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

Science Advisory Committee - UW-Madison

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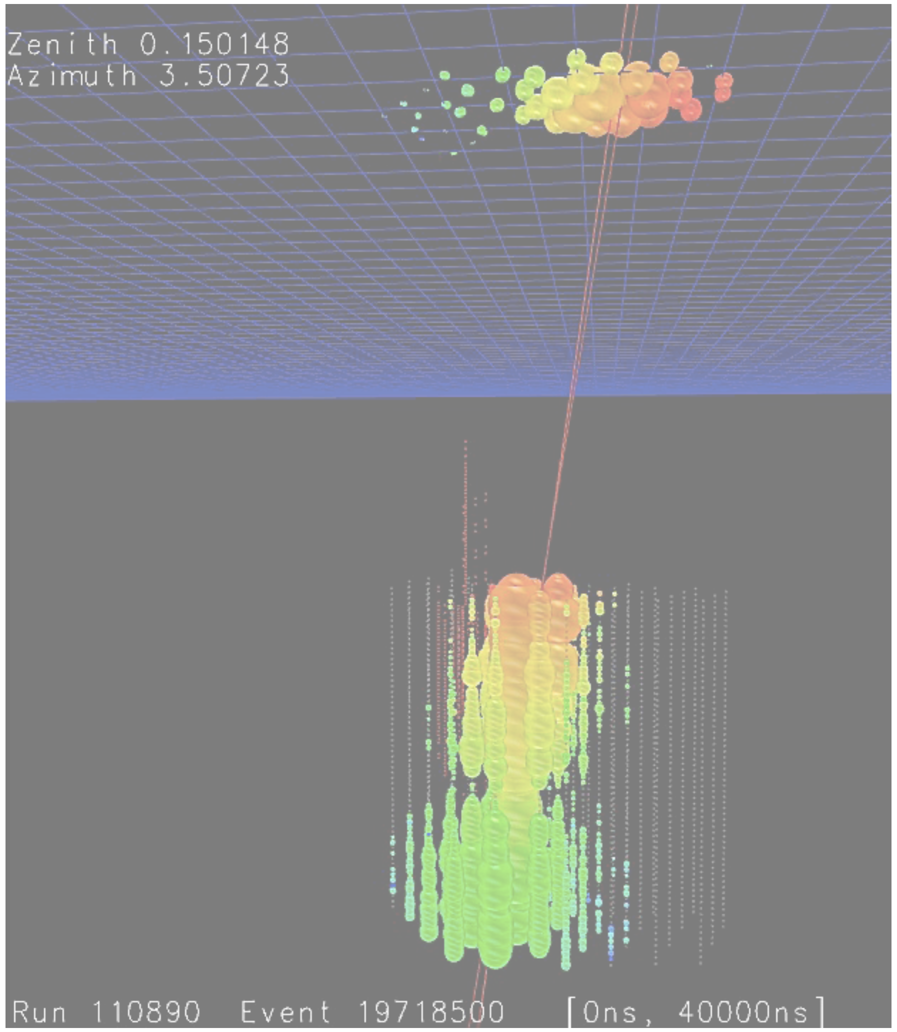
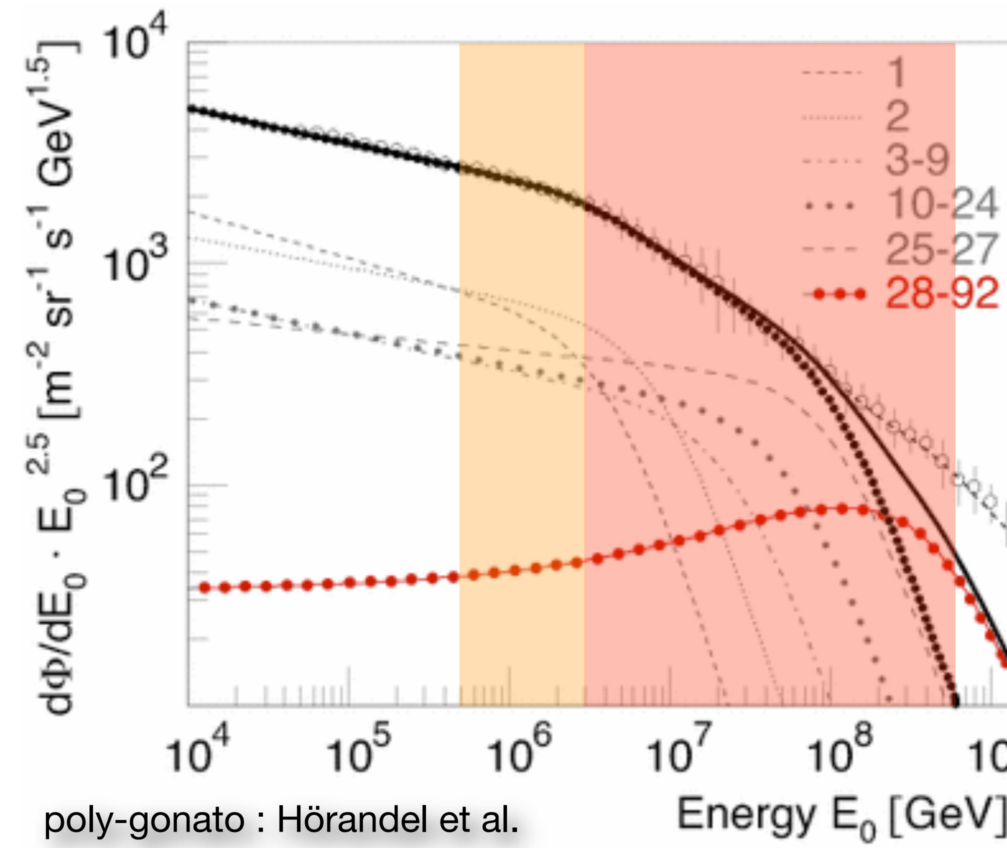


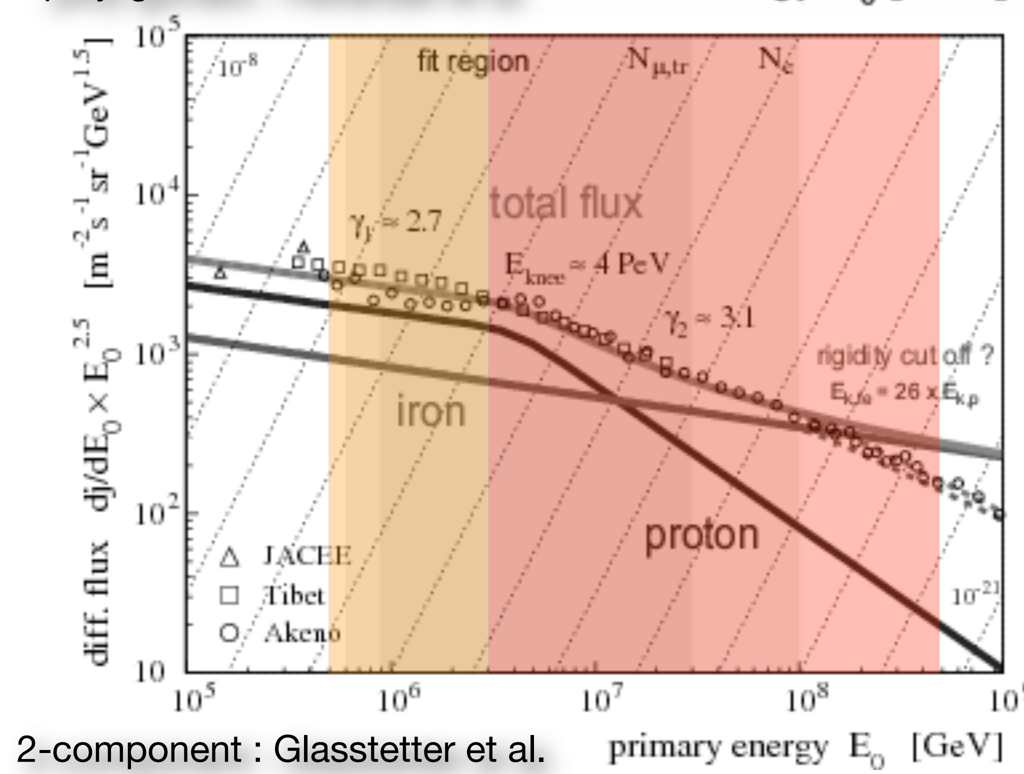
15 slides (12 extra slides)

cosmic rays

- 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

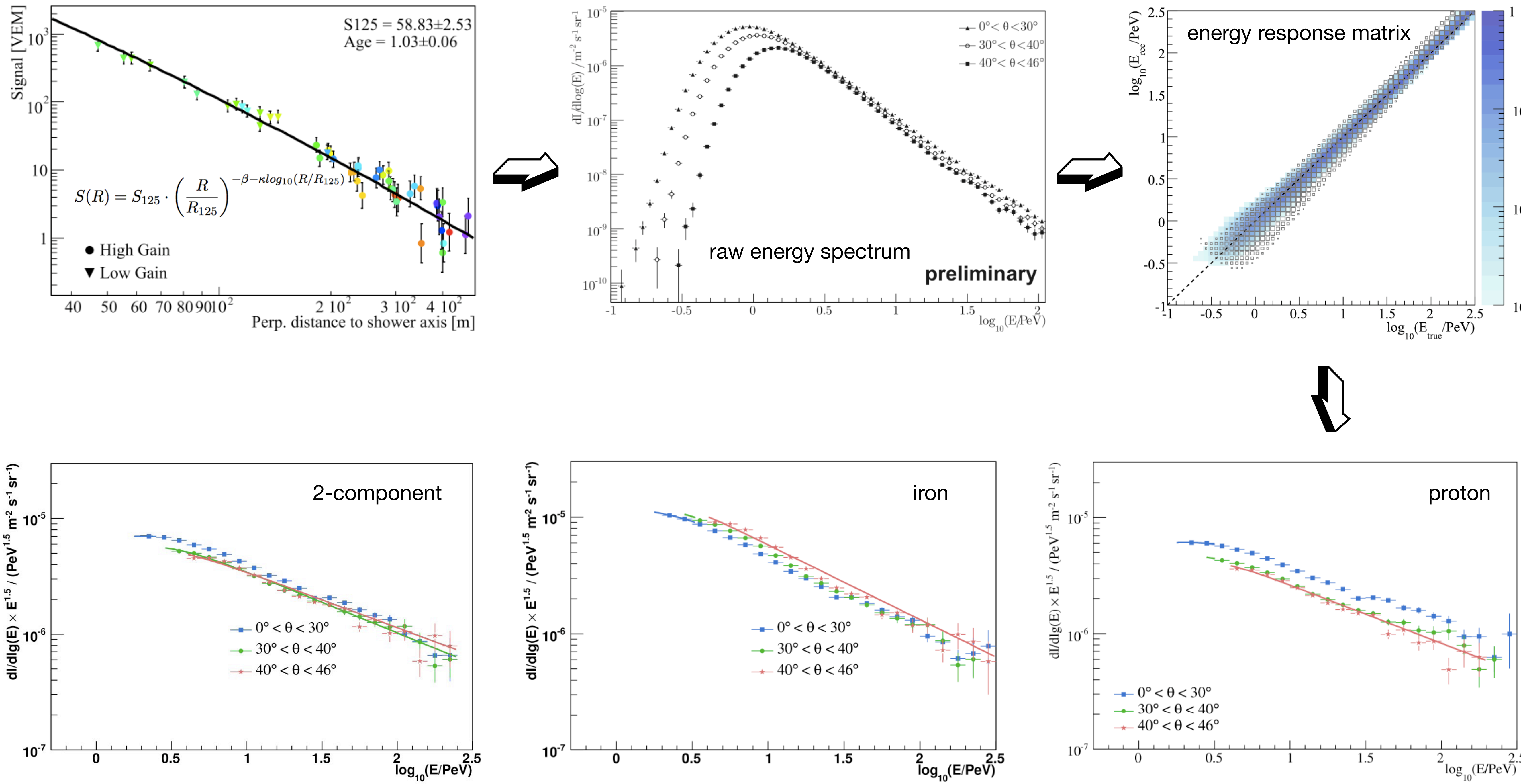


poly-gonato : Hörandel et al.



2-component : Glasstetter et al.

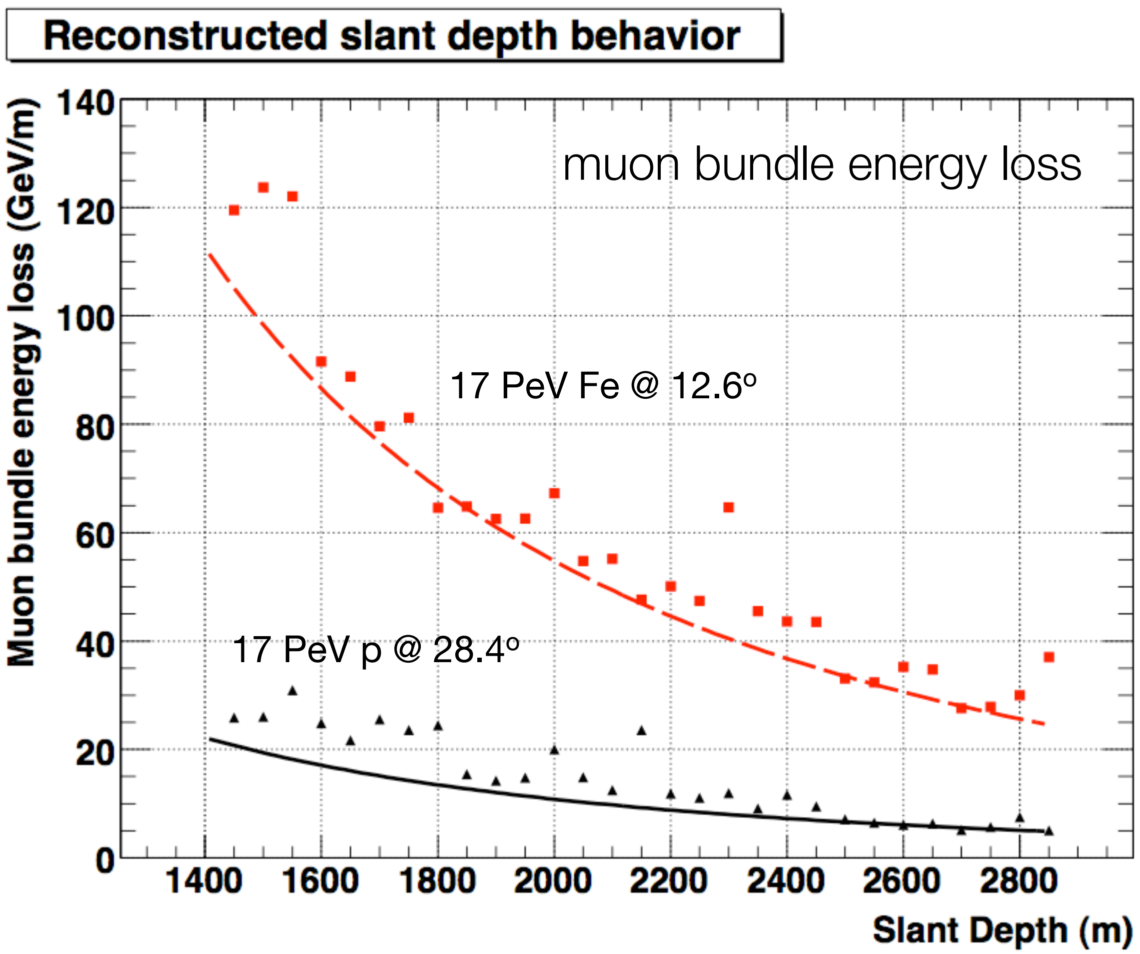
cosmic rays : all-particle spectrum (IceTop-26)

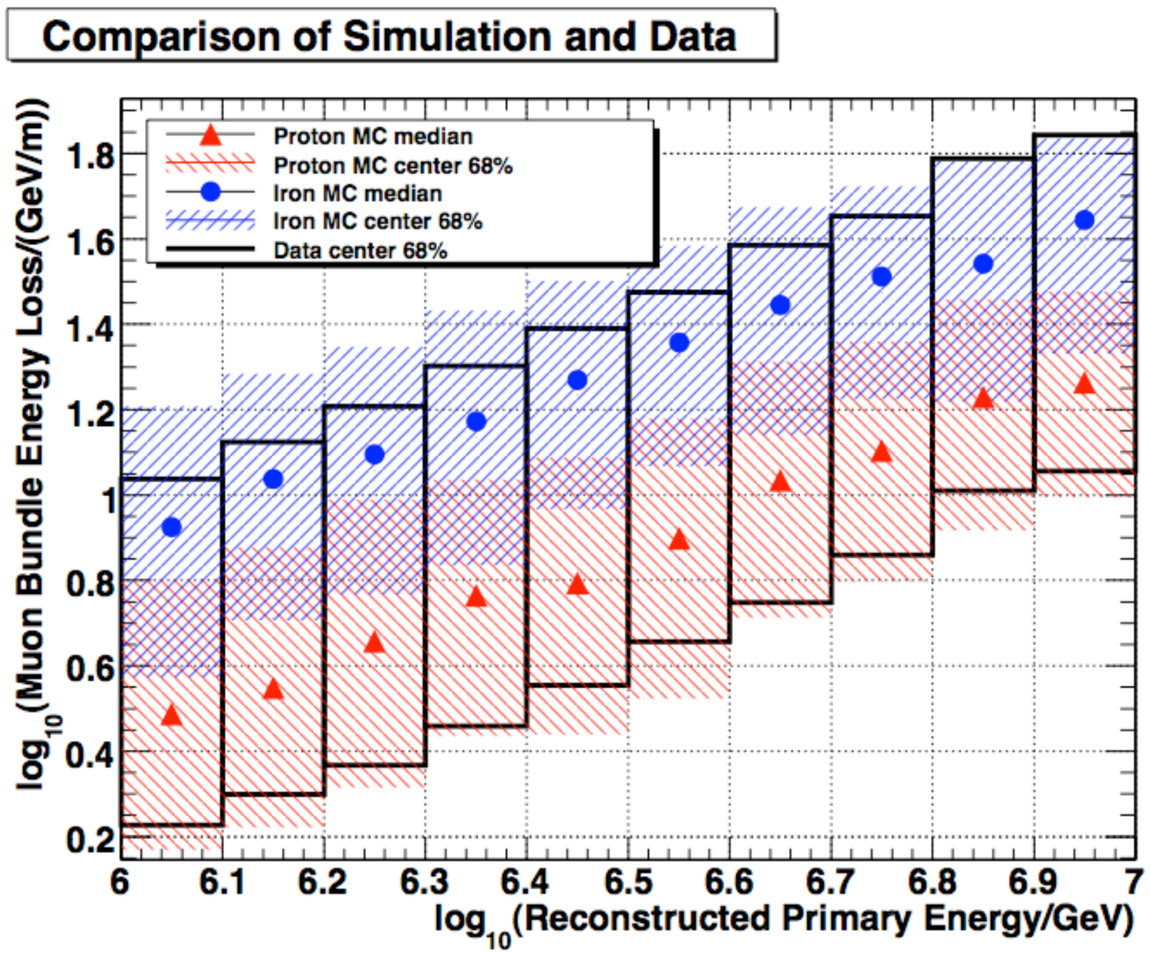


isotropic flux assumption : 2-component model yields the best agreement

cosmic rays : mass composition (IceCube & IceTop)

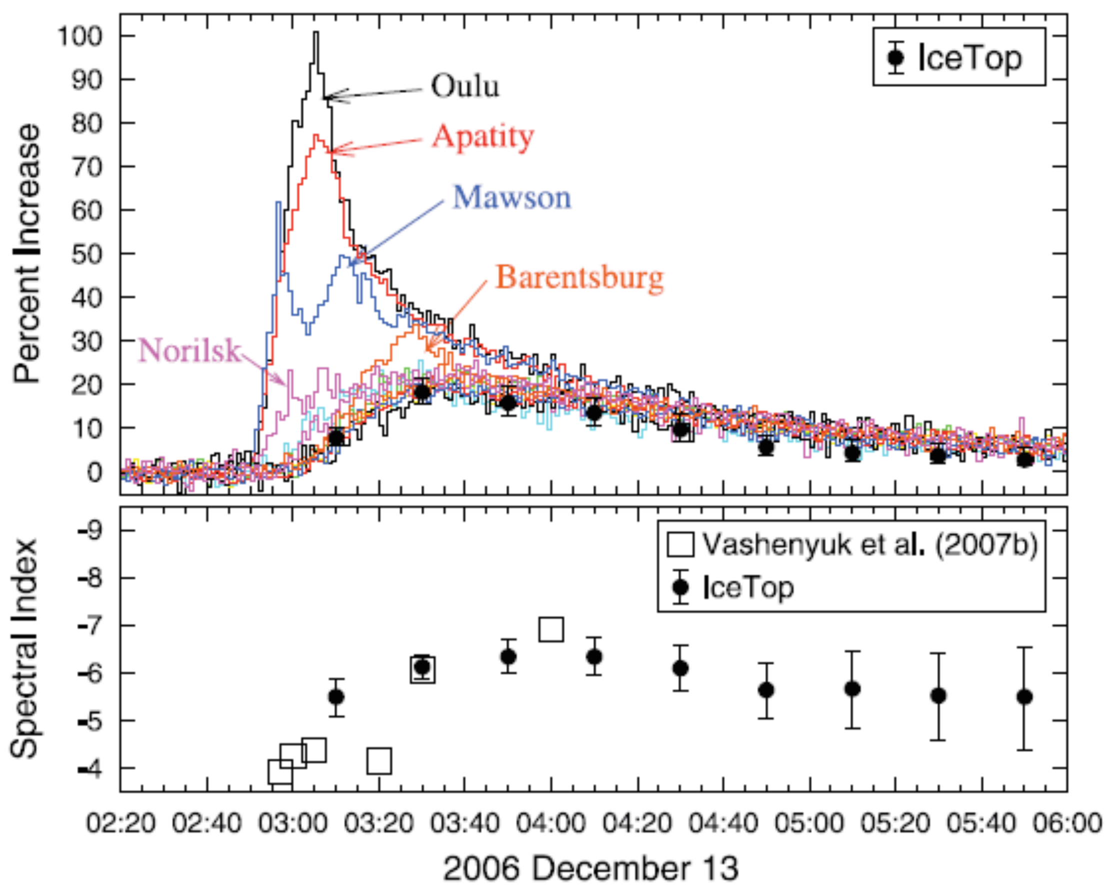
- correlation between **shower energy** and **muon bundle energy**
- coincident event provide good directional reconstruction : ~ 0.5°

