Atmospheric Neutrino :
IceCube 86 (2011) Cascades Analysis

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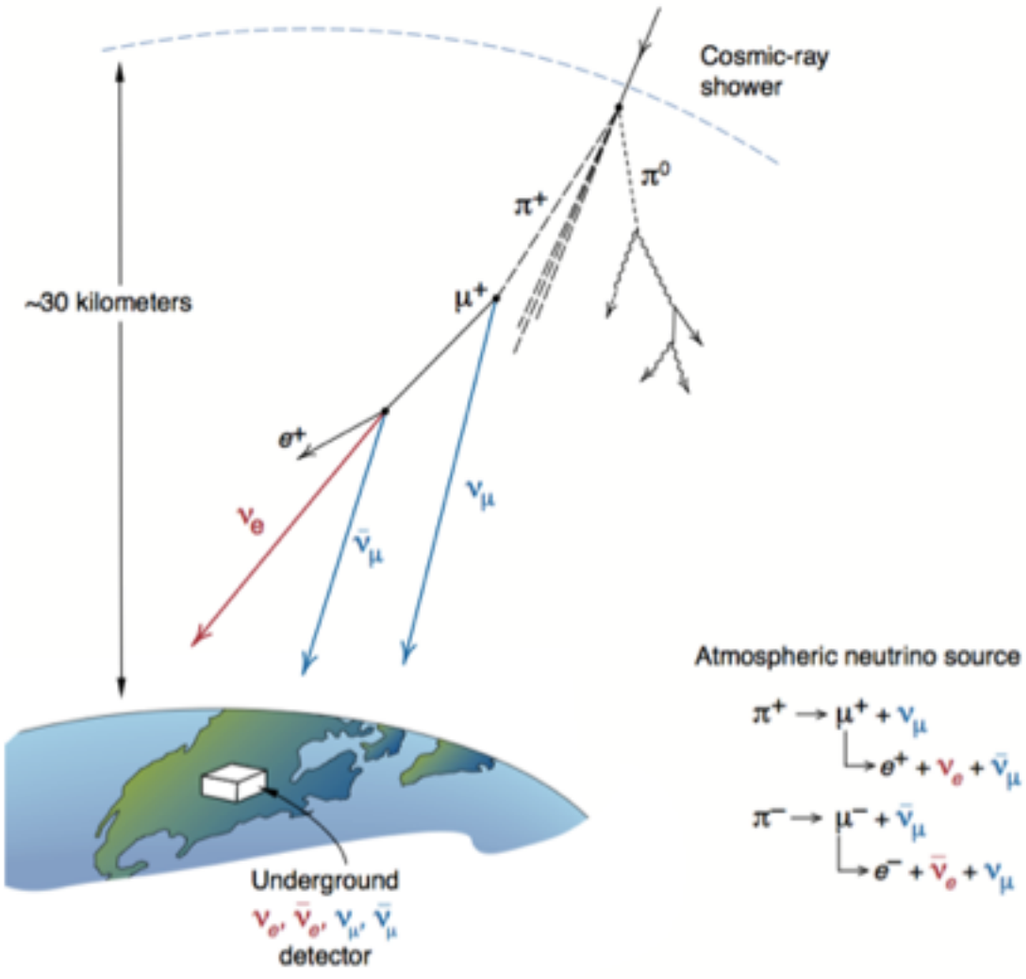
Analysis Overview

- Selection of IC86-1(2011) Cascade sample.
- Maximum likelihood fit to measure the atmospheric neutrino induced cascades by using energy, zenith, and particle identification variables.
- Using the fit results, extract cascade spectrum and NuE spectrum.

Atmospheric Neutrino Production & SelfVeto

Low Energy



Atmospheric neutrino source

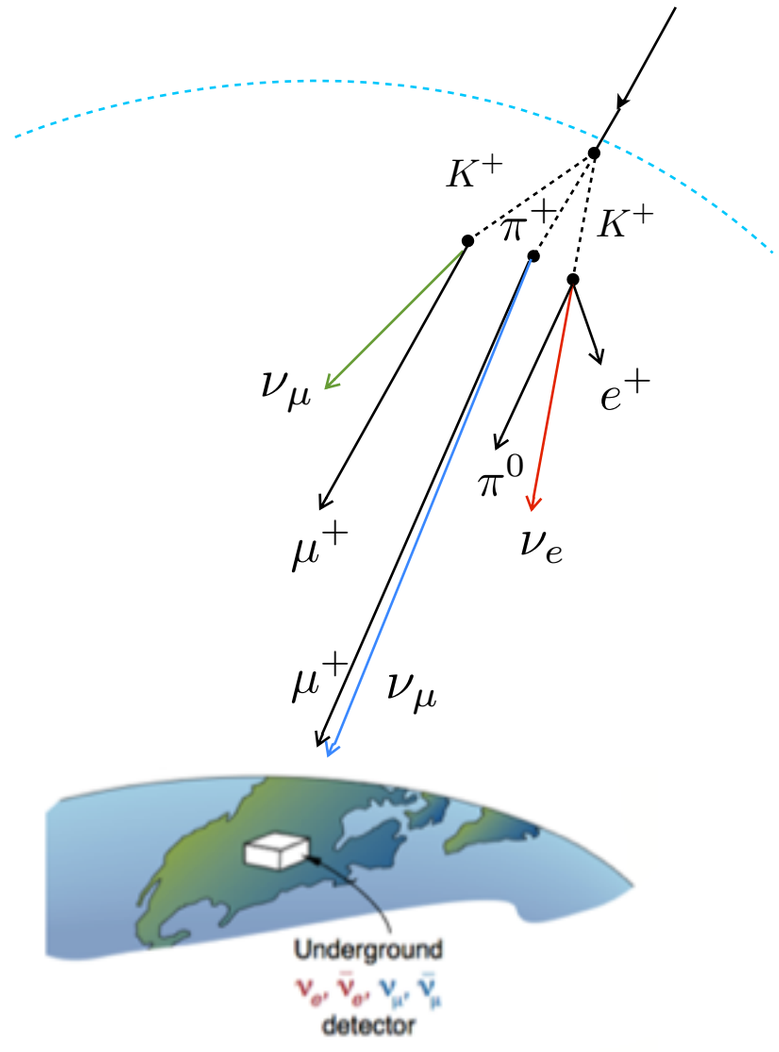
$\pi^+ \rightarrow \mu^+ + \nu_\mu$

$\quad \hookrightarrow e^+ + \nu_e + \bar{\nu}_\mu$

$\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$

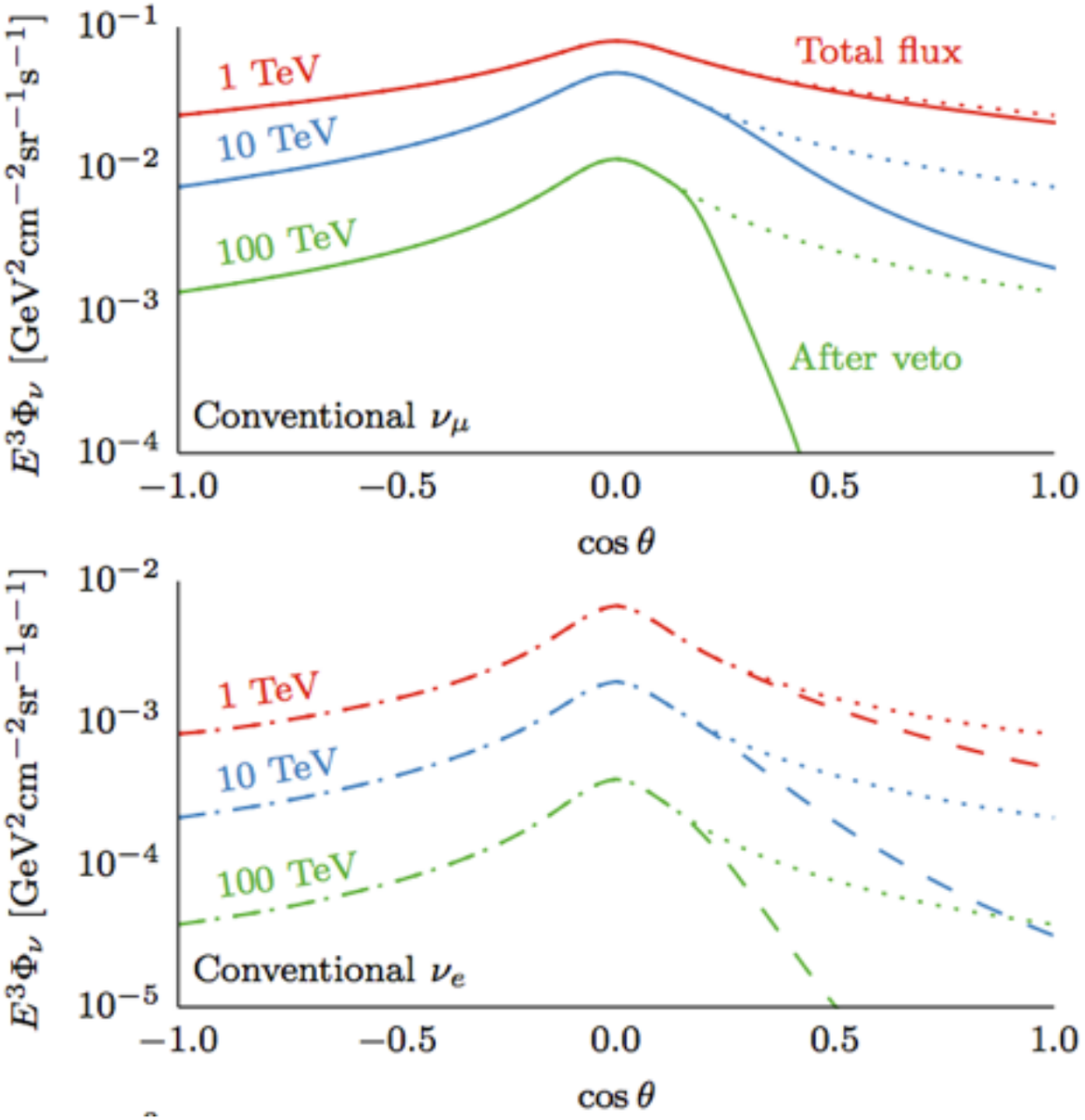
$\quad \hookrightarrow e^- + \bar{\nu}_e + \nu_\mu$

