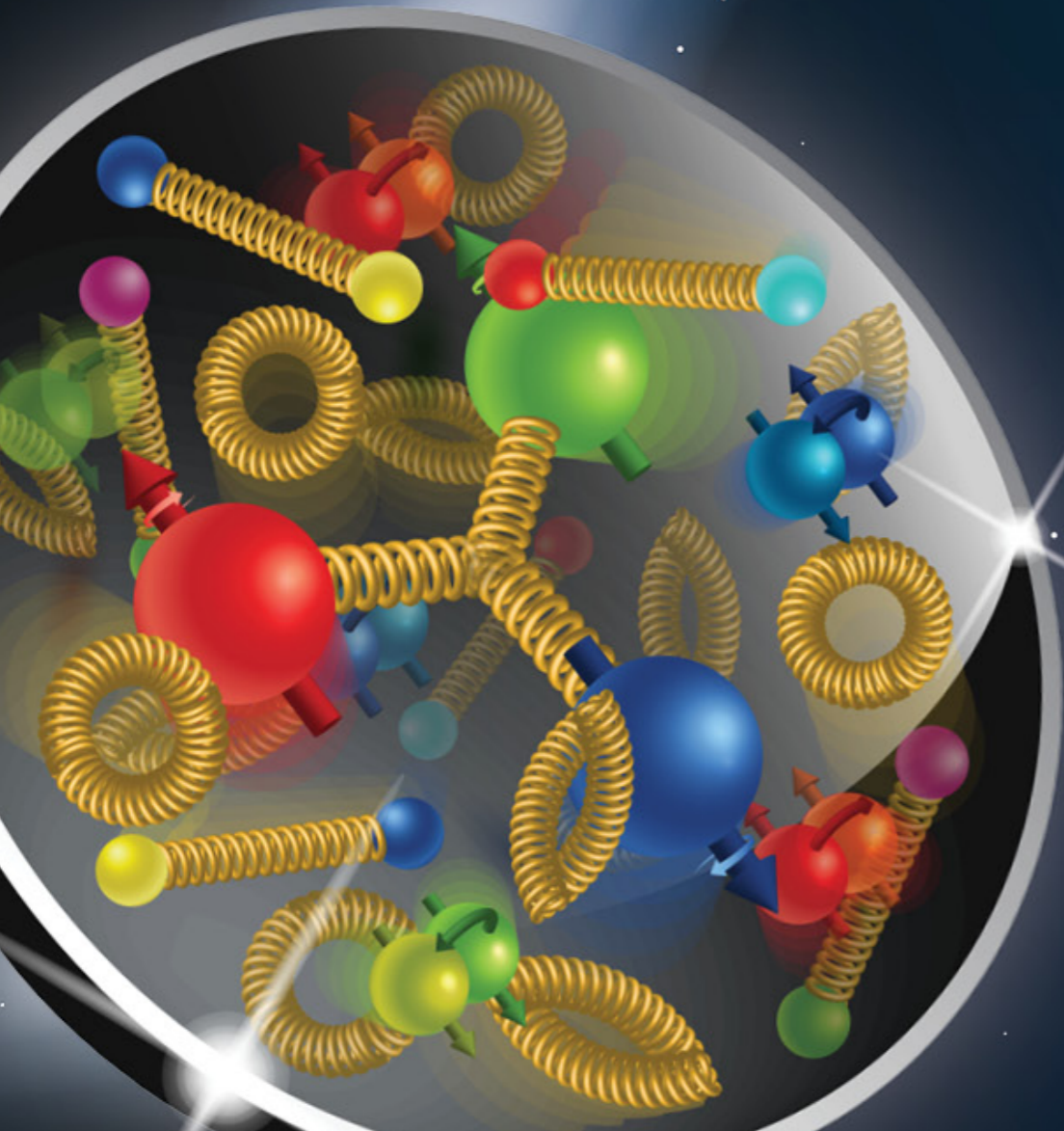