eN Polarimetry at the EIC

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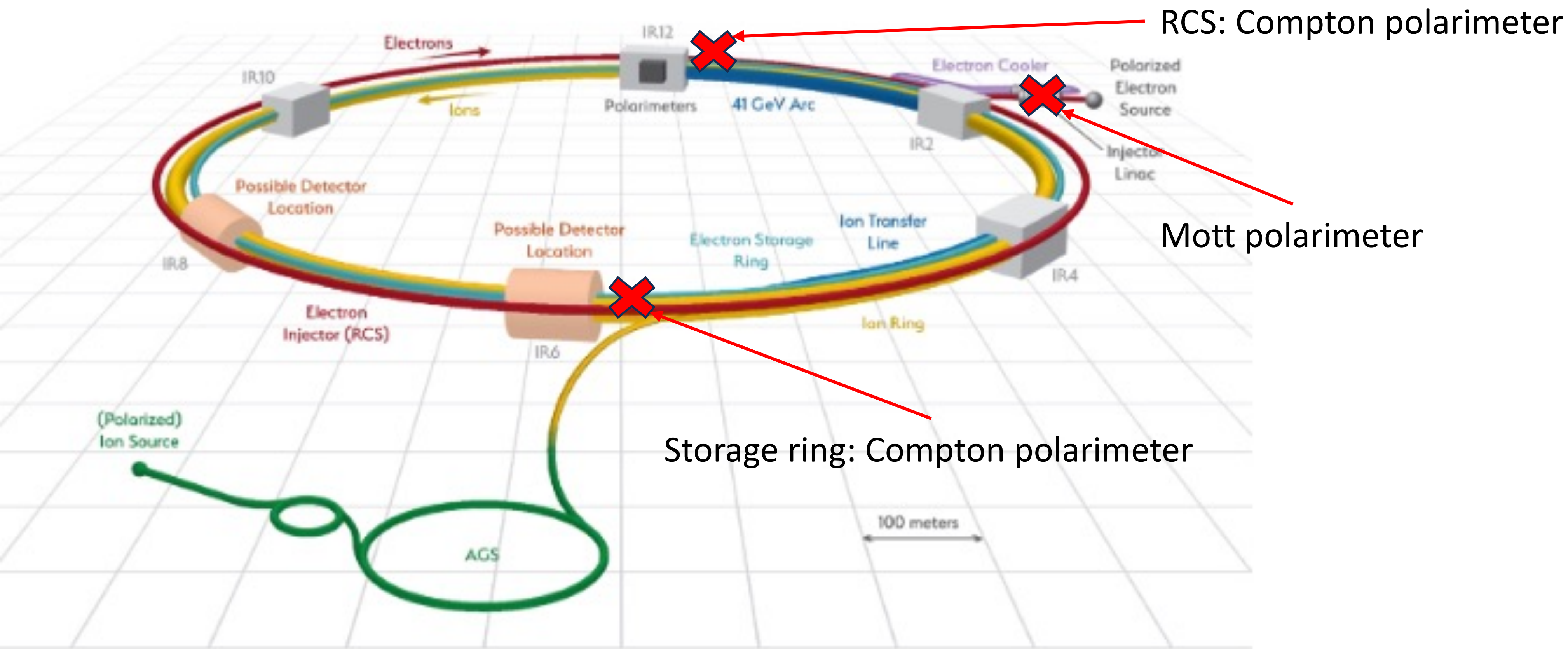
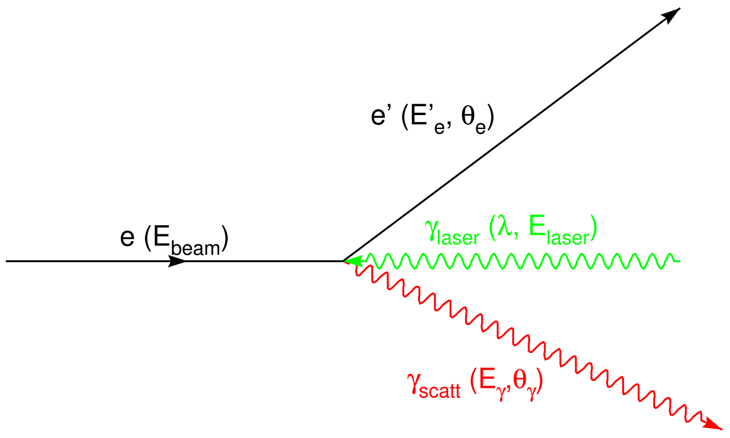
Compton polarimetry at the EIC





- The Compton polarimeters will be able to monitor the beam setup through the acceleration process in the RCS as well as right before collisions in the ePIC detector

E-polarimetry requirements

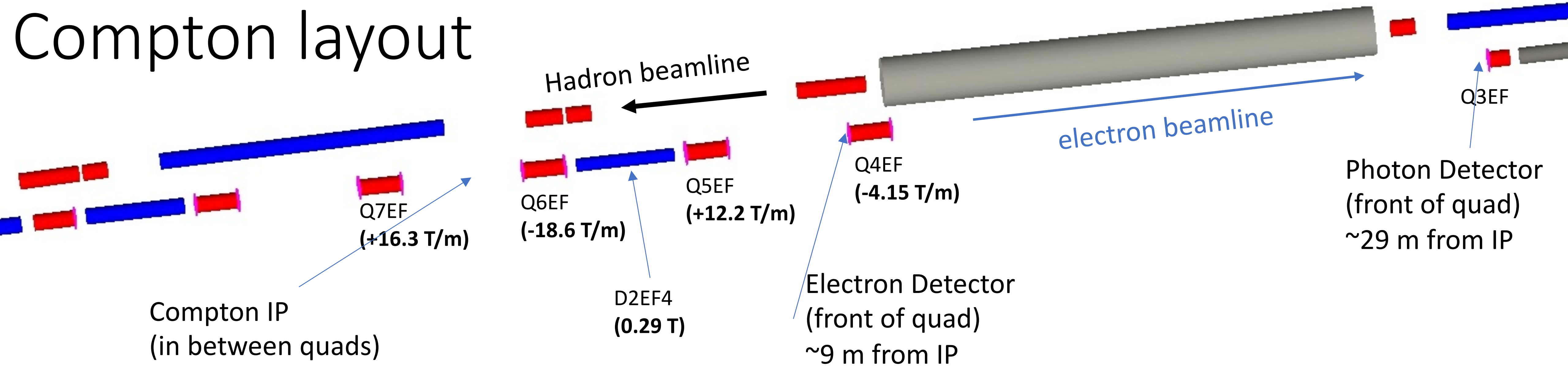
Fast

- At 18 GeV bunches will be replaced every 1-3 min
  - A full polarimetry measurement needs to happen in a shorter time span
- The amount of electrons per bunch is fairly small ~24 nC
  - will need bright laser beam to obtain needed luminosity
- A fast polarimeter will allow for faster machine setup

