ASTROPARTICLE PHYSICS 2014

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Status and recent results of the MAGIC Cherenkov Telescopes

E. Carmona[1] for the MAGIC Collaboration

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Eckart Lorenz

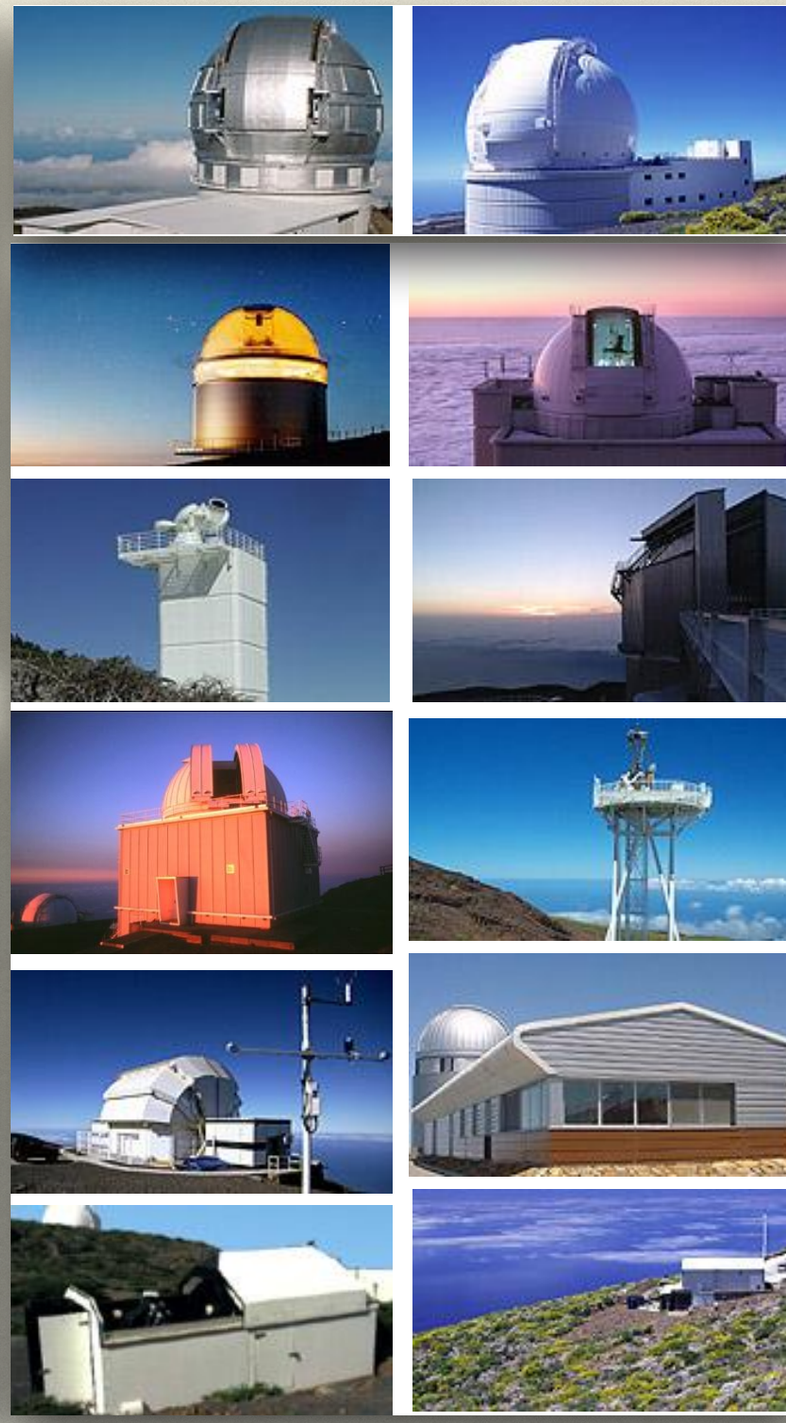
1938 — 2014

The MAGIC project

- 170 collaborators in 10 countries
- Stereoscopic system of 2 telescopes with 17 m diameter mirrors
- Operation started 10 years ago with MAGIC-I
- Located in the island of La Palma (Spain)

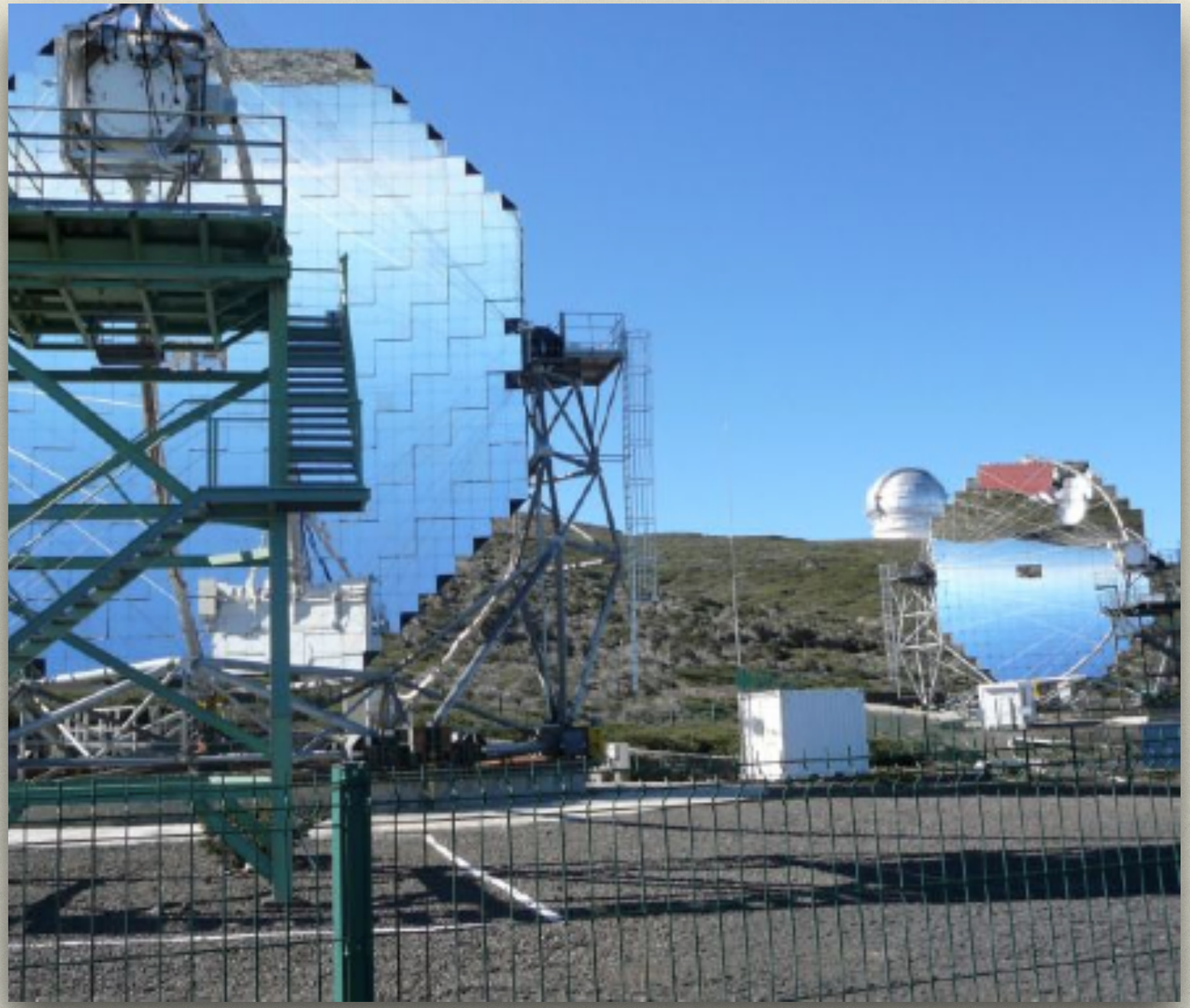
The MAGIC location

- MAGIC telescopes located in an exceptional environment: the Observatory of “El Roque de los muchachos” (28.7636°N 17.8947°W) at 2200 m.a.s.l.
- One of the best astronomical observatories in the world



The MAGIC telescopes

- MAGIC telescopes incorporate many technological novelties first time applied in IACTs:



- Light weight construction allowing fast repositioning of the telescopes (<20s / 180°)
- Active mirror control system
- Cameras equipped with enhanced QE PMTs (superbialkali)
- Optical transmission of signals to the counting house
- Signal digitization at 2 GSample/s

Upgrade

Recent upgrade

- Upgrades take place regularly to improve performance of the telescopes (satisfactory working for 10 years now)
- A major upgrade took place during summers of 2011 and 2012
- First phase (2011):
  - re-arrangement in counting house (electrical power, new electronics room, new computer room)
  - new readout system DRS4 (2GSample/s) installed in both telescopes
  - new calibration system
  - computing upgrade

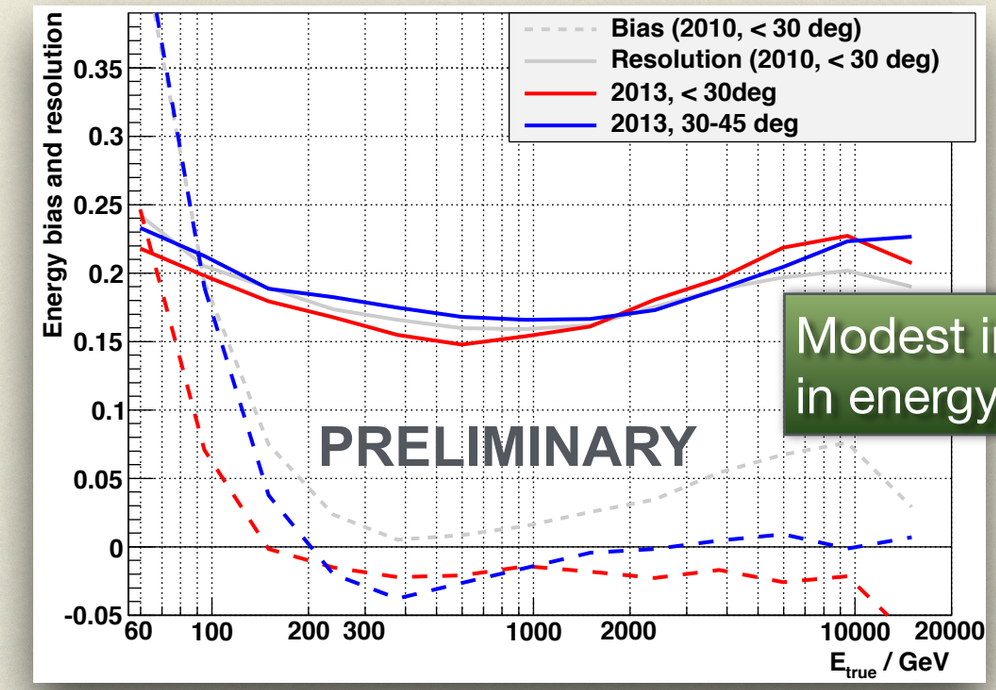
Recent upgrade

- Second Phase (2012):
  - Replacement of old MAGIC-1 camera (577 pixels, 2 sizes) by new MAGIC-1 camera (1039 pixels, 0.1°) equipped with Hamamatsu R10408 (super- bialkali, Q.E. >30% peak, pulse width ~2 ns)
  - New fibres (same as MAGIC-2) to the counting house
  - Upgrade of MAGIC-1 readout to read all new channels
  - Upgrade of MAGIC-1 trigger (×1.7 trigger area)
  - Improvements in MAGIC-1 structure

