Electron Polarimetry CDR Outline

Dave Gaskell (JLab)

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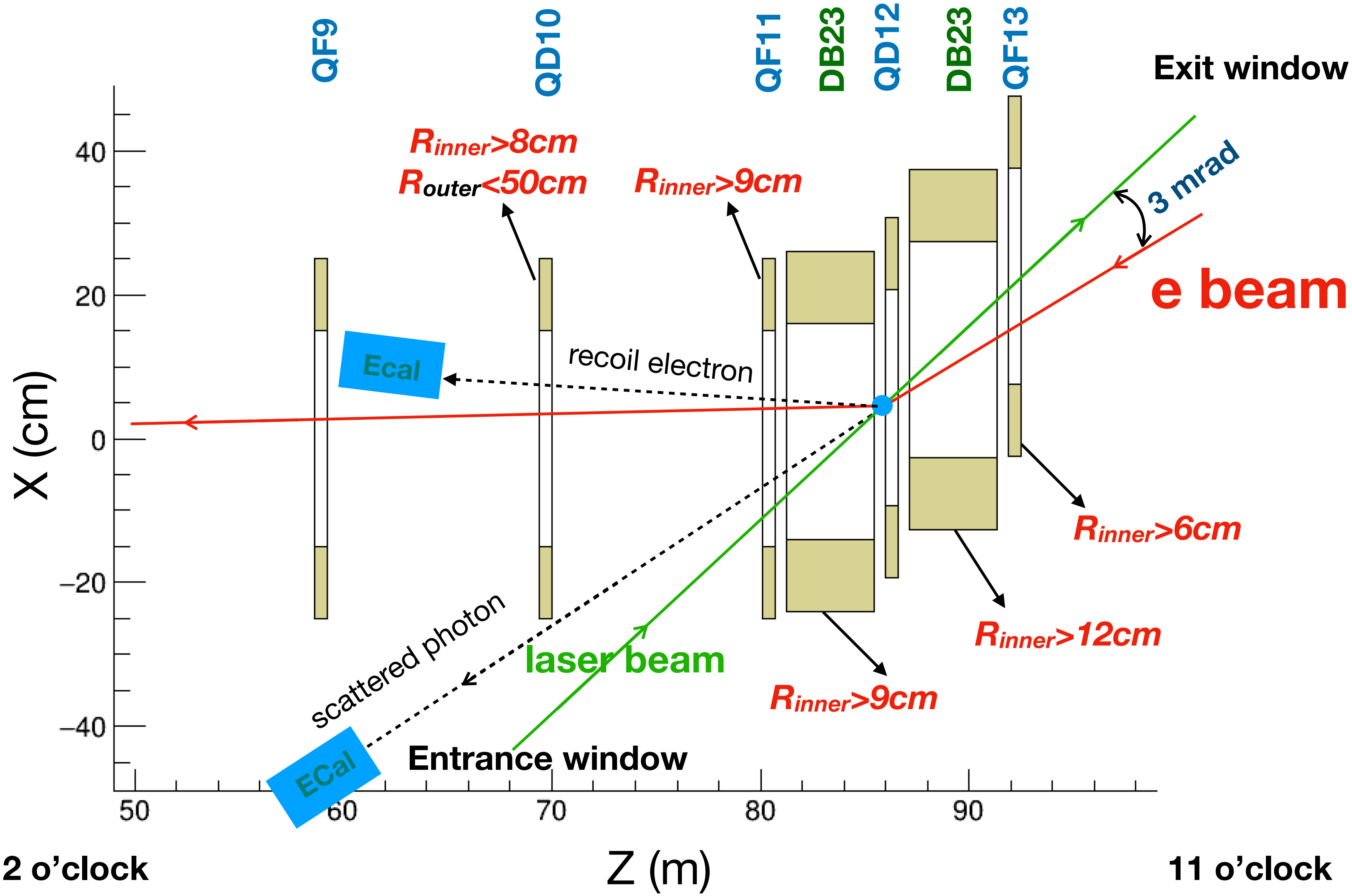
CDR