High Energy



- High Energy Vertical Atm. Neutrinos accompany with Atm. Muons
- Any veto analysis unconsciously rejects these events

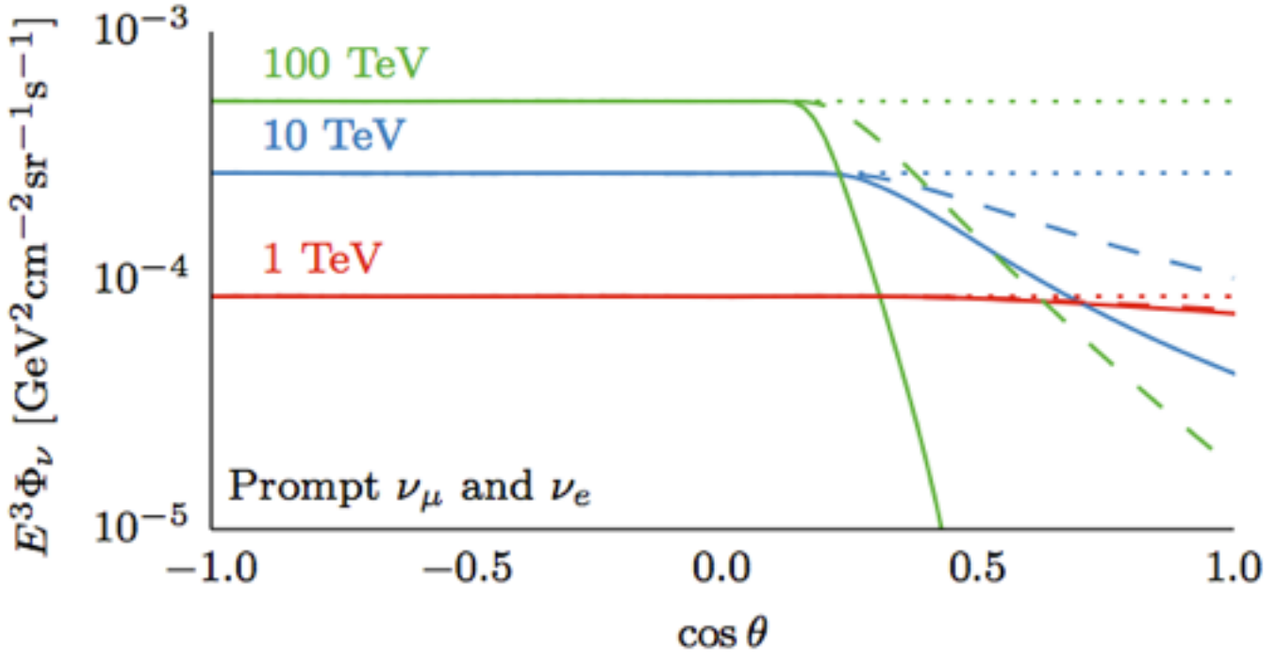
Atmospheric SelfVeto



Generalized self-veto probability for atmospheric neutrinos

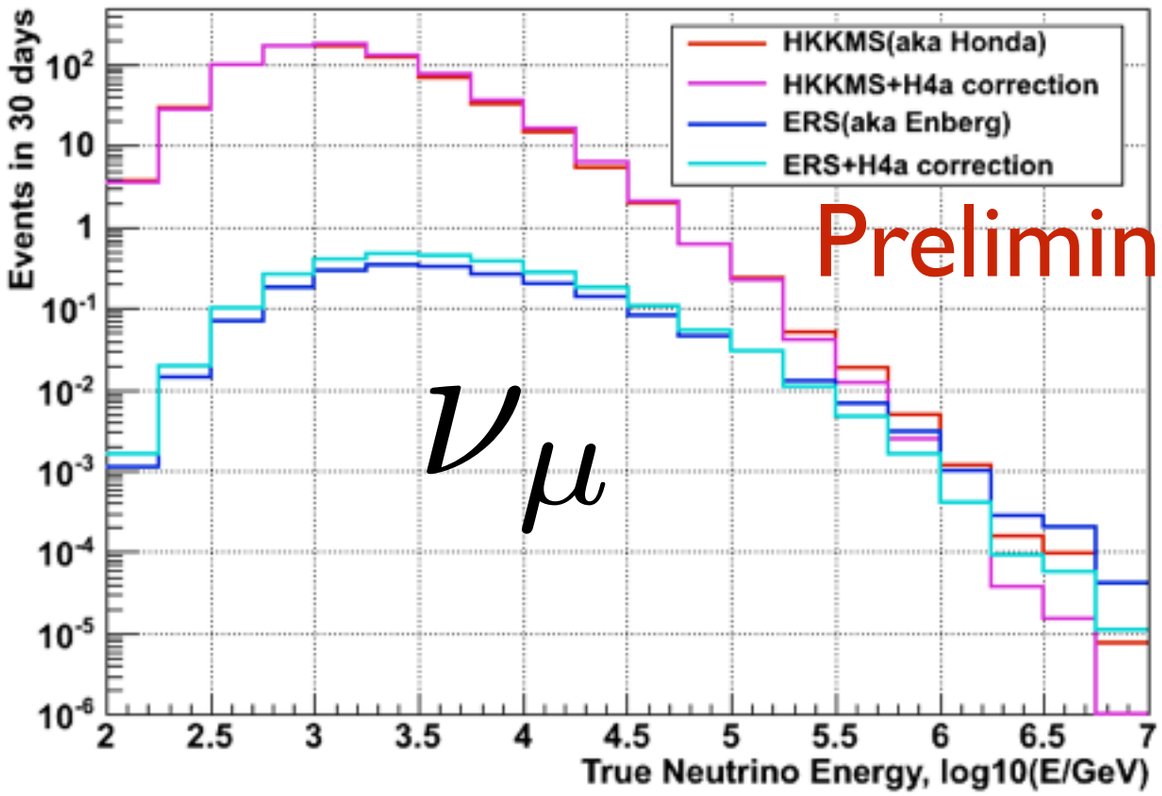
Phys. Rev. D **90**, 023009 – Published 10 July 2014

