

A new optimized optics for the second detector at EIC

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Electron-Ion Collider Detector II

Major facilities need at least two detectors to maximize the science.

Independent confirmation of results and discoveries, reduction of systematic uncertainties.

A 2nd EIC detector will allow for enhanced capabilities in several sectors.

A novel far-forward detection system utilizing a second focus will significantly expand the opportunities for nuclear measurements and for the 3D structure of nucleons and nuclei. Improved muon identification is another example of complementarity with the 1st detector.

A 2nd detector is essential to fully leverage the investment made in the EIC

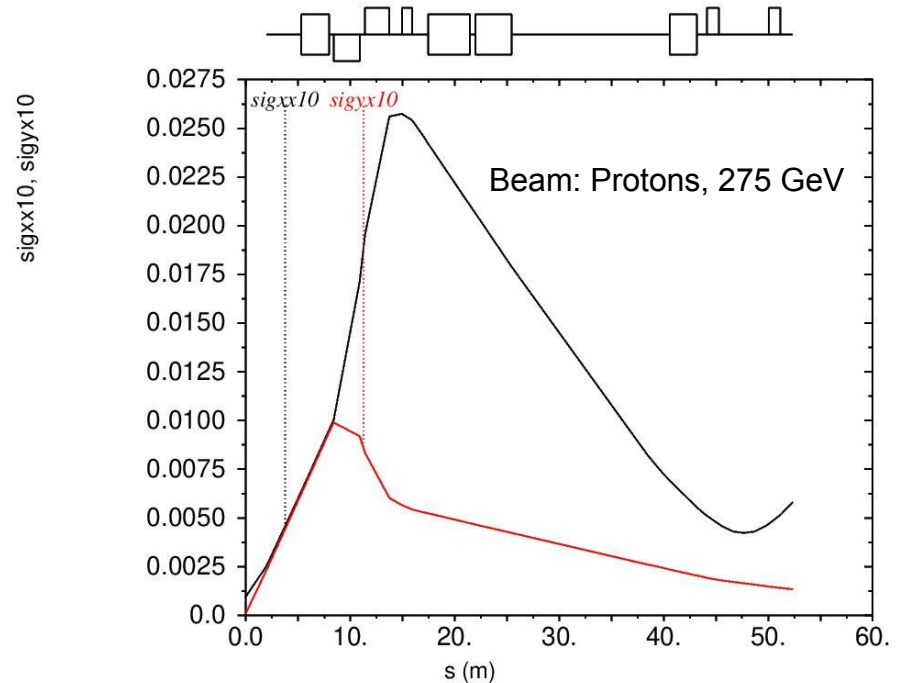
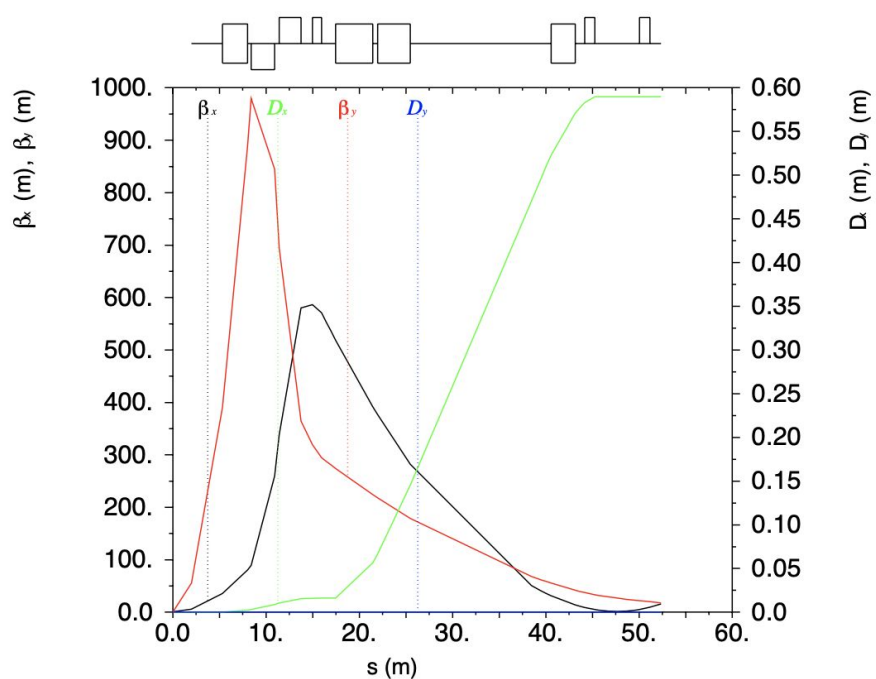
A slightly longer timeline will also make it possible to take full advantage of AI in all aspects of the project, which would be naturally synergistic with the Genesis mission. Completing the 2nd detector after early running would not significantly affect its overall contribution to EIC science (note that the D0 detector at the Tevatron came 7 years after CDF).

