Electron Beam Measurements for Mott Experiment Runs I and II

Joe Grames and Brian Freeman

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1 Introduction

Systematic studies of the Mott experimental asymmetry to electron beam conditions such as beam position, beam size, and energy spread were measured during Runs I and II. The beam conditions are analyzed and summarized in this note. A simple schematic of the relevant beam components is shown in Fig. 1.

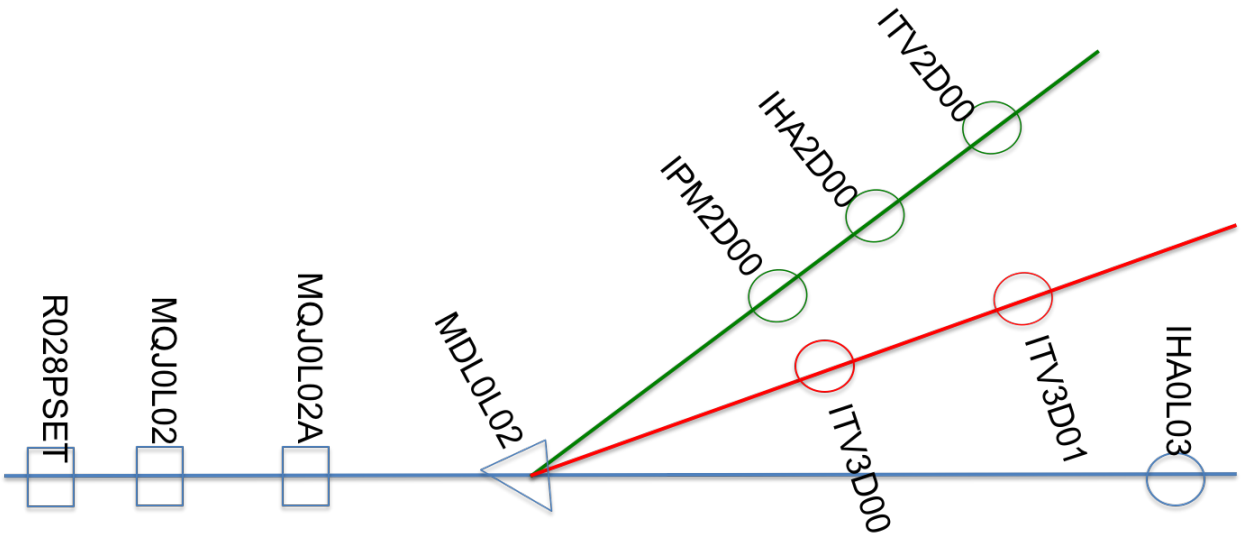

Fig. 1. Schematic shows relative location of elements; the dipole magnet sends beam to the Mott (red) or spectrometer (green) beam lines. Quads MQJ0L02/MQJ0L02A control beam size and SRF cavity phase R028PSEt controls energy spread. Wire scanners IHA0L03 and IHA2D00 are used to measure beam emittance/Twiss at MQJ0L02 and momentum spread, respectively.

