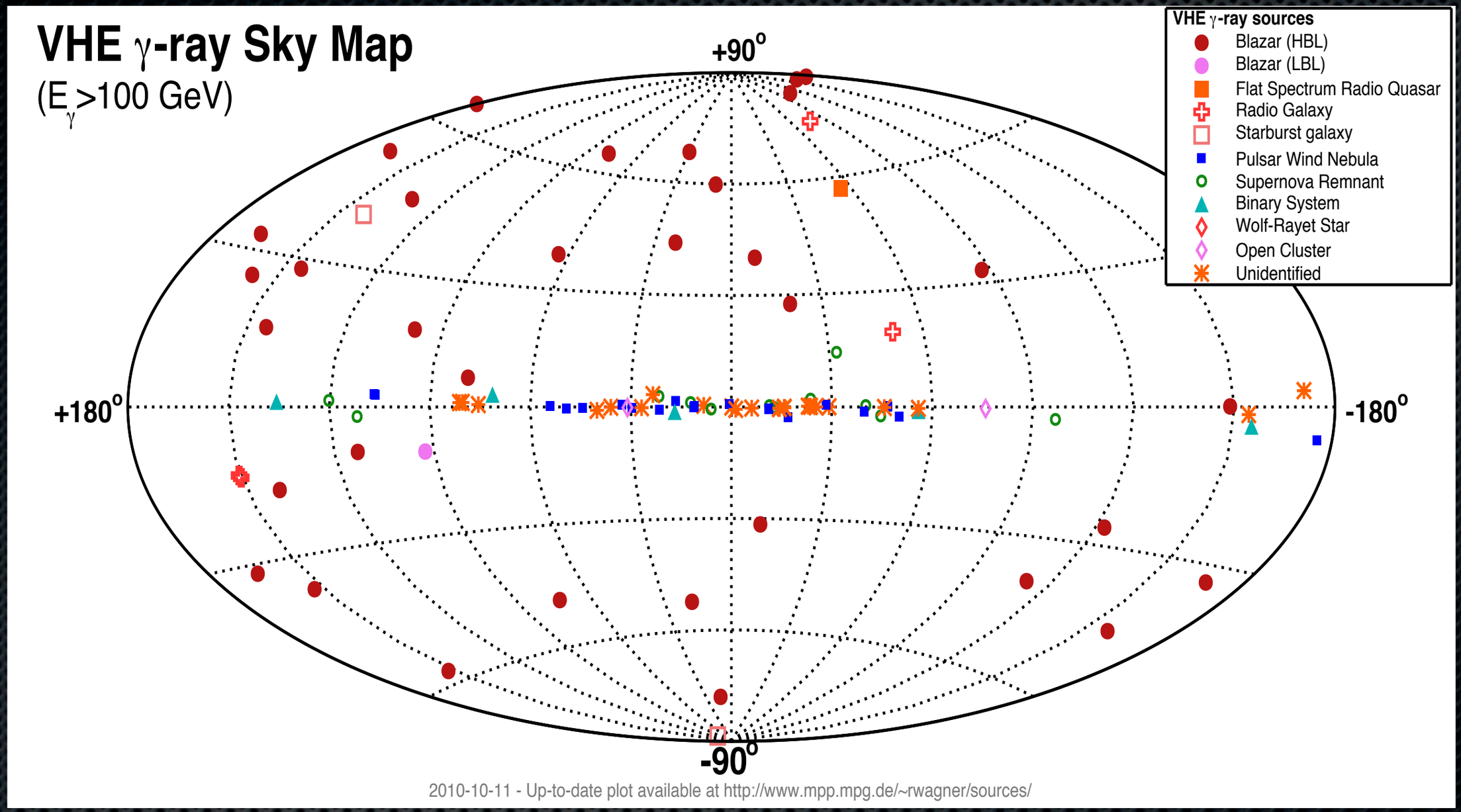
Gamma-ray Opacity Map of the Milky Way Galaxy with CTA

Yoshiyuki INOUE (Kyoto)

Akira Okumura (Nagoya), Stefan Funk (SLAC)

