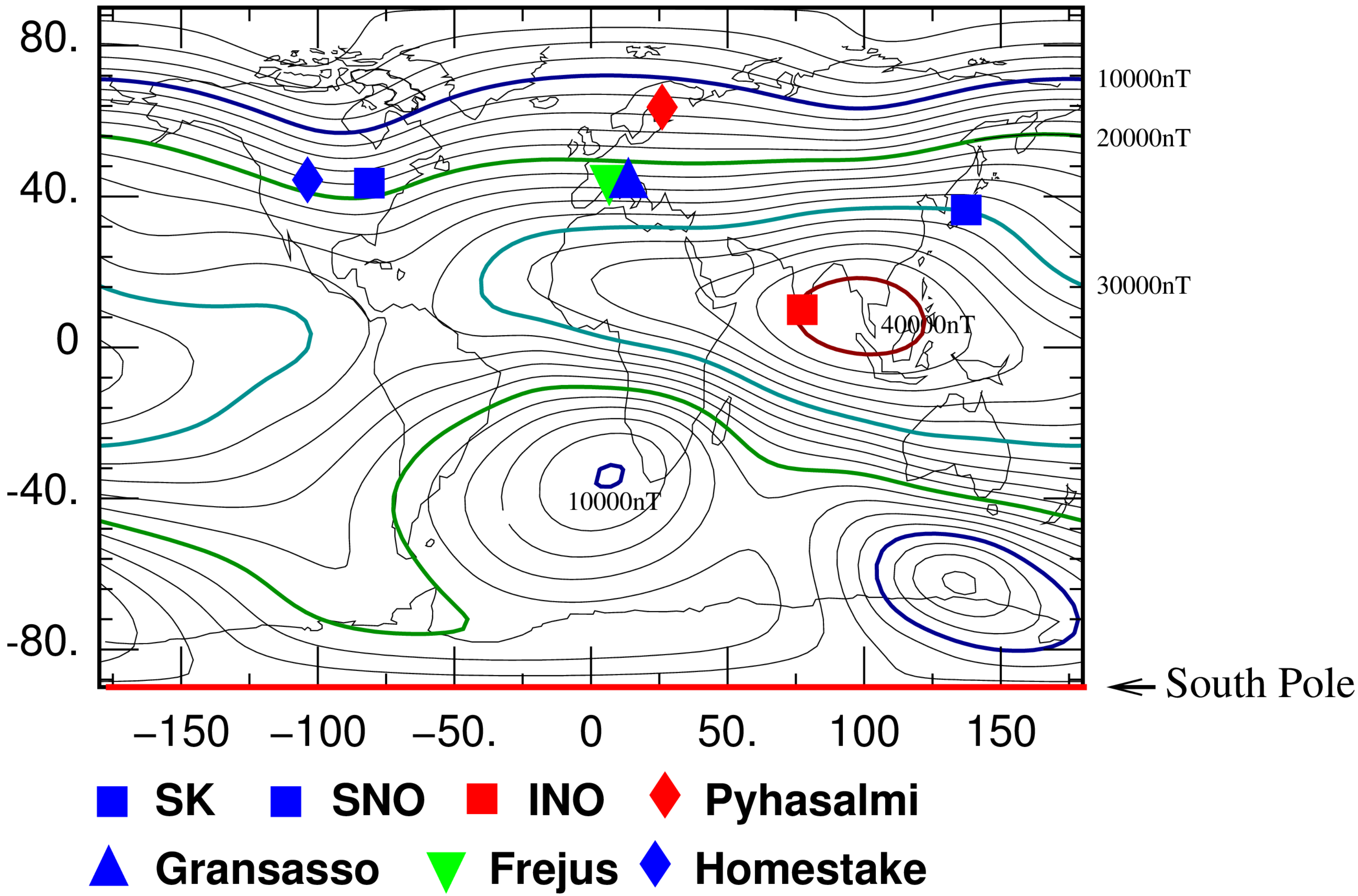
# 大気ニュートリノの精密計算

本田守広＠共同利用成果発表会
(2015-12-19)

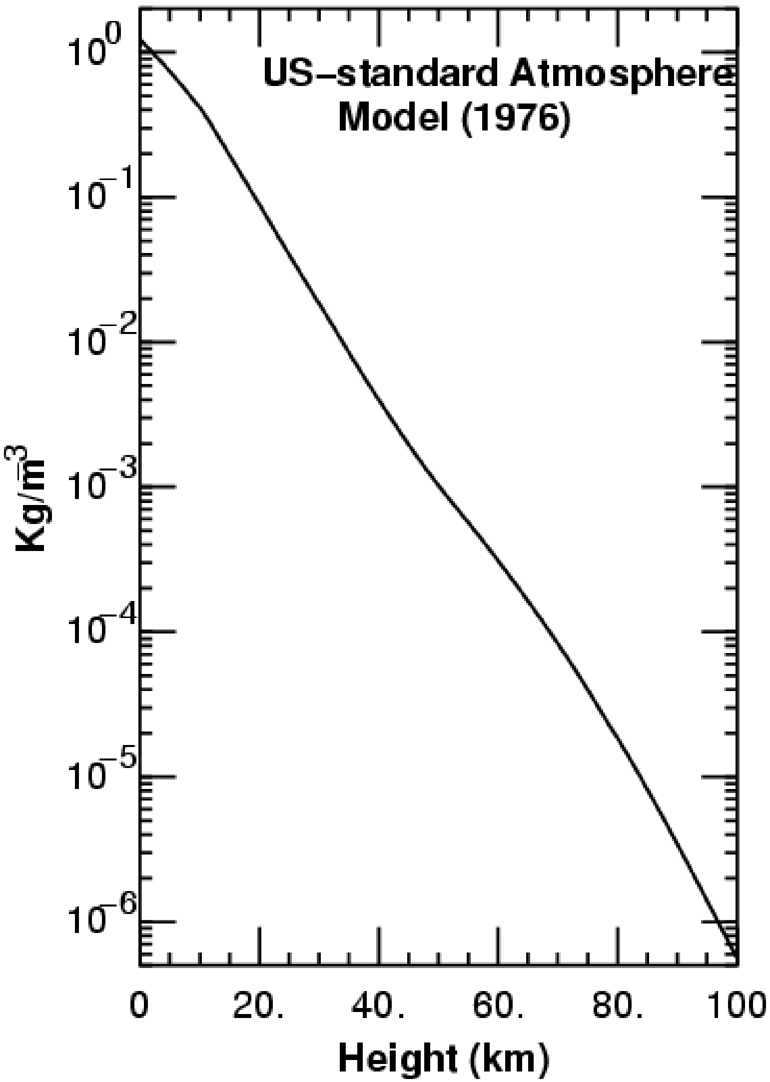
1, 大気モデルNRLMISSIE-00を用いた、神岡以外のサイトおける大気ニュートリノフラックス計算（HAKKM PRD2015）。

2, AMS02,BESS-polarなどの新しい宇宙線観測をとりいれた一次線モデルと、これまでの計算結果との比較(とりあえずの)。

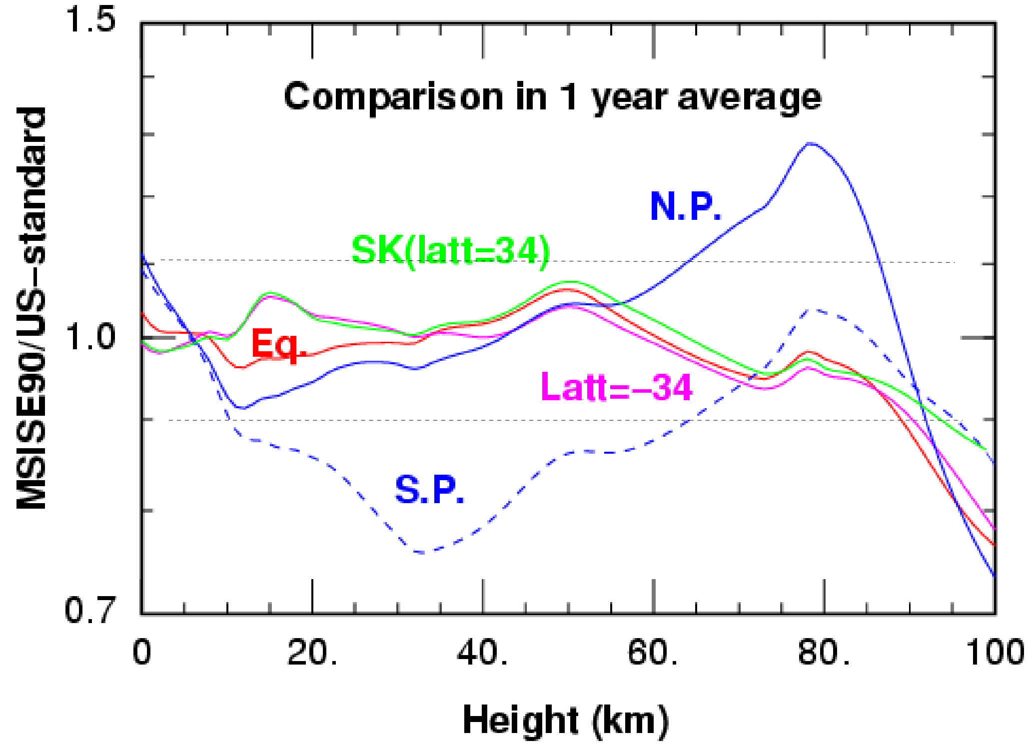
Horizontal component of Geomagnetic Field with IGRF10
and
Atmospheric Neutrino Observing sites.



