Recent highlights of the MAGIC telescopes

Oscar Blanch Bigas
for the MAGIC collaboration

EXCELENCIA
SEVERO
OCHOA

MAGIC
Major Atmospheric
Gamma Imaging
Cerenkov Telescope

Institut de Física
d'Altes Energies

The MAGIC Telescopes

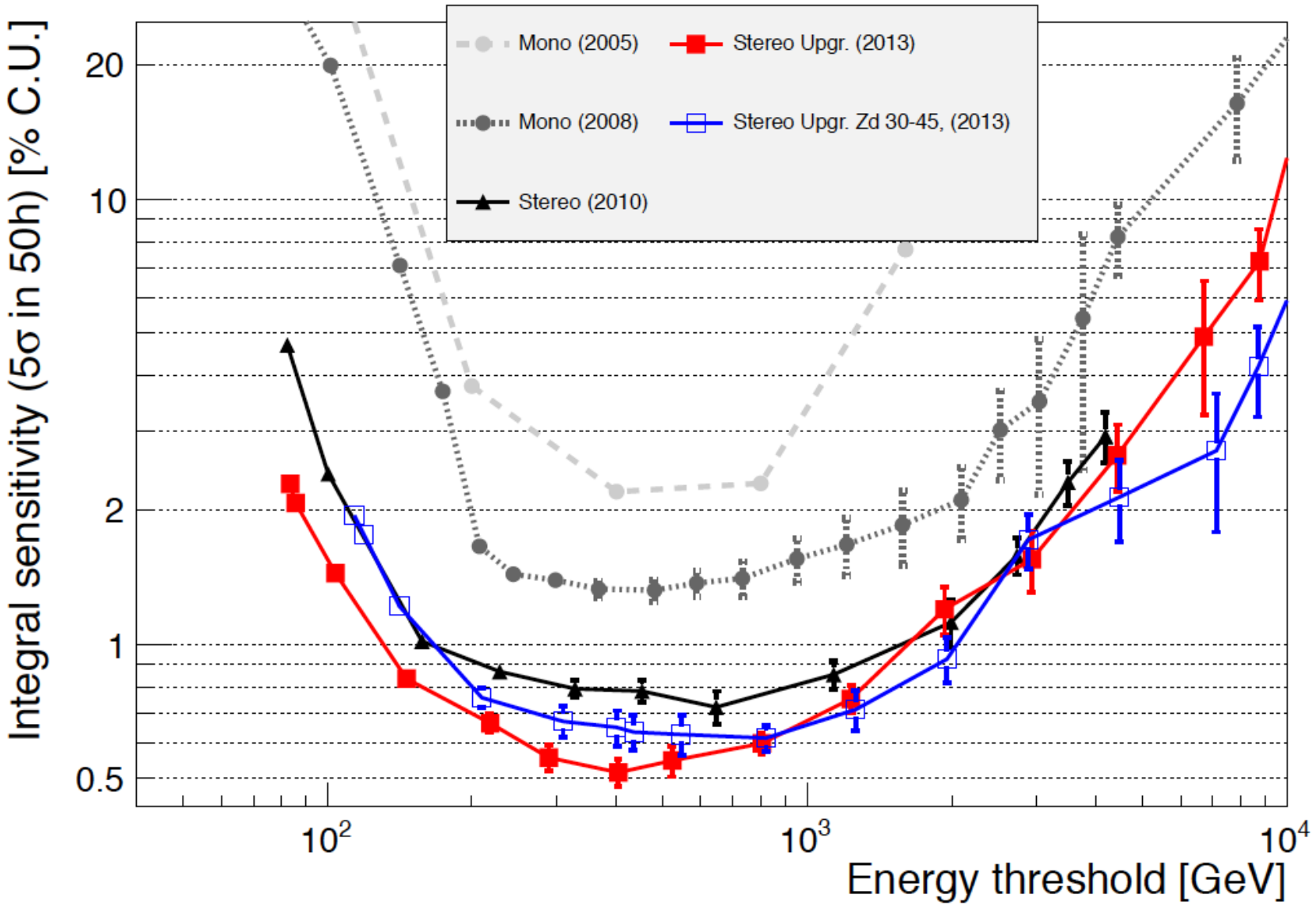
MAGIC is an Imaging Atmospheric Cherenkov Telescope system consisting of two 17m diameter telescopes, located on Canary island La Palma

The MAGIC Collaboration

~170 scientists working in institutes from 10 countries across Europe & Asia: Bulgaria, Croatia, Finland, Germany, India, Italy, Japan, Poland, Spain and Switzerland

MAGIC kept Improving

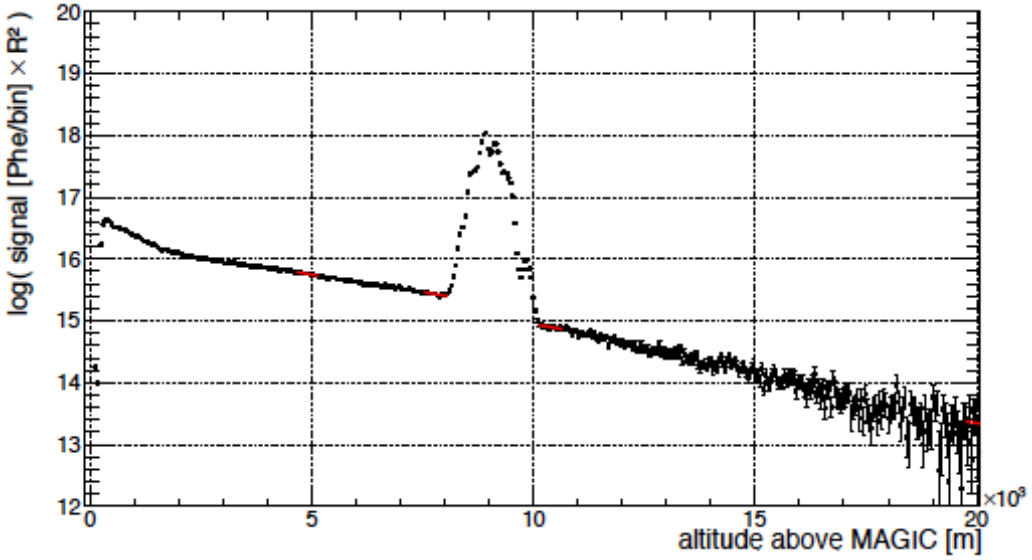
Aleksić et al. (MAGIC) Astropart.Phys, 72, 2016

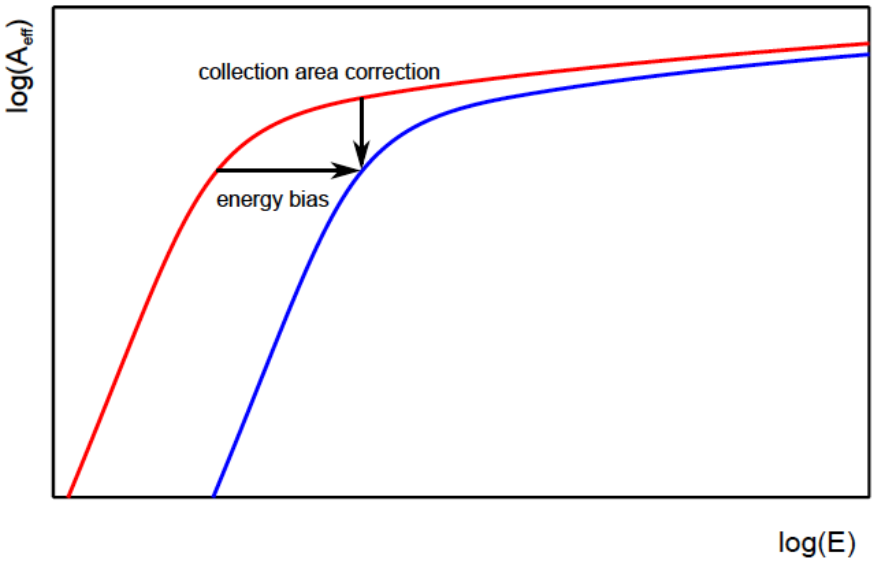


- 2004 – MAGIC-I built
- 2007 – upgraded MAGIC-I readout
- 2009 – MAGIC-II built
- 2011-2012 – upgrade of readout systems and MAGIC-I trigger and camera

Recovering data with LIDAR

Simultaneous to the data taking monitoring of the atmosphere transparency with LIDAR allows us to recover data affected by bad weather condition (clouds, calima)





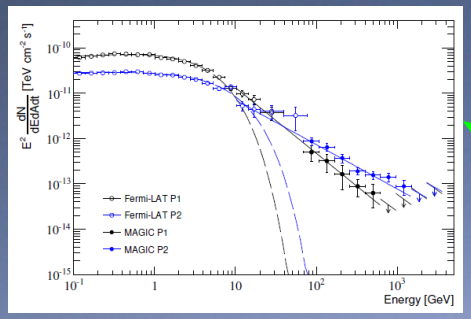
Used to recover MAGIC observations for V339 Del Nova outburst and Mrk501 MWL campaign.

