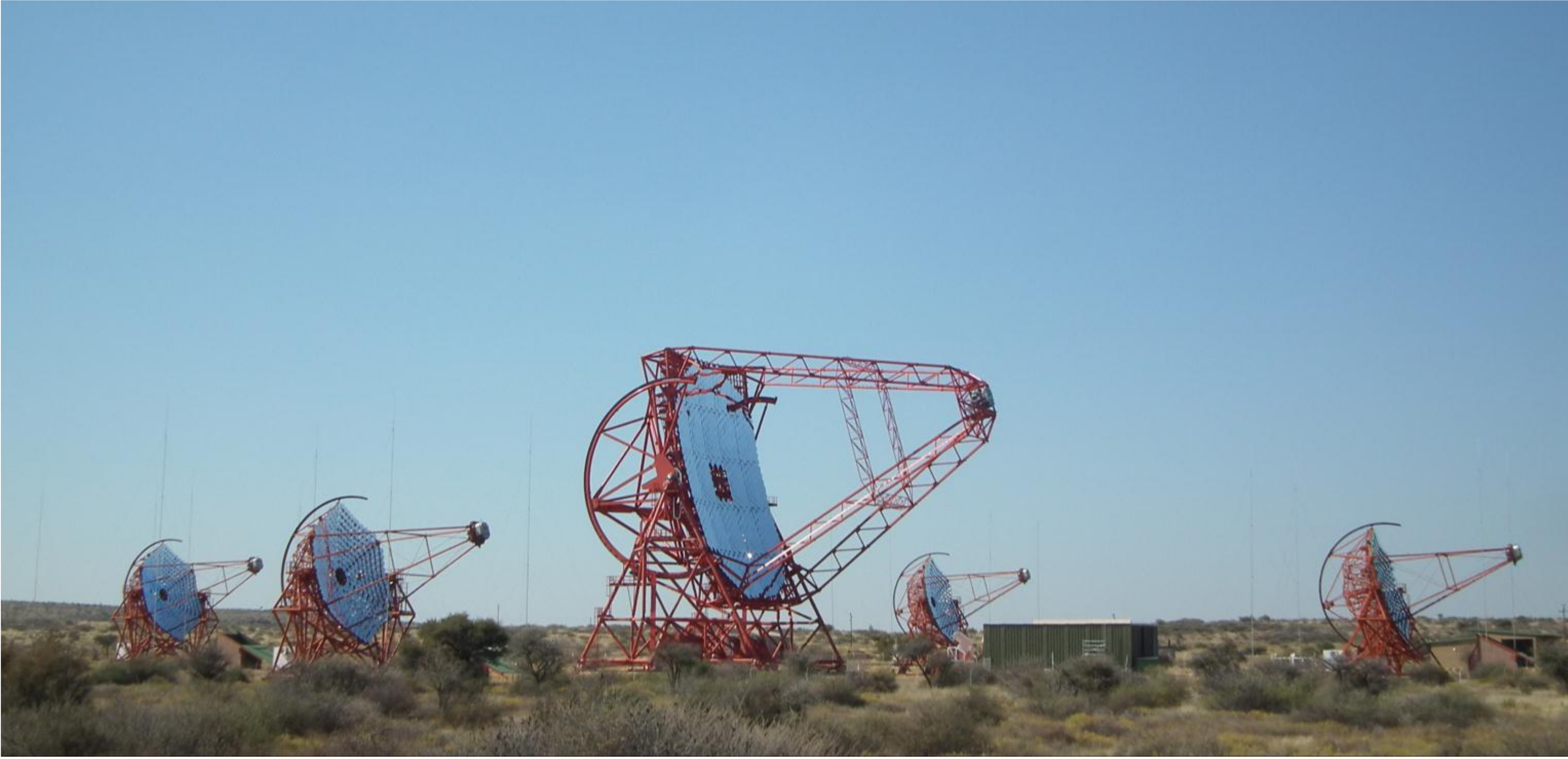


The H.E.S.S. extragalactic sky

Laboratoire d'Annecy-le-Vieux de Physique des Particules

Jill Chevalier (LAPP, CNRS/IN2P3, USMB) for the HE.S.S. Collaboration

H.E.S.S.

CNRS IN2P3 Les deux infinis

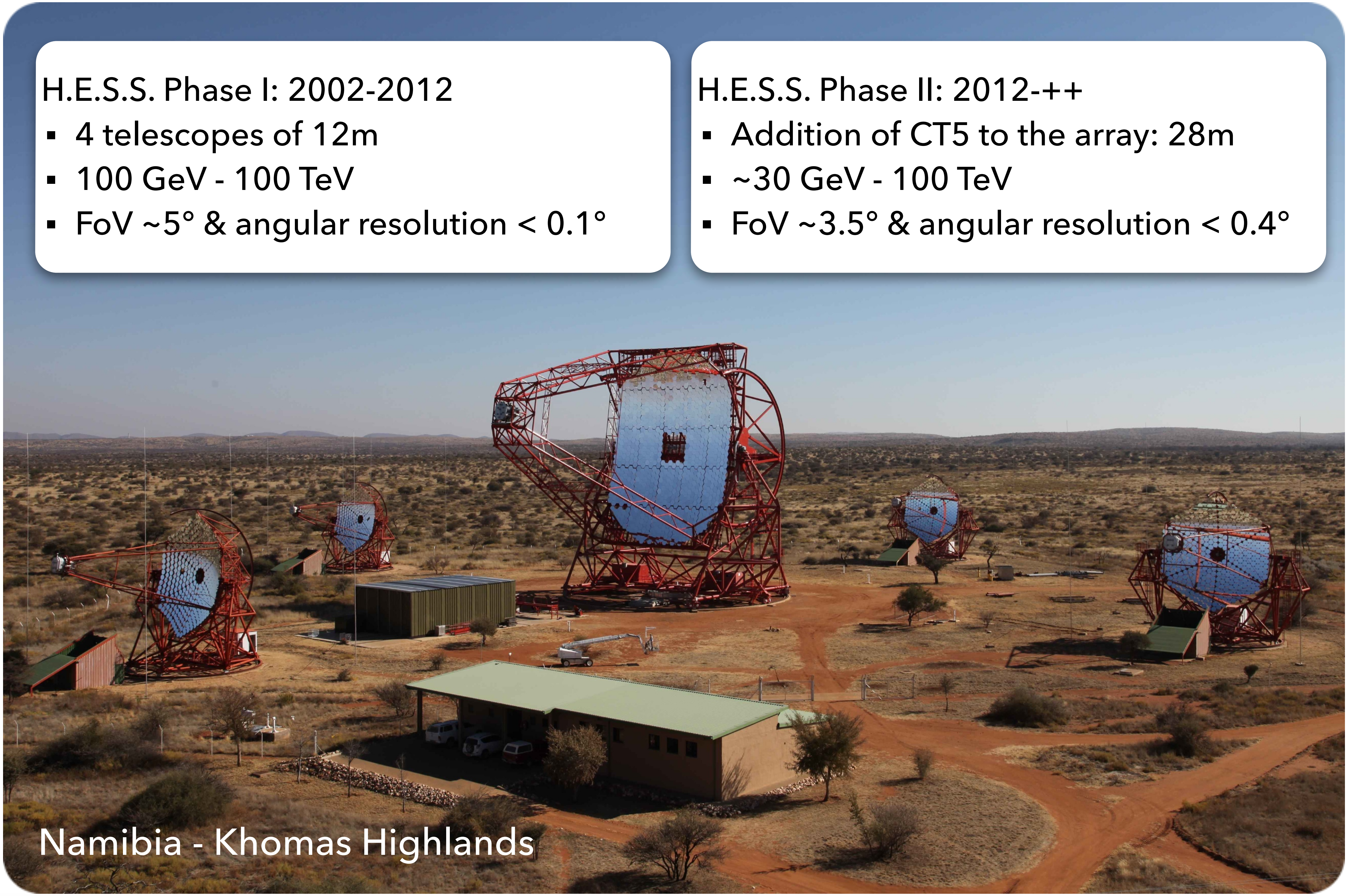
Texas Symposium on Relativistic Astrophysics
13-18 December 2015, Geneva

UNIVERSITÉ SAVOIE MONT BLANC

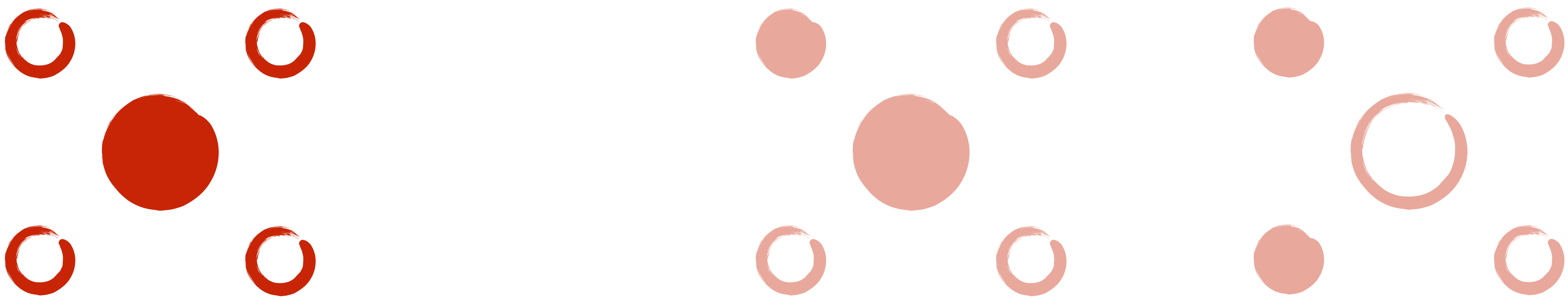
H.E.S.S. = High Energy Stereoscopic System

H.E.S.S. Phase I: 2002-2012
- 4 telescopes of 12m
- 100 GeV - 100 TeV
- FoV ~5° & angular resolution < 0.1°

H.E.S.S. Phase II: 2012-++
- Addition of CT5 to the array: 28m
- ~30 GeV - 100 TeV
- FoV ~3.5° & angular resolution < 0.4°



H.E.S.S. Phase-II



CT5 Mono | CT5 + at least 1 CT1-4 | At least 2 CT1-4

↳ Lowest energy threshold

- CT5 Mono – best for:
  - High redshift AGN + GRBs
  - EBL at z > 1 (gamma-ray horizon)
  - Spectral measurements at E < 100 GeV

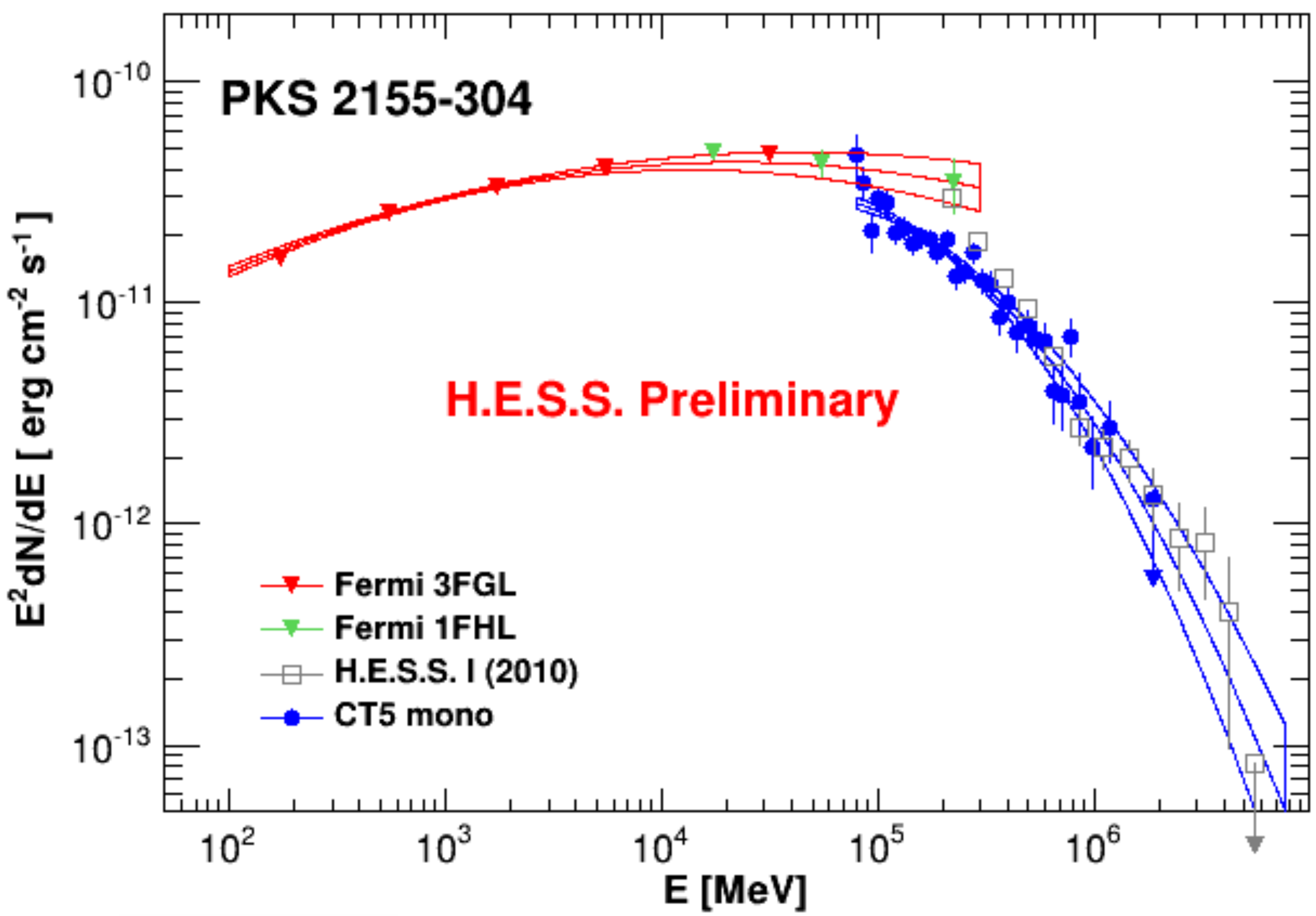
↳ First H.E.S.S. II AGN results

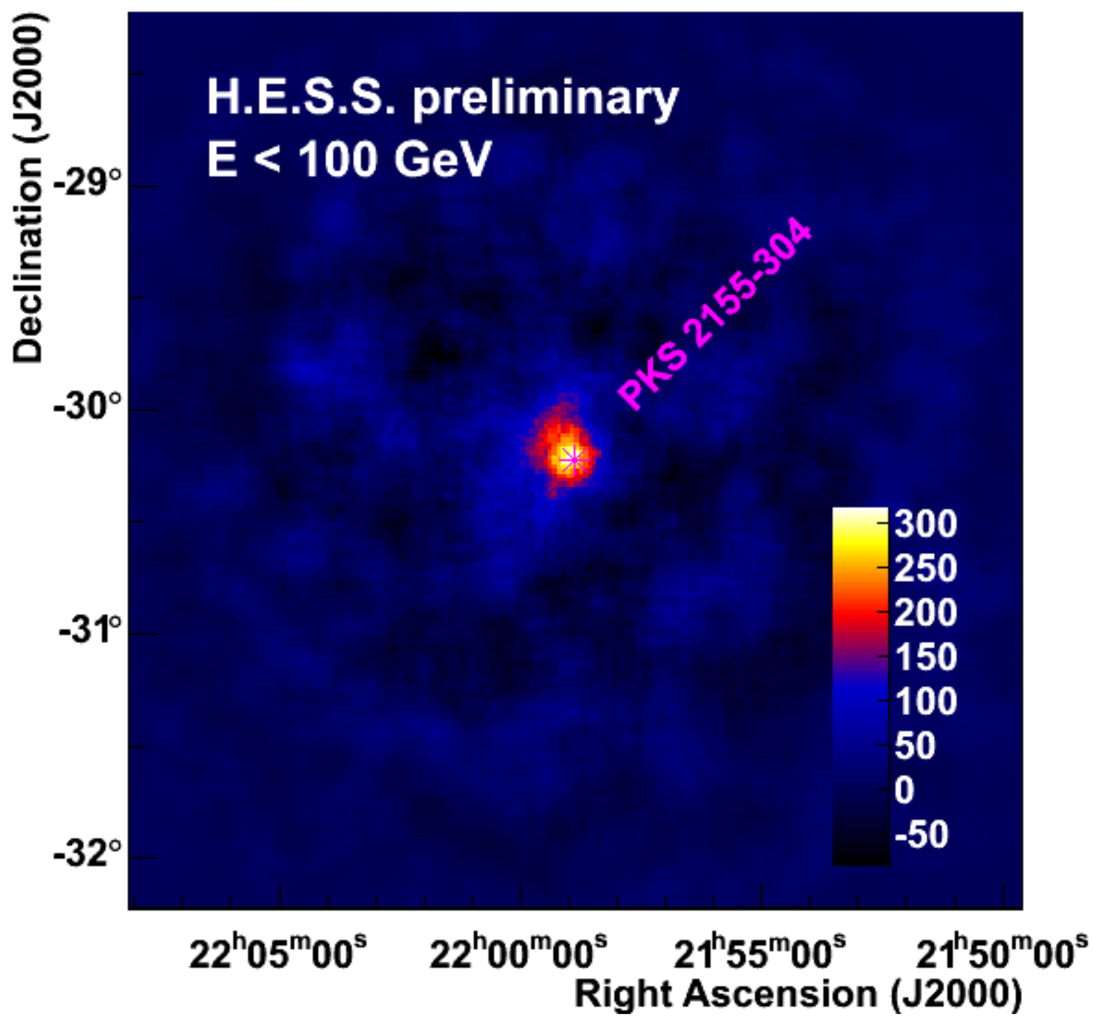
H.E.S.S. Phase-II: First AGN results

Mono configuration

ICRC 2015, arXiv:1509.06509 (D. Zaborov et al.)

- PKS 2155-304
  - Bright HBL at z = 0.116
  - Good agreement with H.E.S.S. Phase-I data





Sky map of PKS 2155-304

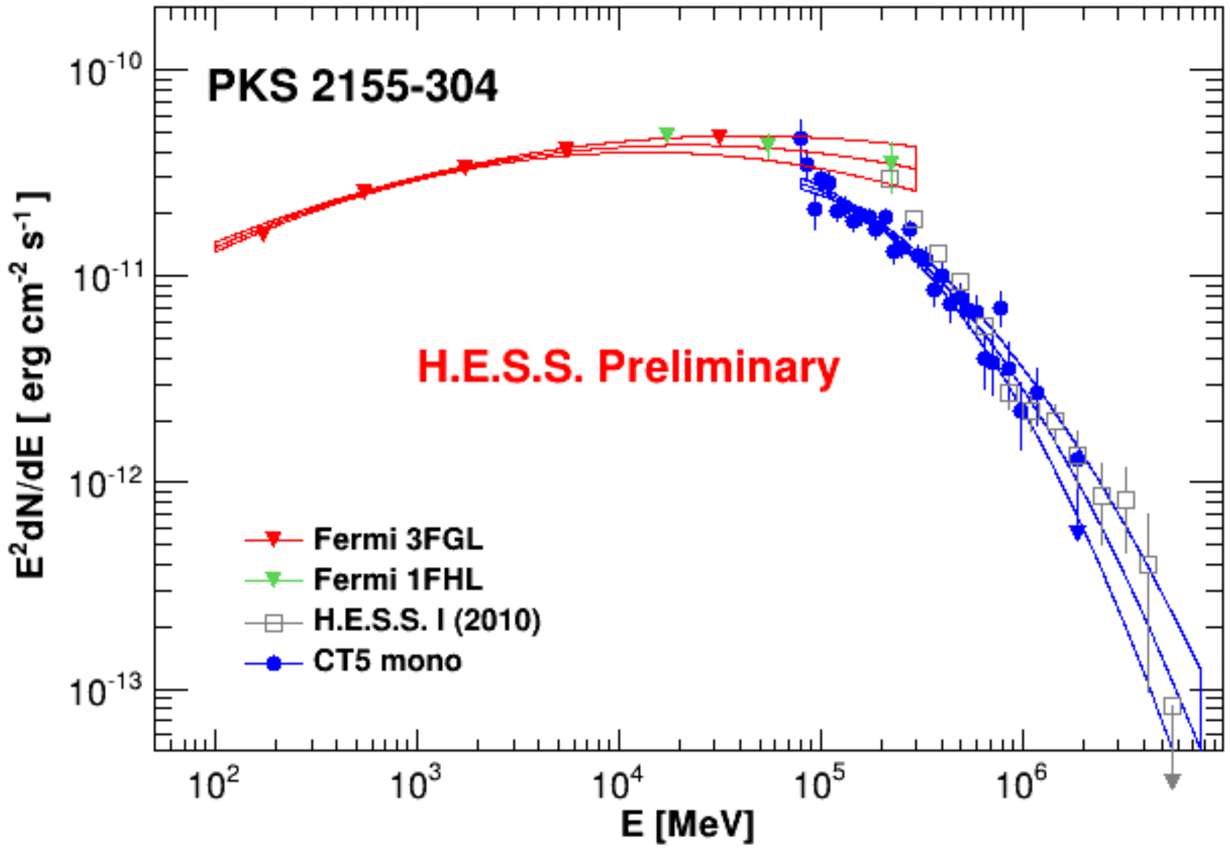
E < 100 GeV

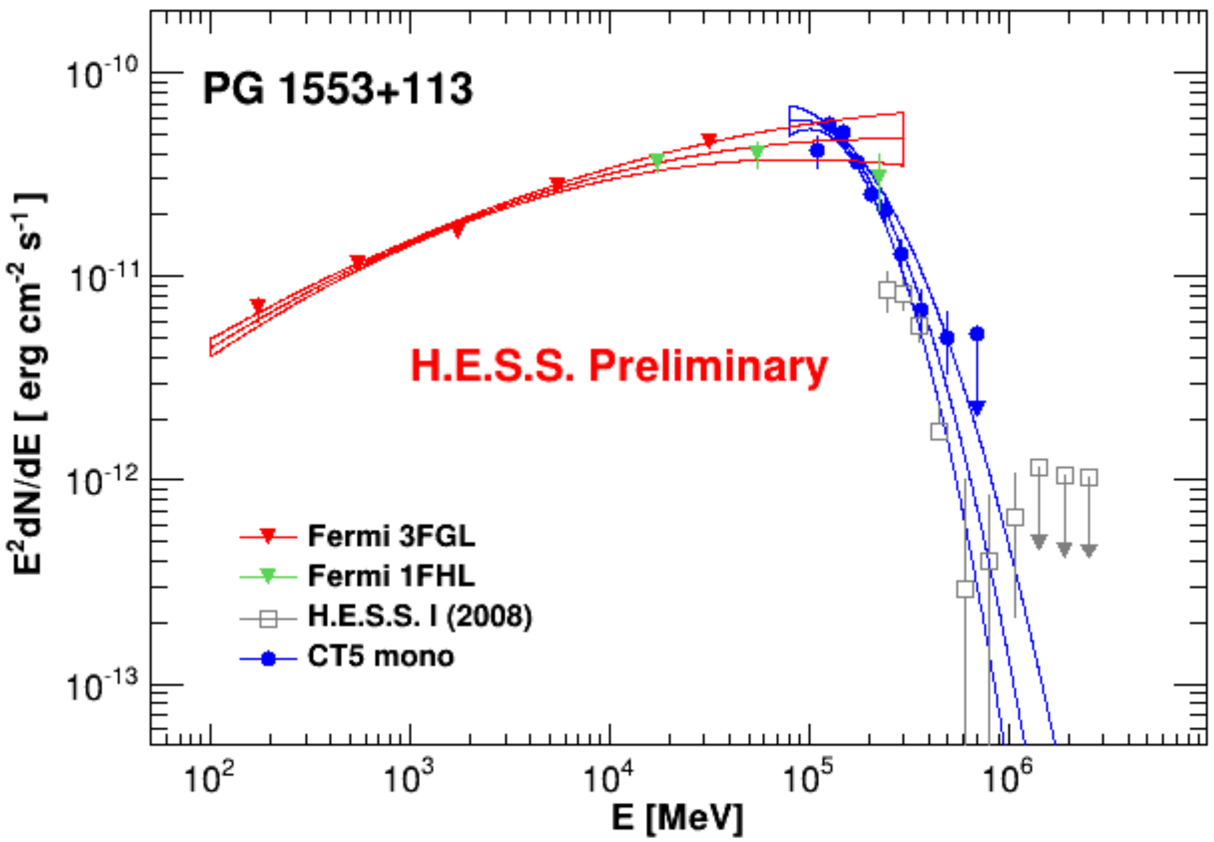
H.E.S.S. Phase-II: First AGN results

Mono configuration

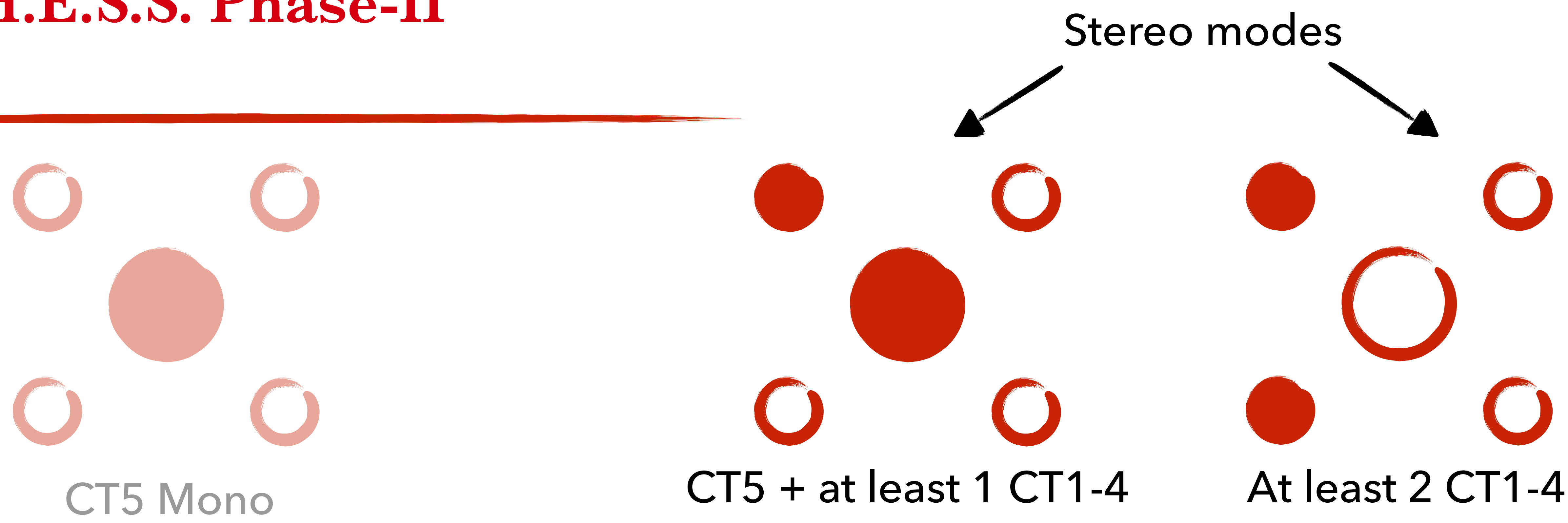
ICRC 2015, arXiv:1509.06509 (D. Zaborov et al.)

