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BCM Calibration for E08-014

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Abstract

In this note, the calibration procedure of the Beam Current Monitors (BCMs) during E08-014 is detailed. The results at each step are listed. While the BCMs have performed very well, the left HRS scaler readback exhibits some unpredictable fluctuations. Therefore, the physics extraction of E08-014 will be performed using only the right HRS scaler readback. This is not a problem as only one DAQ was used for the two HRSs and synchronisation was monitored all along the experiment. Most of the codes used in this analysis was provided by Julie Roche [1].

1 Cross-calibration of the OLO2 cavity with Faraday cup

To perform the cross-calibration the Faraday cup, FC#2, is inserted in the beam path. No beam is entering Hall A at this time. The EPICS data from FC#2 and OLO2 are recorded and save in the following directory: hacuser@hlal00 : /cs/op/iocs/DATA/bcmlog/BCMLOG/ or in the CODA file. Three calibrations were performed during Spring 2011. The data for the cross-calibration performed on April 18 are shown in Fig. 1. For each selected plateau, the average values and the standard deviations of FC#2 and OLO2 readings are calculated. The comparison of FC#2 and OLO2 average currents is summarized in Table 1.

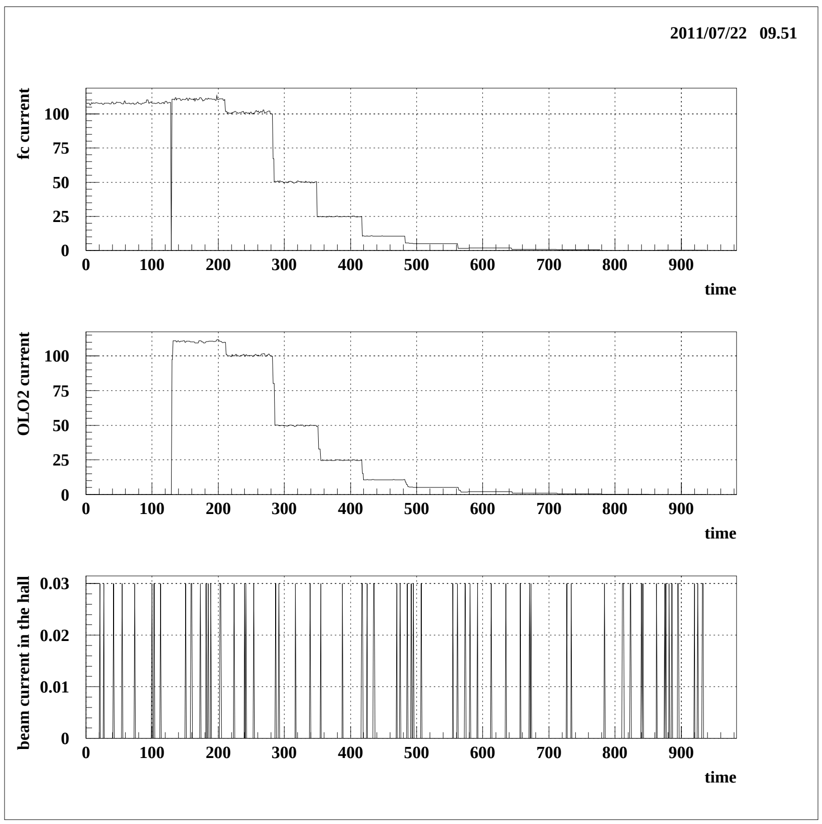

Figure 1: Cross-calibration of the OLO2 cavity with Faraday cup performed on April 18, 2011 (BcmLog174).

These three data sets are shown on Fig. 2 along with the data from Ref. [2] (no error bars were quoted for this calibration). Apart for the data set from March 3, 2011 (which seems to indicate that something was not optimized then), the OLO2 current offset seems to be very consistent between our two measurements in April 18 and May 3, 2011, and even consistent with the calibration done in 2002. However from these two last calibration, the trend at high current suggests a saturation of the Faraday cup above 90μA. Therefore, as our production data were taken at beam current higher than 30μA, the current offset of the OLO2 cavity is determined from the cross-calibration for beam currents between 30 and 90μA. The correction factor applied to the OLO2 cavity current was found to be 1.0065 ± 0.0016.

