

A precise calculation of cosmic muons at the Double Chooz far site with MUSIC

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Motivations

- Knowledge of muon fluxes at underground neutrino experiments is essential for a precise determination of the induced backgrounds: spallation neutrons, radioactive nuclei, bremsstrahlung photons...
- A measurement of muon distribution was performed at Chooz in 1995. They were correctly parametrized, but no detailed information on the energy spectrum was available.
- A detailed simulation is needed for Double Chooz

Measurement of muons at Chooz

A. Baldini, et al. (1995)

Contact: G. Giannini

DRAFT

Geology at the CHOOZ site

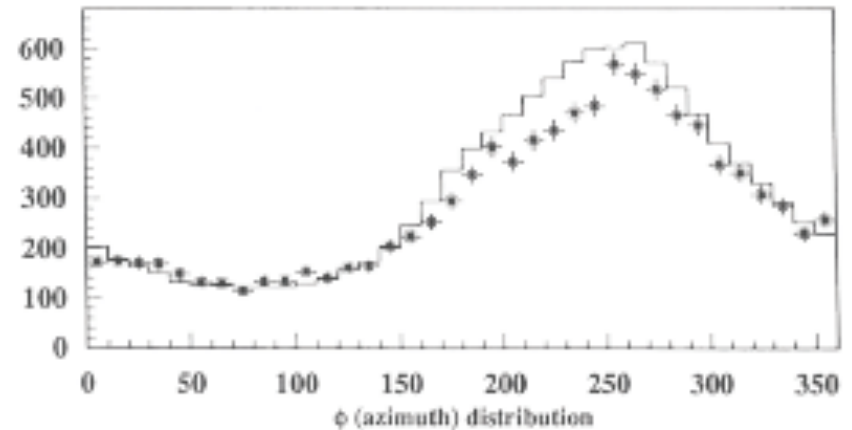
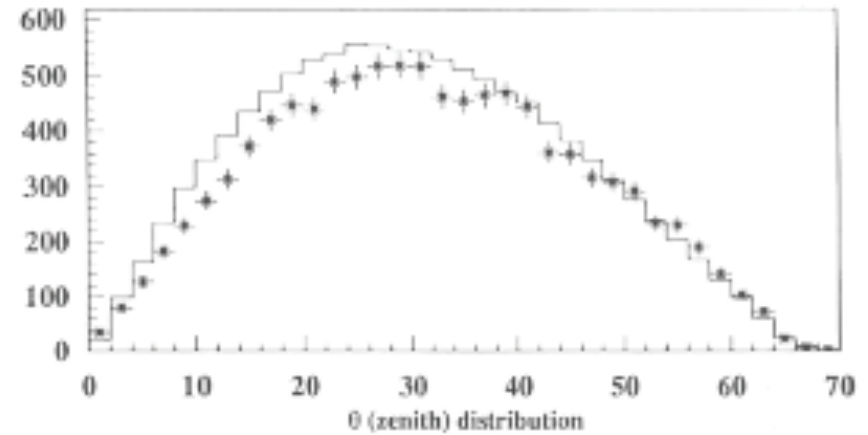
PRELIMINARY PARTIAL DATA.

A. Baldini, C. Bersporod, M. Grani, S. Parlati, G. Pieri, R. Pazzi.
INFN and Dipartimento di Fisica dell'Università, Pisa

F. Cei, D. Nicolò.
INFN and Scuola Normale Superiore, Pisa

E. Caffa, P. Cristaudo, G. Giannini, Y.M. Zhang.
INFN and Dipartimento di Fisica dell'Università, Trieste

May 25th 1995



MUSIC

« A three-dimensional code
for muon propagation through the rock »

P.Antonioli, C.Ghetti, E.V.Korolkova, V.A.Kudryavtsev, G.Sartorelli
hep-ph/9705408

- Surface distribution parametrization
- All relevant interactions with accurate cross-sections:
 - ionization, pair-production, bremsstrahlung, inelastic collisions on nuclei
- Parametrization for scattering, to describe angular deflection
- Results in agreement with other codes (CORSIKA, Geant4), but much faster than detailed simulation

Ingredients of the calculation (1)

Physical properties of the rock:

- $\langle Z \rangle = 11.8$ $\langle A \rangle = 24.1$
- $\langle \rho \rangle = 2.81 \text{ g/cm}^3$
- $\lambda = 23.3 \text{ g/cm}^2$
- Chemical composition
 - SiO_2 58%, Al_2O_3 19%, FeO 17%, MgO 4%, K_2O 2%
 - (approximate values, from 1995 analysis of rock samples)

⇒ Interaction cross-sections

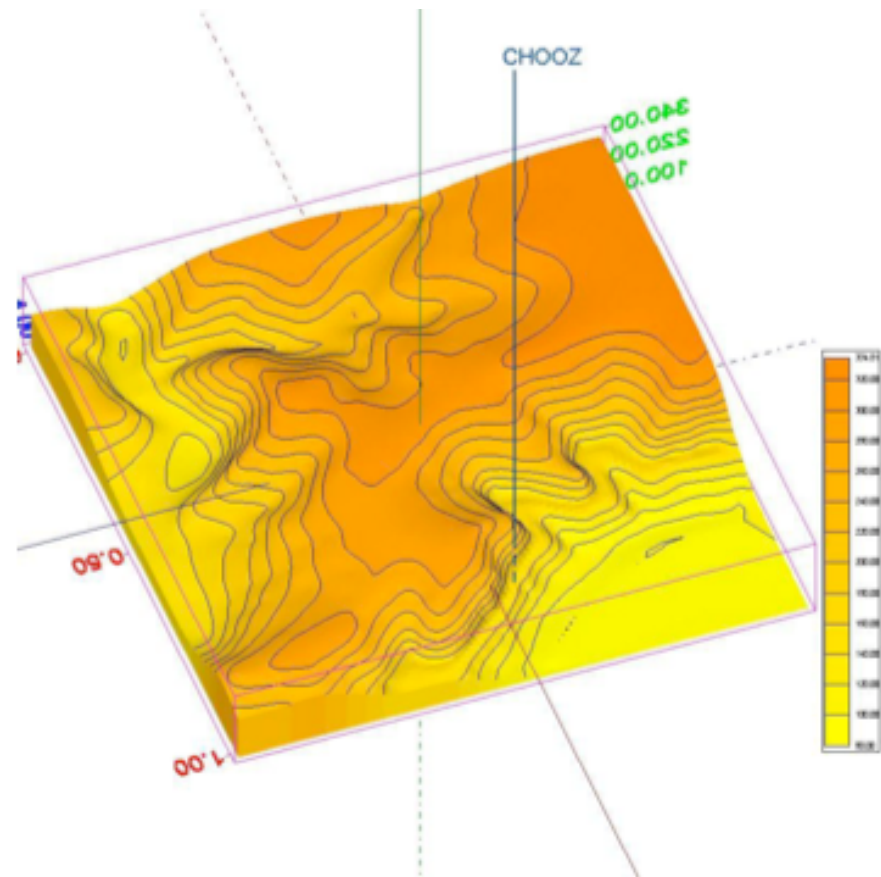
(specifically computed by V.Kudryavtsev)

Ingredients of the calculation (2)

- 3D profile of the rock overburden => depth as a function of direction

Average overburden 300 m.w.e.

