On the Detection Potential of Short Blazar Flares for Current Neutrino Telescopes

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on behalf of the Fermi-LAT presentation

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Fermi Gamma-ray Space Telescope

Blazars as promising neutrino sources

Neutrino output of blazars estimated based on

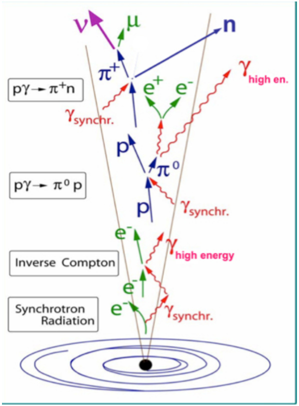
- Mannheim 1993, A&A 269, 67–76
- Mannheim 1995, Astroparticle Physics, 3, 295

$$p + nucleus \rightarrow \pi + X \quad (\pi = \pi^{\pm}, \pi^{0})$$

$$p + \gamma \rightarrow \Delta^{+} \rightarrow \begin{cases} \pi^{0} + p \\ \pi^{+} + n. \end{cases}$$

Resulting pions decay:

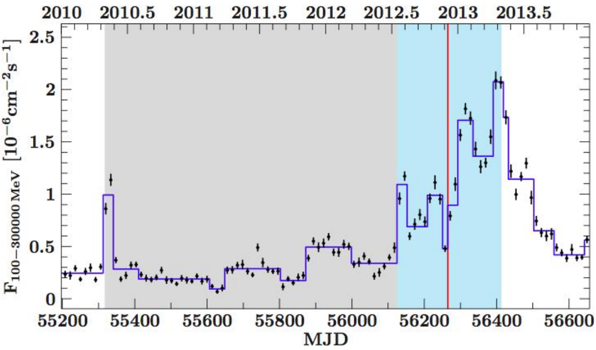
$$\pi^{0} \rightarrow \gamma + \gamma$$
$$\pi^{\pm} \rightarrow \mu^{\pm} + \nu_{\mu} \text{ (or } \bar{\nu_{\mu}}\text{)}$$
$$\mu^{+} \rightarrow e^{+} + \bar{\nu_{\mu}} + \nu_{e}$$
$$\mu^{-} \rightarrow e^{-} + \nu_{\mu} + \bar{\nu_{e}}$$



Credit: Katz & Spiering 2012

Coincidence of a high-fluence blazar outburst with a PeV neutrino event

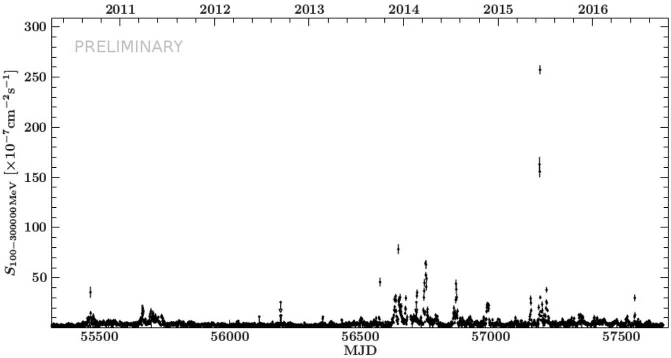
Kadler et al. 2016, Nat Phys 12, 807



⇒ Calorimetric Output in BigBird field dominated by PKS B1424-418

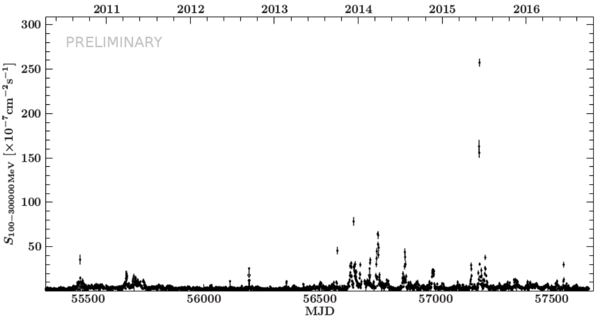
⇒ But: Chance Coincidence ≈ 5%

Test neutrino detection potential for short blazar flares



Choose sources that:

- are highly variable
- show extreme bright short flares

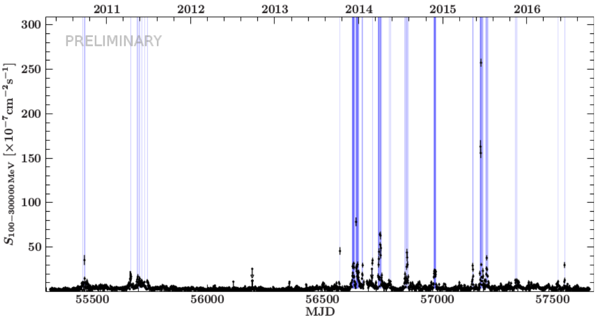


Choose flares that fulfill:

$$\sigma_{\text{indi}} = (\text{Flux} - 3 \times \text{Flux err}) \times \text{A}_{\text{eff}} - \text{G}$$

$$\sigma_{\text{indi}} \geq 3 \times \sigma$$

- G: Flux Ground Level
- σ_{indi}: individual flux variation of each bin
- σ: Intrinsic source variation
- A_{eff}: Effective area



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Which flares to select?

- Start from Fermi's public bright-blazar list
- Identify flares according to flare selection method
- Run daily 6 year (Pass 8) light curves on sources responsible for 100 brightest short flares
- Re-run flare selection method on Pass 8 light curves

$\Rightarrow$ Select the best 50 flares according to their fluence
$\Rightarrow$ Calculate a neutrino expectation for all 50 flares

Estimate maximum neutrino output

Pion Photoproduction:

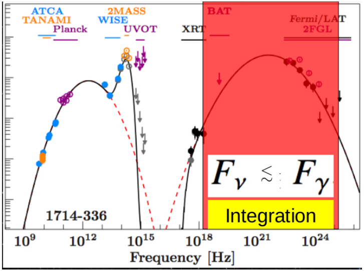
Maximum Neutrino Output:

$$F_\gamma = \frac{1}{3}F_\pi + \frac{1}{4}\cdot\frac{2}{3}F_\pi = \frac{1}{2}F_\pi$$

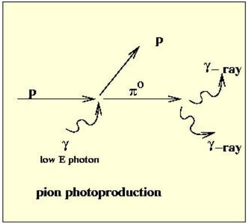
$$F_\nu = \frac{2}{3}\cdot\frac{3}{4}F_\pi = \frac{1}{2}F_\pi$$

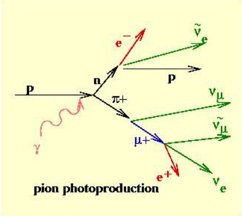
- See Krauss et al. 2014, A&A 566, L7

  Kadler et al. 2016, Nat Phys 12, 807



Credit: Krauss et al. 2014, A&A 566, L7





Credit: Mücke et al. 2000

$$\boxed{\mathbf{N}^{\mathbf{max}}_{\nu,\mathbf{PeV}} = \mathbf{A}_{\mathbf{eff},\mathbf{e}_\nu} \times \left(\frac{\mathbf{F}_\gamma}{\mathbf{E}_\nu}\right) \times \Delta\mathbf{t}}$$

Estimate maximum neutrino output

Scaling Factor:

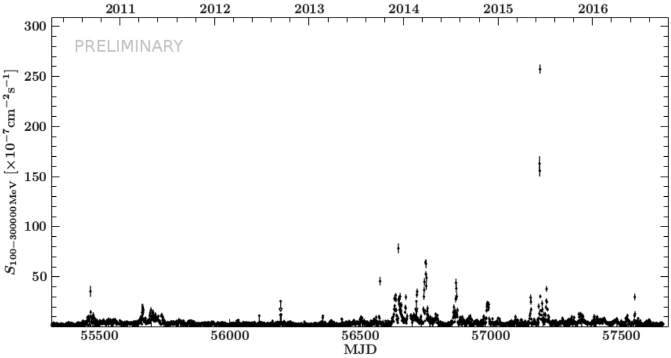
$$N_{\nu,\mathrm{PeV}}^{\mathrm{pred}} = \mathfrak{f} \times N_{\nu,\mathrm{PeV}}^{\mathrm{max}}$$
$$\mathfrak{f} = 0.5 \times 0.05 \approx 0.025 \tag{1}$$

