IceCube Neutrinos from the Local Universe with 2MRS

Stephen Sclafani
For the IceCube Collaboration

Drexel UNIVERSITY

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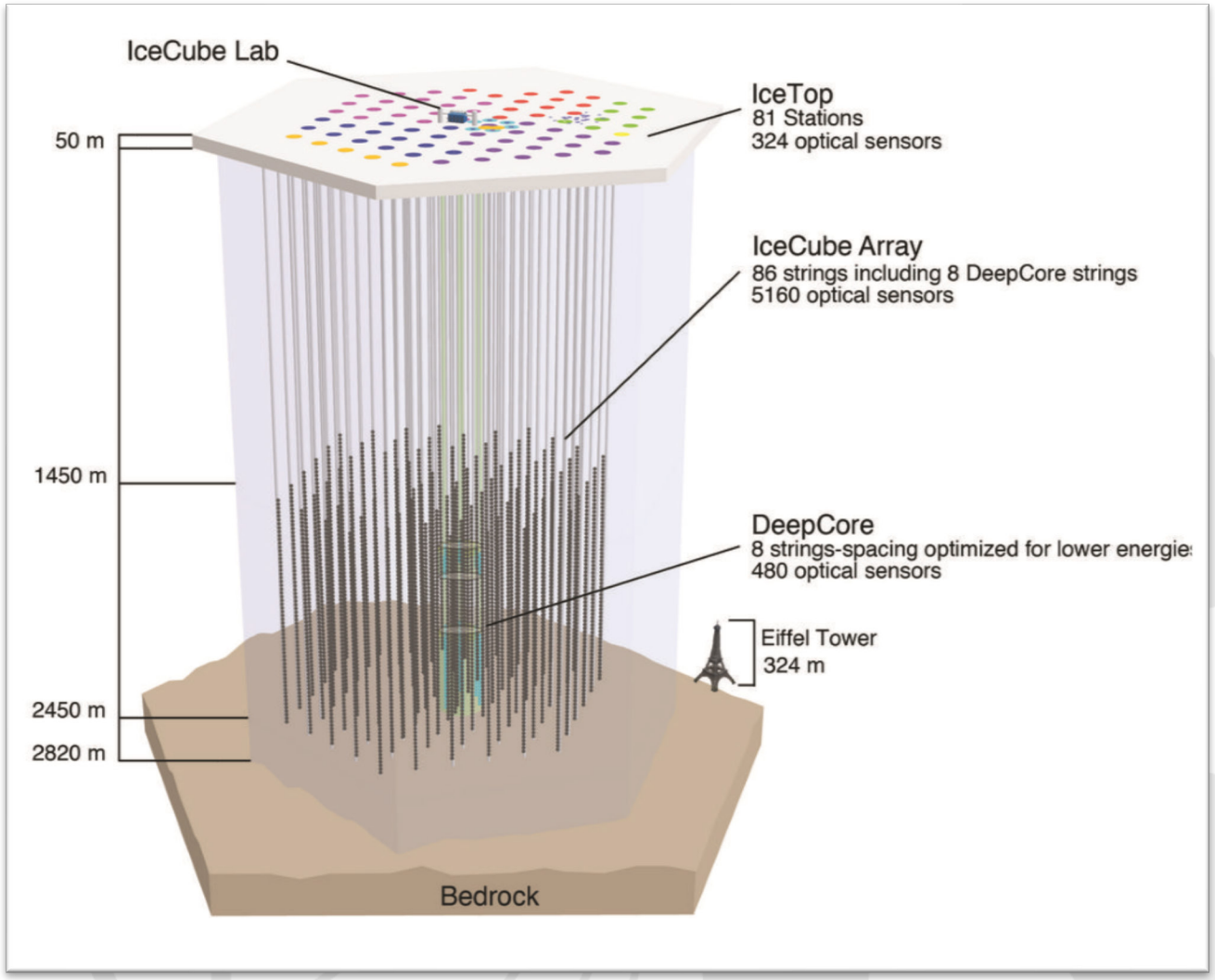
ICECUBE
SOUTH POLE NEUTRINO OBSERVATORY

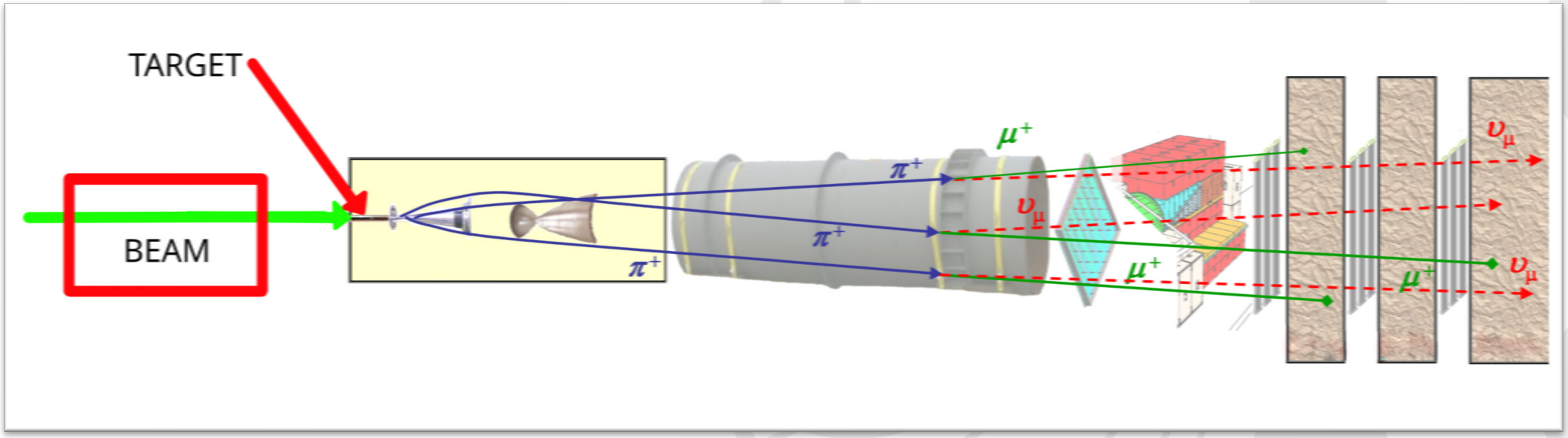
IceCube Sources

- IceCube is a neutrino detector with 5160 PMTs located in the south pole glacial ice
- Identified astrophysical neutrinos, presented evidence for one neutrino source
- Still searching for the sources of most of the astrophysical neutrino flux



Neutrino Sources in the Universe

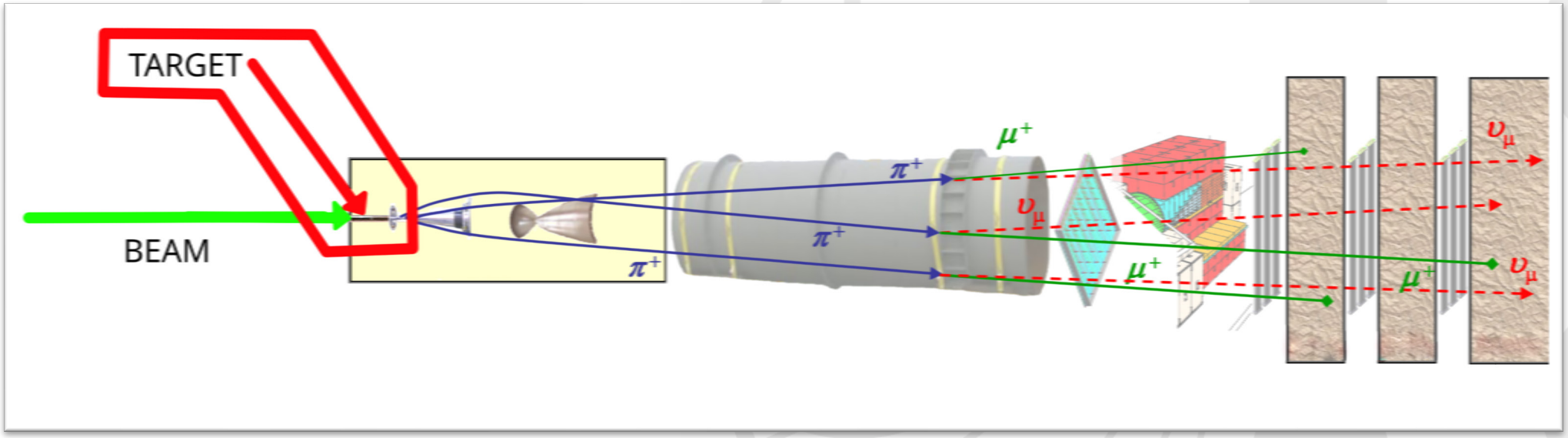
- Need hadronic beam hitting a target
- Focus is on locating the cosmic accelerator beams
- Typically we assume the beam and target are at the same location (same jet[1], same AGN[2], etc.)



