

A 2nd detector at the Electron-Ion Collider - synergies with the LHC?

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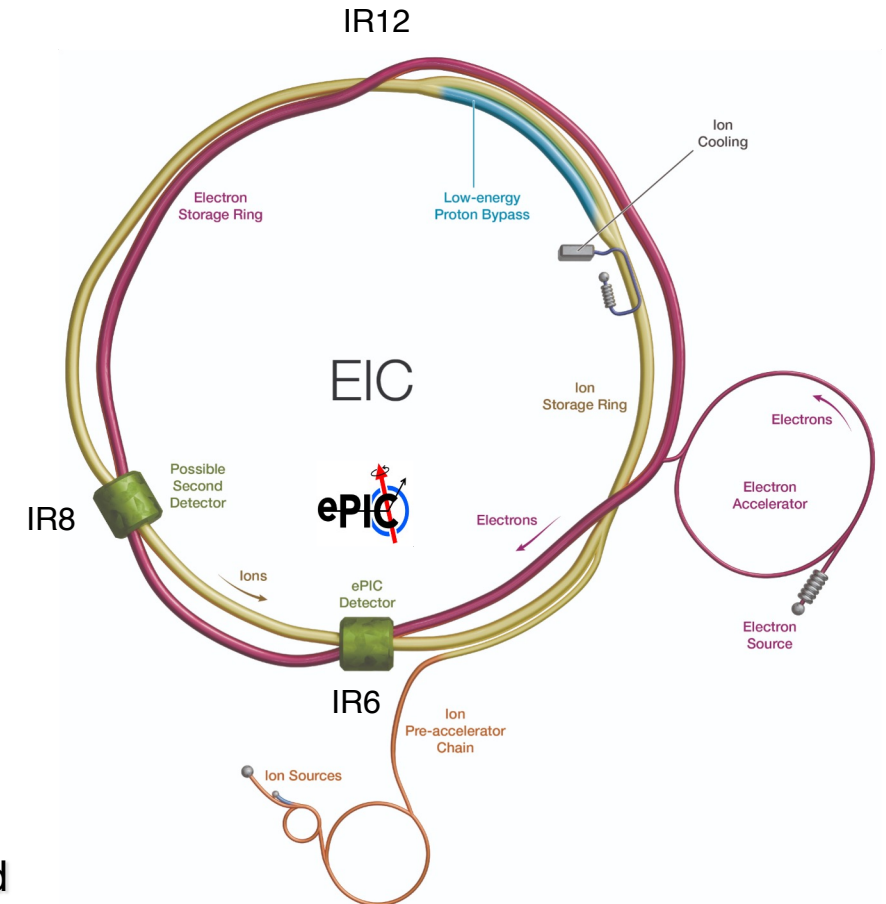


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EMMI Workshop: Mining for gluon saturation at the LHC and
the future EIC, GSI, Darmstadt, Germany, July 6-10, 2026



Electron-Ion Collider Detector II

Slide by the EIC UG 2nd detector WG
presented to the SCAC in May 2026.

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.

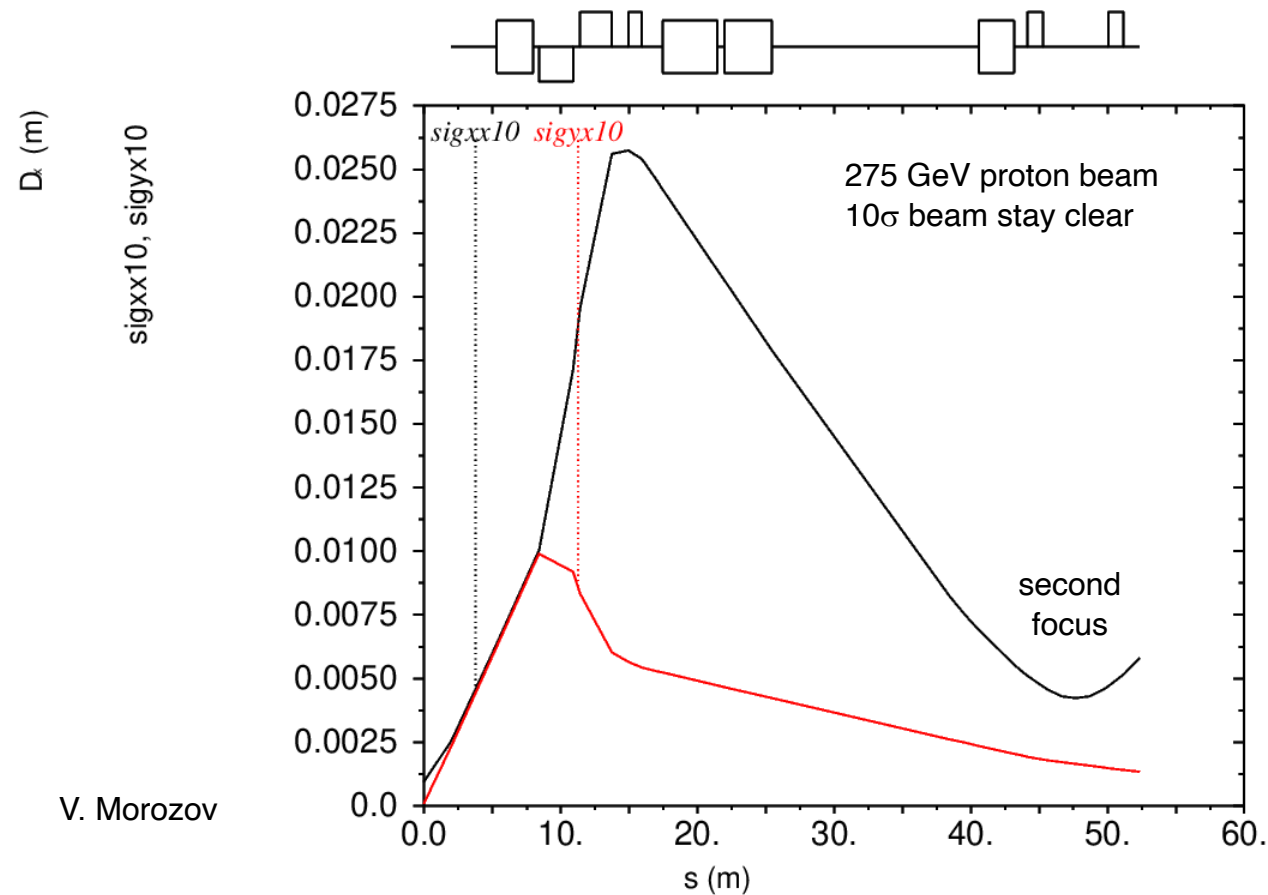
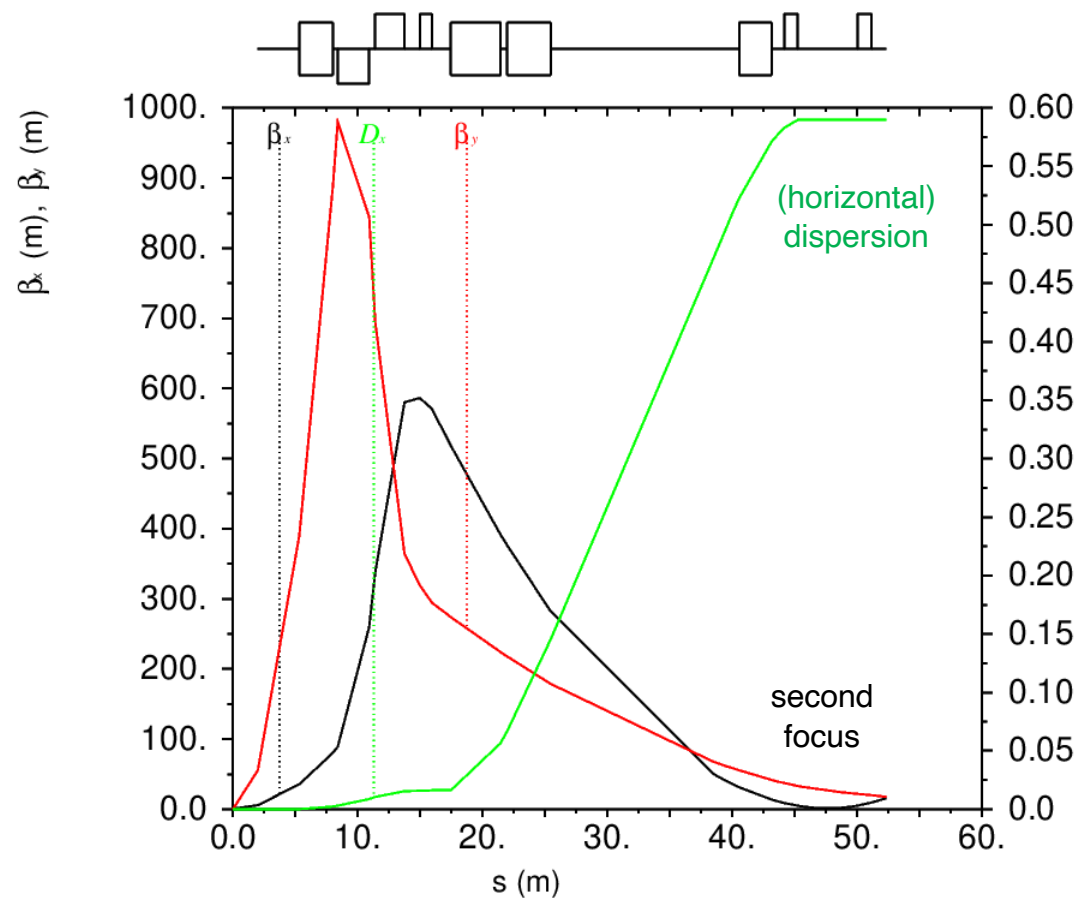
A 2nd detector is essential to fully leverage the investment made in the EIC

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).

