NBI02@CERN
Mar. 17, 2002

K2K beam MC

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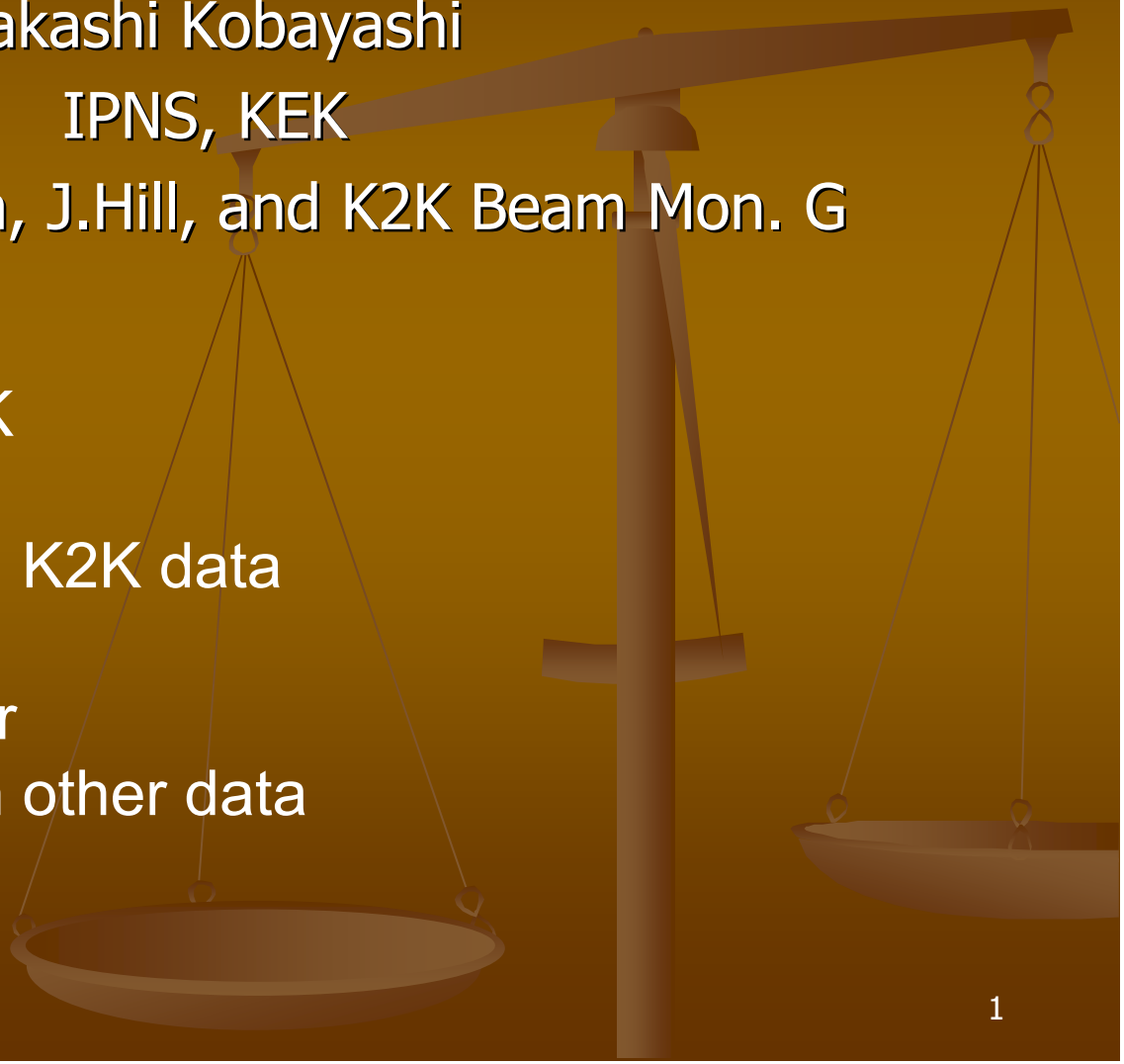


Beam MC in K2K

- How beam MC is used in K2K -

$$N_{SK}^{\exp} = N_{FD}^{obs} \cdot R$$

$$R \equiv \frac{\sum_i \Phi_i^{SK} \cdot \sigma_i^{SK} \cdot \varepsilon_i^{SK}}{\sum_i \Phi_i^{FD} \cdot \sigma_i^{FD} \cdot \varepsilon_i^{FD}} \cdot \frac{M_{SK}}{M_{FD}} \cdot \frac{POT_{SK}}{POT_{FD}}$$

	E_ν<1GeV		E_ν>1GeV
	ε_i^{FD}=0	else	
Cent value	MC(R)		MC(R)=π mon meas
Error	$\Delta\Phi_i^{SK}$ (FD meas.)	ΔR (MC test)	ΔR (π mon meas.)
	Scifi,MRD (Eν<0.5GeV)	**1kt (K2K official)**	

K2K latest results

Results

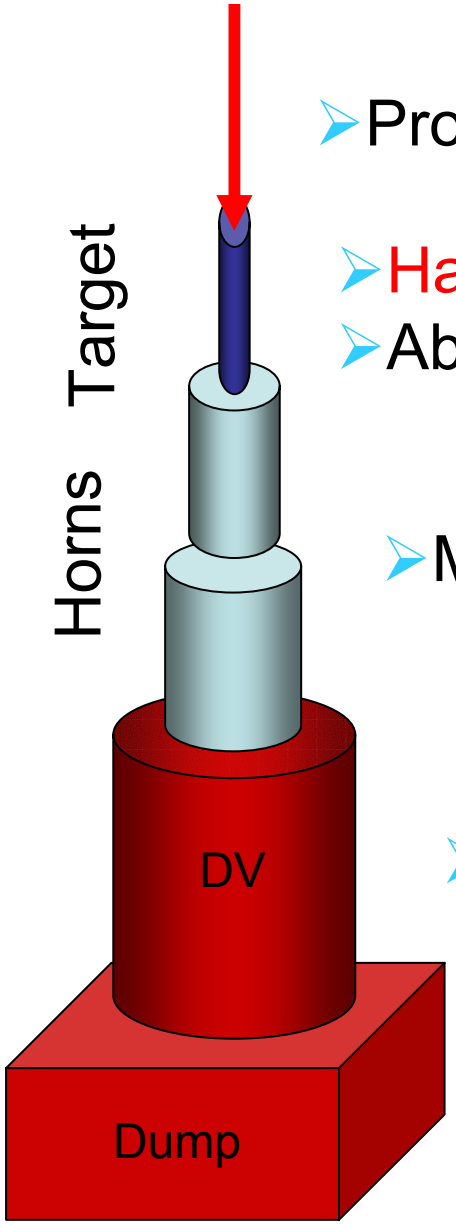
$\sin^2 2\theta = 1.0$

Event Category	Observed	Expected	$\Delta m^2 = 3 \times 10^{-3} eV^2$
Single Ring μ-like	**30**	**44.0±6.8**	**24.4**
Single Ring *e*-like	**2**	**4.4 ±1.7**	**3.7**
Multi Ring	**24**	**32.2±5.3**	**24.3**
TOTAL	**56**	**80.6** $^{+7.3}_{-8.0}$	**52.4**

Dominant Systematic Errors are an uncertainty of far-near ratio (~7%) and an uncertainty of 1kt fiducial volume (~4%).

