EBL signatures from very high energy gamma-ray spectra

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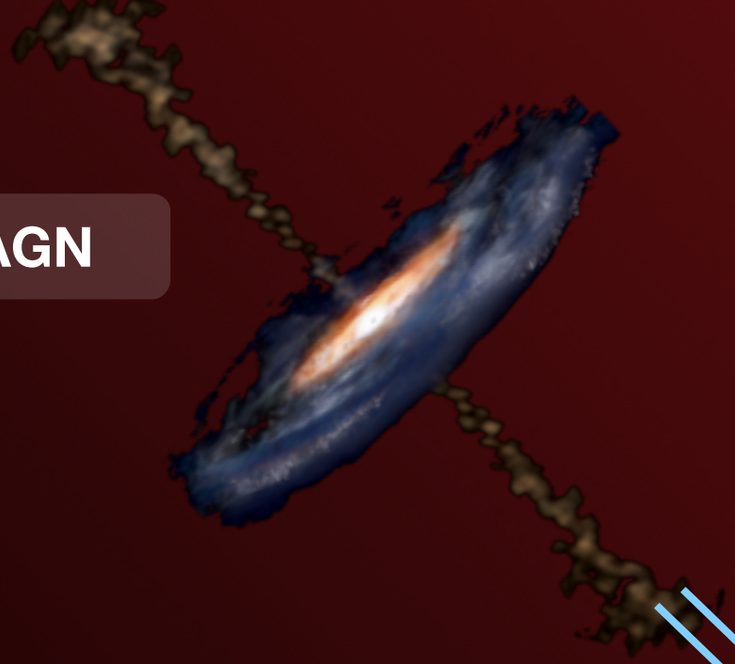
Contents

- Extragalactic Background Light
- Constraints so far
- Pile-ups at high energy: what are they?
- Steady sources for EBL/cosmology studies
- Hubble constant issue

AGN



HE/VHE ϒ-Rays

Nikishov (1962), Jelley (1966), Gould & Schreder (1966)

slide from M Raue

AGN

Stars and **Dust**
in Galaxies

HE/VHE γ-Rays

UV/O/IR
Photons

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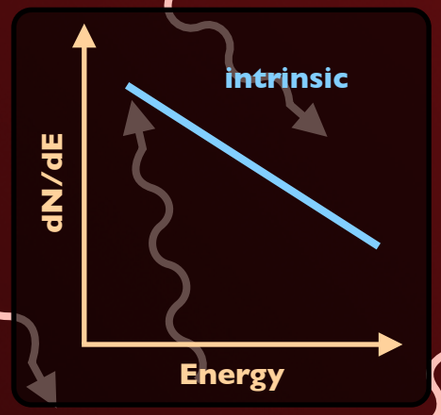

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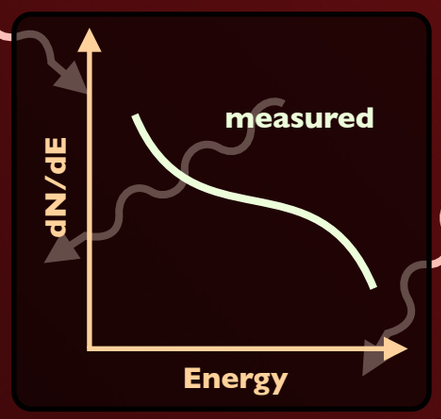

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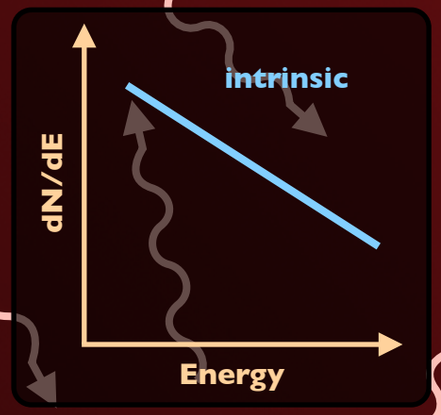
HE/VHE γ-Rays



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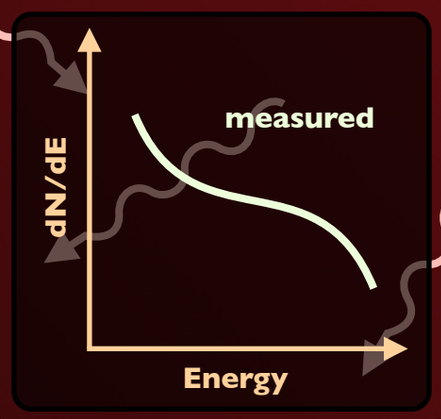
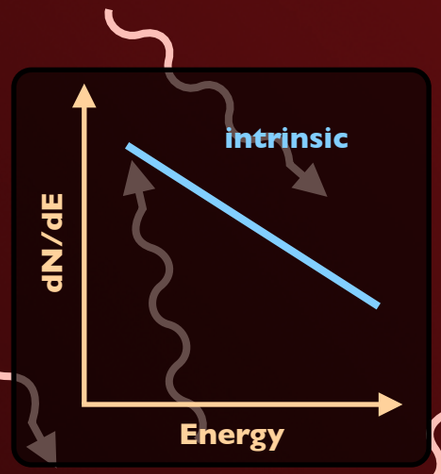


$$E_\gamma E_{\mathrm{EBL}} \approx 4(m_e c^2)^2 \approx 1\,\mathrm{MeV}^2$$
$$E_{\mathrm{EBL}} \sim \mathrm{eV} \rightarrow E_\gamma \sim \mathrm{TeV}$$

Nikishov (1962), Jelley (1966), Gould & Schreder (1966)

slide from M Raue

AGN



Stars and **Dust**
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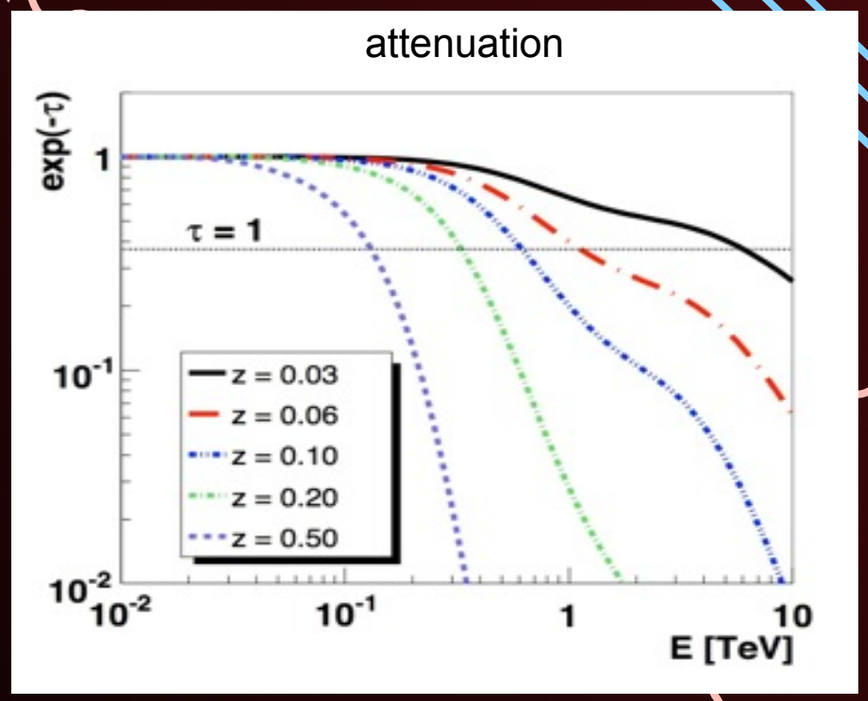
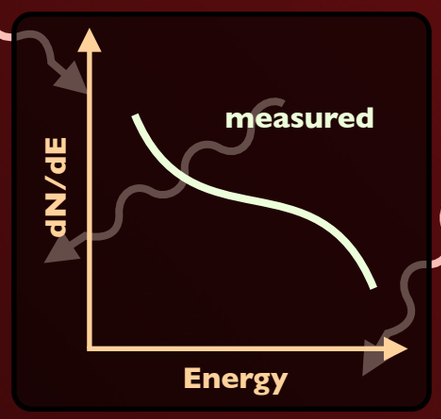


UV/O/IR Photons

e+ e-



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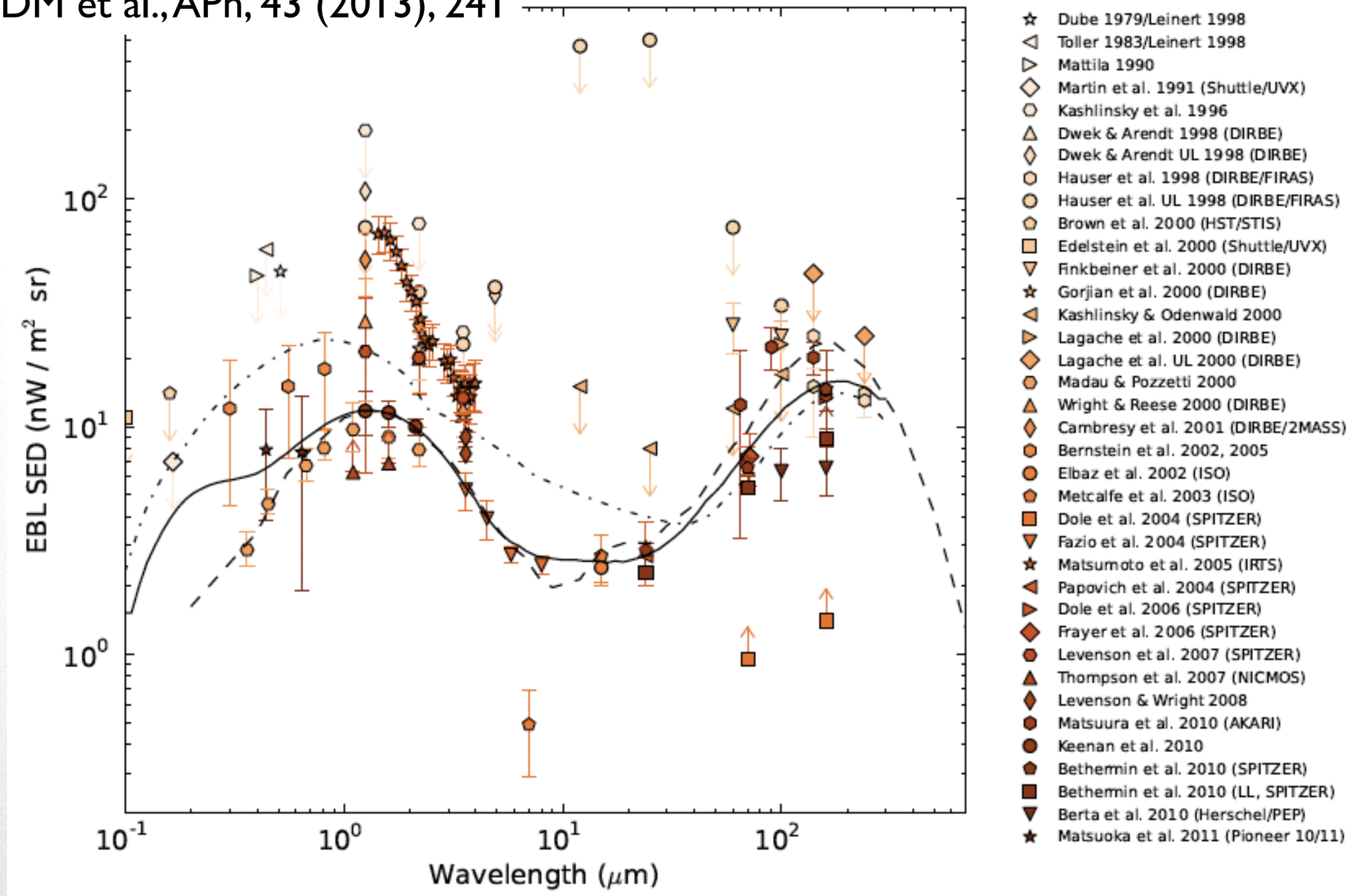
slide from M Raue

