Cosmic ray energy spectrum measurement with AMANDA

Ver. 0.1

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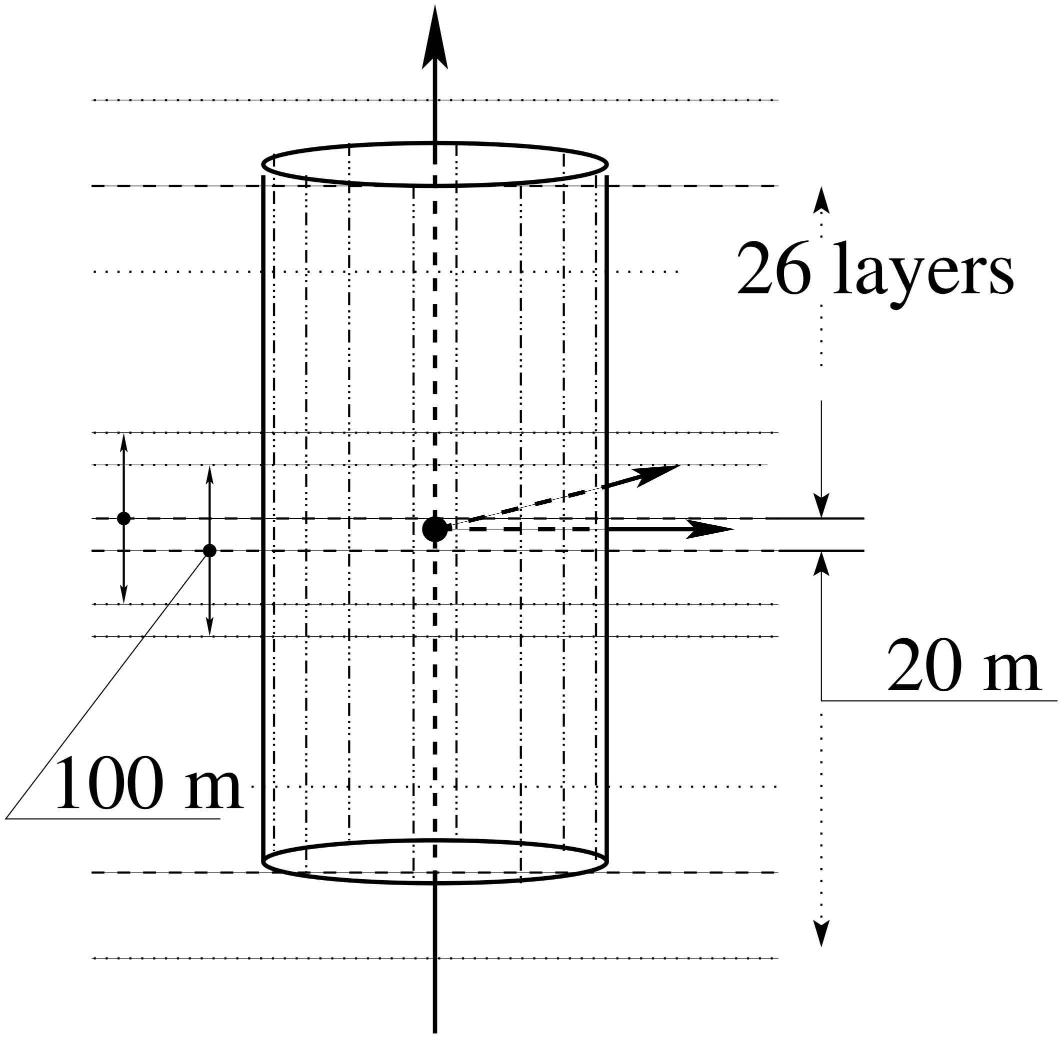
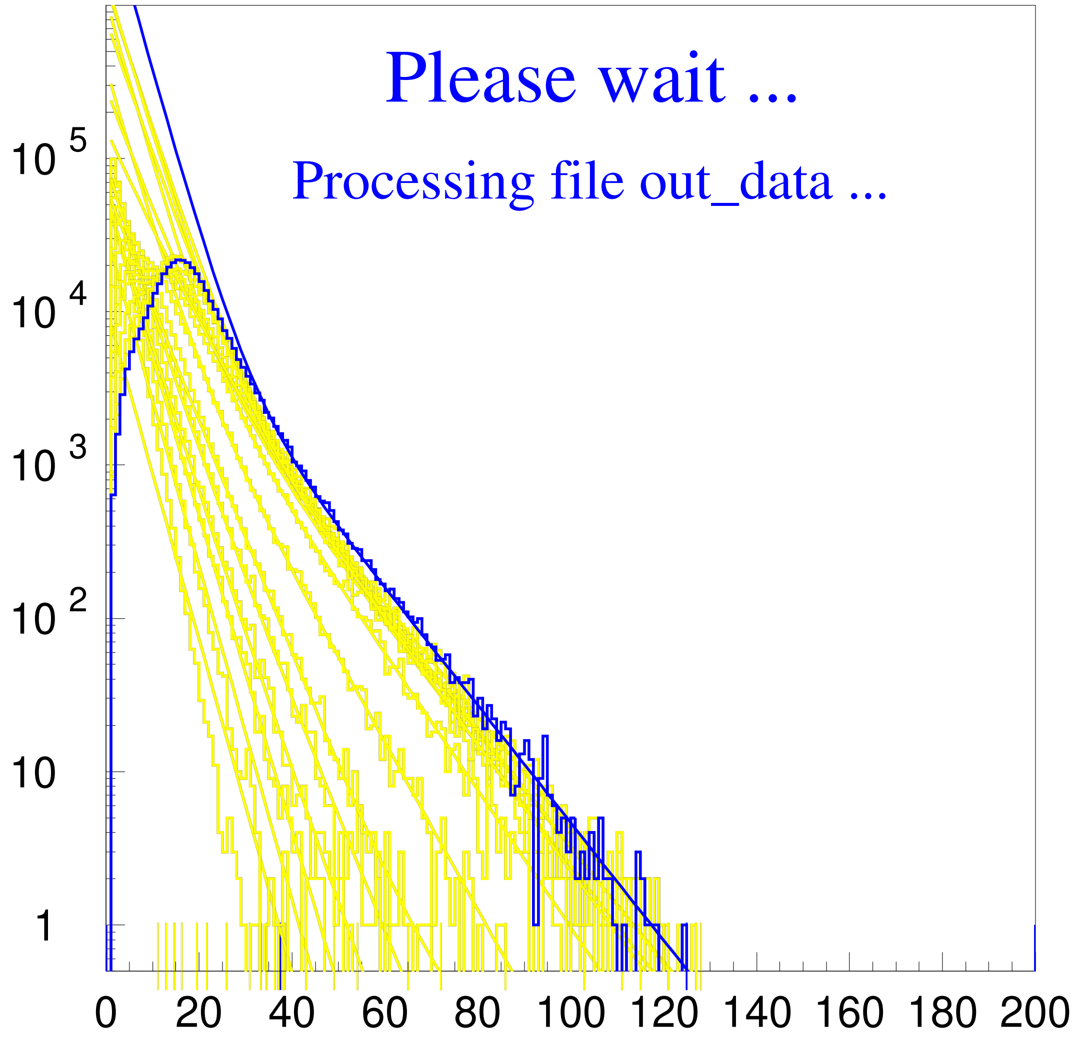
Detector layered model

Different cosmic ray spectral indices and flux normalizations translate into different muon density depth profiles. To study muon flux vs. depth the detector is divided into 26 100-meter layers separated by 20 meters from each other



Detector layered model

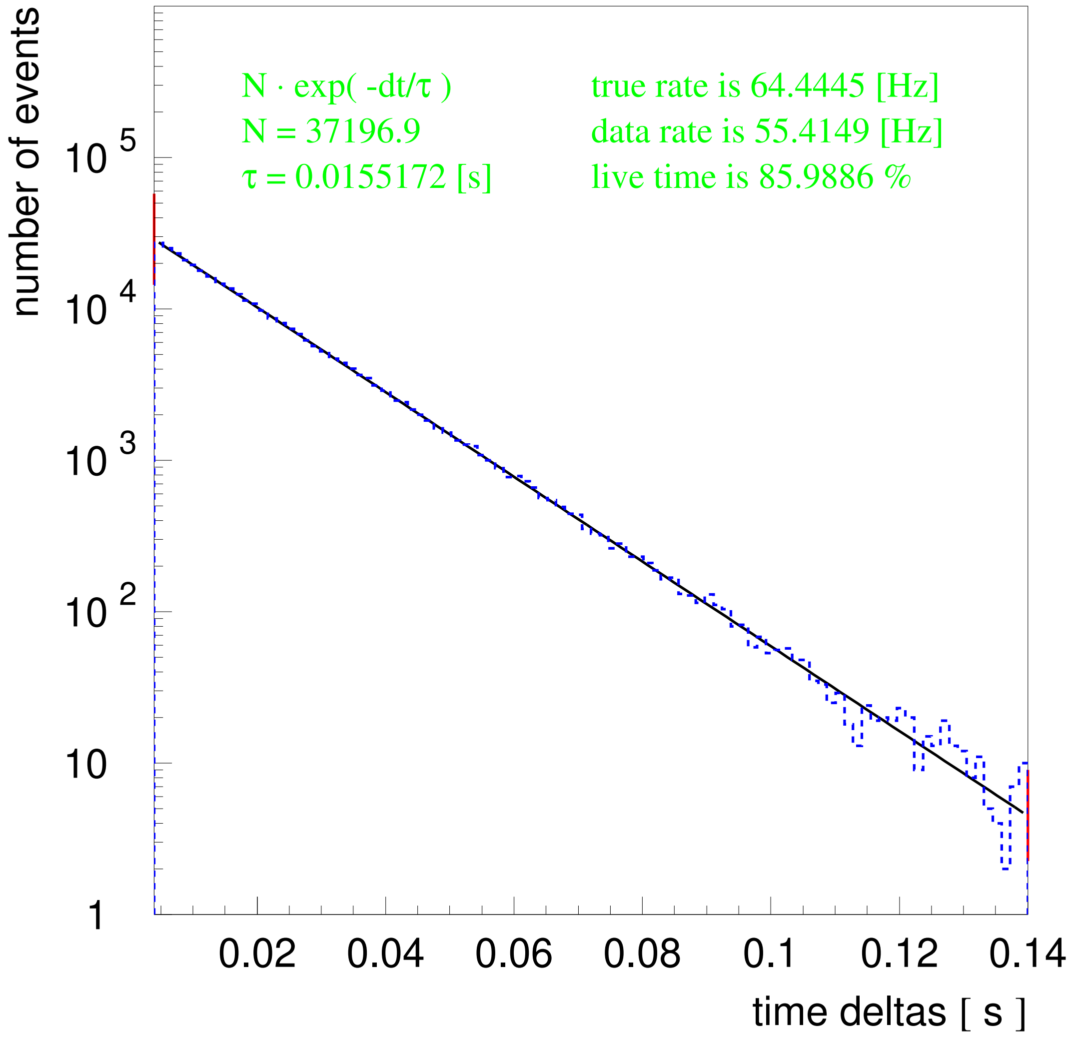
Then for each layer a histogram of the number of hit OMs is produced



The total number of events registered in a layer is plotted vs. depth. Also, the histogram is fitted (shown here is a double exponent sum fit) and the parameters of the hit are plotted vs. depth.

