Hall A Møller Polarimeter Upgrade for 11 GeV

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The Hall A Møller polarimeter was designed for an electron beam energy range of 1 – 6 GeV. Two factors limit the useful energy range of the polarimeter:

- the spectrometer acceptance, defined by the positions of the magnets and the available field strength, and also the positions of the collimators;
- the beam deflection in the Møller dipole caused by the residual field in the shielding insertion.

At the moment, the first factor gives the lower limit for beam energy of 0.8 GeV, while the second factor gives the upper limit at about 6. GeV. In order to operate at 11 GeV a considerable upgrade of the polarimeter is required. In order to minimize the interference of such an upgrade with the rest of the beam line we do not consider moving the Møller target or the Møller dipole magnet, as well as replacing the shielding insertion in the dipole magnet.

A few items have to be considered for the higher energy polarimeter design:

1. the positions and settings of the quadrupole magnets;
2. the dipole magnet bending angle;
3. the dipole shielding insertion;
4. the detector position.

0.0.1 Quadrupoles position and setting

The acceptance of a Møller polarimeter is defined as the accepted range of the scattering angles in CM, around 90°. In Hall A polarimeter a collimator, consisting of two vertical slits between the poles of the dipole magnet and the shielding insertion in the dipole gap plays the most important role in limiting the acceptance. The goal of the quarupole magnets is to direct the scattered electrons into the slits. With the present design, three quadrupole magnets are used (see Table 1). The maximum current allowed for all the quadrupoles is about 300 A, and the new power supply (SORENSEN DHP) can provide this current. The present position of the first quadrupole was chosen close to the Møller polarized target in order to cover the low beam energy region of 0.8-1 GeV. Because of large scattering angles at these energies one needs to bend the particles towards the beam early on the trajectory. With the present design, the acceptance reaches is maximum of $-15^\circ < \theta_{CM} - 90 < 15^\circ$, or 30°, at 3 – 4 GeV and is gradually decreasing with the beam energy and becomes lower than 10° at 11 GeV. Such a low acceptance limits the statistical accuracy of the polarization measurements, and, furthermore, increases the systematic errors associated with the Levchuk effect. Moving the first quadrupole 40 cm downstream would help to improve the acceptance at high energies, but as a side effect would reduce the acceptance at low energies.

In order to cover the energy range of 0.8 – 11 GeV we propose to move the first quadrupole 40 cm downstream and to install the fourth quadrupole (called *LILLY* in Table 1) with its center at 70 cm from the Møller target. This configuration would provide the acceptance greater than 20° in the full energy range (see Fig. 1). A possible magnet setting is shown on Fig. 2.

0.0.2 Dipole bending angle

The present Møller electrons bending angle in the dipole is 10°. A dipole current of about 700 A and a field of about 19.2 kGs is needed to keep this bending angle at 11 GeV. The maximal magnetic field measured in this dipole in Los Alamos was 17.5 kGs. The present dipole power supply provides the maximal current of 550 A which is enough for the beam energy of about 8 GeV and the bending angle of 10°. This limitation, along with the problem of shielding the beam area at high fields, described below, demands a change in the bending angle. We propose to reduced the bending angle from 10° to 7.3°.

0.0.3 Dipole shielding insertion design

The dipole shielding insertion (see Fig. 3 and 4) attenuates the strong dipole magnetic field in the region where the main electron beam passes through the dipole. It was designed for the dipole magnetic field up to 10 kGs (see Fig. 5). For stronger magnetic fields the shielding insertion becomes saturated and the electron beam shift after the dipole grows sharply (see Fig. 6).

The present diameter of the bore in the shielding insertion is 4.0 cm. The diameter of the electron beam line before and after the Møller polarimeter is 2.54 cm. It is possible to increase the attenuation of the shielding insertion by placing a coaxial magnetically isolated pipe, made of magnetic steel AISI-1006, inside the bore (see Fig. 7). The inner pipe diameter is 2.54(2.50!?) cm and the outer diameter is 3.4 cm (see Fig. 8). The shielding pipe is centered in the shielding insertion bore with an additional external isolating pipe of a non-magnetic material (see Fig. 9). The shielding pipe length should be 10 cm longer than the shielding insertion length in order to reduce the influence of the fringe field outside of the shielding insertion. Extending the pipe beyond 10 cm would not reducing the residual field considerably (see Fig. 10).

The new design allows to attenuate to an acceptable level the dipole magnetic field up to 14.8 kGs (see Fig. 11). A field of 14.25 kGs corresponds to the beam energy of 11 GeV and the dipole bending angle 7.3° (see section 0.0.2). This field can be provided with the existing power supply.

The TOSCA simulated fields in the dipole gap, in the shielding pipe and the expected electron beam shift on the Hall A target and in the beam dump are shown in Figs. 11 and 12.

0.0.4 Detector position

As follows from sections 0.0.2 and 0.0.3, for the beam energy higher than 8 GeV the dipole magnetic field will stay the same. The bending angle of Møller electrons will be below 10°. For the present detector shielding box position and the beam energy higher than 8 GeV the Møller electrons would hit an aluminum frame of the beam pipe shielding and the top part of the detector shielding box. To exclude this a few changes have to be done.

- A window in the aluminum frame of the beam line shield has to be cut for the Møller electrons to pass through.
- The beam pipe diameter after the Møller dipole is 6.35 cm (2.5 inches). The beam pipe diameter over the detector shielding box is 10.16 cm (4 inches), and after that 2.54cm (1 inch). The 4 inch diameter electron beam pipe has to be changed to a 2.5 inch pipe.
- Lead bricks from the top of the shielding box have to be removed.
- A window for the beam pipe in the top of the shielding box has to be cut.
- The detector shielding box has to be lifted by 10 cm.
- Slits in the shielding collimator after the dipole have to be cut in accordance to the new dipole bending angle.
- The detector shielding box window has to be cut in accordance with new dipole bending angle.

A layout of the upgraded Møller polarimeter and GEANT simulated trajectories of the scattered electrons for the beam energies of 0.8 and 11 GeV are shown on Fig. 13.

