Electron Polarimeter

Zhengqiao Zhang

BROOKHAVEN NATIONAL LABORATORY
U.S. DEPARTMENT OF ENERGY | Office of Science

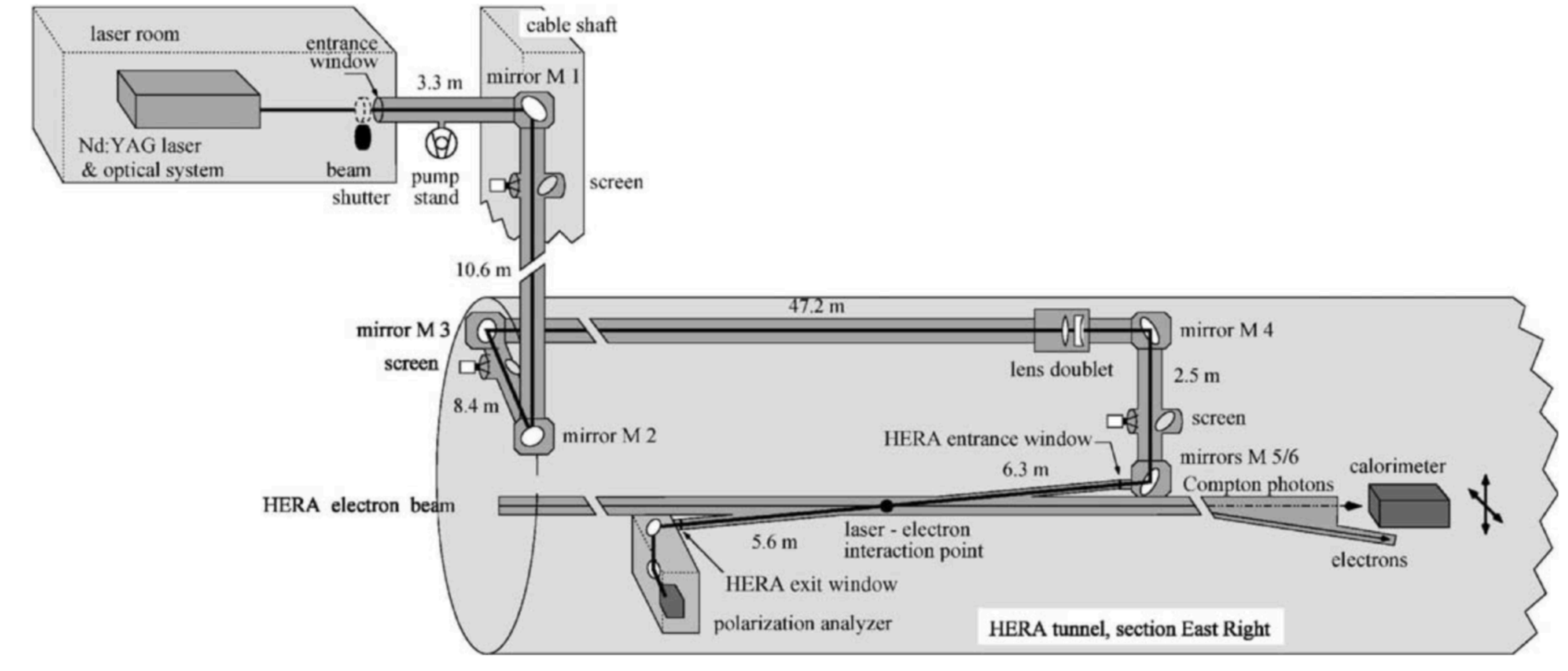
Requirements of electron polarimeter

- To be placed at IR12;
- Need to measure both longitudinal and transverse components;
  - Highly segmented pre-shower and ECal with good energy resolution for γ
  - Highly segmented ECal with good energy resolution and position resolution for lepton
- Need to measure bunch-by-bunch polarization;
- Need to measure with high precision ~1%;
- Moller polarimeter in RCS (interceptive) and Compton scattering polarimeter in storage ring (non-interceptive);

$$A_{exp} = \frac{n^+ - n^-}{n^+ + n^-} = P_e P_\gamma A_l$$

Electron polarimeter in HERA

Layout of the Longitudinal Polarimeter in the HERA East section.



Beckmann M, Borissov A, Brauksiepe S, et al. The longitudinal polarimeter at HERA[J]. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 2002, 479(2-3): 334-348.

Compton scattering

The two leading-order Feynman diagrams for Compton Scattering

We have the routine **comrad.f** that comes from SLAC group.

- It calculates the cross sections for the spin-polarized processes $e^-\gamma \rightarrow e^-\gamma$, $e^-\gamma\gamma$, $e^-e^+e^-$ to order-α^3.
- The code calculates cross sections for circularly-polarized initial-state photons and arbitrarily polarized initial-state electrons.

Swartz M L. Complete order-α 3 calculation of the cross section for polarized Compton scattering[J]. Physical Review D, 1998, 58(1): 014010.

Compton scattering

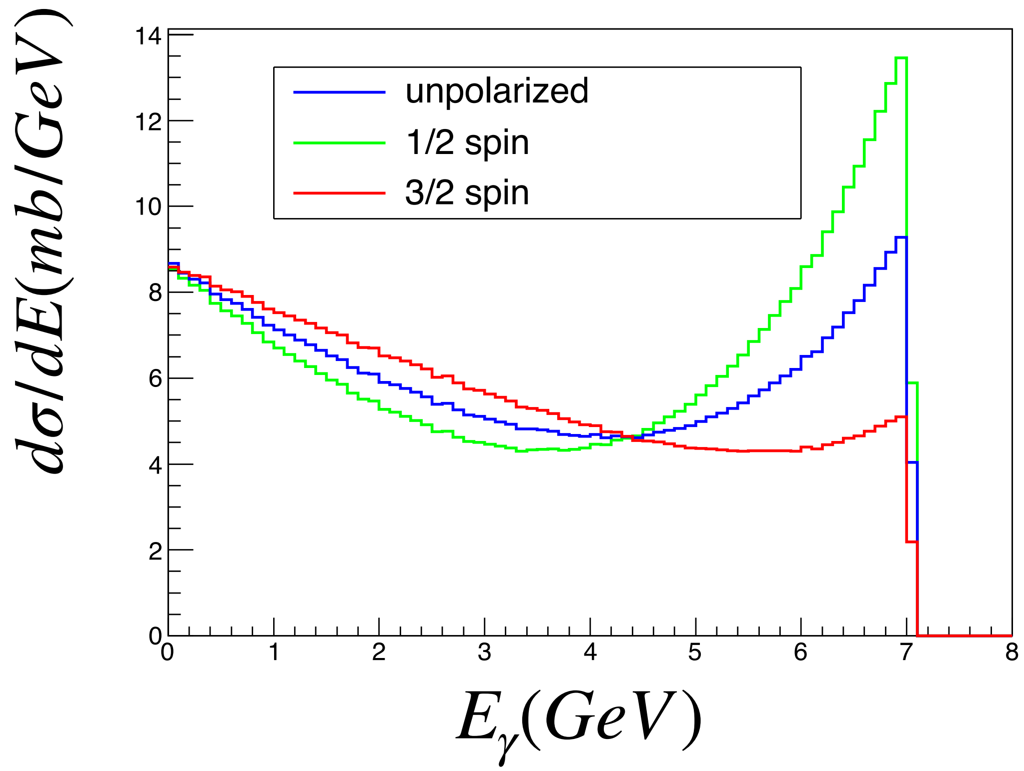
The asymmetry of the energy spectra measured with left and right helicities have been used to measure the longitudinal component of the polarization.

