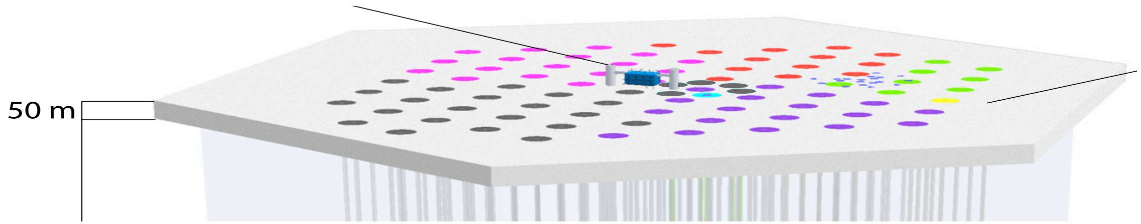
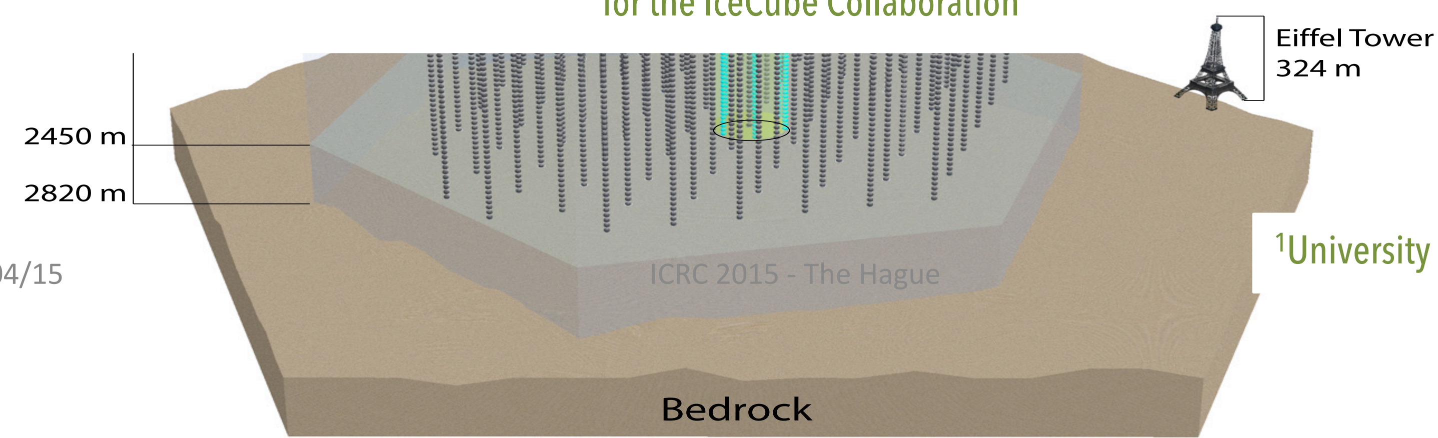


Latest Results on Cosmic Ray Spectrum and Composition from Three Years of IceTop and IceCube

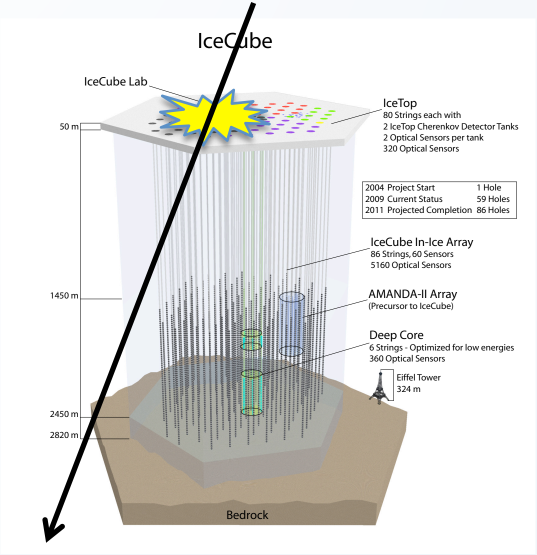
Katherine Rawlins[1]
Tom Feusels, Sam De Ridder, Serap Tilav,
for the IceCube Collaboration



[1]University of Alaska Anchorage

IceCube and Cosmic Rays: analysis styles

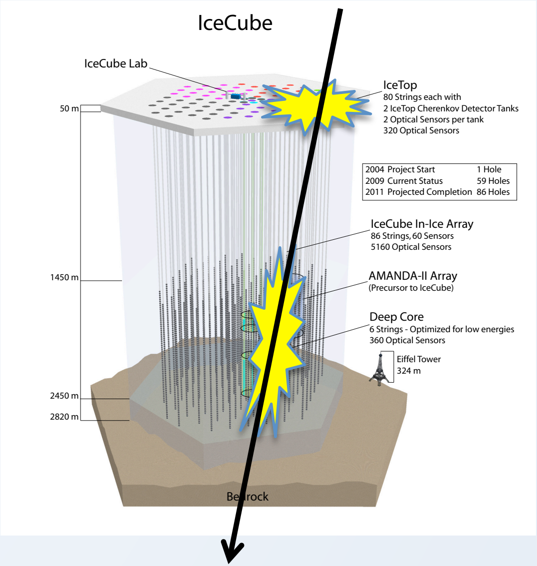
- "IceTop alone"



