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Hadron Production Model Dependence of Neutrino Flux Estimation

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Introduction～Hadron production uncertainty

K2K → Direct measurement of hadron (pion) spectrum.

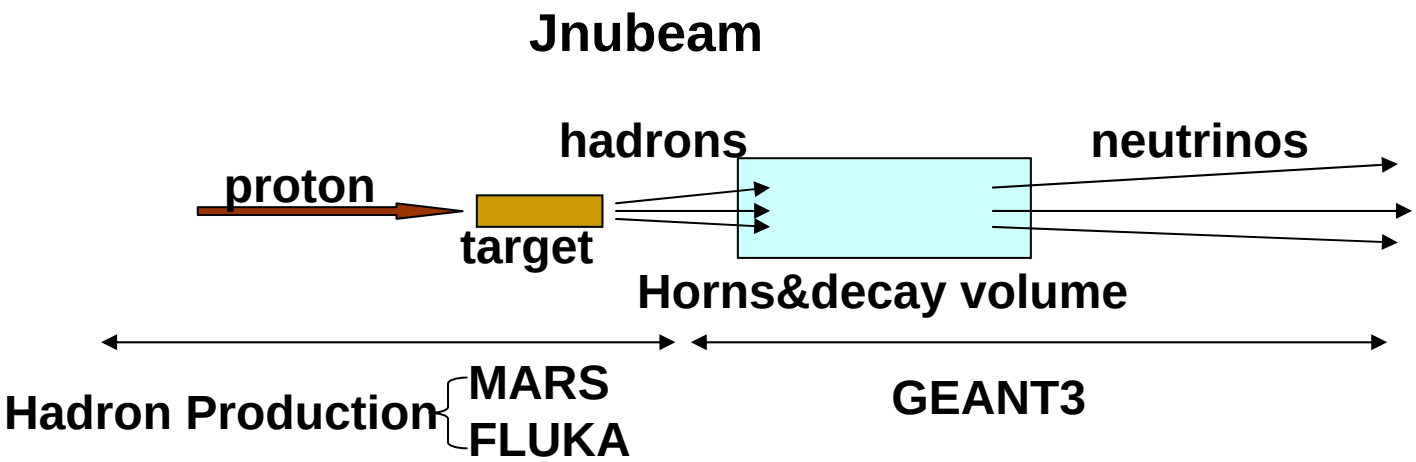
JHF-nu → Impossible due to high momentum and high intensity.

→ Estimated by Simulation !

In order to predict the Neutrino Spectrum at SK, we need to understand the uncertainty of Hadron Production and its effect to the prediction of neutrino beam spectrum.

We study the Hadron Production Model Dependence of Neutrino flux.

Neutrino Beam Simulation



To estimate the Hadron production uncertainty we use two Hadron Production Models (MARS and FLUKA) and compare them.

