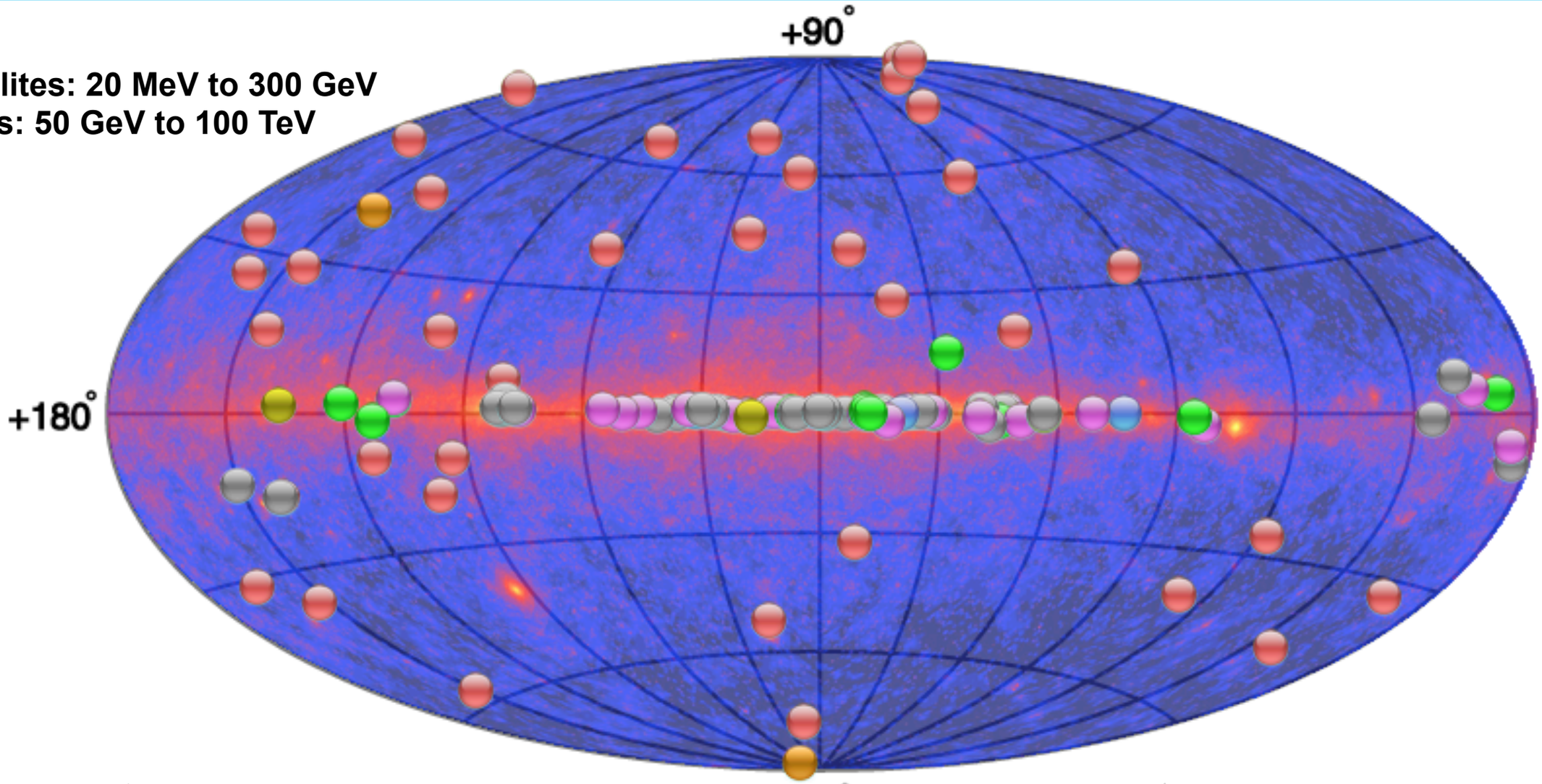
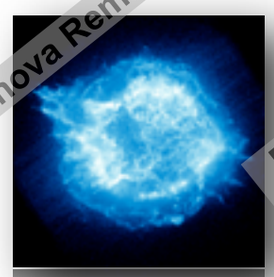
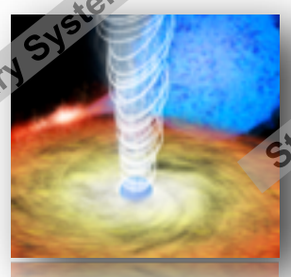
Very-high energy Gamma-ray Astronomy