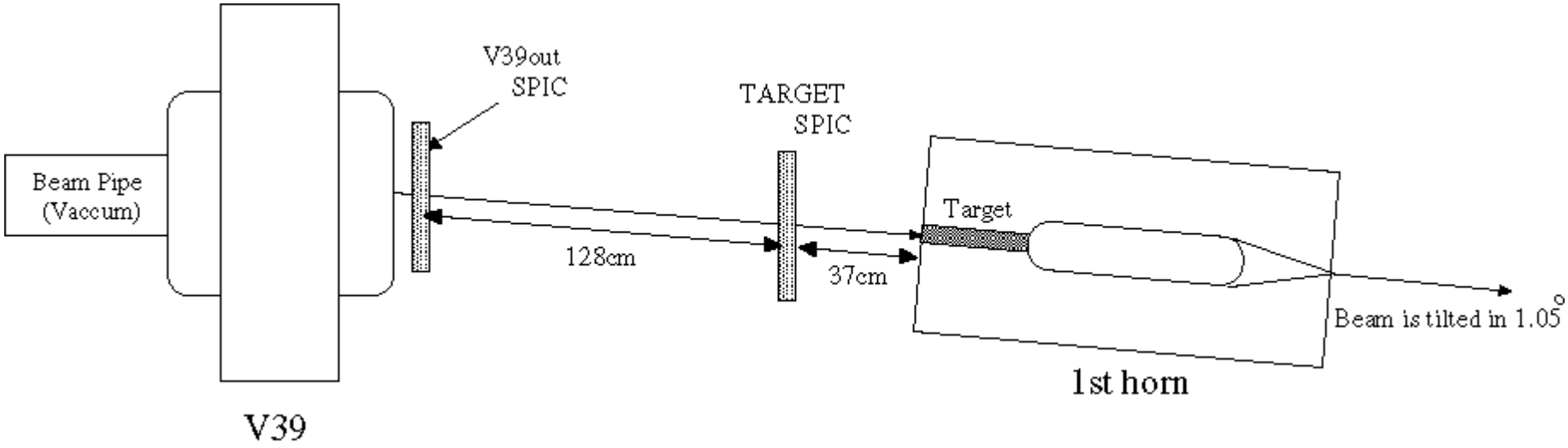
Far/near extrapolation dominates systematic error

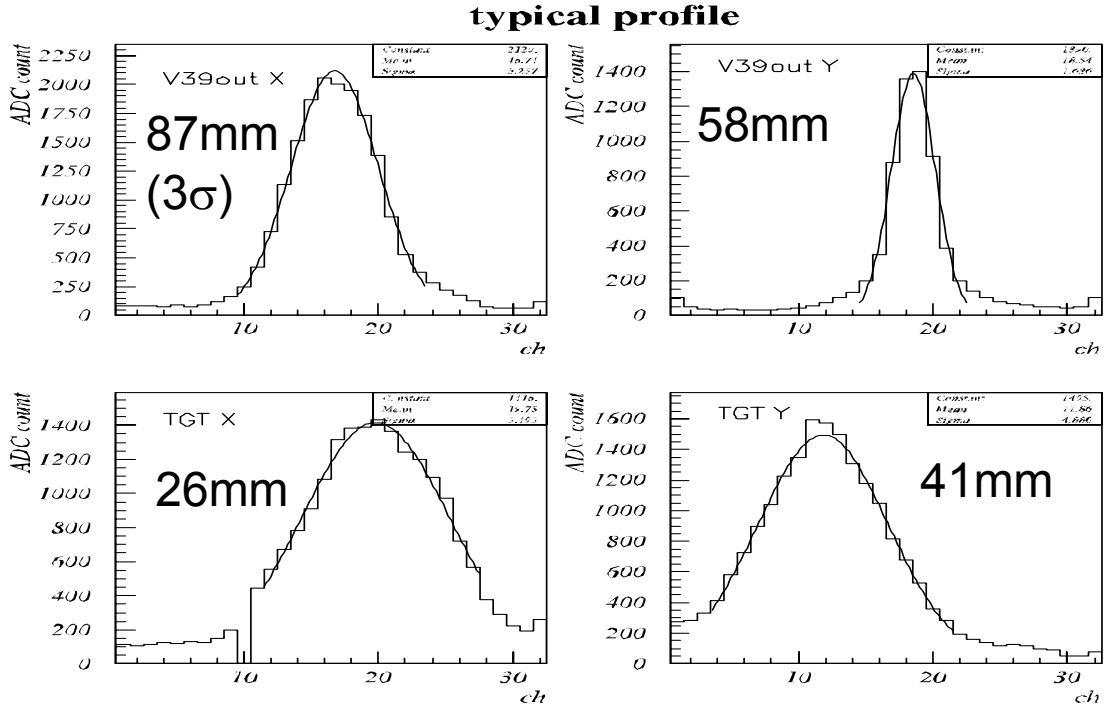
K2K beam MC



- Proton beam ➔Beam emittance meas'ed in situ
- Hadron production ➔ Sanford-Wang w/ Cho
- Absorption ➔ GEANT(Gcalor)
- Magnetic field ➔ calc. confirmed by meas.
- Decay in flight ➔ Handmade code
- Beam stop ➔ Just stop tracking
  ➔ for μmon, dedicated sim.

Measured proton beam profile





@Target (3σ)
X:6mm
Y:36mm

Hadron production

Sanford-Wang formula w/ parameters fitted to Cho data

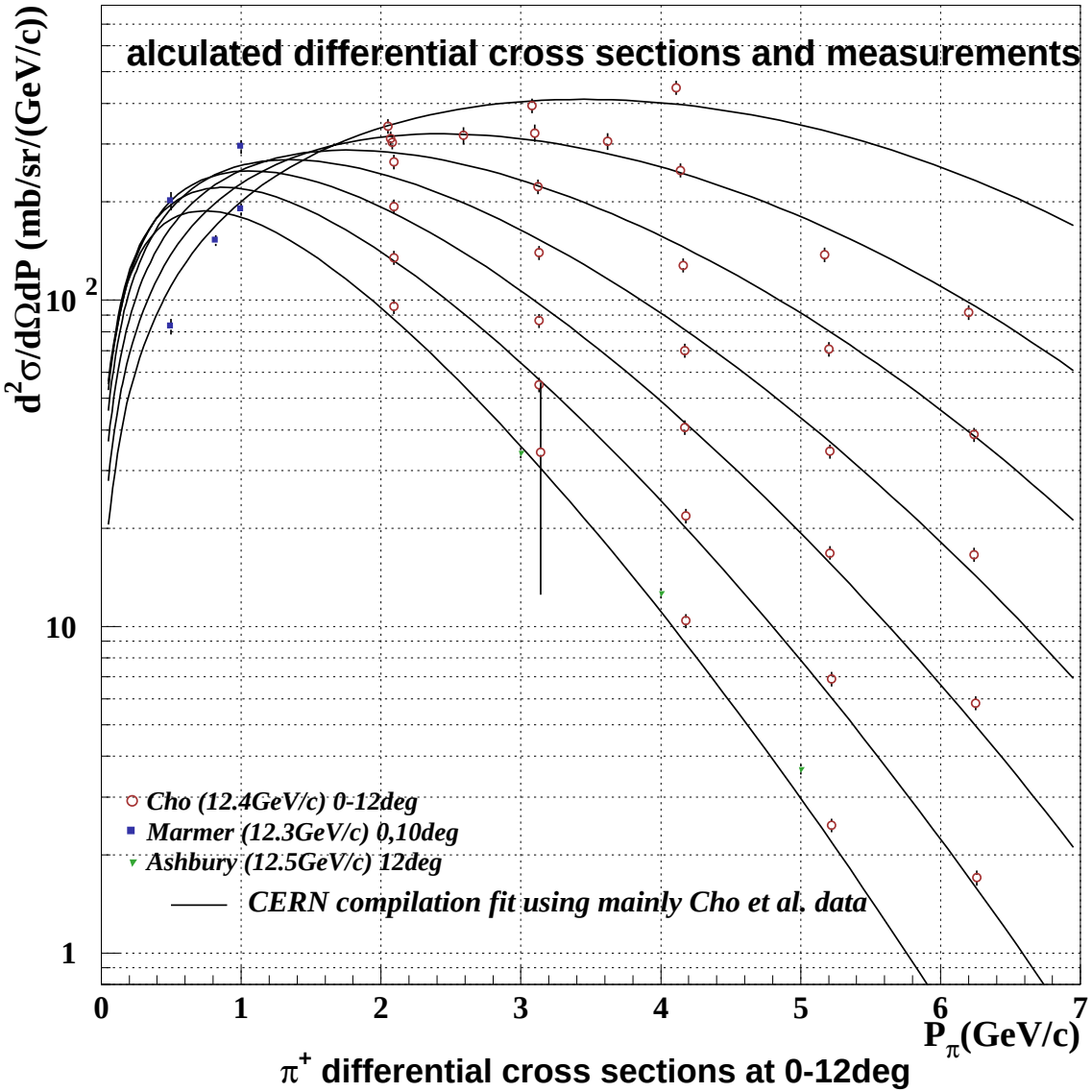
$$\mathrm{E} \times \left(\frac{\mathrm{d}^3\sigma}{\mathrm{dp}^3}\right)(\mathrm{mbarns/GeV^2}) = \sigma_{total} W_1 \mathrm{P}_\pi^{W_2} \cdot (1 - \mathrm{P}_\pi/\mathrm{P_p}) \times \mathrm{e}^{-\left(W_3 \mathrm{P}_\pi^{W_4}/\mathrm{P_p}^{W_5}\right)} \times \mathrm{e}^{-\left(W_6 \theta_\pi \left(\mathrm{P}_\pi - W_7 \mathrm{P_p} (\cos\theta_\pi)^{W_8}\right)\right)}$$

for protons of momentum $\mathrm{P_p}(\mathrm{GeV/c})$ to produce pions at momentum P_π and angle θ_π