- Updated CDR required for CD-1
- Final version will not be complete for a few months, but “new content” will be frozen by end of this month
- Following slides outline the description of what I hope to include in the electron polarimetry section
- This will include:
  - Transverse Compton at IP12
  - Polarimeter for RCS
  - (mostly) Longitudinal Compton at IR (?)
    - Likely just brief discussion outlining the desirability and the challenges
- General requirements
  - Polarization per bunch
  - Polarization profile measurement (longitudinal and transverse)
  - Rapid measurements to aid beam setup
  - High precision (1% or better desired)

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 (diamond strips for baseline) + and calorimetry (scintillating fiber/tungsten powder calorimeter)
- Electron Detector
  - Position sensitivity in vertical and horizontal directions (diamond strips again)

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

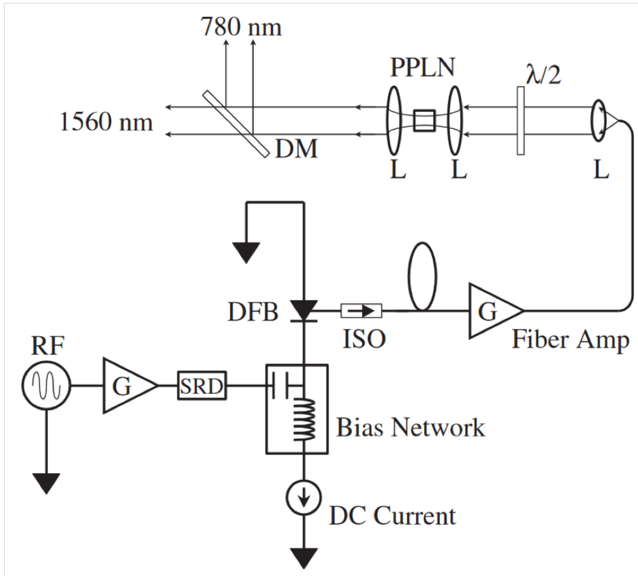
↑ Energy-weighted integral

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



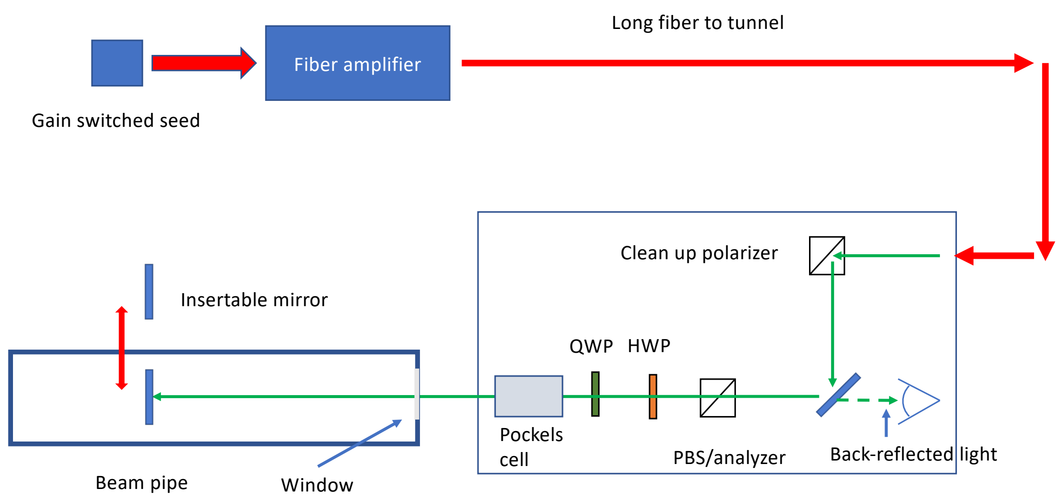
JLab injector laser system

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

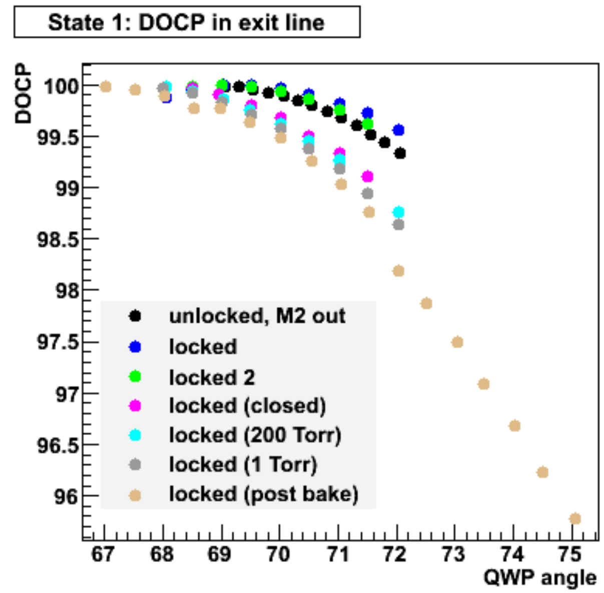
Polarization in vacuum set using "back-reflection" technique
→ Requires remotely insertable mirror (in vacuum)



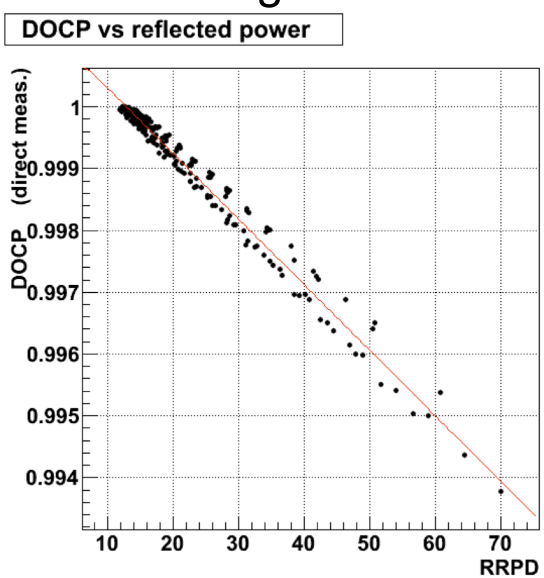
Laser Polarization

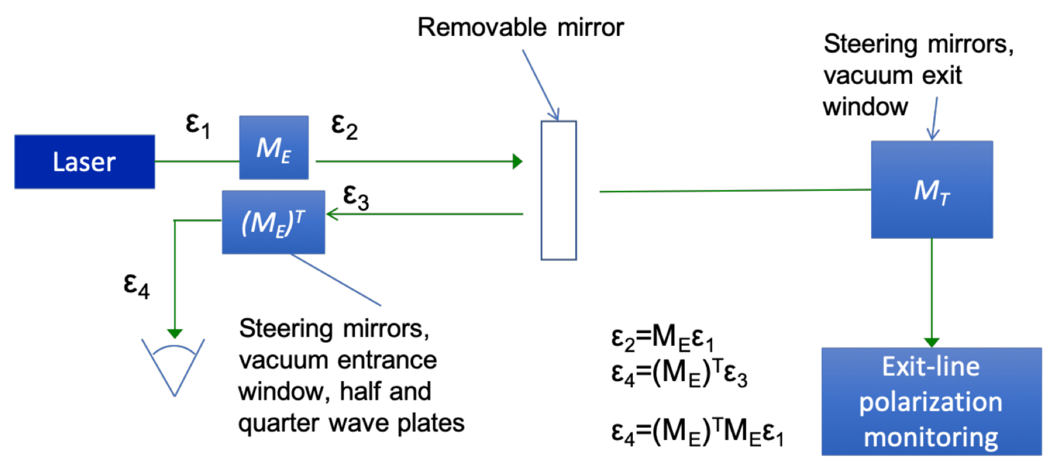
Laser polarization inside vacuum difficult to measure directly – usually inferred from models of polarization transfer function

→ Mechanical and vacuum stresses can induce additional birefringence that are difficult to constrain



