T.K. Gaisser Tokyo Met. U. 12-June-'98

Comment on uncertainty in primary spectrum

1. contained (+ PC) events

2. stopping / throughgoing upward muons

3. Importance of angular distribution

$$\begin{aligned}\phi_{\nu_i} = {} & \phi_p \otimes R_p \otimes Y_{p\to\nu_i} \\ & + \phi_{p(A)} \otimes R_A \otimes Y_{p\to\nu_i} \\ & + \phi_{n(A)} \otimes R_A \otimes Y_{n\to\nu_i}\end{aligned}$$

primary spectrum
p = protons
A = nuclei

geomagnetic cutoff

Yields from interactions of p, n, A in air

$$\text{Signal} = \phi_{\nu_i} \otimes \sigma_i \otimes \epsilon_i$$

For estimates (Lipari, Stanev, TKG astro-ph/9803093)

use σ_i of Lipari, Lusignoli, Sartogo
PRL $\underline{7}4$ (1995) 4384

contribution of nuclei to

SPECTRUM of NUCLEONS

	10 GeV	10^4 GeV
p (1)	81 %	68 %
He (4)	14.5 %	22.5 %
CNO (14)	2.5 %	6 %
Ne-Si (24)	1 %	1.5 %
Fe (56)	1 %	2.0 %

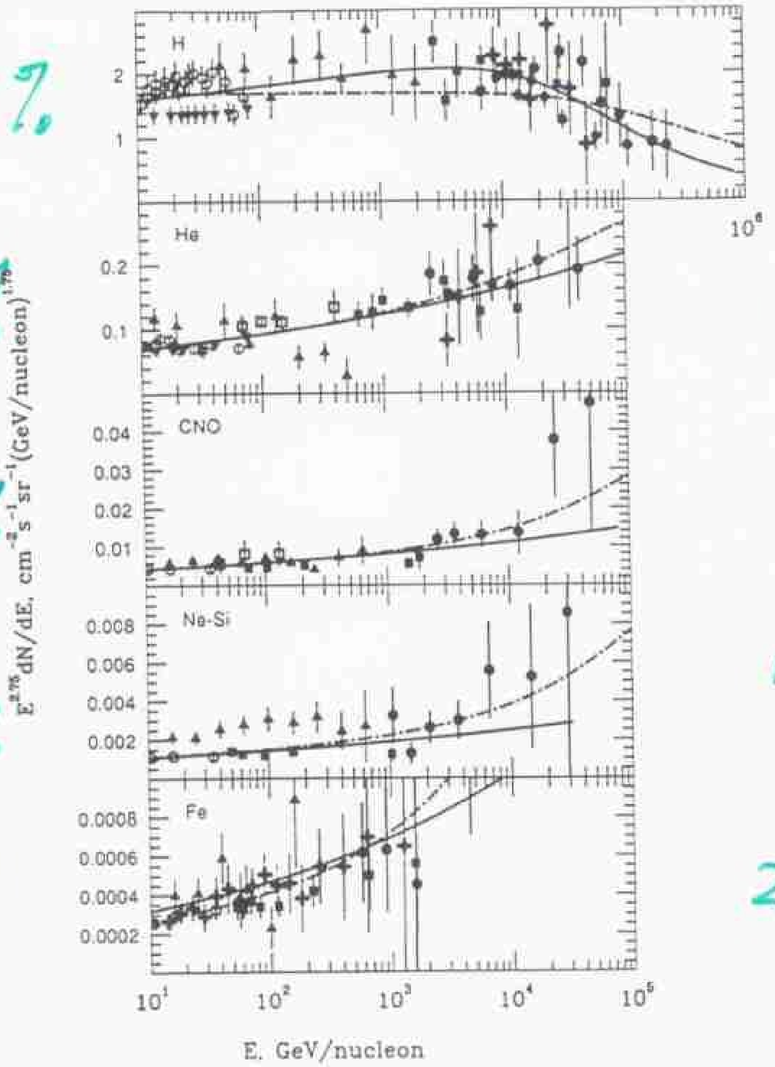


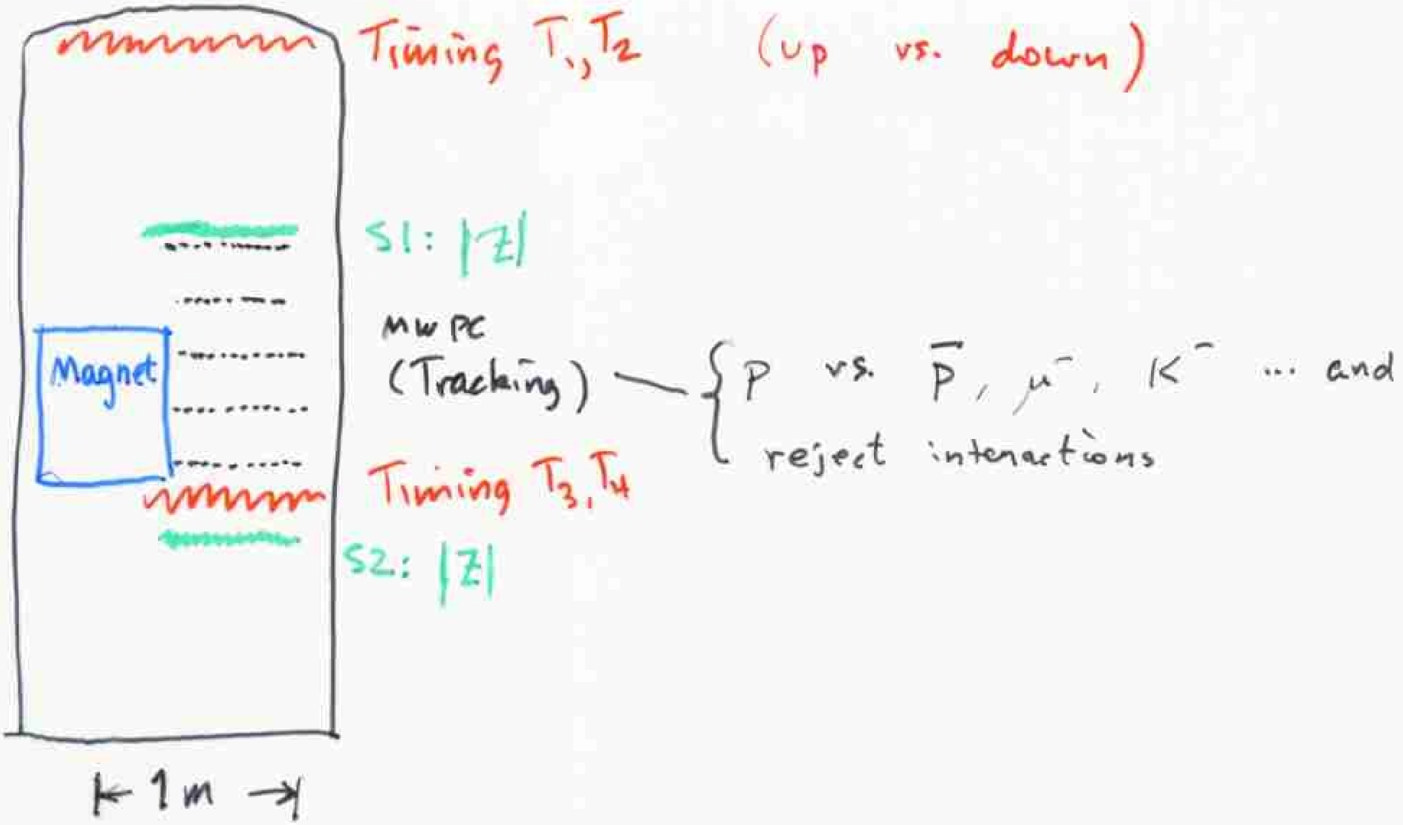
FIG. 2. Direct data on the spectra of different cosmic-ray nuclei. The data for H and He are from: open circles, Ref. [19]; inverted triangles, Ref. [20]; triangles, Ref. [21]; filled squares, Ref. [22]; filled circles, Refs. [23, 24]; crosses, Ref. [25]; hexagons, Ref. [26]; and open squares, Ref. [27]. The data for heavier nuclei are from: open circles, Ref. [28]; triangles, Ref. [29]; open squares, Ref. [30]; filled squares, Ref. [31]; crosses, Ref. [32]; and filled circles, Ref. [24]. The lines represent the two fits discussed in the text: (1) (solid line) steepening H and all nucleon spectrum; (2) (dash-dotted) a gradual bending of the H spectrum which is compensated by flattening of the spectra of all heavier nuclei.

