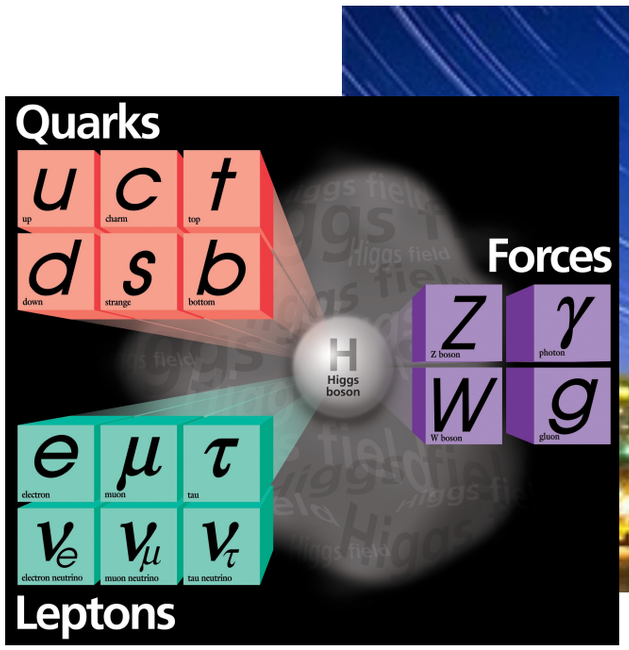
Stony Brook University

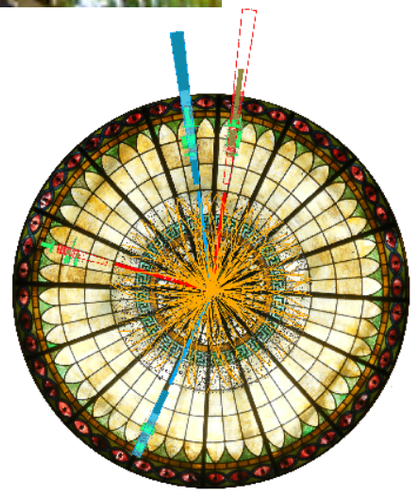
The Evolution Of PHENIX Into An Electron Ion Collider (EIC) Experiment



Nils Feege for the
PHENIX Collaboration

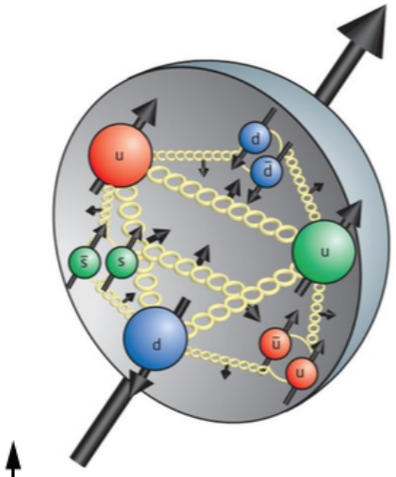
DIS 2015
XXIII International Workshop on
Deep-Inelastic Scattering and
Related Subjects

Dallas, Texas
April 27 – May 1, 2015

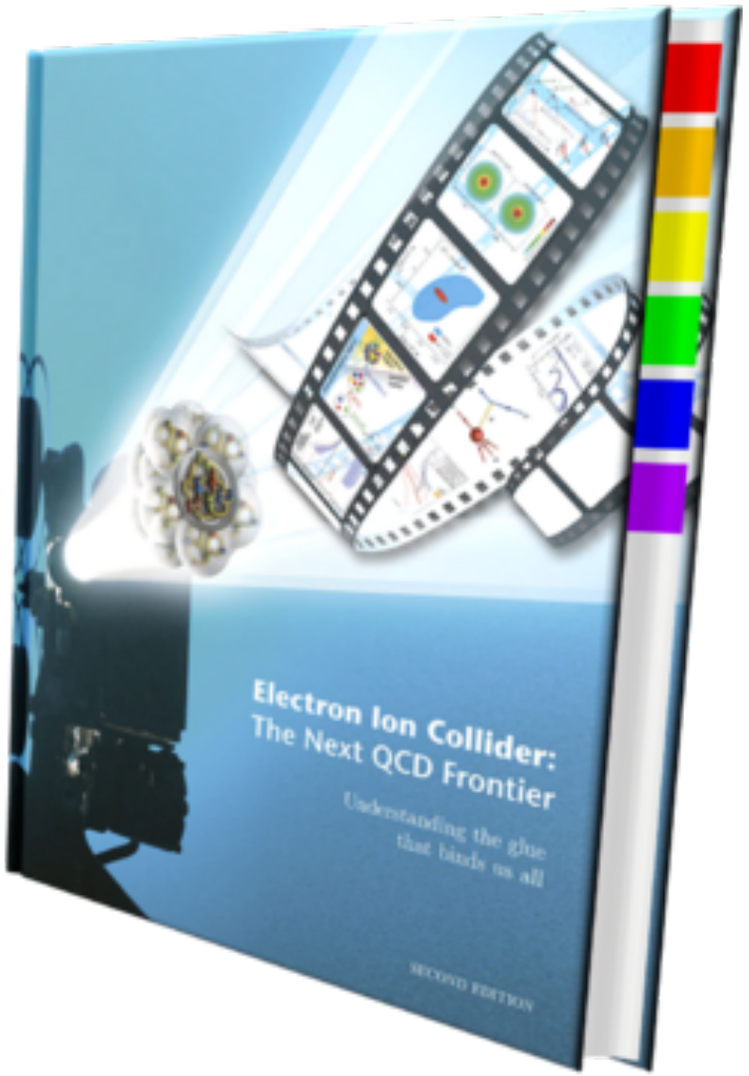


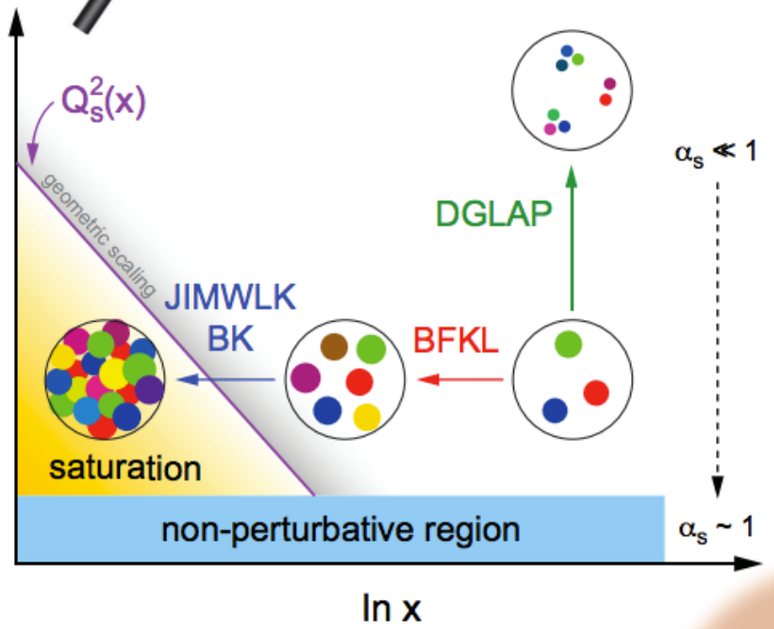
"A Bridge Between Quarks / Gluons And Nuclei"

arXiv:1212.1701v3

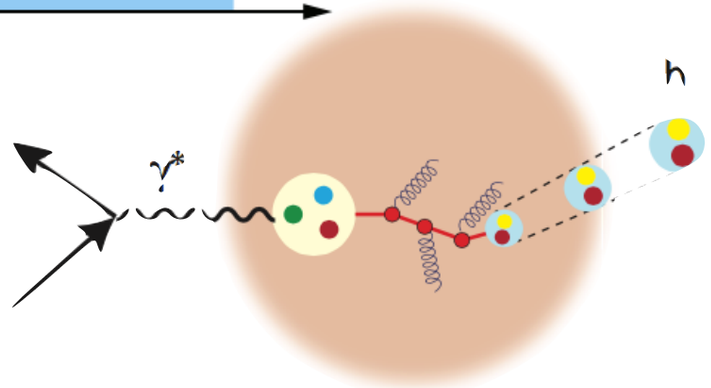


❖How are the sea quarks and gluons, and their spins, distributed in space and momentum inside the nucleon?



