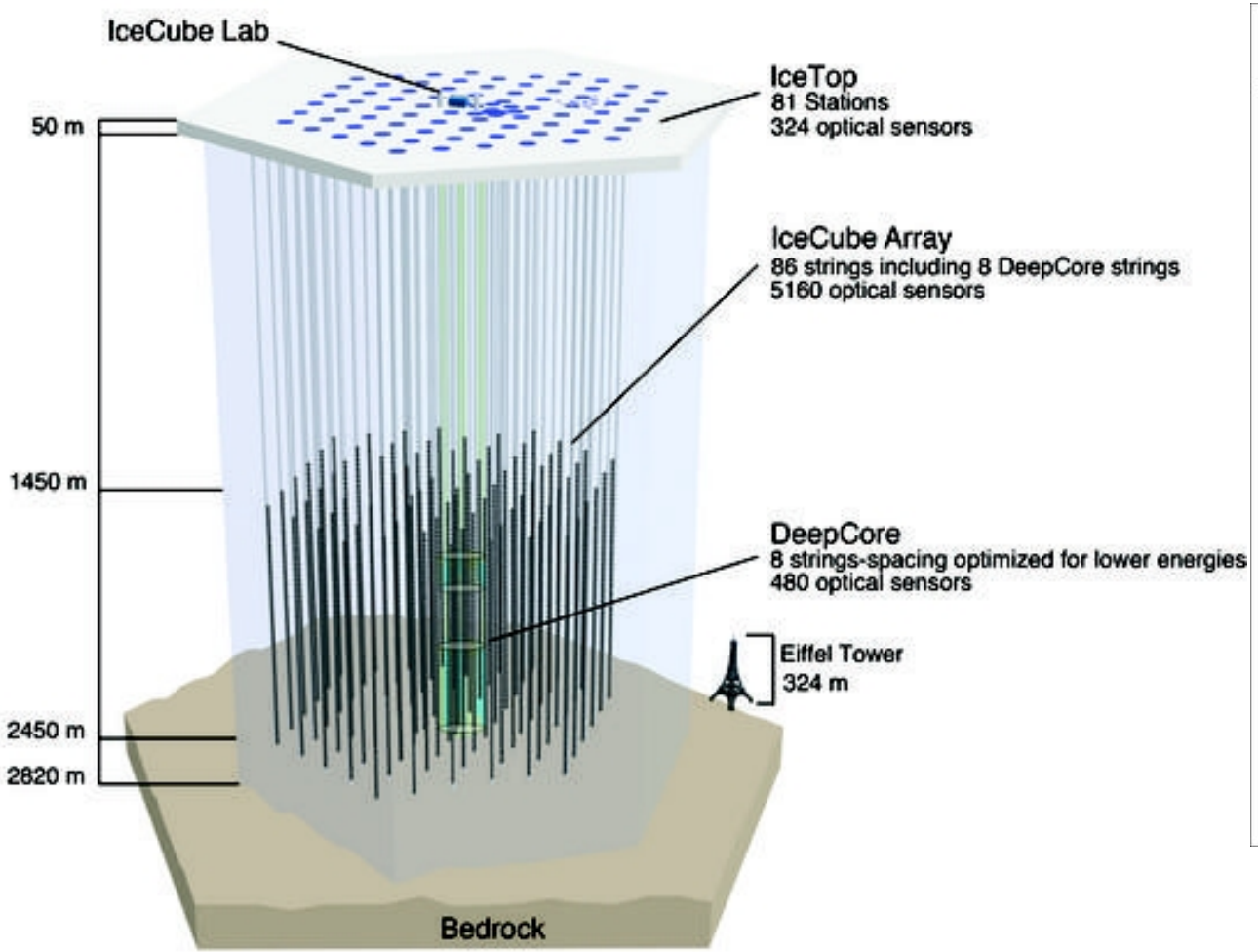
Forward Charm contribution to the Atmospheric Neutrino Flux

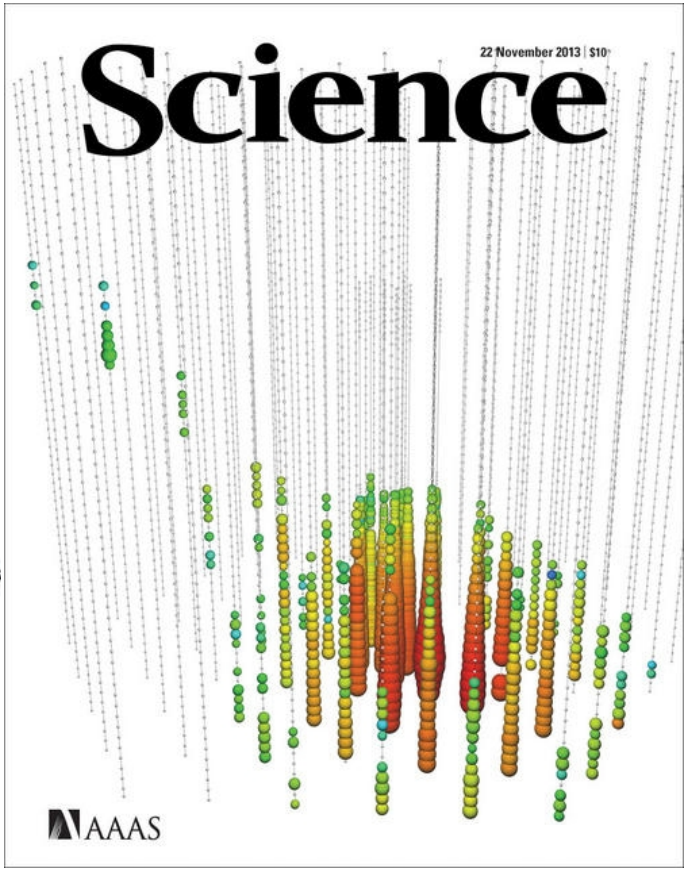
Logan Wille
in collaboration with Francis Halzen

arXiv 1605.01409

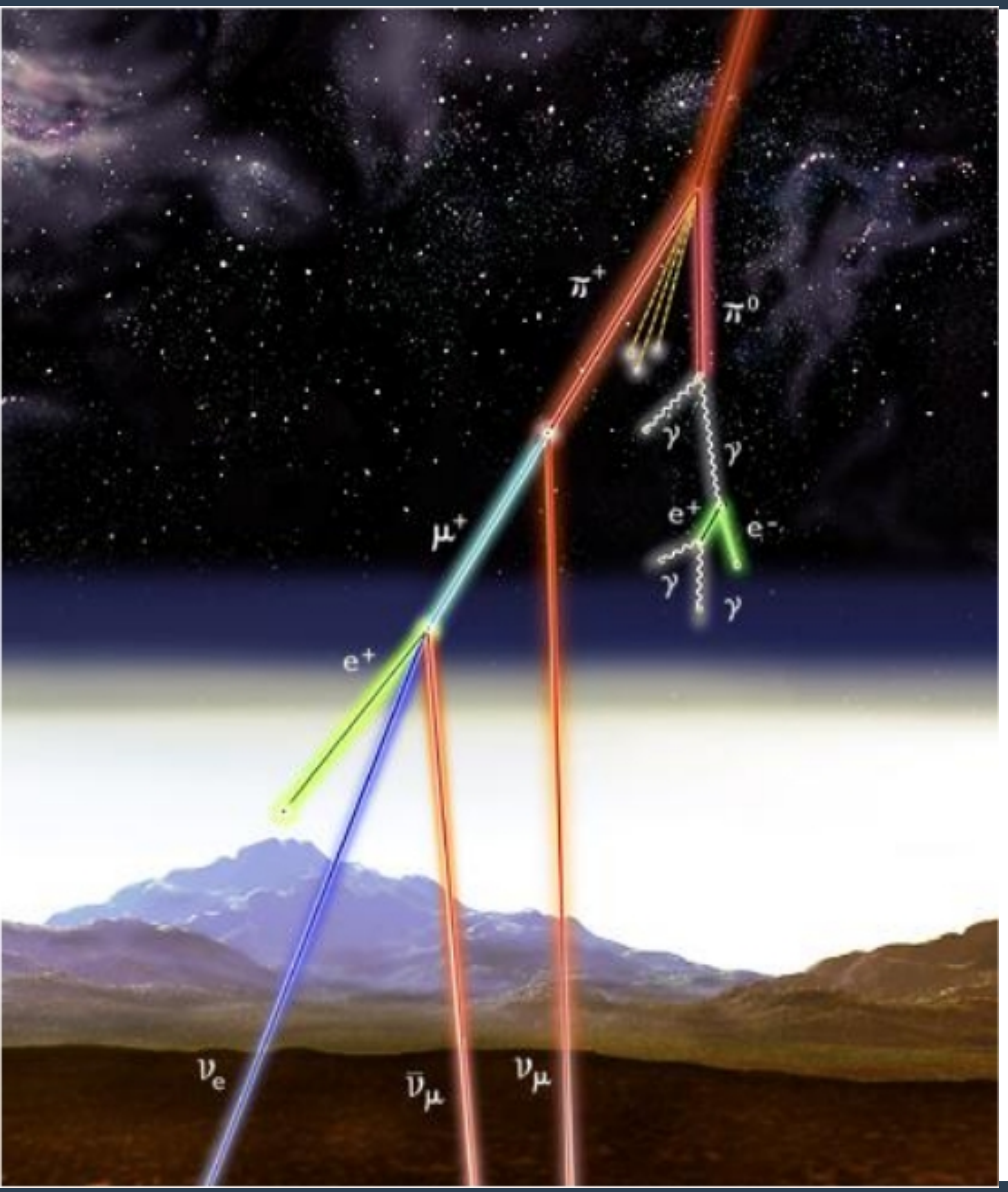
Implication of LHCb Measurements
and Future Prospects Workshop
10/13/2016