Precise

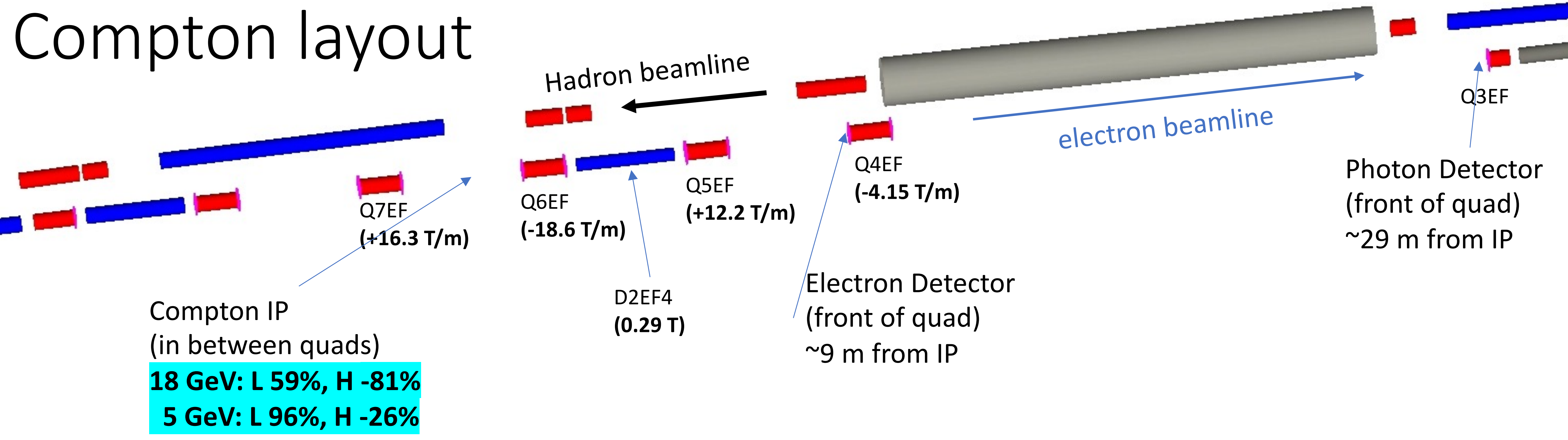
- Distance between buckets is ~10ns (@5,10 GeV)
  - bunch by bunch measurement cannot be done with a CW laser without very fast detectors
- For systematic studies we need the ability to either measure a single bunch (~78kHz) or have interactions with all 1160 (260) bunches at 10 and 5 GeV (18GeV)
- Backgrounds need to be under control
- Laser polarization needs to be known to a high degree

Compton layout



- The configuration allows for the interaction point to be in a magnetic field free region reducing the complexity at the interaction point and allows for relatively access to insert the laser beam
- The electron detector is placed after a dipole which has enough power to energy analyze the scattered electrons at all energy set points
  - The Quad after the dipole is horizontally defocusing increasing the effectiveness of the dipole
- One downside of this configuration is that the dipole upstream of the interaction region produces significant synchrotron radiation that may reach the electron detector

Compton layout

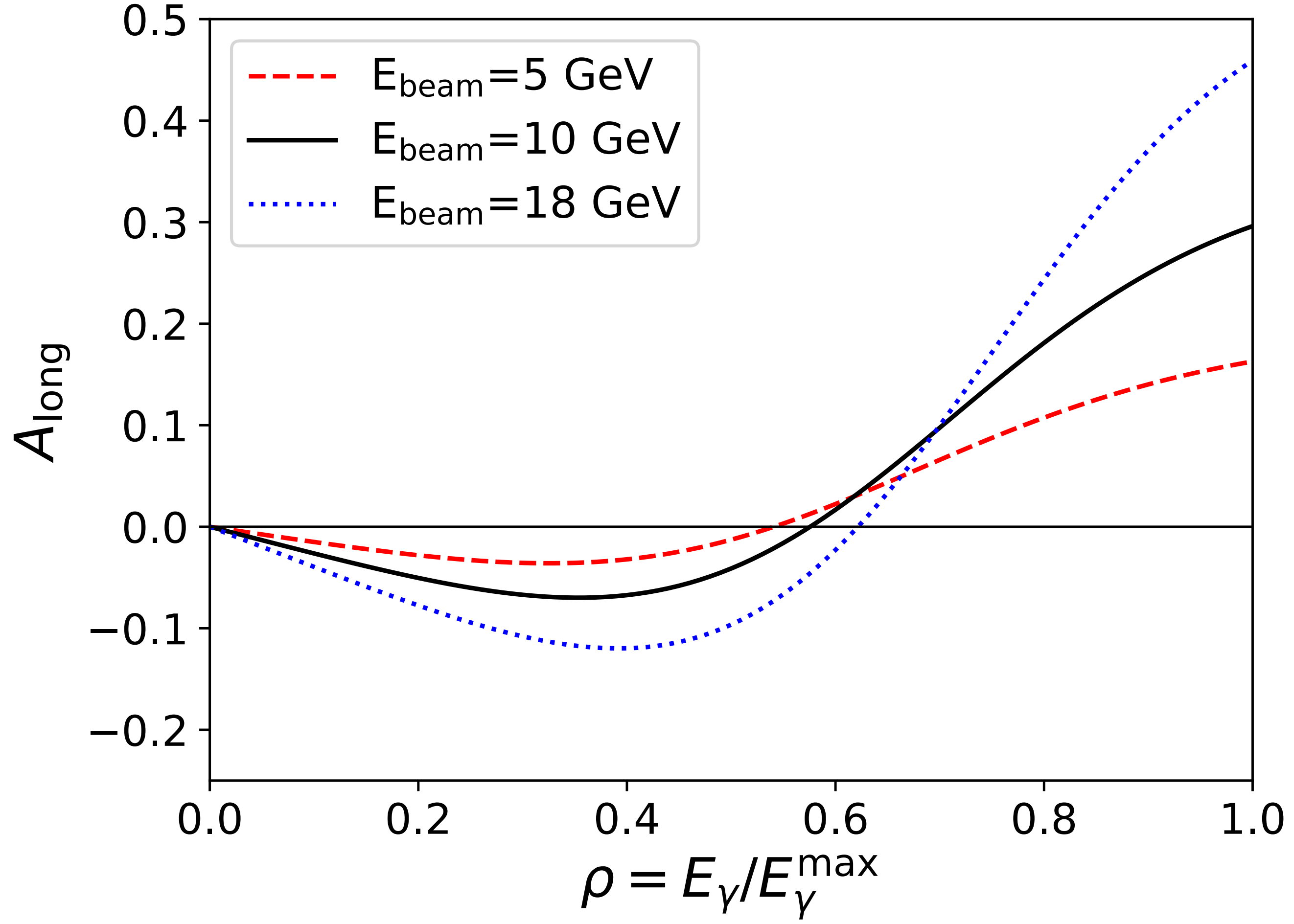


- At Compton interaction point, electrons have both longitudinal and transverse (horizontal) components
  - Longitudinal polarization measured via asymmetry as a function of backscattered photon/scattered electron energy
  - Transverse polarization from left-right asymmetry

