The atmospheric neutrino flux below 100MeV: The FLUKA results

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The atmospheric neutrino flux below 100 MeV: the FLUKA results

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Outline

- **Motivations**
- **Results**
- **The uncertainties on primary spectrum**
- **The uncertainties on particle production**
- **Quotation from works using these fluxes**
- **Other uncertainties: the cross sections**
- **Conclusions**

The interest in the low energy sector of atmospheric ν's

- A LAr detector like ICARUS can detect atmospheric ν interactions reliably down to 50 MeV

- The low energy side of atmospheric ν's can be used to look for the subleading oscillations effects due to θ_{12} (if $\theta_{13} \neq 0$!)

- There is interest in searching for relic ν's from SuperNovae. The atmospheric ν's below 100 MeV constitute one of the sources of irreducible background

- First experimental attempt: SK [Phys. Rev. Lett. 90 (2003) 061101]

- These atmospheric neutrinos can be also a background in the search for neutrinos from Solar Flares (D. Fargion & F. Moscato, hep-ph/0407211)

The FLUKA fluxes below 100 MeV

There are almost no atmospheric flux calculations

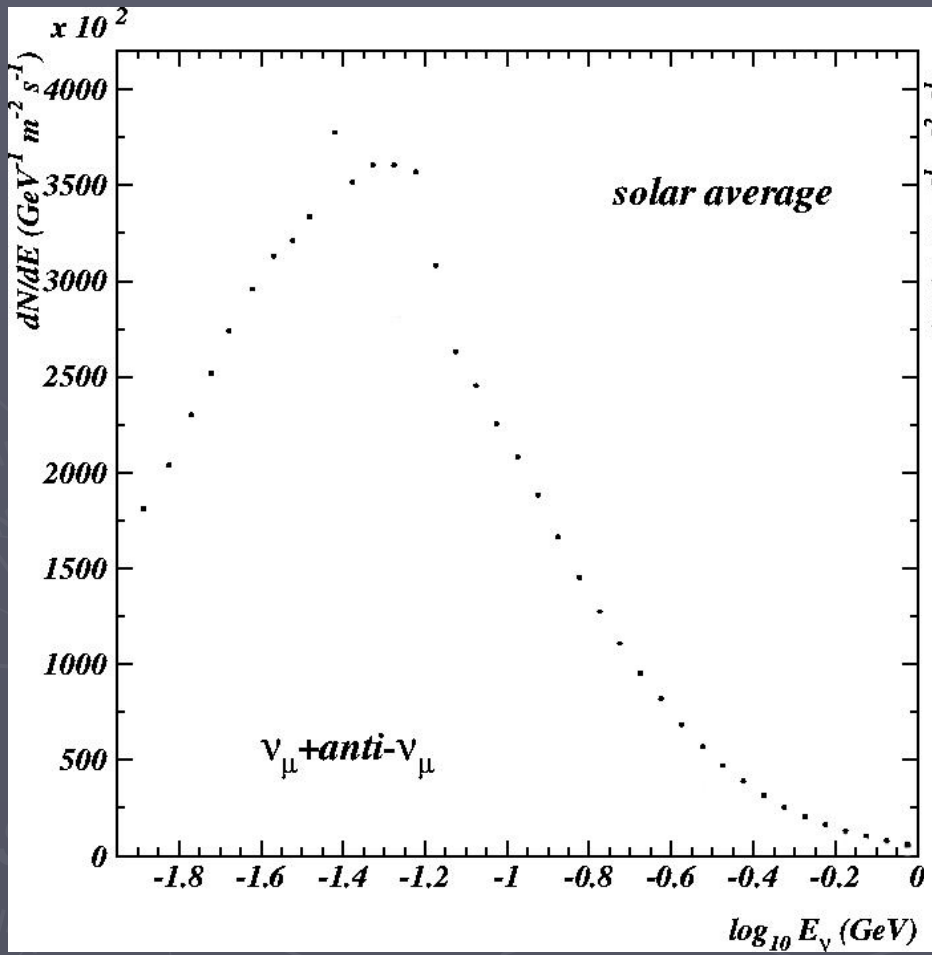
available at these low energies

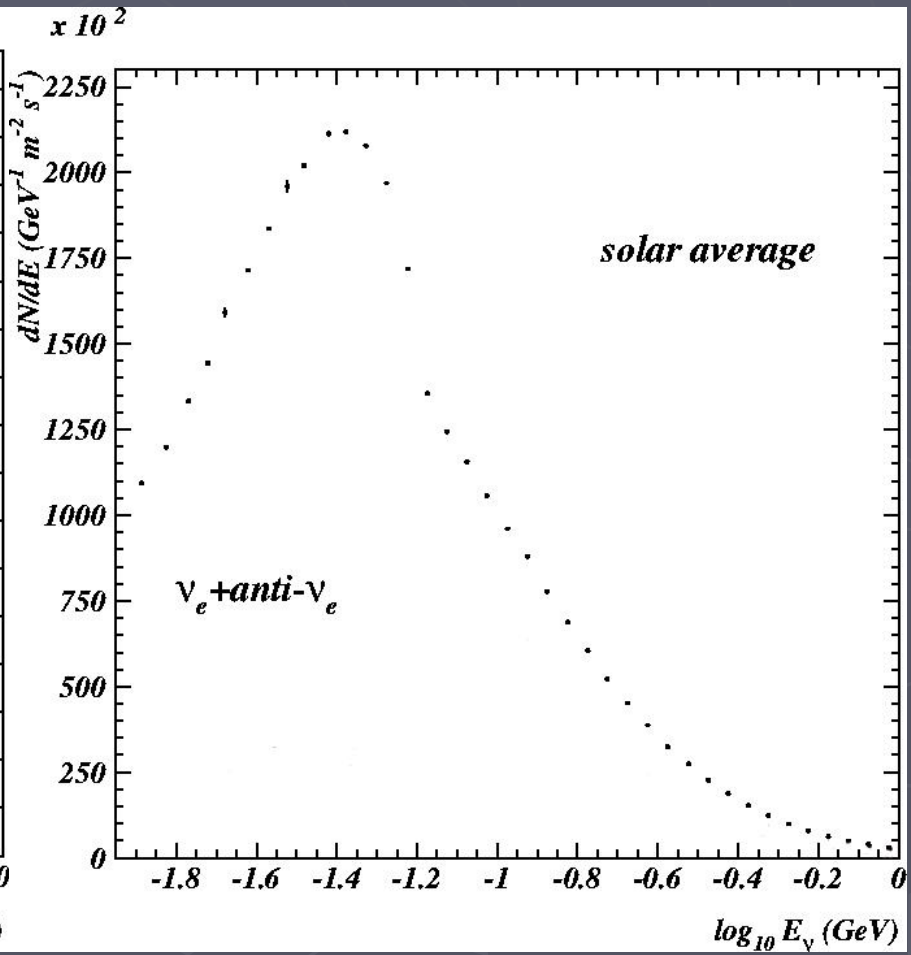
- **The original FLUKA fluxes have been computed using a 30 MeV threshold for all secondary particles (10 MeV for neutrinos), but so far we have shown results only for E>100 MeV**

- **For ICARUS we have used fluxes down to the limit of our available q.e. cross sections (~50 MeV)**

- **Stimulated by the requests of different groups the FLUKA flux tables in the range 10-100 MeV are now available (http://www.mi.infn/~battist/neutrino.html)**

The full SubGeV angle-integrated ν fluxes (SK site) [non-oscillated]