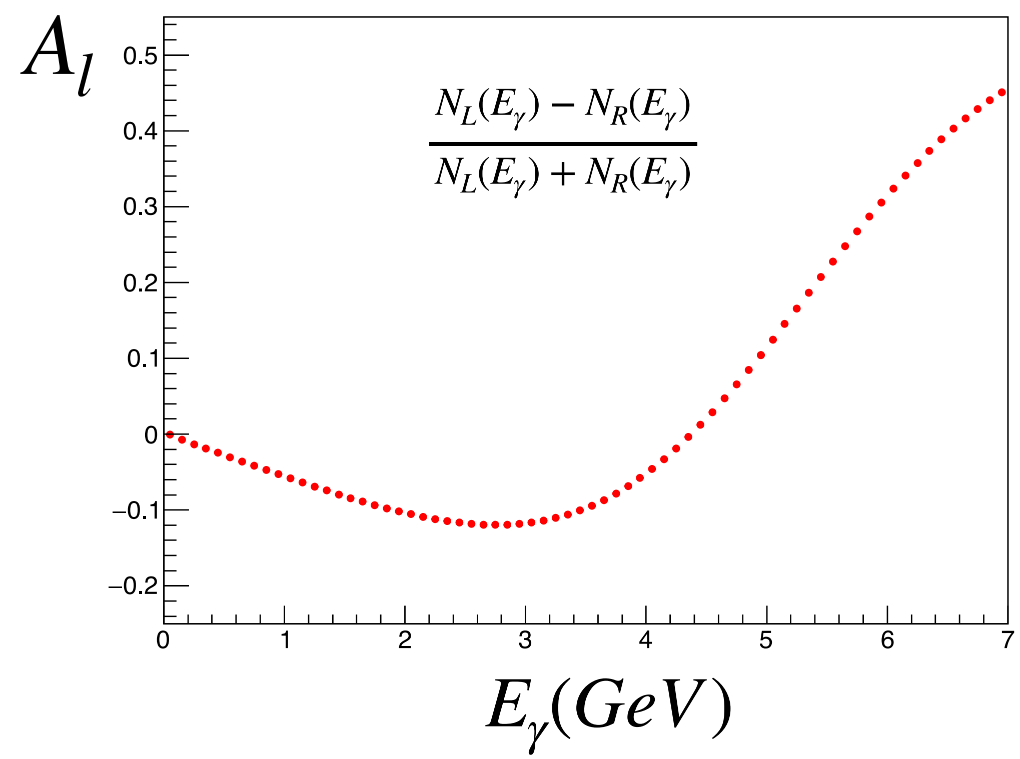
$$A(E_\gamma) = \frac{N_L(E_\gamma) - N_R(E_\gamma)}{N_L(E_\gamma) + N_R(E_\gamma)}$$

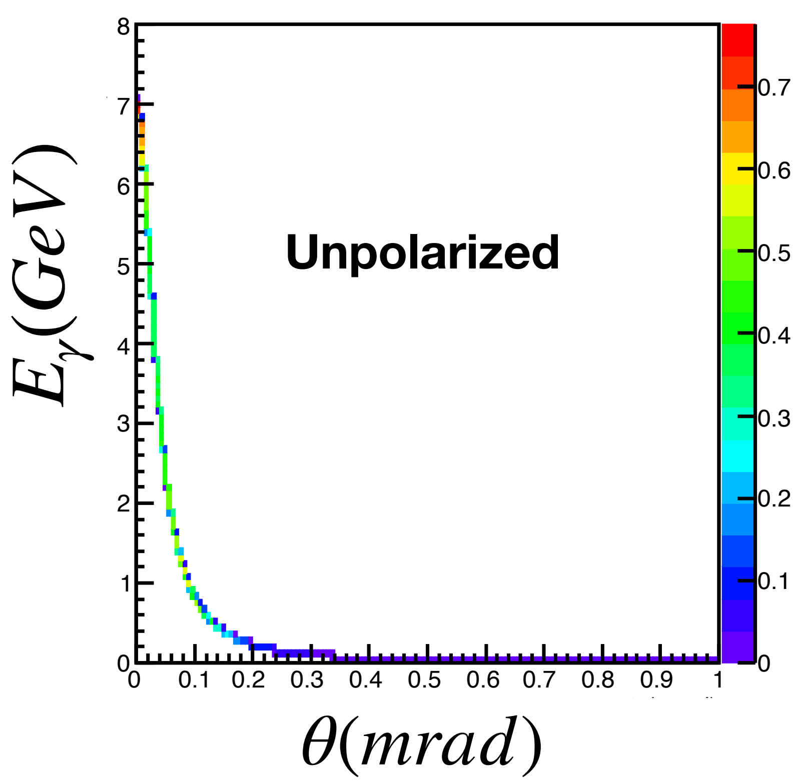
$$A_{exp} = \frac{n^+ - n^-}{n^+ + n^-} = P_e P_\gamma A_l$$

