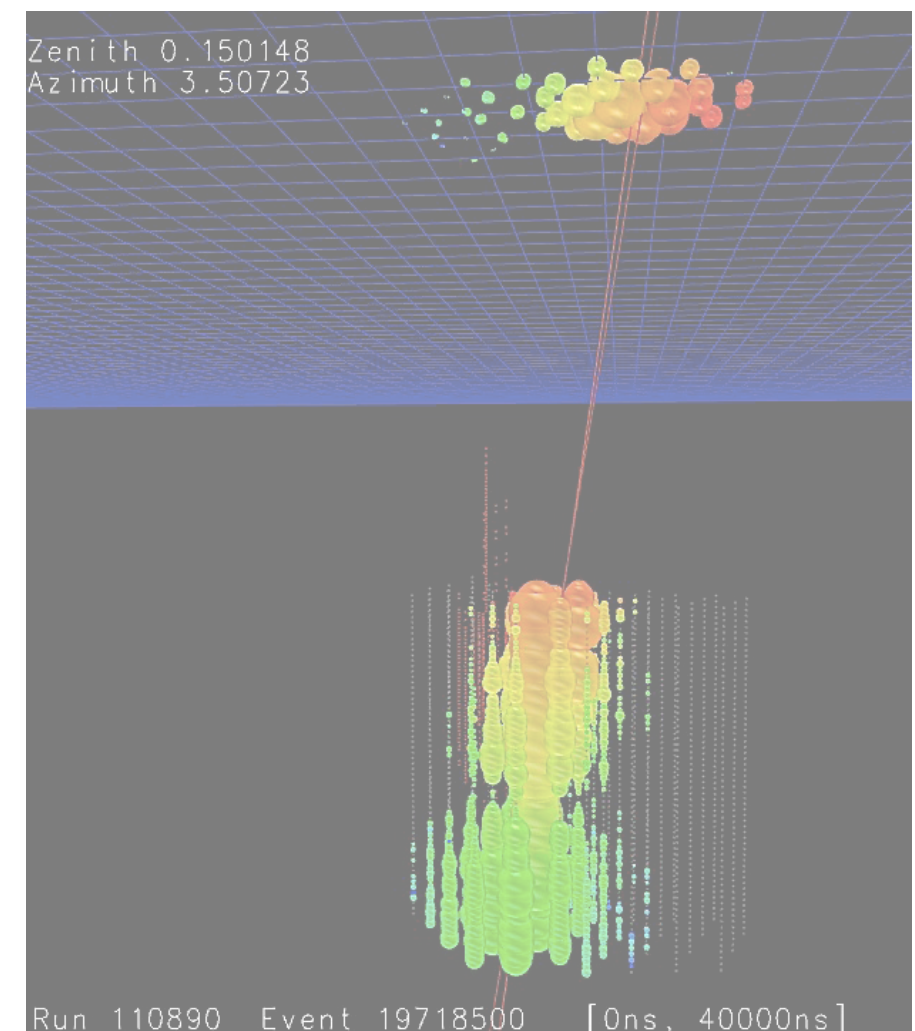


Report on Cosmic Ray and Atmospheric, Diffuse and EHE neutrino searches

Science Advisory Committee - UW-Madison

Paolo Desiati
UW - Madison
desiati@icecube.wisc.edu

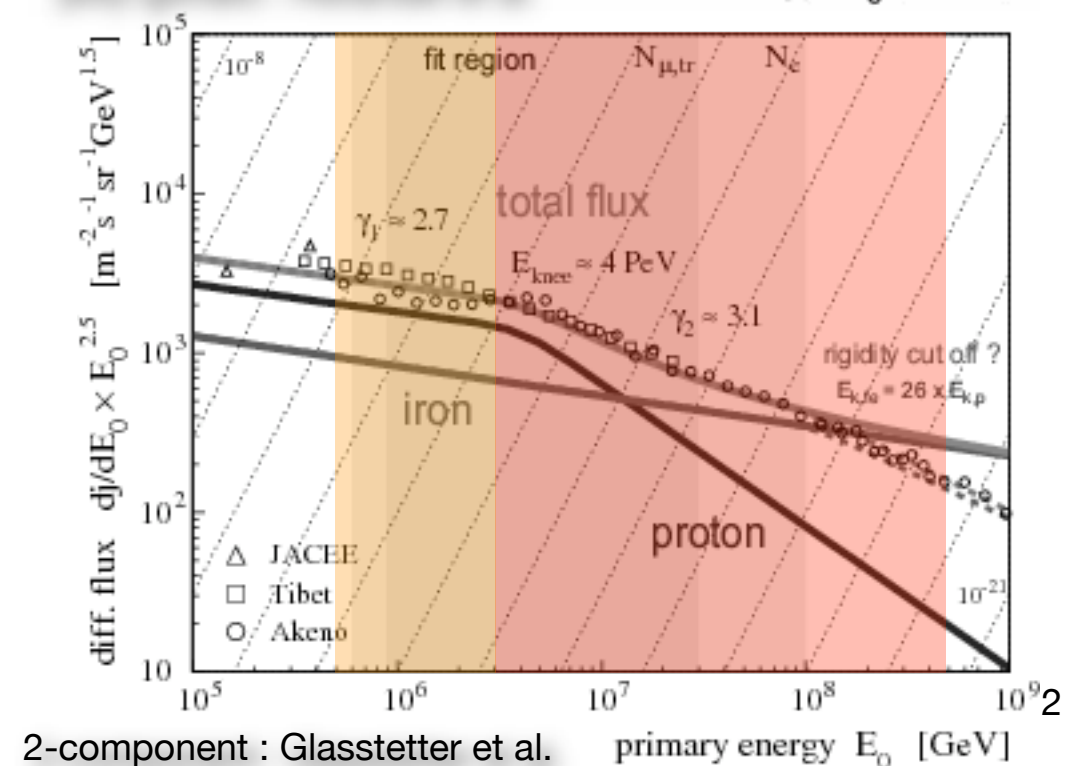
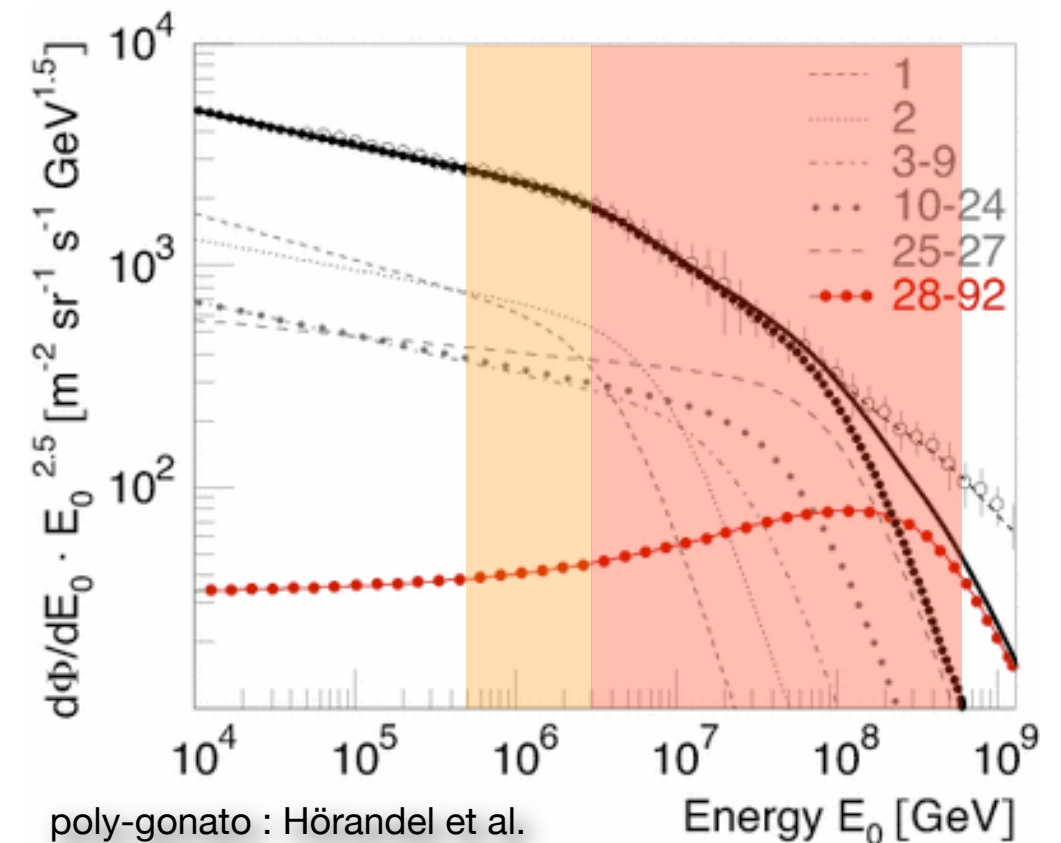
May 20-21, 2009



cosmic rays

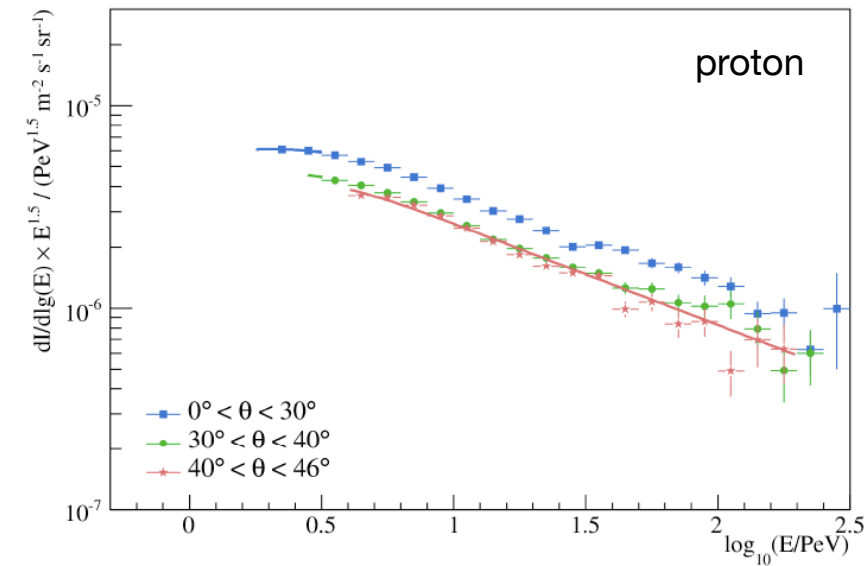
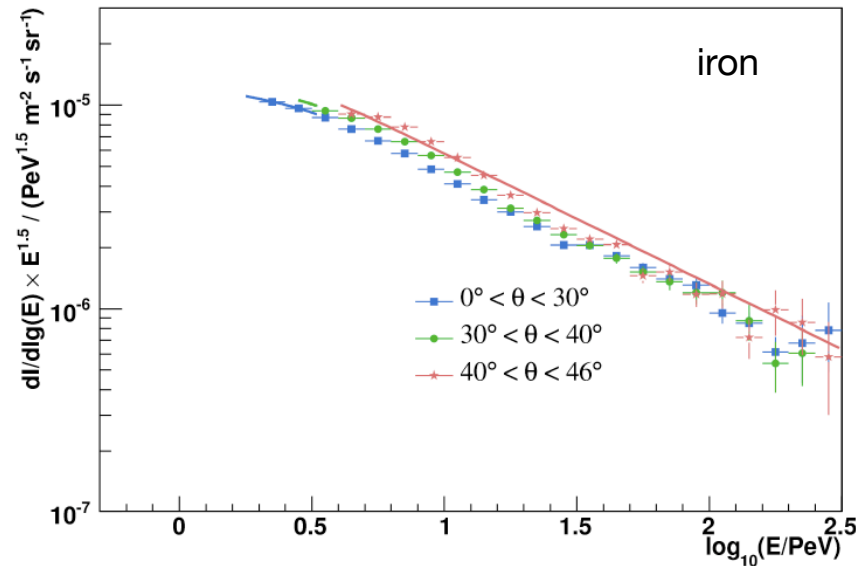
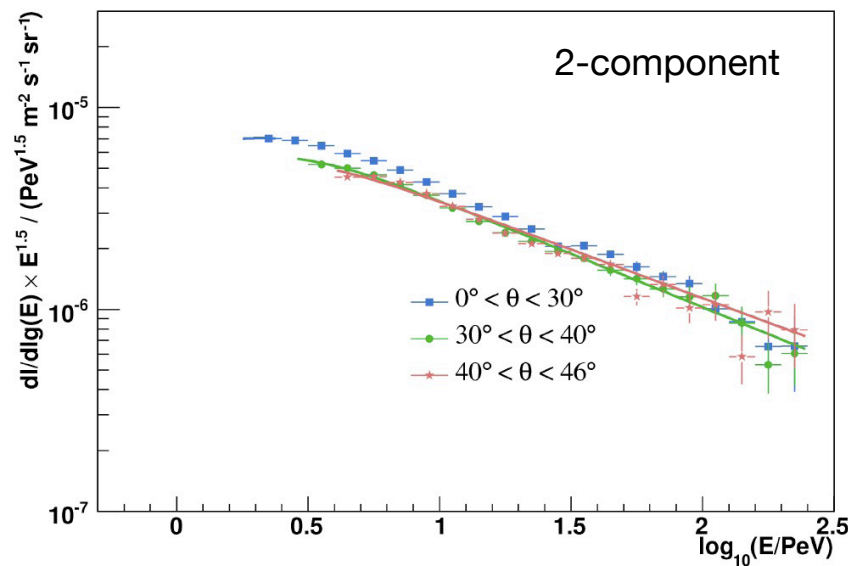
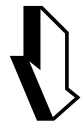
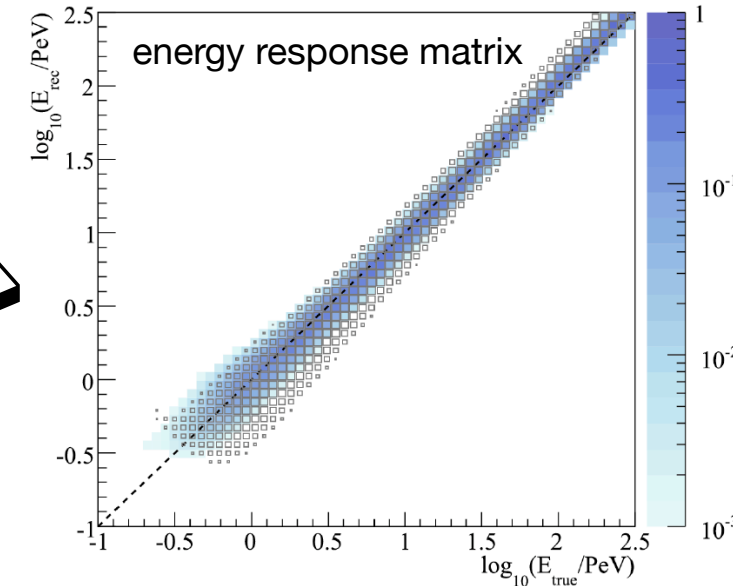
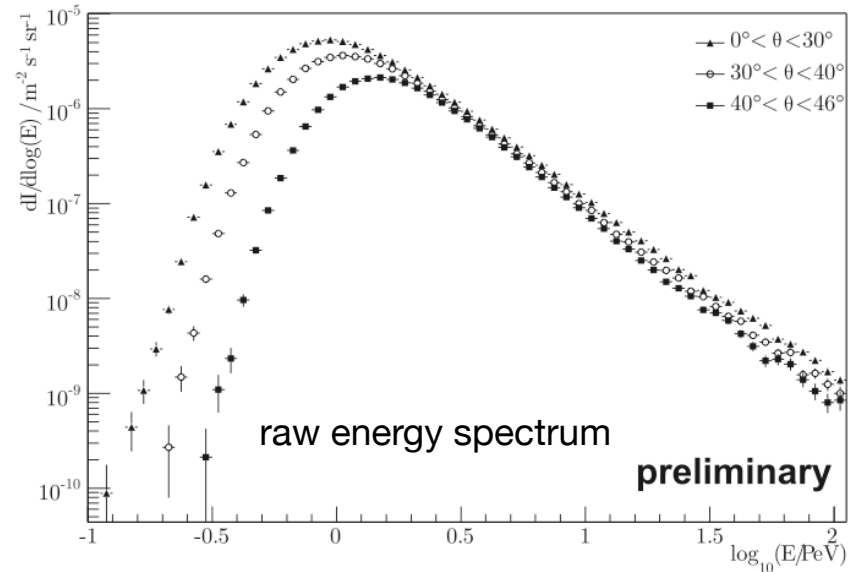
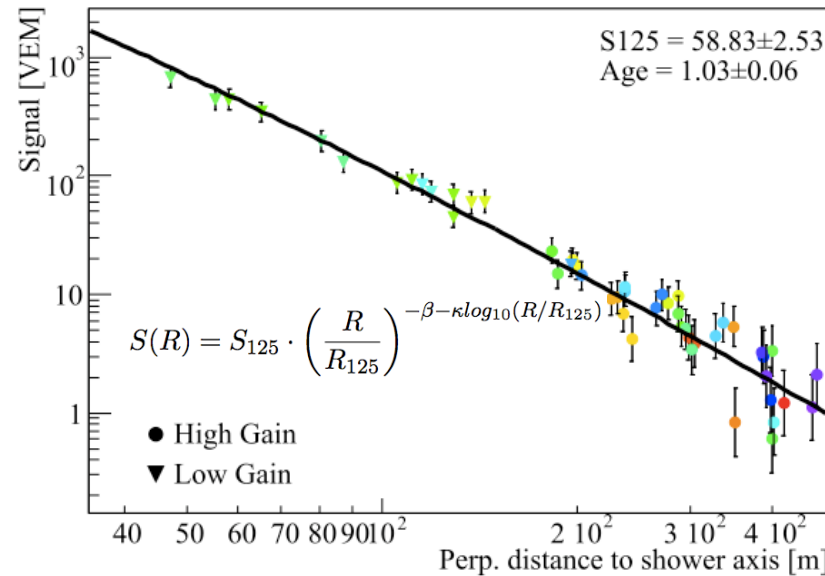
1/5

- measure all particle cosmic ray spectrum in the knee region and above
- measure cosmic ray mass composition in the knee region and above
- mass composition not known and model-dependent (KASCADE)
- extension to lower energy with small showers
- large scale anisotropy of arrival direction of cosmic rays



cosmic rays : all-particle spectrum (IceTop-26)

2/5



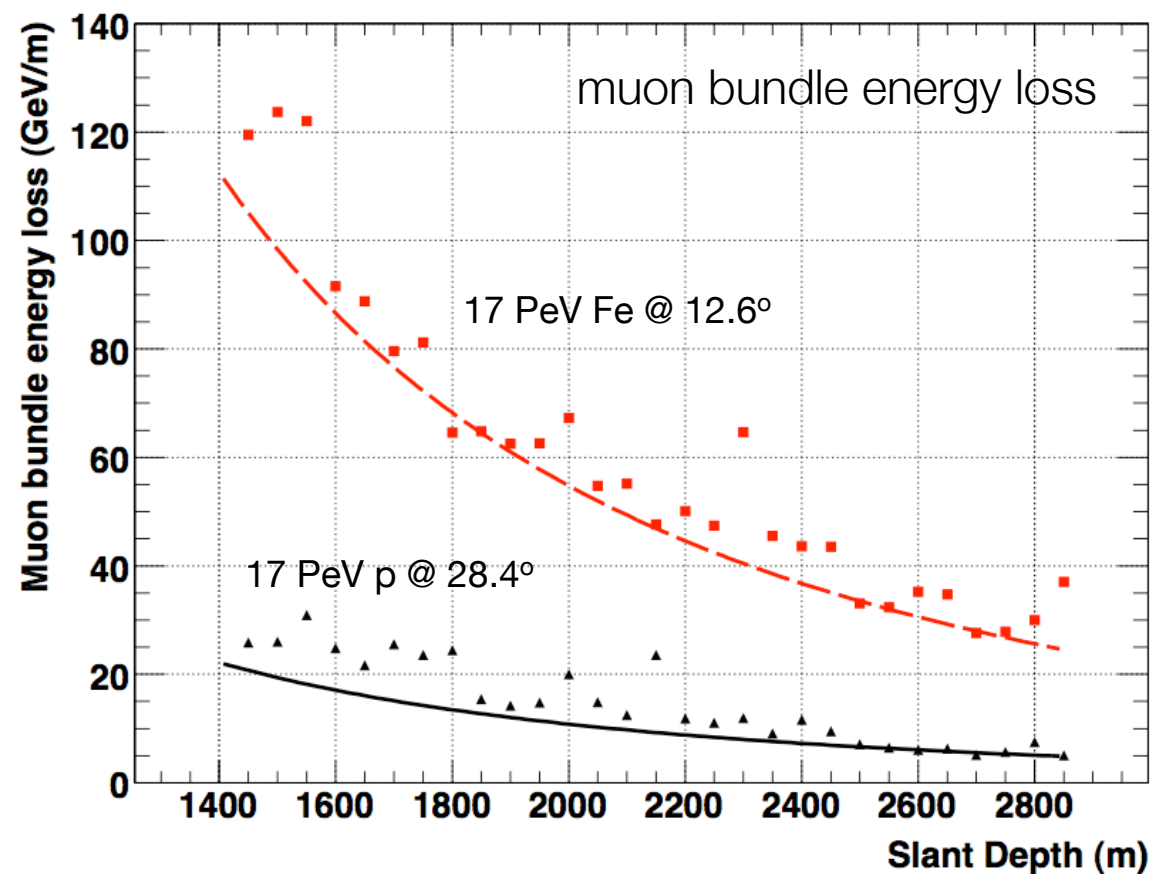
isotropic flux assumption : 2-component model yields the best agreement

cosmic rays : mass composition (IceCube & IceTop)

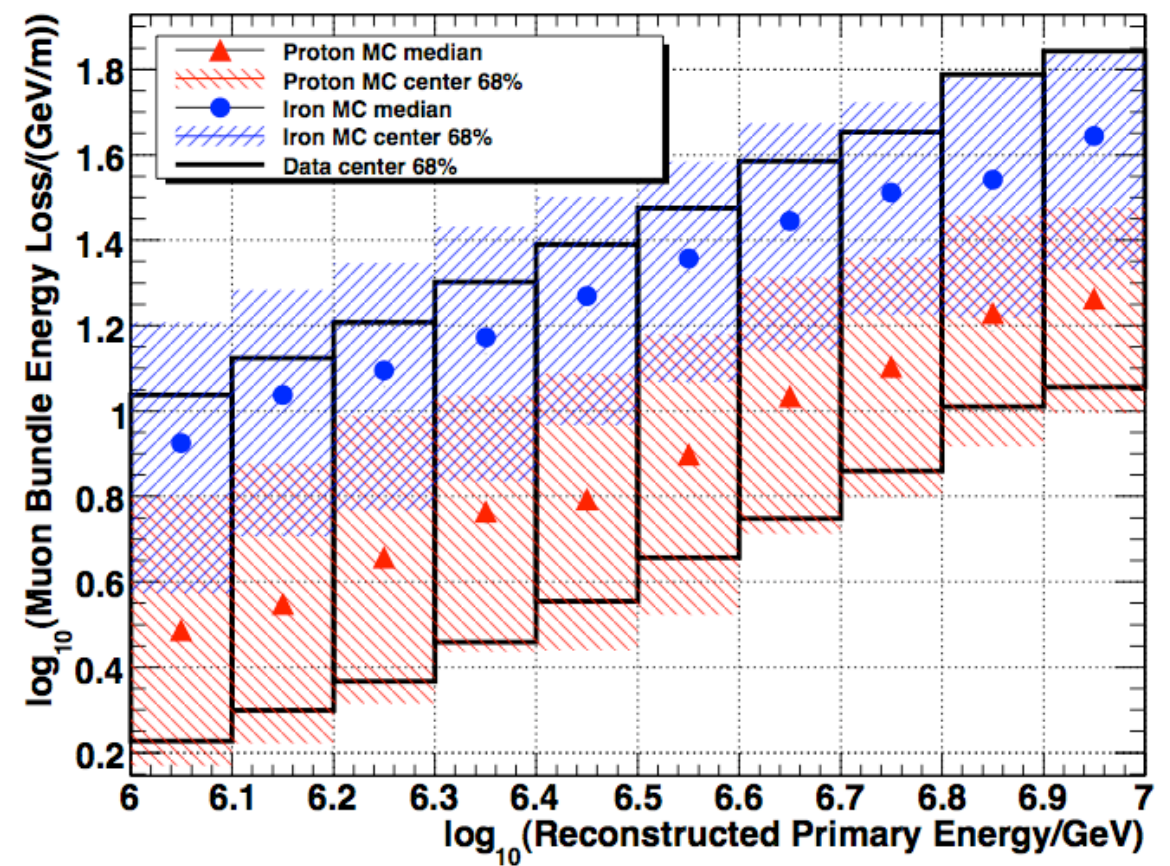
3/5

- correlation between shower energy and muon bundle energy
- coincident event provide good directional reconstruction : $\sim 0.5^\circ$