0.0.5 Summary

The Møller polarimeter of Hall A can be used at 11 GeV with a certain modification. We propose the modifications as follows:

- add the 4-th quadrupole magnet at 70 cm from the Møller target;
- move the 1-st quadrupole magnet 40 cm downstream;
- add a shielding pipe to the magnetic shielding insertion in the dipole magnet;
- change a piece of the beam pipe above the detector to a 2.5 inch pipe;
- lift the detector shielding box by 10 cm;
- rearrange the shielding downstream of the dipole in order to accomodate the particles at the bending angle of 7.3°.

Adding the shielding pipe can be done as early as summer, 2001. This would help running at 6 GeV. The rest can wait till the CEBAF upgrade.

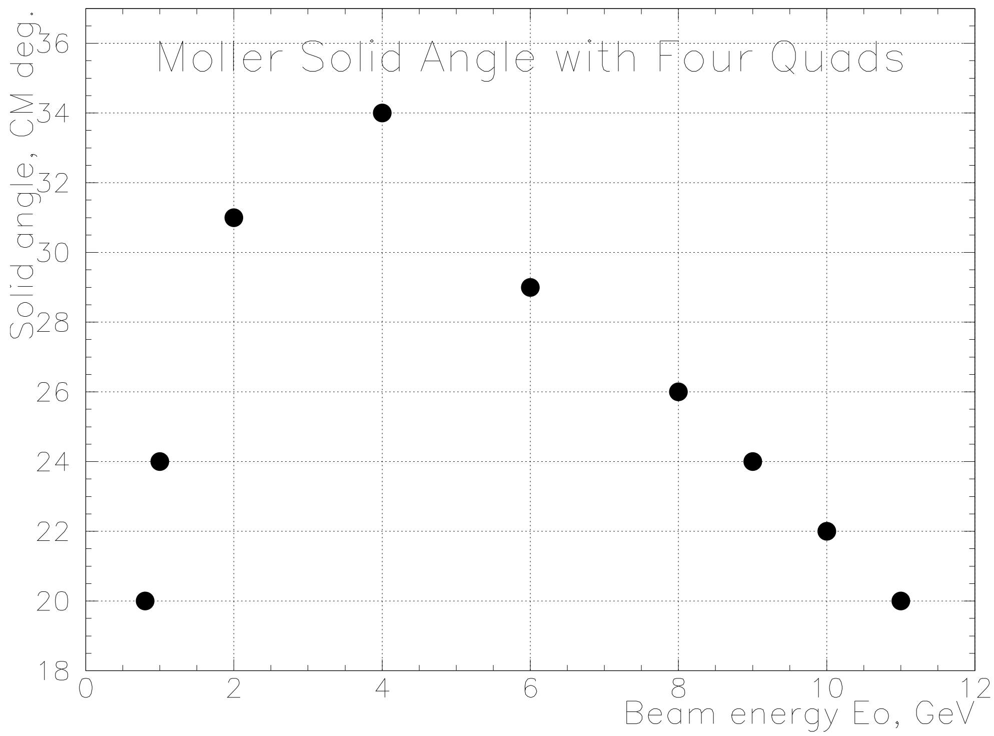

Figure 1: Møller polarimeter solid angle with four quadrupoles

Møller notation	Q1	Q2	Q3	-	Dipole
Name	*PATSY*	*TESSA*	*FELICIA*	*JACKIE*	*LILLY*
Relevant information					
Element	quad	quad	quad	quad	dipole
Bore, cm	10.16	10.16	10.16	10.16	
Effective length, cm	45.72	35.66	35.66	45.72	164.27
Maximum current, A	300	280	280	300	550
Pole tip field at 100A, kGs	2.029	2.371	2.420	≈2.03	2.727
Pole tip field at 300A, kGs	5.801	6.029	6.135	5.809	
Integrated GL at 100A, Gs	18308	17112	17524	≈18300	
Other technical information					
Manufacturer	MagnaTek	Indust.Coil	Indust.Coil		
Part number	LA-446205	LA-446201	LA-446200		
Yoke type	Solid	Solid	Solid		
Yoke material	1006	1006	1006		
Weight, kg	450	500	500		
Color	Red	Blue	Blue	Blue	
Number of coils	4	4	4	4	4
Num. of turns per coil	42	50	50	42	32
Resistance @20C°, ohm	0.1133	0.0767	0.0767		
Shunts and sec. coils	none	none	none	none	none
Voltage drop at max cur	10.6VDC	8.5VDC	8.5VDC		
Total water flow	1.5gpm	1.0gpm	1.0gpm		
Max. oper. pressure	35psi	35psi	35psi		
Cooling medium	LCW	LCW	LCW		

Table 1: The parameters of the magnets.

