\section{Comparison to HERA}

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The design and physics program of the Electron-Ion Collider (EIC) builds upon the foundational experience of the Hadron-Electron Ring Accelerator (HERA), which operated at DESY from 1992 to 2007 as the world's only electron-proton collider to date. HERA consisted of two storage rings housed in a 6.3km underground tunnel, with a 27.5GeV electron or positron beam circulating in one direction and a 920~GeV proton beam in the other, yielding center-of-mass energies up to $\sqrt{s} \approx 318$GeV\cite{hera-design-report, hera-zeus-final}. The facility enabled landmark measurements of the proton structure functions $F\_2$ and $F\_L$ over five orders of magnitude in Bjorken-$x$ and squared four-momentum transfer $Q^2$, particularly in the low-$x$ region where gluon densities become large.

While HERA established the feasibility and scientific impact of high-energy lepton-hadron scattering, its collider configuration had key limitations that constrain its applicability to the open questions in QCD targeted by the EIC. Chief among these is the lack of beam polarization symmetry: HERA operated with unpolarized protons, and longitudinal electron beam polarization (up to $\sim$60%) was implemented only in the final years of data taking through the addition of spin rotators upstream of the interaction regions~\cite{hera-polarization-upgrade}. The EIC, by contrast, is designed from the outset to provide highly polarized beams for both electrons (targeting 80%) and protons or light ions (70%), with full control of helicity orientation on a bunch-by-bunch basis~\cite{eic-yellow-report}.

Another critical distinction is in species flexibility. HERA was limited to $ep$ and $e^+p$ collisions, whereas the EIC will support $eA$ collisions over a broad range of ion masses, including deuterons, helium-3, and heavy nuclei such as gold or uranium. This capability is essential for exploring the modification of parton distribution functions in nuclei, the onset of gluon saturation at small $x$, and potential signals of non-linear QCD dynamics~\cite{eic-whitepaper}. In terms of kinematic coverage, while HERA reached higher $\sqrt{s}$, the EIC offers variable beam energies, enabling detailed binning in both $x$ and $Q^2$ at fixed center-of-mass energies, which is advantageous for unfolding structure functions and cross-section ratios in nuclear targets.

In luminosity, the EIC is projected to exceed HERA's peak performance by roughly three orders of magnitude. HERA achieved a peak luminosity of approximately $5 \times 10^{31}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ in its final years\cite{hera-luminosity}, while the EIC is designed for instantaneous luminosities of $10^{33}$ to $10^{34}~\mathrm{cm}^{-2}\mathrm{s}^{-1}$ for $ep$ and $eA$ collisions respectively. This improvement is essential for precision studies of multidimensional distributions such as transverse-momentum-dependent parton distribution functions (TMDs) and generalized parton distributions (GPDs), which require large statistics across fine-grained kinematic grids. Furthermore, the EIC's beam structure and interaction region design are optimized for modern detection systems, including full hermetic coverage, high-resolution tracking, and dedicated far-forward detectors for tagging nuclear fragments and measuring diffractive final states.

From the perspective of accelerator technology, the EIC incorporates several major innovations not present at HERA. In particular, its use of an energy-recovery linac (ERL) architecture in the electron injector (in some design options) enables sustained high current operation with efficient power consumption~\cite{erl-technical-report}. The ion beam infrastructure will also benefit from the RHIC complex, enabling rapid cycling between species and beam polarization configurations.