Diffractive and Tagging Process in EIC Collider Experiment - ECCE

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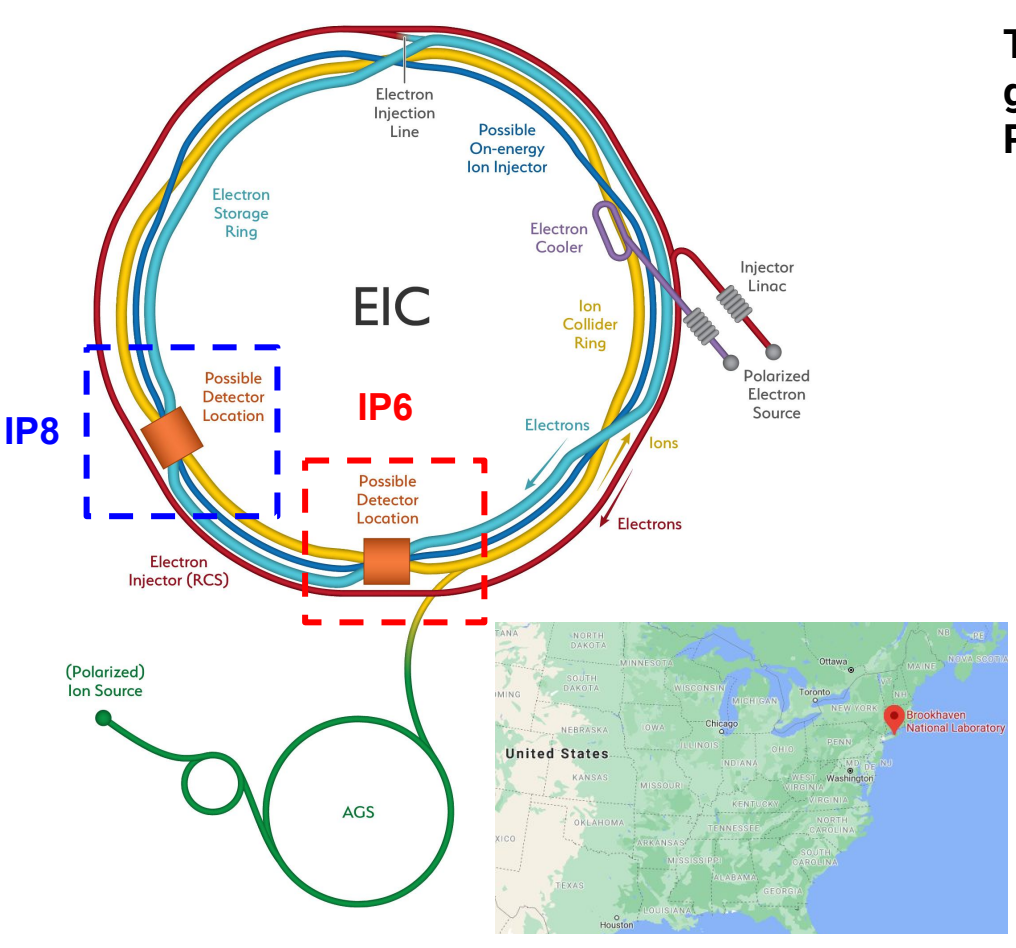
WILLIAM & MARY
CHARTERED 1693

Talk Outline

- **Short intro to EIC and EIC Users Community**
- **EIC Timeline and latest news**
- **What is the ECCE Consortium**
- **ECCE detector stack**
- **Diffractive and Tagging Working Group**
- **Current activities at the ECCE Diffractive and Tagging working group**

Electron Ion Collider (EIC) @ BNL



The Electron-Ion Collider (EIC) is the next generation "Dream Machine" for Nuclear Physics Research.

- Extend current measurement on studying nucleon structure.
- Project Location: Brookhaven National Laboratory (BNL), NY. (site selection was completed in early 2020)
- The project was approved for ~$2 B to construct one project detector
- Physics starts in 2031

EIC Users Group

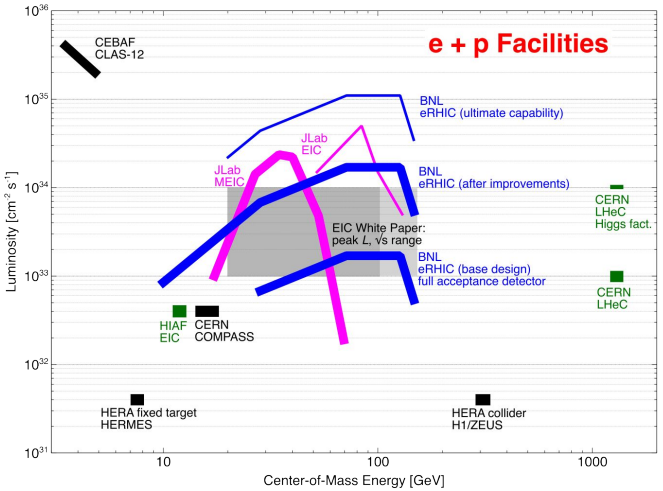
- **EIC Users Group (EICUG)**
  - 1297 Members
  - 264 Institutions
  - 36 Countries

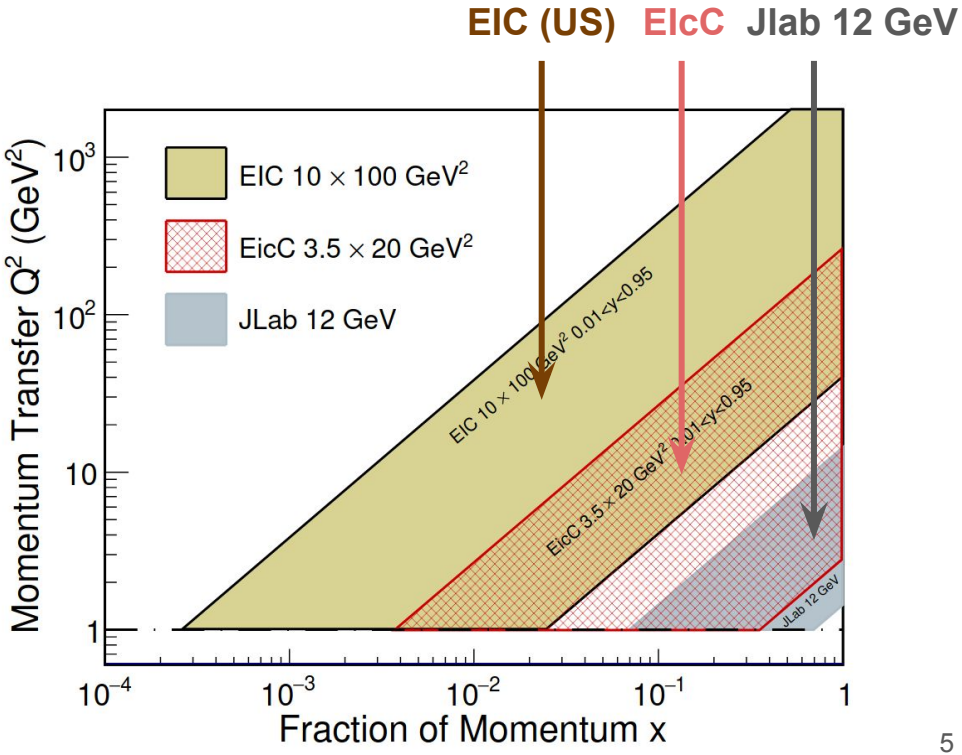
- **EIC Users Community**
  - Chair: Prof. R. Fatemi (UKY)
  - Annual meeting: July-Aug

- **Helping young scientists to gain exposure has become part of the culture**
  - 2nd EIC Early Career Workshop in Warsaw
  - Funding is available to help student and postdoc travel!