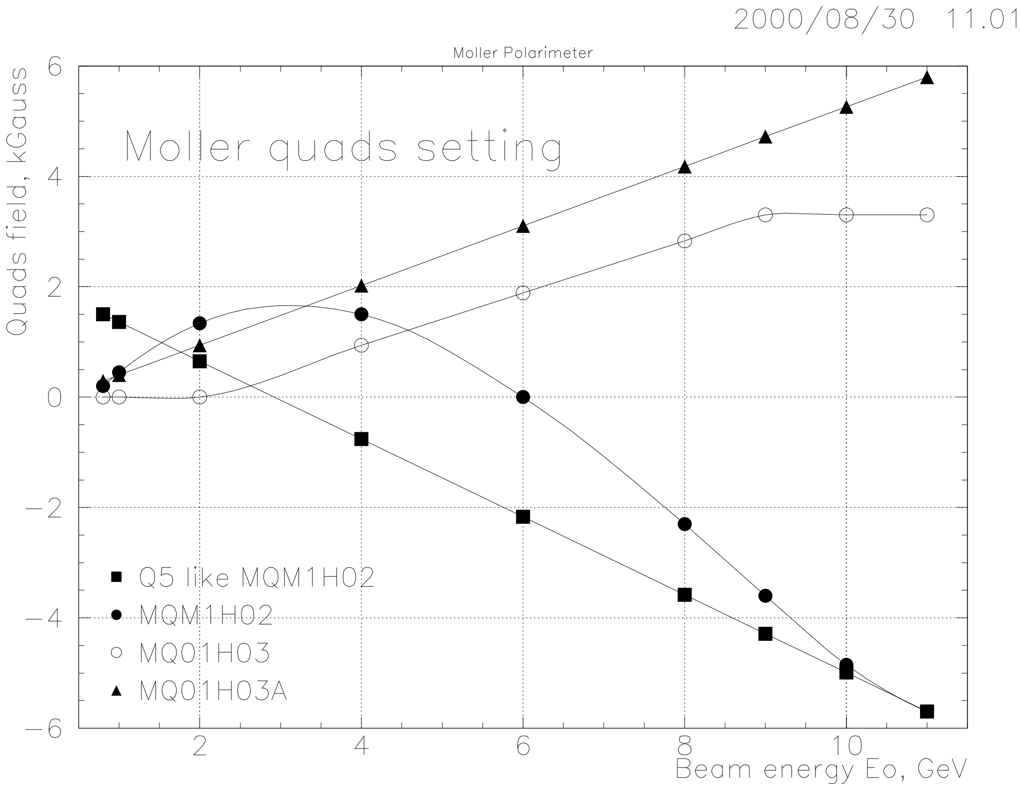

Figure 2: Møller polarimeter with four quadrupoles setting

The Dipole Vacuum Box Design

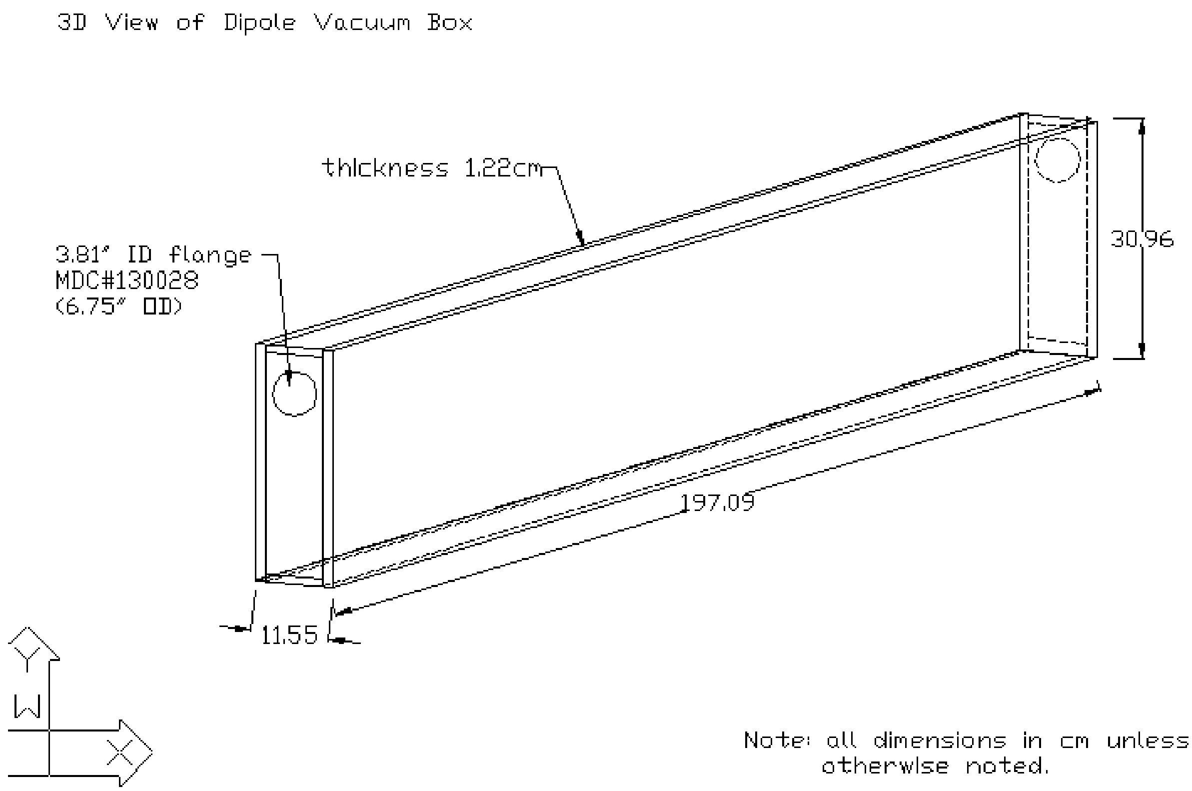

Figure 3: Møller dipole shielding insertion

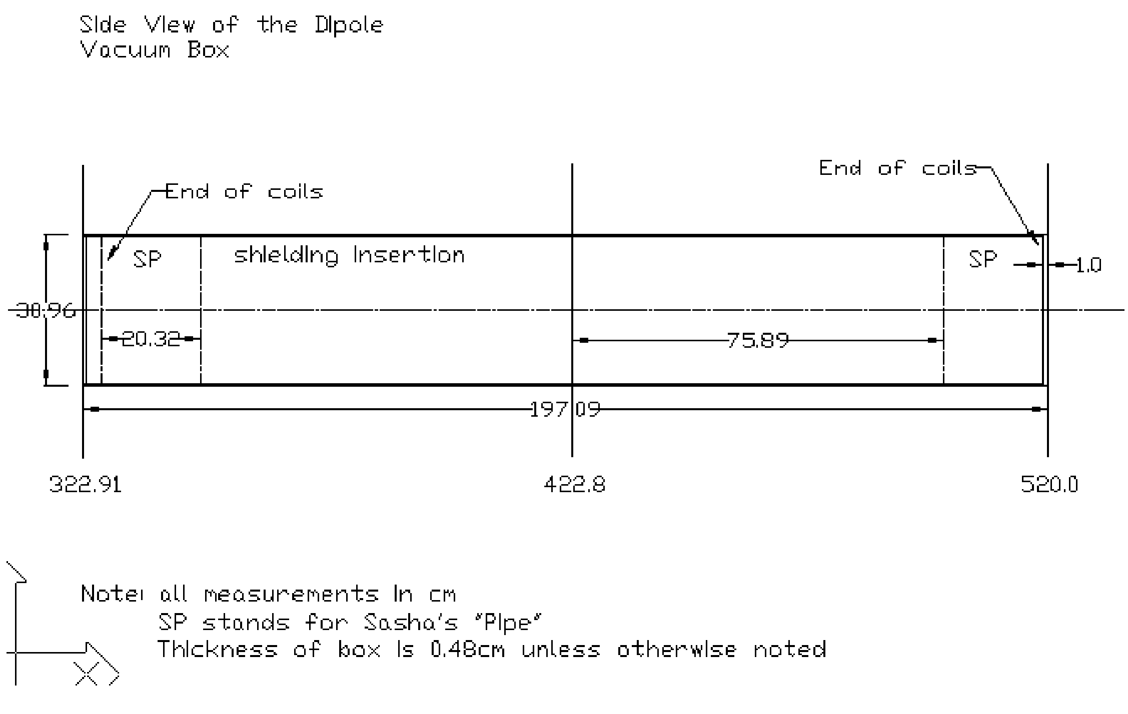

Figure 4: Møller dipole shielding insertion