- PKS 2155-304
  - Bright HBL at z = 0.116
  - Good agreement with H.E.S.S. Phase-I data
- PG 1553+113
  - Bright HBL at 0.43 < z < 0.58
  - Good agreement with H.E.S.S. Phase-I data & Fermi catalogs





H.E.S.S. Phase-II



↳

↳ Best sensitivity

- CT5 Mono – best for:
  - High redshift AGN + GRBs
  - EBL at z > 1 (gamma-ray horizon)
  - Spectral measurements at E < 100 GeV

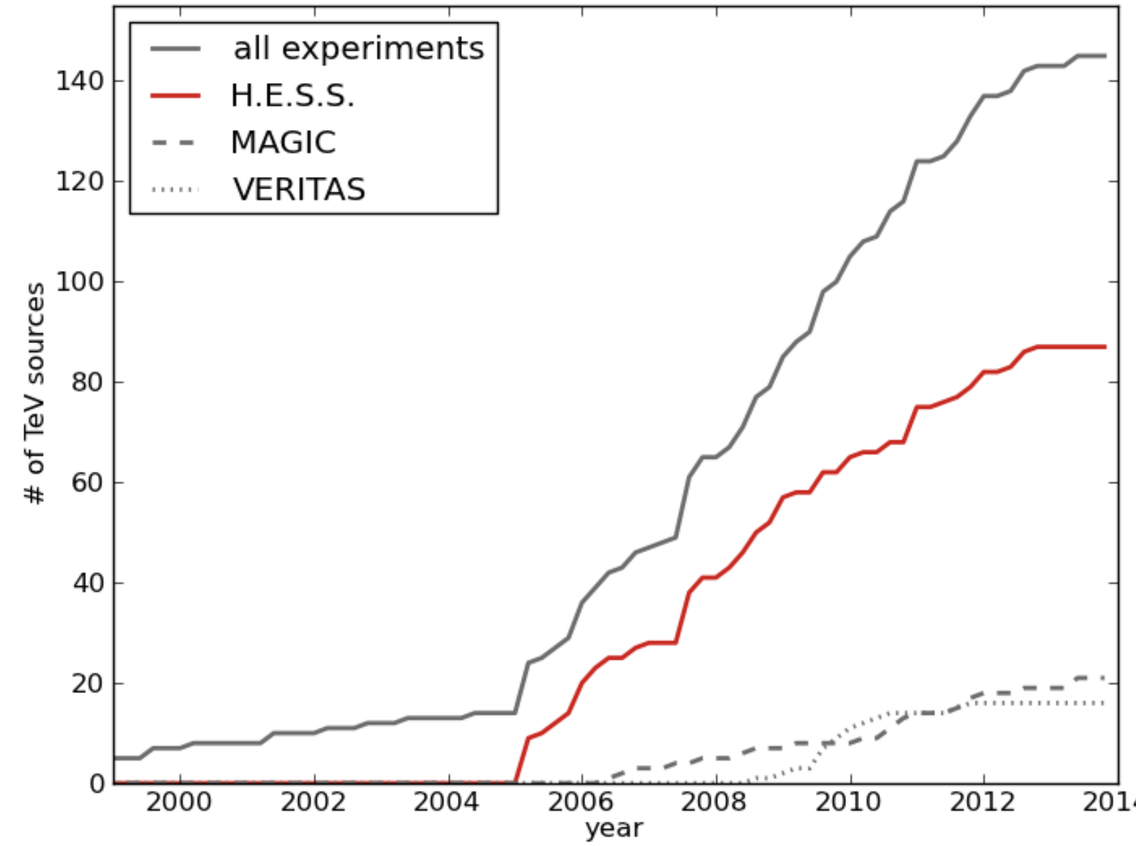
↳

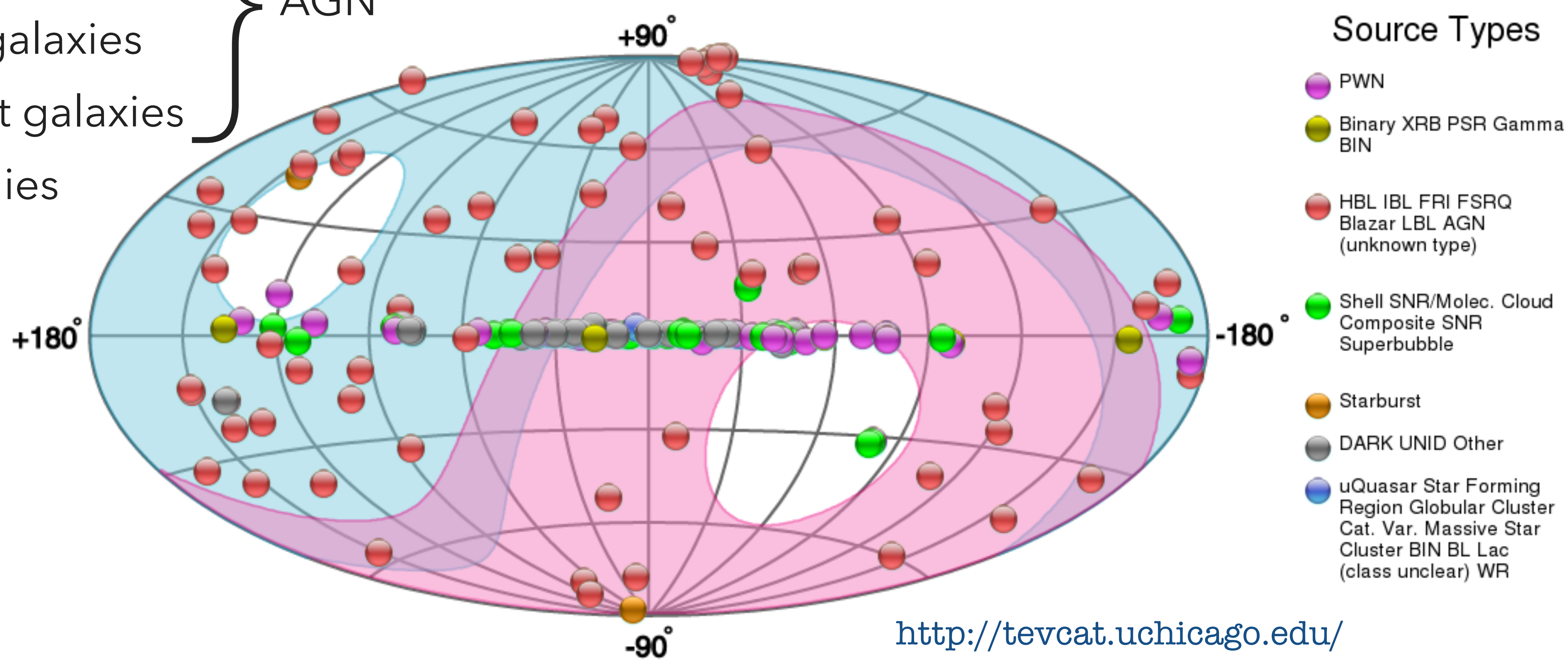
- CT1-5 Stereo – best for:
  - Detection of weak sources
  - Morphology studies
  - Spectral measurements at E > 100 GeV

What we do with H.E.S.S.

- More than 80 (galactic & extragalactic) objects discovered
- Monitoring and ToO observations
  - Blazars
  - Radio galaxies
  - Seyfert galaxies
  - Starburst galaxies
  - EBL studies
  - GRB

AGN (Blazars, Radio galaxies, Seyfert galaxies, Starburst galaxies)

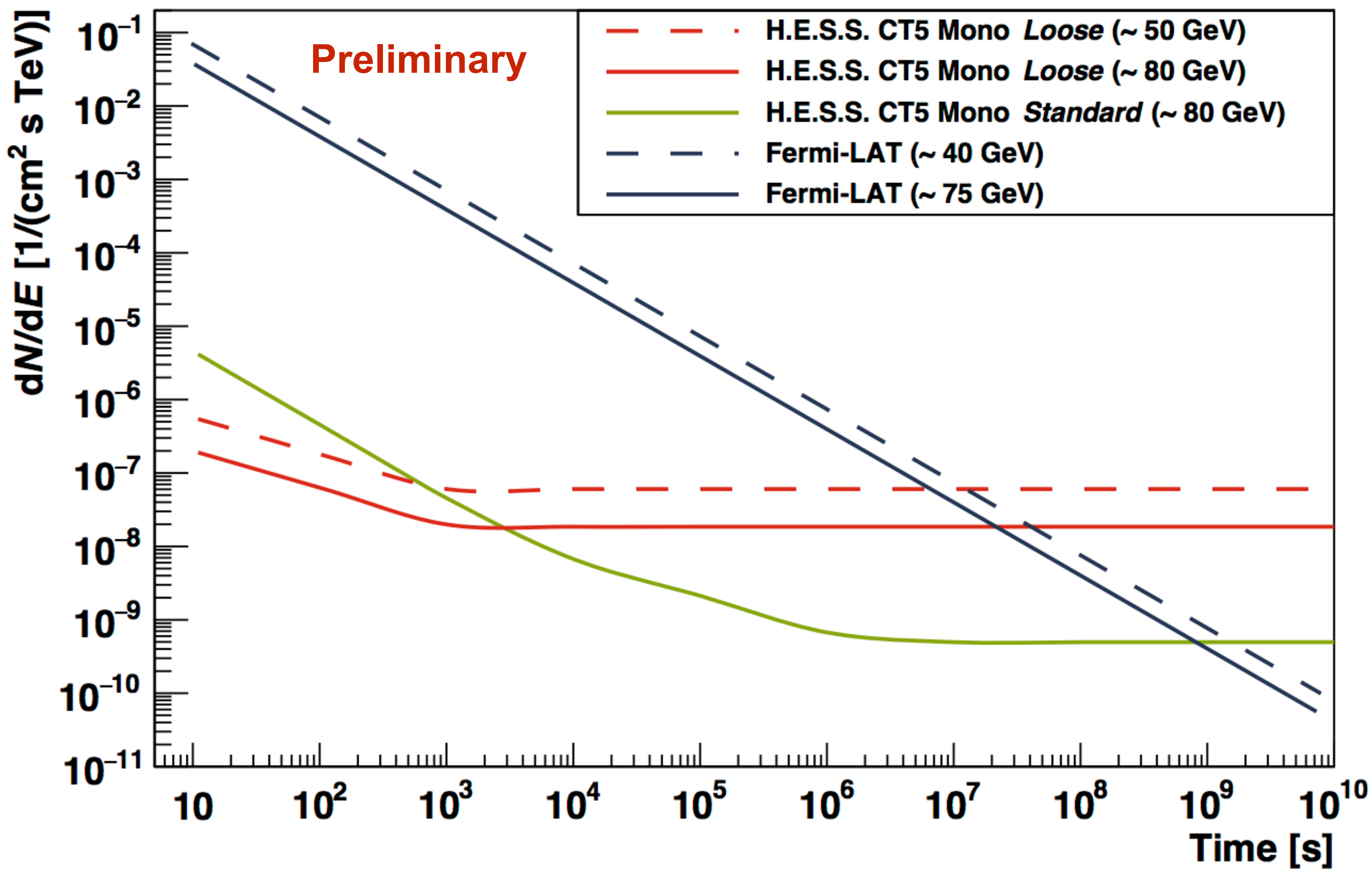




http://tevcat.uchicago.edu/

H.E.S.S. sensitivity vs time

- Short term variability studies with CT5



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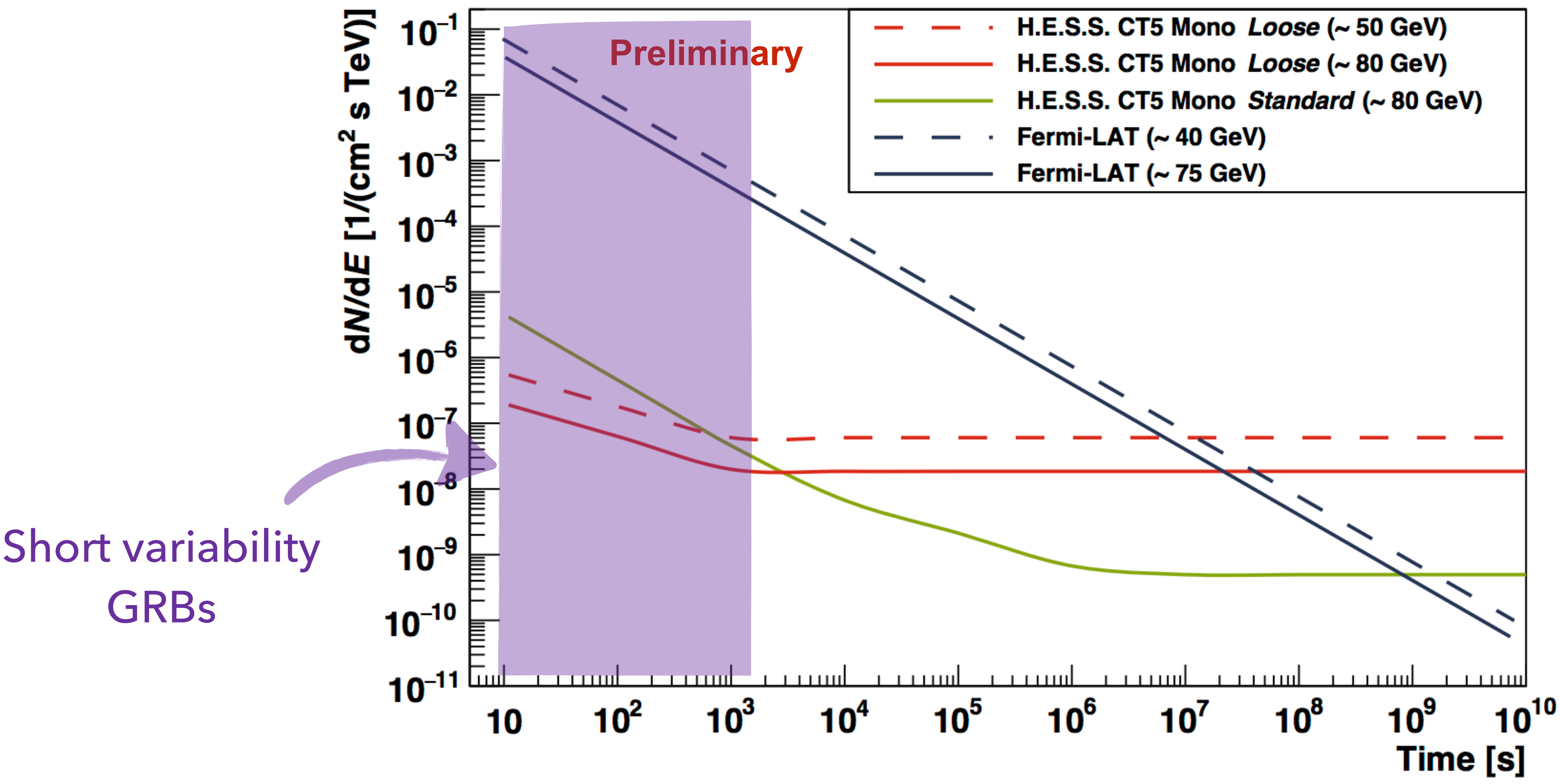

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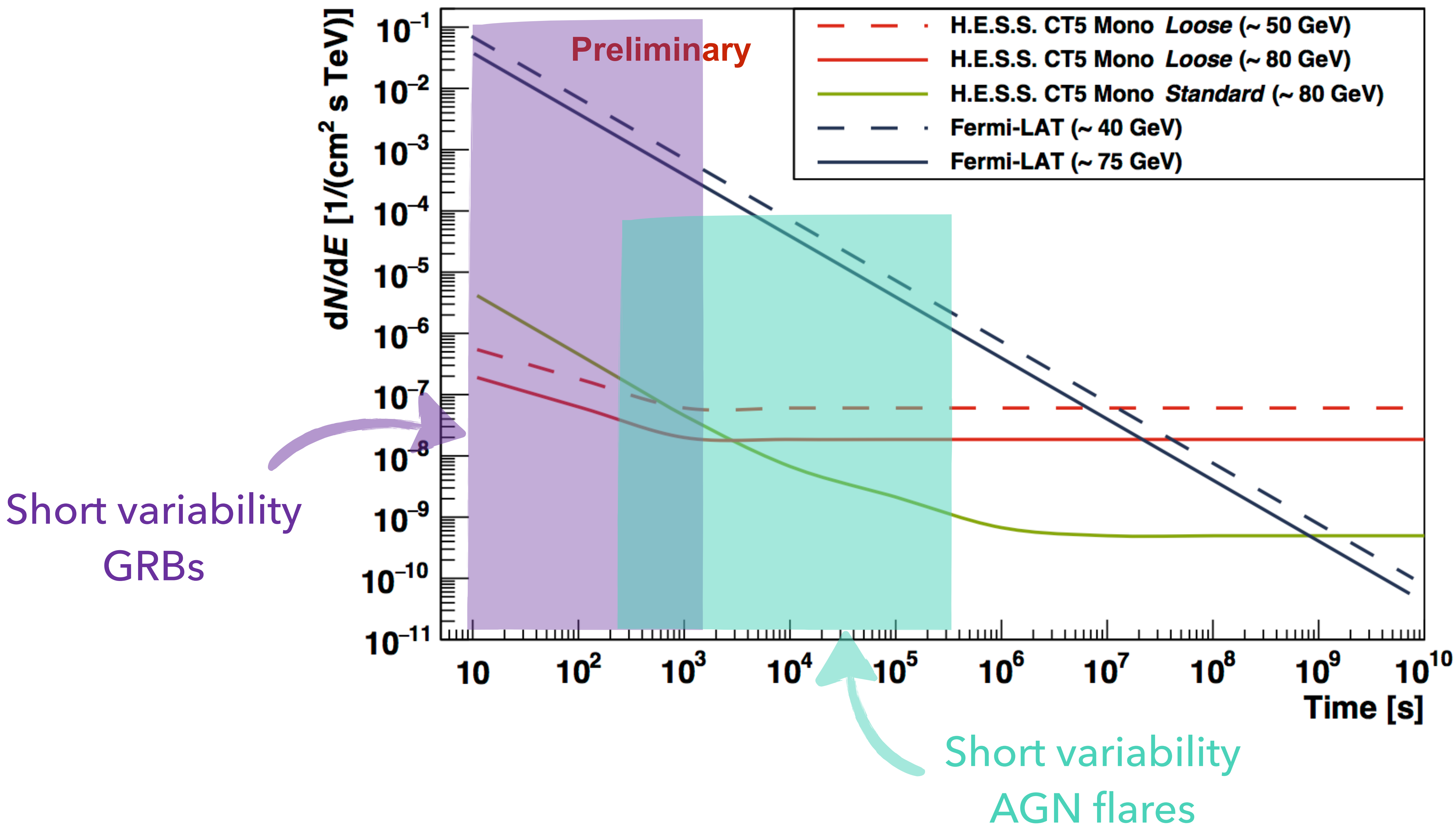

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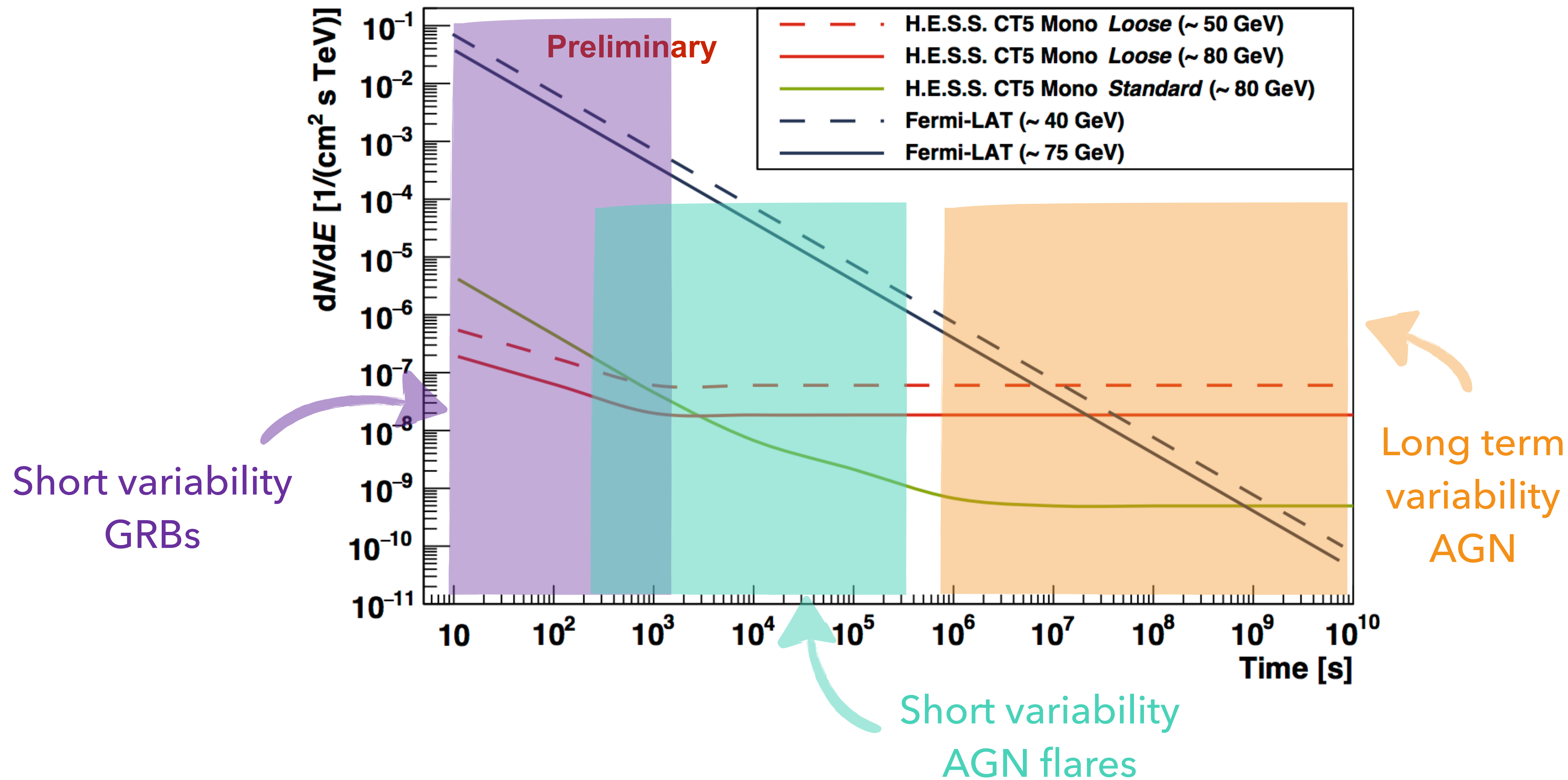


CT5 as a GRB alerts machine

- Gamma Ray Bursts = short & extreme events
- Never detected at TeV

H.E.S.S. II array with CT5 in reverse mode (© M.Lorentz)

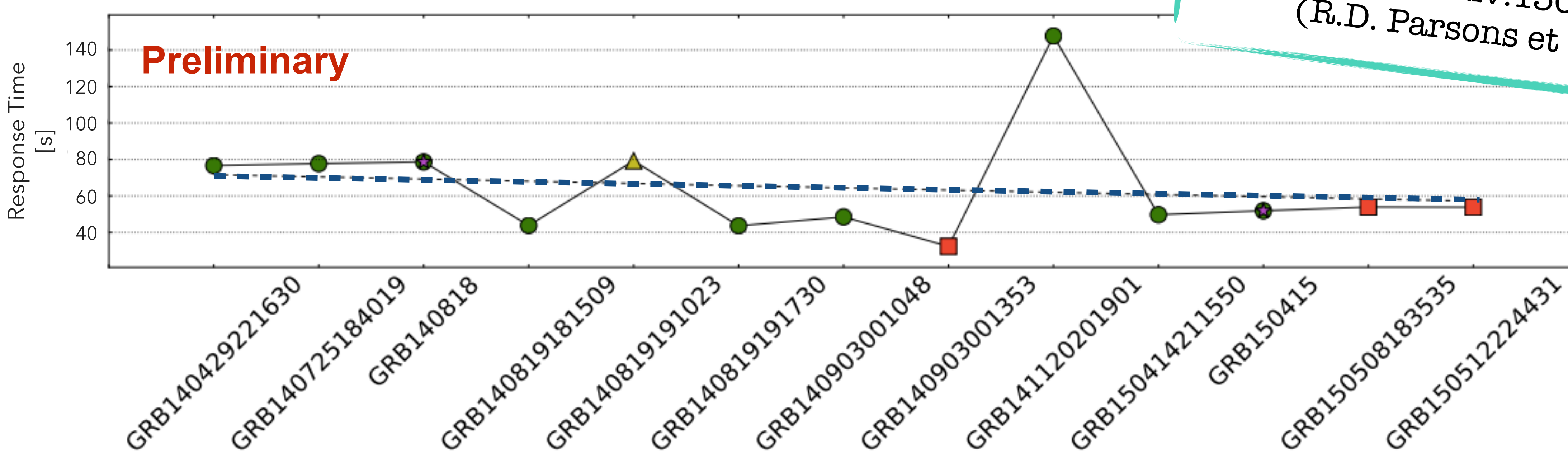
CT5 as a GRB alerts machine

- Gamma Ray Bursts = short & extreme events
- Never detected at TeV
- Fast repointing system to detect GRBs
  - Improvement of the drive system
  - Reverse mode

↳ $T_{repointing} \leq 2$ min

H.E.S.S. II array with CT5 in reverse mode (© M.Lorentz)

➜ 3T camera going at 1 m/s to do 180° in 110 sec



ICRC 2015, arXiv:1509.05191 (R.D. Parsons et al.)