IceCube


IceCube Lab
IceTop
81 Stations
324 optical sensors
50 m
IceCube Array
86 strings including 8 DeepCore strings
5160 optical sensors
1450 m
DeepCore
8 strings-spacing optimized for lower energies
480 optical sensors
Eiffel Tower
324 m
2450 m
2820 m
Bedrock

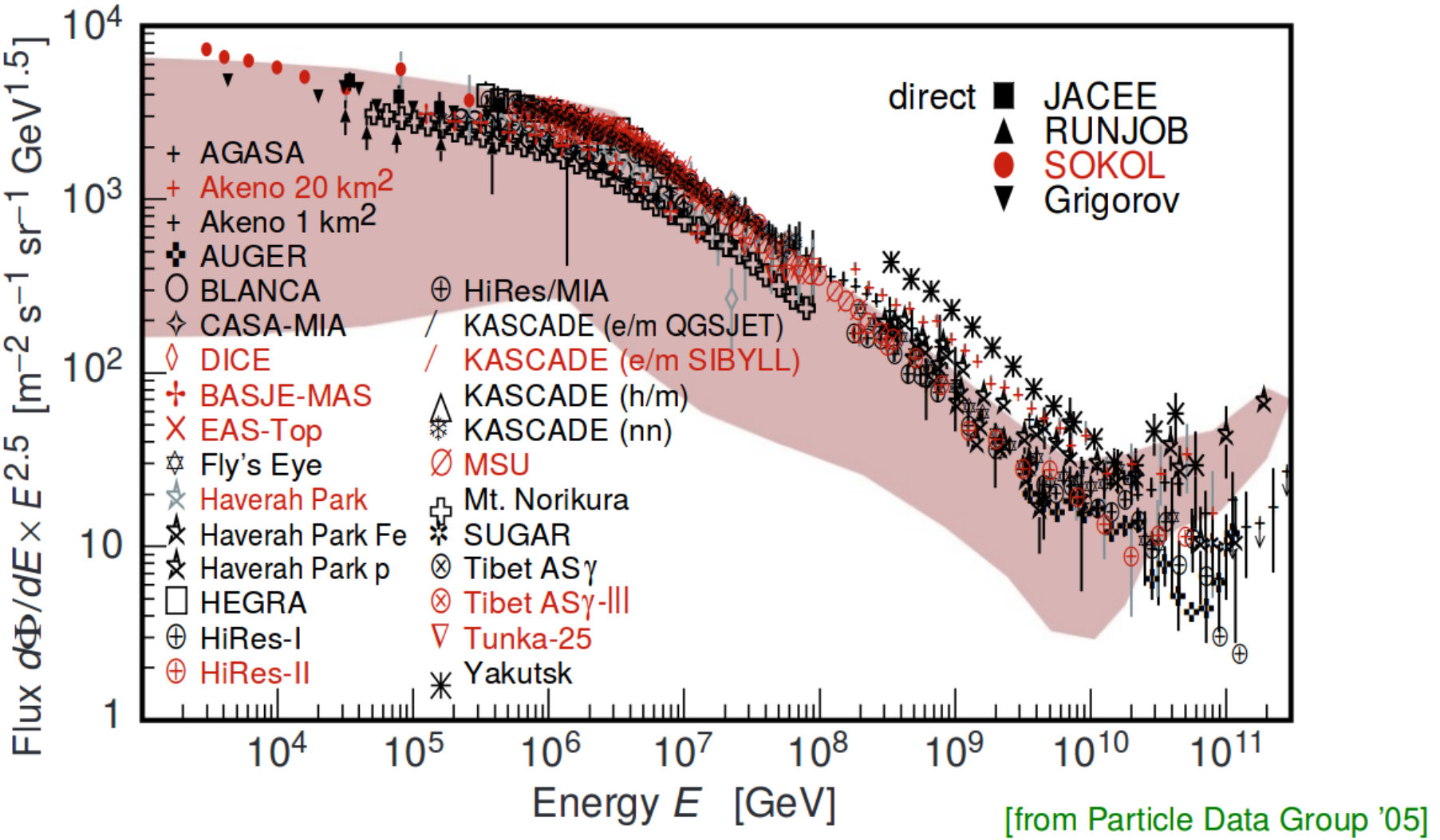

Science
22 November 2013 | $10
AAAS

Atmospheric Neutrinos



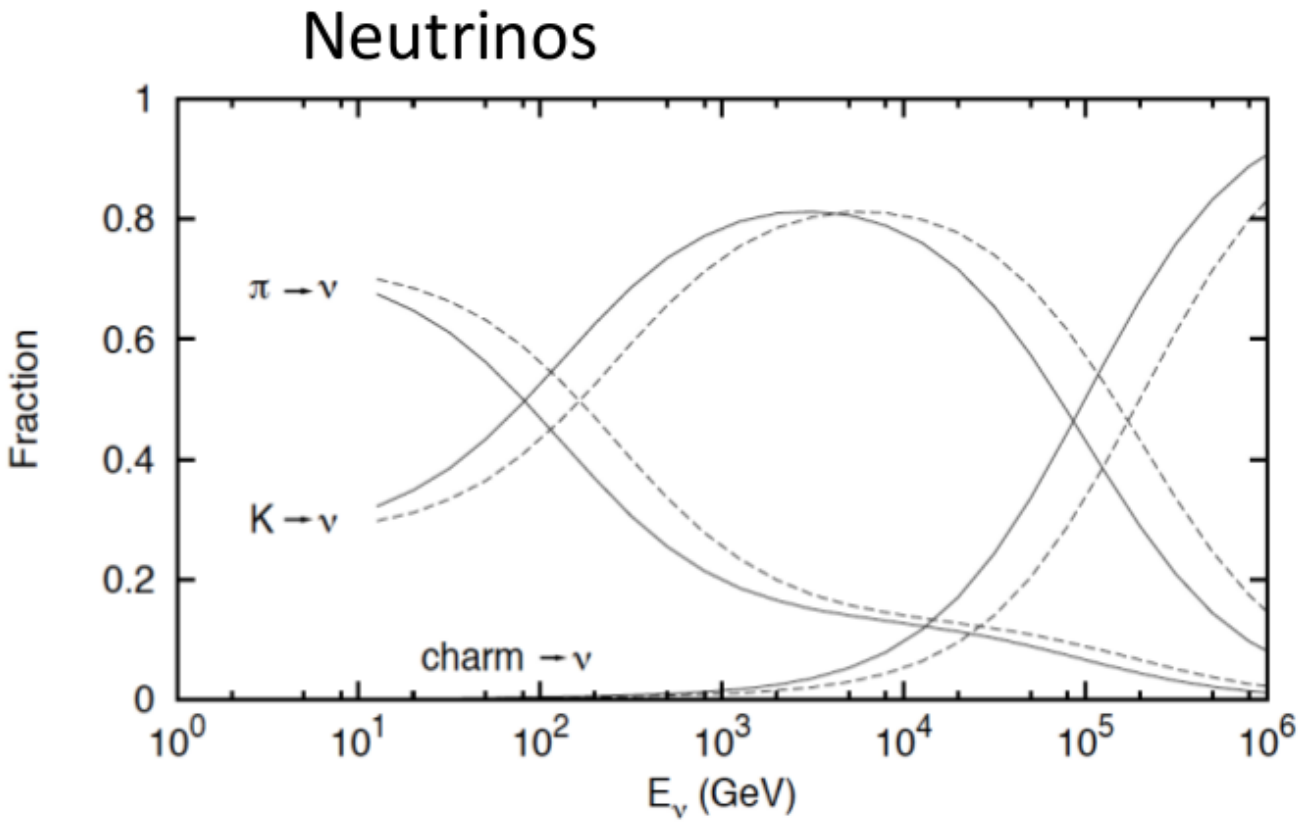
- **Cosmic rays can reach energies of order EeV (10^{19} eV) creating large particle showers**
- **The atmosphere is essentially a beam dump for high energy cosmic rays**
- **While particles produced in all phase spaces reach IceCube, forward production has the largest contribution**

Cosmic Rays



[from Particle Data Group '05]

