

Beam Charge Measurement for g2p/GEp experiment

Pengjia Zhu

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Abstract

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

1 Hardware

The BCM system used for g2p/GEp experiment 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 noisy signal, and the farady cup in injector was not used for calibration due to considerable leak current between the Hall. The location of them are shown in Fig.1.

1.1 BCM receiver

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

The receiver consists of the analog part and the digital part. The analog part includes the amplifies 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-impulse-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 $0\sim 10\text{V}$ 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].

1.2 Data acquisition system

The BCM data from receiver was connected to the DAQ system as shown in Fig.3. The voltage signal from receiver was splitted 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 signal for each event, and delivers them to the data stream when the event trigger coming. 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 ($70\ \mu\text{s}$) indicates the helicity flips, or has unsure helicity status, while the low-level T-Stable ($971.65\ \mu\text{s}$) indicates the reliable helicity status. The rising edge

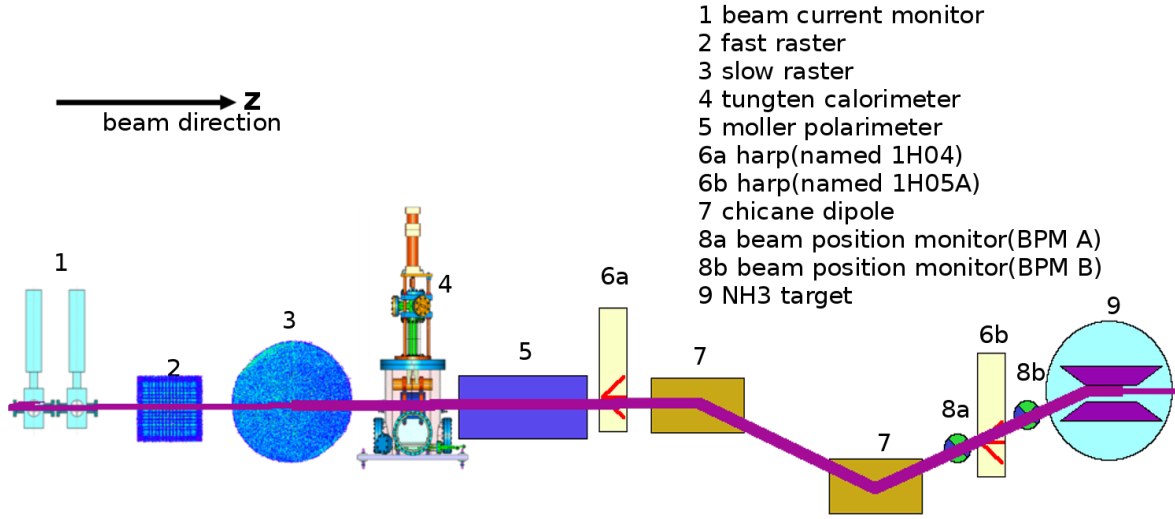


Figure 1: Beamline for g2p/GEp experiment

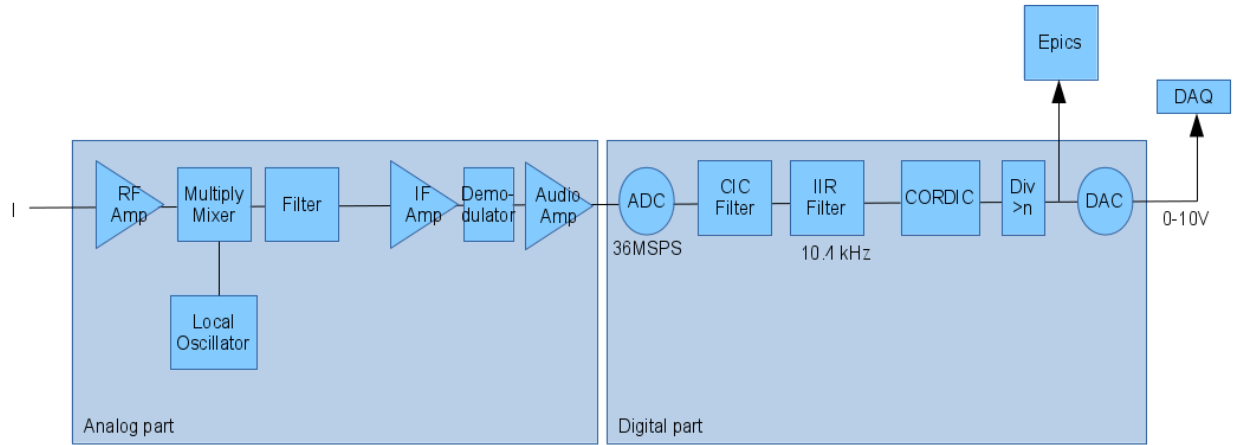


Figure 2: BPM and BCM receiver used for g2p/GEp experiment

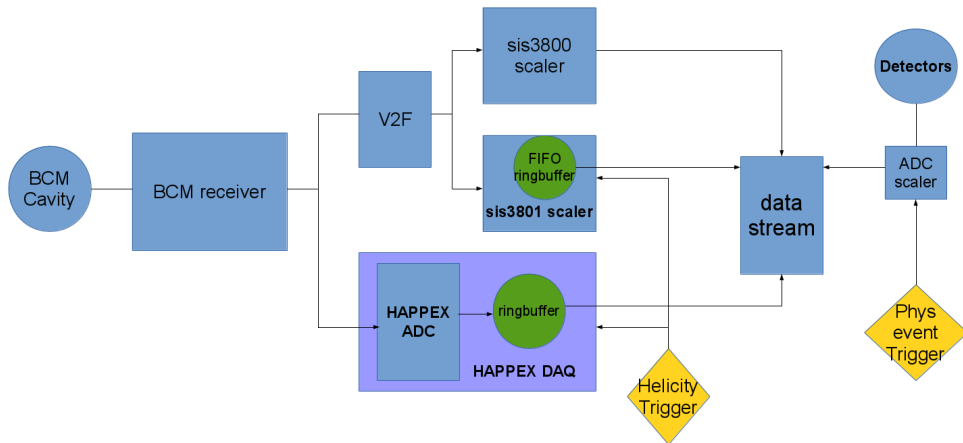


Figure 3: DAQ system for BCM

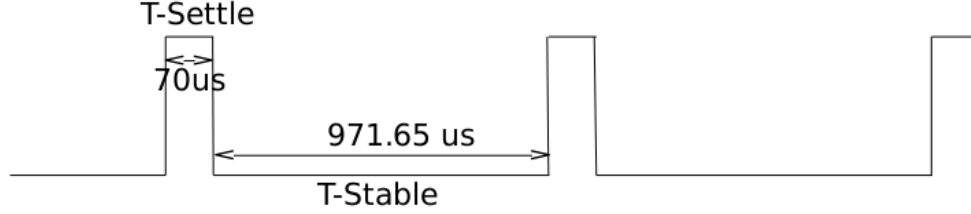


Figure 4: T-Settle signal from helicity control board, with $971.65 \mu s$ T-Stable time and $70 \mu s$ T-Settle time.

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 high bit resolution for getting high precise charge asymmetry. It was reprogrammed and reassembled for g2p experiment.

The HAPPEX DAQ contains a timing board (NIM) [4], several pieces of HAPPEX ADC [5], a flexible IO (FLEXIO,NIM) [6], a trigger interface (TI), 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 ADC. 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 of signals (Fig.6). The reset signal controls the ADC integrating. The delay time between the baseline signal and the peak signal is used as integration time, and the digital value difference between them is used as integrated result. The DAC module in the timing board was used as debugging source during the experiment.