# Atmosphere Model

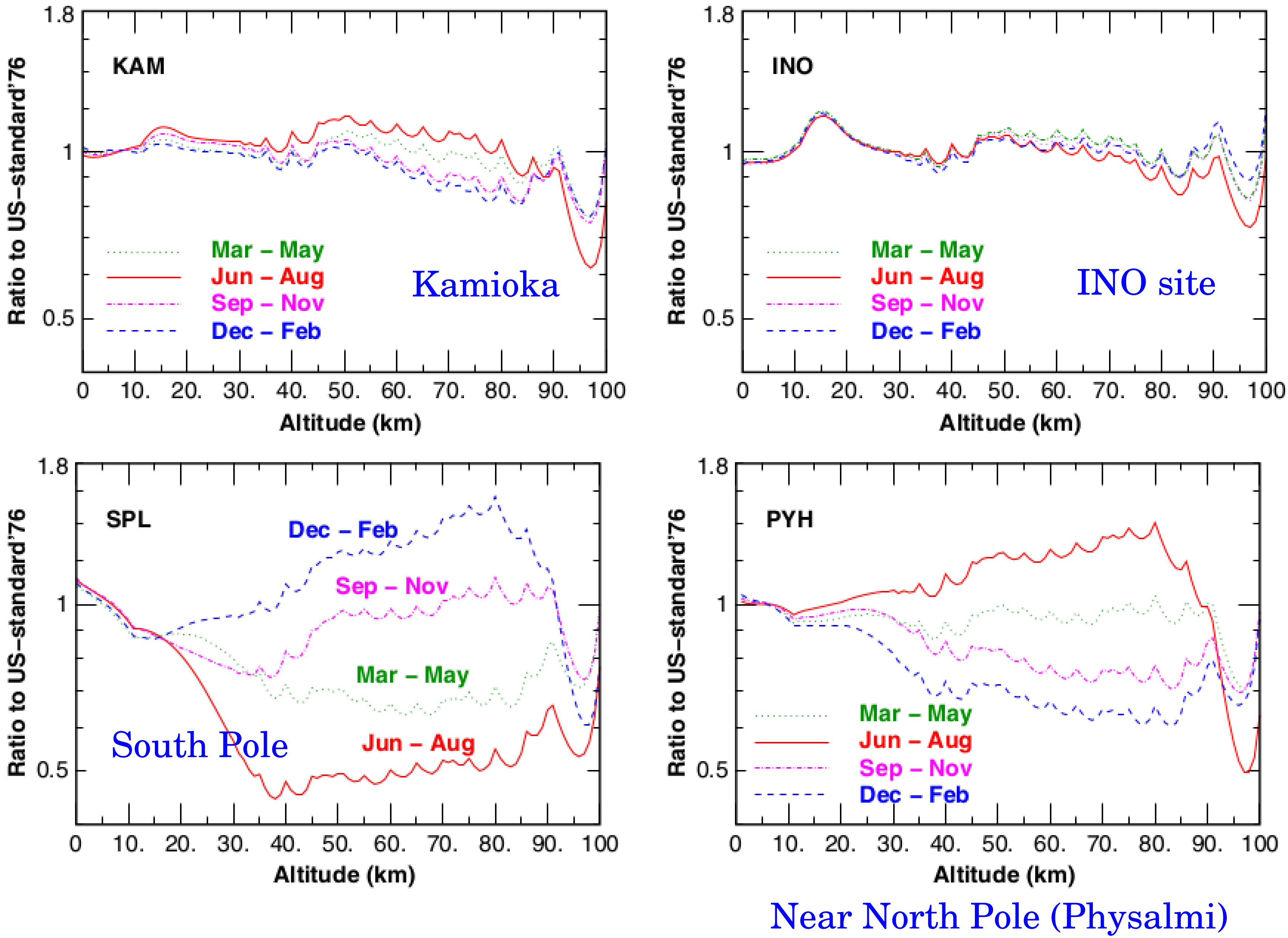



Air density comparison with MSISE90

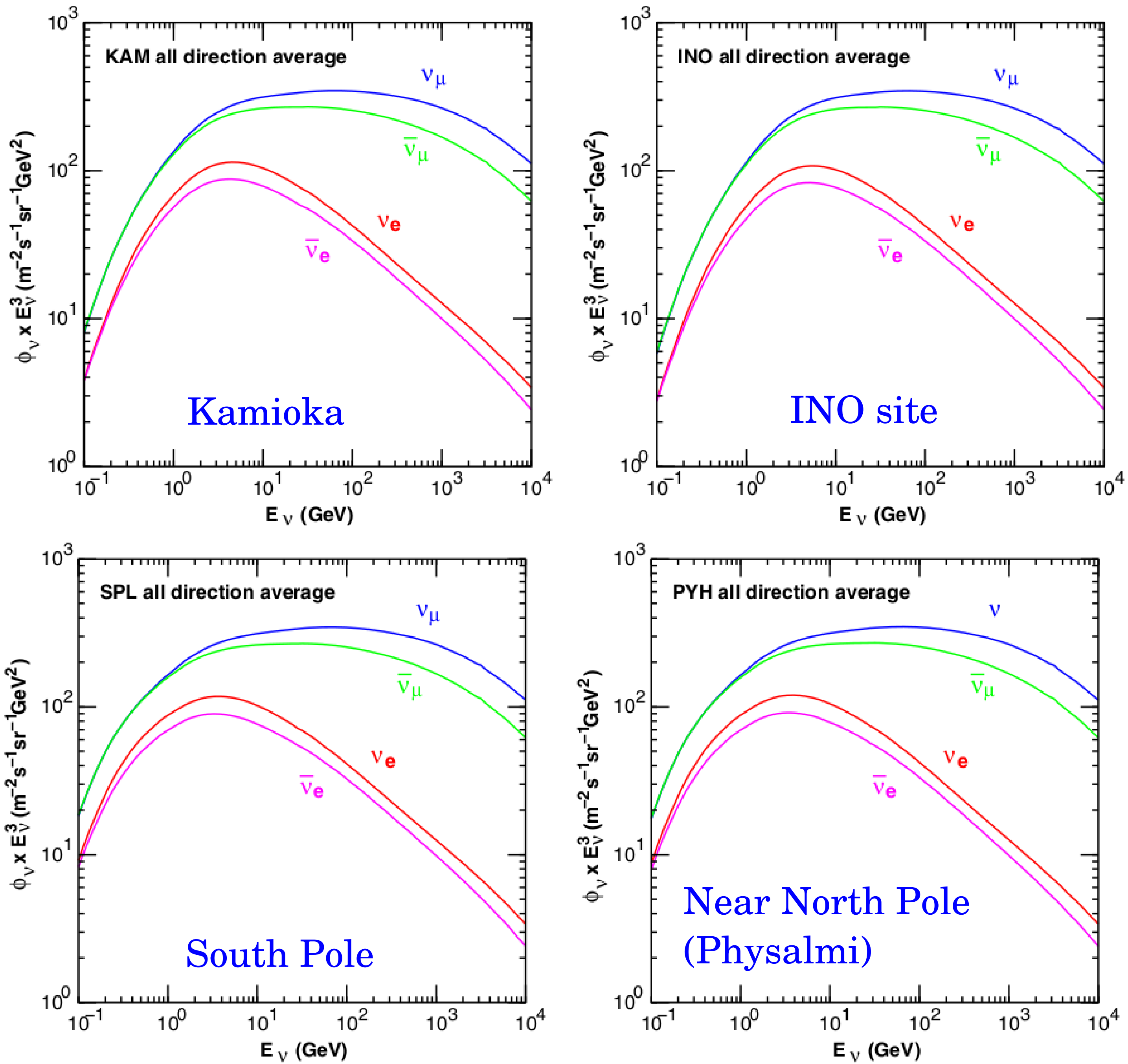



US-starndard'76 may be used as the global approximation of the Atmosphere.

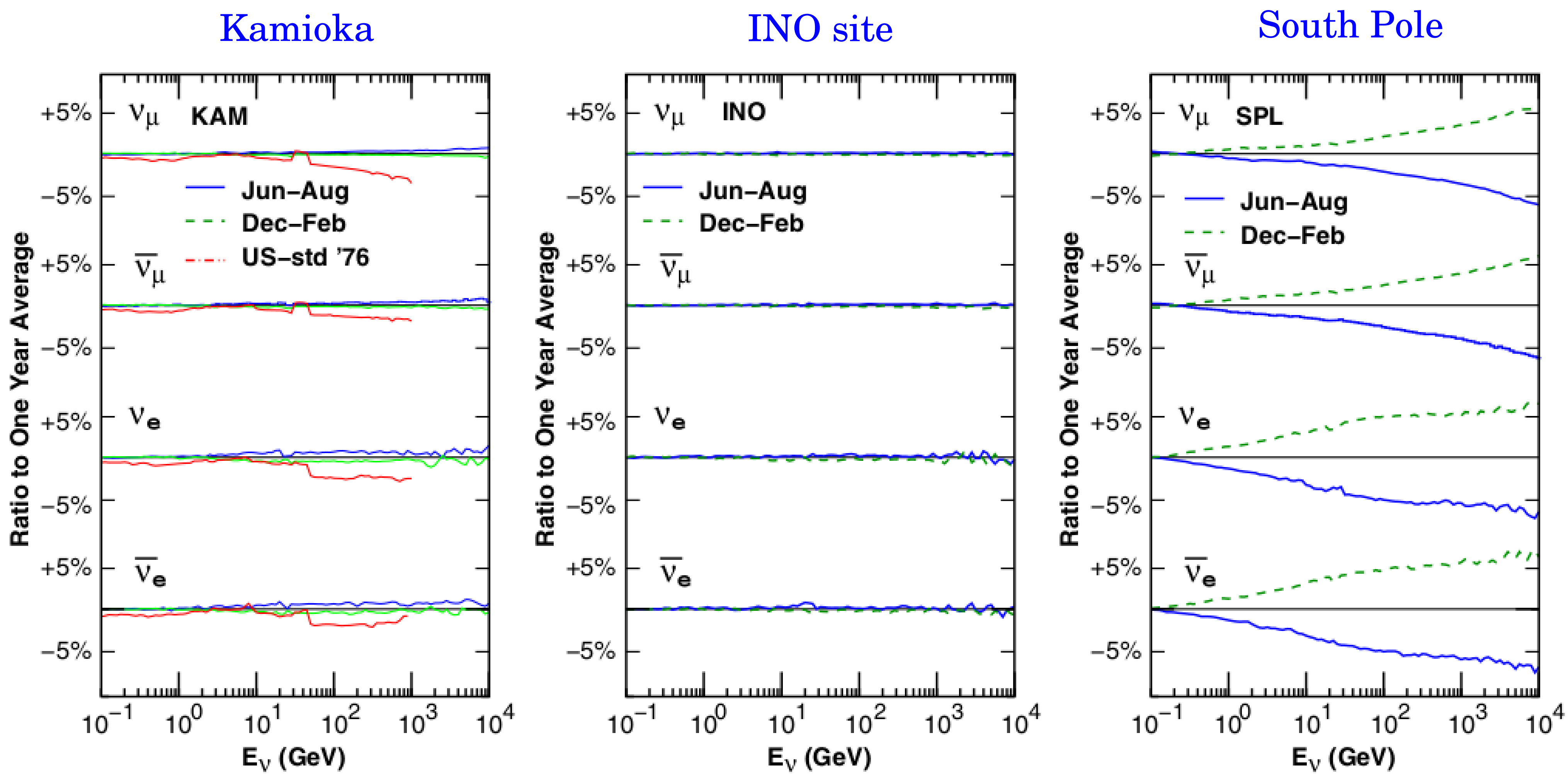
# Atmosphere model (NRLMSISE-00) and seasonal variations



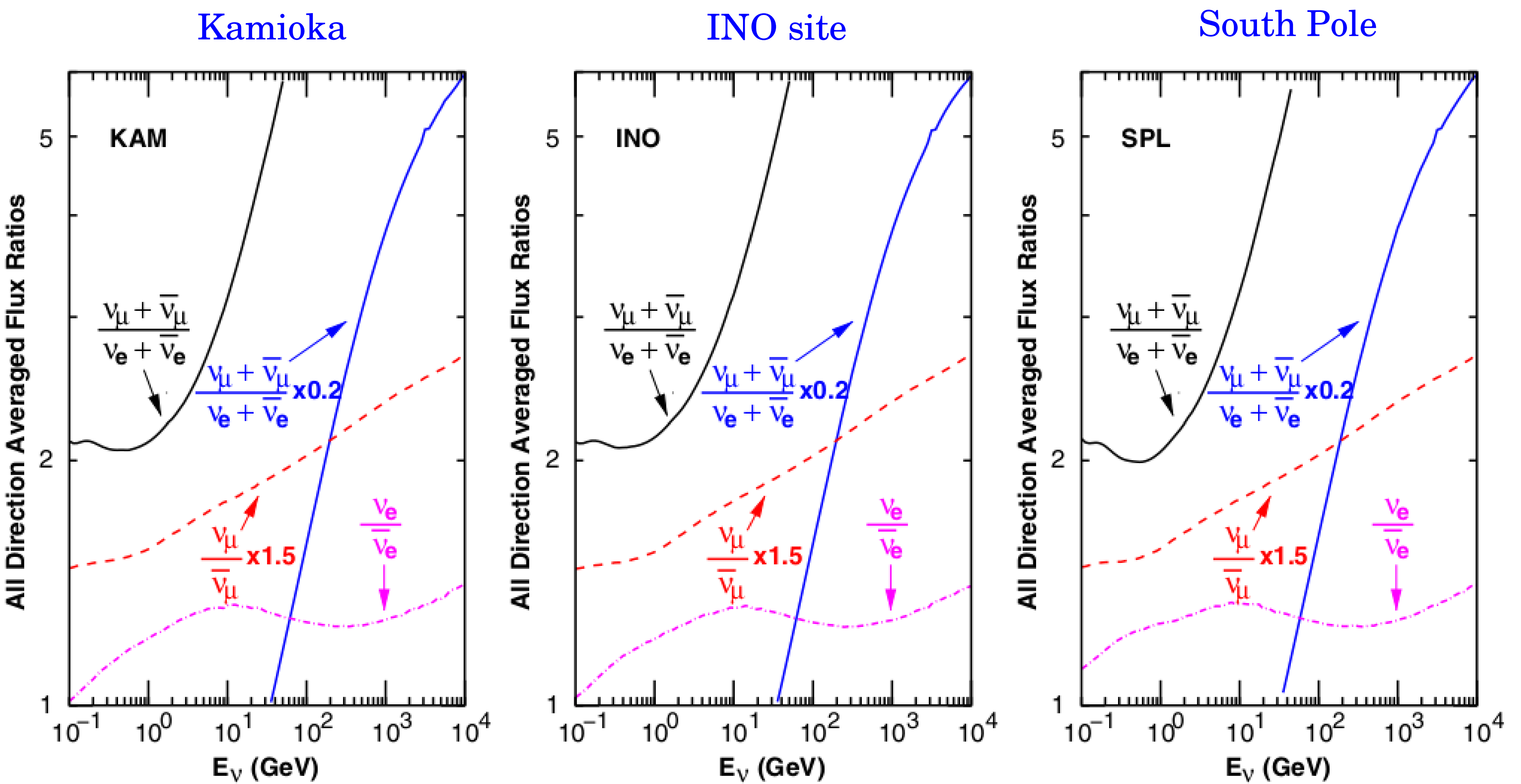
# Calculated Atmospheric Neutrino Flux averaged over all directions



