Bounds on the Cosmic TeV Gamma-ray Background

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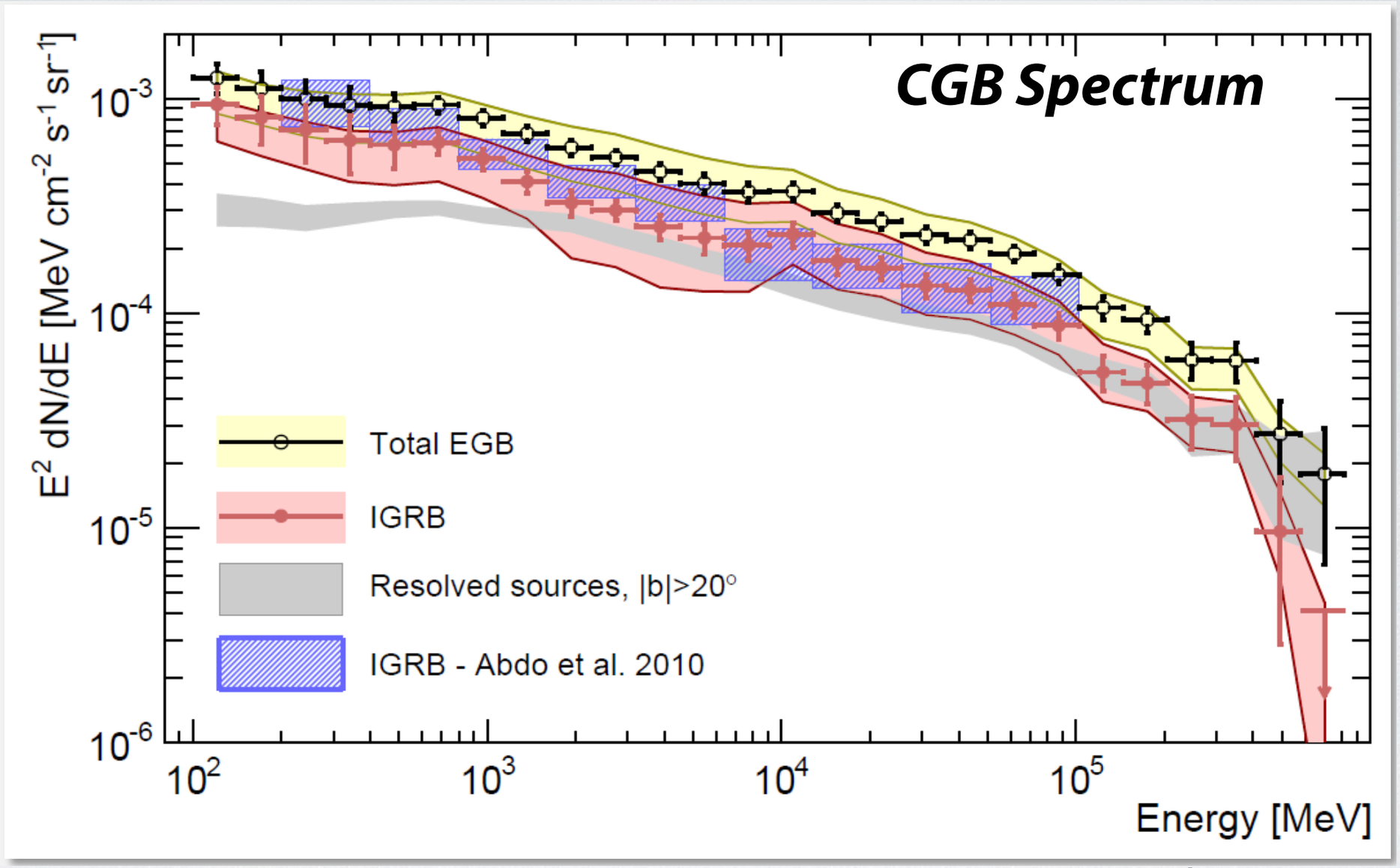
The extreme Universe viewed in very-high-energy gamma-rays 2015, Kashiwa, 2016-01-14

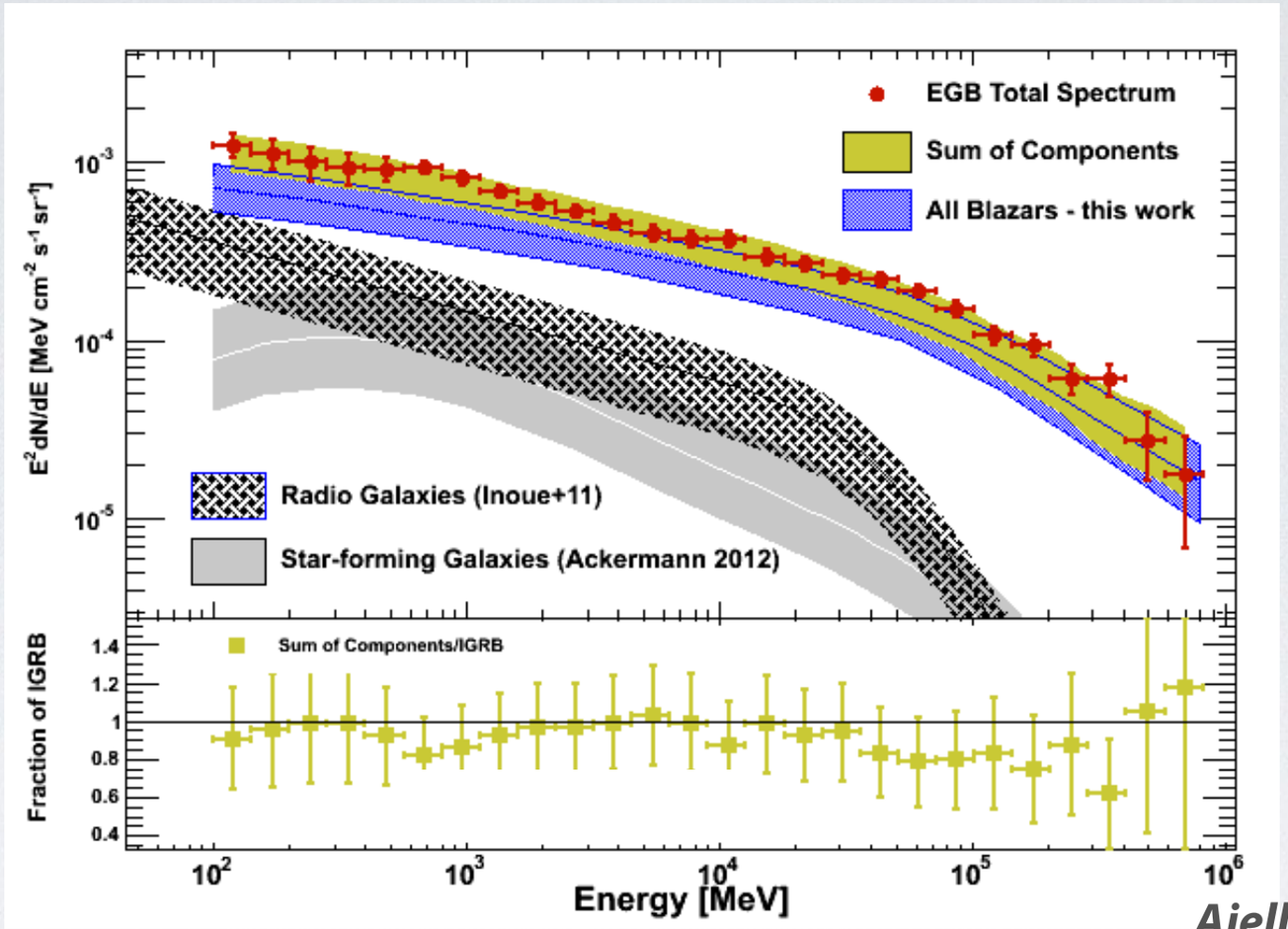
Cosmic Gamma-ray Background Spectrum at >0.1 GeV



Ackerman+'15

- Fermi has resolved 30% of the CGB at ~1 GeV and more at higher energies.

