Geometry calibration of AMANDA with muons

Ver. 0.1

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Idea, motivation, settings

The idea was suggested by Kael in his talk "Geometry calibration using atmosph. muons" in Mainz. At that time it was tested on MC (AMANDA + 3 IceCube strings).

It is interesting to see if this works for data in AMANDA. One could check the existing geometry calibration of the array and determine positions of the outlying OMs at the top and bottom of the detector (in particular those on strings 11-13). Since this could be the most precise method for geometry calibration in IceCube, it is important to see if it works in the existing array.

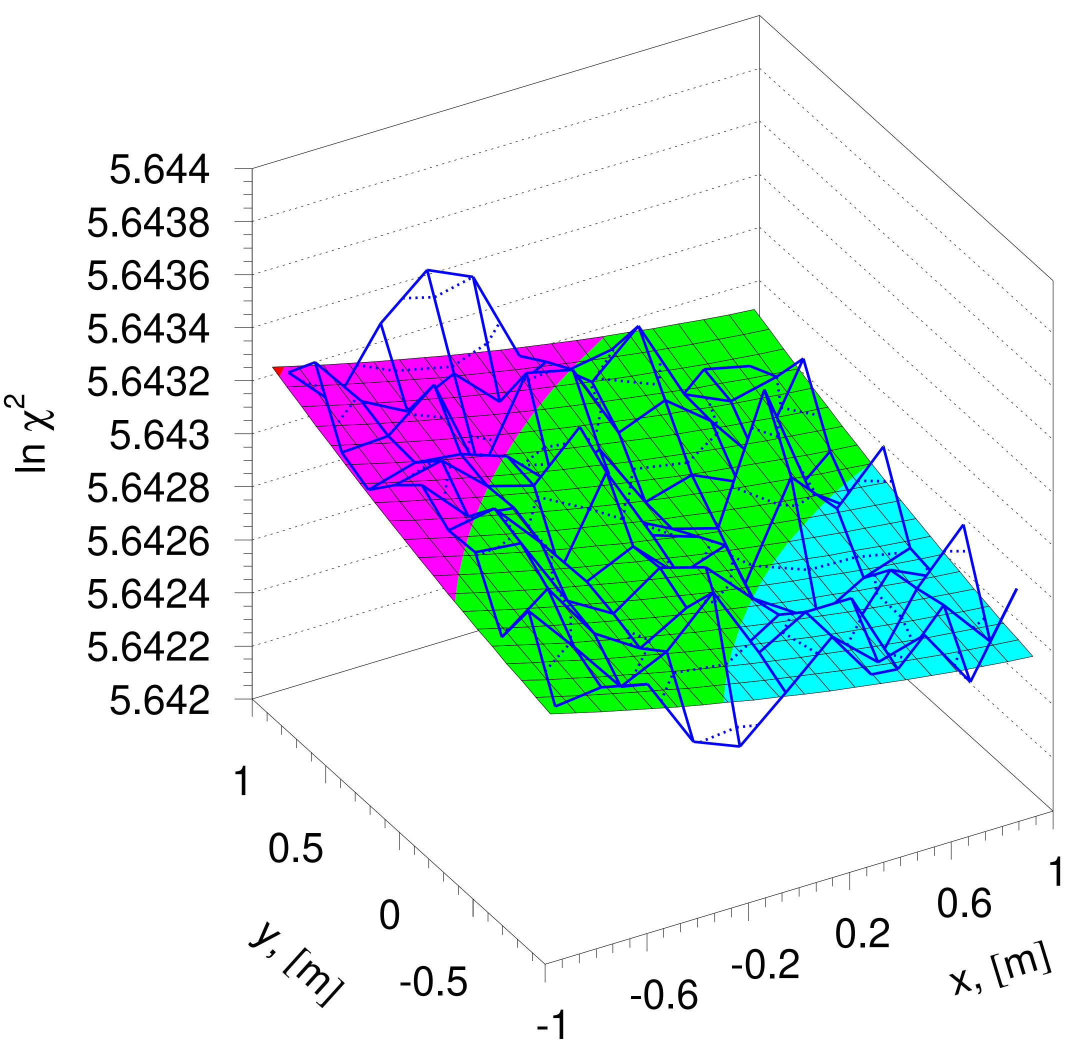
The settings used for the cleaning, reconstruction and pandel function evaluation were mostly the same as in Kael's analysis (opt. model: 2, jitter: 10, att.: 96, hits isolated by 70 m 300 ns removed, only events with tracks no closer than 1 m and no further than 50 m away from the OM were considered).

About 2 hr. of 2000 data were used ($\sim$ 10 files). After cleaning, for each OM this resulted in approx. 10^4 events in the center of the array, as small as about 400 for the lowest OM 344

First try

First, tracks were reconstructed each time the OM was moved. The uncertainty in the location of the found track translated to large uncertainties in the pandel function evaluation and rendered the function unfittable

$\ln \chi^2$, for OM 480 at z = 0 m



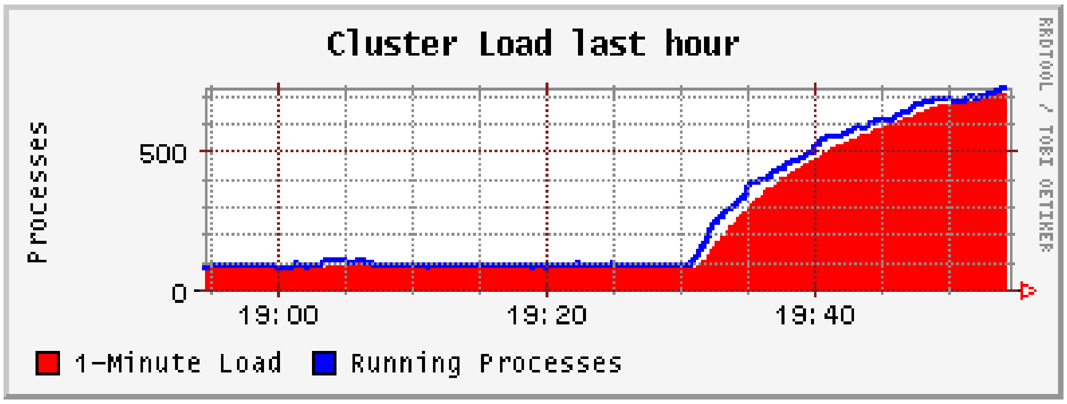
$x_{min} = 2.05225 \pm 0.23787$ $\delta x_{min} = 108.331 \pm 5.2966$

