Beam Charge Measurement for g2p/GEp experiment

Pengjia Zhu

February 15, 2016

Abstract

not italicized NH_3

The g2p/GEp experiment used a solid NH_3 polarized target ~~which~~ where target's the polarization ~~of it~~ is sensitive to temperature and radiation. The beam current was limited to 5~100nA during the experiment to avoid too much depolarization of target. This technical note summarized the method to calibrate the beam charge monitors (BCM) for the g2p/GEp experiment, with the ~~devices of~~ tungsten calorimeter, new BCM receiver, and DAQ system.

Summarizes 5-100 nA

1 Hardware

The BCM system used for the g2p/GEp experiments contains two RF cavities, a BCM receiver with related data-acquisition (DAQ) system, and a tungsten calorimeter for calibration. The Unser monitor was not considered due to a noisy signal, and the farady cup in injector was not used for calibration due to considerable leakage current between the Hall. The location of them ~~are~~ is shown in Fig.1.

1.1 BCM receiver

Since the original RMS-to-DC converter [1] did not work ~~in~~ at low current, a new BCM receiver was designed by John Mosson and his colleagues from the JLab instrumentation group for the purpose of achieving ~~enough~~ a reasonable signal/noise (S/N) ratio in the beam current environment ~~from~~ a range of several nanoampere ~~beam current~~ to several micro-ampere [2]. The design diagram is shown in Fig.2.

beam current

The receiver consists of ~~the~~ an analog part and ~~the~~ a digital part. The analog part includes the amplifiers and the mixer. The multiply mixer converts the ratio frequency (RF) signal to the intermediate frequency (IF) signal. The signal is digitized by a 36 MSPS ADC, and applied by a cascaded-integrator-comb (CIC) filter and an infinite-inpulse-response (IIR) filter (10.4 kHz). The CORDIC system is used to get the amplitude and phase of the digital signal. The 20-bit digital signal is converted back to 0~10V analog signal to match the existed Hall A DAQ system using a 18-bit DAC. A DIV unit is used to intercept the signal from 20 bit to 18 bit by applying an adjustable bit shift. More details can be found in ~~John Musson's technote~~ [2].

reference

or ADC? use a hyphen -

1.2 Data acquisition system

The BCM data from the receiver was connected to the DAQ system as shown in Fig.3. The voltage signal from receiver was ~~splitted~~ split and sent to the V2F module and the HAPPEX ADC.

1.2.1 Scaler

The V2F converts the voltage signal to the frequency signal in order to connect to the scalers for counting. The SIS380x scaler is the VME implement. It has two modes switched by a jumber on the board: SIS3800 and SIS3801. The SIS3800 scaler counts the charge, clock and trigger signals for each event, and delivers them to the data stream when the event trigger ~~coming~~ is accepted. The counter data for the SIS3800 is only cleared at the beginning of the run, thus the SIS3800 was used to get the counts for the whole run.

The SIS3801 was used to get the helicity gated information. Fig.4 shows the T-Settle signal from the helicity control board [3] in injector. The high-level T-Settle (70 μs) indicates the helicity flips, or has unsure helicity status, while the low-level T-Stable (971.65 μs) indicates the reliable helicity status. The rising edge

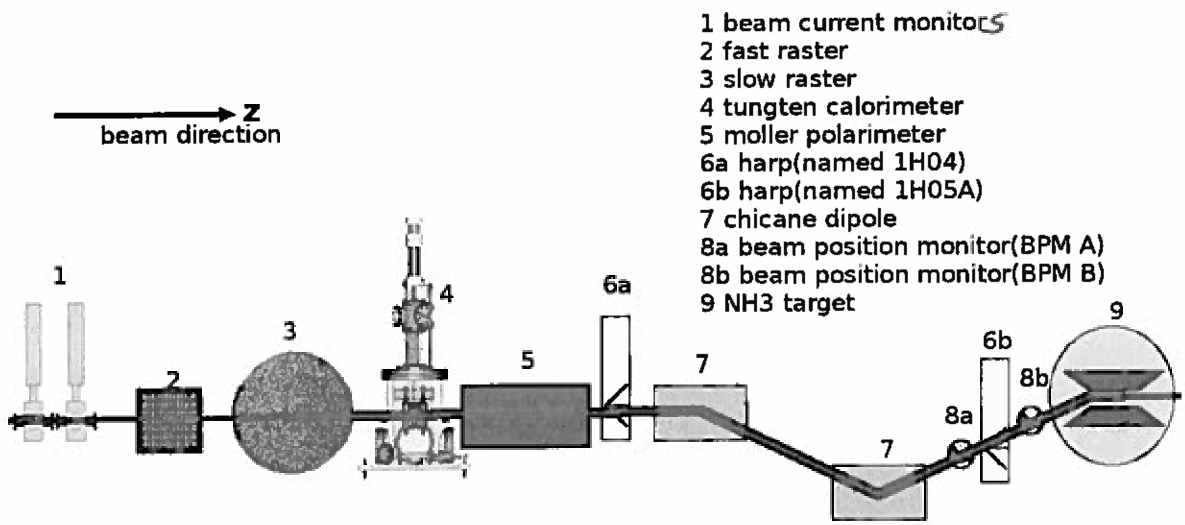


Figure 1: Beamline for g2p/GEp experiment

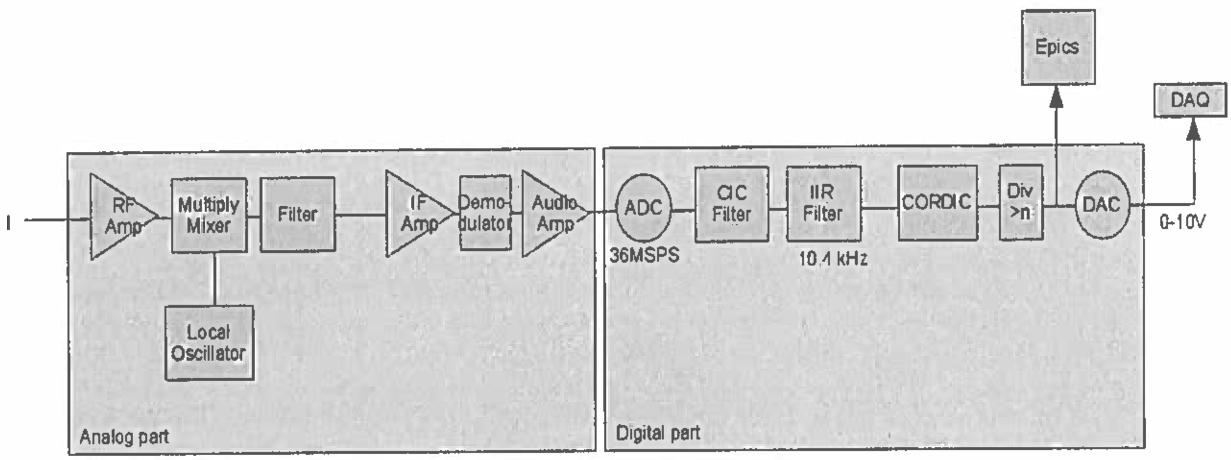


Figure 2: BPM and BCM receiver used for g2p/GEp experiment

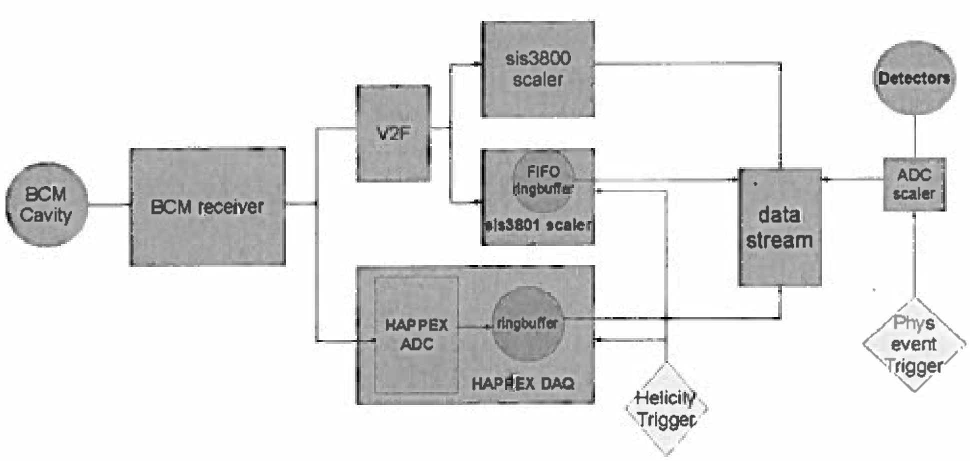


Figure 3: DAQ system for BCM

for measuring small parity violating asymmetries to high precision.

