Hall C Møller Polarimeter Status

Dave Gaskell

Hall C Winter Meeting

January 28-29, 2019

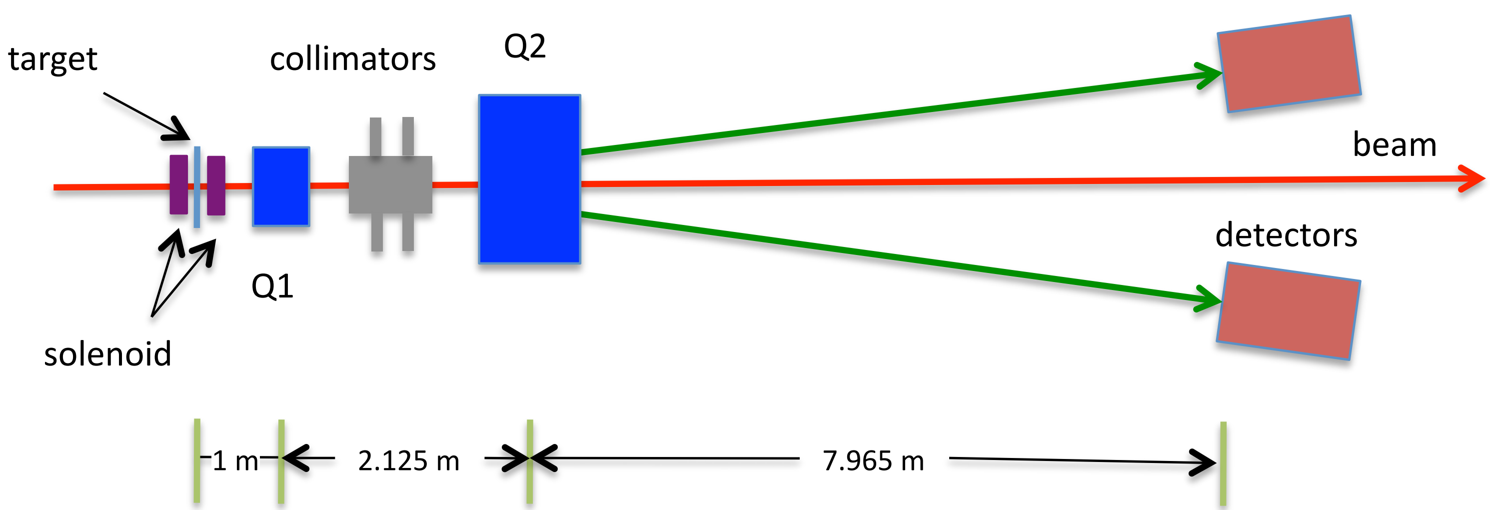
Outline

1. Møller Configuration: 6 GeV → 12 GeV
2. Status
3. To-do list

Jefferson Lab

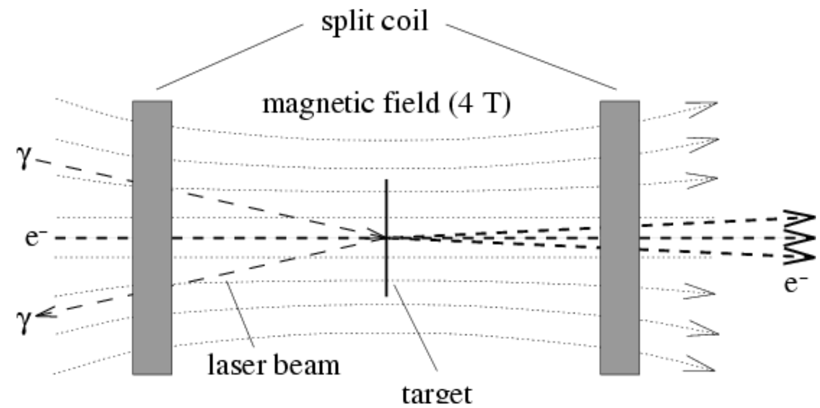
Hall C Møller Polarimeter

- 2 quadrupole optics maintains constant tune at detector plane
- "Moderate" (compared to Hall A) acceptance mitigates Levchuk effect → still a non-trivial source of uncertainty
- Target = pure Fe foil, brute-force polarized out of plane with 3-4 T superconducting magnet → first implementation of this technique
- Capable of <1% precision



Hall C Møller Target

- Fe-alloy, in-plane polarized targets typically result is systematic errors of 2-3%
  - Require careful measurement magnetization of foil
- Pure Fe saturated in 4 T field
  - Spin polarization well known → 0.25%
  - Temperature dependence well known
  - No need to directly measure foil polarization



Effect	$M_s[\mu_B]$	error
Saturation magnetization (T→0 K,B→0 T)	2.2160	±0.0008
Saturation magnetization (T=294 K, B=1 T)	2.177	±0.002
Corrections for B=1→4 T	0.0059	±0.0002
Total magnetization	2.183	±0.002
Magnetization from orbital motion	0.0918	±0.0033
Magnetization from spin	2.0911	±0.004
Target electron polarization (T=294 K, B= 4 T)	0.08043	±0.00015

de Bever et al, NIMA 400 (1997) no.2-3, 379-386

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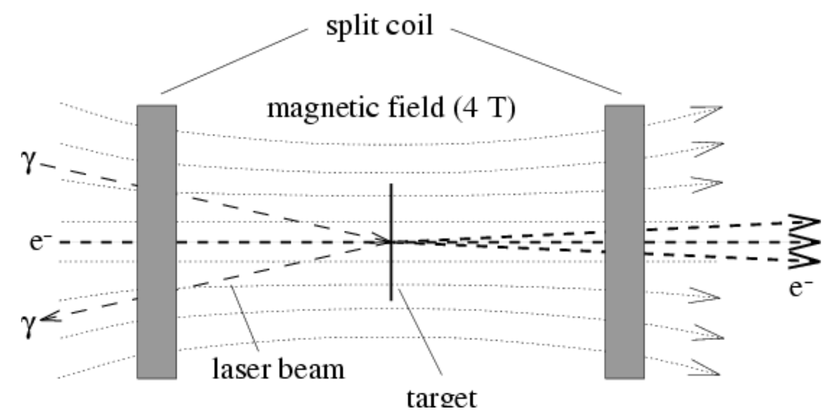

Detailed re-assessment by Don Jones (Temple U.)

→ Few minor corrections
→ Improved fit to existing Fe saturation data – fit data taken at high fields/temperatures rather than using 0 K values and extrapolating