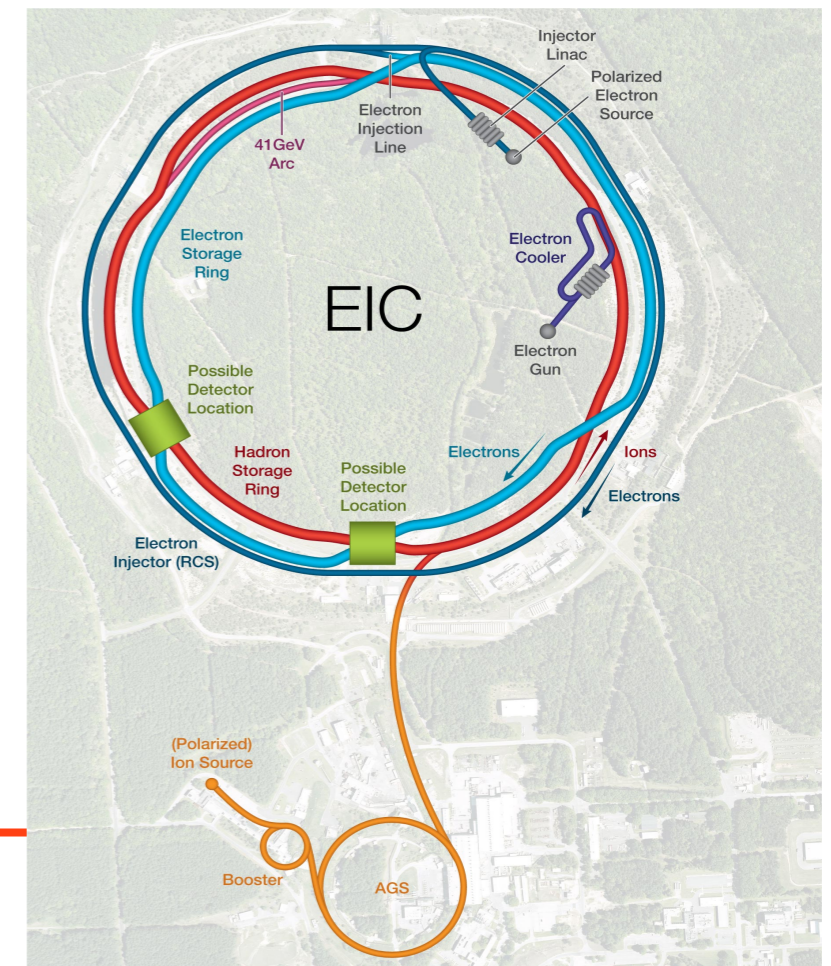# Compton Polarimeters in EIC

