Atmospheric Neutrino and Muon Fluxes

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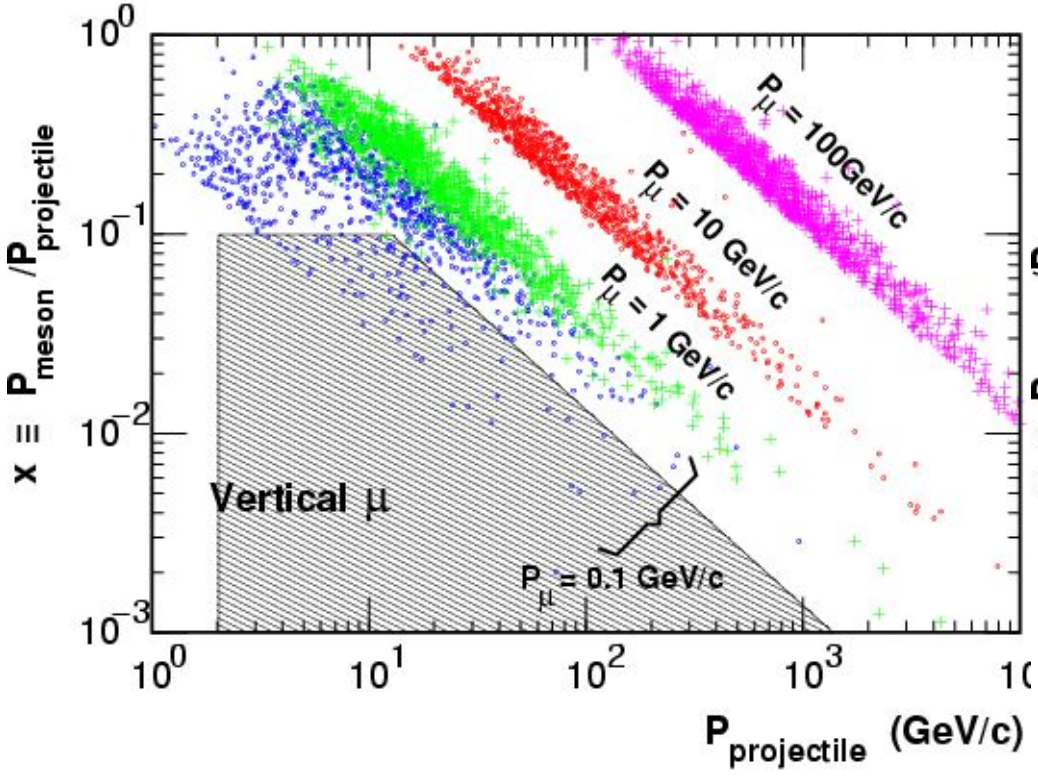
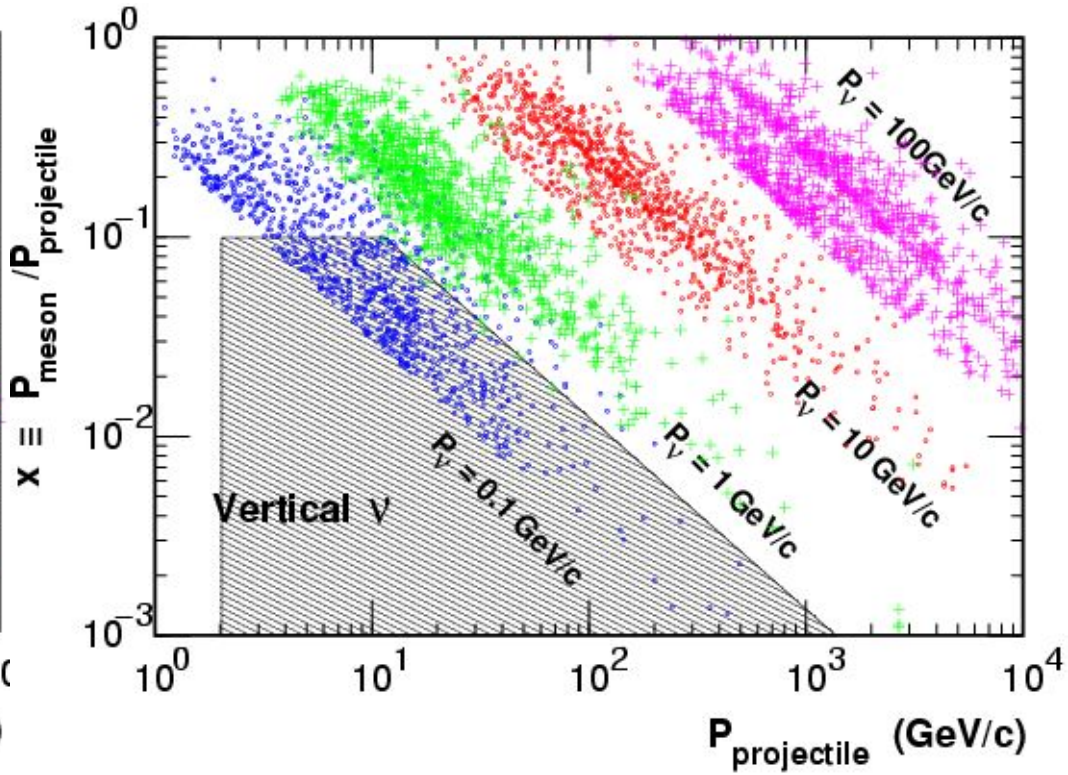
Are the Atmospheric Muon Data Useful for the Calculation of Atmospheric Neutrino Flux?

Mesons' phase space in the hadronic interaction relevant to fixed momentum muons and neutrinos (ground level)

