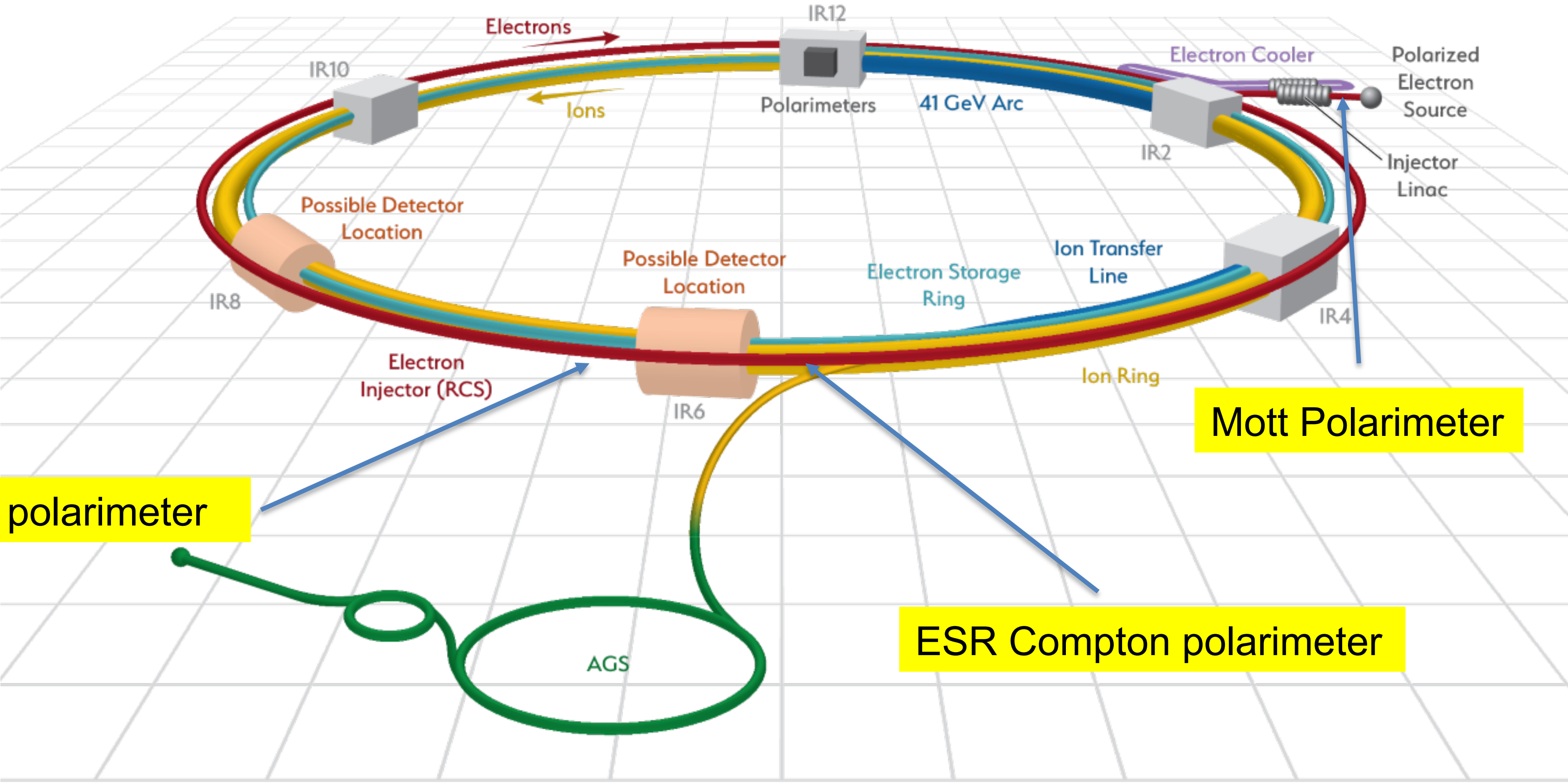
Electron Polarimeter Status

- EIC requires 3 electron polarimeters
  - Compton in ESR
  - Polarimeter for RCS
  - Polarimetry at source → part of injector/accelerator project
- Compton polarimeters for RCS and ESR have similarities but will operate in different modes
  - ESR → single photon/counting mode
  - RCS → multi-photon/integrating mode
- ESR concept more mature, but still work to be done