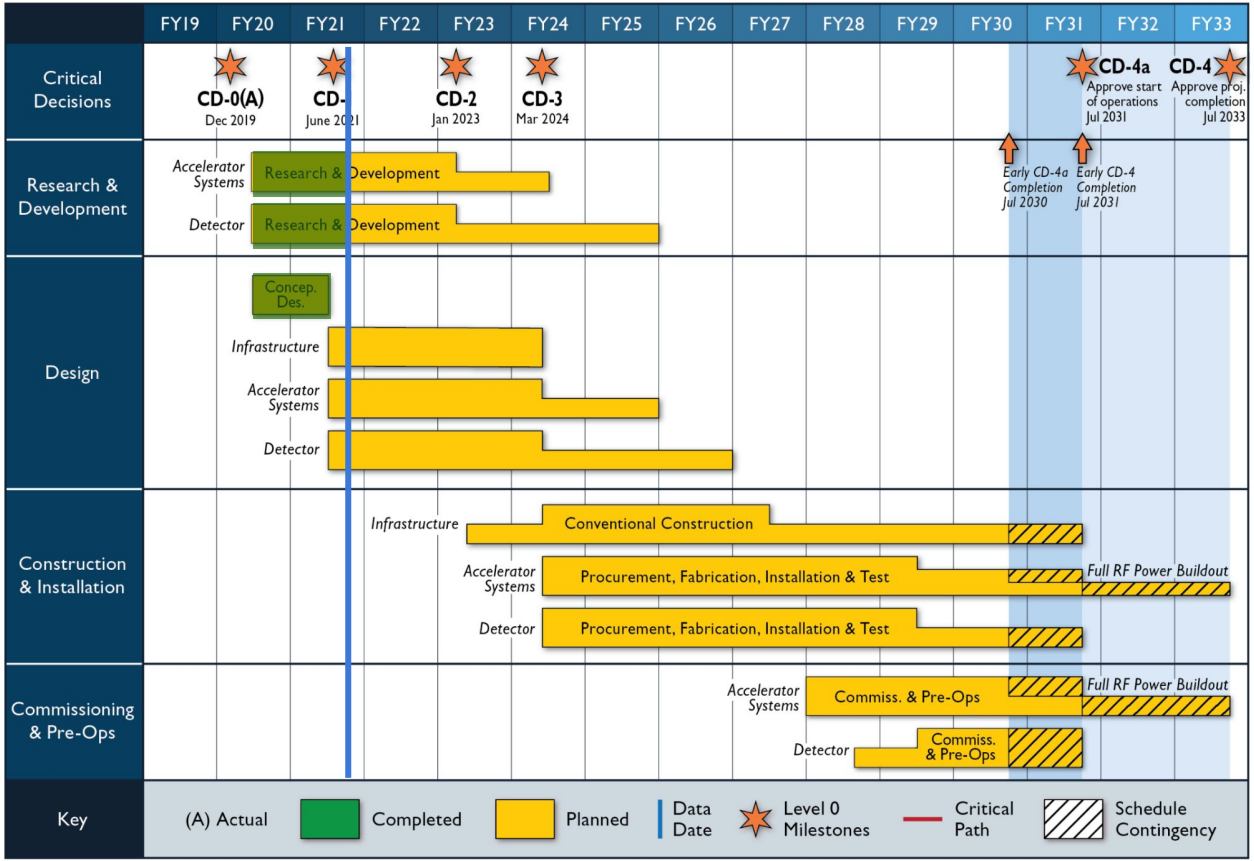
EIC Luminosity and Kinematics

- EIC Luminosity: 100 GeV p on 5 GeV e: 10 x10^{33} $cm^{-2}s^{-1}$ mi





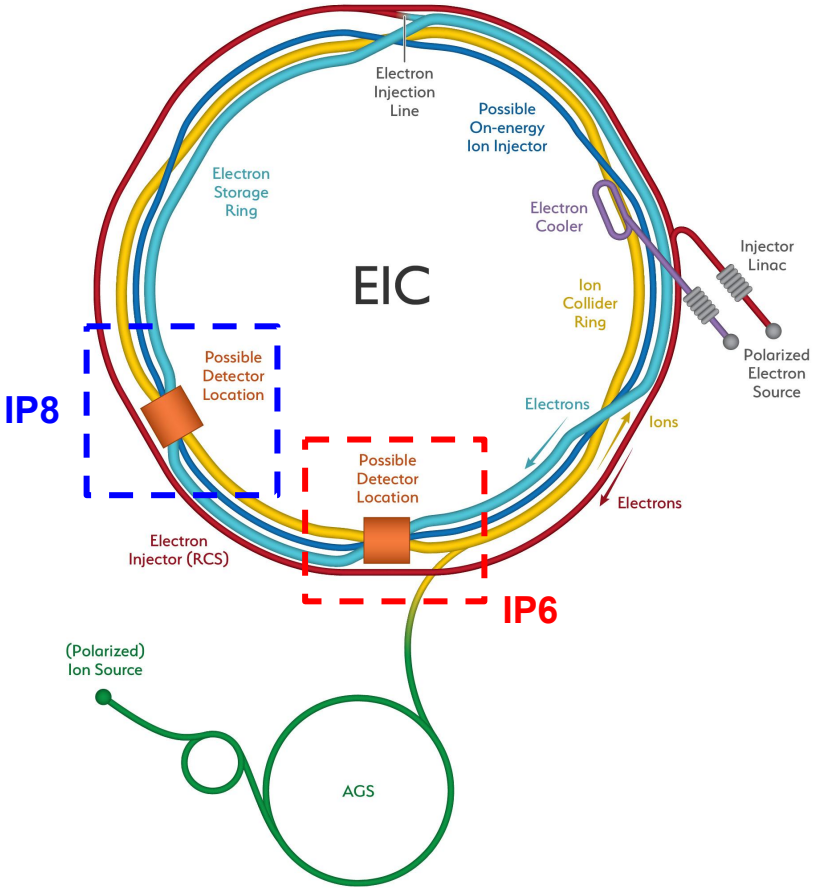
EIC Timeline and Schedule



- CD-0: Dec 2019
- CD-1: June 2021
- **Project detector design proposal: Dec 1, 2021 (explained in the next few slides)**
- CD-2 in Jan 2023
- CD-3 in March 2024
- Physics by 2031
  - EIcC timeline is similar

Information credit to R. Ent and EIC project

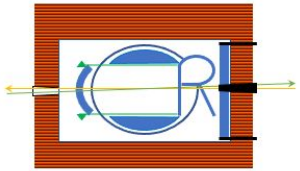
Detector Design and Competition



- **Project detector competition at IP6:**
  - ATHENA Collaboration vs ECCE Consortium

ATHENA vs ECCE

- 2nd IR effort or IP8:
  - CORE Collaboration:

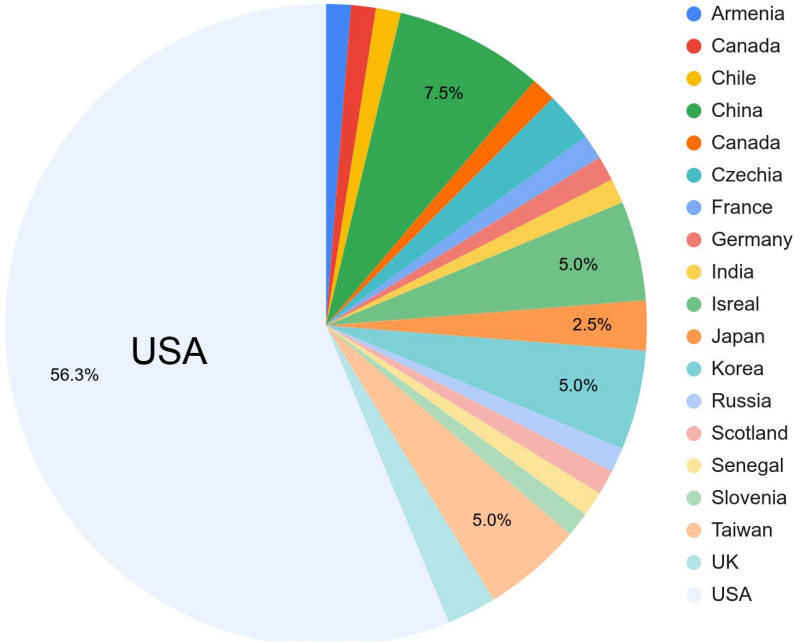


  - EIC@IR2: not a detector proposal

- Deadline for detector proposal submission: **Dec 1st, 2021!**

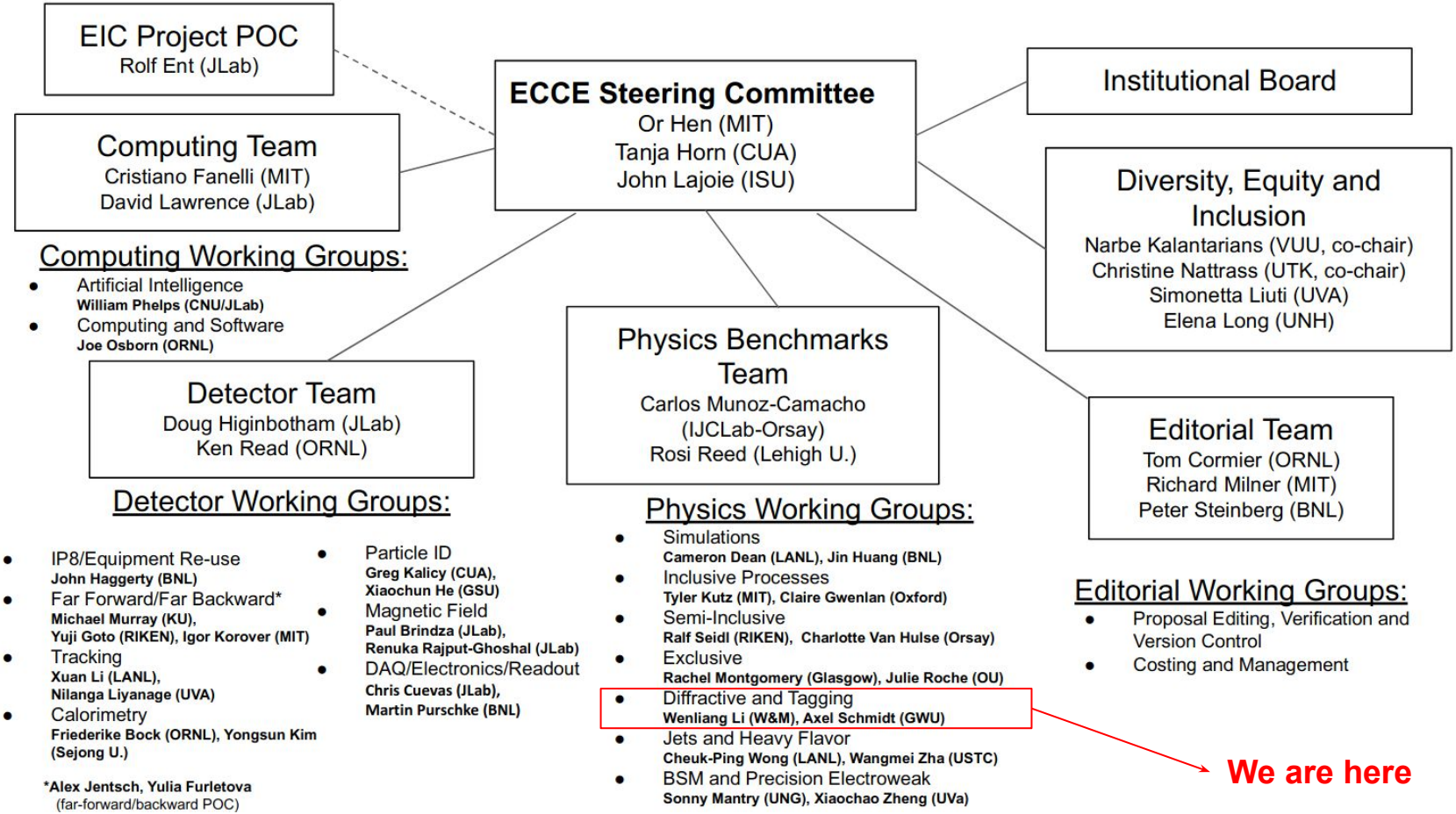
ECCE Consortium

- **EIC Comprehensive Chromodynamics Experiment (ECCE) Consortium**
  - https://www.ecce-eic.org/
- **81 member institutions (across 19 countries)**
- **Consortium objective: Develop a low risk, lower cost, effective project detector @IP6 which satisfies physics requirements of the yellow report**
  - **Re-using the BaBar magnet (sPhenix) at 1.4T**
  - **ATHENA propose to build a brand new 3T magnet**

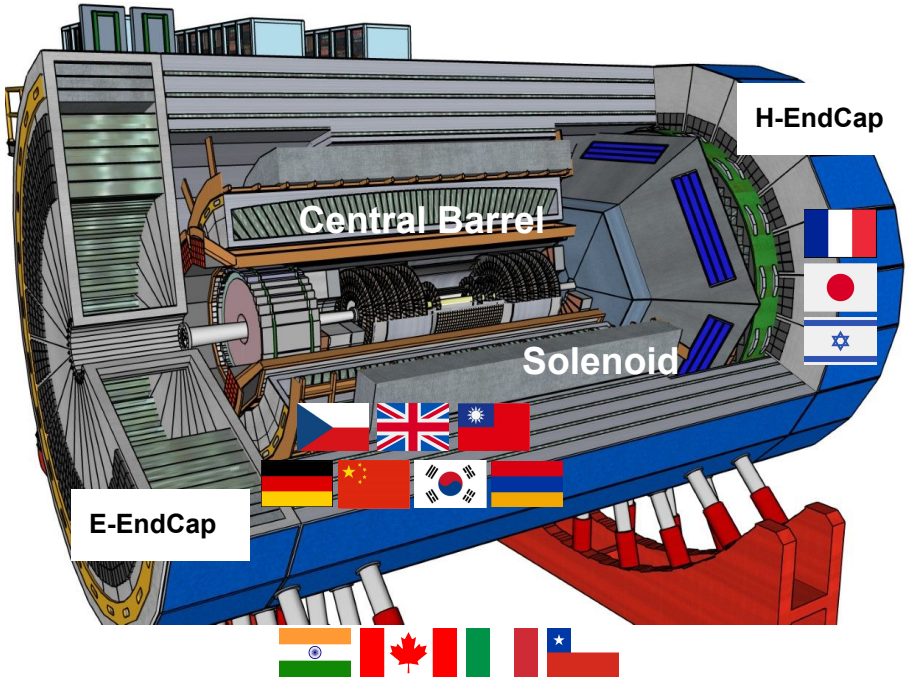


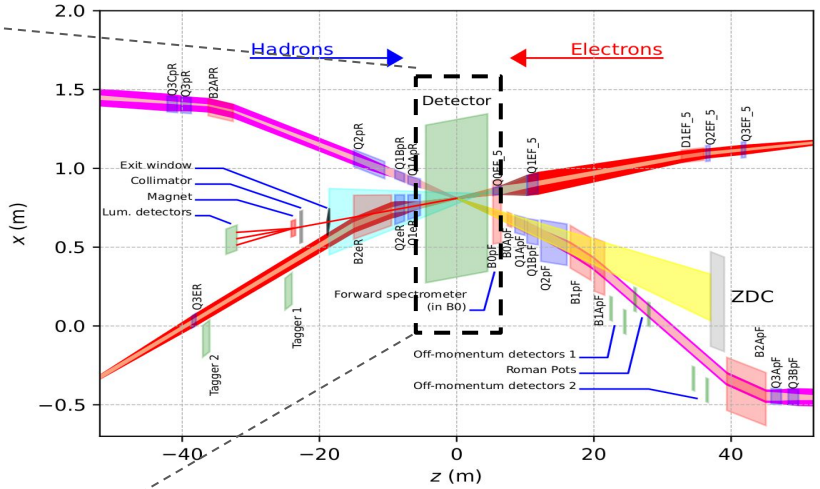
Information courtesy to O. Hen

ECCE Consortium Structure



EIC (ECCE) Detector Concept @ IP6





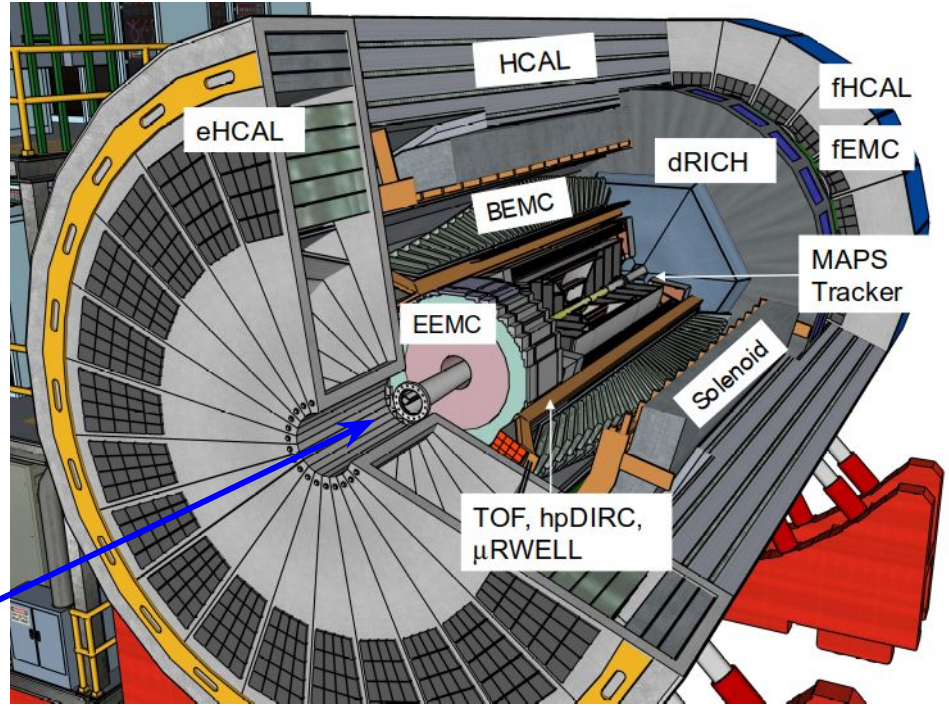
Main Features:

- Utilize BaBar magnet (1.4T)
- Estimated cost: ~200M
- Collaboration from ANL, ONL, JLab, LANL, LBL and other member institutions

More on Central ECCE Detector Design

ELECTRON ENDCAP

Tracking: MPGD (mRWell)
h-PID: mRICH & TOF (AC-LGAD)
Electron ID: PbWO4 crystals
HCAL: Fe/Sc (STAR re-use)



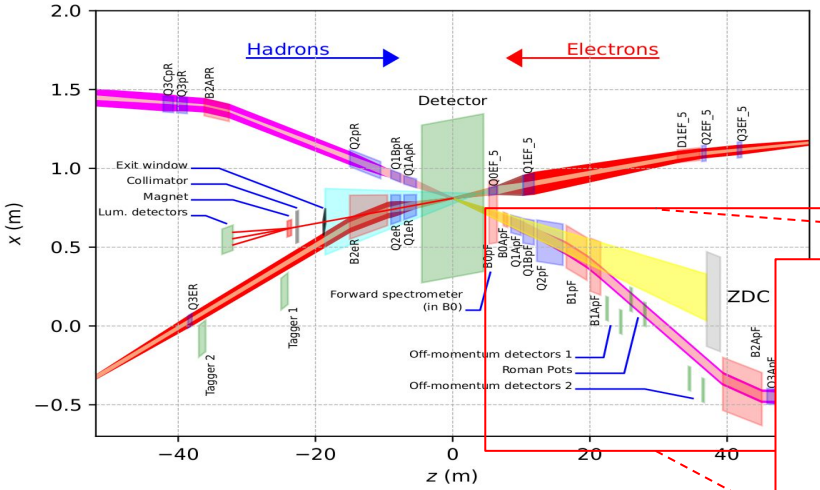
HADRON ENDCAP

Tracking: MPGD (mRWELL)
PID: dual-RICH & TOF (AC-LGAD)
Calorimetry:
Pb/ScFi shashlik (EMCal)
Long. separated HCAL