Components of the Cosmic GeV Gamma-ray Background



Ajello, YI +'15

- Blazars (Ajello+'15), Radio gals. (YI'11), & Star-forming galaxies (Ackermann+'12) make up almost 100% of CGB from 0.1-1000 GeV.

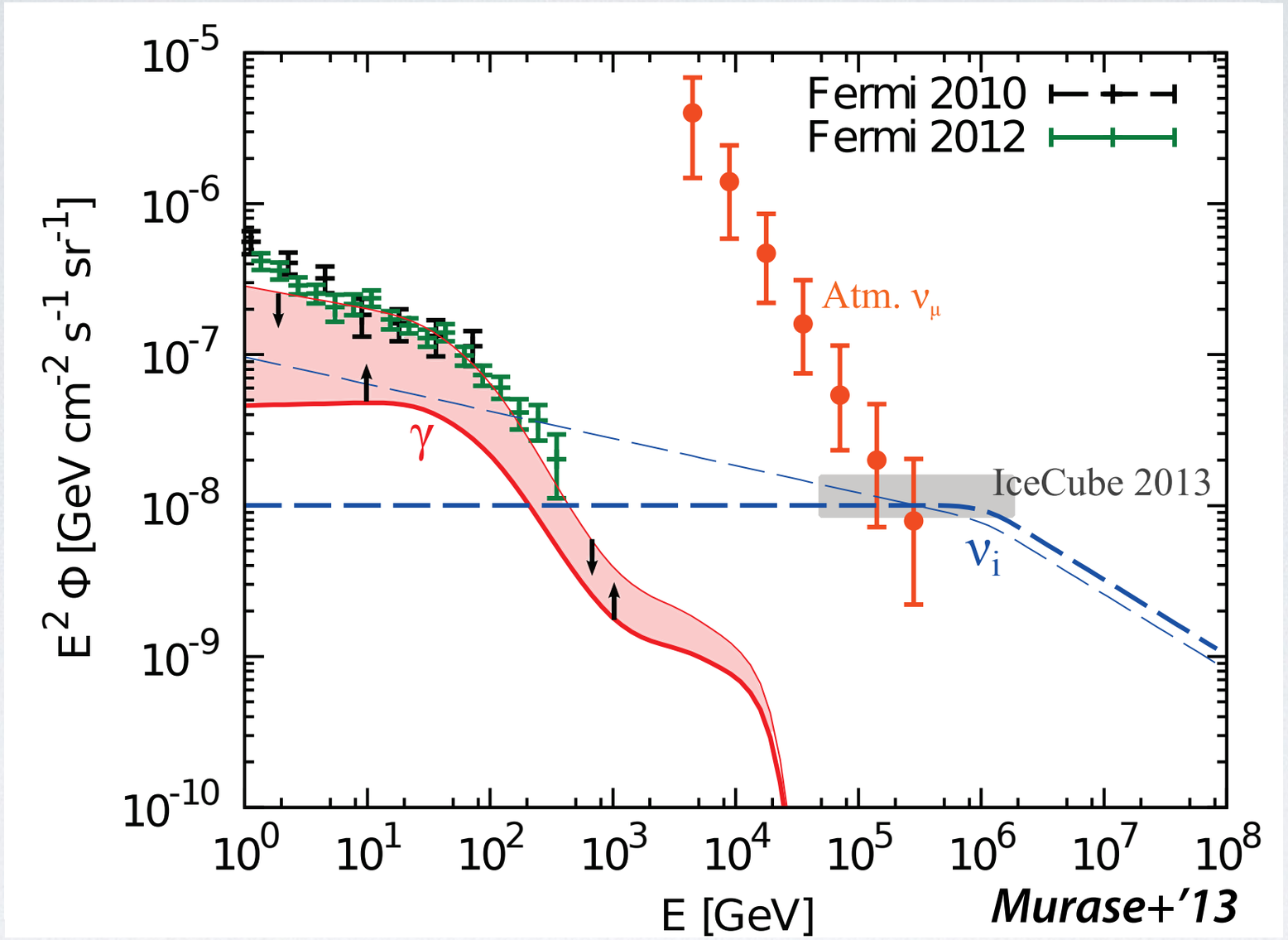
- Next frontiers will be

  - Anisotropy (e.g. Ando & Komatsu '06, Ackermann+'11, Camero+'13, Shirasaki+'14)

  - Cosmic MeV Gamma-ray Background (e.g. YI+'08, Ajello+'09, YI+'13)

  - **Cosmic TeV Gamma-ray Background (This talk)**

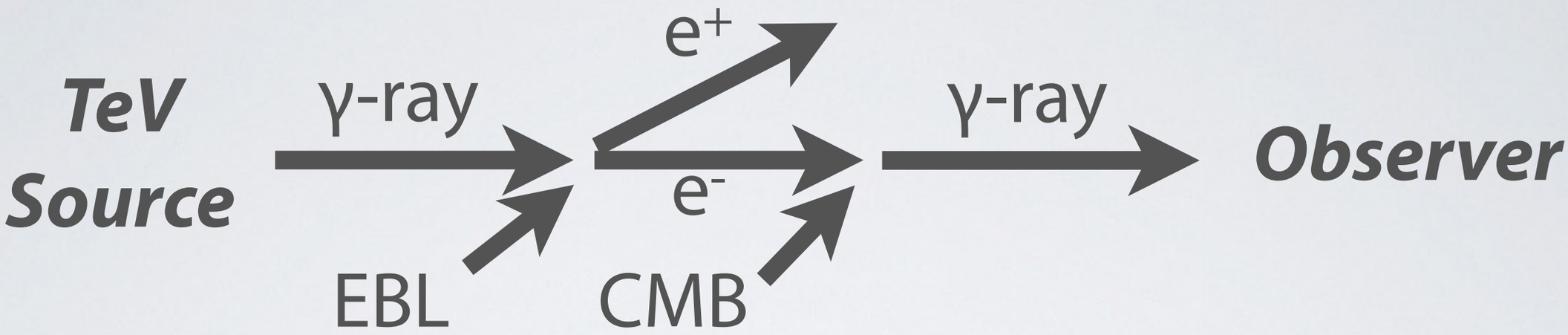
Cosmic TeV Gamma-ray Background



- Above 1 TeV, there is no gamma-ray data, though it is important for neutrino studies.

