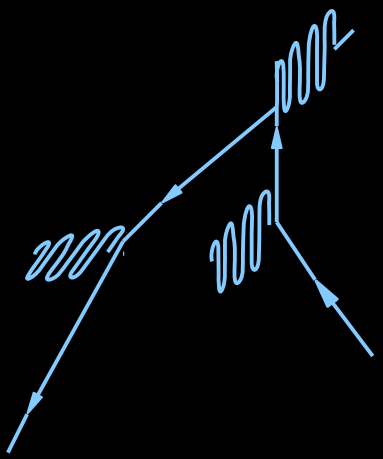
Pulsars with MAGIC



By Jezabel R. Garcia

On behalf of the authors

MAGIC & The Pulsars

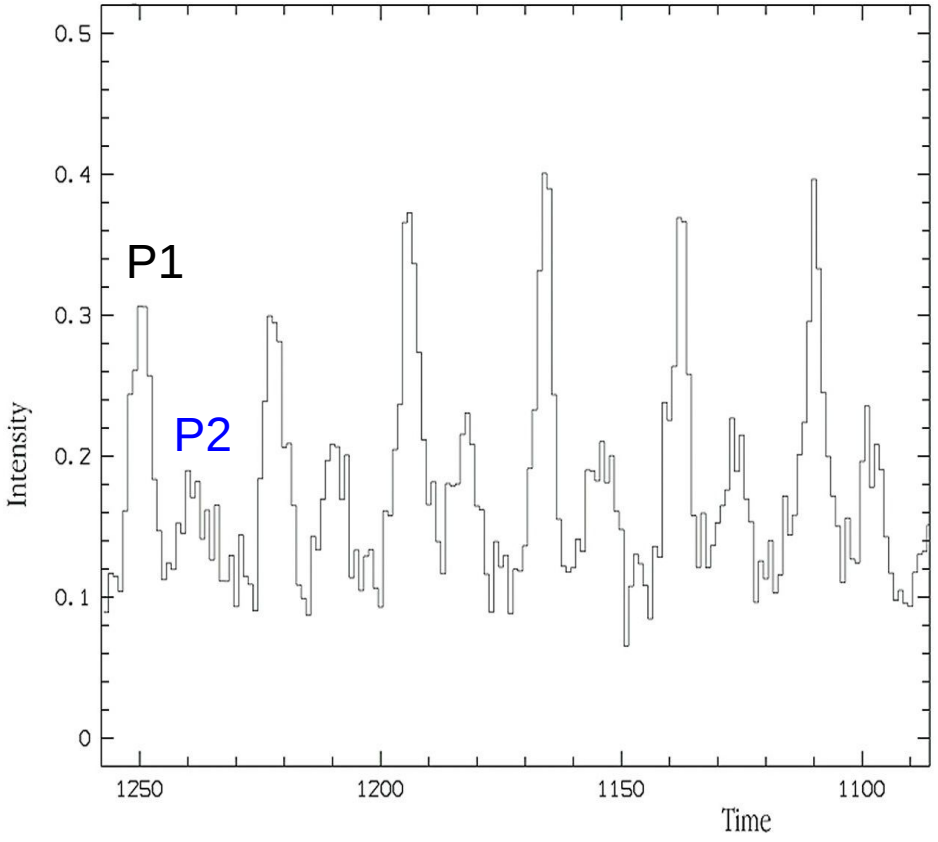
The Crab Pulsars at VHE

Lookig for Geminga

The new Sum-Trigger-II

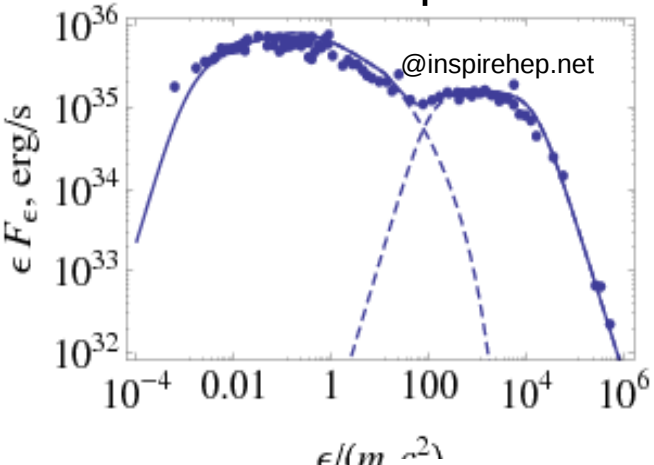
Pulsars at VHE: Very Short Introduction

- **Light Curve**



@ESO

- **SED** Broadband spectrum of the Crab pulsar



> 2200 radio pulsars

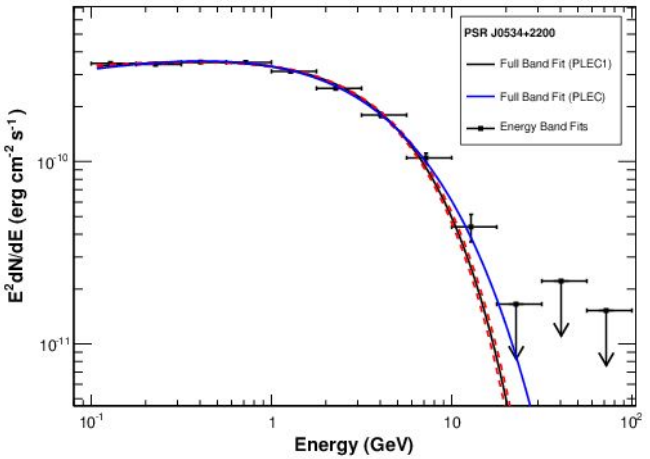
> 160 HE pulsars (FERMI)