Electron Polarimeter Locations



Mott Polarimeter

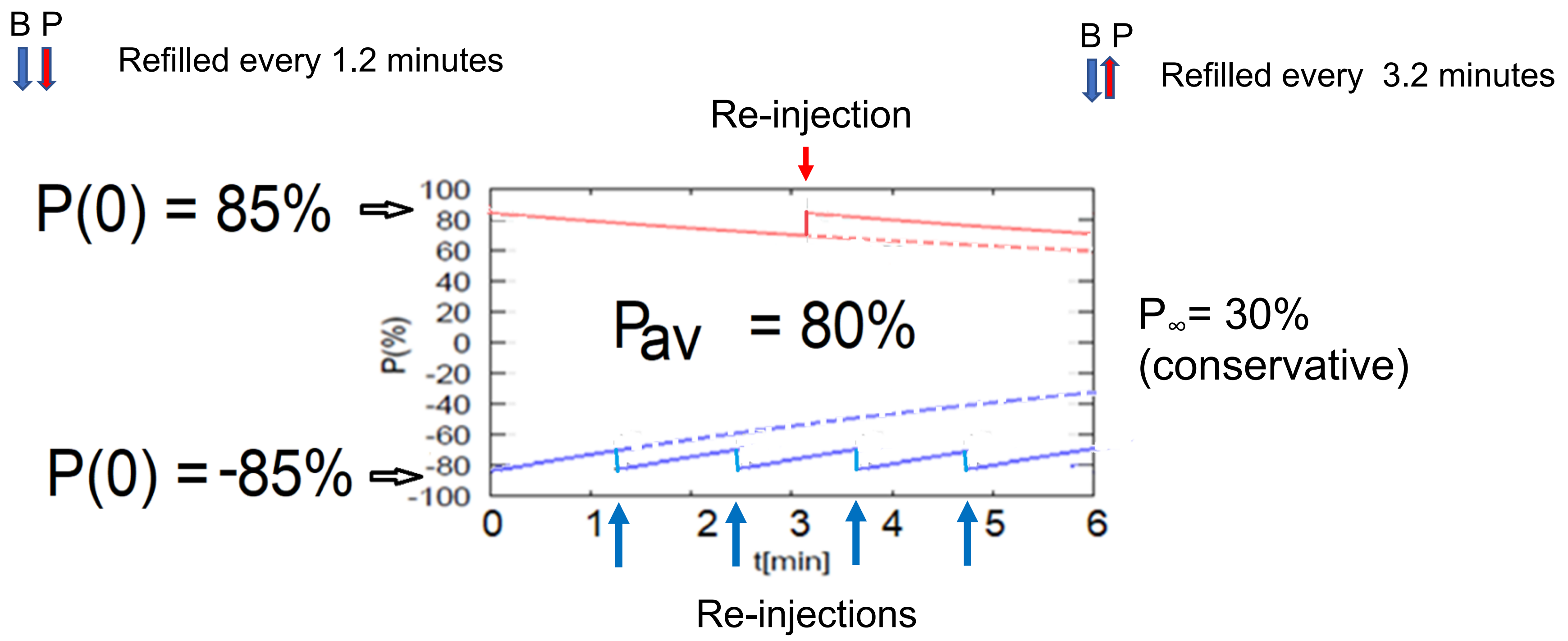
RCS Compton polarimeter

ESR Compton polarimeter

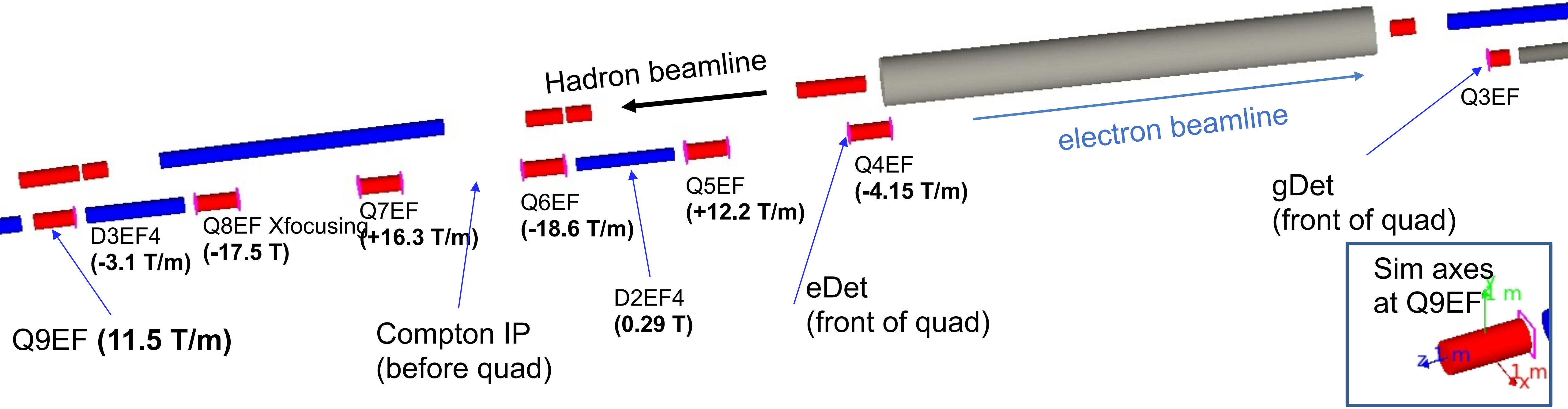
ESR Polarimeter Requirements

- Measure polarization for each bunch
  - Places requirements on measurement time due to lifetime in ring
- Measure longitudinal and transverse polarization
- Non-destructive

Beam energy	P_L	P_T
5 GeV	96.5%	26.1%
10 GeV	86.4%	50.4%
18 GeV	58.1%	81.4%



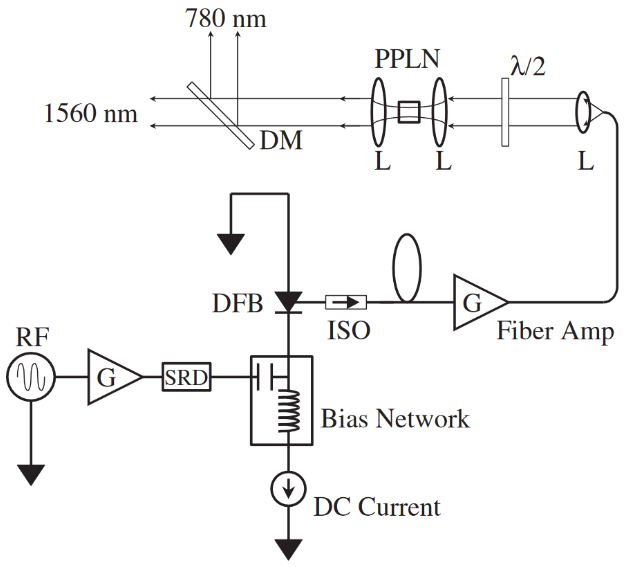
ESR Compton Placement



→ Laser IP in field-free area – space to insert laser in beamline
→ Photon detector 29 m from laser/beam IP
→ Quad after dipole (Q5EF) horizontally defocusing – facilitates use of electron detector
→ Synchrotron from D3EF4 may impact electron detector

Compton Laser System

Average of 1 backscattered photon/bunch crossing will allow Compton measurements on the ~1 minute time scale → can be achieved with pulsed laser system that provides about 5 W average power at 532 nm