First polarimeter that will provide high precision simultaneous measurements of both P_T and P_L

Longitudinal analyzing powers

$$A_{\text{long}} = \frac{2\pi r_o^2 a}{(d\sigma/d\rho)}(1-\rho(1+a))\left[1-\frac{1}{(1-\rho(1-a))^2}\right]$$

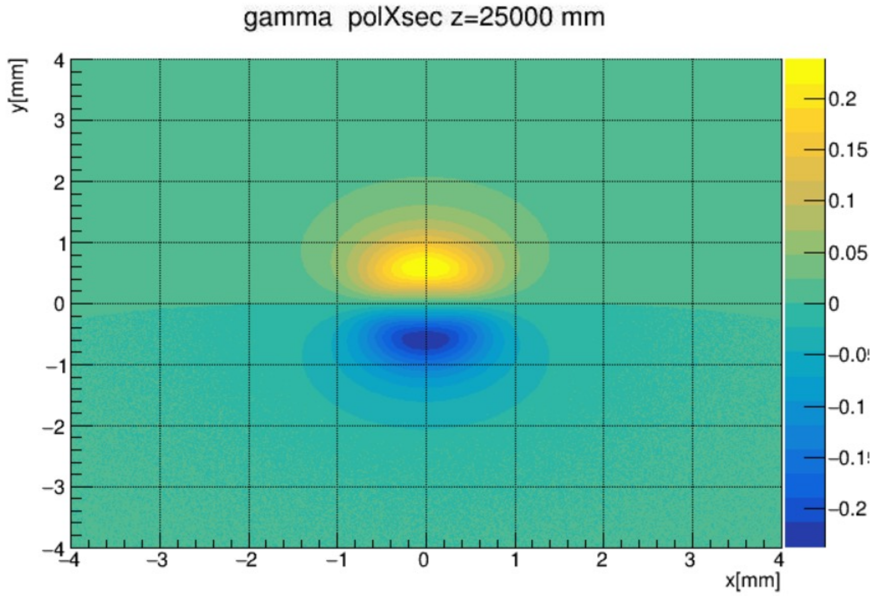


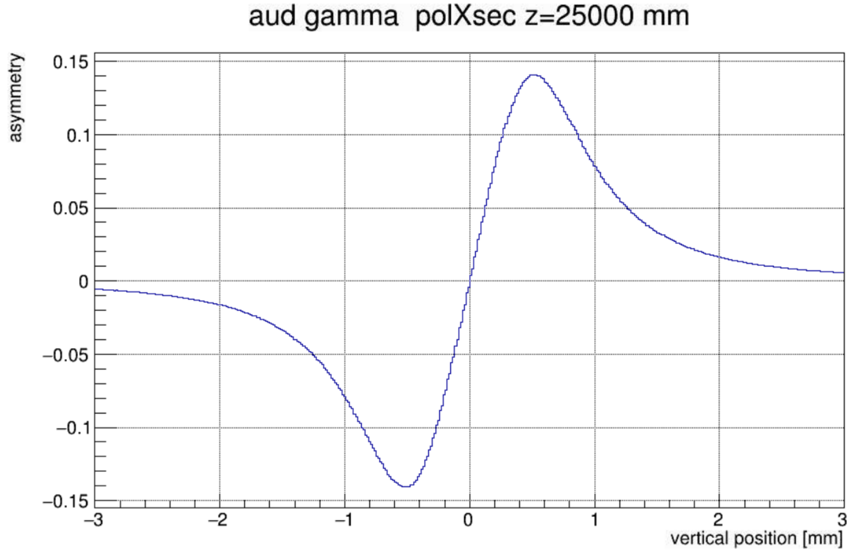
- The large analyzing power as a function of scattered photon energy can be detected in both scattered electron and photon
  - The electron will be momentum analyzed in the dipole and quad downstream of the Compton IP leading to an asymmetry as a function of position away from the beamline
  - The photon energy will be measured with a fast calorimeter and provide a cross check of the electron measurement that will reduce systematics

Transverse analyzing powers

$$A_{\text{tran}} = \frac{2\pi r_o^2 a}{(d\sigma/d\rho)} \cos\phi \left[\rho(1-a)\frac{\sqrt{4a\rho(1-\rho)}}{(1-\rho(1-a))} \right]$$

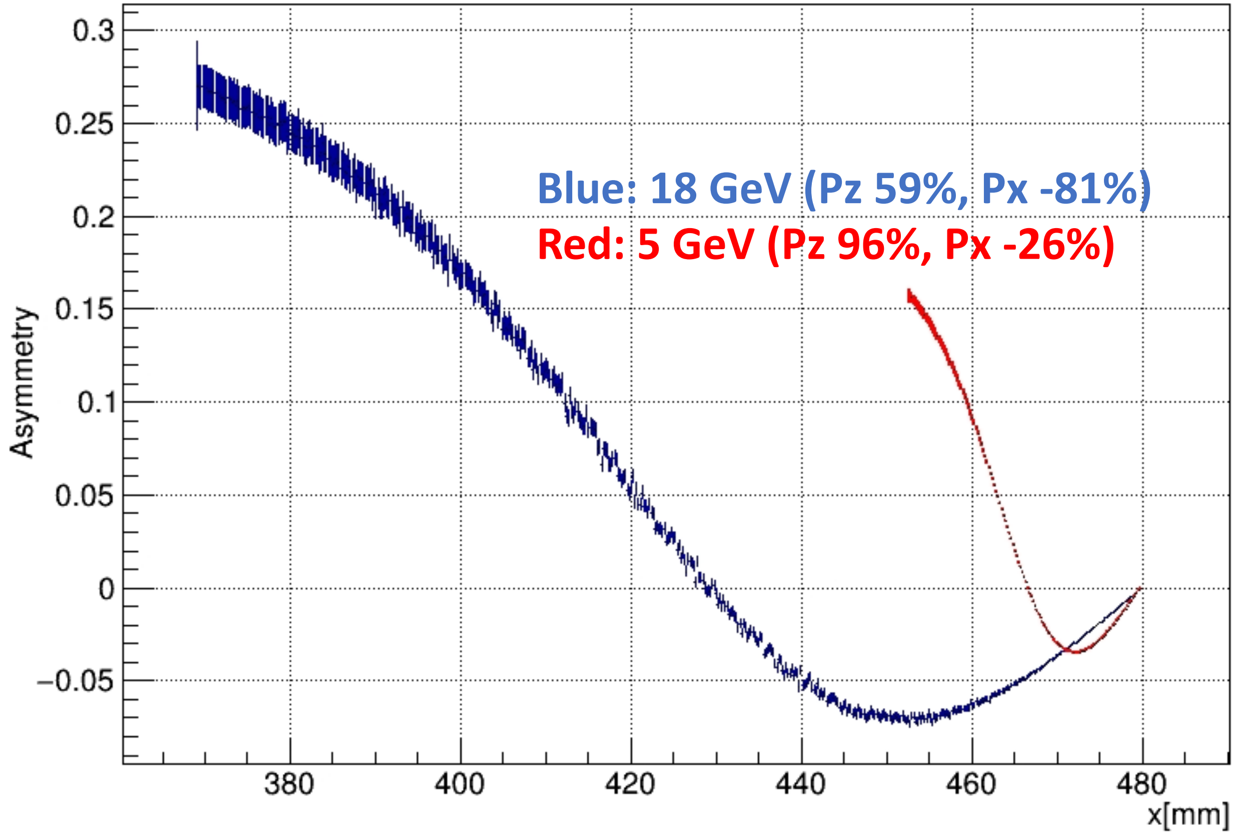
- Asymmetry is usually measured with respect to the vertical axis
- The higher the energy the tighter the collimation for the scattered photons will be
  - This can lead to significant constraints on detector segmentation
- The planned segmentation for the photon detector will allow for the detection of a mixture of vertical and horizontal polarizations

