Electron Polarimetry Expression of Interest

September 15, 2020

Expression of Interest

Expression of Interest summarized here:
https://www.bnl.gov/eic/EOI.php

"The EOI will give the EIC Project guidance on current interest for participating in the EIC experimental program, including an initial understanding of the full scope of the experimental equipment that might be available for the expedient start of science operations at the time of EIC project completion."

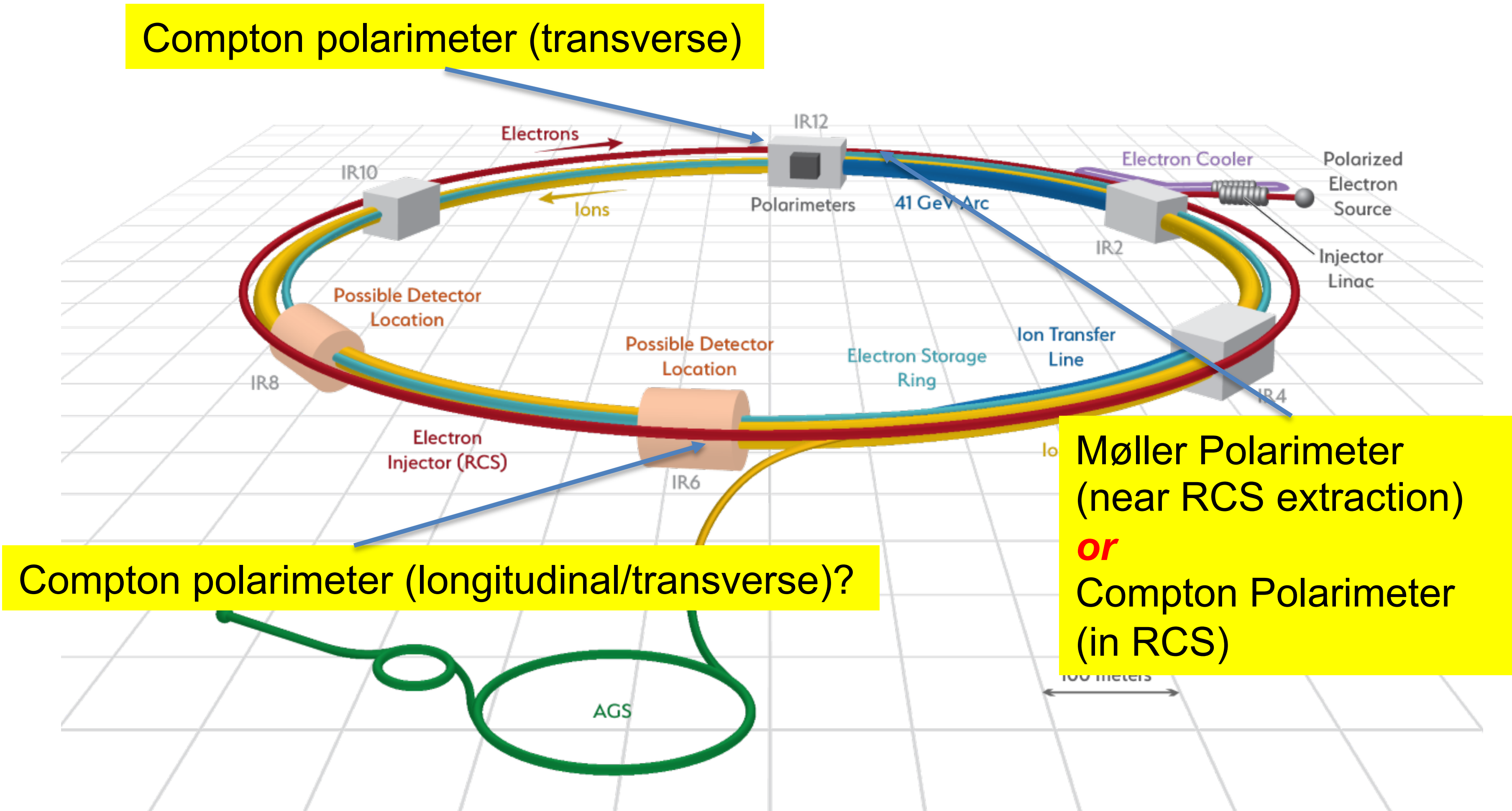
EOI should contain responses to information requested in EOI Questionnaire:
https://www.bnl.gov/eic/docs/EoI-Name_of_Institute_or_Country_or_Consortium.public.docx