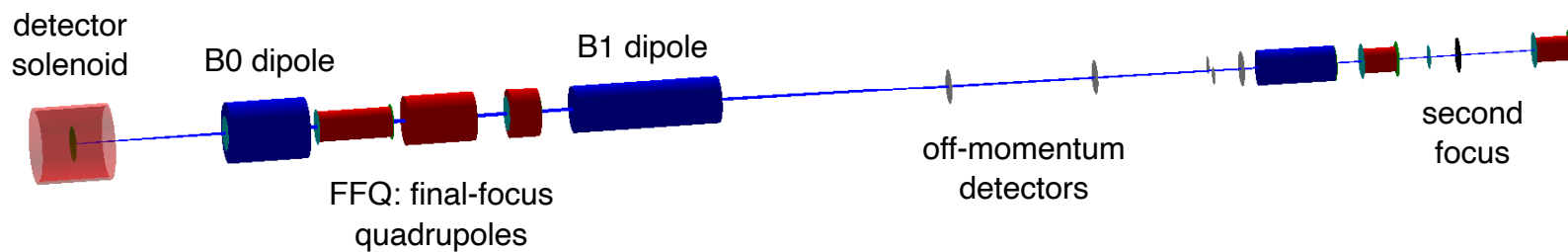
Significant progress has been made on the implementation

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

New ion optics for IR8 or IR12

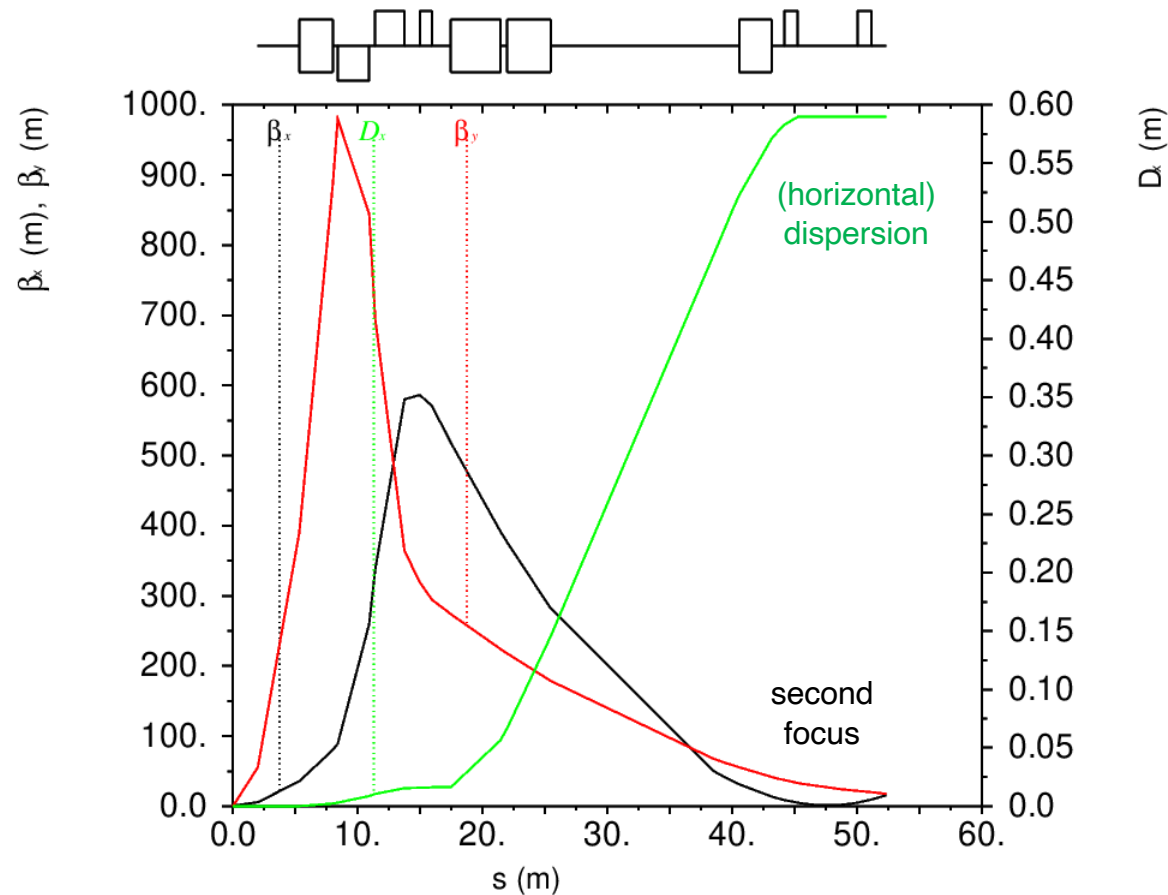


V. Morozov



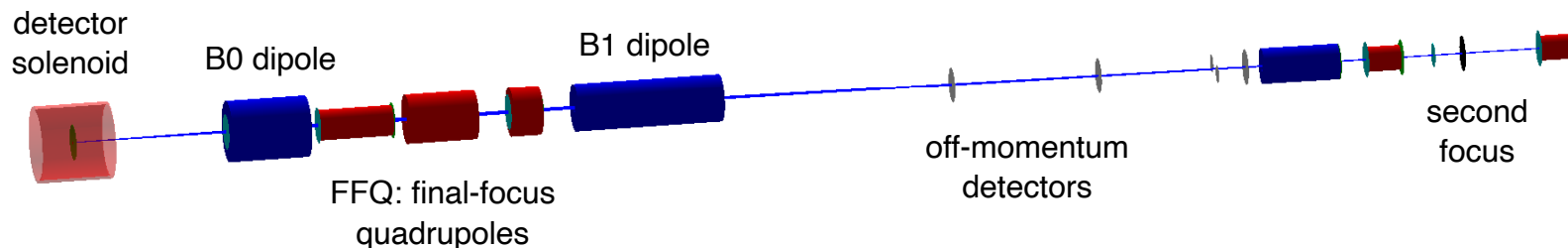
Geant simulation

New ion optics for IR8 or IR12

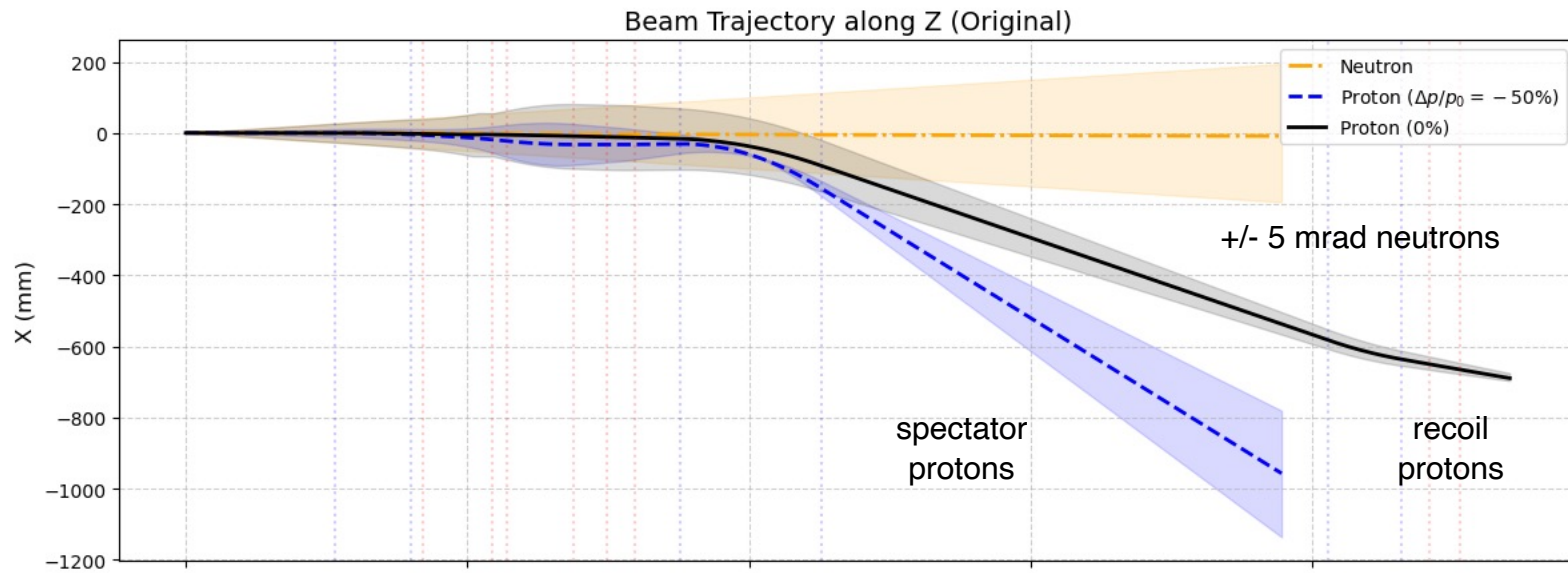


Key features

- A second focus at a location with a large horizontal dispersion
 - Enables detection of particles with $dp/p > 0.7\%$ even at zero degrees ($p_T = 0$)
 - The large dispersion shifts particles out of the beam and spreads them out along the trackers
 - The second focus makes the beam smaller at the Roman pot location.
- New version reduces accelerator requirements
 - A small β_x^{max} minimises chromaticity
 - A (2.7 m long) B0 dipole that can be scaled to any beam energy (B. Parker) allows simpler FFQs compared with ePIC@IR6 (field uniformity specs).