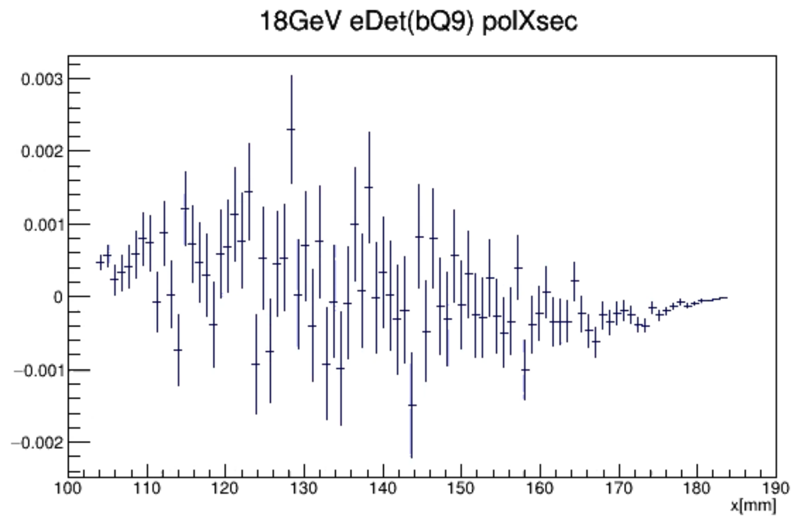




Scattered electrons

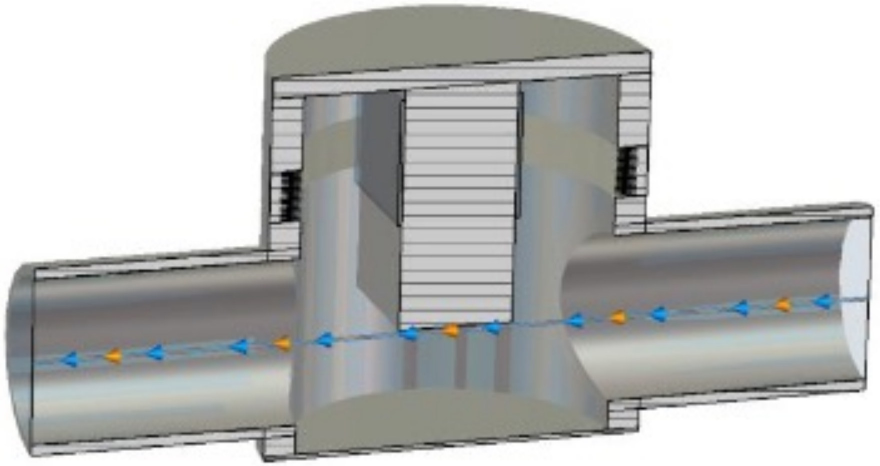
- The scattered electrons produce significantly different positional distributions at the detector location in the different configurations
- The analyzing power here probes only the longitudinal components of the electron beam polarization
- Because of the magnetic configuration the transverse component is washed out by the dipole so the electron detector will be blind to it
    - Horizontal polarization going into a horizontal bend dipole resulting in a spread of the L-R asymmetry that is on the level of microns making it not measurable

