

IceCube



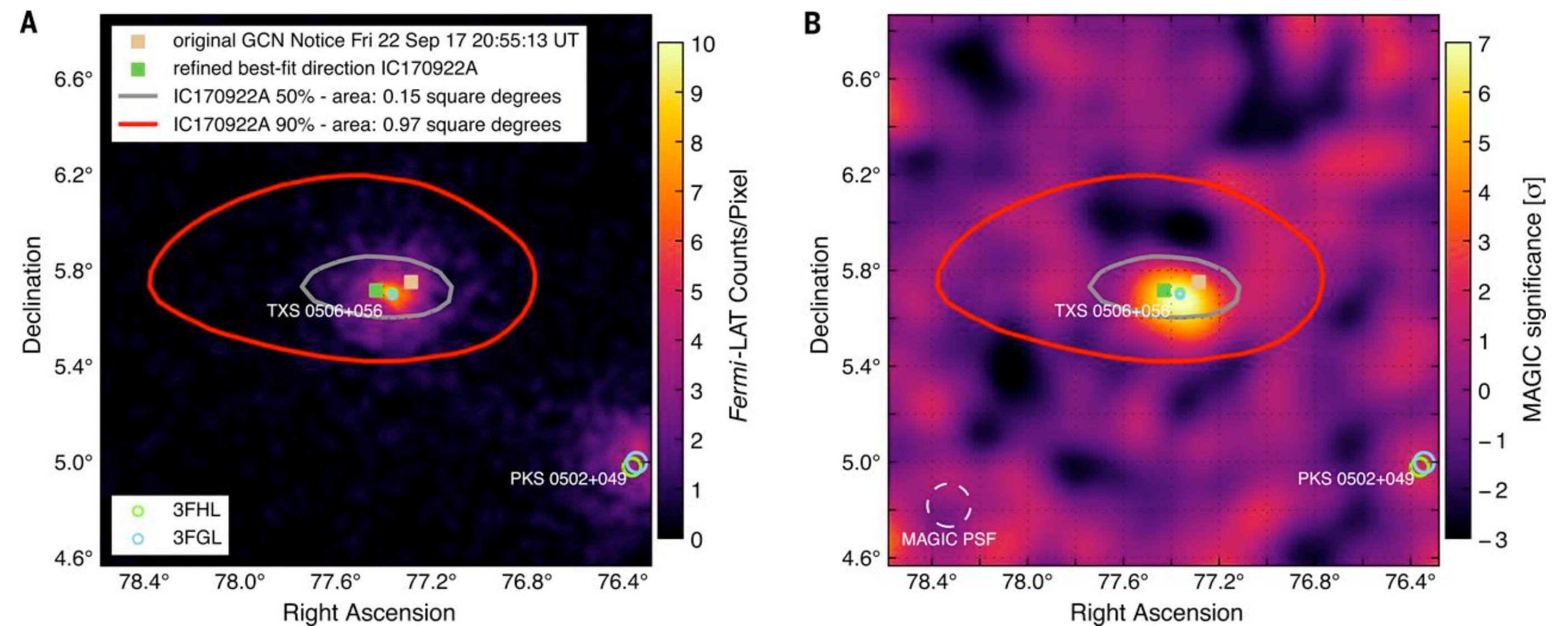
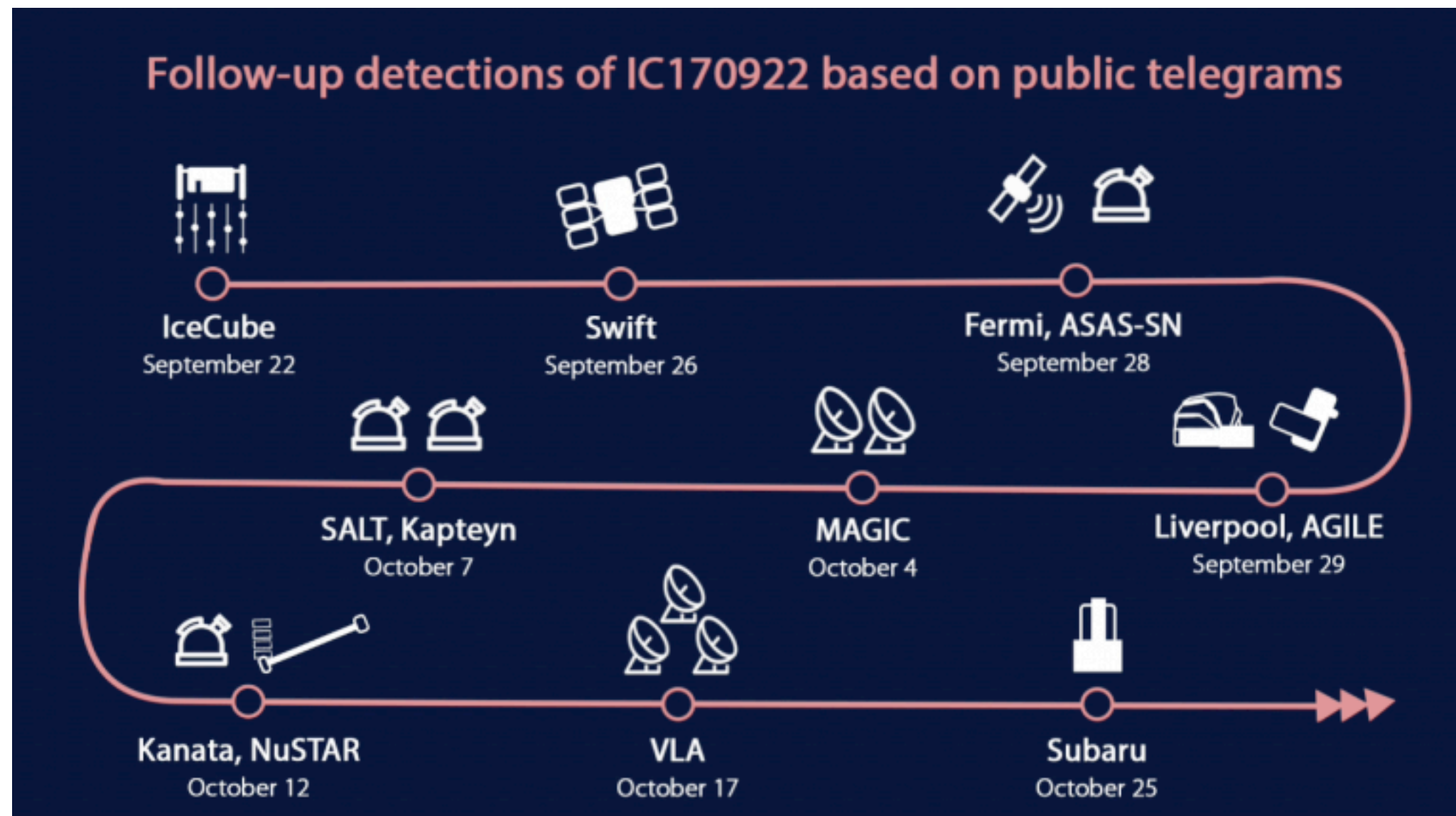
UNIVERSITÉ
DE GENÈVE