Neutrino Beam Simulation

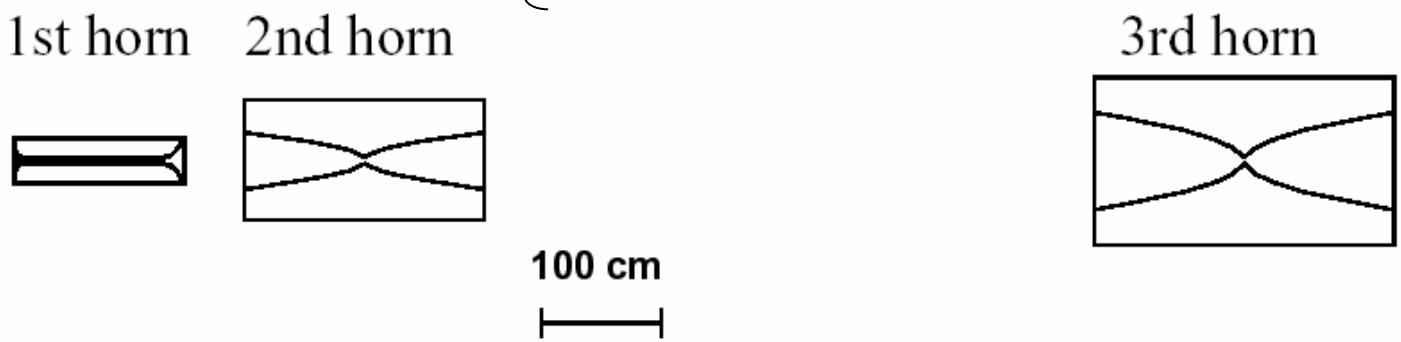
<Simulation Parameters>

- Proton Energy : 50[GeV]
- Target material : Carbon
- Proton On Target : 3.3×10^{14}[#/spill]→10^{21}[#/year]
- Decay Pipe : 130[m]
- Off Axis Angle : 2.0 deg. for SK
- Distance to SK : 295km , to ND : 280m
- ND size : 3×3[m^2]

Neutrino Beam Simulation

This study(J-PARC)

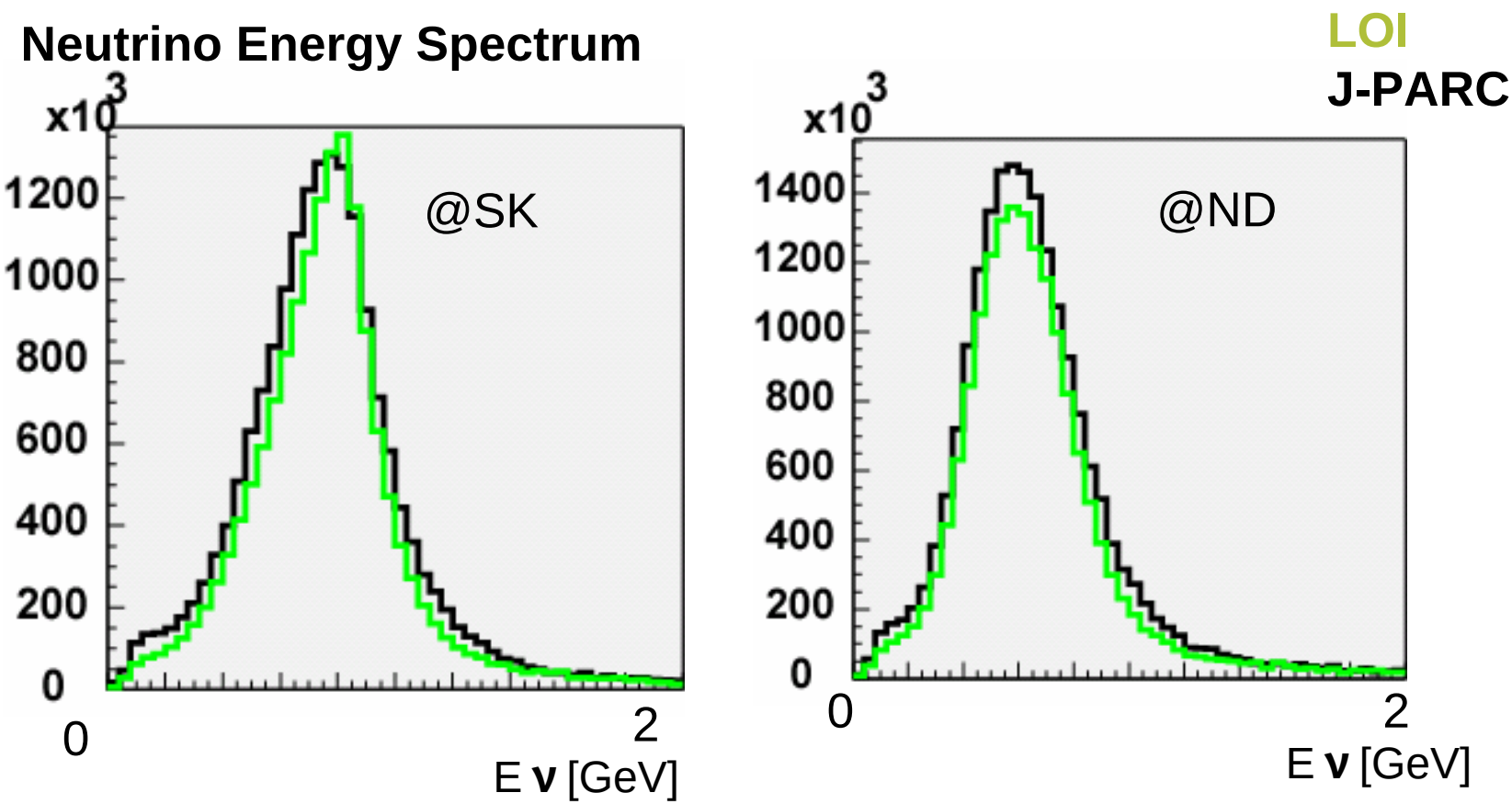
- 90[cm] length ,1.5[cm] radius target
- three sets of horns