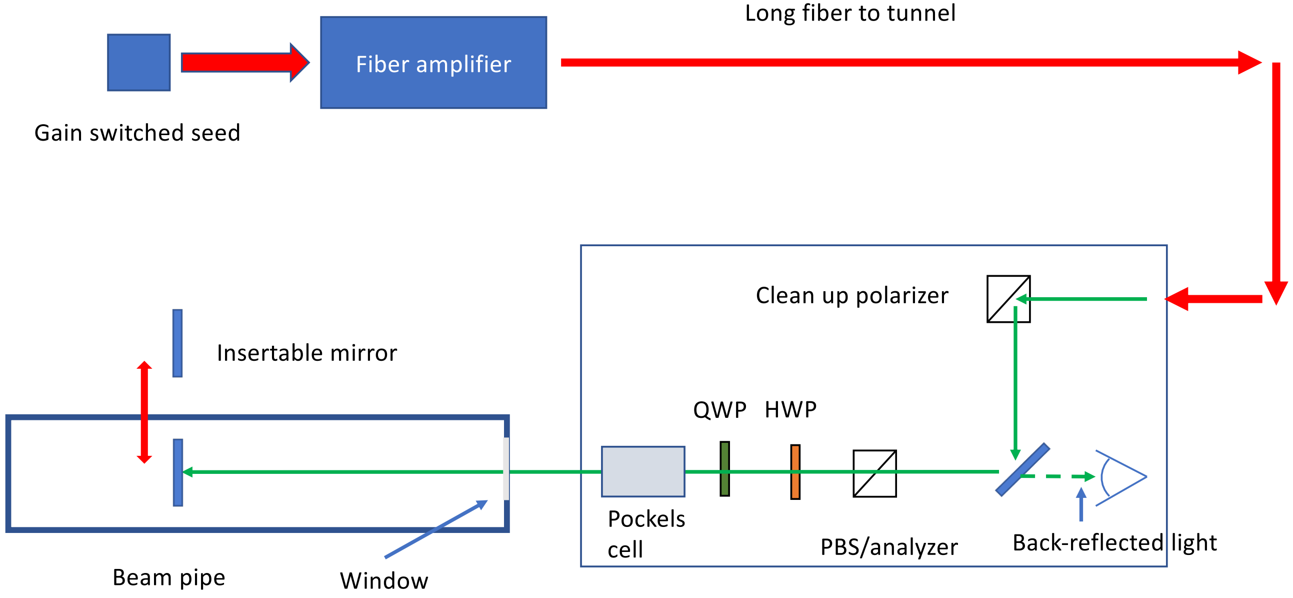


JLab injector laser system

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

Proposed laser system based on similar system used in JLab injector and LERF

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)
4. Insertable in-vacuum mirror for laser polarization setup