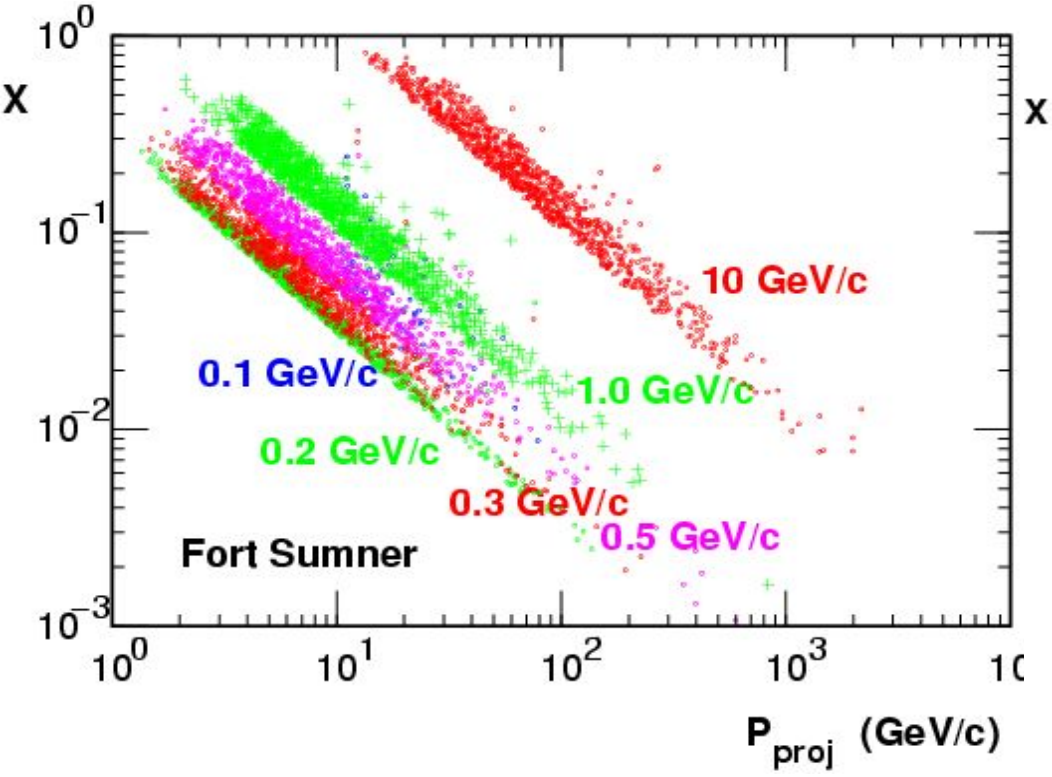




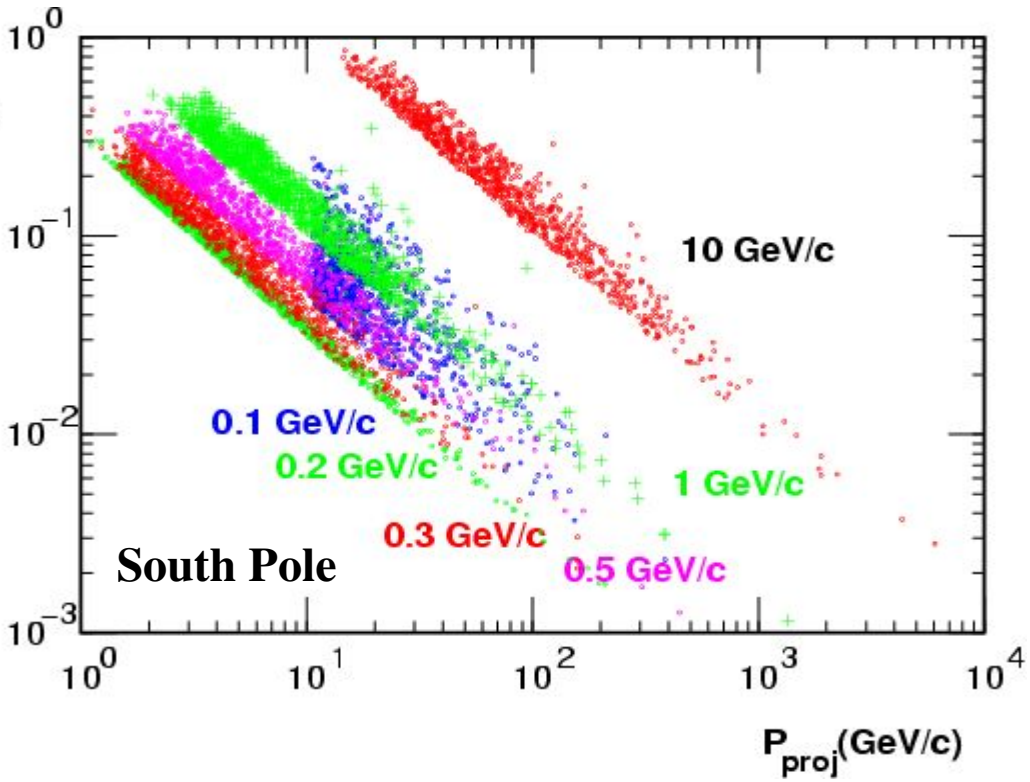
Good correlation above 1 GeV/c !

Phase Space for Muons at Balloon Altitude

Rigidity cut at 3.2 GV

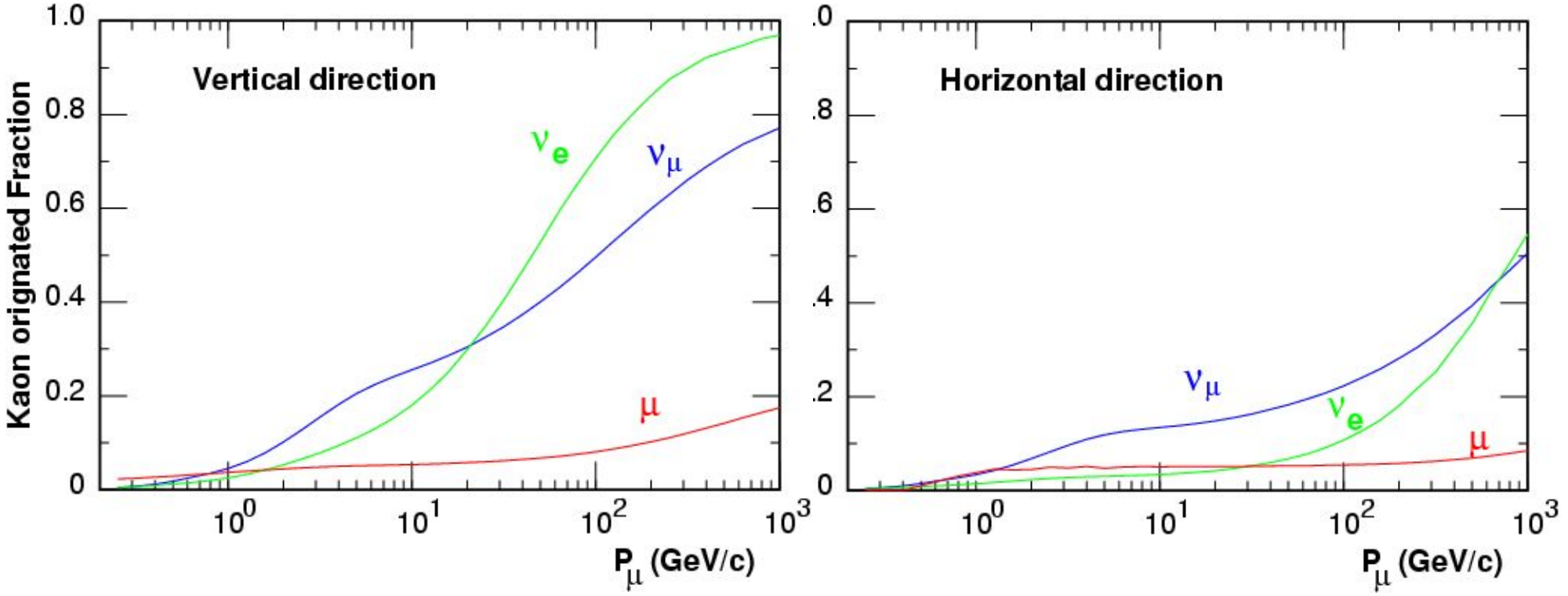


Rigidity cut < 1 GV



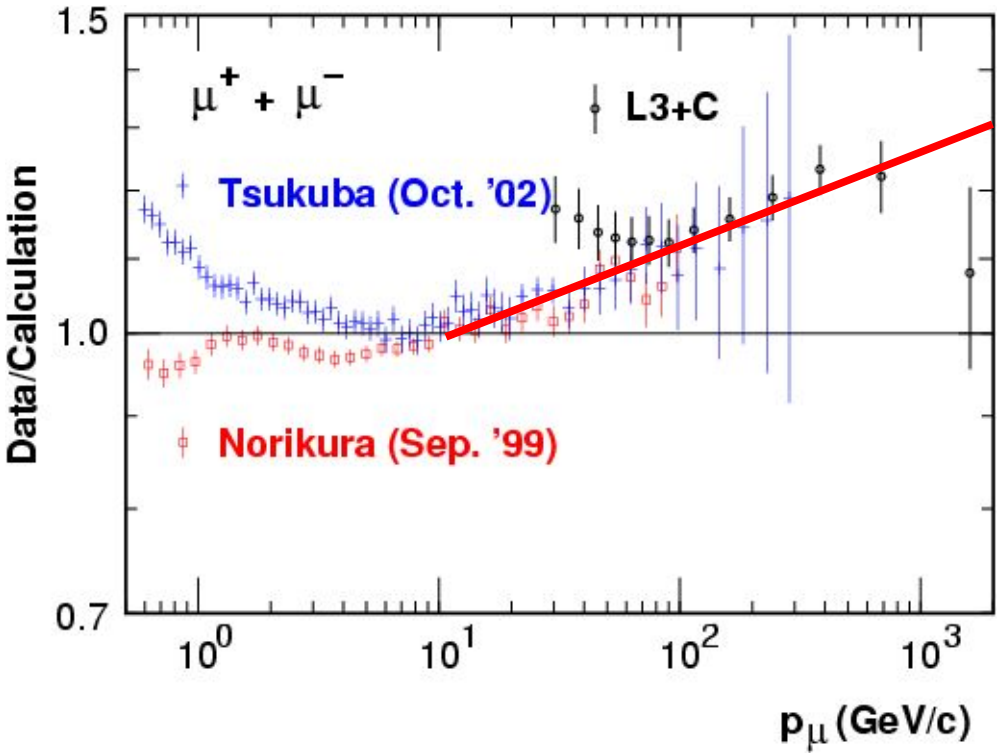
The phase spaces for muons below 1 GeV/c are well resolved for each momentum