Greater acceptance, more events

Energy sensitivity from shower size (assuming a composition model)

- "IceTop-IceCube Coincidence"

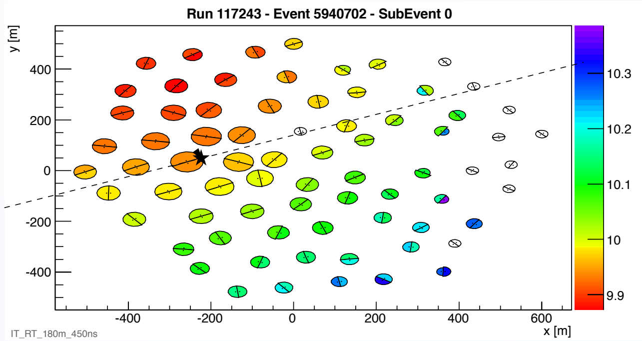


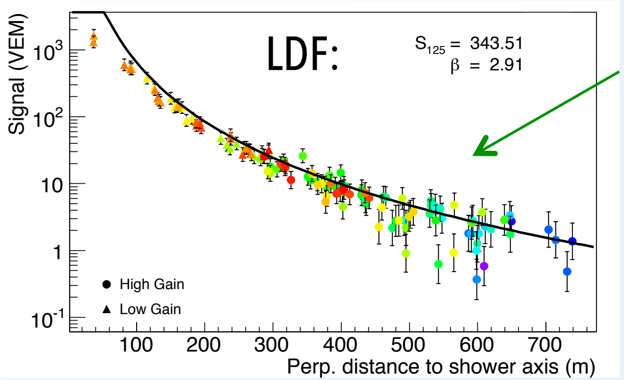
Also measure energy loss profile of high-energy muons that penetrate to depth

Limited number of events, energy *and* composition sensitivity

Analysis Strategy: IceTop-alone

Top view: colors = timing,
bubble size = charge

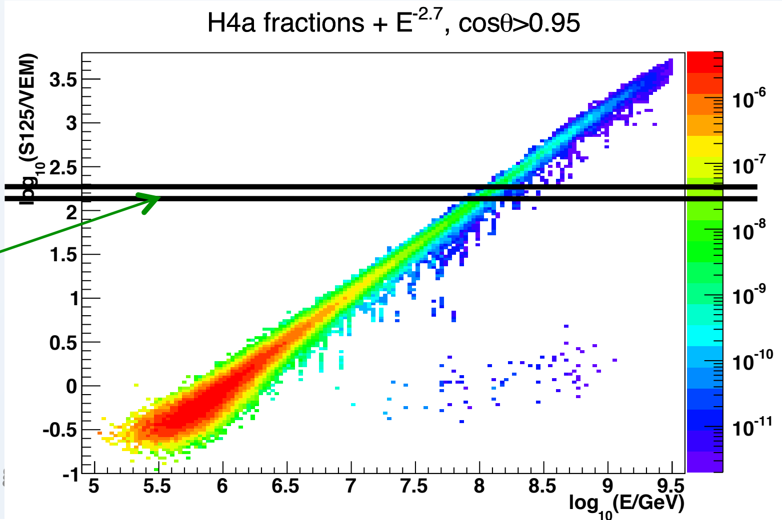




Reconstruct:

Fit tank charges and arrival times

Find best-fit core position/ direction, and LDF (S125, beta)



Build S125 -> Energy conversion functions:

Using Monte Carlo simulations (and assuming a composition model),

Find most likely energy within each slice of S125

Do this separately for 4 zenith angle ranges

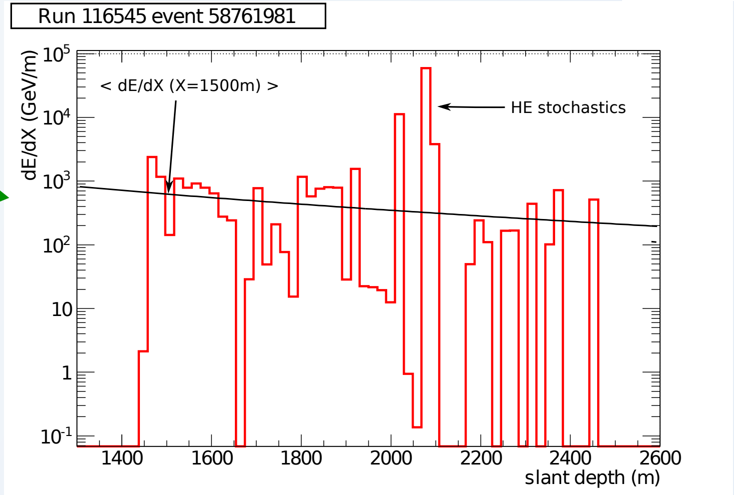
Analysis Strategy: Coincidence

<u>Reconstruct in deep IceCube:</u>

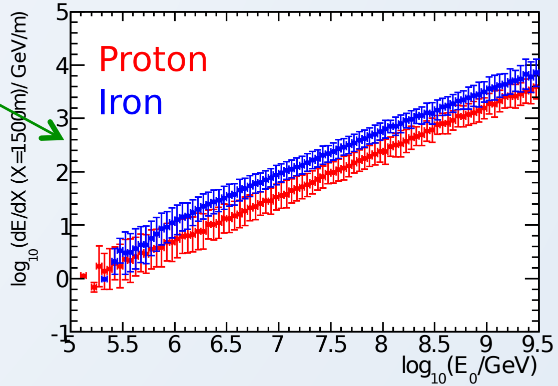
Construct energy loss profile

Fit the profile to find:

- the mean muon energy loss at 1500 m slant depth, and
- the number of large stochastic losses (2 different thresholds)



Muon energy loss at 1500 m is highly composition-sensitive:



The two measures of number of stochastics are also sensitive to composition.

Feed five input variables from both IceTop (S125, zenith) and IceCube (dE/dX @ 1500, Nstoch1, Nstoch2) into a <u>neural network</u>…

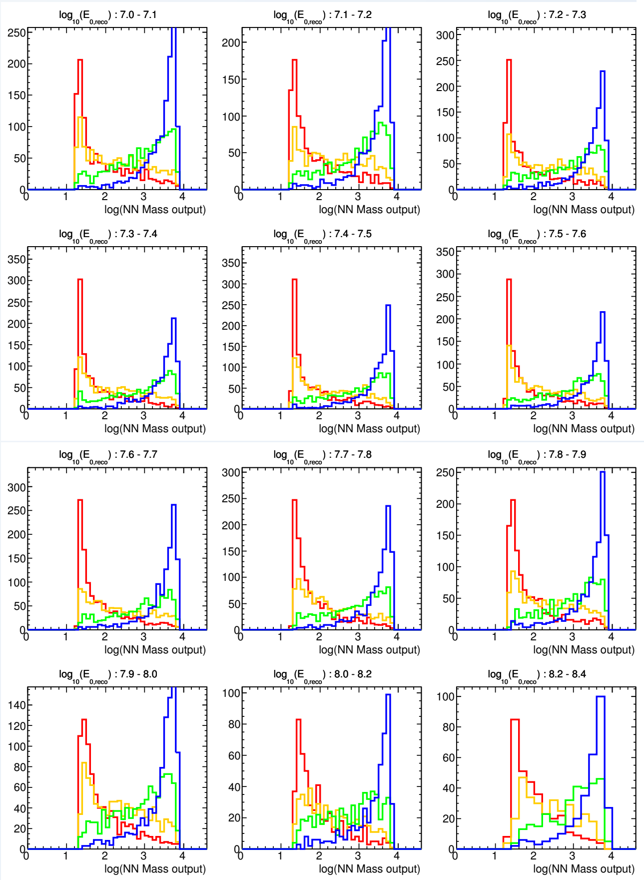
Outputs of the network: Primary energy, Primary mass.

Analysis Strategy: Coincidence

<u>Construct template histograms of NN primary mass</u>

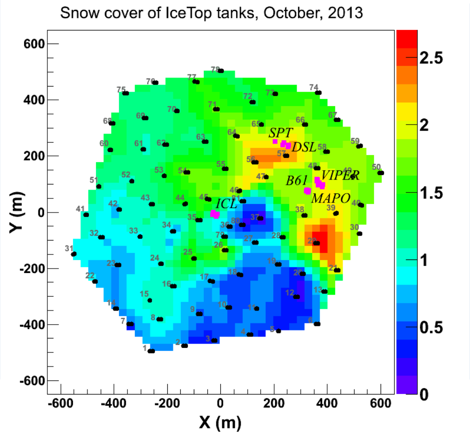
Within each bin of reconstructed energy, compare templates for Monte Carlo (four types: H, He, O, Fe)

Run experimental data through the same NN procedure, and find the fractions of each element that best reproduce the template histogram of the data.

