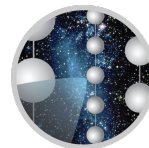


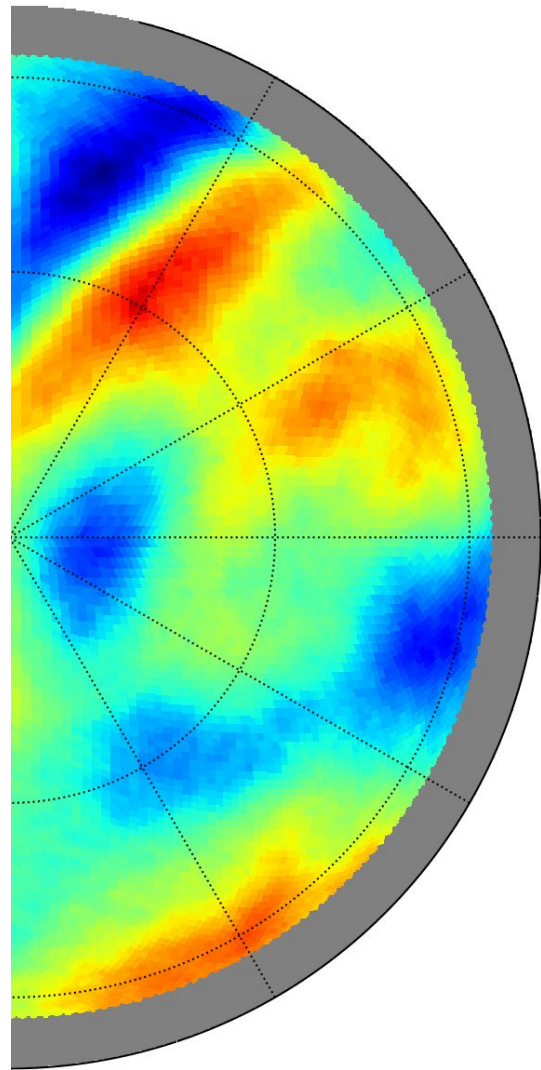
Cosmic-Ray Anisotropy at PeV Energies with IceTop

Rasha Abbasi
Paolo Desiati
Juan Carlos Díaz-Vélez &
Frank McNally
for the IceCube Collaboration



ICECUBE

LOYOLA
UNIVERSITY CHICAGO



History

Anisotropy in IceCube

2010 First observation

[Abbasi et al. \(2010\)](#)

2011 Small-scale structure

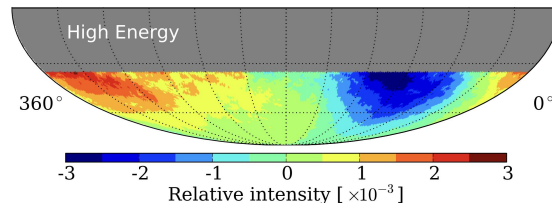
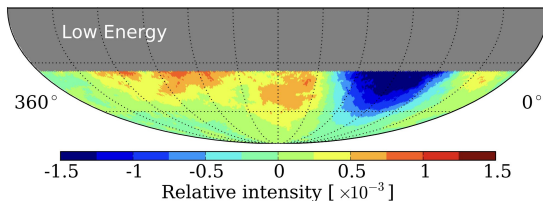
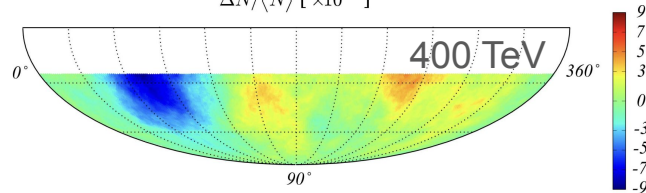
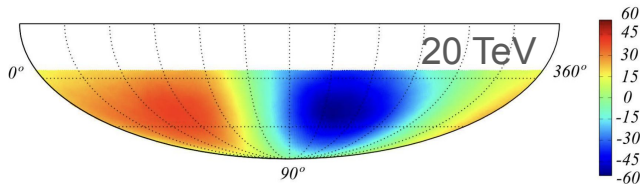
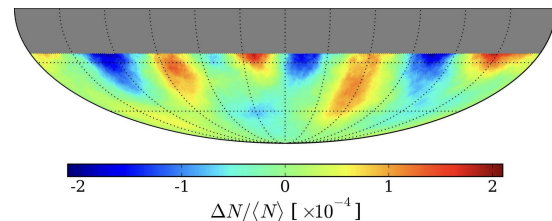
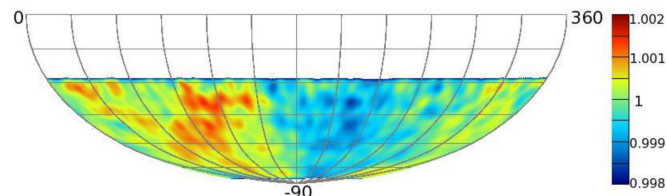
[Abbasi et al. \(2011\)](#)

2012 Energy dependence

[Abbasi et al. \(2012\)](#)

2013 IceTop

[Abbasi et al. \(2013\)](#)