CT5 as a GRB alerts machine

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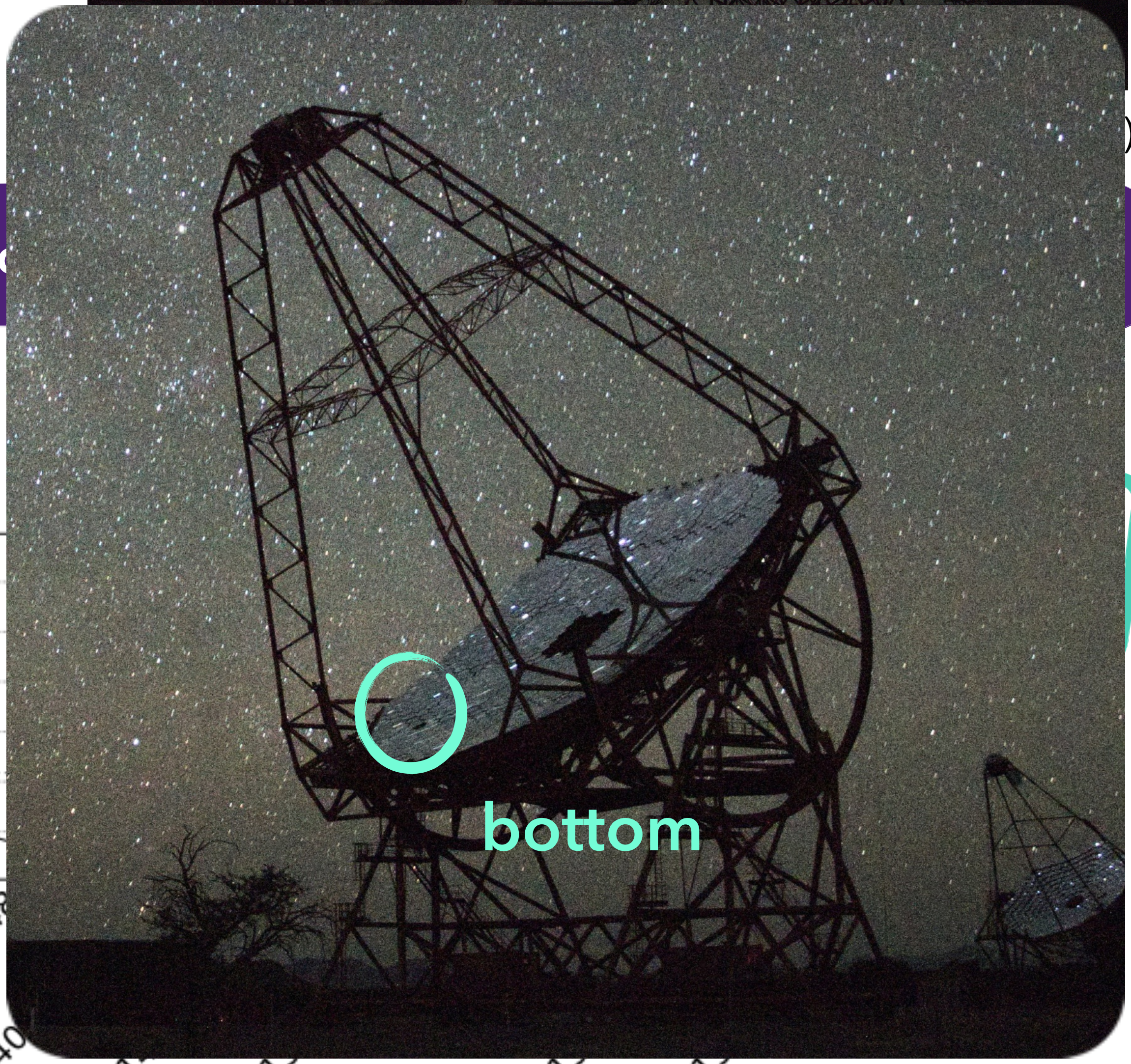
- Fast
  - Im
  - Re

↳ T_{repo}



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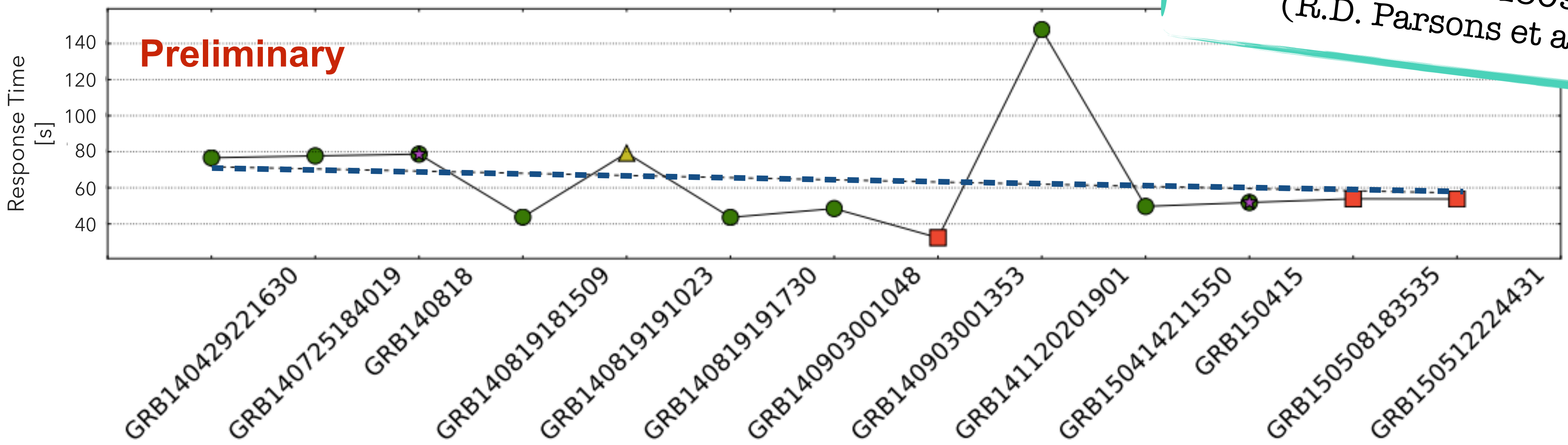
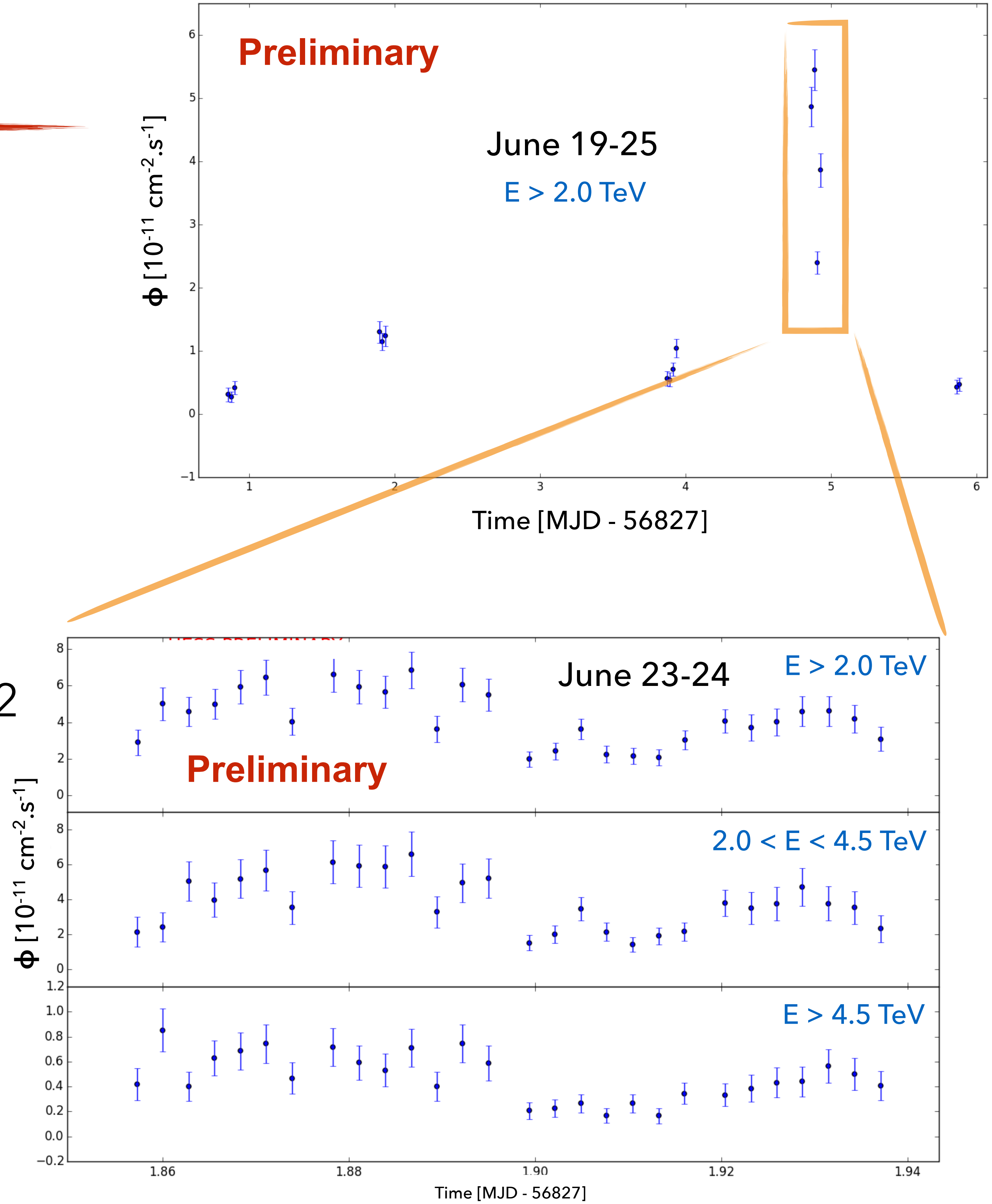


Short variability studies with Mrk 501 flare

- Mkr 501, very luminous HBL @z=0.034
- Discovered as VHE γ-ray source in 1996
- Highly variable object in all wavelength
- Observations June 2014 with E > 2 TeV
  - Flare → ToO



ICRC 2015, arXiv:1509.04893 (N. Chakraborty et al.)

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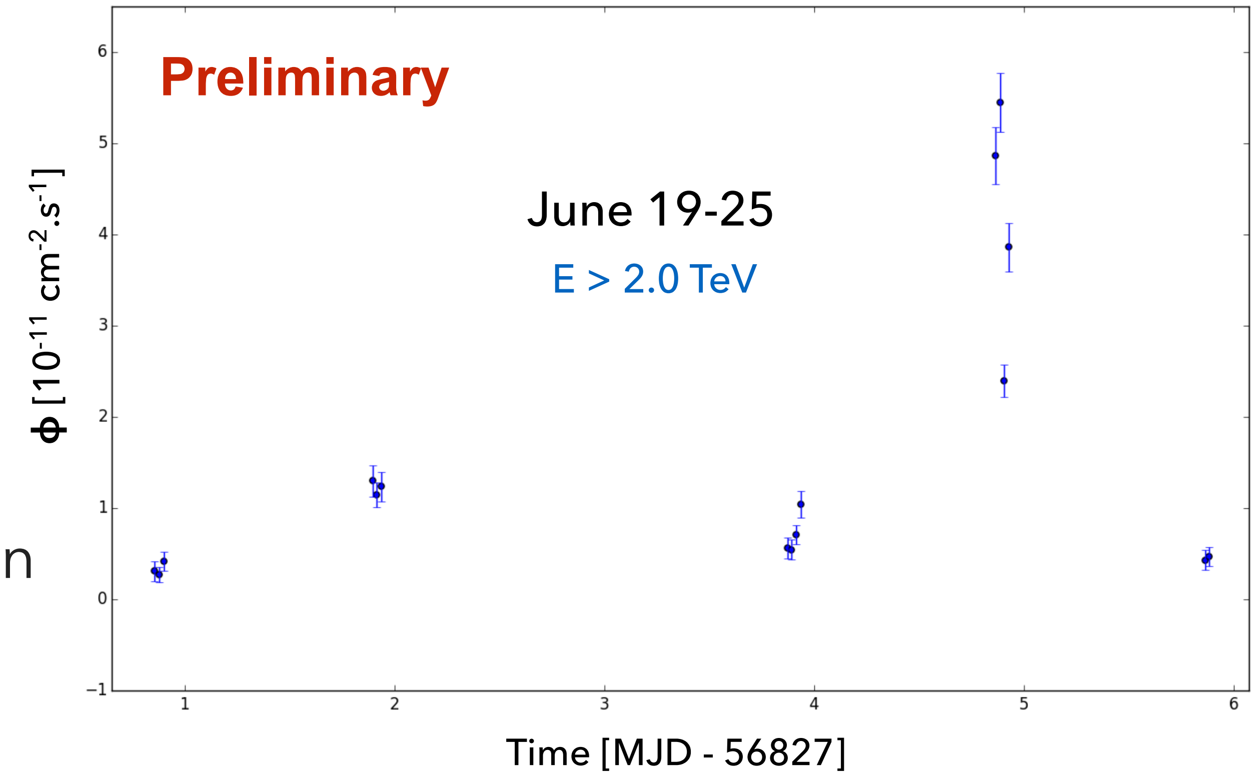
- Quiescent state + flare June 2014
  - Flux doubling time < 10 min
  - F_{var} = 1.1 @E>2TeV

  } flare domination



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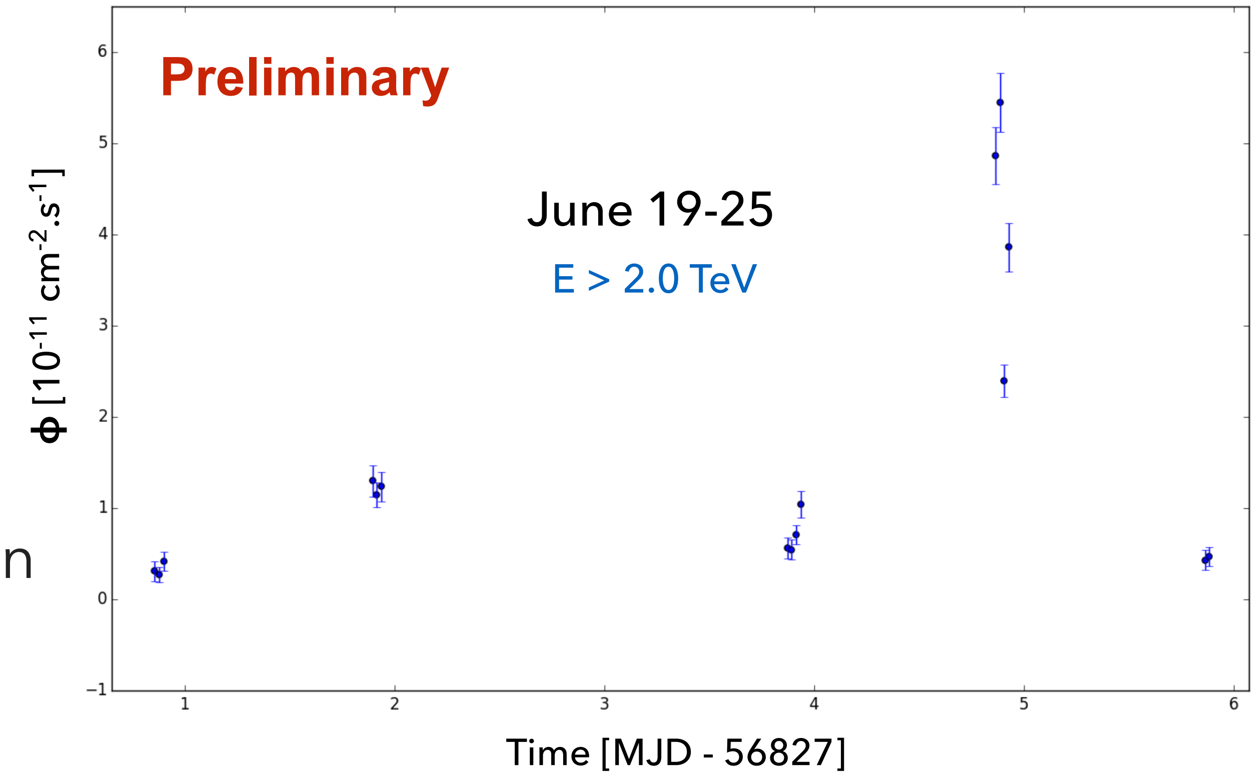
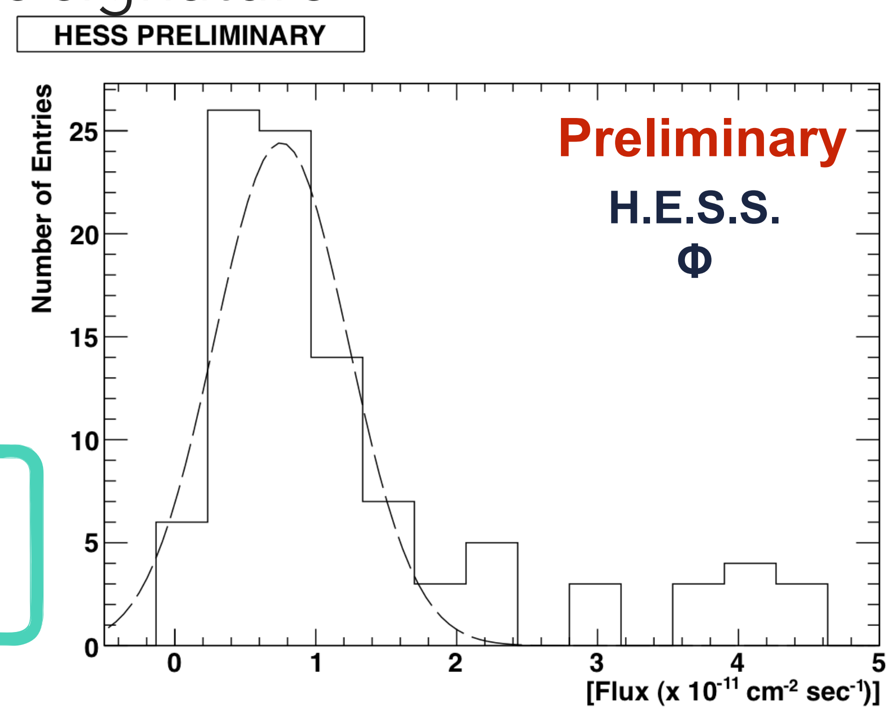