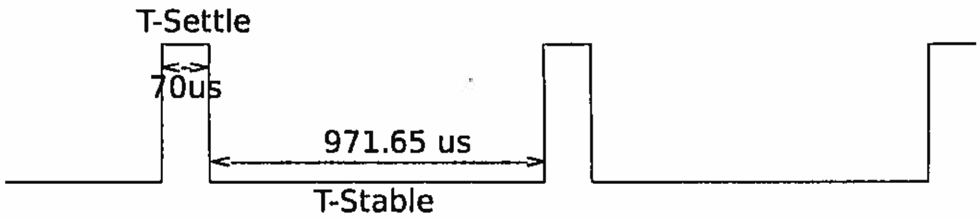


Figure 4: T-Settle signal from helicity control board, with 971.65 μs T-Stable time and 70μs T-Settle time.

of the T-Settle triggers the scaler to save the current counts to the FIFO register, stop the counter and reset the counts. The flipping edge of the T-Settle recovers the counting. The FIFO register is used as a ringbuffer before merging to the standard DAQ system.

1.2.2 HAPPEX DAQ

The HAPPEX DAQ uses ~~the~~ 18-bit ADCs, which were designed for the parity violation experiments. It has a high bit resolution for ~~getting~~ measuring high ~~precise charge~~ precision asymmetry. ~~It~~ This DAQ was reprogrammed and reassembled for g2p experiment.

The HAPPEX DAQ contains a timing board (NIM) [4], several ~~pieces of HAPPEX~~ 18-bit ADCs [5], a flexible IO (FLEXIO,NIM) [6], a trigger interface (TI) module, and a VXWorks CPU. The diagram of HAPPEX DAQ is shown in Fig.5.

Timing board The timing board generates several time signals to control the start and stop integration time of the ADCs. The T-Settle signal was used as the trigger source for the timing board. Based on the trigger signal, the timing board generates a ~~group~~ set of signals (Fig.6). The reset signal controls the ADC integrated. The delay time between the baseline signal and the peak signal is used as the integration time, and the digital value difference between them is used as integrated result. The DAC module in the timing board was used as a debugging source during the experiment.

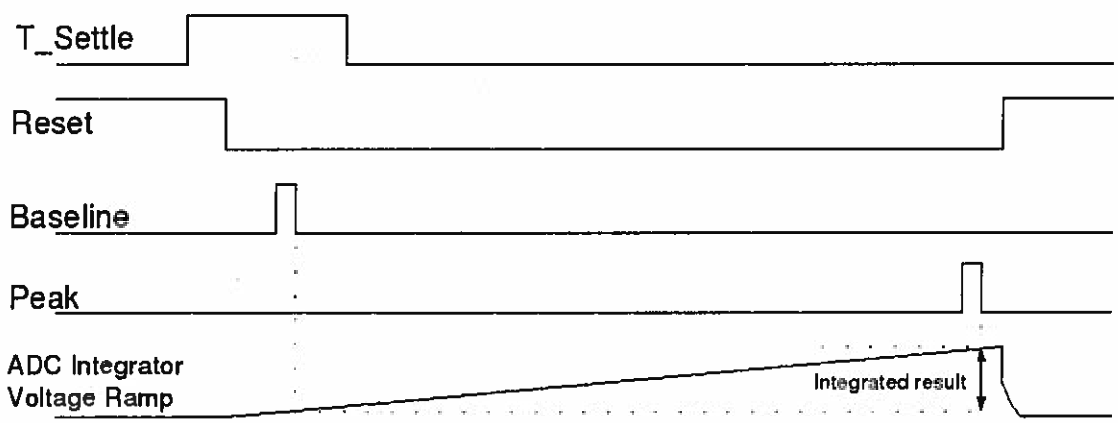


Figure 6: Signals from timing board [6]

HAPPEX ADC The HAPPEX ADC was designed for high bit resolution (18 bit) and a small non-linearity ($\leq 2\times10^{-5}$). From the asymmetry measurement test (Fig.7), the bit resolution for the HAPPEX ADCs was much better than the one for the scaler. The integration time of HAPPEX ADC controlled by the timing board was 875μs, a little bit ~~lower~~ smaller than the helicity period (1041.65μs). It recorded more precise position and current information than the fastbus ADC1881 (with an integration time less than 50 ns during the experiment).

