ePHENIX at eRHIC

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ON BEHALF OF THE PHENIX COLLABORATION

Stony Brook University | The State University of New York

PHENIX

The Electron Ion Collider Project

See A. Deshpande (159) WG6/7

- Many questions for understanding the role of gluons and sea quarks in QCD are unanswered
- US Nuclear Science Community is considering
  - High energy
  - High luminosity
  - Polarized proton–electron
  - Ion–electron

  } Collider EIC
- Two possible scenarios
  - eRHIC: add 5 – 30 GeV electron beam facility to existing RHIC facility
  - MEIC: add 20 – 100 GeV proton (up to 40 GeV/u ion) beam facility to existing CEBAF facility

eRHIC

See A. Deshpande (159) WG6/7
E. Aschenauer (331) WG7

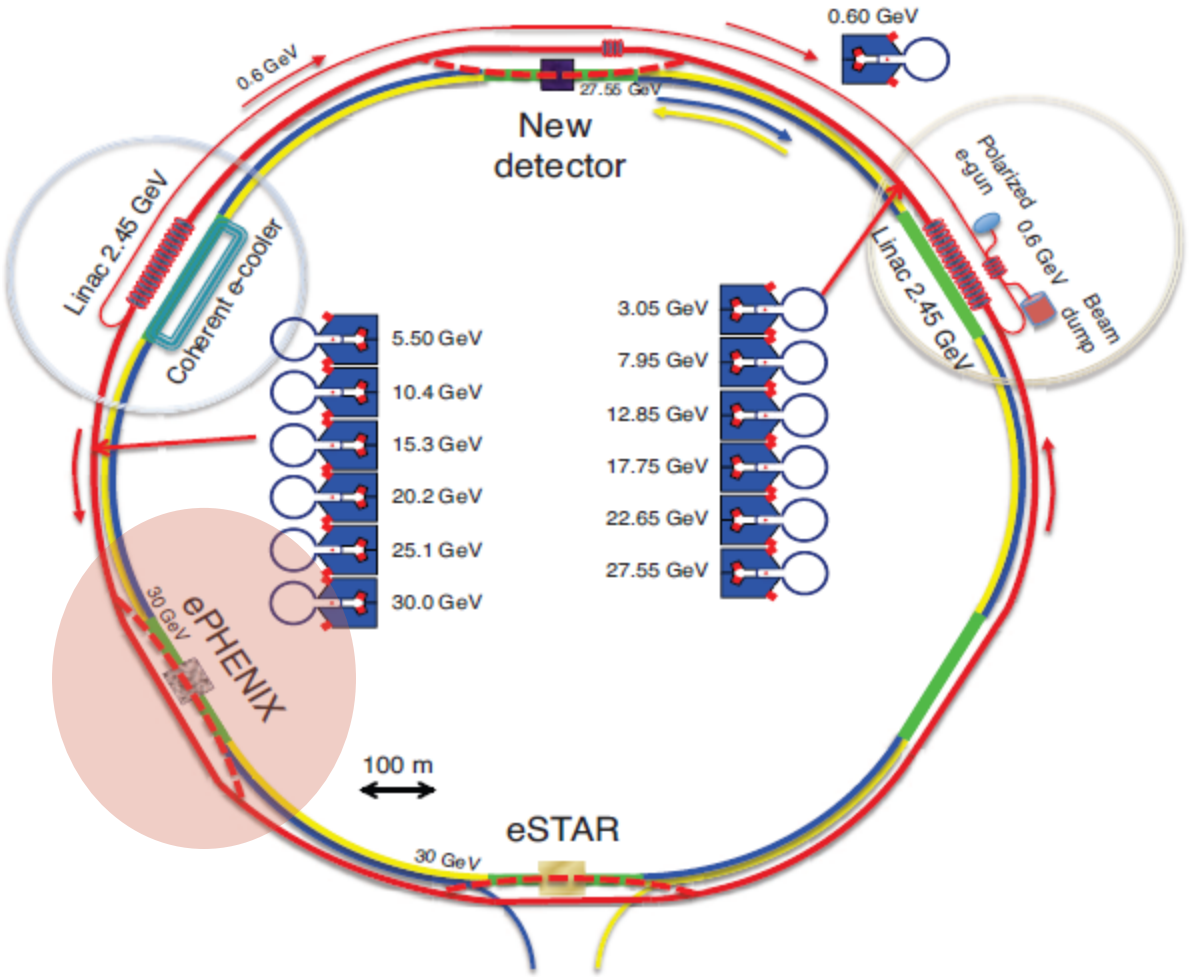
- eRHIC design is based on
  - Using one of the two RHIC hadron rings
  - Building and using a multi-pass Energy Recovery Linac ERL
  - Possibility to have more than one Interaction Region I.R.
- Existing RHIC accelerator complex would provide
  - Polarized protons up to E = 250 GeV
  - Fully stripped uranium ions up to 100 GeV/u
- ERL would provide
  - Polarized electrons up to E = 30 GeV

$\rightarrow 45\ GeV \leq \sqrt{s} \leq 175\ GeV$ for polarized e-p collisions

$\rightarrow 32\ GeV \leq \sqrt{s} \leq 110\ GeV$ for e-A (large A) collisions

$$10^{33} cm^{-2} s^{-1} \leq \mathscr{L} \leq 10^{34} cm^{-2} s^{-1}$$

eRHIC

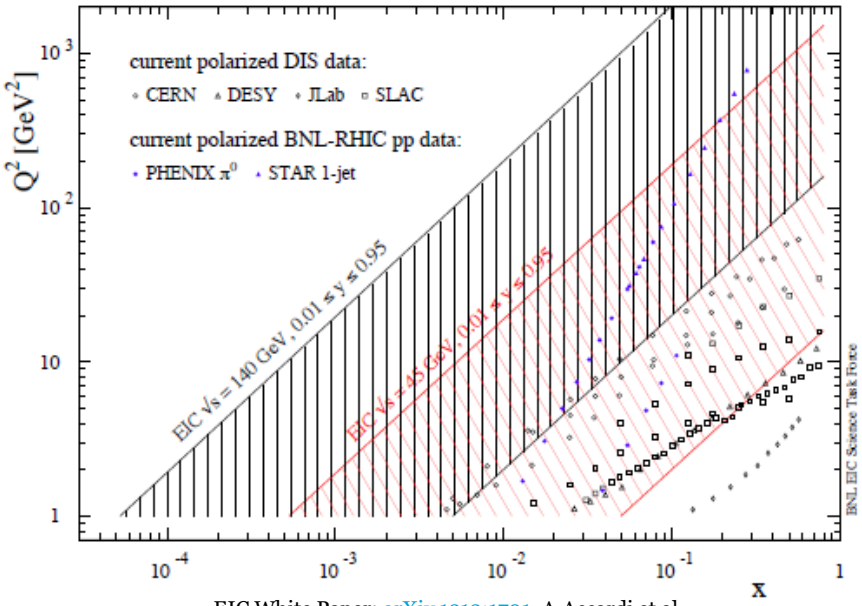


EIC White Paper: arXiv 1212:1701, A.Accardi et al.

eRHIC Staging

See A. Deshpande (159) WG6/7

- Construction proposal for eRHIC is based on staging
  - Initial electron-beam with E = 5 … 10 GeV
  - Colliding with 100 – 250 GeV polarized protons
  - Colliding with d, ^{3}He, Al, Si, Cu, Au, U … d/^{3}He → polarized n