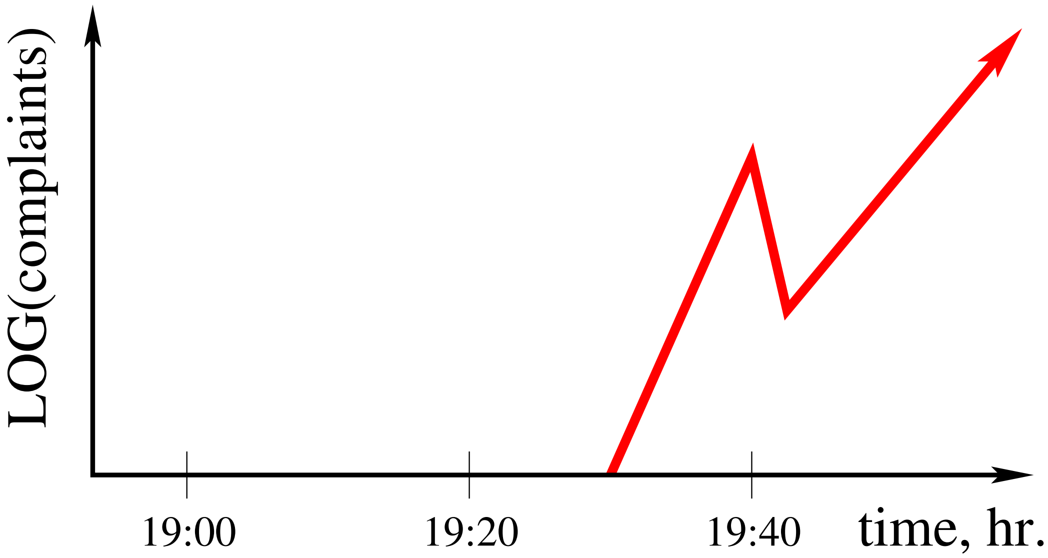
$y_{min} = -2.75663 \pm 0.10969$ $\delta y_{min} = 120.95 \pm 3.4133$

$z_{min} = 0.201761 \pm 0.122445$ $\delta z_{min} = 68.7724 \pm 10.0431$

First try

At the same time the computational time was big which resulted in the huge load on our computing facility, followed by complaints from other users

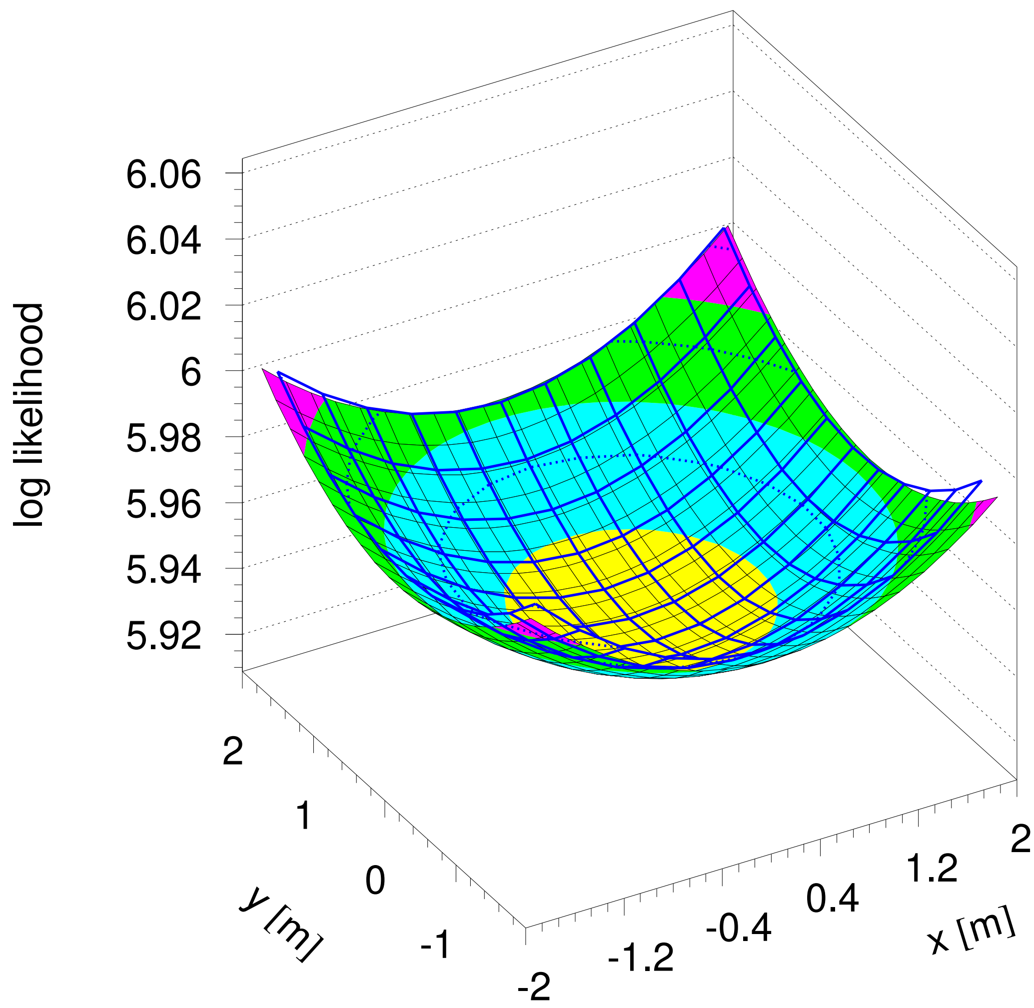




Alternative

A sensible alternative is to reconstruct the track only once, for the default location of the OM, and then determine pandel function contribution for different locations of the OM shifted away from its initial position. This resulted in a well defined smooth surface which turned out to be well fittable with a parabola