FASTBUS

1881 ADC

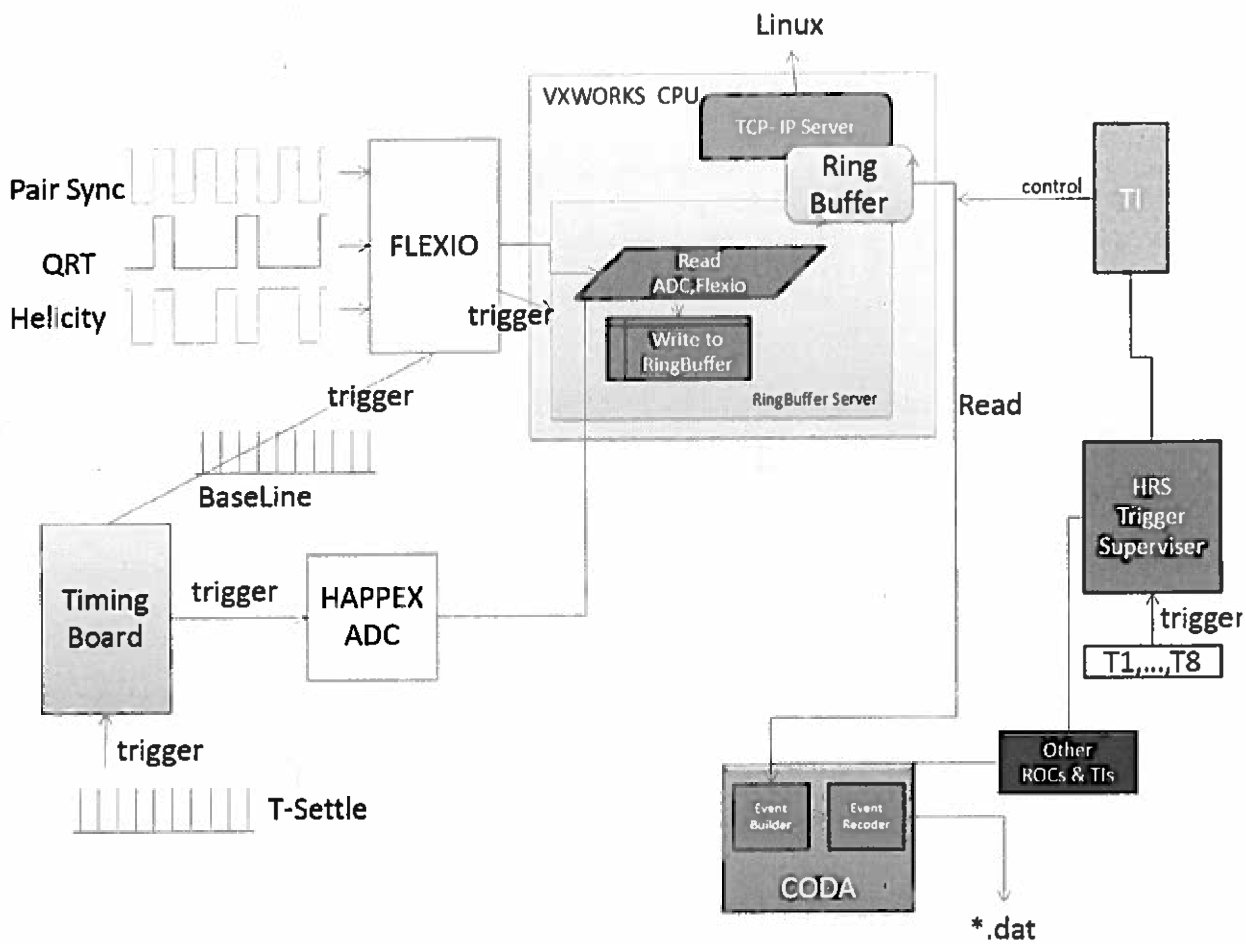


Figure 5: HAPPEX DAQ diagram

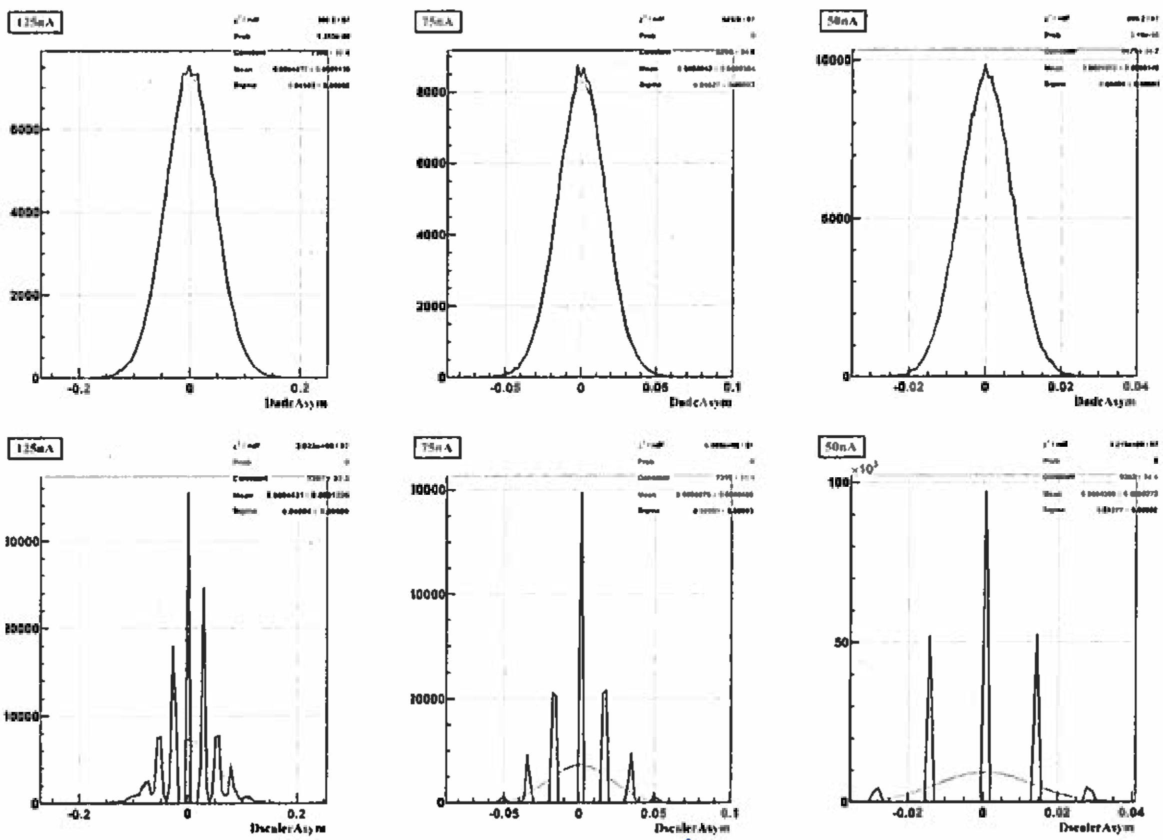


Figure 7: Comparison of charge asymmetry measurements from ~~between~~ ~~using~~ HAPPEX ADCs and scalers. The top three pictures use HAPPEX ADCs while the bottom three pictures use scalers. The beam currents from left to right are 125 nA, 75 nA, and 50 nA. The total number of events are same in each histogram. ~~respectively~~

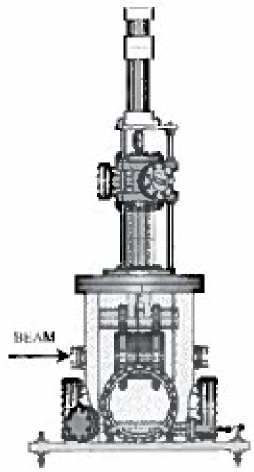


Figure 8: Tungsten Calorimeter

Flexible IO The flexible IO is used to record the digital information. The baseline signal peak from the timing board triggers the flexible IO to record the helicity signals. It also provides a trigger signal for the ringbuffer.

Ring Buffer A vxworks VxWorks CPU controls the data reading from the HAPPEX ADC and the flexible IO to the ringbuffer server in the CPU's register. For more reliable performance and less CPU occupation, a trigger is used instead of checking the pair sync polarity all of the time. The trigger from the flexible IO has the same period as the T-Settle. Each trigger causes the CPU to read out the data from the flexible IO and the ADC once. A trigger interface controlled by the HRS trigger superviser ~~is reading~~ reads the data from the ringbuffer server to the data-stream. For the online debugging, a TCP-IP server was running ~~in~~ on the CPU to readout the data from the ringbuffer from any Linux computer at any time.

1.3 Tungsten Calorimeter

A tungsten calorimeter, [7] ~~was installed~~ located downstream of the BCMs and the two rasters [8] that holds for calibrating the BCMs by measuring ~~using~~ the beam induced ~~caused~~ temperature rise ~~rising~~, as shown in Fig.8. The chamber ~~held~~ the tungsten is pumped down to ~~into~~ vacuum to minimize heat loss. The tungsten is in three positions for the different purpose:

1. Beam charging: The tungsten is in the beam pipe. All of the incoming beam electrons hit the tungsten. The temperature is ~~arising~~ increasing during this period.
2. Equilibrating: The tungsten moves out of the beam pipe but doesn't touch the cooling plate. The beam turns off. The temperature ~~tends to stable.~~ stabilizes. The measurement of the temperature ~~is~~ occurs in this period.
3. Cooling: The tungsten moves to the cooling plate to cool down the tungsten.

For the temperature measurement, ~~6~~ six thermometry devices (RTDs) are mounted on the outer surface at each end of the tungsten slug. write out

2 Calibrate ion of the BCMs

~~The~~ Calibration data were ~~was~~ taken ~~for~~ several times during the experiment ~~for the different periods~~. In order to ~~receive~~ achieve the uniform heat that comes from the beam over the tungsten surface, the rasters were turned on ~~when taking~~ during the BCM calibration. The limited size of the ringbuffer caused ~~the~~ potential loss of data ~~lost~~ when the read-out speed was lower than the read-in speed. For the deadtime consideration, the DAQ system only read out no more than 50 group sets? of data from the ringbuffer. An additional clock trigger with a frequency larger than 20 Hz ($\geq 960/(\text{helicity frequency})/50$) was use $\sim$

added to avoid data loss in the ringbuffer recorded in the datastream. The clock signal was needed for calculating the pedestal of the scaler and the ADC. For HAPPEX ADC, the helicity entries was used as the clock.

There were two types of clocks ~~signal~~: fast clock and slow clock. The frequency of the fast clock was ~103.7 KHz, while the frequency of the slow clock was ~1 KHz. The pedestal value is related to the frequency of the clock signal, thus the calibration constants for them are different. use $\sim$

A complete calibration period is shown in Fig.9. The total temperature ~~arise~~ rise was used to calculate the total charge. The zero-order polynomial fits were taken before the beam charging and after the temperature become stable when tungsten is in the equilibrating position. The relationship between the total charge and the temperature rise is:

$$Charge = K * Temperature, \tag{1}$$

where K is the heat capacity of tungsten. It was measured by Alhamad Mahmoud before the experiment [9]. The result is shown in Fig.10 with the value of $8555.5 \pm 50\, J/K$. T is the average temperature from the 6 RTDs.

There are several devices needed to be calibrated, and each one has ~~its~~ its own special condition. The detail calibration procedures for each device are as follows.