New target polarization (@ T=294 K, B=4 T): 0.08014 +/- 0.00022

Target electron polarization (T=294 K, B= 4 T)	0.08043	±0.00015

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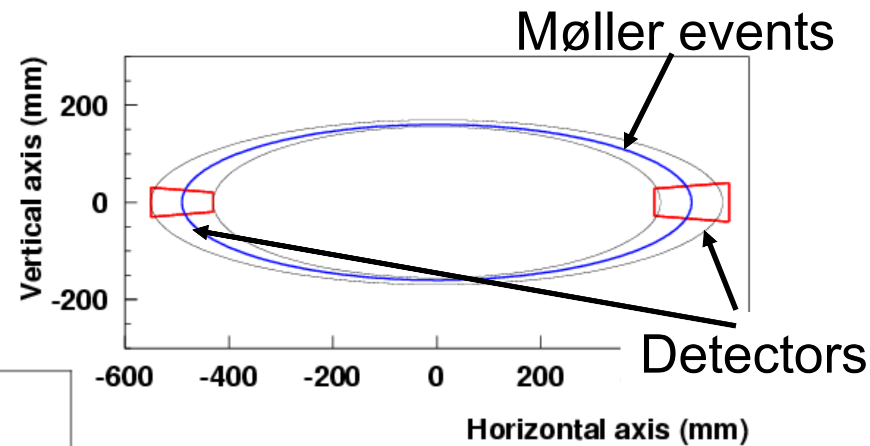
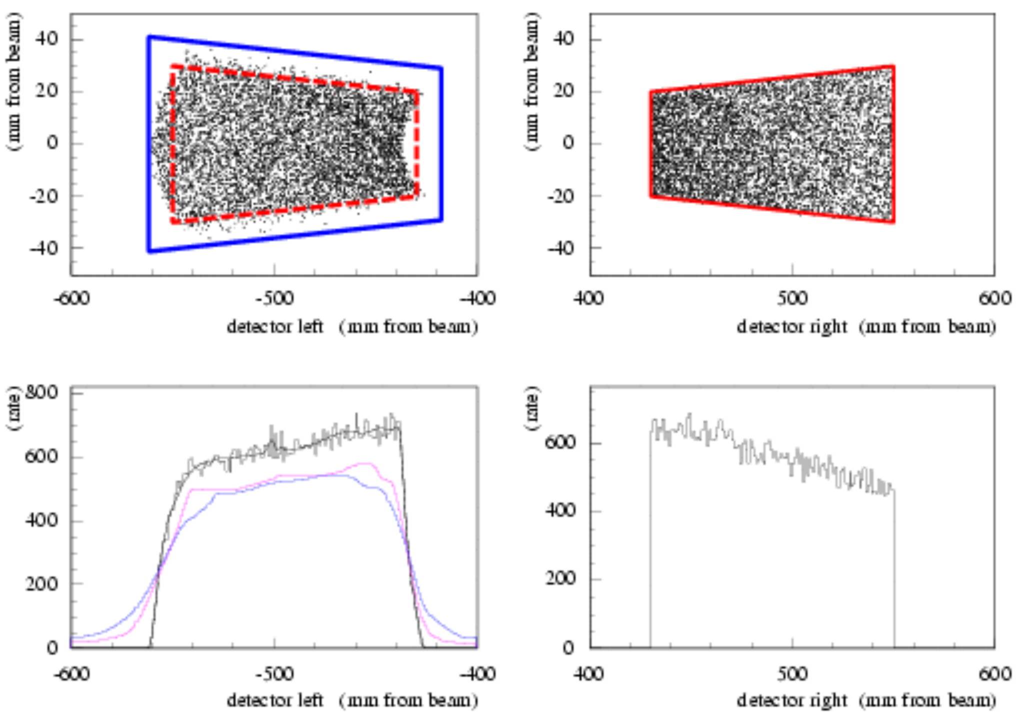
Hall C Møller Acceptance

Optics designed to maintain similar acceptance at detectors independent of beam energy





Collimators in front of Pb:Glass detectors define acceptance

One slightly larger to reduce sensitivity to Levchuk effect

Møller Systematic Uncertainties

Source	Uncertainty	dA/A (%)
Beam position x	0.5 mm	0.17
Beam position y	0.5 mm	0.28
Beam direction x	0.5 mr	0.10
Beam direction y	0.5 mr	0.10
Q1 current	2% (1.9 A)	0.07
Q3 current	2.5% (3.25 A)	0.05
Q3 position	1 mm	0.10
Multiple scattering	10%	0.01
Levchuk effect	10%	0.33
Collimator positions	0.5 mm	0.03
Target temperature	100%	0.14
B-field direction	2^o	0.14
B-field strength	5%	0.03
Spin polarization in Fe		0.25
Electronic D.T.	100%	0.04
Solenoid focusing	100%	0.21
Solenoid position (x,y)	0.5 mm	0.23
Additional point–to–point		0.0
High current extrapolation		0.5
Monte Carlo statistics		0.14
Total		0.85

Systematic error table from Q-Weak (2nd run) in Hall C

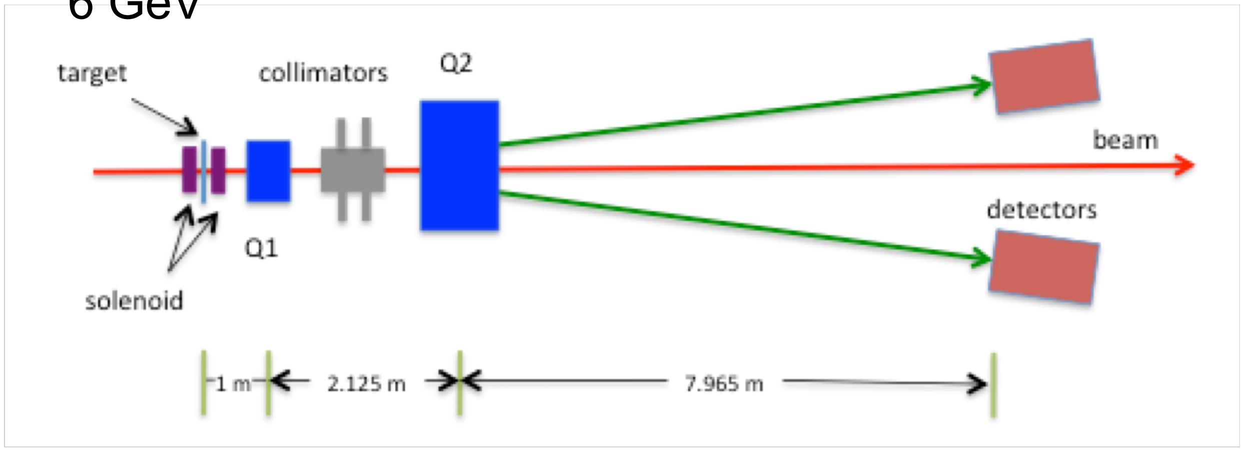
→ Some uncertainties larger than "usual" due to low beam energy (1 GeV)

