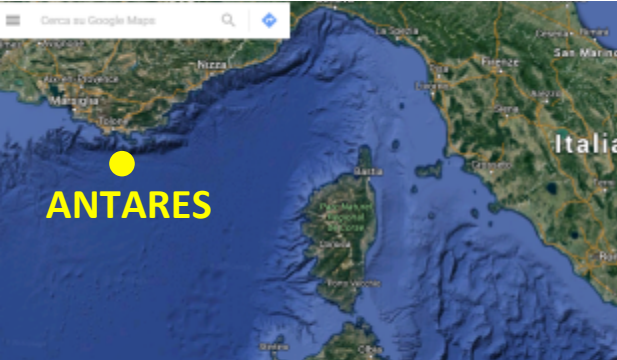


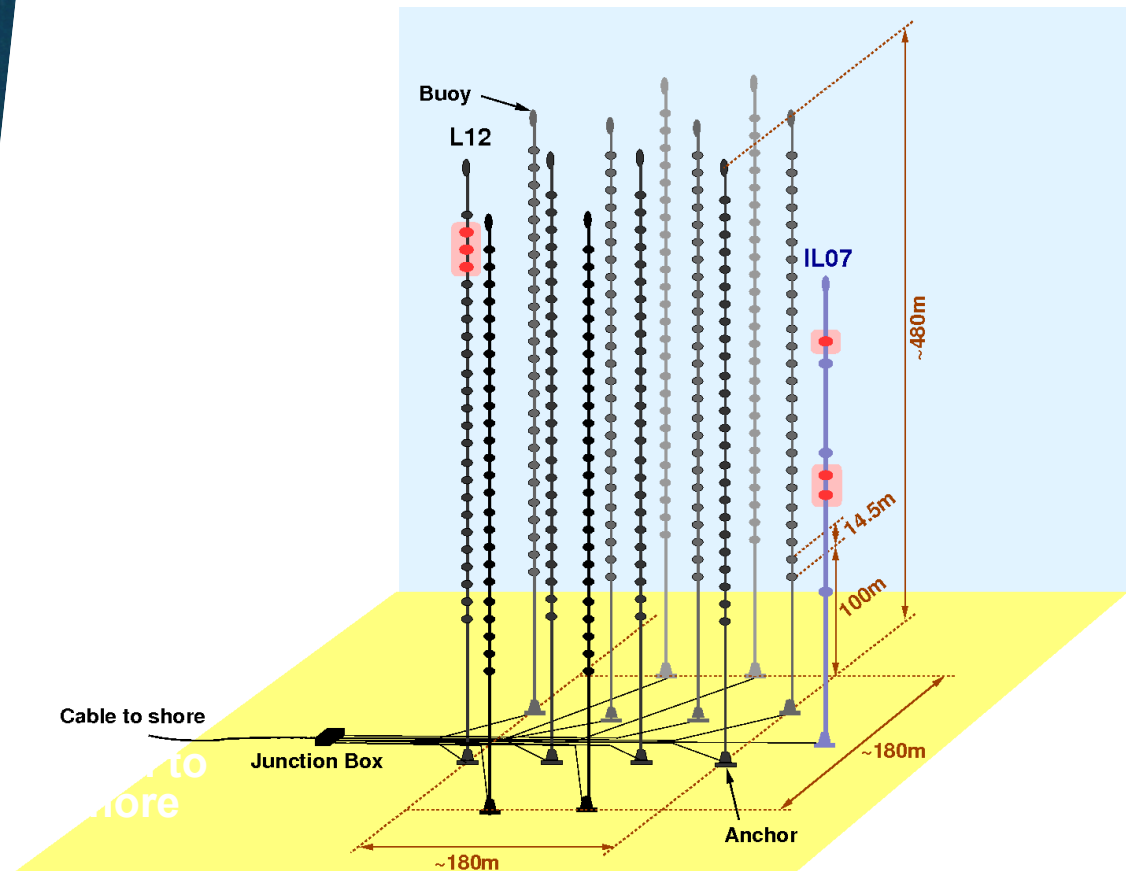
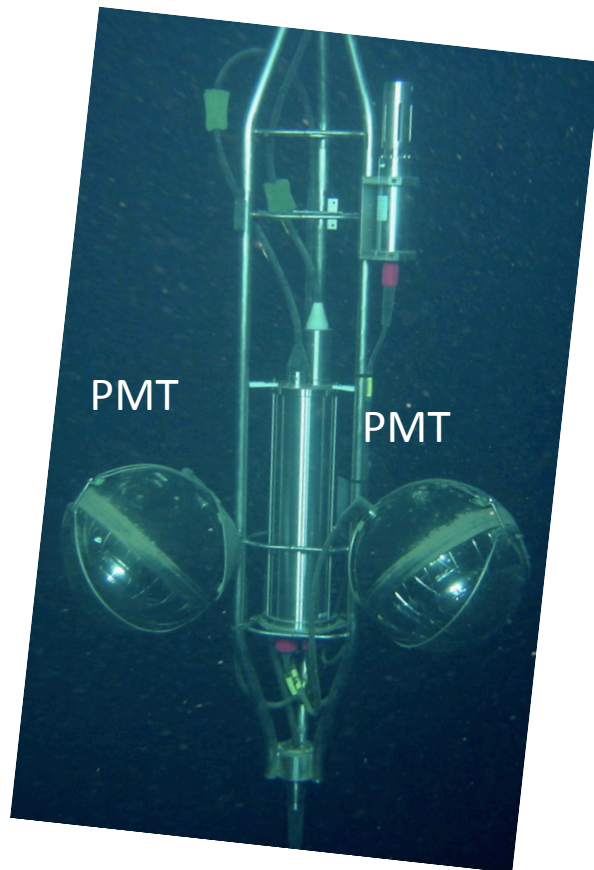
Search for HE neutrino point sources with ANTARES