1. Equipment contributions
2. Labor contributions
3. Assumed contributions from EIC Project
4. Timing constraints

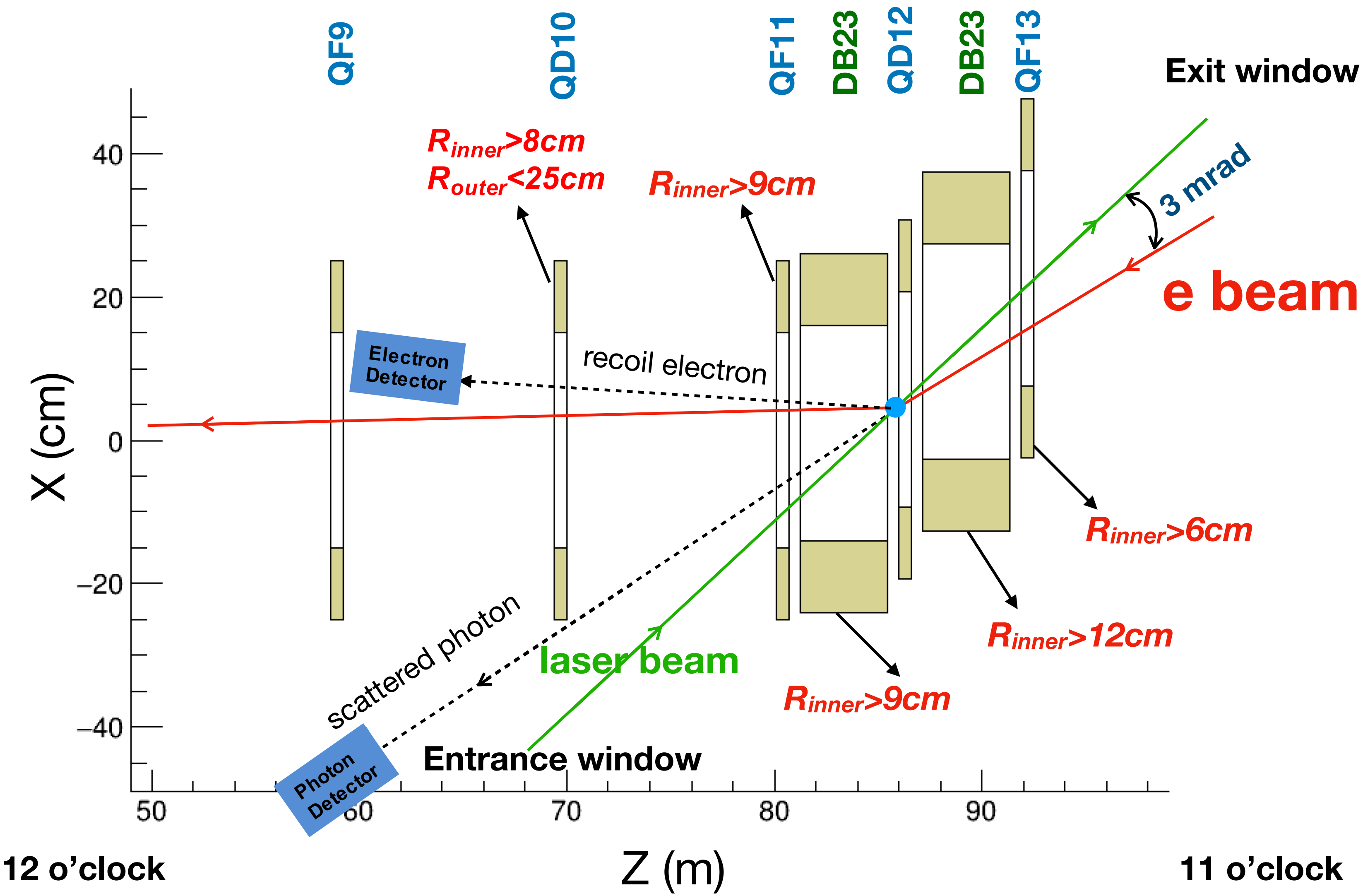
Electron Polarimetry EOI

- Primary goal of Electron Polarimetry is to provide the opportunity for coordination between groups
  - Identify areas/tasks that are not yet addressed
  - Identify areas/tasks with interest from multiple groups to allow collaboration and coordination
  - Explore complementarity: Multiple devices will allow the opportunity for the pursuit of multiple technological solutions
- This EOI should be viewed as supplemental to an institutional/group EOI

Electron Polarimetry at EIC



Compton Polarimeter at IR12



Zhengqiao Zheng (BNL)

Compton Components

- Laser system
  - One-shot, pulsed laser system, ~ 10 W average power
  - Ability to vary pulse frequency desired, pulse width shorter than beam pulse width
  - Polarization monitoring important
- Photon detector
  - Position sensitivity + calorimetry
  - Combination of strip detector (~ 100 μm pitch) + and calorimetry
- Electron Detector
  - Position sensitivity in vertical and horizontal directions (vertical: ~ 25-50 μm, horizontal: ~ 1 mm)

Areas of Possible Contribution

- Equipment
  - Laser system
  - Position sensitive detectors
