Searches for point sources and small-scale anisotropies with IceCube

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IceCube: the largest neutrino detector

- A neutrino detector located at the south pole

- 5160 DOMs (digital optical modules) are installed in a depth of 1450m to 2450m and 162 surface stations (IceTop)

- Goal: observe the universe through high energy neutrinos instead of light

IceCube Lab

50 m

1450 m

2450 m
2820 m

Deep Core

Eiffel-tornet

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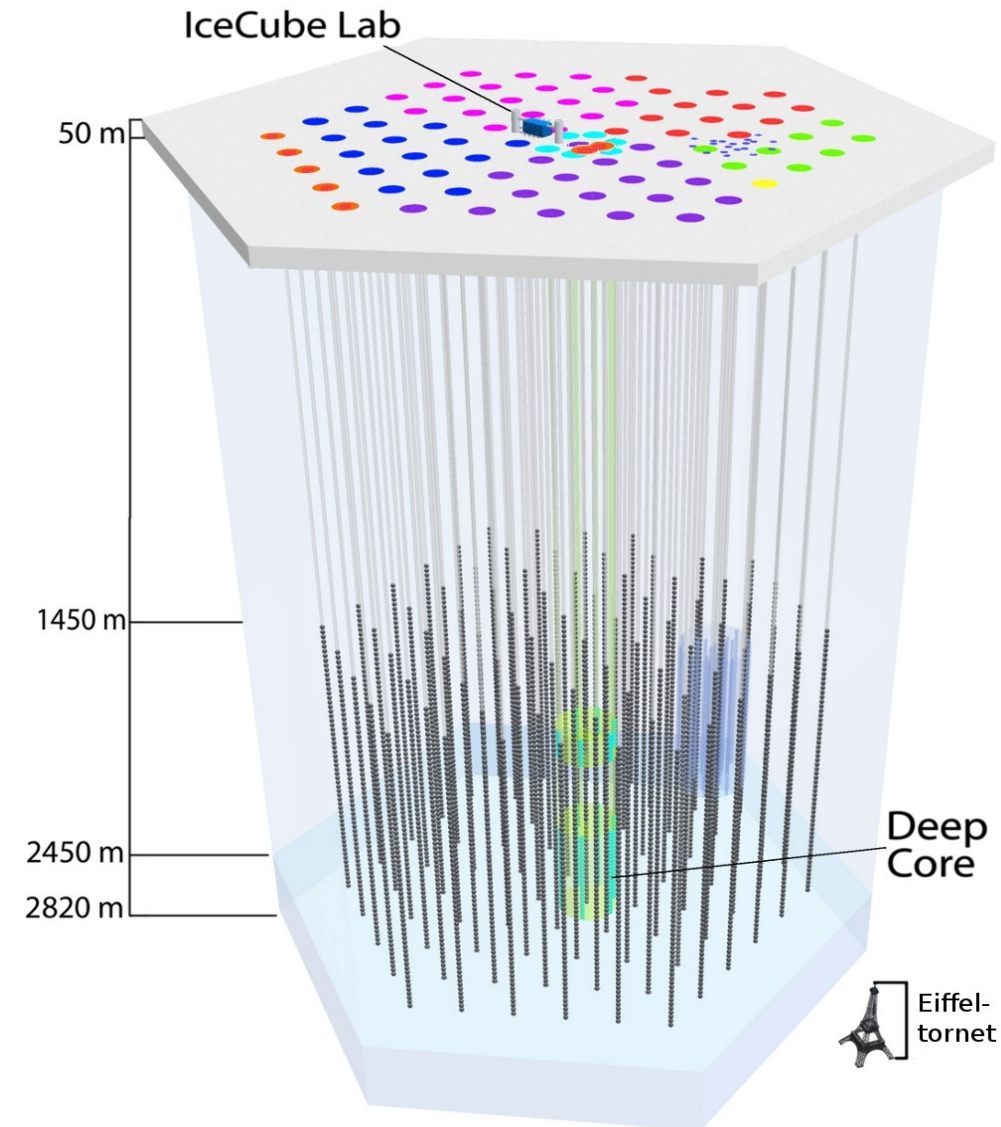
IceCube Configurations