v. Agrawal, TKG, Paolo Lipari, Todor Stanev

Phys. Rev. D53 (1996) 1314

LEAP instrument

ES Seo et al. Ap. J. 378 (1991) 763



$$\left(\begin{array}{c}\text{Differential}\\ \text{Flux}\end{array}\right) = \frac{\#\text{ events reconstructed to TOA, after cuts}}{\underbrace{(\underset{20\text{ hrs}}{T} \times \underset{0.3\pm0.01}{\epsilon_T}) \times \underset{0.33\pm0.04}{\text{efficiencies}}}_{\pm 15\%\text{ estimated systematic uncertainty}} \times \Delta E \times \underset{330\text{ cm}^2\text{ sr}}{(A\,\Omega)}}$$

IMAX, CAPRICE ~similar

BESS ~different

Selection criteria for LEAP

Reconstructible trajectory	0.897 ± 0.011
$\geqslant 6$ good x hits	0.624 ± 0.029
Pass TOF test	0.688 ± 0.078
$\geqslant 3$ good y hits	0.971 ± 0.012
$\chi^2(x)$ cut	0.918 ± 0.014
$\chi^2(y)$ cut	0.972 ± 0.001

Product: efficiency = 0.334 ± 0.041

12%

Live time 0.3 ± 3%

Overall systematic uncertainty

~ ± 15%

the theoretical calculations of (estimated by using the results of other experiments and the actual neutron monitor counts) to find the appropriate secondary fluxes for the IMAX flight. The secondary to primary proton ratio is small (around 1%) for higher energies, but rises dramatically for lower energies. Below ca. 200 MeV the secondary protons even dominate the proton sample. We applied an uncertainty of 20% to the secondary/primary ratio and finally present the IMAX fluxes "Top Of Atmosphere" in figure 2, the actual values are shown in Table 1. In figure 3 we compare the IMAX fluxes with the results of Seo et al. (1992) and Webber et al. (1987). While these measurements represent the lower and upper bounds in the proton flux, the IMAX flux is right between these limits.

