Kathryn Oraas
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Analysis of the CCD camera

There are only a few methods in determining the current of the incoming beam throughout a run. The primary method being used involves analyzing the data received from the elastic monitors and observing how the counts fluctuate with time. As the elastic monitors have been known to be unreliable, alternative methods of determining beam current are needed. A CCD camera has recently been installed in DRAGON, which looks upstream towards the gas target. The reaction between the incoming beam and the gas target creates a small light output, which the camera is able to capture. The main function of the camera has been to help ensure that the beam is centered through the target, but as the camera also produces data that represents light intensity, it can be used to track the current of the incoming beam.

There are many options for how the CCD camera will integrate the data collected over time. The exposure time has been varied from 2-10 seconds, and the number of scans per data point output has been varied from 1 to 5. The CCD camera records the current time at each integration, and because exposure time was not always marked at the beginning of every recording, an initial test was done to see how long the camera took to read in the data for each exposure time. The results turned out to be a bit surprising. Looking at Table 1, it can be seen that it took the camera longer to integrate a three second exposure time than a four second exposure time, which doesn't make a lot of sense. The only three times used in all of the data collecting analyzed was the 2 second, 5 second, and 10 second exposure times.

Table 1[i] – The time interval (in seconds) for different exposure times. The number of scans for each recorded number was set to five.

2 sec	3 sec	4 sec	5 sec	6 sec	7 sec	8 sec	9 sec	10 sec
49	59	49	54	59	64	69	74	79

Data was analyzed for several of the most recent runs, including neon, aluminium, sodium and carbon beams. The CCD camera data was compared with an elastic monitor (EM0) to determine whether the two remain consistent with each other. A computer program was made, called CCD.cxx[ii], whose purpose was to add up all of the recorded intensities between two particular times. The goal would then be to compare this with the total number of counts of the elastic monitors for several different runs. From this, it could then be determined if a correlation existed between how the two numbers relate to each other, depending on pressure of the target and energy of the incoming beam. The program has not actually been used though as another approach was decided upon.

The new approach tracked the recorded intensity of the CCD camera and directly compared it with the counts on the elastic monitor. Another C++ program was written to help simplify the process. The CCD camera outputs seven columns of data: the date, the time, total intensity, background, total intensity minus background, the x position of the bull's-eye and the y position of the bull's-eye. The C++ program entitled ccdToExcel.cxx, which can be found on isdaq04 in the koraas folder, outputs a list consisting of solely the date, time and total intensity minus background. It also deletes the commas that were originally separating all data points in order to more easily transfer the information to excel.

The results of how well the CCD camera and elastic monitor track each other is quite encouraging. The first analysis was done using runs 12702,12725, 12861, 12896, 12897, and 12899. The elastic monitor data was taken from NOVA and transferred into an excel worksheet. As there were generally too many elastic monitor data points to plot, they were put into bigger groupings, with the number per group depending on the length of the run, and how many data points there were for the CCD camera. See Graph 1 for an example of how well the points tracked each other for run 12897. This run consisted of a sodium beam, a target pressure of 4.53 T, and the elastic monitor's prescaler was set to one. The CCD camera data had to be multiplied by 4.4 in order to match the elastic monitor's numbers. This was done in the hopes that a function would be found that would enable us to calculate a multiplication factor that matches the CCD camera data to the elastic monitor's data, which would depend on both the target pressure and the beam energy. Unfortunately not enough runs were conducted with different target pressures to accomplish such a feat. A summary of what was discovered for these six runs can be found in Table 2.