Thomas K. Gaisser, Kyle Jero, Albrecht Karle, and Jakob van Santen

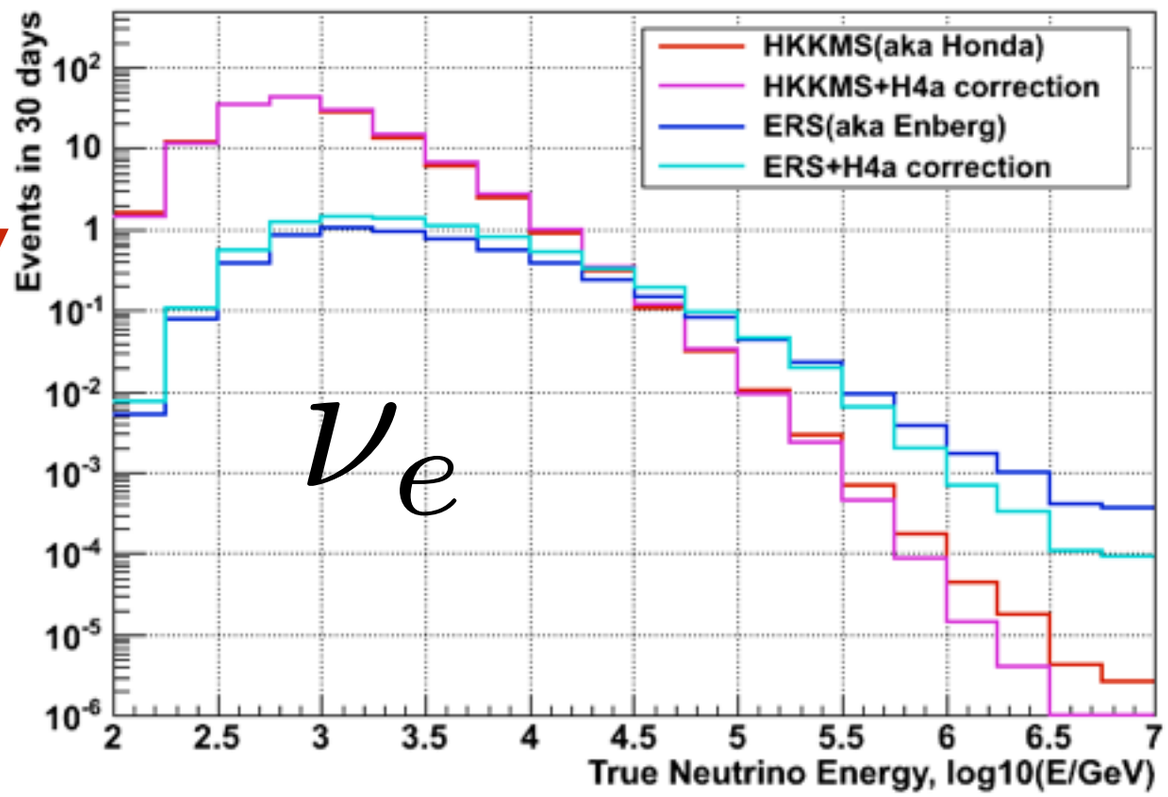


High Energy Downgoing Neutrinos
Vetoed automatically

Atmospheric Neutrino Predictions

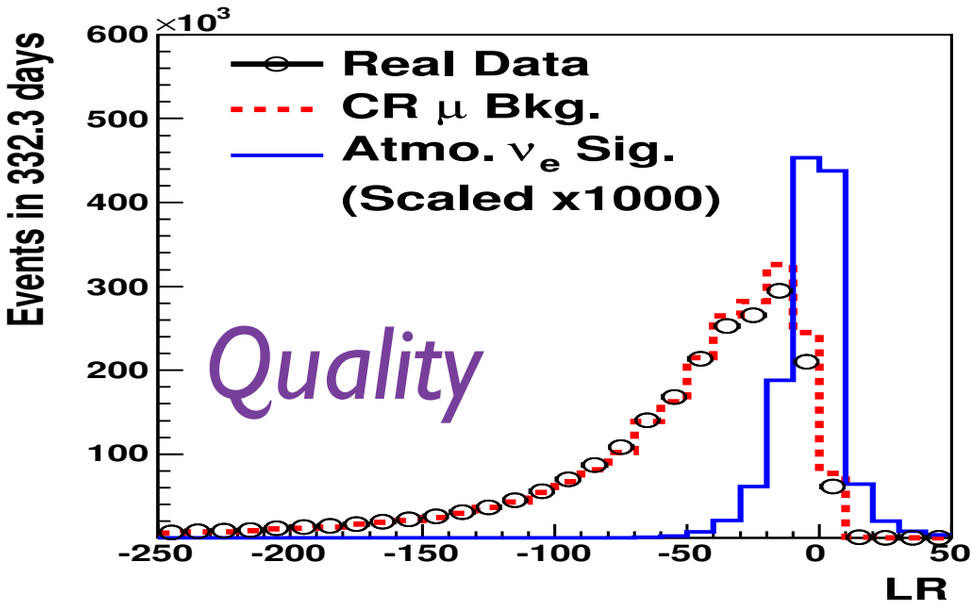


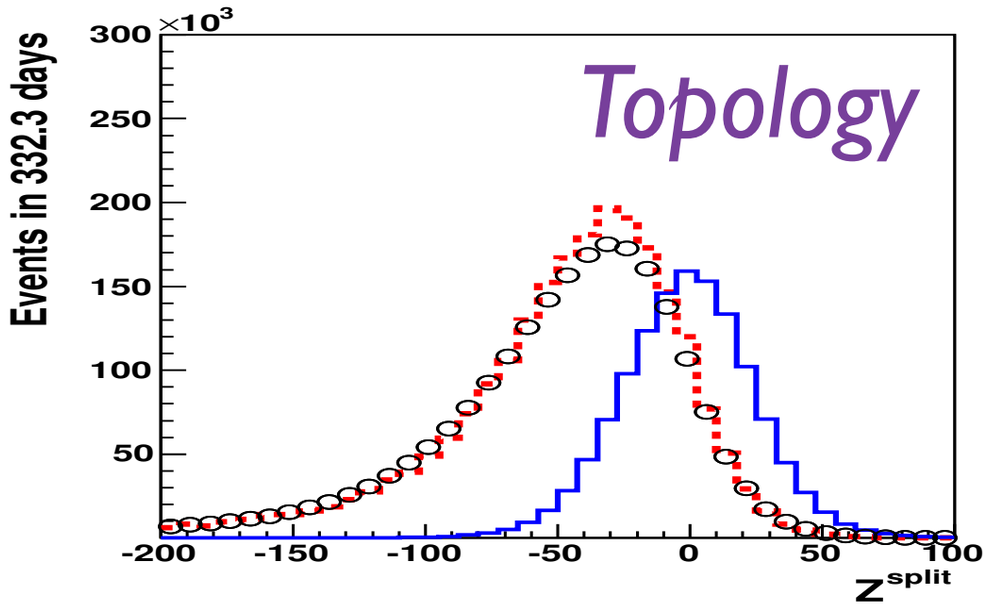
Preliminary



The Cascade channel is advantageous.
Conventional Neutrinos : NuMu flux is higher than NuE flux
(Initial flux ~10 :1 at around 1 TeV)
Charm Neutrinos : NuE flux is higher than NuMu flux
(Initial flux 1:1)