2.1 Calibration for SIS3800 scaler

A reset signal was sent to the SIS3800 scaler at the beginning of the run to clear the counts. Since the scaler was found to cause high deadtime, only clock signals were sampled for each event, while ~~others were~~ scalers were sampled for each 1000 events. Also the DAQ read the scaler once at the end of the run.

The ~~third~~ middle left picture in Fig.9 is for the SIS3800 calibration. The ~~steep range is the~~ rise in the graph is the period when the beam ~~come,~~ hits the tungsten, corresponding to the ~~steep range~~ rise in the ~~first picture~~ top left. The total charge has the following relation with the counts:

hits the tungsten

$$Charge = slope * (\Delta counts - ped * \Delta clockcounts), \tag{2}$$

where $\Delta counts$ is the total BCM counts accumulated in the scaler, $\Delta clockcounts$ is the total clock counts accumulated in the scaler. The ped is the pedestal value, which is calculated from the first-order polynomial fits before and after the beam. To get the $slope$ value, two time points are chosen before and after the beam. Using the $\Delta counts$ and the $\Delta clockcounts$ between these two time points and combining with the charge calculated from the temperature, the $slope$ value is then ~~calculated.~~ determined.

The beam current is calculated from the calibration constants as:

$$Current = slope * (rate - ped * clockrate), \tag{3}$$

where $rate$ and $clockrate$ are defined as the bcm counts and clock counts per second.

per second

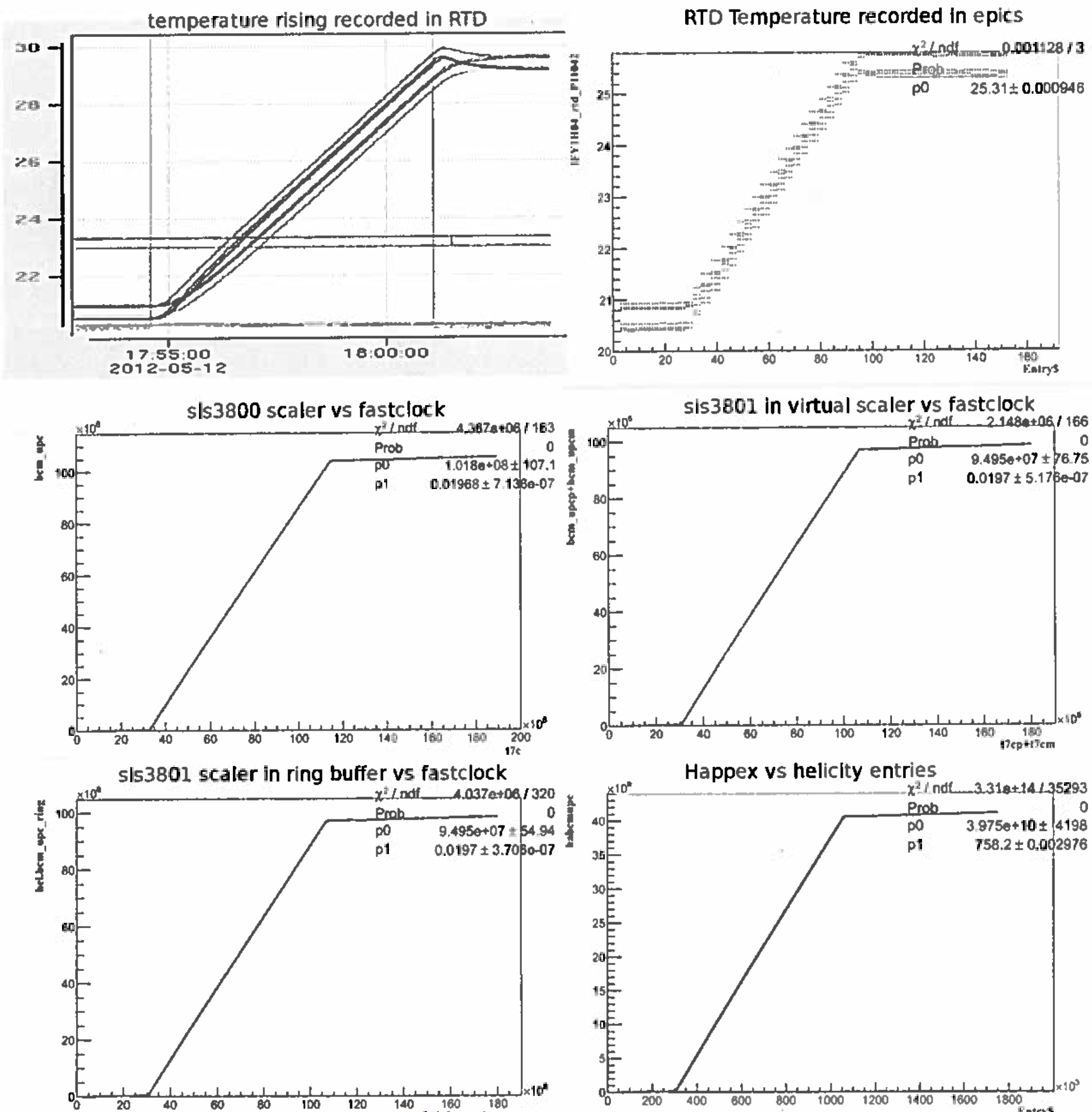
2.2 Calibration for SIS3801 scaler

To calibrate the SIS3801 scaler it is necessary to accumulate all of the counts for each helicity window, ~~which needs no data lost.~~ without any loss of data. There are two methods to get the total counts. One is using the sum counts from two virtual scalers. The offline analyzer [10] automatically accumulates the total counts for positive helicity states and negative helicity states, which present two independent variables (positive and negative virtual scaler) in the raw data. Another is accumulating all of the counts from the ringbuffer. The helicity decoder was used to check if data were lost. The calibrated calibration constants are the same from the two methods. Further procedures are same as the SIS3800. The total charge has the following relation with the counts:

$$Charge = slope * (\Delta counts - ped * \Delta clockcounts), \tag{4}$$

where the $\Delta counts$ and $\Delta clockcounts$ are counted from the SIS3801 scaler. Since the SIS3801 does not count ~~in~~ for 70 μs for each 1041.65 μs, the slopes calculated for the SIS3801 are larger than the slope for the SIS3800. The beam current is calculated as:

$$Current = Slope * (rate - ped * 103700/s * 971.65\mu s)/1041.65\mu s, \tag{5}$$



top left and right figures

Figure 9: BCM Calibration, the ~~first two pictures~~ are the temperature rise of the RTDs, the last four ~~pictures~~ ~~are~~ the counts recorded in different devices at the same time.

plots show

scalers and the Happex ADC

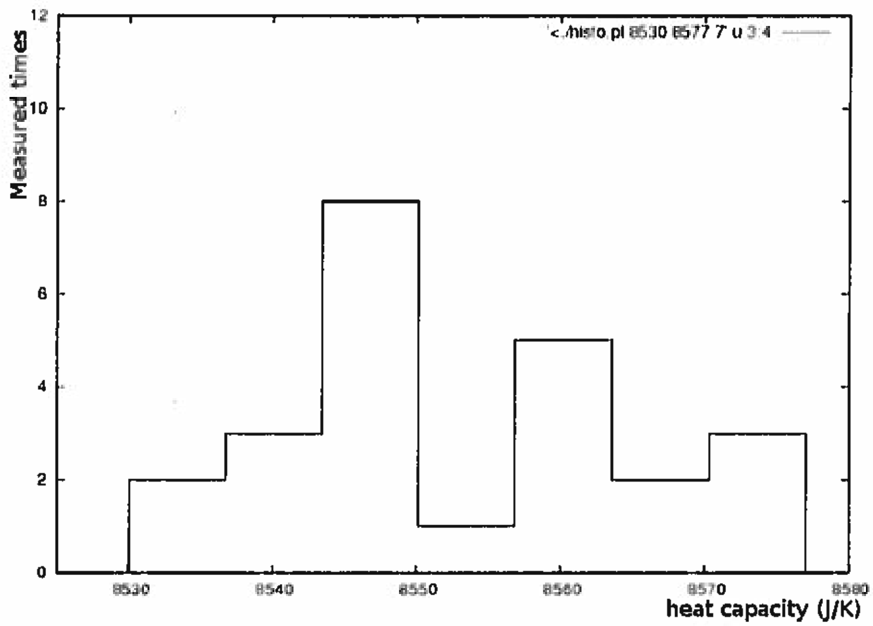


Figure 10: Tungsten Calorimeter Heat Capacity Determination [9]

where $103700/s$ is the frequency of the fast clock, $971.65\mu s$ is the duration of T-Stable, and $1041.65\mu s$ is the duration of a helicity window.