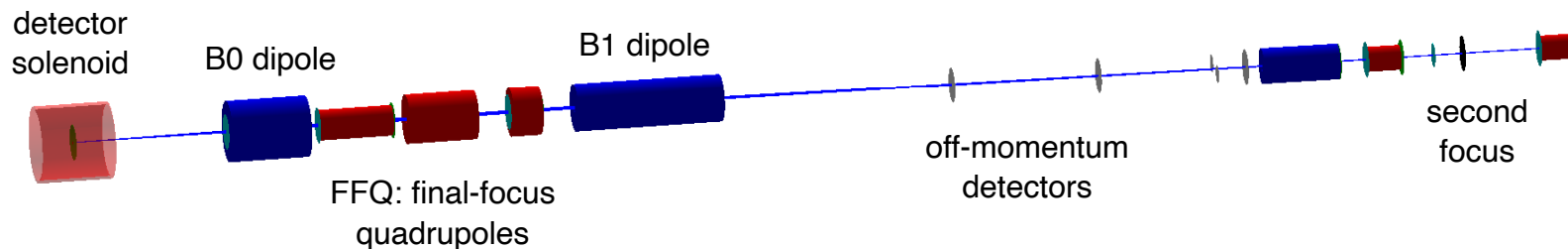


Large- p_T acceptance (first pass)

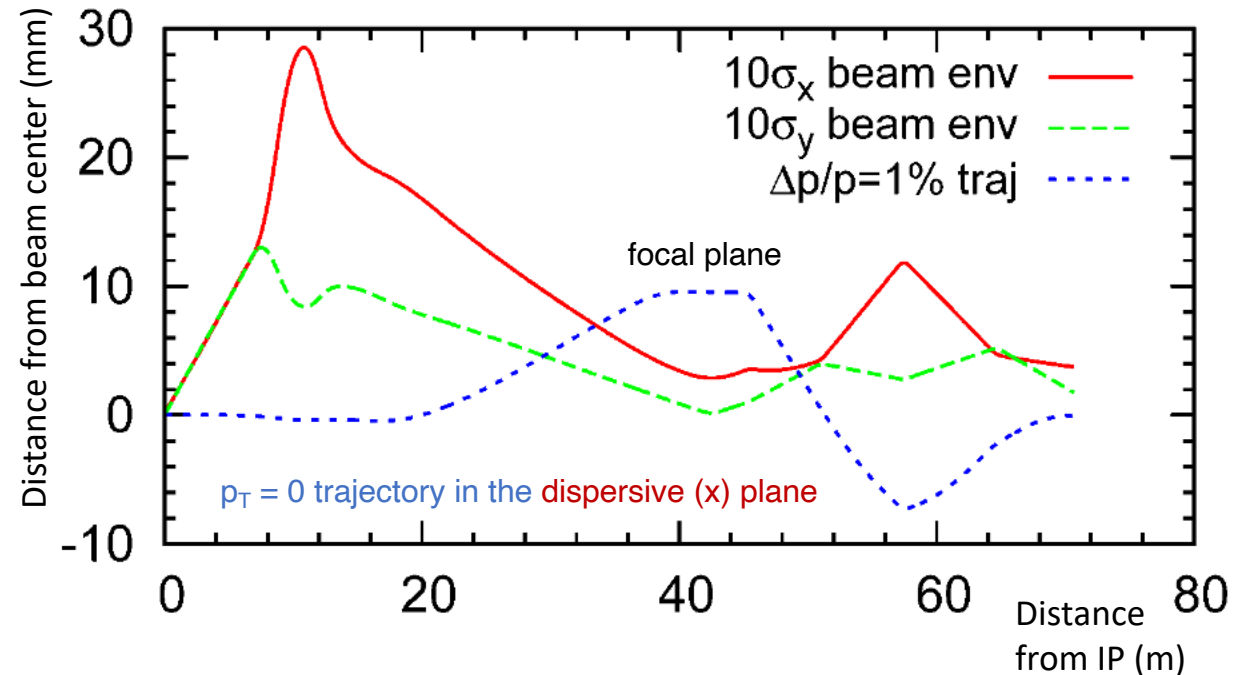
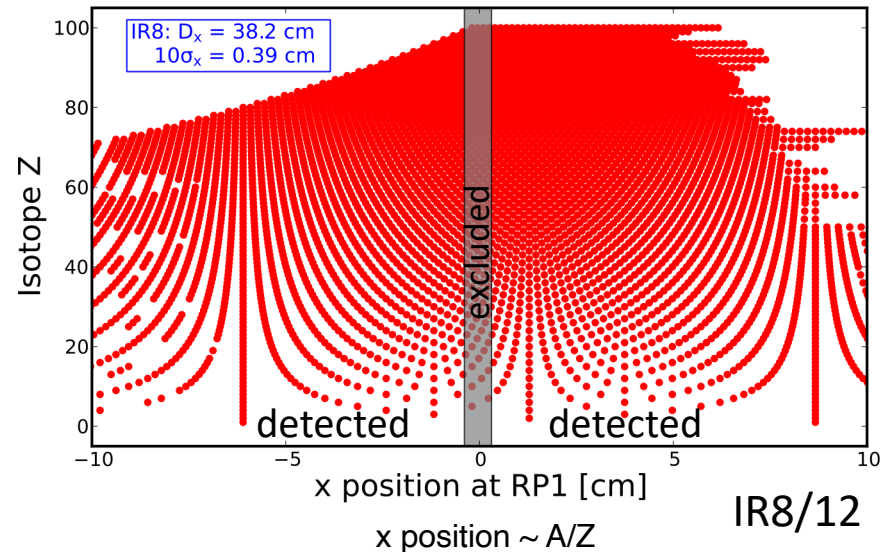
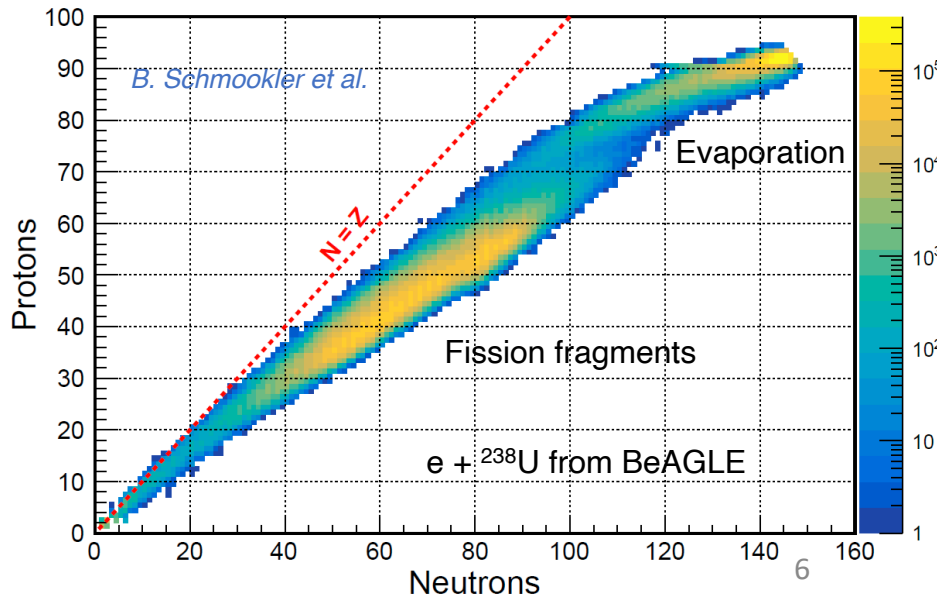


V. Morozov, T. Roth, K. Gopal, PNT

- First-pass apertures
 - Full transport for ± 5 mrad neutrons.
 - Full transport for spectator protons from deuterium.
 - Losses for recoil protons only in first quadrupole.
- Quad peak fields equal to or smaller than for ePIC@IR6.

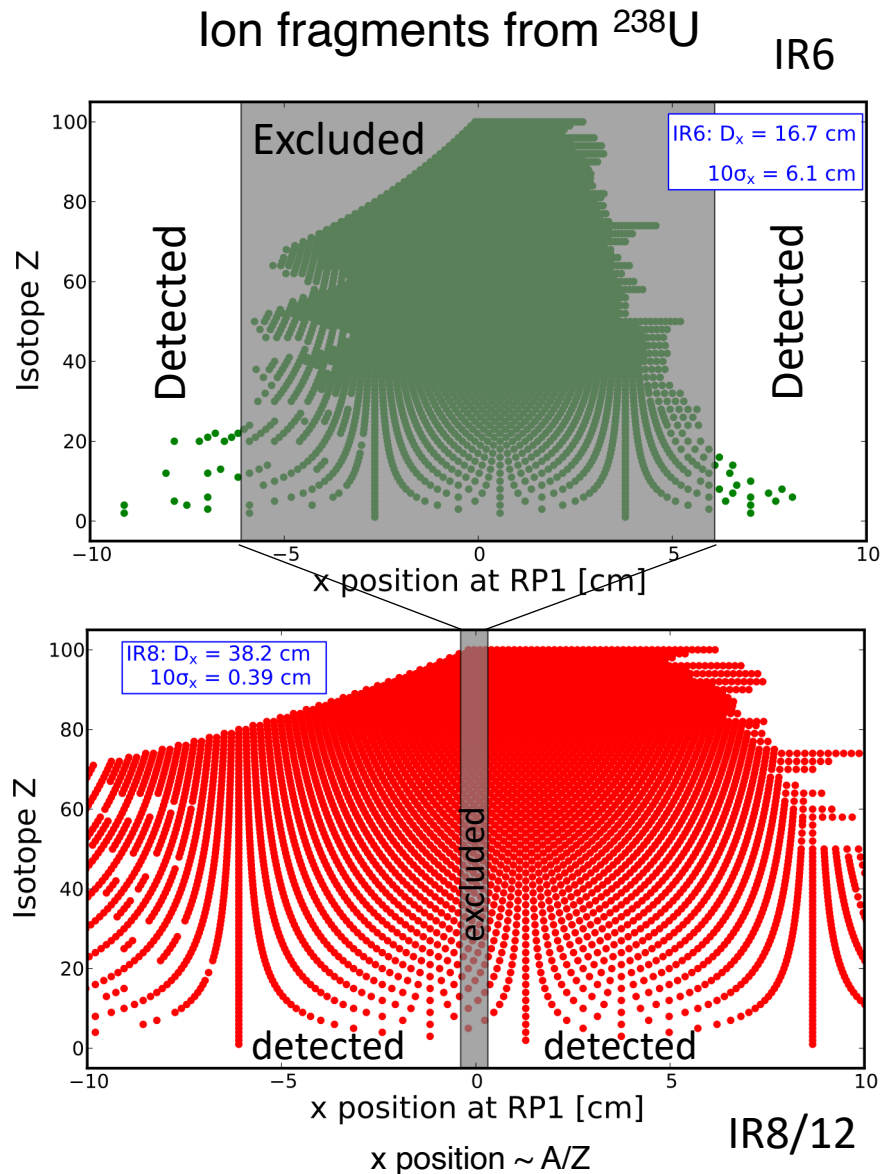


Example: nuclear fragment detection in a 2nd EIC detector (older optics)