A few Cascade Variables





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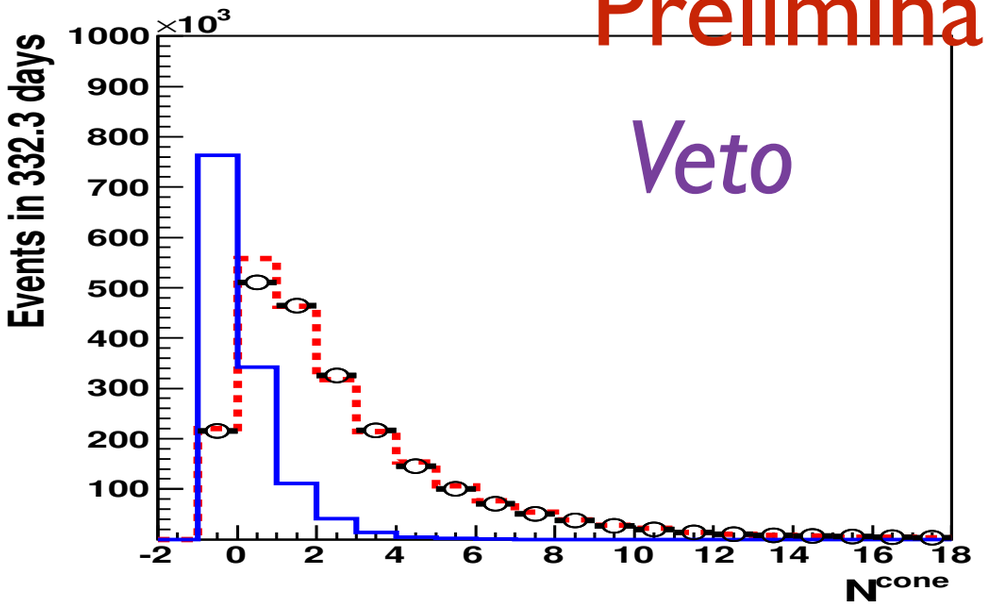
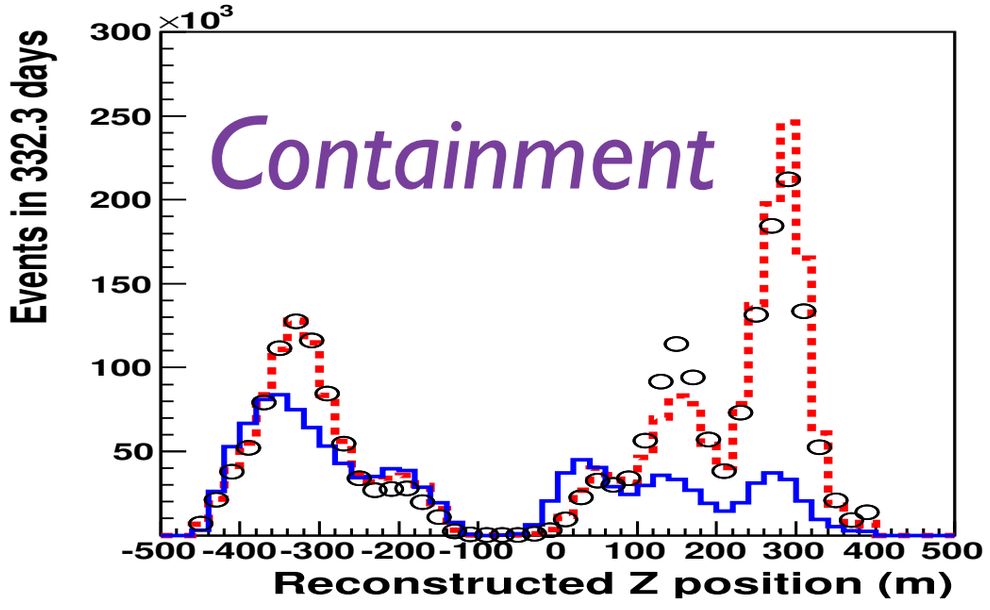
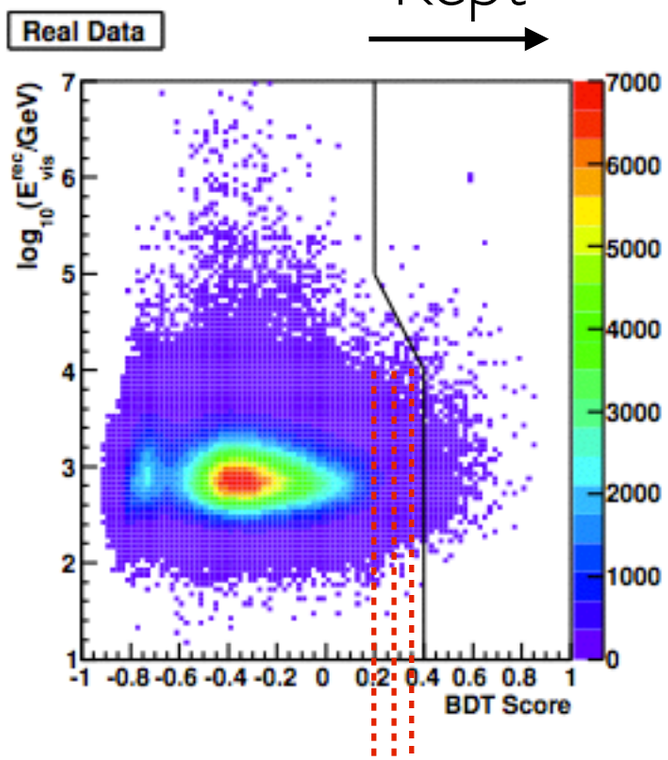


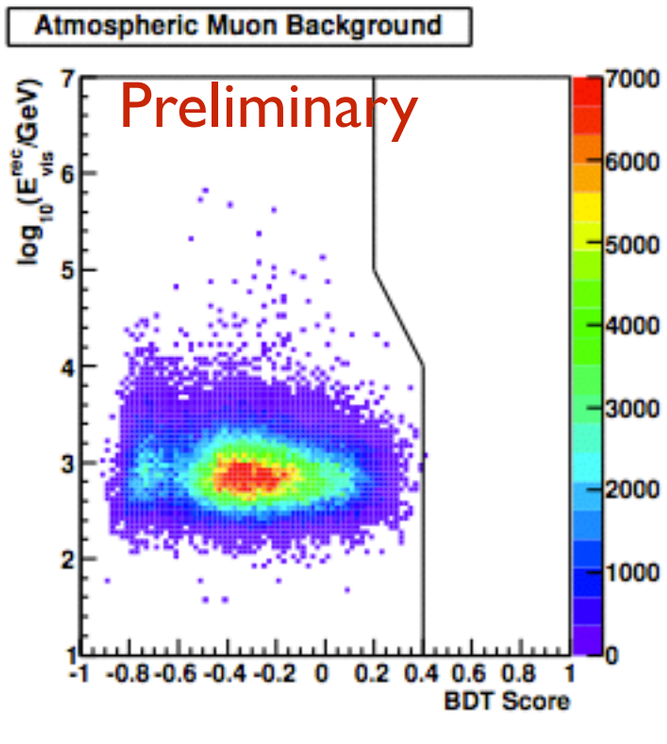


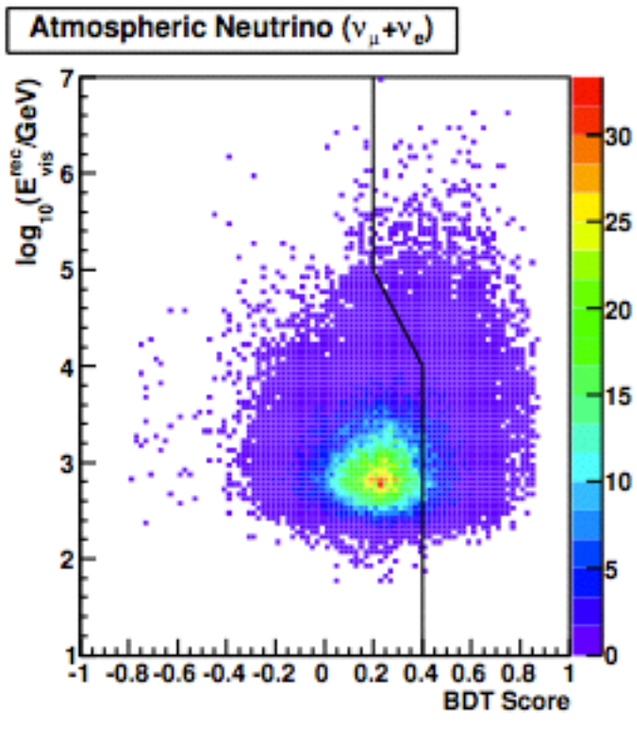
Data/MC Agreement & Good Discrimination

Final Analysis Cut (Cascade BDT Selection)