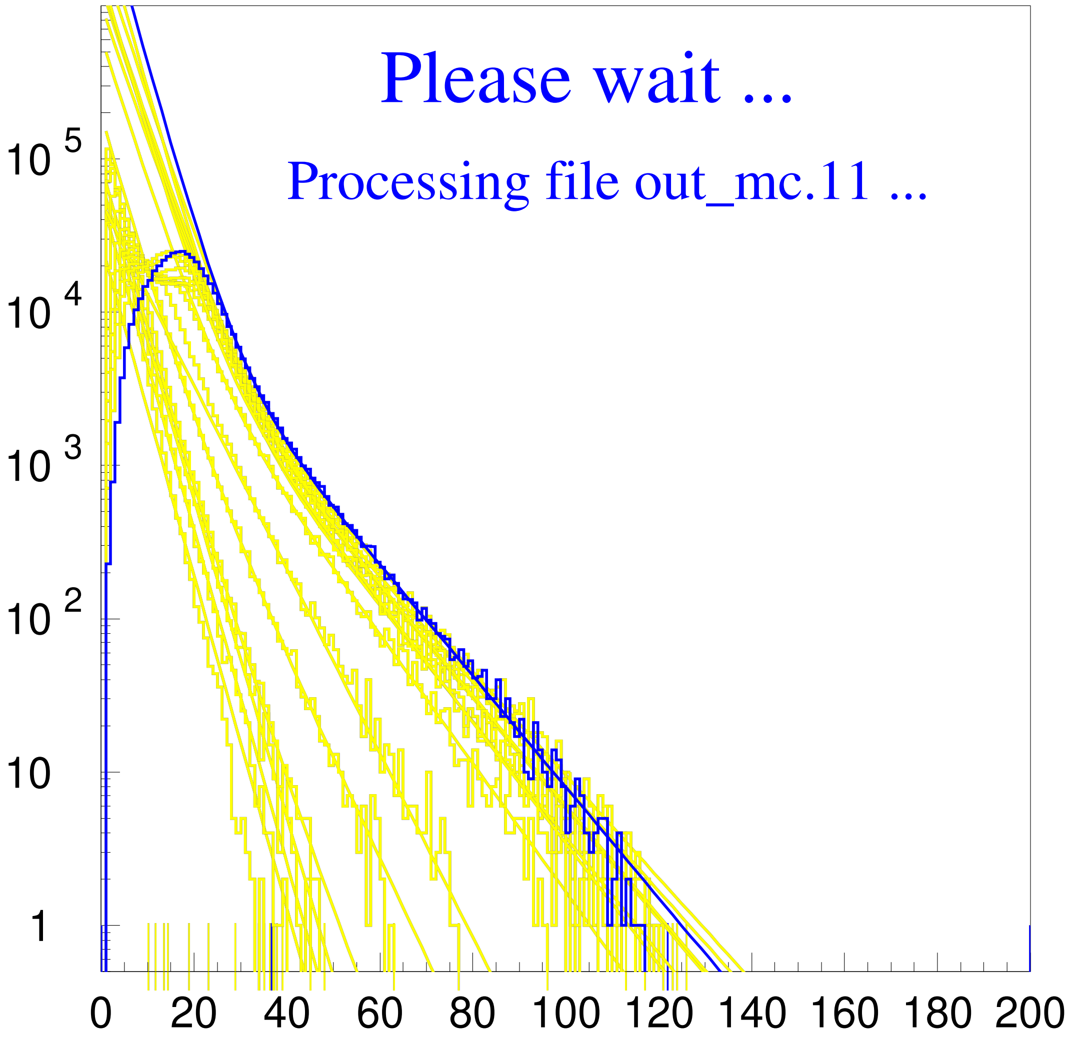
Lifetime of the data sample

Exact lifetime for the data sample is computed (also corrected for dead time). Total sample lifetime is about 2 hr. (10 year 2000 data files)



Monte Carlo sets

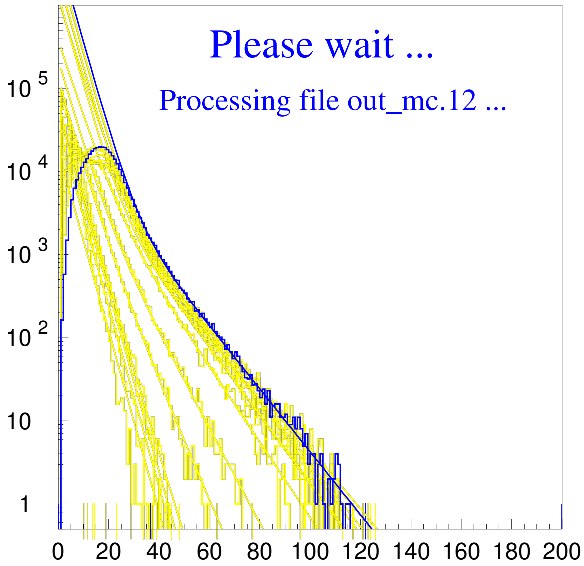
Five MC sets with cosmic ray spectral index corrections (*ic*) of 0, ± 0.1, ± 0.2 of about the same lifetime ($\sim$ 2 hr.) for each *Ice Model* are prepared



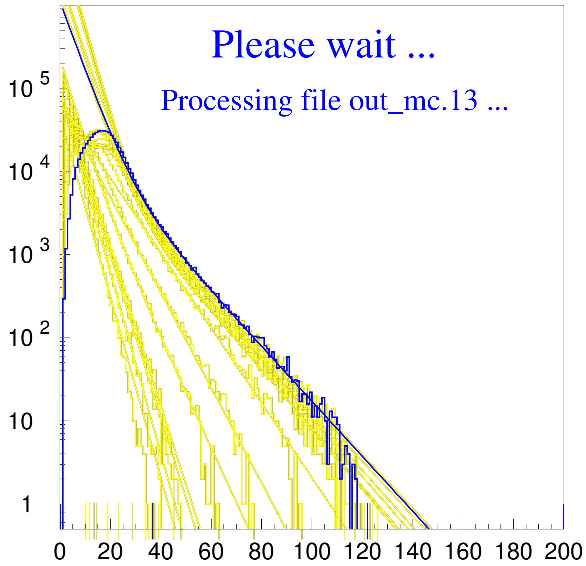
here shown distribution for *ic*=0 for *stdkurt* ice model, layer at 10 m (-40 m to 60 m) is blue (bold)

Monte Carlo sets

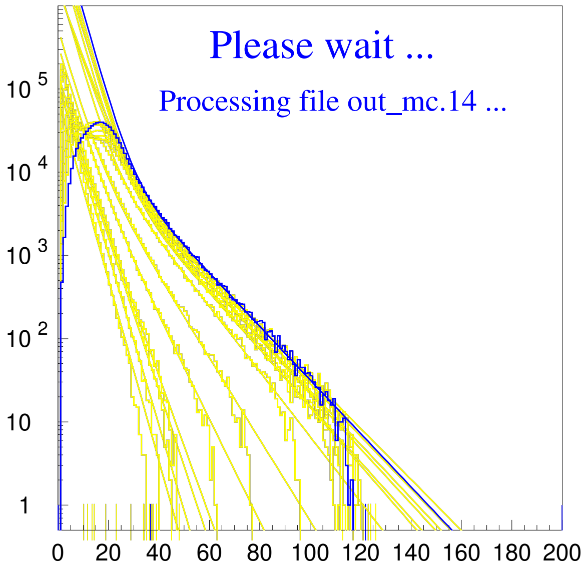
Shown here are Monte Carlo sets for *ic*=± 0.1,± 0.2, *stdkurt* ice model



