GAP 2057-0

Comparison between Herald and Observer

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Abstract

Towards an unbiased unified energy scale.

Reconstructions

There are lots of small differences between the two reconstruction, from the implementation of the same algorithms, station signal calibration, determination of the traces start time, to physics related issues like the assumption of the shower front and of the lateral distribution of signals.

In the following we will discuss the influence of the tiny discrepancies on the final shower variables. The data have been analysed in subsets of showers determined by the number of stations that participate in the reconstruction. The reason for this is that both reconstructions are build depending on the number of stations.

The data sample consists of T5 events within a period of 5 years, from 2004 to end of 2008. The number of events exceeds 1150000. Besides the SD data comparison an assessment with the hybrid reconstruction is performed.

Shower front and axis

- number of stations. The selection of the stations participating in the event reconstruction is different for less than 0.2% of the total number of events (see Fig. 1).
- curvature. The curvature difference is illustrated in Fig. 2(a). The difference comes mainly from different assumptions of the shower front model. The Observer assumes a concentric spherical shower front, while Herald a parallel parabolic one. The difference for 3 and 4 fold events is caused by the different curvature estimations.
- The angular separation between the arrival directions is shown in Fig. 3 and the mean and the RMS are given in Table 1. The large tail for the 3 fold events is caused by the different trace cleaning algorithms, a small change in the start time of one station can cause large deviations in the zenith angle.

No of stations	Mean	RMS
3	0.7± 0.001	1.06± 0.0008
4	0.9± 0.003	1.16± 0.002
5	0.9± 0.005	1.20± 0.004
6	0.8± 0.008	1.04± 0.006
>6	0.7± 0.005	0.7± 0.004

Table 1 Angular separation

Lateral distribution influence

- The difference between the core locations in shower plane coordinate system is illustrated in Fig. 4(a).

- distance to the closest station.

  The distance from the core to the closest station is shown in Fig. 6 in shower plane coordinate system to enhance possible biases due to the lateral distribution assumption. The main differences between the two reconstruction occur for 0.1% of the events which are falling within 200 m from a tank. Both reconstructions seem to shift the core location to larger distances.

  In the case of Observer, this effect is more visible, the bump at ≈100 m is cause by saturated events that are shifted from other distances due to the condition of second derivative cut in the LDF reconstruction. The effect is ameliorated in the Herald case due to the flatness of the LDF assumption near the shower core and due to the different handling of the saturated stations.

  The shift is within the statistical uncertainties deduced from the Golden Hybrid set (see Table. 4).

- The S(1000) relative difference is illustrated in Fig. 5 and in Table 2 the mean and the RMS are given.

No of stations	Mean	RMS
3	0.06± 8e-05	0.08 ± 5e-05
4	-0.02± 0.0003	0.11 ± 0.0002
5	-0.06± 0.0005	0.12 ± 0.0004
6	-0.07± 0.0008	0.11 ± 0.0006
>6	-0.08± 0.0007	0.09 ± 0.0005

Table 2 Relative S(1000) mean and RMS for different multiplicities

Golden hybrid comparisons

The Golden Hybrid events used for this analysis were selected to have a good angular resolution. The selection criteria was:

- a reduced χ^2 for shower detector plane reconstruction smaller than 7
- a reduced χ^2 for the time fit smaller than 8
- distance to the axis smaller than 2 km
- a time offset of less than 200 ns
- the angular track length greater than 15.

The results for the shower core and for the angular separation are shown in Fig. 7 and 8 and the numbers are given in Tables 3 and 4.

No of stations	Reconstruction	30%(degree)	50% (degree)	68% (degree)	84% (degree)
3	Observer	0.94	1.35	1.84	2.58
	Herald	1.03	1.49	2.01	2.73
4	Observer	0.84	1.20	1.66	2.35
	Herald	0.92	1.32	1.79	2.57
5	Observer	0.73	1.07	1.43	2.02
	Herald	0.80	1.18	1.58	2.13
> 5	Observer	0.60	0.86	1.17	1.64
	Herald	0.71	0.99	1.31	1.76

Table 3 Angular separation from the Hybrid geometry reconstruction in degrees. The quantiles at 30, 50, 68 and 84% are given to scan the whole distribution.