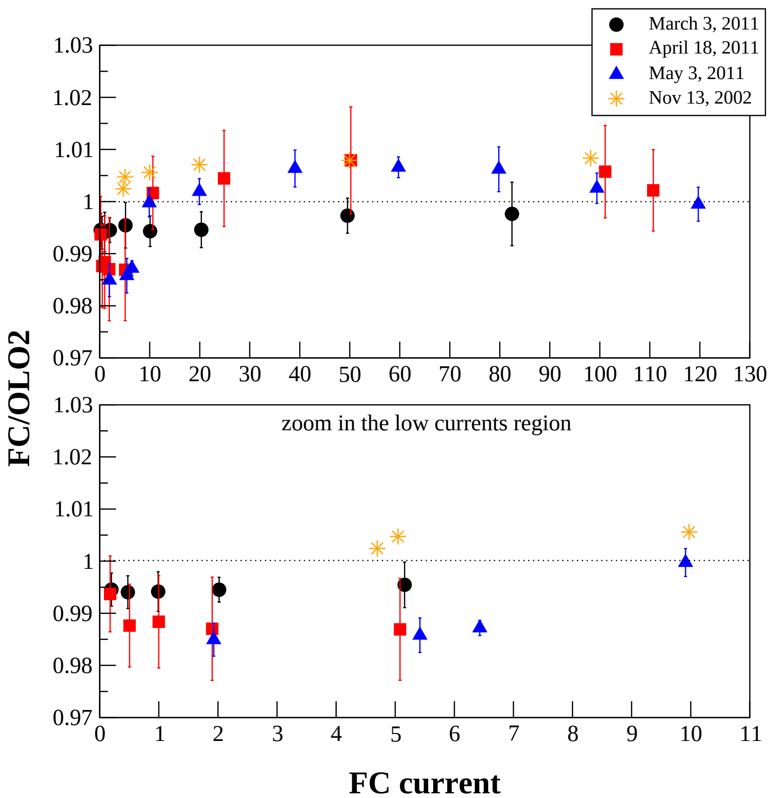

Figure 2: Summary of the cross-calibrations

Table 1: Results of the cross-calibrations of the OLO2 cavity with Faraday cup. The first part of the measurement has another Faraday cup inserted before OLO2 as part of the standard procedure, which explains the zero current reading in OLO2. The EPICS file number used in this analysis are listed in parantheses.