Things to consider:

- Different neutrino flavors
- UV seed photons needed (FSRQs)
- PeV peaks might be smeared out to $\approx (0.03 - 10)$ PeV

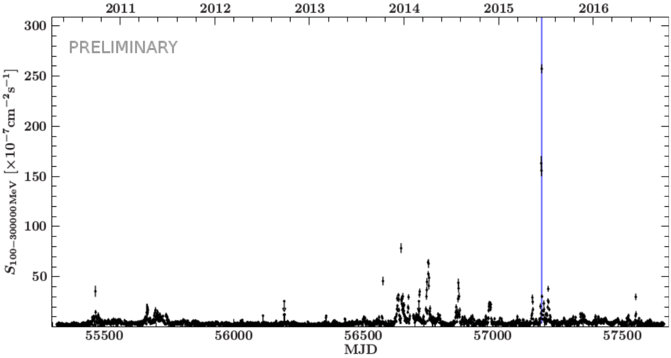
$\Rightarrow$ See Kadler et al. 2016 for details

3C279



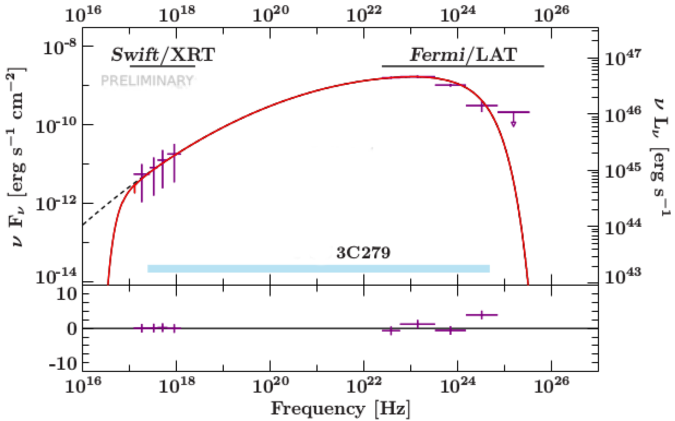
- Halzen & Kheirandish 2016, ApJ. 831,12
- Suggestion of promising neutrino candidate

3C279



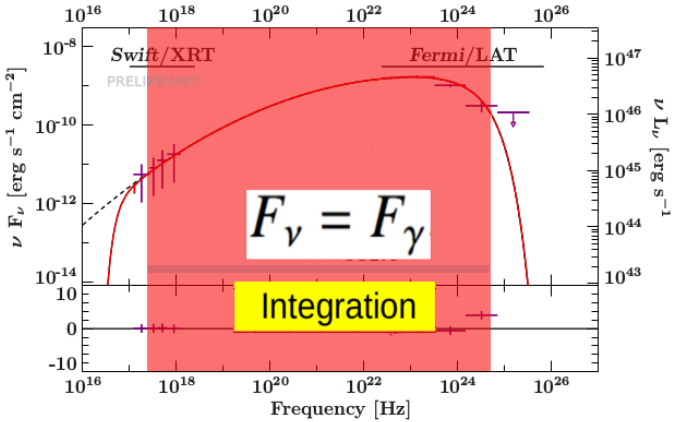
- Halzen & Kheirandish 2016, ApJ. 831,12
- Suggestion of promising neutrino candidate
- Identify flare duration of 6 days

3C279



- Time resolved SED of 2015 flare
- Simultaneous Swift/XRT and Fermi/LAT observations

3C279



- $N^{pred}_{\nu,PeV} \approx 0.02$
- $\approx$ 5 months of non flaring activity

Flare sample

Table 1. Neutrino expectation for the 50 best ranked flares, sorted by the normalized fluence.