for the CTA Collaboration

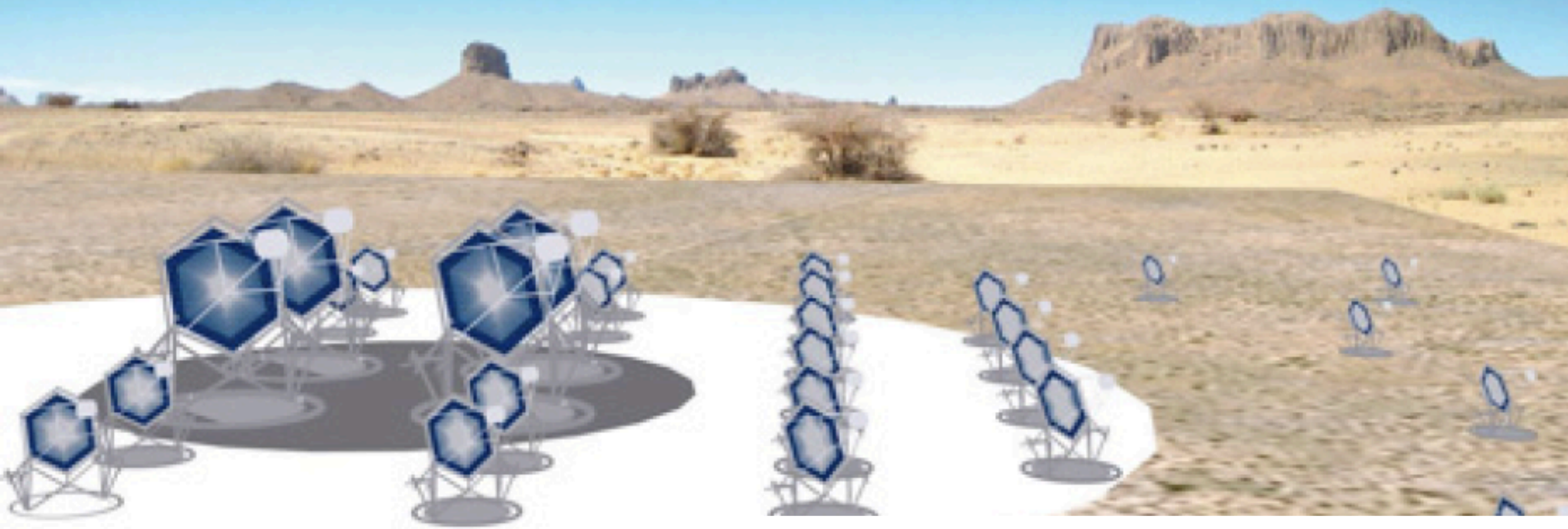
Current VHE Gamma-ray Sky



http://www.mppmu.mpg.de/~rwagner/sources/

- ~60 銀河系内天体。
- 宇宙線加速の起源(PEVATRON)に迫りつつある。

Cherenkov Telescope Array (CTA) Project

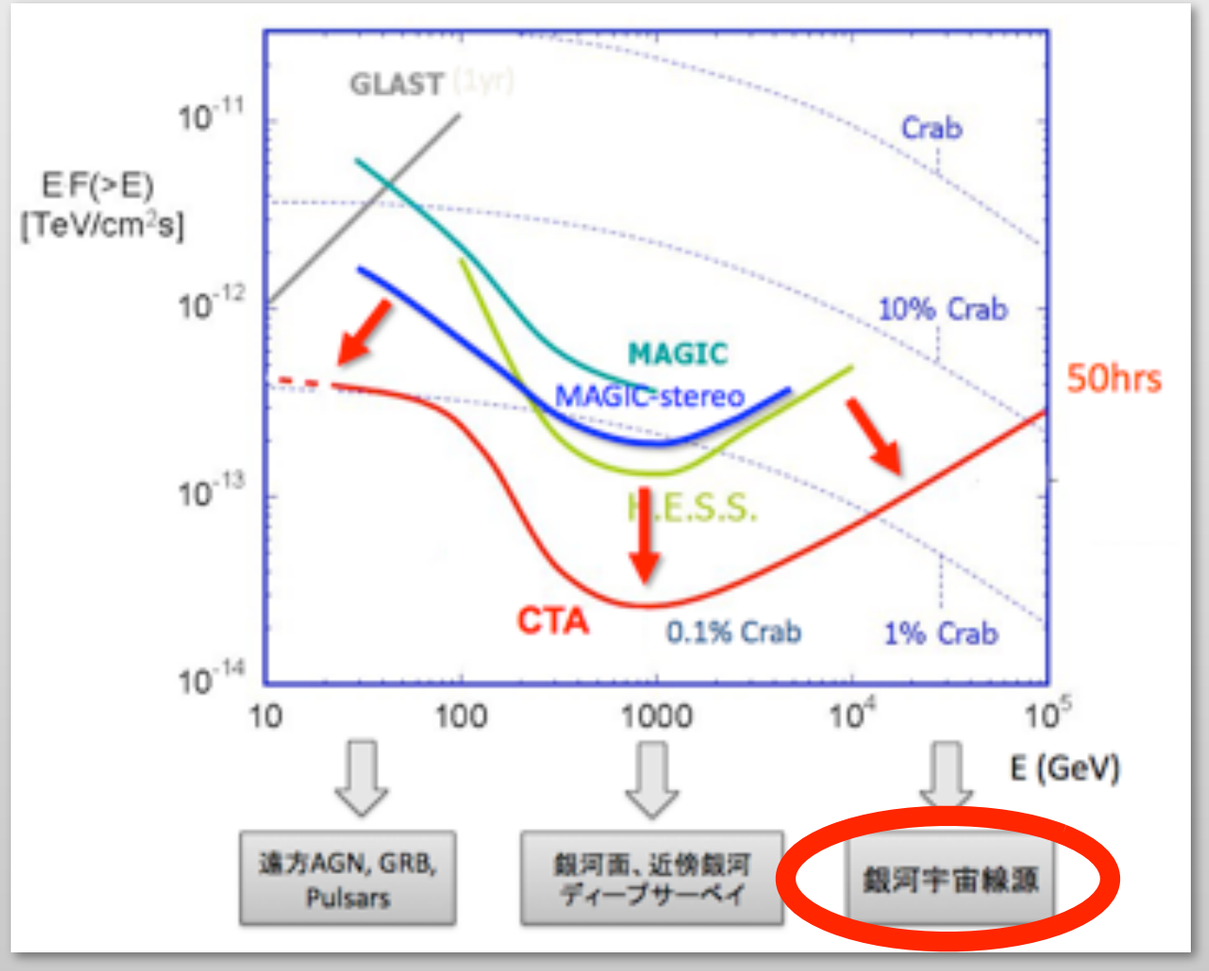


http://www.cta-observatory.jp/

CTA 計画（チェレンコフ望遠鏡アレイ計画）

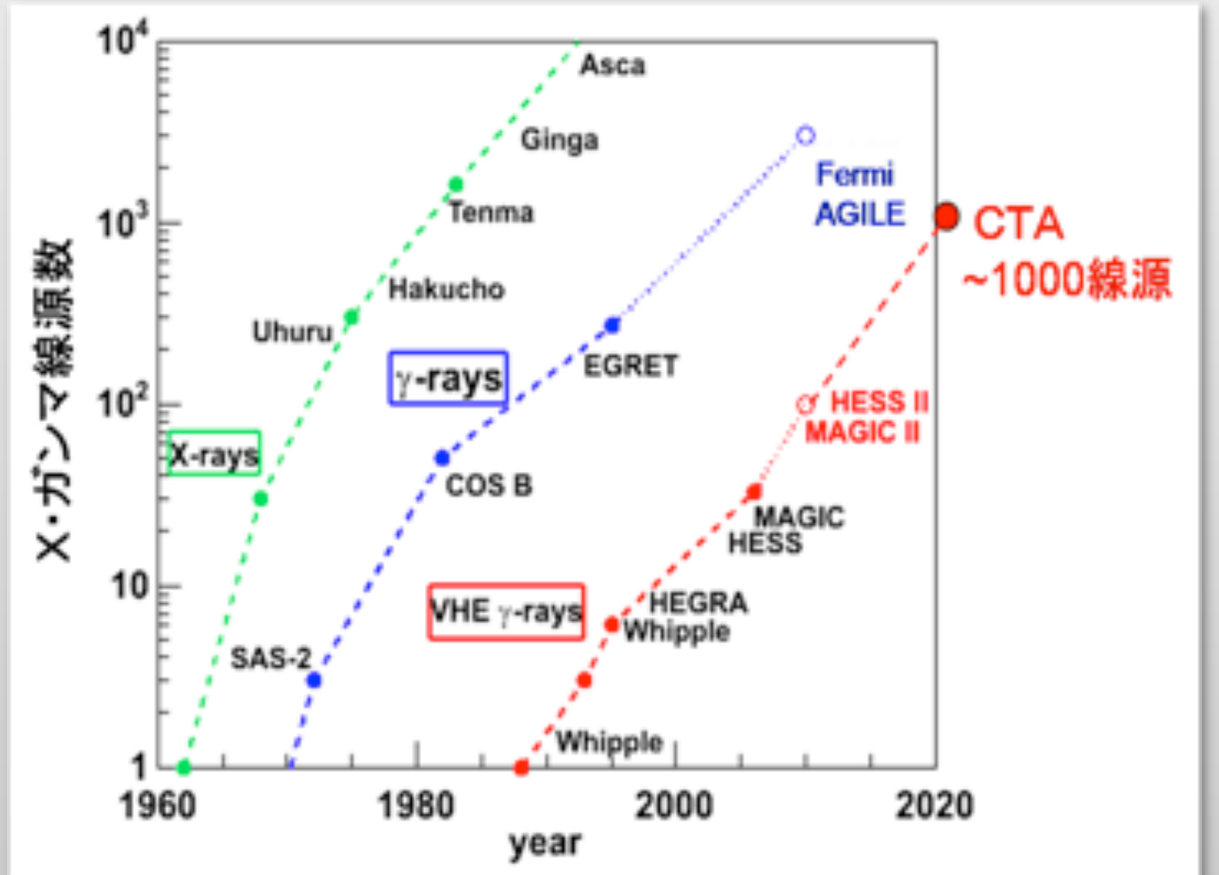
従来より一桁高い感度

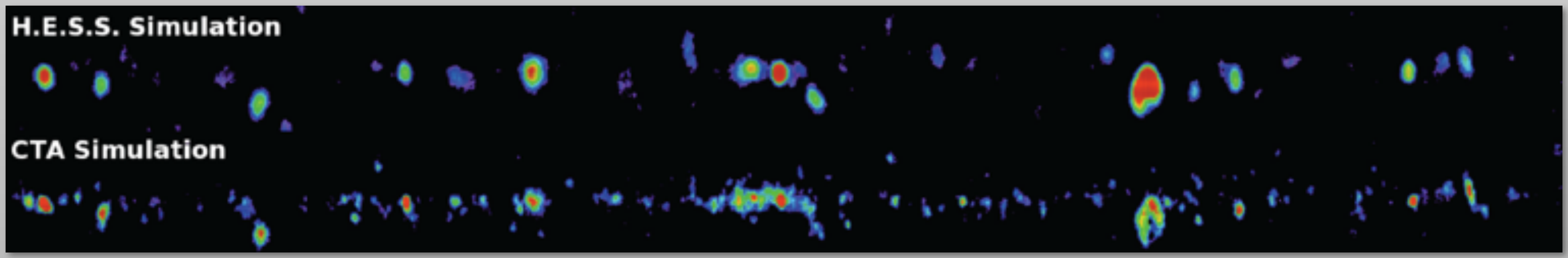
広いエネルギー領域



1000を超えるガンマ線源が

銀河系内・系外に発見されると予想される





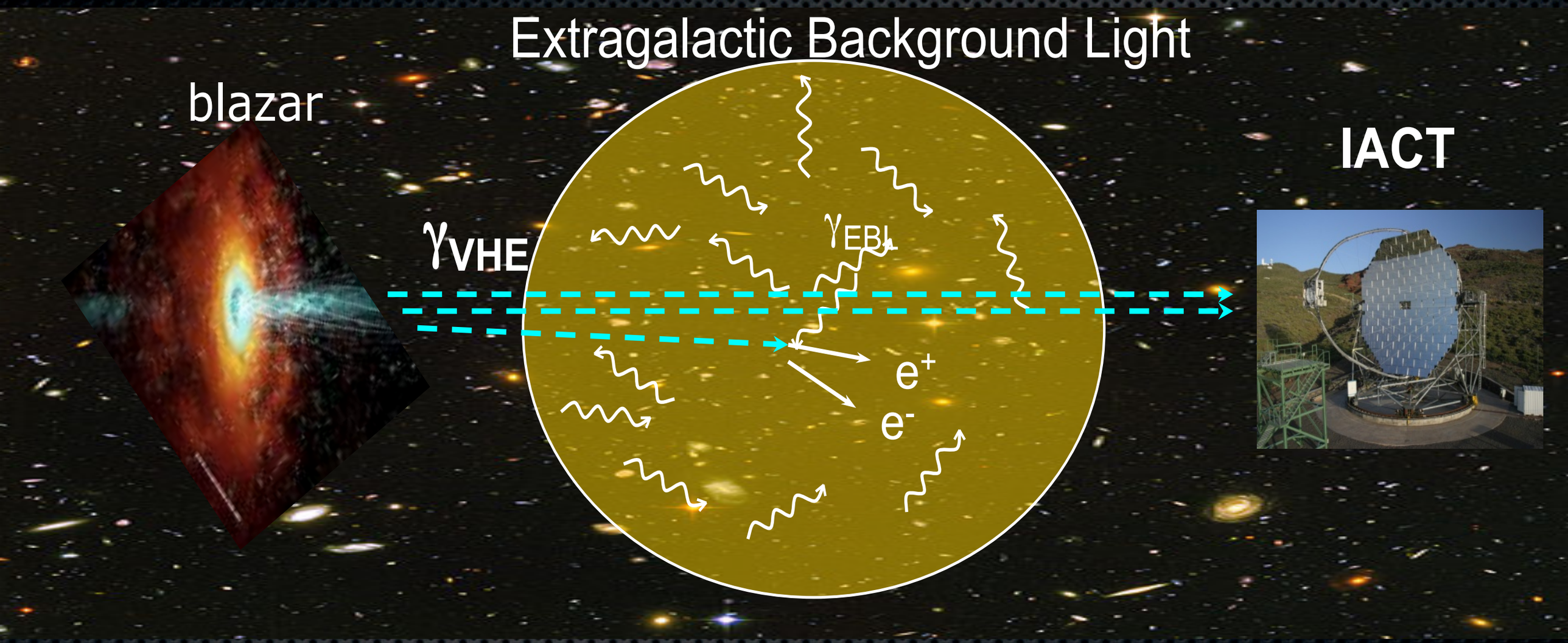
Simulation 銀河面スキャン（HESS and CTA）

Gamma-ray Absorption

- VHE gamma-rays are absorbed by ambient photon field. $\gamma_{(>\mathrm{VHE})}+\gamma_{(\mathrm{opt\text{-}IR})} \rightarrow e^{+}+e^{-}$
  - typical wavelength : $\lambda \sim 1.24(E/\mathrm{TeV})\mu\mathrm{m}$
- This leads to softening and cutoff in gamma-ray spectra of distant sources (e.g. blazars).