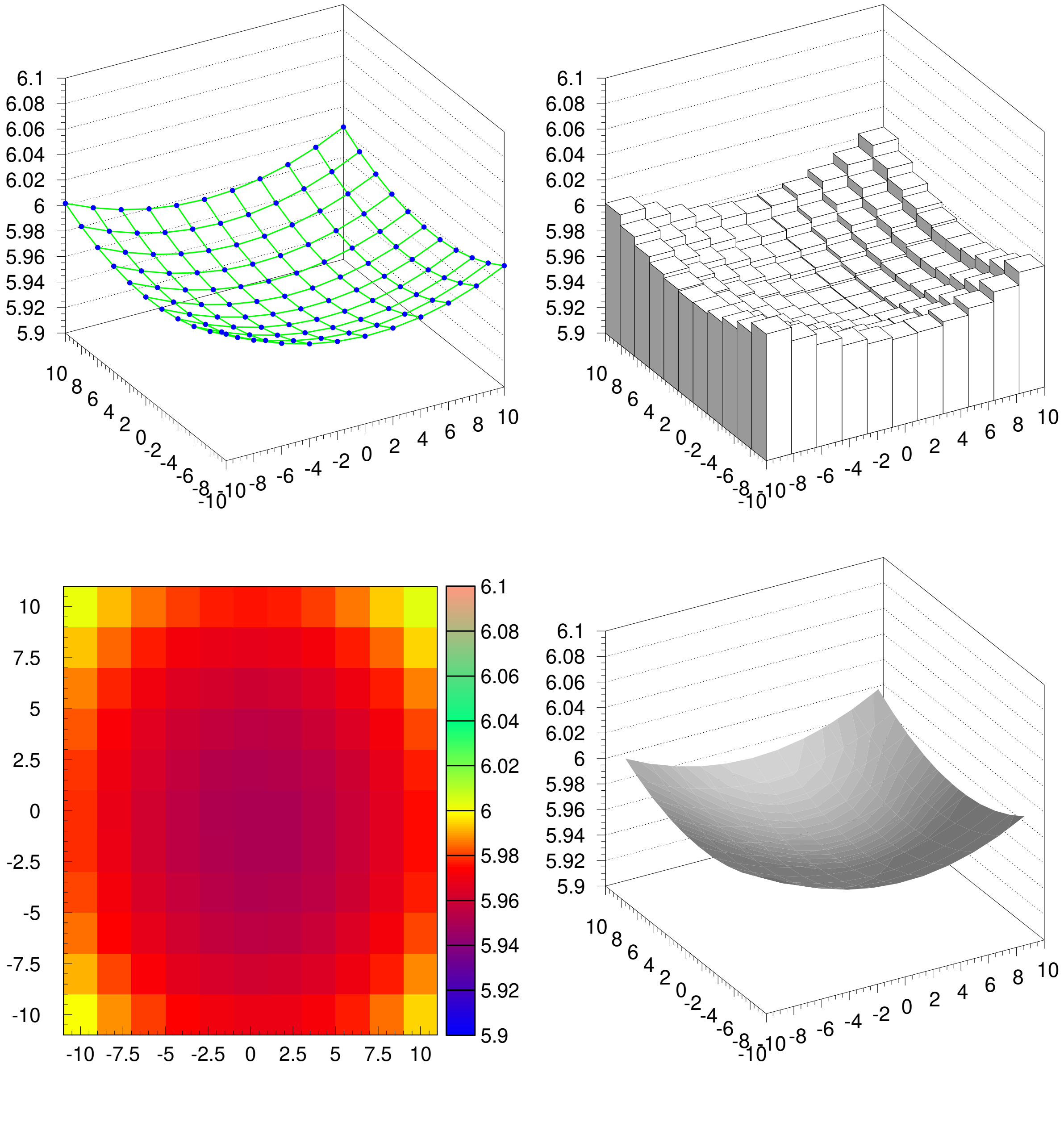
log likelihood for OM 1 at z = 0.8 m



x_{min} = 0.040 ± 0.039 [m]	δx_{min} = 7.54 ± 0.37 [m]
y_{min} = -0.085 ± 0.045 [m]	δy_{min} = 8.09 ± 0.46 [m]
z_{min} = 0.734 ± 0.040 [m]	δz_{min} = 6.91 ± 0.29 [m]

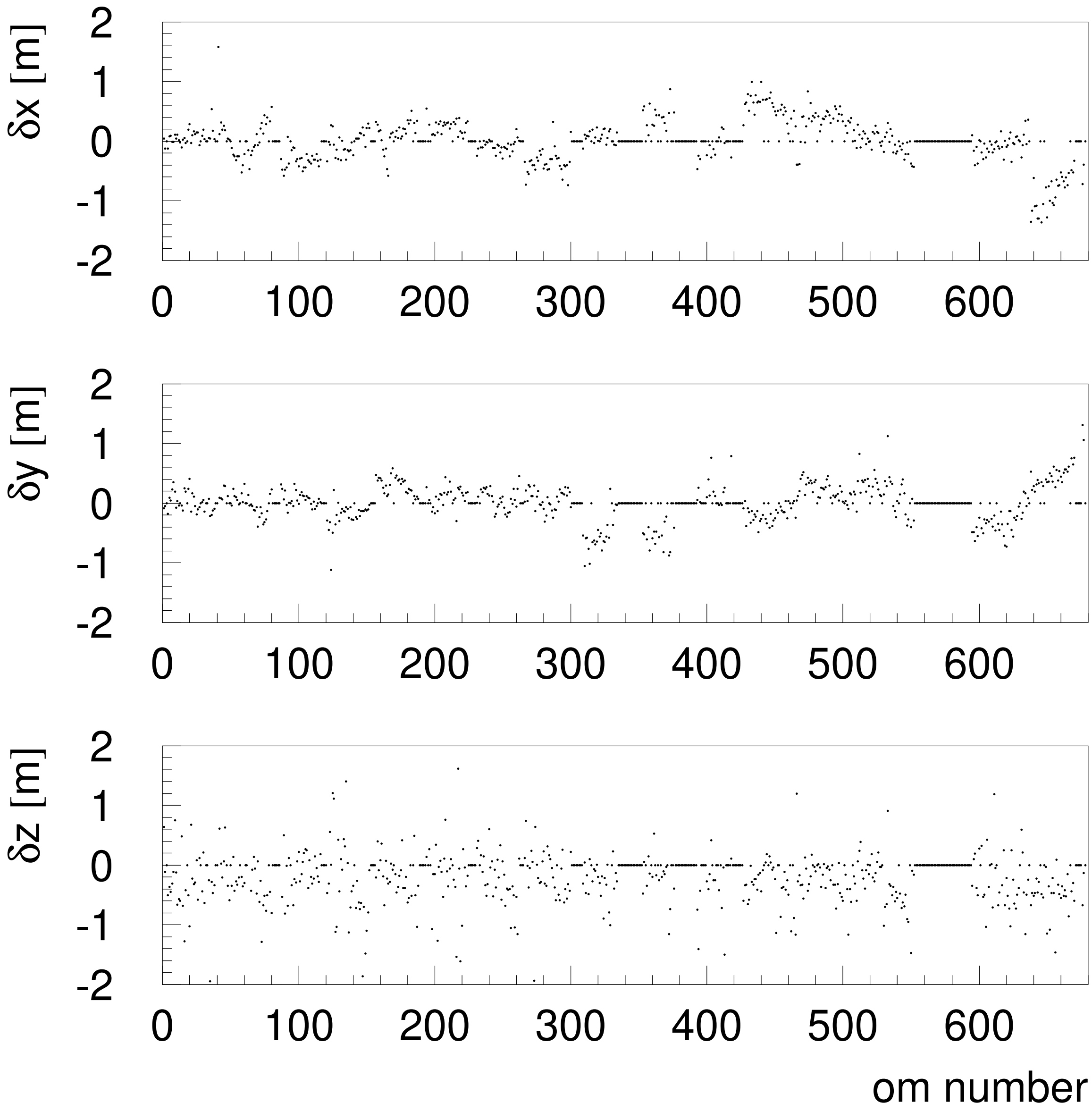
Ways to display the data

Four-dimensional surface could be difficult to visualize, but its 3d projections can be projected onto the screen. Script grid.kumac can display the data in a several different ways