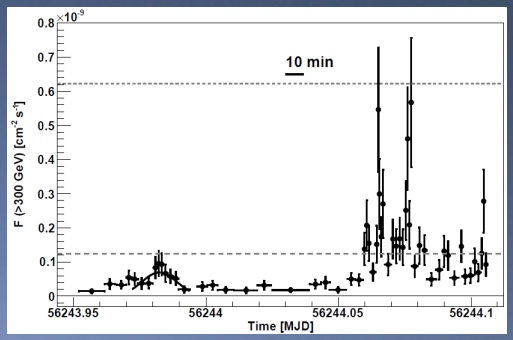
Furniss et al, ApJ, 65, 2015
Aleksić et al. (MAGIC) A&A, 582, 2015

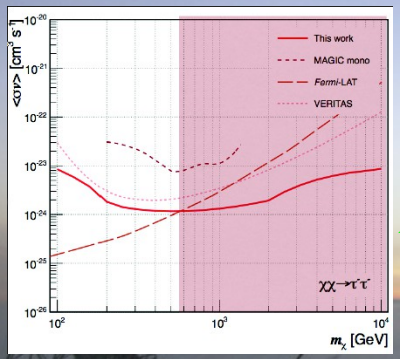
Main scientific targets for MAGIC

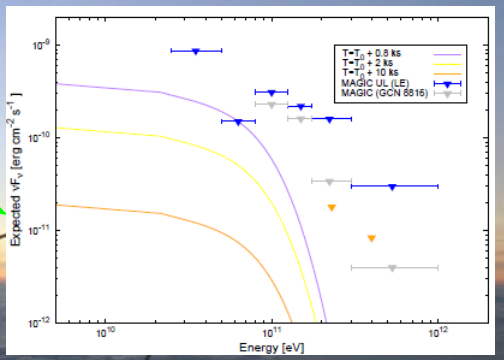
Galactic sources:
Pulsars, PWN, SNR, Binaries

AGNs:
BL Lacs, FSRQs, Radio galaxies









Fundamental physics:
Dark matter, LIV, EBL, IGMF & cosmology

GRBs

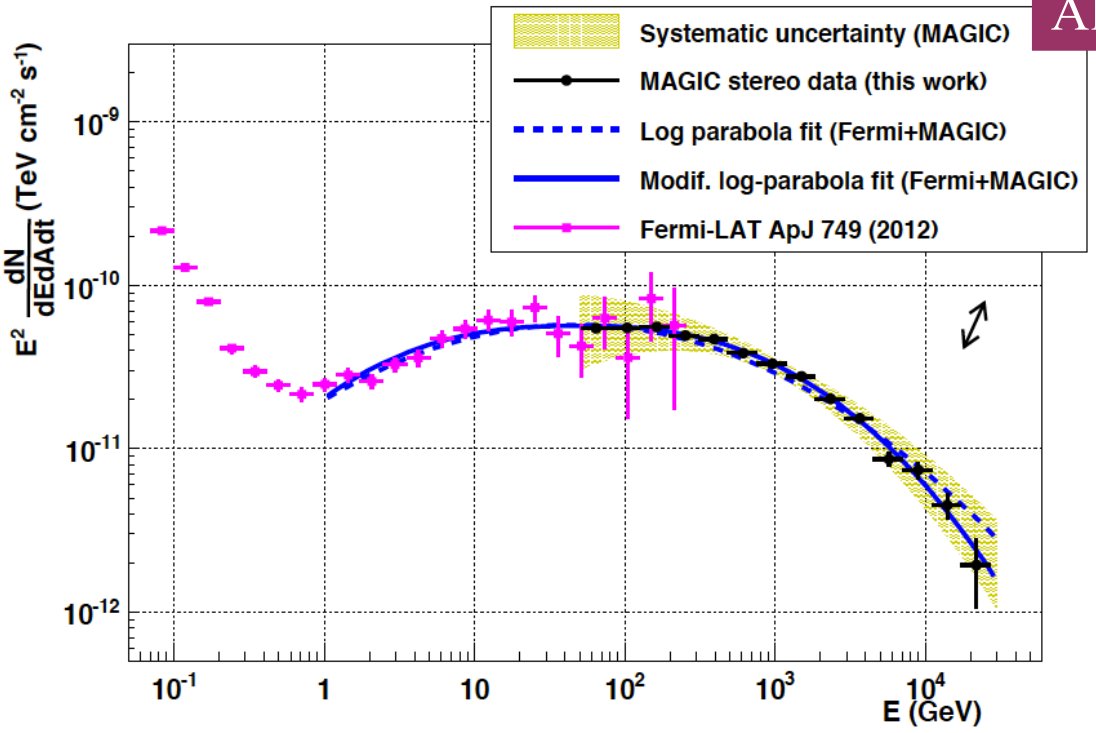
Photo credits: wwwmagic.mppmu.mpg.de

Galactic Physics with MAGIC

Image credits: Daniel López, IAC

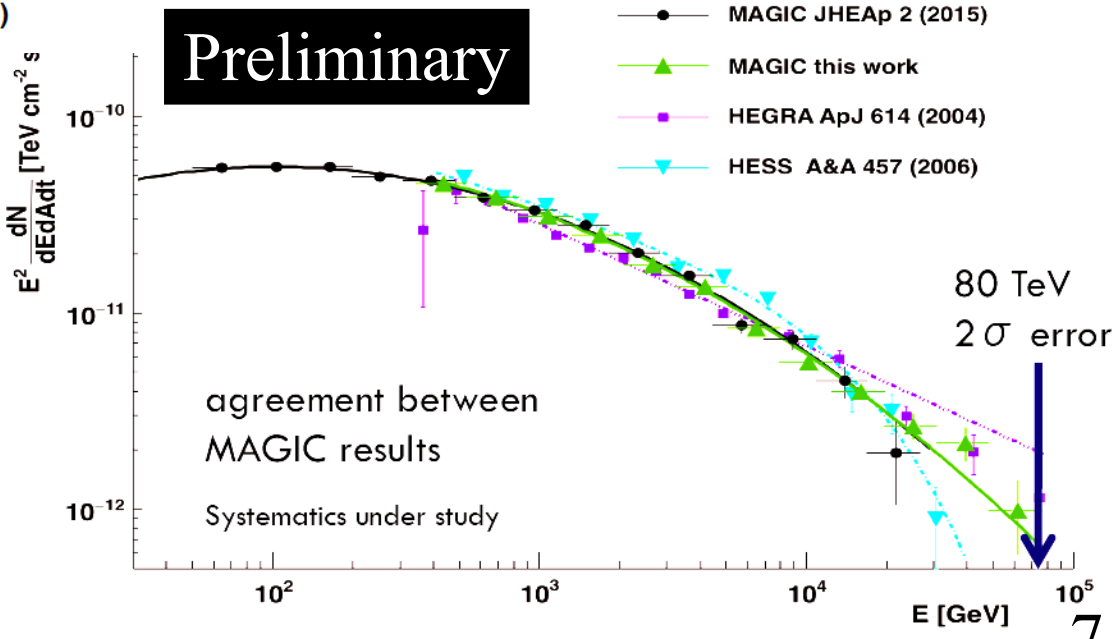
Crab Nebula: from IC peak to Klein-Nishina?

Aleksić et al. (MAGIC) JHEAP, 5, 2015



- Spectrum from 60 GeV to 30 TeV
- Together with *Fermi*-LAT, good coverage of the IC peak

- Large zenith angle observations to explore Klein-Nishina range → ~80 TeV

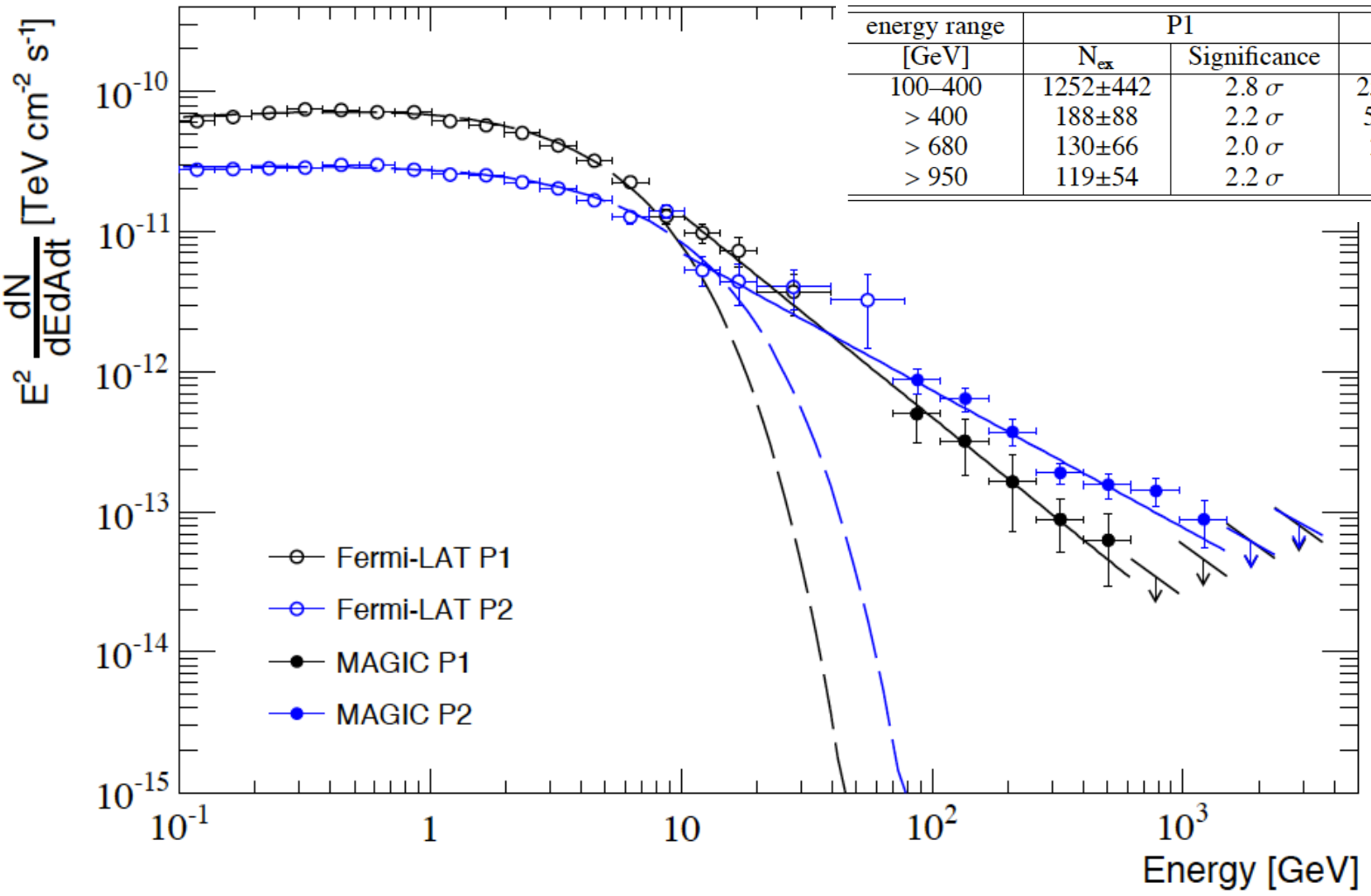


A deeper insight on the most studied source at VHE

Crab Pulsar

Ansoldi et al. (MAGIC) accepted in A&A

energy range	P1		P2	
[GeV]	N_{ex}	Significance	N_{ex}	Significance
100–400	1252±442	2.8 σ	2537±454	5.6 σ
> 400	188±88	2.2 σ	544 ± 92	6.0 σ
> 680	130±66	2.0 σ	293±69	4.3 σ
> 950	119±54	2.2 σ	190±56	3.5 σ