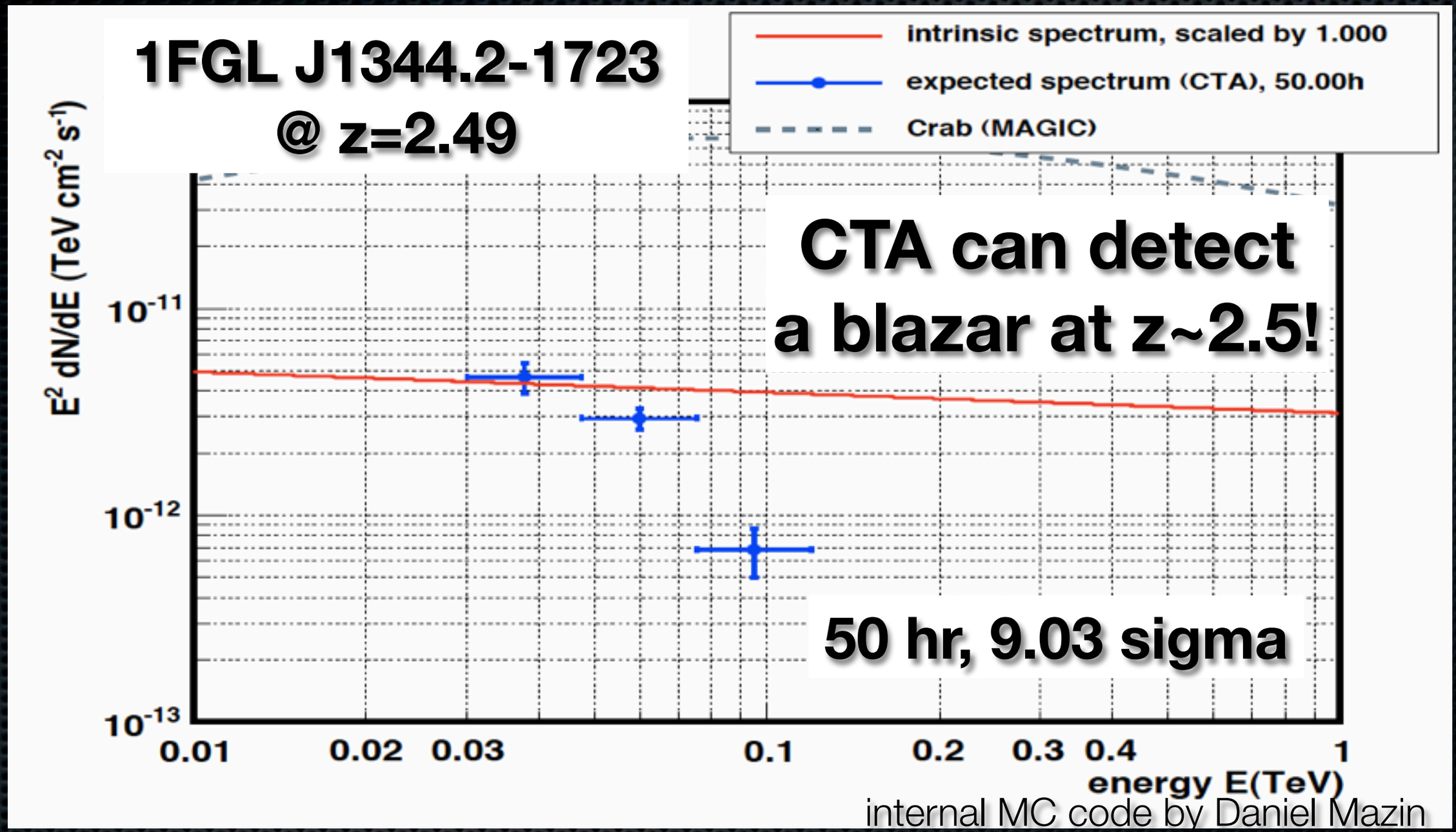
Extragalactic Sources

VHE Gamma-ray Absorption



- High redshift AGNs and GRBs enables us to study the cosmic star formation history.

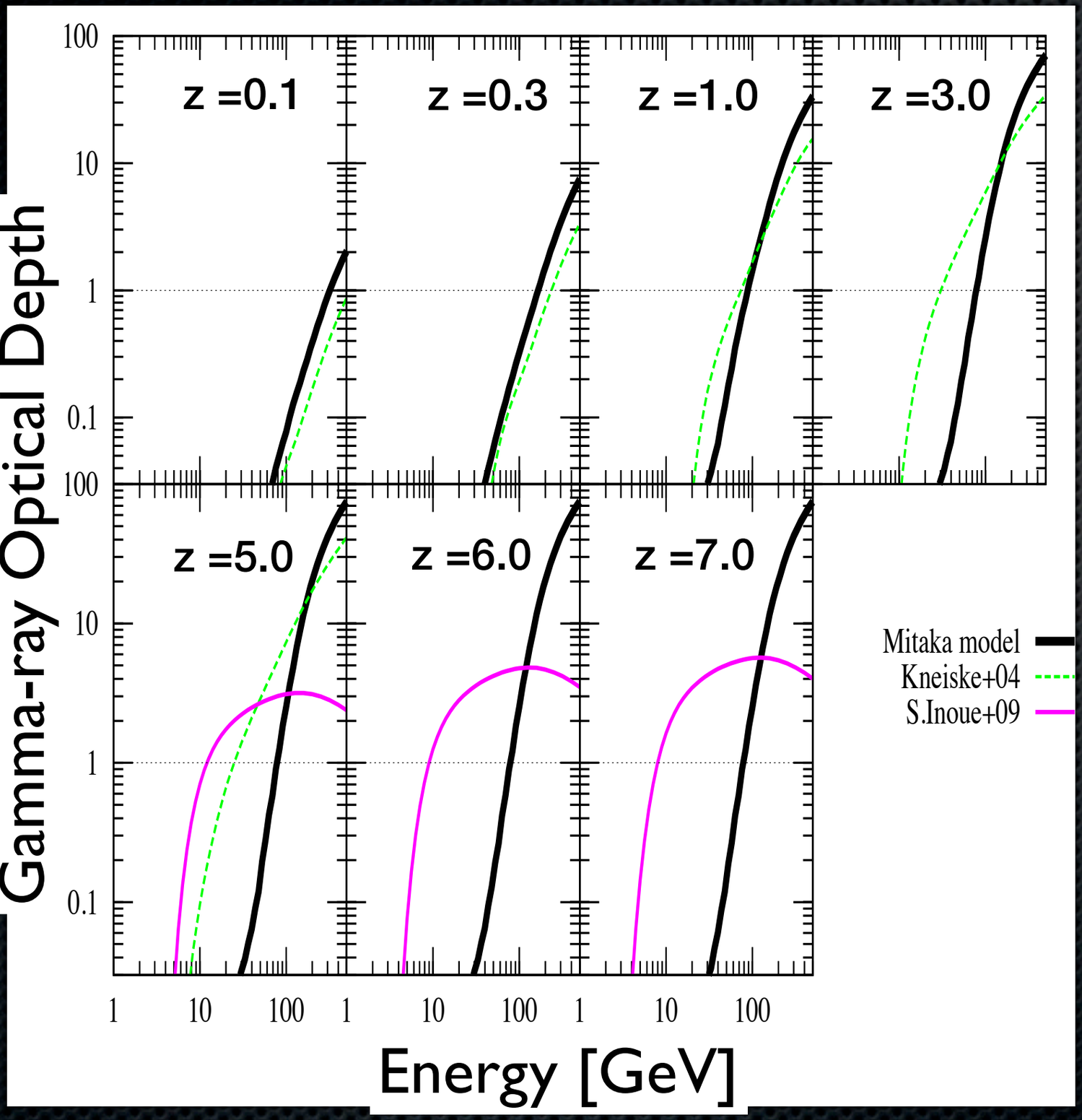
A Distant Fermi Blazar



internal MC code by Daniel Mazin

- Spectrum is simply extrapolated from the Fermi data (Γ=2.11).
- >20 blazars at z>1.

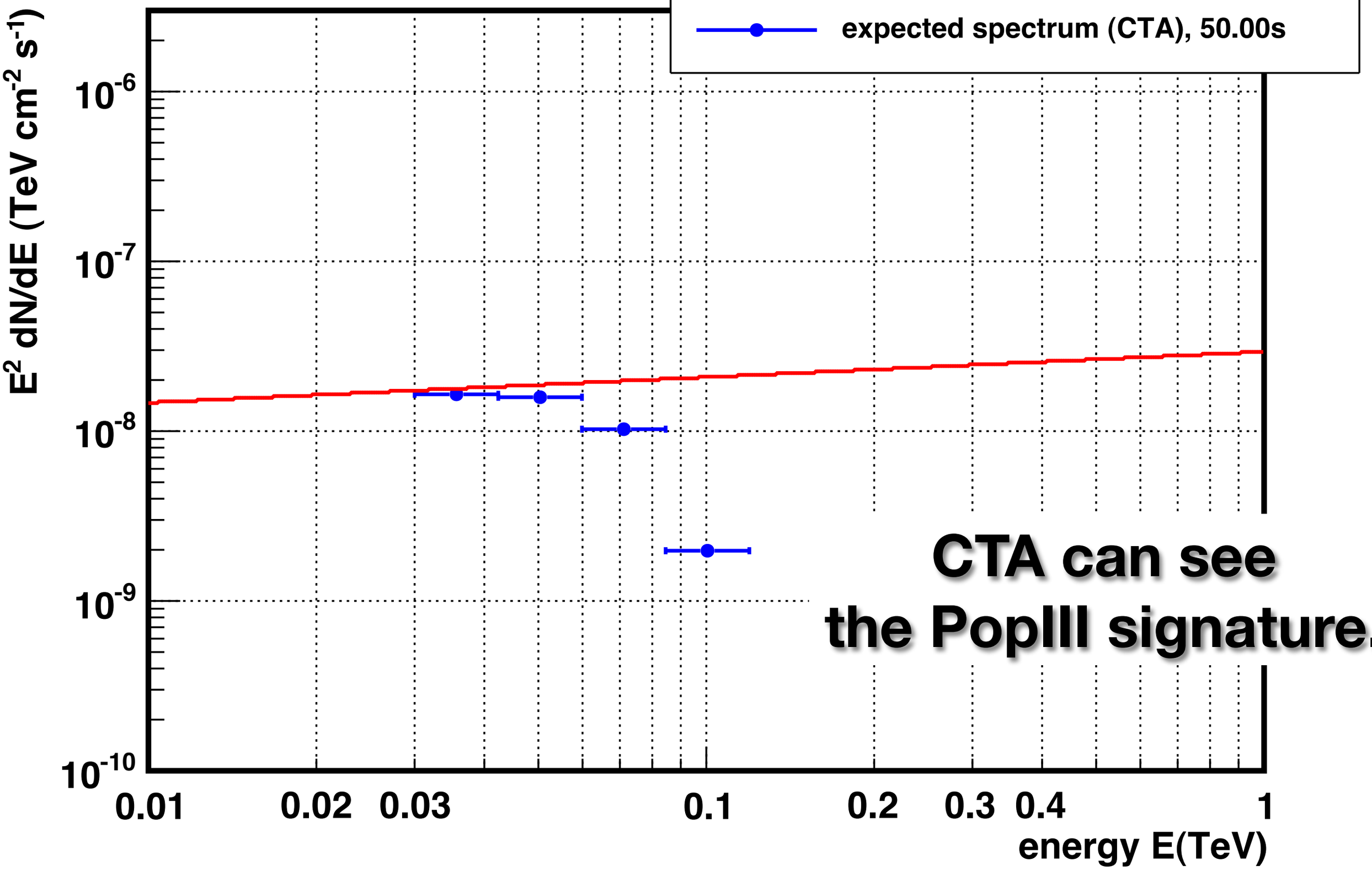
A new probe of reionization epoch: GeV gamma-ray attenuation



