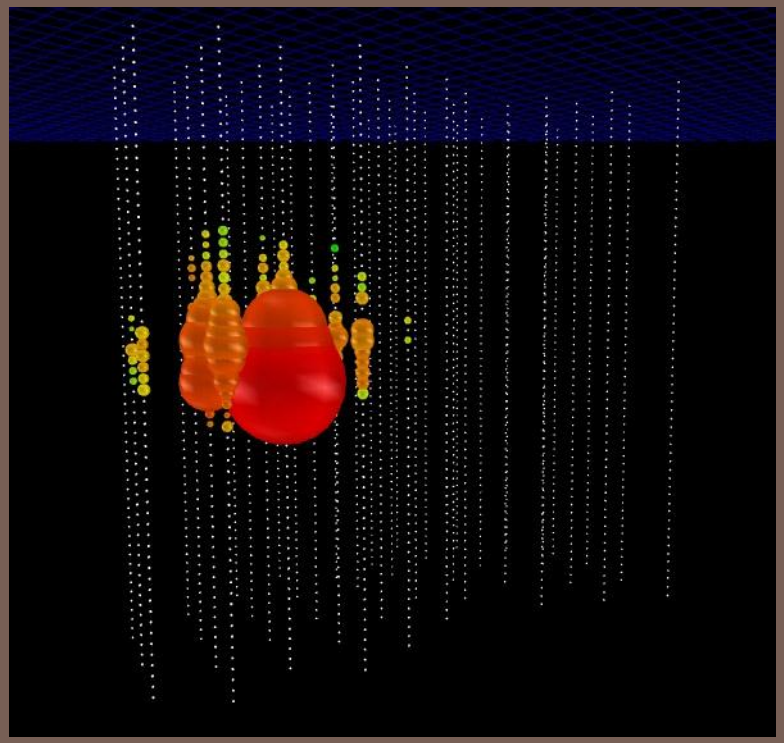
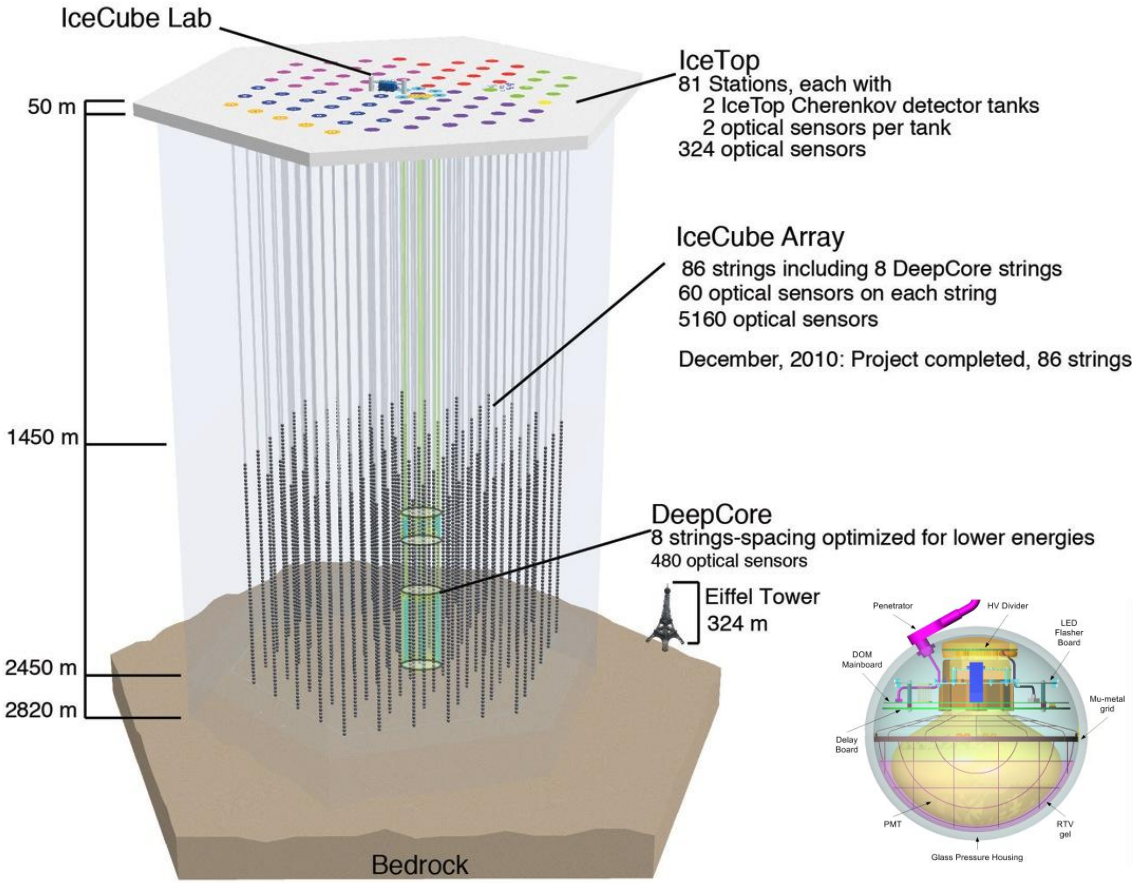


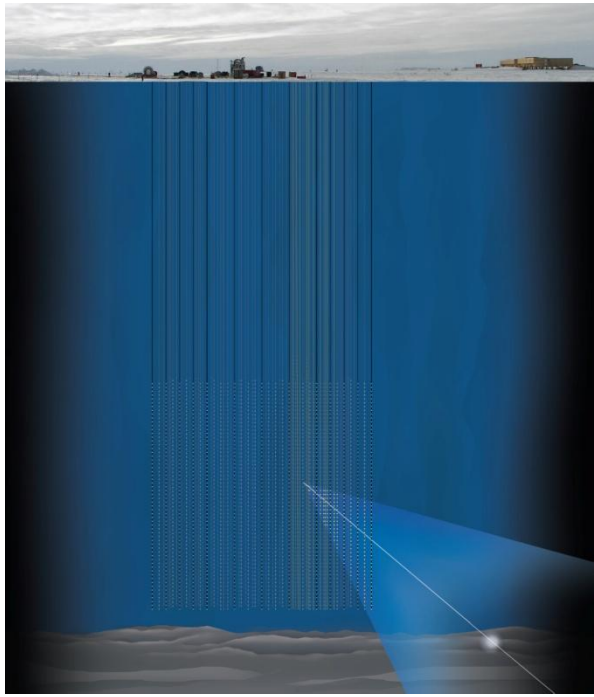
SEARCHING FOR A DIFFUSE FLUX OF ULTRA HIGH-ENERGY EXTRATERRESTRIAL NEUTRINOS WITH ICECUBE