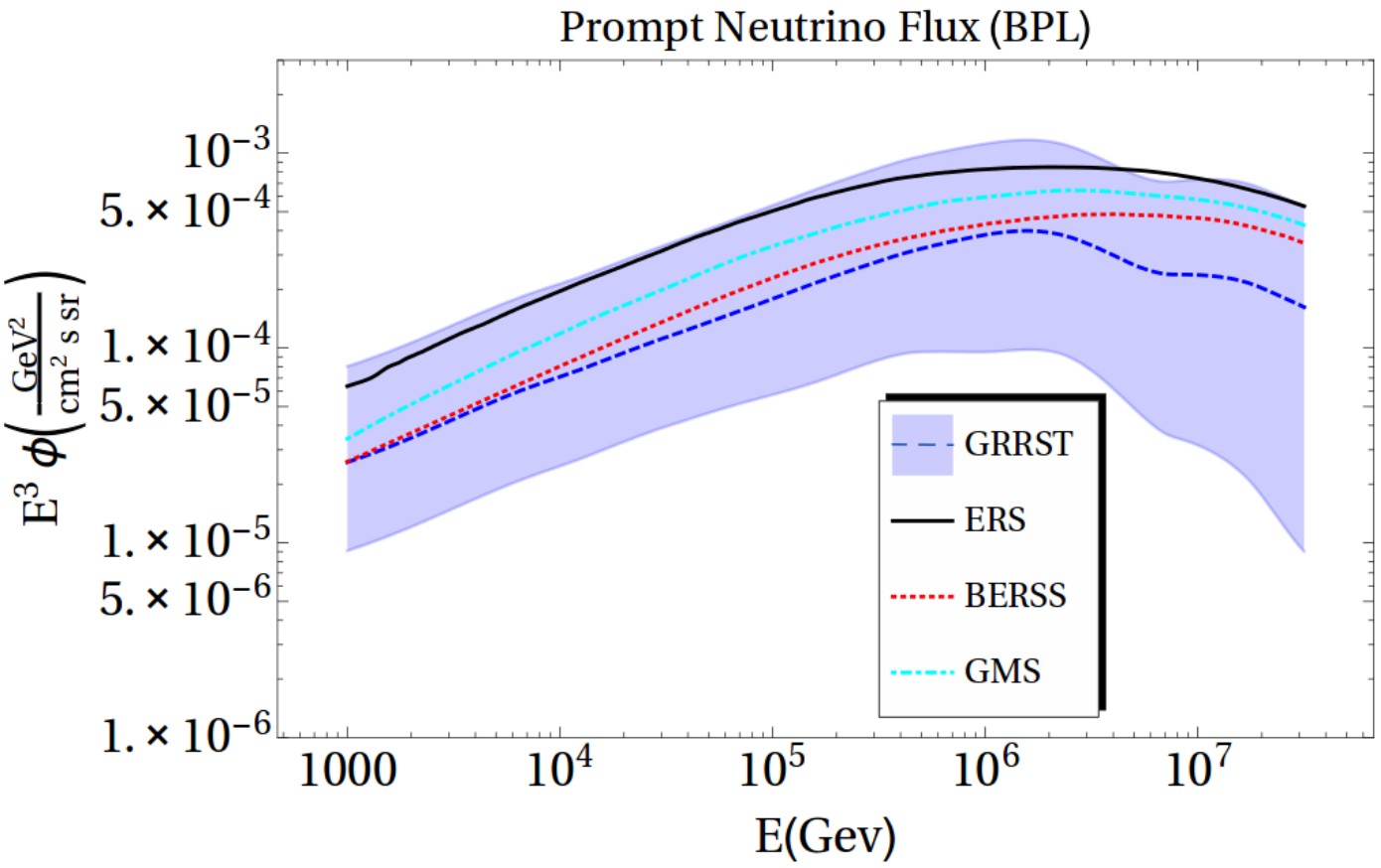
Neutrino Fluxes



- **At high energies, the pions and kaons are long lived and lose energy through interactions in the atmosphere**
- **Charm particles, while produced less often, decay promptly into neutrinos, extending the spectrum to high energies**

P. Desiati et. al.
arXiv: 1008.2211

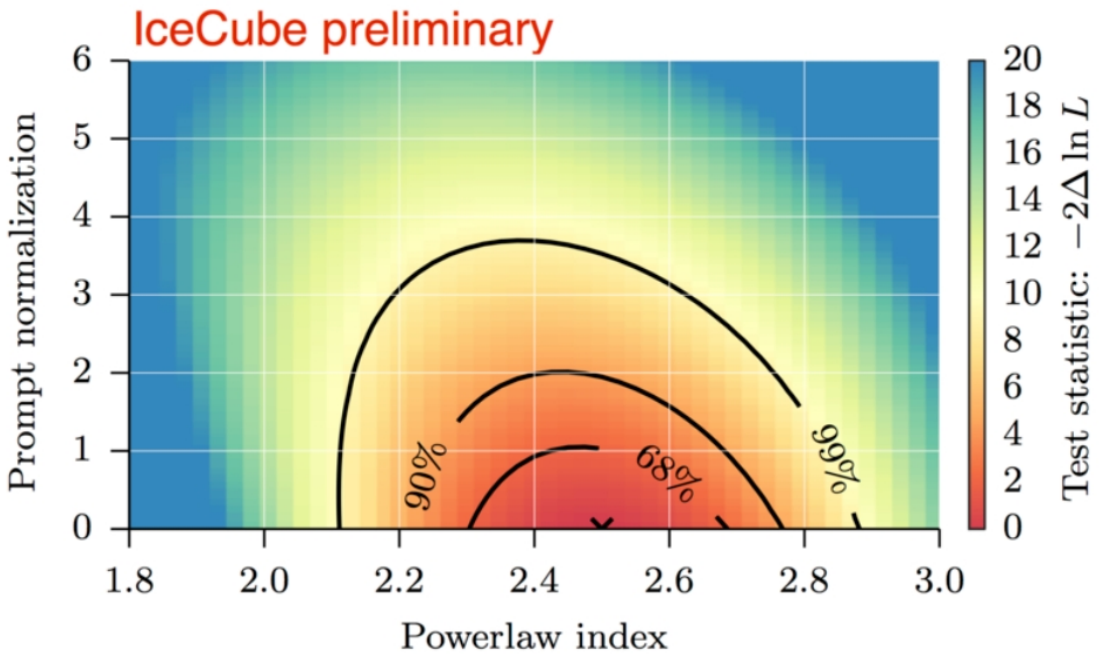
Prompt Neutrino Flux

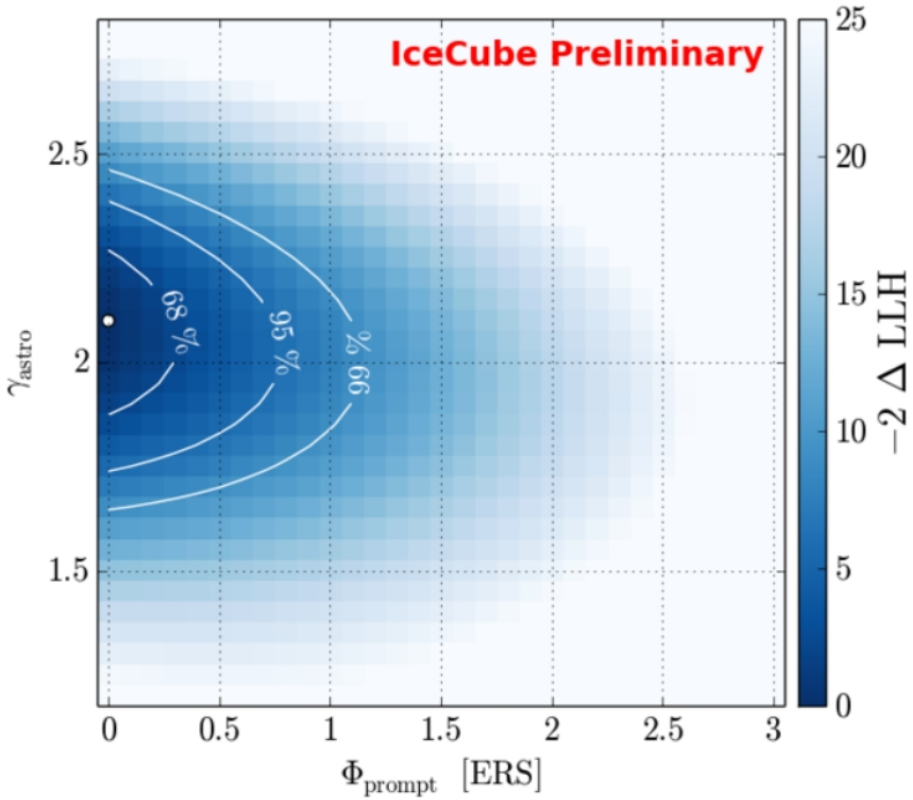


- **Several predictions of the prompt neutrino flux exist, however all focus on pQCD**
- **Large uncertainties in predictions even when only considering pQCD**