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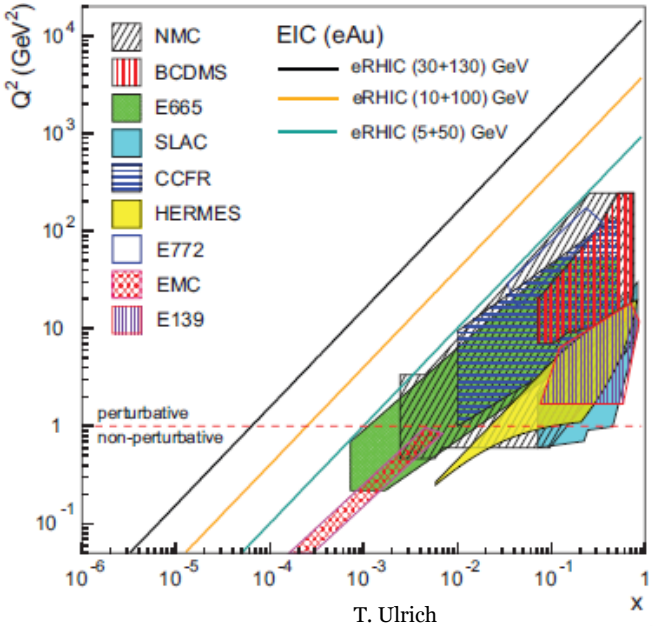


T. Ulrich

Physics Goals of EIC

See M. Stratmann (304) Plenary

Investigation of

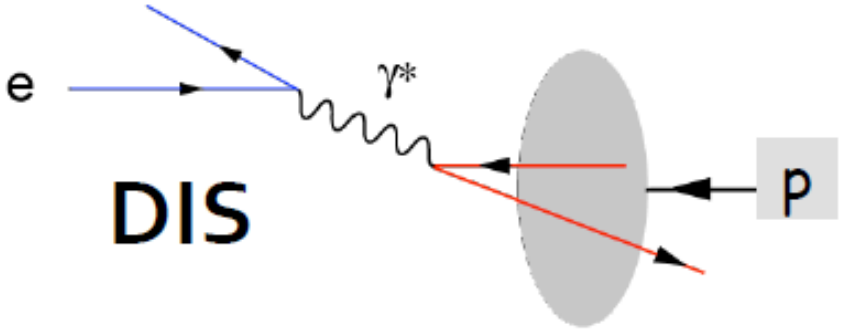
- Nucleon structure
- QCD in nuclei
- Searches beyond Standard Model BSM

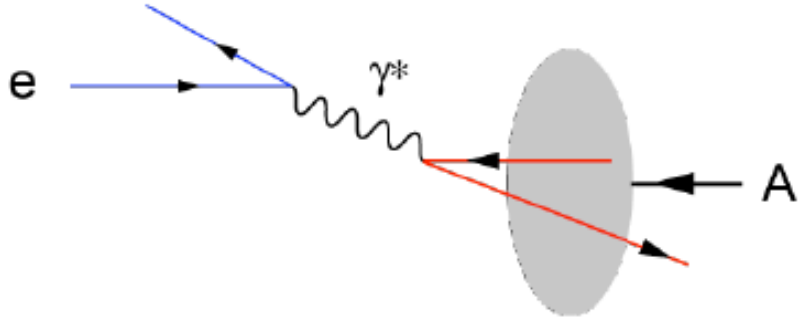
eRHIC Stage 1: ePHENIX will be able to make important measurements in all areas but BSM

sPHENIX: An Upgrade Concept from the PHENIX Collaboration, arXiv:1207.6378, C. Adare et al.

ePHENIX studies were performed within PHENIX by the "ePHENIX task force"

Deep Inelastic Scattering





Measure energy and angle of scattered electron → fully determines two relevant kinematic variables

- Q^2: virtuality of exchanged photon
- x: momentum fraction of probed parton

third variable y: inelasticity related to x, Q^2 through $\sqrt{s}$

For large Q^2 → exchange of W, Z bosons contributes

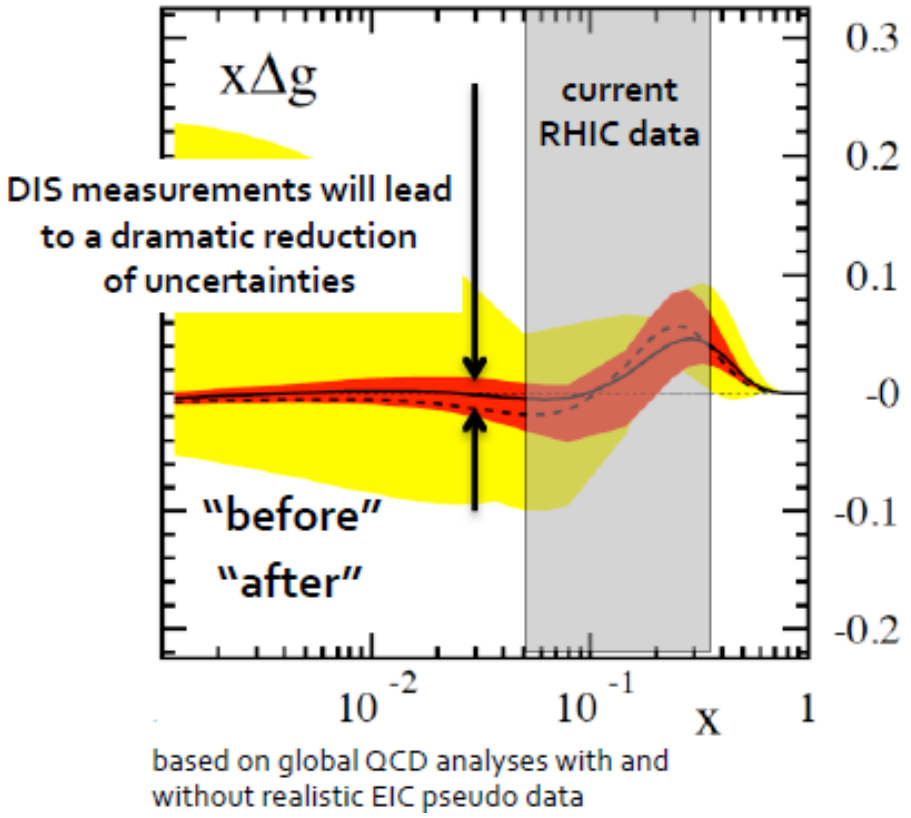
- Need to determine x and Q^2 from hadronic final state

