Detector Requirements and Simulation Results for the EIC Exclusive, Diffractive and Tagging Physics Program using the ECCE Detector Concept

May 16

Bill, Axel, Julie and Rachel
on behalf of Exclusive, Diffractive and Tagging WG

Paper overleaf repository

- **Exclusive, Diffractive and Tagging Summary Paper**

  ecce-paper-phys-2022-03 (being presented today)

- **eA Diffractive study (e + Pb ➜ e’ + J/ψ + X and e + Pb ➜ e’ + ϕ + X)**

  ecce-paper-phys-2022-02 (coming soon)

- **Photoproduction J/ψ Detection and Physics with ECCE**
  - ecce-paper-phys-2022-11 (under review)

ECCE Exclusive, Diffractive and Tagging Summary paper

- **Diffractive and Tagging analysis note: ecce-note-phys-2021-02**
- **Exclusive analysis note: ecce-note-phys-2021-03**
- **Far forward and far backward region detector note: ecce-note-det-2021-06**
- **XYZ meson analysis note: ecce-note-det-2021-06**

Authorship

Detector Requirements and Simulation Results for the EIC Exclusive, Diffractive and Tagging Physics Program using the ECCE Detector Concept

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- **First: Student and postdocs alphabetically**
- **Second: Group members alphabetically**
- **Third: consortium members alphabetically**
- **PWG Sim QA (Cameron and Jing) are in-group**

To be modified to the desired order

Paper Structure

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Section 1: Introduction

The scientific mission at the Electron-Ion Collider (EIC) was summarized in a 2018 report by the National Academies of Science (NAS) [1]:

- While the longitudinal momenta of quarks and gluons in nucleons and nuclei have been measured with great precision at previous facilities – most notably CEBAF at JLab and the HERA collider at DESY – the **full three-dimensional momentum and spatial structure** of nucleons have not been fully elucidated, particularly including spin, which requires the separation of the intrinsic spin of the constituent particles from their orbital motion.
- These studies will also provide insight into how the mutual interactions of quarks and gluons generate the **nucleon mass and the masses of other hadrons**. The nucleon mass is one of the single most important scales in all of physics, as it is the basis for nuclear masses and thus the mass of essentially all of visible matter.

The Yellow Report also identified a set of detector performance requirements that flow down from the physics requirements of the EIC science program articulated in the NAS report:

- The outgoing electron must be distinguished from other produced particles in the event, with a pion rejection of 10^3–10^4 even at large angles, in order to characterize the kinematic properties of the initial scattering process. These include x_B and the squared momentum transfer (Q^2).
- A large-acceptance magnetic spectrometer is needed to measure the scattered electron momentum, as well as those of the other charged hadrons and leptons. The magnet dimensions and field strength should be matched to the scientific program and the medium-energy scale of the EIC. This requires a nearly 4π angular aperture, and the ability to precisely make measurements of the sagitta of its curved trajectory, to measure its momentum down to low p_t, and to determine its point of origin, in order to distinguish particles from charm and bottom hadron decays.
- A high-purity hadron particle identification (PID) system, able to provide continuous e/π and K/π discrimination out

The physics objectives derived from the NAS questions for ECCE can be expressed as follows:

1. Origin of nucleon spin.
2. Three-Dimensional structure of nucleons and nuclei.
3. Gluon structure of nuclei.
4. Origin of hadron mass.
5. Science beyond the NAS Report.

This number scheme is refereed to in Table 4.

Introduction section (Sec. 1)

NAS questions

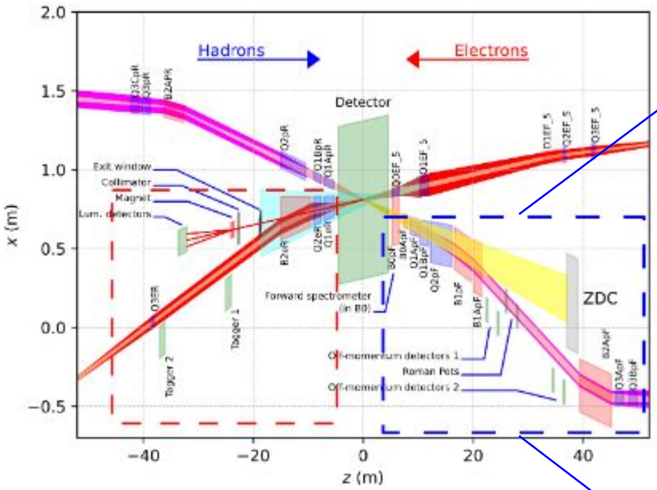
Introduction section (Sec. 1)

