The Beam Energy Report

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In the last week I have been trying to determine the beam energy fluctuations during the Threshold Pi0 experiment (E04-007). In this short report I would like to show you some preliminary results of my work.

In my analysis I have considered three sets of data. First I examined the data that are stored in the HALOG . I have considered entries that are automatically generated at the beginning and at the end of each run. With a use of simple shell scripts I was able to read all the necessary data from these files. I was particularly interested in length of each run, Hall A beam energy, Hall A beam current, Hall C energy and Hall C current. Unfortunately I was not able to extract these information from all runs, because some of them, due to different errors (e.g. ROC crash), do not have both start and stop entries. Therefore I have taken into consideration only those "good" runs that have both HALOG entries. I should also stress out that, for now, I have analyzed only runs that were run in April.

After that I have checked the information that are stored in the "db_run.dat" file. I was able to read the beam energy, run time and run number from this file. I have found out that energies, that are recorded in the db_run files do not match those in the HALOG entries. Therefore I am wandering, which energy (e.g. from the beginning, in the middle or at the end) is stored in the db_run.dat file?

The third set of data are those that are recorded in each run separately. I have examined these information only for a few (more or less) randomly chosen runs.

The First Part of the Analysis

In the beginning of my analysis I have quickly taken a look of how length of a run varies with the run number. Results are shown in figure 1. The difference in the length of runs is of course due to different beam currents and many beam trips that encountered during runs.

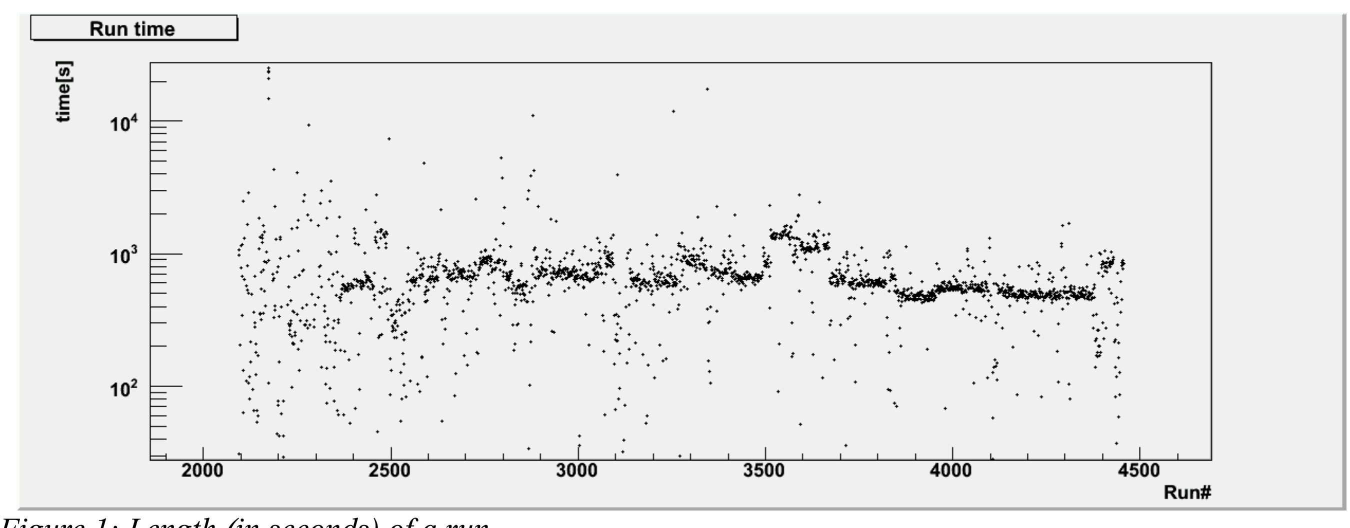

Figure 1: Length (in seconds) of a run .

After that I examined how beam energy changes with a run number. Figure 2 shows data from the HALOG and the db_run file. The blue line corresponds to the beam energy at the beginning of a run, the black line shows the energy at the end of a run, and the green line shows the beam energy, that is read from the the database file. In addition to this graph I have also plotted the difference between the energy at the end of a run and at the beginning of a run. From that graph we can see that the energy can change up to a few MeV , or even more, during some runs. From graphs in figure 2 is also evidently that the beam energy fluctuations are large for runs with run numbers below approx. 3600, whereas for runs with run numbers greater than 3600, the beam energy seams to be, with few exceptions, very stable.

