Moon Shadow observation with Cerenkov Telescopes

Probing the e^+/e^- ratio at TeV regime

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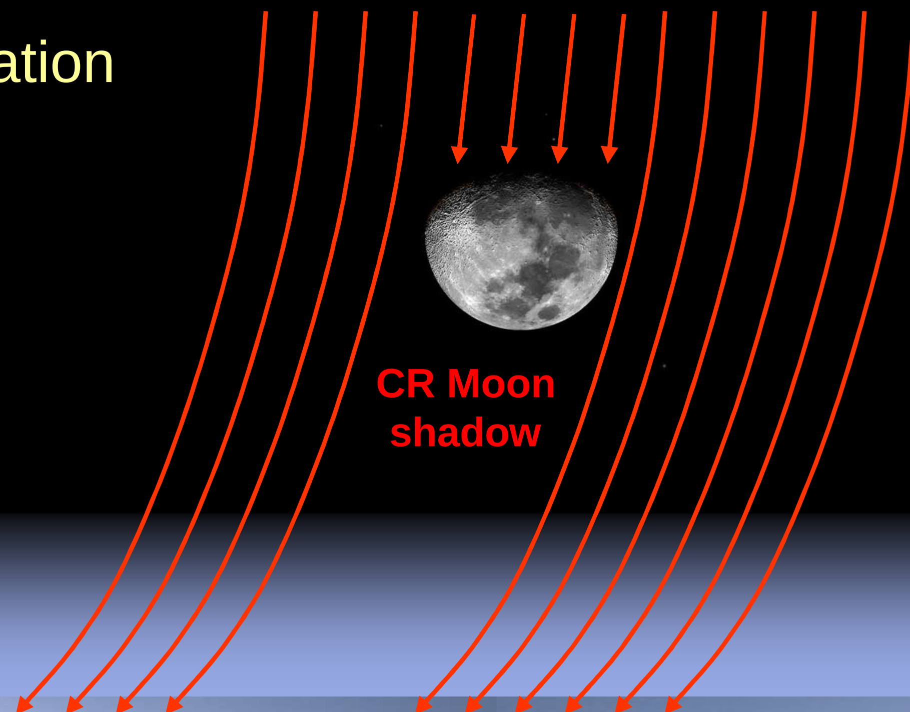
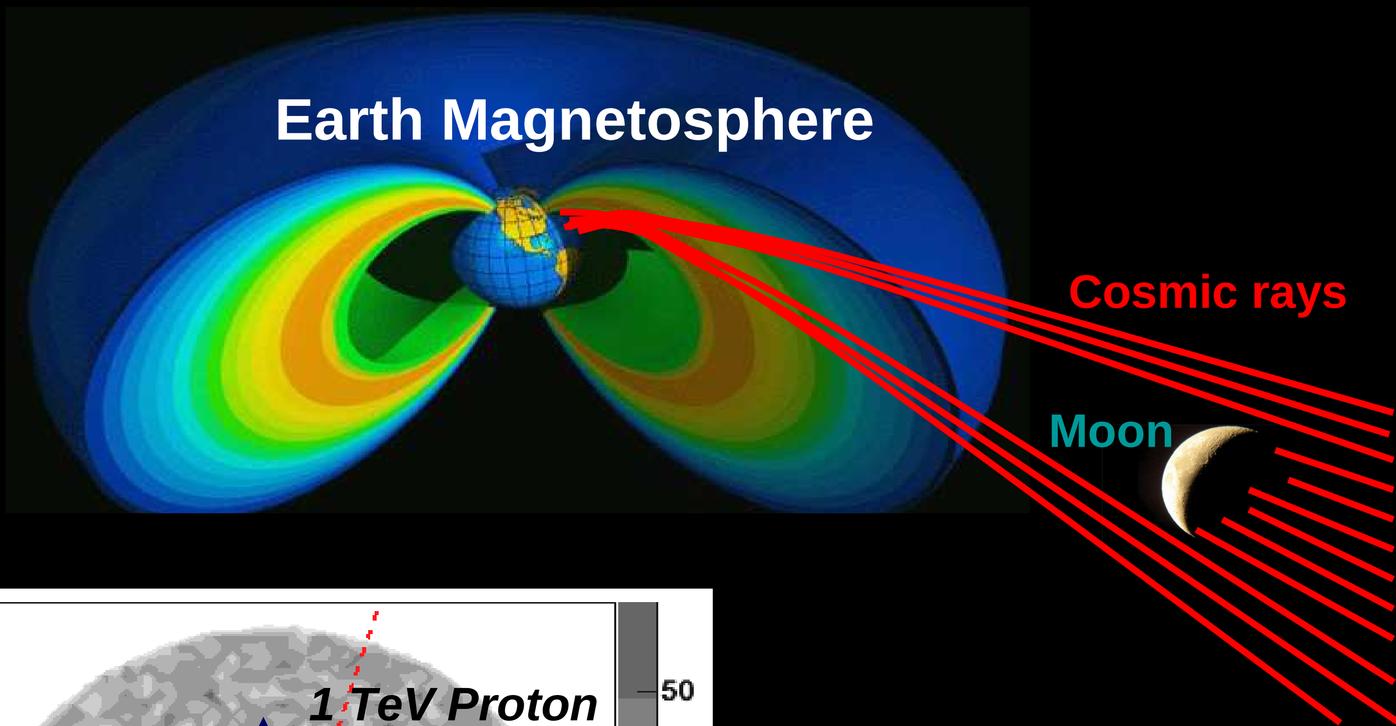
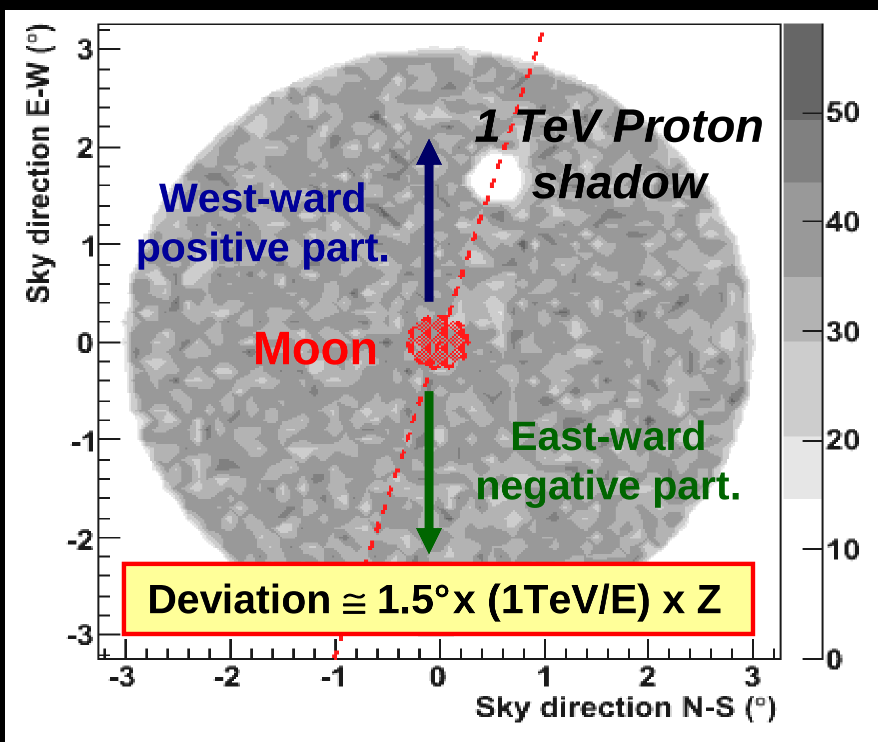


Workshop on Positrons in Astronomy - 21 march 2012

Earth-Moon spectrometer





The Moon shadow position depends on:

- CR charge
- CR kinetic energy

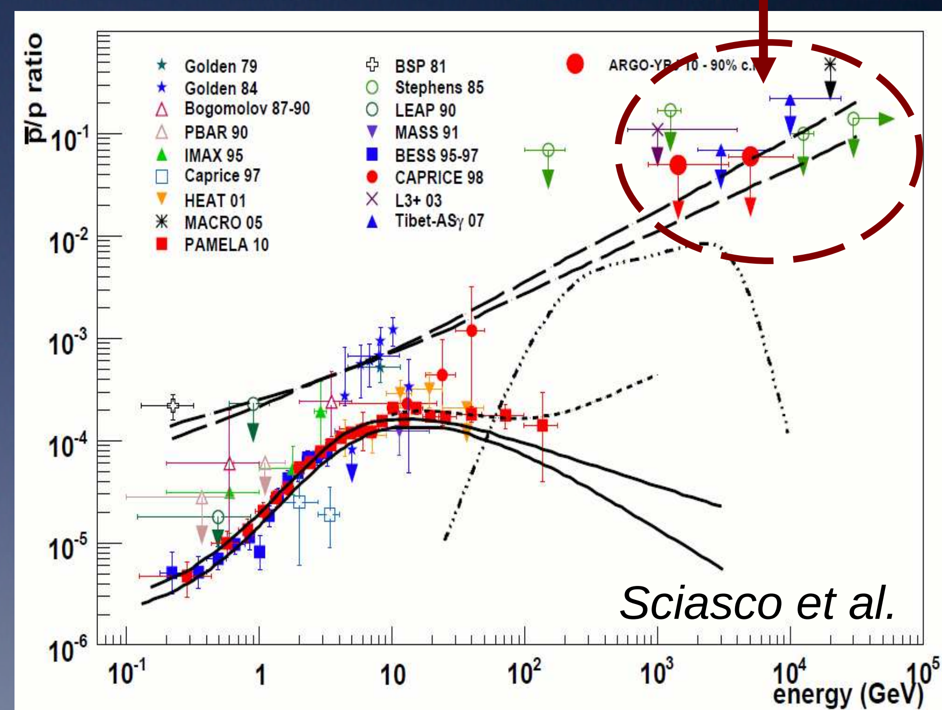
Detection of the Moon shadow effect

- **Neutrino experiments**
  - Used to determine angular resolution and pointing accuracy

