MAGIC OBSERVATIONS OF PULSARS WITH THE SUM-TRIGGER-II

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for the MAGIC Collaboration

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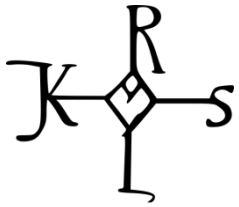
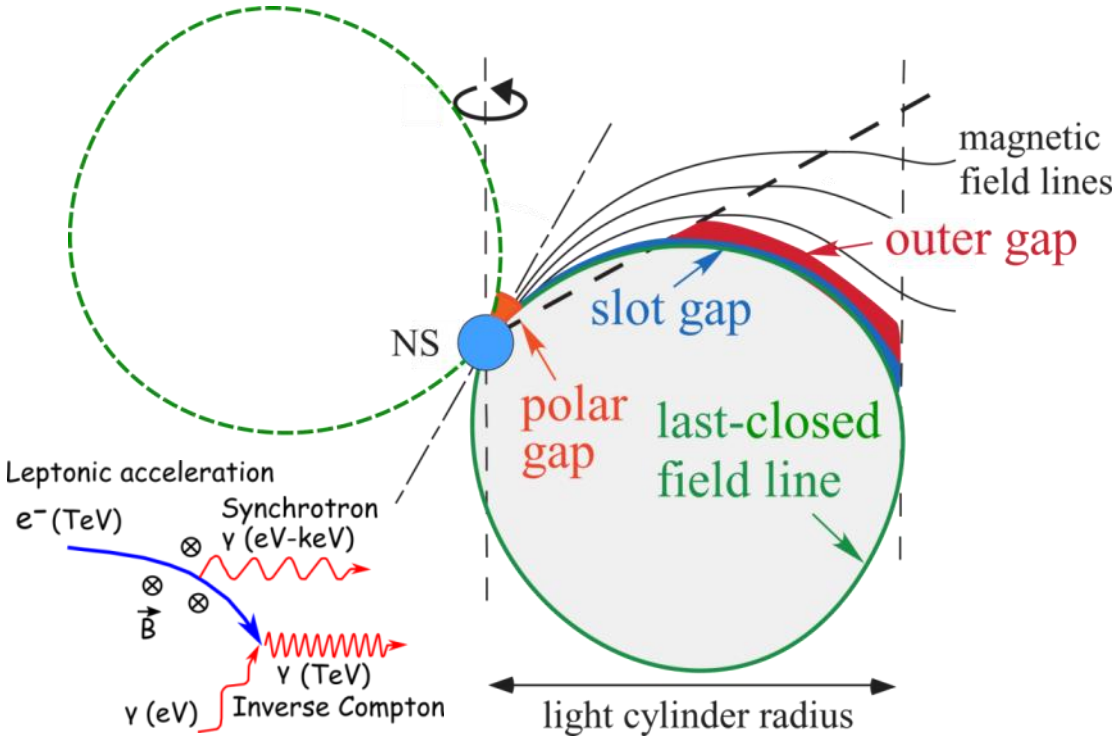


PULSARS AT THE VHE

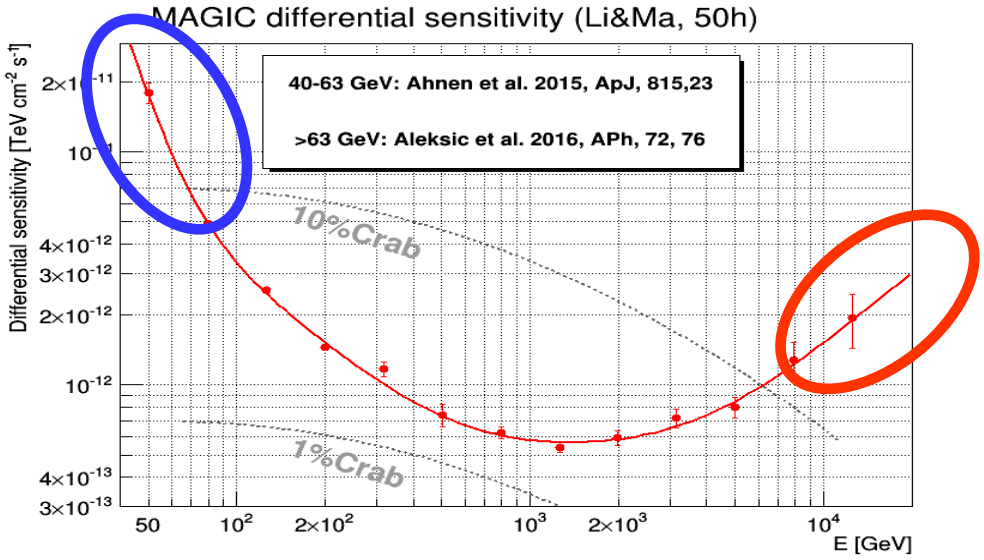
- Among the most **compact γ-ray sources** in the universe
- Many **open questions**:
  - **Where** does the emission come from?
  - **Up to which energy** do they radiate?
  - How do they **evolve**?