- $\gamma_{(>GeV)}+\gamma_{UV}\rightarrow e^{+}+e^{-}$.
  GeV flux attenuated by high-z UV background (Oh '01, Gilmore+09, S.Inoue+09).
- Constraints on first star/galaxy formation.
- GRBs at z>6 by CTA ?

GRB080916C @ z=6.5

YI EBL



CTA can see the PopIII signature.

Galactic Sources

MC simulated Galactic plane map

CTA-Survey in prep.

Expected Source Counts

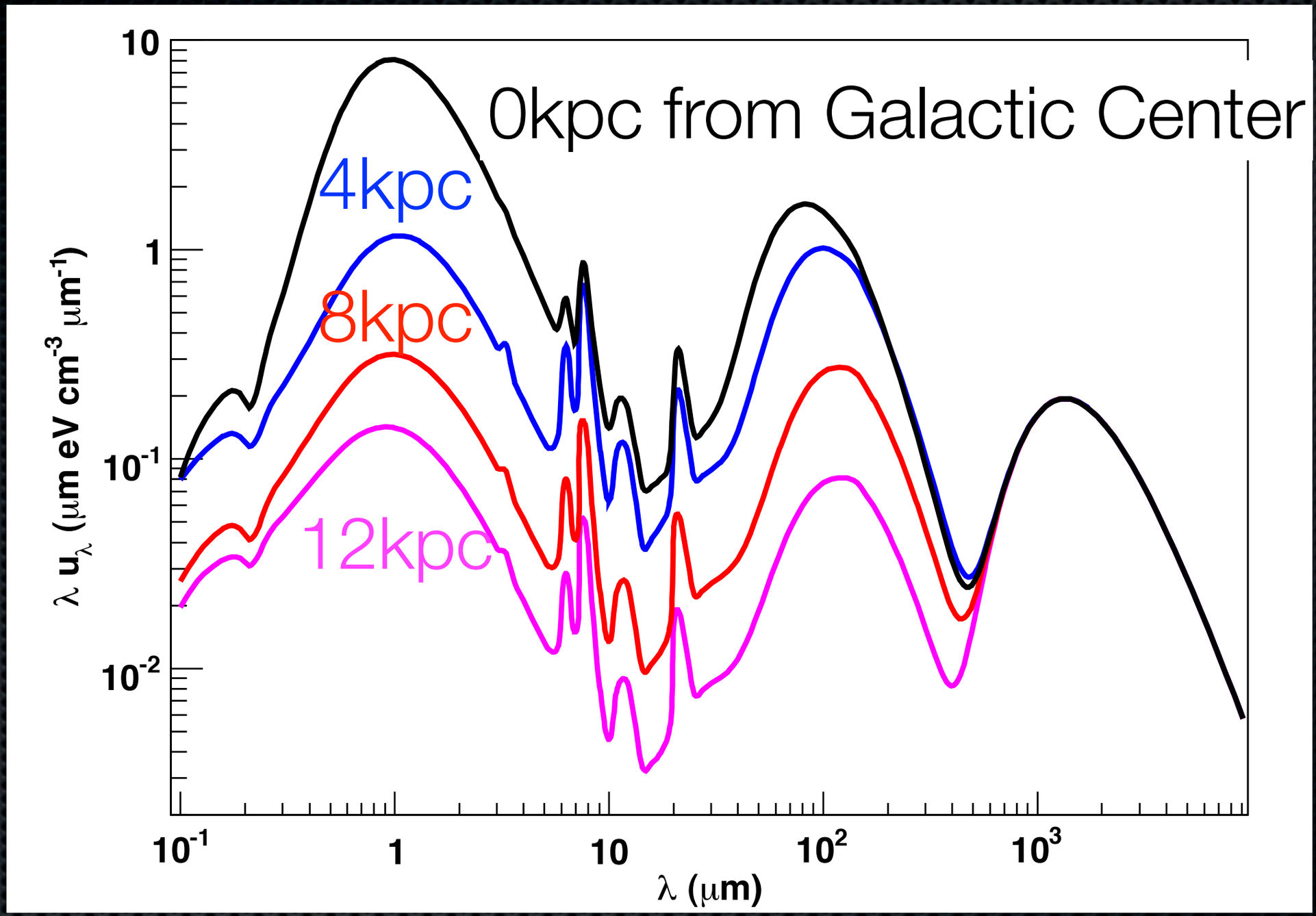
- 20-70 SNRs (>3mCrab, |l|<60°, |b|<5°)
  - Assume 2.5 SNe/century & VHE dominant of 5 kyr
- 300-600 PWNe (>3mCrab, |l|<60°, |b|<5°)
  - Assume 40 kyr lifetime
- 200 sources in |l|<30°, |b|<0.5° (~3 sources/deg^2)
  - cf. ~500 AGNs are expected in the entire sky

    (YI, Totani, & Mori ’10, CTA-AGN in prep., CTA-Survey in prep.).

Gamma-ray Opacity of the Milky Way

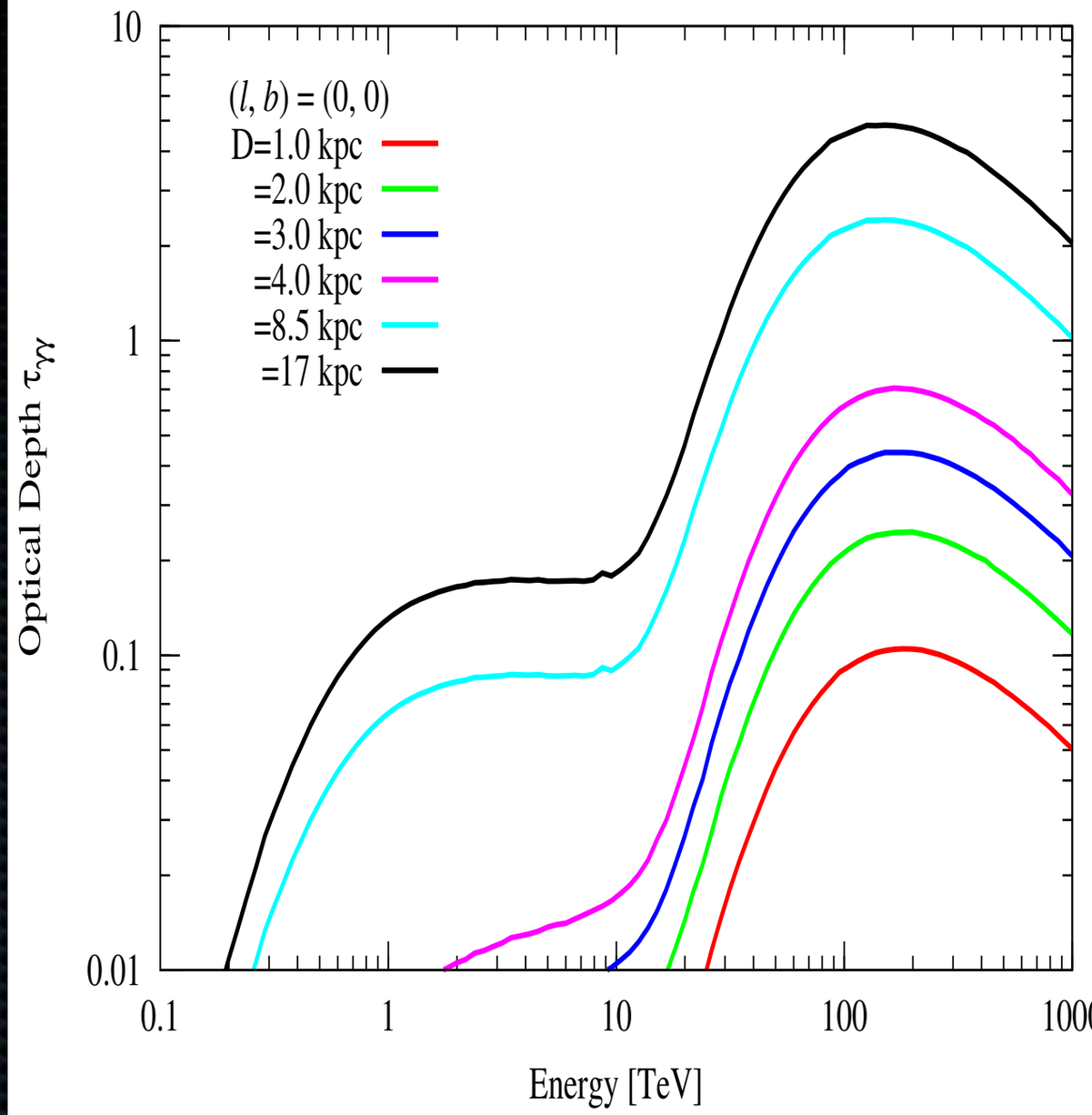
- Same as EBL, Galactic interstellar radiation field (ISRF) would absorb VHE gamma-rays (Moskalenko+'06,Zhang+'06).
- Is it possible to see the PeV CR signature with CTA, HAWC, or LHAASO?
- Is it possible to constrain the 3-D Galactic ISRF with CTA?