Search for neutrinos from the blazar TXS 0506+056 using 10 years of IceCube data

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for the IceCube Collaboration

Motivation

- ▶ IceCube-170922A alert due to a single EHE event with an intensive follow-up campaign
- ▶ Spatial and time coincidence with HE gamma-rays from TXS 0506+056



A. Franckowiak talk

➔ **This search:** Test if the blazar TXS 0506+056 has been a potential source of high-energy neutrinos beyond the single EHE event

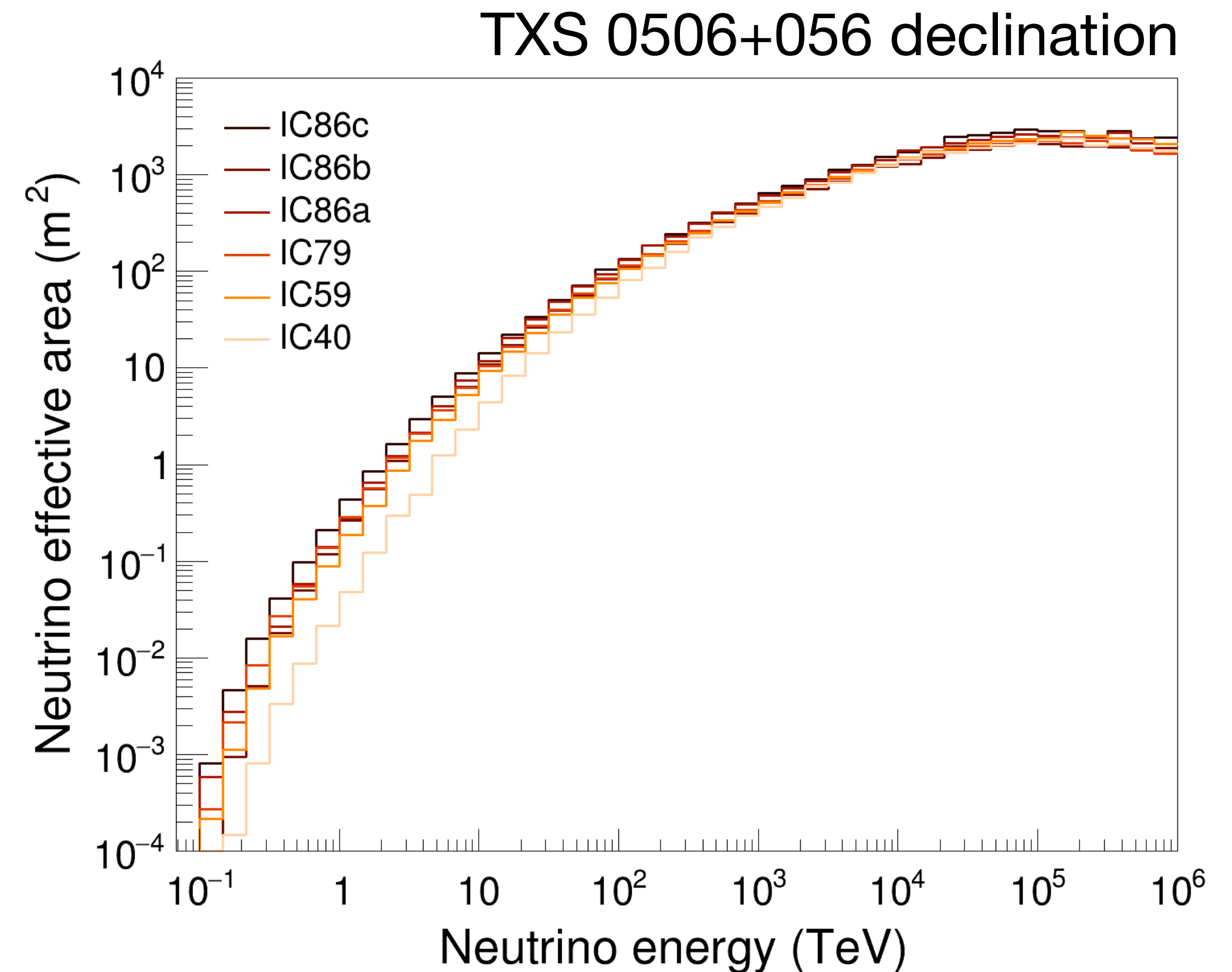
Neutrino search from TXS 0506+056

- ▶ Analysis of **6 distinct data periods** with changing detector configurations, data-taking conditions, and improved event selections

