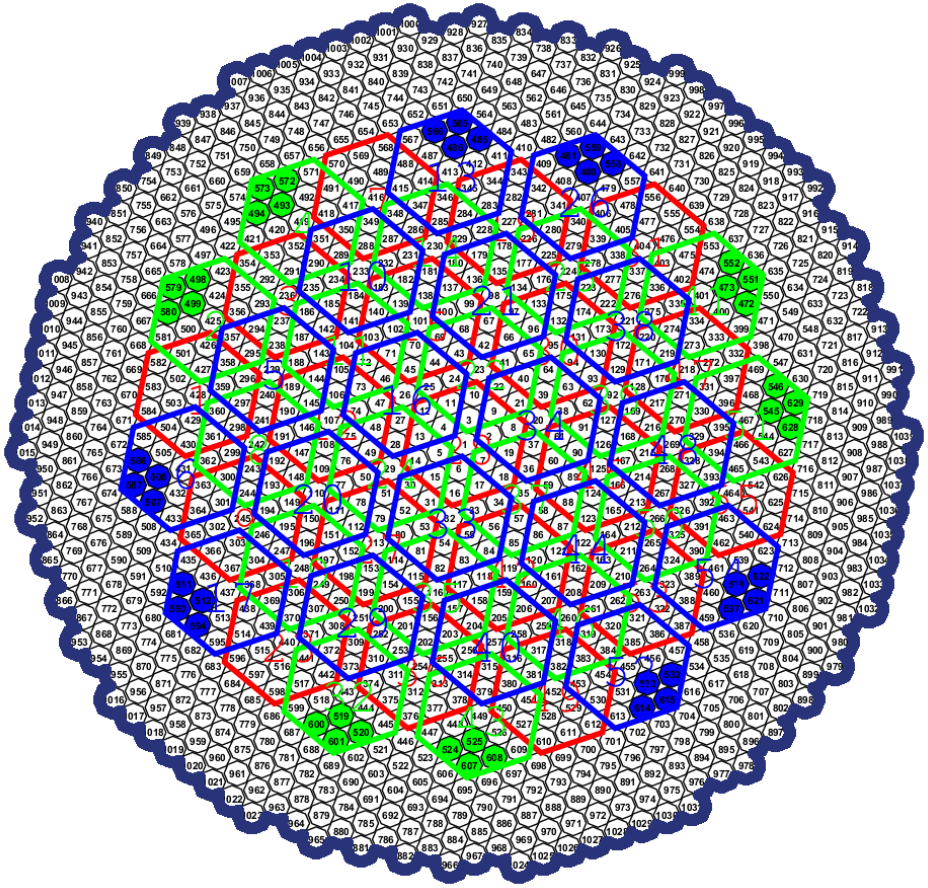


IS THE PULSAR INVOLVED?

- What about the highest energy electrons?
  - Tail of the **nebular** synchrotron emission:
    → the spectral region *where flares show up.*
  - Tail of the **pulsar** synchrotron and IC emission;
- Light distance between pulsar and the termination shock of the wind: *~5 months;*
- Fermi collection area is too small to probe the pulsar emission above few GeV at short timescales;
- **MAGIC** with the new **Sum-Trigger-II** can do that!

MAGIC'S SUM-TRIGGER II

- An analog trigger for the lower energy air showers;
- Performing the **sum of signals** from neighbouring photomultiplier tubes;
- A **lower discriminator threshold** can be applied to the summed signal;
- A lower energy threshold is achieved.



