JLAB-TN-05-081

Upgrade of Hall C Møller Polarimeter Optics for Operation in the Range of 1 to 12 GeV/c

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1. Introduction

The operational range of original Basel Møller polarimeter [1] is from 1 to 6 GeV/c. For G_0 back angle experiment at 360 MeV/c [2], to detect Møller electrons at larger Møller scattering angle (~ 53.2 mr) and keep effective aperture large enough to accommodate beam envelope, either a special tune [3] is created to confine the envelope or the first quad MQ_1 has to be temporarily moved towards Møller target for a certain distance [4]. This is the extreme case of ultra-low momentum application.

In the contrary, beyond 6 GeV/c, due to the strength deficiency of MQ_2, the two quads system is not able to disperse Møller electrons onto right and left detectors as indicated by horizontal separation distance ± 49 cm. In the lab site a spare 10Q36 quad is available. It was installed for application of T_{20} D-channel spectroscopy during past ten years. Therefore, a study of Møller optics is necessary to verify the double MQ_2 system instead of single MQ_2 . It could help us raise the operational beam momentum up to 12 GeV/c range.

2. System geometry and quad parameters

Where do we place the 2nd MQ_2 (named as MQ_3) between MQ_1 and 1st MQ_2 or downstream 1st MQ_2 ? It is proved by optics property of separation ellipse of Møller electrons that the 2nd MQ_2 should be placed at where the largest envelope is, i.e. downstream 1st MQ_2. The following discussion is of course based the geometry of MQ_1 and double MQ_2 (renamed as MQ_2 and MQ_3).

ID	MQ_1	MQ_2	MQ_3
Distance to Møller target (m)	0.8501	3.12153	4.5867
Effective length (cm)	36.192	96.520	96.520
Pole tip radius (cm)	5.08	12.86	12.86
Max. tip field (kG)	4.50	14.82	14.82
Max. gradient (T/m)	8.86	11.52	11.52
Max. strength (Tesla)	3.12	11.41	11.41

The fringing field of all quads is illustrated by Enge's one step approximation [5]. This is the best method for obtaining a better match between TRANSPORT and RAYTRACE. The quadrupole strengths calculated by the aid of TRANSPORT under one step fringing field configuration directly play the role of the first approximation for RAYTRACE. In some cases, if higher accuracy is needed, with minor iteration, the 3rd order TRANSPORT field setting could directly indicate RAYTRACE quad input value.

To simplify the fitting procedure of operational parameters of the quads, the MQ_2 and MQ_3 are considered as a unit elements – both of them share the same field setting. For operational practice, two power supplies could be connected as one-to-one master-slave mode.

3. Modification of separation ellipse

In system optics tune the two original Møller quads are used as defocusing elements rather than focusing. The fitting constraints of MQ_1 and MQ_2 settings is the separation distances in horizontal (49 cm) and vertical (16 cm) directions. Two adjustable fields of elements MQ_1 and MQ_2 are used to fit two parameters.

The separation ellipse has to be changed in higher operational momentum according to momentum and scattering angle of 90° C.M. Møller electrons because MQ_1 can never provide ±16 cm vertical separation. As a promising tunable parameters, we just keep horizontal separation distance ± 49 cm unchanged and have both MQ_1 and MQ_2 fields moderate values.

4. Setting parameters of MQ_1 and $MQ_{2,3}$ in the range of 1 to 12 GeV/c

p_0(GeV/c)	p_3(GeV/c)	θ_3(mr)	s_{MQ1} (kG)	$s_{MQ2/3}$ (kG)	Δx (cm)	Δy (cm)
1.0	0.5	31.95	13.9589	-5.8724	49.0	16.0
2.0	1.0	22.58	22.6660	-13.5344	49.0	16.0
3.0	1.5	18.44	29.8526	-22.6924	49.0	16.0
4.0	2.0	15.97	32.0598	-31.0873	49.0	13.8748
5.0	2.5	14.28	32.0598	-39.8006	49.0	12.4047
6.0	3.0	13.05	32.0598	-49.4534	49.0	11.6572
7.0	3.5	12.08	32.0598	-59.9724	49.0	11.2033
8.0	4.0	11.30	32.0598	-71.1823	49.0	10.8774
9.0	4.5	10.66	32.0598	-82.9682	49.0	10.6164
10.0	5.0	10.11	32.0598	-95.3801	49.0	10.3951
11.0	5.5	9.64	32.0598	-108.2776	49.0	10.1966
12.0	6.0	9.23	-2.5296	-108.7466	49.0	8.0