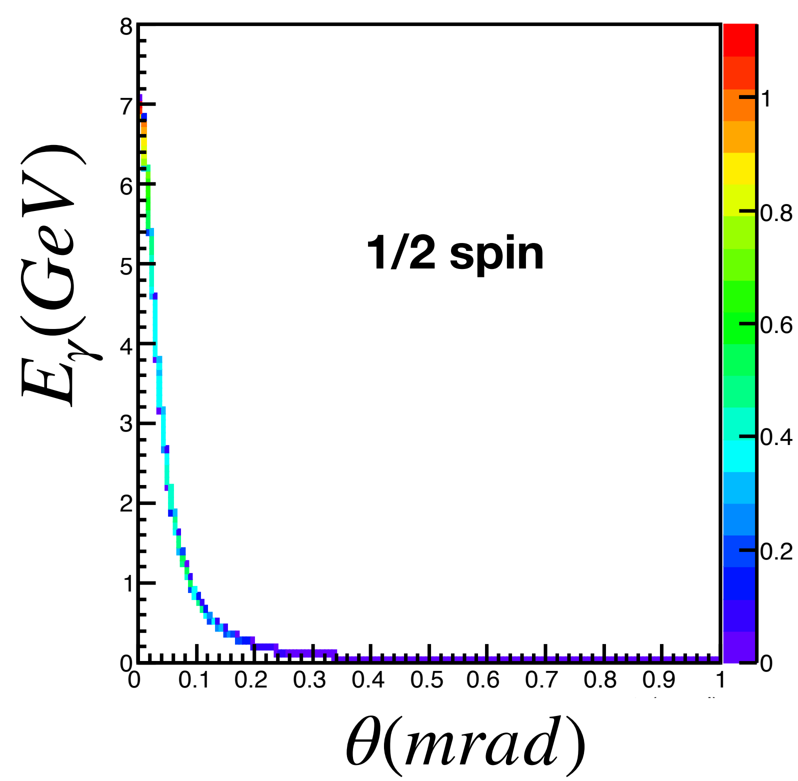
$$P_e = \frac{A_{exp}}{P_\gamma A_l}$$

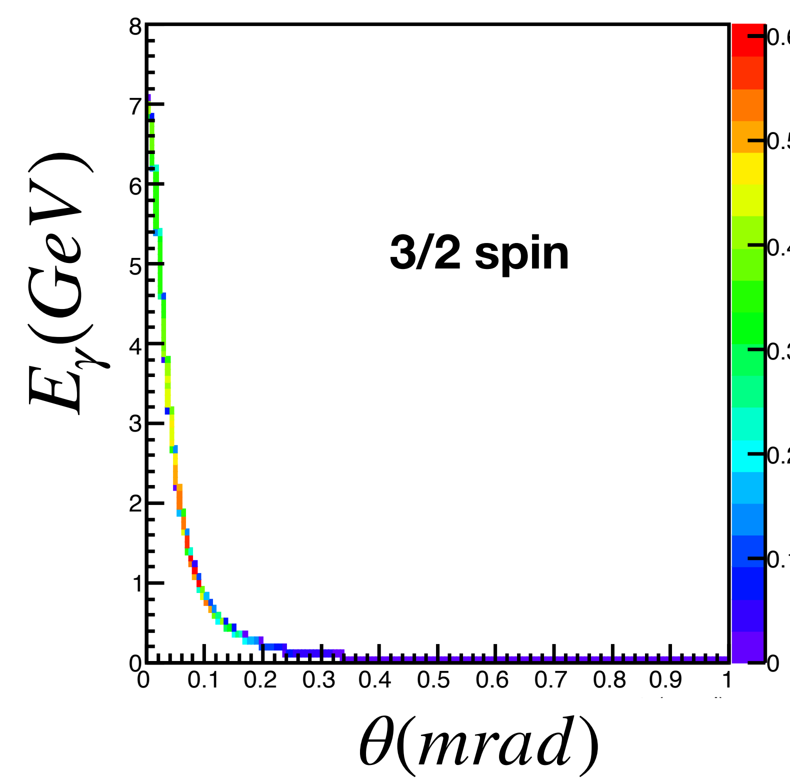
Longitudinal polarization



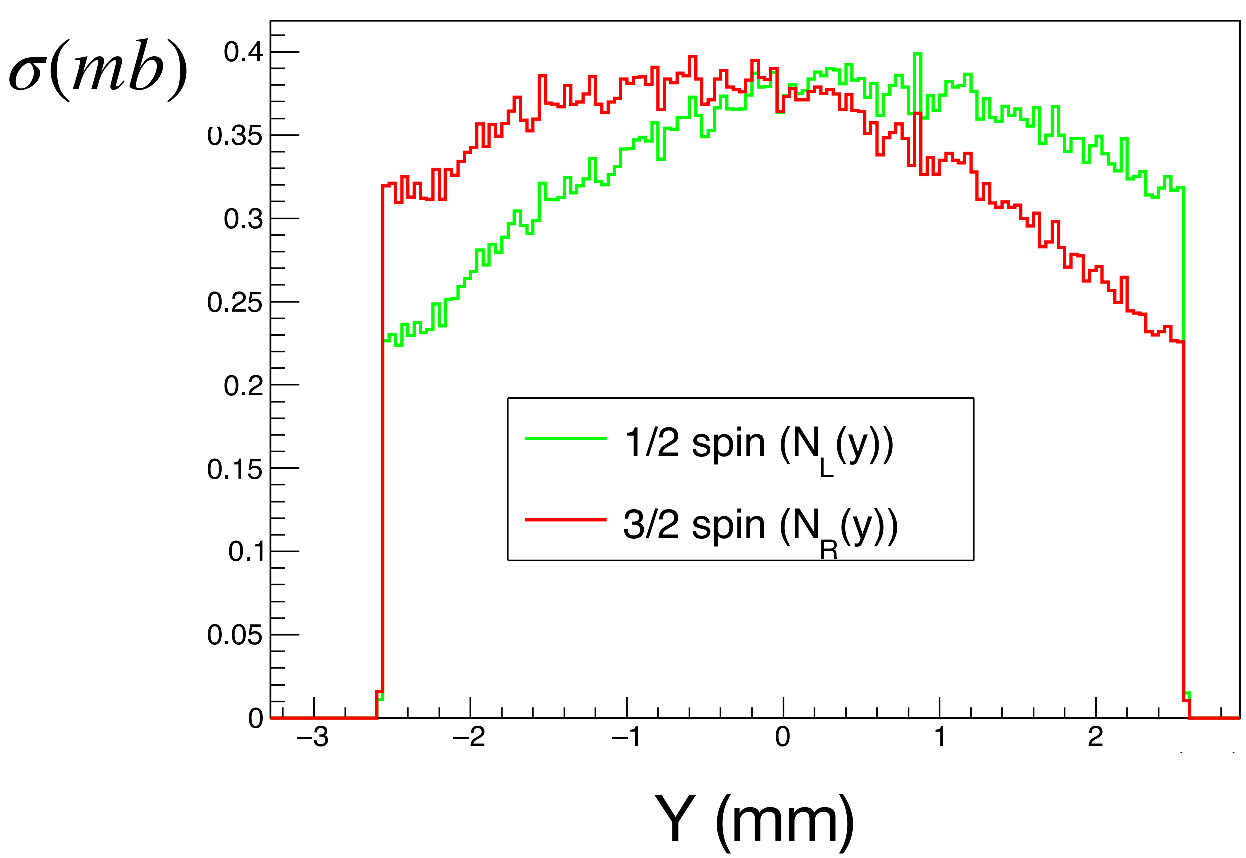