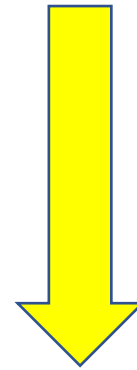


- ePIC forward detection is optimized for protons
 - Nuclear fragments stay within the 10σ beam envelope.
- A 2nd detector would provide point-to-point focusing (second focus) enabling
 - Detection of most fragments from any nucleus
 - Detection of light recoiling nuclei down to $p_T = 0$
 - Better acceptance for low-x exclusive protons (e.g., DVCS)

EIC far-forward acceptance with and without a second focus

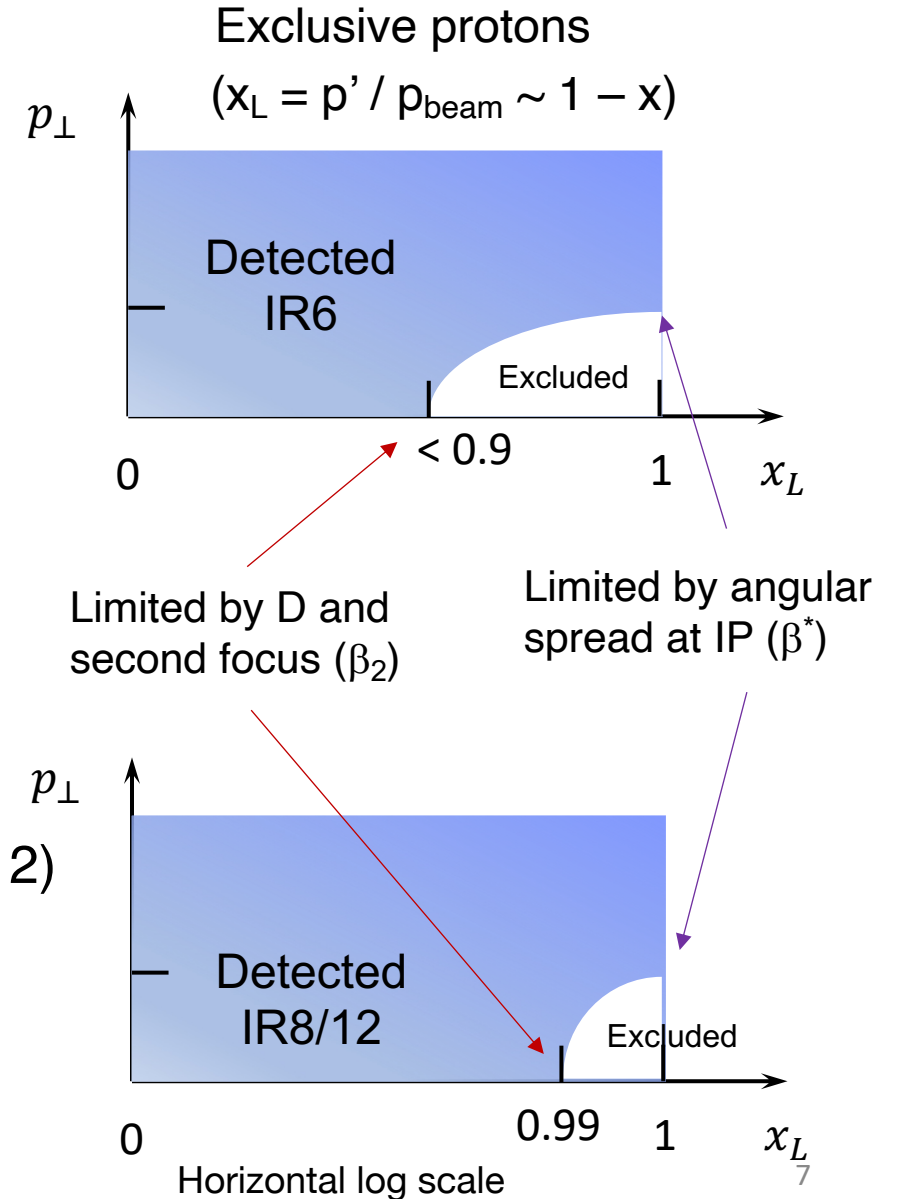


Without 2nd focus:
(ePIC @IR6)



With 2nd focus:
(Detector 2 @ IR8/12)

**Order-of-magnitude
improvement in
forward acceptance**



A second detector for the EIC – complementarity and new opportunities

The details the 2nd detector are not yet defined.

Users will have a significant impact on both design and construction.

Still, there are some natural ways for a second detector to expand the capabilities of the EIC:

- **Taking advantage of near-beam hadron detection in an IR with a *second focus*.** Examples include

- Low- x / low- p_T protons from exclusive / diffractive reactions
- Coherent processes on nuclei – light ions *detected* down to $p_T = 0$ at mid-to-high x
- Bound nucleon structure – in a wide range of spectator nuclei
- Processes benefiting from the measurement of the complete nuclear final state
 - Reaching higher gluon densities in collisions along the long axis of ^{238}U
 - Rare isotopes

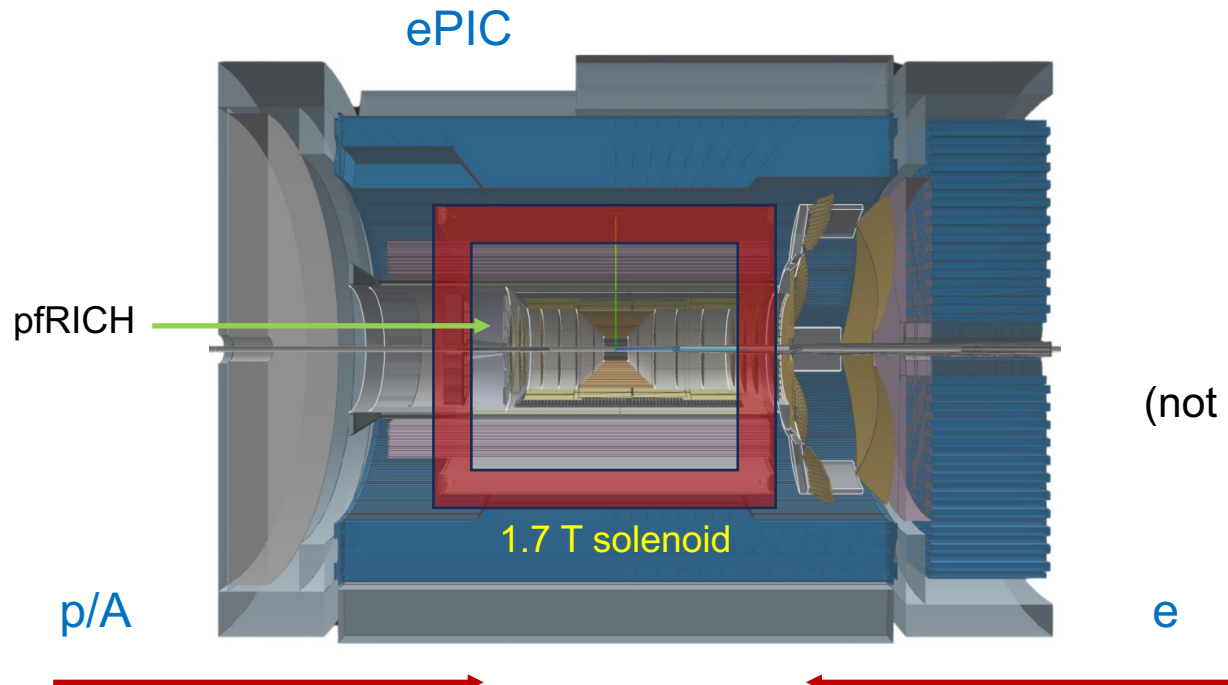
} eA

- **Seeking complementarity with ePIC and synergies with the forward detection.** These could include

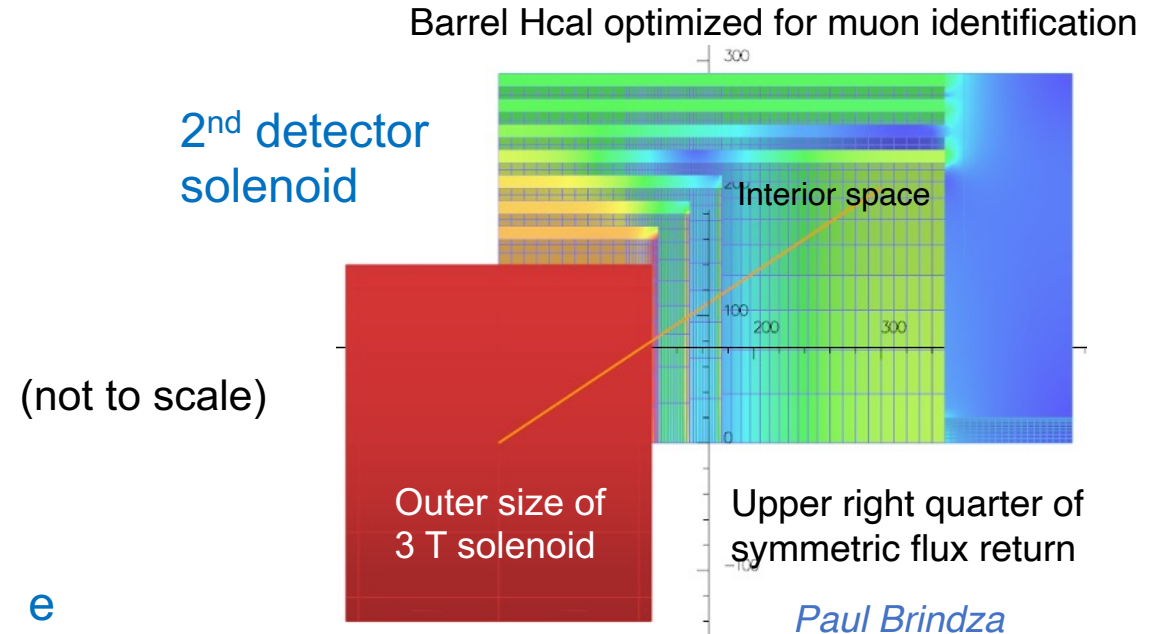
- Improved muon identification in the barrel and (outgoing) electron endcap
- Improved hadron identification in the barrel from continued DIRC R&D (from 6 to 8-10 GeV/c)
- Add your suggestions here!