1. See NU5f: Searching for Time-Dependent Neutrino Emission from Blazars
2. See NU5d: Search for High-energy Neutrinos from AGN Cores
3. Image via Dune Collaboration

Targets as Neutrino Source Locations

- If we have many sources and CR escape without interacting, results in a diffuse flux of intergalactic CR.
- If significant portion of the neutrino production were due to secondary interactions from this isotropic diffuse UHECR flux, the beam is everywhere – how can we identify it?
- Look at the targets, sites of the secondary interactions.



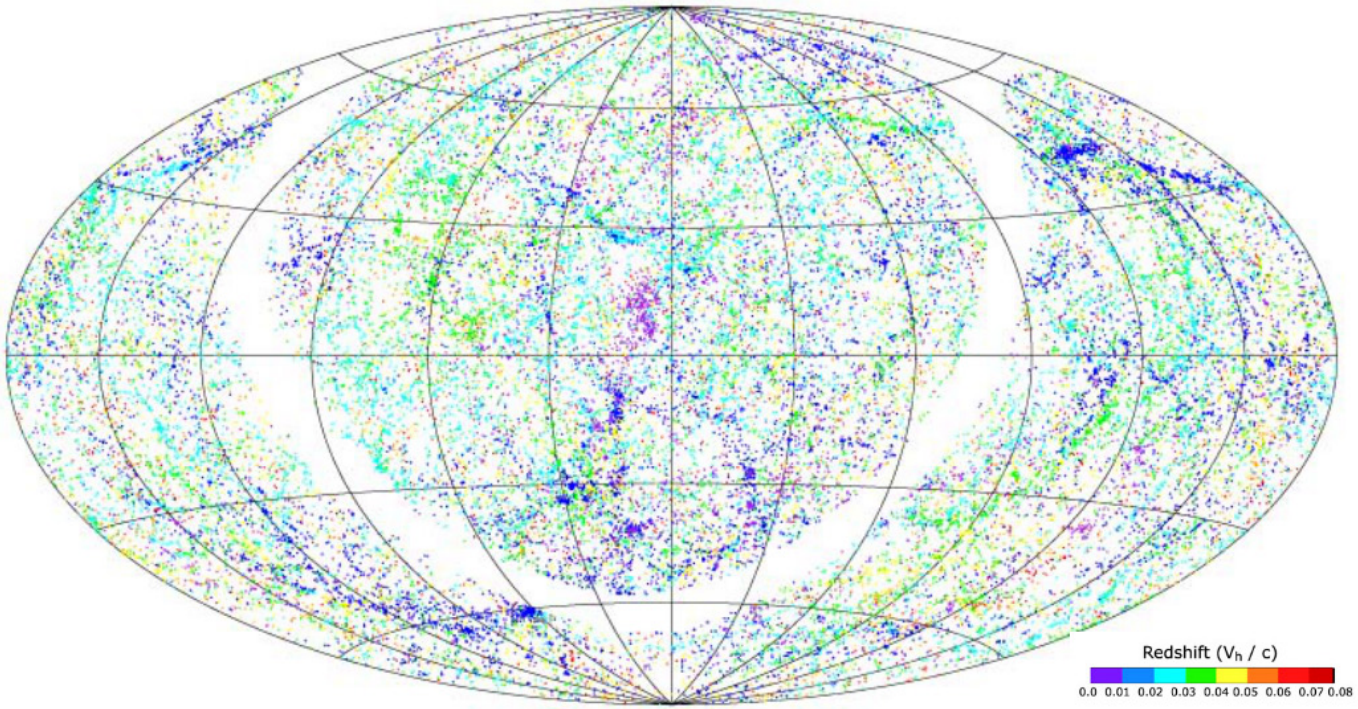
1. Image via Dune Collaboration

Galaxy Density Hypothesis

- Assuming an isotropic beam, neutrino production would be primarily due to interactions in local matter
- Local Universe is anisotropic
- Look for neutrinos from local galaxy targets – correlating arrival directions with column density
- Single galaxy contribution is small, but combined effect may be seen in IceCube.
- Correlation with close, large-scale features – supergalactic plane, filament structure

2MASS Redshift Survey

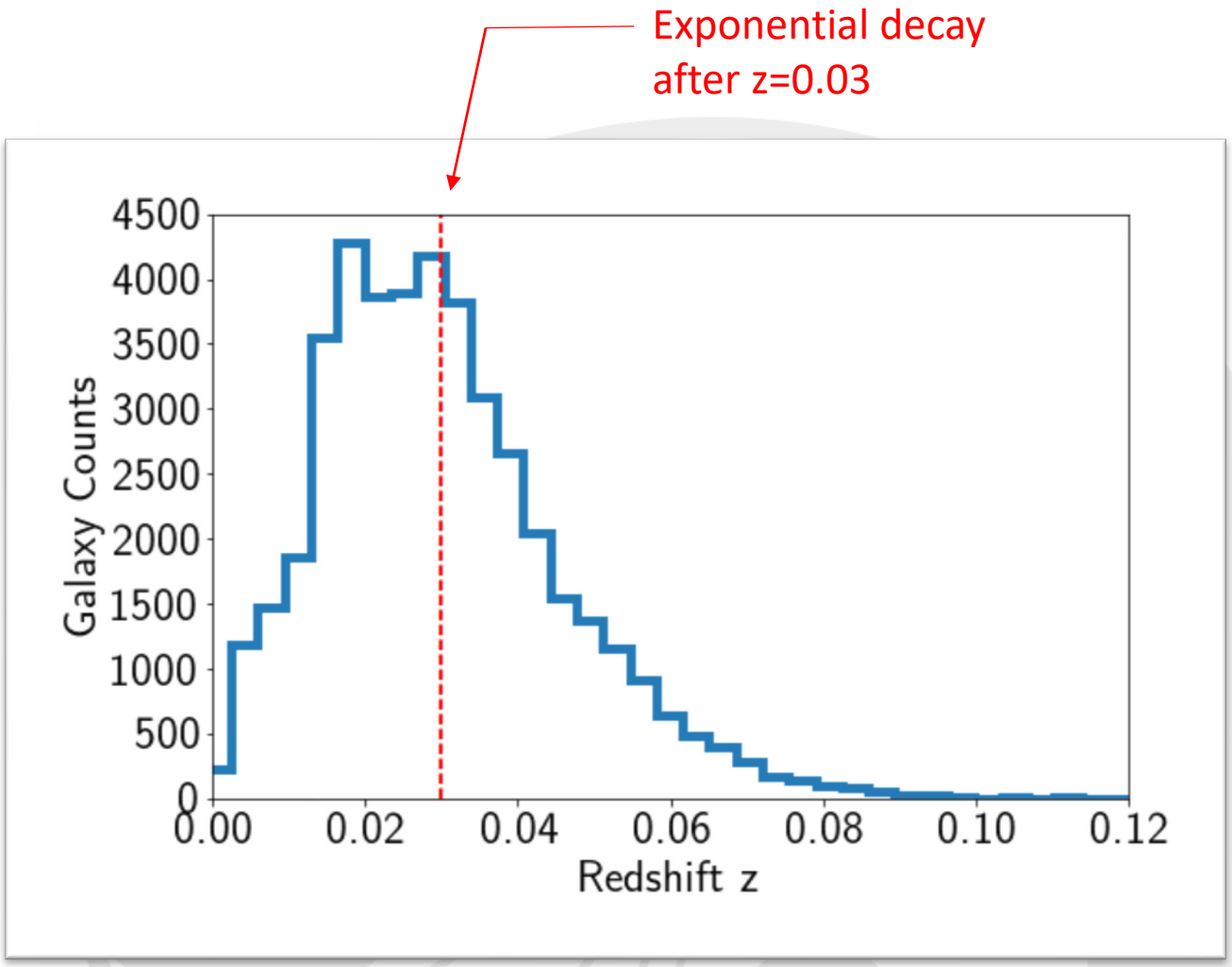
- 2MRS[1] maps position, magnitude, and redshift for 45,000 galaxies, known for its completeness in low redshifts.
- Use redshift information as a template for local matter density and large scale structure.