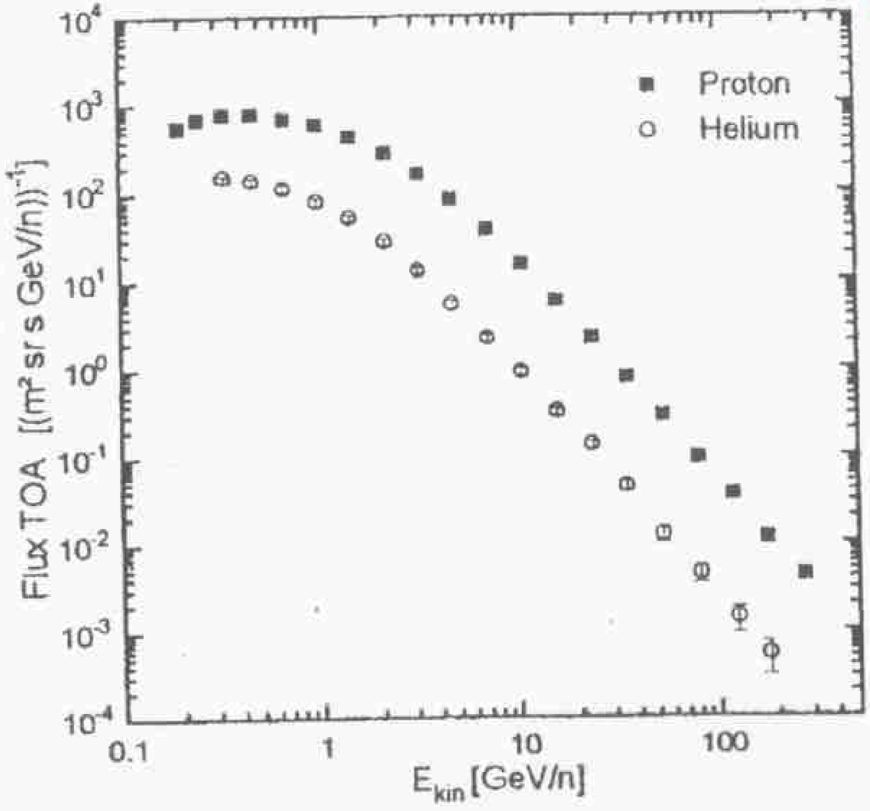


Fig. 2. IMAX proton and helium fluxes TOA