Satellites: 20 MeV to 300 GeV
IACTs: 50 GeV to 100 TeV




Supernova Remnants

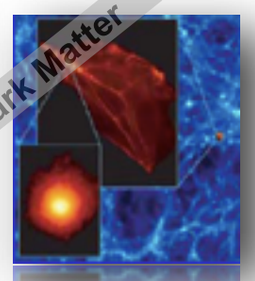

Pulsars and Pulsar Wind Nebula


Binary Systems

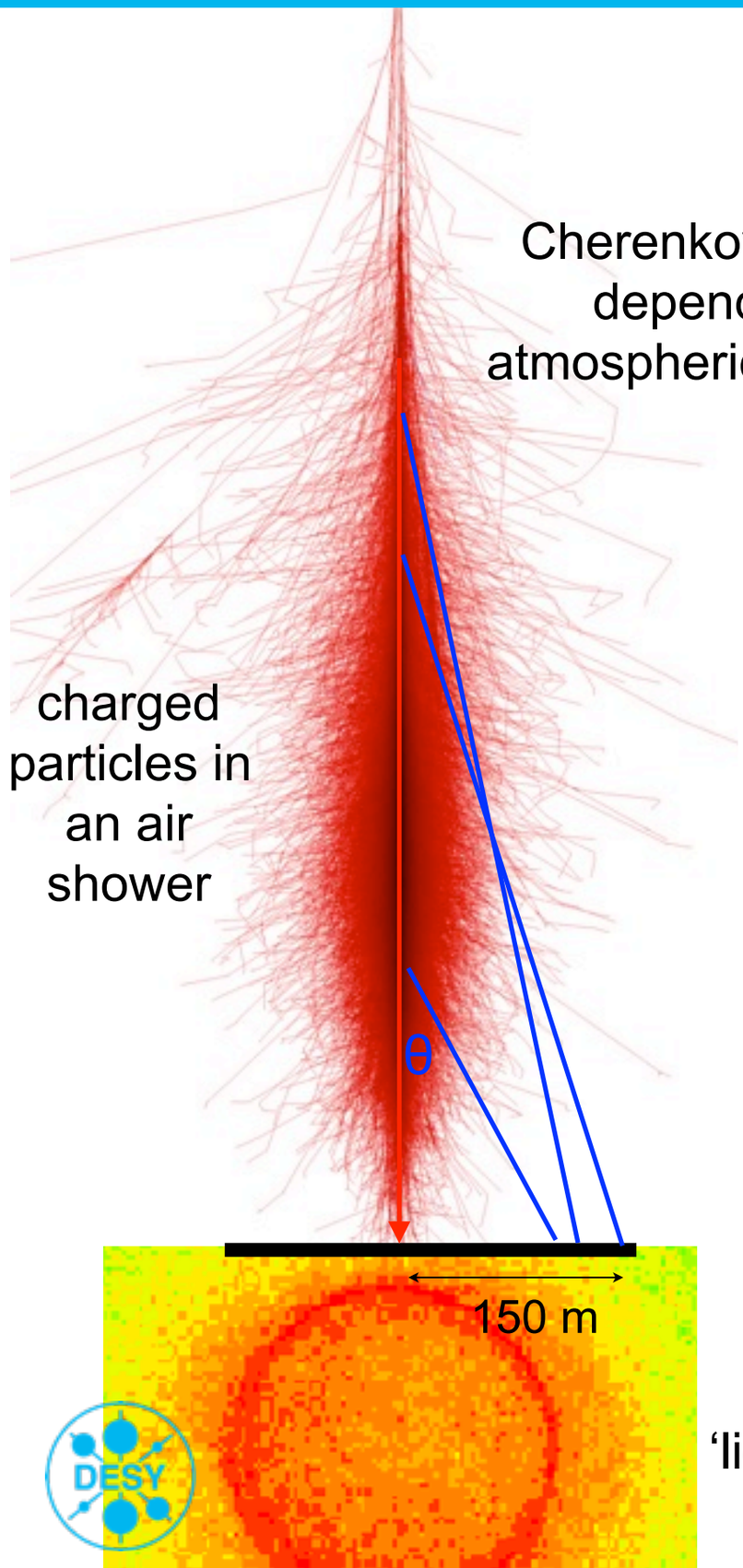

Starburst Galaxies


Active Galactic Nuclei


Gamma Ray Bursts

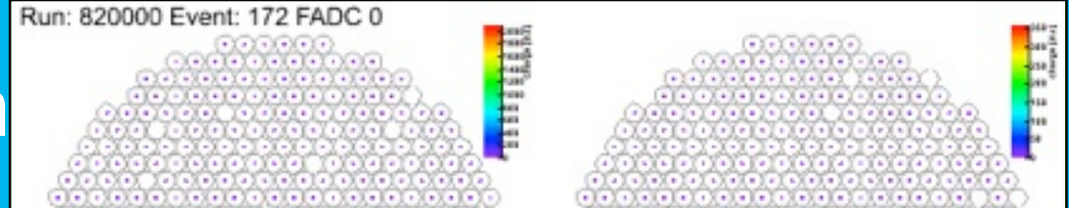

Dark Matter

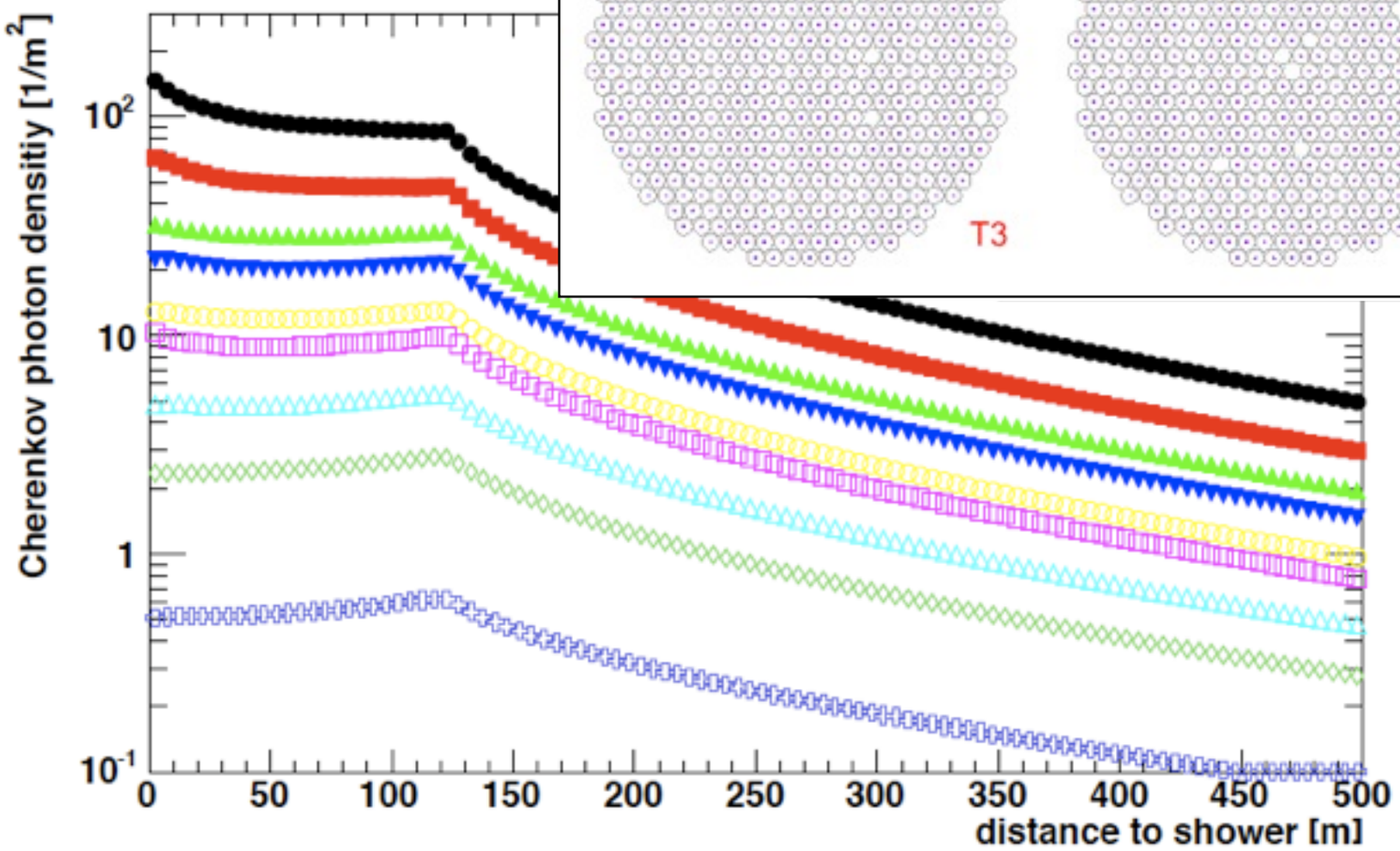
Extensive Air Showers and Cheren



charged particles in an air shower