2 Elegant Model

An Elegant model of the layout in Fig. 1 was constructed beginning at MQJ0L02 and ending at either IHA2D00 or ITV3D00. The lattice is listed here:

```
"cle" ! clear whole RPN stack for safety

% 1 atan 4 * sto pi
% pi 180 / sto cdtor
% 180 pi / sto crtod

! DRIFT BETWEEN QUADS
D1      : DRIFT, L=0.4596
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```
! DRIFT TO 2D LINE
D2        : DRIFT, L=1.0065
D3        : DRIFT, L=3.1385
D4        : DRIFT, L=0.1778
D5        : DRIFT, L=0.1270

! DRIFT TO 3DLINE
D6        : DRIFT, L=1.0041
D7        : DRIFT, L=0.5584
D8        : DRIFT, L=0.2667
D9        : DRIFT, L=0.8113

! NORMAL MOTT
MQJ0L02:  KQUAD, L=0.15, K1= -5.04003396226415
MQJ0L02A: KQUAD, L=0.15, K1= +5.00232327044025

! 2D DIPOLE
MDL0L02_2D: CSBEND, L=0.1230, ANGLE="-30.0 180.0 / -1 acos * ", &
         E1=" 0.0 180.0 / -1 acos * ", E2="-30.0 180.0 / -1 acos * ", &
         EDGE_ORDER=2, HGAP=0.013564, FINT=0.5, NONLINEAR=1, &
         N_KICKS=15, INTEGRATION_ORDER=4

! 3D DIPOLE
MDL0L02_3D: CSBEND, L=0.1278, ANGLE="-12.5 180.0 / -1 acos * ", &
         E1=" 0.0 180.0 / -1 acos * ", E2="-12.5 180.0 / -1 acos * ", &
         EDGE_ORDER=2, HGAP=0.013564, FINT=0.5, NONLINEAR=1, &
         N_KICKS=15, INTEGRATION_ORDER=4

! DIAGNOSTIC IN 2D LINE
IPM2D00: WATCH, FILENAME="%s.ITV2D00", MODE=COORD
ITV2D00: WATCH, FILENAME="%s.ITV2D00", MODE=COORD
IHA2D00: WATCH, FILENAME="%s.IHA2D00", MODE=COORD

! DIAGNOSTIC IN 3D LINE
ITV3D00: WATCH, FILENAME="%s.ITV3D00", MODE=COORD
ITV3D01: WATCH, FILENAME="%s.ITV3D00", MODE=COORD

! BEAM LINES
2D:  LINE=(MQJ0L02, D1, MQJ0L02A, D2, MDL0L02_2D, D3, IPM2D00, D4,
IHA2D00, D5, ITV2D00)
3D:  LINE=(MQJ0L02, D1, MQJ0L02A, D6, MDL0L02_3D, D7, D8, ITV3D00, D9,
ITV3D01)
```

The horizontal dispersion function is calculated at the spectrometer harp IHA2D00 η_x = -1.946 m and at the Mott target foil ITV3D01 η_x = -0.3767 m.

3 Run I Results

Energy

The electron beam kinetic energy reported in [1] is 4.806 ± 0.097 MeV. This corresponds to a total energy of 5.317 ± 0.097 MeV and a momentum of 5.292 ± 0.098 MeV/c.

Beam Emittance

The beam emittance is determined by a quad – drift – profile measurement. Quadrupole MQJ0L02 was scanned over strengths to observe waists in both horizontal and vertical projections at harp IHA0L03. Measurements made on two subsequent days using *qsUtility 3.21* with similar ranges of quad strength are analyzed and reported in e3458895. Plots of the beam size vs. geometric quad strength are shown in Fig. 2. Corresponding emittance and Twiss parameters calculated by *sddsemitproc* at MQJ0L02 are summarized in Table 1.