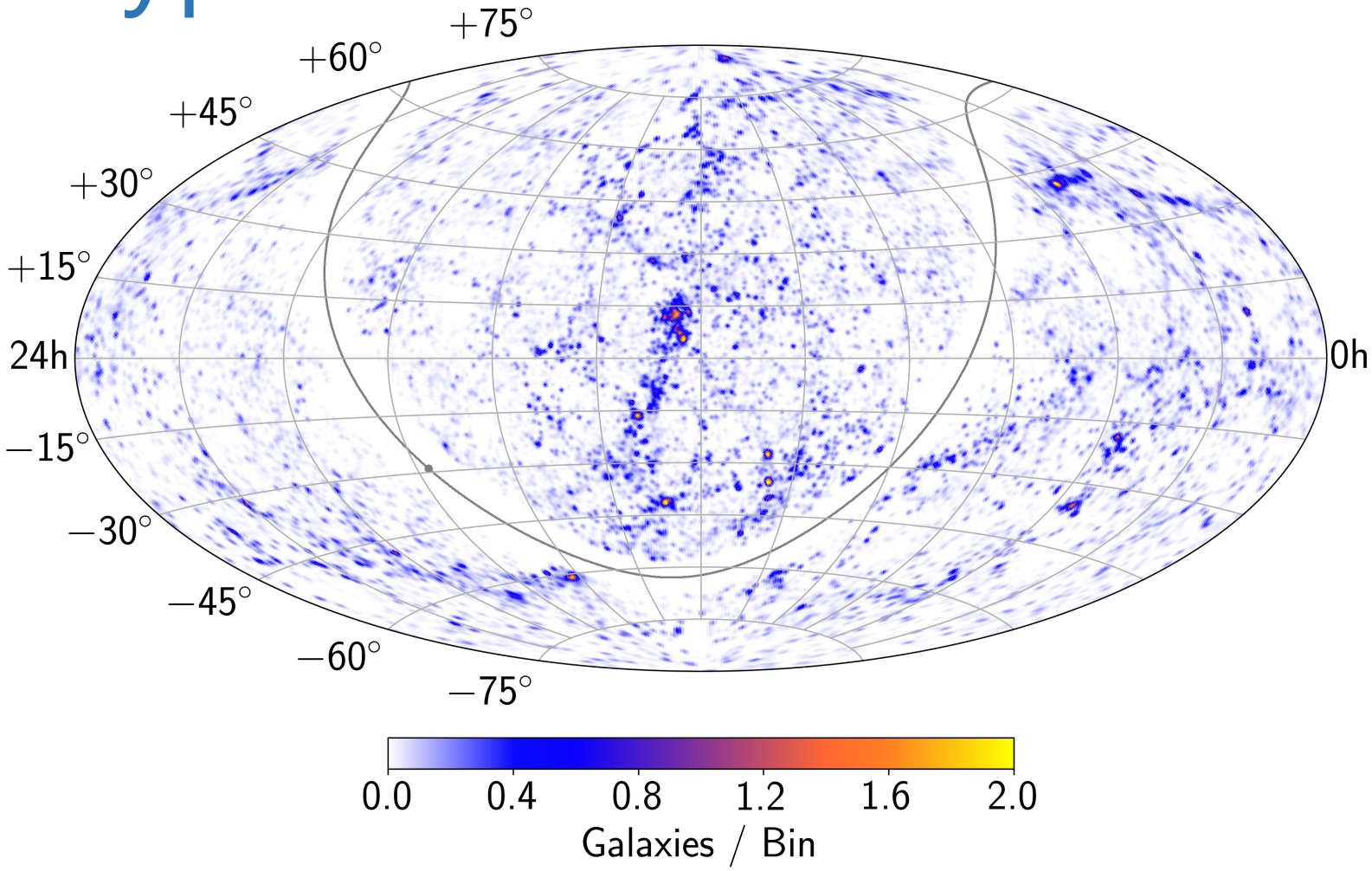
1. Huchra et al. (2012), ApJS Vol 199

2MRS

- Spatial Hypotheses:
  - Full Catalog – each galaxy weighted by redshift distance
  - Full Catalog – each galaxy equally weighted
  - Cutoff at redshift z=0.03, each galaxy equally weighted