Reconstructed slant depth behavior



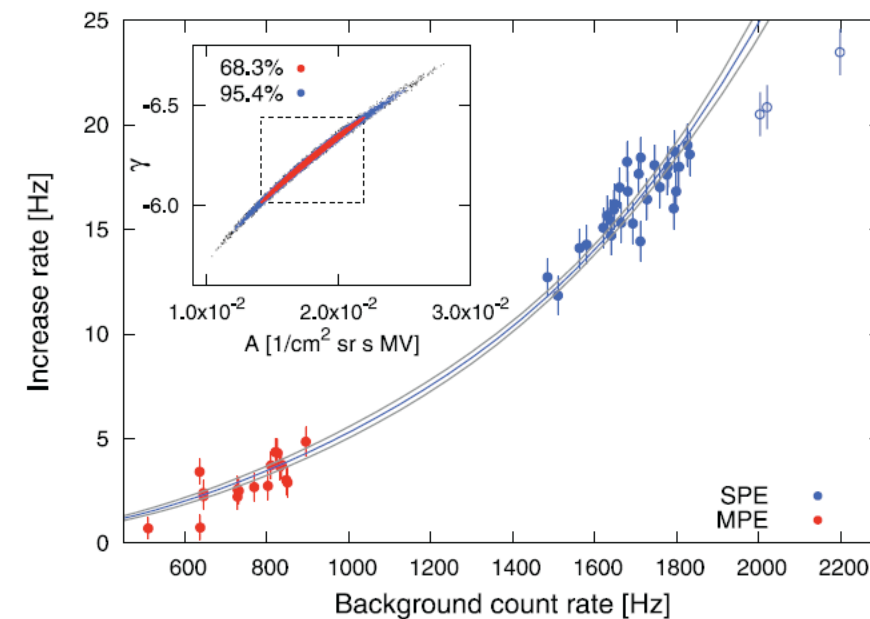
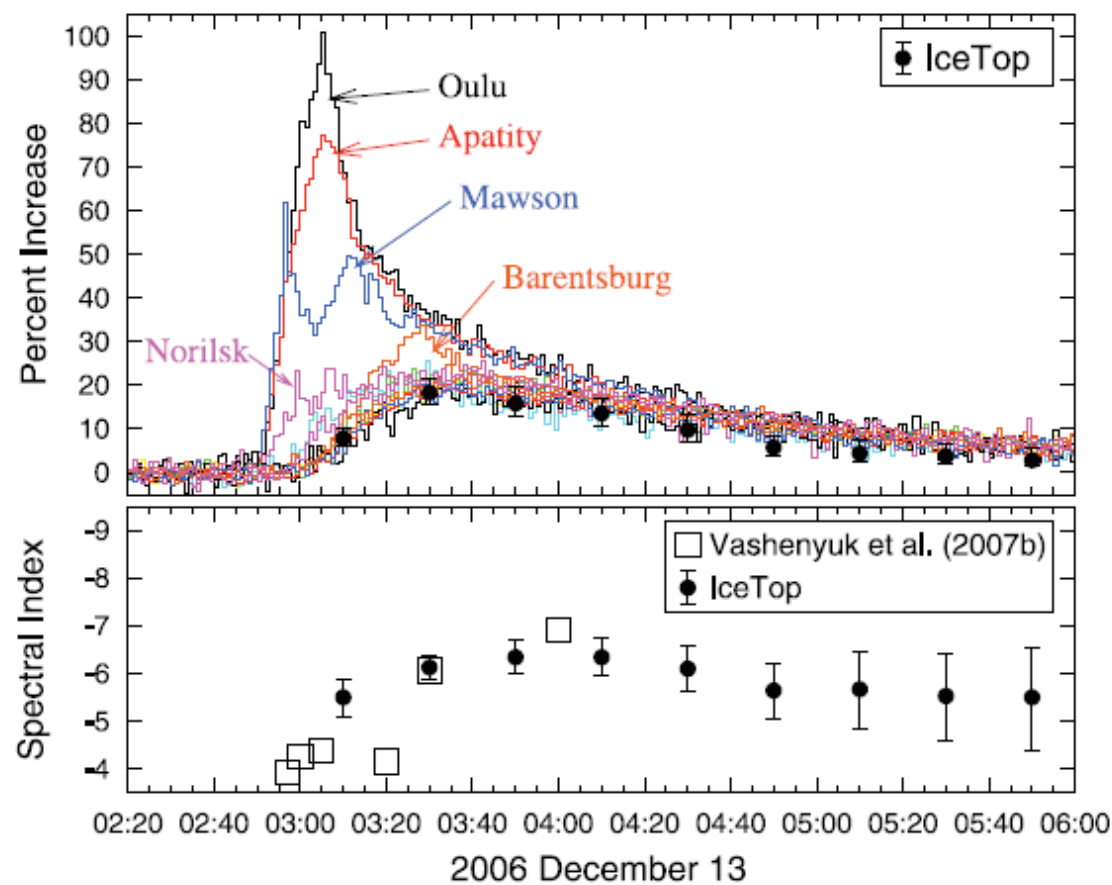
Comparison of Simulation and Data



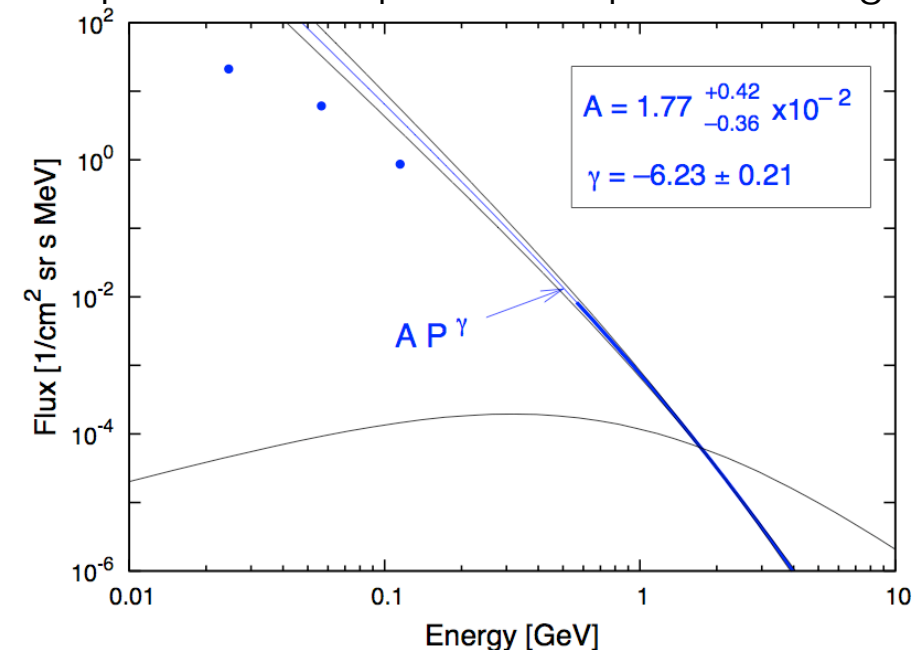
cosmic rays : heliospheric physics

4/5

- energy spectrum of particles from solar flares



proton spectrum compared with proton background

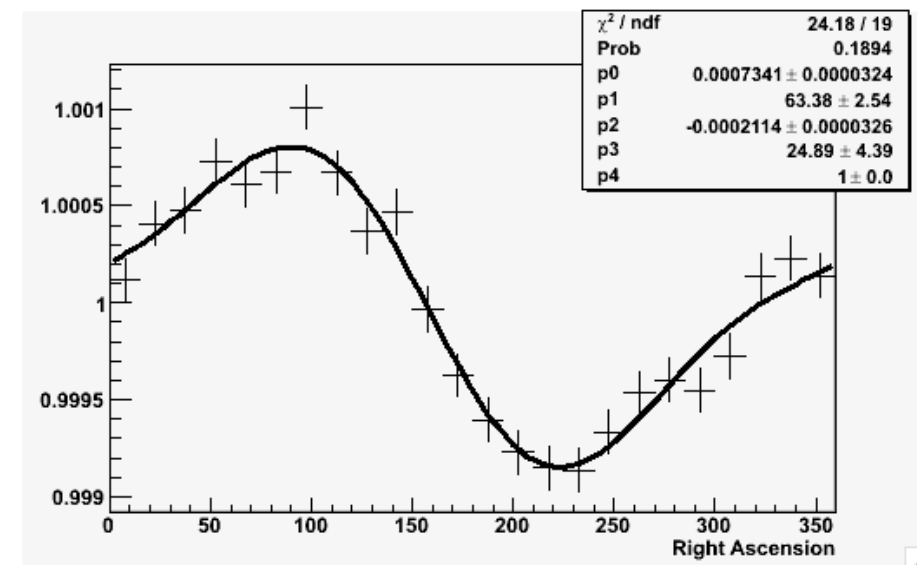
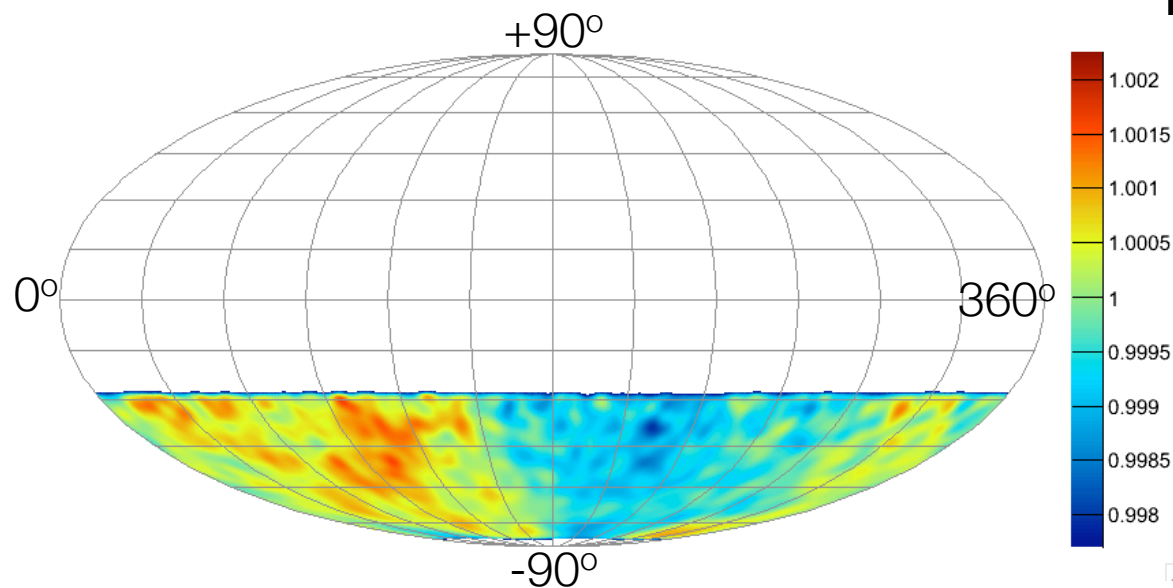


cosmic rays : large scale anisotropy (IceCube-22)

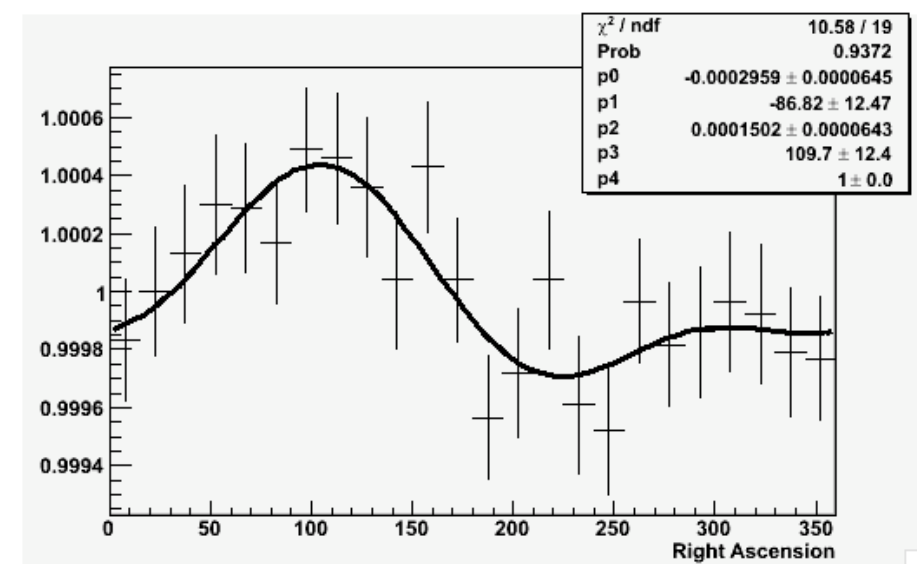
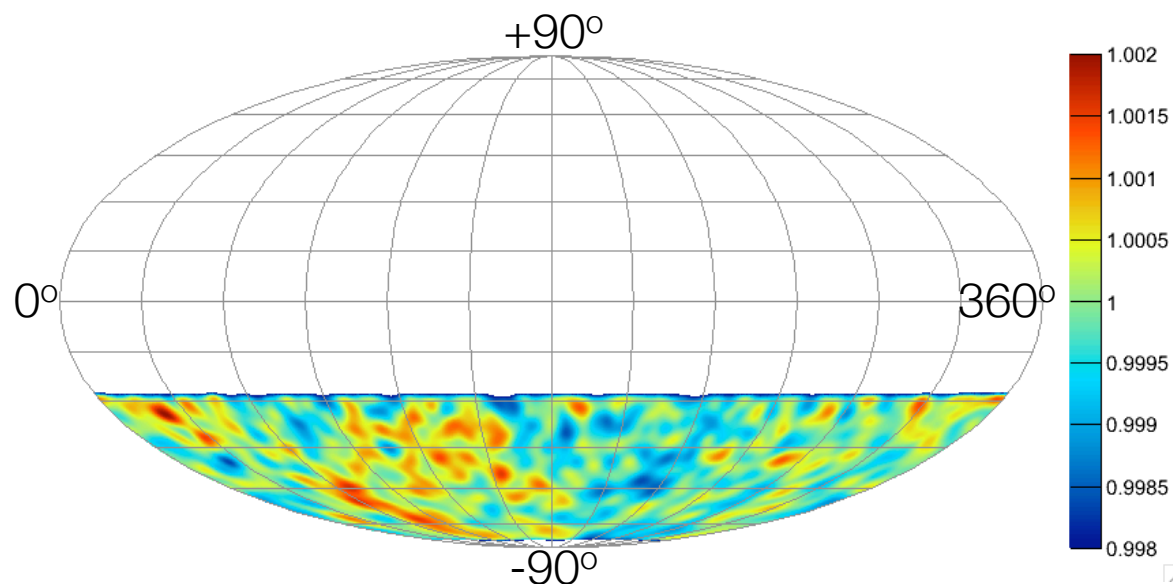
5/5

- measure muon bundles induced by cosmic rays : $E_{\text{CR}} \gtrsim 5 \text{ TeV}$
- arrival direction of CR affected by local interstellar magnetic field structure

12.6 TeV

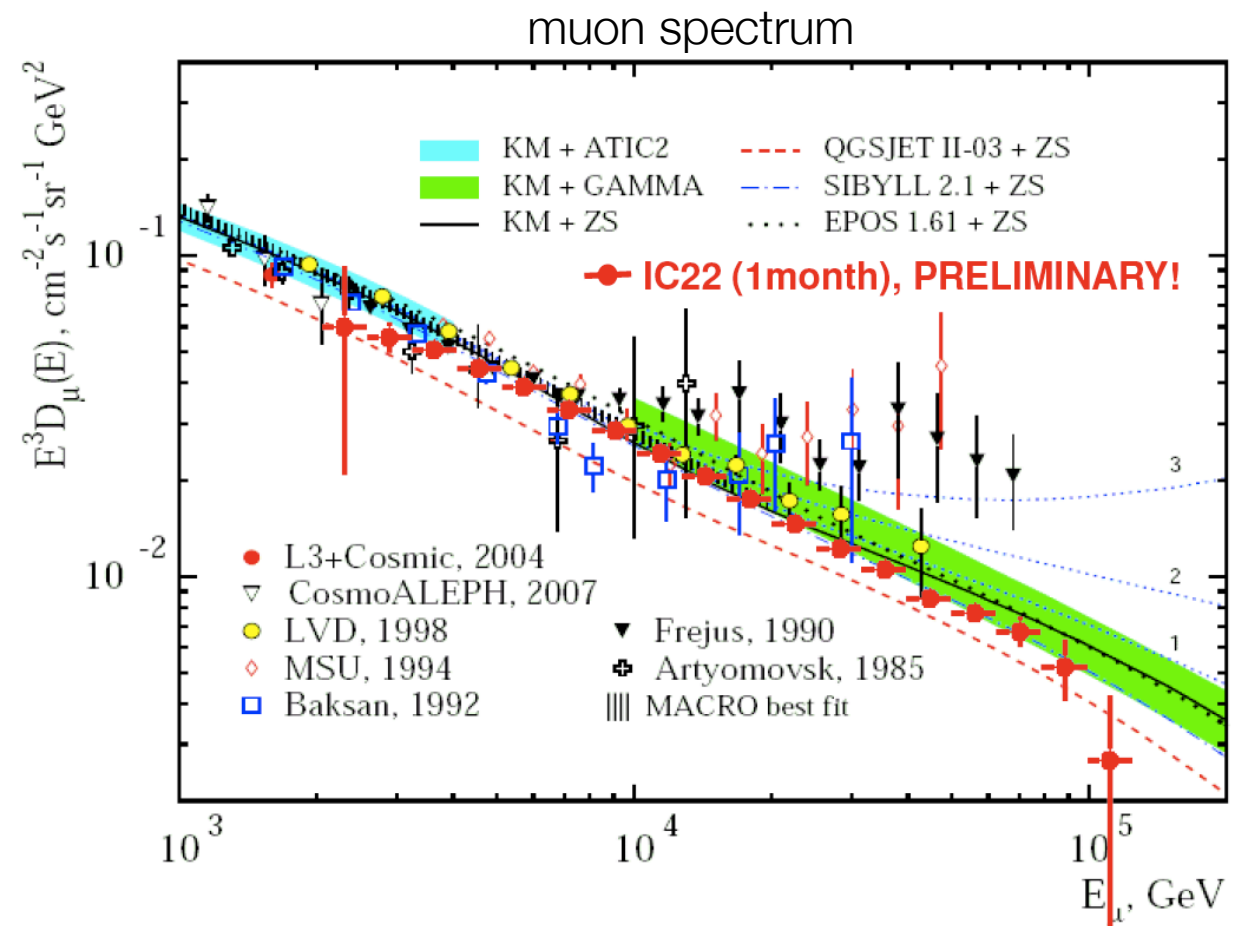
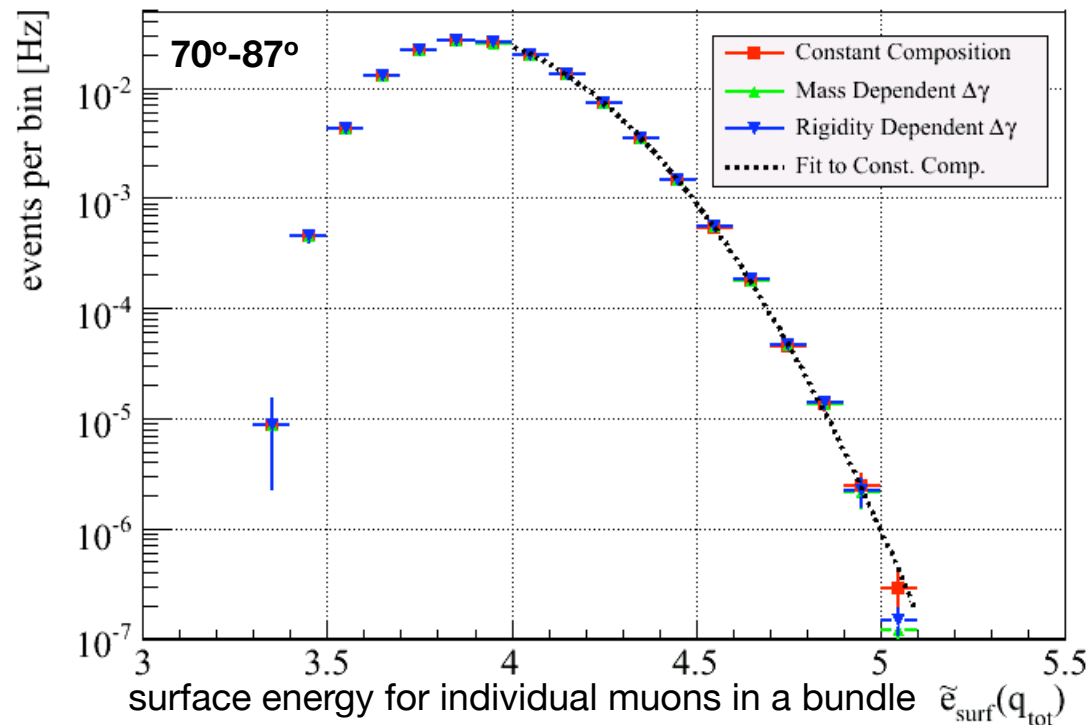
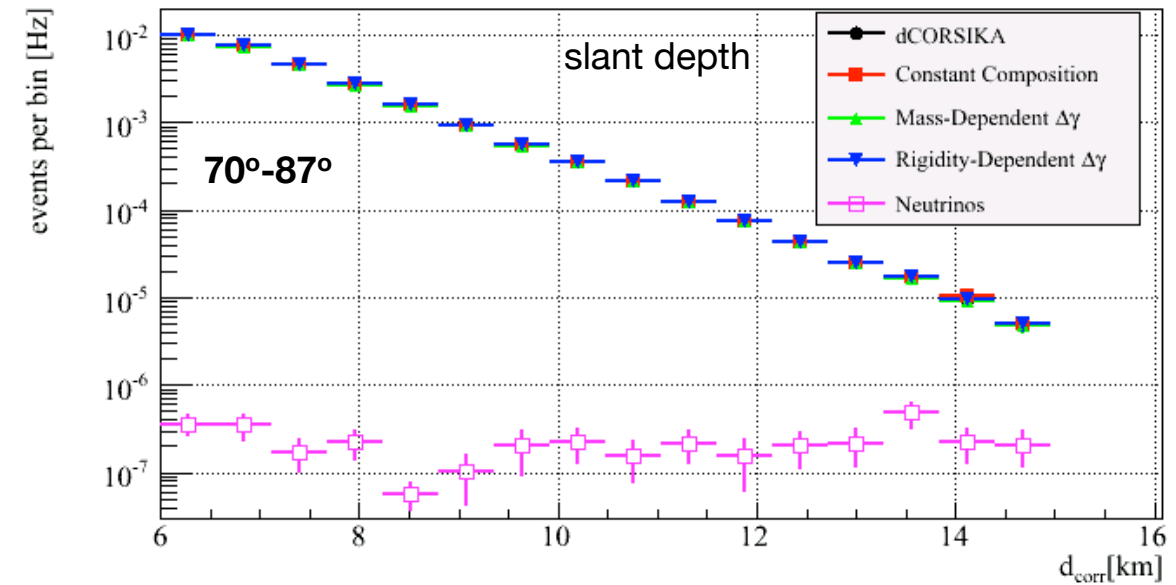
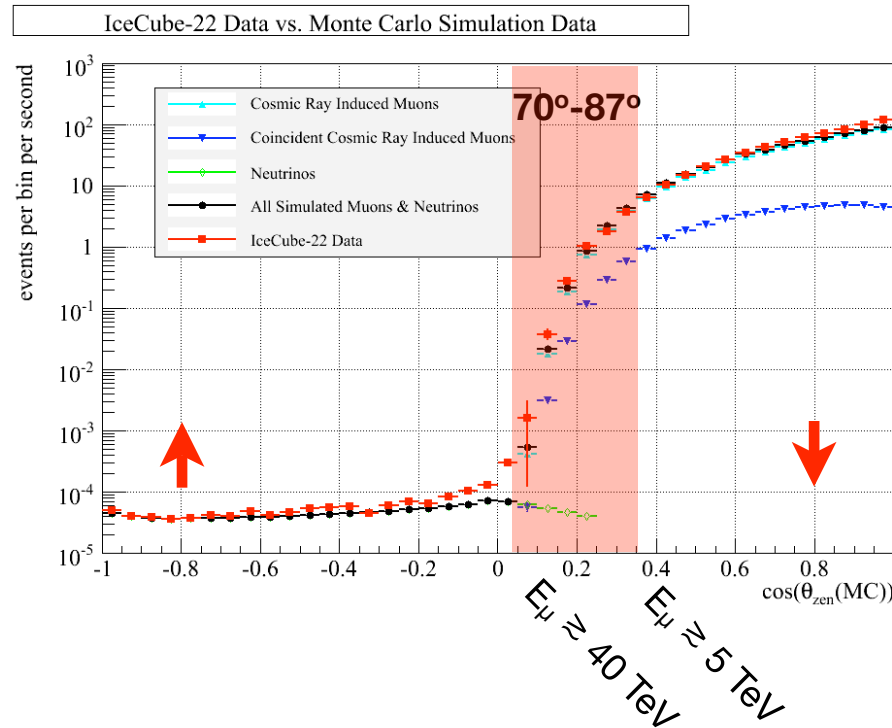