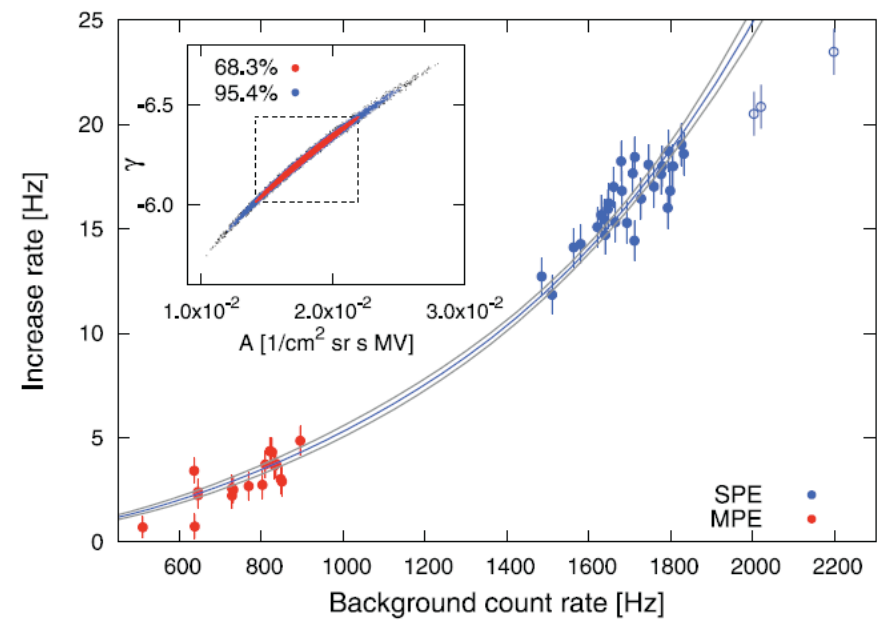




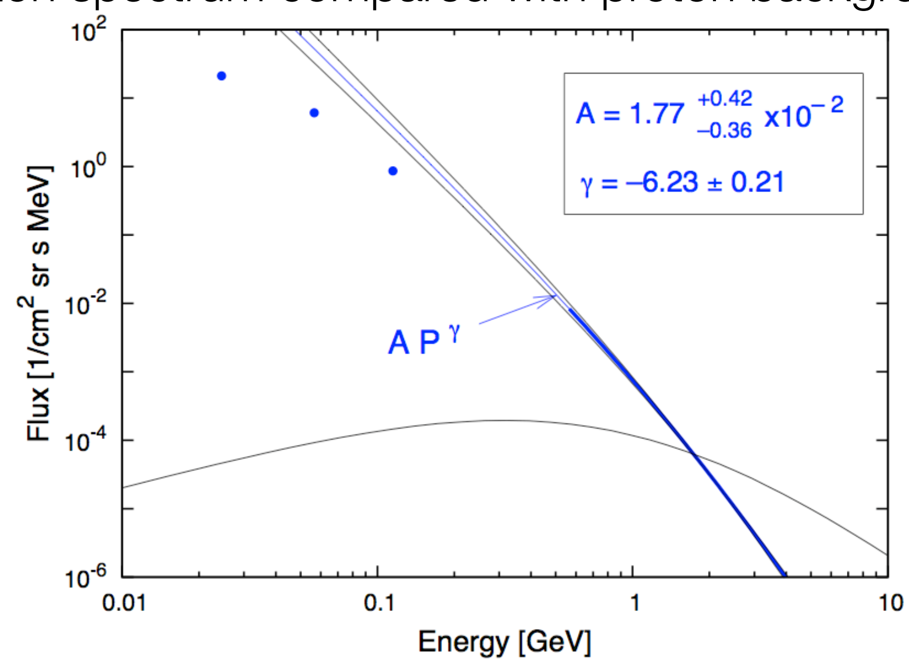
cosmic rays : heliospheric physics

- energy spectrum of particles from solar flares





proton spectrum compared with proton background



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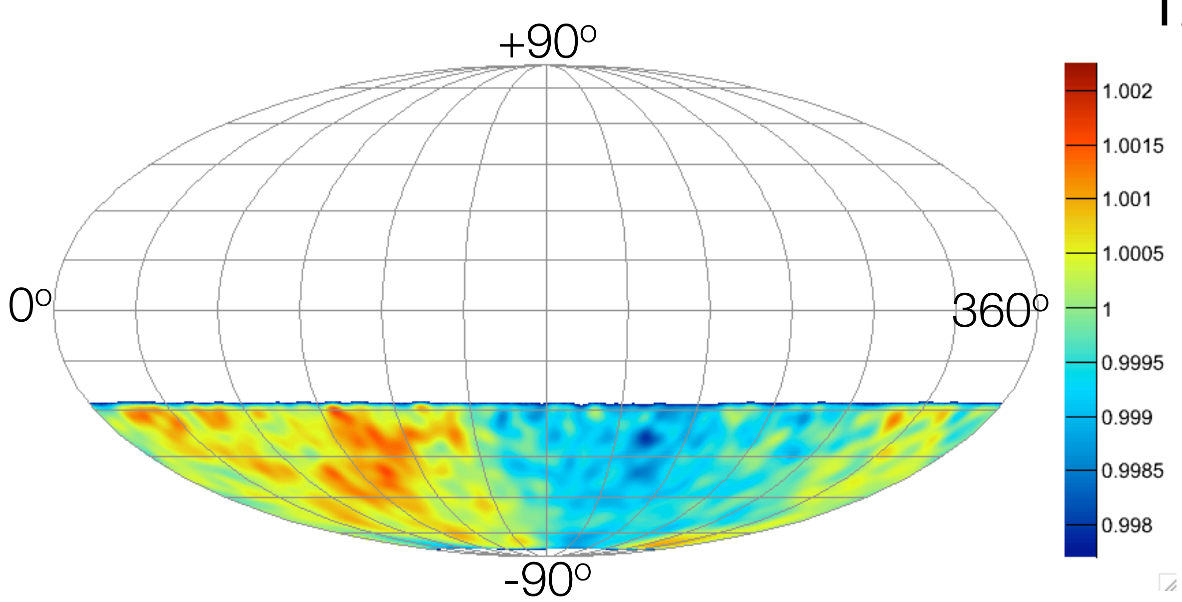
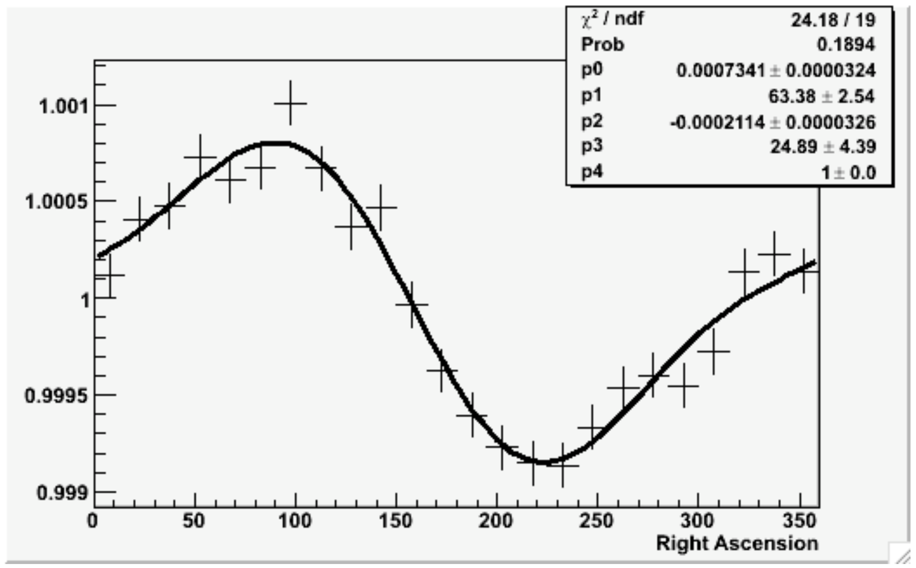
cosmic rays : large scale anisotropy (IceCube-22)

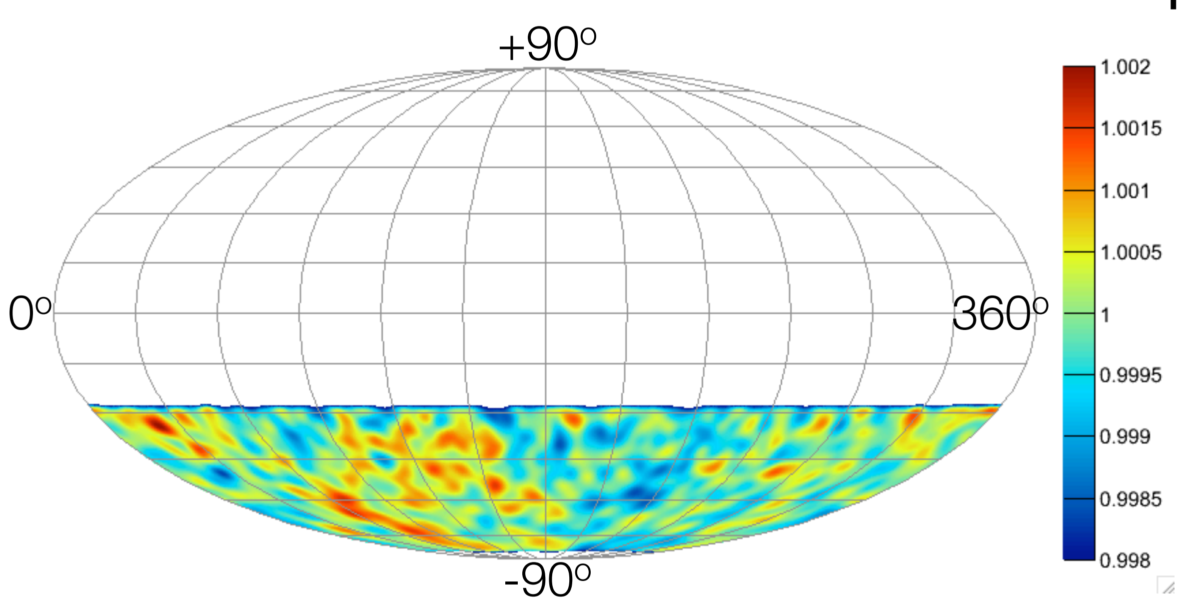
- measure muon bundles induced by cosmic rays : $E_{CR} \gtrsim 500$ GeV
- arrival direction of CR affected by local interstellar magnetic field structure

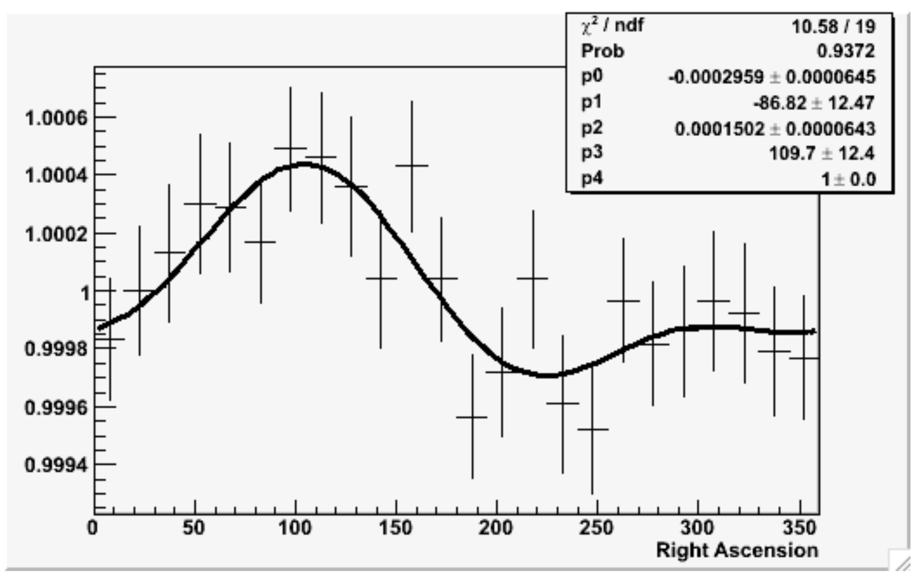
12.6 TeV



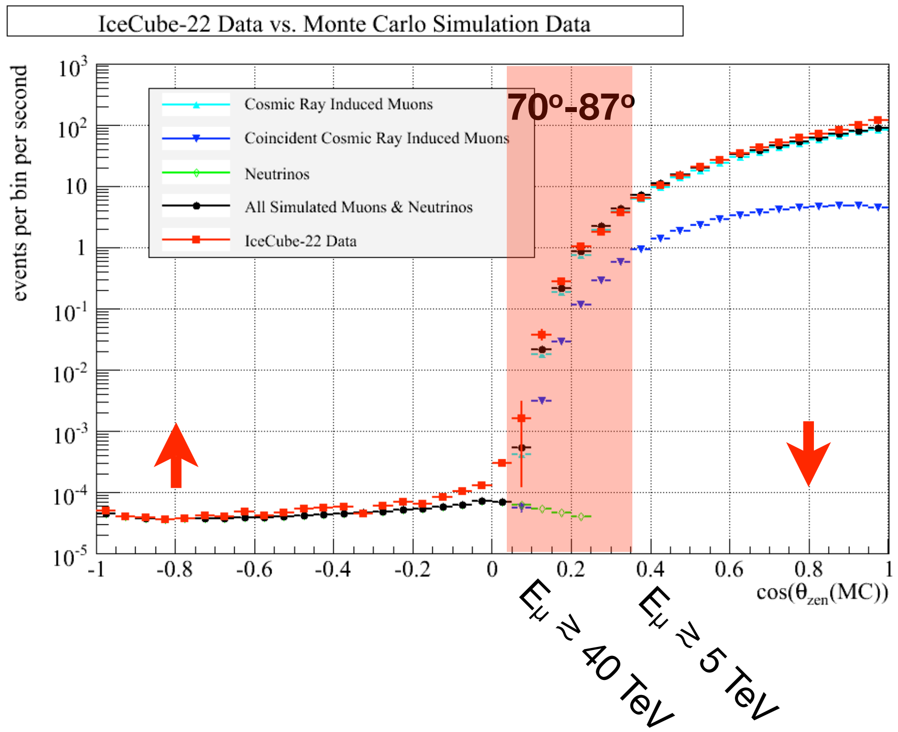


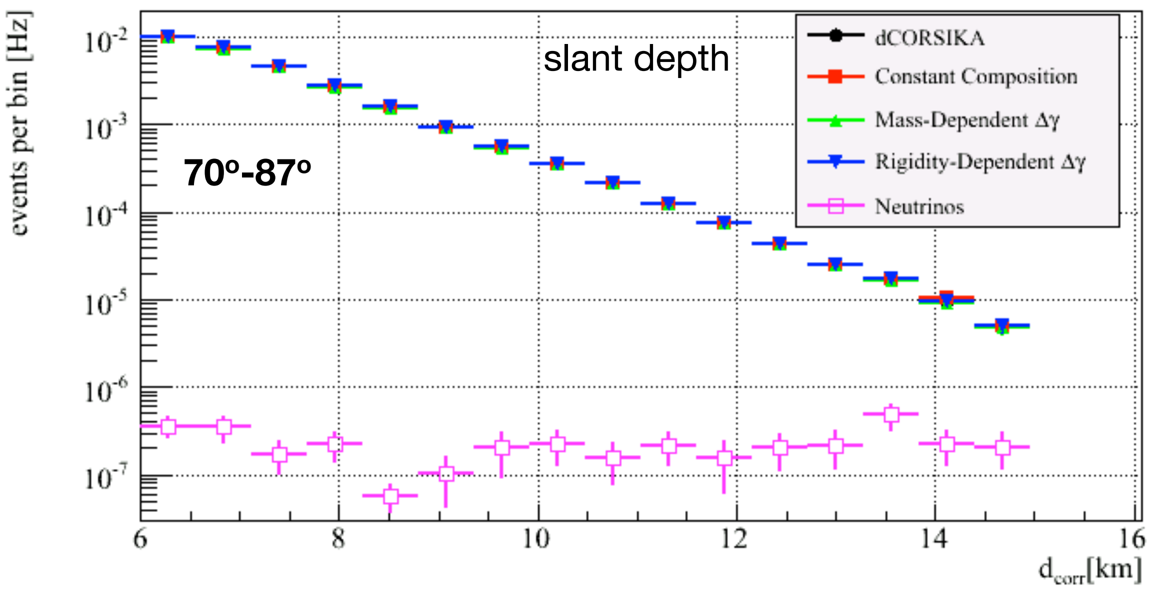
126 TeV

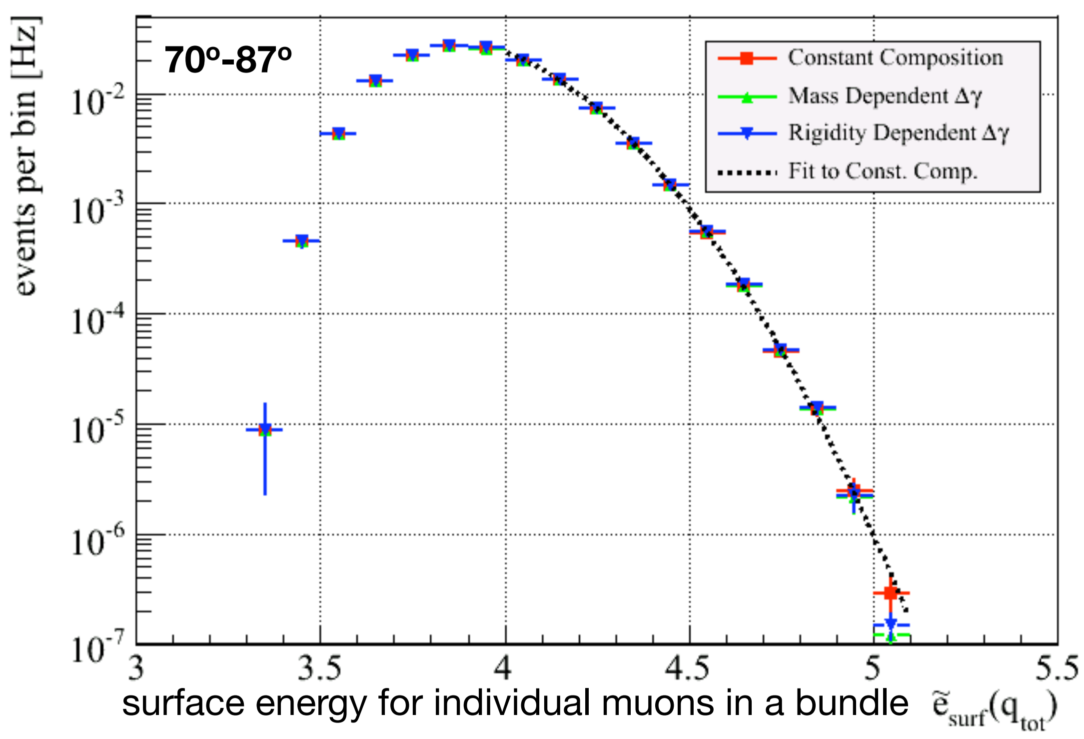




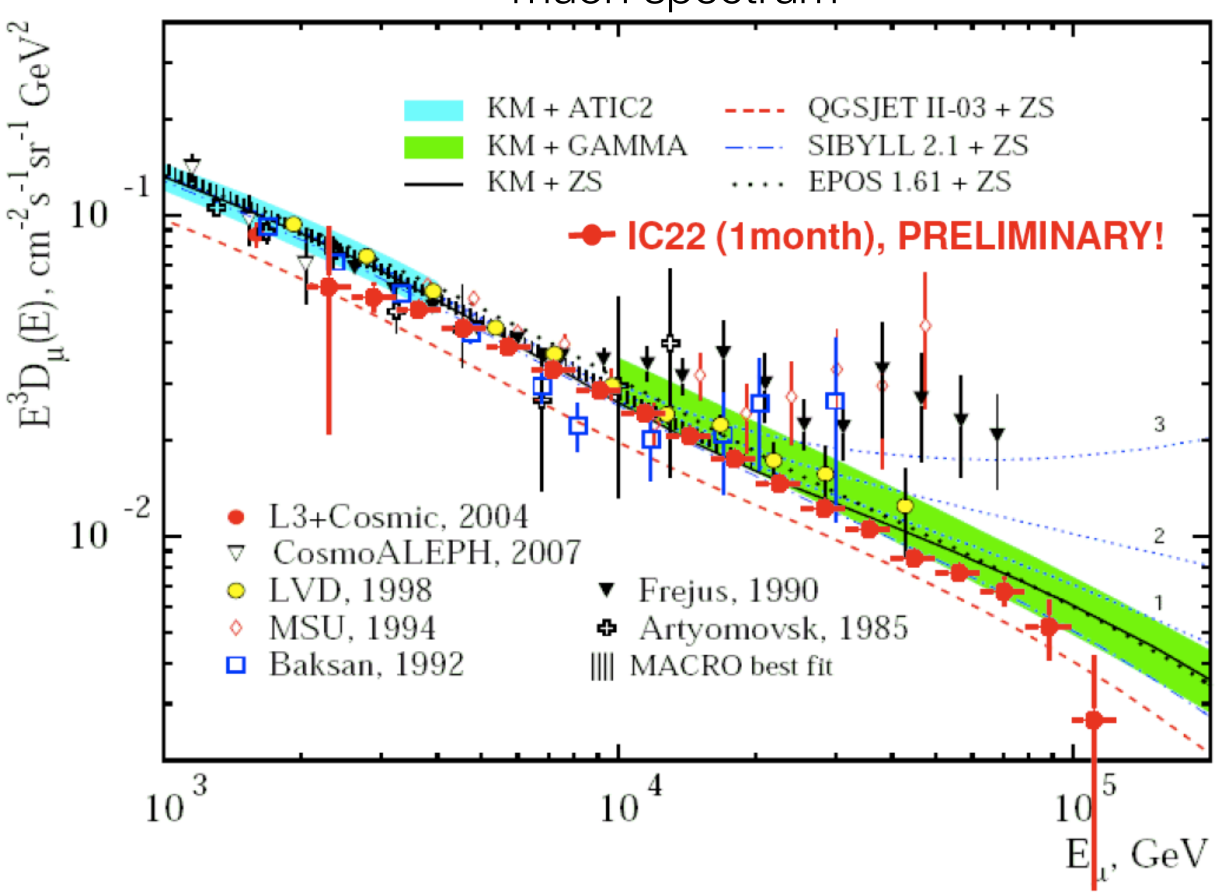
atmospheric horizontal μ bundles (IceCube-22)





