Some Possible sources of IceCube TeV-PeV neutrino events

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Neutrino Underground and in the Heavens II

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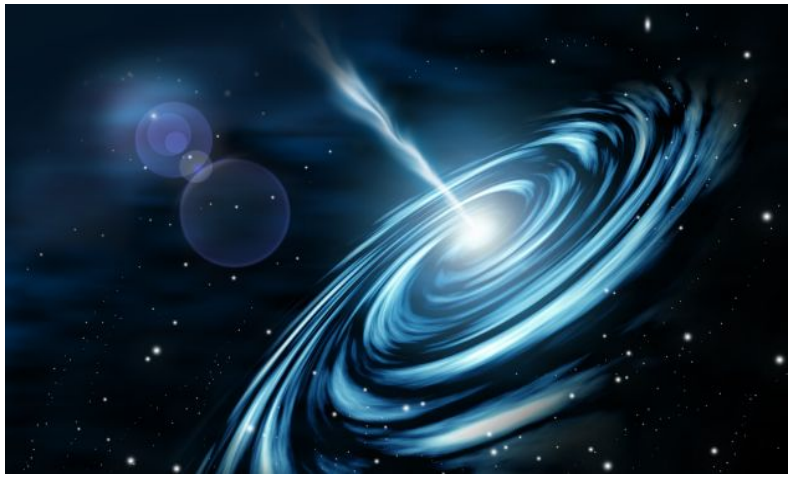
Abstract

We show that 12 high energy blazars and the position of FR-I galaxy Centaurus A coincide within the error circle of ten IceCube events. We propose that photohadronic interactions of the the Fermi accelerated high energy protons with the synchrotron/SSC background photons in the nuclear region of these high energy blazars are probably responsible for some of the observed IceCube events.



Introduction

- In November 2012 the IceCube Collaboration announced the detection of two shower like events slightly above 1 PeV taken during May 2010-May 2012 [M. G. Aartsen et al, Phys. Rev. Lett. 111, 021103 (2013)]

- A follow-up analysis published in November 2013 revealed additional 26 events in the energy range $\sim$30 to 250 TeV, in total 21 are shower like and 7 muon track events [M. G. Aartsen et al. Science 342, no. 6161, 1242856 (2013)]

- The third year (2012-2013) revealed additionally nine events, of which two are track events and the rest are shower events. The 35 is the most energetic one so far observed (2004^{+236}_{-262} TeV) [M. G. Aartsen et al. Phys. Rev. Lett. 113, 101101 (2014)].

- These events have flavors, directions and energies inconsistent with those expected from the atmospheric muon and neutrino background.