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Motivation

Atm. neutrinos

Muon background
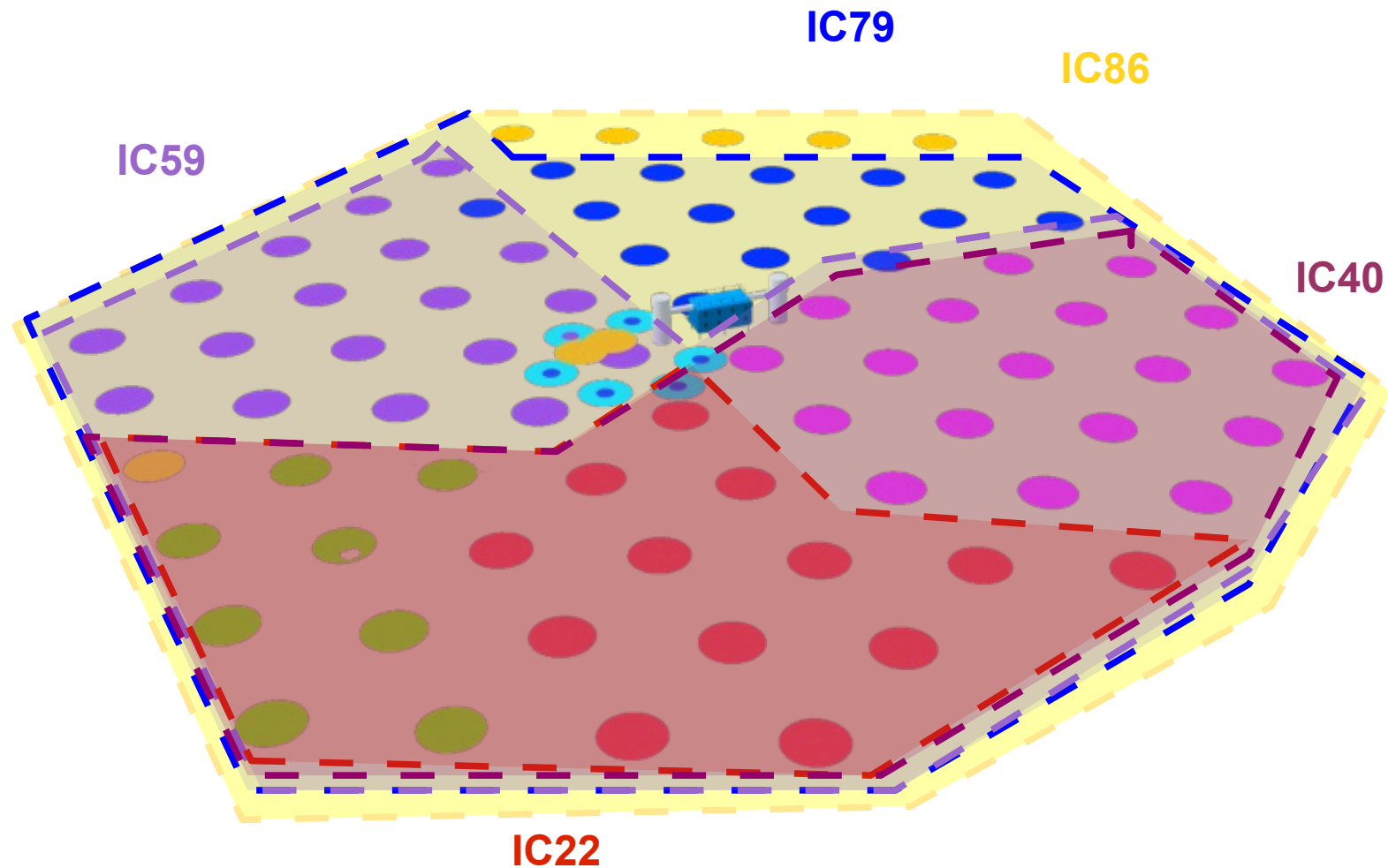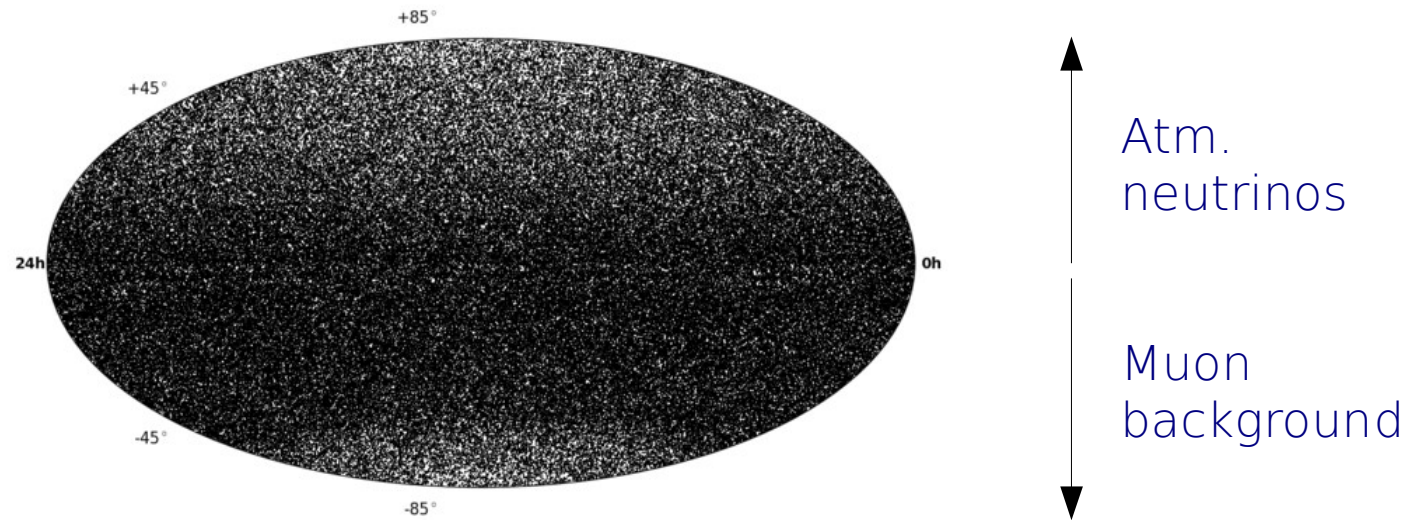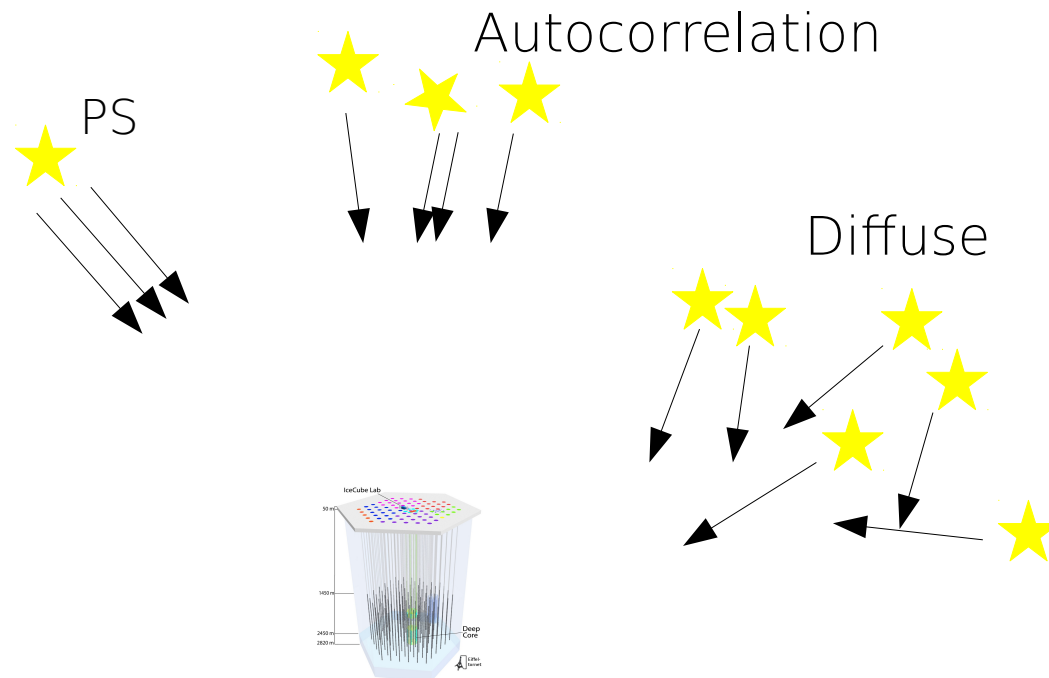
- Data sample with events selected on tracks
- The PS Likelihood is not seeing any strong source
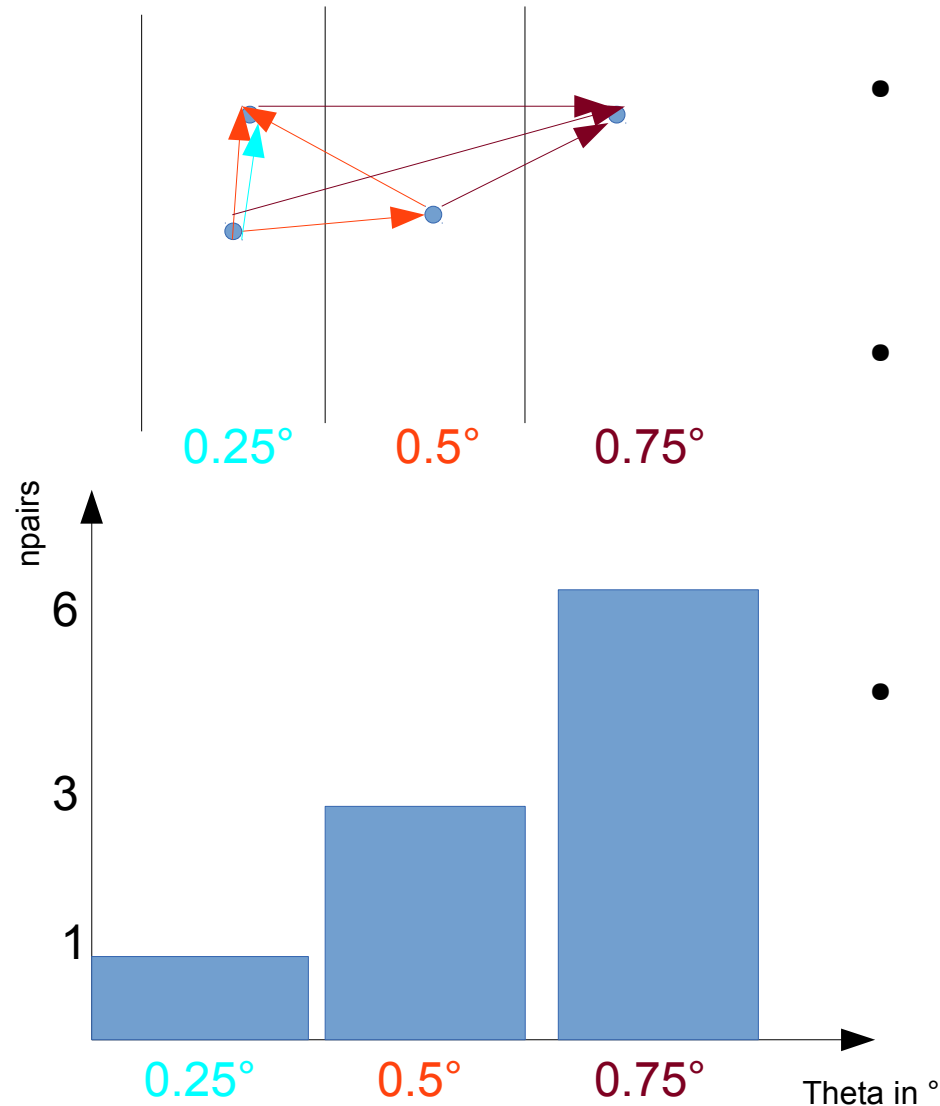- **Is there a hidden signal coming from various weak sources?**