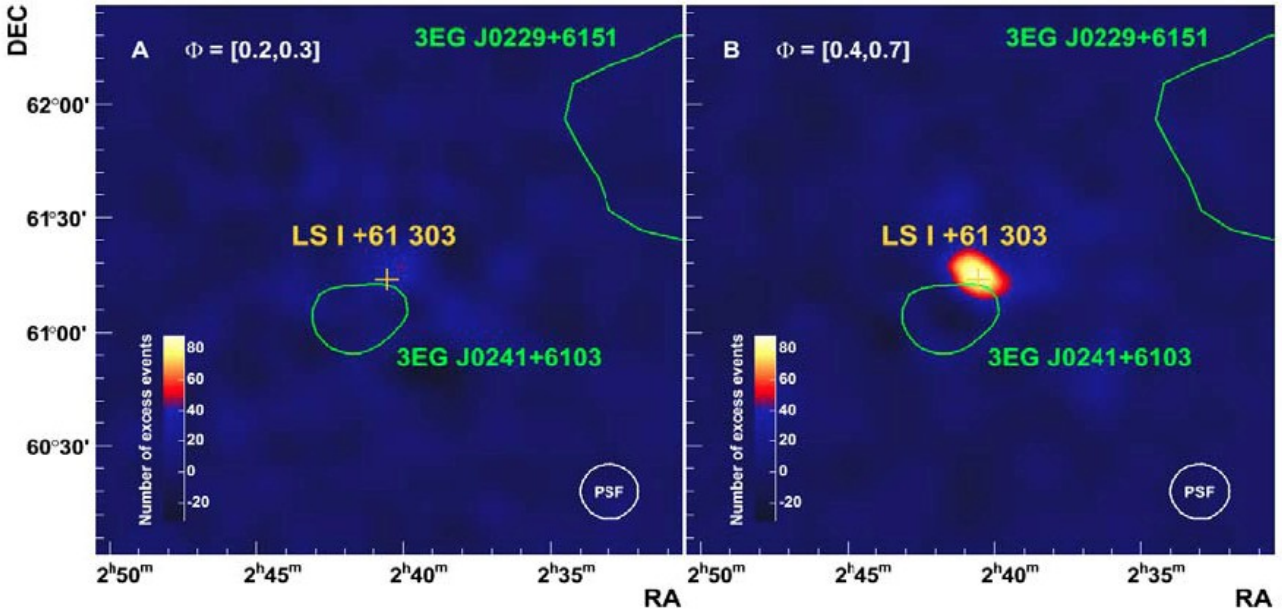


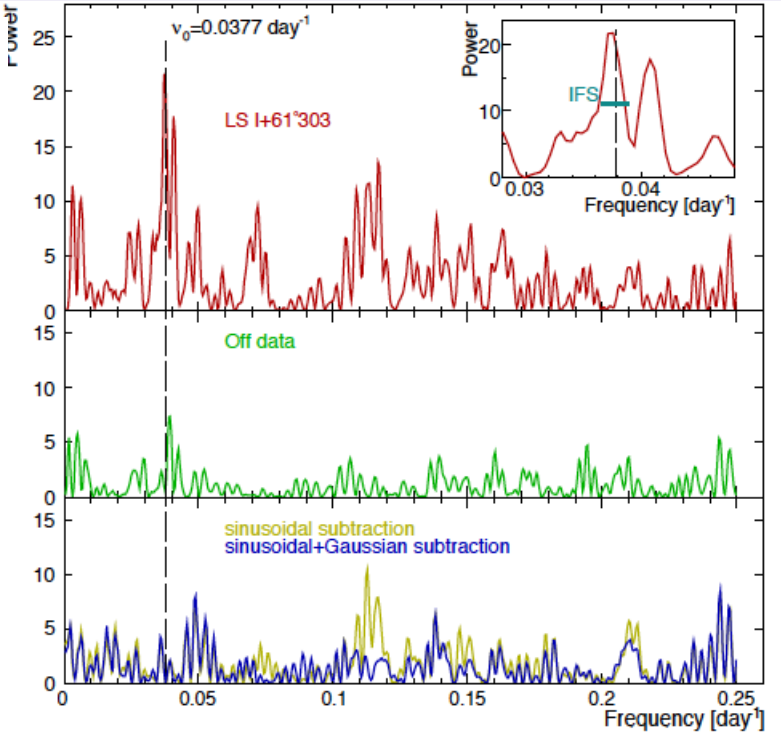
First detection of Crab Pulsar at VHE back in 2008 (E>25 GeV), aggregating 320 hours led to detection above 400 GeV with spectrum extending up to TeV energies

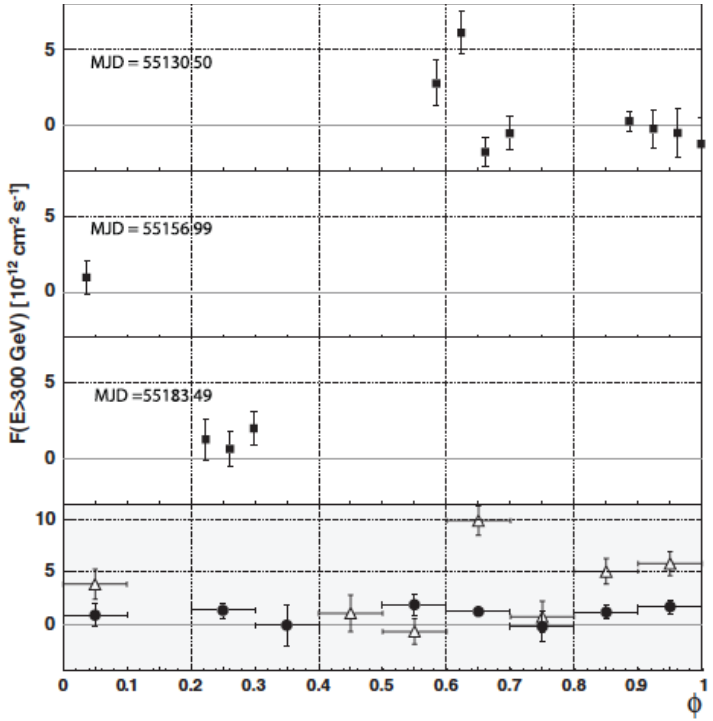
Most likely, IC scattering off low energy photons and gamma rays produced in the vicinity of the light cylinder

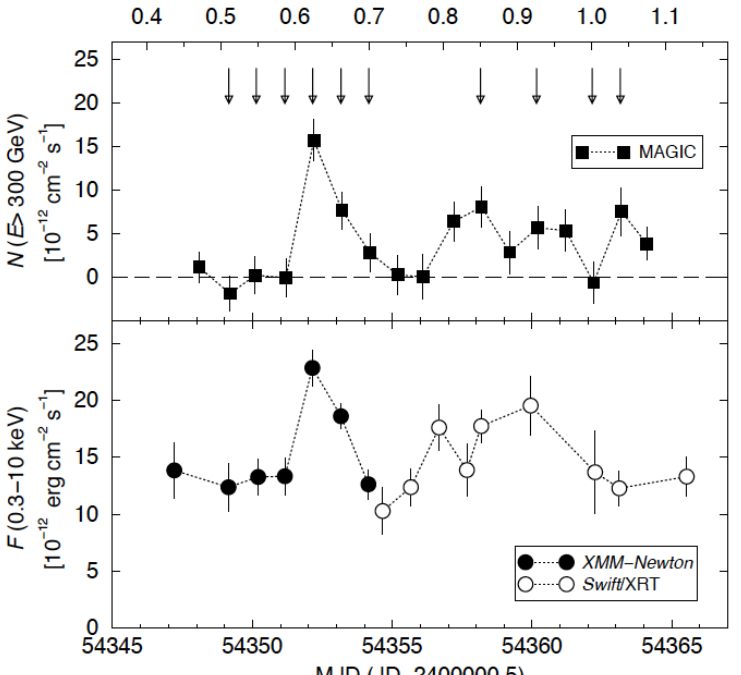
Gamma-ray binaries: LS I 61+303

2006 ...