R. Gauld et. al.
arXiv: 1511.06346

IceCube Prompt Flux Limits





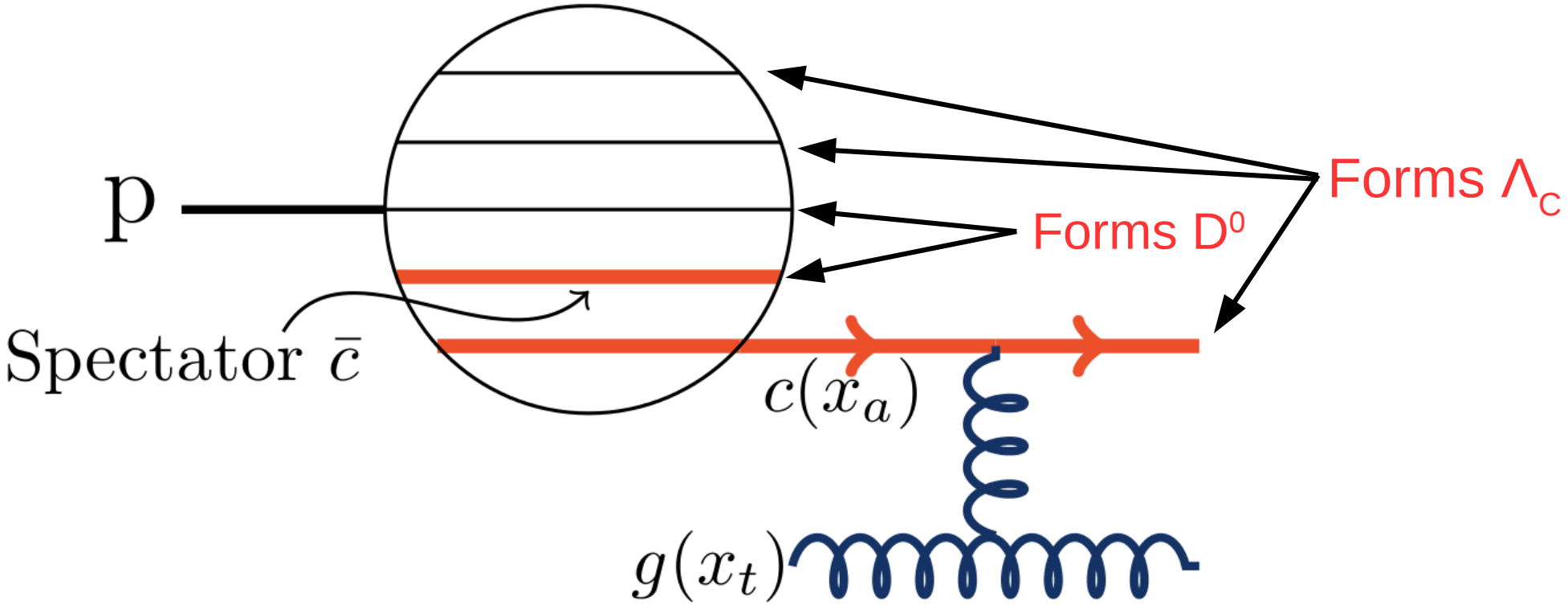
- **IceCube has not observed the predicted prompt fluxes**

arXiv: 1607.08006
ArXiv: 1410.1749

Why investigate Forward charm?

- **IceCube primarily sees the 'beamline' of the cosmic ray interaction, and so forward charm can potentially create a large prompt flux with a harder spectrum**
- **This large prompt flux would create features in the high energy neutrino flux and be a large foreground to cosmic neutrinos**

What is Forward Charm?

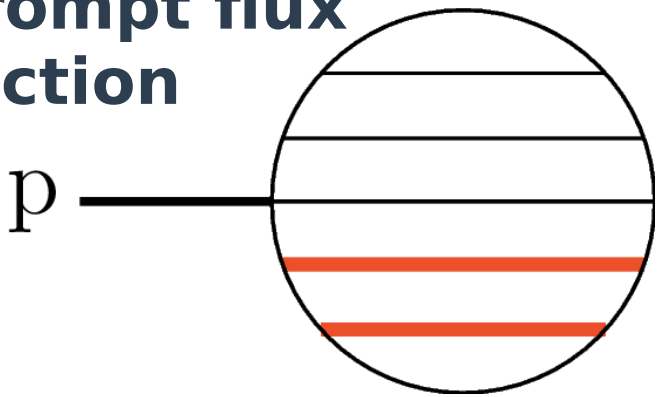


V. Barger, F. Halzen, and W. Y. Keung, Phys. Rev. D **25**, 112 (1982).

The Forward Charm

- **We use a model independent parameterization of forward charm production. This allows us flexibility to investigate how the prompt flux changes in relation to charm production**

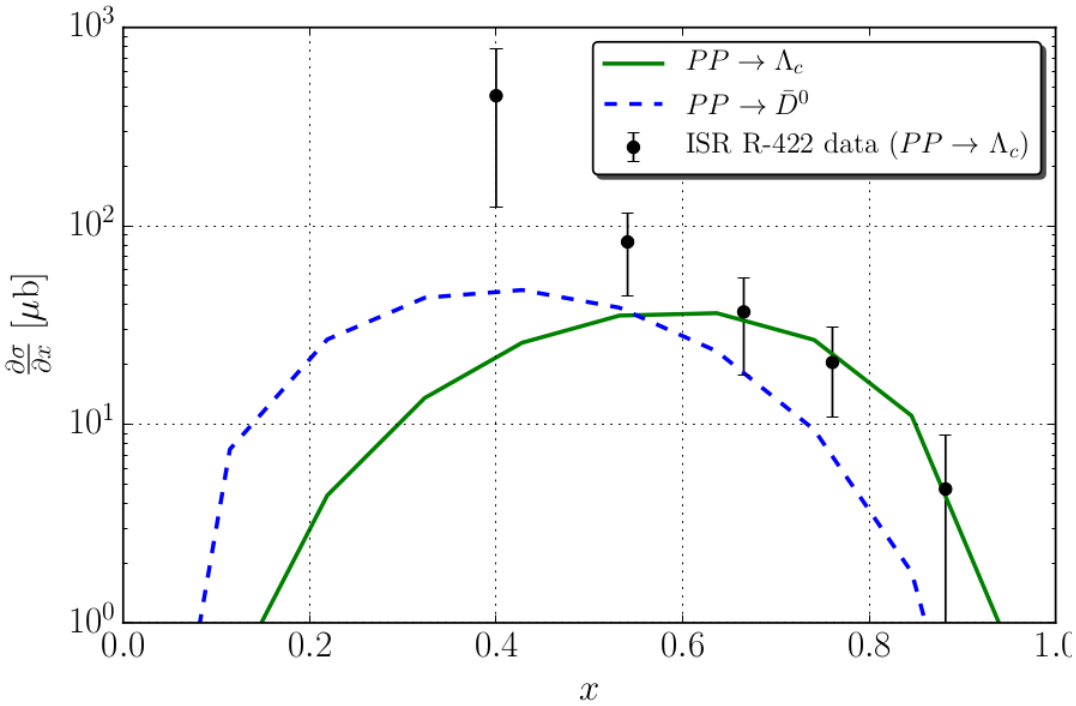
$$\frac{d\sigma}{dx_F} = g(x_F) f(E_p)$$

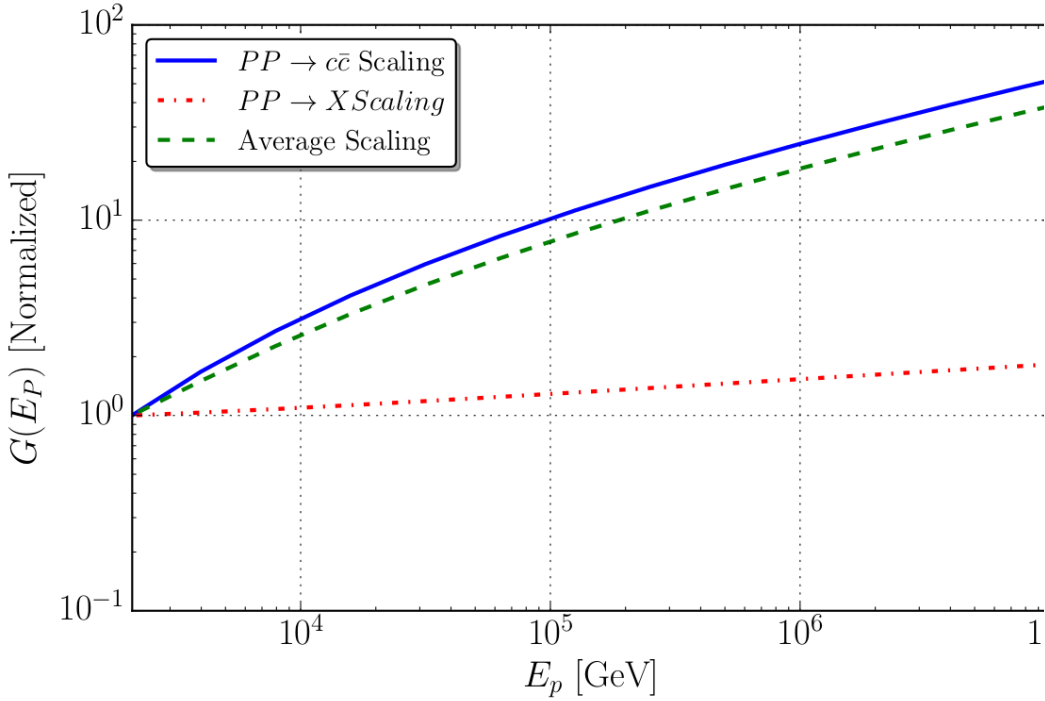


$$x_F = \frac{p_z}{P}$$

- **Our goal is to draw an upper limit prompt flux that matches forward charm data and doesn't exceed measured atmospheric neutrino data**