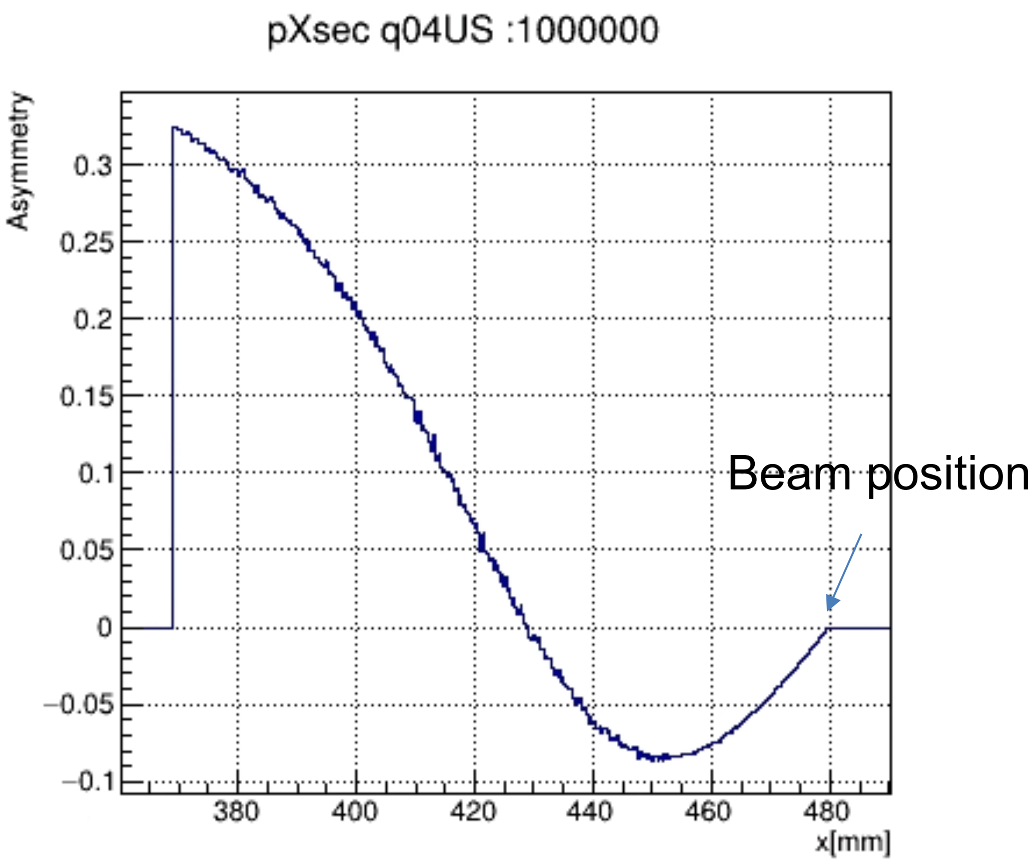


Electron Detector Size and Segmentation

- Electron detector (horizontal) size determined by spectrum at 18 GeV (spectrum has largest horizontal spread)
  - Need to capture zero-crossing to endpoint → detector should cover at least 60 mm

- Segmentation dictated by spectrum at 5 GeV (smallest spread)
  - Scales ~ energy → 17 mm
  - Need at least 30 bins, so a strip pitch of about 550 μm would be sufficient

- At 18 GeV, zero-crossing about 3 cm from beam
  - 5 GeV → 8-10 mm – this might be challenging



Asymmetry at electron detector @18 GeV

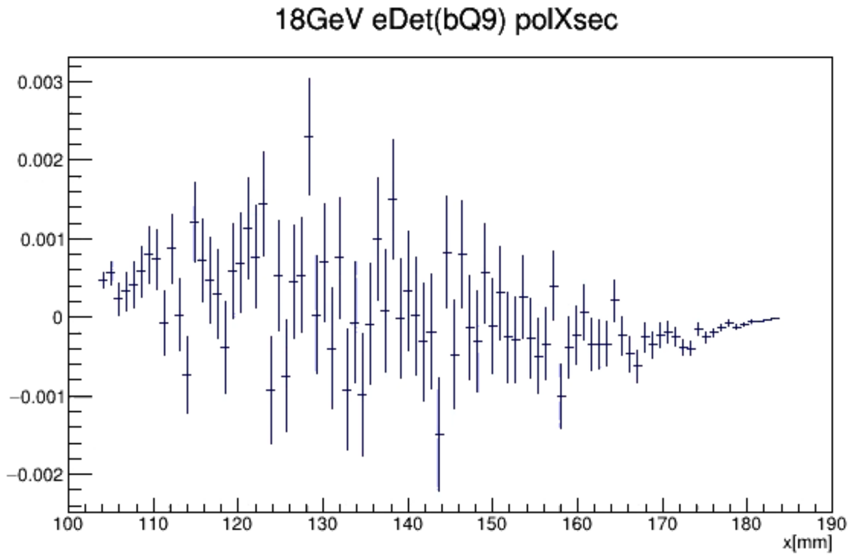
Transverse Polarization Measurement with EDET

At Compton location – significant transverse beam polarization
→ Unfortunately, this transverse polarization is in the horizontal direction
→ Same coordinate as momentum-analyzing dipole

Beam energy	P_L	P_T
5 GeV	96.5%	26.1%
10 GeV	86.4%	50.4%
18 GeV	58.1%	81.4%

In the absence of the dipole, the transversely polarized electrons would result in a left-right asymmetry
→ The ”scattered electron cone” is much smaller than the photons
→ Left-right asymmetry is spread over much smaller distance (μm vs mm)

100% transversely polarized beam



Ciprian Gal

The large dispersion induced by the dipole makes measurement of the left-right asymmetry impossible

Electron detector can only be used for measurements of $\boldsymbol{P_L}$

Polarization Measurement with Photon Detector

Photon detector needs 2 components to measure both longitudinal and transverse polarization

- Calorimeter → asymmetry vs. photon energy (P_L)
- Position sensitive detector → left-right asymmetry (P_T)

