Probing the Extragalactic Background Light with VERITAS

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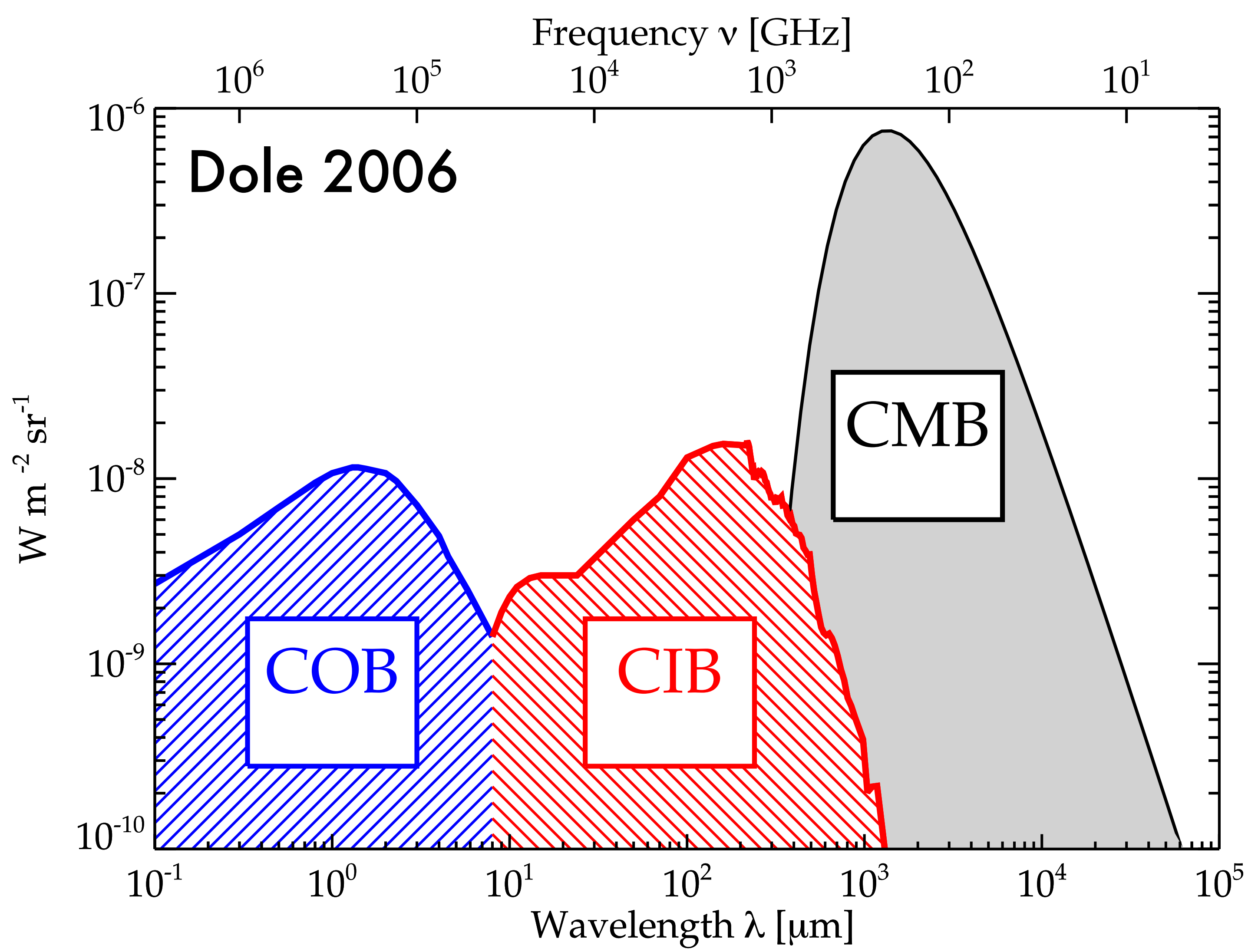
The Extragalactic Background Light

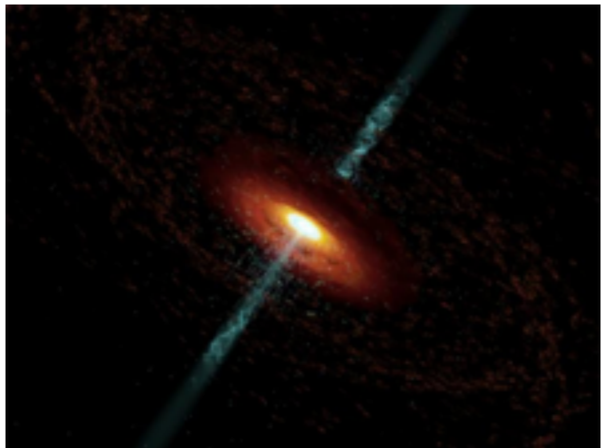


→ COB = Cosmic optical background
→ Light from stars, galaxies, etc

→ CIB = Cosmic infrared background
→ Light reprocessed by dust

Imprint from reionization, star formation, galaxy evolution
Unresolved sources? Dark matter decay? Exotic physics?