Variations by factor ~4

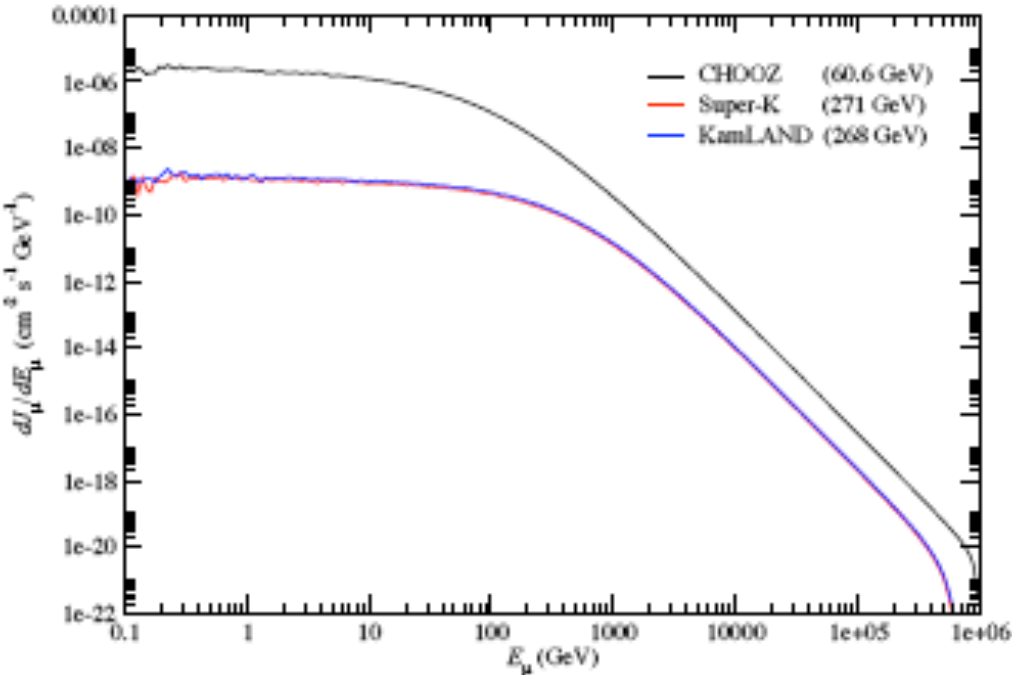


The calculation (by A.Tang)

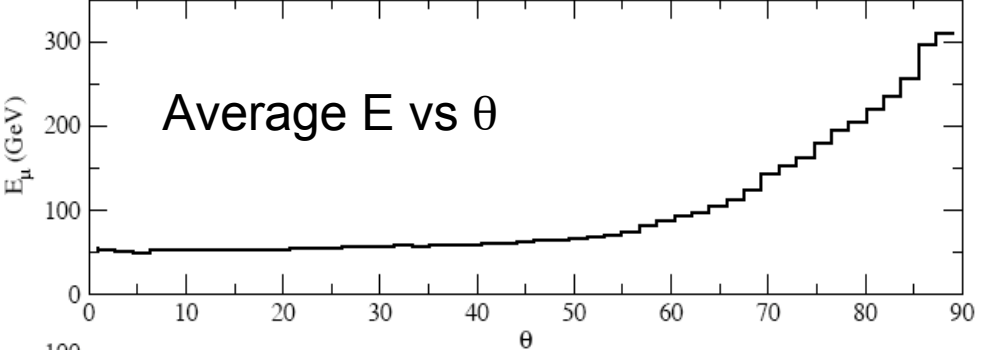
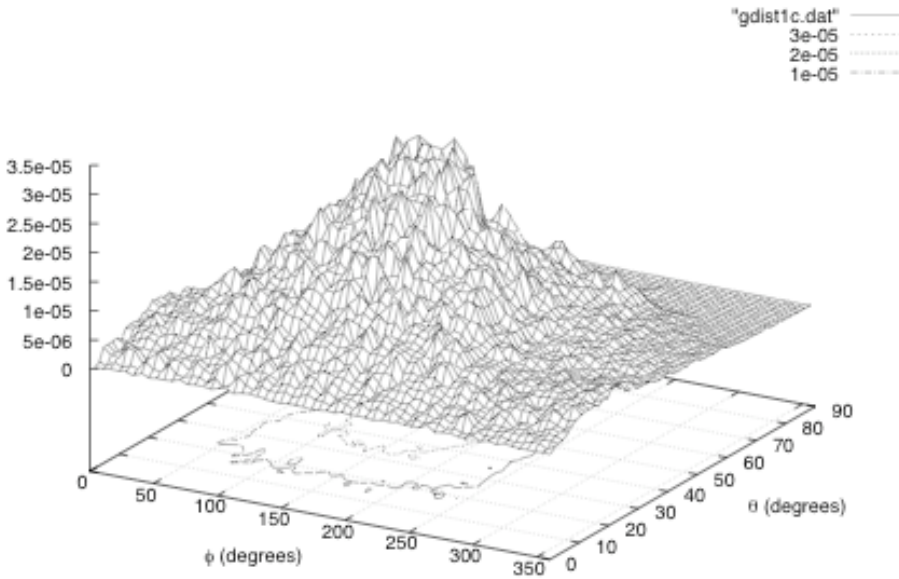
- Single-function parametrization of surface distributions (improved Geisser formulae)
 - Numerical sampling method based on uniform generation of integration variables
 - Propagation through the rock, with direction-dependent depth and the appropriate cross-sections
- ⇒ Muon distributions at « detector » surface
(or at any given surface)