Motivation

- 2 Searches for event clustering at angular scales comparable to detector resolution (small-scale anisotropies):
    1) Autocorrelation study of the full sky (3 years)
    2) Multi Point Source Study of the Cygnus region (4 years)

Autocorrelation

PS

Diffuse

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1) Autocorrelation Analysis of the full sky (3 years)
2) Multi Point Source Analysis of the Cygnus region (4 years)

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Search for Event Autocorrelations

- **Method**: Count the number of event pairs given a maximum angular separation

- Compare this to distributions from isotropic data, which comes from scrambled data (with randomized RA)

- The maximum angular separation can be varied

Finley, C. B., & Westerhoff, S. 2004, Astroparticle Physics, 21, 359

This autocorrelation study

- Use 3 years of IceCube data (IC40+IC59+IC79)

- Use four different energy bins (all events, 10% highest events, 1% highest, 0.1% highest) for a better background suppression

- Scan an angular scale from 0° to 5° in steps of 0.25°

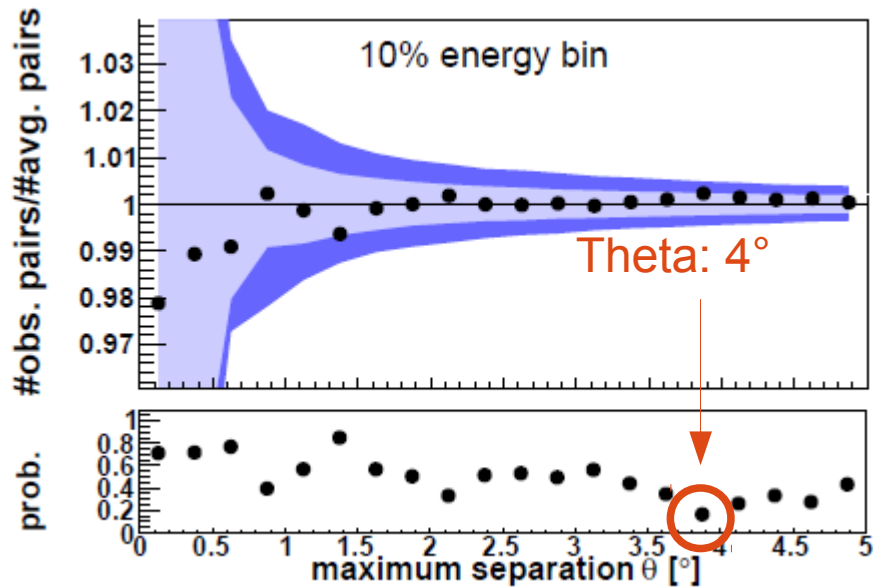- Look at north and south separately

  Challenges:

- Computationally not trivial since there will be many pair

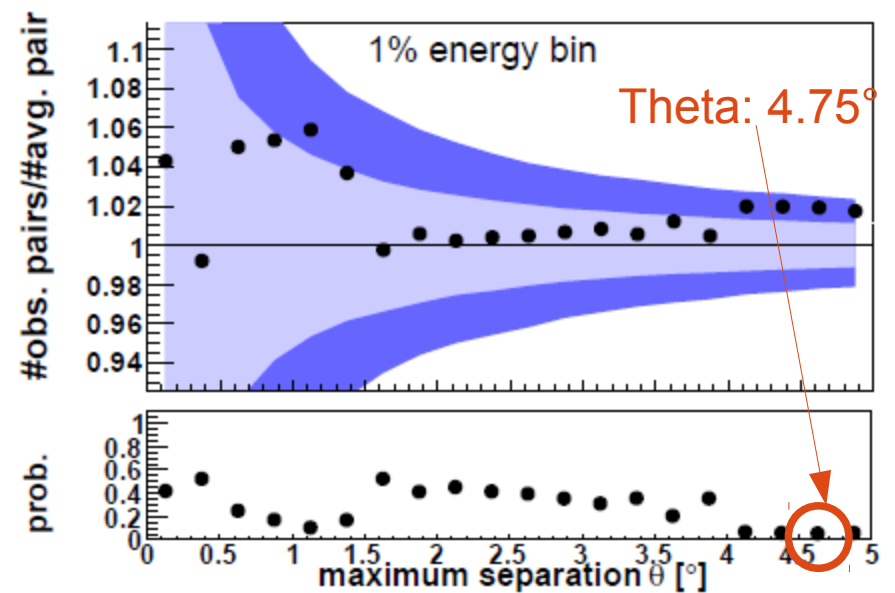 → Bachelor student Kevin Abraham working on a GPU implementation