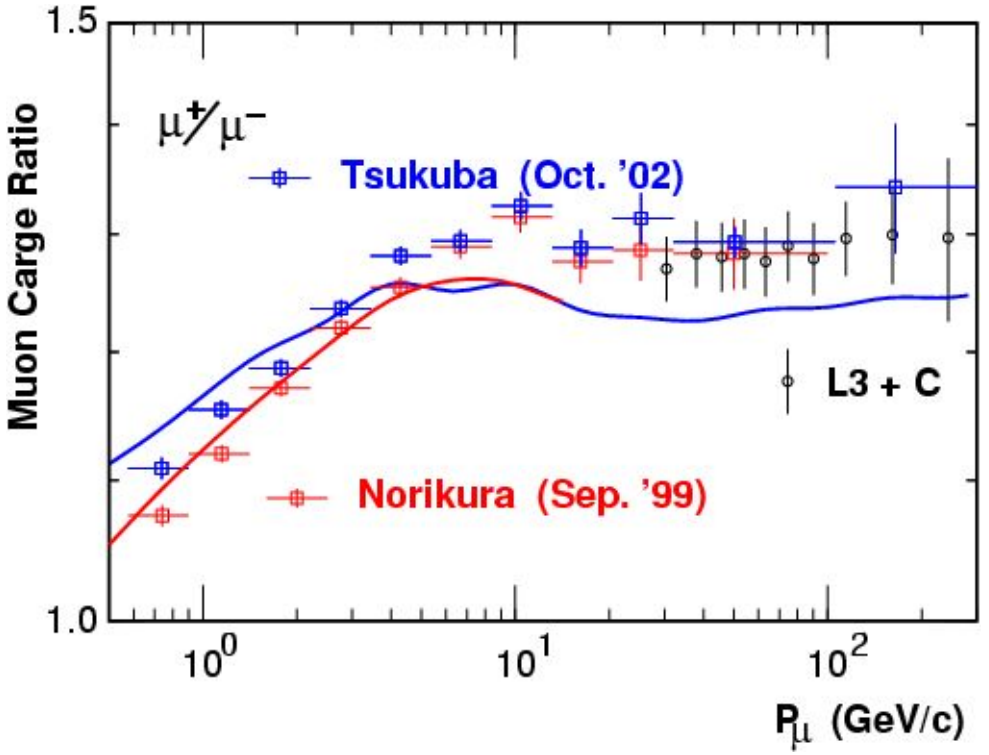
The Contribution of Kaons is Largely Different for Muons and Neutrinos at High Energies.



Comparison of Muon Flux Calculated in HKKM04 and Observed Data.

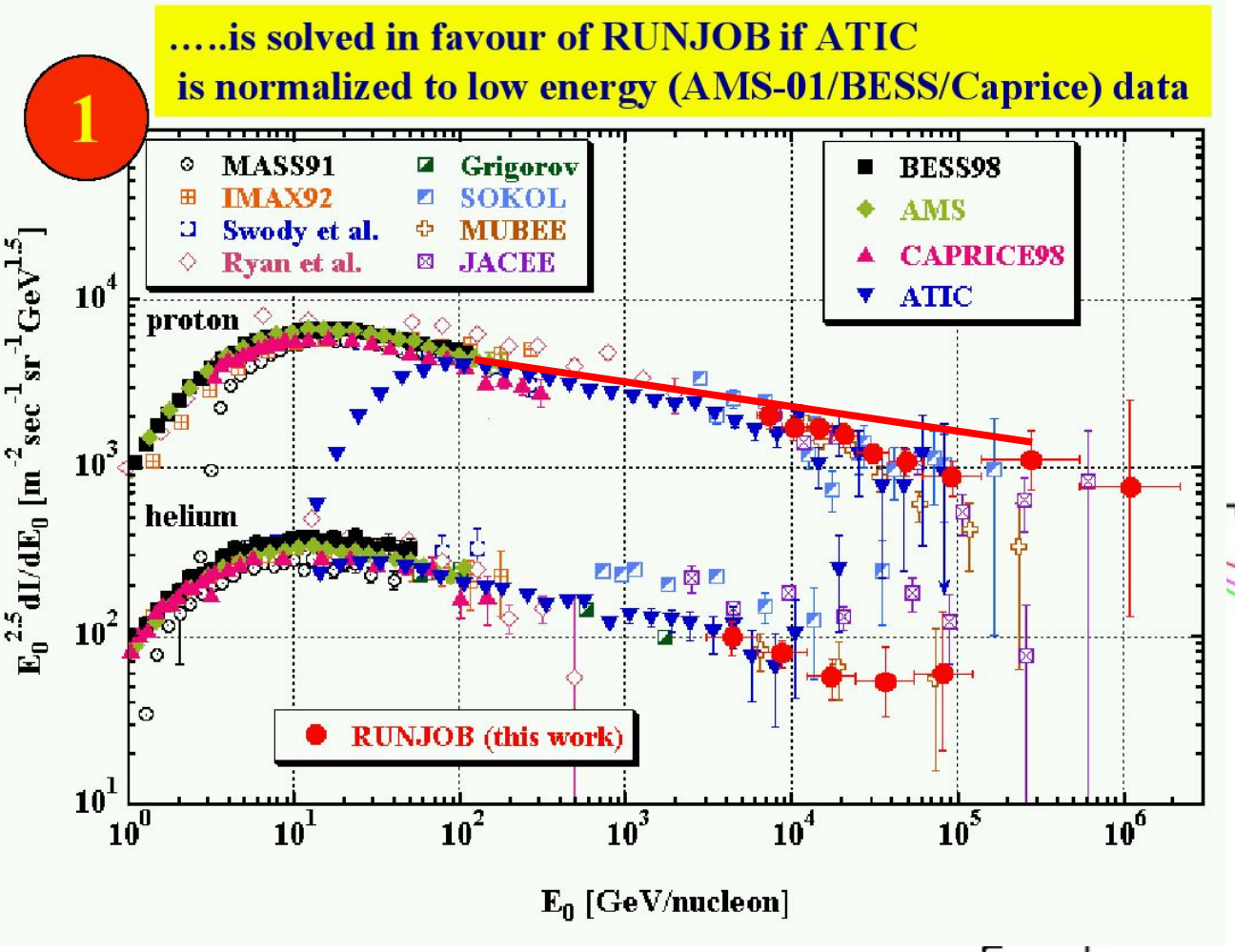
The differences are ~5% in absolute value for 1 ~ 30 GeV/c, and ~ 5% in charge ratio for all momentums.



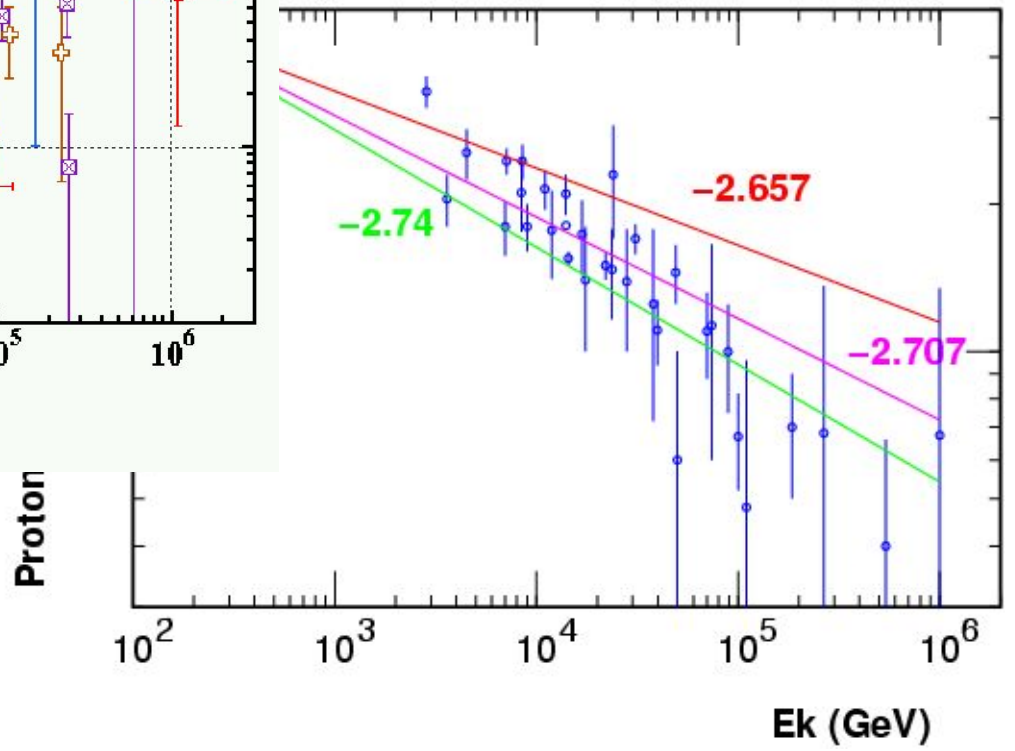


The difference of the absolute value increases at high energies, as $\sim(P/10\,GeV)^{0.05}$.