Faraday cup voltage	**OLO2 cavity voltage**	**FC/OLO2**
March 3, 2011 (BcmLog170)		
82.4429 ± 0.4593	82.6385 ± 0.2048	0.9976 ± 0.0061
49.5472 ± 0.1291	49.6817 ± 0.1053	0.9973 ± 0.0034
20.3177 ± 0.0524	20.4280 ± 0.0467	0.9946 ± 0.0034
10.0823 ± 0.0250	10.1400 ± 0.0158	0.9943 ± 0.0029
5.15839 ± 0.01774	5.18193 ± 0.01397	0.9955 ± 0.0044
2.01972 ± 0.00456	2.03084 ± 0.00146	0.9945 ± 0.0024
0.988931 ± 0.003313	0.994737 ± 0.001777	0.9942 ± 0.0038
0.475656 ± 0.001247	0.478505 ± 0.000832	0.9940 ± 0.0031
0.198117 ± 0.000535	0.199204 ± 0.000334	0.9945 ± 0.0032
April 18, 2011 (BcmLog174)		
110.689 ± 0.641	110.451 ± 0.577	1.0022 ± 0.0078
101.073 ± 0.684	100.496 ± 0.576	1.0057 ± 0.0089
50.2125 ± 0.405	49.8178 ± 0.3149	1.0079 ± 0.0102
24.8568 ± 0.175	24.7466 ± 0.1473	1.0045 ± 0.0092
10.6277 ± 0.0554	10.6102 ± 0.0503	1.0017 ± 0.0070
5.08118 ± 0.04343	5.14857 ± 0.02426	0.9869 ± 0.0098
1.90341 ± 0.01508	1.92843 ± 0.01146	0.9870 ± 0.0099
0.998232 ± 0.006124	1.00997 ± 0.00647	0.9884 ± 0.0089
0.504576 ± 0.003114	0.510894 ± 0.002556	0.9876 ± 0.0079
0.175973 ± 0.001016	0.177086 ± 0.000782	0.9937 ± 0.0073
May 3, 2011 (BcmLog177		
119.703 ± 0.276	119.764 ± 0.275	0.9995 ± 0.0033
99.4182 ± 0.2327	99.1655 ± 0.1705	1.0026 ± 0.0029
79.8047 ± 0.2521	79.3133 ± 0.2309	1.0062 ± 0.0043
59.7295 ± 0.0836	59.3393 ± 0.0836	1.0066 ± 0.0020
39.0473 ± 0.0891	38.8008 ± 0.1052	1.0064 ± 0.0035
19.9255 ± 0.0323	19.8871 ± 0.0372	1.0019 ± 0.0025
9.91186 ± 0.02095	9.91443 ± 0.01612	0.9997 ± 0.0027
6.43052 ± 0.00589	6.51400 ± 0.00728	0.9872 ± 0.0014
5.41731 ± 0.01363	5.49542 ± 0.01187	0.9858 ± 0.0033
1.92961 ± 0.00413	1.95914 ± 0.00455	0.9849 ± 0.0032

2 Linearity test

For the linearity test, the Faraday cup FC#2 is inserted every 90 seconds while the beam current is stepped down by some amount every 180 seconds as shown in Fig. 3.