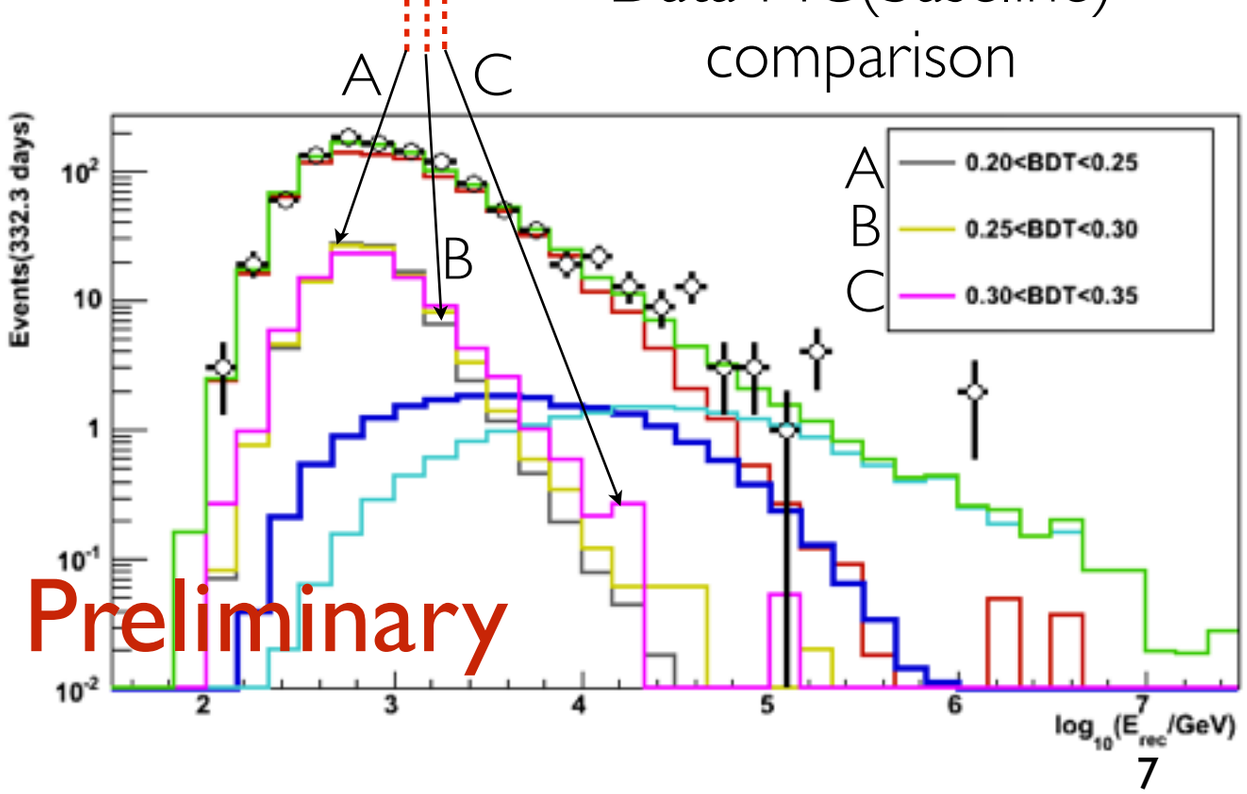
Kept

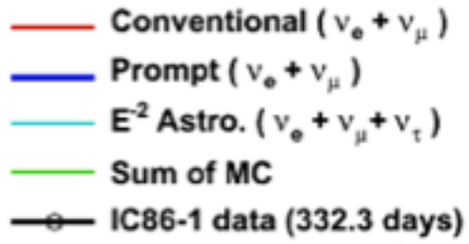






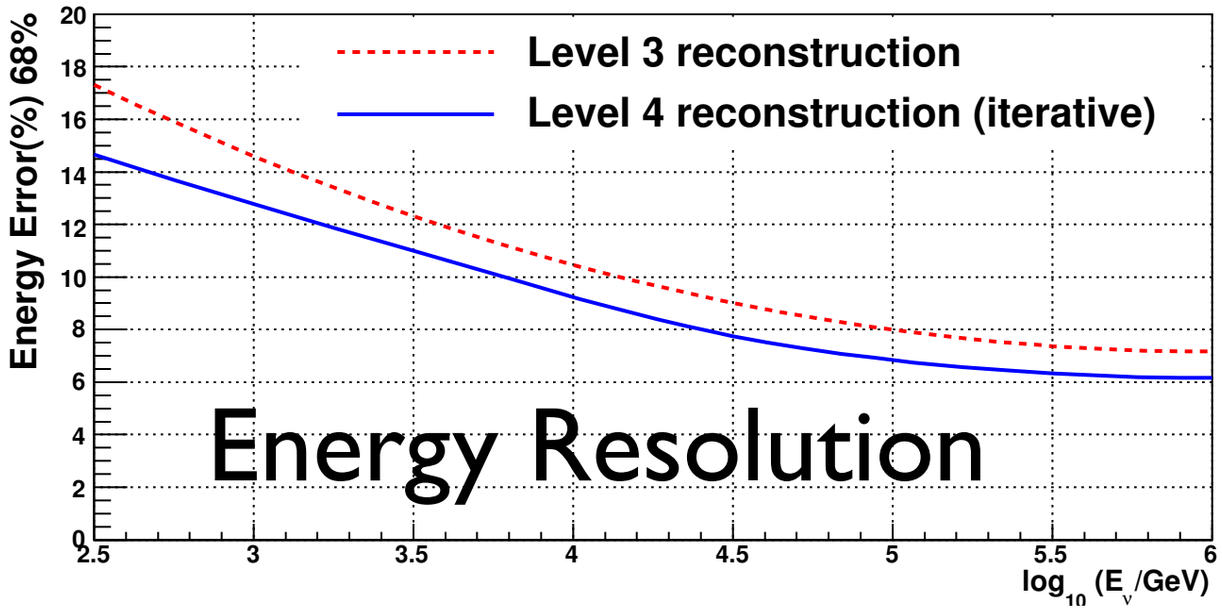
Data-MC(baseline) comparison

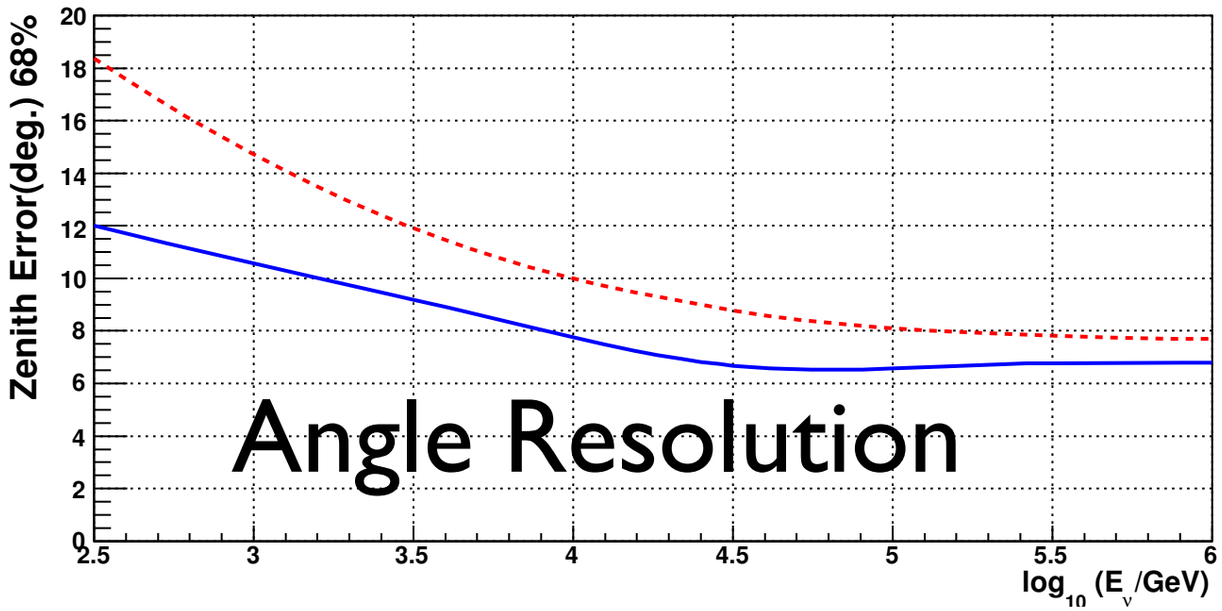




*CR Muon Bkg. is estimated from data (Choice B)