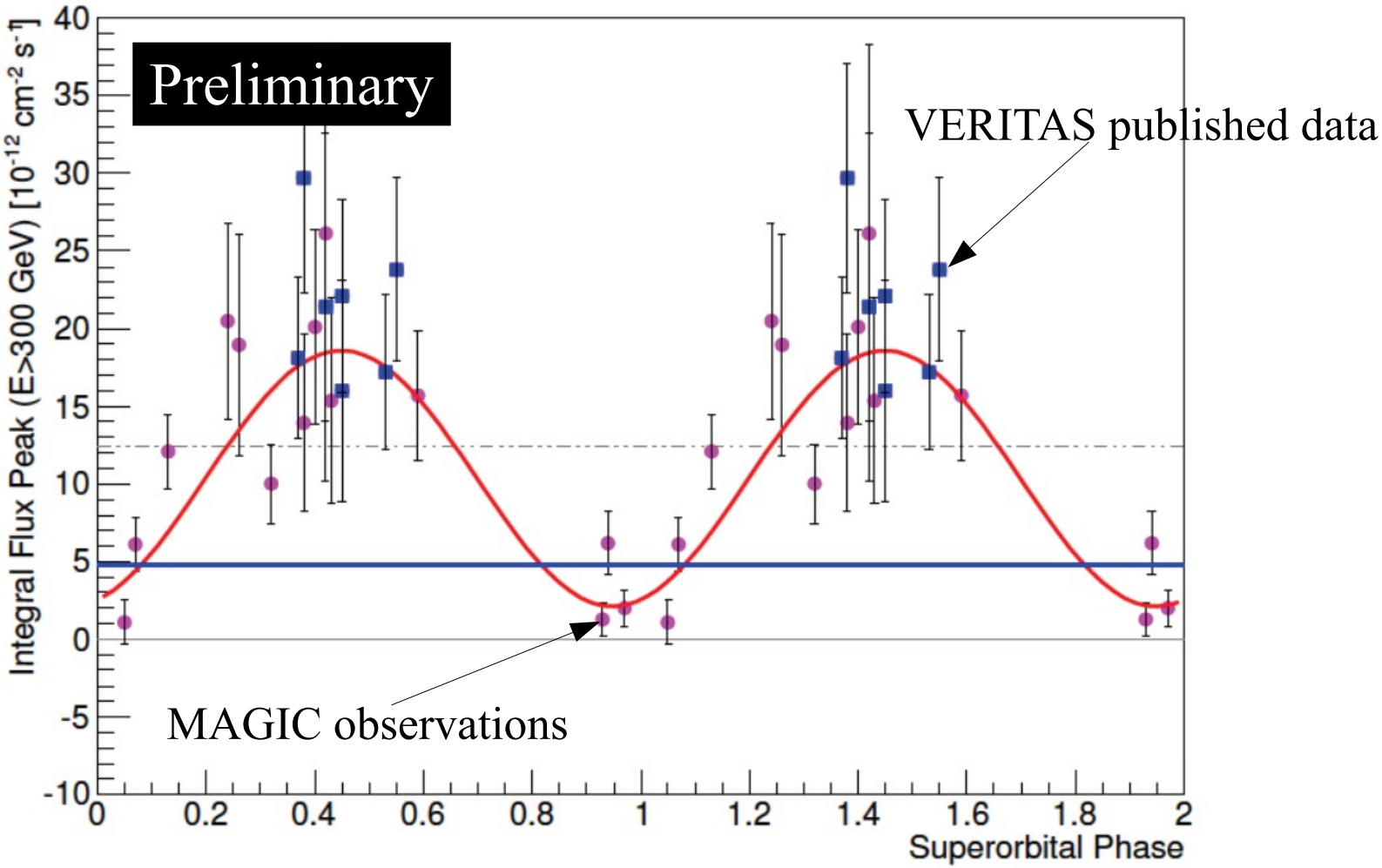




Gamma-ray binaries: LS I 61 +303

… 2014

MAGIC, submitted to A&A



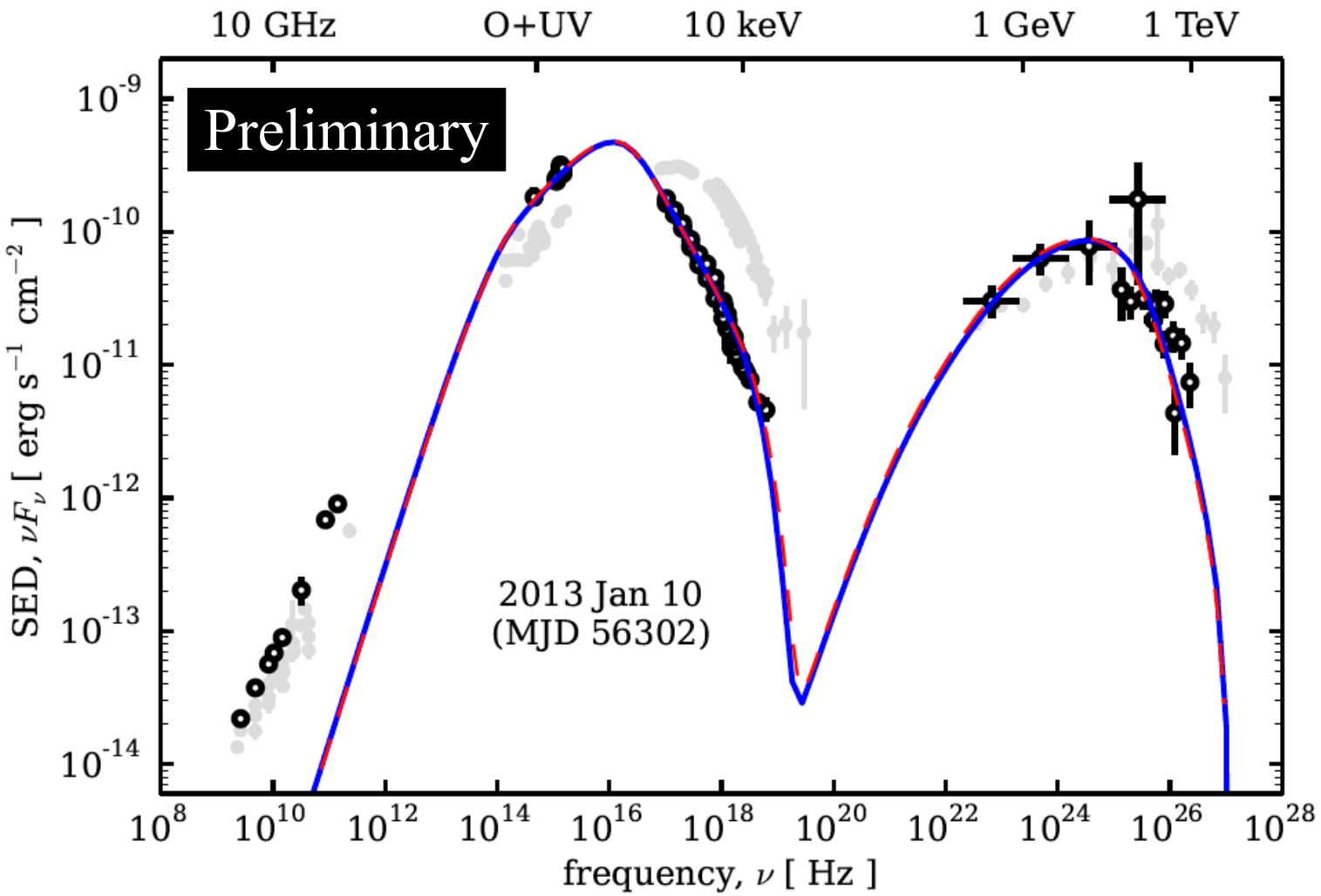
VHE data collected over 8 years → yearly variability consistent with the 4.5 years long-term modulation

Consistent with flip-flop (Zamanov et al. 2001, Torres et al. 2012, Papitto et al. 2012)
model where the system changes from propeller to ejector regime

AGN Physics with MAGIC

MWL SED of Mrk 421 in Jan 2013

Balokovic et al., submitted to ApJ



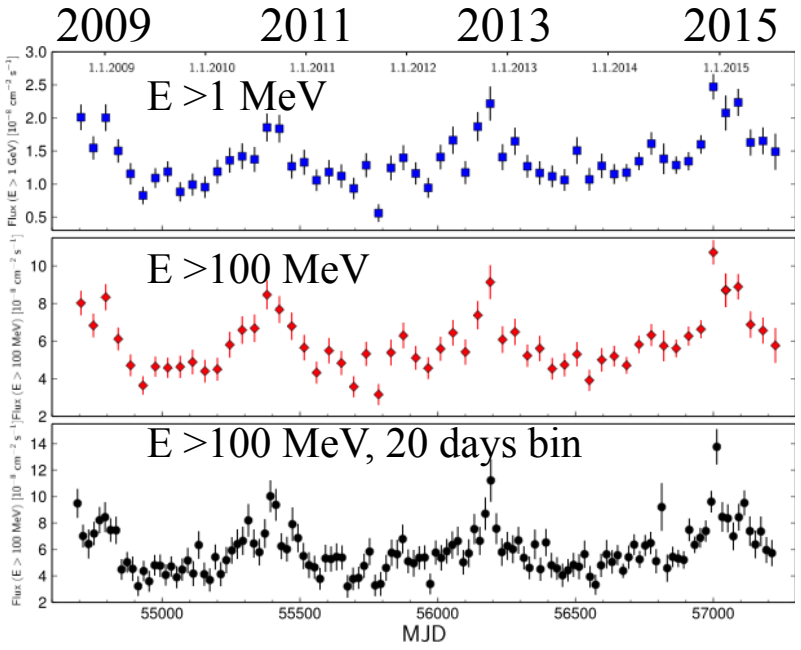
MWL campaign of an old friend in VHE gamma-ray astronomy in low (steady) state

Shift of Synchrotron and IC peaks to lower energies

A canonical HBL moving to IBL observed for the first time

Periodic signal from PG 1553+113?