LLWI 2011

Henrik Johansson, for the IceCube collaboration

The IceCube Neutrino Observatory





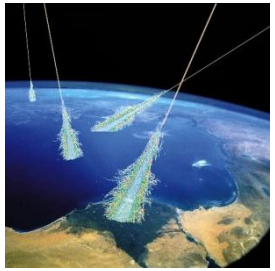
Science goals

Neutrino astronomy is still a young field – only confirmed extraterrestrial sources are the sun and supernova SN1987a. The IceCube neutrino observatory is versatile and allows for a wealth of science. Science goals include:

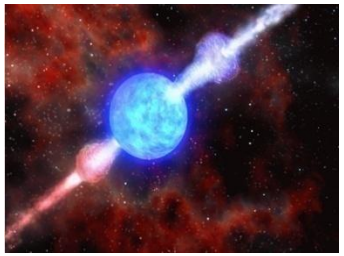
- Reveal sources of the highest energy cosmic rays
- Provide information about the nature of the energy release processes behind objects such as AGNs, GRBs
- Determine the distribution of cosmic accelerators in the universe
- Explore the nature of dark matter
- Constrain neutrino oscillation parameters

Neutrino sources

Supernovae



Atmospheric neutrinos

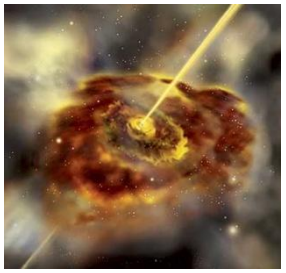


Gamma-ray bursts

GZK neutrinos

Dark matter

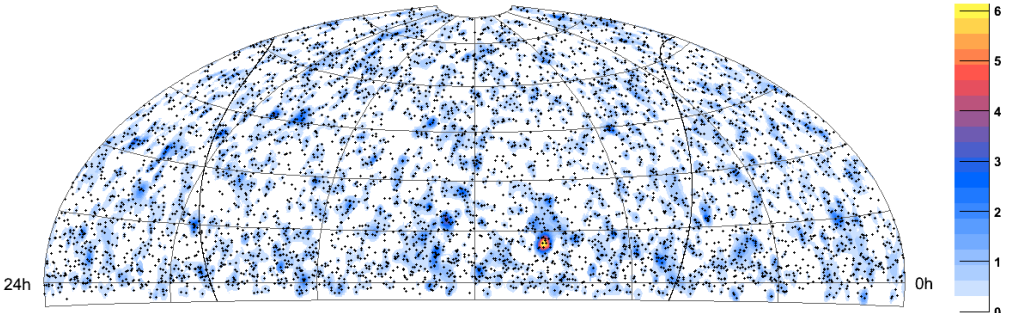
Active galactic nuclei



Supernova remnants

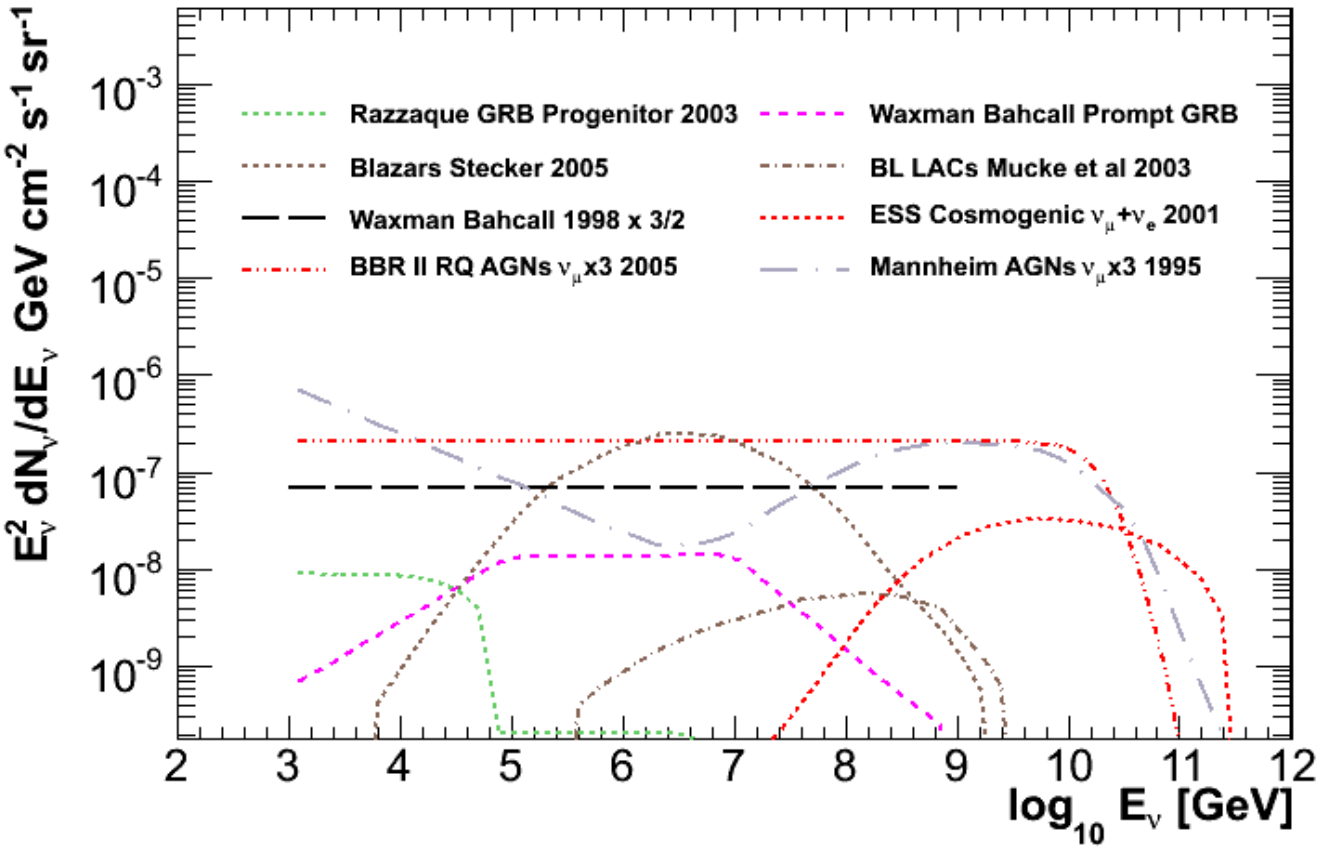
Types of analyses

- **Point source analyses –** resolved and localized flux. Signal region is known, background can be estimated from experimental data.
- **Diffuse analyses –** unresolved flux. Signal region not well known or localized, background estimated from simulation. Simulation verified on subsample of experimental data.