Distributions

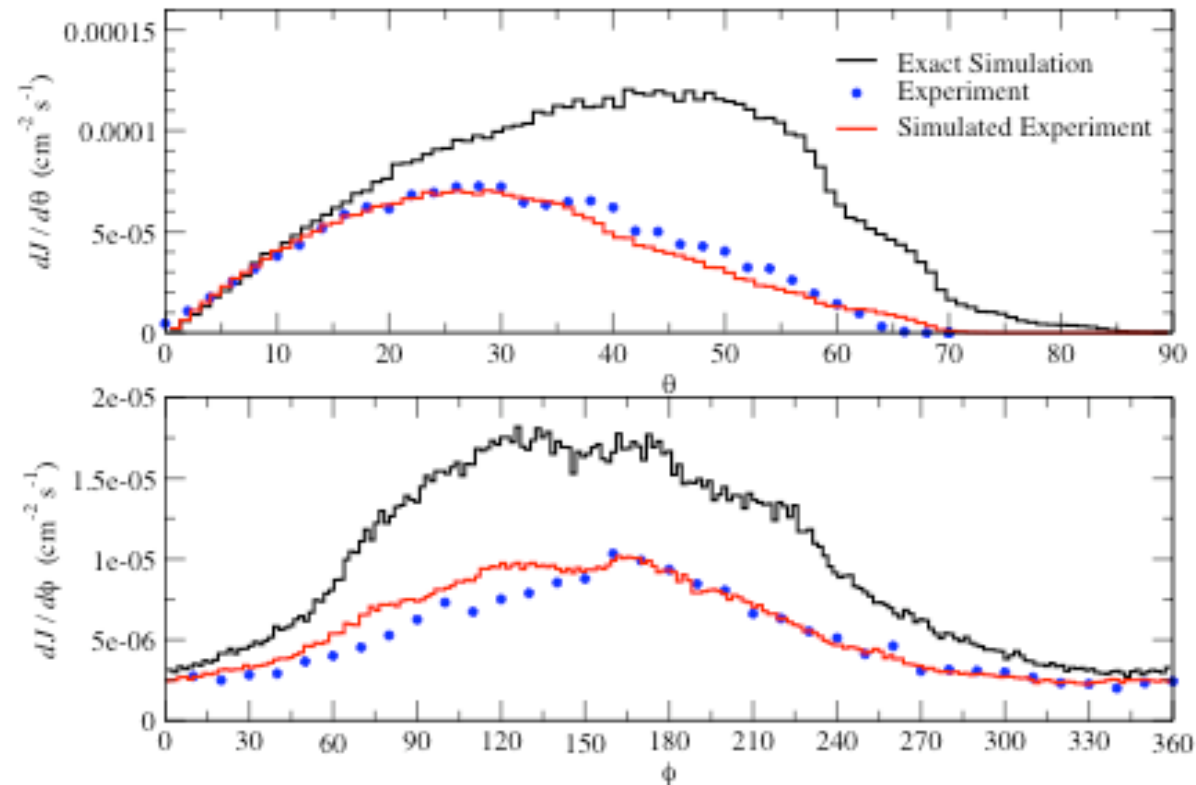
Energy



Polar and azimuthal angles



Comparison with data



- Good agreement with measured angular distributions, once acceptance of the experimental apparatus (RPC planes) is taken into account
- The small discrepancy was explained as a layer of thicker rock (not included in the calculation)

Summary and outlook

- A detailed calculation of cosmic muons at the DChooz far site has been performed
 - MUSIC code for muon propagation
 - Details of the overburden
- Experimental distributions are well reproduced
 - The method can be employed for other underground sites (ask A.Tang !)
 - Paper in preparation
- These muons can be used as input to Fluka or Geant4 for propagation in the proximity of the detector, for detailed simulation of interactions and production of secondaries