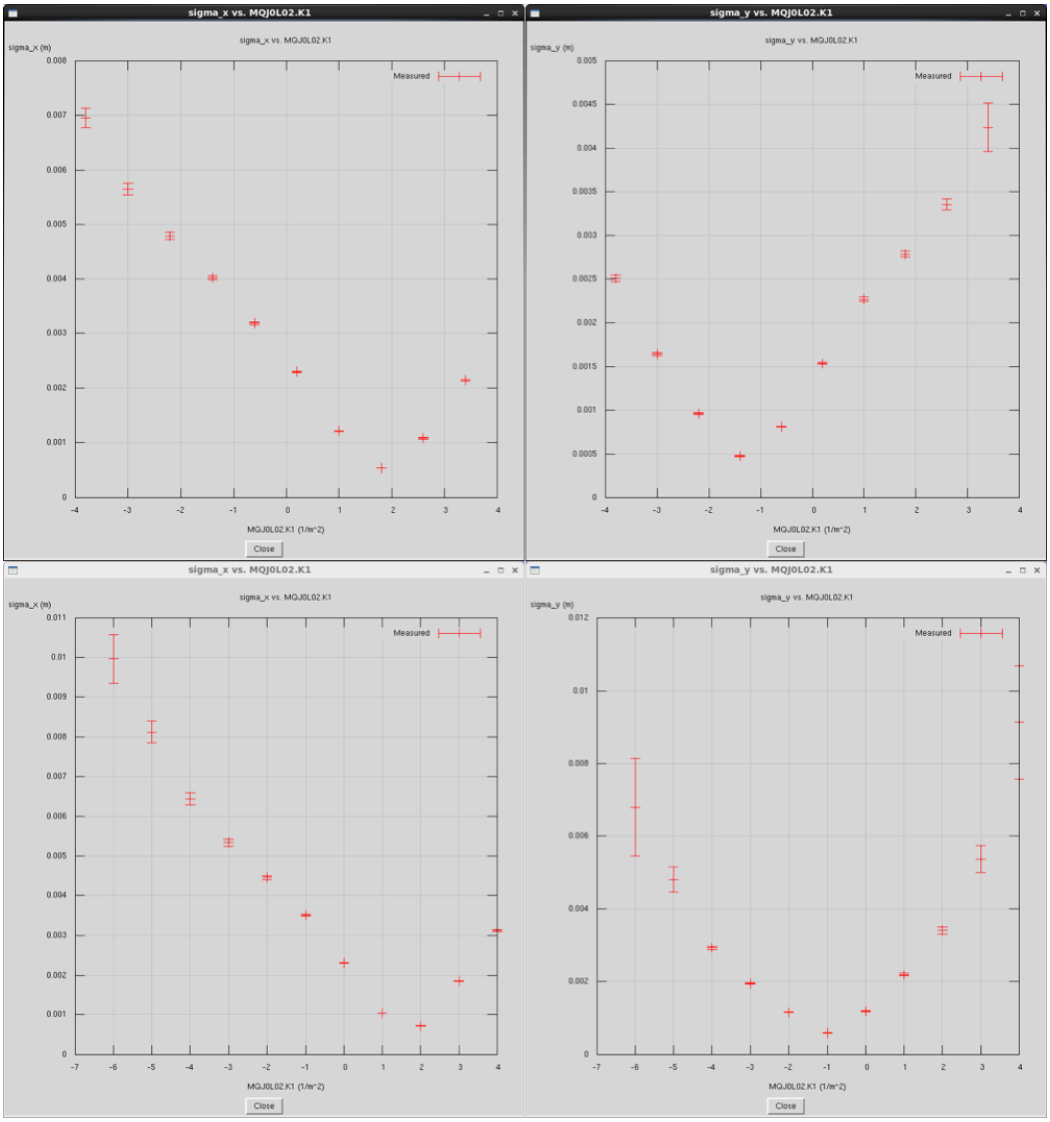

Fig. 2. Upper (lower) plots show plots of beam size measured at IHA0L03 as a function of quad strength MQJ0L02 taken at 2015-01-18_22:36 (IHA0L03_2015-01-19_17:15).

Table 1. Summary of measured normalized emittance and Twiss parameters at MQJ0L02.

qsUtility (run date)	$\varepsilon_{n,x}$ (μm)	β_x (m)	α_x (rad)	$\varepsilon_{n,y}$ (μm)	β_y (m)	α_y (rad)
2015-01-18_22:36	1.077(2)	15.39(5)	-1.985(06)	0.683(43)	13.25(12)	-0.612(12)
2015-01-19_17:15	1.206(5)	14.08(1)	-1.389(17)	0.930(66)	11.06(09)	-0.065(10)

Beam Energy Spread Measurements

The Mott asymmetry was studied as a function of energy spread by varying the phase setting R028PSET of the second QCM SRF cavity about the nominal Run 1 operating set point. The beam energy spread is determined from a measurement of the beam size at a dispersive location according to

$$(S_x)^2 = \varepsilon_x \beta_x + (\frac{dp}{p} x\ \eta_x)^2$$

where S_x is the horizontal beam size. For each case the beam was sent to the spectrometer wire scanner IHA2D00 to measure the beam size and then to Mott target #15 (1um gold) to measure the asymmetry with the IHWP both IN and OUT. The cavity gradient and a steering coil were used to adjusted small amounts as shown in Table 2. The horizontal beam size is determined by a fit of the scanner profile.