Initial study of a 3 T Detector-2 solenoid (next iteration coming soon)

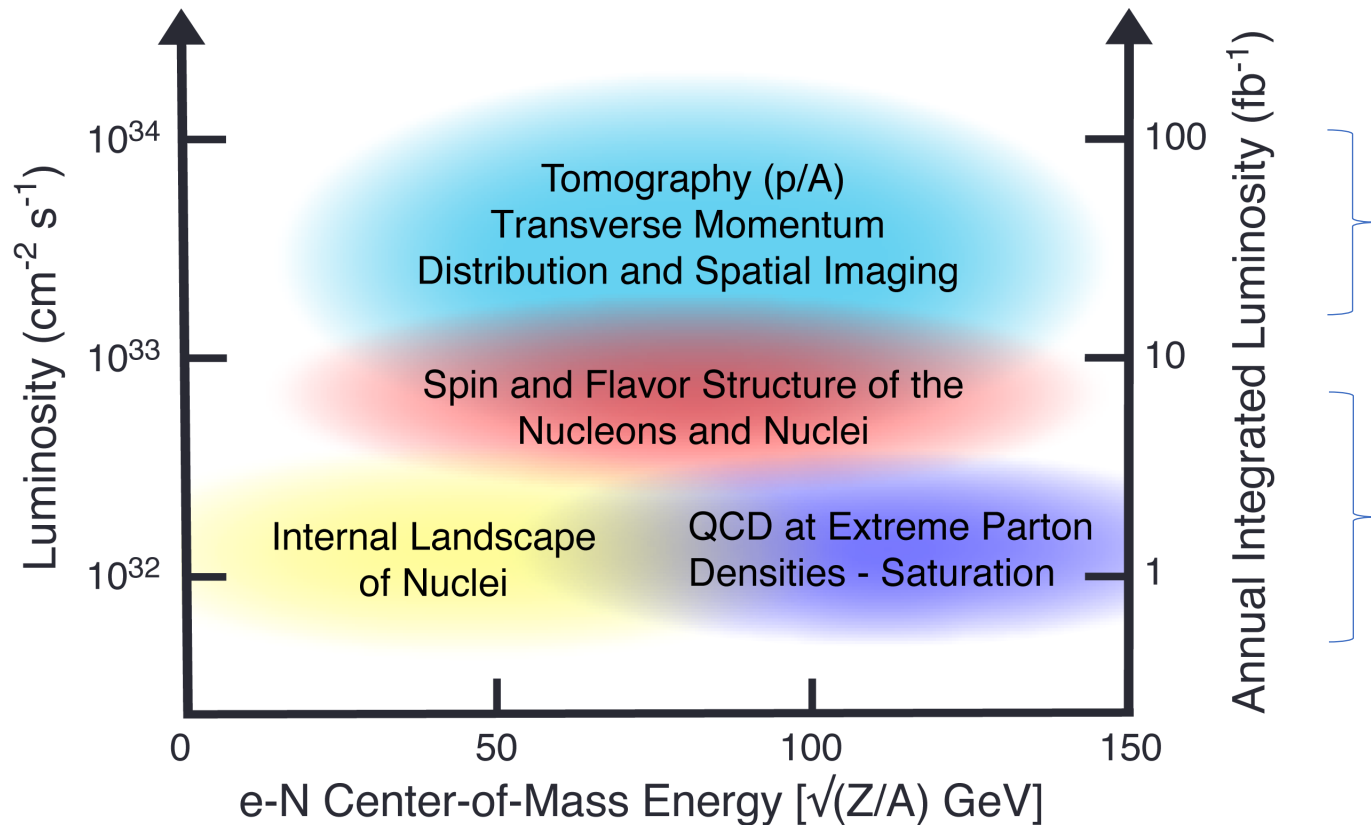
- The ePIC 1.7 T MARCO solenoid is similar to the BaBar solenoid.
- For structural reasons it covers both the tracker and the p/RICH PID detector.



- A shorter 3 T solenoid creates more internal space
 - 30% (1 m) shorter
 - 15% smaller inner (bore) radius
 - The high-field region is matched to the tracker
 - Cables can be routed to the outer parts of the detector much earlier than in ePIC
 - Improves tracking on the (outgoing) electron side



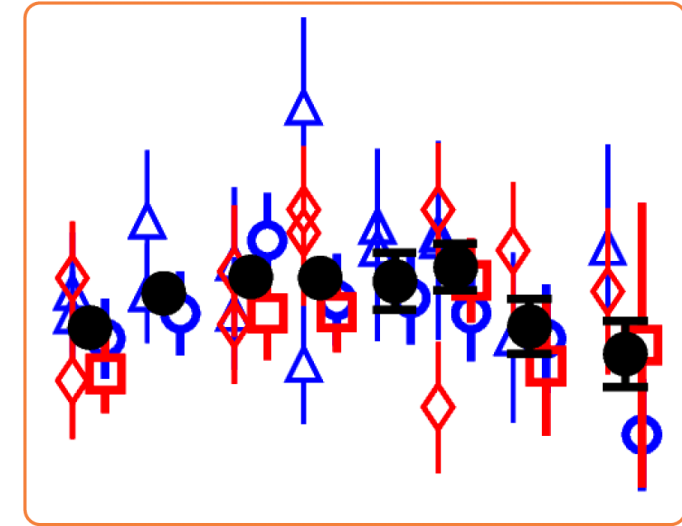
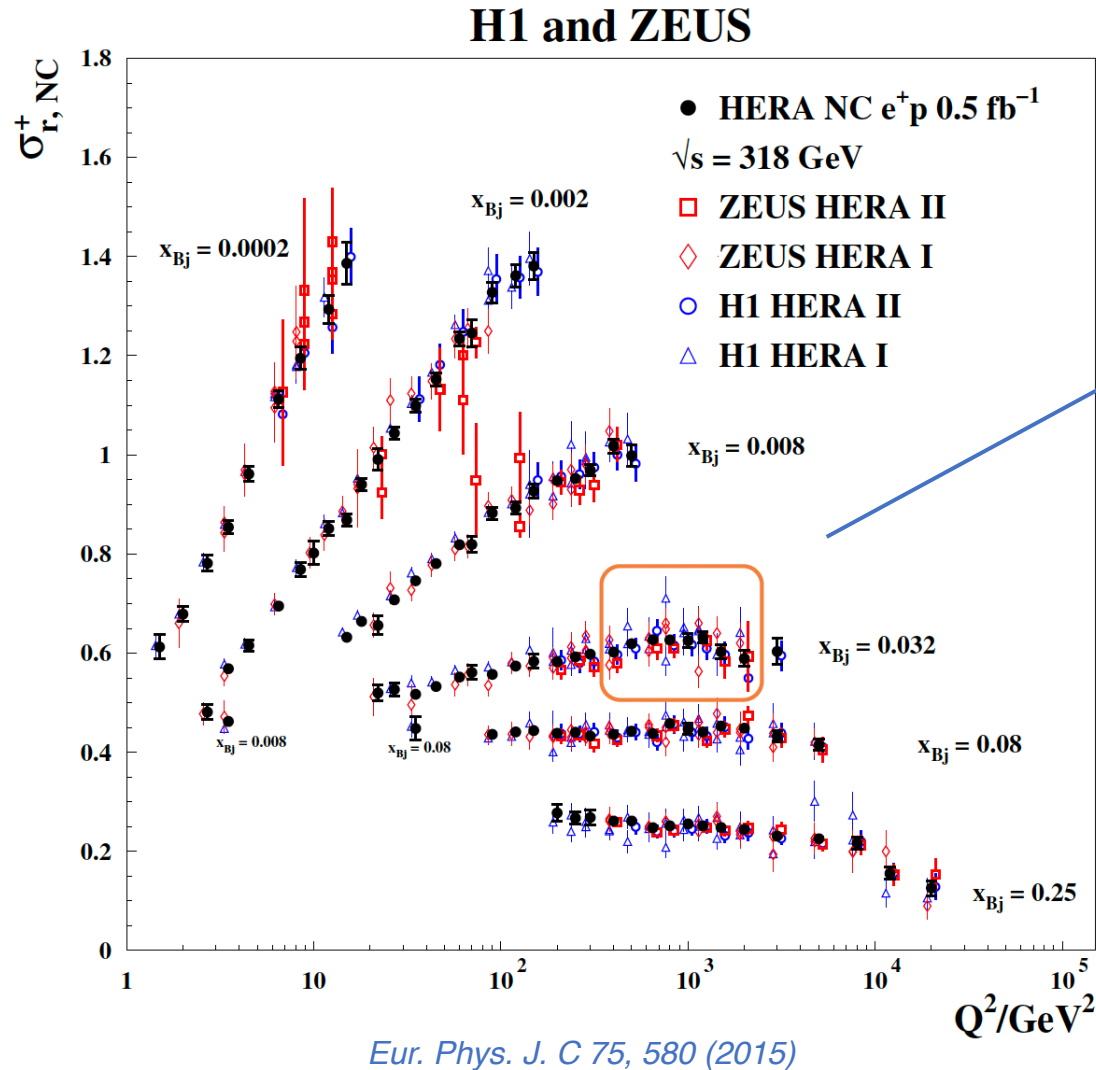
Luminosity, acceptance, and systematics



- Tomography / imaging require high luminosity – but also greatly benefit from better far-forward **acceptance**
- After reaching design luminosity, many EIC measurements will become **systematics** limited.