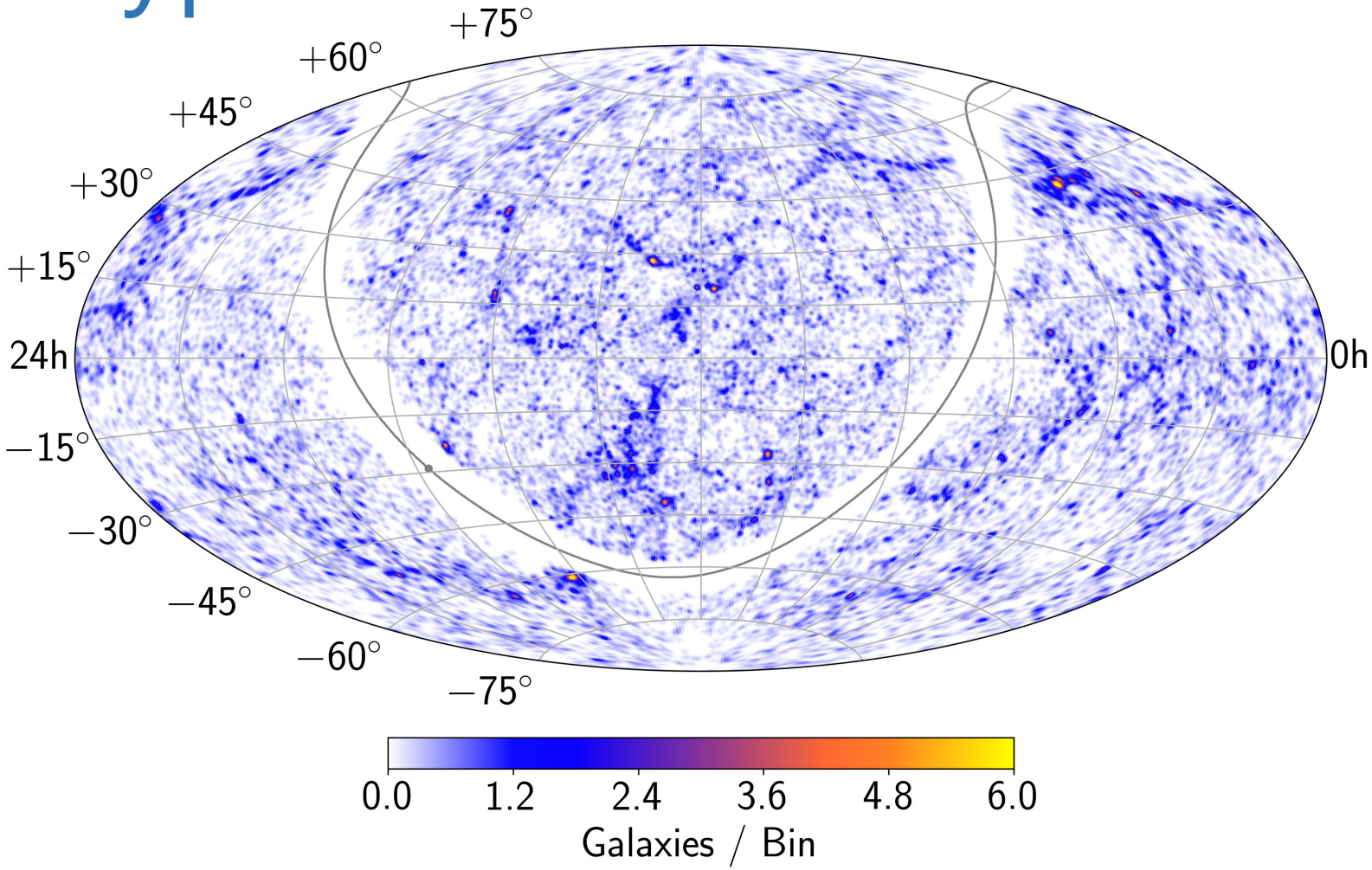


Source Hypothesis 1



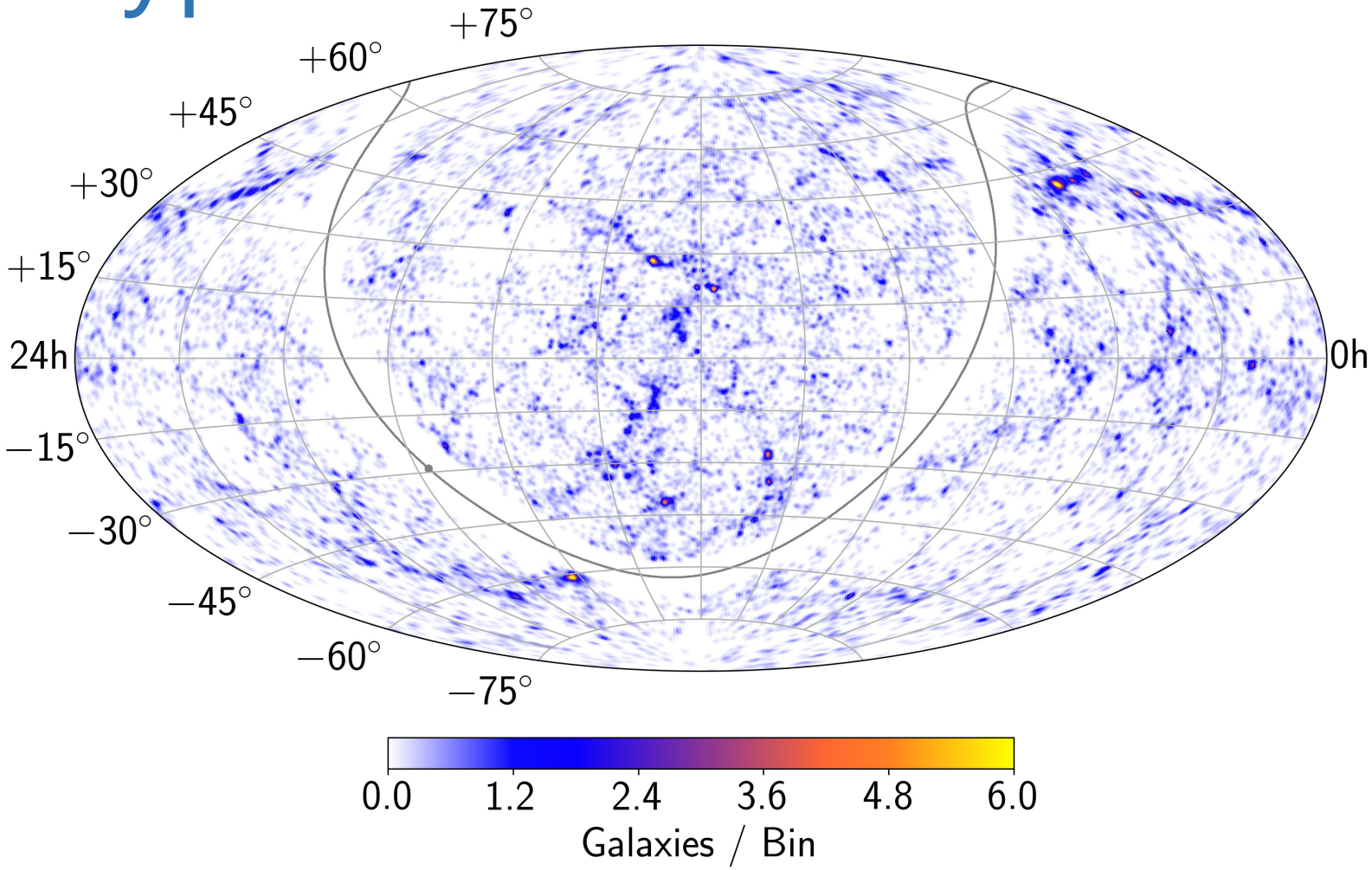
- Full Catalog – each galaxy weighted by redshift distance