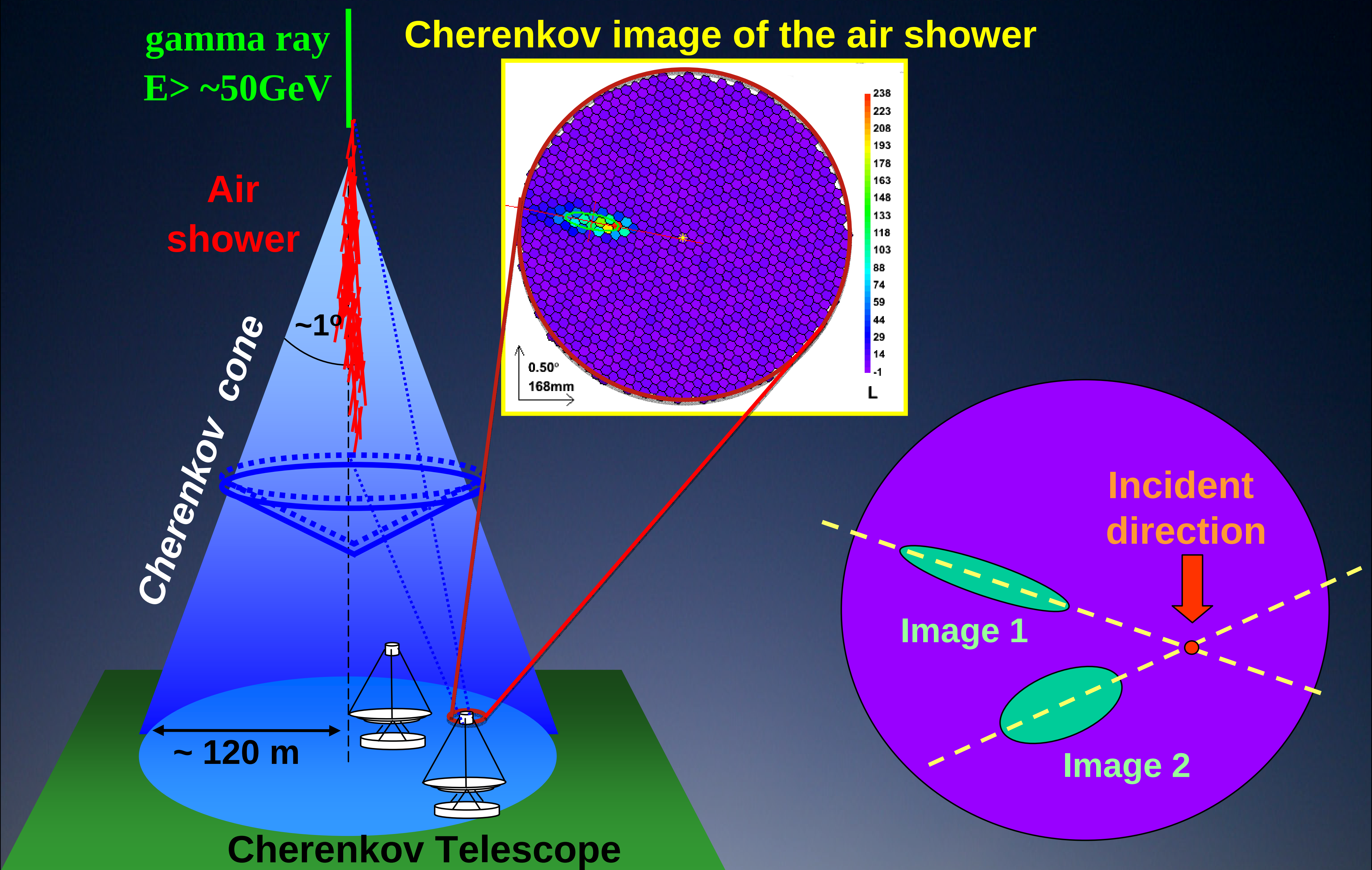
- **Ground EAS array experiments**
  (ARGO-YBJ, Tibet-ASγ, MILAGRO, etc.)
  - Used to determine Angular resolution.
  - Est/West Asymmetry of the shadow probes **anti-proton/proton ratio**.
    (Energy range: 1-10 TeV)

- **Cherenkov Telescopes**
  - First try in the 90s:
    ARTEMIS experiments
  - No detection…