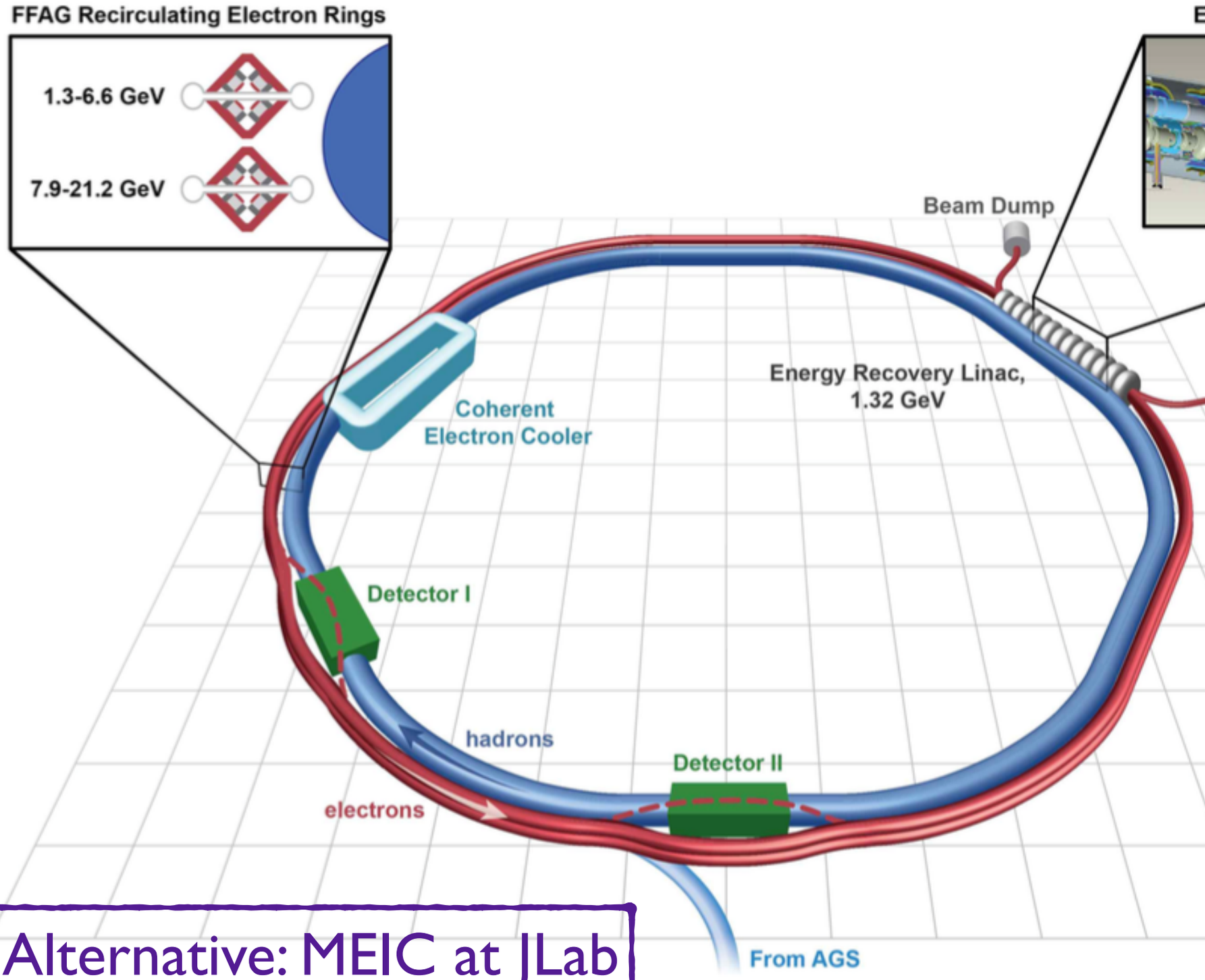


❖Where does the saturation of gluon densities set in?



❖How does the nuclear environment affect the distribution of quarks and gluons and their propagation?

e+p / e+A Collisions at RHIC



Energy:

Electron: 6.6–21.2 GeV
Proton: 25–250 GeV
Ions: 10–100 GeV
$\sqrt{s}$: up to 145 GeV

Polarization:

Electrons: 80%
Protons and He3: 70%

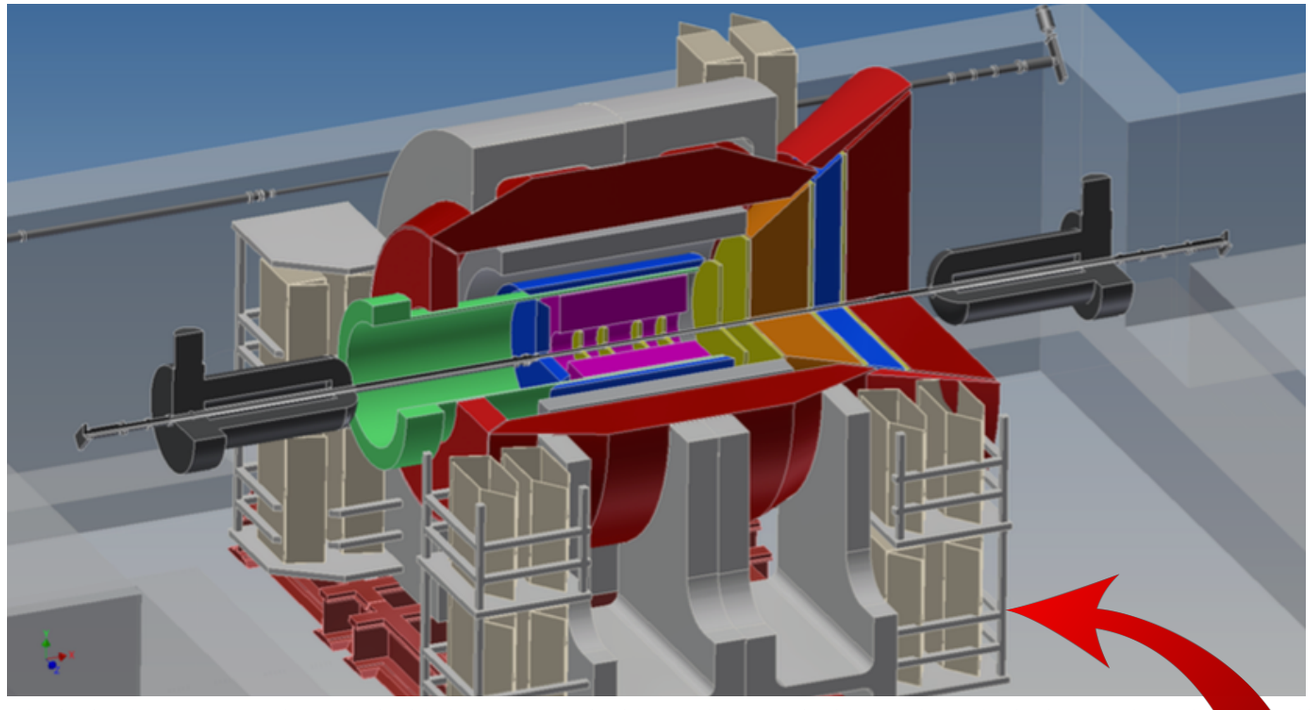
Luminocity:

$>10^{33}$ cm^{-2} s^{-1}

Alternative: MEIC at JLab

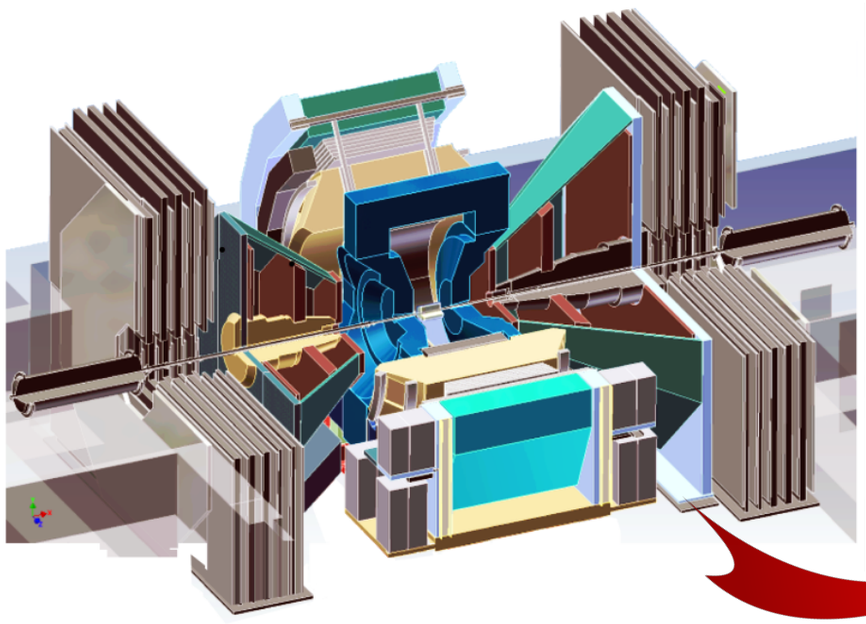
The Evolution Of PHENIX

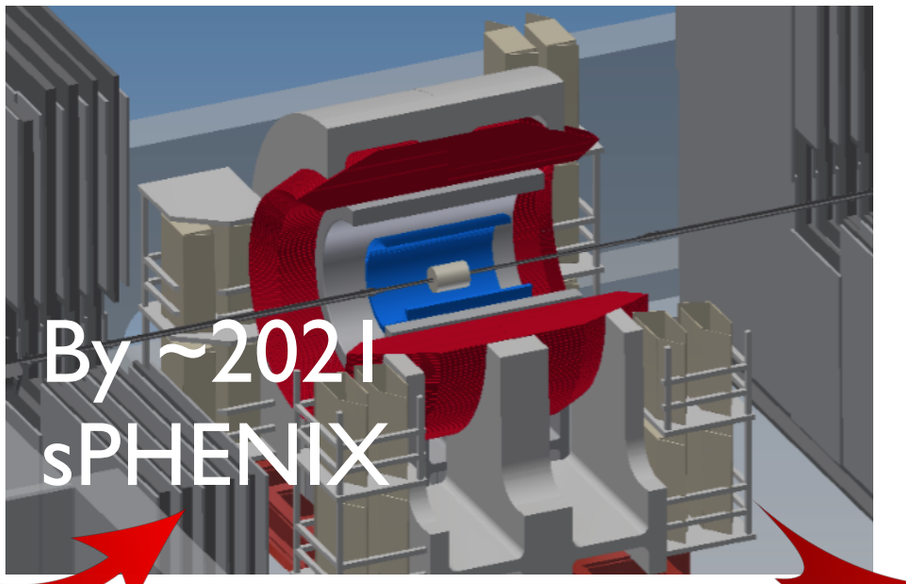
By ~2026
EIC Detector



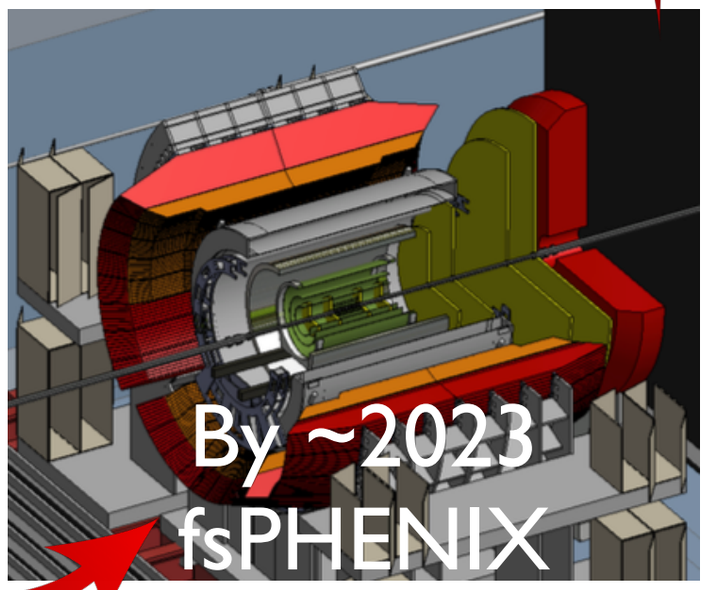
eRHIC (e+p, e+A)

RHIC (p+p, p+A, A+A)





By ~2021
sPHENIX

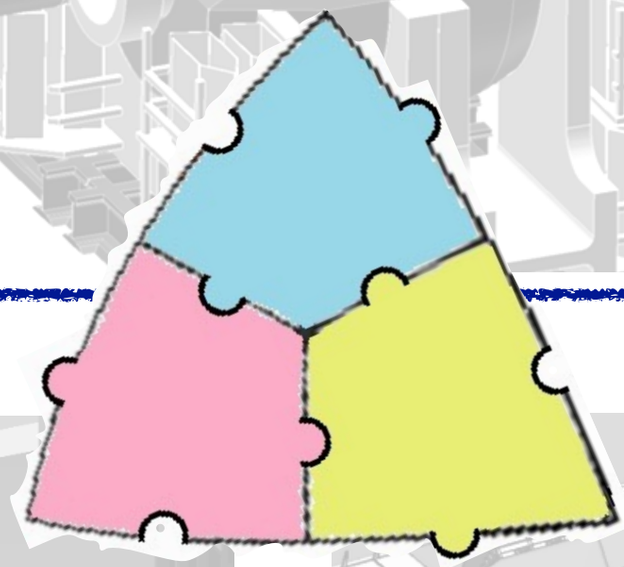


By ~2023
fsPHENIX

Putting The Pieces Together

eRHIC (e+p, e+A)

- Nucleon spin and 3D structure
- Effects of 'cold' nuclear matter
- Color Glass Condensate



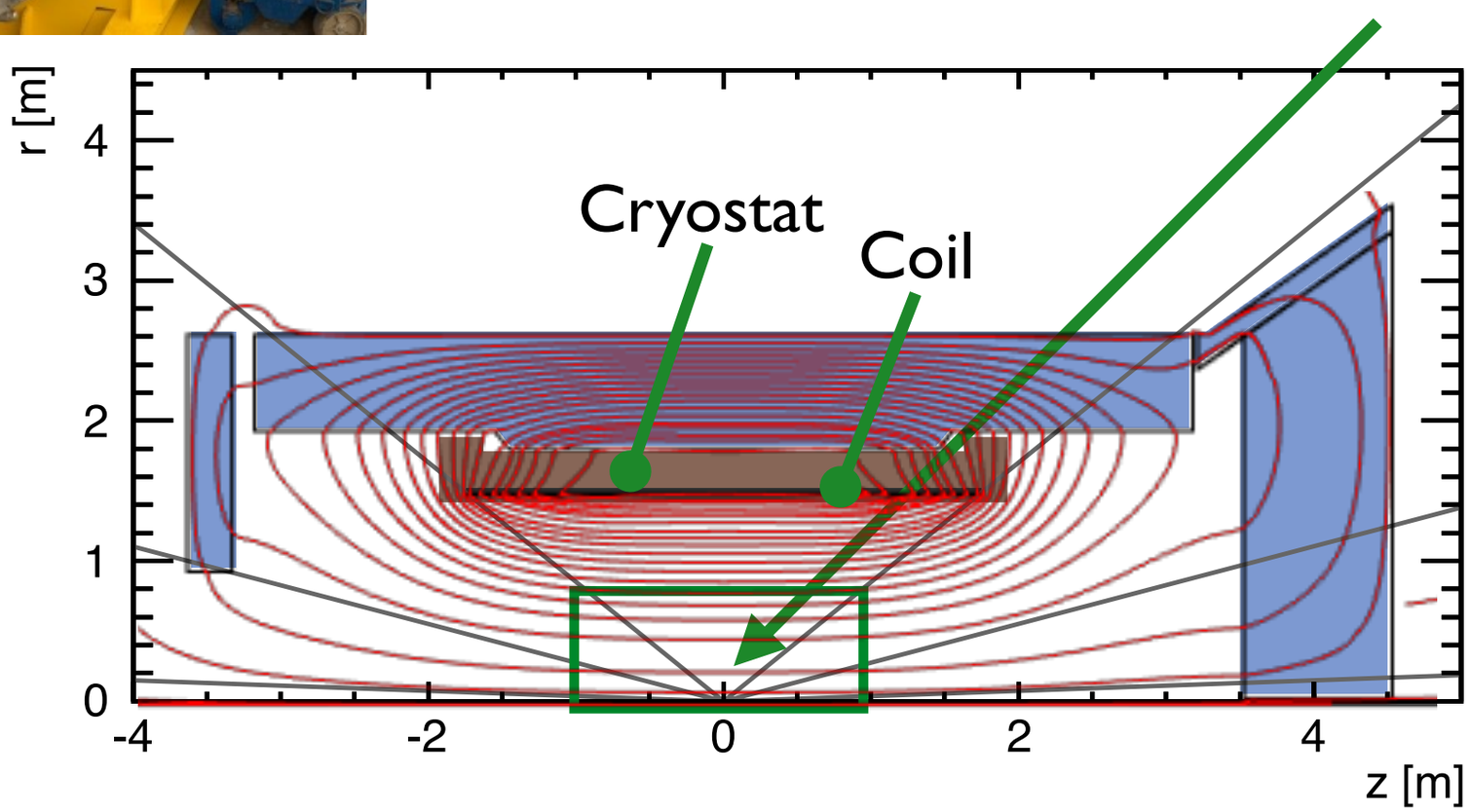
RHIC (p+p, p+A, A+A)

- Quark-gluon plasma
- Effects of 'hot' nuclear matter

- Transverse spin
- Effects of 'cold' nuclear matter

The Central Element: The BaBar Coil

- Superconducting solenoid
- Field: 1.5 T
- Inner radius: 140 cm
- Outer radius: 173 cm
- Length: 385 cm