No of stations	Reconstruction	30% (m)	50%(m)	68%(m)	84%(m)
3	Observer	81	119	164	235
	Herald	85	125	172	244
4	Observer	81	123	176	265
	Herald	89	133	194	290
5	Observer	76	116	166	246
	Herald	91	136	193	284
> 5	Observer	77	116	167	240
	Herald	85	130	185	268

Table 4 Core location comparison with the Hybrid geometry reconstruction in m. The quantiles at 30, 50, 68 and 84% are given to scan the whole distribution.

Attenuation and energy calibration

The attenuation curves have been produced for both data sets for different intensities. The functional shape was assumed:

$$f(x) = 1 + a \cdot x + b \cdot x^2, \tag{1}$$

where $x = cos^2\theta - cos^2 38$. The obtained parameters for an intensity corresponding to S_{38°=47 VEM are

$$a = 0.90 \pm 0.05 \tag{2}$$

$$b = -1.26 \pm 0.21 \tag{3}$$

in the case of the Observer and

$$a = 0.94 \pm 0.05 \tag{4}$$

$$b = -0.94 \pm 0.22 \tag{5}$$

in the case of Herald. At lower energies, S_{38°=25 VEM the parameters are:

$$a = 0.91 \pm 0.03 \tag{6}$$

$$b = -1.25 \pm 0.16 \tag{7}$$

in the case of the Observer and

$$a = 0.95 \pm 0.04 \tag{8}$$

$$b = -0.83 \pm 0.16 \tag{9}$$

in the case of Herald. The parameters as a function of S_{38° are illustrated in Fig. 9(a) and 9(b). For both reconstruction they are stable with respect to the intensity (i.e. energy)within their uncertainties. The two obtained attenuations, shown in Fig. 9(c) and 9(d), are compatible within 6%. (A study on the effect of different LDF assumptions on the attenuation curve has been performed for example in GAP2006-070, where similar values were obtained).

Even though the complete analysis for the attenuation curve has been performed with the same codes for both reconstructions, the S_{38° is still not the same. The zenith angle dependency of the S_{38° has been greatly improved (see Fig. 10(c)) with respect to the S(1000) dependency. The distribution is flat above $cos^2\theta = 0.35$ (54 degrees). There persists a difference for a S_{38° smaller than 15 VEM ($\log_{10}(S_{38^\circ}) < 1.2$) and there is a flattening at higher values with a mean of 5%. Therefore a complete energy calibration has to be done with the Herald reconstruction in order to obtain a unique energy scale.

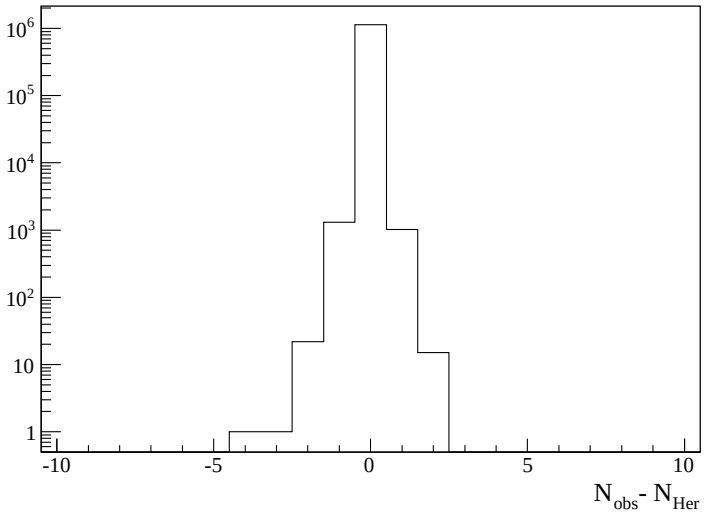
The energy relative difference as a function of the mean energy is illustrated in Fig. **??**. A large difference is observed at energies bellow the trigger threshold. In the highest energy range the difference is at the level of a few percent.

Outlook

The present analysis in ongoing. A detailed inspection of the highest energy events is on the way. Also a independent energy calibration, which is supposed to solve the final details on the energy assignment for the Herald data is being performed. The tails of the distributions are currently under investigation from both reconstructions sides.