Optical reversibility theorem allows determination of DOCP at IP by monitoring back reflected light





Hall C determination of DOCP in vacuum

Photon Detector

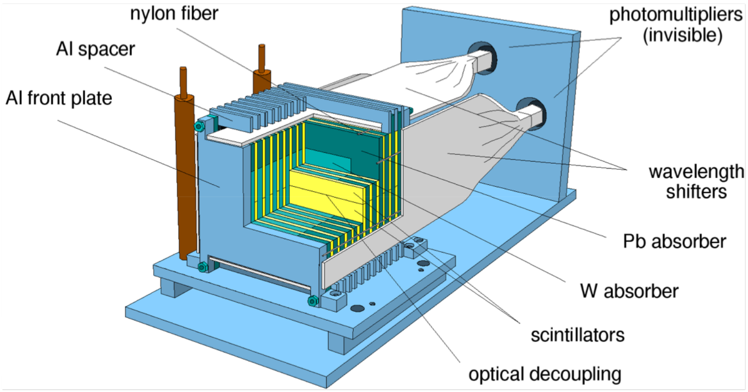
Compton asymmetry for transversely polarized electrons results in up-down asymmetry

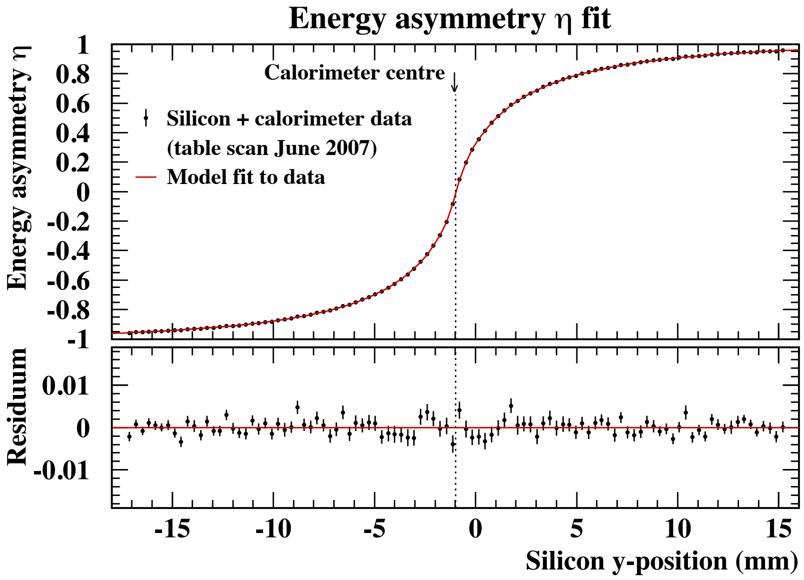
HERA TPOL: Calorimeter with top and bottom optically isolated
→ Shower sharing to get vertical position