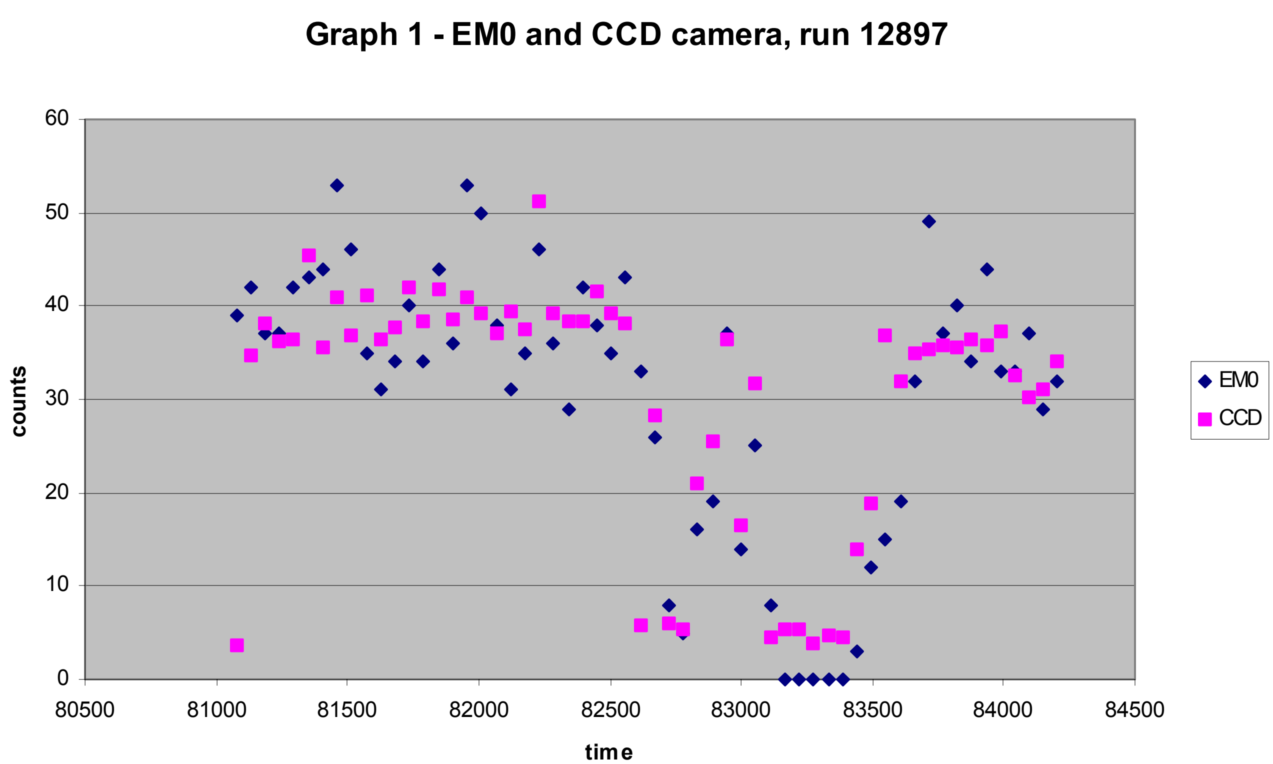


Table 2[iii] – The first six runs analyzed, looking at CCD camera and EM0 data. Note that the first ratio takes into account the EM0 prescaler while both track the exposure time.

Run #	Element	Beam current(epA) FC4	Target pressure (T)	EM0 prescaler	Exposure time (s)	CCD / EM0	FC4 / CCD
12702	^{26}Al	150	7.93	16	10	1	141
12725	^{26}Al	70	7.93	16	10	2.27	117
12861	^{21}Ne	2430	4.5	1	2	0.84	27
12896	^{21}Na	380	4.52	1	5	1.06	213
12897	^{21}Na	310	4.53	1	5	1.47	189
12899	^{21}Na	374	4.53	1	10	2.25	201

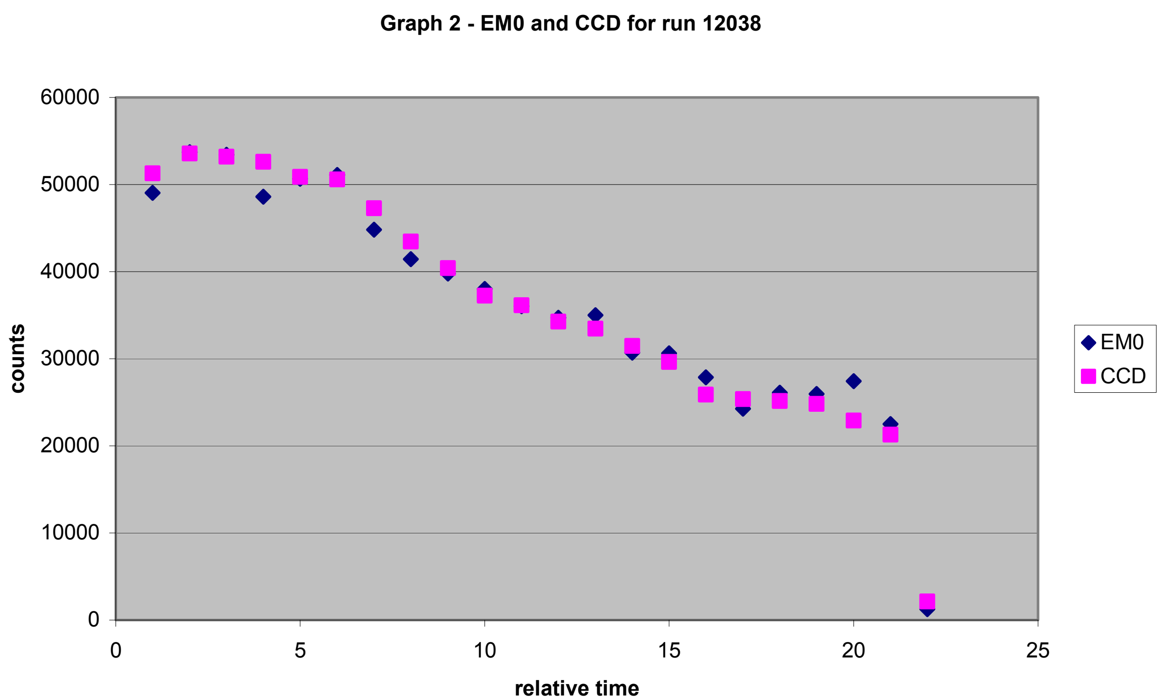
A few things are worth noting from Table 2. It can be seen that the ratio between the CCD camera and the elastic monitor data does not stay consistent, even during similar runs with equal energy, current and target pressure. This is discussed more later, but it appears as though it is the CCD camera data that is remaining constant, whereas it is the elastic monitor data that does not have a linear relationship with the beam current (FC4). Looking at FC4/CCD, these ratios remain quite constant for the runs with the same elements. This is optimistic news for further investigation of the CCD camera, but quite distressing for the analysis of the elastic monitor data. This problem was again found in further analysis of the ^{12}C(a, g).