Discovery Potential E⁻²
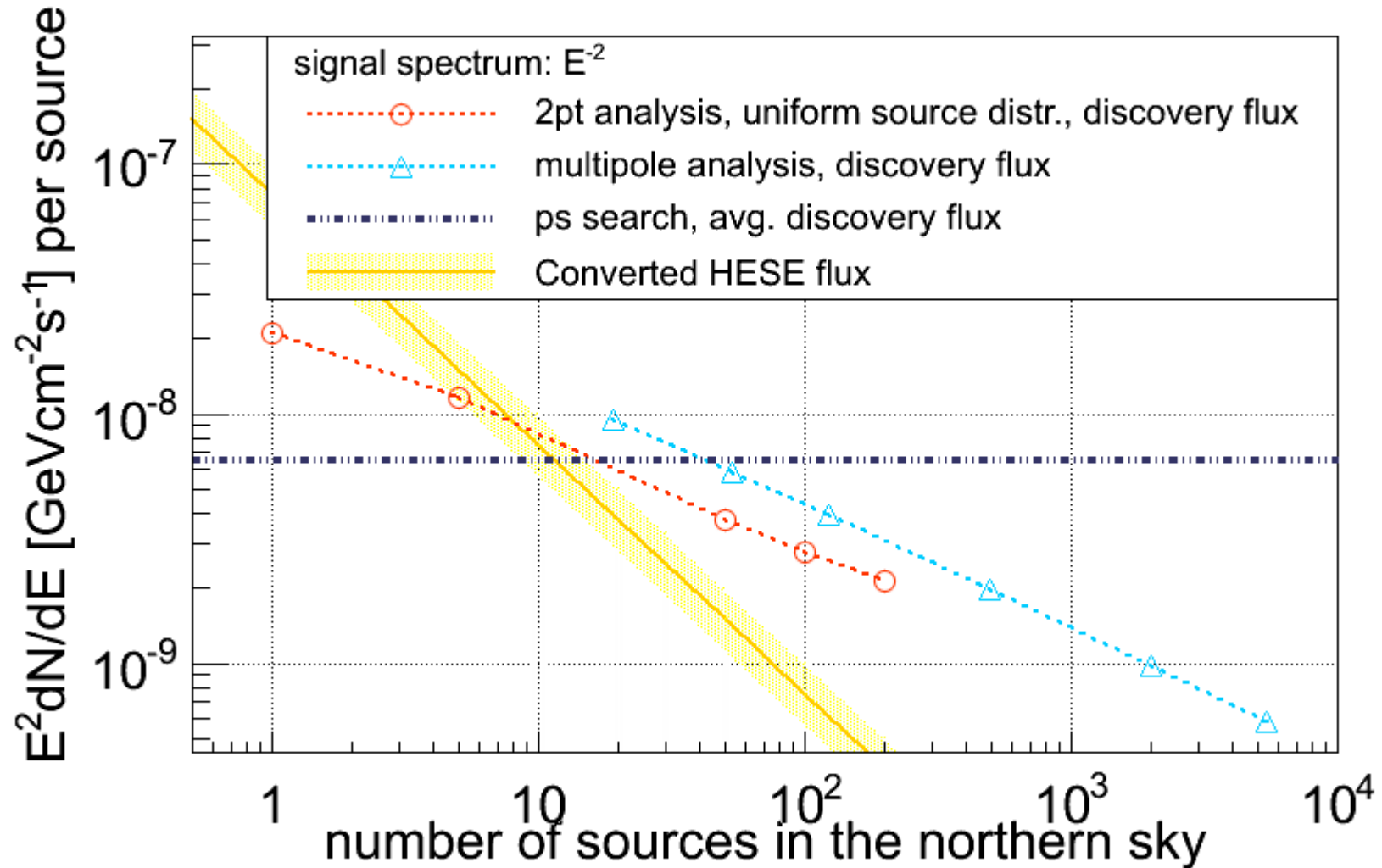
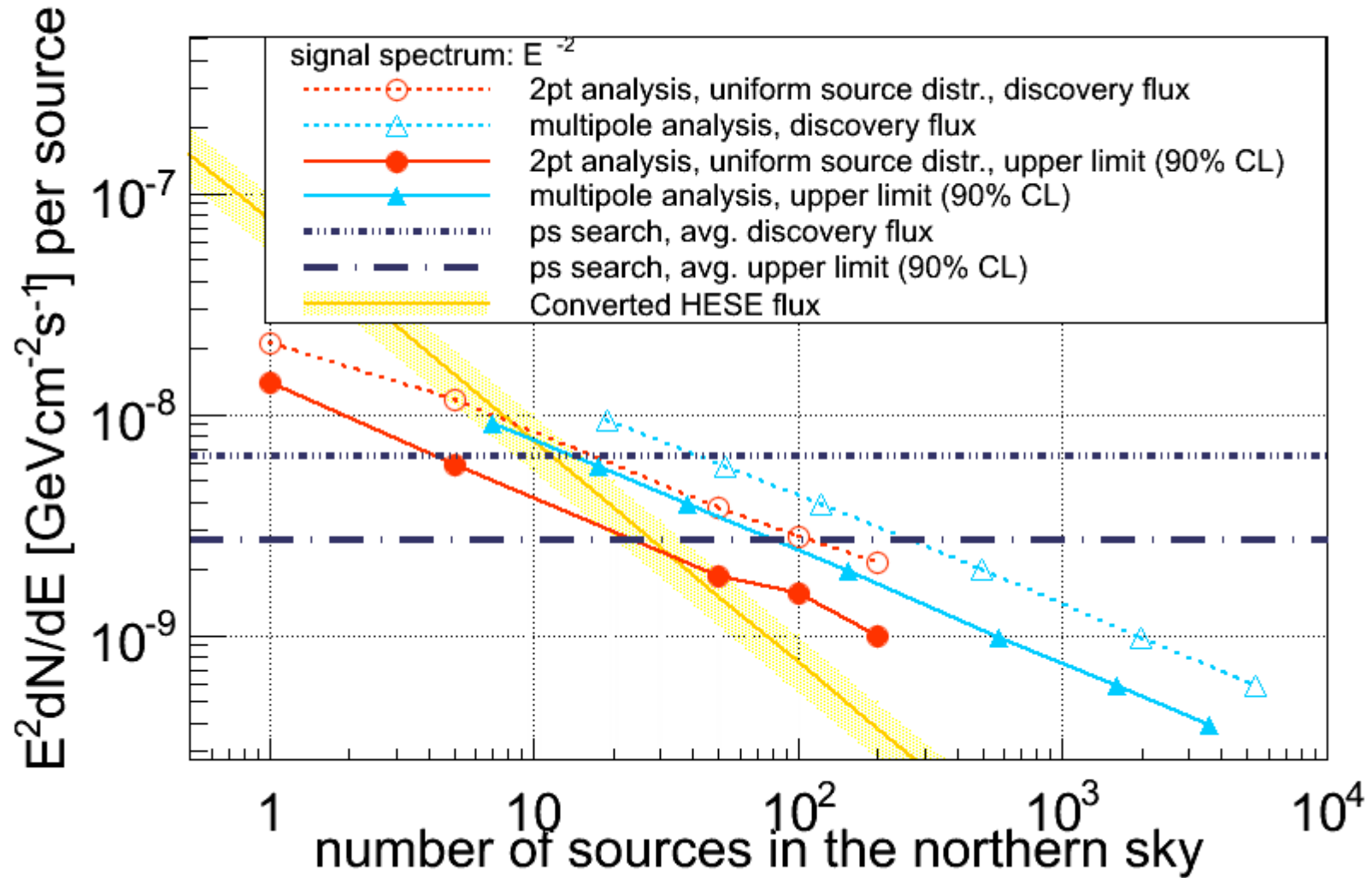# Results