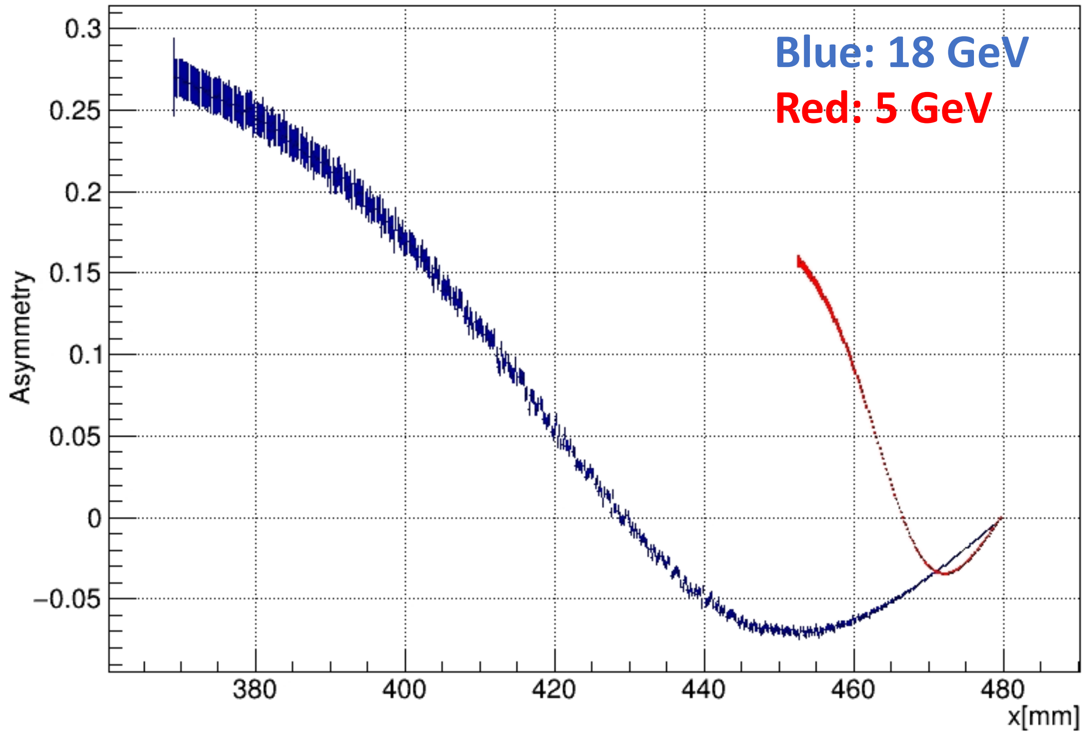




Electron detector challenges

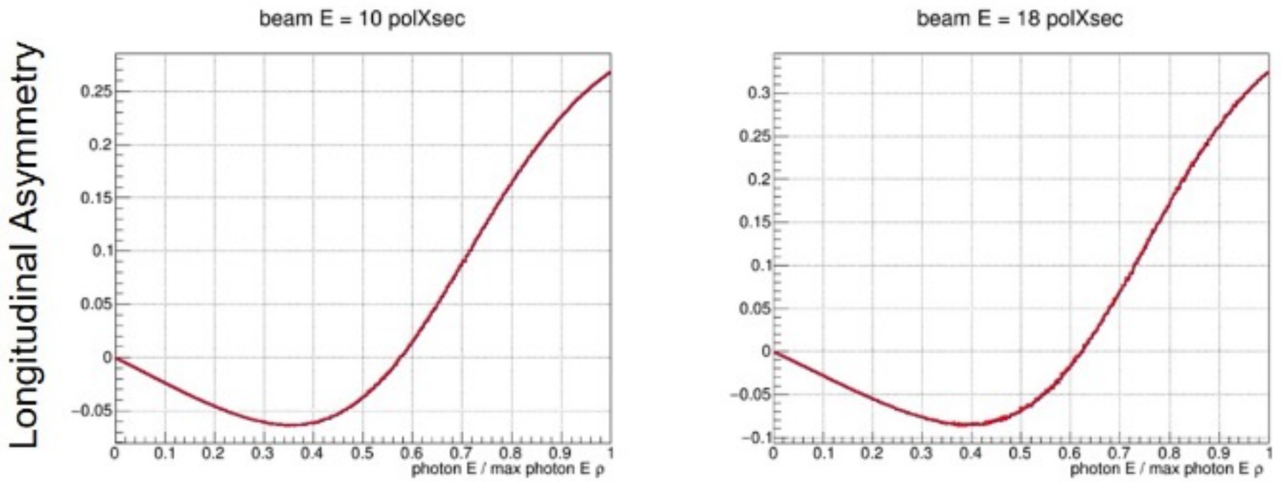
- Getting close enough to the beam to capture the 0-crossing is going to be the biggest challenge
- The vacuum vessel for the detector and moving mechanism (similar to a Roman Pot) will need to be carefully designed to take into account power depositions
- Only horizontal segmentation is going to be required with only modest requirements (5 GeV configuration will set the pitch while the overall size will be given by the 18 GeV configuration)
  - At JLab we obtained very good results with approximately 30 bins from the Compton edge to the 0-crossing leading to about 0.5mm pitch

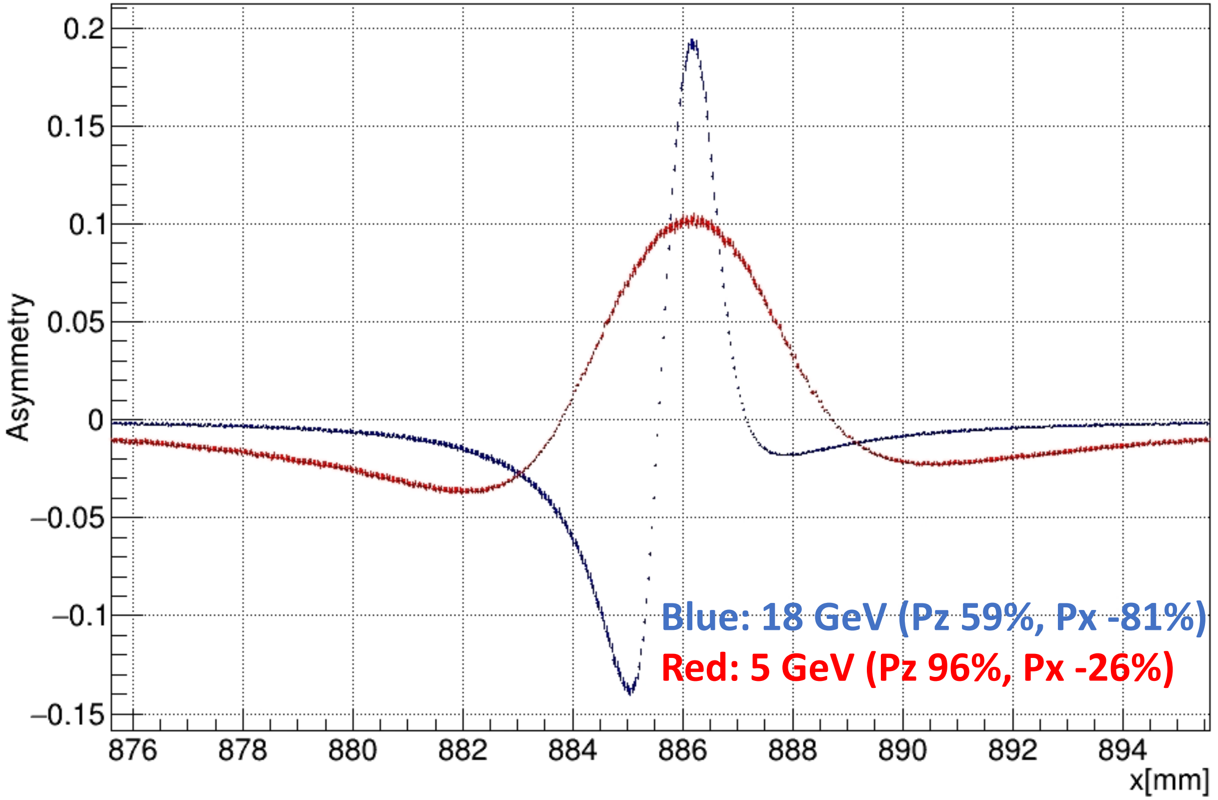




Scattered photons

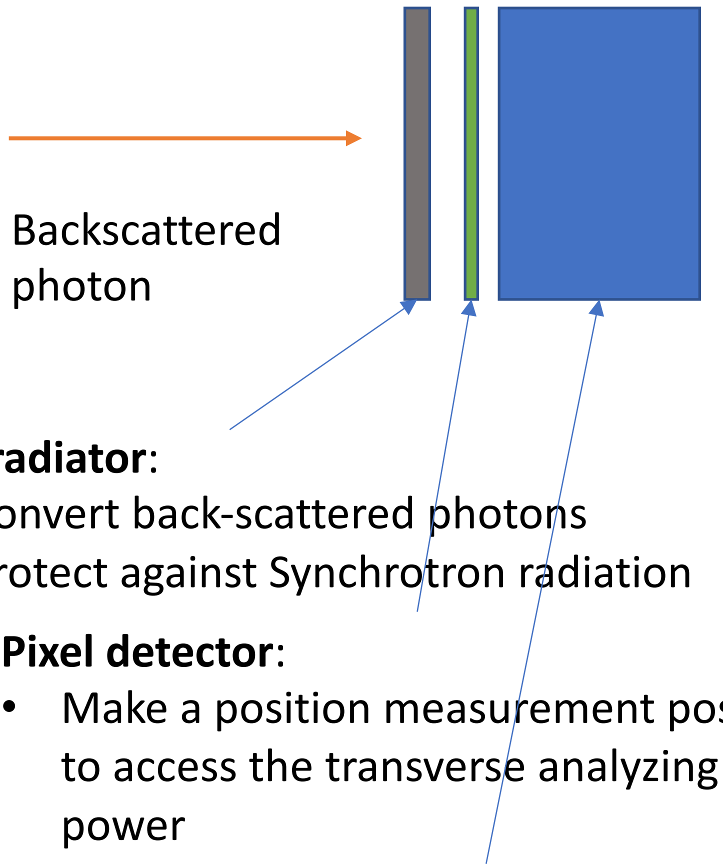
- The scattered photons will carry information about both the longitudinal and transverse electron beam polarization
  - The longer travel distance from the IP makes the transverse measurement manageable
- To extract this information a combination of position and energy information for each photon is required