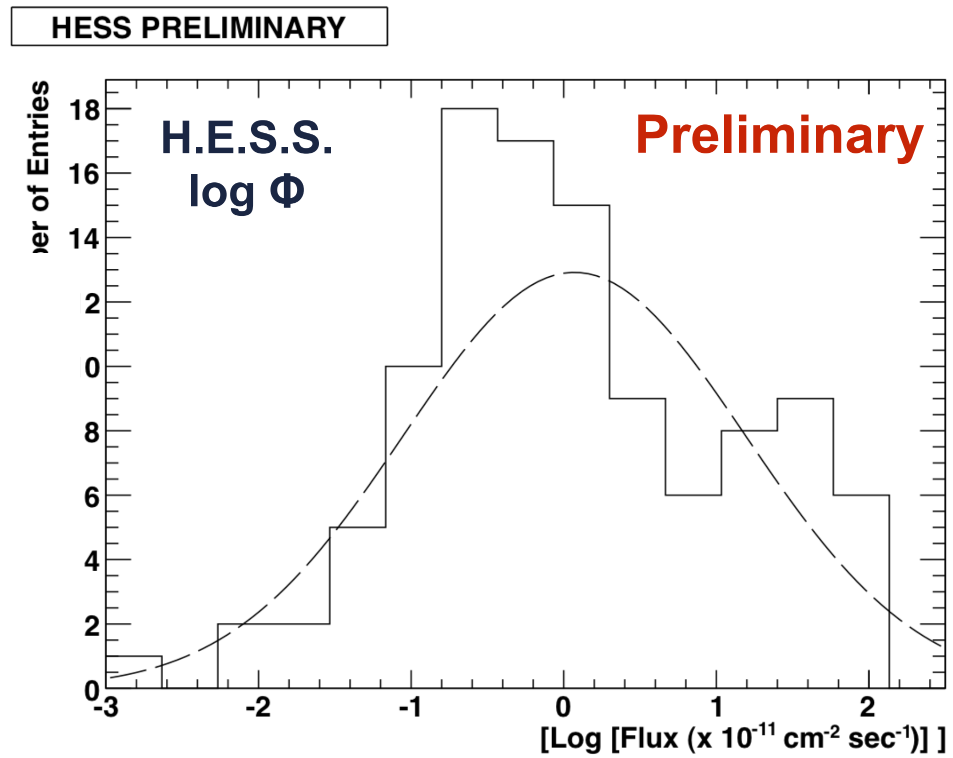
- Lognormal behavior

$S = \log\Phi_1 + \log\Phi_2 + \ldots + \log\Phi_N$

$= \Phi_1 \times \Phi_2 \times \ldots \times \Phi_N$ → multiplicative process

→ Cascade-like events signature





Lognormal distribution

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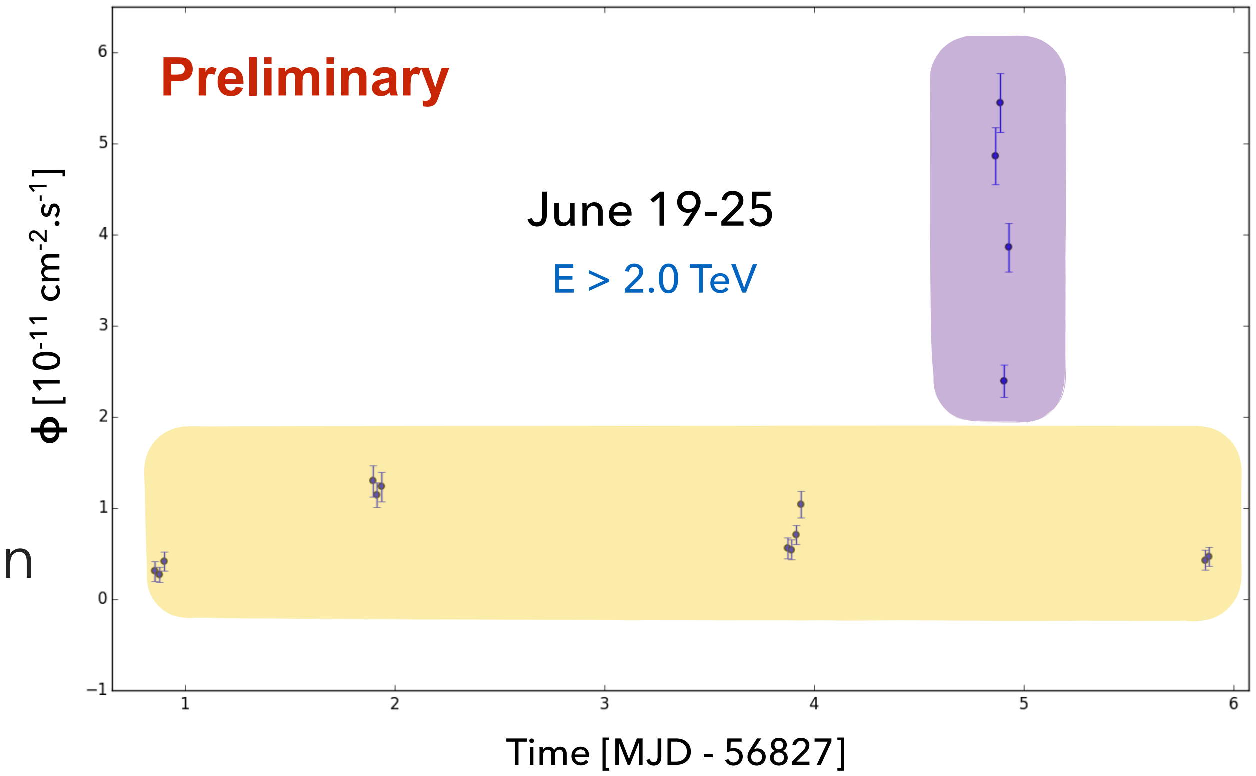
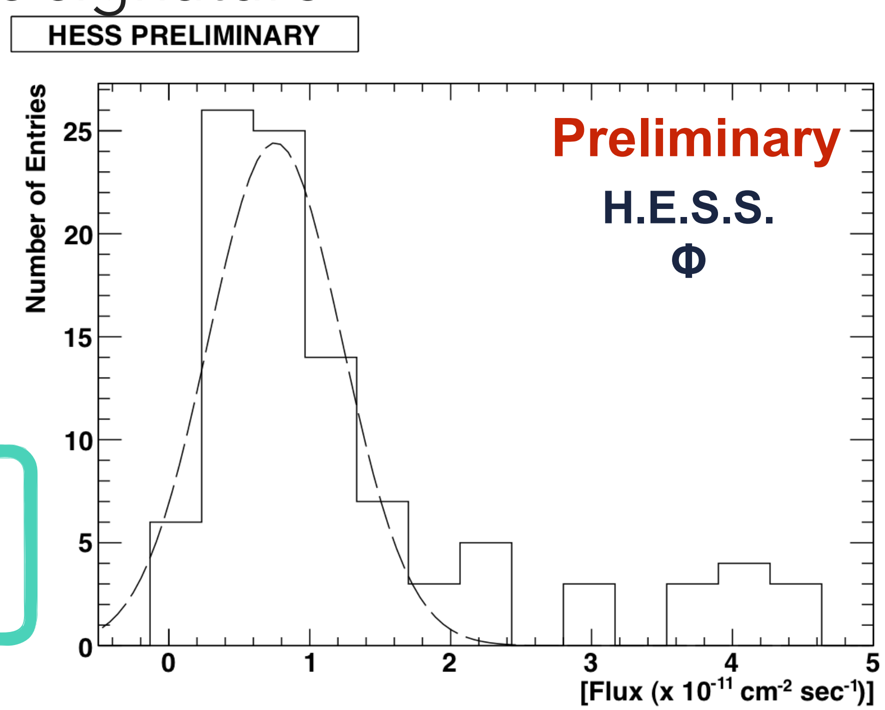
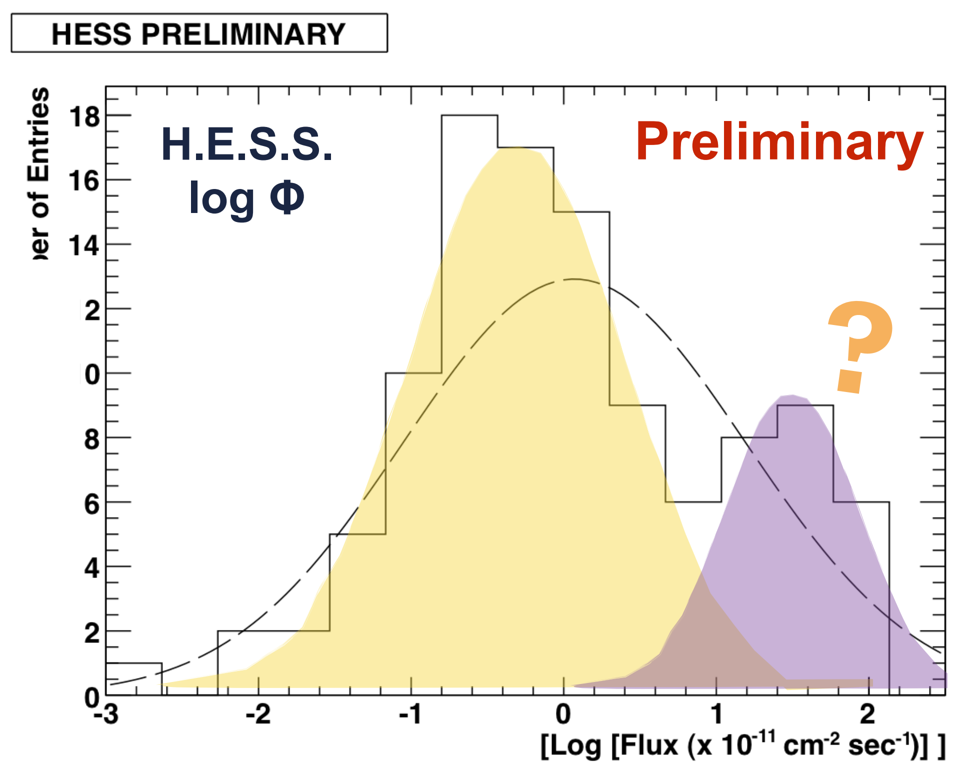




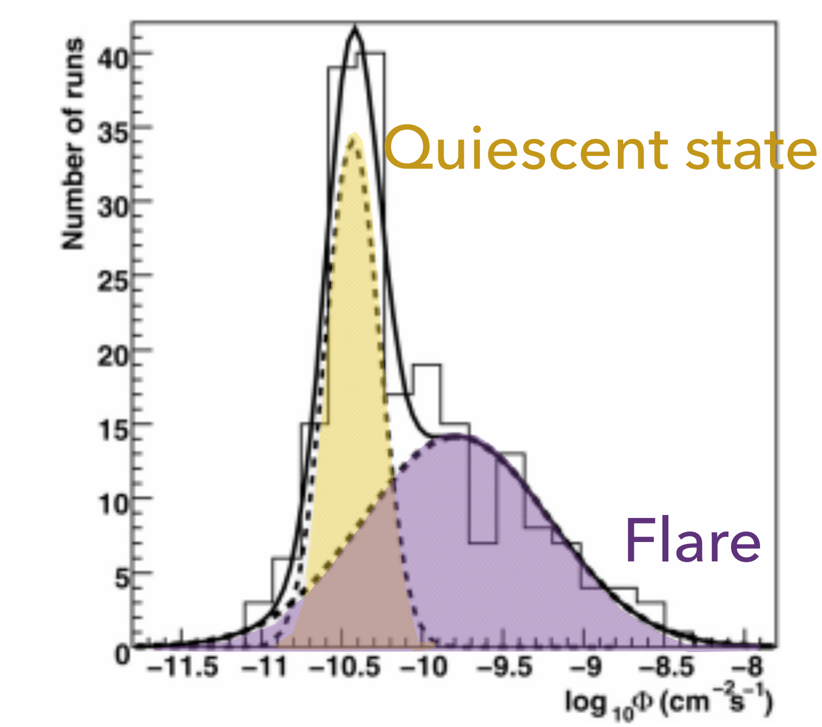


Lognormal distribution

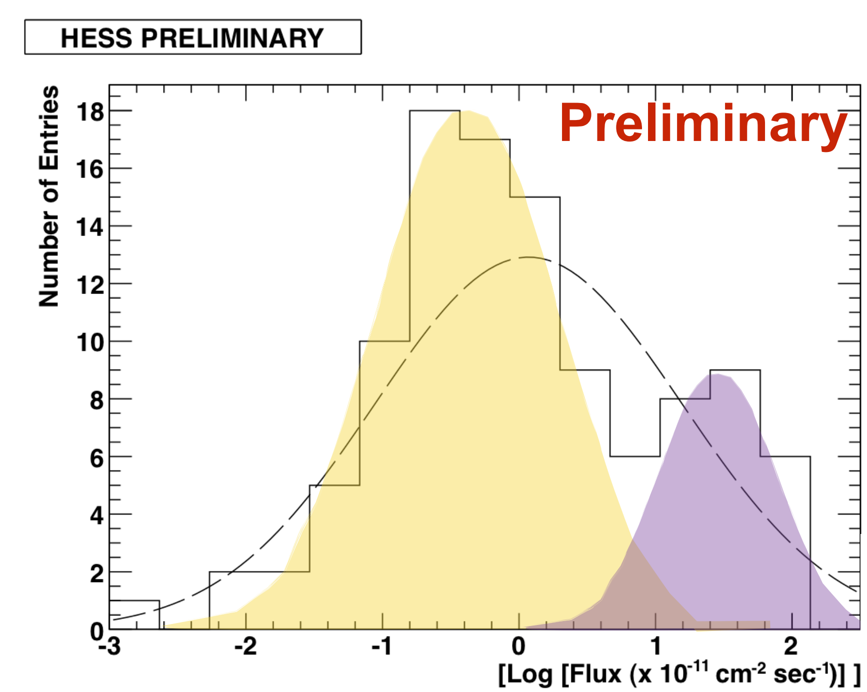
ICRC 2015, arXiv:1509.04893 (N. Chakraborty et al.)

Short variability studies with blazar flares

- PKS 2155-304 – 2005-2007 monitoring + 2006 flare
  - Doubling time scale ~2 min
  - Lognormal behavior found
  - Fvar ≳ 1 @ 0.6<E<5TeV



- Mrk 501 – 2014 monitoring + flare
  - Doubling time scale < 10 min
  - Lognormal distribution of the flux ?
  - Fvar ~ 1 @E>2TeV

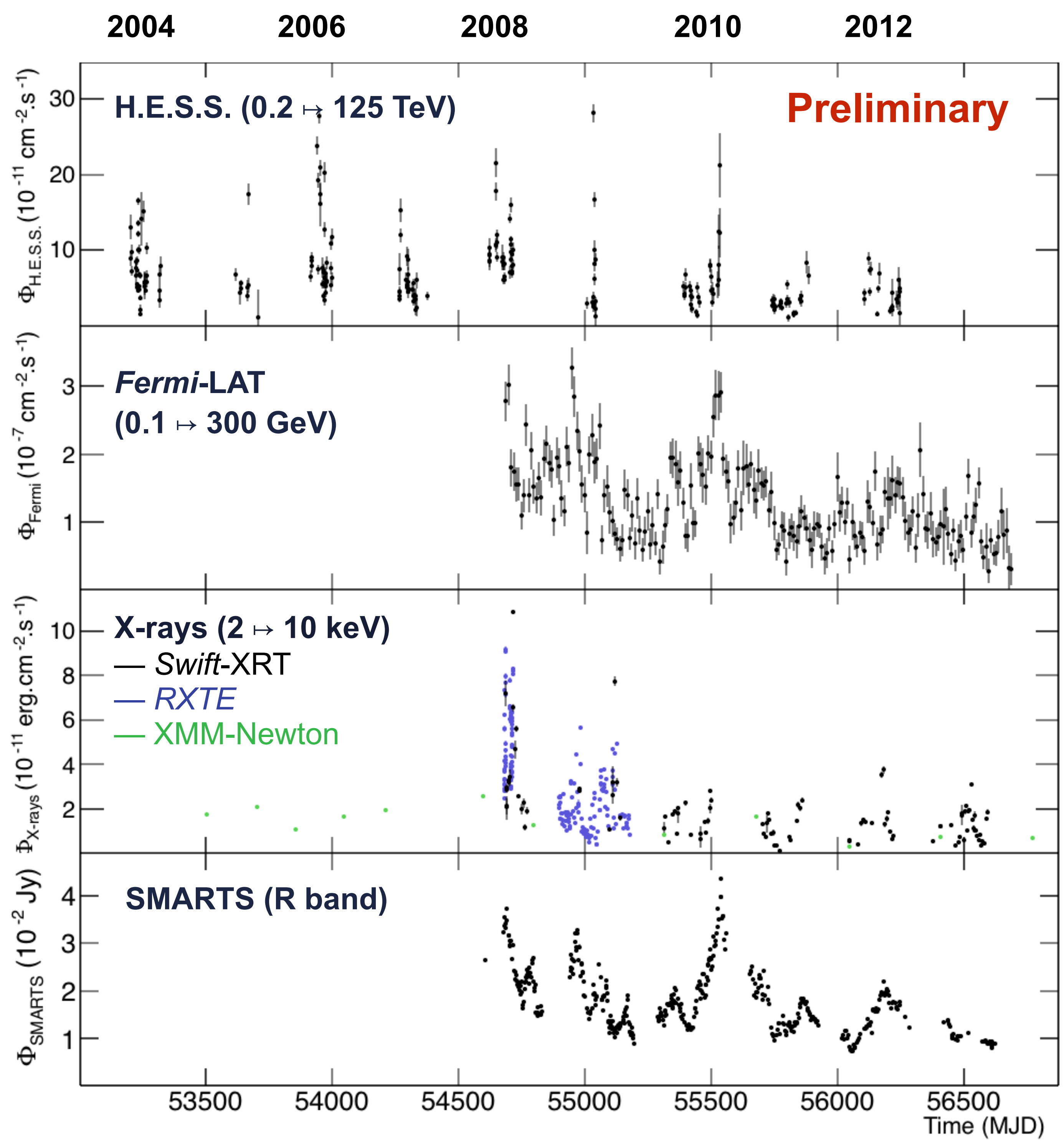


?

Long term monitoring of the blazar PKS 2155-304

ICRC 2015, arXiv:1509.03104 (J.Chevalier et al.)

- Bright HBL @z=0.116
- ~300h in 9 years of VHE data



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- MWL monitoring from *Fermi*-LAT, *Swift*-XRT, *RXTE*, XMM-Newton & SMARTS
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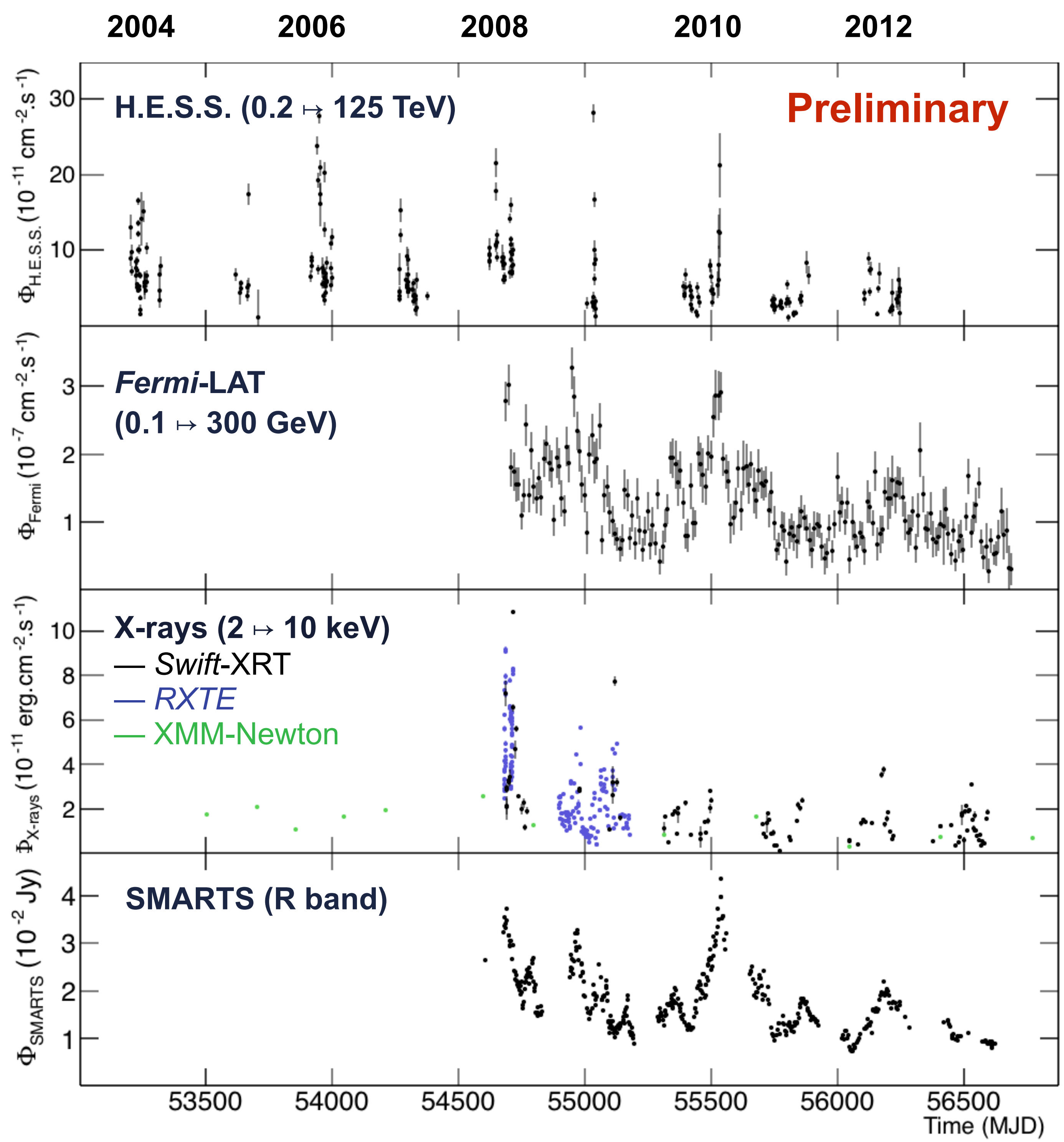

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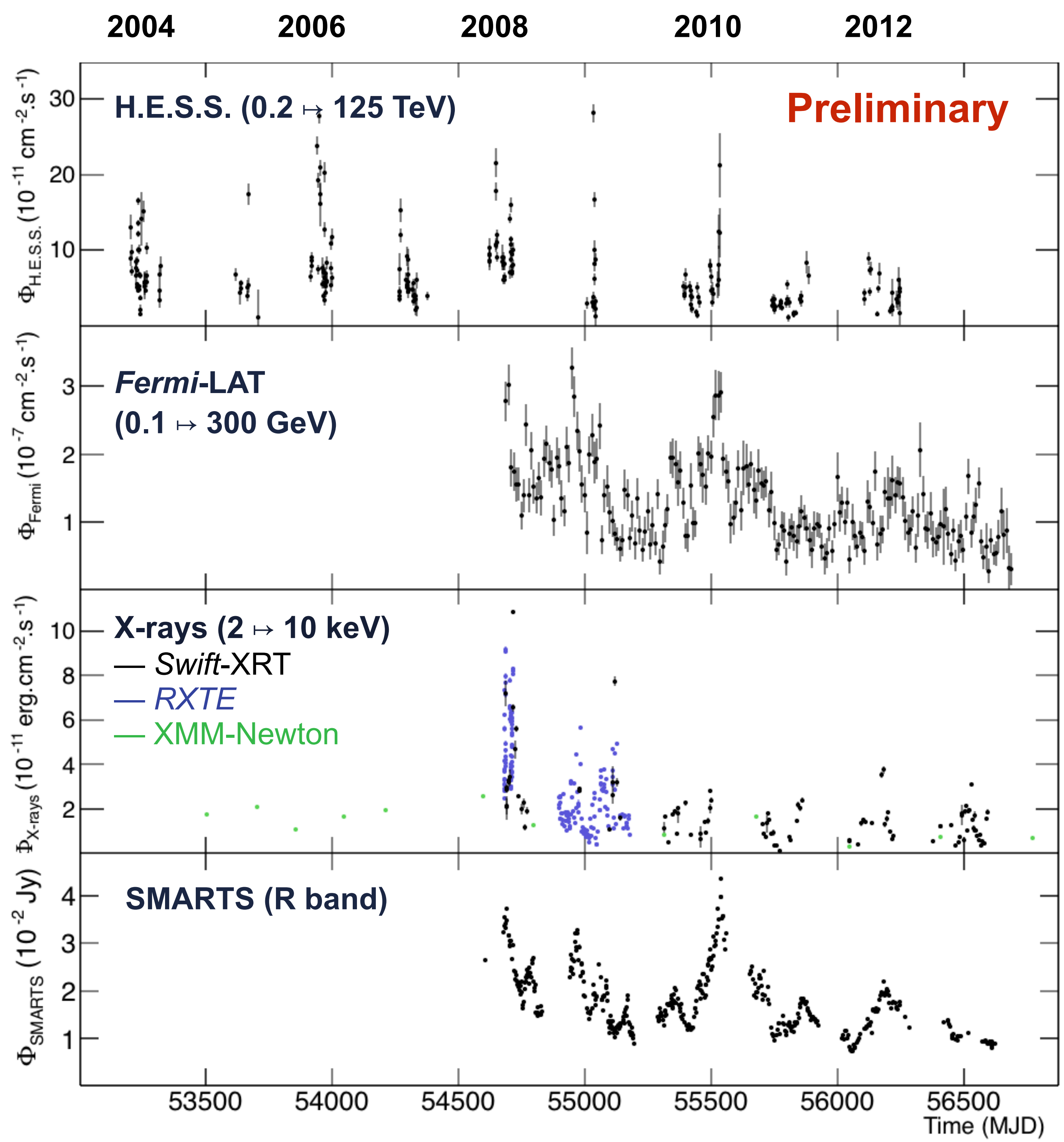
- Variability characterization:
  - Lognormality
  - F_{var} (E)



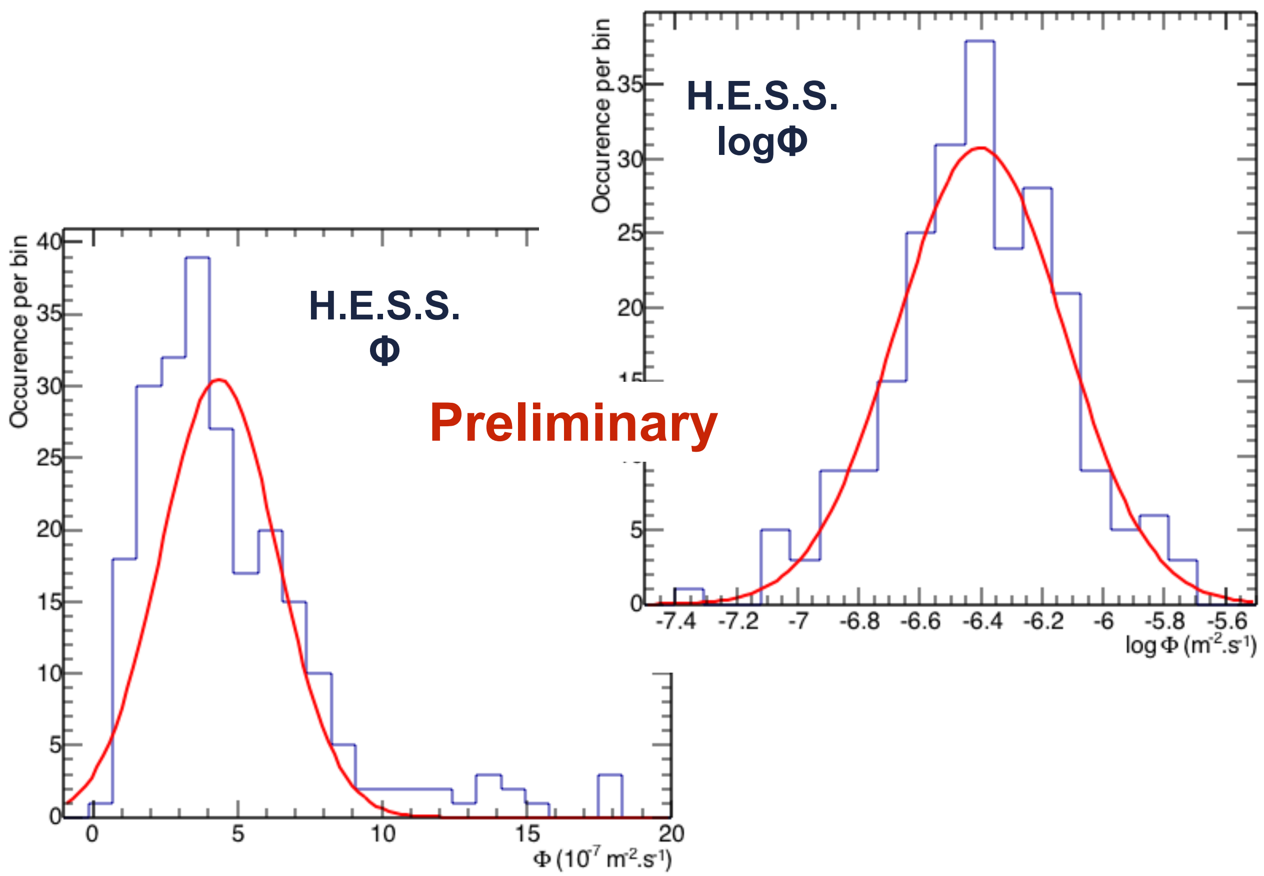
Long term monitoring of the blazar PKS 2155-304

ICRC 2015, arXiv:1509.03104
(J.Chevalier et al.)