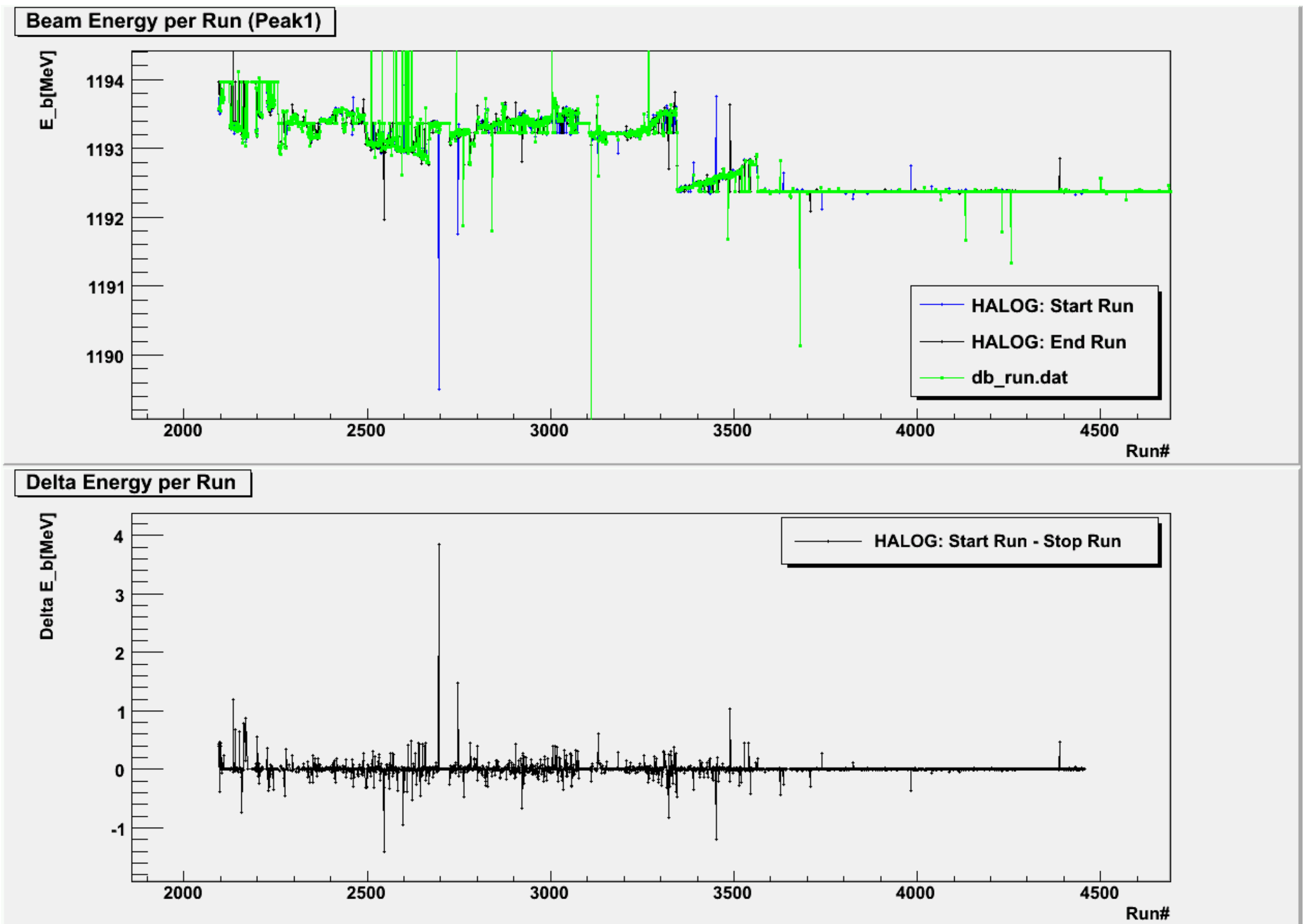

Figure 2: Beam energy for different run numbers and from different sets of data (HALOG, db_run.dat)

If we make a simple assumption that the beam energy changes linearly during each run, we can estimate the energy gradient for a given run. I have plotted these gradients for each run in a figure 3. There are also two histograms that show the distribution of these gradients (or just energy differences between the beginning and the end of a run). As expected we get a peak around the zero energy difference with long tails which indicate that there are some runs with big energy differences.

Using the same assumption of a linear trend of the beam energy in a run, we can also calculate the average beam energy for each run from “start” and “stop” energy, using the arithmetic mean formula. I believe that this mean value is a good first approximation of beam energy. It seems reasonable to use this value if we don't know, how energy changes during each run.

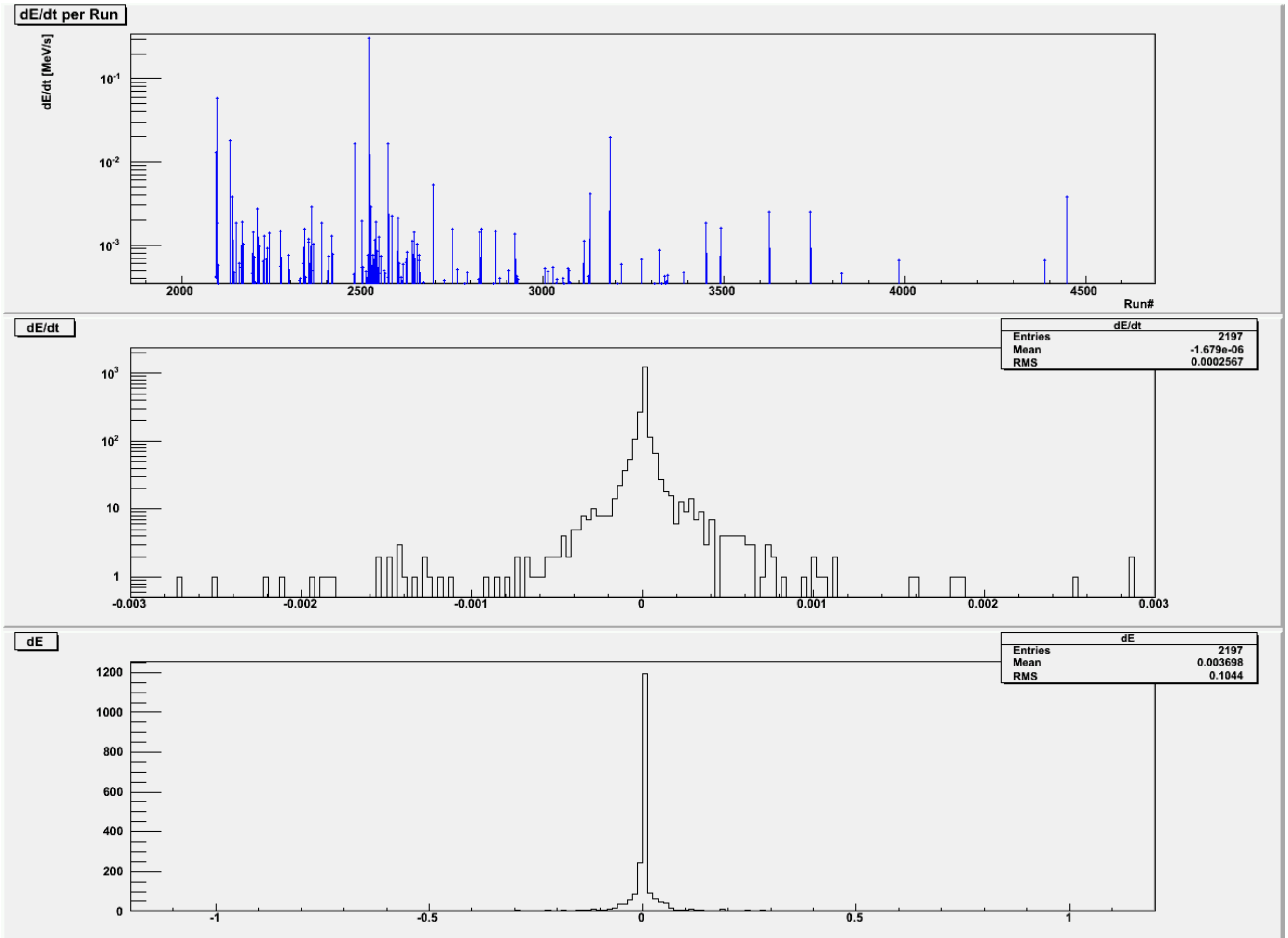

Figure 3: First graph shows the energy gradient for all analyzed runs. The second and the third graph show the distribution of energy gradient.