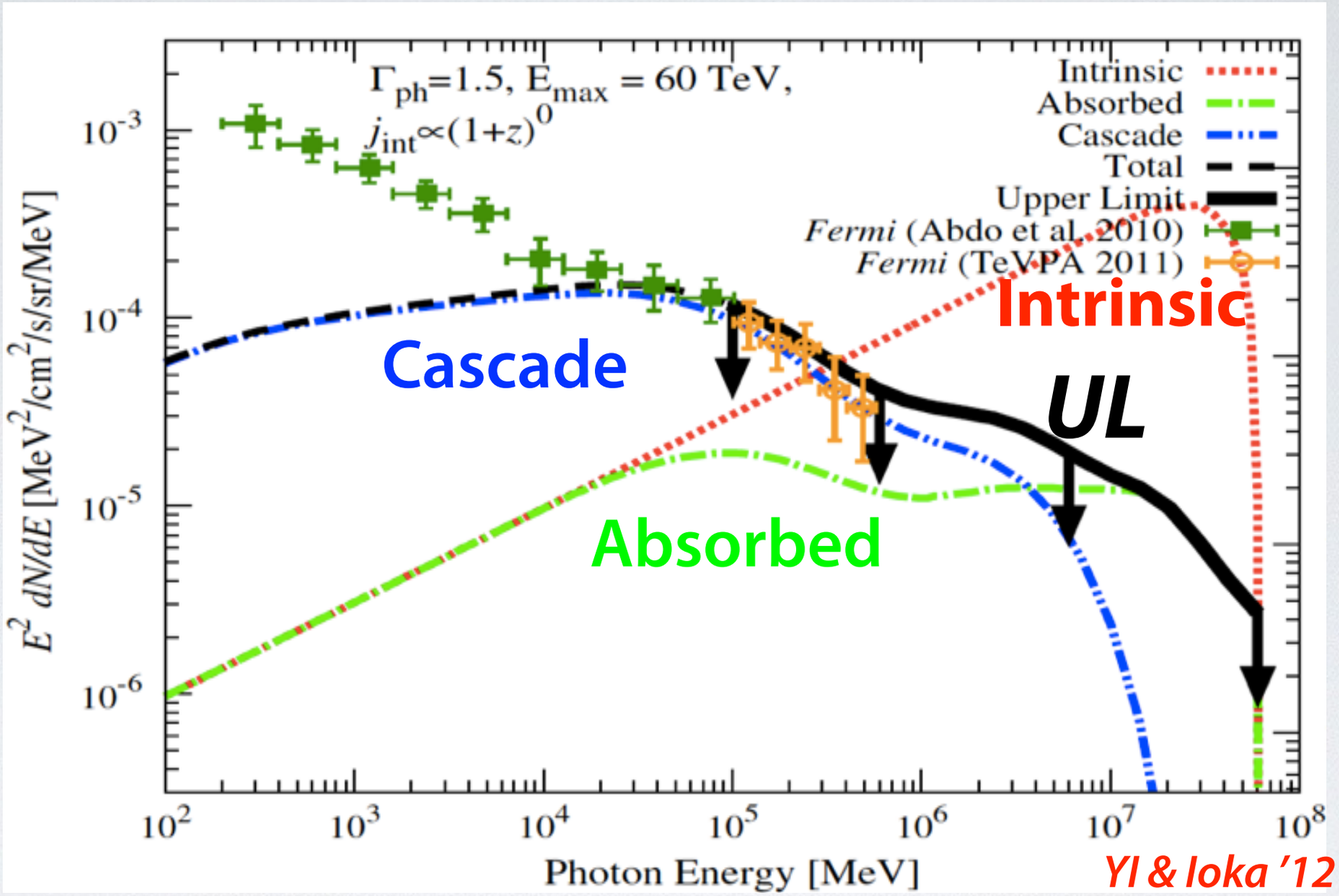
- extragalactic ***pp*** scenario for IceCube events is constrained by the CGB (Murase+'13; Bechtol+'15).

GeV-TeV Gamma-ray Connection: Cascade



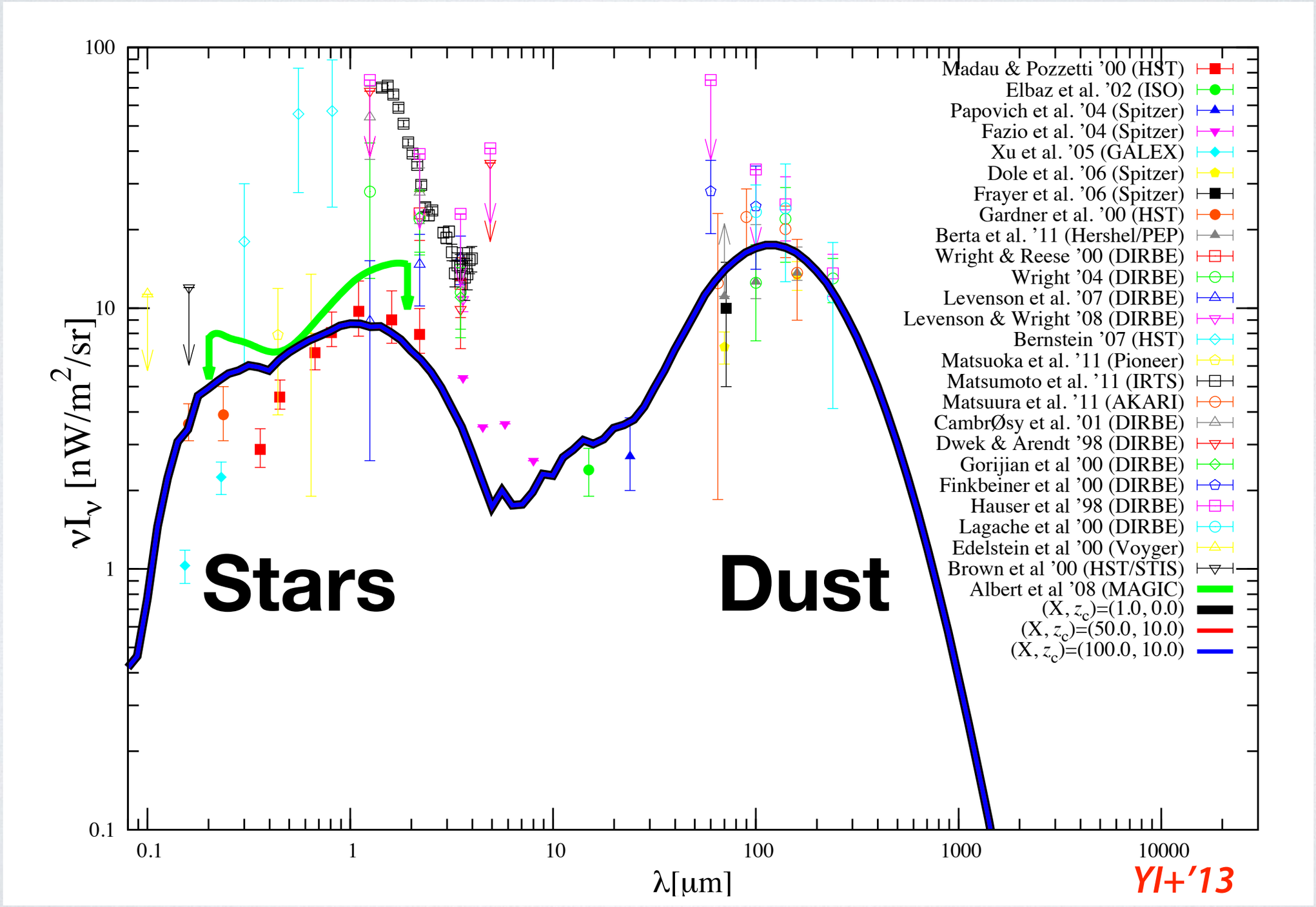
- TeV gamma-ray photons are absorbed by EBL
- electron-positron pairs are created
- pairs scatter CMB via inverse-Compton process
    - 1 TeV (primary) -> ~1 GeV (secondary)
- Note: plasma instability may suppress the cascade
  (Broderick+'12, but see also Sironi & Giannios '14)