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

Silicon strip detector to determine η-y transformation

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



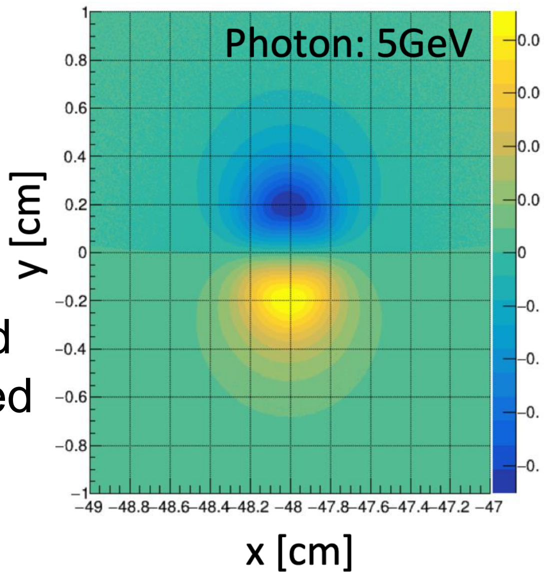


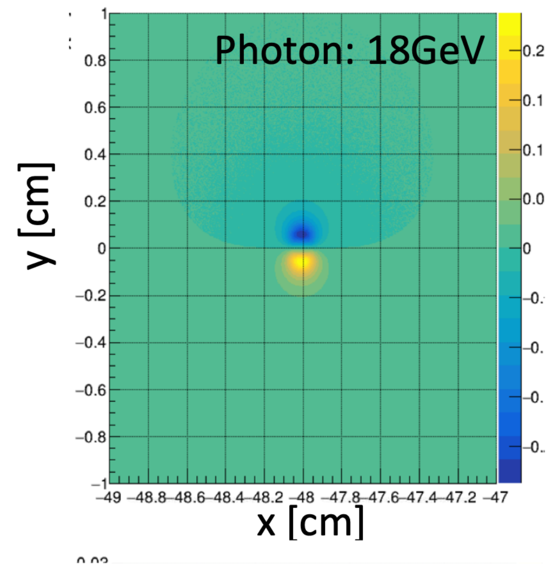
Photon Detector

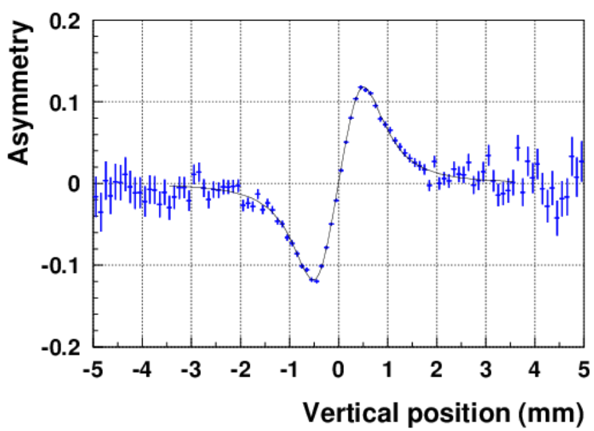
EIC transverse polarimeter will measure y position at photon detector directly using strip detector

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:

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

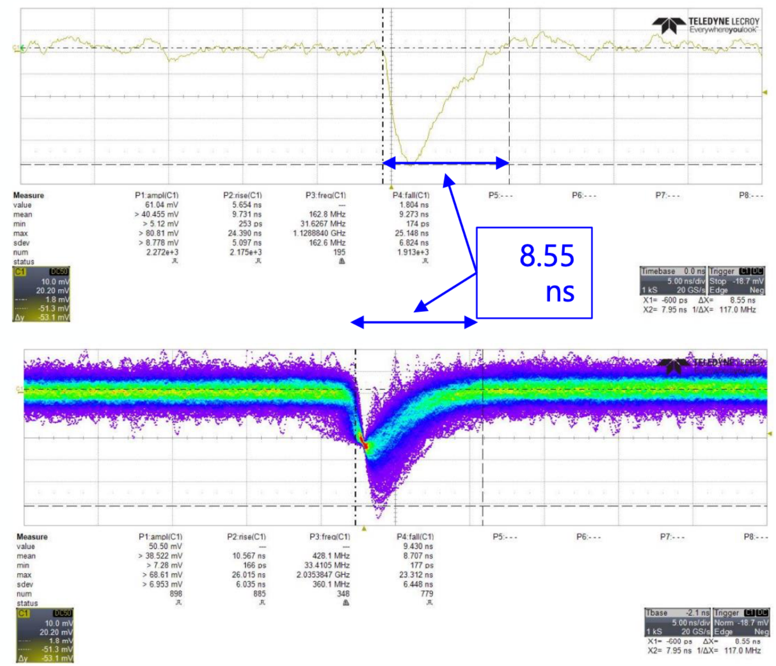
Key requirement is time response: ~ 10 ns