Extragalactic Background Light: Strategy

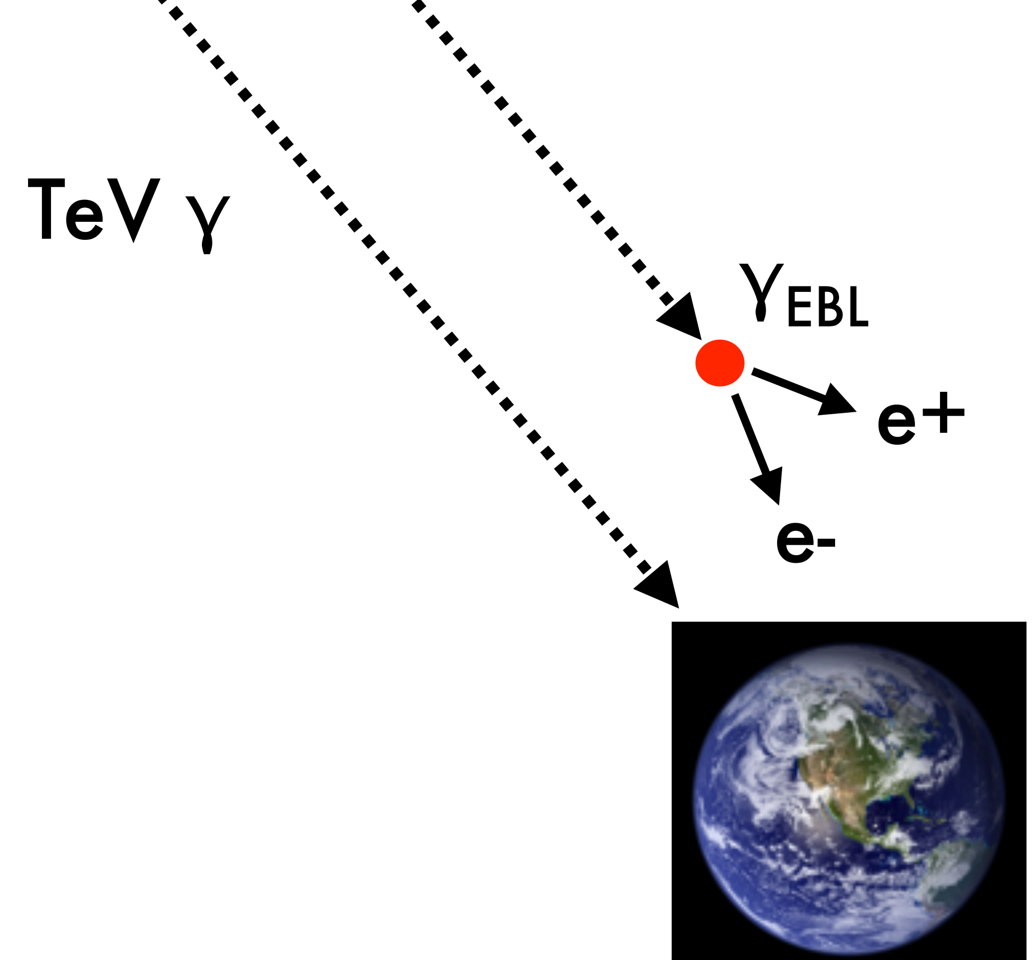


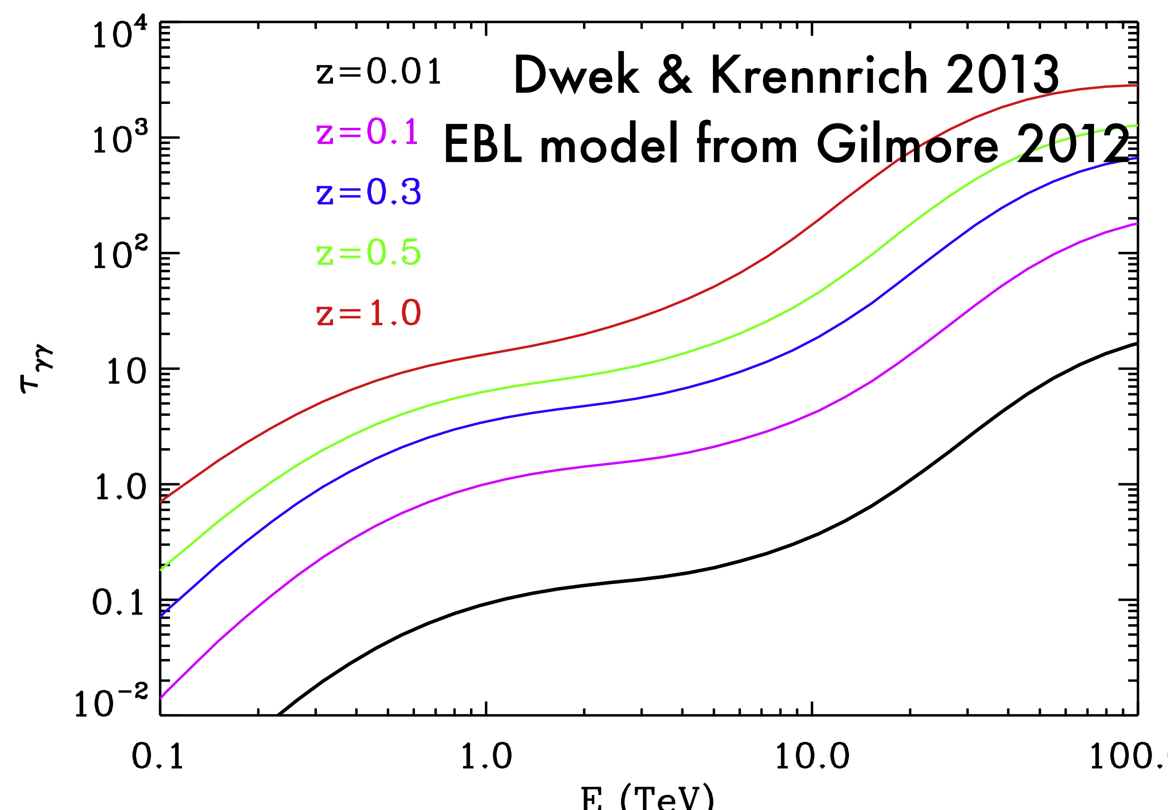
→ TeV γs interact with EBL γs via pair production

→ VERITAS energy range → λ_{EBL} 0.1 - 40 μm

→ Quantify attentuation as optical depth along line of sight

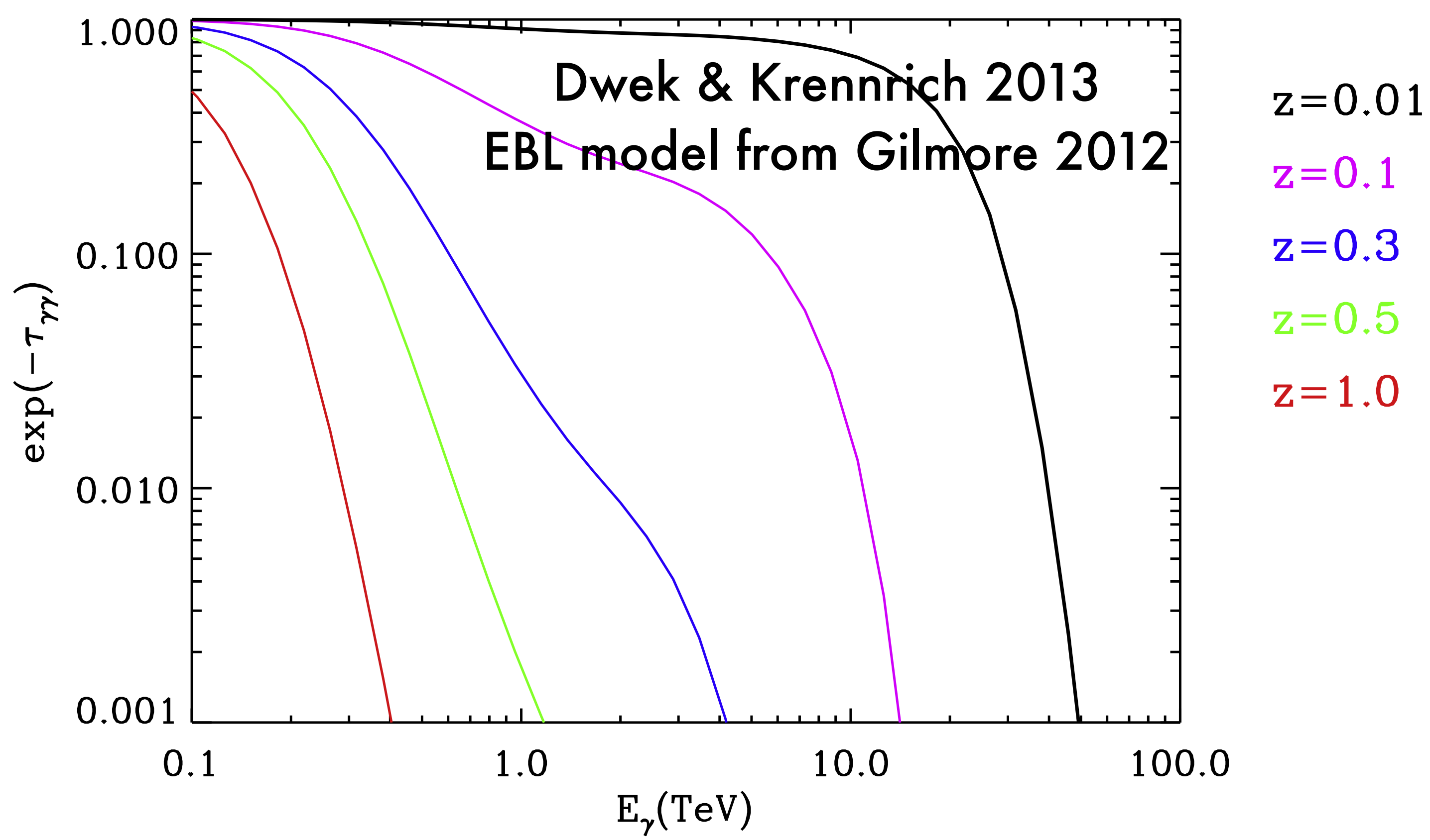
→ More distant, higher energy → more attenuation