Dorothea Samtleben, KM3NeT meeting Schoorl, May 2019



ANTARES

- Running since 2007 at 2475m depth
- 885 10" PMTs
- 12 lines
- 25 storeys/line
- 3 PMTs / storey



The search for cosmic neutrinos:

So far only single high energy neutrino events, no source (aside from – possibly – TXS0506) identified as correlated with other observations (electromagnetic, cosmic rays, gravitational waves)

Guaranteed neutrino sources at positions of IceCube high energy neutrinos

- > ANTARES: Search in time correlation
- > **ANTARES: Search in stacking**

Stacking analysis

Targets:

- Fermi 3LAC Blazars (1420)
- Sample of selected Giant Radiogalaxies (65)
- Star Forming Galaxies (SFGs) (64)
- Dust-obscured AGN (15)
- IceCube 51 HE tracks

Data set :

- ANTARES 9yr PS sample (2007-2015): 7622 up-going tracks

Principle of the analysis

- Two different stacking methods :
 - **Individual stacking** : an independent fit is performed for each source, then TS are summed up (used for IC HE tracks).

$$\log \mathcal{L}_j(\mathbf{H}_1|x) = \sum_i^N \log \left[\mu_s^j S_j(x_i) + \mu_b^j B(x_i) \right] - \mu_s^j - \mu_b^j$$

$$TS_j = \ln \left(\frac{\max(\mathcal{L}_j(\mathbf{H}_1|x))}{\max(\mathcal{L}_j(\mathbf{H}_0|x))} \right)$$

$$TS = \frac{1}{\sum w_j} \sum_{j=1}^{N_{\text{sources}}} w_j TS_j$$

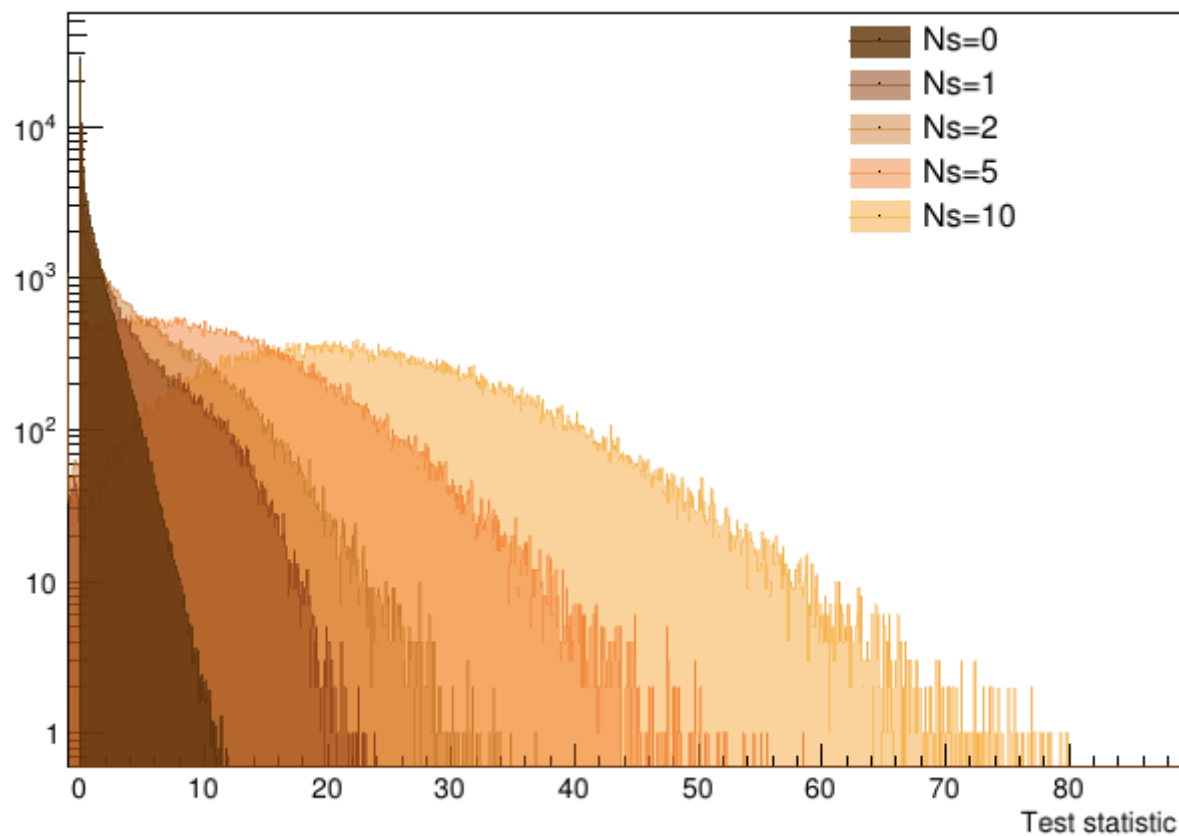
(source weights w_j are discussed on slide 13)

- **Template stacking** : a global fit is performed, signal term is the sum of individual source contributions (used for catalogs).

$$\log \mathcal{L}(\mathbf{H}_1|x) = \sum_i^N \log \left[\mu_s \left(\frac{1}{\sum w_j} \sum_j^{N_{\text{sources}}} w_j S_j(x_i) \right) + \mu_b B(x_i) \right] - \mu_s - \mu_b$$

$$TS = \ln \left(\frac{\max(\mathcal{L}(\mathbf{H}_1|x))}{\max(\mathcal{L}(\mathbf{H}_0|x))} \right)$$