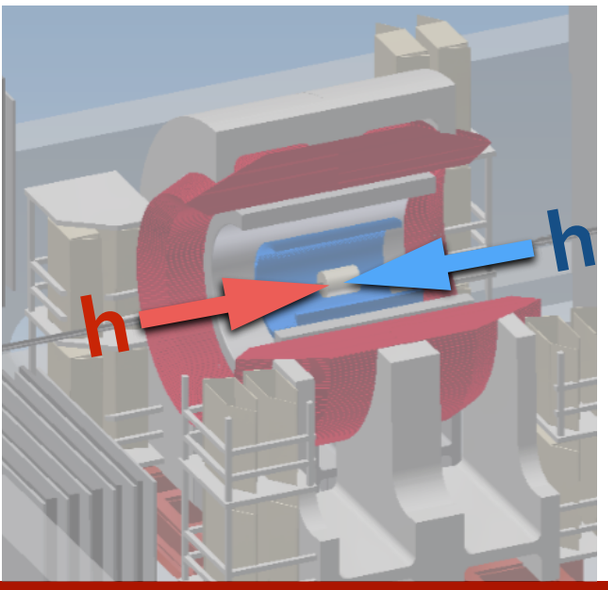
sPHENIX

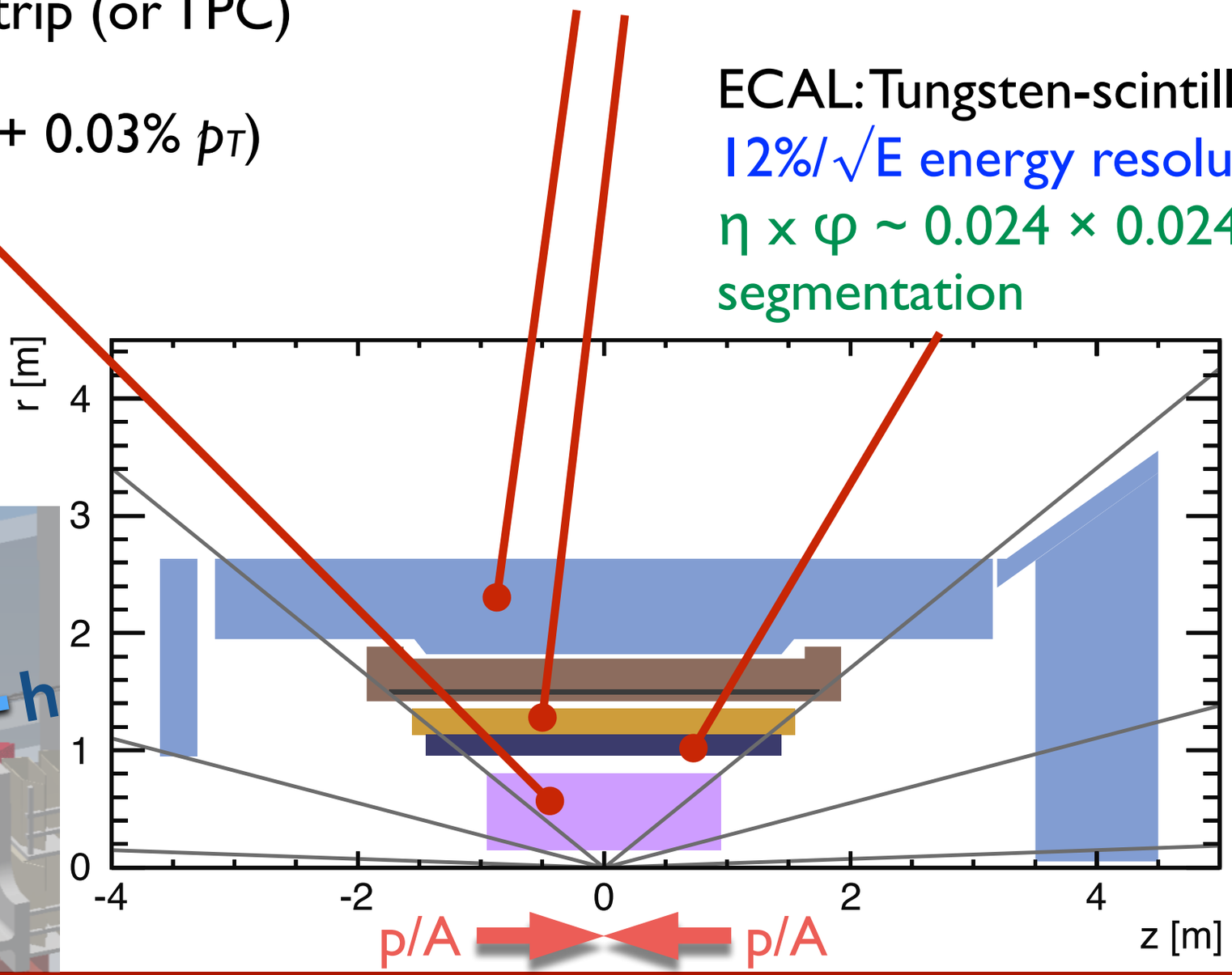
Tracking
- 2 layer Silicon vertex pixel
- 5 layer Silicon-strip (or TPC)

$$\frac{\Delta p_T}{p_T} < (1.2\% + 0.03\%\ p_T)$$

HCAL: Steel-scintillator (5 λ_{int})
100%/$\sqrt{E}$ energy resolution
$\eta \times \varphi \sim 0.1 \times 0.1$ segmentation

ECAL: Tungsten-scintillating fiber (18 X_0)
12%/$\sqrt{E}$ energy resolution
$\eta \times \varphi \sim 0.024 \times 0.024$ (2x2 cm^2) segmentation





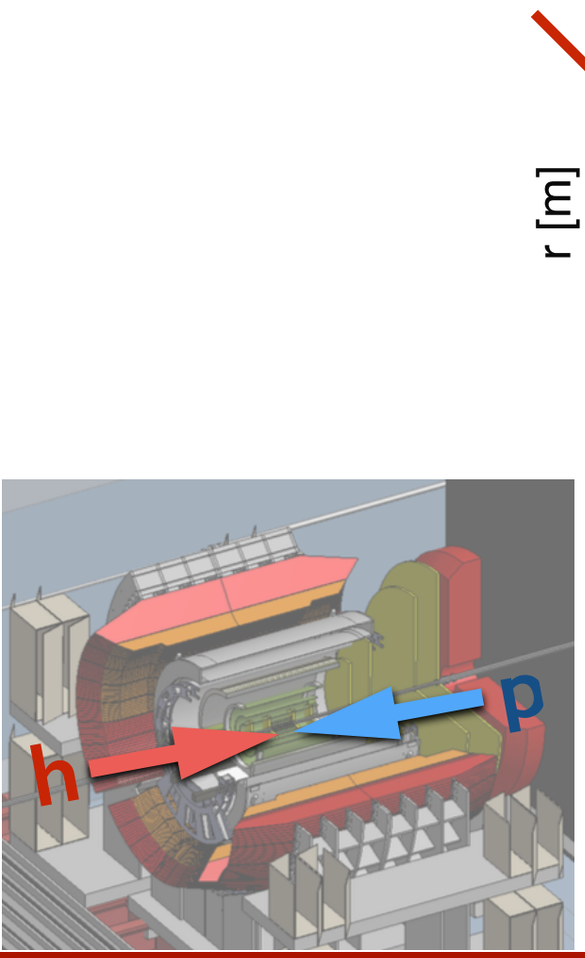
Forward - sPHENIX (fsPhenix)

