Neutrino Point Source Searches with IceCube 22 String Configuration

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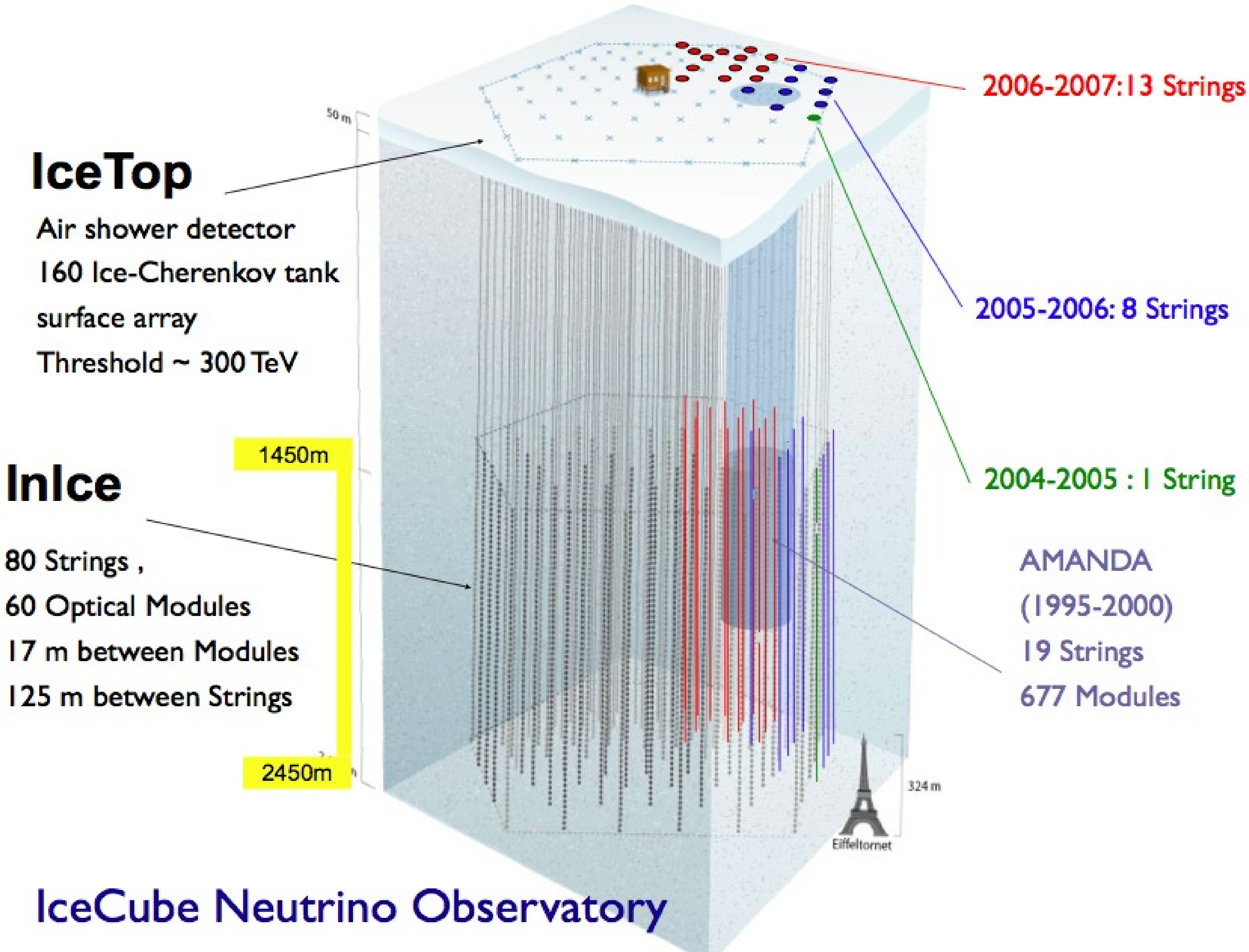
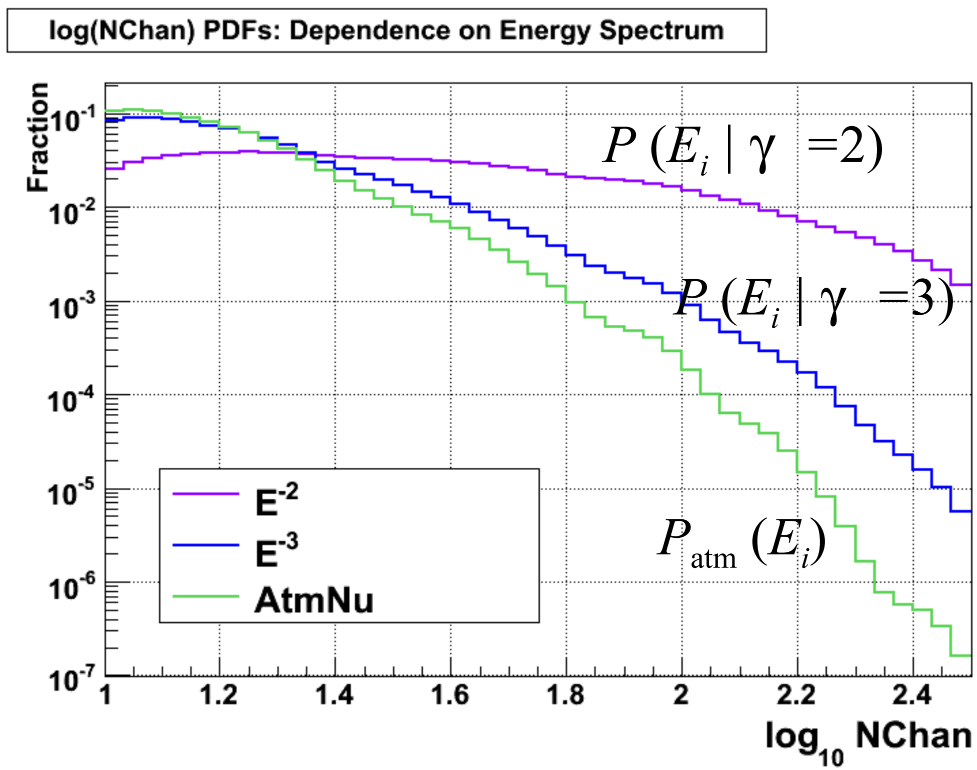
Introduction: IceCube 22-string configuration



Unbinned Analysis

We use a signal Pdf based on the angular resolution of each event and an energy estimator based on the number of DOMs hit (NChan) based on simulated neutrino events.

$$\mathcal{S}_i = \frac{1}{2\pi\sigma_i^2} e^{\frac{-r_i^2}{2\sigma_i^2}} * P(E_i|\gamma)$$

