

Polarimetry at EIC

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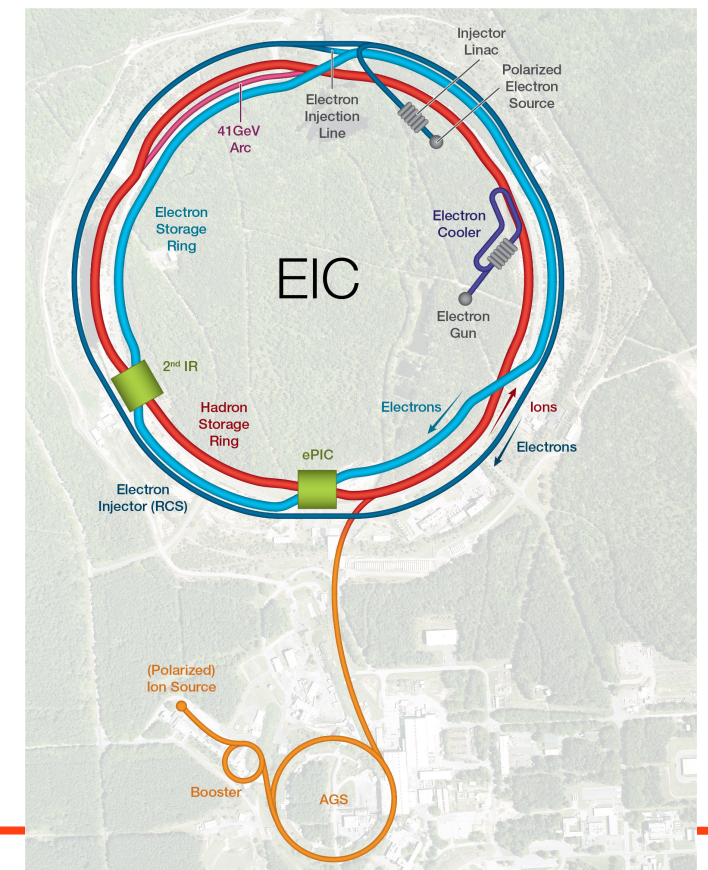
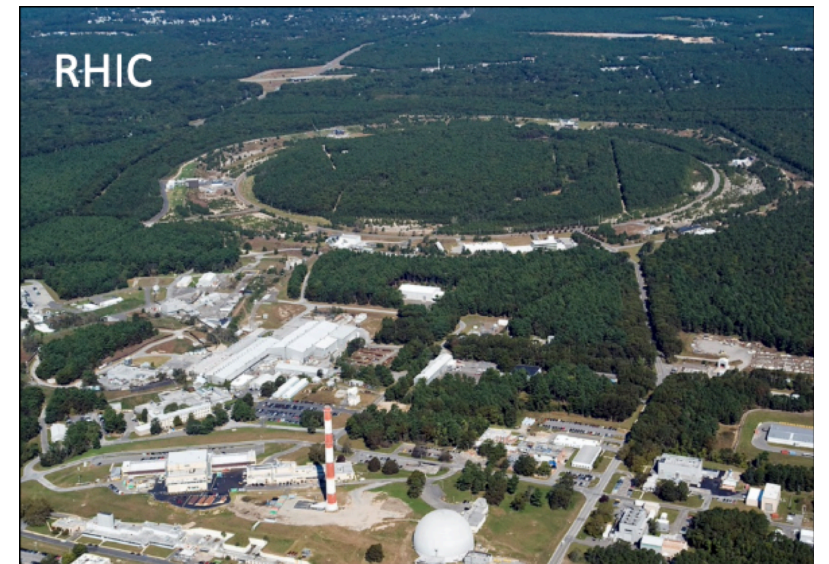
2nd workshop on advancing the understanding of
non-perturbative QCD using energy flow

Electron-Ion Collider

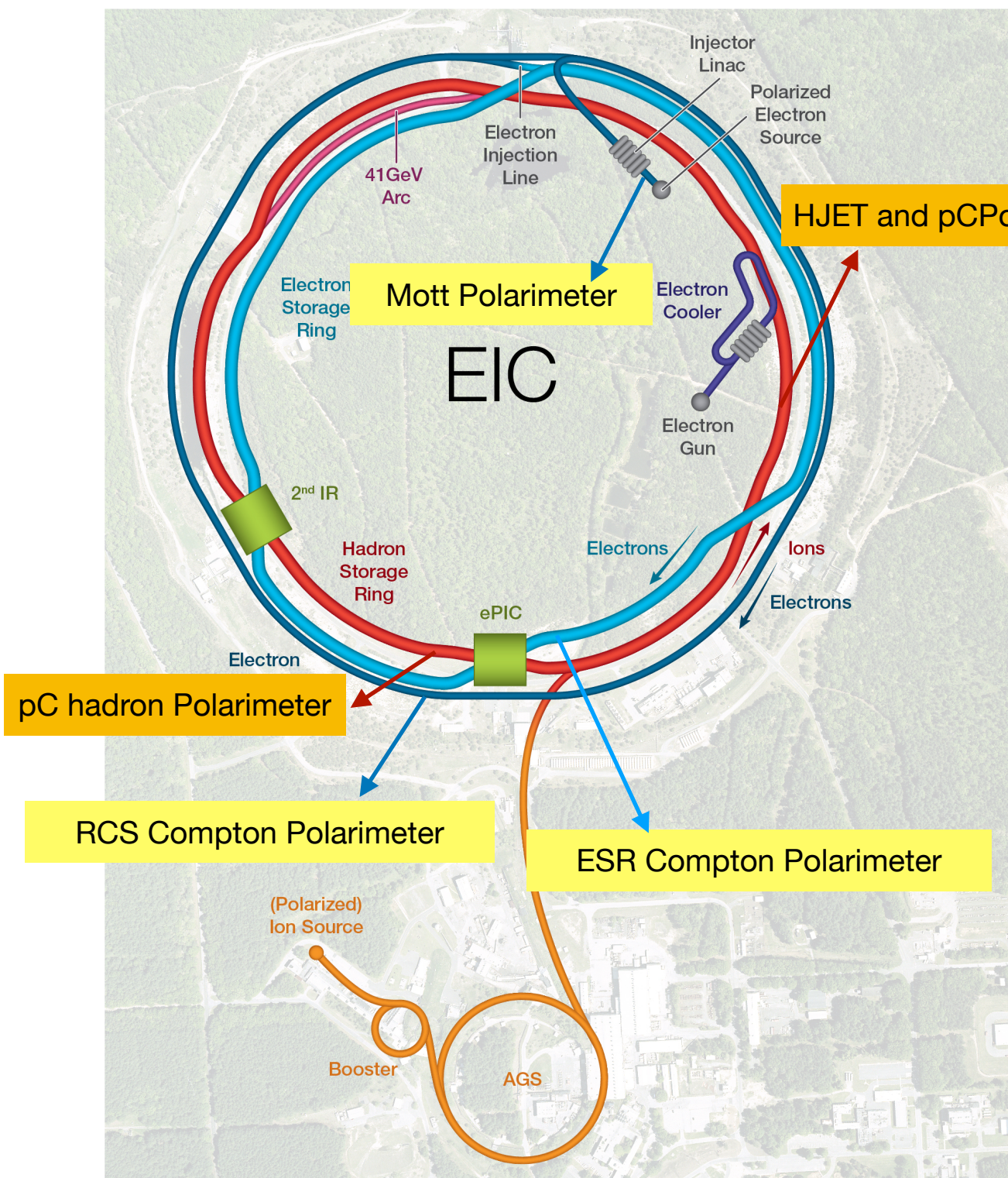
Electron-Ion-Collider (EIC)