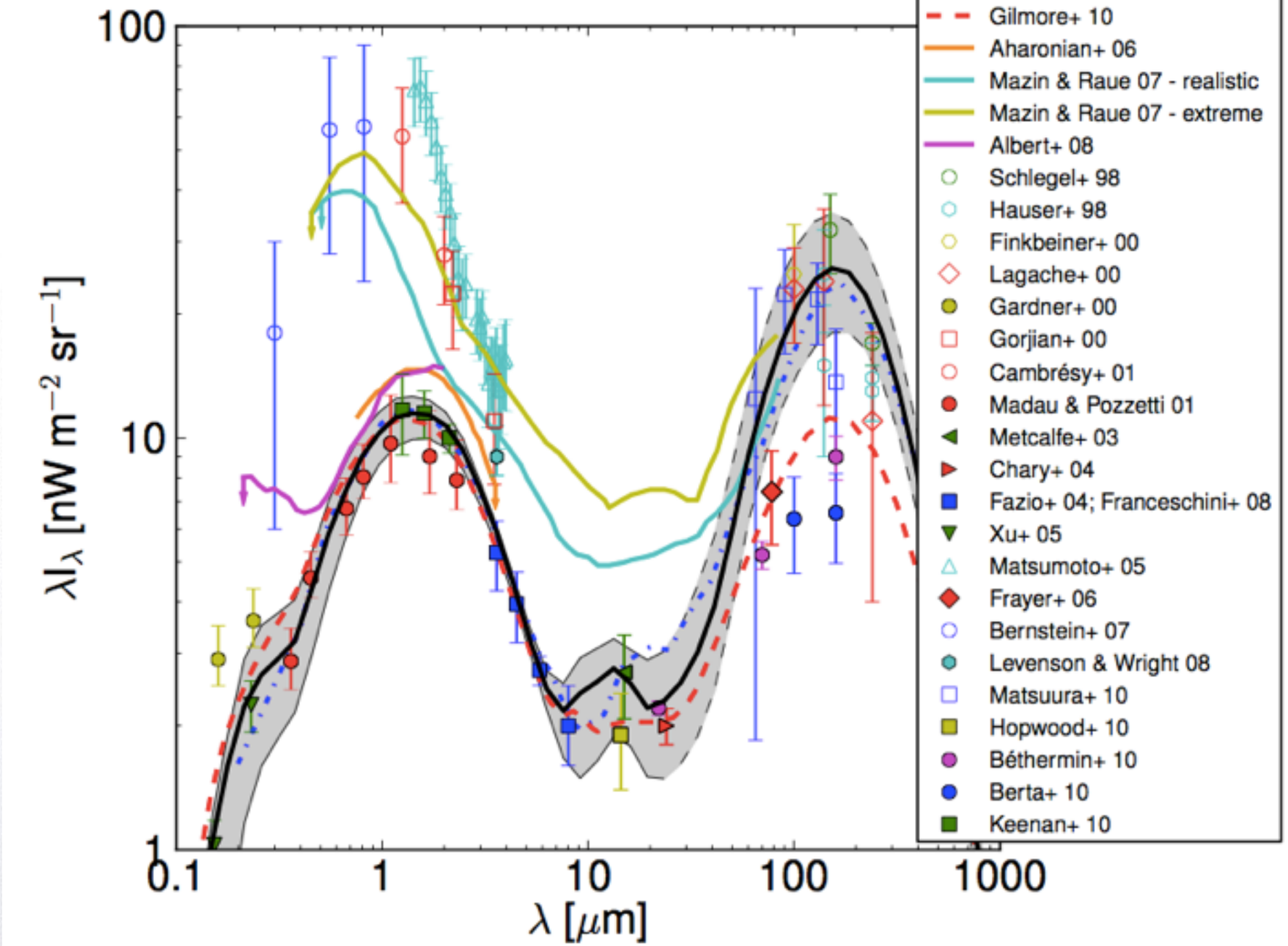
The EBL energy density

DM et al., APh, 43 (2013), 241



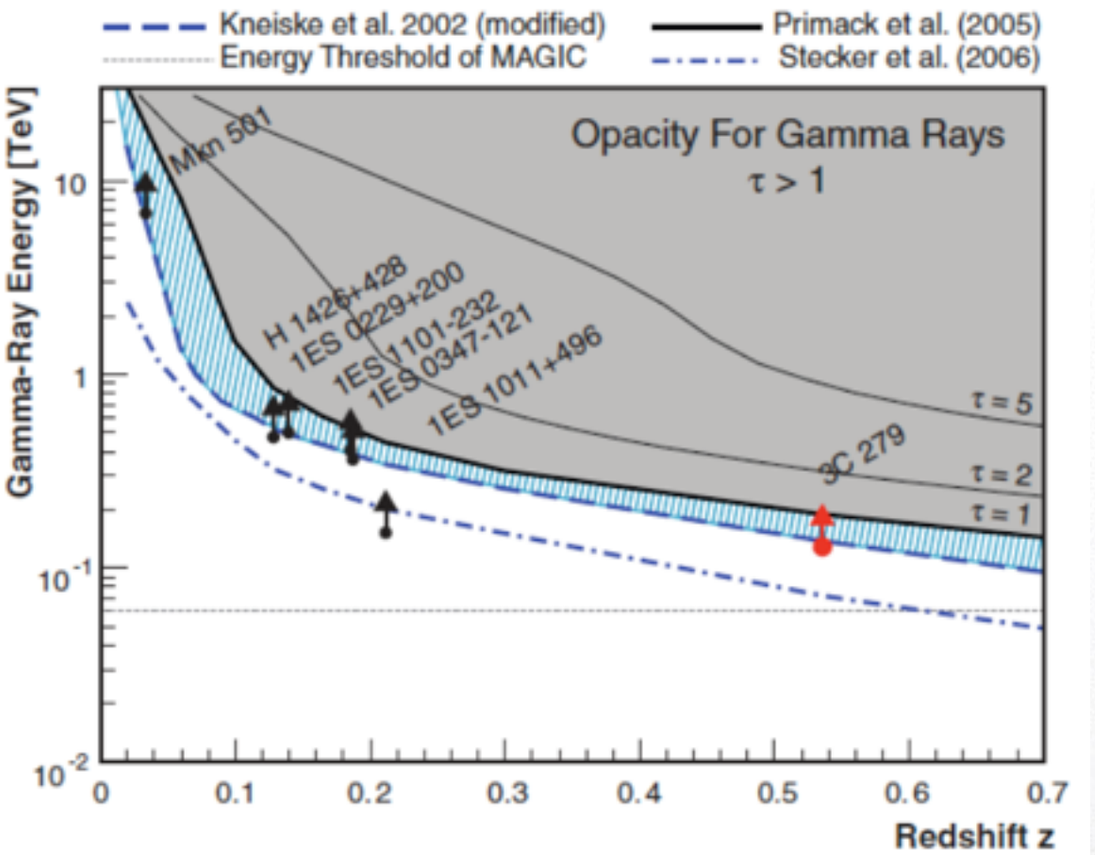
The EBL energy density

Dominguez et al., MNRAS 410, 2556 (2010)

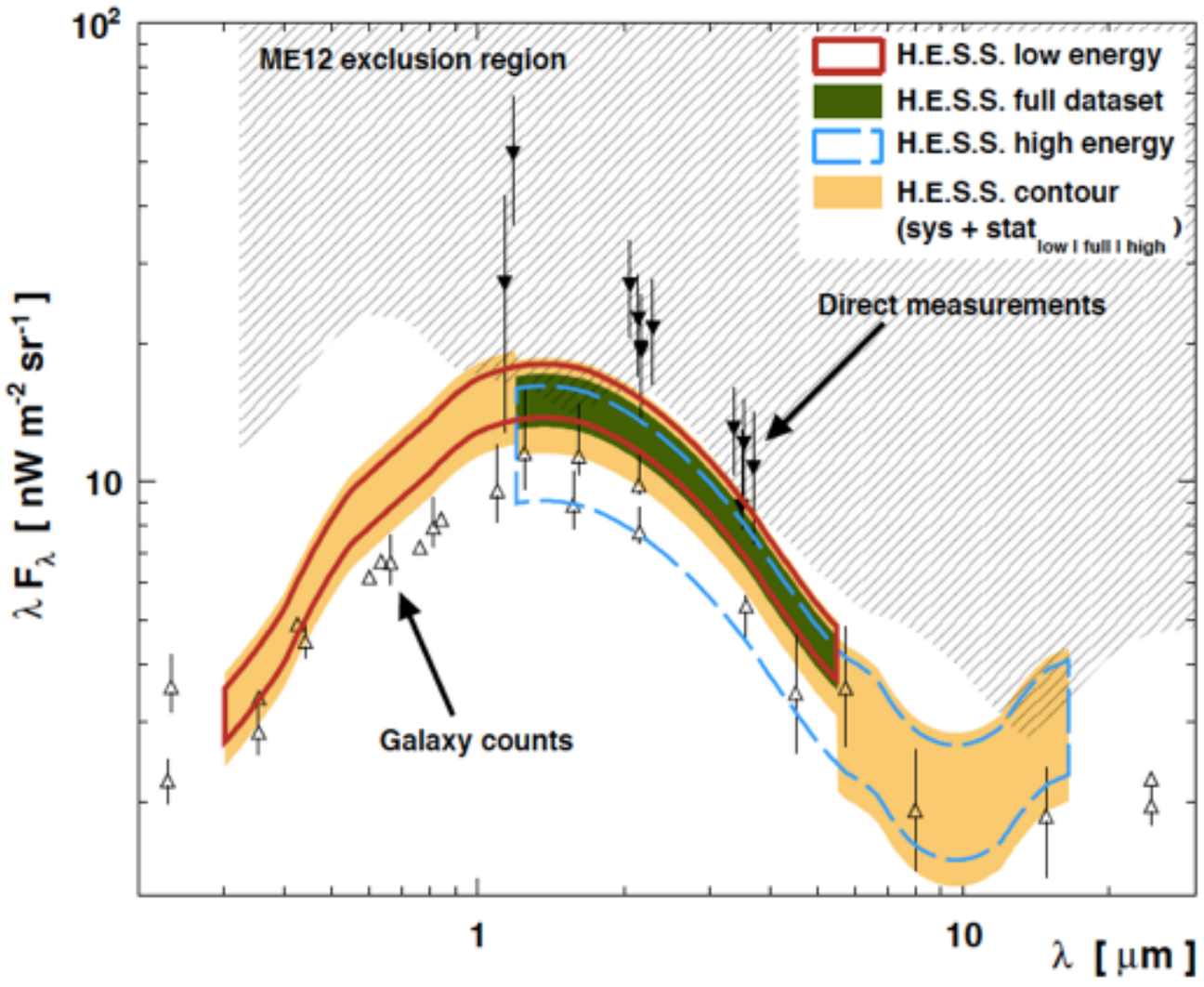


The EBL energy density

MAGIC, Science 320,1752 (2008)



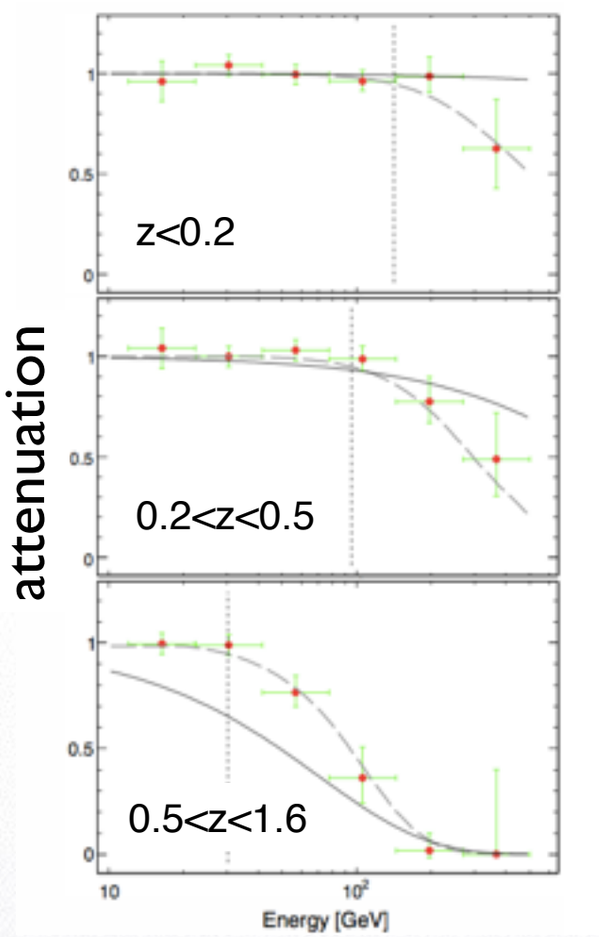
H.E.S.S., A&A 550, 11 (2013)

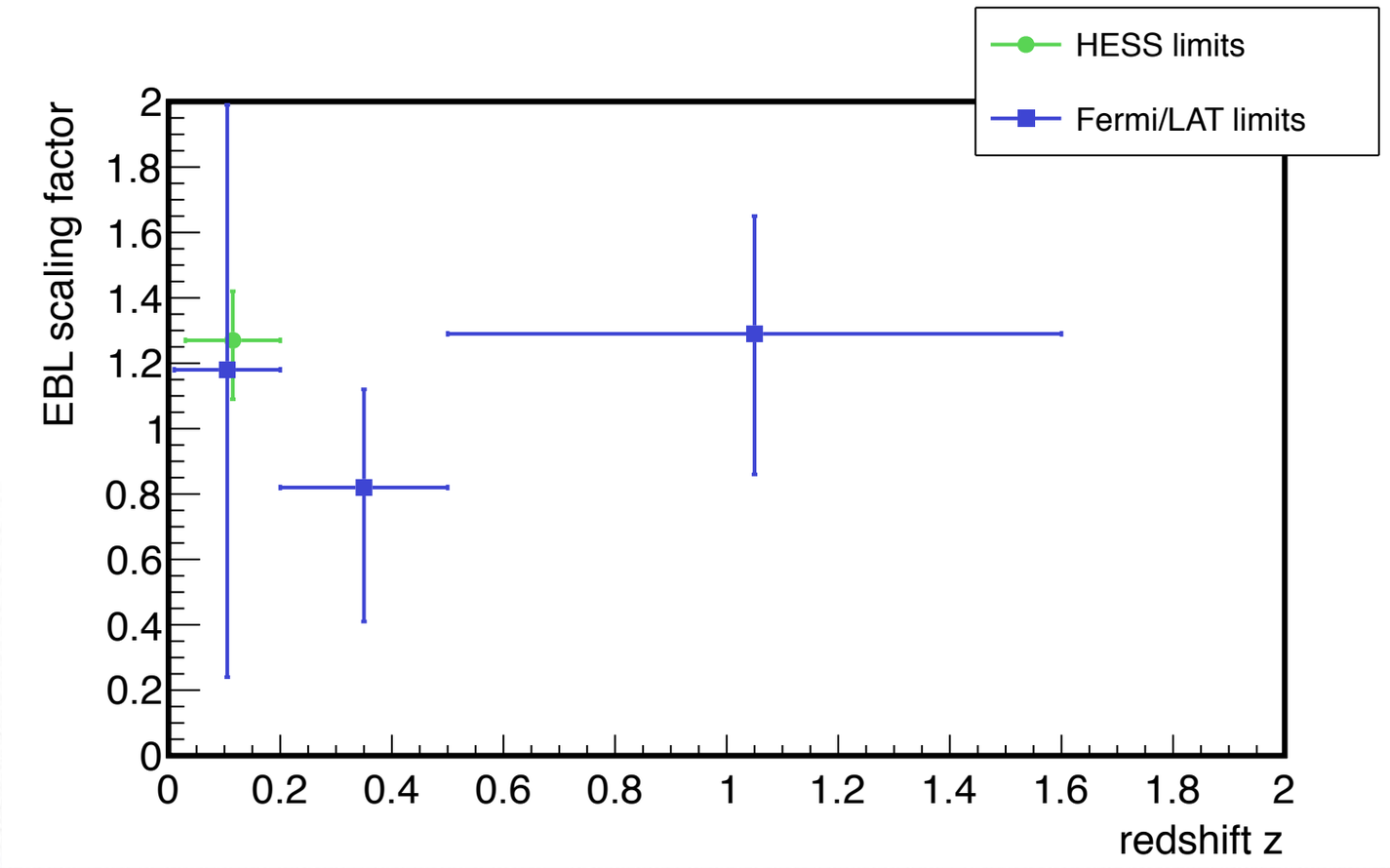


Not much more EBL than the one from the resolved galaxies

Combined Fermi-LAT and H.E.S.S. limits

Fermi/LAT, Science (2012) 338, 1190
see also HESS, A&A (2013) 550, 11



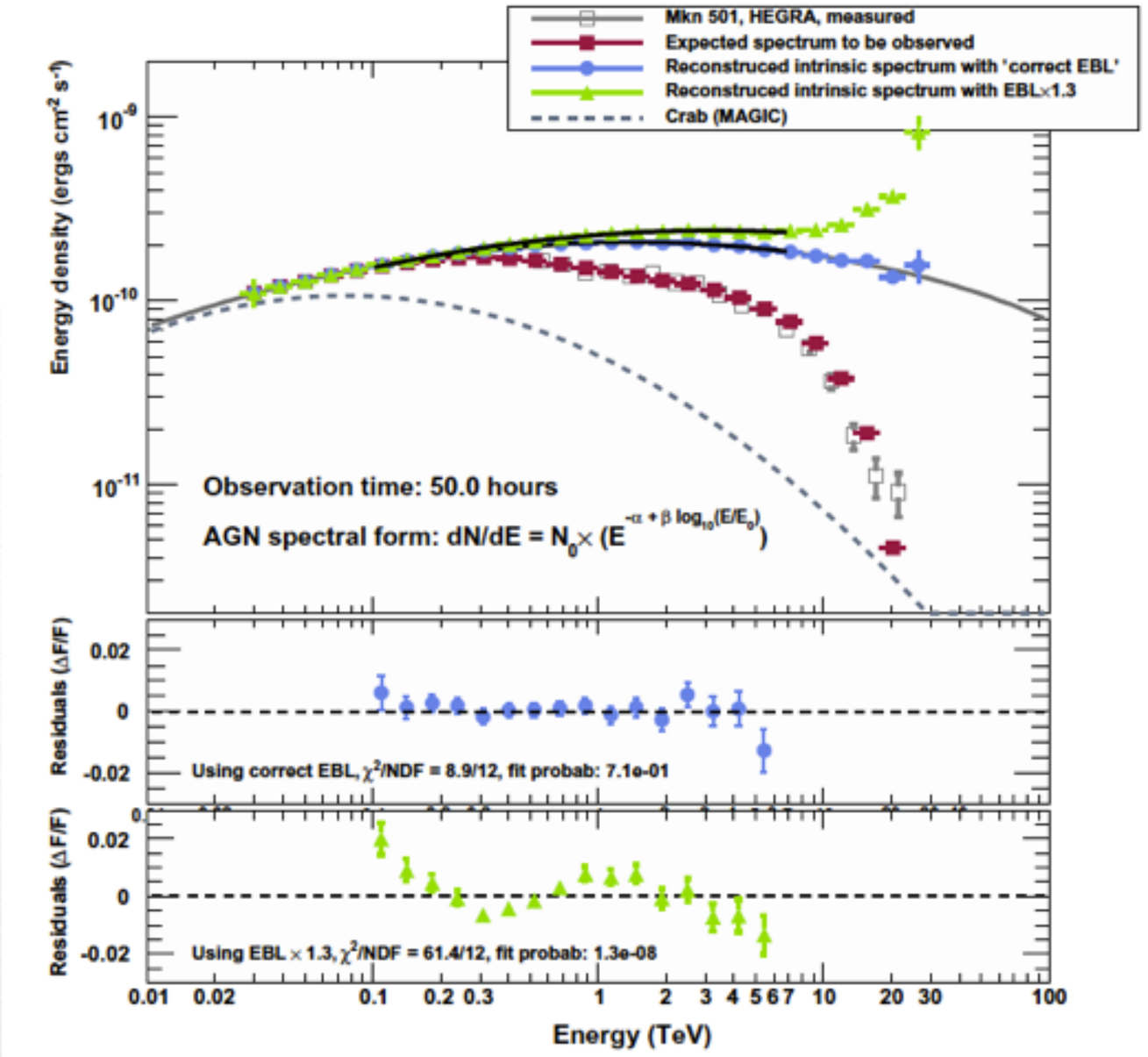


- HESS and Fermi collaborations claim to see a EBL signature in their blazar spectra
- Assumption that there is no EBL can be excluded with 8σ and 6σ by HESS and Fermi, respectively
- The EBL model which best fits the data (i.e. make the spectra smooth) is very close to recent established EBL models