Charm Parameterization

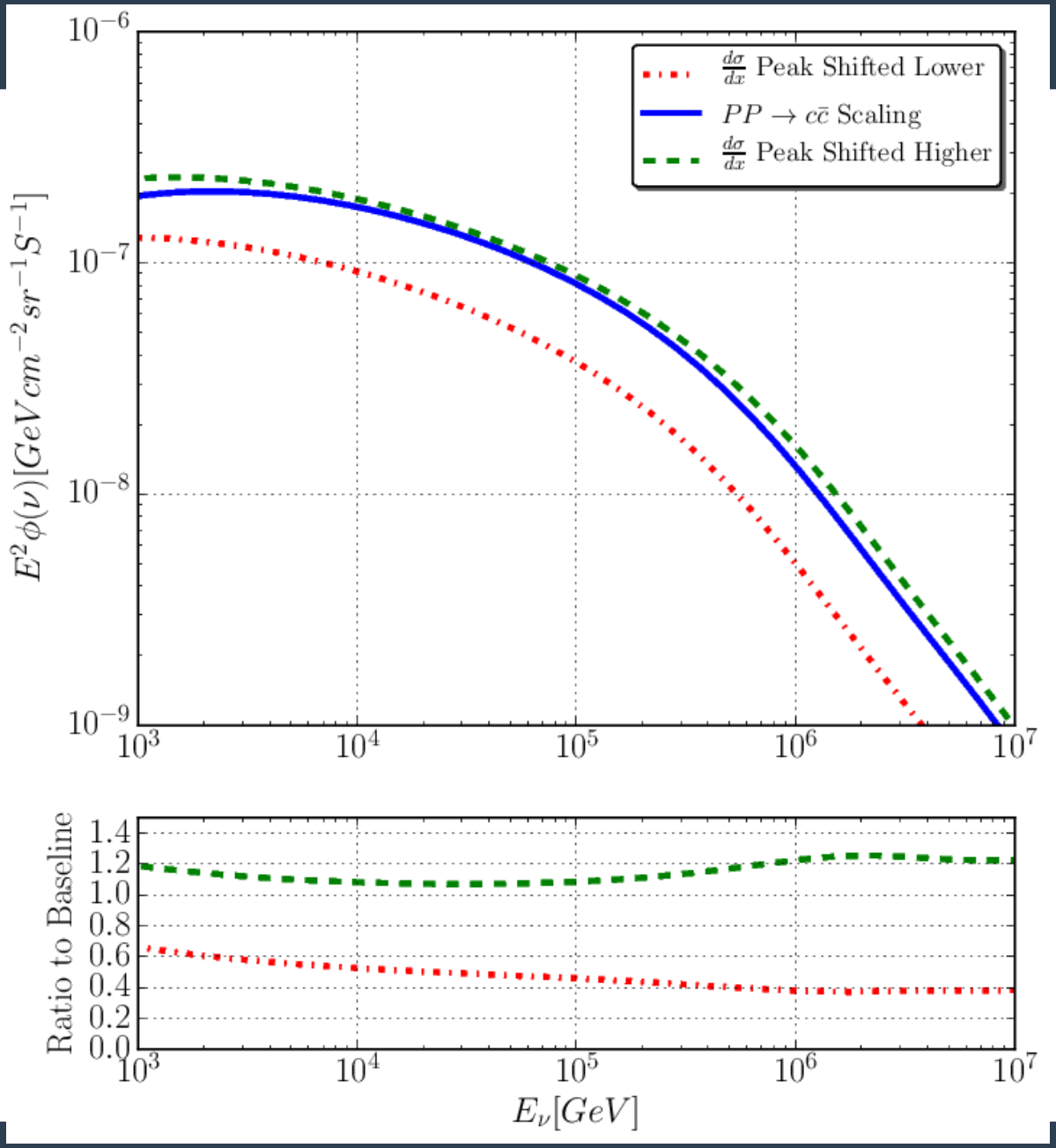




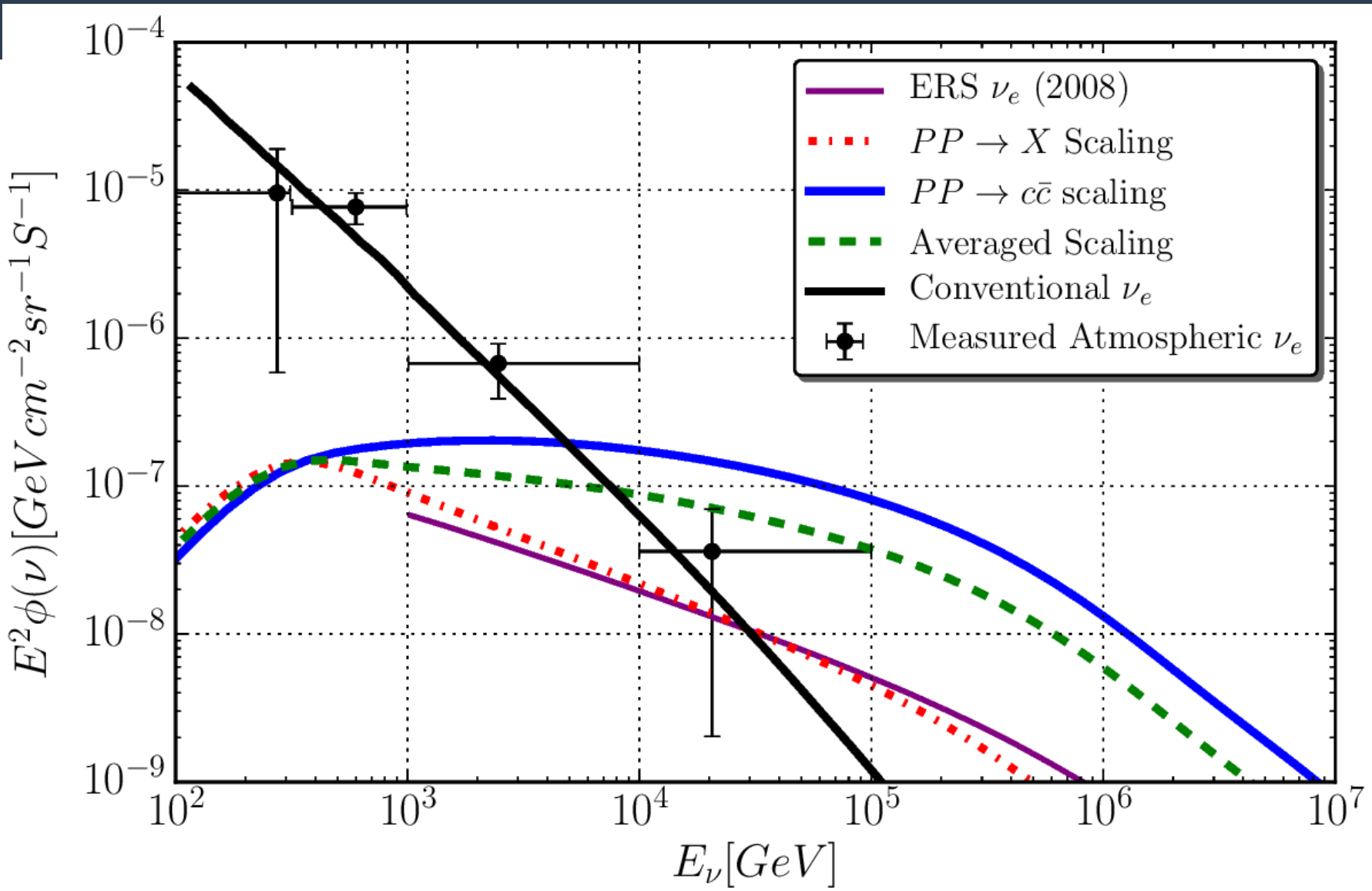
$$\frac{d\sigma}{dx_F} = g(x_F)f(E_p)$$

G. Bari et al., Nuovo Cim. **A104**, 571 (1991).

Fluxes when changing shape

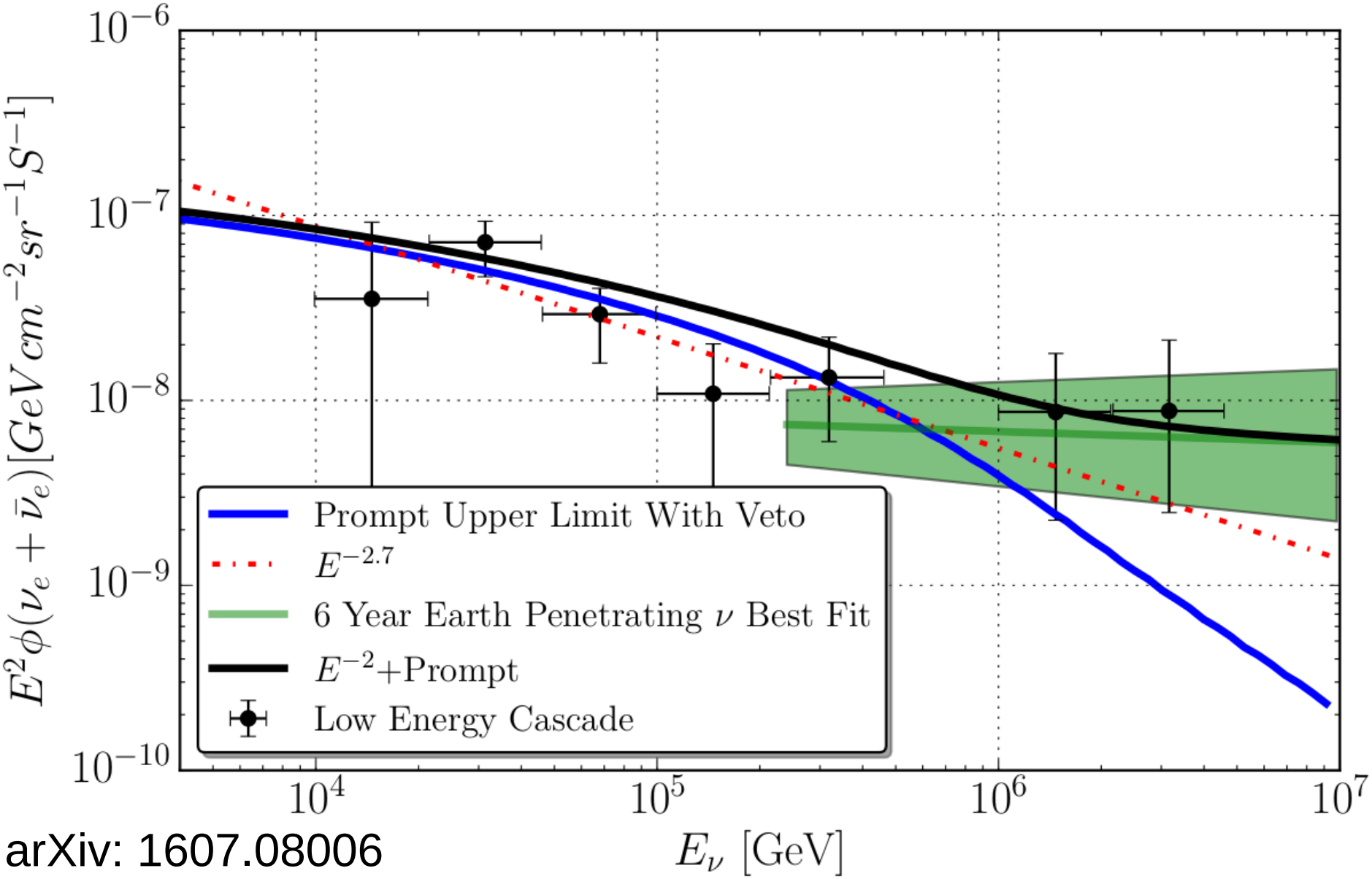


Fluxes when changing Scaling



M. G. Aartsen et al. (IceCube), Phys. Rev. **D91**, 122004 (2015), 1504.03753.

Prompt flux with E^-2 Spectrum

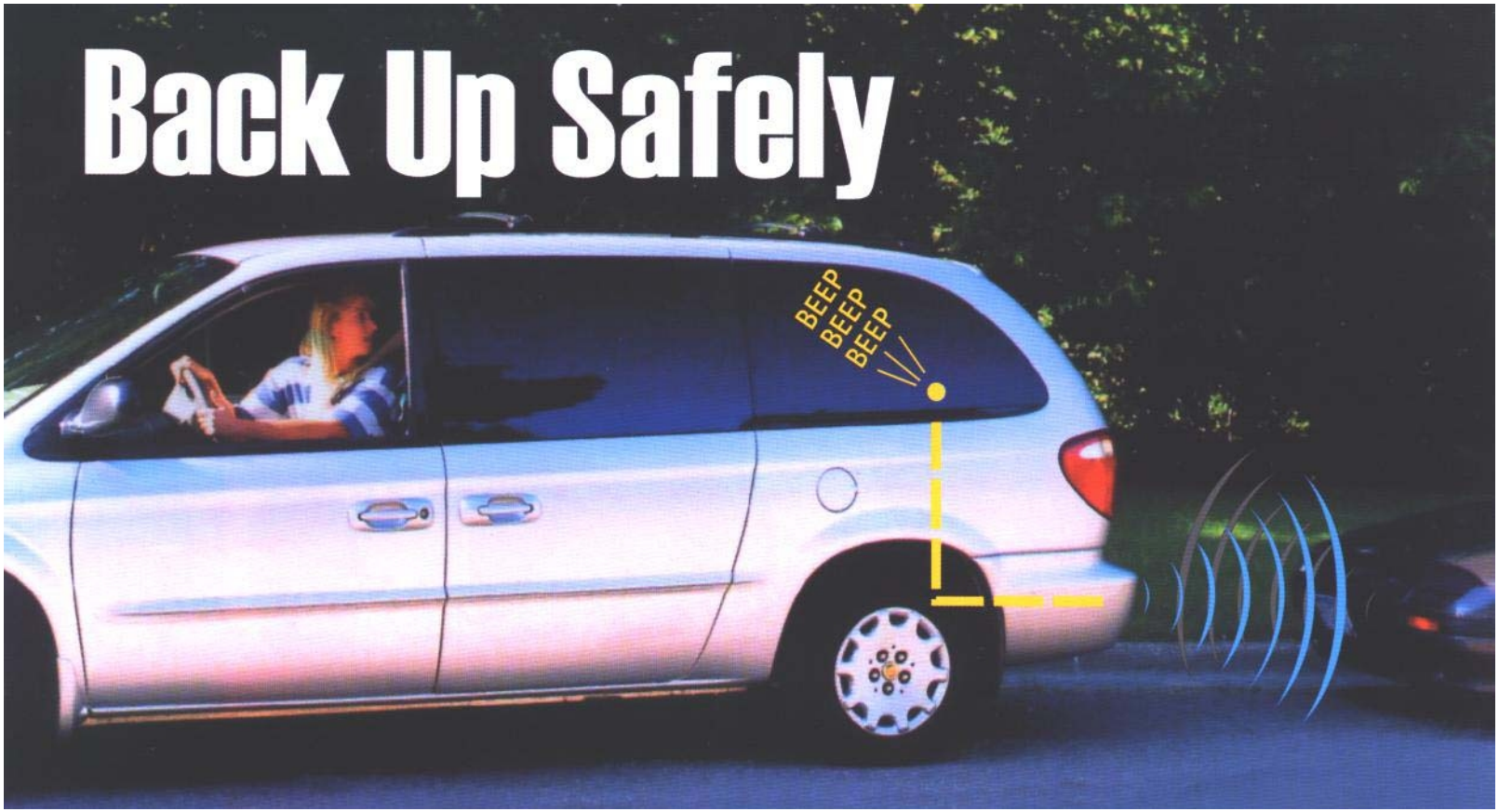


