Search for TeV emission from unbiased survey of high-frequency-peaked BL Lacs

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Overview

- Survey of high-frequency-peaked BL Lacs (HBLs) observed by VERITAS

- Looking for unbiased estimates of TeV flux of HBLs (usually only reported in flaring states), and new detections of TeV blazars

- Ultimate goal – HBL luminosity function

Blazars

- Blazars – AGNs with relativistic jets oriented towards the observer
  - BL Lacs & FSRQs

- Double-peaked spectra:
  - Lower-energy peak: Synchrotron
  - Higher-energy peak: Inverse Compton

- BL Lac classification by lower-energy peak
  - HBL synchrotron peak > 10^{15} Hz (UV or X-ray)

Mrk 421

Matthews et al 2020

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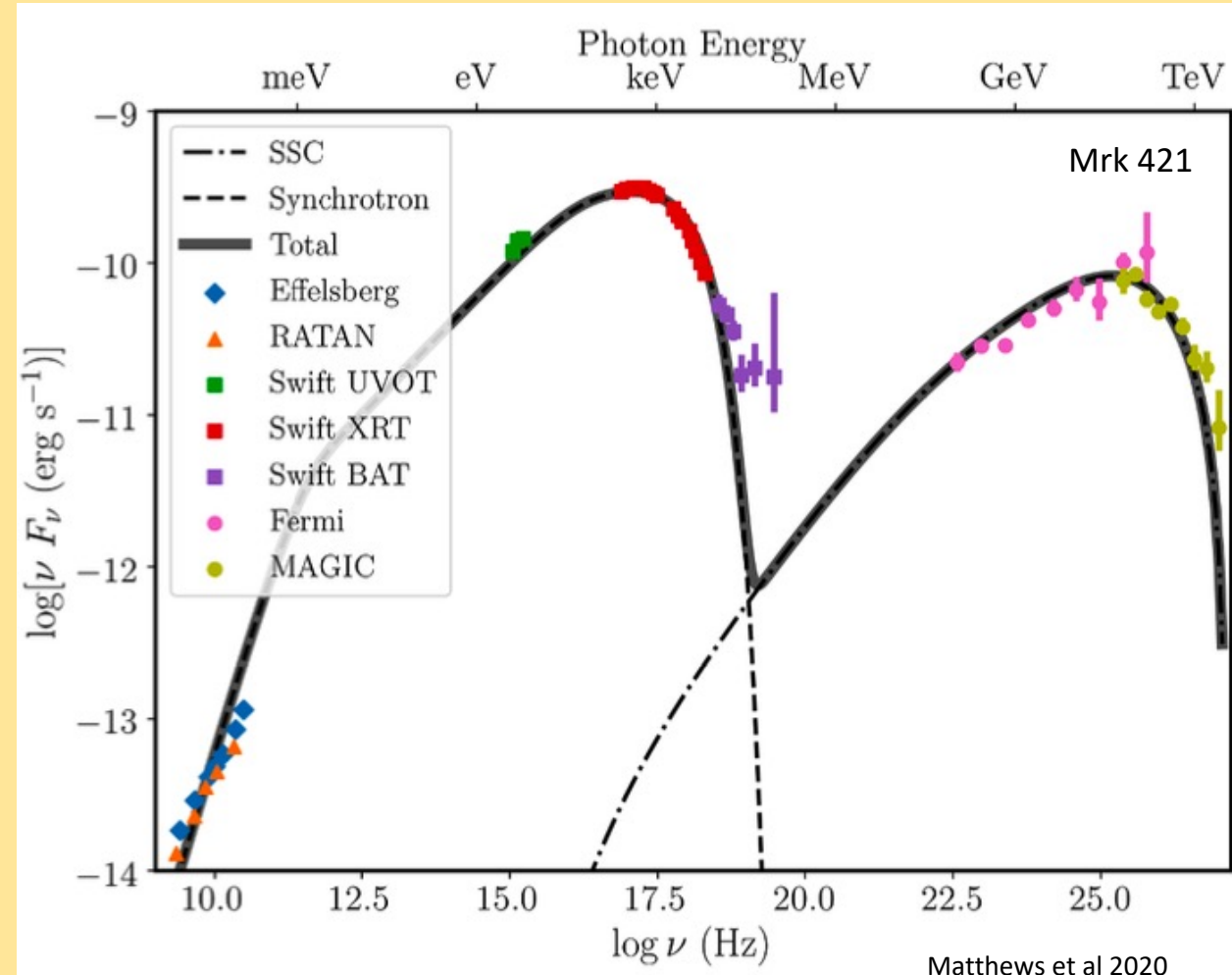
# VERITAS (Very Energetic Radiation Imaging Telescope Array System)