The previous study (LOI)

- 45[cm] length ,0.32[cm] radius target
- two sets of horns

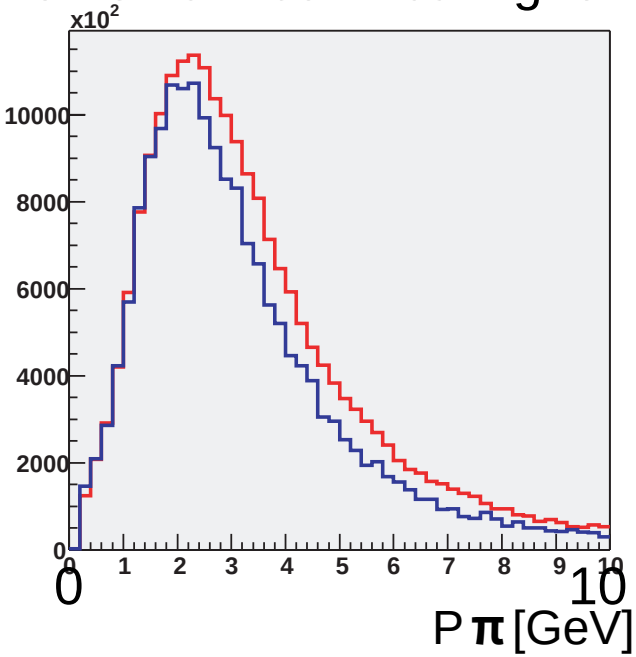
Comparison between LOI and J-PARC



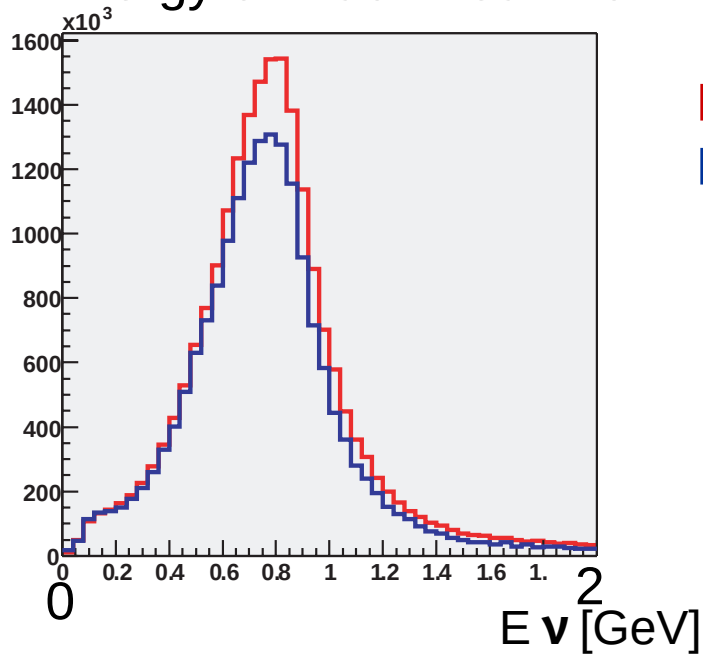
A little difference between two geometries. (~3.1% peak difference)
Total flux of neutrino is about 16% more than LOI.