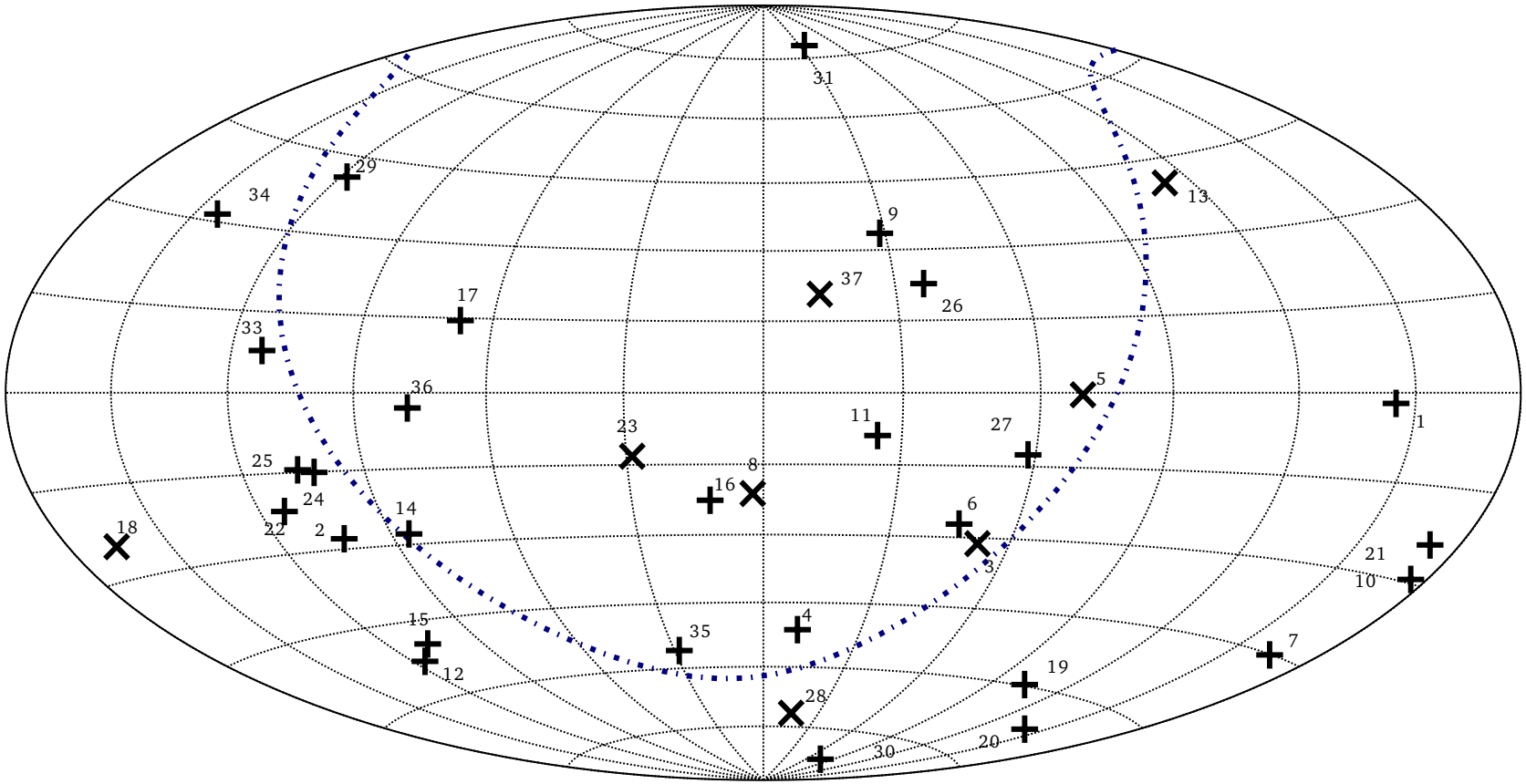


Figure 1: 37 IceCube events in EC

Photohadronic Model

- One group of AGN include HBL and FRI-galaxies viewed at different angles respect to the jet axis.[J. K. Becker, Phys. Rept. 458, 173 (2008)]

- The AGNs are efficient accelerators of particles through shock or diffusive Fermi acceleration processes and the photohadronic processes are proposed to explain multi-TeV emissions.

- Protons can reach ultra high energy and produce pion production via:

$$p\gamma \longrightarrow \triangle^{+} \longrightarrow \begin{cases} p\pi^{0} & \text{fracción } 2/3 \\ n\pi^{+} & \text{fracción } 1/3 \end{cases} \tag{1}$$