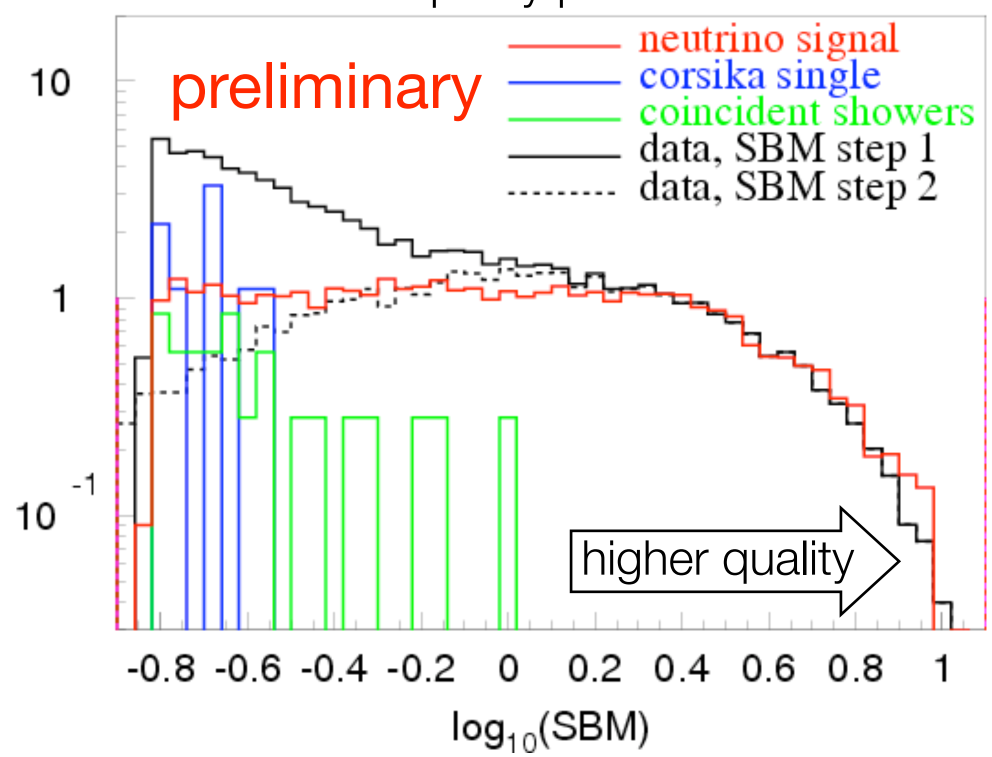


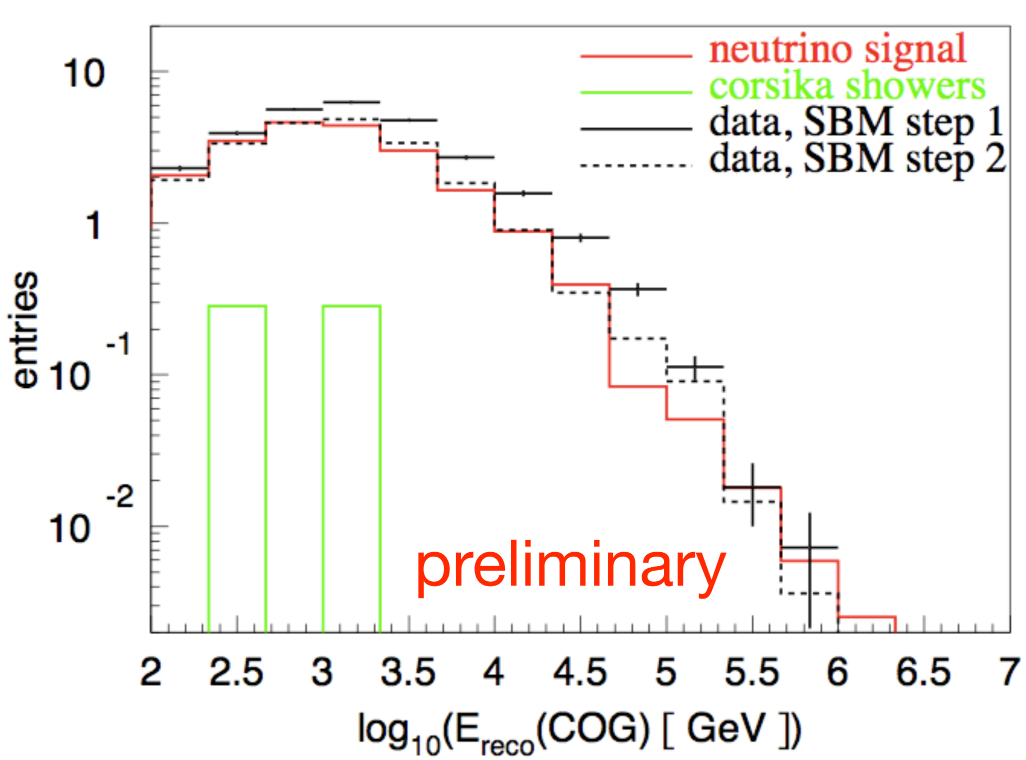
muon spectrum



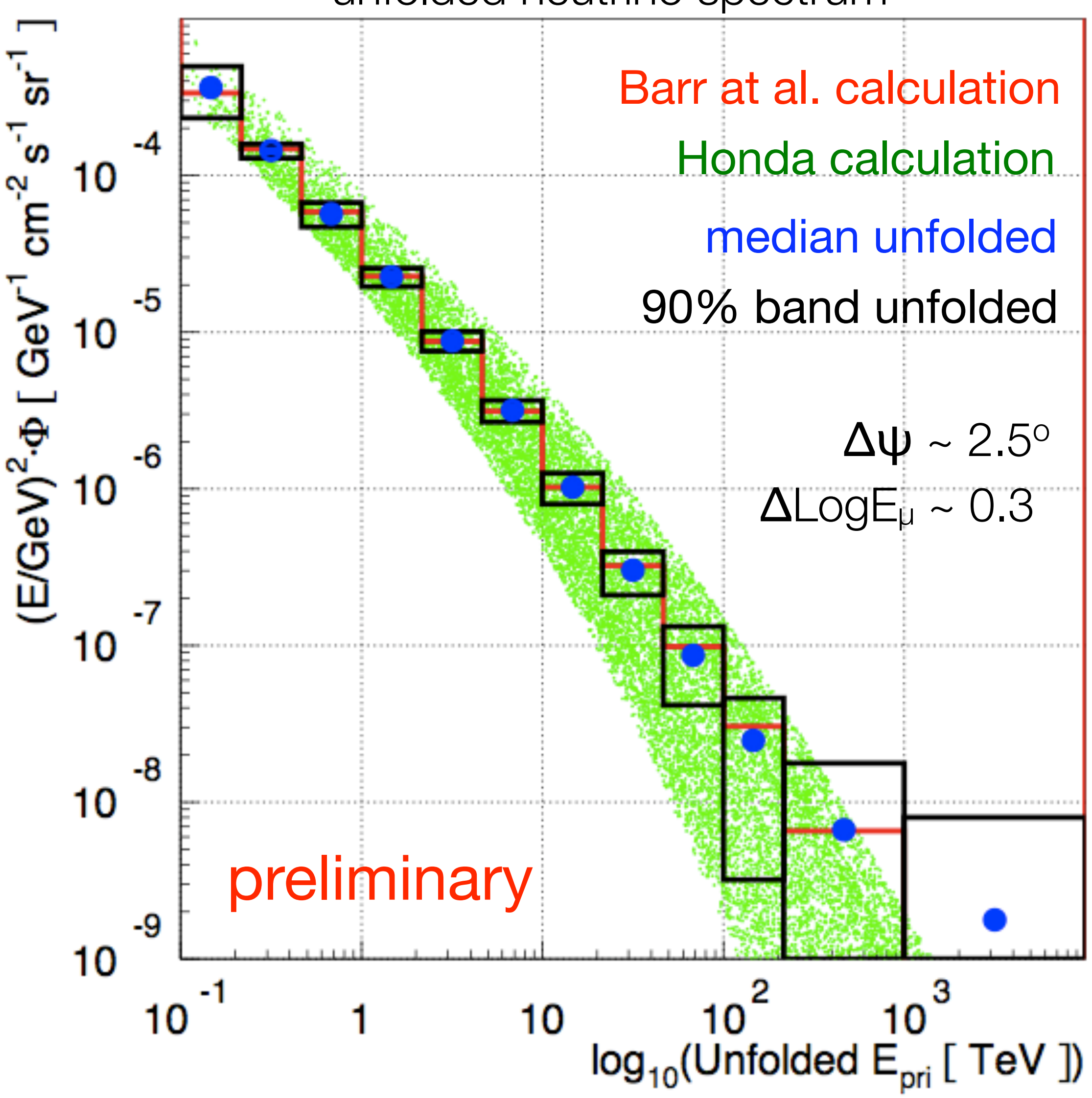
atmospheric ν_μ (IceCube-22)

quality parameter



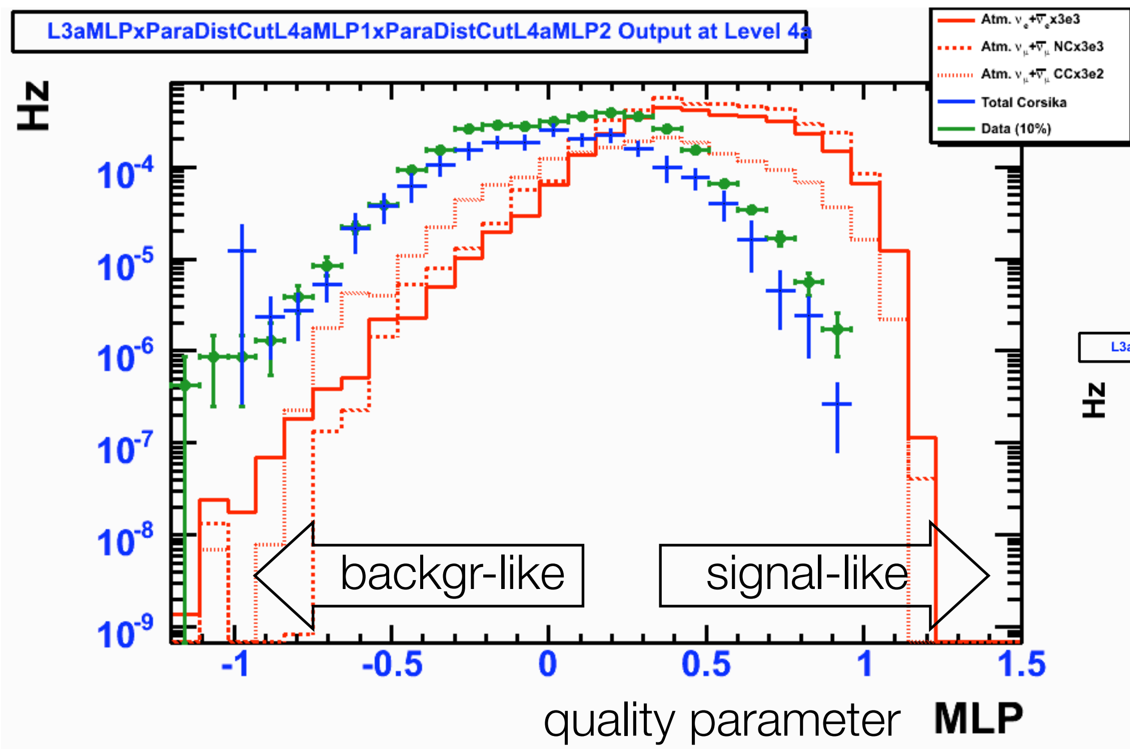


unfolded neutrino spectrum



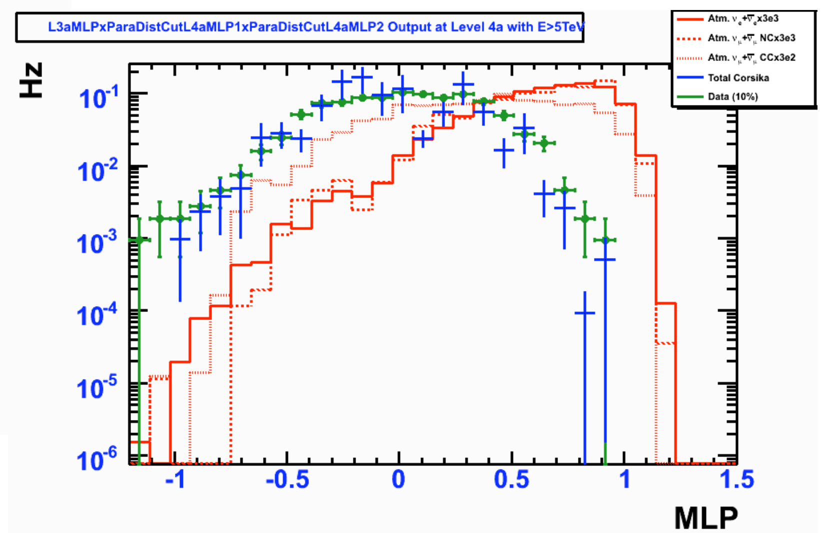
IC-22 (95% purity)	29.0 neutrinos / day
IC-40 (95% purity)	83.1 neutrinos / day
IC-86 (40% purity)	~390 neutrinos / day

atmospheric ν_e (IceCube-22)

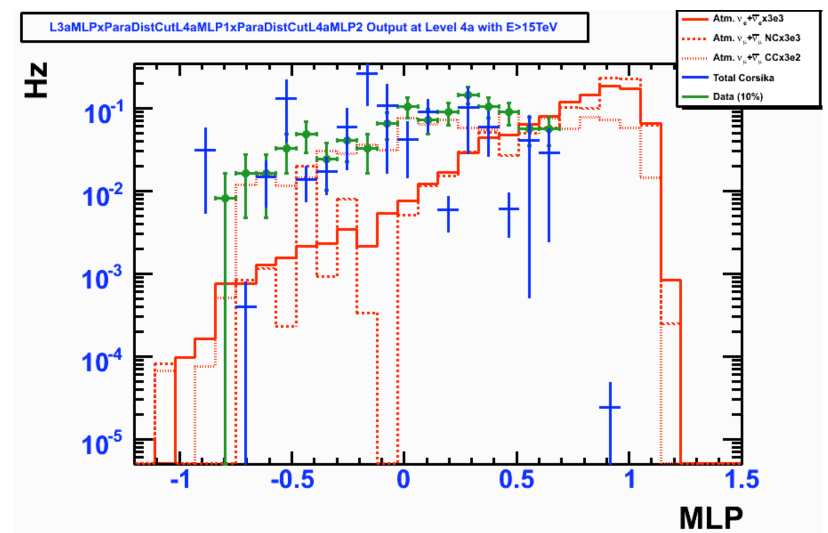


ΔVertex ~ 10 m

$\Delta LogE_{\mu}$ ~ 0.17 - 0.23

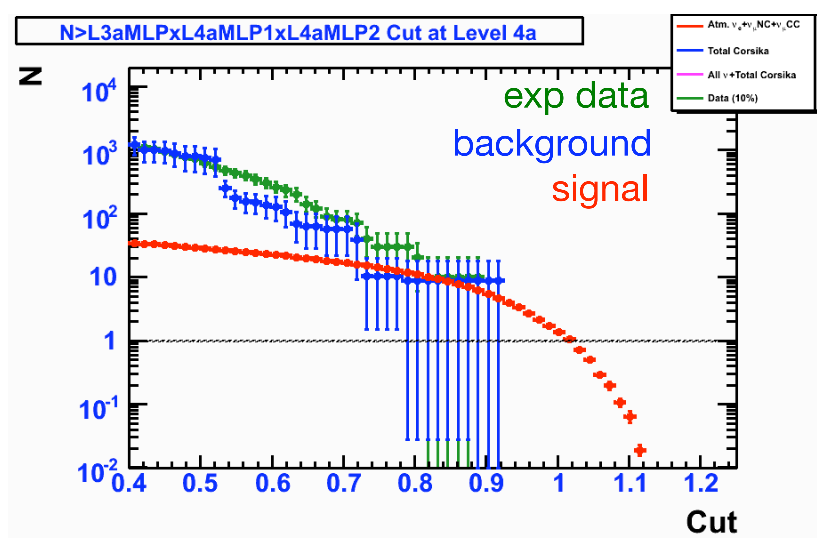


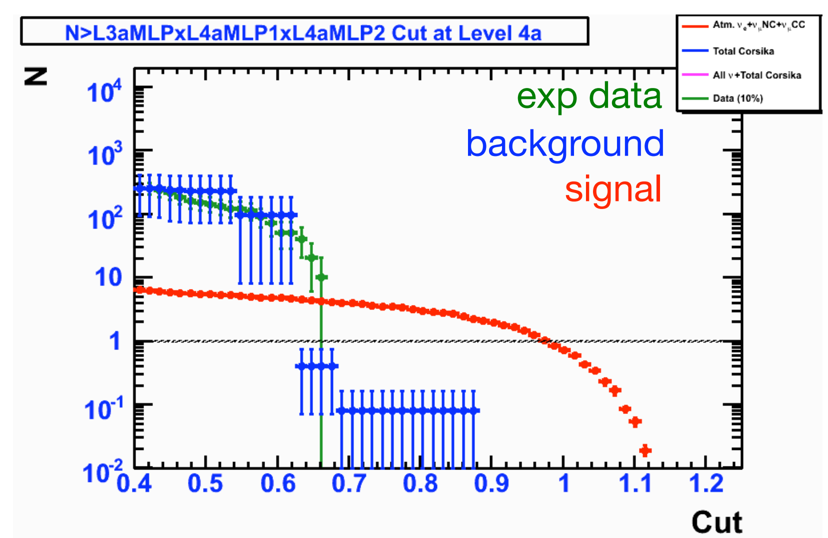
E > 5 TeV



E > 15 TeV

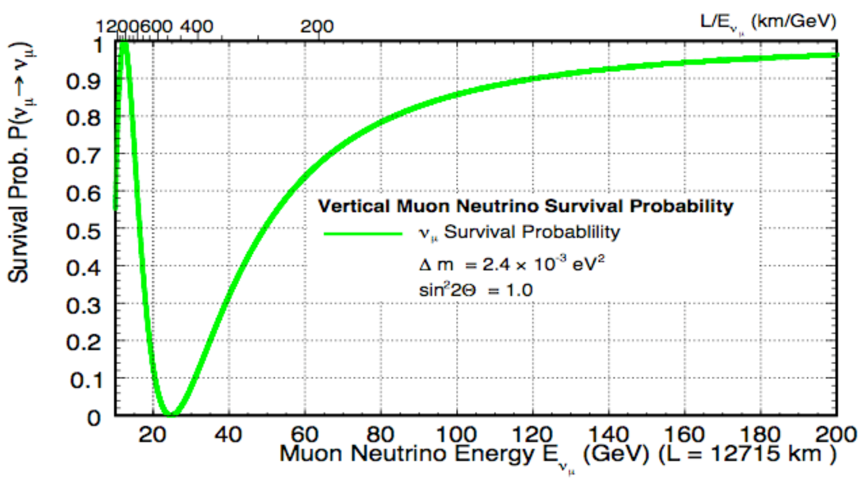
- limited by background statistics
- high cascade-like background
- dedicated simulation for searches of cascades