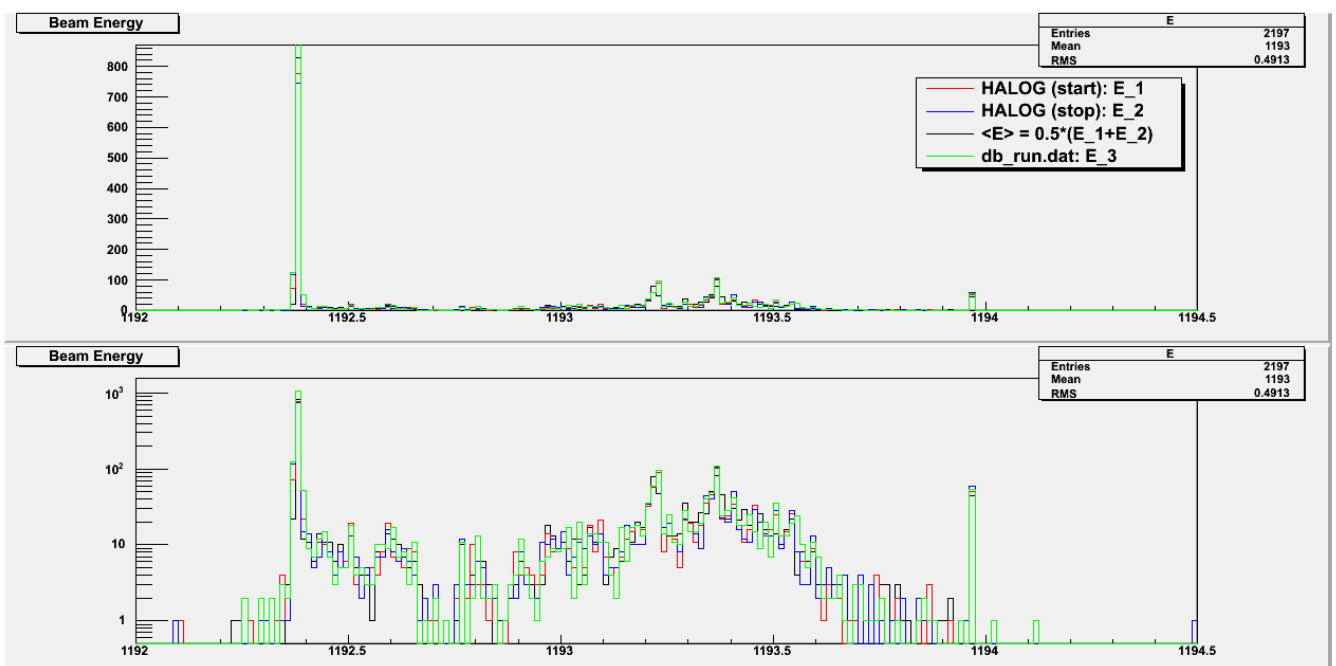

Figure 4: Energy distributions for different sets of data.

Figure 4 shows the distribution of “average” beam energy, “start” and “stop” energies and “db” beam energy. In the given energy spectrum we get four distinct peaks. That means that there are four beam energies that are most commonly met. However there are also many runs where beam energies are more or less randomly distributed.

I was also trying to determine if there is some correlation between the Hall A beam energy and the beam current, which is also changing dramatically with the run number (see figure 5). I made 2D scatter plots of beam current (or it's gradient) versus beam energy (or it's gradient). From the results that are shown in figure 6 we can see, that there are no noticeable correlation between the beam energy and beam current.   Therefore I made a step further and tried to determine if Hall A energy somehow depends of the Hall C beam current (see figure 7), but I didn't found any correlation here either .