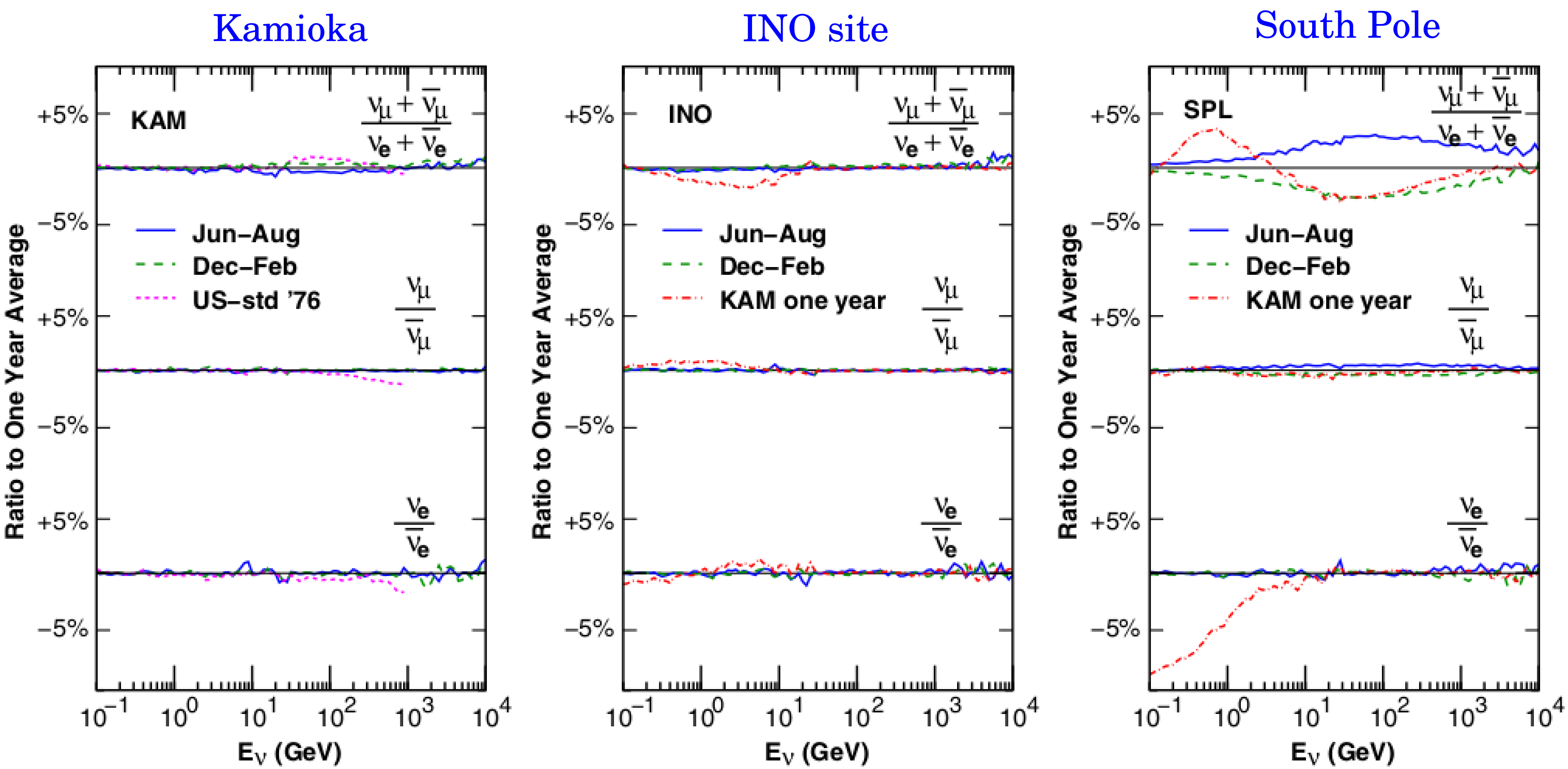
# Seasonal Variation of Atmospheric Neutrino flux



# Flavor Ratios of Atmospheric Neutrino



# Seasonal and Site Variation of Atmospheric Neutrino Flavor Ratios



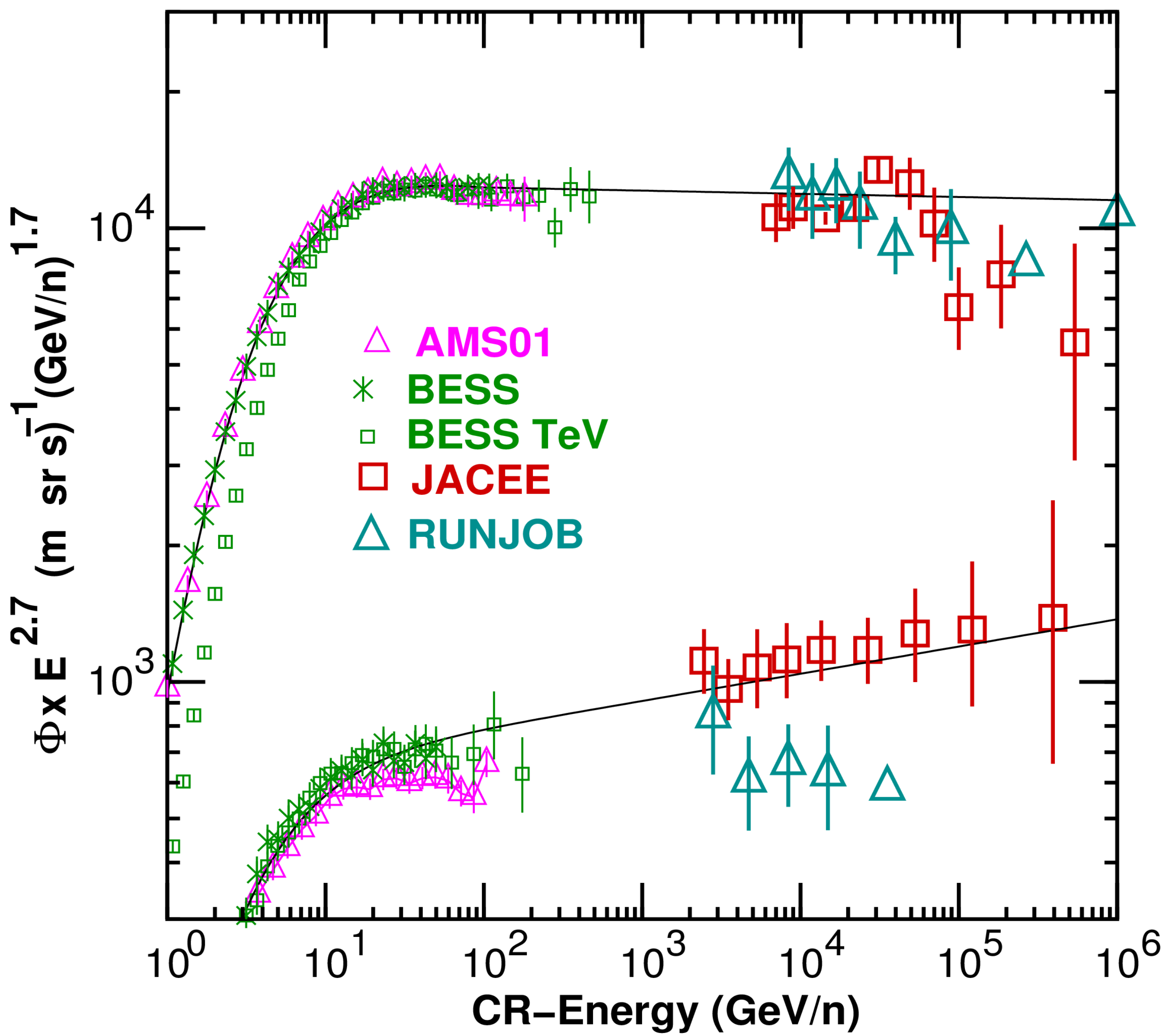

The variation of $\frac{\nu_\mu + \bar{\nu}_\mu}{\nu_e + \bar{\nu}_e}$ at South Pole and the difference from Kamioka are almost equal to the largest estimation of its uncertainty.