Cherenkov angle depend on atmospheric density





'light pool'

Very High-Energy Observatories

Whipple

VERITAS

YIG G. Maier
THEO M. Pohl

MAGIC

YIG E. Bernardini

Fermi LAT

M.Ackermann

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H.E.S.S.

C.Stegmann
HUB T. Lohse
U HH D.Horns

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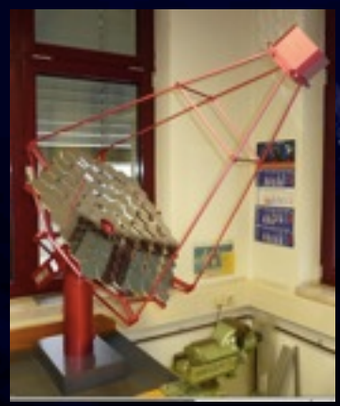
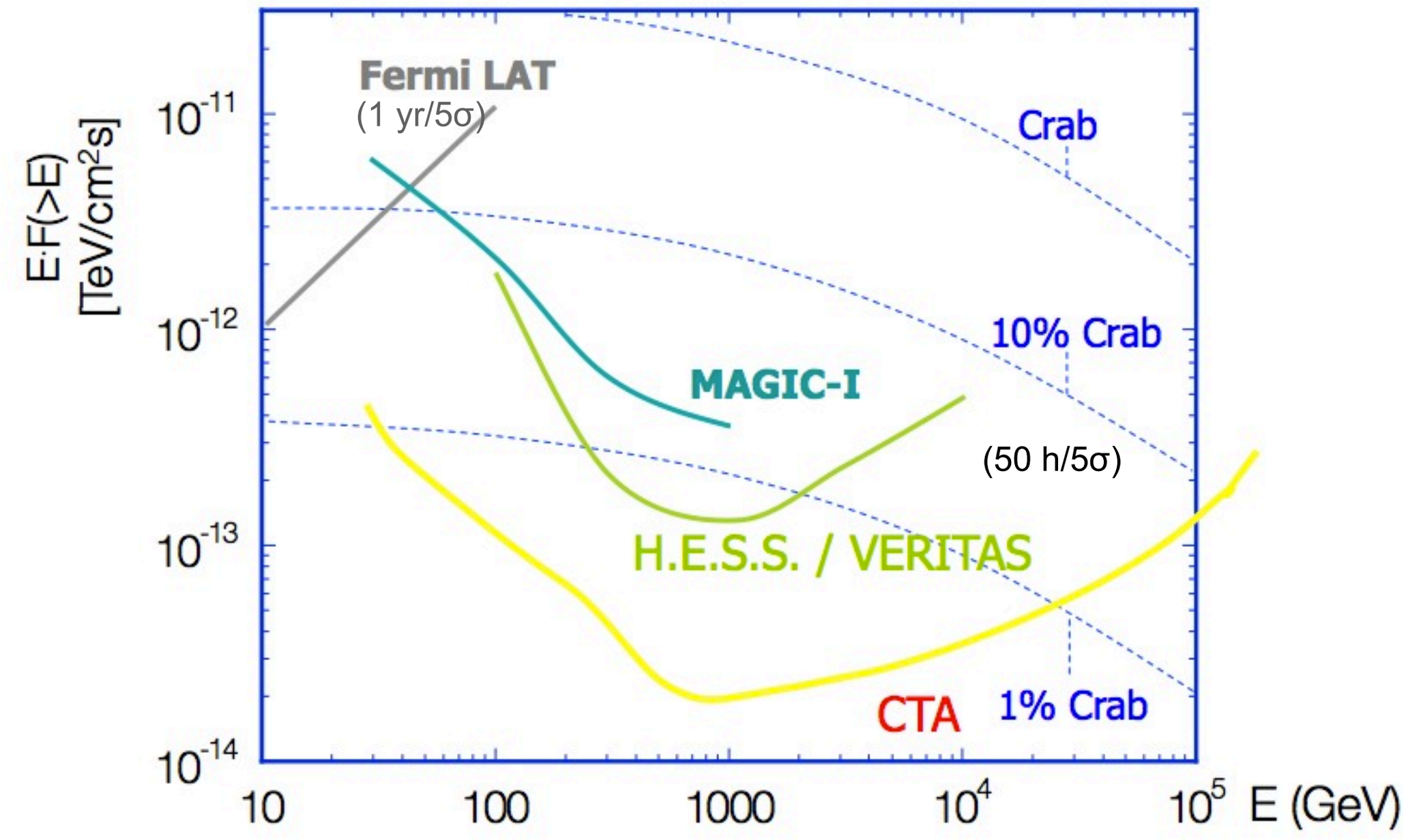