Beam energy	P_L	P_T
5 GeV	96.5%	26.1%
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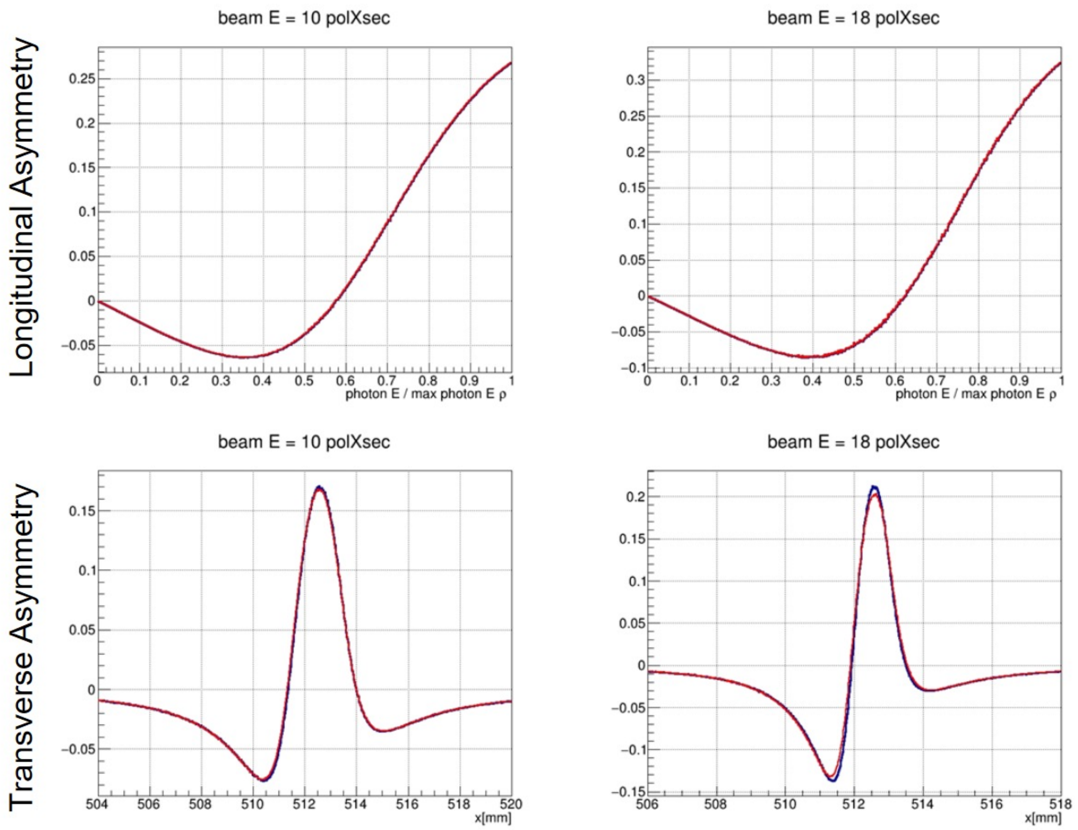


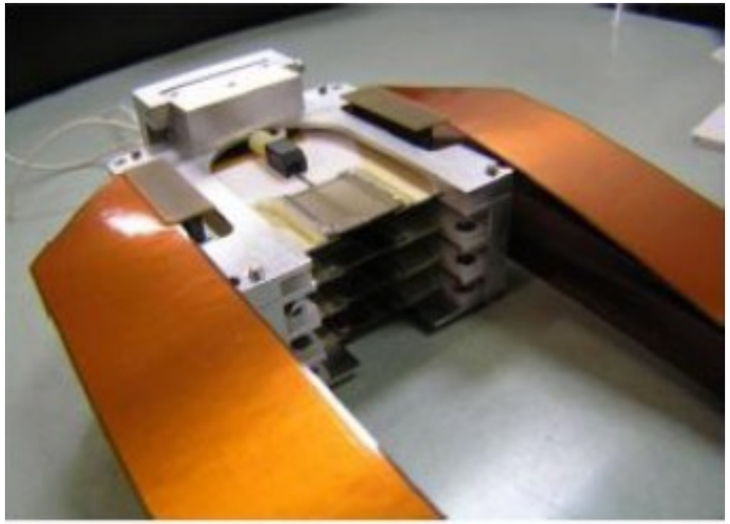
Ciprian Gal

Transverse size of detectors determined by backscattered photon cone at low energy
→ +/- 2 cm adequate at 5 GeV
→ Longitudinal measurement requires good energy resolution from ~0 (as low as possible) to 3 GeV
→ Fast time response also needed (10 ns bunch spacing)
→ PbWO4 a possible candidate, but slow component may be an issue