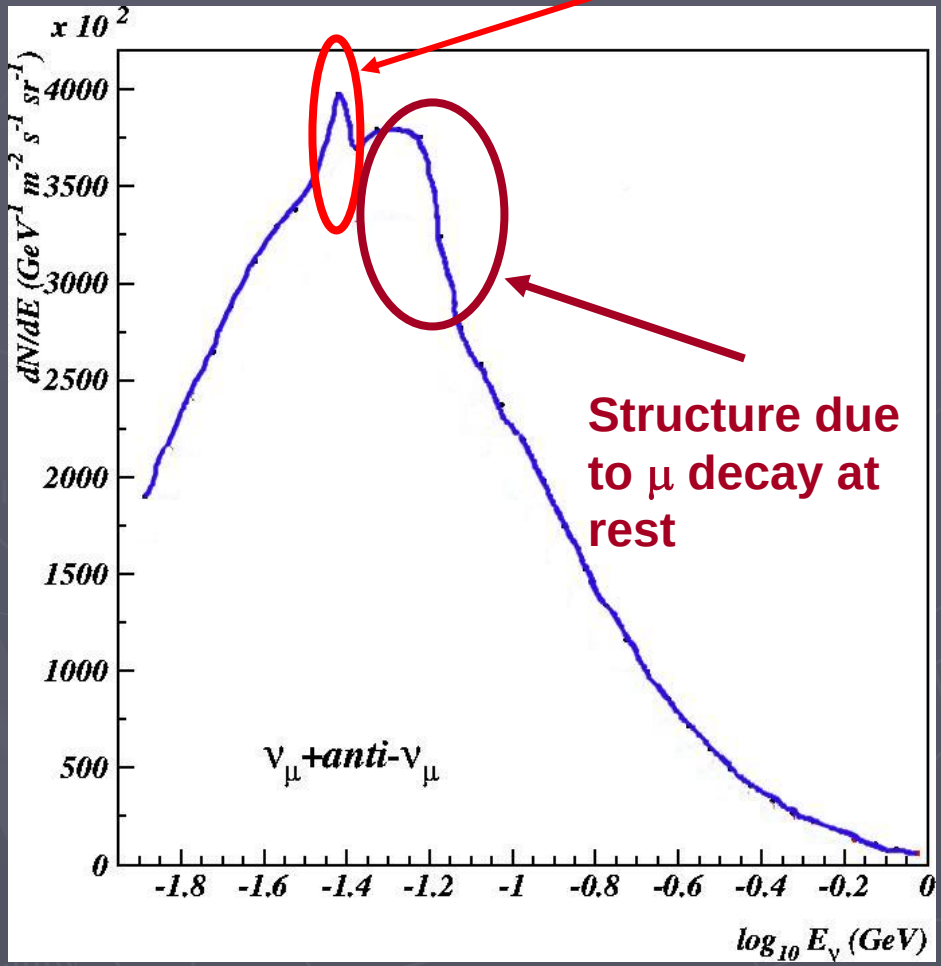




Some features of the flux

monocromatic peak due to π decay at rest

of course only for ν_μ



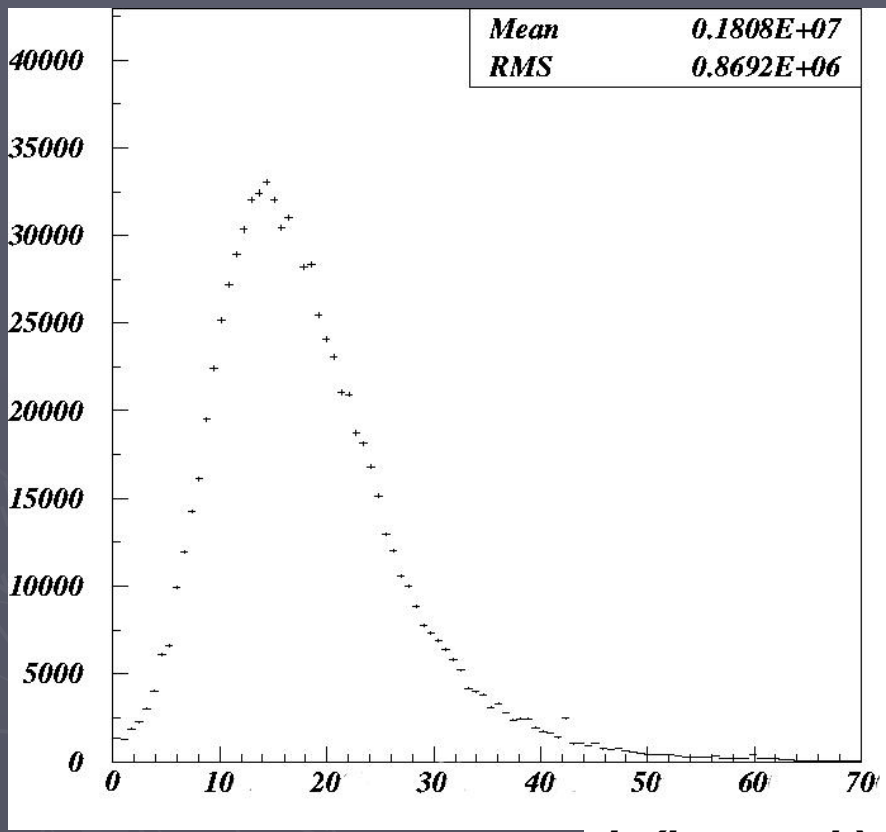
Origin of neutrinos below 100 MeV

	ν_μ	anti-ν_μ	ν_e	anti-ν_e
μ decay at end of range	0.078	0.070	0.124	0.148
μ decay in flight	0.378	0.470	0.876	0.852
π decay at end of range	0.003	0.007	0.00002	~0
π decay in flight	0.541	0.453	0.00003	0.00005
K decay in flight	0.0005	0.0003	0.0007	0.0006
	32.9%	**33.8%**	**18.3%**	**15.0%**

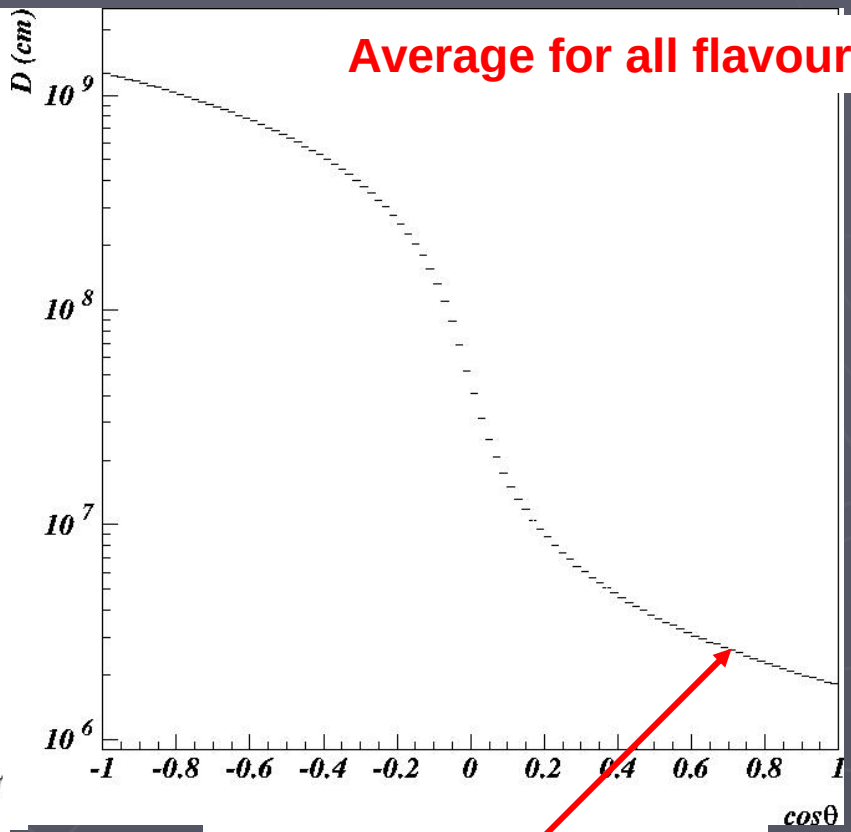
$$\frac{\nu_\mu + \overline{\nu_\mu}}{\nu_e + \overline{\nu_e}} = 2.002$$

It is a regime where you may think that you ~always have the full $\pi \rightarrow \mu \rightarrow \nu$ decay chain