EIC Design Goals:

- Large range of center of mass energies: $E_{\text{cm}} = 20\text{-}140 \text{ GeV}$;
 - ➔ Access to gluon dominated region and wide kinematic range in x and Q^2
- Large range of ion species: Protons – Uranium;
 - ➔ Access the highest gluon densities ($Q_s^2 \sim A^{1/3}$)
- High Luminosity (100x HERA): $L = (0.1\text{-}1) \cdot 10^{34} \text{ cm}^{-2} \text{ s}^{-1} \rightarrow 10\text{-}100 \text{ fb}^{-1}$;
 - ➔ Studying observables as a function of x , Q^2 , A , etc.
- Collisions of highly polarized e and p (and light ion) beams with flexible bunch polarization pattern: $\geq 70\%$;
 - ➔ Access to spin structure and 3D spatial and momentum structure
- Good background conditions;
- EIC is using part of RHIC facility at BNL;

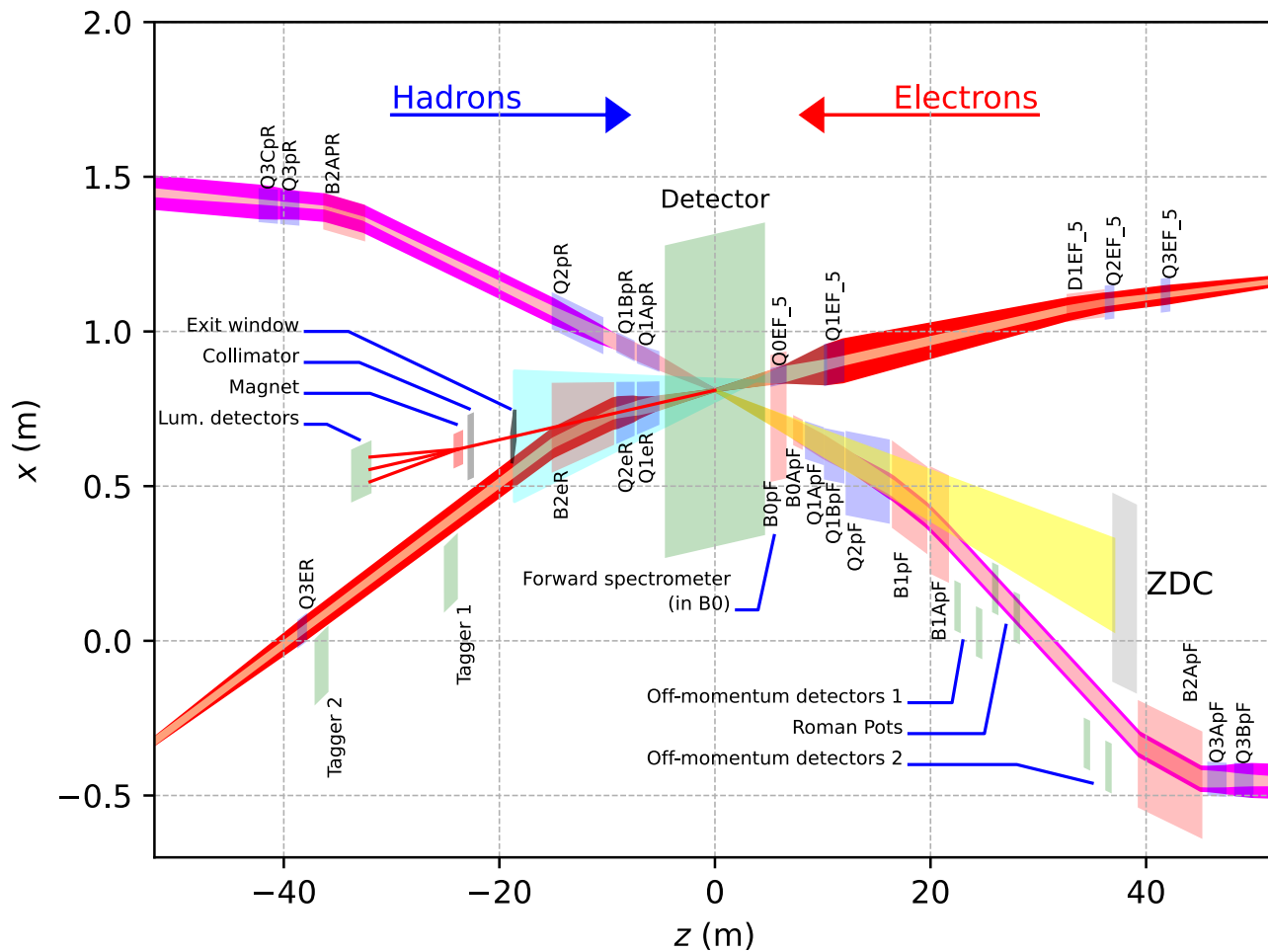


EIC polarimeters



- EIC requires three electron polarimeters;
 - ▶ Compton Polarimeter in ESR
 - ▶ Polarimeter for RCS (A Compton Polarimeter is proposed)
 - ▶ Polarimeter at source (Mott Polarimeter)
- HJET for absolute polarization and pC for time dependence and bunch profile at IR-4;
- pC polarimeter for hadron polarization orientation at IR-6;