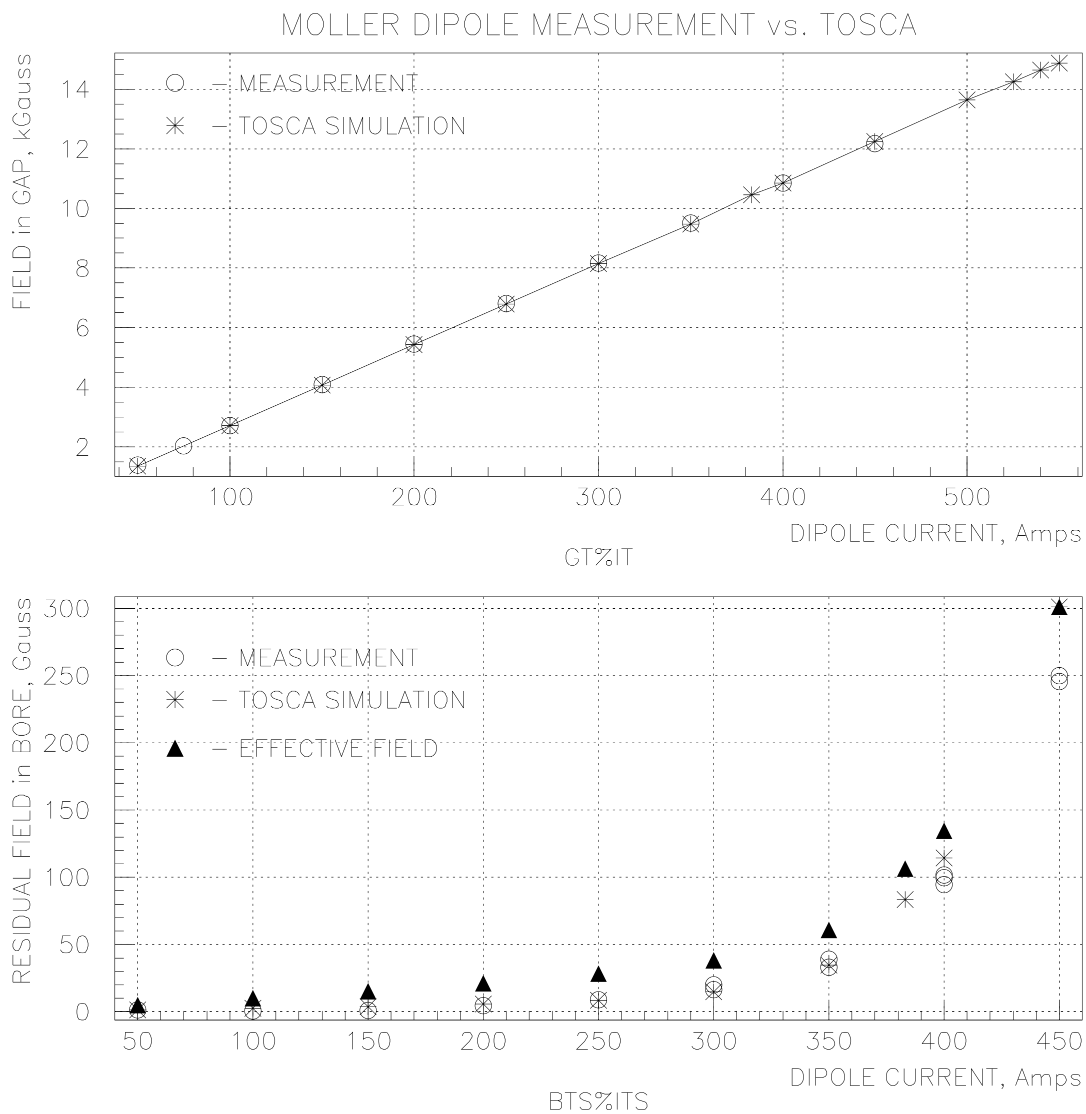

Figure 5: The present Møller polarimeter dipole design. The top picture is the field at the center of dipole gap. The bottom picture is the residual magnetic field in the shielding insertion and the effective bending field (the contribution of the fringe field is added)