126 TeV



atmospheric horizontal μ bundles (IceCube-22)

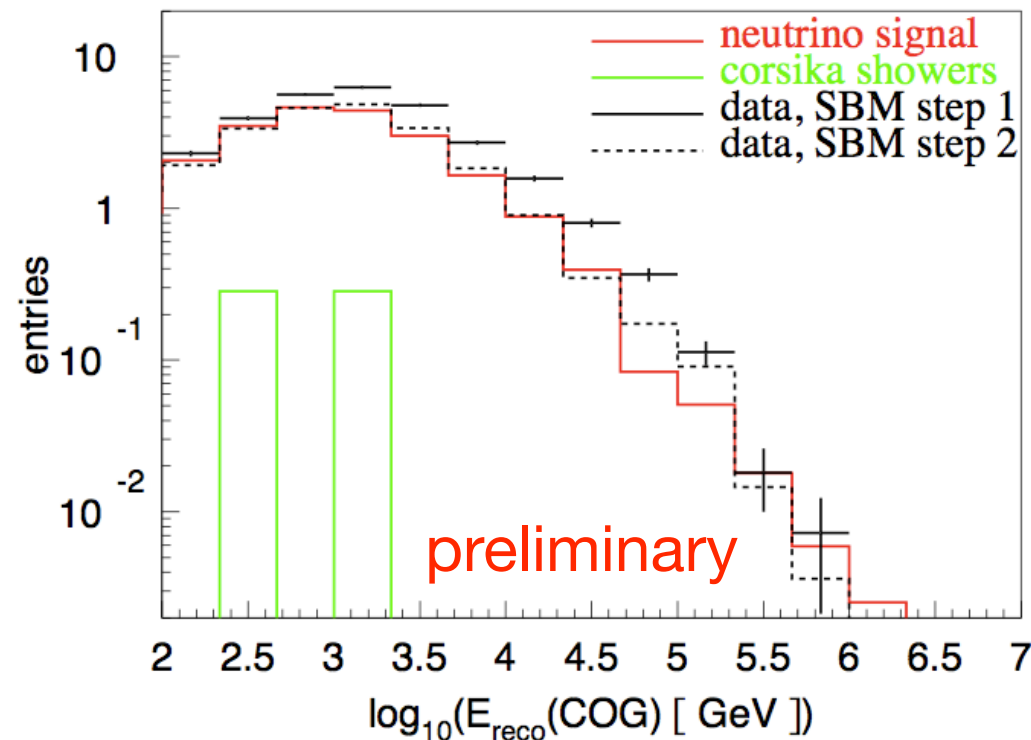
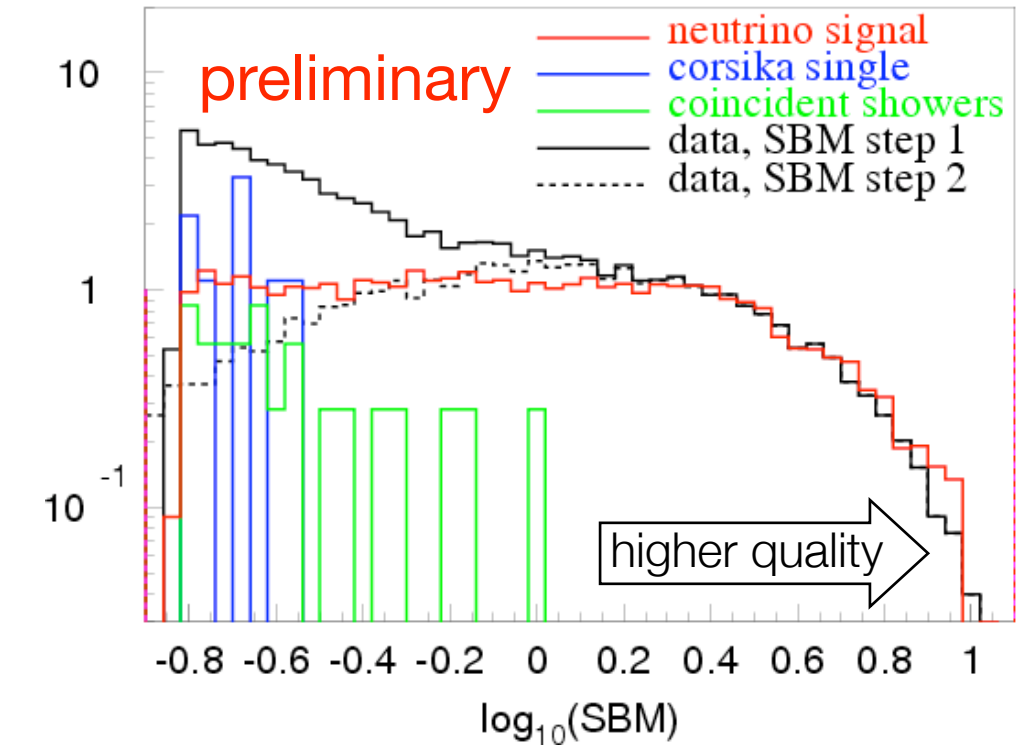
1/5



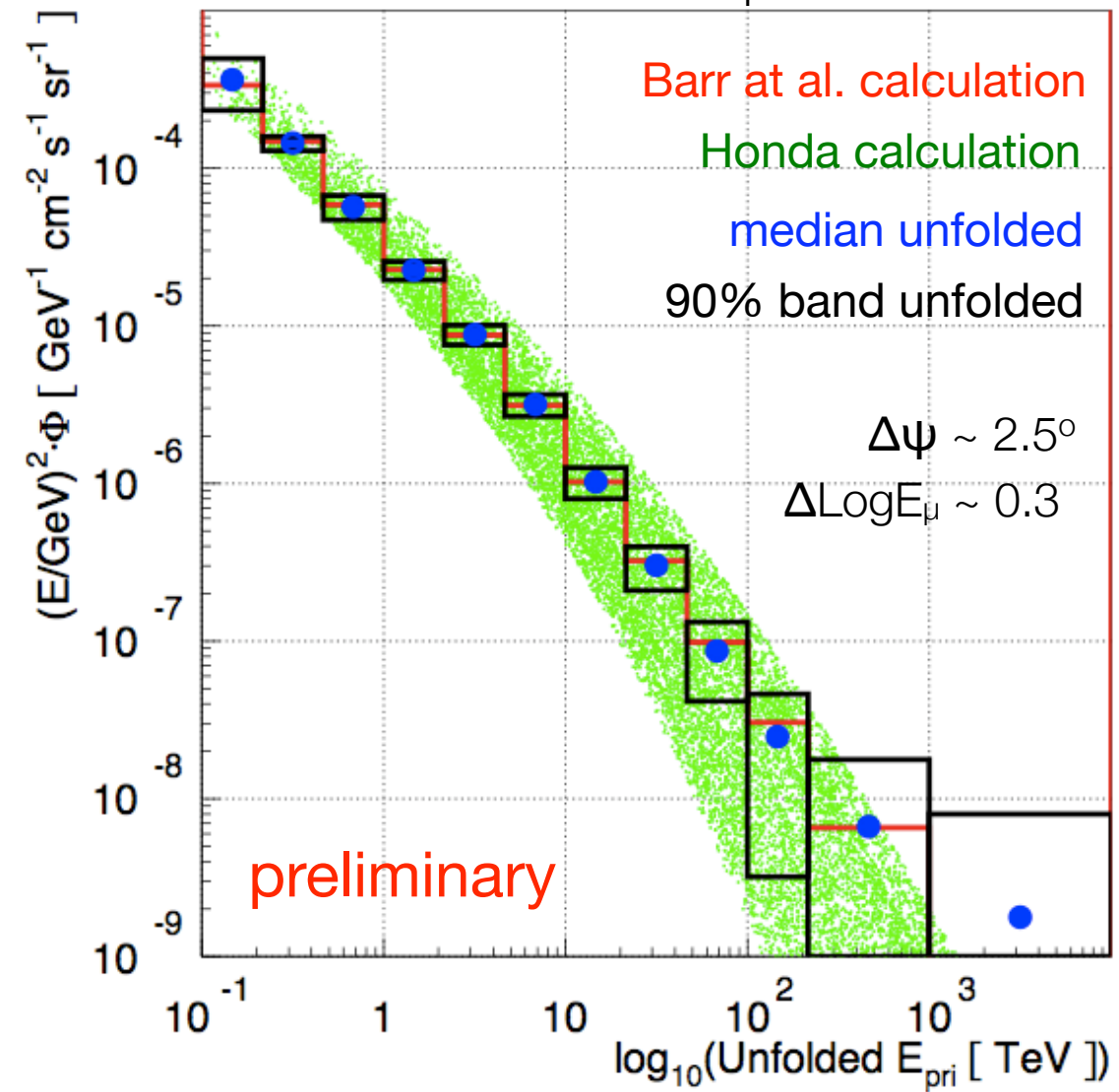
atmospheric ν_μ (IceCube-22)

2/5

quality parameter



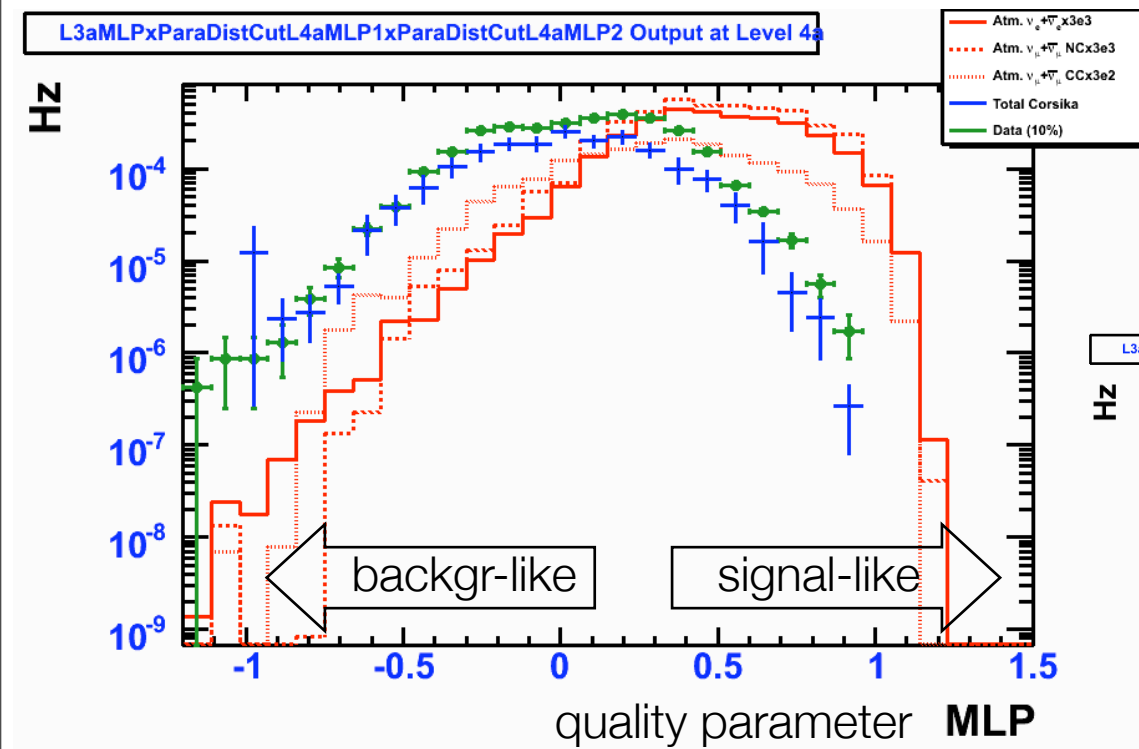
unfolded neutrino spectrum



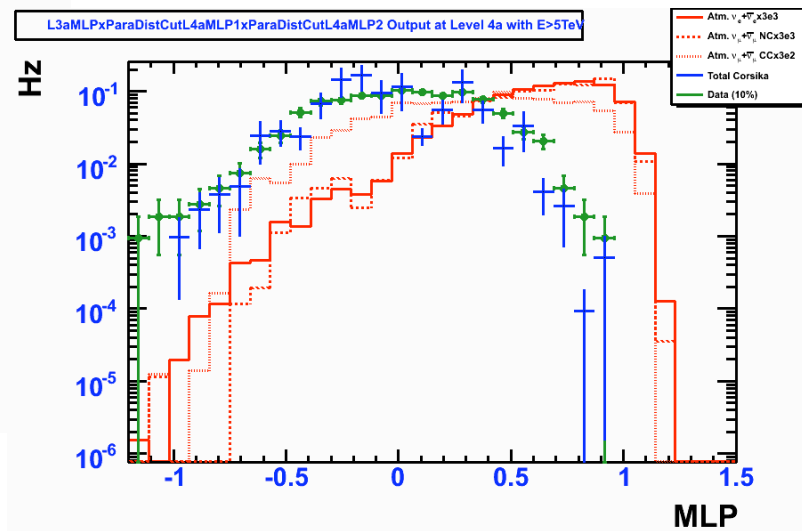
IC-22 (95% purity)	29.0 neutrinos / day
IC-40 (95% purity)	83.1 neutrinos / day
IC-86 (40% purity)	~390 neutrinos / day

atmospheric ν_e (IceCube-22)

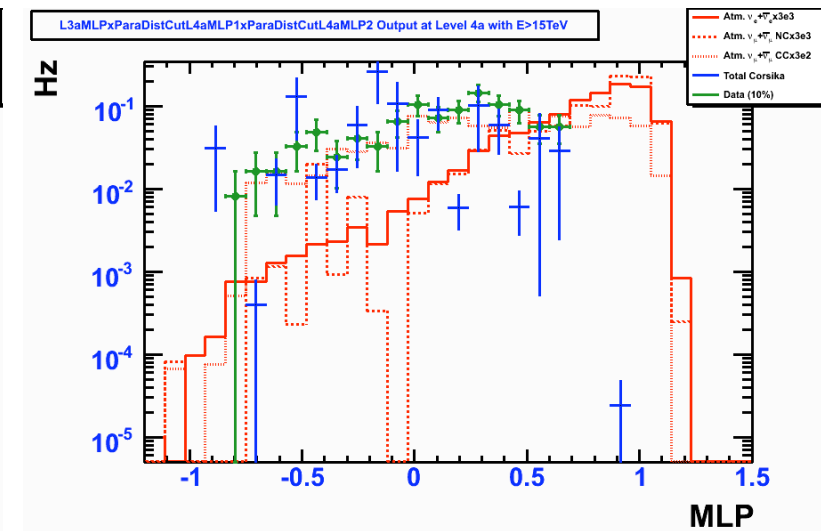
3/5



$\Delta\text{Vertex} \sim 10 \text{ m}$
 $\Delta\text{Log}E_\mu \sim 0.17 - 0.23$



$E > 5 \text{ TeV}$

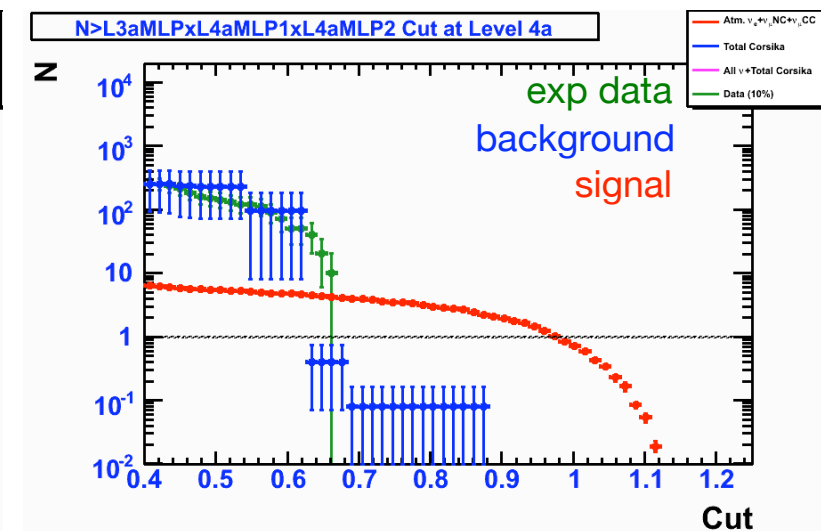
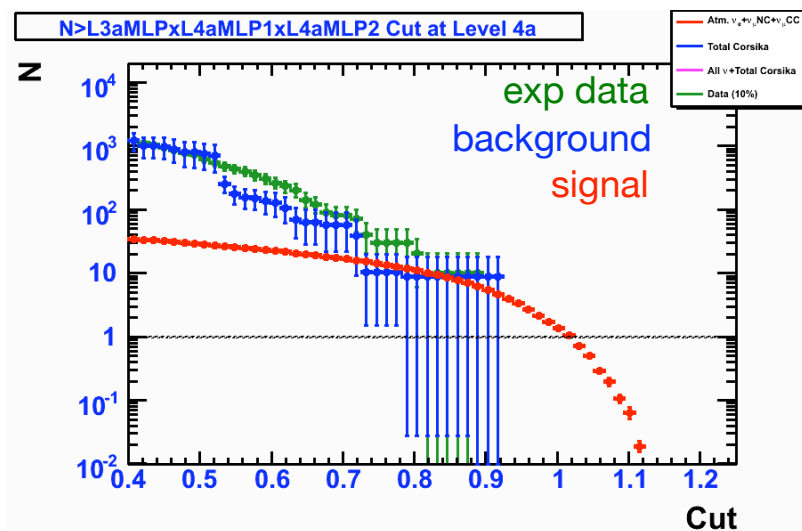