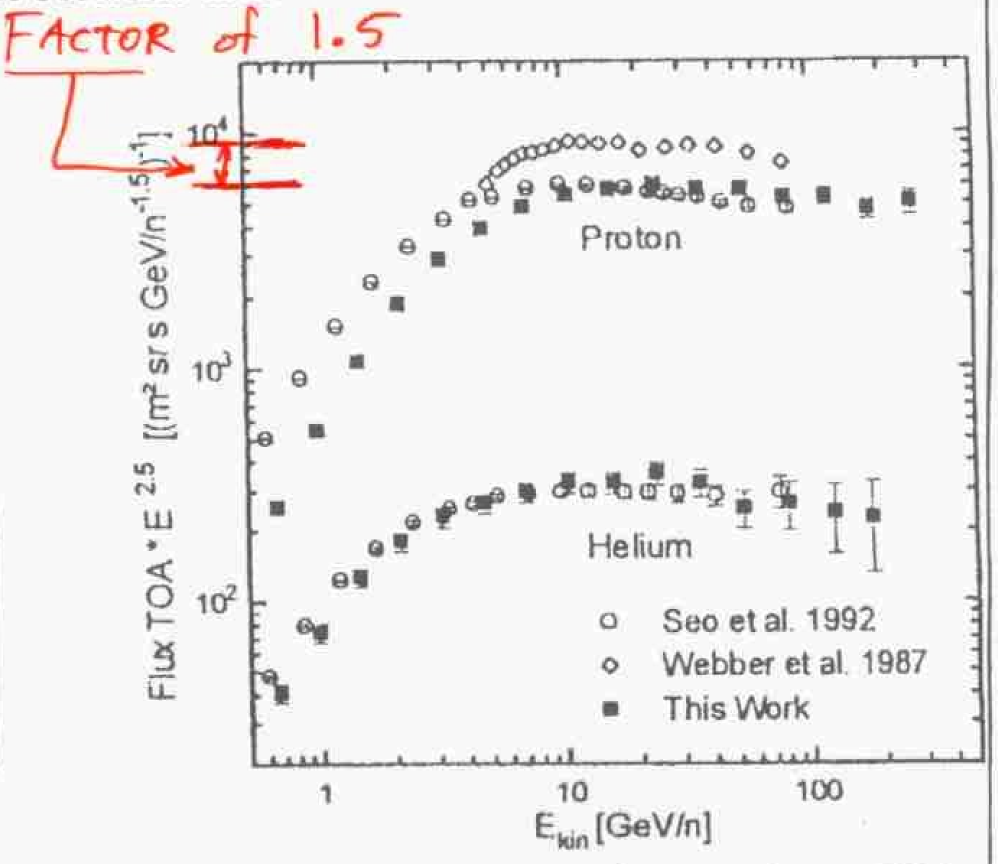
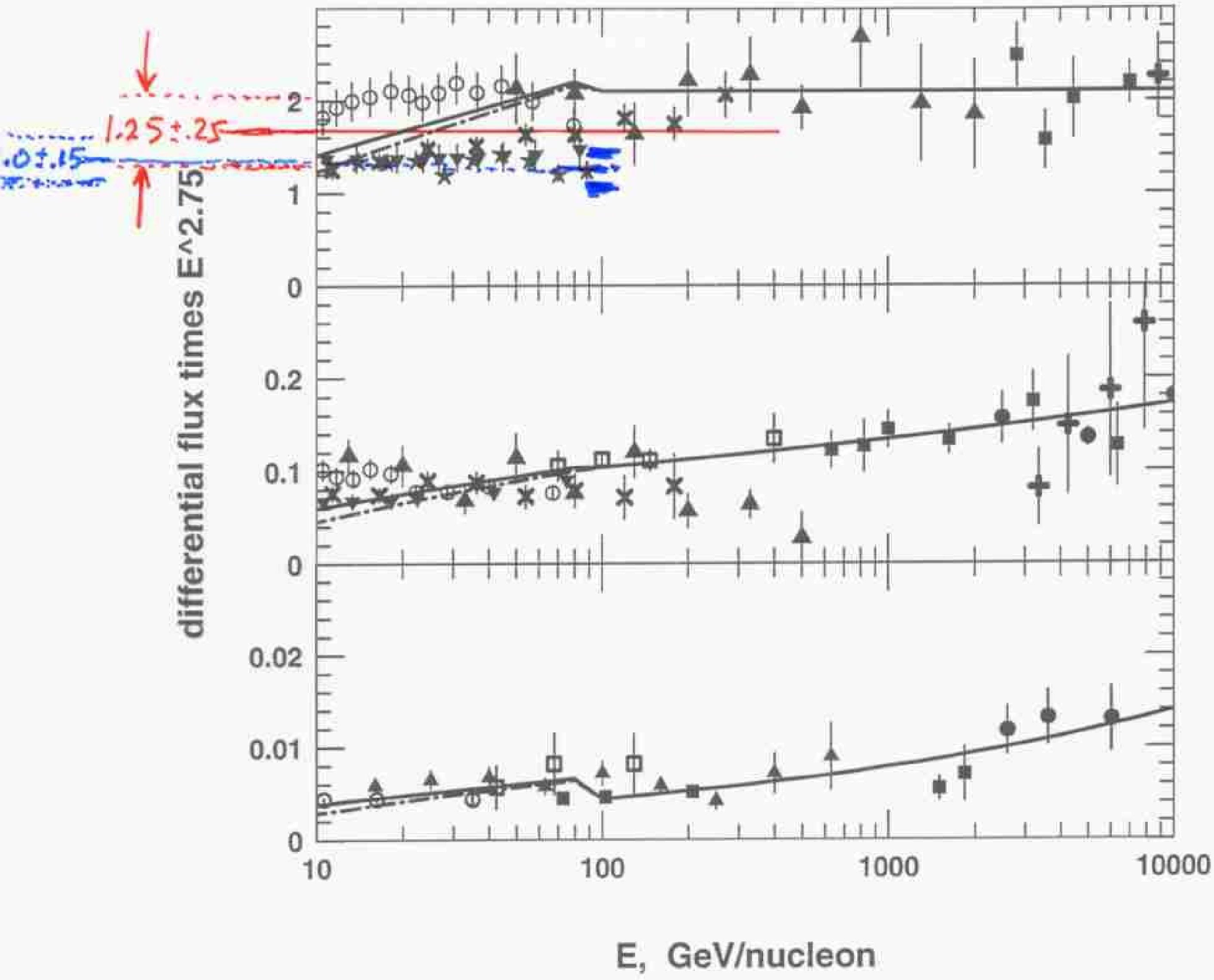