Position sensitive detector segmentation determined by highest energy → 18 GeV
→ More investigation needed, but segmentation on the order of 100-400 μm should work

ESR Compton Detector Technology

Hall C diamond detector



Several choices feasible for position sensitive detectors
→ Diamond strip detectors are baseline choice

- Radiation hard
- Fast time response
- Compatible with segmentation requirements
- ASIC under development for LHC diamond detectors compatible with EIC timing requirements

Tungsten-powder calorimeter

Photon calorimeter more challenging
→ Timing requirements suggest lower resolution calorimeter must be used
→ OK for transverse measurement, but reduces precision on longitudinal

RCS Compton Polarimeter

<u>RCS properties</u>

- 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

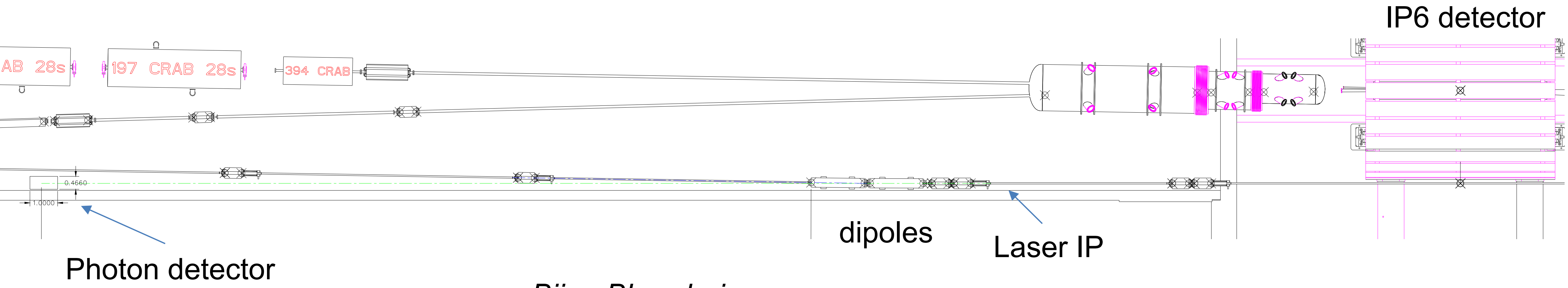
<u>Polarimetry challenges</u>

- Analyzing power often depends on beam energy
- Low average current
- Bunch lifetime is short

Compton polarimeter can also be used for measurement of polarization in RCS

→ Measurements will be averaged over several bunches – can tag accelerating bunches to get information on bunches at fixed energy

→ Requires measurement in multiphoton mode (~1000 backscattered photons/crossing)



Bijan Bhandari

RCS Compton Rate Estimates

$$\mathcal{L} = f_{coll} N_\gamma N_e \frac{\cos(\alpha_c/2)}{2\pi} \frac{1}{\sqrt{\sigma_{x,\gamma}^2 + \sigma_{x,e}^2}} \frac{1}{\sqrt{(\sigma_{y,\gamma}^2 + \sigma_{y,e}^2)\cos^2(\alpha_c/2) + (\sigma_{z,\gamma}^2 + \sigma_{z,e}^2)\sin^2(\alpha_c/2)}}$$

1-2 Hz

$N_\gamma = \langle P \rangle / (f_{laser} E_{laser})$

Example system from RPMC lasers: Pulse energy = 30 mJ @ 2 Hz (<P>=60 mW) → 8.0E16 photons/pulse