EBL Imprint on Blazar Spectra

- → VHE (>100 GeV) emission strongly attenuated by EBL
- → HE (>10 MeV) emission minimally attenuated
  - → Proxy for intrinsic spectrum



<u>Intrinsic spectrum:</u>

$$\frac{dN}{dE} \propto E^{-\Gamma}$$

or

$$\frac{dN}{dE} \propto E^{-\Gamma} \exp\left(-\frac{E}{E_C}\right)$$

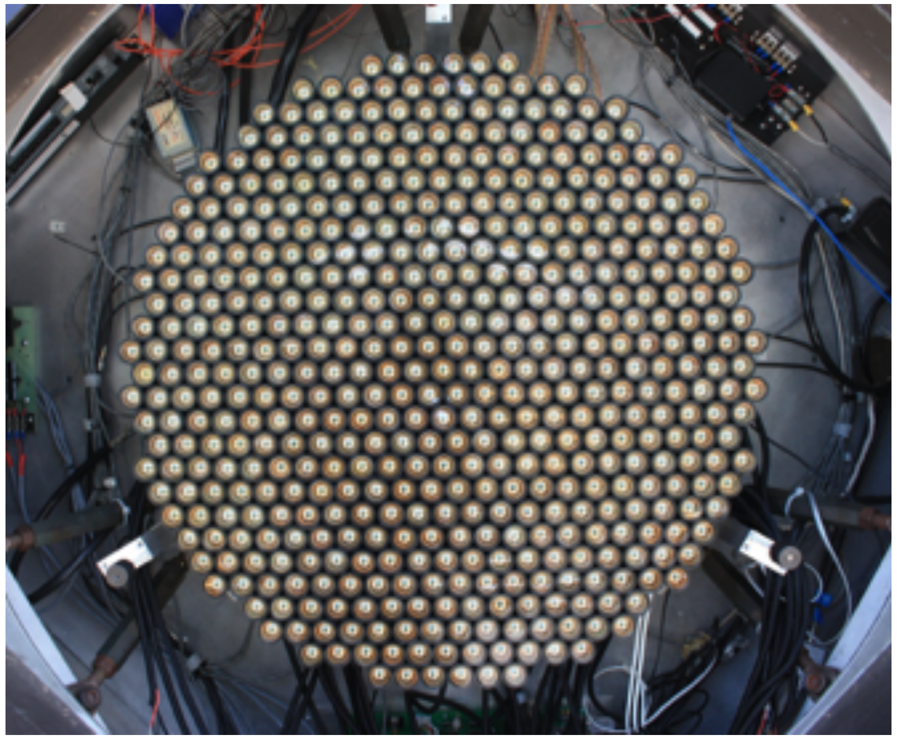
or...?

<u>Observed spectrum:</u>

$$\frac{dN}{dE} \propto \left(\frac{dN}{dE}_{int}\right) \exp(-\tau_{\gamma\gamma})$$

VERITAS

- → Four 12m IACTs located in southern AZ
  - → Davies-Cotton design, 499 PMTs
- → Energy range: 100 GeV to > 30 TeV
- → Energy resolution: 15% at 1 TeV
- → Angular resolution: 0.1° at 1 TeV
- → Field of view: 3.5°
- → Peak effective area: 100,000 m^2