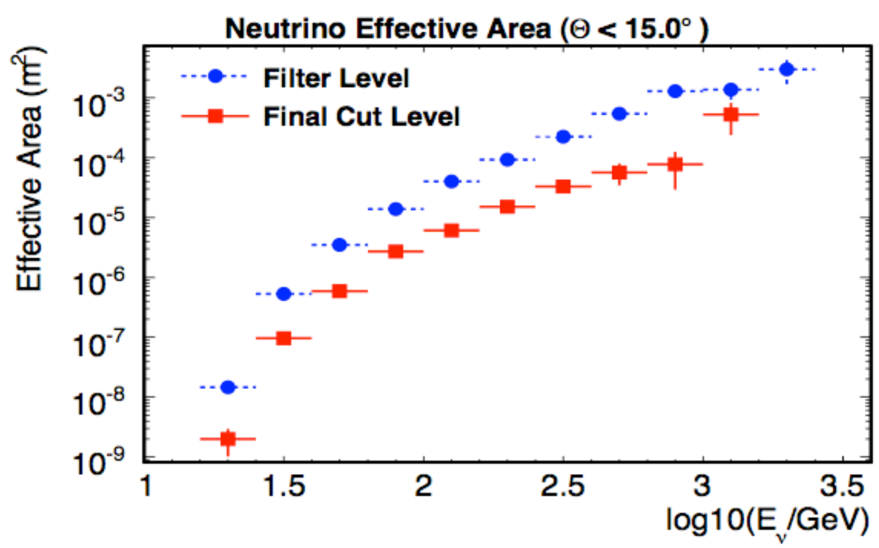


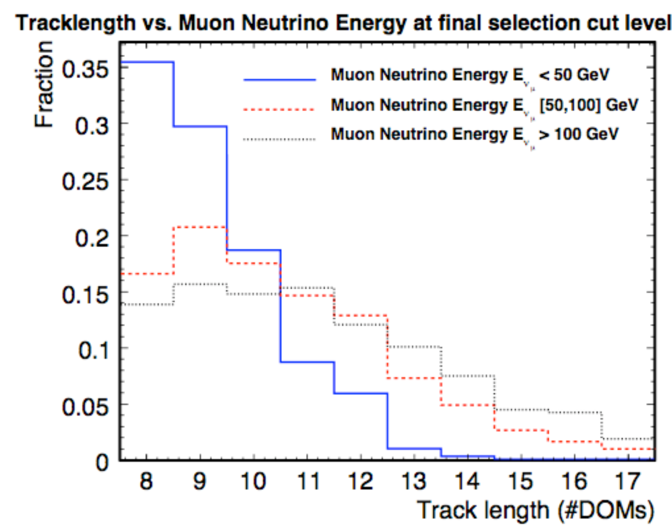


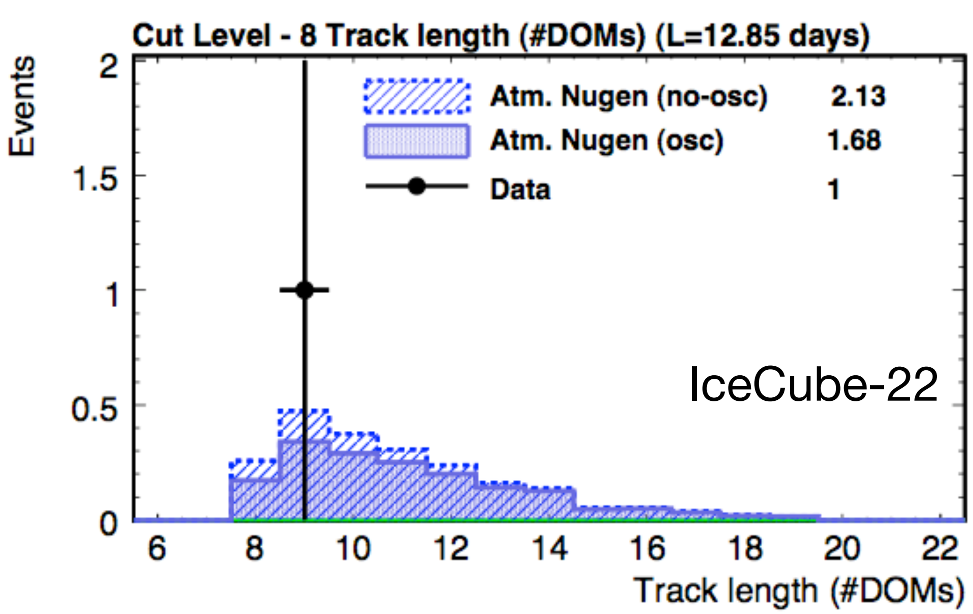
atmospheric ν_μ : oscillations (IceCube-22)

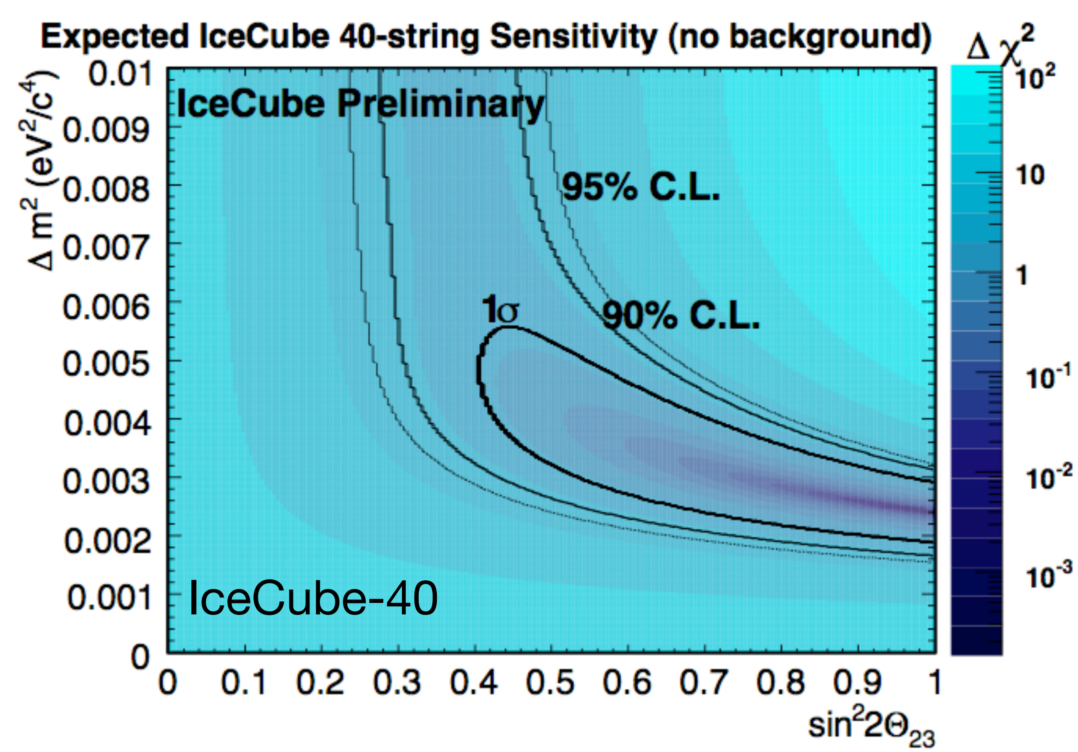
- extend atmospheric neutrino measurement below 100 GeV
- ν_μ disappearance for vertical up-going muons (Deep Core)



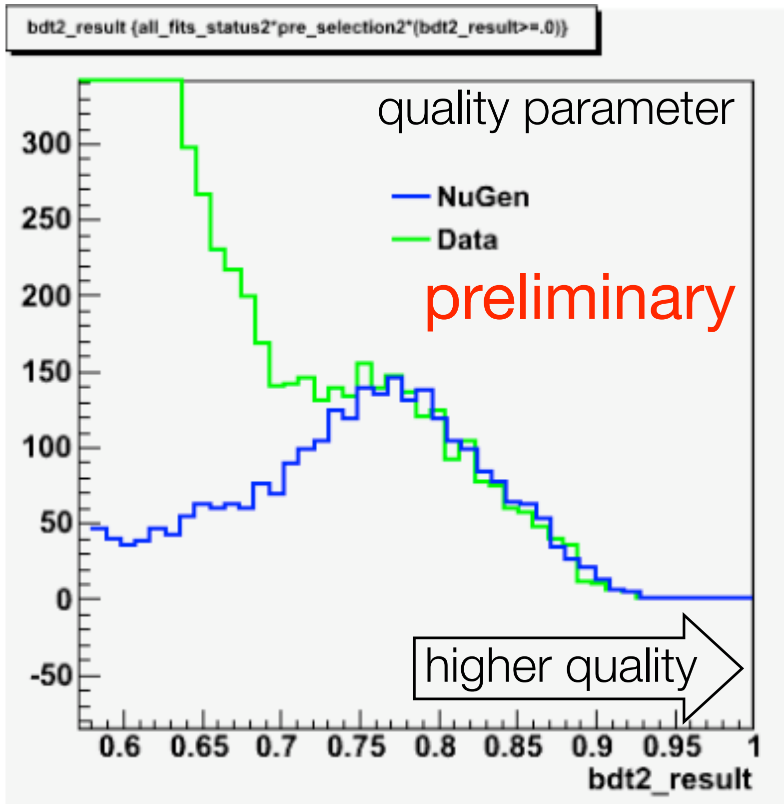


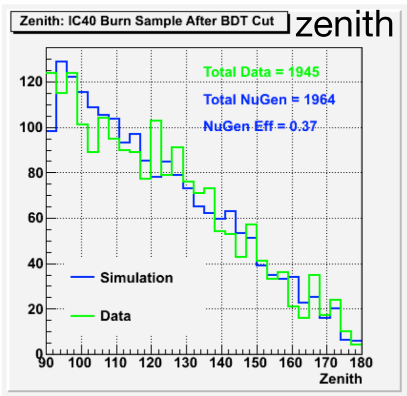


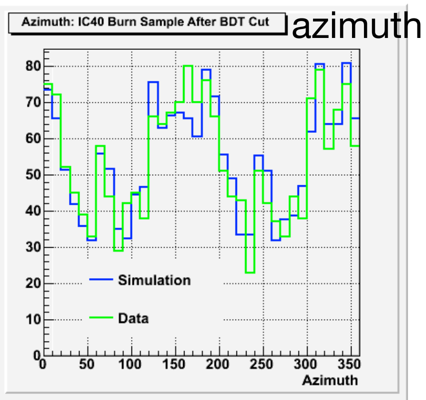


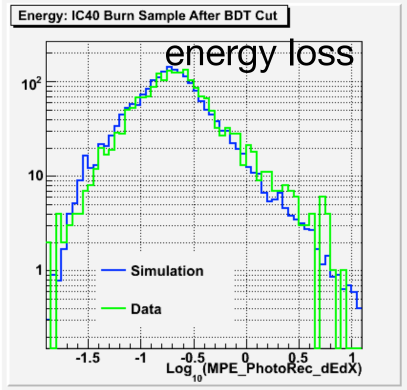


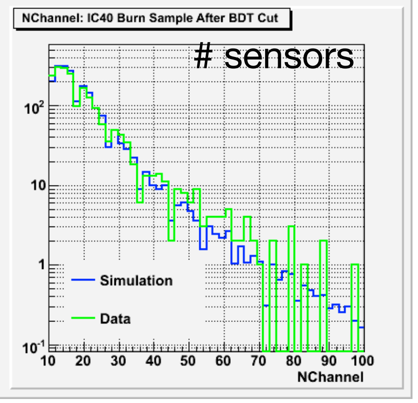
atmospheric ν_μ : VLI & decoherence (IceCube-40)

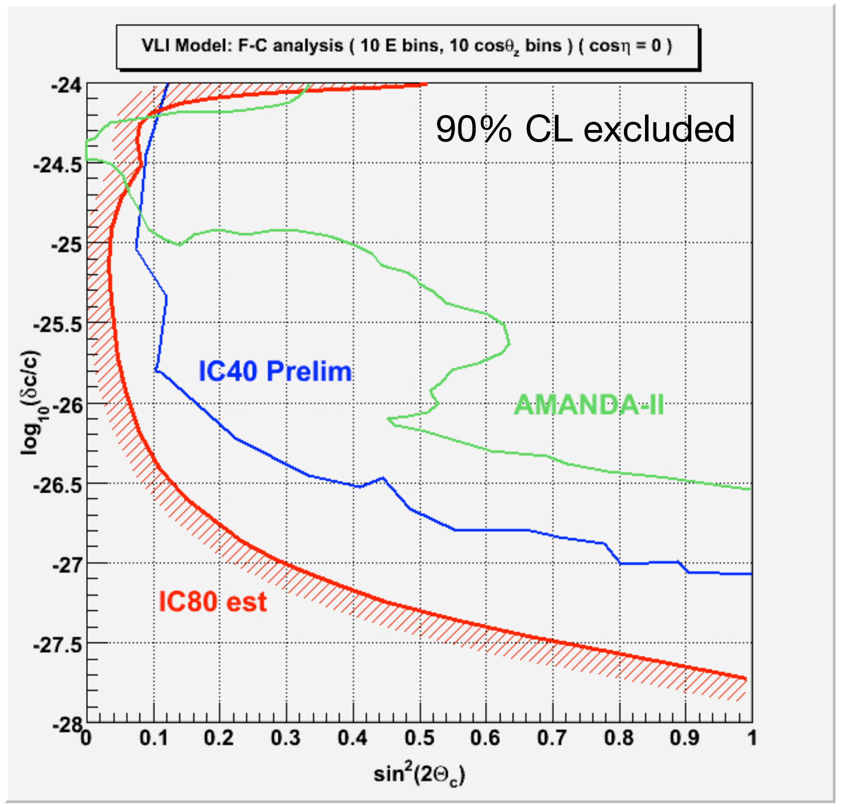




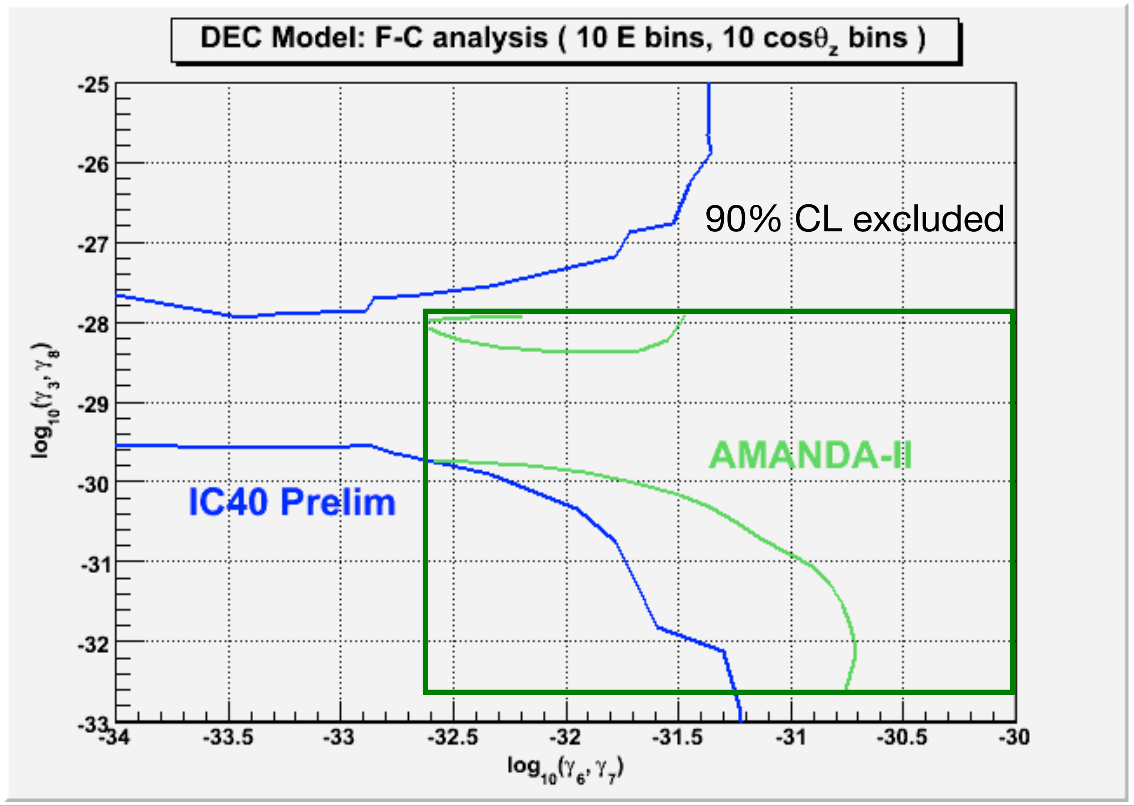








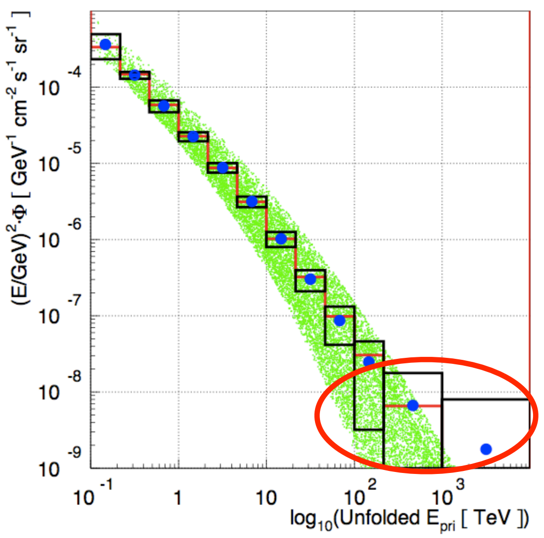
Violation of Lorentz Invariance

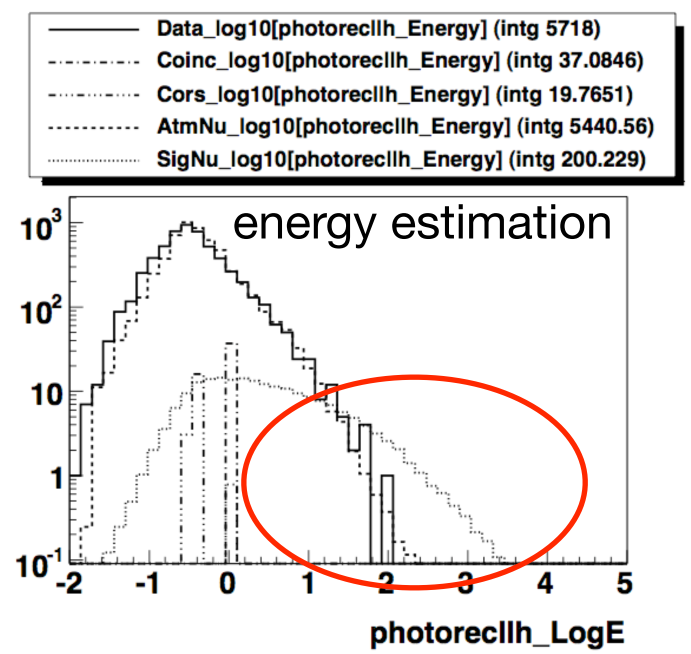


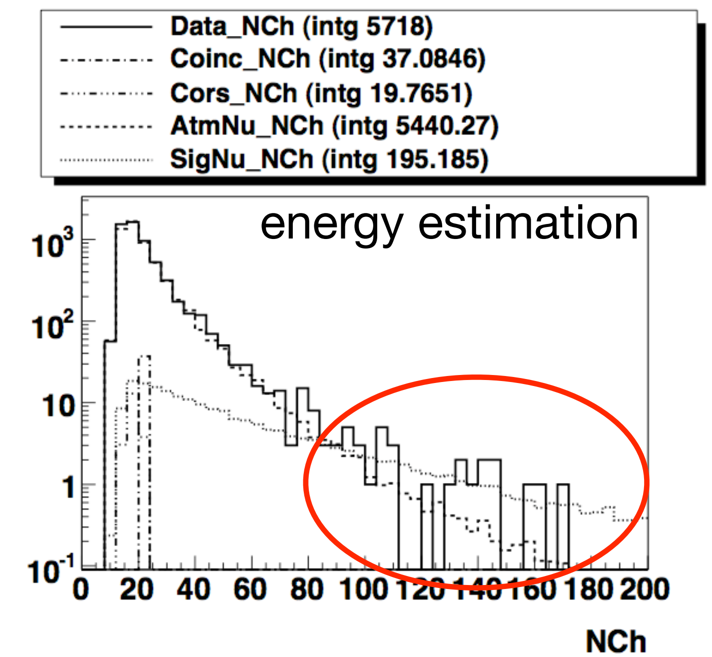
Quantum Gravity

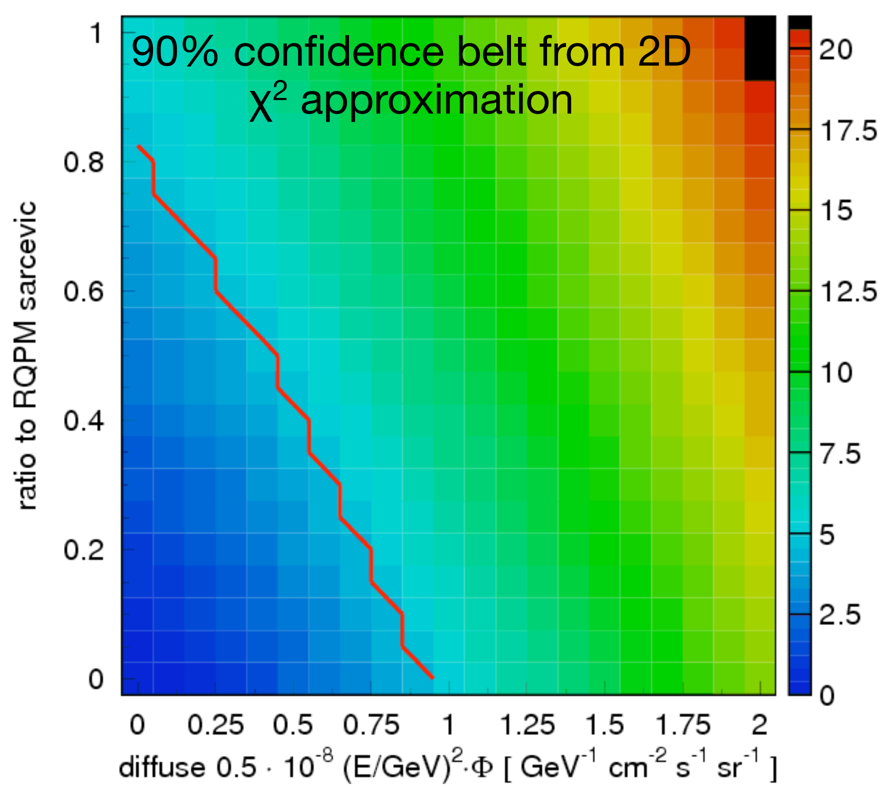
diffuse ν_μ (IceCube-22)