- Began operation in 2007

- Ground-based GeV-TeV gamma-ray observatory in Arizona

- Image Atmospheric Cherenkov Telescope (IACT), four 12-meter optical telescopes

- Most sensitive 100 GeV – 10 TeV

VERITAS

VERITAS HBL Sample

- X-ray selected blazars, synchrotron peak > 10^{15} Hz

- Estimated synchrotron peak luminosity > 6.3×10^{-12} erg cm^{-2} s^{-1}

- Total of 36 sources (21 previously detected at TeV energies)
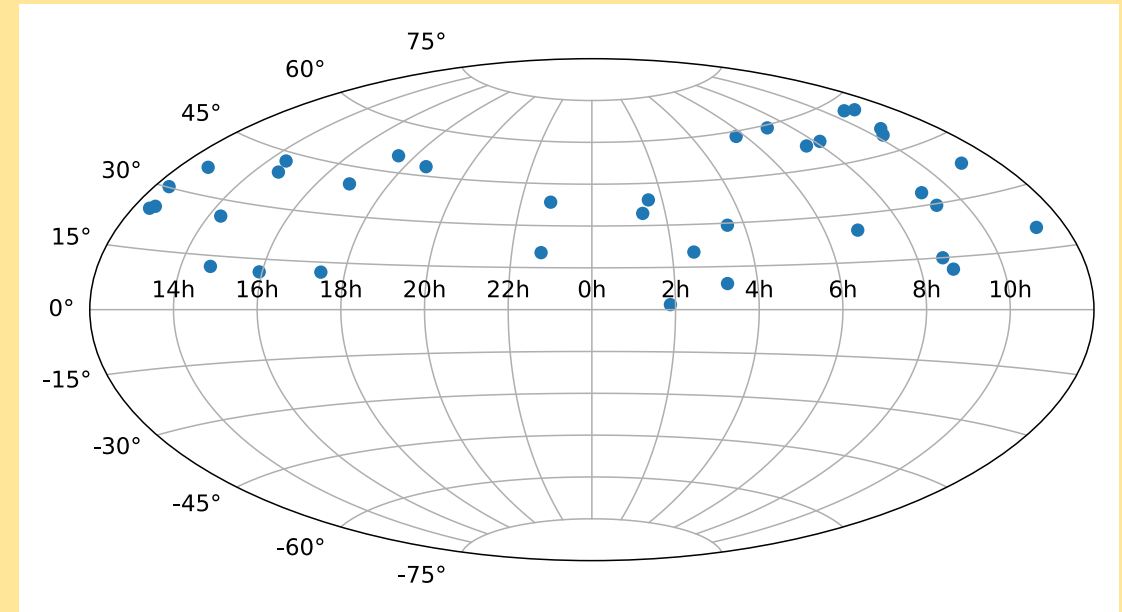
The VERITAS HBL sample, in celestial coordinates.

Strategy

- Our goal is to remove observational bias

  - HBLs generally observed in flaring states

  - Exclude observations triggered by reported high flux states in TeV or other wavelengths

- Combine archival data with new dedicated observations taken in the last three years