Wiggles in spectra of AGN in very high state

precision EBL at Mid infrared

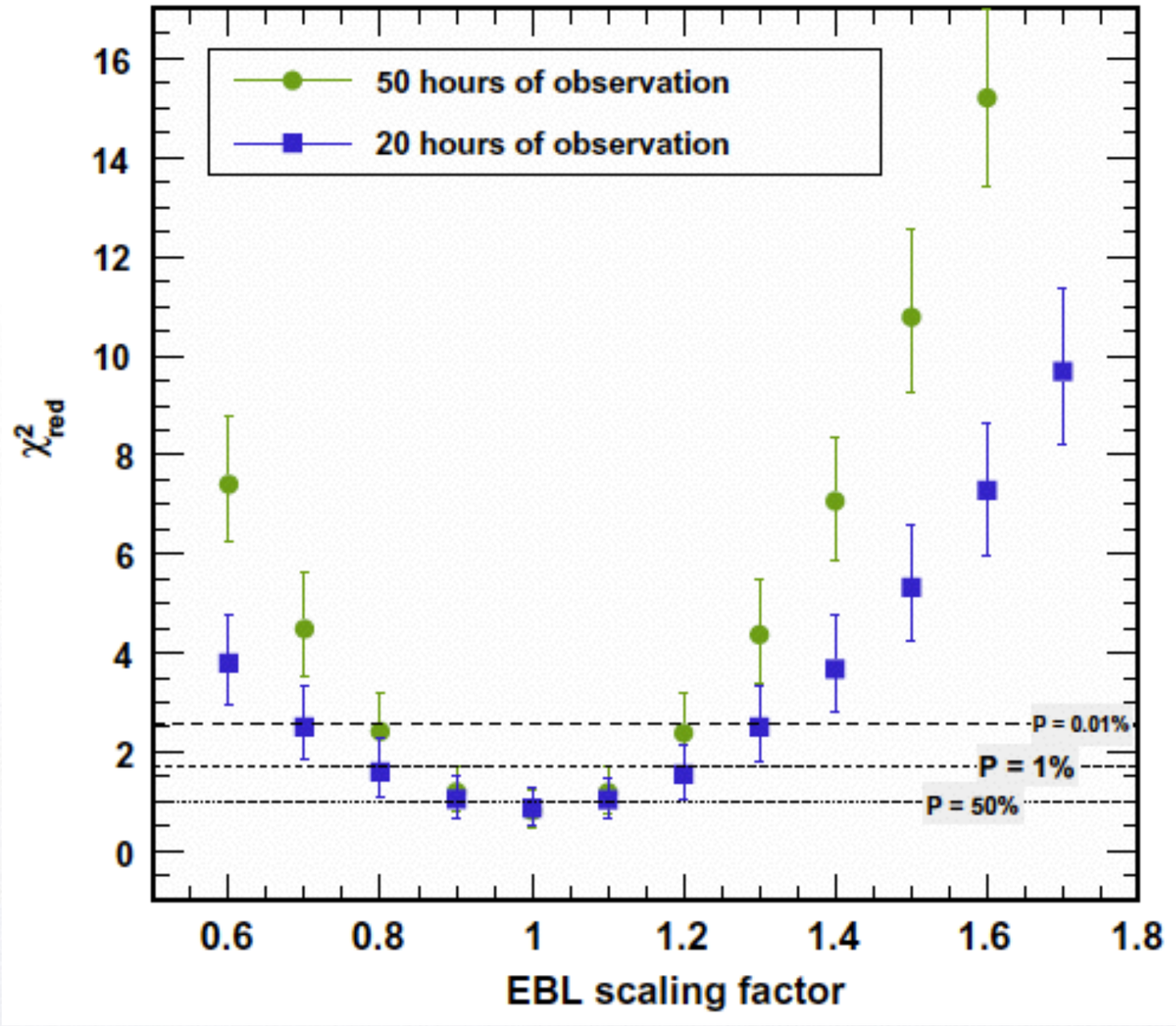
- Idea: if the measurement is precise enough, the spectral form will be sensitive to "wrong" EBL assumptions, and "wiggles" in the reconstructed spectrum would appear
- Here an example of Mrk 501 simulation:
  - **blue points** obtained with proper EBL model, no wiggles in residuals
  - **green points** obtained with a wrong (by 30%) EBL, wiggles clearly seen in the residuals



DM et al., APh 43 (2013), 241

Precision of EBL determination

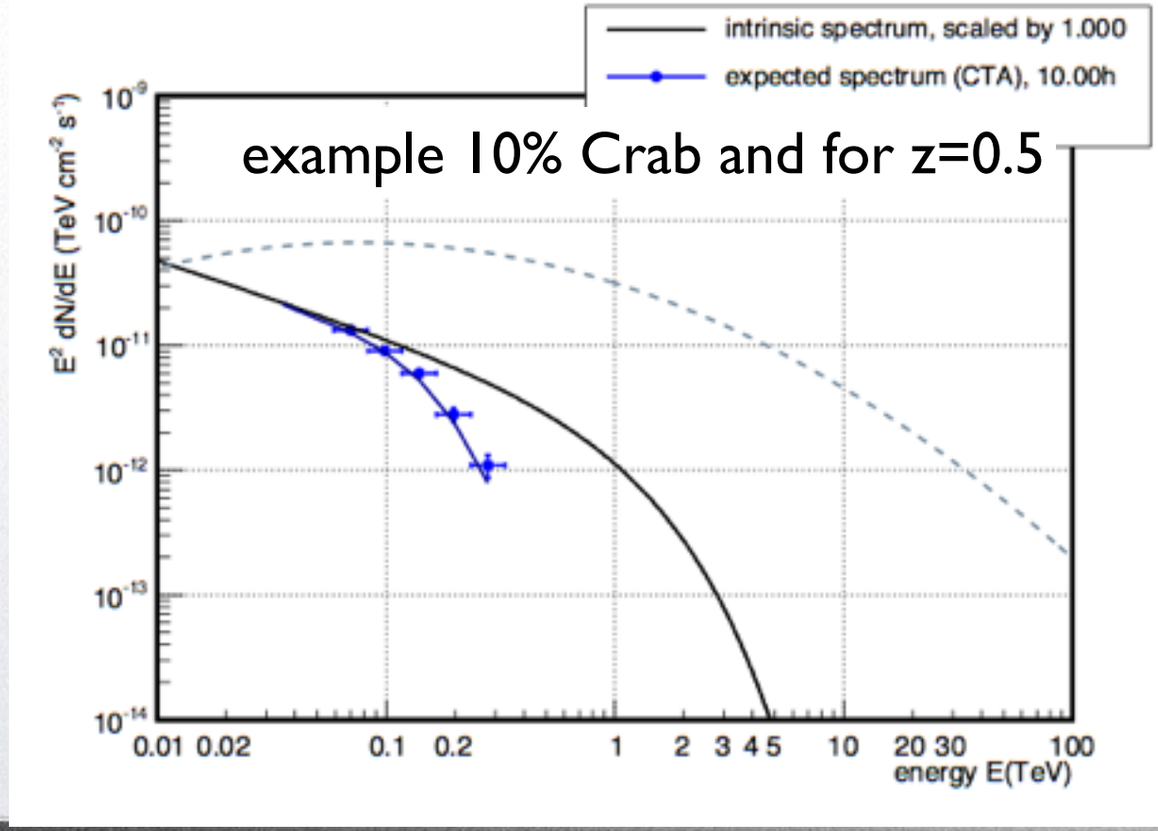
- Precision of the method is between 15 and 30%, depending on the assumed exposure of the AGN in flaring state

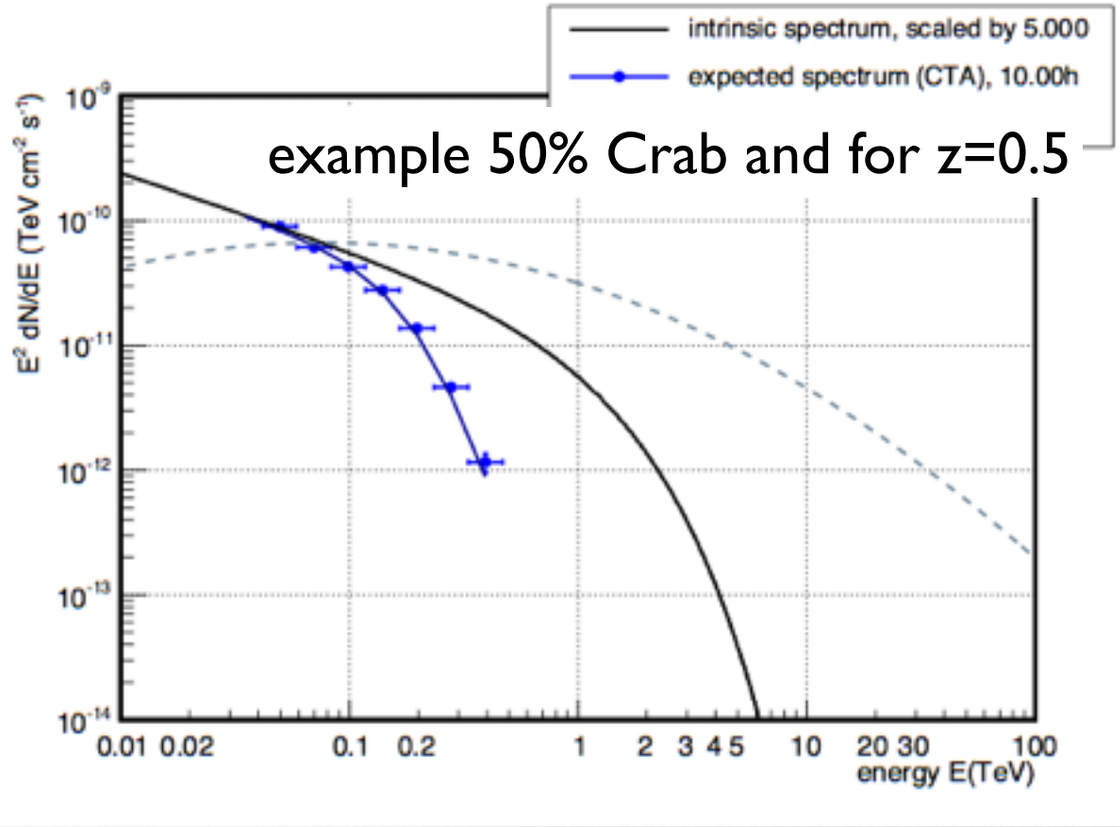


DM et al. , APh 43 (2013), 241

Precision of EBL determination

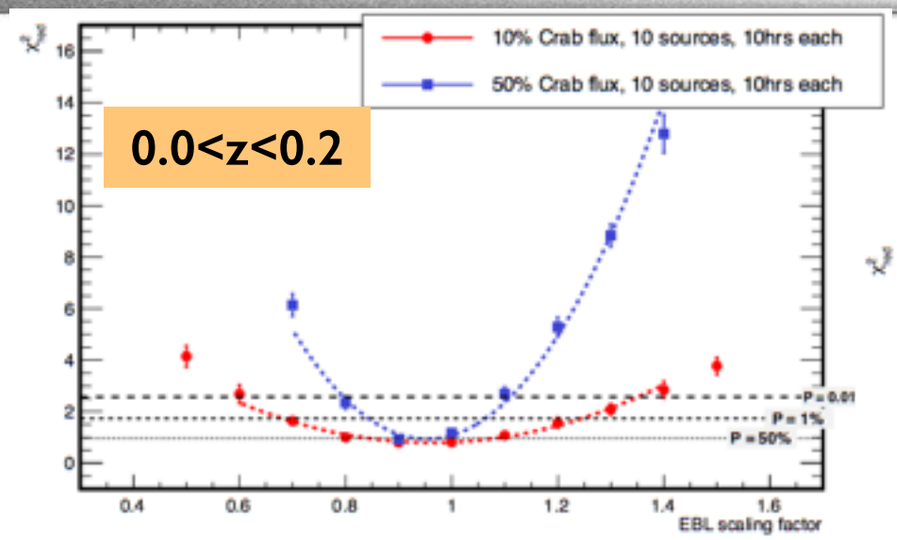
- Assume some 50 AGN at different redshifts, 0 < z < 1, are flaring for 10 hrs each; assume their spectra are known (through fit to intrinsic part of the spectrum where there is no EBL effect)
- Simulated two cases:
  - average flux during flaring episodes is 10% Crab, average index -2.6, intr. cutoff at 1 TeV and
  - average flux during flaring episodes is 50% Crab
- Fit resulting de-absorbed spectrum using $\chi 2$ fit

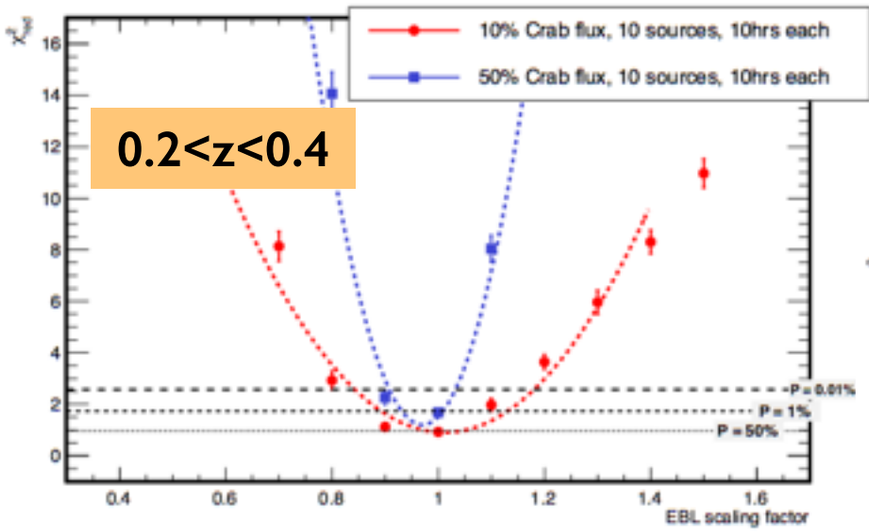


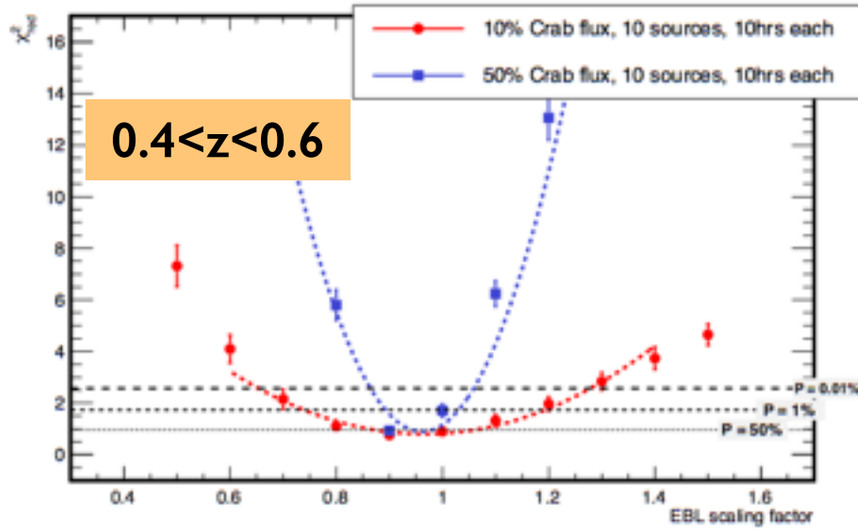


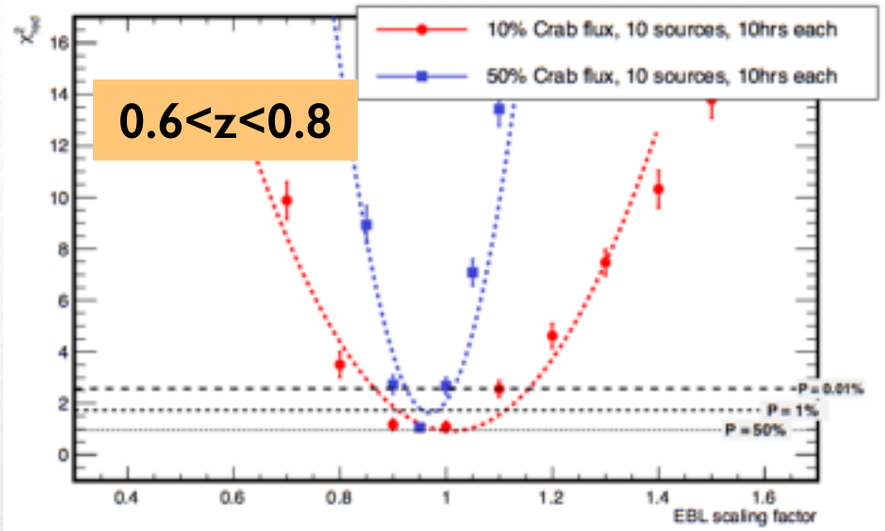
Precision of EBL determination (update)