MAGIC Performances

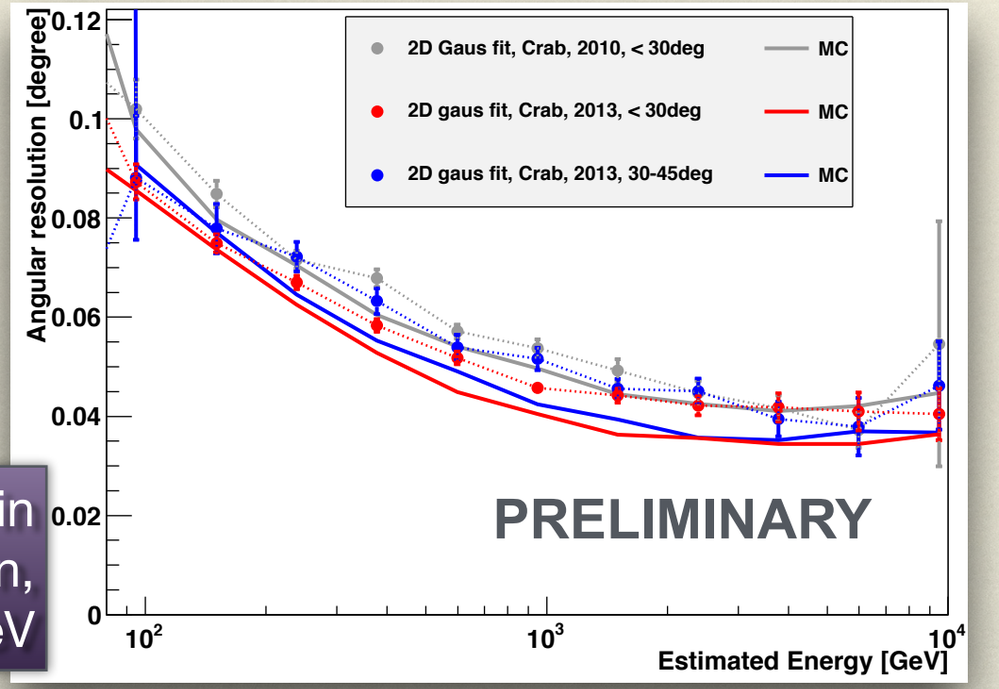
- The upgrades improved reliability and maintainability of the telescopes as well as instrument performances
- MAGIC performances are made public regularly after major changes:
  - 2010 Stereo system (Astroparticle Physics, 35 (2012) & XXXII ICRC)
  - 2013 Upgraded system (XXXIII ICRC & paper about to be submitted)
- Performances of upgraded system today:
  - Trigger threshold reduced to **~50 GeV** (low zenith observations). Analysis threshold down to **70 GeV**
  - Energy resolution **15%—23%** below 10 TeV
  - Angular resolution **<0.07°** above 300 GeV
  - Sensitivity **0.6%** Crab Nebula flux in 50 hours

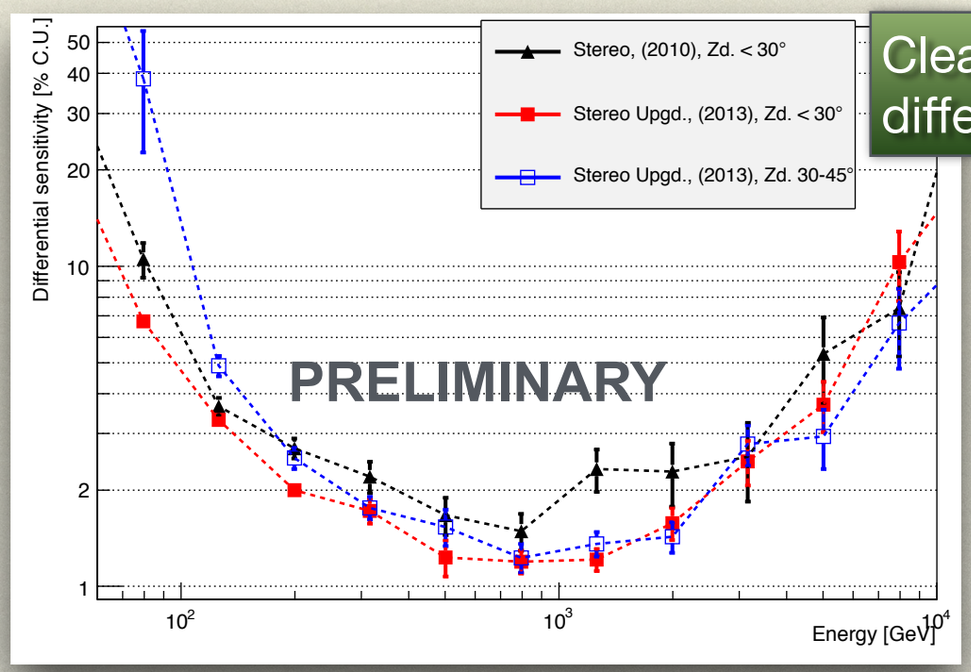
MAGIC Performances



Modest improvement in energy resolution

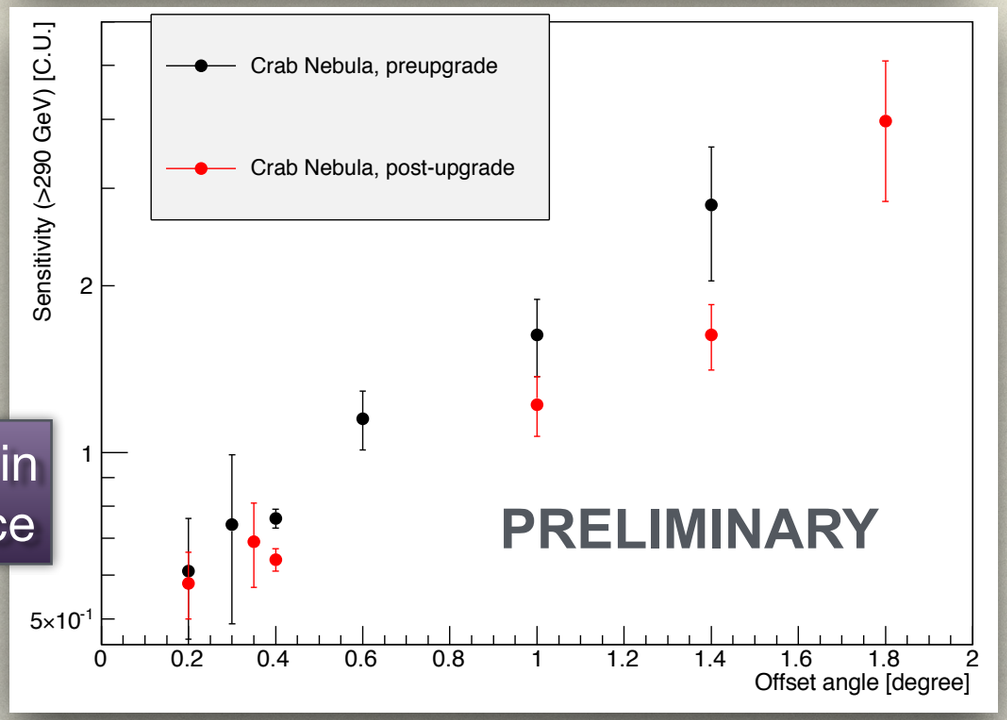
Improvement in angular resolution, specially at E<1 TeV



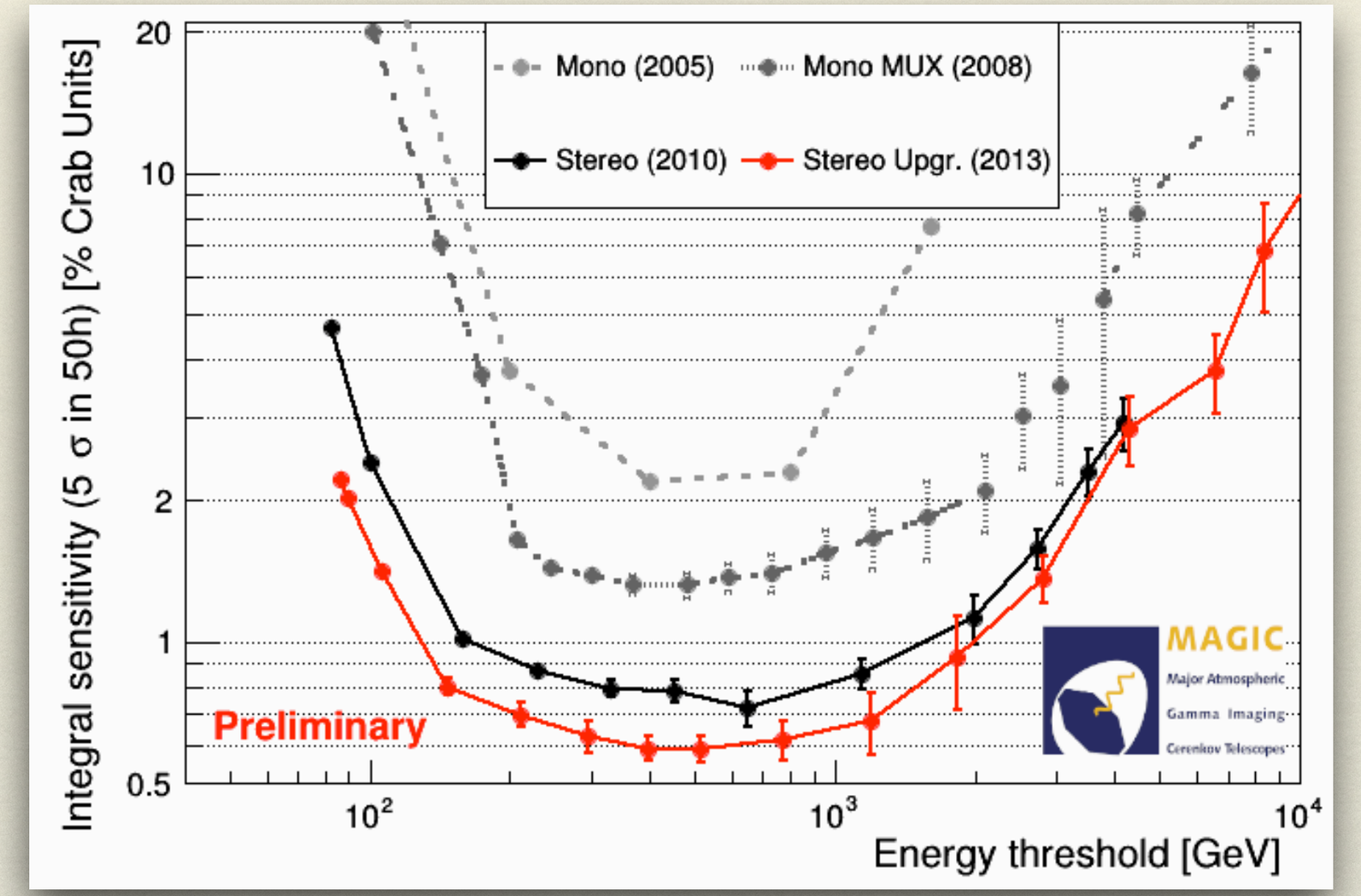


Clear improvement in differential sensitivity

Clear improvement in Off-axis performance



10 years of improvements



Mono (2005): MAGIC-1, 577 pixels, 300 MSamples/s

Mono Mux (2008): MAGIC-1, 577 pixels, 2 GSamples/s

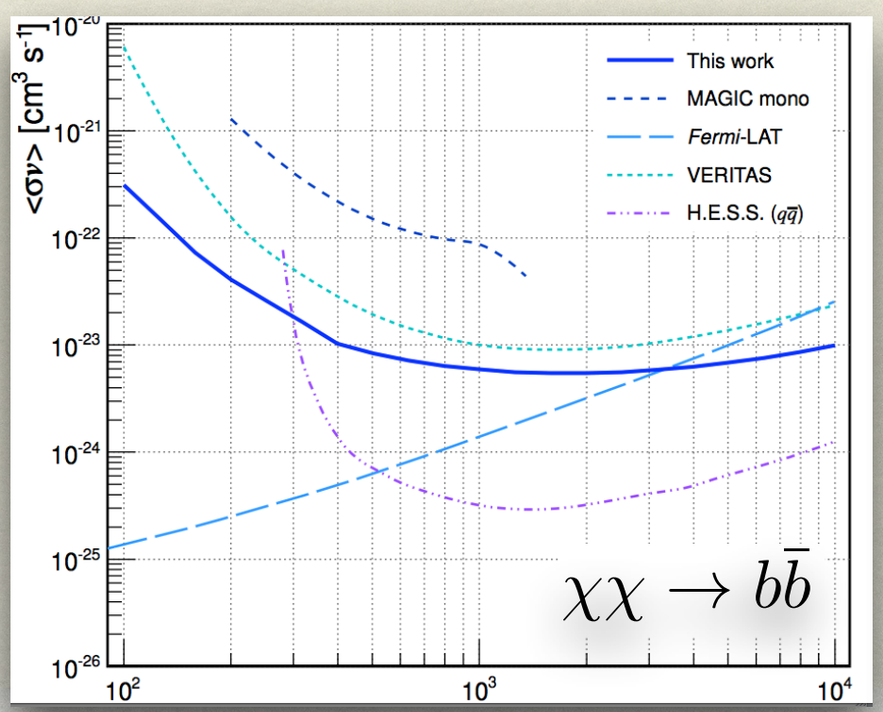
Stereo (2010): Stereo system, 577 pixels MUX readout + 1039 pixels DRS2 readout

