Polarimetry for RCS

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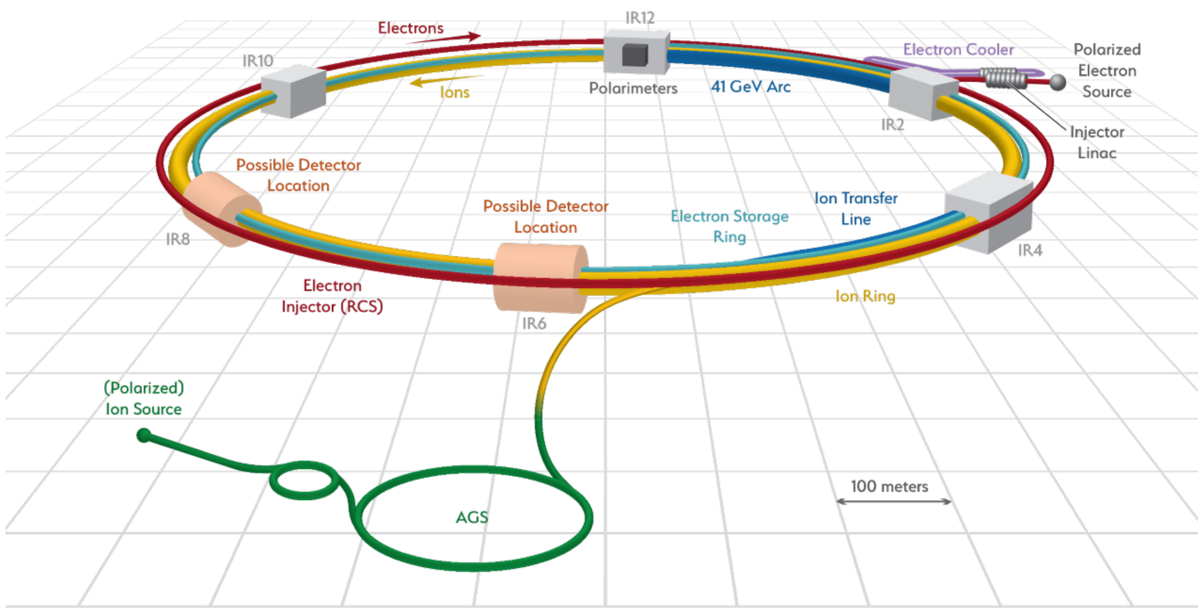
Electrons at EIC



Electrons must be accelerated to full beam energy before entering the electron storage ring

Electron source/injection:

1. Ga-As polarized electron source→ Mott polarimeter
2. Low energy transfer line (0.4 MeV)
3. Electron linac (400 MeV)
4. Rapid Cycling Synchrotron (0.4-18 GeV)
5. High energy transfer line to ESR (5-18 GeV)
6. ESR → Compton polarimeter

Rapid Cycling Synchrotron

RCS accelerates electron bunches from 0.4 to full beam energy (5-18 GeV)

Bunch frequency → 2 Hz
Bunch charge → up to 28 nA
Ramping time = 100 ms

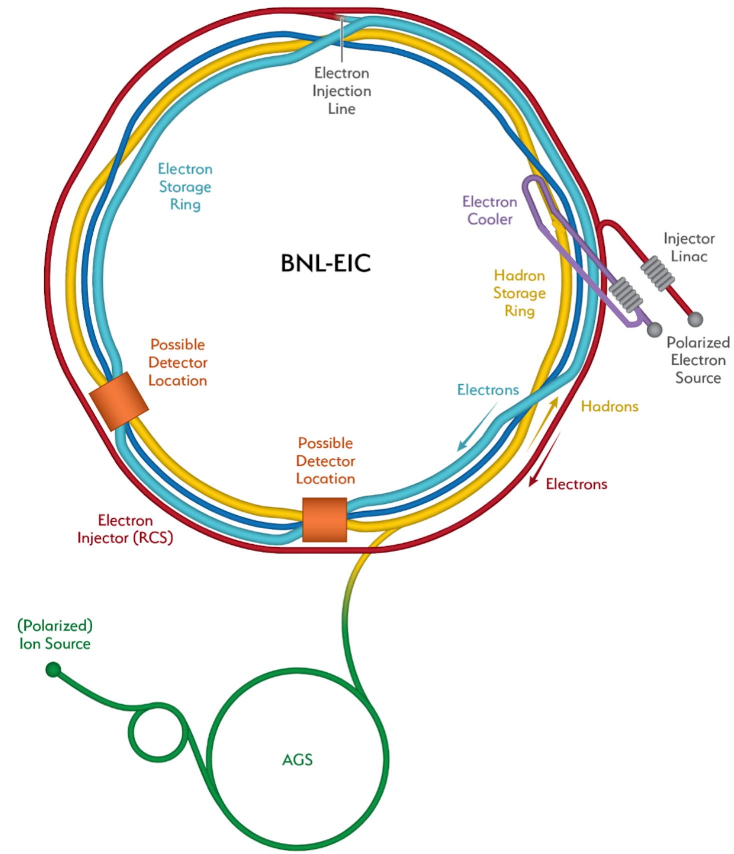
Designed to preserve electron polarization through ramp

