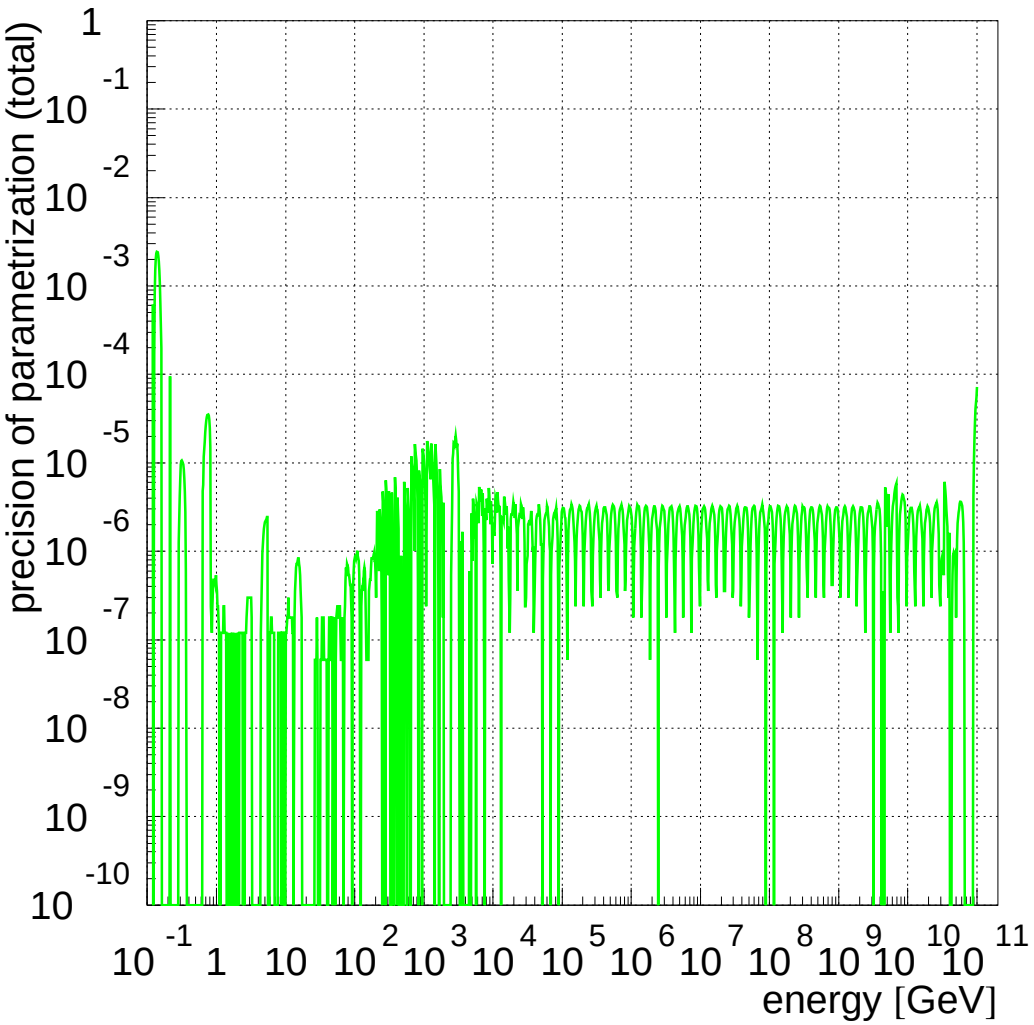
Muon Monte Carlo: version 1.0

Dmitry Chirkin[1,2]**, Wolfgang Rhode**[2]
chirkin@physics.berkeley.edu
rhode@wpos7.physik.uni-wuppertal.de

[1]*University of California at Berkeley, USA*
[2]*Bergische Universität Gesamthochschule Wuppertal, Germany*

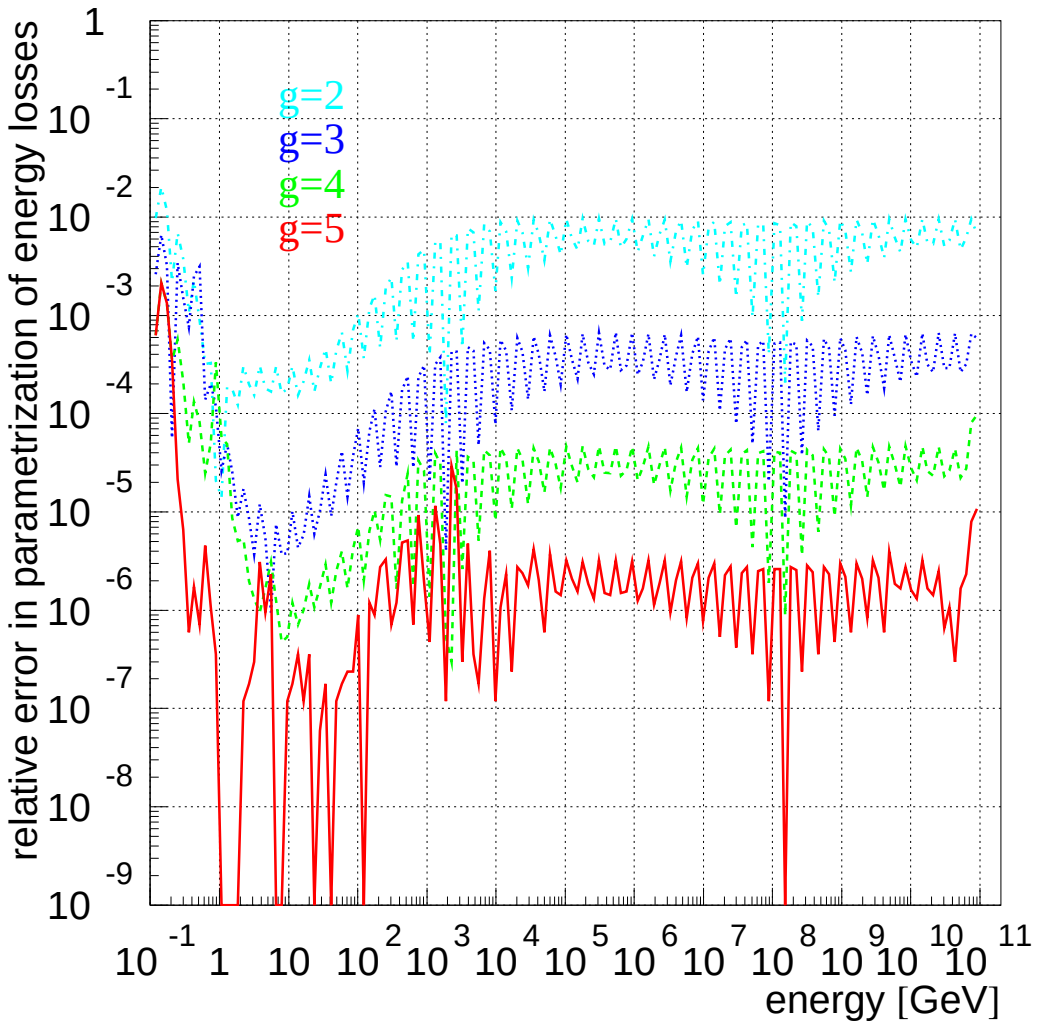
mmc code homepage is
http://area51.berkeley.edu/~dima/work/MUONPR/muonPropagation.html
mmc code available at
http://area51.berkeley.edu/~dima/work/MUONPR/BKP/mmc.tgz

Parametrization errors:

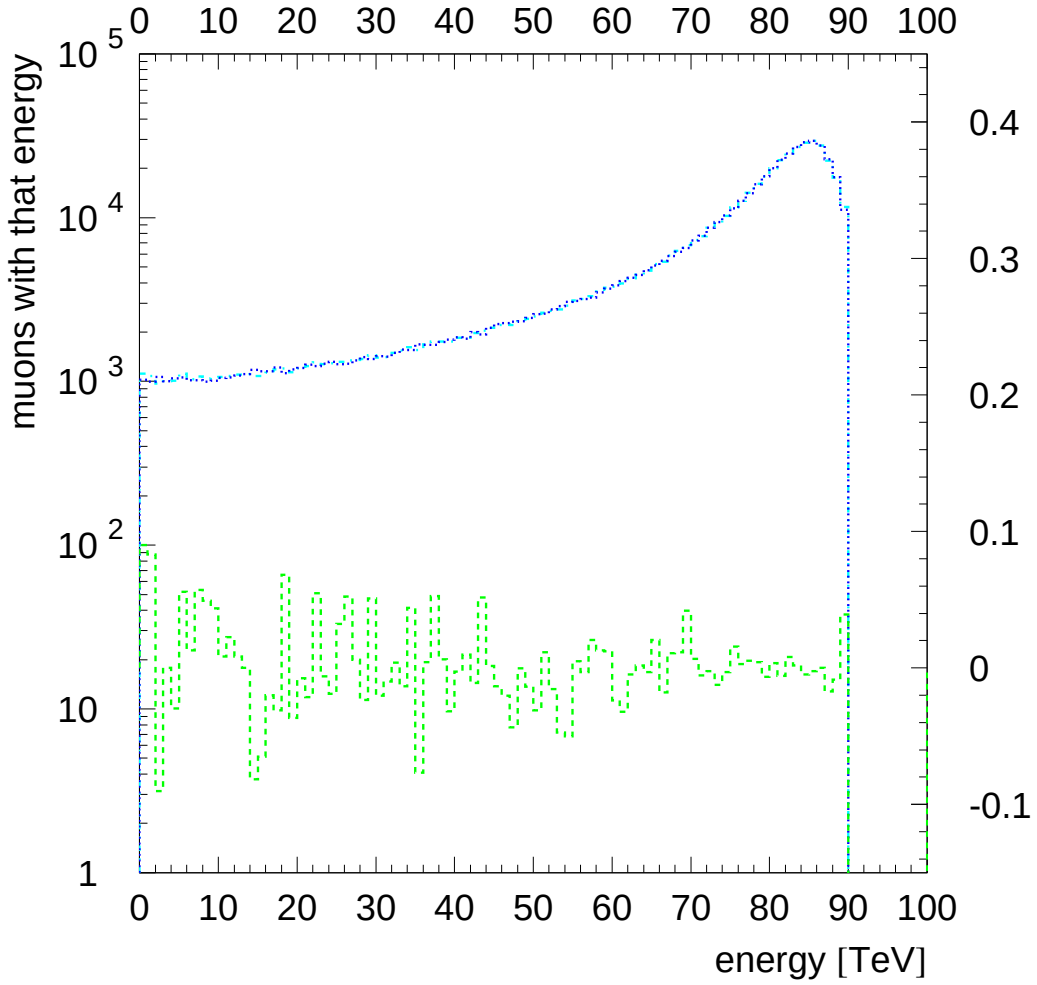


Interpolation precision $(e_{pa} - e_{np})/e_{pa}$

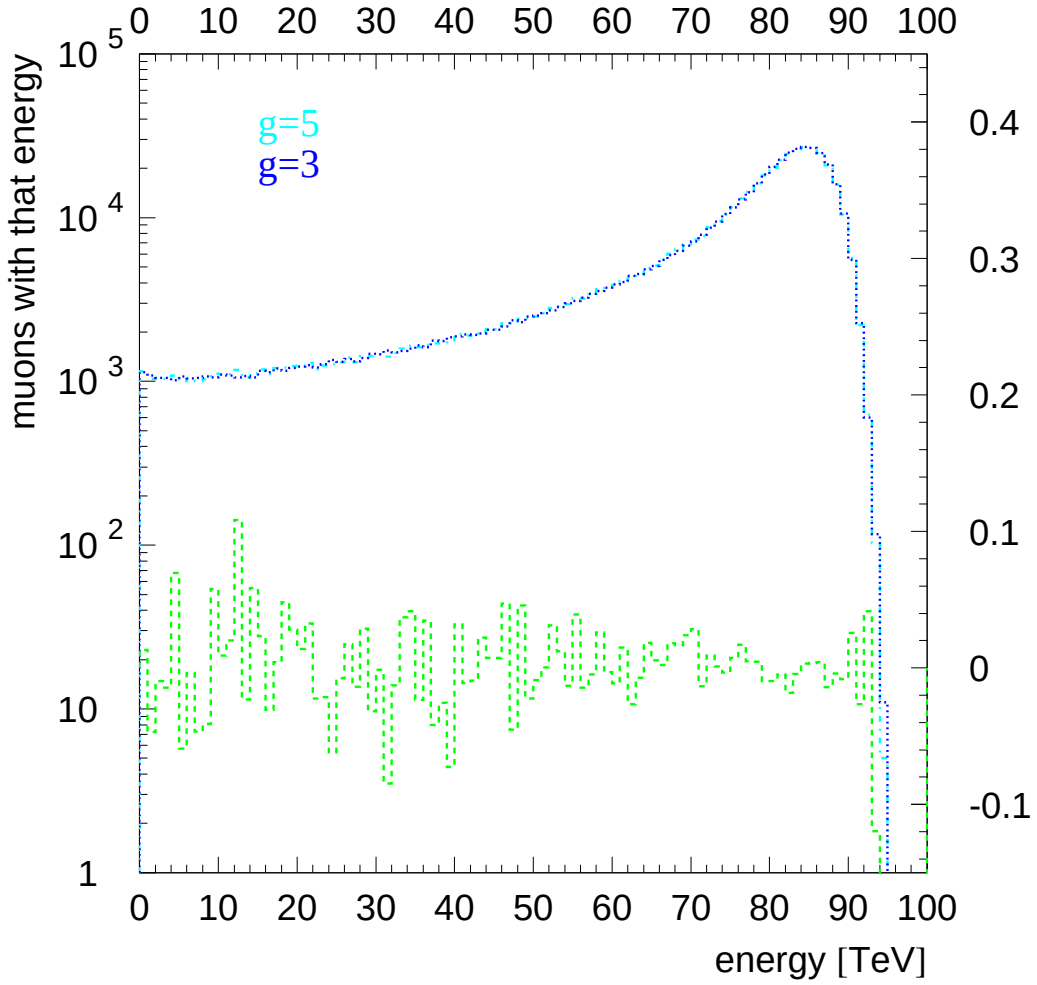
Parametrization errors:



Interpolation precision $(e_{pa} - e_{np})/e_{pa}$

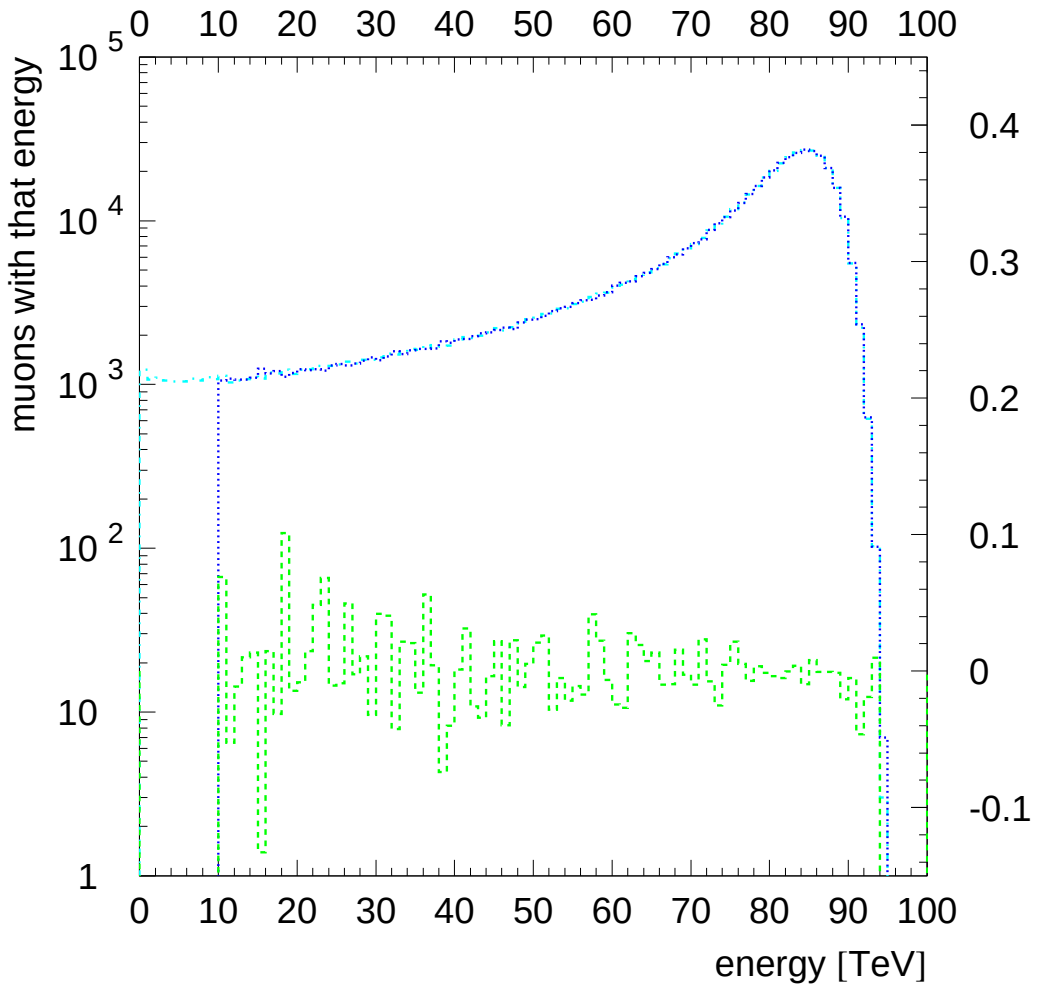


Comparison of paramerized (dashed-dotted) with exact (non-parametrized, dotted) versions for $v_{cut} = 0.01$