Analysis Status

- Completed full analysis of 23 of the 36 sources in the HBL sample
  - All 15 previously non-detected in TeV (3 > 3σ)
  - 8 known TeV sources (4 > 3σ)
  - All exposures >7h after quality selection

|	Sources	TeVCat name	z	TeVCat	Exposure (h)	Significance
0-2 h RA	1ES 0120+340		0.270	n	17.7	1.2
	B3 0133+388	RGB J0136+391		y		
	RGB J0152+017		0.080	y		
2-4 h RA	1ES 0229+200		0.139	y		
	RGB J0316+090			n	10.5	1.1
	1FGLJ0333.7+2919			n	10.5	0.1
4-6 h RA	GB6 J0540+5823			n	13.9	1.1
6-8 h RA	1ES 0647+250		0.203	y	38.5	9.7
	RGB J0710+591		0.120	y		
	NVSS J073326+515355	PGC 2402248	0.065	y	11.0	0.7
8-10 h RA	1ES 0806+524		0.137	y	42.9	10.8
	87GB 083437.4+150850		0.278	n	7.3	2.1
	RGBJ0847+115		0.198	y		
	RXJ0910.6+3329		0.350	n	7.8	0.1
	B2 0912+29		0.190	n	32.4	3.5
10-12 h RA	1ES 1011+496		0.200	y		
	1ES 1028+511		0.360	n	27.7	3.2
	RGB J1037+571		0.330	n	20.2	0.3
	RGB J1058+564		0.143	n	20.6	0.1
	Mkn 421		0.030	y		
	RXJ1117.1+2014		0.138	n	14.4	1.0
12-14 h RA	1ES 1218+304		0.180	y		
	MS 1221.8+2452		0.218	y	13.1	4.8
	S3 1227+25		0.135	y	15.9	2.1
	RGB J1243+364		0.310	n	46.4	2.6
14-16 h RA	RBS 1366		0.240	n	61.3	4.6
	H 1426+428		0.129	y		
	PG1437+398 (RGB J1439+395)		0.344	n	13.8	0.0
	1ES 1440+122		0.160	y		
	PG 1553+113		0.443	y		
16-18 h RA	Mkn 501		0.030	y		
	RGB J1725+118	H 1722+119	0.180	y	24.6	4.4
	1ES 1727+502		0.055	y		
18-20 h RA	RGB J1838+480		0.300	n	9.8	1.4
22-24 h RA	RGB J2243+203			y	17.2	0.8
	B3 J2247+381		0.119	y	29.5	2.6

RBS 1366 (RGB J1417+257)

- z=0.237

- 61.3h exposure

  - 4.7h bias removed (7% of total exposure)