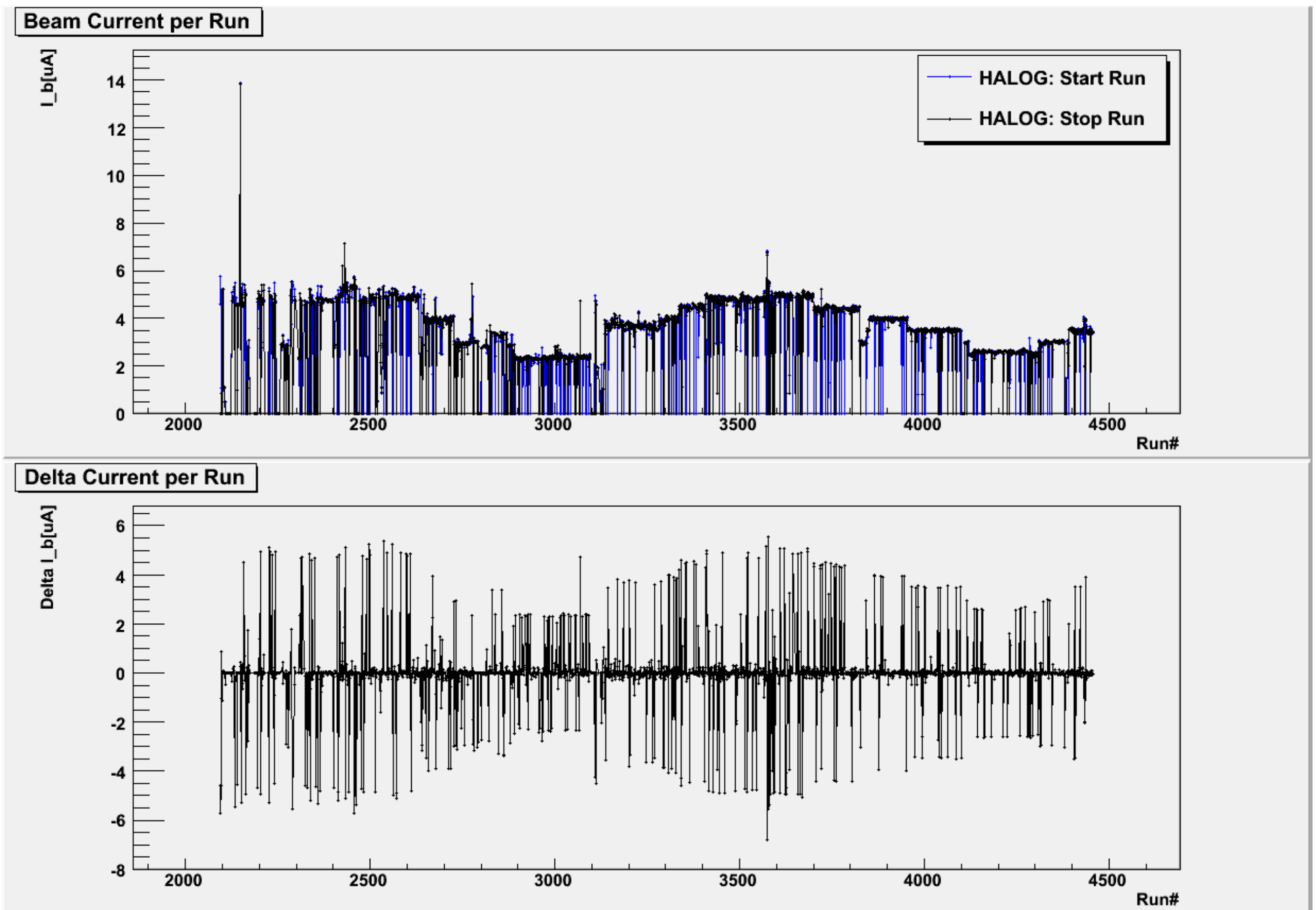

Figure 5: The upper graph shows the beam current at the beginning and at the end of each run. The lower graph shows the difference between these two currents.

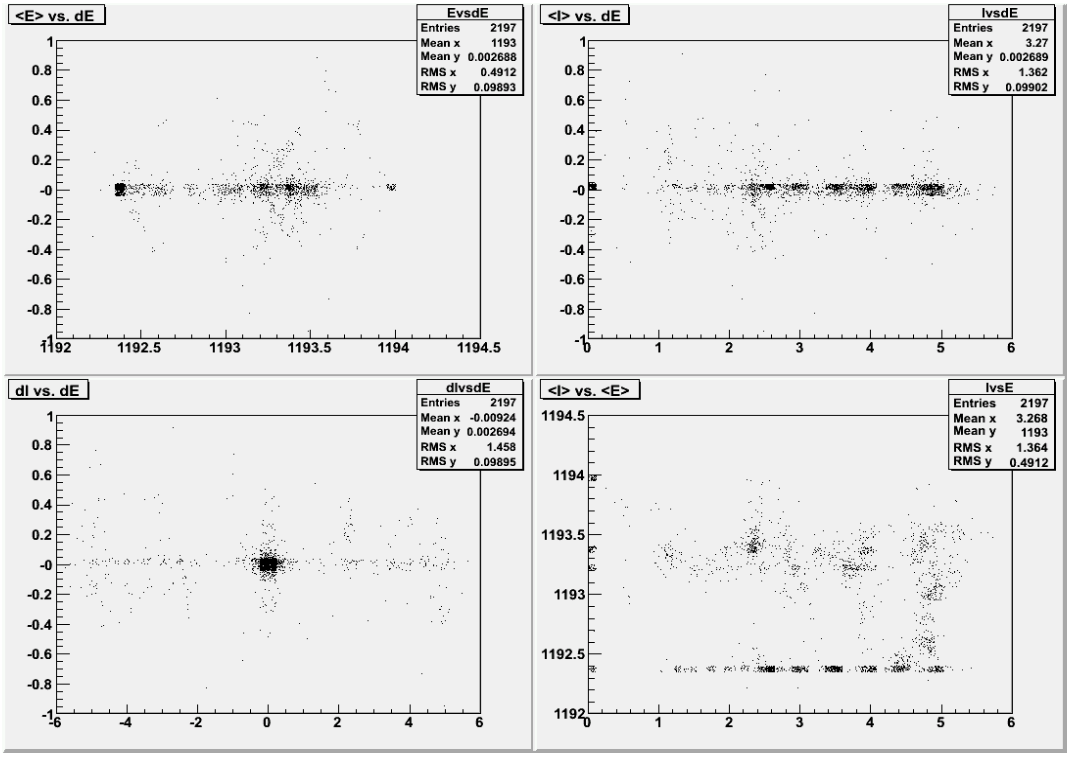

Figure 6: Graphs show how beam energy and beam energy gradient depend on the beam current and the beam current gradient.

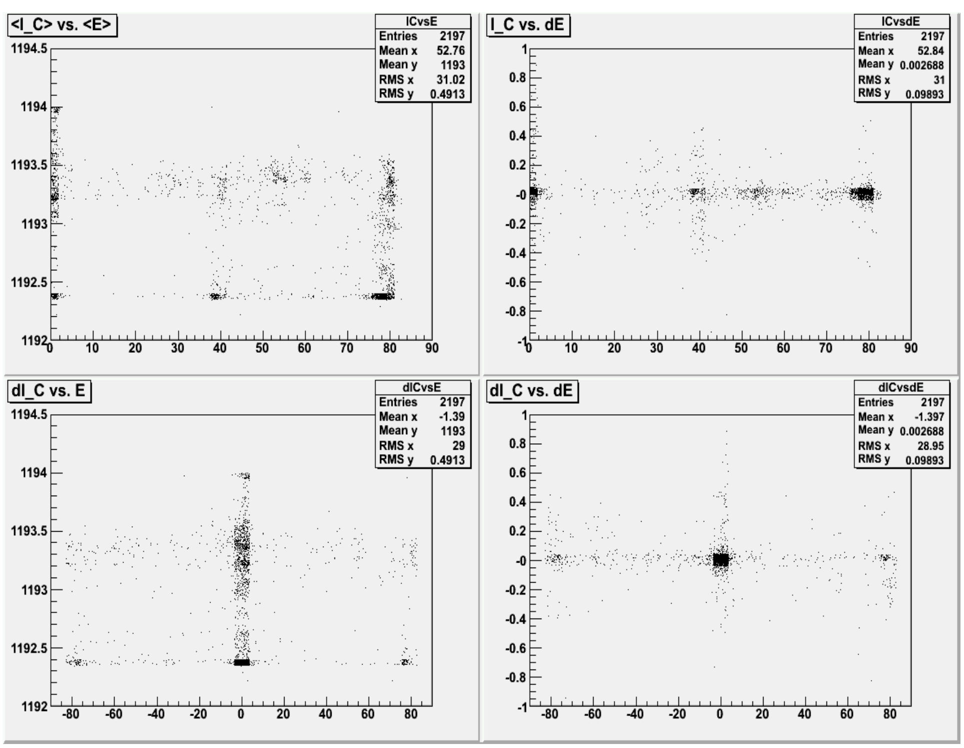

Figure 7: Figures show how Hall A beam energy and it's gradient depend on the Hall C current and it's gradient.