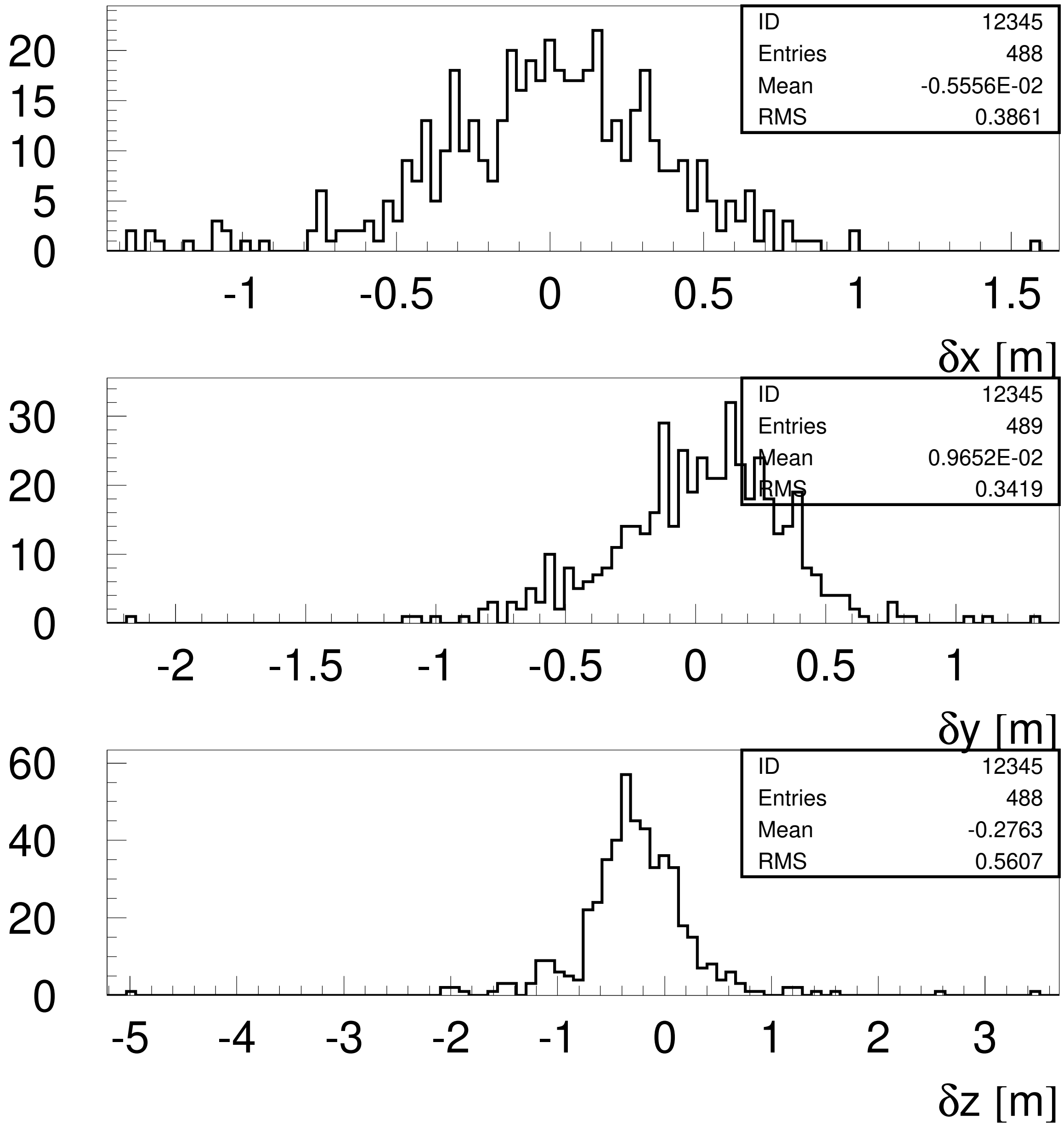
The corrections for day 55

One iteration was applied to 2 hours of day 55. Below are the corrections found



Values that appear to be zeros correspond to the OMs removed from the analysis (as a result of cleaning)

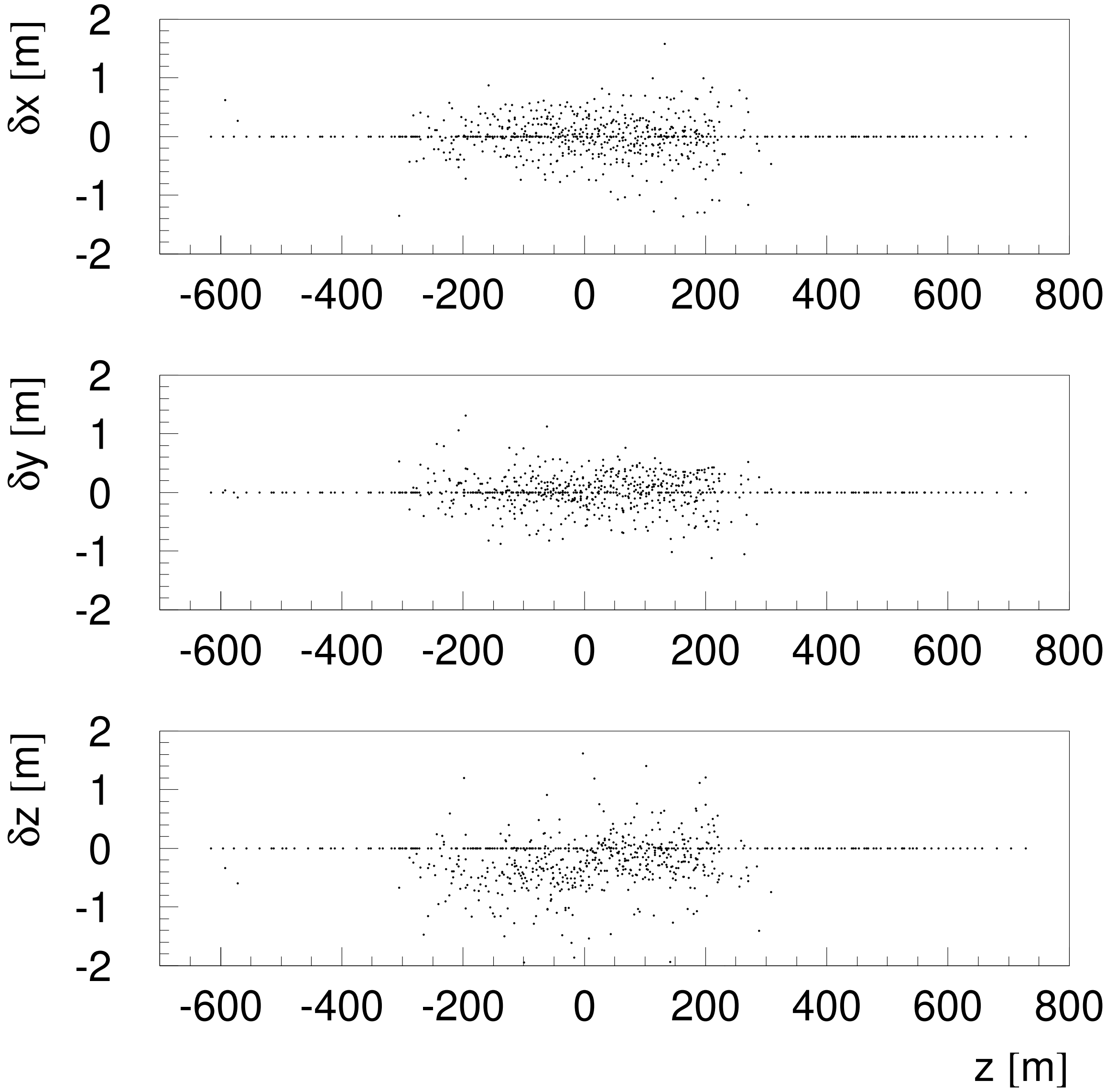
The corrections for day 55



Most corrections are within 40 cm of the calibration table values. Corrections to z are also offset down by 30 cm (weird since array cannot shift itself, the shift on average should be zero, but probably due to the up/down asymmetry of the OMs)