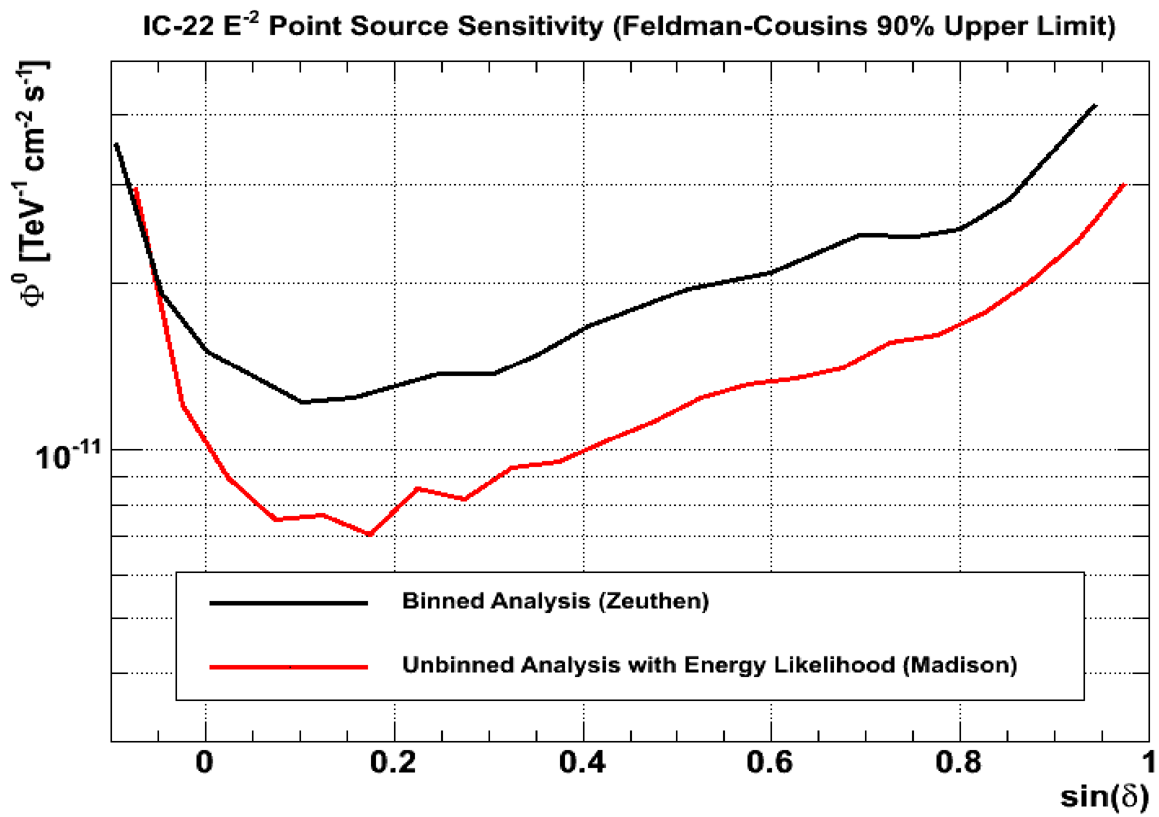


The background Pdf is based on density of events in a declination band and the NChan of the final data sample.

$$\mathcal{B}_i = \frac{N_{band}}{\Omega_{band}} * P_{data}(E_i)$$

Using the resolution of each event is more powerful than using a binned analysis.

Sensitivity and Indepenent Binned analysis

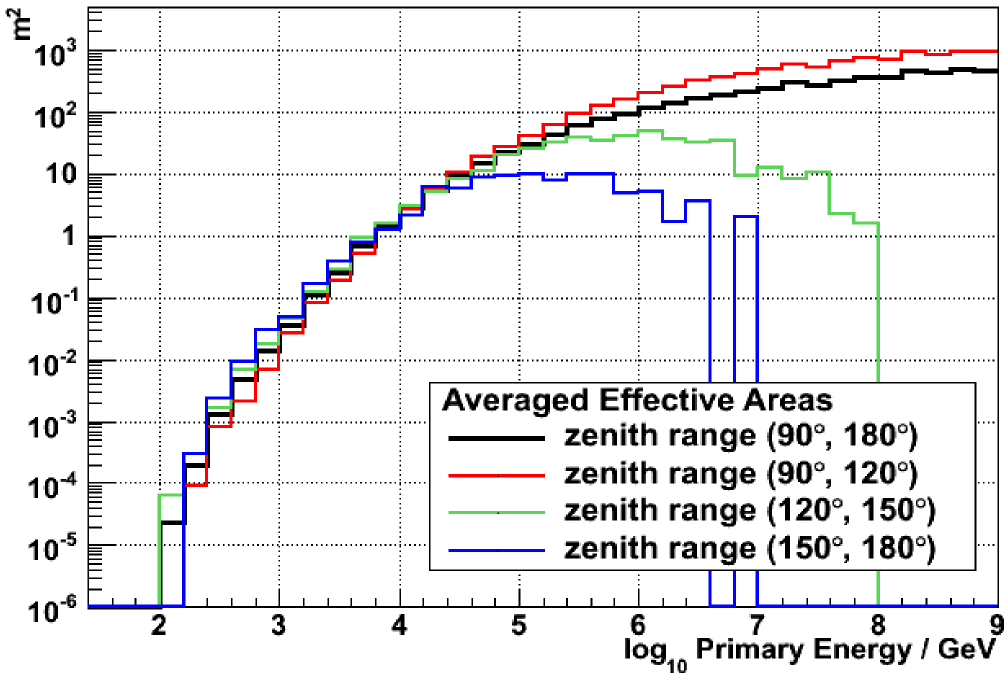


A independent, binned point-source analysis was also performed with the IC-22 data.

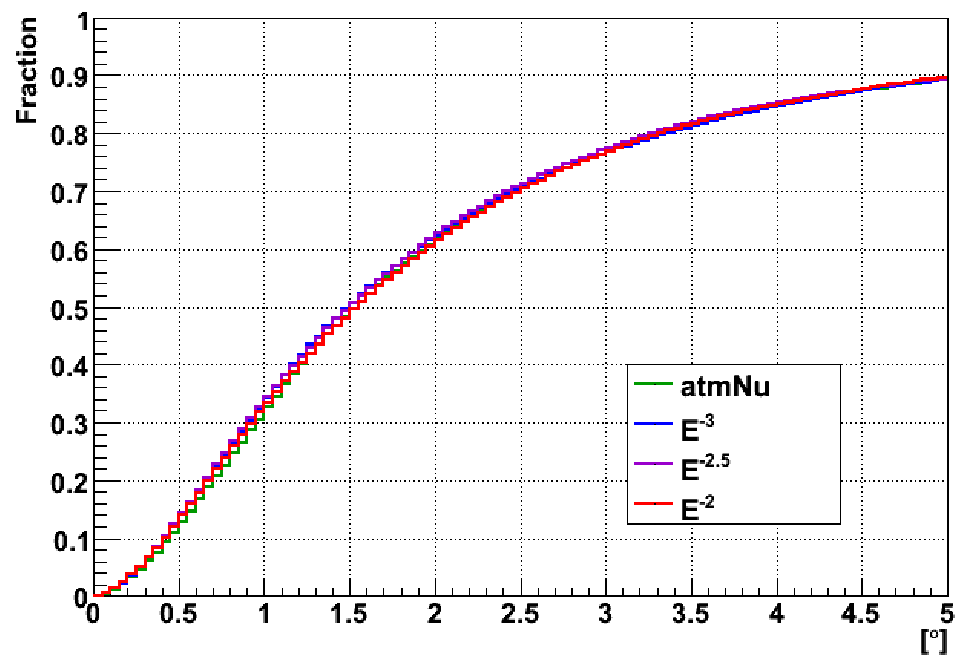
Less sensitive, but useful as a cross-check of the unbinned analysis.