TS distribution for the whole blazar population



Unblinding results

p: pre-trial P: post-trial

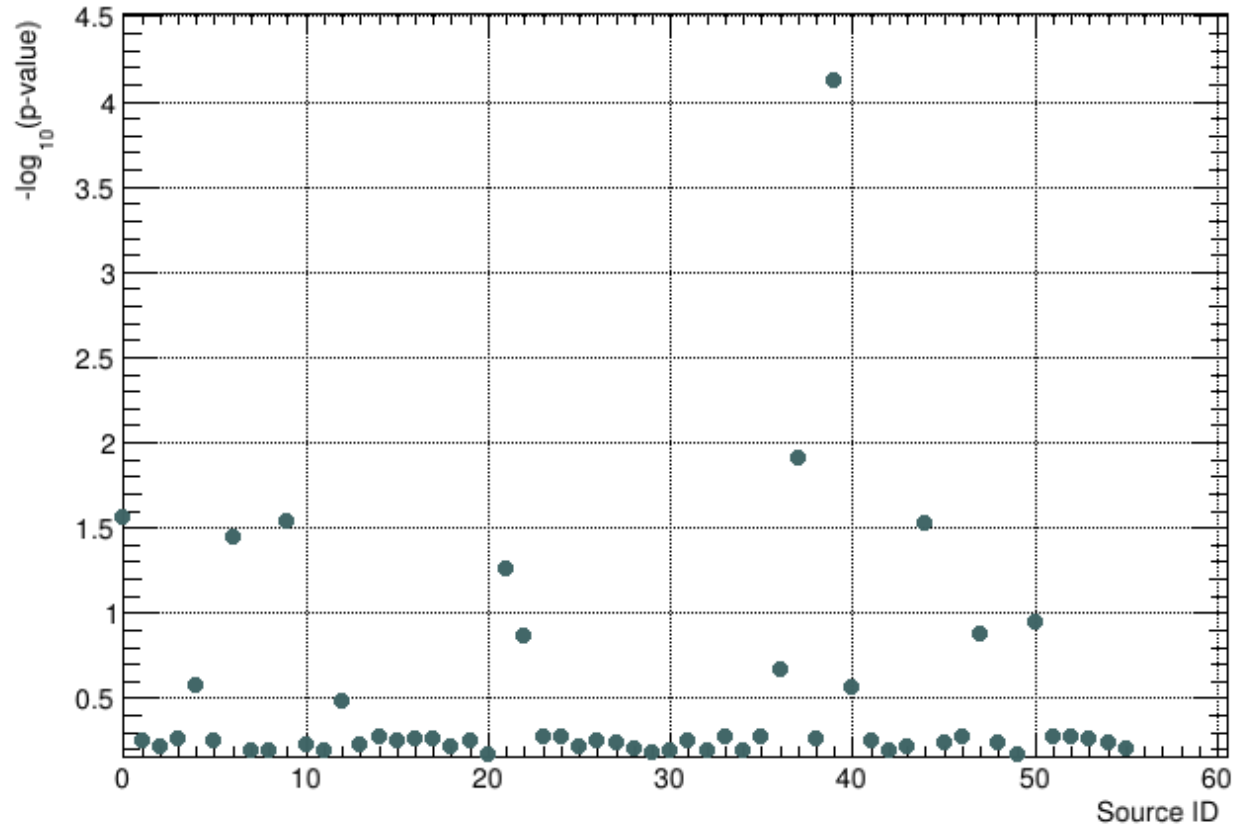
Catalog	Equal weighting				Flux weighting			
	Fitted n_s	TS	p	P	Fitted n_s	TS	p	P
Fermi 3LAC All Blazars	72.2	3.45	0.12		~ 0	~ 0	~ 1	
Fermi 3LAC FSRQ	~ 0	~ 0	~ 1		~ 0	~ 0	~ 1	
Fermi 3LAC BL Lacs	76.9	7.35	0.015		14.6	0.48	0.43	
Radio-galaxies	10.8	3.0	2.10^{-3}		10.9	4.37	2.710^{-3}	
Star Forming Galaxies	2.6	0.08	0.24		~ 0	~ 0	~ 1	
Obscured AGN	1.5	0.12	0.22		~ 0	~ 0	~ 1	
IC HE Tracks	56.7	0.86	0.016		-	-	-	