Photon detector challenges

- The photon detector will necessarily be the workhorse of the EIC Compton measurement
  - The only location where the transverse component can be measured
- Lead tungstate crystals are a good candidate (although the slow component of the response is significantly larger than the minimum spacing of 10 ns)
- Initial studies on the position resolution requirements show that something on the order of 100-400 microns should be sufficient with a transverse size of approximately >1cm to be able to capture most of the cone
- Different technologies are considered for the positional detector including diamond strip detector which provide much higher radiation hardness



Pre-radiator:

- Convert back-scattered photons
- Protect against Synchrotron radiation

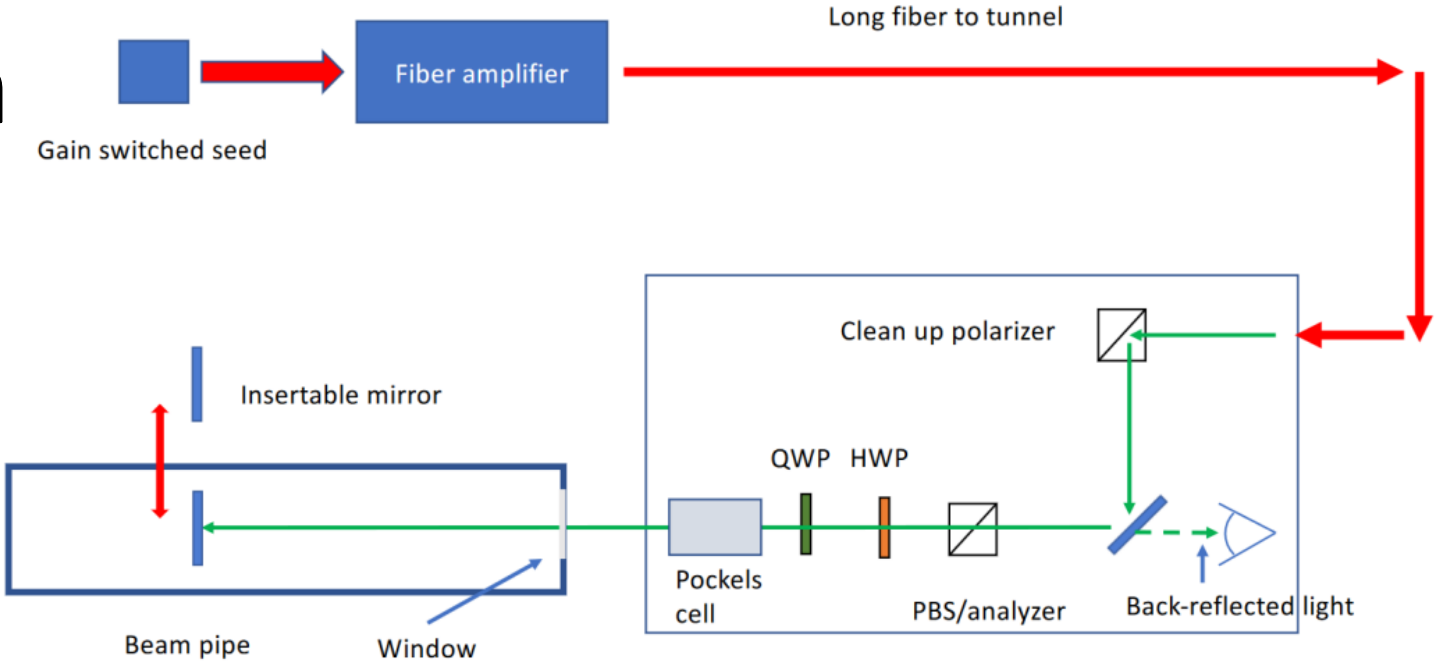
Pixel detector:

- Make a position measurement possible to access the transverse analyzing power

Calorimeter:

- We need a relatively fast response time and good resolution up to 3 GeV
- Redundant measurement of the longitudinal component

Compton laser system

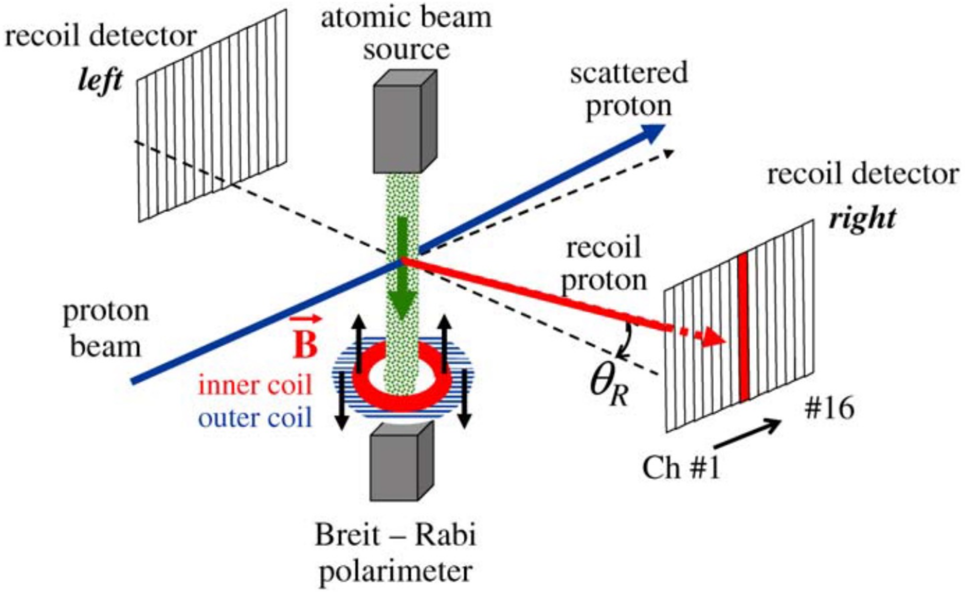


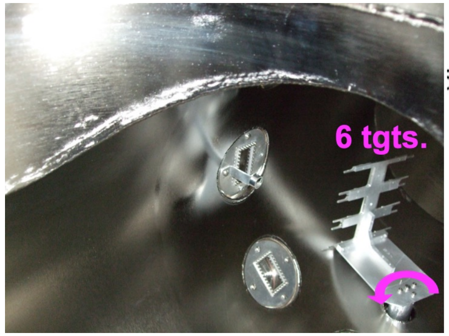
532nm (frequency doubled) pulsed laser system
-> taking inspiration from similar systems implemented at JLab and Maintz