IC22 Point Source Analysis Characteristics

Muon Neutrino Effective Area



Point Spread Function



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IC-22 data taking: 2007 May 31 - 2008 Apr 5

275.70 days livetime after selecting good runs.

Simple set of cuts applied to data, to select good upgoing events and reject downgoing and coincident background, including:

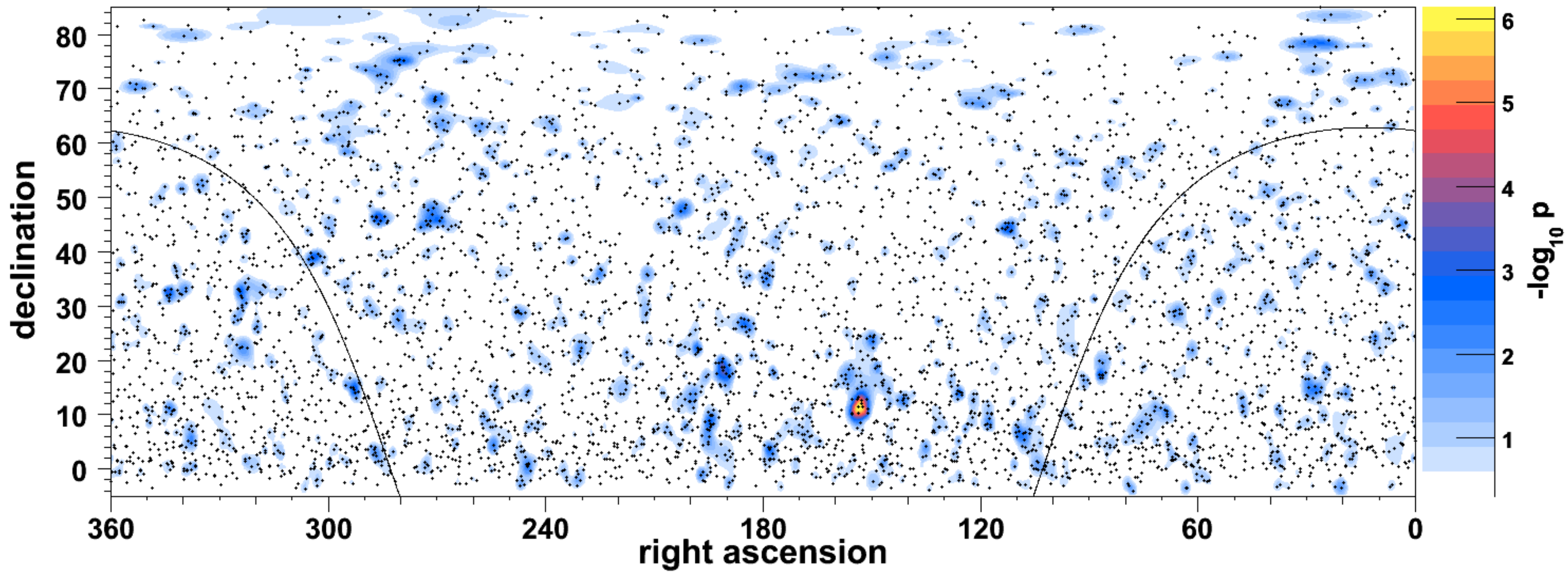
- Estimated event directional uncertainty < 3 deg
- log likelihood ratio of best-fit upgoing track to best-fit downgoing track > 30
- If hit series is split in two, both series have best-fit zenith > 70 deg

5114 Events after cuts

Perform point source search using:

- a priori list of 28 source candidates
- all sky search from -5° to +85° declination

IC22 Point Source Results



Hottest spot found at r.a. 153º , dec. +11º

est. nSrcEvents = 7.7 est. gamma = 1.65

Post-Trials p-value of the hottest spot is 1.35% (2.2 σ)

If it's a steady source, we can confirm it in subsequent years of data
Concern that it could be due to a one-time occurrence.

Time Dependent Analysis of the Hotspot

Time-Integrated likelihood factors → Time-Dependent likelihood factors

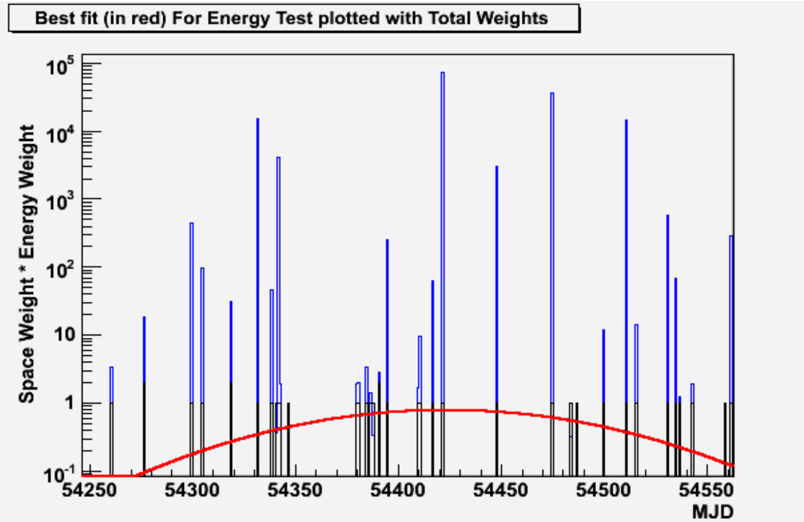
$$\mathcal{S}_i = \frac{1}{2\pi\sigma_i^2} e^{\frac{-r_i^2}{2\sigma_i^2}} * P(E_i|\gamma)$$