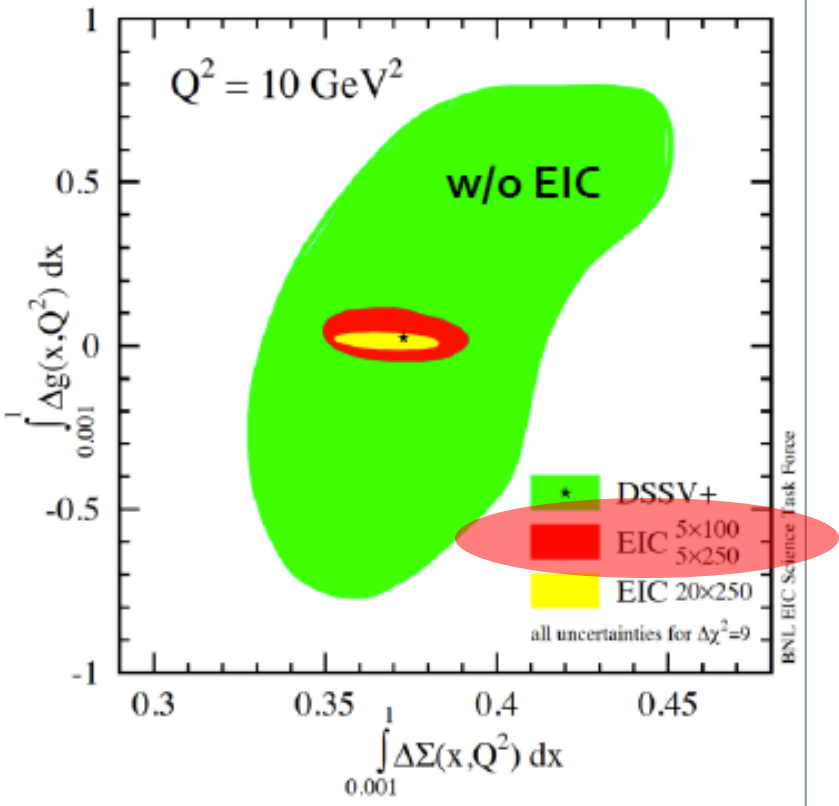
Physics Goals for ePHENIX

- 3-D structure of nucleon
  - Gluon and sea quark helicity contributions to nucleon helicity
    - Inclusive and semi-inclusive measurements
  - Quark and gluon Transverse Momentum Distributions TMD
    - Semi-inclusive measurements SIDIS
  - Spatial gluon and sea quark distribution in nucleon
    - Exclusive measurements Deeply Virtual Compton Scattering DVCS

Spin Structure

DIS: $\Delta g(x, Q^2)$ can be determined for x down to 10^{-4}

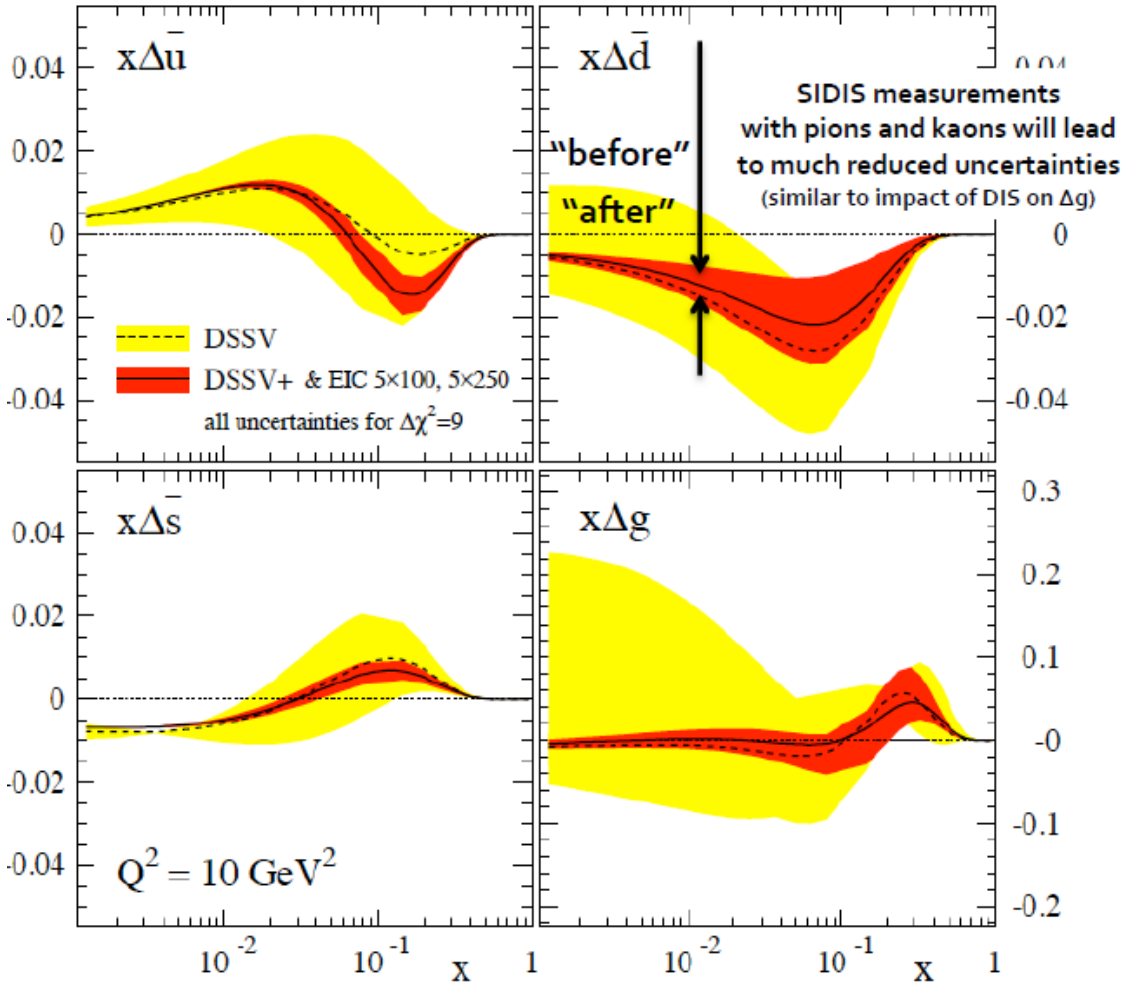




Physics Goals for ePHENIX

- QCD in nuclei
  - Nuclear modification of parton distributions
    - Small x-physics
    - F_2^A , F_L^A inclusive measurements
    - Semi-inclusive measurements for flavor-separated structure functions
  - Parton propagation in Cold Nuclear Matter CNM
    - Transport coefficients: semi-inclusive measurements

Flavor Separated Structure Functions



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ePHENIX Detector

- Considerations regarding
  - Kinematics for various measurements
  - Required precision

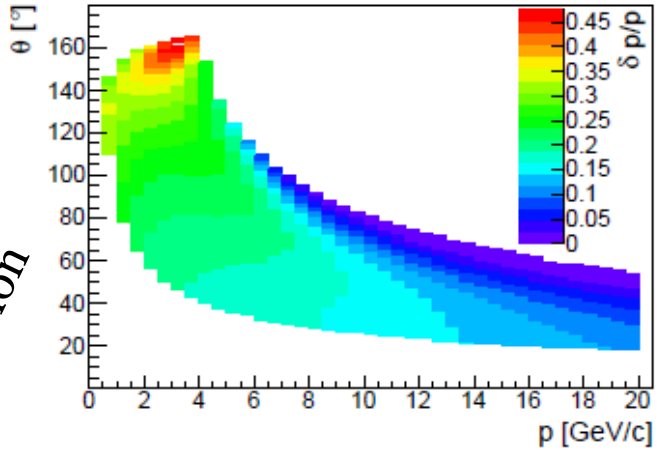
lead to determining

- Tracking
  - Momentum and angular resolution
- Measurement of scattered electron
  - Energy
  - Angular resolution
- Particle Identification PID