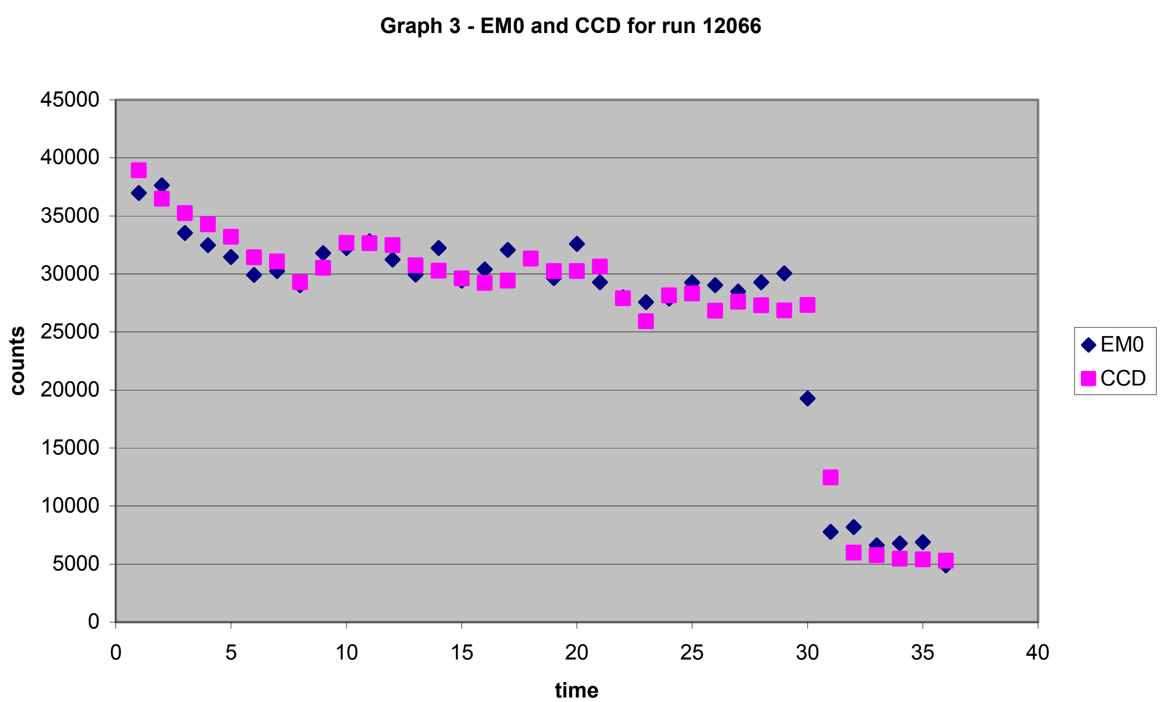
The CCD camera was first used during the ^{12}C(a, g) runs that took place in March and April of 2004. These were interesting runs to analyze as some of them were up to eight and nine hours long. Again, it appears as though the CCD camera data and elastic monitor data track each other very well. As the runs were so extensive, yet another C++ program was written[iv] to help quicken the process of grouping the elastic monitor data points. This program inputs the EM0 file needed to be crunched down and asks for the number of data points per group. Some examples of how well the CCD camera and elastic monitors match up can be found in Graphs 2-5[v]. Table 3 shows the final results of the analysis of ^{12}C(a, g) runs. Note the prescalar remains constant throughout all runs.