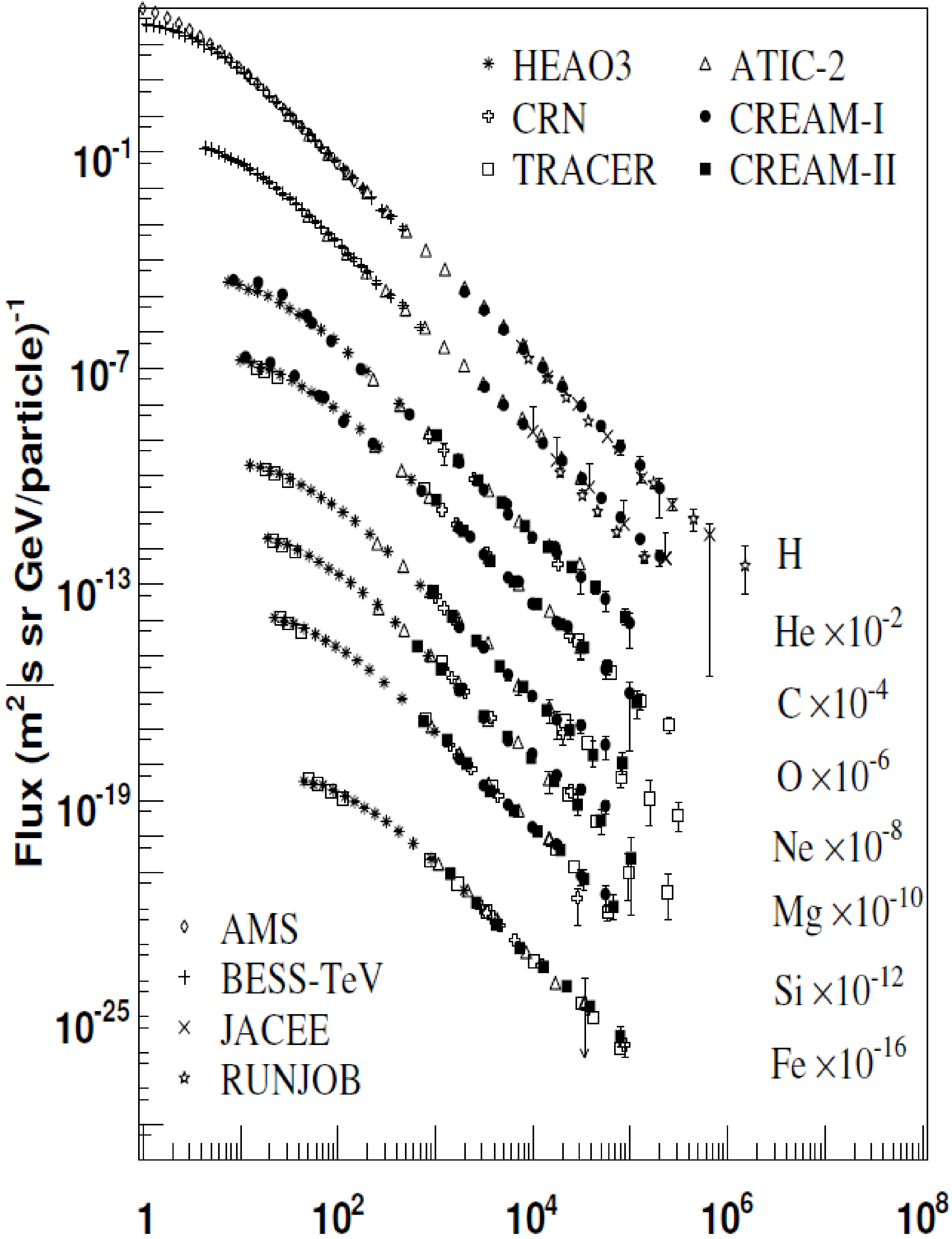
# Impact of AMS02


and

BESS-polar

# Our primary Cosmic Ray model and reference data

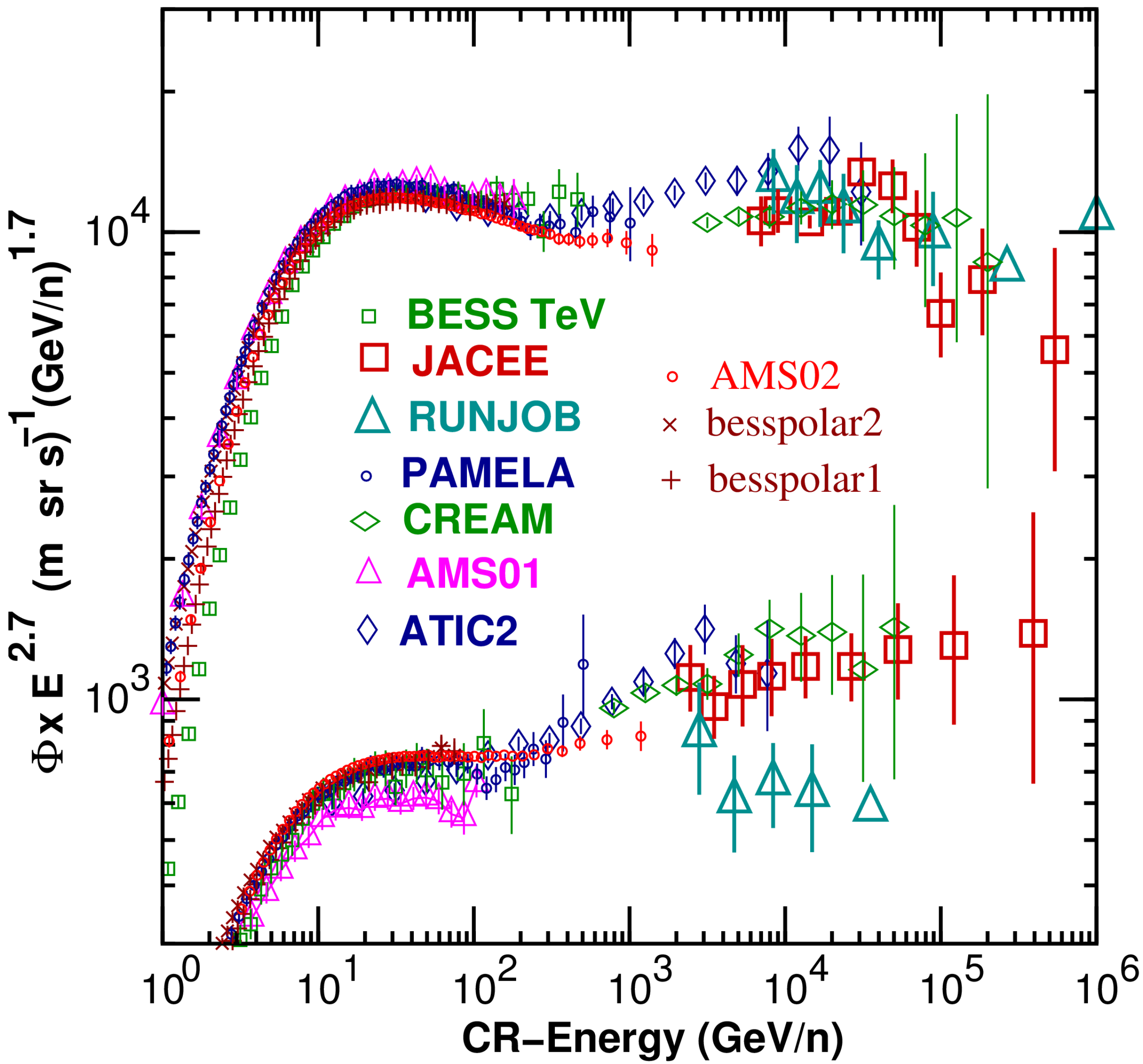




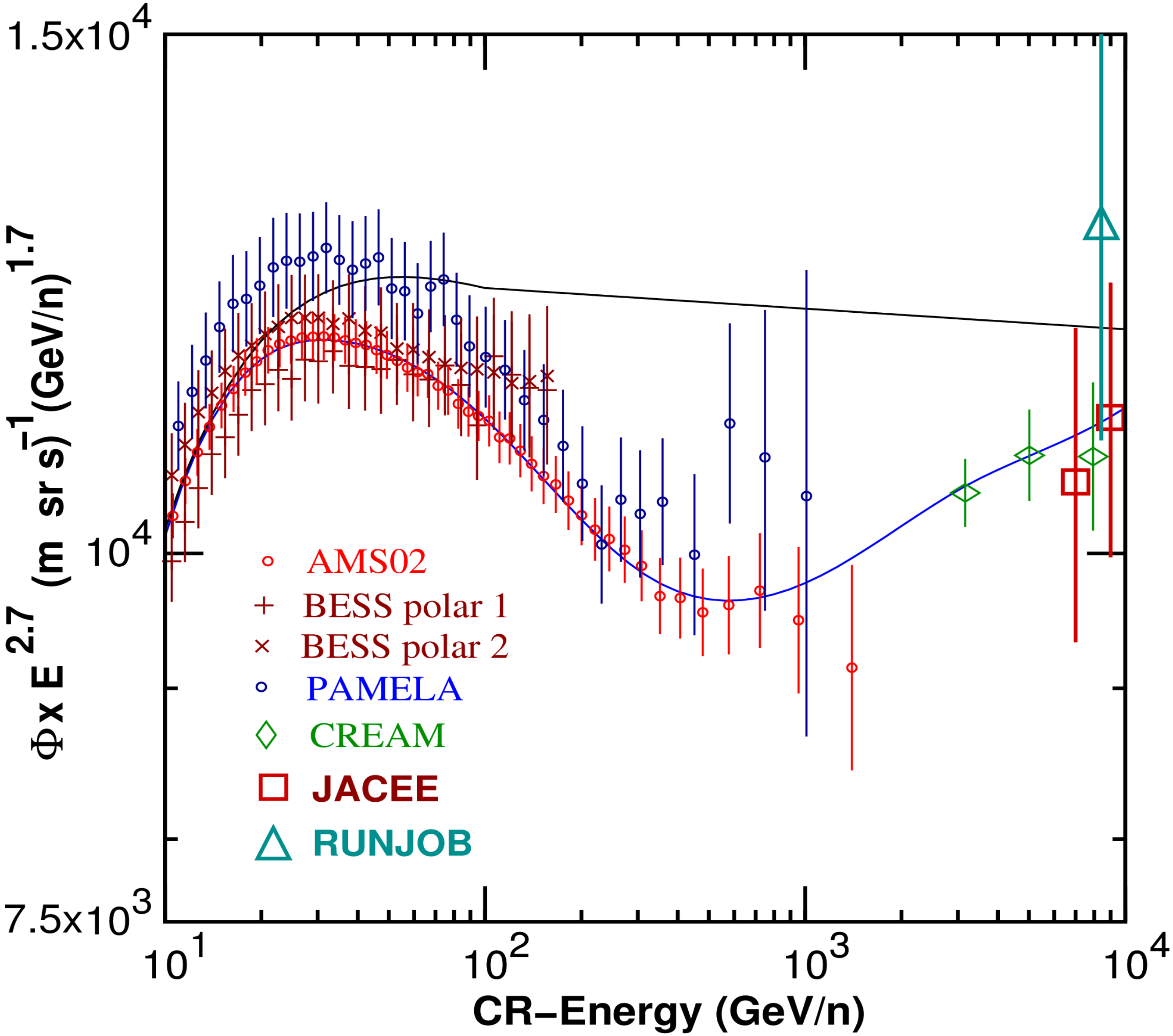

From
E.S. Seo @ ICRC2009

Other chemical compositions are also considered in the calculation, but they give small contributions.

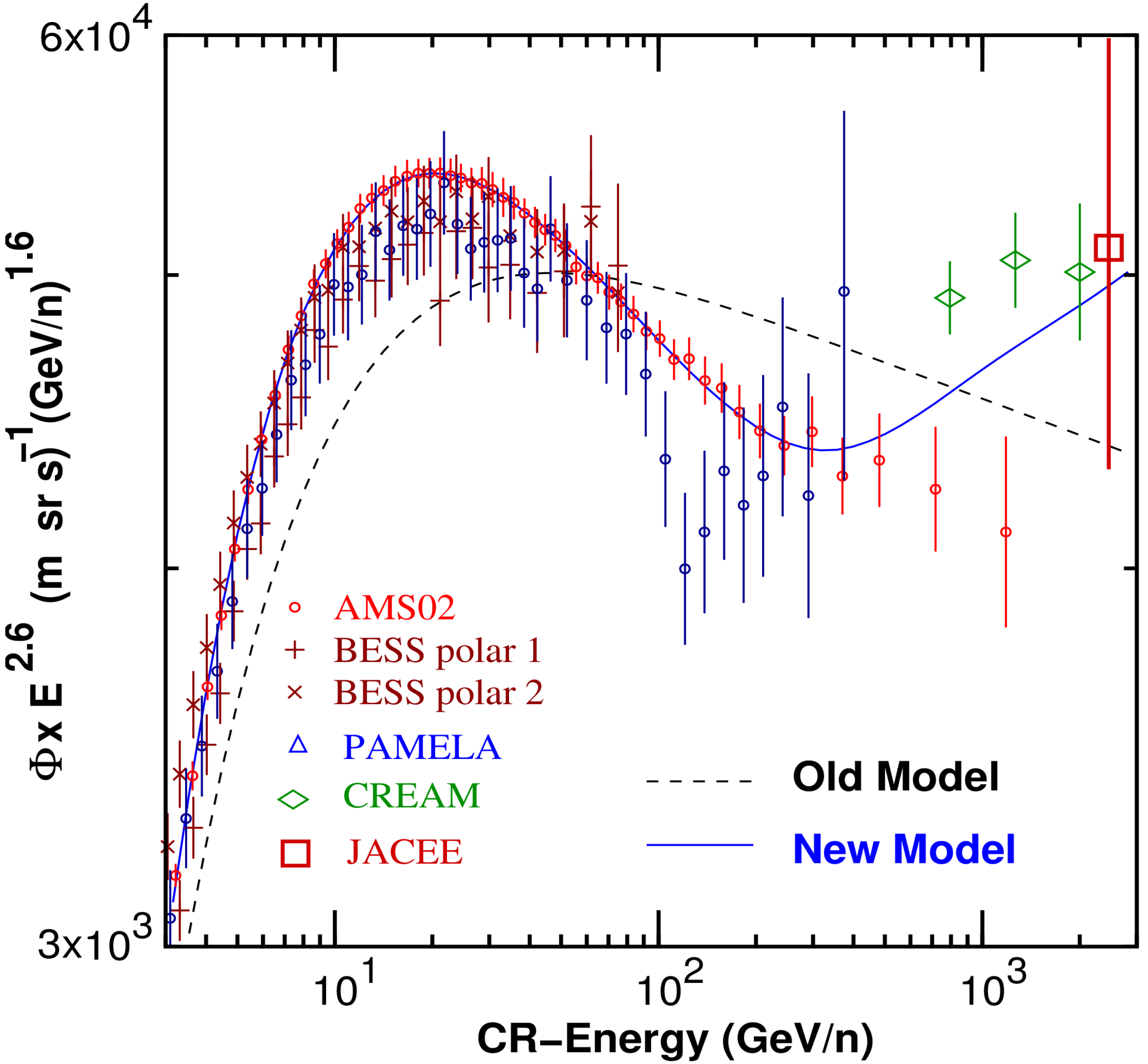
# Recent Cosmic Ray observation and available High Energy data