For CERN's best fit to all data the parameters for π^+ are:

$$W = (0.881, 1.01, 2.26, 2.45, 2.12, 5.66, 0.14, 27.3)$$

Calculation and data



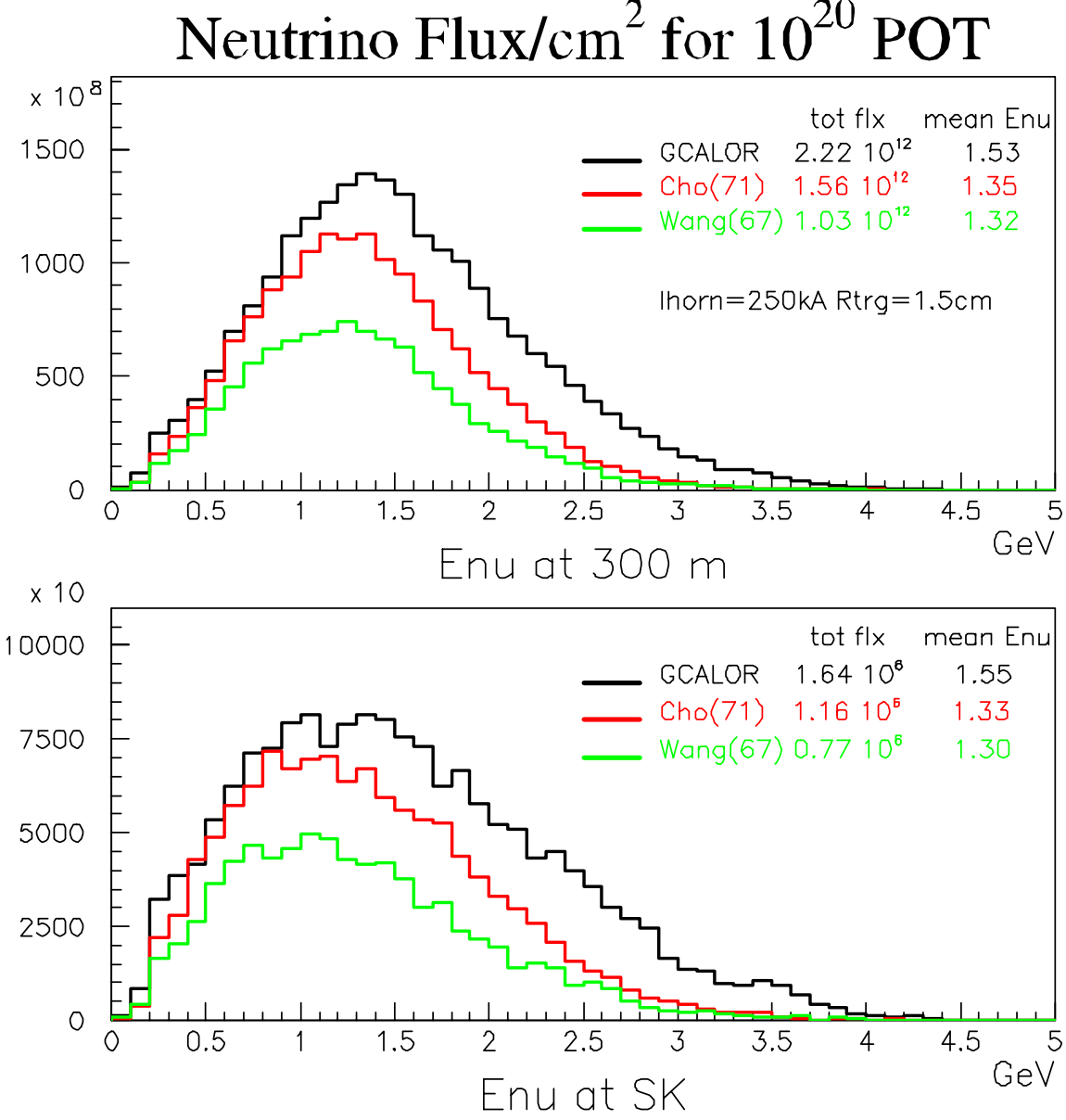
Decay

- $\pi^+ \rightarrow \mu^+ + \nu_\mu$
- $\mu^+ \rightarrow e^+ + \nu_e + \nu_\mu$
- $K^+ \rightarrow \mu^+ + \nu_\mu$
- $K^+ \rightarrow \pi^0 + \mu^+ + \nu_\mu$
- $K^+ \rightarrow \pi^0 + e^+ + \nu_e$
- $K^0 \rightarrow \pi^\pm + \mu^\mp + \nu_\mu$
- $K^0 \rightarrow \pi^\pm + e^\mp + \nu_e$

And their charge conj.

Single parent particle decays 1000 times muon polarization taken into account

MC neutrino spectrum



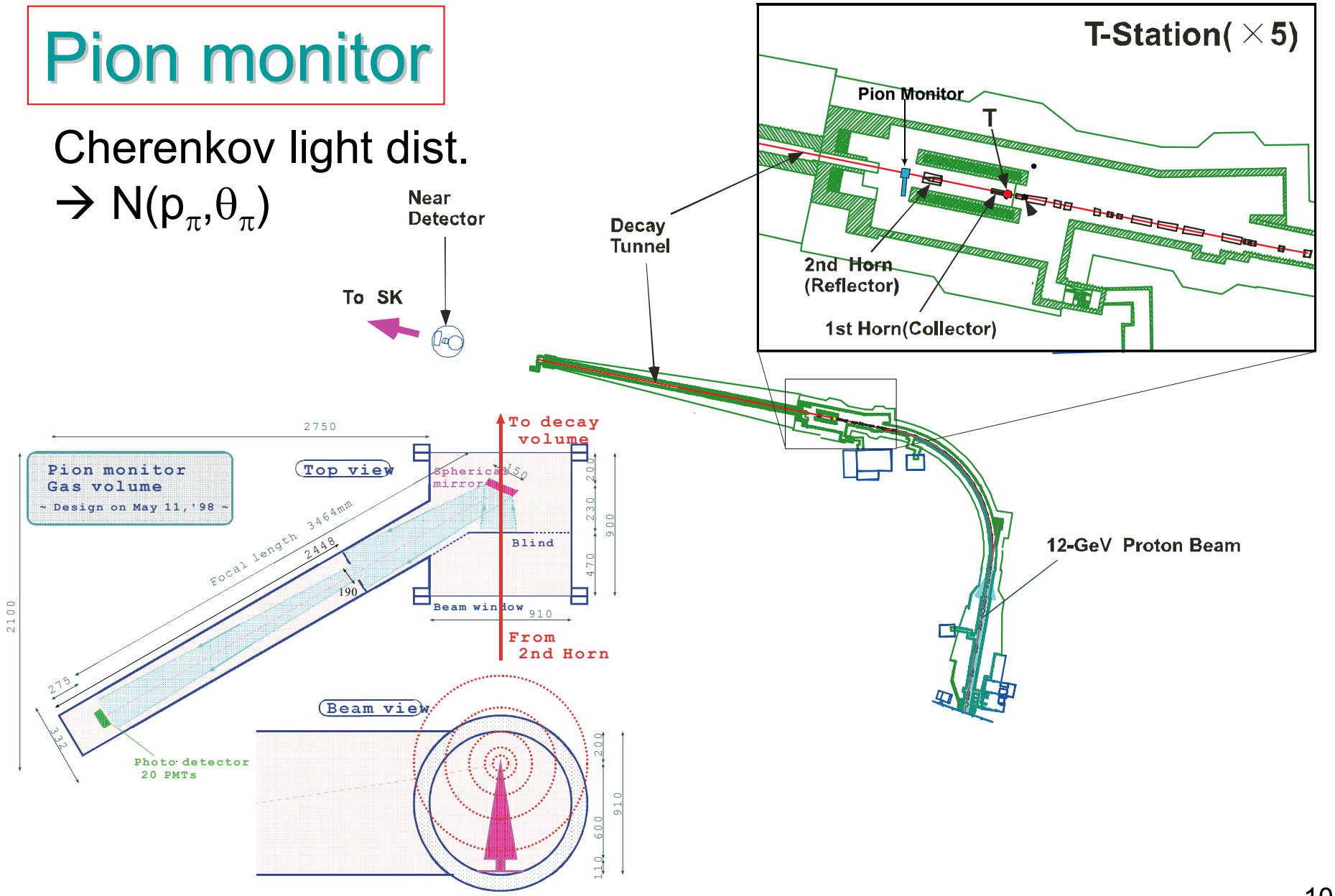
"Cho" is our K2K official reference MC

Comparison w/ K2K data (1)