Primary flux ?

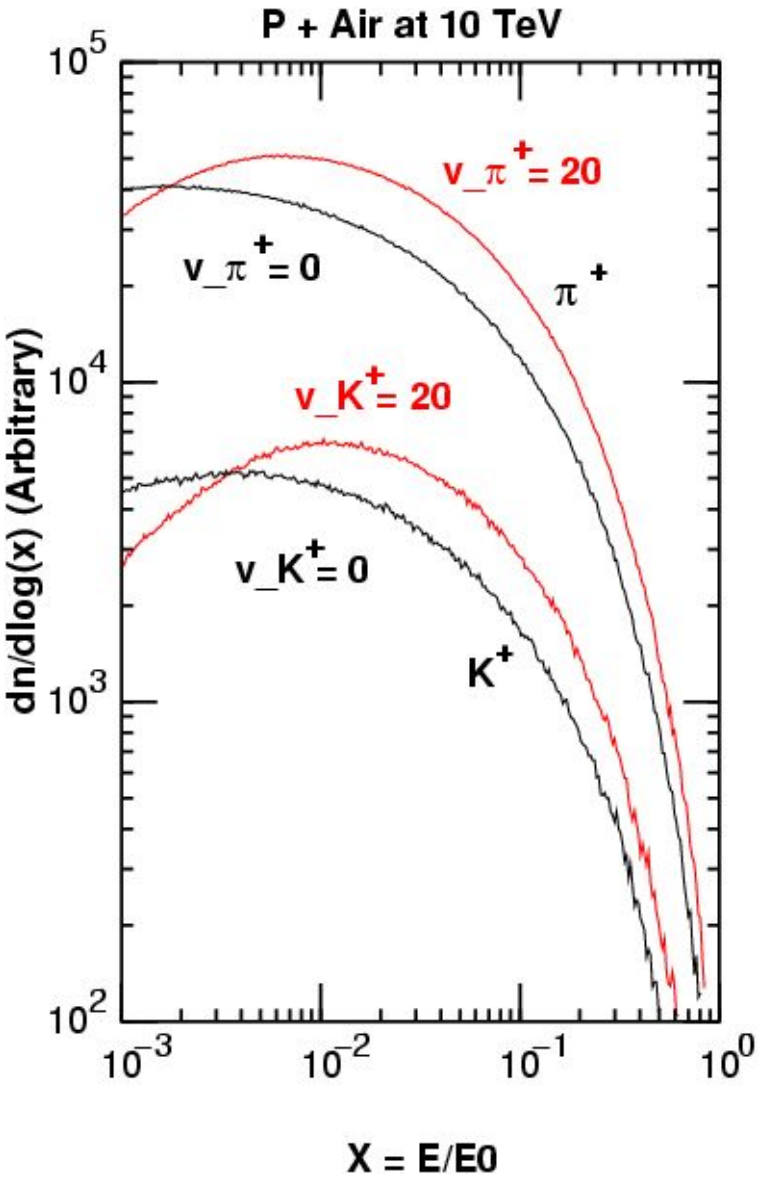


Flux model with
power index ~ -2.66



It is difficult to explain the charge ratio with primary flux only.

Modification of the interaction model



0. Base is the inclusive DPMJET-III.

1. Quark level modification.
The average energy of secondary mesons which have the same valence quark as the projectile are modified by the change of the x-distribution shape. $(x_i = E_i / E_{proj})$

2. Conserve the multiplicity of secondary particles.

3. Nucleons are the counter-balance for the energy conservation.

4. Iso-symmetry (symmetry under $u \leftrightarrow d$ exchange) is retained.

For proton (uud) and neutron (udd) projectiles

π^+	π^-	π^0
$(u\bar{d})$	$(d\bar{u})$	$(u\bar{u}+d\bar{d})/2$
K^+	K^-	K^0
$(u\bar{s})$	$(s\bar{u})$	$(s\bar{d}) \leftrightarrow (d\bar{s})$ Oscillations

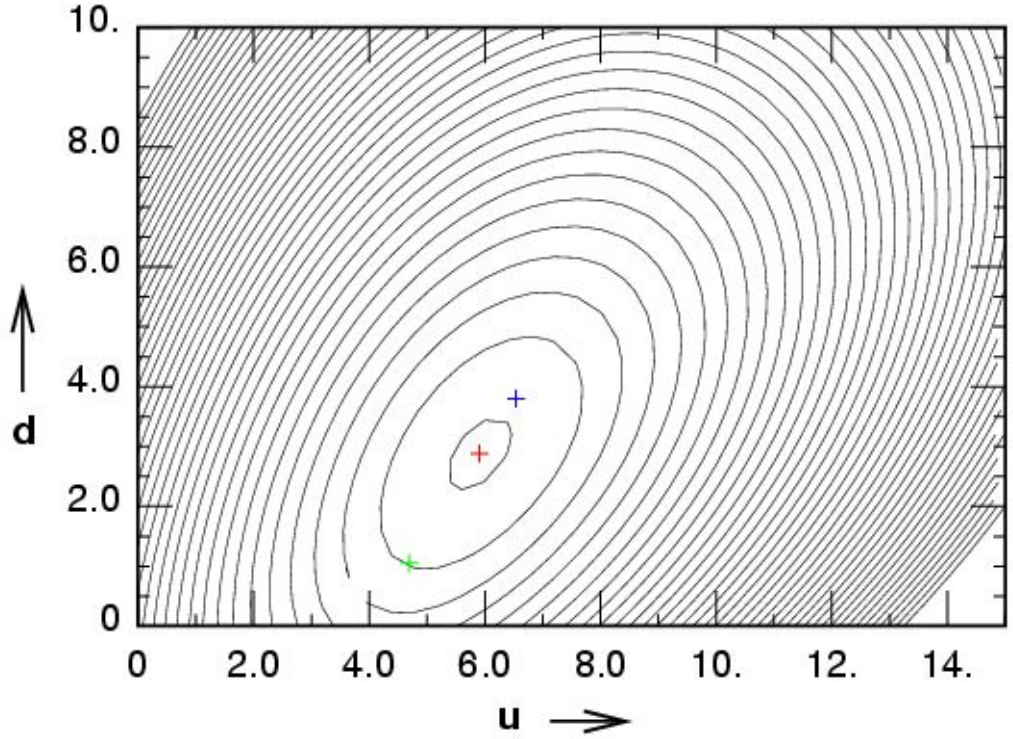
The magnitude of variations for $\begin{Bmatrix} \pi^0 & K^+ \\ \pi^0 & K^0 \end{Bmatrix}$ are $\begin{Bmatrix} ½ & 1 \\ ½ & ½ \end{Bmatrix}$ of $\begin{Bmatrix} \pi^+(u) \\ \pi^-(d) \end{Bmatrix}$

Note, π^0 is bilinear to u and d-variations.