Sources Used

<u>Strongly detected sources:</u>

1ES 2344+514, z=0.044, 45h

1ES 1959+650, z=0.048, 19h

RGB J0710+591, z=0.125, 101h

H 1426+428, z=0.129, 75h

1ES 0229+200, z=0.14, 112h

1ES 1218+304, z=0.182, 117h

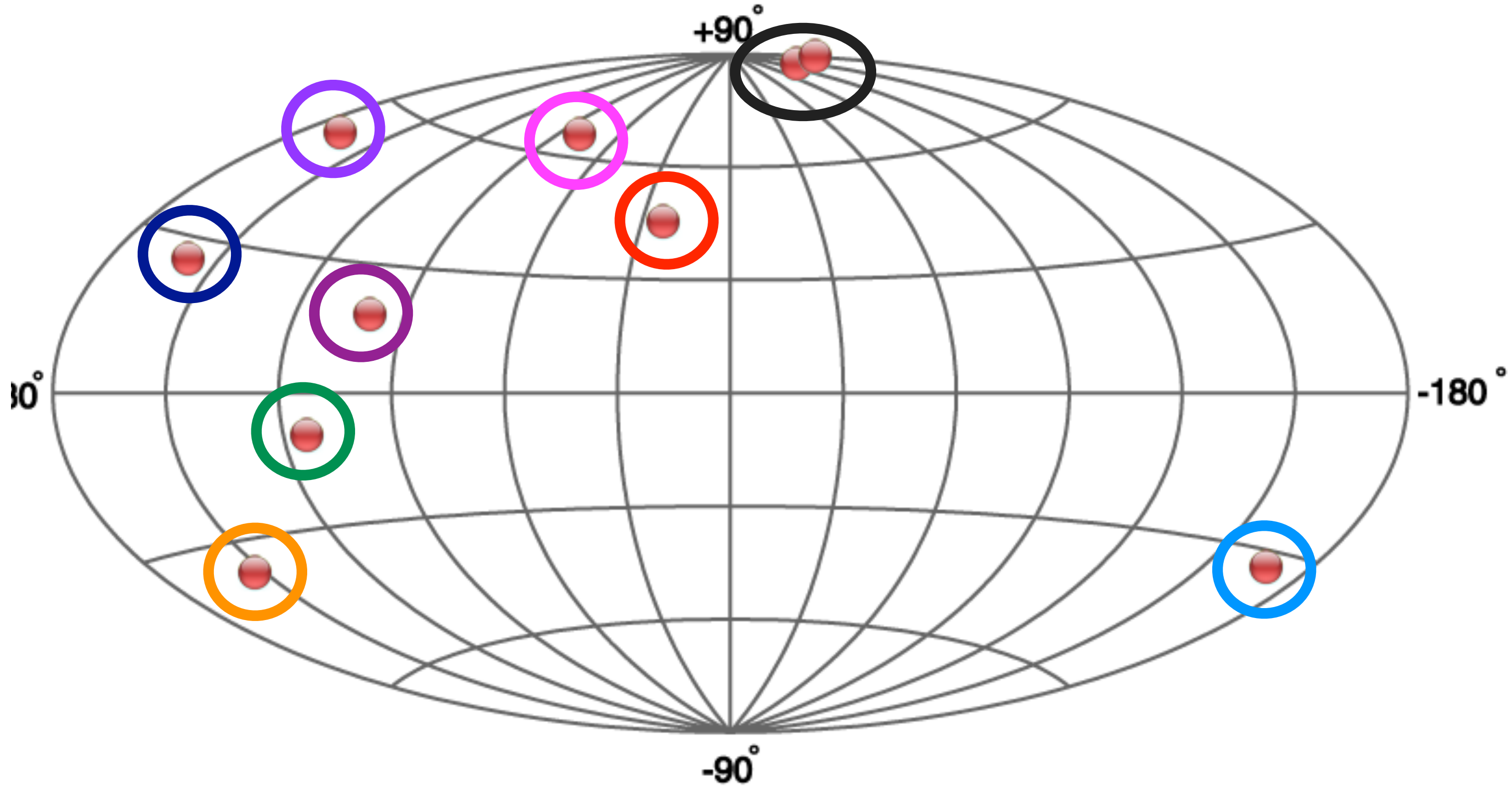
1ES 1011+496, z=0.212, 27h

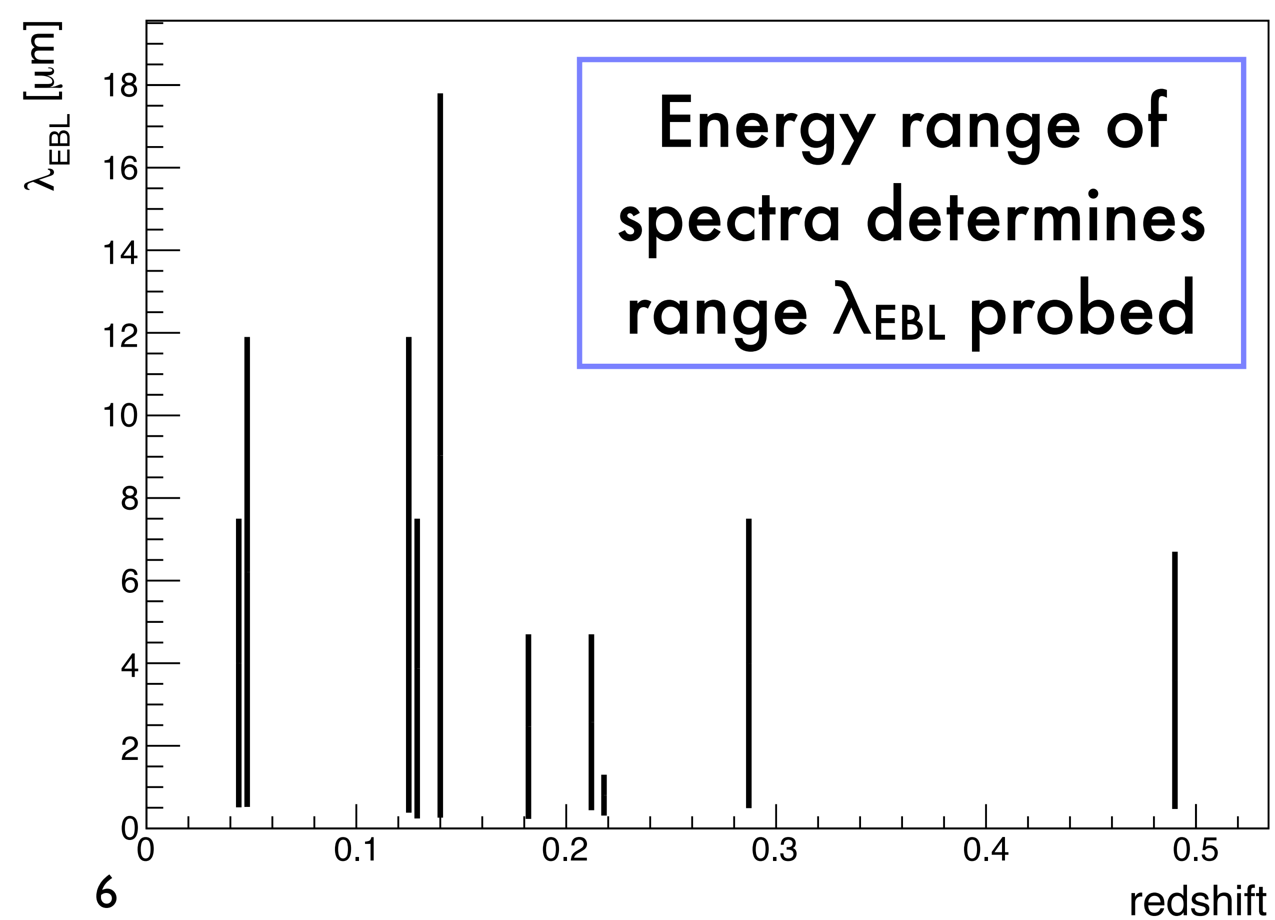
MS 1221.8+2452, z=0.218, 8h