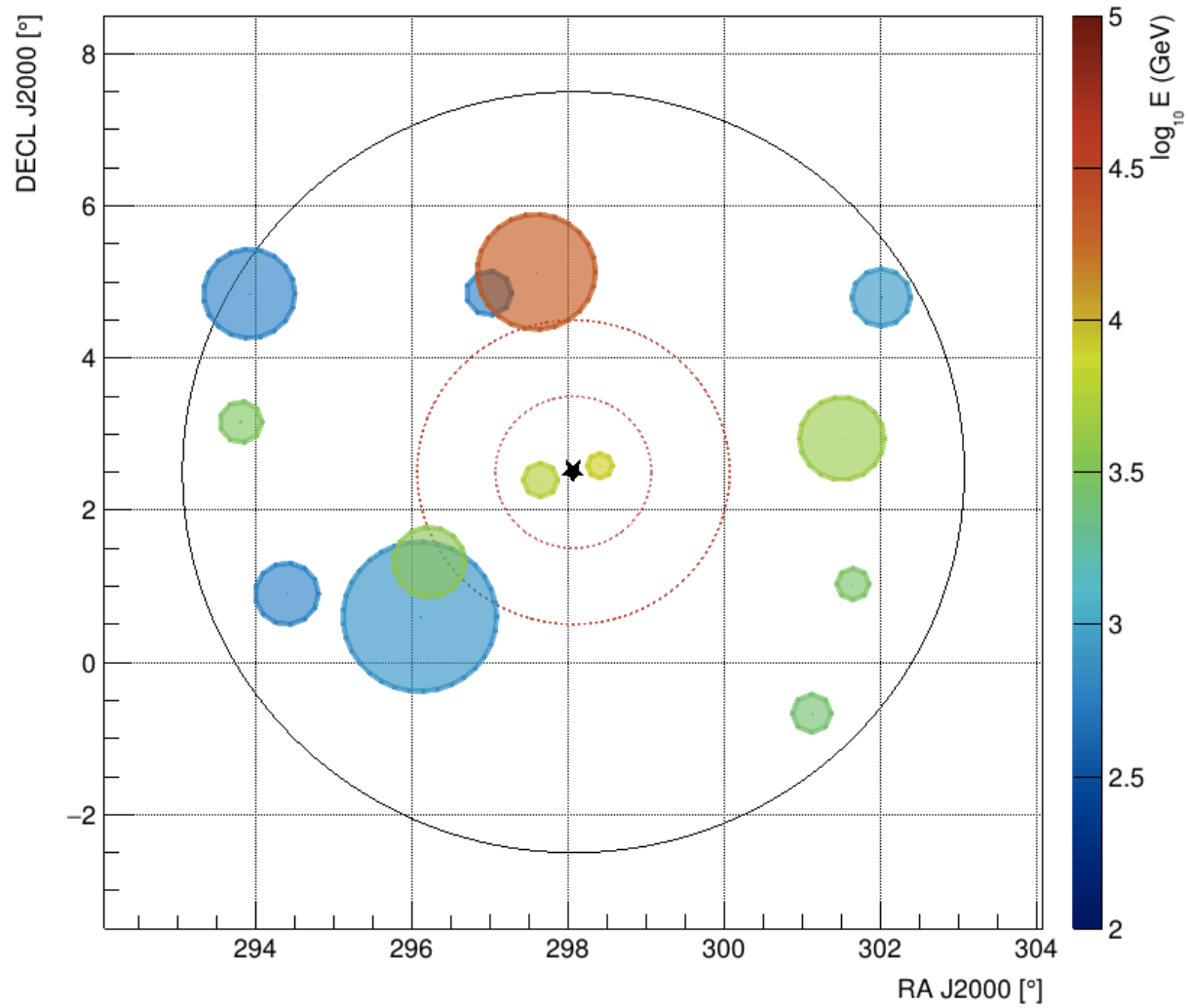
Unblinding results

p: pre-trial P: post-trial

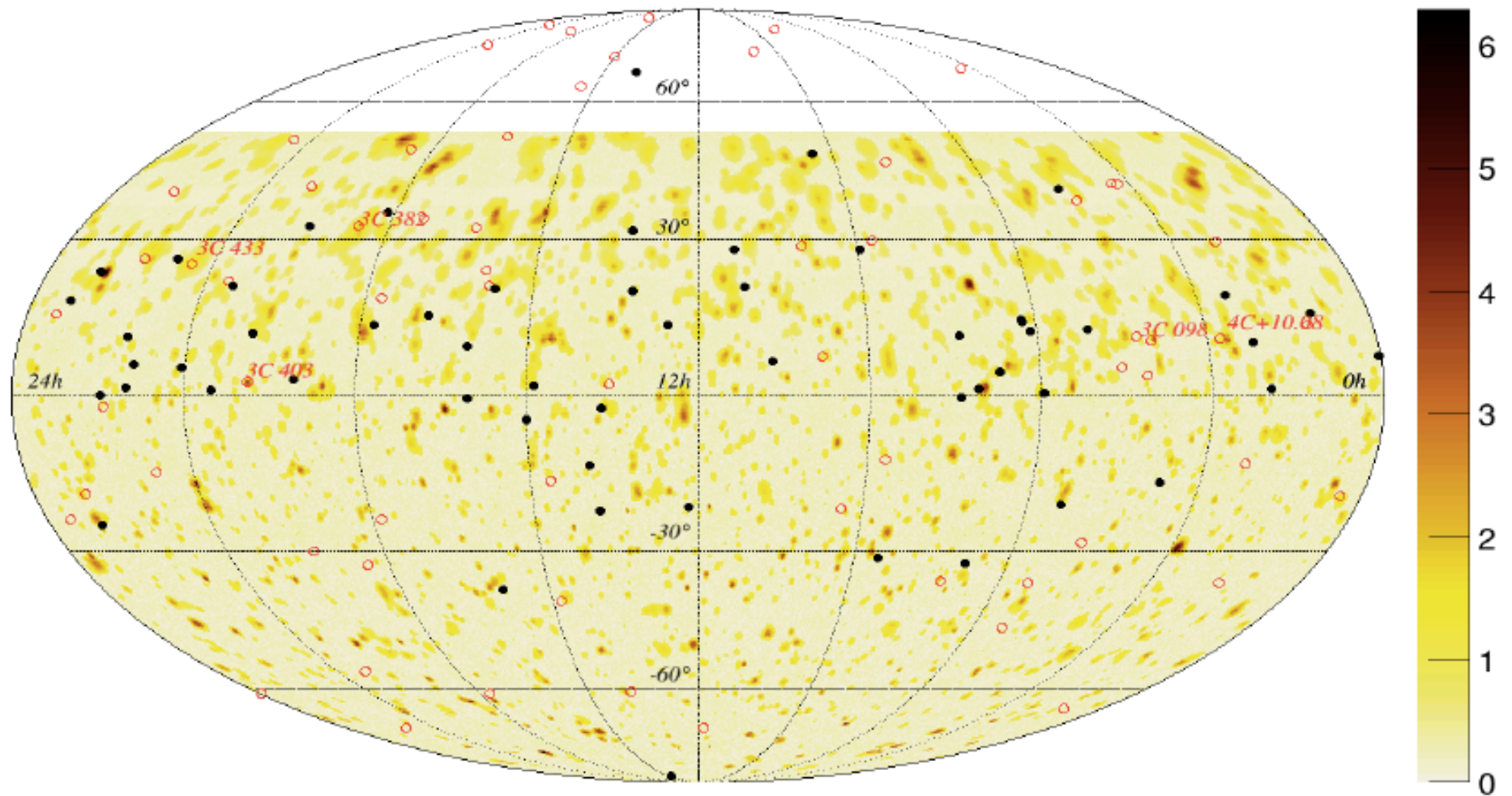
Catalog	Equal weighting				Flux weighting			
	Fitted n_s	TS	p	P	Fitted n_s	TS	p	P
Fermi 3LAC All Blazars	72.2	3.45	0.12	0.76	~ 0	~ 0	~ 1	~ 1
Fermi 3LAC FSRQ	~ 0	~ 0	~ 1	~ 1	~ 0	~ 0	~ 1	~ 1
Fermi 3LAC BL Lacs	76.9	7.35	0.015	0.19	14.6	0.48	0.43	0.99
Radio-galaxies	10.8	3.0	2.10^{-3}	0.034	10.9	4.37	2.710^{-3}	0.044
Star Forming Galaxies	2.6	0.08	0.24	0.94	~ 0	~ 0	~ 1	~ 1
Obscured AGN	1.5	0.12	0.22	0.92	~ 0	~ 0	~ 1	~ 1
IC HE Tracks	56.7	0.86	0.016	0.20	-	-	-	-