  - Calorimeter
- Software and Data Acquisition
  - Simulations (backgrounds, detector response, RF impedance)
  - Fast data acquisition – event rates ~ 100 MHz
  - Analysis software

EOI Timeline

- September 15: Initial meeting
- September 15-October 20: Input and drafting
- October 20: Follow-up meeting, draft comments
- November 1: EOI submission deadline

- Please send your input to Dave Gaskell (gaskelld@jlab.org) and Elke Aschenauer (elke@bnl.gov)
  – If you are planning on incorporating electron polarimetry in an institutional EOI, the draft text of that section would be sufficient
  – We will use this input to draft the ”global” and circulate

Backup and Extra

Measurement Time

Time required for measurement depends on method:

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

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

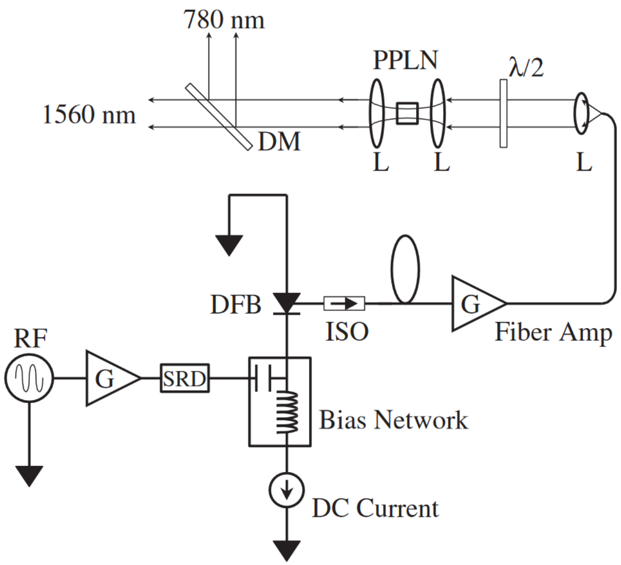
↑ Energy-weighted integral

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
12	0.482	0.057	54	0.056	56	1.62E+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

For nominal beam size/current, pulsed laser with average power of ~5 W sufficient to achieve the required luminosity
→ Plan for a 10 W laser since some power will be lost in transport to IP