Hadron Production Model
Dependence on Neutrino Spectrum

π^+ momentum contributing to ν



Energy of muon neutrino



MARS
FLUKA

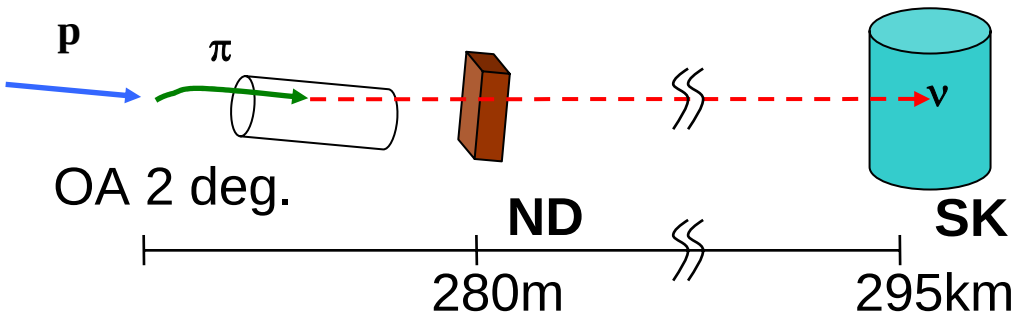
	Peak	Mean	Flux
π contributing to ν	9.1%	6.8%(5.4%)	15.7%(14.9%)
ν energy	3.1%	3.0%(1.4%)	

MARS model is harder than FLUKA model.

Full range

0.4<E ν <1.2

Model Dependence of Far/near ratio

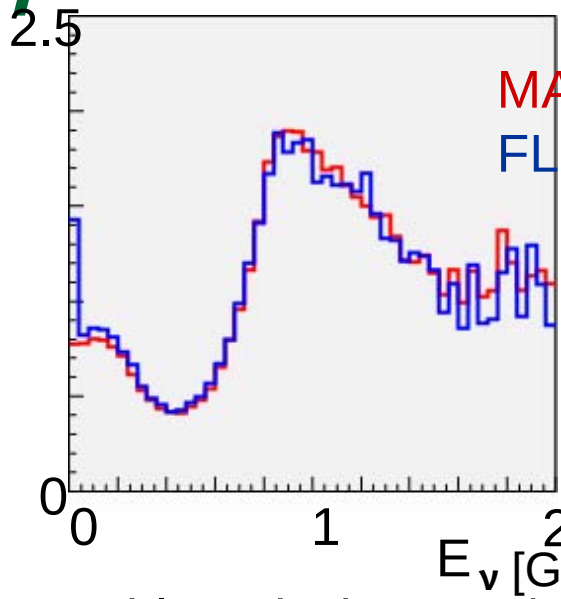


Flux @SK = Flux @ND ✕[Far/near ratio]

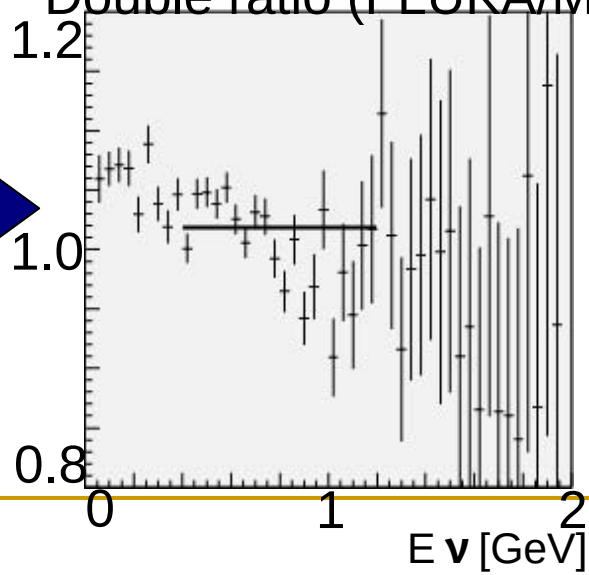
From MC simulation

The Difference of Far/near ratio is ～1.9±0.4%

(Energy range:0.4～1.2[GeV])