Radio galaxy sample





Radiogalaxies vs IceCube



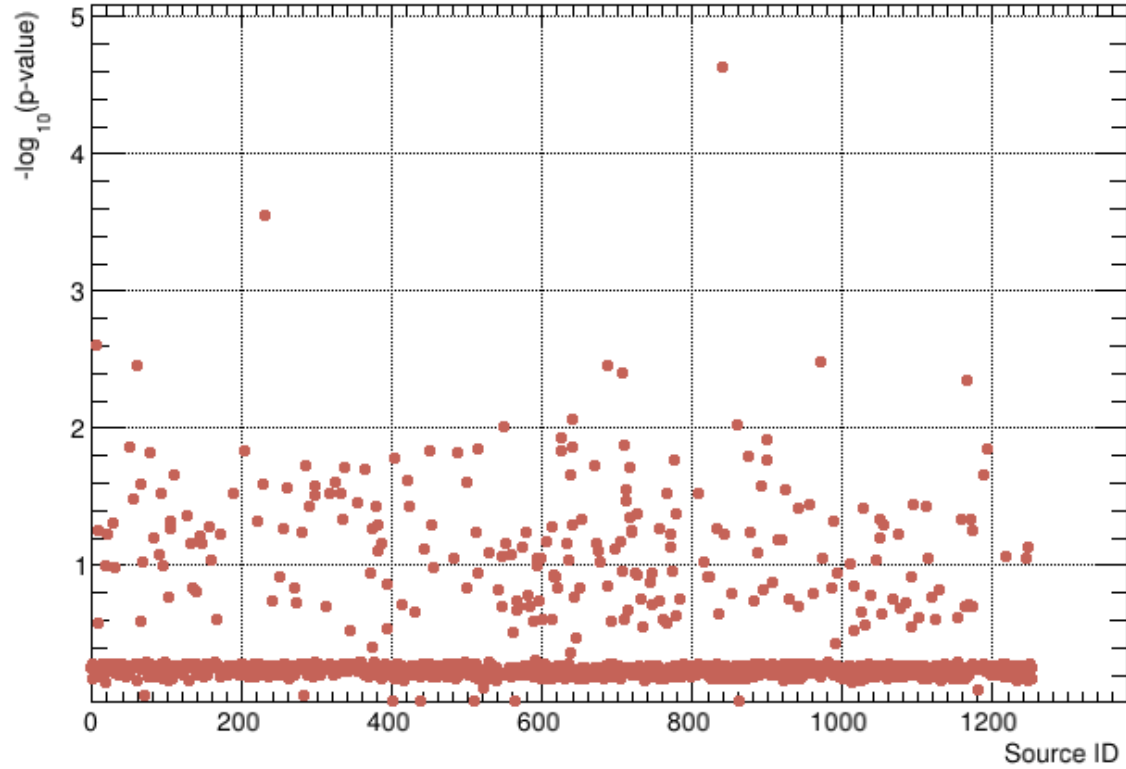
Red empty circles: radio-galaxies

Black filled circles: IceCube HE tracks

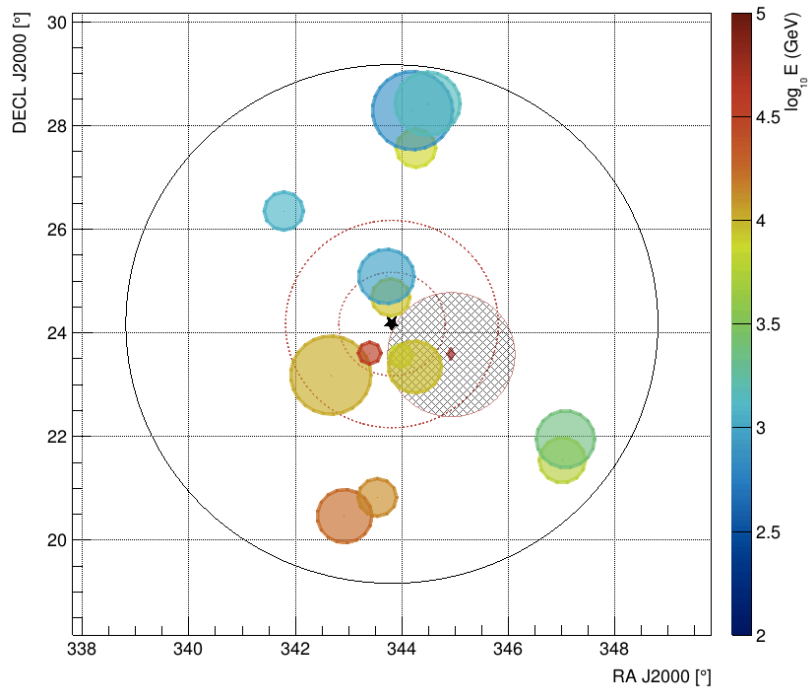
→ No correlation between the IC HE tracks and the radio-galaxies