2.3 Calibration for HAPPEX ADC

To calibrate the HAPPEX ADC, the values are accumulated for all of the events between two time ~~points~~ periods as the total counts. The entries in the HAPPEX DAQ ~~is~~ are used as the time stamp. The total charge has the following relation with the counts:

$$Charge = slope * 875\mu s * (\Delta counts - ped * \Delta entries), \tag{6}$$

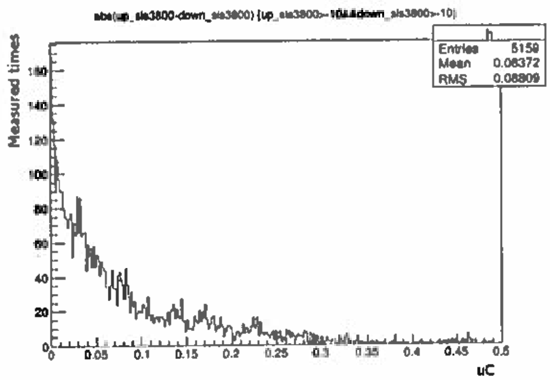
where $875\mu s$ is the integration time of the ADC. The beam current is calculated as:

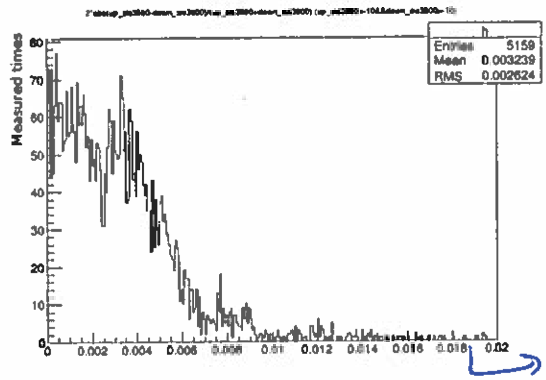
$$Current = slope * (rate - ped) * 875\mu s/1041.65\mu s. \tag{7}$$

2.4 Uncertainty

The uncertainty of the calculated charge from the tungsten calorimeter comes from the beam energy, RTD, the measured tungsten heat capacity, and the heat loss. The accuracy of the beam energy calculated from the ~~ARC~~ measurement is 0.2 MeV in the range of 0.5 to 6 GeV [11], which contributes the uncertainty of calculated charge of 0.34 nC per 1 K temperature rise (2.2 GeV beam energy). The uncertainties of the RTDs are 12.5 mK [12], which contributes uncertainty of $0.046\,\mu C$ (2.2 GeV beam energy). The $50\,J/K$ uncertainty of heat capacity contributes $0.18\,\mu C$ per 1 K temperature rise (2.2 GeV beam energy). The Hall A calorimeter thermal and mechanical design limits heat losses to the 0.2 % level if the measurement is within 20 min [7], which ~~causes~~ results in an ~~the~~ uncertainty of the calculated charge of an additional 0.2 %. The total uncertainty is 0.68 % for the calculated charge from tungsten.

By comparing ~~of~~ the difference between the upstream and downstream BCMs, the fluctuations between ~~upstream and downstream~~ the two are below $0.19\,\mu C$ for 90 % of runs. The relative differences between them for 90 % runs are below 0.7 %, as shown in Fig.11 . The differences indicate the uncertainty of the BCM is below 0.7 %. Combin~~ing~~ed with the uncertainty of the tungsten calorimeter, the final uncertainty of BCMs is below 1 %.





unit?

(a) Absolute difference between upstream and downstream charge

(b) Relative difference between upstream and downstream charge

Figure 11: Comparing (sum) of the charge calculated from (the) upstream and downstream (BCMs). Each ~~event~~ (entry) in (the graph) ~~picture~~ is the total charge calculated from ~~one~~ (each) run from (the) experiment.

3 Calibration constants

The calibration constants are shown in (the) Appendix (Tables 1-9.). Some specials are listed below:

- –Mar.17 3rm downstream scaler abnormal
- Mar.18–Apr.2 left arm upstream scaler noisy
- Apr.2–Apr.9 right arm SIS3801 not working
- Apr.9 changed right arm scaler channel for bcm
- Apr.19–calibration constant changed
- Near May.12 third arm SIS3801 not working
- May.13–May.14 downstream bcm broken

use a dash!

The bcm receiver gain settings for each periods are list below, the values after the date are:
A_Pre_Gain_1/A_Pre_Gain_2/A_Mag_Div
B_Pre_Gain_1/B_Pre_Gain_2/B_Mag_Div
IQ_Filter_K
Mag_Filter_K

- –Mar.2 18:39:42 gain changing
- Mar.2 18:39:43–Mar.5 10:00:12 10/10/1 9/9/1 3 4
- Mar.5 10:00:13–Mar.5 10:27:40 gain changing
- Mar.5 10:27:41–Mar.6 8:51:39 10/10/1 9/9/1 1 4
- Mar.6 8:51:40–Mar.6 13:45:43 10/13/1 9/9/1 1 4
- Mar.6 13:45:44–Mar.6 13:49:05 gain changing
- Mar.6 13:49:06–Mar.7 17:20:10 29/30/4 27/27/4 1 4
- Mar.7 17:20:11–Mar.7 17:23:25 gain changing
- Mar.7 17:23:25–Mar.10 13:12:53 29/30/4 27/27/4 1 4
- Mar.10 13:12:54–Mar.10 13:33:15 gain changing
- Mar.10 13:33:16–end 40/41/4 40/43/4 1 4

References

[1] J.-C. Denard, High Accuracy Beam Current Monitor System for CEBAF's Experimental Hall A, 2001 Particle Accelerator Conference, Chicago (2001) 2326 – 2328.

[2] J. Musson, Functional Description of Algorithms Used in Digital Receivers, JLab Technical Report No. JLAB-TN-14-028.

[3] S. H. Roger Flood, R. Suleiman, Helicity Control Board User's Guide, JLab Internal Manual (unpublished).
URL http://hallaweb.jlab.org/equipment/daq/HelicityUsersGuideFeb4.pdf

[4] Specification of HAPPEX II ADC Timing Board, Revision 1, JLab Technical Report (unpublished).
URL http://hallaweb.jlab.org/experiment/g2p/technotes/others/TimingBoard.pdf

[5] R. Michaels, Precision Integrating HAPPEX ADC, JLab Technical Report (unpublished).
URL http://hallaweb.jlab.org/parity/prex/adc18/prex_adc18_spec.ps

[6] E. Jastrzembski, A Flexible Vme Input/Output Module, JLab Technical Report (unpublished).
URL https://coda.jlab.org/drupal/system/files/pdfs/HardwareManual/misc/FLEXIO.pdf

[7] Bevins M., A. Day, et al., Mechanical and Thermal Design of the CEBAF Hall A Beam Calorimeter, in: Proceedings of 2005 Particle Accelerator Conference, 2005, pp. 3819–3821. doi:10.1109/PAC.2005.1591634.

[8] Pengjia Zhu, et al, Beam Position Reconstruction for the g2p Experiment in Hall A at Jefferson Lab, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 808 (2016) 1 – 10. doi:http://dx.doi.org/10.1016/j.nima.2015.10.086.
URL http://www.sciencedirect.com/science/article/pii/S0168900215013200

[9] G2P Internal Elog, https://hallaweb.jlab.org/dvcslog/g2p/173.

[10] O. Hansen, ROOT/C++ Analyzer for Hall A.
URL http://hallaweb.jlab.org/podd/index.html

[11] JLab webpage, http://hallaweb.jlab.org/equipment/beam/absol_beam.html.