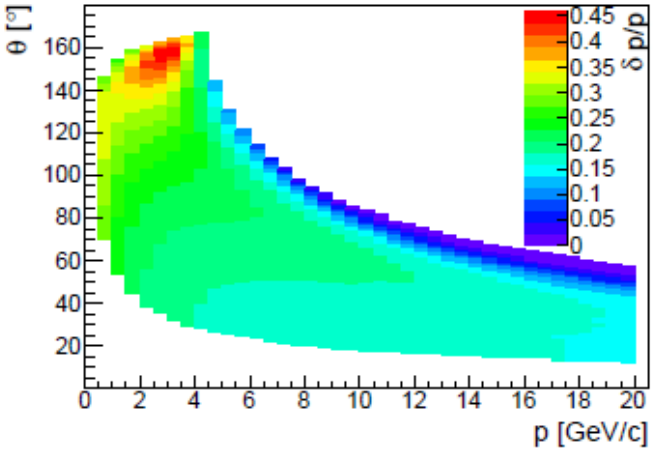
ePHENIX Tracking Requirements

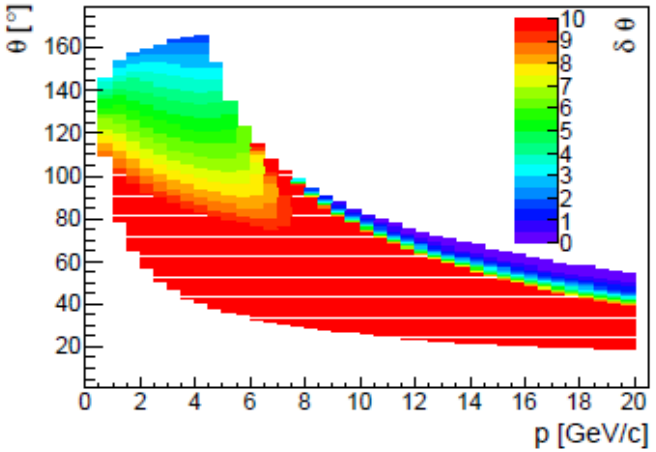
Momentum and angular resolution

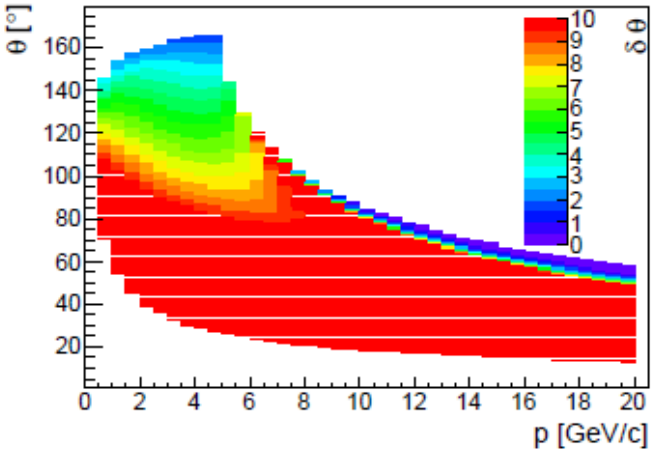
e^-(5 GeV) on p(100 GeV)



e^-(5 GeV) on p(250 GeV)





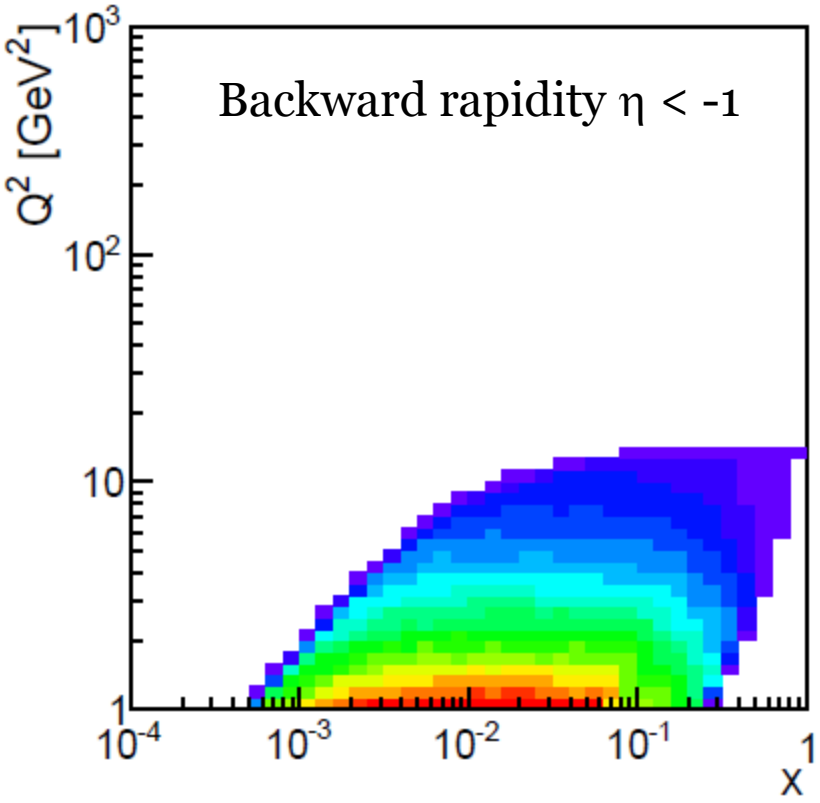


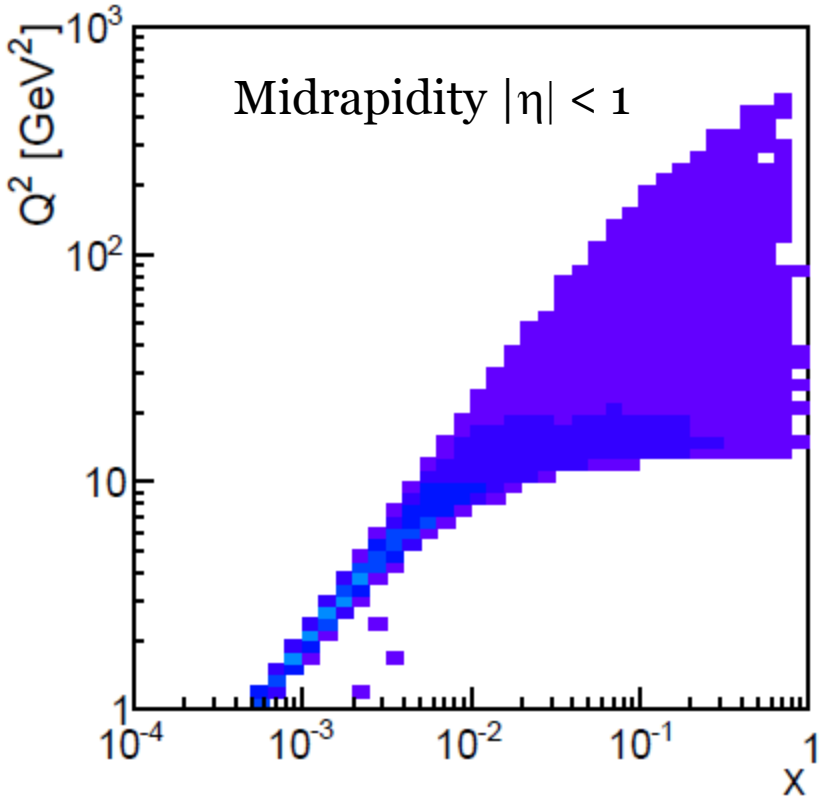
sPHENIX: An Upgrade Concept from the PHENIX Collaboration, arXiv:1207.6378, C. Adare et al.