Source Hypothesis 2



- Full Catalog – each galaxy equally weighted

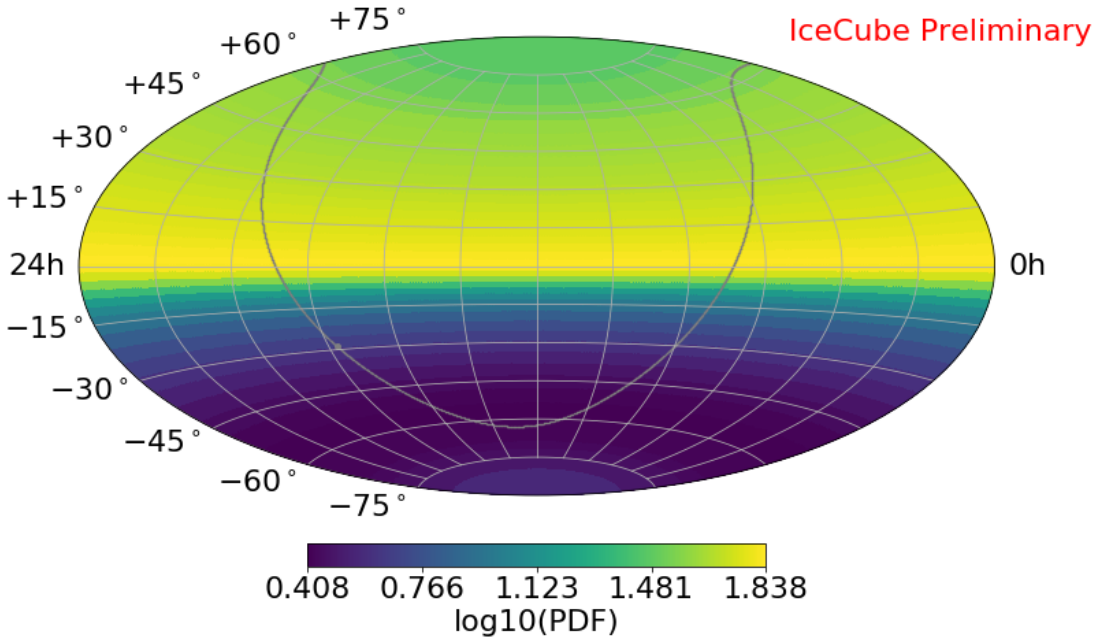
Source Hypothesis 3



- Full Catalog – cutoff at z=0.03

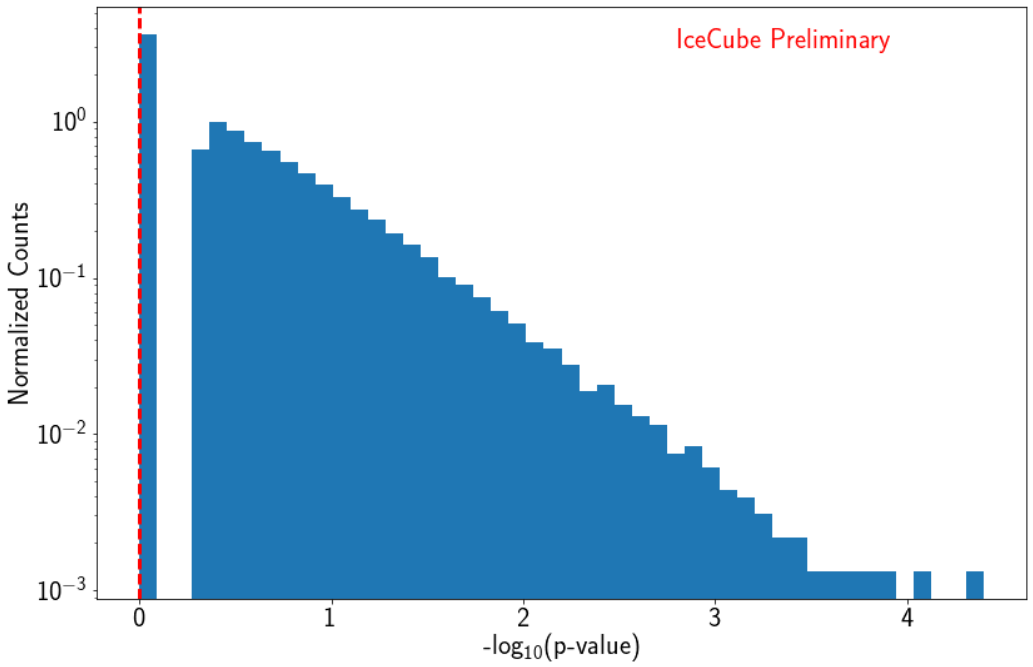
Analysis

- Spatial Templates convolved with detector acceptance assuming E^{-2} signal neutrino energy spectrum.
- Analyze 7 years of well reconstructed muon-neutrino events.
- Test Statistic defined based on LLH Ratio evaluating the correlation between the neutrino direction and column density template.



Results

- Best fit n_s = 0 (Under Fluctuation)
- 33% of trials result in n_s=0 in each

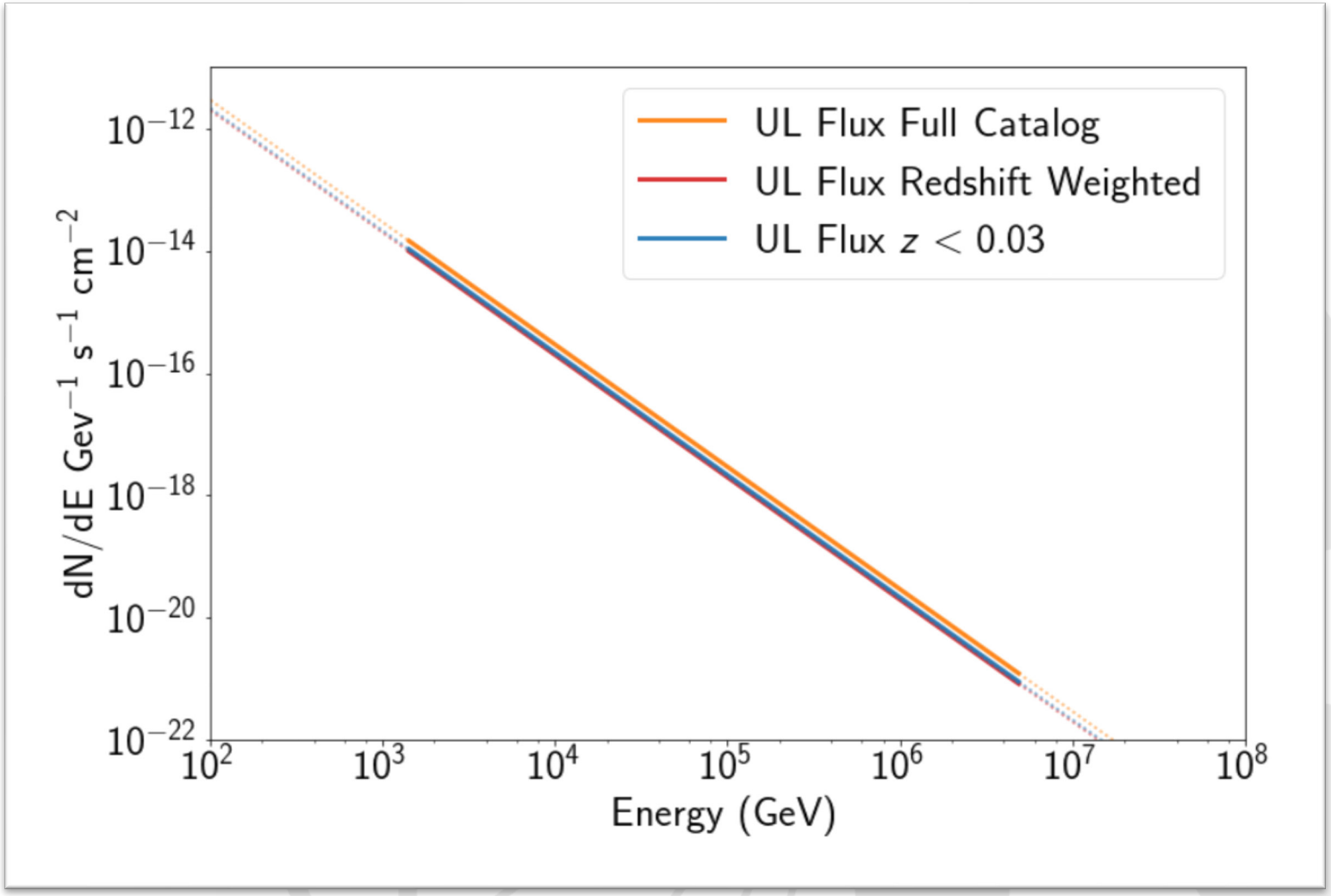


Template	Flux Upper Limit ($GeV^{-1}\ s^{-1}\ cm^{-2}$)[1]	% of IceCube Astrophysical Flux[2]
Weighted by Redshift	1.97×10^{-18}	<20%
Full Catalog	2.89×10^{-18}	<30%
Cutoff at z=0.03	2.15×10^{-18}	<22%

1. $dN/dE = \Phi_{90\%} \times (\frac{E}{100TeV})^{-2}\ \mathrm{GeV}^{-1}\mathrm{cm}^{-2}\mathrm{s}^{-1}$
2. arXiv: 1710:01191