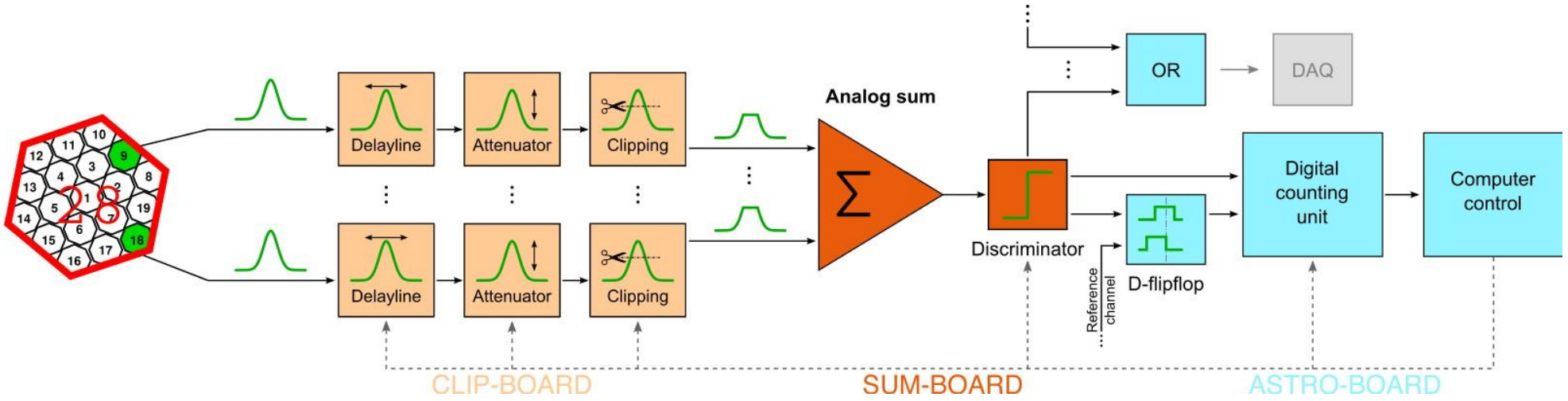
Layout of the *macrocells* (sum regions) of the MAGIC Sum-Trigger-II. Adapted from *[4]*.

HOW DOES IT WORK?

Timing adjustment and flat-fielding

Coping with afterpulsing

Signals sum and trigger formation

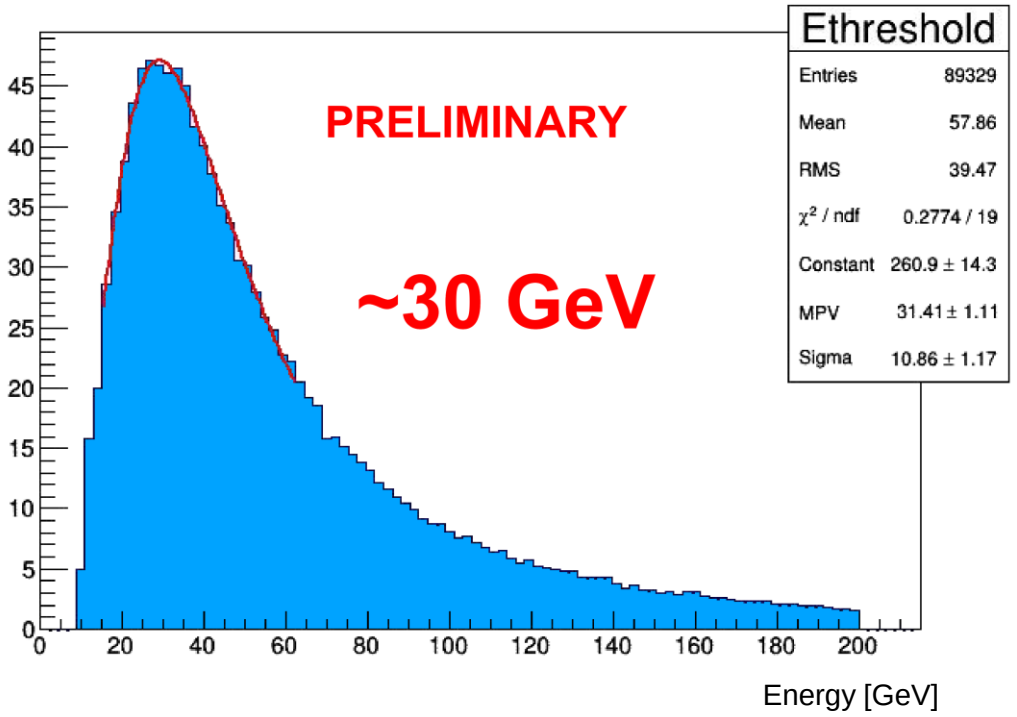


Workflow of the Sum-Trigger-II. Adapted from *[4]*.