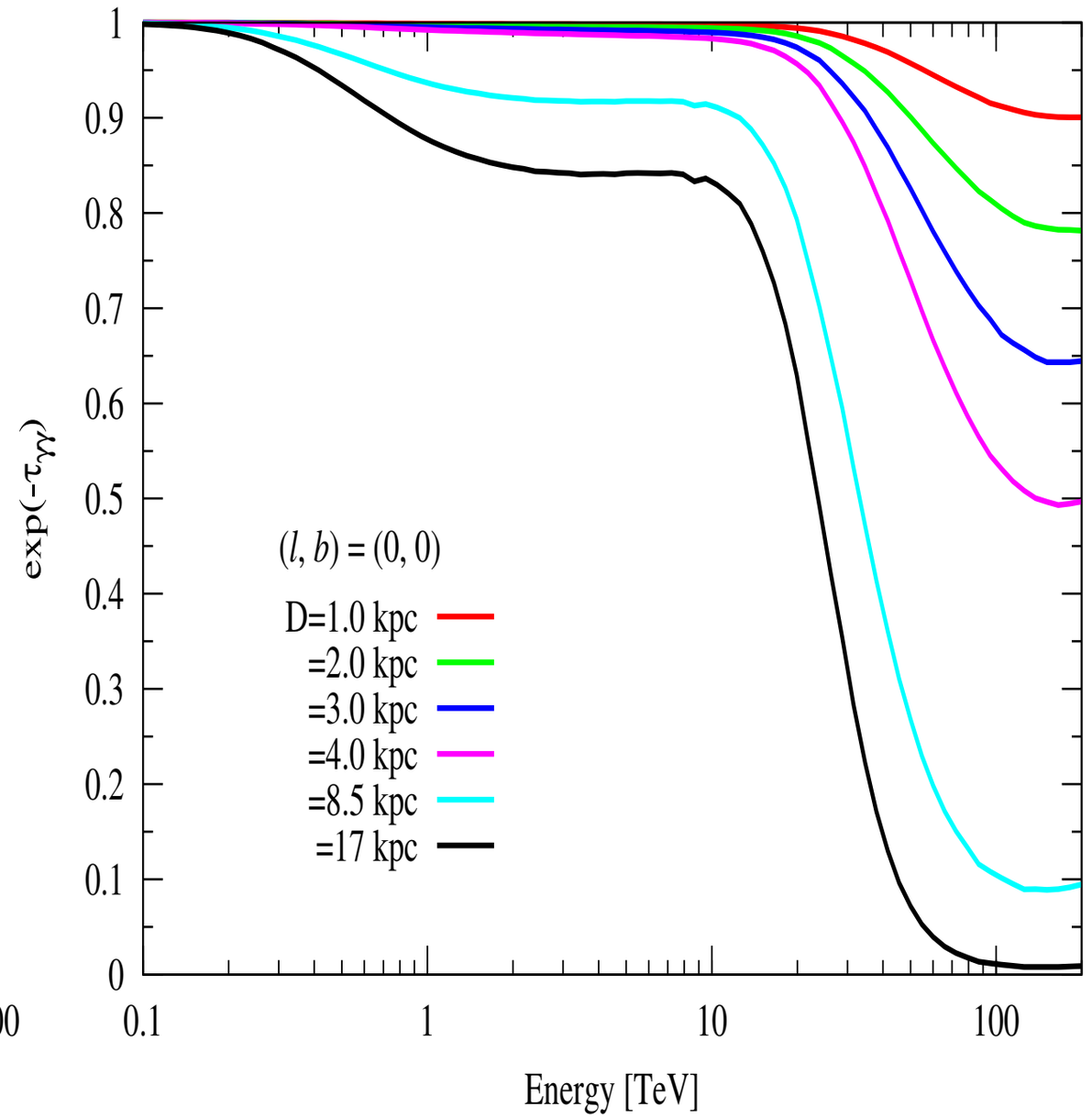
ISRF of the Galaxy



- ISRF model by GALPROP (Porter+'08).
  - Large uncertainty in modeling.
  - e.g. Cylindrical approximation for the 3-D ISRF map.

Optical Depth: Distance
(l, b) = (0, 0)