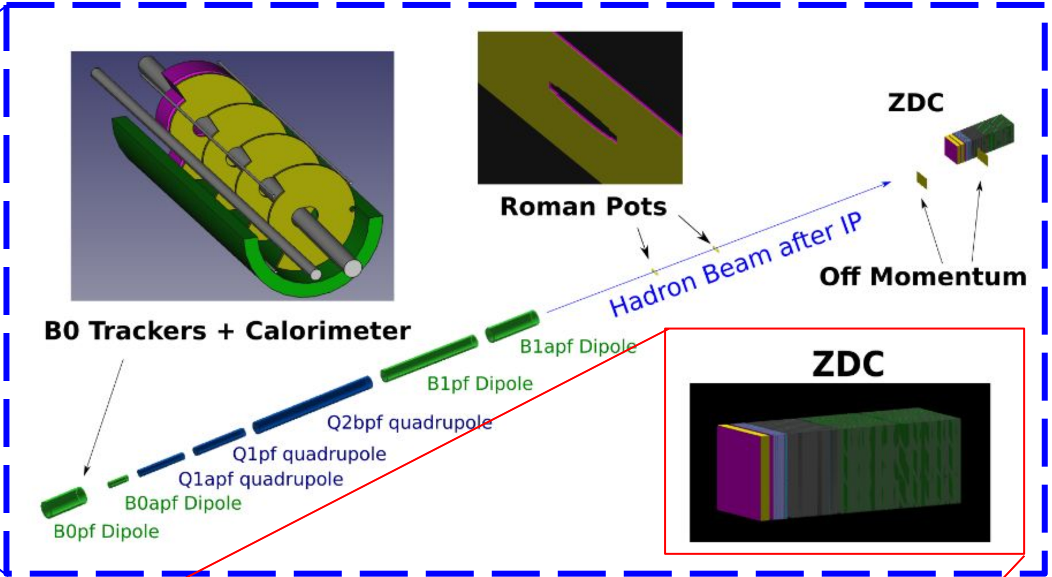
Detector requirements

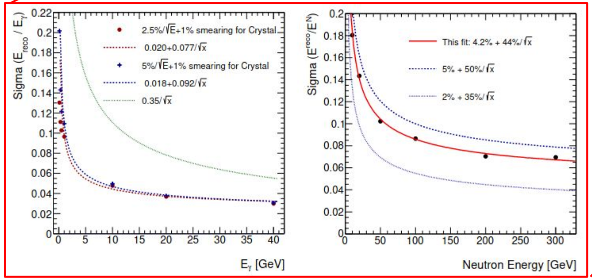
Physics section (Sec. 4)

ECCE science mission

Section 2: Detector

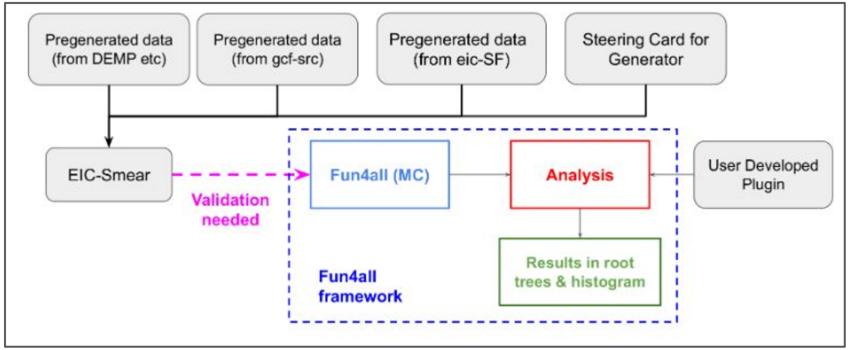






ZDC photon (left) and neutron resolution (right)