$-\log_{10} p\text{-val}$

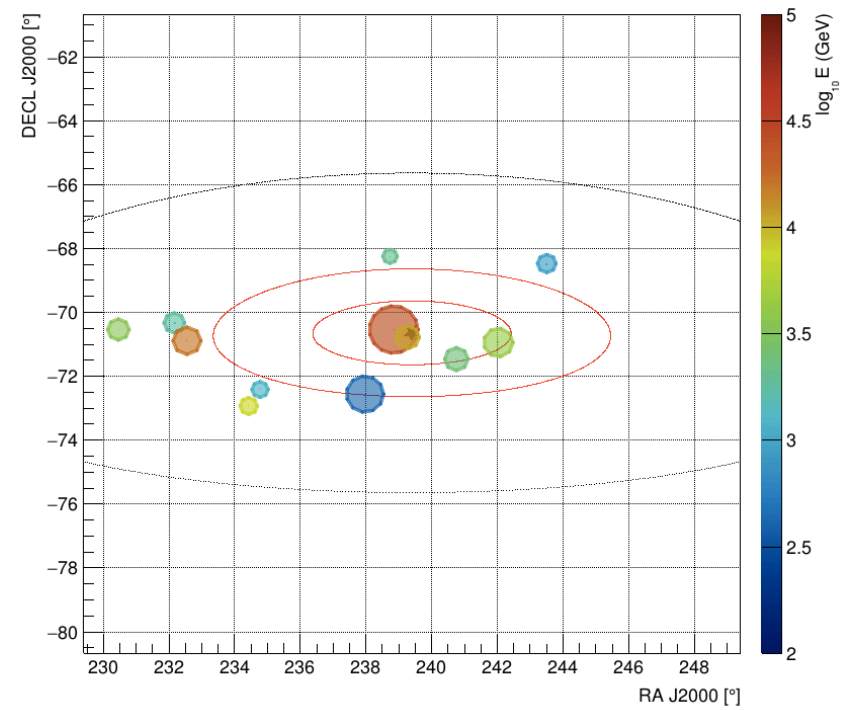
Fermi Blazars



J225517+2409



PKS 1552-705



Known hot-spot of 9-year PS analysis
IC-event coincidence $p \sim 1\%$

<https://fermi.gsfc.nasa.gov/ssc/data/access/lat/FAVA/>



Fermi All-sky Variability Analysis (FAVA) - Light Curve Generator

Coordinate Input

RA:

Dec:

Light Curve Information

Coordinates

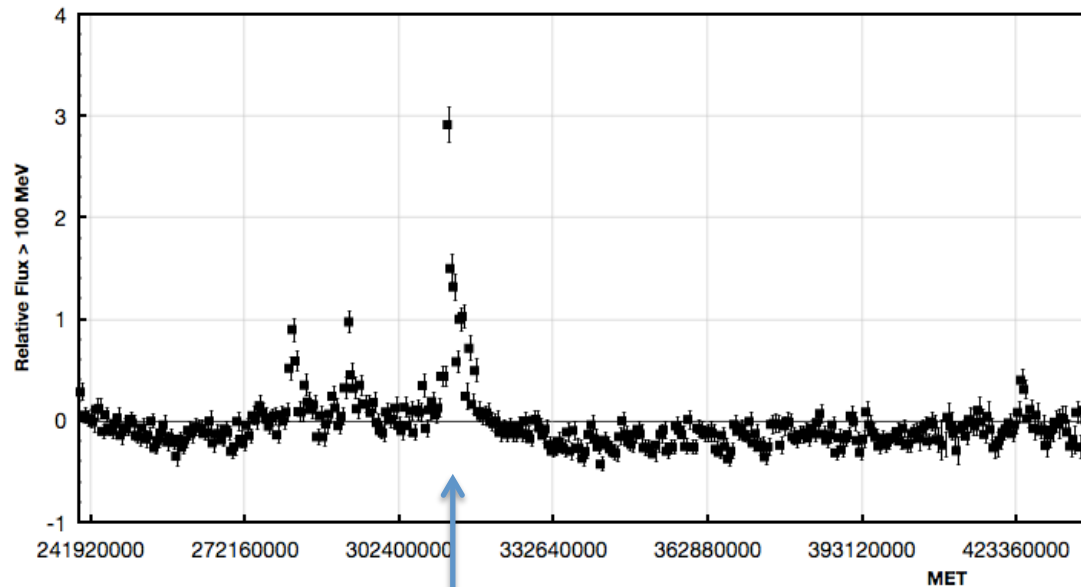
RA: 344°

Dec: 24°

Galactic l: 91.6883°

Galactic b: -31.7763°

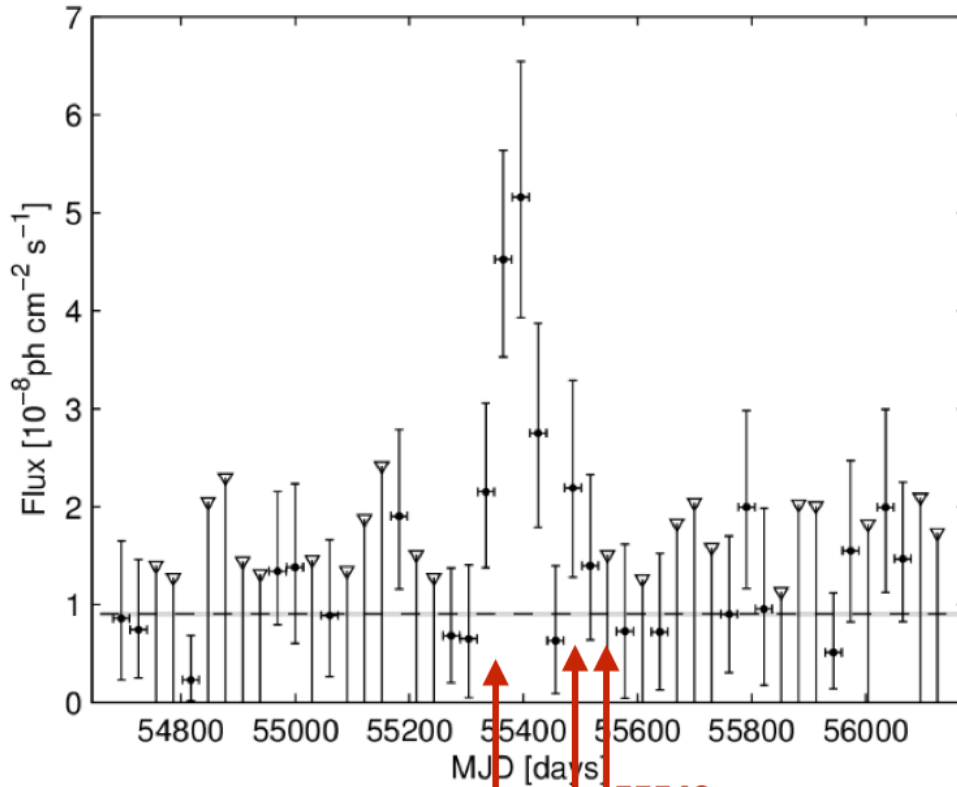
Low Energy Light Curve (100 - 800 MeV)



One of the events directly at flare position!

But: low-energy PSF very large for FERMI

3FGL J2255.1+2411 – MG3 J225517+2409



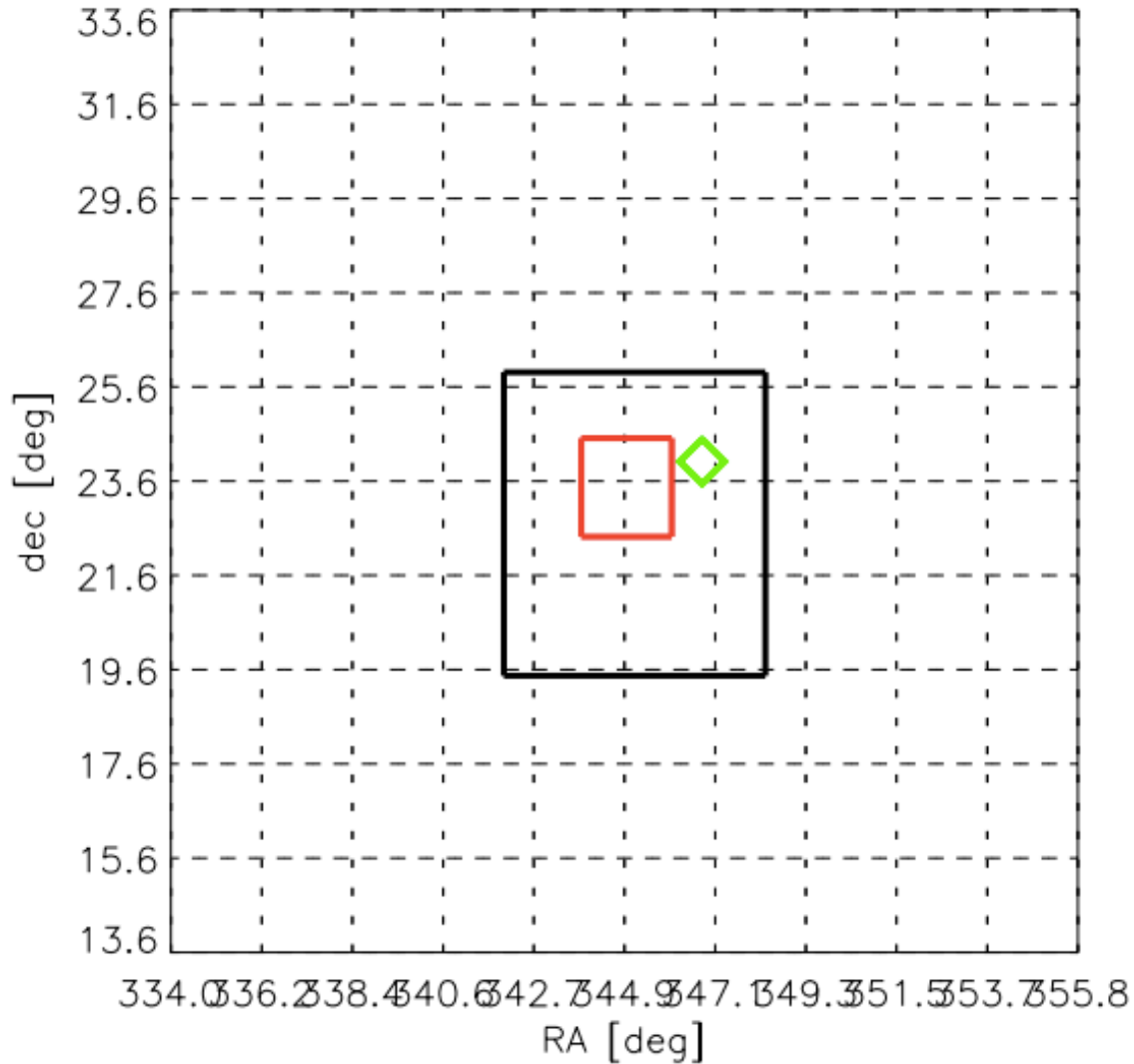
55355 (IC) 55517 55546

MJD	Ra	Dec	$\log_{10} E_{\text{dEdX}}$	β	Ω
55517.5	343.79	24.68	3.94	0.36	0.51
54562.8	343.98	23.56	3.84	0.22	0.63
54846.9	343.40	23.61	4.56	0.21	0.68
55089.6	343.71	25.09	2.96	0.52	0.92
55546.2	344.25	23.34	3.97	0.50	0.92