CTA

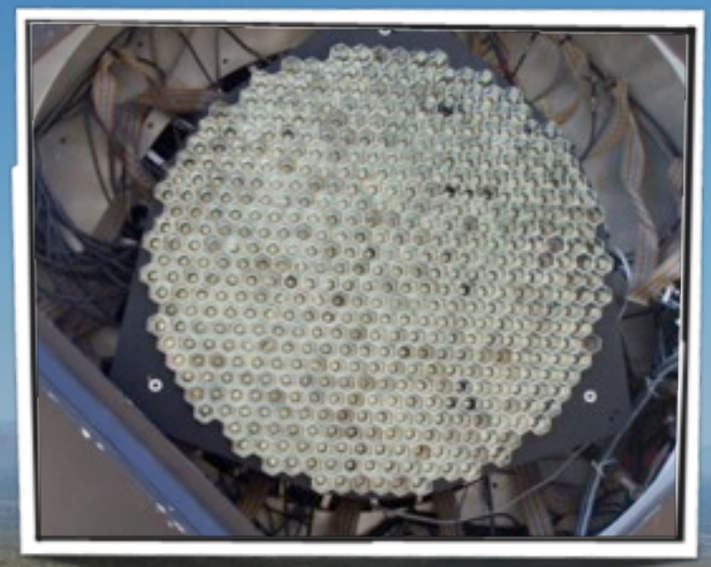
S.Schlenstedt

Sensitivities

www.cta-observatory.org



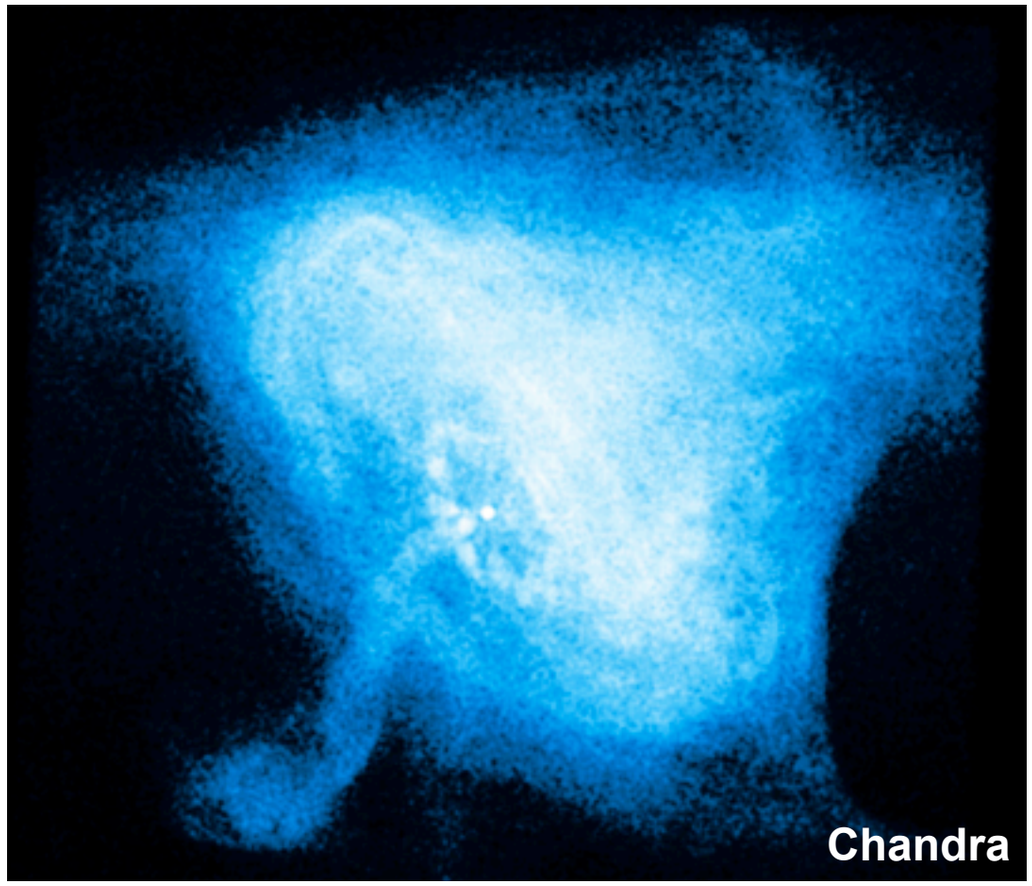
VERITAS



Sophisticated trigger system needed to suppress night sky background (120 MHz -> 20 Hz)