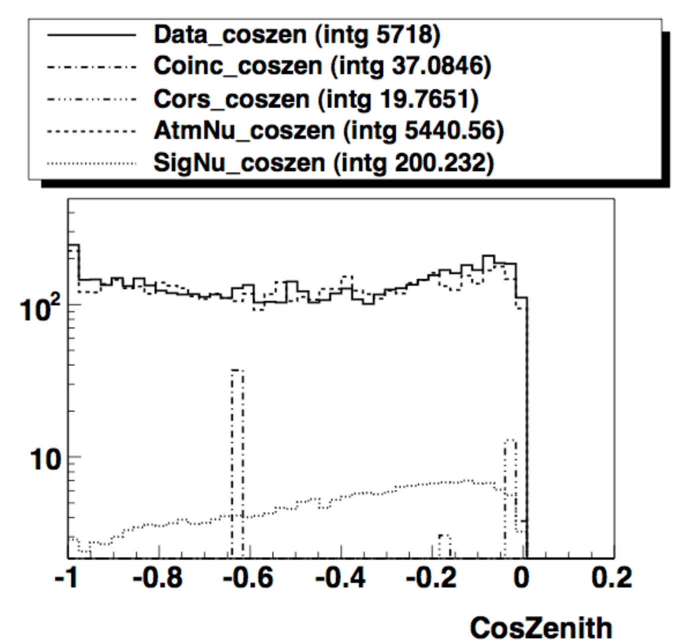
- search for high energy extraterrestrial neutrinos
- understanding detector systematics for bright events (i.e. high energy)







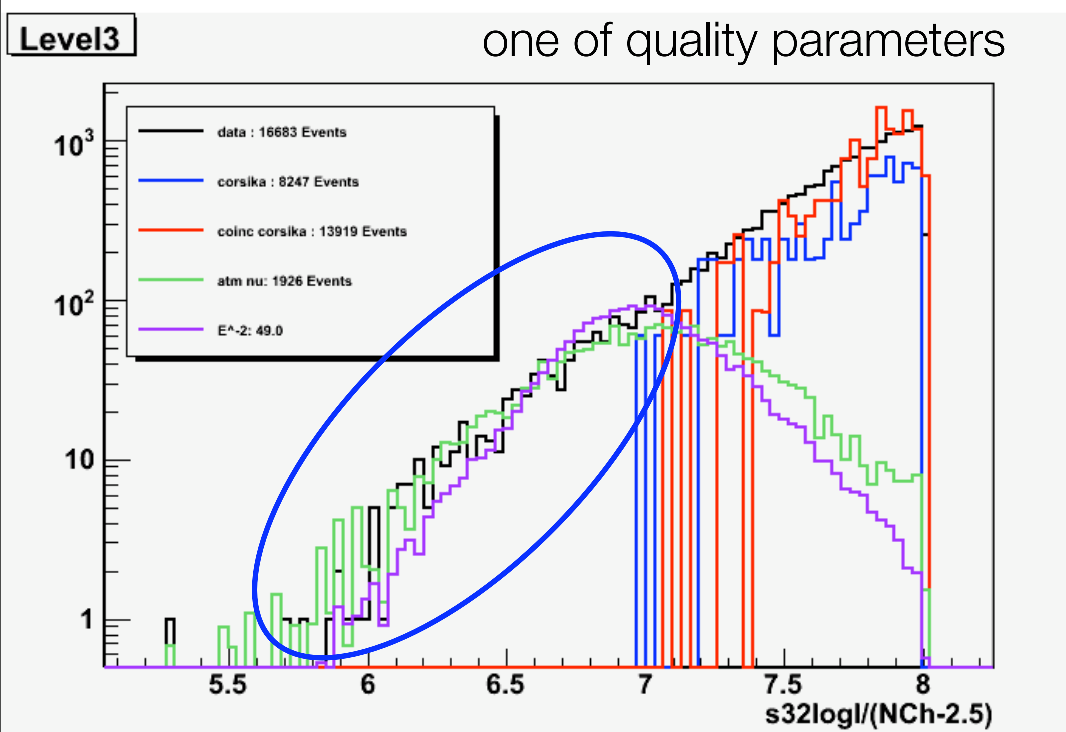


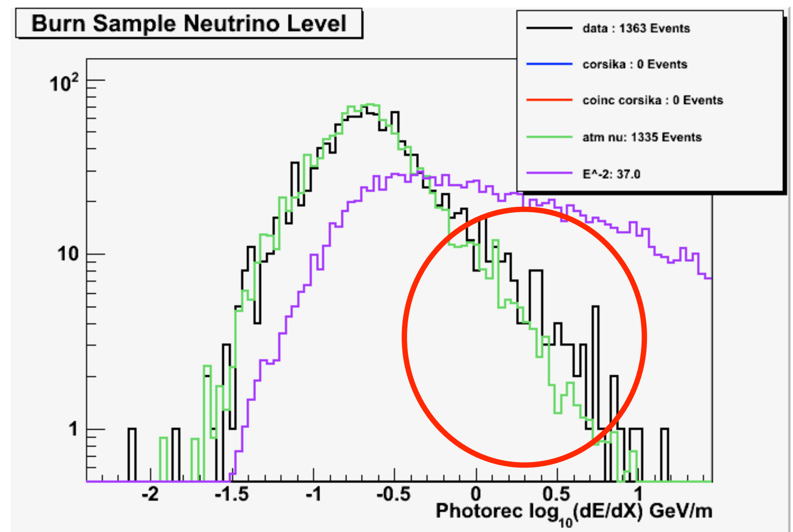


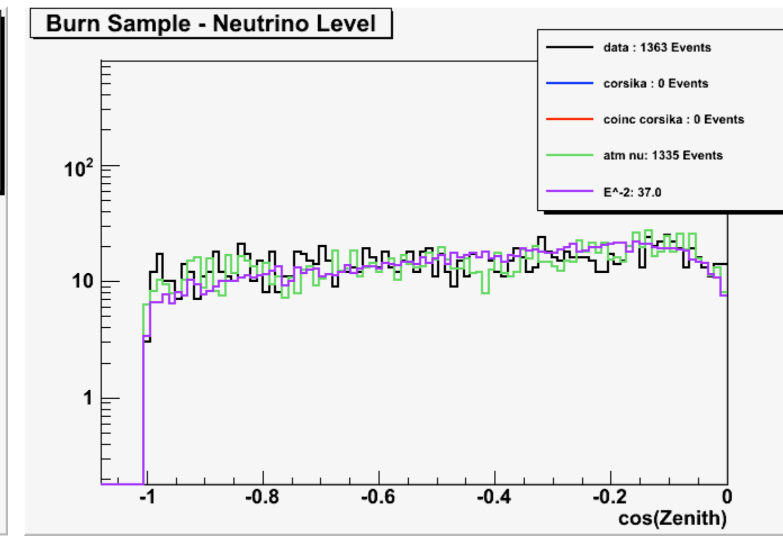
diffuse ν_μ : (IceCube-40)