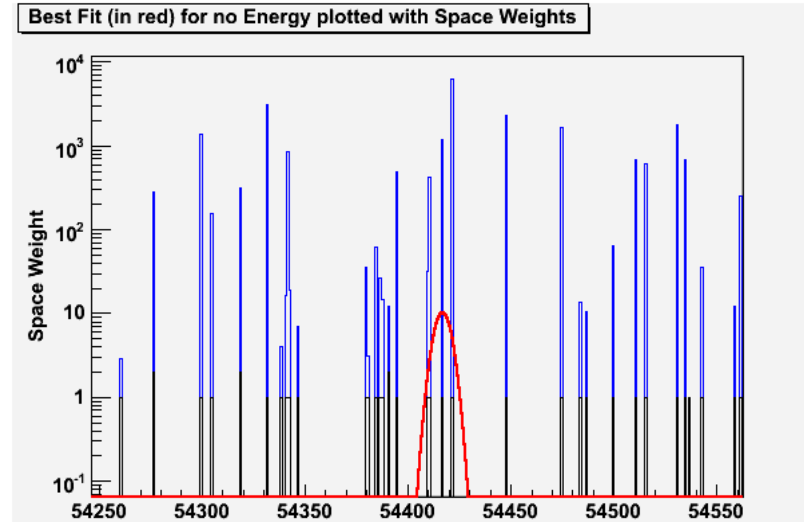
$$\mathcal{B}_i = \frac{N_{band}}{\Omega_{band}} * P_{data}(E_i)$$

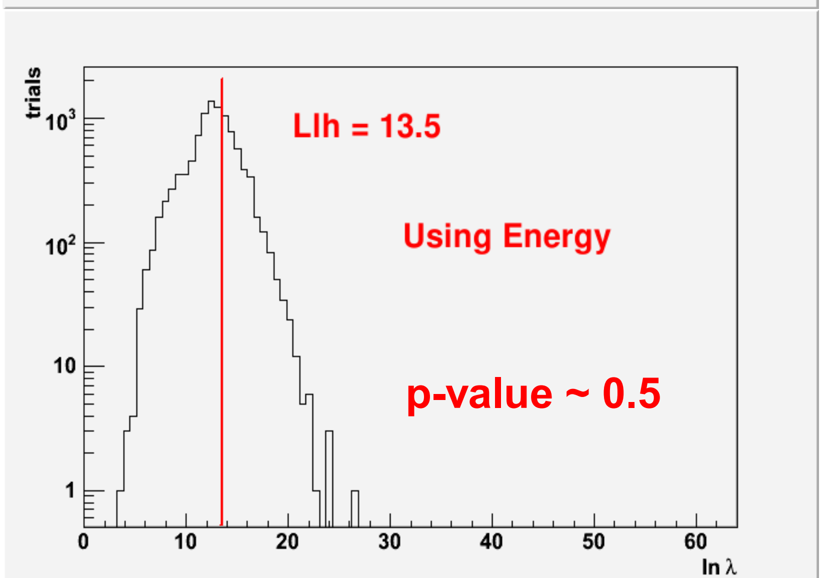
$$\mathcal{S}_i = \frac{1}{2\pi\sigma_i^2} e^{\frac{-r_i^2}{2\sigma_i^2}} * P(E_i|\gamma) * \frac{1}{\sqrt{2\pi}\sigma_t} e^{\frac{-(t_i - t_o)^2}{2\sigma_t^2}}$$

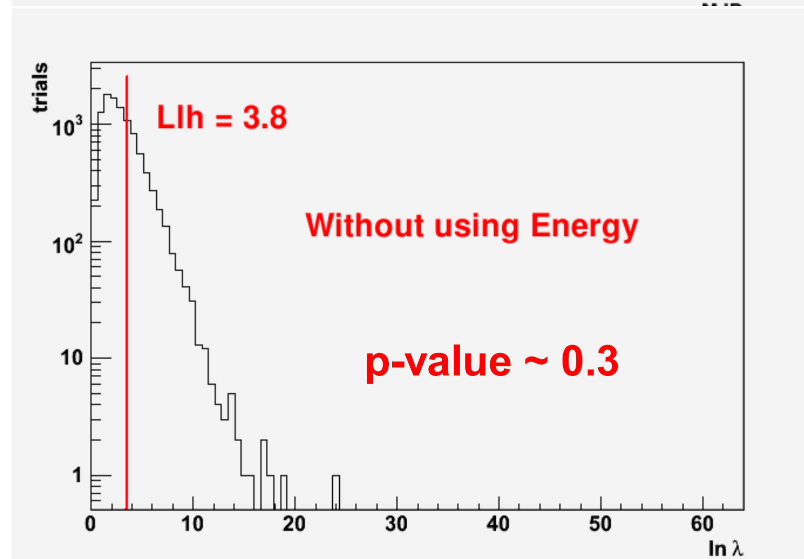
$$\mathcal{B}_i = \frac{N_{band}}{\Omega_{band}} * P_{data}(E_i) * \frac{1}{livetime}$$

Hotspot Analysis – Results









Neither analysis finds any significant clustering of events in time

Microquasars are binary stellar systems which have evidence of a nonthermal radio jet. We also tested to see if using the orbital period of the system can be used to help identify a a neutrino emitter.