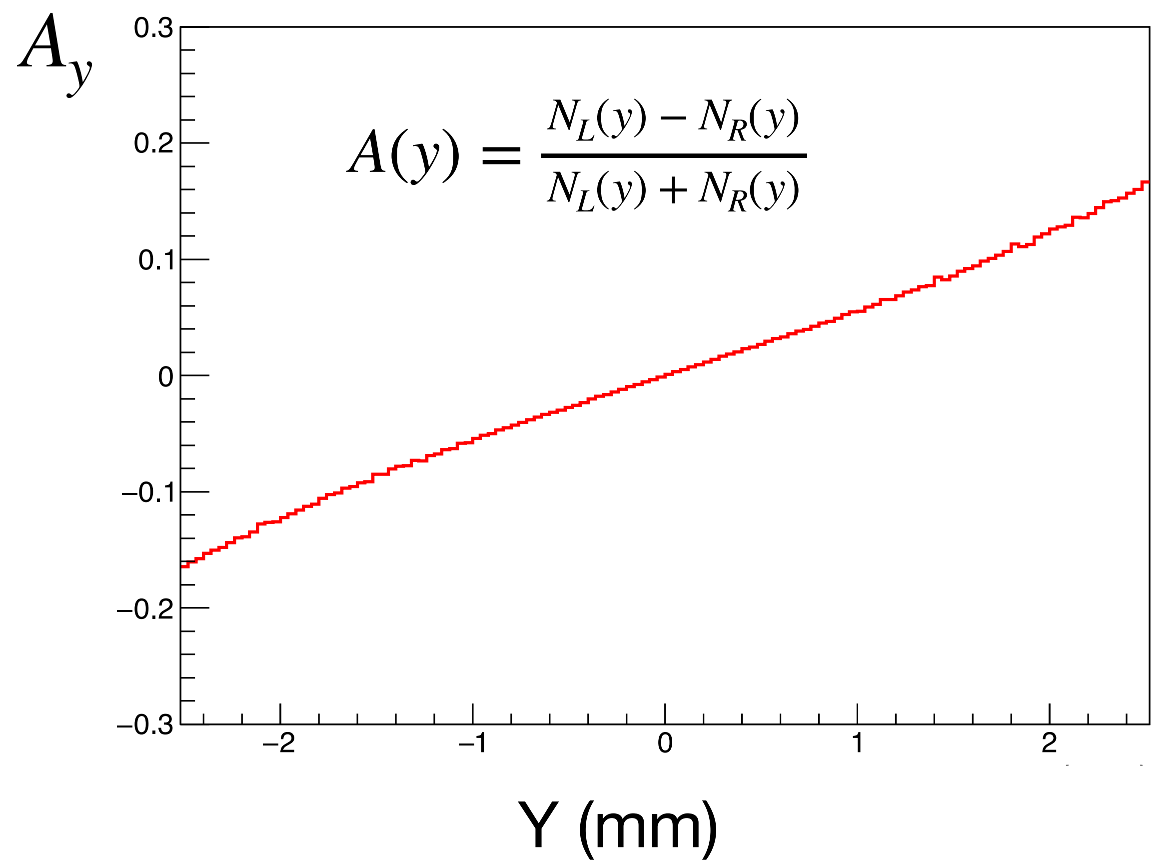






Transverse polarization

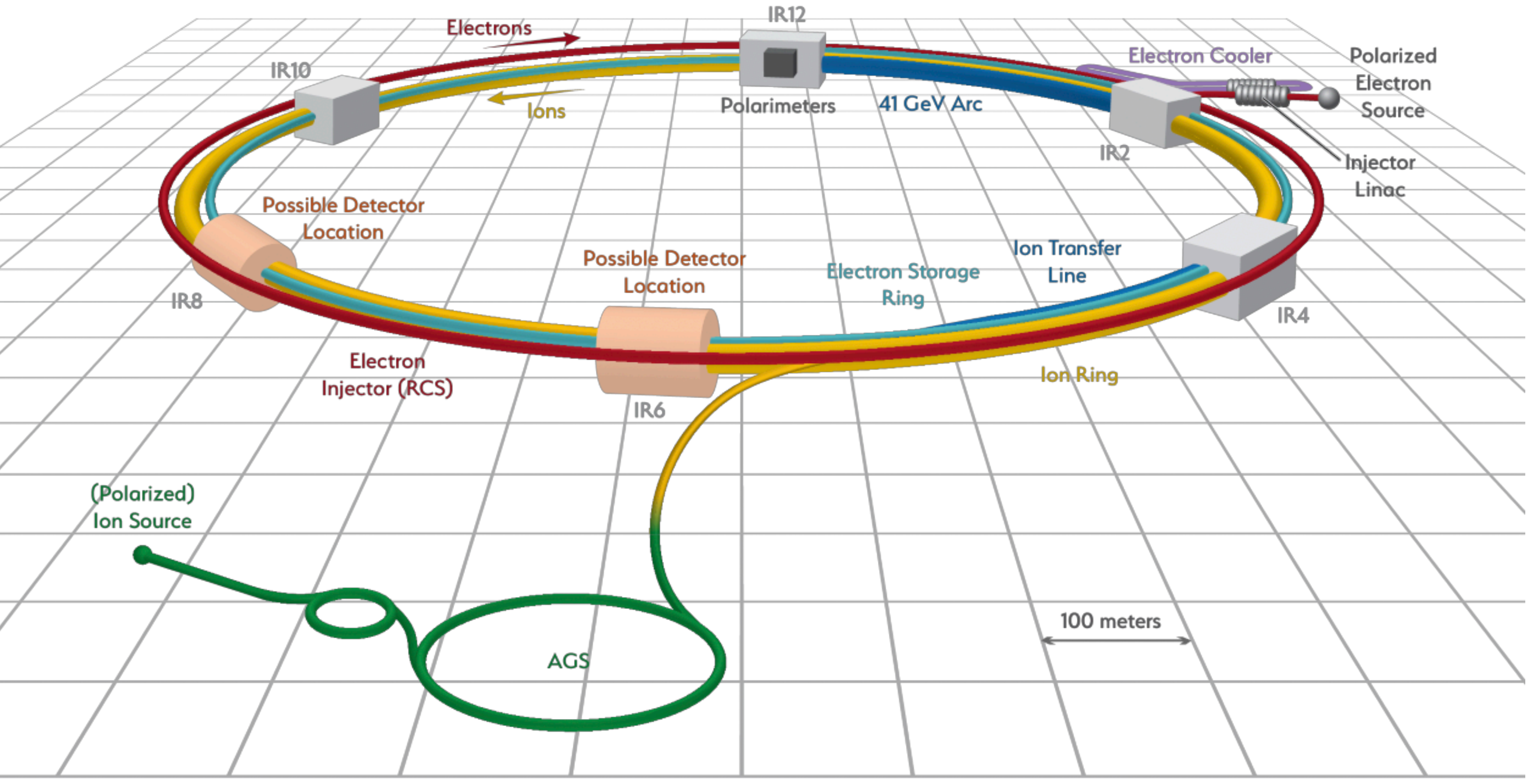




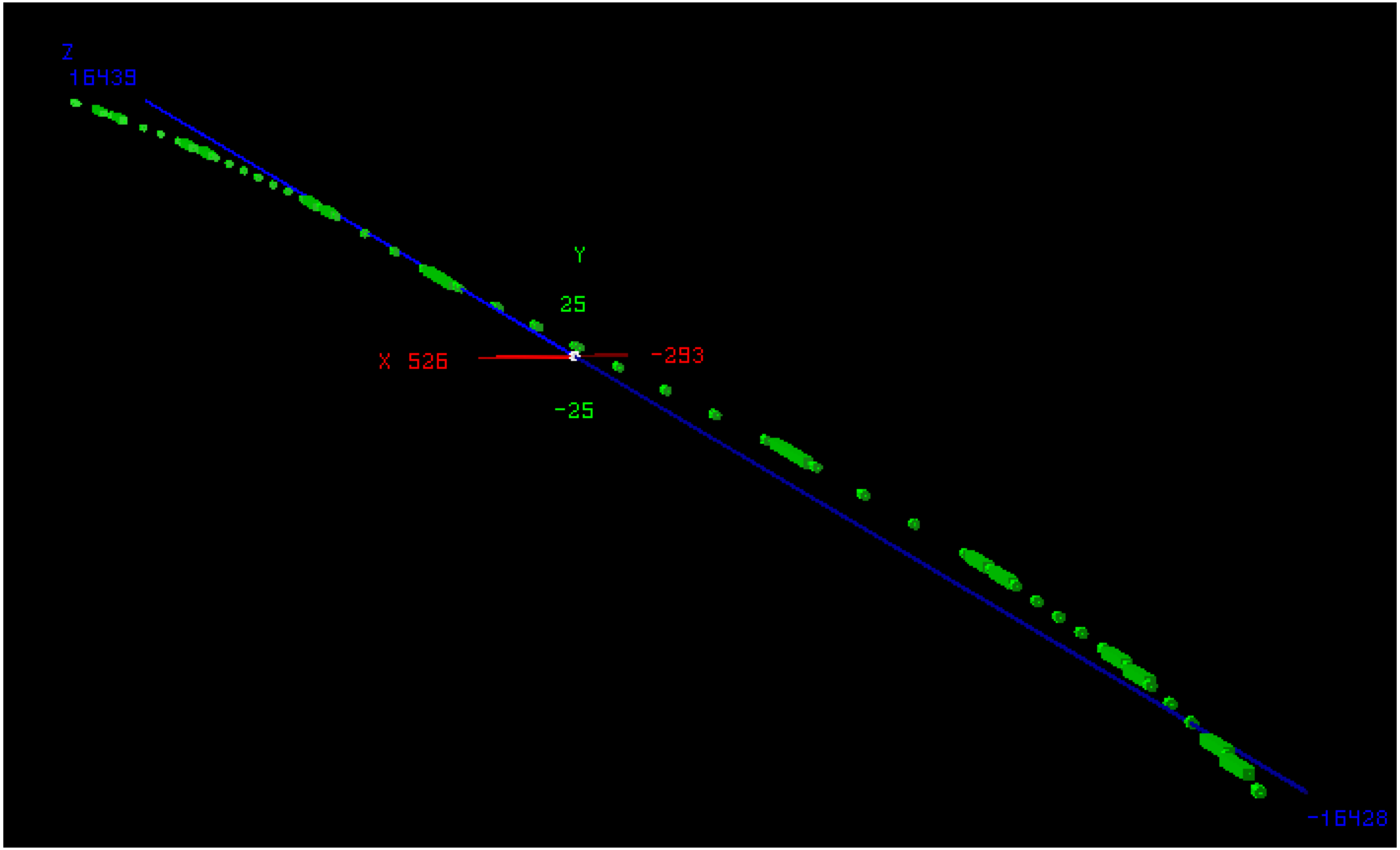
$$A_{exp} = \frac{n^+ - n^-}{n^+ + n^-} = P_e P_\gamma A_y$$