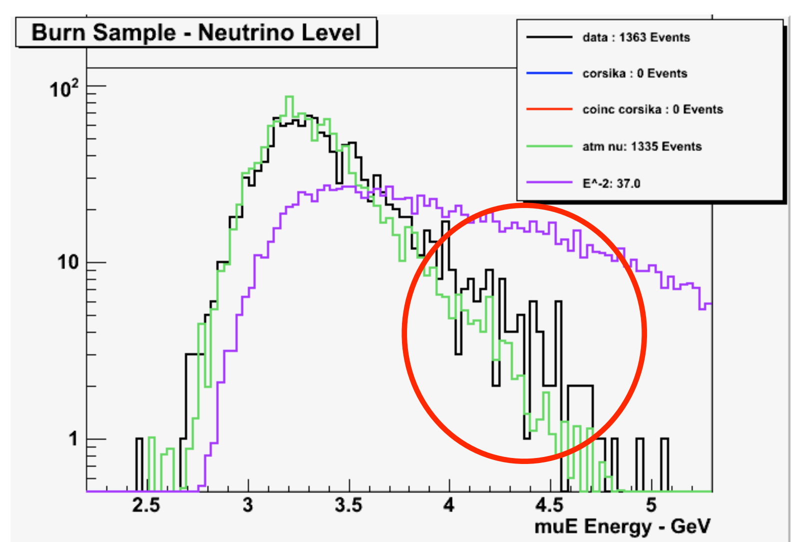
2/2

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



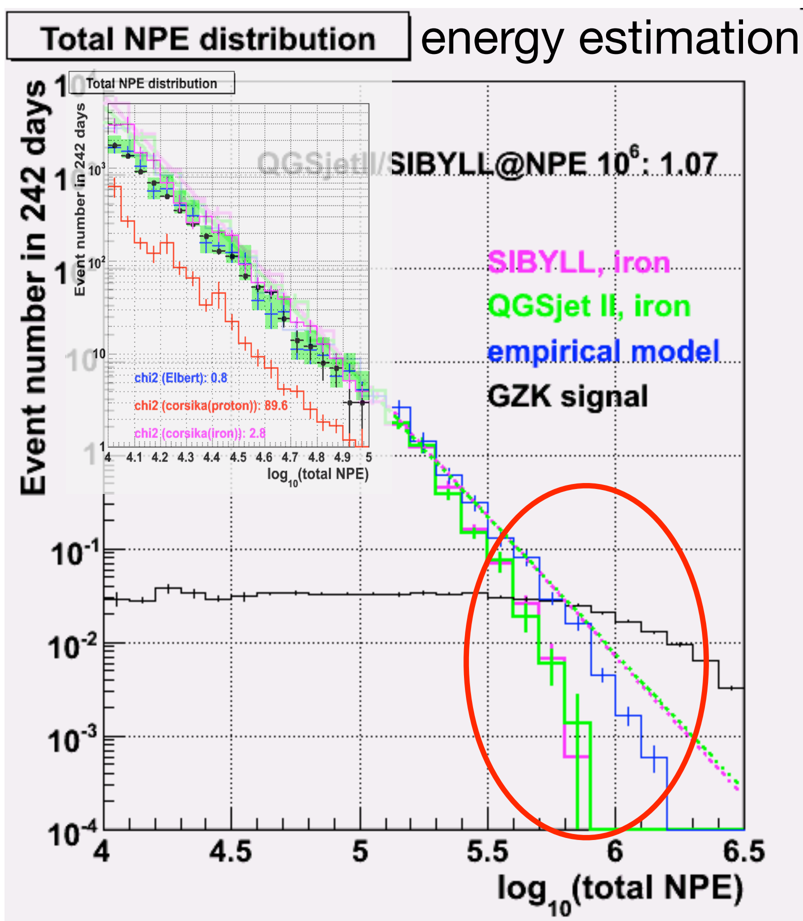


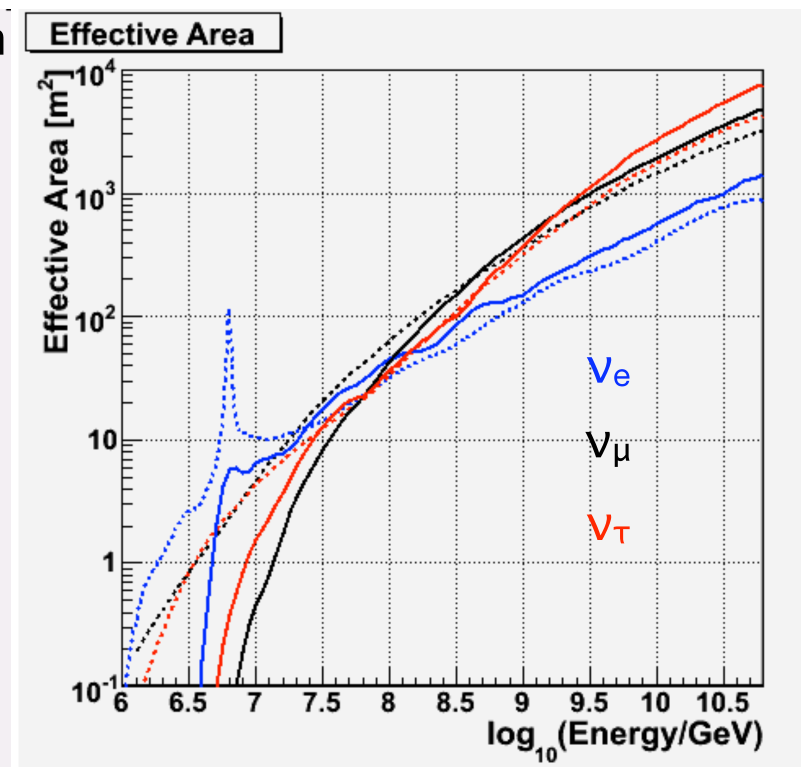


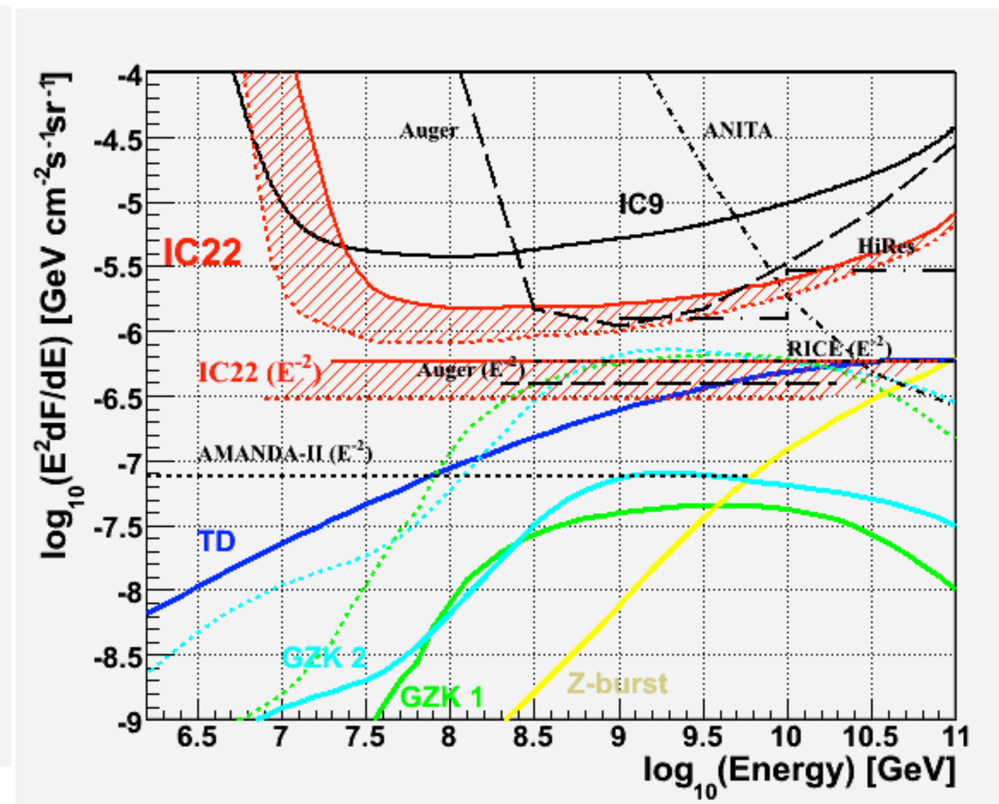


EHE ν : IceCube-22

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







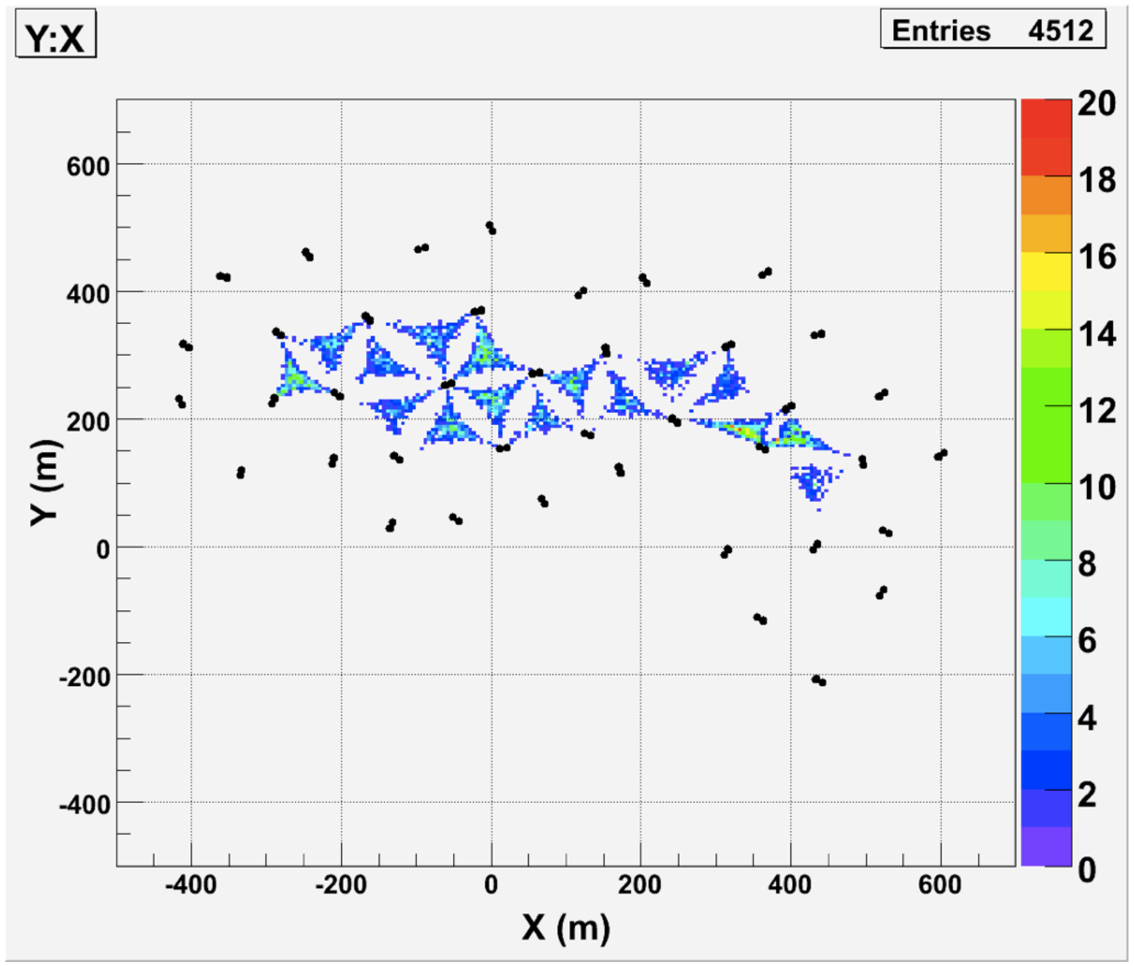
—— IC-22

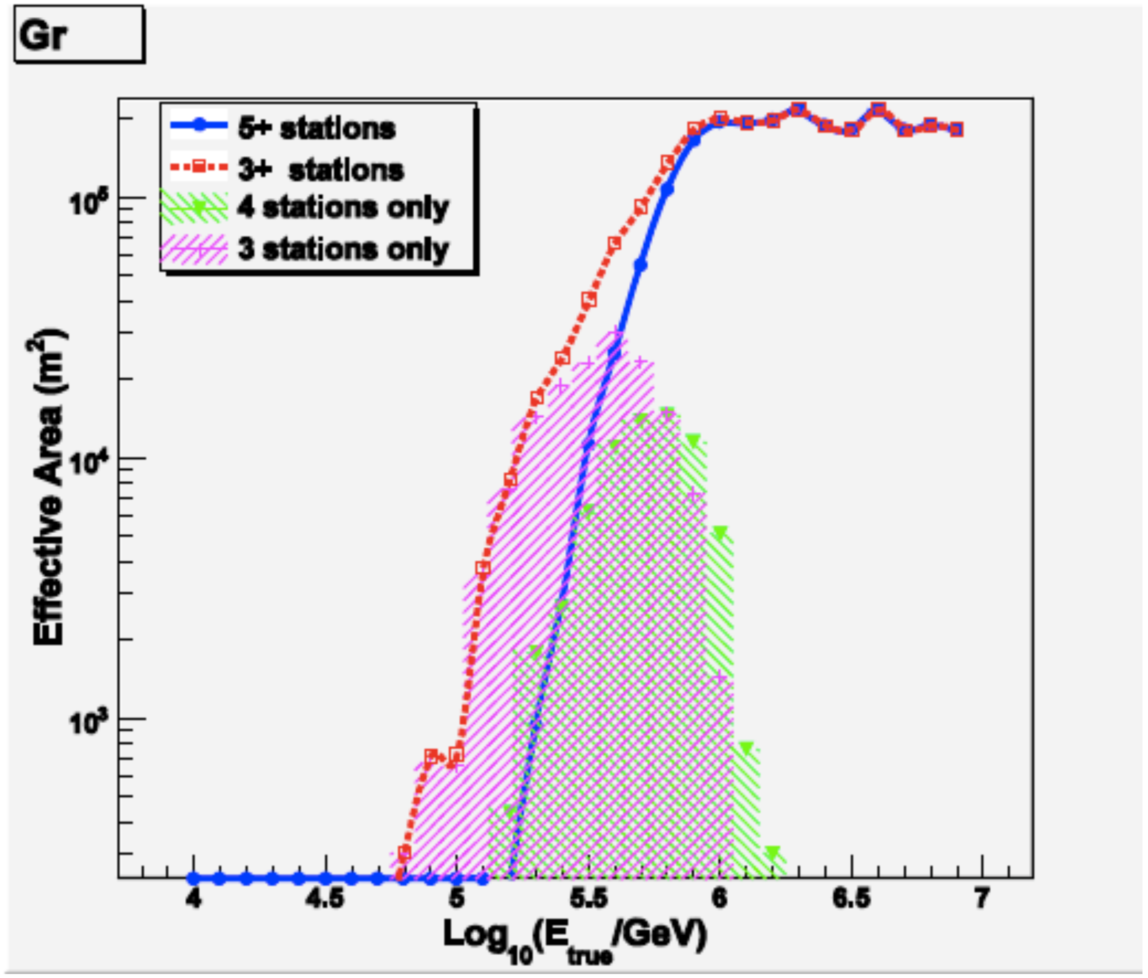
- - - - IC-9

IceCube-40 currently under analysis

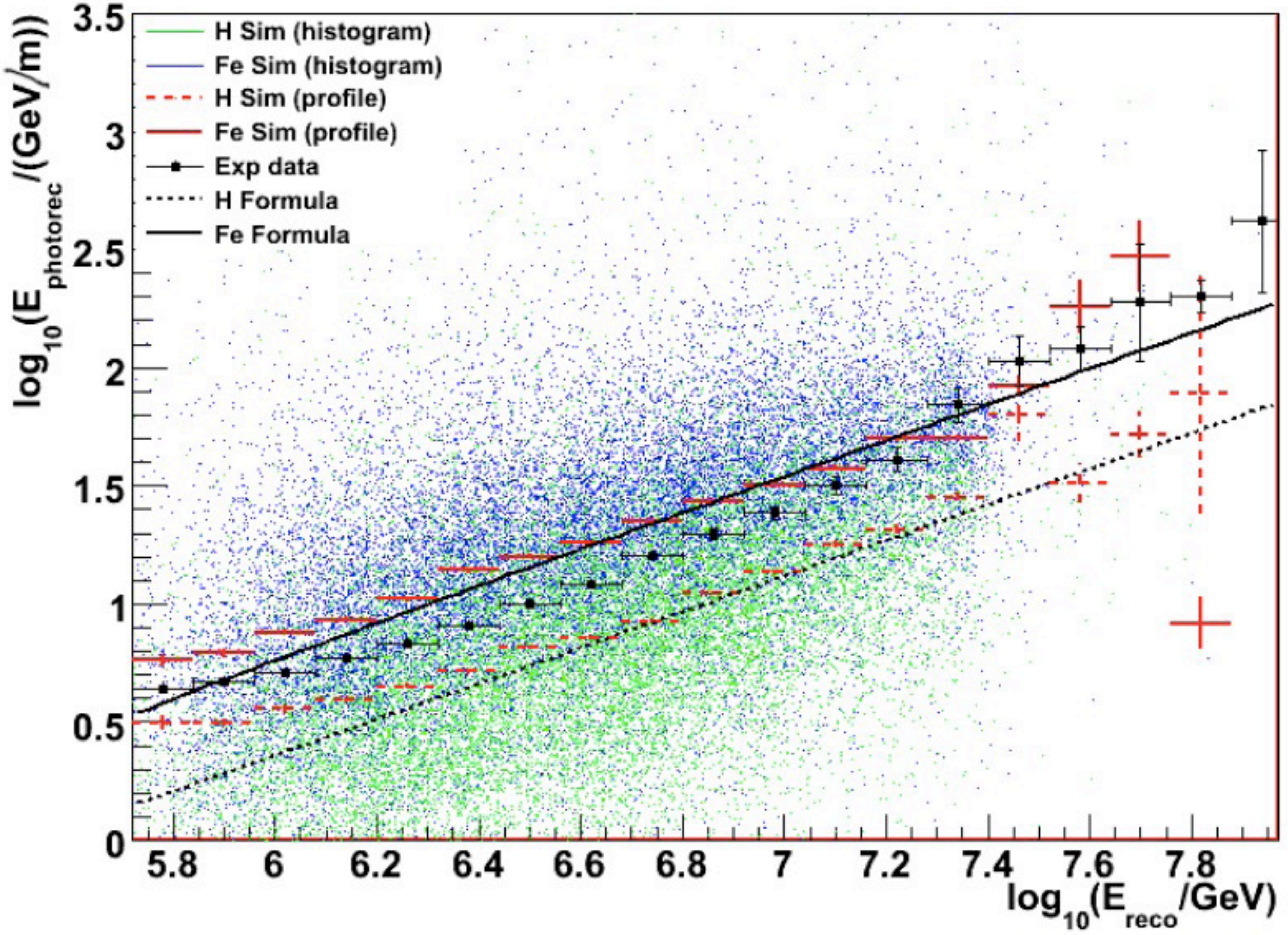
extra slides

cosmic rays : small showers (IceTop-26)