Production Height and flight path vs cosθ



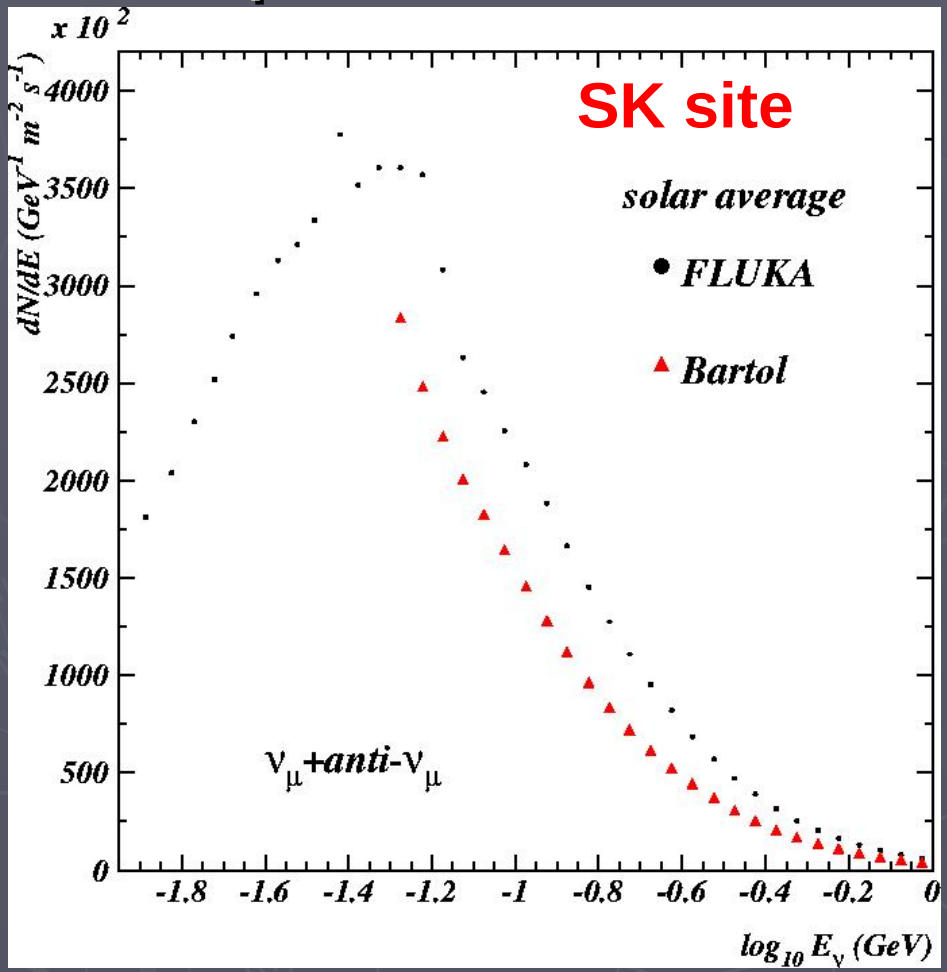
h (km a.s.l.)

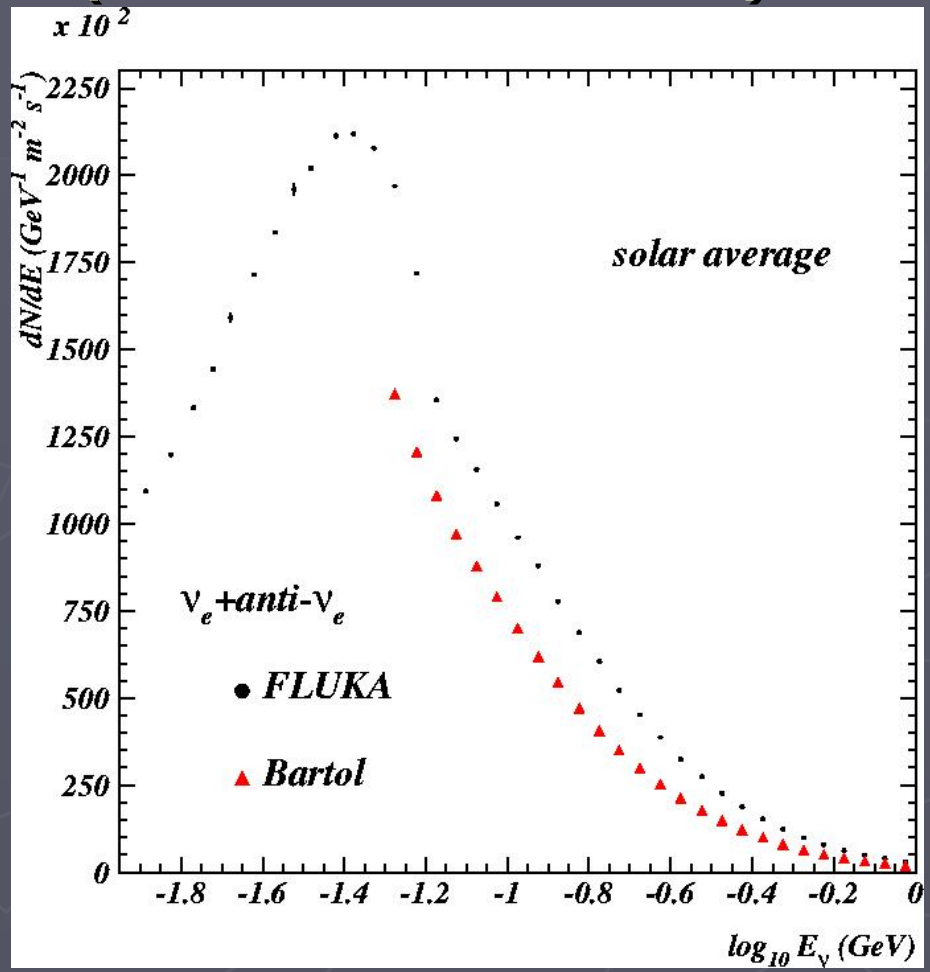


Average for all flavours

ν_e – ν_μ differ at most by 5% here

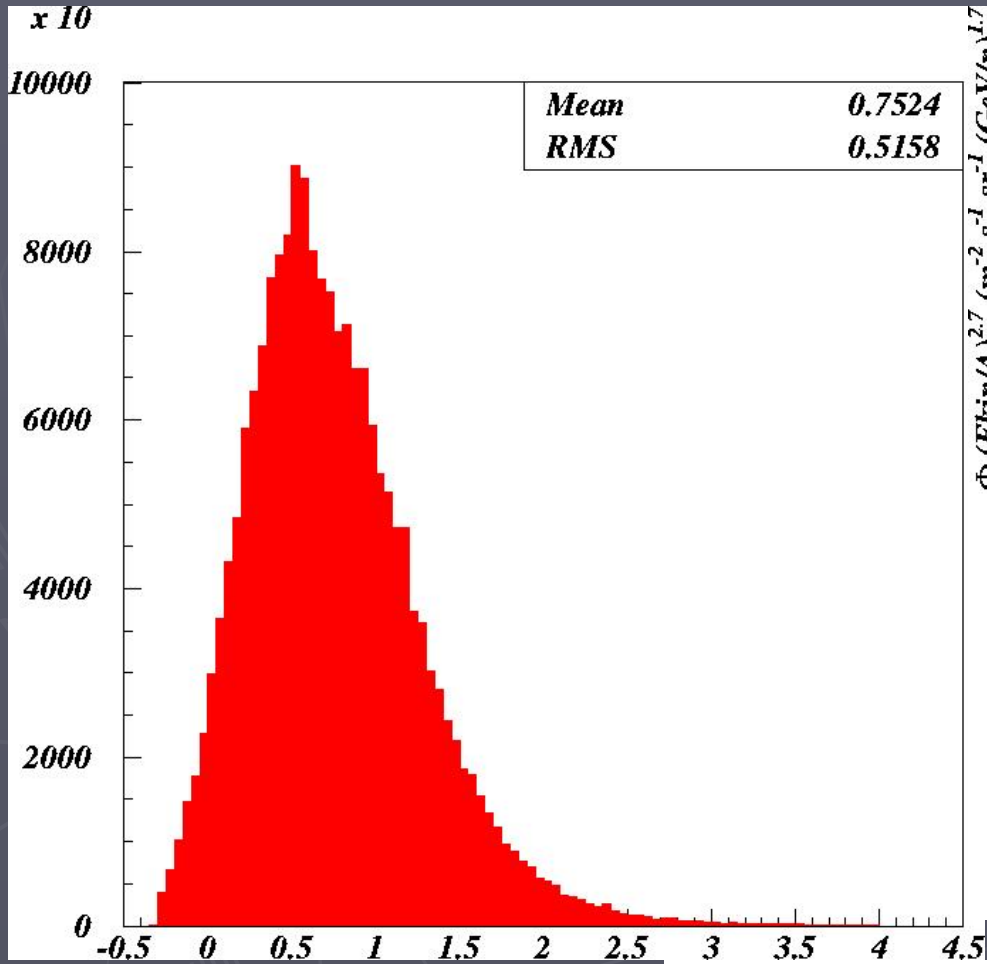
Other products on the market: comparison with BGS (Bartol, ICRC95)