$$P_e = \frac{A_{exp}}{P_\gamma A_y}$$

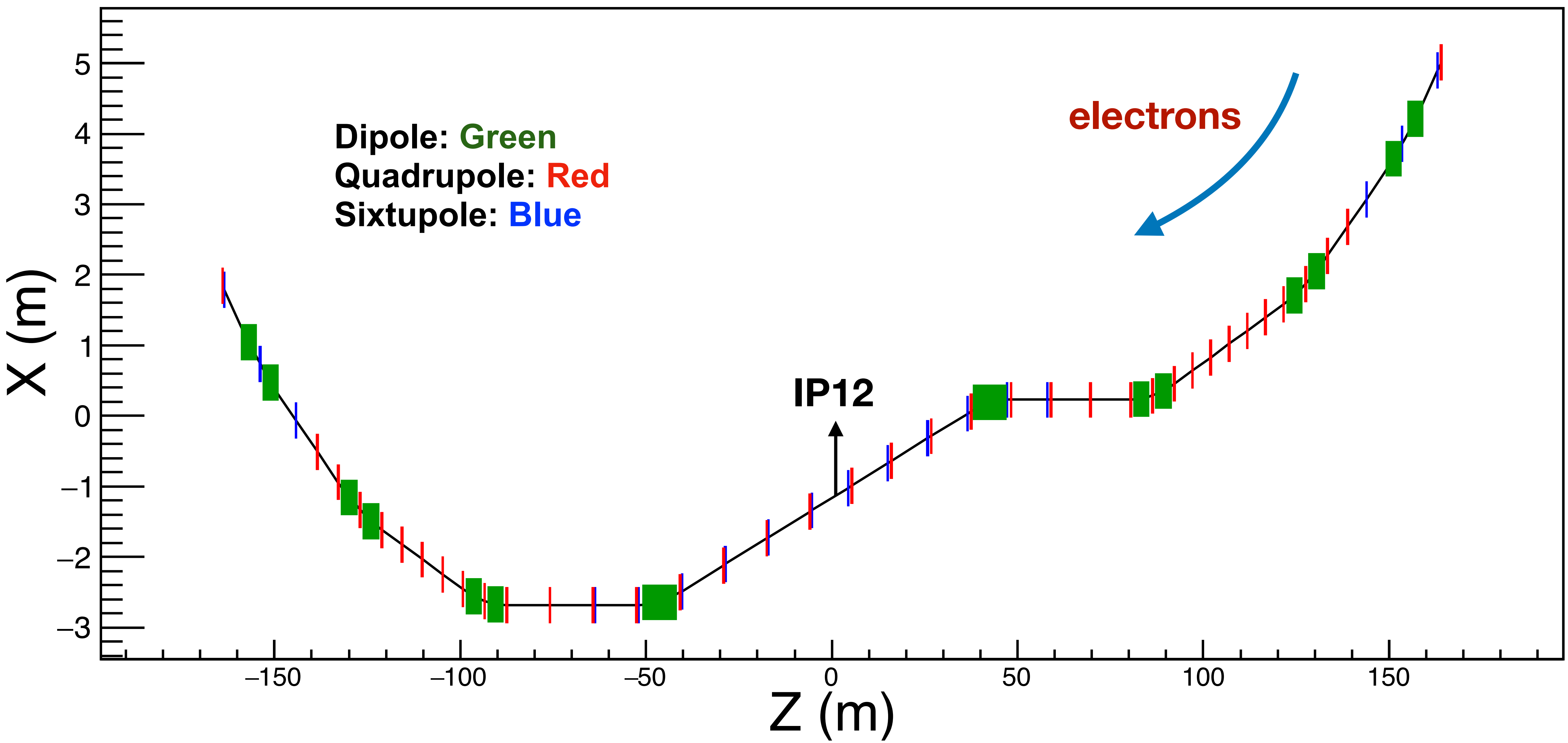
The eRHIC layout



IR12 layout

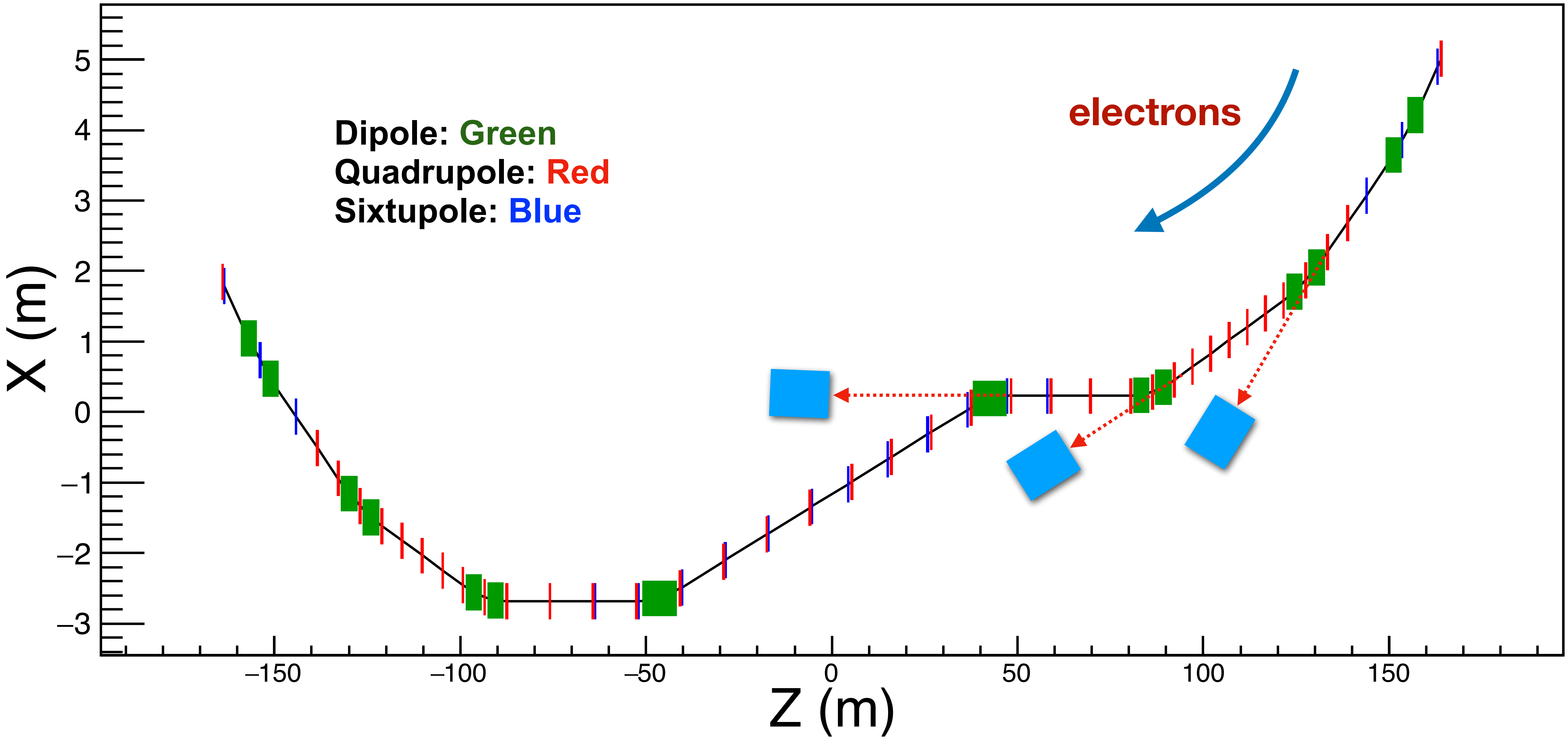


IR12 layout



1 o'clock **12 o'clock** **11 o'clock**