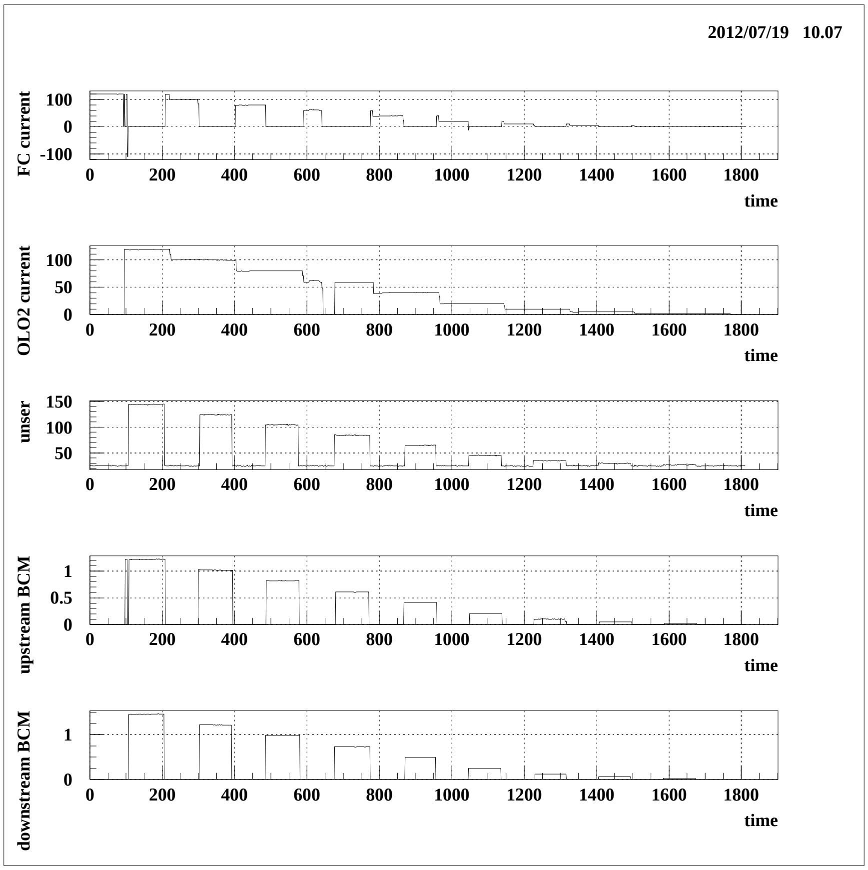

Figure 3: Linearity test performed on May 3, 2011 (BcmLog178). From top to bottom are plotted the response from Faraday cup, OLO2, Unser, Upstream and Downstream BCMs.

From Ref. [2], the EPICS calibration constant of each cavity with respect to the OLO2 cavity current can be extracted as follows:

$$C_{EPICS} = \frac{< I_{OLO2} >_c}{< V_{cavity} > - K_{offset}} \tag{1}$$

where $< I_{OLO2} >_c$ is the average current of the OLO2 cavity after correction from the cross-calibration with the Faraday cup, $< V_{cavity} >$ is the voltage of the element studied (Upstream, Downstream cavities or Unser monitor) and K_{offset} is the value of these cavity voltages when there is no beam in the hall (also called the zero offset). The Unser monitor is placed between the upstream and downstream RF cavities and provides a non-invasive absolute reference of the beam current. See Ref. [3] for a complete description of the Hall A BCM setup.

The first step is to determine the value of K_{offset} for each cavity. Then the EPICs constant for each cavity will be extracted. The data for the cross-calibration performed on April 18 are shown in Fig. 3.

2.1 Zero offsets

The value of K_{offset} for each cavity was extracted for each insertion of the Faraday cup. Figures 4 show the stability of these values for the upstream and downstream cavities and the Unser and their averages which will be used in the rest of the analysis.

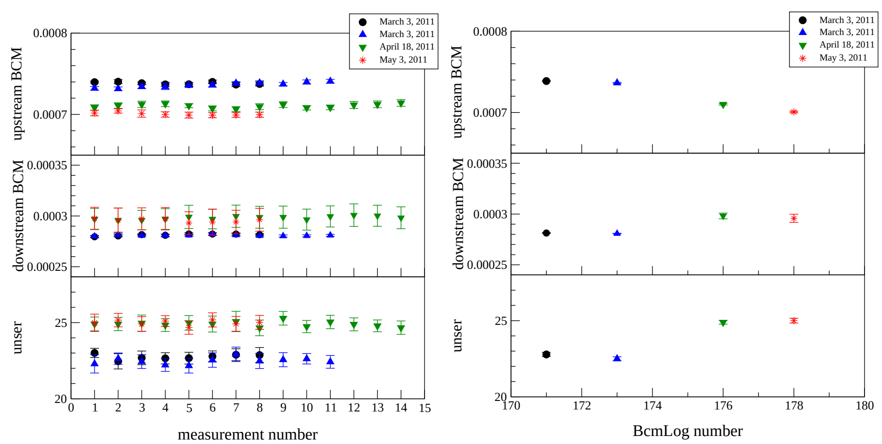

Figure 4: Measurements of the zeros of the cavities. The left plot shows the stability of the offset for each Faraday cup insertion. The right plot shows the average offsets.

Table 2: Final offsets for the upstream and downstream cavities and the Unser monitor.

K_{offset}	upstream $\times 10^-6$	downstream $\times 10^-6$	unser
March 3, 2011 (BcmLog171)	738.71 ± 0.70	281.29 ± 0.35	22.78 ± 0.14
March 3, 2011 (BcmLog173)	736.38 ± 0.69	280.73 ± 0.32	22.50 ± 0.13
April 18, 2011 (BcmLog176)	710.00 ± 0.89	298.11 ± 2.83	24.89 ± 0.12
May 3, 2011 (BcmLog178)	700.68 ± 1.16	295.78 ± 4.01	25.00 ± 0.16

2.2 EPICS constants

The values of the EPICS constant for each cavity were extracted for each OLO2 current step. Figure 5 show the stability of these values for the upstream and downstream cavities and the Unser. For each cavity, the final EPICS constant was obtained by taking the weigthed average of the data collected with only OLO2 currents above 8μA.