The Second Part of the Analysis

From the "general" analysis in the first part I have concluded that we can not determine an "average" value of a beam energy, that we could use for all runs, or for a set of runs. Because of the pronounced energy oscillations I believe that we should use for each run a different value of the beam energy . The question is how to determine the best estimation of the beam energy for a given run. As I see it, we have two options available. The simple way is to use beam energy values from the HALOG or the db_run file. The hard way is to extract the EPICS information from every run and calculate the average beam energy. The second option is of course most accurate but also most time consuming. Therefore I have tried to determine the error that we would make, if we would use the energy value from the HALOG or the db_run file instead of the true energy value.

I my analysis have taken 19 different runs (see figure 8) and read the energy values out of them using the Linux "grep" command (see http://www.jlab.org/~adaq/halog/html/0804_archive/080420082604.html or http://hallaweb.jlab.org/experiment/E02-013/expdocs/dstruct.html).

While I was extracting energy information from different runs I came across some runs, that didn't include any EPICS information. I read in the HALOG (http://www.jlab.org/~adaq/halog/html/0804_archive/080420105948.html) that during the experiment there was a problem with EPICS information being recored in the data stream. This problem affected runs with run numbers from 3345 to 3502 (the red band in the figure 8).

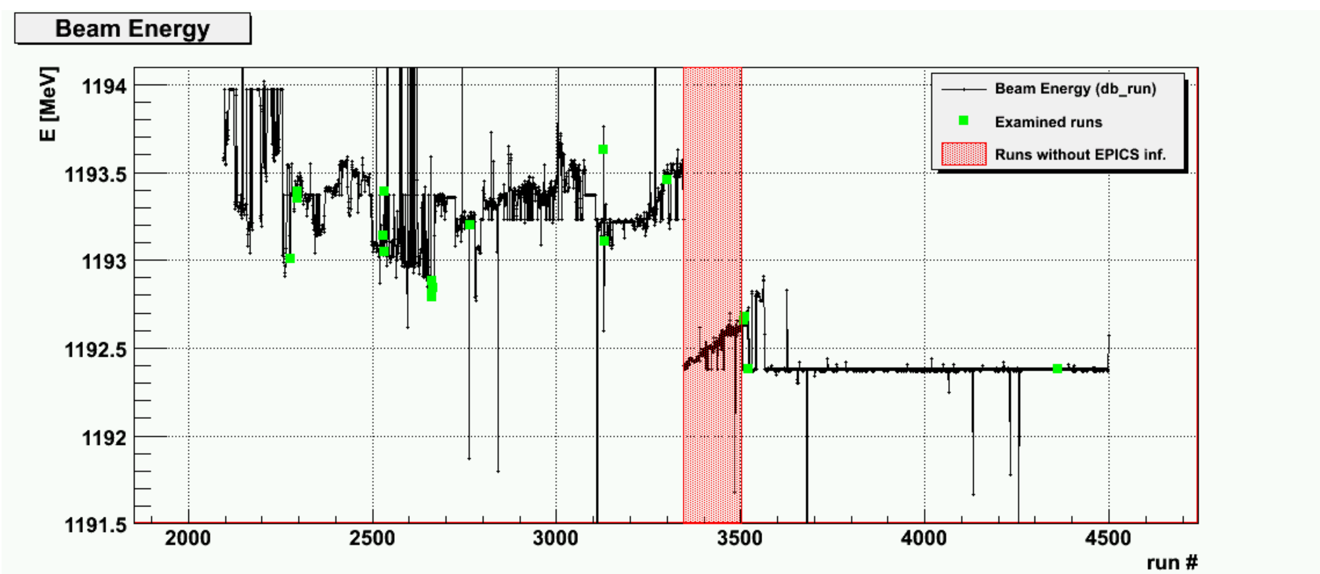

Figure 8: The black line shows how Hall A beam energy changes with the run number. Green squares denote runs that I have analyzed. The red region represents those runs that do not include EPICS information.

From every analyzed file I got an array of values (approx. 100 points) which correspond to beam energies recorded at different times during each run. From these values I was then able to calculate the average energy for a given run and it's standard deviation (see figure 9). I believe that this is the most accurate estimation of the energy that we can use in the analysis.