Compton laser system



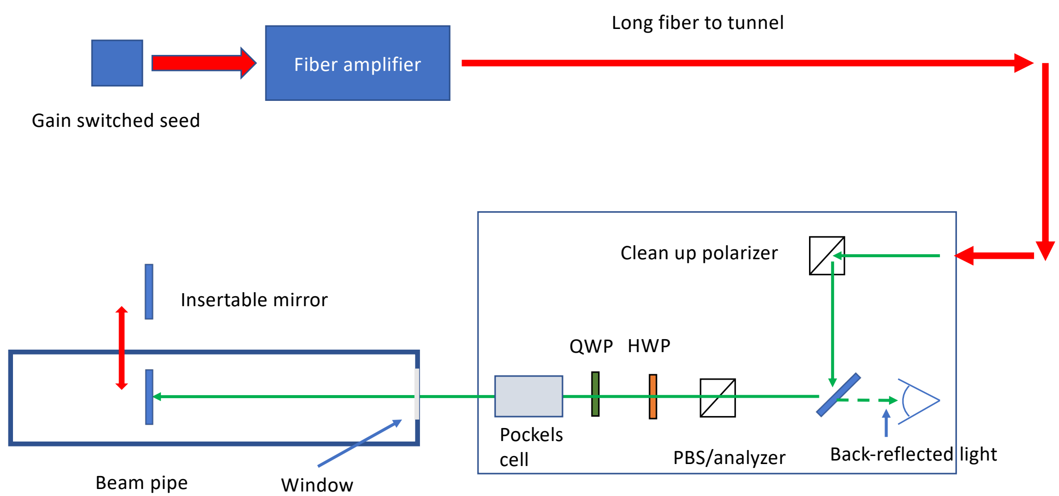
JLab injector laser system

Proposed laser system based on similar system used in JLab injector

1. Gain-switched diode seed laser – variable frequency, few to 10 ps pulses → 1064 nm
   - ➢ Variable frequency allows optimal use at different bunch frequencies (100 MHz vs 25 MHz)
2. Fiber amplifier → average power 10-20 W
3. Optional: Frequency doubling system (LBO or PPLN)

Development of prototype proposed as EIC Detector R&D project

Polarization in vacuum set using "back-reflection" technique
→ Requires remotely insertable mirror (in vacuum)



Photon Detector

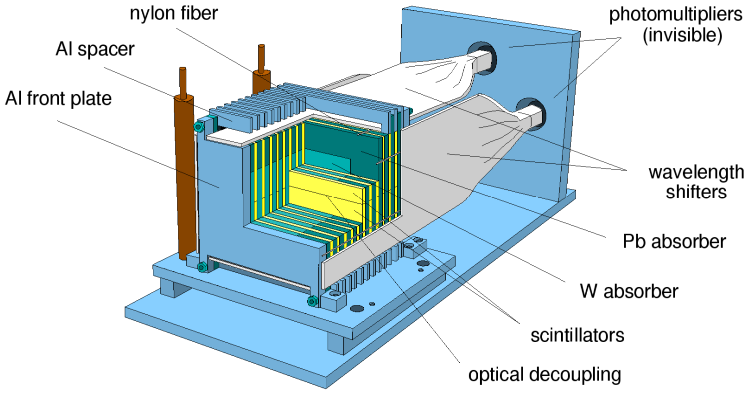
Compton asymmetry for transversely polarized electrons results in up-down asymmetry

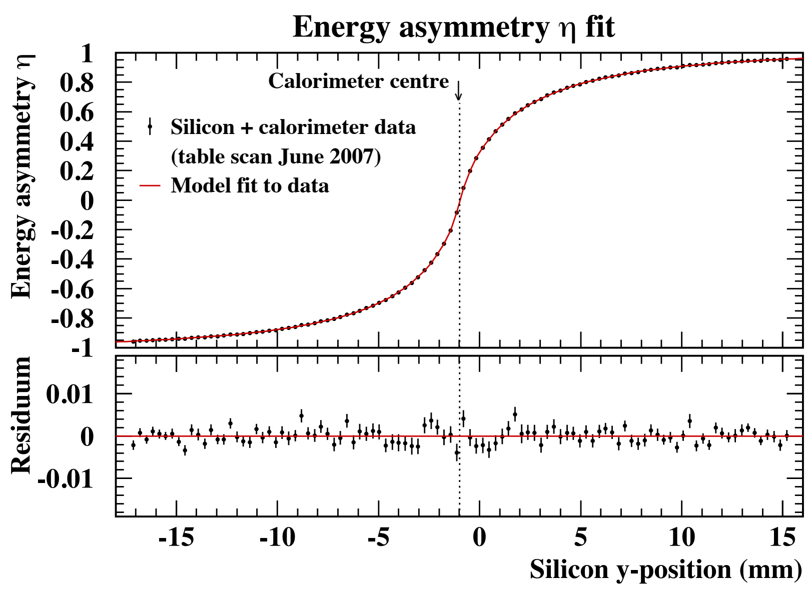
HERA TPOL: Calorimeter with top and bottom optically isolated
→ Shower sharing to get vertical position