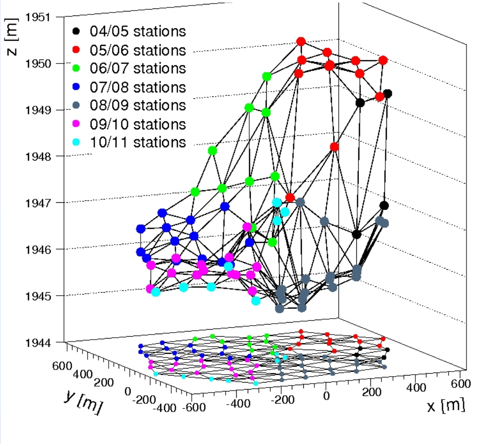


What is new?

IceTop-alone: M.G. Aartsen et al., *Phys. Rev. D* **88**, (2013) 042004. (arXiv:1307.3795)
Coincidence: ICRC 2013, paper 0861

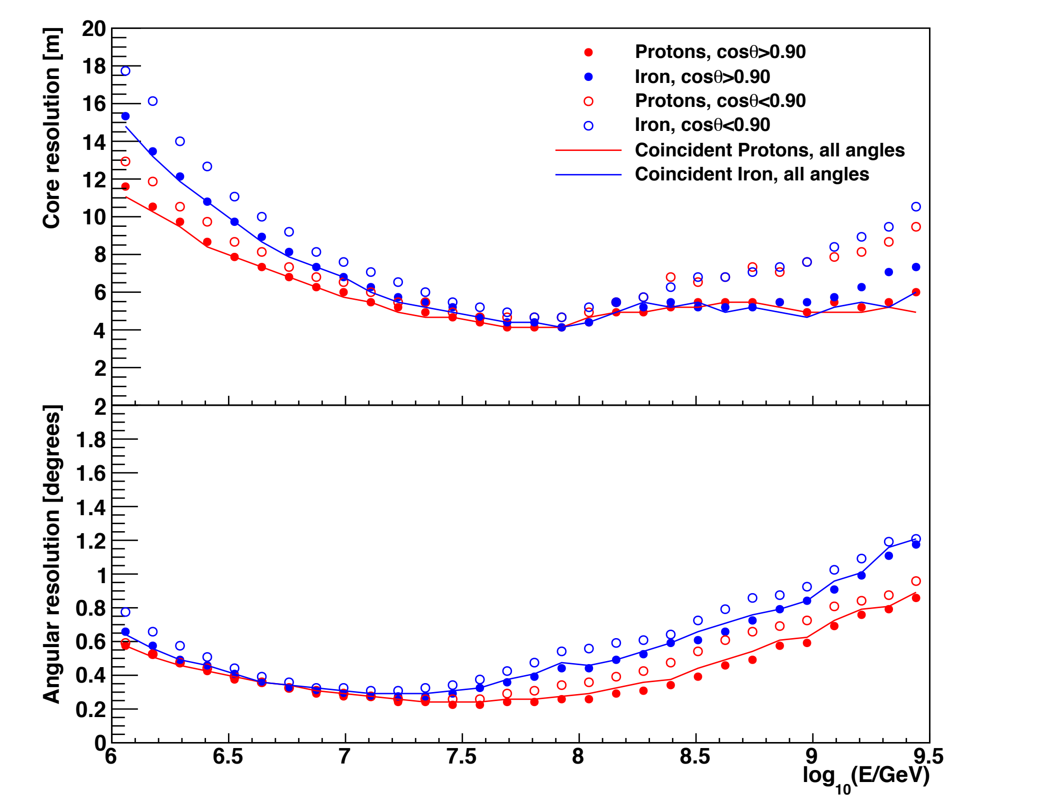


- Both analyses extended from 1 year to 3 years of experimental data
  - IT-81/IC-86 data retriggered to IT-73/IC-79
  - Snow reconstruction optimized separately for the three years



- Problem found in simulation of the northeast corner of the array: under-simulation of snow, leading to overestimation of S125 in Monte Carlo – fixed in both analyses.
  - Reconstruction resolution improved
  - Overall spectrum moved downward

