The Status of CORSIKA at Wuppertal

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The distribution of the program, available at

http://zombie.physics.berkeley.edu/
˜ dima/work/BKP/FLS/CRS/v5945.tar.gz,

consists of:

1. the official CORSIKA distribution
2. card file with changes (all changes are under the keyword AMANDA, so it's easy to transfer them to the new official version of CORSIKA as it comes out)
3. Program ucr to randomize the shower core locations (and to remove such randomization), to enable oversampling, and to cut away muons that die before reaching the detector
4. compile, run, and multi-computer distribution scripts

The changes to the CORSIKA code include:

1. random primary generator (gives a primary from H-Fe according to the measured fluxes)
2. cylindrical geometry implementation (saves calculation time and makes sense)
3. F2K compliant output
4. South Pole Atmosphere and Magnetic Field
5. Curved atmosphere treatment (F. Schroeder)

Features 2, 4 and 5 are now included into the standard CORSIKA distribution.

Features 1 - 4 were presented an 1999 Berkeley meeting and discussed in our ICRC paper

The results of the combination of all 5 improvements are presented here.

```
ucr merges F2000 files, v0.01.  Available options are:
-tr=[NUM] output only events with # of tracks >= NUM
-over=[..]  oversample by this number, default is 1
-r = -randomize randomize shower core xy locations
-LENGTH=[height] of the detector [m]
-RADIUS=[radius] of the detector [m]
-DEPTH=[depth] of the detector center [m]
-HEIGHT=[altitude] of the ice surface [m]
-rmpri remove primaries
-rmusr remove user blocks
-oms output only muons
-ohm leave only muon with highest energy per event
-msn leave only muon and neutrinos, delete others
-cmt=[file] append comments contained in the file
-run=[number] set the run number
-FLUXSUM=[CORSIKA's value] per meter2 second sr
-SHOWERS=[number] of showers generated by CORSIKA
-rr remove possible previous xy randomization
-test [num] [theta] [phi] test xy randomization
-cutfe=[GeV] angle-dependent cutoff energy for muons
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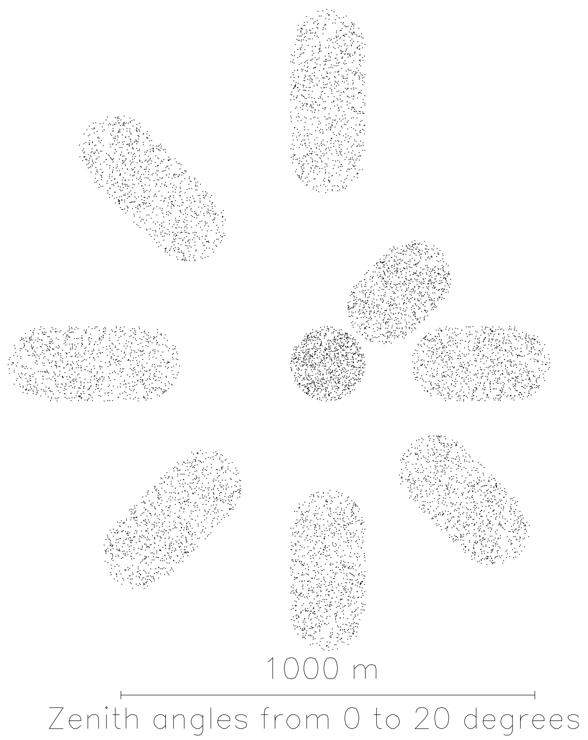
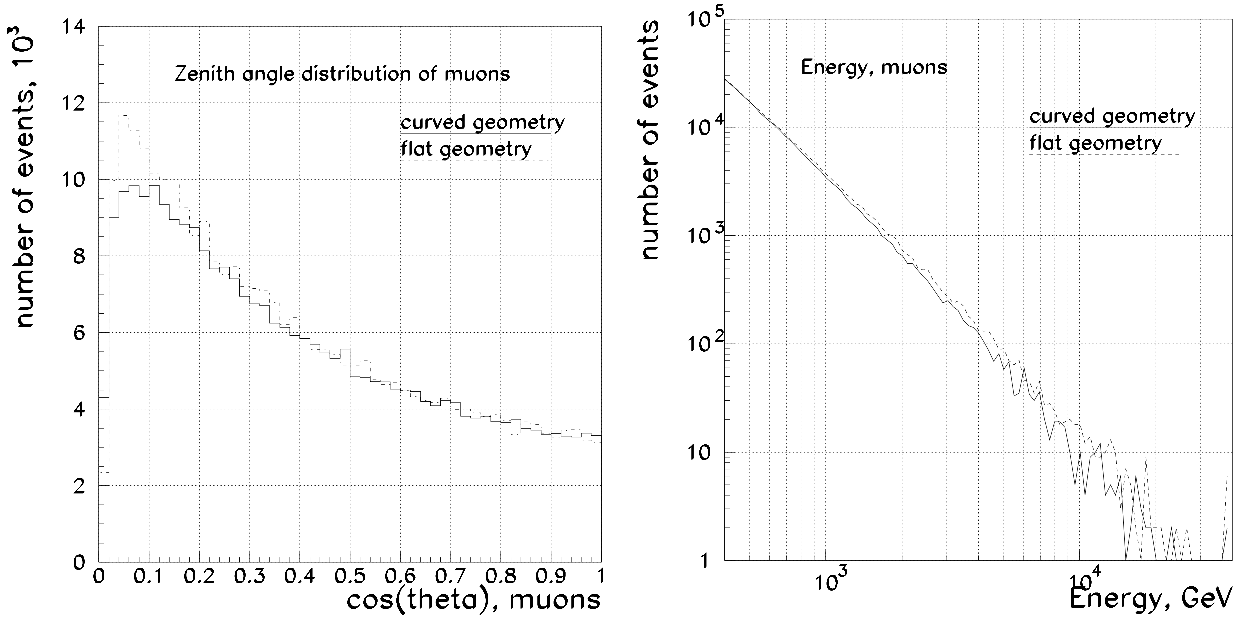


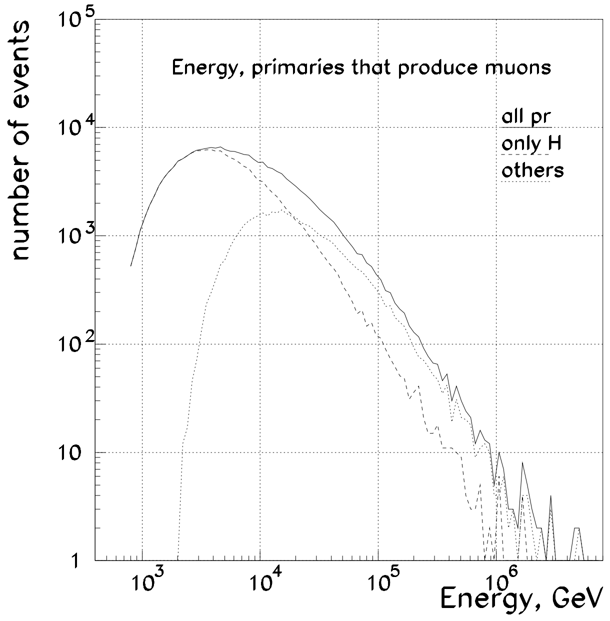
Shower cores are randomized inside the projection of the detector on the xy plane made at an angle of an incident primary

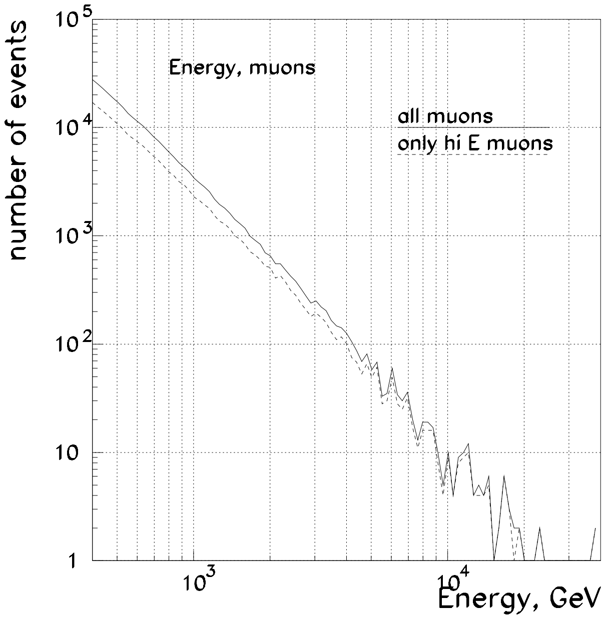
Comparison with earlier results (1999)

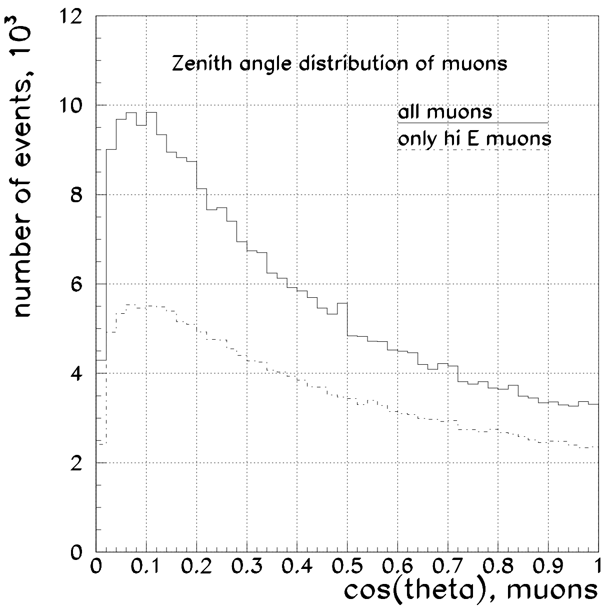


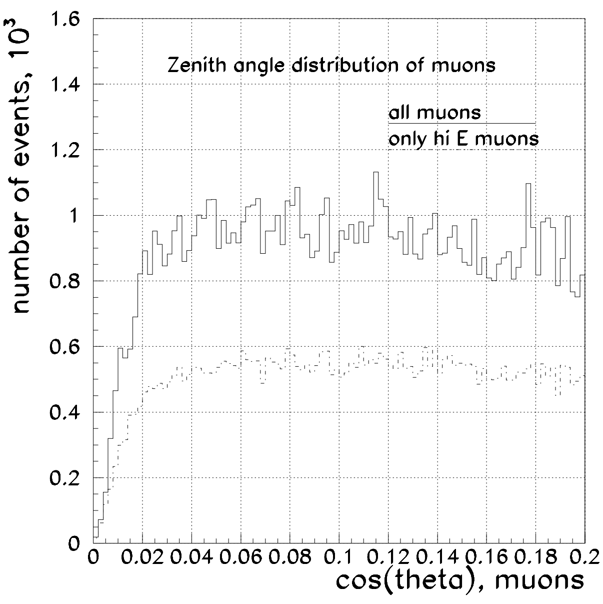