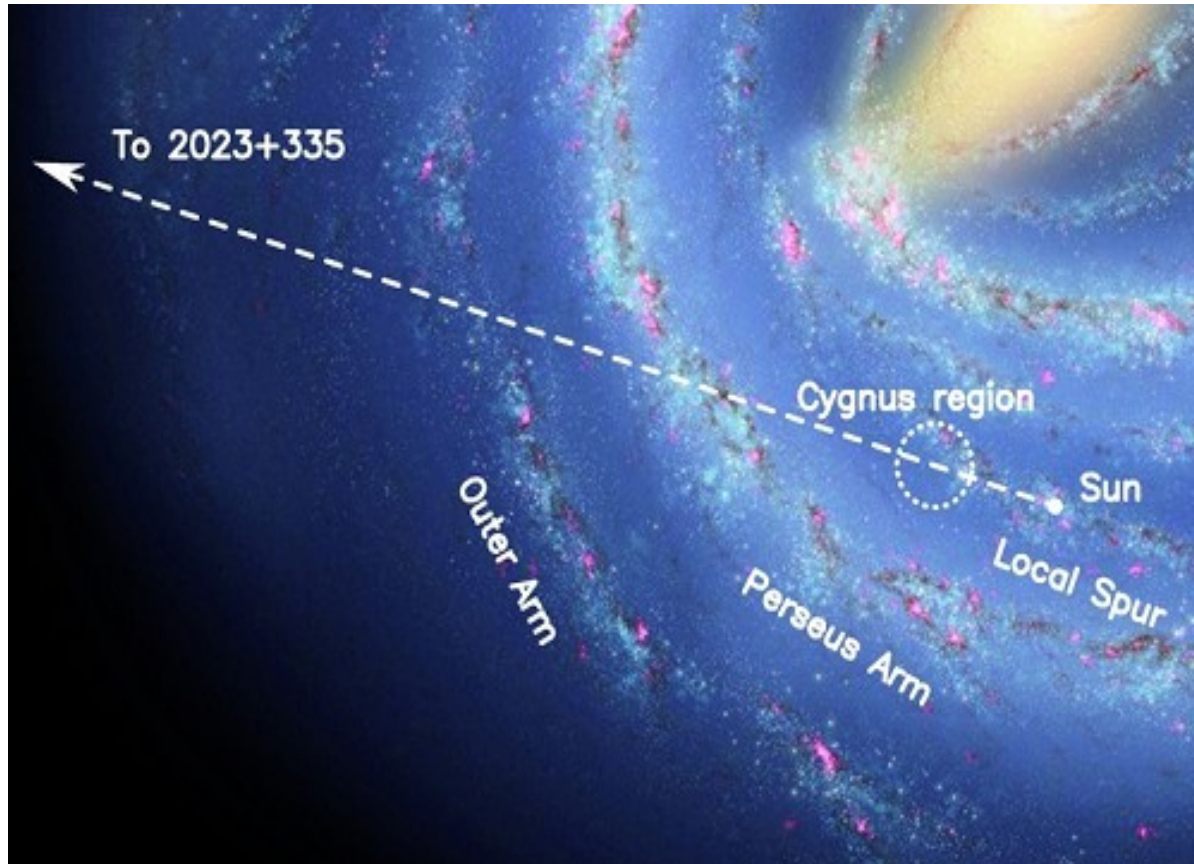Northern hemisphere   Southern hemisphere

- Post-trial p-values are obtained from scrambled data
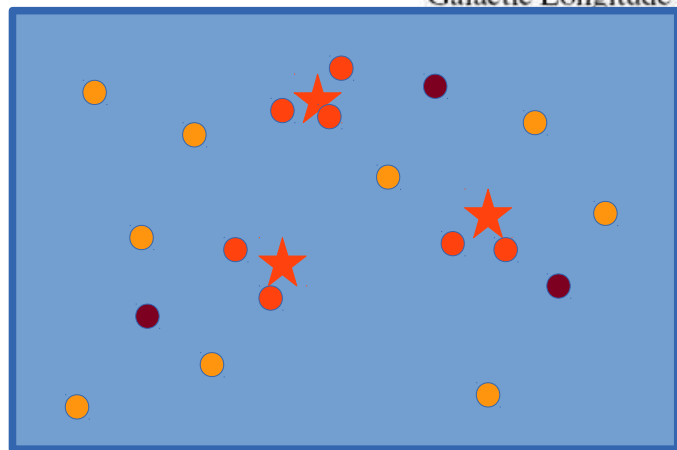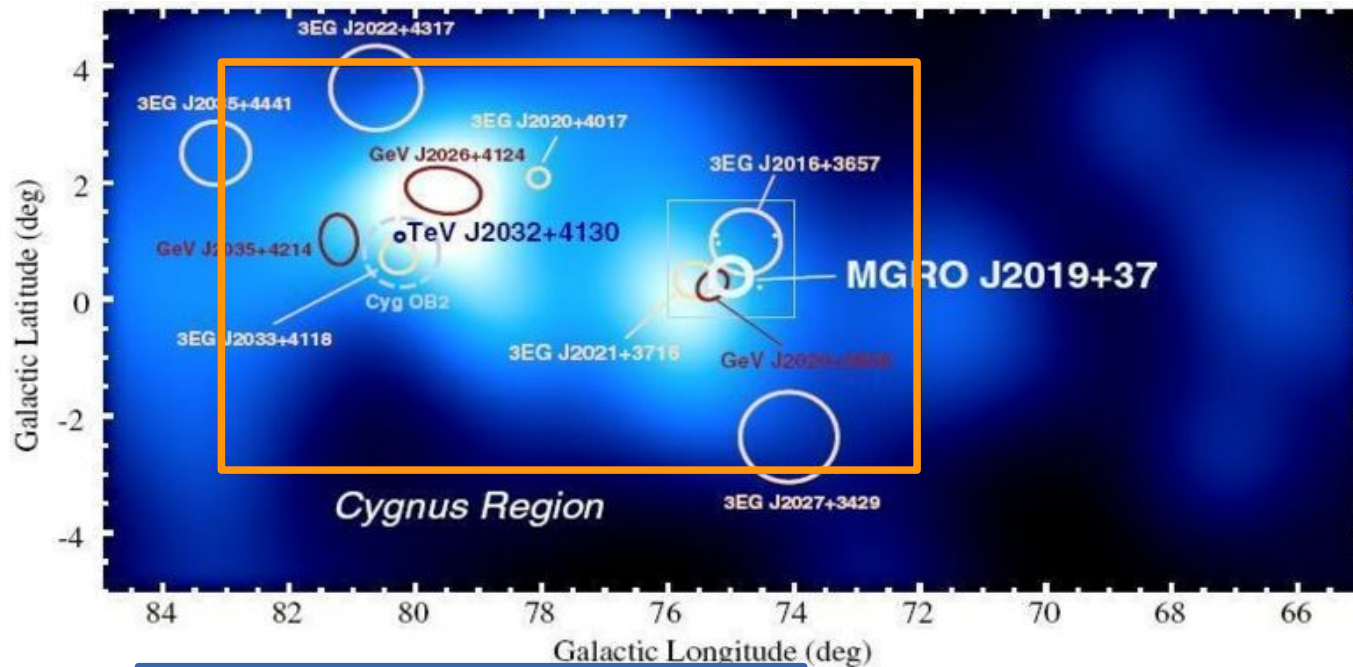
- North:→ 0.84   South:→ 0.73