→ Levchuk effect, target polarization same at all energies

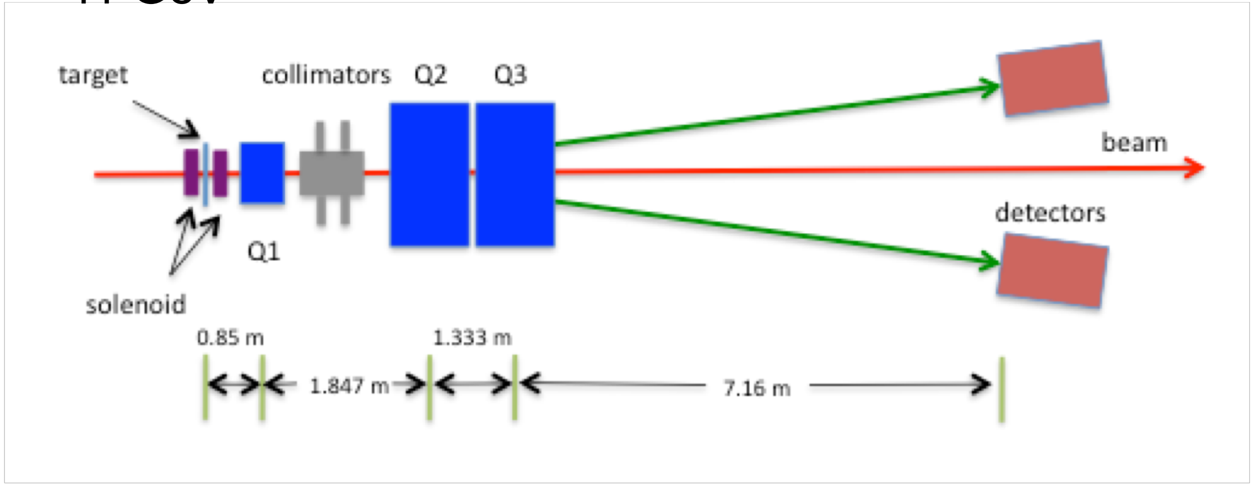
Total uncertainty less than 1%

Møller Polarimeter at 12 GeV – New layout

6 GeV



11 GeV

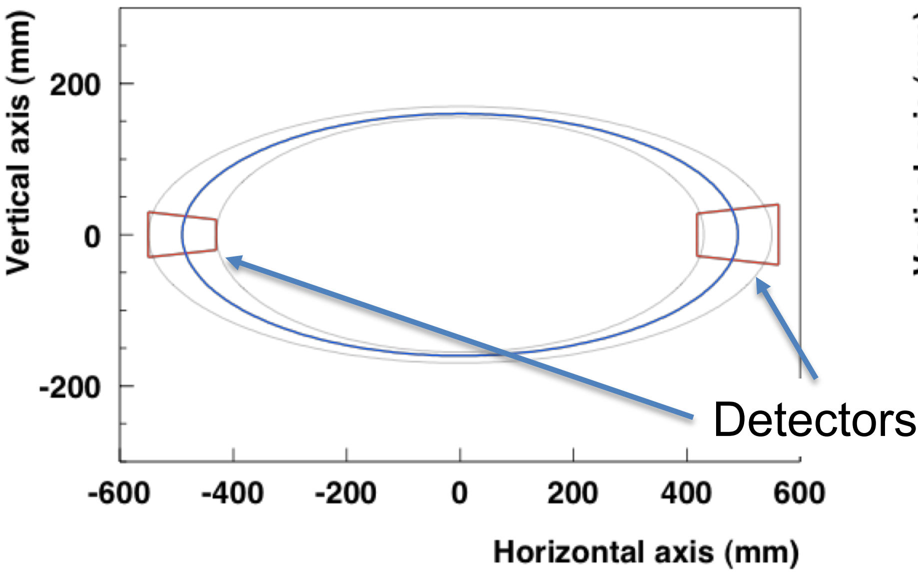


Additional large quad required to steer electrons to detectors

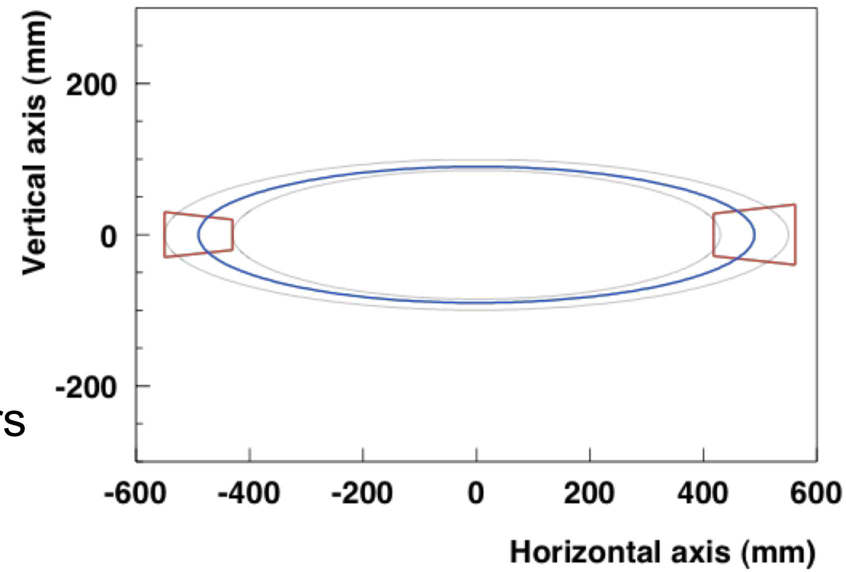
→ Even with new quad, some compromise had to be made with respect to polarimeter optics

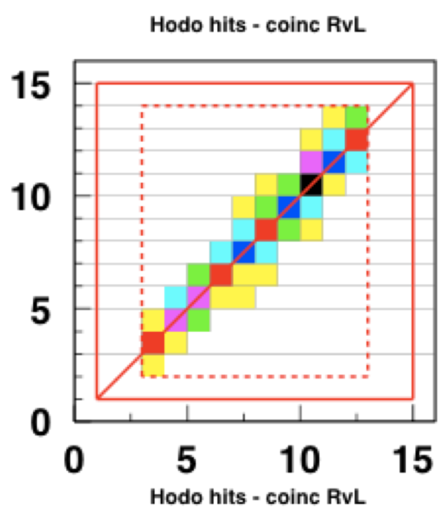
Møller Polarimeter – New optics

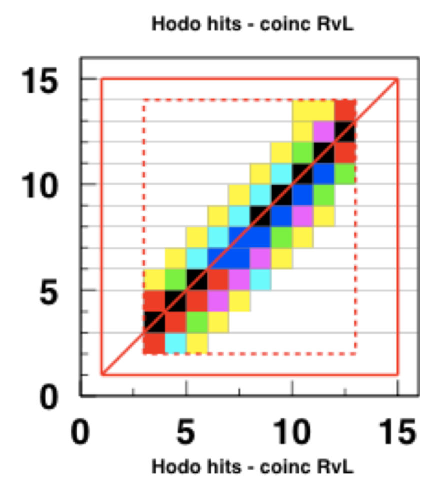
6 GeV



11 GeV







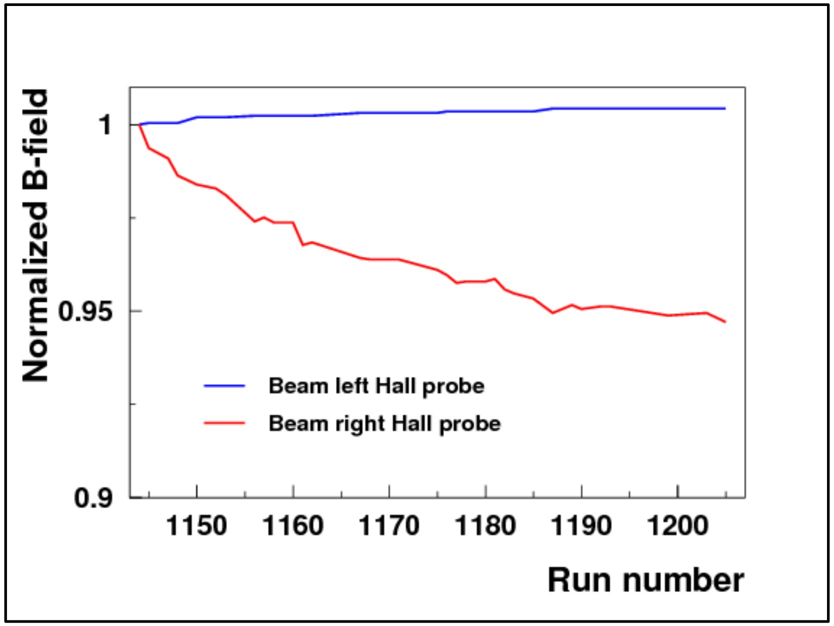
Expected Møller Performance at 11 GeV

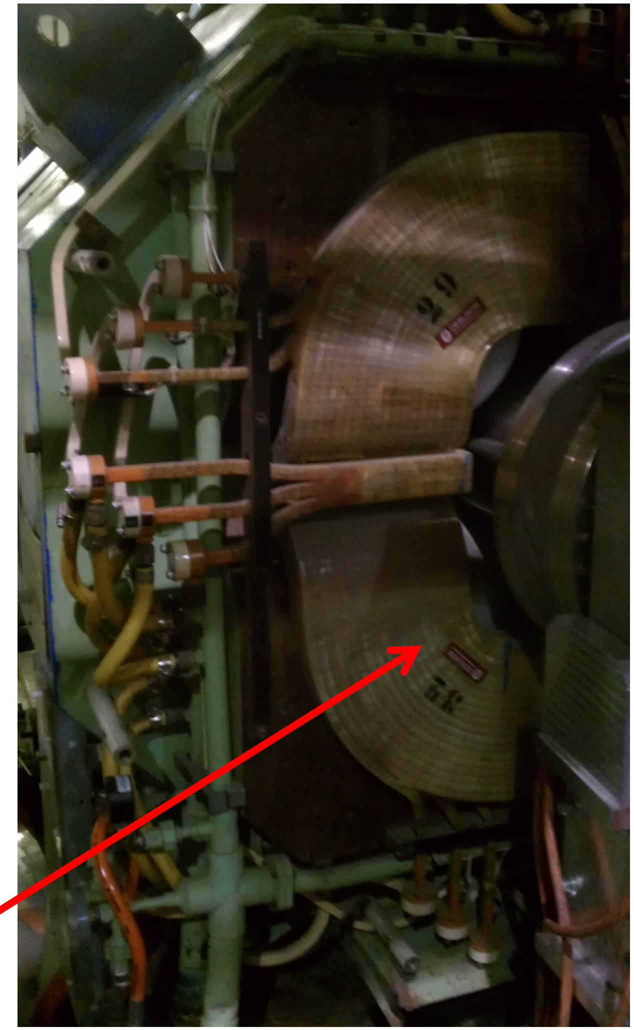
Monte Carlo studies by Kamilah Walker – Phoebus High School