$E > 15 \text{ TeV}$

- limited by background statistics

- high cascade-like background

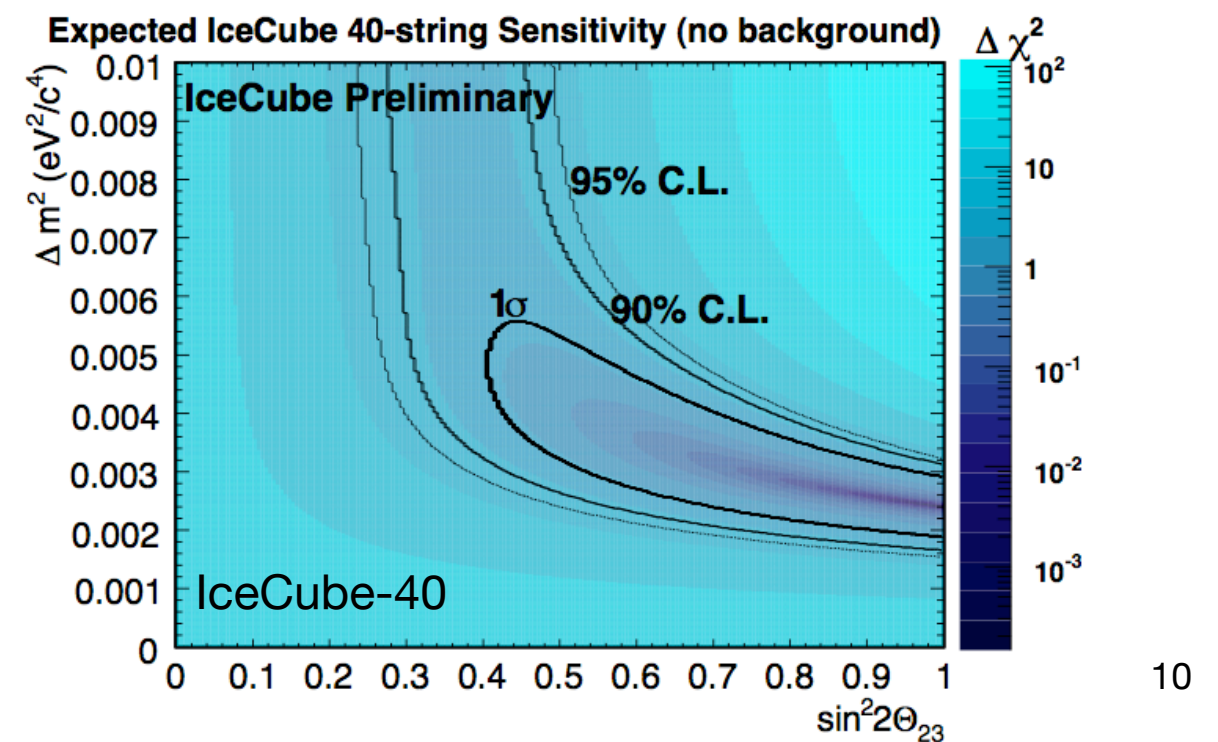
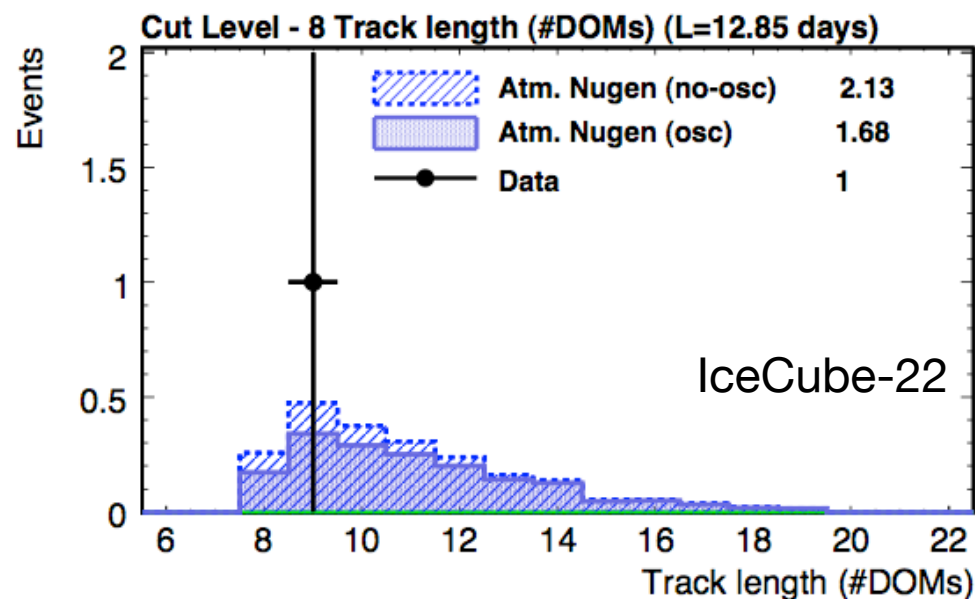
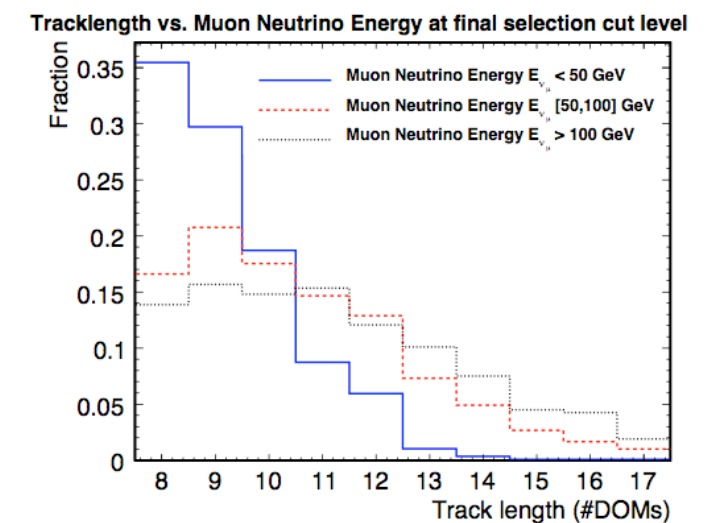
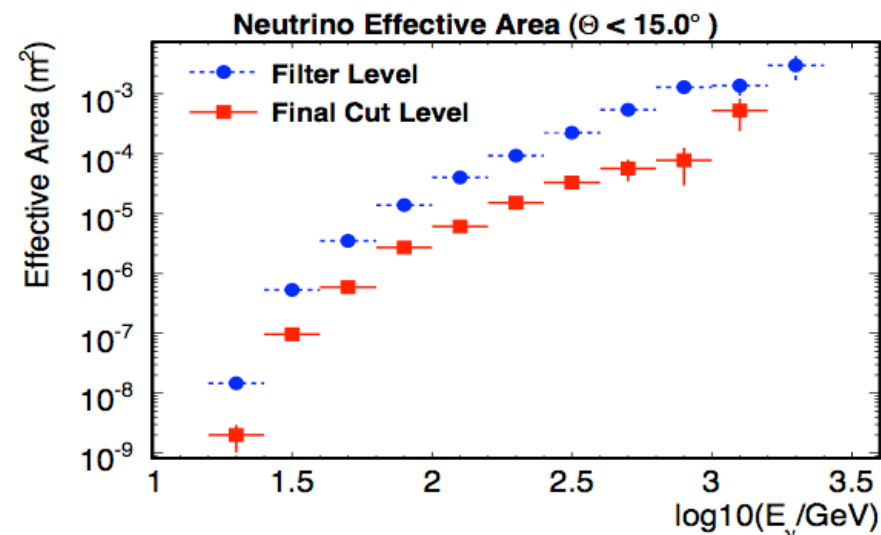
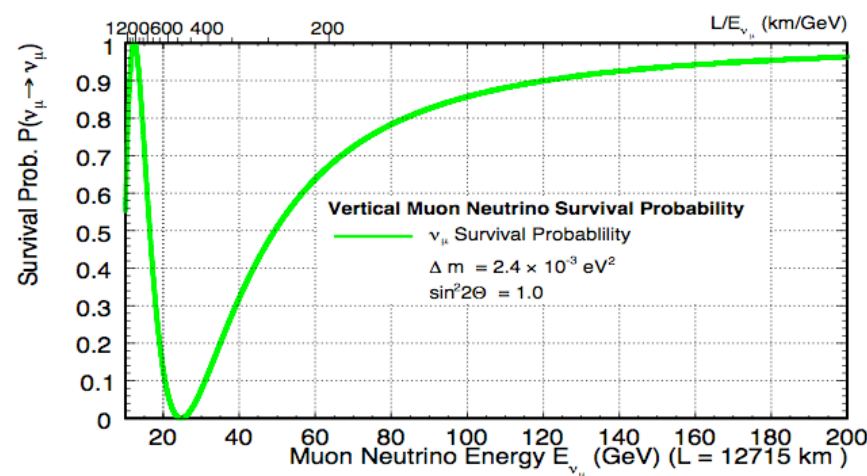
- dedicated simulation for searches of cascades



atmospheric ν_μ : oscillations (IceCube-22)

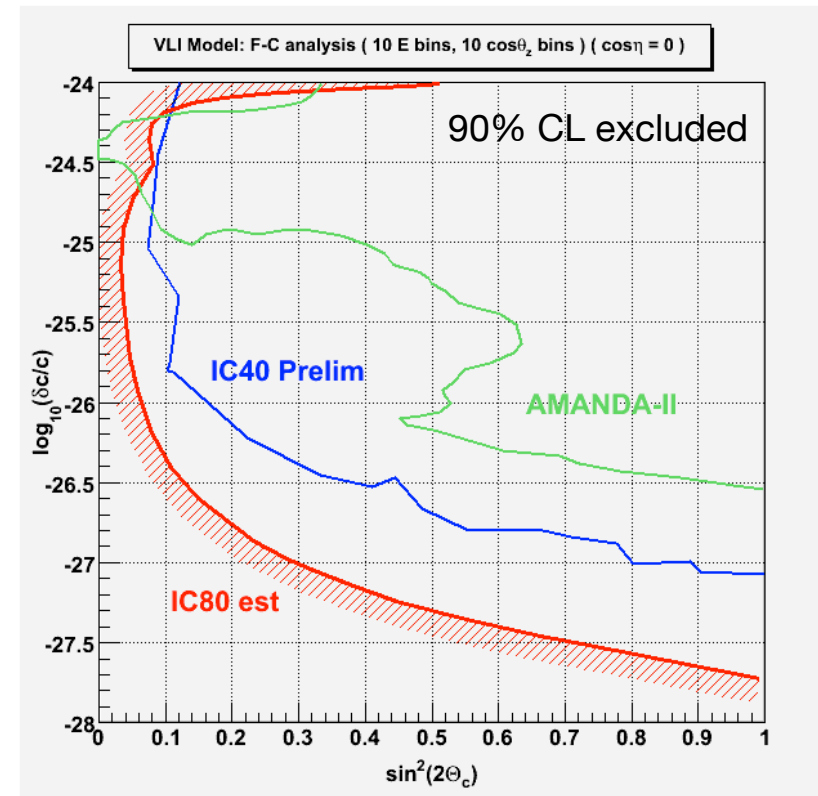
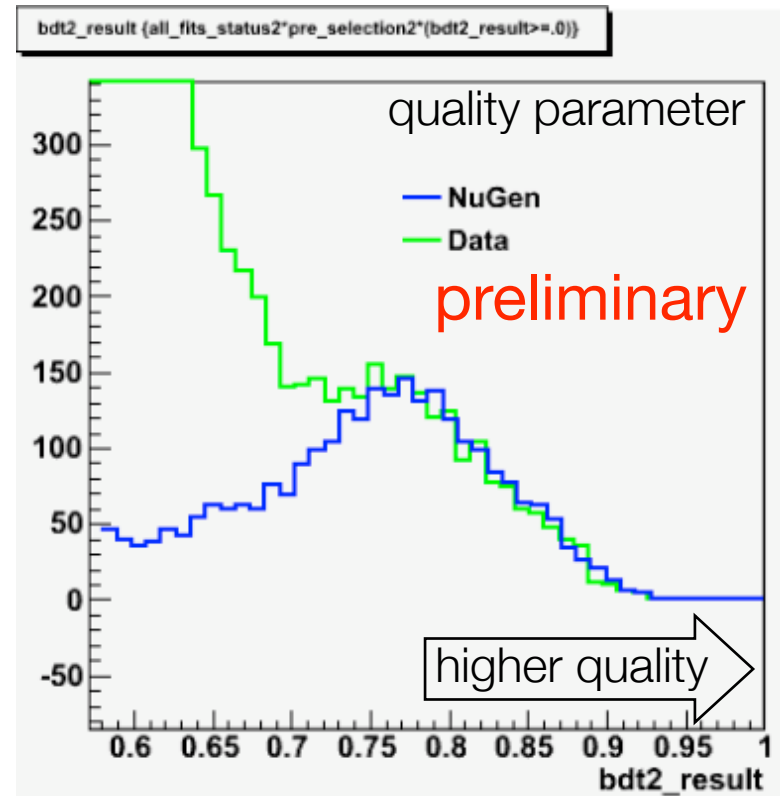
4/5

- extend atmospheric neutrino measurement below 100 GeV
- ν_μ disappearance for vertical up-going muons (Deep Core)

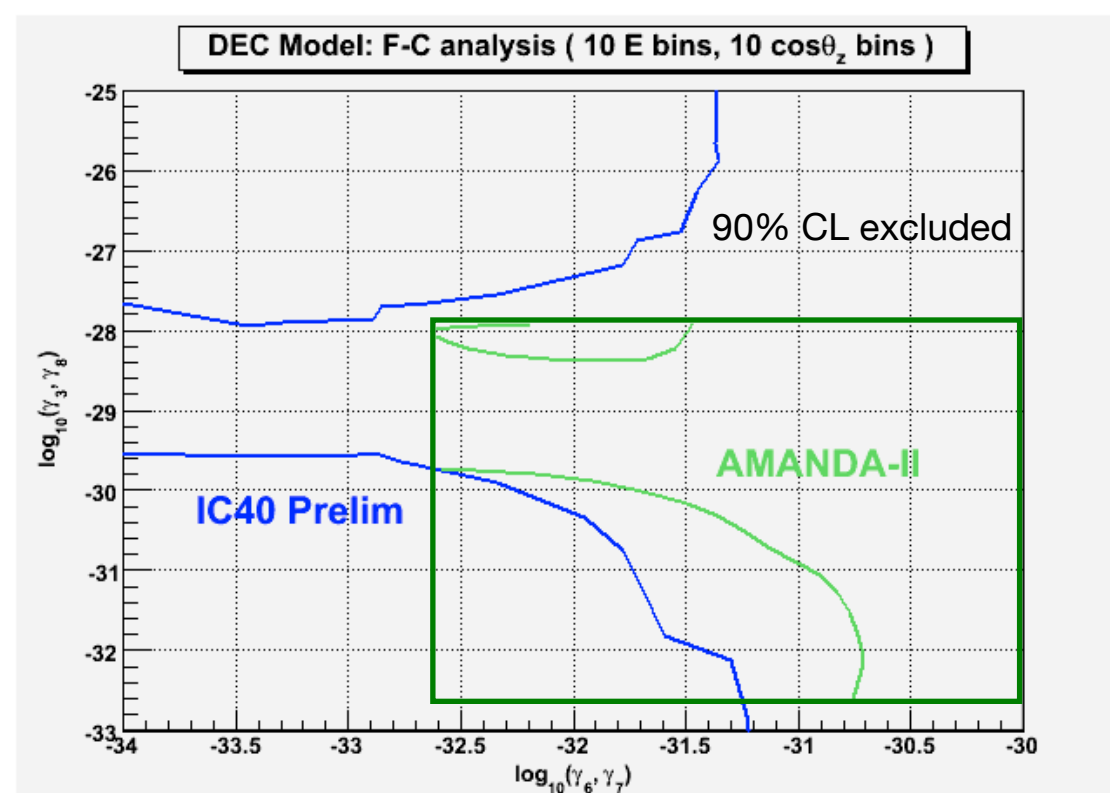
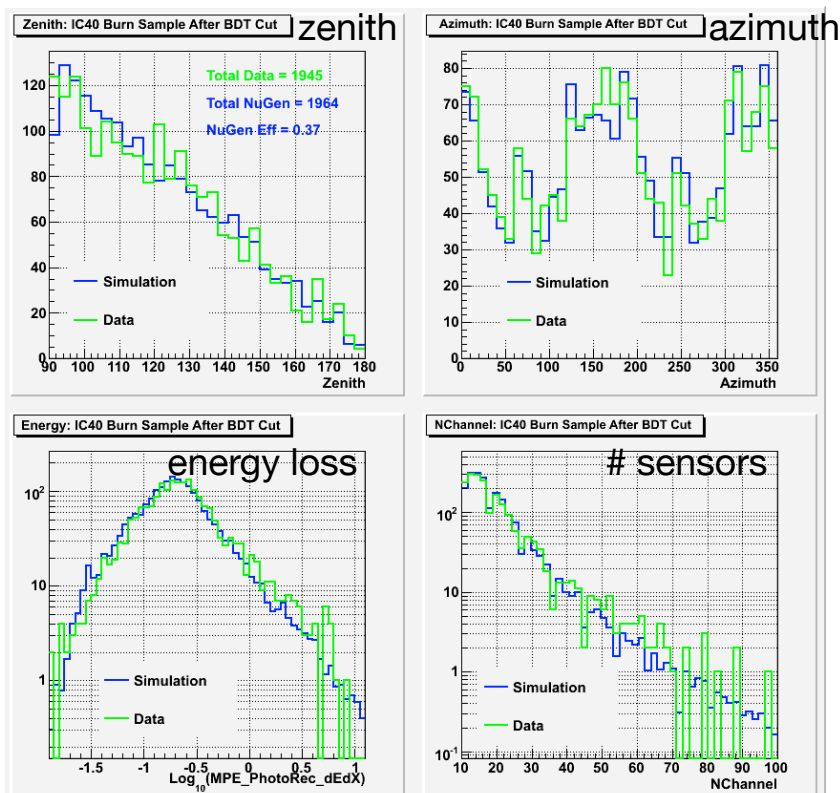


atmospheric ν_μ : VLI & decoherence (IceCube-40)

5/5



Violation of Lorentz Invariance

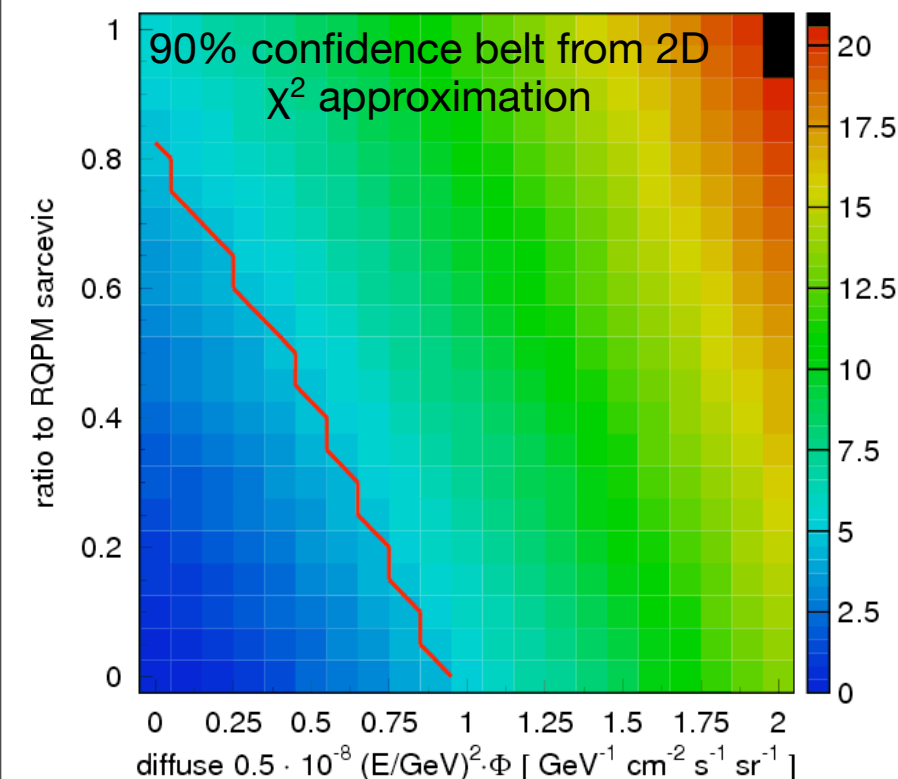
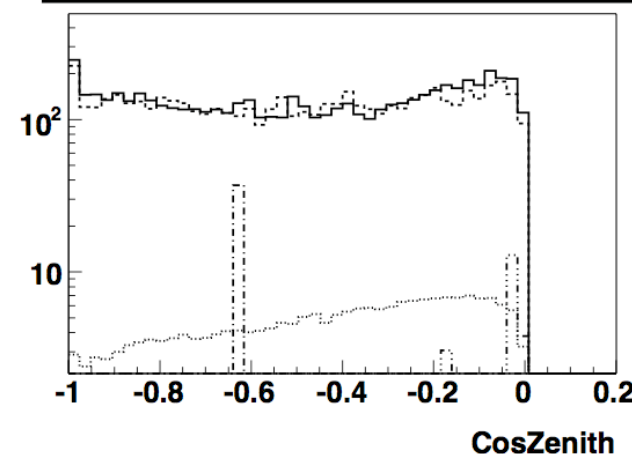
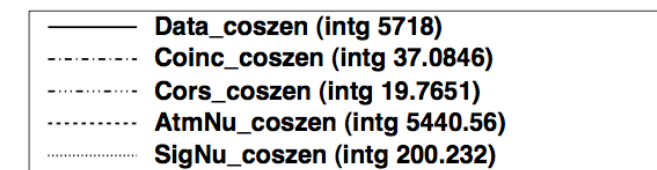
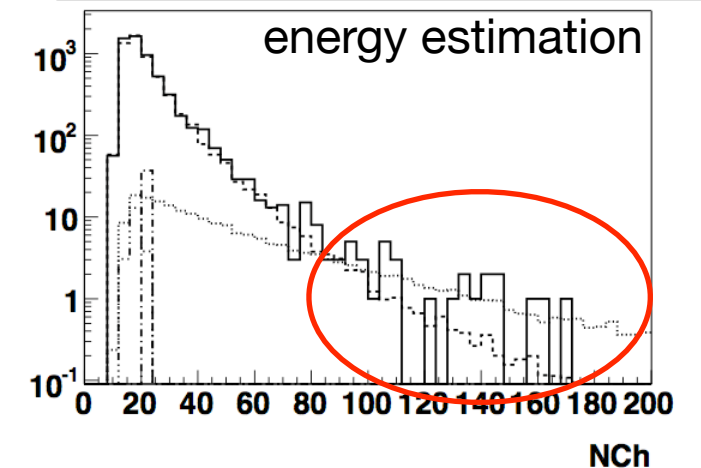
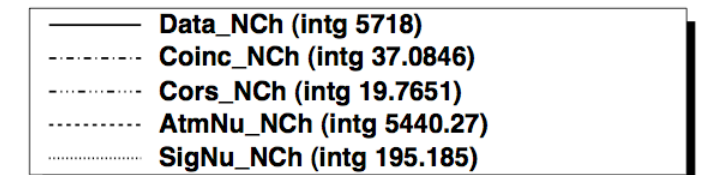
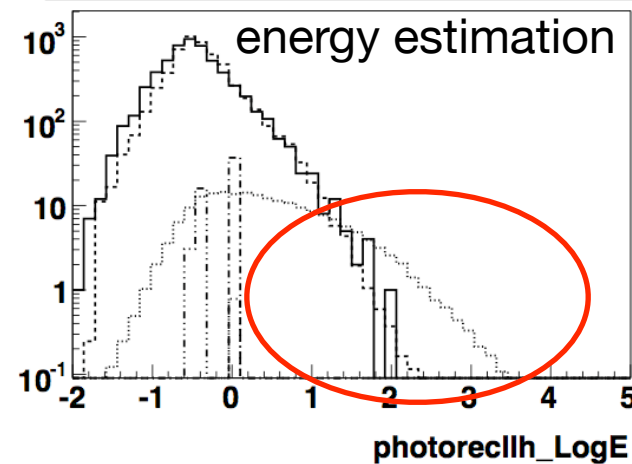
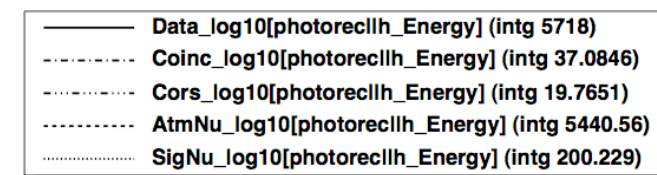
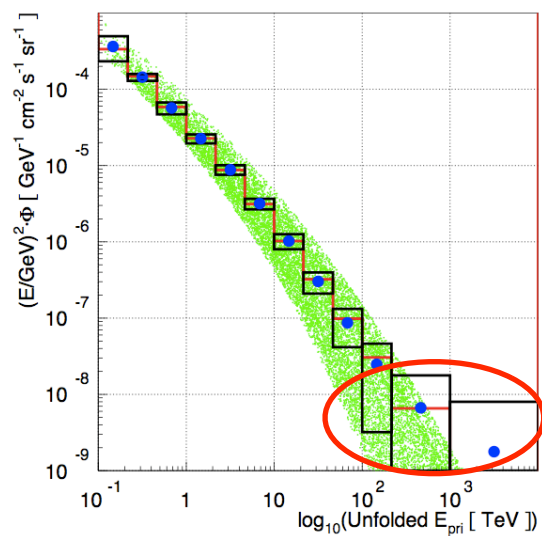


Quantum Gravity

diffuse ν_μ (IceCube-22)