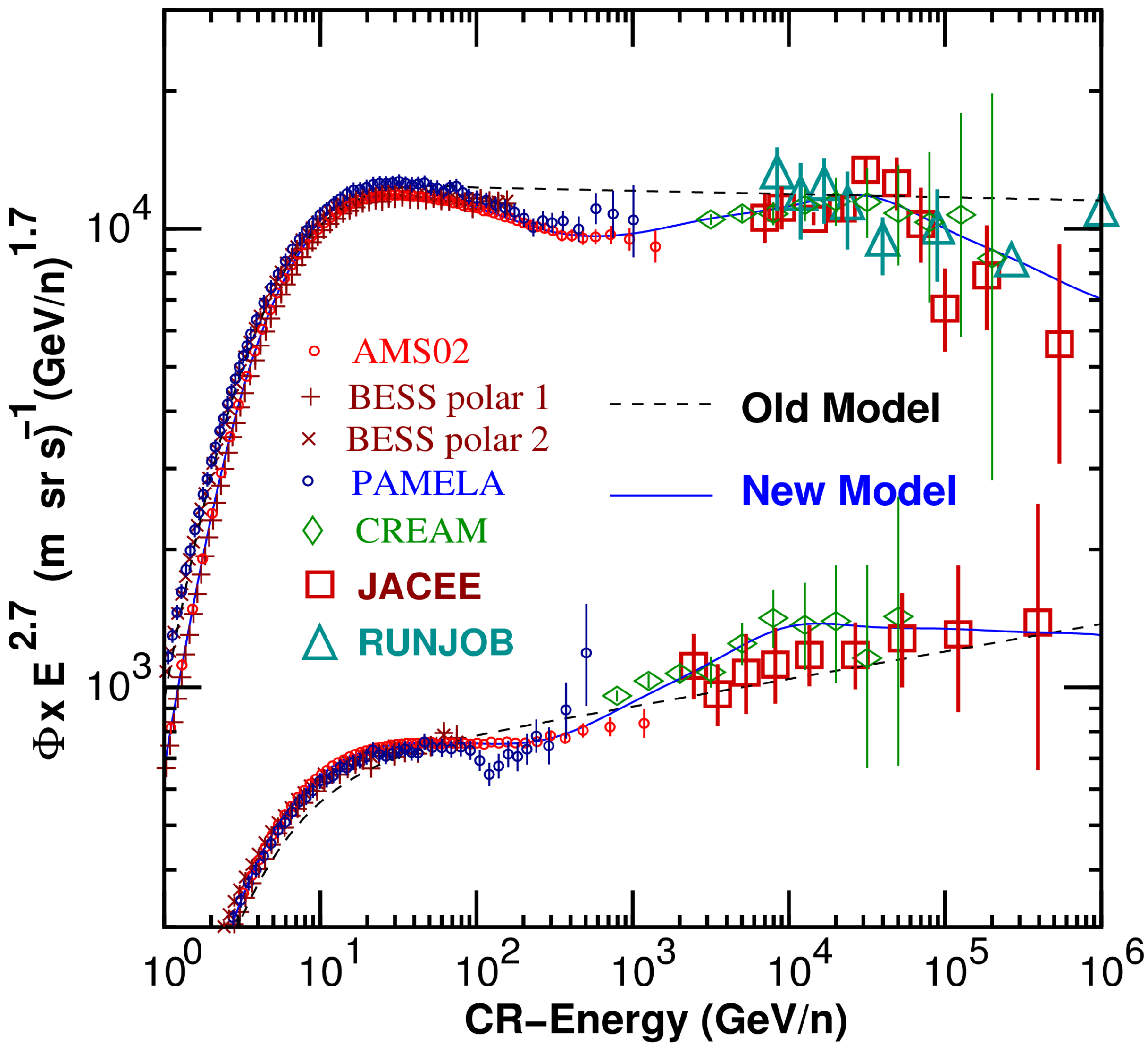
# Proton closeup



# Helium closeup

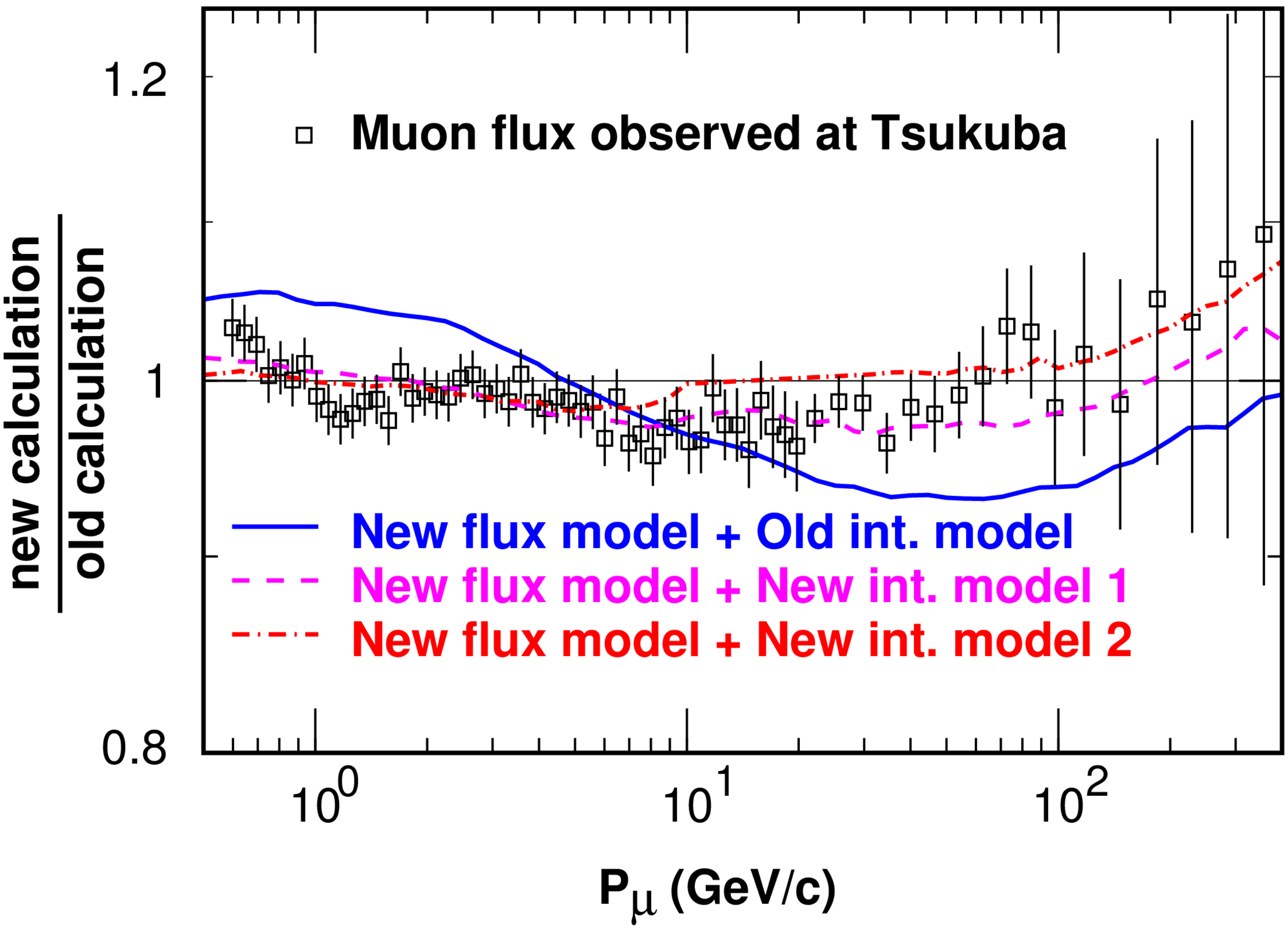


# New Cosmic Ray Model with AMS02 and BESS-polar

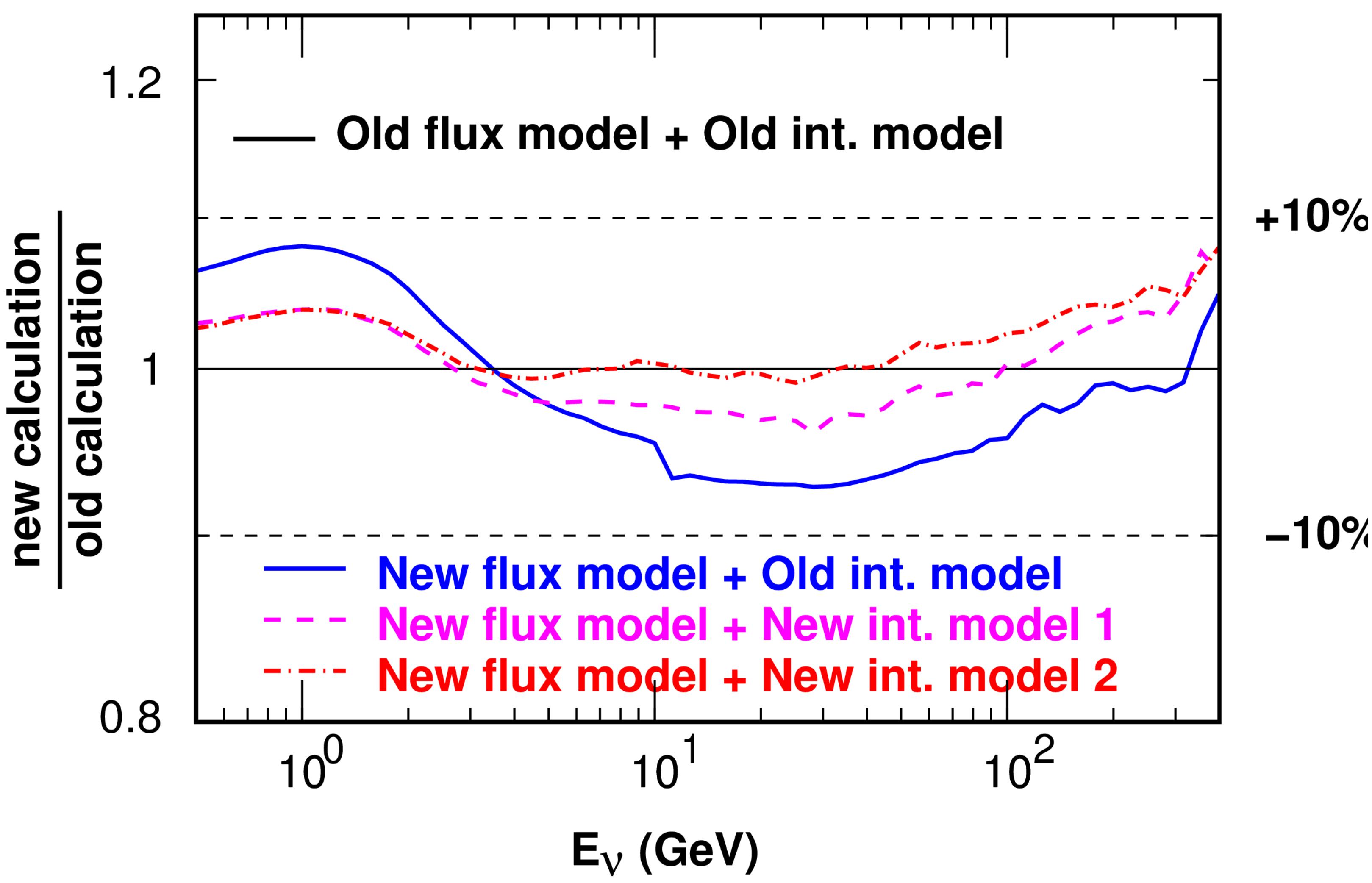



Discarded some data from model construction.

# Muon Calibration of Interaction Model
# with
# New Cosmic Ray Model

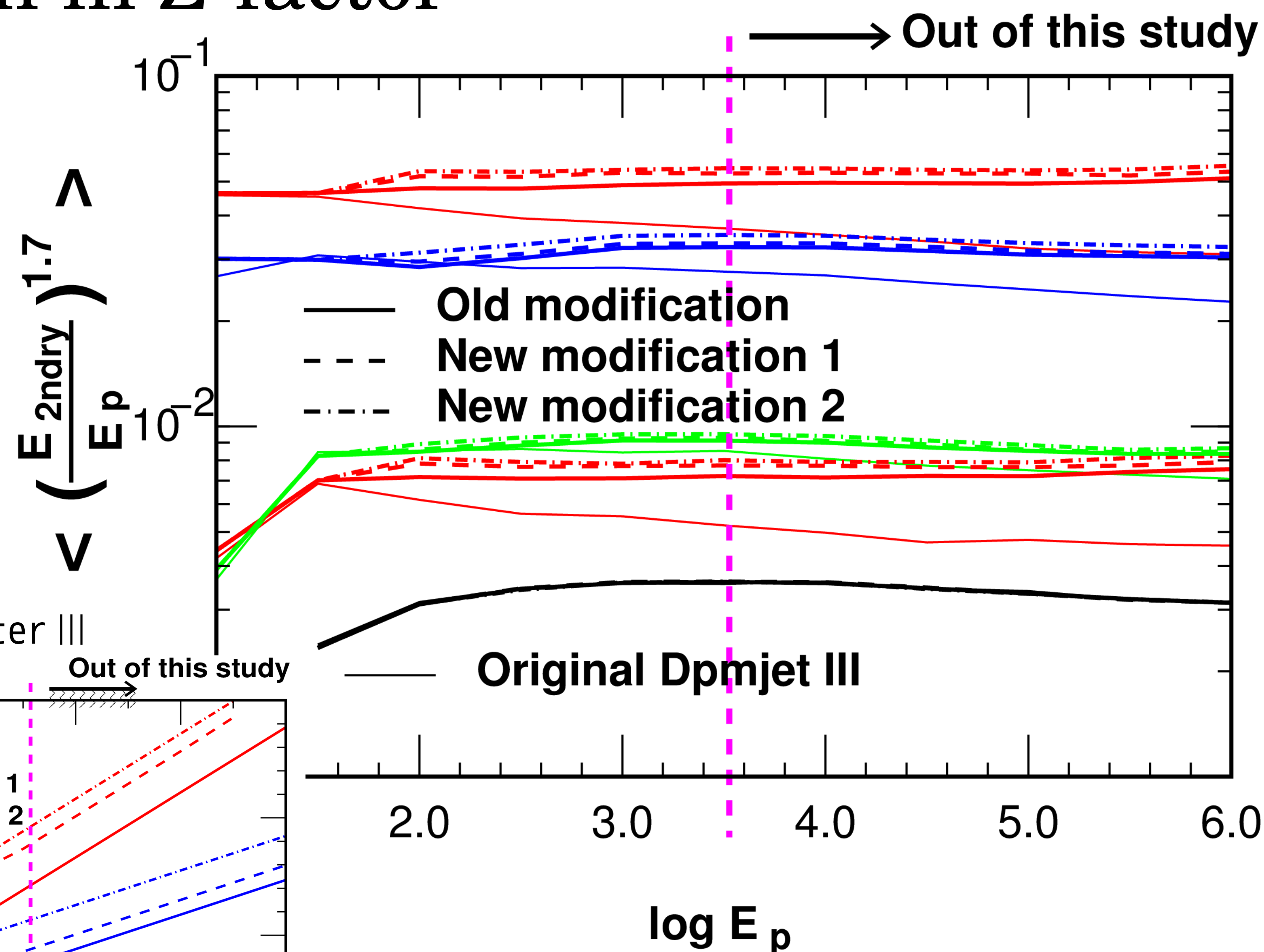


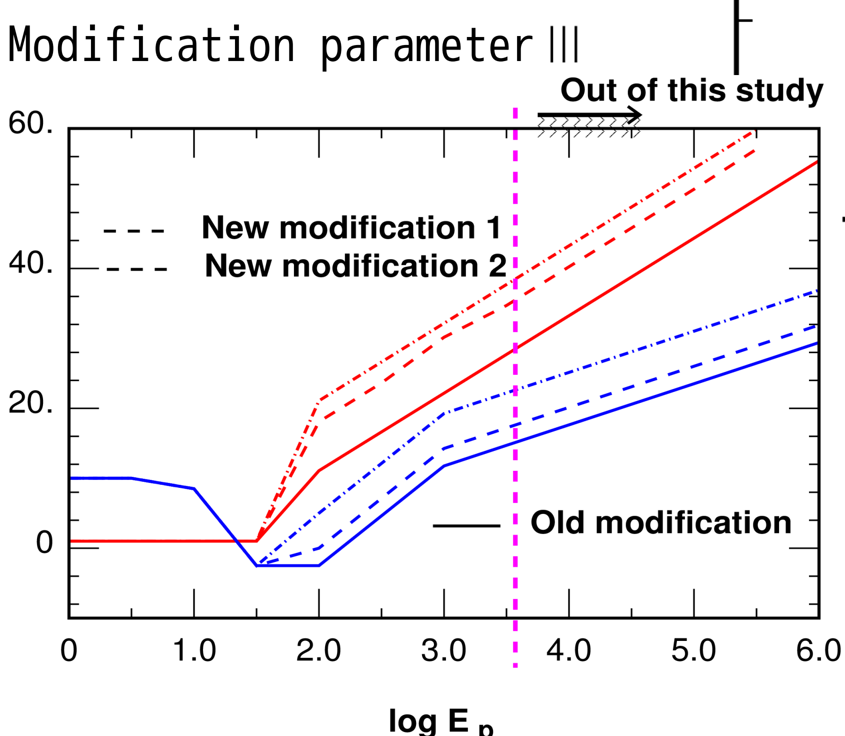
Resulting Neutrino Flux (all ν sum)