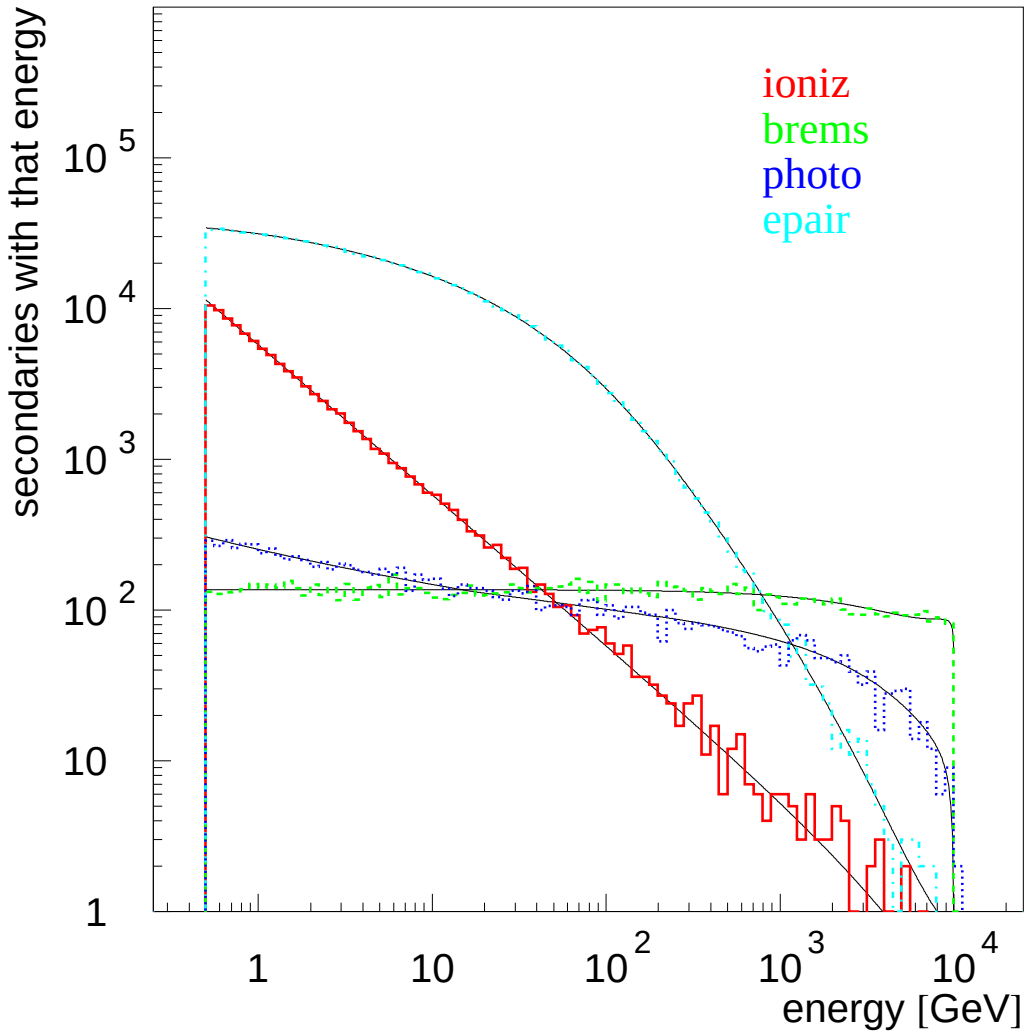


Comparison of paramerized versions run with different g

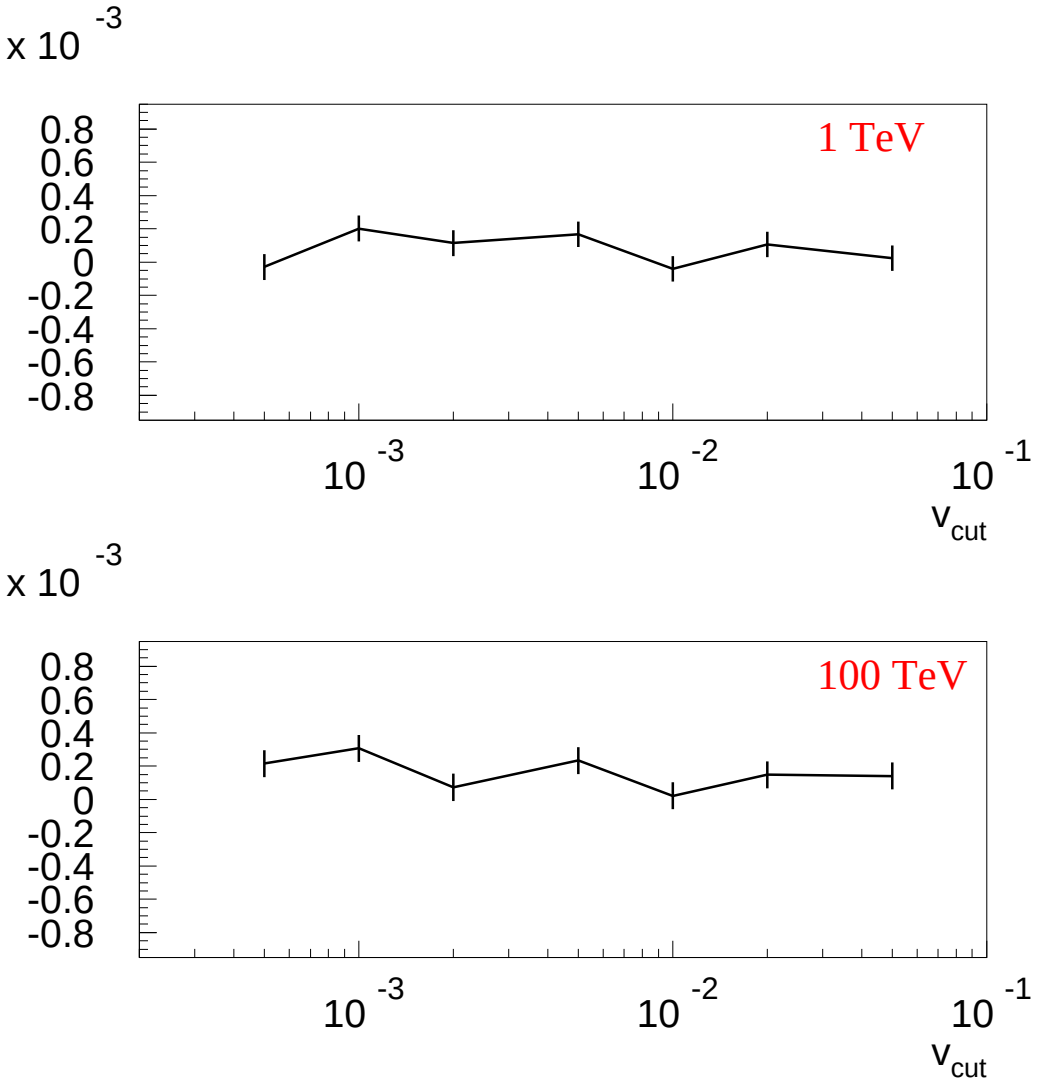
Final energy distribution of the muons that crossed 300 m of Fréjus Rock with initial energy 100 TeV:



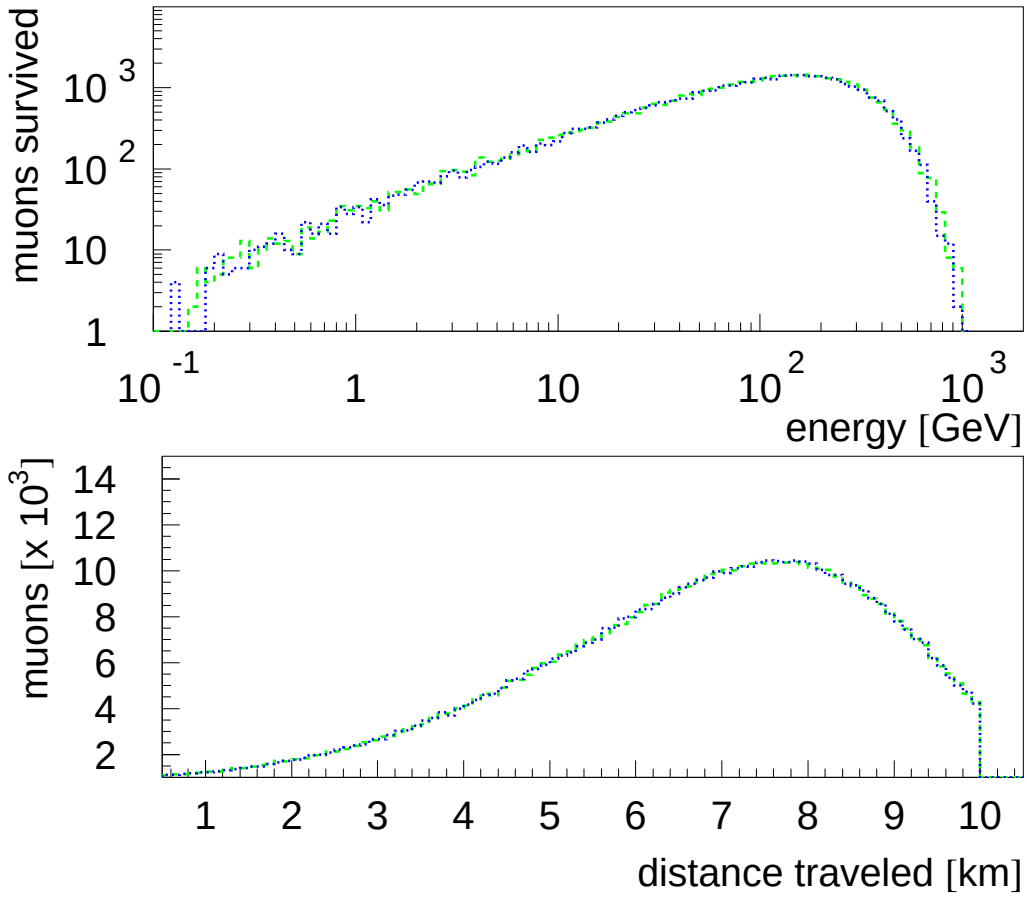
Comparison of $e_{low} = m_\mu$ (dotted-dashed) with e_{low}=10 TeV (dotted). Also shown is the relative difference of the curves.



ioniz (upper solid curve), brems (dashed), photo (dotted), epair (dashed-dotted) spectra for E_μ=10 TeV in the Fréjus rock



Average final energy deviation from the purely "continuous" prediction

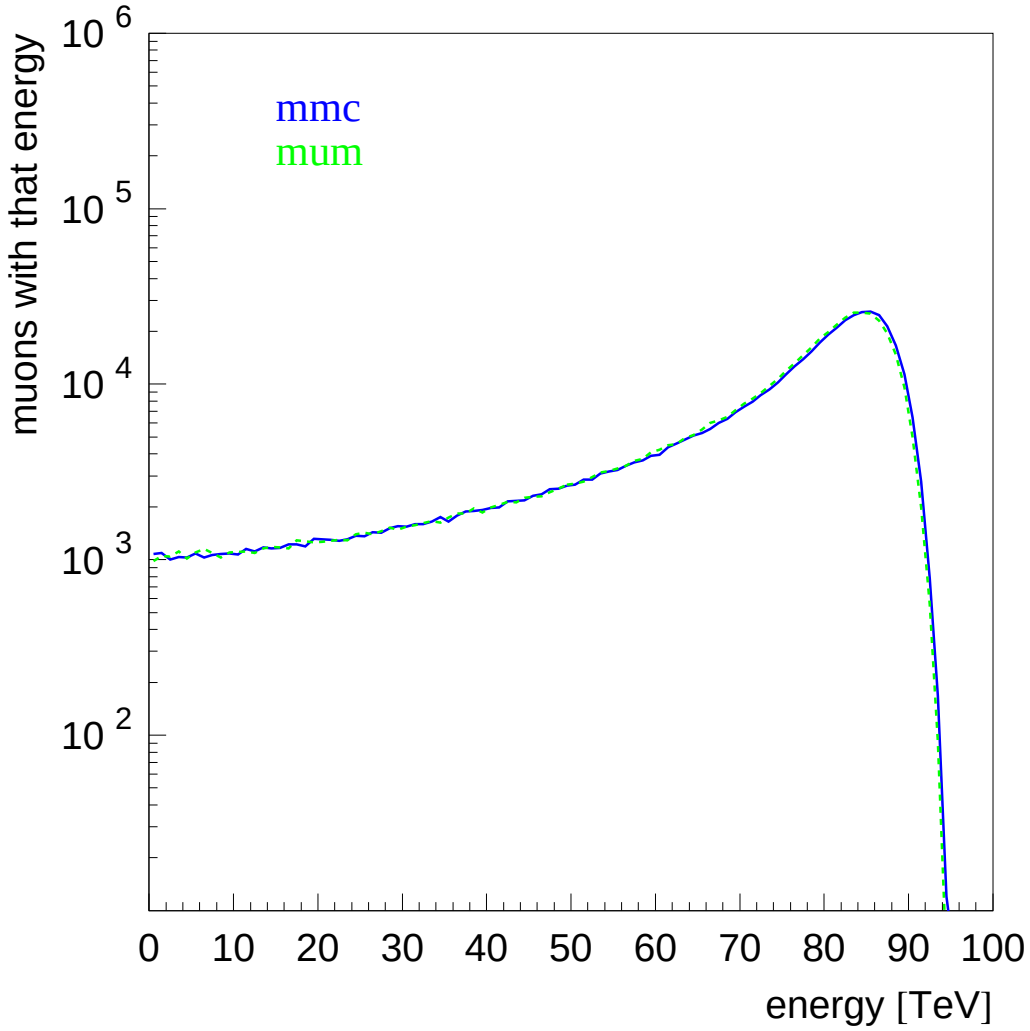


10^6 muons with energy 9 TeV propagated through 10 km of water: regular (dashed) vs. "cont" (dotted)