Table 3 – Looking at the CCD camera and EM0 data for the ^{12}C(a, g) runs. The multiplication factor does not take the CCD integration time into account.

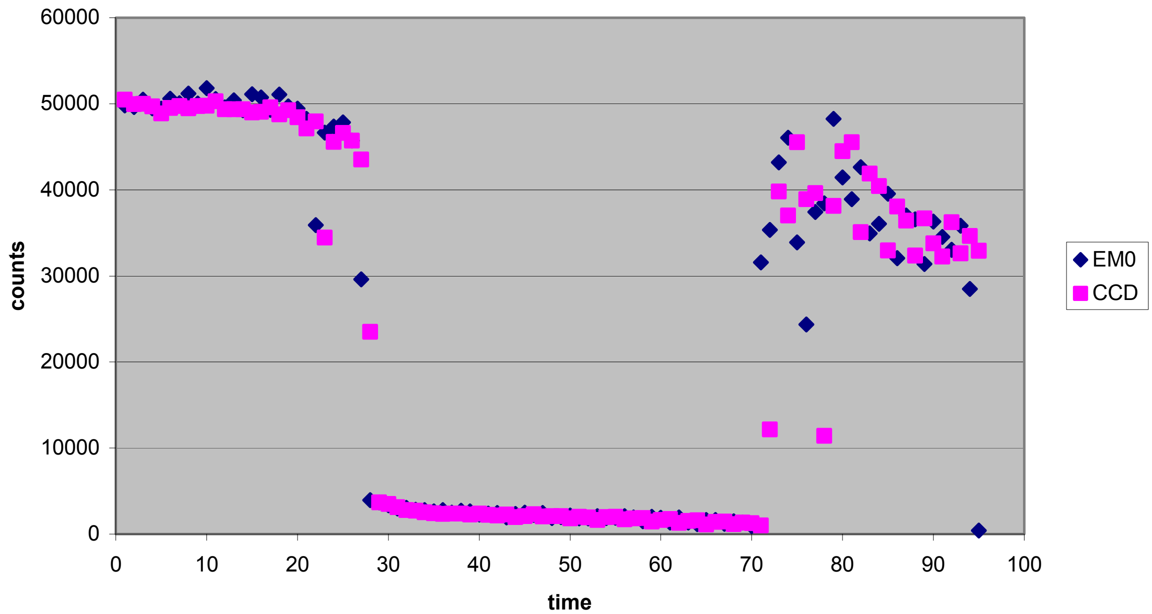
Run #	Current (enA)	Energy (MeV/u)	Pressure (Torr)	Time interval(secs)	Multiplication factor
12038	45	1.76	3.03-2.97	10	74.0
12045	30	1.76	3.02-2.99	10	62.5
12065	60	1.81	4.05-3.91	10	32.5
12066	70	1.81	4.11-4.04	10	33.4
12089	100	1.52	3.91-3.39	79	6.35
12106	105	1.63	4.16	54	4.10
12113	80	1.69	3.94	15	70.4
12116	165	1.45	4.03-3.95	79	20.7