Source	Uncertainty	dA/A (%)		Average
Beam x position	0.5 mm	0.058	0.103	0.081
Beam y position	0.5 mm	0.000	0.045	0.023
Beam x angle	0.5mradians	-0.039	0.289	0.125
Beam y angle	0.5mradians	0.039	0.116	0.078
Q1 current	2.00%	0.077	0.129	0.103
Q3 (and Q2) current	2.50%	-0.019	0.411	0.196
Q1 position	1 mm	-0.008	-0.008	-0.008
Q3 position	1 mm	0.000	0.000	0.000
Multiple scattering	10.00%	0.064	0.064	0.064
Radiative corrections	10.00%	-0.022	-0.022	-0.022
Levchuk effect	10.00%	0.295	0.295	0.295
Collimator positions	0.5 mm	0.088	0.088	0.088
Solenoid focusing	100.00%	0.013	0.013	0.013
Solenoid position	0.5 mm	-0.006	-0.006	-0.006
Constant sources of unc.				
Target temperature	100.00%	0.14	0.14	0.14
B-field direction	2 deg.	0.14	0.14	0.14
B-field strength	5.00%	0.03	0.03	0.03
Spin polarization in iron		0.25	0.25	0.25
Electronic DT	100.00%	0.04	0.04	0.04
High current extrapolation		0.5	0.5	0.5
Monte Carlo statistics		0.12	0.12	0.12
Total		0.69	0.87	0.74

Total systematic error comparable to Q-Weak

Møller Polarimeter Quad Problems





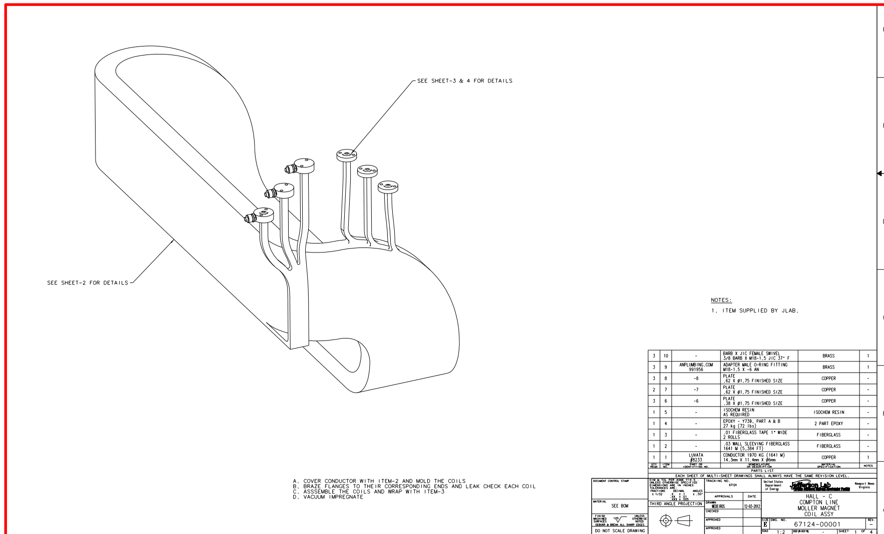
Bad coil

During Q-Weak run, discovered that large Møller quad had issues

→Problem traced to a bad coil, but along the way found that most coils were not "healthy"

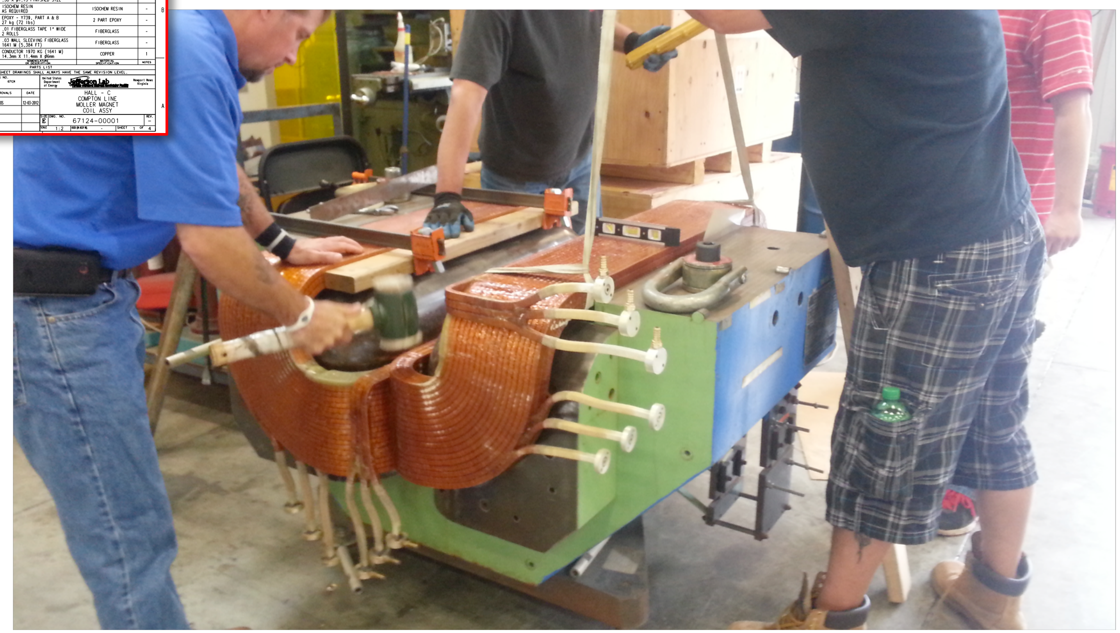
→ Needed to replace all coils (8 sets of coils + 2 spares)

New Møller Coils



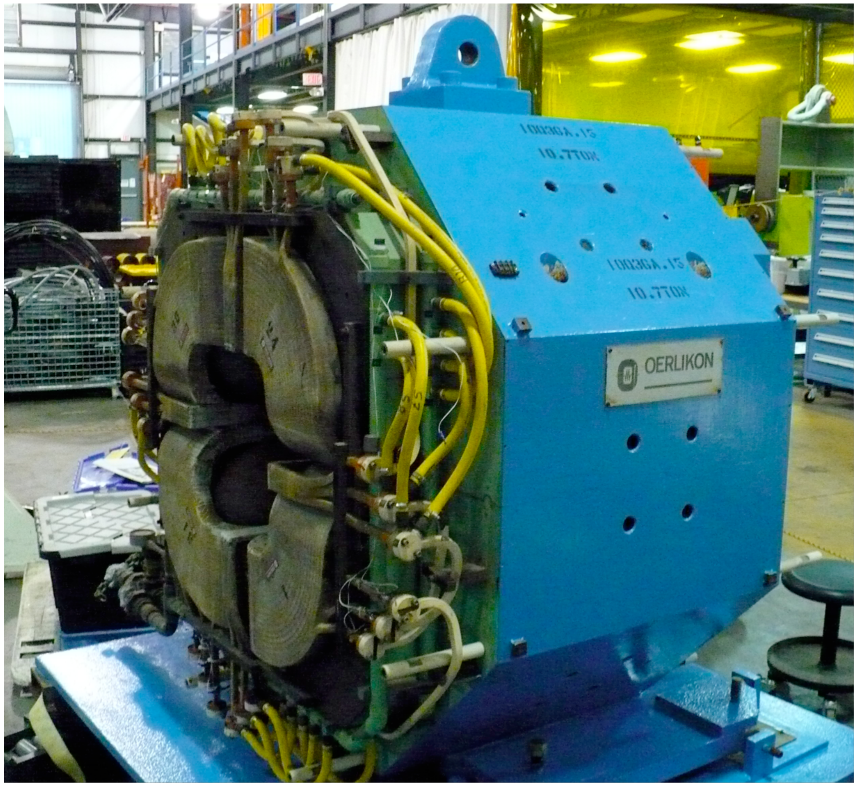
New coils designed at JLab – copied original configuration as much as possible