ePHENIX and Scattered Electron

e^- (5 GeV) on p(100 GeV) configuration

x-Q^2 coverage of the scattered electron





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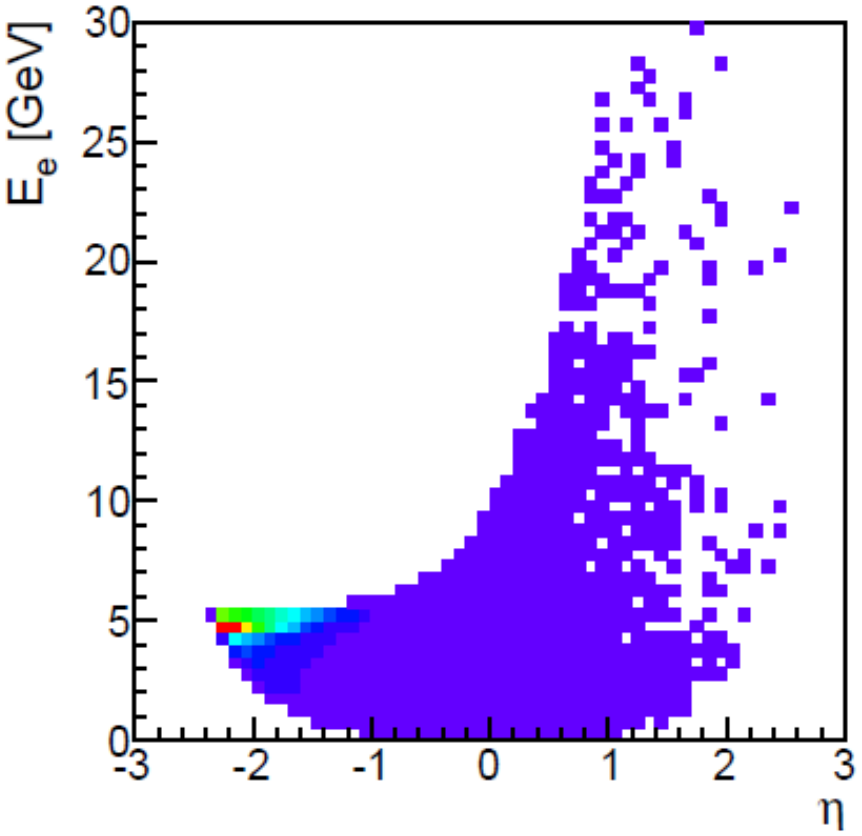
PHENIX

ePHENIX and Scattered Electron

e^- (5 GeV) on p(100 GeV) configuration

η-Energy coverage of the scattered electron



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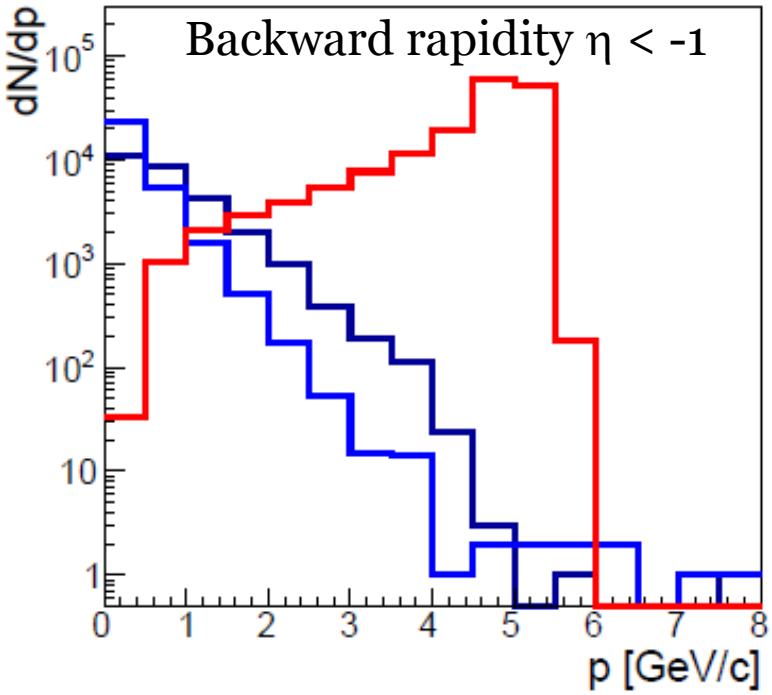
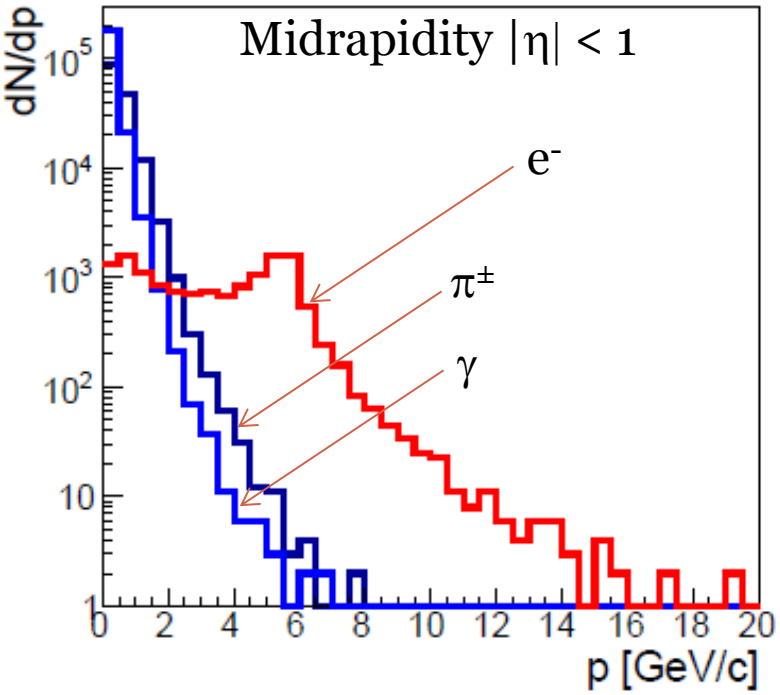
ePHENIX and Scattered Electron

