Report on BCM calibration
(updated 8/31 /00)

There are two BCM cavities and one Unser in Hall A as shown in Fig. 1. The following description is taken from the Hall A operating Manual. The BCM cavities produce a signal which is proportional to the beam current. A RF

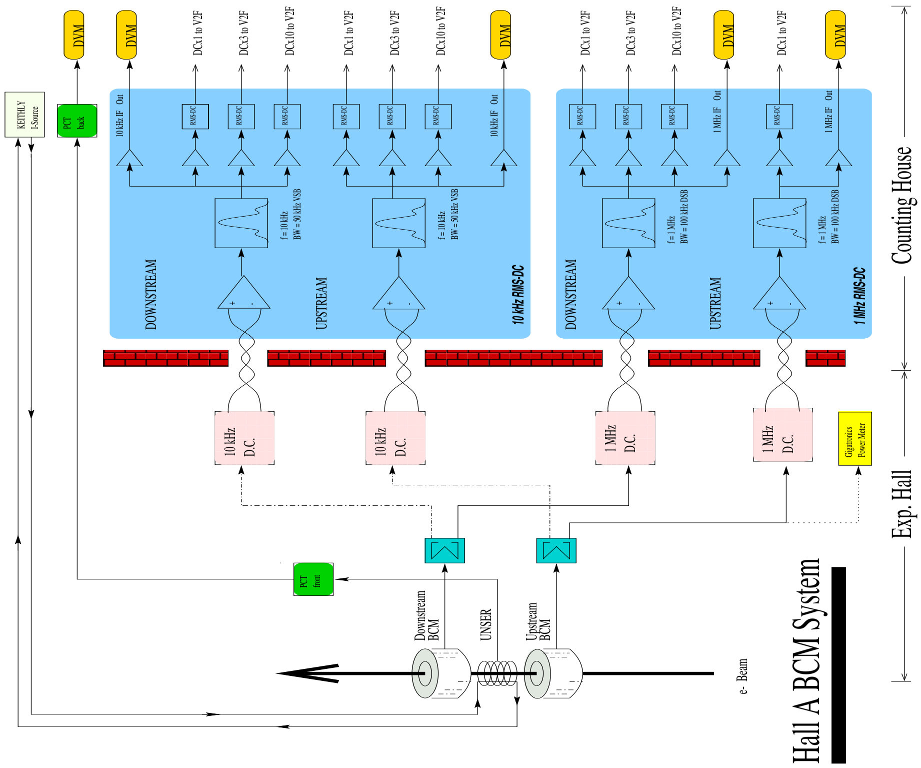

Figure 1:

output signal from the cavity is convert to 10kHz signals by a downconverter and fed to an RMS-to-DC converter board with a 50 KHz bandpass filter. After this conversion two output signals are produced.

1. One is sent to a high precision digital AC voltmeter which produces a digital output which is the RMS value of the input over a one second period. The digital output is sampled as an EPICS variable. One has to determine the conversion of the voltage to current for each cavity.

2. The other is split into three signals that are proportional to 1x,3x and 10x of the voltage level. Each signal is sent to an RMS-to-DC converter

and the DC voltage level is sent to a voltage-to-frequency converter (V-to-F). The output from the V-to-F is sent to a scaler. The number of counts measured by the scaler is proportional to the integrated charge. The constant of proportionality between V-to-F frequency and current has to be determined. For the 1x signal, the output of the RMS-to-DC converter is linear down to 5 μA. The 3x and 10x signal are useful for current below 5 μA.