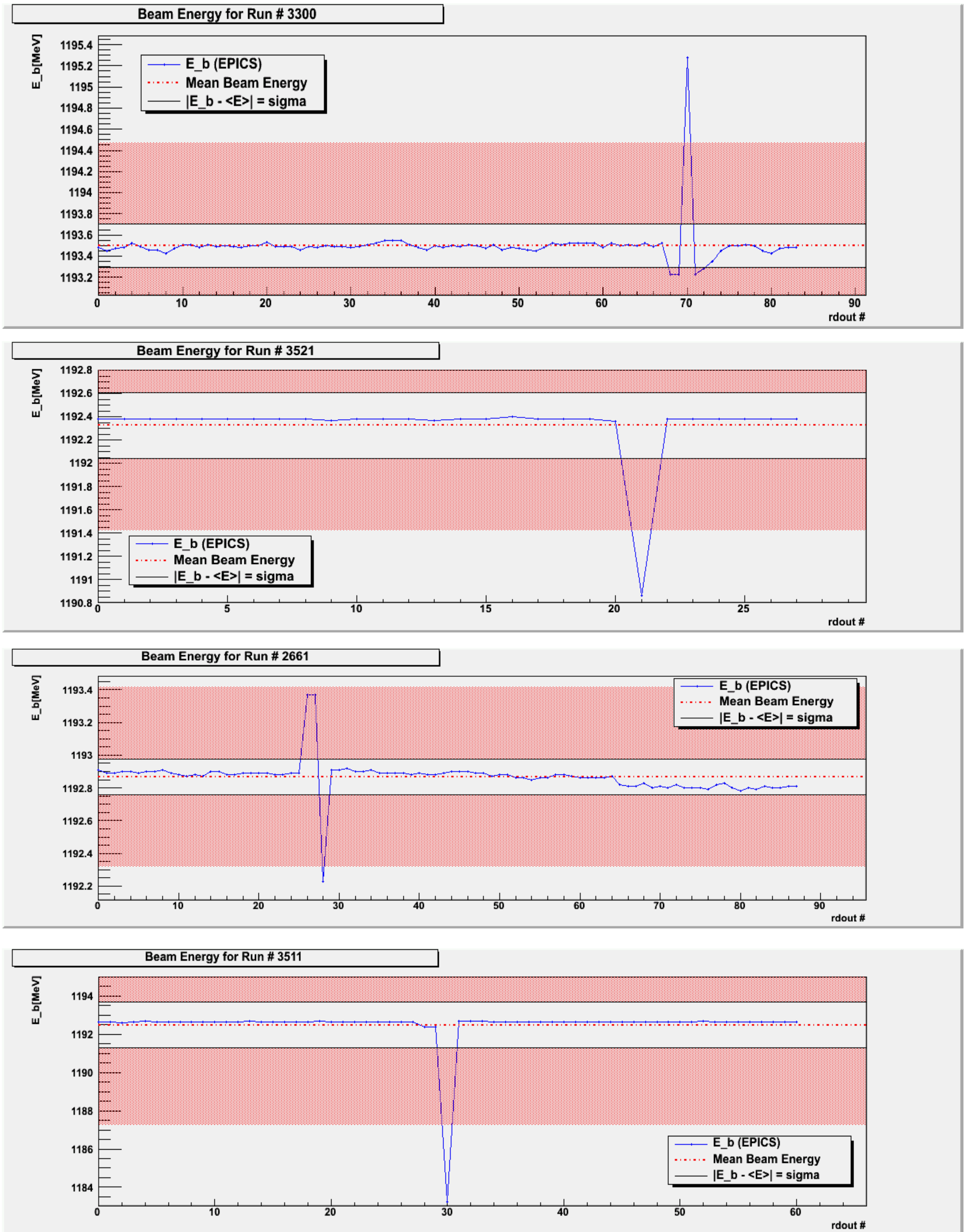

Figure 9: Graphs show how energy fluctuates during different runs (blue lines). The dotted red lines show the average energies and the shaded areas correspond to energies that are more than sigma away from the average value.

I was then able to compare this average energy with values that I extracted from the HALOG or the db_run file. The results of the analysis are shown in table 1 and in graphs 10 – 13.

No.	Run #	<E> [MeV]	σ [MeV]	Edb[MeV]	E1 [MeV]	E2[MeV]	0.5(E1+E2)
1	2277	1193.015	0.0136	1193.01	1193.04	1193.03	1193.035
2	2295	1193.360	0.0136	1193.35	1193.35	1193.38	1193.365
3	2296	1193.604	0.0883	1193.39	1193.63	1193.39	1193.51
4	2531	1193.338	0.0622	1193.14	1193.39	1193.13	1193.26
5	2532	1193.363	0.0254	1193.39	1193.37	1193.38	1193.375
6	2533	1193.073	0.0382	1193.05	1193.27	1193.07	1193.17
7	2661	1192.868	0.1085	1192.88	1192.82	1192.89	1192.855
8	2662	1192.818	0.2818	1192.81	1192.79	1192.80	1192.795
9	2663	1192.806	0.0164	1192.79	1192.81	1192.79	1192.8
10	2664	1192.807	0.0189	1192.84	1192.78	1192.81	1192.795
11	2766	1193.231	0.0143	1193.20	1193.24	1193.2	1193.22
12	3127	1193.631	0.0158	1193.63	1193.76	1193.65	1193.71
13	3130	1193.158	0.2578	1193.11	1193.26	1193.11	1193.185
14	3300	1193.499	0.2046	1193.46	1193.47	1193.48	1193.475
15	3509	1192.486	1.1198	1192.66	1192.68	1192.65	1192.67
16	3511	1192.488	1.1949	1192.68	1192.63	1192.64	1192.635
17	3520	1192.379	0.0058	1192.38	1192.38	1192.38	1192.38
18	3521	1192.325	0.2820	1192.38	1192.38	1192.38	1192.38
19	4360	1192.380	0.0	1192.38	1192.38	1192.38	1192.38

Table 1: Analyzed runs and corresponding beam energies from different sets of data. The <E> is the mean energy calculated from the EPICS information stored in each run and the sigma is it standard deviation. Edb is a beam energy that is read from db_run file while E1 and E2 are beam energies at the beginning and at the end of each run, read from the HALOG.

The standard deviation (sigma) of a run (in graphs 12 and 13 shown with gray strips) determines the final accuracy of the beam energy. Therefore every energy estimation that differs less than sigma from the average energy is good approximation. From graphs we can see that the most promising approximations are the energy read from the db file and the arithmetic mean of the HALOG's start and stop energies. From results I got it is hard to decide which approximation is better. However, in the most cases both of them are within the sigma region around the true energy. In these cases it is arbitrary which approximation we use.

In the end I would say that it would be probably best, to extract EPICS information from every raw data file and calculate the average energy. This will give you the most accurate estimation of the beam energy for a particular run. Using the “grep” command it took me approx. 5min to read all energies from one raw data file. However, for runs where there is no EPICS information stored in raw data files, it will be necessary to use one of the approximations.