Upper Bound on the Cosmic Gamma-ray Background

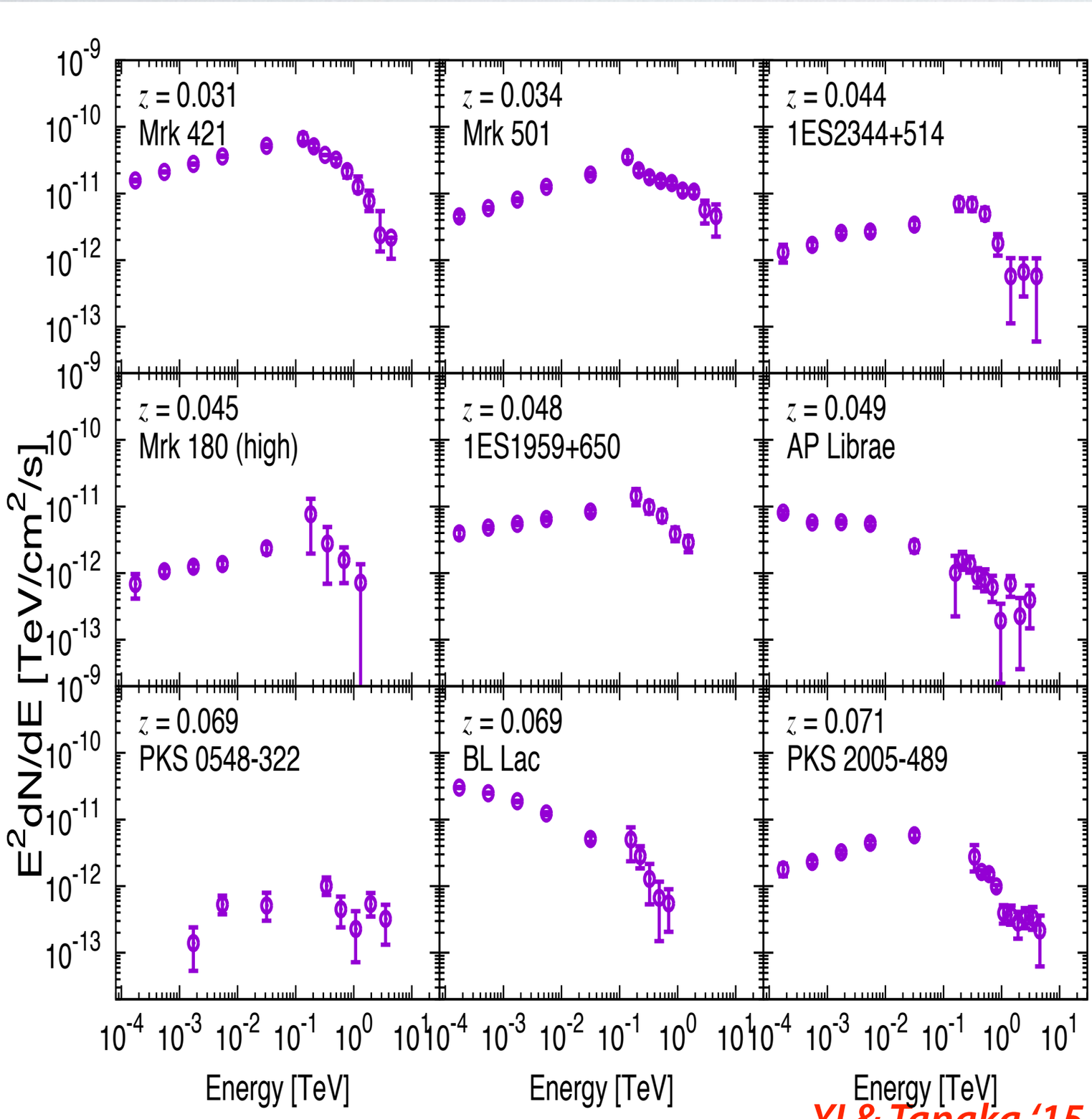


- Cascade component from the TeV background can not exceed the Fermi data (Coppi & Aharonian '97, YI & Ioka '12, Murase+'12, Ackermann+'14).