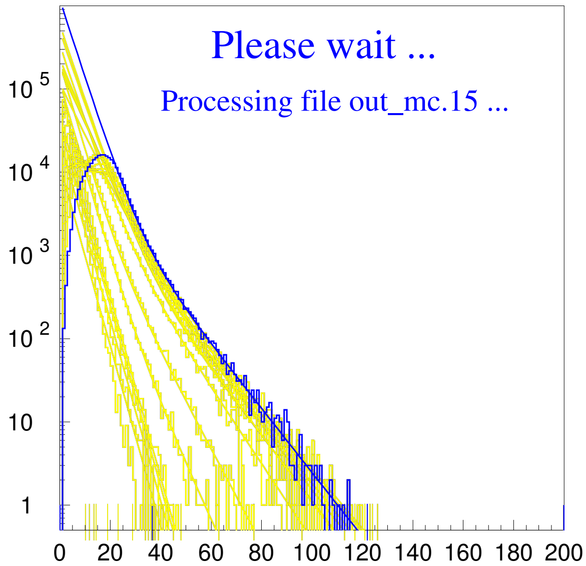
+0.1



-0.1



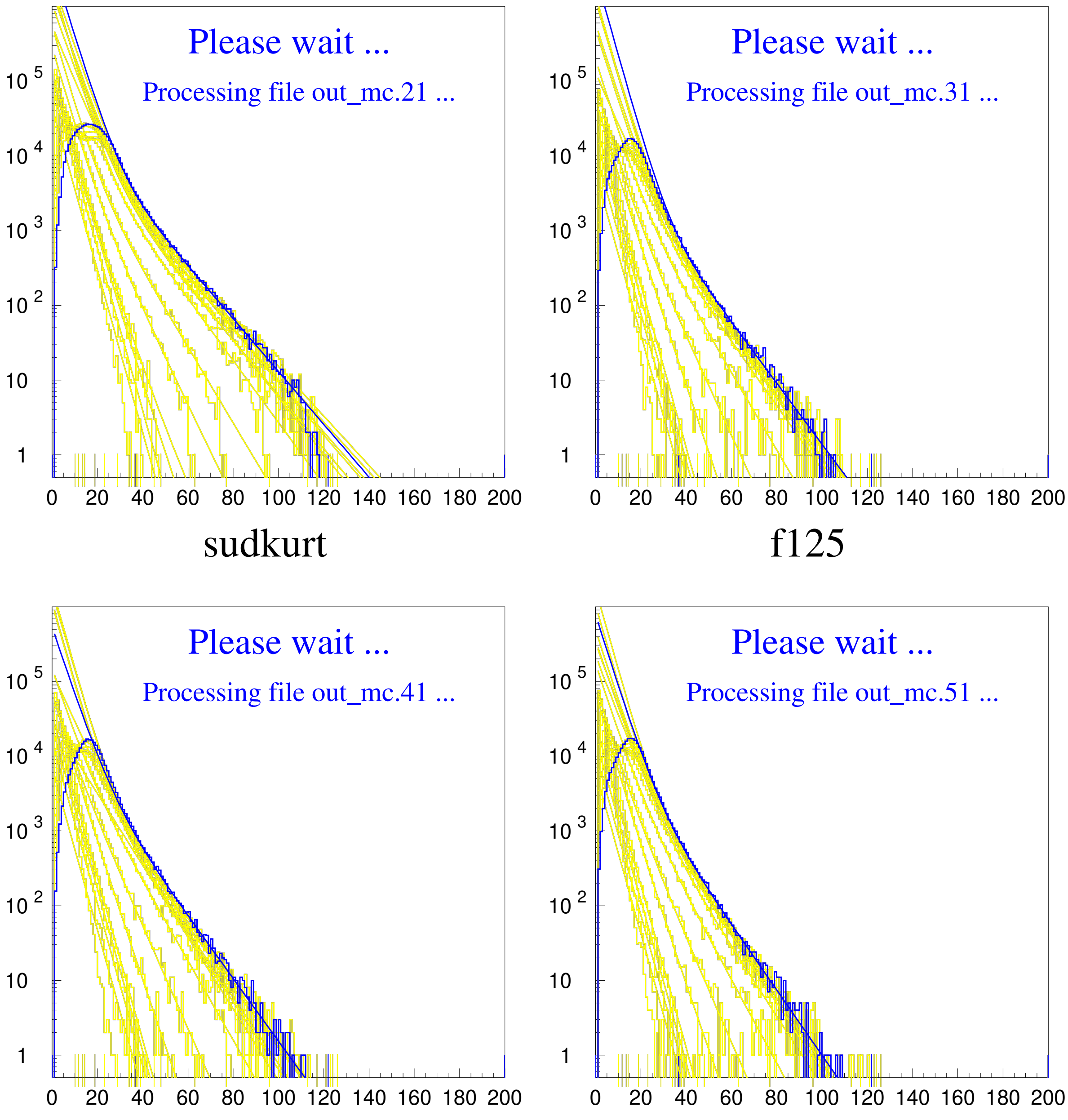
-0.2



+0.2

Monte Carlo sets

Shown here are Monte Carlo sets for *sudkurt, f125, mam, bulk* ice models, *ic*=0

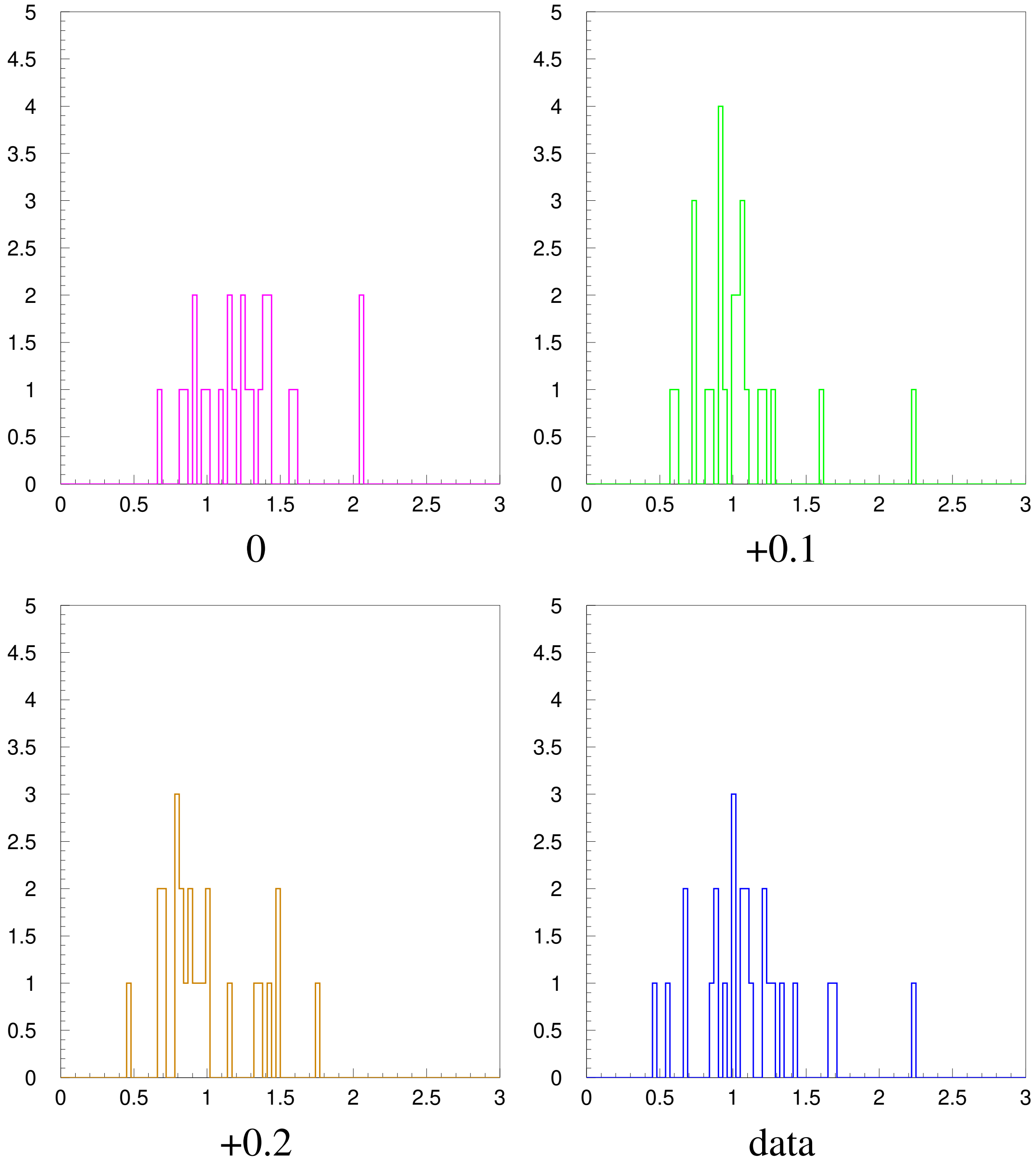


sudkurt f125

mam bulk

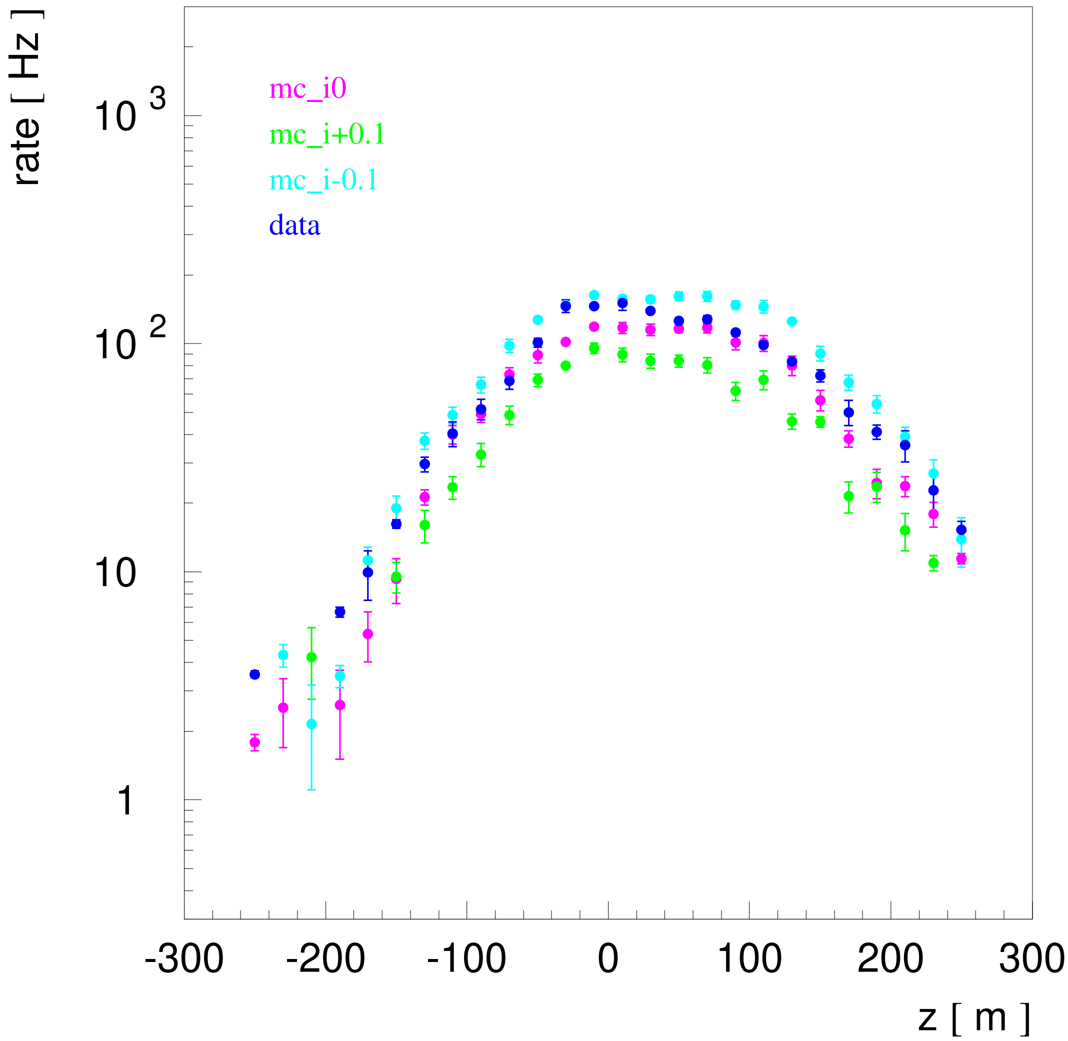
Fit quality

Fits to the distributions were rather good. χ^2 was on average 1, occasionally much bigger for bad fits