Coils fabricated by Everson Tesla – took a few iterations to get coils that fit



Test fit of new coils at manufacturer

Møller Quadrupole Refurbishment



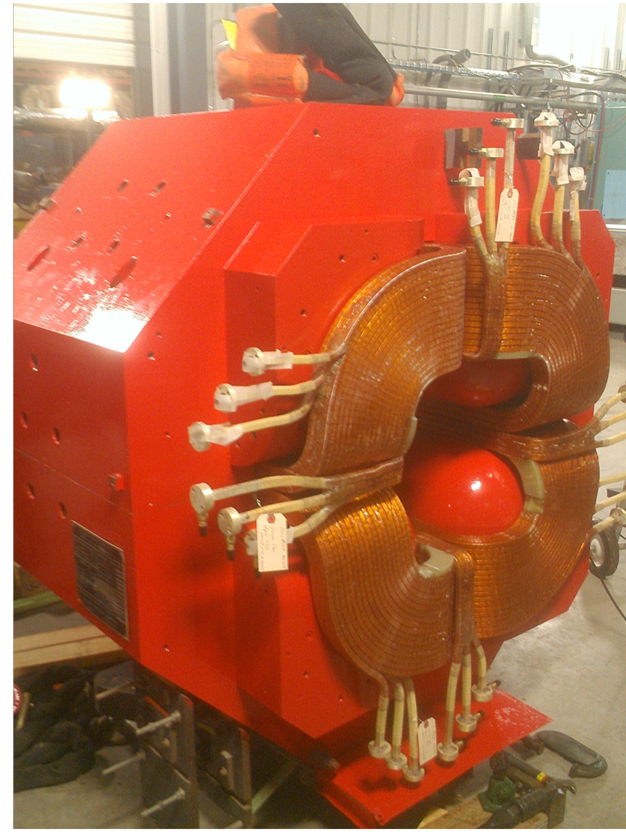


Photo: Mike Beck – MAG-TEST

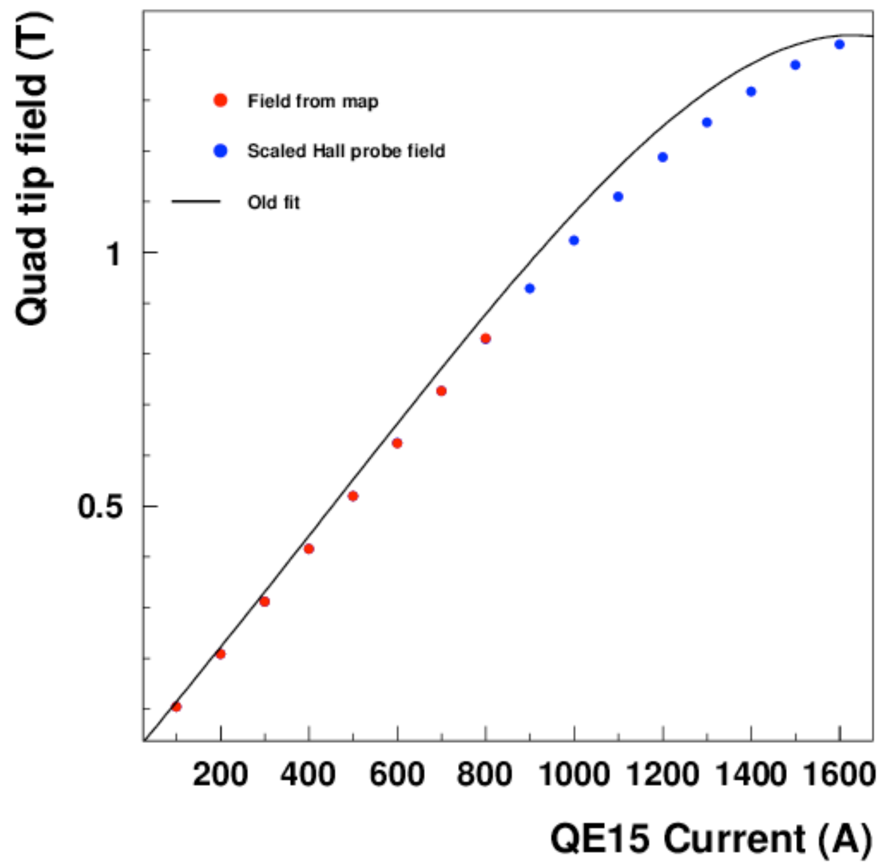
In addition to installing new coils, MAG-TEST performed full refurbishment of both large quadrupoles (sand off rust, paint, new water hoses, etc.)

Large Quad – Full Current Test

After refurbishment, new coil installation, JLab Magnet Test group only able to check large quad strength up to 800 A in their lab

New Hall C power supply required for ~1600 A operation → Summer 2018 tested magnet and extended field measurements to full field

Measured field not totally consistent with old, 6 GeV era expectation



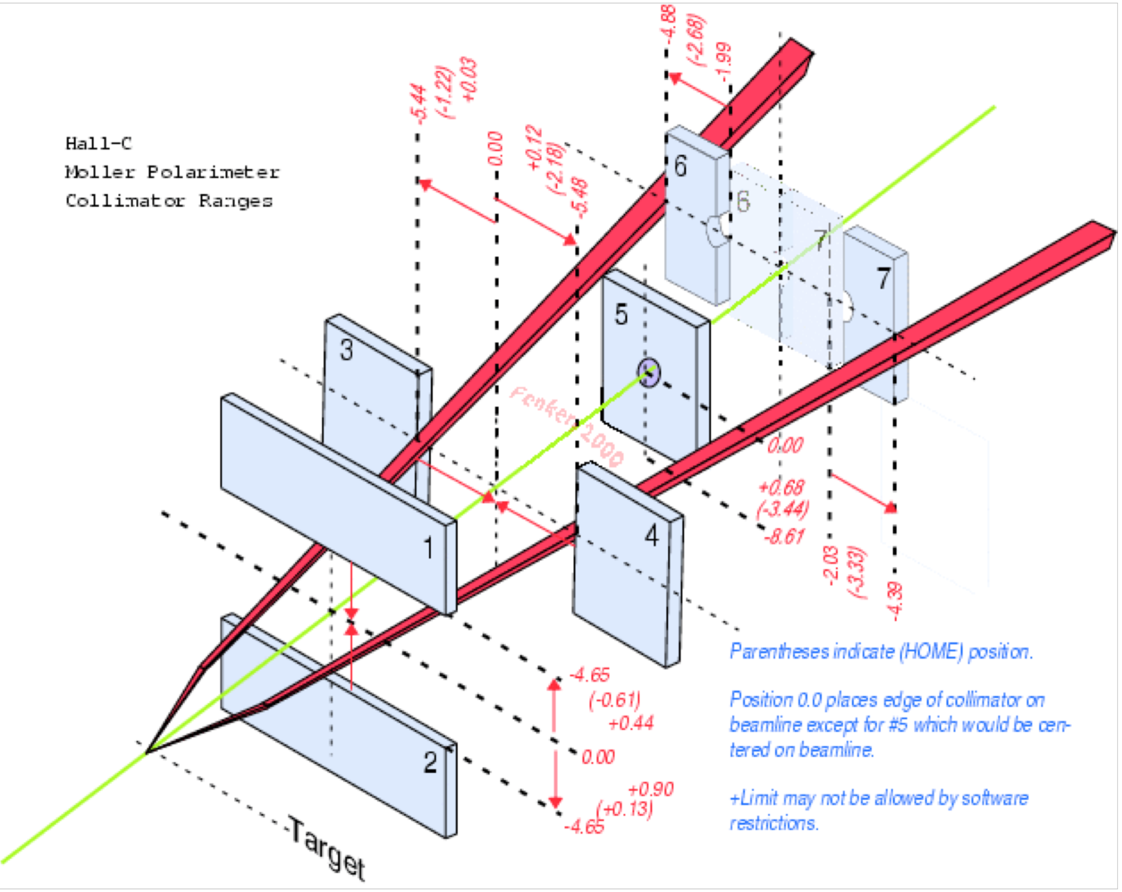
Refurbished quads capable of fields needed for 11 GeV operation

Møller Collimators

Movable collimators to reduce background from Mott scattering

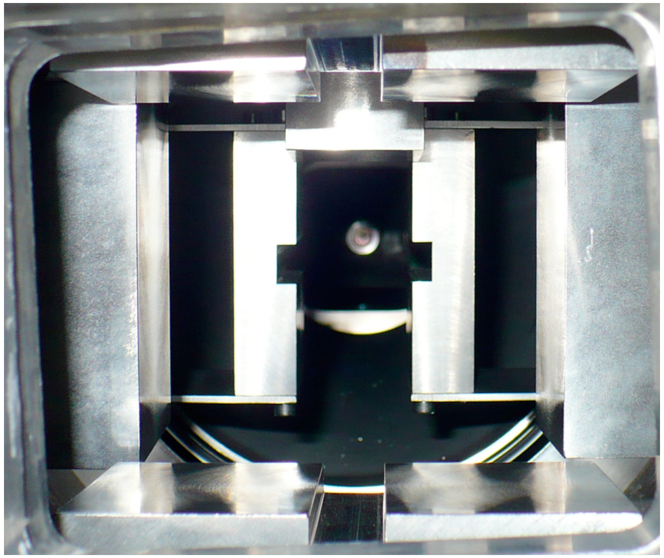
→ Collimators 5,6,7 used to block electrons with scattering angles smaller than Møller events
→ Minimum width ~ 4.7 cm
→ At 11 GeV, this would block Møller events