On May 21, 2000 a series of measurements were done to calibrate the beam current monitors. The basic technique is to normalize the the cavities to the OLO2 cavity at the injector. During the measurements beam only went to Hall A. The beam was interrupted by inserting a Faraday cup after the OLO2 cavity so that the zeroes for the cavities and the Unser could be determined. The procedure was to set the beam current at one setting for one minute and then insert the Faraday cup for one minute and then step down to the next current. This is demonstrated in Fig. 2 in which the current measured by the Unser is plotted as a function of time. On May 2, 2000 the OLO2 cavity was normalized to the Faraday cup. The OLO2 was found to be 1.006 higher than the Faraday Cup. The calibration of the OLO2 was not changed, so that constants determined had to be changed by hand.

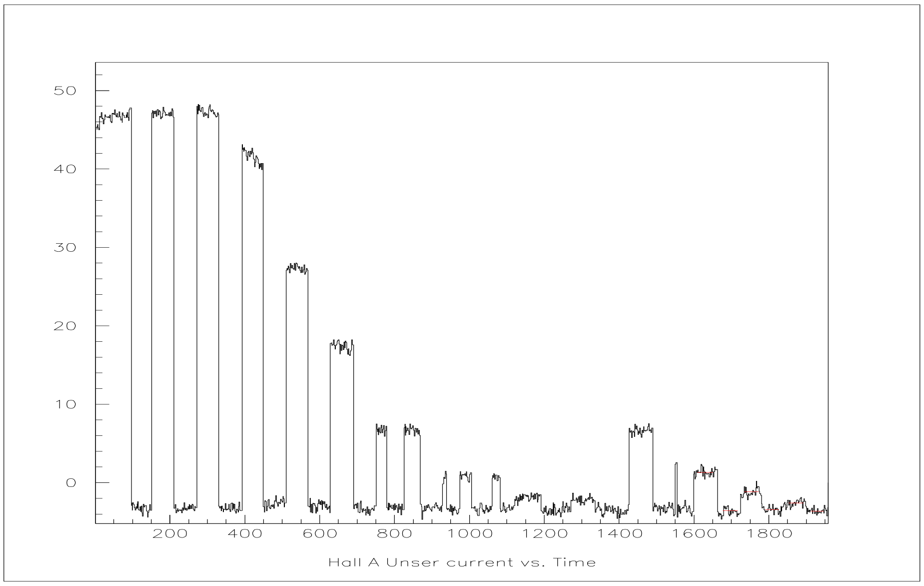

Figure 2:

First, an explanation of how the EPICS BCM calibration constants were determined. While the beam was being stepped through various currents the EPICS values for the upstream BCM voltage, downstream BCM voltage,Unser current, injector Faraday cup current, OLO2 current and the OLO2 power meter are written to once a second to a file. During this calibration the beam was not centered on the Faraday cup, so the current from the Faraday cup is unreliable. The analysis was done in directory */work/halla/ndelta-2/bcm* and the EPICS values are in the file *bcm_log_may21_2000.orig*. The program *bcmcal-step-new.f* written by Arun Saha was used to determine the EPICS BCM calibration constants. The file *bcm_log_may21_2000.orig* has to be manipulated slightly. The zero for the OLO2 has to be inserted as the second line in the input file. During the procedure there was a time when the beam was off and this was used to determine the zero for the OLO2 of 0.0014 . Next, the line with the values -1,-1,-1,-1,-1,-1,-1,-1 has to be insert where one wants the program to average the current over a time interval. The data has to be arranged so that the interval with beam in the hall is followed by an interval with no beam in the hall. Also, during the transition between beam on and beam off, an EPICS read would not have all the EPICS variables being consistent and those lines of data are eliminated. The program determines the average and standard deviation of the OLO2 current, upstream BCM voltage and downstream BCM voltage in each interval and groups them with matching beam on and off. The final value of each variable is determined by $\sqrt{ave^2_{\text{beam}} - ave^2_{\text{nobeam}}}$. The values for each interval are given in Table 1. In Fig. 3, the ratio of Unser current to OLO2 current, the ratio of downstream BCM voltage to OLO2 current and the ratio of upstream BCM voltage to OLO2 current are plotted as a function of OLO2 current. The low current runs with large standard deviation were not plotted in the figure. For currents below 5 μA the BCM calibration constants become non-linear. The reason for this is not understood and was not see in an earlier calibration on April 1999. The BCM calibration constants were determined by averaging the intervals with currents at 5 μA or greater and are given in Fig. 3 without the correction to the OLO2 current of 0.994 . In Table 2 the EPICS BCM calibration constantd are corrected by the factor and compared to values determined in April 1999. The constants have changed by -0.66% and -0.35% .