2 Pulsar at VHE

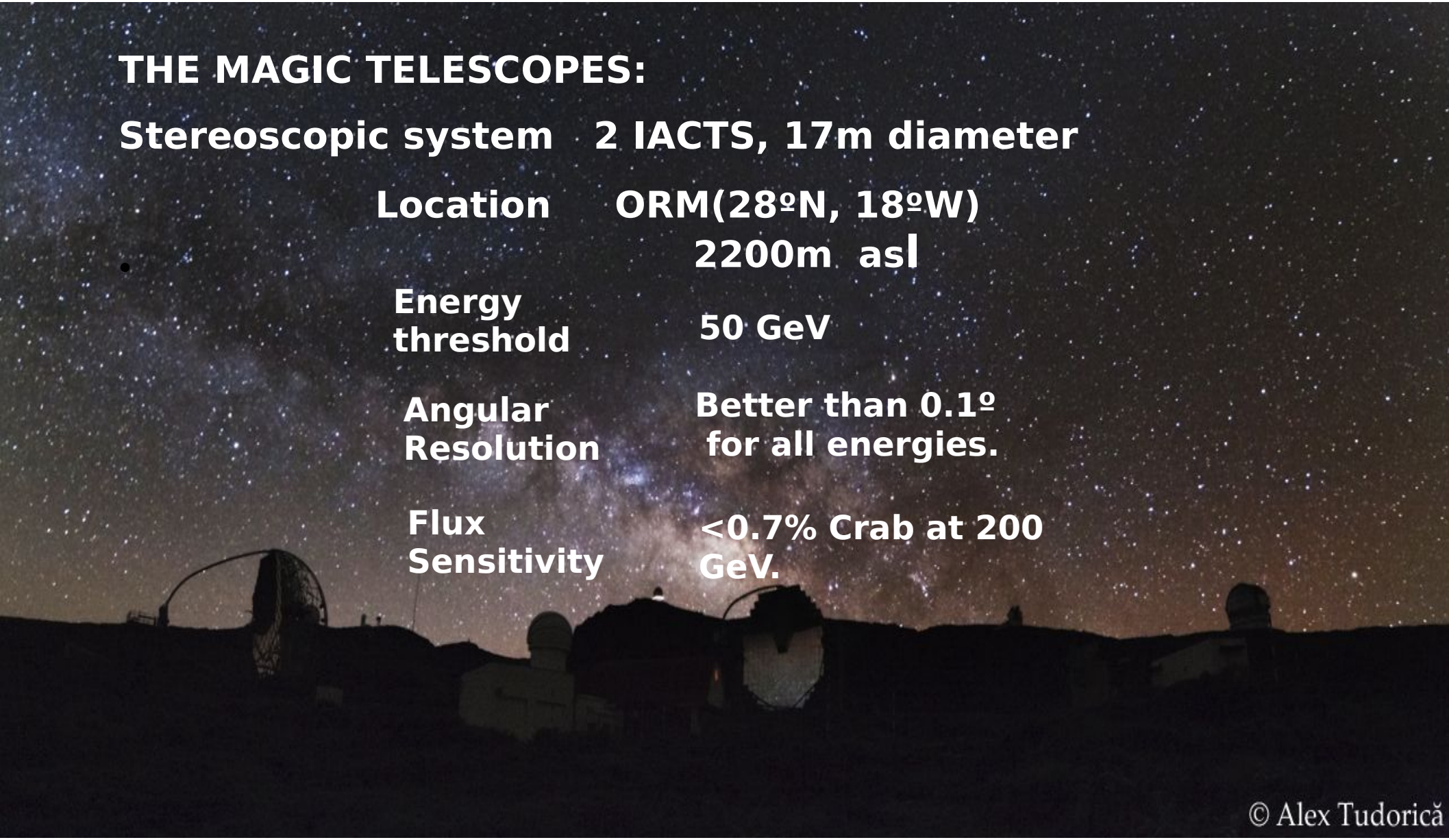
Crab unique source

- **HE SED**

Power law with spectral break & exponential cut-of



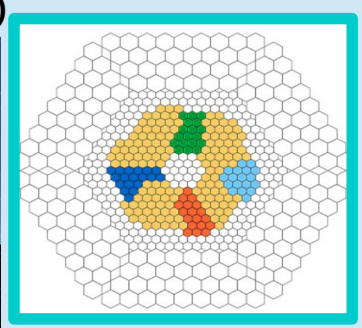
@FERMI (2PC)


THE MAGIC TELESCOPES:
Stereoscopic system 2 IACTS, 17m diameter
Location ORM(28ºN, 18ºW)
2200m asl
Energy threshold
50 GeV
Angular Resolution
Better than 0.1º for all energies.
Flux Sensitivity
<0.7% Crab at 200 GeV.
© Alex Tudorică

Magic & Crab Pulsar History

MAGIC Mono 2004

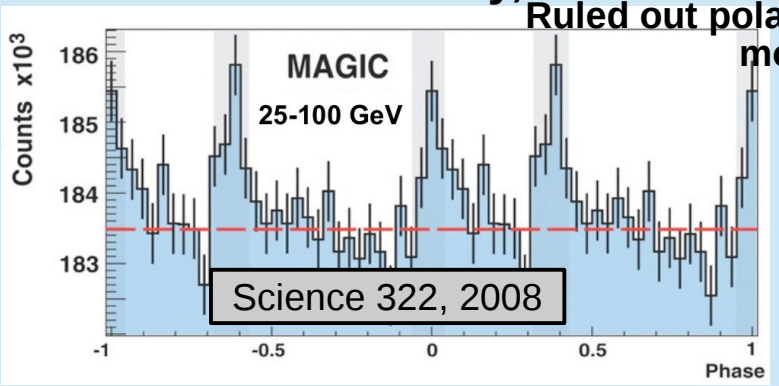
(2007: Readout Upgrade)



2008
Sum-Trigger I

- **2008: VHE Discovery, Science!**

Ruled out polar cap model



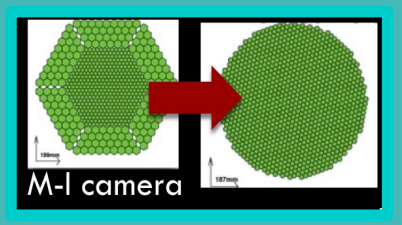
- **2011: Detection up to 100 GeV**

(Mono data)

Excluded exponential cutoff at more than 6σ

Aleksic et al. (MAGIC Collab.) ApJ 742 (2011) 43

MAGIC Stereo 2009



2012 M1 camera & Readout upgrade

2014 Sum-Trigger-II see presentation T 52.8 by F. Dazzi Tue at 18:30

- **2012: Detection up to 400 GeV**

(Stereo data, 2009 – 2011)

Not follow a power law with an exponential **cutoff**, but has an **additional hard component**

Aleksic et al. (MAGIC Collab.) A&A 540 (2012) A69

- **2014: Detection of bridge emission**

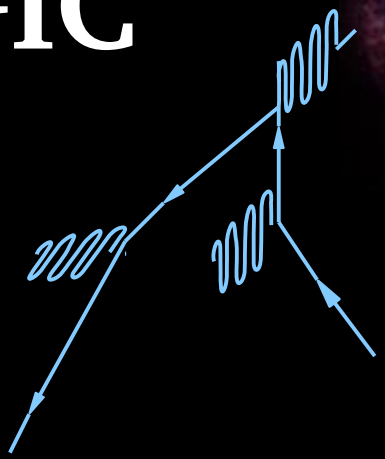
(Stereo data, 2009 – 2013)

This emission can **not** be **explained** with the existing **theories**

Aleksic et al. (MAGIC Collab.) A&A 565 (2014) 12

- 2011, Detection Above 100 GeV VERITAS (Science, Volume 334, Issue 6052)