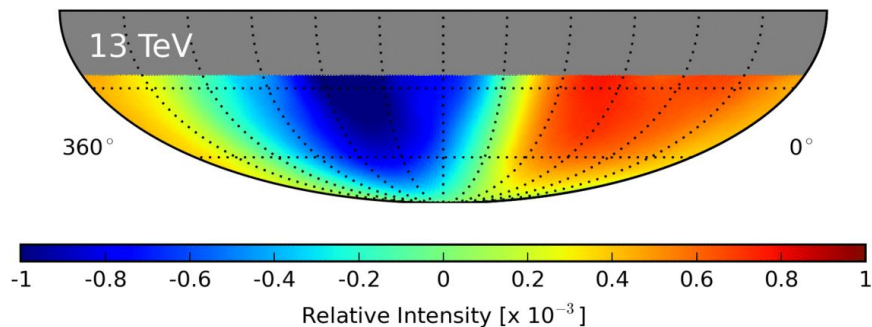


History

Anisotropy in IceCube

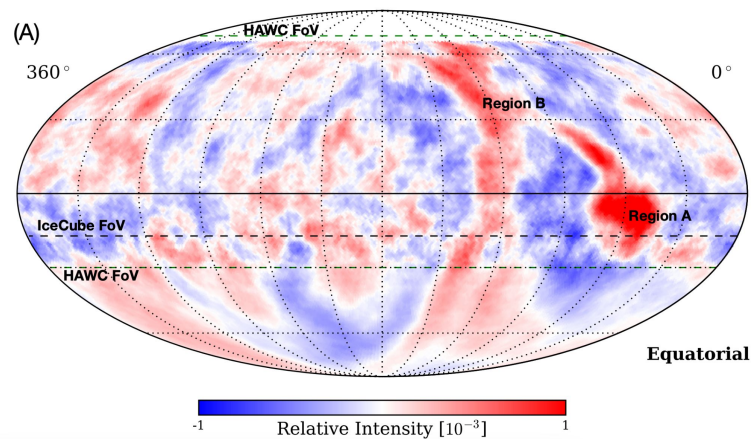
2016 Six-Year Update

[Aartsen et al. \(2016\)](#)



2019 Full-Sky with HAWC

[Abeysekara et al. \(2019\)](#)

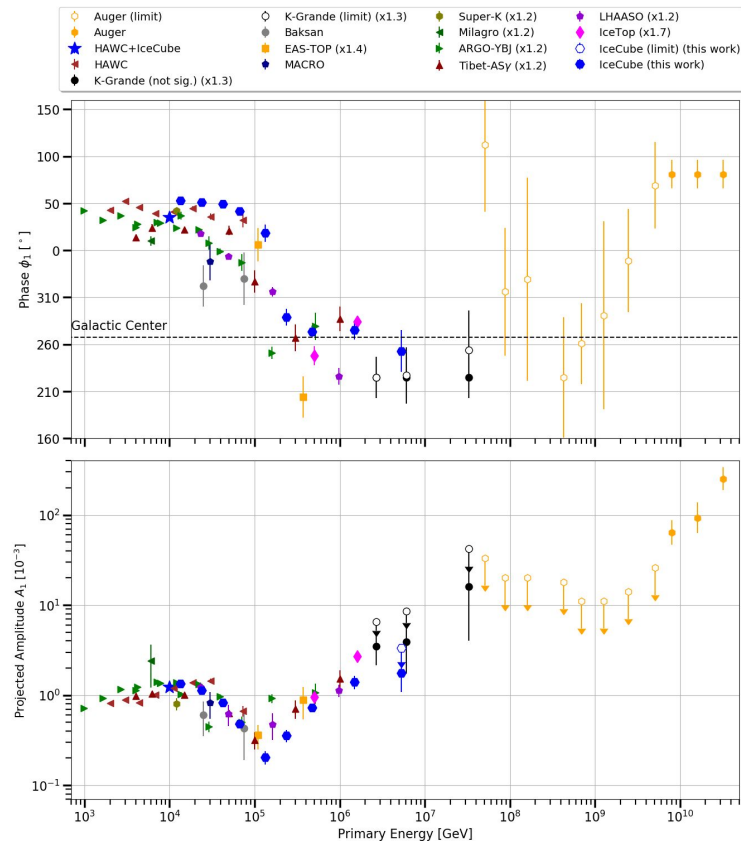
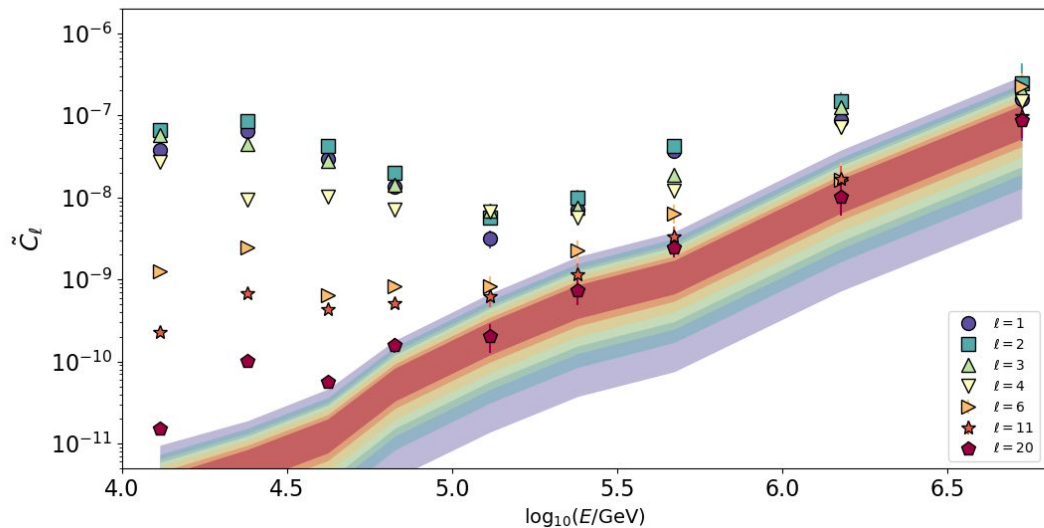


History

Anisotropy in IceCube

2025 Twelve-Year Update

[Abbasi et al. \(2025\)](#)