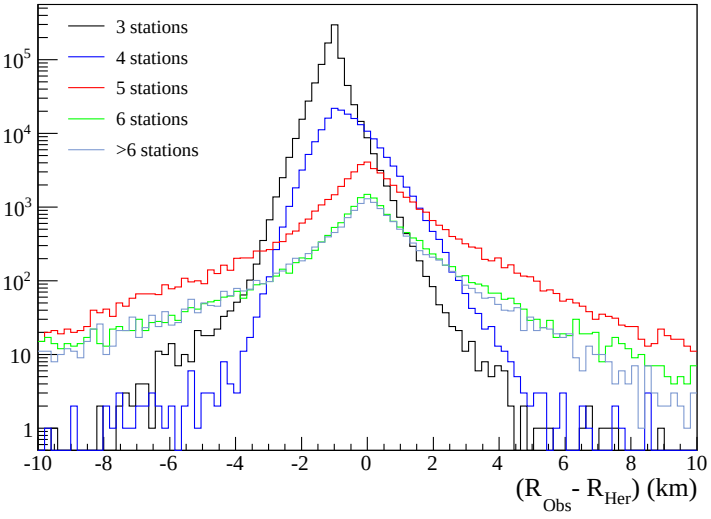
No of stations	Mean	RMS
3	0.076 ± 7e-05	0.07± 5e-05
4	-0.007± 0.0002	0.10± 0.0002
5	-0.047± 0.0005	0.12± 0.0004
6	-0.058± 0.0008	0.10± 0.0006
>6	-0.059± 0.0006	0.08± 0.0005

Table 5 Relative S_{38° mean and RMS for different multiplicities



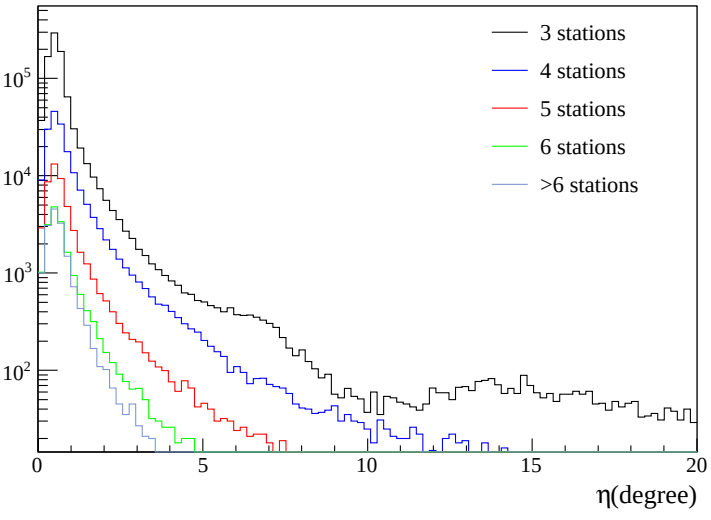
(a) *number of stations*

Figure 1 Number of stations difference.



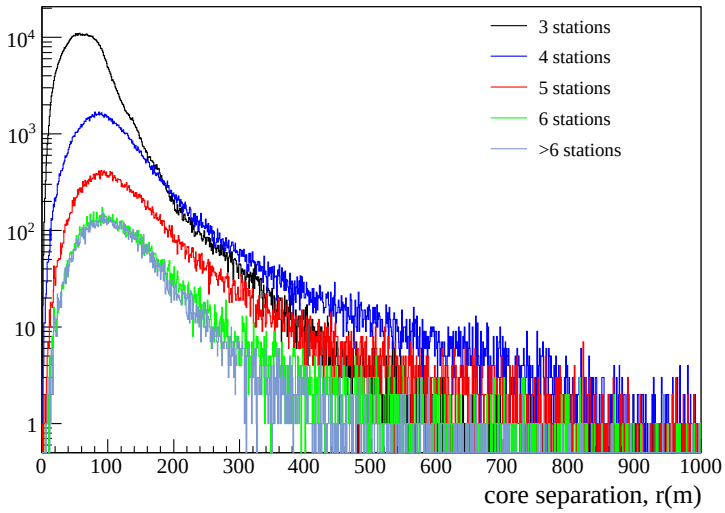
(a) *radius of curvature*

Figure 2 Radius of curvature.