arXiv: 1607.08006
arXiv: 1502.03376

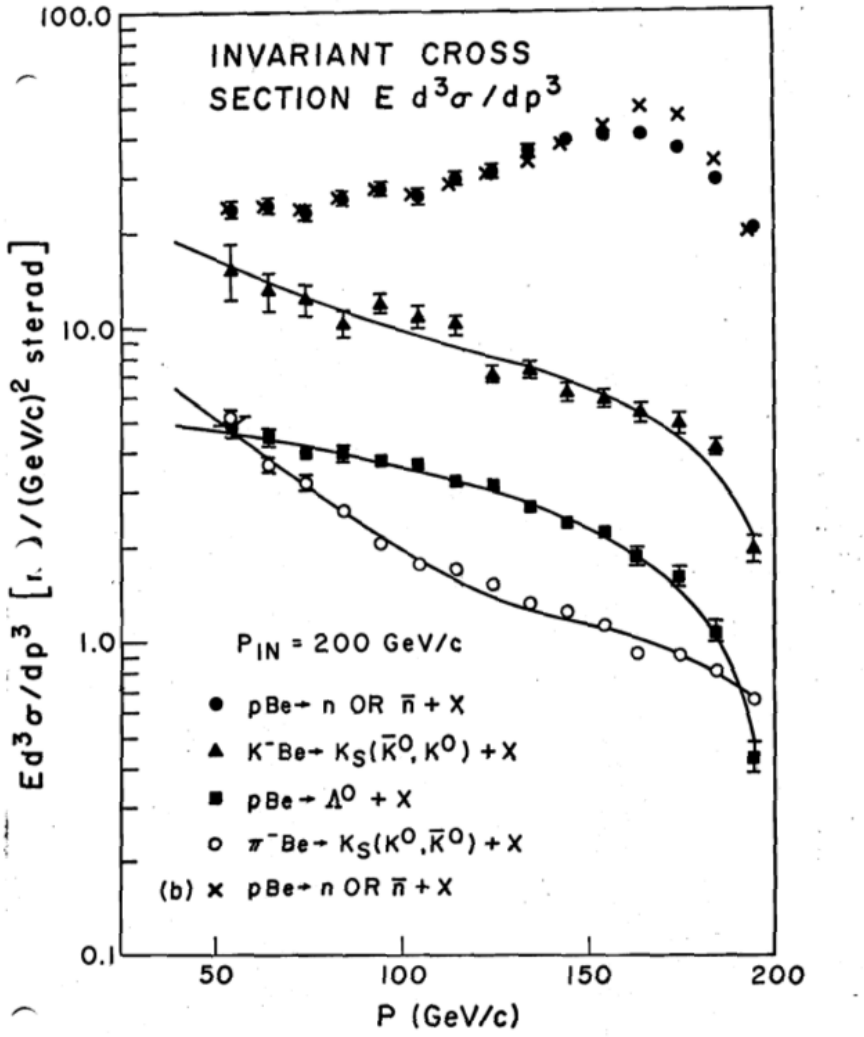
What we can conclude

- **Forward charm can add a very significant prompt neutrino flux, however, it is difficult to make a prediction due to very limited data**
- **IceCube could look for forward charm which would compliment LHCb searches**
- **We need more data of charm production in the forward direction for better predictions**

Thanks!