Objective: Revisit recent in-ice analysis with IceTop surface array

Improved statistics

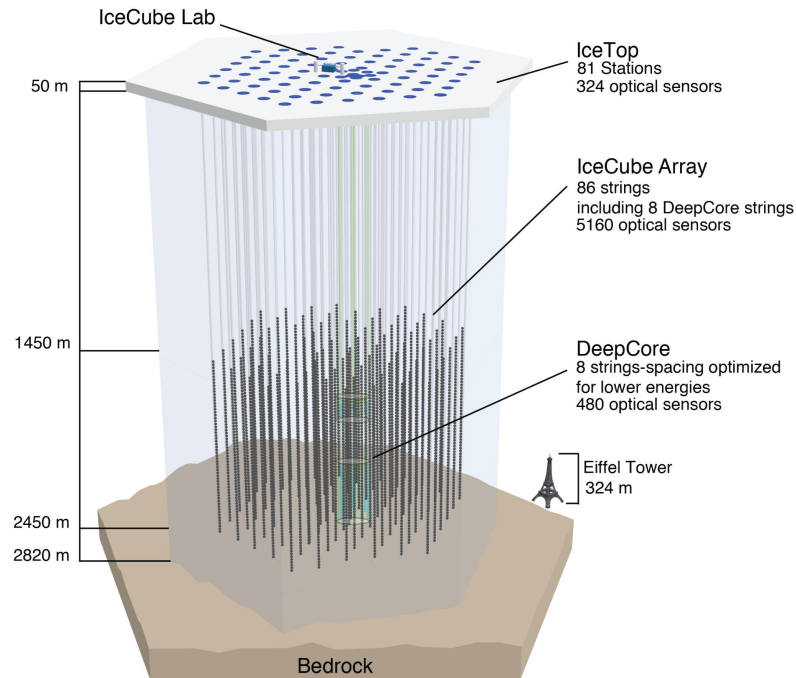
Eleven years of data
(~1 billion events)

Same location and methods...

Systematic test for
previous observations

...different detector

Electromagnetic (IceTop) vs
muonic (in-ice) sensitivity



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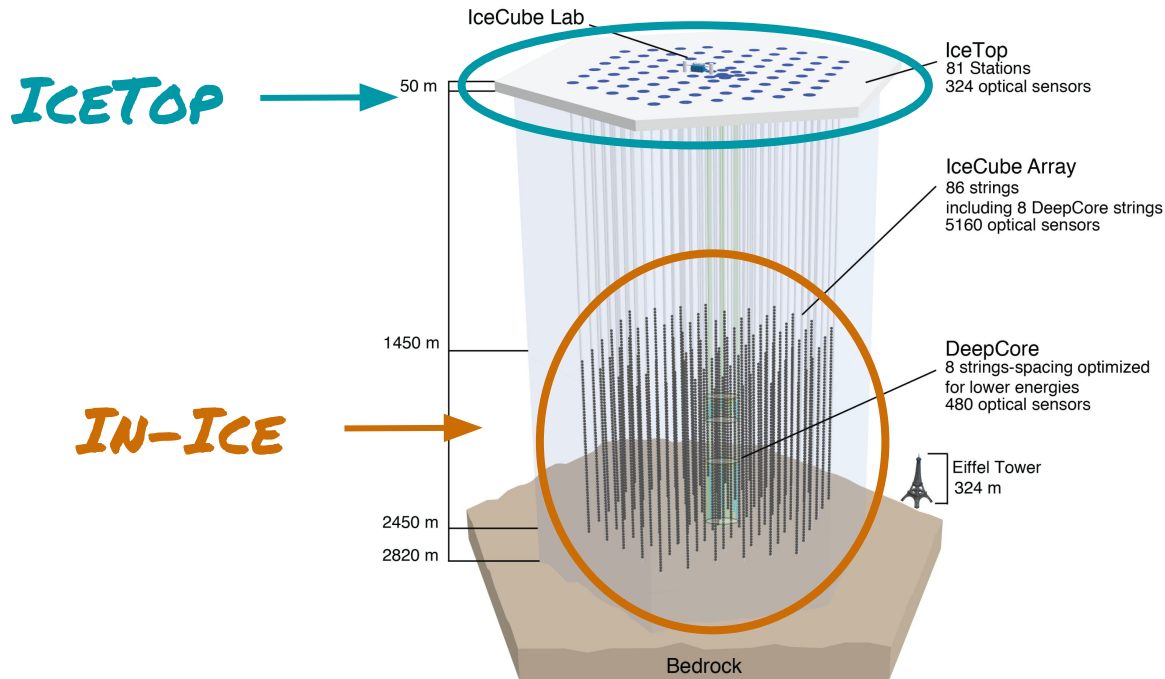
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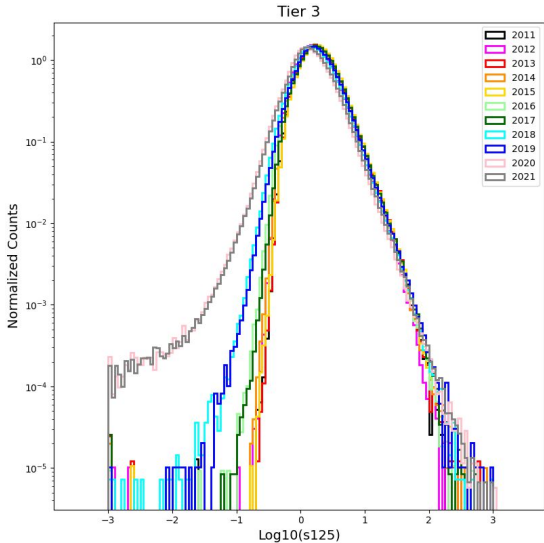