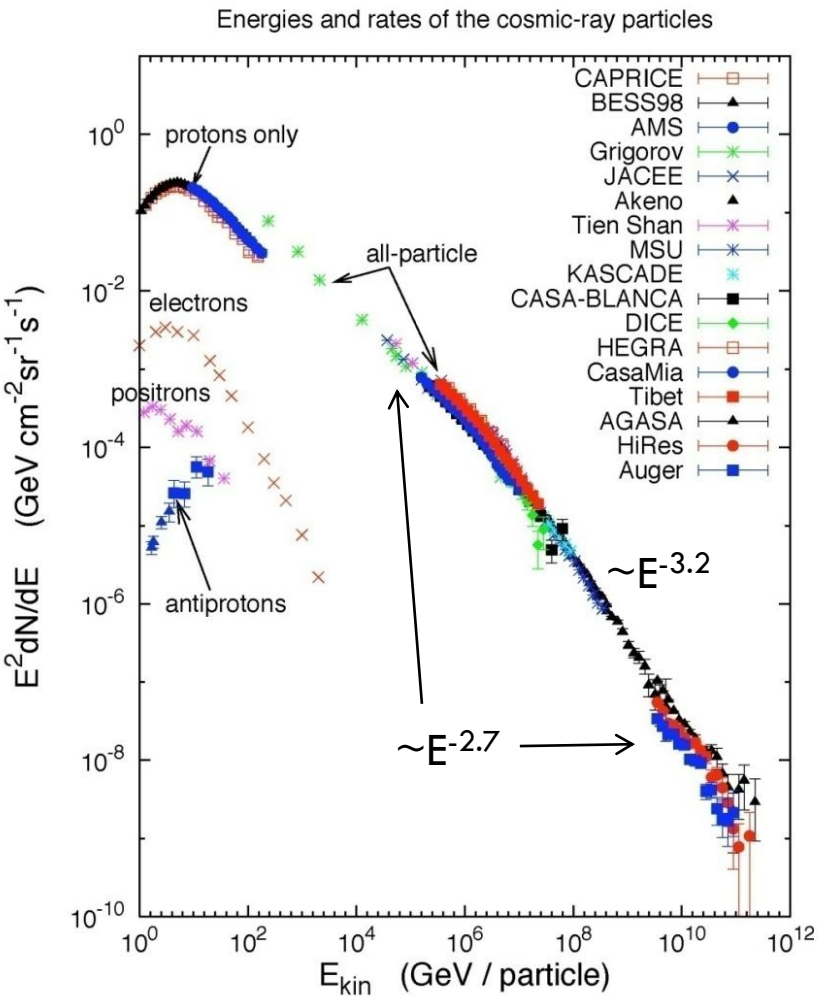


Signal – diffuse analyses

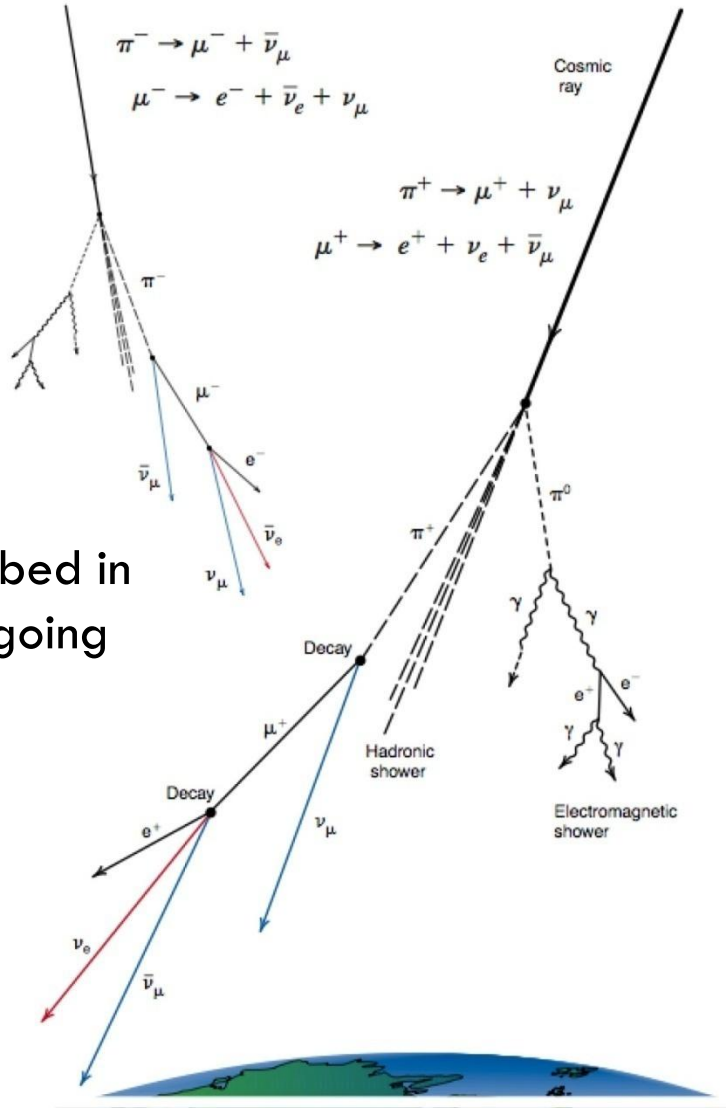
- **Waxmann-Bahcall upper bound** for an all-flavor neutrino flux with **energy spectrum E^{-2}** is 6.75e-8 GeV cm^{-2} s^{-1} sr^{-1}.