IR12 layout

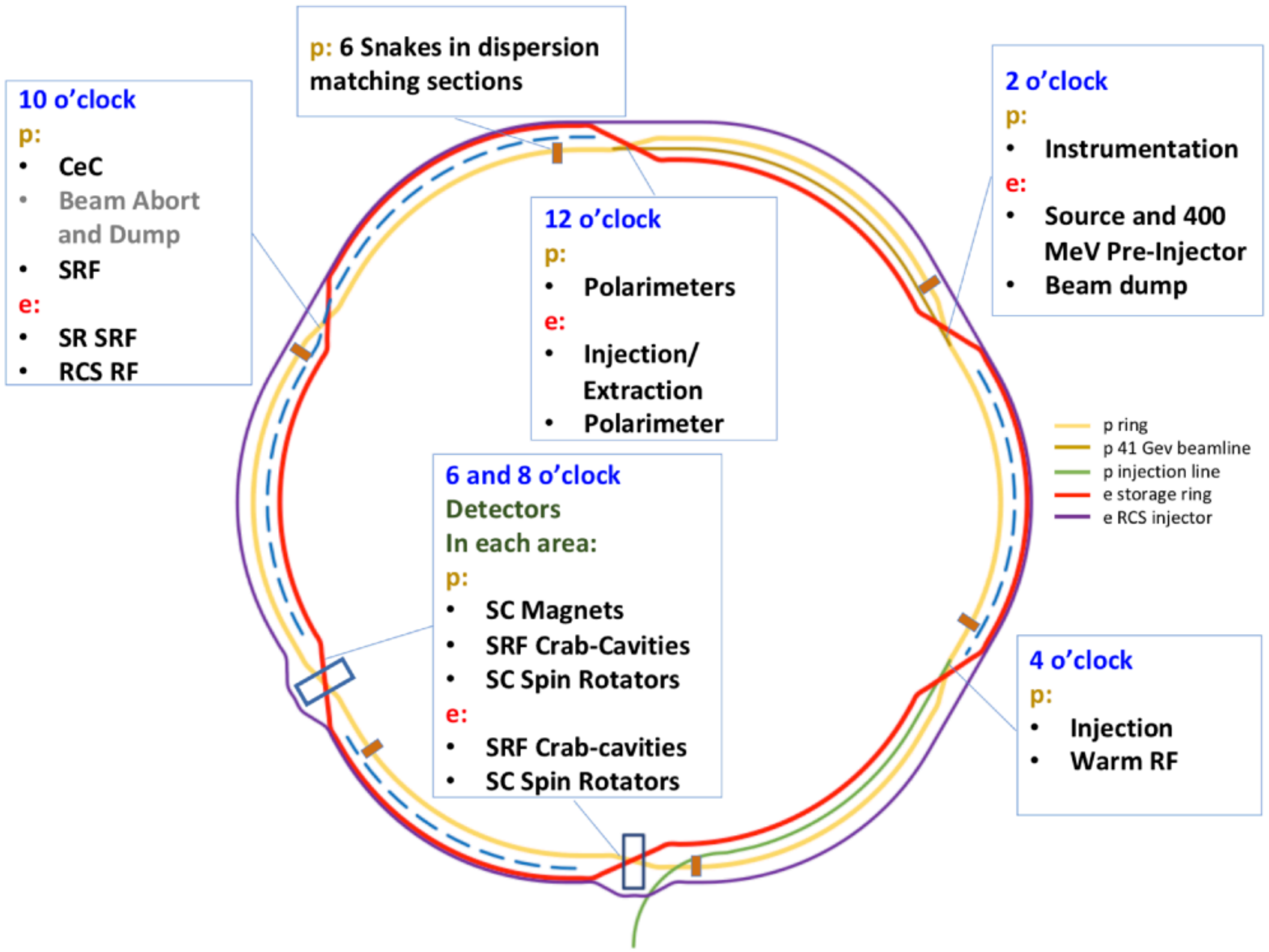


1 o'clock

12 o'clock

11 o'clock

IR12 layout



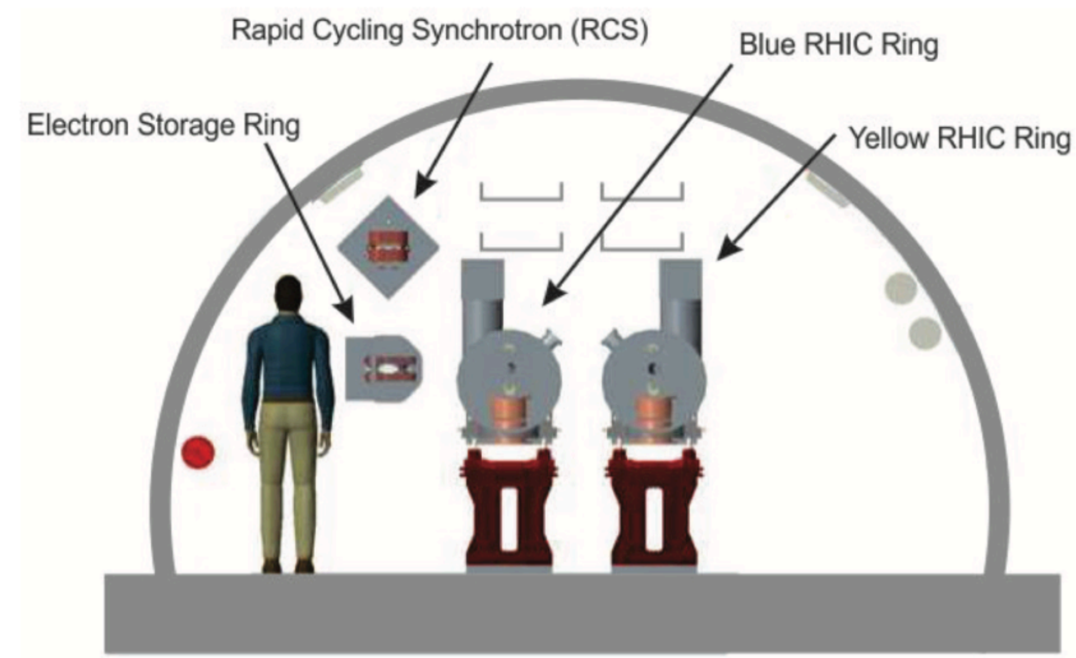
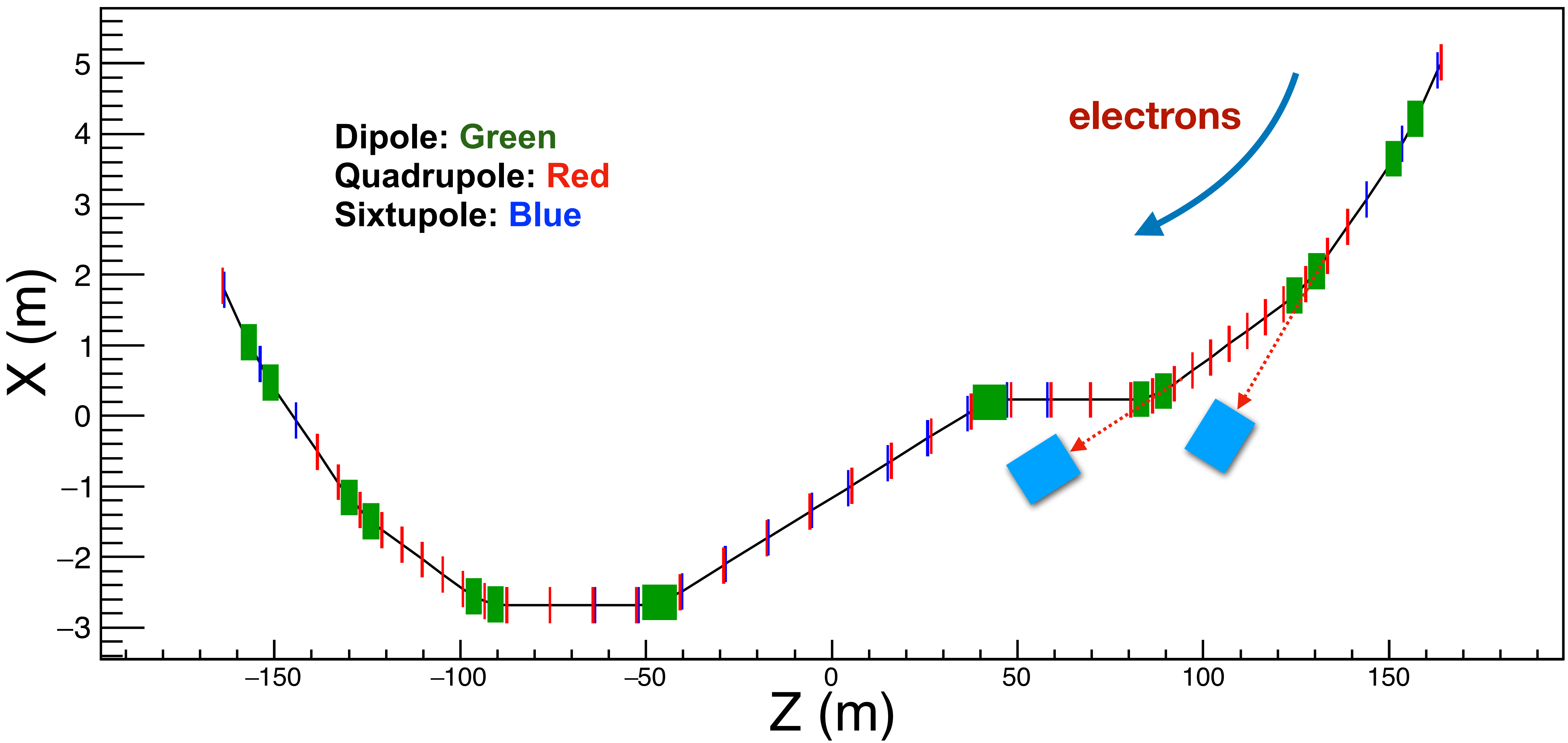