Adapted from *Hirotani, 2001*

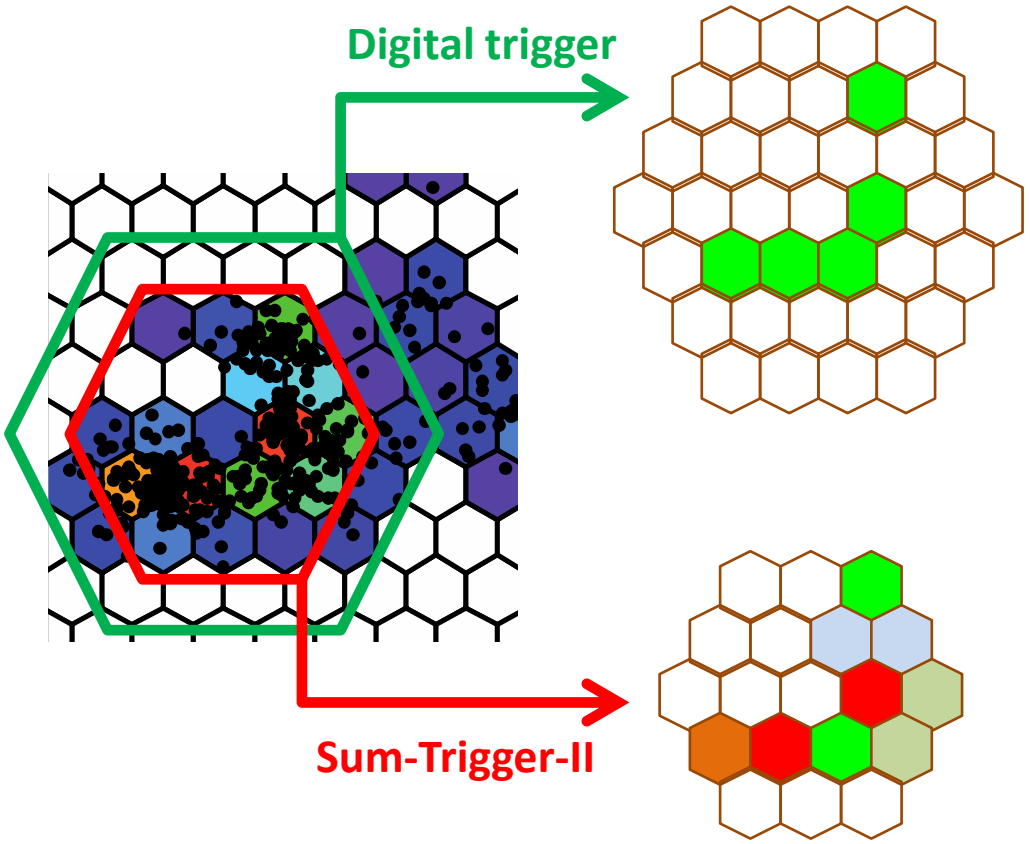
MAGIC TELESCOPES

- **Stereoscopic** system of **two IACTs** on the Canary island of La Palma (Spain)
- Camera of 1039 PMTs
- Energy range: **tens of GeV** to several **tens of TeV**
- Recent improvements at the **lowest** (**Sum-Trigger-II**) and **highest** (**Very High Zenith-angle observations**) energies.