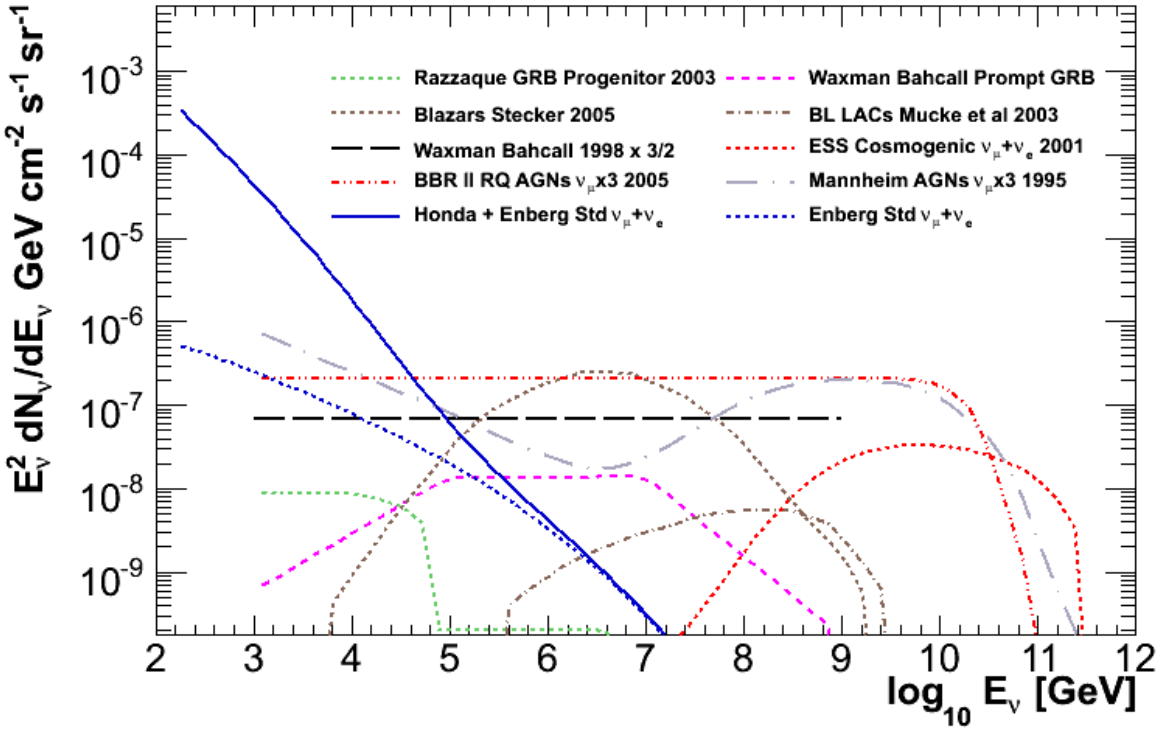
Background – atmospheric μ and ν



- Atm μ absorbed in Earth – down-going in detector

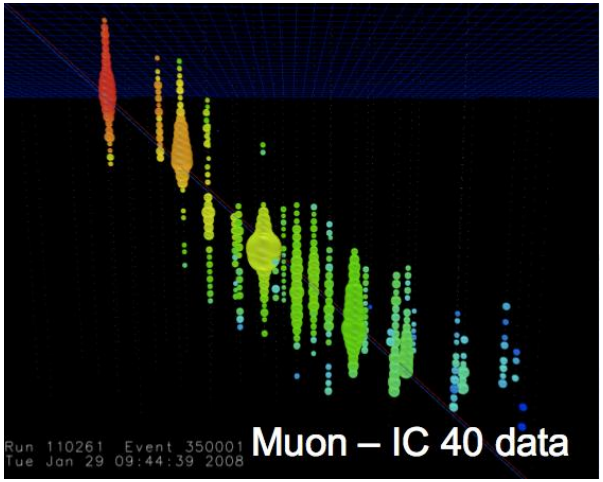


Background – atmospheric ν

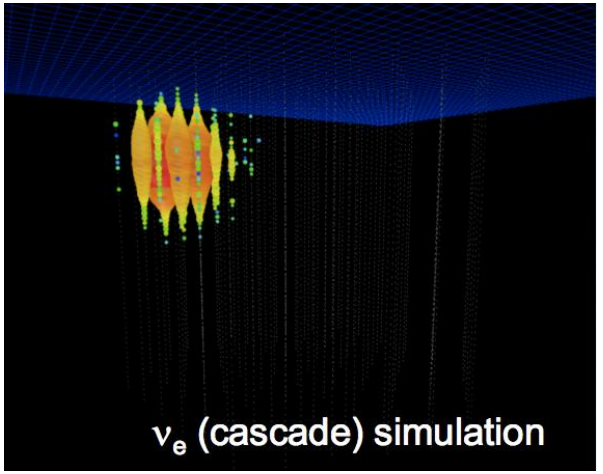


- **Signal energy spectrum,** typically E^{-2}, is **harder than for atmospheric muons and neutrinos,** which follows cosmic-ray spectrum or softer.