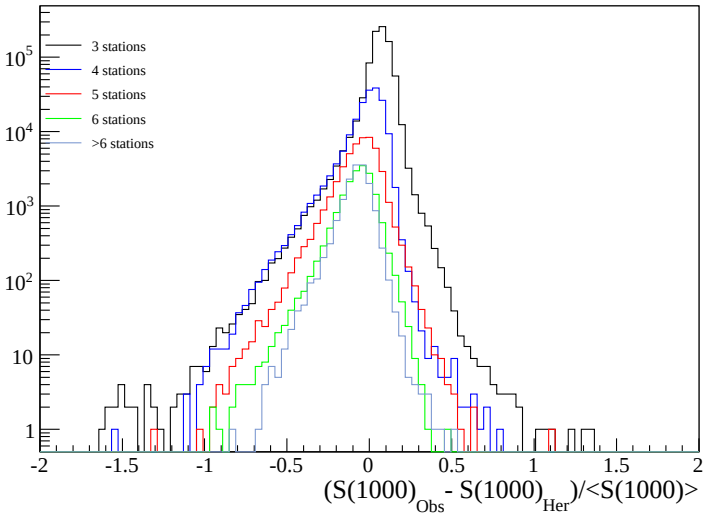
(a) *angular separation (v5r2)*

Figure 3 Angular separation.

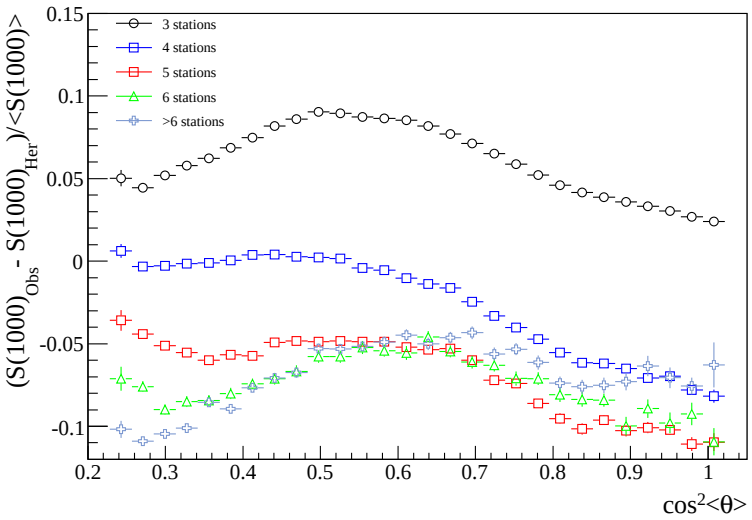


(a) *relative difference*

Figure 4 Core difference.

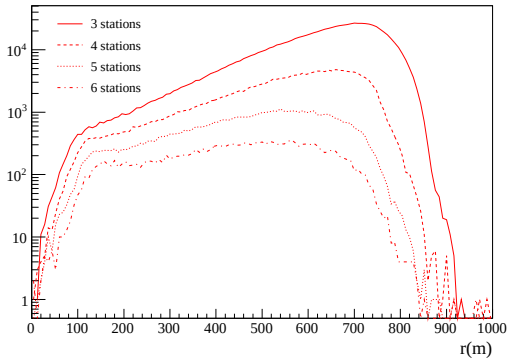


(a) *relative difference*

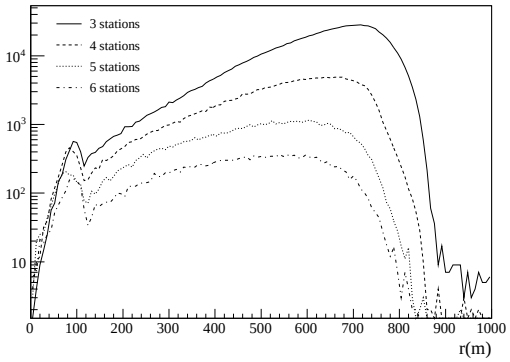


(b) *relative difference*

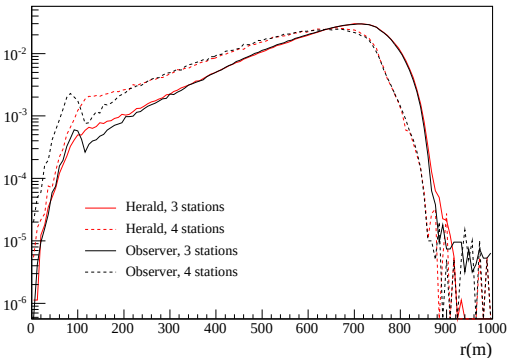
Figure 5 The distribution of events as a function of the distance to the closest station in the shower plane coordinate system.