Fit area vs. depth

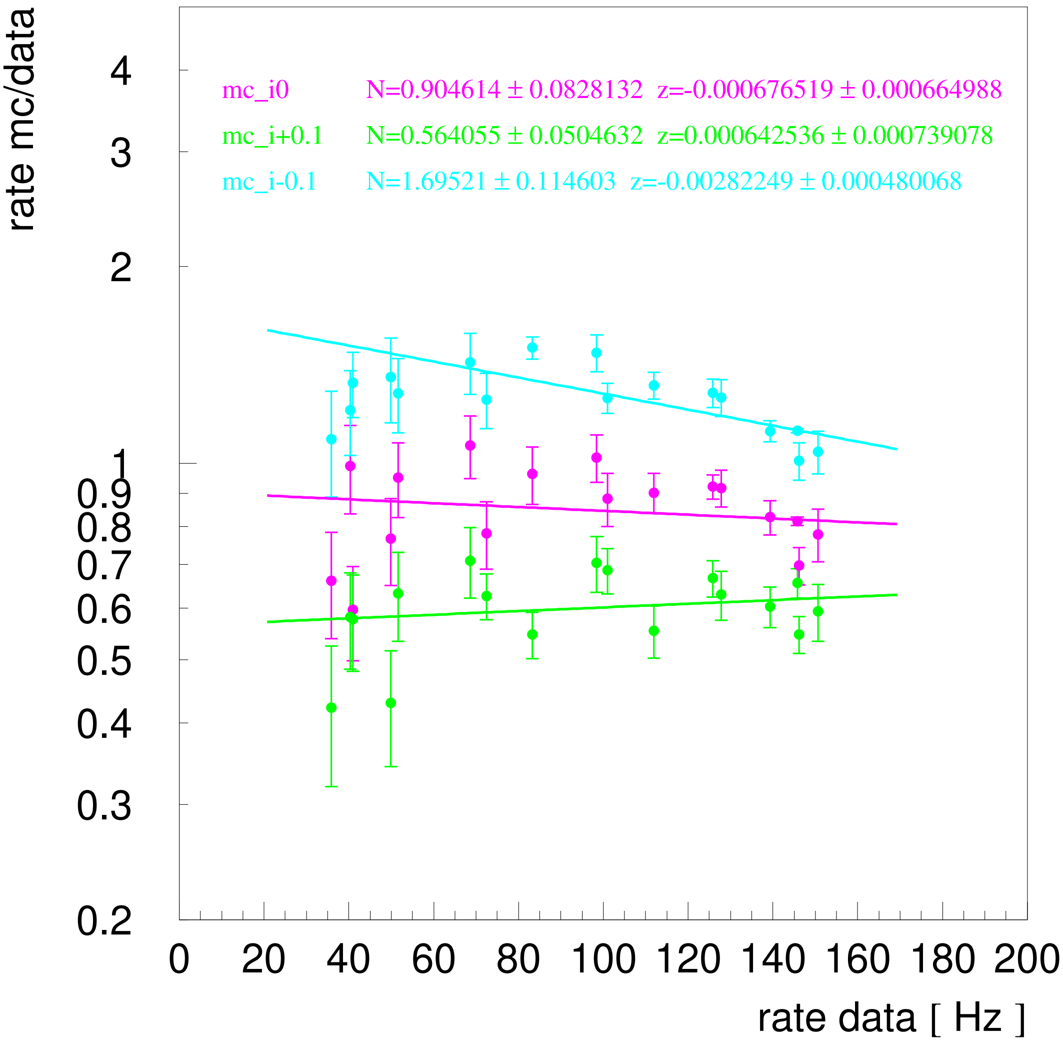
A function of the fit parameters (approx. area under the higher exponent) was plotted vs. depth; here shown for 0,± 0.1, mass01v001 MC and Data V4; hits in the USES lines removed



One can see that the shape of the data is close to MC +0.1, even though the normalization for data is higher. The shape of MC changes gradually from +0.1 to -0.1, best seen in -50 to 150 m range

Fit MC/Data vs. depth

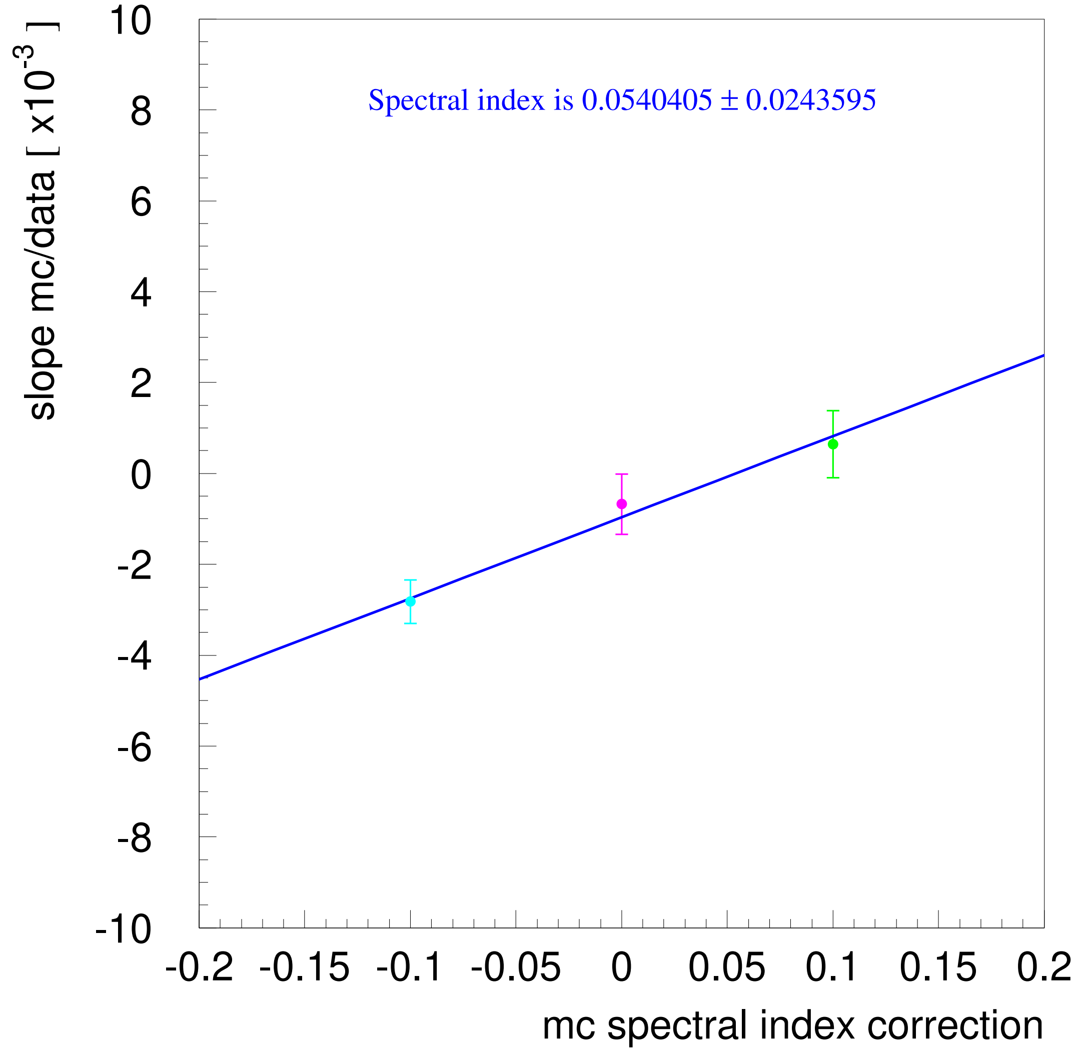
To quantify these observations, ratio of MC to Data is plotted vs. Data. All distributions are fitted with lines



Parameters of the fit are normalization and slope. MC should be close to data for as wide an interval as possible, i.e. the sample with the slope close to zero determines which MC is closest to Data