No variation for K^-

Parameter search using muon data

parameter search (example)

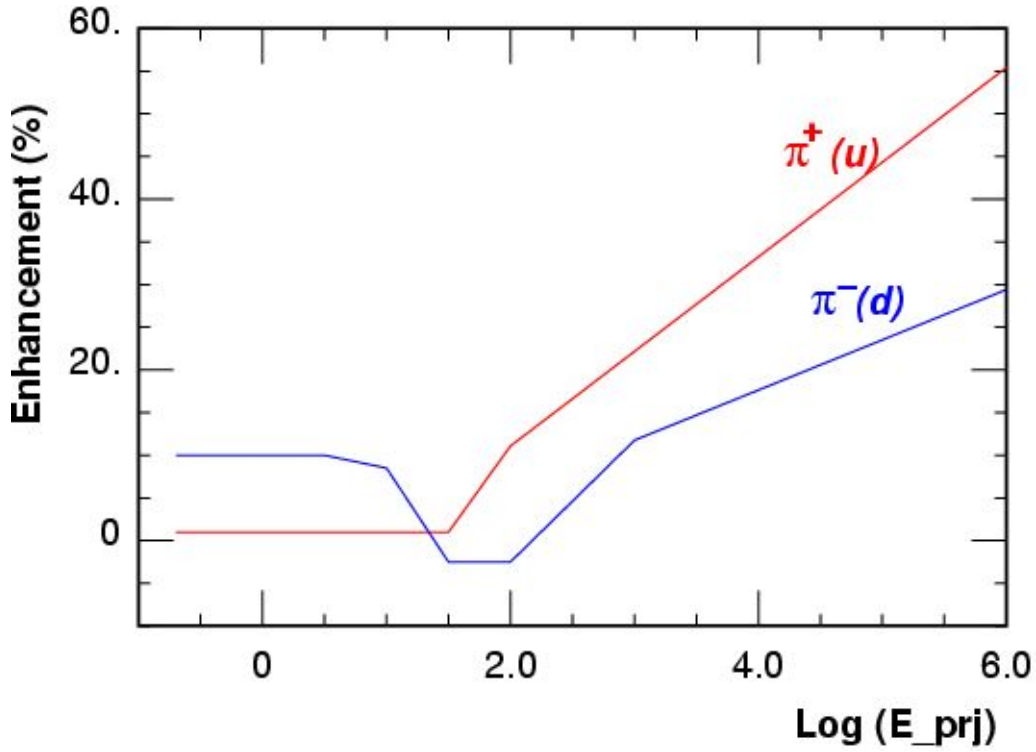


Vertical all: x,y,z = 5.91000E+00 2.88000E+00 2.23195E+01

L3+c : x,y,z = 6.54000E+00 3.80000E+00 5.32674E+00

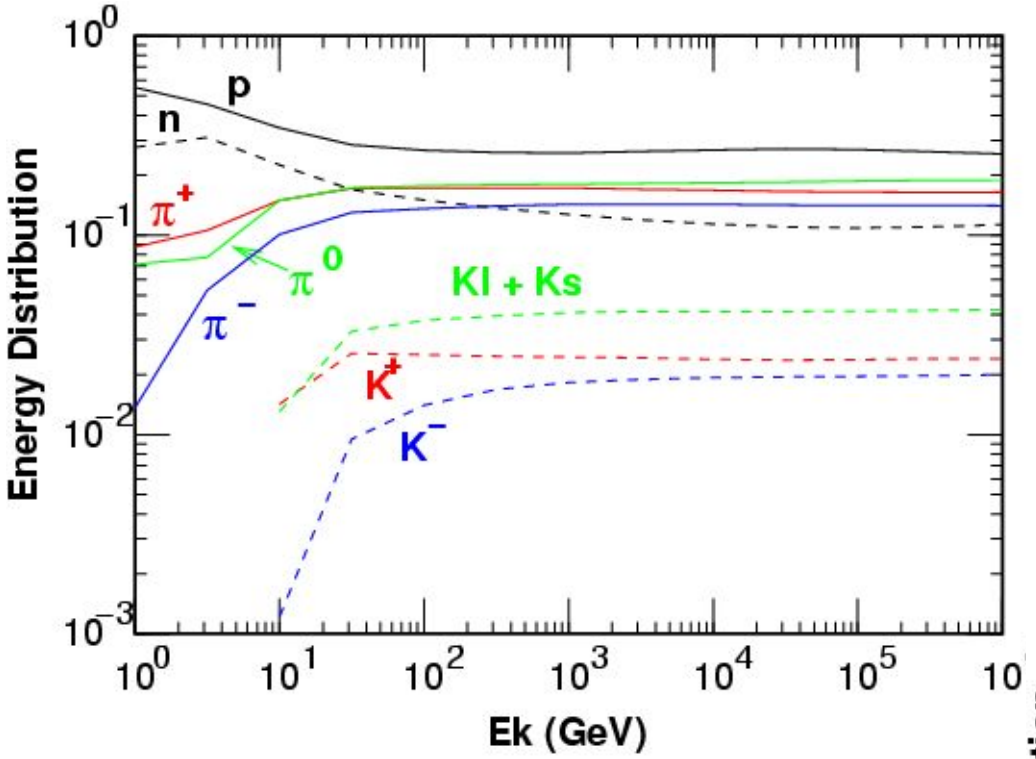
BESS: x,y,z = 4.69000E+00 1.05000E+00 3.82626E+00

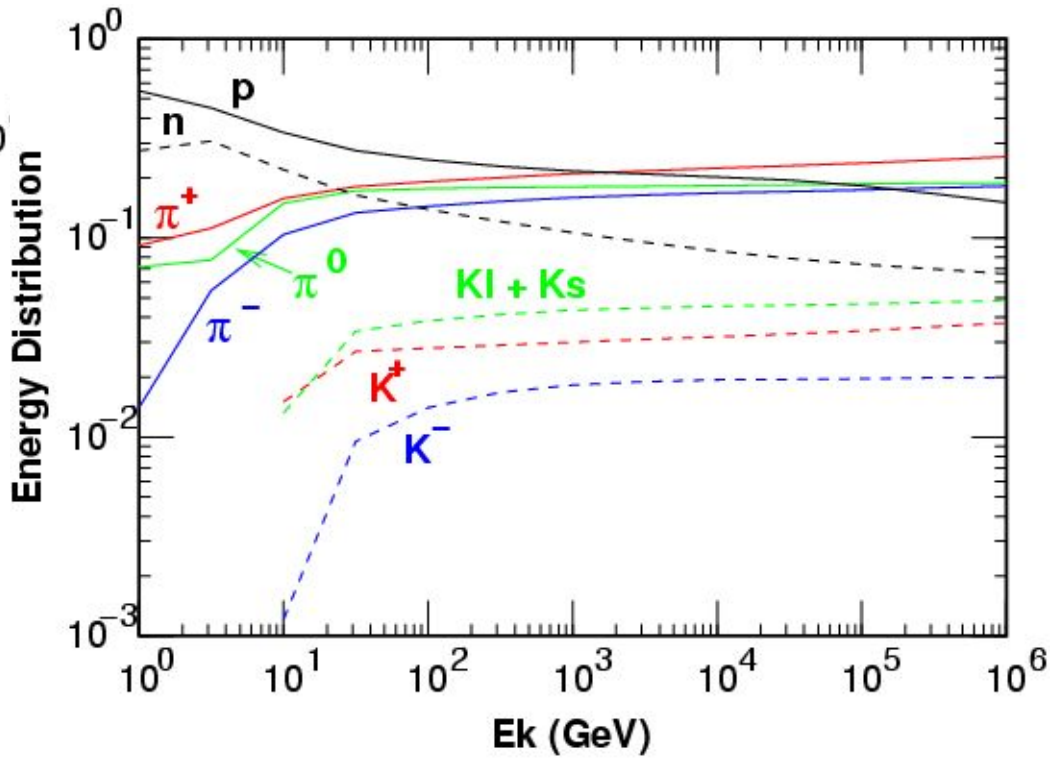
Magnitude of variation as the function of projectile energy



Before and After the Interaction Modification (I)