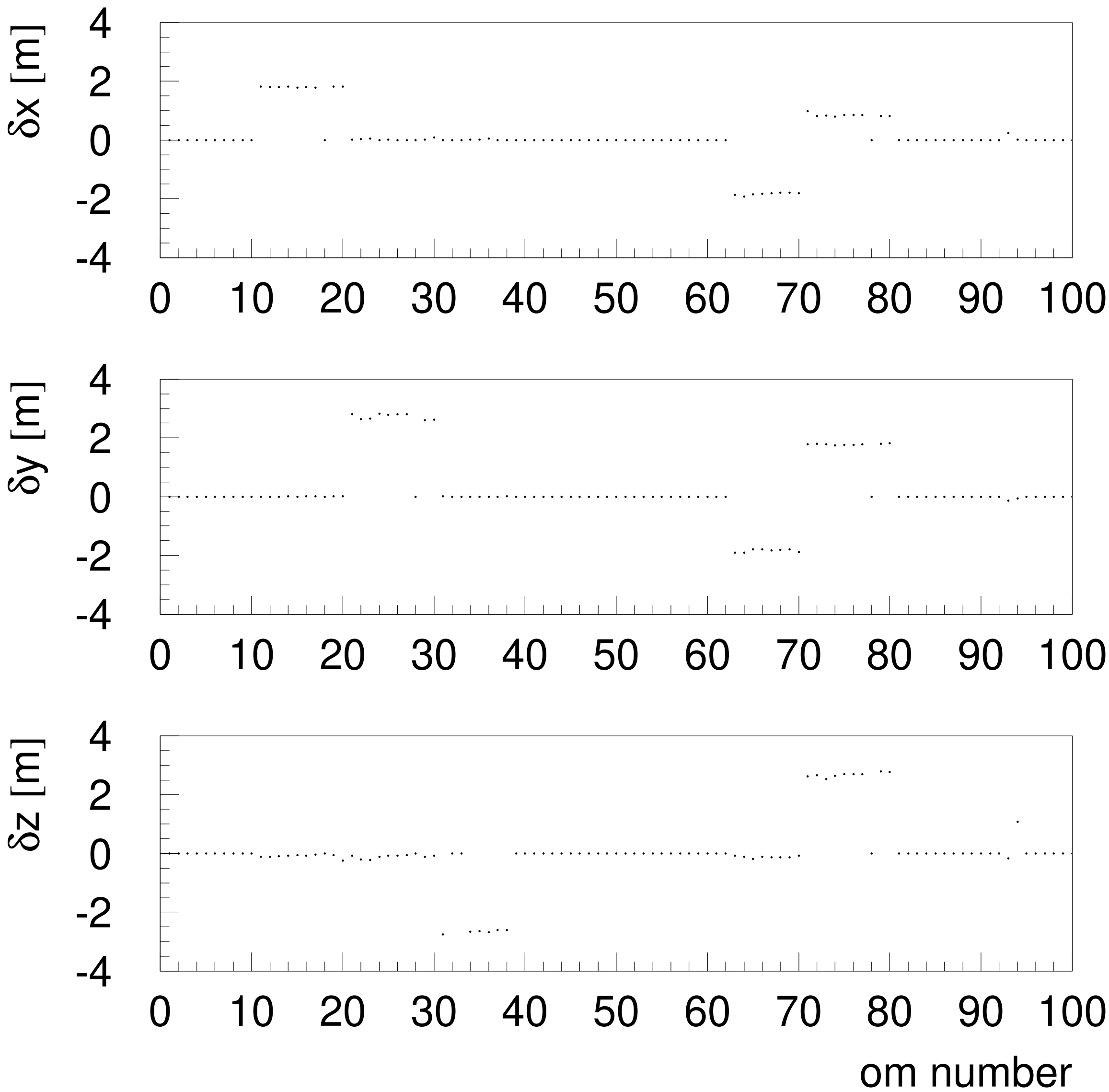
The corrections for day 55

Also plotted vs. z



Precision of the method, 1

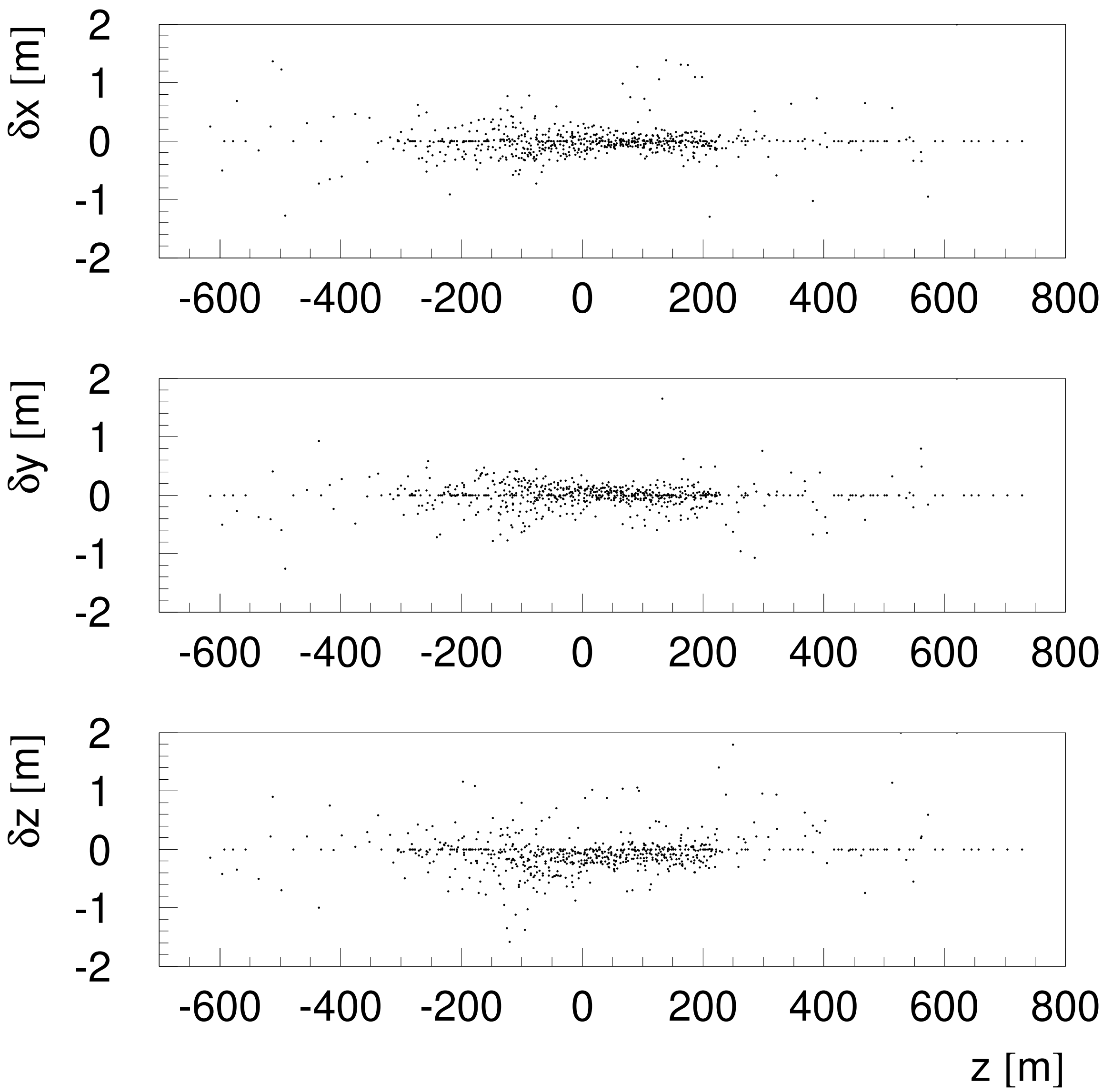
Kurt shifted some OMs by 1-5 meters in 1-3 coordinates to see if the method can find which OMs they are and how precisely they can be shifted back. Deviations here are plotted for the changed data from unchanged both processed with 1 step calculation. To locate the minimum shifted by as far at 5 meters, it was first searched on a 5x5x5 m grid and then refined on a 2x2x2 m grid