p_0 = momentum of primary electron beam in GeV/c

p_3 = momentum of C.M. 90° scattering Møller electrons in GeV/c
θ_3 = lab scattering angle of C.M. 90° scattering Møller electrons
s_{MQ1} = strength of 1st quad in kG
$s_{MQ2,3}$ = strength of 2nd and 3rd quad in kG
Δx = horizontal separation distance in front of detection arms in cm
Δy = vertical separation distance in the central beam pipe in cm

5. Typical trajectories of the central Møller electrons

P_0 (GeV/c)	1.0		6.0		12.0	
Position (cm)	Δx	Δy	Δx	Δy	Δx	Δy
Length (m)						
0.00000	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000
0.16010	0.52051	0.52051	0.23207	0.23207	0.17873	0.17873
0.64374	2.04102	2.04102	0.84579	0.84579	0.60248	0.60248
0.66914	2.12123	2.12123	0.87870	0.87870	0.62561	0.62561
0.69454	2.19816	2.20476	0.91113	0.91213	0.64878	0.64875
1.00566	2.86250	3.52189	1.26468	1.36782	0.93497	0.93208
1.03106	2.89209	3.65748	1.28955	1.40929	0.95851	0.95516
1.05646	2.91746	3.79787	1.31369	1.45157	0.98209	0.97823
1.85020	3.71124	8.18513	2.06979	2.77353	1.72038	1.70070
2.57840	4.44067	12.21029	2.76471	3.98693	2.39889	2.36471
2.64270	4.50512	12.56571	2.82610	4.09408	2.45882	2.42337
2.70700	4.57659	12.89904	2.89350	4.19248	2.52448	2.47639
3.54360	6.14461	15.42768	4.35958	4.66732	3.95150	2.64931
3.60790	6.31918	15.47592	4.52415	4.63979	4.11226	2.62200
3.67220	6.50216	15.50124	4.69807	4.60238	4.28248	2.58858
4.04360	7.55907	15.64745	5.70268	4.38632	5.26566	2.39558
4.10790	7.74206	15.67277	5.87660	4.34892	5.43587	2.36218
4.17220	7.93808	15.67407	6.06343	4.30236	5.61910	2.32329
5.00880	11.64489	13.73209	9.77785	2.98221	9.32351	1.40659
5.07310	12.03137	13.43755	10.17974	2.83173	9.72913	1.30913
5.13740	12.43193	13.11871	10.60038	2.67478	10.15465	1.20839
11.00730	49.00000	16.00000	49.00000	11.65717	49.00000	8.00000