e^- (5 GeV) on p(100 GeV) configuration

e - γ - π: E/p matching and shower profile should provide satisfactory rejection





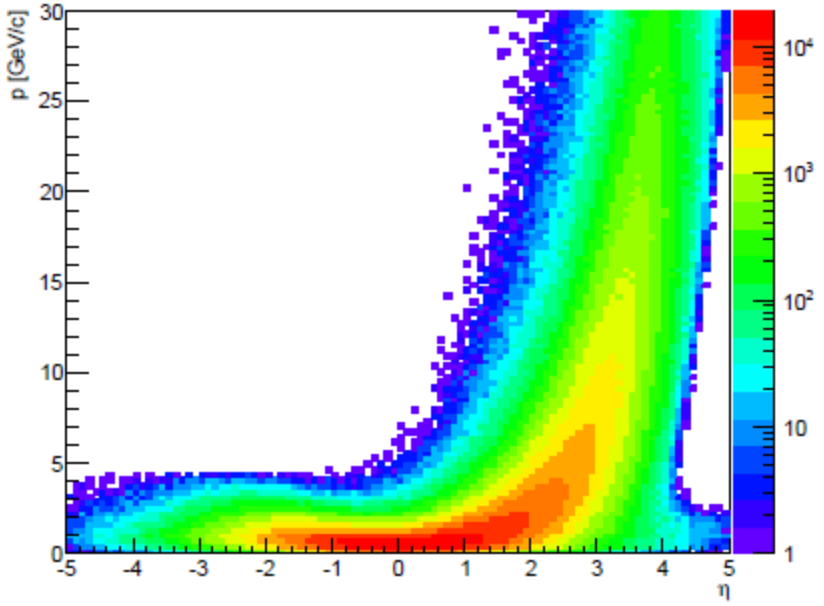
ePHENIX and PID

- Electron ID required to reconstruct event kinematics
- SIDIS requires pion and Kaon ID
  - Extract Δs
  - Tag pions and Kaons
    - Transverse spin structure of proton
    - Flavor dependence of nPDF
- DVCS needs to tag scattered proton → remains in beam-pipe

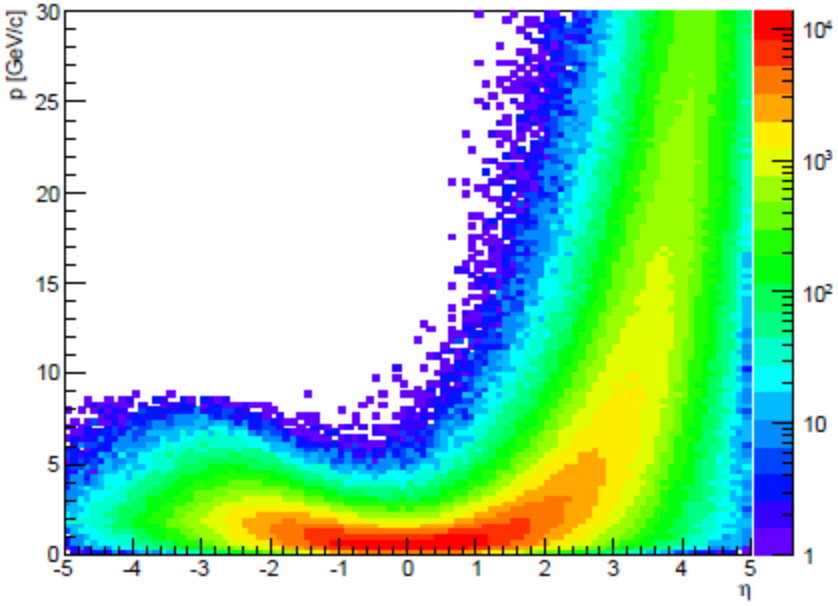
ePHENIX and PID

η-momentum coverage of π^+

e^- (5 GeV) on p(100 GeV) configuration



e^- (10 GeV) on p(250 GeV) configuration



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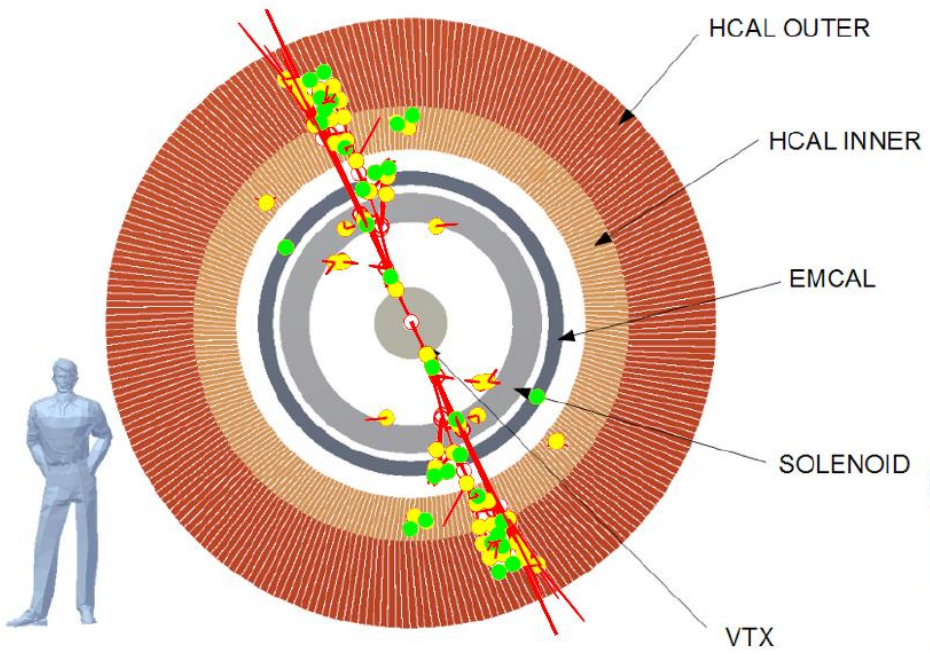
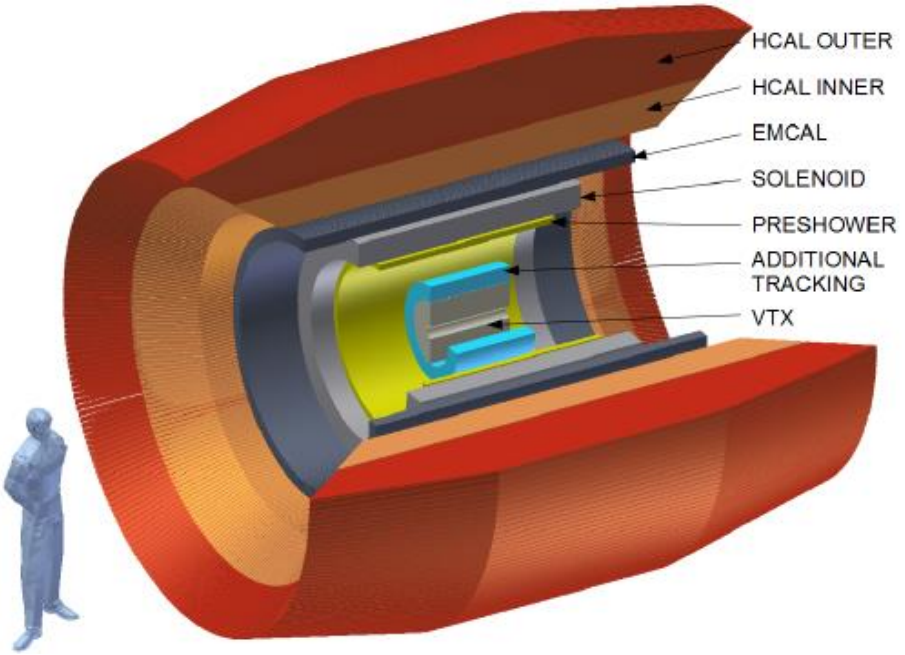
ePHENIX Evolution