Next the calibration constants for converting the V-to-F scalers to charge were determined. During the data taking, the scalers were written to a regular data file every 8 seconds. This was broken up into runs 1158 and 1159 (for the last three intervals show in Fig. 2). The scalers were extracted from the data file using the program *read_scalar*. Then a paw kumac, *bcm_calib.kumac*, was used to determine to constants. The scaler data was broken into a time intervals and the average value of the V-to-F rate was determined for the interval. The zero offsets for the V-to-F rate was determined for the following time interval. The zero offsets were 78.4, 67.2, 155.0, 11.7, 107.4, 339.9 for the up 1x,3x,10x and down 1x,3x,10x. The calibration constants are listed in Table 3 and are plotted

OLO2 current	Up BCM voltage	Down BCM voltage	Unser current
50.1589±0.1798	0.6507±0.0014	0.6511±0.0013	49.9925±0.6800
50.3763±0.2377	0.6523±0.0010	0.6527±0.0010	50.3860±0.4967
50.3170±0.2350	0.6537±0.0012	0.6540±0.0012	49.7598±6.0170
43.6849±0.2355	0.5670±0.0011	0.5672±0.0009	43.5349±0.7654
30.3043±0.0473	0.3930±0.0006	0.3933±0.0006	29.2343±4.6008
20.4842±0.0617	0.2653±0.0005	0.2655±0.0005	20.7065±0.7661
10.0392±0.2580	0.1310±0.0003	0.1310±0.0004	9.9893±0.6026
10.1195±0.0274	0.1309±0.0003	0.1310±0.0003	9.7751±0.8912
10.0515±0.0387	0.1303±0.0004	0.1304±0.0004	9.9009±0.6257
5.0201±0.0219	0.0650±0.0003	0.0650±0.0003	5.0487±0.6368
4.3074±0.2782	0.0566±0.0006	0.0567±0.0005	4.2087±0.5640
4.3674±0.0117	0.0567±0.0002	0.0567±0.0002	4.0225±0.4490
2.2435±0.0077	0.0294±0.0001	0.0294±0.0001	2.1773±0.6374
1.8215±0.0055	0.0240±0.0001	0.0241±0.0001	1.7497±0.5783
1.1347±0.0232	0.0156±0.0004	0.0155±0.0004	0.9774±0.5393
1.0527±0.0025	0.0145±0.0001	0.0145±0.0001	1.0306±1.9801

Table 1:

versus OLO2 current in Fig. 4. Again below 5 μA there is a non-linearity. The average value for the constants was determined for the upstream cavity by weighted average of the values for OLO2 current greater than or equal to 10 μA and for the downstream cavity by weighted average of the values for OLO2 current greater than or equal to 5 μA. The weighted average of the V-to-F calibration constants are given in Table 4 with a correction from the OLO2 calibration and compared to constants determine in April 1999. The values have changed by less than a percent.

In conclusion, the mystery of the non-linearity at low currents needs to be understood. The end-of-run scalars are saved in a file *scaler_history_ndelta.dat*. The runend TCL script was modified so that it would go through the file and produce new charge values for each run. The new scalar values are in the directory *new_scal* for each run with the name *####.scal*. Joe Mitchell has volunteered to put the new values in the database.