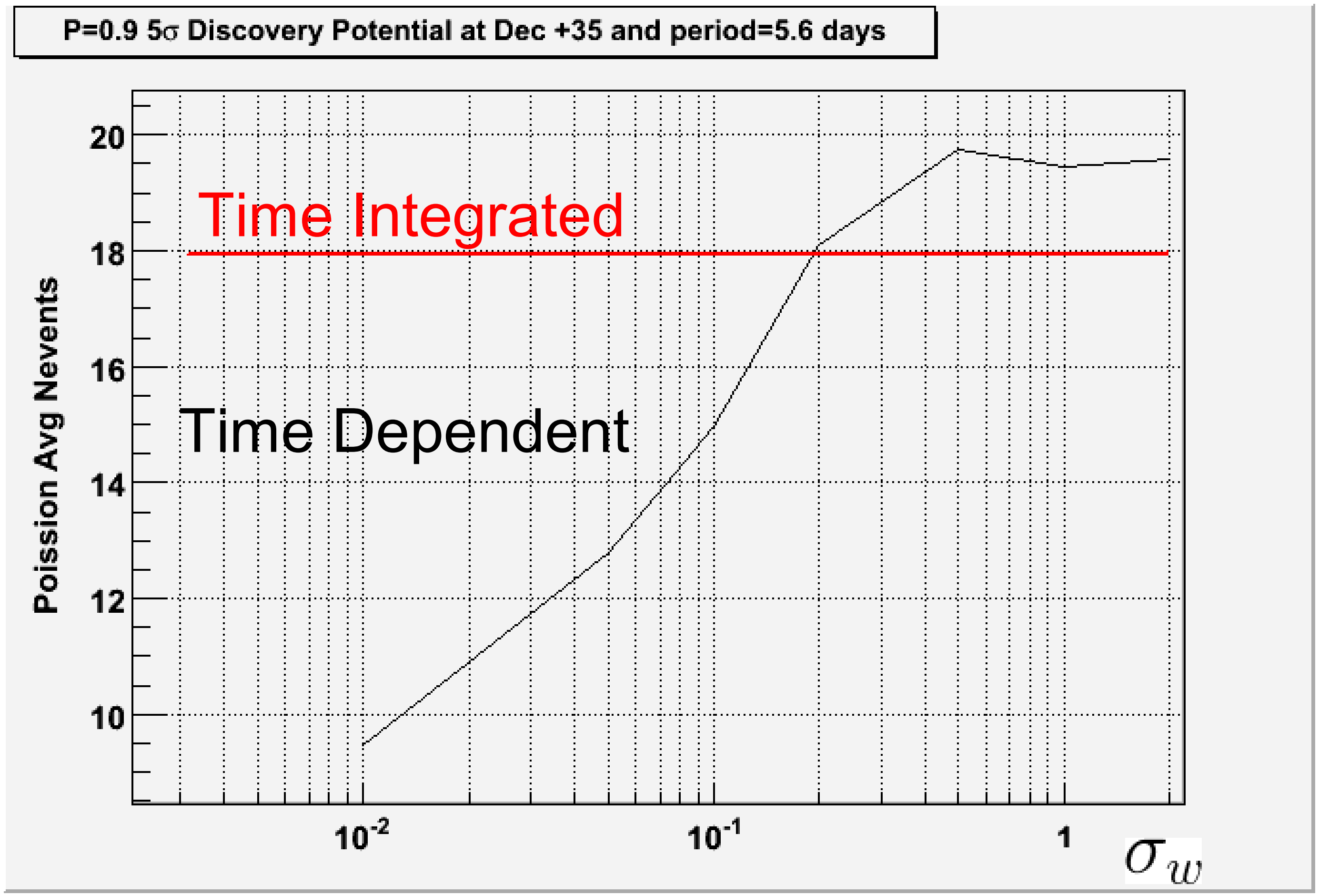
Here we take the same idea as the hot spot and look for a Gaussian from the events' time modulo the period of the particular object, which is known with good precision from other astronomical measurements.

$$S_i = \frac{1}{2\pi\sigma^2} e^{\frac{-|\vec{x}_i - \vec{x}_s|^2}{2\sigma^2}} * E(Nchan, \gamma) * \frac{1}{\sqrt{2\pi}\sigma_w} e^{\frac{-|\phi_i - \phi_e|^2}{2\sigma_w^2}}$$

σ_w : phase normalized to one period

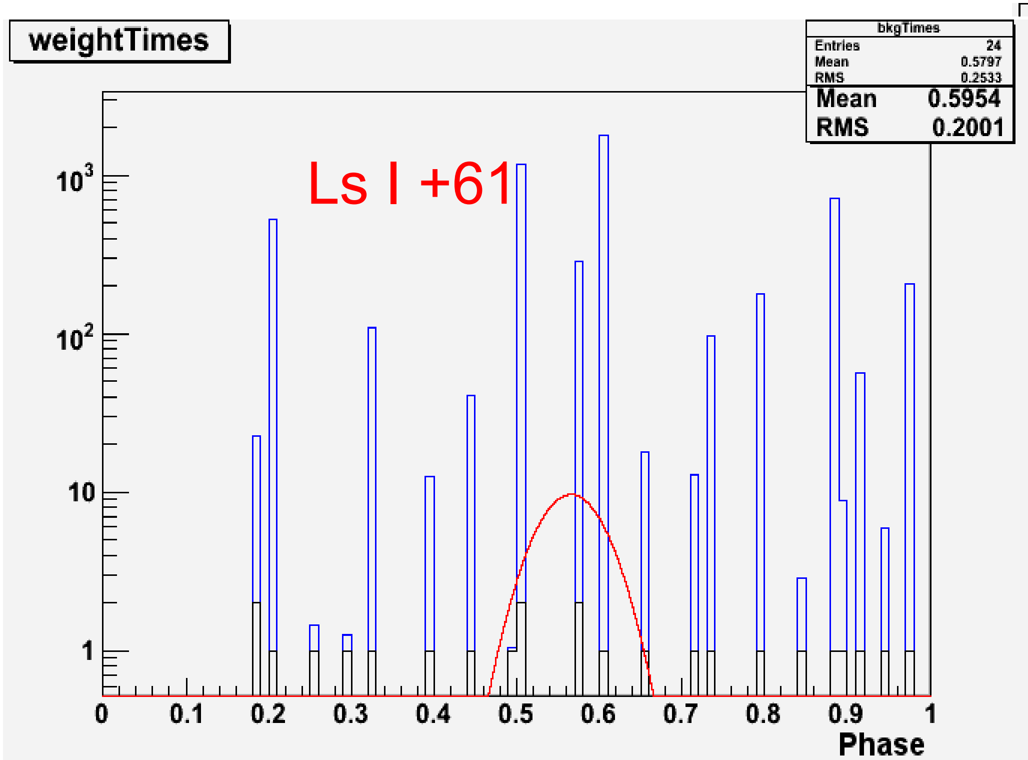
Discovery Potentials

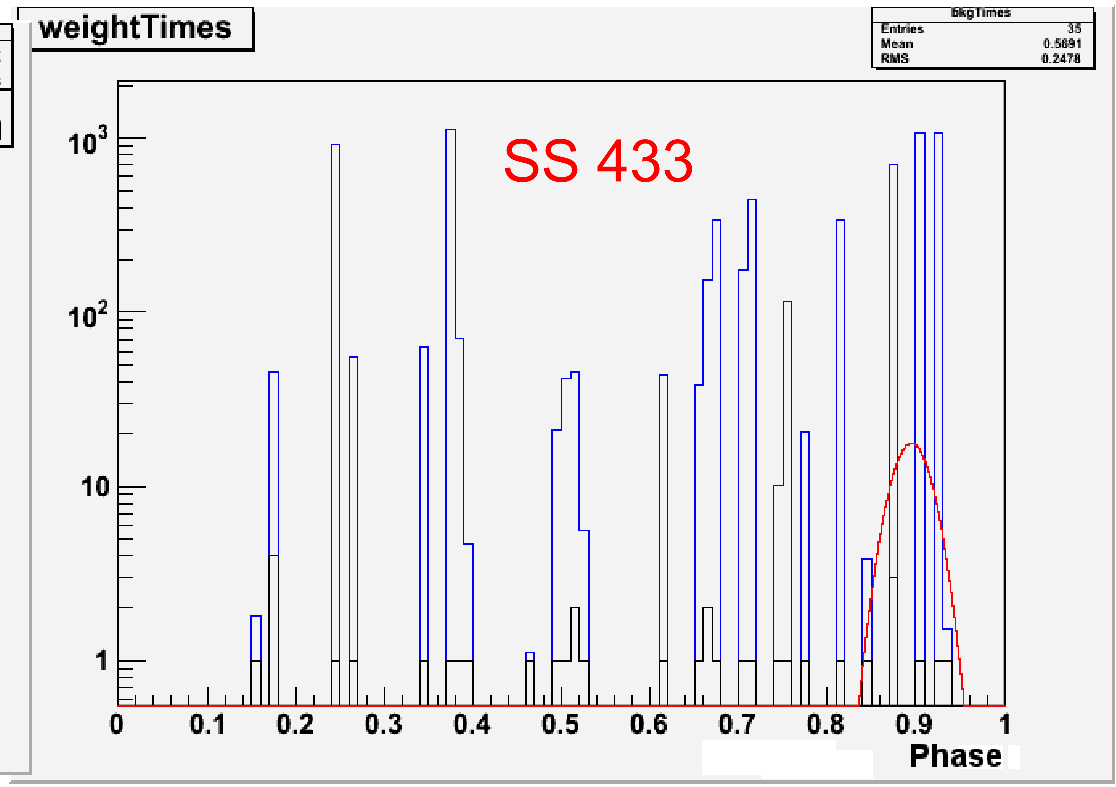
We found that the discovery potential is better than the time-integrated analysis if the sigma of the emission is less than one fifth of the period.