1/2

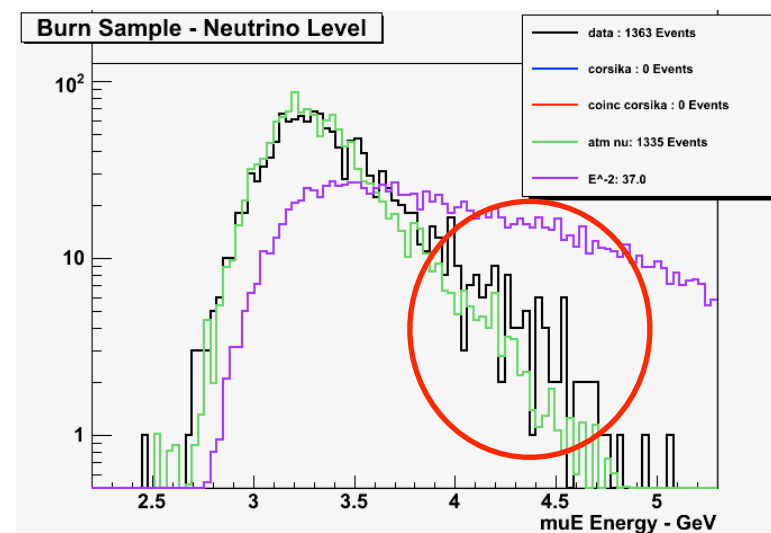
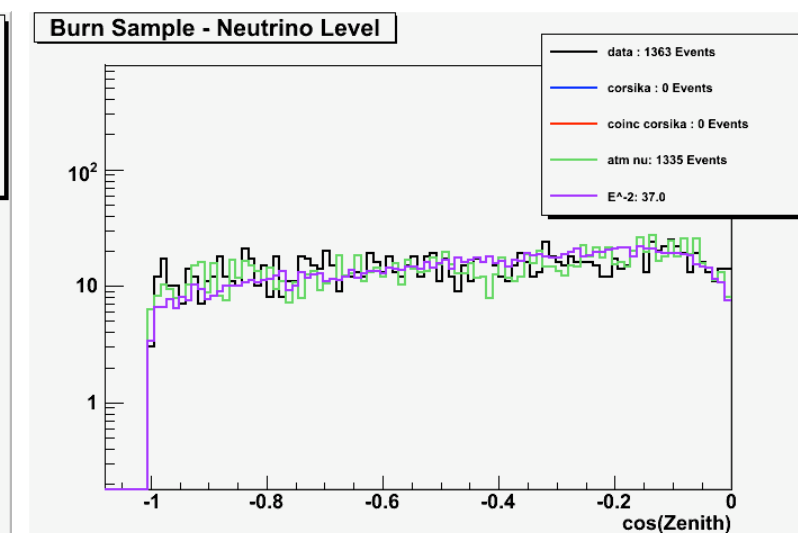
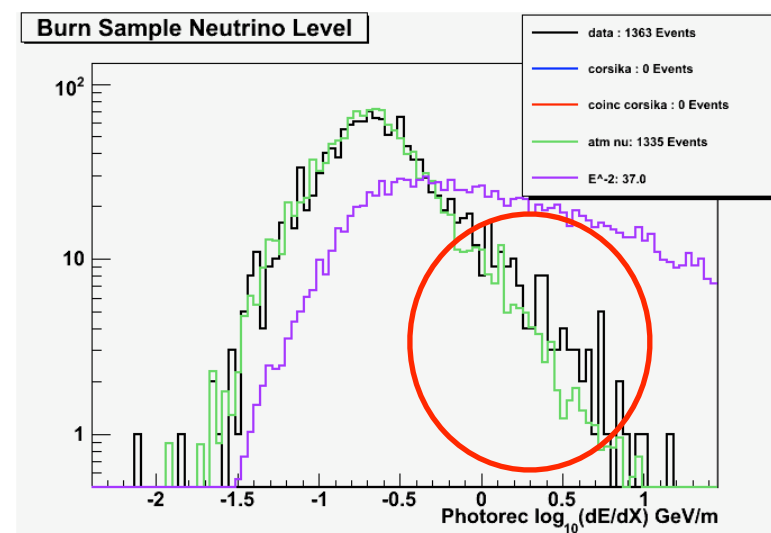
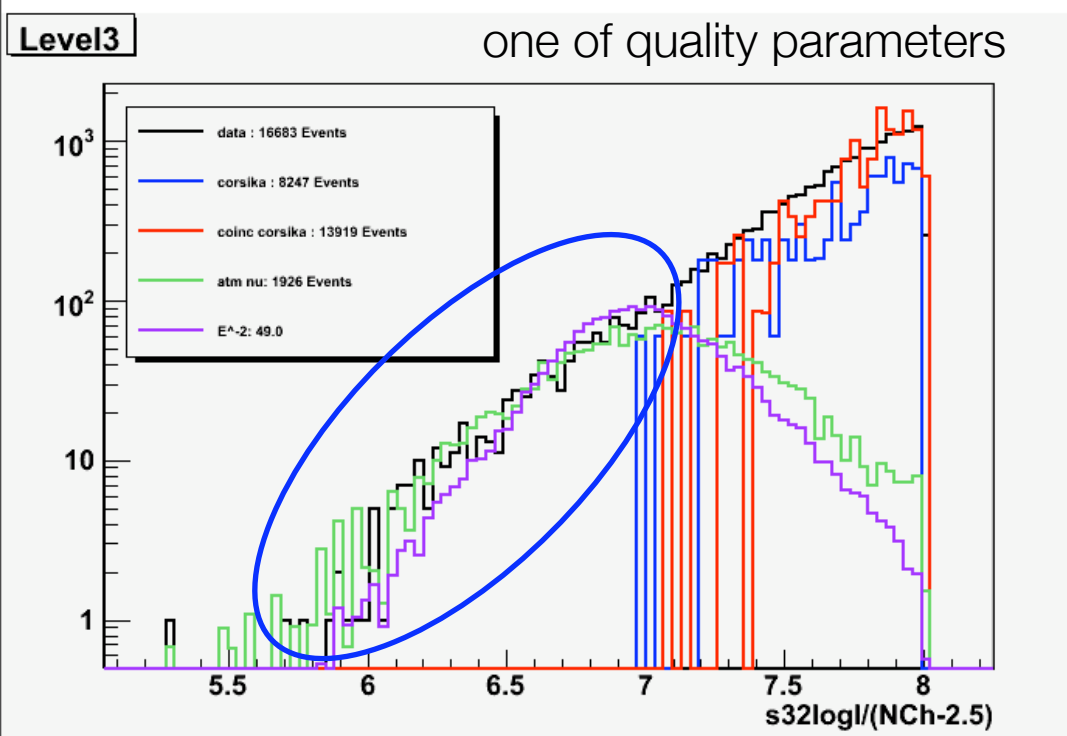
- search for high energy extraterrestrial neutrinos
- understanding detector systematics for bright events (i.e. high energy)



diffuse ν_μ : (IceCube-40)

2/2

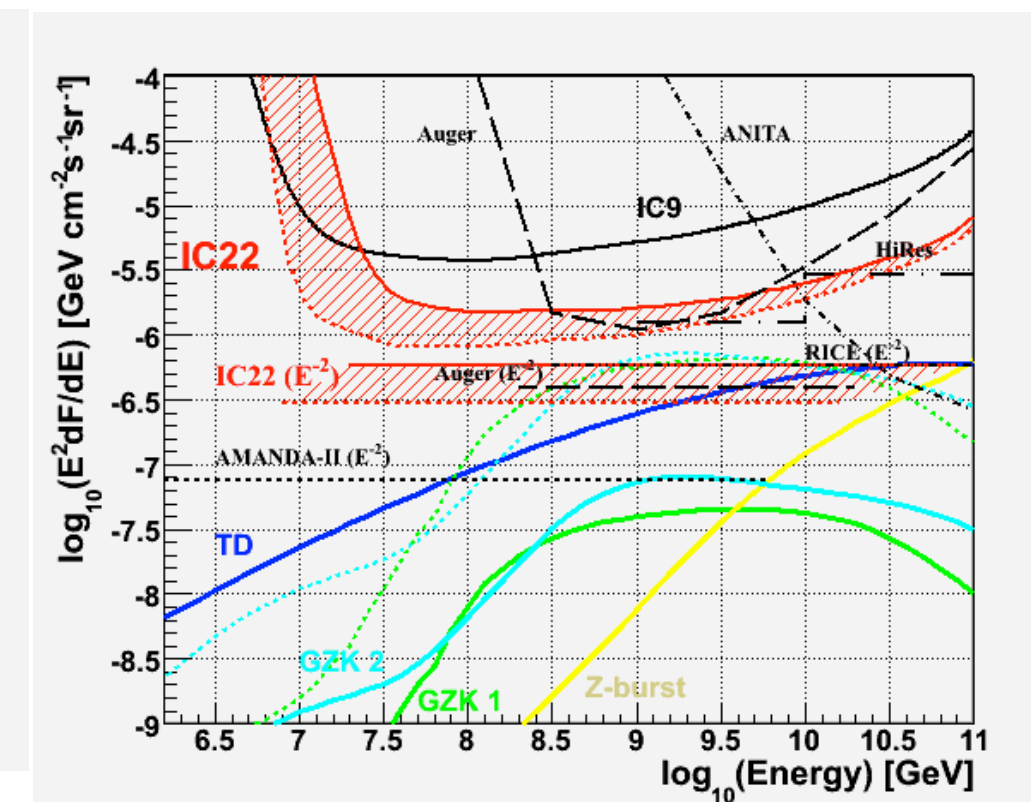
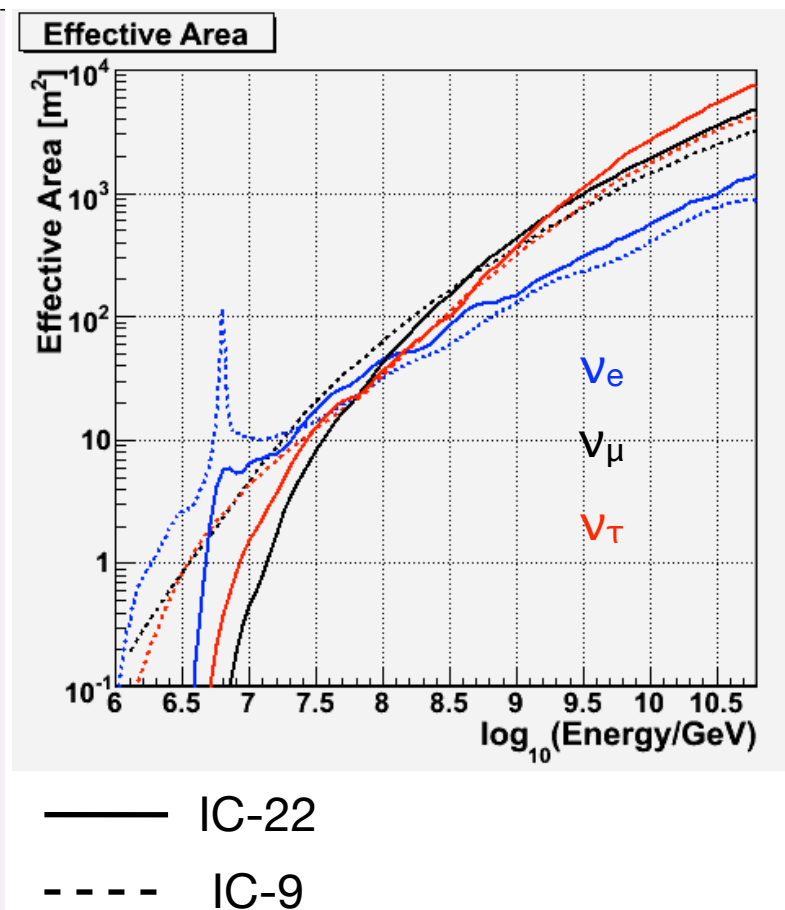
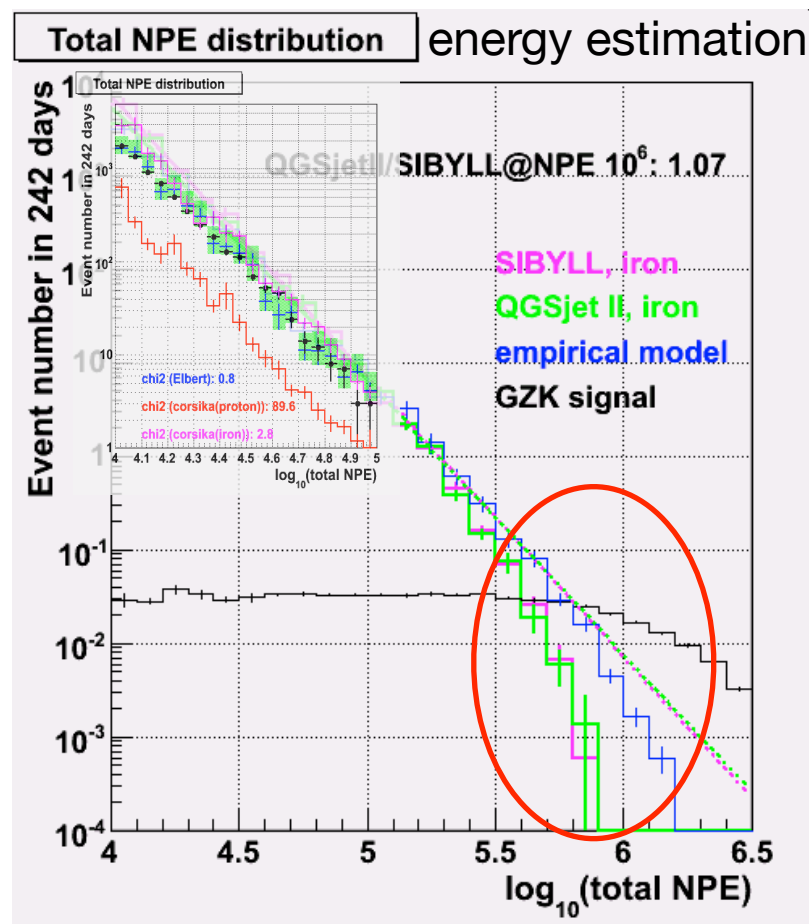
- event selection capability increases with detector size
- understand systematics in signal region : different energy estimators



EHE ν : IceCube-22

1/1

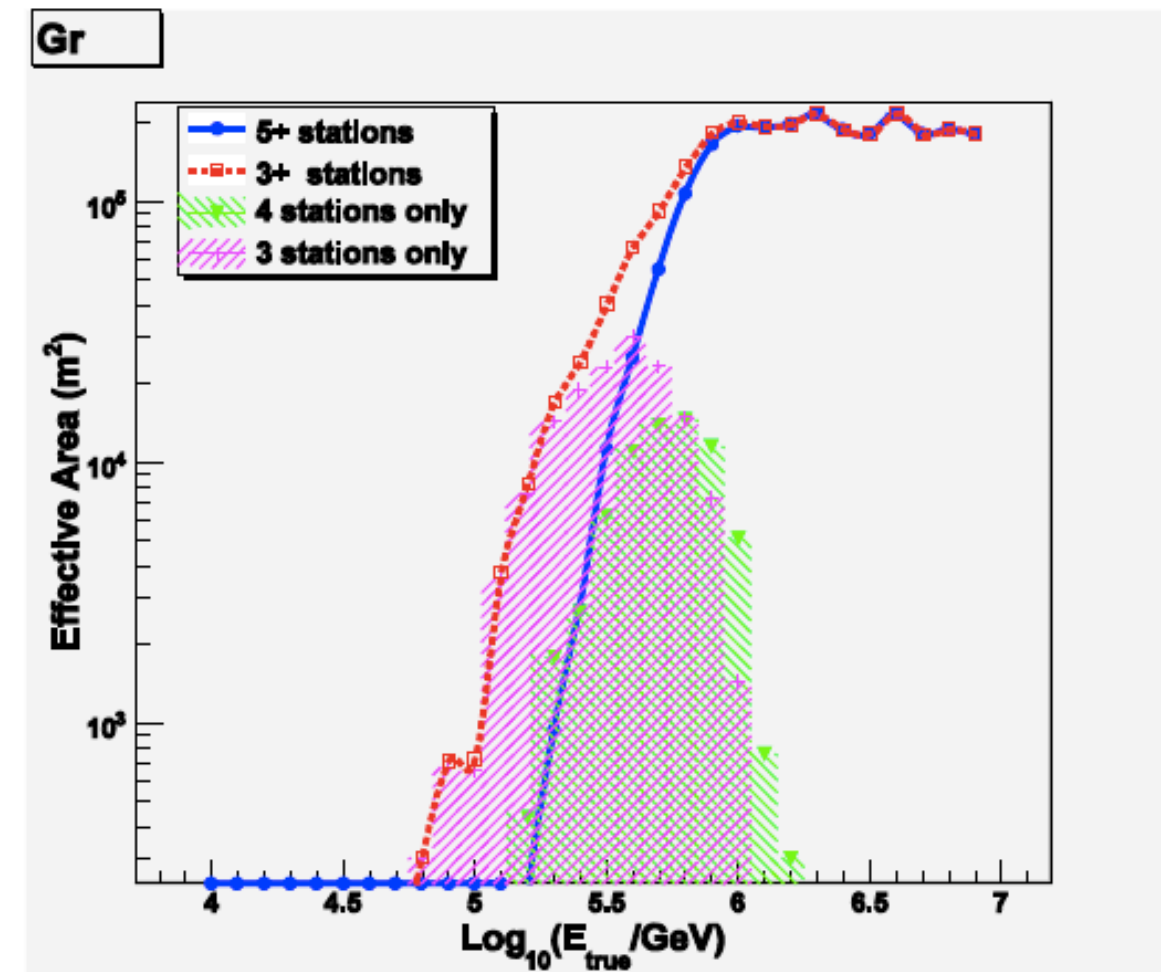
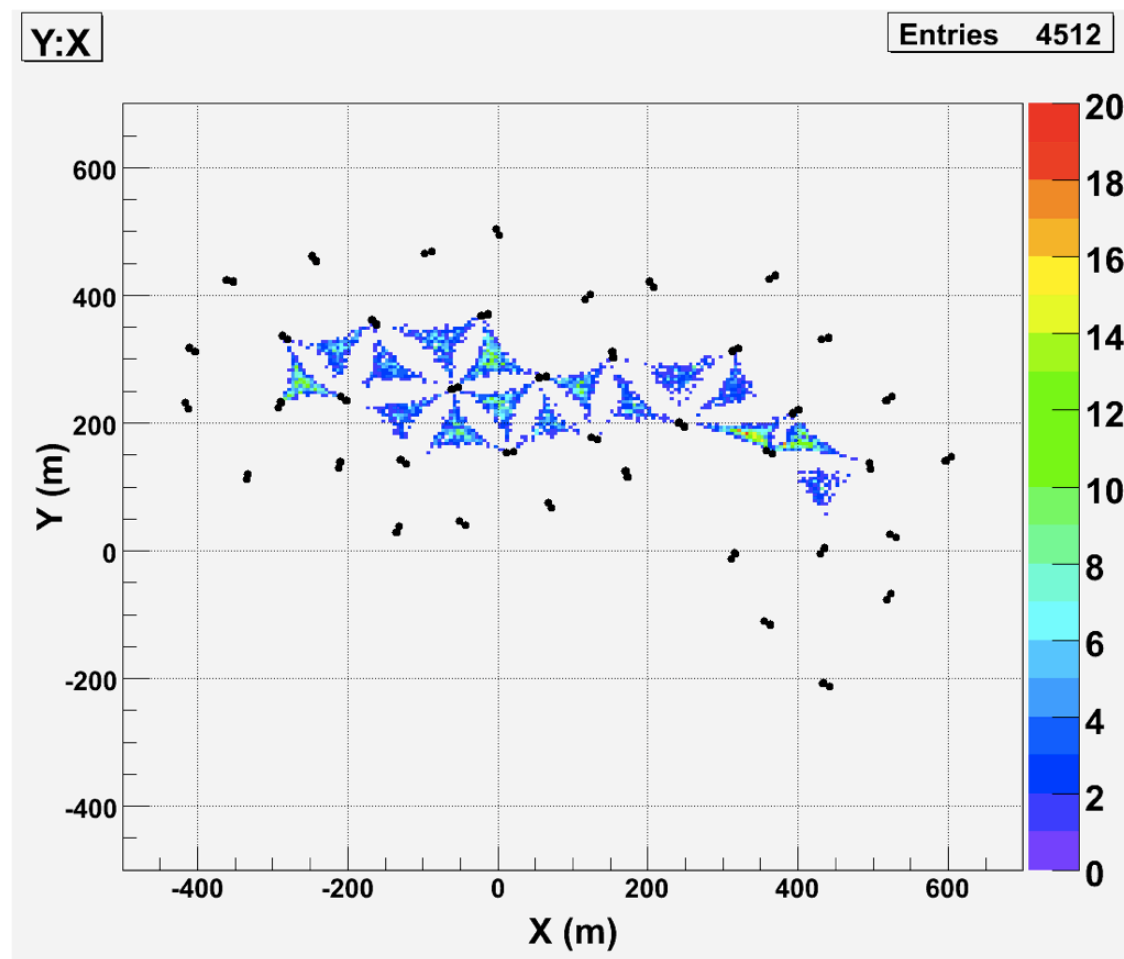
- unknown cosmic ray composition above 10^7 GeV
- physics input for extrapolated background estimation
- energy calibration with in-situ devices