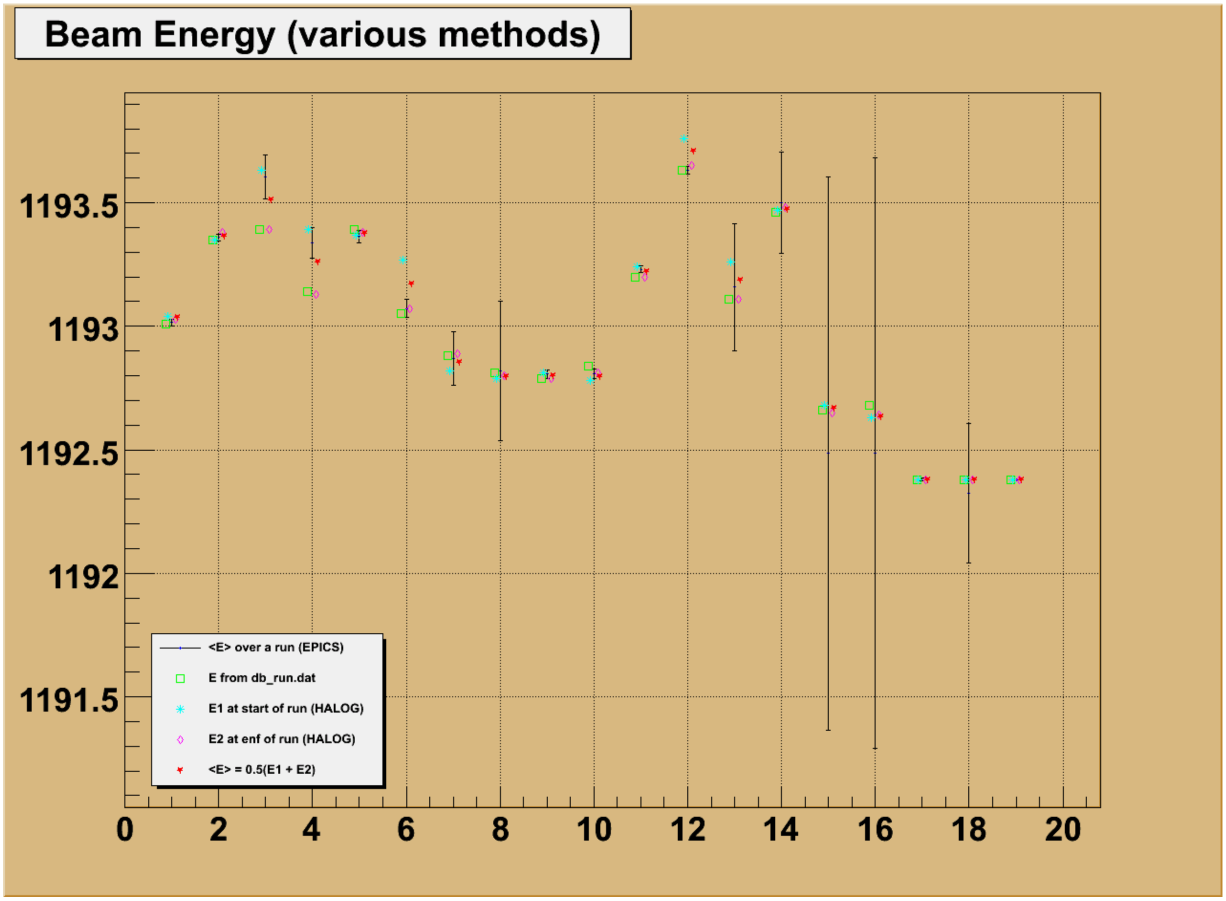

Figure 10: Graph shows values of the beam energy extracted from raw data files (with their errors) and energies read from the HALOG and the db_run file.

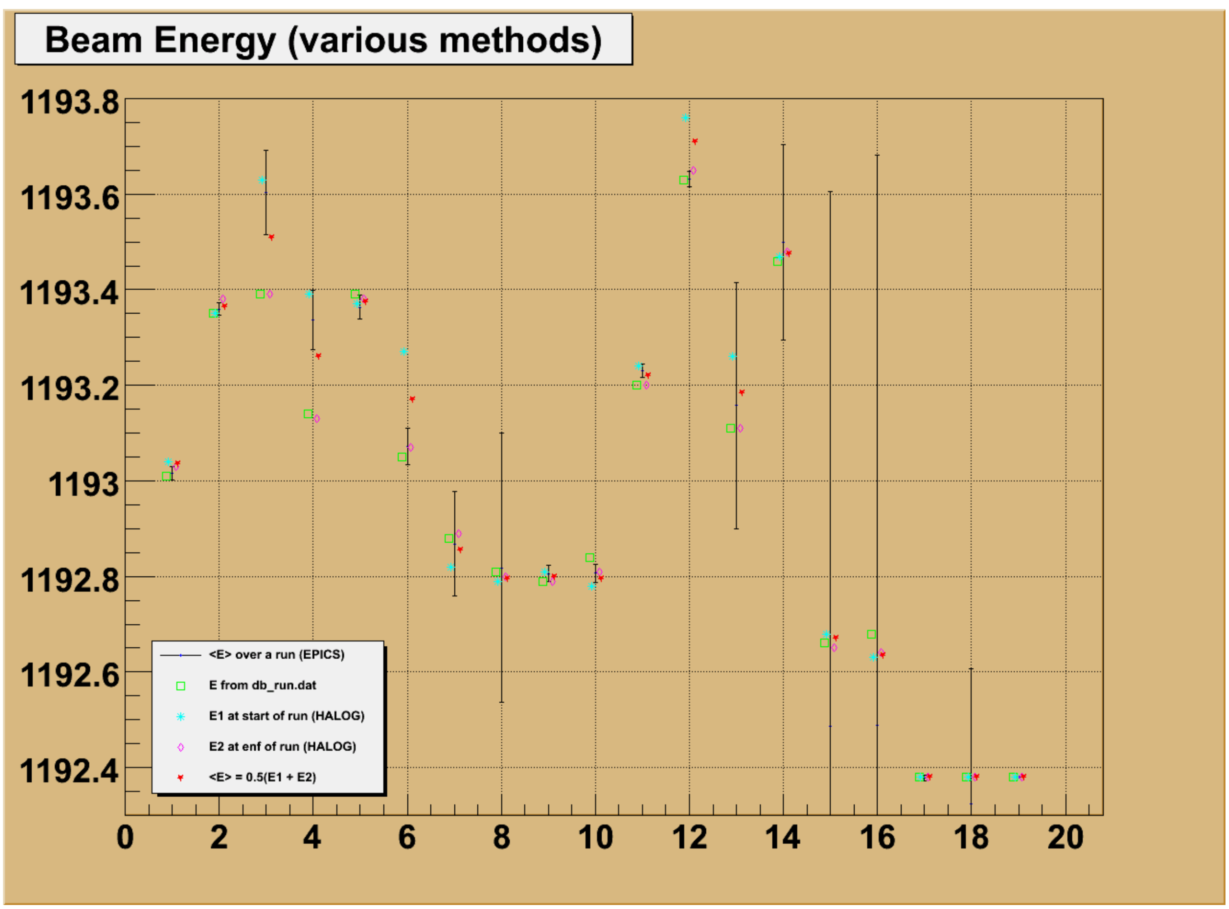

Figure 11: Graph shows values of the beam energy extracted from raw data files (with their errors) and energies read from the HALOG and the db_run file.