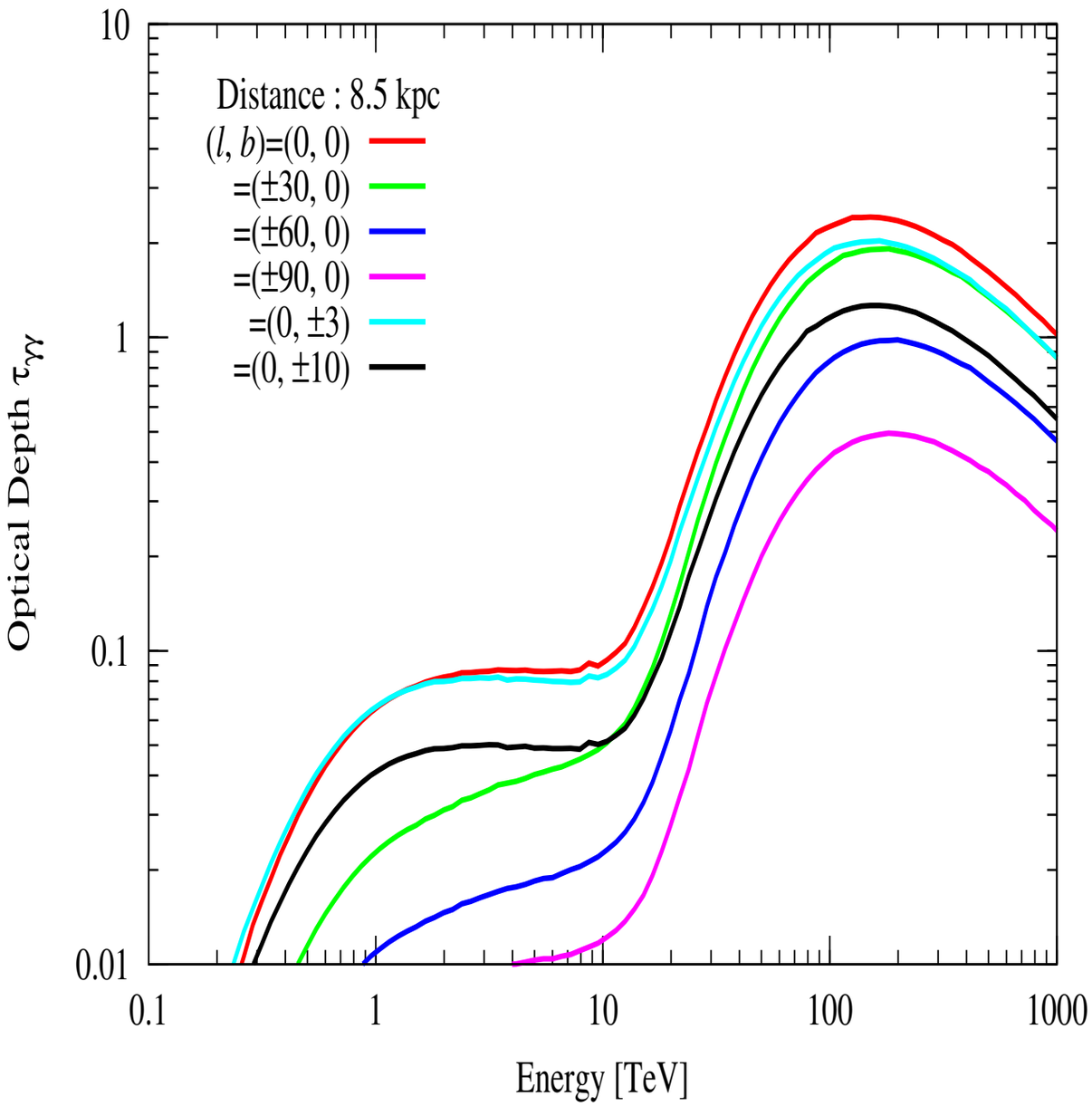


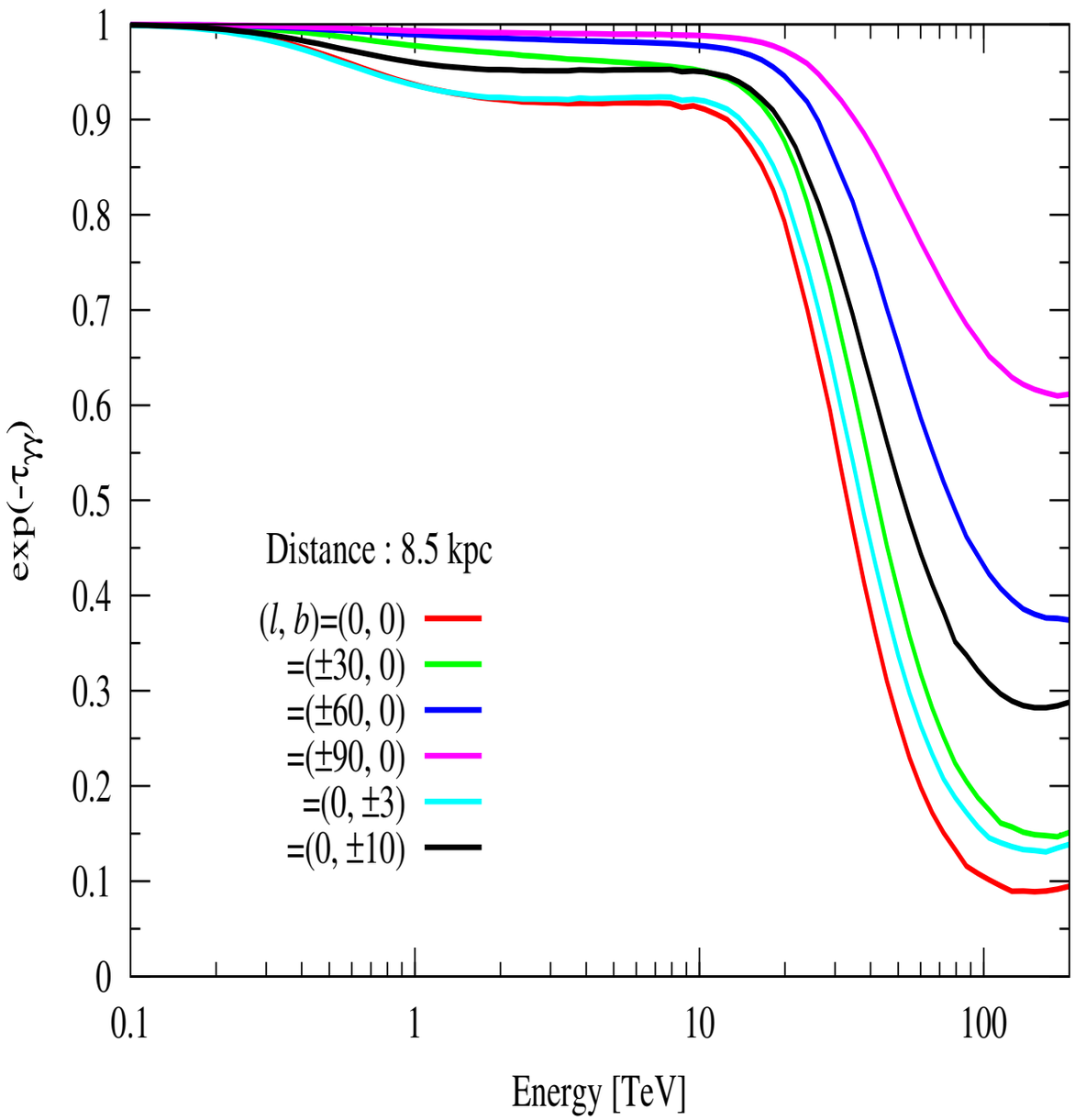


see Moskalenko+'06

- Absorption is significant above 30 TeV at >4 kpc away from us.

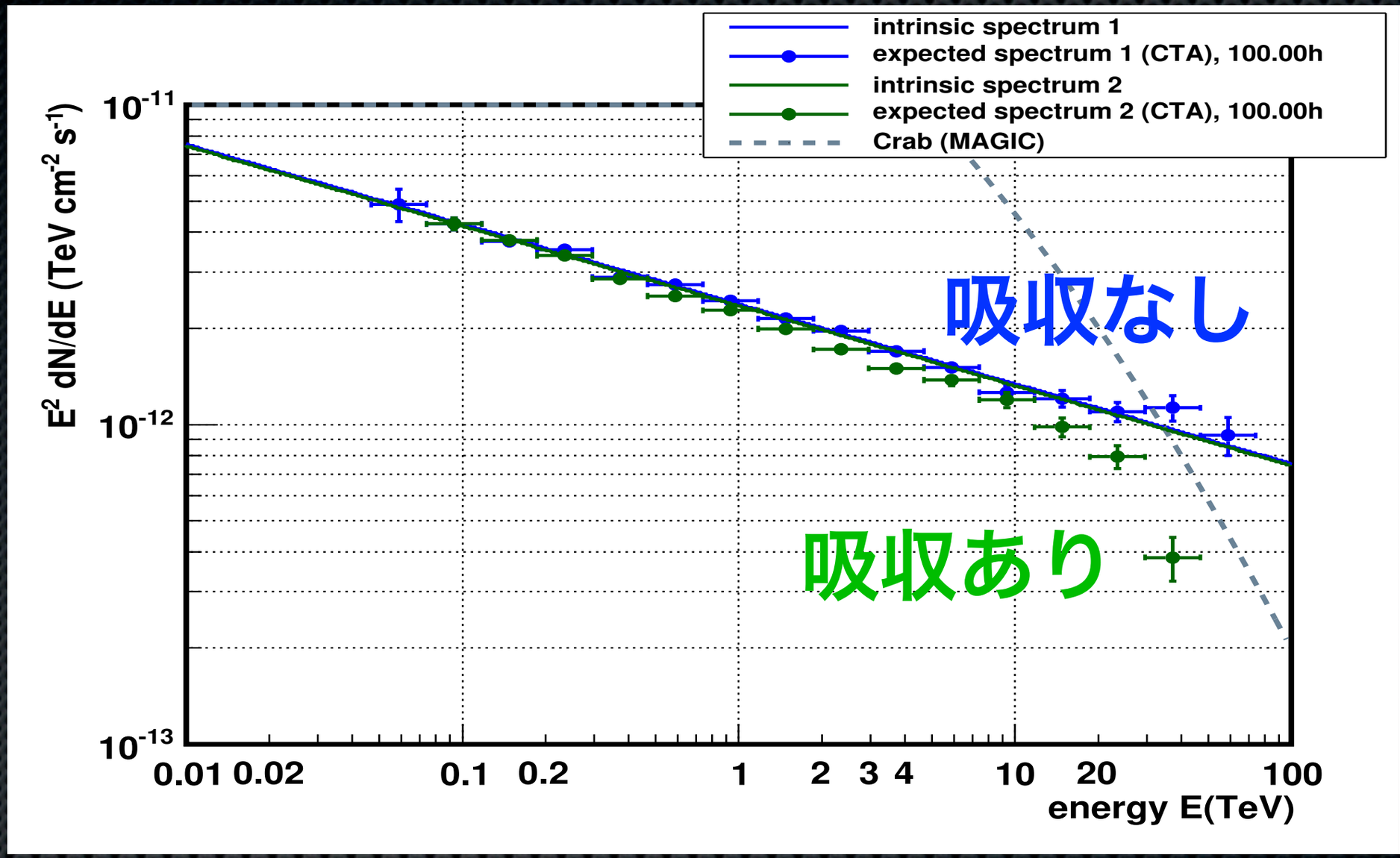
Optical Depth : Coordinate Distance = 8.5 kpc





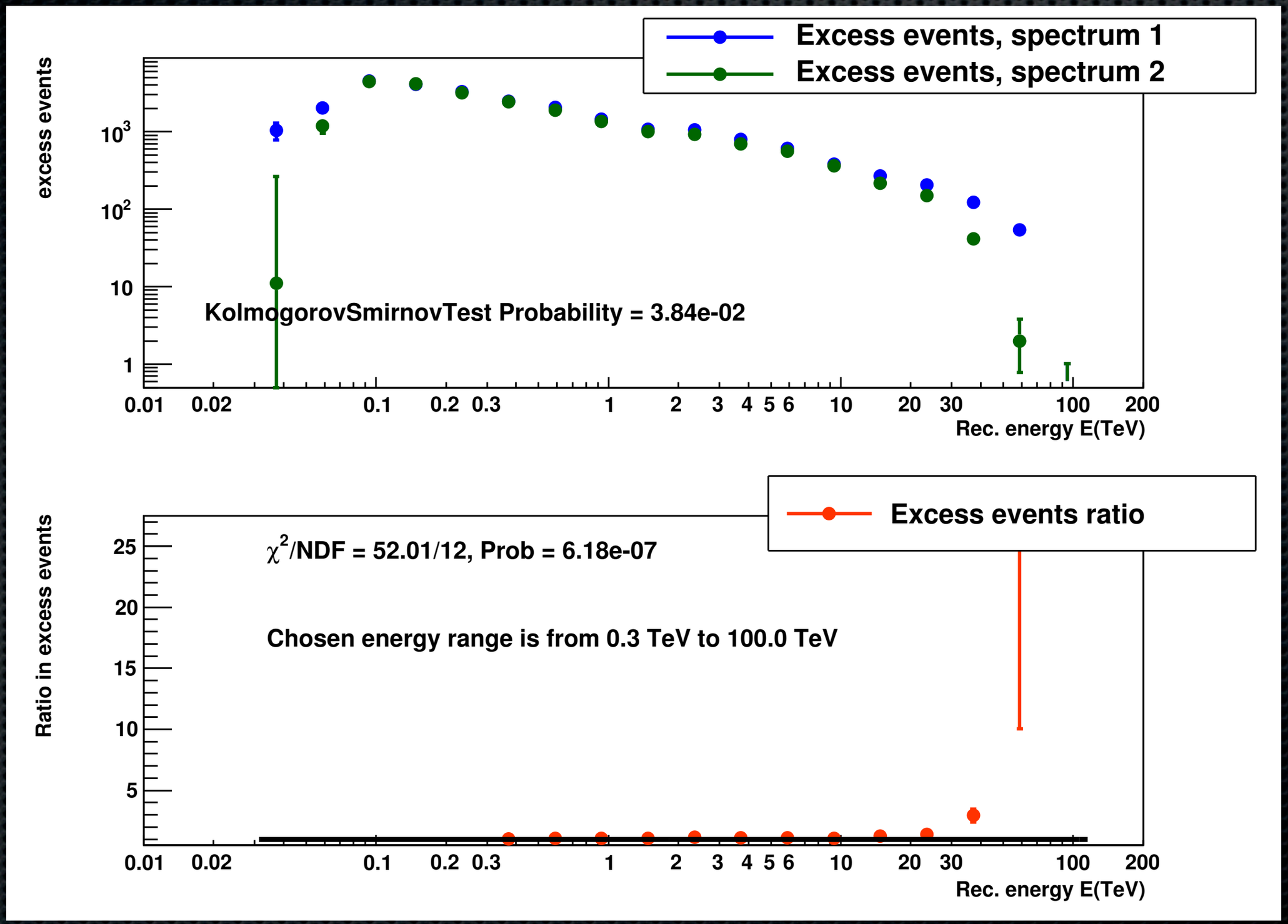
see Moskalenko+'06

Galactic Center @ 8.5 kpc w/ CTA (100 hr)