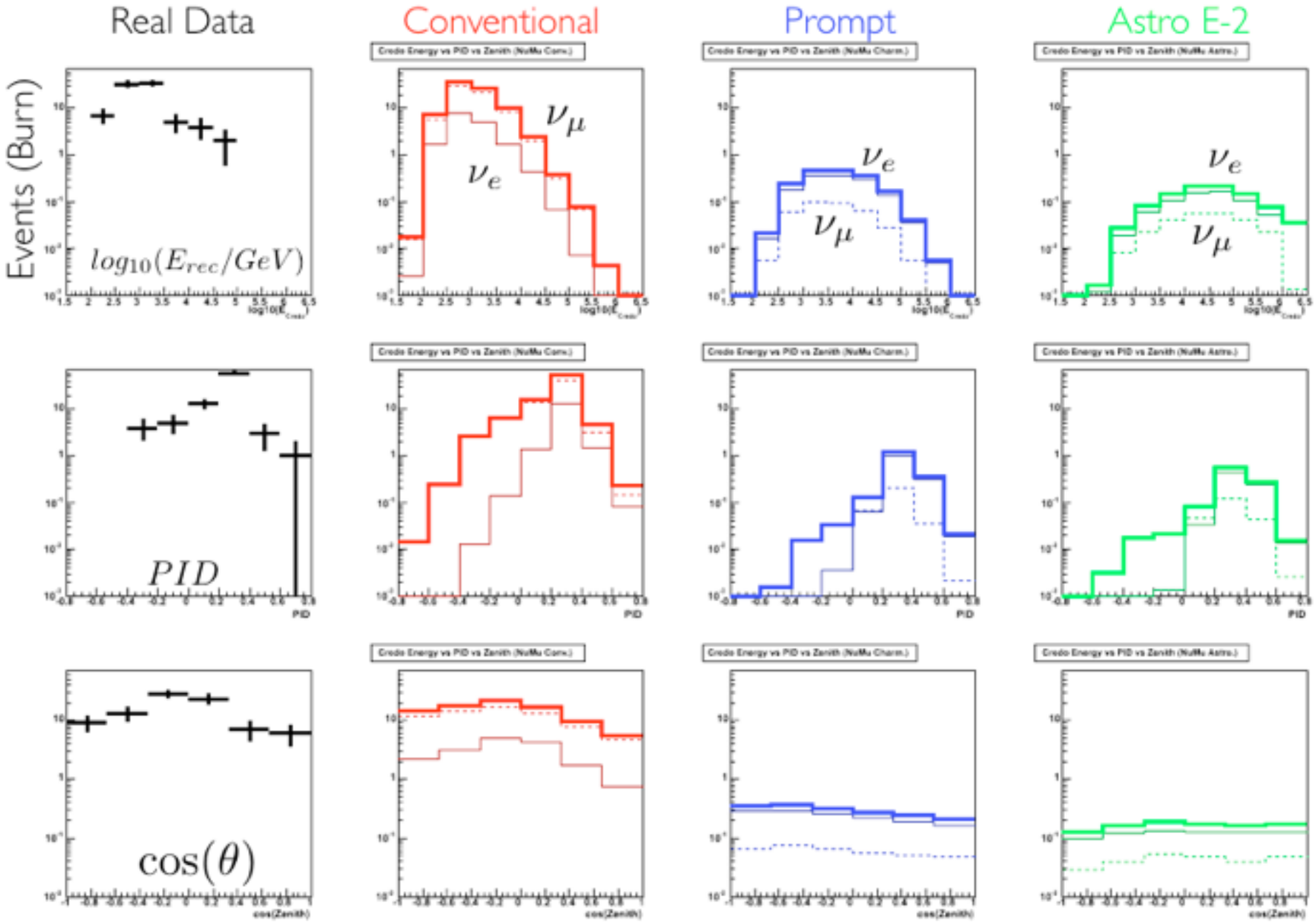
Cascade Reconstruction Resolutions





- At 10 TeV, 9% Energy Resolution & 8 deg. Zenith Resolution (shown statistical only)
- Systematics :: ***Ice Parameters (scattering& absorption), Ice Anisotropy, and DOM efficiency*** add 12% in Energy Resolution and 2 deg. in Zenith Resolution.