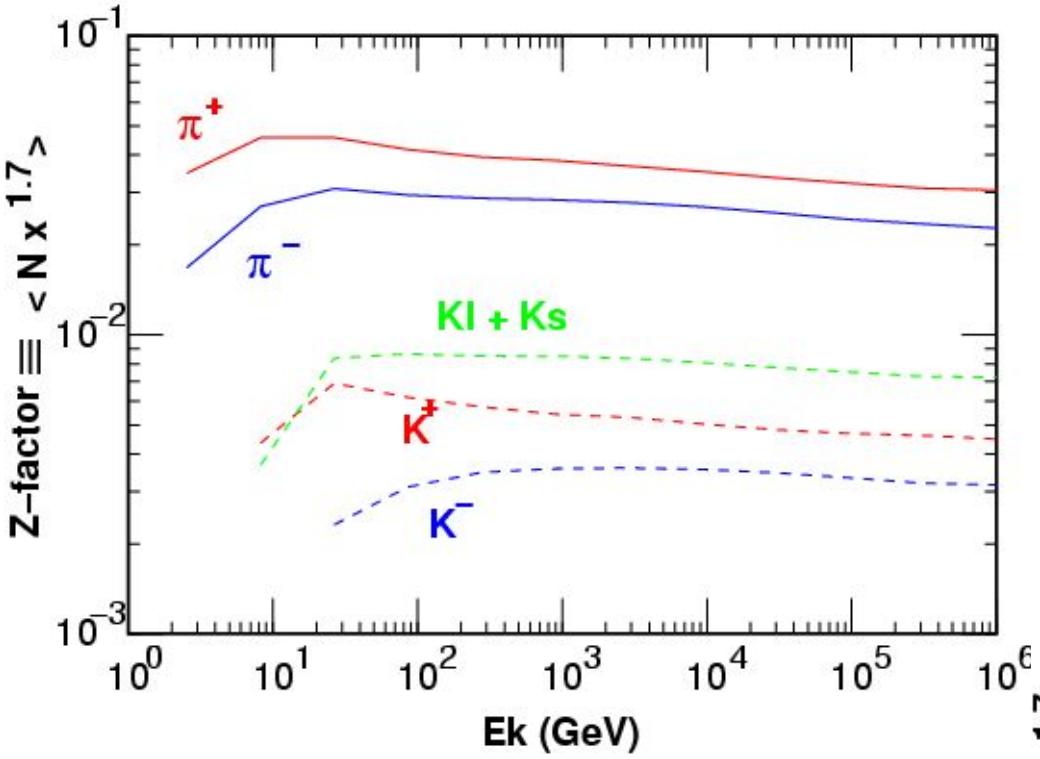
Energy distribution

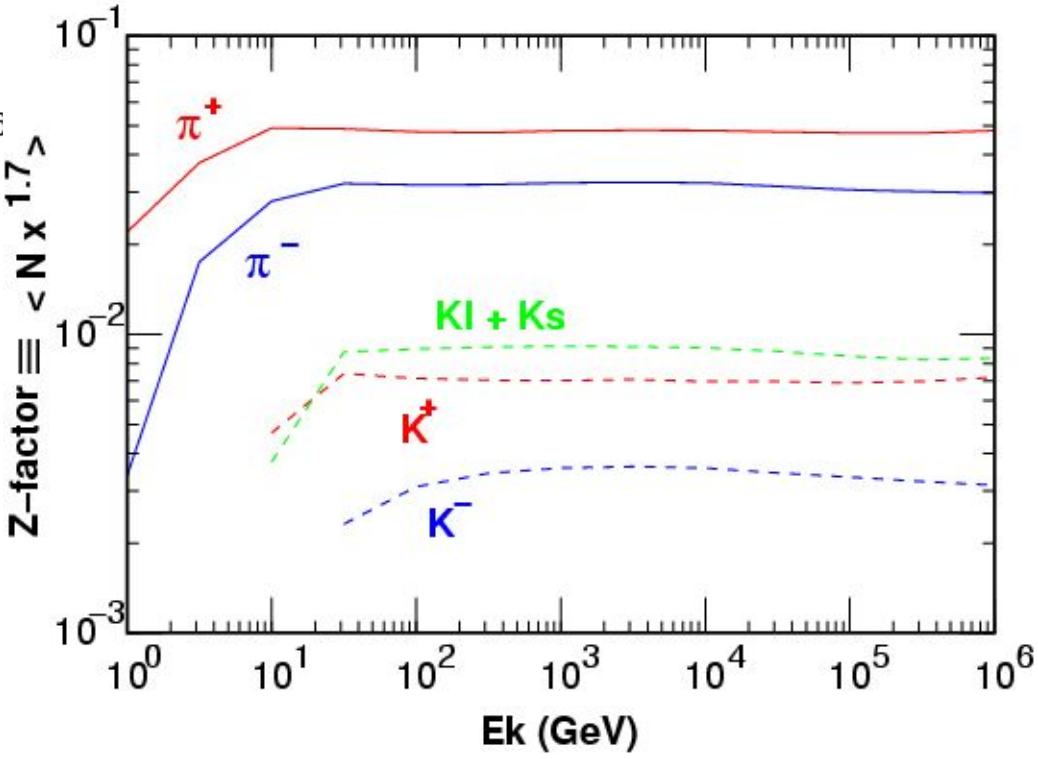




Before and After the Interaction Modification (II)