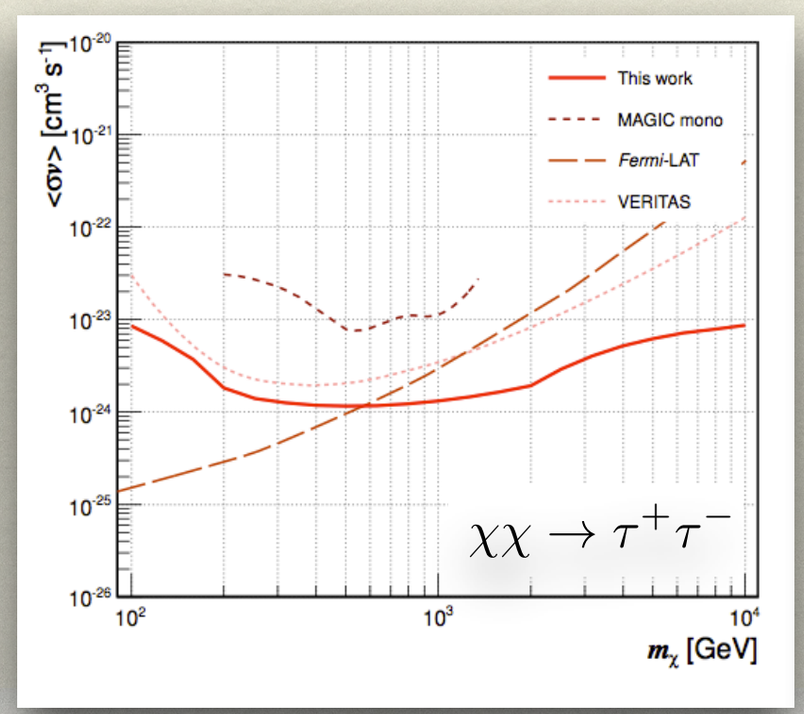
Stereo upgraded (2013): Stereo system, 2 × 1039 pixels DRS4 readout

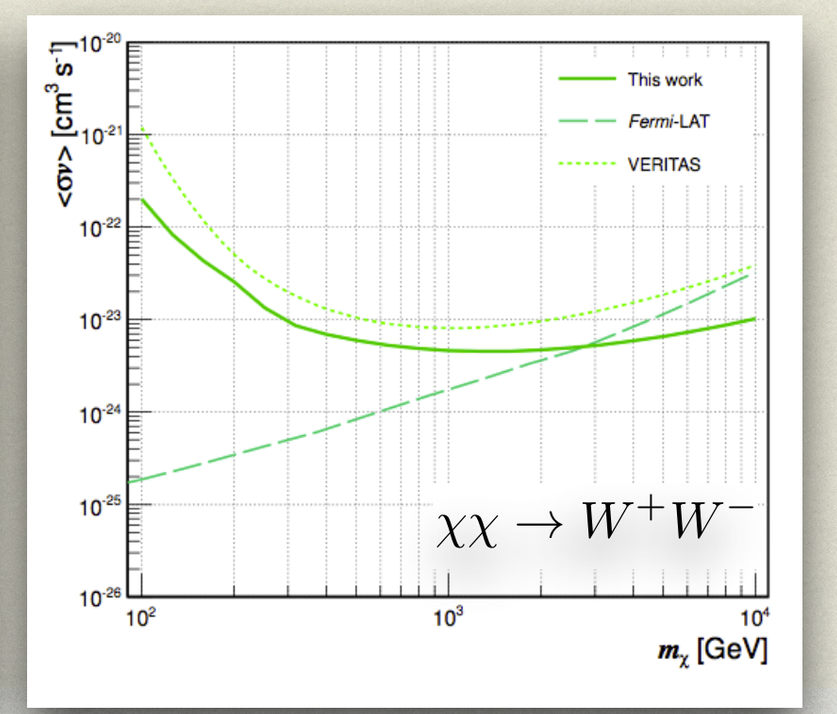
Highlights

Dark Matter searches

- MAGIC has collected 160 h of stereo data in Segue-1 (JCAP 02 (2014) 008) deepest observation of a dSph by an IACT
- Full likelihood method optimised to recognised spectral features like those expected from DM annihilation and decay
- Computed limits for spectral features from secondary gamma-rays expected from decay into $b\bar{b}$, $t\bar{t}$, $\mu^+\mu^-$, $\tau^+\tau^-$, $W^+ W^-$ and ZZ as well as from gamma-ray lines, etc.







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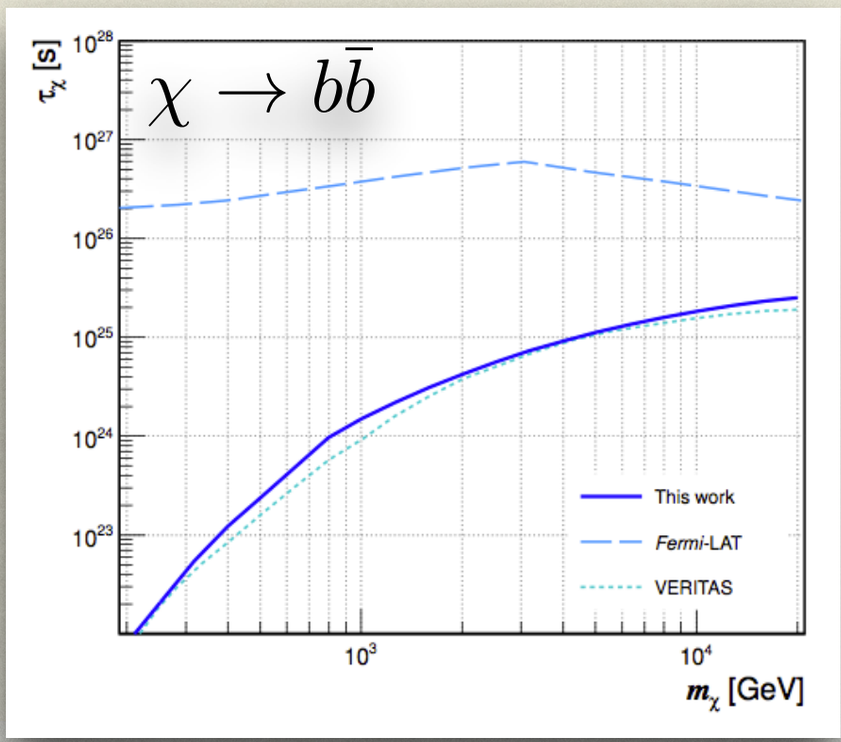

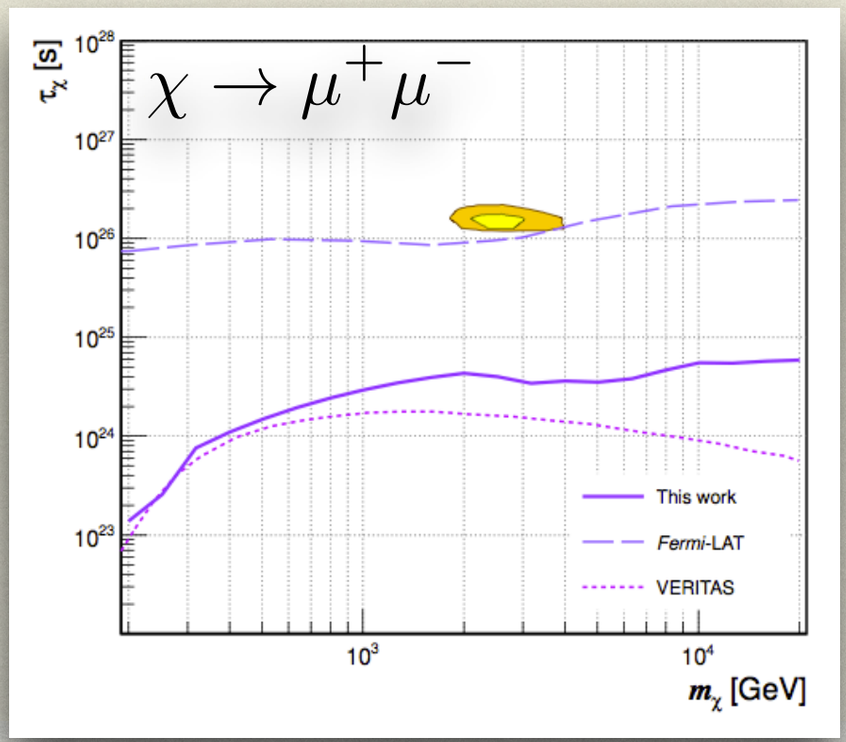

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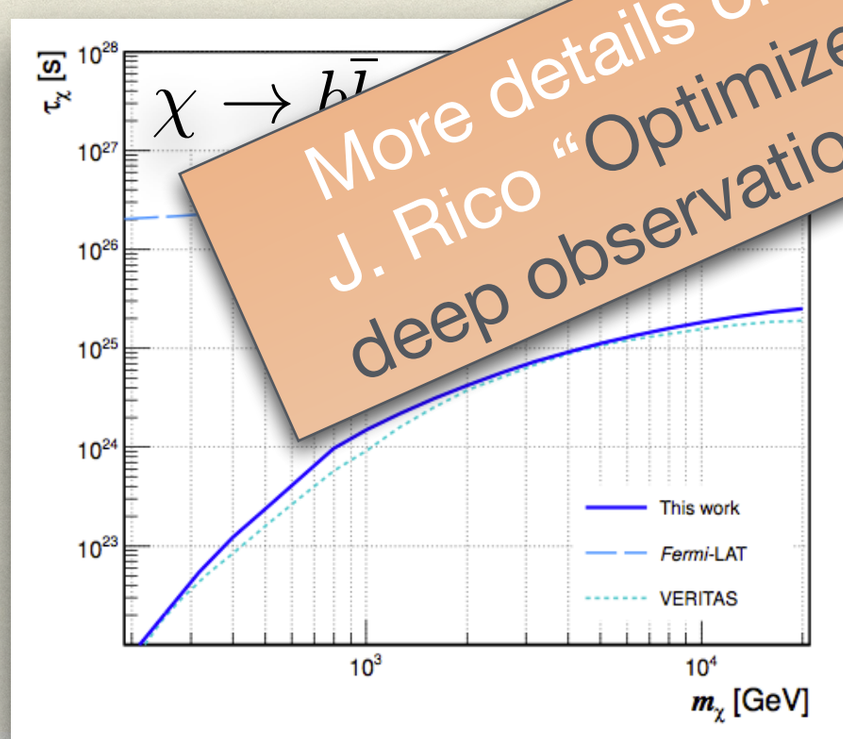
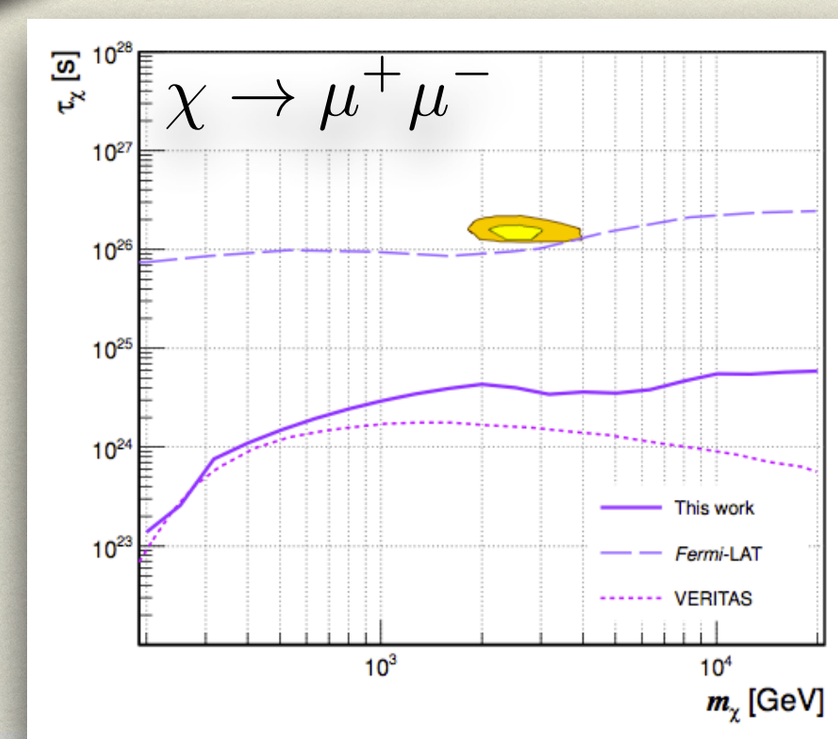
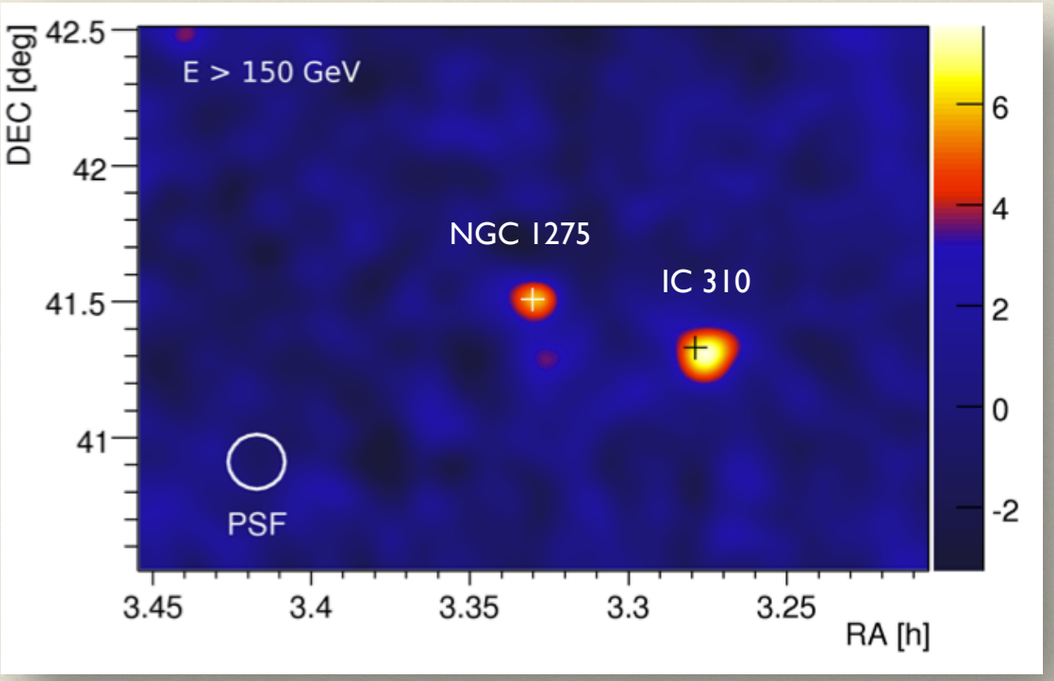
More details on Segue-1 results in talk by J. Rico "Optimized dark matter searches in deep observations of Segue 1 with MAGIC"