- **Spectral Energy Distribution**

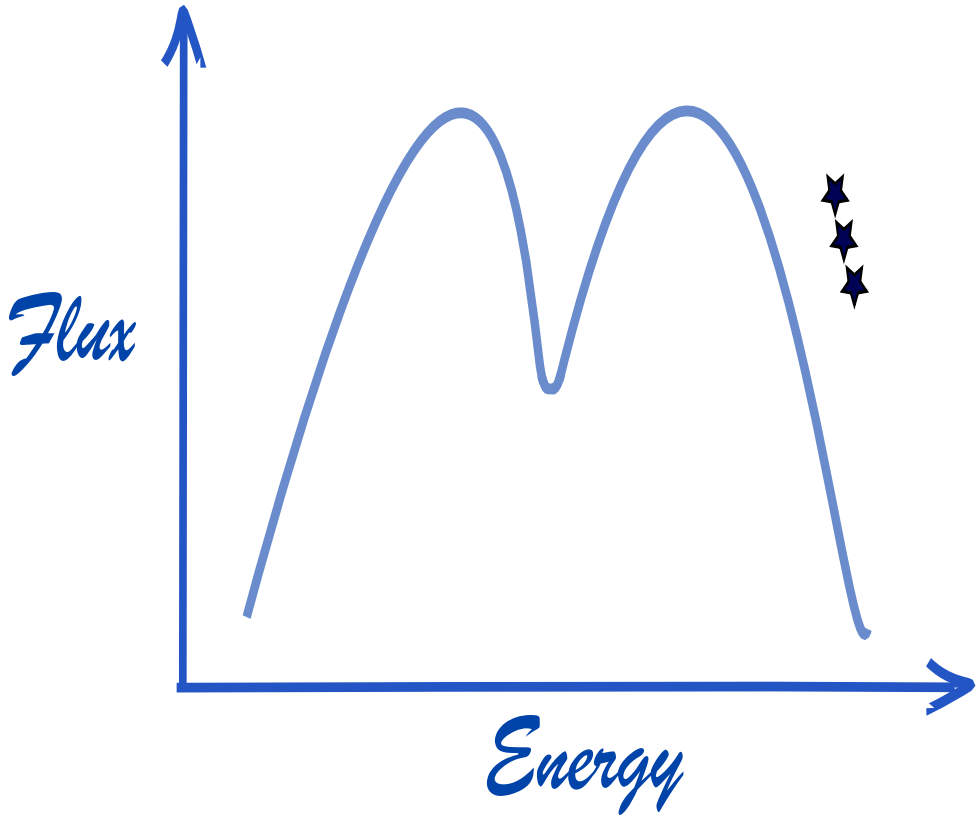


Figure 2: SED

- We propose that the multi-TeV flaring in a blazar occurs within a compact inner region ($R_f^{'} < R_b^{'}$) that overcomes the problem of photon density low, taking $\tau_{p\gamma} \sim 1$

- The observed seed photon and proton energies are correlated via the kinematical condition by the equation:

$$E_p \epsilon_\gamma = 0.32 \frac{\Gamma \delta}{(1+z)^2} GeV^2 \tag{2}$$

- The individual neutrino is $E_\nu = E_p/20$. This gives:

$$E_\nu \epsilon_\gamma = 0.016 \frac{\Gamma \delta}{(1+z)^2} GeV^2 \tag{3}$$

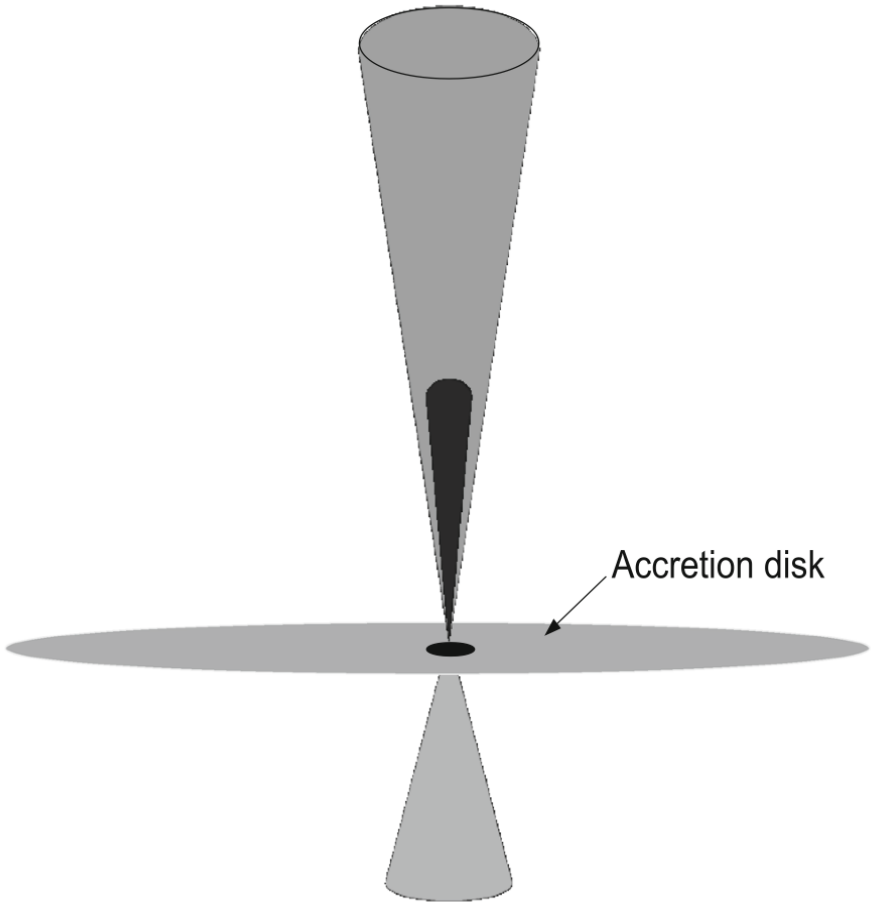
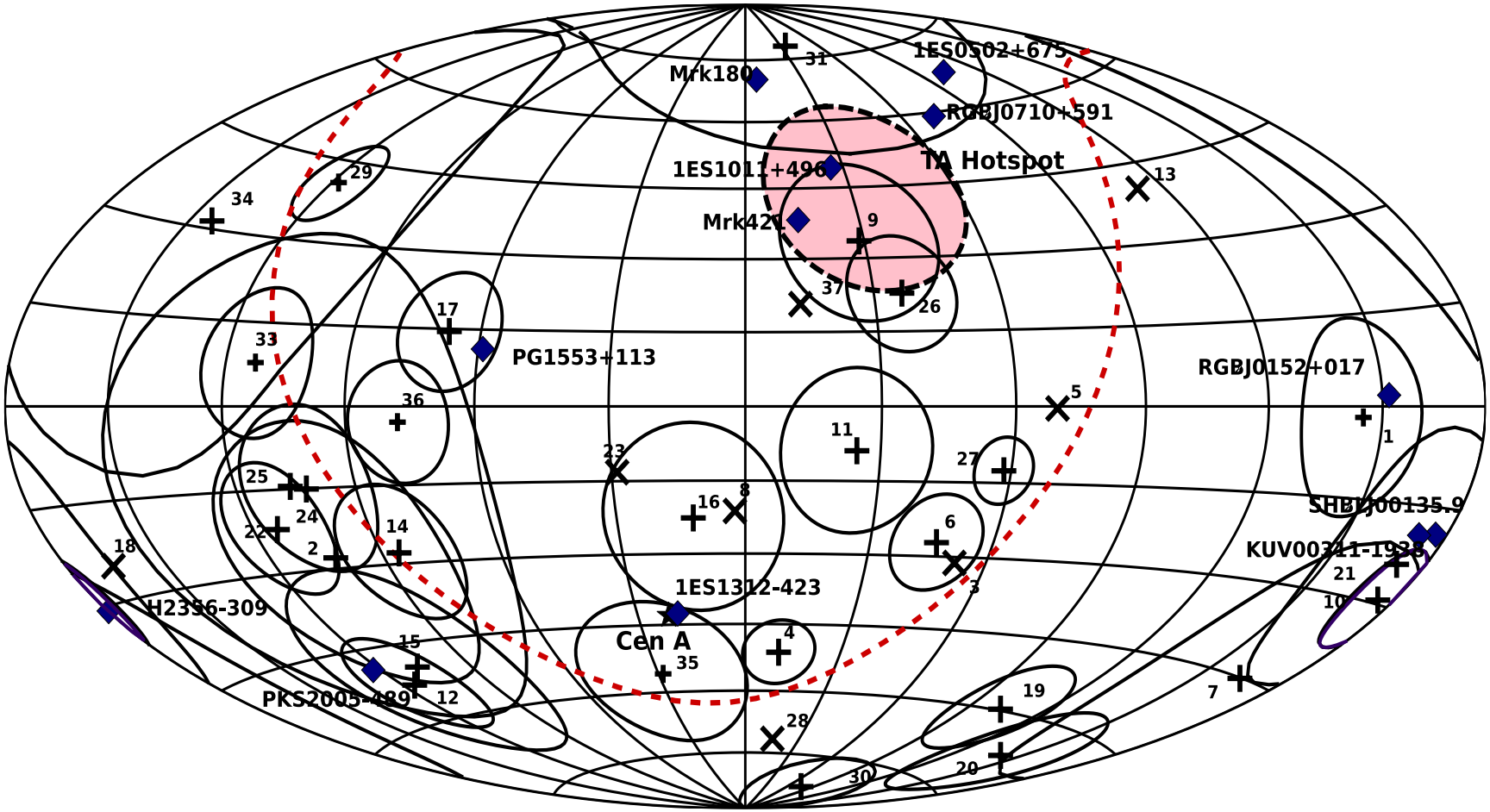