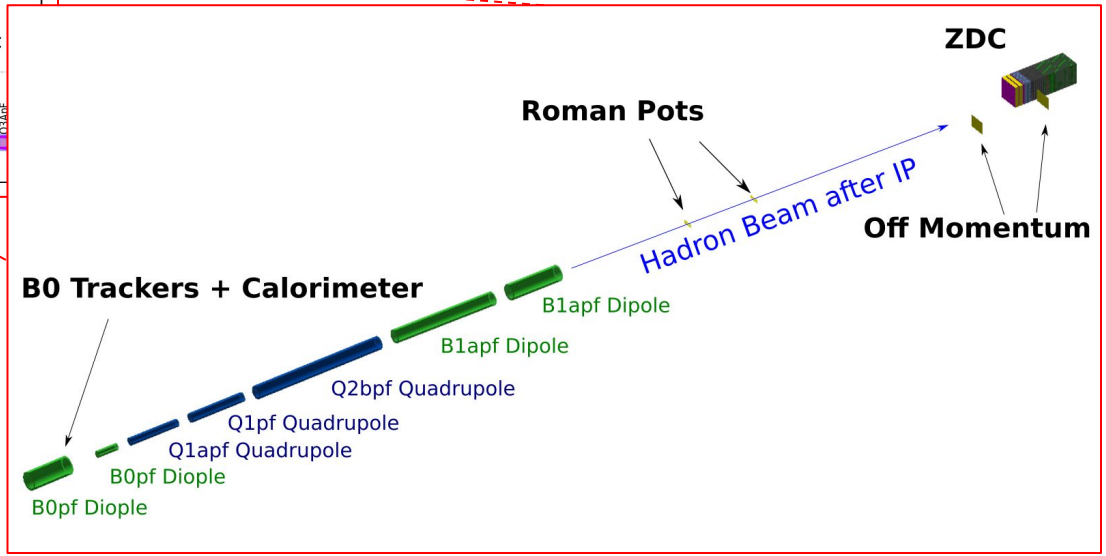
CENTRAL BARREL
Tracking: Monolithic Active Pixel Sensors (MAPS) and mRWell
h-PID: hpDIRC & TOF (AC-LGAD)
Electron ID: SciGlass
HCAL: Fe/Sc (sPHENIX re-use)

How does the central detector slots together?
https://physdiv.jlab.org/EIC/Menagerie/docs/Animations/20210115-IP-6.mp4

The Far Forward Region @ IP6



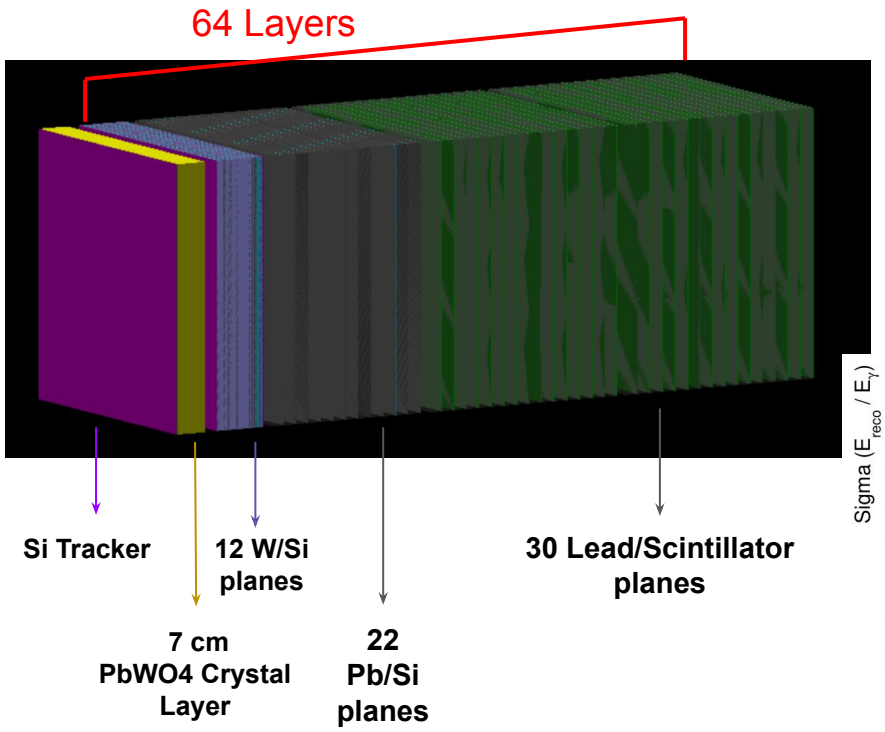
Beamline tagging provides access to the kinematics closer to the fixed target (JLab) scenario



Far Forward Region (FFR)

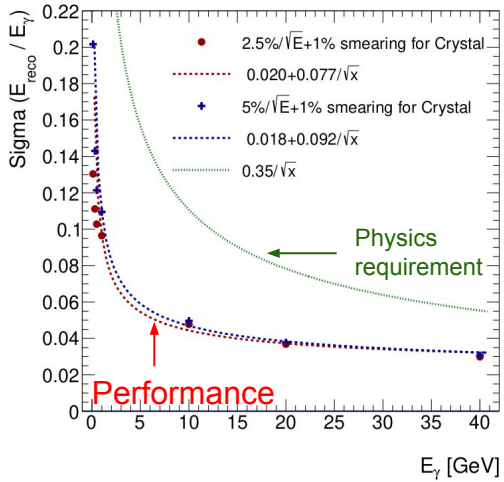
- **B0**
  - **Charged and neutral particles**
- **Zero Degree Calorimeter**
  - **Neutral particles**
- **Roman Pots**
  - **Beamline tagging**
- **Off Momentum detector**

Far Forward Detector Systems: ZDC

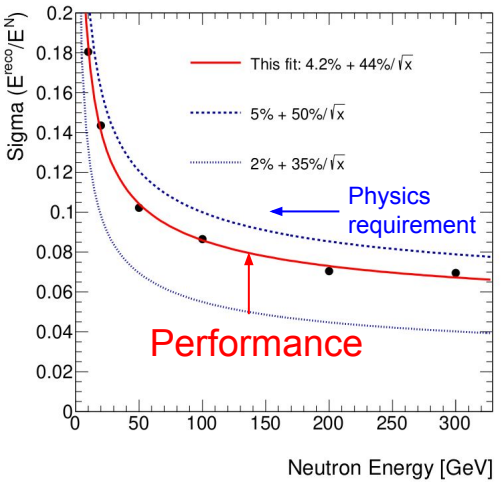


- **Zero Degree Calorimeter:**
  - **Dimension: 60 cm x 60 cm x 168 cm**
  - **30 m from IR**
  - **Detect spectating nucleon**
  - **Acceptance: +4.5 mrad, -5.5mrad**
  - **Position resolution ~1.3mm at 40 GeV**