Significant progress has been made on the implementation

Includes an optimized beam optics that could be used in IR8 or IR12.

Presented to the SCAC future facilities subpanel!

Beam Optics

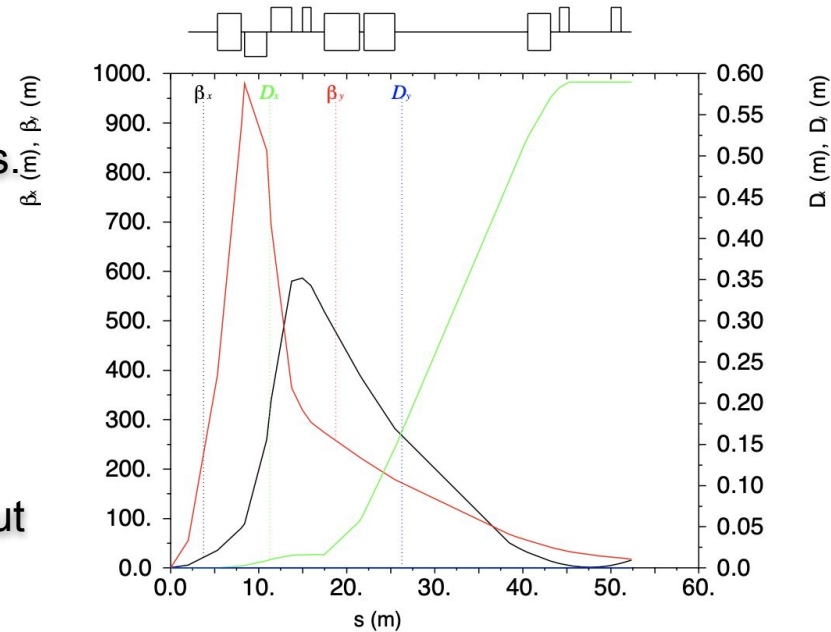


- ❑ Near beam acceptance at the second focus
- ❑ Dispersion converts momentum loss into transverse displacement:
- ❑ With this optics we get beam size that $\Delta x = 10 \sigma = 4.23 \text{ mm}$, which means that particles with $\Delta p/p > 0.7\%$ can be detected even with a zero degree initial angle