Galaxy Counts: Lower Bound on the Cosmic Optical/Infrared Background



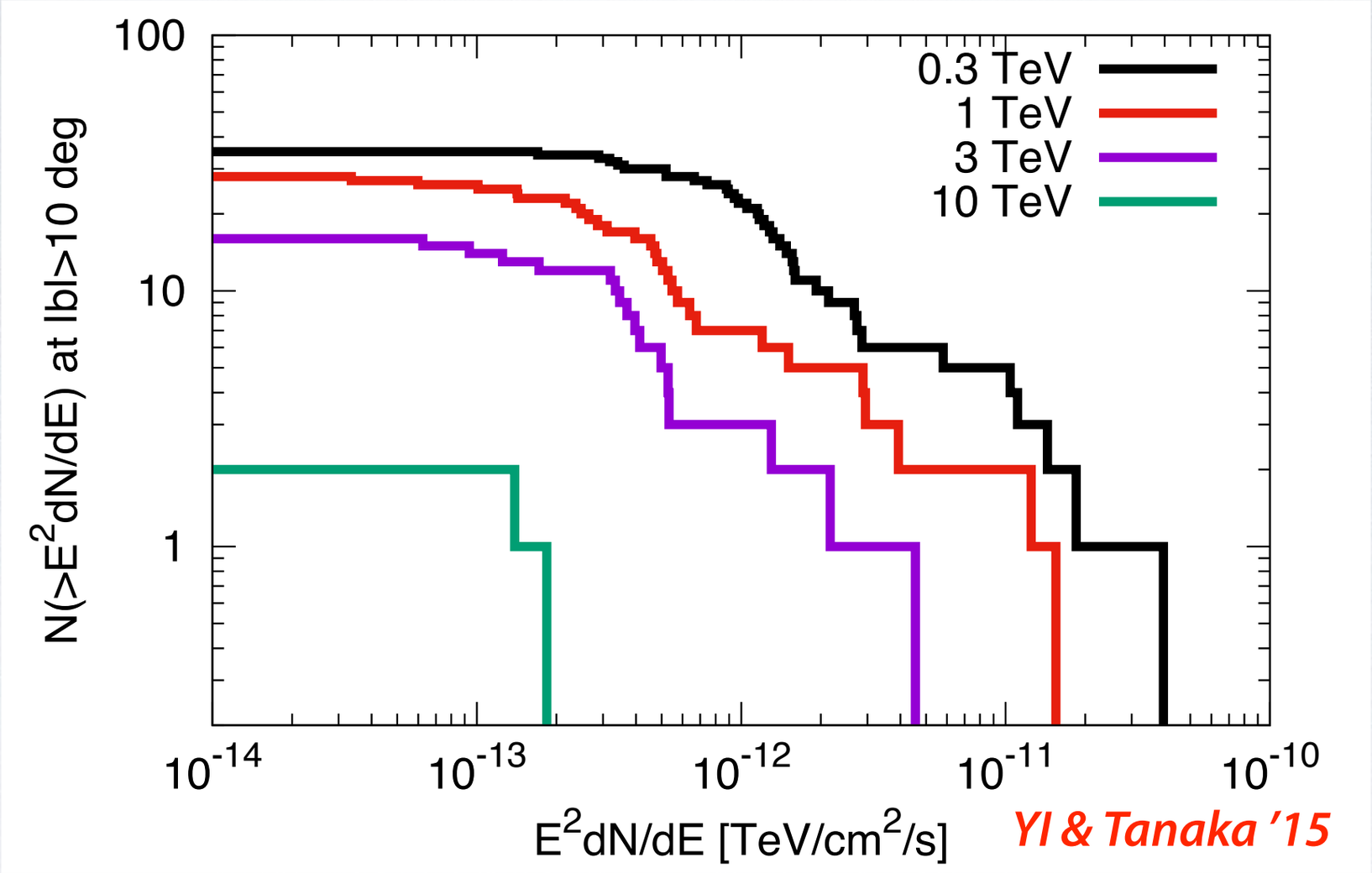
Known TeV sources



YI & Tanaka '15

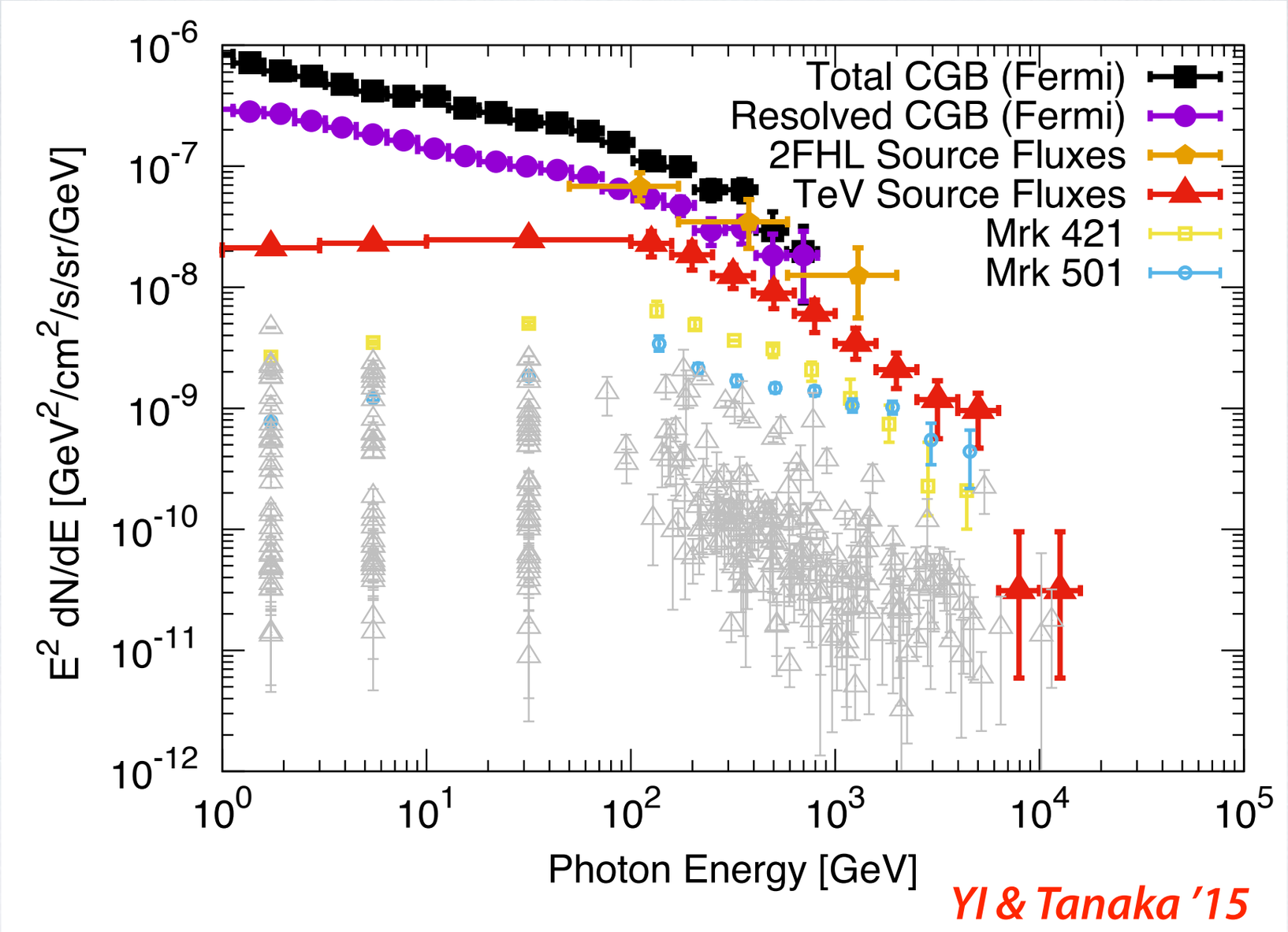
- Select 35 known TeV sources at |b|>10 deg from the default TeVcat catalog.
  - low-state data only
  - 30 are blazars, 3 are radio galaxies, 2 are starbursts
- 3FGL SED data for the GeV data.

Source Count Distribution



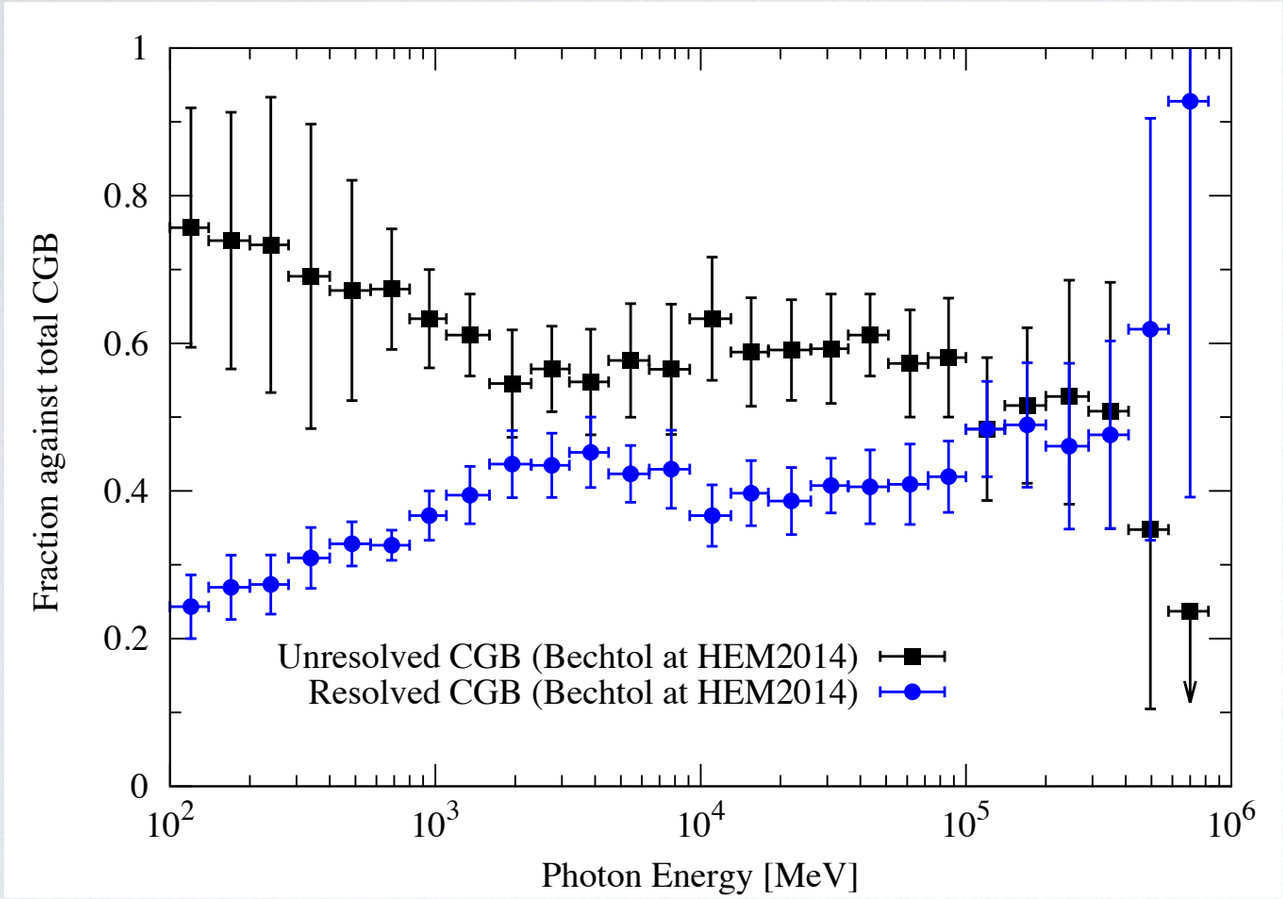
- different from a uniform distribution.
- More uniform and wide sky coverage is required.