[12] Y. Rousseau, Calibration of the Calorimeter, JLab Technical Report (unpublished).
URL http://hallaweb.jlab.org/experiment/g2p/technotes/others/calorimeter%20RTD.pdf

Appendix

current(nA)	280	25	50	75	100
energy(MeV)	2253.13	2252.94	2252.94	2252.94	2252.94
time	03/03/12 09:30 PM	03/13/12 04:00 PM	03/16/12 10:15 PM	03/29/12 12:21 AM	04/07/12 03:00 PM
Avail period	Start 3.10 13:25	3.10 13:33 3.17 10:00	3.10 13:33 3.17 10:00	3.27 21:00 4.2 14:00	4.2 18:00 4.9 9:00
run avail(left SIS3800 up)	Start 3051	3052 3295	3052 3295	broken	3660 4695
run avail(left SIS3800 down)	Start 3051	3052 3634	3052 3634	3052 3634	3636 4695
run avail(left SIS3801 up)	Start 3051	3052 3295	3052 3295	broken	3660 4695
run avail(left SIS3801 down)	Start 3051	3052 3634	3052 3634	3052 3634	3636 4695
run avail(left HAPPEX up)	Start 3051			3073 3634	3636 4695
run avail(left HAPPEX down)	Start 3051			3073 3634	3636 4695
runnumber	2665	3149	3254	3437	3856
SIS3800 upslope(slowclk)	1.37309e-06	3.32775e-07	3.34603E-07	2.30692e-07	3.22991E-07
SIS3800 upped(slowclk)	5.24344E+00	2.04717E+00	2.01363E+00	2.40785E+00	2.01757E+00
SIS3800 downslope(slowclk)	1.30711e-06	2.58036e-07	2.57738E-07	2.56379e-07	2.49656E-07
SIS3800 downped(slowclk)	6.91734E+00	2.76818E+00	2.73600E+00	2.58978E+00	2.73382E+00
SIS3800 upslope(fstclk)	1.37346e-06	3.32774e-07	3.34604E-07	2.30693e-07	3.22990E-07
SIS3800 upped(fstclk)	5.17426E-02	2.01725E-02	1.98515E-02	2.37558E-02	1.98845E-02
SIS3800 downslope(fstclk)	1.30736e-06	2.58035e-07	2.57739E-07	2.5638e-07	2.49655E-07
SIS3800 downped(fstclk)	6.82245E-02	2.72772E-02	2.69731E-02	2.55486E-02	2.69437E-02
SIS3801 upslope(fstclk)	1.47161e-06	3.65962e-07	3.58951e-07	2.4832e-07	3.46231e-07
SIS3801 upped(fstclk)	5.15461E-02	3.09438E-02	1.98588E-02	2.37232E-02	1.98880E-02
SIS3801 downslope(fstclk)	1.40127e-06	2.83756e-07	2.76493e-07	2.7518e-07	2.67616e-07
SIS3801 downped(fstclk)	6.81238E-02	4.11454E-02	2.69735E-02	2.55914E-02	2.69484E-02
HAPPEX upslope	not avail			9.76018e-07	9.44277E-07
HAPPEX upped	not avail			7.47561E+02	7.64707E+02
HAPPEX downslope	not avail			7.81678e-07	7.59977E-07
HAPPEX downped	not avail			7.06877E+02	7.27266E+02

Table 1: BCM calibration constants for the left arm

current(nA)	50	75	50	25	50
energy(MeV)	1712.19	1708.35	1156.7	1156.7	2253.65
time	04/10/12 08:09 AM	04/14/12 07:07 PM	04/25/12 02:38 AM	04/28/12 10:15 AM	05/06/12 02:43 PM
Avail period	4.10 0:00 4.19 8:00	4.10 0:00 4.19 8:00	4.20 4:00 5.2 8:00	4.20 4:00 5.2 8:00	5.2 21:00 5.13 1:00
run avail(left SIS3800 up)	3660 4695	3660 4695	4698 5440	4698 5440	5485 6100
run avail(left SIS3800 down)	3636 4695	3636 4695	4698 5440	4698 5440	5485 6043
run avail(left SIS3801 up)	3660 4695	3660 4695	4698 5440	4698 5440	5485 6100
run avail(left SIS3801 down)	3636 4695	3636 4695	4698 5440	4698 5440	5485 6043
run avail(left HAPPEX up)			4698 5440	4698 5440	5485 6100
run avail(left HAPPEX down)			4698 5440	4698 5440	5485 6043
runnumber	4088	4405	5015	5214	5751
SIS3800 upslope(slowclk)	3.19668E-07	3.23814E-07	3.55483E-07	3.53225E-07	3.48943E-07
SIS3800 upped(slowclk)	2.02148E+00	2.02217E+00	1.99755E+00	2.03317E+00	2.00619E+00
SIS3800 downslope(slowclk)	2.47684E-07	2.48227E-07	2.58163E-07	2.57395E-07	2.54841E-07
SIS3800 downped(slowclk)	2.73704E+00	2.74181E+00	2.71992E+00	2.75600E+00	2.74454E+00
SIS3800 upslope(fstclk)	3.19669E-07	3.23815E-07	3.55483E-07	3.53221E-07	3.48942E-07
SIS3800 upped(fstclk)	1.99247E-02	1.99301E-02	1.96837E-02	2.00331E-02	1.97694E-02
SIS3800 downslope(fstclk)	2.47685E-07	2.48228E-07	2.58163E-07	2.57392E-07	2.54841E-07
SIS3800 downped(fstclk)	2.69776E-02	2.70227E-02	2.68033E-02	2.71552E-02	2.70453E-02
SIS3801 upslope(fstclk)	3.42781e-07	3.4717e-07	3.81166e-07	3.78808e-07	3.7418e-07
SIS3801 upped(fstclk)	1.99254E-02	1.99350E-02	1.97021E-02	2.00361E-02	1.97749E-02
SIS3801 downslope(fstclk)	2.65591e-07	2.6613e-07	2.76814e-07	2.76033e-07	2.73271e-07
SIS3801 downped(fstclk)	2.69789E-02	2.70306E-02	2.68191E-02	2.71594E-02	2.70443E-02
HAPPEX upslope			1.04042E-06	1.03394E-06	1.02106E-06
HAPPEX upped			7.58219E+02	7.74628E+02	7.63704E+02
HAPPEX downslope			7.86150E-07	7.84135E-07	7.76177E-07
HAPPEX downped			7.25062E+02	7.39477E+02	7.35583E+02

Table 2: BCM calibration constants for the left arm

current(nA)	75	100	50	75
energy(MeV)	2253.34	2253.37	2252.94	3352.4
time	05/11/12 06:26 PM	05/12/12 05:48 PM	05/13/12 02:59 PM	05/16/12 11:41 PM
Avail period	5.2 21:00 5.13 1:00	5.2 21:00 5.13 1:00	5.13 1:00 5.14 8:00	5.14 15:00 end
run avail(left SIS3800 up)	5485 6100	5485 6100	5485 6100	6101 end
run avail(left SIS3800 down)	5485 6043	5485 6043	broken	6101 end(NR)
run avail(left SIS3801 up)	5485 6100	5485 6100	5485 6100	6101 end
run avail(left SIS3801 down)	5485 6043	5485 6043	broken	6101 end(NR)
run avail(left HAPPEX up)	5485 6100	5485 6100	5485 6100	6101 end
run avail(left HAPPEX down)	5485 6043	5485 6043	broken	6101 end(NR)
runnumber	5986	6035	6062	6174
SIS3800 upslope(slowclk)	3.49032E-07	3.47590E-07	3.50492E-07	3.55051e-07
SIS3800 upped(slowclk)	2.01442E+00	2.01317E+00	2.01224E+00	2.00844E+00
SIS3800 downslope(slowclk)	2.54925E-07	2.53945E-07	1.96575E-06	2.57619e-07
SIS3800 downped(slowclk)	2.72054E+00	2.71869E+00	2.71795E+00	2.73275E+00
SIS3800 upslope(fstclk)	3.49036E-07	3.47589E-07	3.50490E-07	3.55056e-07
SIS3800 upped(fstclk)	1.98566E-02	1.98398E-02	1.98255E-02	1.97970E-02
SIS3800 downslope(fstclk)	2.54928E-07	2.53944E-07	1.96567E-06	2.57623e-07
SIS3800 downped(fstclk)	2.68156E-02	2.67923E-02	2.67783E-02	2.69365E-02
SIS3801 upslope(fstclk)	3.74239e-07	3.72691e-07	3.75909e-07	3.80653e-07
SIS3801 upped(fstclk)	1.98584E-02	1.98459E-02	1.98381E-02	1.97998E-02
SIS3801 downslope(fstclk)	2.73332e-07	2.72283e-07	2.10829e-06	2.76198e-07
SIS3801 downped(fstclk)	2.68168E-02	2.67972E-02	2.68024E-02	2.69430E-02
HAPPEX upslope	1.02102E-06	1.01675E-06	1.02575E-06	1.03841e-06
HAPPEX upped	7.66377E+02	7.66642E+02	7.65561E+02	7.60940E+02
HAPPEX downslope	7.76257E-07	7.73150E-07	5.97952E-06	7.84284e-07
HAPPEX downped	7.26879E+02	7.26759E+02	7.23959E+02	7.29082E+02