Ackermann et al., ApJL 813, 2015

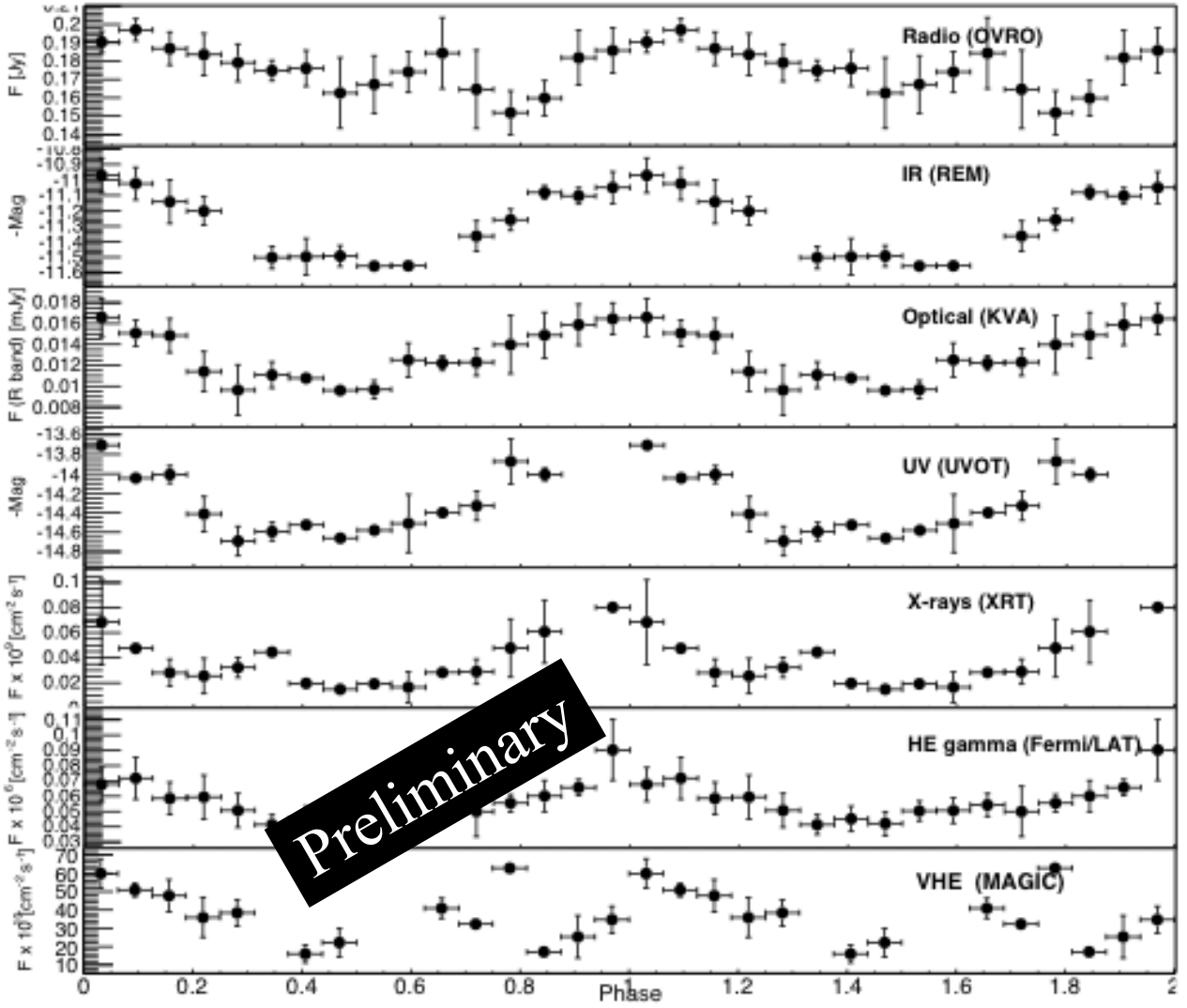


Fermi Collaboration has reported the detection of periodic signal (T=798 d)

Since 2014, intense MWL campaign

Well known at VHE, sparse sampling since 2005

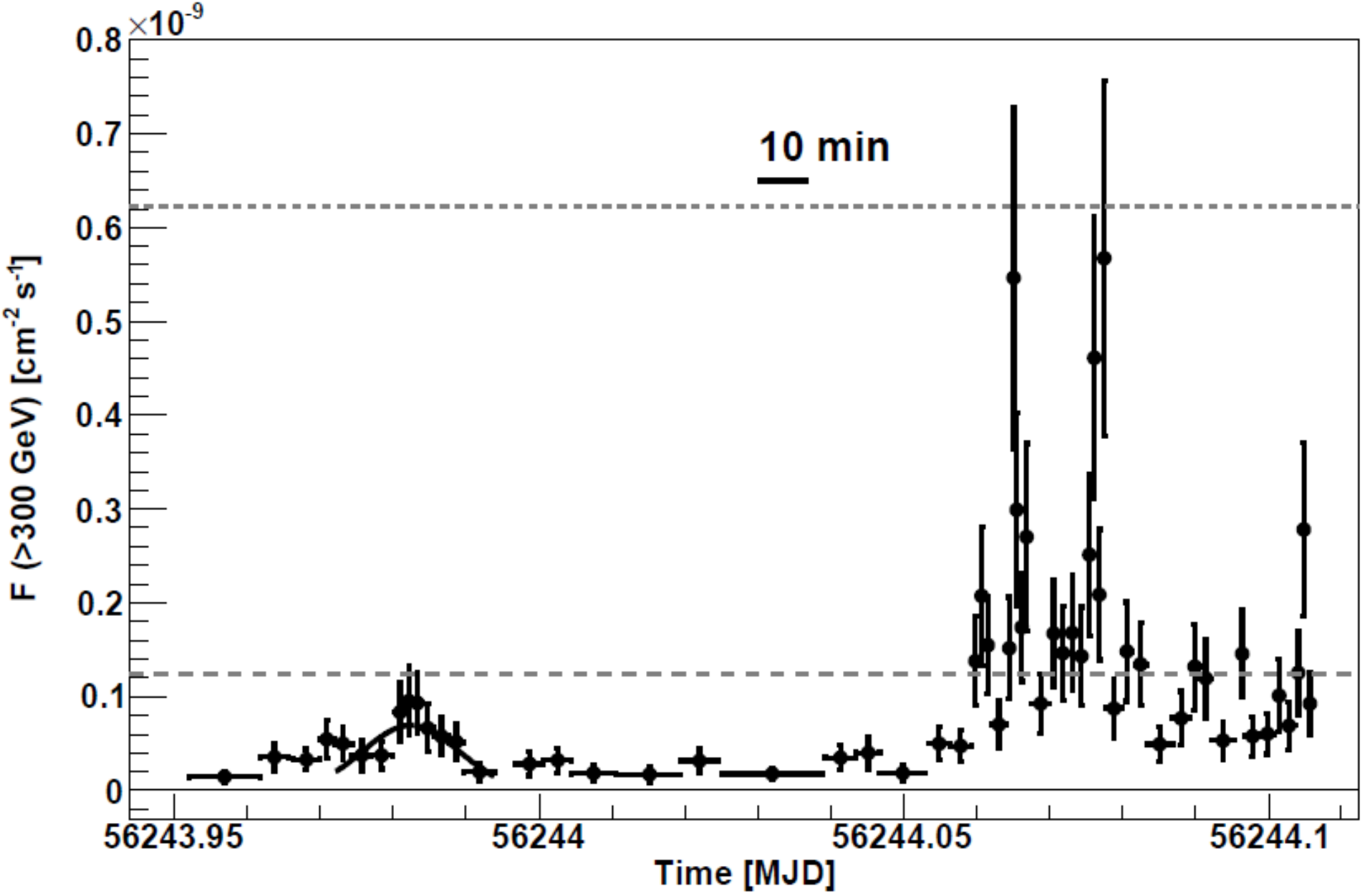
Folded MWL Light Curves



VHE data with MWL coverage may shed light on the underlying mechanism

Extreme flare from radio galaxy: IC 310

Aleksić et al. (MAGIC) Science 346, 2014



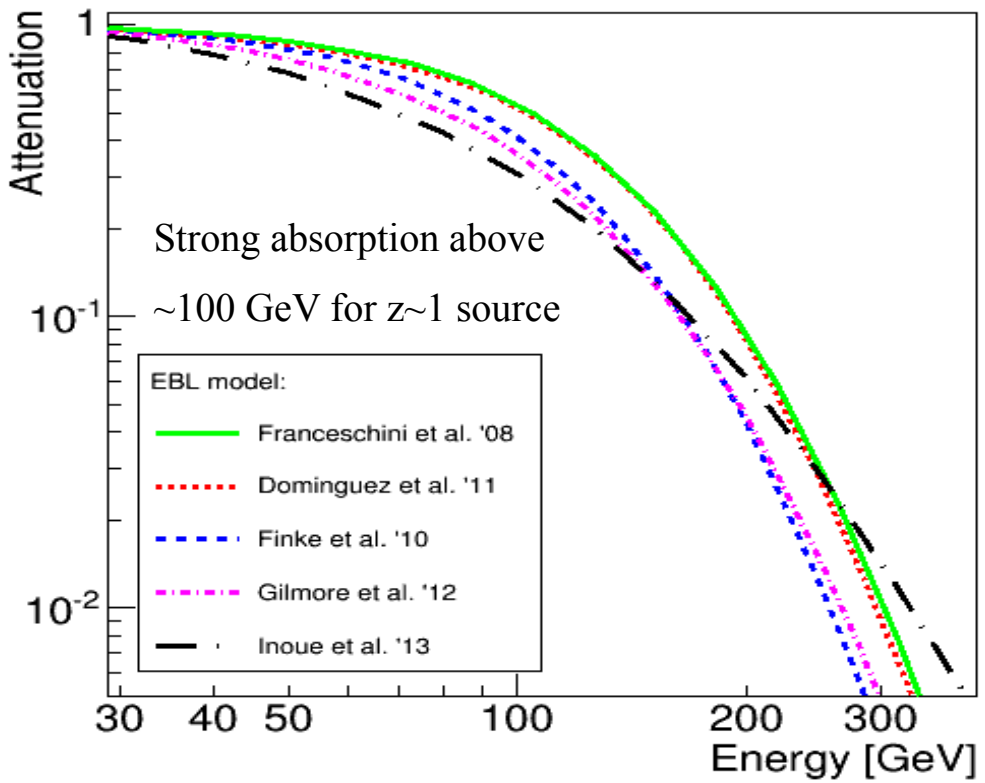
Expanding the VHE gamma-ray universe

Furthest AGN detected: FSRQ

For distant sources sub-TeV gamma-rays are absorbed in extragalactic background light