Key location to check beam polarization

→ High polarization verified at source w/Mott polarimeters

→ Polarization measured in ESR with Compton polarimeter

  → If low polarization observed at Compton, difficult to isolate problem location



Polarimetry for RCS

Challenges:

→ Beam energy increases from 400 MeV to 5/10/18 GeV
→ Bunch lifetime in RCS is short → 100 ms
→ Low average current: 28 nC bunches at 2 Hz

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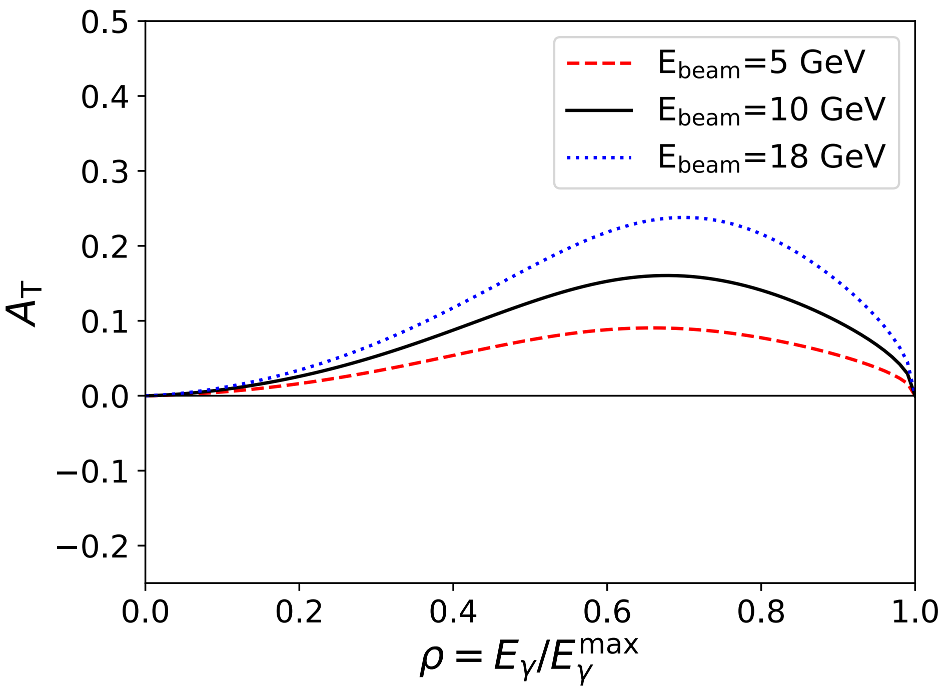
Compton polarimetry

→ Analyzing power depends strongly on beam energy – nearly impossible to measure polarization of a single bunch while accelerated in RCS
→ Time in RCS also very short → measurement times (next slide) on the order of minutes

Compton transverse analyzing power



Compton Measurement Time (CDR)

Time required for measurement depends on method:

$$t_{meth} = \left(\mathcal{L}\ \sigma_{\rm Compton}\ {\rm P_e^2 P_\gamma^2} \left(\frac{\Delta {\rm P_e}}{\rm P_e} \right)^2 {\rm A^2_{meth}} \right)^{-1}$$

Integrated → $\langle {\rm A} \rangle^2 < \frac{\langle {\rm E \cdot A} \rangle^2}{\langle {\rm E^2} \rangle} < \langle {\rm A^2} \rangle$ ← Differential measurement

↑ Energy-weighted integral

beam energy [GeV]	σ_{unpol} [barn]	$\langle A_\gamma \rangle$	t_γ[s]	$\langle A_e \rangle$	t_e[s]	L[1/(barn·s)]
5	0.569	0.031	184	0.029	210	1.37E+05
10	0.503	0.051	68	0.050	72	1.55E+05
18	0.432	0.072	34	0.075	31	1.81E+05