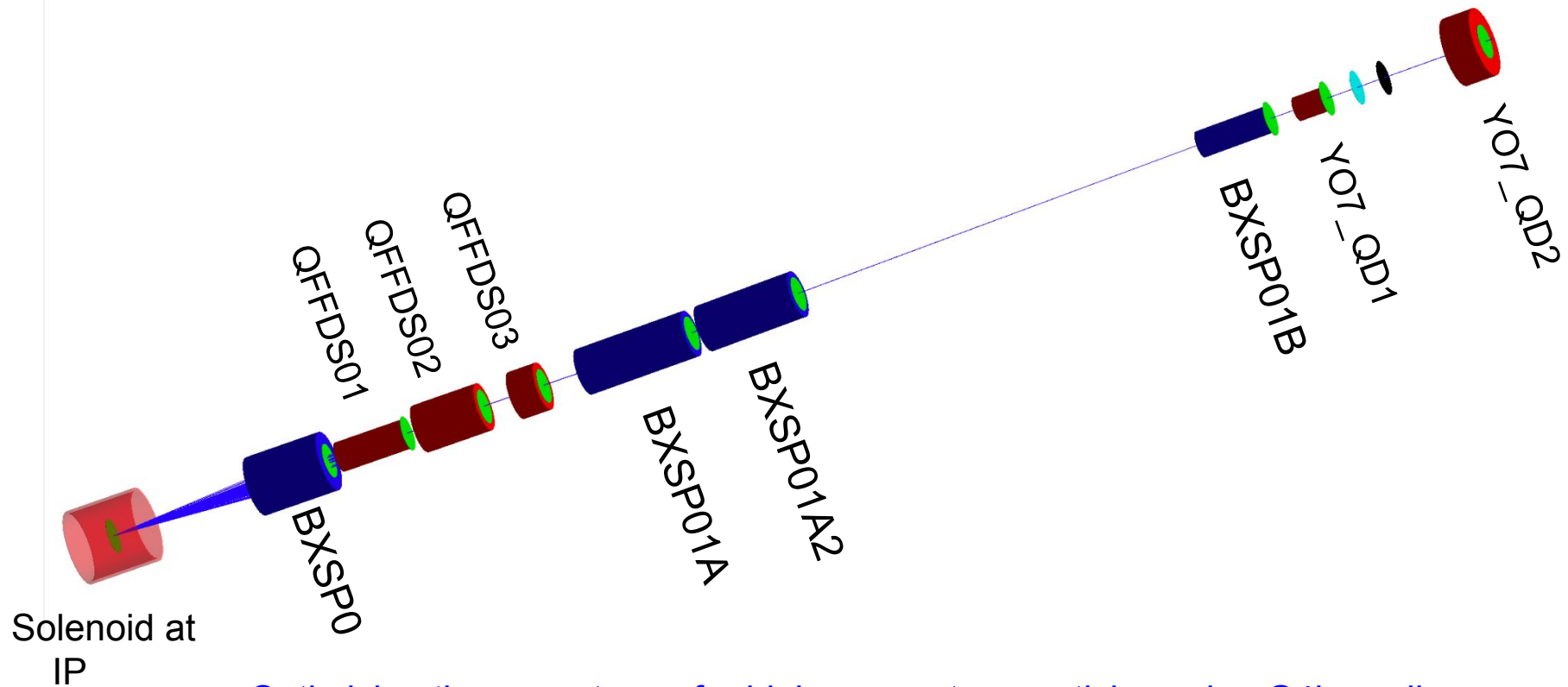
$$dx = D \frac{\Delta p}{p}$$

Key Features

- ❑ Layout can be used in IR12 or IR8
- ❑ B0 dipole: 2.7 m long with 0.6 T max field which can be scaled to all ion energies (Brett Parker). Relaxes specs on field uniformity of quadrupoles.
- ❑ Small β_x^{\max} minimizes chromaticity
- ❑ Horizontal second focus with Roman pots in front of vertical one
- ❑ Large dispersion at the second focus spreads out the signal over the tracker
- ❑ The derivative of the dispersion is zero, which means that a particle going at zero degrees at the IP will go at zero degrees at the second focus.



IInd Detector Layout in Geant



Optimizing the acceptance for high momentum particles using G4beamline

Selected example at IInd Focus

A novel far-forward detection system with a second focus significantly expands nuclear physics capabilities, enabling precision studies of nuclear structure and reaction dynamics.