Partial detector configurations

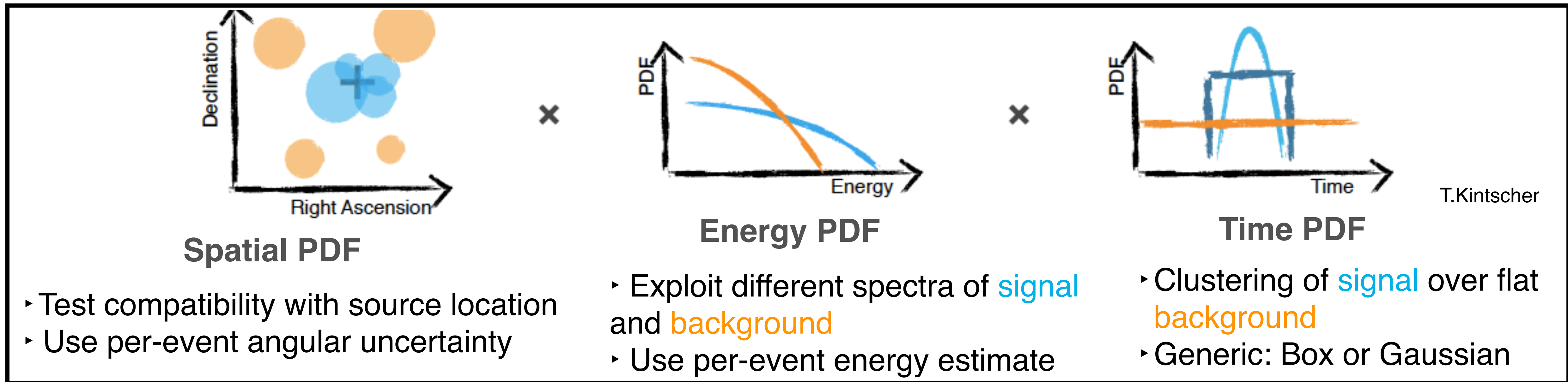
Sample	Start	End
IC40	2008 Apr 5	2009 May 20
IC59	2009 May 20	2010 May 31
IC79	2010 May 31	2011 May 13
IC86a	2011 May 13	2012 May 16
IC86b	2012 May 16	2015 May 18
IC86c	2015 May 18	2017 Oct 31

Up to $> \sim 1$ month after the alert



Neutrino search from TXS 0506+056

- ▶ **Unbinned maximum likelihood method:** $\mathcal{L} = \prod_i^{\text{events}} \left[\frac{n}{N} S_i + \left(1 - \frac{n}{N} \right) B_i \right]$ Astroparticle Physics 33, 175 (2010)

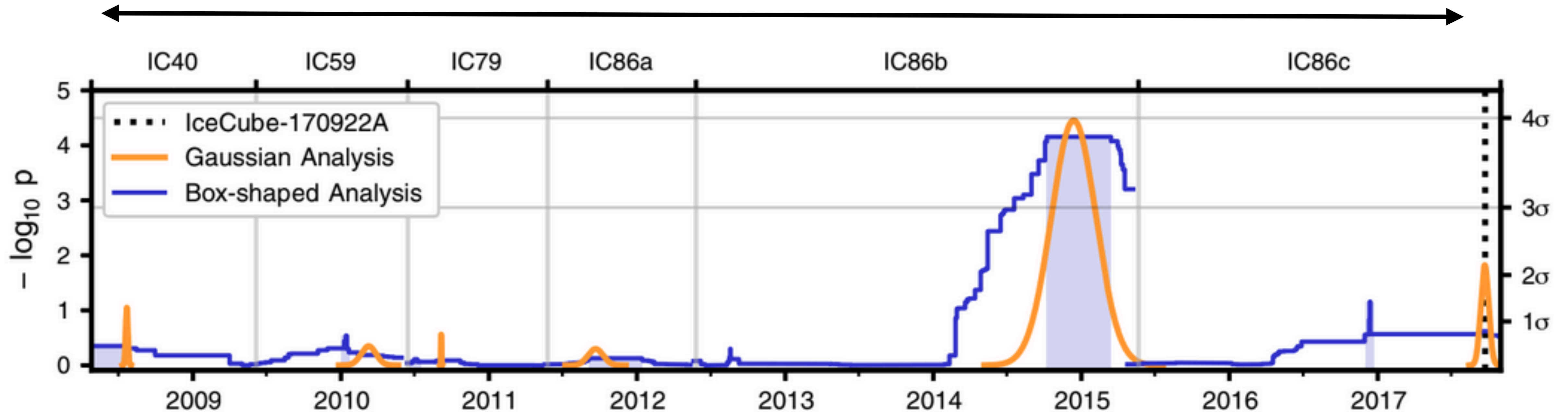


- ▶ **Time-integrated approach:** $TS = 2 \log(\mathcal{L}(\Phi_{100}, \gamma) / \mathcal{L}(\Phi_{100} = 0)) \Rightarrow$ **Best-fit values: (n, γ)**

- ▶ **Time-dependent approach:** $TS = 2 \log \left[\frac{T_W}{T} \times \frac{\mathcal{L}(\Phi_{100}, \gamma, T_0, T_W)}{\mathcal{L}(\Phi_{100} = 0)} \right] \Rightarrow$ **Best-fit values: (n, γ , T_0 , T_W)**