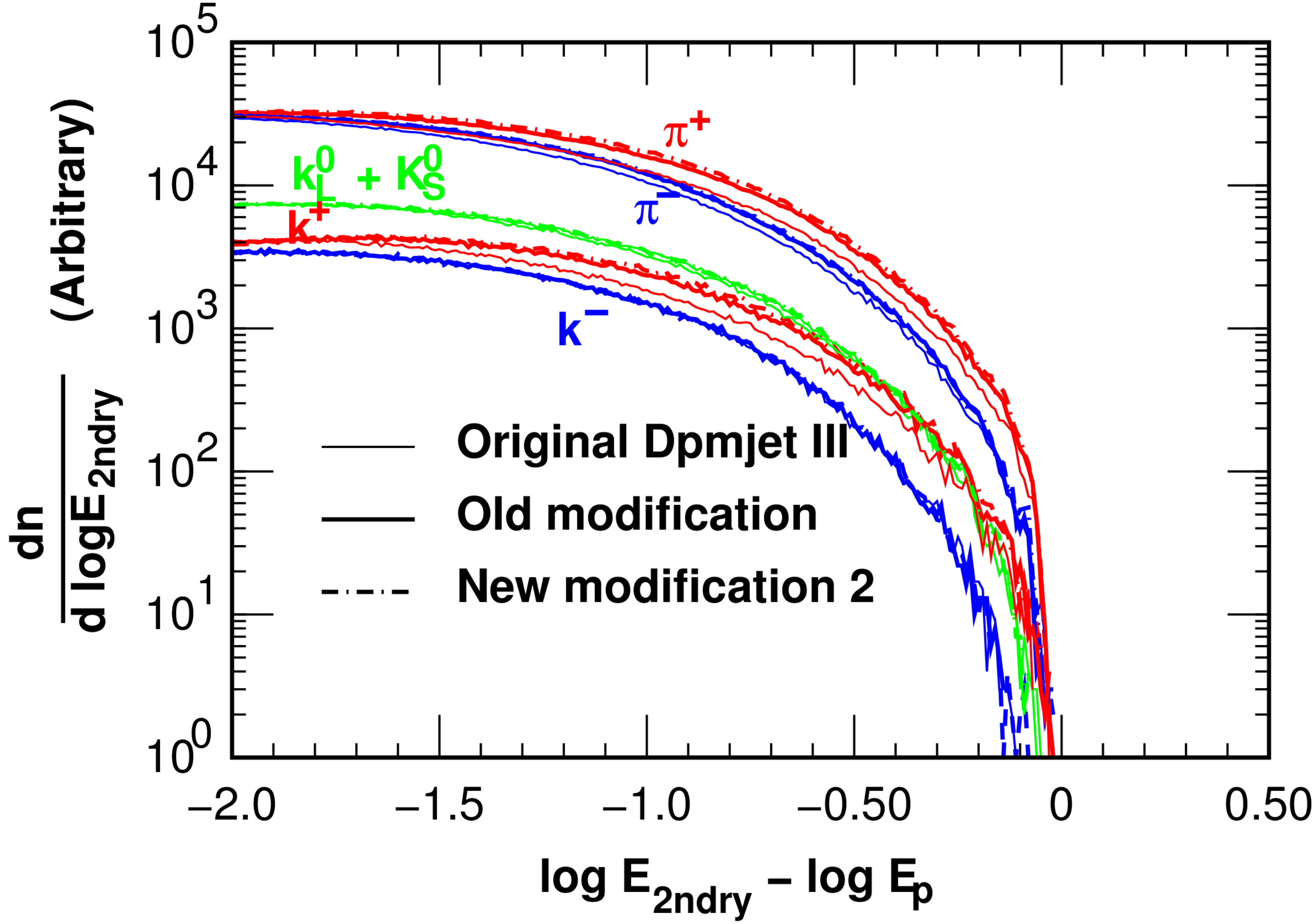

Muon calibration works !

# Comparison in Z-factor

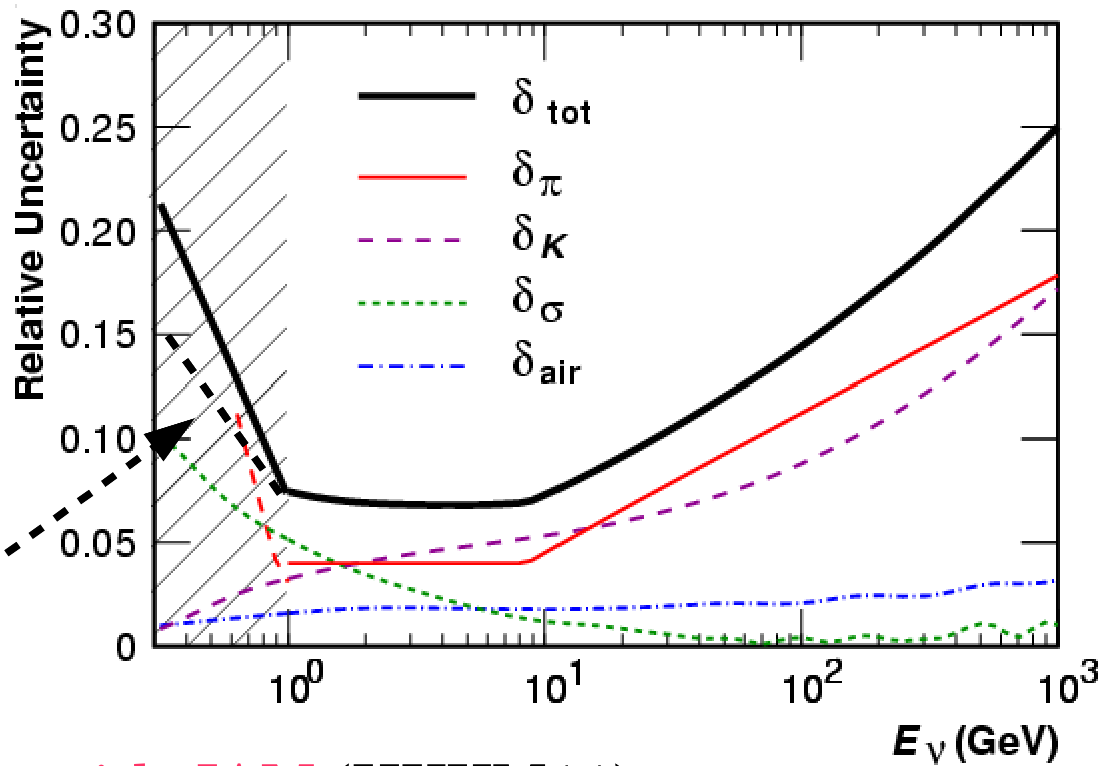


# Comparison of secondary spectra of interaction models at 1 TeV



# Possible Error in Atmospheric ν-flux (HKKMS07)




Possible Error with JAM (HKKM11)

$\delta_\pi$ μ -observation error + Residual of reconstruction

$\delta_K$ Kaon production uncertainty

$\delta_\sigma$ Mean free path (interaction crossection) uncertainty

$\delta_{air}$ Atmosphere density profule uncertainty

# まとめ

• NRLMSISE-00 大気モデルにより、計算する対象を赤道から極地まで広げた。

•極地での大気ニュートリノの季節変動は低エネルギーでも大きく、また

$\frac{\nu_\mu+\bar{\nu}_\mu}{\nu_e+\bar{\nu}_e}$ 比も神岡とは数%異なり、その季節変化も大きい。

•AMS02、CREAMなどの比較的新しい宇宙線観測は、水素原子核では500GeV付近、ヘリウム原子核では250GeV付近でスペクトラムの折れ曲がりを示唆している。これにより、我々の従来の一次宇宙線モデルと比較して、この折れ曲がり付近で最大20%ほど少ないフラックスが予想される。

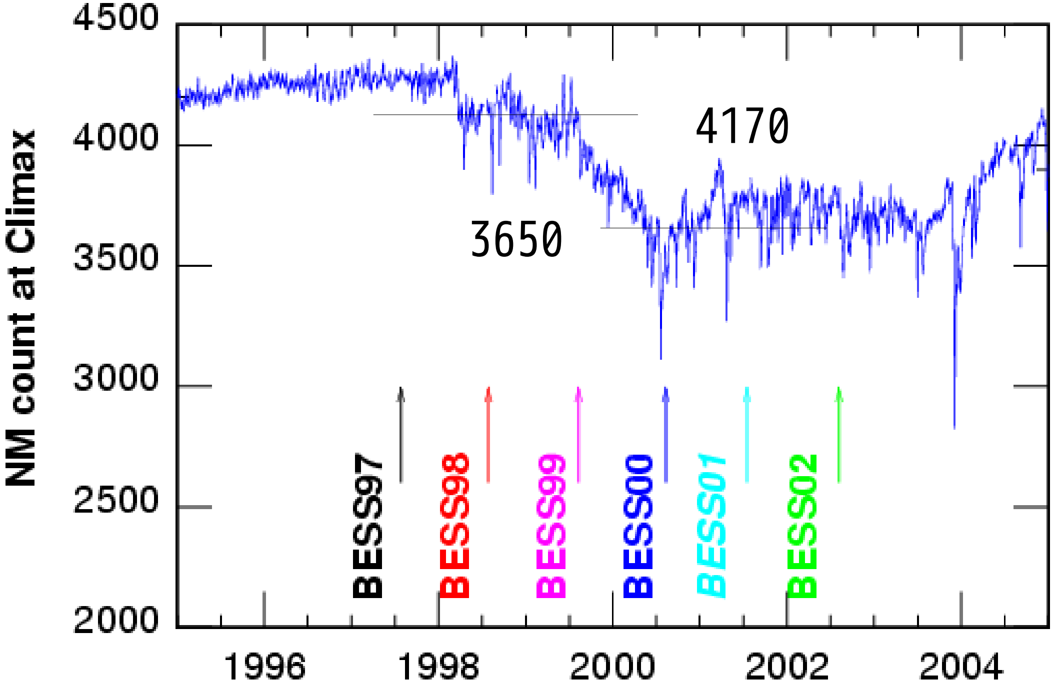
•これは、従来の相互作用モデルをそのまま使用した場合、20〜30GeVで〜7%の大気ニュートリノの減少として表れる。