Time estimate for 1% measurement using integrated asymmetry
→ Estimate for a single bunch, assuming ~ 1 collision/crossing
→ 532 nm laser

Time estimated using beam parameters at IP12 → transverse polarization measurement

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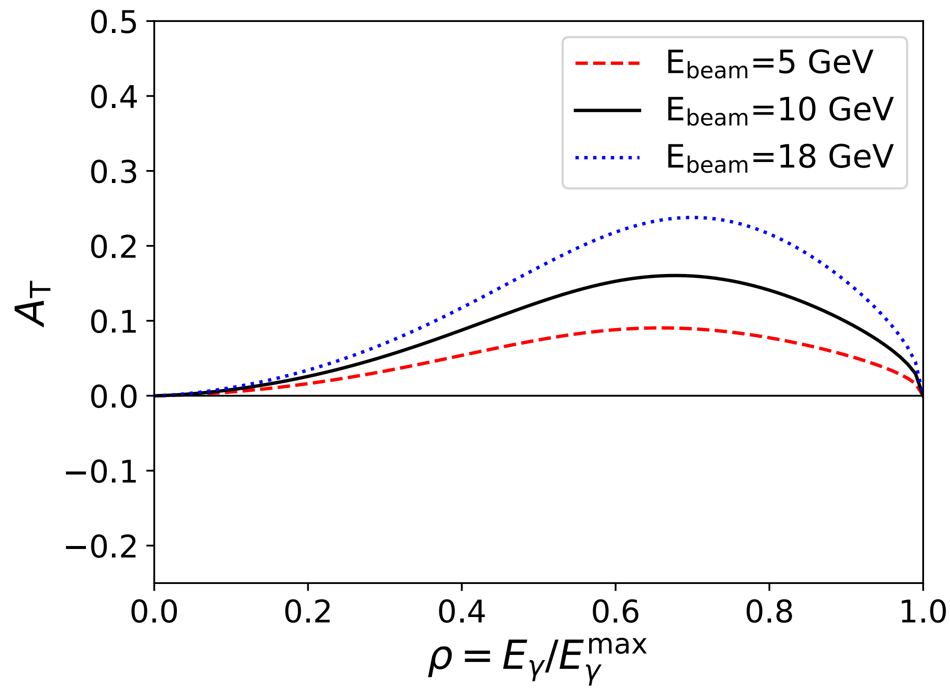
Compton polarimetry:

→ Operation of Compton in RCS in flat-top mode?
→ Accelerate bunch, and leave it in RCS at fixed energy for some time
→ Unfortunately, beam can not be “stored” in RCS long enough to make this feasible