In the first picture the plots are almost identical at the angles of up to 70 degrees, as expected. There are more muons at large angles for the flat geometry because a pion created by the first interaction of a primary has more chance to propagate undisturbed to decay into muons (The first interaction is shifted into the higher altitudes where density of air is smaller). Notice, however, that the dip at 90 degrees for the flat geometry is bigger. This is consistent with the discussion below.

For the comparison purposes files with spherical detector geomerty and energy cuts 800 GeV (primaries) and 400 GeV (secondaries) were generated. Each file contained 10^7 primaries with the zenith angles from 0 to 89.999 and azimuth angles from 0 to 360 degrees.





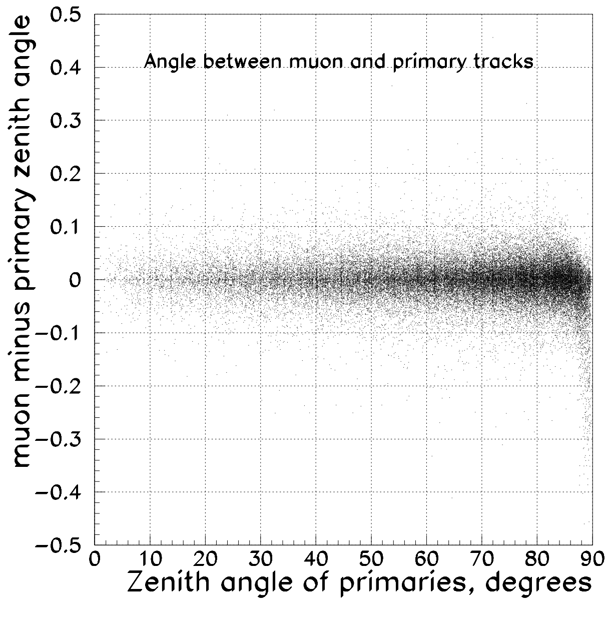


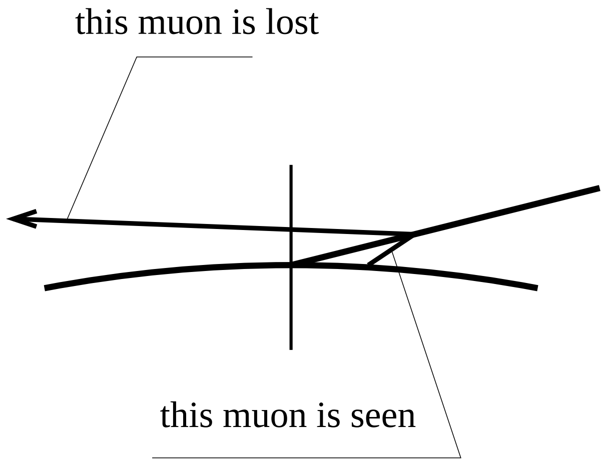


We have seen a very good agreement in energy spectra and zenith angle distributions (ZAD) with one exception. Our distribution at Zenith angles higher than 88.9 degrees shows a clear dip whereas the plots from Peter Steffen lack this feature. We have thought of the following possible reasons why this dip should exist:

1. magnetic field influence, however assuming the average altitude of muon production of 21 km above the ice surface, and a resulting muon energy of 400 GeV, the angle of the muon's direction change is 3' (3 minutes). Moreover, no change in the ZAD was observed in the specially generated files with magnetic field turned off.