Constant	April 1999 values	May 2000 Values	% Change
EPICS Downstream cavity constant	77.149	76.64 $\pm$ 0.10	-0.66 %
EPICS Upstream cavity constant	76.963	76.69 $\pm$ 0.10	-0.35 %

Table 2: EPICS BCM calibration constants which are the ratio of output voltage for the cavity to the OLO2 current. The constant have been corrected by a factor of 1.006 to take into account the calibration of OLO2 to injector Faraday cup.

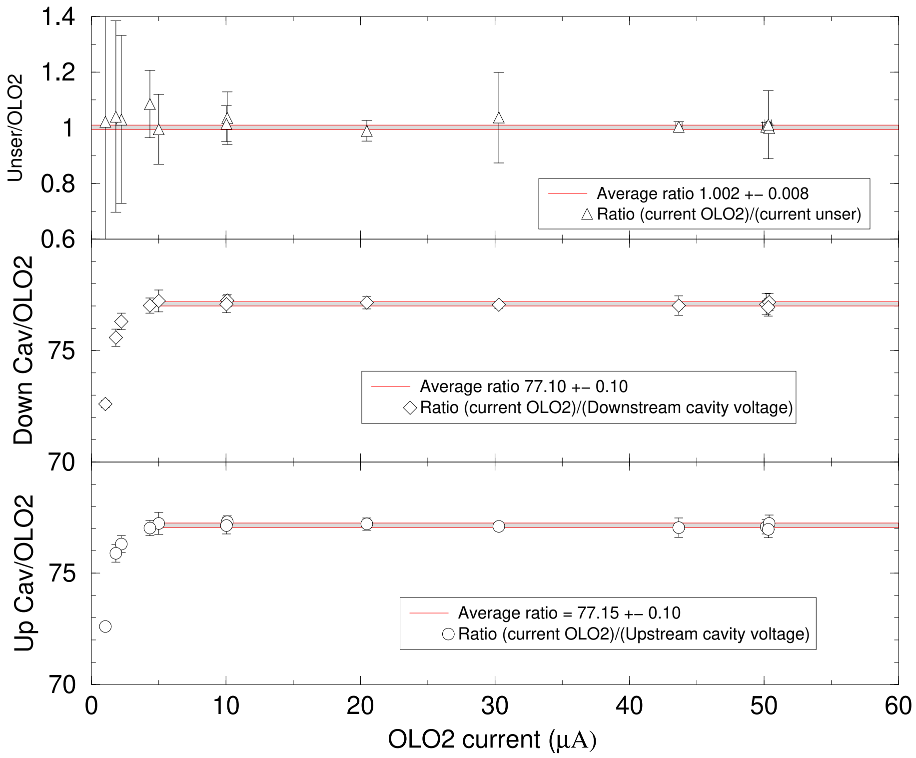

Figure 3: The average values for the ratios have not been corrected for the fact that the calibration of the OLO2 current was slightly off. This is done in Table 2.

OLO2 current	V-to-F U1x	V-to-F U3x	V-to-F U10x
50.16270	1331.8± 4.6	4100.5±14.4	12467.6±43.9
50.36150	1330.2± 6.6	4095.9±20.3	12452.5±61.8
50.34480	1332.3± 6.5	4102.3±20.0	12471.4±60.8
43.64370	1333.2± 2.6	4105.8± 8.0	12500.4±24.4
30.30270	1330.0± 2.7	4097.6± 8.4	12481.5±25.6
20.48270	1327.5± 4.4	4092.8±13.8	12468.1±42.1
10.11120	1323.0± 4.1	4087.8±12.6	12453.2±38.6
10.05030	1322.6± 5.4	4086.7±17.0	12450.0±51.7
5.01958	1315.4± 4.7	4080.8±14.9	12432.6±45.6
2.23633	1316.7± 5.1	4120.9±15.9	12556.4±48.7
1.11395	1355.9± 11.0	4322.4±29.8	13172.4±91.7
OLO2 current	V-to-F D1x	V-to-F D3x	V-to-F D10x
50.16270	1332.48± 4.7	4123.6± 14.5	12981.1± 45.7
50.36150	1330.95± 6.6	4118.8± 20.4	12964.5± 64.3
50.34480	1333.03± 6.5	4125.3± 20.1	12983.8± 63.2
43.64370	1334.10± 2.6	4128.9± 8.0	13033.2± 25.5
30.30270	1331.44± 2.7	4120.9± 8.4	13016.7± 26.7
20.48270	1329.70± 4.4	4115.6± 13.9	13002.9± 43.9
10.11120	1327.67± 4.1	4108.1± 12.7	12983.7± 40.1
10.05030	1327.25± 5.5	4106.8± 17.0	12979.9± 53.9
5.01958	1325.18± 4.8	4096.8± 15.0	12952.1± 47.5
2.23633	1338.63± 5.1	4127.4± 16.0	13058.1± 50.7
1.11395	1404.46± 9.8	4308.7± 30.7	13662.0± 94.6