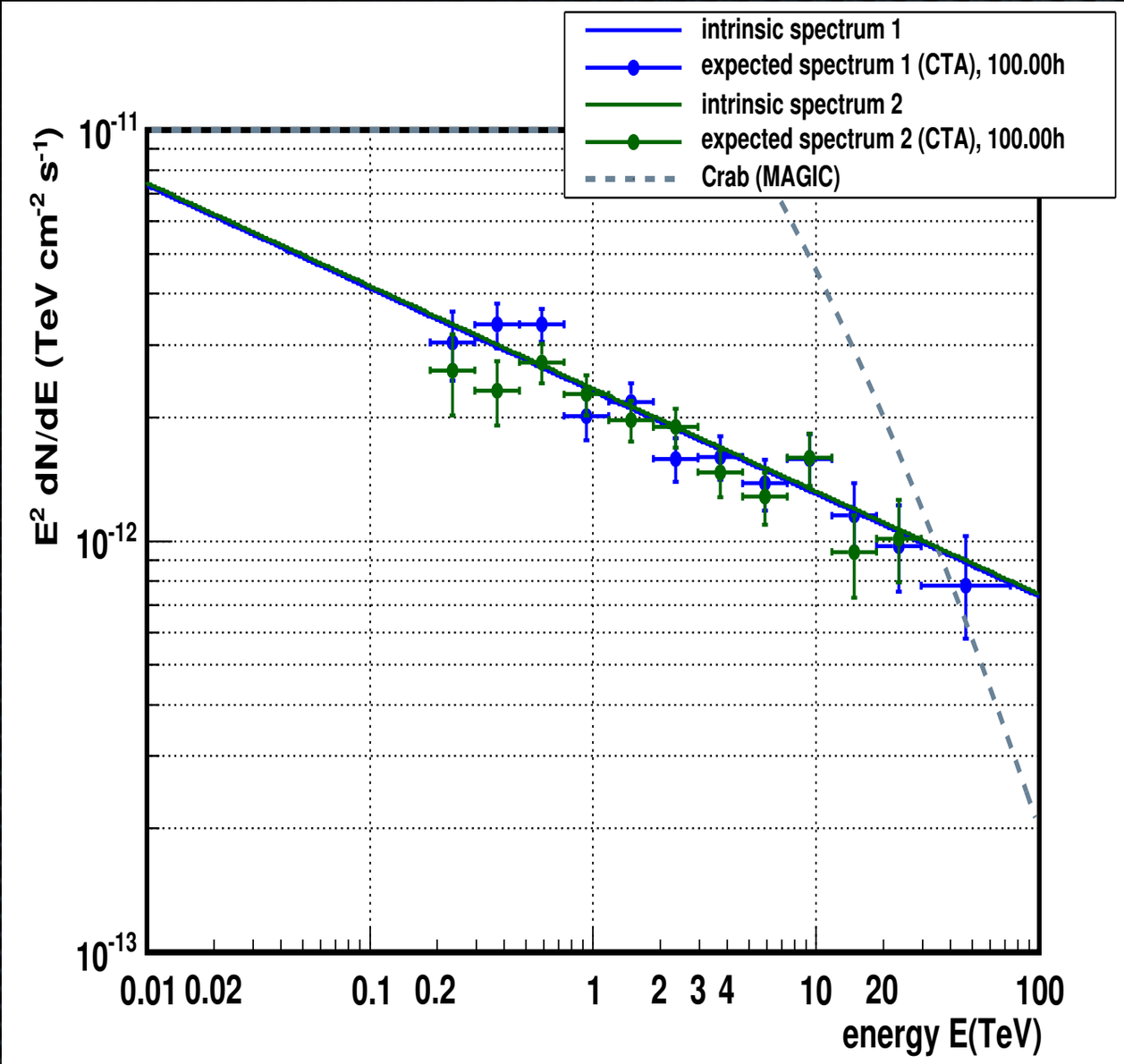


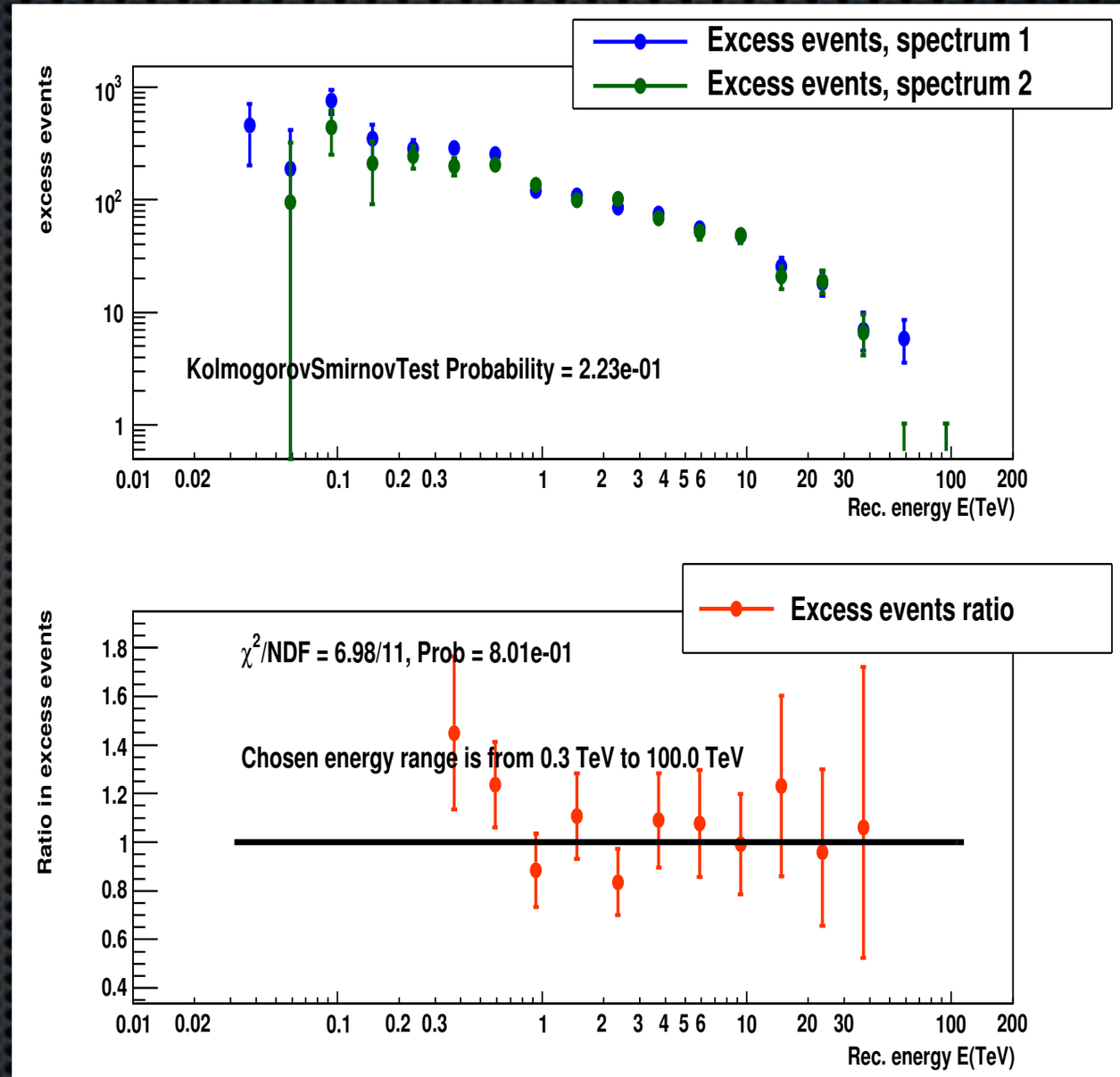
- absorption signature at >20 TeV
- it would be difficult to see >100 TeV gamma-rays
  - hard to see signatures of PeV CRs with distant sources

Galactic Center w/ CTA (100 hr)



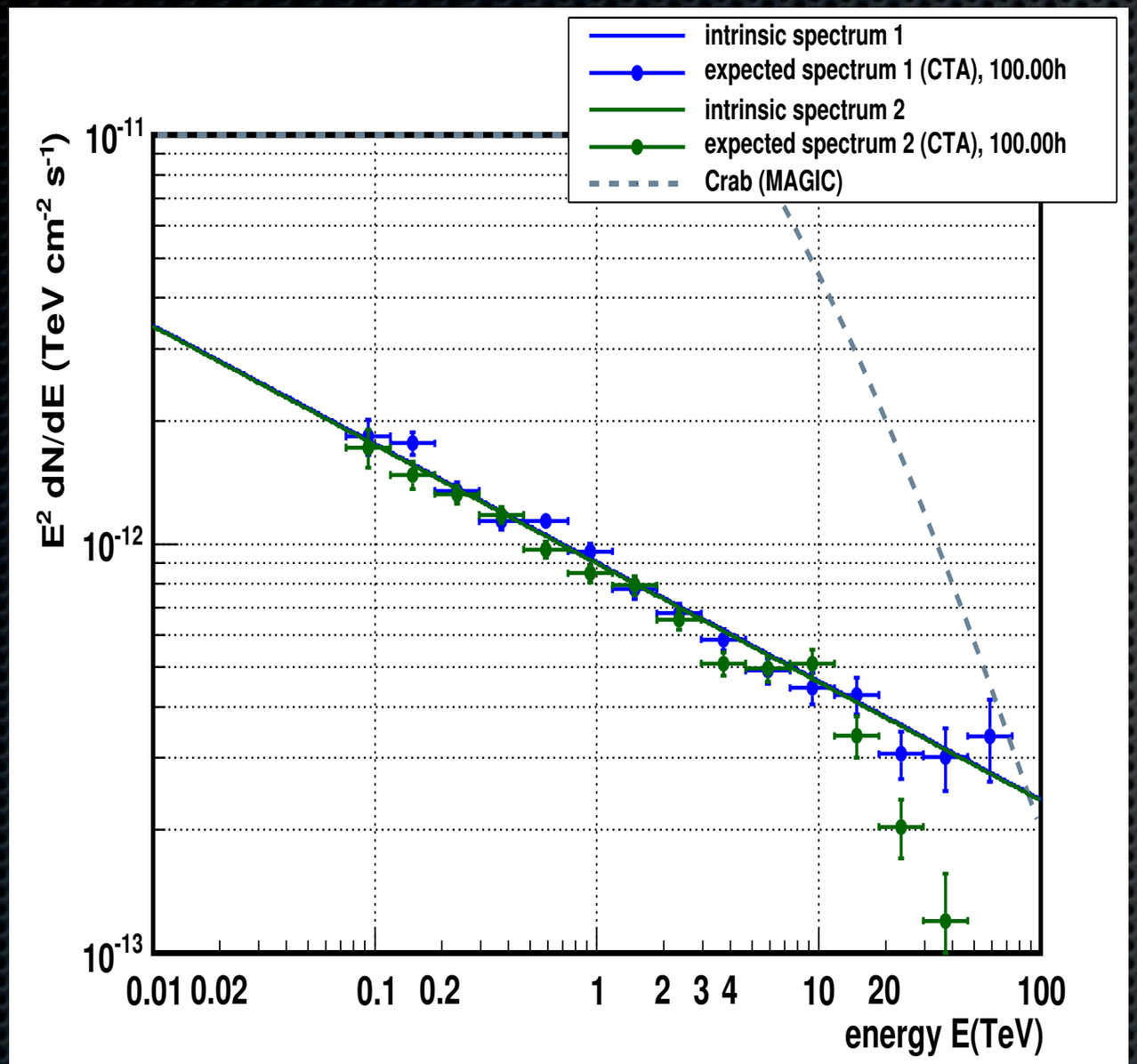
GC with H.E.S.S. (100 hr)