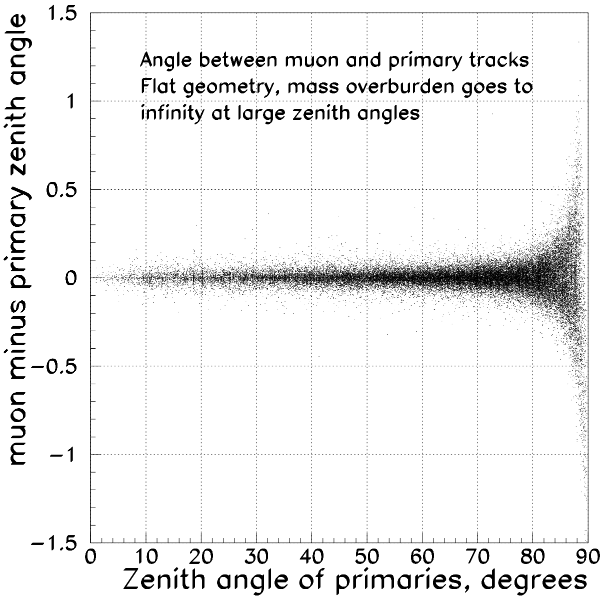
2. all particles inside CORSIKA are cutted away it at any point their ZA > 90 deg. A tipical muon scatters 100 times at large angles (350 mwe to cross with 377g/cm2 free path). If it starts with an angle just below 90 deg., it has 1/2 probability to scatter away and get lost from the calculation. After N scatterings probability to remain is $1/f(N)^N$, i.e. goes to zero.

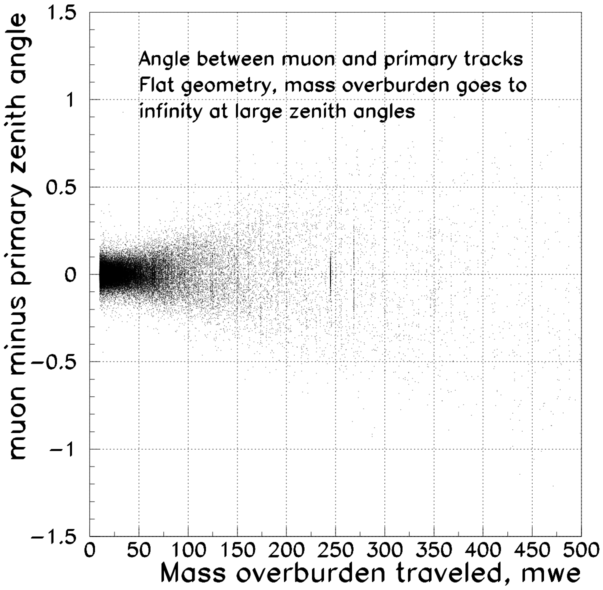




The asymetry can be explaned: muons that deviate up from the proton track have less chance to reach the observation level than those that deviate down (or else they are just cutted away because their angle becomes bigger than 90 degrees).

These two plots are made for the flat atmosphere to demonstrate the effect of scattering. From the second plot it can be seen that the angle between muon and primary consits of two parts: One is gained when the muon is created and the other during the muon scattering; the latter part rises with increasing mass overburden.