SUM-TRIGGER-II

- Stereo analog trigger for dimmer air showers
- **Stacking PMT signals** and applying a higher threshold:
- Huge development in the past years (hardware, software)
- Improved **energy threshold** at **lower energy: 30 GeV**



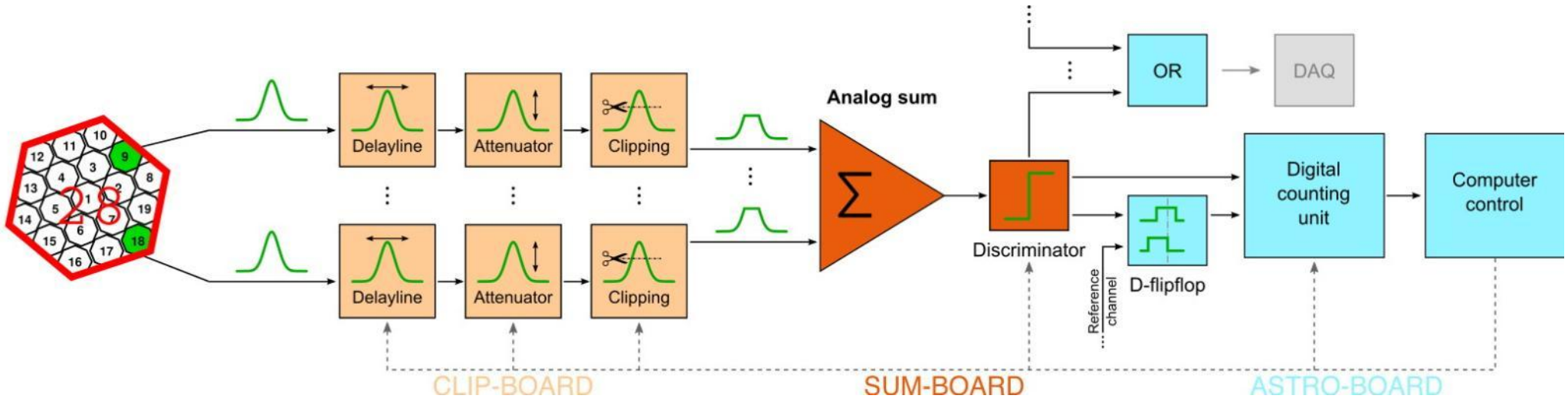
Scheme of the MAGIC Sum-Trigger-II principle. Adapted from *F. Dazzi, 2012*.

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*.

MAGIC (AND IACT) PULSAR RESULTS

2008 **Discovery** of **pulsed VHE** emission of the **Crab** (>25GeV) [2]

- Excludes polar-cap model

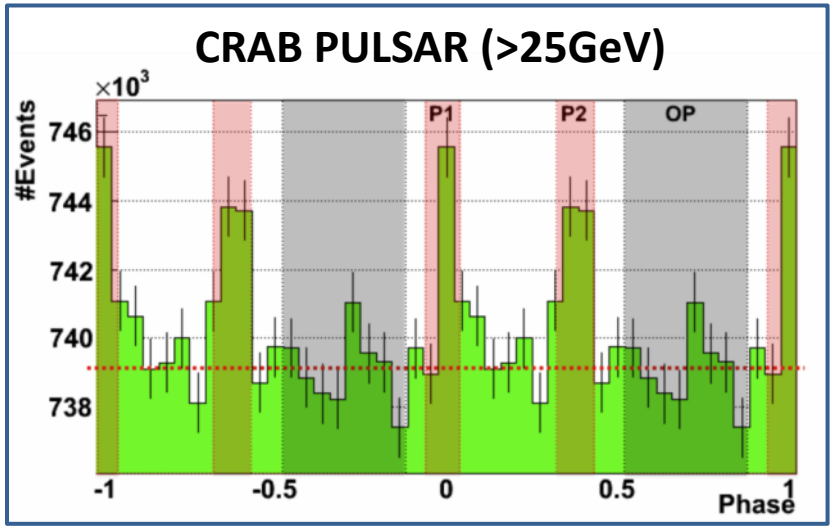
2011 **VERITAS:** Crab pulsar above 100 GeV