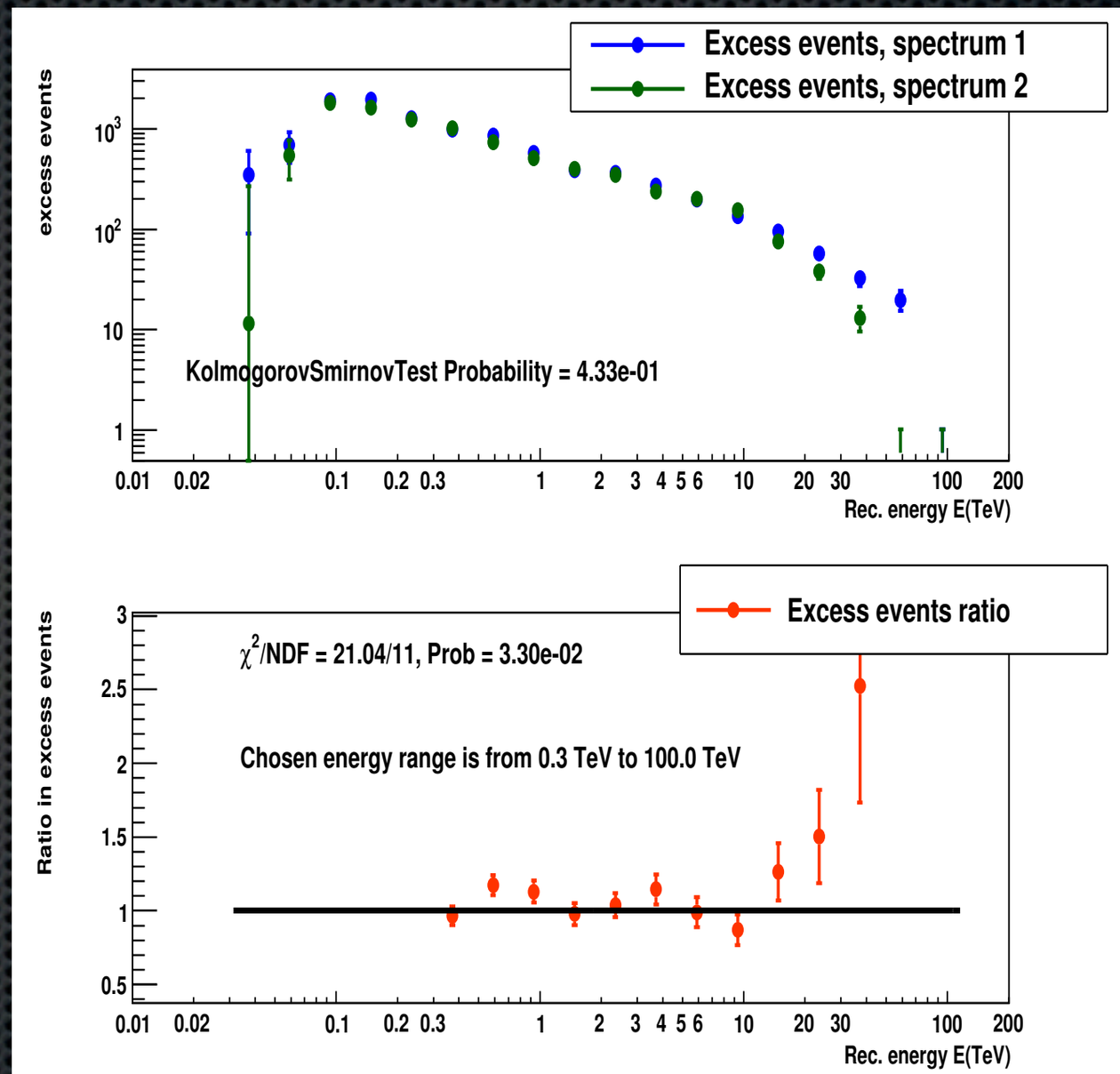




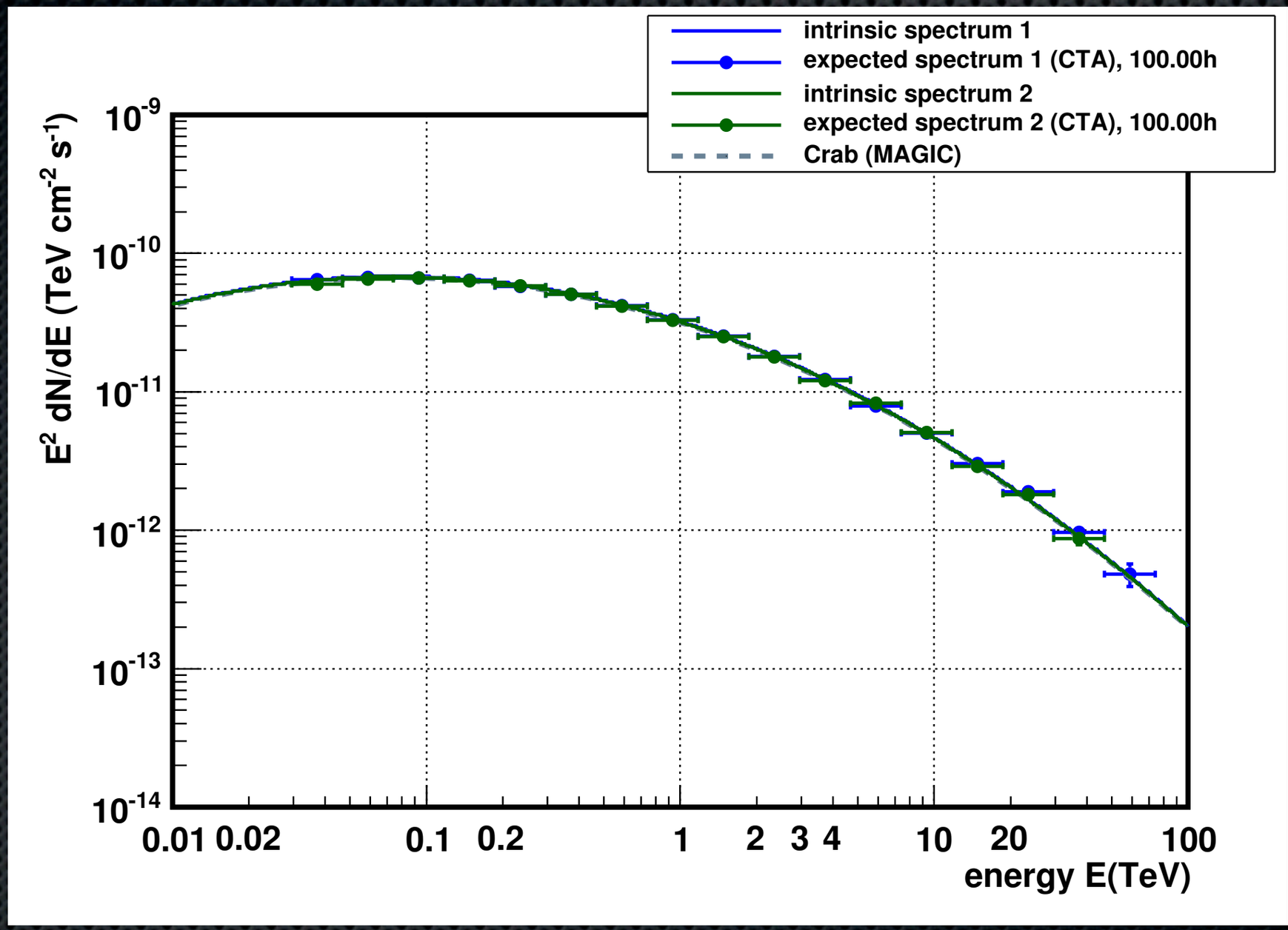
- CTA の有効面積の1/10を仮定。
- H.E.S.S. クラスでは吸収の兆候を探るのは厳しい。

G0.9+0.1(PWN) @ 8.5 kpc w/ CTA (100 hr)





Crab @ 2kpc w/ CTA (100 hr)



- Absorption would not affect nearby sources.

Future Works

1. Deabsorbed spectra catalogs of Galactic TeV sources are required for the opacity map.
   - Population studies of the Galactic sources

2. Do created e^+e^- pairs contribute to the Galactic e^+e^- spectrum?

Summary

- CTA will detect ~300 galactic sources.
- Gamma-ray absorption is significant at >4kpc above 30 TeV for CTA.
  - Gamma-ray opacity map would be a key to understanding the Galactic ISRF map.
- To search PeV CRs, deep observations of nearby sources are preferred.