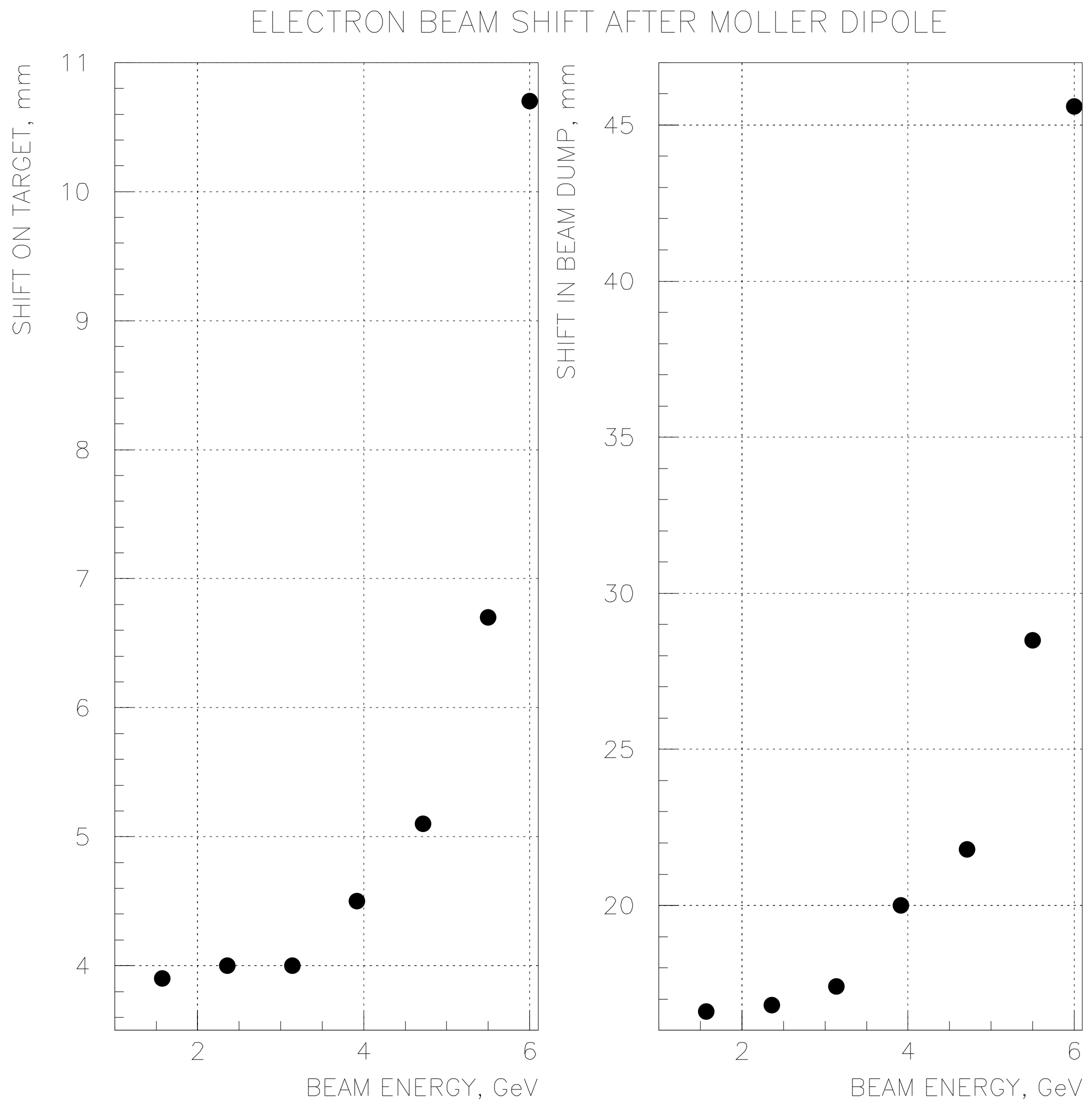

Figure 6: The present Møller polarimeter dipole design. The electron beam shift on the Hall A target (left picture) and in the Hall A beam dump (right picture).