$\overline{P}$/P ratio upper limits from moon shadow asymmetry

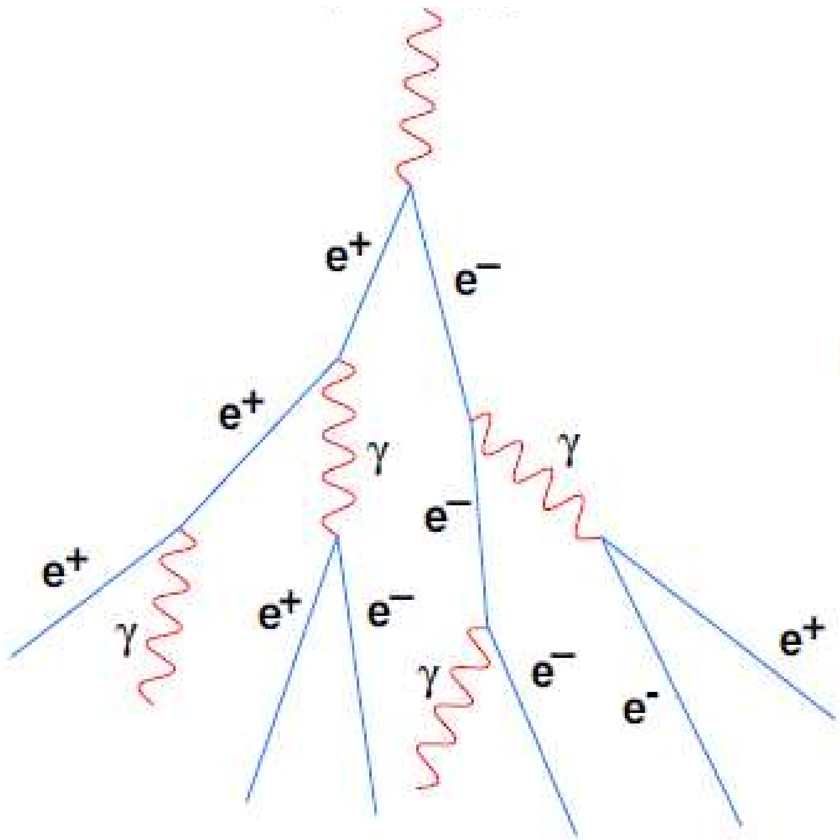


Atmospheric Cherenkov Technique



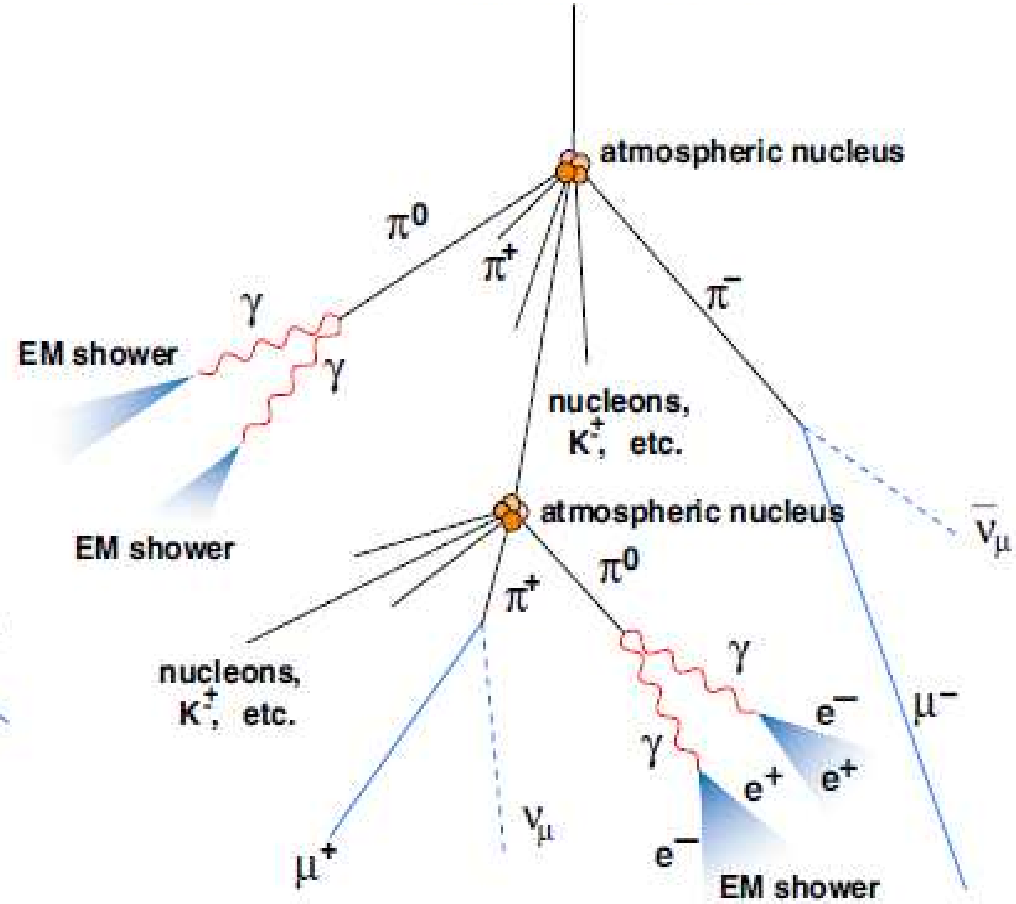
Types of air shower

Primary γ (or e^+ / e^-)



Pure electromagnetic Cascade

Primary hadron (P, α, Fe …)

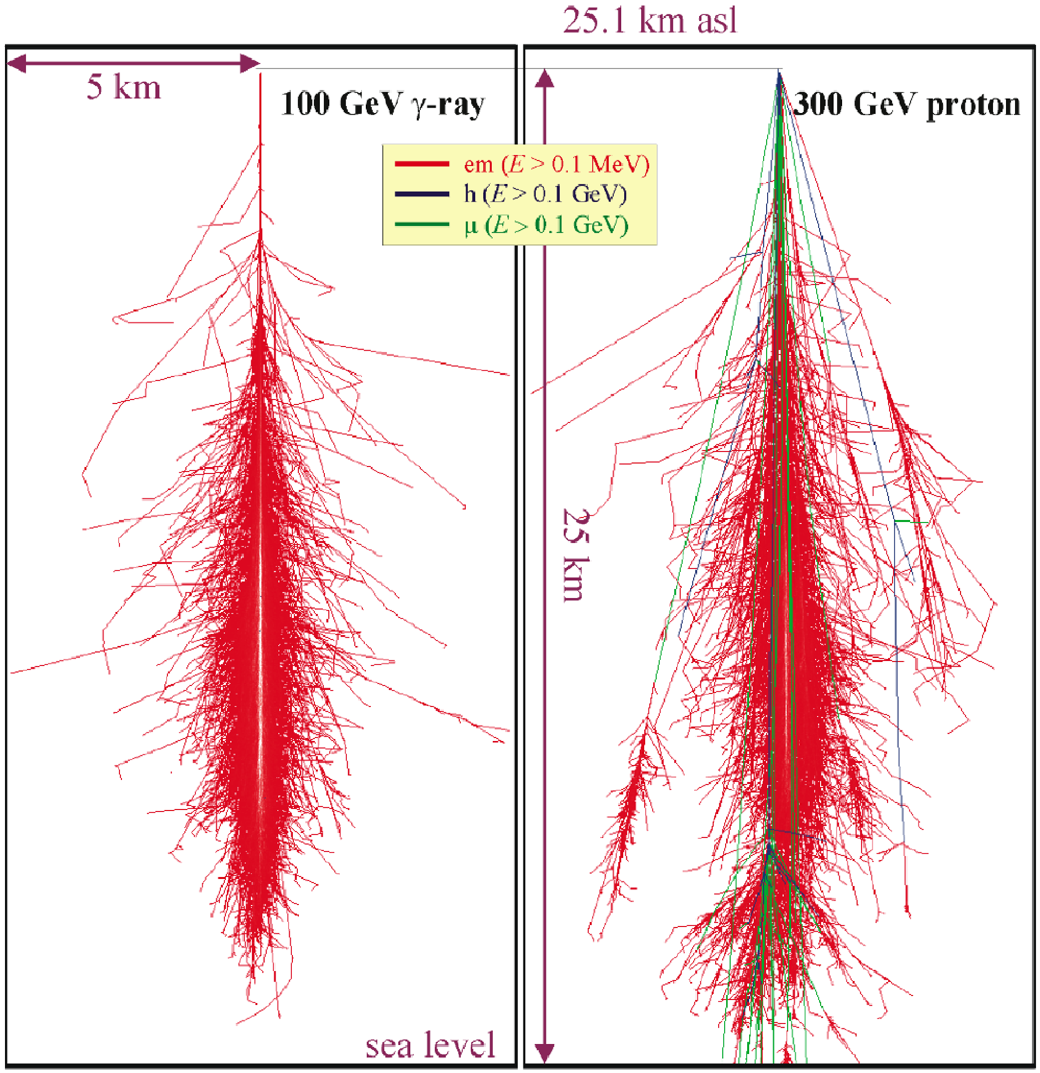


Hadronic Cascade:

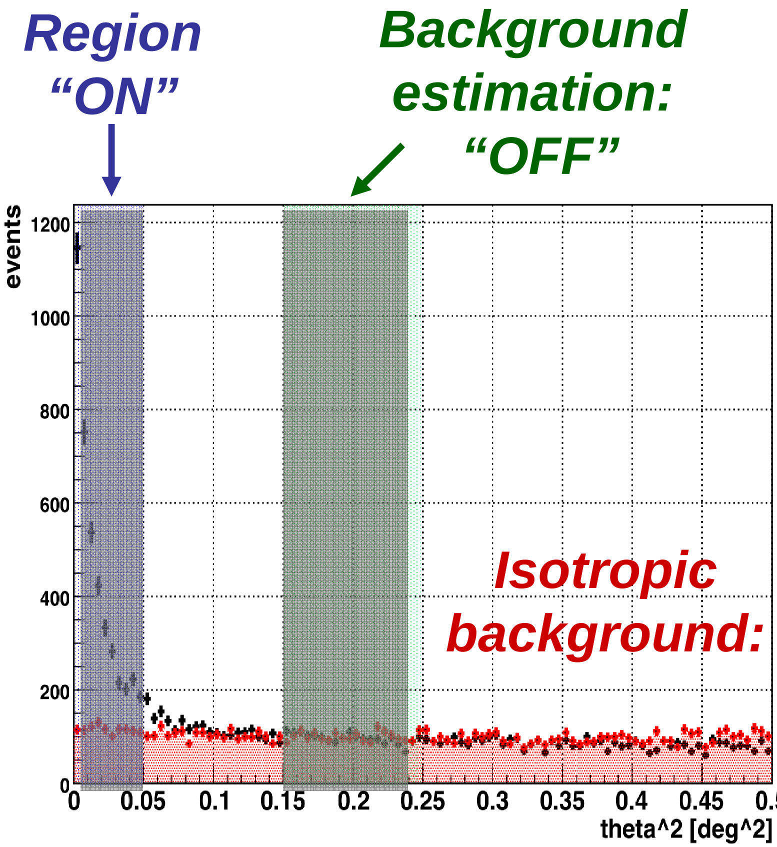
- ⅓ electromagnetic (π^o)
- ⅔ "lost" ($\pi^\pm \rightarrow \mu^\pm + \nu$)

Gamma/Cosmic-Ray Discrimination

Shape of the shower image:

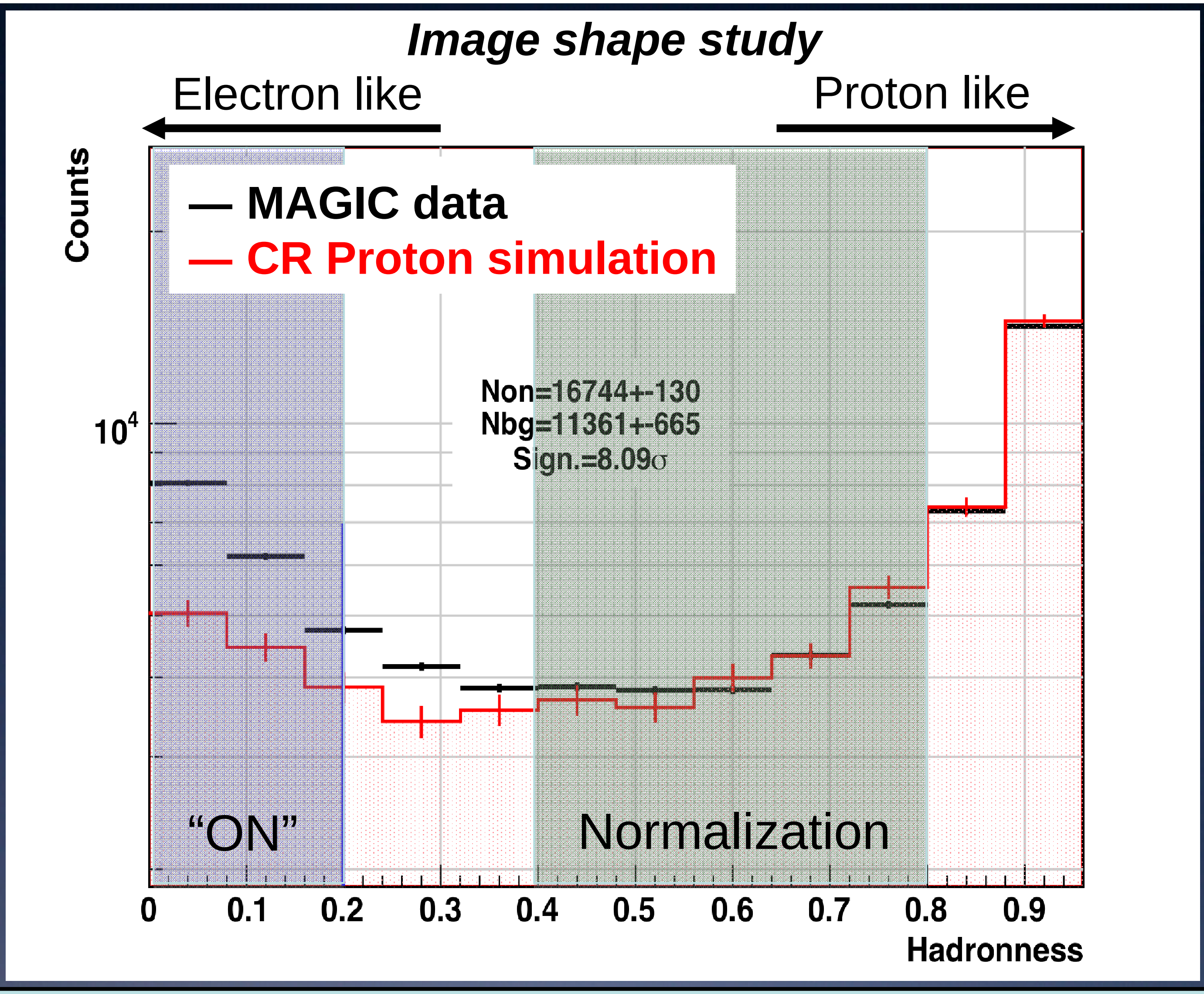


Reconstructed direction



Efficient for point-like Gamma-ray source

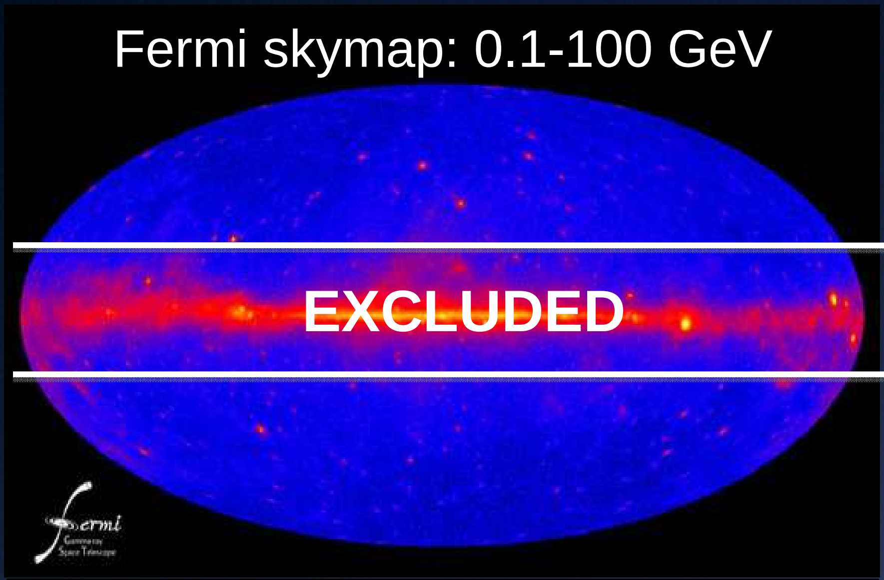
Cosmic electrons ($e^{+}+e^{-}$) signal

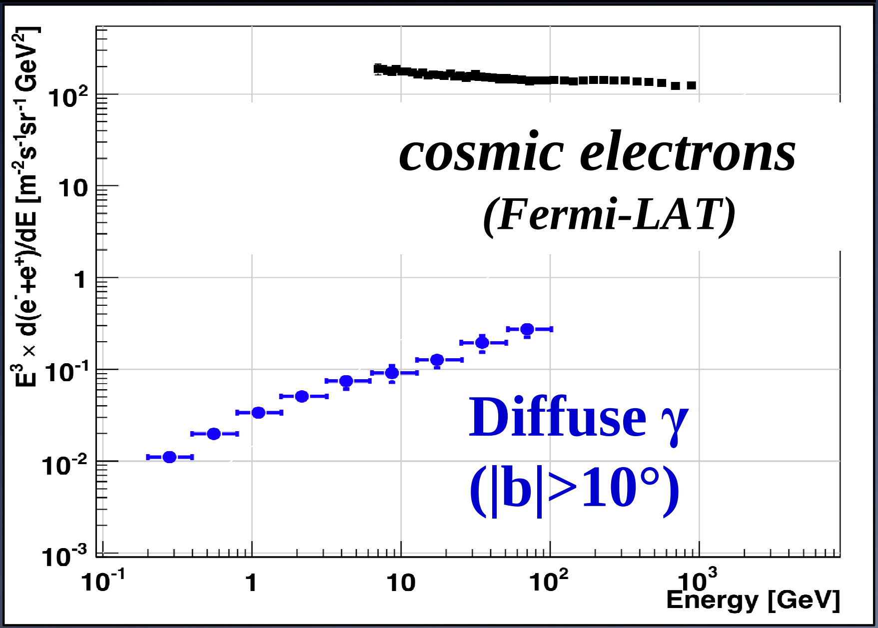


<u>Electrons flux is isotropic</u>

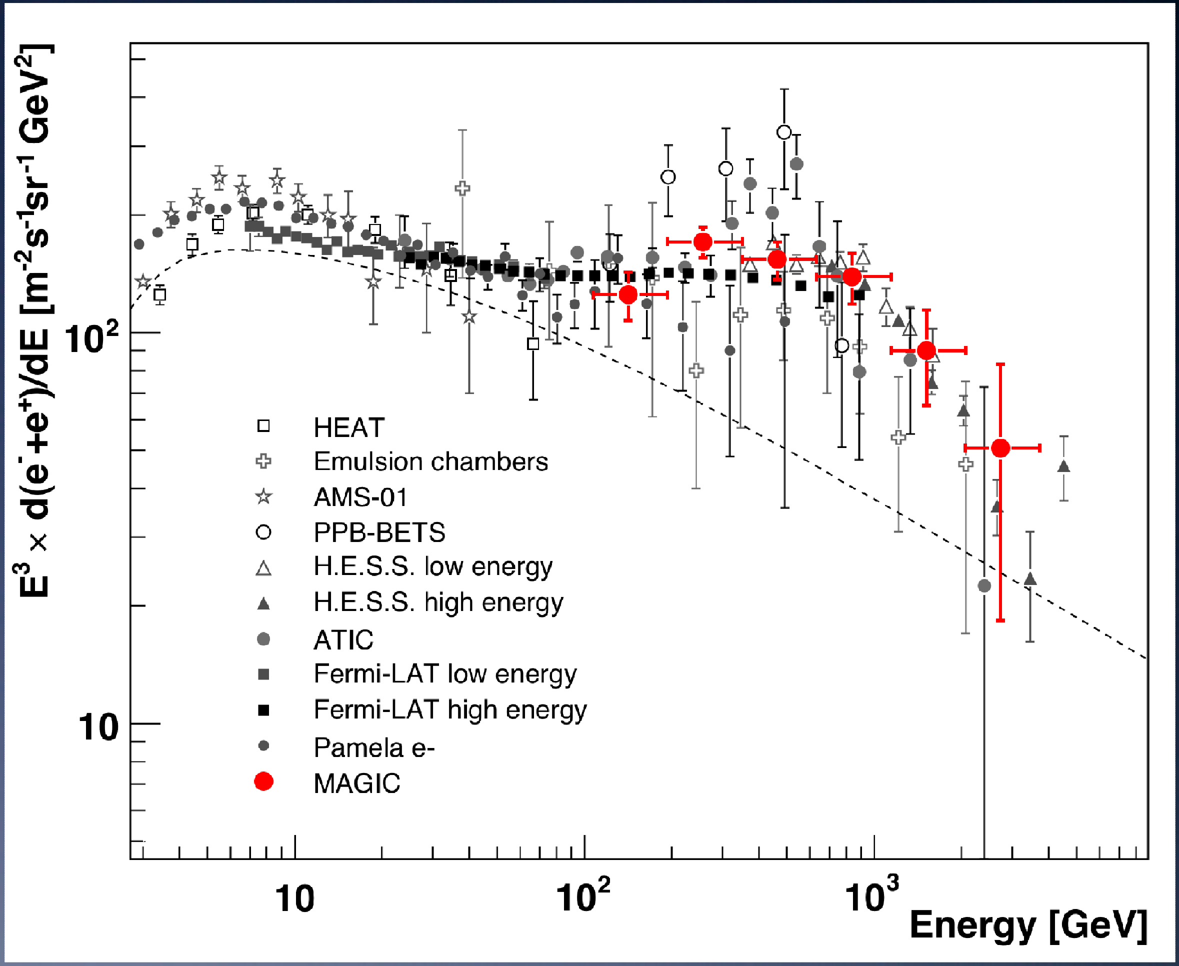
- **Discrimination only based on air shower images**
- **Hadron background estimated with MC simulations**