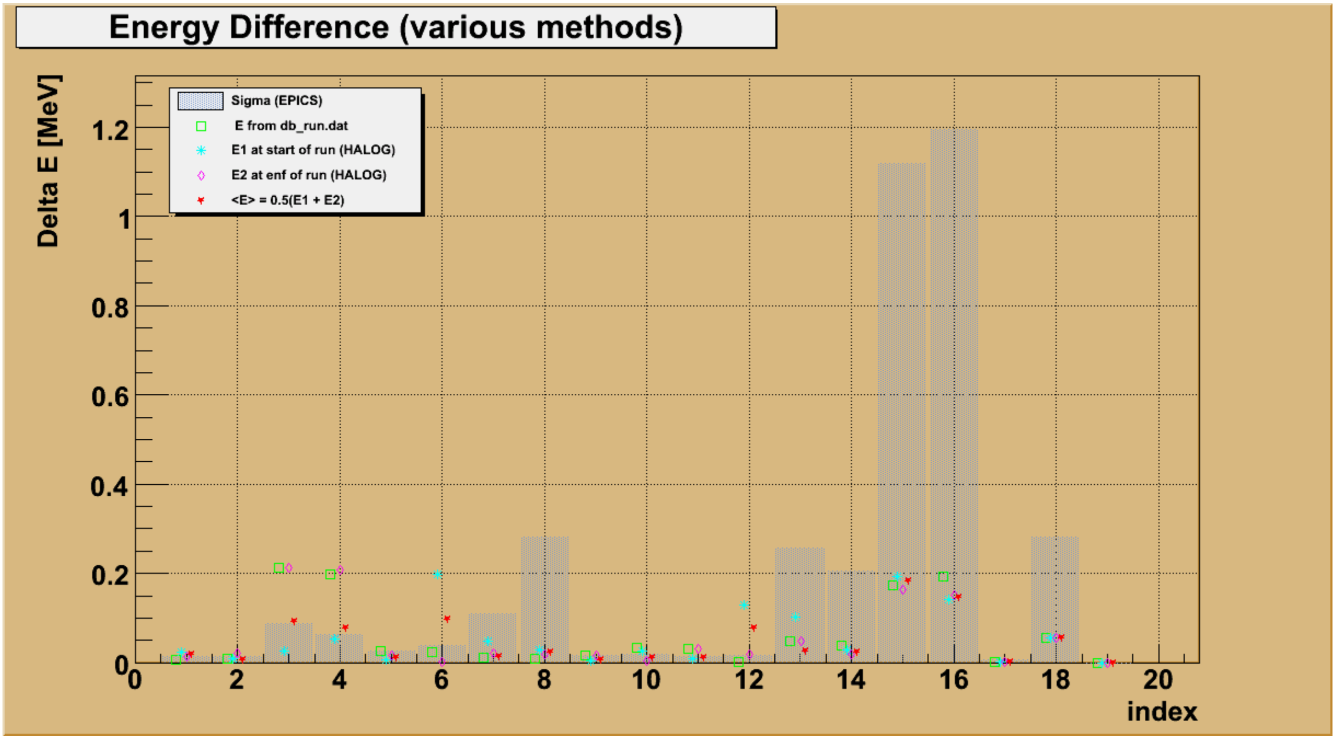

Figure 12: Graph shows how much beam energies that are read from the HALOG and the db_run file differ from the average beam energy calculated from the data stored in the raw data files.

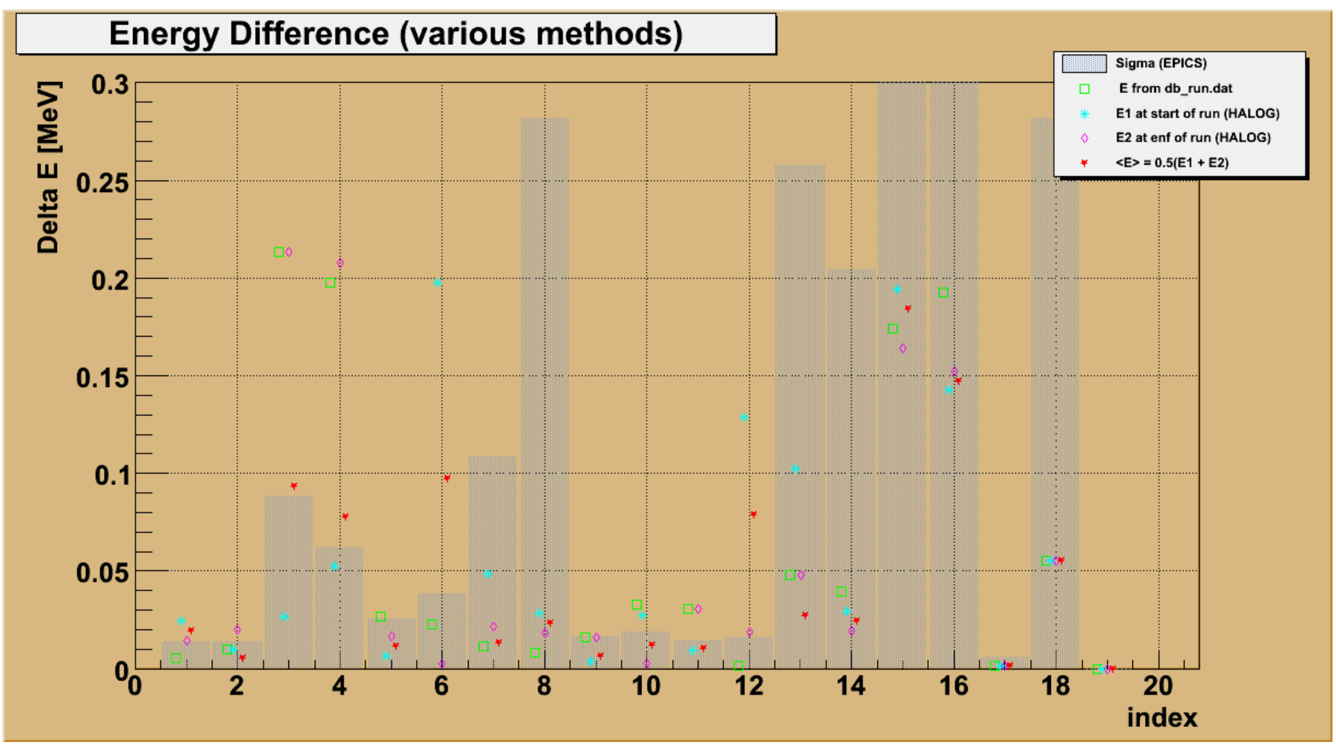

Figure 13: Graph shows how much beam energies that are read from the HALOG and the db_run file differ from the average beam energy calculated from the data stored in the raw data files.