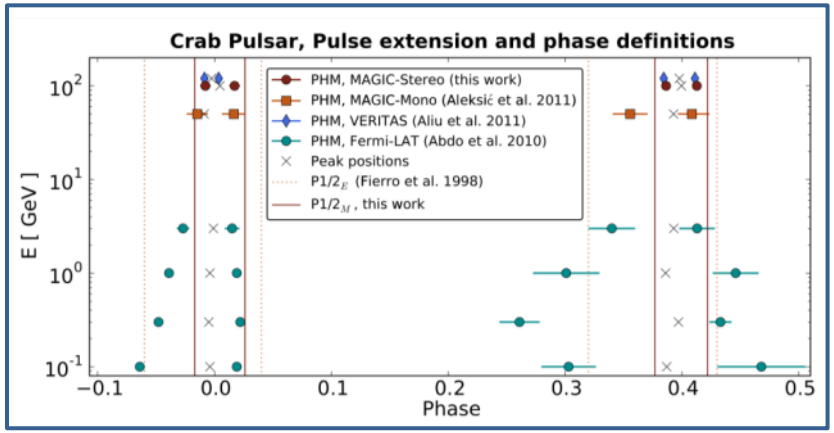
2011 Pulsed emission detected **up to 100GeV** [3]

- Consistent with a power-law!

2012 **Phase-resolved spectrum** up to **400GeV** [4]

- Peak width decreases with energy





MAGIC (AND IACT) PULSAR RESULTS

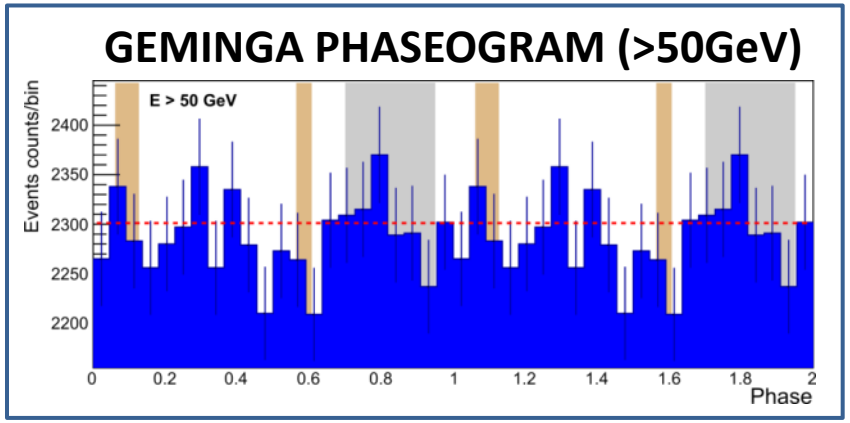
2016 **Geminga searches** with standard trigger above 50GeV [8]

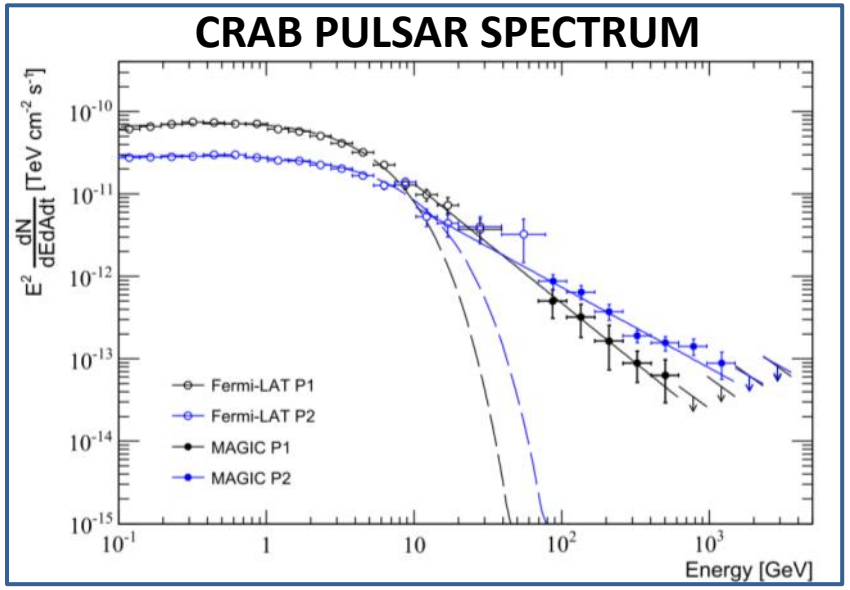
2016 **TeV pulsed emission** from the **Crab**! [6]