Figure 3: Internal Jet

Results

- We found coincidence of 12 HBLs and Cen A within the error circles of ten IceCube events, taken from the online catalog TeVCaT [http://tevcat.uchicago.edu/]



- We neglect events 25 and 34 , estimate the radius of the inner blob $R_s < R_f^{'} < R_b^{'}$ and an optical depth of $\tau_{p\gamma} \sim 0.01$ and $n_{\gamma,f}^{'} \sim 2x10 R_{f,15}^{'} cm^{-3}$.

- For all neutrino flavors α we assume [R. Moharana and S. Razzaque, JCAP 1508 (2015) no.08, 014] :

$$J_{\nu_\alpha}(E_\nu) = A_{\nu_\alpha} \left(\frac{E_\nu}{100\,TeV} \right)^{-\kappa} \tag{4}$$

and the neutrino flux:

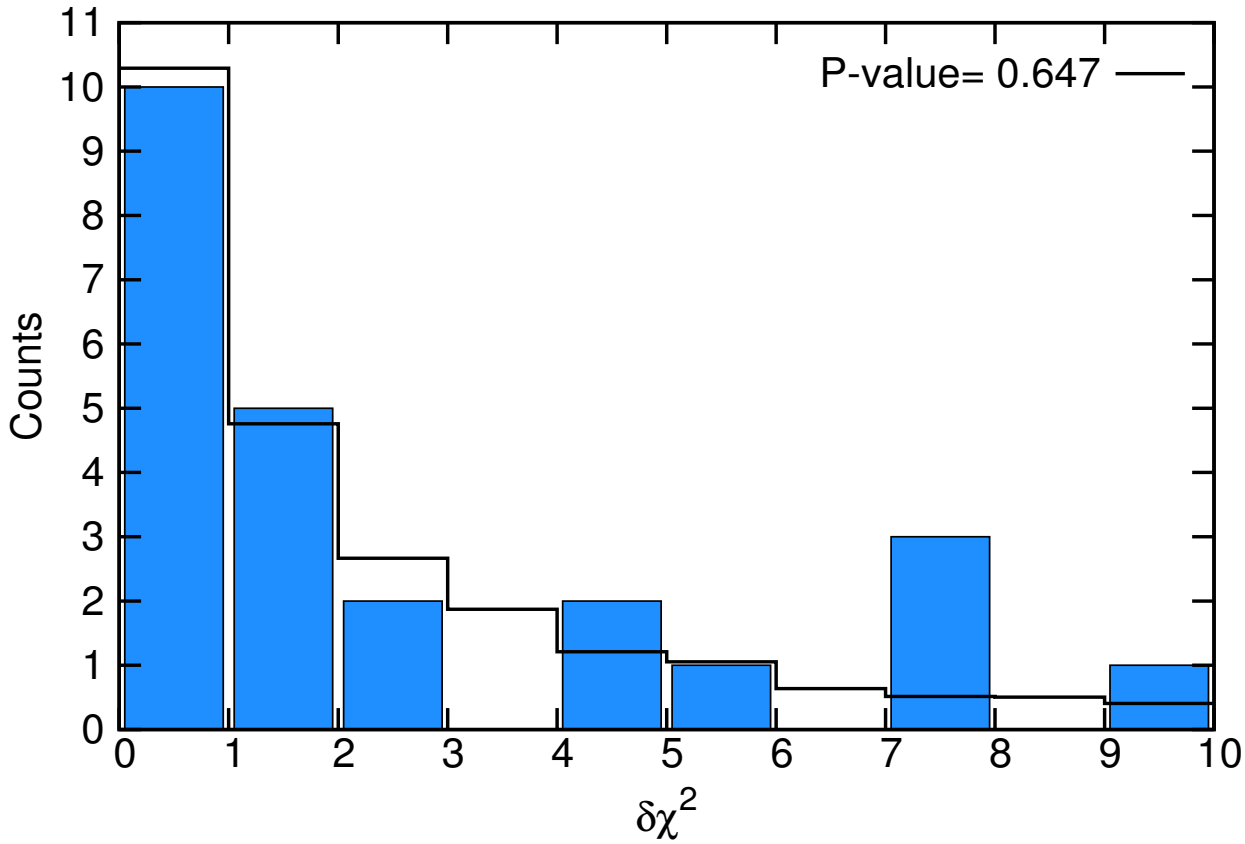
$$F_\nu = \sum_\alpha \int_{E_{\nu_1}(1+z)}^{E_{\nu_2}(1+z)} dE_\nu E_\nu J_{\nu_\alpha}(E_\nu) \tag{5}$$