Table 3: BCM calibration constants for the left arm

current(nA)	280	25	50	75	100
energy(MeV)	2253.13	2252.94	2252.94	2252.94	2252.94
time	03/03/12 09:30 PM	03/13/12 04:00 PM	03/16/12 10:15 PM	03/29/12 12:21 AM	04/07/12 03:00 PM
Avail period	Start 3.10 13:25	3.10 13:33 3.17 10:00	3.10 13:33 3.17 10:00	3.27 21:00 4.2 14:00	4.2 18:00 4.9 9:00
run avail(right SIS3800 up)	Start 22130	22131 22658	22131 22658	22131 22658	22660 22987
run avail(right SIS3800 down)	Start 22130	22131 22658	22131 22658	22131 22658	22660 22987
run avail(right SIS3801 up)	Start 22130	22131 22658	22131 22658	22131 22658	broken
run avail(right SIS3801 down)	Start 22130	22131 22658	22131 22658	22131 22658	broken
run avail(right HAPPEX up)	Start 22130			22158 22658	22660 23618
run avail(right HAPPEX down)	Start 22130			22158 22658	22660 23618
runnumber	21751	22238	22338	22470	22885
SIS3800 upslope(slowclk)	1.37212e-06	3.33141E-07	3.35299E-07	3.33446E-07	3.22819E-07
SIS3800 upped(slowclk)	5.23480E+00	2.04715E+00	2.01363E+00	1.88817E+00	2.01757E+00
SIS3800 downslope(slowclk)	1.30632e-06	2.58320E-07	2.58274E-07	2.56520E-07	2.49523E-07
SIS3800 downped(slowclk)	6.91143E+00	2.76815E+00	2.73599E+00	2.58975E+00	2.73382E+00
SIS3800 upslope(fstclk)	1.37253e-06	3.33139E-07	3.35301E-07	3.33445E-07	3.22818E-07
SIS3800 upped(fstclk)	5.16652E-02	2.01720E-02	1.98516E-02	1.86263E-02	1.98844E-02
SIS3800 downslope(fstclk)	1.30656e-06	2.58318E-07	2.58276E-07	2.56521E-07	2.49521E-07
SIS3800 downped(fstclk)	6.81632E-02	2.72768E-02	2.69733E-02	2.55485E-02	2.69437E-02
SIS3801 upslope(fstclk)	1.46934e-06	3.65342e-07	3.59699e-07	3.57709e-07	broken
SIS3801 upped(fstclk)	5.16033E-02	2.97348E-02	1.98585E-02	1.86580E-02	broken
SIS3801 downslope(fstclk)	1.39902e-06	2.83277e-07	2.77067e-07	2.75175e-07	broken
SIS3801 downped(fstclk)	6.81575E-02	3.95893E-02	2.69721E-02	2.55542E-02	broken
HAPPEX upslope	not avail			9.55044e-07	9.23204E-07
HAPPEX upped	not avail			1.75740E+03	1.75756E+03
HAPPEX downslope	not avail			7.81495e-07	7.59968E-07
HAPPEX downped	not avail			1.07545E+03	1.07213E+03

Table 4: BCM calibration constants for the right arm

current(nA)	50	75	50	25	50
energy(MeV)	1712.19	1708.35	1156.7	1156.7	2253.65
time	04/10/12 08:09 AM	04/14/12 07:07 PM	04/25/12 02:38 AM	04/28/12 10:15 AM	05/06/12 02:43 PM
Avail period	4.10 0:00 4.19 8:00	4.10 0:00 4.19 8:00	4.20 4:00 5.2 8:00	4.20 4:00 5.2 8:00	5.2 21:00 5.13 1:00
run avail(right SIS3800 up)	22600 23618	22600 23618	23621 24216	23621 24216	24259 24727
run avail(right SIS3800 down)	22600 23618	22600 23618	23621 24216	23621 24216	24259 24706
run avail(right SIS3801 up)	23075 23618	23075 23618	23621 24216	23621 24216	24259 24727
run avail(right SIS3801 down)	23075 23618	23075 23618	23621 24216	23621 24216	24259 24706
run avail(right HAPPEX up)			23621 24216	23621 24216	24259 24727
run avail(right HAPPEX down)			23621 24216	23621 24216	24259 24706
runnumber	23082	23360	23890	24040	24458
SIS3800 upslope(slowclk)	3.19449E-07	3.23652E-07	3.55750E-07	3.53327E-07	3.48757E-07
SIS3800 upped(slowclk)	2.02144E+00	2.02219E+00	1.99750E+00	2.03317E+00	2.00620E+00
SIS3800 downslope(slowclk)	2.47514E-07	2.48103E-07	2.58357E-07	2.57469E-07	2.54705E-07
SIS3800 downped(slowclk)	2.73699E+00	2.74179E+00	2.71988E+00	2.75600E+00	2.74454E+00
SIS3800 upslope(fstclk)	3.19451E-07	3.23653E-07	3.55750E-07	3.53323E-07	3.48756E-07
SIS3800 upped(fstclk)	1.99248E-02	1.99306E-02	1.96839E-02	2.00331E-02	1.97694E-02
SIS3800 downslope(fstclk)	2.47516E-07	2.48103E-07	2.58357E-07	2.57466E-07	2.54705E-07
SIS3800 downped(fstclk)	2.69778E-02	2.70229E-02	2.68034E-02	2.71552E-02	2.70453E-02
SIS3801 upslope(fstclk)	3.42548e-07	3.46997e-07	3.81454e-07	3.78918e-07	3.7398e-07
SIS3801 upped(fstclk)	1.99254E-02	1.99350E-02	1.97020E-02	2.00361E-02	1.97749E-02
SIS3801 downslope(fstclk)	2.6541e-07	2.65997e-07	2.77022e-07	2.76114e-07	2.73125e-07
SIS3801 downped(fstclk)	2.69789E-02	2.70307E-02	2.68188E-02	2.71595E-02	2.70442E-02
HAPPEX upslope			1.01836E-06	1.01194E-06	9.98575E-07
HAPPEX upped			1.76323E+03	1.77658E+03	1.76456E+03
HAPPEX downslope			7.86595E-07	7.84236E-07	7.75621E-07
HAPPEX downped			1.09454E+03	1.10431E+03	1.10078E+03