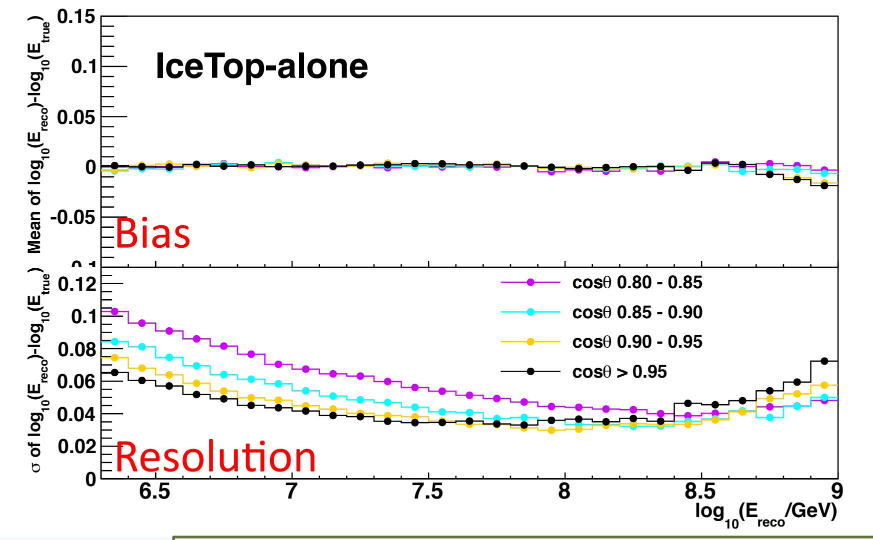
Position/Direction Performance

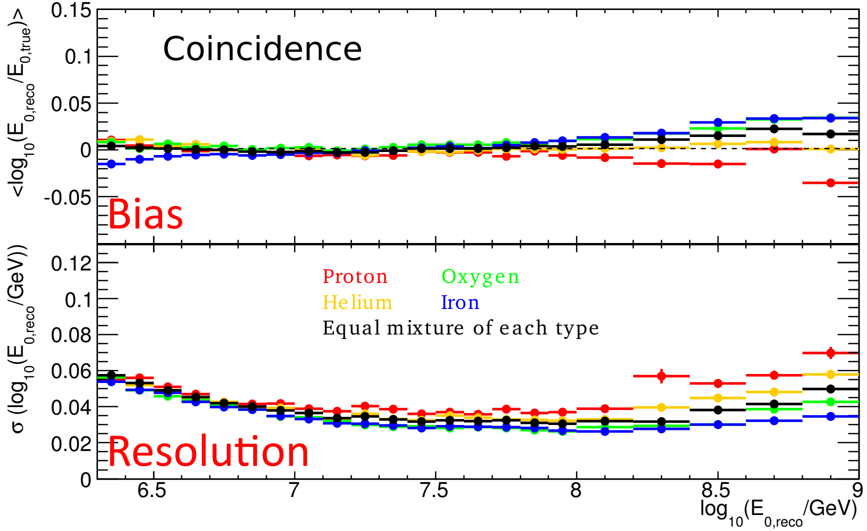


Core position: between 5-10 meters

Direction: less than 1°

Energy Reconstruction Performance



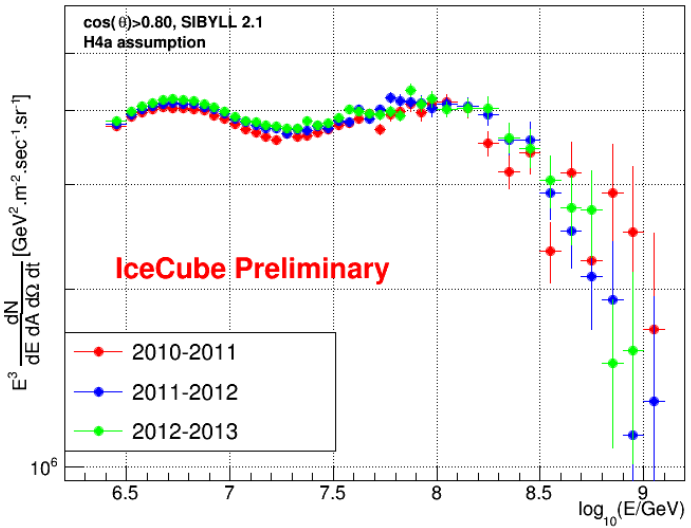


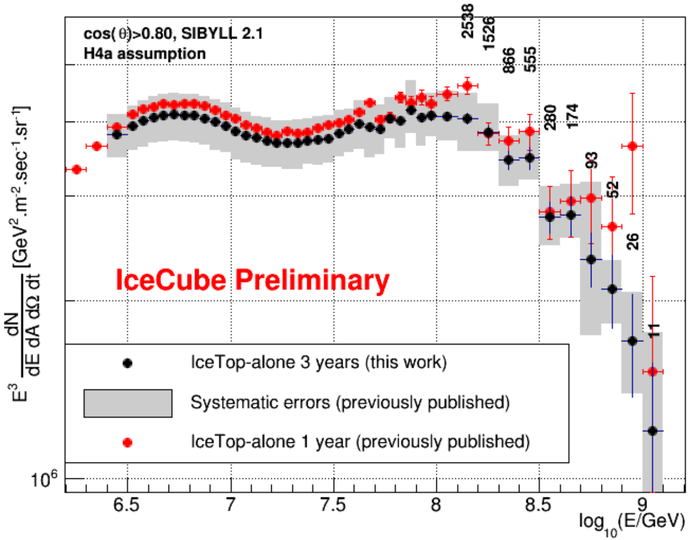
Bias = near zero

Resolution: best between 10 and 300 PeV, worsening in regions where position/ direction resolution suffers (misreconstructions)