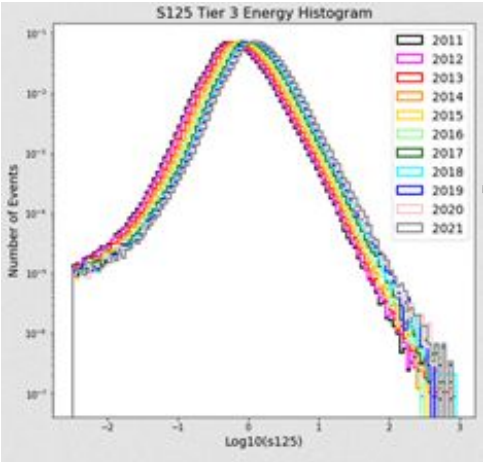
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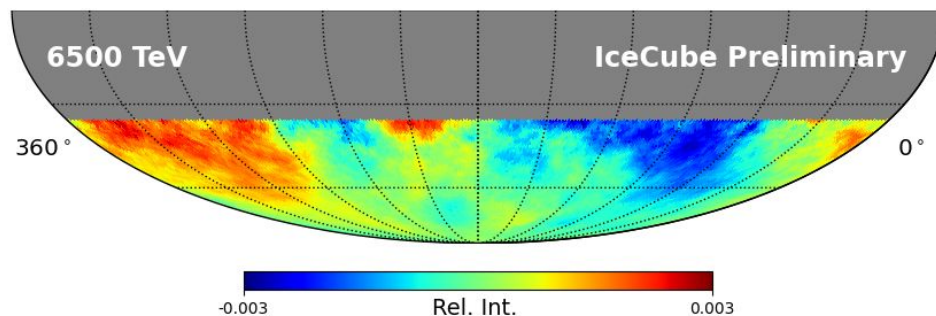
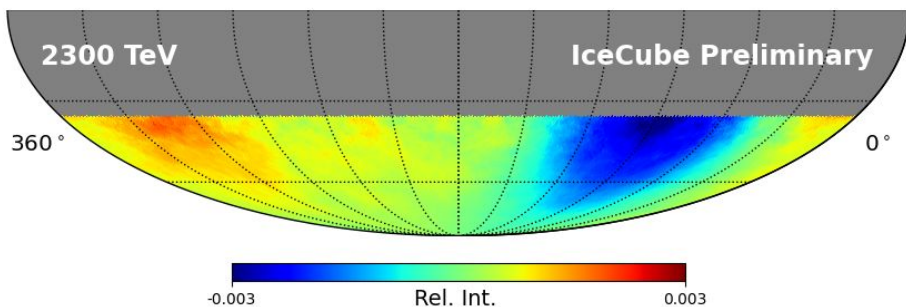
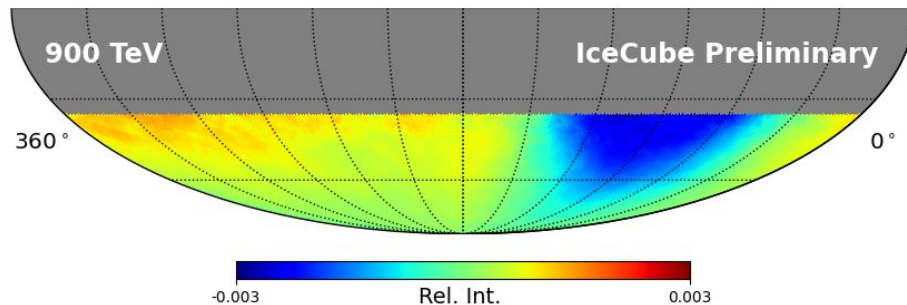
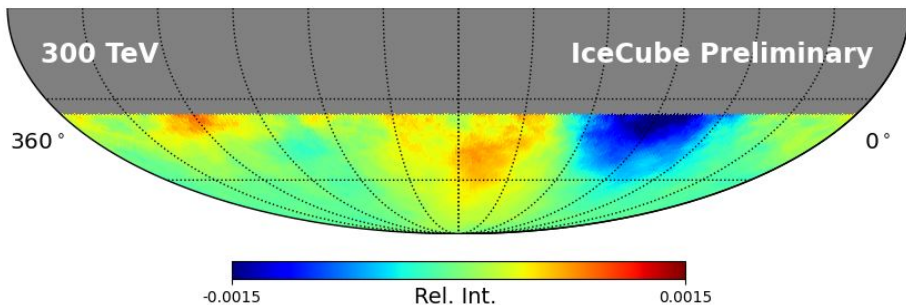
- Snow accumulation over time diminishes detector response
- Data driven approach: adjust cuts on number of stations hit (N_{Stations}) so energy proxy (S_{125}) distribution remains roughly constant