Zhengqiao Zhang

Brookhaven National Laboratory

Electron-Ion Collider

Electron-Ion-Collider (EIC)

EIC Design Goals:

- Large range of center of mass energies: E_{cm} = 20-140 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): $L = (0.1\text{-}1)\cdot 10^{34}\ cm^{-2} s^{-1}$ —>10-100 fb^{-1};

  ➡ Studying observables as a fact of x, Q^2, A, etc.

- Collisions of highly polarized e and p (and light ion) beams with flexible bunch by bunch spin patterns: $\geq 70\%$;

  ➡ Access to spin structure and 3D spatial and momentum structure

- Good background conditions;

- EIC is using part of RHIC facility at BNL which is operating at its peak ;

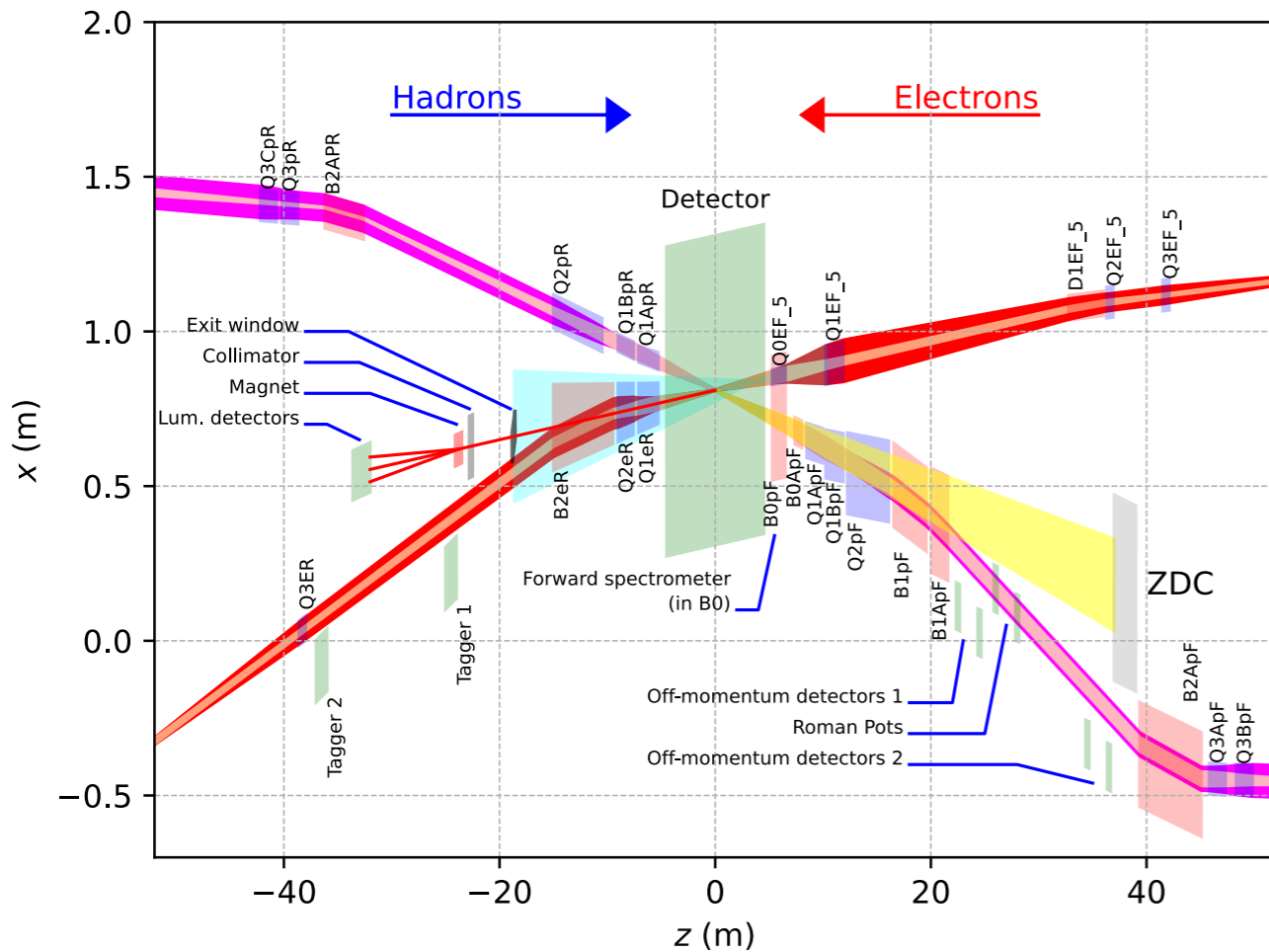# EIC polarimeters
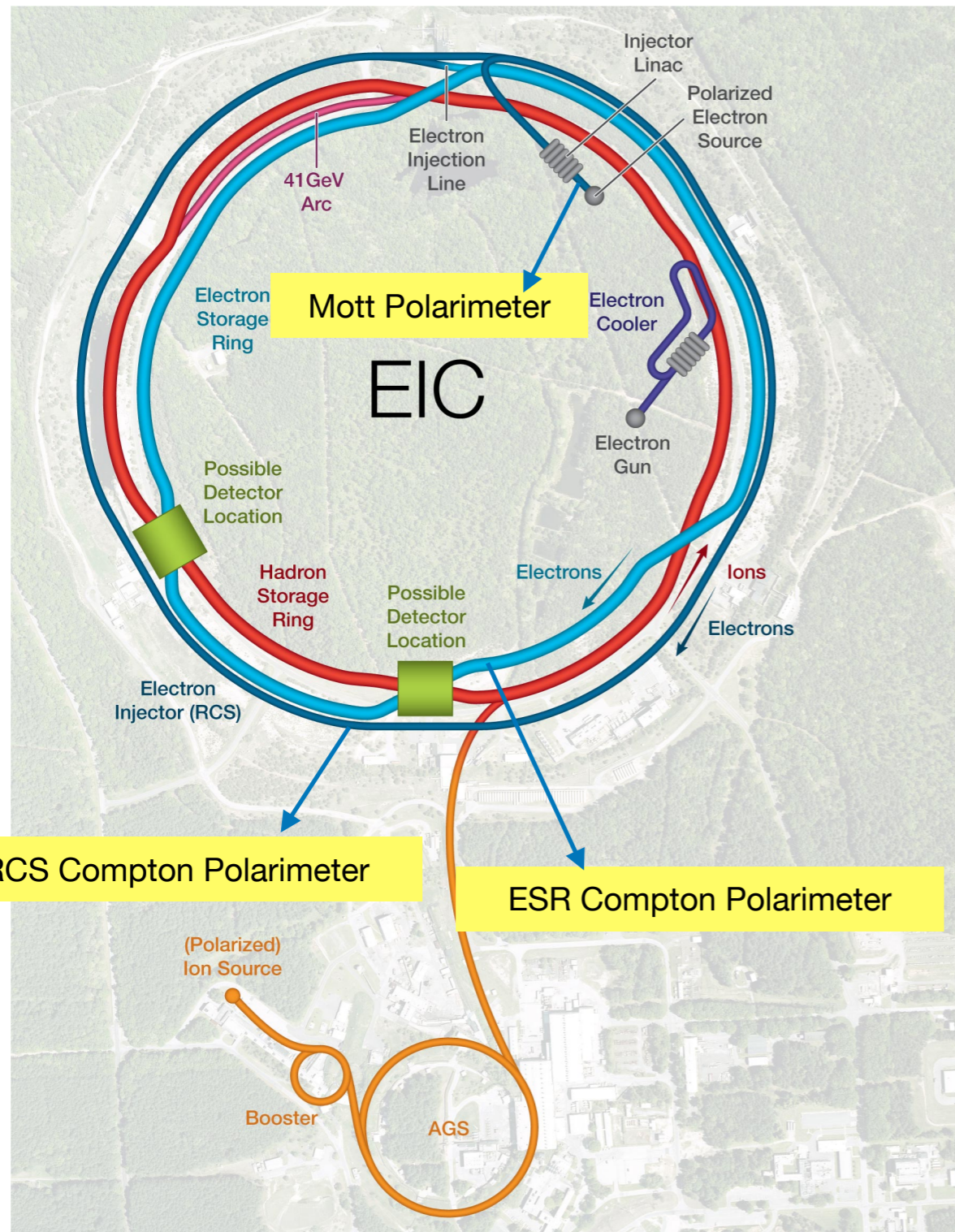
- EIC requires 3 electron polarimeters;