Fig. 3. IMAX proton and helium fluxes TOA compared with other balloon measurements



This is a comparison of the energy spectra of H (top), He (middle) and CNO (bottom panel) nuclei at solar minimum (solid) ands solar maximum (dash-dot) used by HKKM to a collection of experimental data.

Φ_{min} —— Honda et al. primary spectrum

Φ_{max} -·-·-

—— Bartol

		pub. date
▼	Seo et al. (LEAP)	(1991)
○	Webber et al.	(1987)
×	IMAX	(1997)
✱	CAPRICE	(1997)
▲	Ryan et al.	(1972)

Super-K ratios: $\frac{\text{observed}}{\text{expected}^*}$

Sub-GeV, μ-like $\frac{1041}{1365} = 0.76$

Multi-GeV μ-like $\frac{176}{229} = 0.77$

Sub-GeV e-like $\frac{967}{821} = 1.18$

Multi-GeV e-like $\frac{218}{183} = 1.19$

* Honda et al. calculation
(similarly to Bartol fluxes)

has high yields.

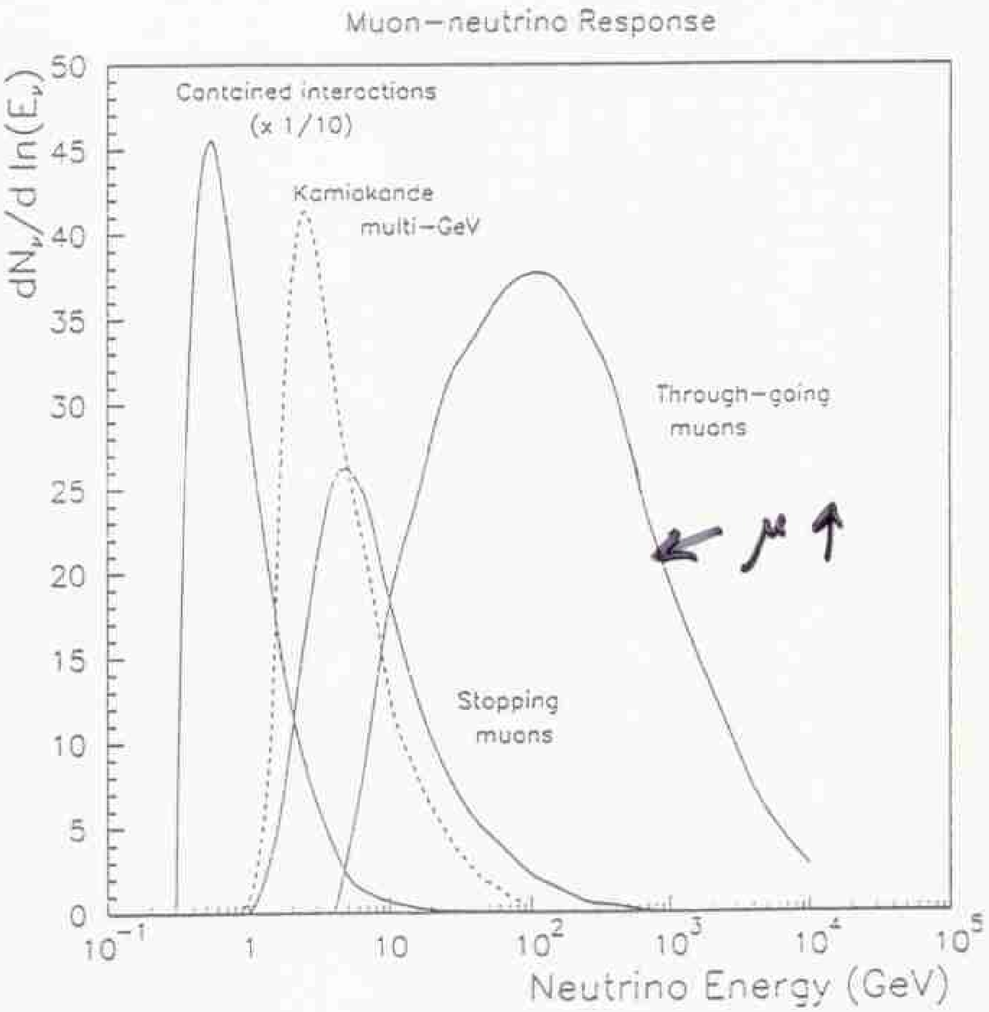
Also, recent measurements tend to lower primary flux: Excess of ν_e ?

What if . . .

$$\phi_p = 1.25 \pm 0.25 \longrightarrow 1.0 \pm 0.15$$

$$\frac{\nu_e)_{\text{observed}}}{\nu_e)_{\text{calc.}}} = 1.18 \pm 0.24 \longrightarrow 1.48 \pm 0.22$$

$$\frac{\nu_\mu)_{\text{observed}}}{\nu_\mu)_{\text{calc.}}} = 0.76 \pm 0.15 \longrightarrow 0.95 \pm 0.14$$