➢ Inverse Compton component

2017 **Lorentz Invariance Violation** studies with the **Crab pulsar** [7]

2018 **H.E.S.S.** Vela pulsar detection [16]

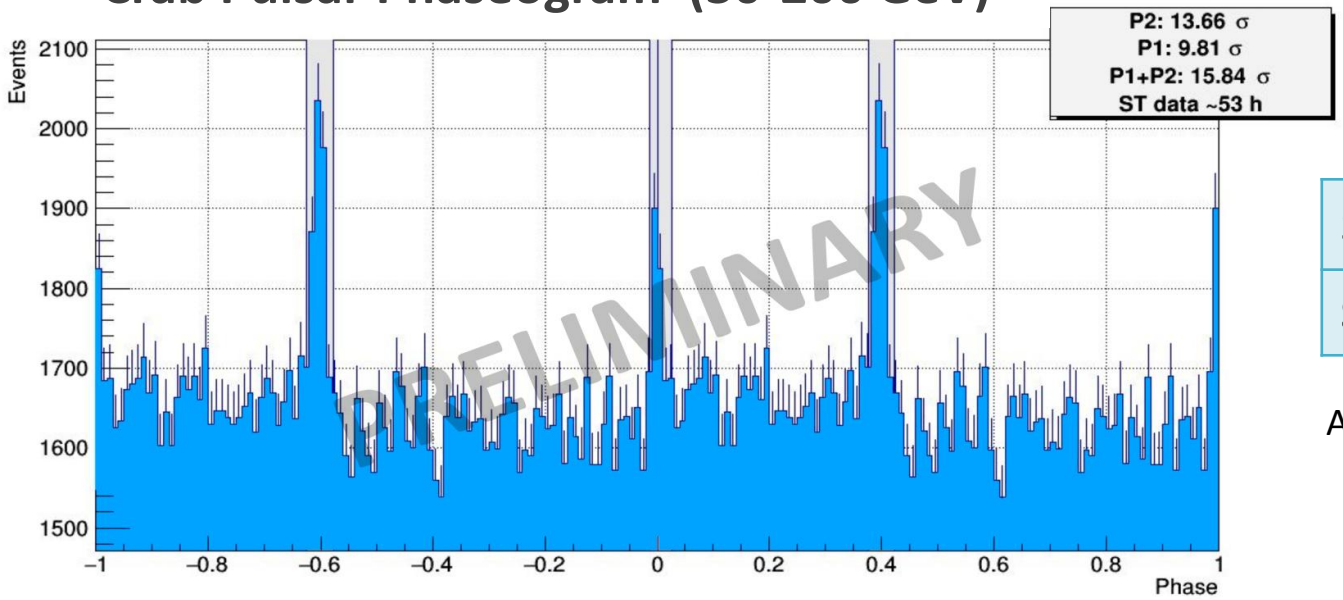




SUM-TRIGGER-II RESULTS

- **Higher sensitivity** for **pulsars** (on the Crab: ***5 hours → 5 sigma***)

Crab Pulsar Phaseogram (30-200 GeV)