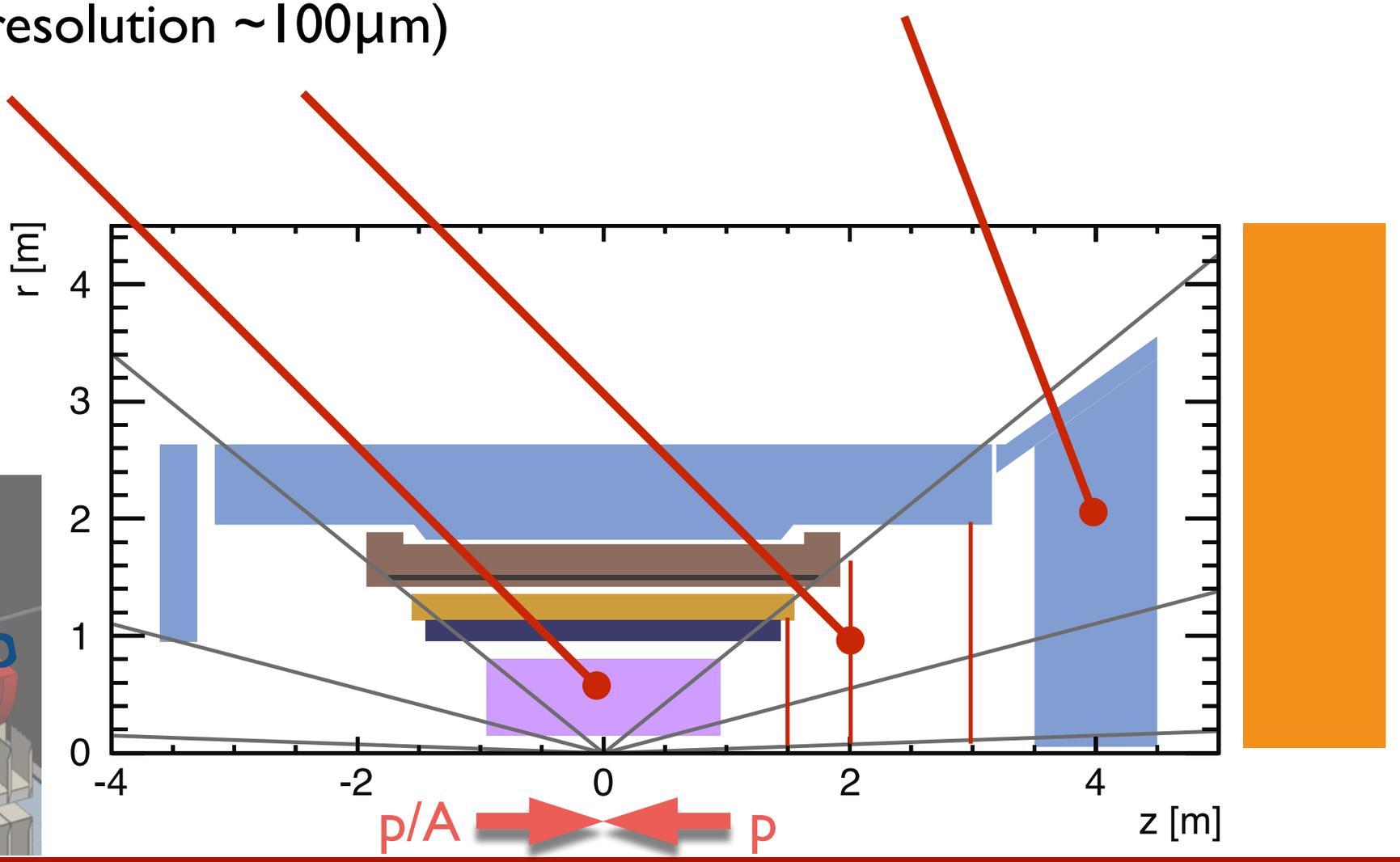
Tracking
- 2 layer Silicon vertex pixel
- Silicon-strip (or TPC)
- Forward vertex
- GEM (rδφ resolution ~100μm)

Hadron Calorimeter
- Steel-scintillator (5 λ_{int})