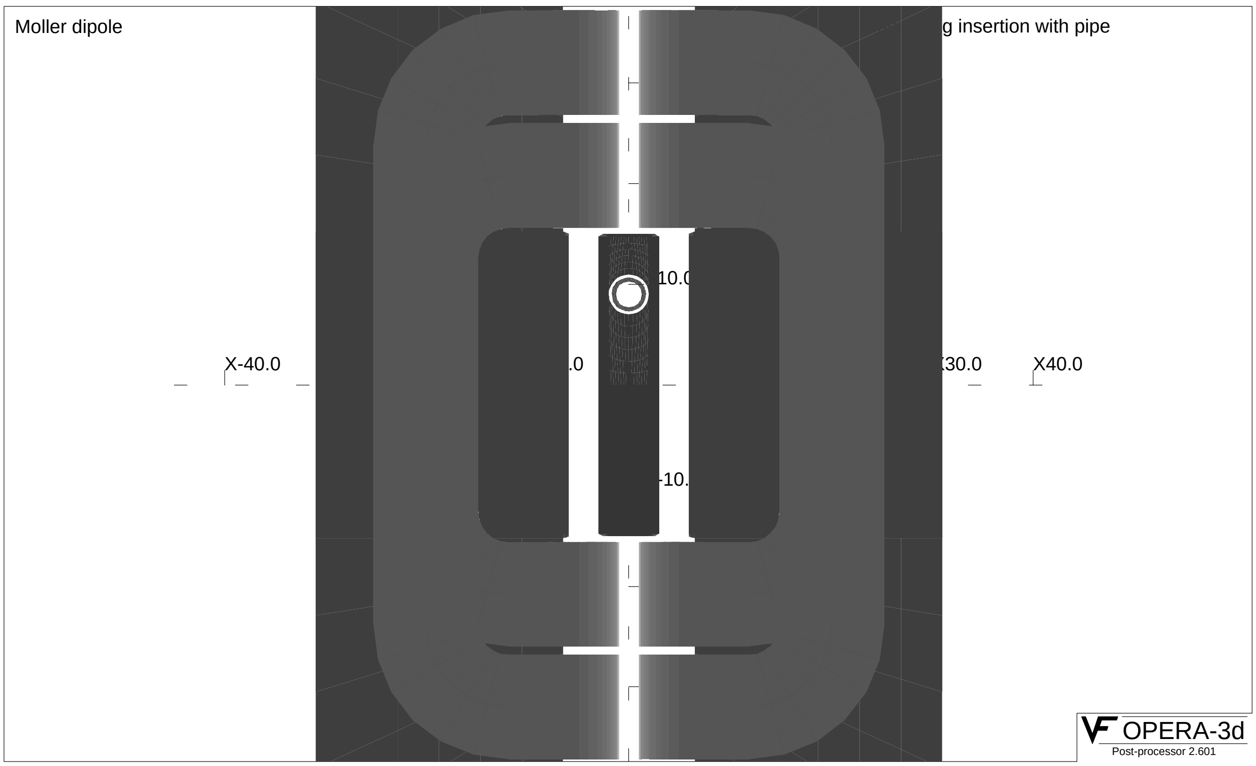

Figure 7: Dipole shielding insertion with additional coaxial pipes inside

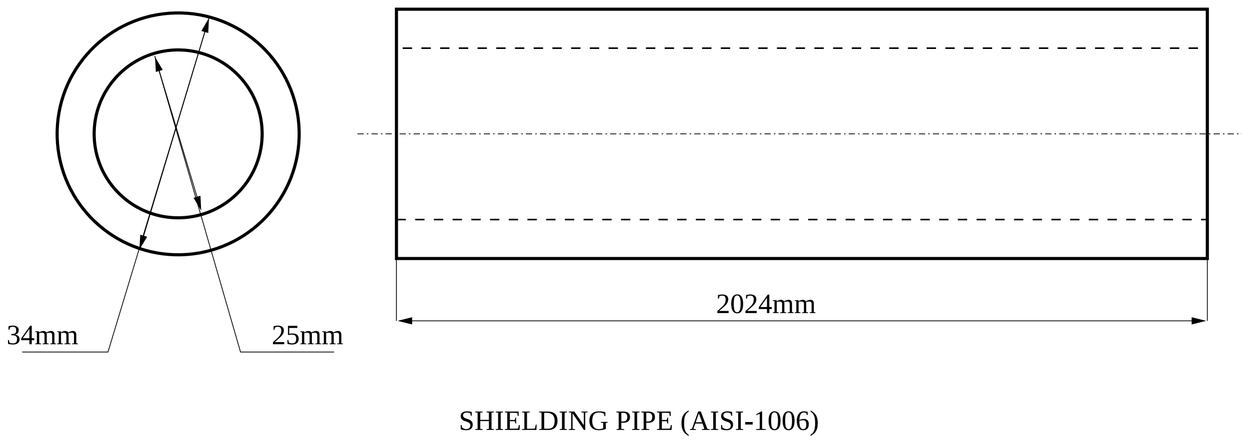

Figure 8: Dipole shielding pipe

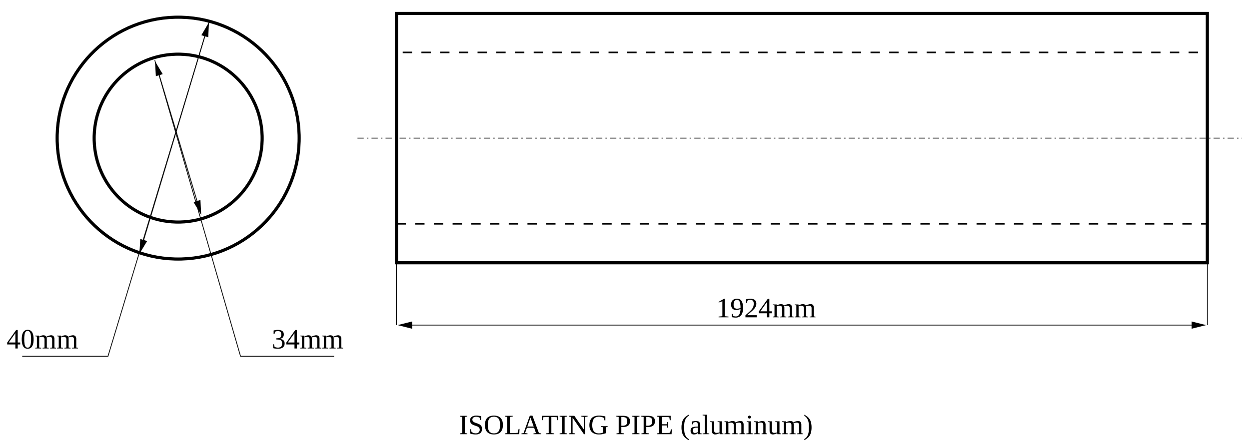

Figure 9: Dipole isolating pipe

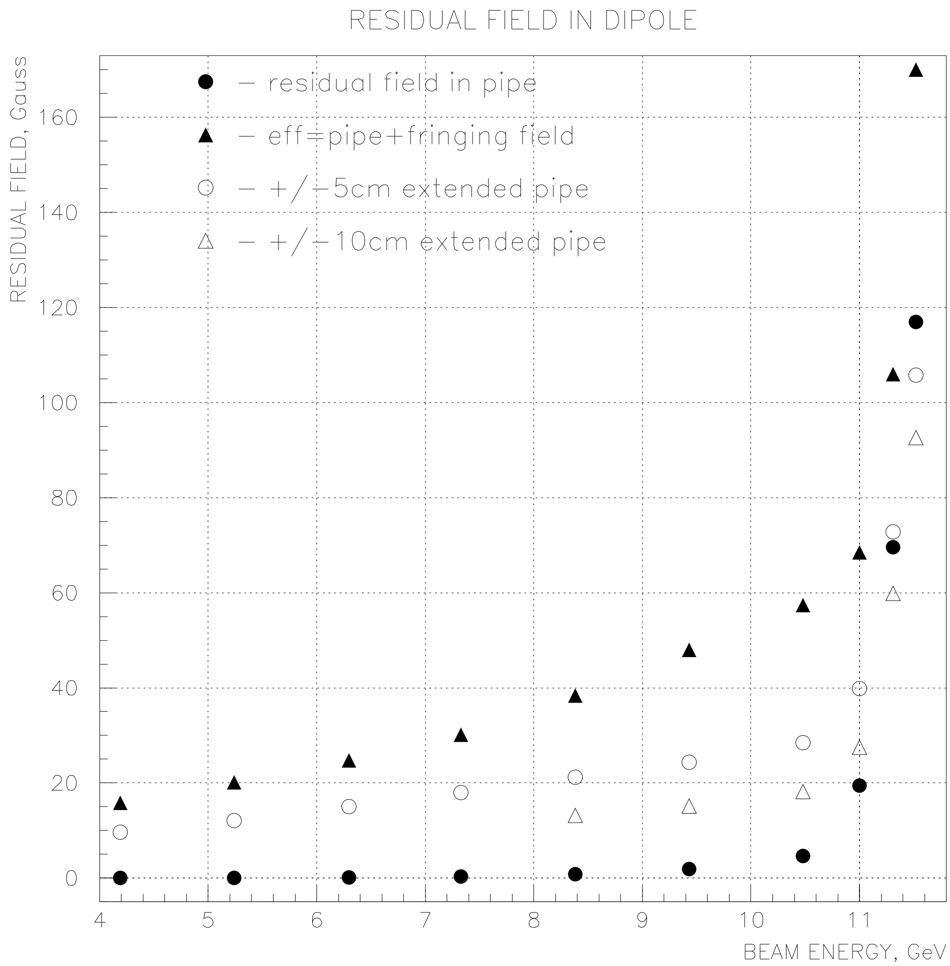

Figure 10: Effective residual dipole field for the different shielding pipe designs