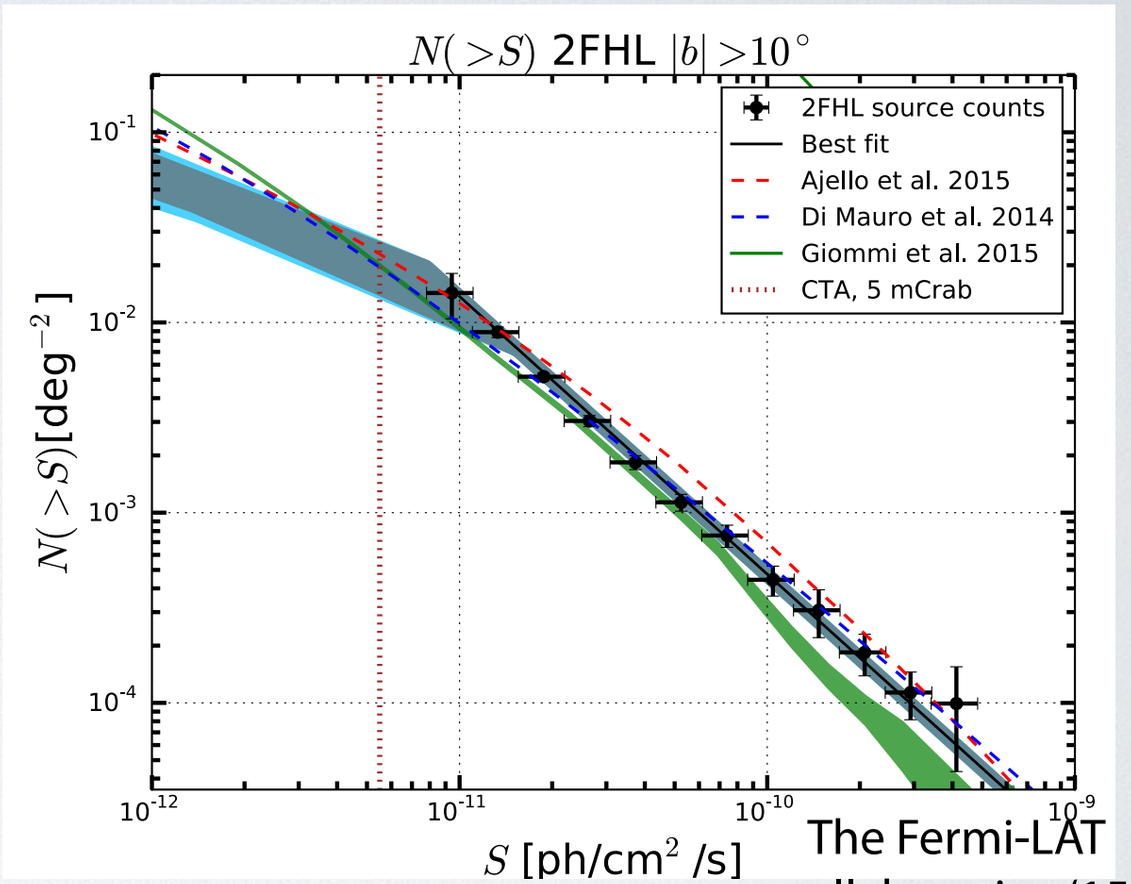
Lower Bound on the Cosmic Gamma-ray Background



- TeV source counts give lower limit on to the cosmic gamma-ray background.
- Fermi has resolved more portion of the TeV sky than IACTs do.
  - CTA & HAWC surveys will be important (YI, Totani, & Mori 10; Dubus, YI, +'13)

How large fraction of the VHE sky resolved by Fermi?