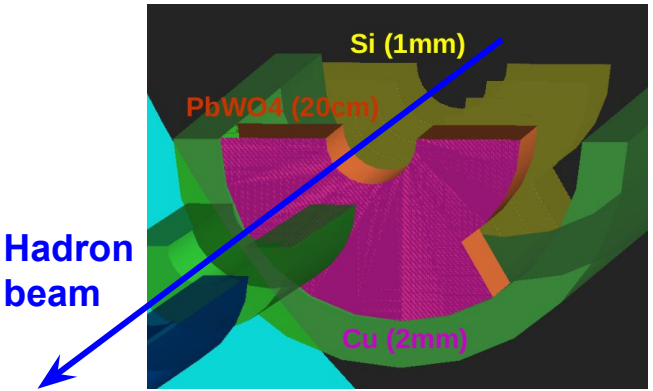
Photon energy resolution

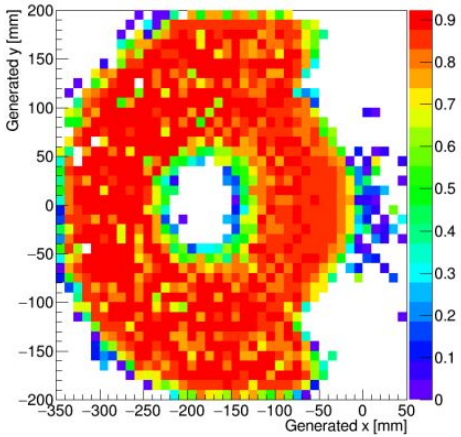


Neutron energy resolution

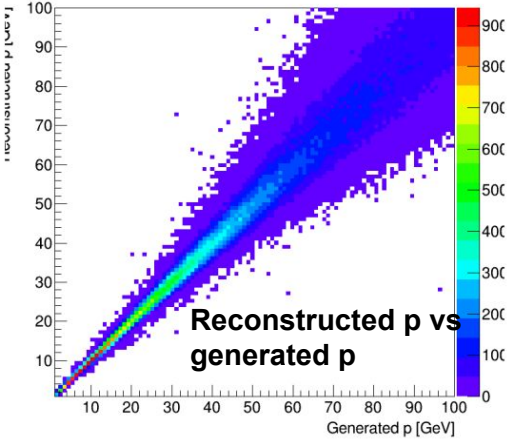


Far Forward Detector Systems: B0



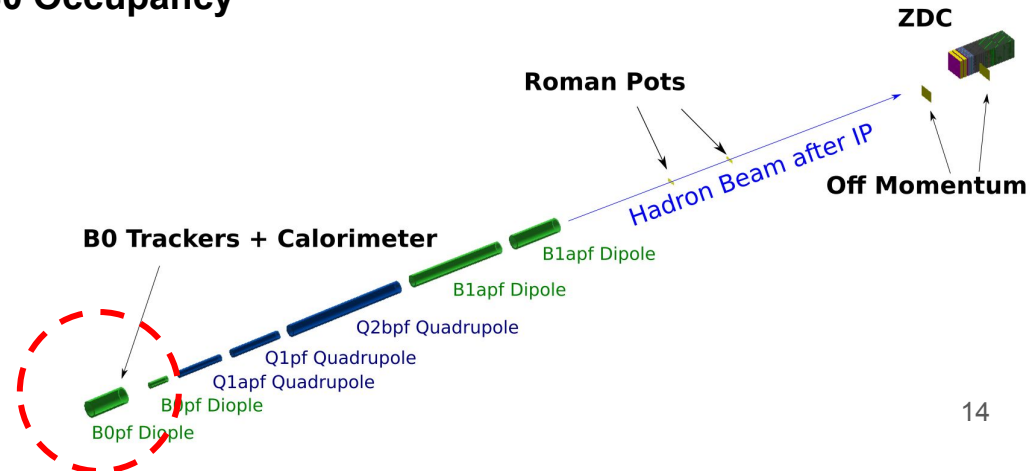


B0 Occupancy

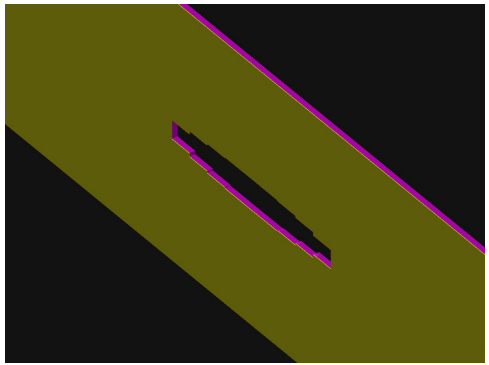


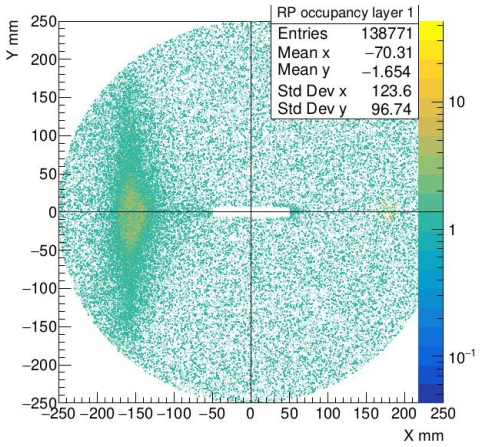
B0 detector stack

- B0 Dipole (2m in length)
- Include 4 layers of Si Tracker + 20 cm Calorimeter
- Detector both charged particle and neutral particles
- Optimization effort is ongoing

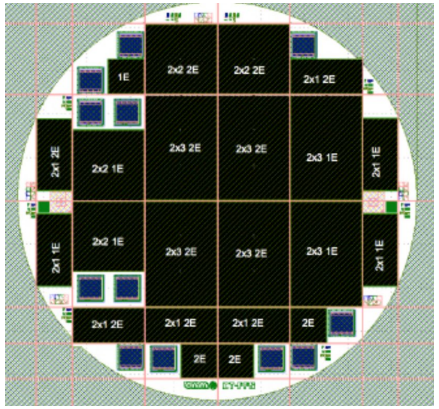


Far Forward Detector Systems: RP





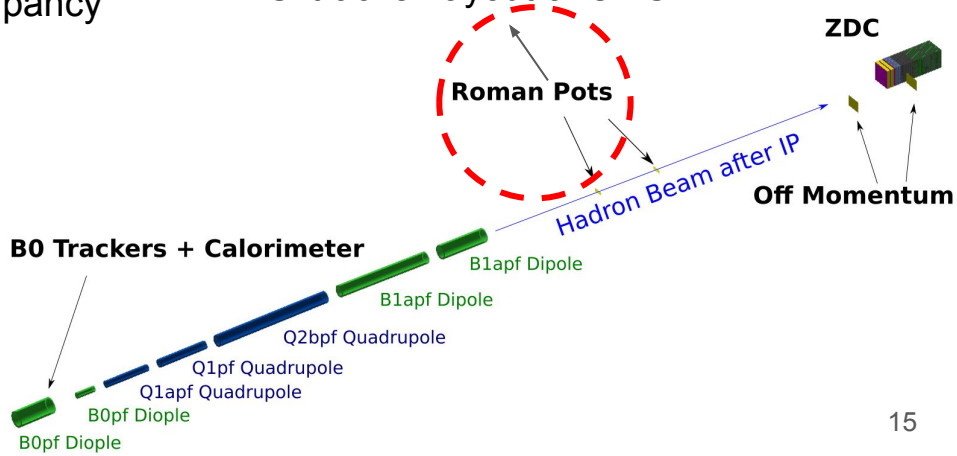
Roman pot occupancy



Si tracker layout of CMS RP

Roman pots:

- Used to detect slightly disturbed/recoiled nucleon
- Perfect to access low -t distribution of meson production processes
- Central hole represents the 10σ (beam width) boundary away from the beam



ECCE Diff & Tagg Working Group

- **Convenors:** R. Reed (Lehigh U.), C. Camacho (IJCLAB-Orsay)
- **Co-Convenors:** A. Schmidt (GW), W. Li (W&M)
- **Different studies groups:**

Studies	Group Member	Institution
π and K Form Factor	M.Ali, G. Huber, S. Kay	UofR (Canada)
π and K Structure Function	R. Trotta	CUA
A1n through e+He3	D. Nguyen, J. Pybus	JLab, MIT
SRC e+A	F. Hauenstein	ODU, MIT
u-Channel pi0	W. Li	W&M
eA Diffractive Study	M. Baker, D. Gangadharan, A. Schmidt, P. Steinberg	BNL, UH
u-Channel omega	Z. Sweger	UC Davis
Upsilon Production	D. Bhattacharyya, D. Das, A. Jahan	SAHA Inst.
XYZ Meson	D. Glazier, J. Stevens	Glascow, W&M

Underlined names: students and postdocs (majority of our group members)

WG Philosophy: we support anyone and everyone who would like to do work under ECCE; Delivering the high priority physics products/plots for the proposal (decided by the Editorial/Steering committee).

Studies and Priorities

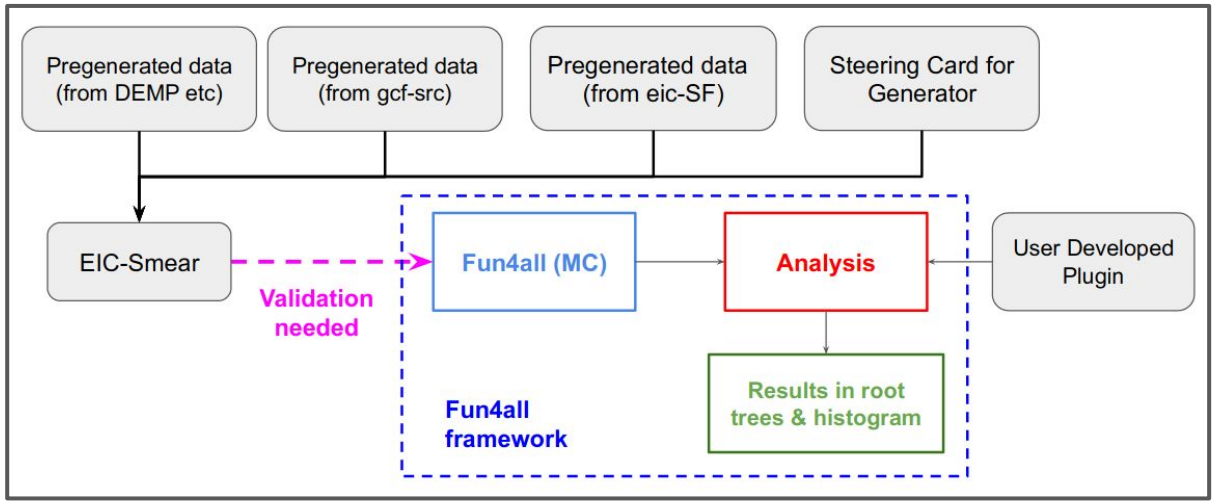
Studies	Detector used	NAS Objectives
π and K Form Factor	ZDC, Off Mom, ECap, HCap	1) Tomographic Imaging of Quarks and Gluons
π and K Structure Function	ZDC, Off Mom, ECap, HCap	1) Tomographic Imaging of Quarks and Gluons
A1n via e+He3	ZDC, Off Mom, B0, RP, ECap, HCap	7) Properties of Nuclei in QCD
eA Diffractive Study	ZDC, Off Mom, B0, RP, 2nd RP, ECap, HCap	8) Diffraction
SRC e+A	ZDC, Off Mom, B0, ECap, HCap	7) Properties of Nuclei in QCD
u-Channel pi0	ZDC, ECap, HCap	1) Tomographic Imaging of Quarks and Gluons
u-Channel omega	ZDC, Off Mom, B0, Far back.	1) Tomographic Imaging of Quarks and Gluons
Upsilon Production	ZDC, ECap, HCap, Barrel	2) Heavy-quarkonia exclusive production at threshold
XYZ Meson	HCap, RP, ECap, Far Back., Barrel	2) Heavy-quarkonia exclusive production at threshold