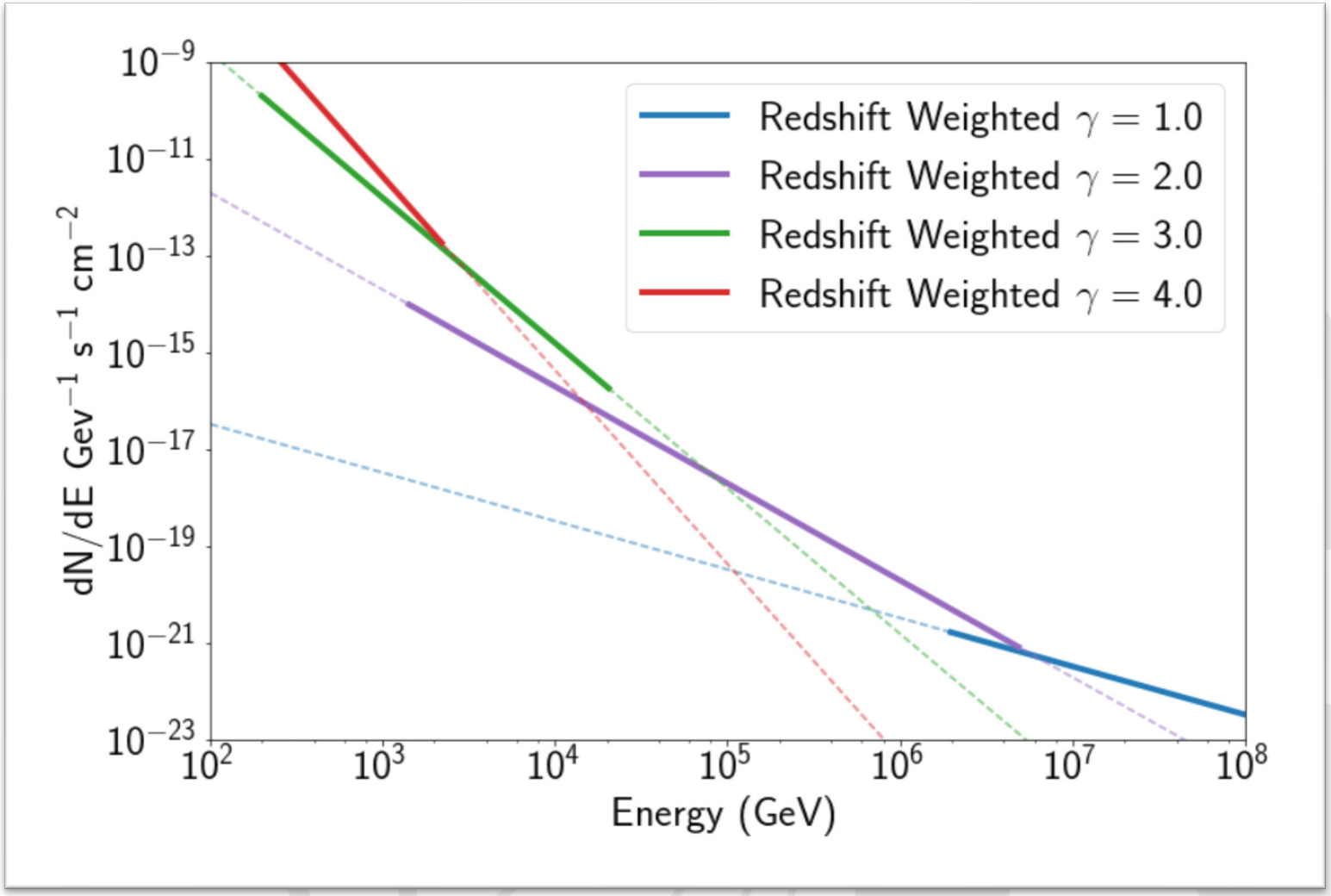
Flux Upper Limits – E^{-2}

- Three hypotheses yield similar flux limits
- Darker line indicates the central energy region for each spectrum
- Upper limits here assume astrophysical neutrino energy spectrum follows E^{-2}