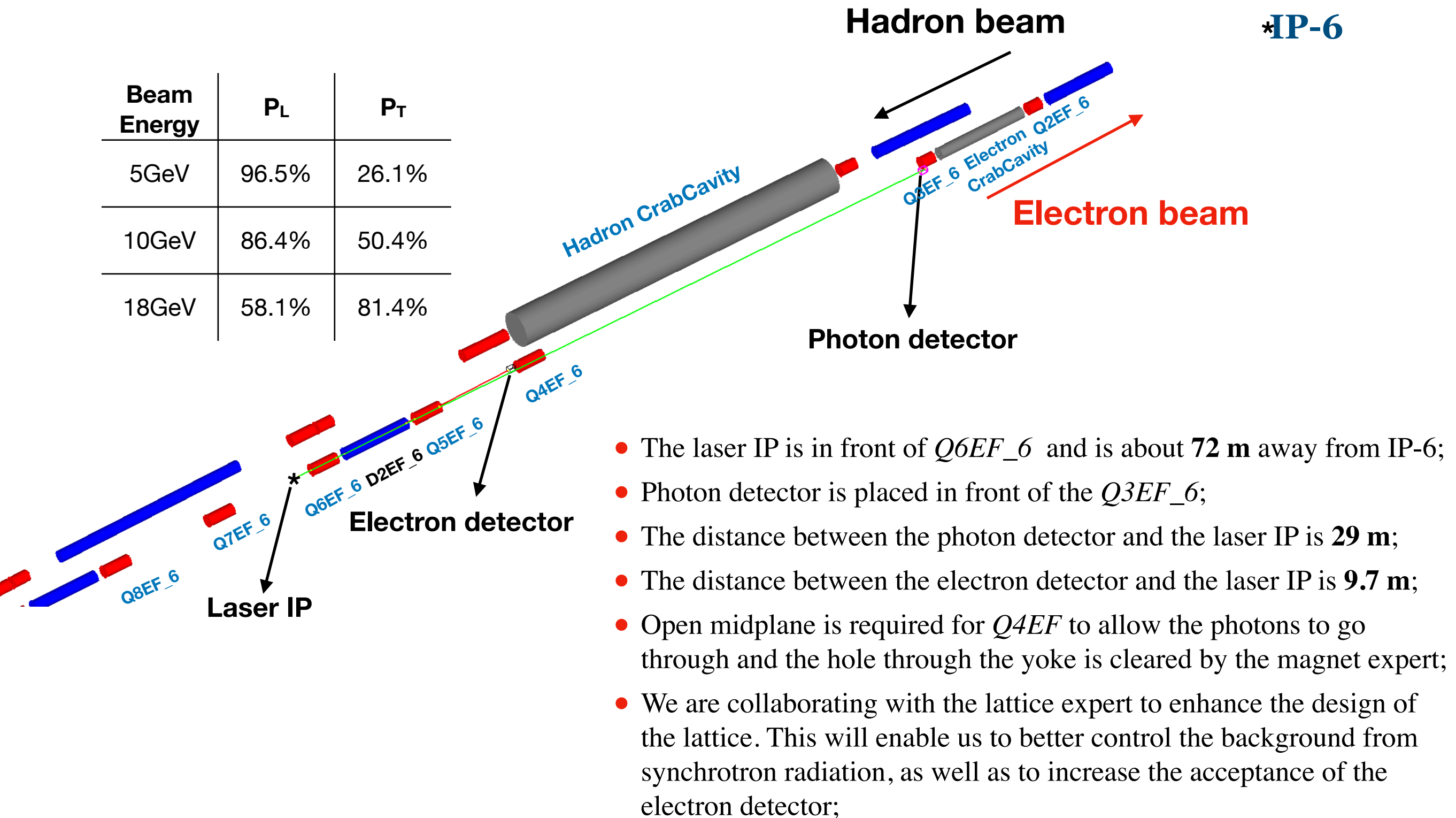
Requirements of electron polarimeter



- The polarimeter needs to be placed as close to IP-6 as possible;
- The inner IR-6 region is very crowded, it is not possible to place the whole Compton Polarimeter system;
- Compton Polarimeter in ESR is placed at 72 m away from IP-6;

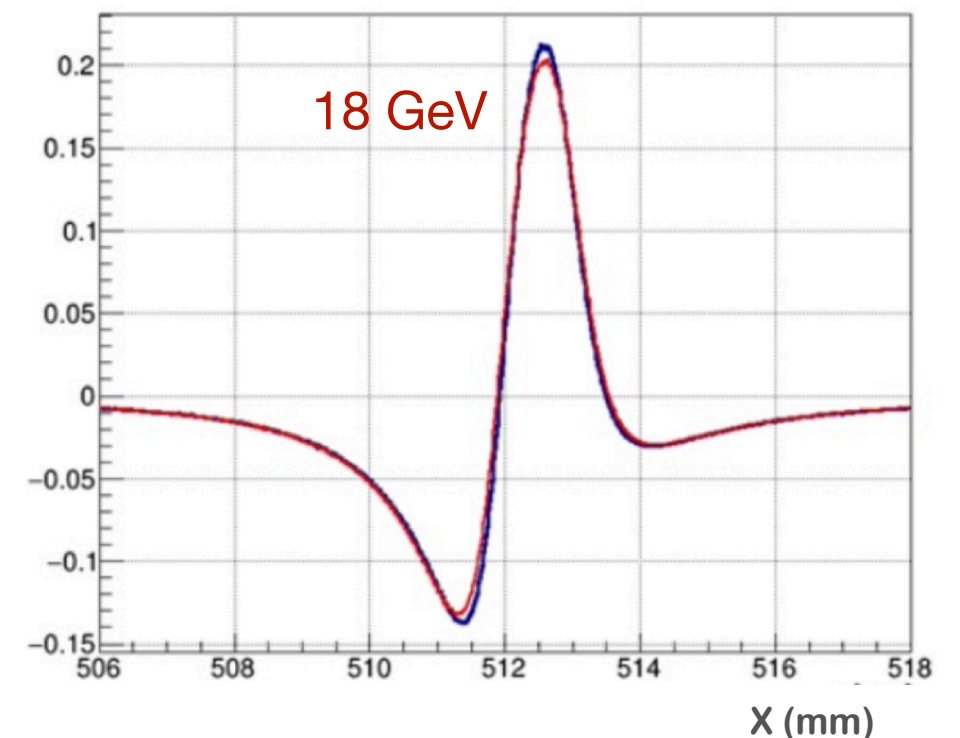
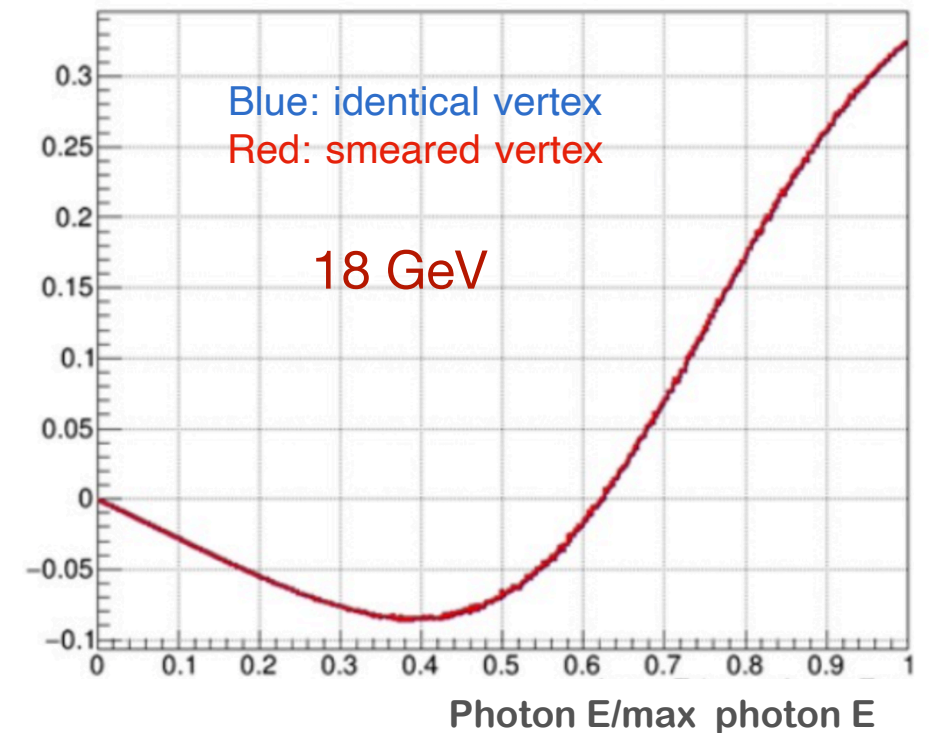
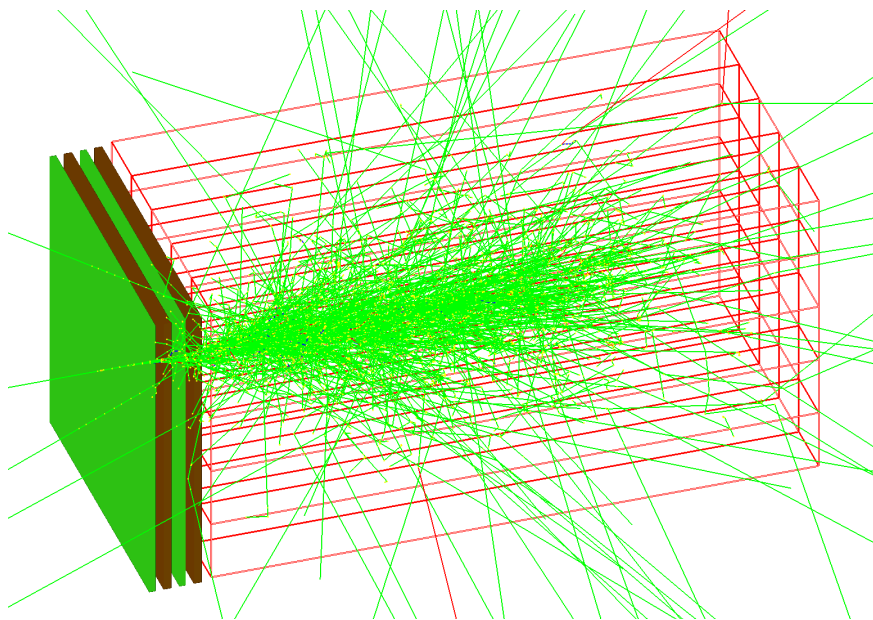
- Non-destructive
- Need to measure both longitudinal and transverse components;
 - ▶ The longitudinal polarization can be measured by an energy asymmetry of the Compton photons & electrons flipping the circular laser polarization direction;
 - ▶ The transverse polarization (horizontal) can be measured by a spatial asymmetry of the Compton photons;
- Measure bunch-by-bunch polarization;
- Measure with high precision $\Delta P / P < 1\%$;