The Crab pulsar at TeV energies with MAGIC



arXiv:1510.07048

The Crab Pulsars at VHE: Combining all the data

- **All data available since 2007 were reanalyzed: 8 years of data.**

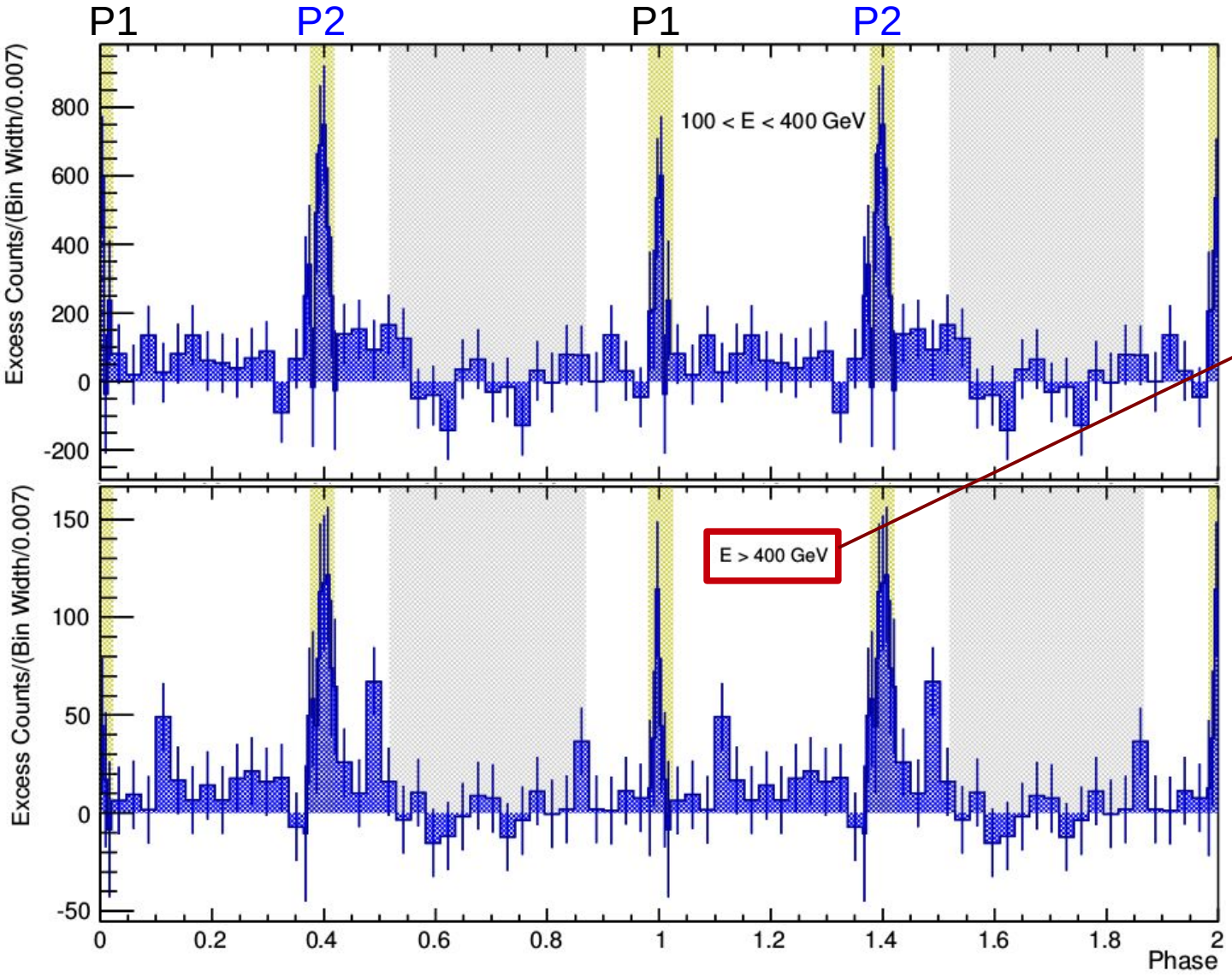
- **The data was divided into 19 data sub-samples to account for differences in the hardware/observations settings.**

- **After quality selection cuts, 97 hours of mono and 221 hours of stereo data were obtained! ~320 h**

- **6 persons involved in the analysis.**

- **Results highly cross-cheeked.**

The Crab Pulsars at VHE: Profile



- Pulse detection above 400 GeV:

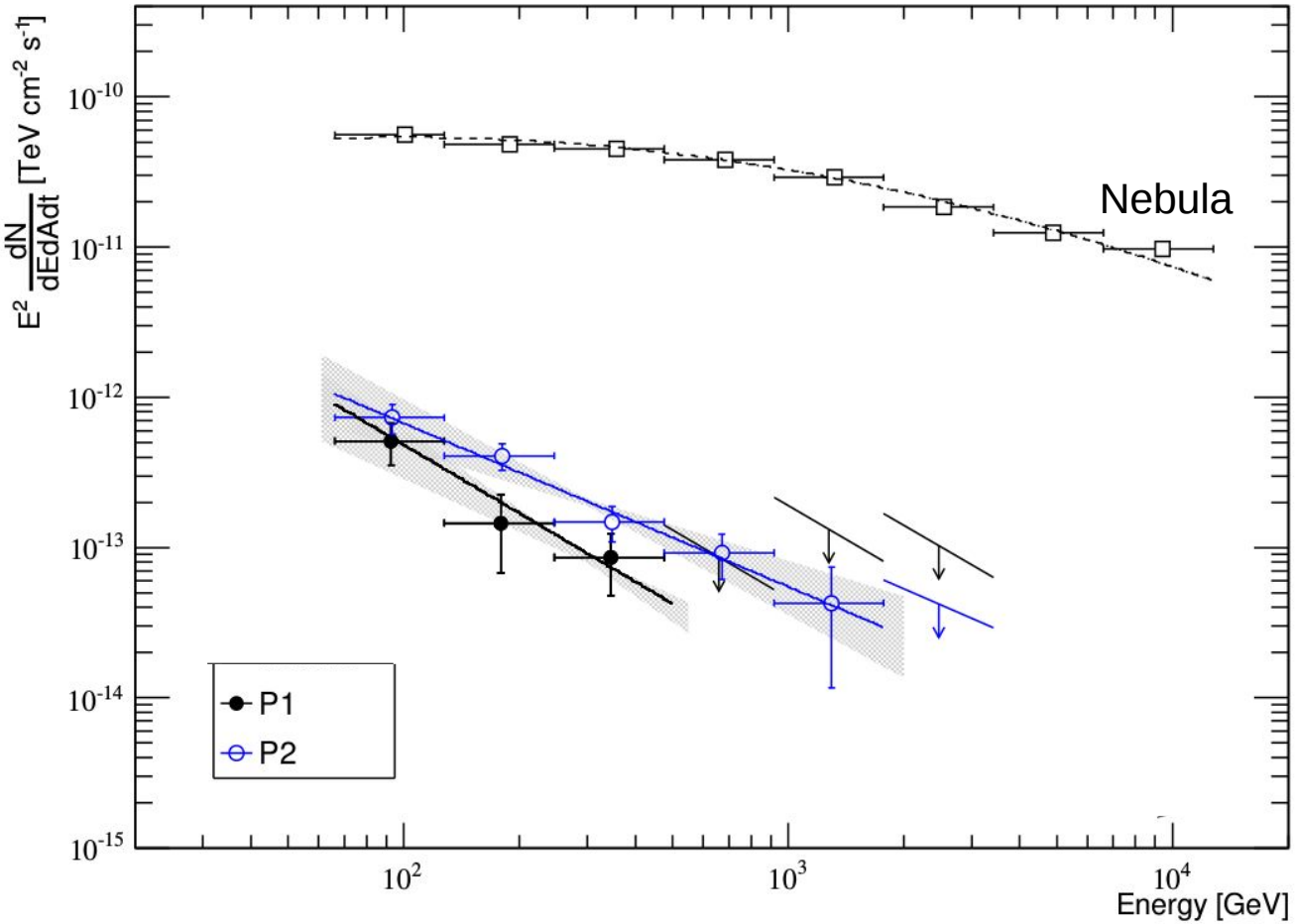
P1: 2.2σ

P2: 6.0σ

- Pulse profile:

FWHM of P1 half at 400 GeV that in the lower energy bin (2σ)