$$\eta = \frac{E_U - E_D}{E_U + E_D}$$

Silicon strip detector to determine η-y transformation

EIC: Measure y directly with strip detector
→ Calorimeter will supplement strip detector, provide possible energy binning

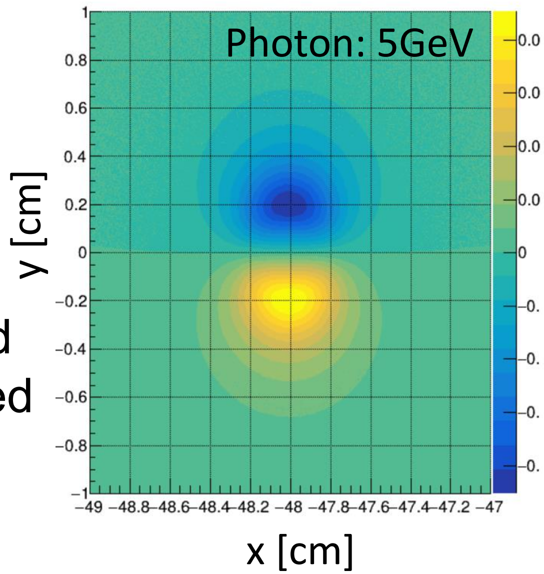


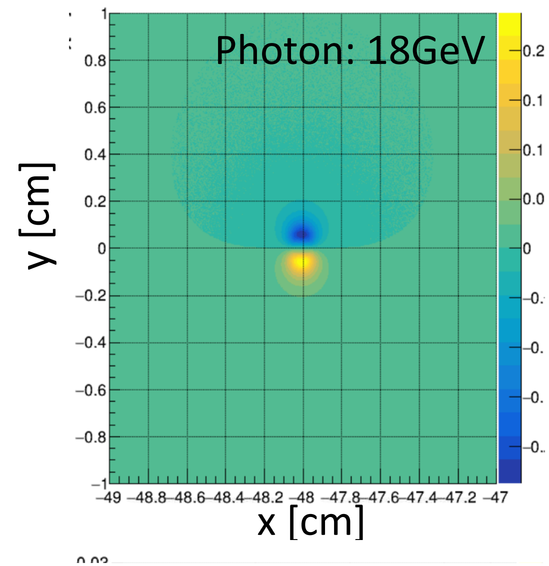


Photon Detector

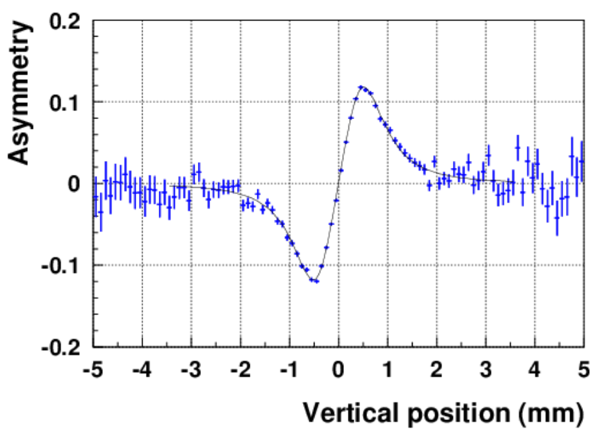
EIC transverse polarimeter will measure y position at photon detector directly using strip detector

Ideally, cover +/- 5 mm
→ Horizontal segmentation beneficial but not required





Simple strip detector with lead radiator at front – pitch dictated by small photon cone at 18 GeV



At 25 m from interaction point, pitch of 100 um, sufficient to extract polarization with minimal distortion
→ Only 100 channels for a single plane detector

Photon Detector Technology

Two detectors for photon detection:

Key requirement is time response: ~ 10 ns

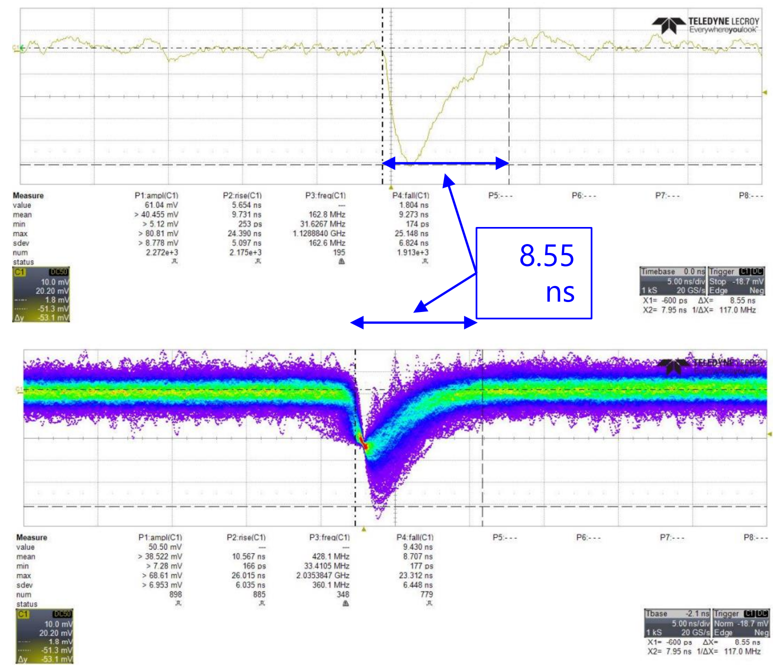
1. Position sensitive strip detector
2. Calorimeter for energy information/triggering

Strip detector options

1. Silicon
2. ***Diamond*** → Radiation hard, fast
3. HVMaps

Photon calorimeter

- High resolution not required
- PbWO4 too slow (see J. Adam's talk last meeting)
- Tungsten powder calorimeter?