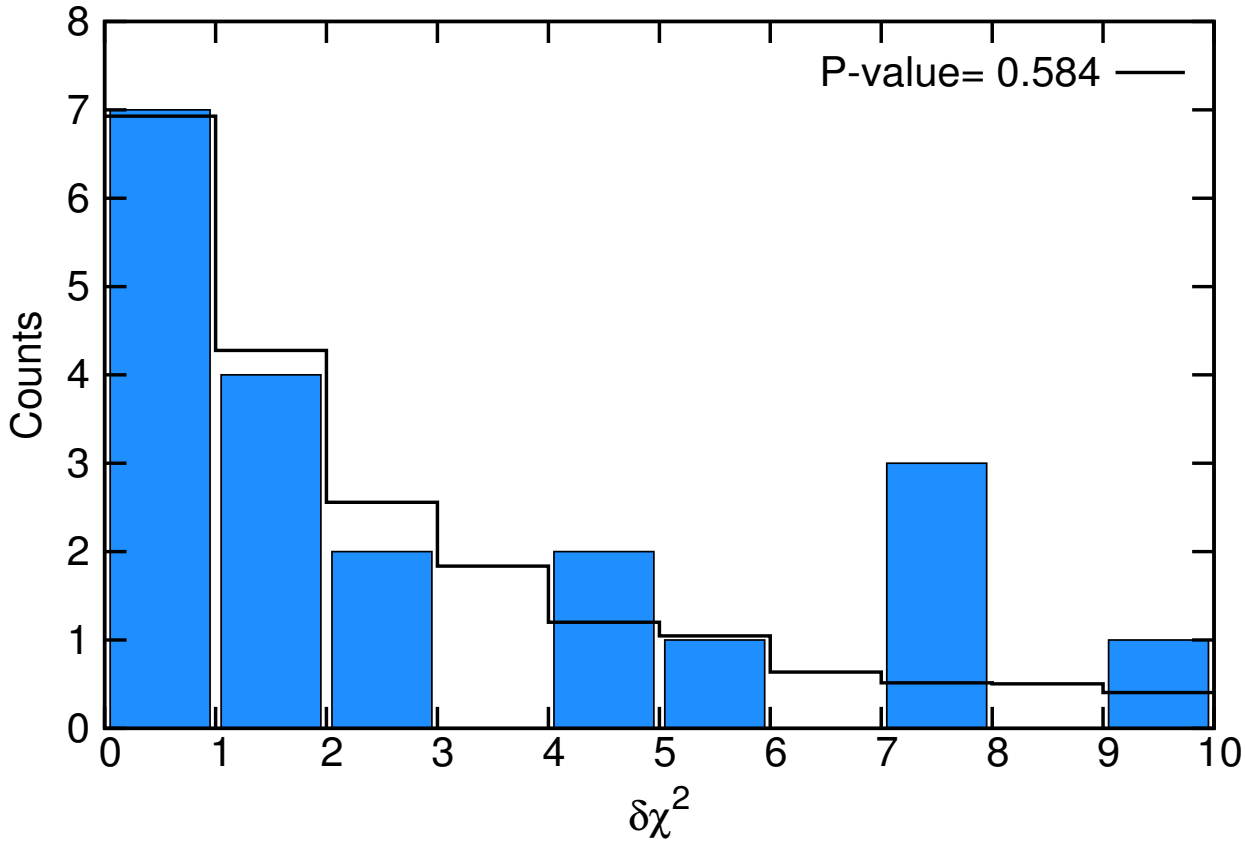
$$\tag{6}$$

- Using 988 days data, limits from 25 TeV to 2.2 PeV.