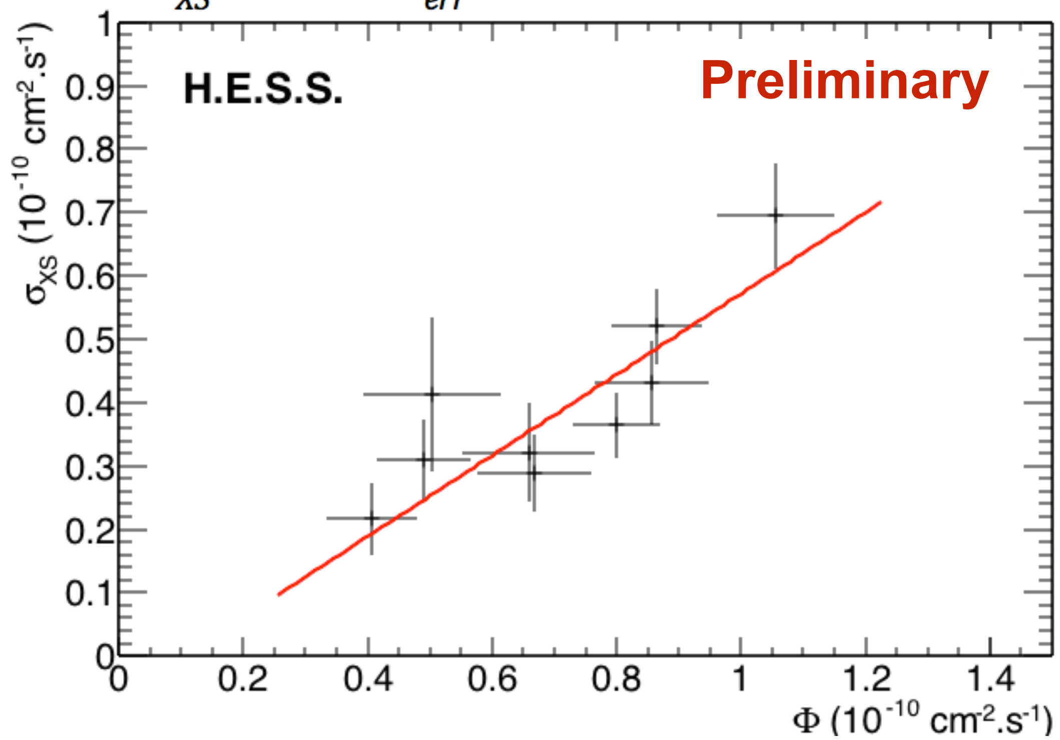
- Lognormal behavior
  - Lognormal flux distribution

    $S = \log\Phi_1 + \log\Phi_2 + \ldots + \log\Phi_N$ → Multiplicative process(es)

    $= \Phi_1 \times \Phi_2 \times \ldots \times \Phi_N$
  - Correlation σ_{XS} & mean ϕ
- Seen in H.E.S.S., X-ray & SMARTS

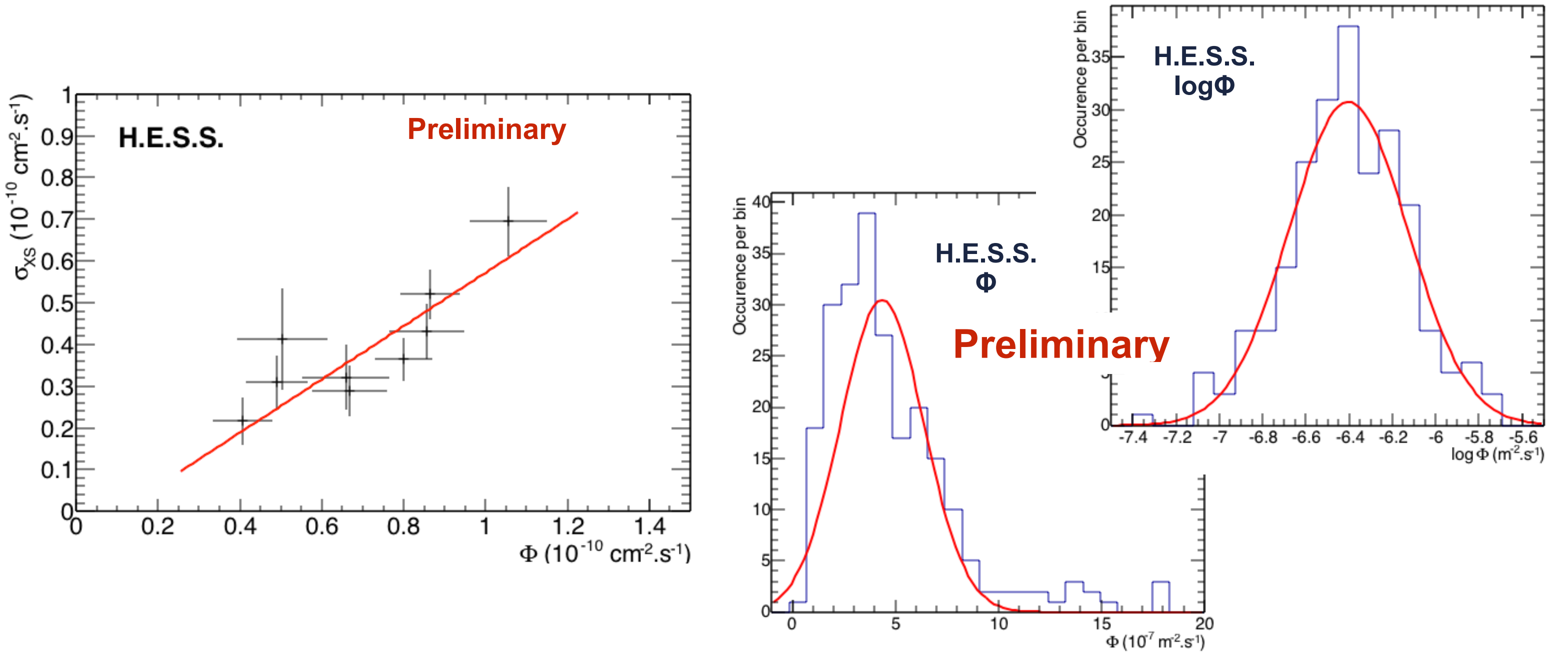


$$\sigma_{XS}^2 = S^2 - \overline{\sigma_{err}^2}$$



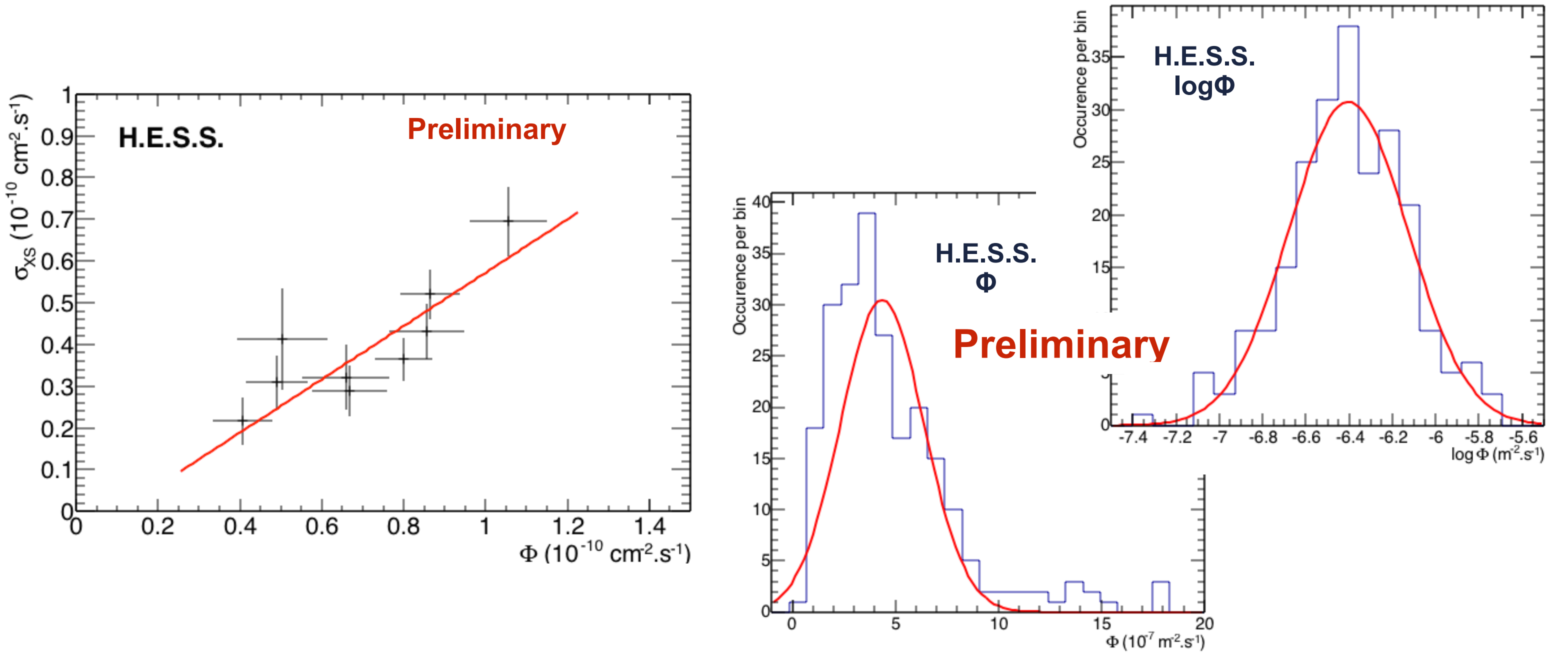
Blazars and lognormality

Blazars and lognormality



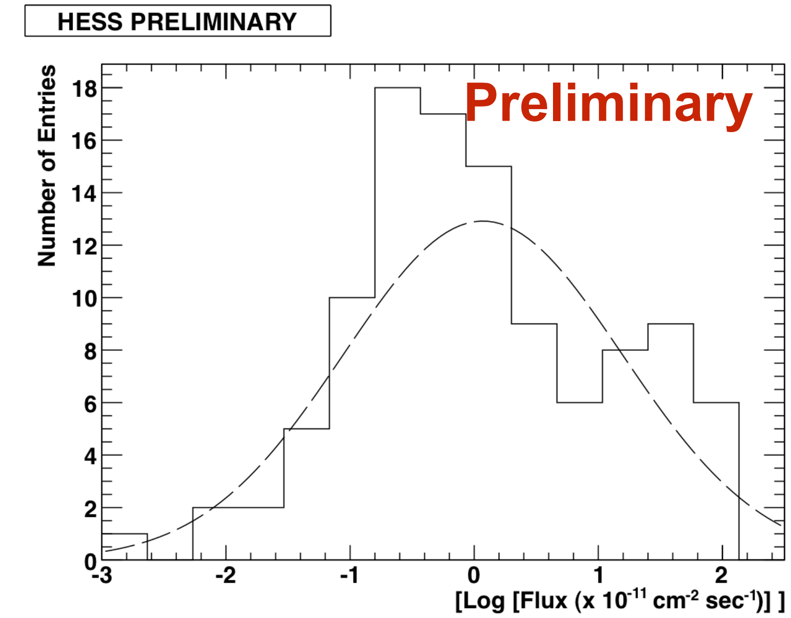
PKS 2155-304 — long term monitoring

Blazars and lognormality



PKS 2155-304 – long term monitoring

Mrk 501 – 2014 flare



Blazars and lognormality

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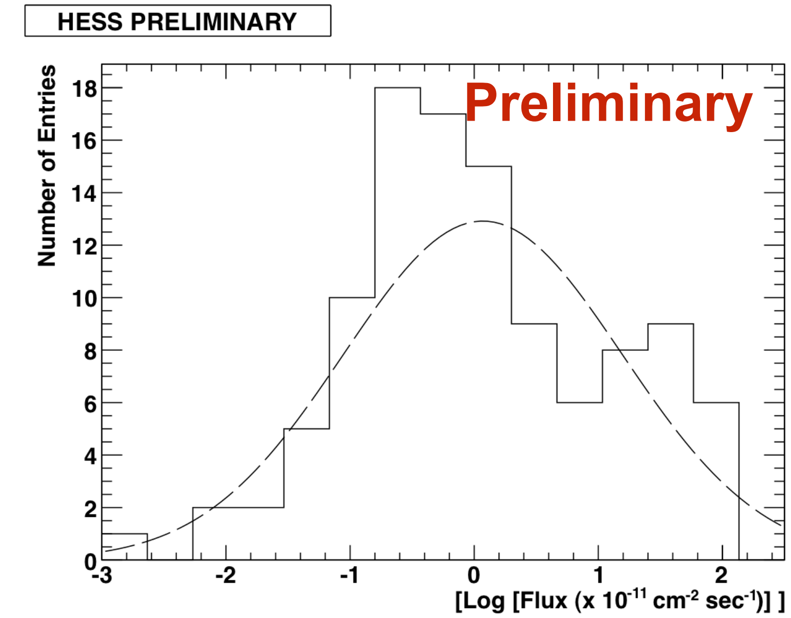
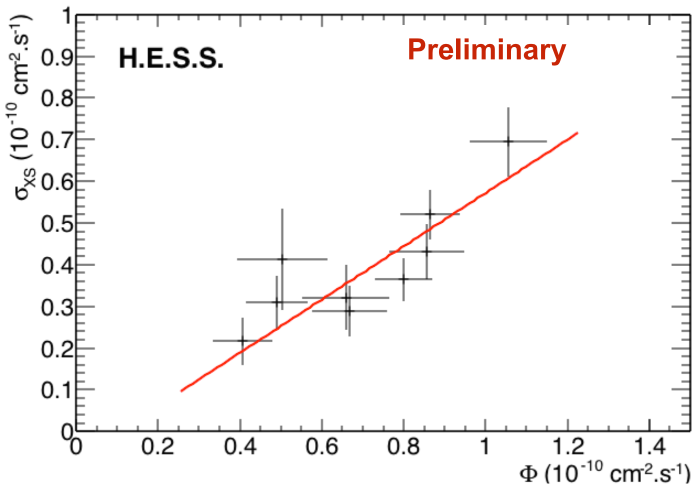
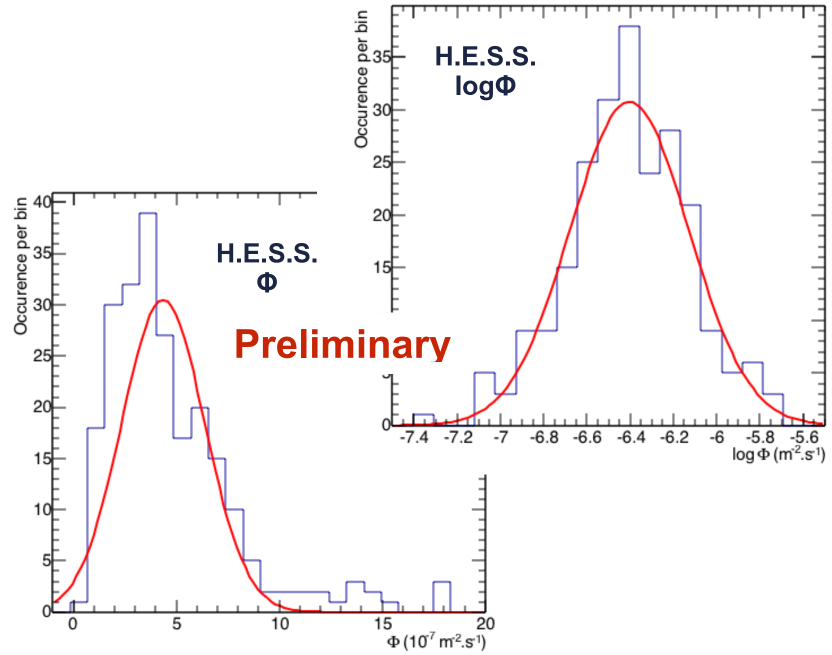
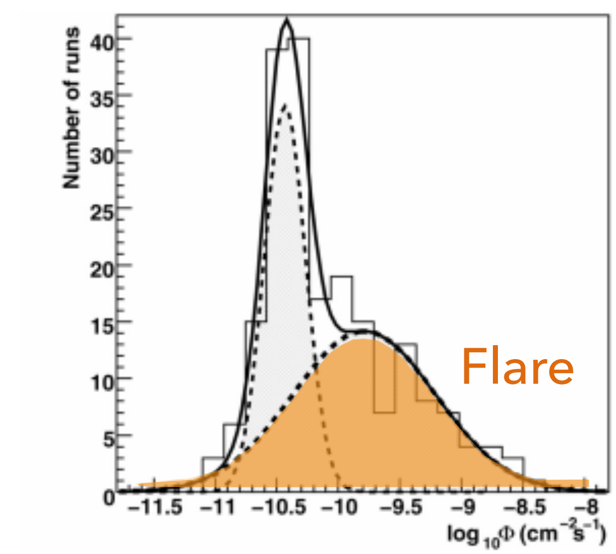






PKS 2155-304 – long term monitoring

PKS 2155-304 – 2006 flare



Blazars and lognormality

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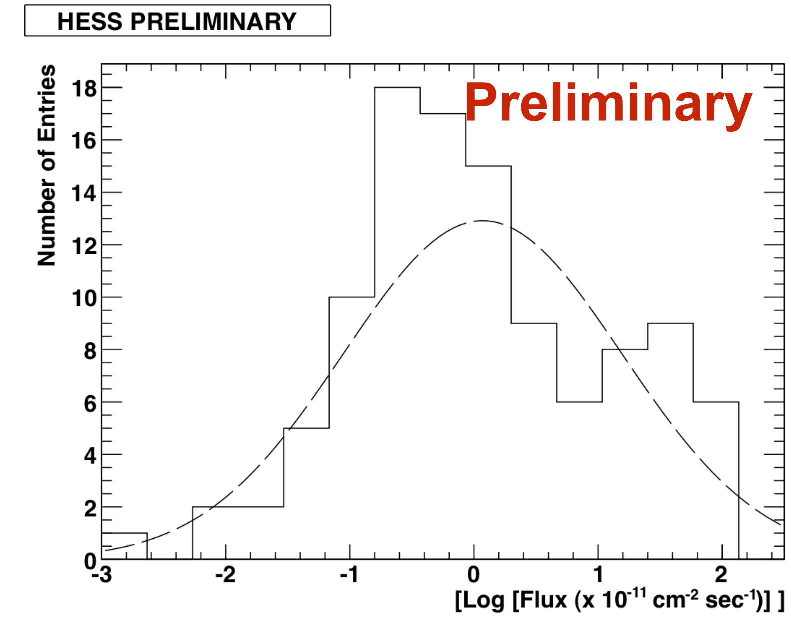

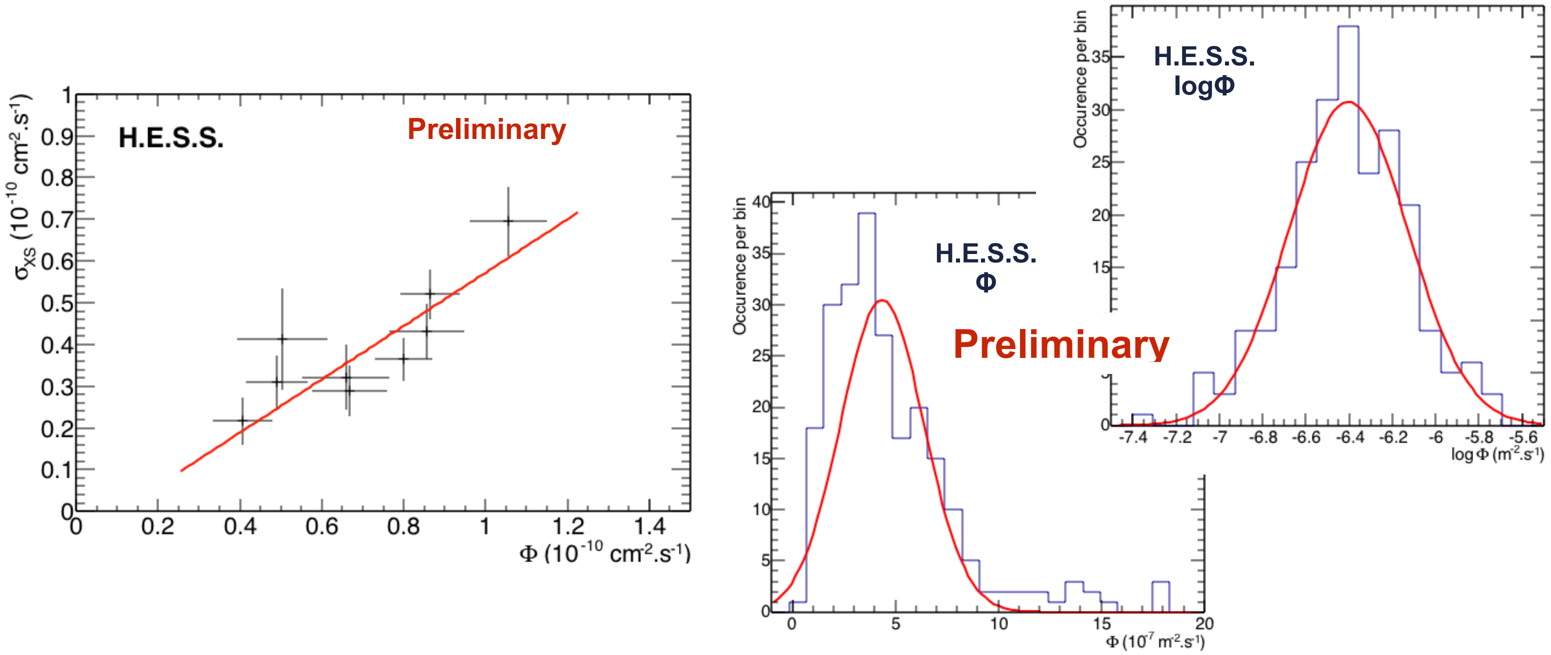

PKS 2155-304 – long term monitoring

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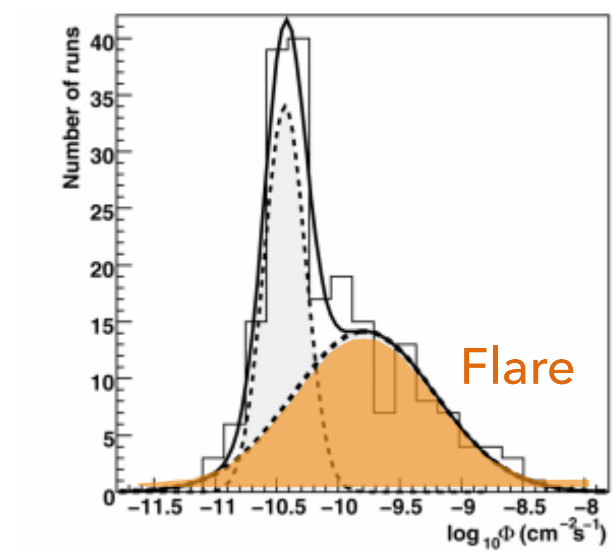
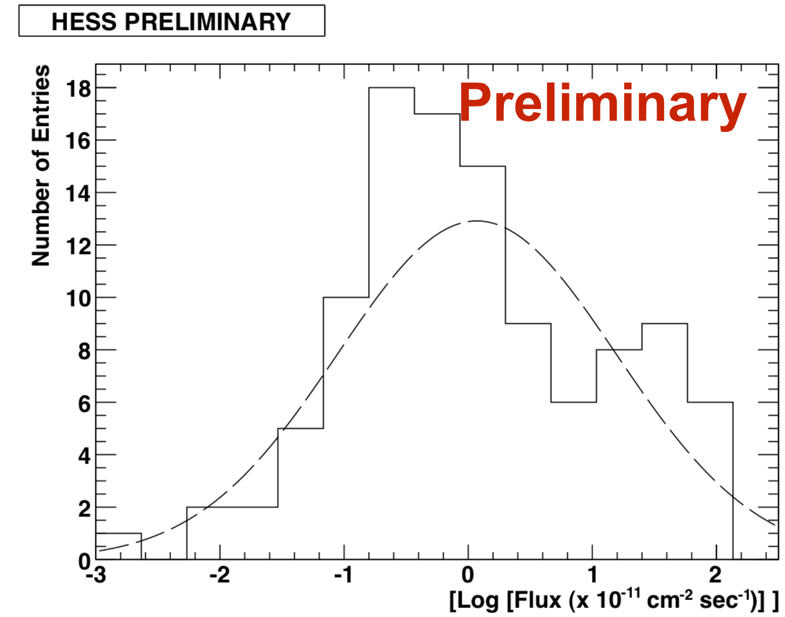
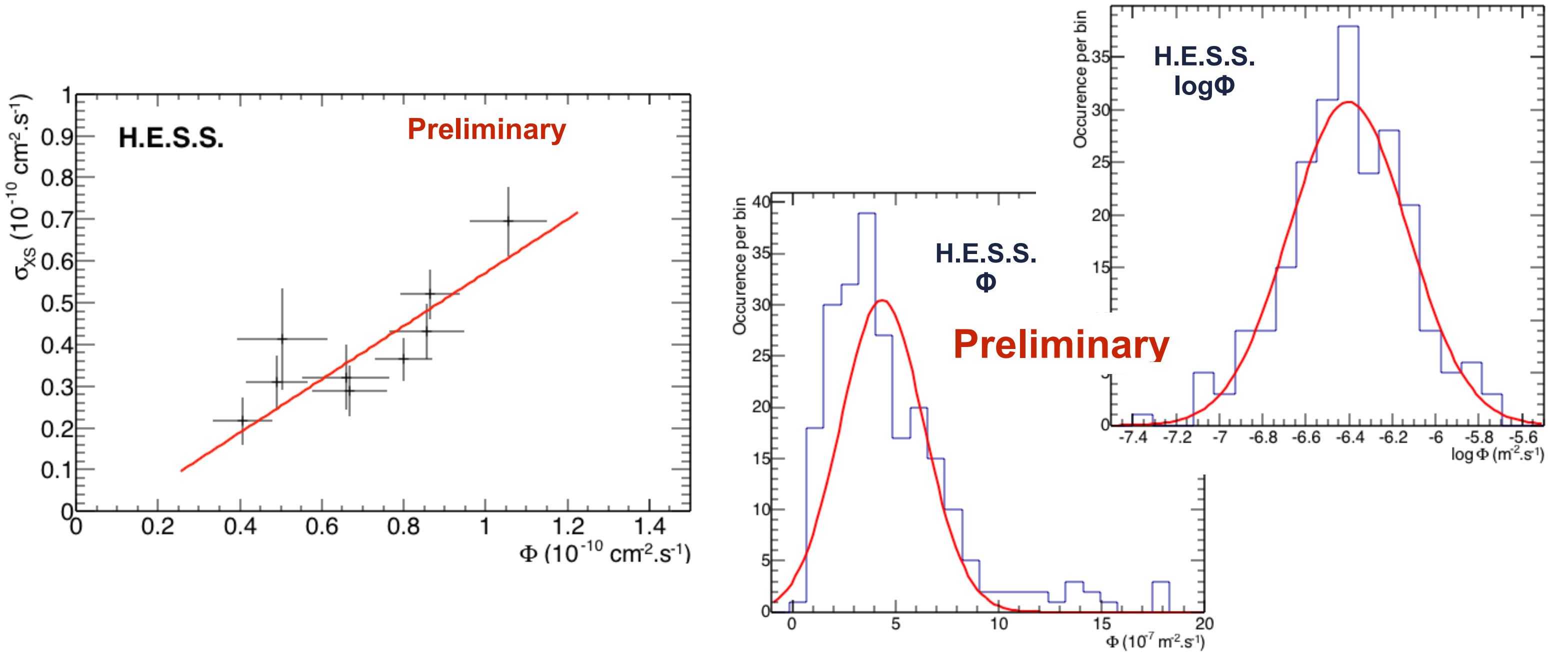


