indico.bnl.gov/event/11669/

CORE*: A Detector for Precision QCD

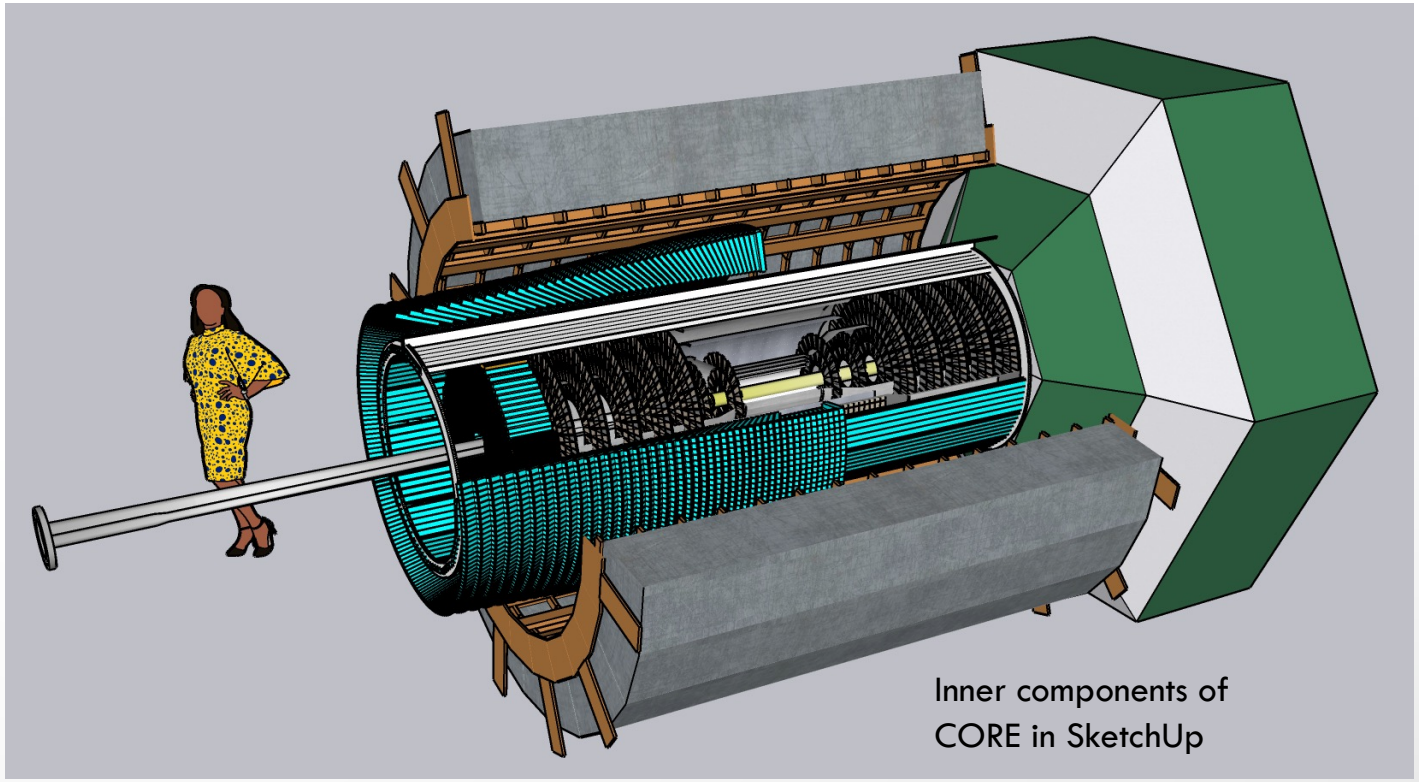
CHARLES HYDE

OLD DOMINION UNIVERSITY

*COmpact detectoR for the Eic

CORE Principles

- Compact:
  - Affordable as a 2nd detector for IR8
  - Magnet no larger than necessary
  - Investment in key technologies
  - Compatible with ±4.5 meter IP detector space:
    - Optimize luminosity and forward acceptance