Spectrum result: IceTop-alone

- 3 years compared to each other
- 3-year result compared to previously published



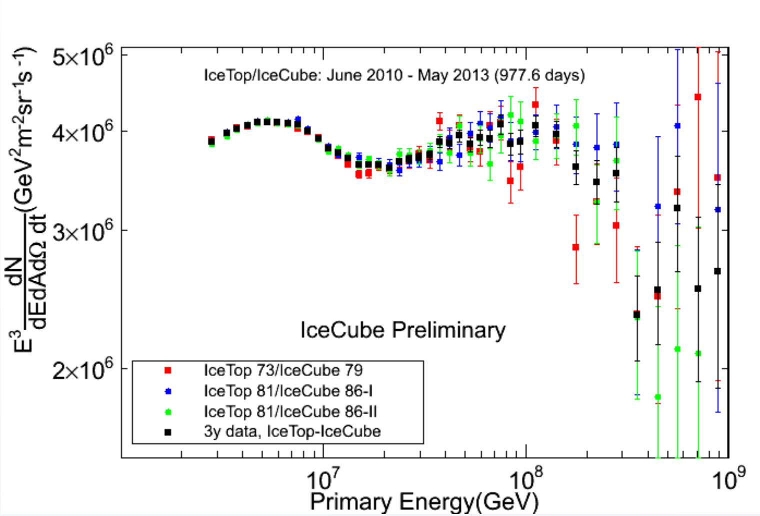


Good agreement between years

Shift due to correction of a simulation problem (under-simulation of snow)