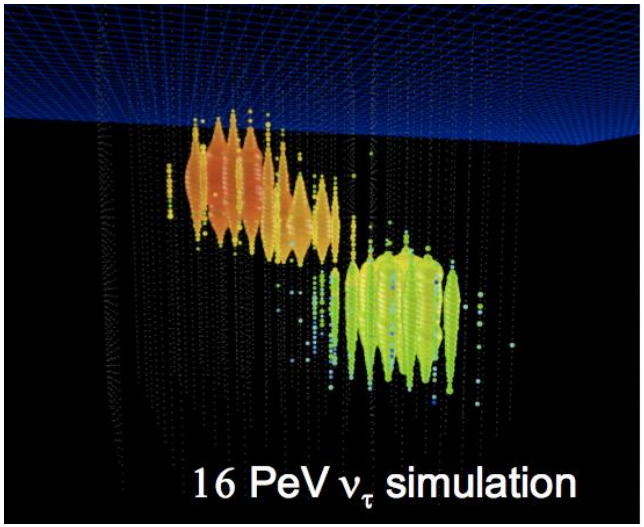
Event topology



Tracks:
- Through-going muons
- Pointing resolution < 1°



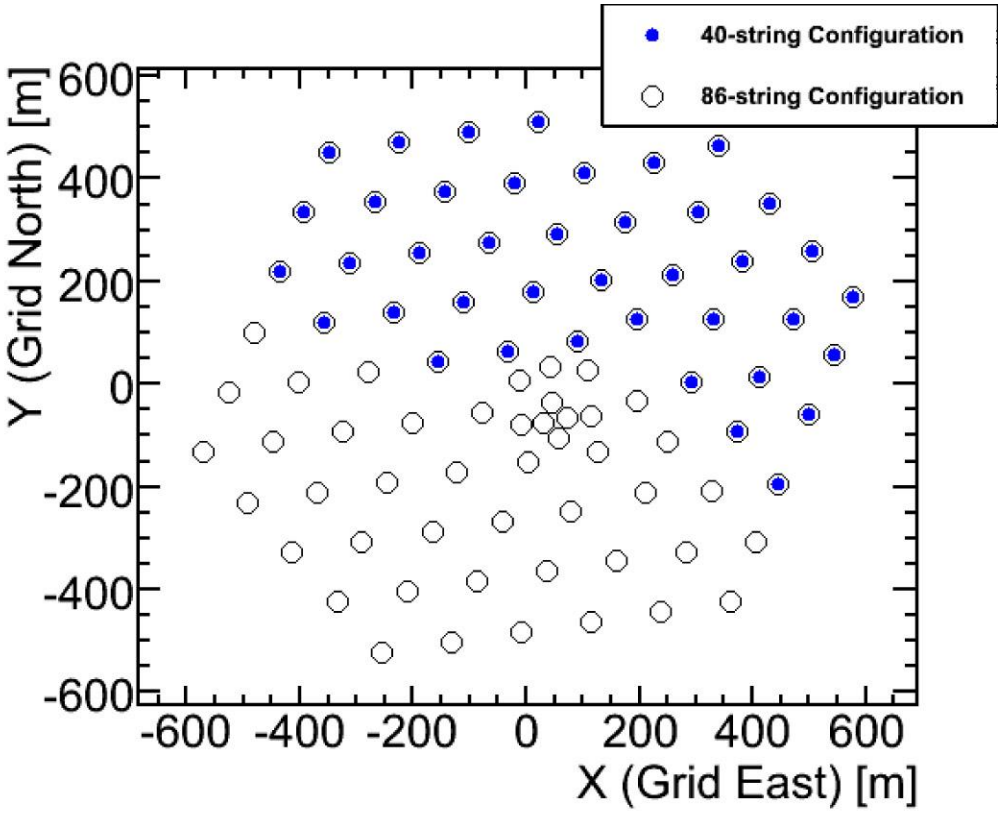
Cascades:
- All-flavor ν neutral current
- ν_e and low energy ν_τ charge current
- Energy resolution contained events ~10% in log(E)



Composite:
- Starting tracks
- High energy ν_τ (double bangs, lollipops)
- Good directional and energy resolution