Layout of polarimeter in ESR

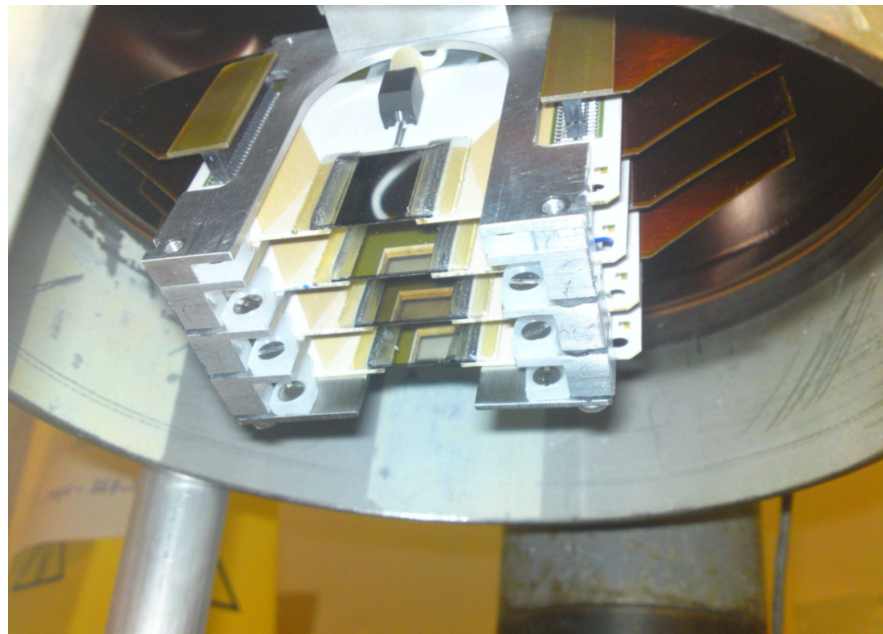
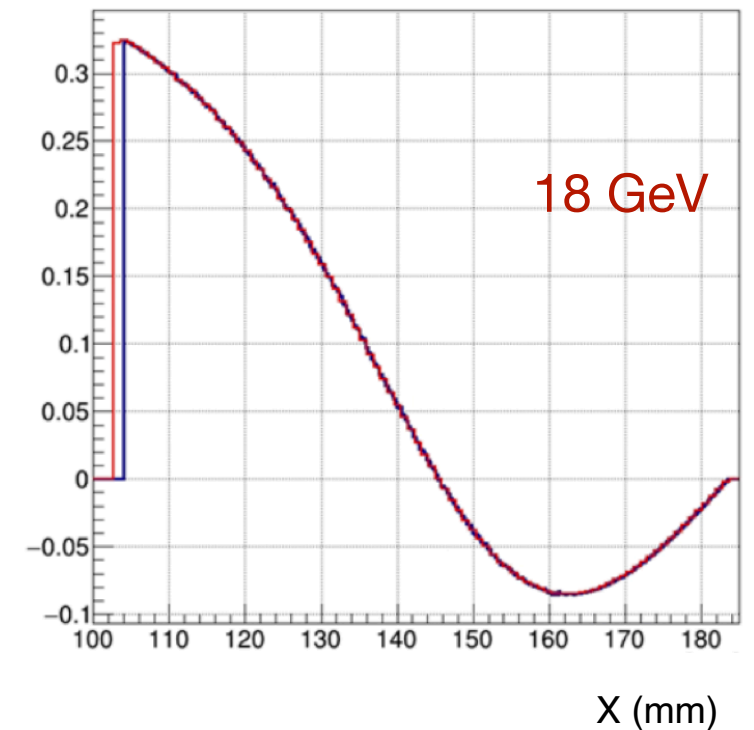
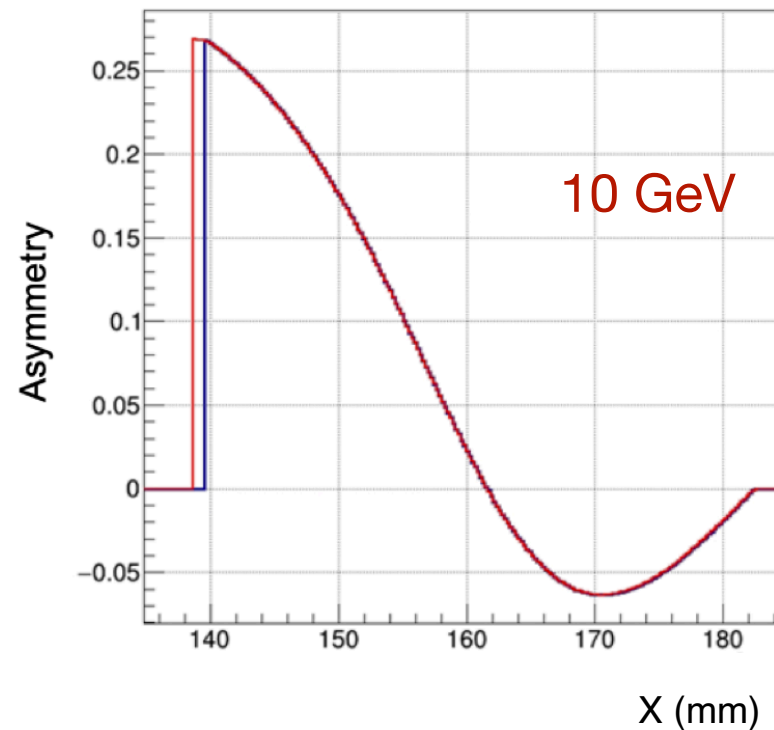
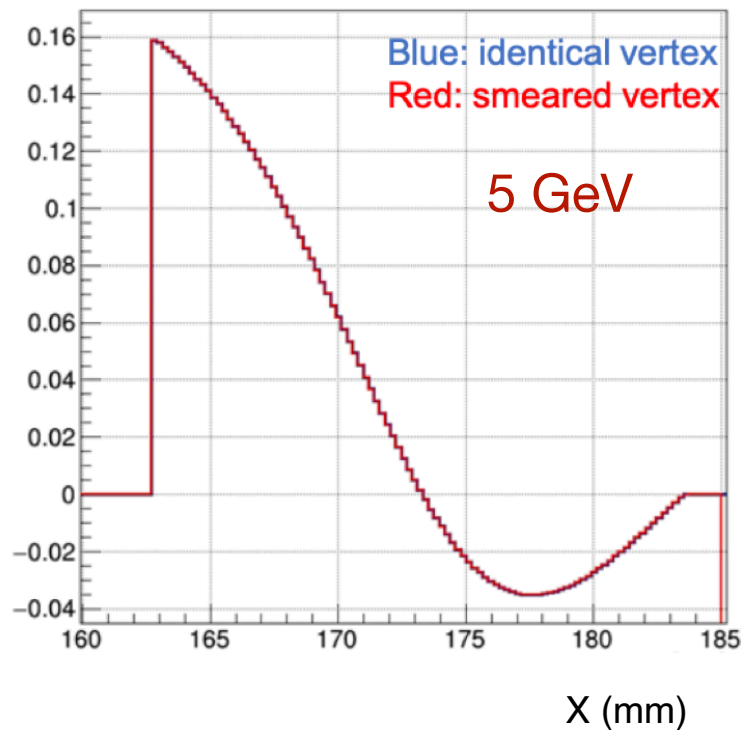