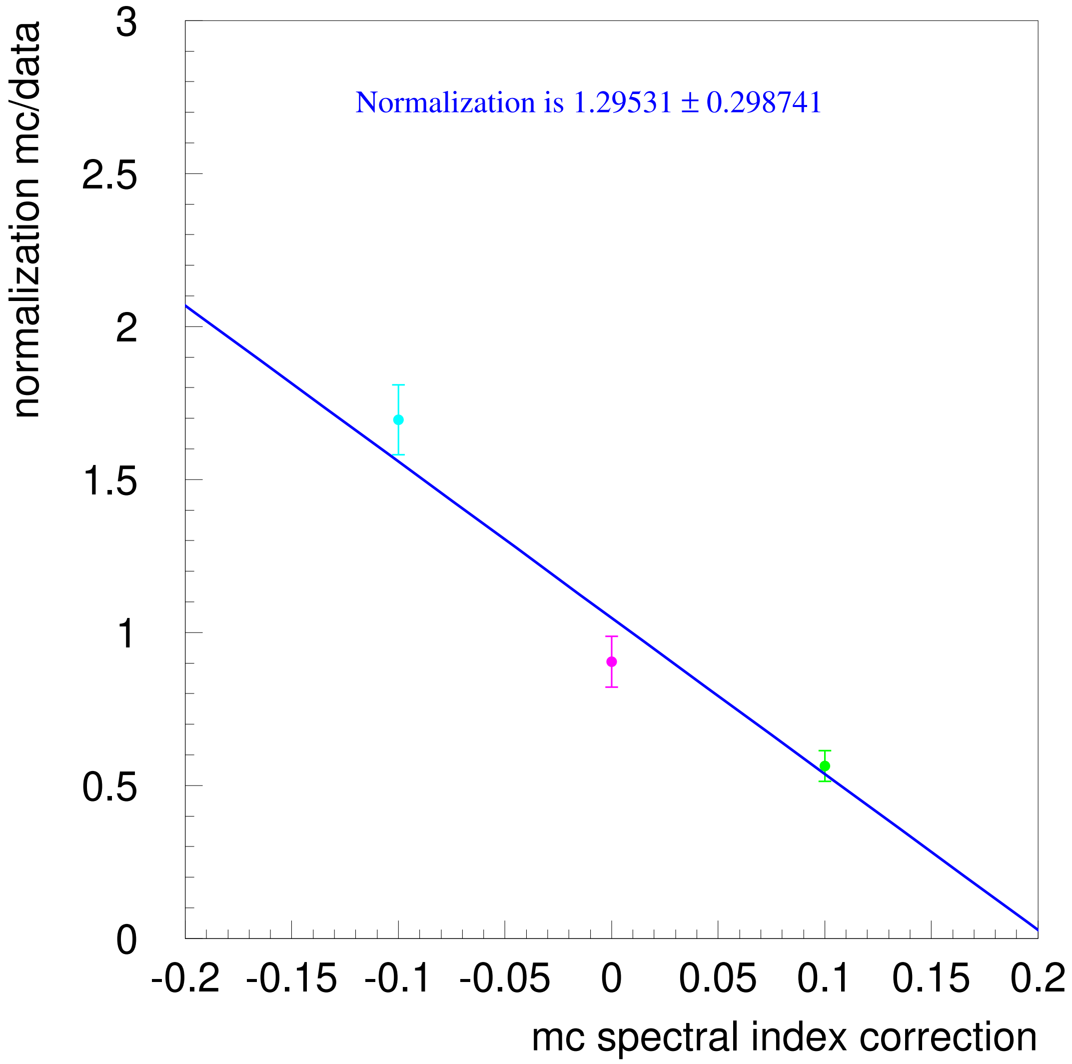
Fit to the Spectral Index

Slopes of the fits in the previous graph are plotted vs. *ic* (spectral index corrections). Spectral index for which MC is closest to data is determined as the point where the fitted line intersects zero in slope



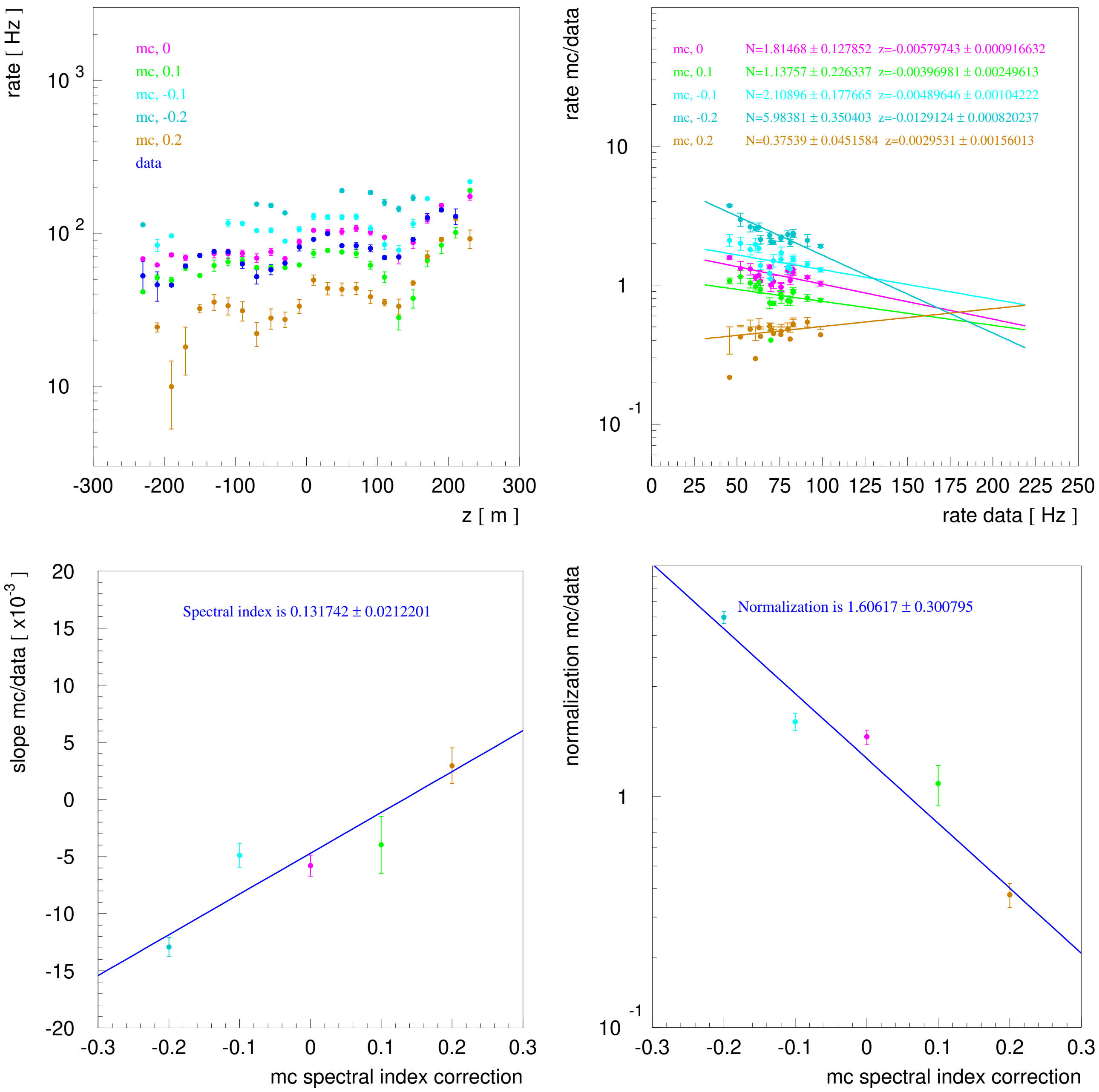
Fit to the Normalization

Normalization of the fits are also fitted with the line (exponent). The normalization of the MC closest to Data is determined as the value of the fit in the *ic* point determined from the *ic* fit above

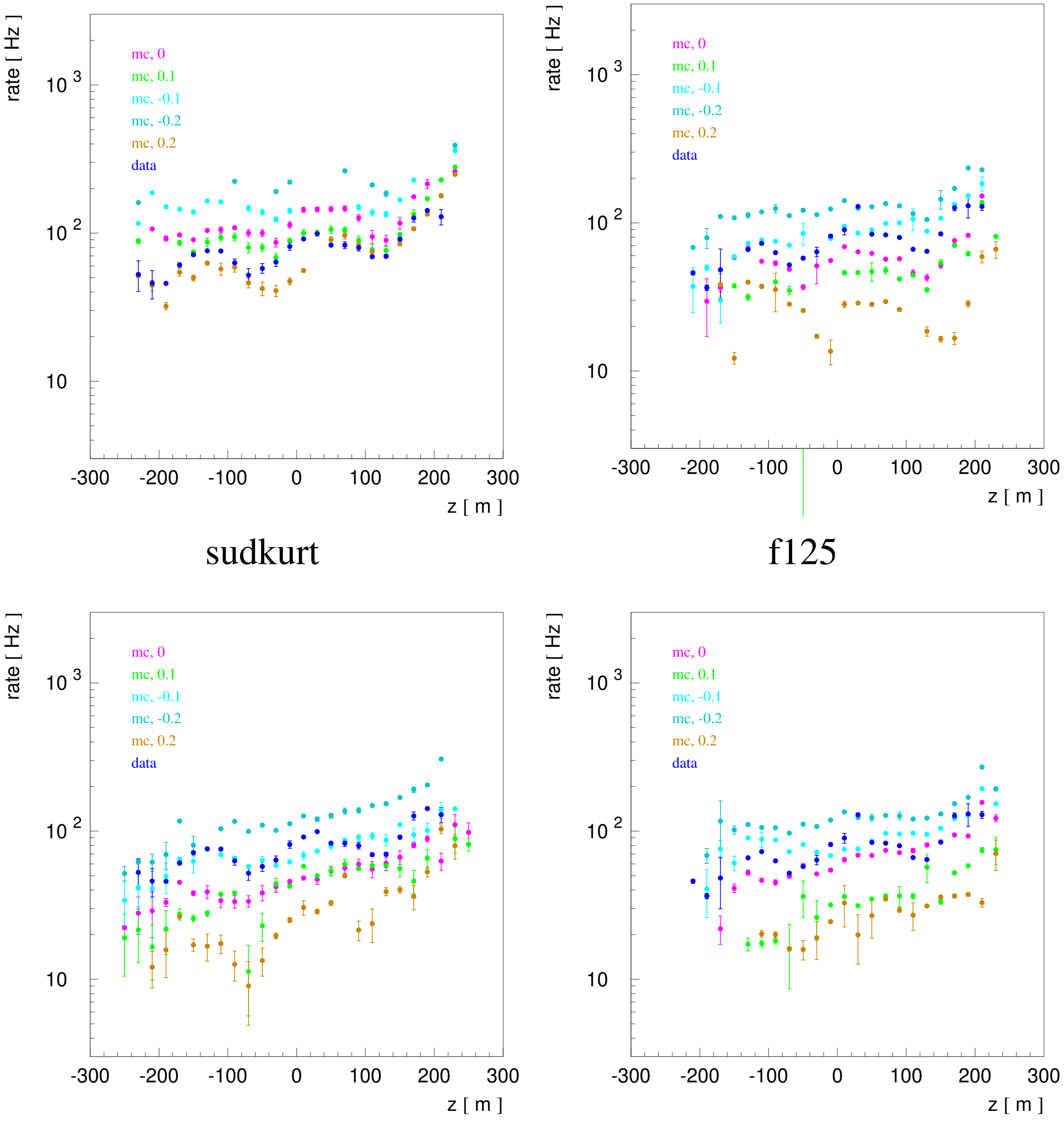


Fits with mass01v002

The same procedure was applied to all MC sets produced with mass01v002 and Data processed with V5; *stdkurt* ice model plots are shown here