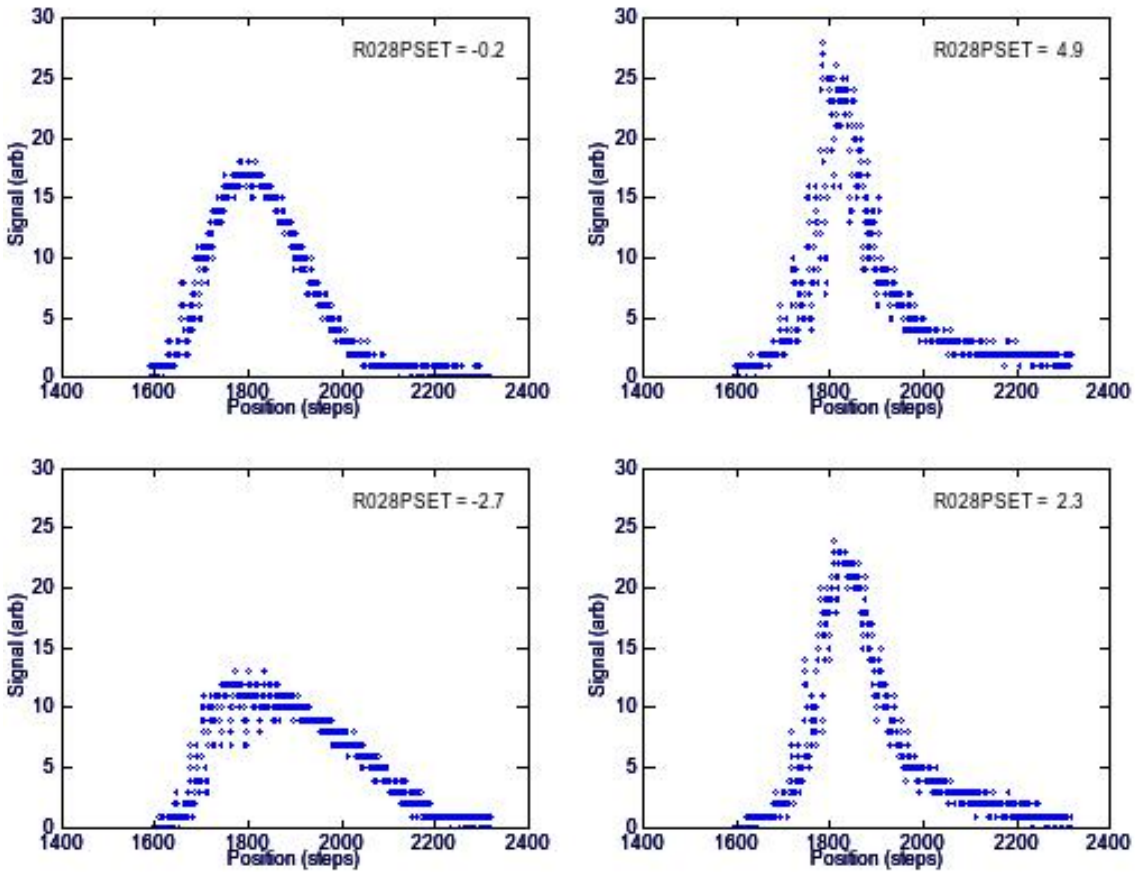

Fig. 3. Plots shows horizontal wire scanner signal as a function of motor potentiometer position with a conversion of 0.02041 mm/step.

Table 2. Parameters and results of energy spread measurements.

R028-PSET	Δ-PSET	R028 GSET	MAD 3D00H	IHWP IN	IHWP OUT	Harp File	S_x (RMS)		δp/p	δT
deg	deg	MV/m	G-cm	Mott	Mott	Prefix = IHA2D00_	steps	mm	10^{-3}	(keV)
-0.2	0.0	4.81	0	8180	8181	2015-01-19_22:55	107.48	2.19	0.1117	4.897
4.8	-5.0	4.82	20	8182	8183	2015-01-19_22:44	136.29	2.78	0.1421	6.232
-2.7	2.5	4.81	-9	8184	8185	2015-01-19_22:53	137.63	2.81	0.1435	6.293
2.3	-2.5	4.81	11	8186	8187	2015-01-19_22:51	118.55	2.42	0.1234	5.410

Applying the emittance results (2015-01-19_17:15) collected prior to the energy spread measurement and the corresponding quad values MQJ0L02 = -133.65 G (K = -5.048 m^{-1}) and MQJ0L02A = 132.95 G (K = 5.010 m^{-1}) the beam size without dispersive effects at harp IHA2D00 is 0.3001 mm. Consequently, the relative momentum spread (δp/p) and energy spread (δT) are computed and are shown in Table 2 and plotted in Fig. 4 The relatively low value (compared to usual CEBAF operation) is indicative of running the injector for conditions to minimize energy spread.