Figure 1.7: Schematic view of the location of the electron storage ring in the tunnel arcs. The Rapid Cycling Synchrotron injector is mounted above the collider ring plane.

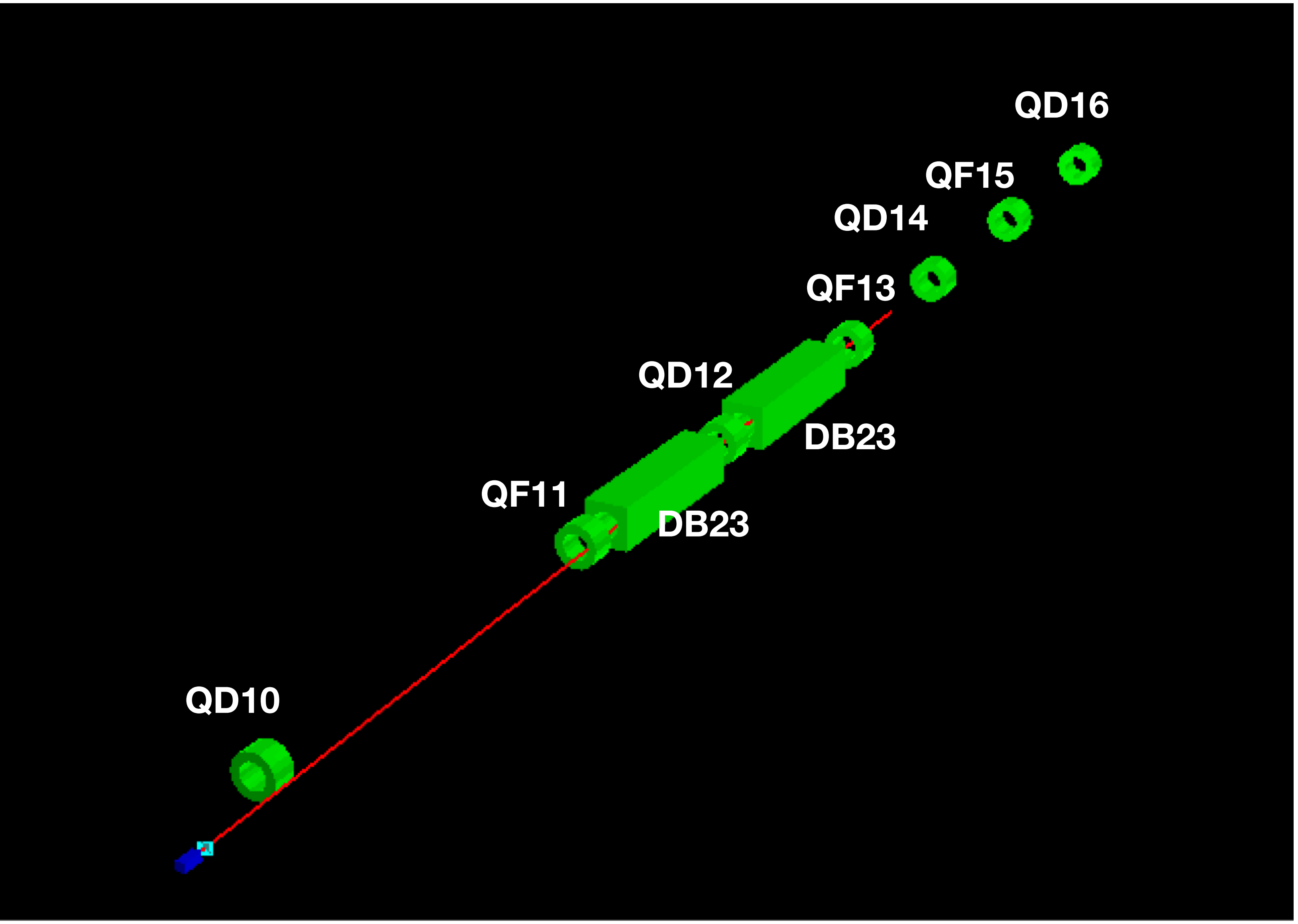
In the region near 11 o'clock side, the outer side (the left) of the Electron Storage Ring has more space than the inner side (the right);