  100%/$\sqrt{E}$ energy resolution

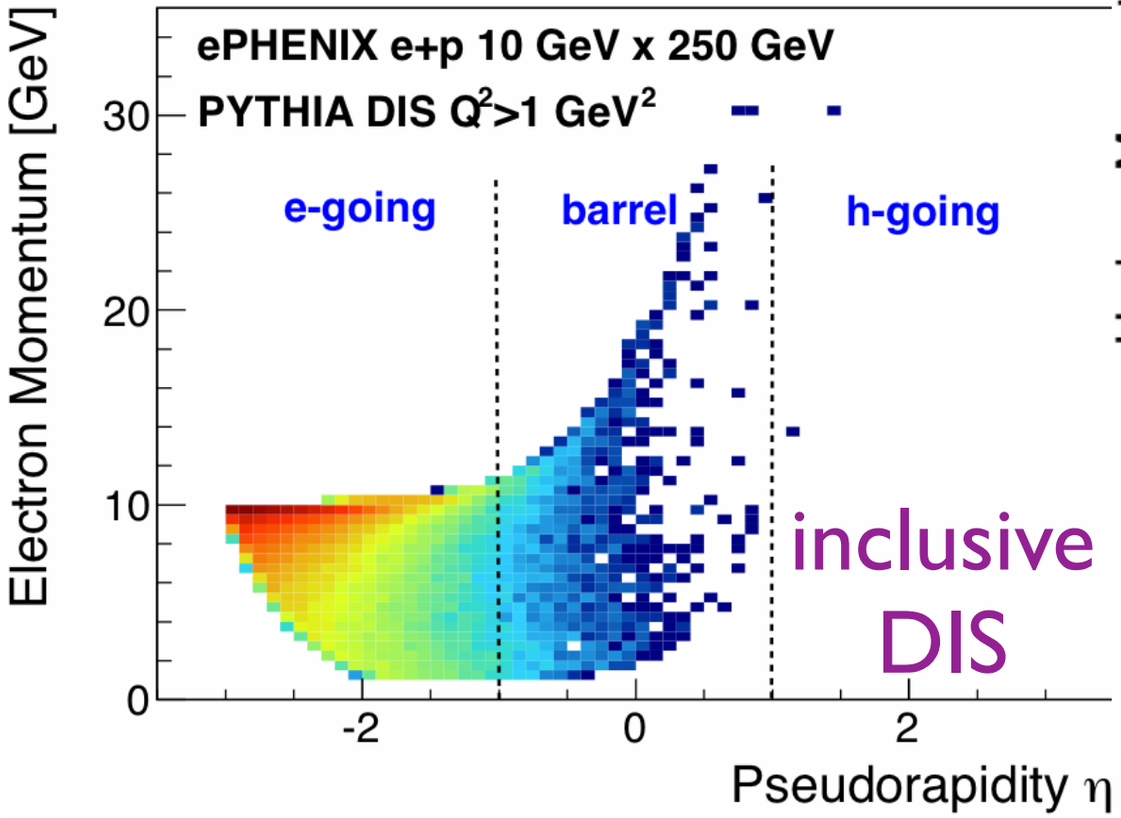
  ~ 10 × 10 cm^2 segmentation

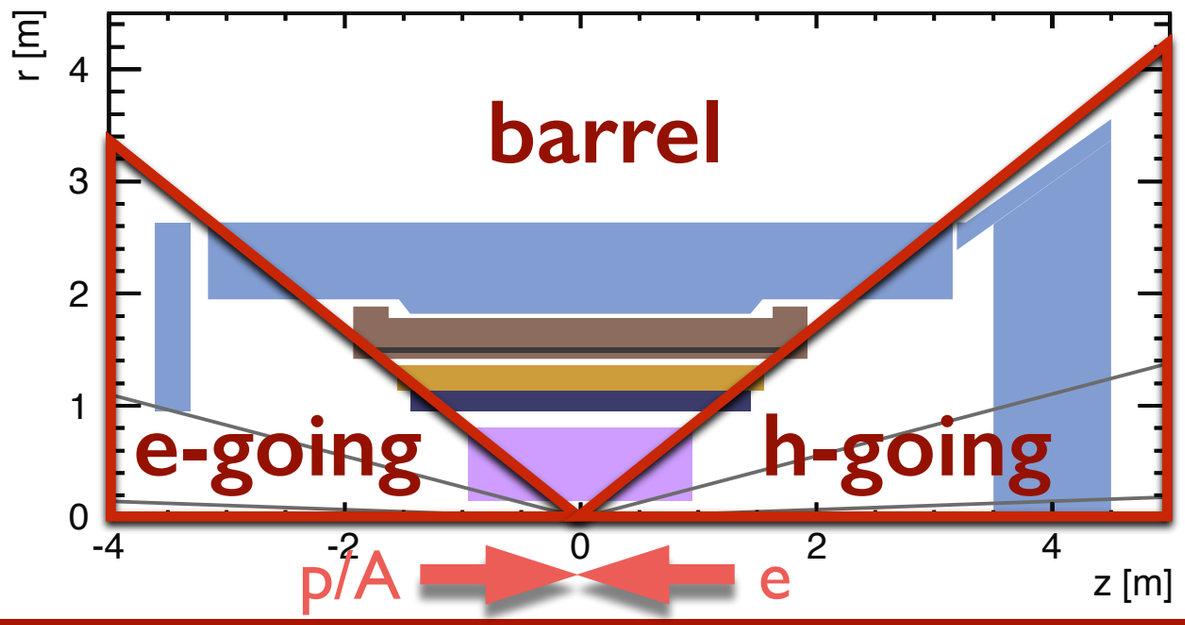


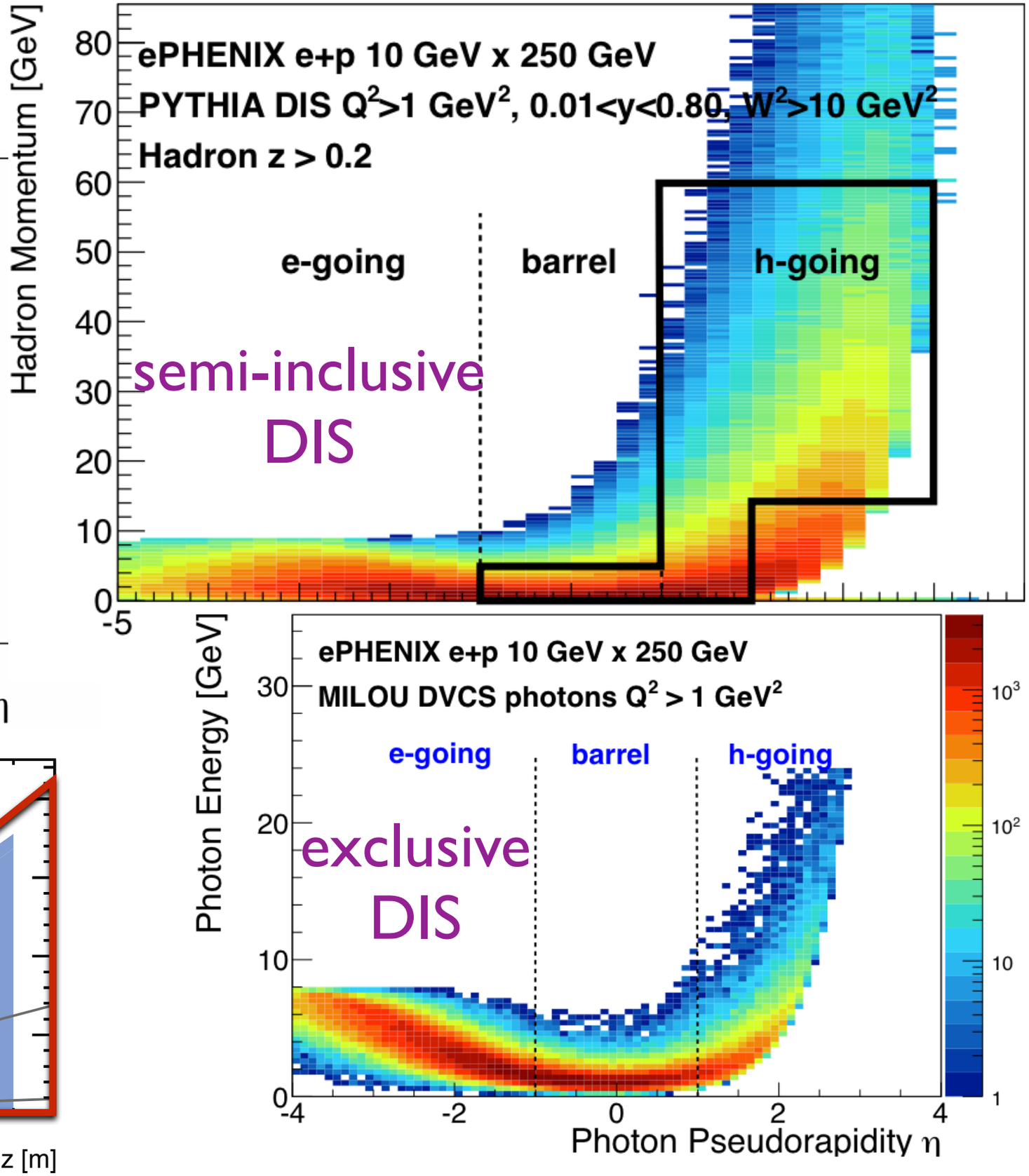


Muon ID

Measuring DIS







EIC Detector

Tracking

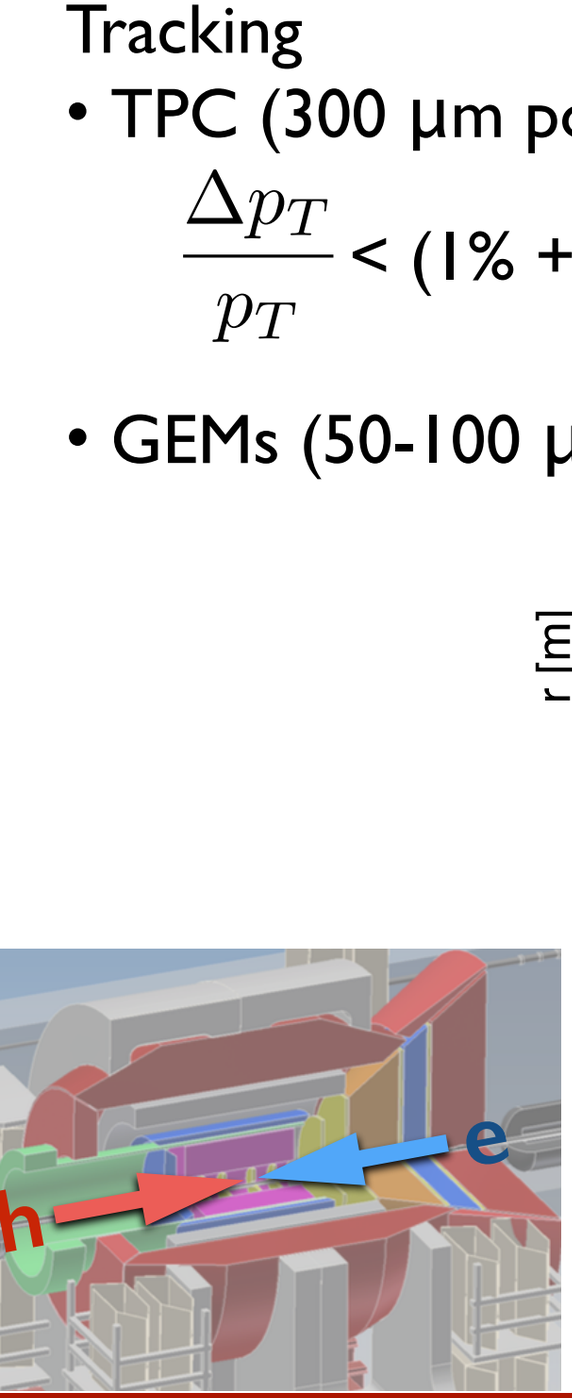
- TPC (300 μm position resolution)

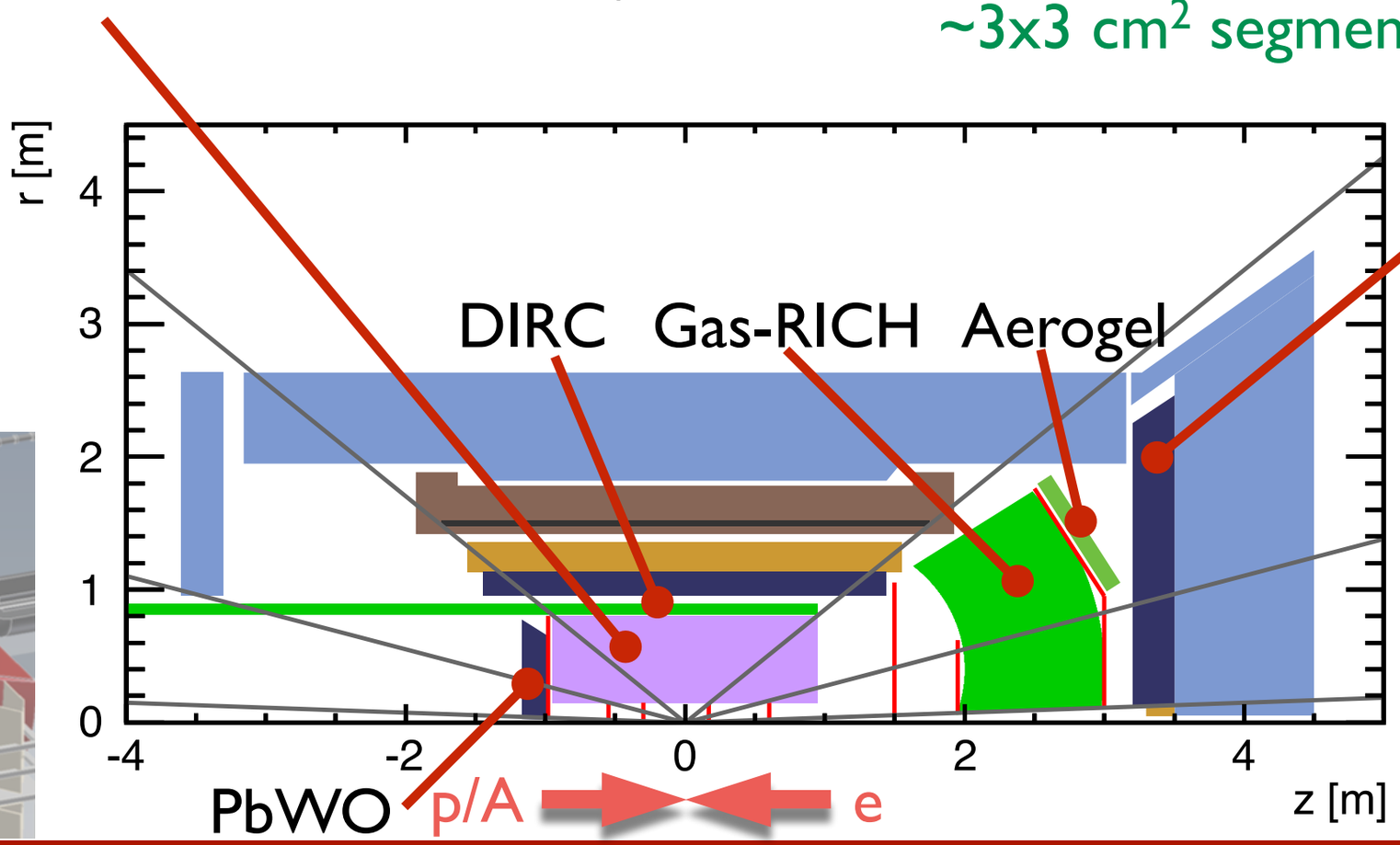
$$\frac{\Delta p_T}{p_T} < (1\% + 0.4\%\ p_T)$$