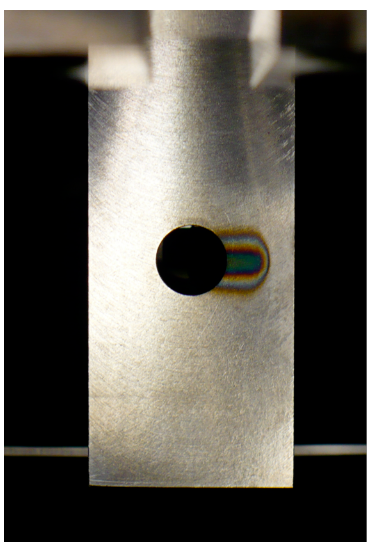
→ Collimators were modified so minimum width ~ 2 cm



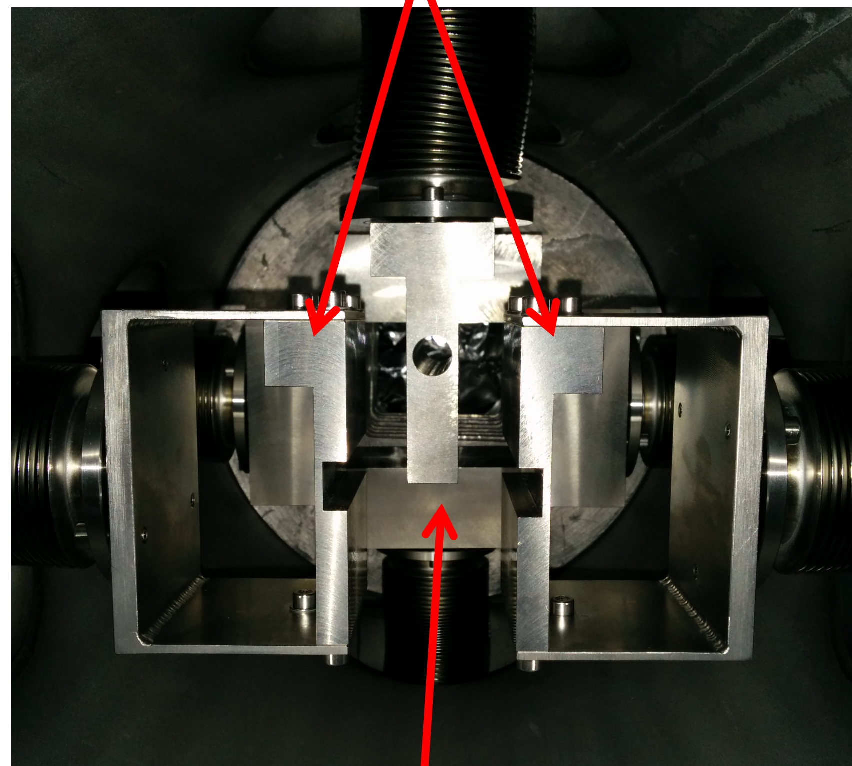
Møller Collimators

Unmodified

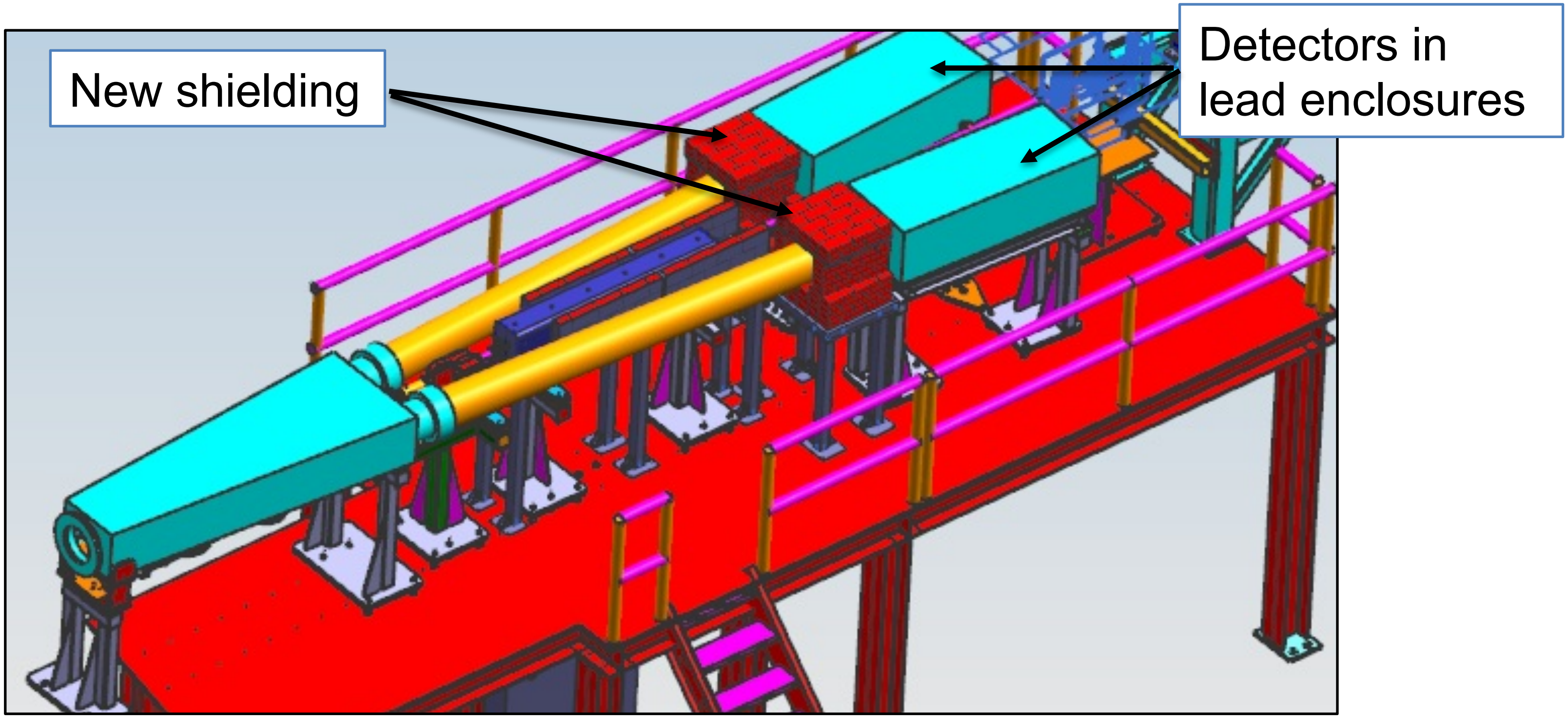




Modified

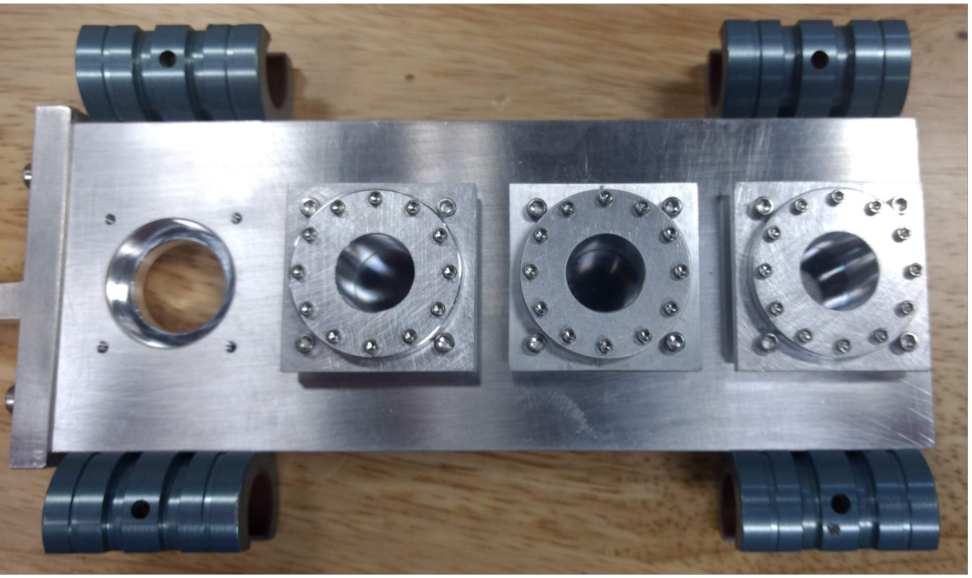


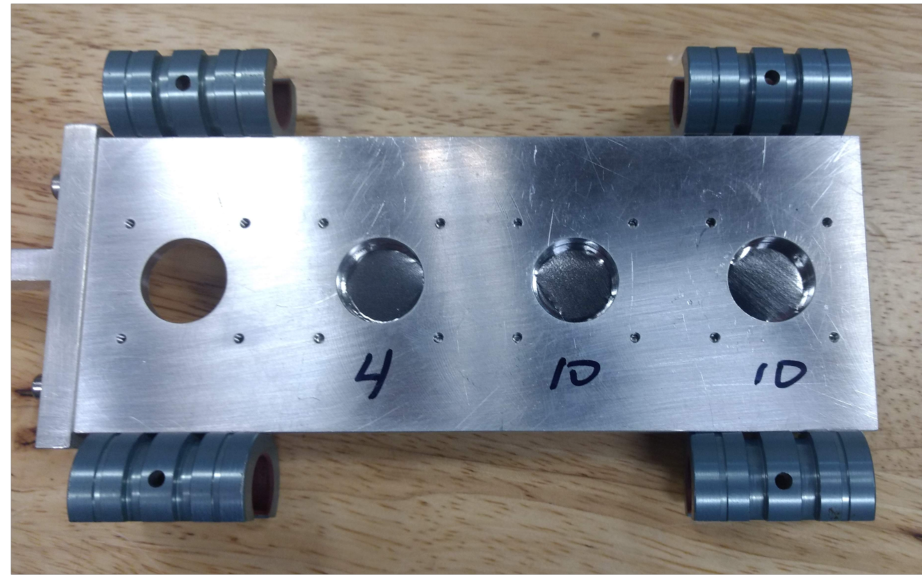
Møller Shielding



Extra detector shielding added as part of 12 GeV beamline design (Q-Weak saw higher backgrounds) → part of this extra shielding installed during summer 2018 SAD

New Møller Target Foils and Ladder





During Summer 2018, Dave Meekins designed new target ladder → smaller foil aperture, easier to get thick foils "flat"
→ New iron foils installed (4 μm, 10 μm, 10 μm)

Test Cooldown and Ramp

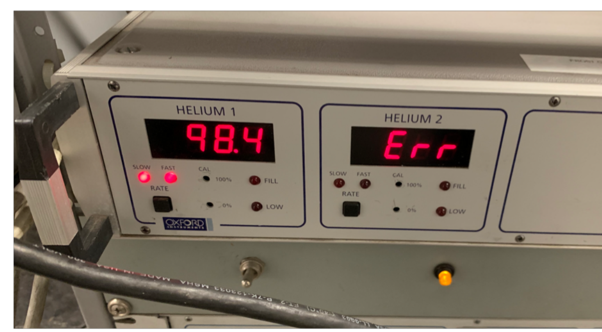
January 24, performed a test cooldown of the Møller solenoid

→ Solenoid has not been cooled or turned on since 2012

→ Cryo configuration during Q-Weak was unusual – Wanted to test after return to normal configuration

Solenoid cooled down successfully – ramped to 3 T

Solenoid at 3 T



Møller Task-list

During cooldown – discovered some issues to be resolved

1. LHe/LN2 level meter not working
2. Supply instrumentation not reading out (T and P sensors)
3. (Software) readback of solenoid field not correct
4. Cooldown valve, warm return bypass valves not acting correctly