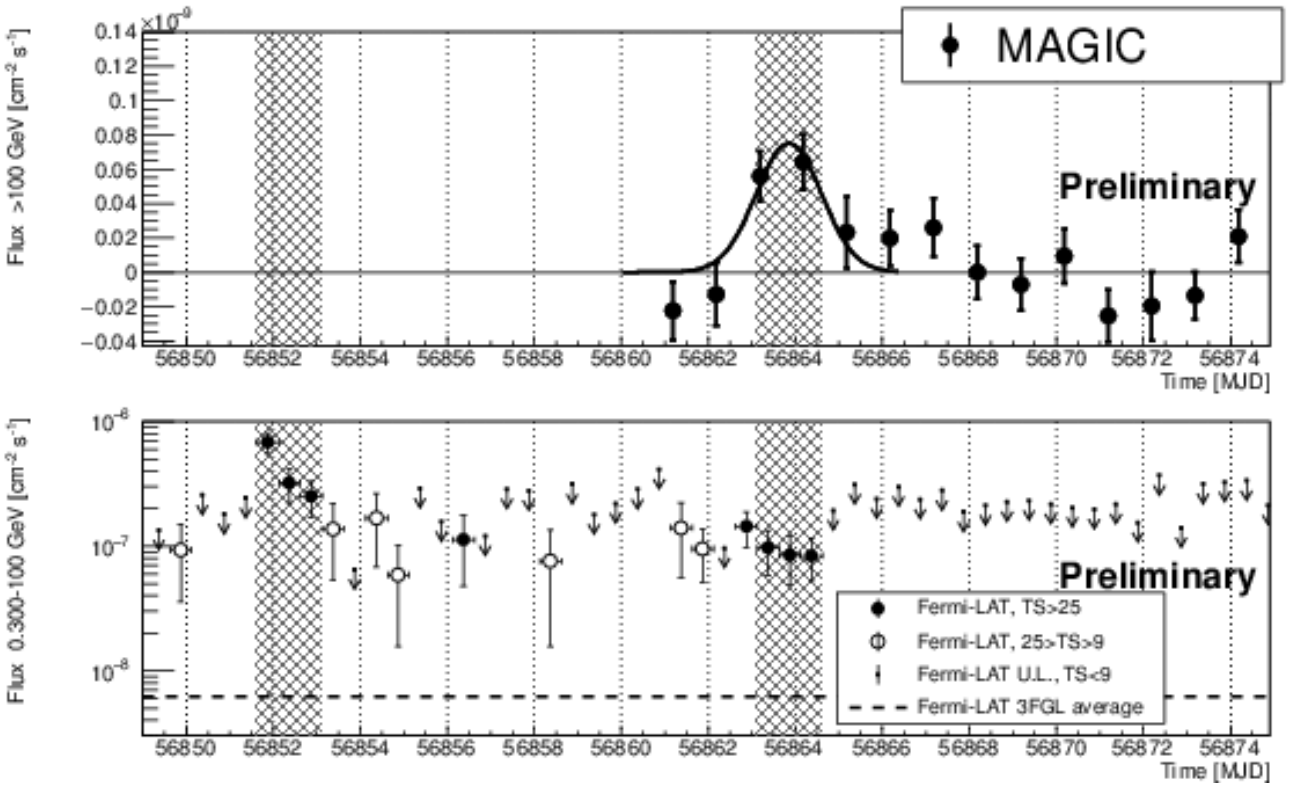
FSRQ has strong broad line region which can absorb VHE photons

Until recently the furthest FSRQ detected at VHE was at z~0.6



FSRQ	*Redshift*	*First VHE detection by:*	*Year*
3C 279	0.536	**MAGIC**	2006
PKS 1510-089	0.361	HESS	2009
PKS 1222+216 (4C +21.35)	0.432	**MAGIC**	2010
B0218+35	**0.944**	**MAGIC**	**2014**
PKS 1441+25	**0.939**	**MAGIC**	**2015**
S4 0954+65*	0.368	**MAGIC**	**2015**

FSRQ at redshift ~ 1



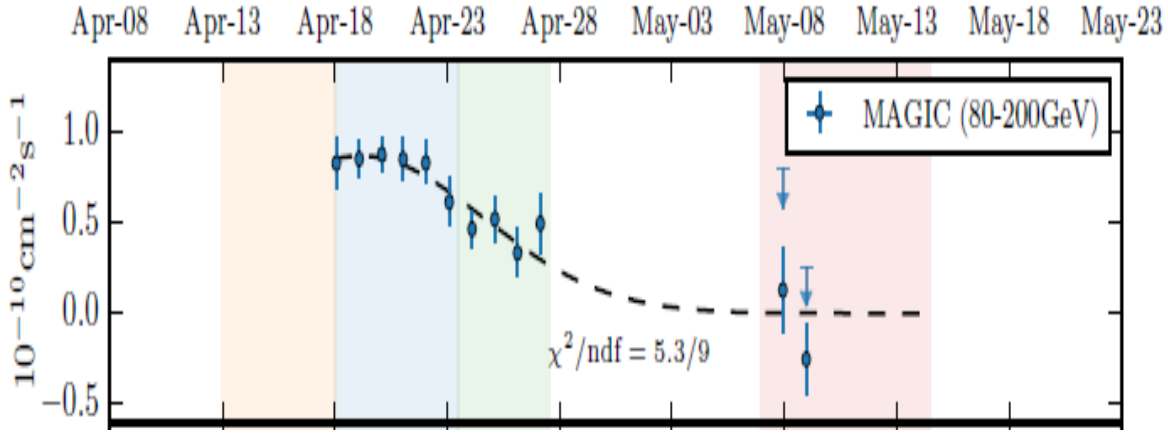
B0218+357 (z=0.944) gravitationally lensed FSRQ

Delayed emission at expected time detected by MAGIC

M.L. Ahnen et al (MAGIC) , ApJL 815, 2015

PKS 1441+25 (z=0.939) trigger by outburst in April observed with Fermi

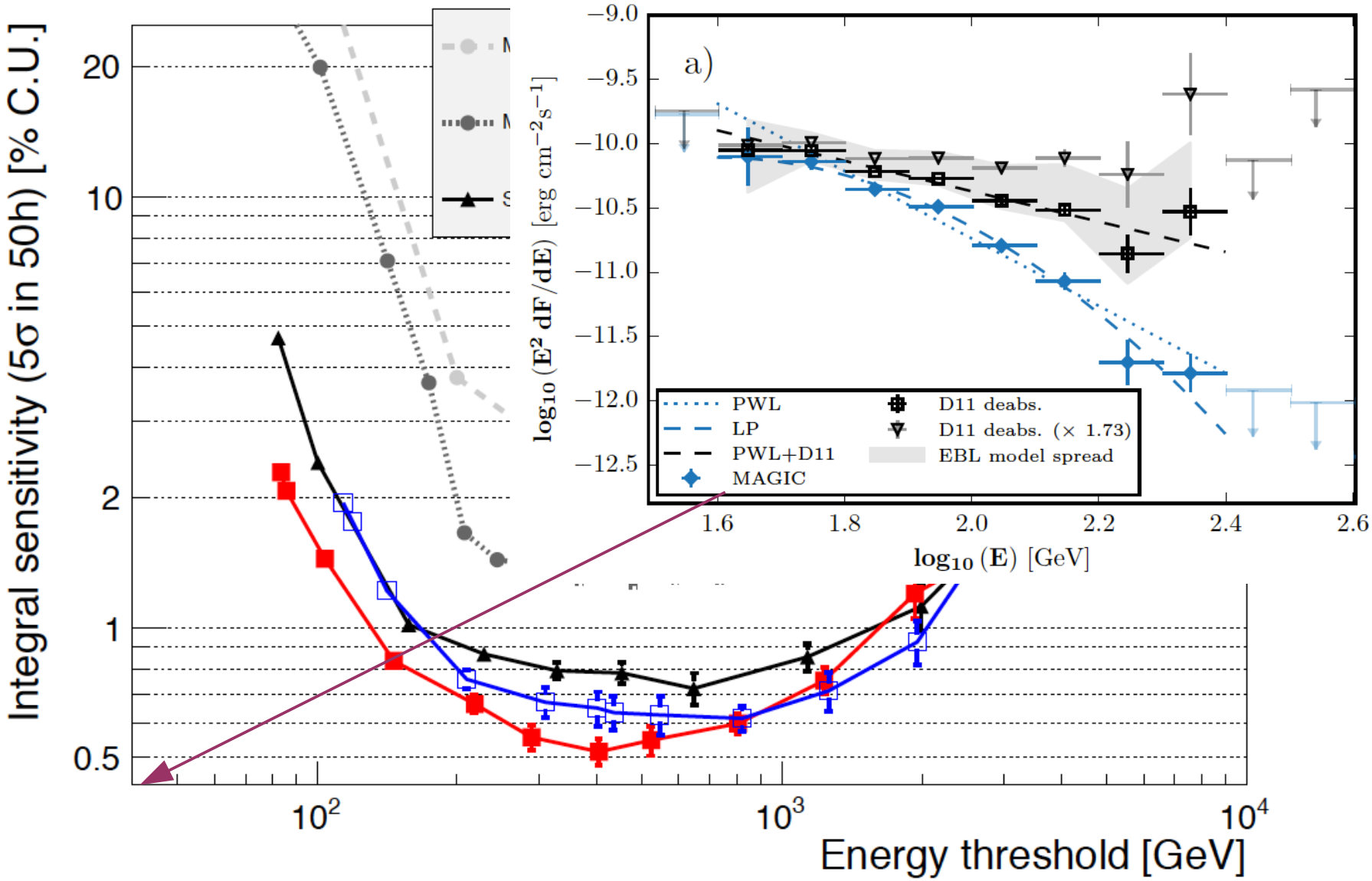
Also detailed spectrum with MWL coverage → emitting region outside BLR