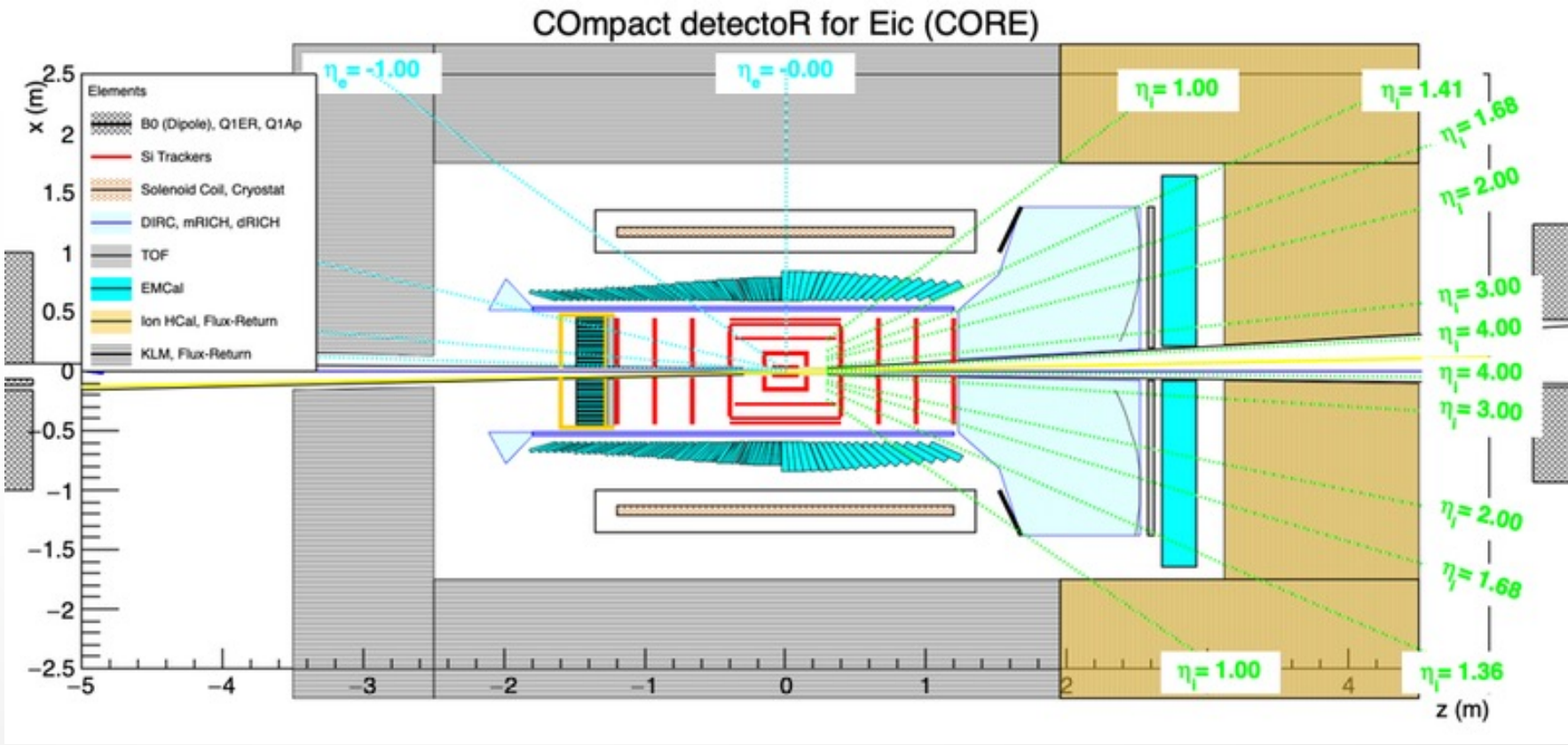


Inner components of CORE in SketchUp

- Tracking and PID based on "Generic Detector R&D for an EIC" program 2011-2021
  - Low technical risk
- Integrated with secondary focus optics of IR8
- A high performance detector capable of realizing the full EIC physics program

CORE Elements

eic.jlab.org/core/



- Solenoid: 2.5 T
  B ~ projective in dRICH
  B < 2T @ DIRC photosensors
  Cryostat
  - Inner bore 2.0mØ
  - Length 2.8 m
- All Si Tracker (MAPS)
- Barrel High Performance DIRC (e/π/K/p)
  - $\geq 3\sigma$ π/K up to 6 GeV/c, $\geq 2\sigma$ up to 8 GeV/c
  - Simulations in process to evaluate thinning bars (from 17 to 10 mm) to enhance performance at large $|\eta|$
- EMCal
  - $PbWO_4$ in full electron hemisphere ~ $1\% \oplus \frac{2\%}{\sqrt{E}} \oplus \frac{1\%}{E}$
  - W-Shashlik in ion hemisphere ~ $2\% \oplus \frac{6\%}{\sqrt{E}} \oplus \frac{2\%}{E}$
- Dual RICH $1.7<\eta<4.0$
  - π/K/p separation > 3σ from 1 to 50 GeV/c