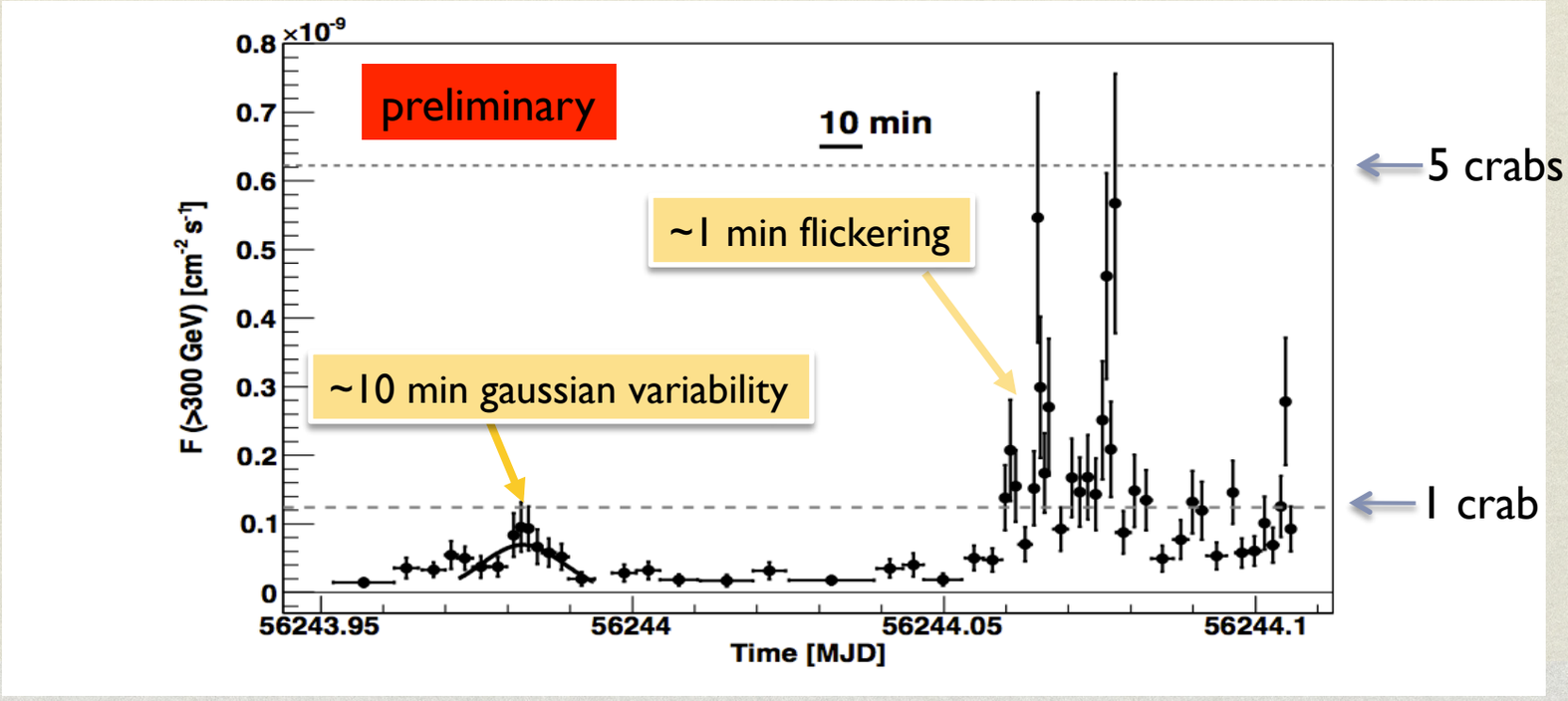


J. Aleksić et al.,(MAGIC Coll.), A&A. 541, 99 (2012)



IC 310

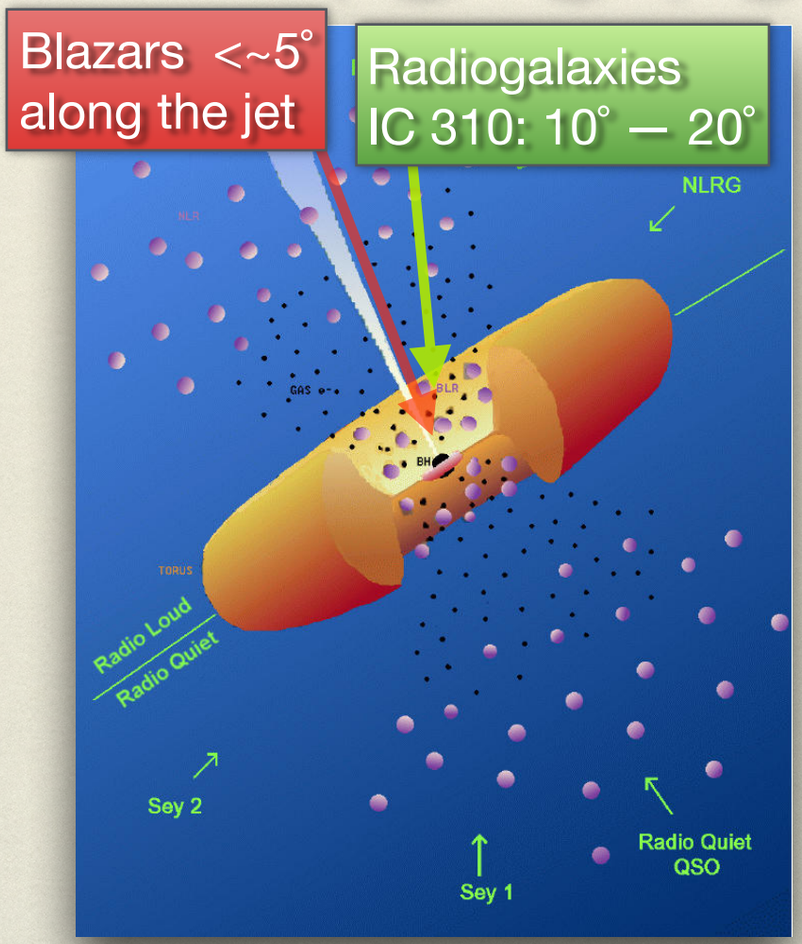
- Discovered at VHE on Fermi data (Neronov, A., Semikoz, D., & Vovk, I.2010, A&A, 519) and MAGIC (ApJ, 723 (2010) L207)
- Same field of view as the radiogalaxy NGC1275 (also discovered by MAGIC)
- IC 310 showed day to day variability in 2011(A&A 563 (2014) A91)
- During flare in 2012 variability was observed with a timescale of 9.5±1.9 min and large amplitude flickering where flux was doubling in timescales of ~1 min



MAGIC Collaboration
Submitted

IC 310

- For a 2×10^8 $M_\odot$ BH, 1 minute time corresponds to 25% of the of the event horizon light-crossing-time
- Similar fast variability has been found in VHE Blazars like Mrk 501 or PKS2155-304 but Blazars have Doppler factors of ~10. IC 310 could have a Doppler factor of 3 – 4 with the jet at 10°-20° from the line of sight. Intrinsic variability is much shorter in IC 310
- Emission seen by MAGIC hard to explain by models:
  - Shocks in the Jet? But difficult to explain the 25% event horizon light-crossing-time measured
  - Minijets in the Jet pointing towards the line of sight? But would make luminosity of IC 310 huge
  - Jets crossing dense matter clouds or stars? But crossing and pp cooling times are typically longer)



IC 310

More details on IC 310 in talk by K. Mannheim "Radio galaxies and their central machine" today

- For a 2×10^8 $M_\odot$ BH, 1 ... nds to 25% of the of th ... crossing-time
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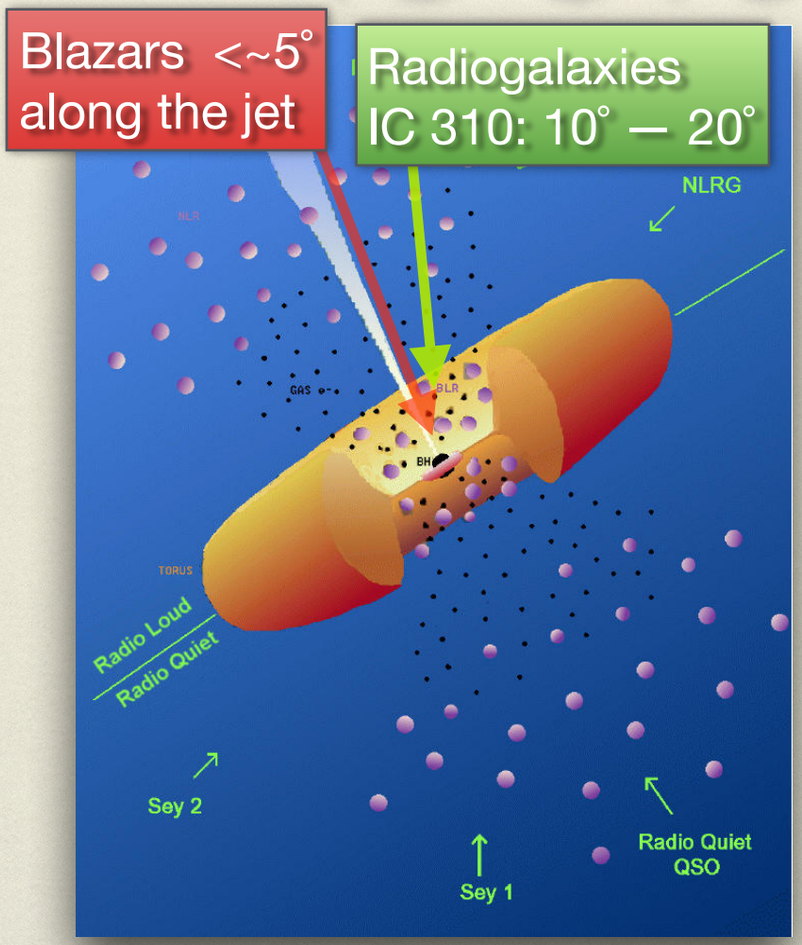