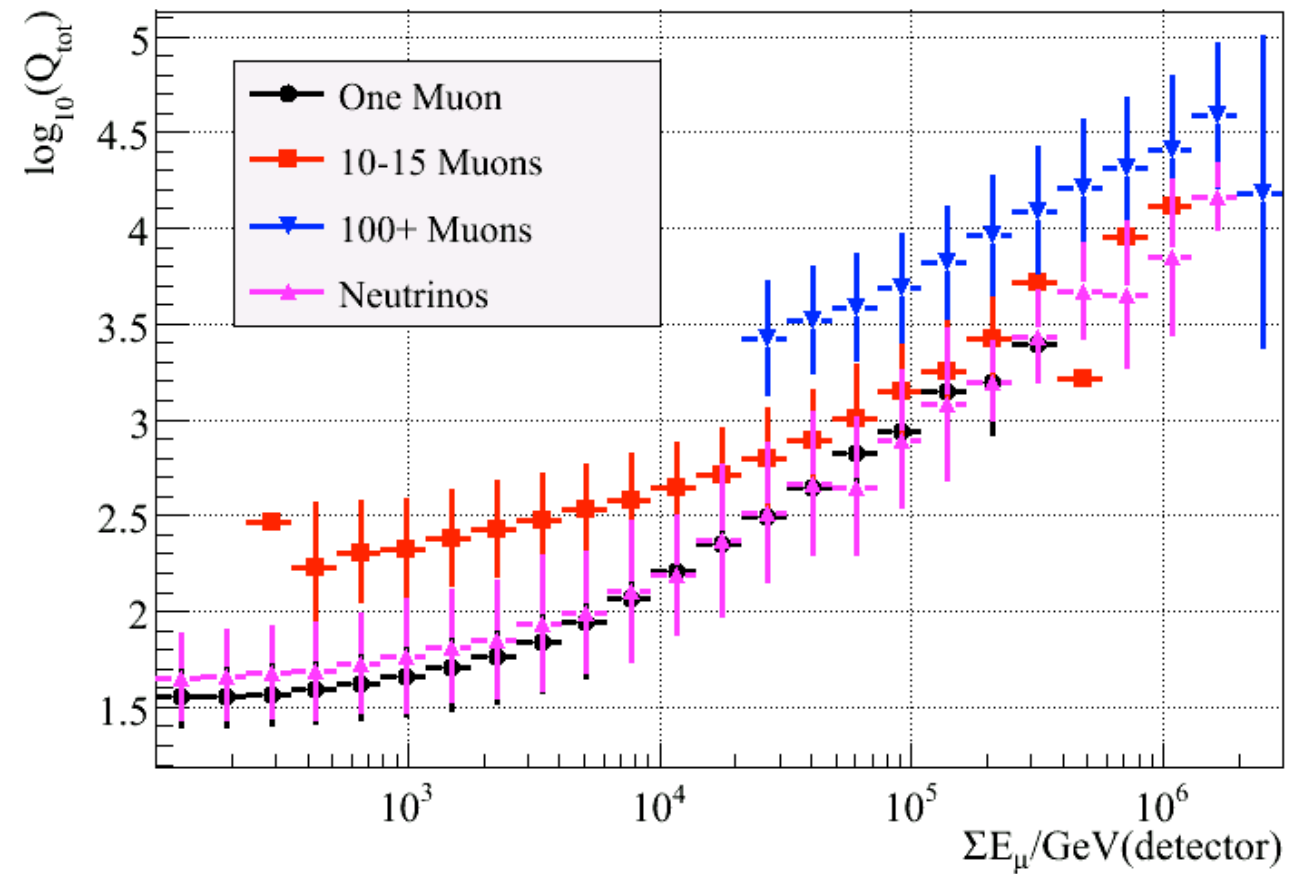
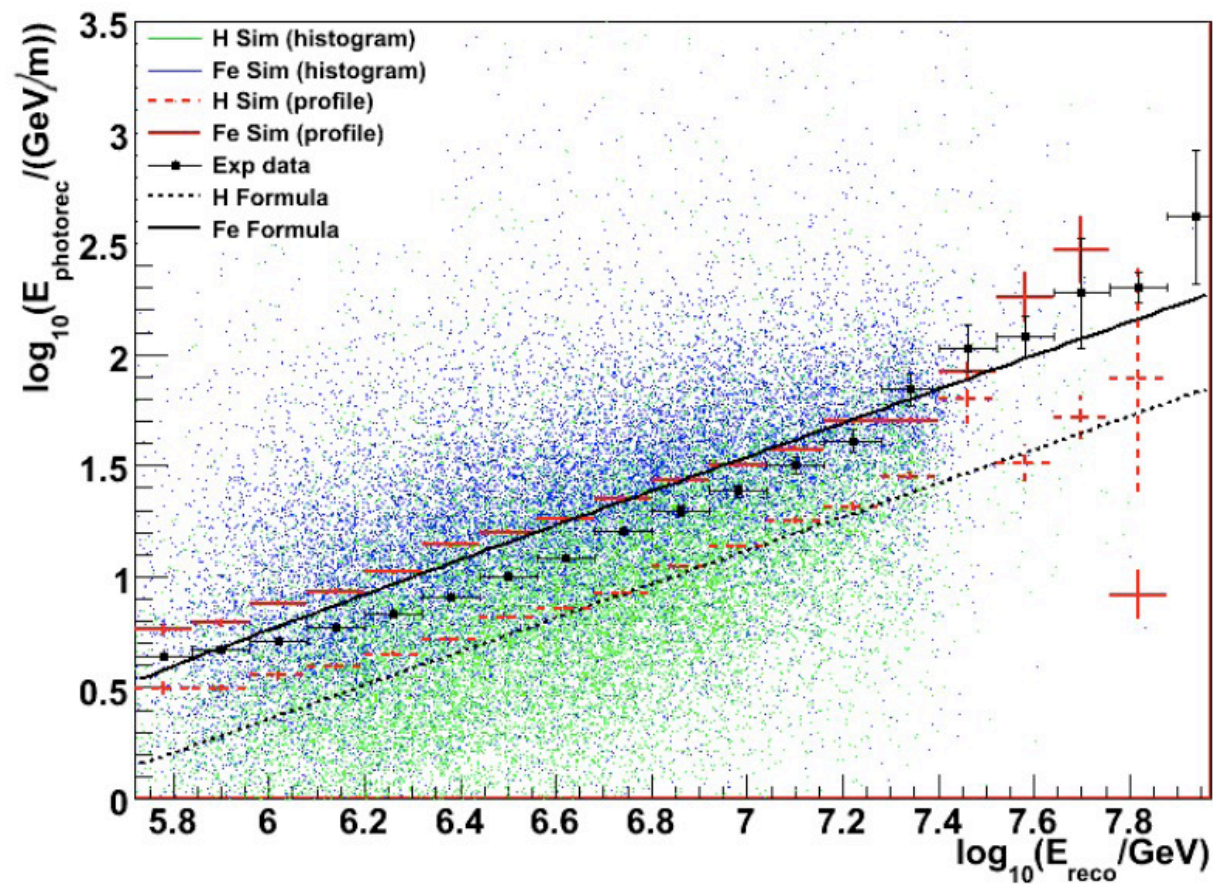
IceCube-40 currently under analysis

extra slides

cosmic rays : small showers (IceTop-26)



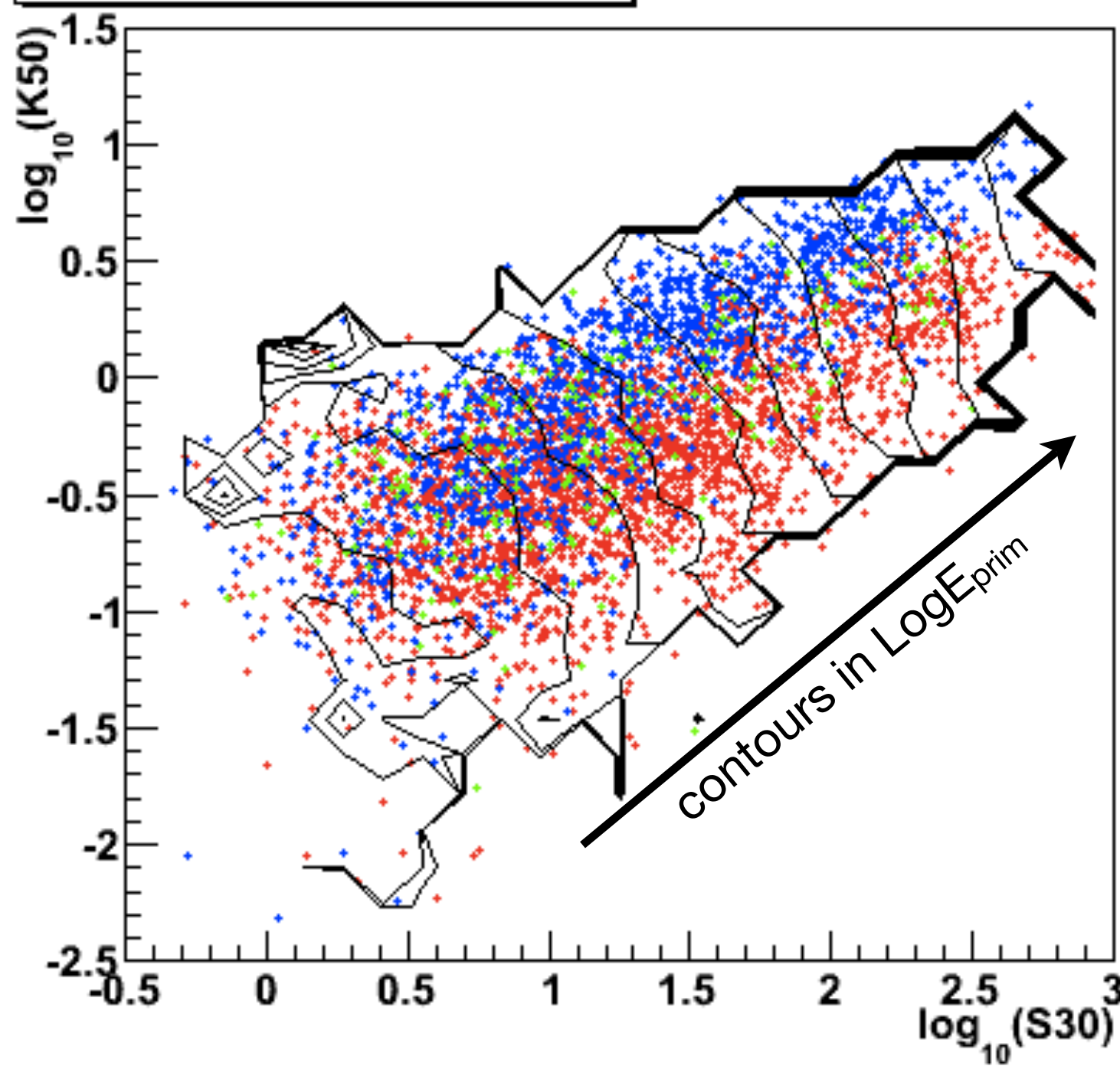
- extend sensitivity to lower energy



cosmic rays
muon bundle energy deposit

IceCube-only cosmic ray mass
and muon multiplicity
dependency

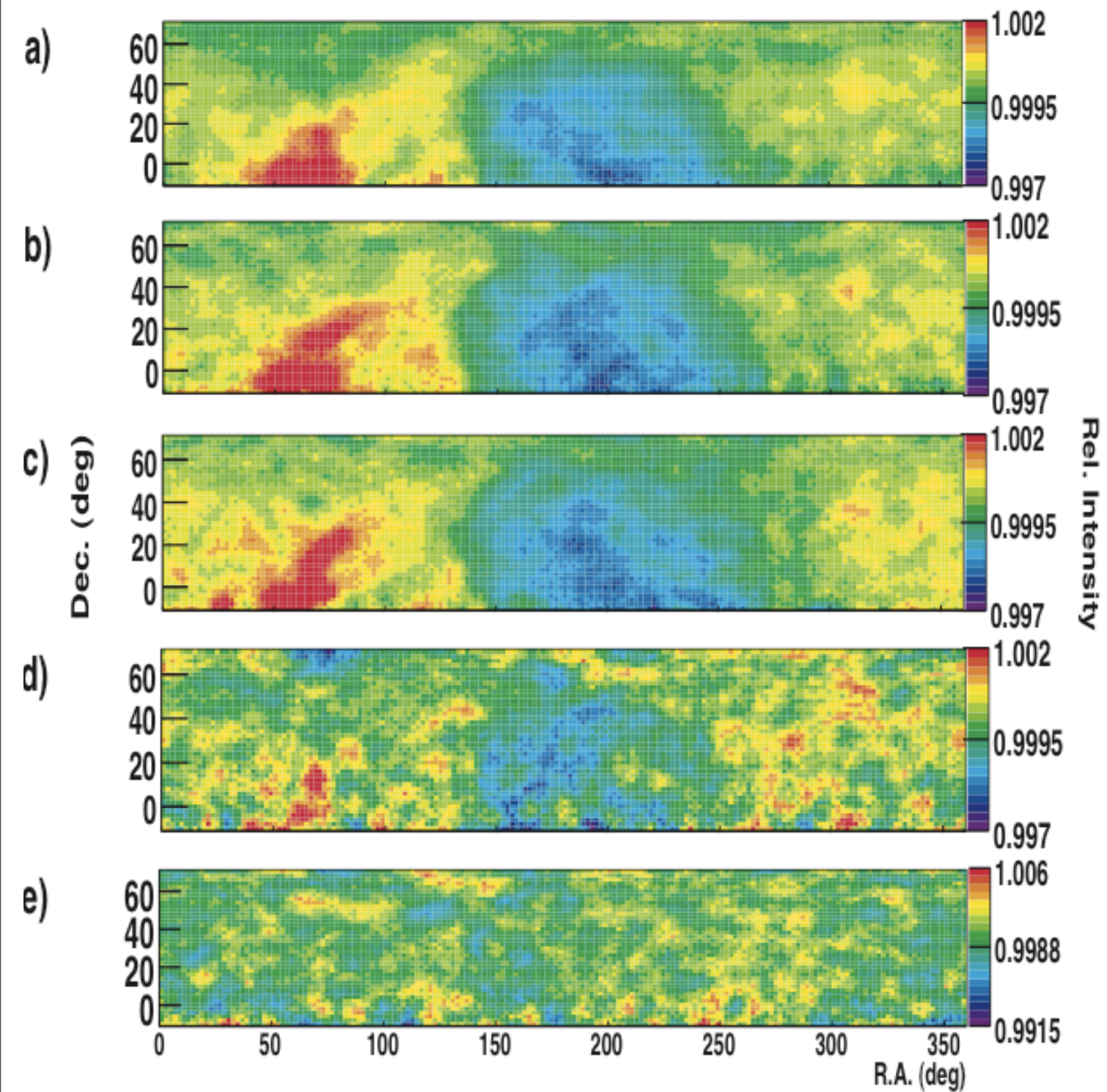
$\log_{10}(\text{K50})$ vs $\log_{10}(\text{S30})$



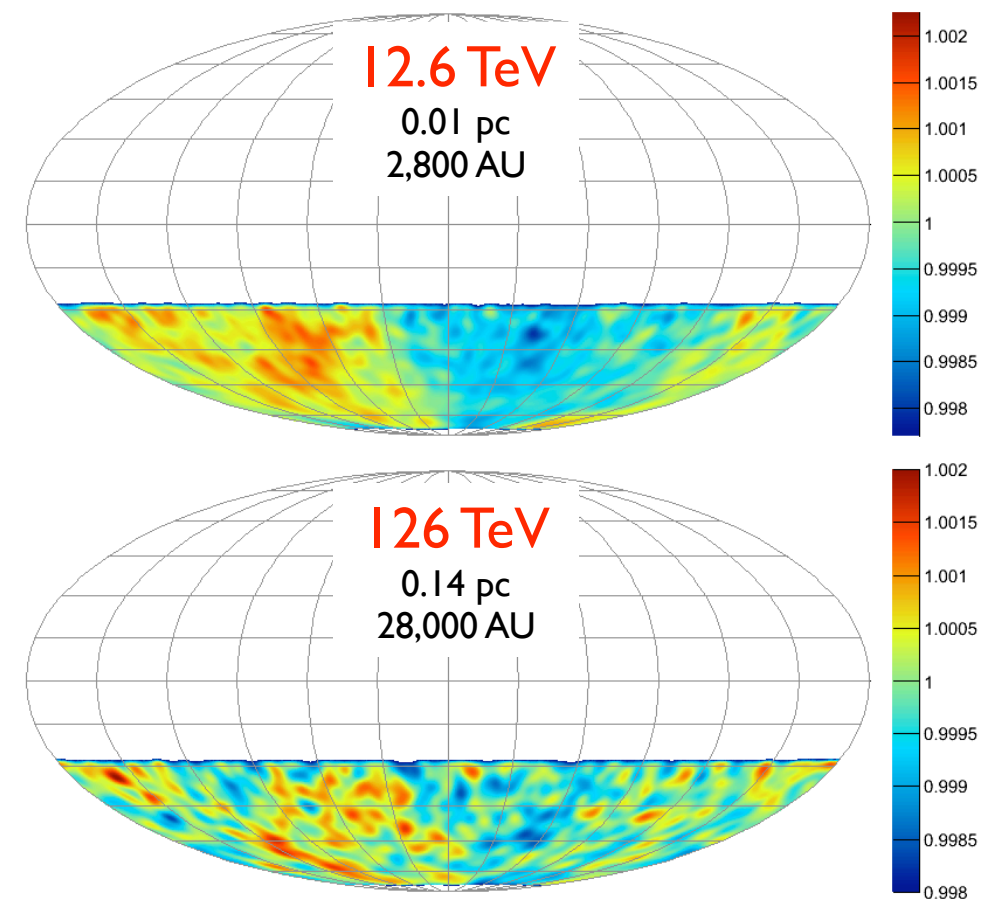
iron
oxygen
protons

cosmic rays
mass composition

SPASE-AMANDA coincident
events

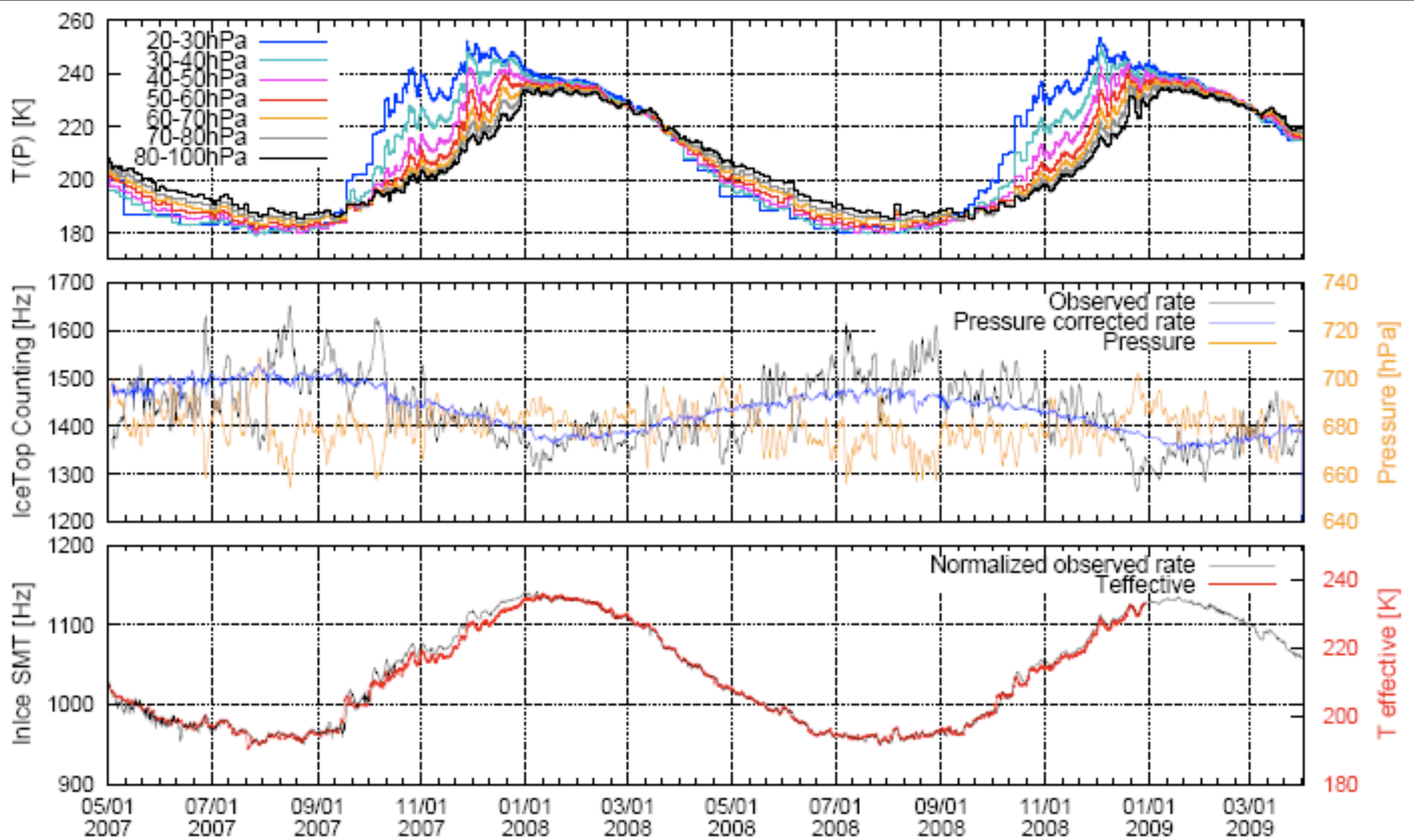


IceCube-22

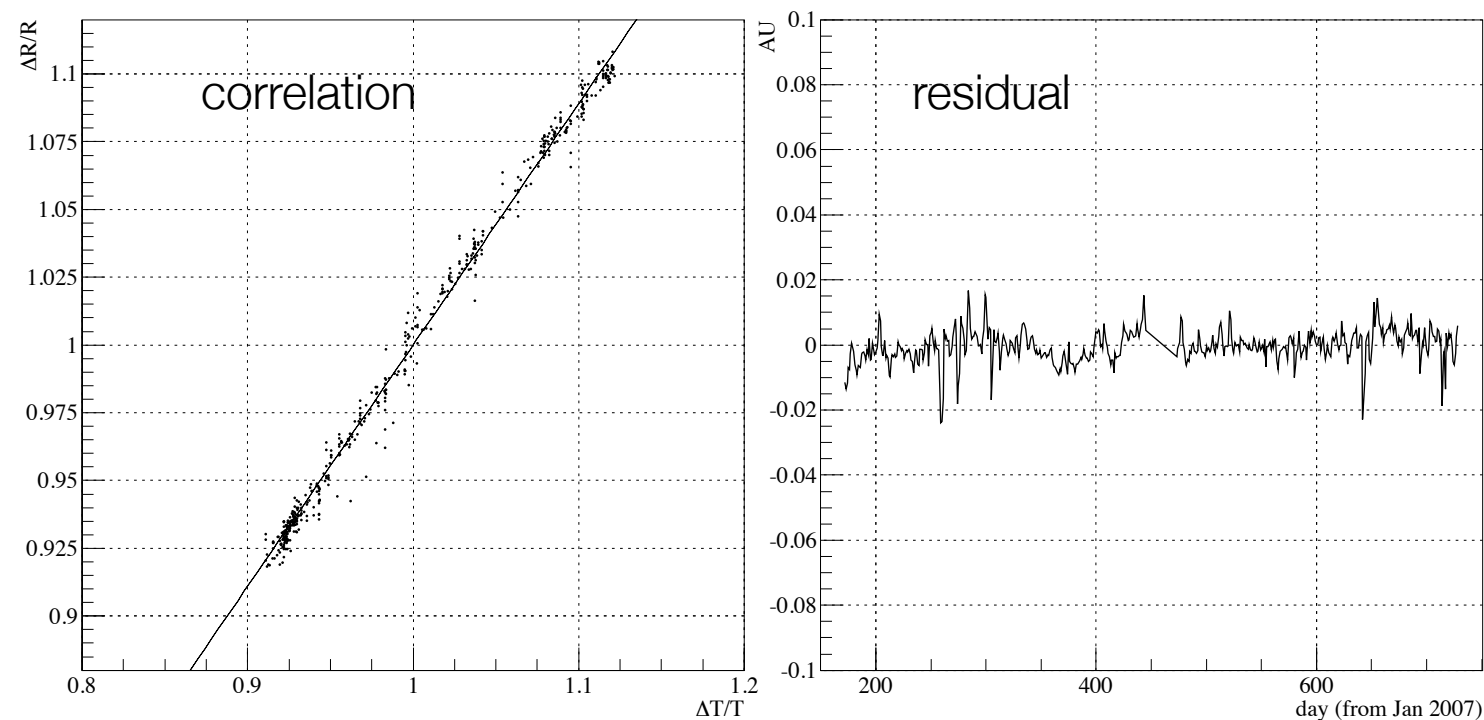
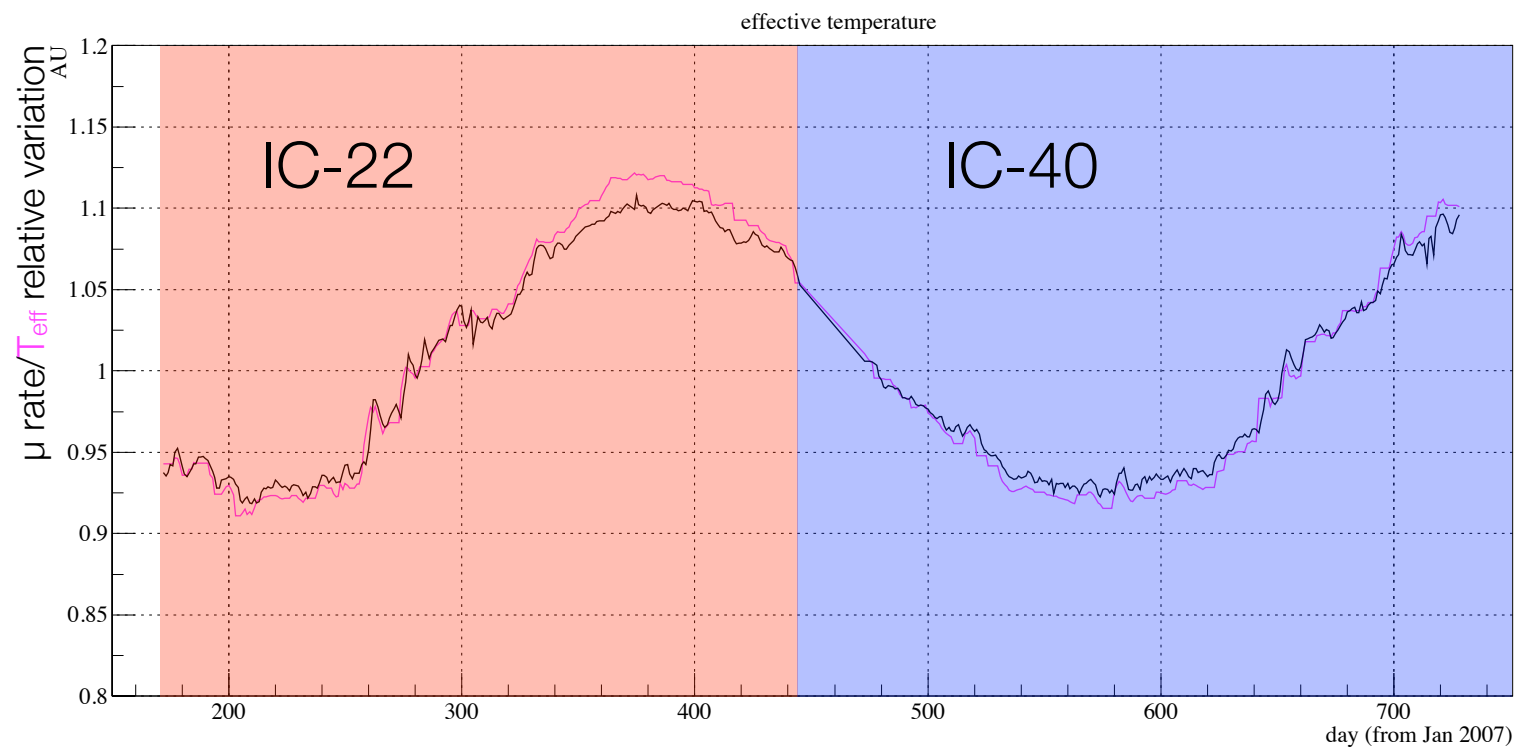