	Tier 1	Tier 2	Tier 3	Tier 4
2011	3 - 4	5 - 9	10 - 16	≥ 17
2012-13	3 - 4	5 - 8	9 - 15	≥ 16
2014	3 - 4	5 - 7	8 - 14	≥ 15
2015			8 - 14	≥ 15
2016-17			7 - 13	≥ 14
2018-19			6 - 12	≥ 13
2020-21			5 - 11	≥ 12

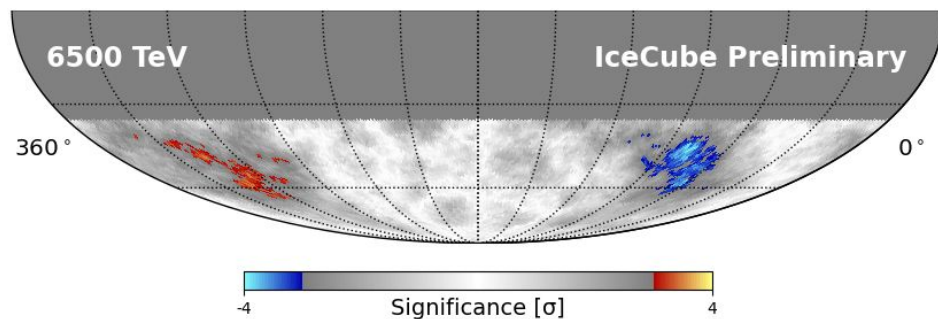
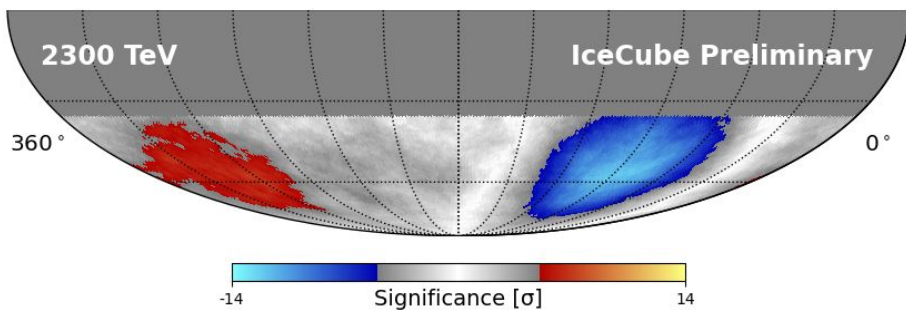
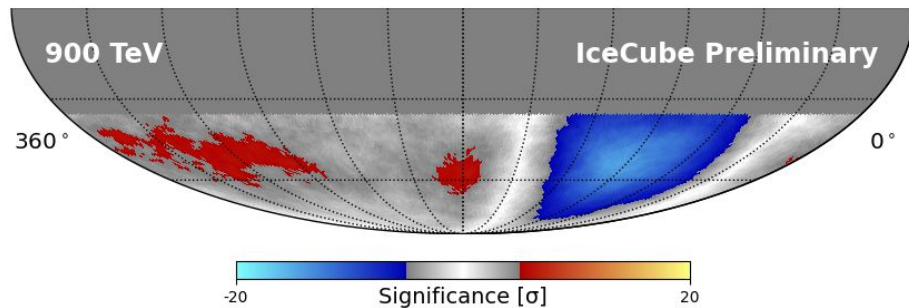
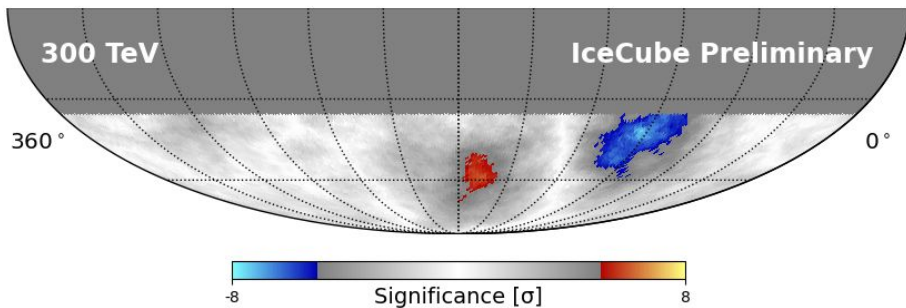
Results