12117	167	1.45	3.82-3.31	79	8.9

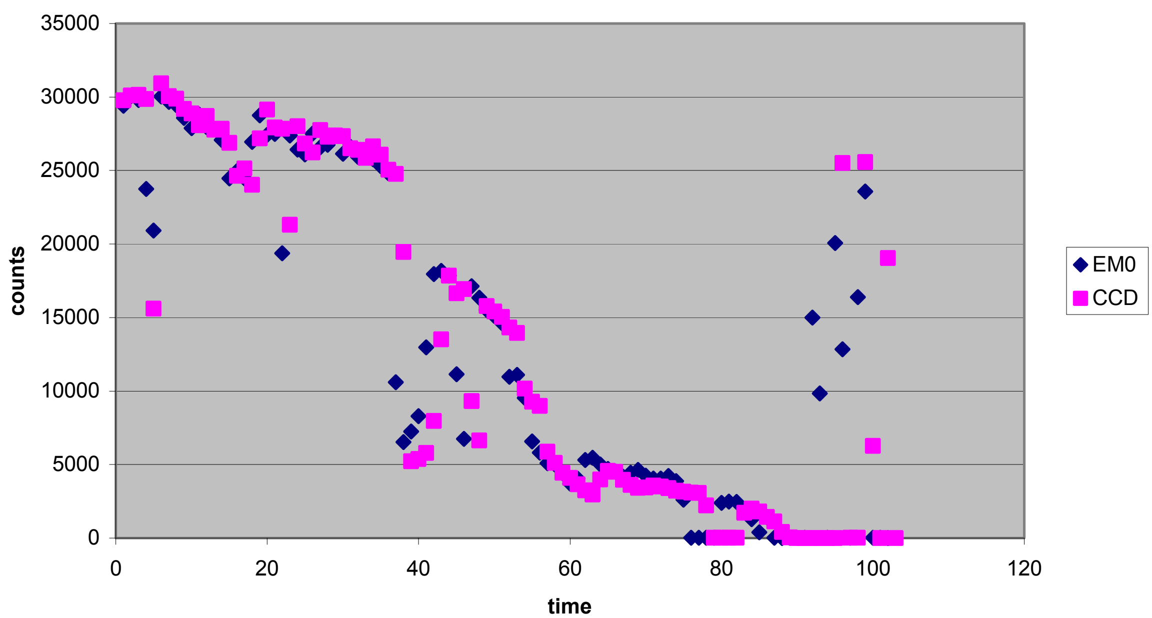




Graph 4 - EM0 and CCD for run 12089



Graph 5 - EM0 and CCD for run 12106



In Table 3, the multiplication factor does not take into account the exposure time of the CCD camera because this information is not known. Both this information and the number of scans per group were missing in the logbook. Again the problem of the lack of consistency of the elastic monitors is brought into view. It can be seen looking at runs 12116 and 12117 that the multiplication factor should be roughly the same, as both the energy, target pressure and current remain constant. Looking at the data, both the CCD camera data and recorded current remain approximately the same from one run to the next while the elastic monitor data jumps by a factor of two[vi]. There is a chance that the prescaler was changed between runs but this is unlikely as it was not recorded in the logbook. It is interesting that the shape of the graphs remain so consistent while the elastic monitor data jumps by a factor of two from run to run. It was suggested that another reason for the cause of this inconsistency could be due the fact that the run was sitting on an elastic scattering resonant energy (1.45 MeV/u). This would mean that even a slight change in energy (caused by a decrease in target pressure) would cause a large change in the elastic scattering data. While this is true, what should then be observed is a noticeable change of ratios between the elastic monitor and CCD camera data throughout run 12117, which is a long run of over eight hours (Note that there is a significant change of target pressure as the run progresses). Looking at Graph 8, it can be seen that the ratio stays fairly consistent throughout the entire run.

As it appears as though the elastic monitors cannot be entirely trusted, the next thing analyzed was the data from one of the faraday cups (fcm2). This scalar also tracks the current throughout the run similar to the elastic monitor. Unfortunately, there was not enough time to do a full analysis with this data, but a few trends were observed. Table 4 shows how the data from fcm2 and the CCD camera compare. Due to a lack of time, only the data from the beginning of the run was gathered from both the faraday cup and the camera, and this data was compared to see if it remained consistent with constant pressure and current. Unlike the elastic monitor reading, the ratio between the camera and the faraday from runs 12116 to 12117 remains fairly consistent, and does not jump by a factor of two. This result alone shows that until the elastic monitor becomes more consistent, it may be more reliable to observe how the current fluctuates by looking at the faraday cup fcm2.