On average the found values are 10-20 cm below the given even ± 1.0, ± 2.0 or ± 3.0 m shifts

Precision of the method, 2

In order to see if the OMs in at the bottom of the strings 11, 12 and 13 are shifted with time (due to ice flow), day 55 fit was compared to day 298 fit

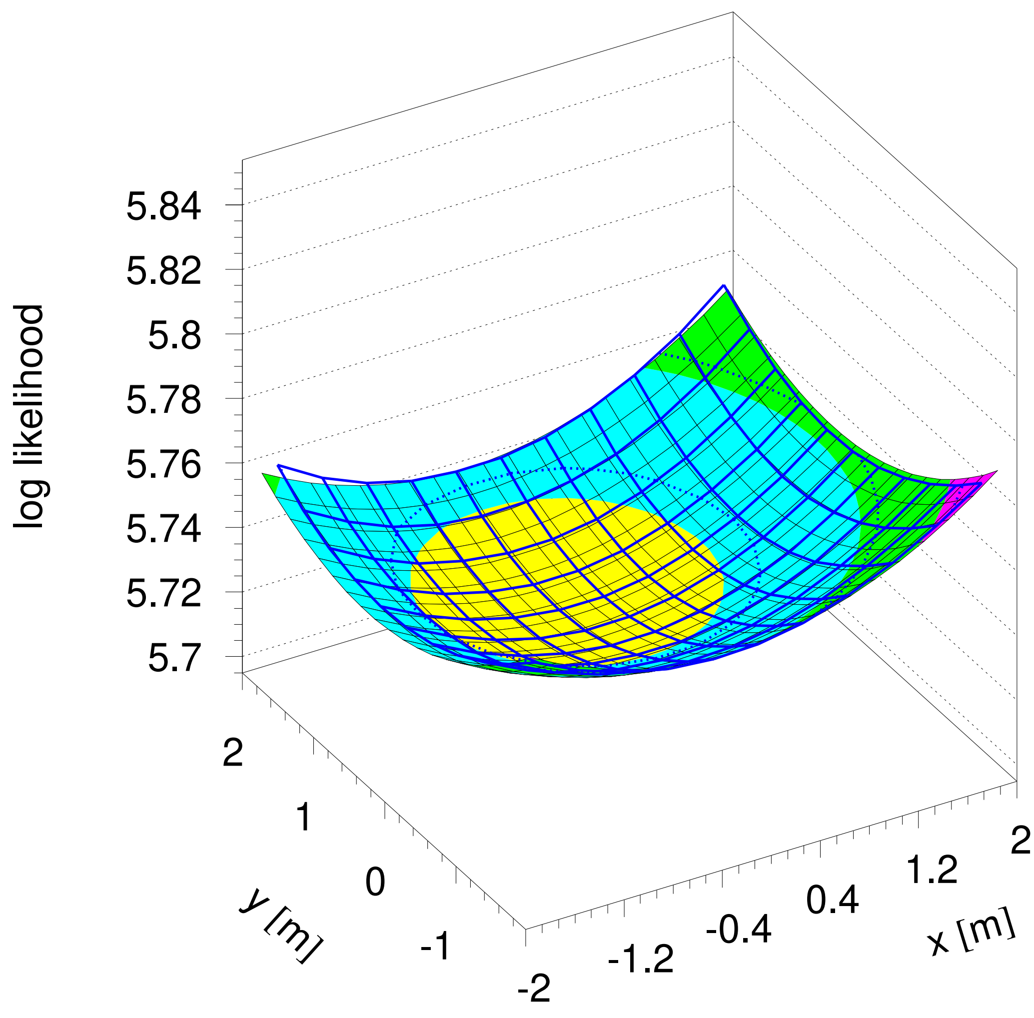


No apparent systematic shifts can be seen, although some change in the location of OMs is possible

OMs at the bottom and top

OMs at the bottom and very top of the detector are often discarded from the general analysis. Many of them appear to be in a good working order. Here is a fit for OM 344, the lowest OM in the detector