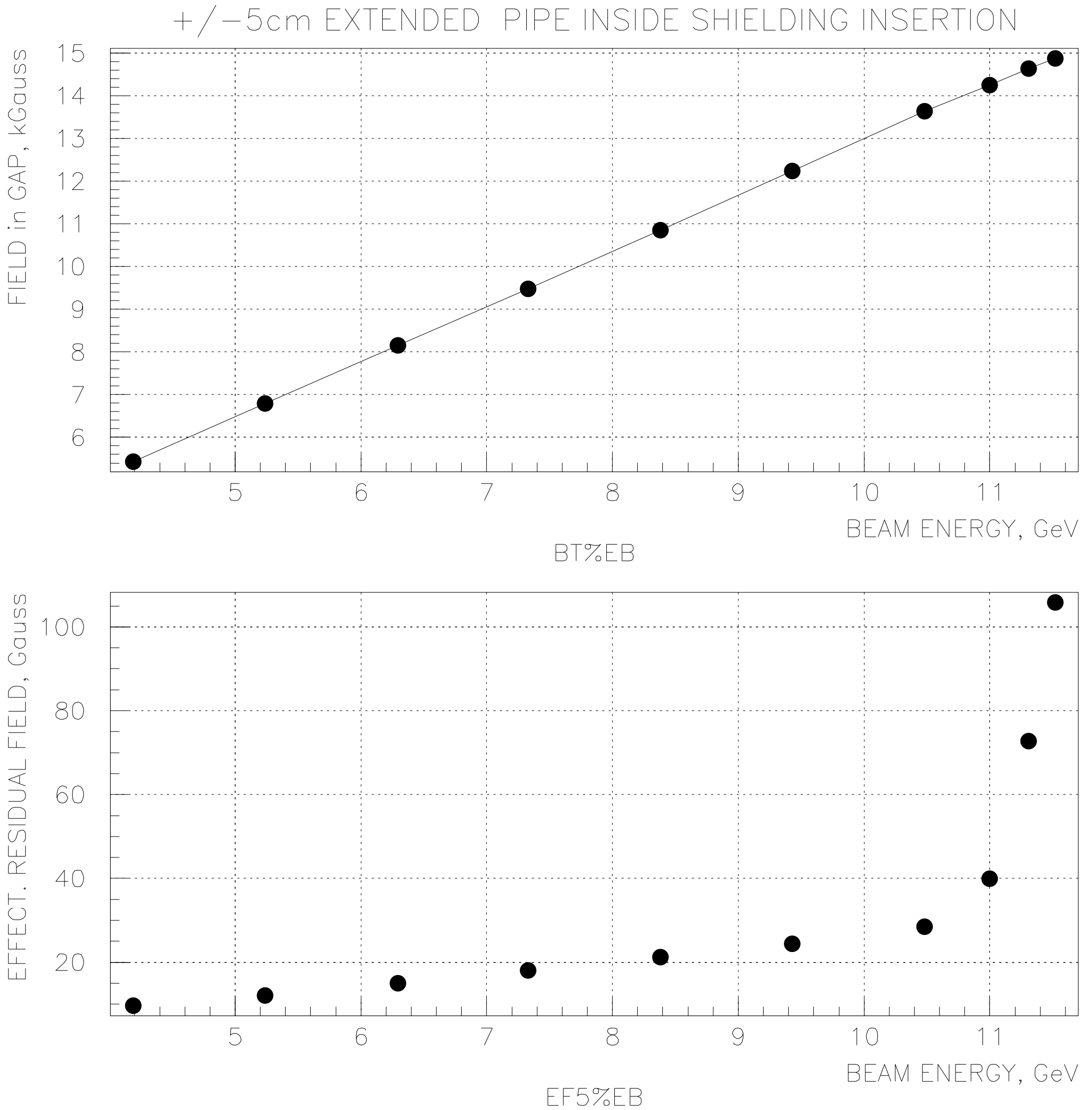

Figure 11: The Møller polarimeter dipole design with a 10cm extended shielding pipe. The top picture shows the field in the center of dipole gap. The bottom picture is the residual magnetic field in the shielding insertion and the effective bending field (a contribution of the fringing field is added)