Fits with mass01v002, step 1



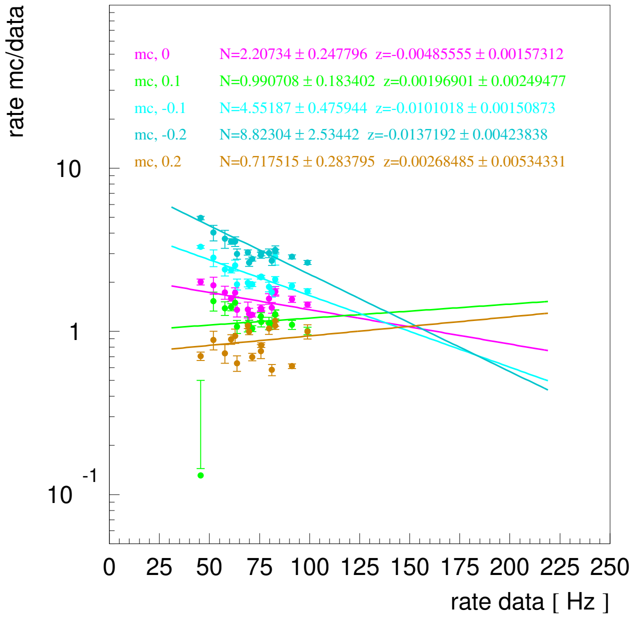
sudkurt

f125

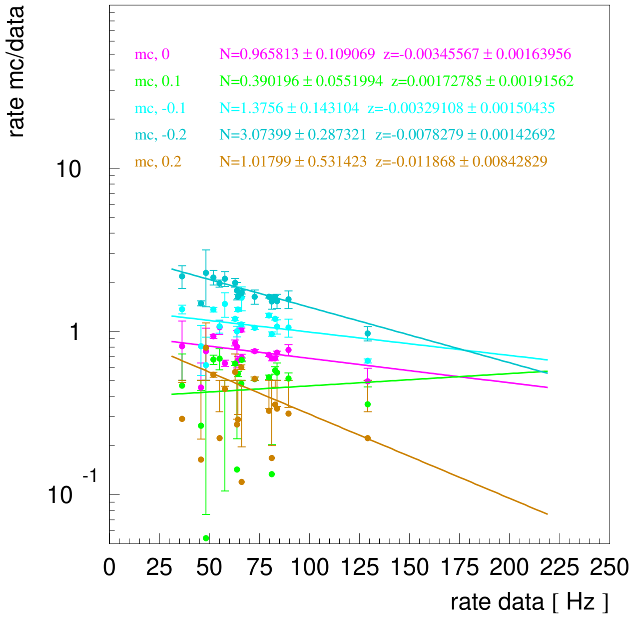
mam

bulk

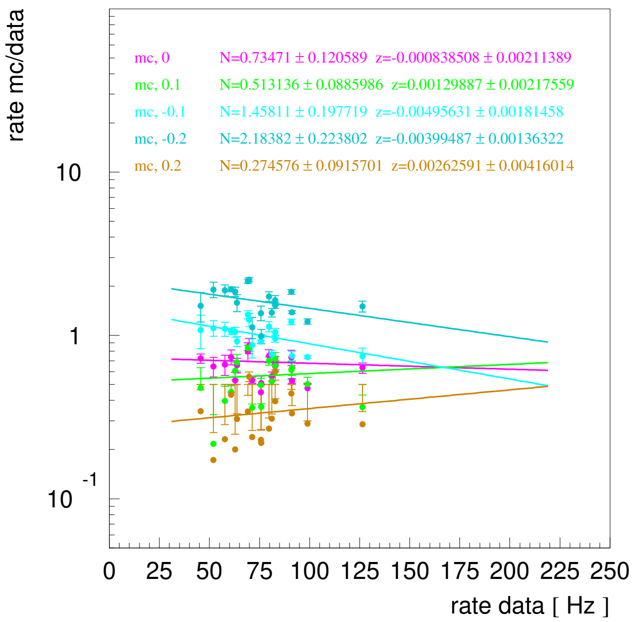
Fits with mass01v002, step 2



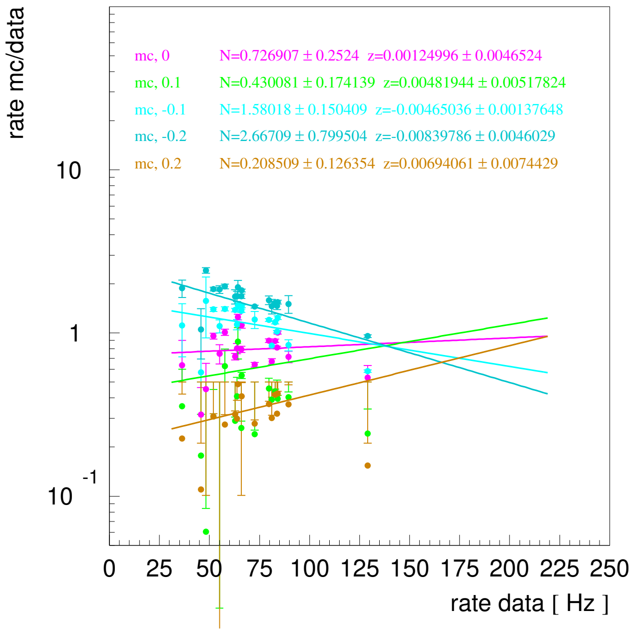
sudkurt



f125

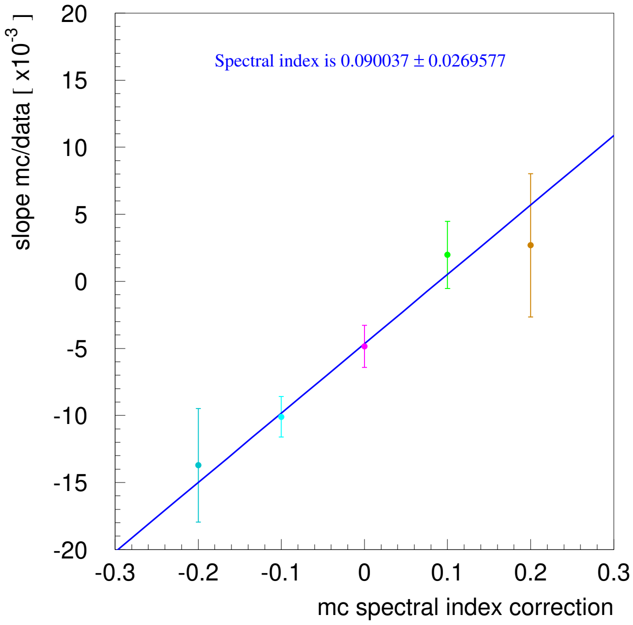


mam

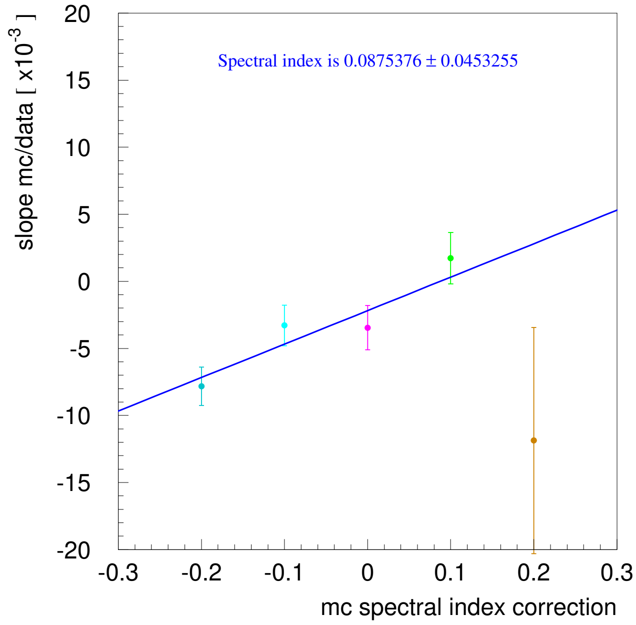


bulk

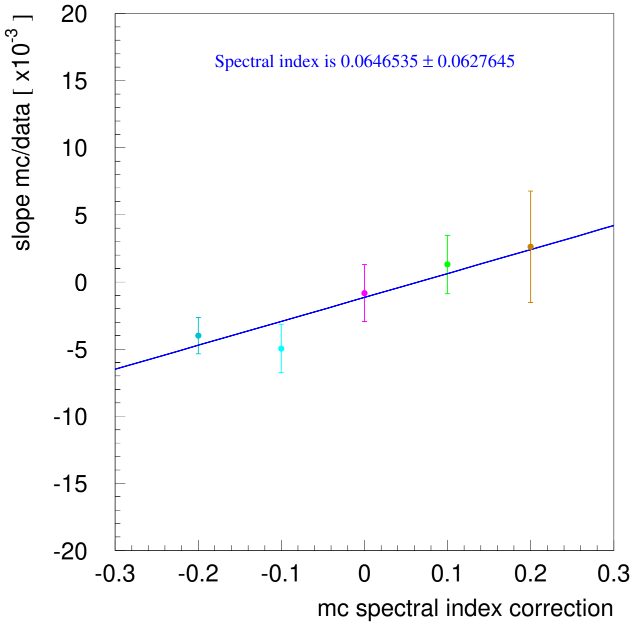
Fits with mass01v002, step 3



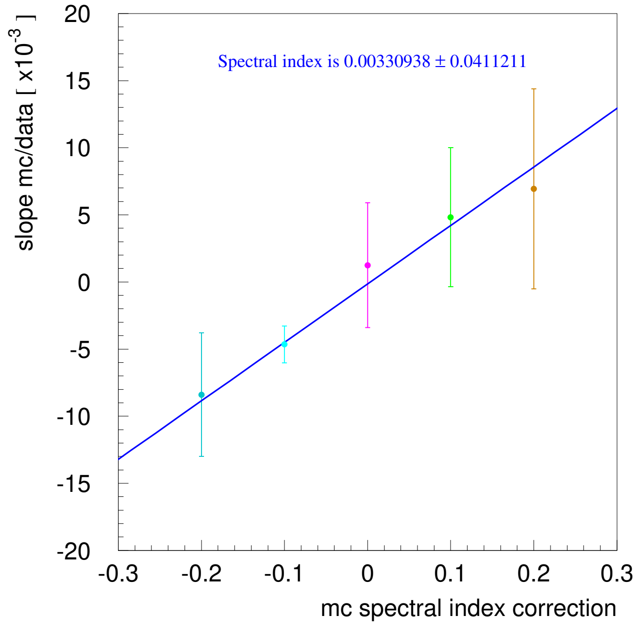
sudkurt



f125

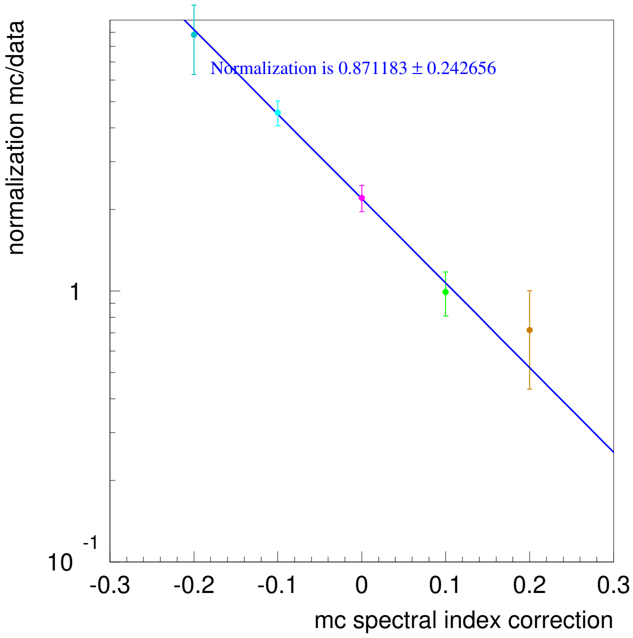


mam

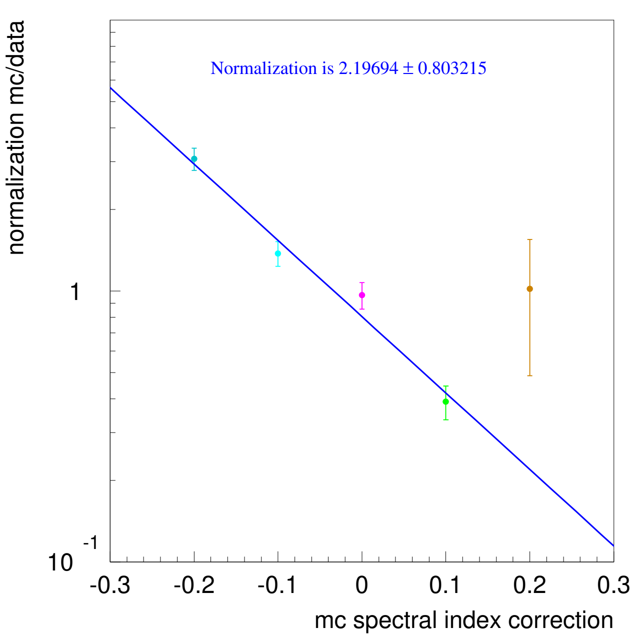


bulk

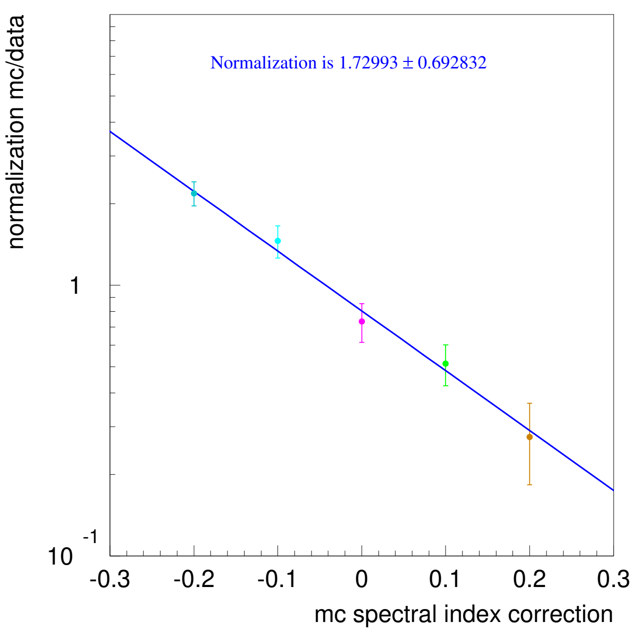
Fits with mass01v002, step 4



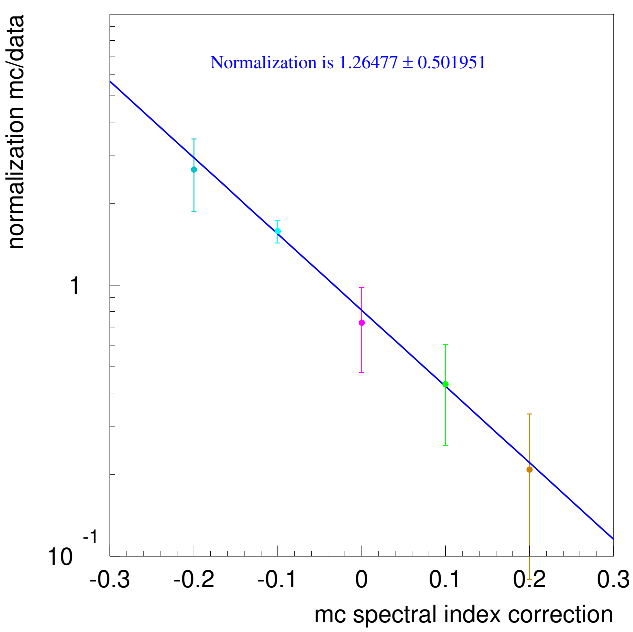
sudkurt



f125