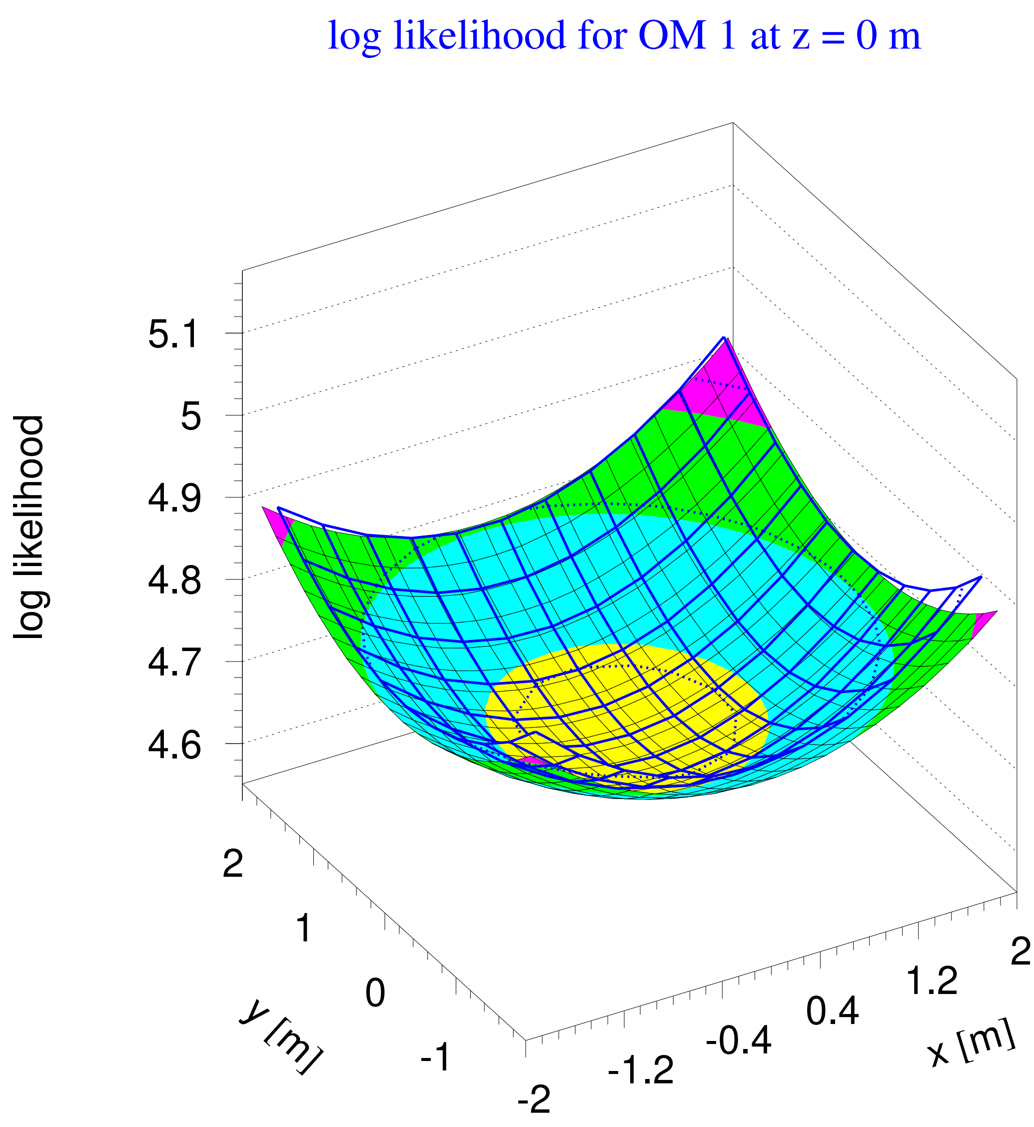
log likelihood for OM 344 at z = 0 m



x_{min} = -0.275 ± 0.209 [m]	δx_{min} = 8.70 ± 2.25 [m]
y_{min} = 0.402 ± 0.224 [m]	δy_{min} = 9.12 ± 2.55 [m]
z_{min} = -0.060 ± 0.154 [m]	δz_{min} = 6.64 ± 1.00 [m]

Precision of the method, 3

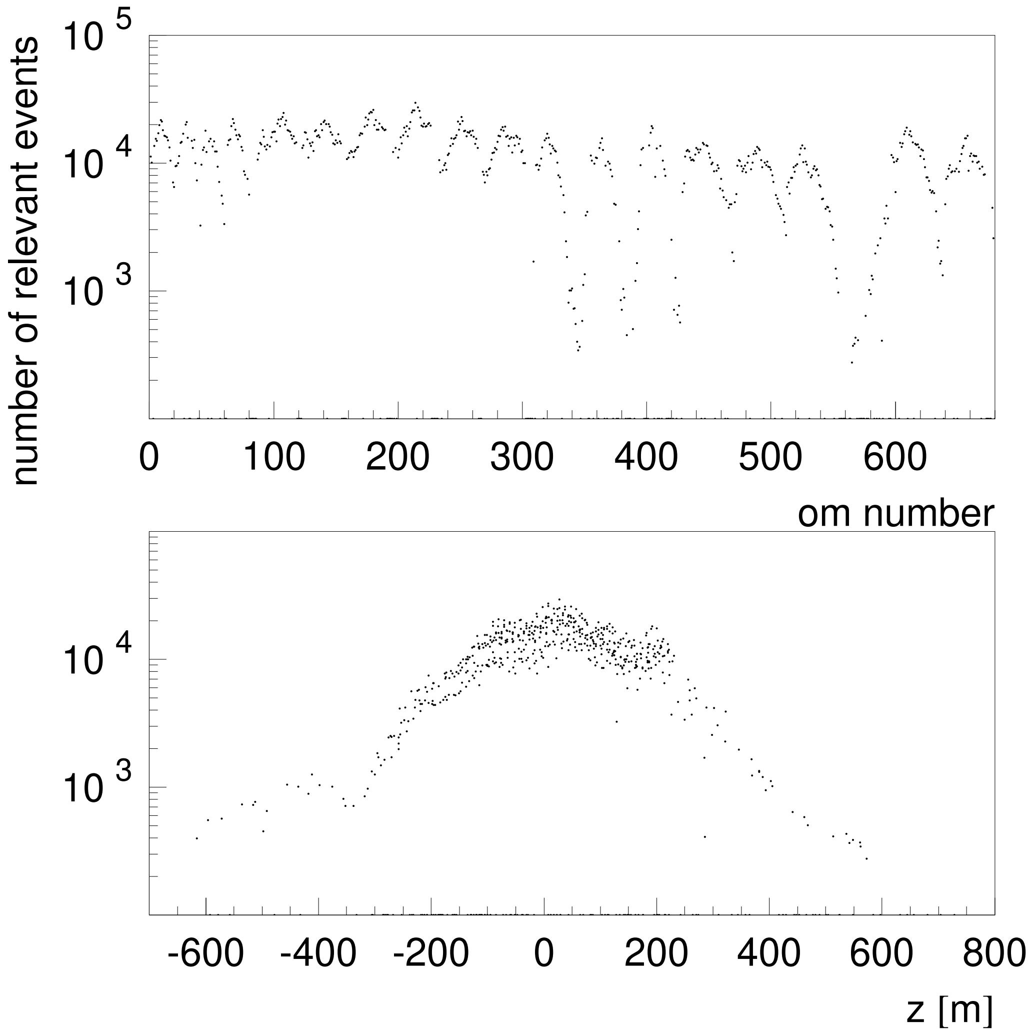
If the only acceptable events are restricted to those that produce tracks within 10 m of the OM (instead of 50), the half width of the function is reduced to about 4 m (from about 10)



$x_{min} = -0.072 \pm 0.114$ [m]	$\delta x_{min} = 3.90 \pm 0.85$ [m]
$y_{min} = -0.102 \pm 0.135$ [m]	$\delta y_{min} = 4.19 \pm 1.04$ [m]
$z_{min} = 0.140 \pm 0.105$ [m]	$\delta z_{min} = 3.55 \pm 0.65$ [m]

Precision of the method, 4

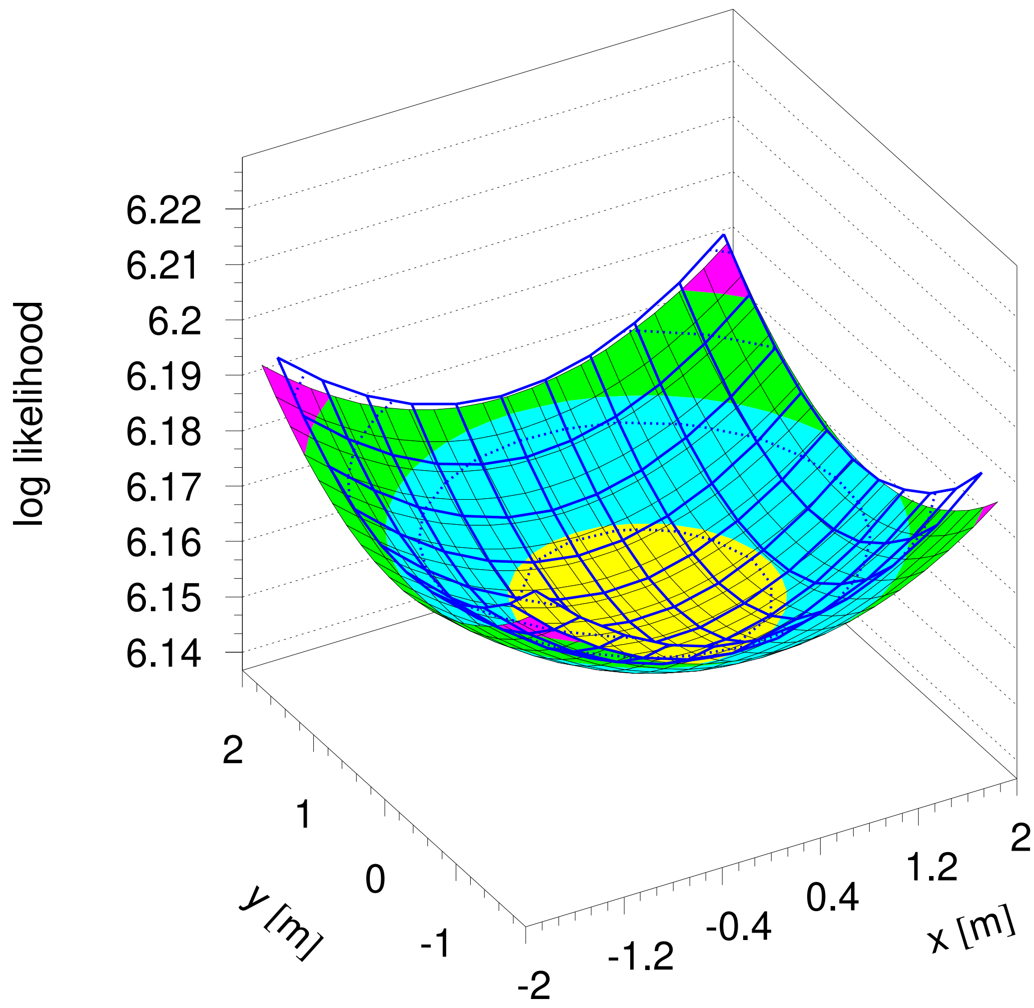
The errors in function minimum evaluation are statistical, they are the smaller the more event are relevant to the OM. These errors are smaller for the OM in the middle of the detector