1ES 0414+009, z=0.287, 80h

PG 1553+113, z=0.49, 93h

Observations taken
2007 - Feb 2015



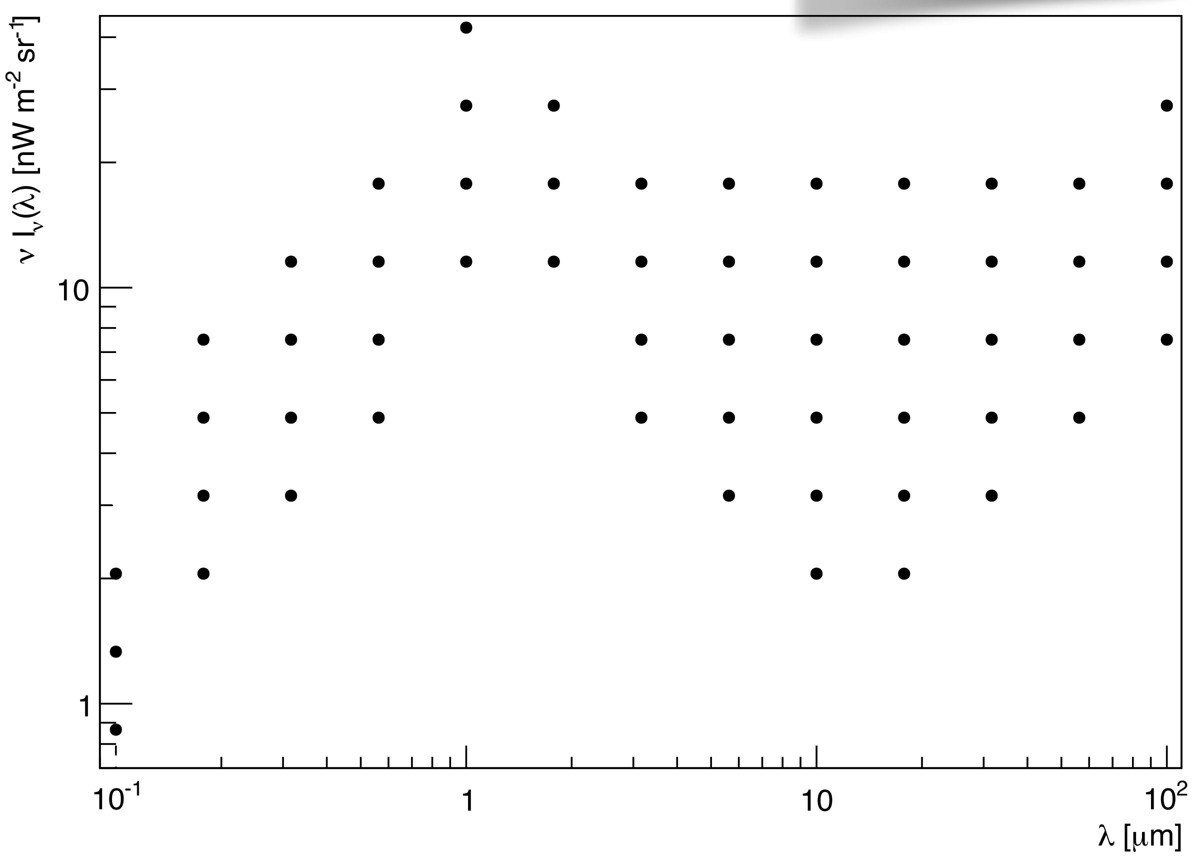


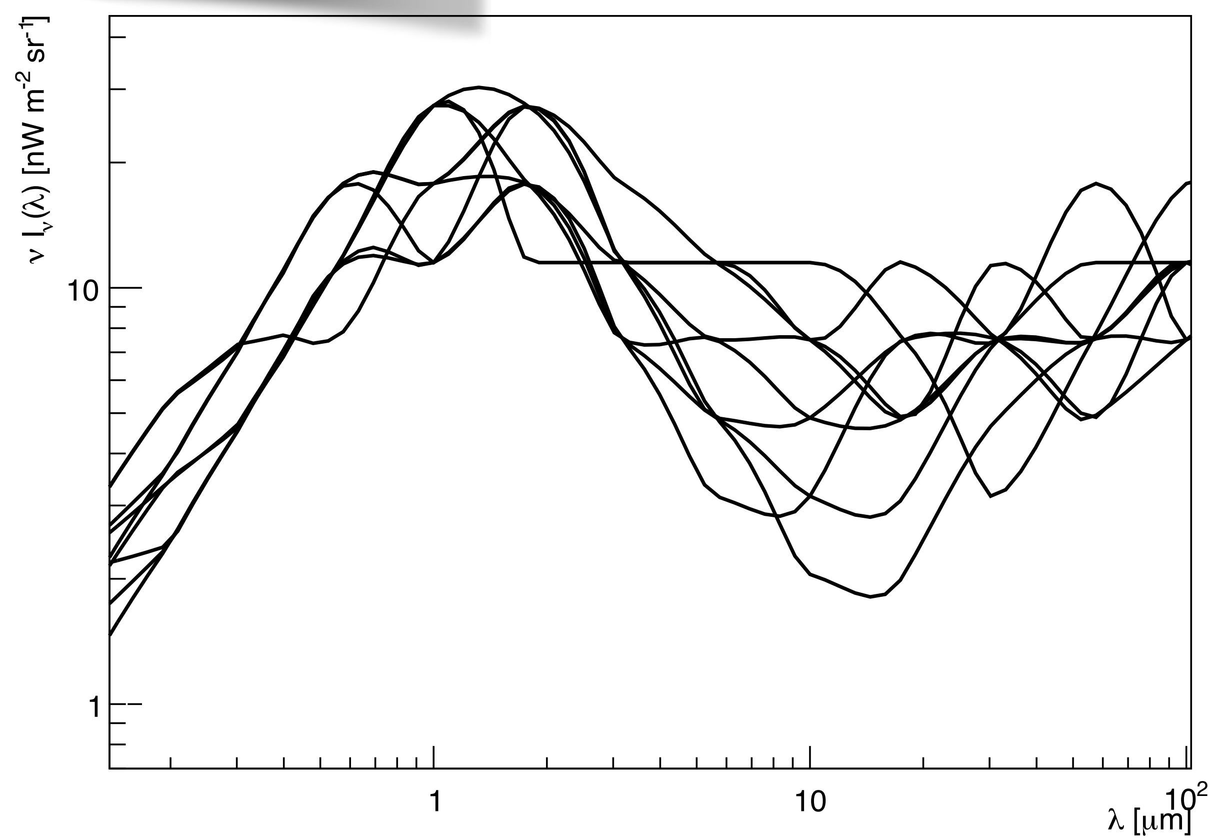
Building Blocks: Generic EBL Models

→ Grid points [λ, EBL intensity] define ensemble of splines/EBL models

→ Require grid points satisfy direct constraints on EBL intensity