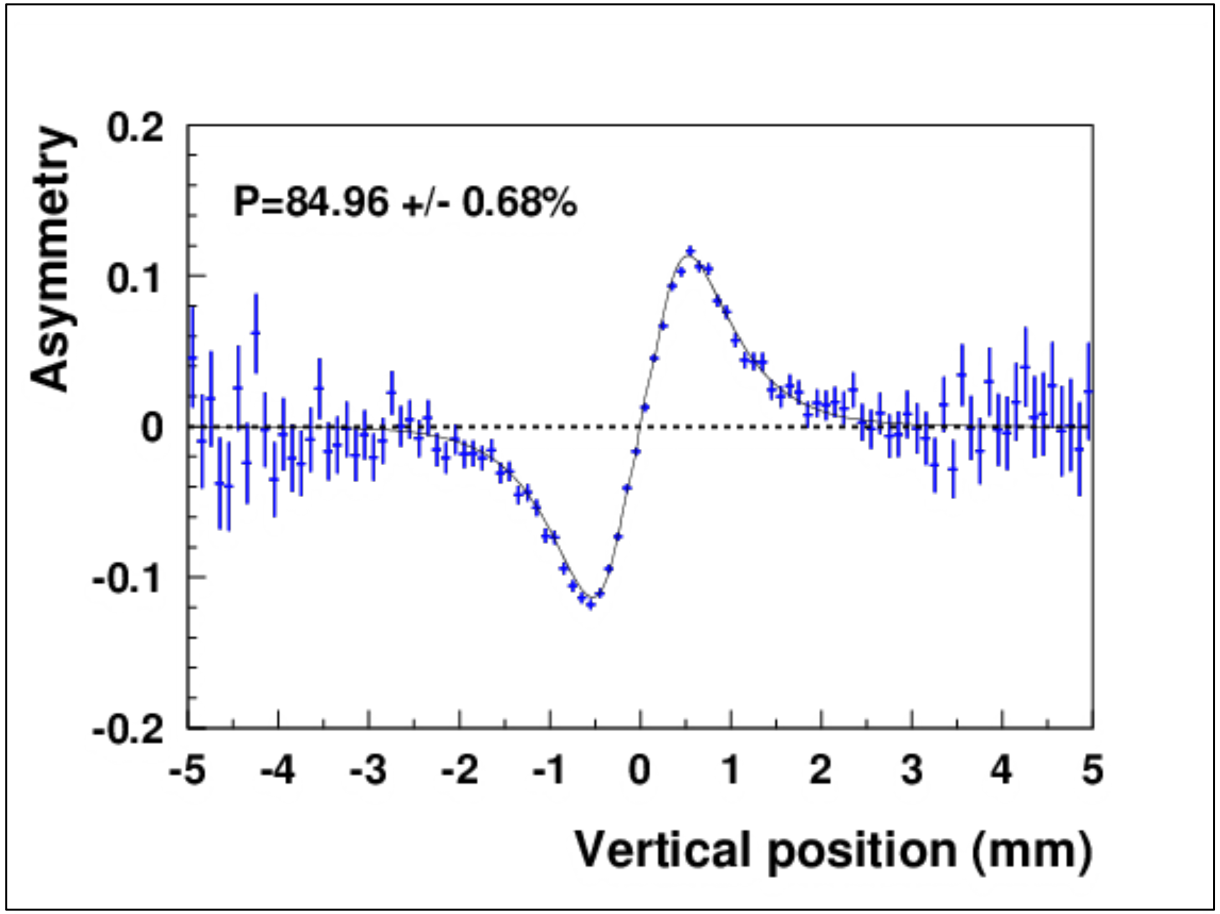
Assuming 28 nC electron bunches at 2 Hz, backscattered photon rate is about 240 kHz – measurement times on the order of a few s

Differential Asymmetry measurement

Differential measurement of asymmetry vs. position at detector allows us to incorporate offsets in the fit

Example using Toy MC for counting-mode asymmetry vs. y assuming 0.1 mm segmentation
(240 bunches)

→ **Requires detector operated in integrating mode (~10,000 photons/bunch) with signal proportional to number of photons in each channel**



Electron polarimeter tasks

- ESR Compton
  - Design photon exit window, synchrotron shield/absorber
  - Additional background studies
  - Detailed simulations of detector response (radiator for photons, etc.)
  - Check electron detector compatibility with electron beamline – design interface
  - Incorporate clearance for “photon cone” in beamline quads
  - Design laser/beamline interface
  - Laser R&D
  - Finalize detector choices
- RCS Compton
  - Build simulation for RCS Compton – get more detailed estimates for rates
  - All of the above, except:
    - No laser R&D needed – can buy off-the-shelf
    - No electron detector – will only use photon detector
  - Additional challenges
    - Detector choice must be compatible with wide range of analyzing powers (all at once)
    - Detector readout will differ - need signal proportional to energy deposited in position sensitive detectors