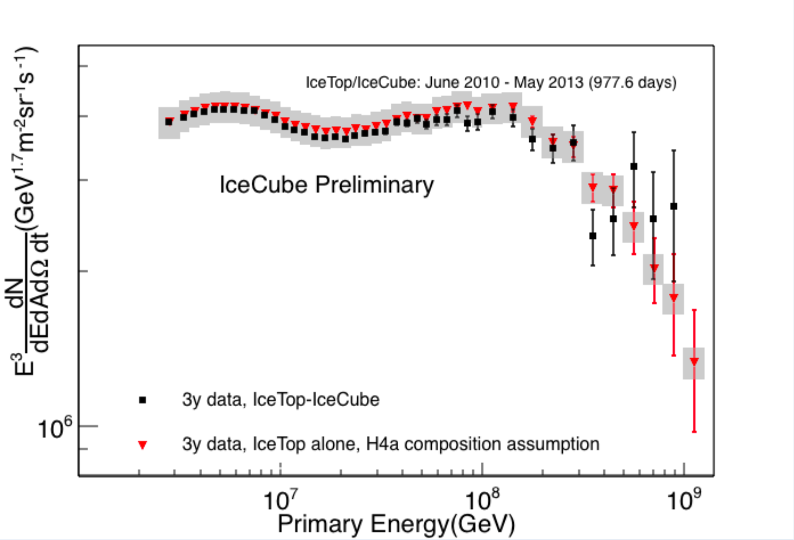
Spectrum Result: Coincidence

- 3 years compared to each other



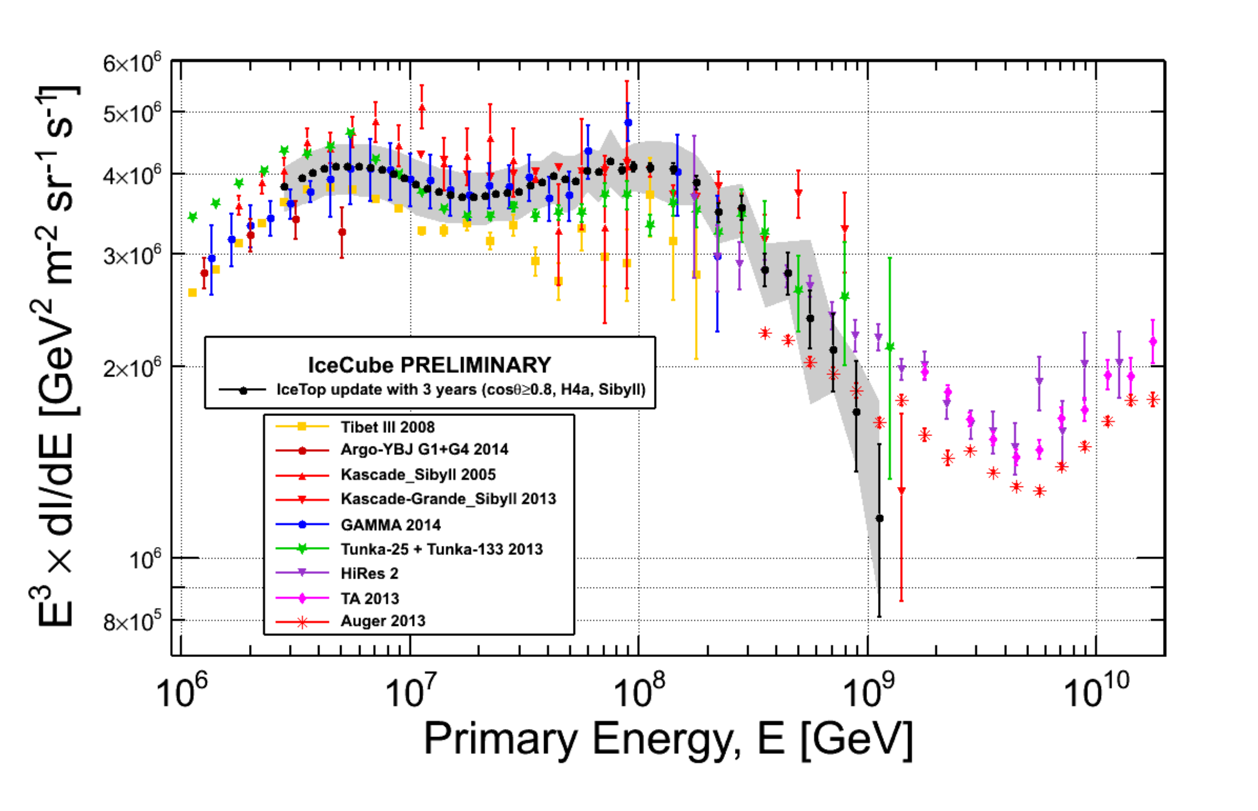
Good agreement between years

- Coincidence result compared to IT-alone result



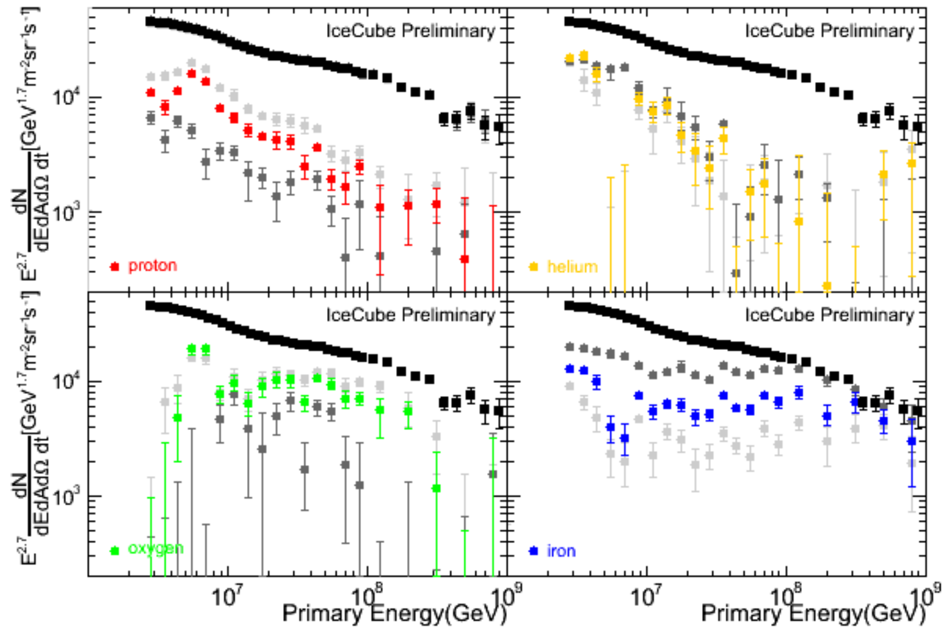
Good agreement between complementary techniques