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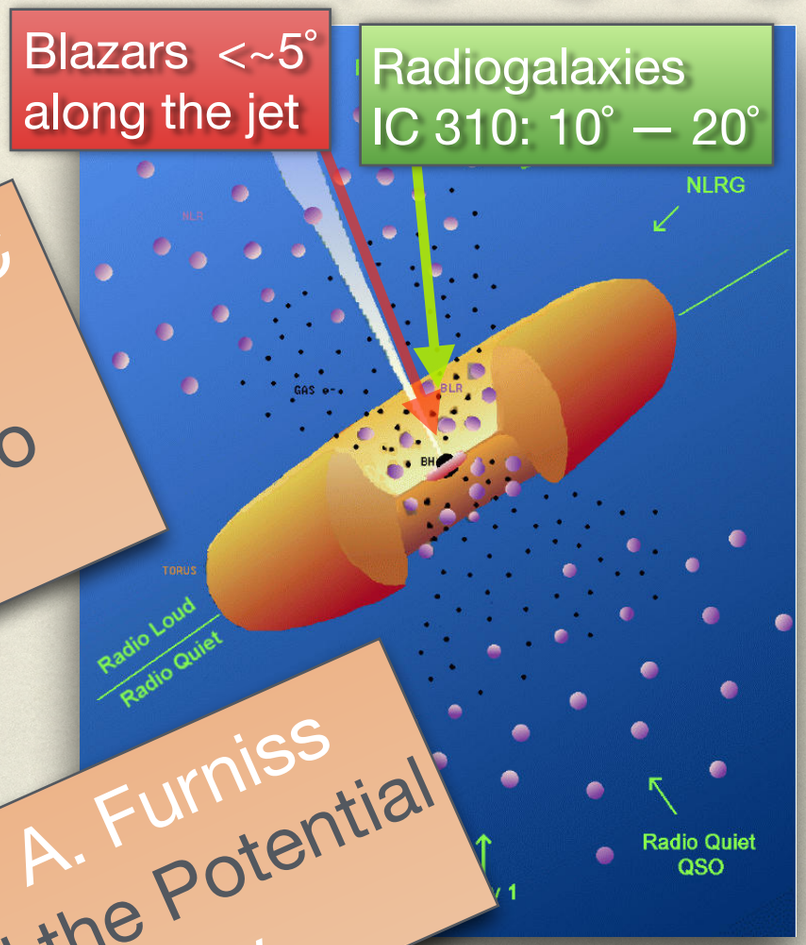
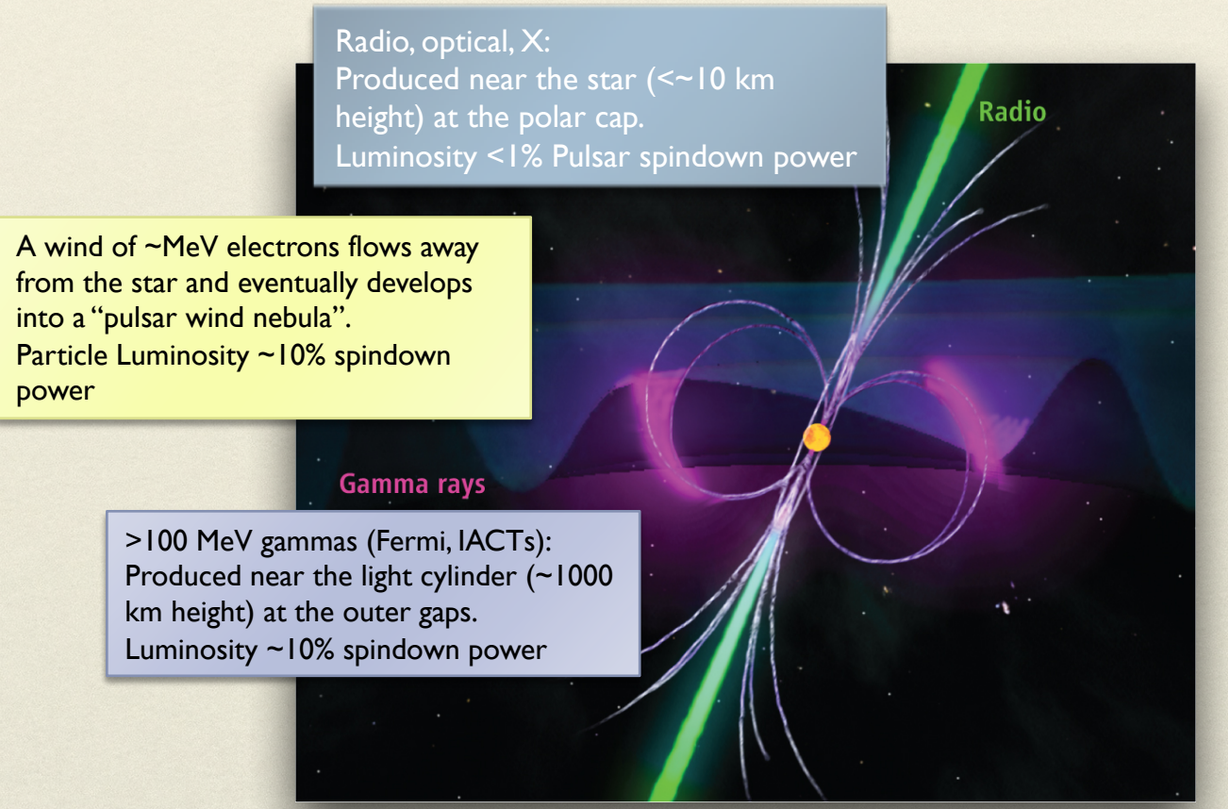


More details on IC 310 in talk by K. Mannheim "Radio galaxies and their central machine" today

More results on FSRQ detected by MAGIC in talk by E. Lindfors "Very High Energy Gamma-rays from Flat Spectrum Radio Quasars" in this session

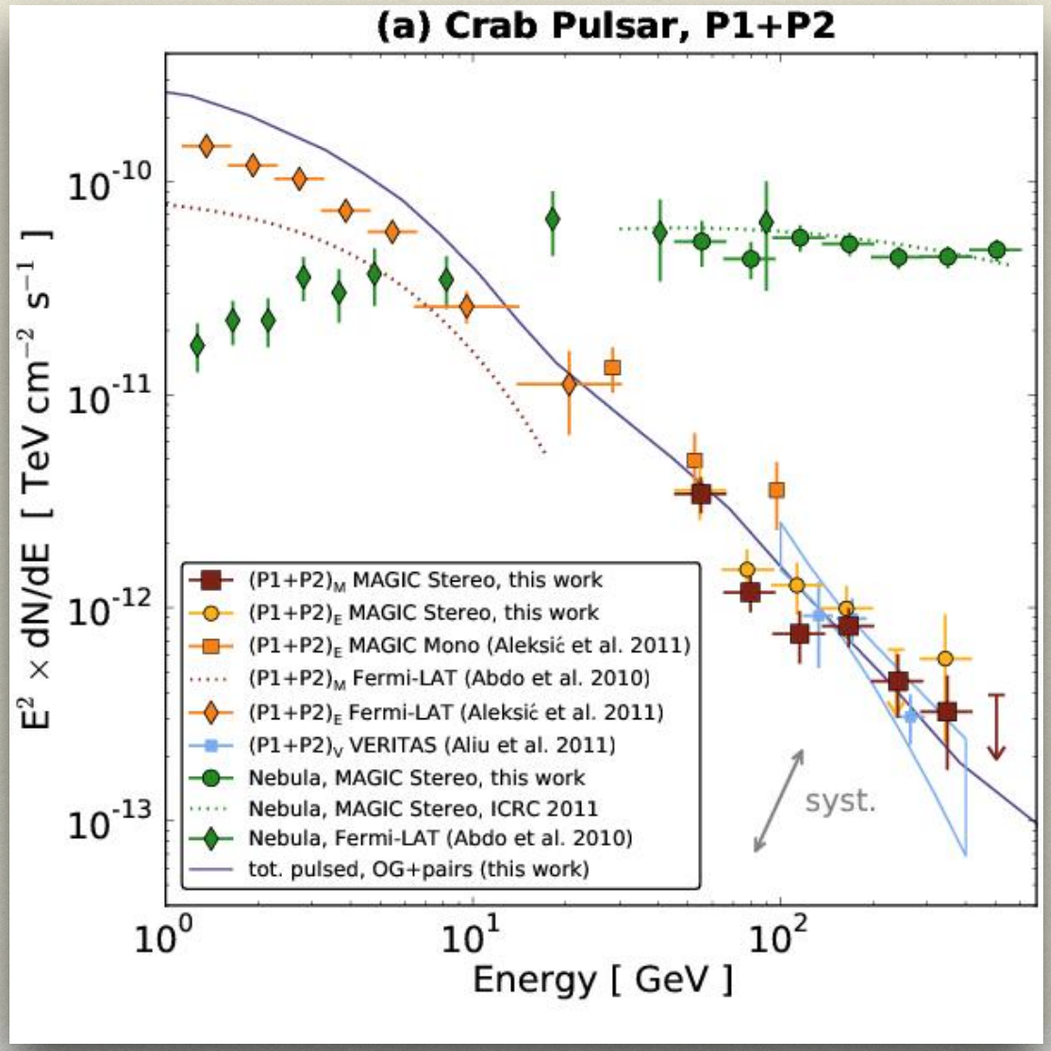
Blazars sources on in talk by A. Furniss "Very High Energy Blazars and the Potential for Cosmological Insigh" today

Crab Pulsar



- MAGIC discovered VHE emission from the Crab pulsar above 25 GeV (Science 2008)

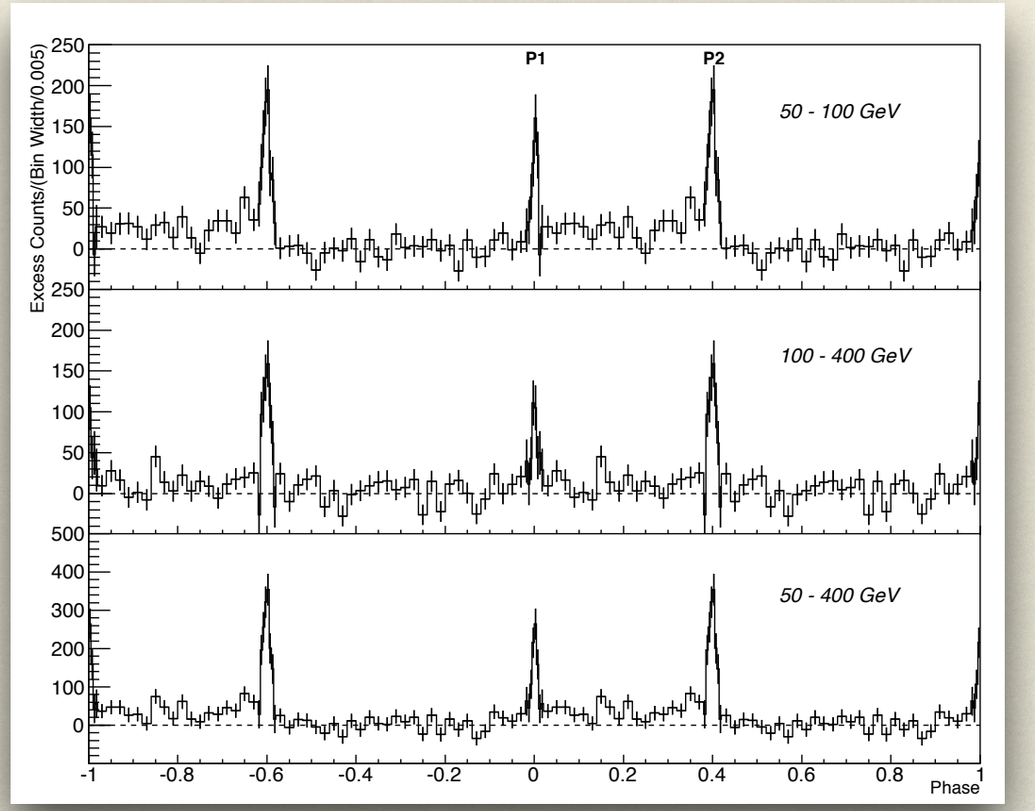
J. Aleksić et al.,(MAGIC Coll.), A&A. 541, 99 (2012)



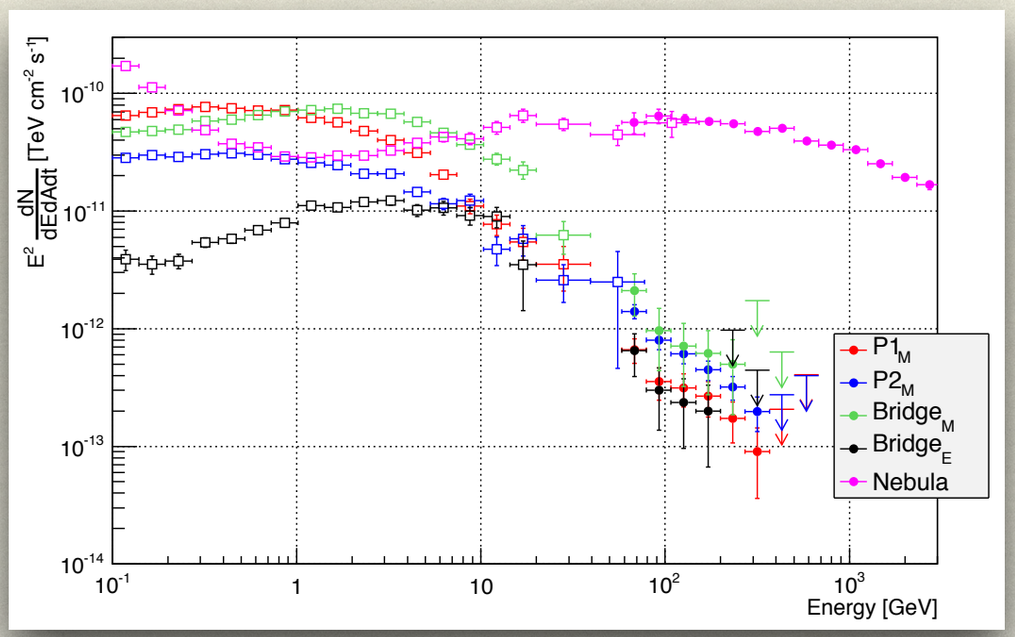
- We know today that emission extends above 100 GeV up to 400 GeV (VERITAS, Science 2011 and MAGIC A&A 2012)
- More recently MAGIC has discovered that the bridge emission itself extends above 100 GeV (MAGIC 2014)