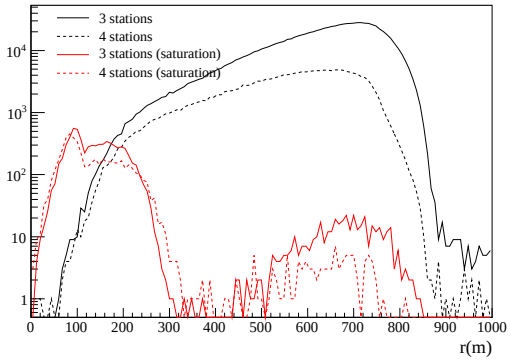
(a) *Herald*



(b) *Observer*

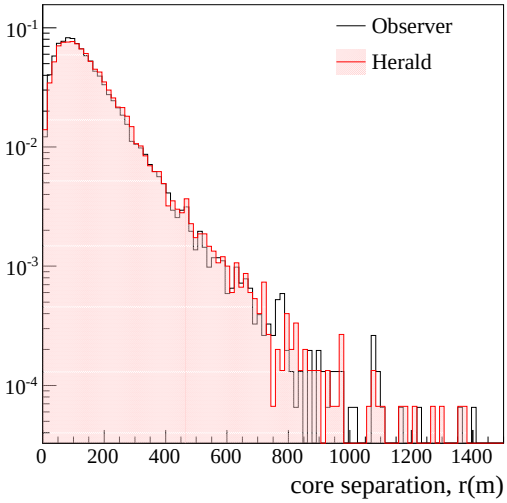


(c) *normalised distributions*

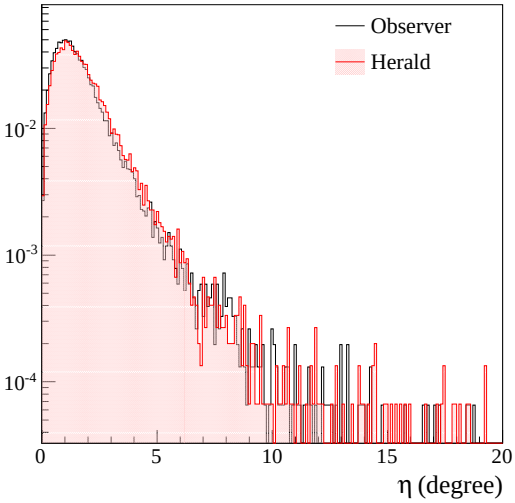


(d) *Observer, saturation*

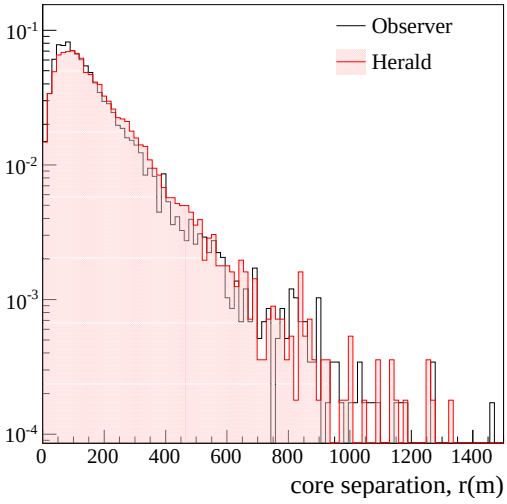
Figure 6 The distribution of events as a function of the distance to the closest station in the shower plane coordinate system.