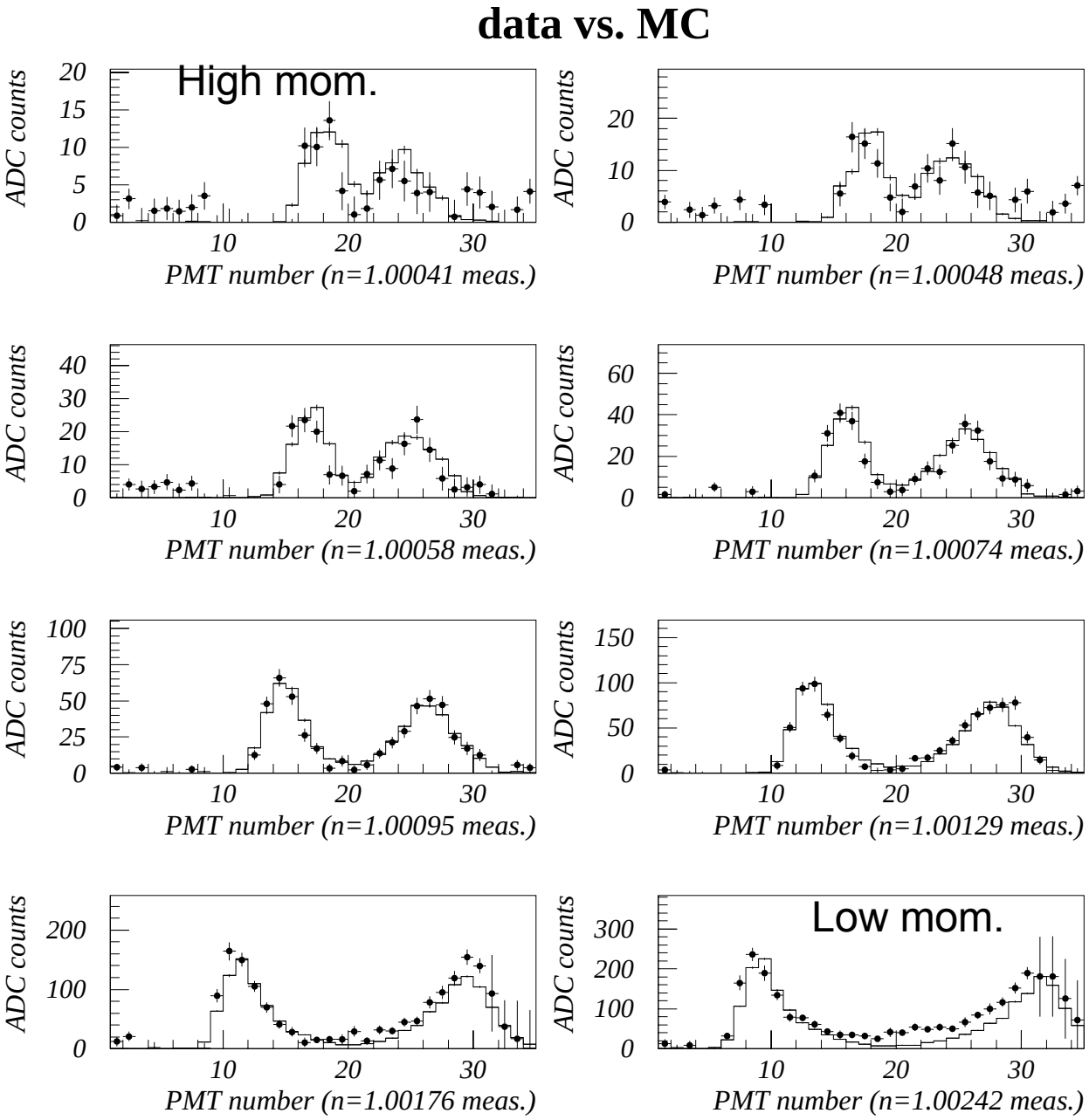
Pion monitor

Cherenkov light dist.

→ $N(p_\pi, \theta_\pi)$



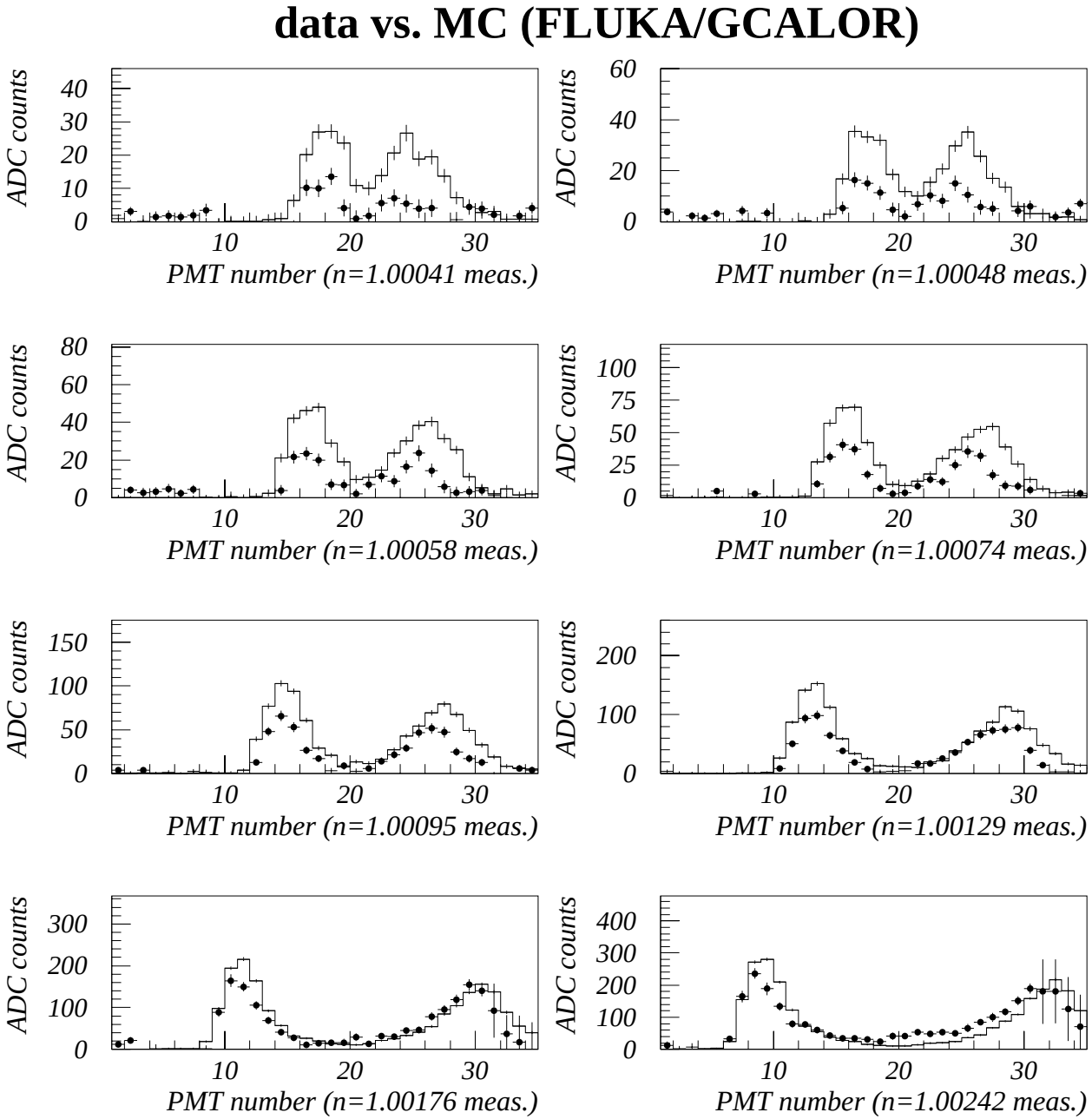
Data vs K2K ref. MC (Cho)