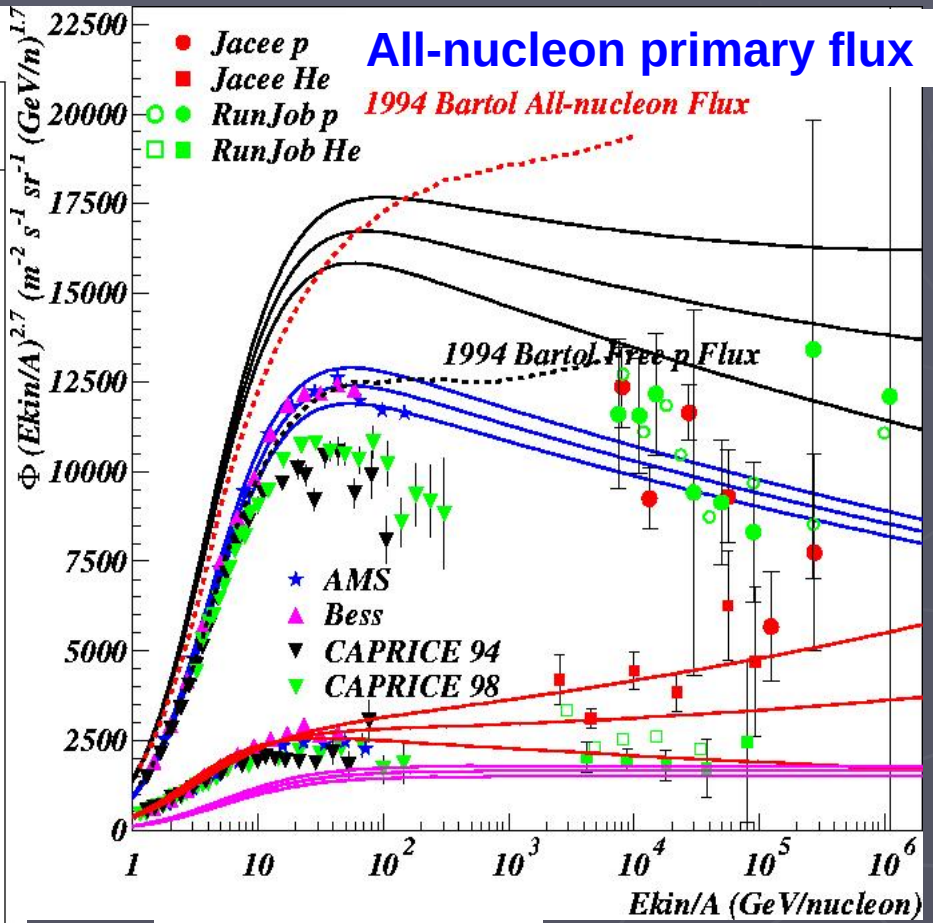




Warning: there is a non negligible difference in primary spectrum
FLUKA makes use of primary Bartol fit 2001: this accounts from 5% to 10% diff.

Primary energy/nucleon contributing to ν's below 100 MeV (low cut-off site)





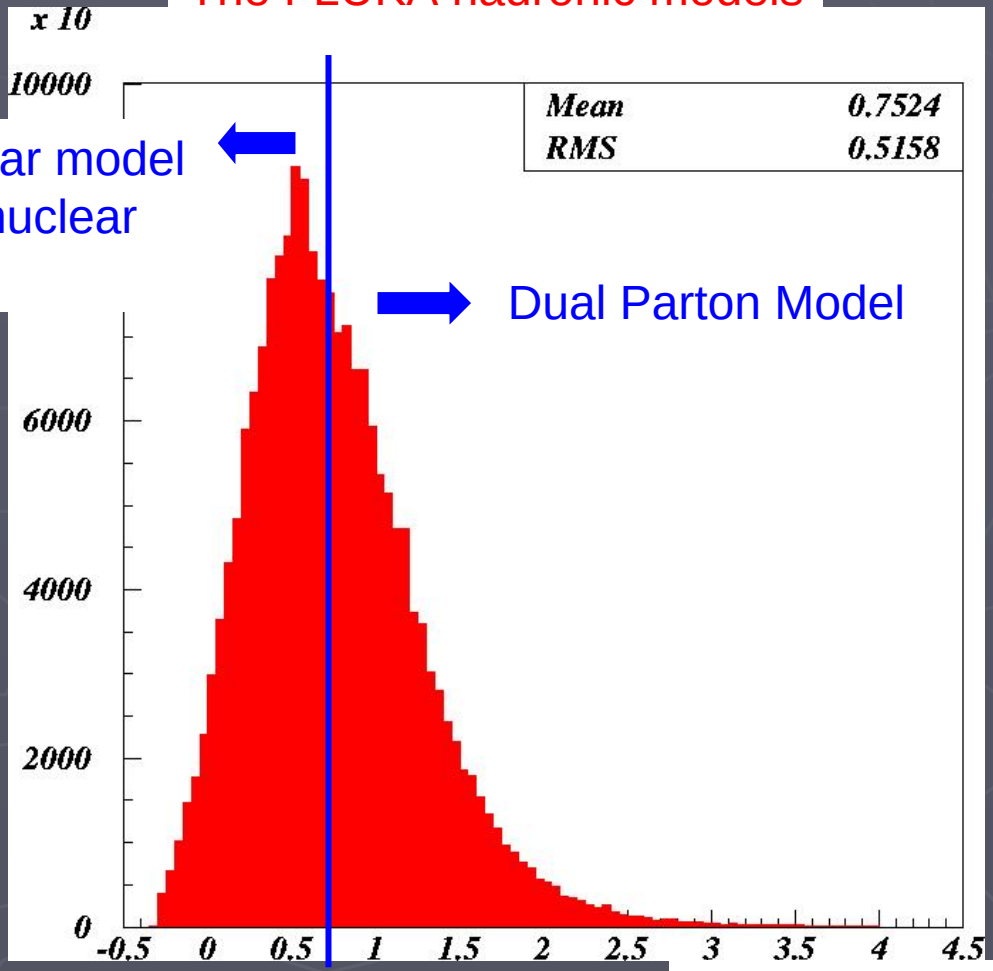
Bartol fit of 2001
Constrained by AMS and BESS