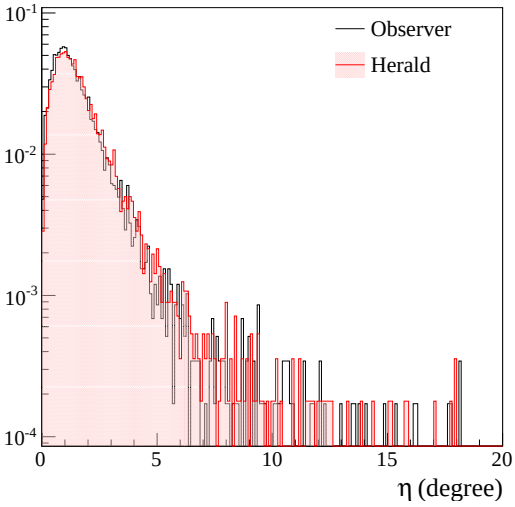
(a) *3 stations*



(b) *3 stations*

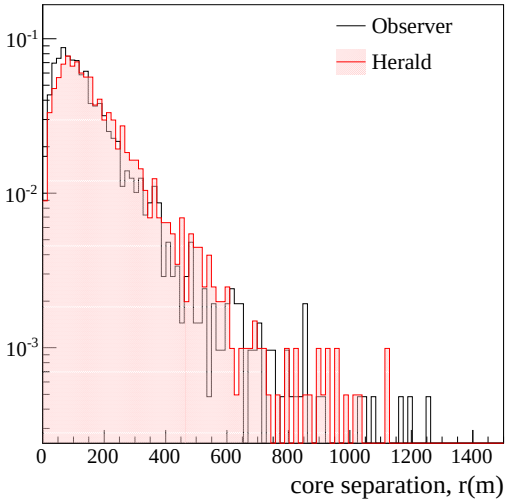


(c) *4 stations*

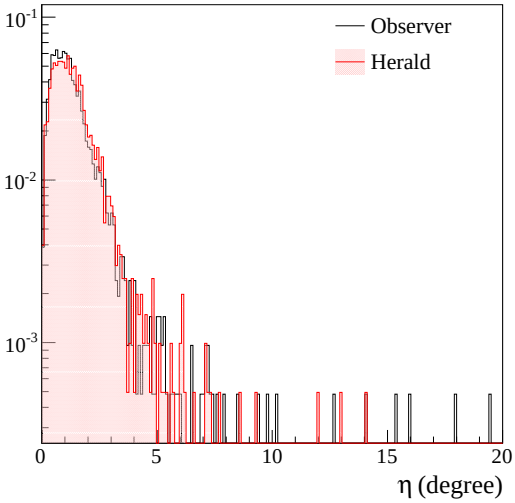


(d) *4 stations*

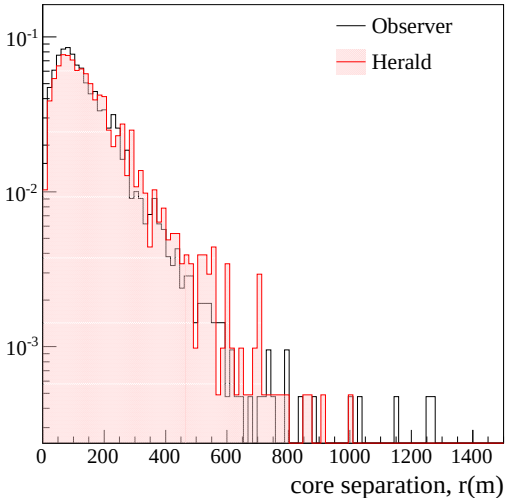
Figure 7 The difference to the golden hybrid reconstruction.