The Crab Pulsars at VHE: SED



- **Spectral indices:**

  P1: 3.5 ± 0.4 ± 0.3

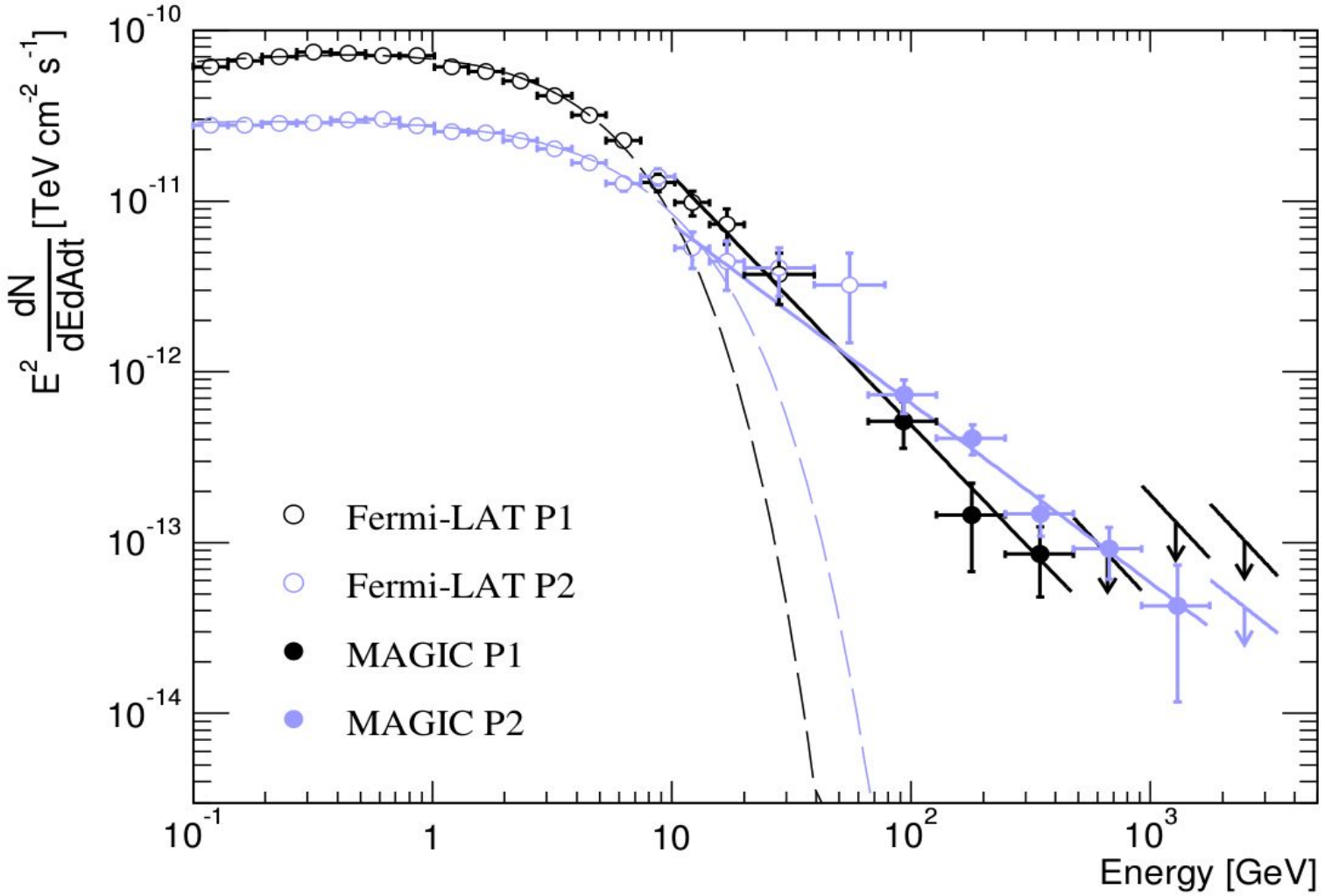
  P2: 3.1 ± 0.2 ± 0.3

- **Spectrum extends up to:**

  ~0.5 TeV, P1

  ~1.7 TeV, P2

The Crab Pulsars at VHE: SED



MAGIC + FERMI

- Spectral indices:

P1: 3.5 ± 0.1

P2: 3.1 ± 0.1

Δα= 0.4±0.1 (3σ)

The Crab Pulsars at VHE: Physics Outcomes

- **MAGIC detected the most energetic pulsed photons from the Crab, up to about 2 TeV.**

- **P1 could not be measured beyond 500 GeV. Power-law 3.5.**

- **P2 power-law spectrum extends up to ~2 TeV with a photon index of 3.1.**

- **Constraining the mechanism:**

The detection of TeV photons implies that they are emitted:

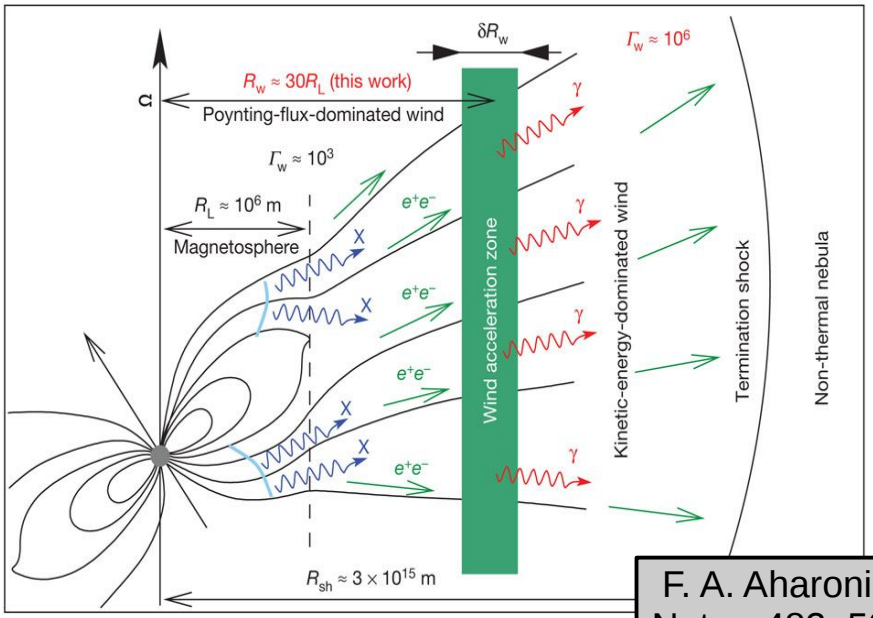
* **by a population of electrons with $\Gamma > 5\times10^6$**
  (Close to the maximum theretically perdicted)

* **Via inverse Compton, Synchrotron-curvature ruled out.**

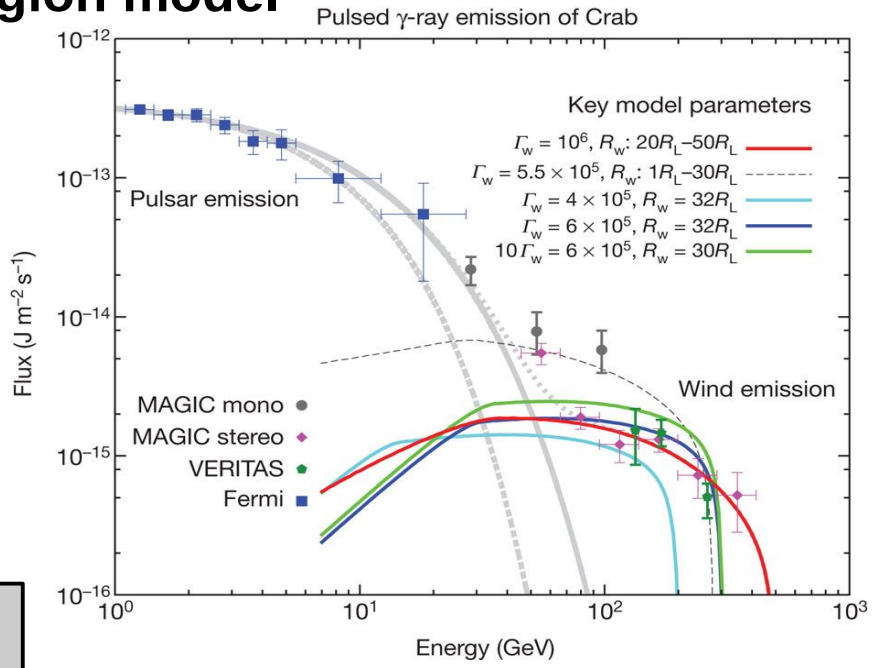
It would require unrealistic curvature radii (R_c~20R_{LC})