Limits E⁻²

1) Autocorrelation Analysis of the full sky (3 years)
2) Multi Point Source Analysis of the Cygnus region (4 years)

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Where is the Cygnus region?

- It is roughly located within Galactic longitudes 70°- 90° and latitudes -4°- 8°
- We see a superimposition of the local spiral arm and the projection of the Perseus and outer arm of the Galaxy

Why is it interesting for us?

- one of the richest known regions of star formation in the Galaxy
- Contains several massive giant molecular cloud complexes
- strong TeV gamma-ray emission
- use Multi Point Source Method with additional energy weighting (eMPS)

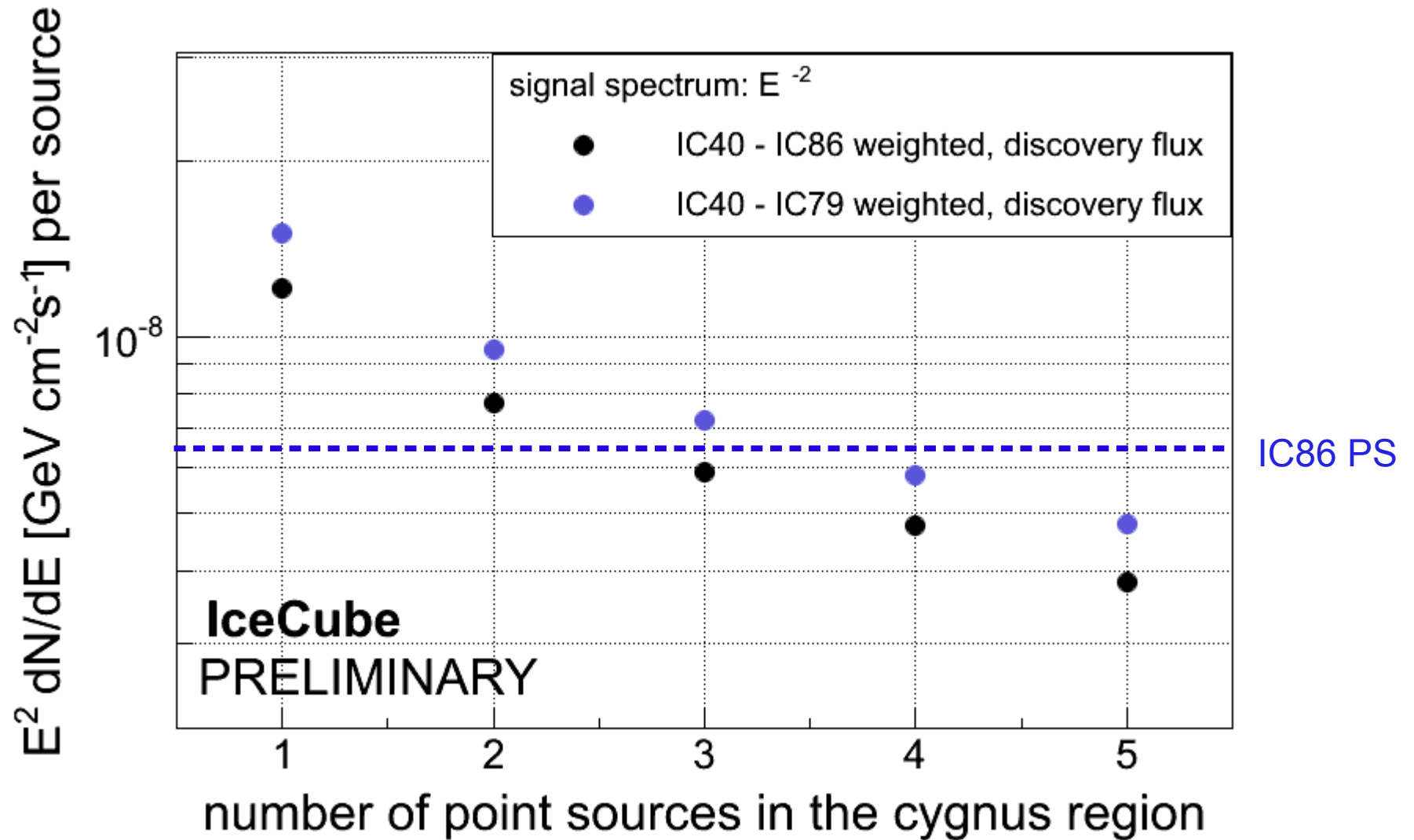Anna Bernhard, Physics Department, TU München, Astroparticle Conference 2014, Amsterdam

How does the eMPS work?