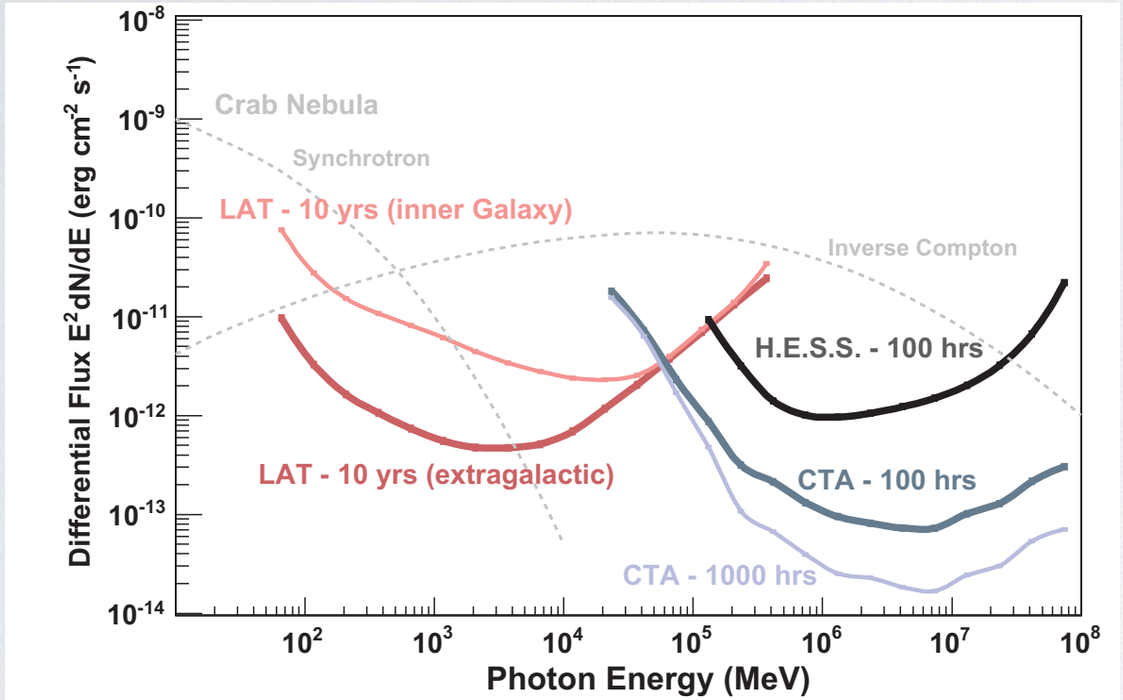


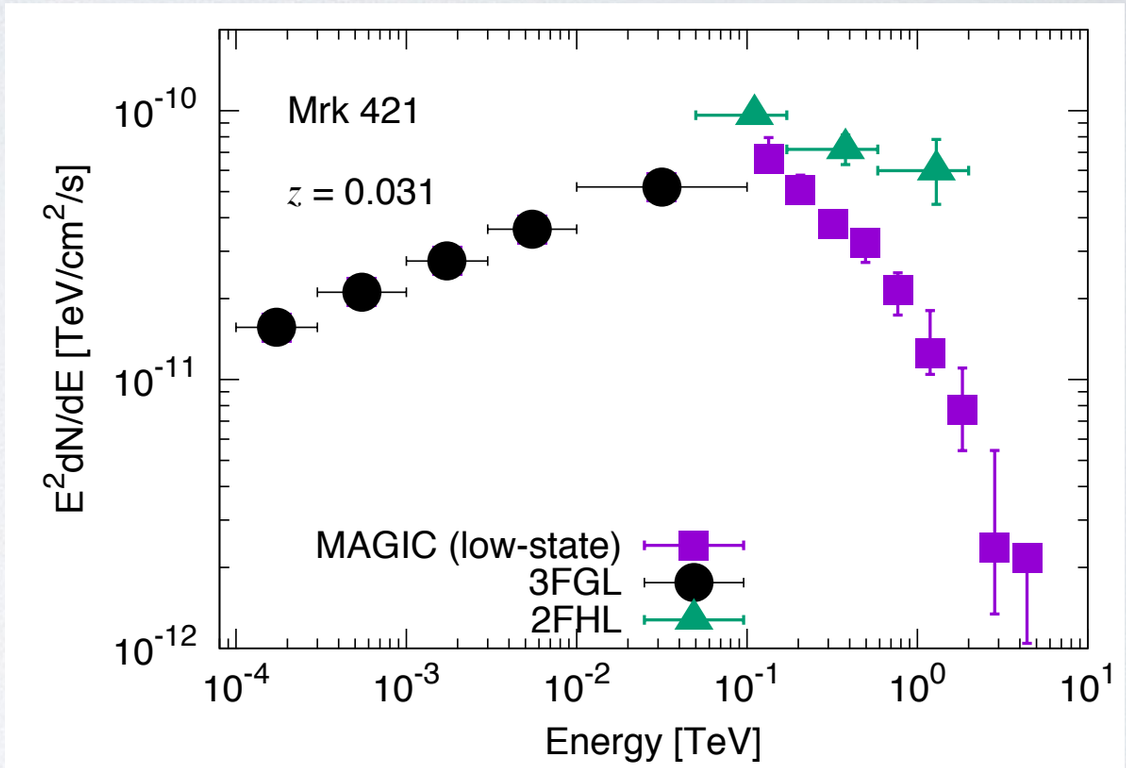


The Fermi-LAT collaboration '15

- Fermi has resolved 50-80% of the VHE sky (0.1-1 TeV).
- CTA survey (at >50 GeV) will not drastically change the source counts.

Why Fermi has resolved the sky more even at ~1 TeV?





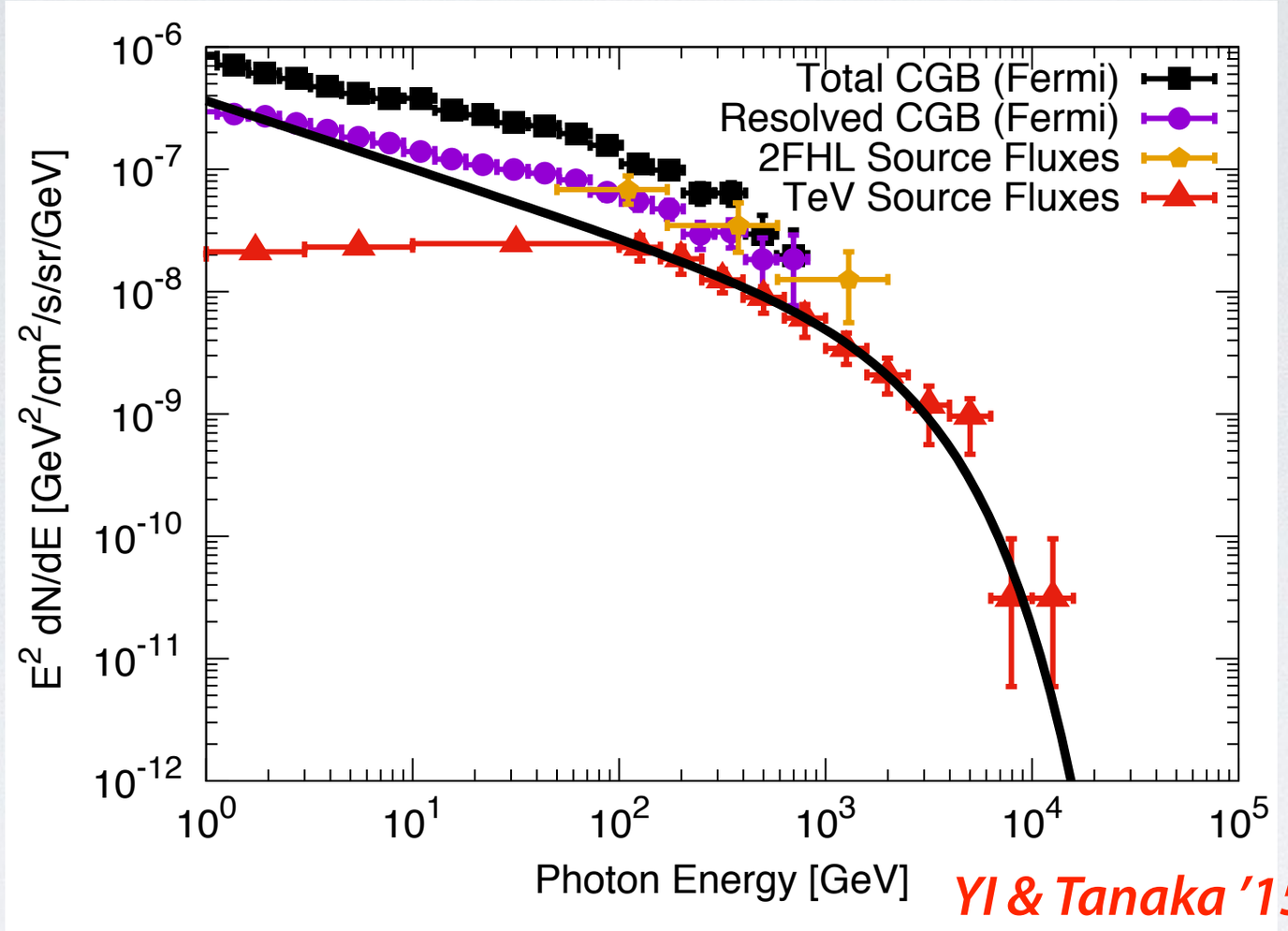
- 14 sources at the highest energy (585-2000 GeV) bin in the 2FHL samples, while 30 sources at >585 GeV in our sample. ⇒ Sky coverage is not the cause.

- The dominant object Mrk 421 is variable.

  - The CGB is the time-averaged spectrum. e.g. Fermi accumulated data 80 months for 2FHL.

  - We need long-term monitoring of TeV sources. ⇒ HAWC & current IACTs in the CTA era.