6. Summary and discussion

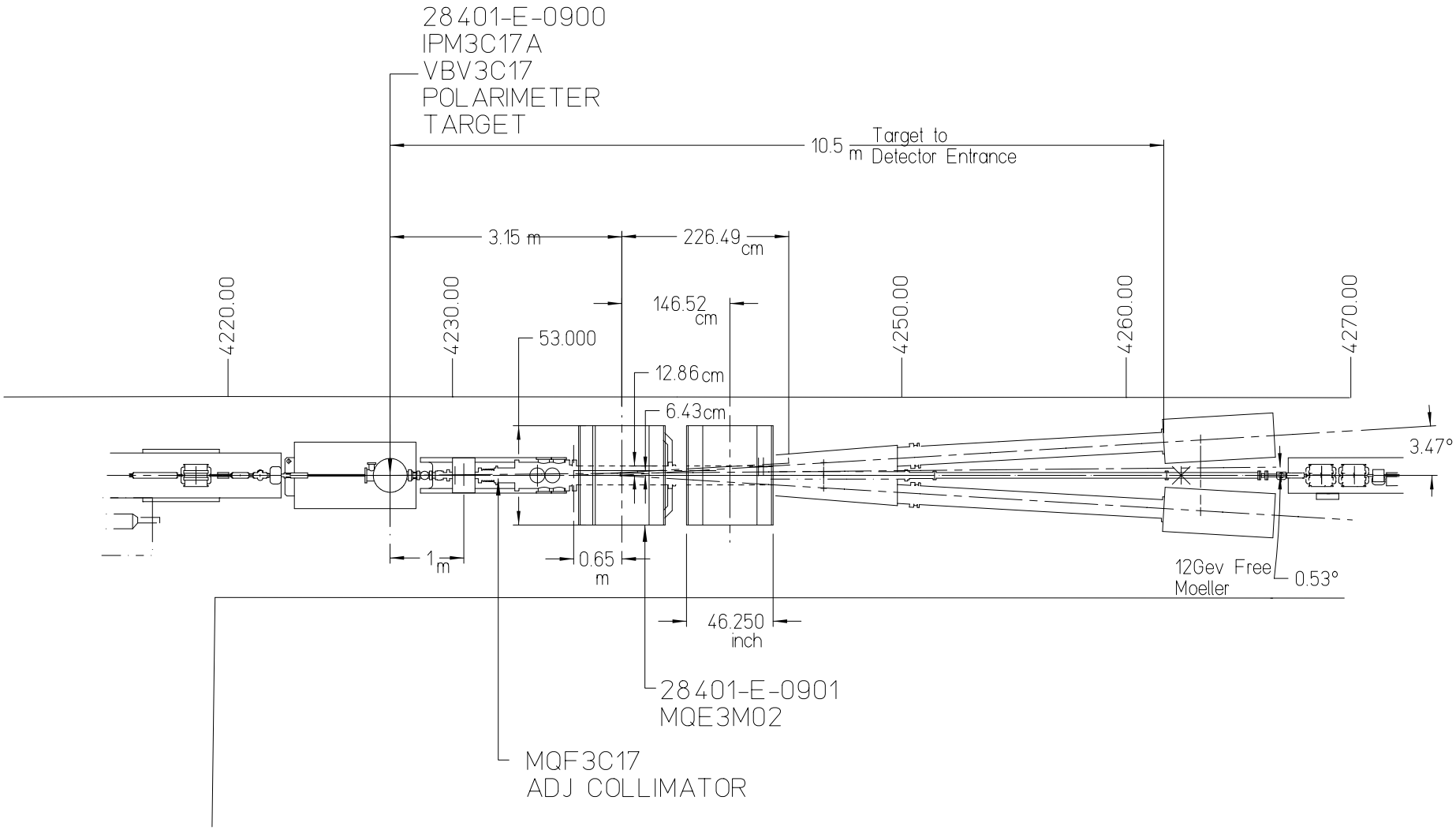
   a. With presumed three quad geometry, the optics tuning looks very good – reasonable strength setting and full acceptance by quad apertures.
   b. No matter how does beam line alternate (switch between Møller and Compton), with minor modification of vacuum pipe of MQ_2

section, directly insert MQ_3 can be easily done without changing orientation of the triple vacuum beam pipe, see attached drawing.

c. The second 10Q36 (MQ_3) is available in the lab. Refurbishing and mapping is necessary.
d. The optics tune is not the only solution. By setting different constraint of vertical separation distance, other fitting results of quad strengths may appear. But I believe the tune in this report is the optimal one.
e. For operation, the two power supplies of MQ_2 and MQ_3 should be locked together.
f. Engineering drawing - attached is the engineering drawing of Hall C Møller polarimeter upgrade for 12 GeV/c operation produced by J. Smith.

7. Reference

[1] Matthias Loppacher, PhD Thesis “Møller polarimetry for CEBAF Hall C” , Universität Basel, Basel 1996.
[2] D. Beck , The G^0 experiment backward angle measurement, May 2001
[3] C. Yan, Jlab-TN-05-076
[4] J. Benesch, D.Gaskell, C.Yan, Communication about TRANSPORT optics tuning referring Q1 move ~ 20 cm upstream, October 4, 2005
[5] H. A. Enge, Proceedings of the PILAC optics workshop, p83, 08/12/91



3 Quad Option
Hall C 12 GeV Moeller

'/home/smithj/WORKING/ACC/3QUADMoeller-HallC-12Gev'

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