- Constraining the emission site *(highly model dependent)*

1. Inverse Compton in the pulsar wind region model



F. A. Aharonian et al. Nature482, 507–509



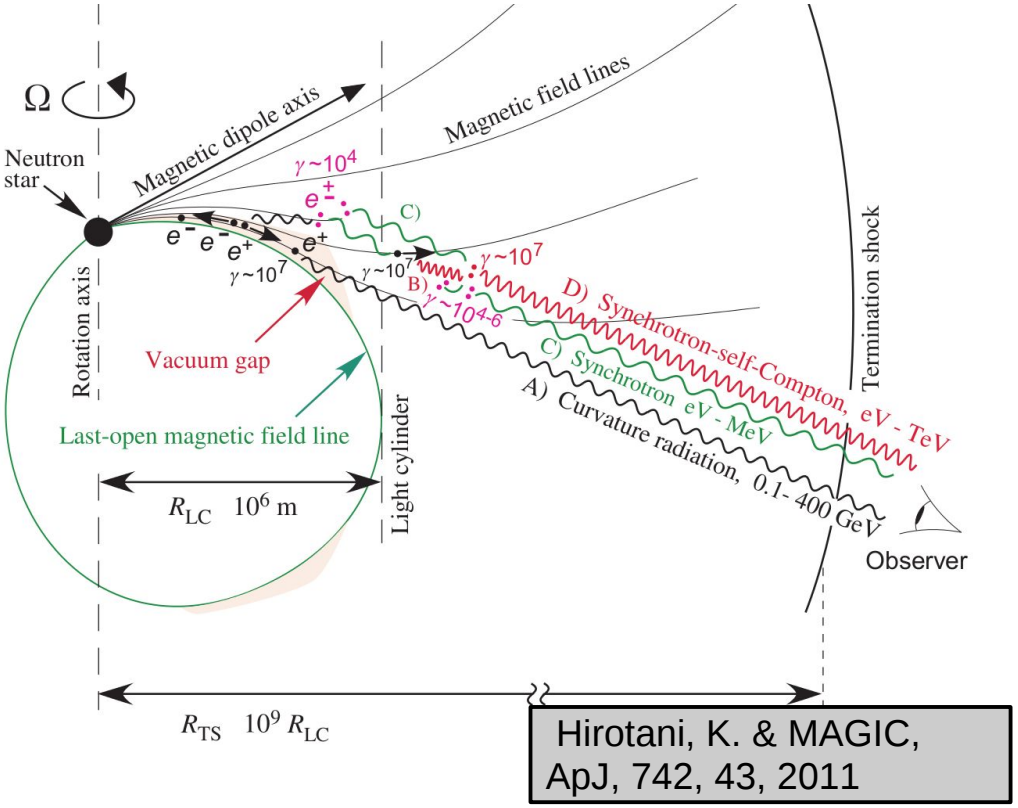
- TeV energies, the region in which particles are accelerated has to extend up to a much larger radius. Model can not reproduce Emission above 400 GeV.

- It fails in reproducing the Phaseogram

Ruled out! *(Need to be revised)*

- Constraining the emission site *(highly model dependent)*

2. Magnetospheric synchrotron-self-Compton model



Hirotani, K. & MAGIC, ApJ, 742, 43, 2011

- **Can explain VHE photons**

Primary electrons escaping the gap
Compton up-scatter soft photons
to TeV.

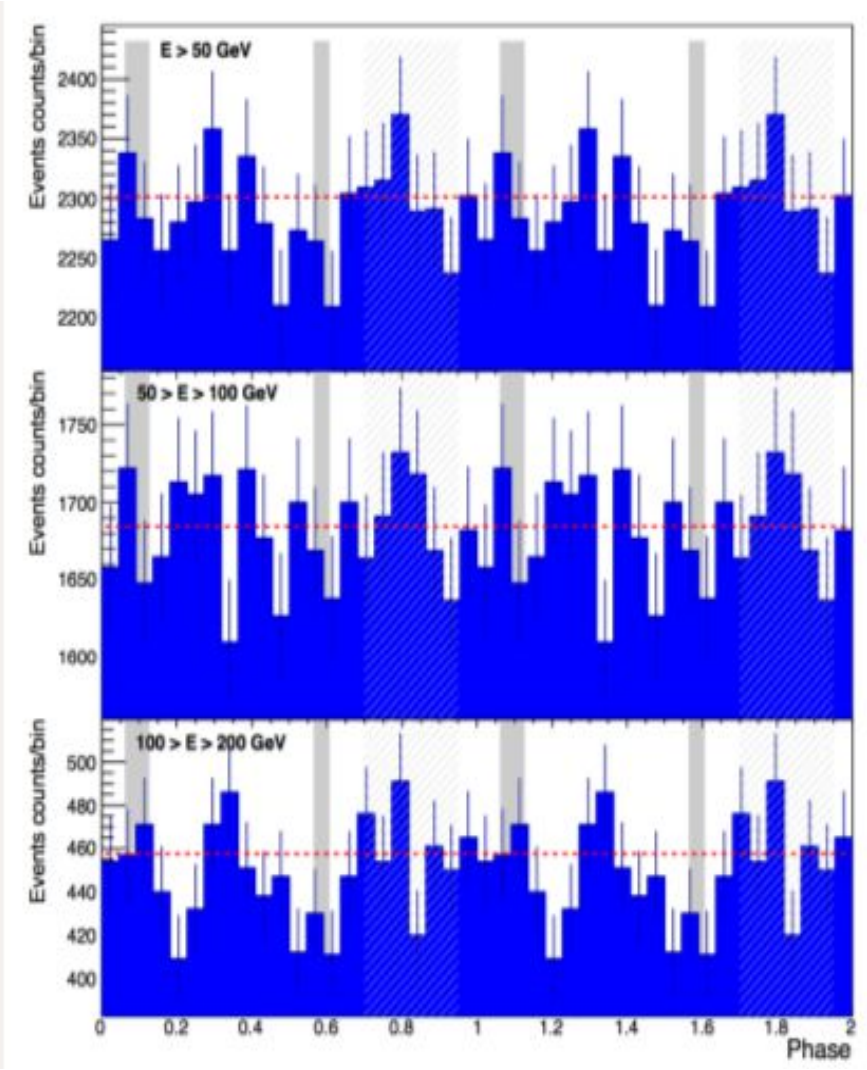
Re-absorbed, shower of secondaries.
(e ±) pairs (with Γ ∼ 10 4−7)
repeat the same process

- **BUT:** Synchronization of the pulse profile in the GeV and TeV suggest a similar region of generation.