Cosmic electron spectrum with MAGIC

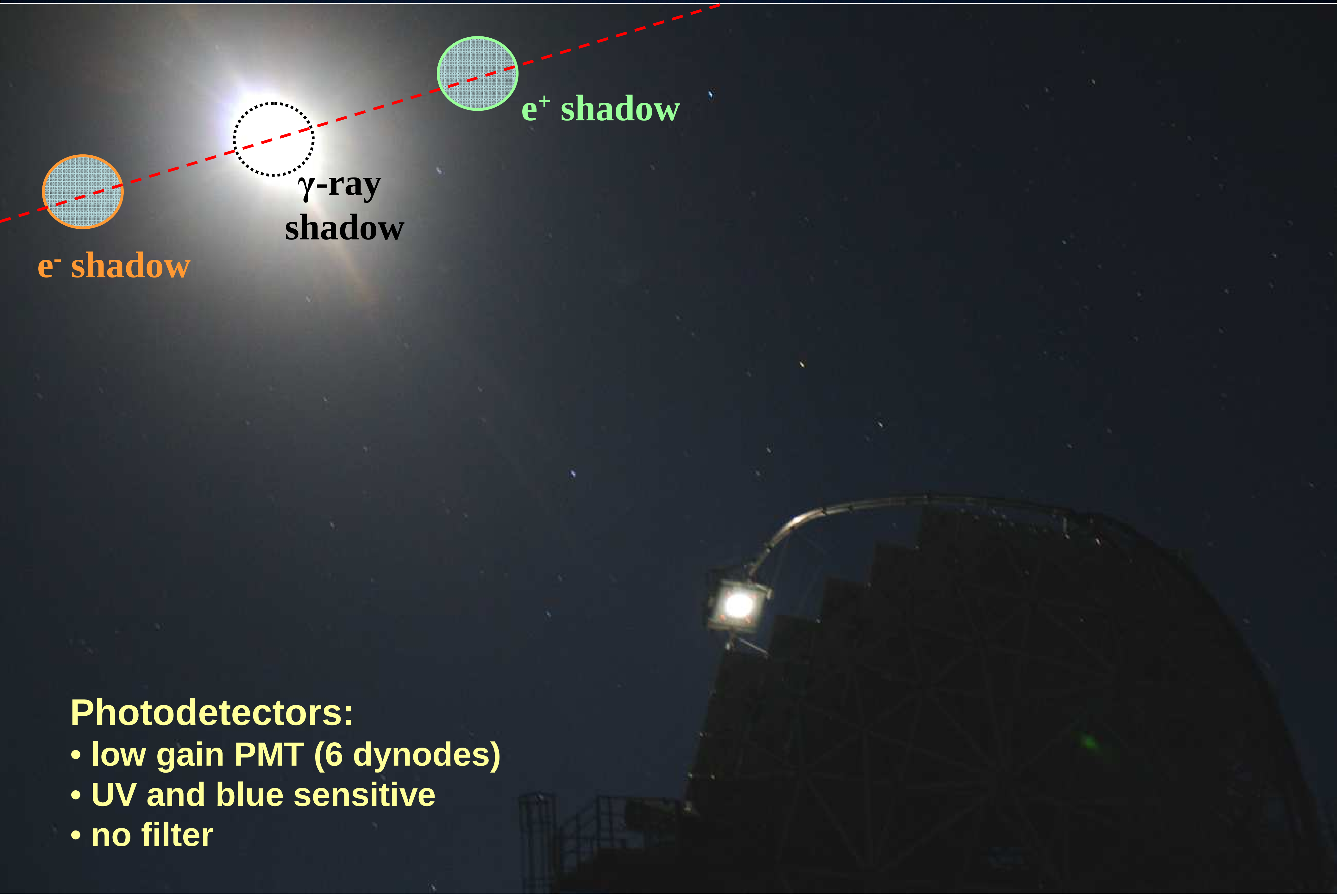




No gamma/electron discrimination
→ We use only extragalactic data



Moon shadow observation with MAGIC



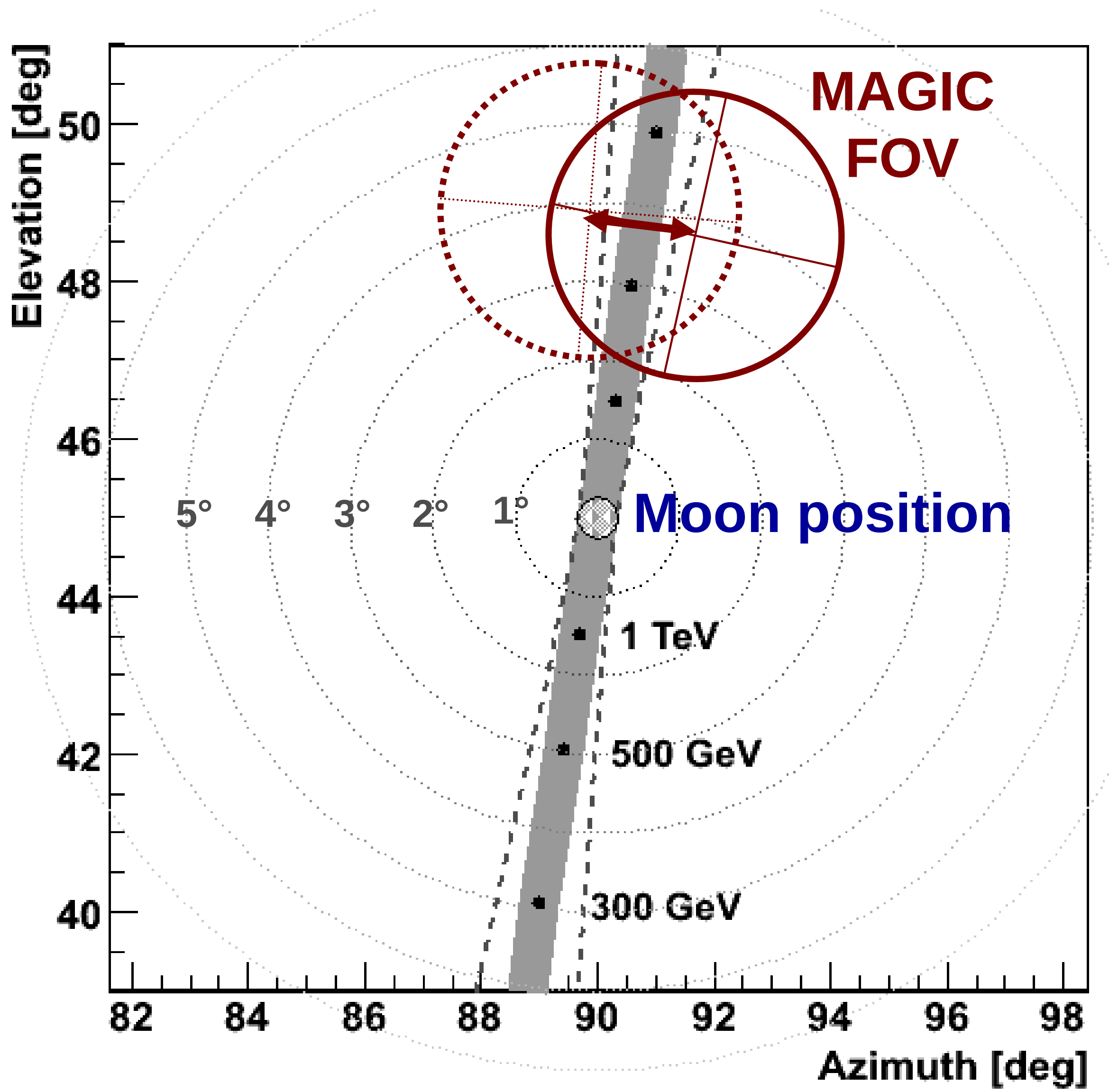
Photodetectors:
- low gain PMT (6 dynodes)
- UV and blue sensitive
- no filter