VERITAS Physics Result: Crab Pulsar

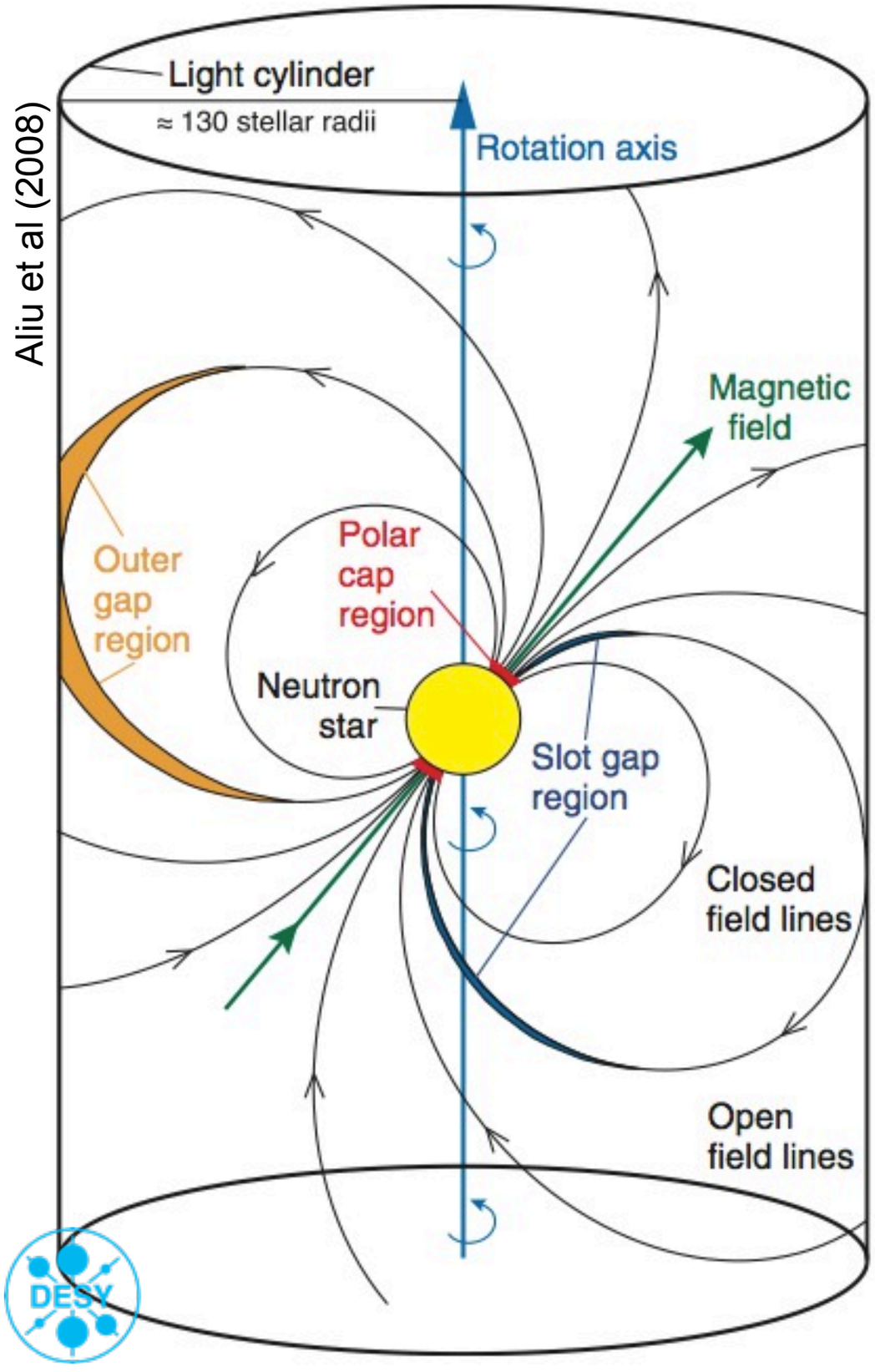
- remnant of historic supernova observed in 1054 A.D.
- one of the most powerful pulsars: spin-down energy of 4.6 x 10^{38} erg/s
- Fermi-LAT measures spectral break at ~6 GeV
- MAGIC detected the pulsar at 25 GeV using dedicated hardware (2008)
- VERITAS observations 2007-2010: total exposure of 107 h (standard configuration): emission between 100 and 400 GeV



P	0.03308471603	s
$\dot{P}$	4.227654×10^{-13}	s/s
B_{surf}	3.78×10^{12}	G
B_{LC}	9.8×10^{5}	G
$\dot{E}$	4.6×10^{38}	$ergs/s$
Spin down age	1240	yr
R_{LC}	1.58×10^{6}	m

Science October 6, 2011

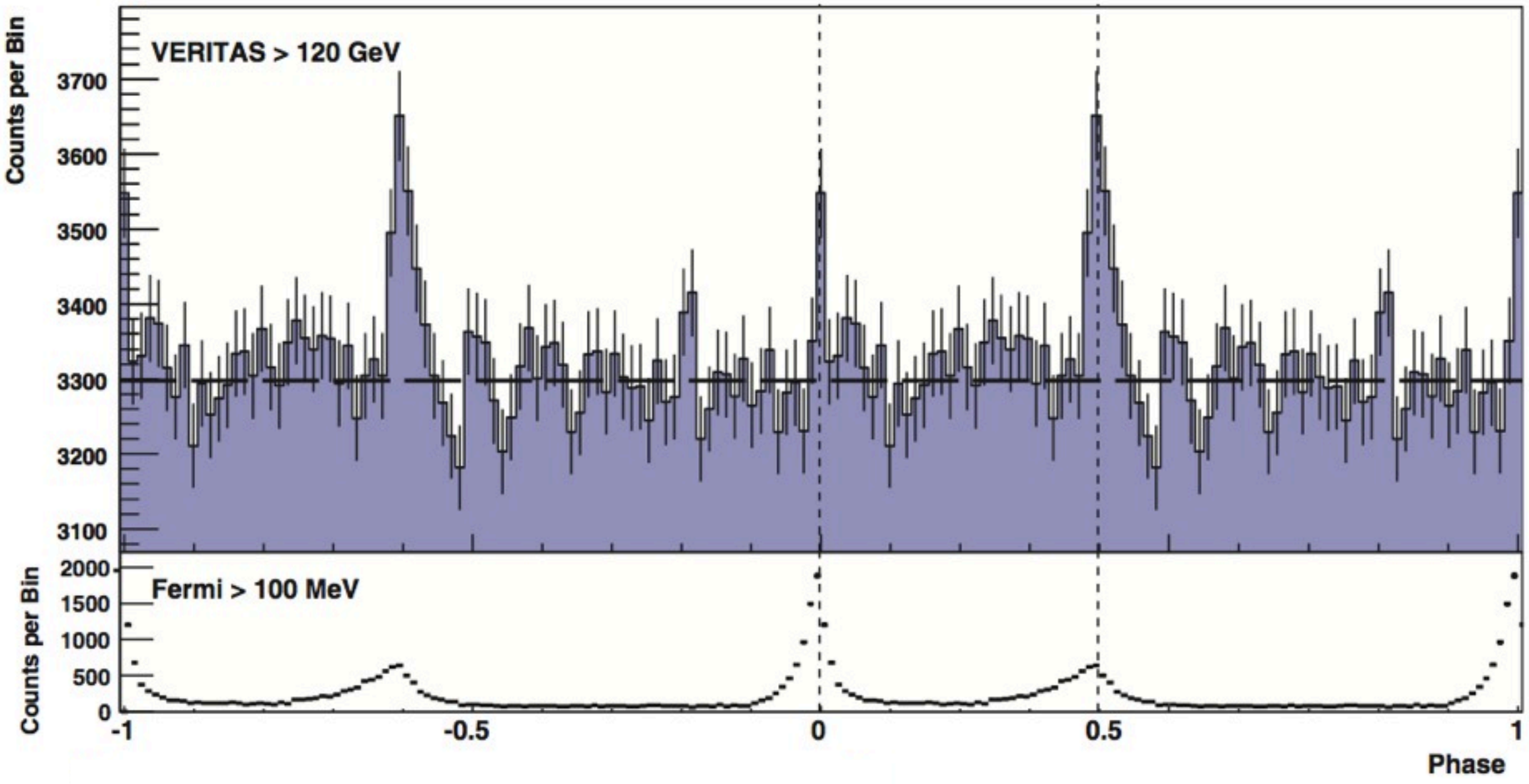
Gamma-ray emission from pulsars



- magnetic field structure a presently unsolved problem
- most parts of the magnetosphere: induced electrical field is saturated
- regions of low plasma density (vacuum gaps) are acceleration sites
- maximum electron energy given by balance between acceleration and radiation losses
- absorption of gamma rays in the magnetosphere
  - magnetic pair production
  - photon-photon pair production