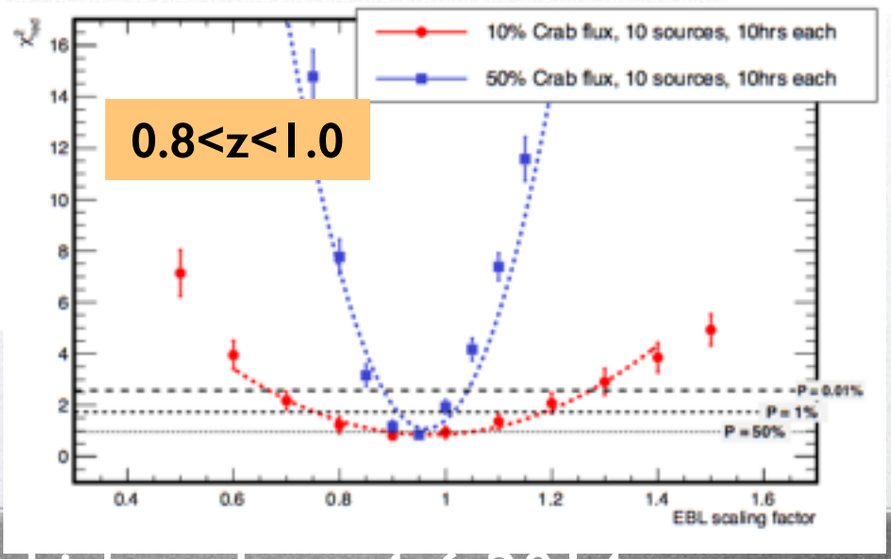
Quality of the fit for different EBL scaling factors





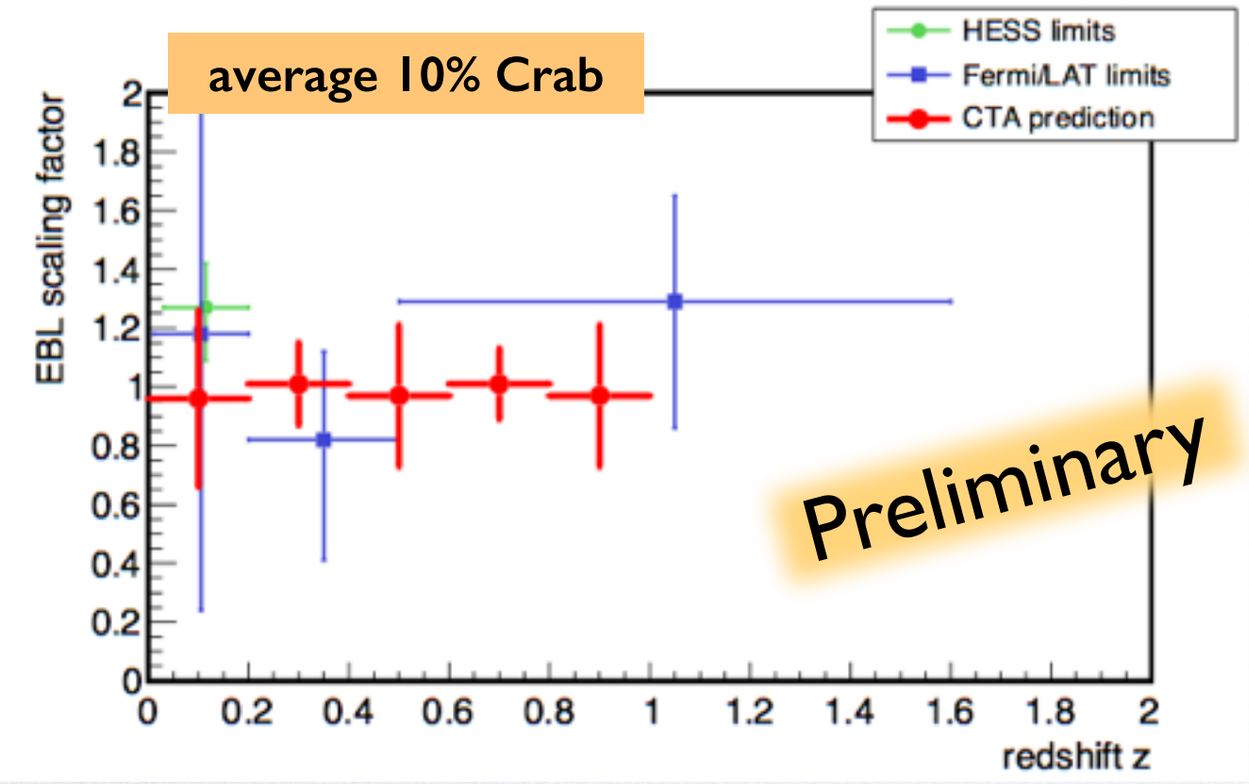


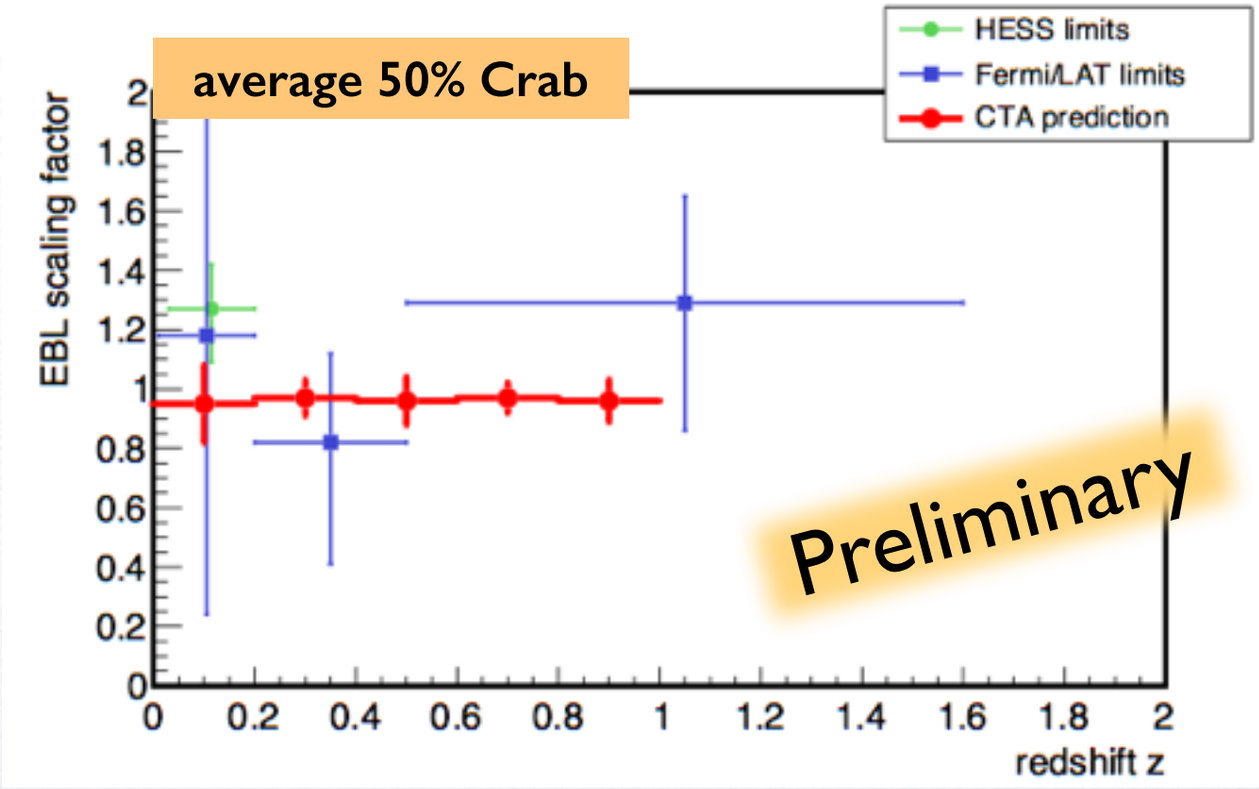




Precision of EBL determination (update)

- Obtained precision (preliminary) of the EBL level: 15-25% for 10% Crab level flares and and 10-15% for the 50% Crab flares
- Can go beyond z>1 if there are sources detectable by CTA





one can derive strong constraints as long as one has enough sources

Pile ups in spectra of distant sources

can we actually assume smooth spectra to derive EBL constraints?

Earlier pile-ups

- Earlier observed pile-ups led to:
  - EBL constraints
  - reanalysis of the data
- It is understood that the last spectral point has a strong bias: point derived on a positive fluctuation (no point derived from a negative fluctuation)

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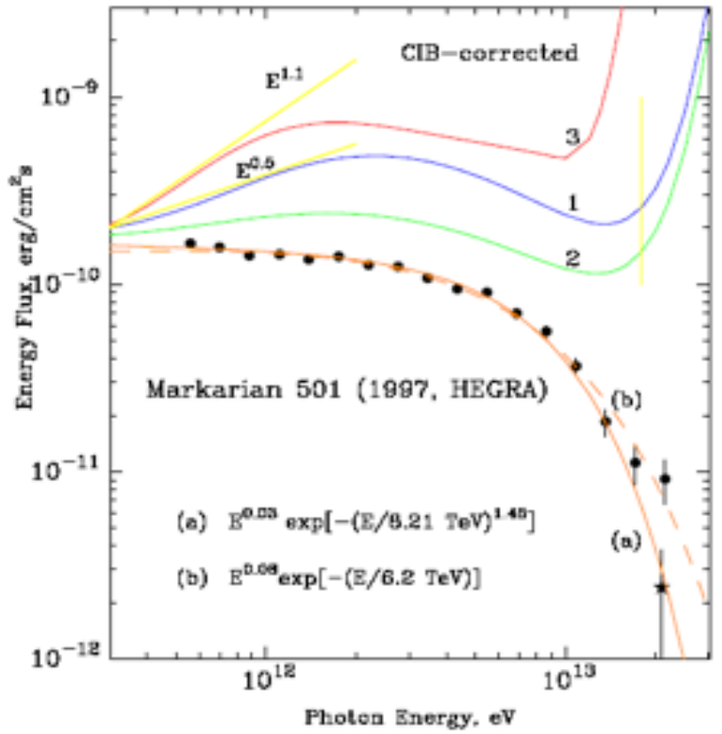
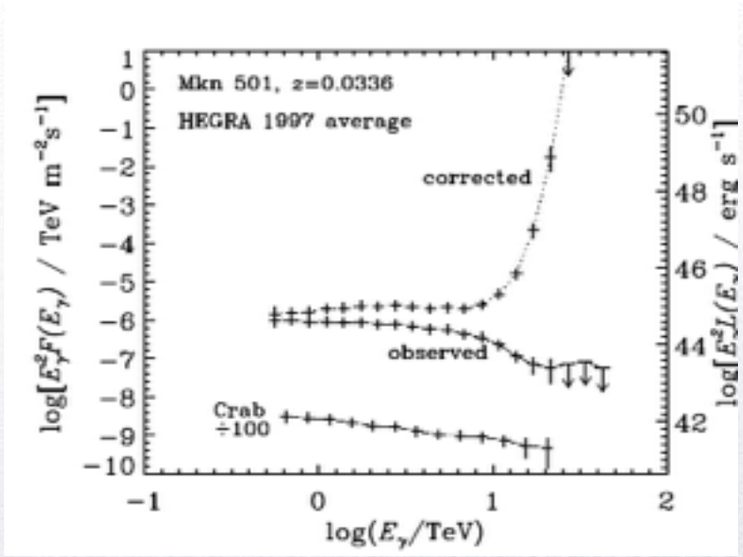
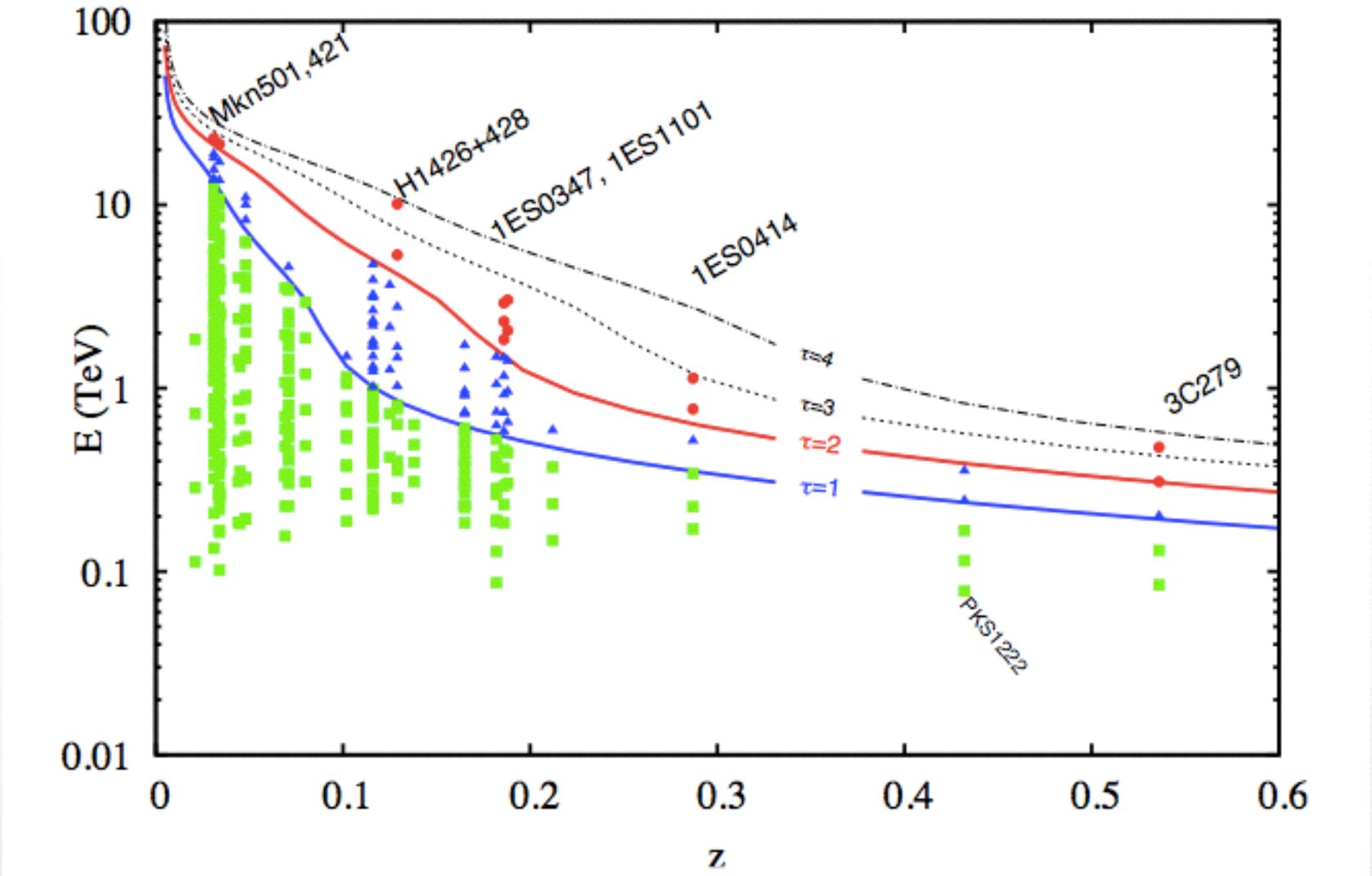