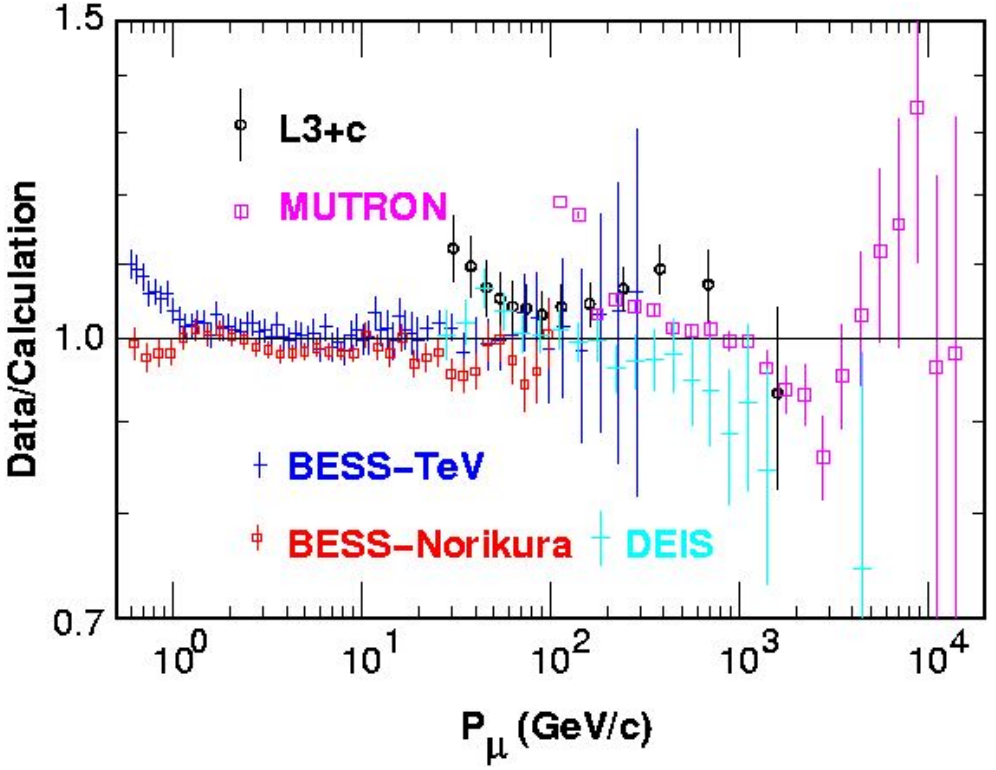
Z-factor $(Z \equiv N_i < x^{1.7} >)$

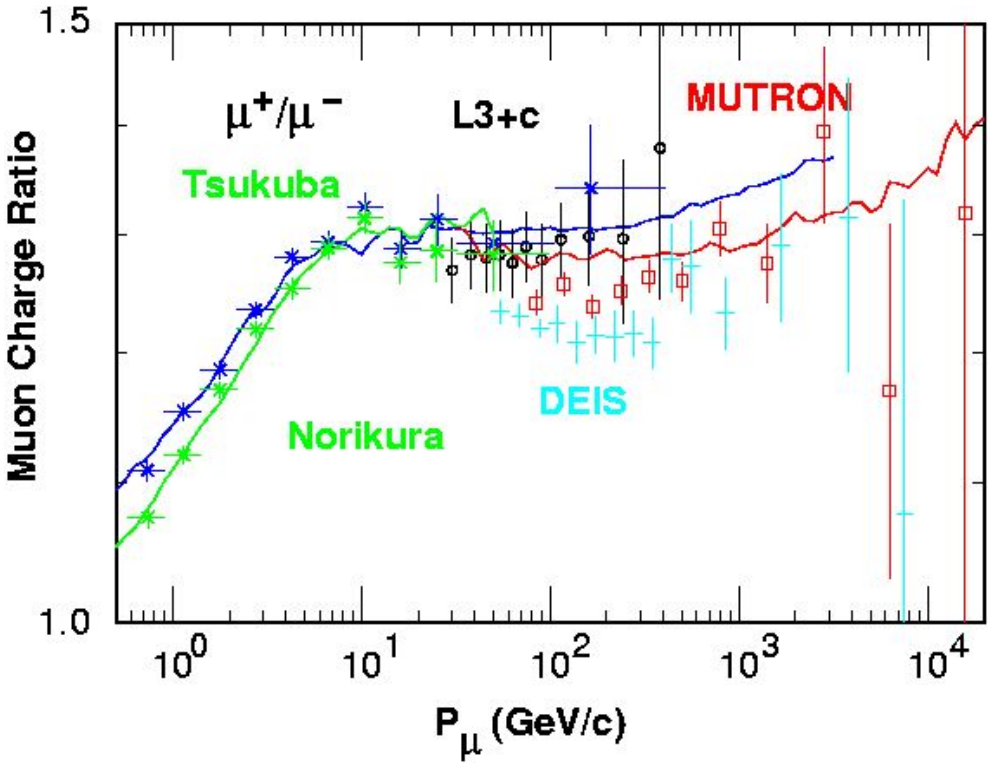




Modified interaction model recover the scaling hypothesis.

Comparison of Modified Results with the Observations

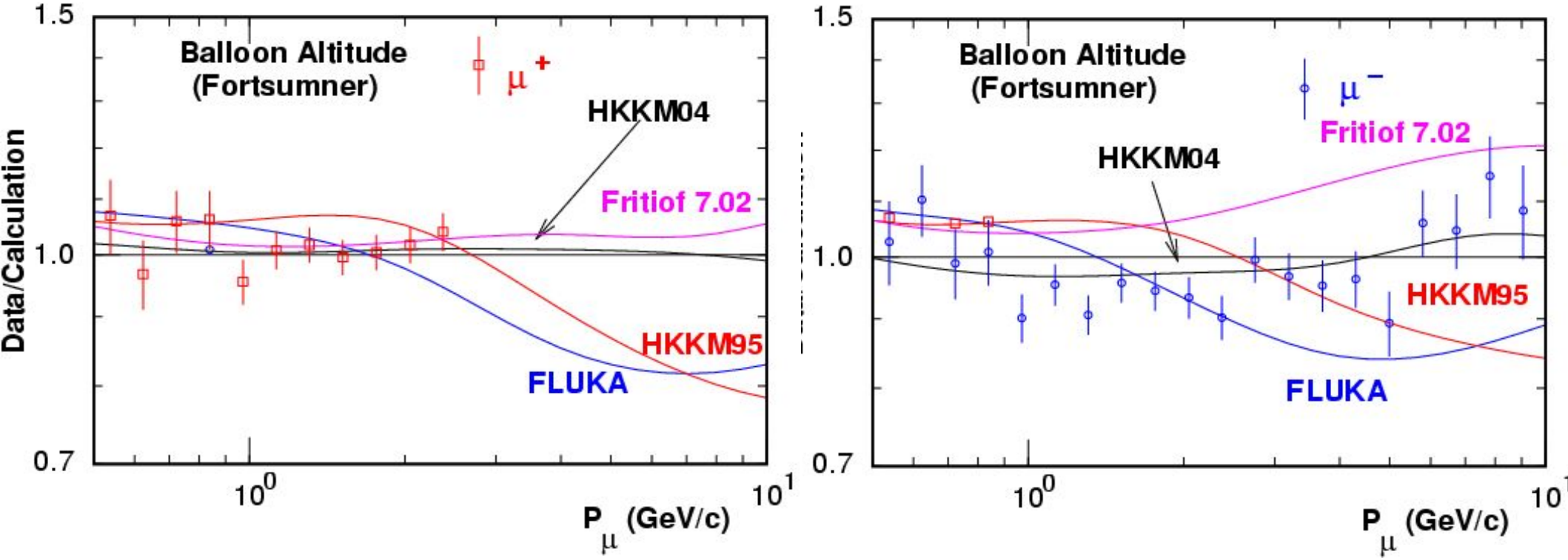




The calculation and data agree well within 10 % in 0.5 GeV/c ~1 TeV/c, and < 5% in 1~30GeV/c.

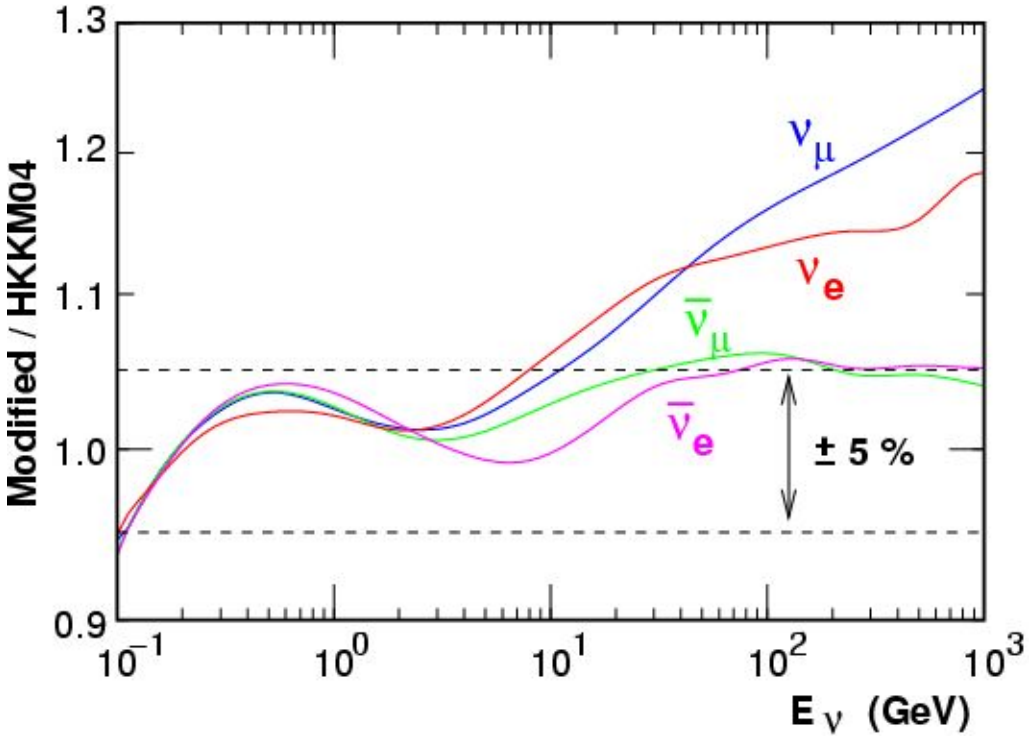
Muons at balloon altitude

Comparison of <Flux / depth> between calculation and observation



Agreement is better in the original DPMJET-III,
but Modified one is not so bad !

Comparison of Modified Neutrino Flux with HKKM04



They agree within 5% below 10 GeV.