Observation strategy

- Distance to Moon for electron or proton shadow at 300-700 GeV: **~ 4 deg**

- Wobbling ⊥ dev. Axis
  - about same Zd
  - same dist. to Moon
  - Amplitude: **+/- 0.6 deg**
  - Fast wobbling: **10 min**

- Low HV settings
  - PMT gain/~1.5
  - Observation possible until:
    - **30 x Dark-night NSB**
    - **50% Moon phase**



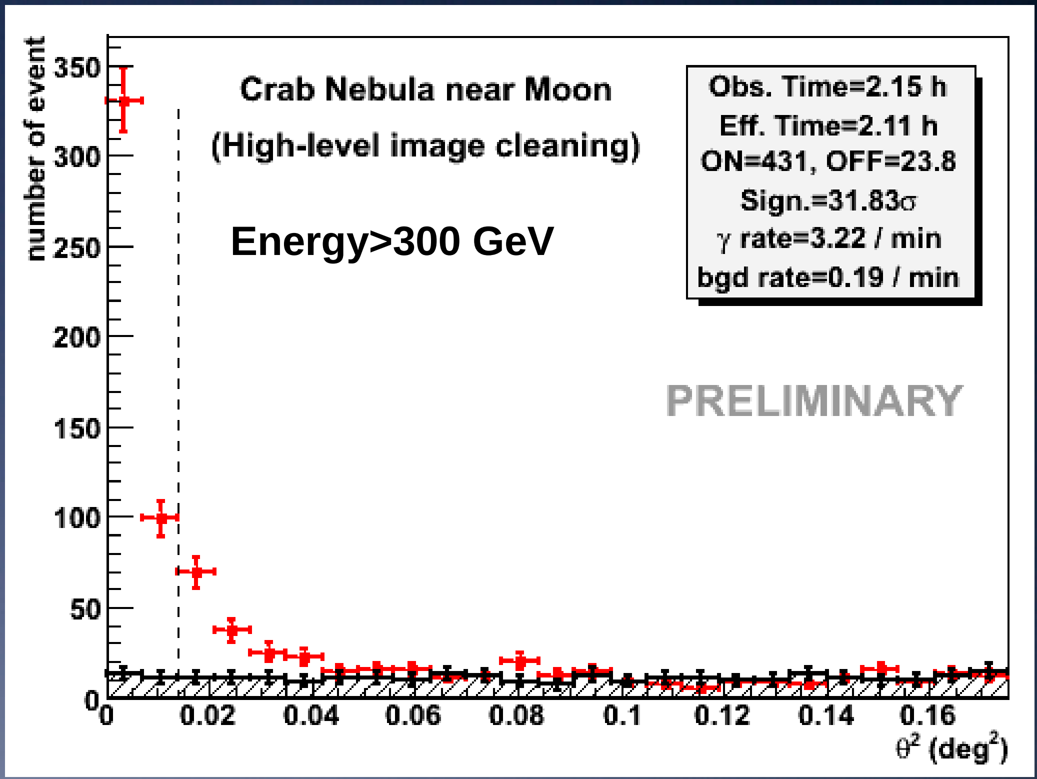
MAGIC Performance with strong Moon

Observation of Crab Nebula in the Moon shadow condition

- Moon distance: **~11 deg**
- Moon phase: **70%**
- Zenith Distance: **8-40 deg**
- NSB: **~20 × standard observation**

MAGIC Performance:

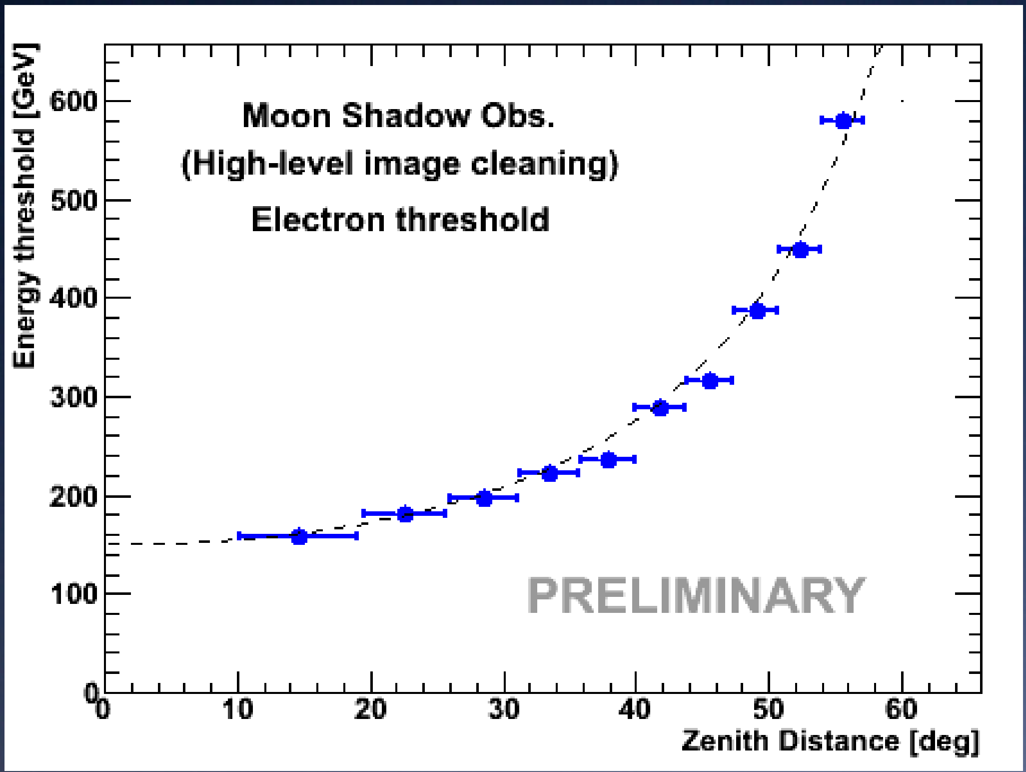
	Energy threshold	Sensitivity (E>300GeV)
Dark night	~50 GeV	0.8% crab
Moon Shadow	~200 GeV	1.2% crab

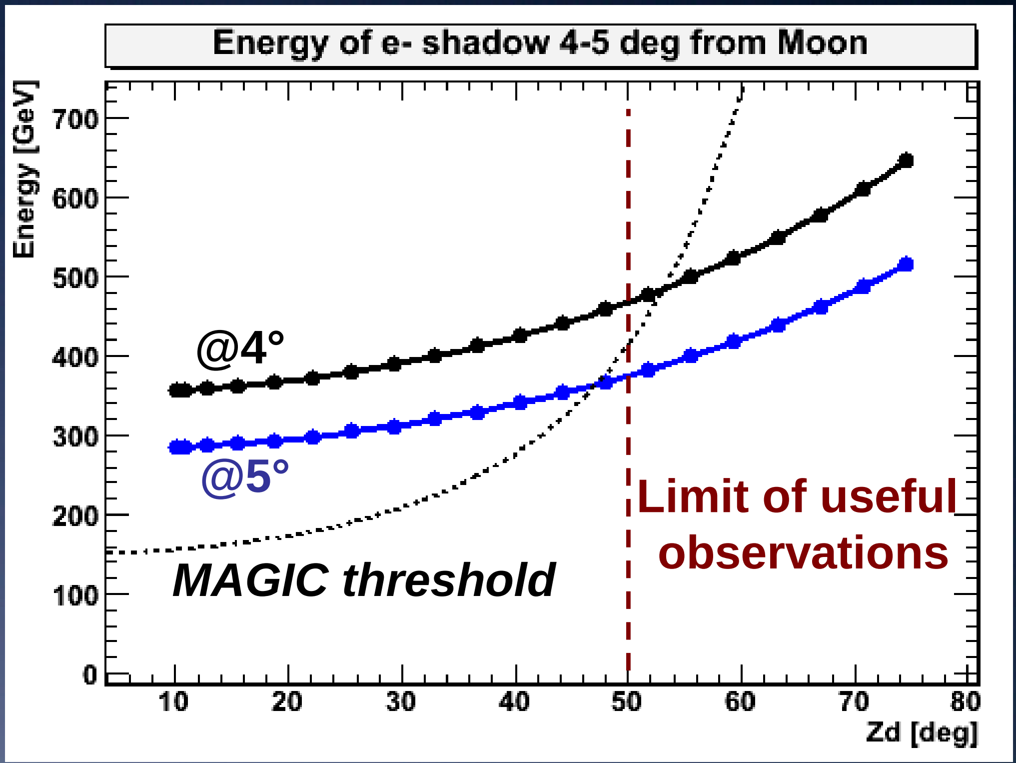


Energy threshold for electrons

Observation ~4° from Moon requires high image cleaning but energy threshold of electrons must be below ~300 GeV