- Seen for a couple of other AGN objects (blazar + Seyfert) in X-ray and TeV

Blazars and lognormality

Mrk 501 – 2014 flare





PKS 2155-304 – long term monitoring

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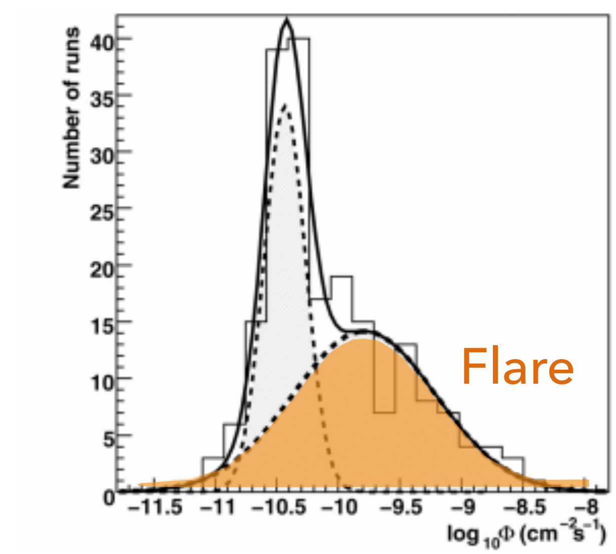


- Seen for a couple of other AGN objects (blazar + Seyfert) in X-ray and TeV
- Historically, lognormality is linked with accretion disk (X-ray binaries studies see Uttley & McHardy 2001)

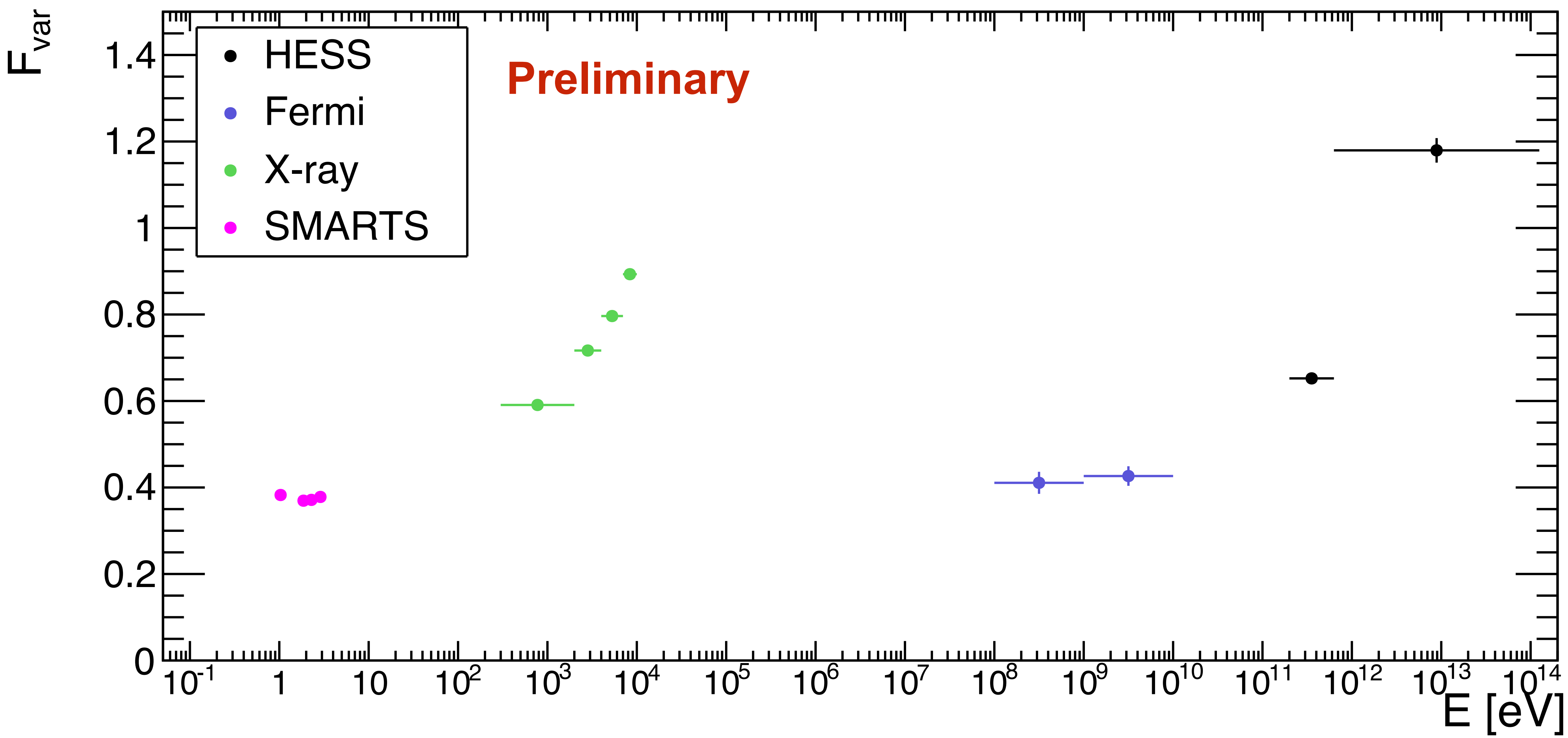
↳ Imprint of cascade-like events in the disk onto the jet? (Giebels & Degrange 2013)

Long term monitoring of the blazar PKS 2155-304

ICRC 2015, arXiv:1509.03104 (J.Chevalier et al.)

- Strong variability with Fvar increasing throughout SED components

$$F_{var} = \sqrt{\frac{S^2 - \overline{\sigma_{err}^2}}{\bar{\Phi}^2}}$$



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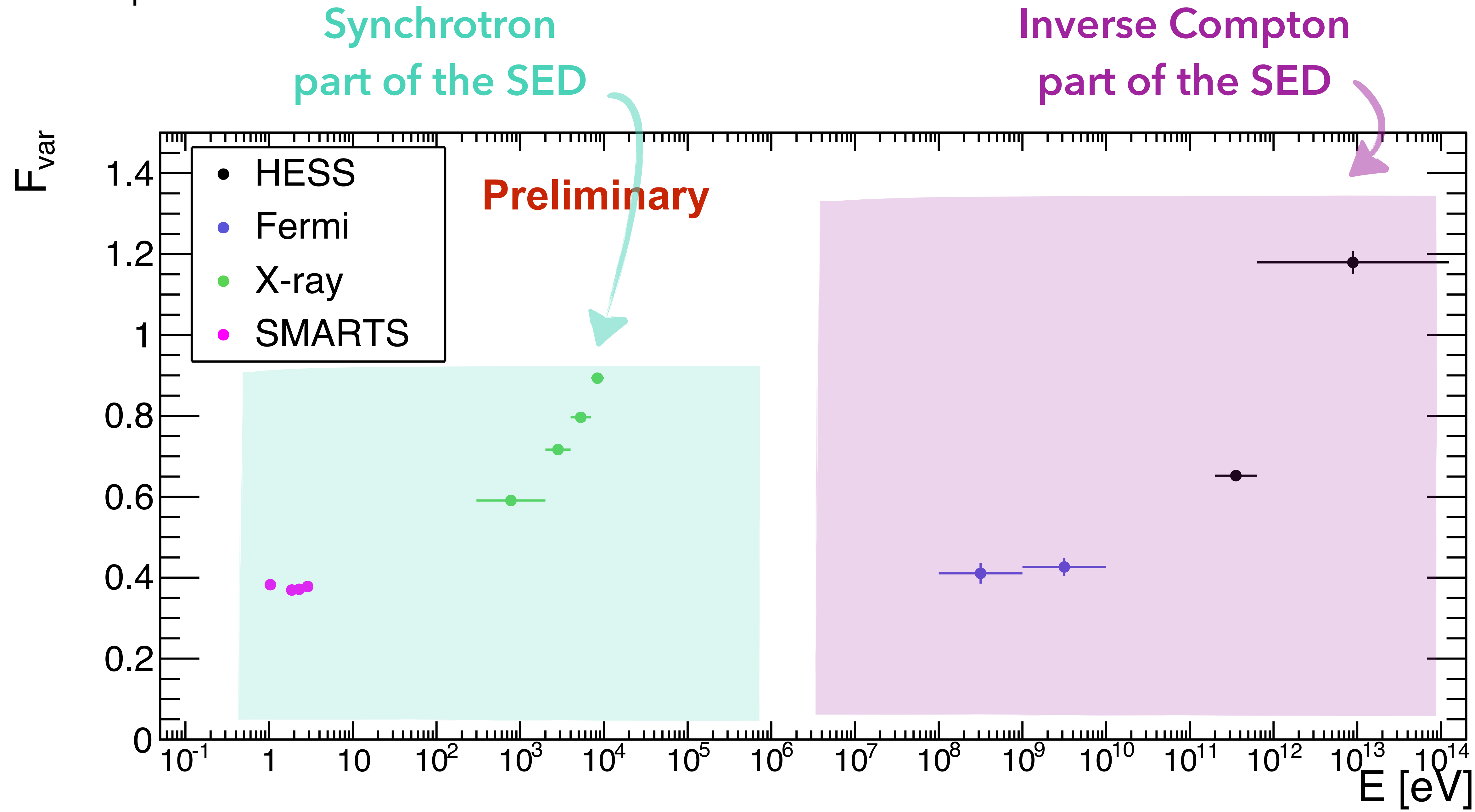
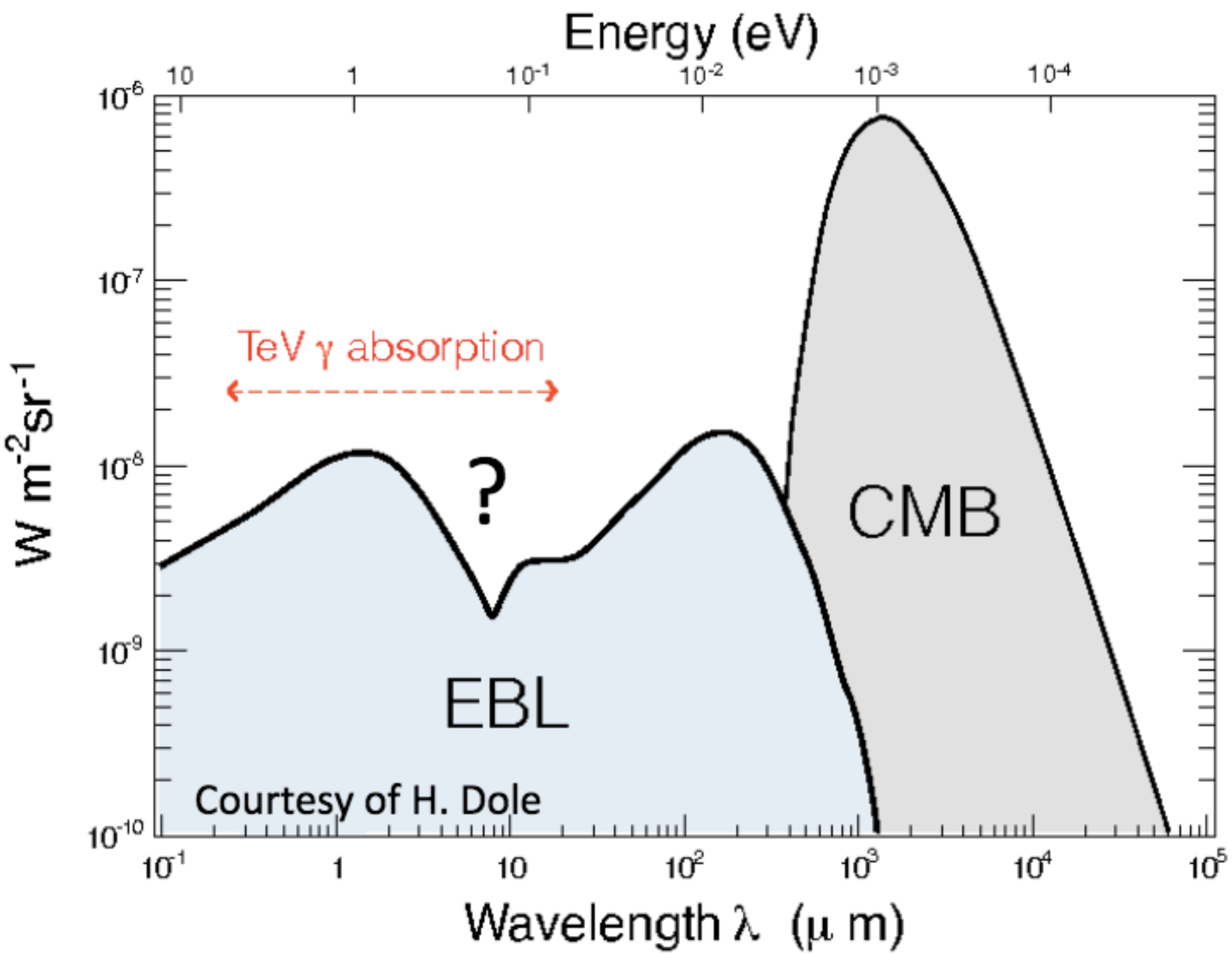
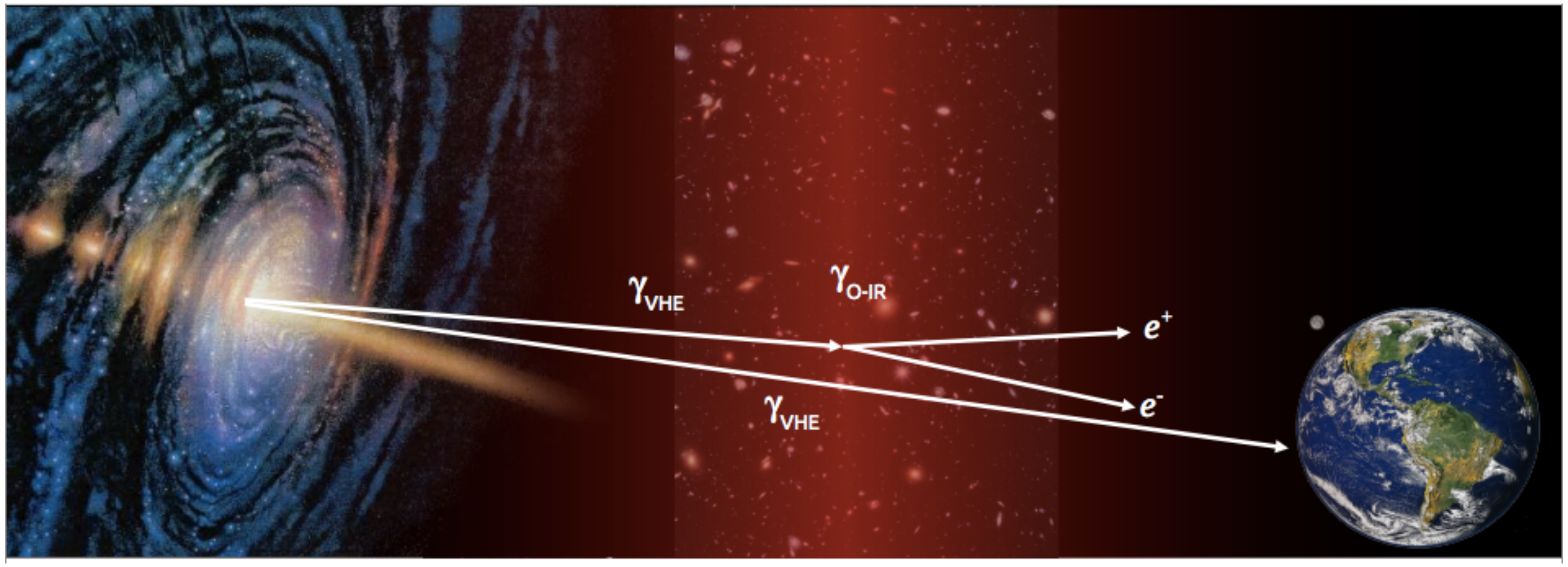


Determining the shape of the EBL



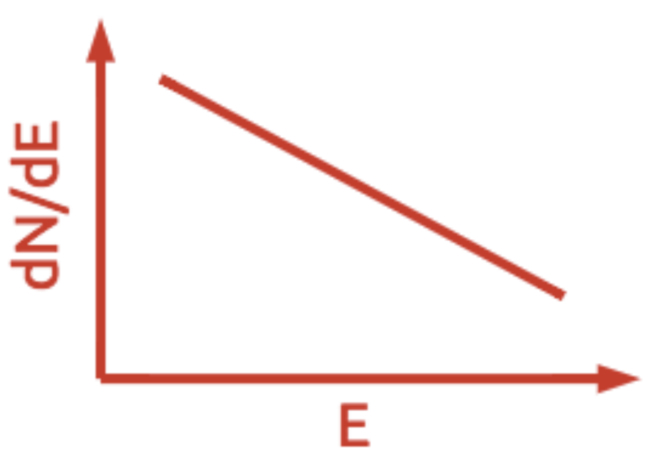
- Background photon field originating starlight and dust re-emission
- Universe not transparent to gamma-rays over extragalactic distances → optical depth τ

Determining the shape of the EBL



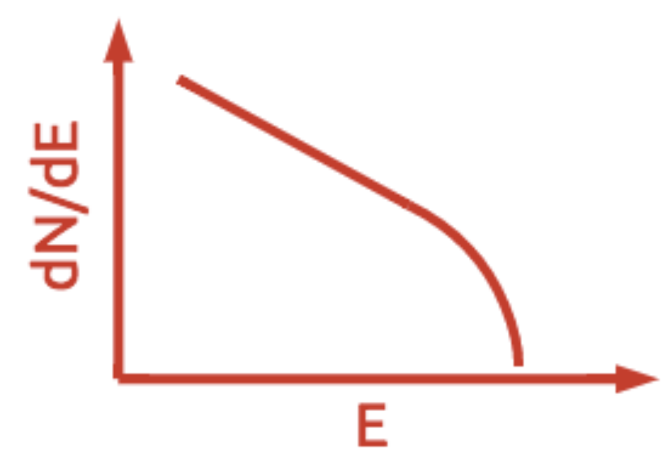
$$\Phi_{obs}(E_\gamma) = \Phi_{int}(E_\gamma) e^{-\tau(E_\gamma, z_s)}$$

