Hall A Beamline

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The control and measurement equipment along the Hall A beamline consists of various elements necessary to transport beam with the required specifications onto the reaction target and the dump and to simultaneously measure the properties of the beam relevant to the successful implementation of the physics program in Hall A. The resolution and accuracy requirements in Hall A are such that special attention are paid to the following:

1. Determination of the beam energy
2. Control of the beam position, direction emmittance and stability.
3. Determination of the beam current, total charge and polarization.

Parameter	Method		Accuracy	Comments
Energy	ARC	Absolute	2×10^{-4}	Invasive
			5×10^{-4}	Non-Invasive
		Relative	$\pm 1 \times 10^{-4}$	Non-Invasive
	eP	Absolute	2×10^{-4}	Invasive
Energy Width	OTR $\star$		$\frac{\Delta E}{E}(\sigma) \sim 1 \times 10^{-5}$	Non-Invasive
Current ($\geq 0.5\mu A$)	2 RF Cavities	Absolute	$\leq 2 \times 10^{-3}$	Non-Invasive
Charge ($\geq 0.5\mu A$)	2 RF Cavities	Absolute	$\leq 2 \times 10^{-3}$	Non-Invasive
Position (at Target)	2 BPM/Harp	Absolute	$140\mu m$	x,y online
Direction (at Target)	2 BPM/Harp	Absolute	$30\mu rad$	θ, ϕ online
Stability (at Target)	Fast Feedback $\star$		$\leq$ 720 Hz motion	
	Position		$\leq 20\mu m(\sigma)$	
	Energy		$\leq 1 \times 10^{-5}(\sigma)$	
Polarization	Moller	Absolute	$\frac{\Delta P}{P} \approx 3\%(\Rightarrow 2\%)$	Invasive
	Compton $\star$	Absolute	$(\frac{\Delta P}{P} \Rightarrow 2\%)$	Non-invasive

$\star$ Still under Development

Table 1: Determination of Beam Parameters in Hall A

Table 1 gives a list of all the beam parameters monitored along the Hall A beamline and the requisite instrumentation. In nearly all cases, we have two or more independent methods to determine and monitor the various parameters both in order to gain confidence in the absolute measurements and also to have enough redundancy in the system if any of the instrumentation should fail during a run. The various elements along the beamline are already listed and described in the Hall A Operational Manual. As seen in Table 1, we determine and monitor the absolute values of the beam parameters at a level which in most cases meets or exceeds the needs of many of the approved experiments.

0.1 Hall A Absolute Energy Measurements

We have systematically started making beam energy measurements both with the Hall A Arc-Energy method and the eP method. The Arc method uses instrumentation in the Hall A arc section (Scanners, BdL measurements of the arc dipoles etc...) developed initially by the French Collaboration (Pascal Vernin and the Saclay group). The eP method has been developed by the Clermont-Ferrand group of the French Collaboration (Pierre Bertin et al.,) and is a stand alone device along the Hall A beamline located 17 meters in front of the target. Since October 1998, both methods have made many measurements to determine the absolute energy of the beam and these are listed and described in the Hall A electronic logbook.

The Hall A Arc-Energy method has consistently determined the beam energy with an absolute uncertainty of $\simeq 2 \times 10^{-4}$ (as designed) over this time period. With better understanding of the system and the residual magnetic field strengths along the arc section, we are able to understand the systematics to a factor nearly twice better. The eP-method has made significant progress in this same time period and is also approaching the same level of certainty in their systematics as the Arc-Energy method. In Table 2 we list the measurements where both methods have been performed together optimally (i.e. when the eP has been run with both arms).

We have greatly improved the beam optics tuning through the arc section into the hall. We have degaussed and deactivated all the beam correctors, sextupoles and all other extraneous magnetic elements in the arc section.

We also maintain the same Dipole field strength in the arc section between the regular achromatic and energy measuring Dispersive tunes of the beam. This enables us to track and maintain the knowledge of the energy of the beam throughout the whole running period non-invasively. By not using the correctors and other magnetic elements within the arc section, we are also able to deliver a more stable and clean beam to the hall. We have been able to demonstrate this all during the first part of the HAPPEX2 experiment (April - May 99), where we were able to measure and control the energy at 3355 MeV to Hall A.

Date	Pass	ARC (MeV)	eP (MeV)
Oct 24, 98	4 Pass	3385 ± 0.6	3384 ± 1
Nov 6, 98	5 Pass	4236.2 ± 0.8	4240 ± 3
April 23, 99	3 Pass	3355.2 ± 0.7	3354.4 ± 0.7
May 29, 99	3 Pass	3355.1 ± 0.7	3355.0 ± 0.7
Sept 22, 99	2 Pass	1266.1 ± 0.4	1266.9 ± 0.5

Table 2: Summary of Hall A Beam Energy measurements

0.2 Hall A Current and Charge Calibrations

The Beam Current Monitor (BCM) for Hall A is designed for stable, low noise, non-intercepting beam current measurement. It consists of an Unser monitor, two rf cavities, the electronics and a data acquisition system and is described in detail in the Hall A Operational Manual. The cavities and the Unser monitor are enclosed in a box to improve magnetic shielding and temperature stabilization. The box is located 25 meters in front of the target.

In addition to the Unser monitor, we have also incorporated the use of the OLO2 Cavity Monitor and the Faraday Cup 2 at the Injector section to provide an absolute reference during calibration runs. We are therefore able to provide absolute current and total charge values for any run down to 0.5 μA with high accuracy. Several comprehensive and detailed calibration and linearity runs were performed since Oct 98 and the results are posted in the Hall A logbook. The latest results are listed in Tables 3 and 4 (details are posted in HALOG Nos. 16690 and 16689).

Cavity	Coefficient
Upstream cavity	76.963
Downstream cavity	77.149

Table 3: BCM Calibration Coefficients, April, 1999

Current Ranges (μA)	U x 1	D x 1	U x 3	D x 3	U x 10	D x 10
$\geq$ 40	1348	1341	(4139)	(4141)		
0.5 - 100	1348	1341	4139	4141		
0.2 - 50					12552	13081

Table 4: Coefficients for Charge Determination, April, 1999

0.3 Hall A Beam Position and Direction

To determine the position and the direction of the beam on the experimental target point, two Beam Position Monitors (BPMs) are located at distances 7.524 m (IPM1H03A) and 1.286 m (IPM1H03B) upstream of the target position. The standard difference-over-sum technique is then used to determine the relative position of the beam to within 100 microns for currents above 1 μA. The absolute position of the beam can be determined from the BPMs by calibrating them with respect to wire scanners (superharps) which are located adjacent to each of the BPMs (IHA1H03A at 7.353 m and IHA1H03B at 1.122 m upstream of the target). The wire scanners are surveyed absolutely with respect to the Hall A coordinates. Table 5 shows the results of several separate calibration runs to relate the absolute positions for the beam as determined from the scanners and the BPMs.

The scanners have been surveyed several times and at present the results disagree with respect to each other at the level of 300 microns. We are trying to understand these differences and seeing whether we are able to absolutely survey these scanners to better than 100 microns.

BPM	Offset (μA)
IPM1H03Ax	345
IPM1H03Ay	365
IPM1H03Bx	-220
IPM1H03By	900

Table 5: Hall A BPM/Harp Calibration Offsets (GEOFFS)