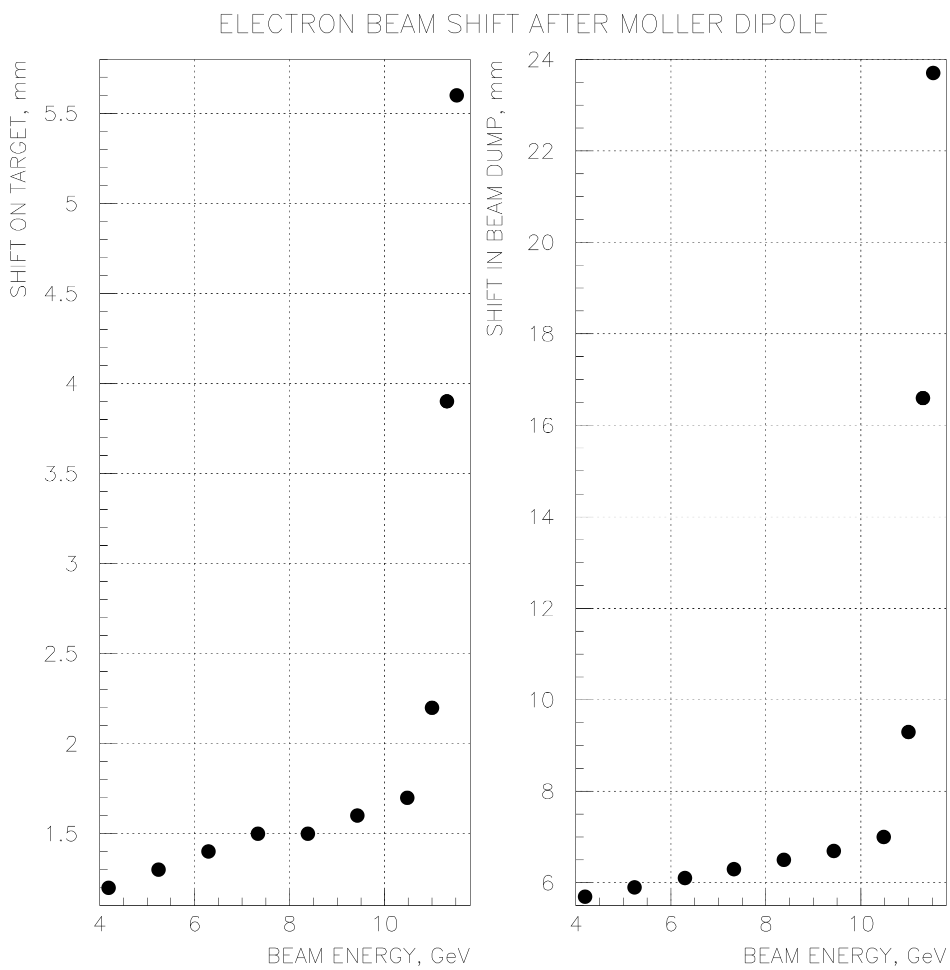

Figure 12: The dipole with the 10 cm extended shielding pipe. The electron beam shift on the Hall A target (left picture) and in the Hall A beam dump (right picture).

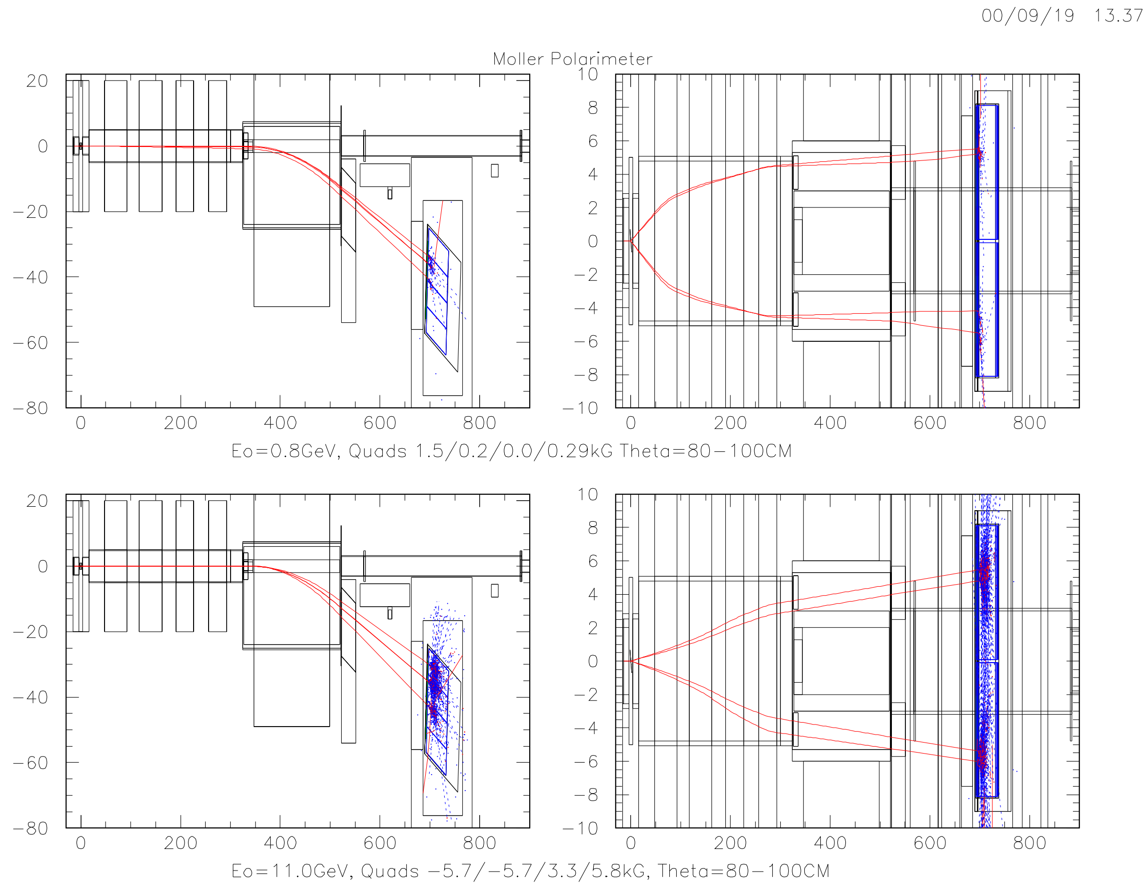

Figure 13: Upgraded Møller polarimeter layout and Møller electrons trajectories for 1.5 and 11 GeV