- Use a box of 11°x7° around the center of the Cygnus
- Count pairs of events that are closer together than a certain angular threshold
- Angular scale goes from 0.25° to 5° in steps of 0.25°
- Produce background TS on scrambled events (in RA)
- Add different signal scenarios

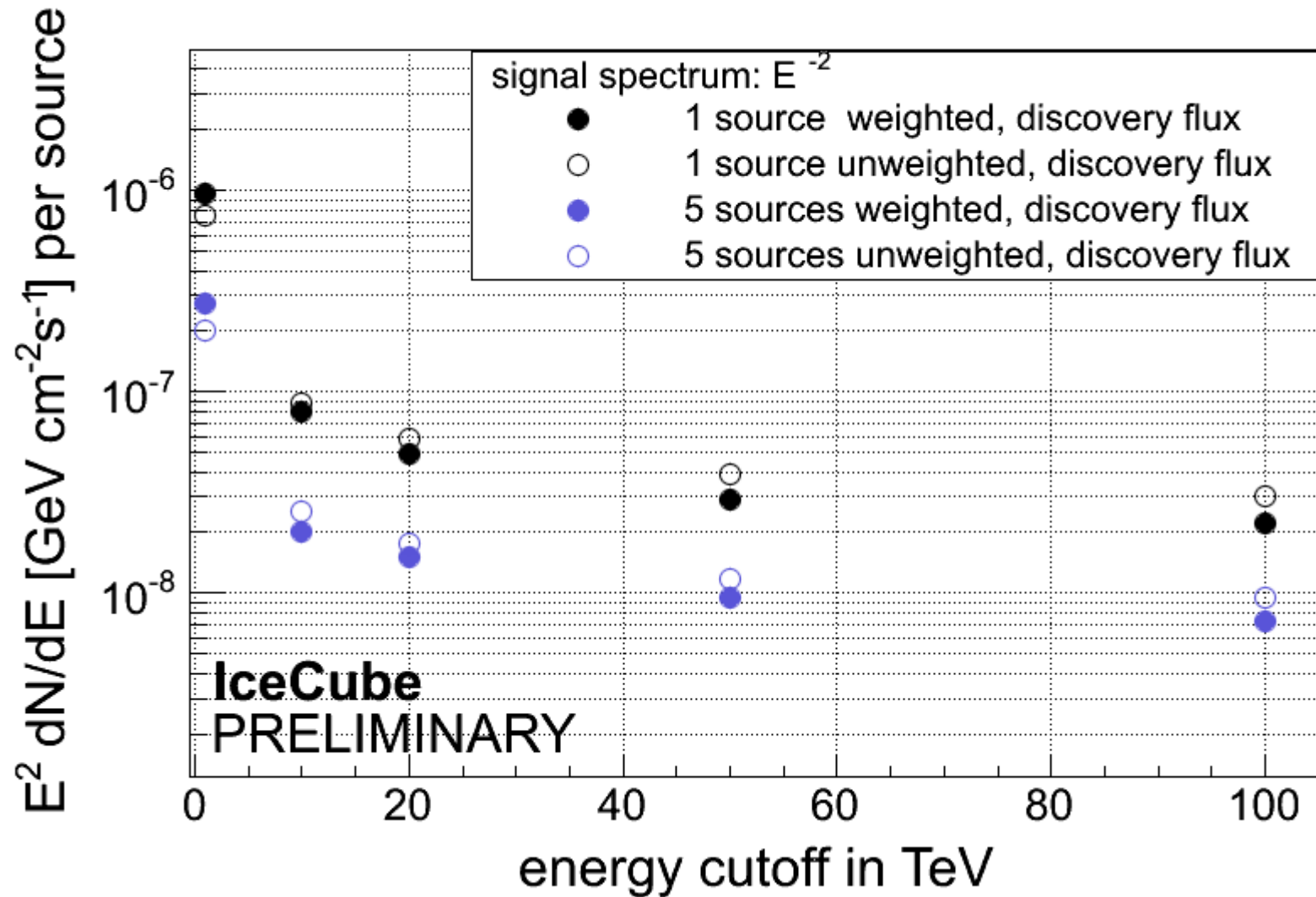Sestayo, Y. & Resconi, E. 2013, Astroparticle Physics, 44, 15-23
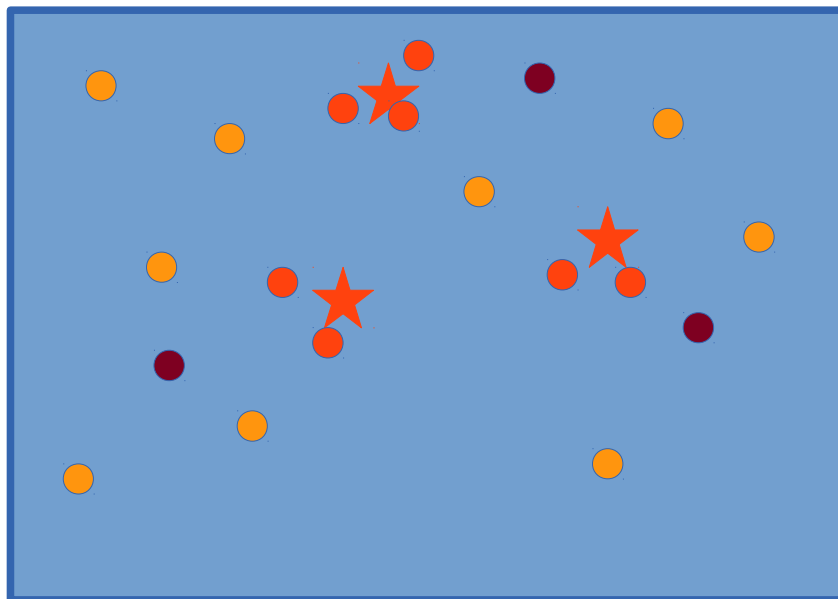
Background events