77440 models_considered



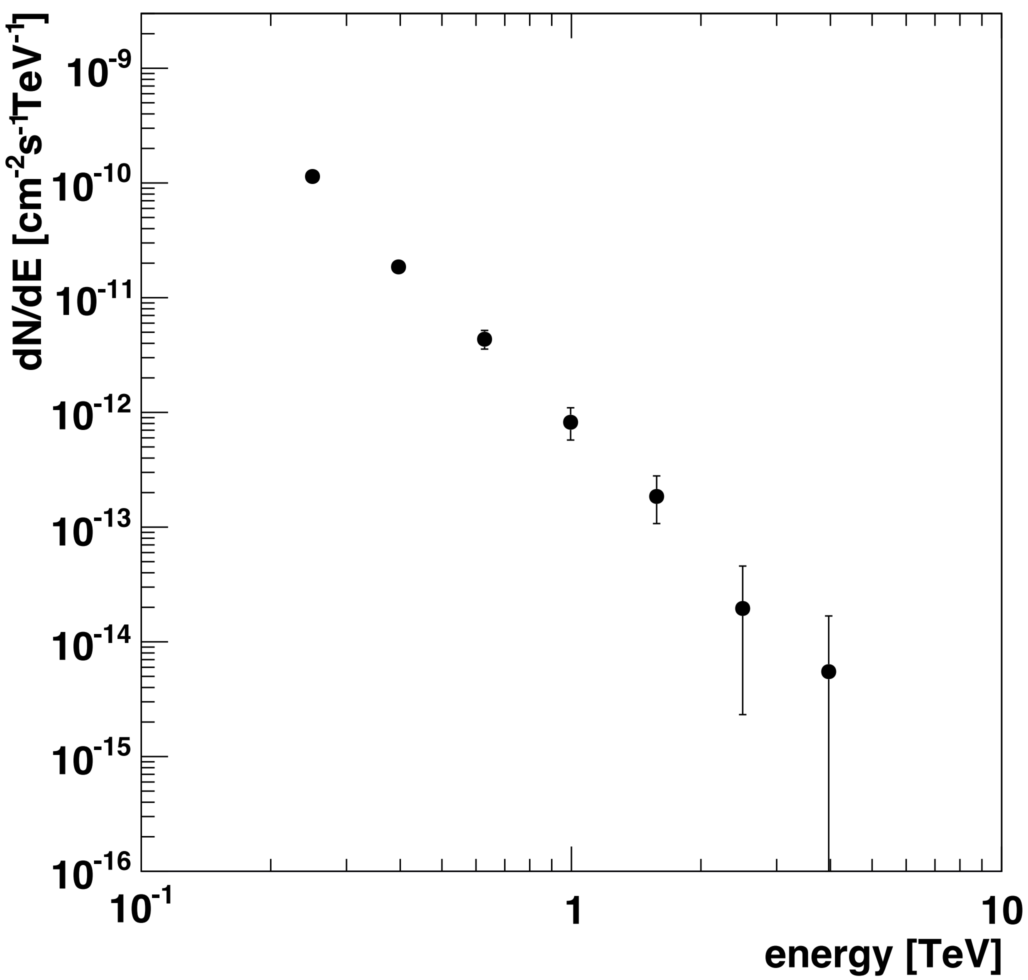


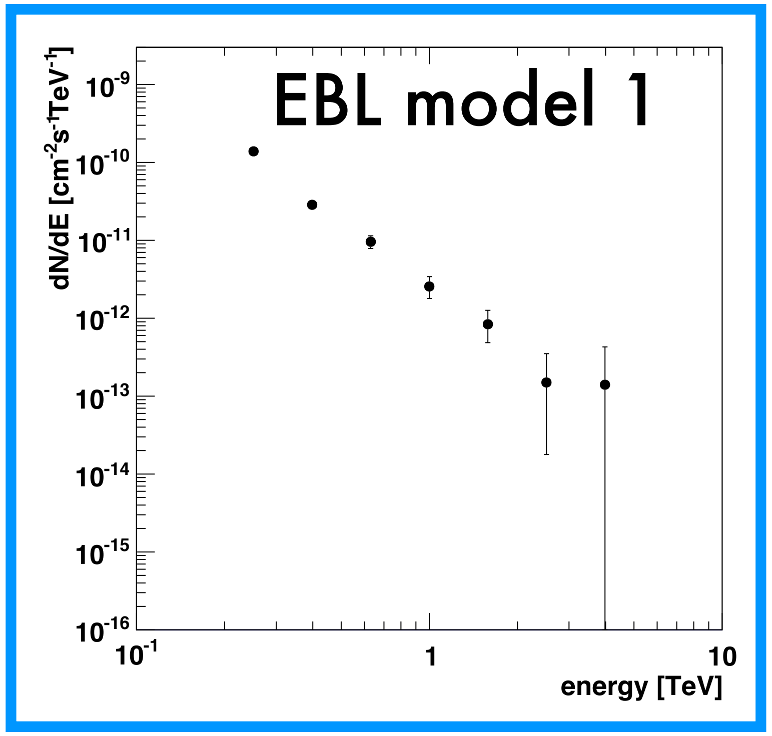
→ For each EBL model, calculate opacity exp($\tau_{\gamma\gamma}$) for z & energy

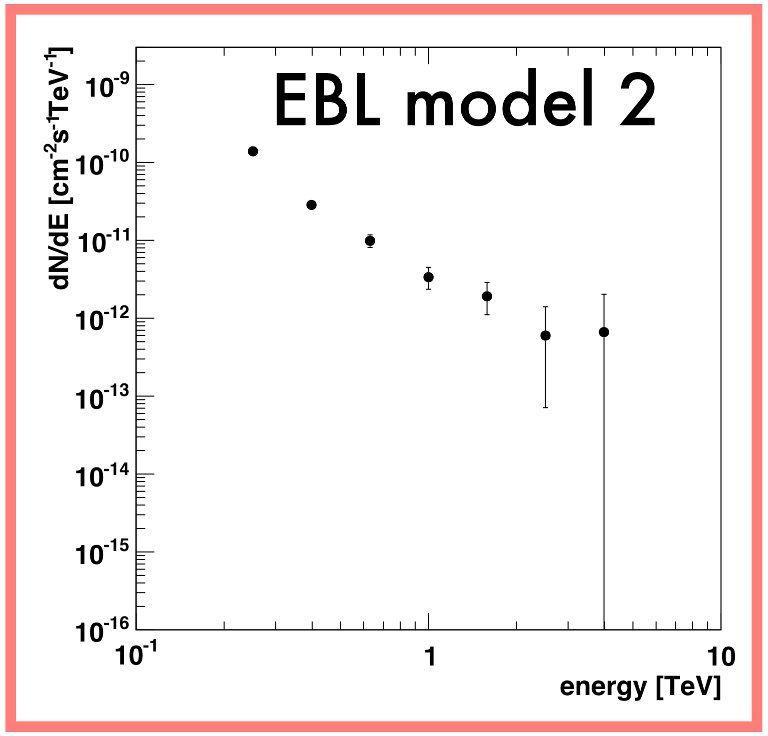
→ Account for EBL evolution

$$n_{EBL} \propto (1+z)^3 \rightarrow n_{EBL} \propto (1+z)^{3-f_{evo}}, f_{evo} = 1.2$$