Intrinsic spectrum



$$\gamma_{VHE} + \gamma_{O\text{-}IR} \rightarrow e^+ + e^-$$

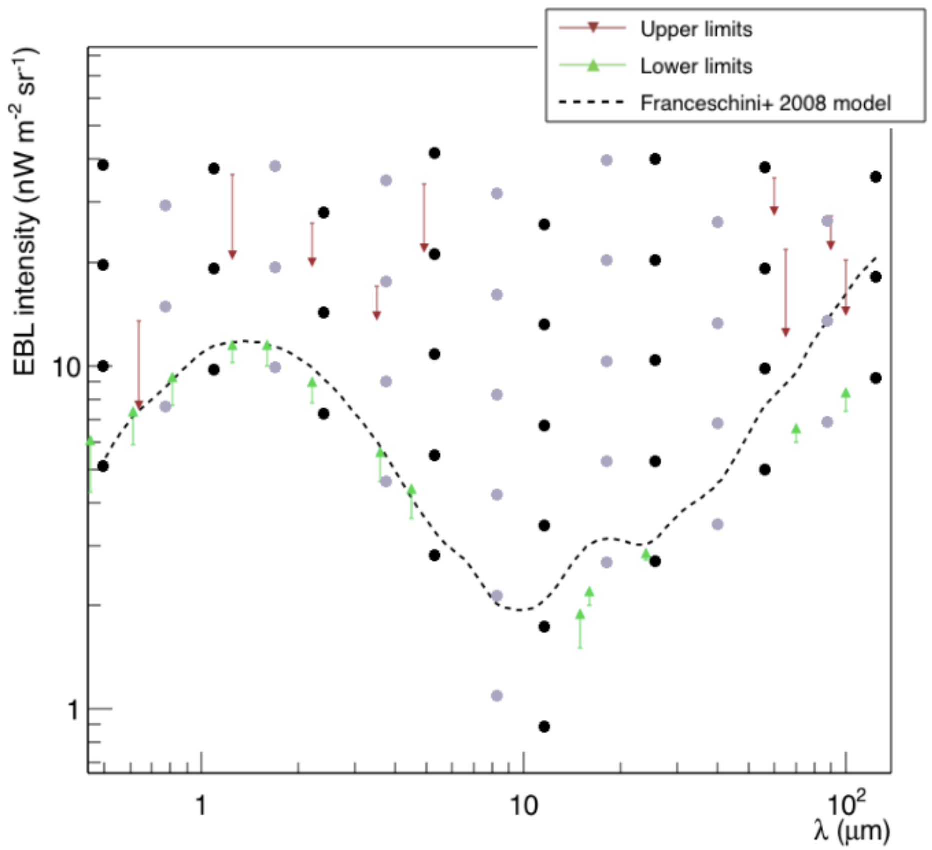
Observed spectrum

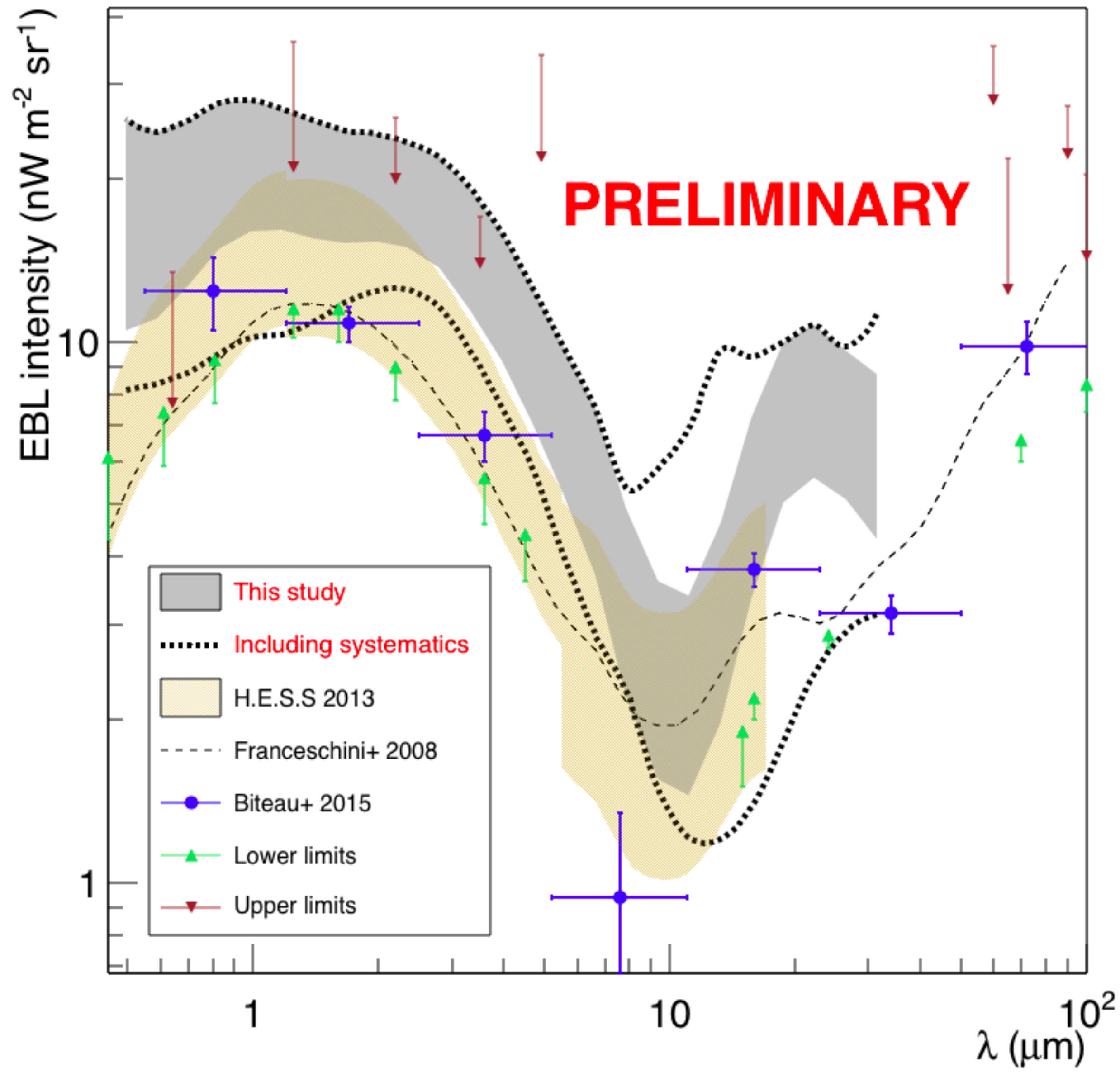


Determining the shape of the EBL

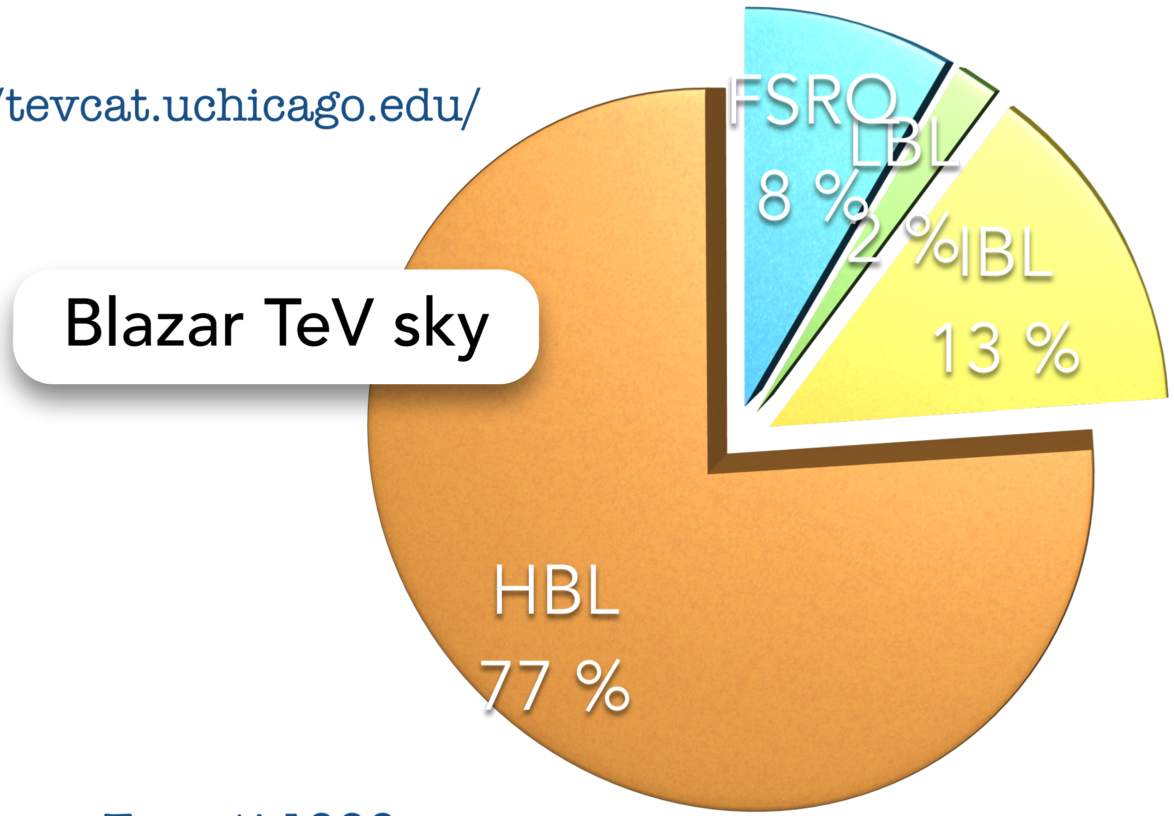
ICRC 2015, arXiv:1509.03477 (M.Lorentz et al.)

- A 1st model-independent study of the EBL with H.E.S.S.
  - Shape determination
  - Intensity determination
- Spline method to explore the EBL space





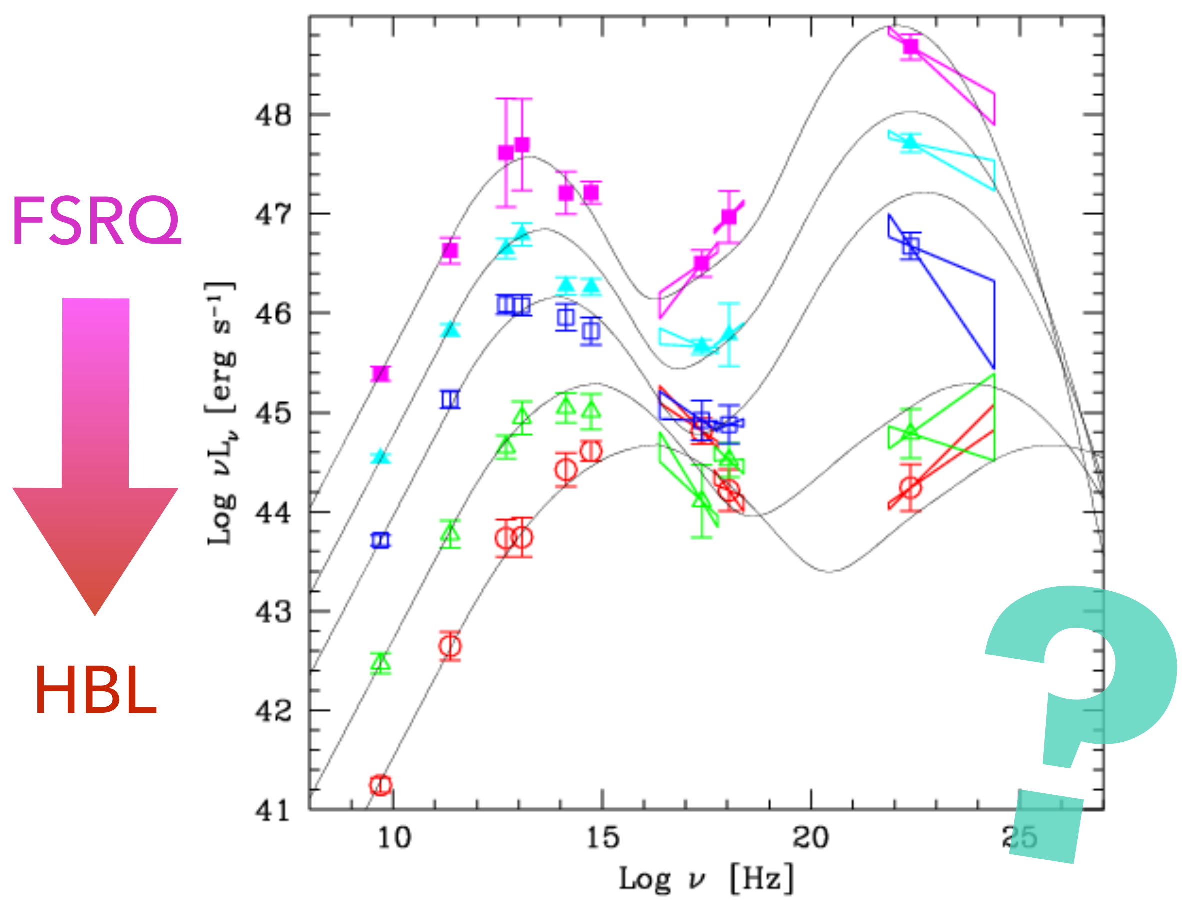
http://tevcat.uchicago.edu/



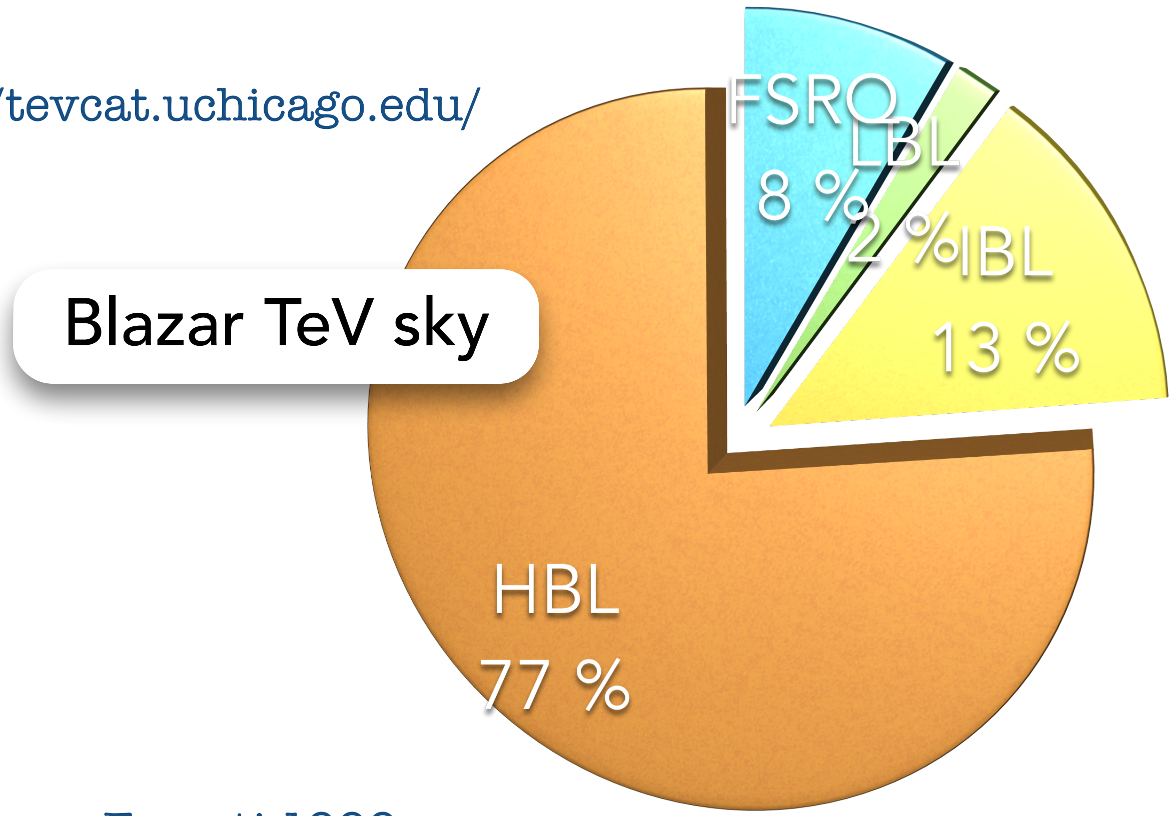
Blazar status

- Blazars = FSRQ + BL Lac (LBL+IBL+HBL)
- Blazars are mainly dominated by HBL
  - Observational bias
  - Sequence?

Fossati 1999



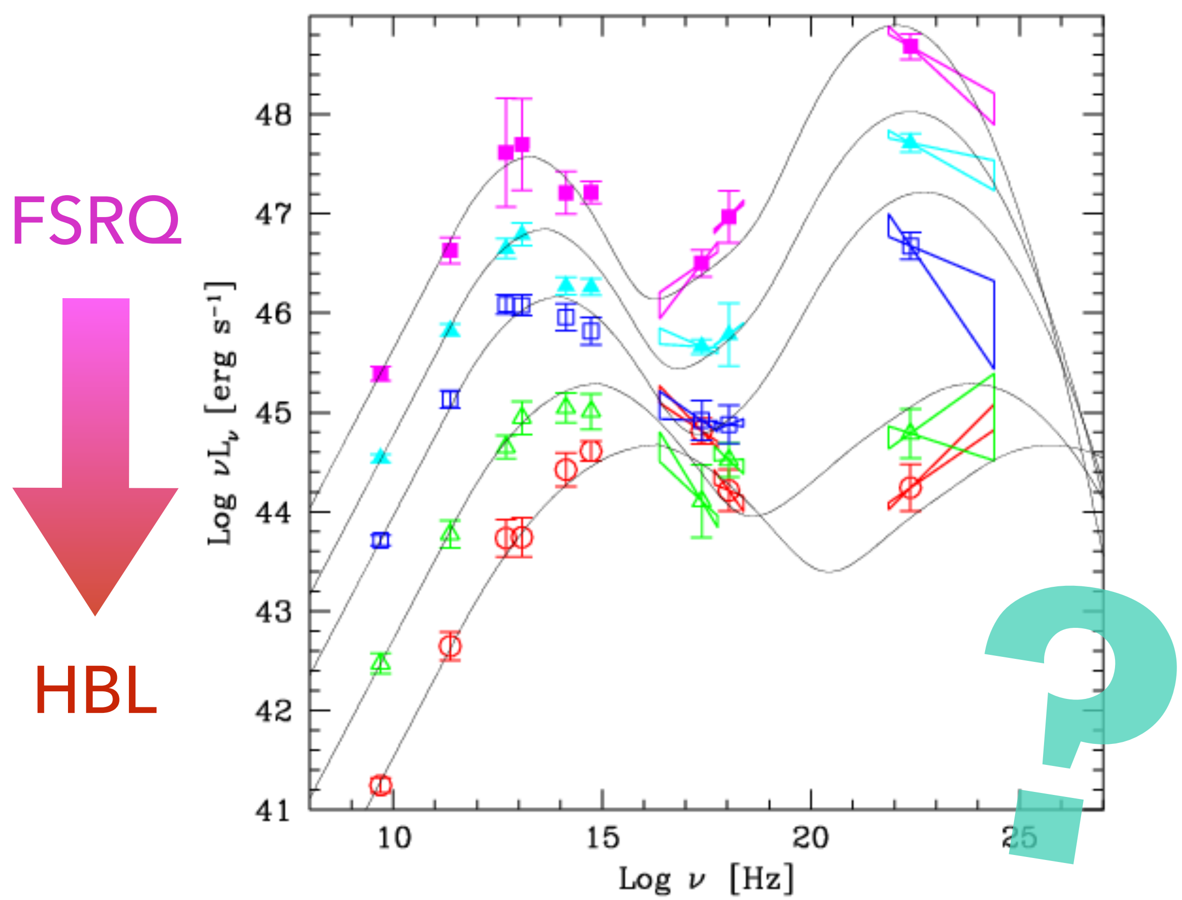
http://tevcat.uchicago.edu/



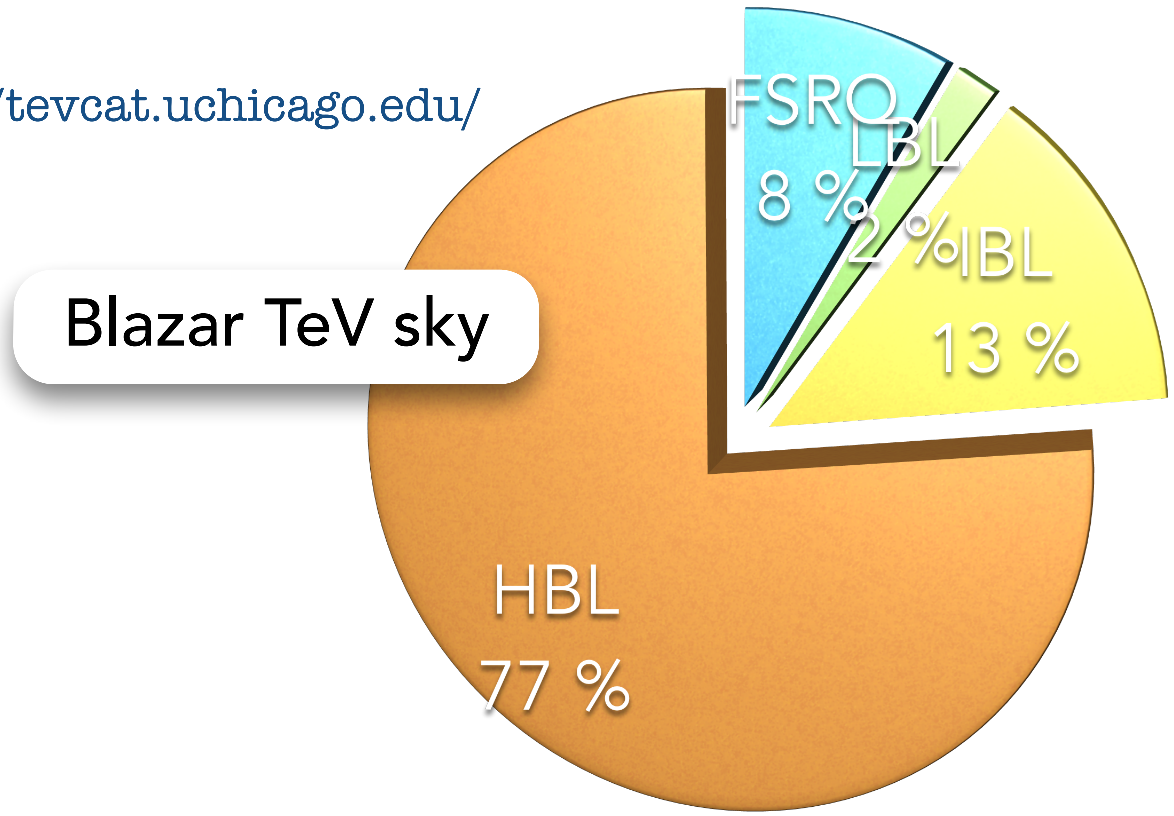
Blazar status

- Blazars = FSRQ + BL Lac (LBL+IBL+HBL)
- Blazars are mainly dominated by HBL
  - Observational bias
  - Sequence?
- HBLs (PKS 2155-304, Mrk 501…) are generally well described by one zone, time-independent SSC model
  - Not the case for LBLs and FSRQs

Fossati 1999



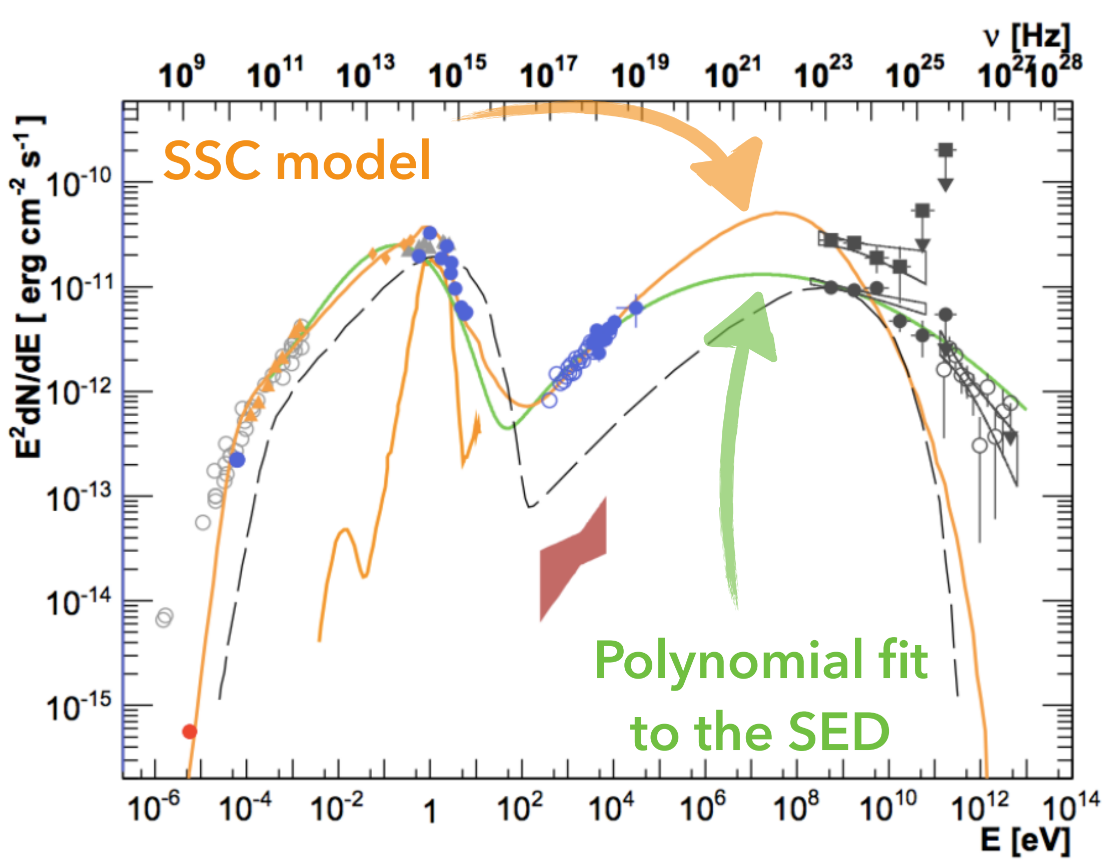
http://tevcat.uchicago.edu/



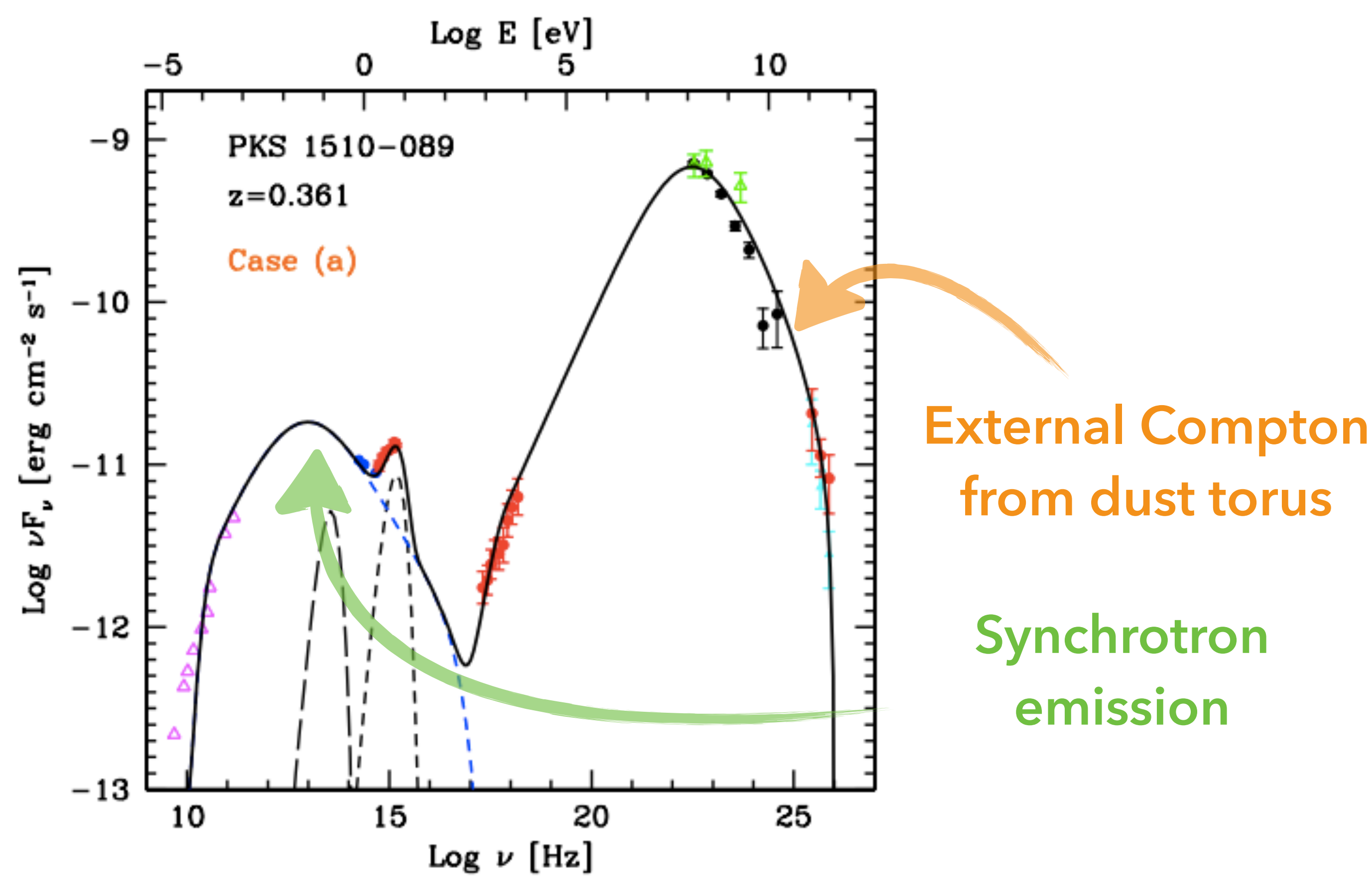
Blazar status

- Blazars = FSRQ + BL Lac (LBL+IBL+HBL)
- Blazars are mainly dominated by HBL
  - Observational bias
  - Sequence?