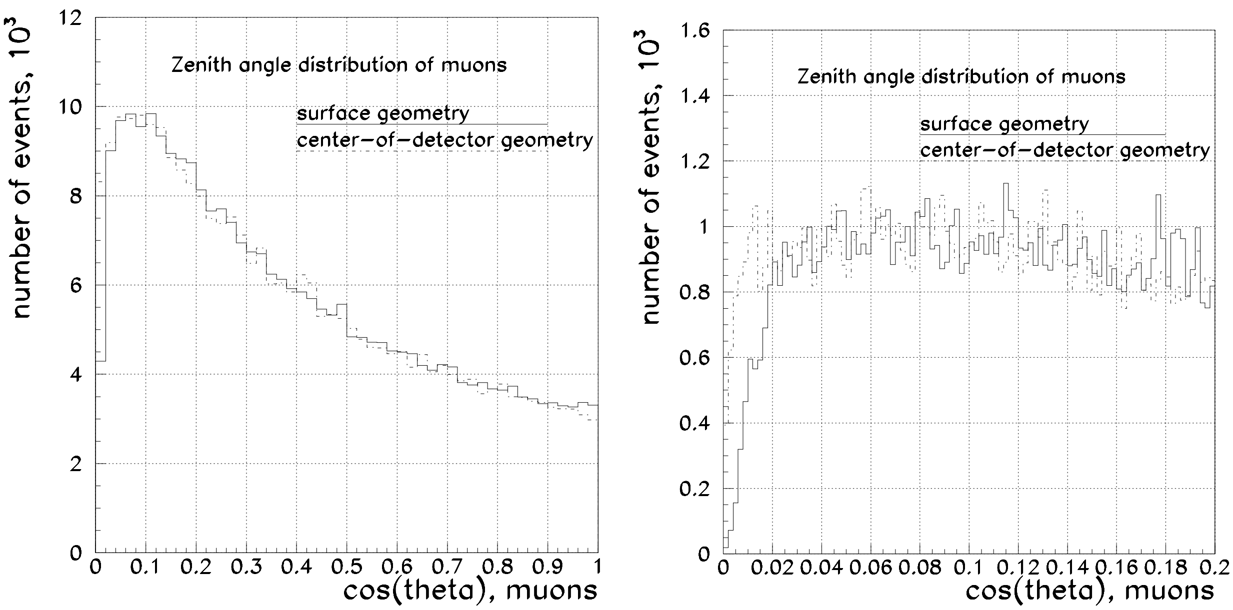


More reasons in favour of the dip:

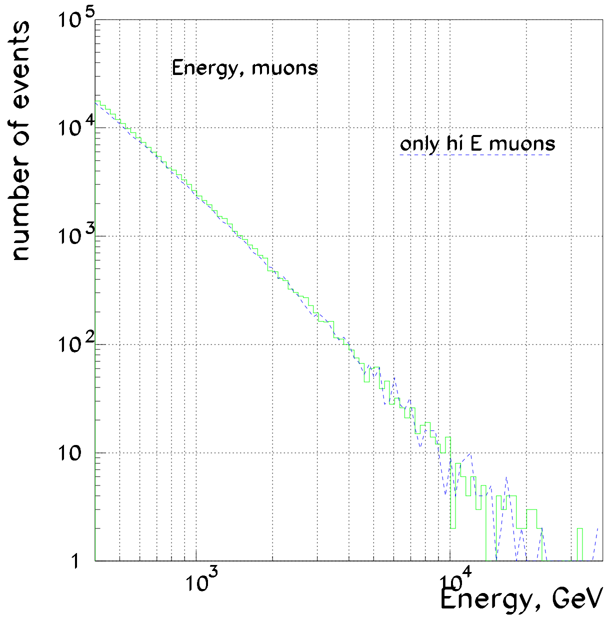
3. the muon decays: the free path is 2500 km, and the length it goes through (for a tipical muon at 90 deg) is 570 km, i.e. the probability of survival is 80%.

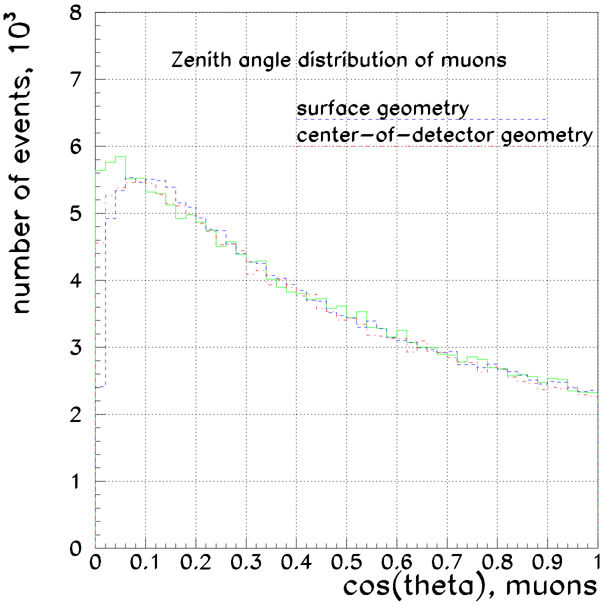
4. the muon looses its energy (from 550 GeV to 400 at 90 deg.) and is cutted away because of that. Only about 30% of muons survive the energy cuts at 90 deg.

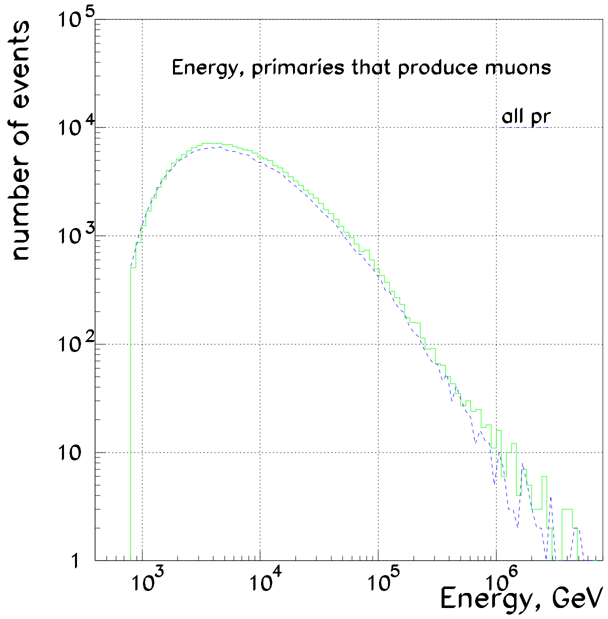
5. different systems of reference (SOR): one is on the ice surface, and the other at the center of the detector. To be complient we have implemented the shifted SOR that seats in the middle of the detector and measures zenith and solid angles from there. However, this was done for the comparison purposes only, since the depth at which the contribution from the atmospheric neutrino flux is greater than atompheric muons (13 km) is much less than the distance at which we see the discrepancy (88.9 degrees: 70 km).