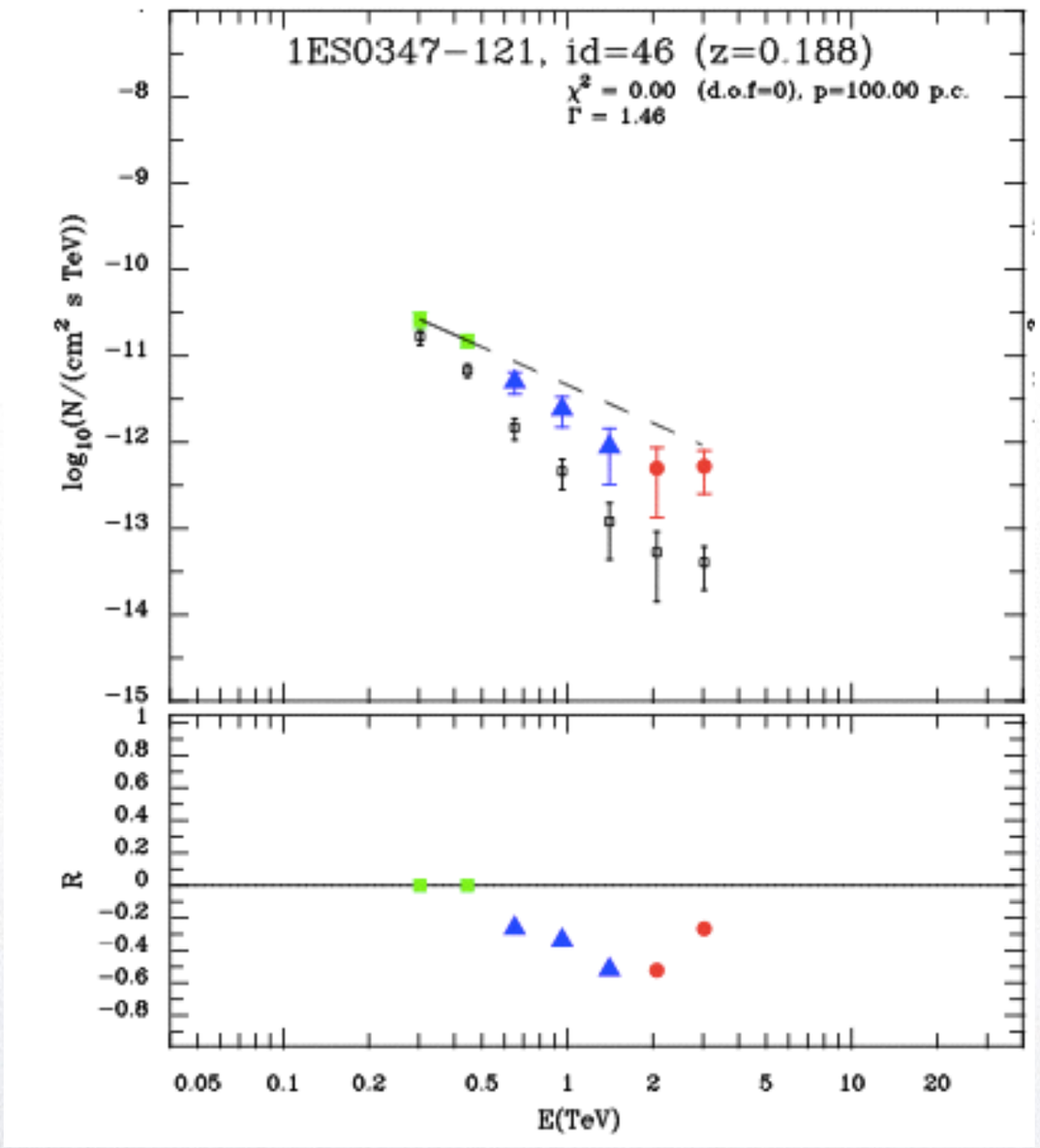
More recent hints

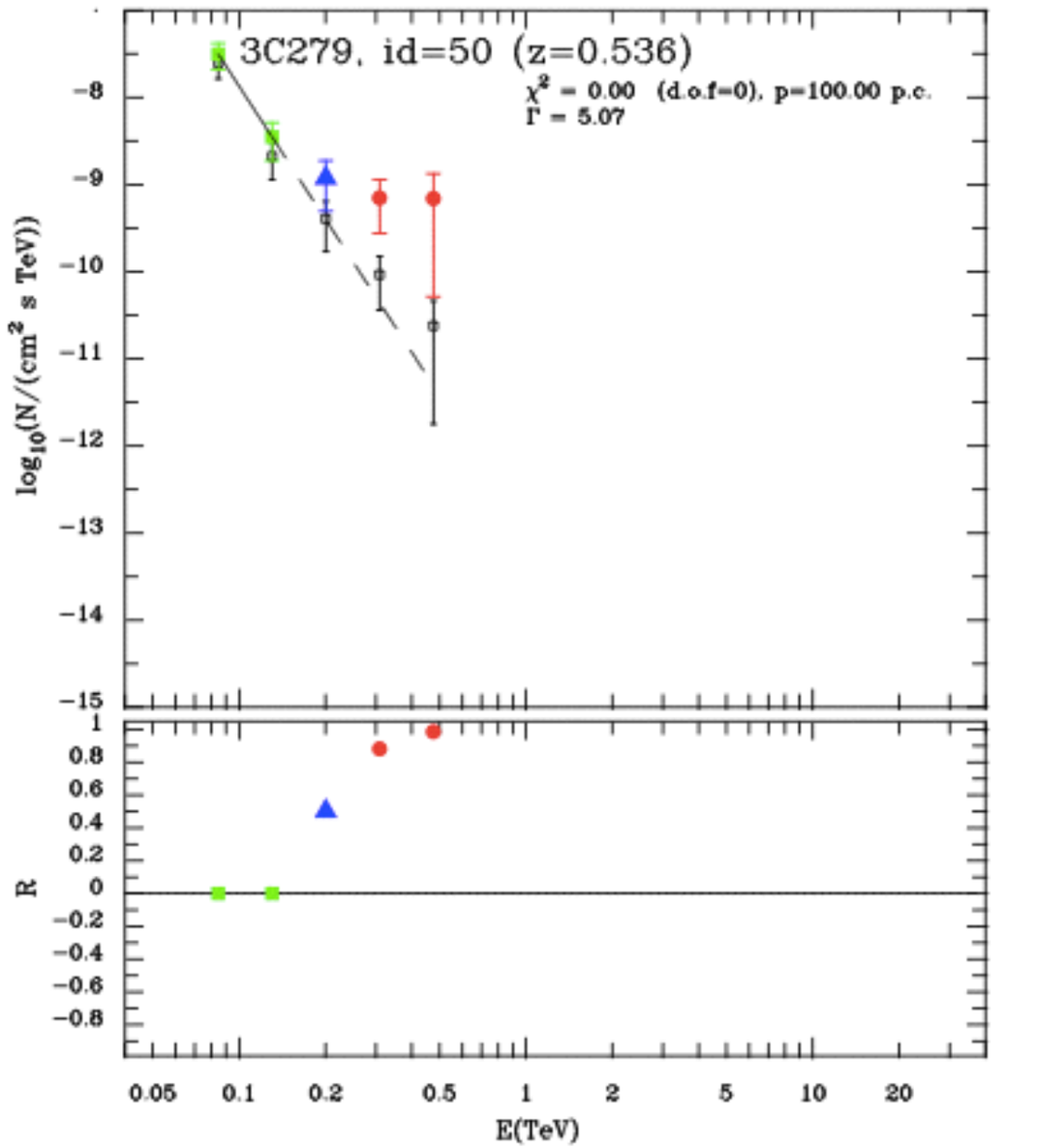
highest points in measured VHE spectra often have tau>2