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

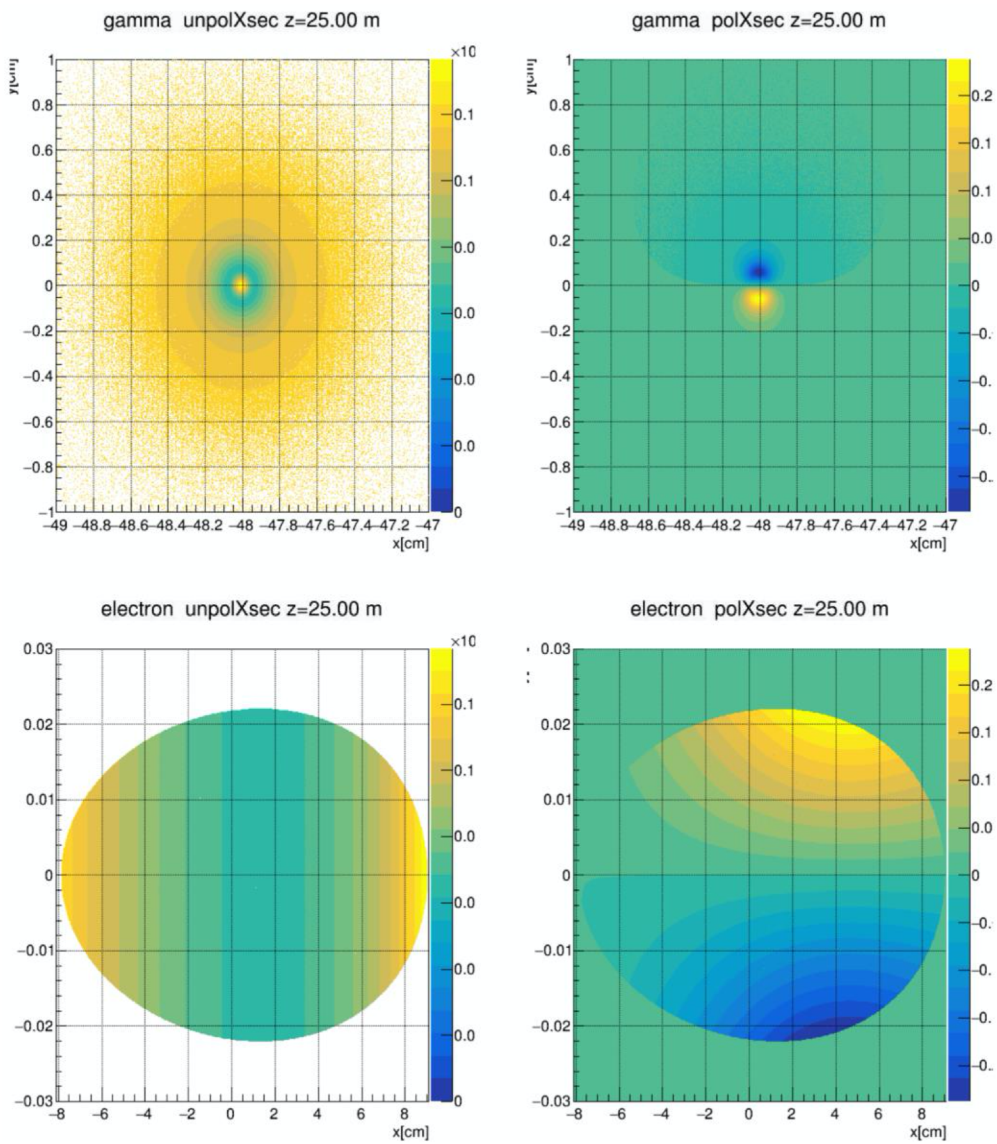
Ciprian's studies suggest 50 um pitch would be sufficient (but smaller strips better)