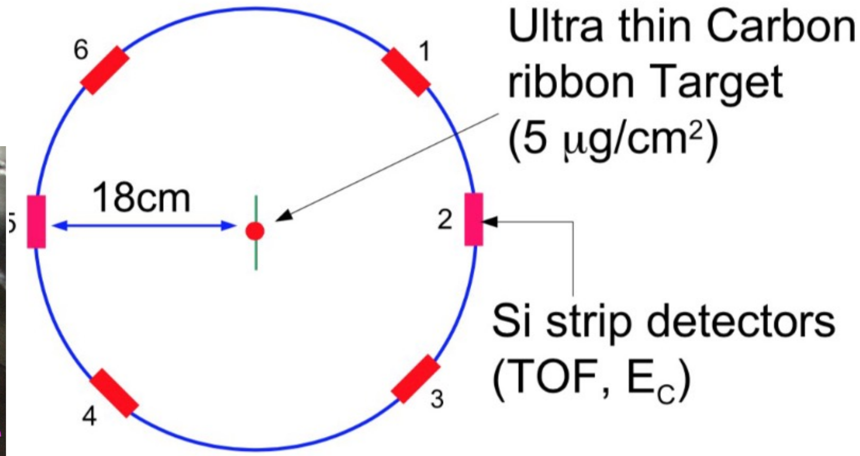
- This laser system needs to deliver 10W of power to have enough luminosity to make these measurements in a short amount of time (on the level of 1 minute at 18GeV for 1% statistical precision)
- The laser will be locked to the RF which will enable longitudinal polarization profile measurements with minimal tuning
  - Background measurements will be feasible again through tuning the phase of the laser with respect to the RF

Some thoughts about ion polarimetry

- To design an effective polarimeter for deuteron and He3 we can start looking closely at what we do for polarized protons
  - The Hjet measurement is non-invasive (low luminosity) absolute measurement of the proton polarization
  - The pC measurement is invasive but high luminosity giving information about the polarization degradation through the life of the store and the polarization profile in the beam







W. Schmidke: https://indico.bnl.gov/event/7583/contributions/38670/attachments/29062/45020/EIC_Polar_Wrkshp_RHIC2EIC.pdf

3Helium measurements

https://indico.bnl.gov/event/5376/contributions/25370/attachments/20976/28310/EICnhb2018nov30.pdf
https://indico.bnl.gov/event/7583/contributions/38674/attachments/29059/45014/2020.06.29_HJET-He3.pdf

- Calculations by N. Buttimore show that 3He analyzing powers could be sizeable for both jet and C measurements
  - Further refinements are still needed that take into account electromagnetic and hadronic form factors
  - Vector polarized d-C A_N is ~10% of the 3He-C A_N
- Making measurements scattering polarized 3He from a jet of polarized 3He could potentially significantly reduce theoretical uncertainties (see discussion from A.A. Poblaguev)
- Having experimental determinations of these analyzing powers would be ideal

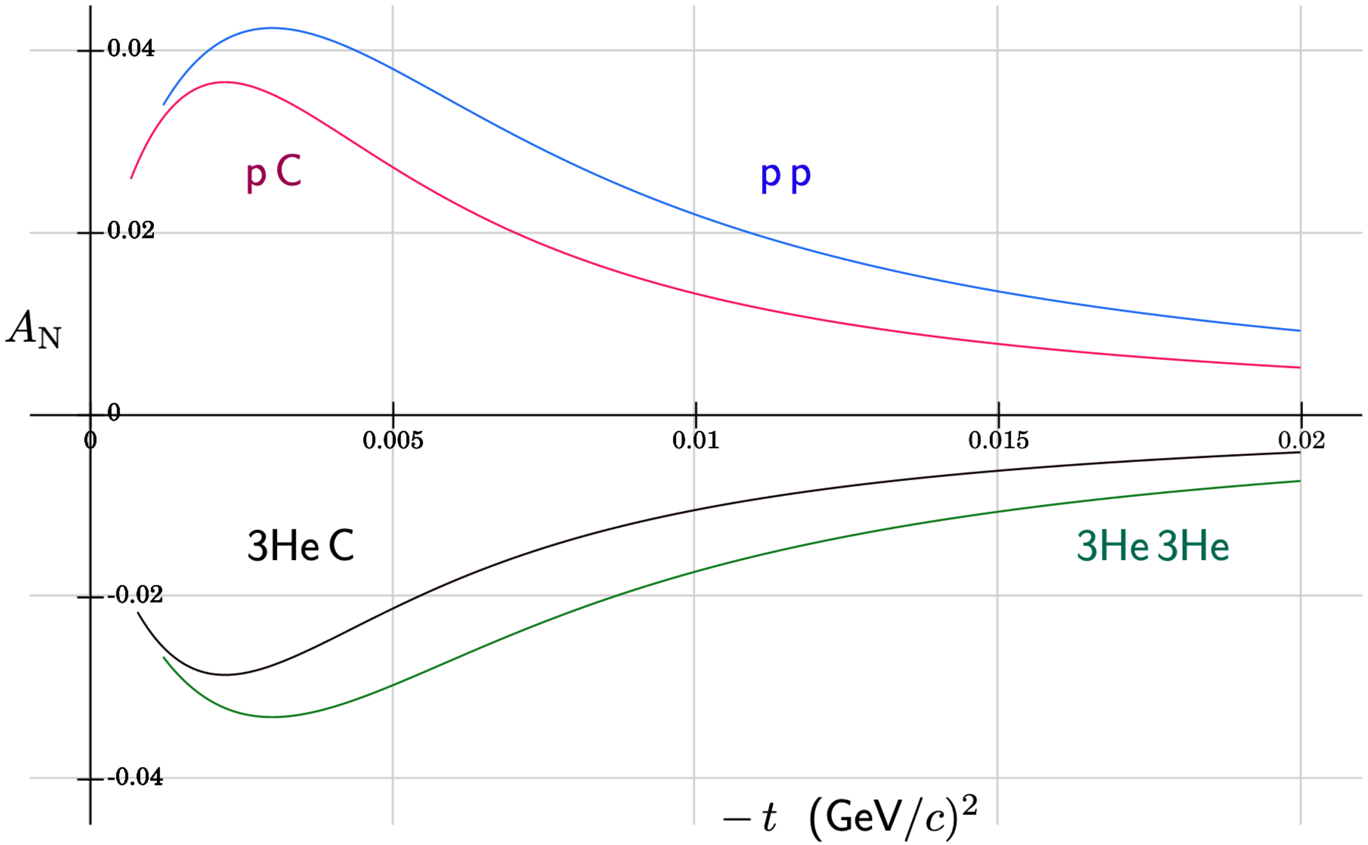


Figure 3: Analyzing power A_N versus invariant momentum transfer (-t) in $(\mathrm{GeV}/c)^2$ for (1) p p and p h scattering, (2) p C scattering, (3) h C scattering, (4) h h and h p scattering