CORE Proto-Collaboration

eic.jlab.org/core

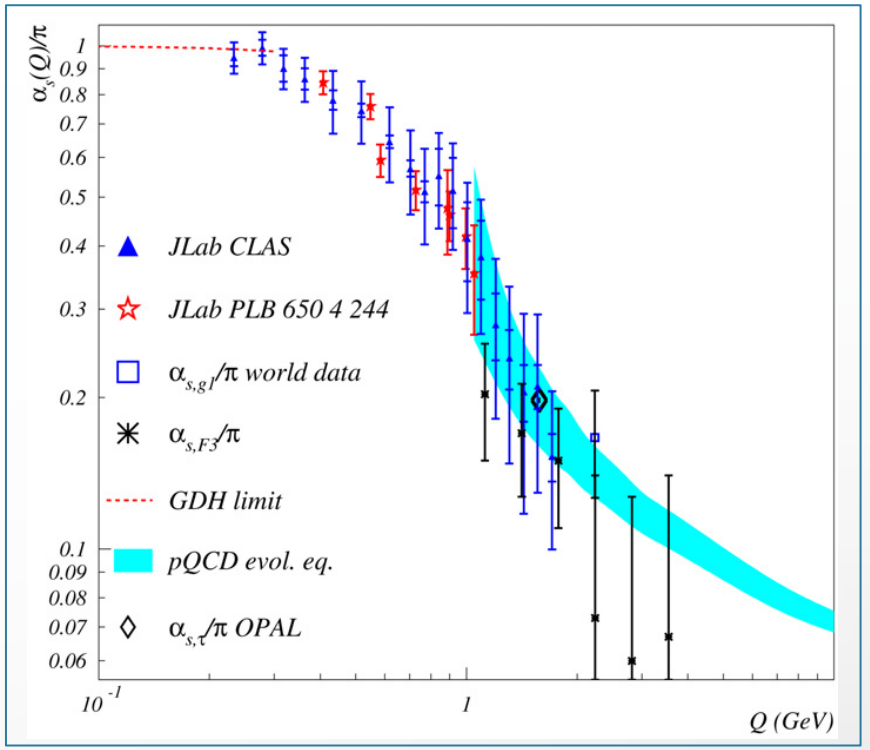
- All are Welcome!
- Catholic University of America (CUA)
- Duke University (Duke)
- GSI Helmholtz Centre for Heavy Ion Research, Germany
- Erlangen-Nuremberg University, Germany (GAU)
- Hampton University (HU)
- Indiana University (IU)
- Jefferson Lab (JLab)
- Kansas University (KU)
- Oak Ridge National Lab (ORNL)
- Old Dominion University (ODU)
- Penn State University (PSU)
- Stony Brook University (SBU)
- University of the Basque Country (UPV/EHU), Spain
- University of Connecticut (UConn)
- University of Hawaii (UH)
- University of South Carolina (USC) University of York, U.K.

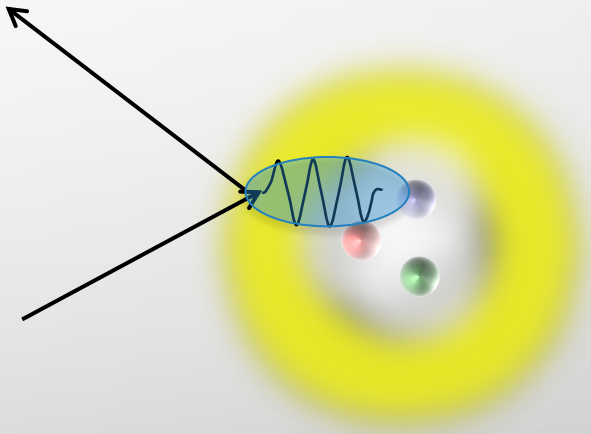
Working Group Conveners

- Inclusive:
  - Eric Christy, Hampton U.
- Semi-Inclusive:
  - Alexey Prokudin, Penn. State U.
  - Gunar Schnell, U. Basque Country (UPV/EHU), Spain
  - Timothy Hayward, U. Connecticut
- Exclusive:
  - Andrey Kim, U. Connecticut
  - Mohammed Hattawy, Old Dominion U.
- Jets
  - TBD