Summary

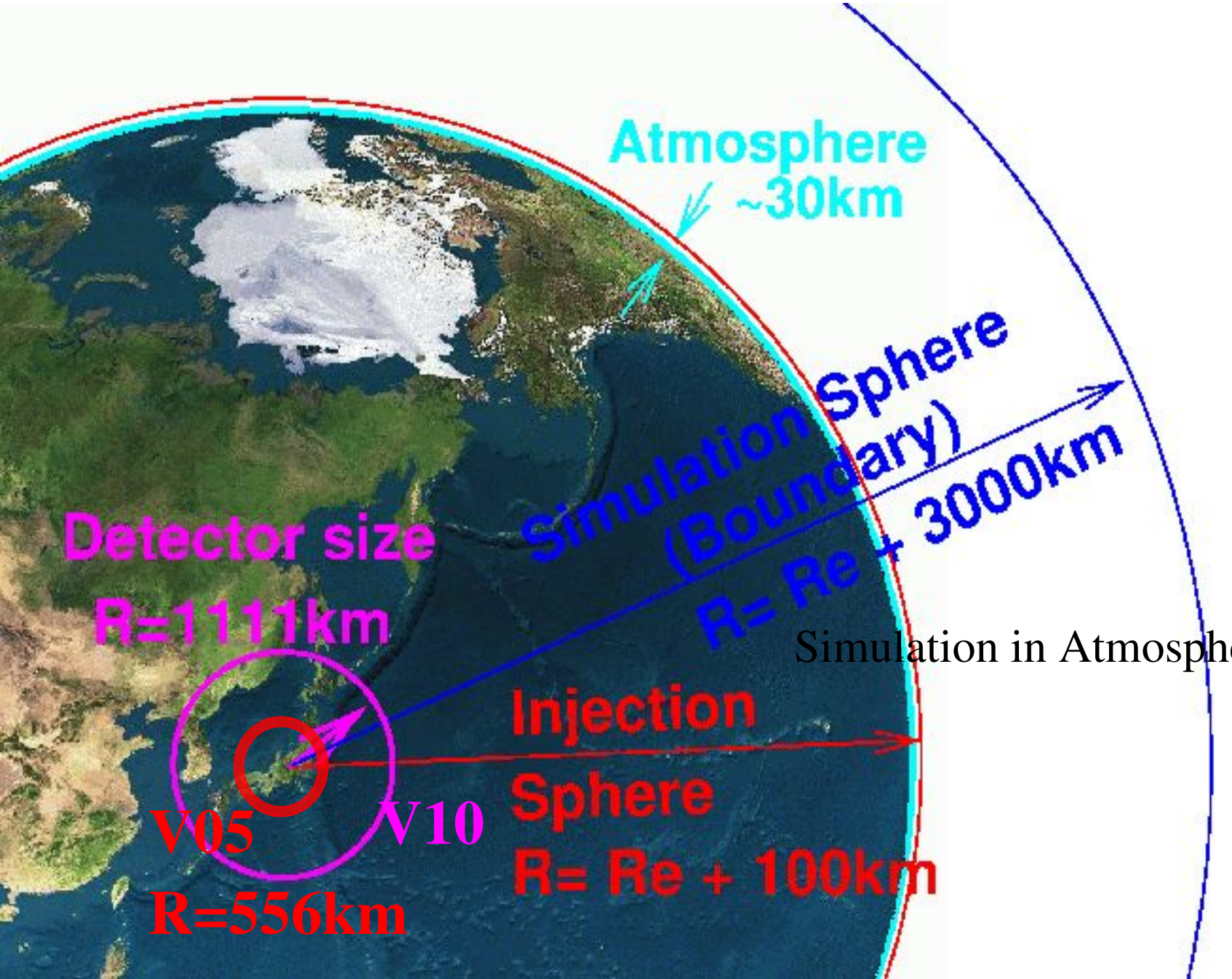
1. The comparison of calculated and observed muon fluxes suggests that DPMJET-III should be modified.

2. Our modification of the DPMJET-III successfully reproduces the observed muon flux in a wider momentum range of 1 ~ 1000 GeV/c.

3. The atmospheric neutrino fluxes calculated with the modified interaction model are largely increased above 100 GeV/c.

Size of the virtual detector

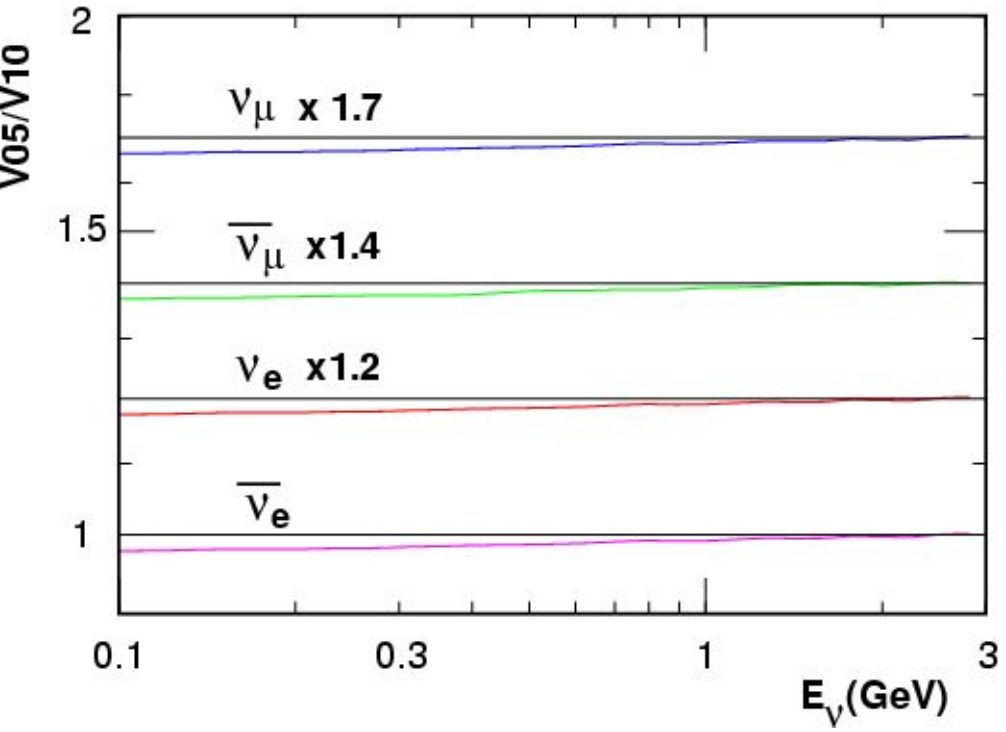
(Re = 6378km)



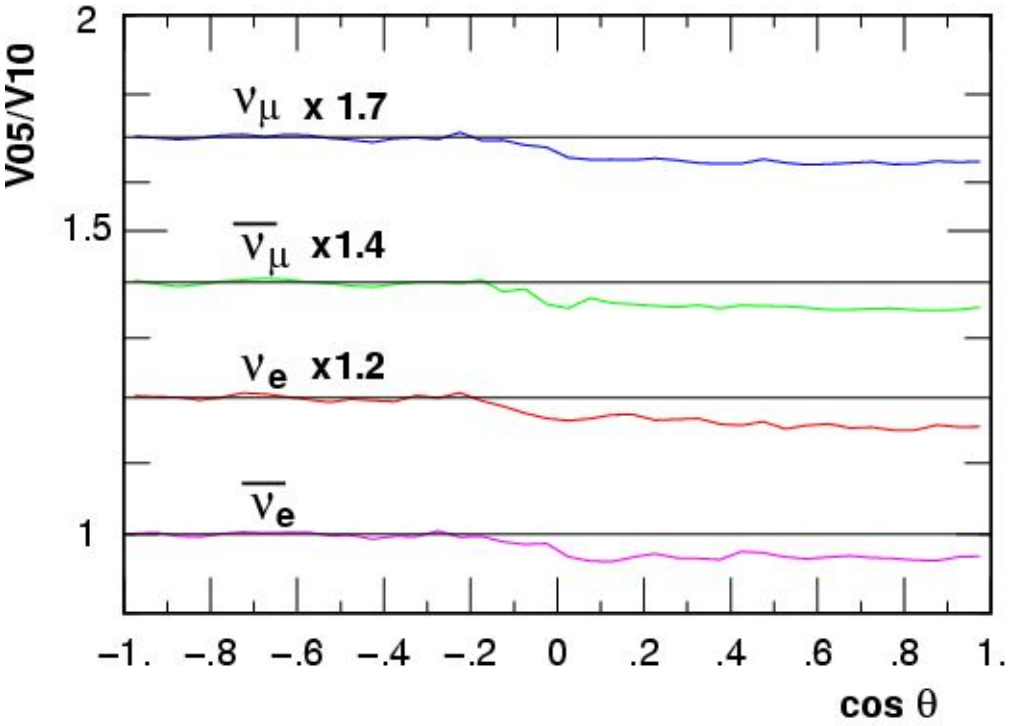
Simulation in Atmosphere

Comparison of the results between V10 and V05

All direction average



at 0.3 GeV/c



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