SED of Ap Librae, from D.A.Sanchez et al. (2015)



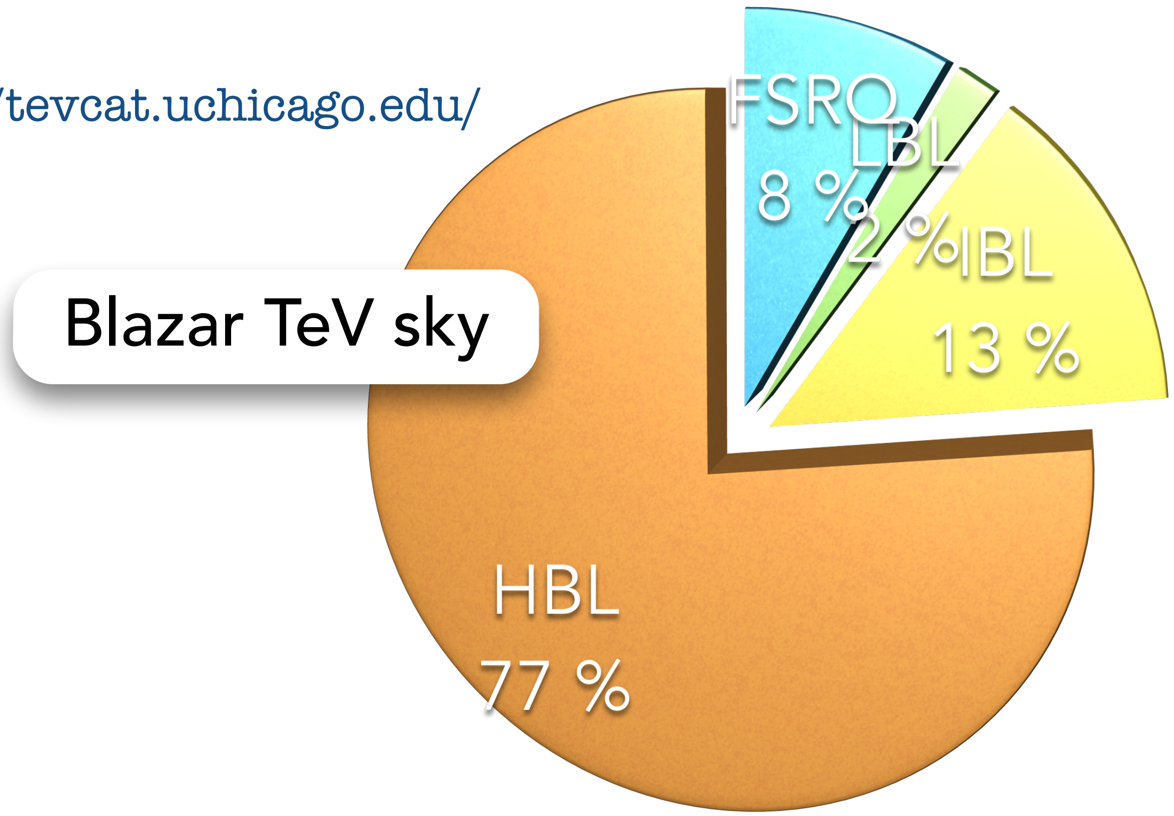
SED of PKS 1510-089, from J.Aleksic et al. (2014)



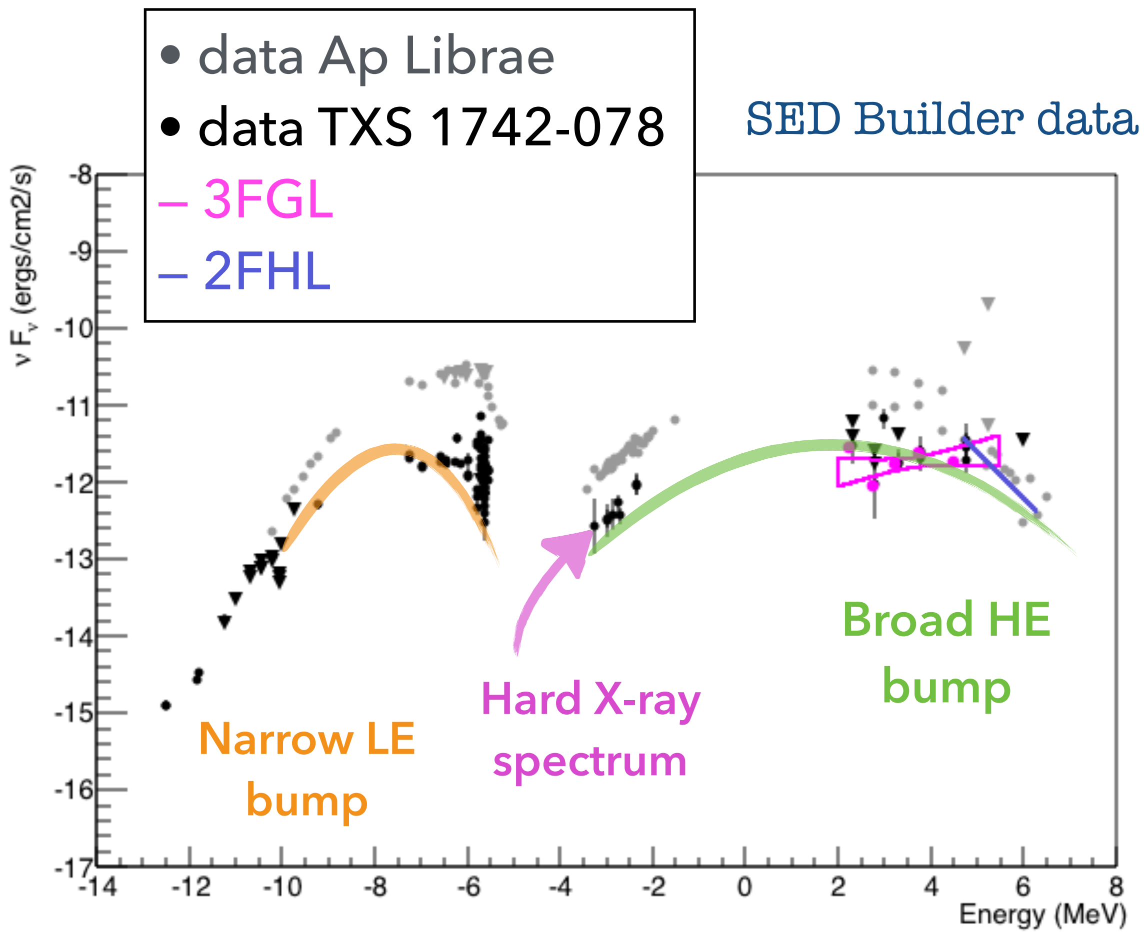
H.E.S.S.

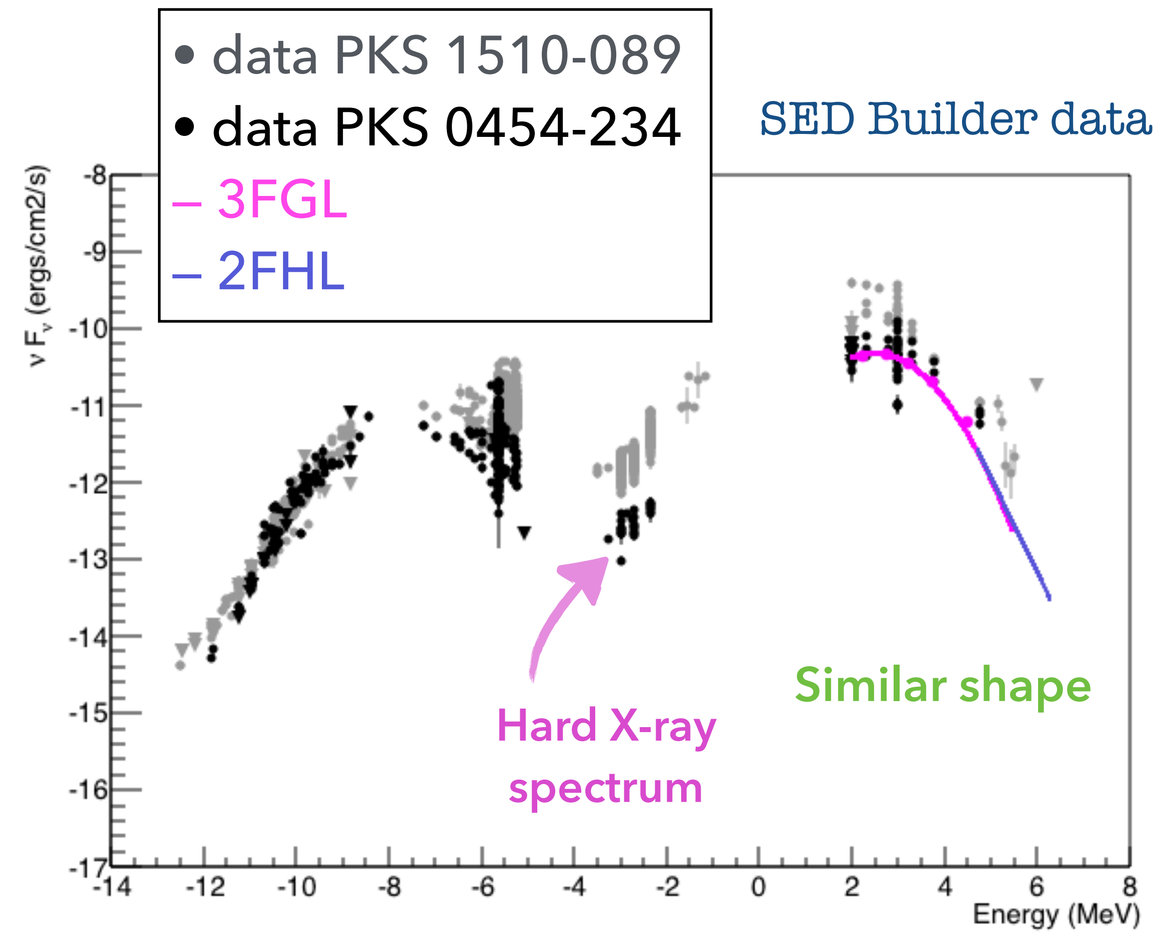
Blazar status – New candidates

http://tevcat.uchicago.edu/



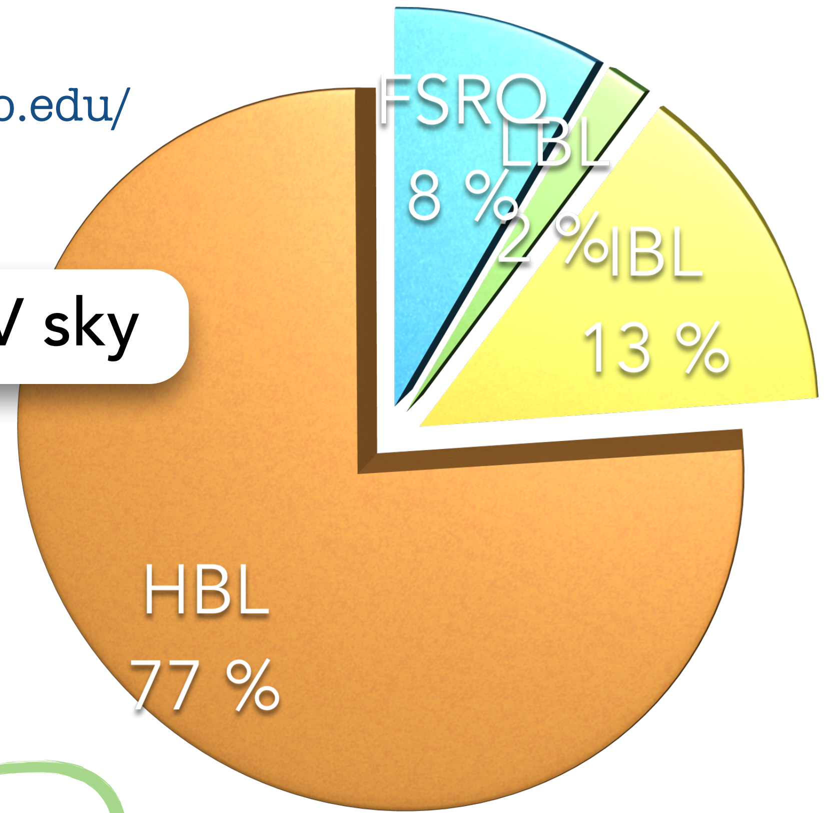
- Blazars = FSRQ + BL Lac (LBL+IBL+HBL)
- Blazars are mainly dominated by HBL
  - Observational bias
  - Sequence?





http://tevcat.uchicago.edu/

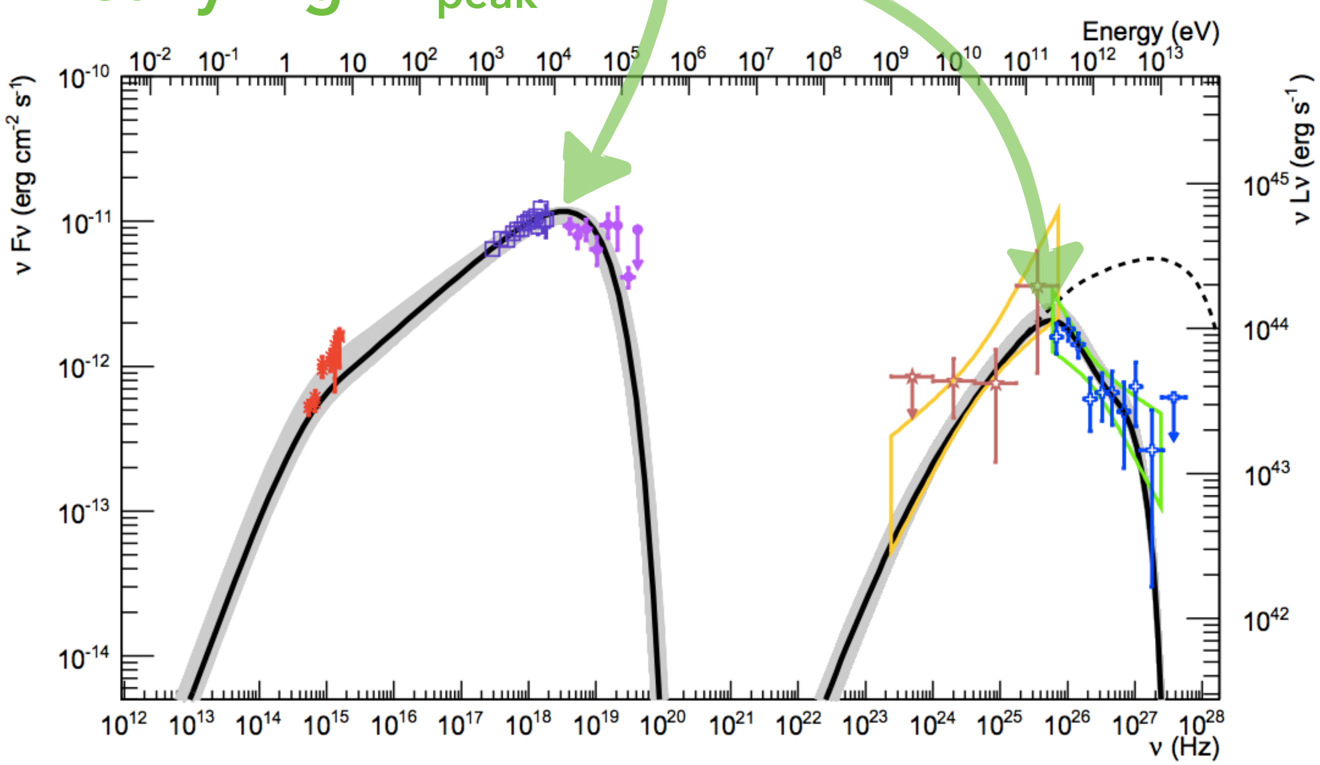
Blazar TeV sky



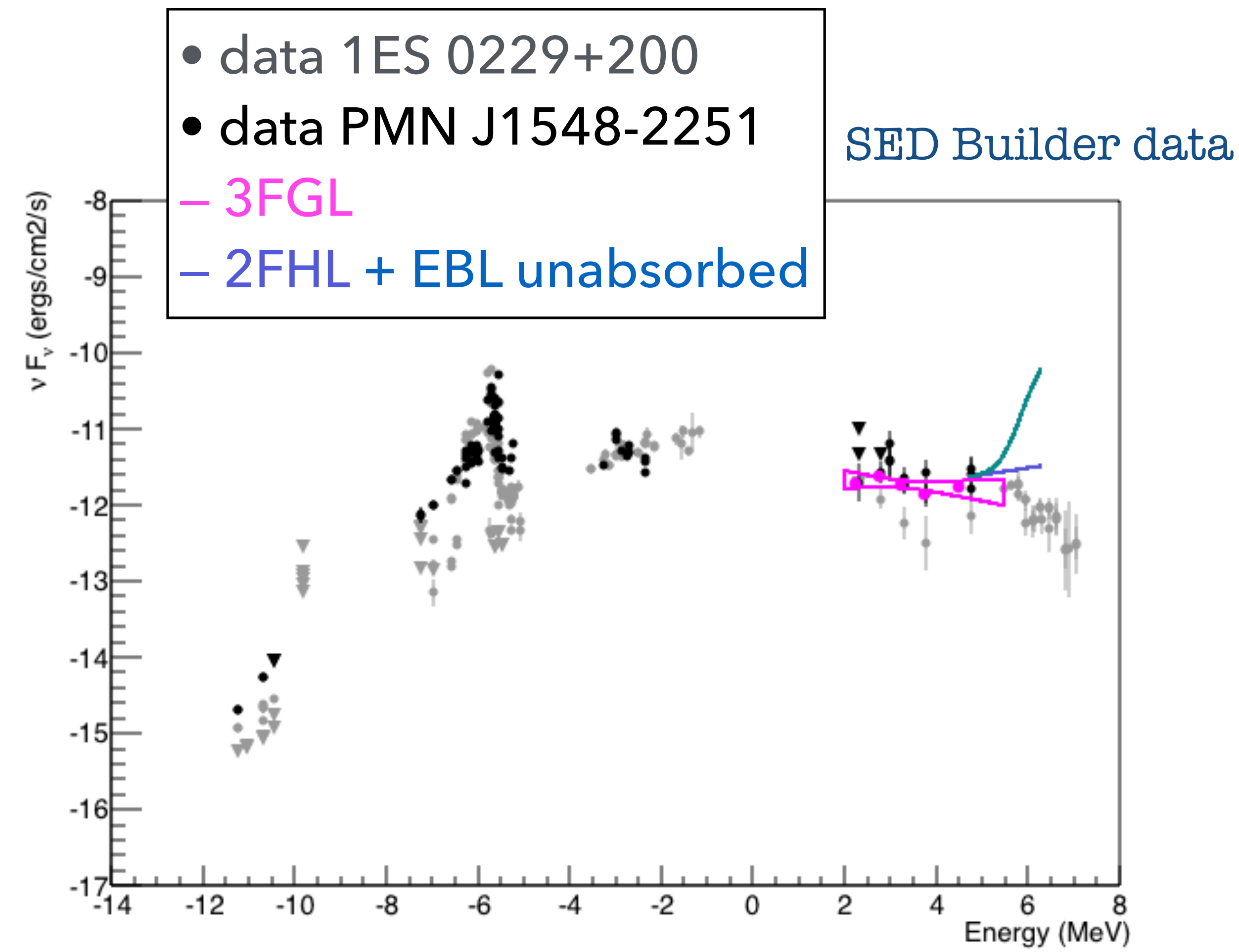
Blazar status – X-HBLs

- Blazars = FSRQ + BL Lac (LBL+IBL+HBL)
- Blazars are mainly dominated by HBL
  - Observational bias
  - Sequence?

Really high ν_{peak}

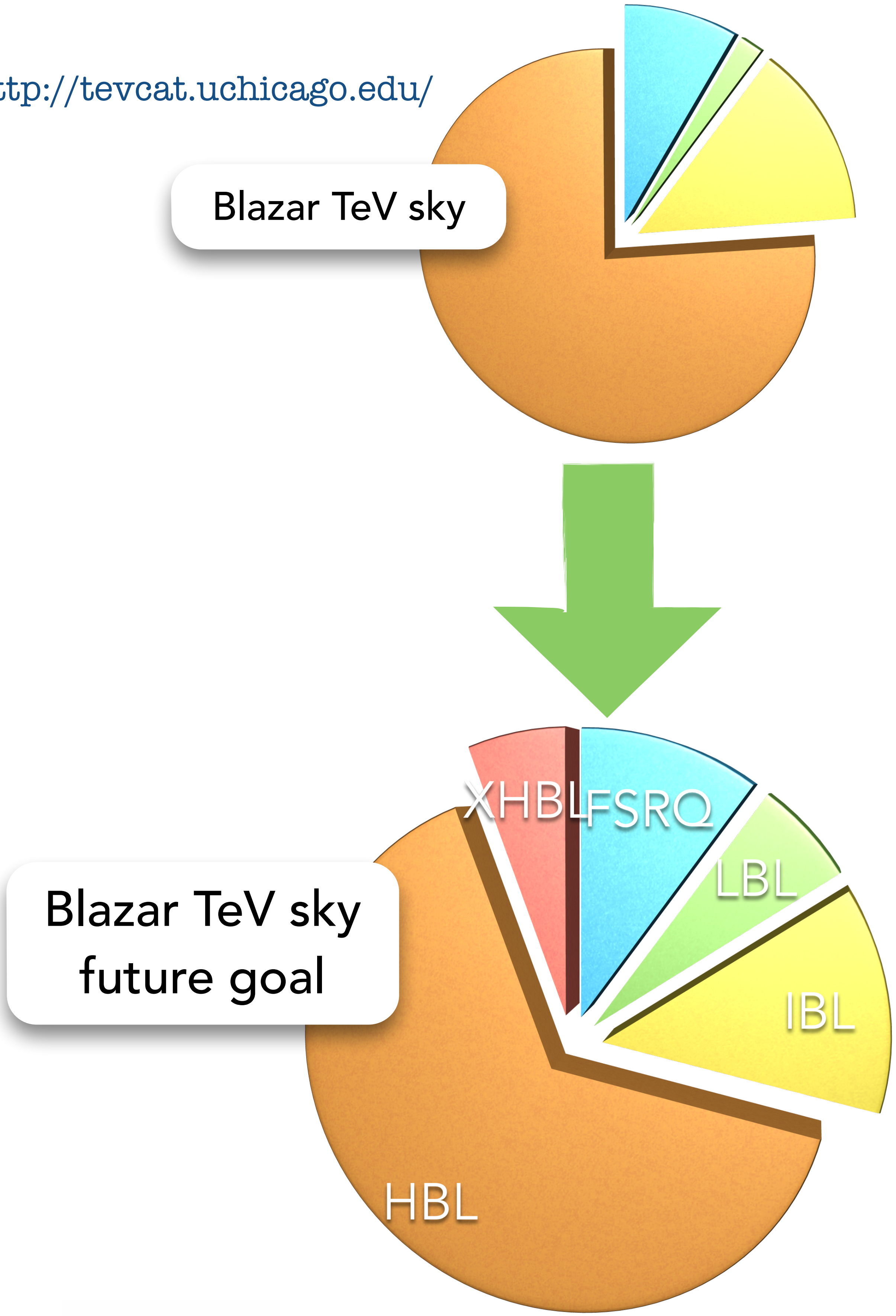


SED of 1ES 0229+200, from E.Aliu et al. (2013)



SED Builder data

http://tevcat.uchicago.edu/



Future observation strategy

- Blazars = FSRQ + BL Lac (LBL+IBL+HBL)
- Blazars are mainly dominated by HBL
  - Observational bias
  - Sequence?
- HBLs (PKS 2155-304, Mrk 501…) are generally well described by one zone, time-independent SSC model
  - Not the case for LBLs and FSRQs
- Need new observations of other objets to understand better the blazar physics.
- More:
  - FSRQs, LBLs & X-HBLs

More fun, more physics ahead!

Stay tuned . . .