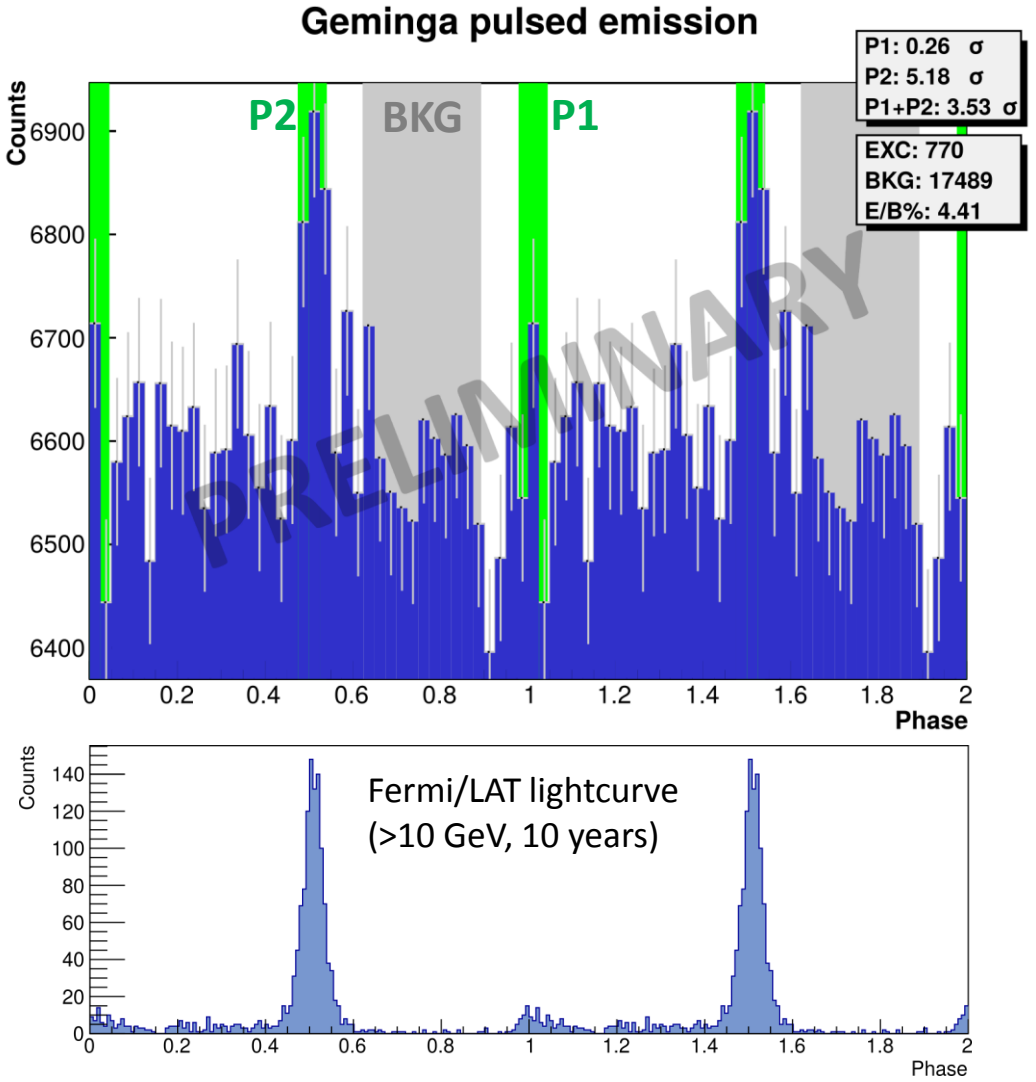
Standard trigger	1.4 $\sigma/\sqrt{h}$
Sum-trigger-II	**2.3** $\sigma/\sqrt{h}$

Adapted from *J. R. García, 2017*

- Enhanced **collection area** and better **background rejection**:
  - **Precise light-curves** and **spectra** in the tens of GeV range
  - **Short-time monitoring** of the pulsed emission

SUM-TRIGGER-II RESULTS

- **Detection of Geminga pulsar at VHE!**
  - Third known VHE pulsar
- **30 h** of **Sum-Trigger-II observations**, winter 2017
- Pulsar ephemeris from 10 years of Fermi/LAT data
- **P2** pulse detected at **5.2σ**
- Work on-going, **stay tuned**!



SUMMARY

- **MAGIC** and other **IACTs** contributed significantly to **pulsar physics at the VHE**
- Recent **hardware upgrades** enable us to improve our potential in this field
- With the discoveries of **Crab** (MAGIC), **Vela** (H.E.S.S.) and **Geminga** (MAGIC) we start to have kind of a **"population" of VHE pulsars**:
  - **Age dependence** of the VHE emission?
  - How do different pulsars relate to their **nebulae**?
  - Are there **other VHE pulsars** out there?
- … next challenges for us and for future instruments.

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16) 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;

SUM-TRIGGER-II macrocell layout