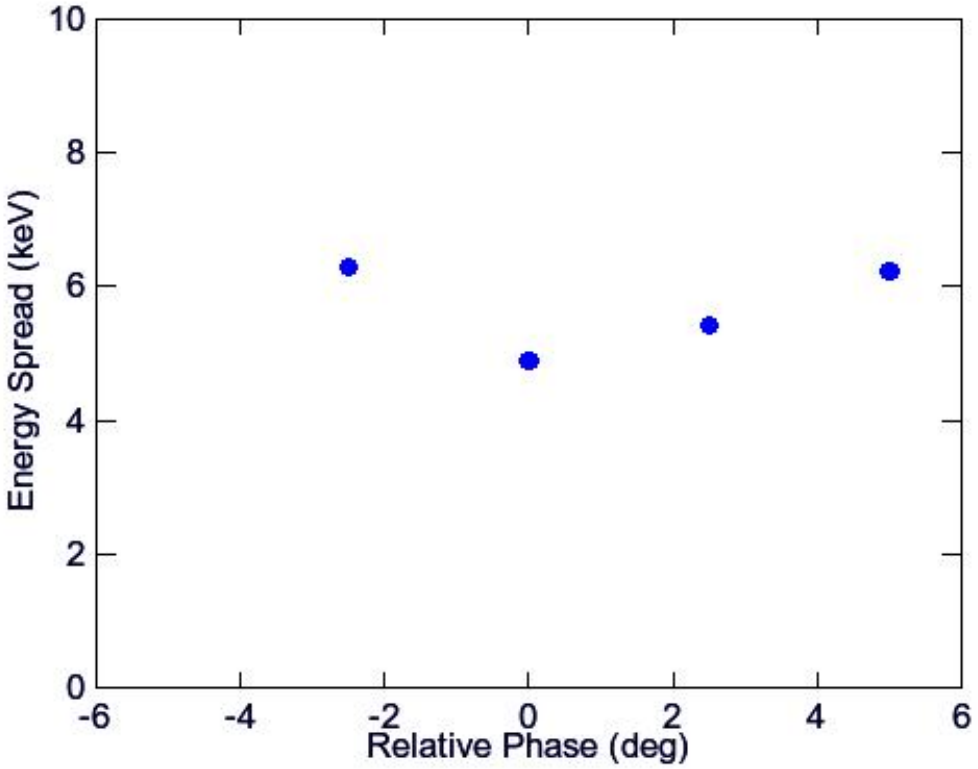

Fig. 3. The computed energy spread as a function of relative phase of second SRF cavity about the value used for Run 1 (R028PSET = -0.2 deg).

Beam Spot Size

The Mott asymmetry was studied as a function of beam spot size on foil #15 (1μm gold) with about 2 μA of beam current while varying the quad values for MQJ0L02 and MQJ0L02A about their nominal Run 1 operating set points at shown in Table 1. Applying the corresponding emittance (2015-01-19_17:15) and relative momentum spread (1.117×10^{-3}) Elegant is used to calculate the beam profile at the target foil for the quad values studied.

Table 3. Parameters and results of spot size measurements. "Name" corresponds to the beam size we expected during Run 1 (in millimeters) and "Fig." is the label for the corresponding OTR foil image in e3318205.

Name	Fig.	MQJ0L02		MQJ0L02A		IHWP IN	IHWP OUT	Sx	Sy
		G	1/m	G	1/m			mm	mm
0.100	1	-133.00	-5.0231	153.00	5.7785	8163	8164	0.57	0.42
0.250	2	-115.00	-4.3433	139.00	5.2497	8165	8166	0.67	0.33
0.500	3	-164.00	-6.1939	153.00	5.7785	8167	8169	0.93	0.95
1.000	4	-188.00	-7.1003	141.00	5.3252	8170	8171	1.65	1.47
2.000	5,6	-264.00	-9.9707	130.00	4.9098	8172	8173	3.29	2.96
0.750	7	-182.00	-6.8737	148.00	5.5896	8174	8175	1.33	1.33
1.500	8,9	-225.00	-8.4977	135.00	5.0986	8176	8177	2.45	2.21
0.475	10	-133.65	-5.0477	132.65	5.0099	8178	8179	1.08	0.53

Beam Position Study

Information will come from Brian.

4 Reference

1. J. Grames, "*Mott Experiment Run I/II Beam Energies*", JLAB-TN-17-001 (2017).