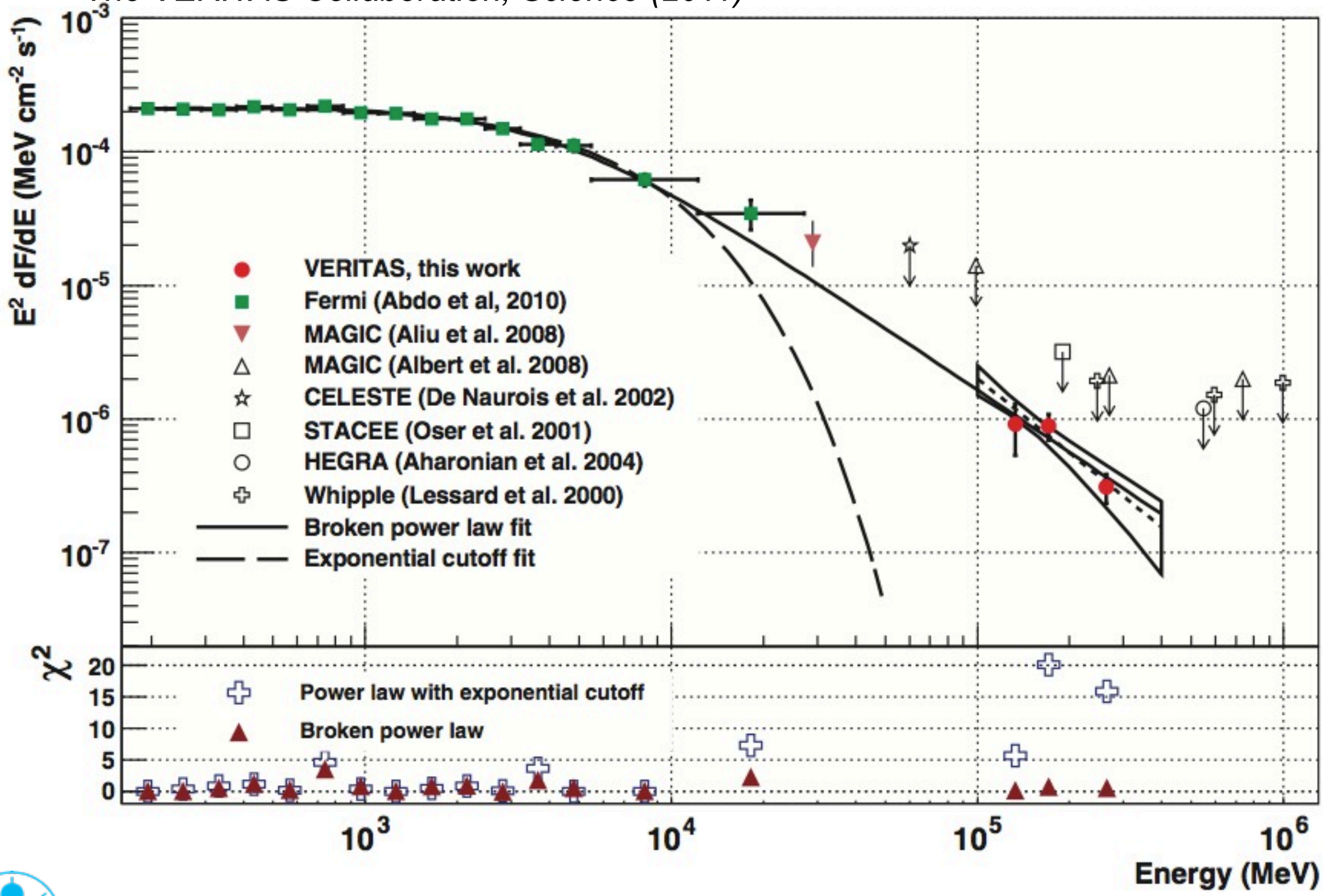
Crab Pulsar > 100 GeV

The VERITAS Collaboration, Science (2011)