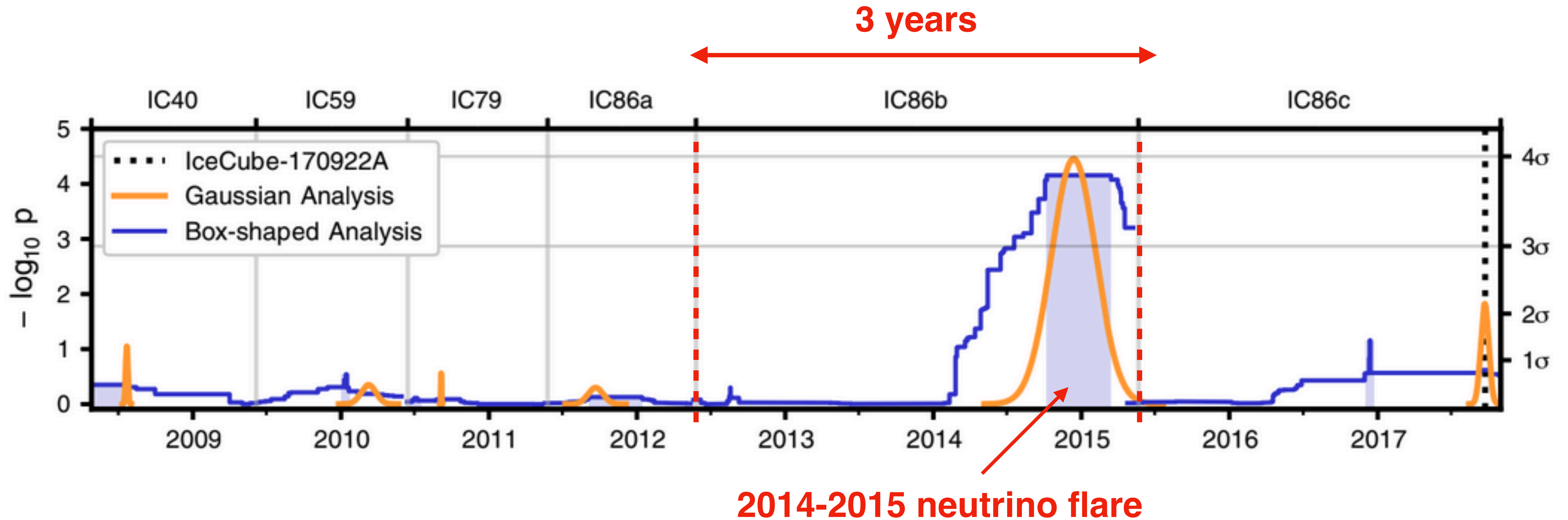
Time-dependent results at TXS 0506+056

6 independent analyses periods



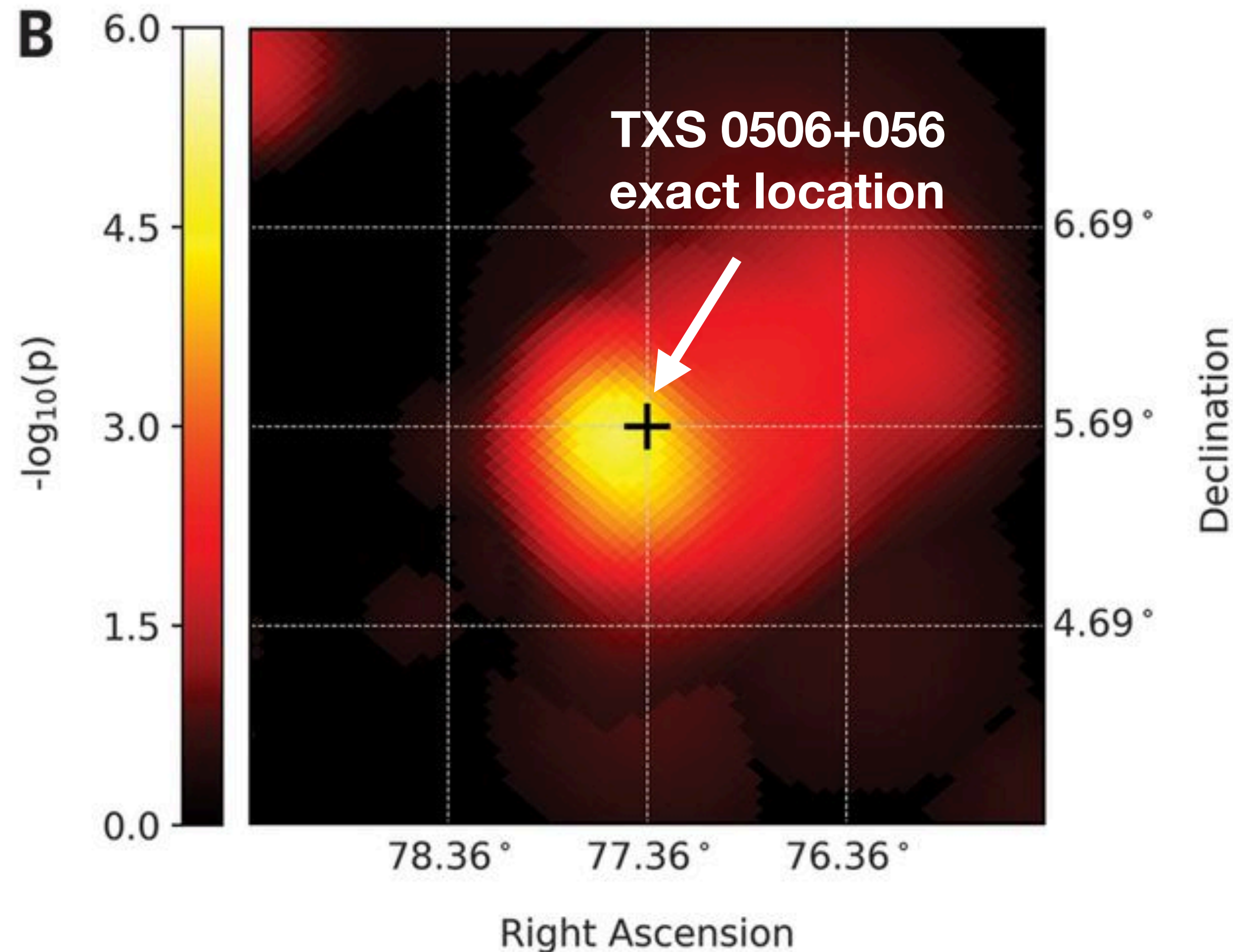
- ▶ Best-fit flares are given for each analyzed data sample

Time-dependent results at TXS 0506+056



2014-2015 neutrino flare

Significance map around TXS 0506+056



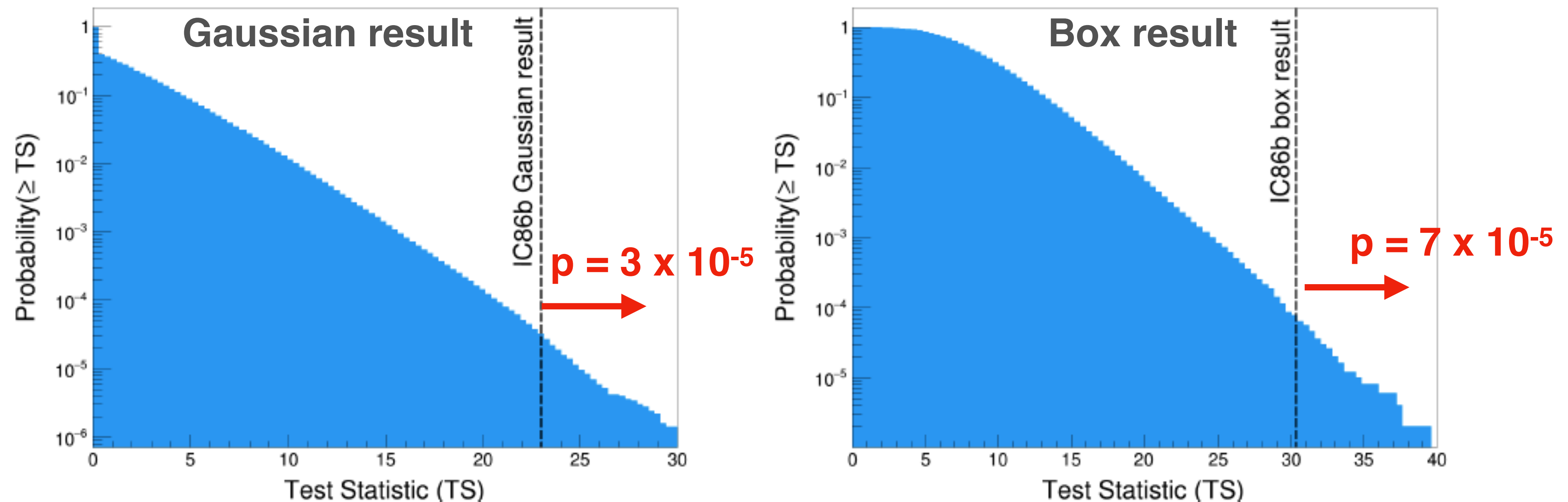
2012-2015 period	Gaussian PDF	Box PDF
ns	13	14
γ	2.1	2.2
Width	110 days	158 days
Time	2014-12-13	2014-12-26
Significance	3×10^{-5}	7×10^{-5}