Tibet array
large scale anisotropy

probing local interstellar
magnetic field



correlation with atmospheric
temperature



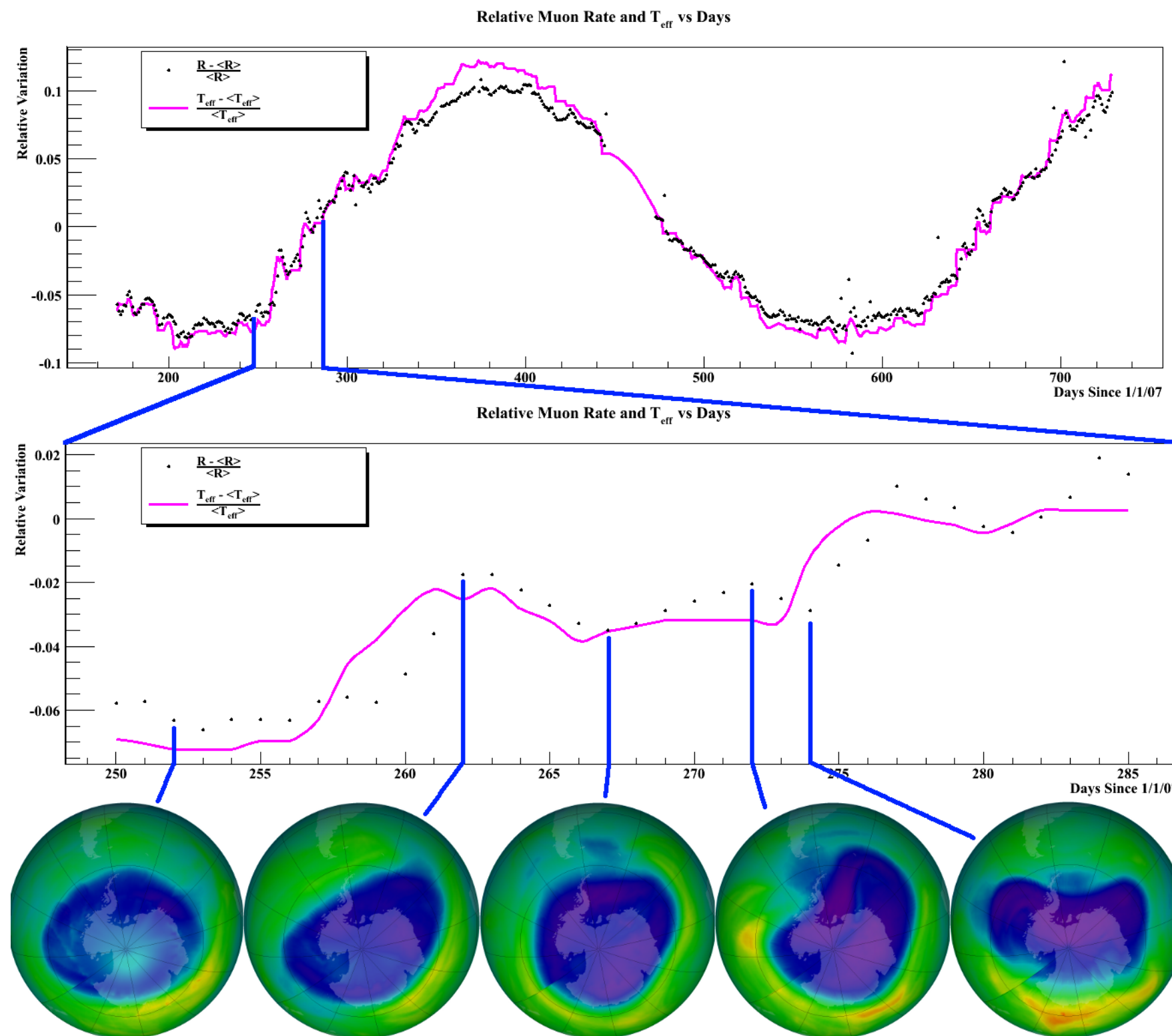
$$\frac{\Delta R_{\mu}}{R_{\mu}} = \alpha \cdot \frac{\Delta T_{\text{eff}}}{T_{\text{eff}}}$$

$$T_{\text{eff}} = \frac{\int_0^{\infty} \frac{dX}{X} T(X) (e^{-X/\Lambda_{\pi}} - e^{-X/\Lambda_N})}{\int_0^{\infty} \frac{dX}{X} (e^{-X/\Lambda_{\pi}} - e^{-X/\Lambda_N})}$$

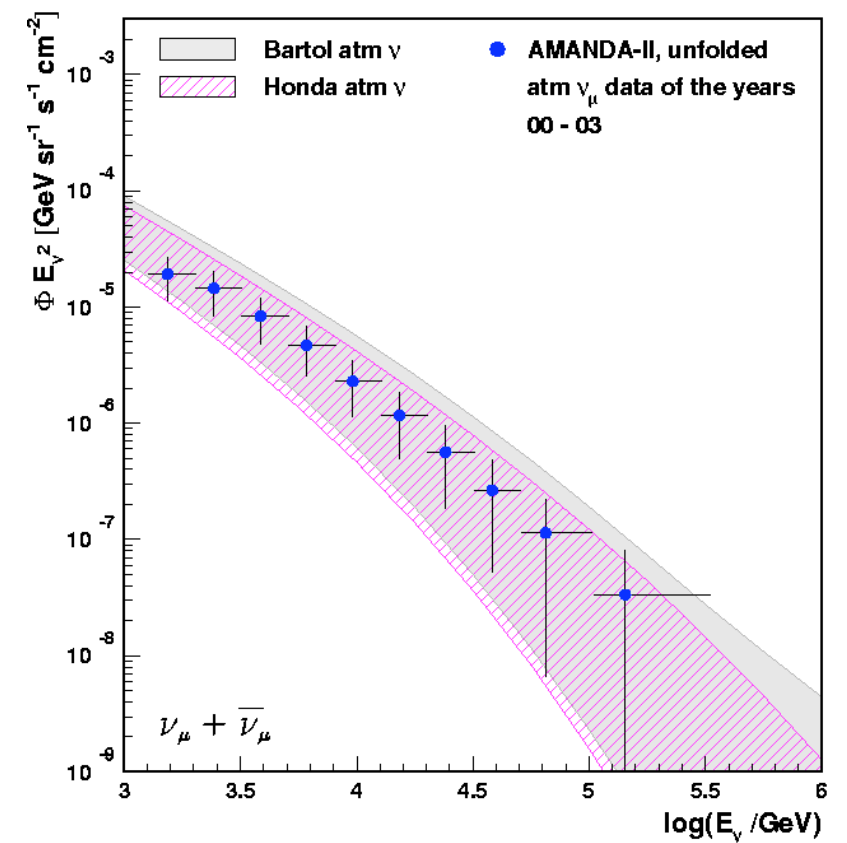
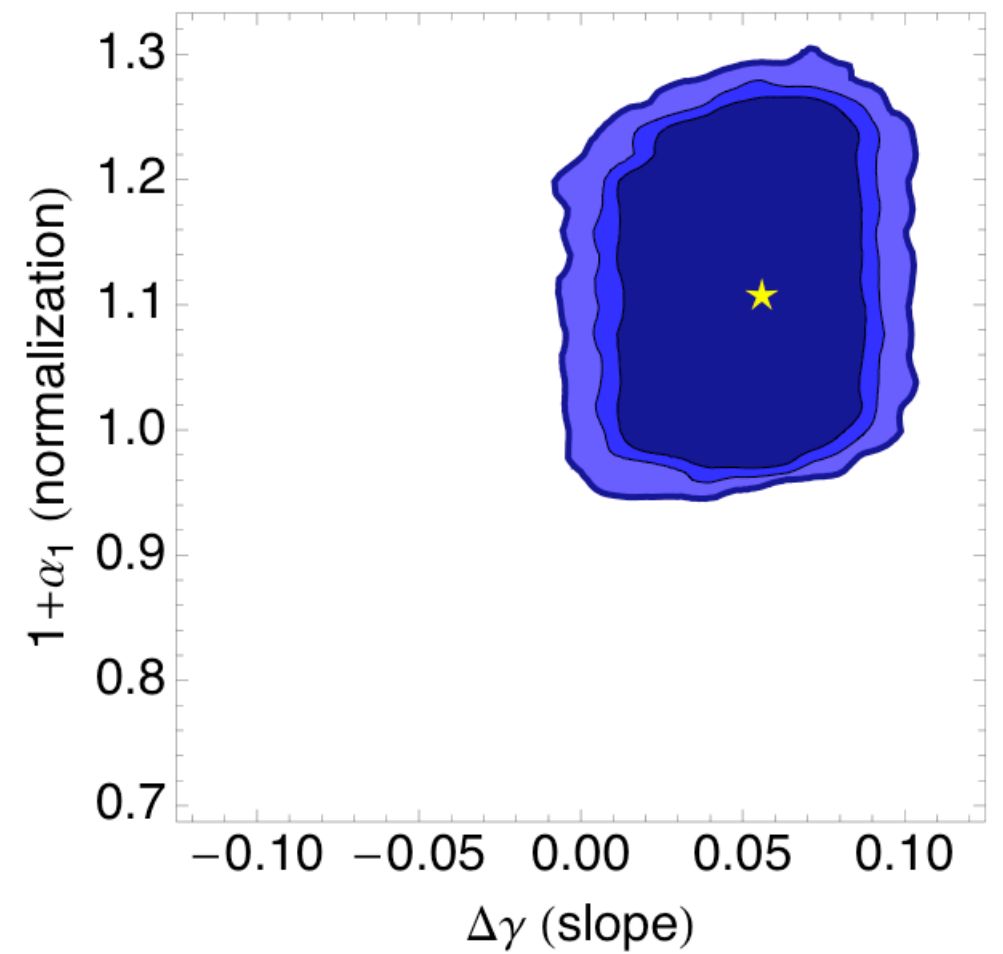
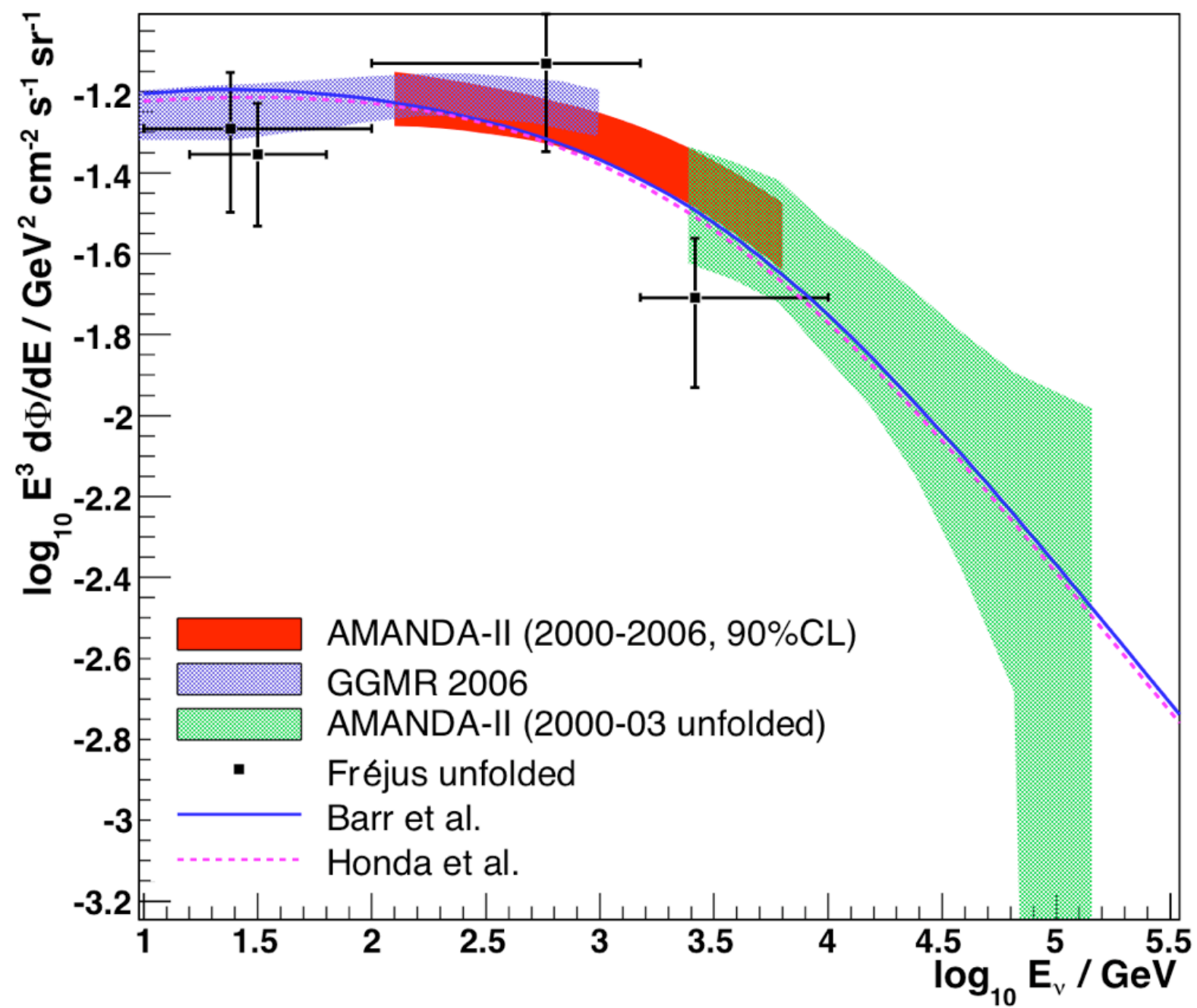
$$\alpha_T = \left\langle \frac{1}{1 + \frac{\gamma}{\gamma+1} \times \frac{\epsilon_{\pi}}{1.1 E_{th} \cos \theta}} \right\rangle$$

correlation with atmospheric temperature

IceCube stable within ~2%

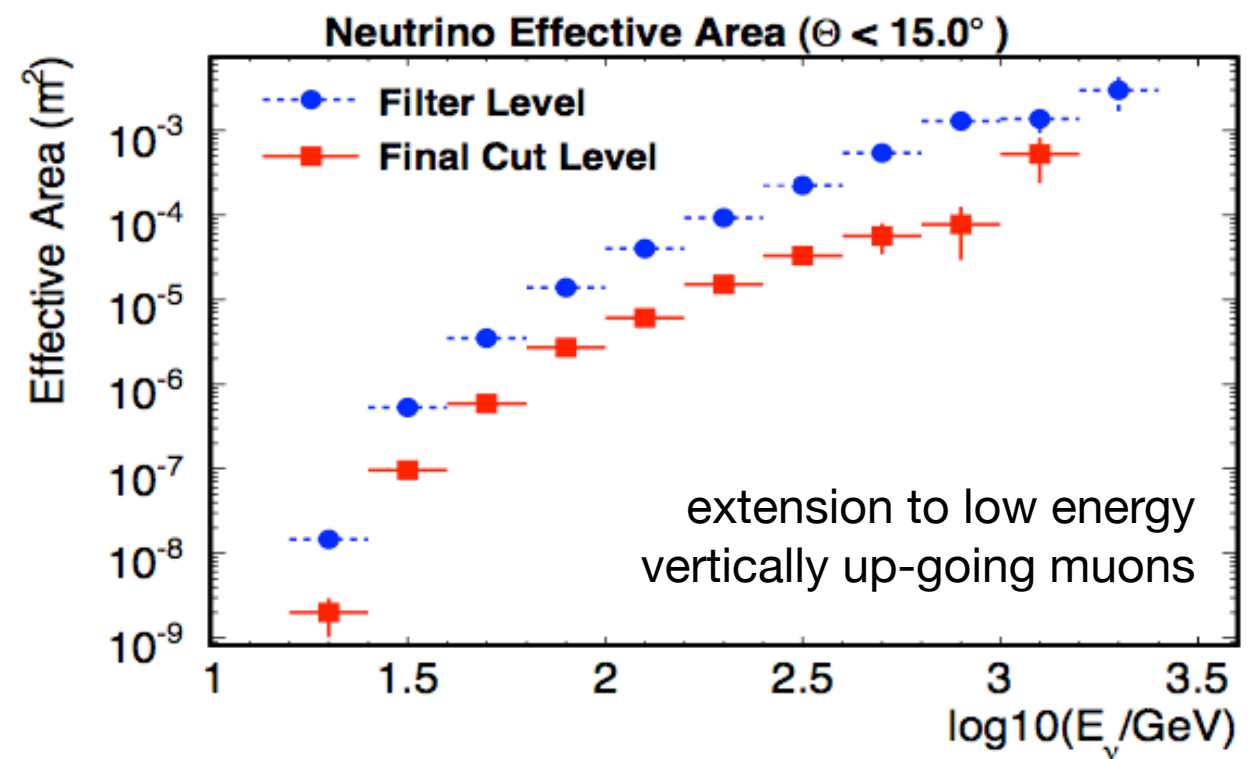
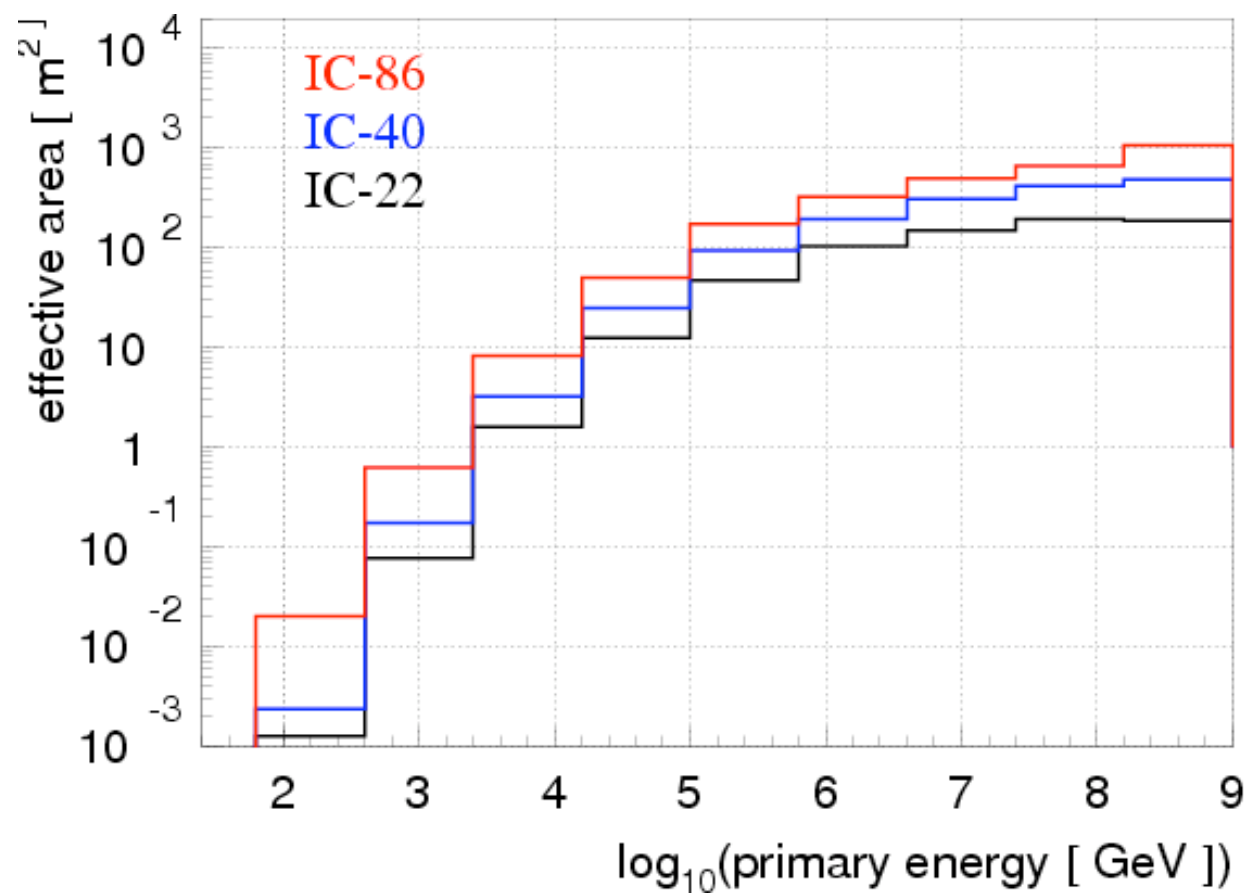