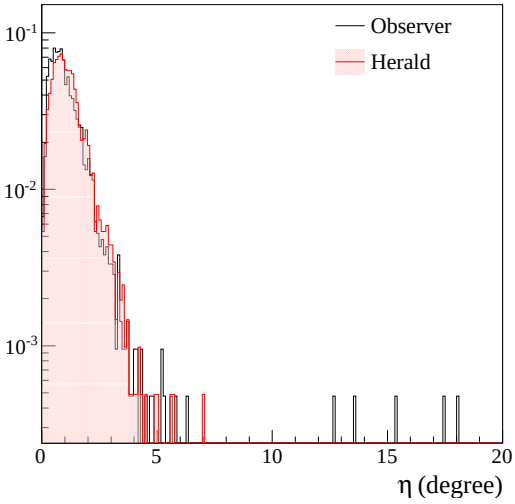
(a) *5 stations*



(b) *5 stations*

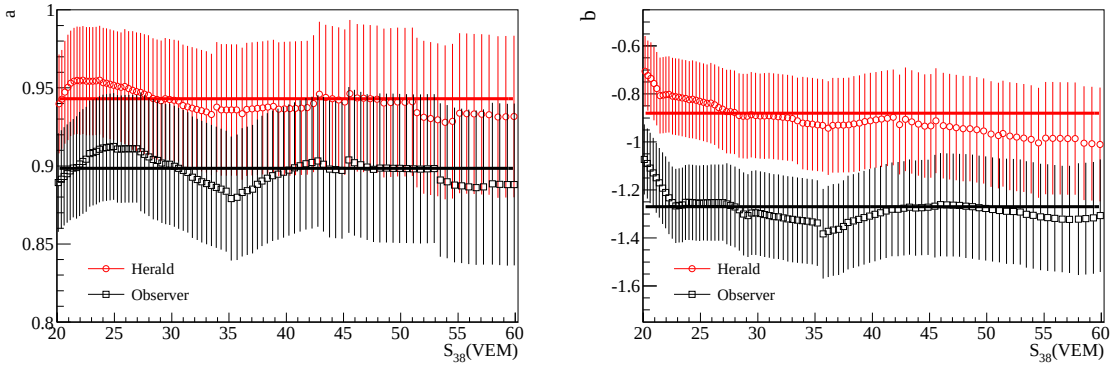


(c) *more than 5 stations*

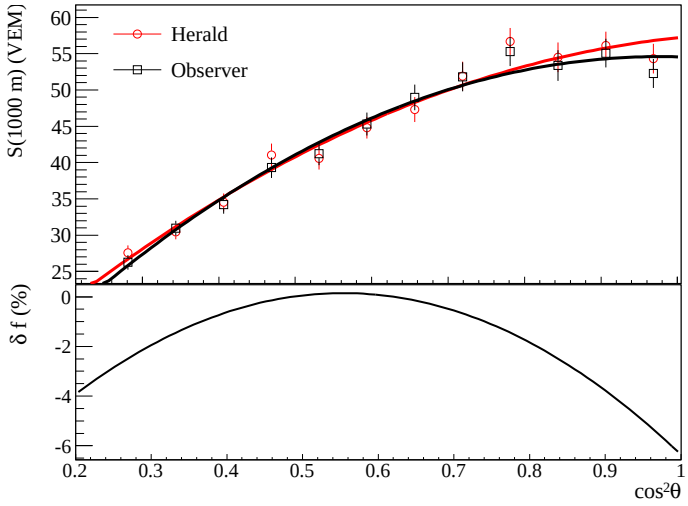


(d) *more than 5 stations*

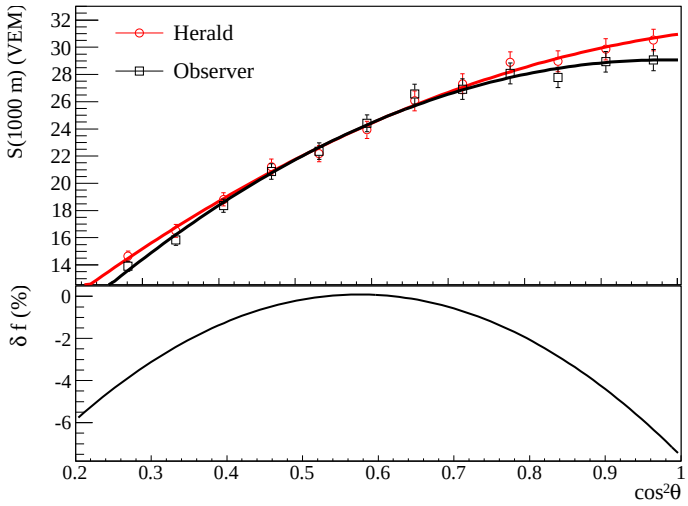
Figure 8 The difference to the golden hybrid reconstruction.