Threshold and timing controller

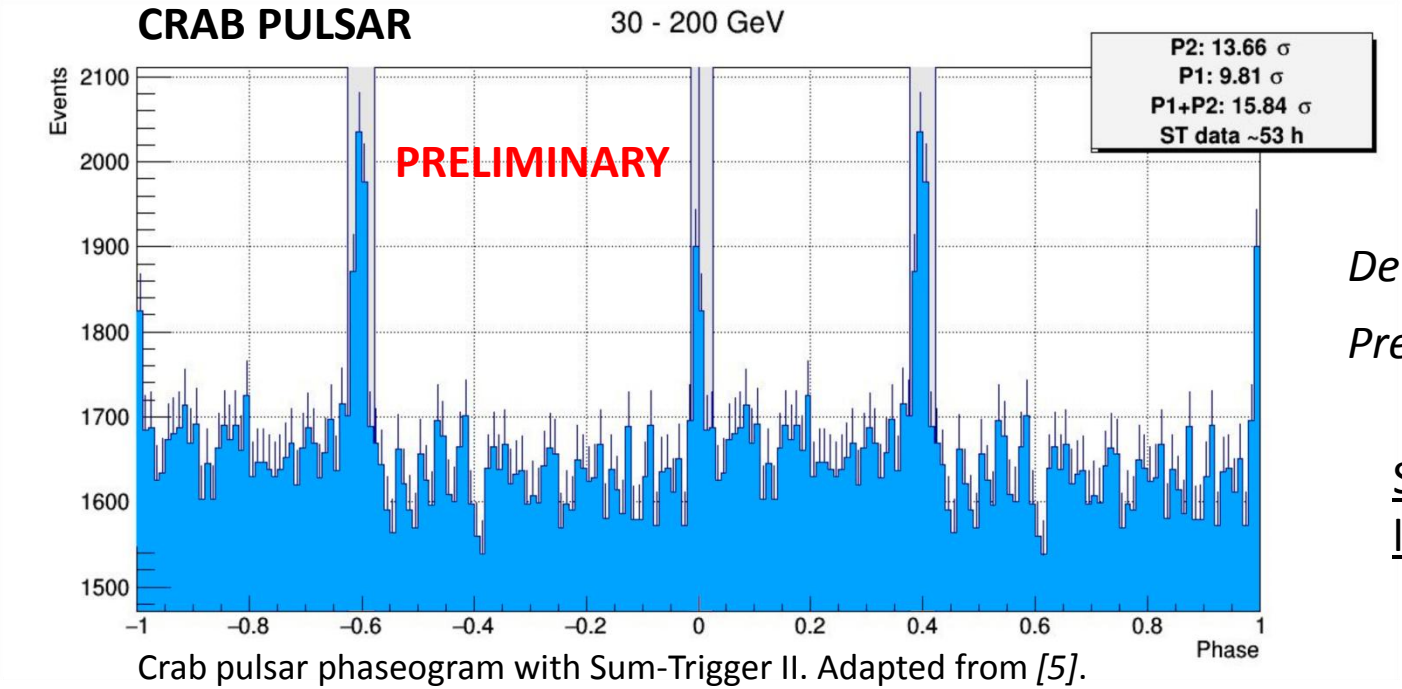
PRELIMINARY RESULTS

- Energy threshold at **30 GeV** computed from Monte Carlo simulations;
- The efficiency reduces to ½ at **15 GeV**;
- The detection capability of low energy events is largely enhanced:
  - Previous result with the standard digital trigger: 50 GeV.



Global analyis efficiency on Monte Carlo simulated gamma events, energy threshold fit. Adapted from *[5]*.

PRELIMINARY RESULTS



Crab pulsar phaseogram with Sum-Trigger II. Adapted from *[5]*.

Detection efficiency **2.3** $\sigma/\sqrt{h}$

Previous value 1.4 $\sigma/\sqrt{h}$

Same results in 2,7 times less observation time!

- Improved threshold → probe the largely unexplored 10-50 GeV band;
- Enhanced detection efficiency → fast determination of the phaseogram:
  - 5 σ detection in 4 hours of observation time.

FUTURE PLANS

- With the improved performace in the 20 – 50 GeV range, MAGIC became an unique instrument for gamma pulsar physics;
- We have proposed to monitor the flux of the Crab pulsar in the VHE regime:
  - Is it stable?
  - Can it be correlated with flares in the nebula?
- MAGIC with the Sum-Trigger II can do much more: new pulsars, distant AGNs, GRB.
- Stay tuned!

REFERENCES

1) The Fermi/LAT collaboration, ***Gamma-Ray Flares from the Crab Nebula***, Science 2011.02, pp. 739-742;

2) The Fermi/LAT collaboration, ***Fermi Large Area Telescope Observations of the Crab Pulsar And Nebula***, ApJ 2010.01, pp. 1254-1267;

3) The MAGIC collaboration, ***Teraelectronvolt pulsed emission from the Crab Pulsar detected by MAGIC***, A&A 2016.01, A133;

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

5) Jezabel Rodriguez Garcia, ***Pulsars with MAGIC***, TeVPa 2017.