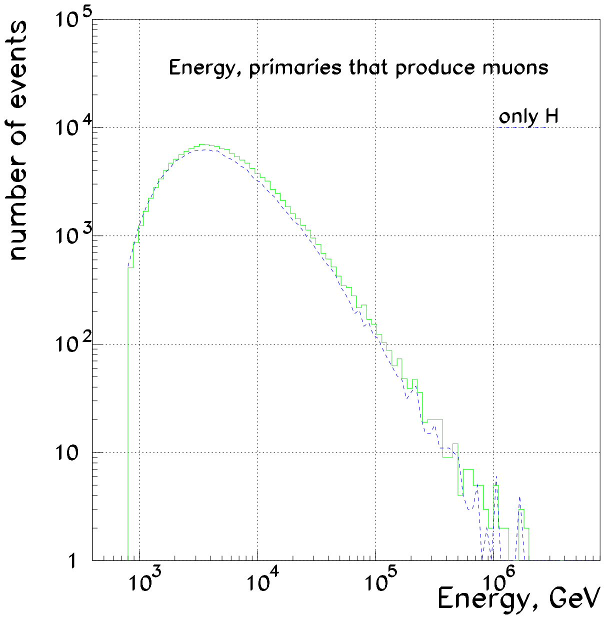


Comparison of the test results with Peter Steffen

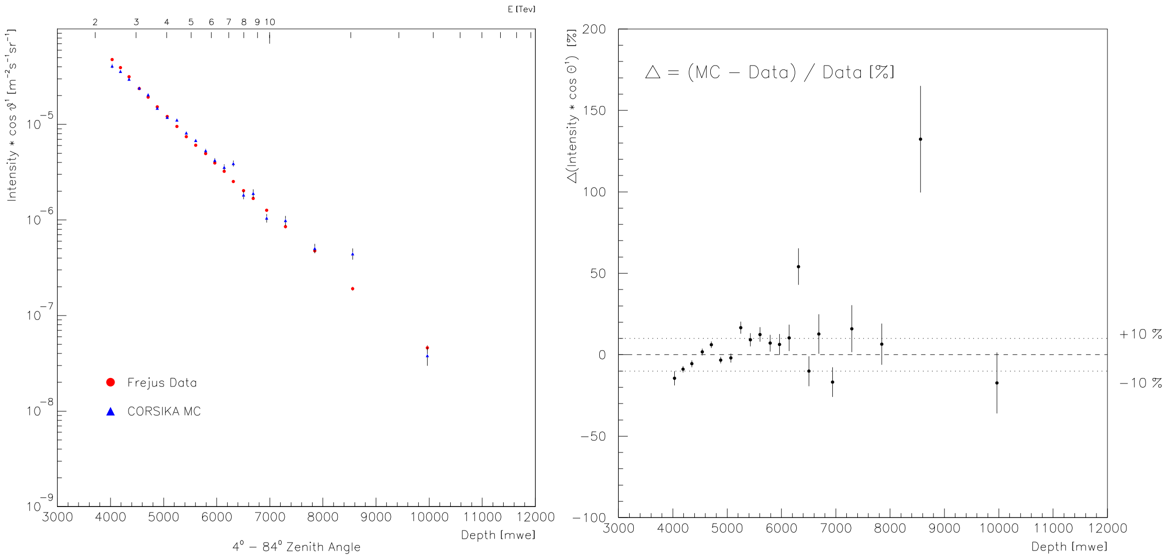




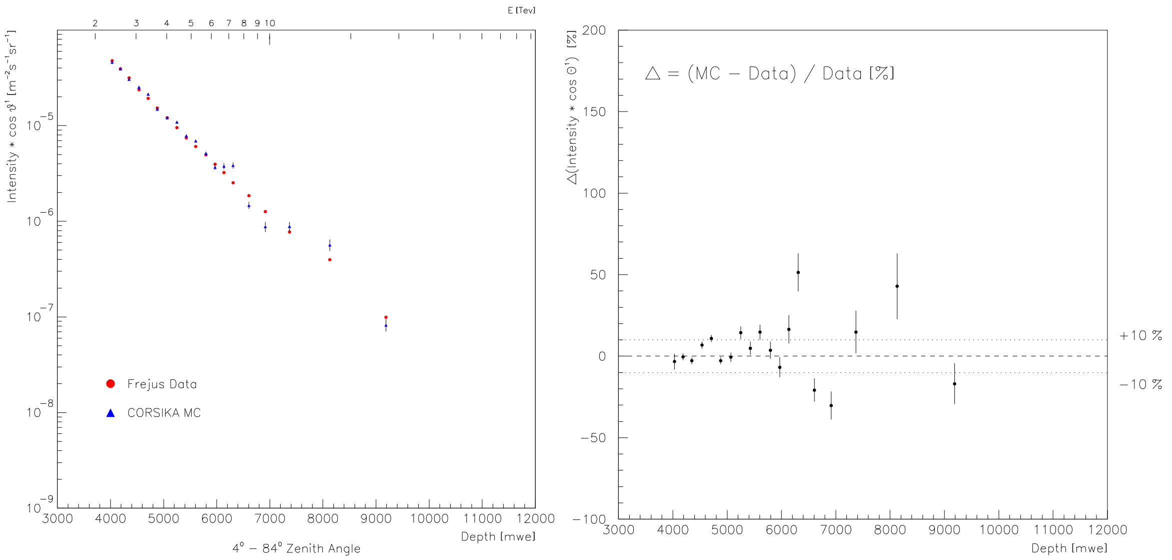




Comparison with Frejus data (Frank Schroeder



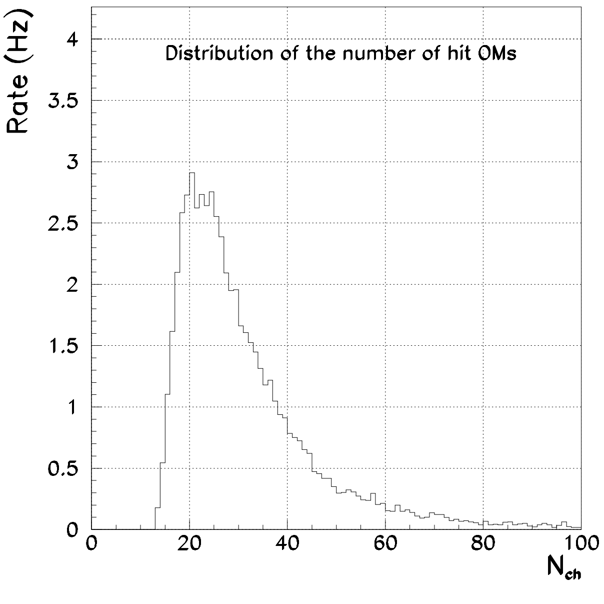
MC using MuProp

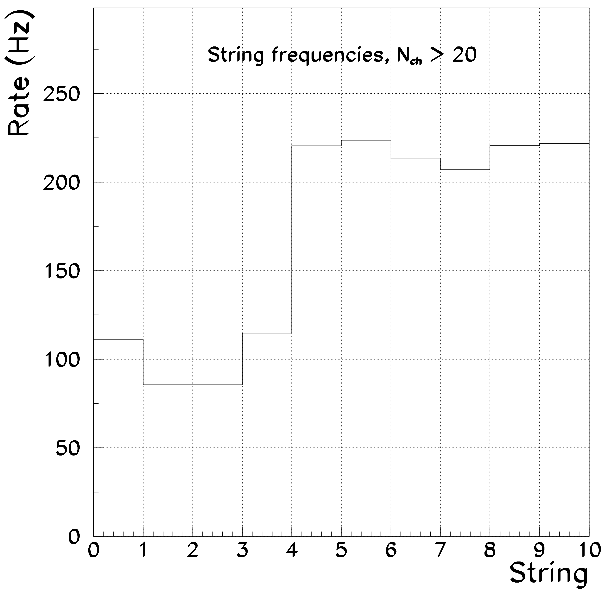


MC using energy loss approximation

Trigger rate: 60 Hz

Primaries	length	radius	l/d	Life, sec	Triggers	Trigger rate
$125 \cdot 10^6$	800	400	1.	134.8	8177	60.7 ± 0.7
$125 \cdot 10^6$	600	300	1.	239.6	14389	60.1 ± 0.5
$125 \cdot 10^6$	400	200	1.	539.1	32480	60.2 ± 0.3
$51 \cdot 10^6$	800	200	2.	132.0	7901	59.9 ± 0.7
$51 \cdot 10^6$	600	150	2.	234.6	14205	60.5 ± 0.5
$51 \cdot 10^6$	400	100	2.	527.9	30947	58.6 ± 0.3