Photon Detector

- Photon detector needs 2 components to measure both longitudinal (photon energy asymmetry) and transverse polarization (left-right asymmetry);
- Longitudinal measurement requires good energy resolution from ~ 0 (as low as possible) to 7 GeV. A homogeneous Calorimeter with Preshower detector is being considered (10cmX10cmX20cm). A fiber-tungsten or lead sampling calorimeter is another (perhaps safer) option, but would likely result in reduced precision for P_L on the photon side;
- Position sensitive detector segmentation determined by highest energy, segmentation on the order of 100-400 μm would work;
- Fast time response is also needed (10 ns bunch spacing);
- Radiation hardness: 80 Gy/h;
- Background studies are being conducted for the photon detector;



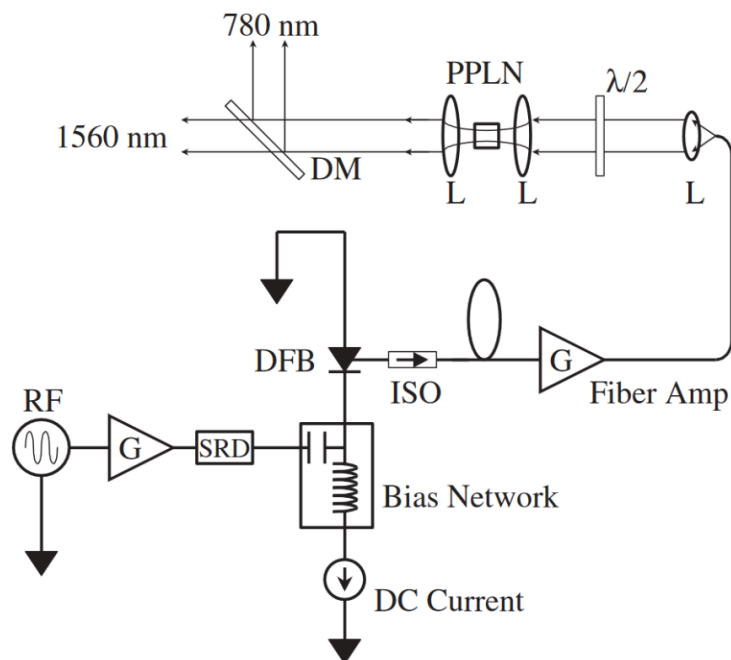
Electron Detector



- Electron detector (horizontal) size determined by spectrum at 18 GeV (which has the largest horizontal spread);
 - ▶ Need to capture zero-crossing to the endpoint → detector should cover at least 60 mm;
- Segmentation is dictated by the spectrum at 5 GeV (smallest spread);
 - ▶ Need at least 30 bins, so a strip pitch of about 550 μm would be sufficient;
- Electron detector can only be used for the measurements of P_L due to the large dispersion induced by the dipole;
- Diamond strip detector similar with JLab Hall C diamond detector is being considered;
 - ▶ Radiation hard, fast time response, compatible with segmentation requirements;

Compton Laser System

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

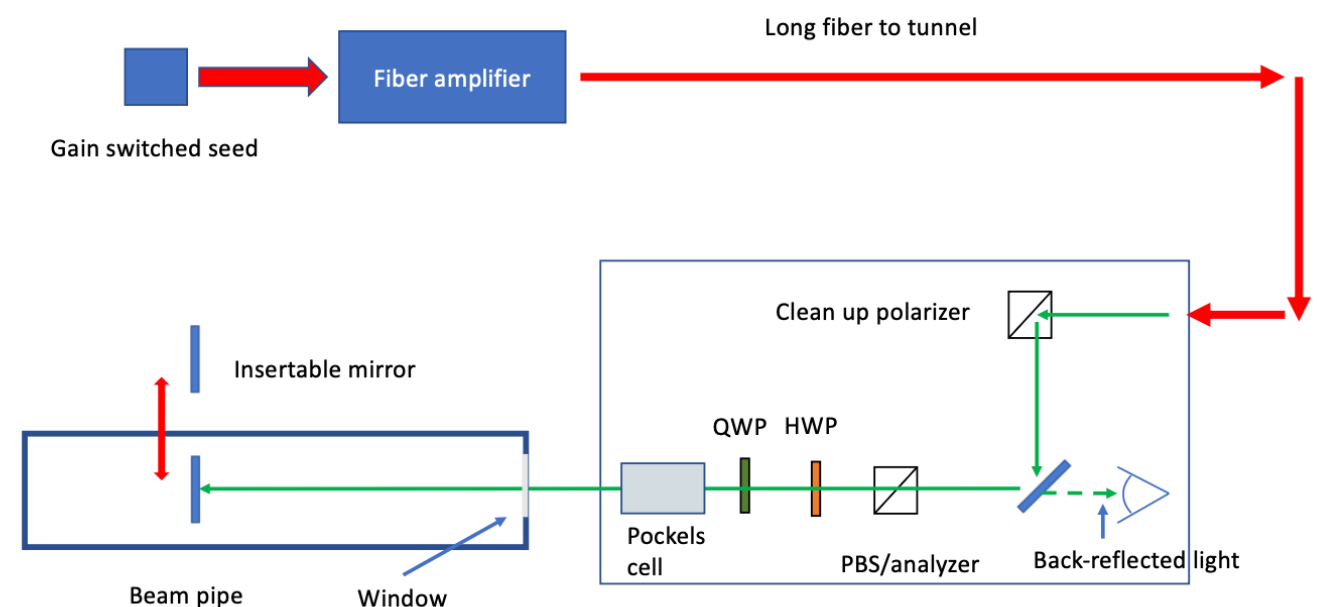


JLAB injector laser system

Polarization in vacuum set using “back-reflection” technique \rightarrow Requires remotely insertable mirror (in vacuum)