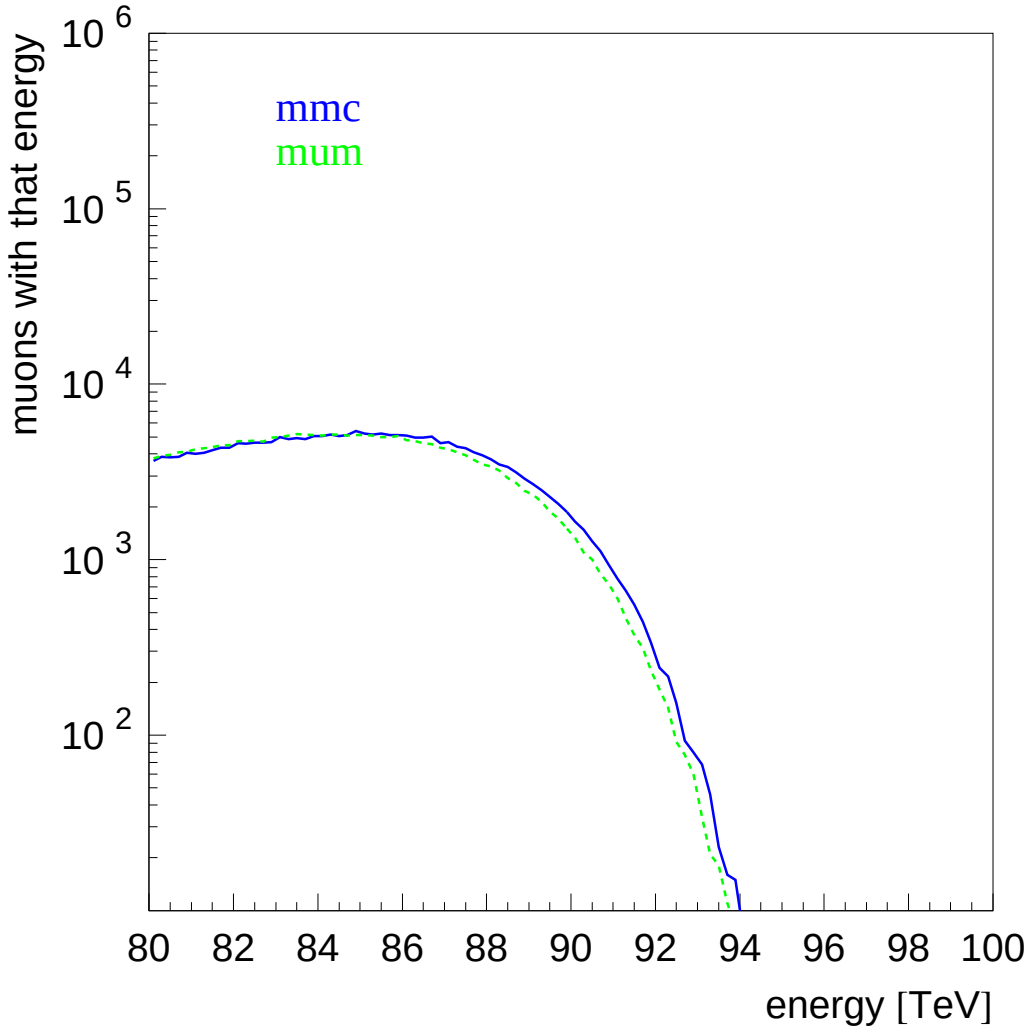
Survival probabilities

v_{cut}	"cont"	1 TeV 3 km	9 TeV 10 km	10^6 TeV 40 km
0.2	no	0	0	0.153
0.2	yes	0.010	0.057	0.177
0.05	no	0	0.035	0.143
0.05	yes	0.045	0.039	0.139
0.01	no	0.030	0.037	0.142
0.01	yes	0.034	0.037	0.139
10^{-3}	no	0.034	0.037	0.140
10^{-3}	yes	0.034	0.037	0.135

v_{cut}	"cont"	1 TeV 3 km	9 TeV 10 km	10^6 TeV 40 km
10^{-3}	MMC (default)	0.034	0.037	0.140
10^{-3}	MMC (ZEUS)	0.034	0.037	0.090
10^{-3}	MUM	0.029	0.030	0.078
10^{-3}	MUSIC	0.033	0.031	0.084
10^{-3}	PROPMU	0.19	0.048	0.044