Building Blocks: Source Spectra

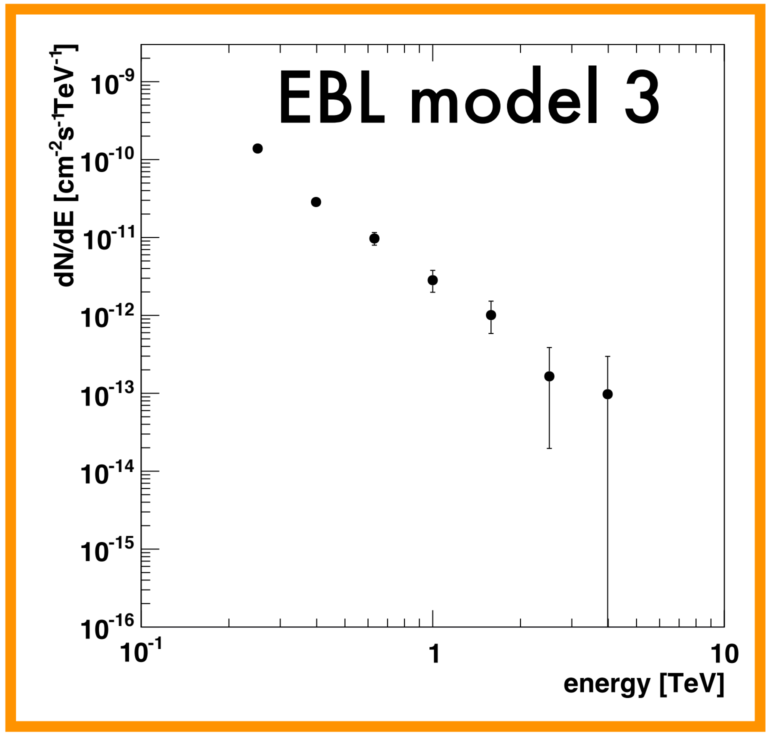






example observed spectrum

$\longrightarrow \times \exp(\tau_{\gamma\gamma})$ to deabsorb



example deabsorbed spectra

Two Methods

Method I

Source spectrum

Method II

Deabsorbed spectra
(77440 spectra)

1) Fit w. power law
2) Fit w. power law + exp. cut-off
3) Take best fit

Keep EBL model if:
$\Gamma > 1.5$
$\Gamma > \Gamma_{Fermi}$

based on Mazin 2007

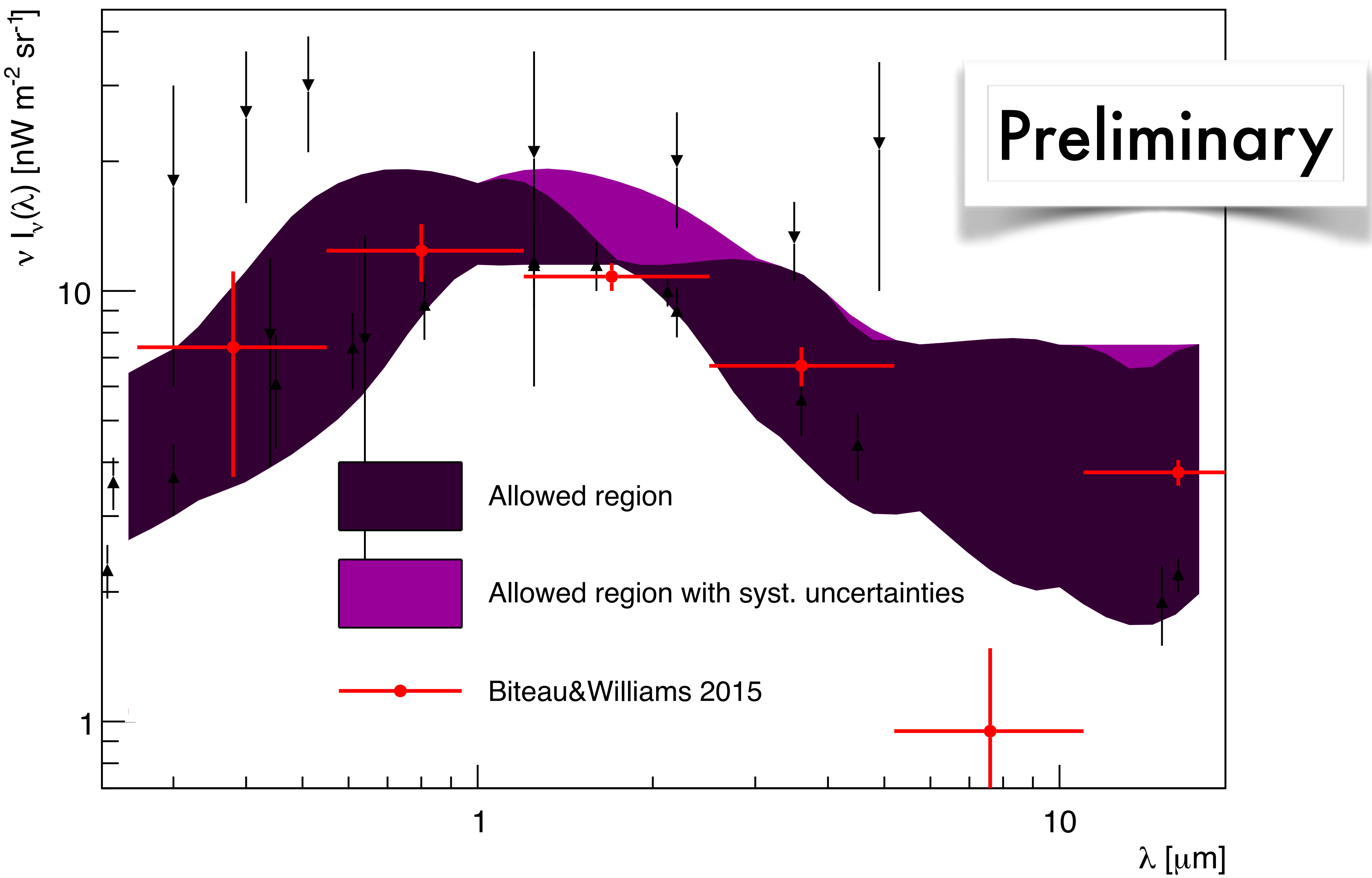
Keep EBL model if:
$\chi 2 \leq \chi 2_{min}+1$
$\rightarrow$ 68% confidence band