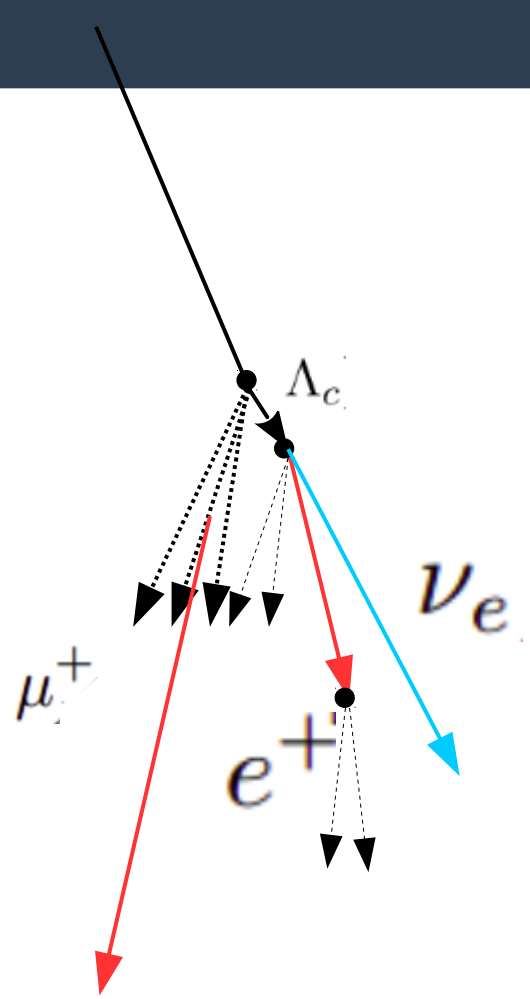

Back Up Safely
BEEP
BEEP
BEEP

Forward strange production also occurs for $K^+\Lambda$

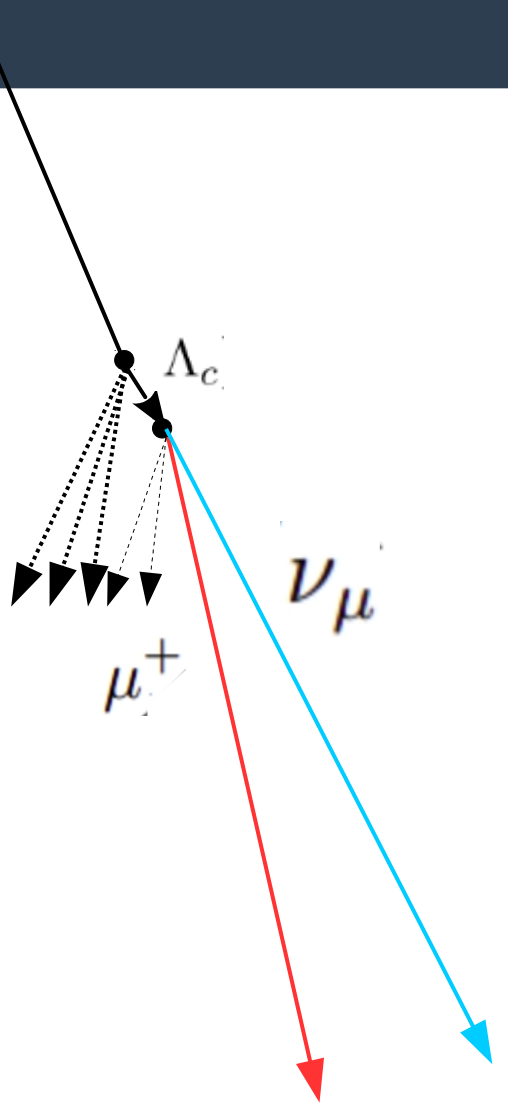


R. T. Edwards et al., Phys. Rev. **D18**, 76 (1978).

Muon Airshower Types

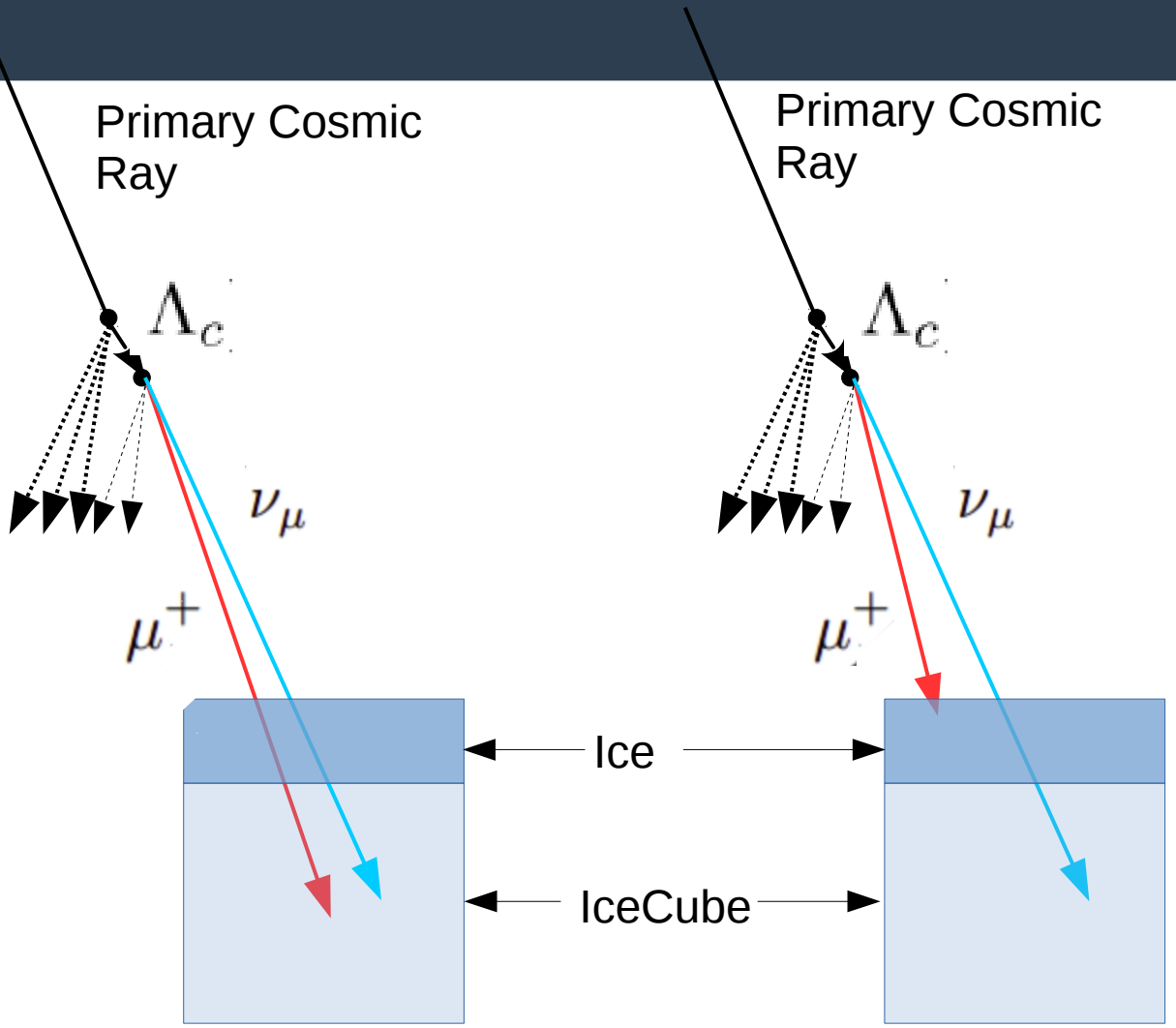


Uncorrelated Muon



Correlated Muon

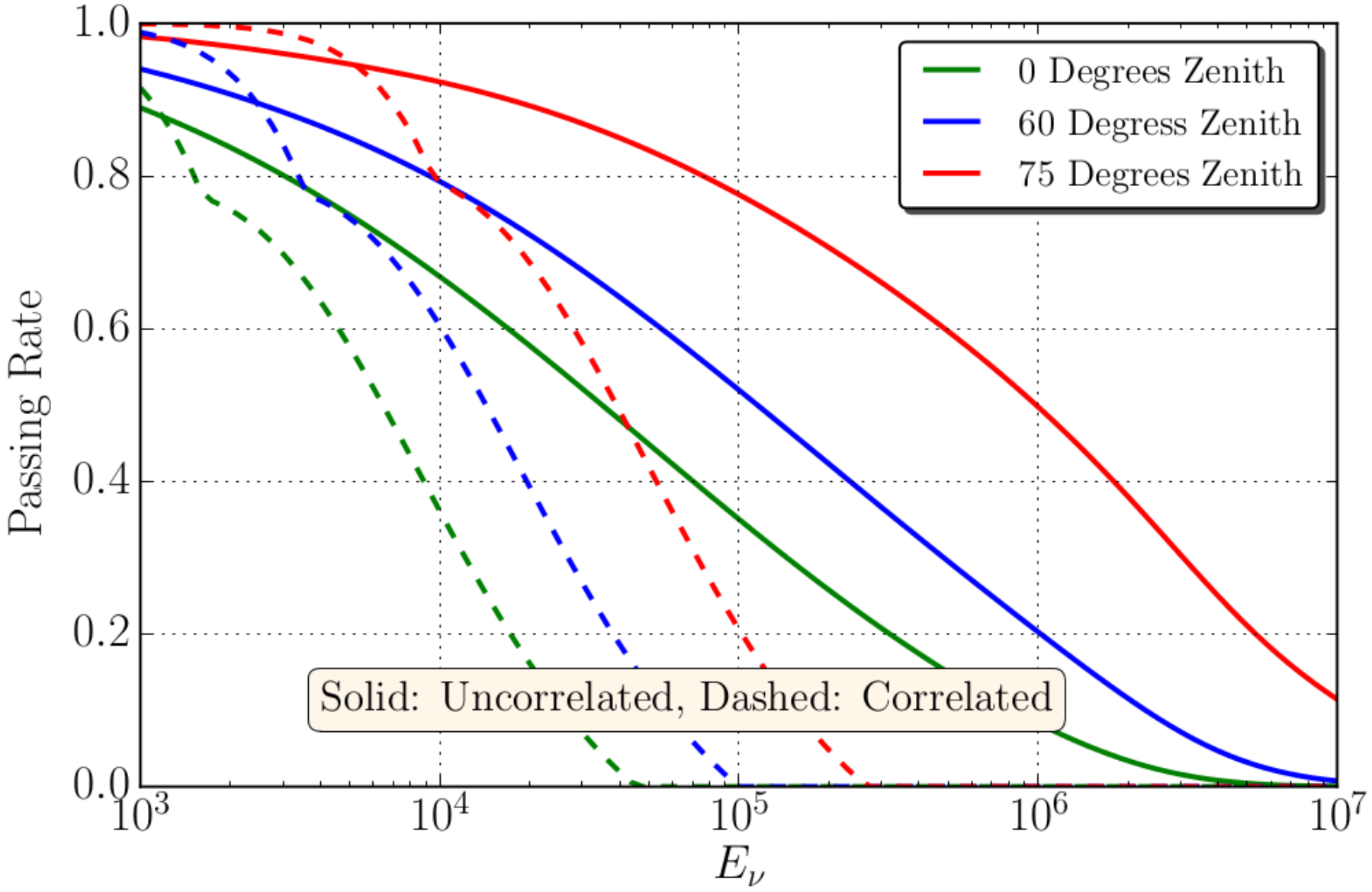
The Self-veto effect



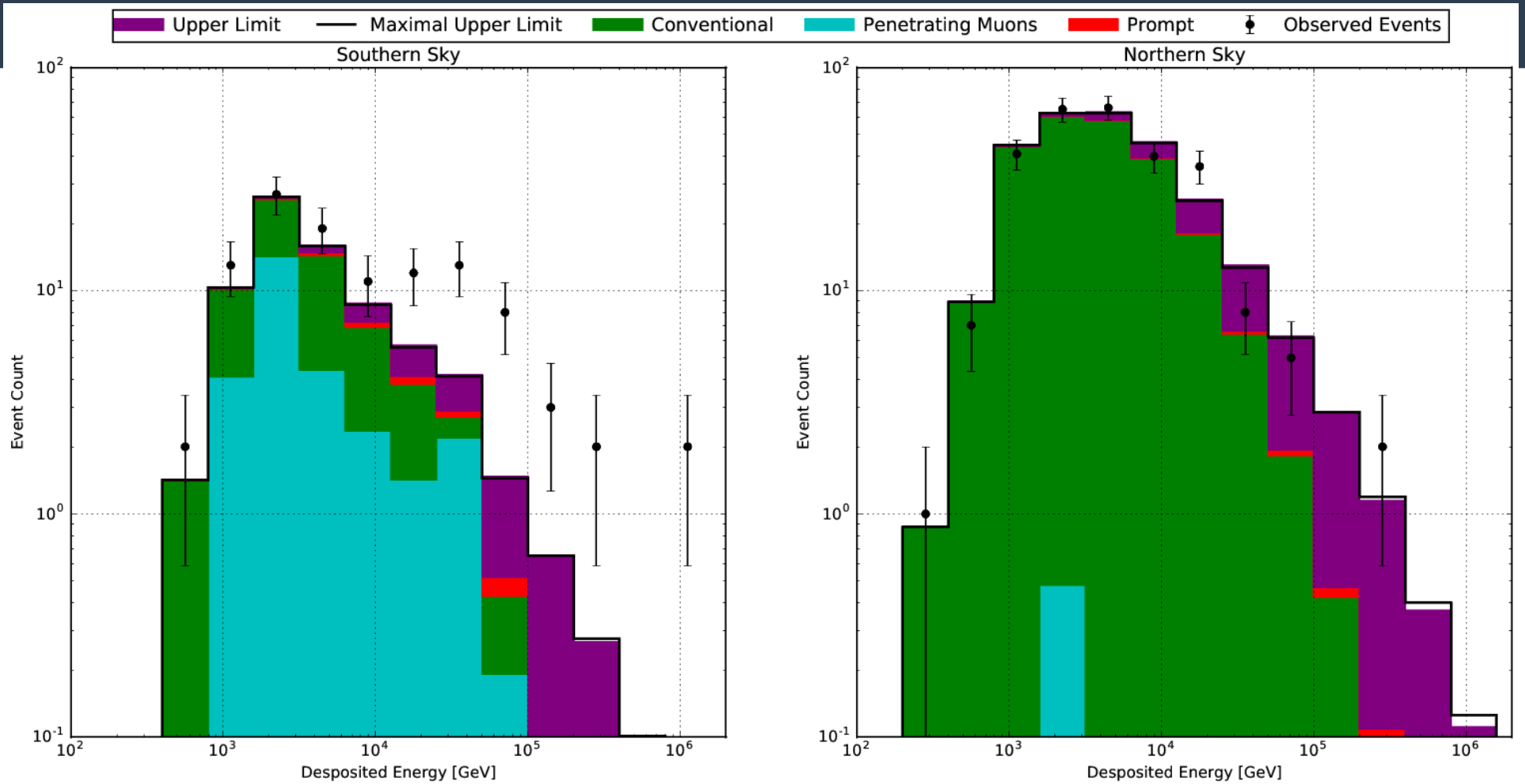
- **We used Gaisser et al.'s technique to calculate the self-veto probability of prompt neutrinos**

T. K. Gaisser, K. Jero, A. Karle, and J. van Santen, Phys. Rev. D **90**, 023009 (2014).

Self-veto Probabilities



What does this look like in IceCube?



- **Forward produces significant number of events, but cannot explain the highest energy events or the 100 TeV bump**

M. G. Aartsen et al. (IceCube), Phys. Rev. **D91**, 022001 (2015), 1410.1749.