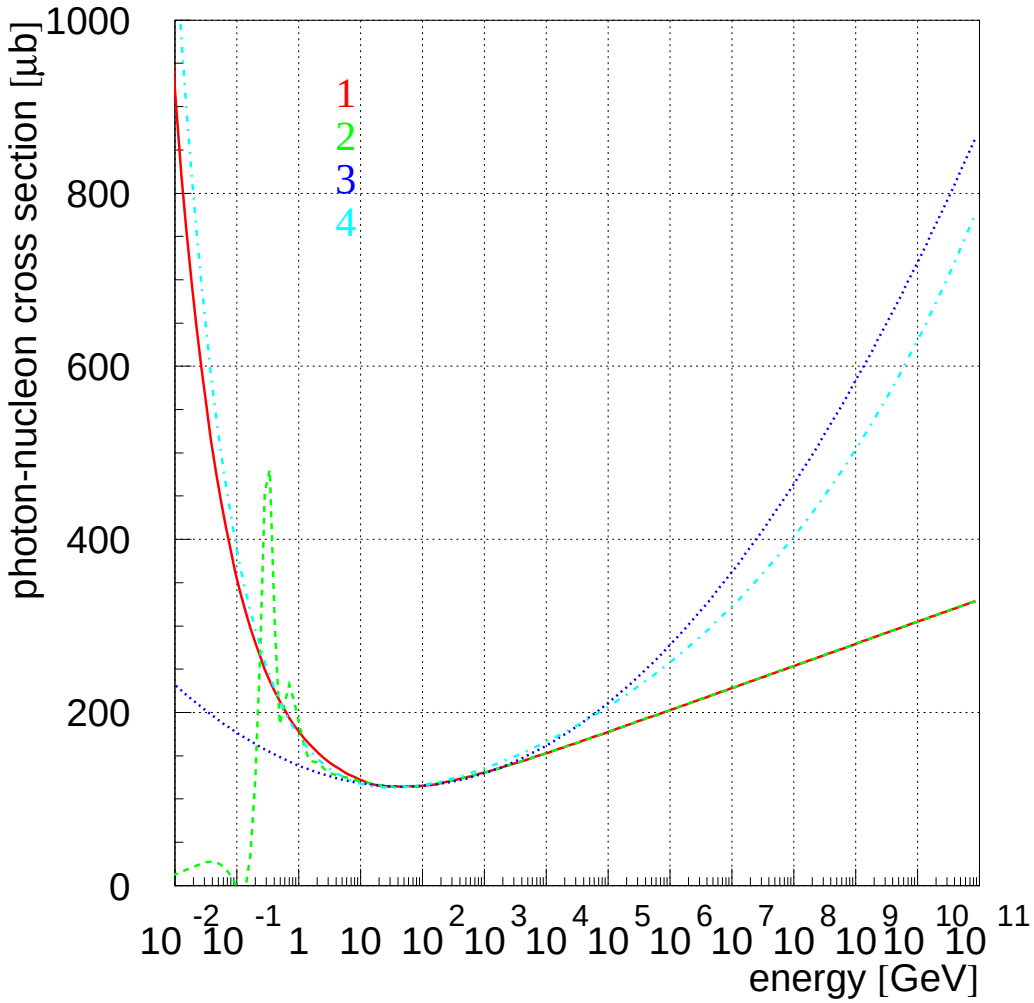


Comparison of MMC with MUM

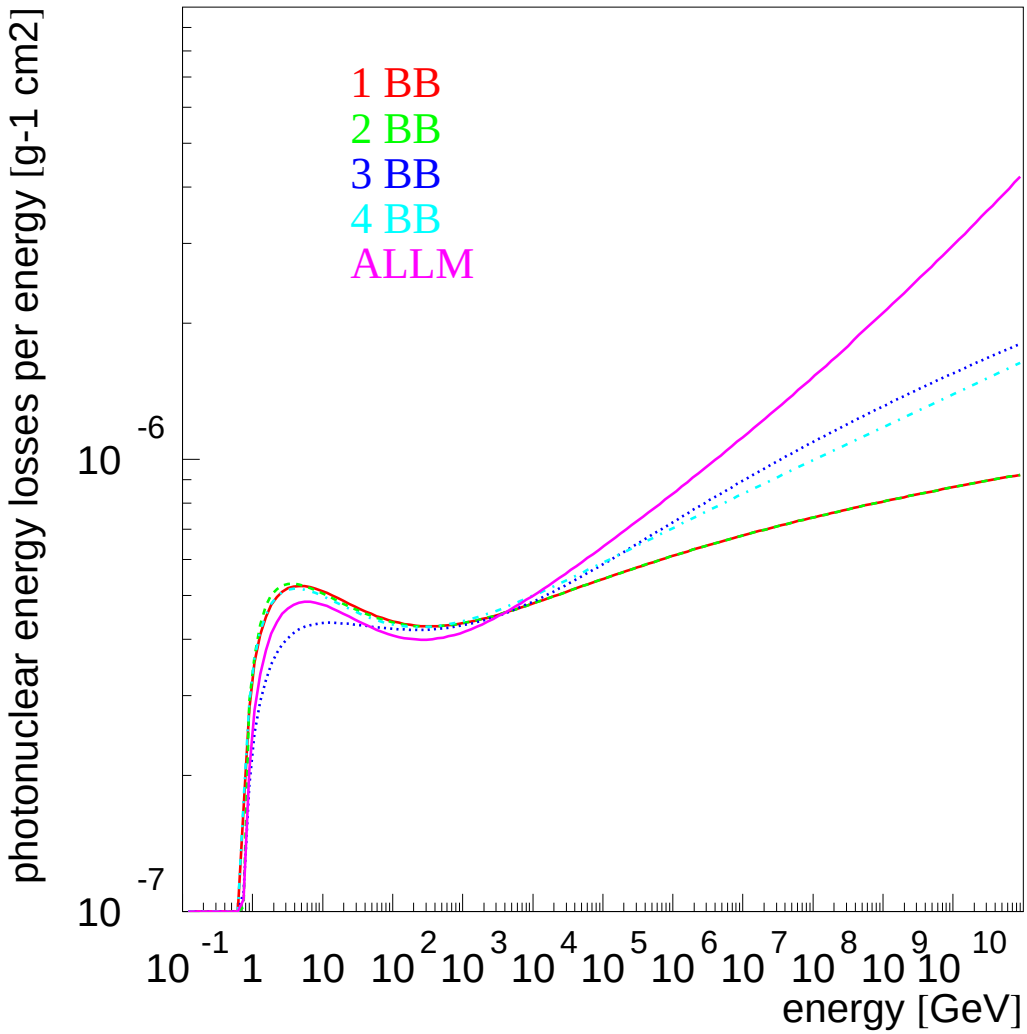


Comparison of MMC with MUM

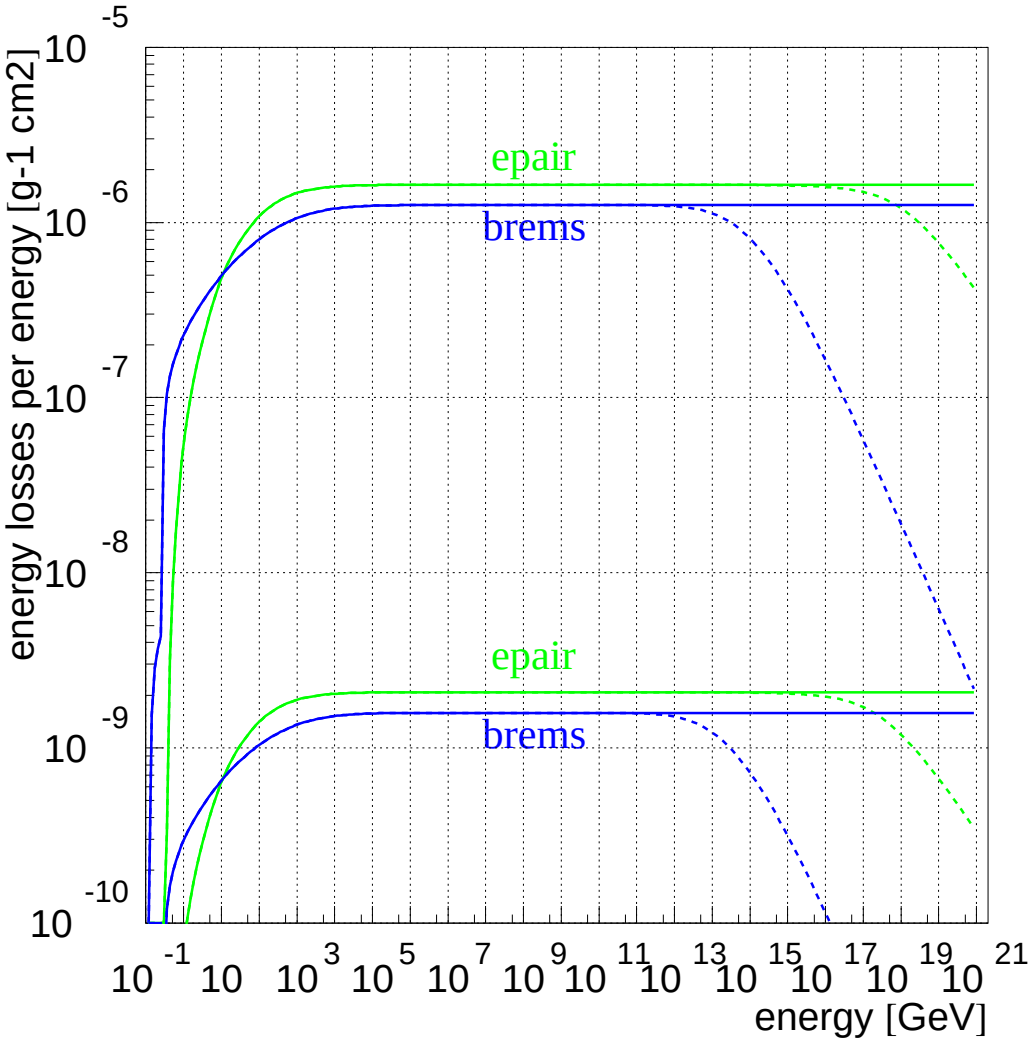
Photonuclear losses, LPM effect and Molière scattering



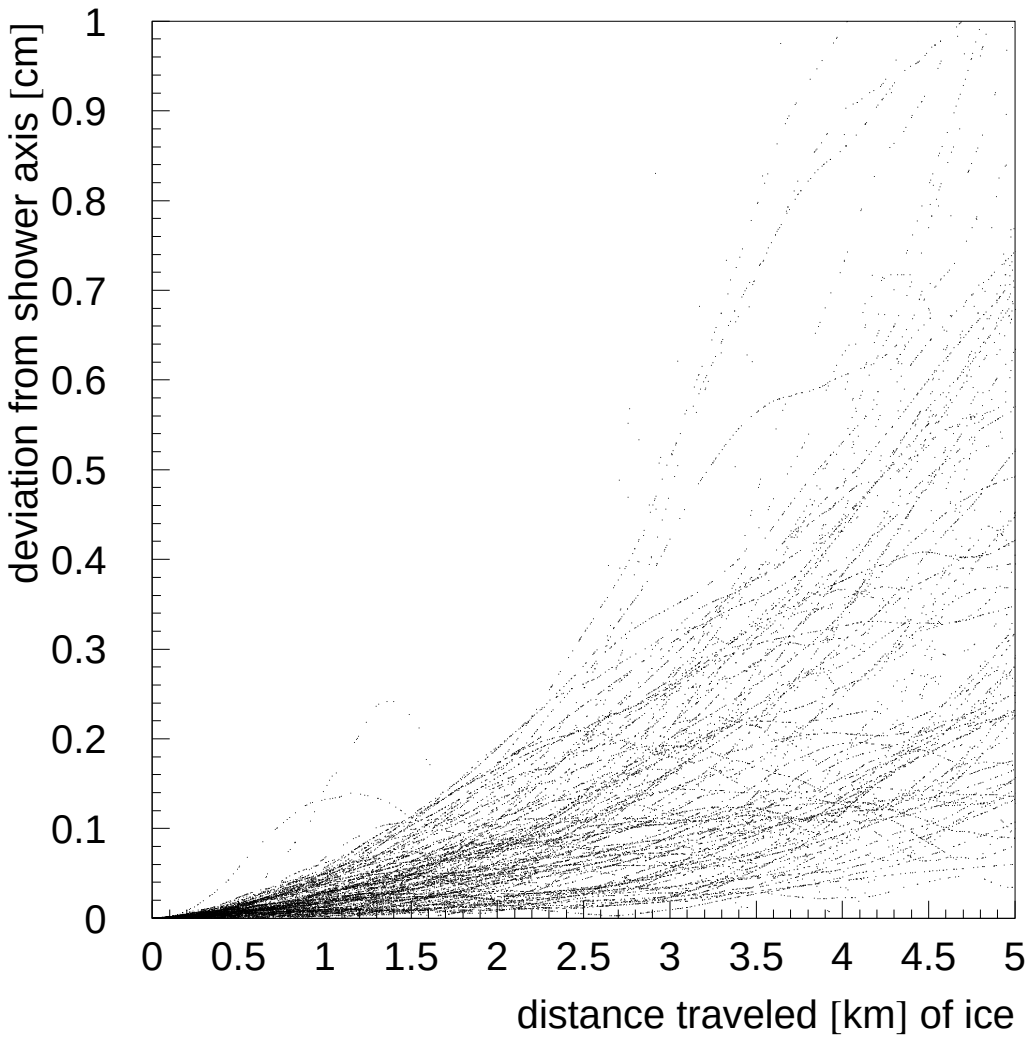
different photon-nucleon cross sections implemented in MMC, Bezrukov Bugaev parametrization



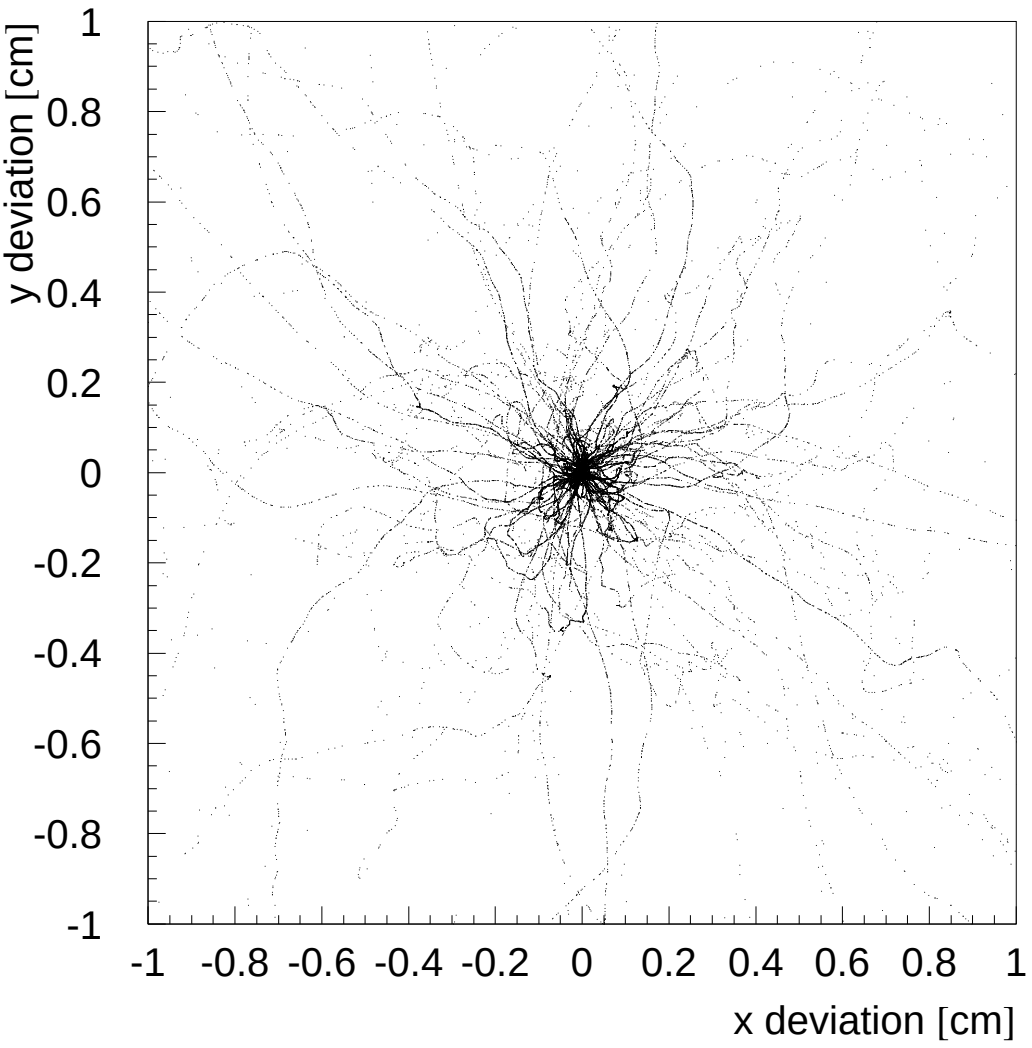
photonuclear energy losses (divided by energy), according to different formulae.