Compton transverse analyzing power



Polarimetry for RCS

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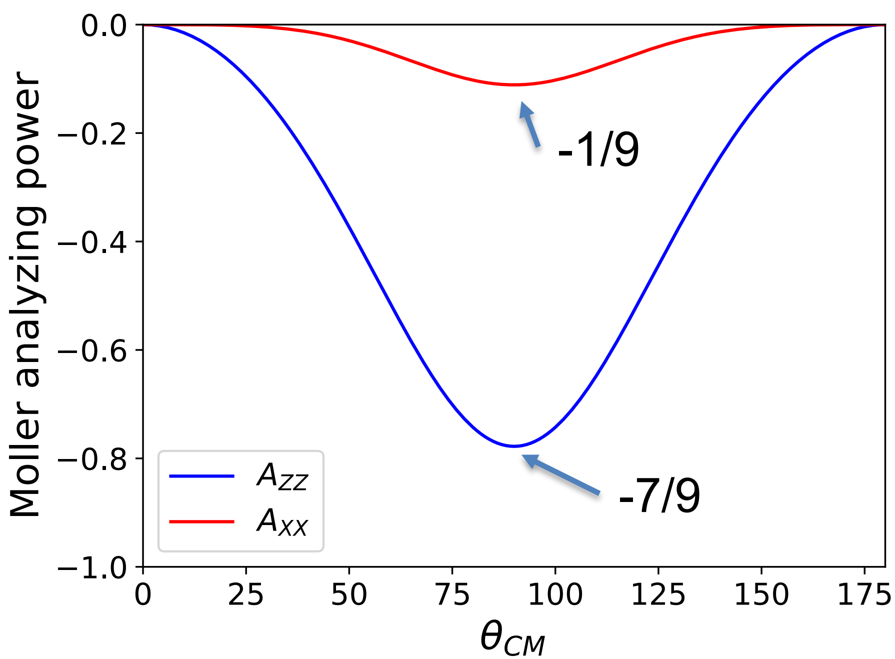
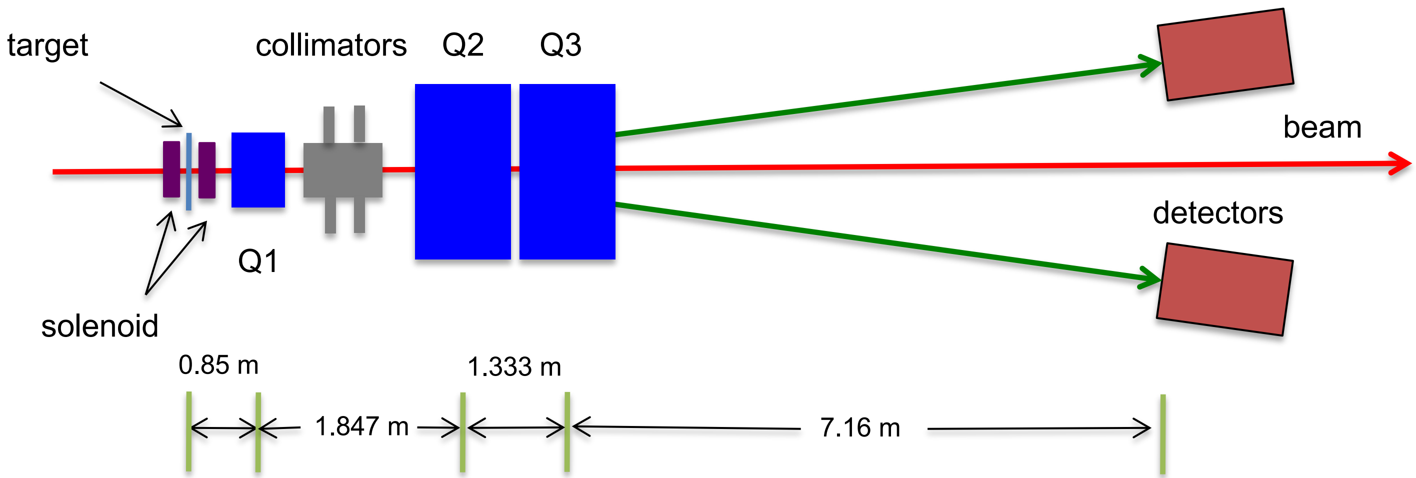
Møller polarimetry:

→Analyzing power independent of energy
→Most polarimeters require spectrometer to separate scattered electrons from beam
→Targets typically made from ferromagnetic foils → destructive to beam



Møller polarimeter could be deployed in transfer line between RCS and ESR

Møller Measurement Time

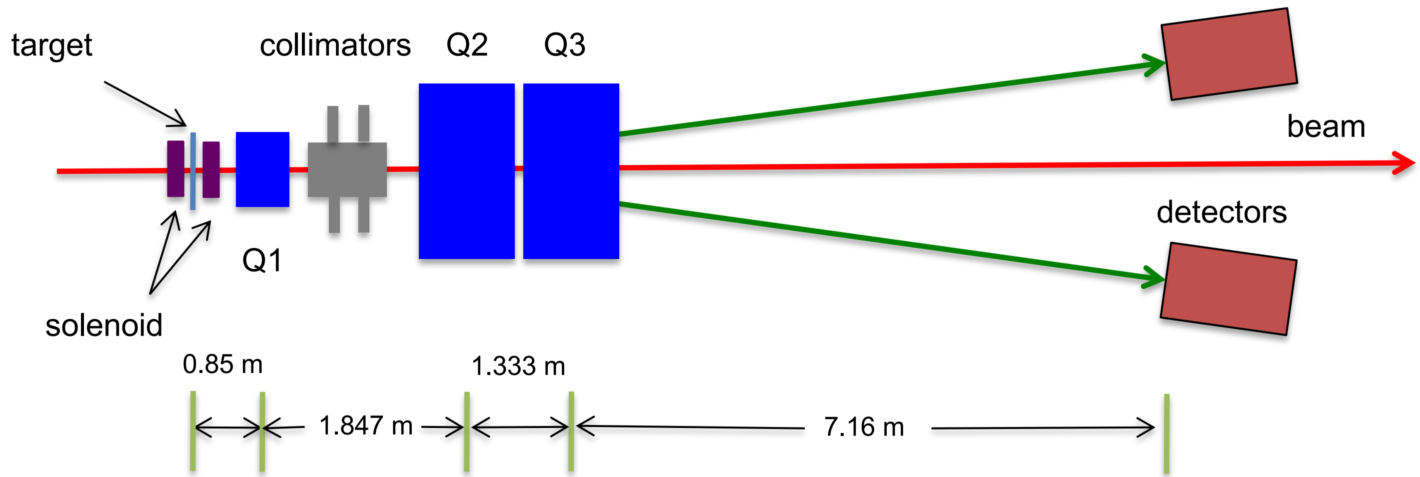


Time estimates scaled from experience in Hall C @11 GeV
→ 15 minutes for 1% measurement of P_L at 1 μA, 4 μm iron target