Red: High priority range
Blue: Far forward detector stack

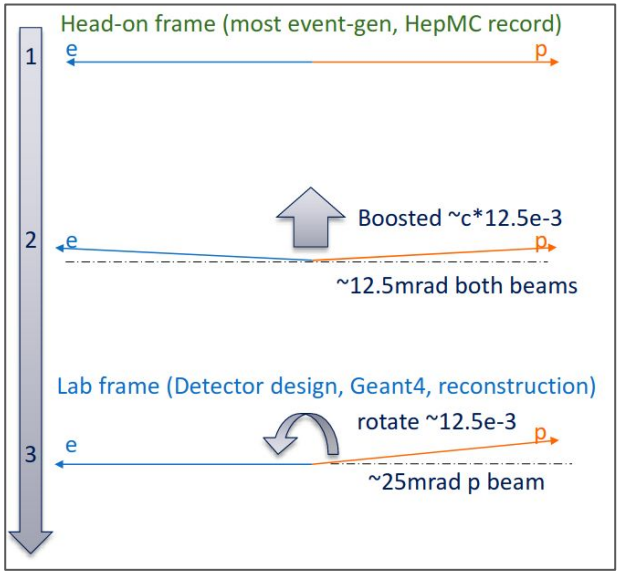
Simulation tools

- Fun4all Full simulation package
  - Standard simulation and reconstruction of sPHENIX experiment
    - https://github.com/ECCE-EIC/macros
  - Fun4all takes generated events in head-on collision in HEPMC or other formats

Simulation workflow



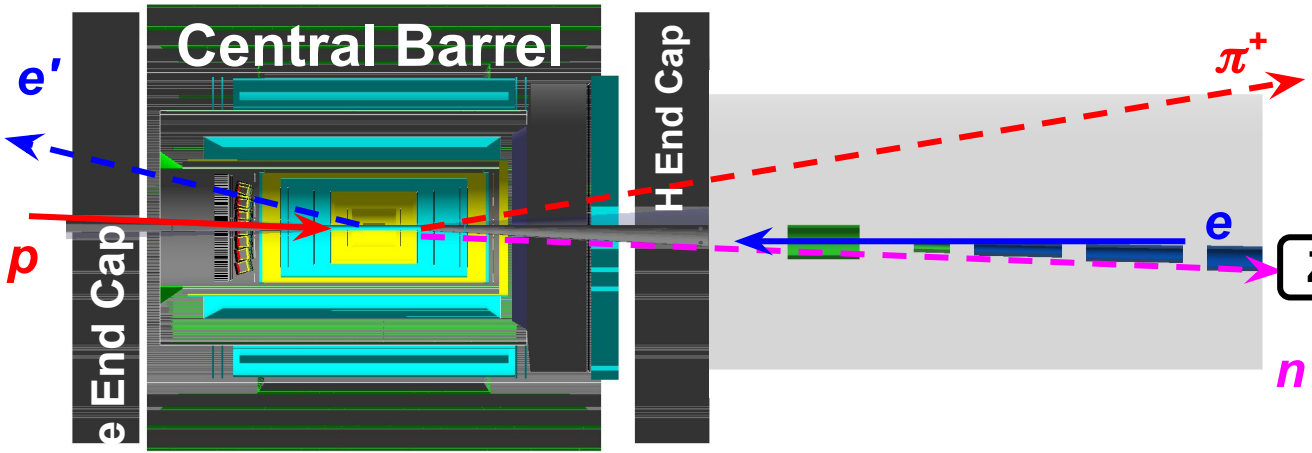
Fun4all handles beam effect such as cross angle, divergence, etc.

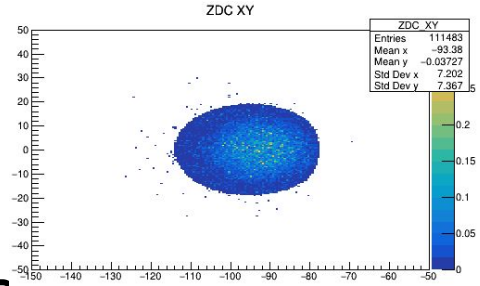


Example (by J. Huang) on crossing angle handling

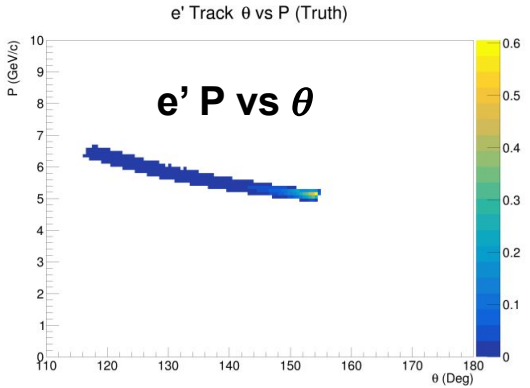
Physics Results Highlights: Pion Form Factor