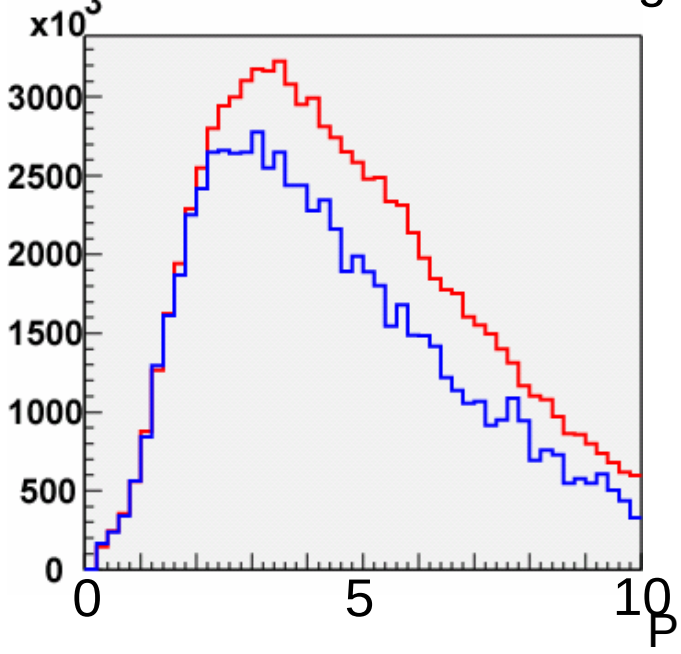
Double ratio (FLUKA/MARS)



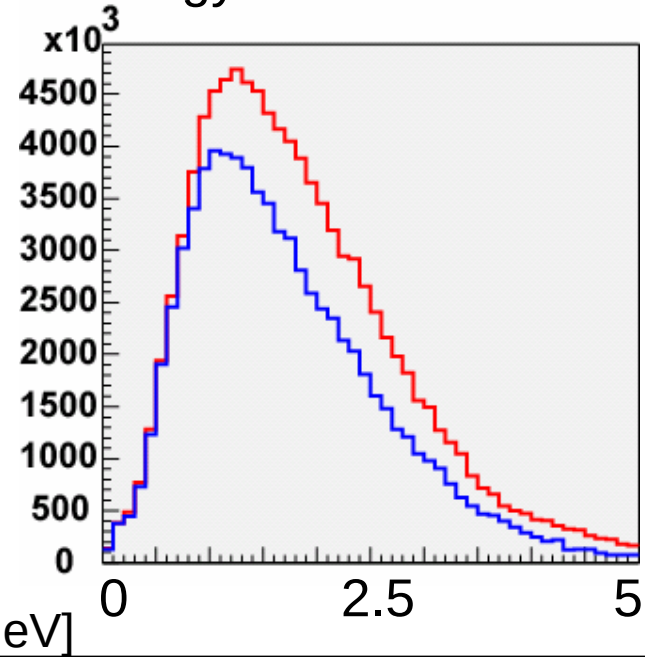
Model Dependence of Neutrino Flux at On Axis ND