Primary energy/nucleon contributing to ν's below 100 MeV

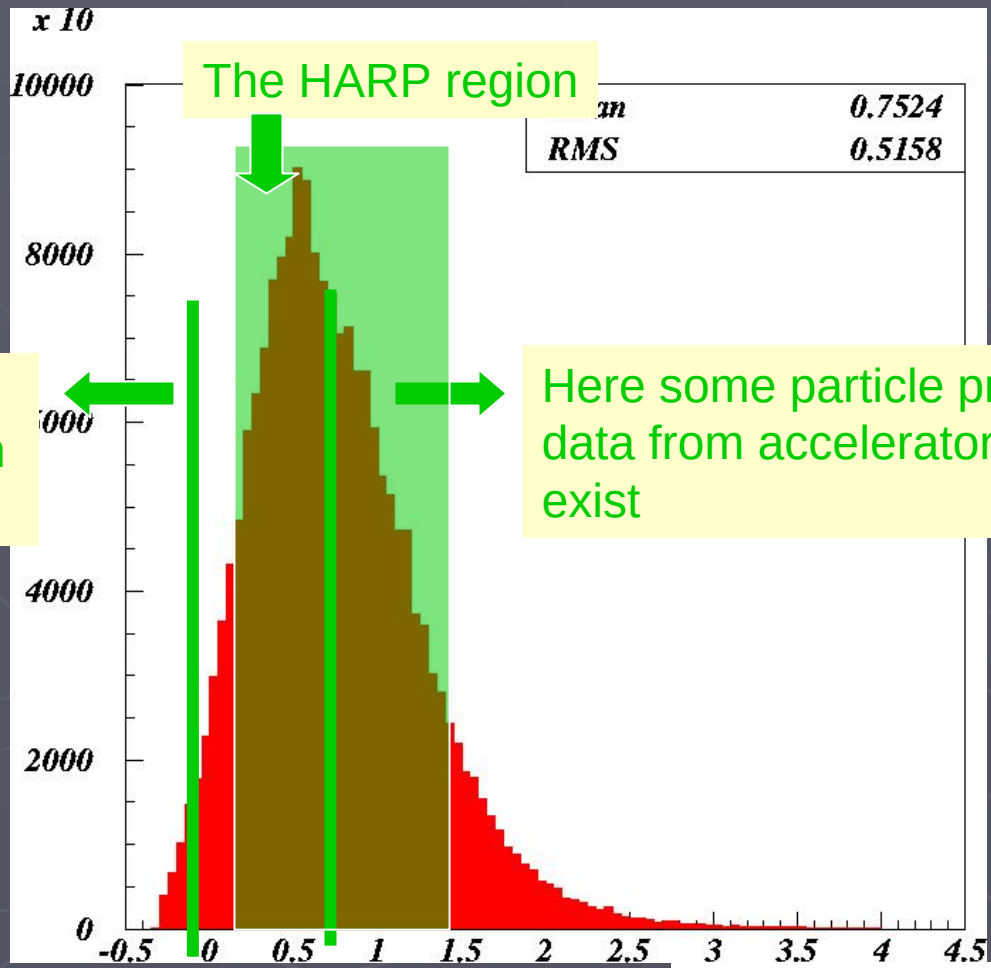
The FLUKA hadronic models

Preequilibrium nuclear model
Generalized Intranuclear cascade

Dual Parton Model



Primary energy/nucleon contributing to ν's below 100 MeV



The HARP region

Here some particle production data from accelerators exist

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The flux uncertainties

Most important factors:

particle production:

We rely on accelerator data, where available

(difficult to quantify the error in an absolute way)

primary spectrum + geomag. cutoff+solar modulation:

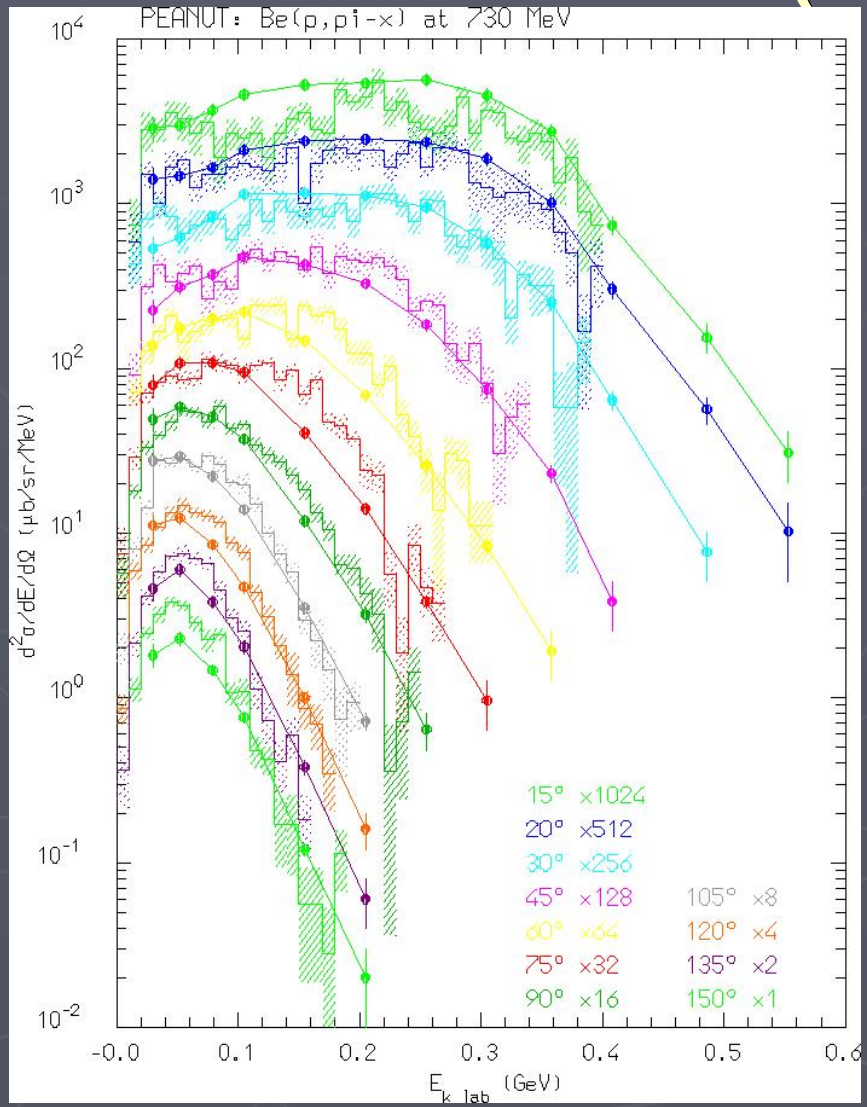
We test other data on particle production in atmosphere

transport details

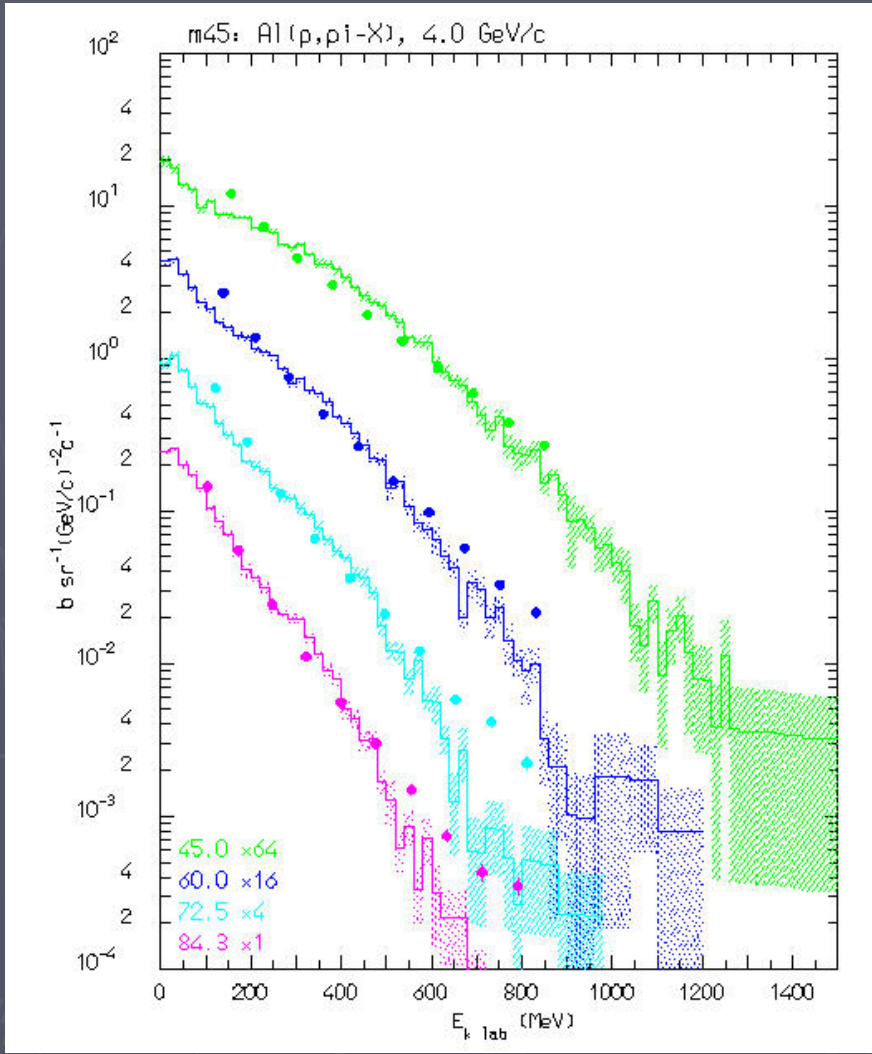
In the regime of complete decay, the integrated flux should not depend significantly on atmosphere, mag. field, ecc.