Working on estimating significance of coincidence at/close to the flaring

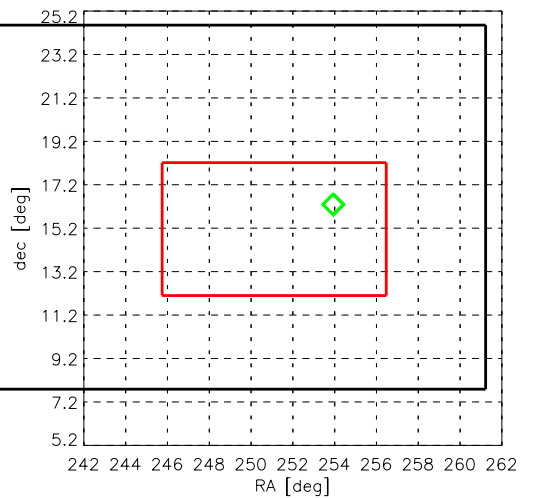
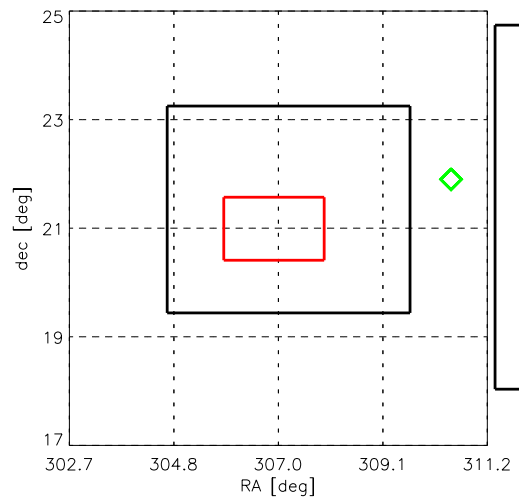
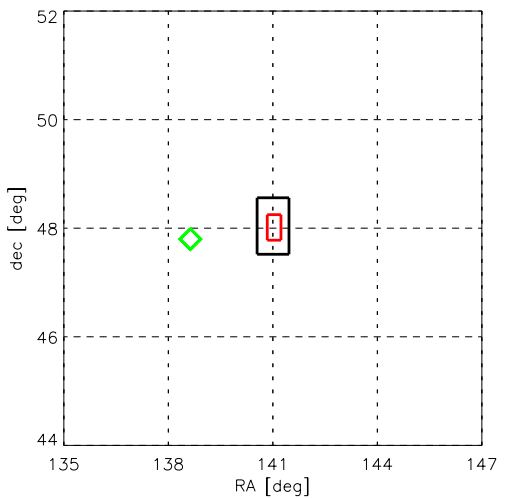
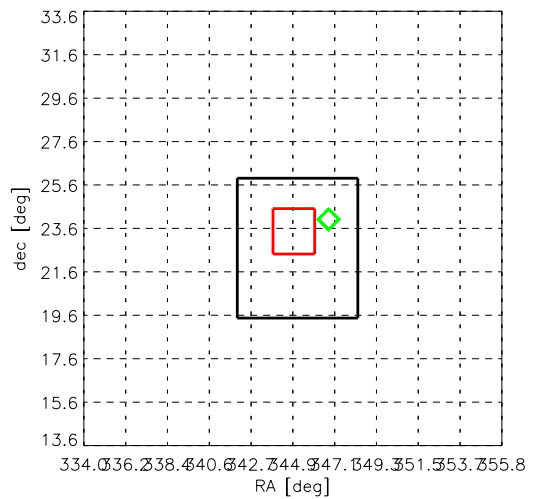
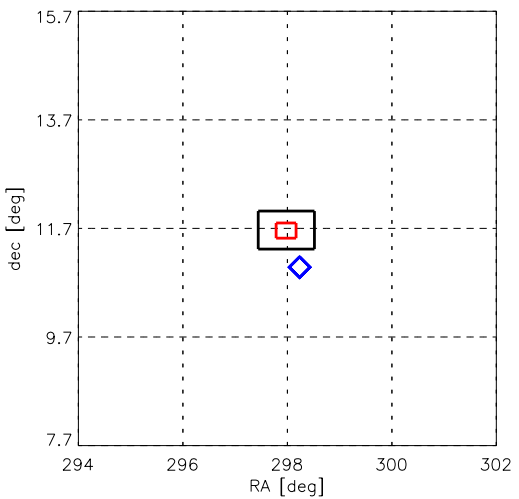
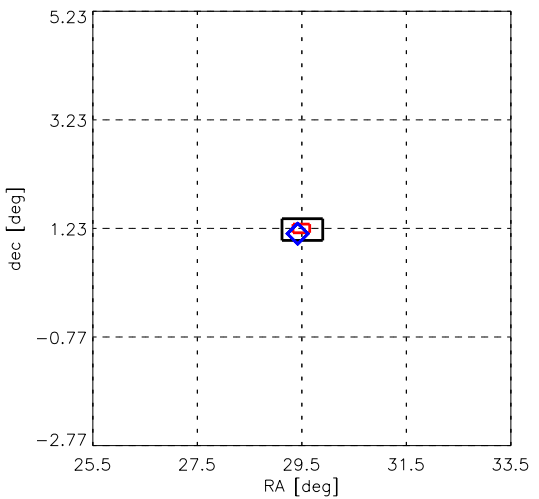
IC track: Large uncertainty region

Green: Public Point Source Sample, Black/Red: 50/90CL publication



An aside: Reconstruction changes in IC HE muon tracks:

Green: Public Point Source Sample Blue: First publication (web), Black/Red: 50/90CL publication



The search for HE neutrino point sources continues ...