THE TOOLS OF DIS

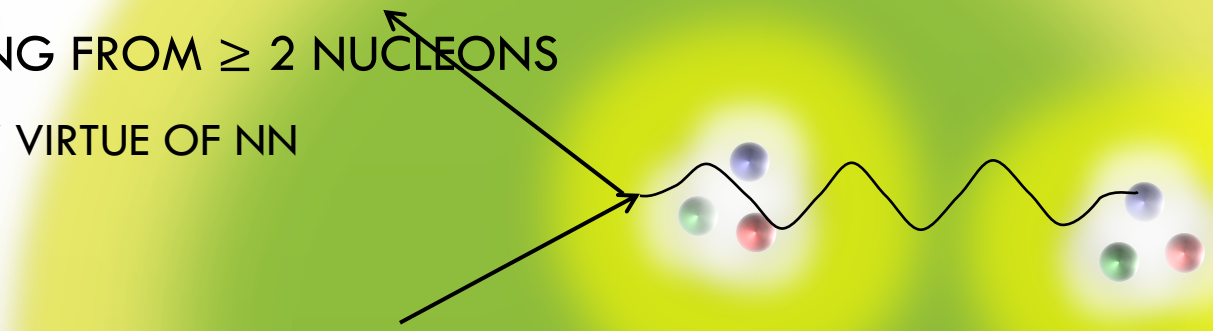
- *Basic Variables:* Q^2, x_{Bj}
  - $\alpha_S(Q^2)/\pi < 0.5$ *for* $Q^2 > 1$ *GeV*^{2}
  - *Transverse spatial resolution*
    $\delta b \sim 1/[Q^2]^{1/2}$
- Longitudinal coherence length (target rest-frame)
  of virtual photon $\lambda \approx 1/(2Mx_{Bj})$
  - $x < 0.1 \quad \leftrightarrow \quad \lambda \geq 1$ fm
  - x<<0.1➔ coherent probe of distances greater than average NN spacing in a nucleus





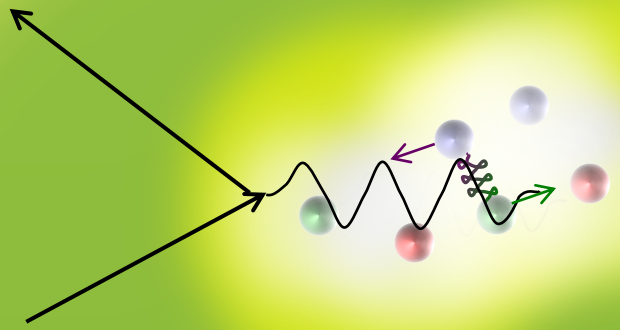
NUCLEAR DYNAMICS PROBED BY DIS:

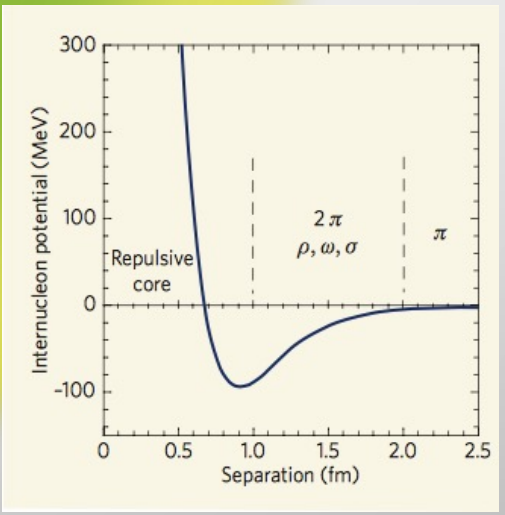
- $X_{BJ} < 0.05$: "SHADOWING"
- COHERENT DIFFRACTIVE SCATTERING FROM ≥ 2 NUCLEONS
  - INTERFERENCE IS DESTRUCTIVE BY VIRTUE OF NN ANTISYMMETRY
  - NN PAIR MUST BE BACK-TO-BACK
    - TRANSVERSE RESOLUTION $1/Q^2$ POST-SELECTS NUCLEAR STATE



NUCLEAR DYNAMICS PROBED BY DIS

- $x_{Bj} \approx 0.1$: "Anti-Shadowing"
  - $q(x) + \bar{q}(x)$ enhanced (DIS)
  - No $\bar{q}(x)$ enhancement seen in Drell-Yan.
  - Hard Core of NN-interaction from q-q-g exchange?
  - Predictions of gluon anti-shadowing enhancement
    - Open Charm Production
    - High precision Si Vertex Tracker for heavy flavor tagging