Horns&Meyer 2012

Example spectra

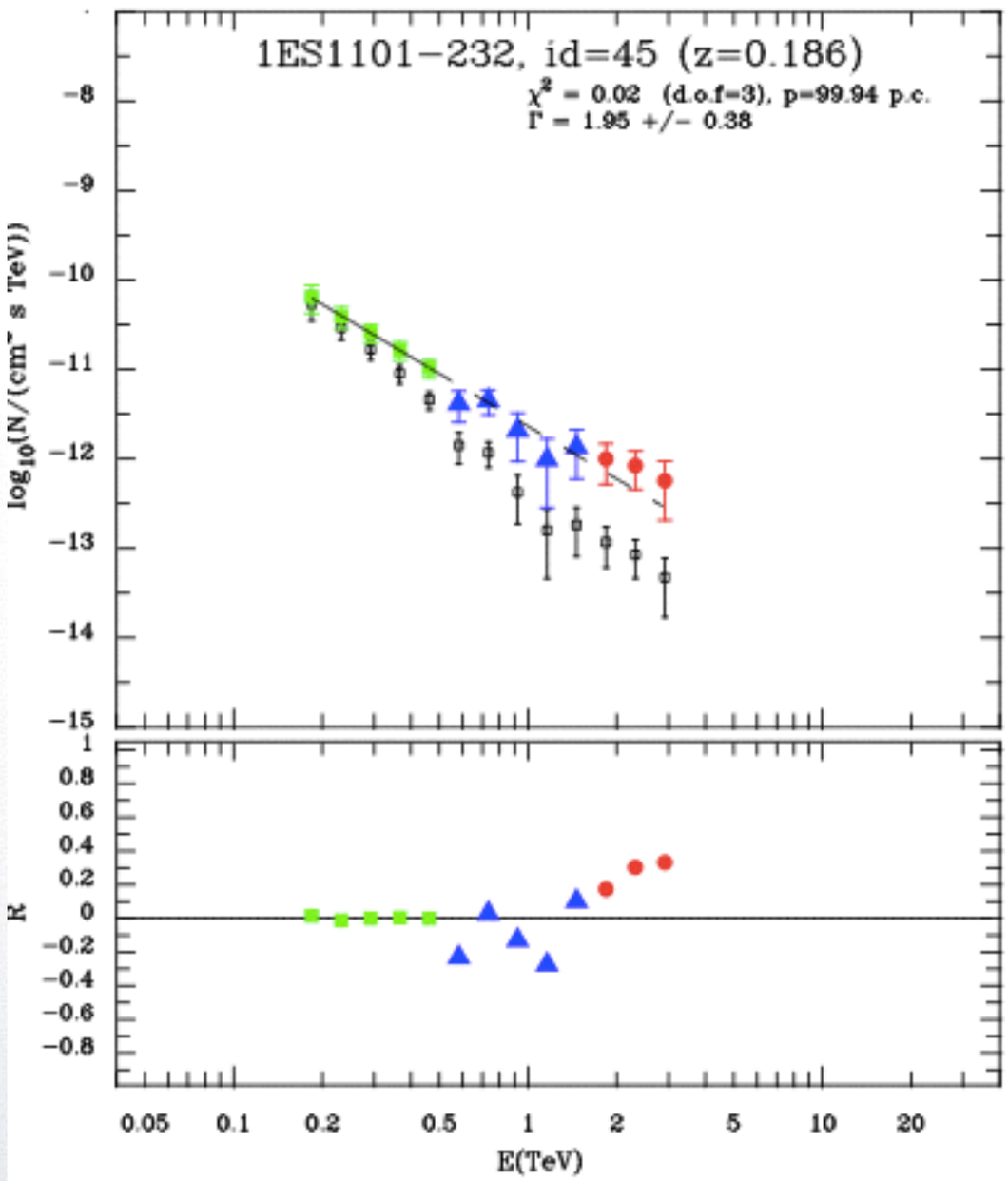


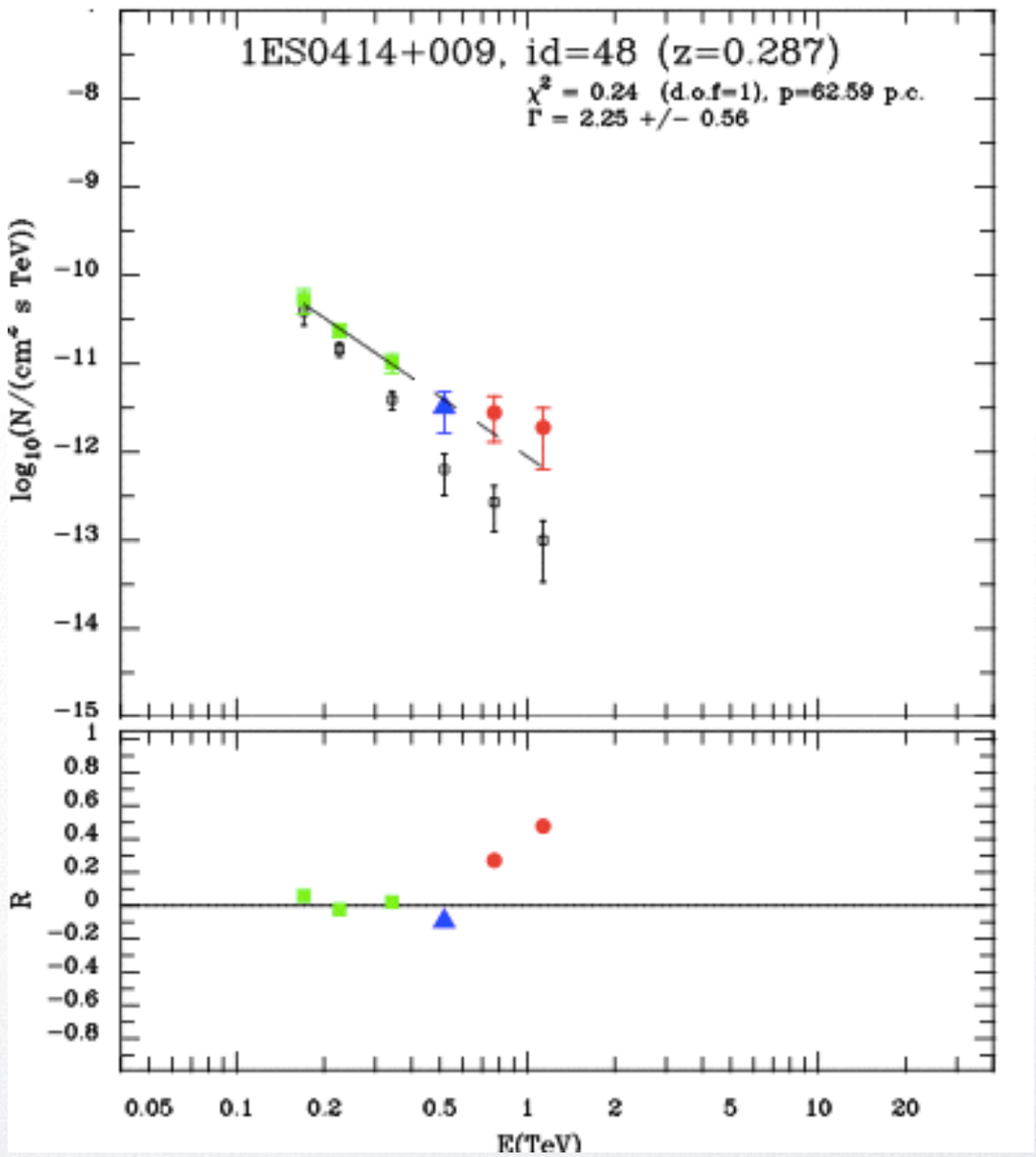


blue: 1 < τ < 2

red: τ > 2

Example spectra



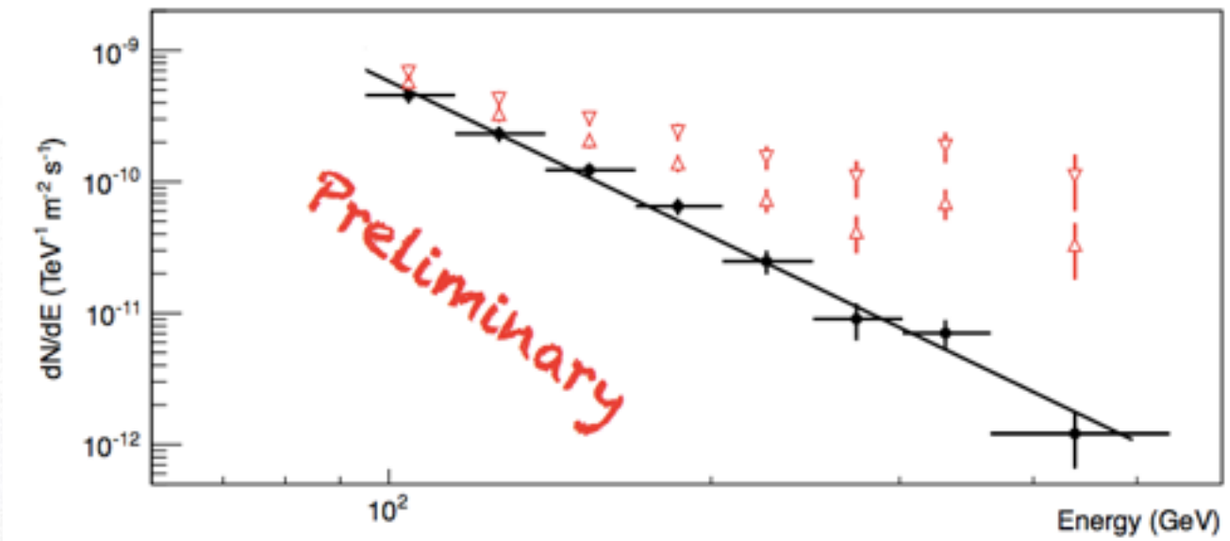


blue: 1 < τ < 2

red: τ > 2

Latest pile-ups: quite significant!

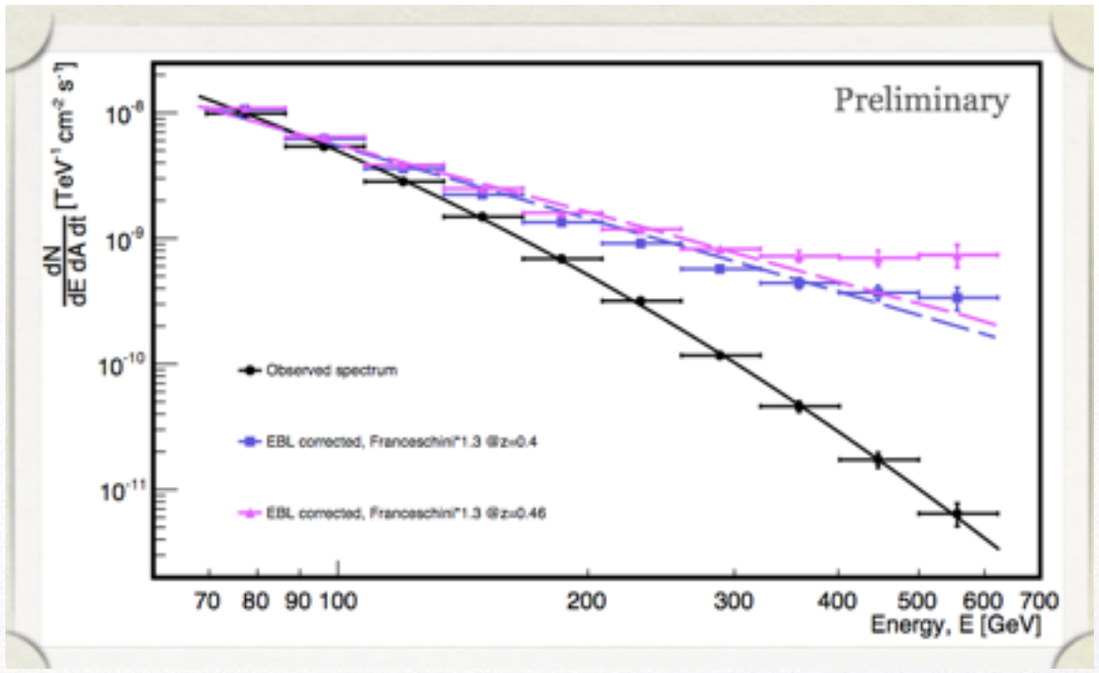
Amy Furniss et al., VERITAS
PKS1424+240, z>0.6



- Gilmore: Γ=2.4±0.2
- Finke: Γ=1.7±0.2

Neither is strictly constraining by Γ>1.5, but the spectral shape starts to curve upward above 300 GeV with even the lowest density EBL models

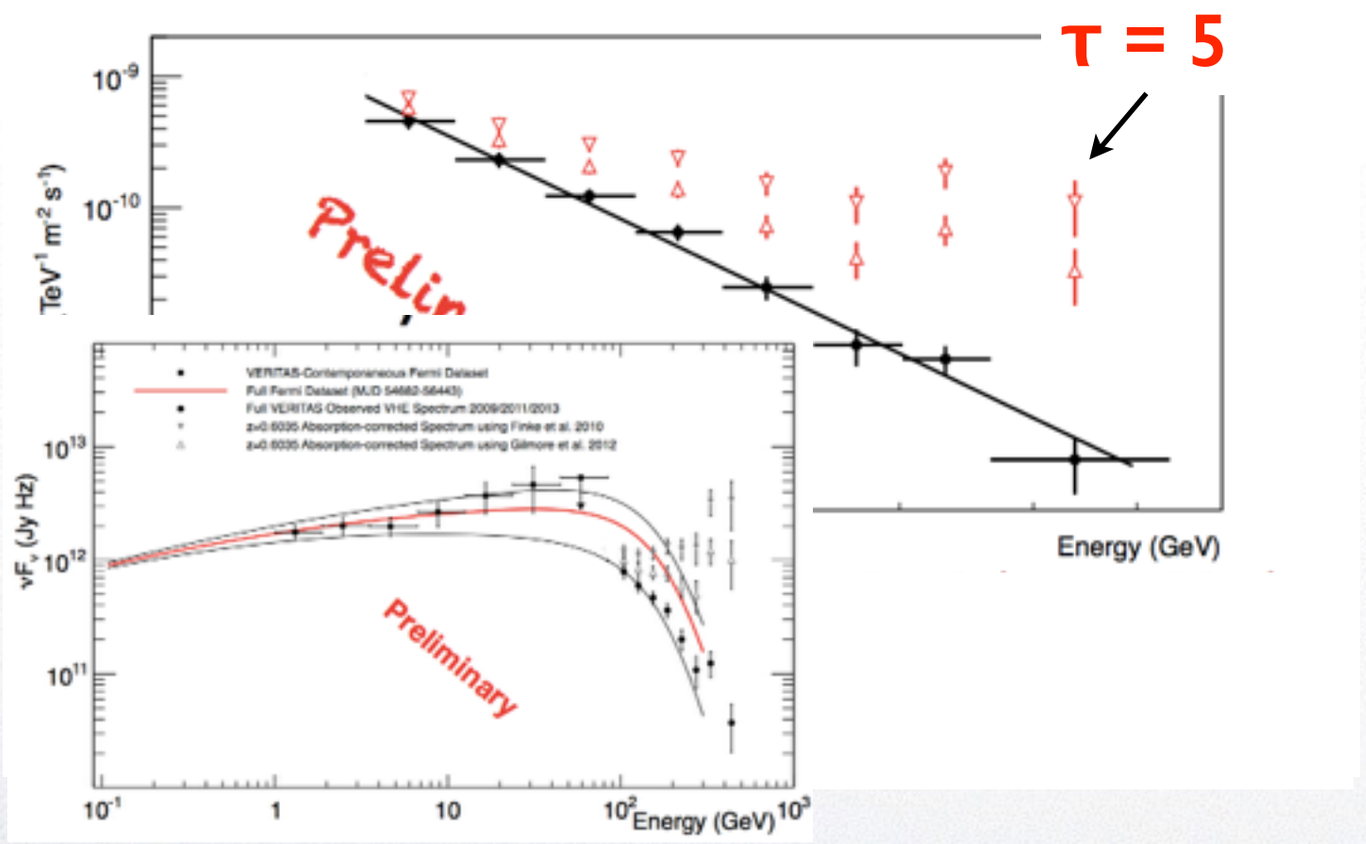
Pepa Becerra et al., MAGIC
PG1553+113, z>0.4



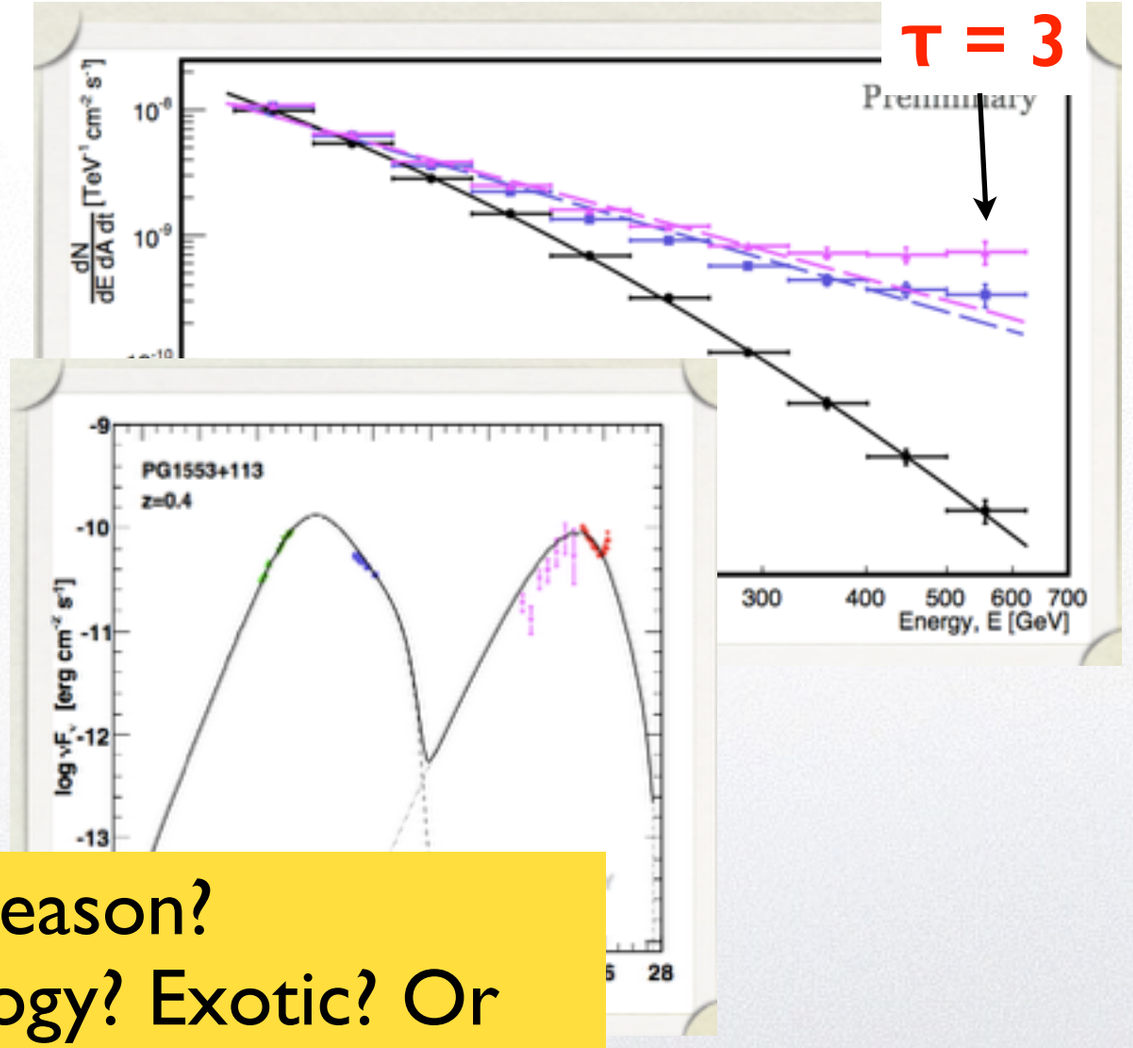
we cannot go lower in the EBL density!

Pile-ups at high energies

Amy Furniss et al., VERITAS
PKS1424+240, z>0.6



Pepa Becerra et al., MAGIC
PG1553+113, z>0.4



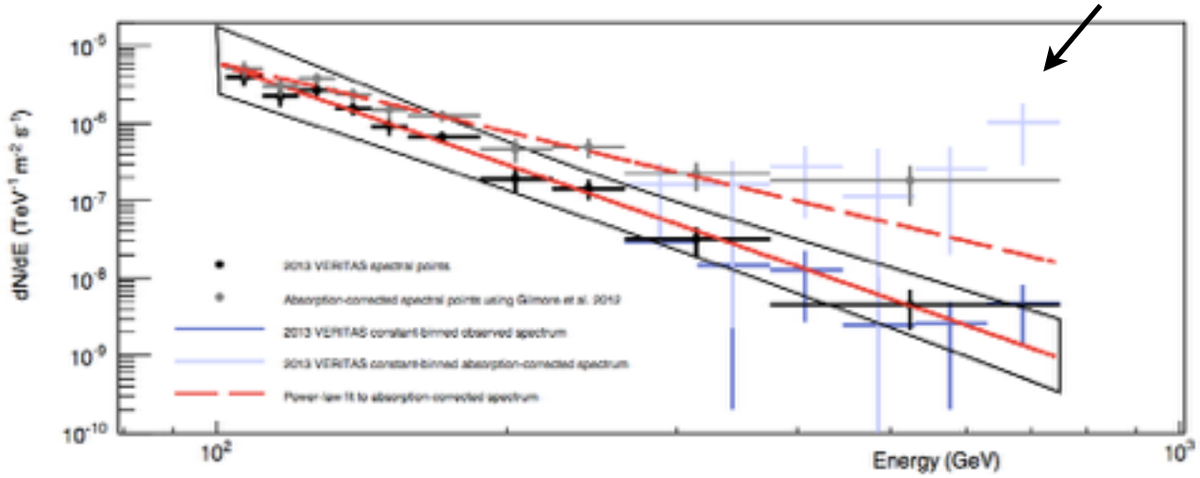
What is the reason?
Energy scale? Cosmology? Exotic? Or simply averaging different flux states?