(a) *first parameter* (b) *second parameter*

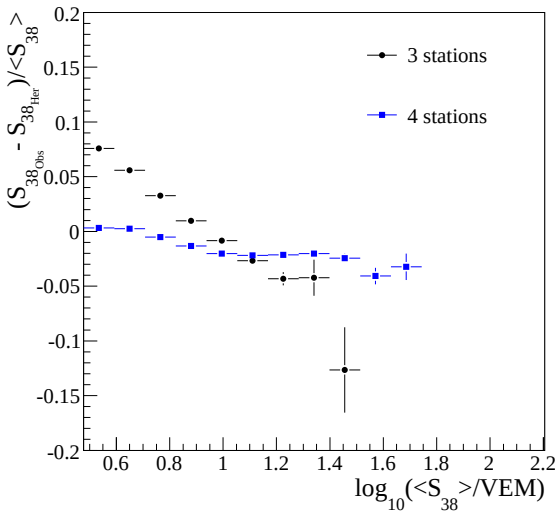


(c) *attenuation at 47 VEM*

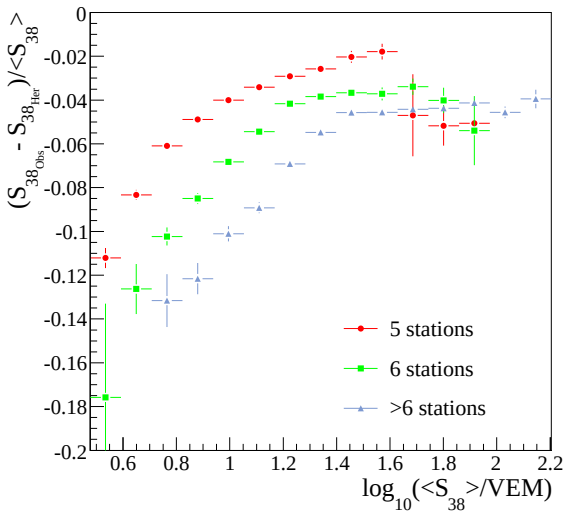


(d) *attenuation at 25 VEM*

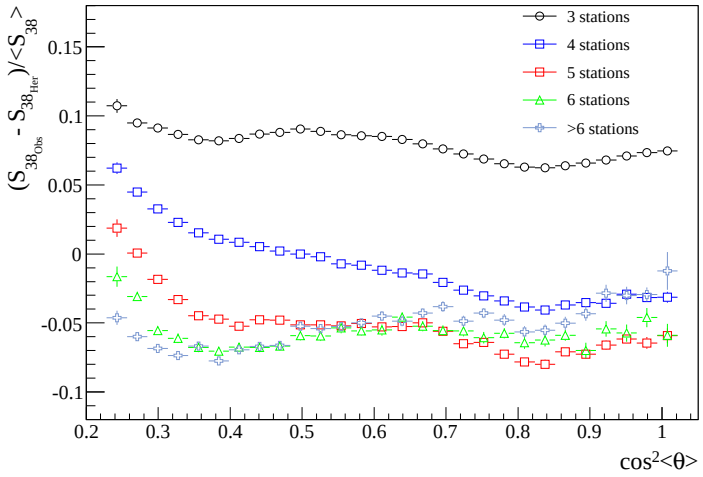
Figure 9 Differences in the attenuation curves. The two parameters are shown as a function of S_{38°, i.e. the intensity cut.



(a) *low multiplicity*

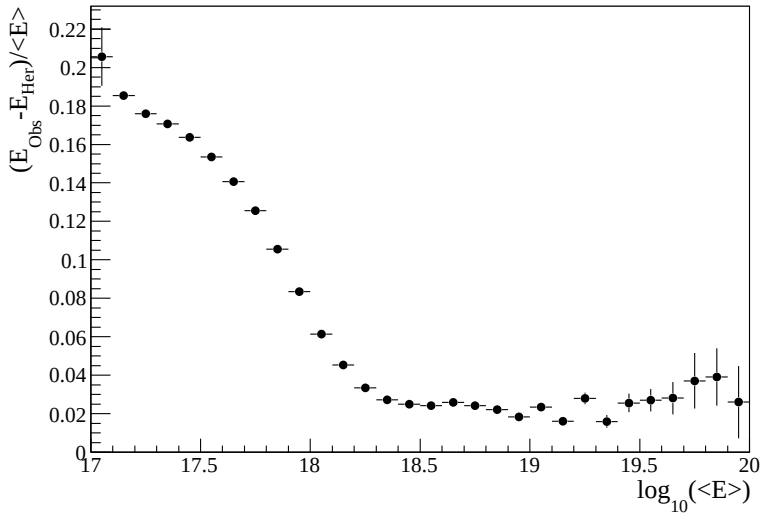


(b) *high multiplicity*



(c) *zenith angle dependence*

Figure 10 Differences in S_{38°.



(a)

Figure 11 Relative energy difference. Above $\log_{10}(E/\mathrm{eV}) = 18.4$ there is a constant underestimation of the energy in the Herald data with respect to the Observer energies of about 3% to 4%.