Convolution of

- Proton profile
- Hadron production
- Absorption
- Horn mag. field

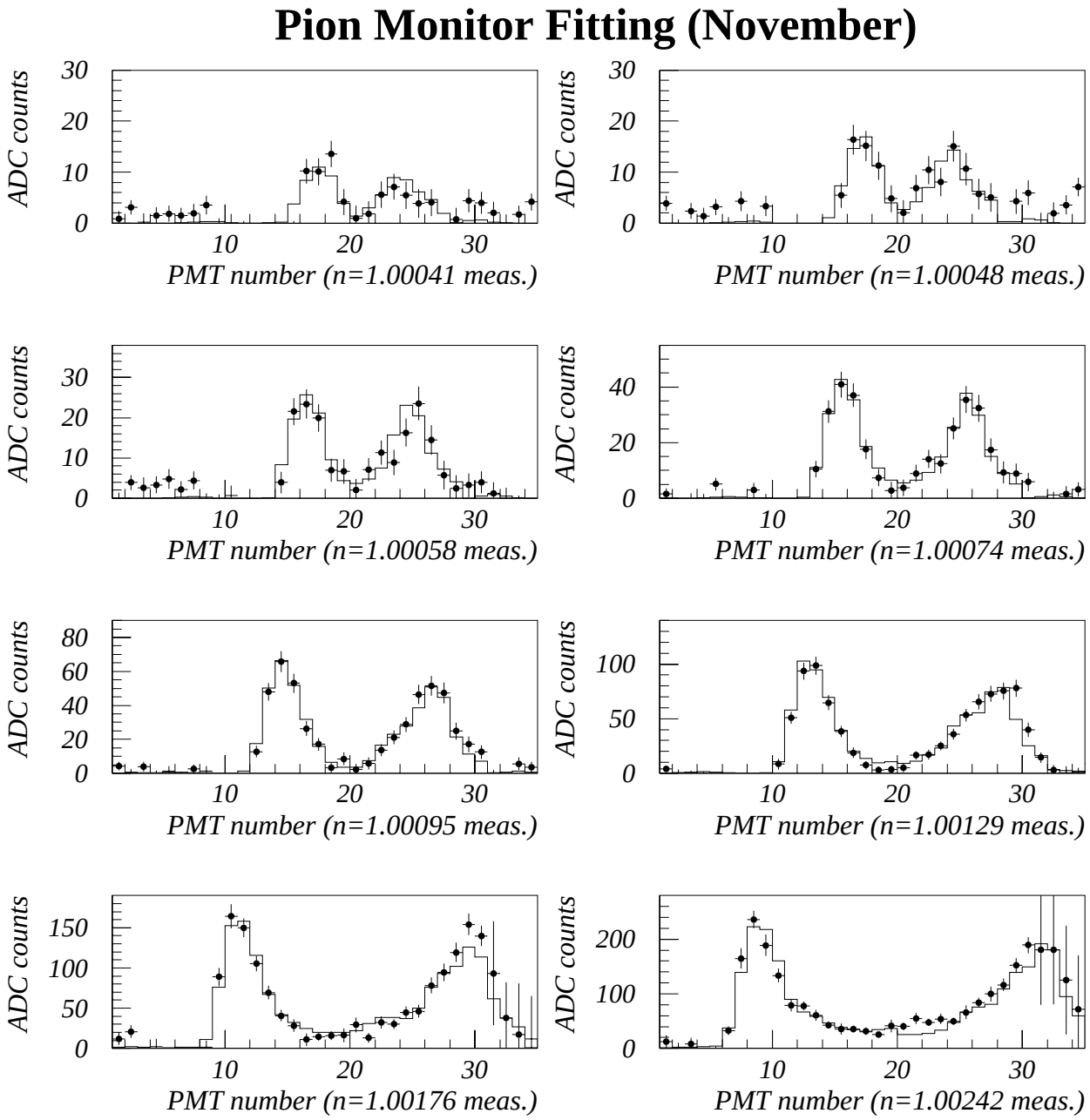
Data vs Gcalor MC



Convolution of

- Proton profile
- Hadron production
- Absorption
- Horn mag. field

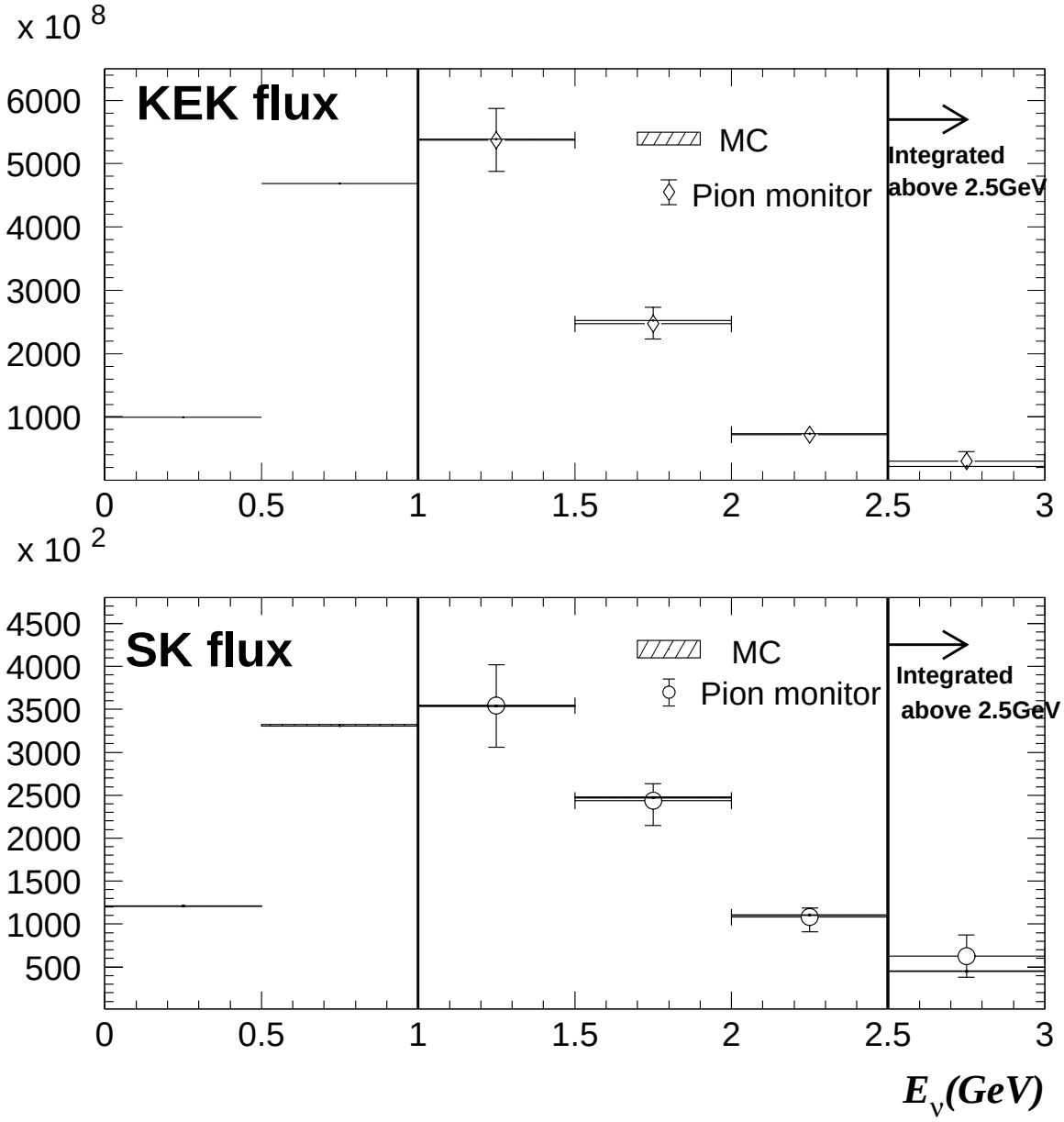
Data vs Fitted dist.