→ **Observation Zenith angle < ~50°**



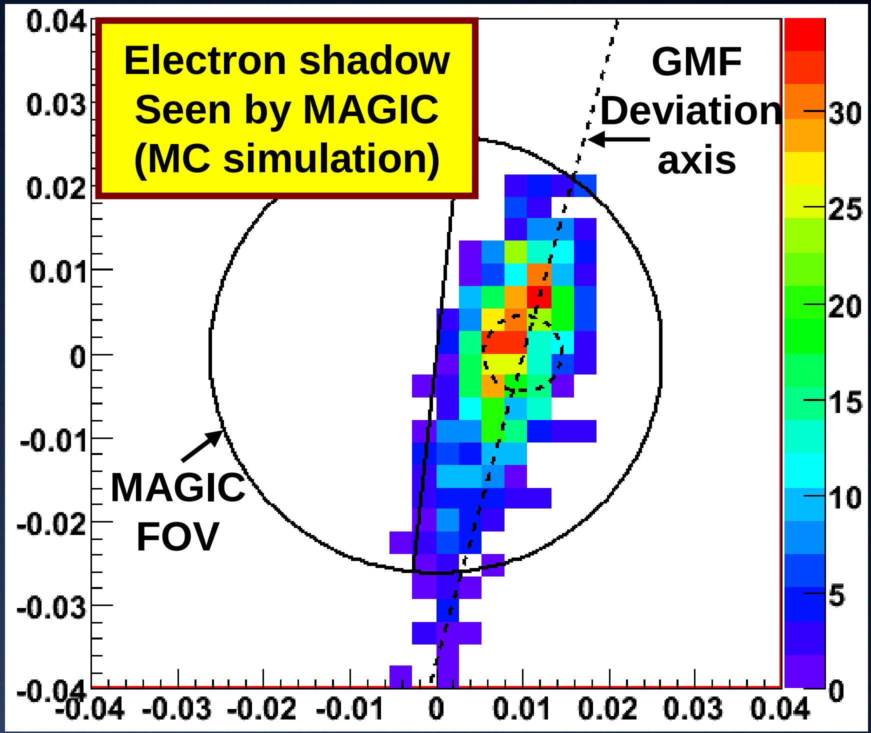


<u>Observation window:</u> only 10-20h /year for each shadow (e^- and e^+)

Expected signal

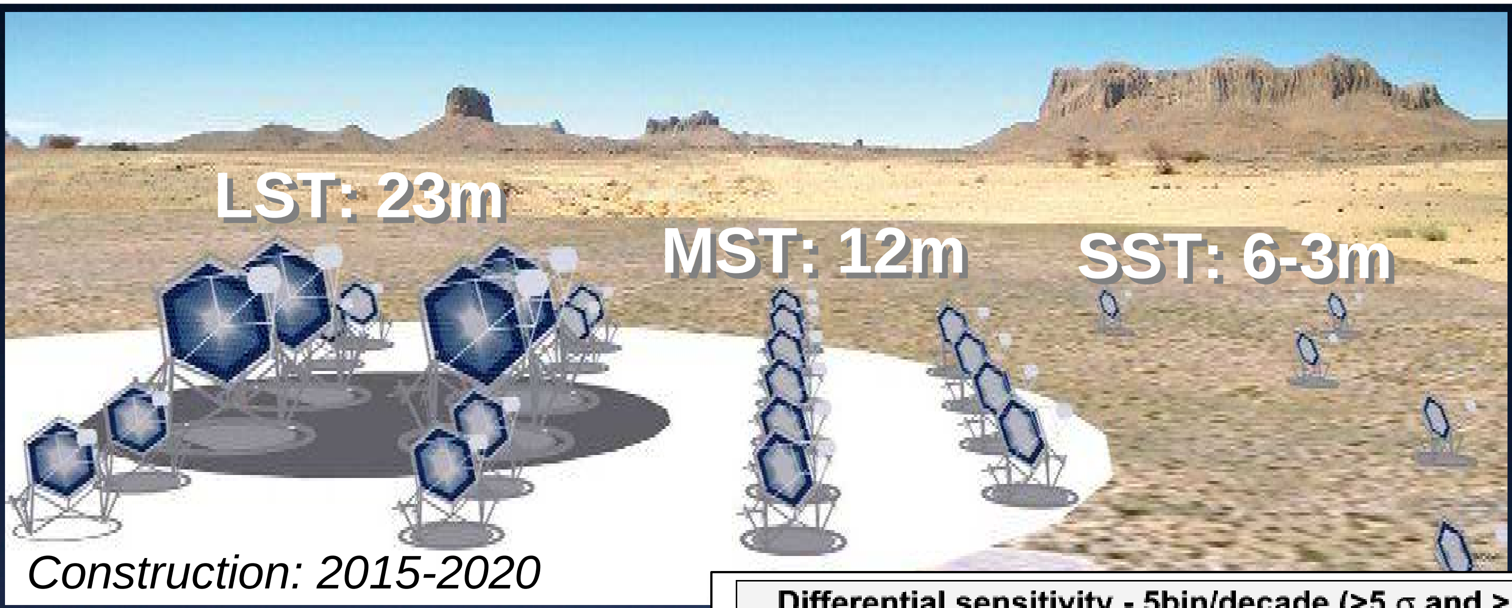
Moon shadow characteristics:

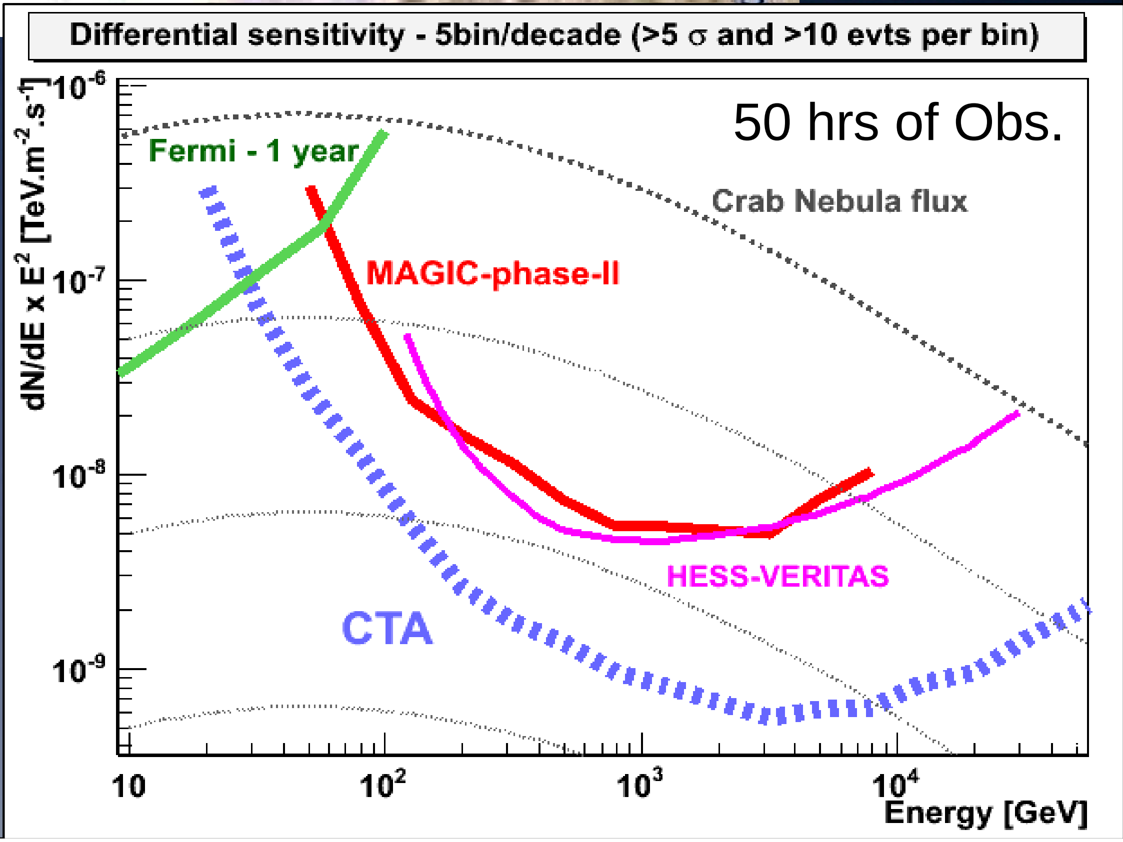
- “anti”-Flux = e$^-$ flux × Ω_{Moon}
  Moon solid angle Ω_{Moon}= *(6.6 ± 0.8) 10^{-5} sr*
- Extension: ~0.5°×1°
- MAGIC sensitivity (50h):
  - Moon shadow 300-700GeV: ~4.4% crab