Section 3: Simulation



Simulation workflow and Fun4all introduction

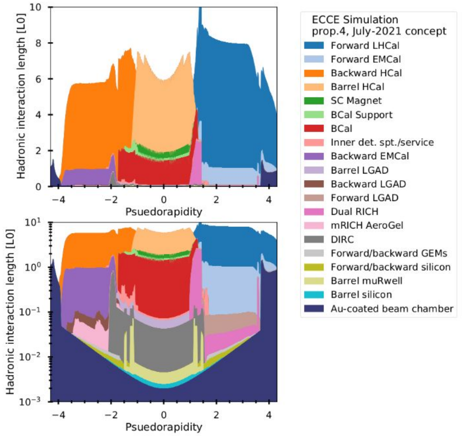
as the **high-acceptance** configuration. For about 90% of the time, the EIC will operate at small β_x^* for **high-luminosity** but with a divergence angle exceeding 73 μrad and this is referred to as the **high-divergence** configuration. Because of the large cross section for small p_T a large amount of data can be collected in a short amount of time so there is eventually an equal amount of data at all p_T values from 200 MeV to 1.3 GeV. This scenario substantially increases the effective luminosity of the facility [26].

Beam parameters

3.3. Simulation campaign status

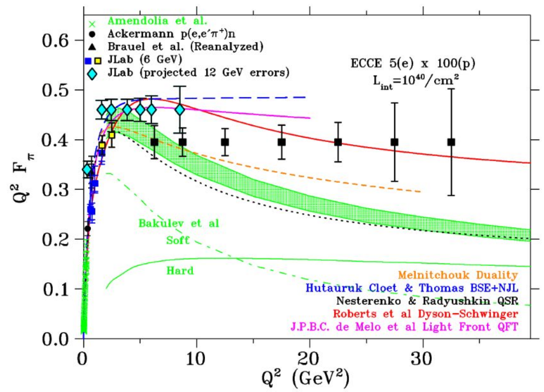
Four detector concepts were assembled in the ECCE simulation, one for each simulation campaign. The information and overall simulation status are documented in the wiki database: `https://wiki.bnl.gov/eicug/index.php/ECCE_Simulations_Working_Group`. The corresponding software branch name for the simulation campaign are given below:

1. First simulation campaign: June-Concept (2021), which is tagged with proposal software build **prop.2**.
2. Second simulation campaign: July-Concept (2021), which is tagged with proposal software build **prop.4**.
3. Third simulation campaign: October-Concept (2021) and a variation with a AI-optimized inner tracker, which is tagged with proposal software build **prop.5**.
4. Forth simulation campaign: January-Concept (2022) with the full beam configuration set, which is tagged with proposal software build **prop.7.1**.