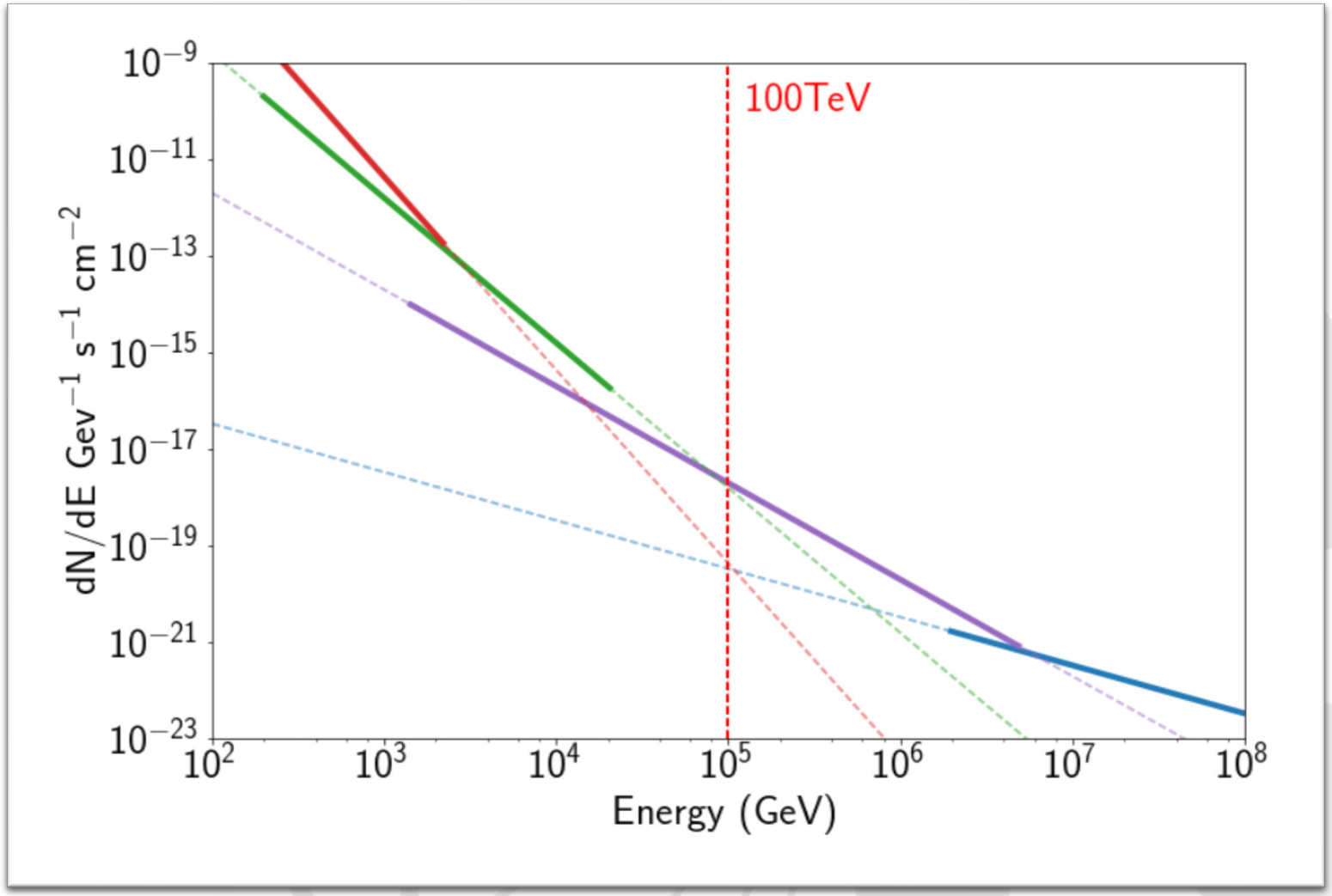
Flux Upper Limits – Redshift Weighting

- For one hypothesis, vary energy spectrum $E^{-\gamma}$ power law



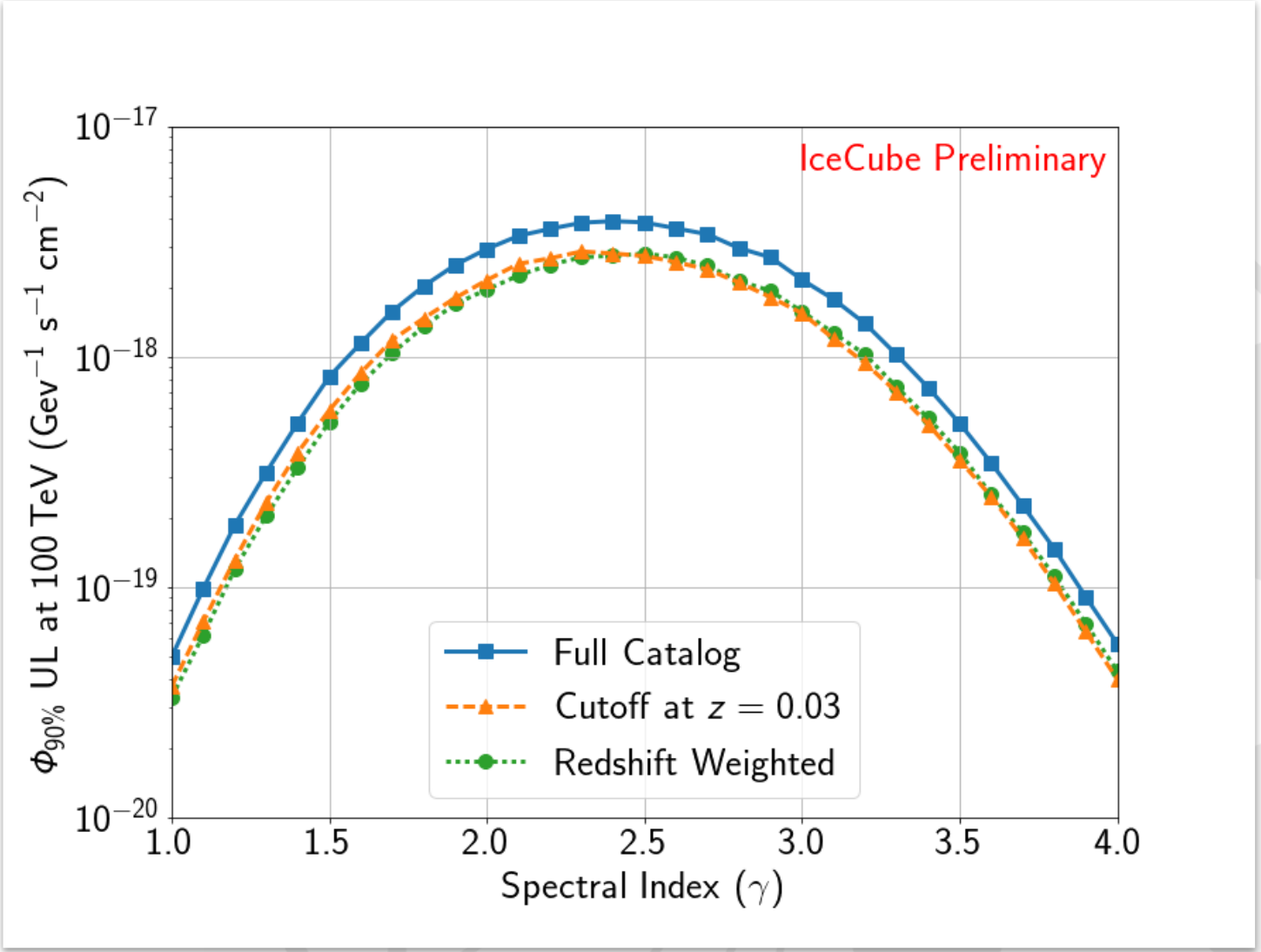
Flux Upper Limits – Redshift Weighting

- Pick one reference energy (100TeV) to show range of spectra for each hypothesis



Flux Upper Limits – 100TeV

- Flux upper limits at 100TeV as a function of spectral index for each template
- All sky Diffuse Flux: 1.26×10^{-17} in these units



Conclusion

- Results were consistent with background
- Assuming E^{-2} energy spectrum this analysis finds no evidence that most of our astrophysical neutrino flux is due to a diffuse beam with targets in the local universe. Encouraging for future source identification.
- Can use this model to set limits on neutrino production in local universe via diffuse intergalactic UHECR interactions
- Method can be revisited as we have a more complete picture of the local universe with new surveys

BACKUP SLIDES

LLH Function

$$LLH : \mathcal{L}(n_s) = \prod_{i=1}^{N} \left(\frac{n_s}{N} S_i(\mathbf{x}_i, \sigma_i, E_i) + (1 - \frac{n_s}{N}) B_i(sin\delta, E_i) \right)$$

Data:

$$\tilde{D}_i(\sin\delta_i, E_i) = \frac{n_s}{N} \tilde{S}_i(\sin\delta_i, E_i) + (1 - \frac{n_s}{N}) B_i(\sin\delta_i, E_i)$$

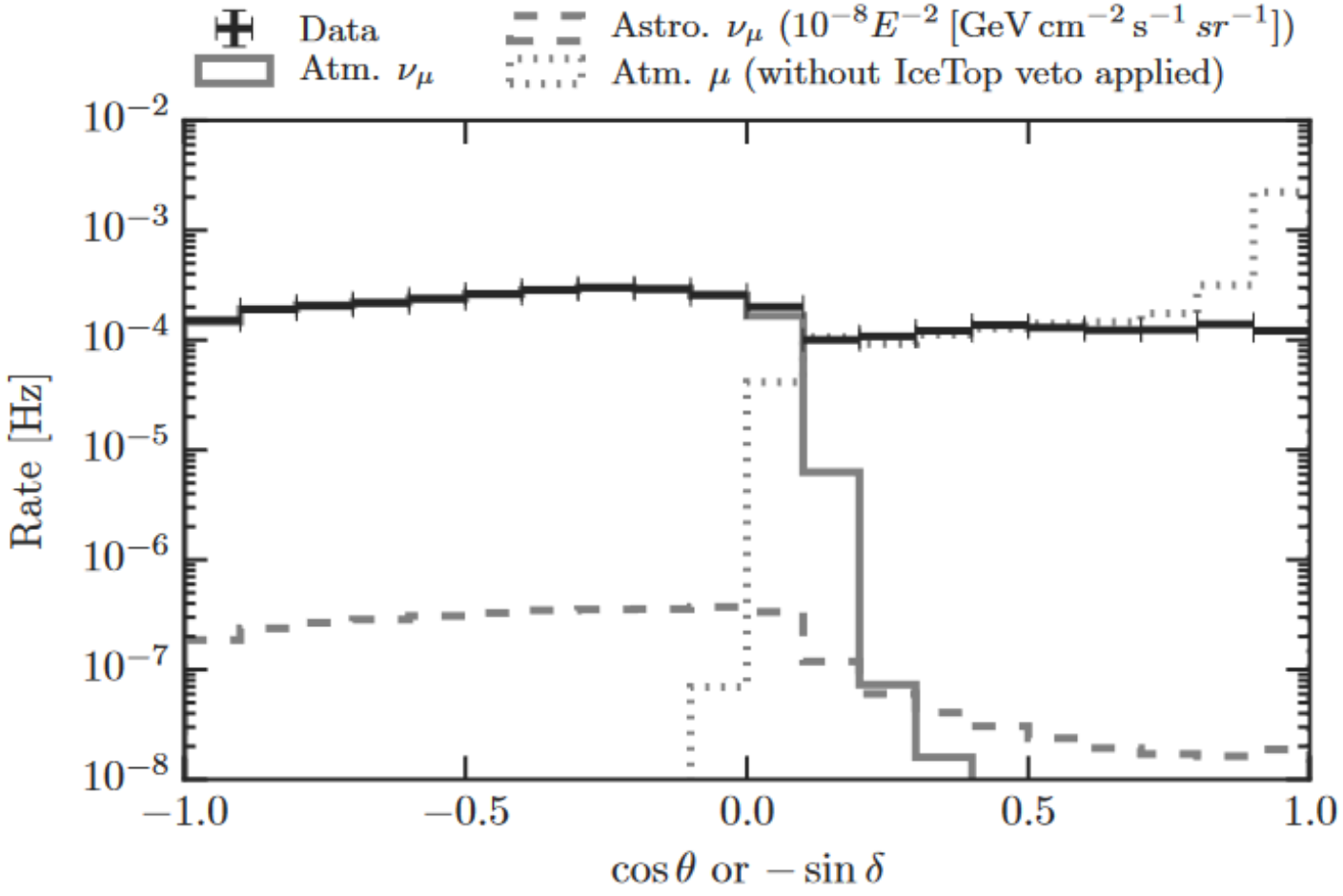
Modified LLH:

$$\mathcal{L}(n_s) = \prod_{i=1}^{N} \left(\frac{n_s}{N} S_i(\mathbf{x}_i, \sigma_i, E_i) + \tilde{D}_i(\sin\delta_i, E_i) - \frac{n_s}{N} \tilde{S}_i(\sin\delta_i, E_i) \right)$$