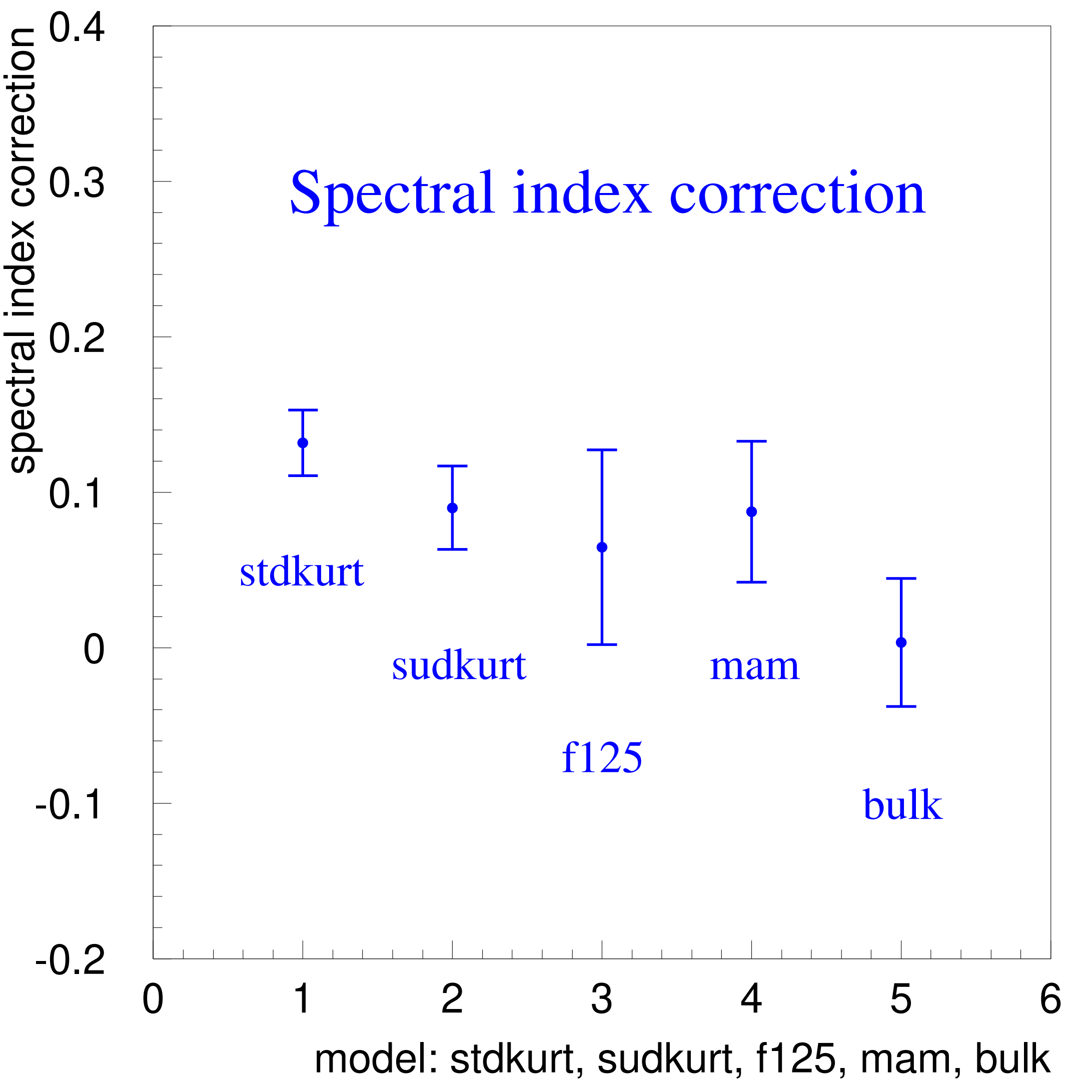


mam



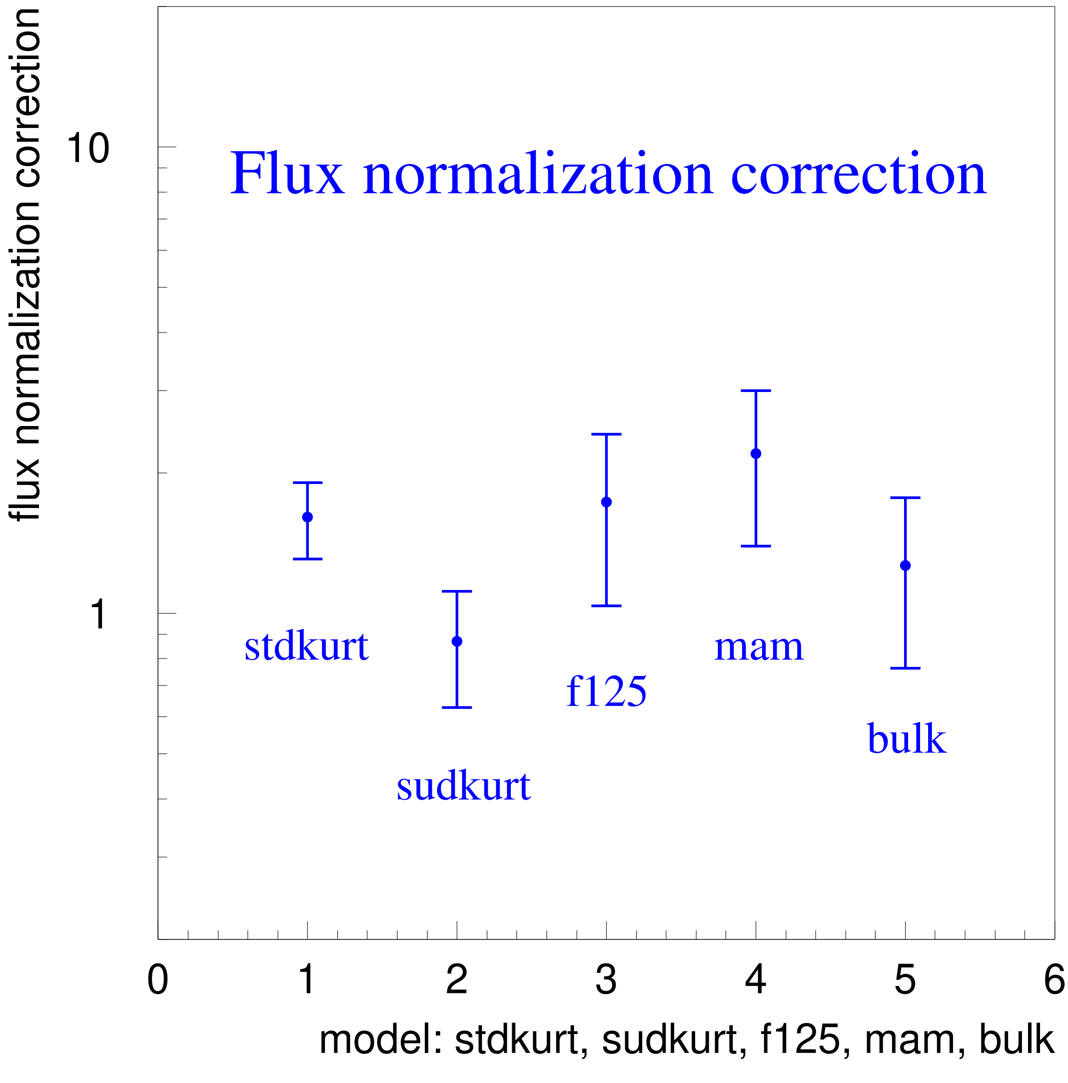
bulk

Results, spectral index corrections



All ice models predict a value of the spectral index correction higher than zero, on average 0.08, i.e. for hydrogen, e.g., spectral index of 2.76+0.08=2.84

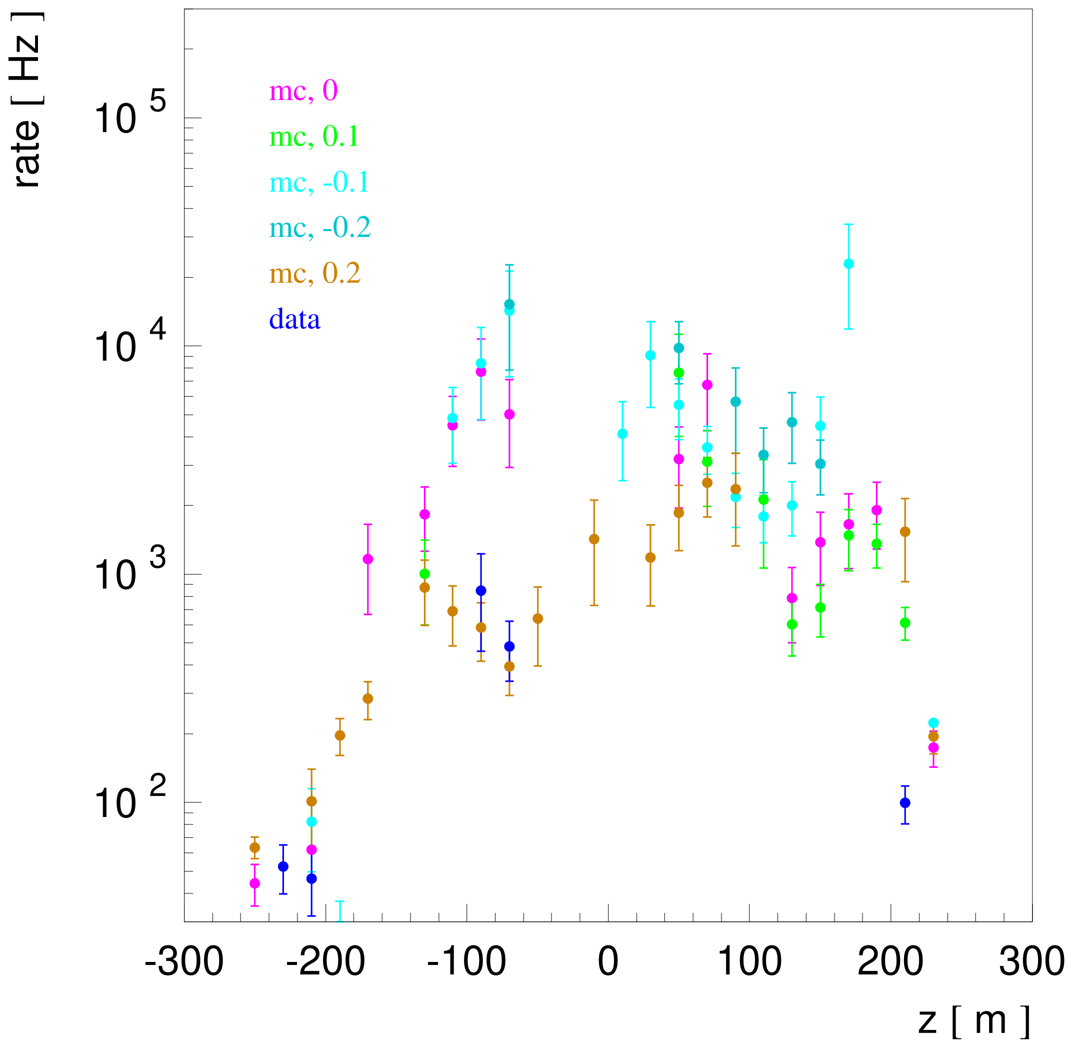
Results, normalization



All ice models except *sudkurt* predict a value of the normalization higher than one, on average by 50%

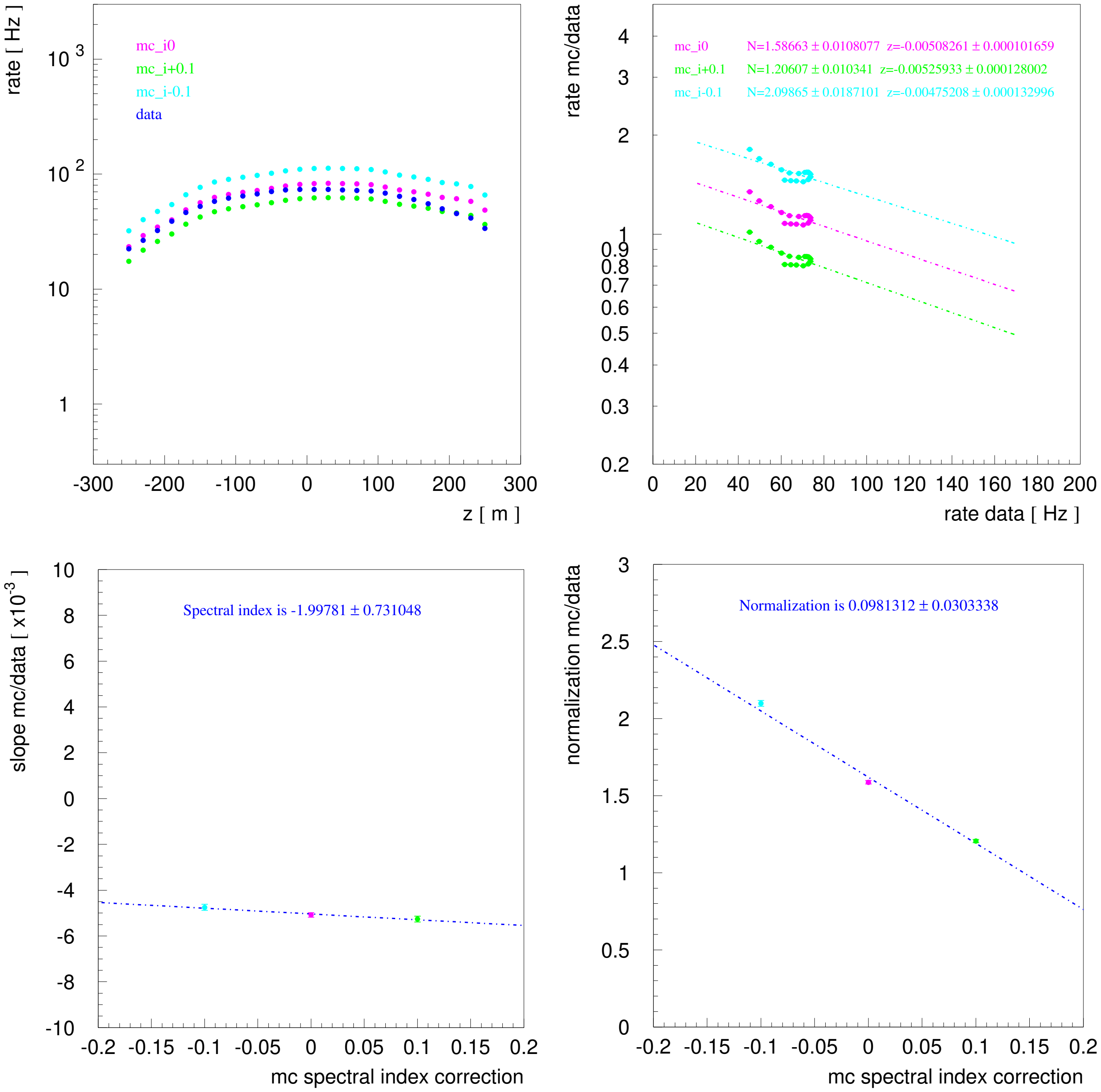
What about other functions of fit parameters?

Several other functions have been looked at. The results of the fits were less sensible, though. Below is a plot of the approx. area under the lower exponent, a fit for which produced a lot less stable results



What about counting raw hits in each layer?

The results turn out to depend quite a bit on the cleaning procedure, often giving unreasonable answers



Conclusions, observations and further analysis

1. Method works, gives reasonable results.
2. The errors are not very carefully evaluated yet, sometimes causing instability in the results. Errors analysis will be improved in the next version. Hopefully errors will decrease as well.
3. All ice models are compatible with each other. This is what one would hope to achieve trying to arrive at model-independent results.
4. Robust results can be obtained with mass01v001/V4, less so with mass01v002/V5. Analysis using the latest mass production software will need to be improved.