Convolution of

- Proton profile
- Hadron production
- Absorption
- Horn mag. field

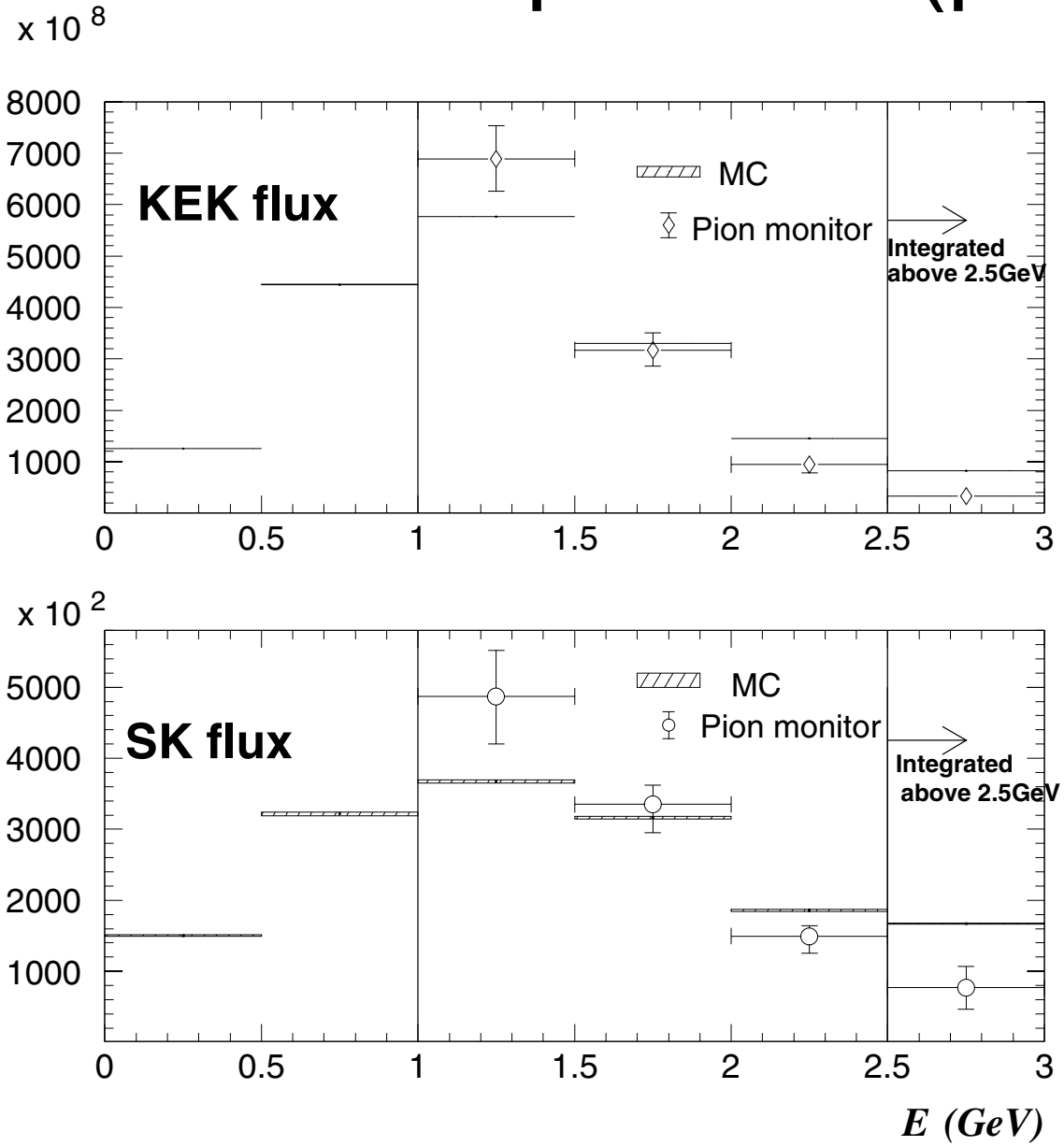
Neutrino spectrum (πmon vs Cho)



Convolution of

- Proton profile
- Hadron production
- Absorption
- Horn mag. field
- TS,DV geom.

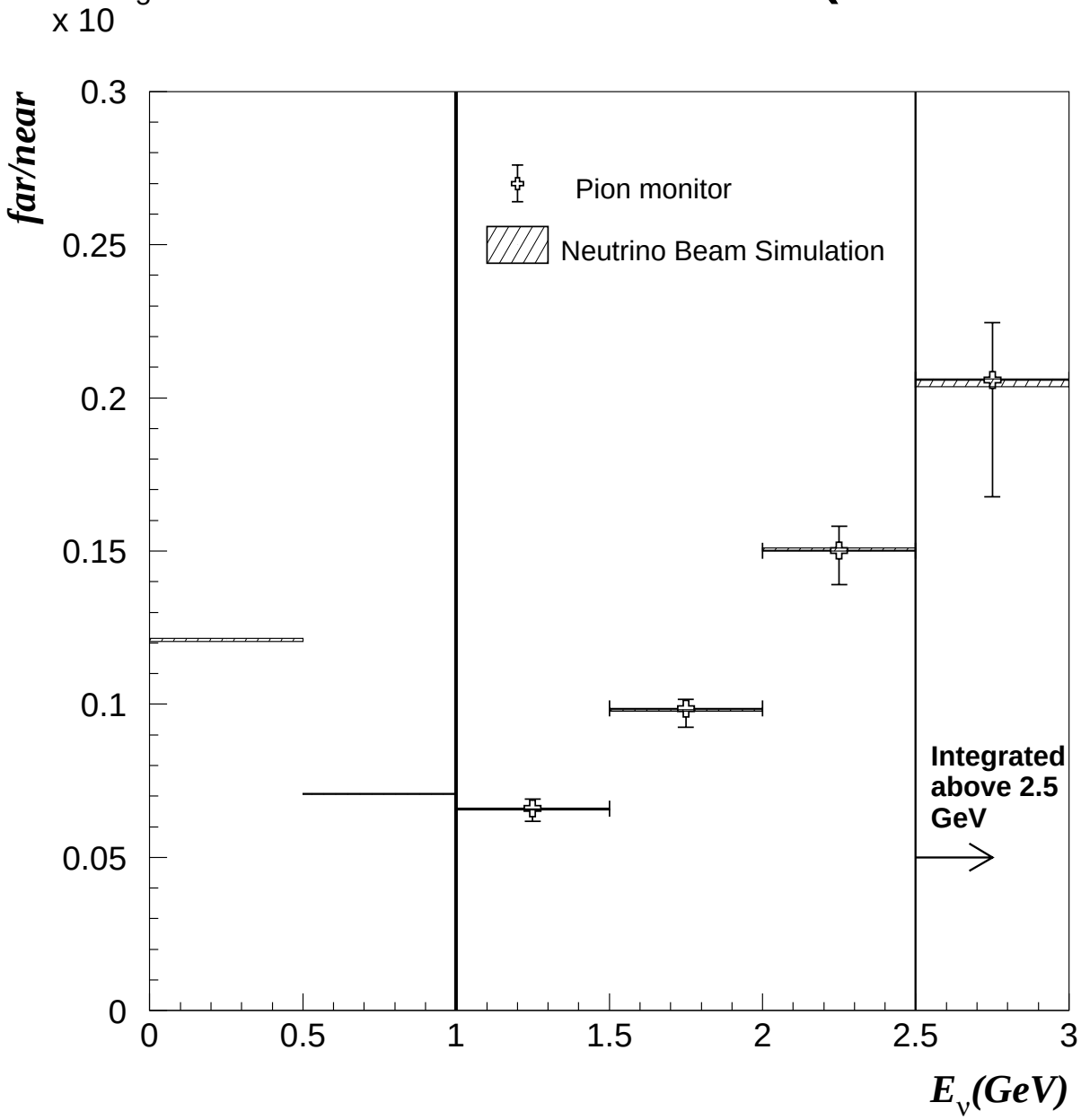
Neutrino spectrum (pmon vs Gcalor)



Convolution of

- Proton profile
- Hadron production
- Absorption
- Horn mag. field
- TS,DV geom.