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

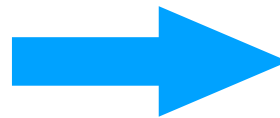
- Gain-switched diode seed laser -variable frequency, few to 10 ps pulses @ 1064 nm \rightarrow Variable frequency allows optimal use at different bunch frequencies (100 MHz vs 25 MHz)
- Fiber amplifier \rightarrow average power 10-20 W
- Optional: Frequency doubling system (LBO or PPLN)
- Insertable in-vacuum mirror for laser polarization setup



RCS Compton Polarimeter

RCS properties

- RCS accelerates electron bunches from 0.4 GeV to full beam energy (5-18 GeV)
- Bunch frequency \rightarrow 2 Hz
- Bunch charge \rightarrow up to 28 nA
- Ramping time = 100 ms

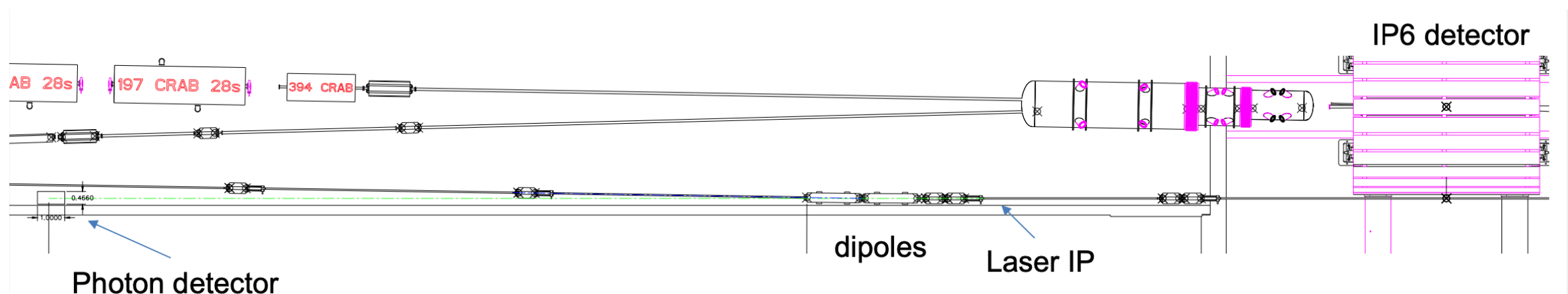


Polarimetry challenges

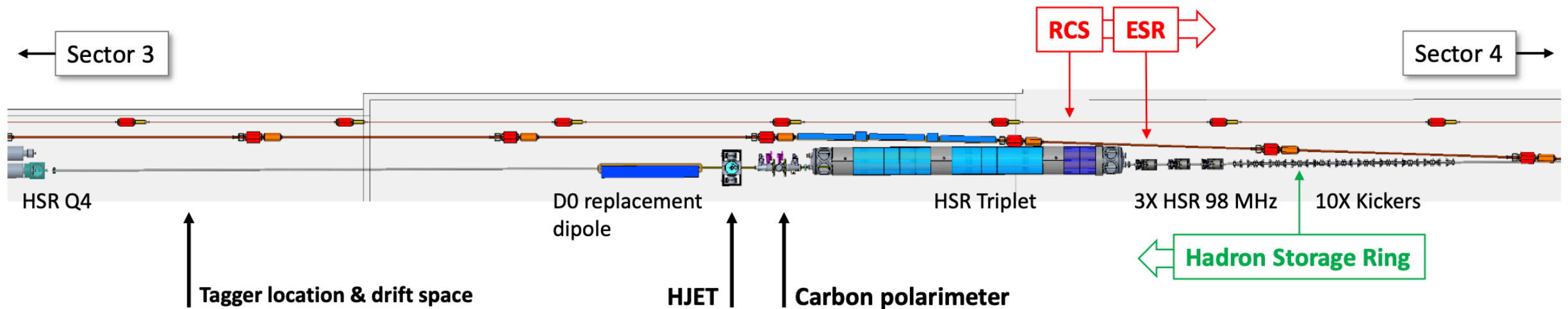
- Analyzing power depends on beam energy
- Low average current
- Bunch dwell time is short

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)