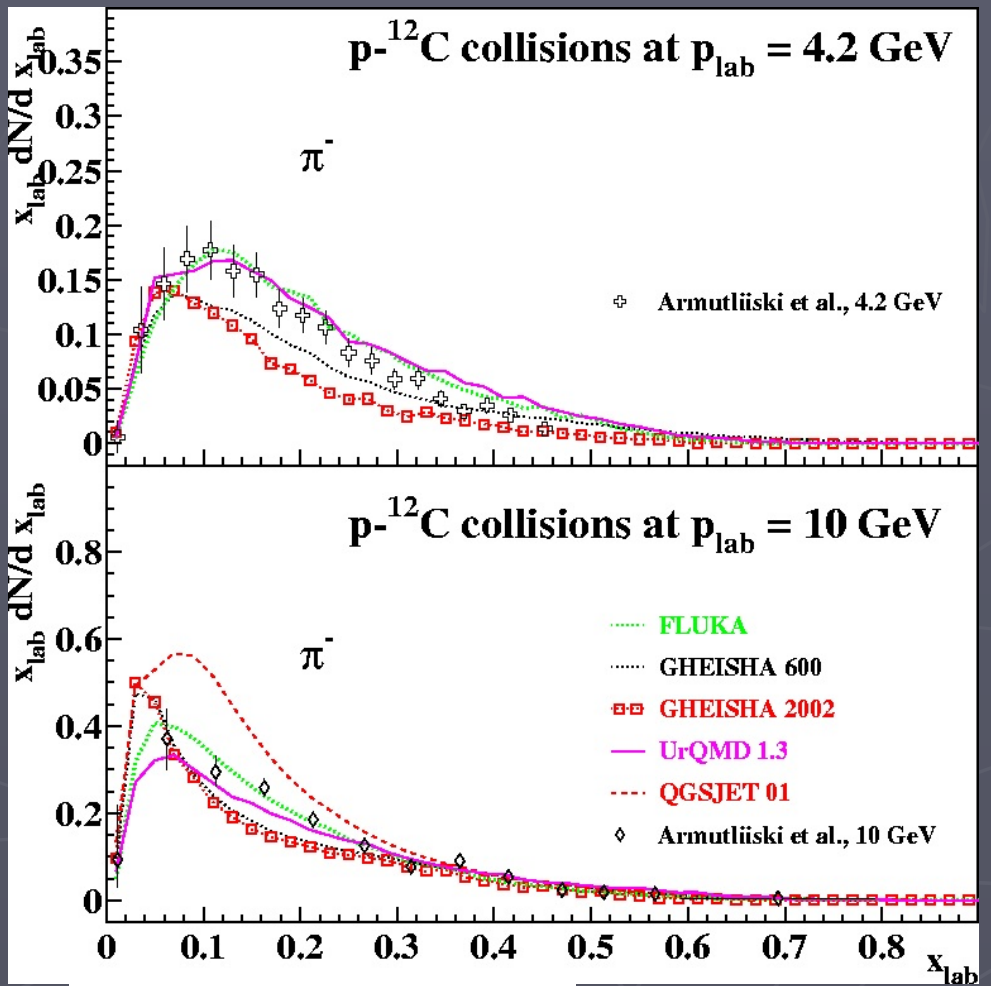
This might not be true for angular distribution

The most important test of pion production for the preequilibrium model + GINC (below 1 GeV)



Transition between the 2 model in FLUKA



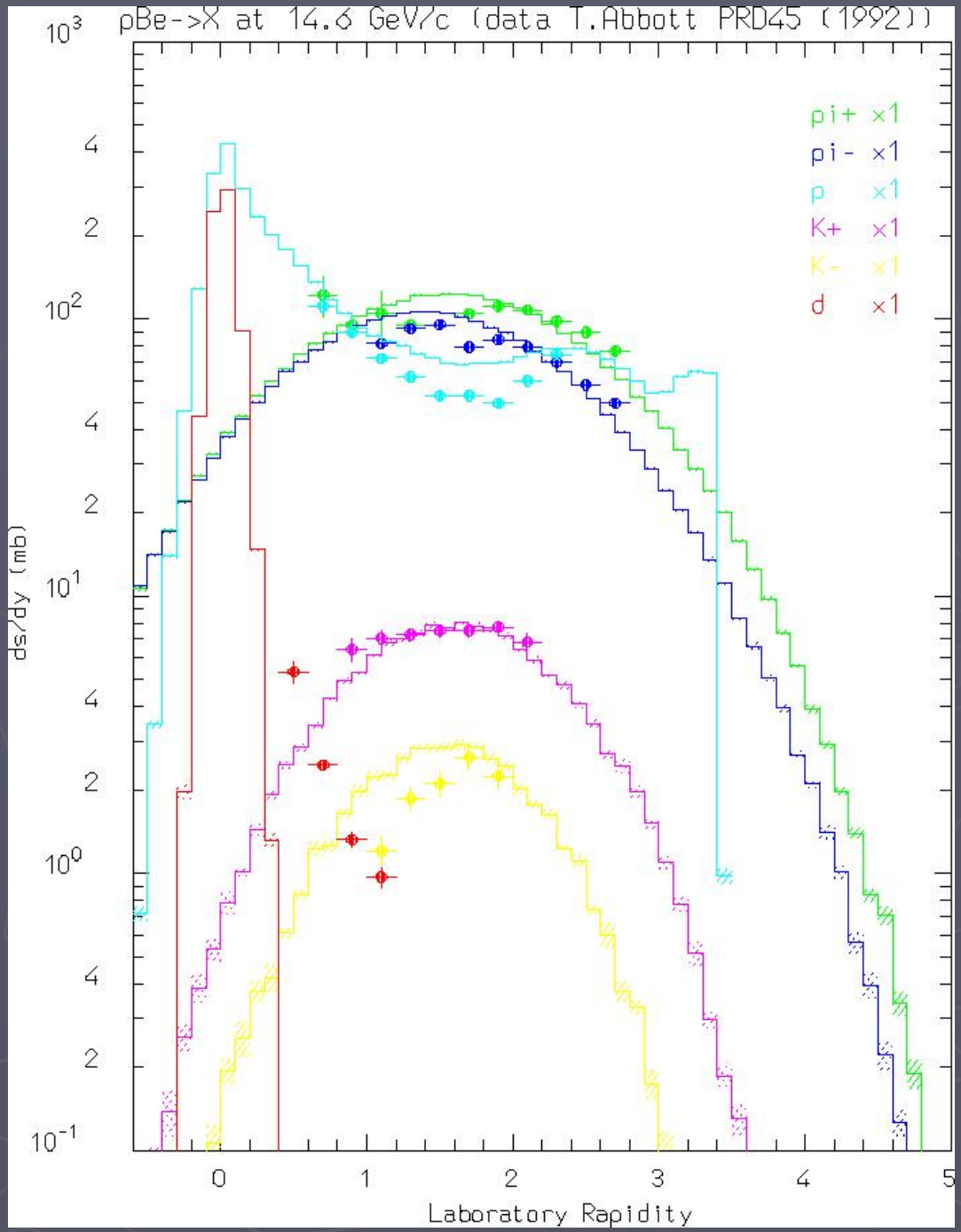


Seems satisfactory!!