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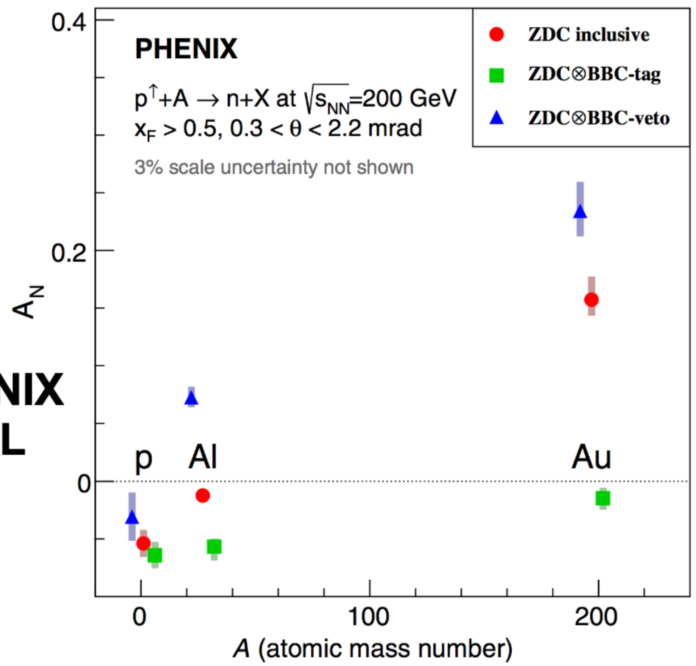
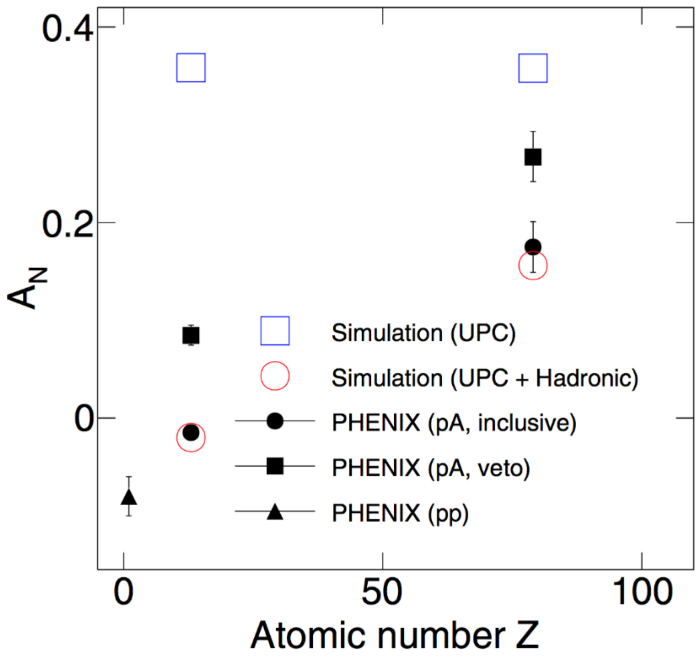
Ultra-peripheral collision asymmetry

PHENIX PRL

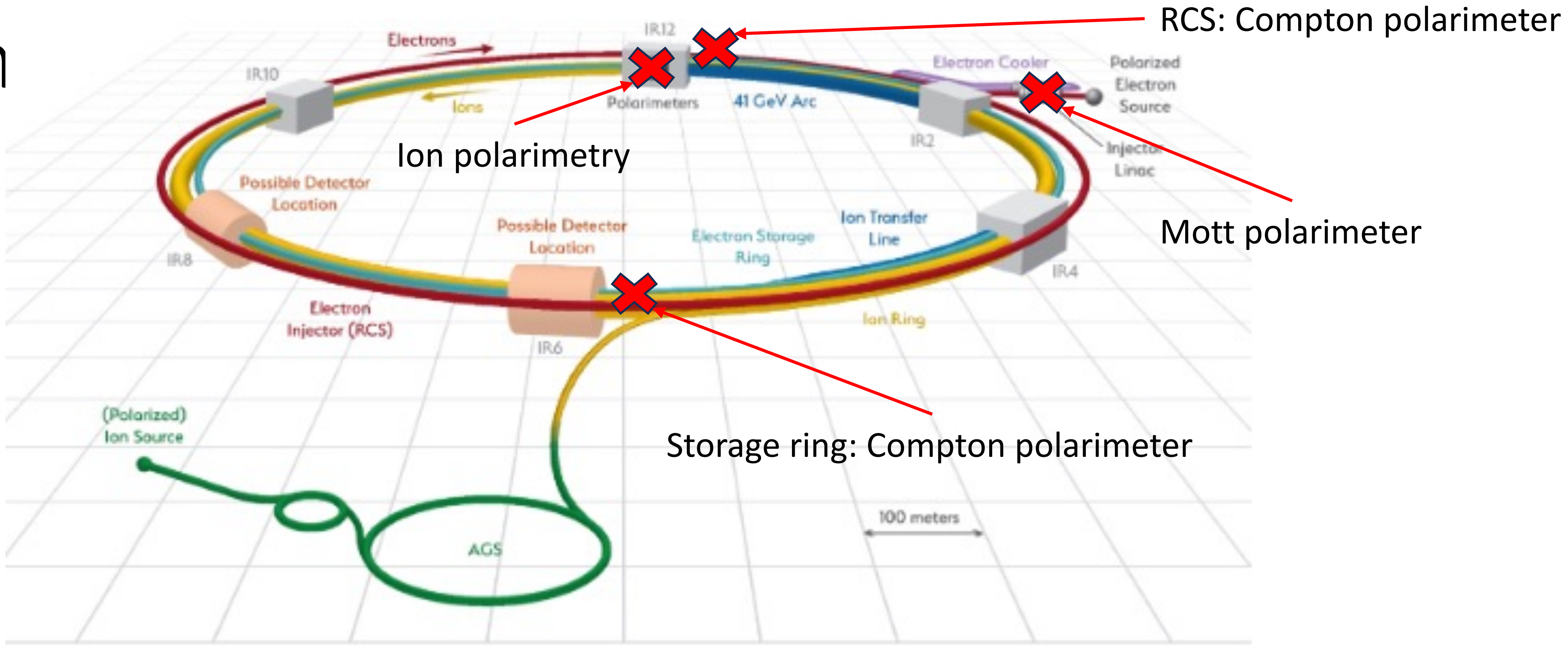




Mitsuka PRC

- Collisions between polarized protons and high Z targets (Al, Au) has shown a significant analyzing power when measuring the neutrons in a ZDC at PHENIX
  - The UPC models seem to describe the results fairly well
- It would be interesting to see if we could get similar effects in measurements with polarized d of 3He
  - Studies underway at RHIC to see if this could be used as proton polarimeter so setup would be available once polarized d and 3He can be run

Conclusion



- With the current design of the Compton polarimeter we should be able to reach the high precision goal of 1% for electron polarization measurements
- There are several ideas on how we could make measurements of polarized light ions, but those will require more work both theoretically and experimentally to put them on solid ground

Backups