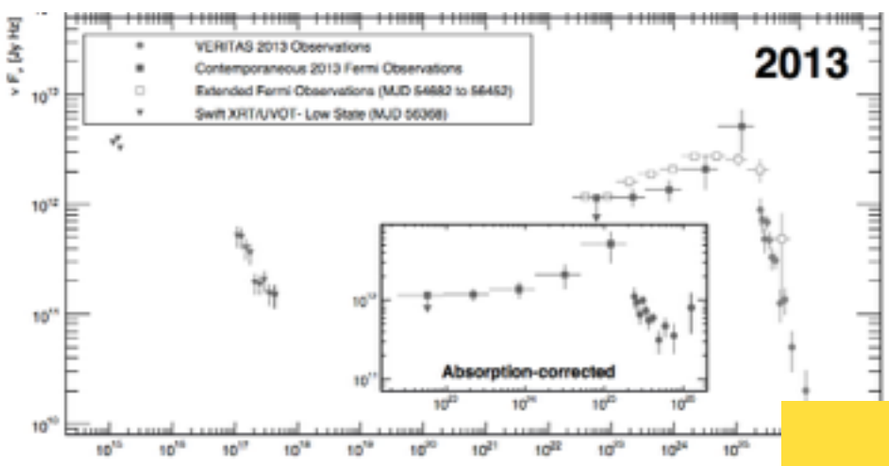
Pile-ups at high energies: update

VERITAS, published
PKS1424+240, z=0.6

2014ApJ...785L..16A

τ = 5





Pepa Becerra et al., MAGIC
PG1553+113,z=0.4

not significant ….

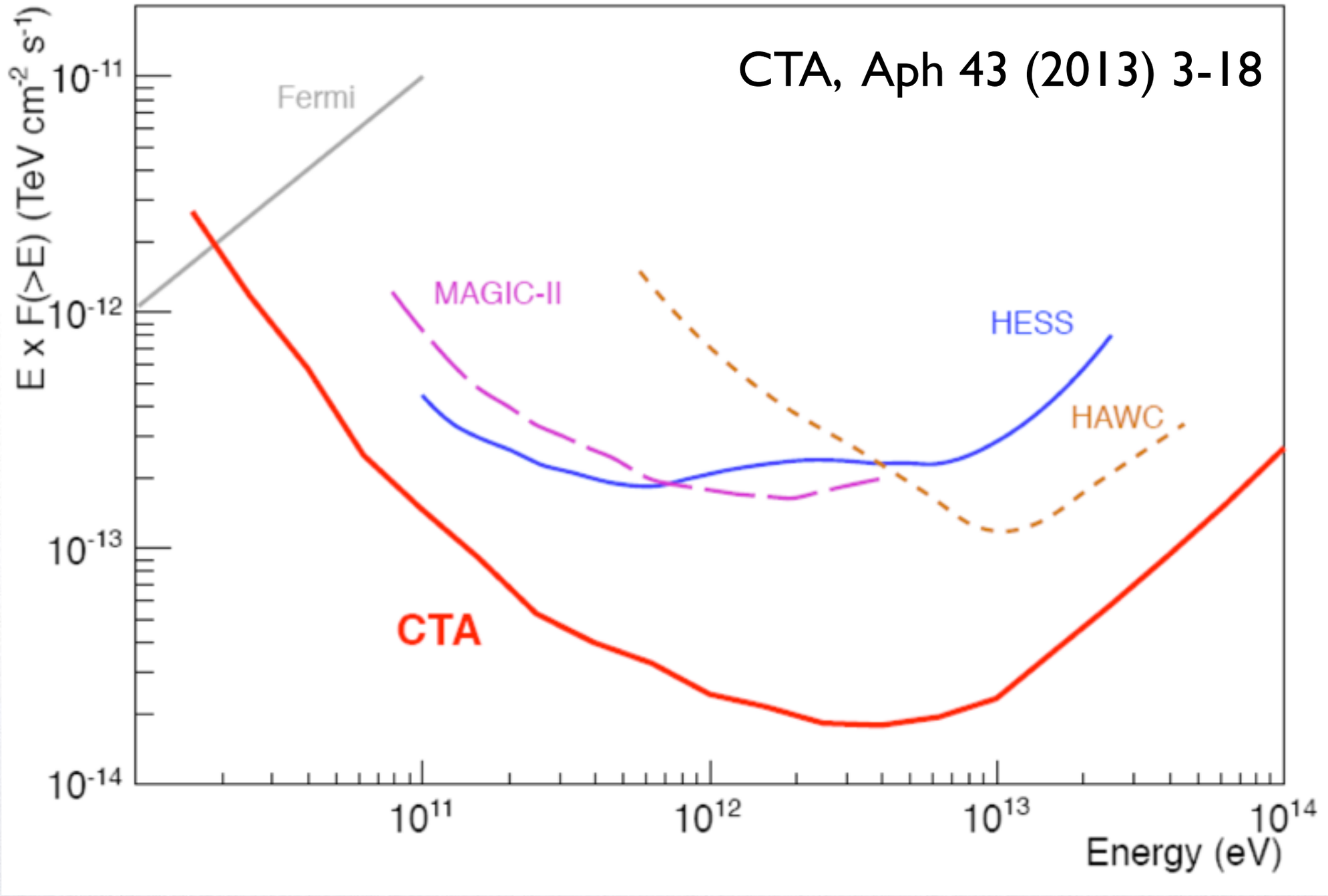
Pile ups in spectra of distant sources

can we actually assume smooth spectra to derive EBL constraints?

so far no clear evidence that we can't!

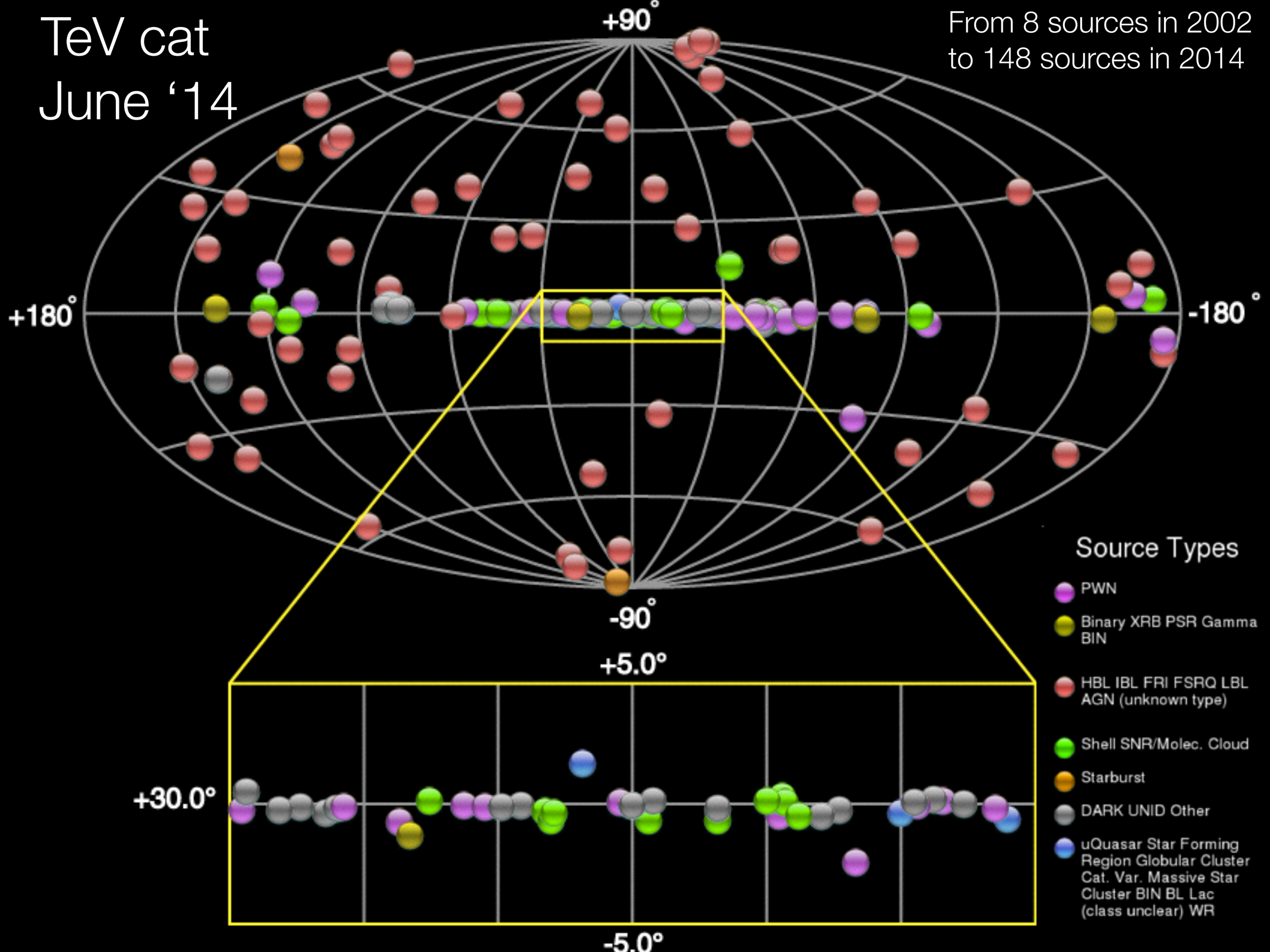
Sources of the EBL

Sensitivity

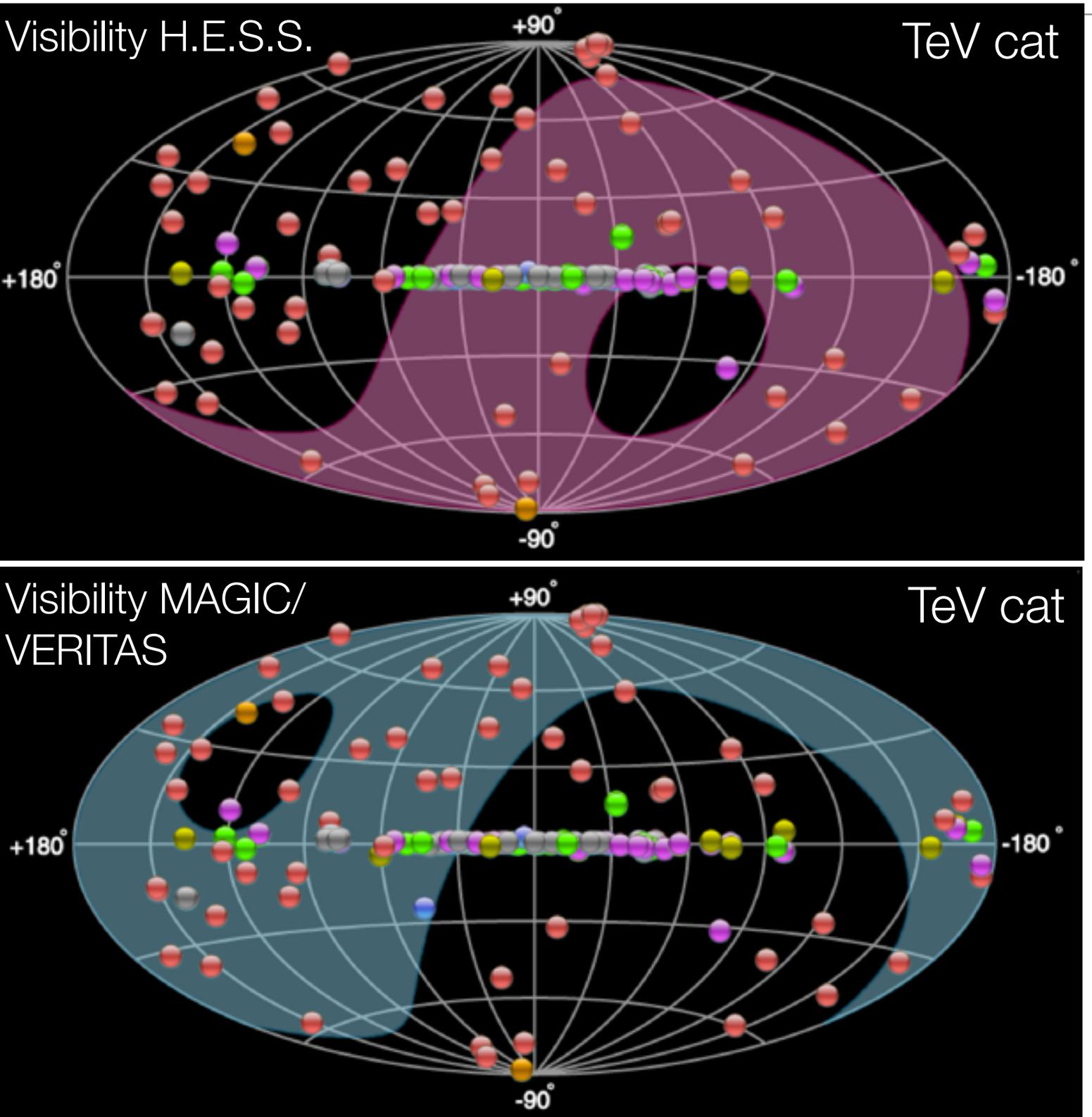


TeV cat June ‘14

From 8 sources in 2002 to 148 sources in 2014



Observability of the sky



- Visibility is shown for culmination below ZD=30°
- One can see that sources with culmination up to ZD=45° are also detected (but fewer)
- Good complementarity of the sites
- Number of useful hours: ~1200h per year, including moon time

How many sources will be useful for EBL/cosmology studies?

DM & D. Semikoz, A. Zech 2014, in preparation

- Self-made Fermi/LAT catalog of AGN's at E>50 GeV using 2FGL sources
- Consistent with 1FHL catalog (E>10GeV)
- Comparison of CTA sites for detection of Fermi AGN's
- Detection of AGN's within redshift bins, step towards determination of EBL
- Hard spectrum sources and detection of IGMF

Method

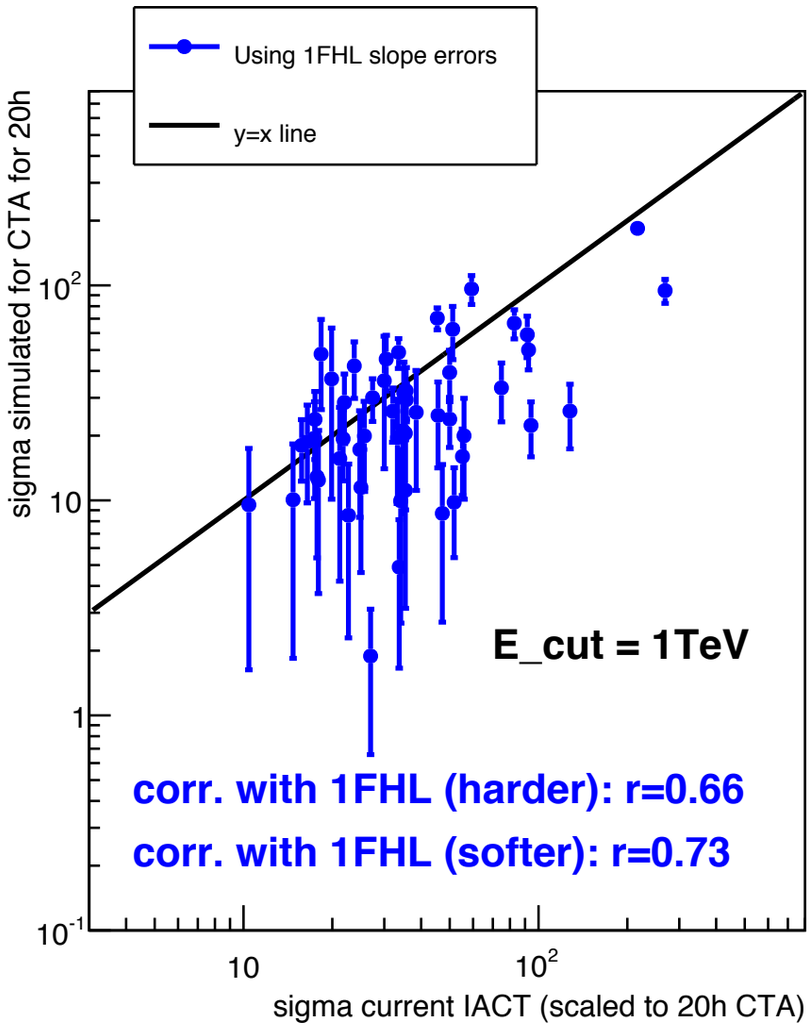
DM & D. Semikoz, A. Zech 2014, in preparation