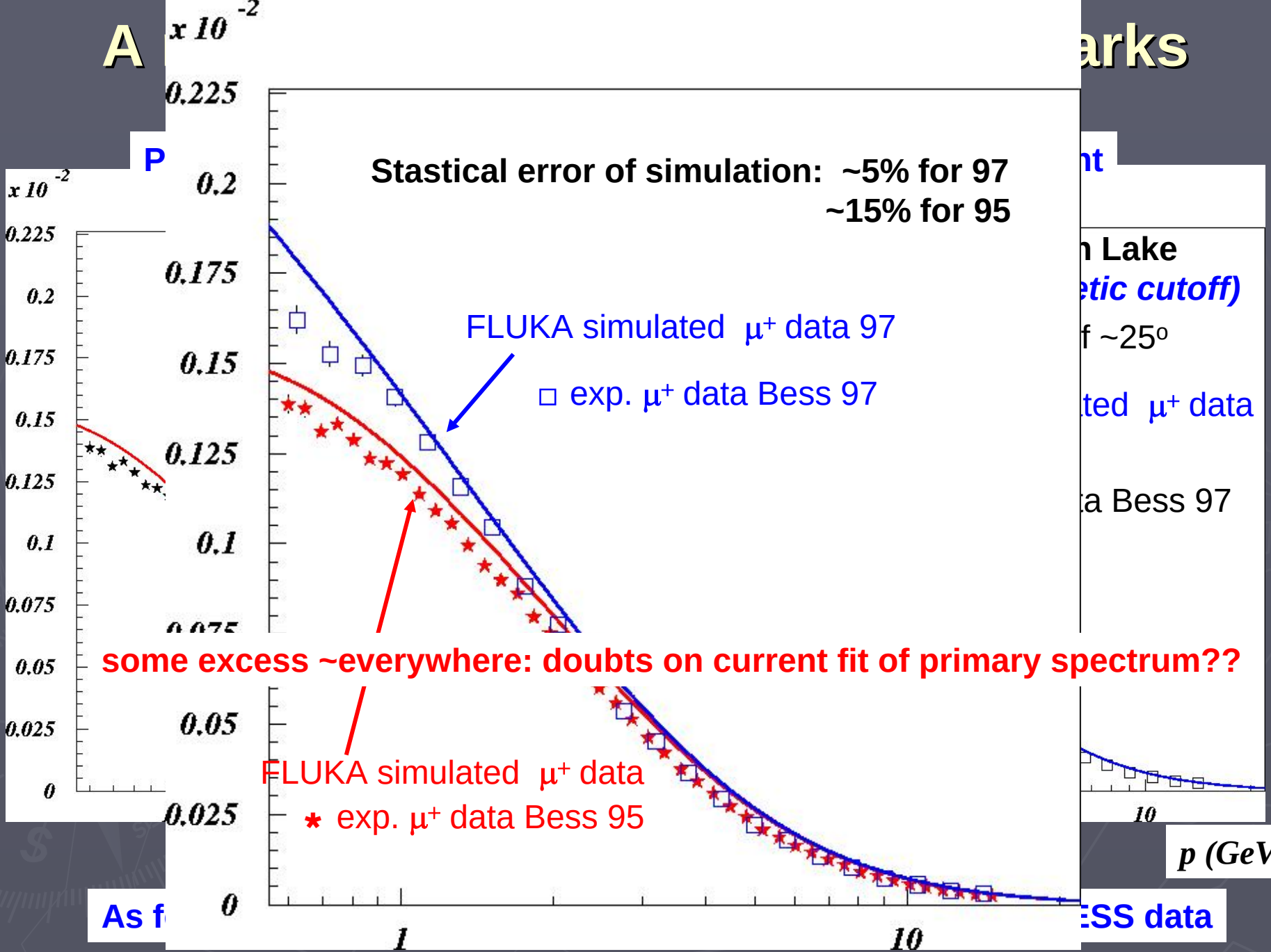
Other tests

We estimate that, integrating inthe relevant phase space, the FLUKA hadronic uncertantiny for pion production E<20-30 GeV is at most ~10%

Kaons may be discussed but are not relevant here.



A … arks

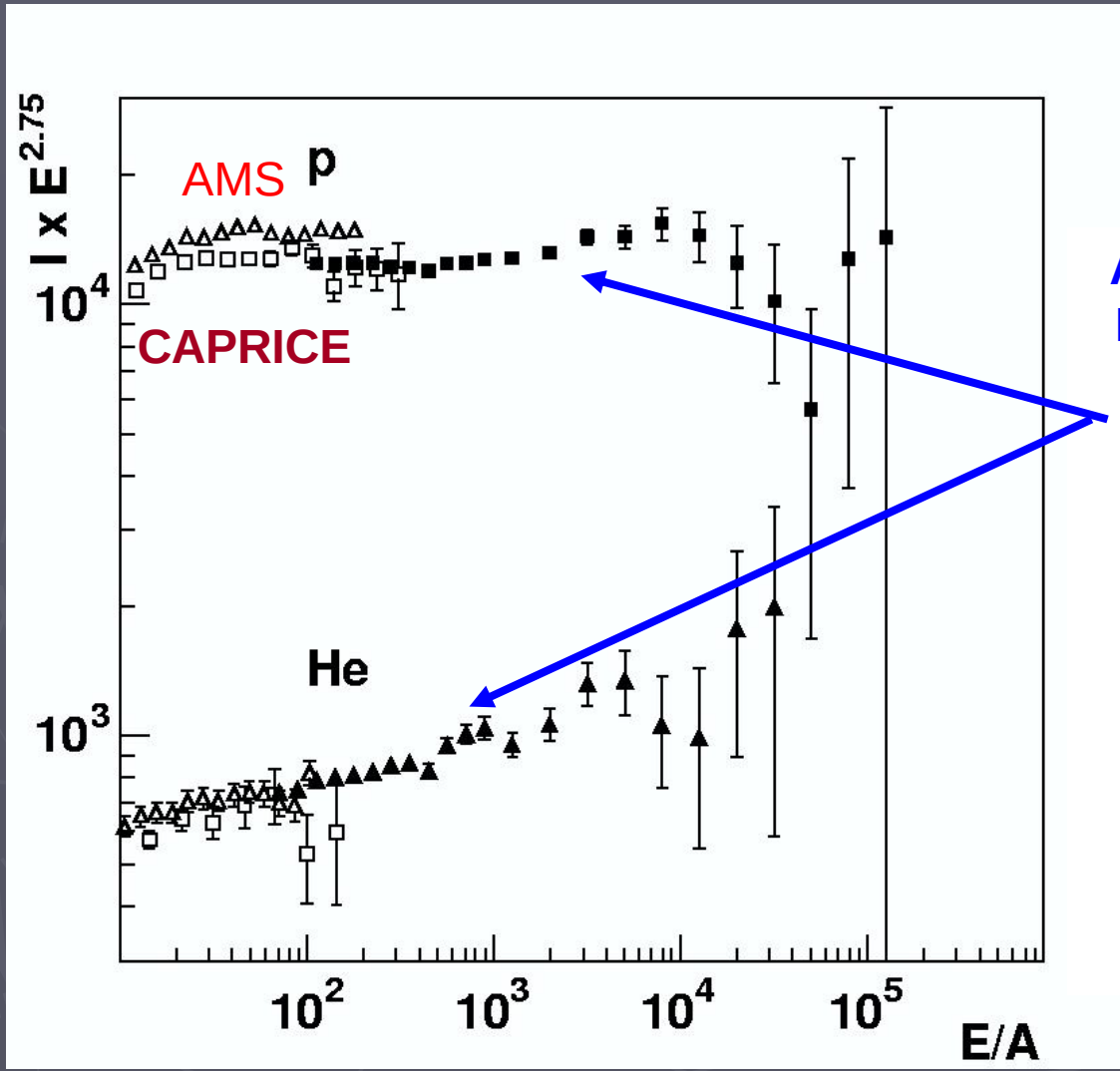


P … nt

… Lake
…etic cutoff)
…f ~25°
…ted μ+ data
…a Bess 97

As f … ESS data

Does the primary flux saga still go on?...