Hadron Polarimeters at IR-4

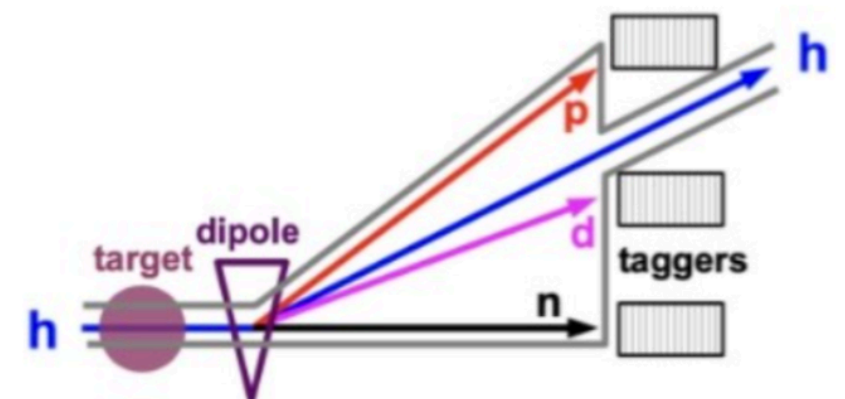


Recoil particles from elastic scattering

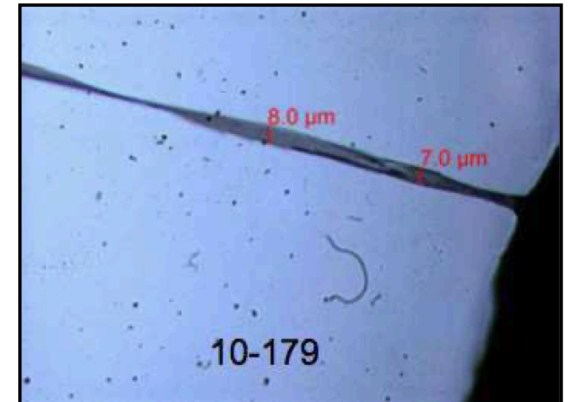
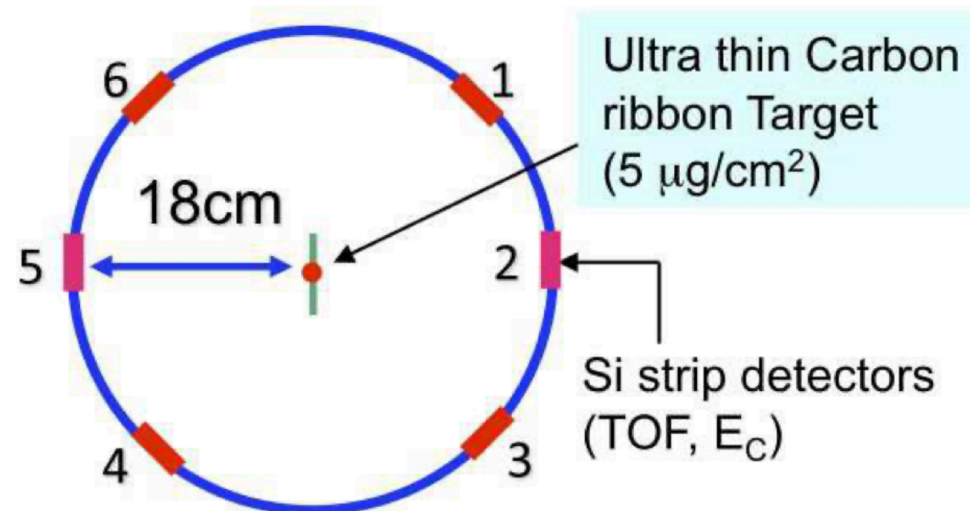
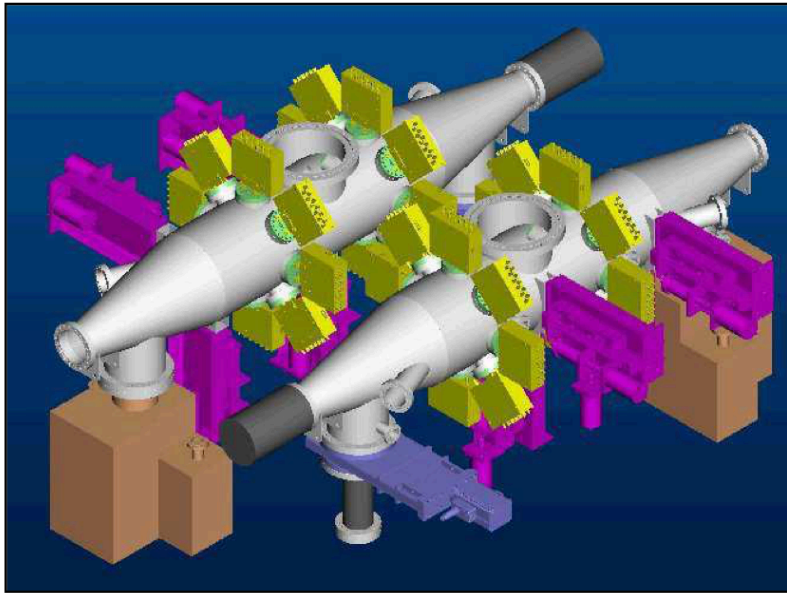
- Strong dipole magnet, vacuum chamber with exit windows and drift space and space for taggers
- HJET polarimeter move from IR-12 to IR-4 after RHIC shutdown (06/2025)
- Update/refurbish some components
- Upgrade silicon detectors and readout
- Add target gas analyzer

$$A_N = \frac{d\sigma_{left} - d\sigma_{right}}{d\sigma_{left} + d\sigma_{right}}$$

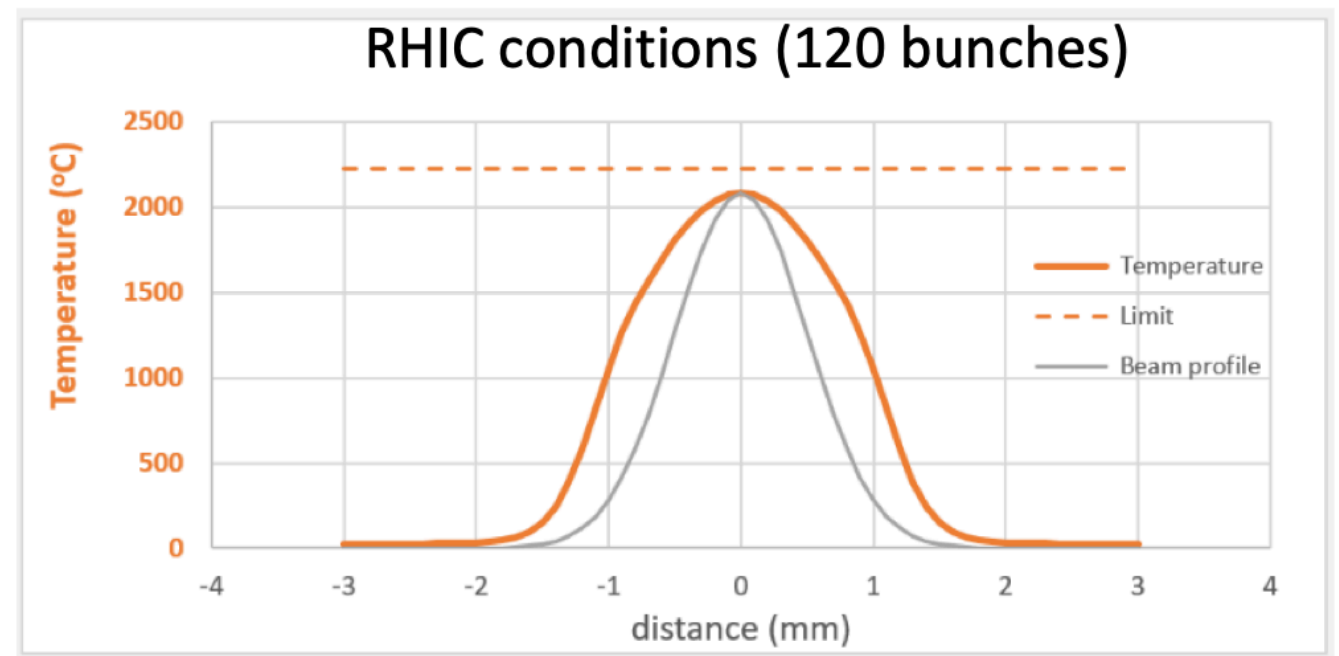
$$P_{Beam} = \frac{\epsilon_{Beam}}{\epsilon_{Target}} P_{Target}$$