1. Gluon Saturation Studies with U-238

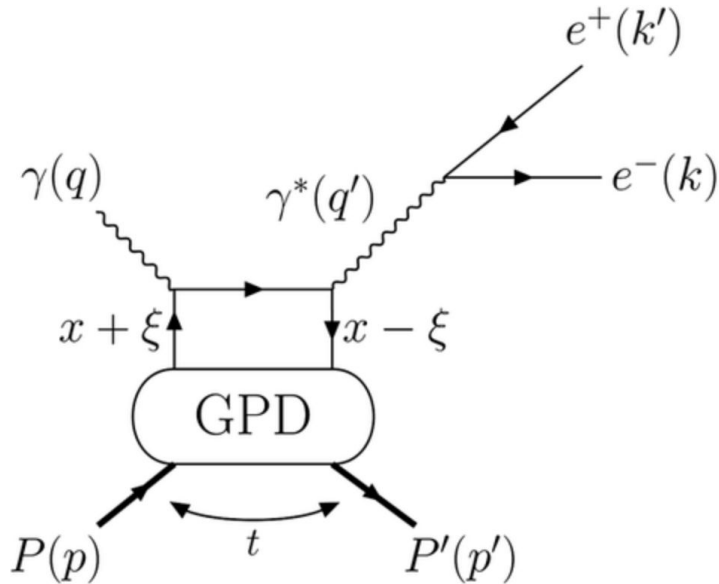
Complete final-state reconstruction enables probing high gluon density when the long axis of the nucleus is along the beam axis (bigger oomph than with 18 GeV electrons)

2. Exclusive processes on nucleons and nuclei (coherent)

Essential for access to low t region in light nuclei

Second Focus for Exclusive Processes

Timelike Compton Scattering (TCS): $ep \rightarrow e' \gamma p \rightarrow (e') e^+ e^- p'$



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TCS process interferes with Bethe-Heitler at the amplitude level.

$$\frac{d^4\sigma}{dQ'^2 dt d\Omega} = \sigma_{TCS} + \sigma_{BH} + \sigma_{INT}$$

- ❑ TCS provides access to the imaginary and real parts of the CFF associated with the unpolarized GPD, $H(x, \xi, t)$ through BSA and FBA, respectively.
- ❑ For small Q^2 of incoming electron and small momentum transfer (t) of proton, the scattered protons stay in the forward region and can be detected at the second focus

Summary and Outlook

- ❑ The second detector extends far-forward physics capabilities, providing access to low- t exclusive reactions and gluon saturation studies.
- ❑ Optimized beam optics provide good acceptance needed for precision measurements of forward-scattered particles.
- ❑ Studies of exclusive processes at small momentum transfer are important for evaluating the performance of the second focus.
- ❑ We are using timelike Compton scattering (TCS) as a benchmark exclusive process on the proton. We simulate it using the EplC event generator.

Collaborators: Vasilij S. Morozov (ORNL), Pawel Nadel-Turonski (USC), Arda Gülser and Tyler Roth (summer students)

Thank you for your attention!

Hill's Equation

Hill's equation (transverse motion in accelerators):

$$\frac{d^2 x}{ds^2} + K(s)x = 0$$

A particle undergoing transverse motion in an accelerator is characterized by:

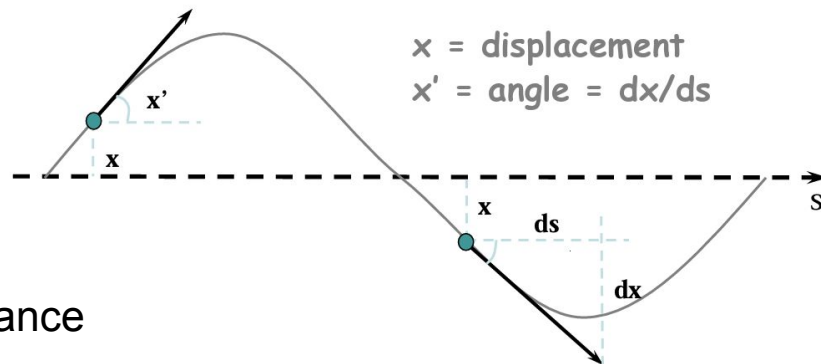
- Position (displacement from the central orbit)
- Angle with respect to the central orbit

The particle trajectory can be written as:

$$x(s) = \sqrt{\epsilon \beta(s)} \cos(\psi(s) + \phi)$$

$\beta(s)$: beta function (controls beam size), ϵ : emittance

$\psi(s)$: betatron phase advance, ϕ : initial phase



MAD-X: Solves Hill's equation to compute β and beam size.