RCS: average (extracted) current ~ 56 nA (28 nC bunch at 2 Hz)
→ Transverse analyzing power smaller by factor of 7, ***figure of merit worse by factor of 49***
→ Time estimate for 1% measurement of beam from RCS: 15 min * (1/0.056) * 49 = too long
→ ***Thicker foil (30 μm), reduced precision (10%): Measurement time = 17.5 minutes***

Some discussion of running at larger bunch charge for these measurements

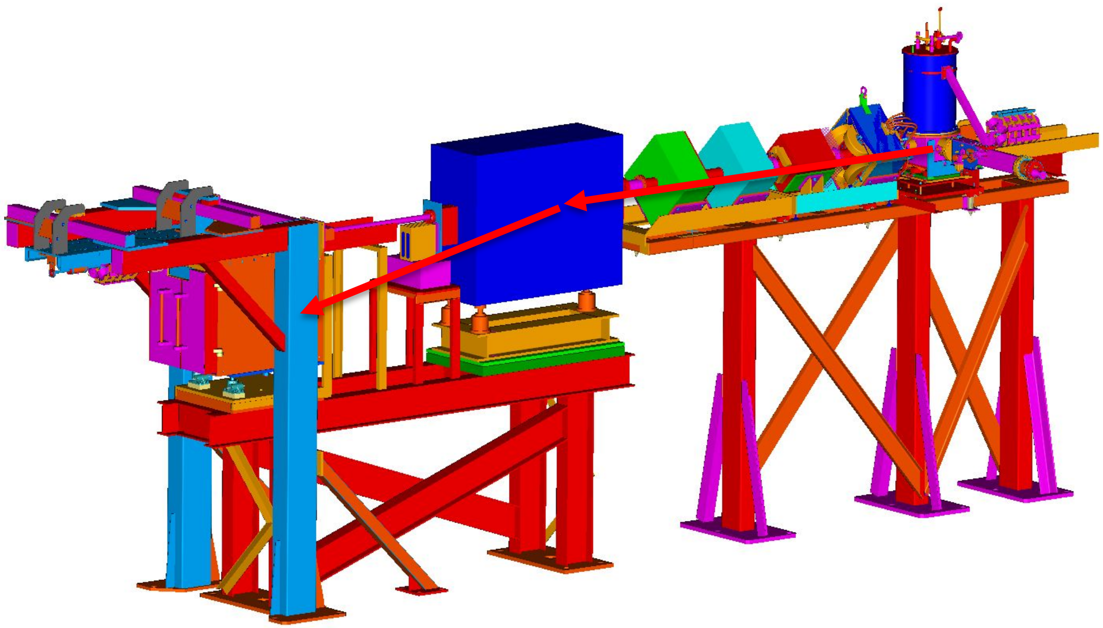
Møller Polarimeter Space Requirements



Hall C Møller Polarimeter uses "2-quadrupole" spectrometer that allows fixed optics/acceptance for full energy range

- → Length along beamline ~ 11 m
- → Operates up to 11 GeV
- → Requires large bore (10 inch) quadrupole
- → Some space can be recovered after large quads
- → Operation at 18 GeV would require either longer drift to detector, or smaller separation of detectors from beamline

Møller Polarimeter Space Requirements



Hall A Møller Polarimeter uses 4-quadrupole + dipole system
→ Flexible system that allows multiple optics solutions at each energy
→ Acceptance not defined at a single point
→ More compact than Hall C Møller, ~ 7 m long
→ Like Hall C system, operation at higher energy would likely require more space

Summary

- Polarimetry in or just after the RCS important for tracking down potential electron beam polarization issues
- Polarimetry in RCS itself not feasible – best option appears to be a Møller polarimeter in transfer line between RCS and ESR
- To-do list:
  - Determine polarimeter configuration, i.e., integrated in transport, or dedicated beamline with its own dump
  - Design polarimeter (depends on decision above) → must work for range 5-18 GeV
  - Design decisions:
    - Optics - quadrupole only, quads+dipole, dipole only?
    - Target technology (high field vs. low field target)
    - Detector technology