<Absolute Value>

π^+ momentum contributing to ν



Energy of muon neutrino



MARS
FLUKA

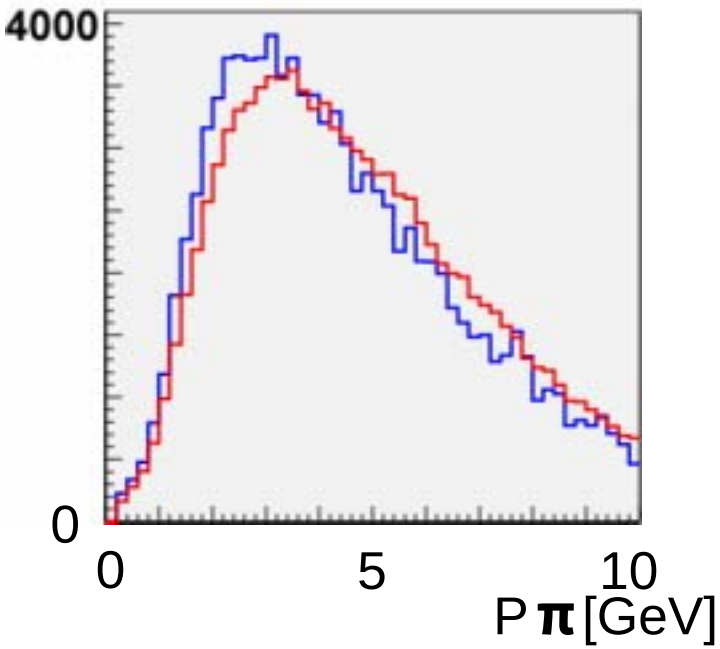
	Peak	Mean	Flux
π contributing to ν	13.3%	5.3%	26.6%
ν energy	16.6%	6.8%	