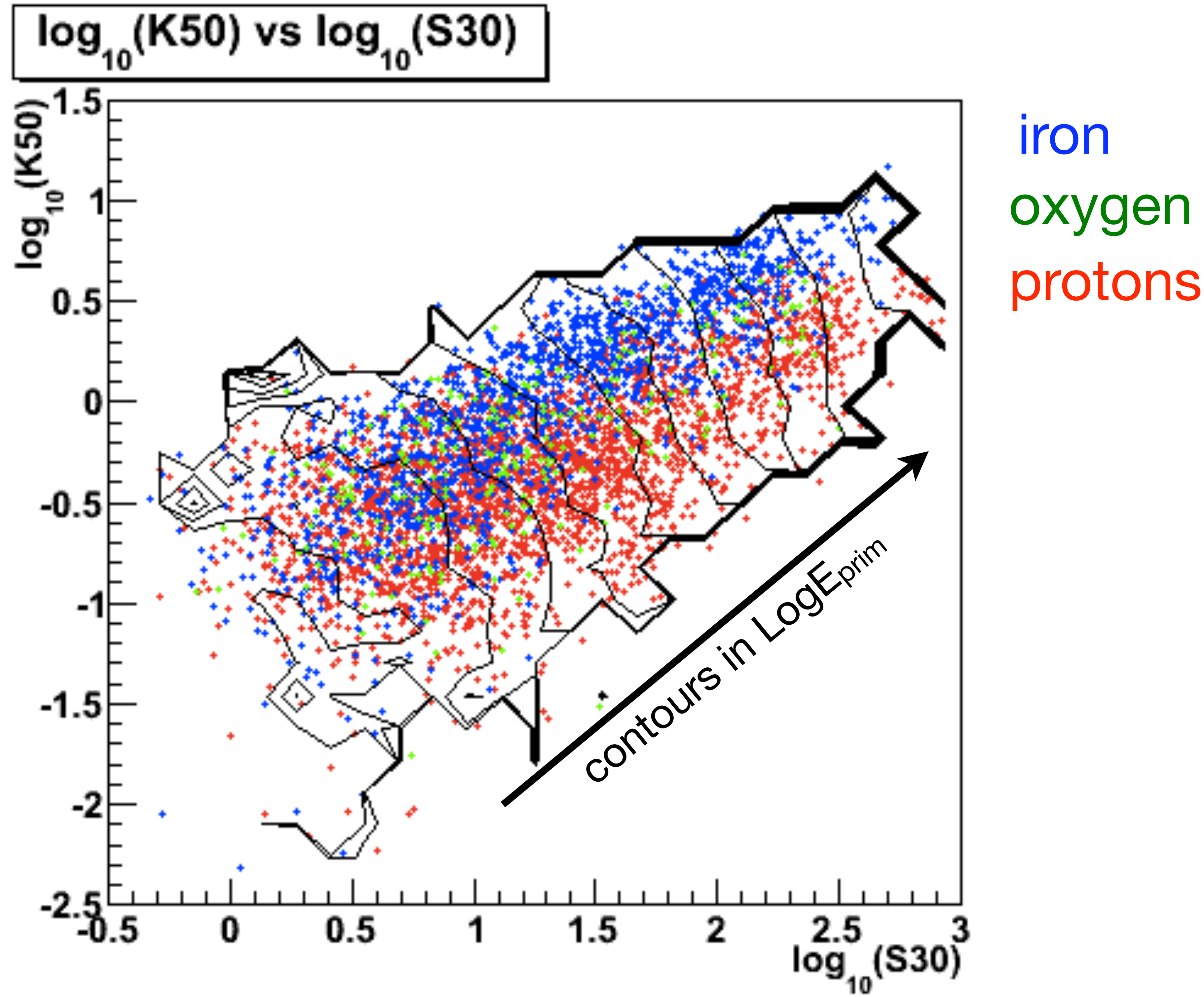


- extend sensitivity to lower energy



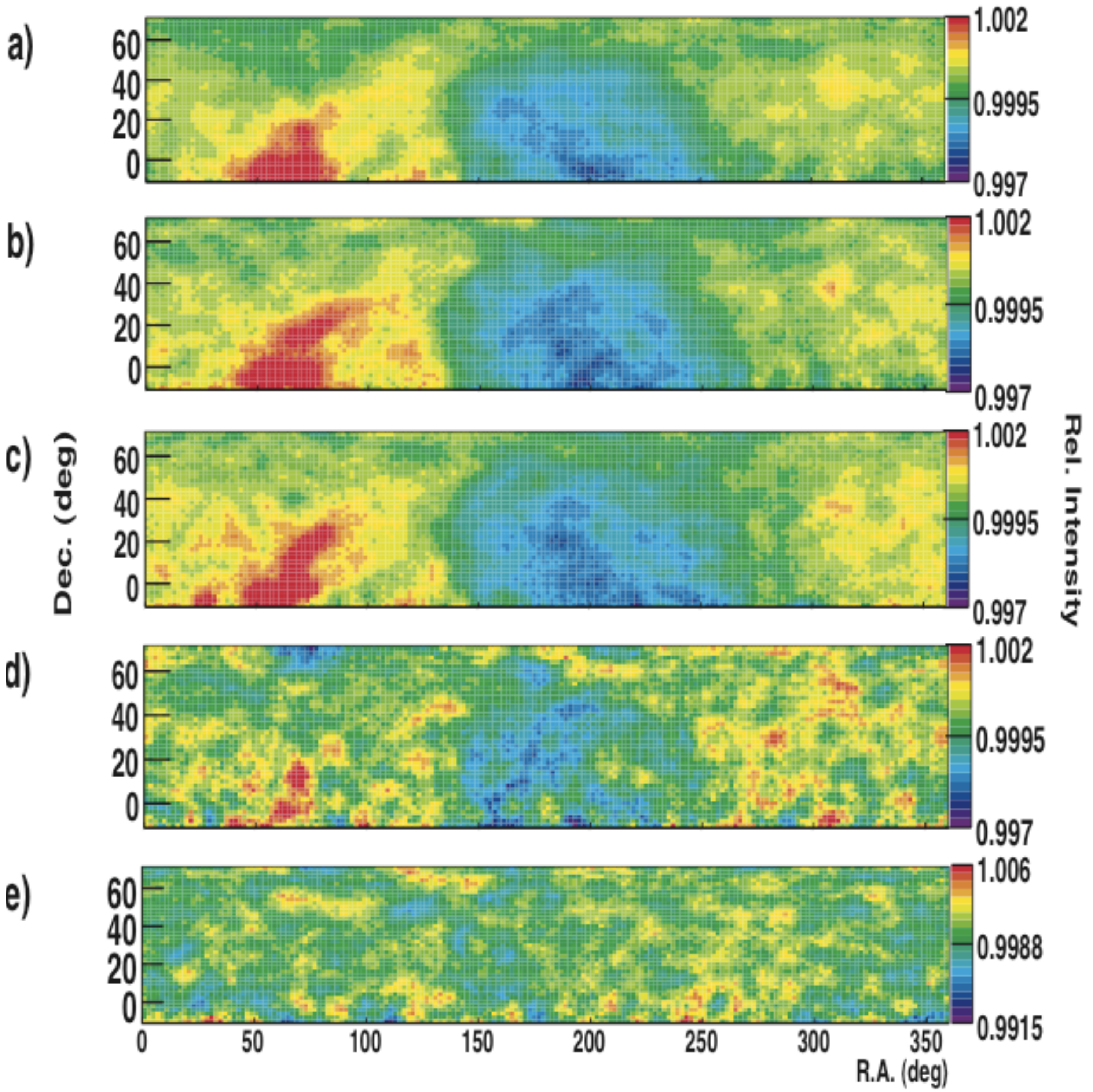
cosmic rays
muon bundle energy deposit

IceCube-only cosmic ray mass dependency



cosmic rays
mass composition

SPASE-AMANDA coincident events



Tibet array

4 TeV
0.004 pc
880 AU

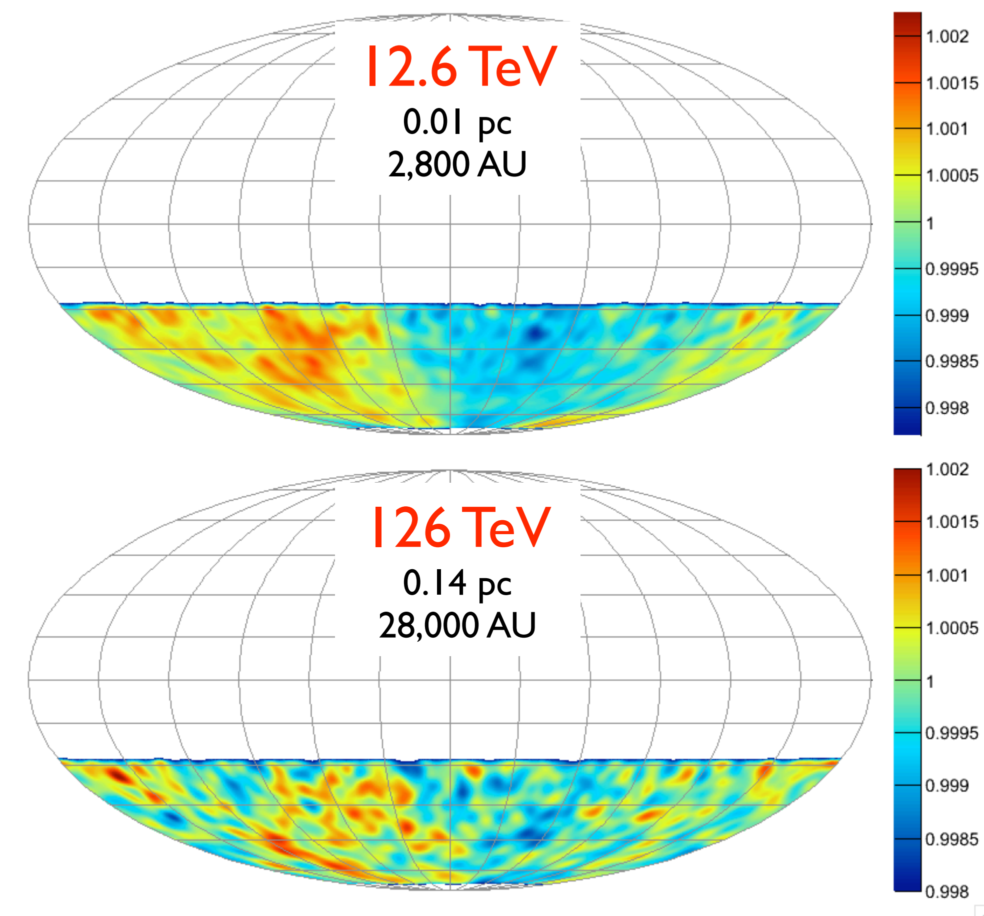
6.2 TeV
0.007 pc
1,400 AU

12 TeV
0.01 pc
2,600 AU

50 TeV
0.06 pc
11,000 AU

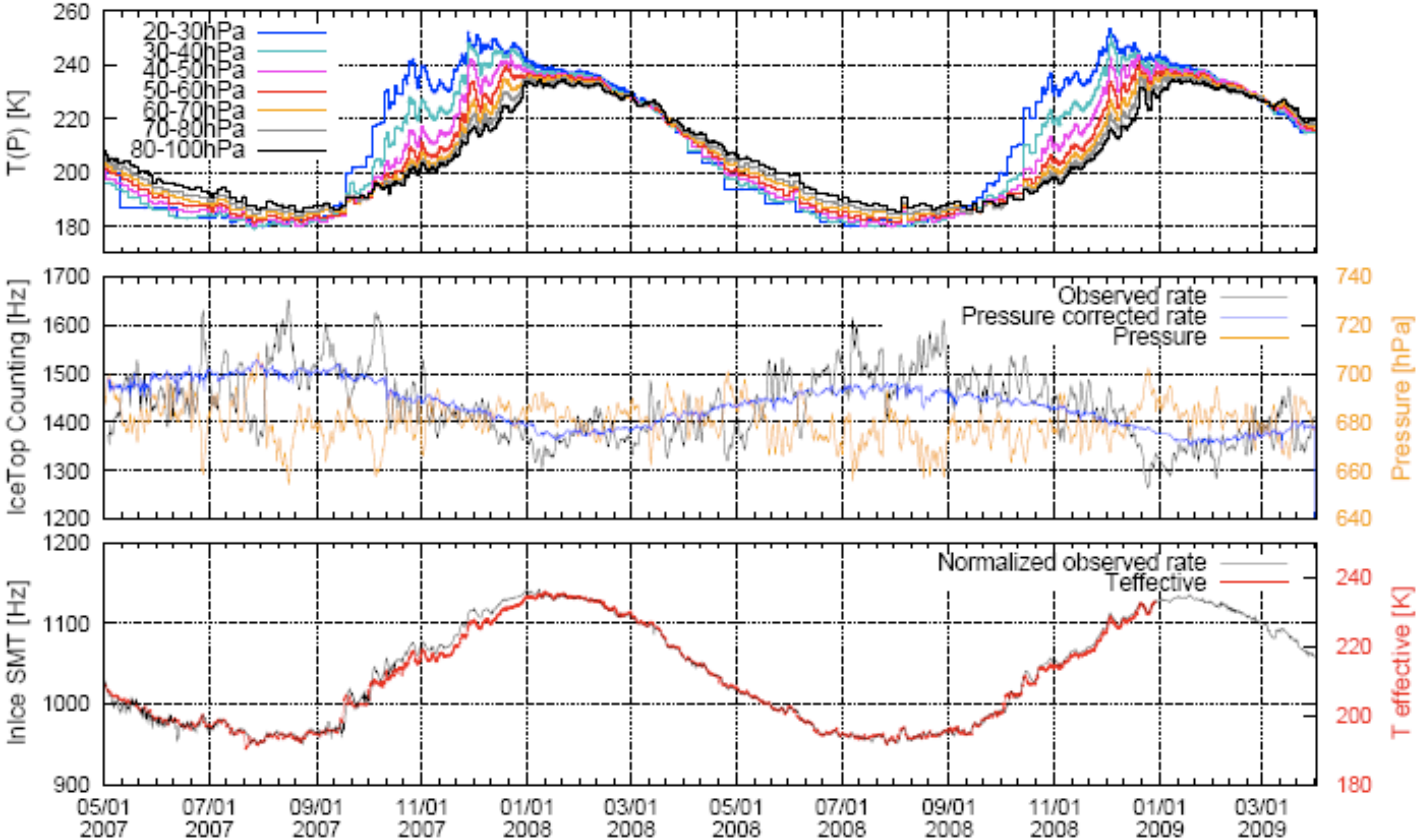
300 TeV
0.3 pc
66,000 AU

IceCube-22

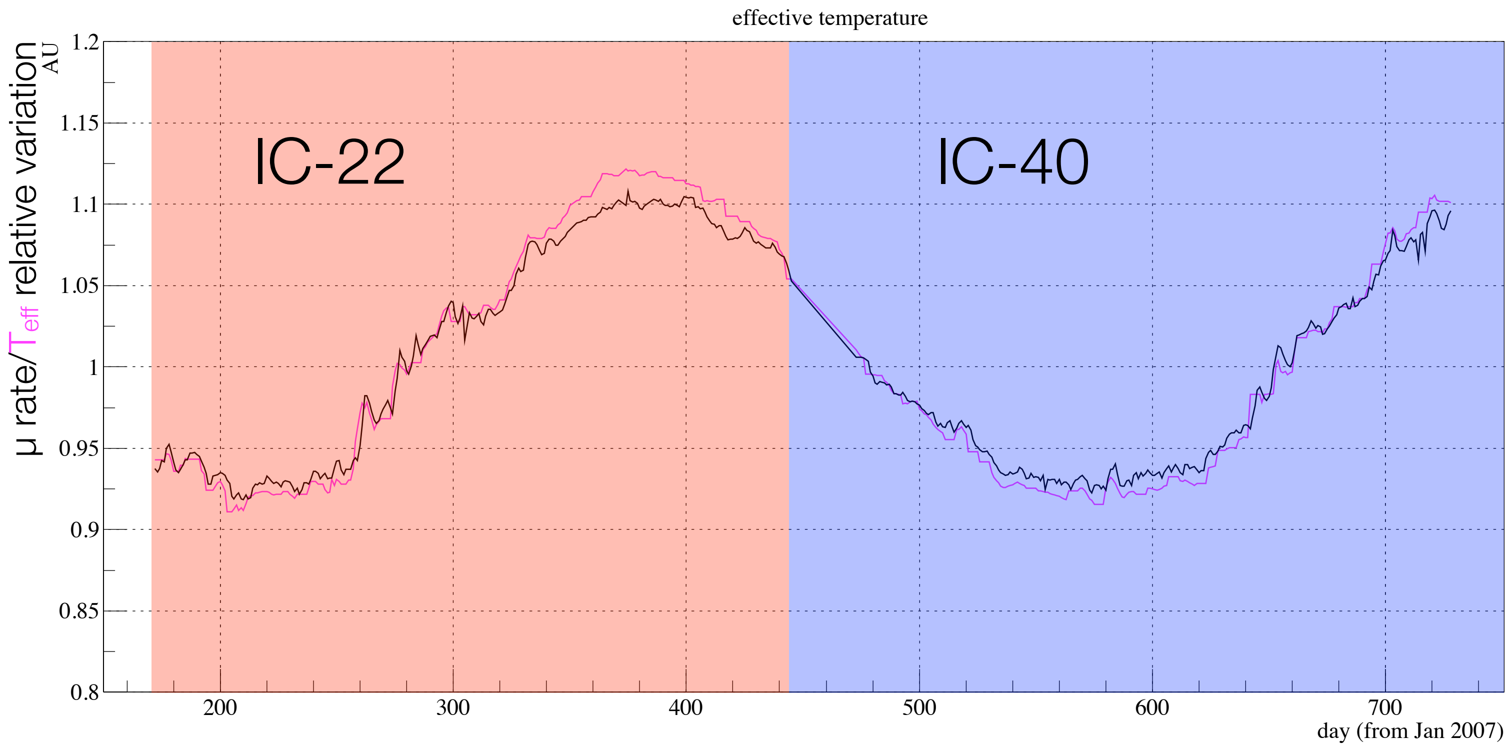


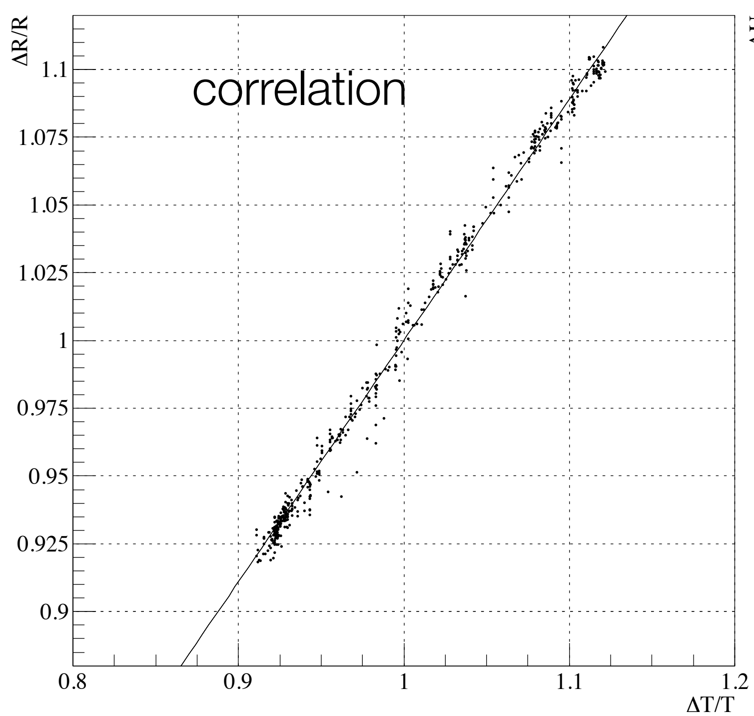
large scale anisotropy

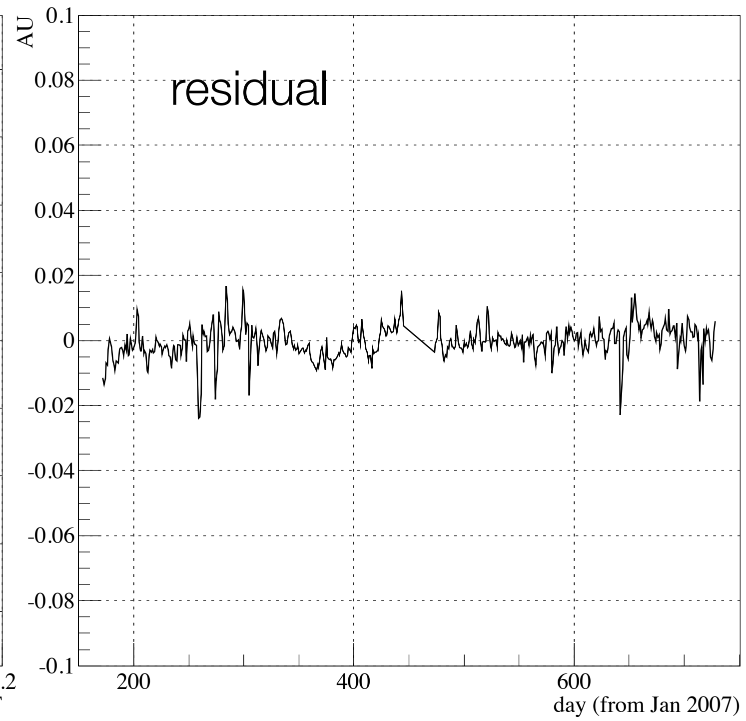
probing local interstellar magnetic field



correlation with atmospheric temperature







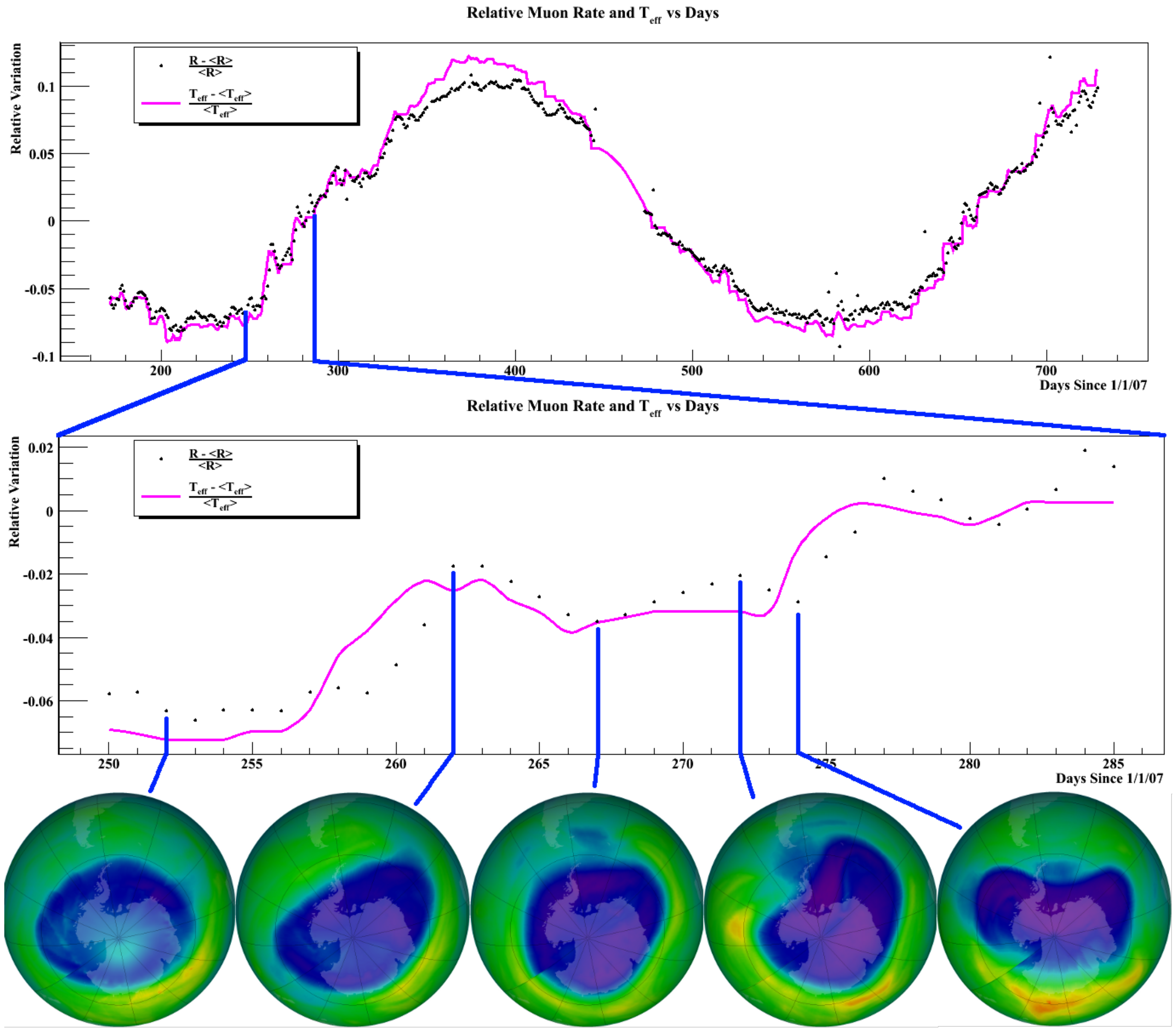
$$\frac{\Delta R_\mu}{R_\mu} = \alpha \cdot \frac{\Delta T_{eff}}{T_{eff}}$$

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

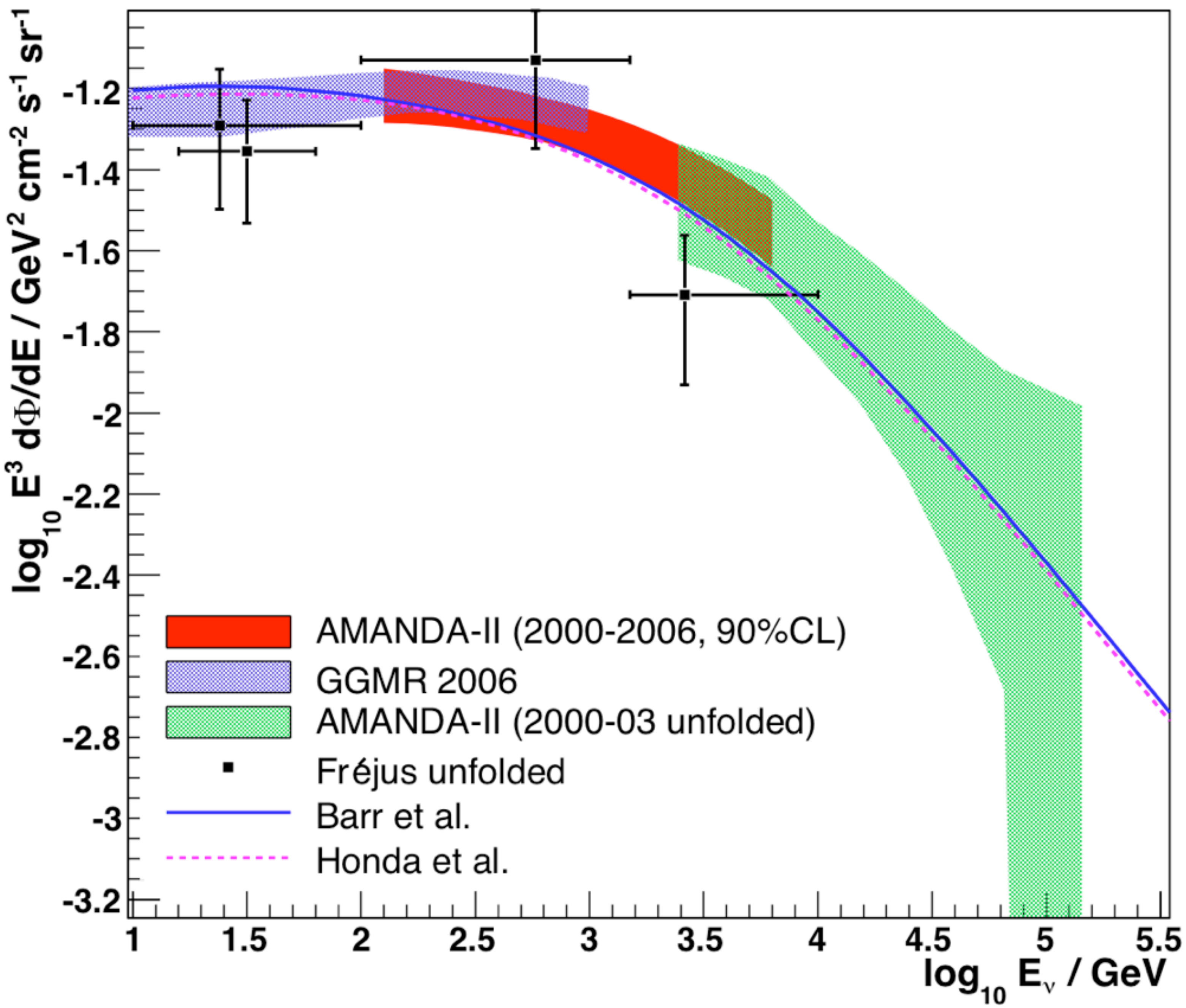
$$\alpha_T = \left\langle \frac{1}{1 + \frac{\gamma}{\gamma+1} \times \frac{\epsilon_\pi}{1.1 E_{th} \cos\theta}} \right\rangle$$

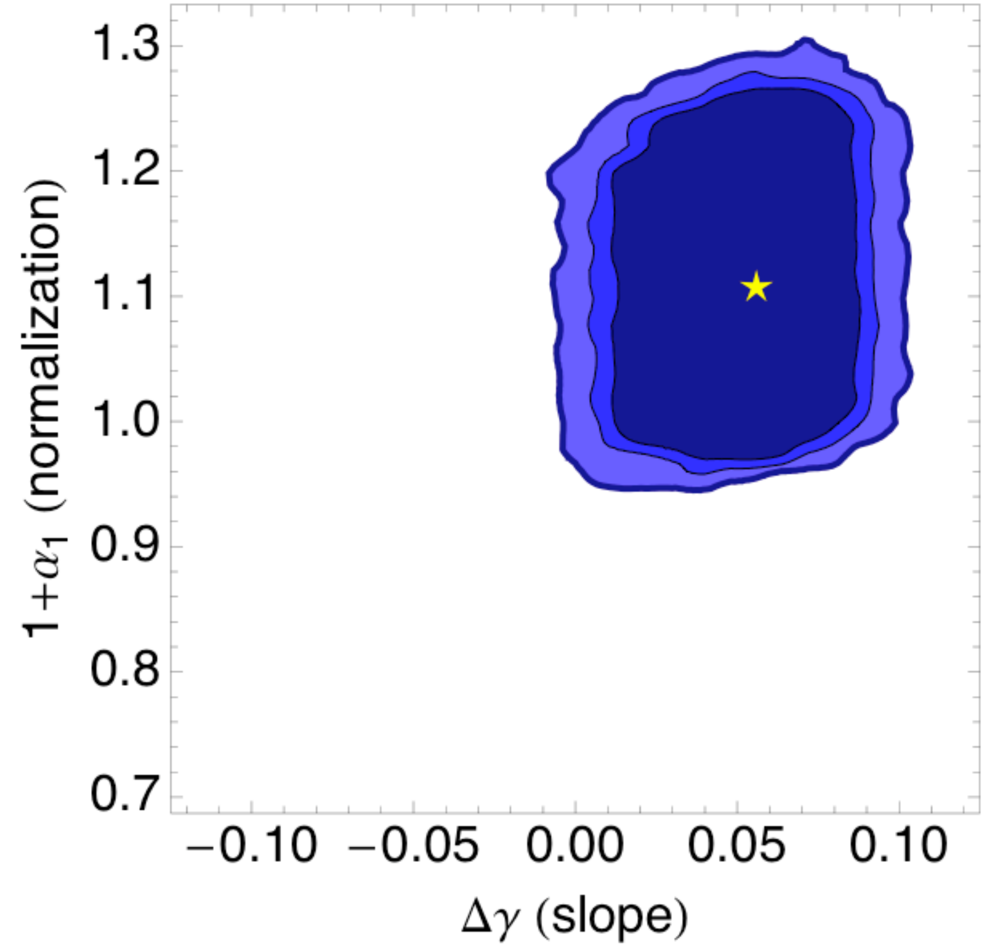
correlation with atmospheric temperature