Object (Dec,RA);z,δ	ID	$\frac{E_\nu}{TeV}$	$\frac{\epsilon_\gamma}{keV}$	$R'_{f,15}$	$R'_{b,15}$	$n'_{\gamma,f,10}$	$F_{\nu,-9}$	$\delta\chi^2$
RGBJ0152+017[1]	1	47.6	179.	0.9	1.5	2.2	2.41	**0.24**
(1.77,28.14);0.08,25								
H2356-309[2]	7	34.3	111.	0.5	3.4	4.0	2.38	**0.66**
(-30.62,358.79); 0.165, 18	10	97.2	39.					**0.47**
	21	30.2	125.					**0.29**
SHBLJ001355.9 [3]	21	30.2	45.	1.0	35.	2.0	2.41	**0.13**
(-18.89,3.46);0.095,10								
KUV00311-1938	21	30.2	-	-	-	-	-	**0.05**
(-19.35,8.39);-,-								
Mrk421 [4]	9	63.2	46.	3.0	7.0	0.7	2.43	**0.61**
(38.19,166.01); 0.031, 14								
1ES1011+496 [5]	9	63.2	69.	5.0	10.	0.4	2.36	**0.94**
(49.43,153.77);0.212,20								
PKS2005-489 [6]	12	104.	31.	5.0	400.	0.4	2.42	**0.33**
(-48.83,302.36);0.071,15	15	57.5	53.					**0.25**
PG1553+113 [7]	17	200.	50.	3.0	10.	0.7	2.29	**0.59**
(11.19,238.94);0.4,35								
Mrk180 [8]	31	42.5	34.	5.0	20.	0.4	2.43	**0.18**
(70.16,174.11);0.045,10								
1ES0502+675 [9]	31	42.5	35.	5.0	10.	0.4	2.31	**0.66**
(67.62,76.98);0.341,13								
RGBJ0710+591 [10]	31	42.5	267.	5.0	20.	0.4	2.39	**0.77**
(59.15,107.61);0.125,30								
1ES1312-423 [11]	35	2004.	0.32	5.0	240.	0.4	2.40	**0.85**
(-42.6,198.75);0.105,7.								
Cen A (FR-I) [12]	35	2004.	0.056	0 .6	3.0	3.3	2.45	**0.73**
(-43.01,201.36);.00183,1								

- The mean free paths for the TeV-PeV photons satisfy $\alpha_{\gamma\gamma} >> R_f^{'}$ so there will be negligible attenuation in the inner region.
- We made a statistical analysis to look for the correlation between the IceCube events and the 42 TeV emitting HBL and Cen A from the TeVCat. We use the quantity $\delta\chi_i^2 = min(\gamma_{ij}^2/\delta\gamma_i^2)$ [R. Moharana and S. Razzaque, JCAP 1508 (2015) no.08, 014].





- Two statistics with the ICeCube events $\leq 40^o$ and $\leq 20^o$ respectively.
- But we there is no significant correlation between IceCube events and the 42 events in the TeV Catalog.

Conclusions

- We found coincidence of 12 HBLs and one FR-I galaxy Cen A position within the error circles of ten iceCube events.
- We propose the photohadronic model interpretation for some of the IceCube events and their chances.
- From the statistical analysis we found no significant correlation between the Icecube events and the TeVCat sample.
- Years of data taking are necessary to confirm or refute then positional correlations of the HBls/AGN with the IceCube events.
- Work published in: S. Sahu and L. S. Miranda, Eur. Phys. J. C 75, no. 6, 273 (2015).

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THE GROUP:



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