These issues will be resolved during next down

→ Plan to perform initial commissioning during summer 2019 run

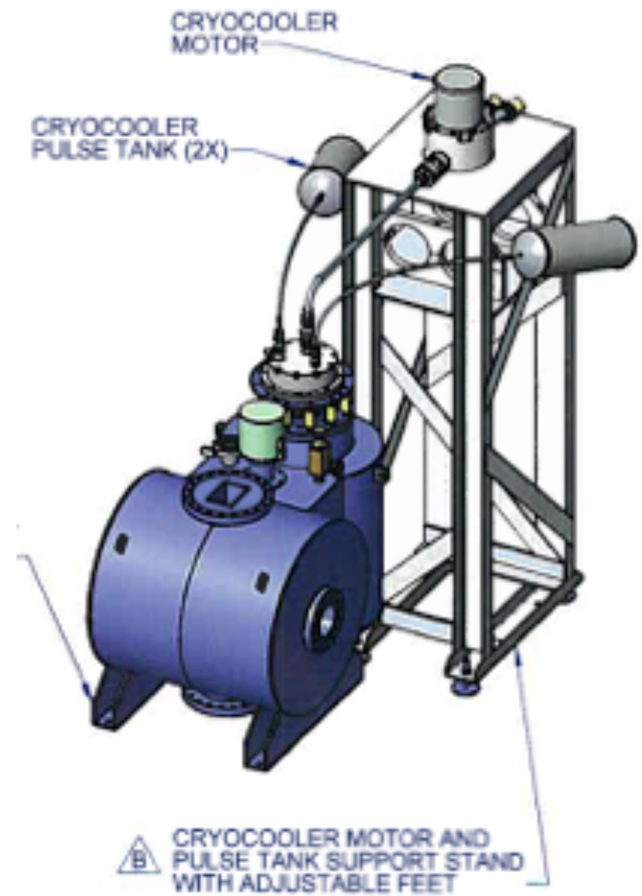
→ Will be used for A1n/d2n run in 2019/2020

Possible New Møller Solenoid

Looking into replacing existing target solenoid with conduction-cooled (cryogen free) magnet → In use in Hall A starting 2014

Assessing whether Hall A-style magnet compatible with space in Hall C beamline
→ May require changes to target ladder, beamline stand, etc., but so far looks relatively straightforward

→ Depending on quote/delivery time, may be available in time for A1n/d2n, but would require additional installation work



Møller Analyzer

- Existing Møller analyzer has been in use since 1990's → FORTRAN/HBOOK based
- Some work was done in 2010 to try and port the analyzer to C++/Root
  - This was partially completed (could analyze scaler data, but not ADCs/TDCs), but never finished or used for production data
- Would like an analyzer based on "modern" language, but minimizing dependence on other, large packages
- Michael Berkowitz (Grad student – Columbia) has expressed interest in looking at this (low priority task)

GEANT4 Simulation

Existing/6 GeV Møller simulation is a FORTRAN, aperture-checking Monte-Carlo

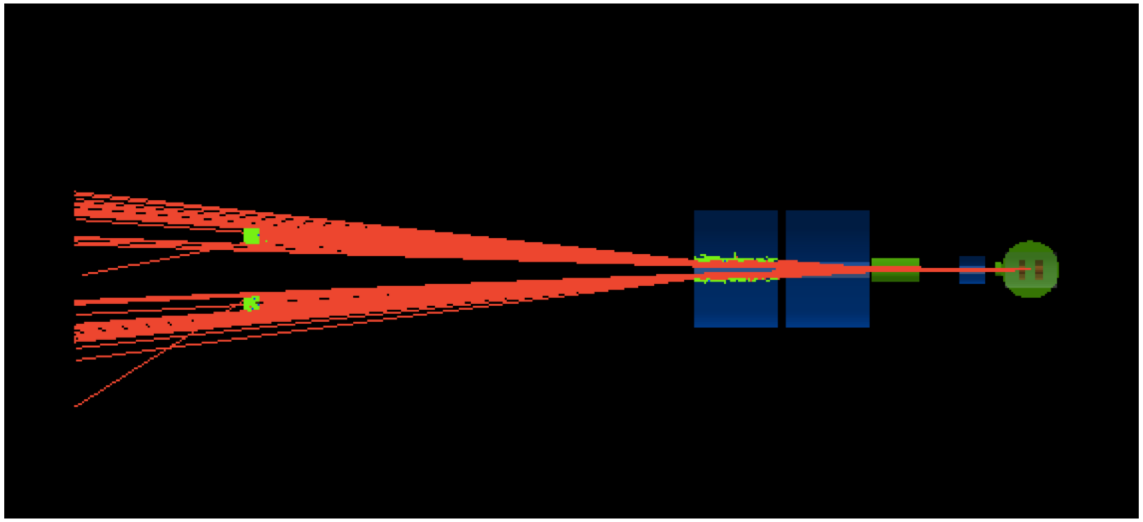
→ Based on simulation from SLAC SLC-linac Møller polarimeter