- ▶ Signal identified during **5-month period** with an excess of **13 +/- 5** muon-neutrino events
- ▶ Clear separation from PKS 0502+049: **1.22°** away from TXS

2014-2015 neutrino flare

Chance probability

- ☑ Generate random realizations allowing a new fit for Φ_{100} , γ , T_0 , T_w in each trial

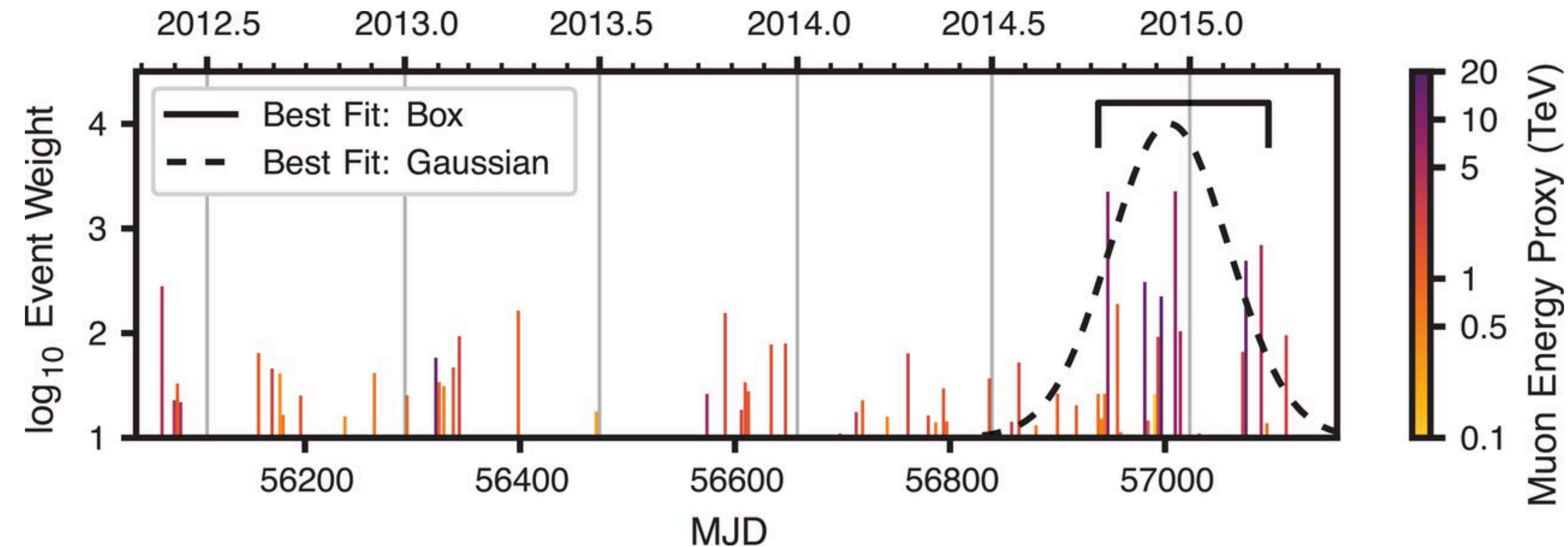


- ☑ Correct for the ratio of the total observation time to the IC86b observation time (9.5 years/3 years)
➔ The final significance is 3.7σ using the Gaussian time profile and 3.5σ using the box time profile