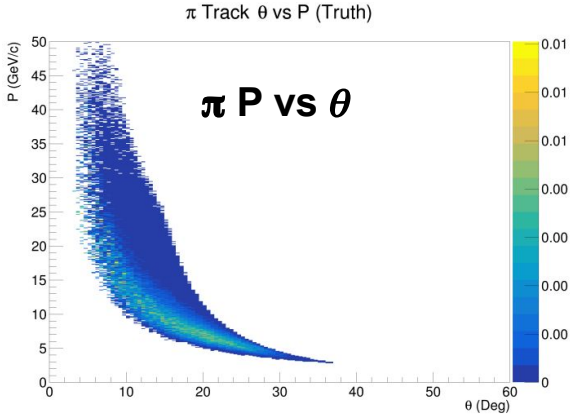
5 GeV e on 100 GeV p

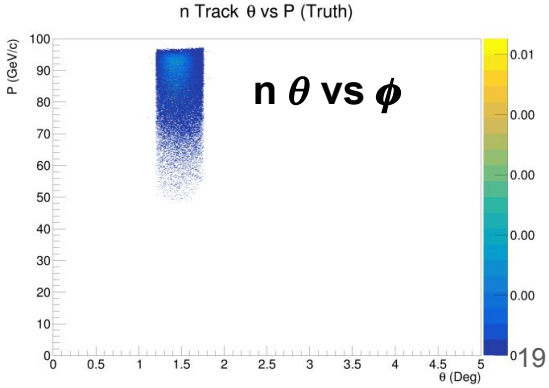




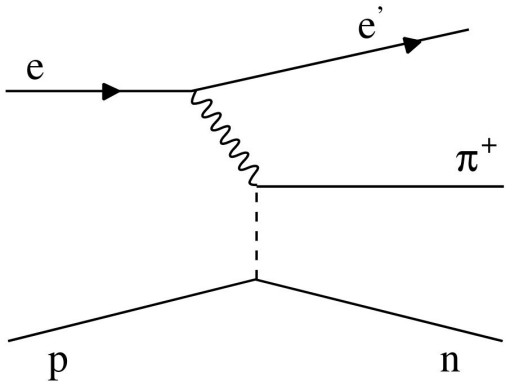
ZDC Occupancy

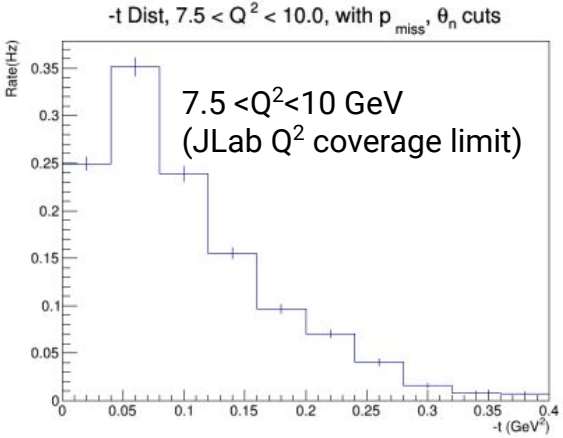


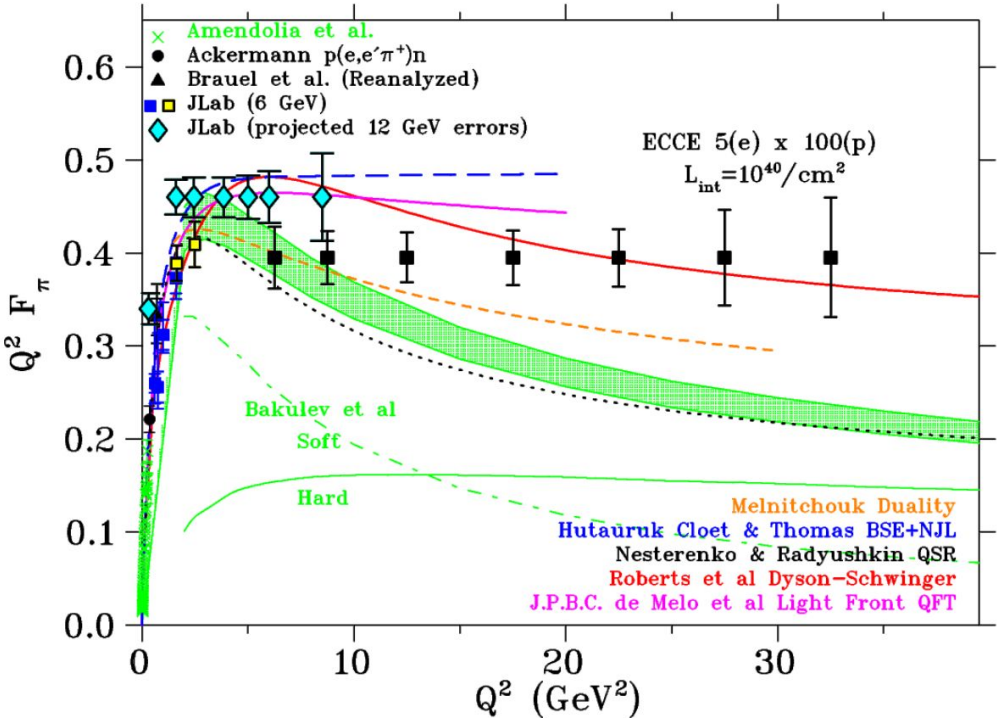




Money Plot on Pion Form Factor

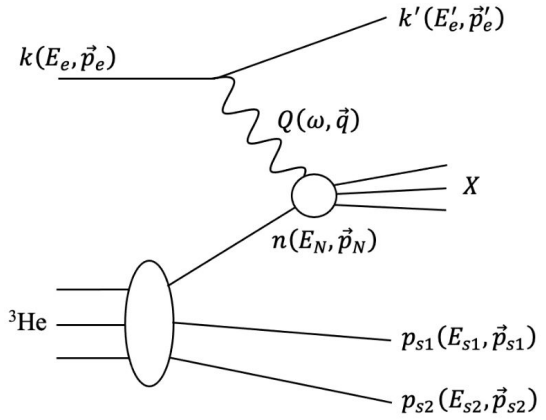






Extrapolated form factor $Q^2 F_\pi$ vs Q^2, NAS topic 1.
Person in charge: S. Kay, G. Huber

A1n through e-^{3}He Observable



$$A_1^{^3\mathrm{He}} = P_n \frac{F_2^n}{F_2^{^3\mathrm{He}}} A_1^n + 2P_p \frac{F_2^p}{F_2^{^3\mathrm{He}}} A_1^p$$

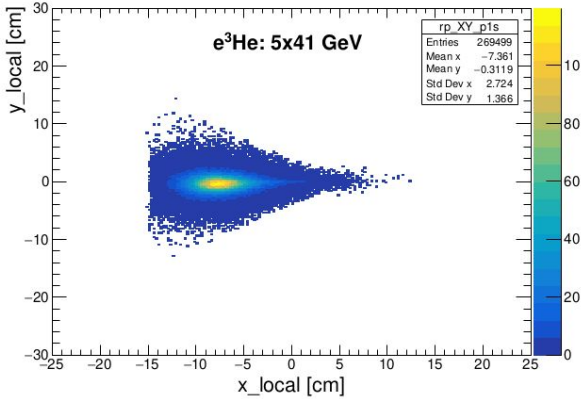
Extract

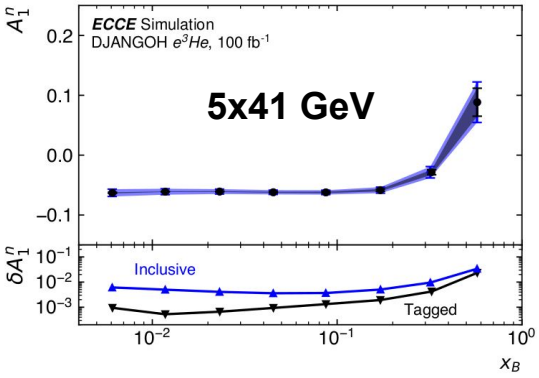
Parameterized

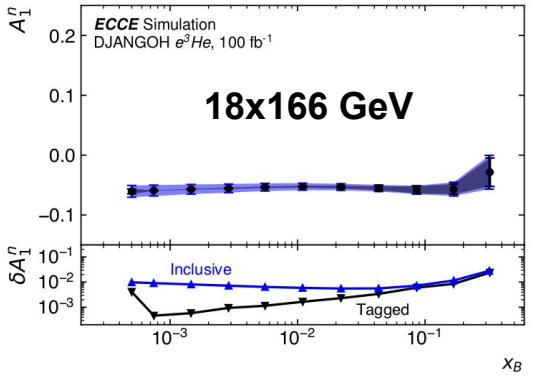
Measured through

1) Inclusive: e+^{3}He→ e'+X
2) Double tagged: e+^{3}He→ e'+p_1+p_2+X

Spectating p distribution at Roman Pots





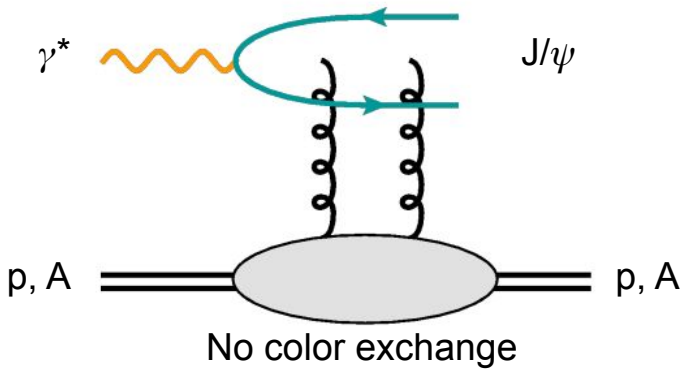


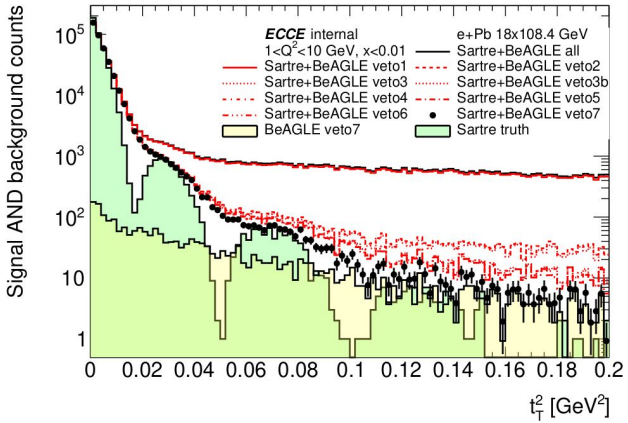
Asymmetry vs x_B, credit to D. Nguyen, J. Pybus

eA Diffractive Studies

- Most challenging measurement
  - e+A→e'+(A-1)+J/ψ through diffractive process
  - e+Zr, e+Pb and e+Au were studied
    - e + ^{208}Pb → e' + ^{208}Pb + J/ψ + γ + X
    - e + ^{90}Zr → e' + ^{90}Pb + J/ψ + γ + X
    - e + ^{197}Au → e' + ^{197}Au + J/ψ + γ + X
  - Objective: observe/resolve the coherent diffractive background with the incoherent background, link to the nucleon PDF.

- Strict Measurements are required to ensure no nuclear break-up or fragment of events (rejection of incoherent background).





Study credit to P. Steinberg, , M. Baker, D. Gangadharan.

Summary and invitation to join us!

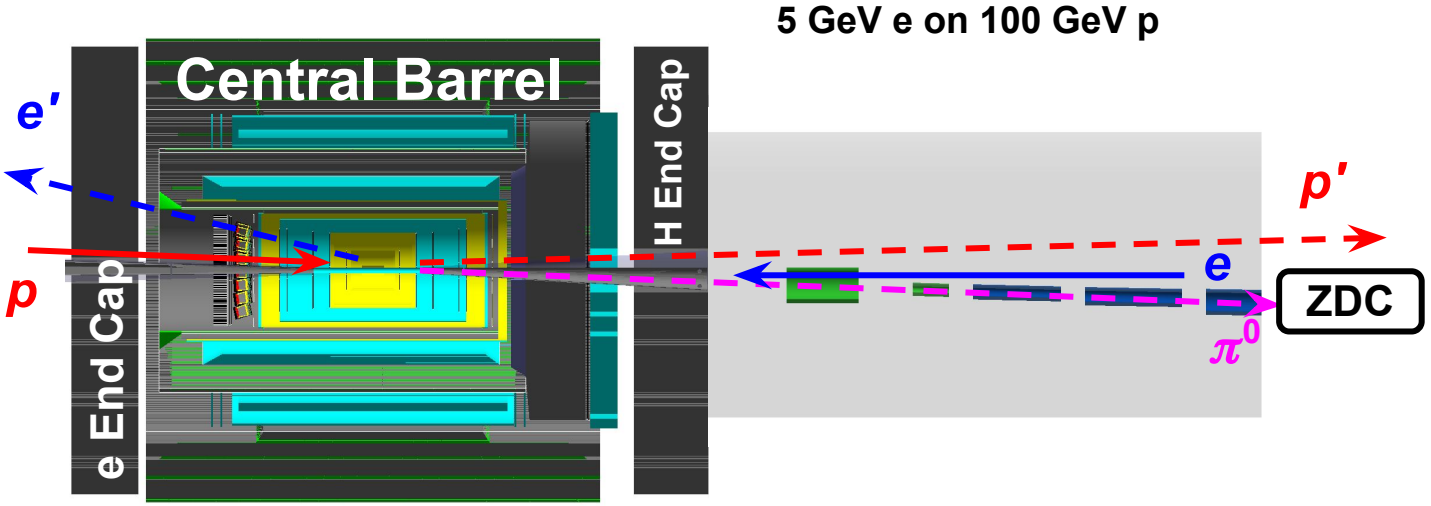
- Short Introduction to the ECCE consortium
- Show cased the Physics results from the ECCE Diffractive and Tagging
- One winner for the detector competition
  - Everyone will be working together on one project detector design.
- EIC project is developing fast. Now is the best time to get involved! Join us!
  - My contact info: wenliang.billlee@gmail.com