500 pCVD diamond w/TOTEM electronics

Electron Detector

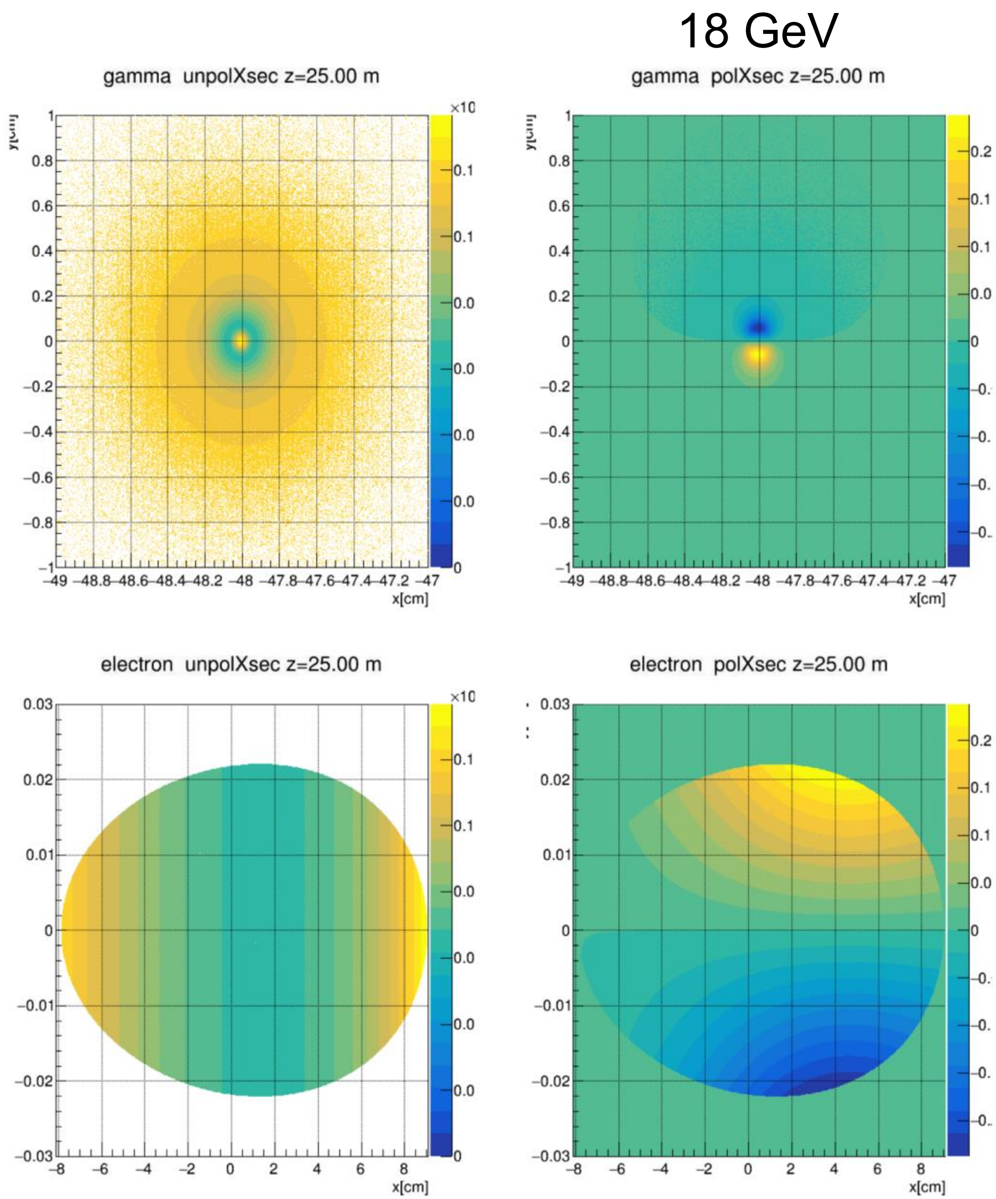
Compton cone smaller for electrons than photons
→ +/- 250 um at electron detector at 18 GeV

Ciprian's studies suggest 50 um pitch would be sufficient (but smaller strips better)

Horizontal segmentation also required

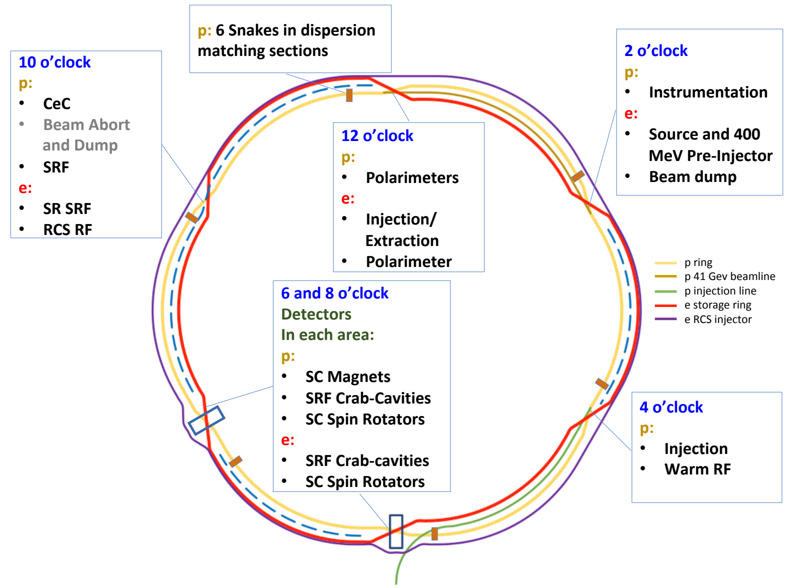
→ Assuming +/- 500 um detector, 25 um pitch → 40 strips vertically
→ Horizontal pitch ~ 1 mm sufficient

Also suggest diamond as default for electron detector



Polarimetry for RCS

Polarimetry also required for RCS electron injector



Challenges:

→ Beam energy rapidly increases from 400 MeV to 5/10/18 GeV

→ Low average current: 10 nC bunches at 1 Hz

Compton polarimetry:

→ Analyzing power changes rapidly with energy

→ Difficult to measure polarization during acceleration, but possible (average over many bunches)

→ Could measure a single bunch in the ring in “flat-top” mode.