- Detection significance 4.61σ

- Flux UL > 0.2 TeV: 7.22E-12 cm^{-2}s^{-1}
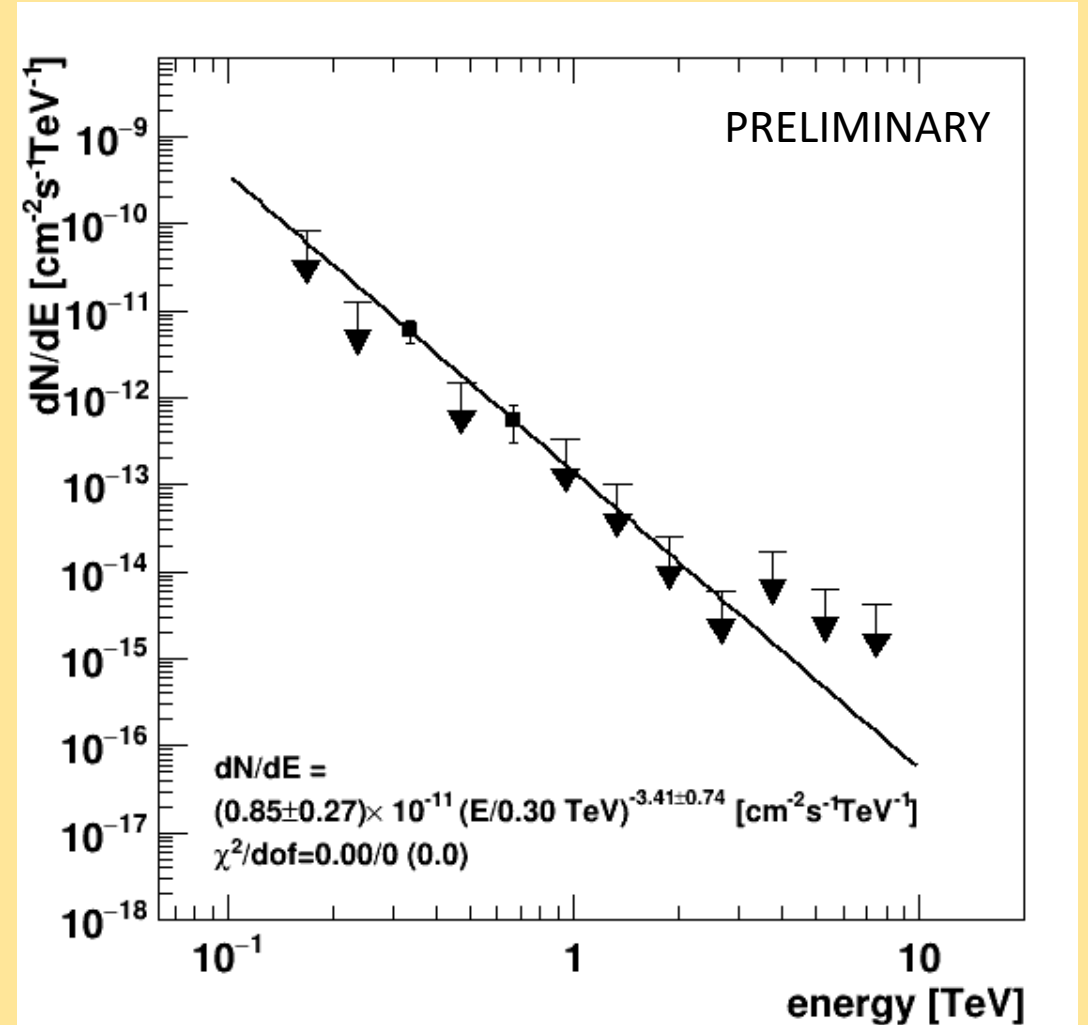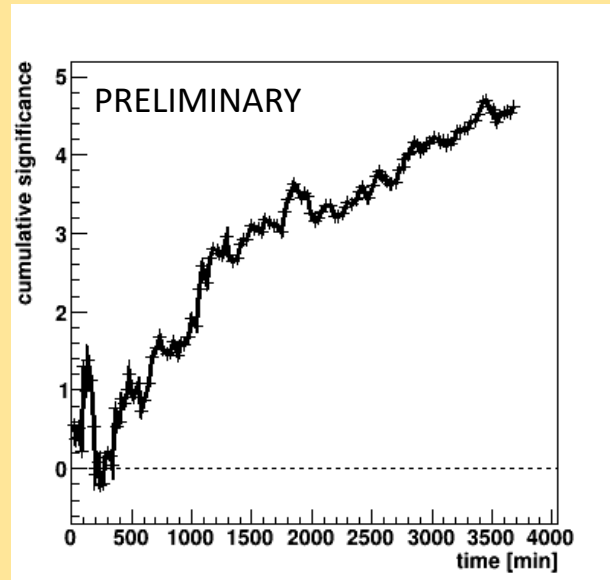