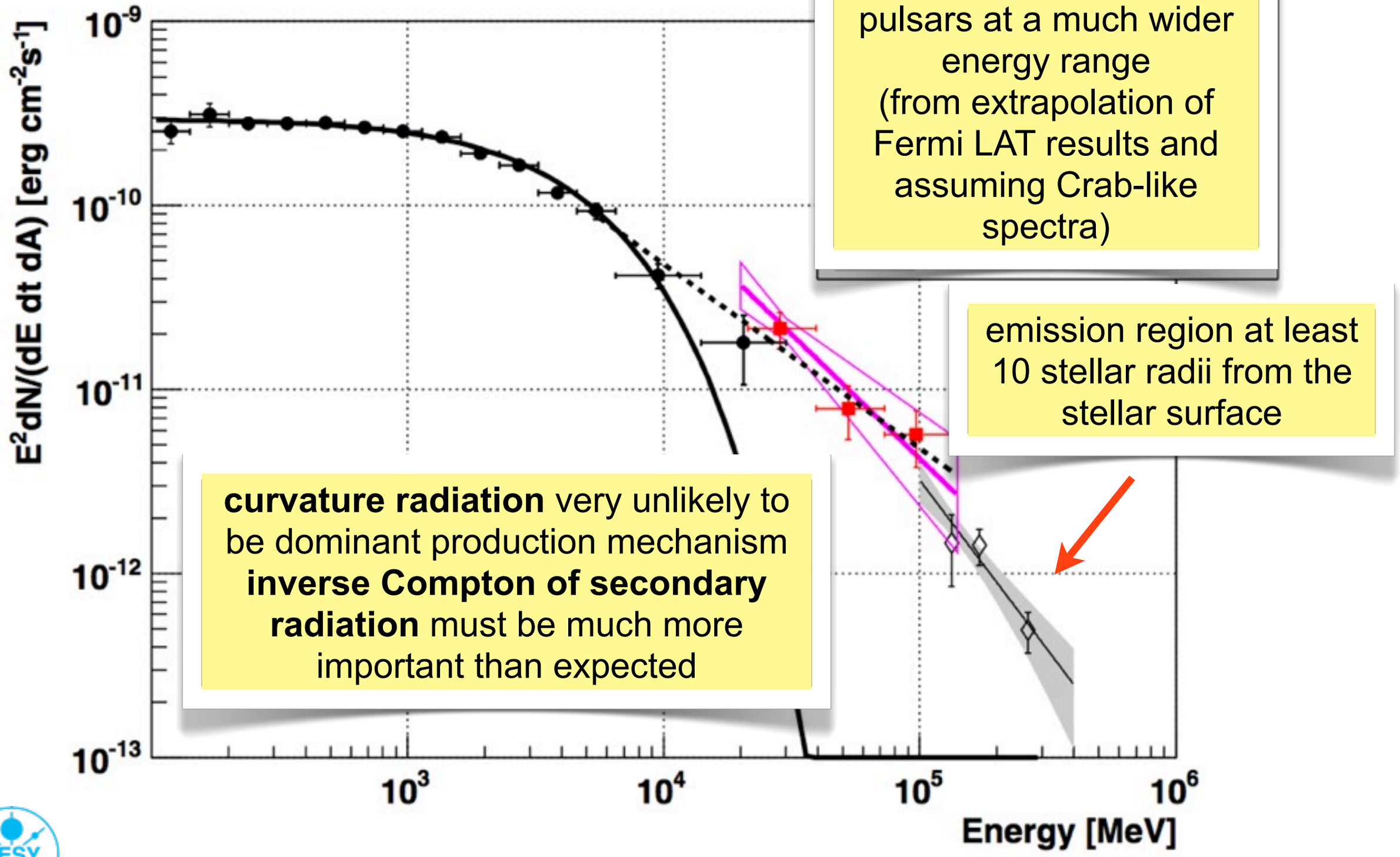
Crab Pulsar > 100 GeV

The VERITAS Collaboration, Science (2011)



Crab Pulsar > 100 GeV

The MAGIC Collaboration, ApJ (Nov 2011)



CTA will detect 10-15 pulsars at a much wider energy range (from extrapolation of Fermi LAT results and assuming Crab-like spectra)

emission region at least 10 stellar radii from the stellar surface

curvature radiation very unlikely to be dominant production mechanism **inverse Compton of secondary radiation** must be much more important than expected

Testing Lorentz Invariance

- most (all?) quantum theories of gravity introduce fluctuations at the Planck scale ($E_P \approx 10^{19}$ GeV; $L_P \approx 10^{-33}$ cm)
- dispersion of light:

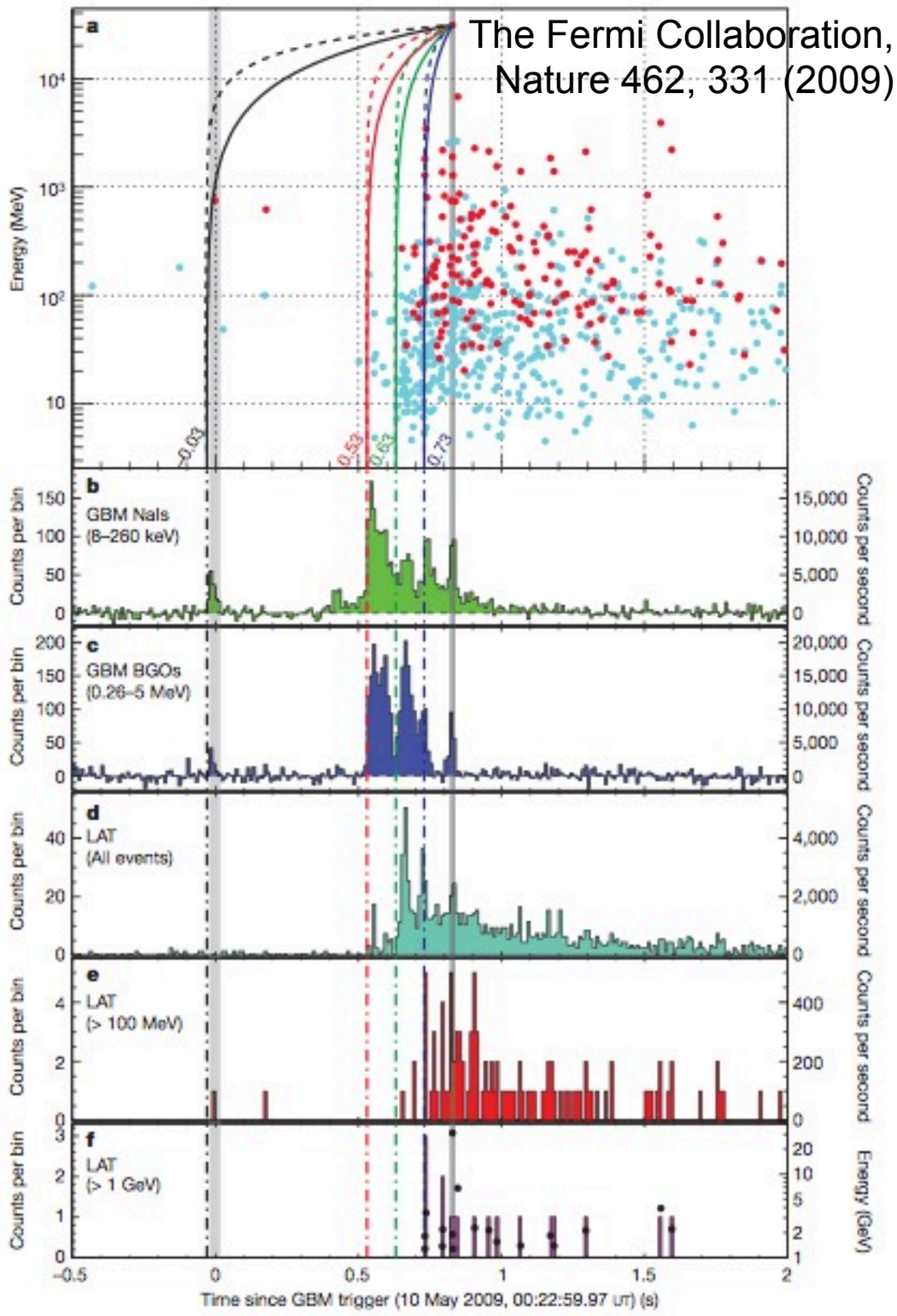
$$p^2c^2 = E^2[1 + f(E/E_{QG})]$$

- two photons emitted simultaneously with energy difference ΔE:

$$\Delta t\big|_{small-z} \simeq s_{\pm}\frac{\Delta E}{M_{QG}}L$$

- existing upper limits from pulsars, flaring AGNs and Gamma-ray Bursts; best "limit": 31 GeV photon from GRB 090510
  ⇒ $E_{QG} > 1.5 \times 10^{19}$ GeV

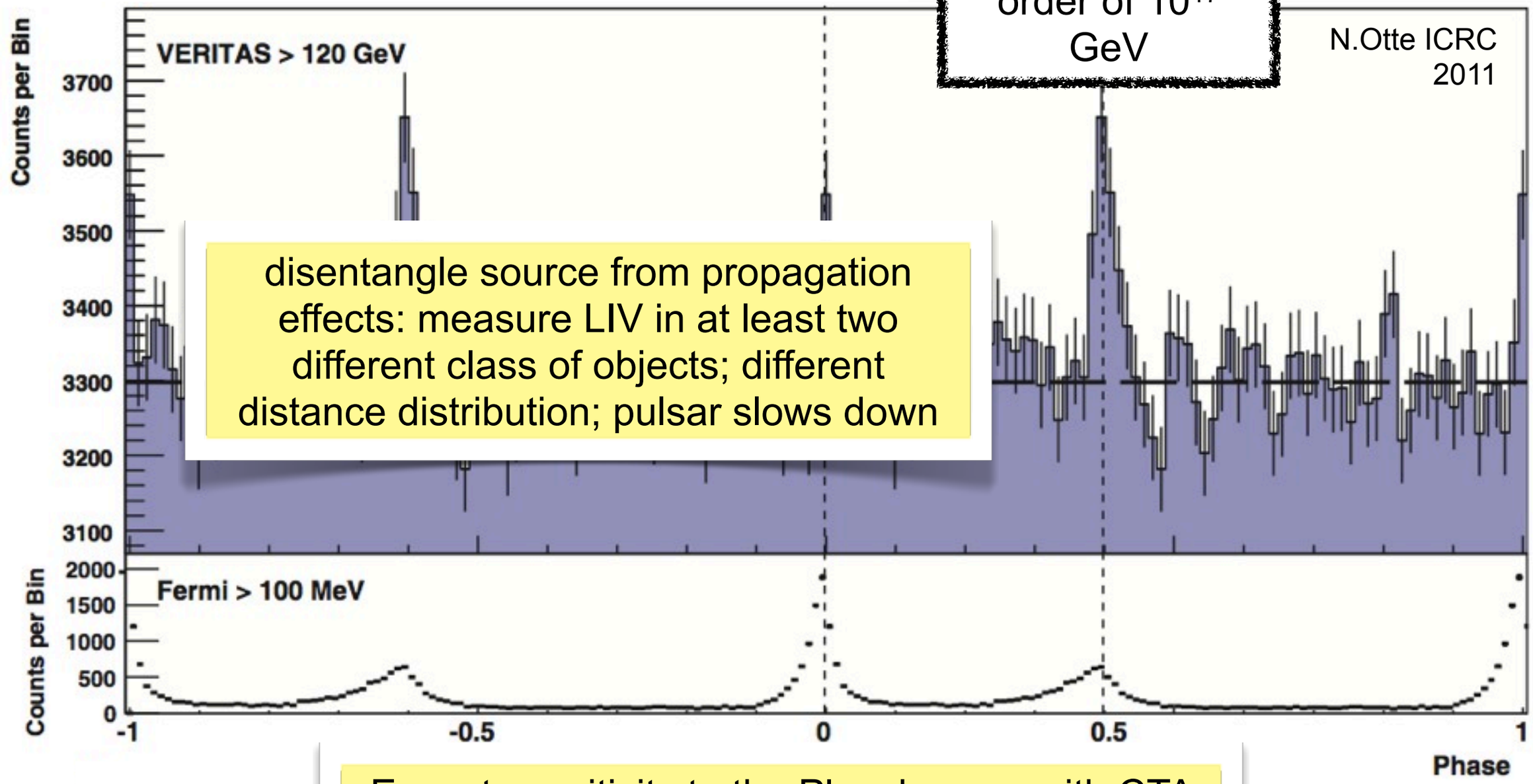
but: spectra might get harder with time...



Testing Lorentz Invariance with the Crab Pulsar

limits in the order of 10^{17} GeV

N.Otte ICRC 2011



disentangle source from propagation effects: measure LIV in at least two different class of objects; different distance distribution; pulsar slows down

Expect sensitivity to the Planck mass with CTA (possibly factor of 10 better determination of peak position; extended energy spectrum; ...)

Summary - very-high energy gamma rays

- astrophysics, cosmology, fundamental physics
- ground-based Cherenkov astronomy is taking the next steps:
  - HESS II: a 5th very large telescope with an energy threshold ~30 GeV (2012)
  - MAGIC II: a 2nd telescope for stereoscopic observations (2010)
  - VERITAS upgrade: camera replacement with high-efficiency PMTs (2012)
  - ***the Cherenkov Telescope Array: factor of 10 in sensitivity (2016)***
- DESY plays a key role in the preparation of CTA

DESY World Map

Theory

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