Microquasar Results

Here are two examples of the 7 microquasars, the events are plotted in phase. Black is the # events per bin, blue the space and energy in the bin, and red is the best-fit Gaussian reconstruction.





The smallest p-value pretrial we got for the microquasar analysis is 0.06 for SS 433, which isn't significant given we looked at 7 objects

IC-22 Multiwavelength Flares Search

Interested in testing for correlation between neutrino emission and multiwavelength observations of high states in astronomical objects

S5 0716
Lightcurve

R

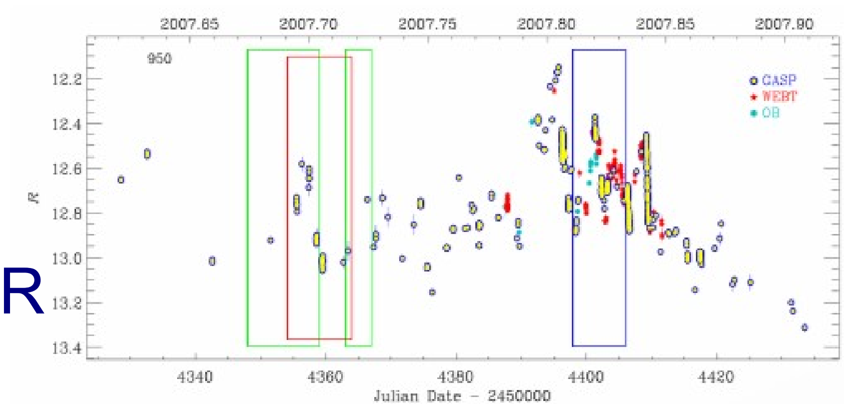


Fig. 1. *R*-band light curve of 0716+714 in August–November 2007, composed with data from the GASP (blue, yellow-filled circles) and from other WEBT telescopes (red stars); the cyan filled circles labelled "OB" (i.e. "other bands") represent GASP *J*-band data converted to *R* band. The boxes indicate various periods of AGILE observations, as explained in the text.

F (Jy) @37 GHz

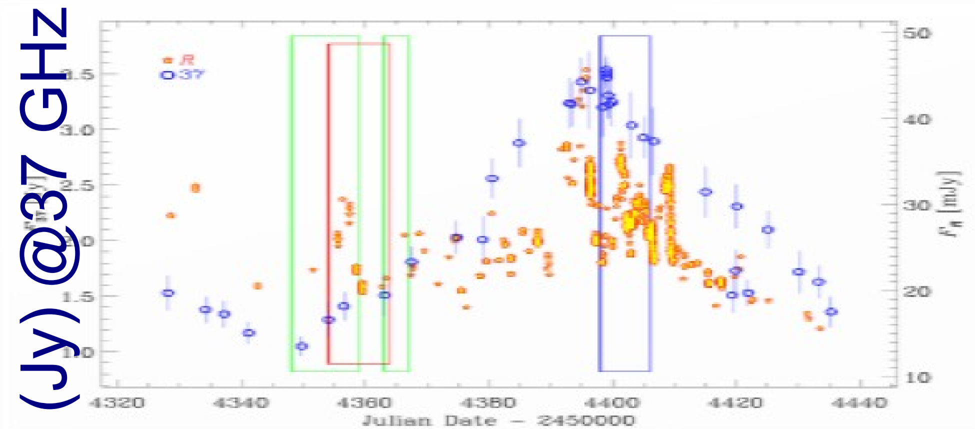


Fig. 4. 37 GHz light curve of 0716+714 in August–November 2007 (blue circles) compared to the *R*-band flux densities in the same period (red, yellow-filled stars), rescaled to have the optical and radio maxima at the same level.