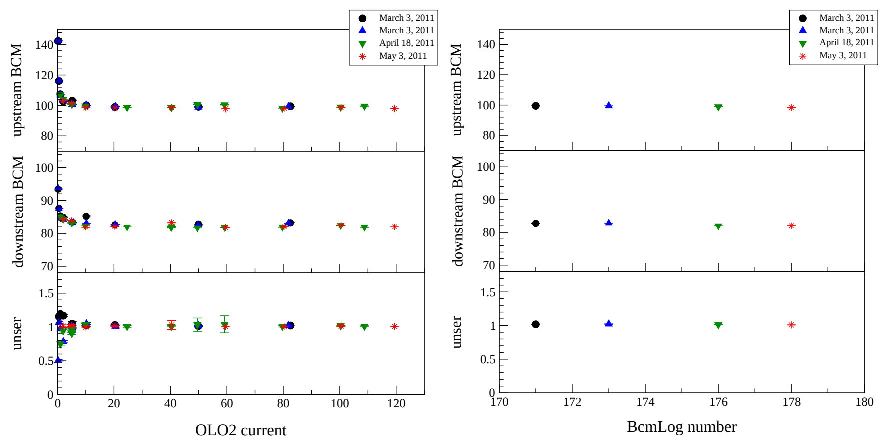

Figure 5: Extraction of the EPICS constant for each cavity. The left plot shows the stability of the constant versus the OLO2 current. The right plot shows the average constants.

Finally, using the zero offset and the EPICS constant extracted above, the current read by the Unser monitor is cross-checked against the OLO2

Table 3: Final EPICS constants for the upstream and downstream cavities and the Unser monitor.

EPICS constant	upstream	downstream	unser
March 3, 2011	99.468 ± 0.002	82.738 ± 0.002	1.018 ± 0.004
March 3, 2011	99.442 ± 0.002	82.796 ± 0.002	1.022 ± 0.004
April 18, 2011	98.874 ± 0.003	81.995 ± 0.003	1.013 ± 0.003
May 3, 2011	98.317 ± 0.001	82.001 ± 0.001	1.009 ± 0.002

cavity reading. Fig. 6 shows the good agreement between them.

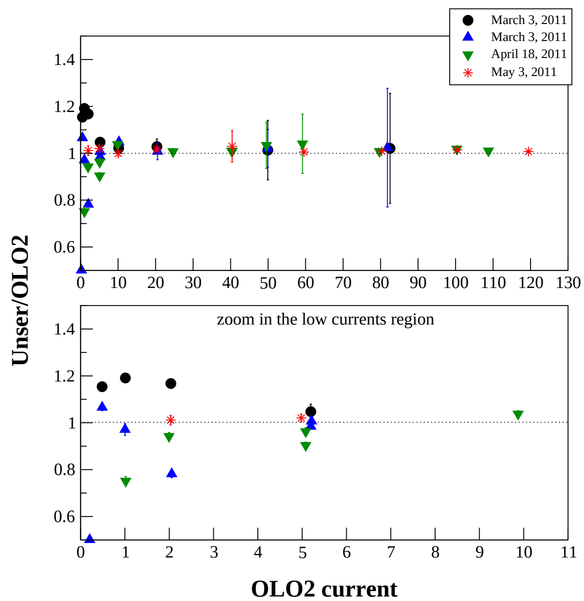

Figure 6: Comparison of the Unser monitor and OLO2 cavity.