Energy Dependence



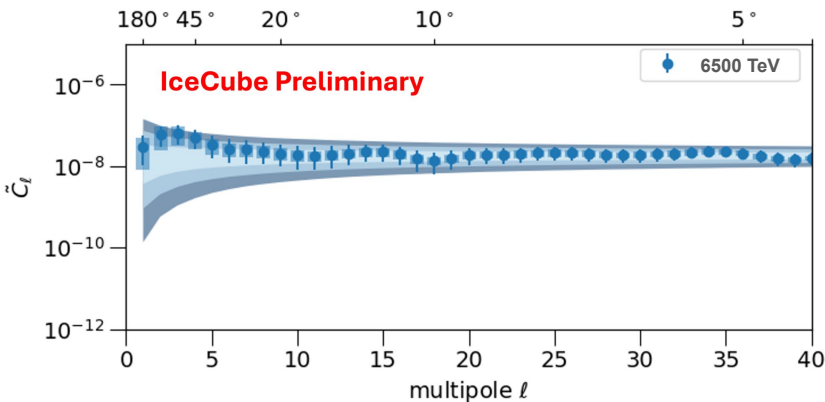
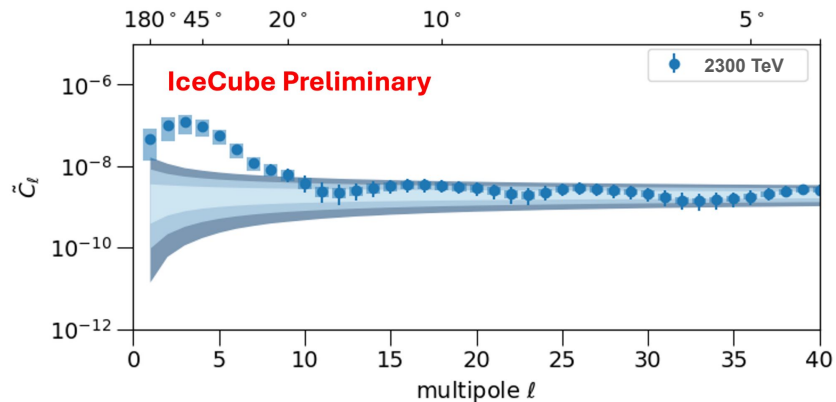
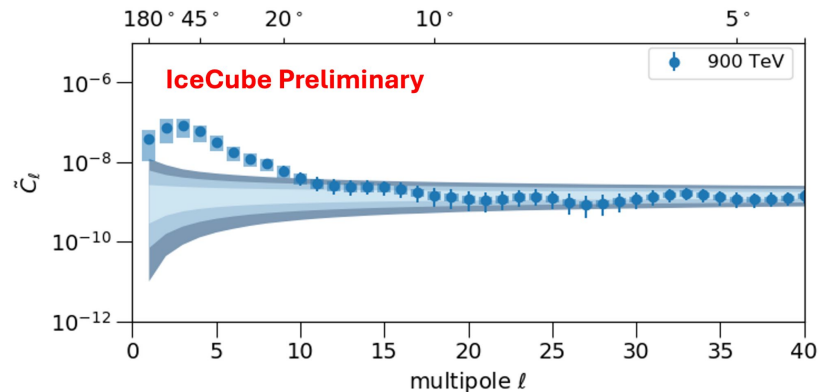
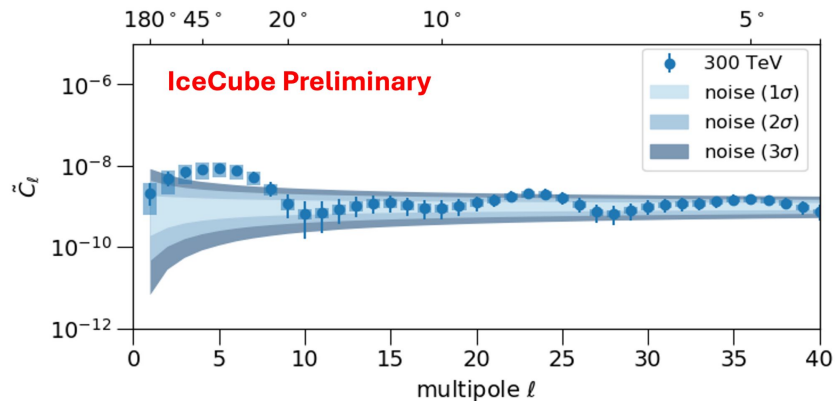
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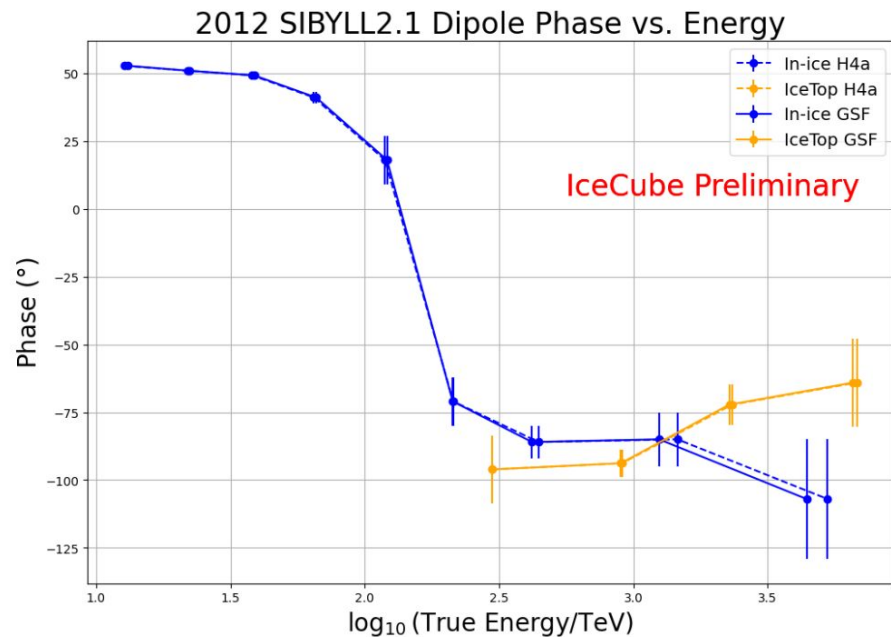
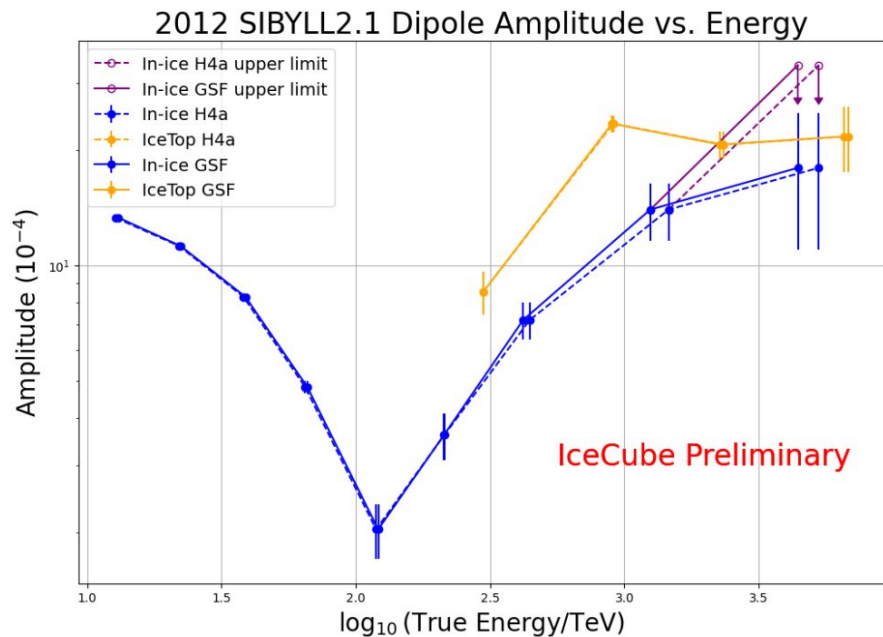
Results