[M . Swartz et al, NIMA 363 (1995) 526-537]

GEANT4 MC has been under development in Hall A

→ Summer 2018, this simulation was ported for Hall C setup (Alyssa Petroski, Holly Szumila-Vance)

→ Major components in place – a few detailed geometry issues to be resolved



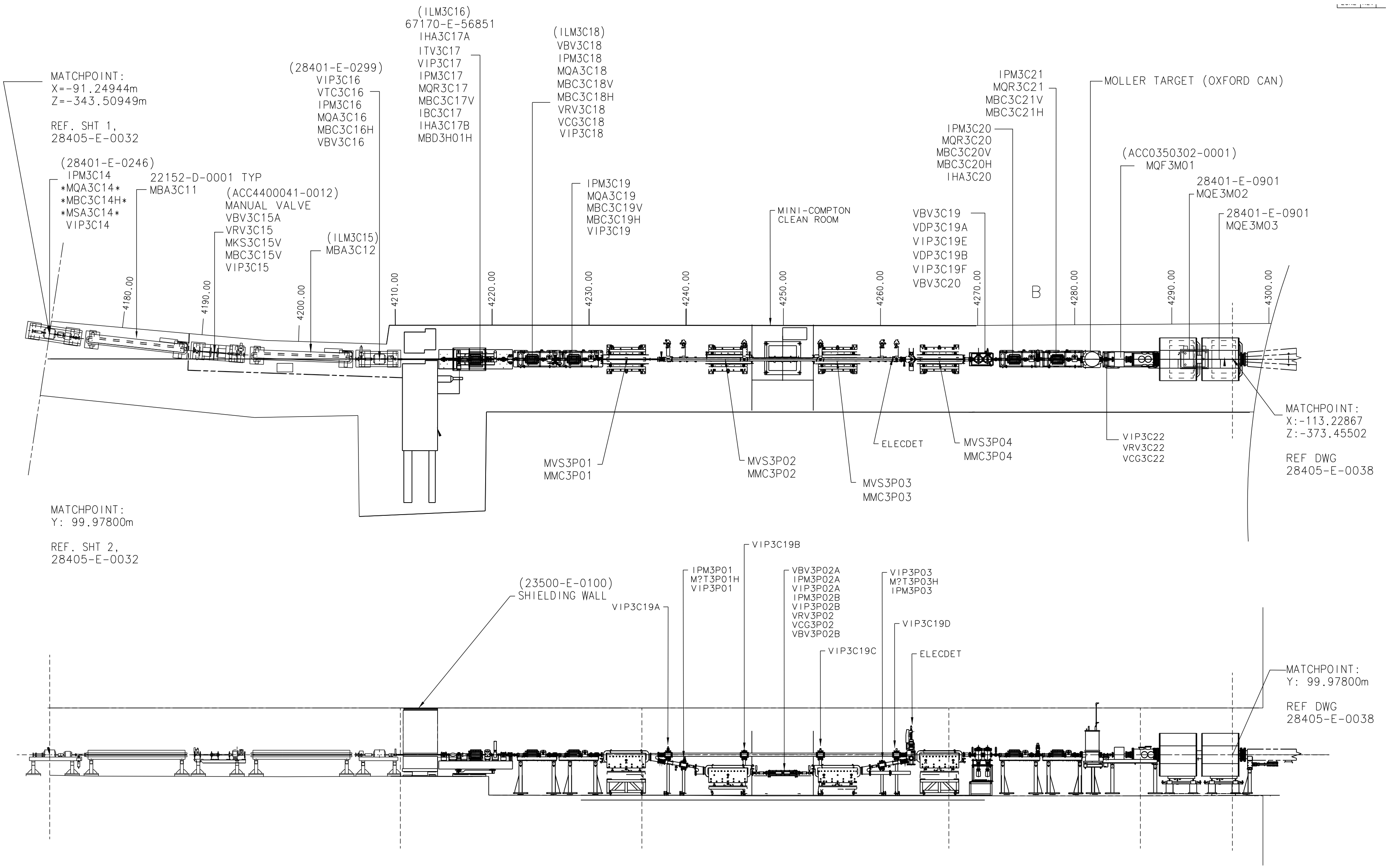
https://github.com/JeffersonLab/hallc-moller-polarimeter

Summary

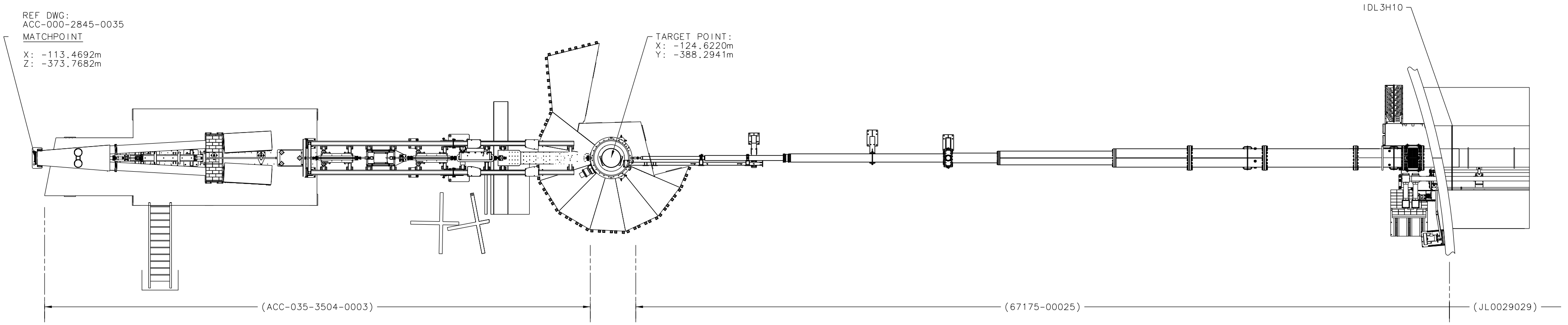
- Hall C Møller configuration has been updated for operation at 12 GeV
  - Expected performance similar to that at 6 GeV
- Polarimeter components (magnets, detectors, DAQ) have been checked
  - Some work to be done on solenoid cryo system
- Initial commissioning with new configuration will be in summer 2019
- Will be used for A1n/d2n during 2019/2020 run

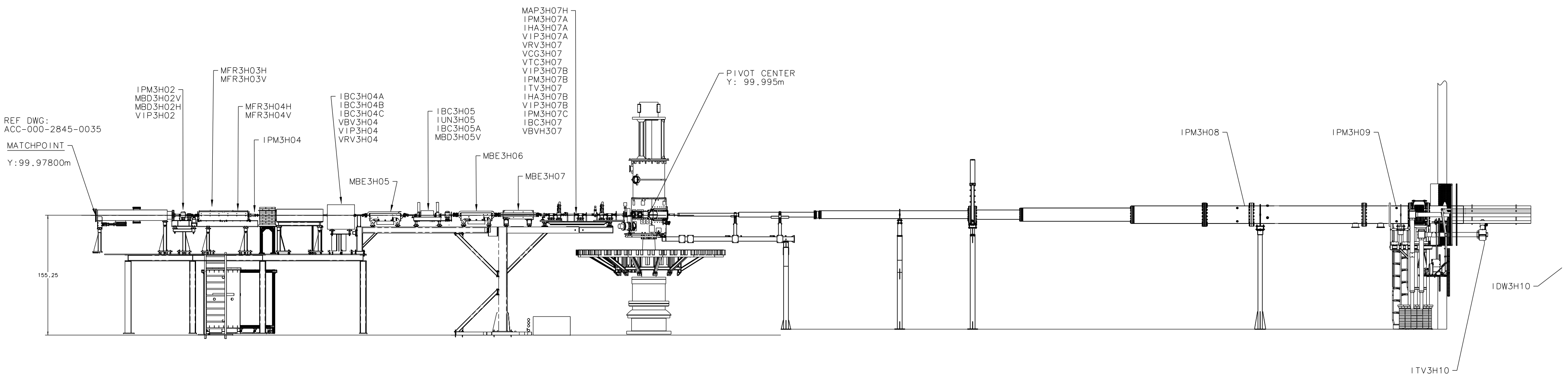
EXTRA

Hall C Songsheet – Green wall to Hall



Hall C Songsheet - Hall





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