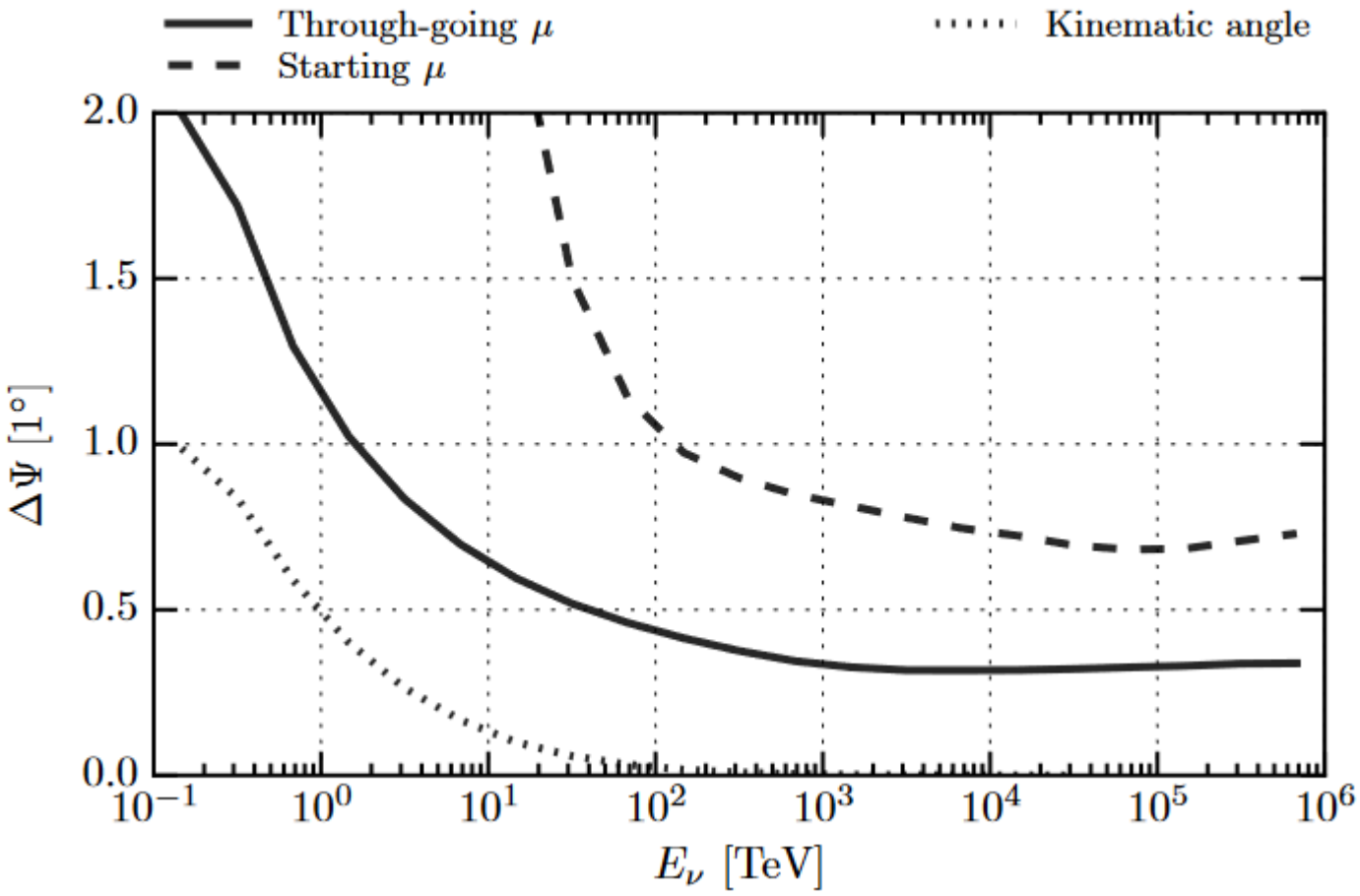
$$TS = -2 \ln \left[\frac{\mathcal{L}(n_s = 0)}{\mathcal{L}(\hat{n}_s)} \right]$$

- Spatial PDF component from template maps, Energy PDF based on 2D Signal and Background histograms

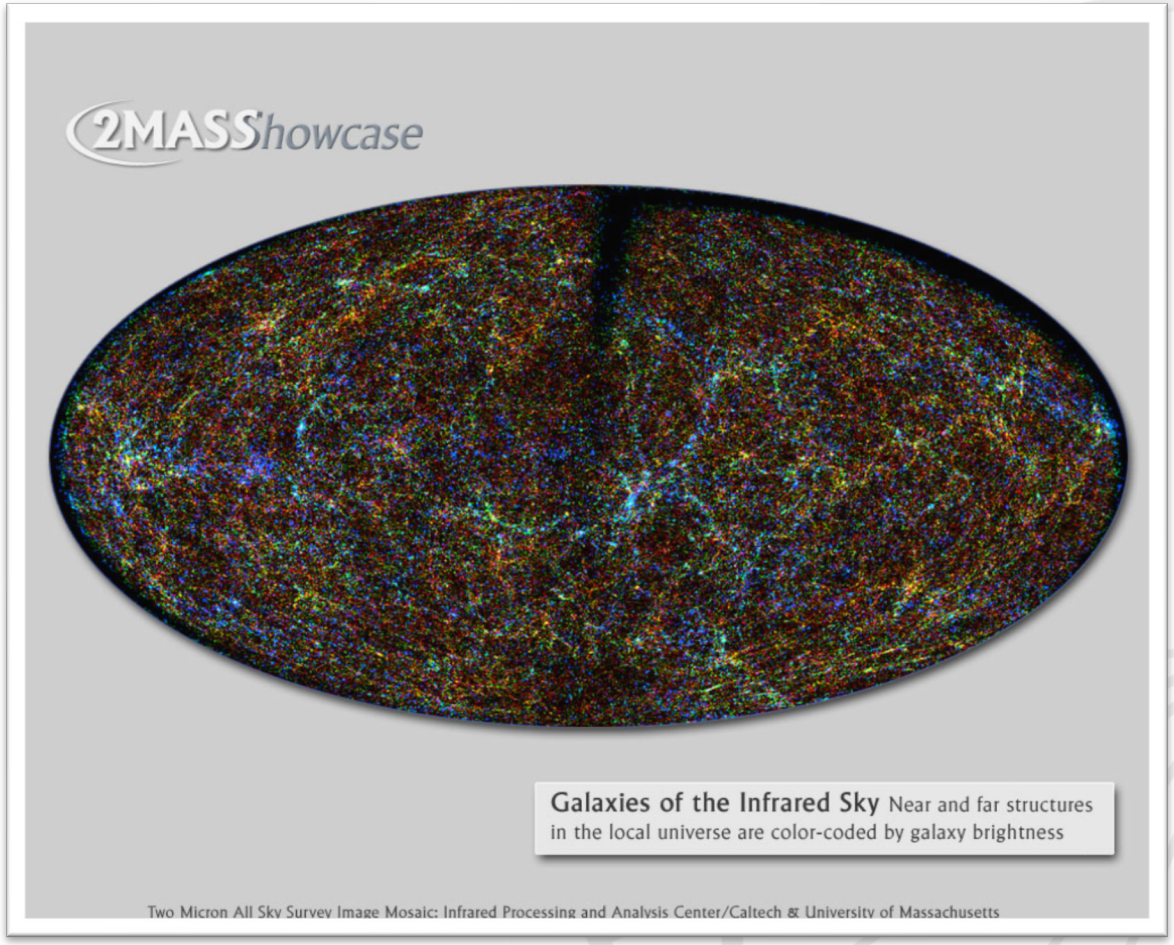
Event and Background Rate



Event Angular Resolution



2MRS Sky


2MASShowcase
Galaxies of the Infrared Sky Near and far structures in the local universe are color-coded by galaxy brightness
Two Micron All Sky Survey Image Mosaic: Infrared Processing and Analysis Center/Caltech & University of Massachusetts