•しかし、観測された大気ミューオンのフラックスが再現されることを条件として計算すると、従来の大気ニュートリノフラックスとの差は、ほとんど無くなる。

# おまけ

今年度一番の成果！

# Solar Modulation of Primary Cosmic Rays and Atmospheric Neutrino

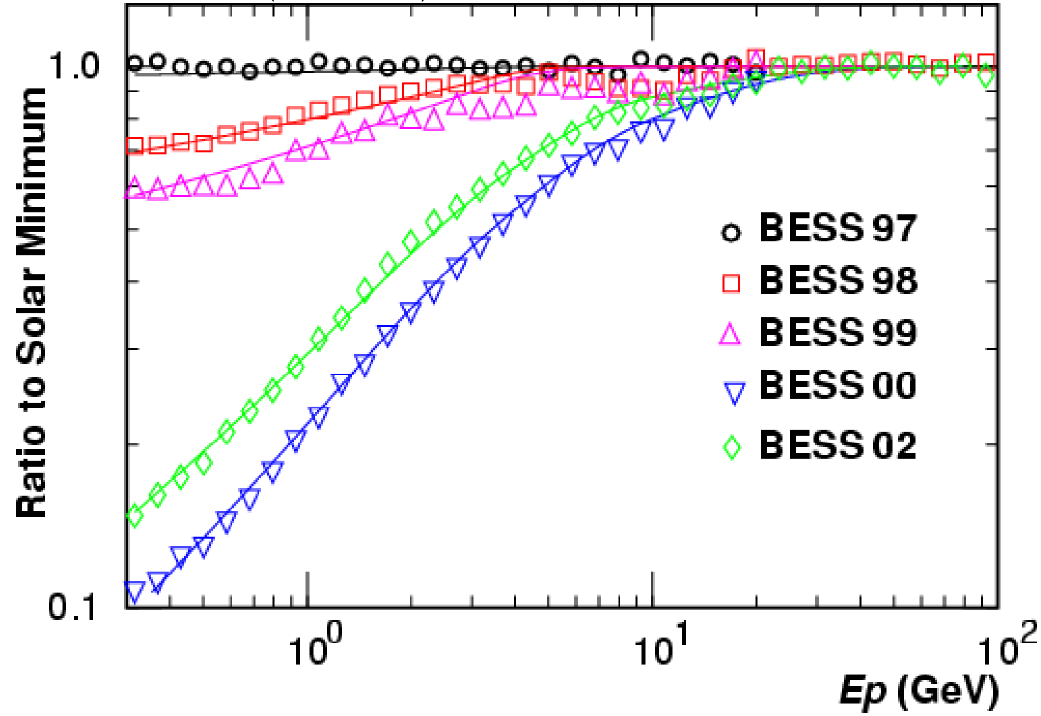


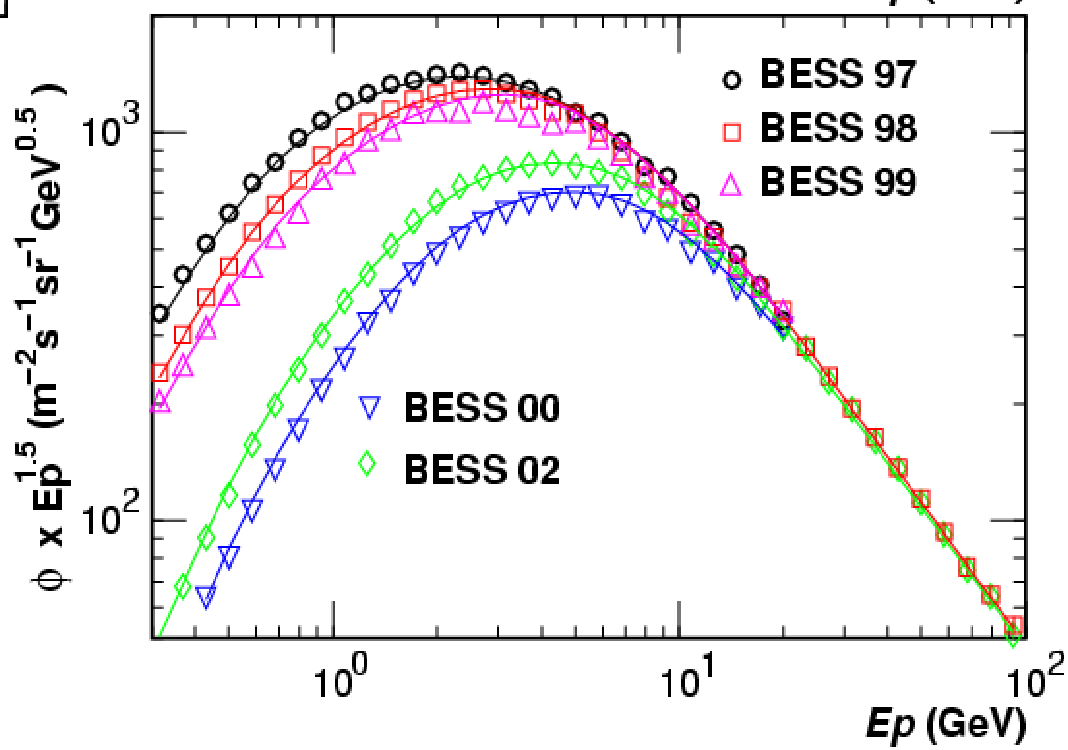

BESS flight

$$\phi_i(N, E_k) = \phi_i^{min}(E_k) \cdot M(N, r)$$

$$\phi_i^{min}(E_k) \equiv \phi_i^{1997}(E_k)$$

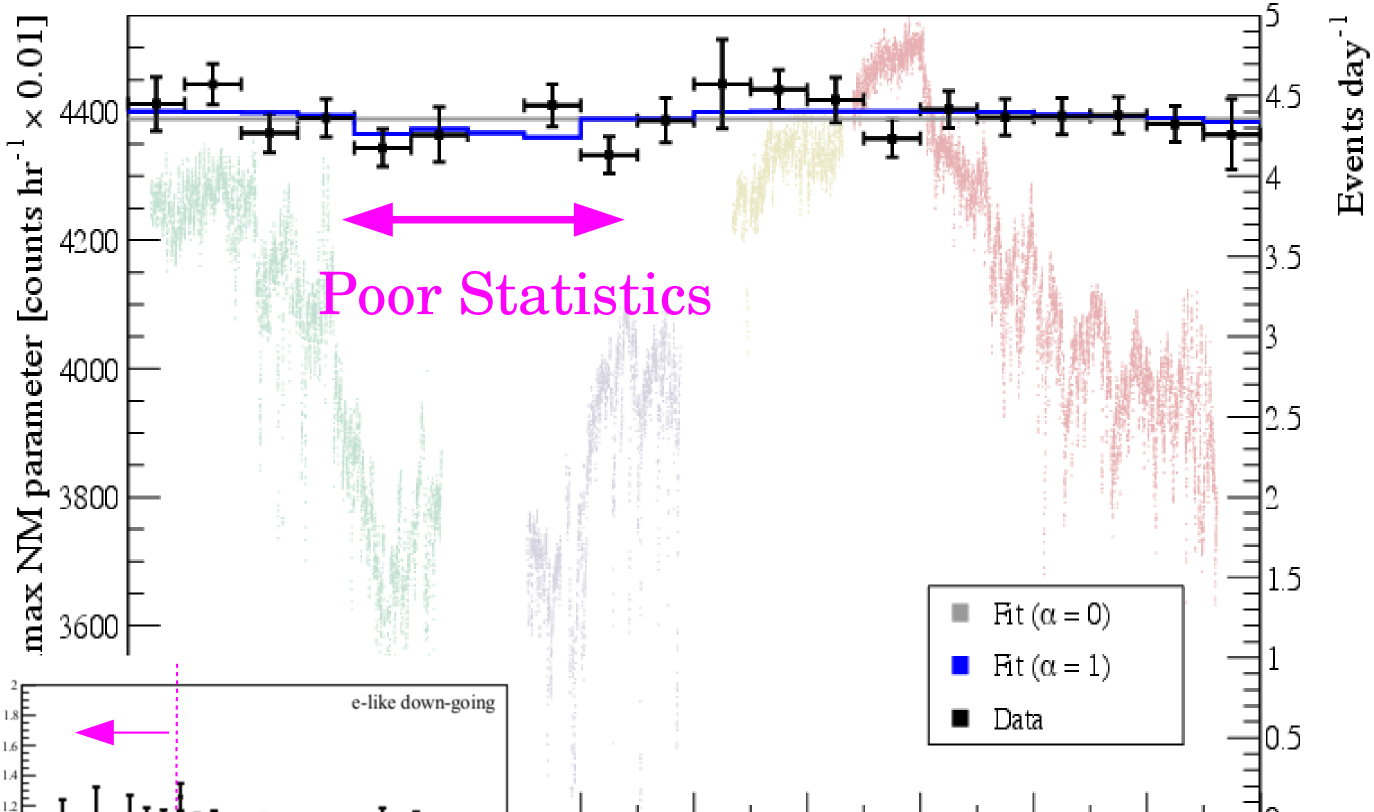
$M(N, r)$: modulation function

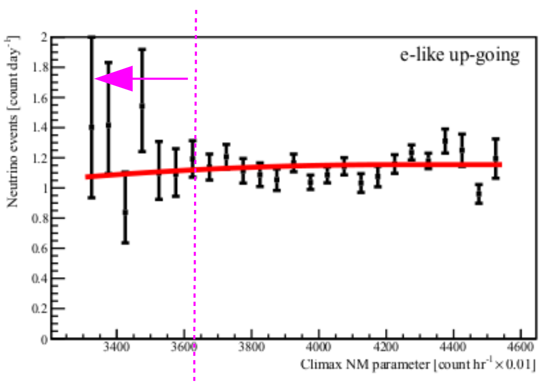


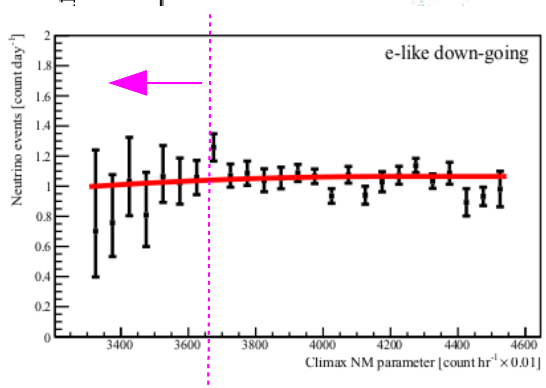



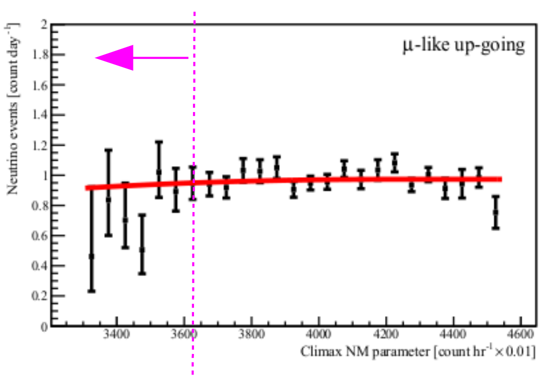
# Solar Modulation of Atmospheric Neutrinos

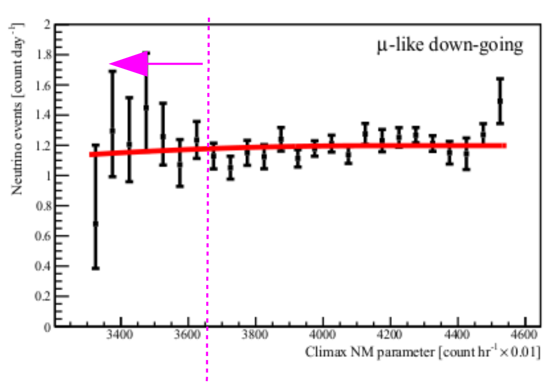
From PHD thesis of
E. Richard



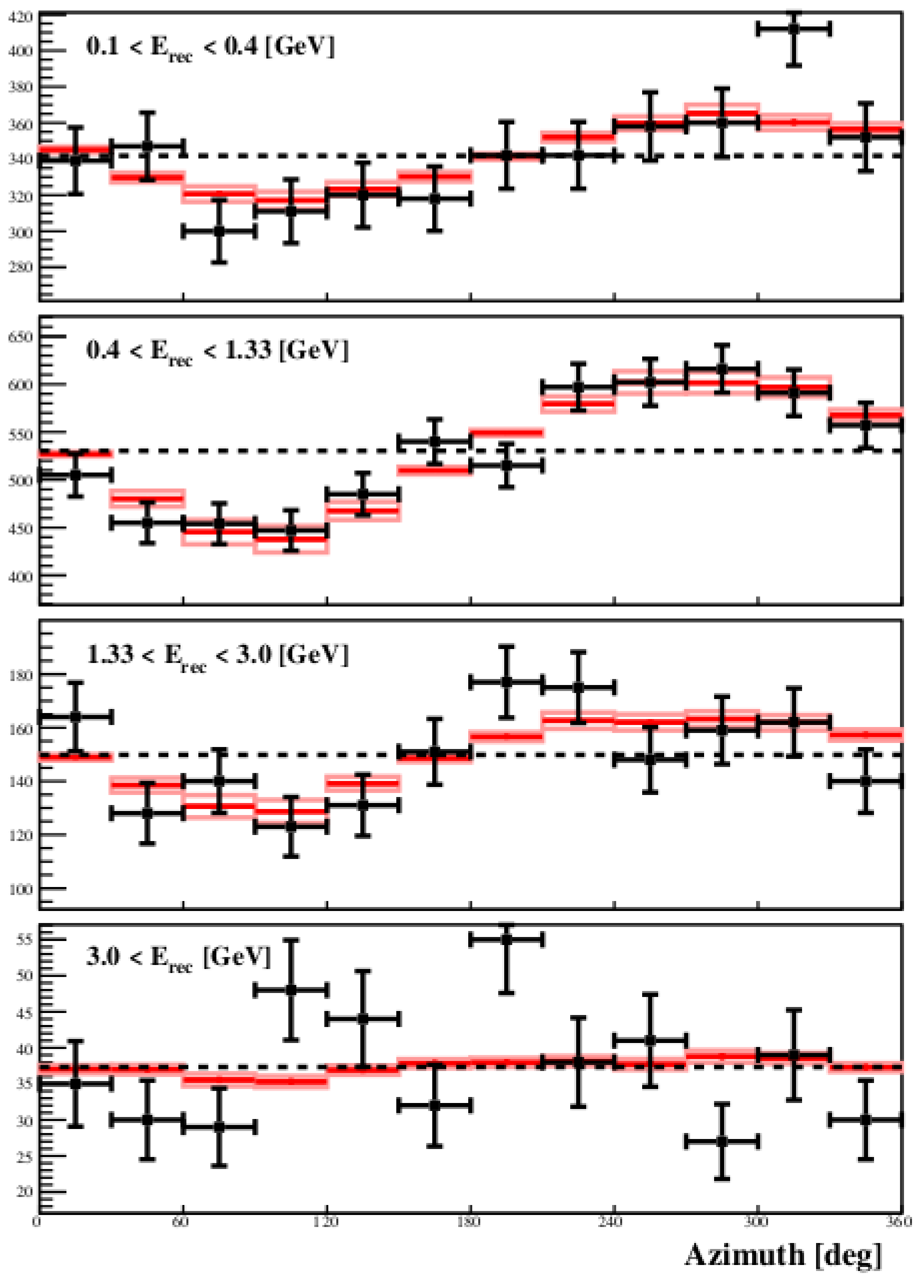



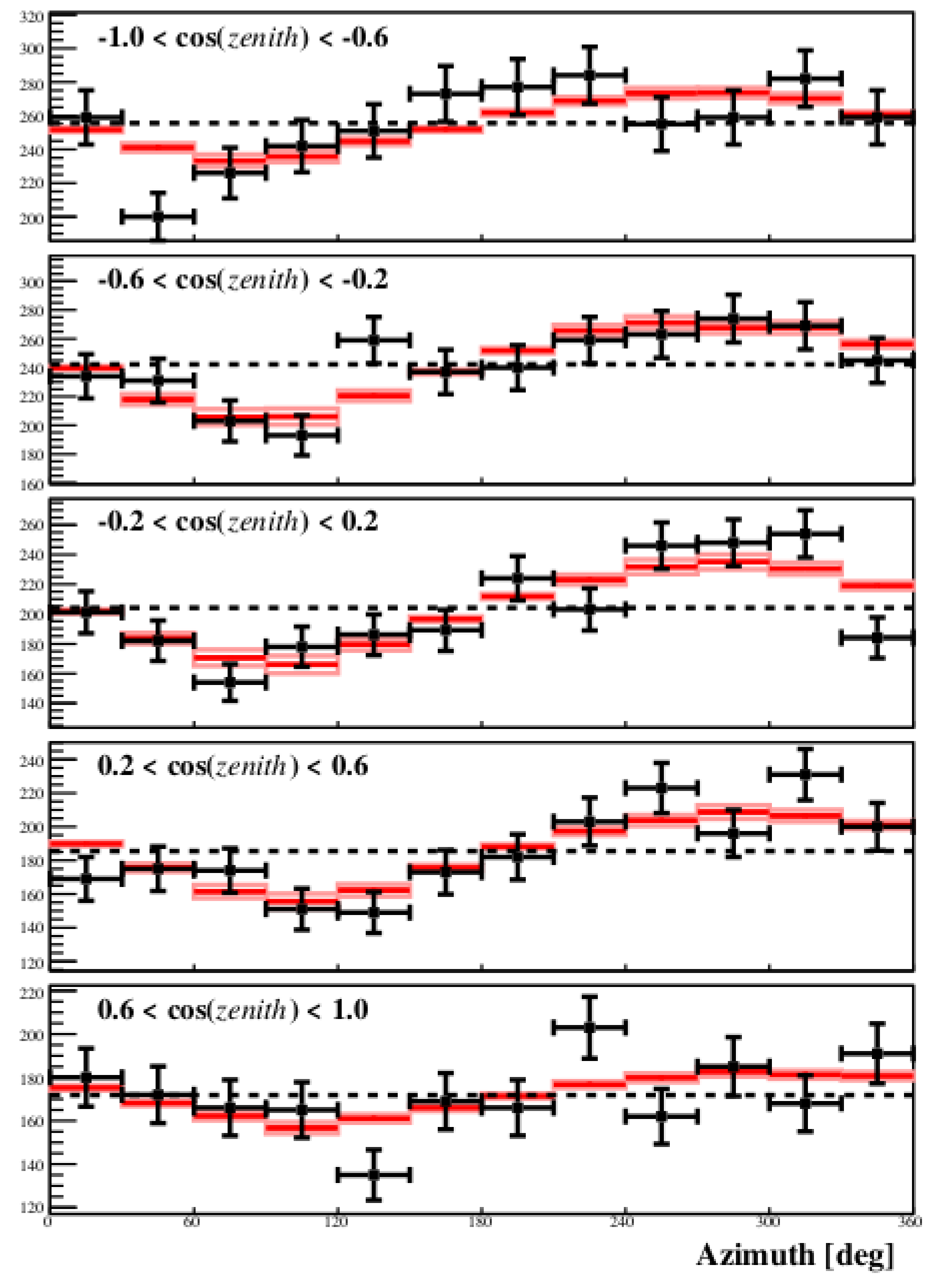

Best fit corresponds to 62 % of the predicted variations

Amplitude of variation is determined in the poor statistics region.