Fiber Target Polarimeters

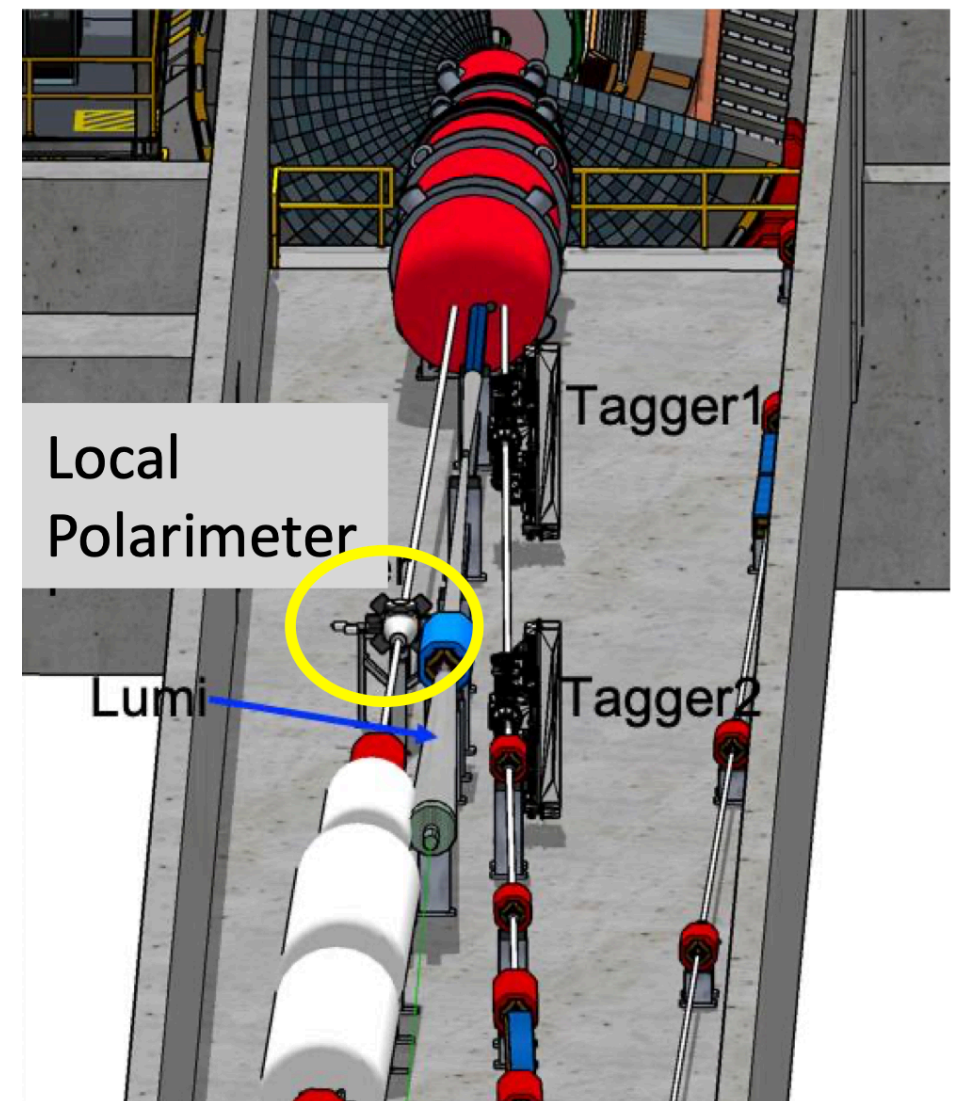
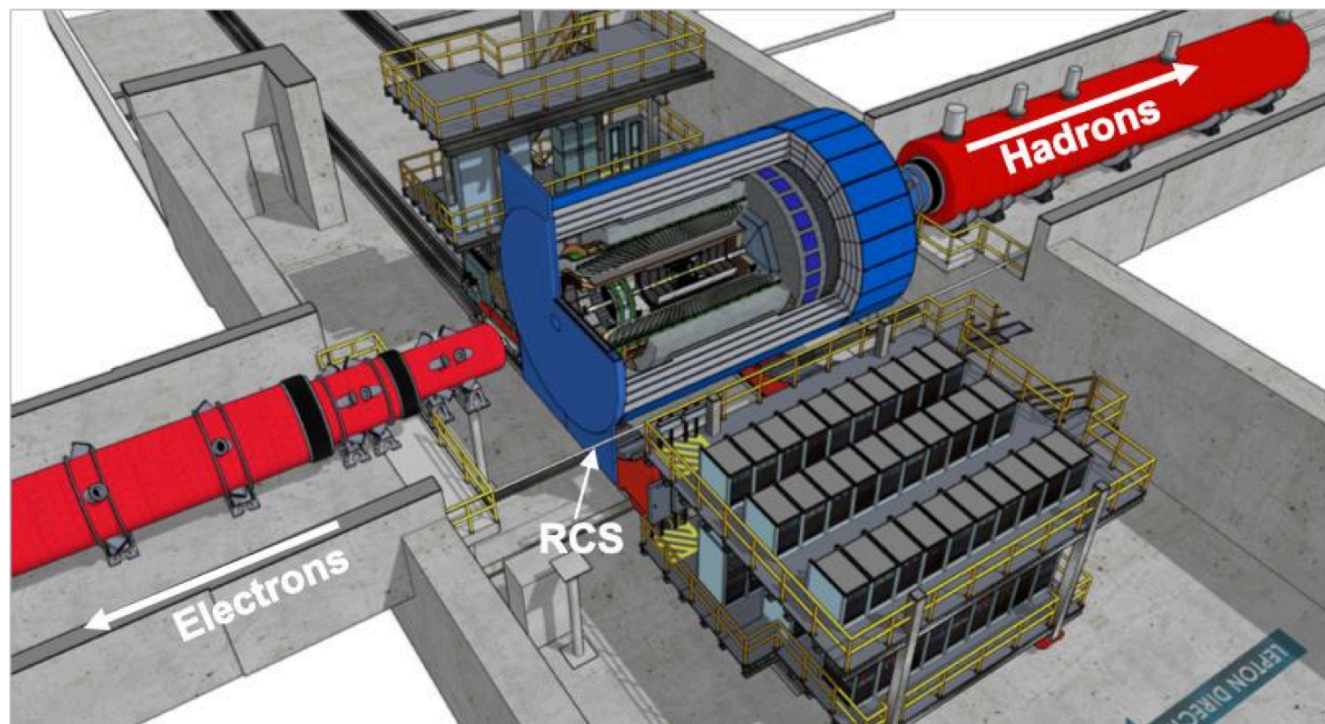


- Ultra-thin ribbon targets: $\approx 10 \mu\text{m} \times 100 \text{ nm}$
- Target holder inside the beam pipe
- Targets heat up due to energy loss of proton beam
- Two p-C polarimeters exist, move double target chamber to IR-4, move single target chamber to IR-6



Hadron Local Polarimeter at IR-6

- Spin rotators for longitudinal polarization → monitor degree of polarization
- Crab cavities for increased luminosity in collision → monitor possible impact
- Limited space in hall / straight section
- Polarimeter in incoming hadron beam



Summary

- Polarimeters are necessary for polarized beam commissioning (04/2031)
- ESR Compton polarimeter design is based on experience from previous transverse and longitudinal polarimeters
 - Investigating suitable photon detectors to meet all requirements
 - Diamond strip are default position sensitive detectors
 - Laser system is higher power version of JLab polarized source laser
- Hadron polarimeters are based on existing devices at RHIC
 - $\sigma_P/P \approx 1.4\%$ has been achieved
 - HJET provides absolute beam polarization measurement and limited information about polarization lifetime.
 - Transverse polarization profile may require changes to the target and/or other mitigation of rapid heating

Thanks.