Looking for Geminga

arXiv:1603.00730

Lookig for Geminga



Geminga is one of the most interesting targets since:

- **It is the one of the most bright pulsar in X-Ray**
- **At 3 GeV, 5 times brighter than Crab**
  Nearby 2.5 pc
- **Power-law-like extension after the break is reported based on Fermi data**
- **25 GeV pulsation is also detected (1FHL)**

But with 63 h of data after quality cuts, we have no detection.

Lookig for Geminga

- Cutoff power law fit to LAT data above 0.1 GeV

$$\frac{dF}{dE} = N_0 \left(\frac{E}{E_0}\right)^{-\alpha} exp(-(E/E_c)^b),$$

	N_0	α	E_c [GeV]	b
P1	3.0 ± 0.3	1.12 ± 0.04	1.2 ± 0.1	0.81 ± 0.04
P2	4.3 ± 0.4	0.78 ± 0.03	1.1 ± 0.1	0.70 ± 0.03
PA	28.3 ± 1.8	0.94 ± 0.02	0.8 ± 0.1	0.67 ± 0.02

< 1

- Power law fit to LAT data above 10 GeV

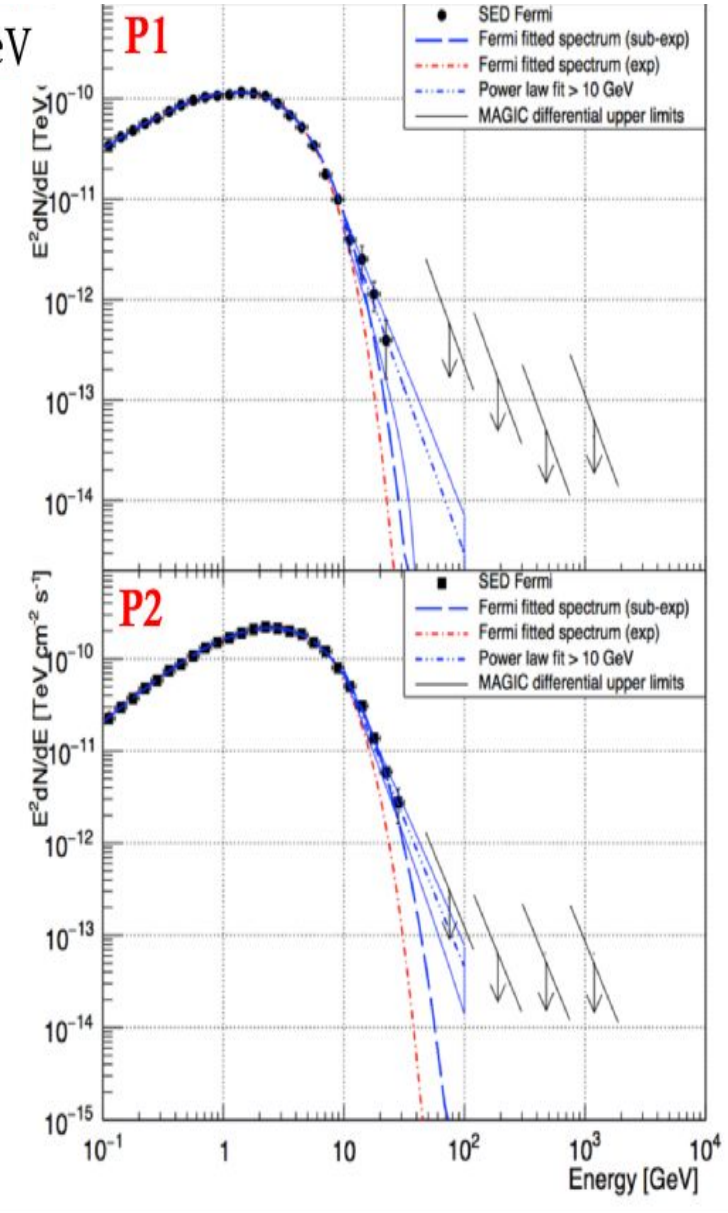
$$\frac{dF}{dE} = N_0 (E/10GeV)^{-\alpha}$$

	N_0	α
P1	$(5.9 \pm 1.4) \times 10^{-5}$	5.3 ± 0.7
P2	$(7.2 \pm 0.1) \times 10^{-4}$	5.2 ± 0.3

N_0 [10^{-10}MeV^{-1}s^{-1}cm^{-2}]

- P2 limits are close to but slightly above the power law extension.

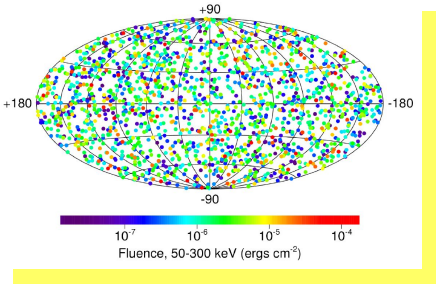
- Lowering energy threshold is important.



The New Sum-Trigger-II

The Sum-Trigger-II: Low Energy Observation, Goals

- **Discovery**
- **Variability studies**
- **Energy evolution stuides**
- **Spectrum component**