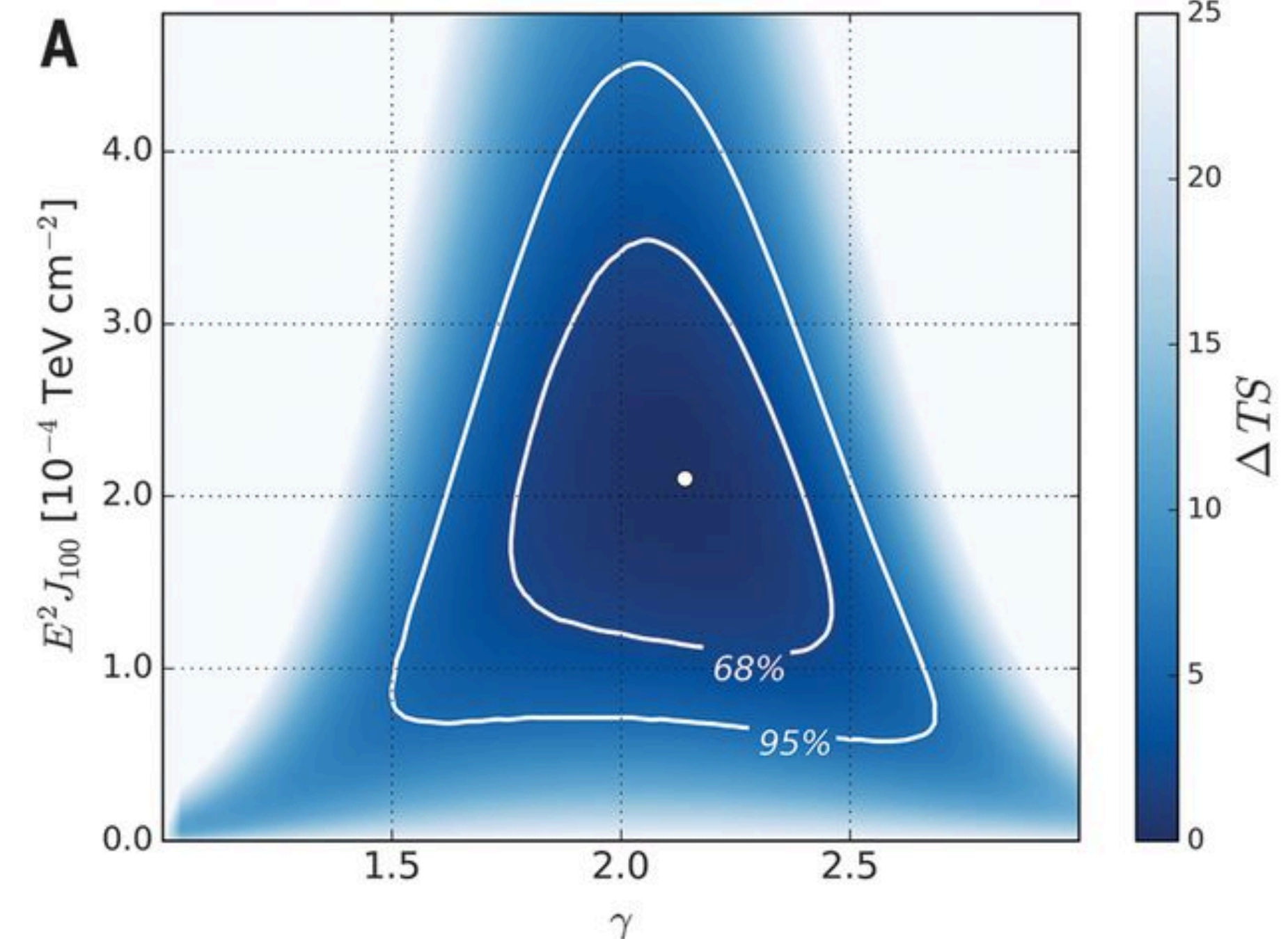
Post-trial significance = 3.5σ

2014-2015 neutrino flare

- ▶ The significance of the excess is due to both the **number of events and their energy distribution**
- ▶ Higher energy events increasing the significance and leading to the best fit $\gamma = 2.1$



Time-independent event weights assuming $\gamma = 2.1$

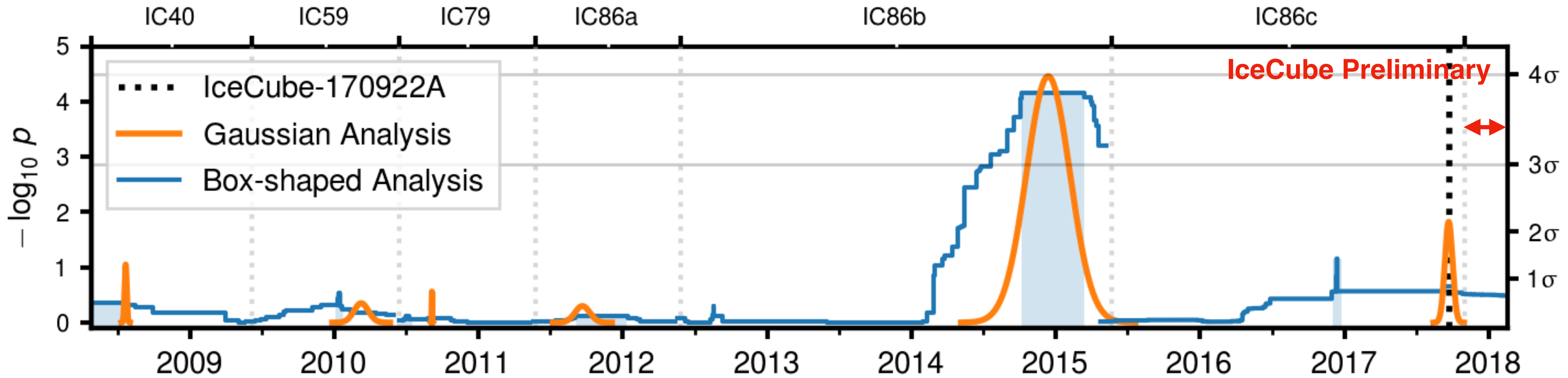


Fluence: $E^2 J_{100} = 2.1^{+0.9}_{-0.7} 10^{-4} \text{ TeV cm}^{-2}$ at 100 TeV
spectral index $\gamma = 2.1 \pm 0.2$