ATIC results presented at Moscow meeting in June 2004 (at ICRC 2003 there was not yet a normalization)

Preliminary!!!

The AMS/BESS vs CAPRICE discrepancy points to a sys. error of 20%

Groups working with FLUKA fluxes

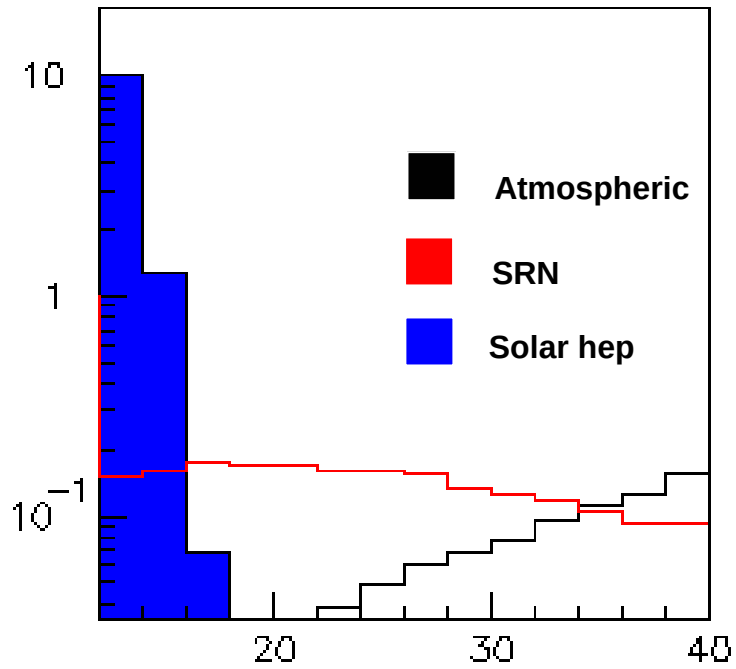
G.Fogli, E.Lisi, A.Mirizzi, D.Montanino (Bari)
(talk by Mirizzi@now2004)

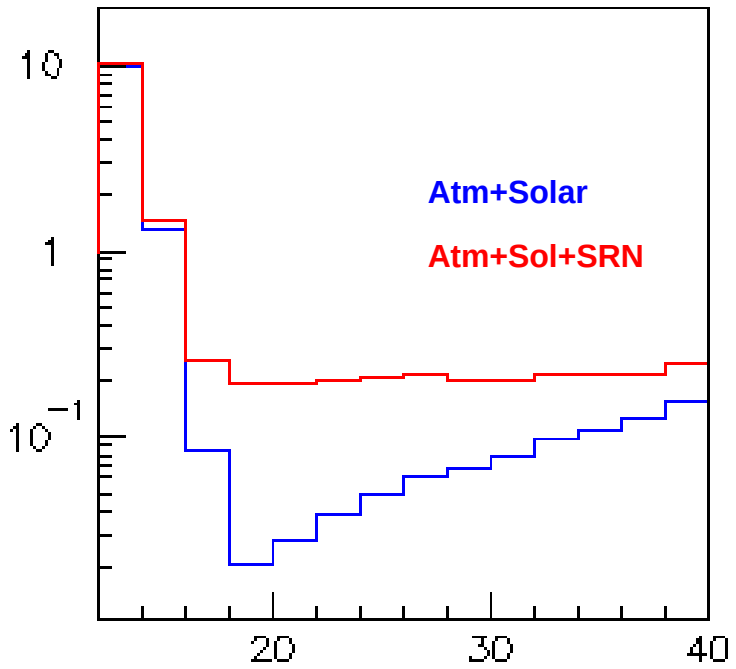
A.G. Cocco, A.Ereditato, G.Fiorillo, G.Mangano, V.Pettorino (Napoli)
Detection of SRN in Liquid Argon

From the work of Cocco et al.:
SRN and background in T3000 (5 yrs)

hep-ph/0408031

Rate (N/MeV in 5 yrs) α=1, β=2.5



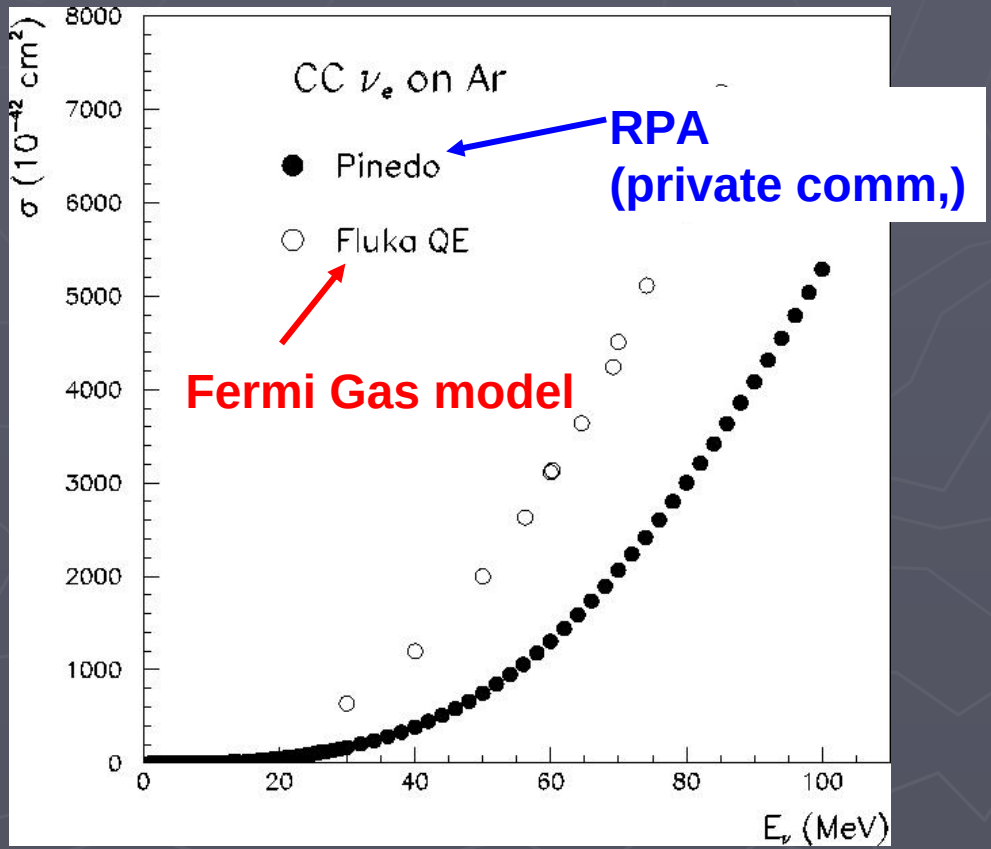


$$R_{SN} = \begin{cases} \rho_0 (1+z)^{\beta} & z < 1 \\ \rho_0 2^{\beta-\alpha} (1+z)^{\alpha} & z > 1 \end{cases}$$

Consideration on cross sections

Factorized with respect to the flux question there is the topic of cross sections at these energies.

For ν_e, there is a contribution of quasi-elastic that certainly cannot be considered reliable on nuclei if simple Fermi Gas model is adopted



Conclusions

- **The atmospheric neutrino flux evaluation even below 100 MeV is an important topic expecially for LAr detectors and in general for background evaluation in all detectors**

- **At these energies, the FLUKA fluxes are practically the only available, among the modern computations, at this time**

- **The uncertainties in this region, as far as the flux is concerned, are of the same order of the whole SubGev region. We are still worried by the issue of primary spectrum...**

~20% from c.r. spectrum ⊕ ~10% from particle production

→ ~22%