Model Dependence of Neutrino Flux at On Axis ND

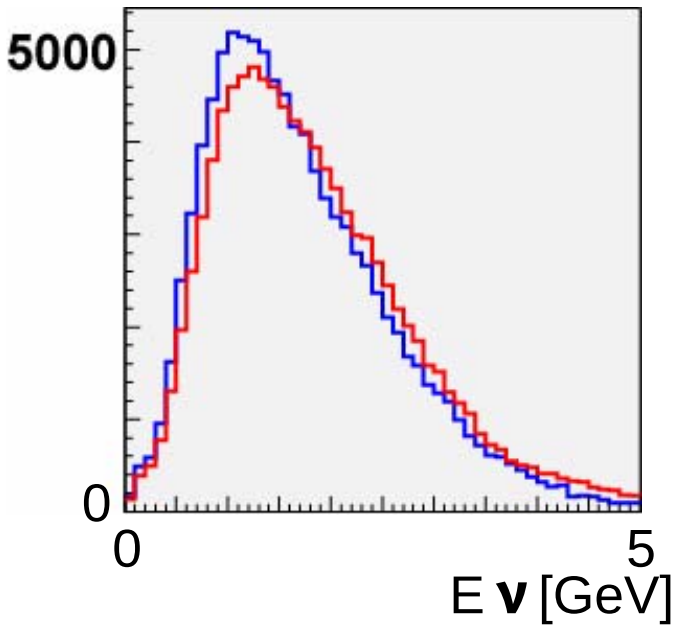
<The shape>

<Histograms are normalized by the total entories>

π^+ momentum contributing to ν



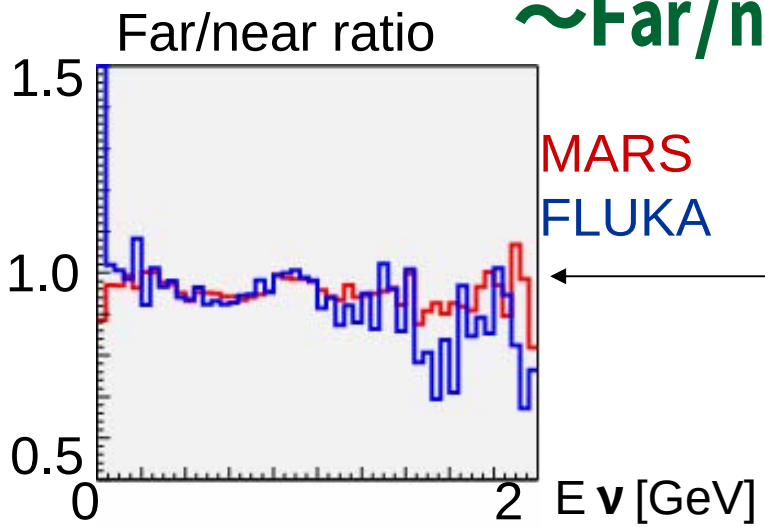
Energy of muon neutrino



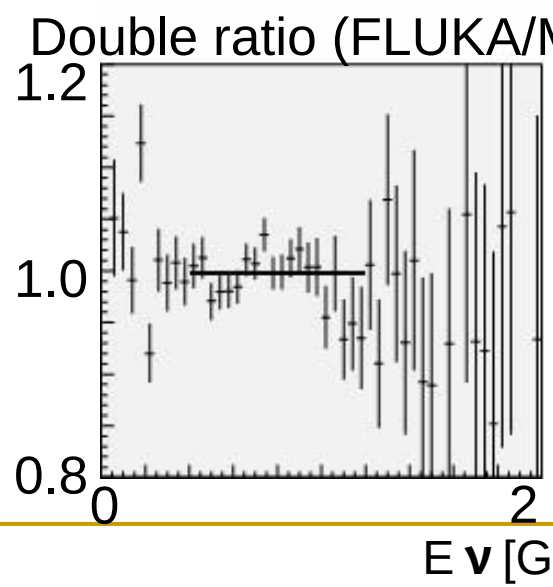
There are some shape differences in both spectra: peak ~15% mean ~5%

In the case of 2km Detector

～Far/near ratio Model Dependence



Very flat



The Difference of Far/near ratio is ～0.2±0.4%

(Energy range:0.4～1.2[GeV])

Very small model dependence!!

Introduction~Neutrino Beam

Bombarding 50 GeV proton beam to Carbon Target

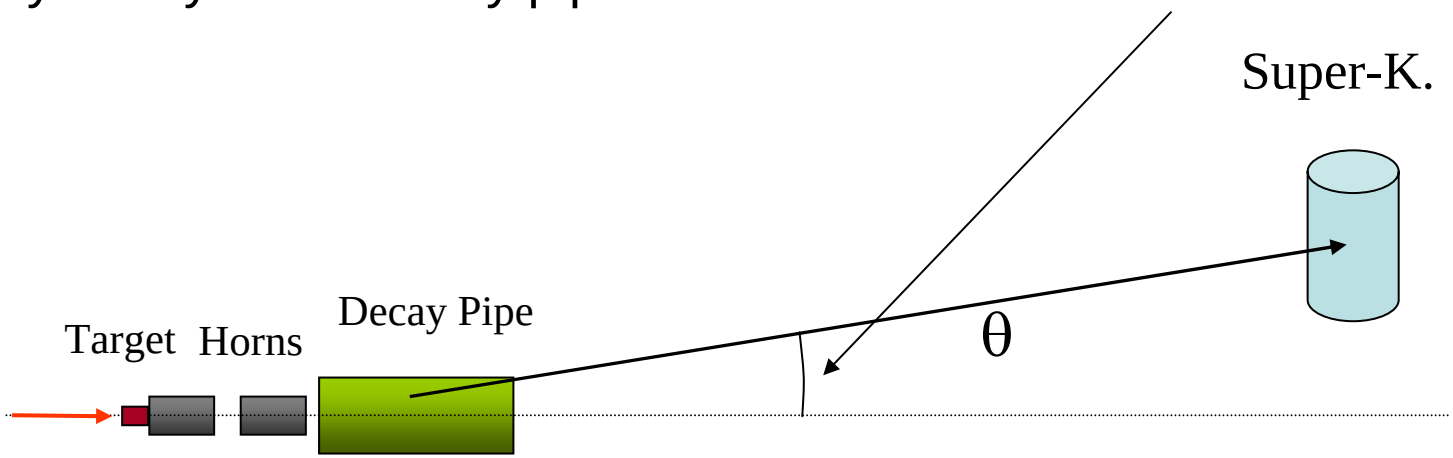
↓

Secondary hadrons are focused by horns

↓

They decay in the decay pipe.

Off Axis Beam (2~3 degree)



Conclusion

We study the Hadron Production Model Dependence of predicted Neutrino Flux.

○Model dependence on

total flux	~15%	(@SK)
π+ momentum	~9%	Off Axis effect
ν energy	~3%	

○Model dependence on Far/near ratio

~1.9% @280m

~0.2%@2km