A 2nd detector with improved far-forward acceptance will have a large impact on all aspects of the EIC science program.

Complementarity: reduction of systematics at HERA

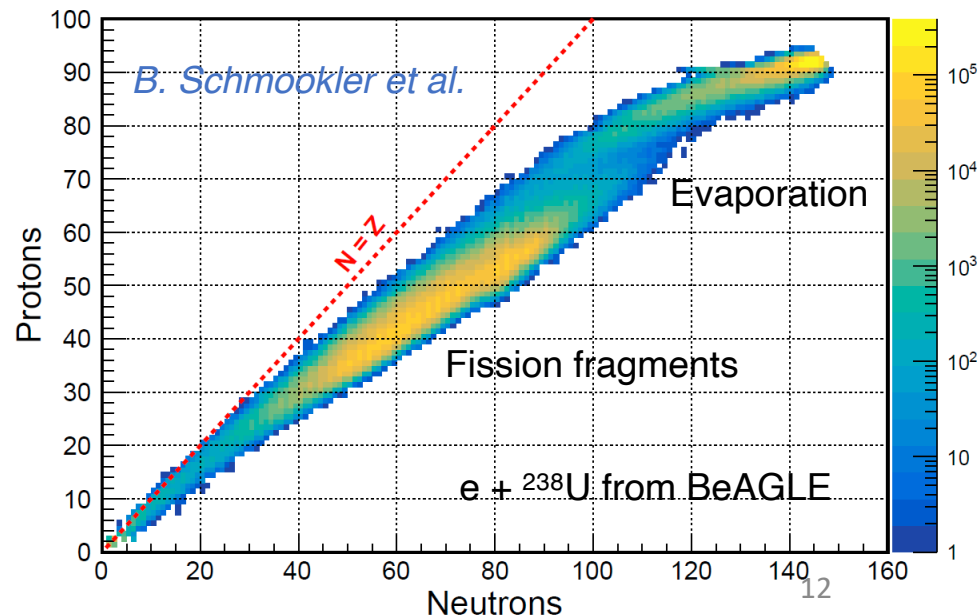


- If two complementary detectors are not *too* different and use similar binning, it may be possible to combine the data.
- At HERA the combined data had significantly reduced systematic uncertainties.
- The EIC luminosity will be 100 times higher, making systematics even more important.

Example: fragmenting nuclei

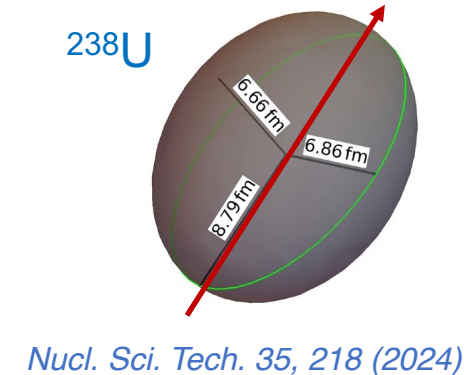
Rare isotopes

- In eA collisions, all kinds of isotopes are produced through evaporation and fission.
- With a 2nd focus these can be detected and identified. Gamma photons from their de-excitation can reveal the internal structure



Increasing the nuclear thickness?

- Nuclear targets make it possible to map out the onset of gluon saturation at the EIC.
- If one could select events where a deformed nucleus (${}^{238}\text{U}$) is struck along the long axis, the effective nuclear thickness would increase.
- With a 2nd focus, we can use the complete final state to efficiently select such a subset.



^{238}U – using deformed nuclei to increase the effective nuclear thickness

- At the EIC, nuclei will be used to probe the transition to gluon saturation

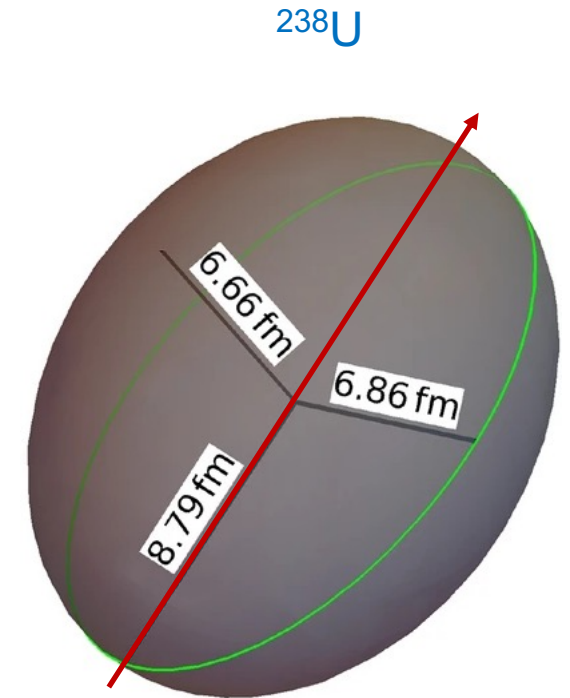
$$Q_s^2 \sim A^{1/3}/x^{0.3} \sim T(b) \cdot (E_e E_A)^{0.3}$$

- where $T(b)$ is the nuclear thickness as a function of the impact parameter
- and E_e and E_A are the electron and ion beam energies, respectively.

- Striking the nucleus *centrally* along the *long* axis creates an enhancement

$$\frac{T(b=0)_{\text{long axis}}}{\langle T(b) \rangle_{\text{min bias}}}$$

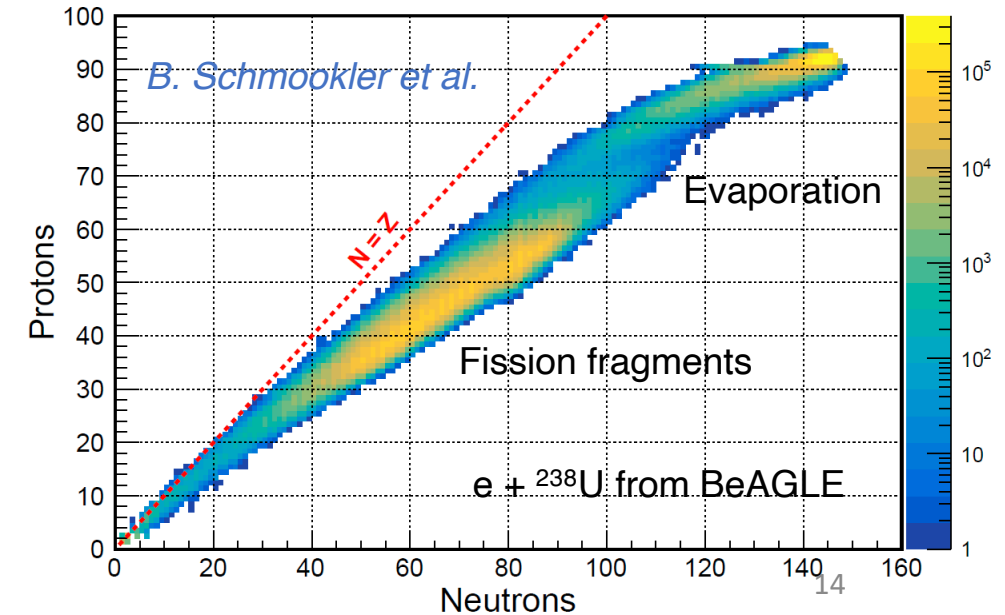
- This is equivalent to a very substantial increase in E_e .
 - A preliminary study showed that selecting a subsample of a few percent of the events using the final-state information from the second focus could be equivalent to a factor 4.5 increase in E_e .
 - A more comprehensive evaluation using ML-methods is underway (Fanelli, Schmookler, Li, Vossen, PNT)



PNT et al, POETIC8,
Regensburg, Germany (2018)

Correlating nuclear thickness with forward activity

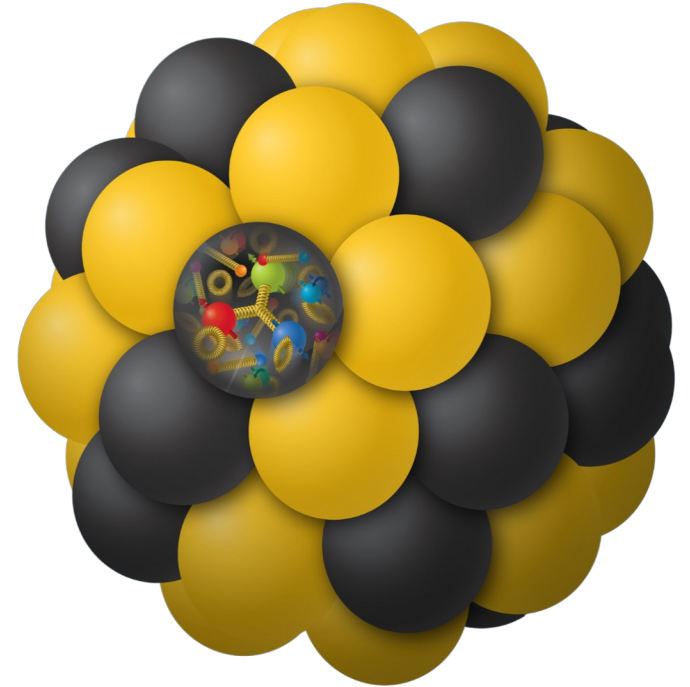
- In high-energy eA scattering most nuclei can fission, but ^{238}U fissions most of the time.
- An event with a large thickness is likely to produce more breakup, but the forward activity is more than "evaporation" neutrons.
 - Fission fragment produce neutrons. The number depends on which fragments are produced.
 - Protons and light ions are also emitted.



- With a second focus we can detect the complete final state including the fission fragments.