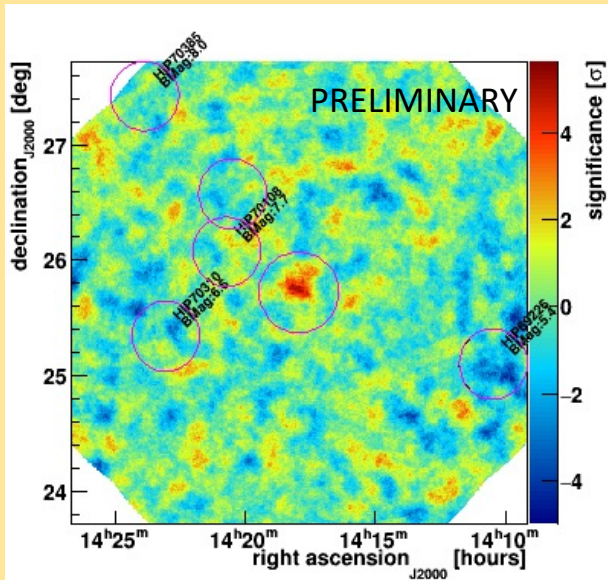
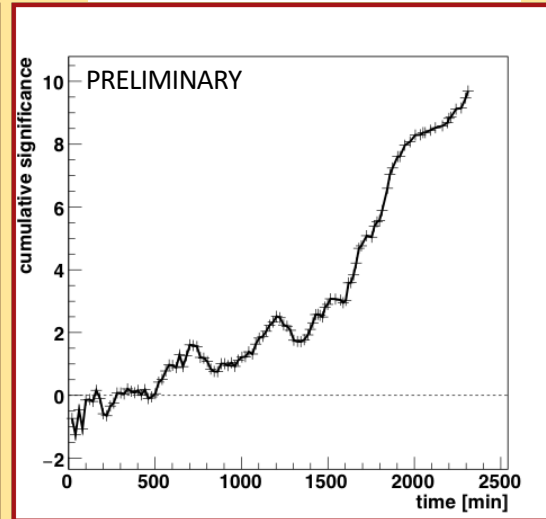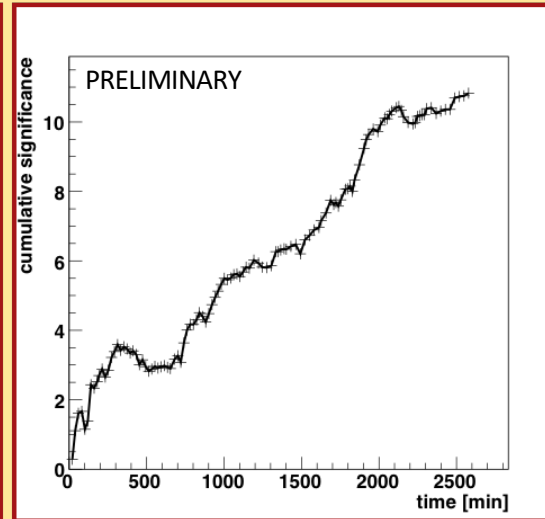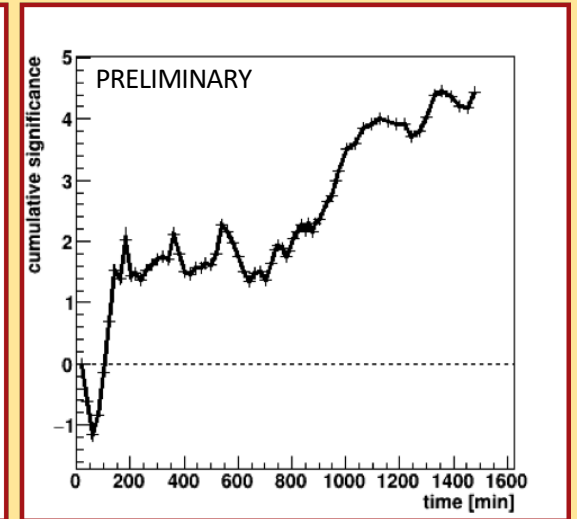