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Hall C Møller Optics at 360 MeV/c for G_0 Back-Angle Experiment

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1. Introduction

The lowest beam momentum for G_0 back angle experiment (2005 – 2006) is 360 MeV/c. In order to make beam polarization measurement by using Basel Møller polarimeter [1] available, a special optics tune is studied referring the existing geometry and physical apertures of two Møller quadrupoles. The fundamental idea is to increase focus power of the first quad MQ_1 to confine horizontal beam envelope of Møller electrons in the region of MQ_1 entrance fringing field. The second quad MQ_2 is going to defocus the electrons to fit 49 cm in location of detector package. The dumbbell shape of beam envelope eventually could get the maximum horizontal transmission of Møller electrons at ultra-low beam momentum.

2. Geometry and quad parameters

The geometry is taken from April 07, 2005 survey data transmittal [2]. The distance from Møller target to the center of the first quad (QF3M01) is 850.1 mm and 3125.3 mm to the center of the second quad (QE3M02). The total path length of scattering electrons is 11 m. The quads are specified by effective length, field value at pole tip, and pole radius.

	QF3M01 (MQ_1)	QE3M02 (MQ_2)
Distance to target (m)	0.8501	3.1253
Effective length (cm)	36.192	96.52
Pole tip radius (cm)	5.08	12.86
Max. tip field (kG)	4.50	14.82
Max. Gradient (T/m)	8.86	11.52
Max. Strength (Tesla)	3.12	11.41
Tip field at 0.36 GeV/c (kG)	1.2	-1.54425
Strength at 0.36 GeV/c (Tesla)	0.8549	- 1.159

The fringing fields of the two quads are illustrated by Enge's one step approximation [3]. Møller optics is a non-focusing optics and beam envelope occupied relatively large volume of phase space. The SCOFF quad model could have 10% discrepancy to the real fringing field model.

3. Input diameters determined by physics of Møller scattering

- Beam dimension = 1 mm by 1 mm
- 90° Møller scattering angle $\theta_3 = (2 \times 0.511 \times E_1)^{1/2} / (E_1 + 0.511)$ in rad (E_1 in MeV)
- 90° Møller scattering momentum $p_3 = 0.5\ p_1 = 0.18$ GeV/c
- To determine the boundary error momentum p_3 as well as related scattering angle θ_3 the following formula can be used: $p_3 = 0.5\ p_1\ (1 \pm \Delta\theta/\ \theta_3\ )$, usually $\Delta\theta \sim 4$ mr.

- At 0.36 GeV/c, $p_{3\ central}$ = 0.18 GeV/c $\theta_{3\ central}$ = 53.2 mr
  $p_{3\ high}$ = 0.194 GeV/c $\theta_{3\ high}$ = 49.2 mr
  $p_{3\ low}$ = 0.166 GeV/c $\theta_{3\ low}$ = 53.0 mr

These three typical rays define the maximum envelope of Møller scattering in the extreme case.

4. Input data file of TRANSPORT 3rd order optics

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'MOLLER OPTICS AT 0.36 GeV/c,  06/21/2005'
0
PLOT    L   XBEAM   YBEAM   XPBEAM    YPBEAM          ;
ORDER    3.                                           ;
BEAM     0.1   49.2   0.1   49.2   0.    0.01    0.18      'BEAM';
SOLENOID     0.1605     30.                              'SOL2';
DRIFT          0.50864                                    'DRF1';
DRIFT         -0.0254                                     'DRF2';
QUAD           0.0508        1.2        10.16             'QM01';
QUAD           0.31112       1.2         5.08             'QM01';
QUAD          0.0508         1.2        10.16             'QM01';
DRIFT         -0.0254                                     'DRF3';
DRIFT          0.81914                                    'COLL';
DRIFT          0.79300                                    'DRF5';
DRIFT         -0.0643                                     'DRF6';
QUAD           0.1286       -1.54425  25.72               'QM02';
QUAD           0.8366       -1.54425  12.86               'QM02';
QUAD           0.1286       -1.54425  25.72               'QM02';
DRIFT         -0.0643                                     'DRF7';
DRIFT          7.3916                                     'DRF8';
-FIT       1.       1.       49.       0.0001             'FT01';
-FIT       3.       3.       16.       0.0001             'FT02';
SENTINEL
SENTINEL
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5. Horizontal beam envelope from 3rd order TRANSPORT output files

LENGTH (m)	XBEAM (H)	XBEAM (0)	XBEAM (L)	Aperture
0.00000	0.10000	0.10000	0.10000	
0.16060	0.77708	0.83625	0.89110	
0.64374	2.98599	3.19840	3.38636	Q_1 (r=5.08)
0.66914	3.10231	3.32277	3.51771	Q_1 (r=5.08)
0.69454	3.21055	3.43768	3.63809	Q_1 (r=5.08)
1.00566	3.89999	4.11404	4.22709	Q_1 (r=5.08)
1.03106	3.90116	4.10625	4.25885	Q_1 (r=5.08)
1.05646	3.89294	4.08761	4.22709	
1.85026	3.63781	3.50761	3.23857	
2.57890	3.40721	2.98106	2.34321	Q_2 (r=12.86)
2.64320	3.38706	2.93497	2.26524	Q_2 (r=12.86)
2.70750	3.39205	2.91079	2.20310	Q_2 (r=12.86)
3.54410	5.86570	4.73208	3.04906	Q_2 (r=12.86)
3.60840	6.28791	5.07506	3.26257	Q_2 (r=12.86)
3.67270	6.75205	5.45684	3.50549	
11.00000	59.66732	49.00000	31.30706	Δx = 28.4 cm

6. Physical aperture of MQ_1

O.D. of the vacuum duct of MQ_1 = 88 mm
Thickness of the duct = 0.06" = 1.524 mm
The effective physical aperture = 88 – 1.524 x 2 = 84.95 mm → r = 42.476 mm
The space between pole tip and vacuum duct = 101.6 – 88 = 13.6 mm

It looks like the present vacuum duct just matches the horizontal envelope critically. Under a precision alignment in horizontal plane, the present geometry should be ok for 0.36 GeV/c Møller measurement.

7. Impact of the change of vertical separation at 0.36 GeV/c

In original design, the 49 cm horizontal and 16 cm vertical separations are used for all tunes from 1 GeV/c to 6 GeV/c. At either lower energy like 0.36 GeV/c or higher energies beyond 8 GeV/c, the vertical separation 16 cm cannot be preserved as tuning constraint. Due to the fact that vertical transmission is determined by physical aperture of vacuum pipes as well as collimators, the 16 cm separation in any case is just a virtual parameter. It doesn't disturb optics and the symmetry of measurement.

At 0.36 GeV/c, the separation is centered at 49 cm and spread over 28 cm in each arm, which is larger than acceptance of hodoscope (12 cm). The horizontal acceptance of detection plane is defined by trapezoid collimator between hodoscope and shower counter, in this case, no significant influence can be observed.

8. Reference

[1] M. Hauger et all, Nuclear Instruments and Methods in Physics Research A462(2001)382
[2] Kelly Tremblay, Data transmittal C985, 04/07/2005
[3] H. A. Enge, p83, Proceedings of the PILAC Optics Workshop, 08/12-13. 1991