LPM effect in ice (higher plots) and Fréjus rock (lower plots, multiplied by 10^{-3})



Molière scattering of 100 10 TeV muons going straight down through ice



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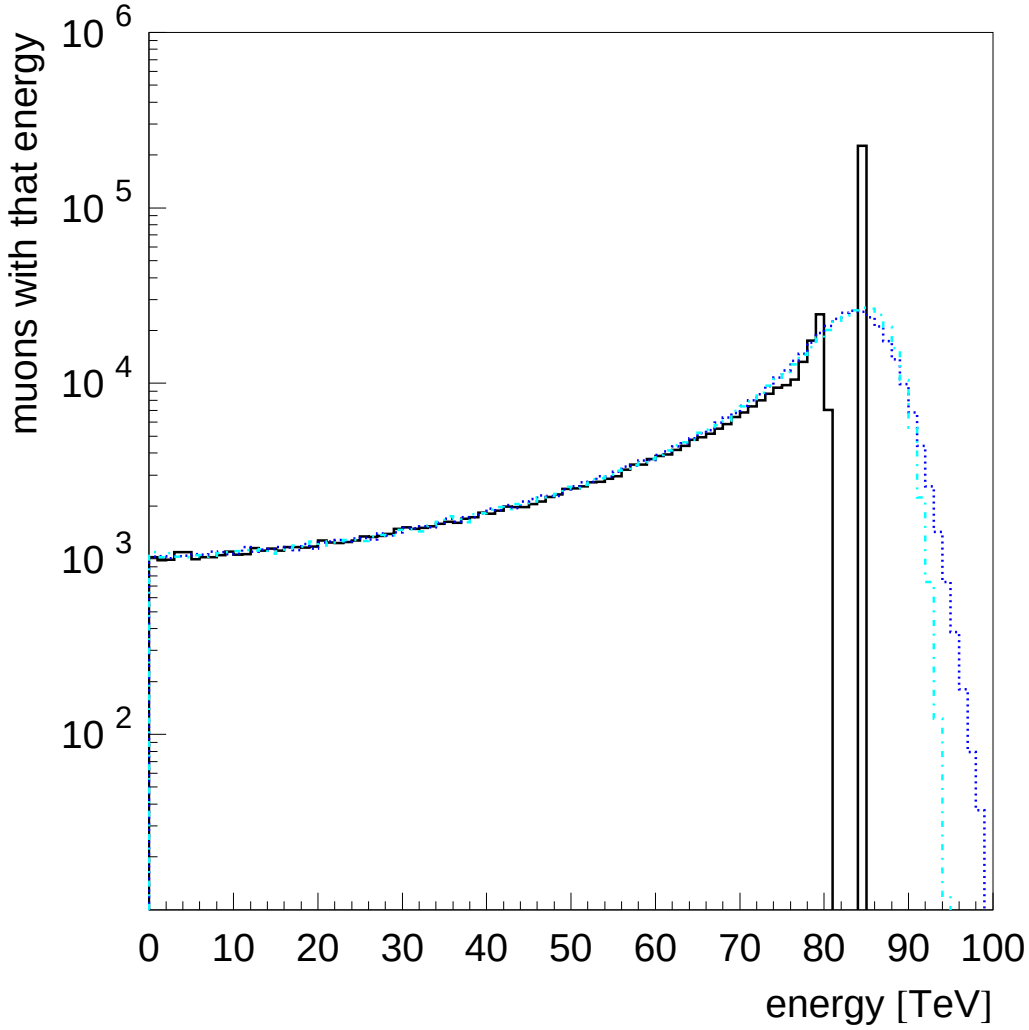
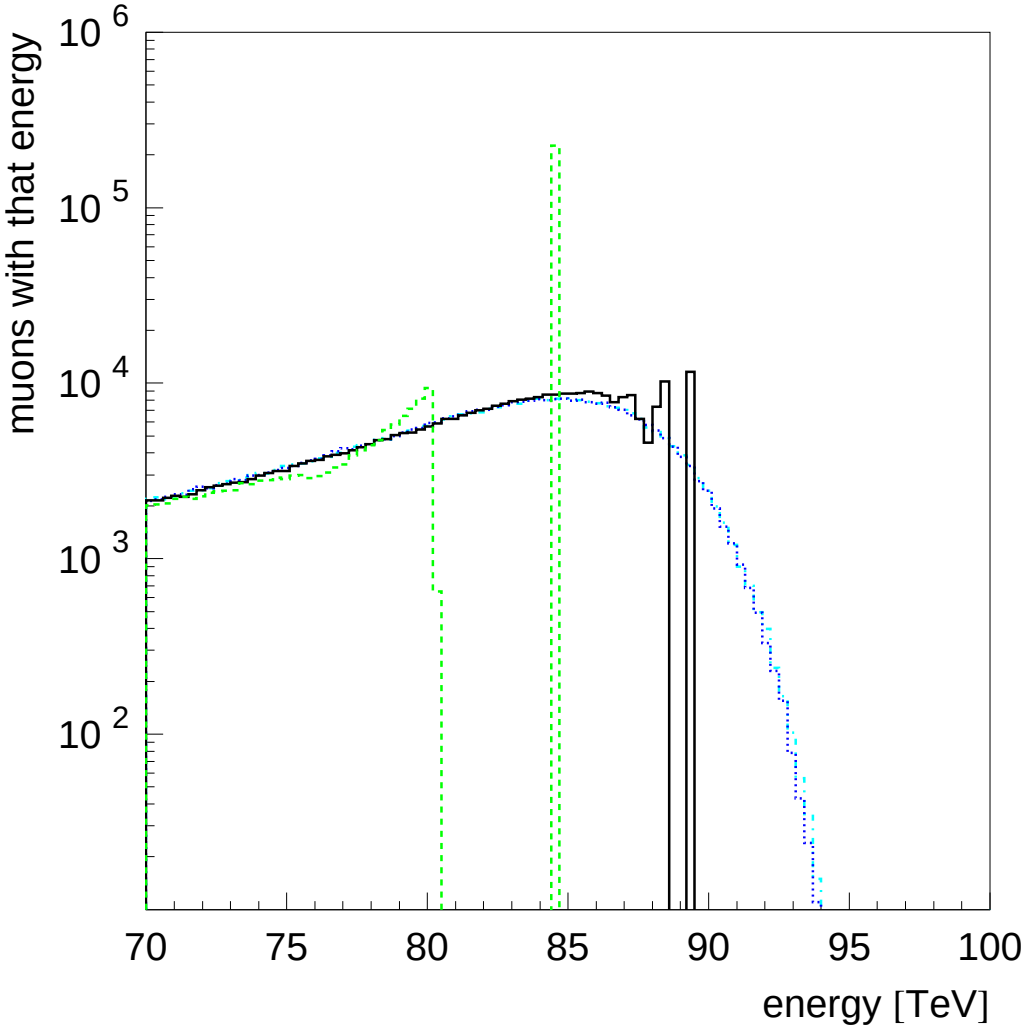
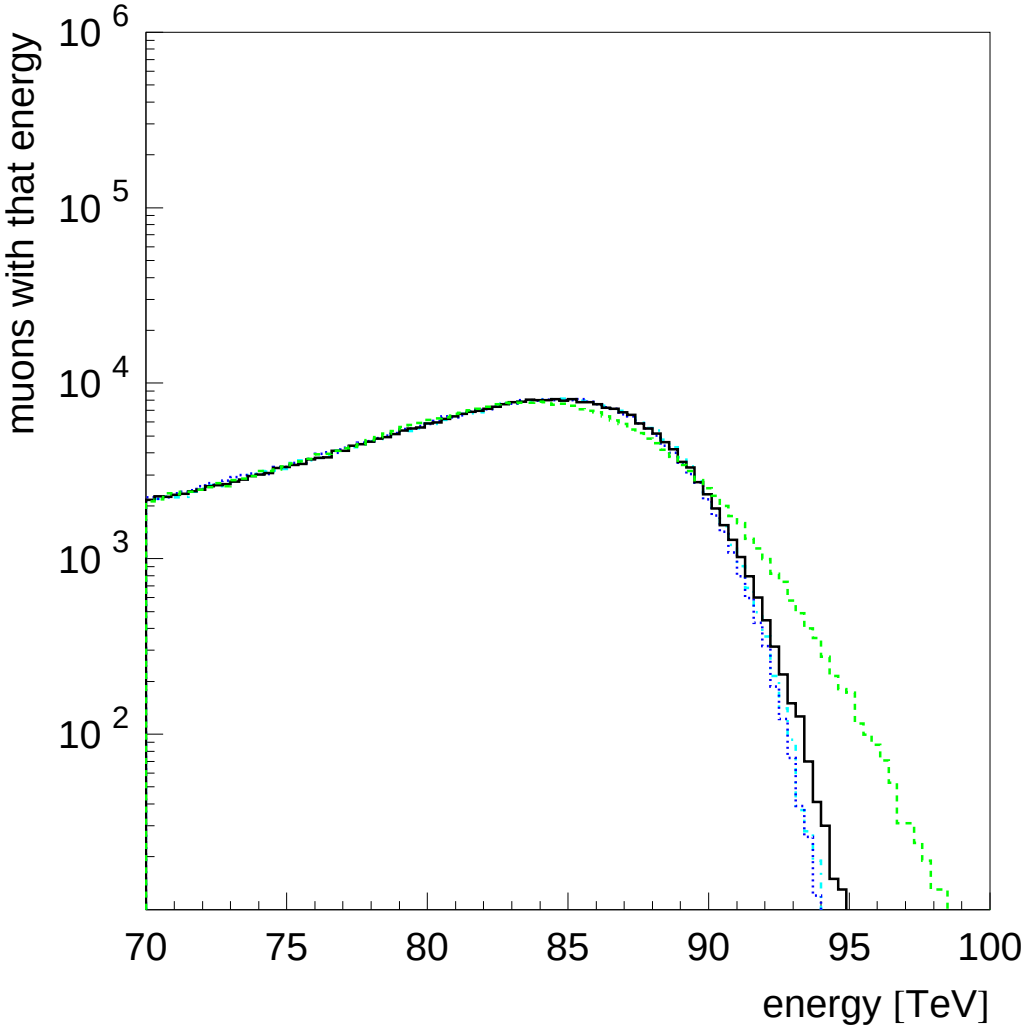
Final energy distribution of the muons that crossed 300 m of Fréjus Rock with initial energy 100 TeV:



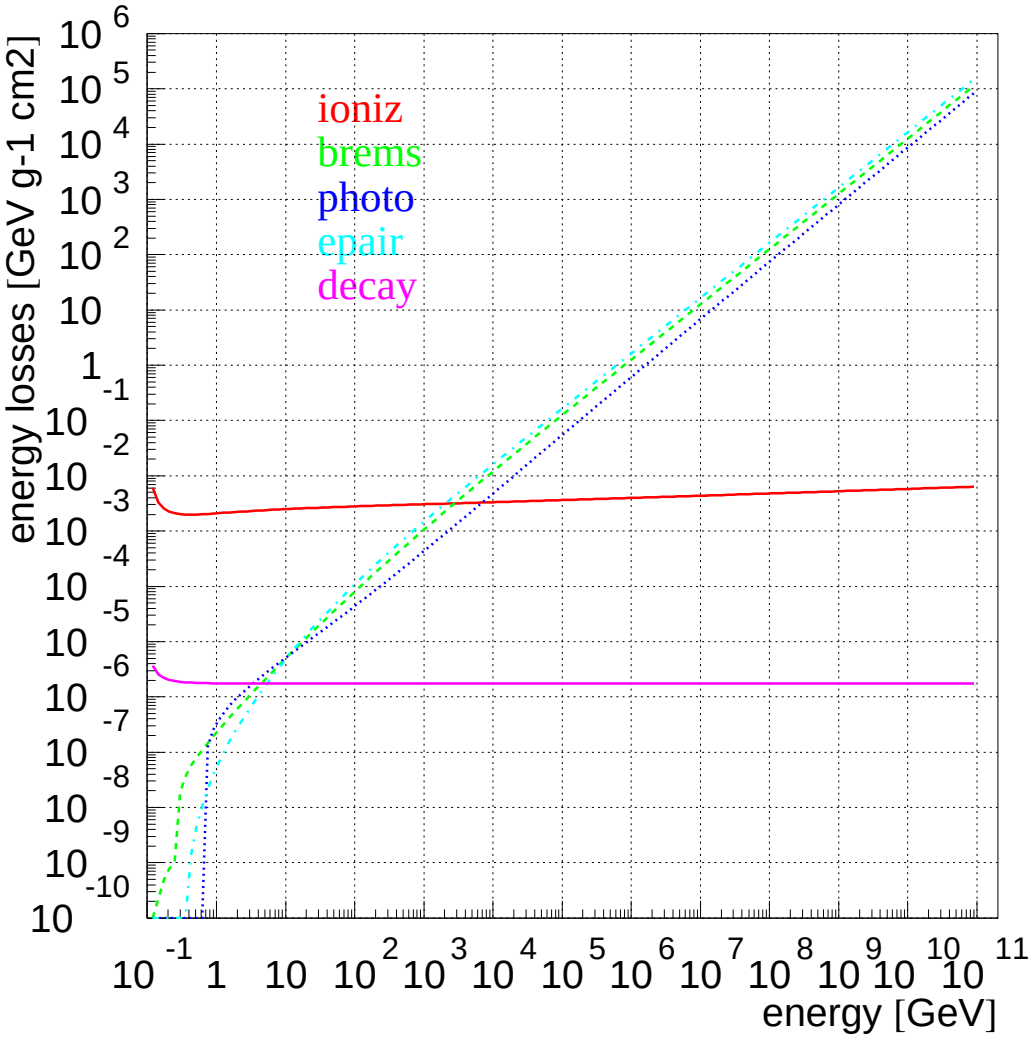
$v_{cut} = 0.05$ (solid), $v_{cut} = 10^{-4}$ (dashed-dotted),
$v_{cut} = 0.05$ and "cont" option (dotted)



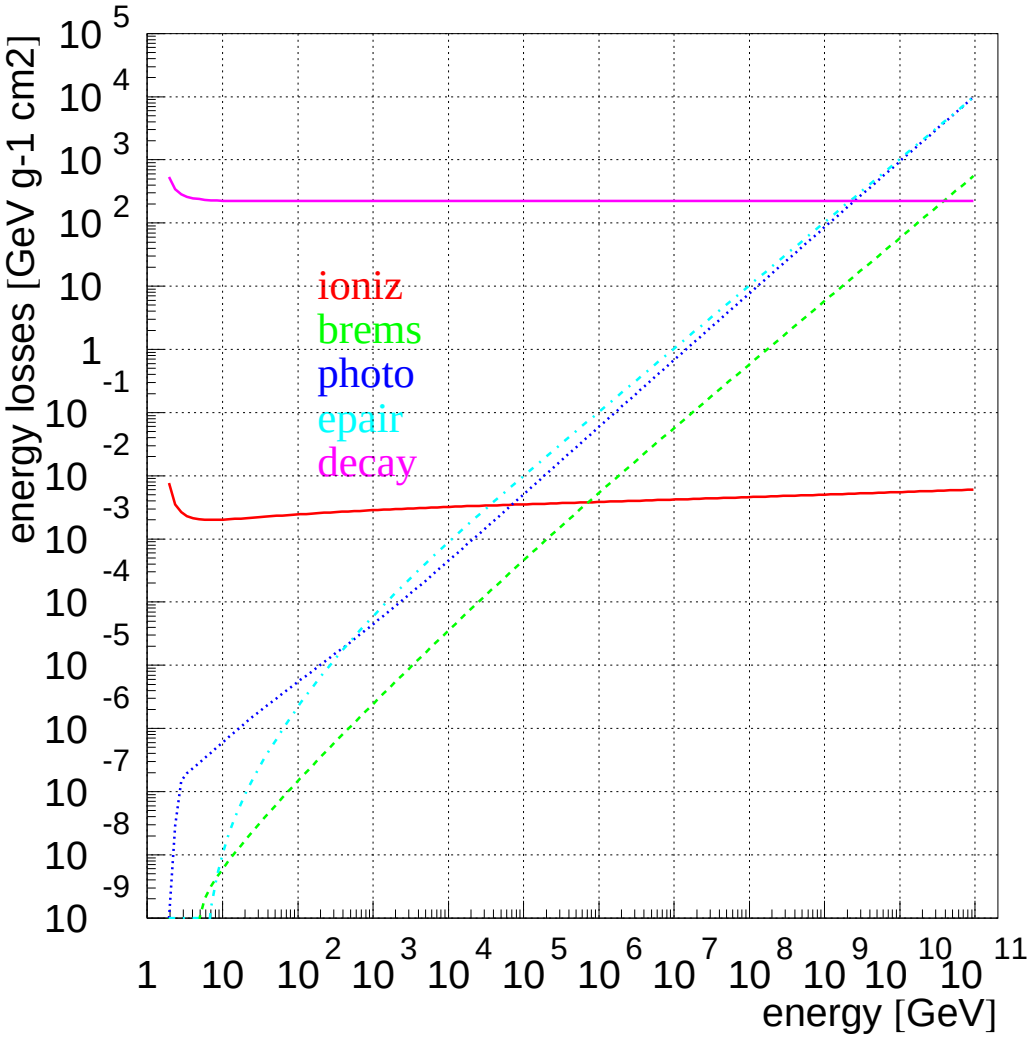
no "cont": $v_{cut} = 0.05$ (dashed), $v_{cut} = 0.01$ (solid), $v_{cut} = 10^{-3}$ (dotted), $v_{cut} = 10^{-4}$ (dashed-dotted)



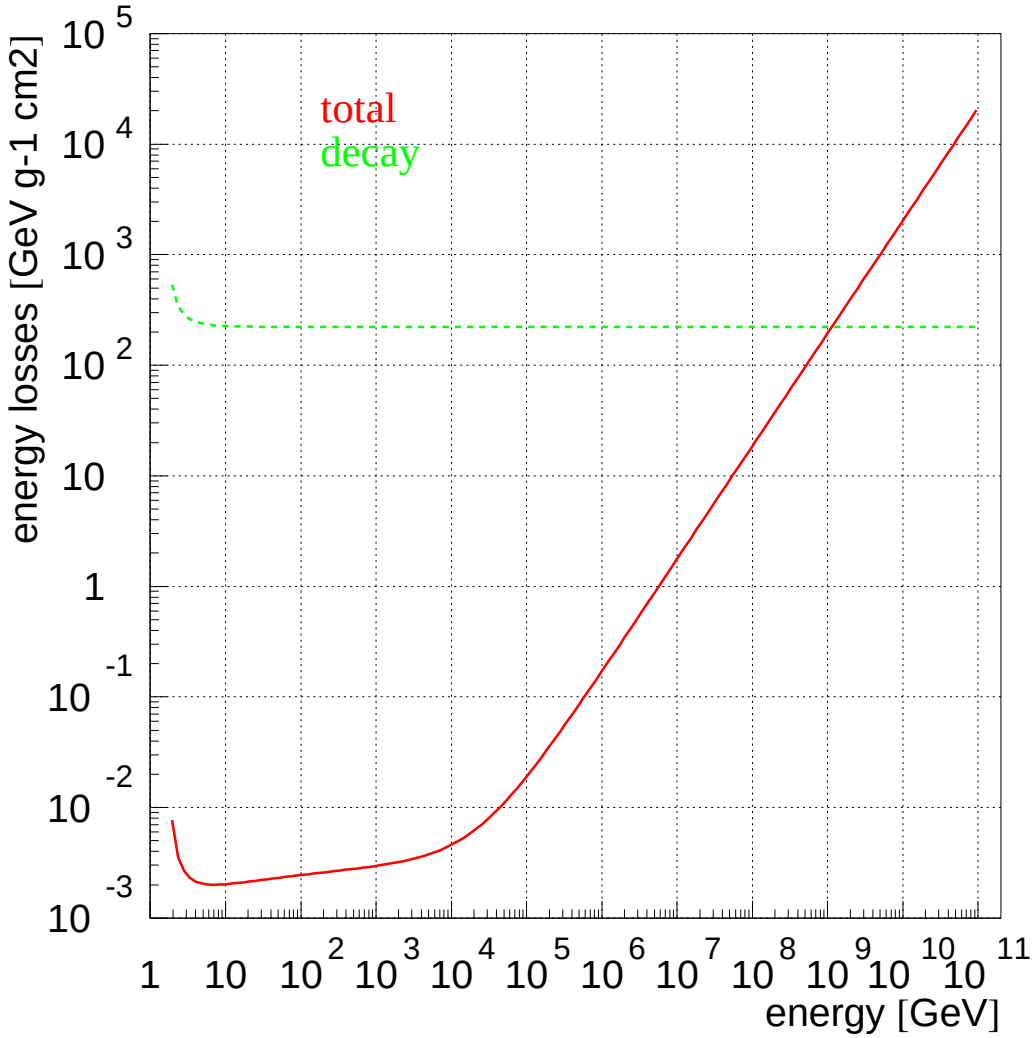
with "cont" option: $v_{cut} = 0.05$ (dashed), $v_{cut} = 0.01$ (solid), $v_{cut} = 10^{-3}$ (dotted), $v_{cut} = 10^{-4}$ (dashed-dotted)