Lower Bound on the Cosmic Gamma-ray Background



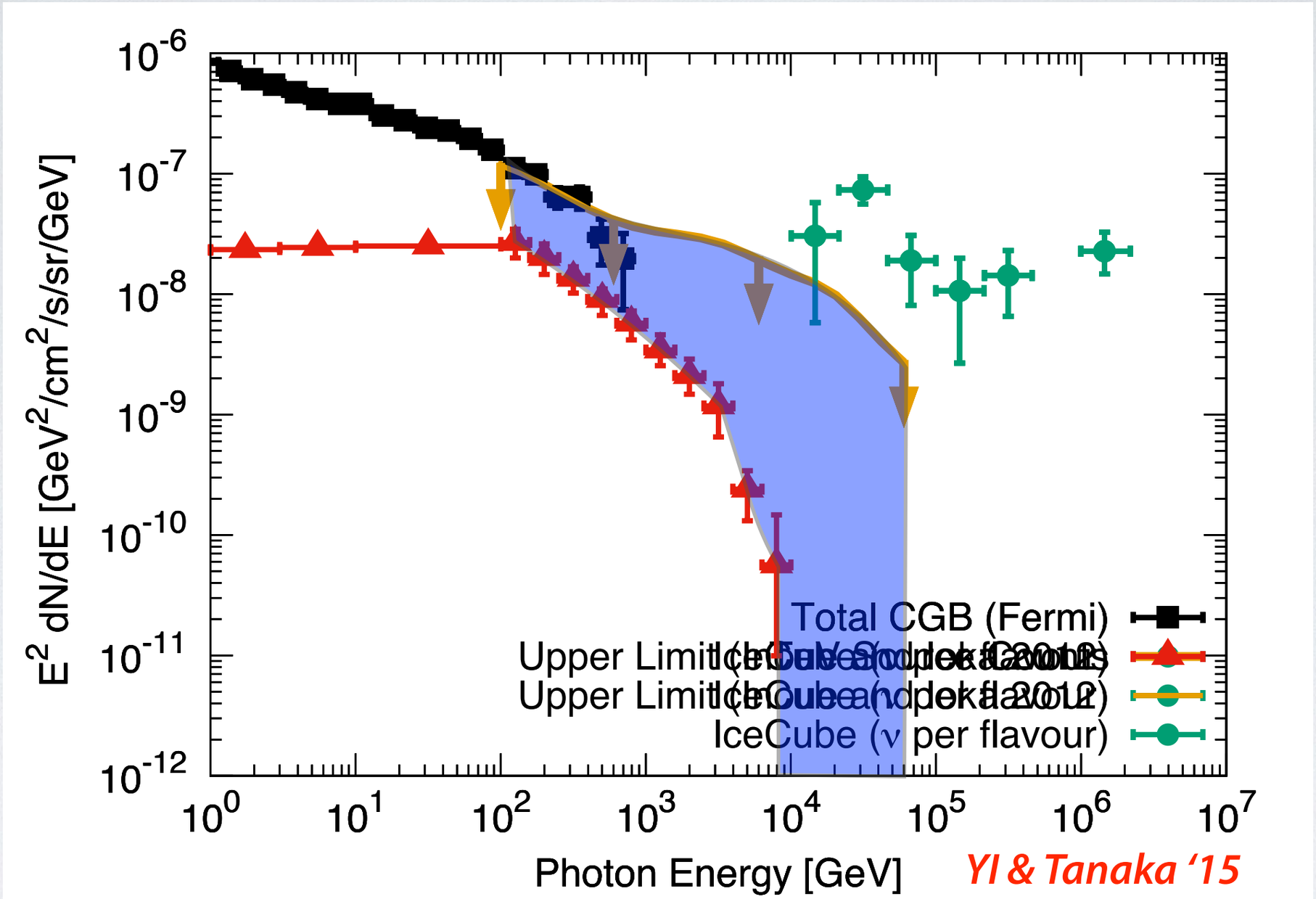
YI & Tanaka '15

- The bounds above 100 GeV is approximated as:

$$3 \times 10^{-8} \left(\frac{E}{100\ \mathrm{GeV}} \right)^{-0.6} \exp\left(-\frac{E}{2 \times 10^3\ \mathrm{GeV}} \right)\ [\mathrm{GeV/cm^2/s/sr}]$$

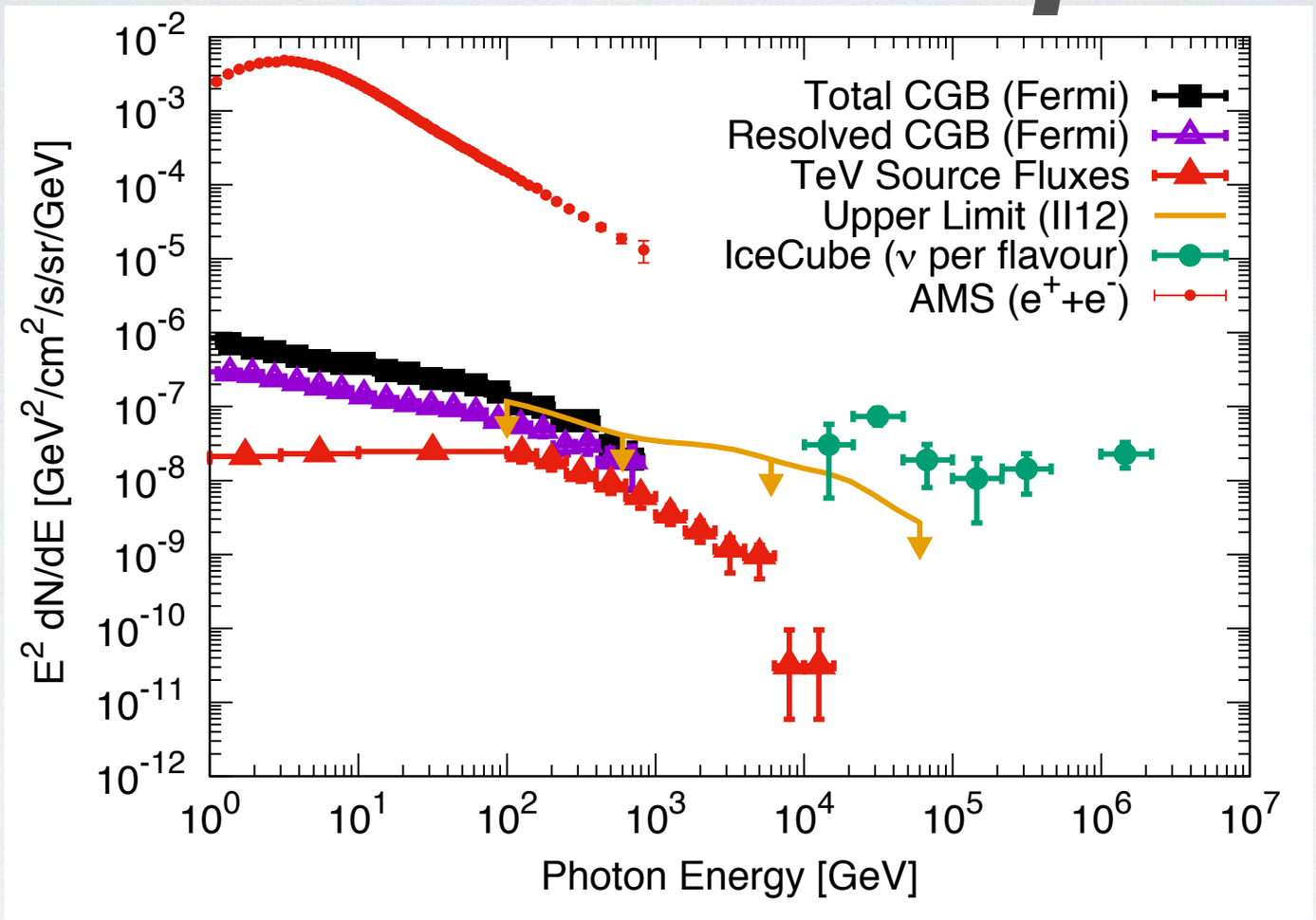
- Exponential cutoff may not be due to the EBL attenuation. The gamma-ray horizon energy for Mrk 421 & 501 is ~7 TeV.

Bounds on the Cosmic TeV Gamma-ray Background



- Current limit at 0.1-10 TeV is
  - $3\times10^{-8}\ (E/0.1\ \mathrm{TeV})^{-0.8} \exp(-E/2\ \mathrm{TeV}) < E^2 dN/dE < 1\times10^{-7}\ (E/0.1\ \mathrm{TeV})^{-0.5}$ [GeV/cm^2/s/sr]

Requirement for CTA to measure the CGB spectrum



- Need to remove electron background events which is $10^{4\text{-}5}$ times higher than the CGB events.

Summary

- Cosmic TeV gamma-ray background is not well investigated yet.

- Current GeV gamma-ray background gives upper limits on the TeV gamma-ray background through the cascade argument

- Ensemble of low-state TeV blazar flux gives lower limit on to the cosmic gamma-ray background.

- Current limit on the TeV background is

  - $3\times10^{-8}\ (E/0.1\ \mathrm{TeV})^{-0.8} \exp(-E/2\ \mathrm{TeV}) < E^2 dN/dE < 1\times10^{-7}\ (E/0.1\ \mathrm{TeV})^{-0.5}$ [GeV/cm^2/s/sr].