See Y. Goto (182) WG7

- sPHENIX will evolve in ePHENIX

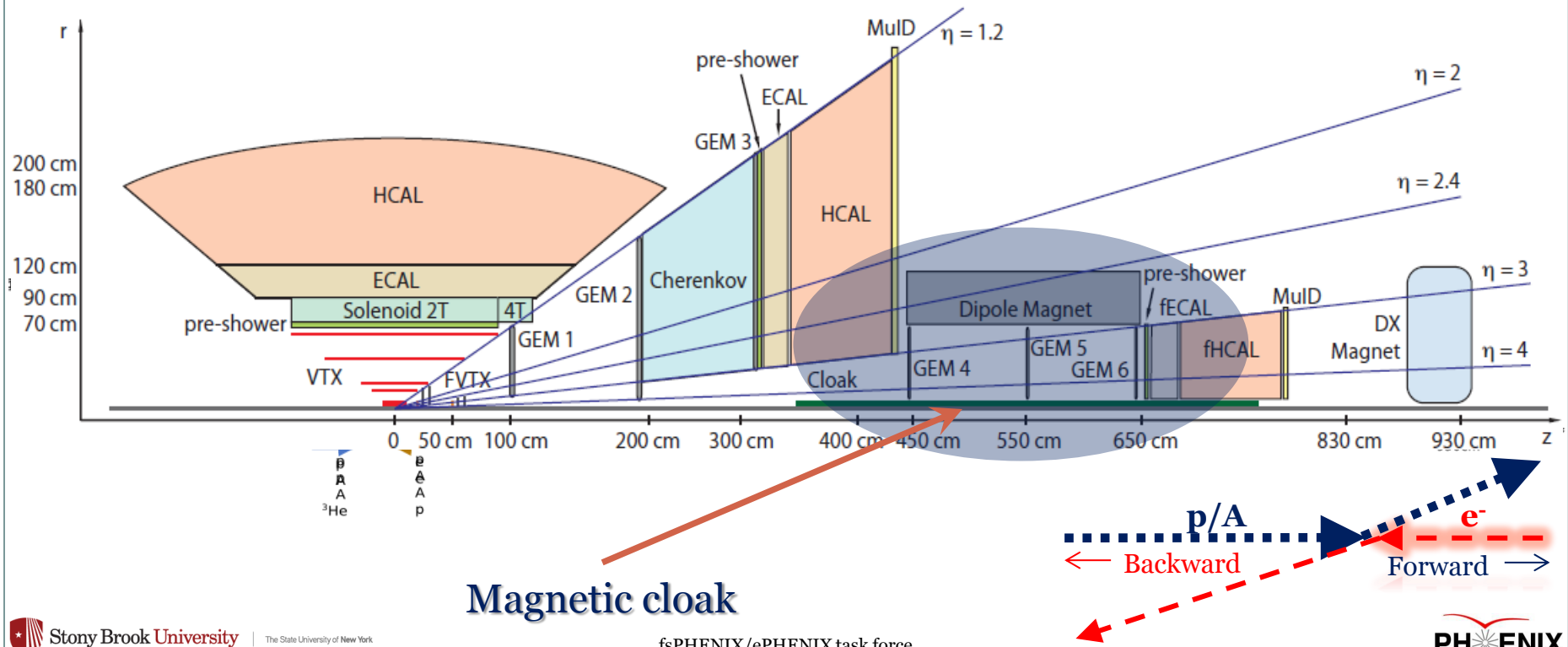




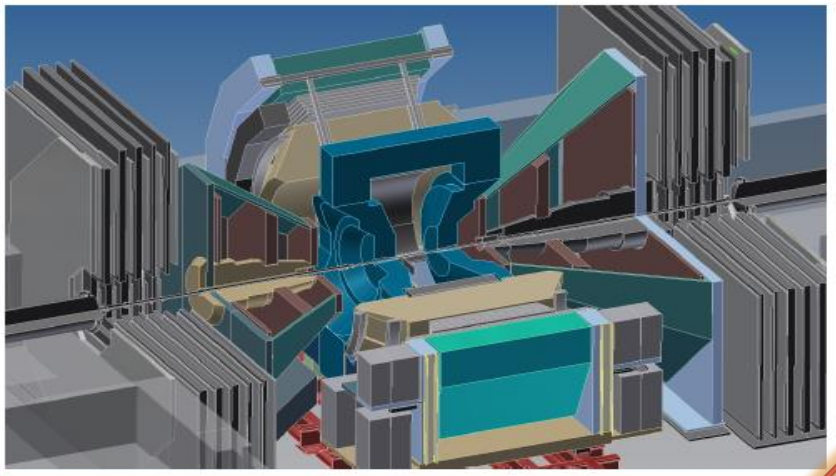
sPHENIX: An Upgrade Concept from the PHENIX Collaboration, arXiv:1207.6378, C. Adare et al.

ePHENIX Evolution

- sPHENIX + Forward will evolve in ePHENIX



PHENIX – sPHENIX - ePHENIX



Summary

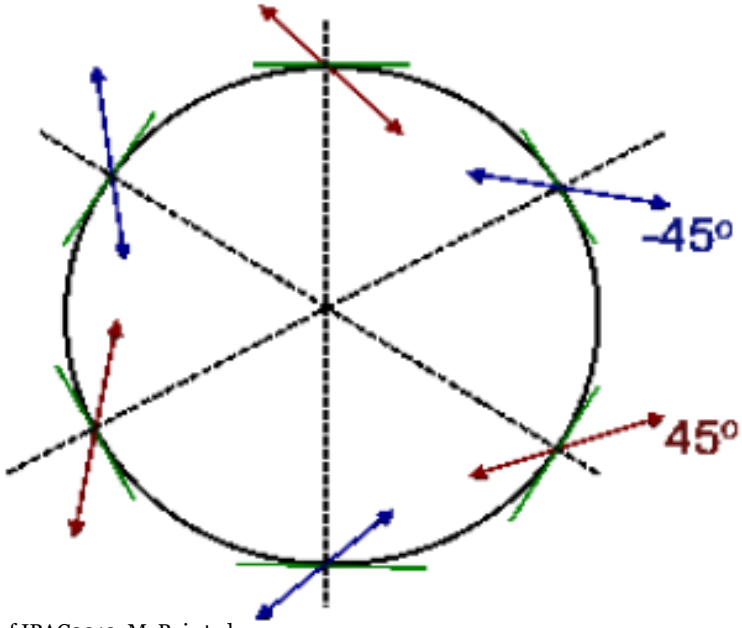
- Day-1 physics at **ePHENIX** → Stage 1 **eRHIC**
- **ePHENIX** designed for kinematic reach and luminosity reach
  - With gradually increase of E_e to 10 GeV → $\sqrt{s}$ up to 100 GeV
  - $\mathscr{L}$ up to $\approx 4 \times 10^{33} \frac{1}{cm^2 sec}$
- Full use of **PHENIX** upgrades to **sPHENIX** and Forward **sPHENIX**
- Additional specific modifications for **ePHENIX**
- Generic Detector R&D for an EIC
  - https://wiki.bnl.gov/conferences/index.php/EIC_R%25D

Extra Slides

Polarized Neutrons at eRHIC

- Polarized ^{3}He beams offer an effective way to provide polarized neutron beams
- Similar to polarized protons, accelerating polarized ^{3}He also requires Siberian snakes

Cancelation of spin perturbation on the spin motion requires six snakes (two existing + four new)



MOPPC021 Proceedings of IPAC2012, M. Bai et al.