Angular Power Spectra

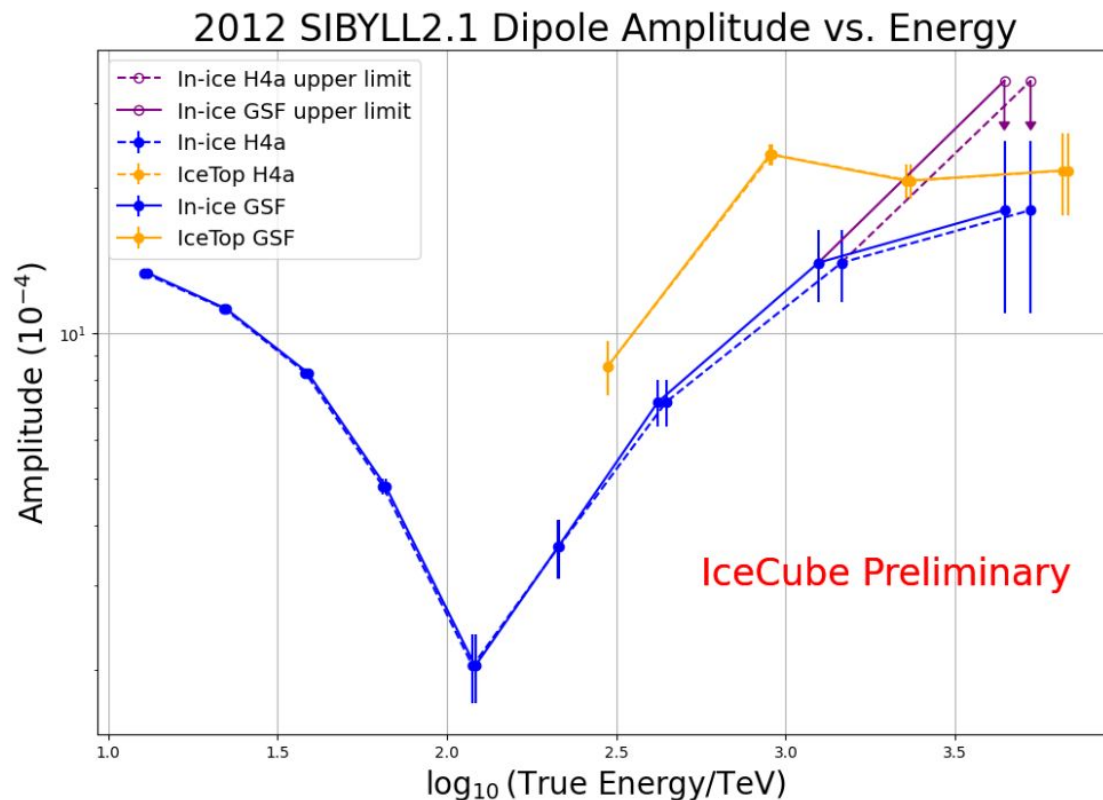


Results

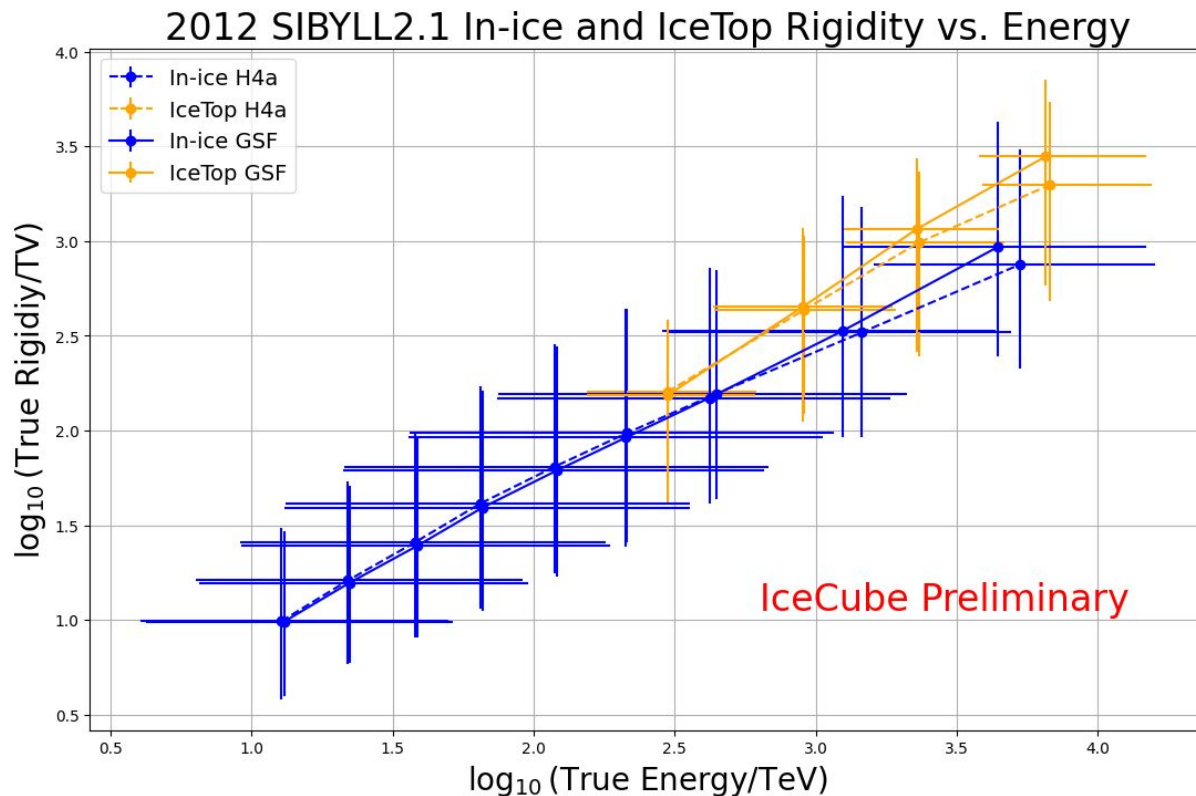
Dipole Phase & Amplitude



- Data put into energy bins based on measurables
 - IceTop: NStations
 - In-Ice: number of hits and reconstructed zenith
- Plot displays median Monte Carlo energy for each energy bin
- What if we displayed the median Monte Carlo **rigidity** instead?

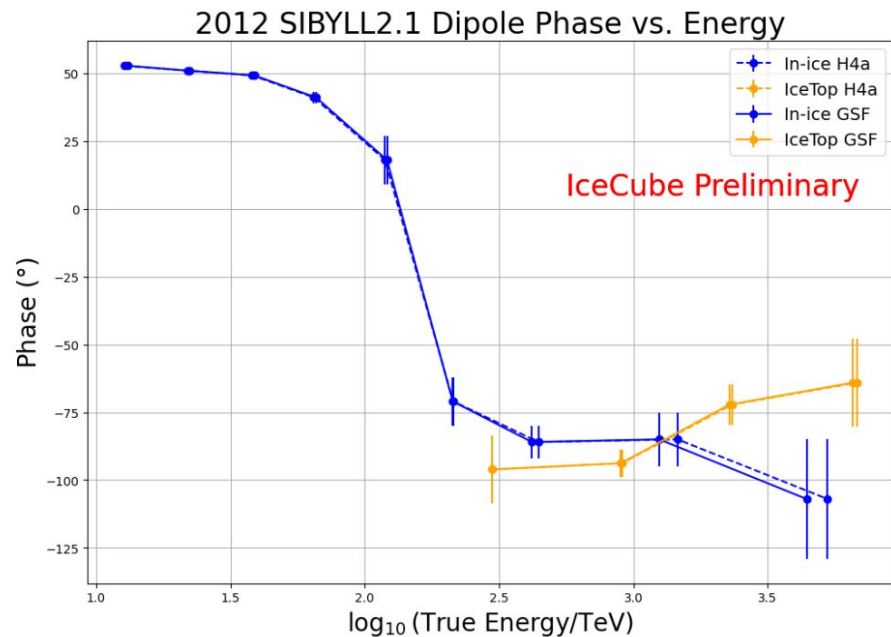
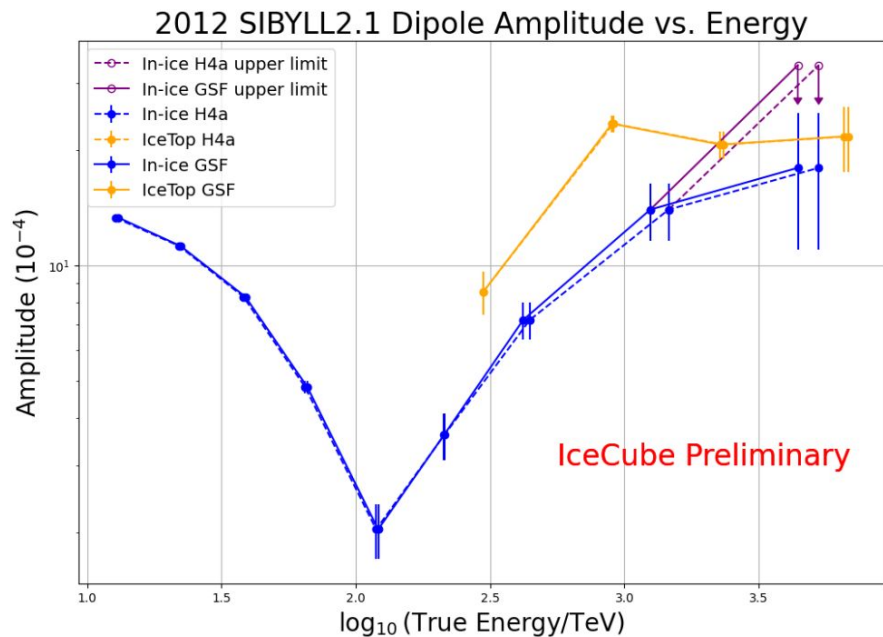