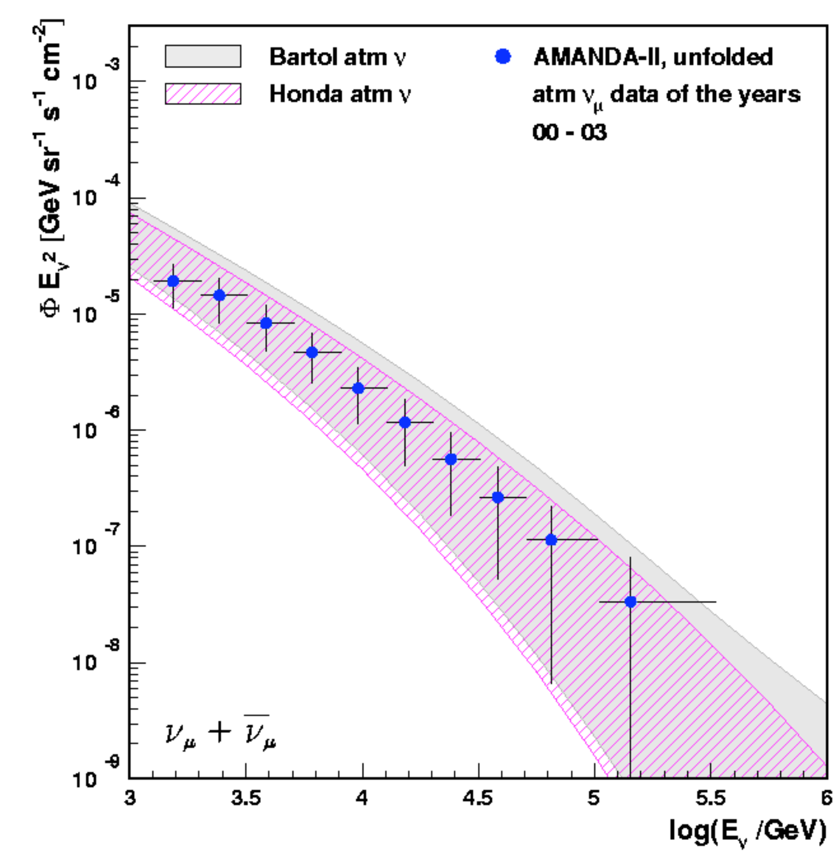
IceCube stable within ~2%



muon rate and sudden stratospheric warming

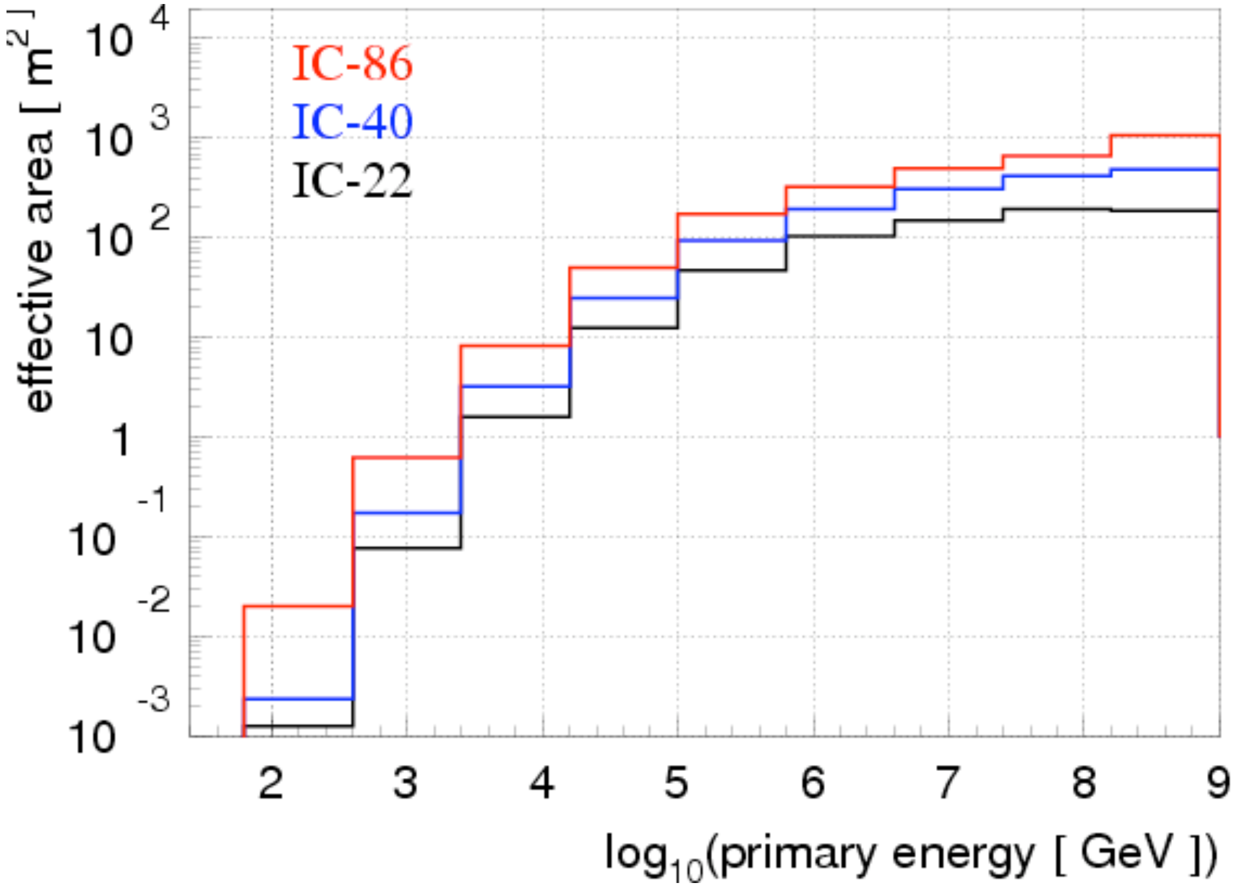


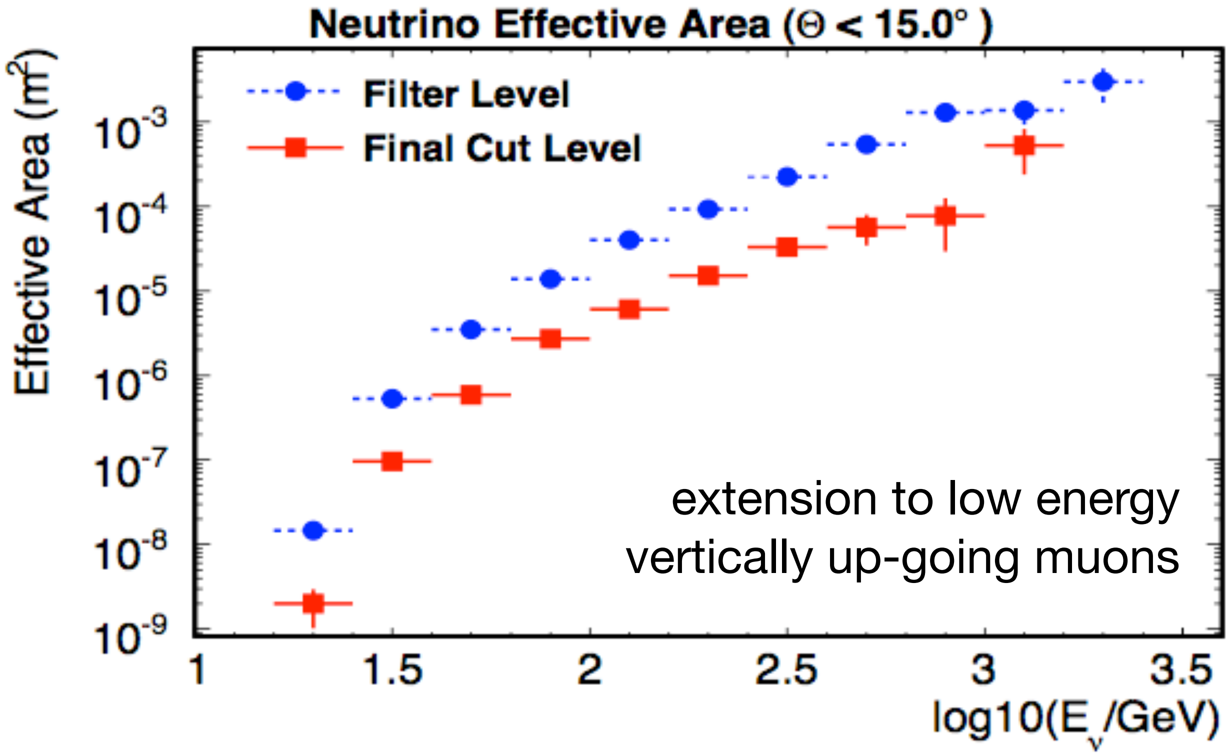




atmospheric muon neutrinos

AMANDA



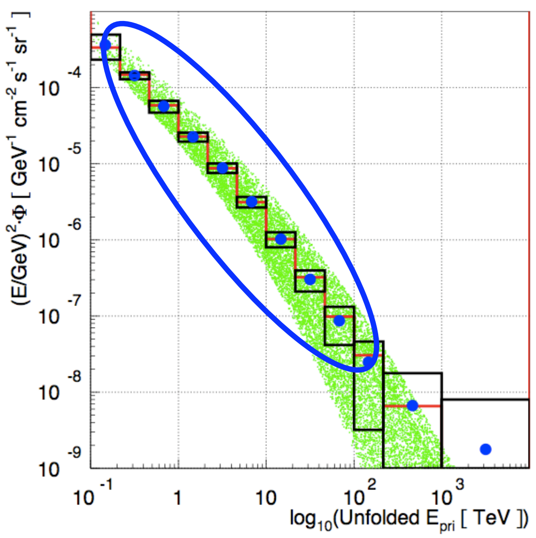


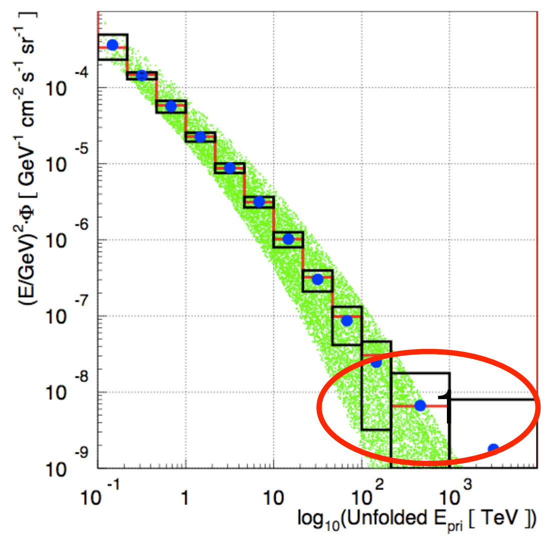
atmospheric muon neutrinos

effective area for IceCube

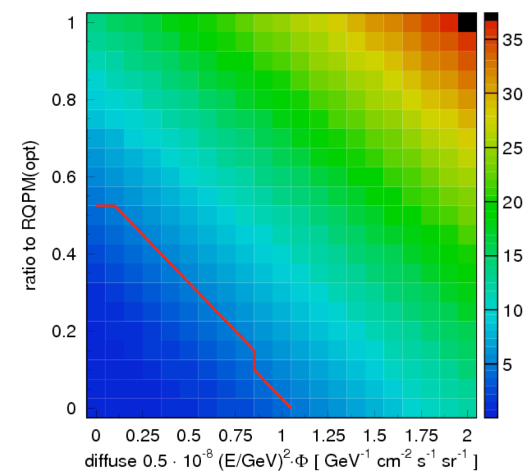
diffuse ν_μ (IceCube-22)

- search for high energy extraterrestrial neutrinos

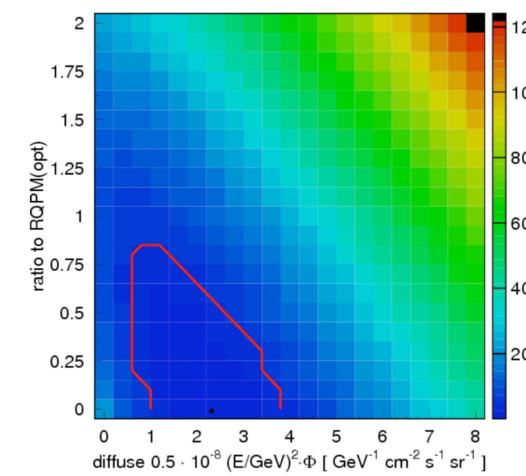


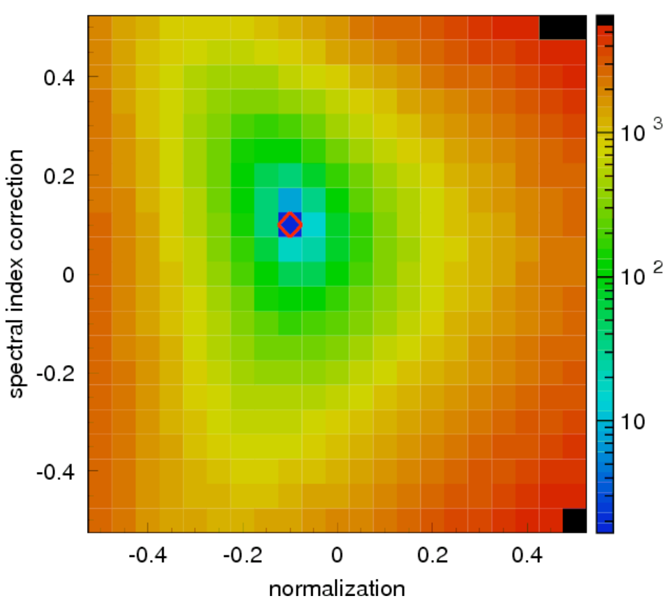


no signal



$3 \cdot 10^{-8}$ E^{-2}

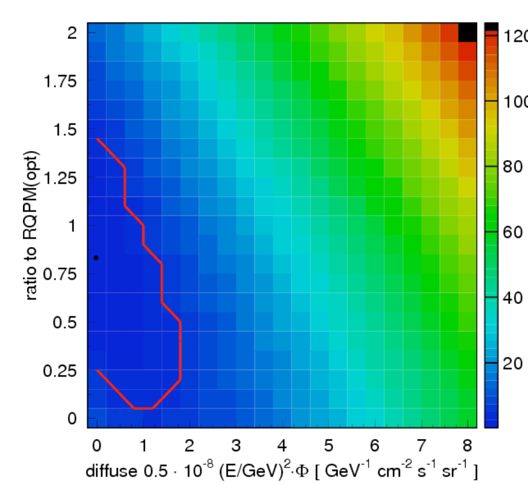




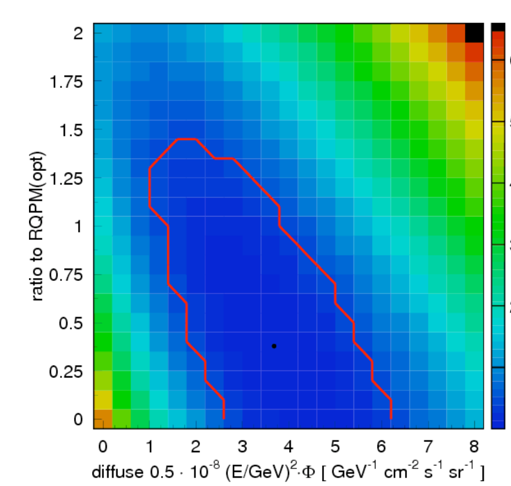
likelihood fit for deviations from Barr et al. atm spectrum

simulation study

$1 \cdot$RPQM

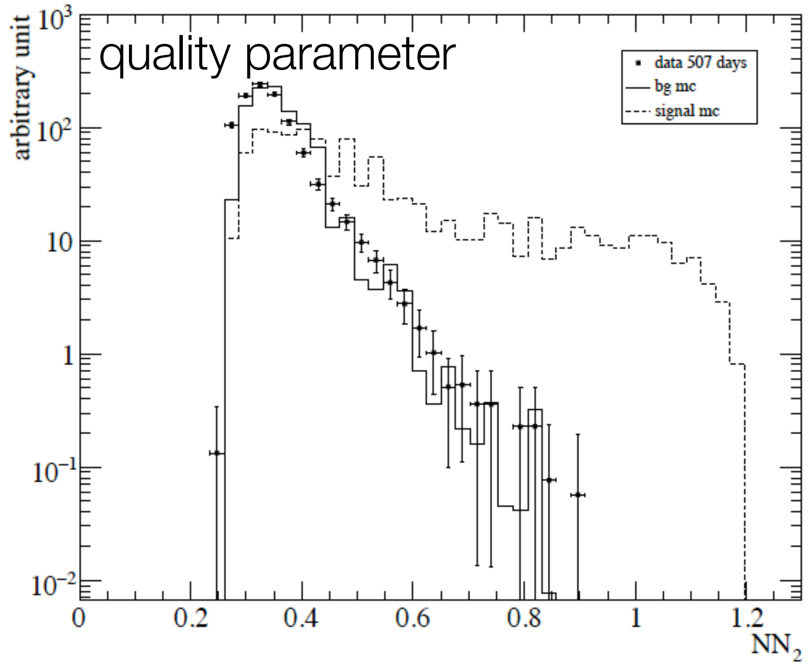


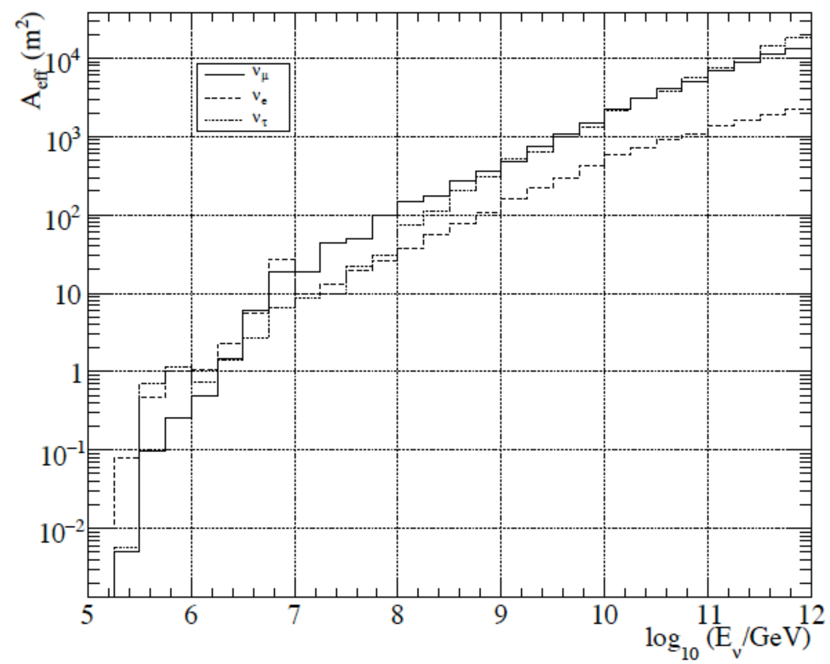
$1 \cdot$RPQM + $3 \cdot 10^{-8}$ E^{-2}

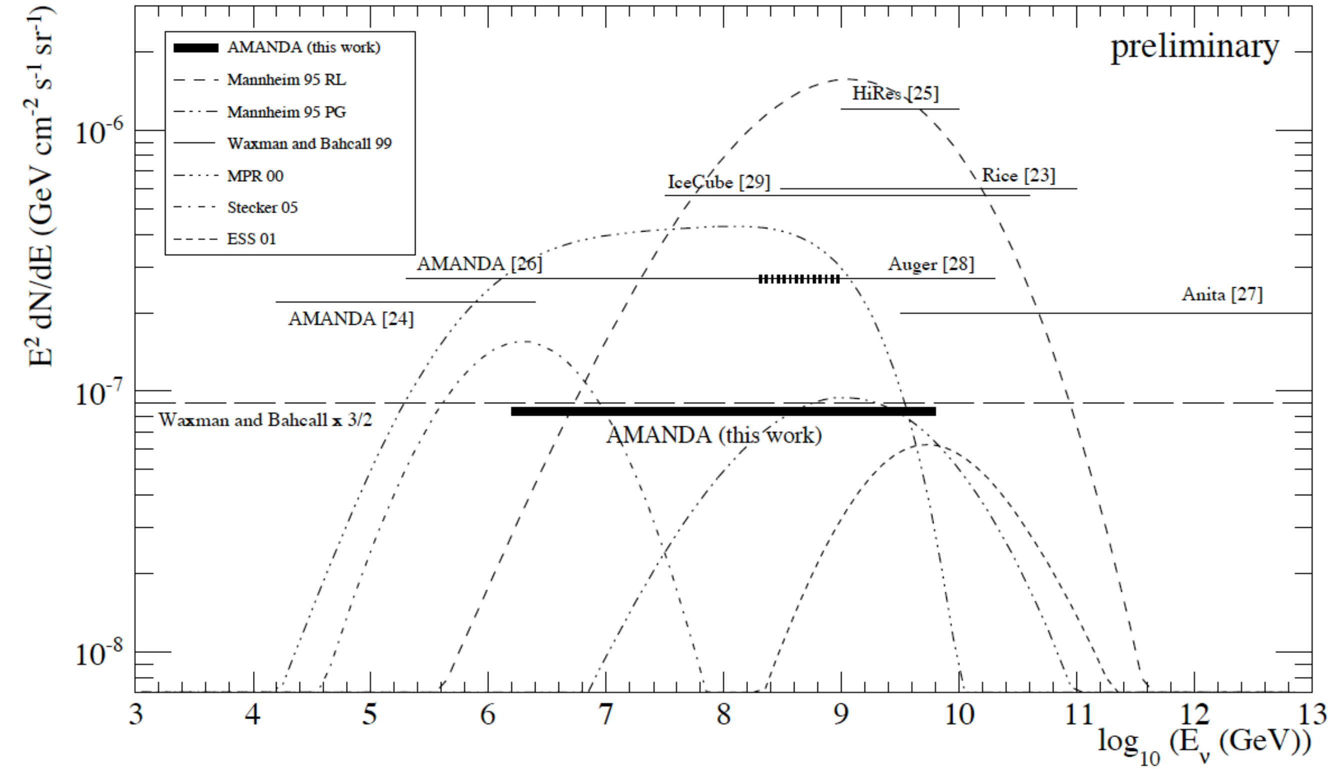


EHE ν : AMANDA

- data collected in 2003-2005







EHE ν : IceCube-22

Preliminary Error Budget

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