  ▸ Compton Polarimeter in ESR

  ▸ Polarimeter for RCS (A Compton Polarimeter is proposed)

  ▸ Polarimeter at source (Mott Polarimeter)

- Compton polarimeters for RCS and ESR have similarities but will operate in different modes (ESR single photon/counting mode; RCS multi-photon/integrating mode)
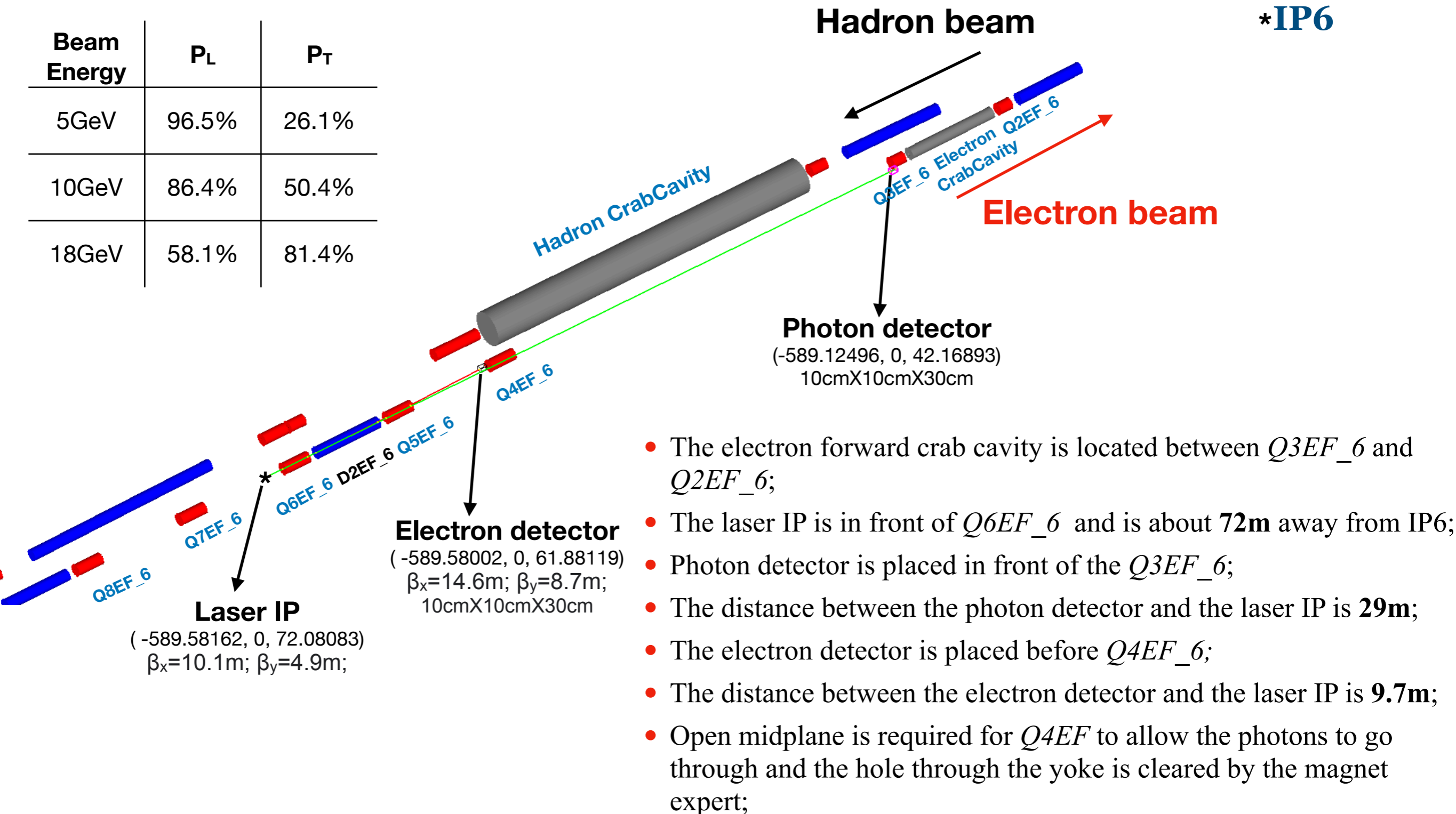
Requirements of electron polarimeter

- The polarimeter needs to be placed as close as possible to IP-6;

- 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 72m away from IP6;

- 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 can be measured by a spatial asymmetry of the Compton photons & electrons;
- Measure bunch-by-bunch polarization;
- Measure with high precision ~1%;

Layout of polarimeter in ESR

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

Hadron beam

***IP6**

Hadron CrabCavity

Q3EF_6 Electron Q2EF_6 CrabCavity

Electron beam

Photon detector
(-589.12496, 0, 42.16893)
10cmX10cmX30cm

Q4EF_6

Q5EF_6

Q6EF_6 D2EF_6

Q7EF_6

*

Q8EF_6

Electron detector
(-589.58002, 0, 61.88119)
β_x=14.6m; β_y=8.7m;
10cmX10cmX30cm

Laser IP
(-589.58162, 0, 72.08083)
β_x=10.1m; β_y=4.9m;

- The electron forward crab cavity is located between *Q3EF_6* and *Q2EF_6*;
- The laser IP is in front of *Q6EF_6* and is about **72m** away from IP6;
- Photon detector is placed in front of the *Q3EF_6*;
- The distance between the photon detector and the laser IP is **29m**;
- The electron detector is placed before *Q4EF_6;*
- The distance between the electron detector and the laser IP is **9.7m**;
- Open midplane is required for *Q4EF* to allow the photons to go through and the hole through the yoke is cleared by the magnet expert;