Crab Pulsar

Astronomy & Astrophysics, 565 (2014) L12



Astronomy & Astrophysics, 565 (2014) L12

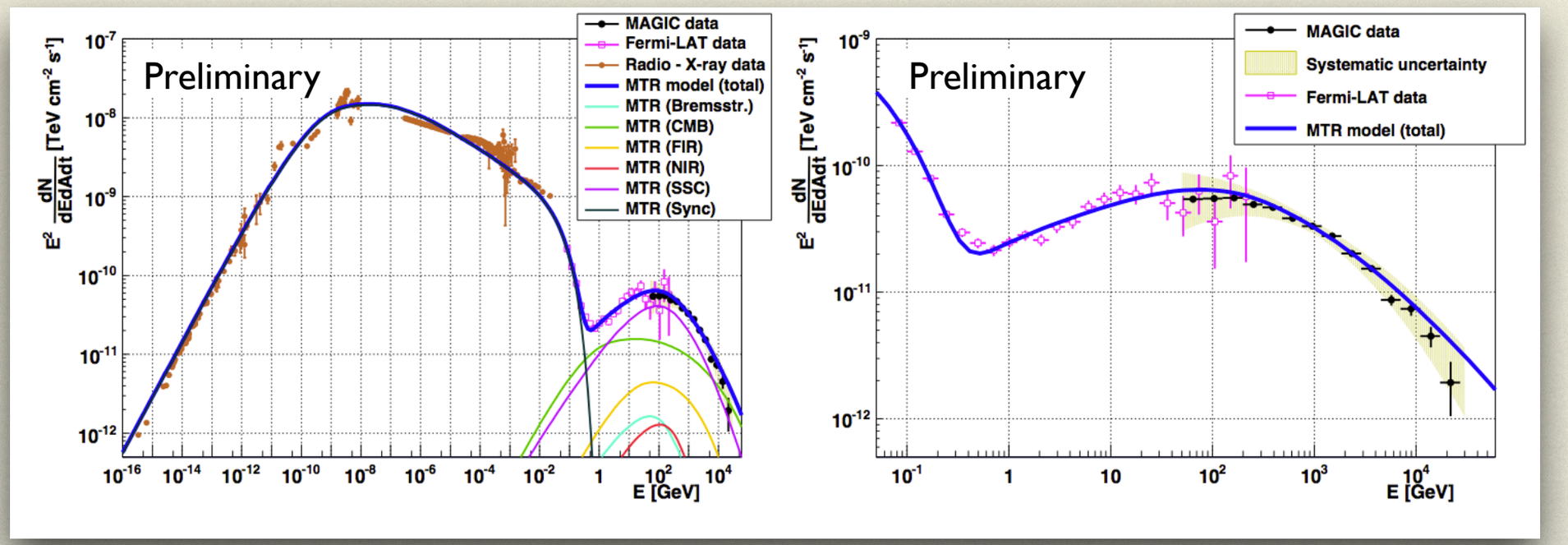


- Thanks to cumulated observation time (135 h 2009-2013) it has been possible to find
  - P1 and P2 narrow emission extending above 100 GeV
  - >6 σ bridge excess above 50 GeV
  - Spectra of P1, P2 and Bridge
- Different models could explain this emission:
  - Aharonian et al. (Nature 2012) explain the emission by production of gammas ray in the wind region. Bridge is predicted but peaks should be broader
  - Hirotani K. (ApJ, 733, L49, ApJ, 766, 98) proposes production of gamma rays in the magnetosphere in an outer gap. Bridge emission can be explained with toroidal component of B field

Crab Nebula

- New results with 70 hours of stereo observations (2009-2011)
- Spectrum extends from 50 GeV to ~30 TeV (statistical error 5% at 100 GeV)
- In combination with FERMI-LAT provides the most precise measurement of the IC peak at 52.5±2.6 GeV

About to be submitted for publication



- 2 Models used to fit the data
- Not bad agreement but also not fully satisfactory:
  - Meyer, Horns et al. predicts a too narrow IC
  - Martin, Torres et al. hard to fit assuming real dependence of PWN morphology with energy

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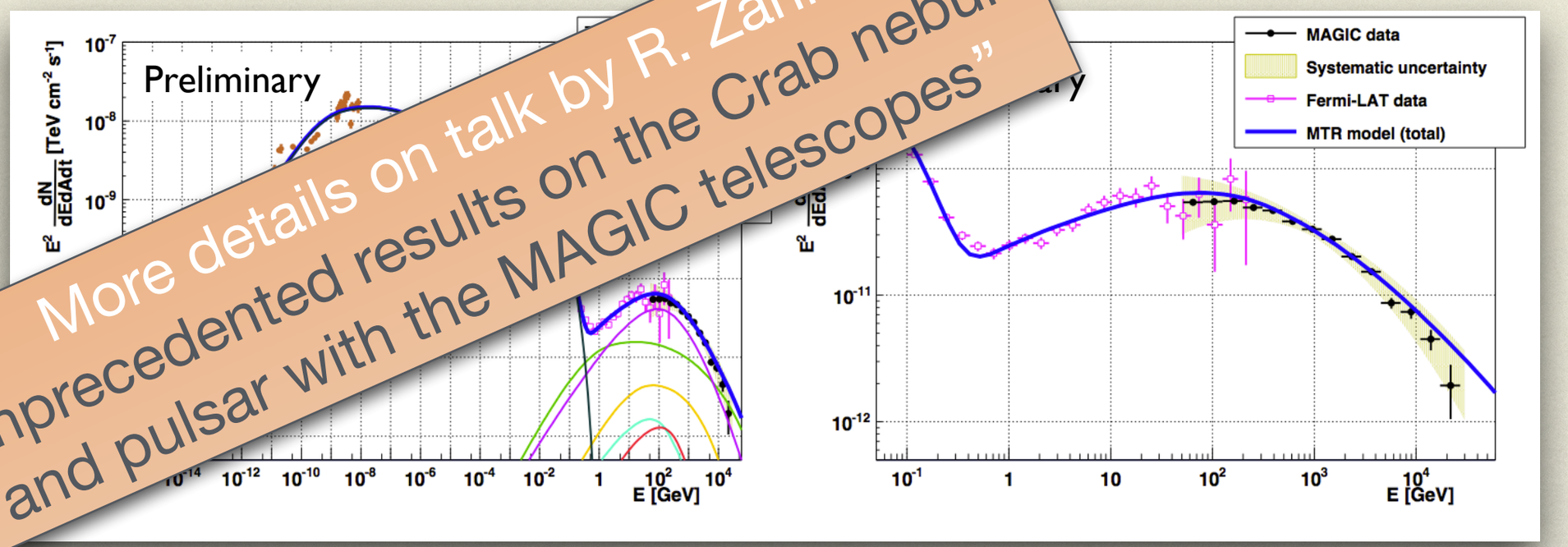

More details on talk by R. Zanin
"Unprecedented results on the Crab nebula and pulsar with the MAGIC telescopes"

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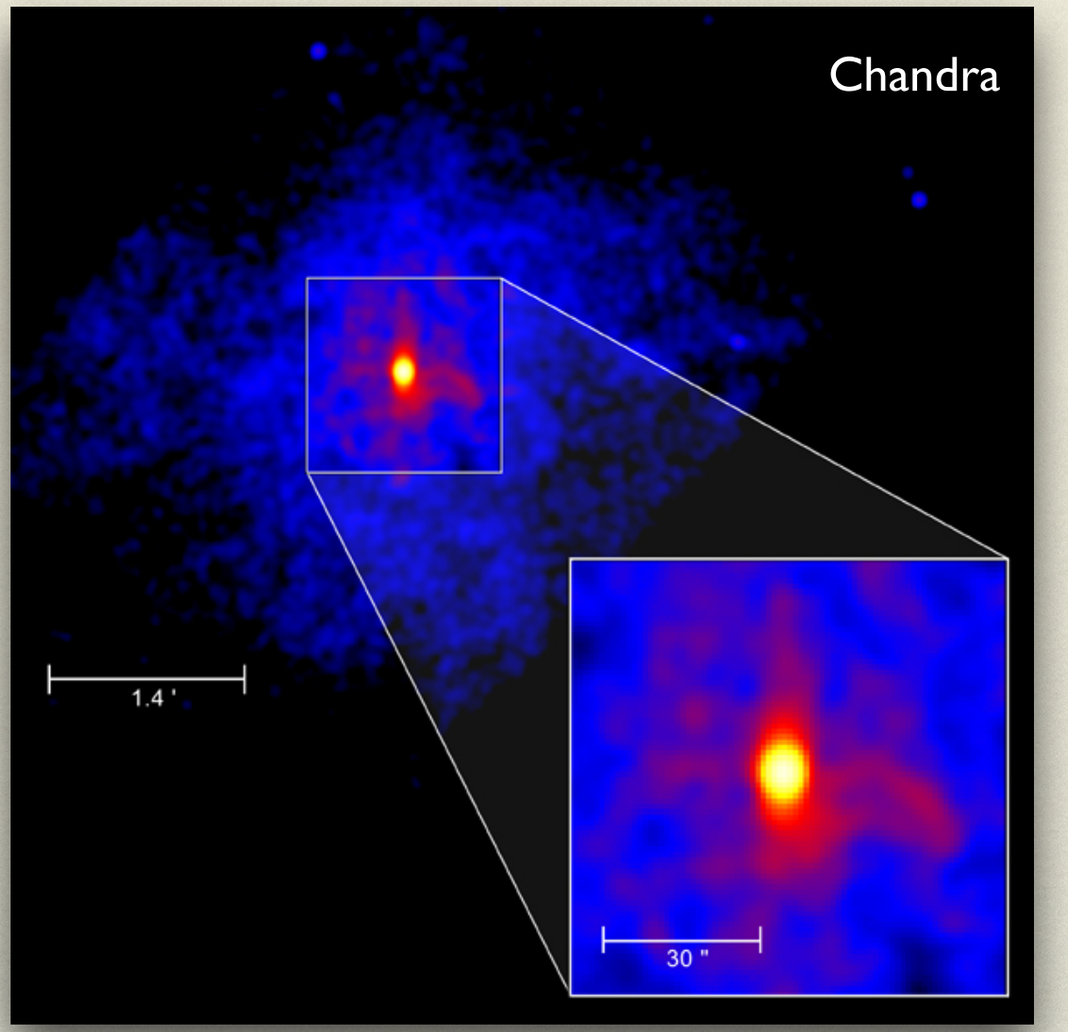
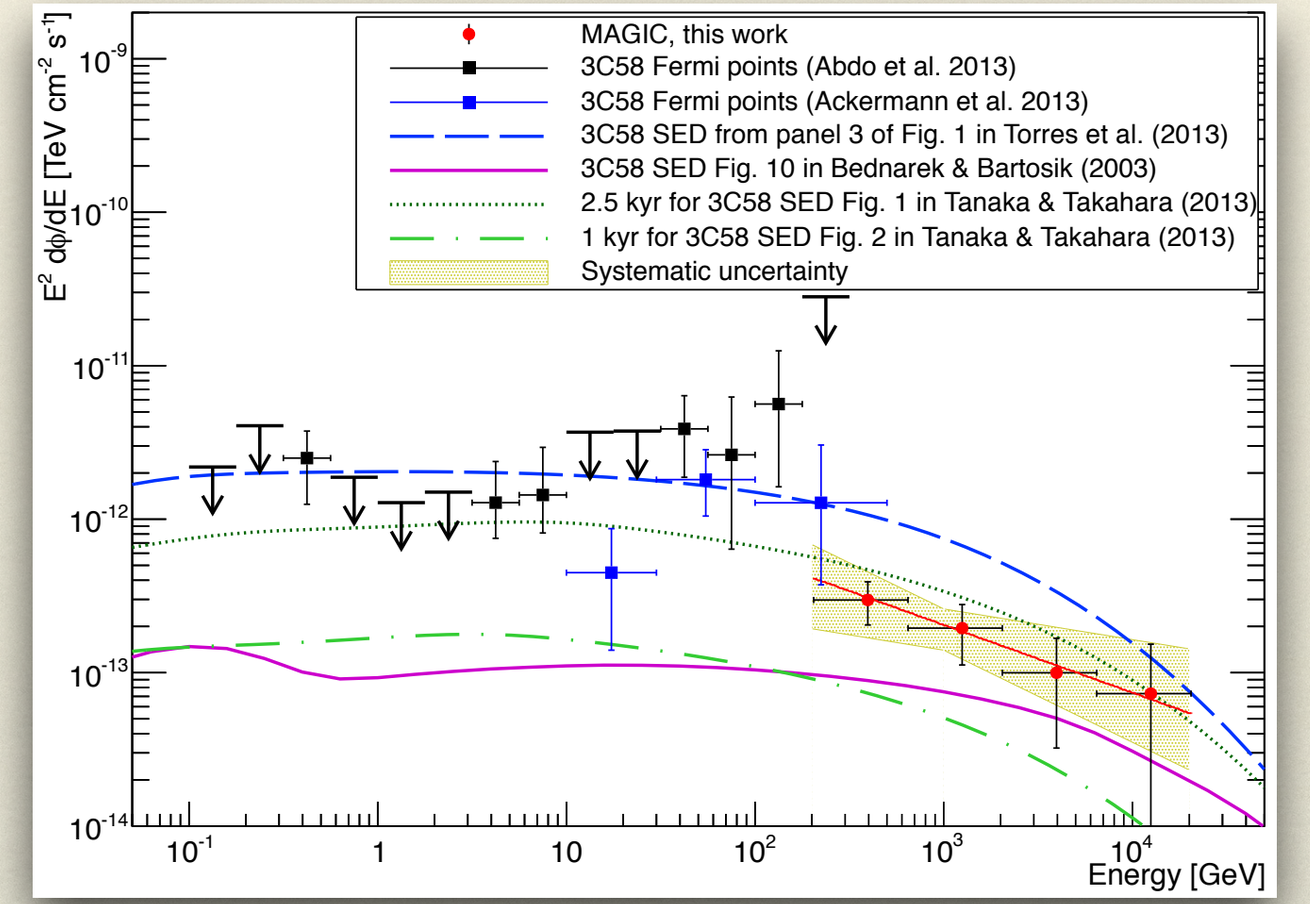
3c58 PWN