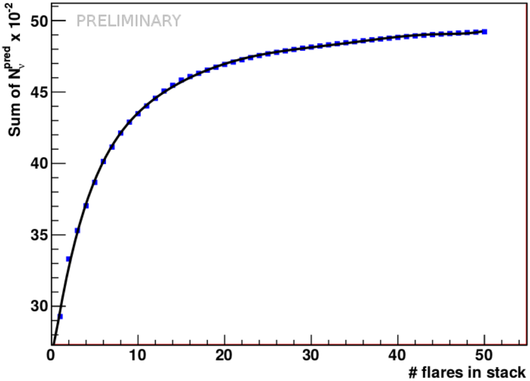
Source	Flare Number	Normalized Fluence	t_{min} in MJD	t_{max} in MJD	N_ν^{max}	N_ν^{pred} $\times10^{-2}$	Duration in Days	Normalized N_ν^{pred} $\times10^{-3}$
3C 279	1	260238	57186	57192	0.797	1.99	6	3.32
PKS 1510-089	2	192902	55849	55854	0.306	0.764	5	1.53
PKS 1510-089	3	151569	55866	55877	0.586	1.46	11	1.33
PKS 1510-089	4	151262	55856	55857	0.0405	0.101	1	1.01
3C 279	5	138636	56717	56718	0.0272	0.0681	1	0.681
3C 279	6	128078	56749	56754	0.214	0.535	5	1.07
PKS 1510-089	7	125857	57241	57251	0.393	0.982	10	0.982
3C 279	8	119379.	56866	56868	0.0993	0.248	2	1.24
PKS 1510-089	9	119033	56553	56557	0.159	0.398	4	0.995
PKS 1510-089	10	116956.	55766	55768	0.0605	0.151	2	0.757
				⋮				
3C 454.3	38	74620	55408	55648	11.71	29.28	240	1.22

- 50 best flares are generated by a group of only seven different sources:

  3C 279, PKS 1510-089, PKS 0402-362, CTA 102, 3C 454.3, PKS 1424-418, PKS 1329-049

- 3C 279 and PKS 1510-089 responsible for 42 flares

Flare sample



- Detection probability shows saturating tendency

  ⇒ Extending the sample size does not substantially increase the detection probability

  ⇒ Highest fluence flares provide by far the largest contribution

TXS 0506+056

Fermi-LAT detection of increased gamma-ray activity of TXS 0506+056, located inside the IceCube-170922A error region.

ATel #10791; ***Yasuyuki T. Tanaka (Hiroshima University), Sara Buson (NASA/GSFC), Daniel Kocevski (NASA/MSFC) on behalf of the Fermi-LAT collaboration***
on ***28 Sep 2017; 10:10 UT***
Credential Certification: David J. Thompson (David.J.Thompson@nasa.gov)

Subjects: Gamma Ray, Neutrinos, AGN

Referred to by ATel #: 10792, 10794, 10799, 10801, 10817, 10830, 10831

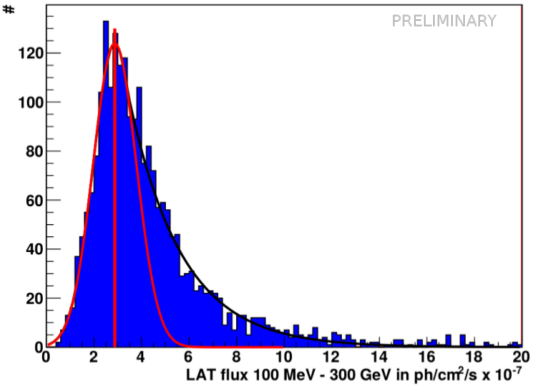
- First track like IceCube EHE event consistent with a LAT source

Summary

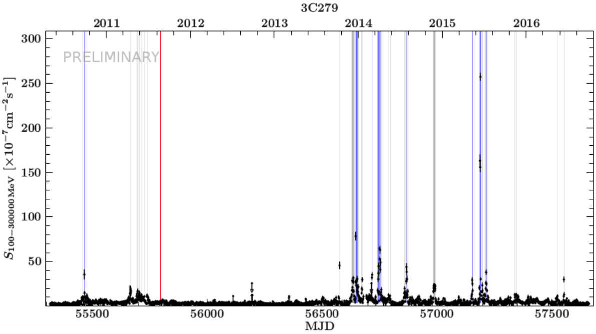
- Short blazar flares yield only a small neutrino detection probability
- No substantial improvement by adding more (fainter) flares
- Top-ranked flares produced by only a handful of individual blazars