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

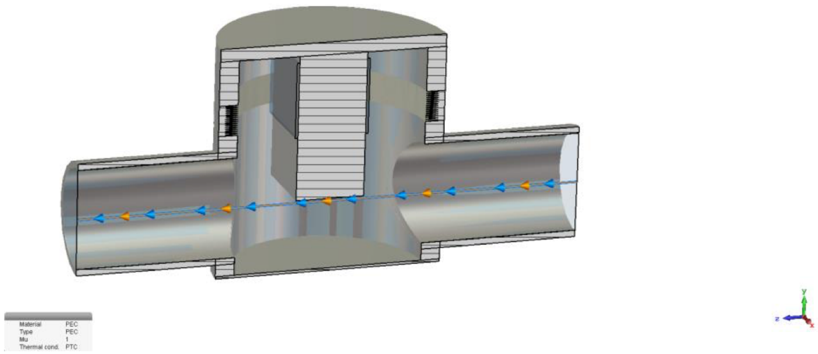
18 GeV



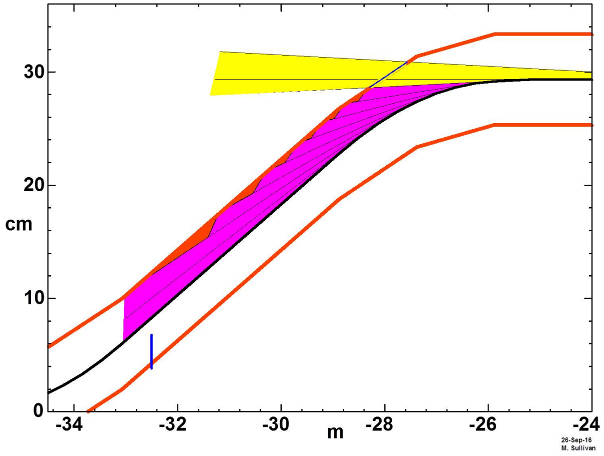
Electron detector considerations

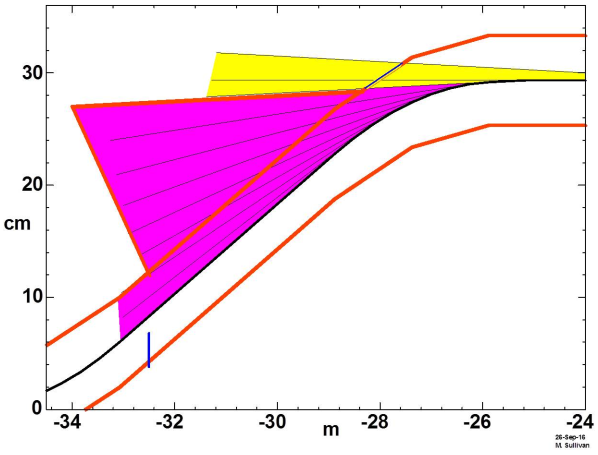
Electron detector likely cannot live in vacuum directly – needs to be housed in a structure similar to Roman Pot

→ Preliminary wakefield calculations for JLEIC configuration suggest power deposited manageable, but more work needed



Electron detector out of direct synchrotron fan, but single-bounce can deposit significant power on detector
→ Synchrotron can be mitigated by possibly using tips in beam pipe or special antechamber