- Centered in PSR J0205+6449, a high spin-down pulsar (2% of Crab)
- X-ray morphology similar to Crab
- Distance estimates of 2 or 3.2 kpc and age estimates between 0.8 and 7 kyears. Coincident with SN1181
- Until very recently only upper limits by Whipple (19% Crab), MAGIC (4% Crab) and VERITAS (2.3% Crab)
- Fermi detected pulsar at E < 4 GeV, PWN detected up to ~100 GeV



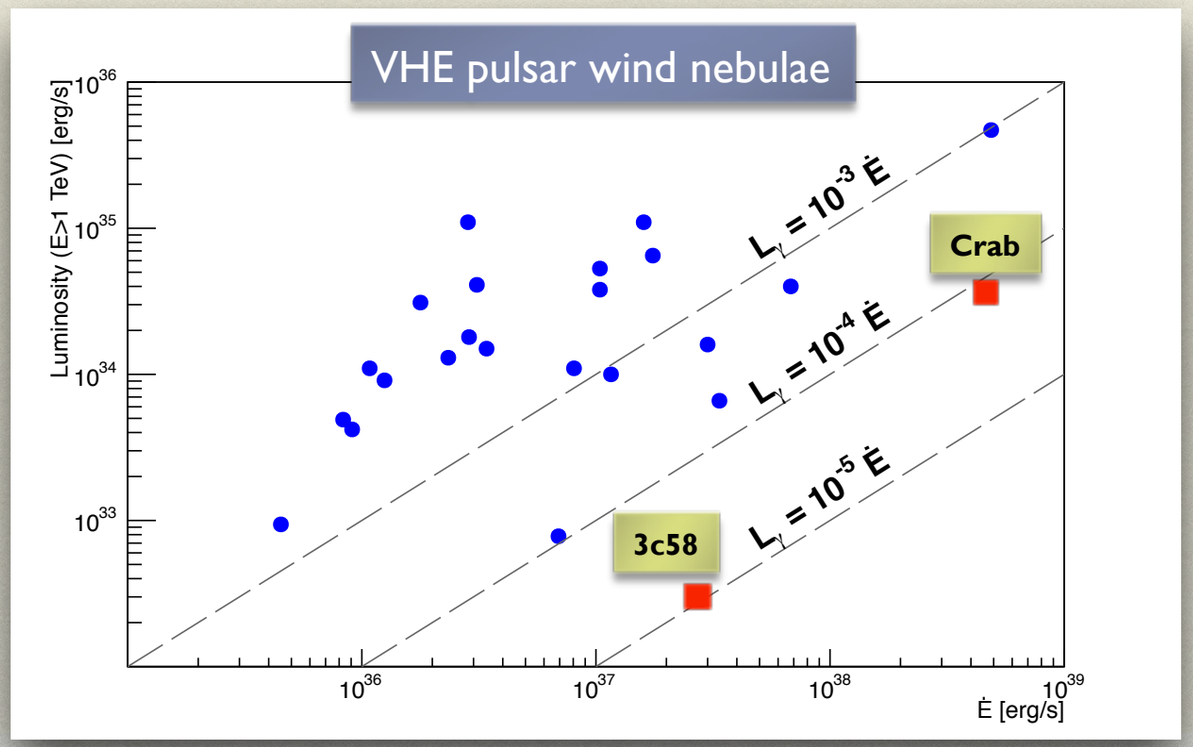
3c58 PWN

Accepted for publication A&A 2014



- MAGIC observed for 81 hours on 2013 and 2014
- Detected with 5.7 σ and estimated flux of 0.6% Crab (weakest PWN detected at TeV). Spectral index 2.4

- Models can fit the data if:
  - Distance of 2 kpc is used (instead of 3.2 kpc)
  - A very high, unrealistic, IR density is assumed
- The 2 kpc assumption is favoured. A B field ≤35 μG is derived by all models



3c58 PWN

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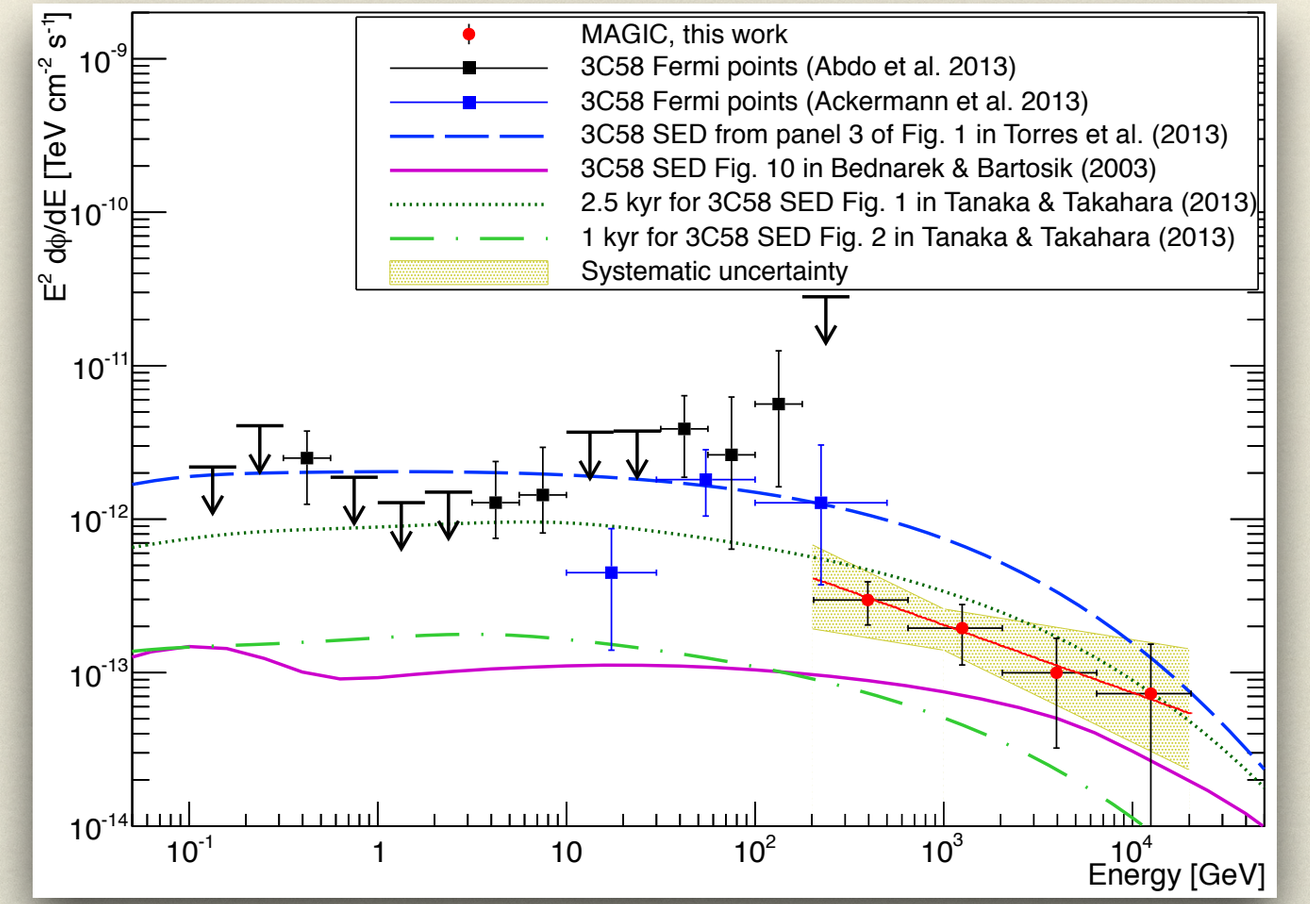

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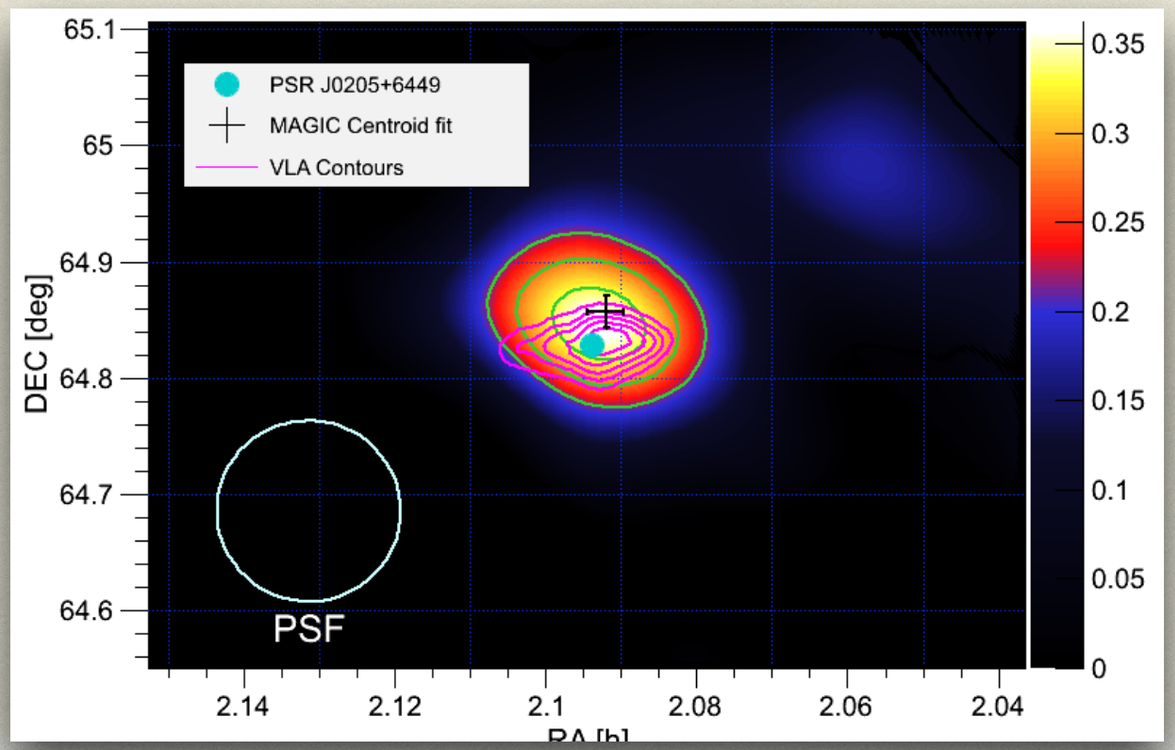