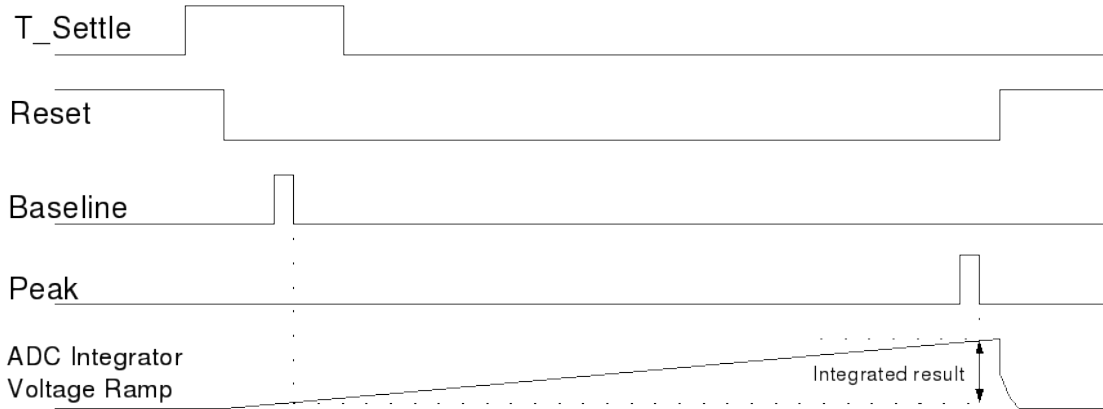


Figure 6: Signals from timing board [6]

HAPPEX ADC The HAPPEX ADC was designed for high bit resolution (18 bit) and small non-linearity ($\leq 2 \times 10^{-5}$). From the asymmetry measurement test (Fig.7), the bit resolution for HAPPEX ADC was much better than the one for scaler. The integration time of HAPPEX ADC controlled by the timing board was $875 \mu s$, a little bit lower than the helicity period ($1041.65 \mu s$). It recorded more precise position and current information than the fastbus ADC1881 (with integration time less than $50 ns$ during the experiment).