EIC Milestone

Event	Date
DOE Mission Need Statement Approved	January 22, 2019
DOE Independent Cost Review	July 2019
DOE Electron Ion Collider Site Assessment	October 2019
Critical Decision – 0 (CD-0) Approved	December 19, 2019
DOE Site Selection Announced	**January 9, 2020**
BNL TJNAF Partnership Agreement	May 7, 2020
DOE Office of Science Status Review	September 9-11, 2020
Independent EIC Conceptual Design Review	November 16-18, 2020
DOE Office of Science CD-1 Review	January 26-29, 2021
DOE Independent Cost Review	January - February 2021
CD-1 Approval Target Date*	***June 2021***
Project Detector Proposal Deadline	**Dec 1, 2021**

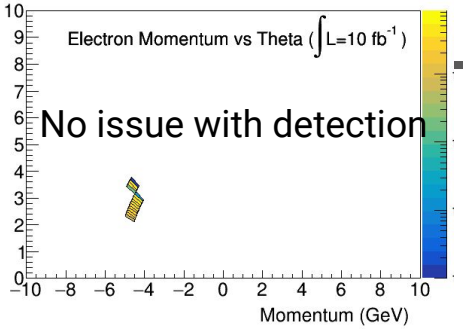
Information credit to R. Ent and EIC project

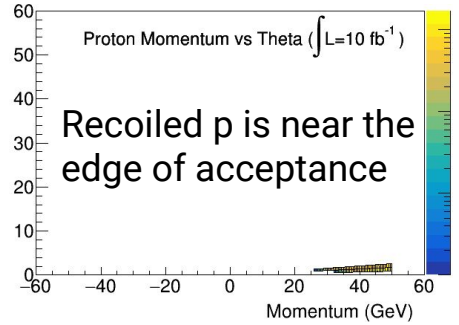
u-Channel Meson Production Setup

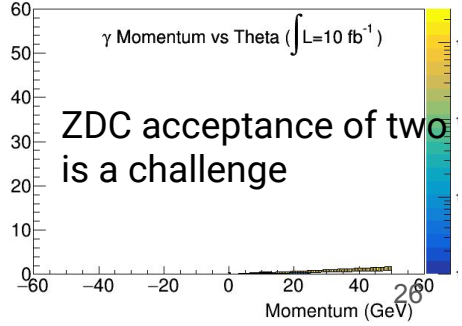


Q^2 (GeV^2)	W (GeV)	x_B	$\theta_{e'}$ (deg)	$\eta_{e'}$	$P_{e'}$ (GeV)	$\theta_{p'}$ (deg)	$\eta_{p'}$	$P_{p'}$ (GeV)	θ_{π^0} (deg)	η_{π^0}	P_{π^0} (GeV)	$-t$ (GeV^2)	$-u$ (GeV^2)
6.2	3.19		152	1.39	5.31	-1.84	4.13	43.40	1.43	4.38	56.29	14.84	-0.37
7.0	3.19		150	1.32	5.35	-1.92	4.09	45.50	1.43	4.38	54.12	16.19	-0.39
8.2	3.19		148	1.24	5.40	-1.85	4.12	49.74	1.43	4.38	49.84	16.80	-0.42
9.3	3.19		146	1.19	5.46	-1.92	4.09	51.90	1.43	4.38	47.60	18.19	-0.44
10.5	3.19		144	1.12	5.52	-1.94	4.07	54.96	1.43	4.38	44.50	19.32	-0.47

e' p' π^0

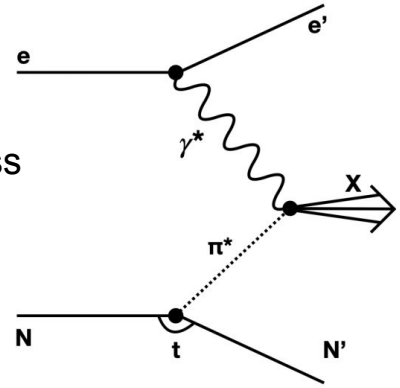


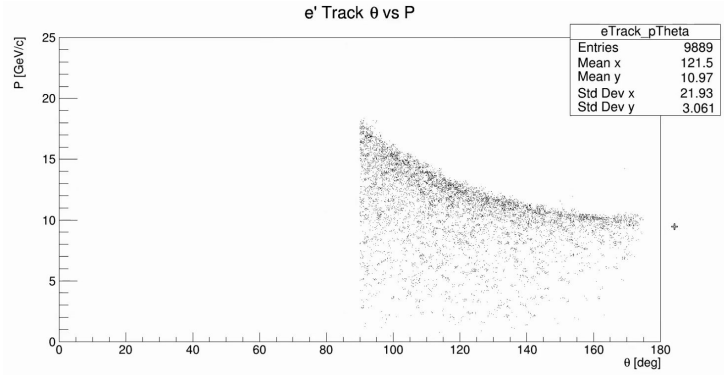




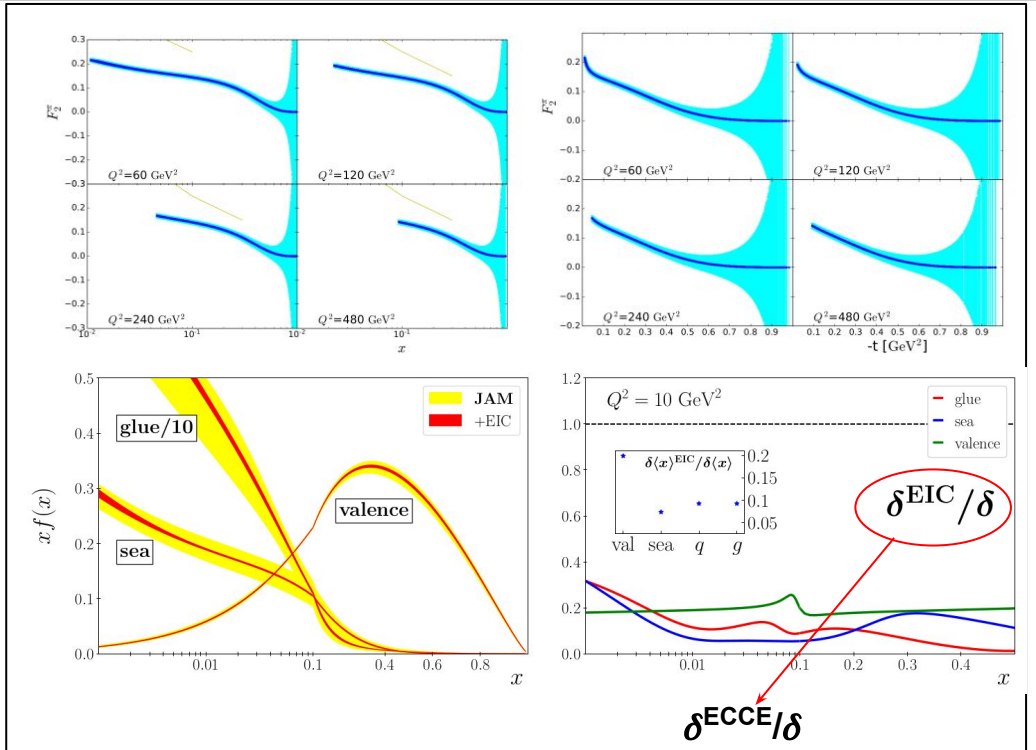
Pion Structure Function (Through Sullivan Process)

Sullivan process probes pion structure





- Validation is ongoing
- Catching to form factor study



Goal plot for the proposal: uncertainty ratio plot δ^{ECCE}/δ vs x, NAS topic 1. Person in charge: R. Trotta

Extract measure A1n

$$A_{||} = \frac{\sigma_{\downarrow\Uparrow} - \sigma_{\uparrow\Uparrow}}{\sigma_{\downarrow\Uparrow} + \sigma_{\uparrow\Uparrow}} \quad \text{and} \quad A_{\perp} = \frac{\sigma_{\downarrow\Rightarrow} - \sigma_{\uparrow\Rightarrow}}{\sigma_{\downarrow\Rightarrow} + \sigma_{\uparrow\Rightarrow}}.$$

$$A_1 = \frac{A_{\parallel}}{D(1+\eta\xi)} - \frac{\eta A_{\perp}}{d(1+\eta\xi)}$$

Review of the A1n prediction at large x: https://arxiv.org/pdf/nucl-ex/0405006.pdf