High Z

GRBs

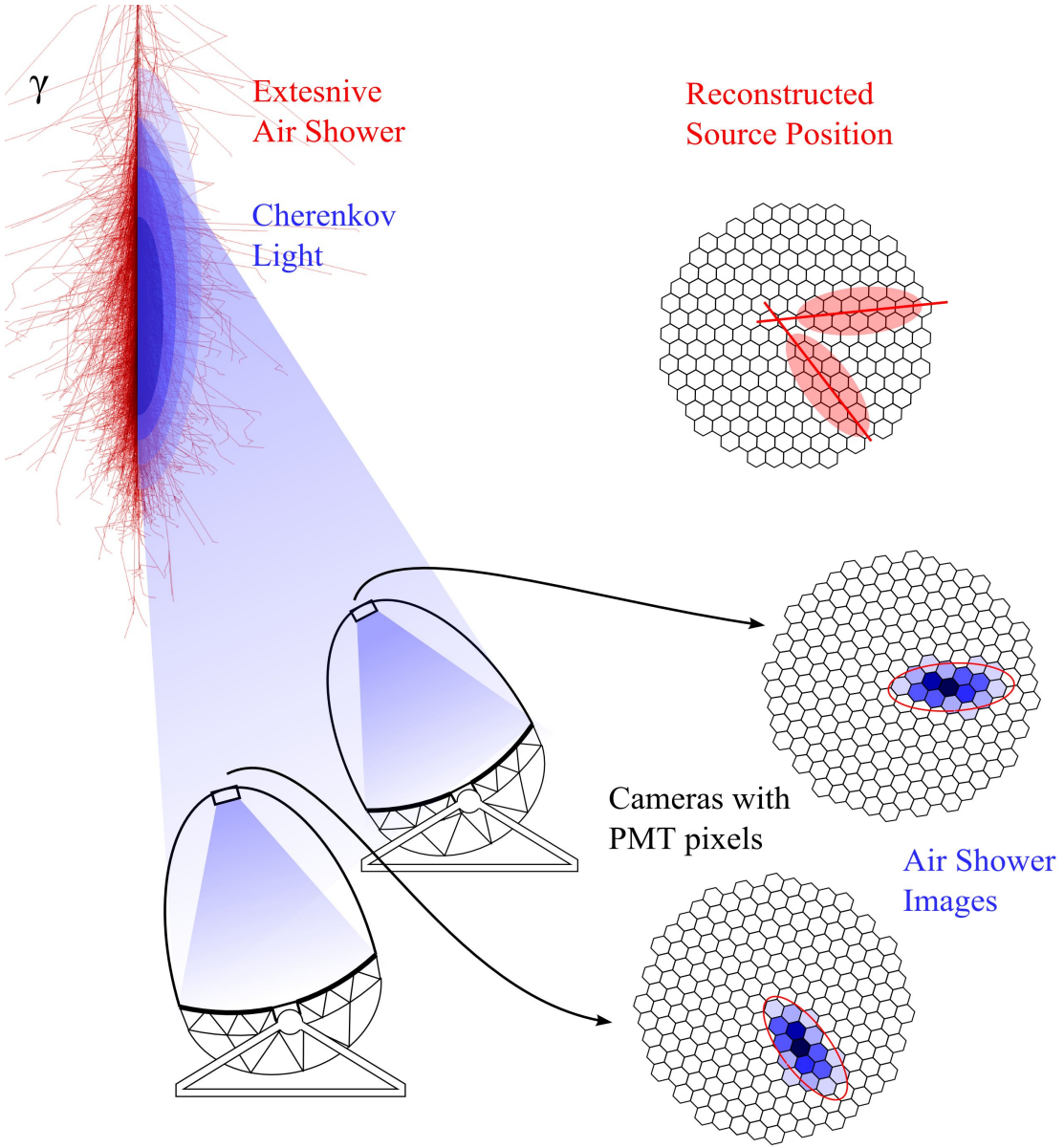
AGNs

PULSARs

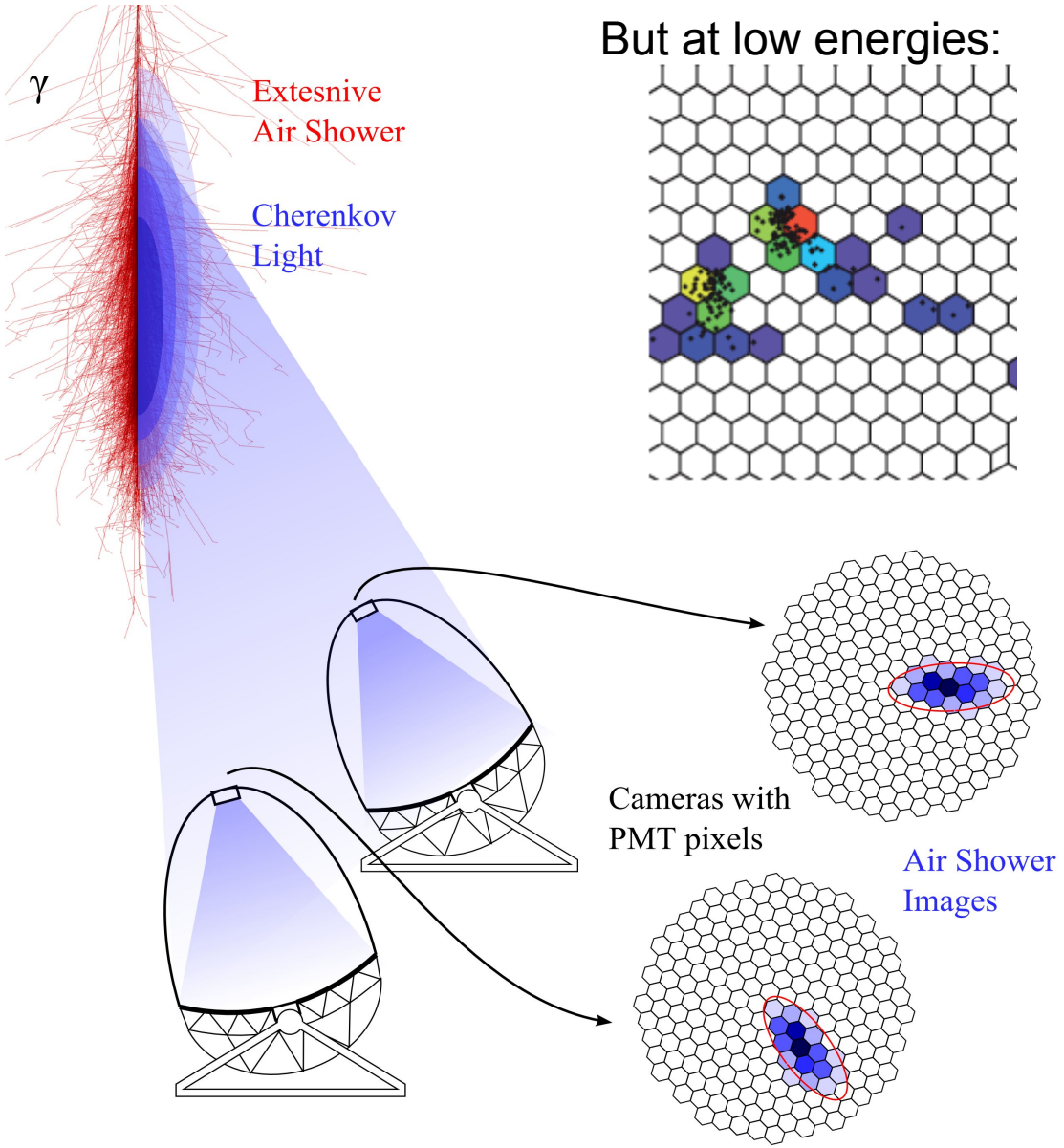
Quamtum Gravity effects

EBL

The Sum-Trigger-II: Low Energy Observation, difficulties



The Sum-Trigger-II: Low Energy Observation, dificulties



But at low energies:

Shower develops max 11-12km

Low n:

$$s(\Theta_c) = 1/(n\beta)$$

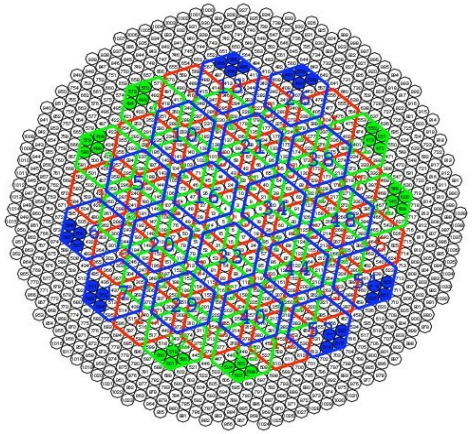
***High E_t to produce Cherenkov light**