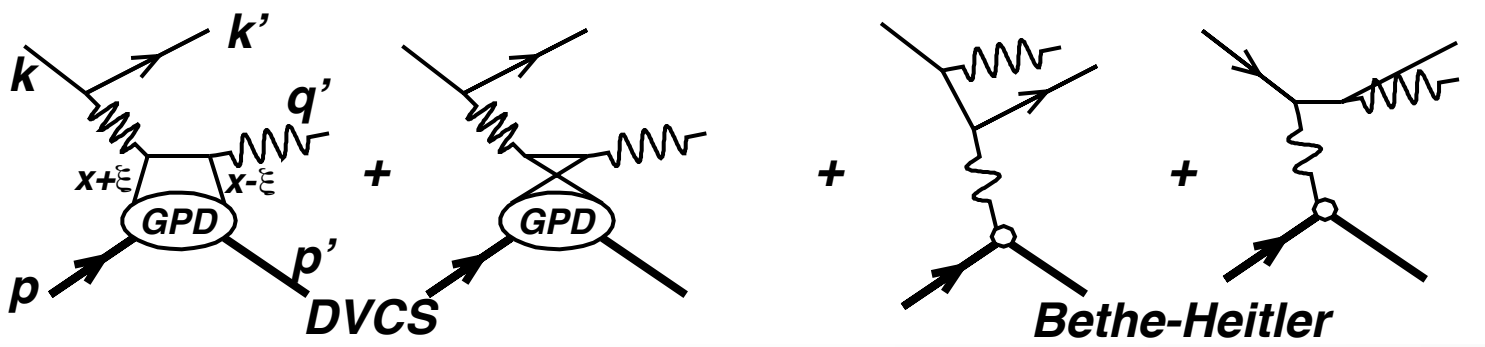




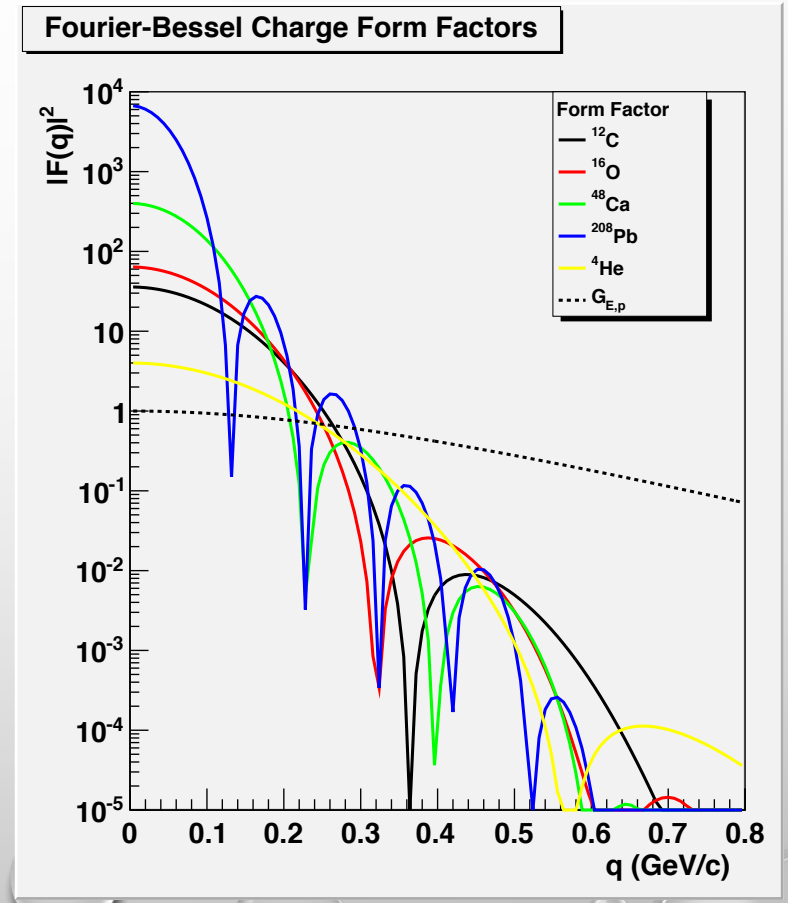
DIS IS JUST THE BEGINNING

- For fixed DIS (e,e') kinematics (Q^2, x_{Bj}), observables include
  - Jets
  - SIDIS
  - Diffraction
  - Deeply Virtual Exclusive Scattering (DVES)
- All are tools for probing Quark and Gluon Structure of Nucleons and Nuclei
  - Coherent nuclear DVCS
  - Double tagging Diffractive DIS