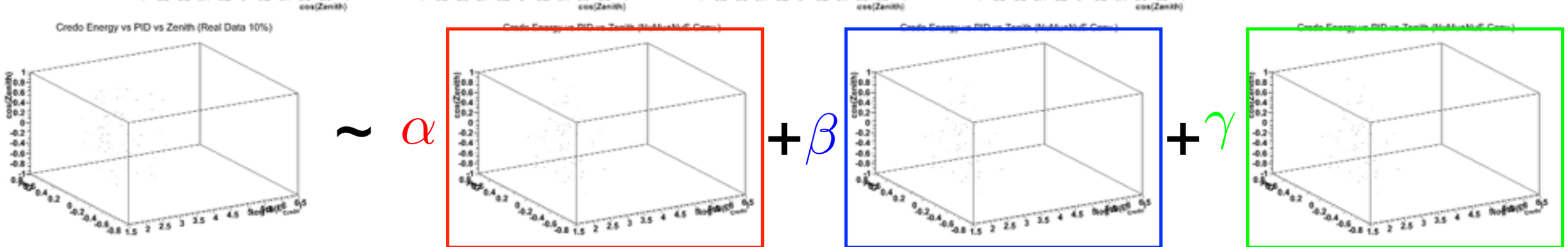
3-D Likelihood Fitter



Preliminary

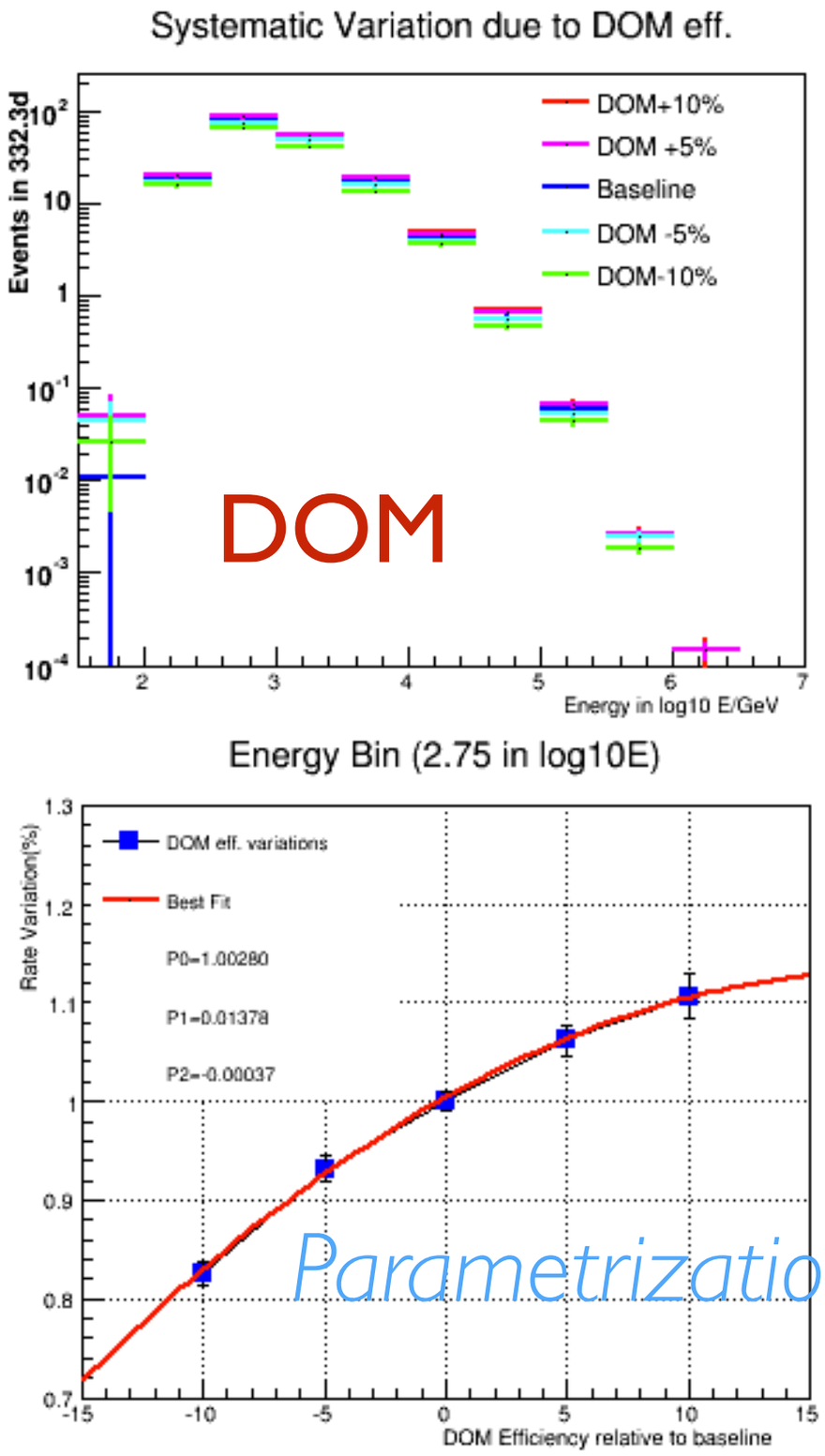
…

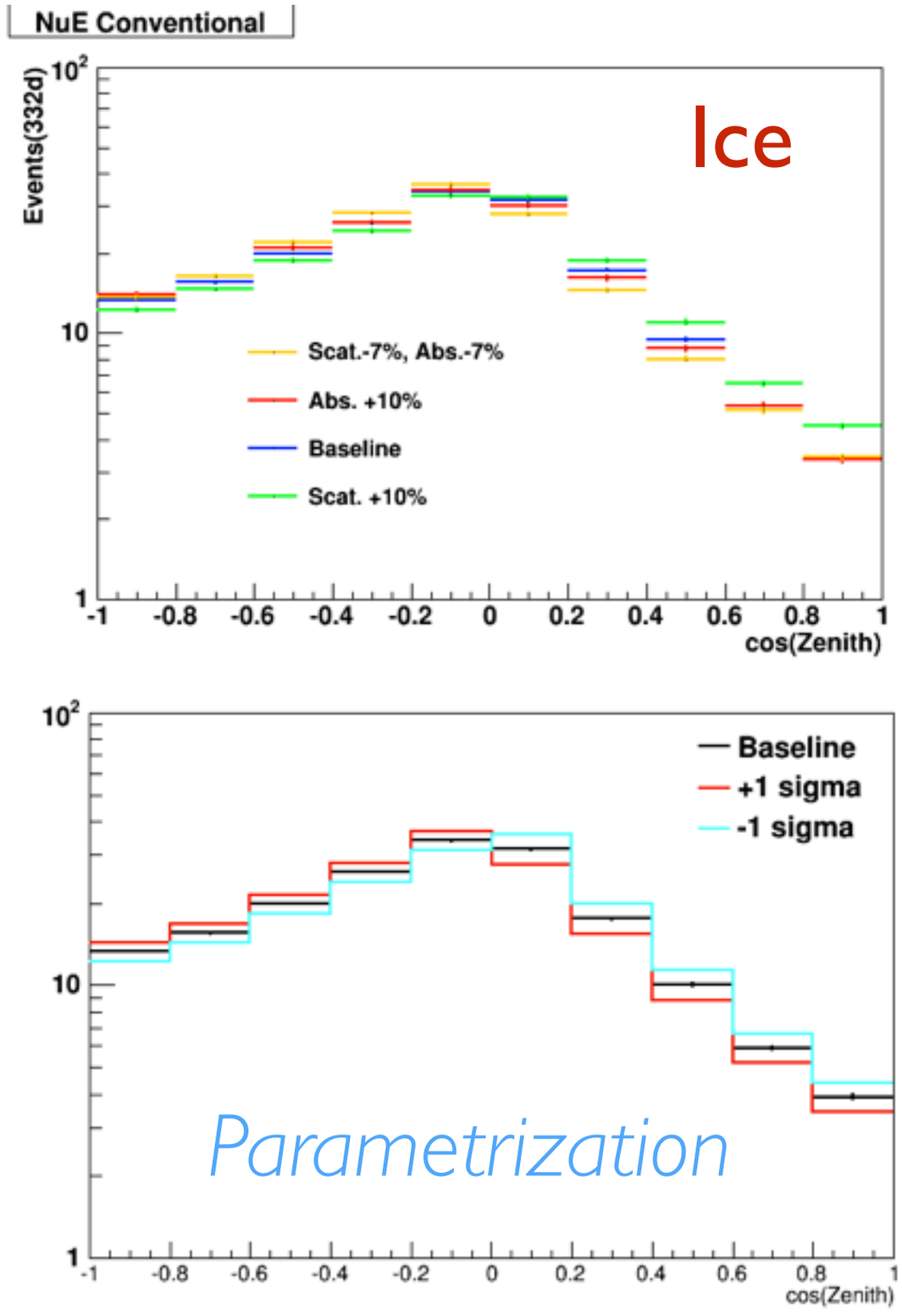
CR Muon,
Systematics …



data MC Sum

Systematics





Fit Component Signature

Observed Events : 1078 in 332.3 days

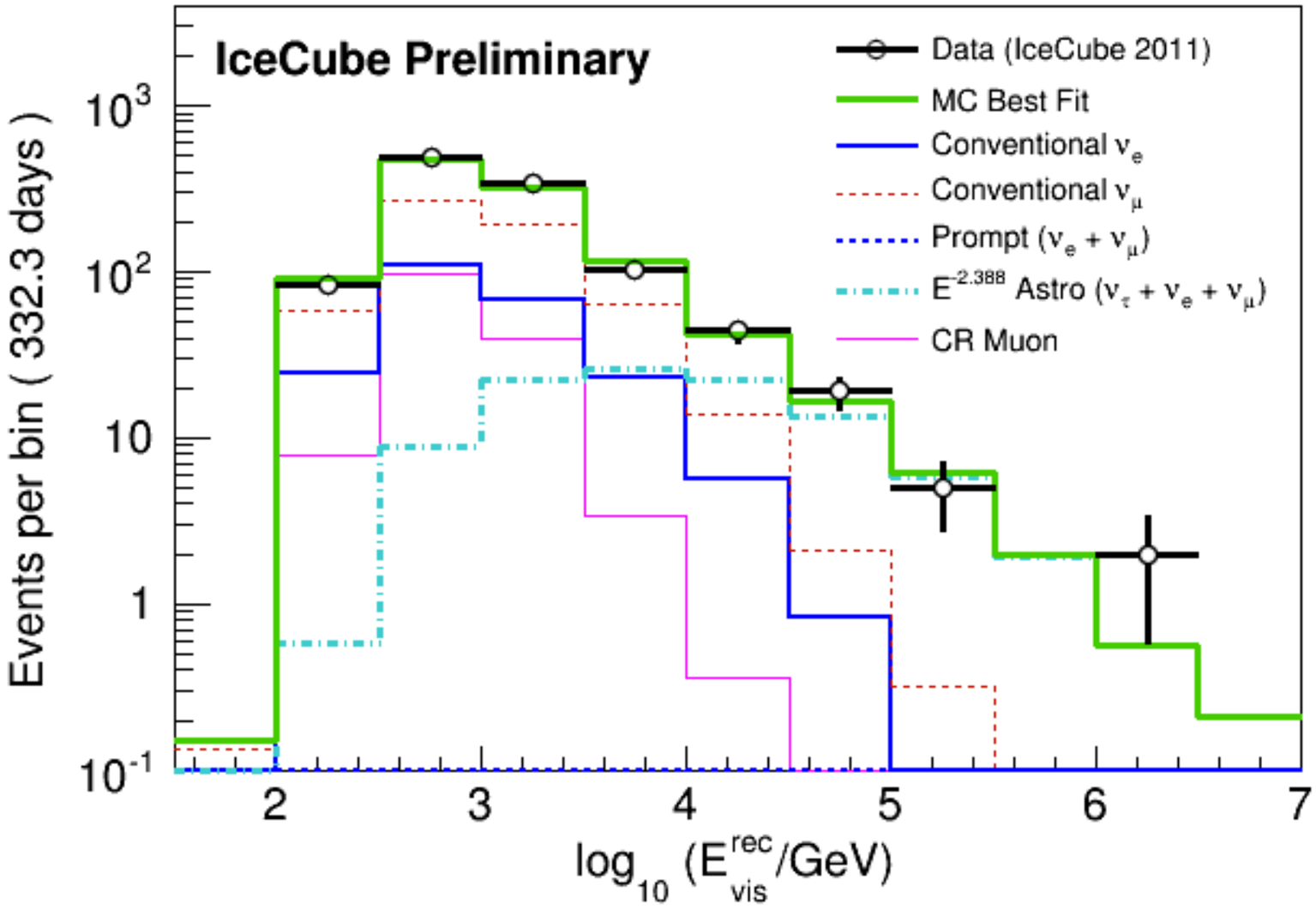
Fit Params	E-2.39 Best Fit (Events)	Energy	PID	Zenith
Cosmic-Ray Muon	148+/-25	Low	Muon-like	Down
Conventional NuMu (Honda)	0.86+0.2-0.14 (596)	Medium	Muon-like (NC cascade-like,50%)	Broad peak Horizon
Conventional NuE (Honda)	1.36+0.4-0.32 (230)	Medium	Cascade-like	Sharp peak Horizon
Prompt (ERS)	<1.63 (0)	High	Cascade-like	Up
E-2.39 Astrophysical	3.31+1.6-0.8 (102)	Very High	Cascade-like (nue,nutau 80%)	Flat
Best Fit MC	**1076**			

Each component has a unique signature.

Unblinded Data

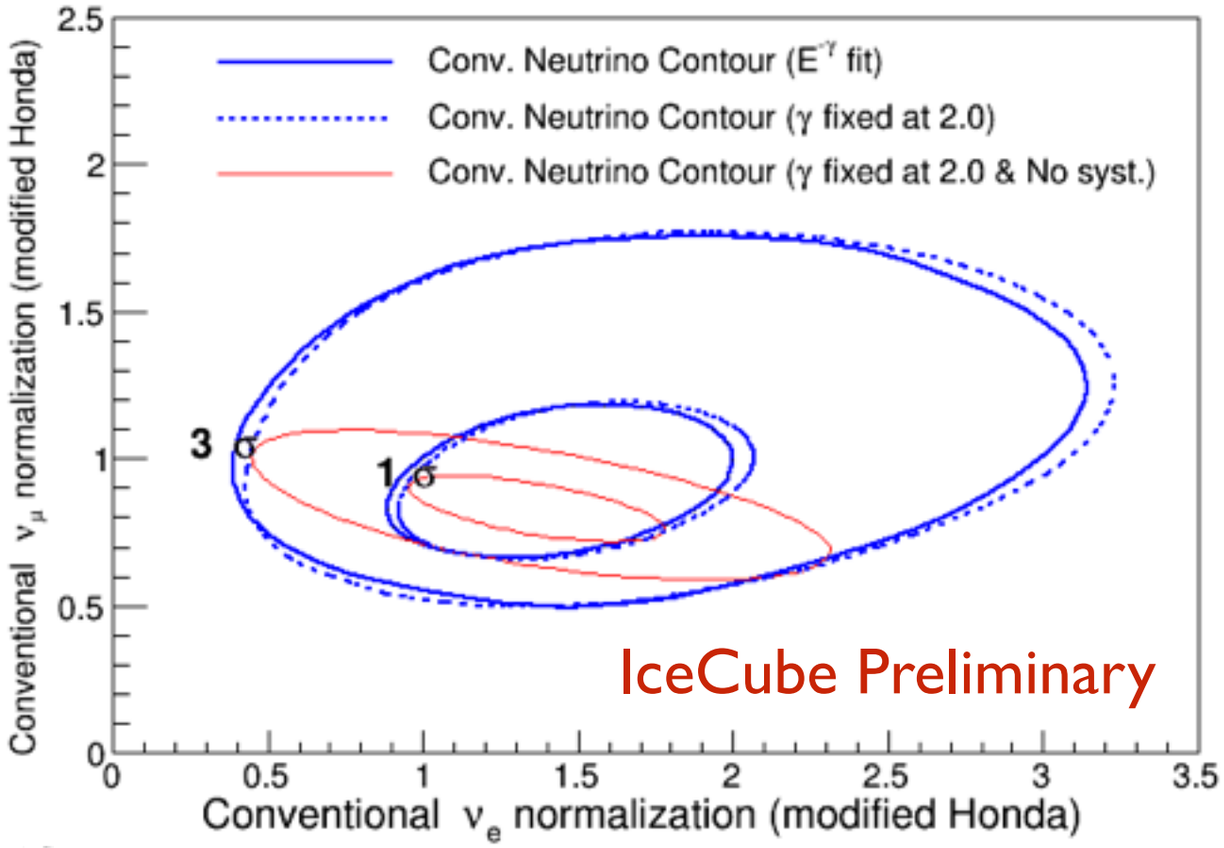
- **1078 Events** observed (90% [0.3 - 14] TeV)
  - **70 Events** above 10 TeV
- Very good data/MC agreement
- Good purity of the sample in cascade analysis : 15% CR Muon contamination estimated from data
- Good Particle Identification between cascade and starting tracks (NuMu-CC events) achieved.