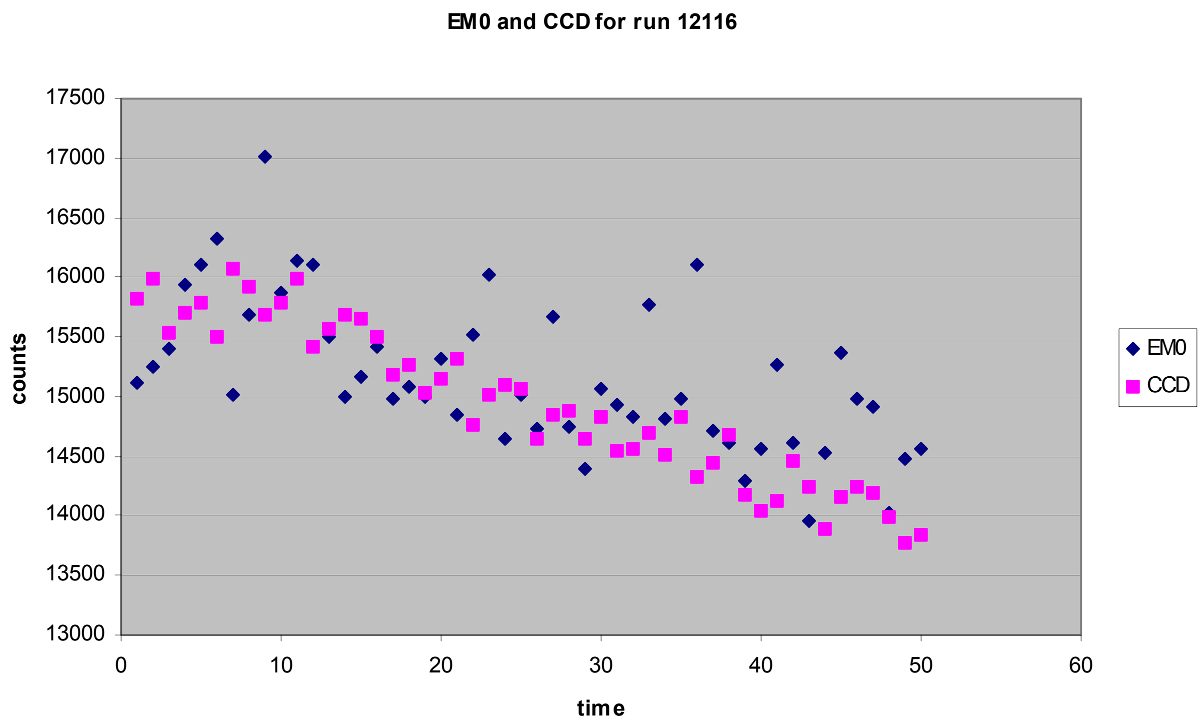
Table 4[vii] – Comparing the CCD camera data to the fcm2 data

Run #	Energy (MeV/u)	Pressure (Torr)	Time interval	Fcm2	CCD	Norm CCD	Fcm2 / CCD
12038	1.76	3.03-2.97	10	274	1700	850	0.32
12045	1.76	3.02-2.99	10	178	1000	500	0.36
12065	1.81	4.05-3.91	10	412	2666	1333	0.31
12066	1.81	4.11-4.04	10	0.5	3550	1775	
12089	1.52	3.91-3.39	79	800	12700	254	3.15
12106	1.63	4.16	54	1000	7378	295	3.39
12113	1.69	3.94	15	650	9500		
12116	1.45	4.03-3.95	79	1183	15800	316	3.74
12117	1.45	3.82-3.31	79	1100	14500	290	3.80

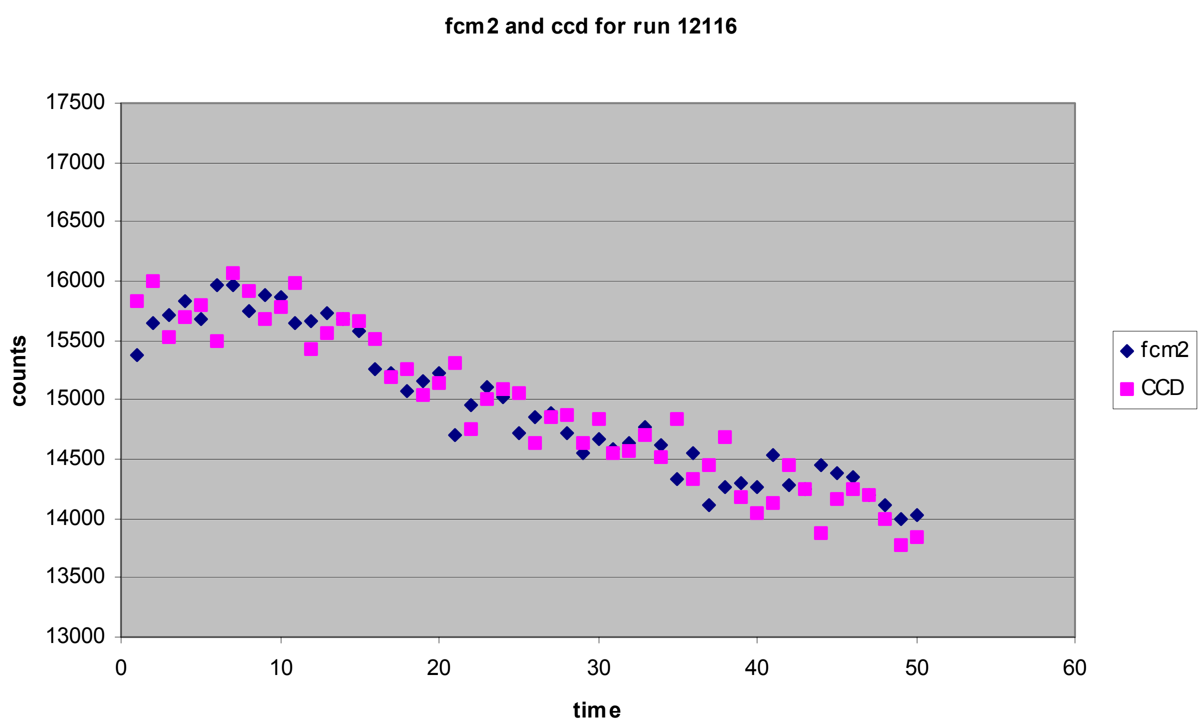
There are a few reasons for the blank boxes in Table 4. For run 12066, there appeared to be a problem with the fcm2 data, a value of 0.5 is totally unreasonable. Fortunately, this problem was fixed for run 12089. For run 12113, the time interval between each data point was recorded to be 15 seconds, and as there was no mention in the logbook as to what either the exposure time or number of scans this included, there is no way to normalize the CCD data. For the time interval of 10 seconds, it was assumed that the exposure time was 2 seconds and there was one scan per group. This assumption is most likely incorrect as the ratio of fcm2/CCD jumps by a factor of ten, but in this case it is easiest to compare only the runs with equal exposure times. Perhaps when the documentation becomes more consistent than full comparisons can be made between runs with different exposure times.