Images from http://arXiv.org/pdf/0802.3012v2

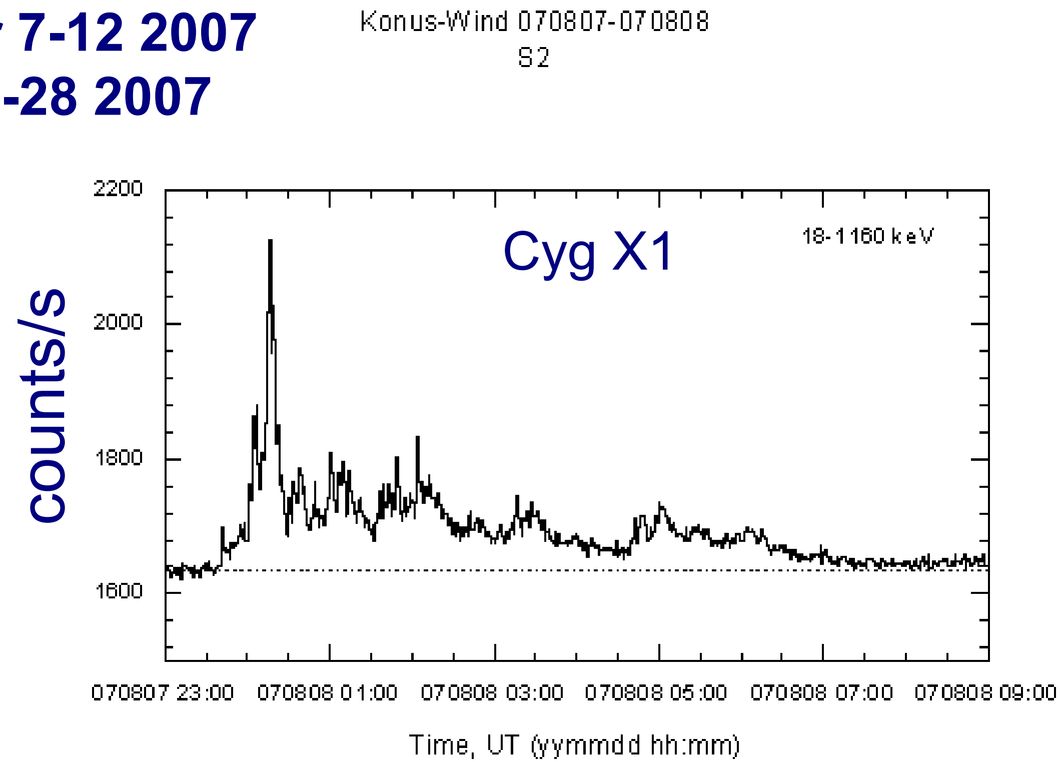
IC-22 Multiwavelength Flares Search

3C 454.3: July 24-30 2007 and Nov. 11-21 2007

1ES 1959: Nov 25-28 2007 and Dec 2-7 2007

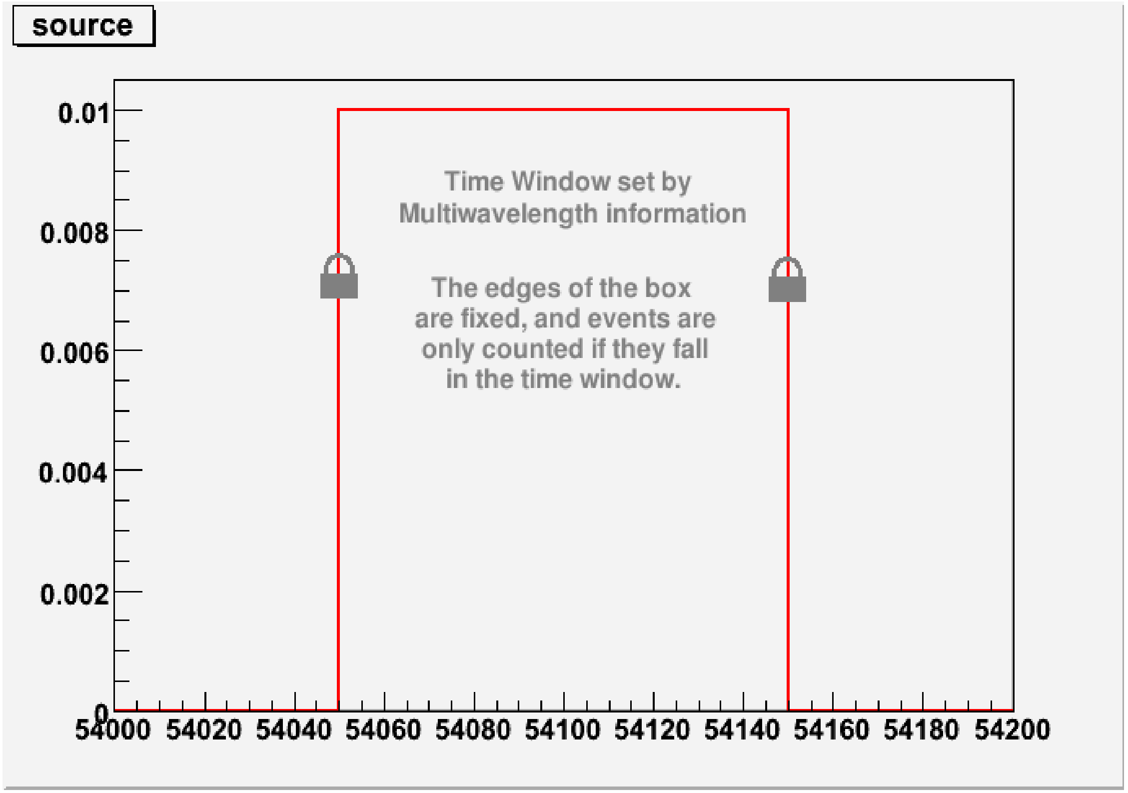
Cygnus X-1: August 8 2007

S5 0716+71: September 7-12 2007
and Oct 19-28 2007



Flares Method

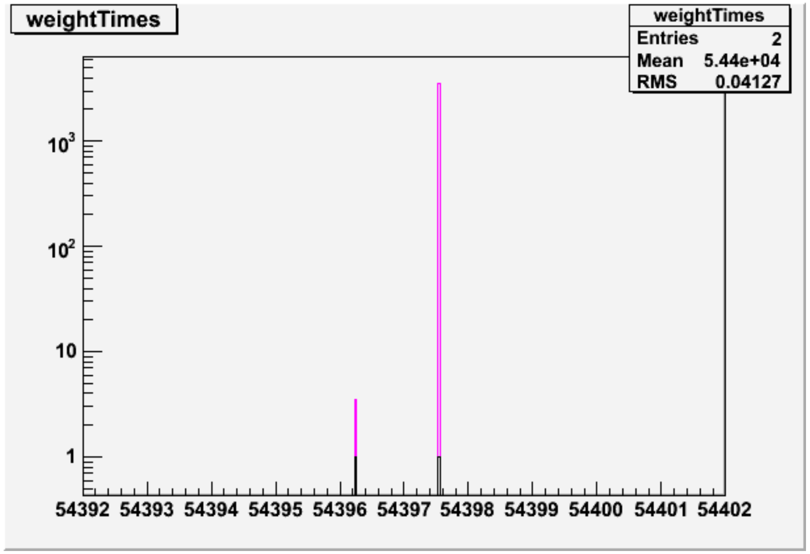
We used the lightcurves to define a time-window of interest, and tested if the events which contributed in the unbinned analysis came in our time window.



5 of 7 time windows returned under-fluctuations (), two time windows show events:

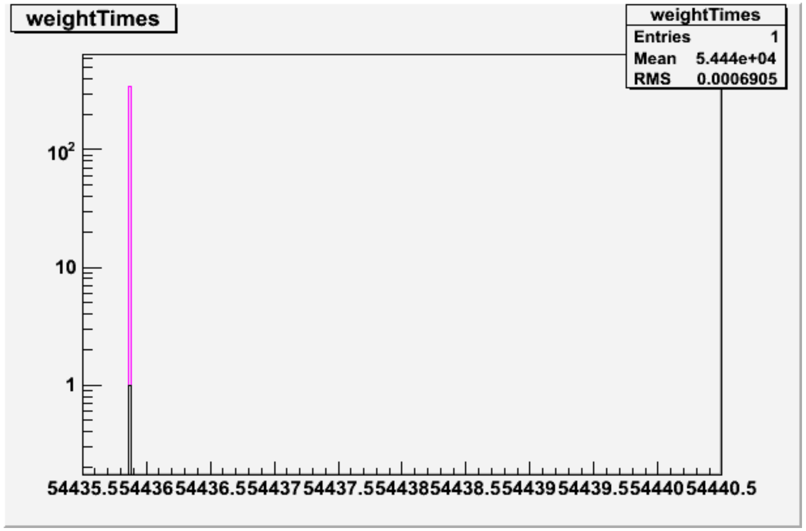
S5 0716+71 Oct 19-28 2007

p=0.02
nsrc=0.99

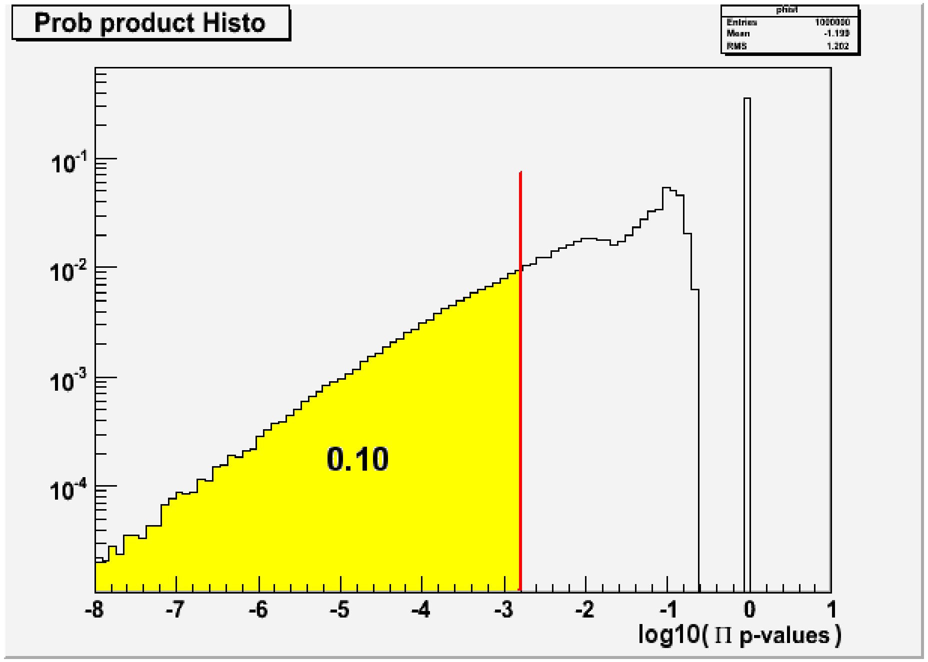


1ES 1959+650 Dec 2-7 2007

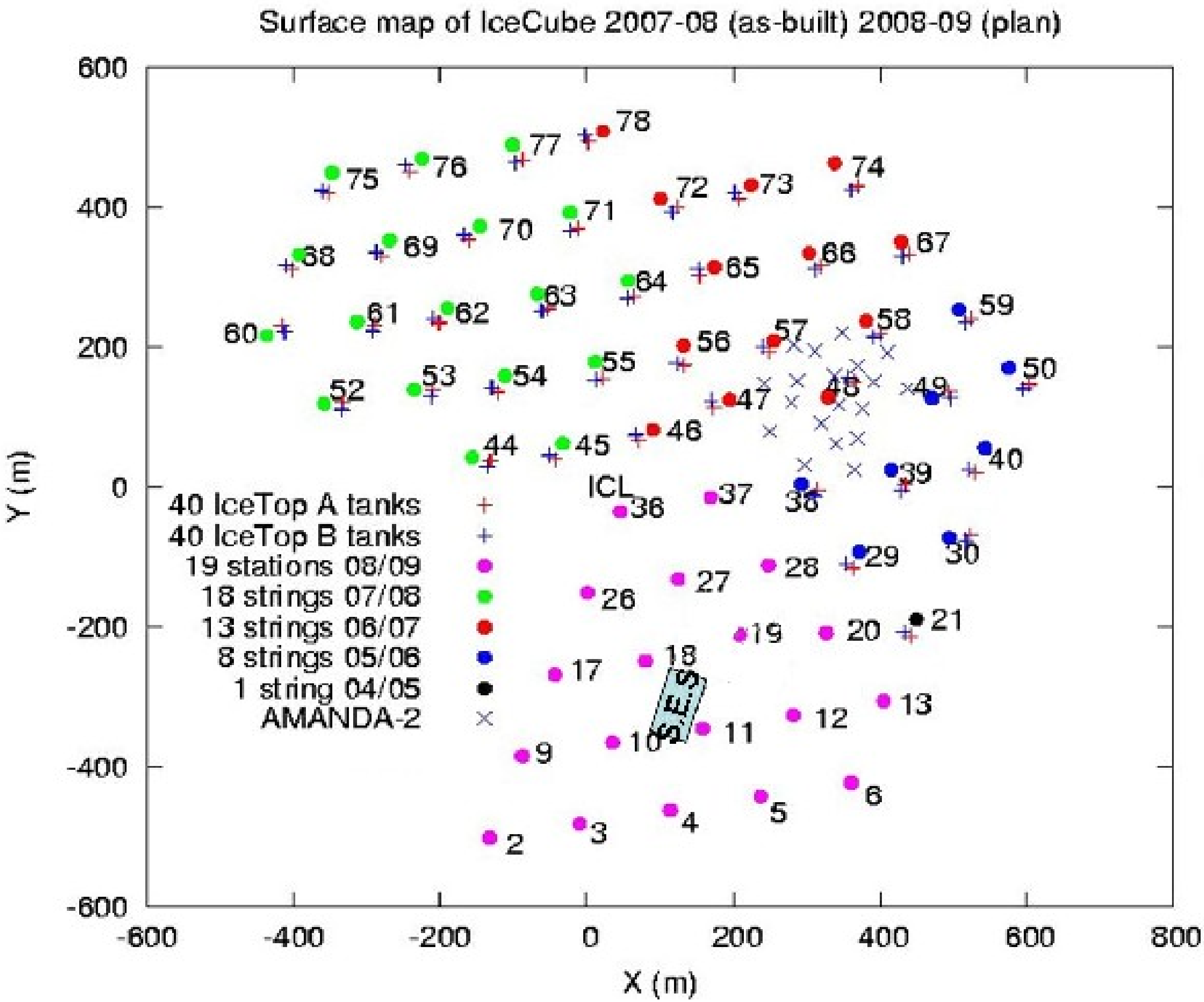
p=0.08
nsrc=0.76



We took samples of random p-values for all 7 time windows we looked at, and find that the product of the p-values is less than 0.02*0.08=0.0016 in 10% of trials.



With the IceCube 22 string dataset, we tested several different time-dependent hypotheses in conjunction with the pointsource analysis.



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Confidence level of the test is the fraction of scrambled background trials which yield higher values for the log likelihood.

Detection is for 5σ confidence level (p=5.73e-7)

The power is the fraction of trials with a particular level of signal which yield higher values of the log likelihood.