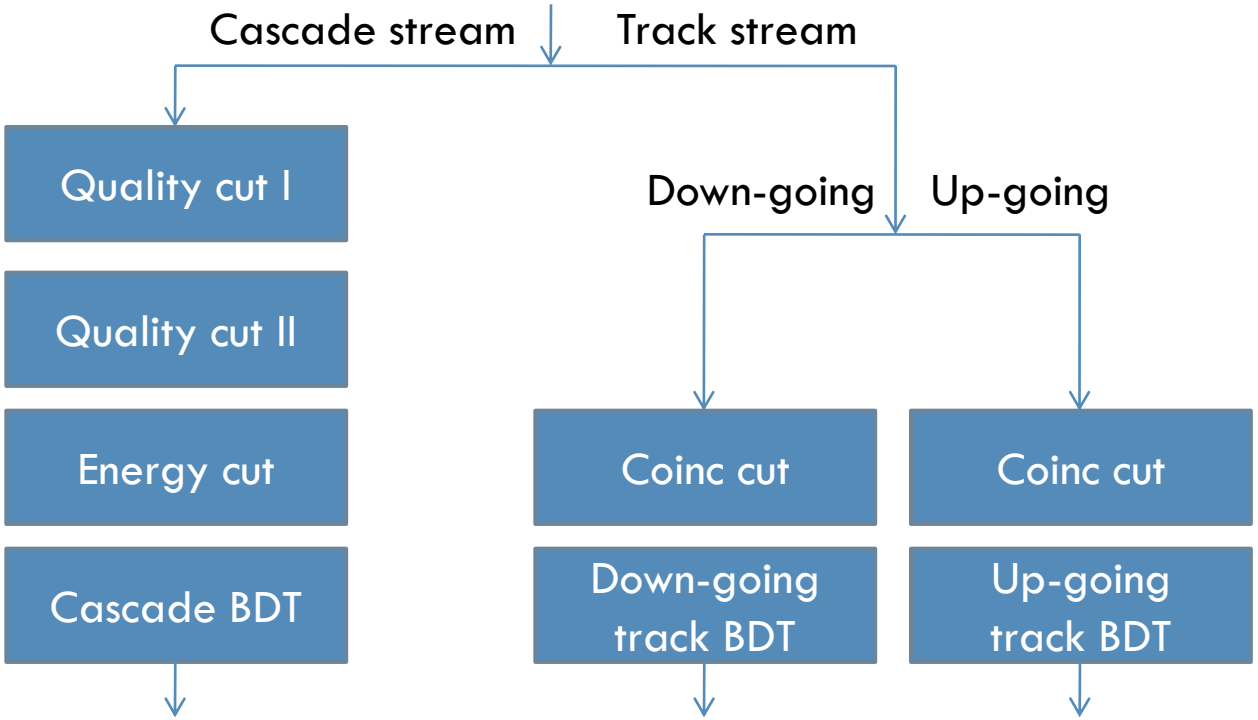
IC40 UHE diffuse analysis

- Experimental data from 2008 - 2009

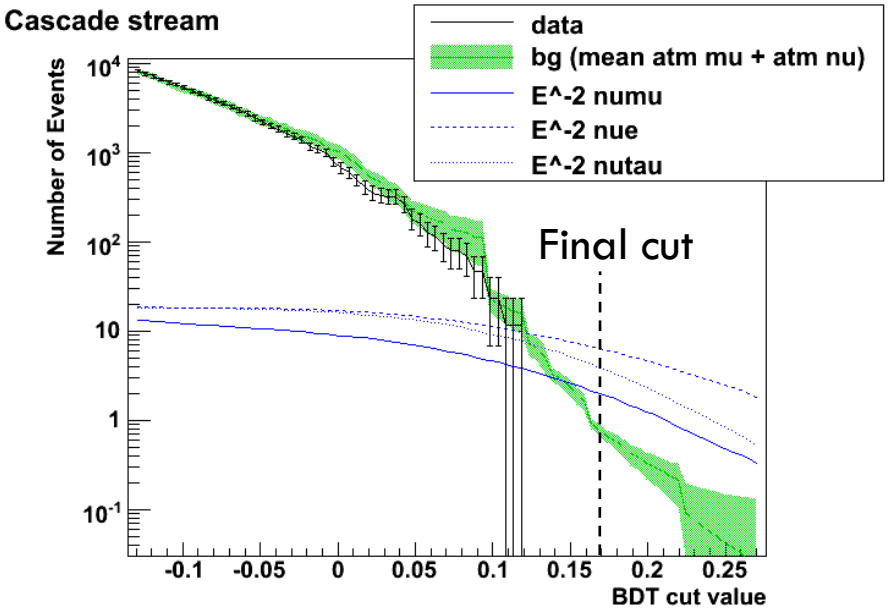


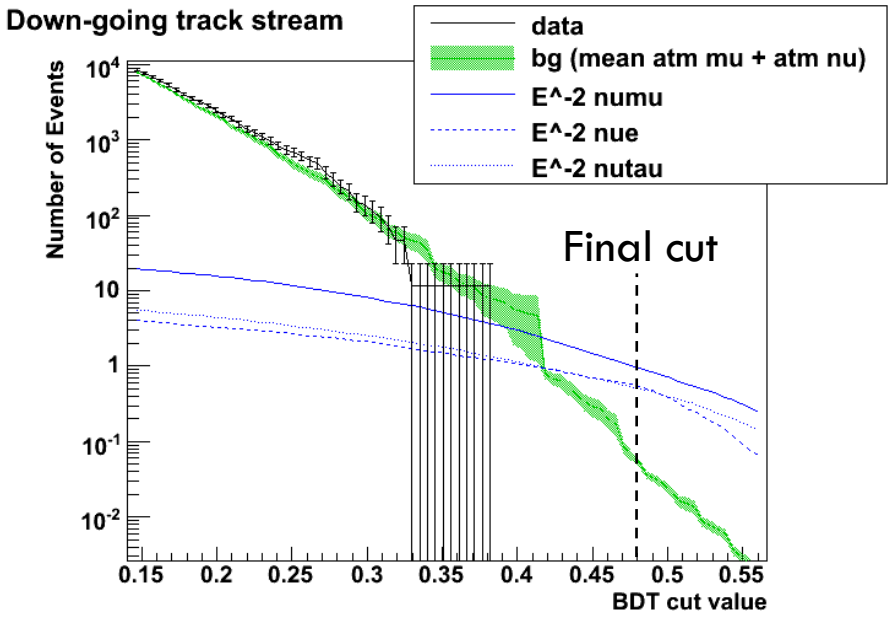
IC40 UHE diffuse analysis

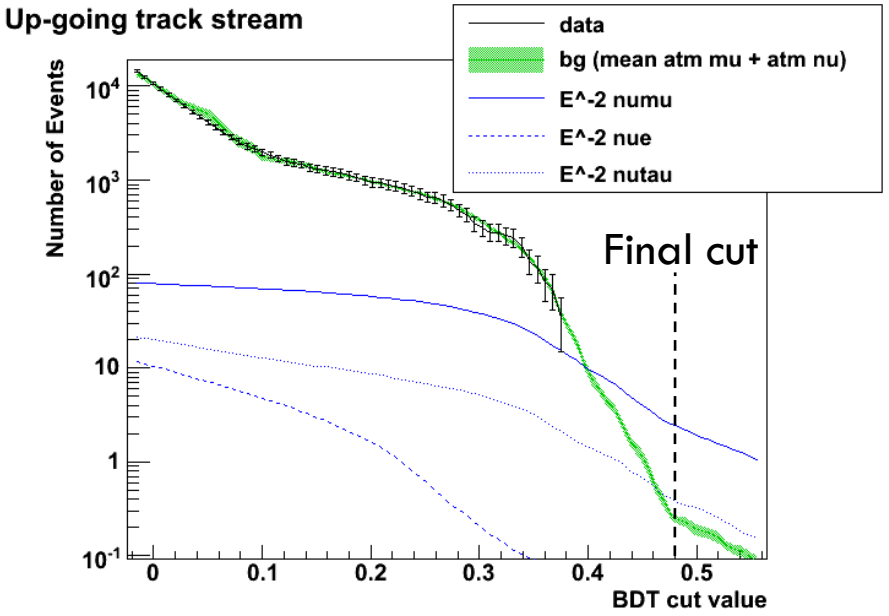
- **Three event streams** are defined **based on signal and background event topology.**
- **First** IceCube analysis to employ this type of structure.



- A **final cut** was defined as **an OR between cuts on each of the three BDTs.**
- The final cut was **optimized** to give the best sensitivity ("model rejection factor") to a Waxmann-Bahcall $\mathbf{E^{-2}}$ test signal flux with **energy > 1 PeV.**
- The analysis follows a **blindness** procedure. A subsample of experimental data is used to verify simulation predictions. This subsample is not used in the search for a signal.







IC40 UHE diffuse analysis

Preliminary

- The final cut predicts **1.2 +/- 0.5 background events** for a livetime of 345.7 days. A Waxmann-Bahcall signal flux predicts 17.2 signal events.
- The **most signal efficient stream is the cascade stream**. The cascade stream also lets in most background.