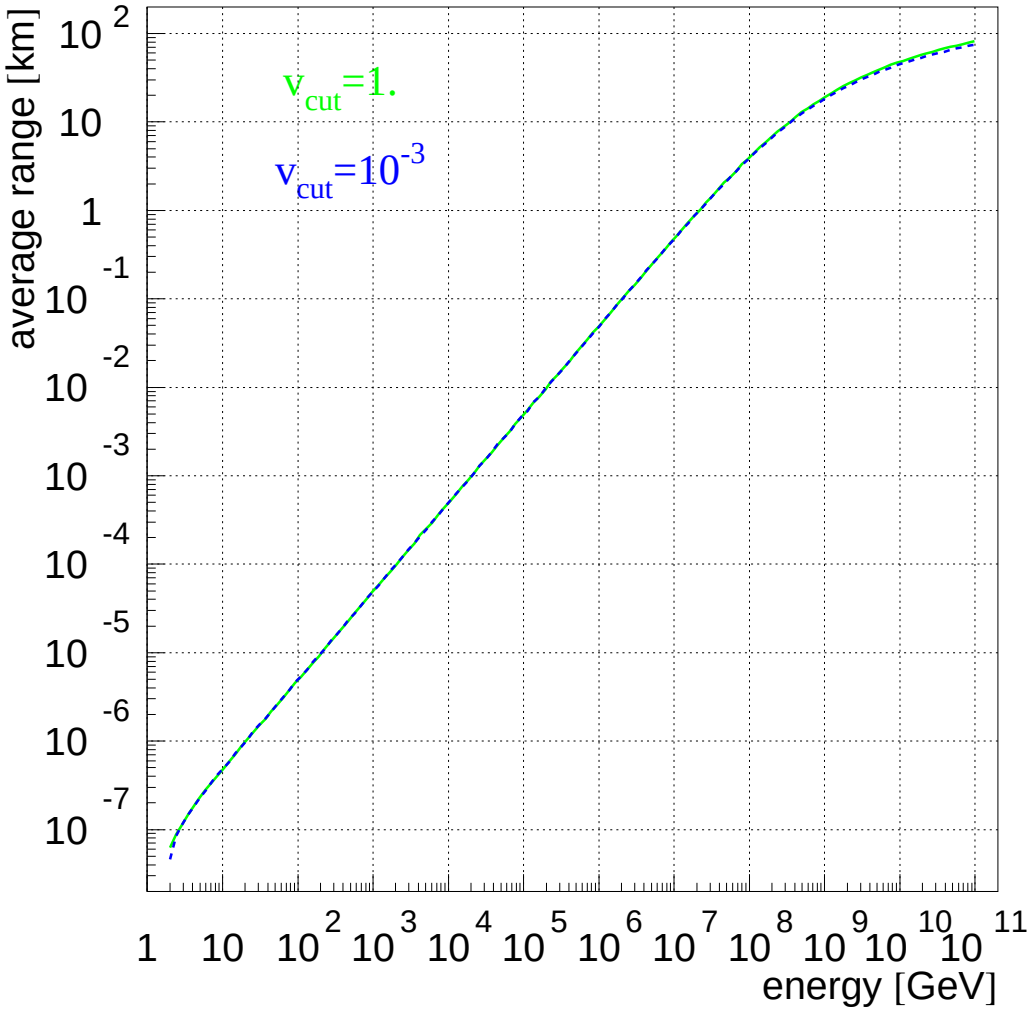
muon energy losses in ice



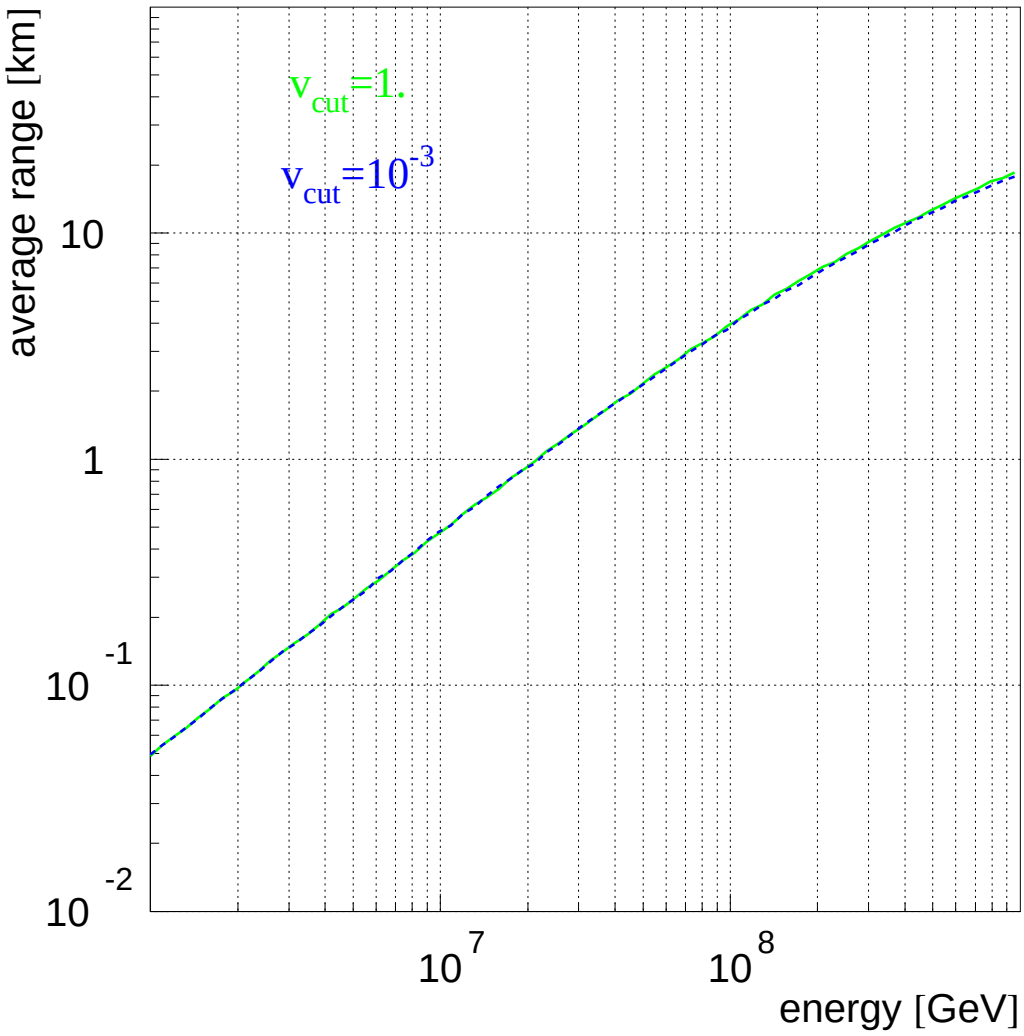
tau energy losses in ice



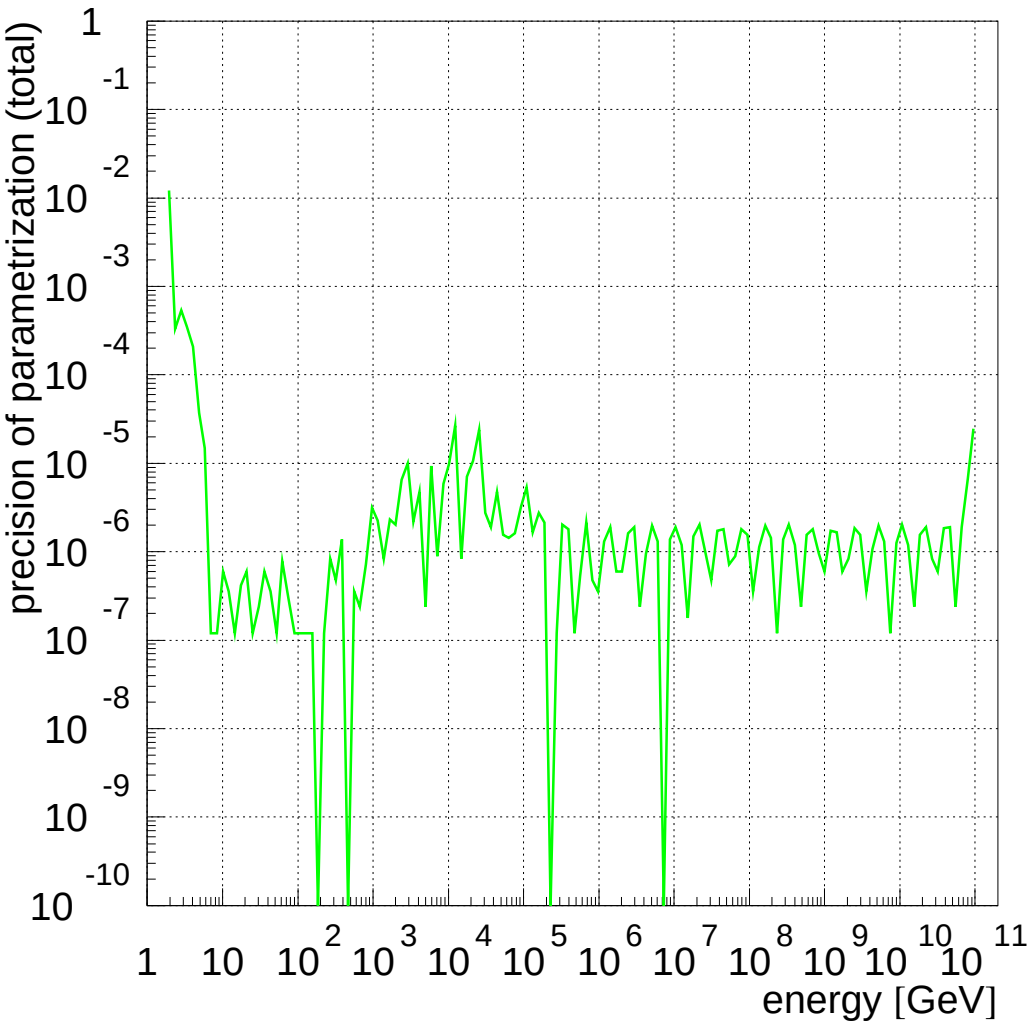
tau energy losses in ice



tau range


average range [km]
10
1
10 -1
10 -2
10 7
10 8
energy [GeV]
v cut =1.
v cut =10-3

tau range



tau parametrization errors

Execution speed, same settings

tracking	execution time, sec
MMC (ibm), basic	600
MMC (ibm), all, g=5	1000
MMC (gcc), all, g=5	1400
mudedx (loh)	1500
mudedx (lip)	900

Conclusions

1. Version 1.0 has been frozen and tested for all possible combinations of parameters
2. It is available at the AMANDA Software page and MMC homepage http://area51.berkeley.edu/~ dima/work/MUONPR/ muonPropagation.html
3. MMC gives very reliable, reproducible results that were checked against MUM
4. MMC is FAST, very fast
5. The number of options (ALLM and LPM, continuous randomization, exact time of flight, moliere scattering, stopped muon decay) and numerical settings (double, float, hifi, different romb settings) are not available anywhere else
6. MMC was tested to propagate muons and taus for energies up to 10^{20} eV for all possible numerical settings mentioned above and double romb=5 version is guaranteed to work for energies up to 10^{30} (with the usual disclaimer about the precision of our knowledge of the cross sections).