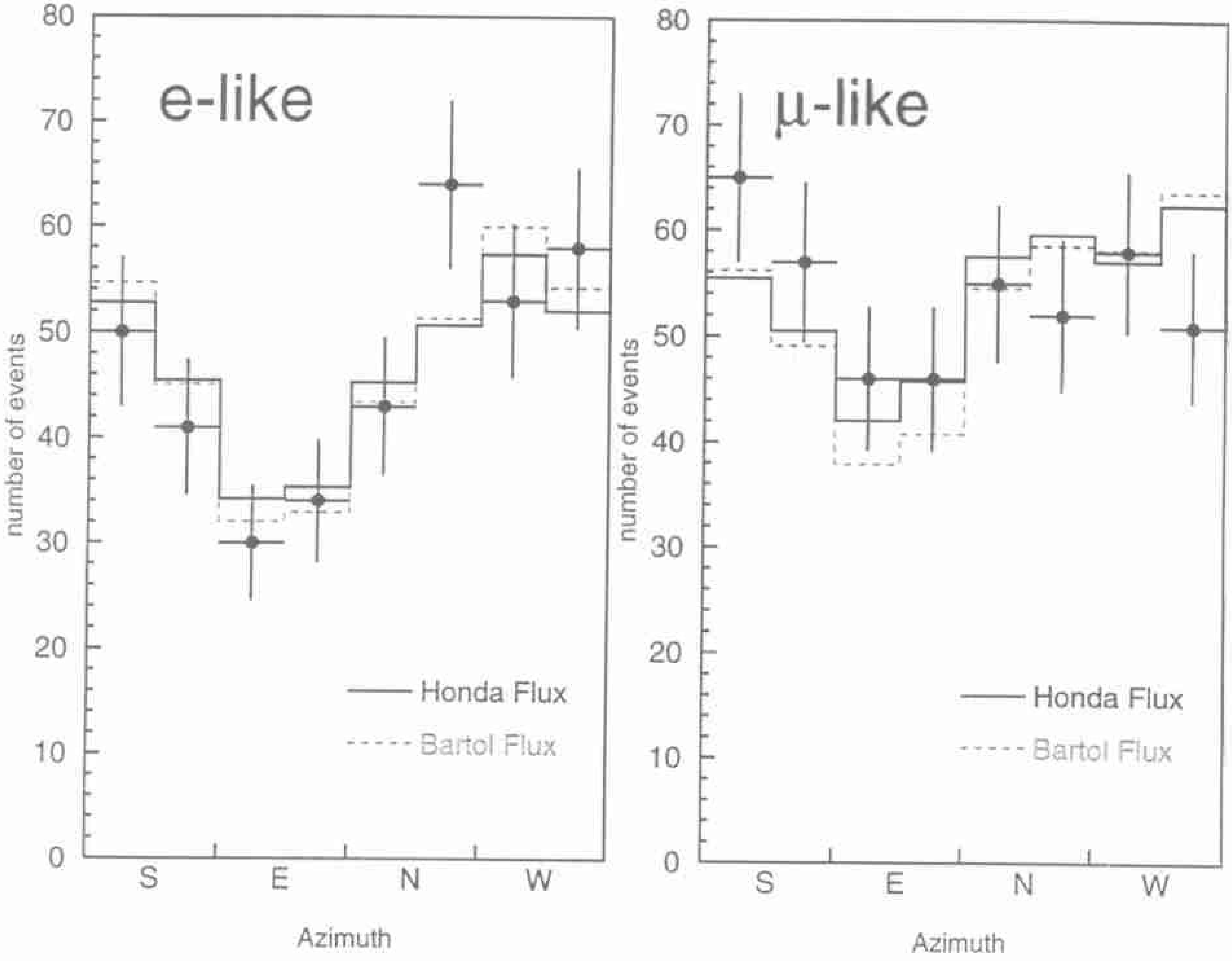
$$\phi_{\mu\uparrow} = \phi_{\nu_\mu} \otimes \sigma_{\nu\to\mu} \otimes R_\mu$$

$\propto E_\nu^{-3}$

$\propto E_\nu$ up to 3 TeV

$\propto E_\mu \propto E_\nu$ up to TeV

Super-K Preliminary 33 kton-yr



$\frac{\chi^2}{d.o.f.}$ — $\frac{5.6}{7}$ — $\frac{6.5}{7}$

---- $\frac{5.1}{7}$ ---- $\frac{8.6}{7}$