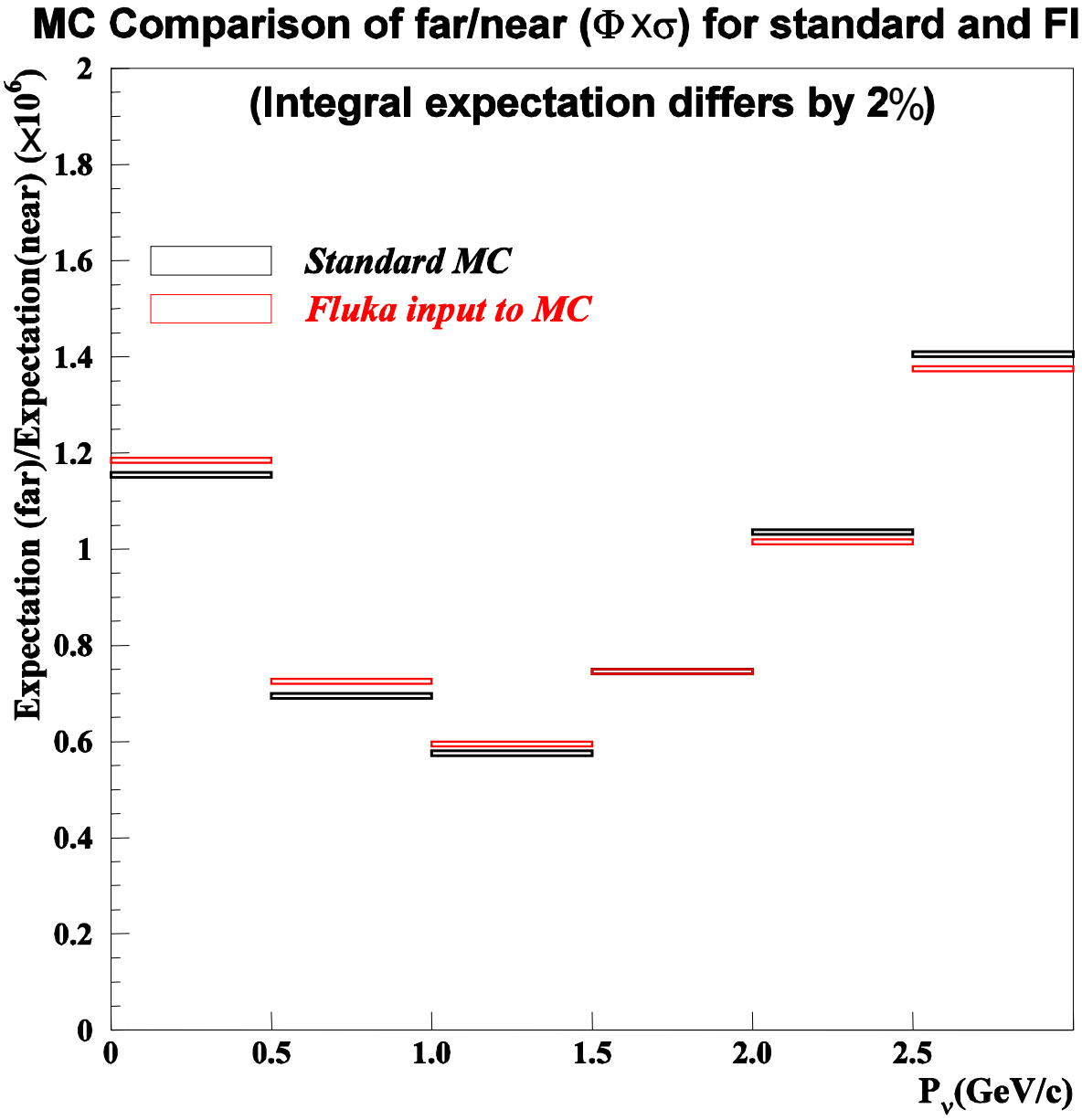
Far/near ratio (πmon vs Cho)



Convolution of

- Proton profile
- Hadron production
- Absorption
- Horn mag. field
- **TS,DV geom.**

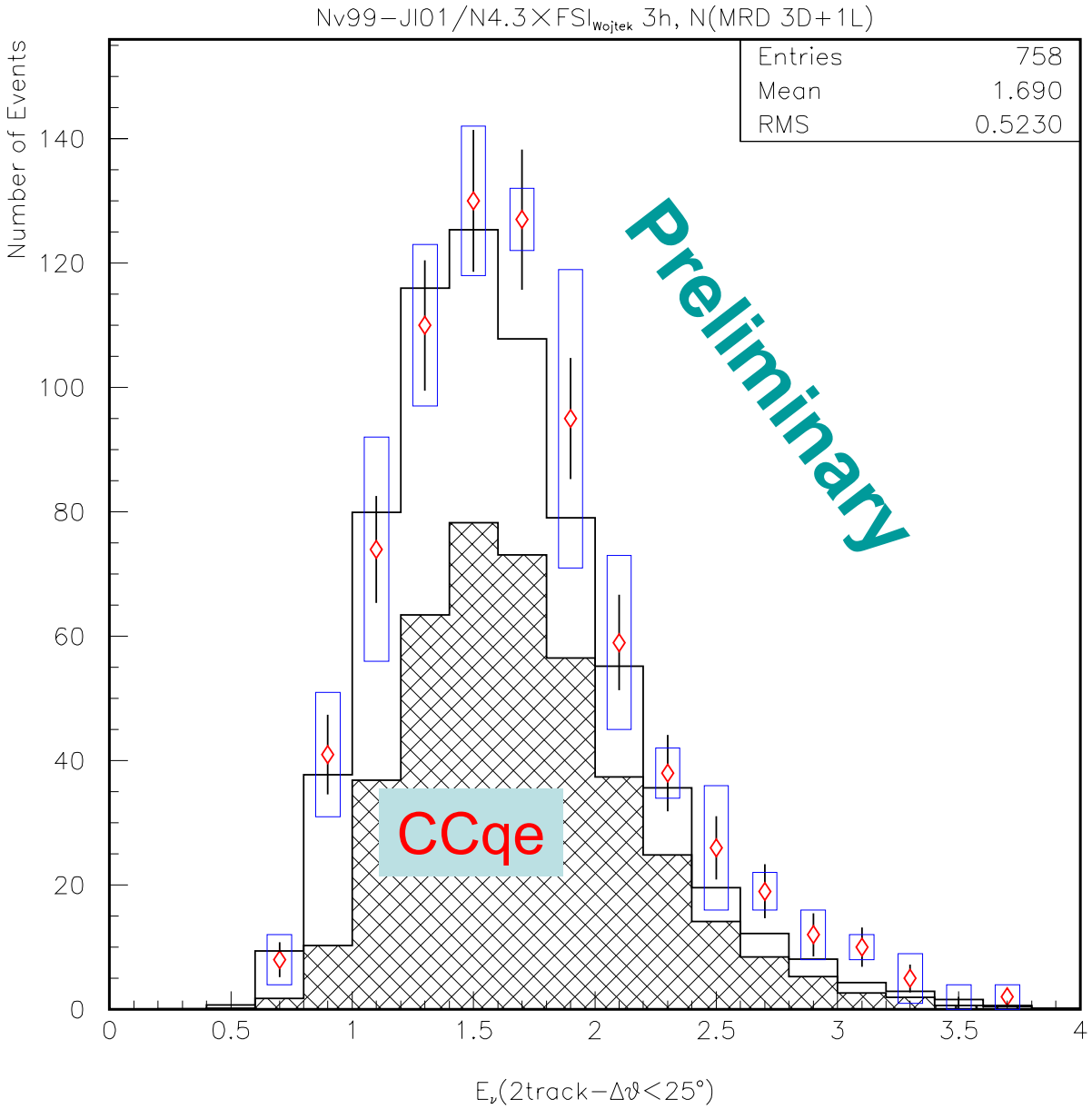
Far/near (Cho vs Gcalor)



Convolution of

- Proton profile
- **Hadron production**
- **Absorption**
- Horn mag. field
- TS,DV geom.