Bound and quasi-free nucleon structure through spectator tagging

- The EIC forward detectors make it possible to measure processes on a single nucleon in coincidence with spectator nucleons and nuclei.
 - Due to final-state interactions this is essential for interpretation.
- **Quasi-free neutron structure** can be accessed by measuring the spectator proton(s) in deuterium or polarized ^3He .
- **Bound nucleon structure** can be accessed by measuring the spectator nucleus (A-1 system).
- The ePIC forward detectors are good for spectator protons, but a 2nd EIC detector would be able measure A-1 nuclei over the full mass range.



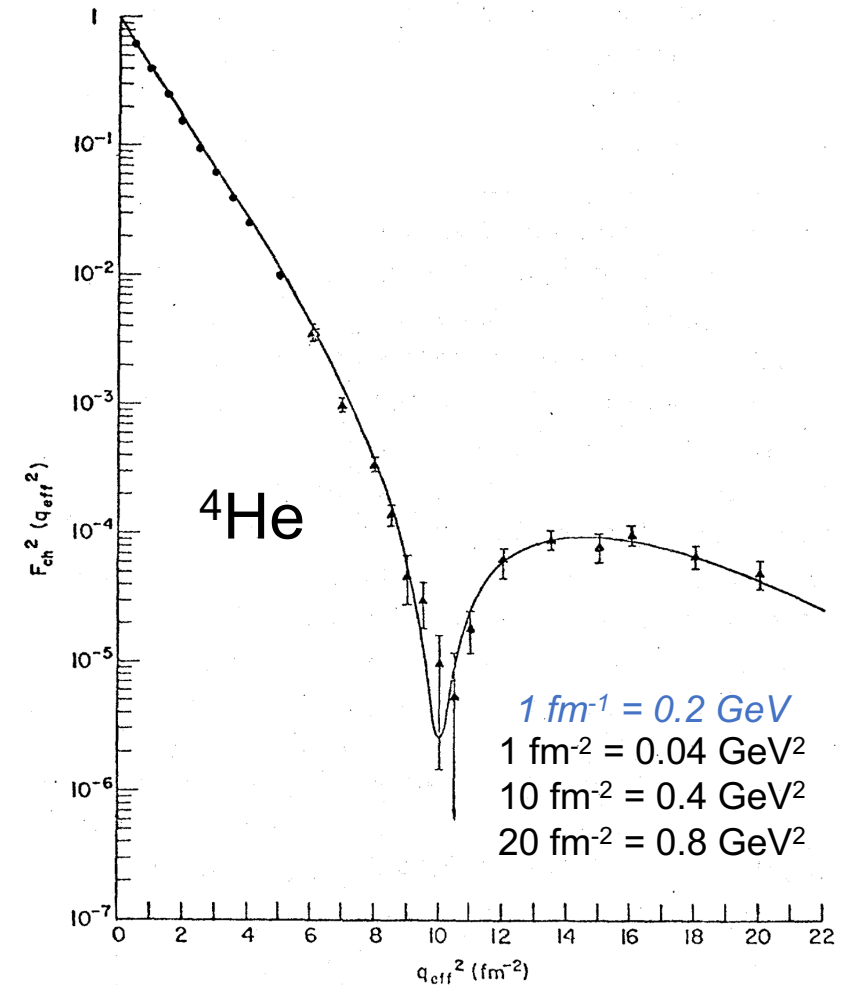
Coherent nuclear processes

Light ions

- Access to 3D structure (GPDs)
 - Exclusive reactions like DVCS, DVMP
 - Combines spin and nuclei
- Recoiling ion is *detected* in Roman pots
 - ePIC can detect ^3He over a range in t , but a second focus would be essential for heavier light ions such as ^4He , ^6Li , and ^7Li . (Li could be polarized in the future).

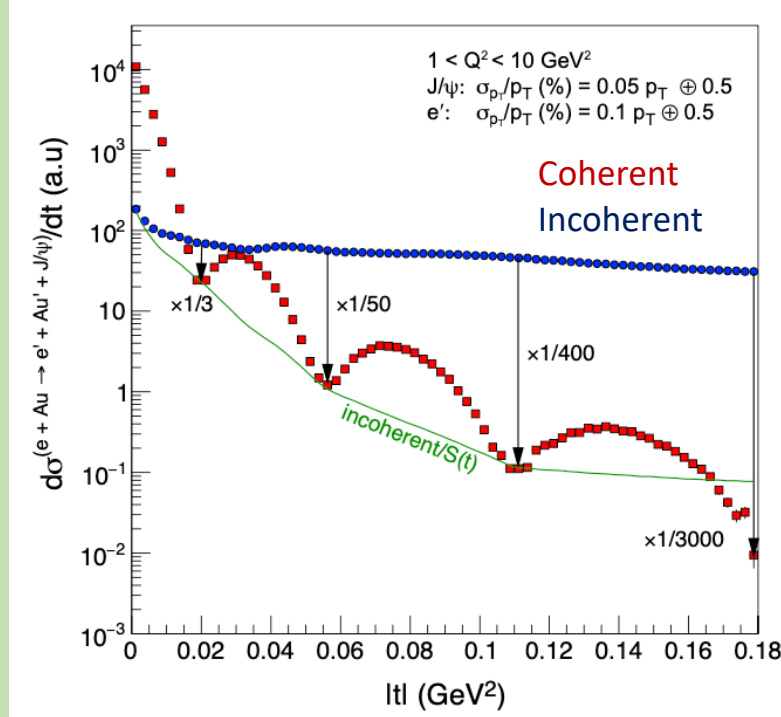
Medium- and heavy ions

- Coherent diffraction (right)
 - Spacing of minima is reduced at larger A
- Incoherent events are separated by vetoing of breakup
 - Detection of neutrons, protons, and photons
 - With a 2nd detector also light ions and nuclear fragments



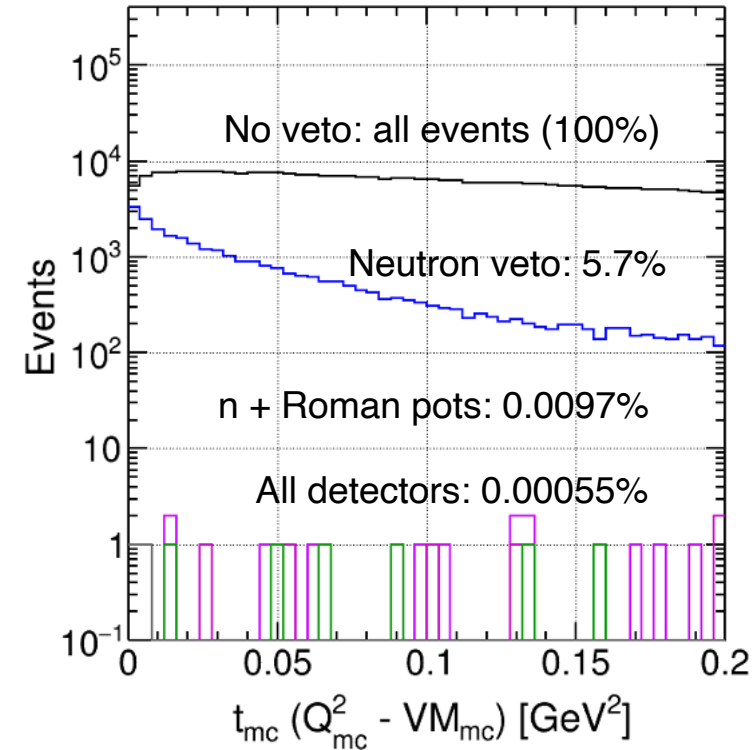
Coherent diffraction on heavy nuclei vetoing breakup with a second focus

Reference from EIC YR p.352



At the third diffractive minimum, a rejection factor for incoherent event better than 400:1 (0.0025% inefficiency) must be achieved

Veto inefficiency for incoherent events



J. Kim et al

Fragment detection in Roman pots at the second focus suppresses incoherent backgrounds even at large t .

Also applicable to, e.g., DVCS on medium nuclei

Double DVCS ($Q^2 < Q'^2 \Rightarrow$ TCS-like)

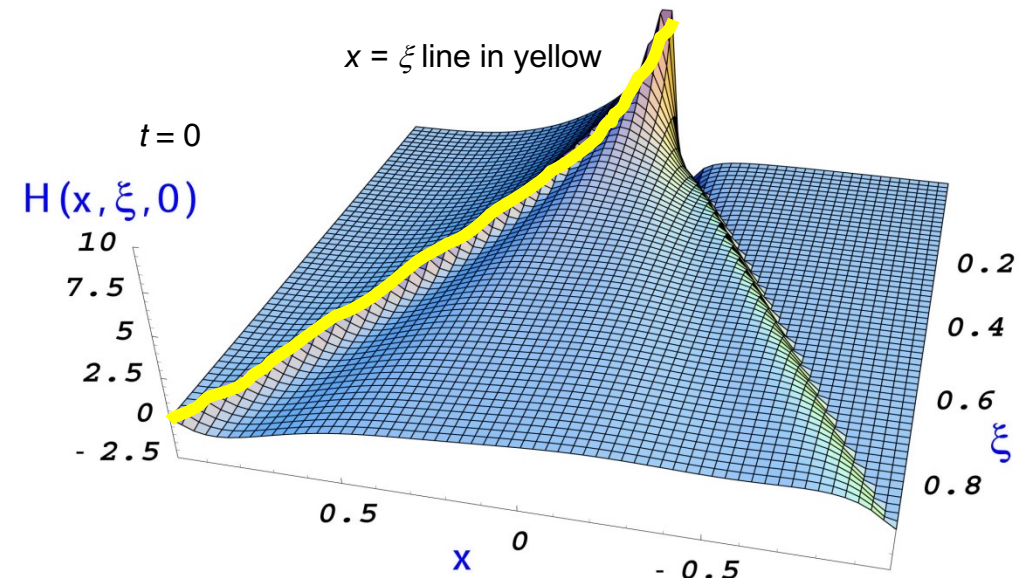
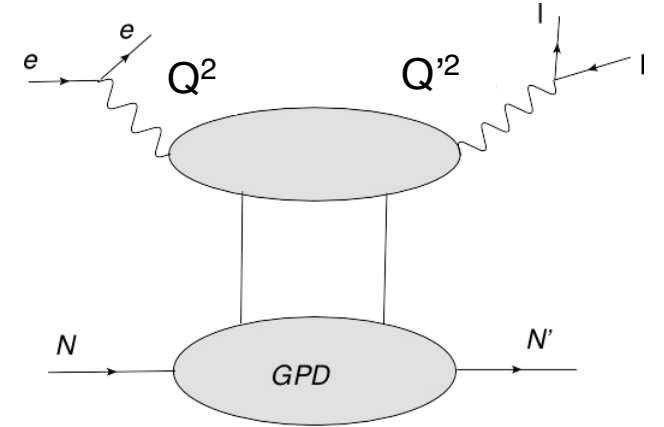
Challenging measurement Illustrative of many EIC / D2 features

events = luminosity x cross section x acceptance x time

- Double DVCS can probe GPDs outside of the $x = \xi$ line.
 - Low rates challenging, but cross section increases at lower x
 - 0.14 pb - JLab @ 10.6 GeV
 - 4.7 pb - EIC @ 10 x 100 GeV
- Lepton acceptance and identification
 - Good muon ID is *necessary* to distinguish the scattered electron from the DDVCS decay leptons
 - The EIC has excellent di-lepton acceptance.
- Proton acceptance in an IR with a second focus
 - DDVCS measurements will provide data mostly at low t
 - The 2nd focus gives a low- t proton acceptance close to 100%