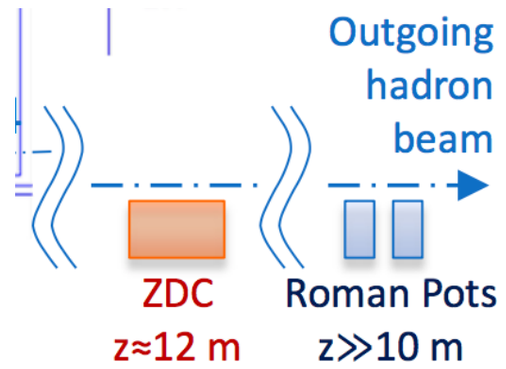
- GEMs (50-100 μm resolution in rΔφ)

Electromagnetic Calorimeter

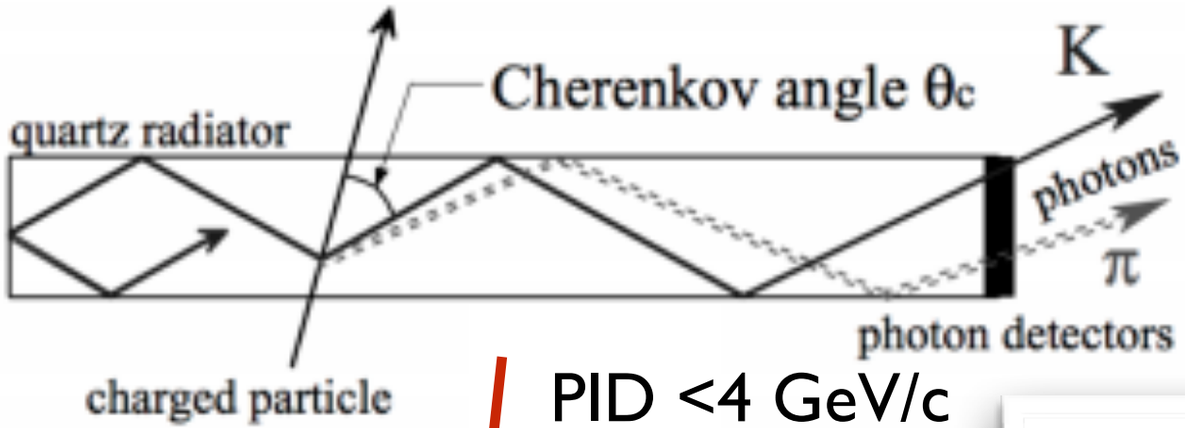
- Lead-tungstate (20 X_0)
  1.5%/$\sqrt{E}$ energy resolution
  3mm/$\sqrt{E}$ position resolution
- Lead-scintillating Fibre (18 X_0)
  12%/$\sqrt{E}$ energy resolution
  ~3x3 cm^2 segmentation