# Observed Azimuthal Variation of $\nu_e$ flux (from PHD thesis of E.Richard)

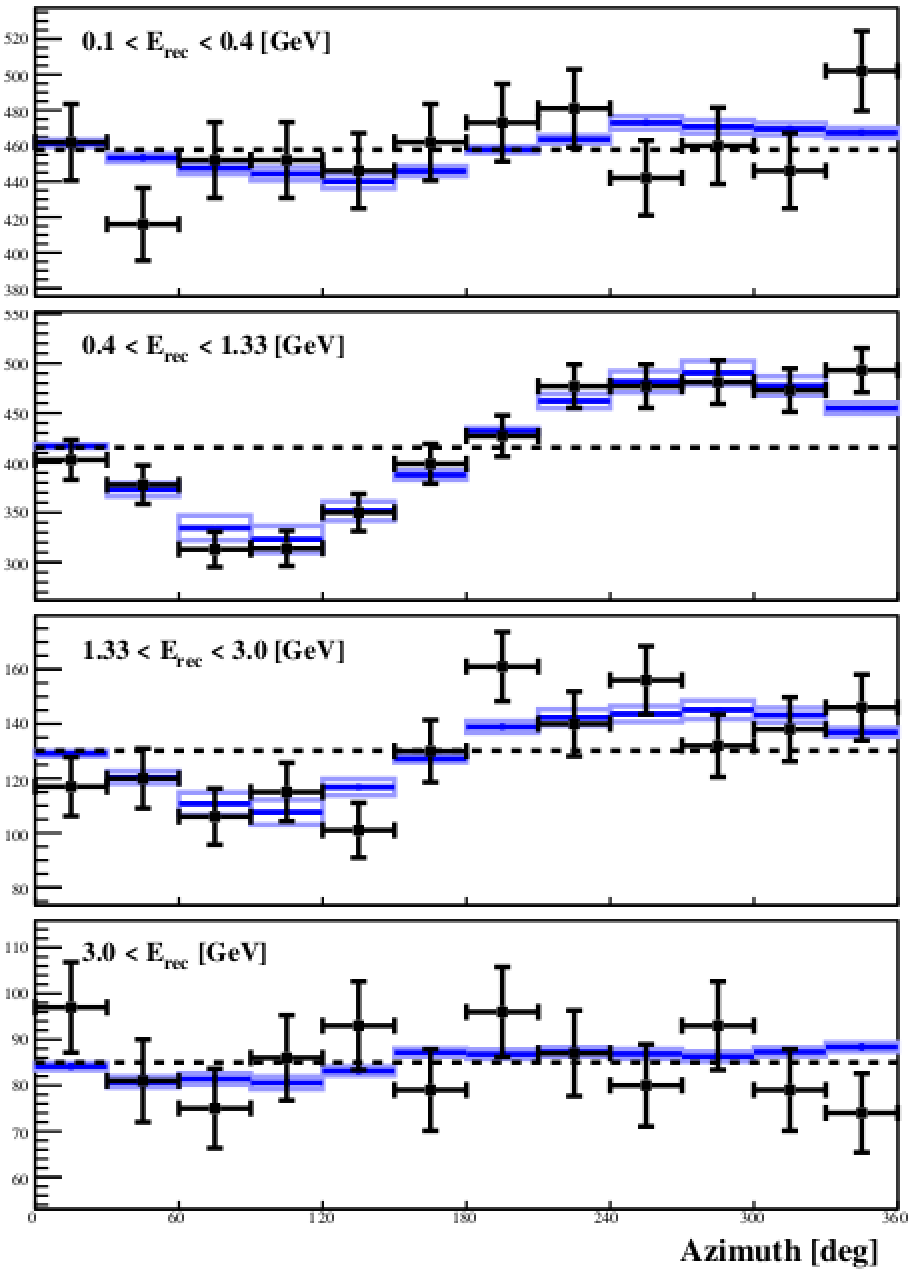


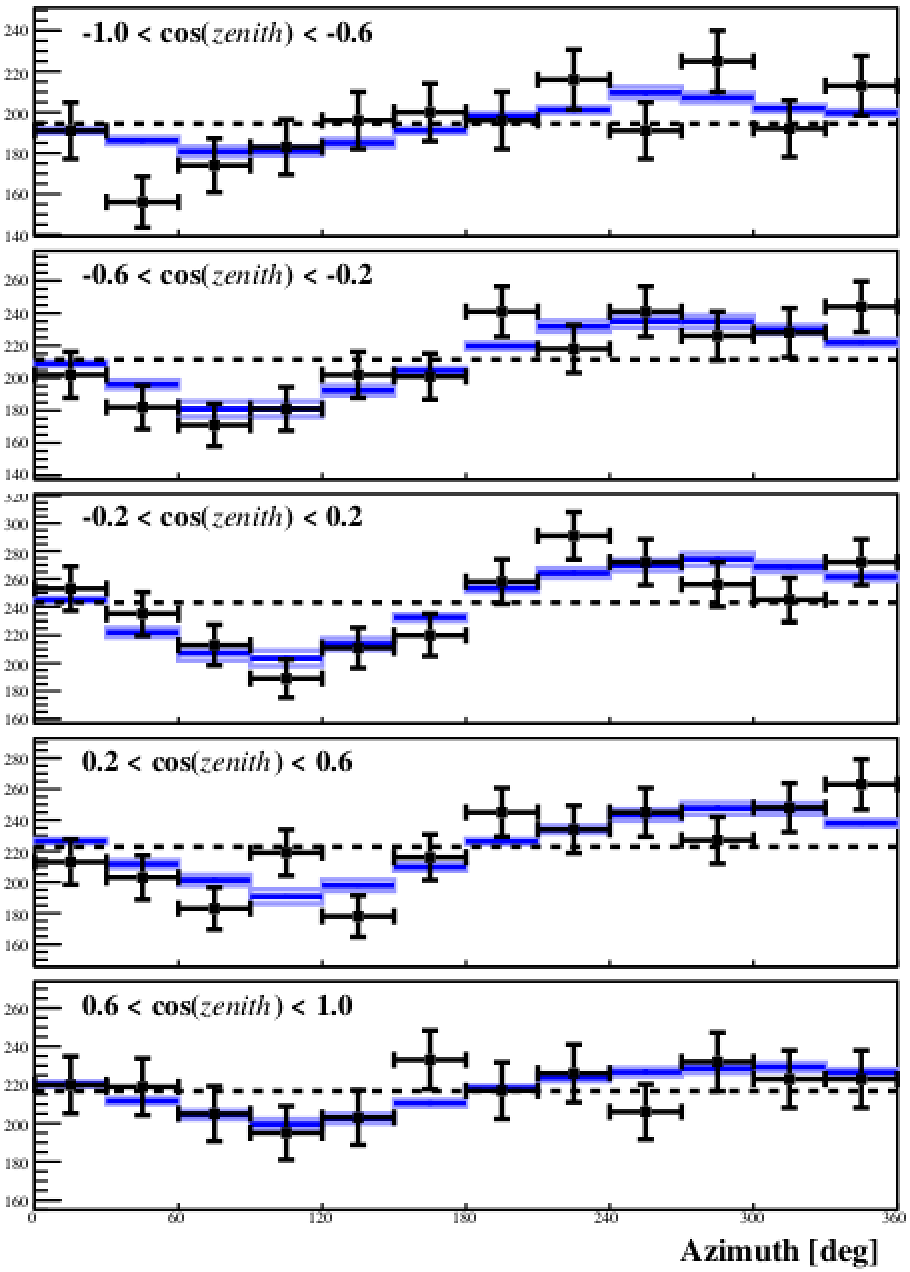

Energy Binned All Azimuth angles




Zenith Angle Binned All Energies

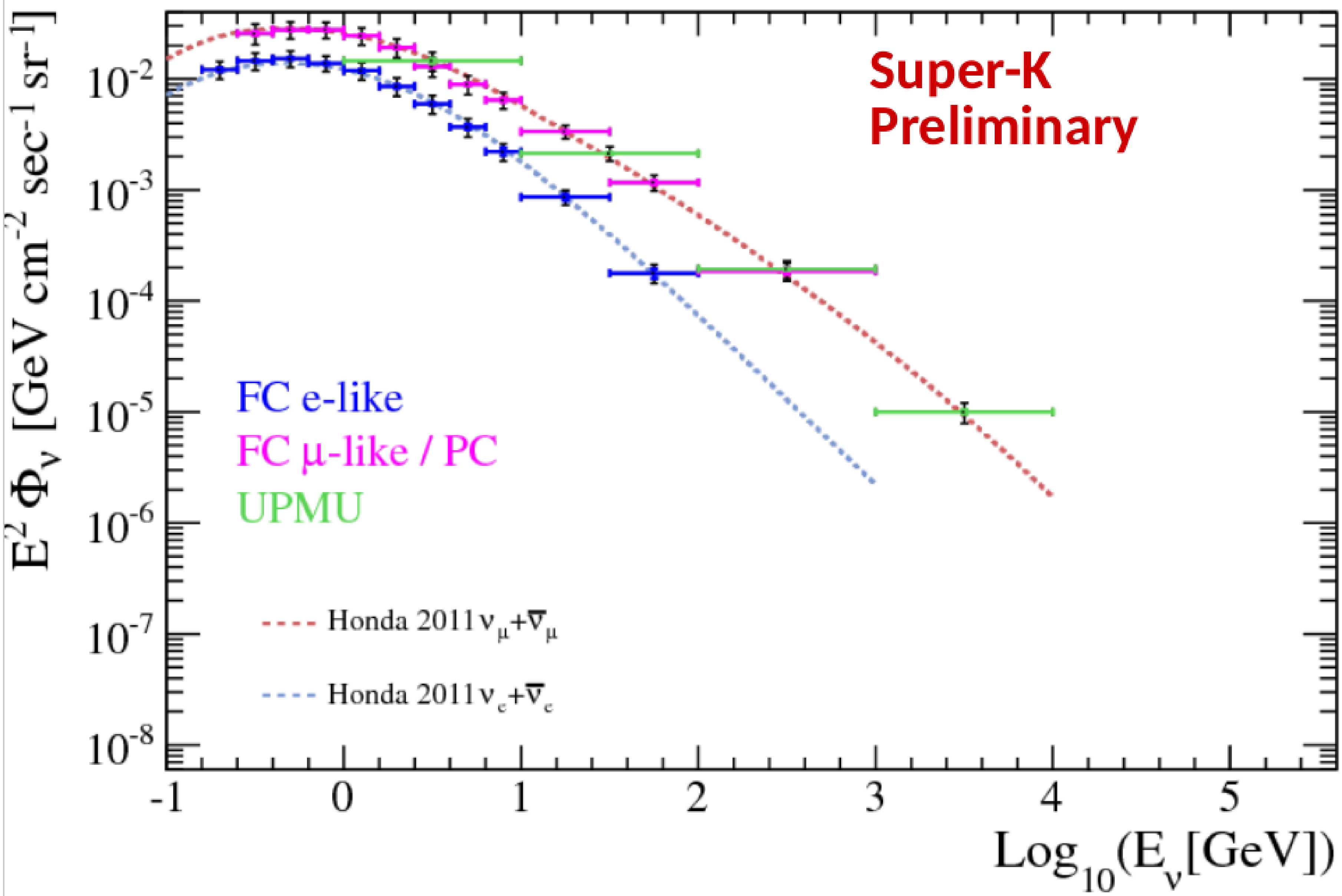
# Observed Azimuthal Variation of $\nu_\mu$ flux (from PHD thesis of E.Richard)




Energy Binned All Azimuth angles

Zenith Angle Binned All Energies




From K.Okumura in ICRC2015