COHERENT DVCS ON NUCLEI AT LOW X

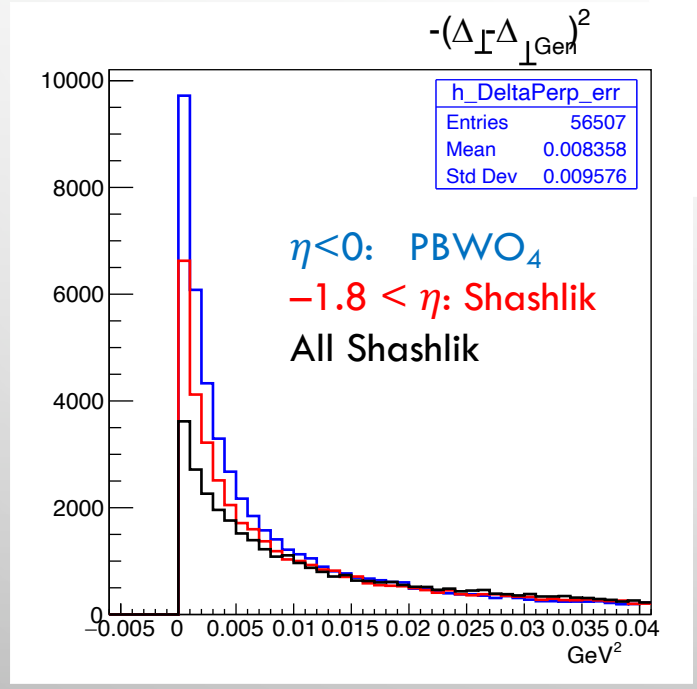


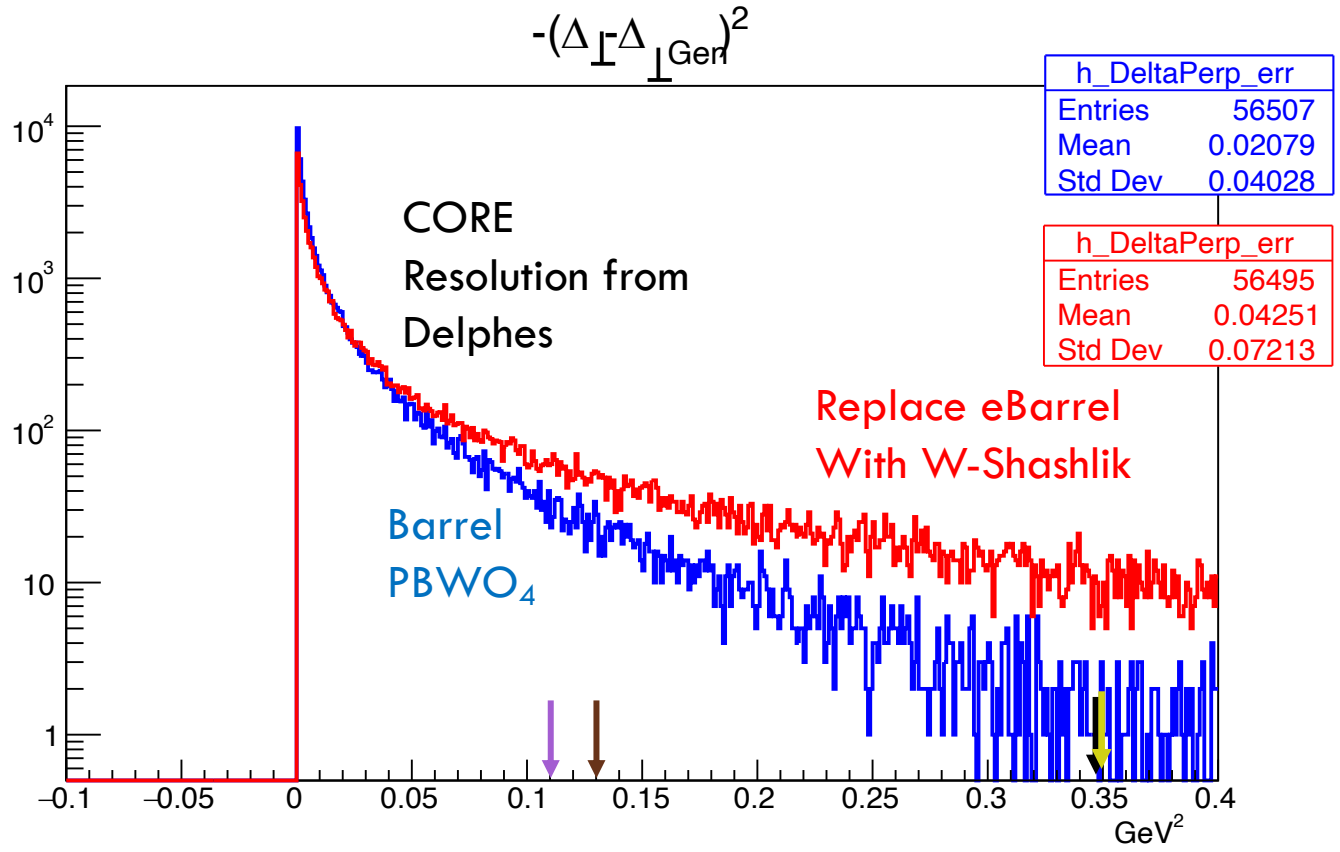
- Probe samples long-range correlations of quarks and gluons over multiple nucleons.
  - What is the transverse spatial distribution of these correlations?
  - Nucleon slowly grows transversely at low x,
  - Nucleus is optically thick only at the center.
- Next slide:
  - Resolution of CORE for nuclear DVCS
    - Necessary complement to Deep-ϕ, Deep-J/Ψ
    - DVCS relies on high resolution EMCal