Sources with signal events

Diffuse component

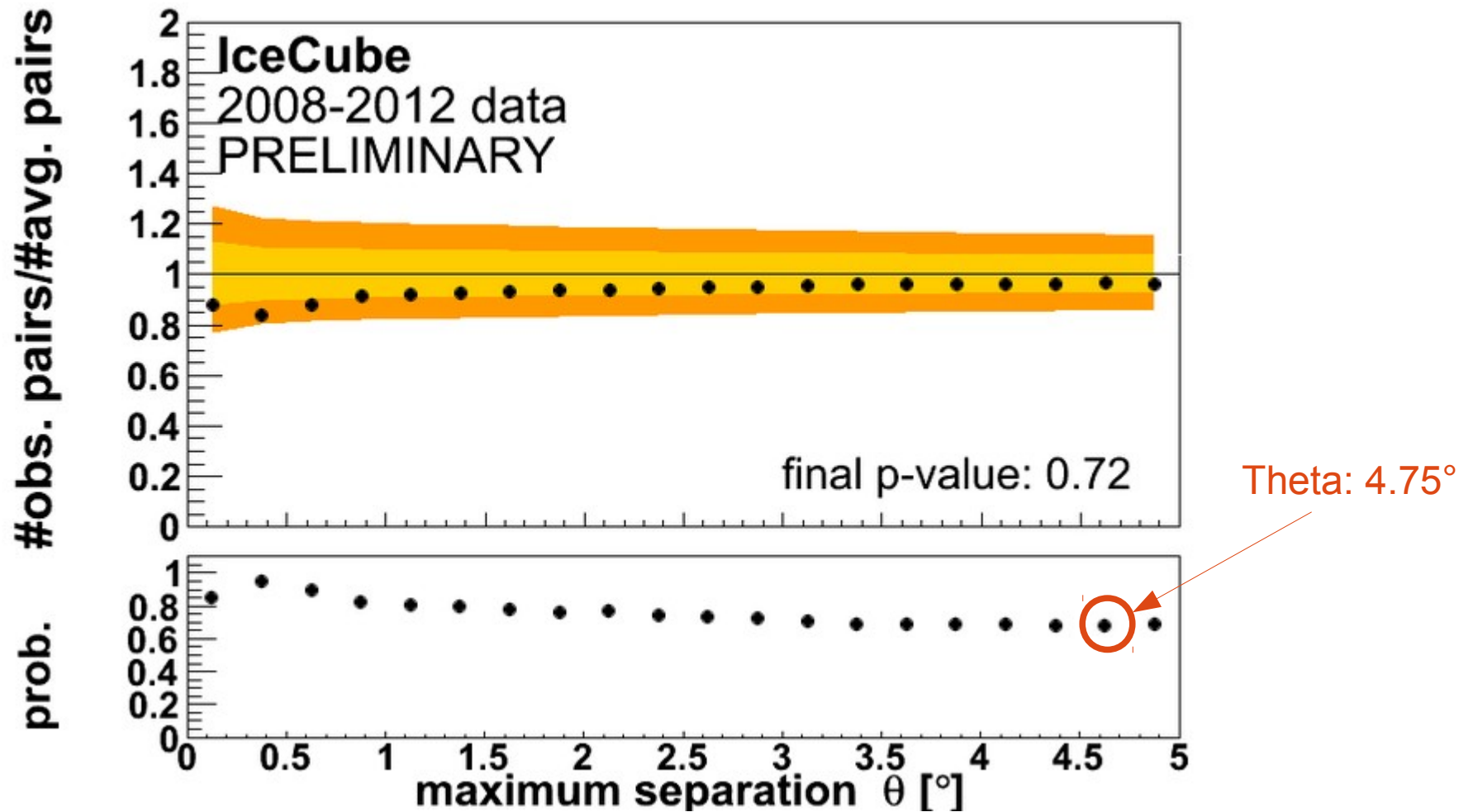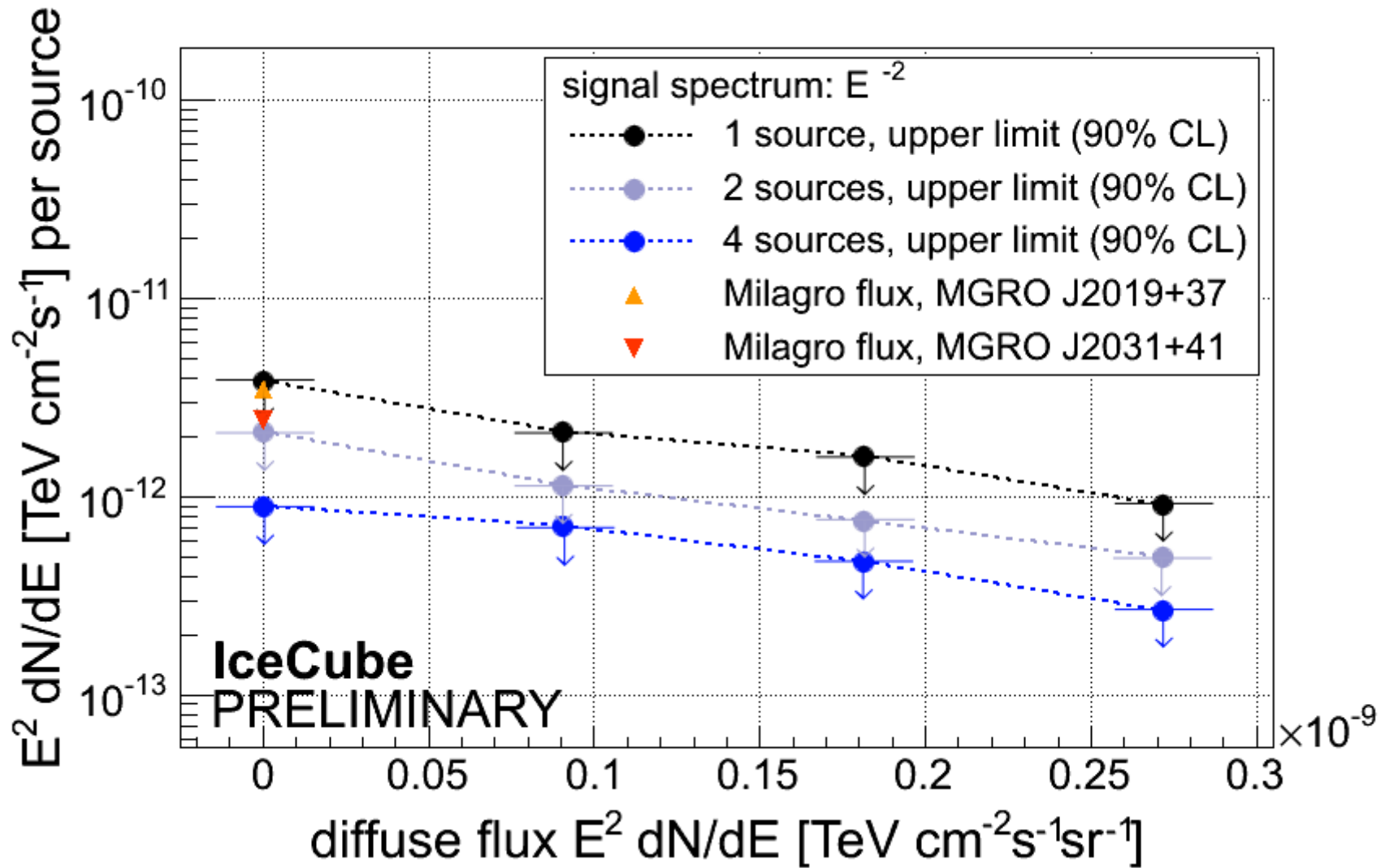# Discovery Potential

Discovery Potential

Results

- Final post-trial p-value: <u>0.72</u>

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Limit E⁻²

MILAGRO gammay ray flux:(Astrophys.J.658:L33-L36,2007)

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Summary and Outlook

- We presented two analyses:

  1) Autocorrelation study of the full sky with 3 years
      → Results: Underfluctuations in both hemispheres

  2) MPS Analysis of the Cygnus region with 4 years
      → Result: Underfluctuation

- Outlook
- Autocorrelation analysis for the full sky with four years
- Investigate the application of the MPS to other regions of the sky (GC, CenA, Fermi Bubbles)