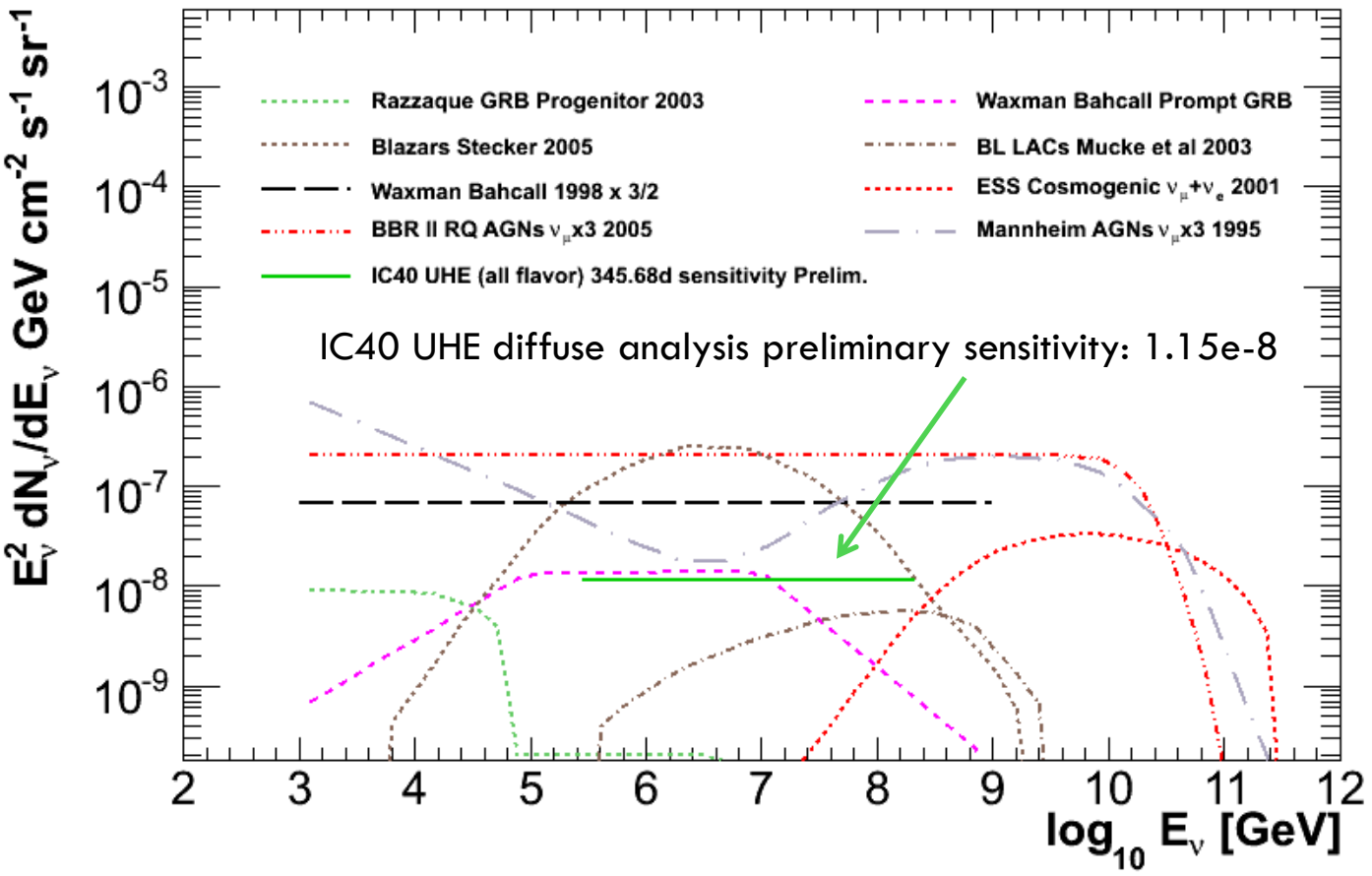
Stream	Atm μ	Atm ν_μ	Atm ν_e	E^{-2} ν_μ (WB)	E^{-2} ν_e (WB)	E^{-2} ν_τ (WB)
All	**0.17**	**0.62**	**0.43**	**5.59**	**6.68**	**4.94**
Track down	0.01	0.05	0.01	1.03	0.57	0.54
Track up	0	0.27	0.00	2.60	0.02	0.42
Cascade	0.17	0.30	0.43	2.14	6.63	4.20

IC40 UHE diffuse analysis

- Systematic and statistical uncertainties

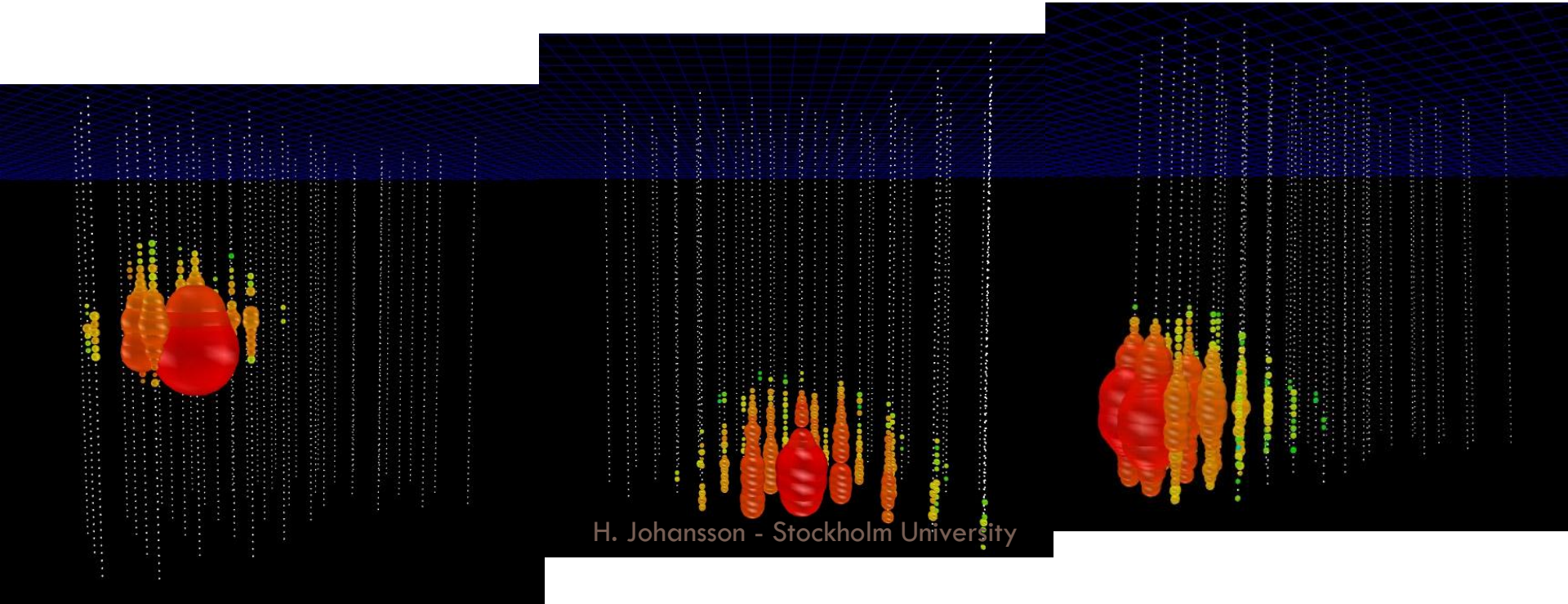
Source	Signal (E^{-2} ν)	Background (tot)
DOM efficiency	-7.9 %, +7.1 %	-15.5 %, +28.6 %
Ice model	+/- 12.0 %	+/- 12.4 %
Abs energy scale	-3.9 %	-7.9 %
ν x-section	-3.7 %, +2.6 %	-3.4 %, +9.3 %
Atm ν flux norm	-	-22.6 %, +17.1 %
CR flux norm	-	+/- 1.7 %
CR composition	-	+/- 11.4 %
Seasonal variation	-	-10.6 %, +10.7 %
Statistical	+/- 0.97 %	+/- 10.5 %
Total	**-15.4 %, +14.2 %**	**-36.5 %, +41.4 %**