COHERENT DVCS ON NUCLEI

- $\Delta^\mu = (k - k' - q')^\mu$
- Form light-cone basis $n^\mu, \tilde{n}^\mu$ from q=(k-k') and P
- $\Delta_\perp^\mu$ =components of Δ^μ orthogonal to $n^\mu, \tilde{n}^\mu$
- Spatial imaging from $\Delta_\perp^\mu$





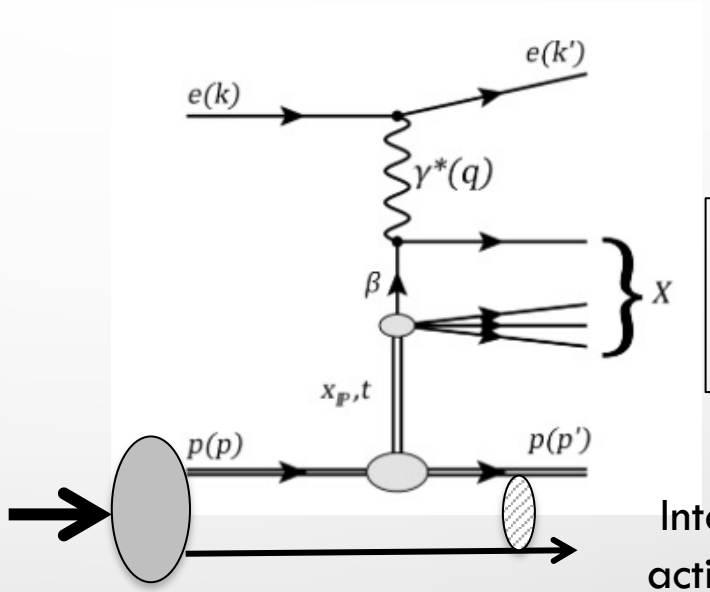
Nucleus	First miminum in charge FF
^{4}He	0.35 GeV^2
^{12}C	0.13 GeV^2
^{16}O	0.11 GeV^2

REAL & IMAGINARY PARTS OF THE COMPTON AMPLITUDE

- Im[$\mathcal{A}$]
  - Single spin asymmetries
- Re[$\mathcal{A}$]
  - Double spin asymmetries
  - Beam charge (e^+/e^-) asymmetry
  - s-dependence of the cross section (Generalized Rosenbluth Separation)
    - M. Defurne *et al.*, *NATURE COMMUN.* 8 (2017) 1, 1408
    - B. Kriesten and S. Liuti, ArXiv.org/2011.04484
- Need an EIC program over full energy range!

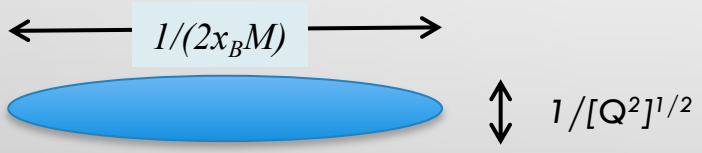
NUCLEAR INITIAL AND FINAL STATES IN DIFFRACTIVE DIS.

- INCOHERENT DIFFRACTION: A CLEAN PROBE OF MULTI-NUCLEON DYNAMICS.
  - RAPIDIDY GAP:
    ONLY LOW-ENERGY *NN, NNN*... FSI
- EVENT-BY-EVENT INITIAL &
  FINAL STATE:
  - ELLIPTICAL SOURCE
    ≥ 2 NUCLEONS