Species	proton	electron
Energy [GeV]	275	18
CM energy [GeV]	140.7	
Bunch intensity [10^{10}]	18.9	6.2
No. of bunches	290	
Beam current [A]	0.69	0.227
RMS norm. emit., h/v [μm]	5.2/0.46	845/70
RMS emittance, h/v [nm]	17.6/1.6	24.0/2.0
β^*, h/v [cm]]	417/38	306/30
IP RMS beam size, h/v [μm]	271/24	
K_x	11.1	
RMS $\Delta\theta$, h/v [μrad]	65/65	89/82
BB parameter, h/v [10^{-3}]	3/3	92/100
RMS long. emittance [10^{-3}, eV·s]	36	
RMS bunch length [cm]	6	0.9
RMS $\Delta p/p$ [10^{-4}]	6.8	10.9
Max. space charge	0.007	neglig.
Piwinski angle [rad]	2.8	0.9
Long. IBS time [h]	2.0	
Transv. IBS time [h]	2.0	
Hourglass factor H	0.99	
Luminosity [10^{33}cm^{-2}s^{-1}]	0.32	

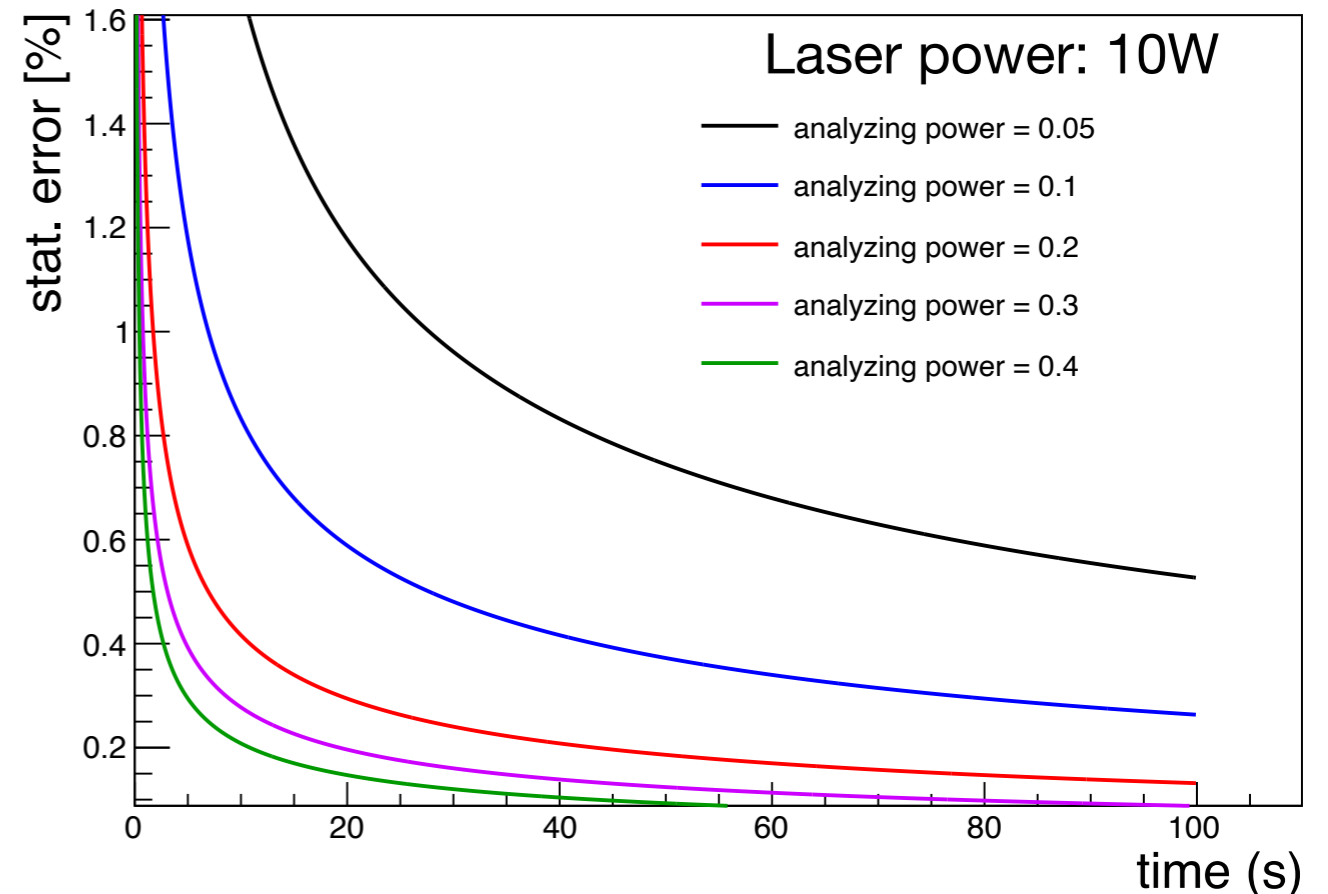"EIC Conceptual Design Report", BNL,
Up- ton, NY, USA, Rep. **EIC CDR, 2021**