IR12 layout



1 o'clock **12 o'clock** **11 o'clock**

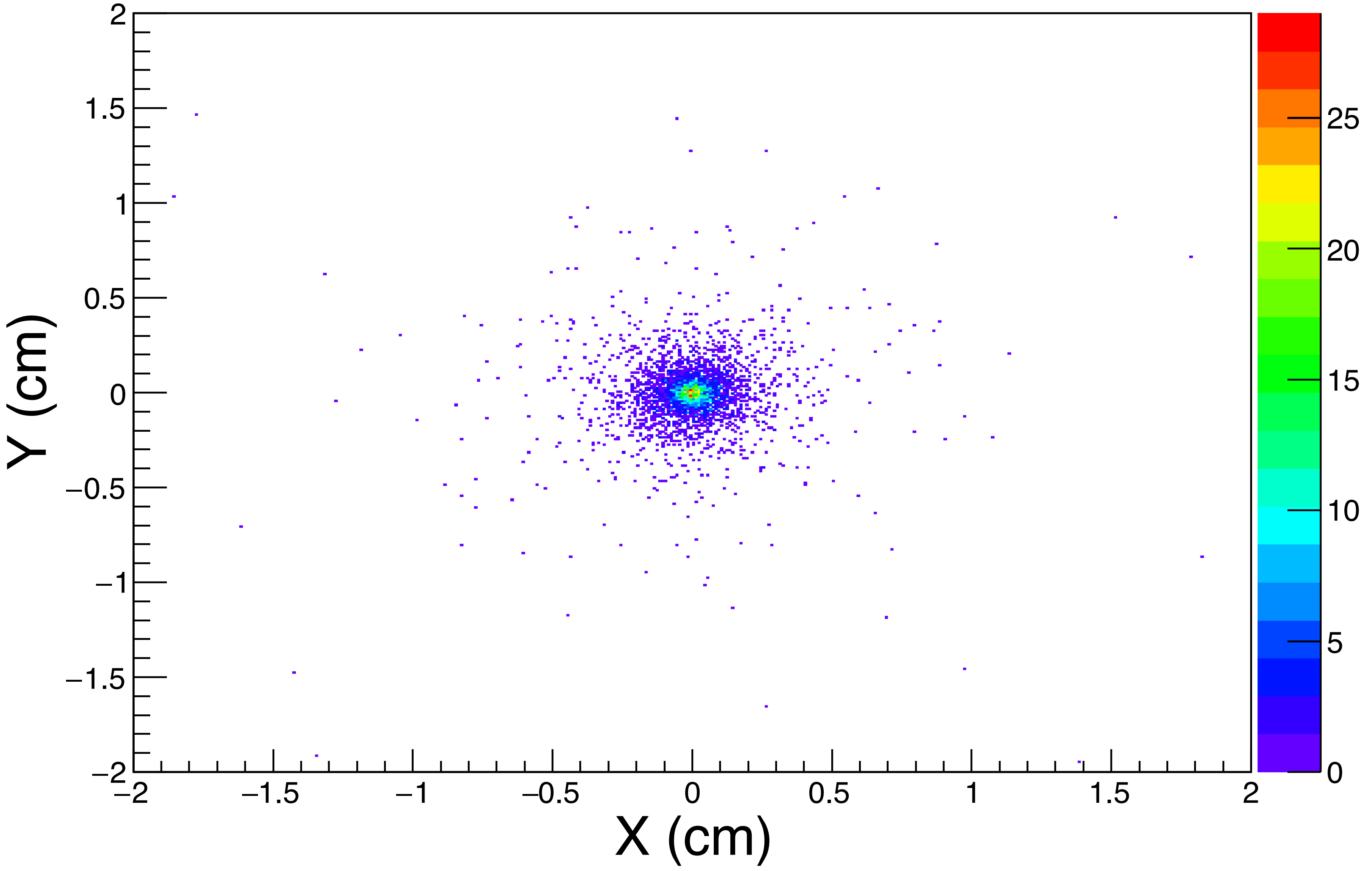
IR12 layout



- The detector is located at ~30m away from the interaction point of laser;
- The center of the detector is about 0.99 meter off the beam line;
- The width and height of the detector is 20 cm;
- For now, we don't have the exact information for the aperture. The inner radius of the magnets in this simulation is 30cm. **The photons can't pass through if the inner radius is too small;**
- We use 18 GeV longitudinal polarized electron beam for our simulation;

Hits position

The acceptance is 99.8%;



NEXT

- Simulate the recoil electron detection;
- More details on the pre-shower and ECal;
- Background study, like synchrotron radiation, synchrotron radiation that bouncing off the inner surface of the beam pipe and so on;
- Moller polarimeter in RCS;


Thank you!
The solar system was destroyed
by Two-dimensional foil

Electron polarimeter

Compton-laser polarimeters, widely used at e^+e^- storage rings (LEP, TRISTAN, etc.), utilize the spin dependent cross section for Compton scattering of polarized photons on electrons: the scattering of circularly polarized photons (from a laser) on vertically polarized electrons is asymmetric with respect to the orbital plane of the electrons, and the magnitude of the asymmetry is proportional to the vertical polarization of the electrons. The longitudinal component of the electron polarization is measured through the energy dependence of the cross section. The polarization can be deduced from measurements of the final electron [21] but at storage rings it is more practical to detect the scattered photon.

Radiative Polarization

Sokolov-Ternov effect: by means of spin-flips caused by a small fraction of synchrotron emissions in the magnetic field of bending dipoles, the spin of emitting particles align parallel or anti-parallel with the transverse magnetic field, leading to a gradual build-up of polarization.

In an ideal machine the build-up of radiative polarization P proceeds exponentially with

$$P(t) = P_{st}(1 - e^{-t/\tau_{st}})$$

Where $\tau_{st} = \frac{5\sqrt{3}}{8}(\frac{c\lambda_c r_0 \gamma^5}{\rho^3})^{-1}$

with the asymptotic polarization limit and build-up time given by

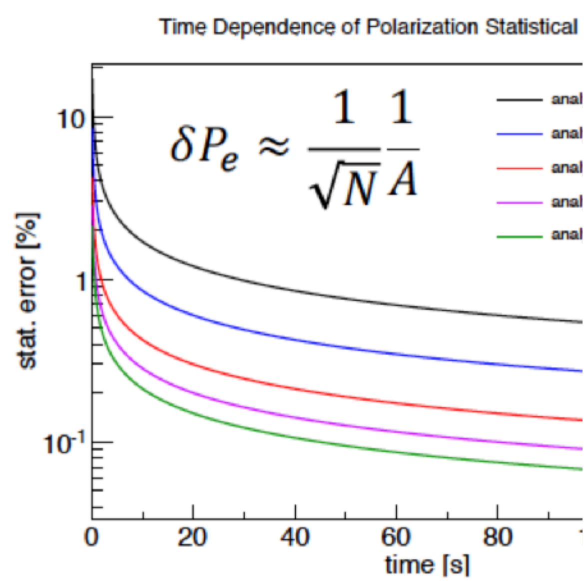
$$P_{st} = 8/(5\sqrt{3}) \approx 0.924$$

$$\tau_{st} \approx 100s\,.\,\rho^3/E^5 \cdot GeV^5/m^3$$

electron polarimeter

Estimation of time needed for measurement

- Estimate an effective bunch rate by accounting for: **for linac ring:**
  - 111 out of 120 bunches filled
  - Half the bunches are one particular polarization direction
  - 20 individual cathodes produce bunches and we desire bunch cathode by cathode monitoring to look for polarization differences from the sources
  - → effective rate 2.2 x 10^5
- Expect 1% level statistical precision in less than 2 minutes
- Assumes measuring in single photon mode
  - Advantages:
    - Can choose large asymmetry
    - Easy comparison with cross section
  - Disadvantages:
    - Detector is more complex



Multi-photon mode advantages ar disadvantages:

- Advantages:
  - Essentially independent o Brem. Bg and detector cut energy
- Disadvantage: no easy monitoring

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Update on study of laser power

$$L = \frac{f_b N_e N_\gamma}{2\pi \sigma_{x\gamma}\sigma_{y\gamma}\sqrt{1 + (\theta\sigma_{z\gamma}/2\sigma_{y\gamma})^2}}$$

- Estimate the laser power needed to achieve roughly one Compton scattering per beam crossing
- Some basic assumptions:
  - Scheme assumes the linac-ring design
  - f_b = 9.4 MHz
  - N_e = 0.07 x 10^{11}
  - $\sigma_{x\gamma} = \sigma_{y\gamma}$ = 400 microns
  - $\sigma_{z\gamma}$ = 0.4 cm
  - θ = 25 mrad
  - Assume the laser is clocked with the eRHIC 9.4 MHz clock
  - $\sigma_{Compton}$ = 400 mb (roughly for a 20 GeV electron on a 2.33 eV photon)
- The above parameters leads to needing 3.6 x10^{12} photon pulse → 1.3 uJ per pulse → 12 W laser power in total
- Achievable with an off the shelf laser

electron polarimeter

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To determine the electron polarization with an absolute accuracy of 1% requires approximately 10^6 scattered photons. The detection of individual photons is called the "single-photon" method. It can be used if the background from beam-gas bremsstrahlung is small and the time between electron bunches is short. Otherwise, the "multi-photon" method is more appropriate, when a pulsed high power laser is utilized to produce thousands of backscattered photons on each interaction with an electron bunch [22]. Compton scattering then dominates over the background and a high statistical accuracy can be reached in a short time. However, the single-photon method allows detailed crosschecks and diagnostics. This method has been adopted for the measurements at HERA, and we measure by scattering 2.41 eV laser photons in a continuous beam of 10 W

The degree of vertical electron polarization is obtained by measuring the asymmetry with respect to the plane of the storage ring of the scattering of circularly polarized light off the electrons. The asymmetry of the scattering rate measured, for example, with left polarized light ($S_3 = +1$) is

$$\mathscr{A}(y, E_\gamma) = \frac{N_L(y, E_\gamma) - N_L(-y, E_\gamma)}{N_L(y, E_\gamma) + N_L(-y, E_\gamma)} \tag{29}$$

$$= P_Y \frac{\Sigma_{2Y}}{\Sigma_0}, \tag{30}$$