$51 \cdot 10^6$	240	60	2.	1466	59145	40.34 ± 0.17
$10 \cdot 10^6$	800	200	2.	25.88	1599	61.8 ± 1.5
10^7 x10	800	200	2.	258.8	15374	59.4 ± 0.5

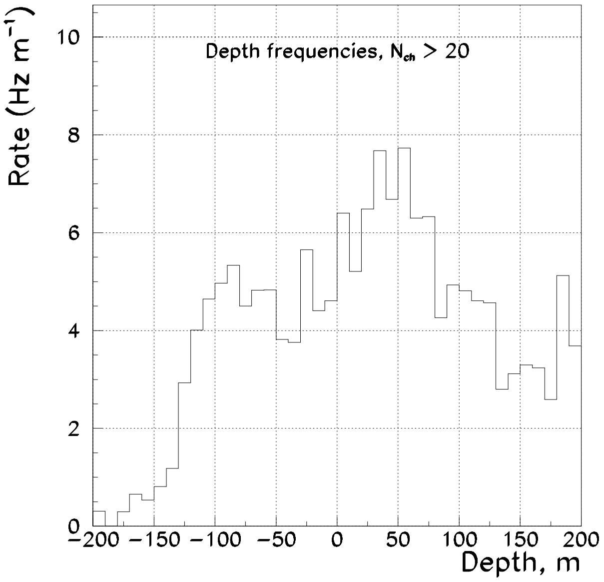


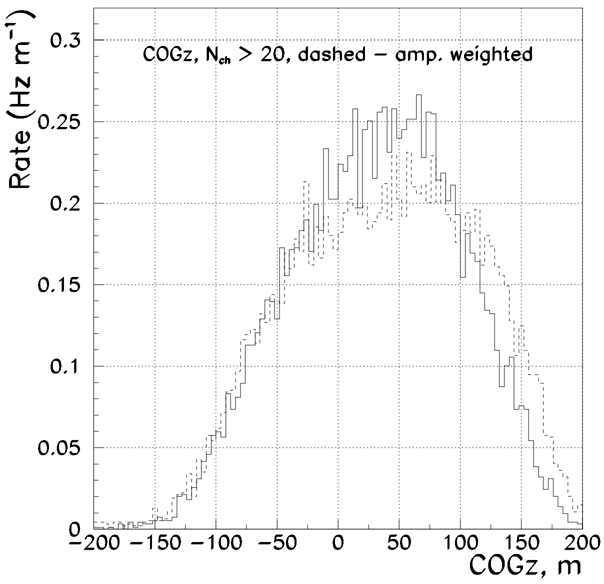


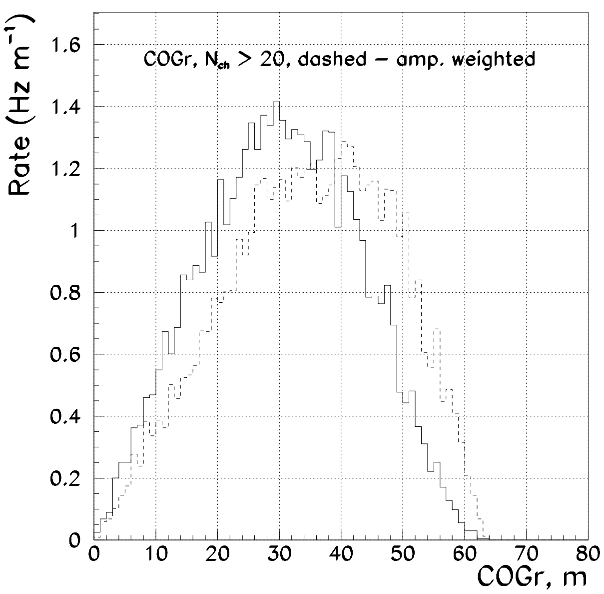
Energy cutoffs: for primaries: 860 GeV, for secondaries: 430 GeV.

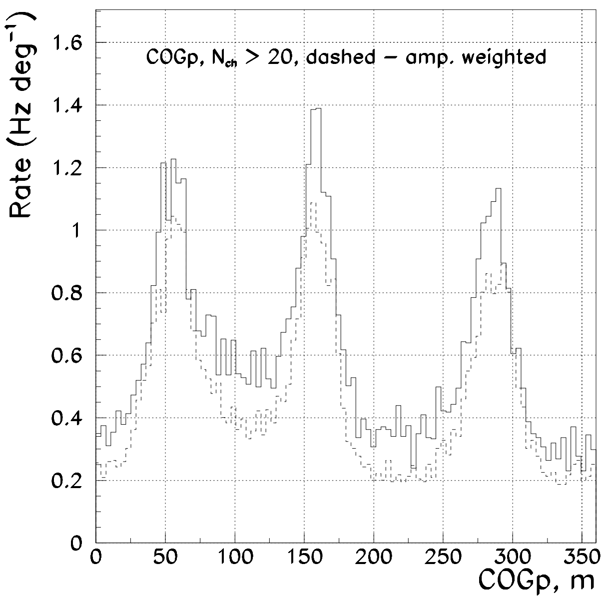
Angle range: Zenith angle 0 ... 89.999, azimuth angle: 0 ... 360.

Primaries H ... Fe with zenith-angle-dependent energy cutoff.









To Conclude:

1. In one day CORSIKA chain set up is such a way generates on a cluster of 27 P2 (300-500MHz) processors about 70 mil. primaries that correspond to a lifetime of 224 sec. and result in 13400 triggers. Results of the calculation are collected on one computer (zombie) and it takes it 2-3 hours (P3-700) to put the daily doze of them through the mass00 chain. The whole process is fully automatic and the scripts are able to recover from hangs or reboots without external intervention. It will take 124 months to complete the 100 mil. triggers, or 12 months if 10x oversampling is enabled. Clearly, help is needed.

2. (a) CORSIKA 5.9x generated flux agrees within 10% with the Frejus measurement up to the depths of 6000 m. For the bigger depths, however, some points indicate a significantly larger difference.

   (b) Muprop calculated muon energy loss is too small. It results in a too hard undeground muon spectrum (with the index of 2.4). This calls for a better muon energy loss MC.