Two graphs were produced to ensure that the faraday cup and CCD camera tracked each other throughout the run. This was done for runs 12116 and 12117 and can be seen in Graphs 6-9[viii]. The graphs with the elastic monitor data are also shown as a comparison. It can be seen that all three data points do track each other, which is further proof the methods being used to track the fluctuations of the beam current are consistent.

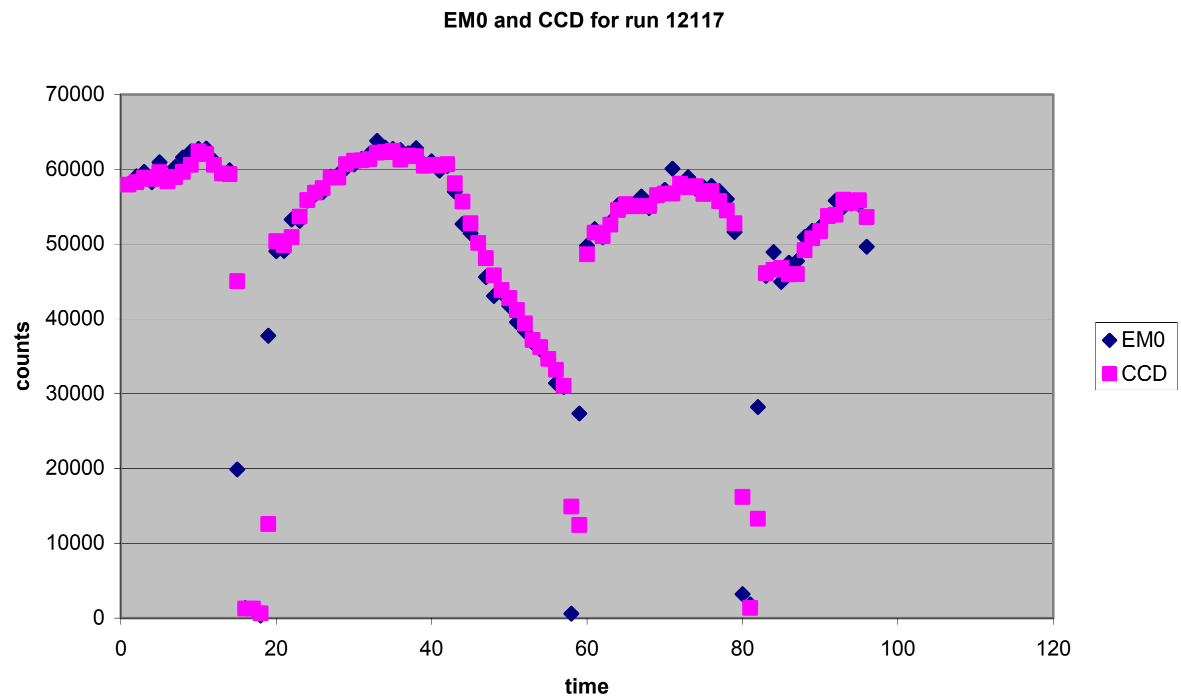
More work needs to be done with the analysis of the CCD, but the work done so far is promising. A method should be created to ensure that the parameters of the CCD camera recording are clearly marked, to avoid future complications. It would also be helpful to keep the exposure time consistent until a solution is found in how to compare different exposure times.