Detection of FSRQ at z~1 have increased the accessible universe at VHE

MAGIC kept Improving

Aleksić et al. (MAGIC) Astropart.Phys, 72, 2016



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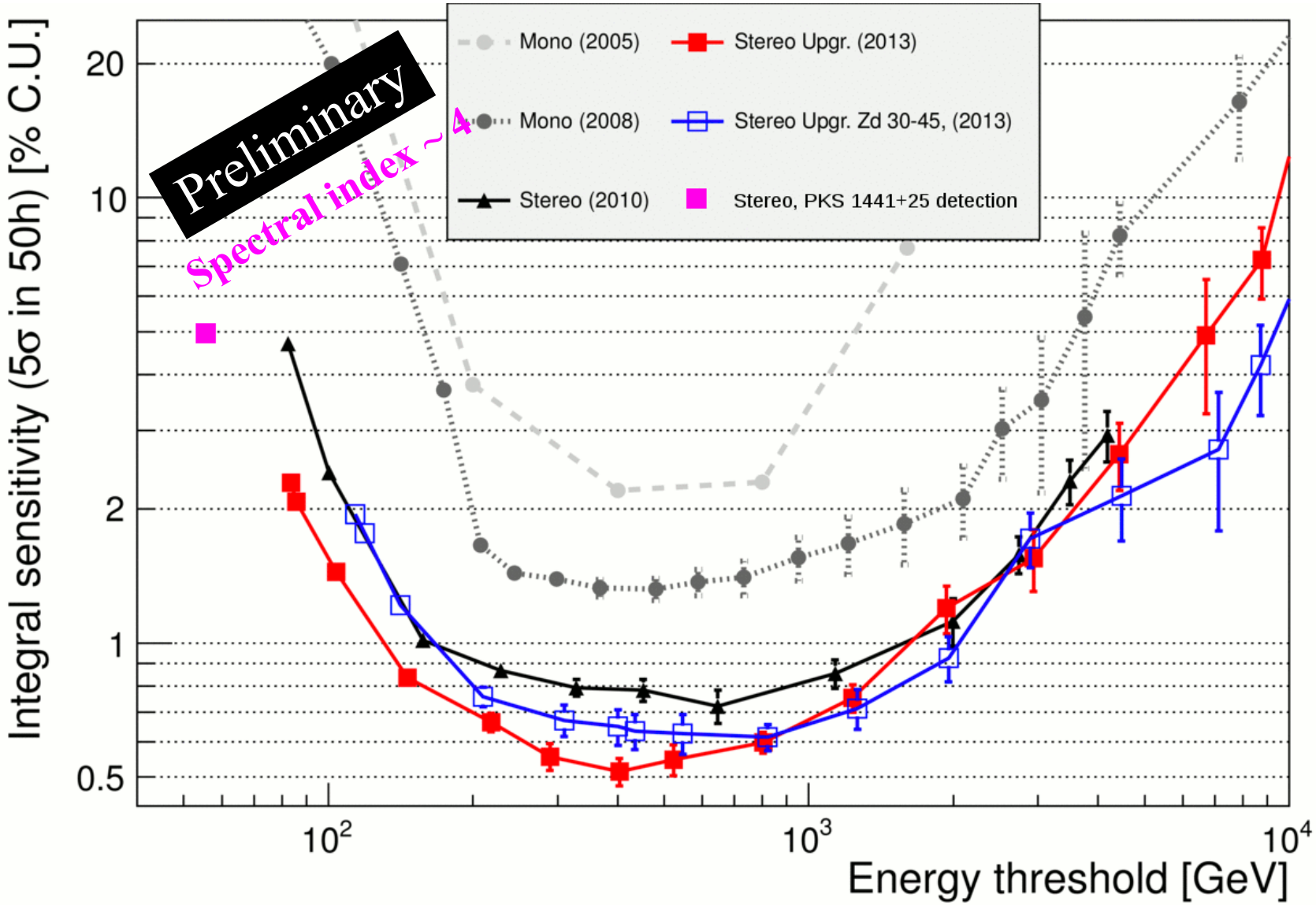

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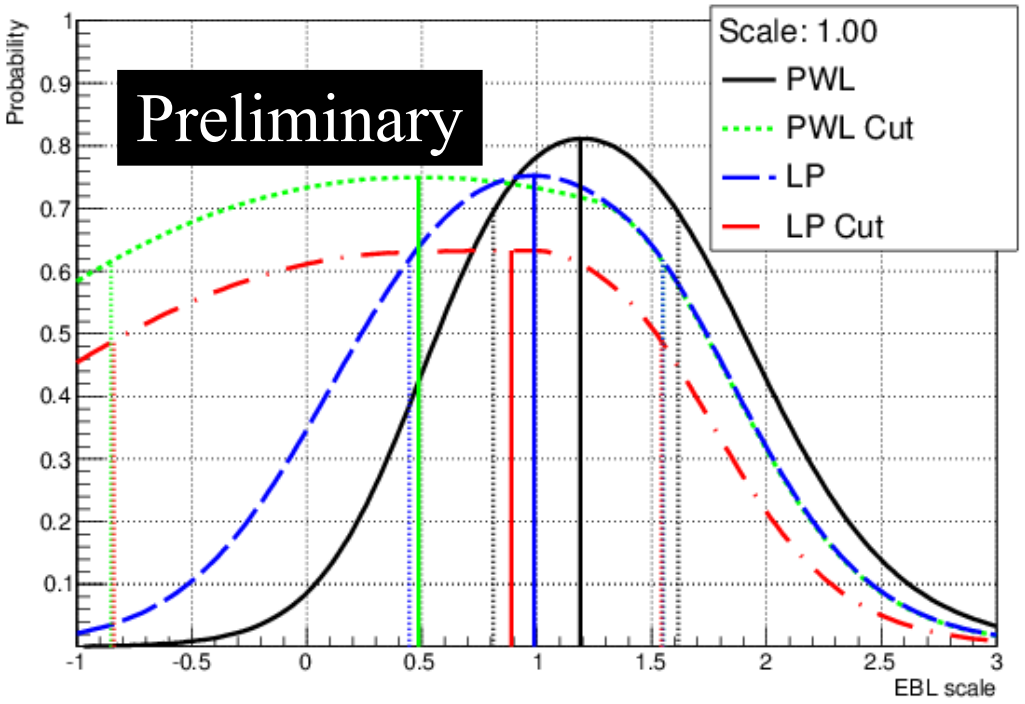
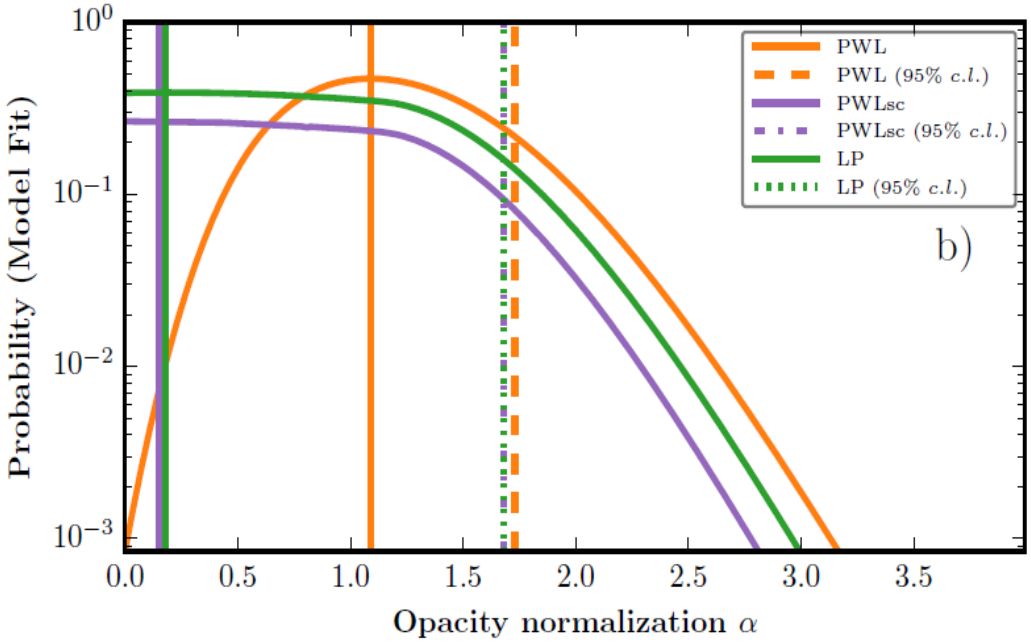
Cosmology and Fundamental Physics

Constraints on EBL

One of the key observation programs of MAGIC



M.L. Ahnen et al (MAGIC) , ApJL 815, 2015

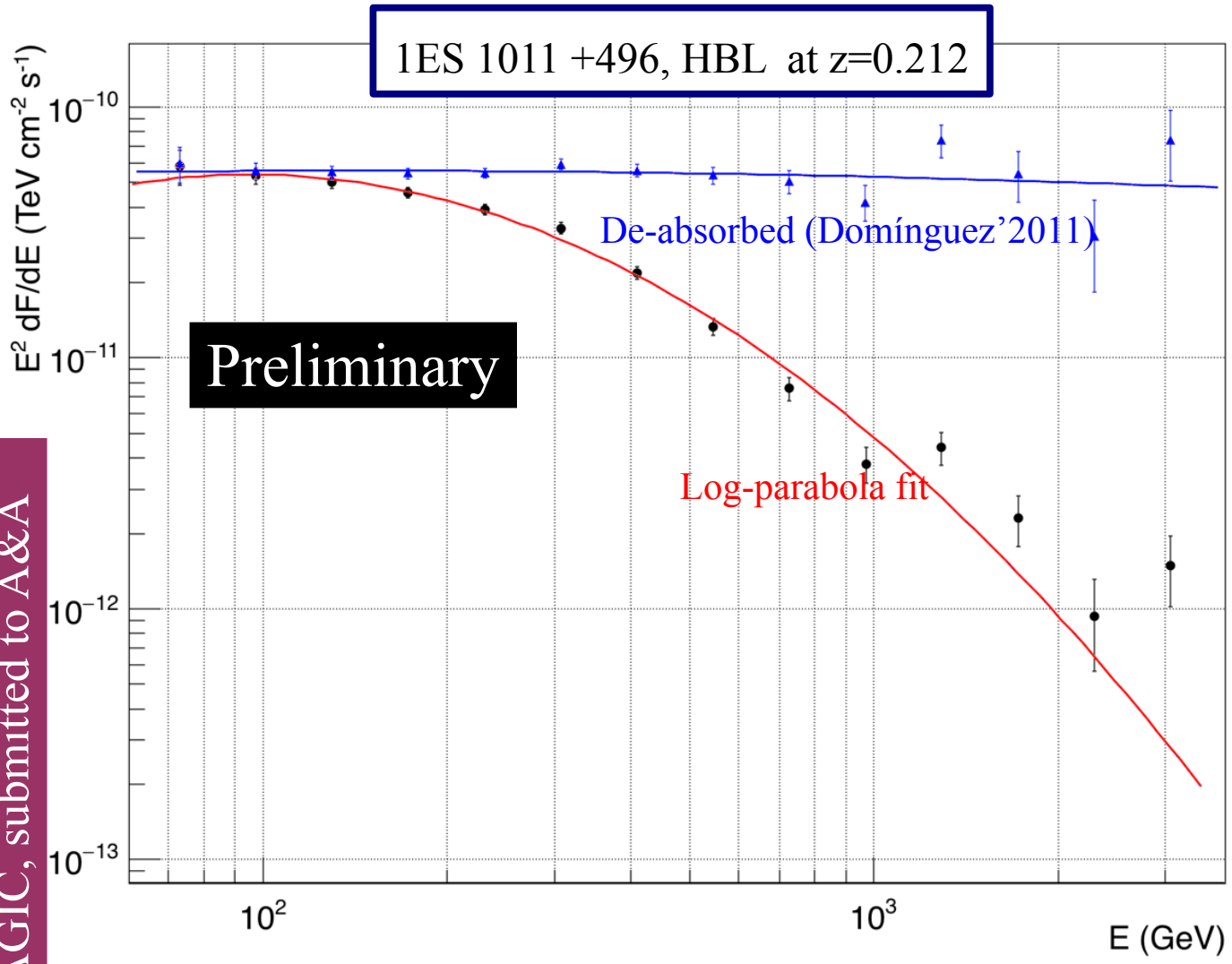


B0218+357 → EBL scaling factor $\alpha = 1.2 \pm 0.4_{sta}$; 95% C.L limit including systematics $\alpha < 2.6$