$$L = f_b N_e N_\gamma G$$

Geometric factor:

$$G = \frac{1 + \beta cos\theta}{2\pi\sqrt{\sigma_y^2 + \sigma_{\gamma y}^2}\sqrt{\sigma_x^2(\beta + cos\theta)^2 + \sigma_{\gamma x}^2(1 + \beta cos\theta)^2 + (\sigma_z^2 + \sigma_{\gamma z}^2)sin^2\theta}}$$

$$f_b = 2.2852 \times 10^7; Ne = 6.2 \times 10^{10}; N_\gamma = 2.84974 \times 10^{12};$$

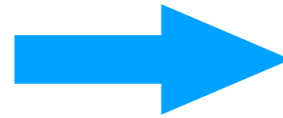$$\sigma_{\gamma x} = 0.1 mm; \sigma_{\gamma y} = 0.1 mm; \sigma_{\gamma z} = 1.3 mm;$$

RCS Compton Polarimeter

RCS properties

- RCS accelerates electron bunches from 0.4GeV to full beam energy (5-18 GeV)

- Bunch frequency —> 2Hz

- Bunch charge —> up to 28 nA

- Ramping time = 100 ms

Polarimetry challenges

- 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)
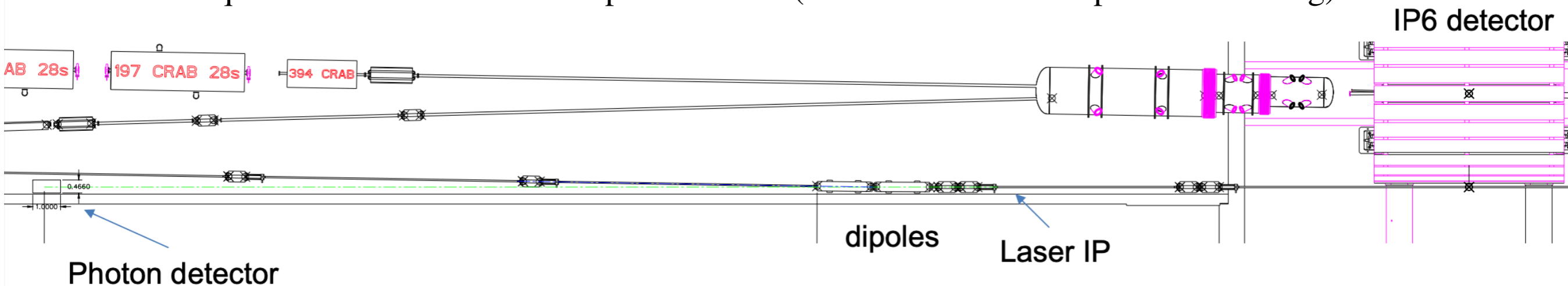
Summary

- EIC requires 3 lepton polarimeters;

- RCS Polarimetry integrated in the inner IR-6 region;

- ESR Polarimeter integrated 72 m away from IP-6;

- High precision bunch by bunch polarization measurements are critical for the EIC physics program;

Thanks.