based on Lorentz 2015

Method I Results

→ Combination: retain models that are acceptable for ALL sources

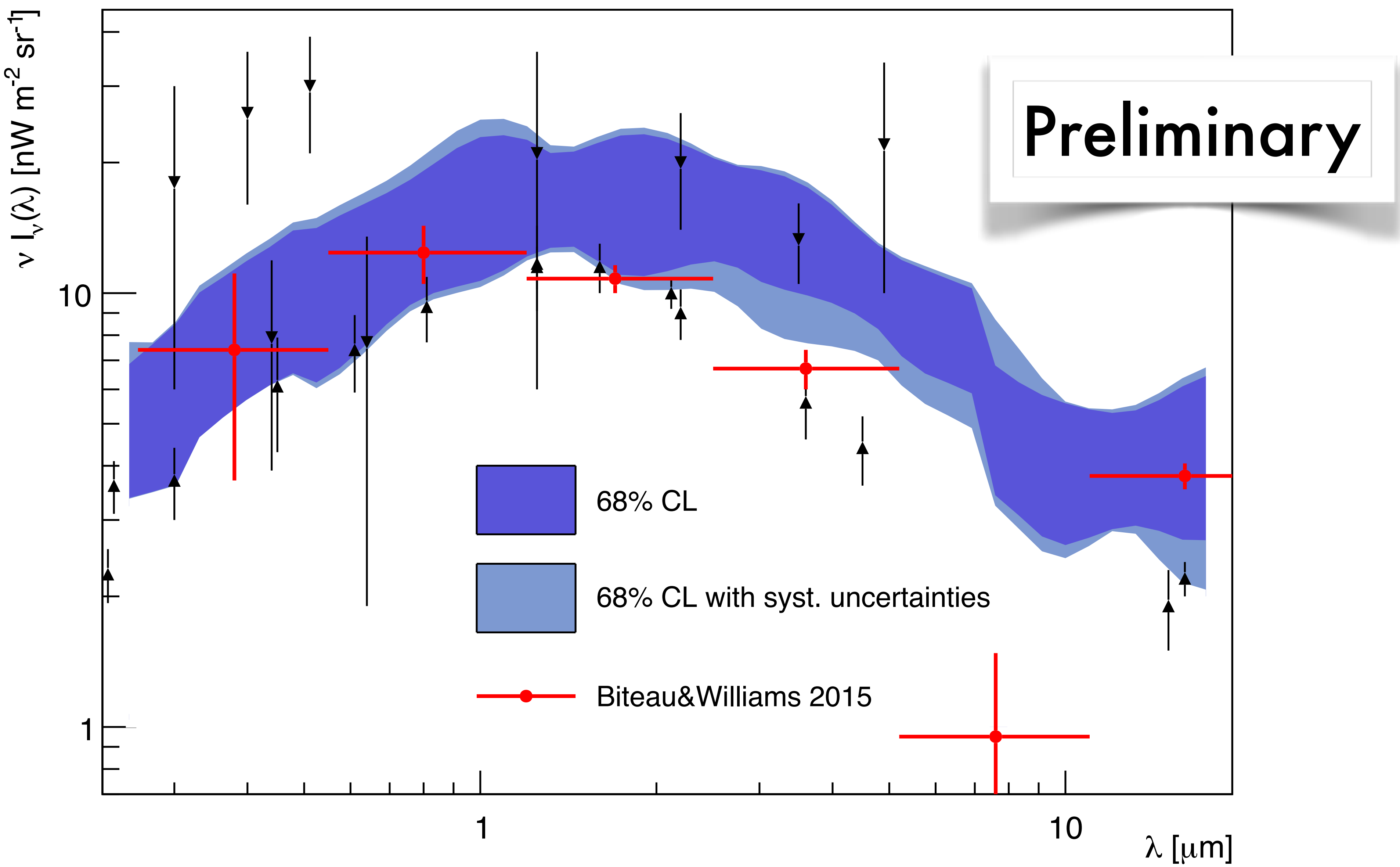
→ Systematic uncertainty: soften fitted spectral index by 10% (propagating uncertainty on energy resolution)



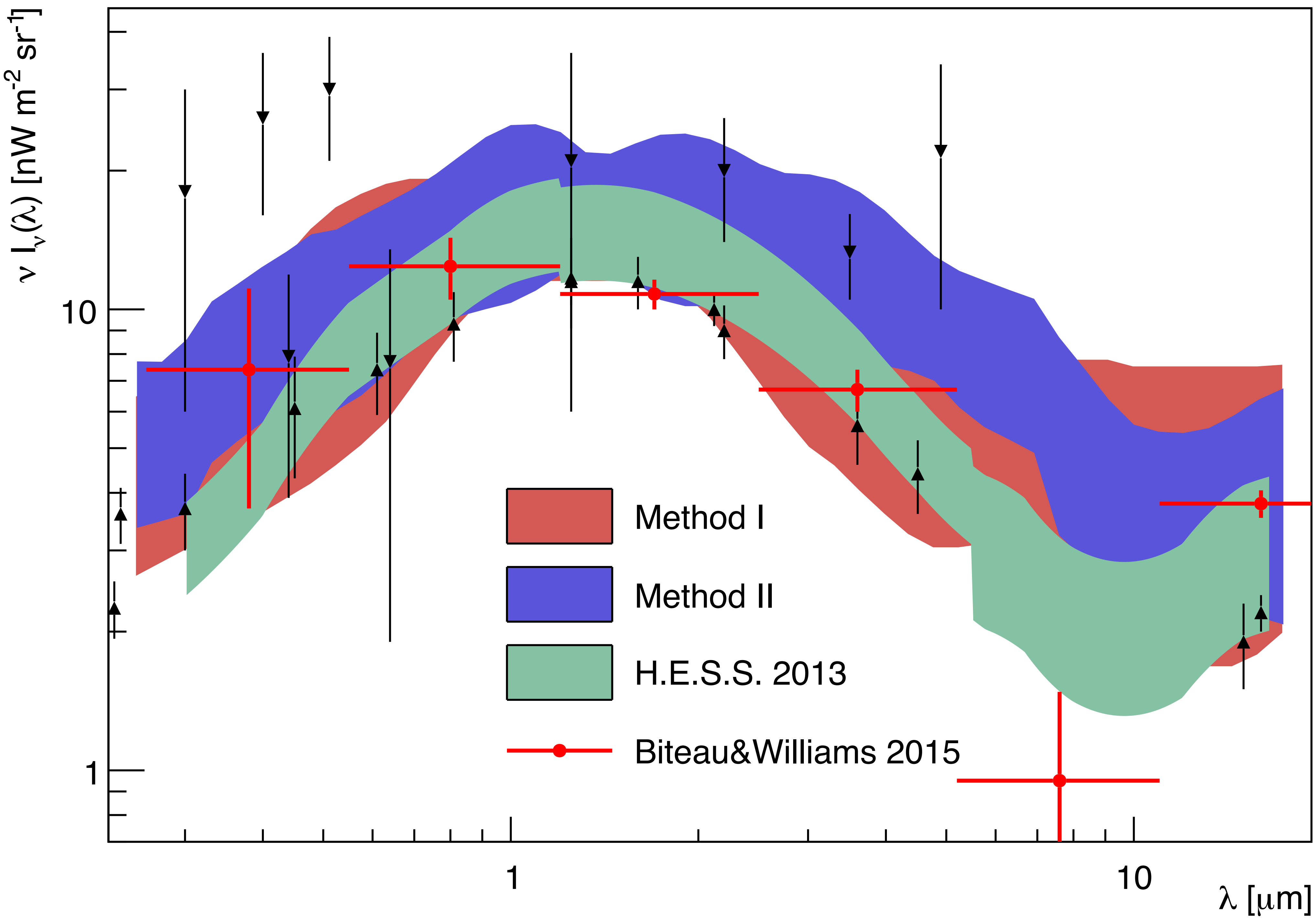
Method II Results

→ Combination: sum individual confidence bands, find mean & RMS

→ Systematic uncertainty: remove sources one by one, find maximum change in confidence band



Comparison to Previous Results



Conclusions.

- New VERITAS constraints on EBL
  - Sources
    - 10 sources, redshifts z=0.044 - 0.49
    - *Add more sources, more data (long-term plan objects)*
  - Constraints
    - Two methods
      - Agree well with each other & existing constraints
    - *Increase granularity of [λ, EBL intensity] grid*
    - *Increase granularity of [z, energy] opacity calculation*

Thanks for your attention!