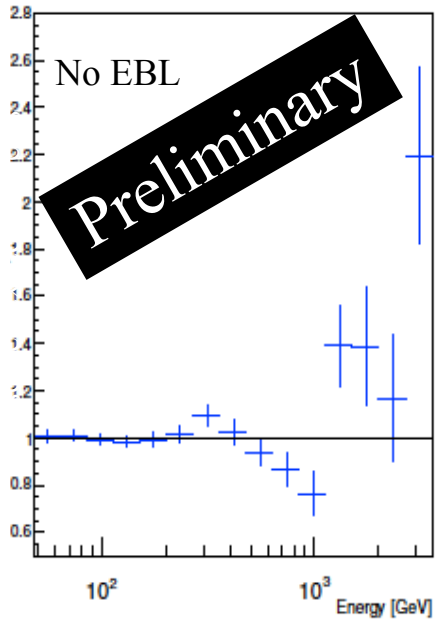
PKS 1441+25 → 95% C.L. Limit including systematics $\alpha < 1.73$

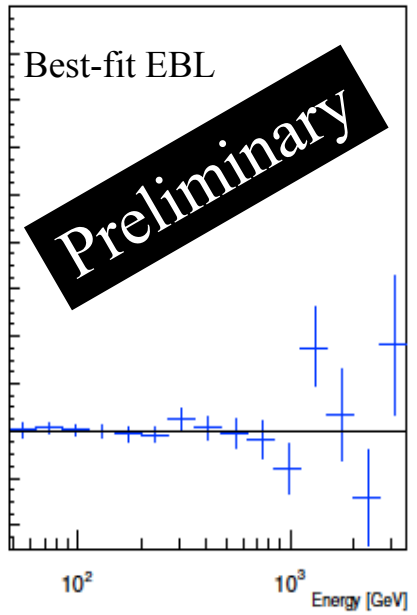
Exploring the EBL at z~0.9 with MAGIC data

Constraints on EBL



MAGIC, submitted to A&A



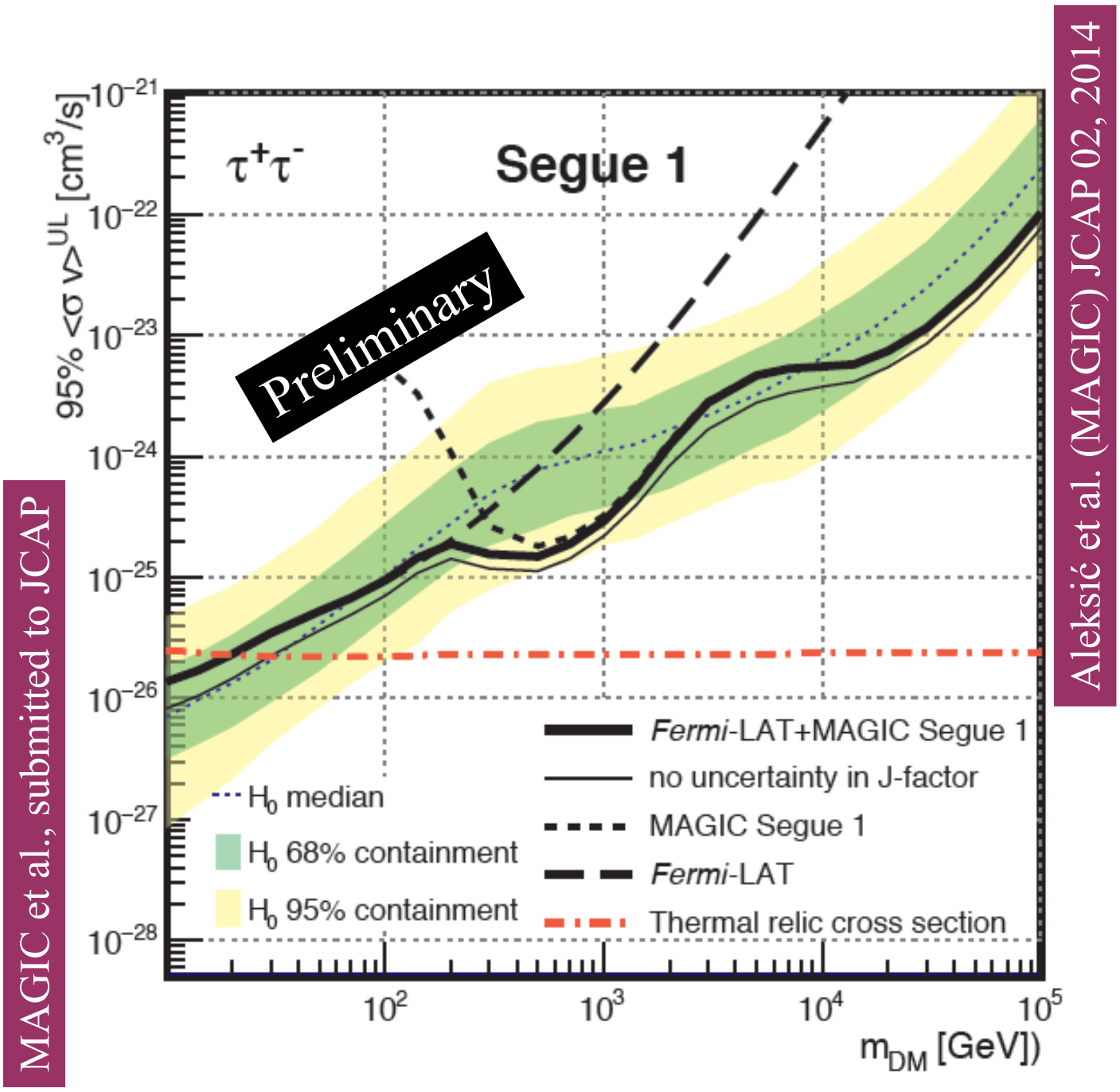


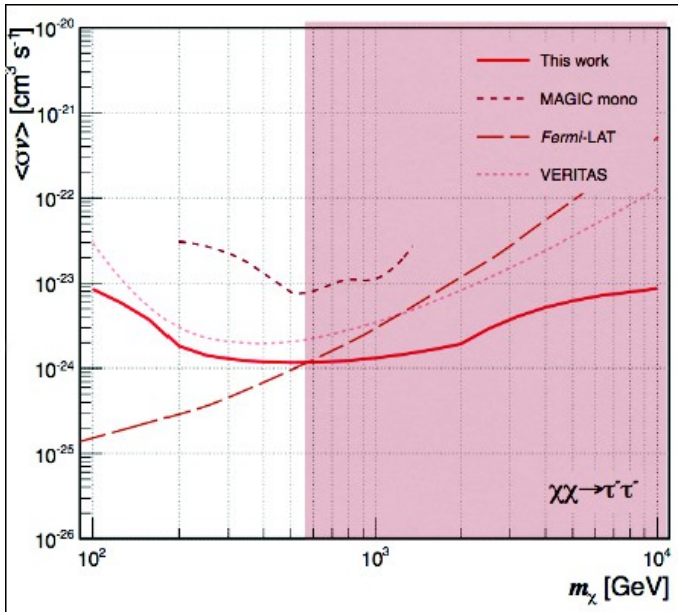
12 hours of good data from 6th Feb'14 to 7th Mar'14, following an alert issued by VERITAS

Spectral points up to optical depth τ=4

EBL scaling factor = 1.07(+0.24-0.20)$_{sta+sys}$

Dark matter searches with MAGIC





Large exposure (158h) of Segue 1 dSph galaxy

Result acknowledged by PDG

Combining MAGIC with Fermi data to further improve the limits

New inclusive analysis approach that is able to combine data from other detectors

Summary

- The **first eleven successful** years of scientific operation (and counting): 32 new VHE detections (24 AGNs); > 110 peer reviewed papers, 5 in Science Magazine

- MAGIC is at its most productive time in terms of physics (also best sensitivity)
  - Un-solving the comprehension of **acceleration mechanism in pulsars**
  - Detailed broad band studies of Crab Nebula, searching for Klein-Nishina range
  - **Long term behaviour** of binary systems and AGNs
  - Transition from an HBL to IBL-like for low emission state in Mrk 421
  - **Ultra fast variability** in AGNs (minute scale)
  - Increasing the accessible volume of the Universe with **sources at z~1**
  - Measurements on the **EBL density** at different redshifts
  - **Dark matter searches** leading to best limits on dark matter cross-section from dSph

- **Collaboration** efforts with **VERITAS, HESS and HAWC** as well as **follow ups** of gravitational waves and neutrinos will hopefully soon get into highlight talks

  (Fermi alerts already here)

- 8 more MAGIC talks in Texas Symposium 2015:
  - Intergalactic Magnetic Fields, Paolo da Vela
  - PG 1553 +113 periodicity, Gareth Hughes
  - First detection at VHE of S4 0954+65, Giovanna Pedaletti
  - Detection of the FSRQ PKS 1441+25, Josefa Becerra
  - Extreme X-ray flaring activity of Mrk 501, Josefa Becerra
  - Brightest outburst of S5 0716+714, Marina Manganaro
  - Pulsar Observations, Takayuki Saito
  - Insight into Black Hole Lightnings: IC 310, Pierre Colin

THANKS !!!

The end