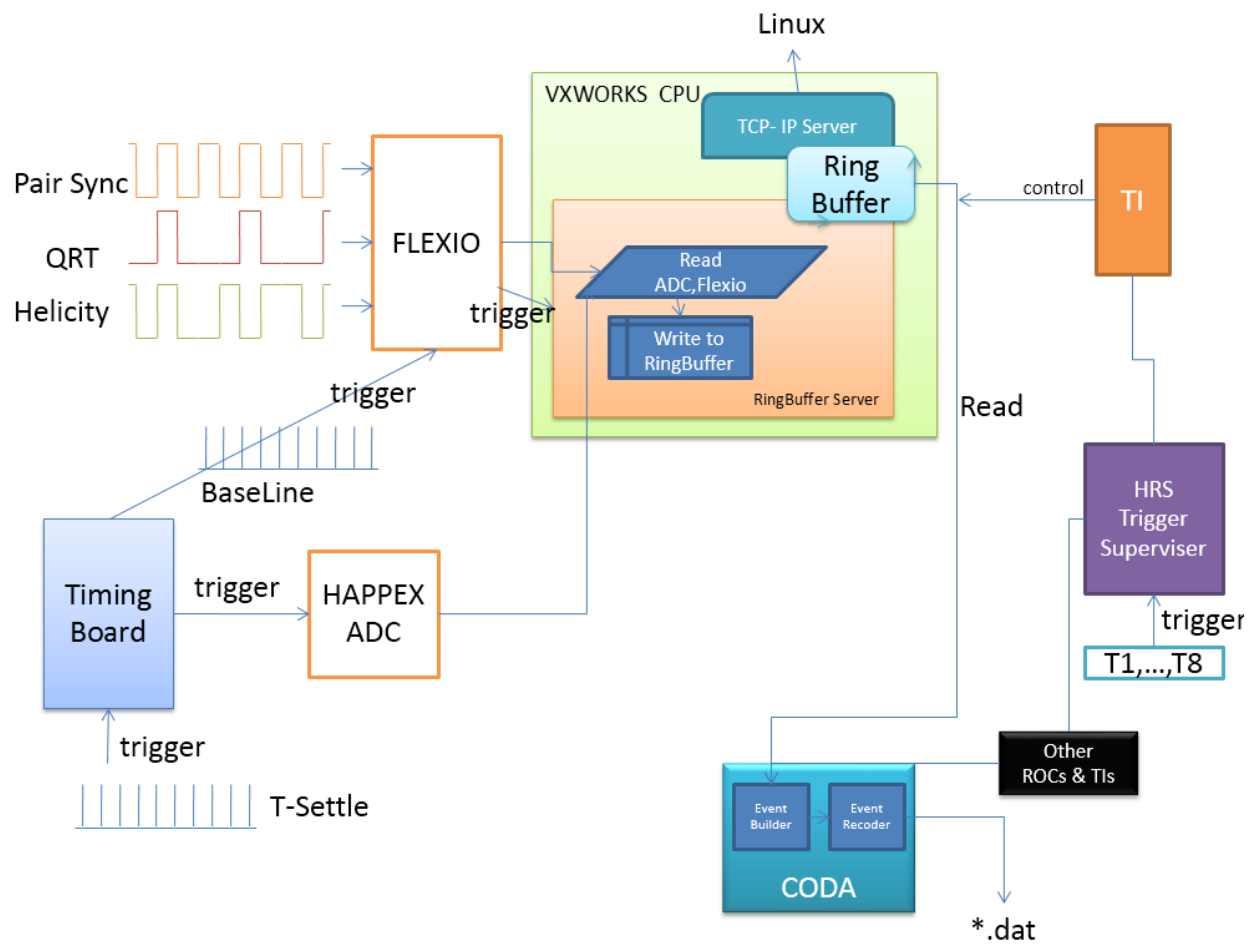


Figure 5: HAPPEX DAQ diagram

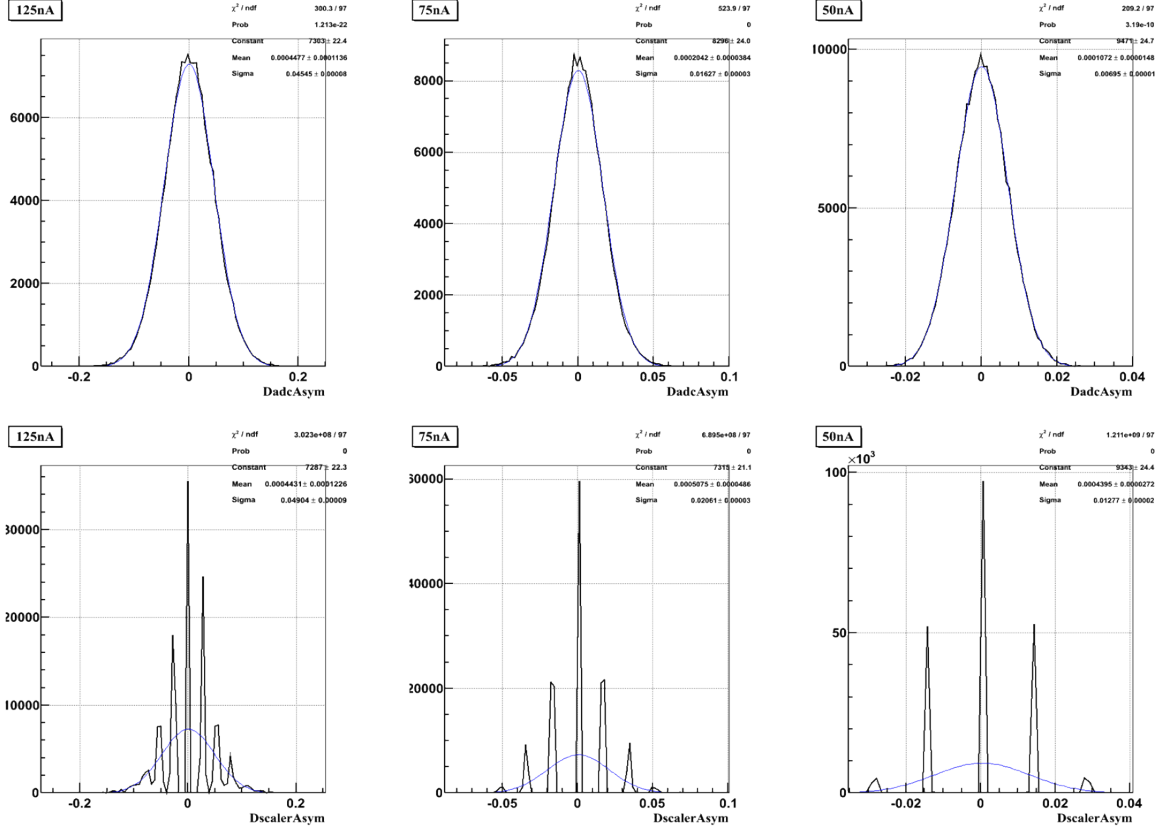


Figure 7: Comparison of charge asymmetry measurement between using HAPPEX ADC and scaler. The top three pictures use HAPPEX ADC, while the bottom three pictures use scaler. The beam currents from left to right are 125 nA, 75 nA, and 50 nA. The total events are the same.

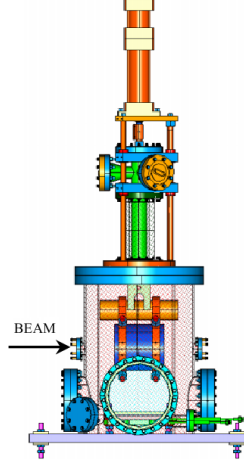


Figure 8: Tungsten Calorimeter

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 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 read out the data from the flexible IO and the ADC once. A trigger interface controlled by the HRS trigger supervisor is reading the data from the ringbuffer server to the data-stream. For the online debugging, a TCP-IP server was running in 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 downstream of the BCM and two rasters [8] for calibrating the BCM using the beam caused temperature rising, as shown in Fig.8. The chamber held the tungsten is pumped 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 during this period.
2. Equilibrating. The tungsten moves out the beam pipe but doesn't touch the cooling plate. The beam turns off. The temperature tends to stable. The measurement of the temperature is in this period.
3. Cooling. The tungsten moves to the cooling plate to cool down the tungsten.

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

2 Calibrate the BCM

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

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

There were two types of clock 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 of them are different.

A complete calibration period is shown in Fig.9. The total temperature arise 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 in the equilibrating position. The relationship between the total charge and the temperature arise is:

$$Charge = K * Temperature, \quad (1)$$

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

There are several devices needed to be calibrated, each one has it's 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 run to clear the counts. Since the scaler was found to cause high deadtime, only clock signals were sampled for each event, others were sampled for each 1000 events. Also the DAQ read the scaler once at the end of the run.

The third picture in Fig.9 is for SIS3800 calibration. The steep range is the period when the beam come, corresponding to the steep range in the first picture. The total charge has the following relation with the counts:

$$Charge = slope * (\Delta counts - ped * \Delta clockcounts), \quad (2)$$

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.

The beam current is calculated from the calibration constants as:

$$Current = slope * (rate - ped * clockrate), \quad (3)$$

where $rate$ and $clockrate$ are defined as the bcm counts and clock counts 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. 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 status and negative helicity status, 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 calculated calibration constants are same from two methods. Further procedures are same as the SIS3800. The total charge has the following relation with the counts:

$$Charge = slope * (\Delta counts - ped * \Delta clockcounts), \quad (4)$$

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

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

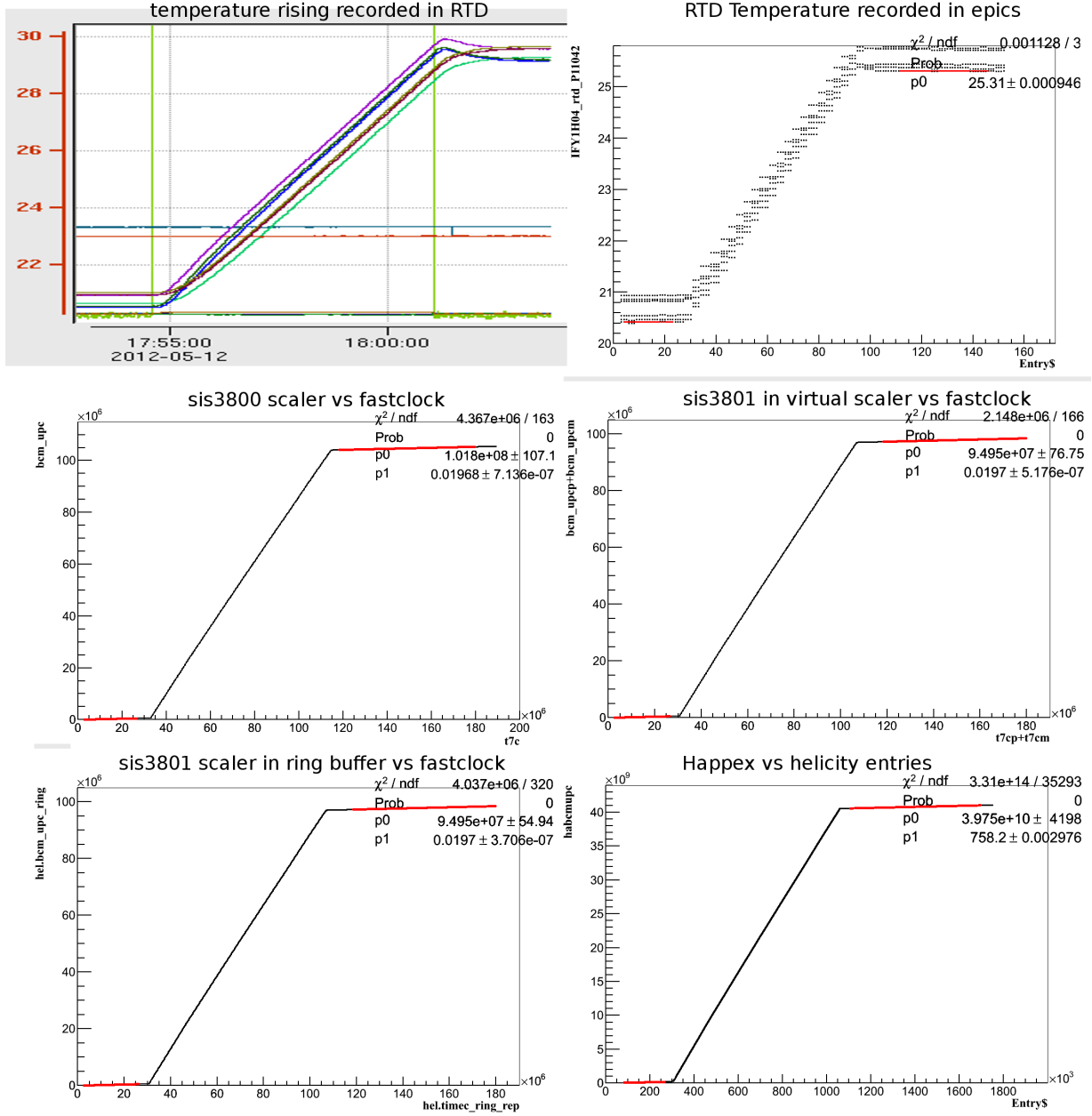


Figure 9: BCM Calibration, the first two pictures are the temperature arise of the RTDs, the last four pictures are the counts recorded in different devices at the same time.