Polarized Neutrons at eRHIC

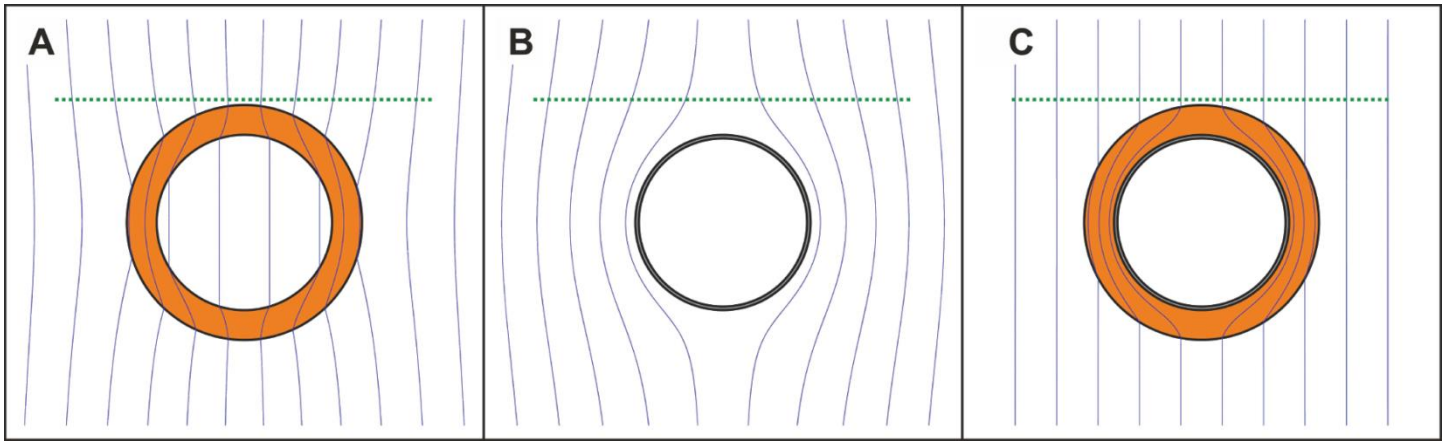
- Accelerating polarized ^{3}He faces more and stronger spin depolarizing resonances
- Overlap of imperfection resonances excites also even order snake resonances
- Other sources for even order snake resonance errors in snake settings

species	y_{rms} required	y_{rms} achieved	ΔQ_y required	ΔQ_y achieved
proton	0.5mm	0.1mm	0.003	0.005
He-3	0.15mm	N/A	0.001	N/A

Errors of beam parameters for polarized beam acceleration in RHIC

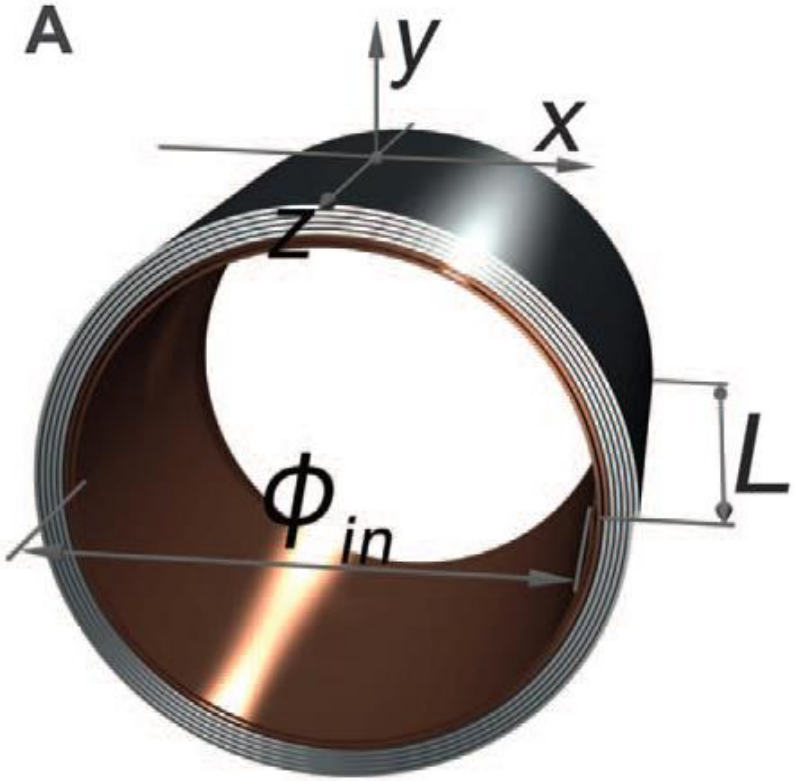
Magnetic Cloak

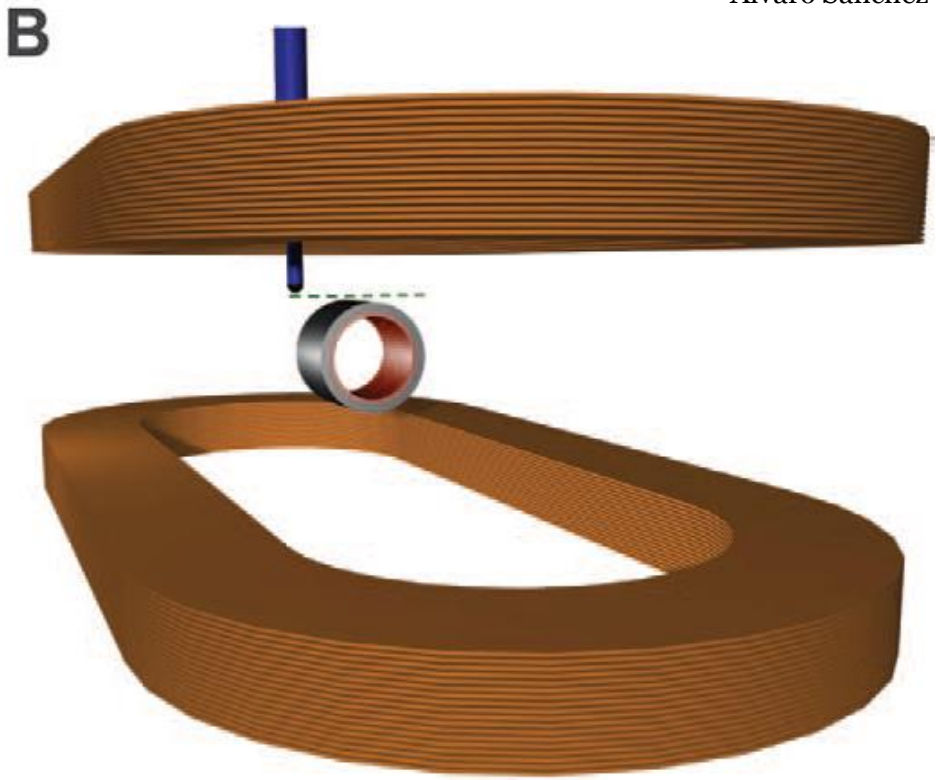
- "Cloak" the beam with a tube
- Desired: Null interior field and external field unaffected
- Controlling magnetic fields with superconductor-metamaterial hybrids



Magnetic Cloak

Alvaro Sanchez





Studies for application in a beam-pipe ongoing