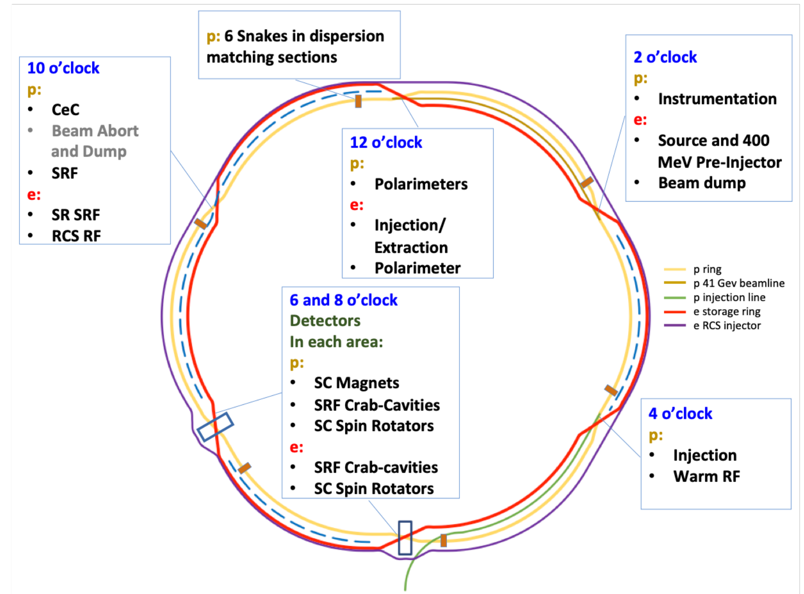




Mike Sullivan – estimates for JLEIC

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

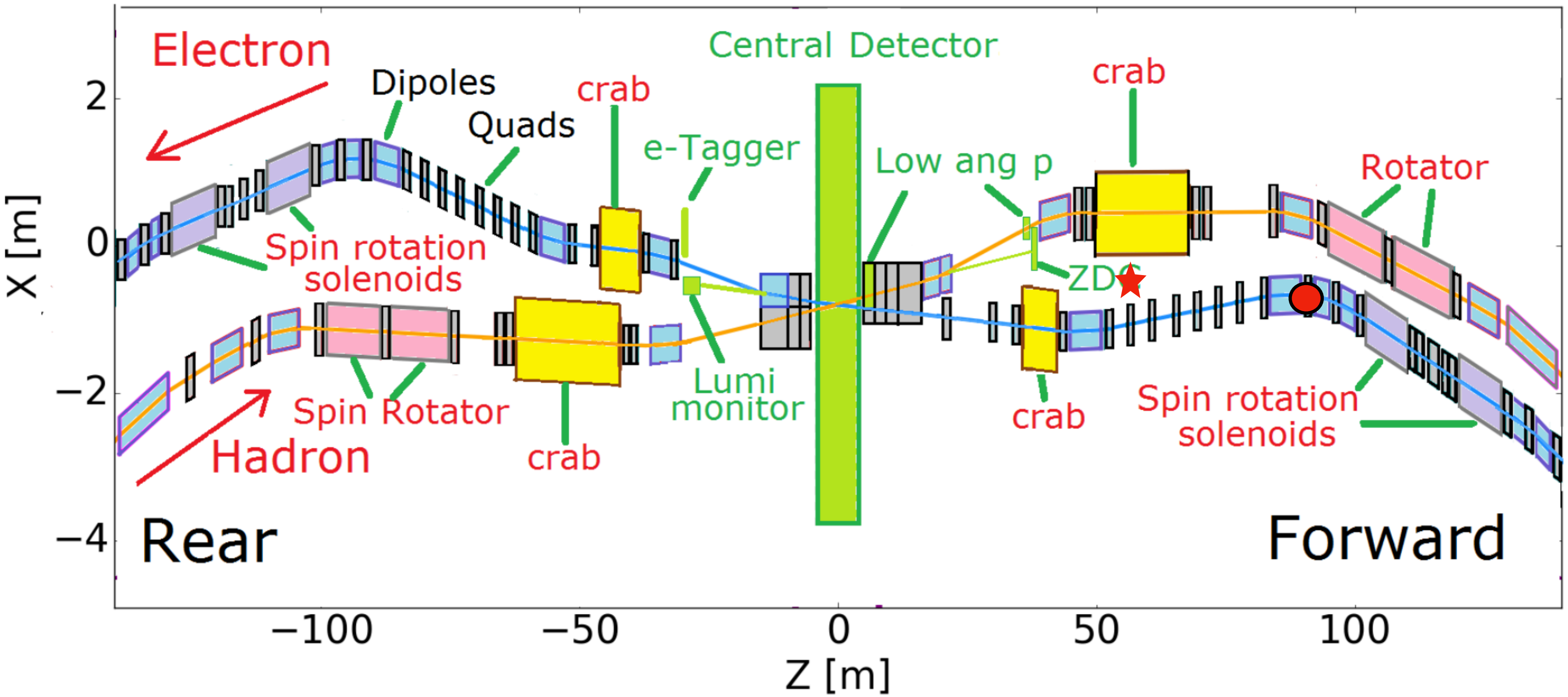
Moller polarimetry:

→ 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