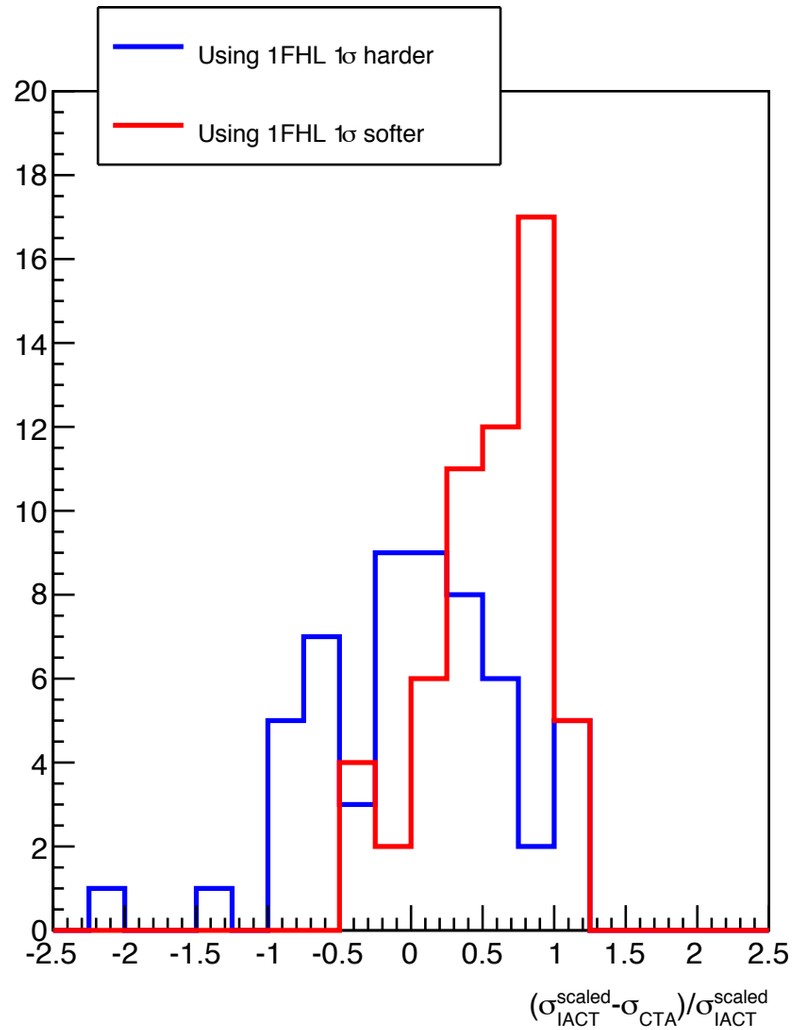
- Fermi/LAT spectra are extrapolated to the CTA energy regime using the redshift when available (used Shaw et al. lower limits for unknown redshifts)
- Exposure of 20h per source
- EBL model of Franceschini et al. (2008) is used
- Take into account zenith angle of culmination at site
- Caution: these are averaged fluxes, no flaring activity is considered in the analysis. However, no dramatic change when flaring sources are removed

Cross-checks

DM & D. Semikoz, A. Zech 2014, in preparation

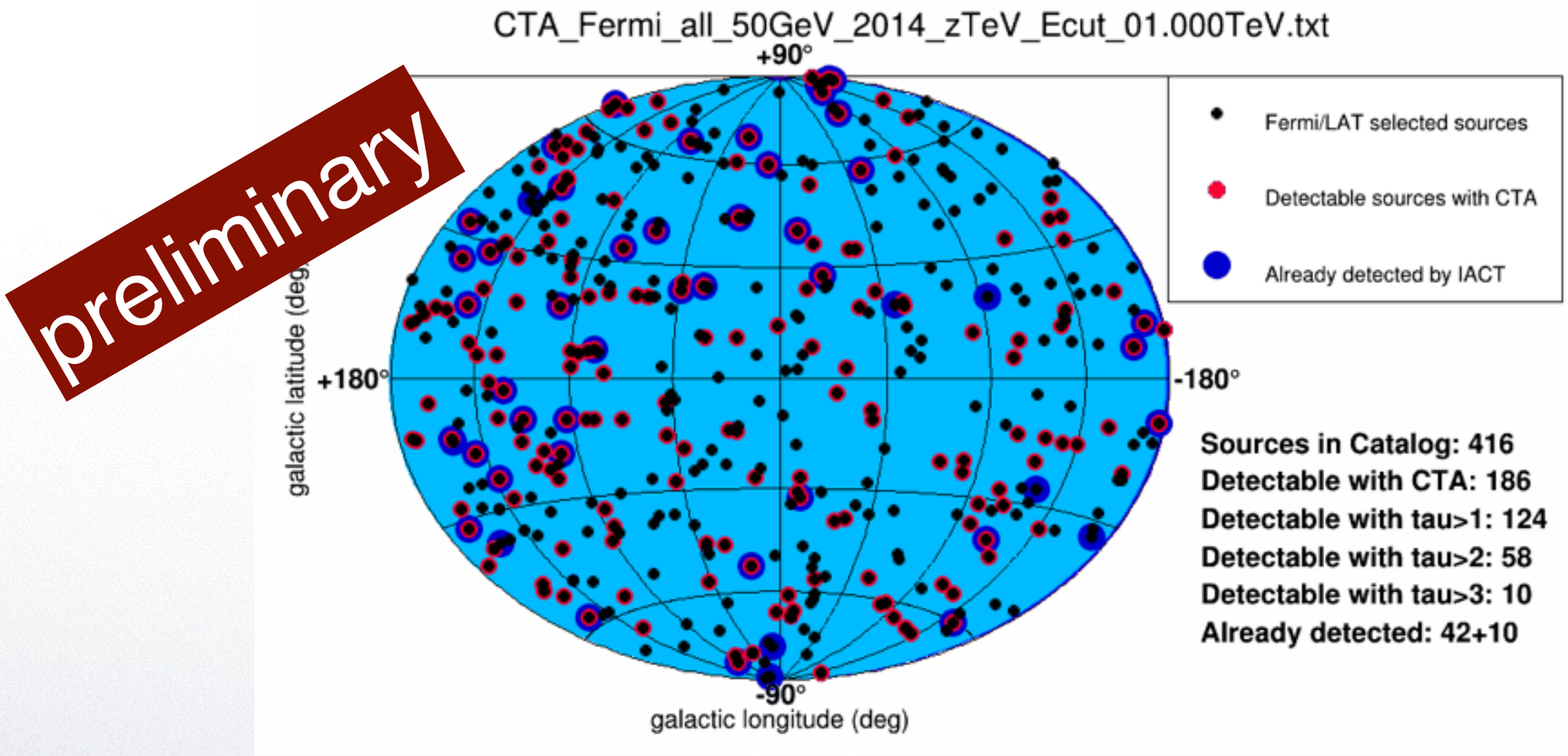
good correlation between detected blazars and CTA prediction





Results

DM & D. Semikoz, A. Zech 2014, in preparation 20h exposure of every source



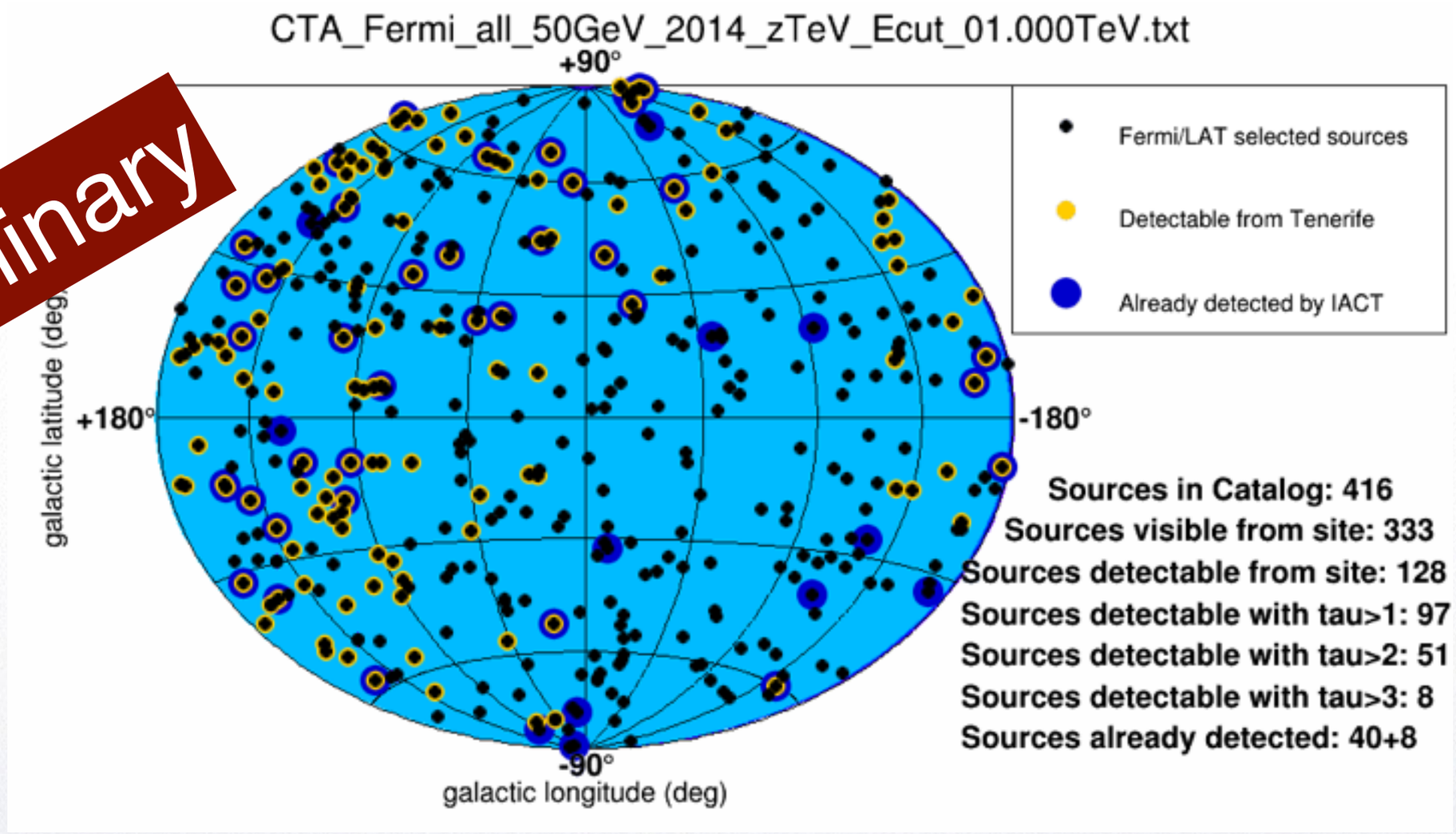
1) from 416 hard spectra sources, CTA can detect 186 (44%) **if built everywhere**

2) 52 sources (13%) already detected

Results

DM & D. Semikoz, A. Zech 2014, in preparation

NORTH



preliminary

1) from 416 hard spectra sources, CTA-NORTH can detect 128 (31%)

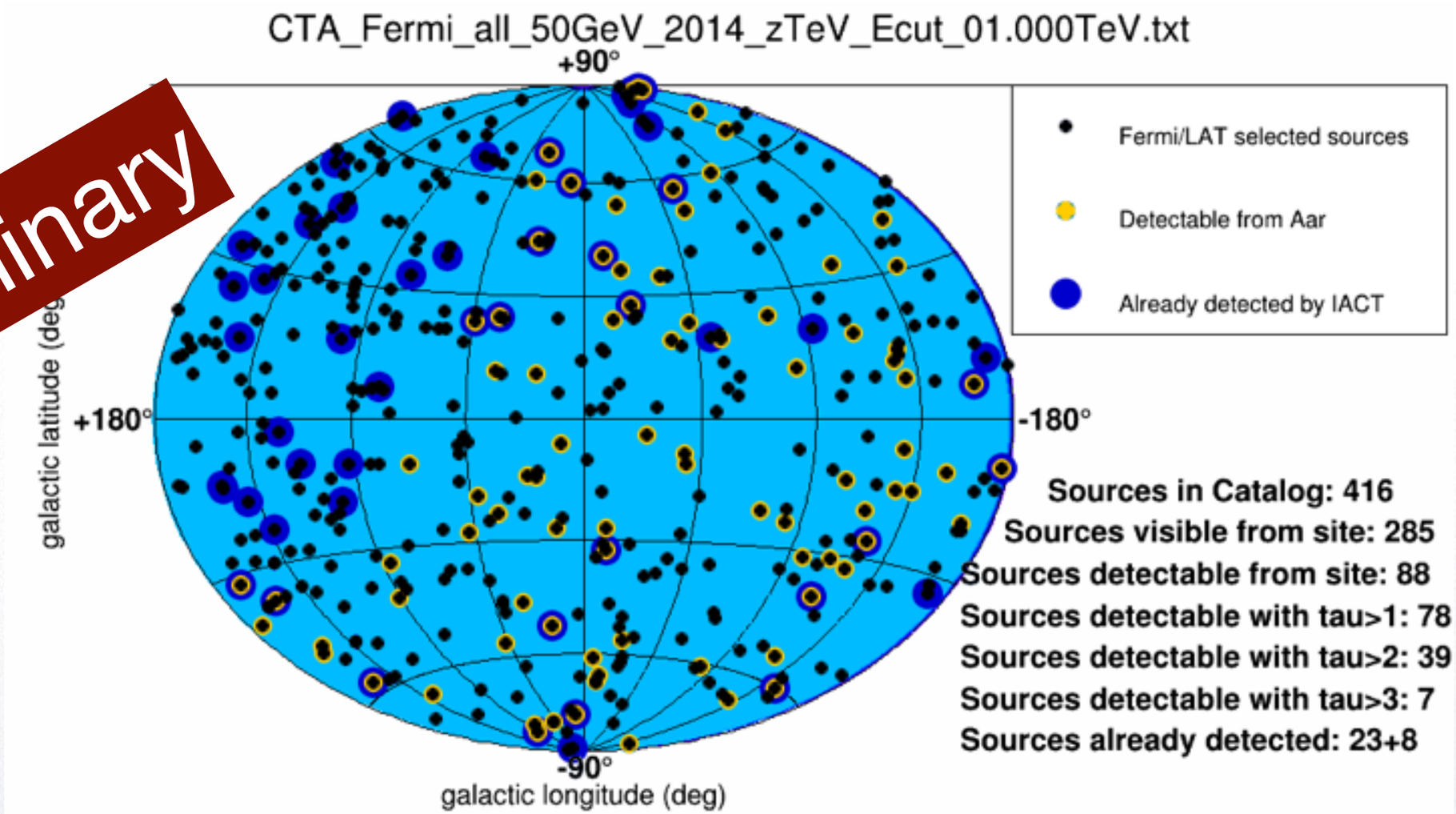
2) 48 sources (12%) already detected

Results

DM & D. Semikoz, A. Zech 2014, in preparation

SOUTH

preliminary



1) from 416 hard spectra sources, CTA-SOUTH can detect 88 (21%)

2) 31 sources (7%) already detected

Expectations for North+South

	z<0.2	0.2<z<0.4	0.4<z<0.6	0.6<z<0.8	z>0.8	Total
South	19	17	4	1	3	63
North	33	16	12	3	2	76
South +North	52	33	16	4	5	139

DM & D. Semikoz, A. Zech 2014, in preparation

Conclusions

- Good times for EBL constraints
- Even with lowest EBL possible, pile-ups at high energy. This is intriguing / disturbing
- GRBs: CTA can detect them up to z=6 if they are bright enough
- Sources for EBL/cosmology studies:
  - need redshift determination!
  - need monitoring of flaring activity, not many sources that can be detected otherwise
  - good potential to get 1-2 sources beyond z=0.8