3 Conversion from V-to-F scalers to charge

To determine the conversion coefficients between V-to-F scalers and accumulated charge, data were taken at multiple incident beam currents. The principle rests on the fact that in the absence of beam the BCM scaler rates are constant and when the beam is turned ON the BCM scaler rates increase proportionally to the beam current. Therefore, by alternating beam OFF and beam ON periods, the conversion factor can be extracted. For the E08-014 BCM calibration, the beam ON episodes were set at different currents from about 120μA down to 2μA. as shown on Fig. 7.

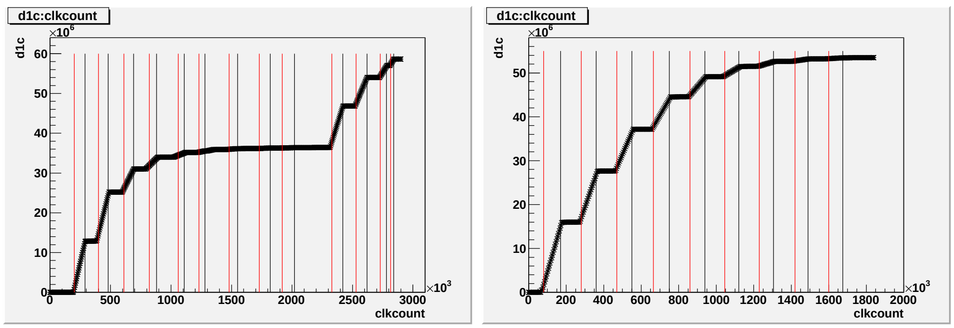

Figure 7: Beam ON selection: red and black lines are the lower and upper cuts respectively for each period with electron beam. April 18, 2011 (Run 3686) and May 3, 2011 (Run 4110).

From Ref. [2], the conversion from V-to-F scaler to charge (and current) can be performed as follows:

$$< I_{beam} > \quad = \quad \frac{\frac{Scalar}{time} - K'_{offset}}{C_{V-to-F}} \tag{2}$$

$$Q \quad = \quad < I_{beam} > *time \tag{3}$$

The conversion coefficients for the upstream (U) and downstream (D) BCMs are listed in Table 4. The "1x" and "3x" attached to the BCM letter U or D correspond to the amplification number. For E08-014, the beam current for the production data was higher than 40μA so "10x" is not useable in this analysis.

The left HRS BCM scaler readback seem to have been instable all along the experiment as can be seen on Figs 8-10. Therefore the analysis of the production runs will use the right HRS BCM scaler readback to determine the charge and current of each run.

Table 4: Final V-to-F constants for the upstream and downstream cavities. The numbers correspond to the calibration number for the LEFT/RIGHT HRS scalers.

	April 18, 2011		**May 3, 2011**	
	C_{V-to-F}	K'_{offset}	C_{V-to-F}	K'_{offset}
V-to-F U1x	2064/1032	433/217	2075/1038	366/183
V-to-F U3x	6358/3174	-1/66	6391/3181	-206/283
V-to-F D1x	1251/1251	44/42	1274/1274	-3/-5
V-to-F D3x	7751/3870	-245/-6	7834/3934	-823/49

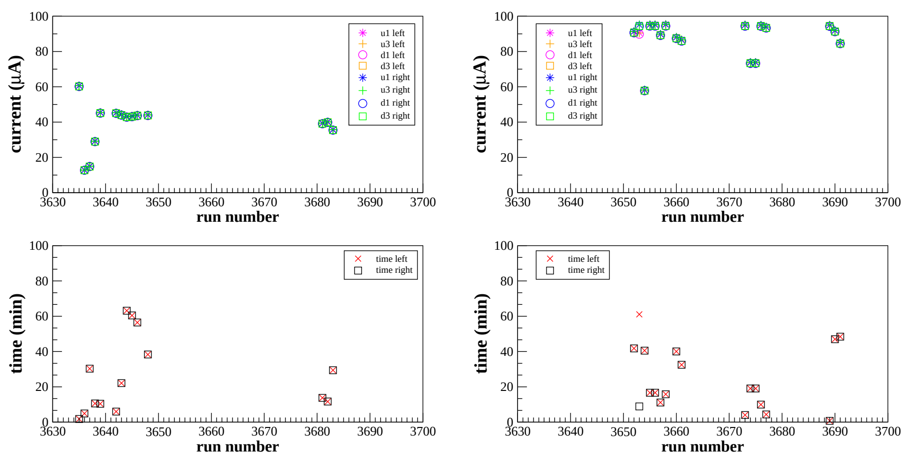

Figure 8: Beam currents for ^{2}H (left) and ^{4}He runs (right).