IC40 UHE diffuse analysis

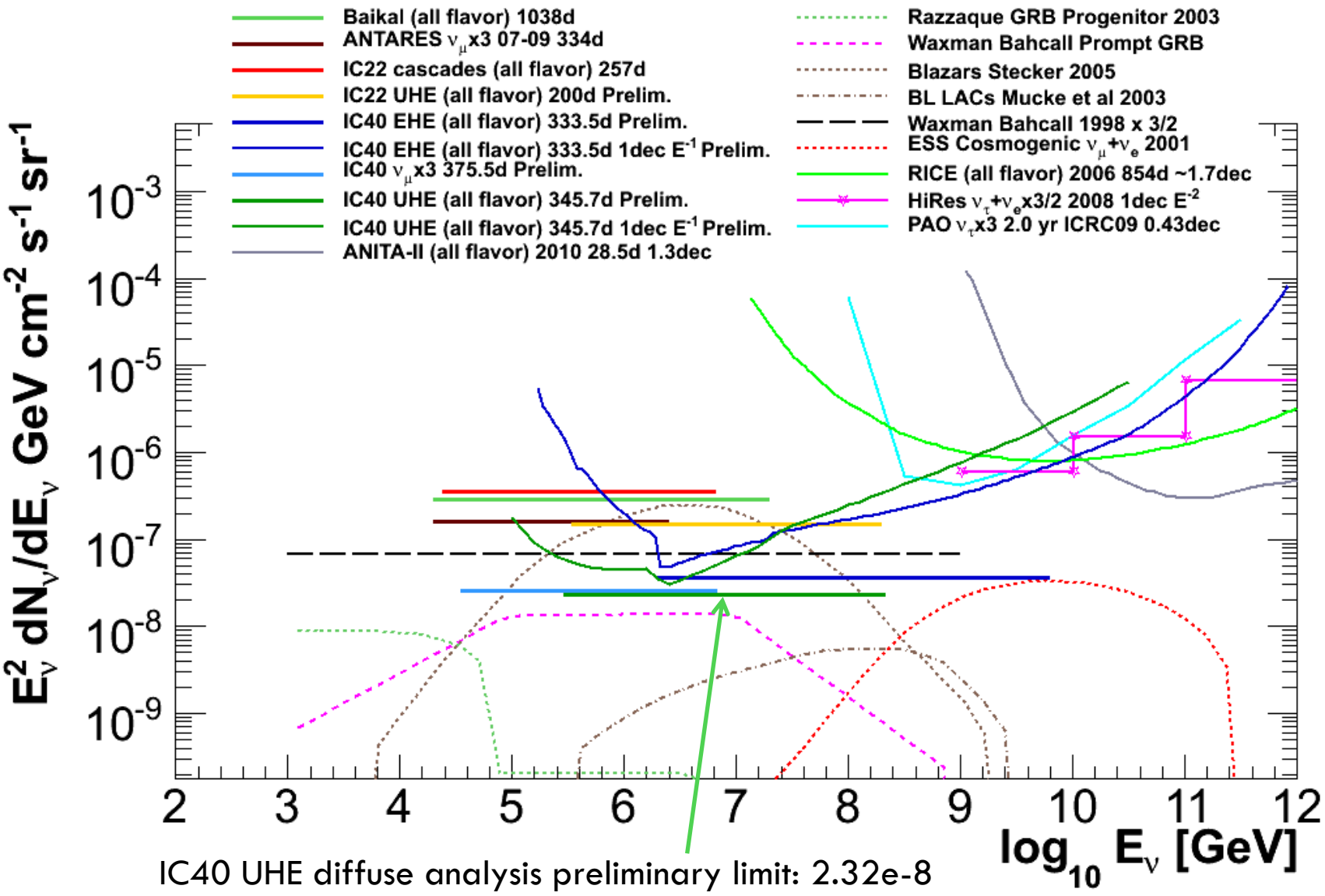


IC40 UHE diffuse analysis

- Three events survive the final cut, passing through the cascade stream
- Events still under a posteriori investigation regarding the possibility that they could be atmospheric muon background



All-flavor 90% CL limits and model fluxes



IC40 UHE diffuse analysis preliminary limit: 2.32e-8

Outlook

The final phase of construction of the IceCube Neutrino Observatory was recently completed, resulting in a detector volume of one cubic kilometer.

With increased exposure an improvement in sensitivity to a UHE diffuse neutrino flux of more than an order of magnitude is anticipated. Other improvements are expected from better modeling and simulation of:

- The detector
- Ice properties
- Cosmic-ray composition and flux normalization
- Atmospheric neutrino flux normalization and spectrum
- Neutrino cross-sections

IceCube collaboration