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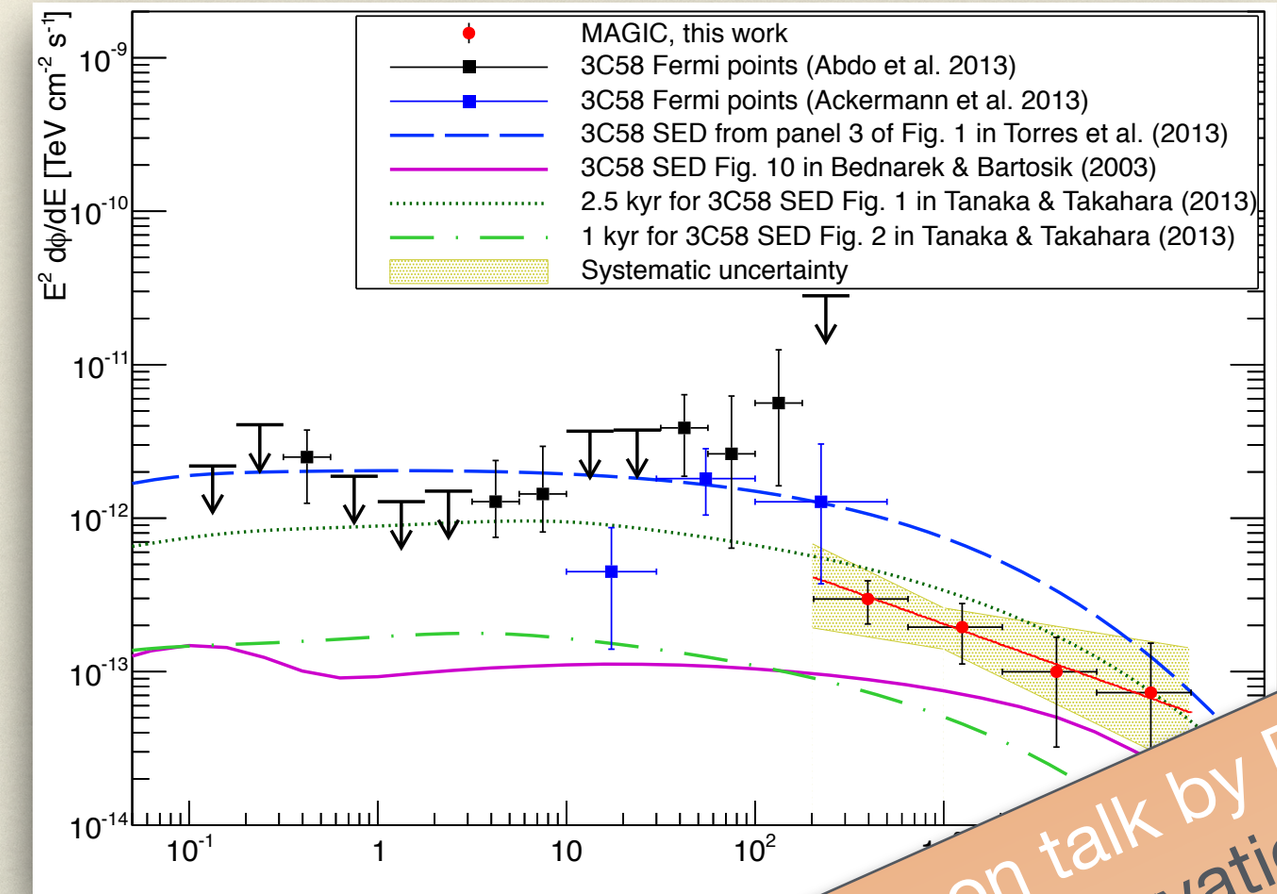

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More details on talk by E. de Oña Wilhelmi "Status of observations of PWNe and SNRs in the gamma-ray regime" tomorrow

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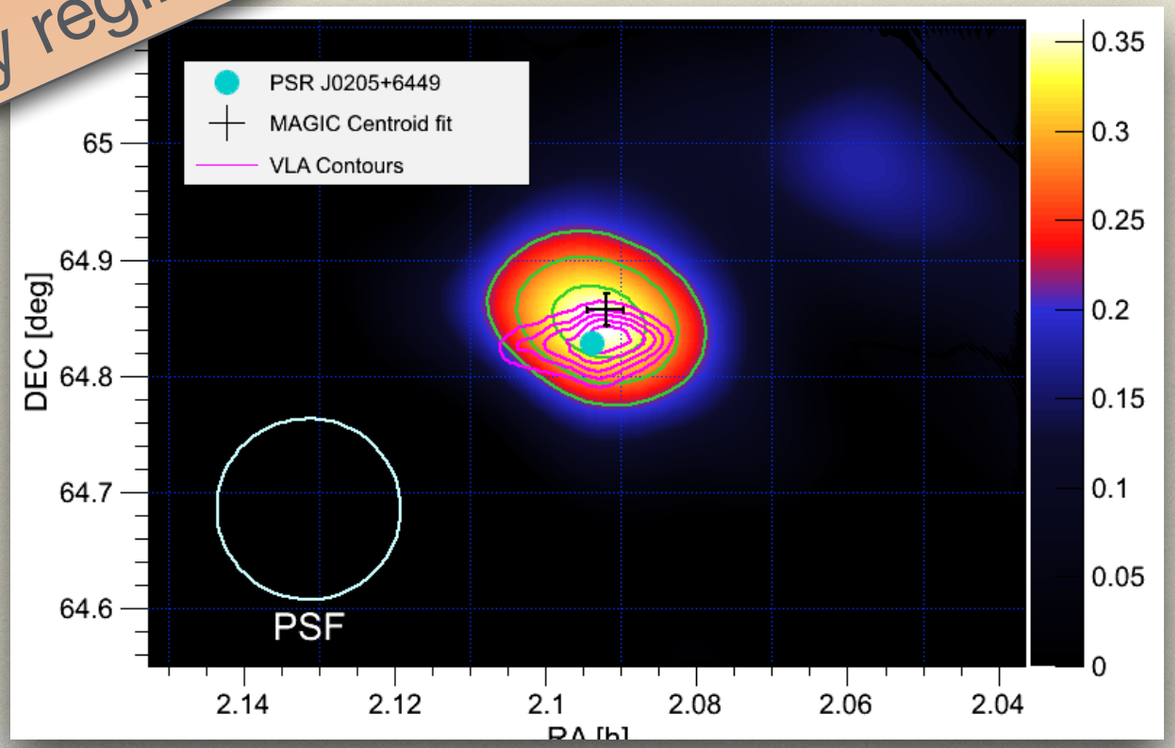
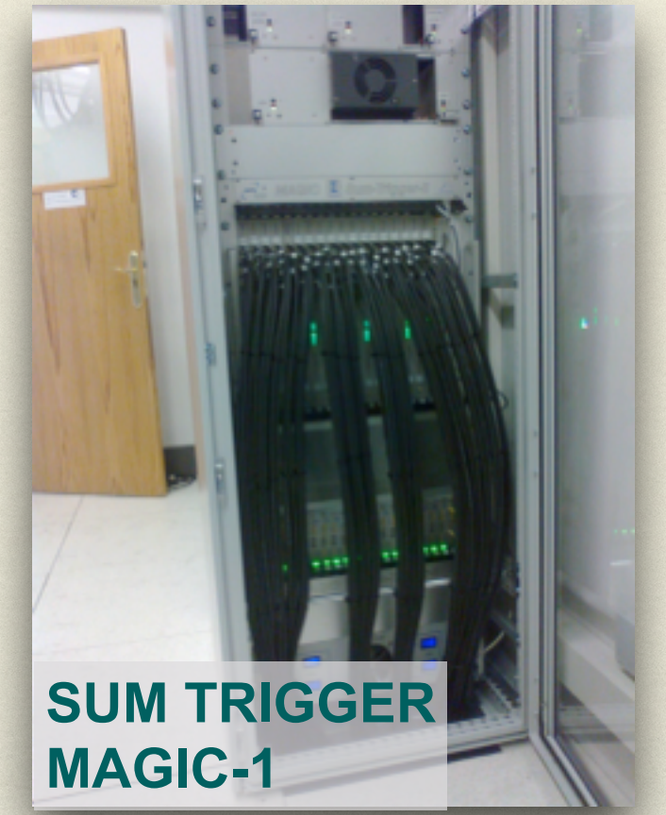
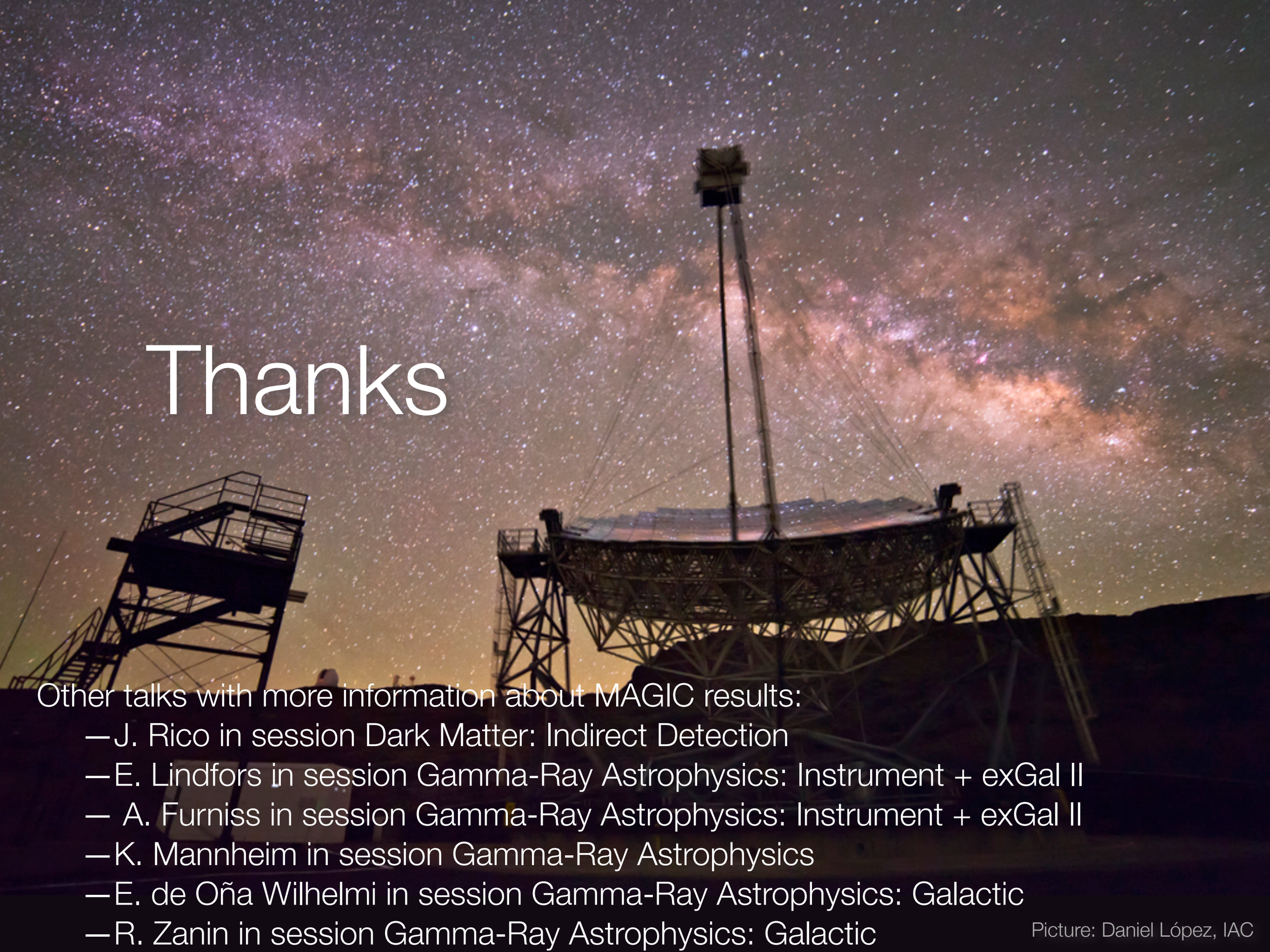


Future & Summary

Future & Summary

- Another hardware upgrade: **SUM-trigger** system is now installed and being tested
  - Same concept used in 2008 to detect the Crab pulsar above 25 GeV
  - Could bring stereo trigger down to **30 GeV**
- MAGIC telescopes are in optimal shape to operate for some more years:
  - Better performance than ever
  - Interesting results being produced: IC 310, Crab Pulsar & Nebula, 3c58, Dark matter ULs, more new sources (MS1221.8+2452 on 05/2013, RBS 0723 on 01/2014, RX J1136.5+6737 on 04/2014), …
- Observation strategy changing to include Key Observation Programs
- Expecting more exciting results in near future: Key Observation Programs, SUM-trigger, a GRB detection?, …





Thanks

Other talks with more information about MAGIC results:

- J. Rico in session Dark Matter: Indirect Detection
- E. Lindfors in session Gamma-Ray Astrophysics: Instrument + exGal II
- A. Furniss in session Gamma-Ray Astrophysics: Instrument + exGal II
- K. Mannheim in session Gamma-Ray Astrophysics
- E. de Oña Wilhelmi in session Gamma-Ray Astrophysics: Galactic
- R. Zanin in session Gamma-Ray Astrophysics: Galactic

Picture: Daniel López, IAC