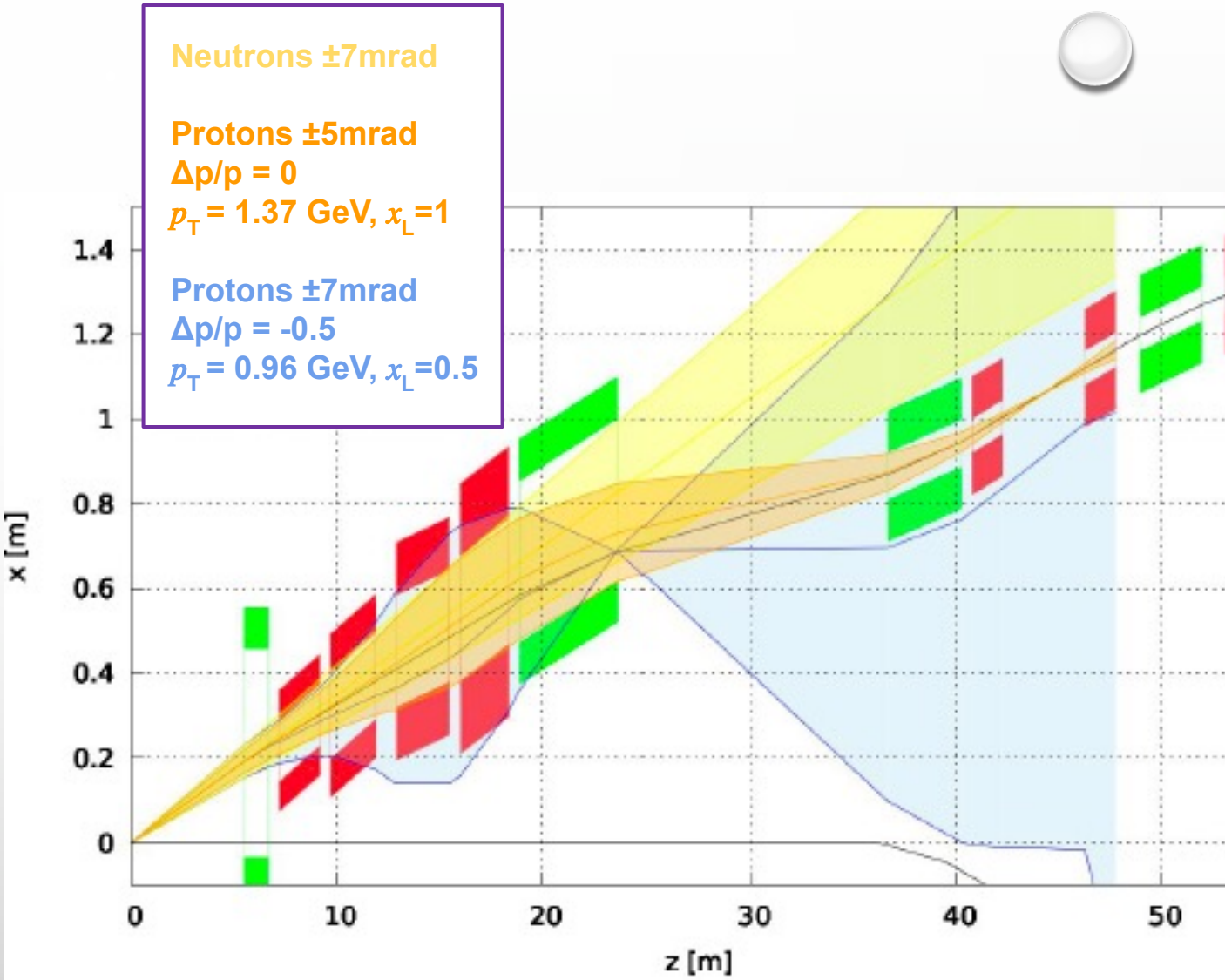
Color-neutral
$\delta b < 1/[Q^2]^{1/2}$
No FSI!

Interference:
active/spectator in
NN pair



A COMMENT ON FAR-FORWARD DETECTION

- Preliminary IR-8 Downstream Ion Optics
- Secondary Focus at ~45 m
- Spectators in light nuclei / evaporation residues in heavy nuclei
- Magnetic Rigidity K = Momentum/Charge
- Consider ^{3}He and ^{3}H daughters from ^{4}He
  - P(^{4}He) = 2 P_0, rigidity P_0
  - P(^{3}He) $\approx \frac{3}{4}(2P_0)$, rigidity = (3/4) P_0
  - P(^{3}H) $\approx \frac{3}{4}(2P_0)$, rigidity = (3/2) P_0 > P_0
- Need trackers on both sides of the beam line [25,35]m and at Roman Pot location 45m



MY PERSONAL TAKE-AWAY FROM THIS WORKSHOP

- FAMOUS QUOTE OF YURI DOKSHITZER
  - "FOLKS, WE NEED TO STOP "TESTING" QCD AND START UNDERSTANDING IT", ICHEP 1998, VANCOUVER, BC , CONFERENCE SUMMARY TALK
- After listening to many fascinating talks, this workshop reinforces my strong impression that we have only just begun to understand the potential of the EIC to reveal the nature of QCD.
- The physics program and detector performance must be considered very broadly