Hypotheses	Flux 300-700 GeV (in crab unit)	Expected MAGIC detection time
MAGIC spectrum = *100%* e$^-$ (*80%* e$^-$ / *20%* e$^+$)	5.4 % (4.3% / 1.1%)	~30h (~50h / ~800h)
ATIC spectrum = *100%* e$^-$ (*60%* e$^-$ / *40%* e$^+$)	7.2 % (4.3% / 2.9%)	~20h (~50h / ~100h)

The future observatory CTA:





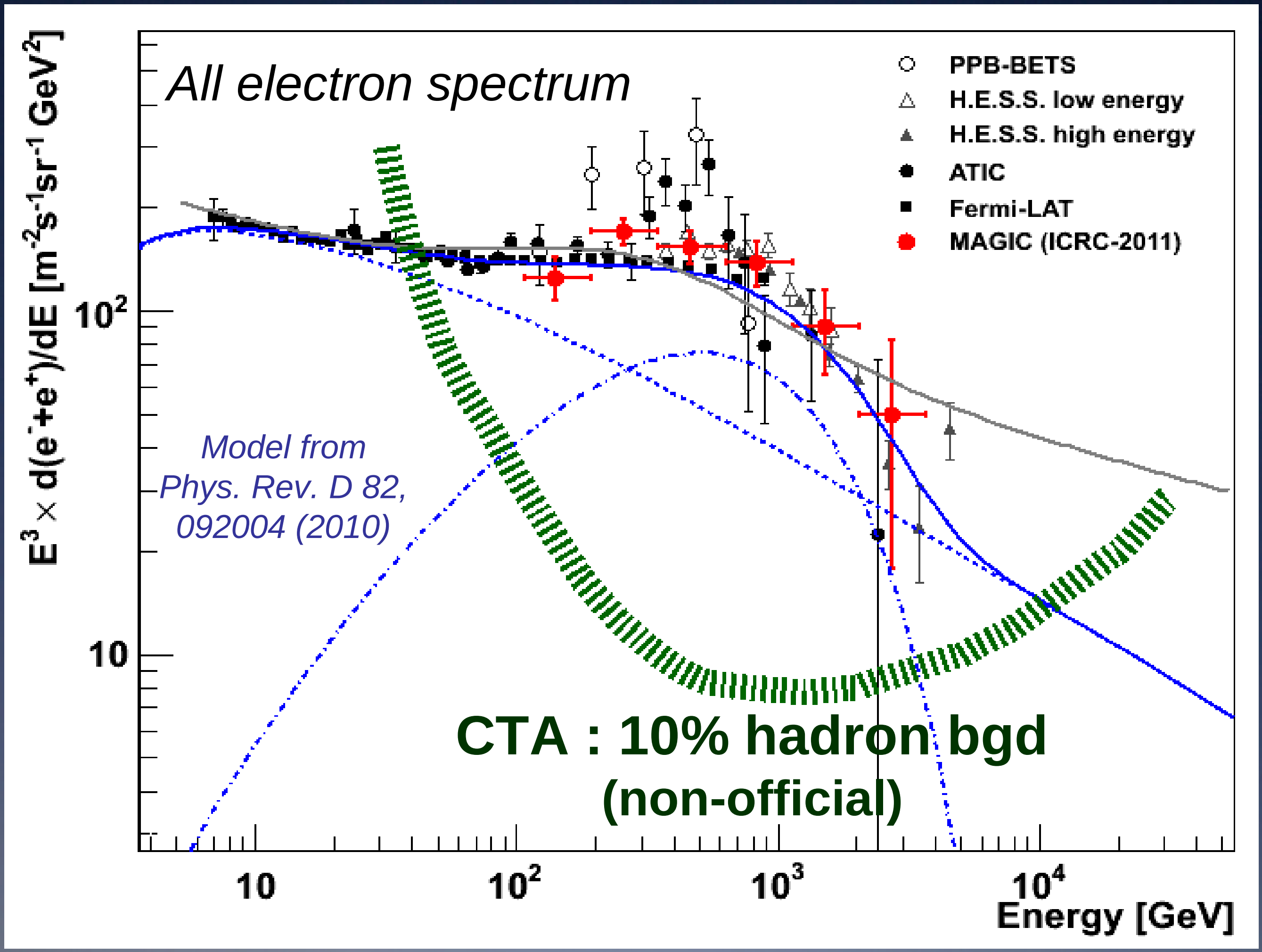
Performance:

➢ For gamma point source:

- Sensitivity: ~0.1% crab in 50h
- Energy range: 20 GeV – 200 TeV
- Angular resolution: 4' @ 1TeV
- Field of view: ~8°
- Energy resolution: <10%

Cosmic electron with CTA

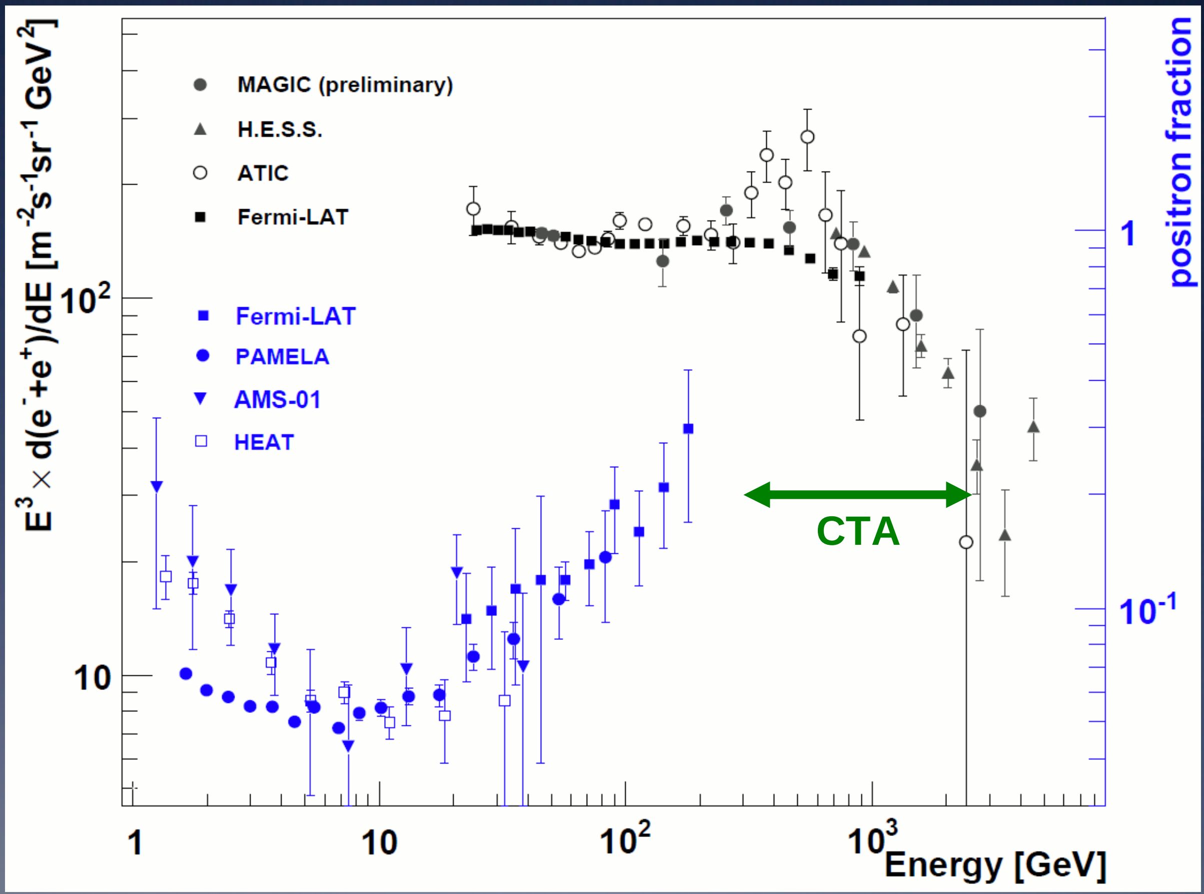
- $(e^- + e^+)$ spectrum from ~50 GeV to ~20 TeV
- Anisotropy at ~10% (or diffuse Gamma)
- Continue monitoring of the CTA performance



Moon shadow with CTA

- Sensitivity: ~10 times better than MAGIC
- Require robust photo-detector (UV filter, SiPM?)
- With MAGIC strategy: $e^+/(e^+ + e^-)$ = ~20% measurable
- Energy range: ~300 GeV to ~2TeV

  (if observation near the Moon is possible)



Conclusion

- Antimatter / matter ratio can be probed with the Moon shadow effect :

$\longrightarrow$ e^+/e^- ratio with Cherenkov Telescope

- MAGIC results :
  - (e^+ + e^-) spectrum measured with MAGIC
  - Moon shadow observed:
    - Target : e^- moon shadow at 300-700 GeV
    - Performance: detection expected in 30-50h
    - Data in one year: ~10h
    - Analysis ongoing
- Prospect with the future observatory CTA
  - (e^- + e^+) spectrum from ~50 GeV to ~20 TeV
  - e^+/e^- ratio measurable at TeV regime