Spectrum: comparisons



Individual Nuclear Spectra

- … with light yield systematics

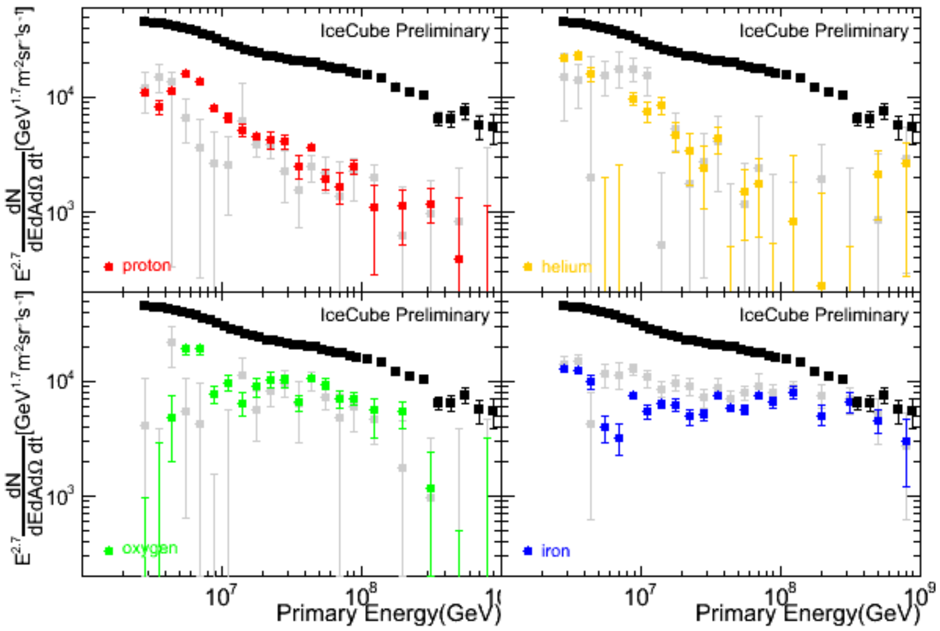


Colors = nominal
Dark Grey = -12.5%
Light Grey = +9.6%

Protons/Helium spectra are steeper. Oxygen/Iron maintain harder spectrum out to higher energies.

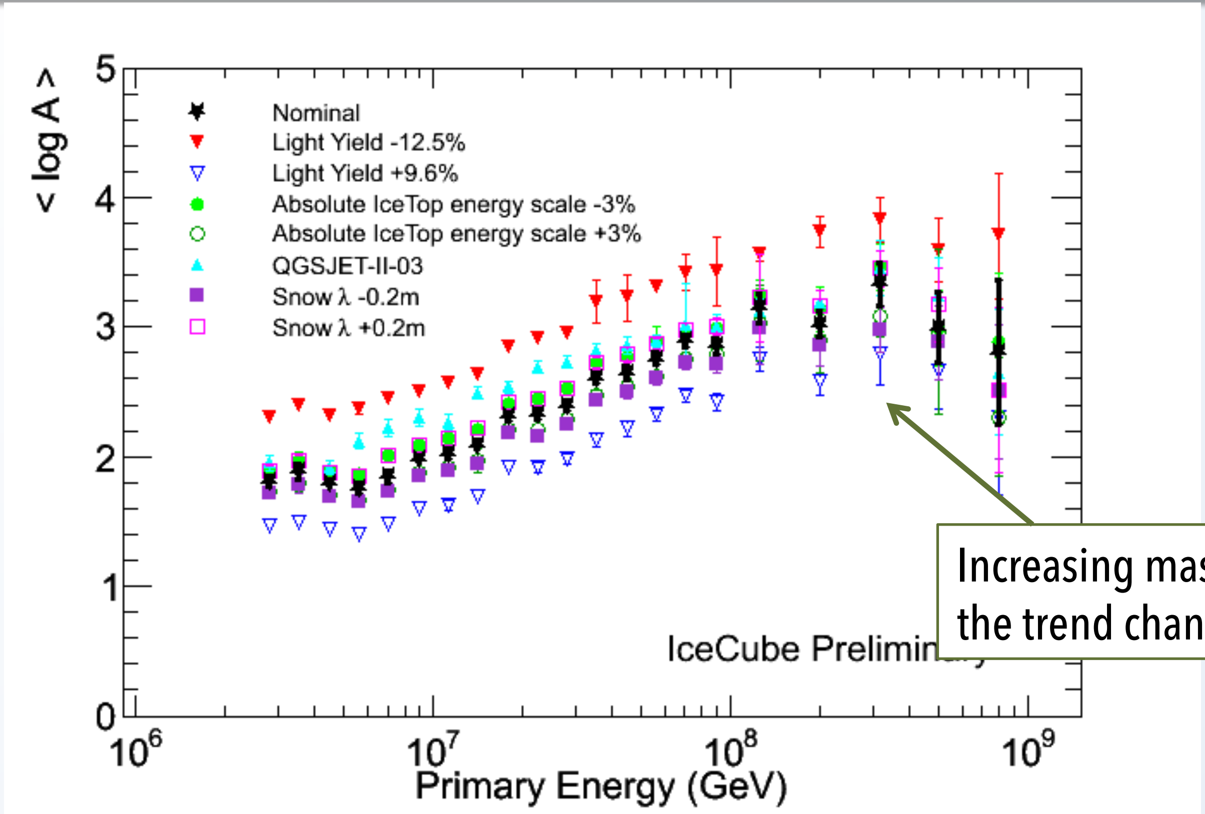
Individual Nuclear Spectra

- … with hadronic interaction model systematics



Colors = SIBYLL 2.1
Grey = QGSJET-II-03

Mean log mass <lnA>



Increasing mass up until ~100 PeV, where the trend changes slope

The end!

- Thank you for your attention.

Backup slides…