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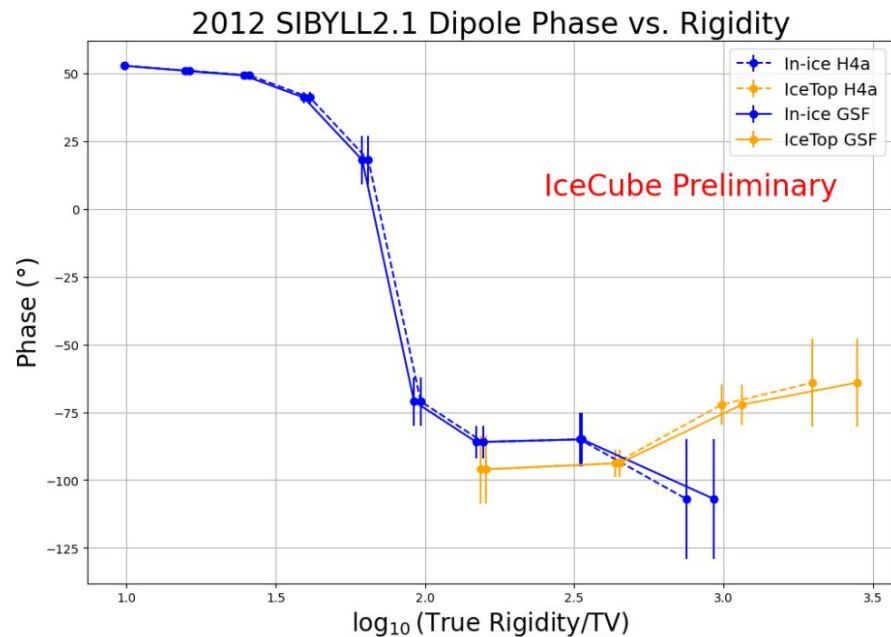
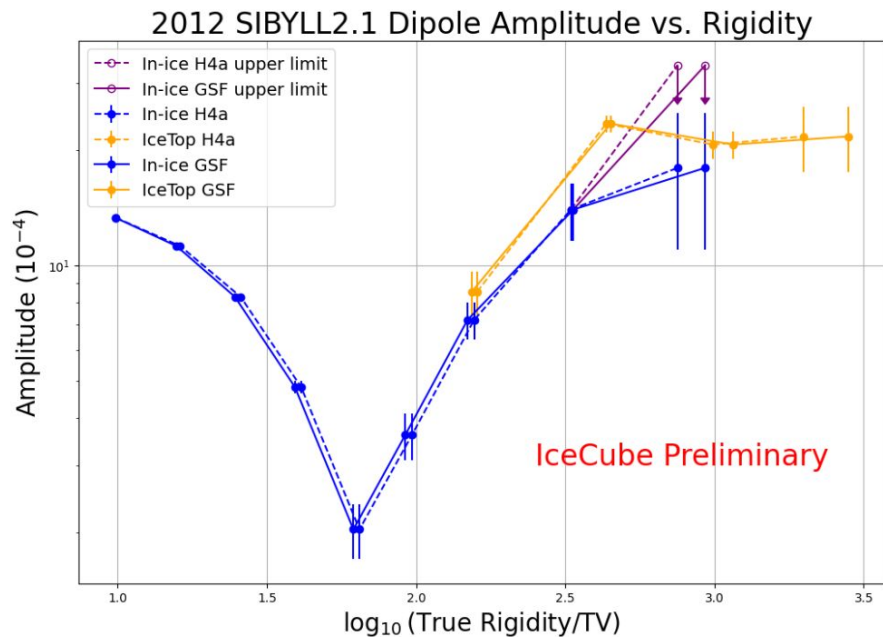
Results

Dipole Phase & Amplitude



Results

Dipole Phase & Amplitude



Summary



Results

- New IceTop **skymaps** and **angular power spectra** provide additional detail for studying cosmic-ray anisotropy in the PeV energy region
- Dipole phase and amplitude more consistent with in-ice measurements when considered as a function of **rigidity**

Upcoming Work

- Time modulation, anti- and extended sidereal frames
- Compton-Getting analysis
- Joint IceTop / TALE analysis
- Joint in-ice / HAWC analysis
- Spectral anisotropy

Mercer

Rajwol Chapagain

Simulation study of energy distributions over time

Robert Futrell

Rigidity analysis

Aidan Hayes

Simulation study of energy distributions over time

Aiden Hinnners

Angular power spectrum, rigidity analysis

Charles Joiner

Systematic checks of detector stability

Loyola

Gunwati Agrawal

Simulation study, snow accumulation study, IceTop data processing/analysis

Elizabeth Bastow

IceTop Data processing/analysis, data stability

Grace Bratrud

IceTop data processing/analysis

Katherine “Jo” Gruchot

Anisotropy time dependence

Will Hayes

Events lifetime/rates

Savannah Lehrman

Simulation study, snow accumulation study, IceTop data processing/analysis

Alexandra McClure

IceTop Data processing/analysis, rigidity analysis

Andrew Moy

Anisotropy time/energy dependence

Joe Summers

IceTop simulation/data comparison

Backup Slides