Time-dependent results at TXS 0506+056

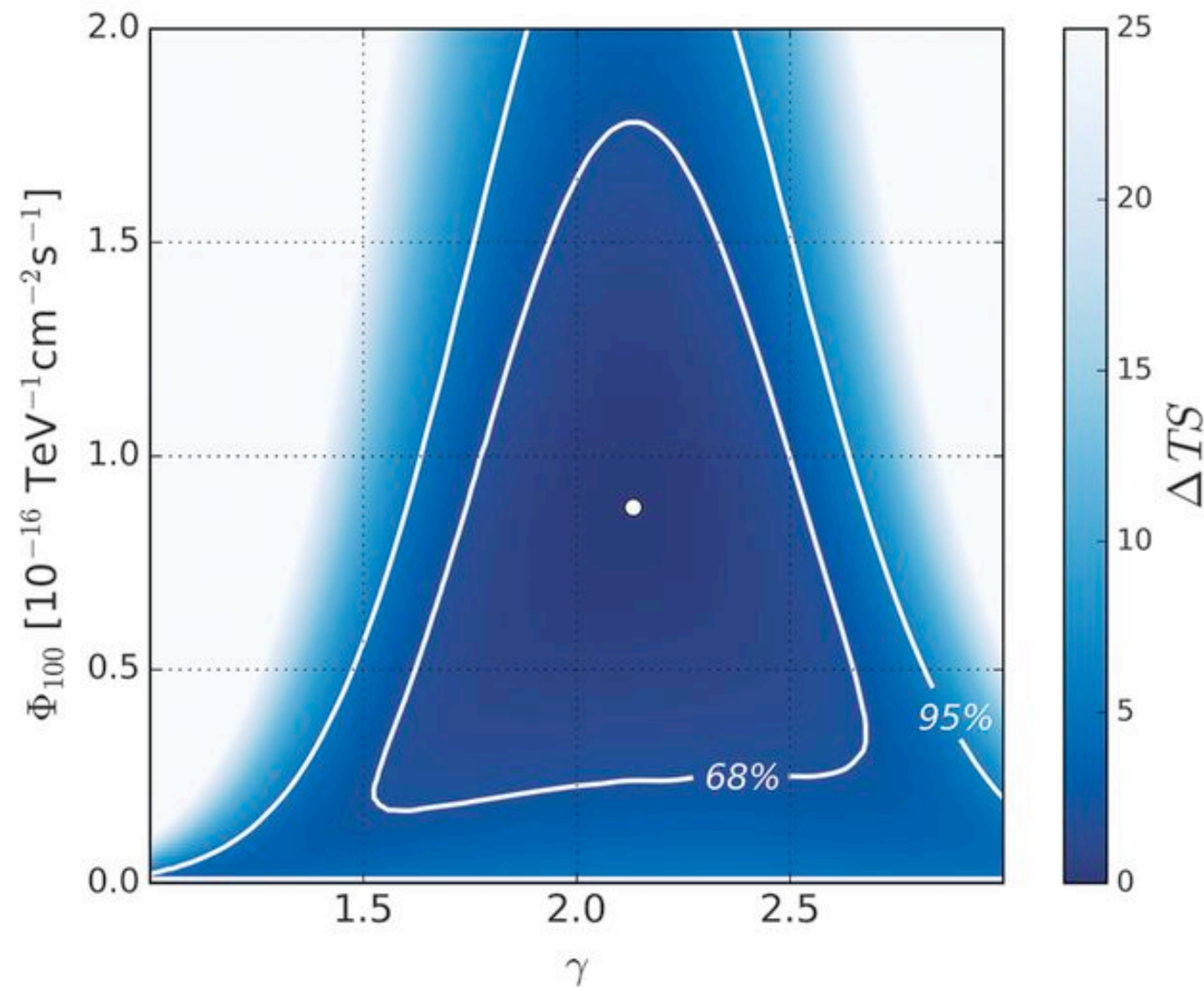
- ▶ The next most significant excess is found in 2017 using the Gaussian time window driven by IceCube-170922A event
- ▶ No additional neutrinos contributing to the significance
- ▶ **Monitoring up to 2018-03-25**: no additional signal events in 2017

ns	1.4 +2.5/- 1.0
γ	1.7 +/- 0.6
Width	19 days
Time	2017-09-22
Significance	1.4 σ



Time-integrated results

- ▶ The significance found at TXS 0506+056 using **full data sample** is **4.1 σ** (a-posteriori significance)
- ▶ Removing the IC86c period (2015-2017) which contains the EHE event, the **p-value is 1.6%** (**2.1 σ**)

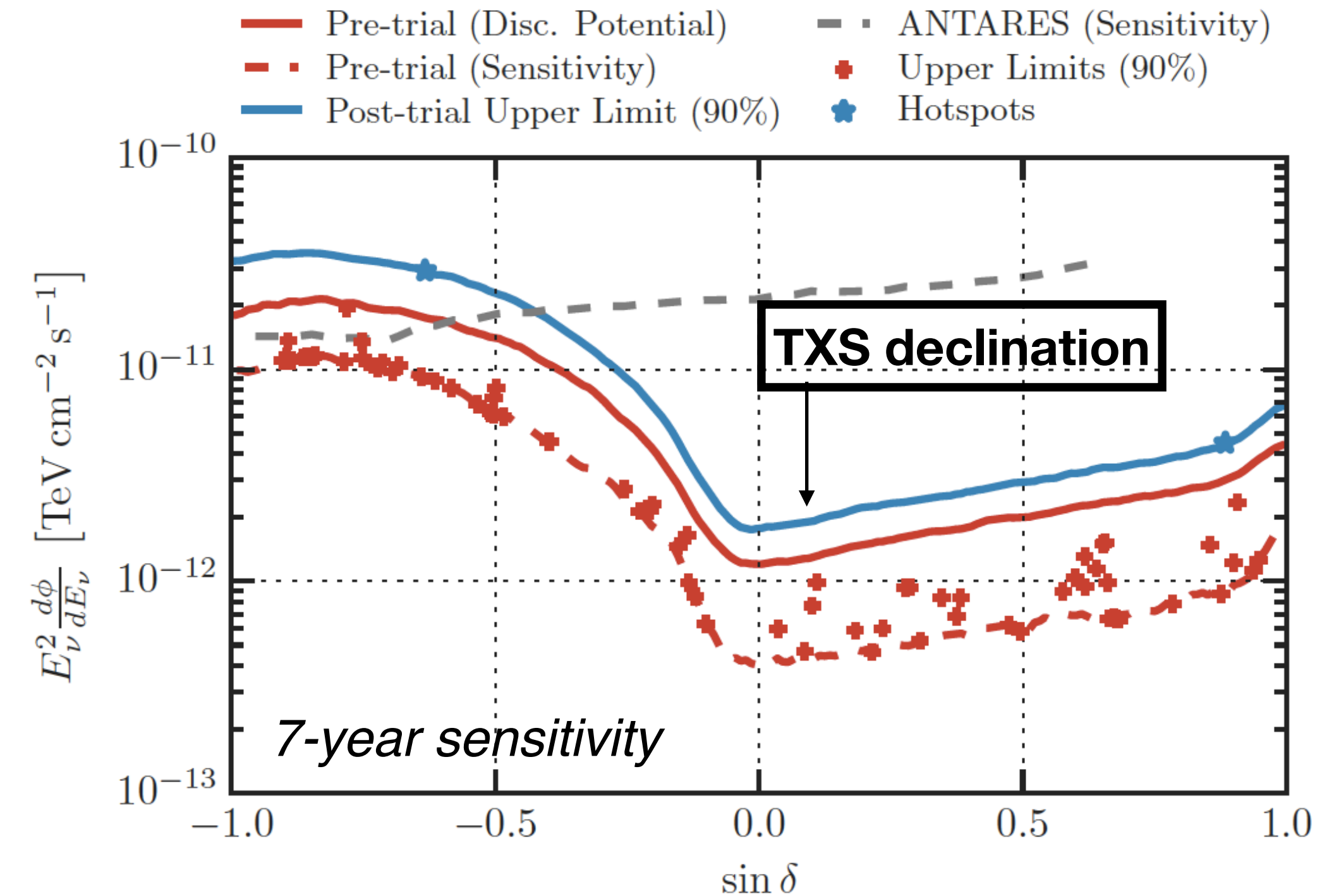


	Full sample	2008–2015
Φ_{100} ($\text{TeV}^{-1} \text{cm}^{-2} \text{s}^{-1}$)	$0.8^{+0.5}_{-0.4} \times 10^{-16}$	$0.9^{+0.6}_{-0.5} \times 10^{-16}$
γ	2.0 ± 0.3	2.1 ± 0.3