Comparison w/ K2K data (2)

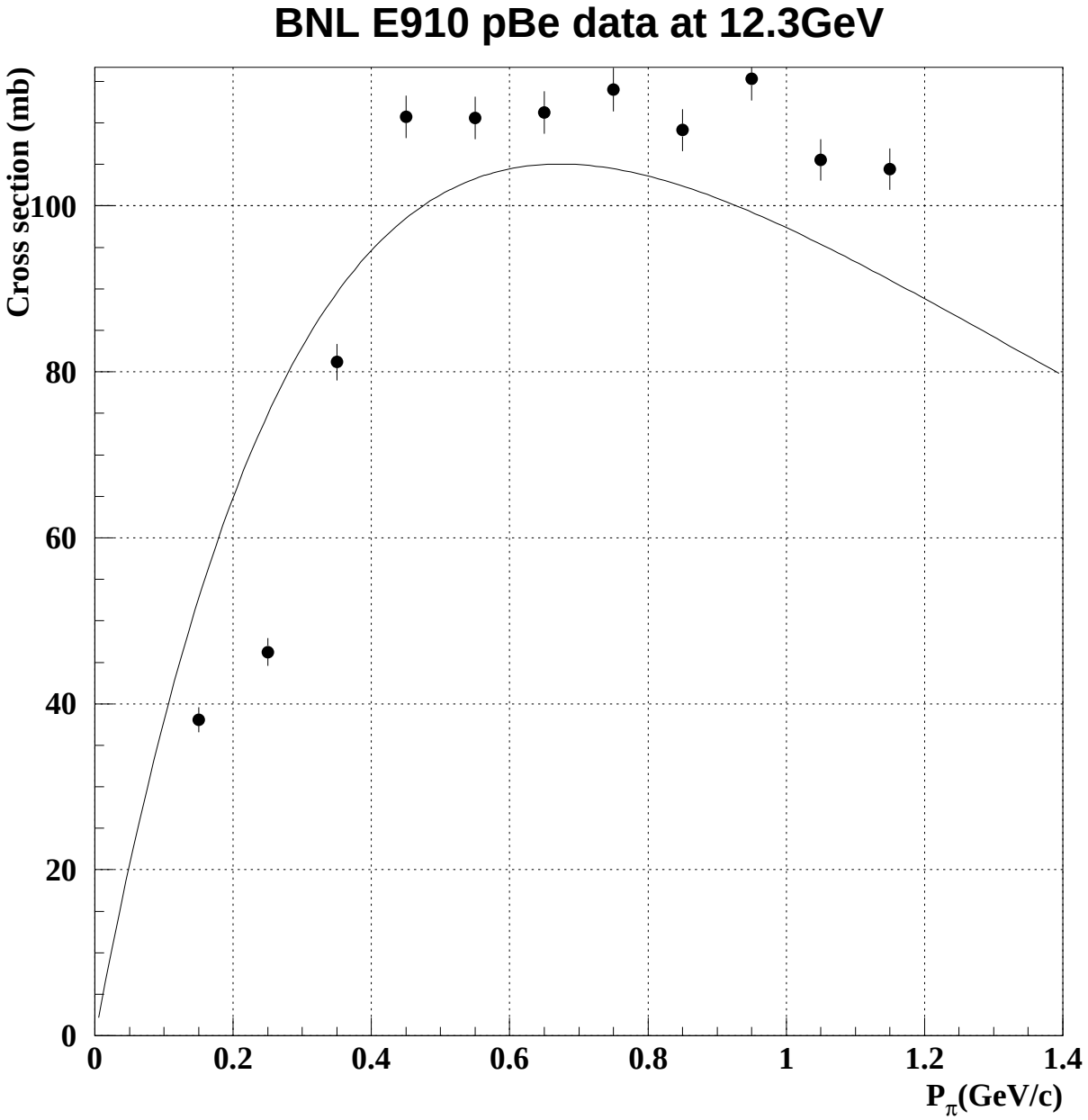


front detector (Scifi tracker)

Convolution of

- Proton profile
- **Hadron production**
- **Absorption**
- Horn mag. field
- TS,DV geom.
- **Cross section**
- Detector acceptance
- Energy reconstruction
- Resolution

Comparison w/ other data



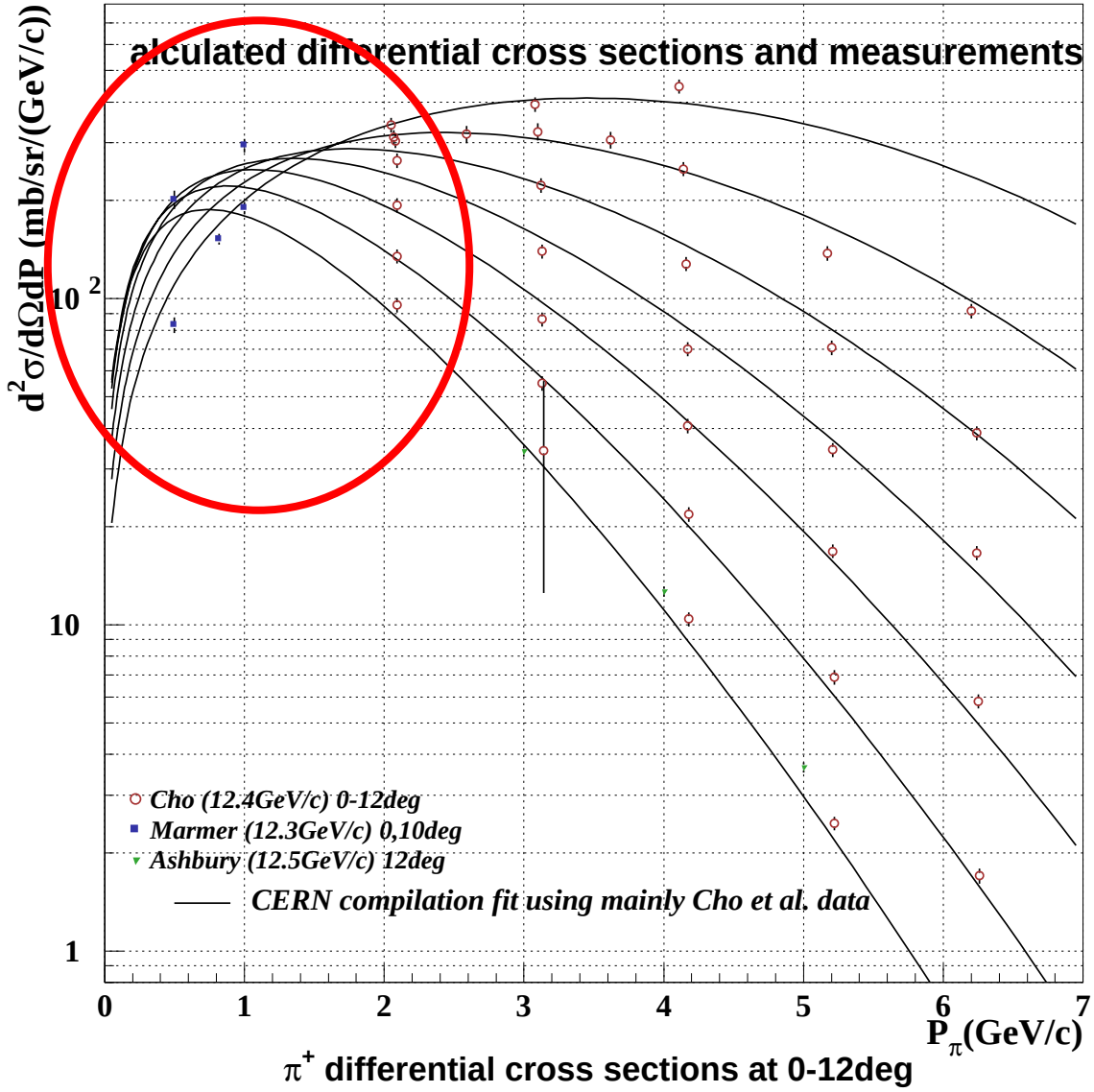
Convolution of

- Proton profile
- **Hadron production**

Future

- Measure hadron production by 12GeV protons on K2K Al target (HARP)
  - End of summer in 2002
  - measure (p_π,θ_π) dist.
- Put the data into beam MC
  - No need of any parameterization
  - Just put the distribution (in principle)
- Replace far/near ratio (central value and error) by the value based on the new MC

Calculation and data



Few data points at interested region

➔far/near ratio in this region determined by model

measurement at low E region important.

Summary

- K2K relies on beam MC for far/near extrapolation only for <1GeV, essentially
- K2K std. MC (SW w/ Cho) reproduces
  - pion dist. fairly well
  - ν spect. and **far/near ratio** very well
- Gcalor(Fluka) produces more flux and harder spectrum
- Absolutely need pion production data (HARP) to reduce far/near syst. error.