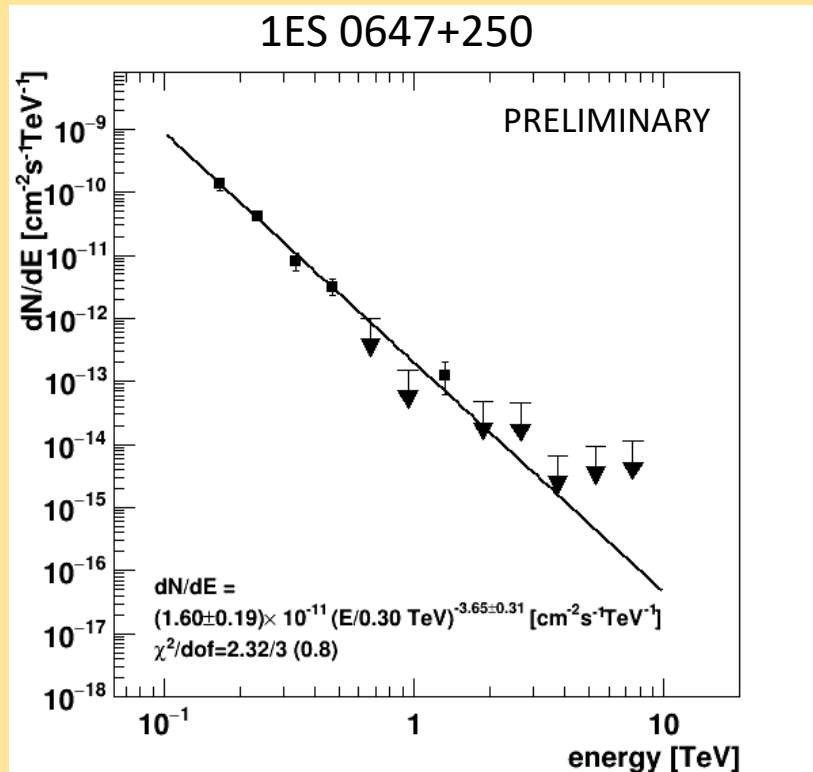# Known TeV source results
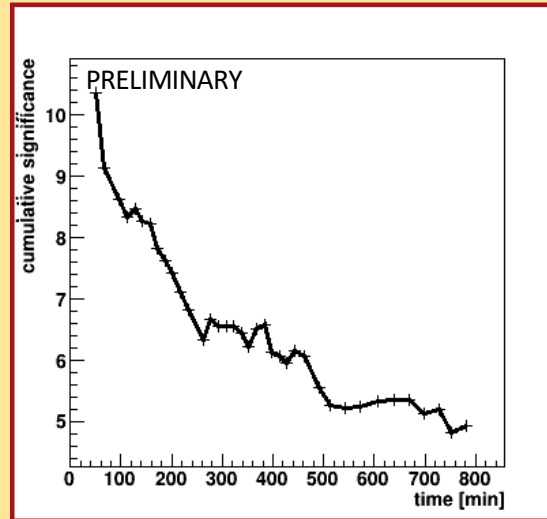
MS 1221.8+2452   1ES 0647+25   1ES 0806+524   RGB J1725+118