- ➔ Similar values for the **spectral index and total fluence:**
 $E^2 J_{100} = 2.0 \times 10^{-4} \text{ TeV cm}^{-2}$ at 100 TeV over the 7-year period
- ➔ The time-integrated fit is dominated by the **same excess** as found in the time-dependent analysis

TXS as a neutrino source

- IceCube is most sensitive to high-energy neutrinos from sources at declinations near the equatorial plane
- In the 3rd FERMI AGN catalog: **Among the 50 brightest objects**
- ➔ **Favorable combination of TXS0506+056 properties and the observational properties of the detector**

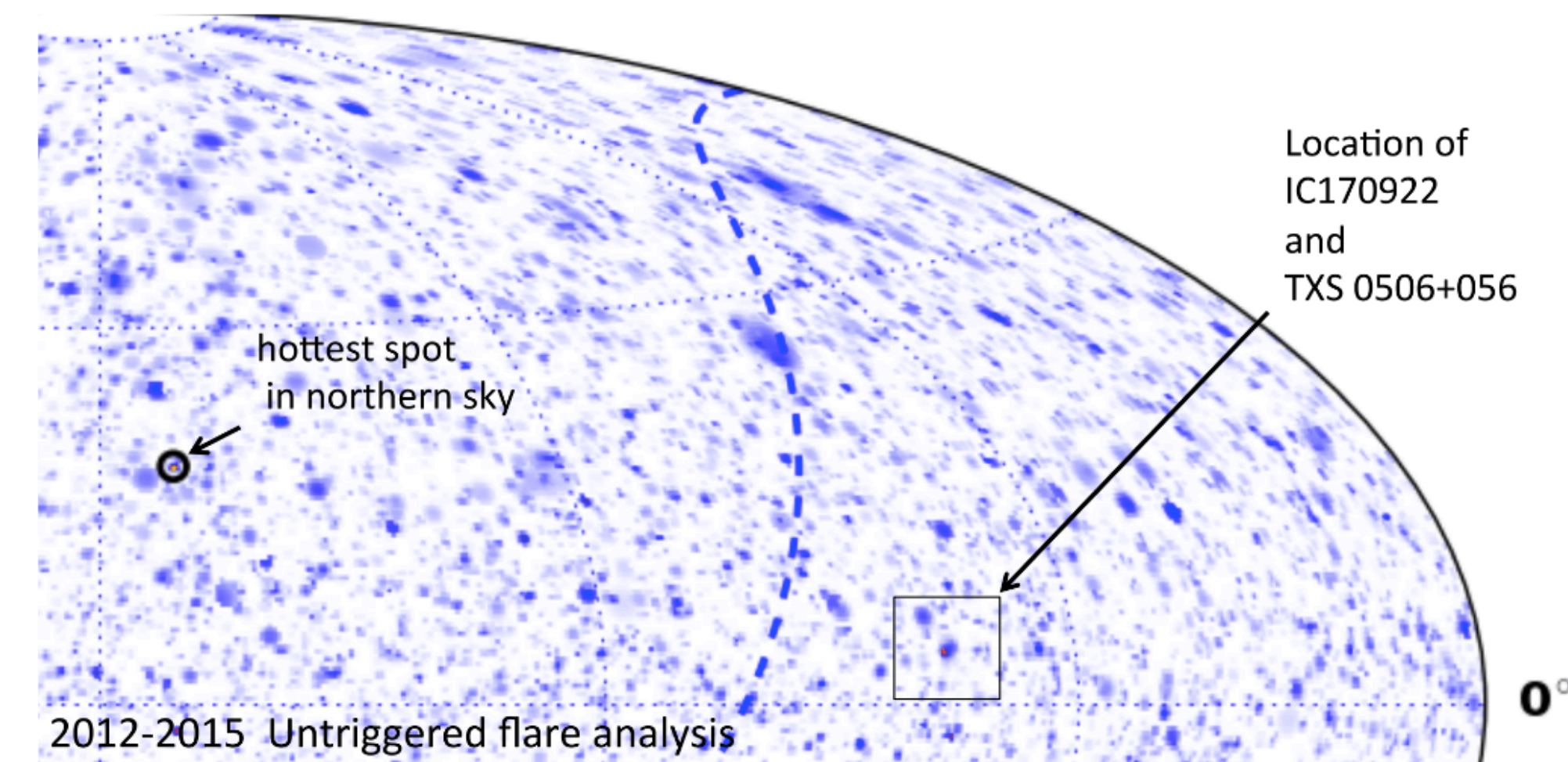


- **Isotropic ν luminosity [32 TeV – 3.6 PeV] > isotropic γ luminosity [100 MeV-100 GeV]**
- Absorption of gamma rays related to the neutrino production?
- Gamma rays arriving at energies above/ below the Fermi-LAT energy band?

talk by T. Glauch

Conclusion

- ▶ An archival search for neutrinos in the direction of TXS 0506+056 blazar identified **13 events in 5 months time period**
- ▶ No other accompanying neutrino in addition to the EHE event that triggered the alert is found
- ▶ TXS 0506+056 is found to be the **second brightest source in the Northern hemisphere in the time-dependent all-sky search** in 2012-2015 but not significant due to large trial factors
- ➔ The **multi-messenger program** enabled to pinpoint a location allowing the search for past flaring periods in a single direction



A. Christov. TeVPA 2016

TXS 0506+0560 is the first successful example paving the way for a further understanding of the gamma ray-neutrino relation in blazars