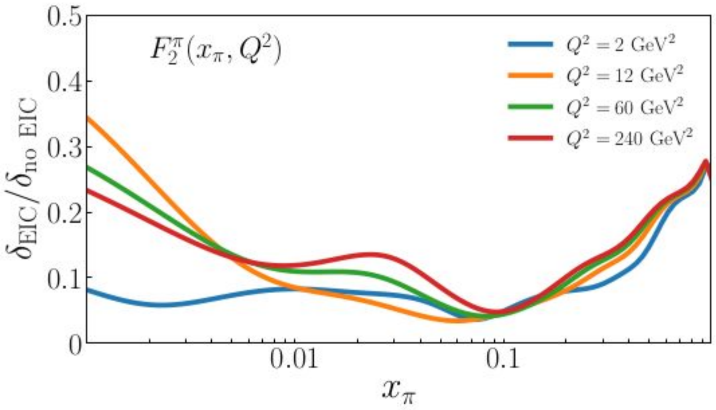


Production branch

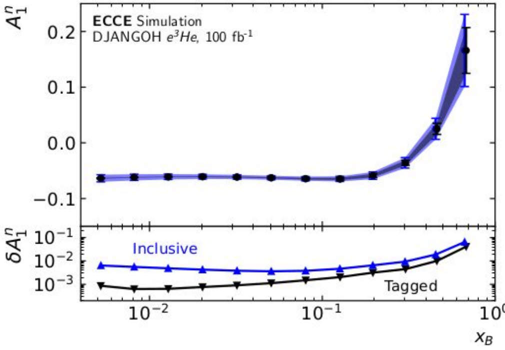
Section 4: Physics



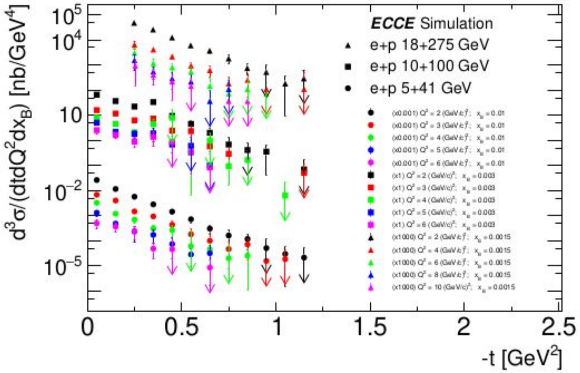
π FF



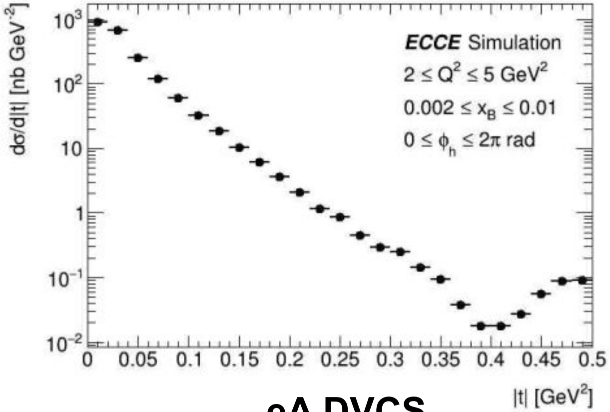
π Structure function



e-^{4}He Double tag

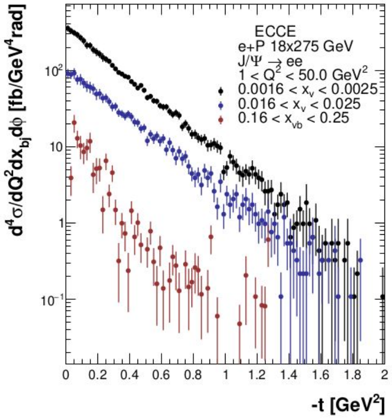


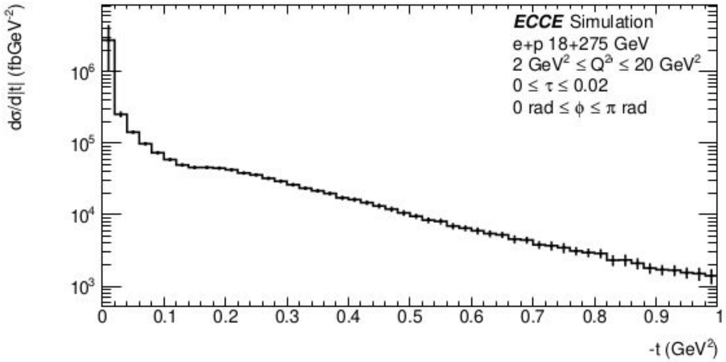
ep DVCS

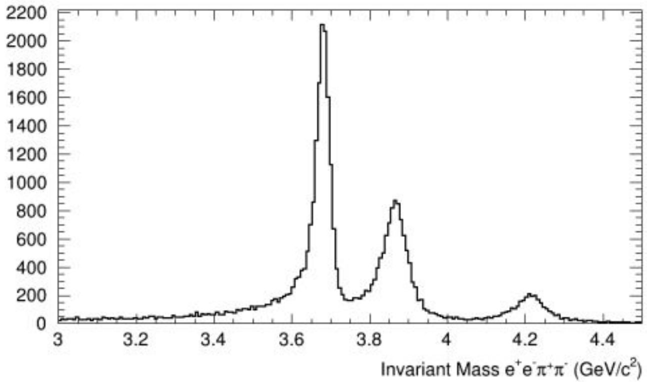


eA DVCS

Section 4: Physics

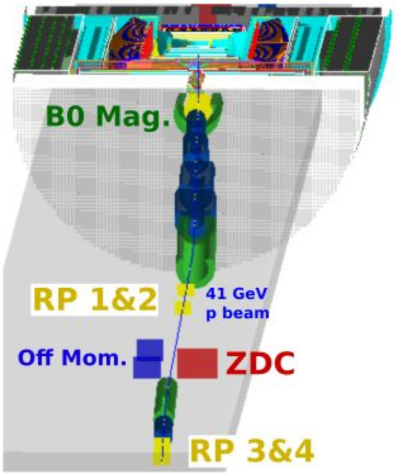






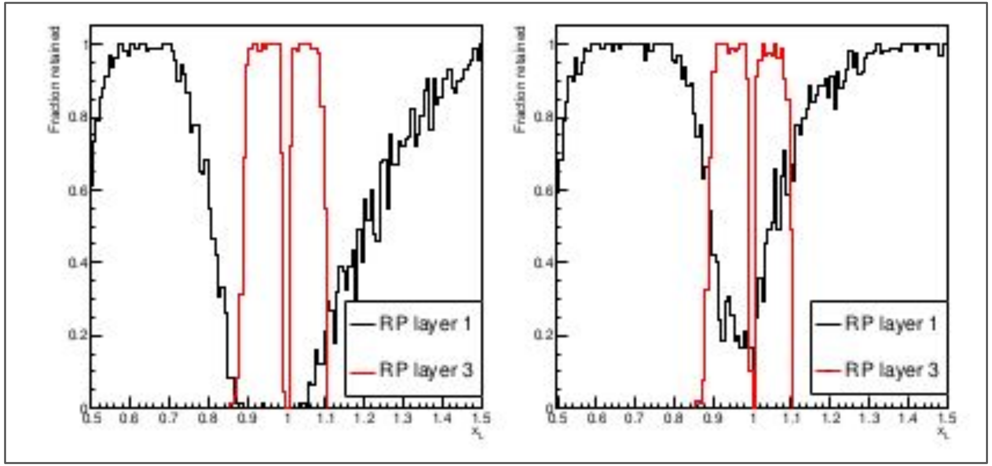
ep J/ψ **TCS** **XYZ spectroscopy**

Section 5: IP8



1. The addition of the secondary focus at IP8;
2. The crossing angle is 35mrad at IP8 compared to 25mrad at IP6. Consequently, the ZDC acceptance is larger ±8 mrad at IP8 compared to ±5 mrad at IP6.

IP8 baseline measurement is =-5 mrad. +- 8 mrad is only possible with new magnet design



RP impact

	IP6		IP8	
Energy [GeV]	Detector Fraction	Δt	Detector Fraction	Δt
5×41	59%	0.019	78%	0.018
5×100	100%	0.007	100%	0007
10×100	100%	0.007	100%	0.007
18×275	100%	0.005	100%	0.008

ZDC impact

Standardization

- **Energy:** 5x18 or 5x18 GeV^2
- **Momentum:** GeV/c
- **Q^2, t:** GeV^2
- **Bjorken x: x_B**
- **E:** GeV
- **Atomic symbols:** He (no italic)
- Fig. XXX
- Table XXX
- Eqn.
- far-forward region
- far-backward region

Timeline and to-do list

- Timeline:
  - 1st internal review completed (comments are being addressed)
  - Second internal review start soon
  - Paper ready for consortium review by May 20

- To-do list:
  - Authorship orders
  - Summary section to be written by Axel
  - Abstract to be written (Axel, Garth, Julie and Zisis)
  - Addressing the comment from the review

Thank you!

- **Any questions, feedback and comments are welcome**