Table 5: BCM calibration constants for the right arm

current(nA)	75	100	50	75
energy(MeV)	2253.34	2253.37	2252.94	3352.4
time	05/11/12 06:26 PM	05/12/12 05:48 PM	05/13/12 02:59 PM	05/16/12 11:41 PM
Avail period	5.2 21:00 5.13 1:00	5.2 21:00 5.13 1:00	5.13 1:00 5.14 8:00	5.14 15:00 end
run avail(right SIS3800 up)	24259 24727	24259 24727	24259 24727	24728 end
run avail(right SIS3800 down)	24259 24706	24259 24706	broken	24728 end(NR)
run avail(right SIS3801 up)	24259 24727	24259 24727	24259 24727	24728 end
run avail(right SIS3801 down)	24259 24706	24259 24706	broken	24728 end(NR)
run avail(right HAPPEX up)	24259 24727	24259 24727	24259 24727	24728 end
run avail(right HAPPEX down)	24259 24706	24259 24706	broken	24728 end(NR)
runnumber	24671	24700	24719	24769
SIS3800 upslope(slowclk)	3.49296E-07	3.47708E-07	3.50342E-07	3.54078E-07
SIS3800 upped(slowclk)	2.01441E+00	2.01317E+00	2.01224E+00	2.00686E+00
SIS3800 downslope(slowclk)	2.55118E-07	2.54031E-07	1.96491E-06	2.56913E-07
SIS3800 downped(slowclk)	2.72053E+00	2.71870E+00	2.71795E+00	2.73056E+00
SIS3800 upslope(fstclk)	3.49301E-07	3.47708E-07	3.50340E-07	3.54078E-07
SIS3800 upped(fstclk)	1.98572E-02	1.98398E-02	1.98256E-02	1.97767E-02
SIS3800 downslope(fstclk)	2.55121E-07	2.54031E-07	1.96483E-06	2.56913E-07
SIS3800 downped(fstclk)	2.68159E-02	2.67923E-02	2.67784E-02	2.69082E-02
SIS3801 upslope(fstclk)	3.74523e-07	3.72818e-07	3.75748e-07	3.79606e-07
SIS3801 upped(fstclk)	1.98591E-02	1.98461E-02	1.98382E-02	1.97795E-02
SIS3801 downslope(fstclk)	2.7354e-07	2.72376e-07	2.10737e-06	2.75437e-07
SIS3801 downped(fstclk)	2.68172E-02	2.67970E-02	2.68023E-02	2.69125E-02
HAPPEX upslope	9.99842E-07	9.95083E-07	1.00323E-06	1.01328E-06
HAPPEX upped	1.77152E+03	1.77303E+03	1.77264E+03	1.76628E+03
HAPPEX downslope	7.76667E-07	7.73271E-07	5.97638E-06	7.82040E-07
HAPPEX downped	1.08914E+03	1.08845E+03	1.08867E+03	1.09584E+03

Table 6: BCM calibration constants for the right arm

current(nA)	280	25	50	75	100
energy(MeV)	2253.13	2252.94	2252.94	2252.94	2252.94
time	03/03/12 09:30 PM	03/13/12 04:00 PM	03/16/12 10:15 PM	03/29/12 12:21 AM	04/07/12 03:00 PM
Avail period	Start 3.10 13:25	3.10 13:33 3.17 10:00	3.10 13:33 3.17 10:00	3.27 21:00 4.2 14:00	4.2 18:00 4.9 9:00
run avail(third SIS3800 up)	not avail	40296 40668	40296 40668	40296 40668	40670 41419
run avail(third SIS3800 down)	not avail	broken	broken	40465 40668	40670 41419
run avail(third SIS3801 up)	not avail	40296 40668	40296 40668	40296 40668	40670 41419
run avail(third SIS3801 down)	not avail	broken	broken	40465 40668	40670 41419
runnumber		40368	40388	40486	40928
SIS3800 upslope(fstclk)	not avail	3.32885e-07	3.34957E-07	3.36286e-07	3.23371E-07
SIS3800 upped(fstclk)	not avail	2.01732E-02	1.98517E-02	1.98266E-02	1.98850E-02
SIS3800 downslope(fstclk)	not avail	1.2906e-07	1.29005E-07	2.5868e-07	2.49949E-07
SIS3800 downped(fstclk)	not avail	5.45561E-02	5.39468E-02	2.68700E-02	2.69434E-02
SIS3801 upslope(fstclk)	not avail	3.57236e-07	3.59326e-07	3.60744e-07	3.46631e-07
SIS3801 upped(fstclk)	not avail	2.02169E-02	1.98582E-02	1.98876E-02	1.98876E-02
SIS3801 downslope(fstclk)	not avail	1.38495e-07	1.38383e-07	2.77492e-07	2.67924e-07
SIS3801 downped(fstclk)	not avail	5.46740E-02	5.39542E-02	2.69487E-02	2.69487E-02

Table 7: BCM calibration constants for the third arm

current(nA)	50	75	50	25	50
energy(MeV)	1712.19	1708.35	1156.7	1156.7	2253.65
time	04/10/12 08:09 AM	04/14/12 07:07 PM	04/25/12 02:38 AM	04/28/12 10:15 AM	05/06/12 02:43 PM
Avail period	4.10 0:00 4.19 8:00	4.10 0:00 4.19 8:00	4.20 4:00 5.2 8:00	4.20 4:00 5.2 8:00	5.2 21:00 5.13 1:00
run avail(third SIS3800 up)	40670 41419	40670 41419	41420 41915	41420 41915	41922 42052
run avail(third SIS3800 down)	40670 41419	40670 41419	41420 41915	41420 41915	41922 42017
run avail(third SIS3801 up)	40670 41419	40670 41419	41420 41915	41420 41915	41922 42052
run avail(third SIS3801 down)	40670 41419	40670 41419	41420 41915	41420 41915	41922 42017
runnumber	41027	41256	41671	41846	41918
SIS3800 upslope(fstclk)	3.19302E-07	3.23944E-07	3.56080E-07	3.53600E-07	3.48498E-07
SIS3800 upped(fstclk)	1.99247E-02	1.99308E-02	1.96874E-02	2.00331E-02	1.97662E-02
SIS3800 downslope(fstclk)	2.47400E-07	2.48326E-07	2.58596E-07	2.57668E-07	2.54516E-07
SIS3800 downped(fstclk)	2.69776E-02	2.70230E-02	2.68065E-02	2.71551E-02	2.70411E-02
SIS3801 upslope(fstclk)	3.46631e-07	3.47304e-07	3.81801e-07	3.79211e-07	3.73698e-07
SIS3801 upped(fstclk)	1.98876E-02	1.99356E-02	1.97044E-02	2.00362E-02	1.97719E-02
SIS3801 downslope(fstclk)	2.67924e-07	2.66232e-07	2.77274e-07	2.76326e-07	2.72918e-07
SIS3801 downped(fstclk)	2.69487E-02	2.70302E-02	2.68213E-02	2.71590E-02	2.70400E-02

Table 8: BCM calibration constants for the third arm

current(nA)	75	100	50	75
energy(MeV)	2253.34	2253.37	2252.94	3352.4
time	05/11/12 06:26 PM	05/12/12 05:48 PM	05/13/12 02:59 PM	05/16/12 11:41 PM
Avail period	5.2 21:00 5.13 1:00	5.2 21:00 5.13 1:00	5.13 1:00 5.14 8:00	5.14 15:00 end
run avail(third SIS3800 up)	41922 42052	41922 42052	41922 42052	42053 end
run avail(third SIS3800 down)	41922 42017	41922 42017	broken	42053 end(NR)
run avail(third SIS3801 up)	41922 42052	not avail	41922 42052	42053 end
run avail(third SIS3801 down)	41922 42017	not avail	broken	42053 end(NR)
runnumber	41968	42008	42036	42126
SIS3800 upslope(fstclk)	3.49381E-07	3.47768E-07	3.50458E-07	3.54554E-07
SIS3800 upped(fstclk)	1.98550E-02	1.98381E-02	1.98268E-02	1.97758E-02
SIS3800 downslope(fstclk)	2.55180E-07	2.54075E-07	1.96554E-06	2.57258E-07
SIS3800 downped(fstclk)	2.68130E-02	2.67914E-02	2.67804E-02	2.69069E-02
SIS3801 upslope(fstclk)	3.74607e-07	not avail	3.75868e-07	3.80113e-07
SIS3801 upped(fstclk)	1.98589E-02	not avail	1.98389E-02	1.97786E-02
SIS3801 downslope(fstclk)	2.736e-07	not avail	2.10805e-06	2.75803e-07
SIS3801 downped(fstclk)	2.68173E-02	not avail	2.68024E-02	2.69116E-02

Table 9: BCM calibration constants for the third arm