EM0 and CCD for run 12116
17500
17000
16500
16000
15500
15000
14500
14000
13500
13000
counts
0
10
20
30
40
50
60
time
EM0
CCD



fcm2 and ccd for run 12116
17500
17000
16500
16000
15500
15000
14500
14000
13500
13000
counts
0
10
20
30
40
50
60
time
fcm2
CCD


EM0 and CCD for run 12117
counts
time
EM0
CCD
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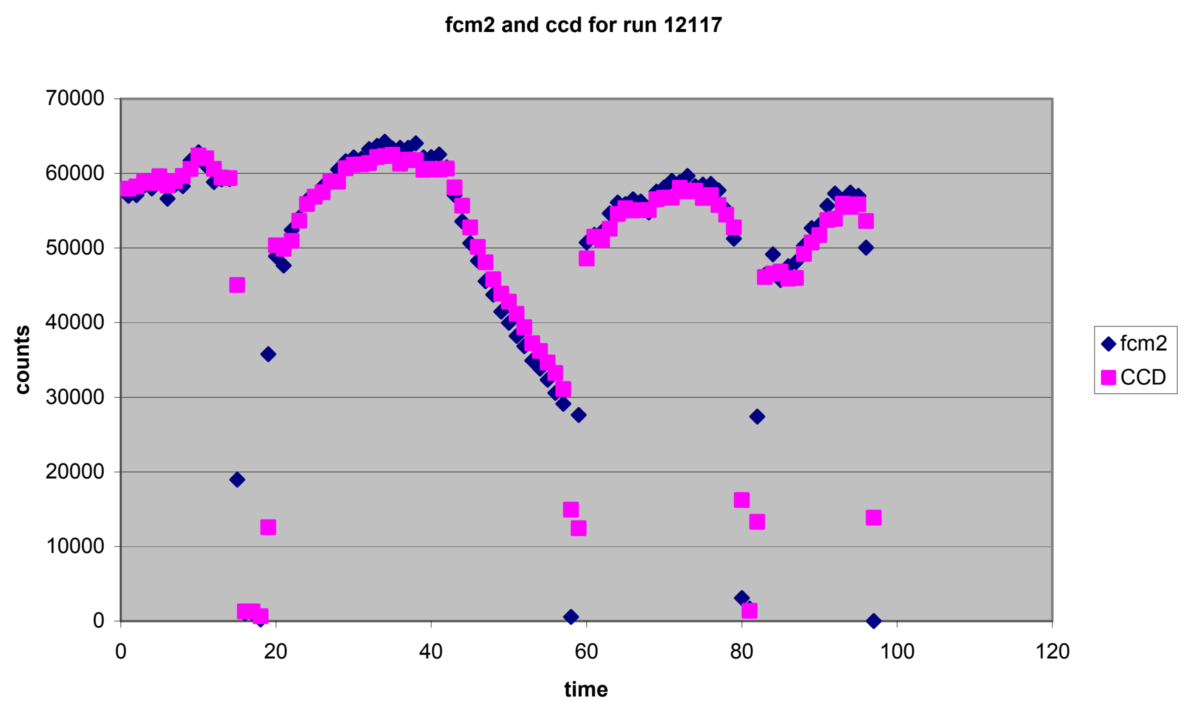
60000
50000
40000
30000
20000
10000
0
0
20
40
60
80
100
120


fcm2 and ccd for run 12117
counts
time
fcm2
CCD
70000
60000
50000
40000
30000
20000
10000
0
0
20
40
60
80
100
120

[i] The data from this table can be found on isdaq04 in the koraas/CCD/testing seconds folder

[ii] This program can be found on isdaq04, in the koraas folder

[iii] The data from Table 2 can again be found on isdaq04, in the koraas/CCD/final folder

[iv] This program is called makingLifeEasy.cxx and can be found on isdaq04 is the koraas folder

[v] These graphs can be found on isdaq04, in the koraas/CCD/EM0run12*** folder

[vi] This information can be found on isdaq04, in the excel worksheet found in the koraas/CCD/EM0run12105 folder

[vii] This information can be found in my logbook, on page 106

[viii] These graphs can be found on isdaqo4, in the koraas/CCD/EM0run12105 folder