PRD 107, 094035 (2023)

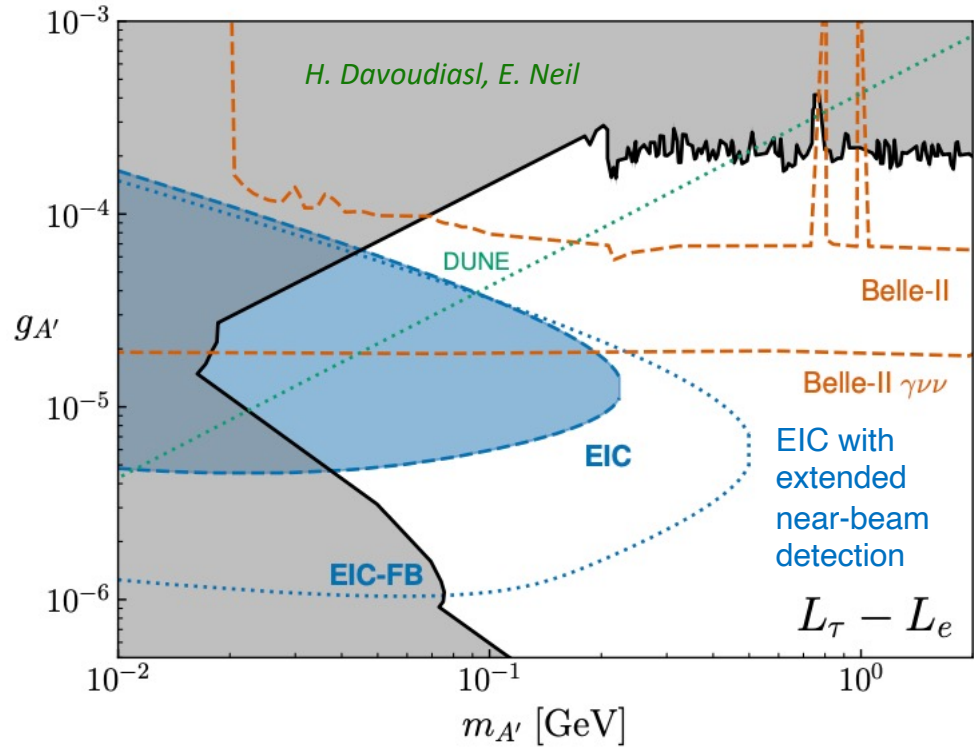
DDVCS: initial *and* final photon virtual



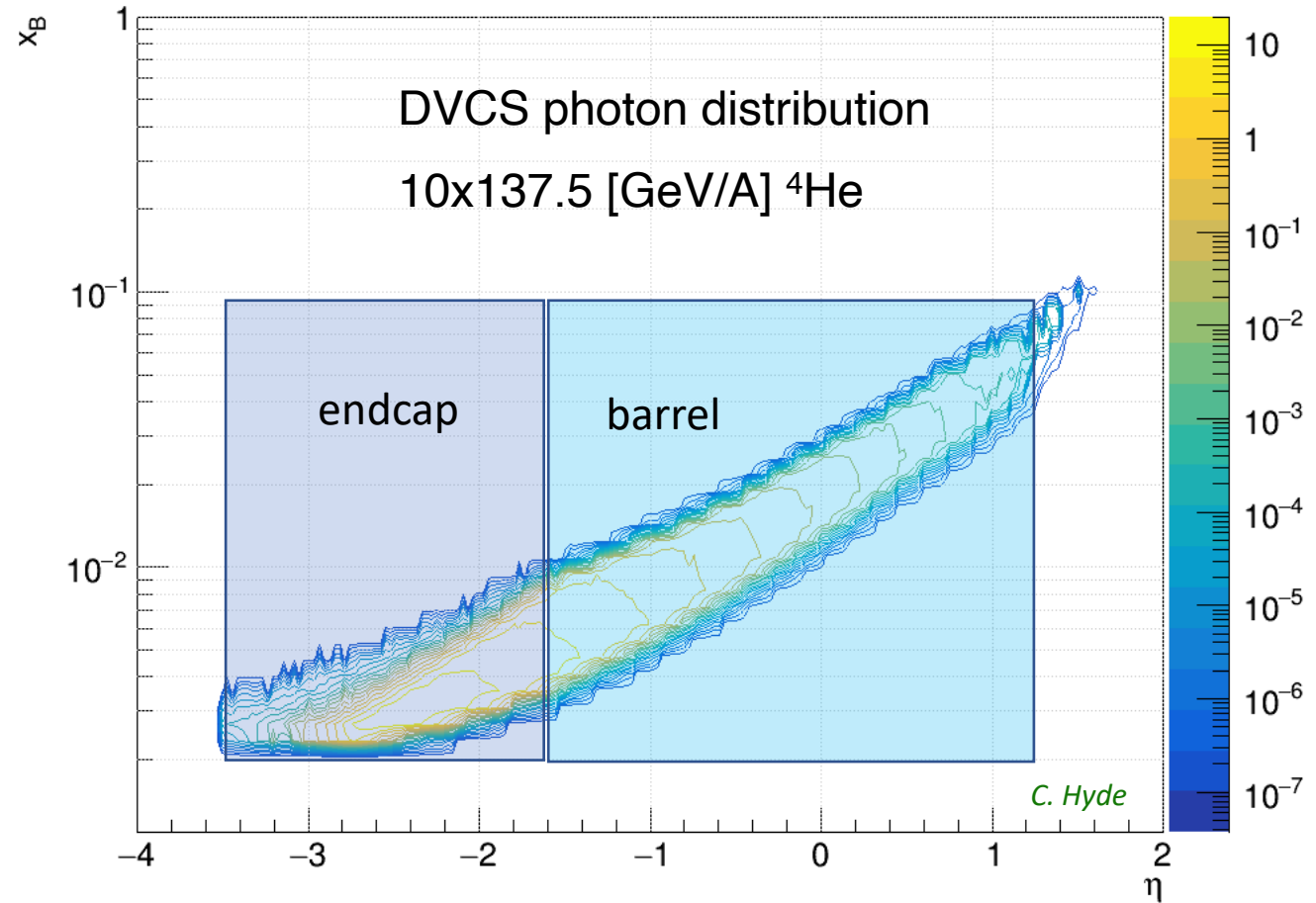
The 2nd EIC detector could provide an excellent opportunity for measuring DDVCS

Example: EM calorimetry

Displaced vertices of dark sector bosons



- Displaced decays can suppress SM backgrounds in searches for dark photons and L_i - L_j gauge bosons..
- They would predominately be produced at small angles in the electron-going direction (challenging).



- For DVCS on nuclear targets the momentum transfer to the nucleon t is determined from the photon. One thus needs:
 - **low- t acceptance** (provided by the 2nd focus)
 - **high-resolution EMcal** coverage in the barrel

The EIC user group 2nd detector working group

- Formed in 2022 following DPAP and the establishment of the ePIC collaboration
- The current focus is on developing simulation tools reflecting the envisioned capabilities
- We aim for a short publication early next year and then starting the work on a longer white paper
 - Your input will be essential, and synergies with the LHC will be of great interest!
- We organize regular WG meetings. Please let us know if you have something you would like to share!
- Conveners
 - Anselm Vossen (Duke U) [anselm.vossen at duke.edu](mailto:anselm.vossen@duke.edu) (chair-elect of the EIC UG steering committee)
 - Björn Schenke (BNL) [bschenke at bnl.gov](mailto:bschenke@bnl.gov)
 - Charles Hyde (ODU) [chyde at odu.edu](mailto:chyde@odu.edu)
 - Charlotte van Hulse (Vrije Universiteit) [charlotte.barbara.van.hulse at cern.ch](mailto:charlotte.barbara.van.hulse@cern.ch) (also an EIC UG SC member)
 - Pawel Nadel-Turonski (U of SC) [turonski at sc.edu](mailto:turonski@sc.edu)
 - Simonetta Liuti (UVA) [sl4y at virginia.edu](mailto:sl4y@virginia.edu)
 - Vasiliy Morozov (ORNL) [morozovvs at ornl.gov](mailto:morozovvs@ornl.gov)
 - Wenliang “Bill” Li (MS State U) [wenliang.li at msstate.edu](mailto:wenliang.li@msstate.edu)

Summary

- Having two detectors is important to maximize EIC science and take full advantage of the investment made into the EIC.
- A 2nd detector would provide new science opportunities, for instance related to eA.
 - It would benefit from far-forward detection in an interaction region with a second focus
- Complementarity with ePIC but also the LHC experiments would be important!
- Please let us know your ideas and suggestions!

Thank you!