	Exposure (h)	Removed bias data (% of total exposure)	Significance	Flux >0.2 TeV (10^{-12} cm^{-2}s^{-1})
1ES 0647+250	38.5	27%	9.7σ	4.8 ± 0.7
1ES 0806+534	42.97	44%	10.8σ	7.2 ± 0.8
RGB J1725+118	24.6	6%	4.4σ	< 4.96
MS 1221.8+2452	13.1	28%	4.8σ	3.34 ± 0.8

Spectra for known TeV sources

1ES 0647+250

PRELIMINARY

$dN/dE = (1.60\pm0.19)\times 10^{-11} (E/0.30\ \text{TeV})^{-3.65\pm0.31}\ [\text{cm}^{-2}\text{s}^{-1}\text{TeV}^{-1}]$
$\chi^2/\text{dof}=2.32/3\ (0.8)$

Flux: $4.8 \pm 0.7 \times 10^{-12}\ \text{cm}^{-2}\text{s}^{-1}$

Index: -3.65 ± 0.31

1ES 0806+524

PRELIMINARY

$dN/dE = (2.21\pm0.28)\times 10^{-11} (E/0.30\ \text{TeV})^{-3.27\pm0.24}\ [\text{cm}^{-2}\text{s}^{-1}\text{TeV}^{-1}]$
$\chi^2/\text{dof}=0.78/3\ (0.3)$
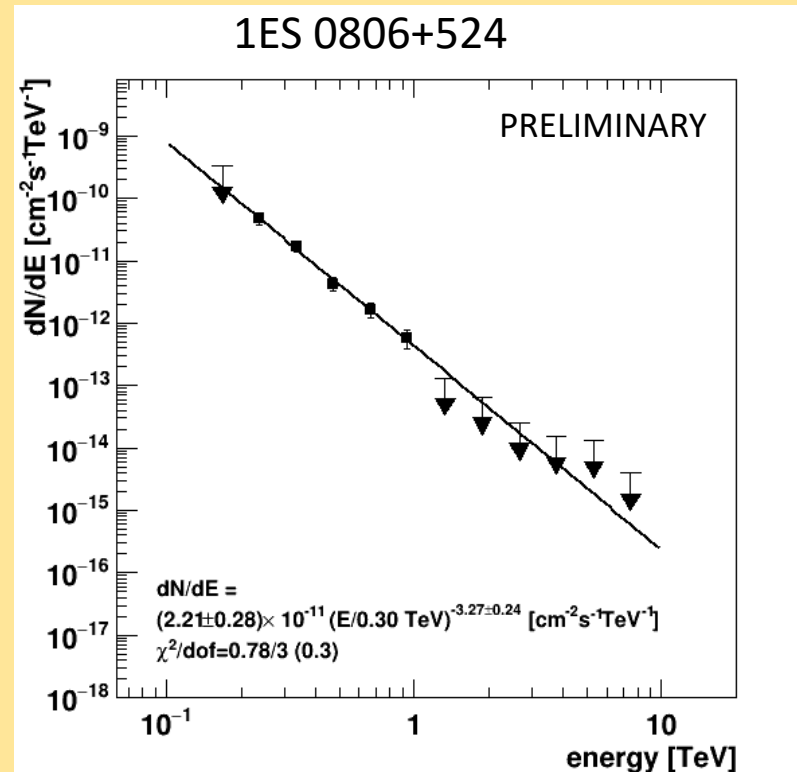
Flux: $7.2 \pm 0.8 \times 10^{-12}\ \text{cm}^{-2}\text{s}^{-1}$

Index: -3.27 ± 0.24

MS 1221.8+2452

PRELIMINARY

$dN/dE = (1.38\pm0.26)\times 10^{-11} (E/0.30\ \text{TeV})^{-3.05\pm0.41}\ [\text{cm}^{-2}\text{s}^{-1}\text{TeV}^{-1}]$
$\chi^2/\text{dof}=1.83/3\ (0.6)$
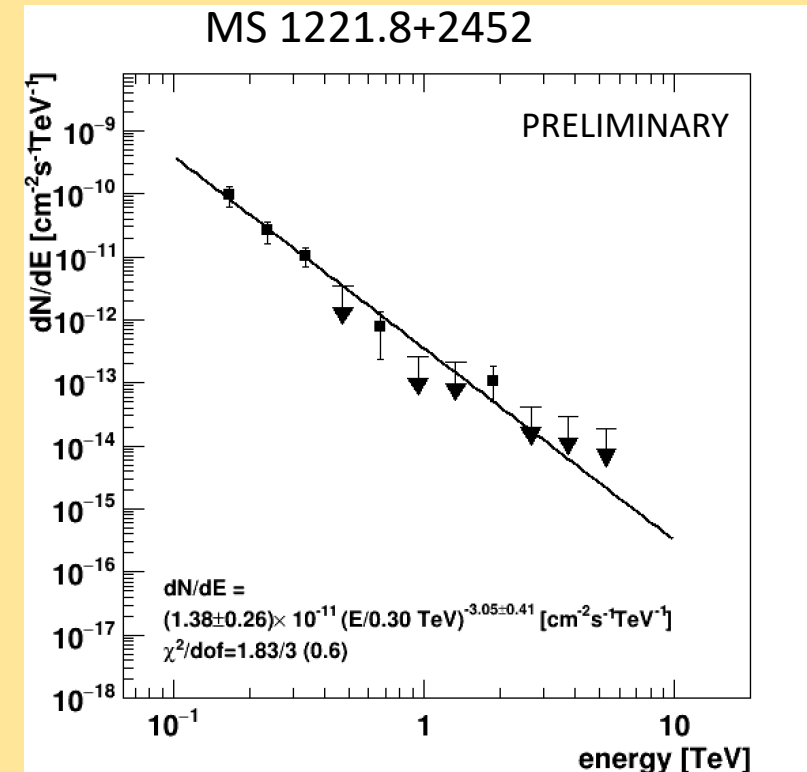
Flux: $3.34 \pm 0.8 \times 10^{-12}\ \text{cm}^{-2}\text{s}^{-1}$

Index: -3.05 ± 0.41

Summary and outlook

- Analysis is underway (~2/3 sources completed)

  - One >4 sigma observation from new TeV blazar

  - Revised unbiased flux estimates for many others

- Will find fluxes or flux upper limits and spectral information when possible for each source

- Survey results will lead to first measurement of luminosity function of TeV blazars