Backup

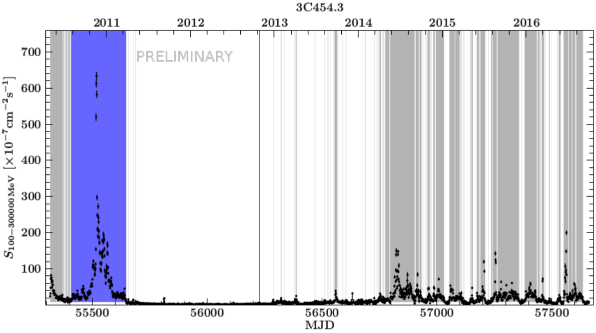
Light curve ground level calculation



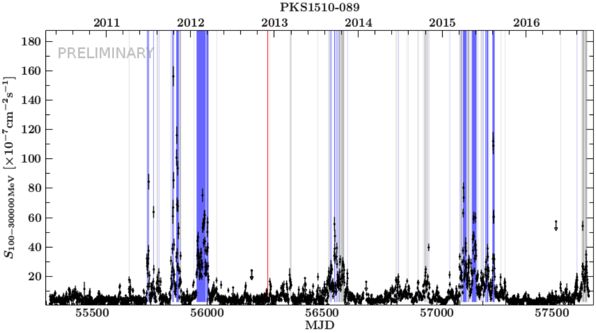
Light curve of 3C 279



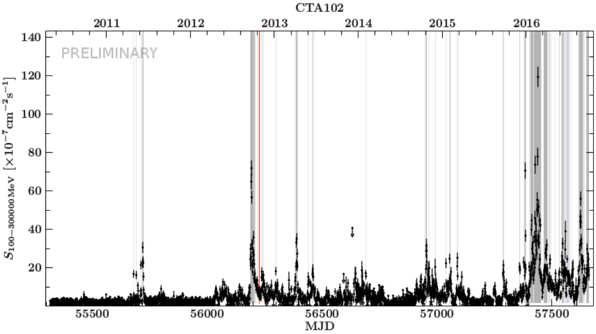
Light curve of 3C 454.3



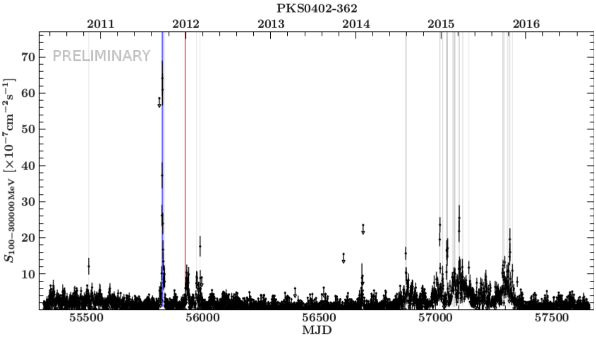
Light curve of PKS 1510-089



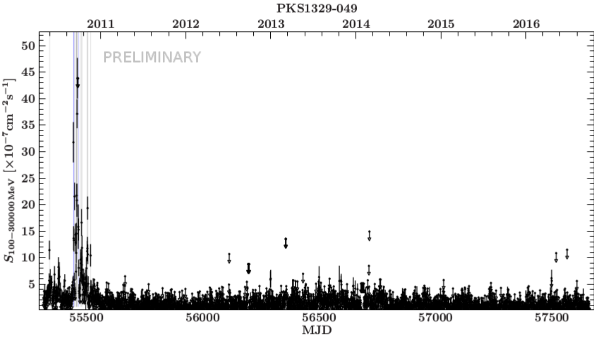
Light curve of CTA 102



Light curve of PKS 0402-362



Light curve of PKS 1329-049



Light curve of PKS 1424-41