→ Could deploy in extraction line, but this could lengthen measurement time

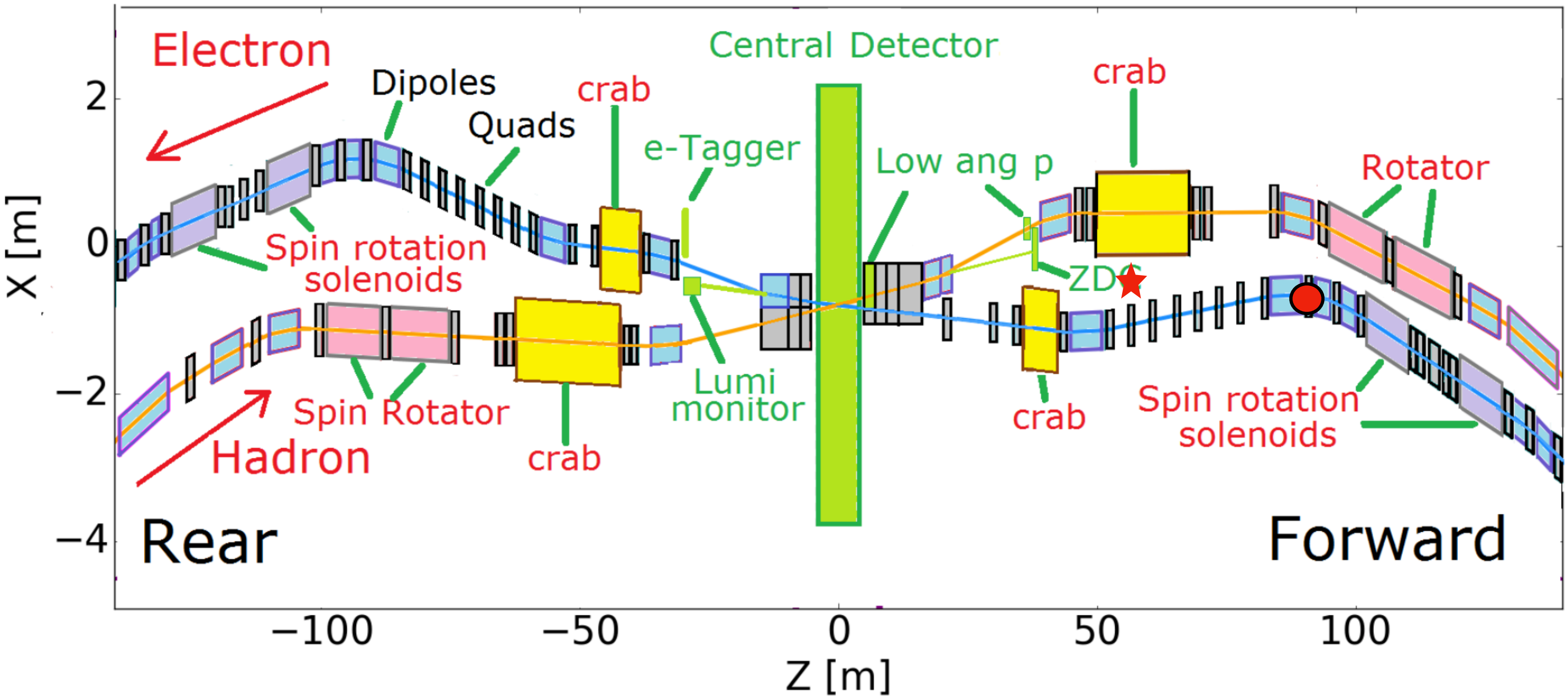
Moller polarimetry:

→ Relatively constant analyzing power, but requires spectrometer

→ Only practical at a fixed energy (for a given measurement)

→ Destructive

Compton Polarimeter at IR 6



Investigating option of having additional polarimeter closer to IR

→ Electron beam would be significantly longitudinal – less spin transport to extract polarization at IP

→ Region very crowded – needs very careful consideration of detailed geometry