*** Small Θ_c**

- Small size

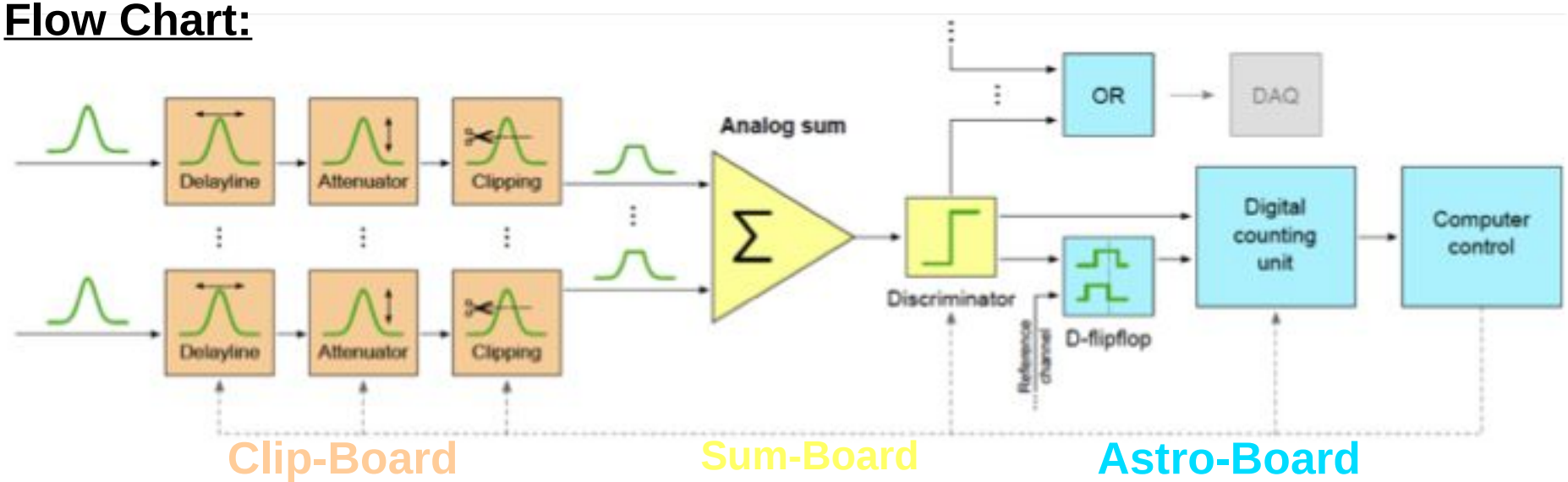
- Collimated beam, less triggers at large impact parameter

The Sum-Trigger-II

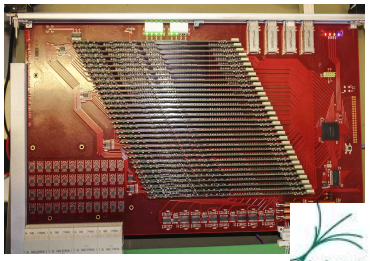


- Sum of analog signals of a patch of 19 PMTs.
- Use small photon signals below the single channel threshold.
- Integration of larger area (size of shower) increases S/N.
- Camera subdivide in 55 macrocells that operate independently.
- The final trigger is a Global OR of the local macrocells trigger.

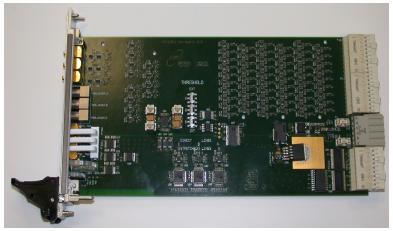
Flow Chart:



The Sum-Trigger-II

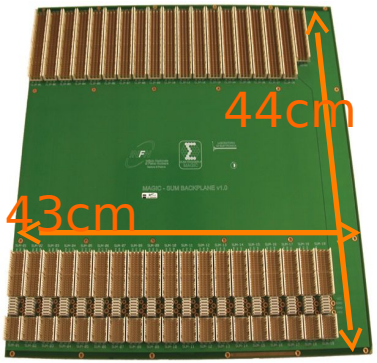


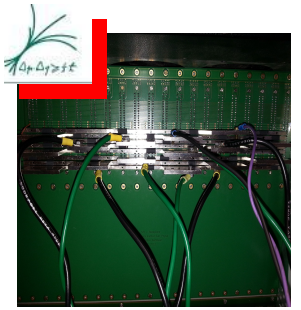
Clip-Board



Sum-Board

Astro-Board

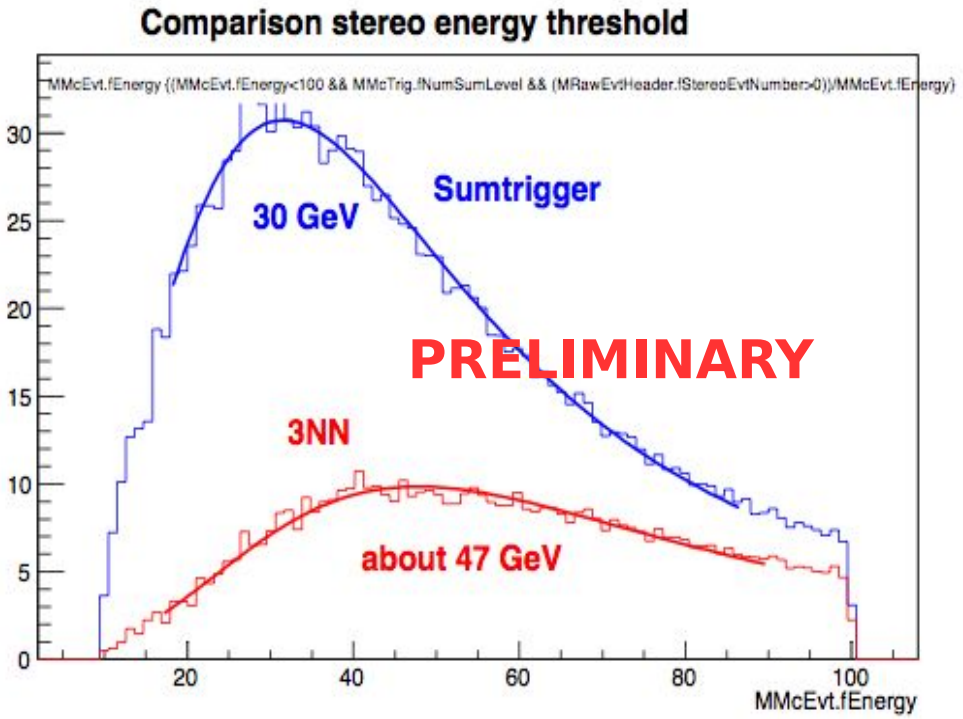




Fast "status of the art" analog electronics.

-Work with analog 2,6 ns signal in the ps order, and gain adjustment 0.5db

First Results and work on going



- Sum-Trigger: 4.2 sigma in 1.2 h (standard analysis)
- Previous MAGIC : 10.4 sigma in 72 h

http://arxiv.org/pdf/1202.3008.pdf

THANKS!!

On behalf of the Authors:

D.Fidalgo, R.Zanin, E.de Oña Wilhelmi, D.Galindo, D.Garrido Terrats, W.Idec, T.Schweizer, W.Bednarek, D.F.Torres, T.Saito, M.Gaug, M.López,

S.Bonnefoy,

F.Dazzi for the MAGIC collaboration

Acknowledgments

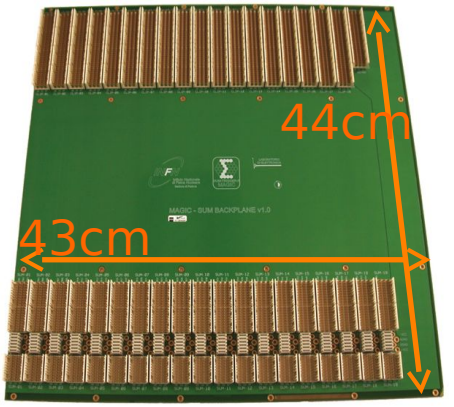
(Technical support)

M. Bettini, D. Corti, A. Dettlaff, D. Fink, M. Fras, P. Grundner, C. Knust, R. Maier, S. Metz, M. Nicoletto, O. Reimann, Ma. Reitmeier, Mi. Reitmeier, K. Schlammer, T. S. Tran, H. Wenninger, P. Zatti

Max Planck Institut für Physik

University of Padova &

INFN Sezione di Padova


44cm
43cm