muon rate and sudden
stratospheric warming



atmospheric muon neutrinos

AMANDA

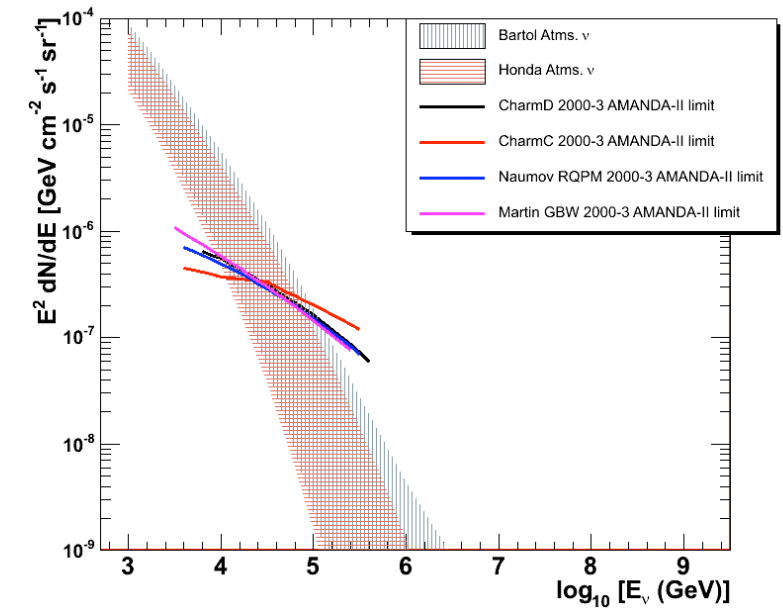
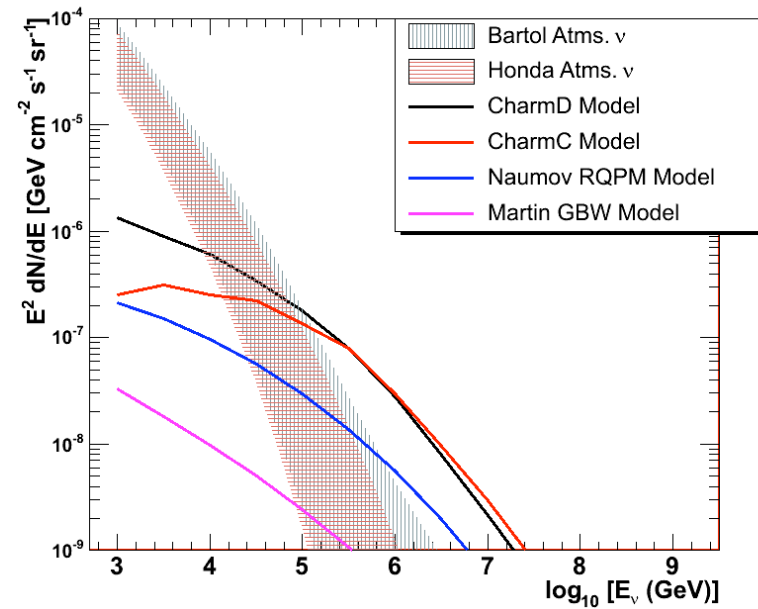
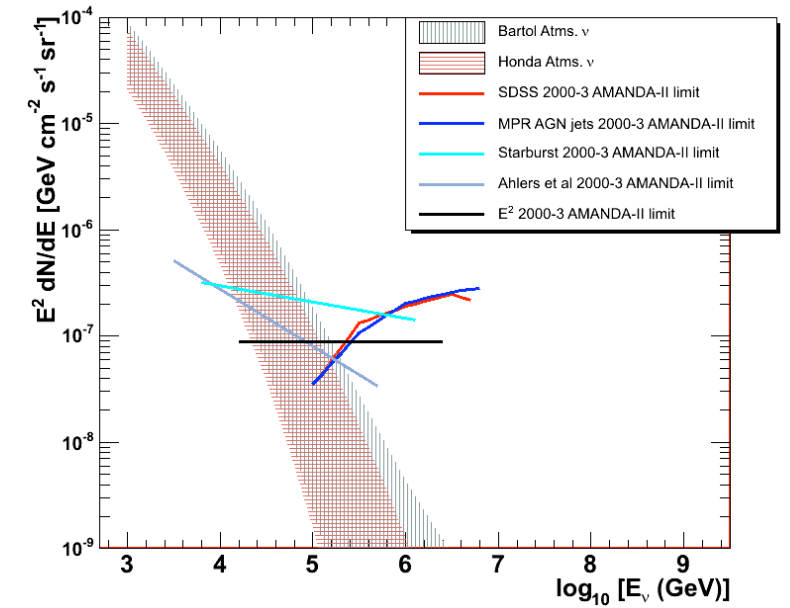
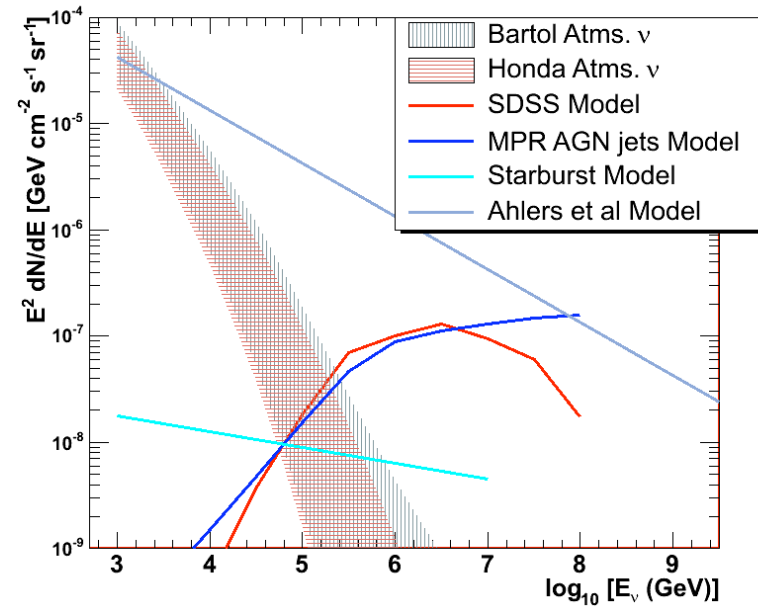
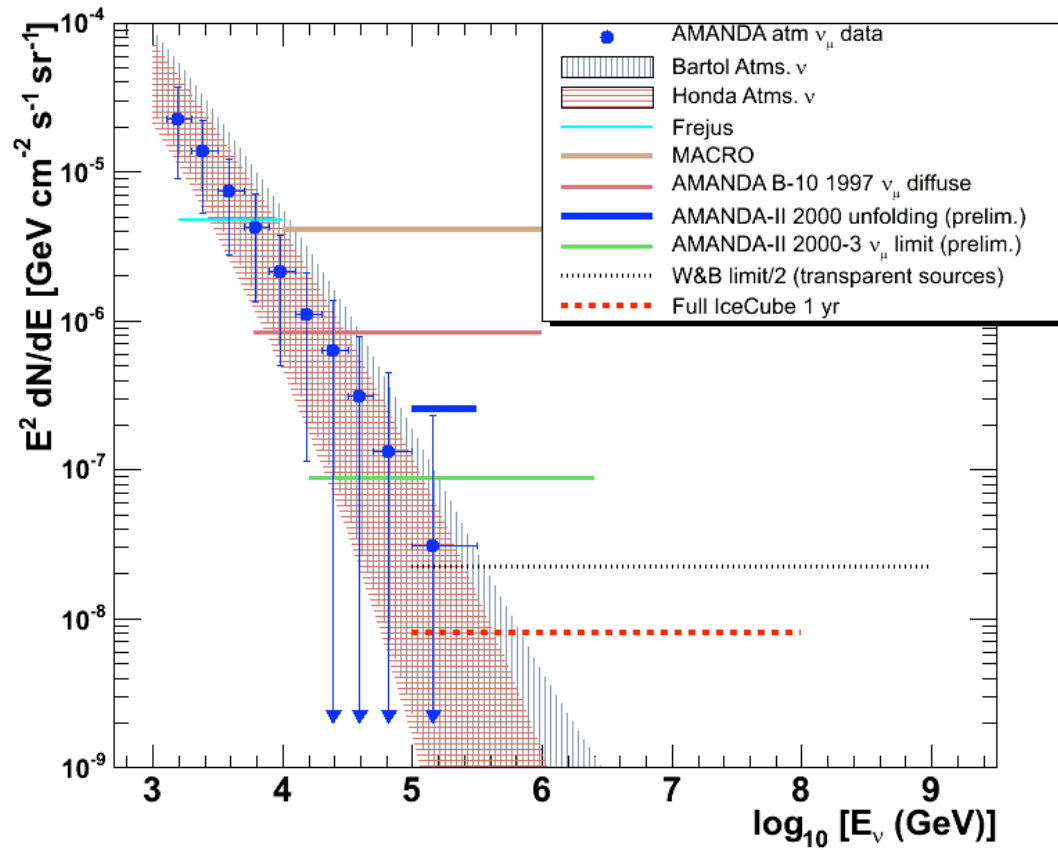


atmospheric muon neutrinos

effective area for IceCube

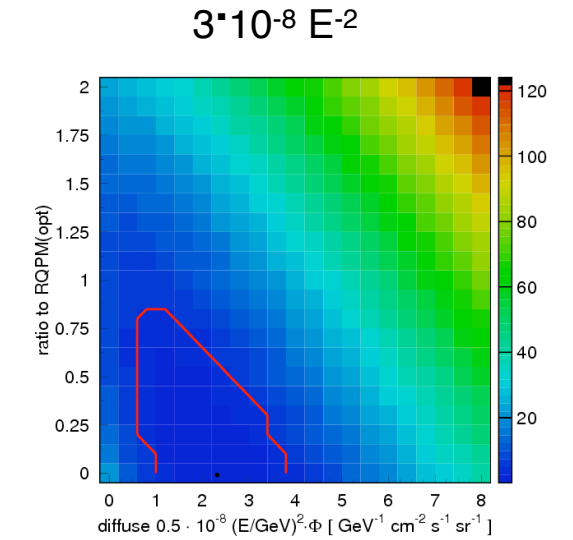
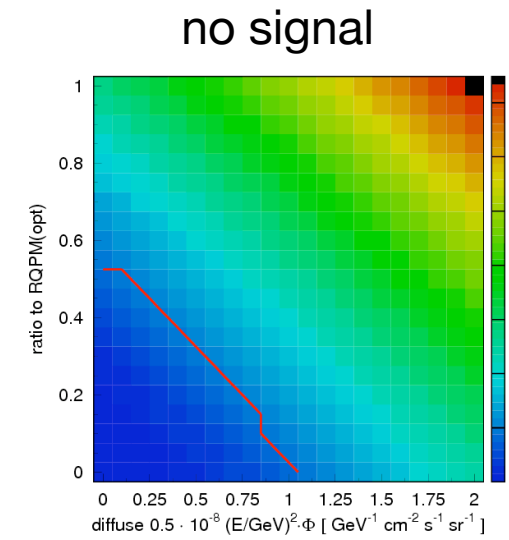
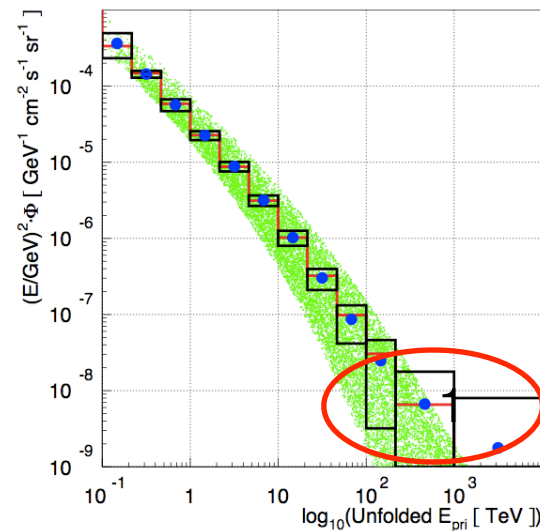
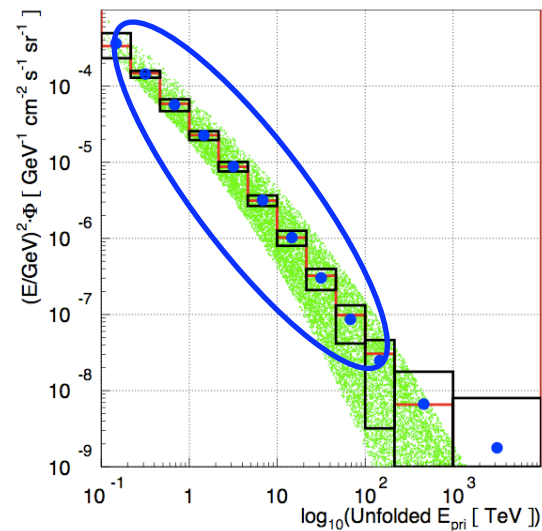
diffuse ν_μ (AMANDA)

90% c.l. limits and sensitivities on ν_μ E^{-2} diffuse fluxes

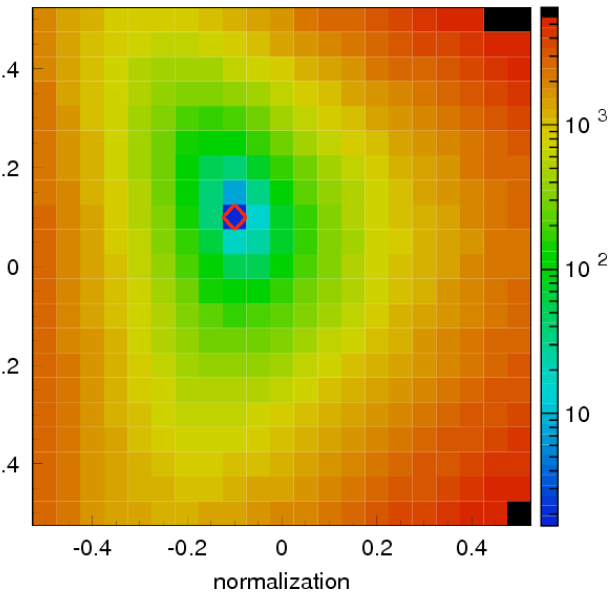
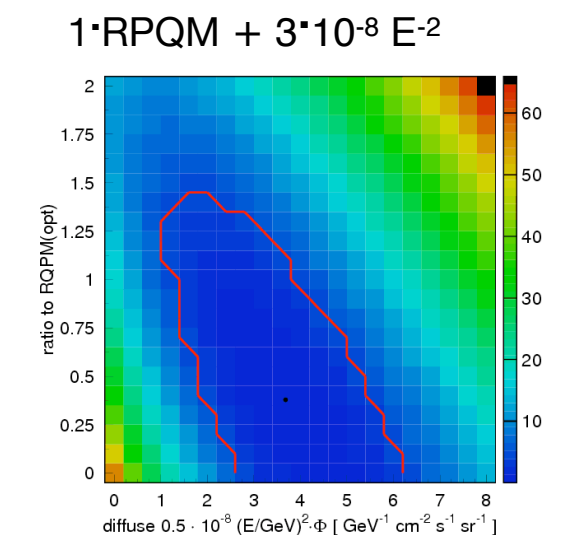
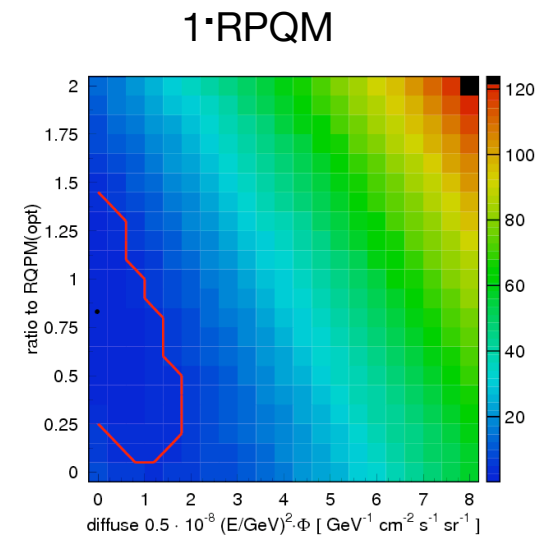


diffuse ν_μ (IceCube-22)

- search for high energy extraterrestrial neutrinos



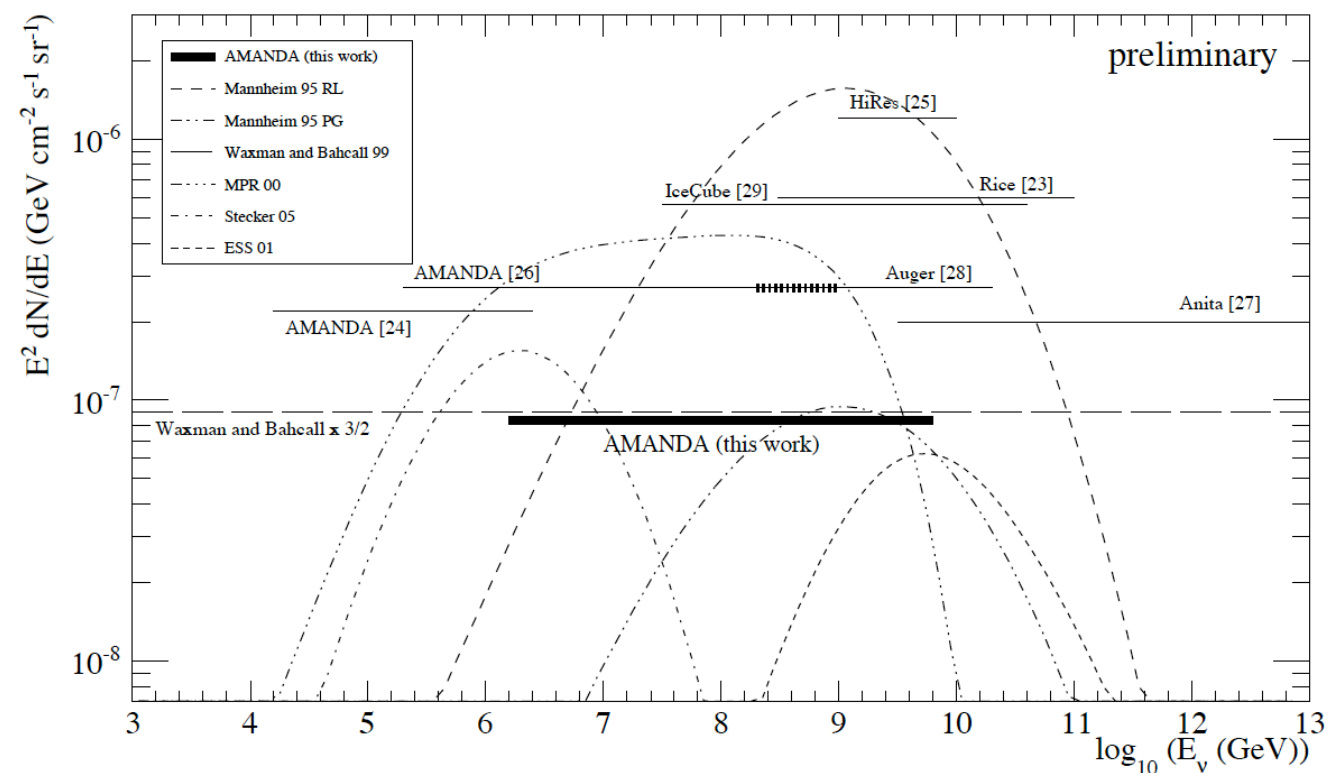
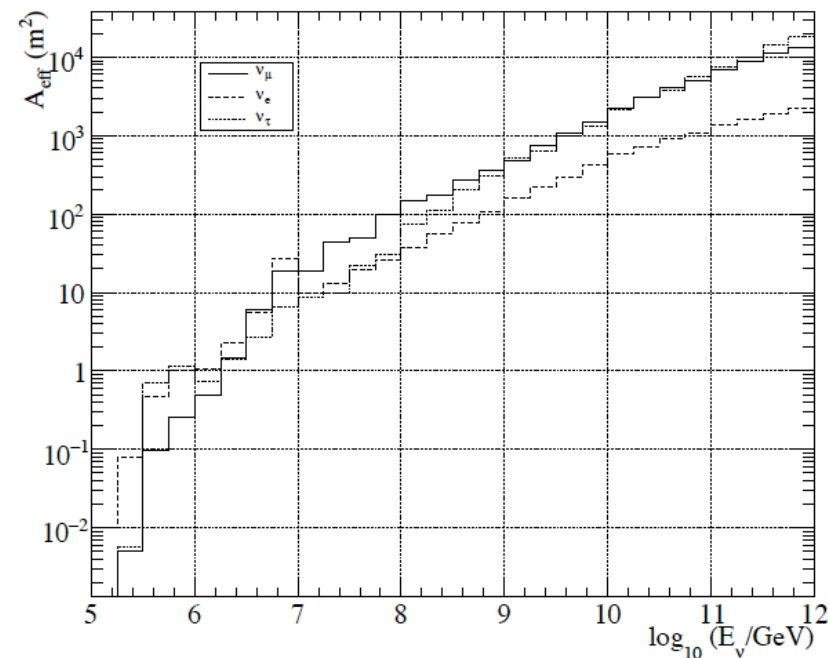
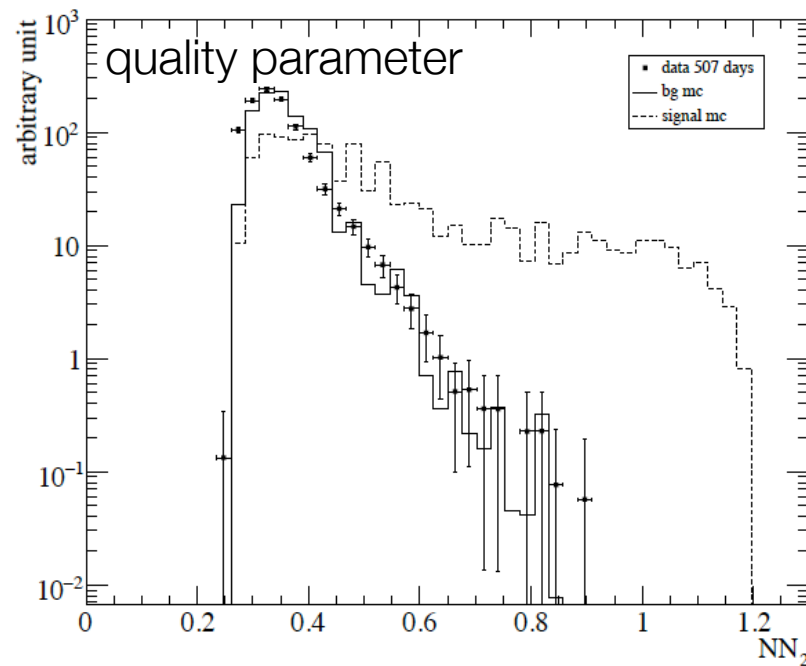
simulation study



likelihood fit for deviations
from Barr et al. atm spectrum

EHE ν : AMANDA

- data collected in 2003-2005



Preliminary Error Budget

	BG	Signal (GZK)
Statistical error	$\pm 22\%$	$\pm 0.6\%$
Empirical model uncertainty	+99% -59%	-
Detector sensitivity	$\pm 8\%$	$\pm 8\%$
NPE shift	-	-32%
Yearly variation	$\pm 16\%$	-
Neutrino cross section	-	$\pm 9\%$
Photo-nuclear interaction	-	+10%
LPM effect	-	$\pm 1\%$
Hadronic interaction model	Negligible	-
Total	$\pm 22\%$ (stat.) +101% -62% (sys.)	$\pm 0.6\%$ (stat.) +16 -34% (sys.)