Conventional Neutrinos
1-Projection of Best Fit

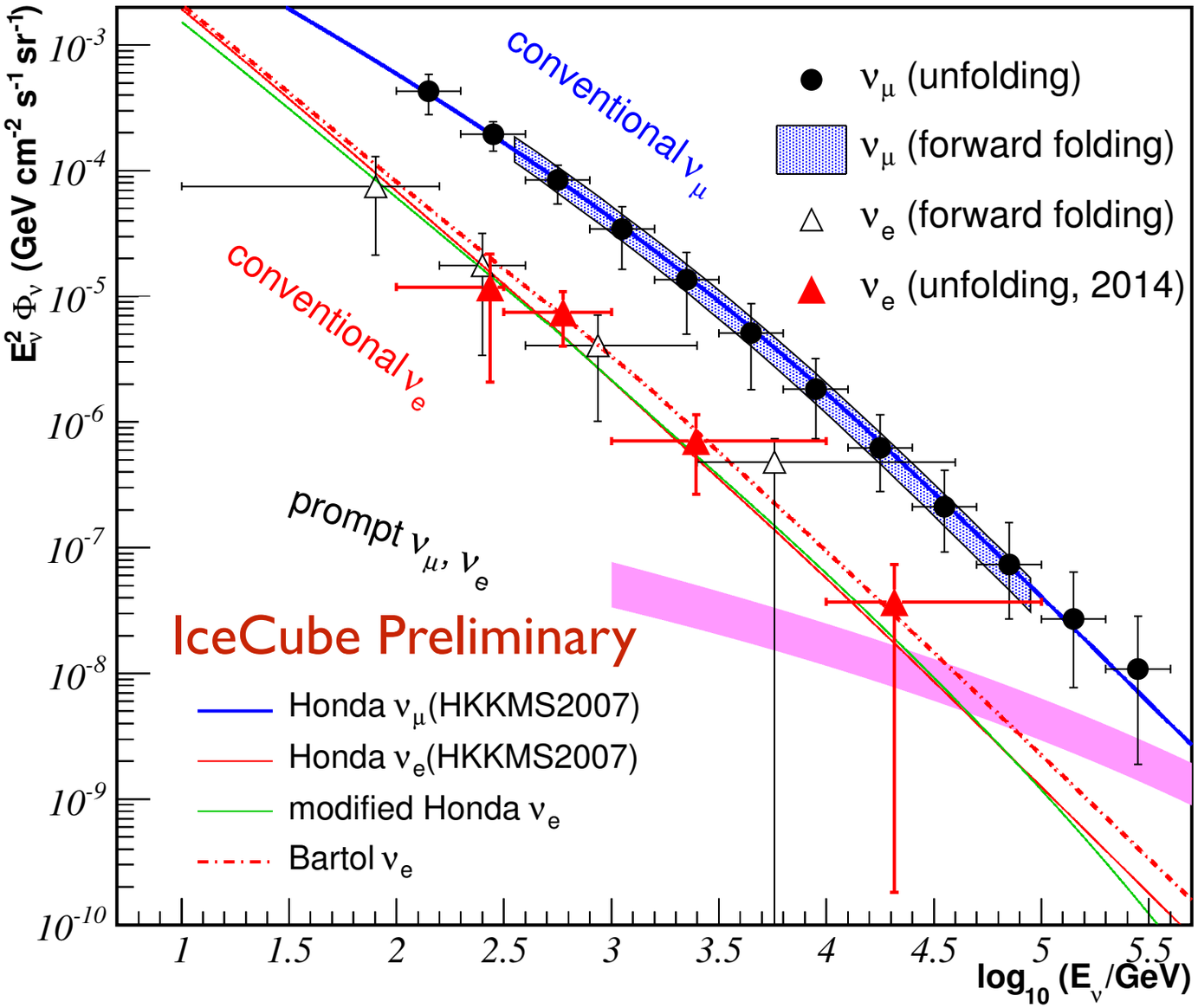


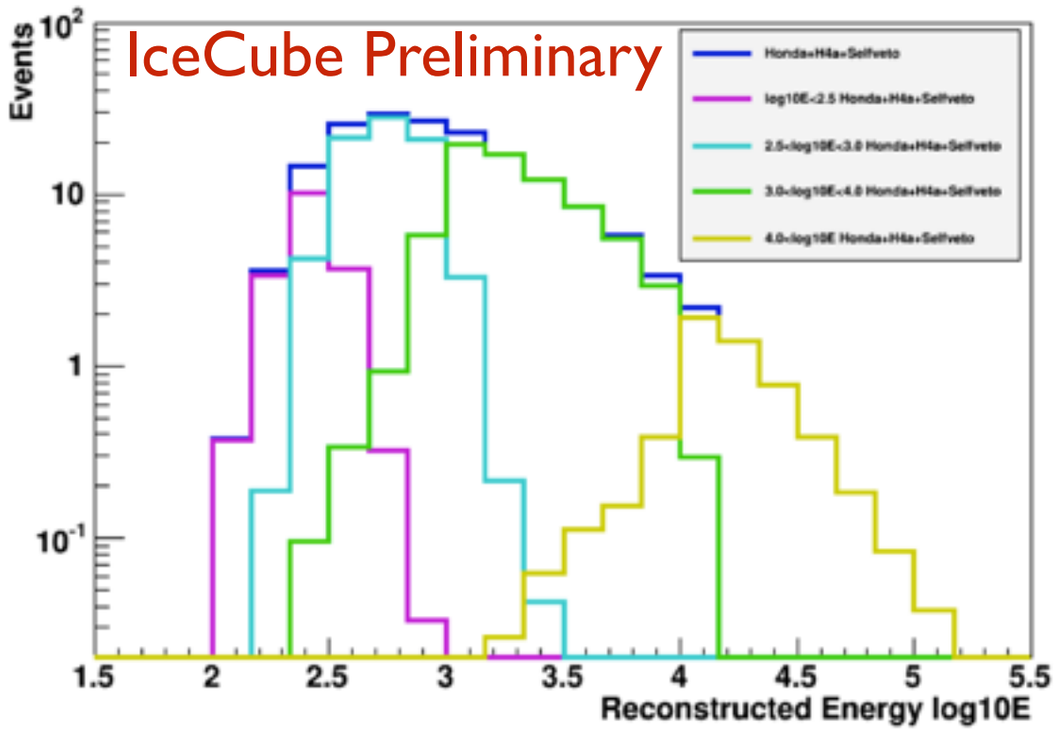
Conventional Neutrinos

- High Energy conventional NuE (230 events) measured.
- Conventional components have little impact on astrophysical component or charm component
- Strong impact comes from systematics (DOM eff. & Ice Scattering)
- Best fit favors higher NuE compared to Honda



Conventional NuE Spectrum





Non-param. fit :
Fit Normalizations of
each chunks.

Improved result at higher energies (Cascade Filter & 3D-LLH Fit)

Summary

- We have conducted atmospheric neutrino-induced cascade analysis with 1 year of IC86 data.
- 1078 events with energy range extend to 300 GeV and constrain conventional neutrino spectrum.
- Conventional Components (NuMu, NuE) are less dependent of Prompt and Astrophysical components.
- Conventional NuE flux is measured at $1.36^{+0.40}_{-0.32}$ x (Honda+H3a) and the unfolded spectrum is presented

Backup

K short to NuE