Table 3: Listing ratio of V-to-F rate to OLO2 current as function of OLO2 current.

Constant	April 1999 values	May 2000 Values	% Change
V-to-F U1x	1348	1337.7± 1.4	-0.76 %
V-to-F U3x	4139	4122.8± 4.3	-0.39 %
V-to-F U10x	12552	12527.5± 13.1	-0.20 %
V-to-F D1x	1341	1339.0± 1.3	-0.15 %
V-to-F D3x	4141	4143.8 ± 4.1	+0.07 %
V-to-F D10x	13081	13055.0± 13.1	-0.20 %

Table 4: The V-to-F calibration constants . A correction was applied to correct for a recalibration of the OLO2 current by 0.994

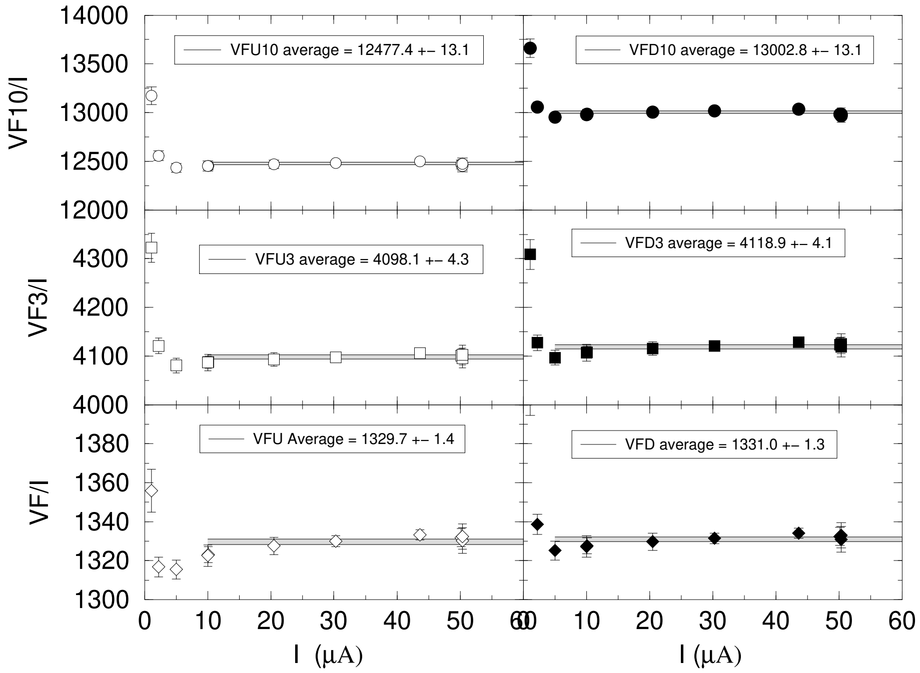

Figure 4: The average values for the ratios have not been corrected for the fact that the calibration of the OLO2 current was slightly off. This is done in Table 4.