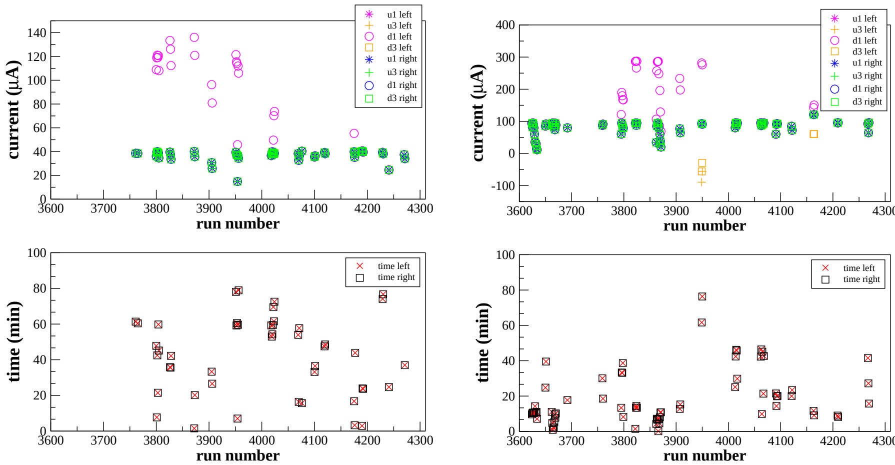

Figure 9: Beam currents for Aluminum dummy (left) and ^{12}C (right) runs.

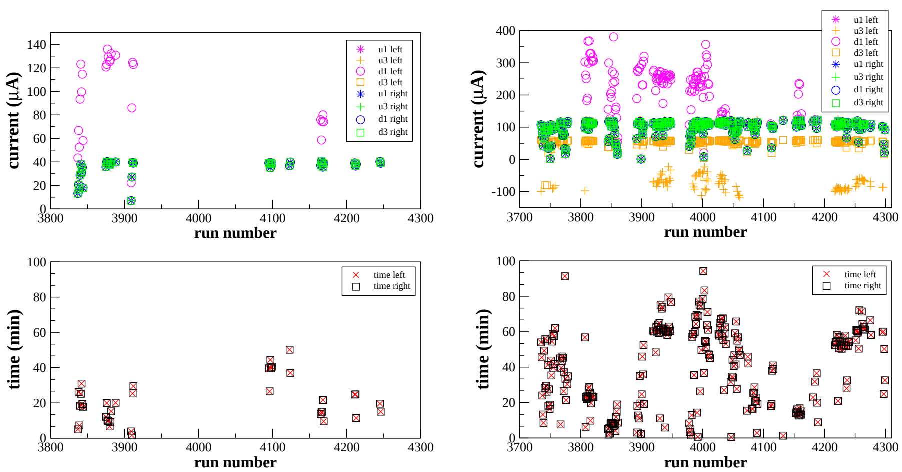

Figure 10: Beam currents for ^{40,48}Ca (left) and ^{3}He (right) runs.

References

[1] J. Roche,"*How I calibrated the BCMs for the DVCS2 experiments*", Fall 2010.

[2] M. Jones,"*Report on BCM calibration for Nov 13 2002 run*".

[3] E. Chudakov,"*JLab Hall A General Operations Manual*", http://hallaweb.jlab.org/news/minutes/OSP/osp-27feb2011.pdf