Precision of the method, 4

OM 69 is in the center of the detector, the statistical errors in minimum evaluation should be smaller than for other OMs

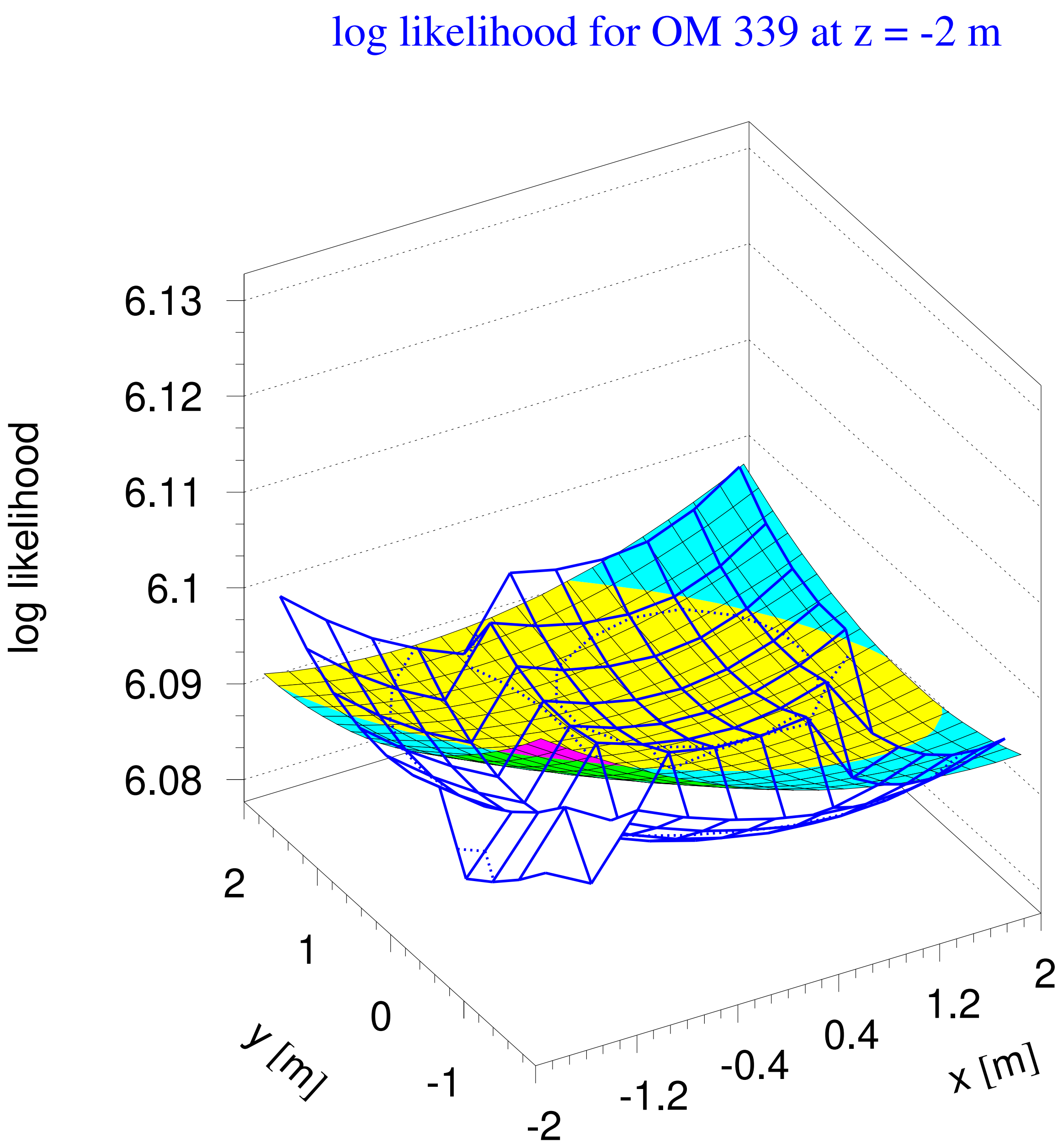
log likelihood for OM 69 at z = -0.4 m



$x_{min} = 0.112 \pm 0.051$ [m]	$\delta x_{min} = 10.19 \pm 0.71$ [m]
$y_{min} = -0.060 \pm 0.051$ [m]	$\delta y_{min} = 10.33 \pm 0.74$ [m]
$z_{min} = -0.413 \pm 0.047$ [m]	$\delta z_{min} = 9.98 \pm 0.65$ [m]

Queer OMs

And of course, there are special cases



x_{min} = 0.003 ± 0.600 [m]	δx_{min} = 20.00 ± 14.23 [m]
y_{min} = 0.800 ± 1.534 [m]	δy_{min} = 20.00 ± 12.23 [m]
z_{min} = -2.000 ± 1.496 [m]	δz_{min} = 13.90 ± 1.91 [m]

Conclusions

1. Method works, pandel function contribution to most OMs can be minimized around the OM true location (or close to it)

2. There are 2 main sources of errors:

   (a) errors in function minimization algorithm ($\sim$ 30 cm)

   (b) systematic offset of the function minimum from the true OM location (many sources of errors); expected (believed) to be of the order of 1 m. Kurt suggested these errors should be evaluated from the likelihood half width (at which it increases by 1/2), but this gives much bigger estimates ($\delta x \cdot \sqrt{3.53}$)

3. This method is very useful for providing information about the OMs at the bottom and the top of the detector

4. Analyzing only year 2000 data was insufficient to see the shift in low OMs. Looking at all years from 98 to 2001 will increase the effect (and our capability to reliably detect it) by a factor of 5.