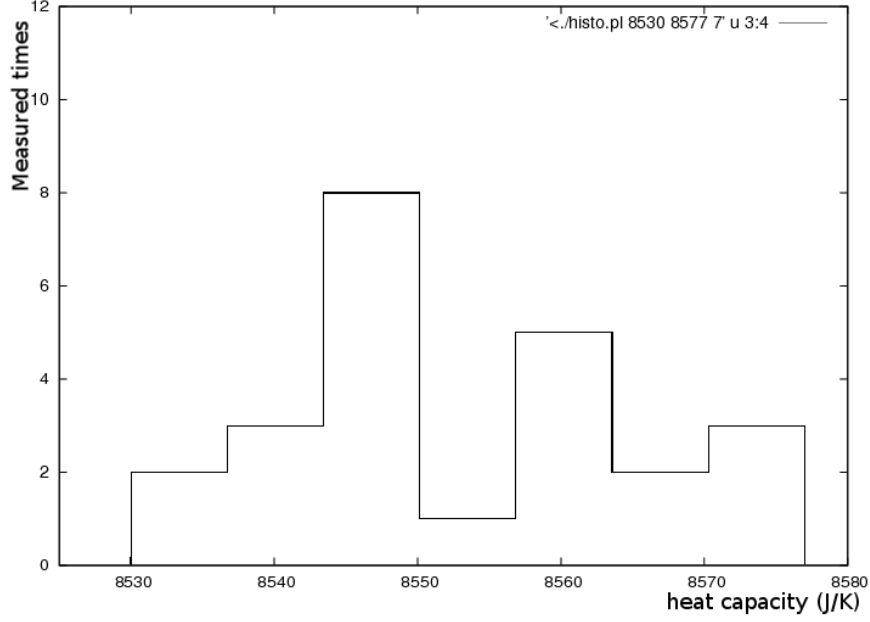


Figure 10: Tungsten Calorimeter Heat Capacity Determination [9]

where 103700/s is the frequency of the fast clock, 971.65 μ s is the duration of T-Stable, and 1041.65 μ 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 as the total counts. The entries in the HAPPEX DAQ is used as the time stamp. The total charge has the following relation with the counts:

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

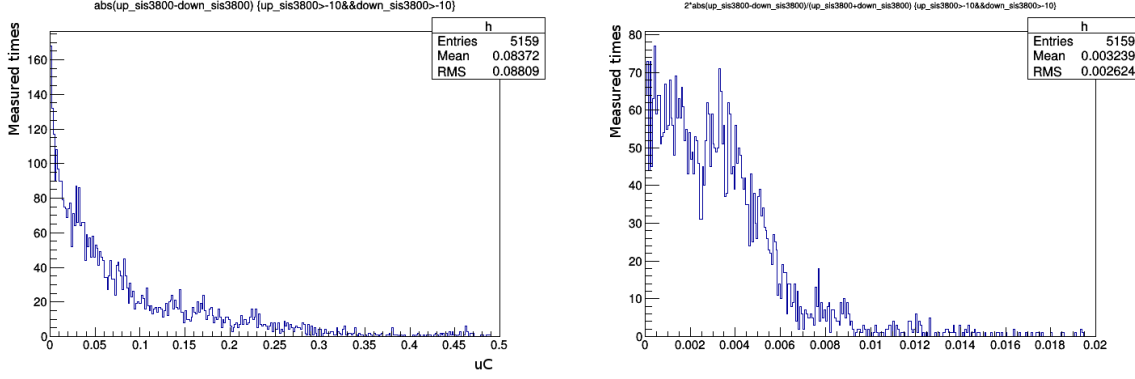
where 875 μ s is the integration time of the ADC. The beam current is calculated as:

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

2.4 Uncertainty

The uncertainty of the calculated charge from tungsten comes from the beam energy, RTD, measured tungsten heat capacity, and the heat loss. The accuracy of the beam energy calculated from 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 μ C (2.2GeV beam energy). The 50 J/K uncertainty of heat capacity contributes 0.18 μ C per 1 K temperature rise (2.2GeV beam energy). The Hall A calorimeter thermal and mechanical design limits heat losses to the ~ 0.2 % level if the measurement within 20 min[7], which causes the uncertainty of calculated charge additional 0.2 %. The total uncertainty is ~ 0.68 % for the calculated charge from tungsten.

By comparing of the difference between upstream and downstream BCM, the fluctuations between upstream and downstream are below 0.19 μ C for 90 % 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 %. Combining with the uncertainty of the tungsten calorimeter, the final uncertainty of BCM is below 1 %.



(a) Absolute difference between upstream and downstream charge (b) Relative difference between upstream and downstream charge

Figure 11: Comparing of the charge calculated from upstream and downstream. Each event in picture is the total charge calculated from one run from experiment.

3 Calibration constants

The calibration constants are shown in appendix. 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

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

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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 constant for 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 constant for 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 constant for 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	22131 22658	22131 22658	22158 22658	22660 23618
run avail(right HAPPEX down)	Start 22130	22131 22658	22131 22658	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 constant for 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 constant for 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 constant for 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 constant for 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 constant for 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 constant for third arm