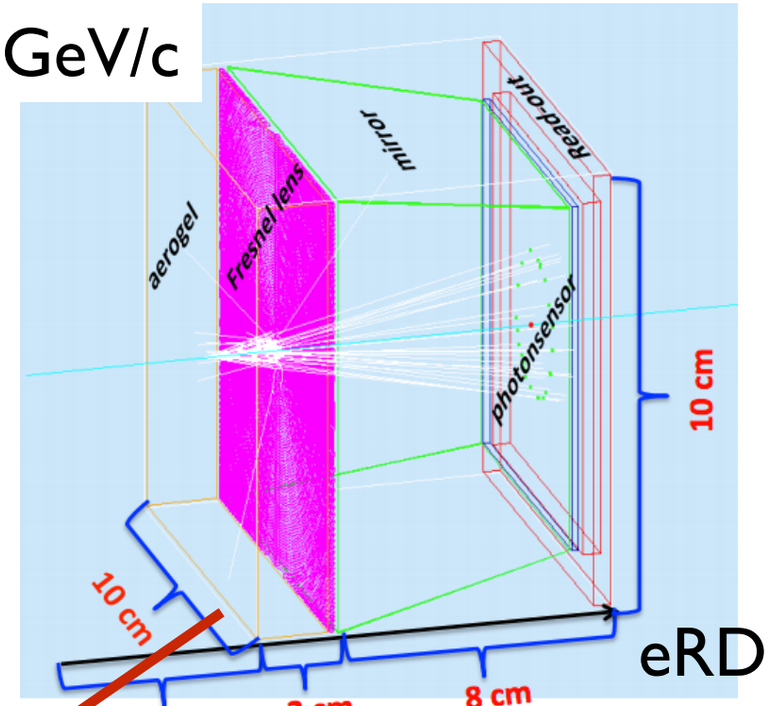




RICH Detectors for Hadron ID



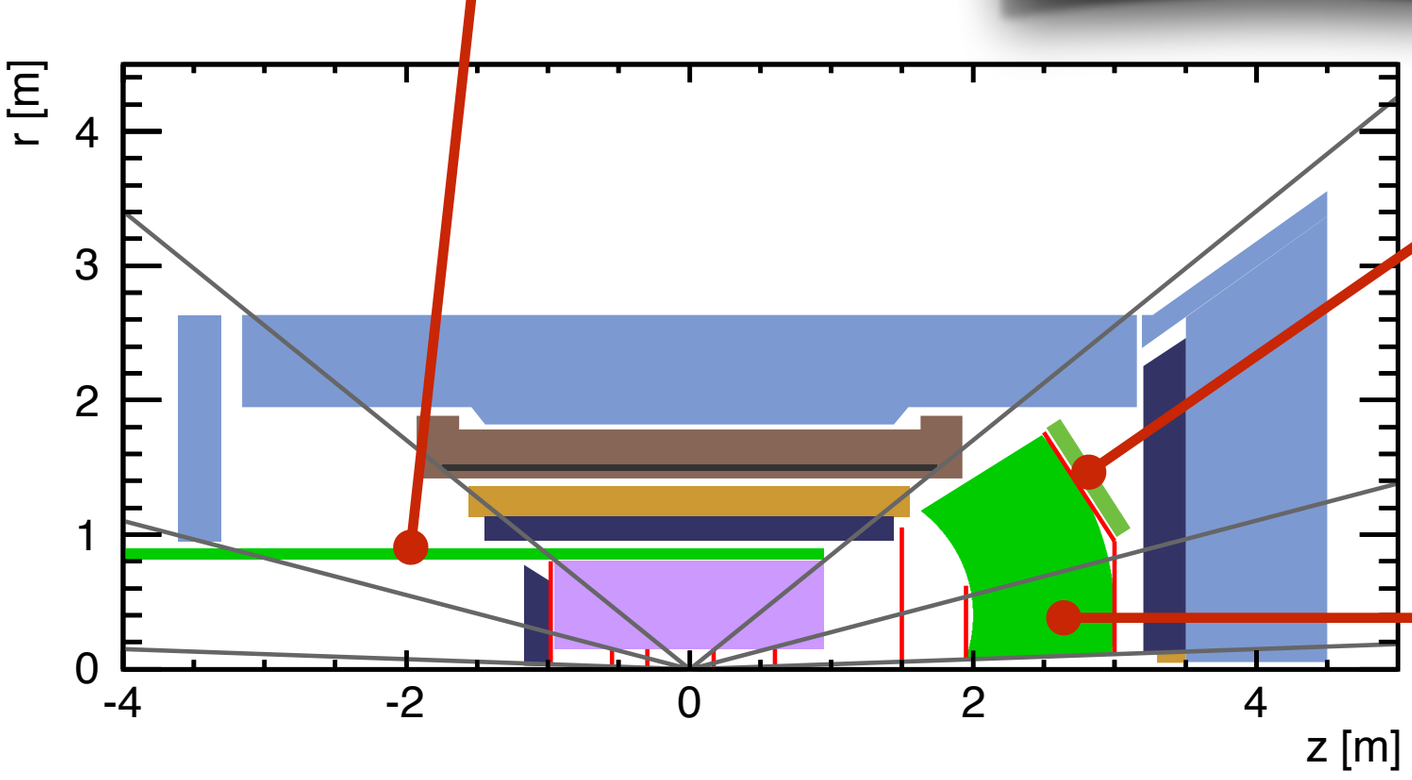
PID ~ 3–15 GeV/c

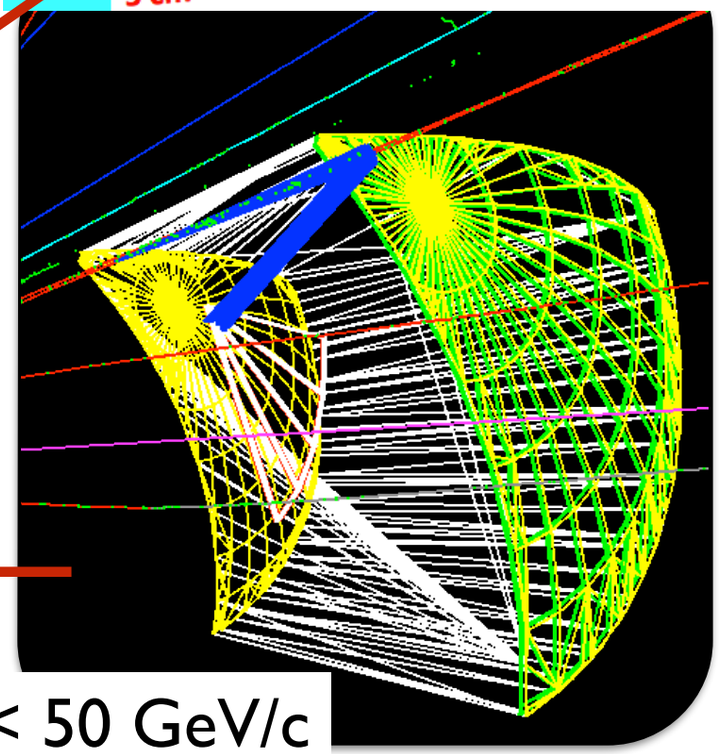


eRD11

PID <4 GeV/c

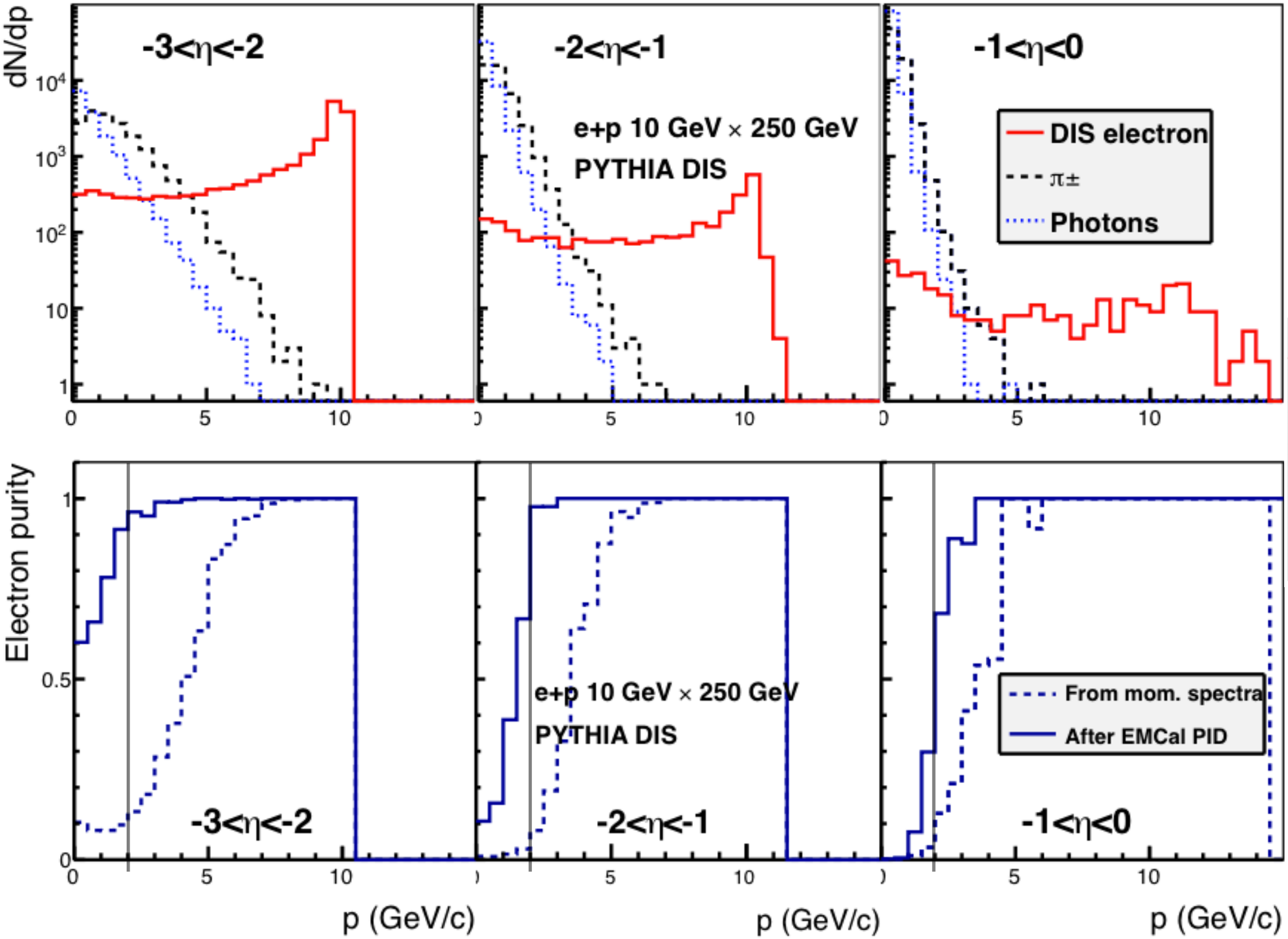
$$\theta_C = \cos^{-1}\left(\frac{1}{\beta n}\right)$$

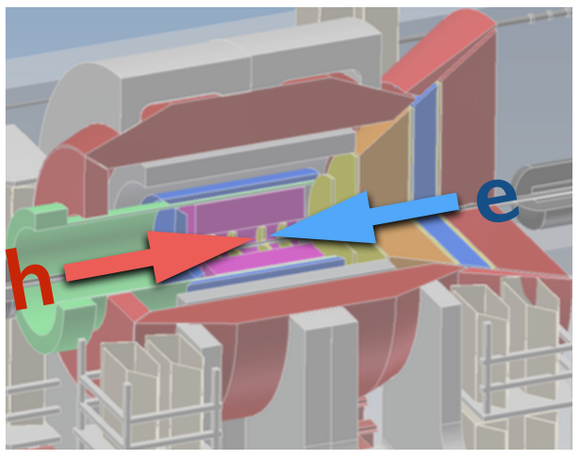


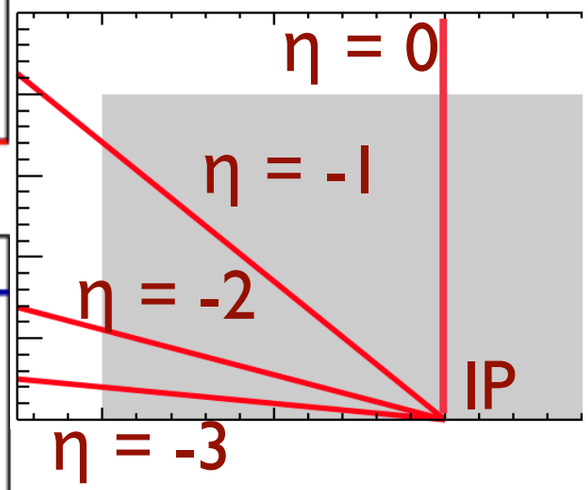


PID < 50 GeV/c

Electron ID via E/p matching

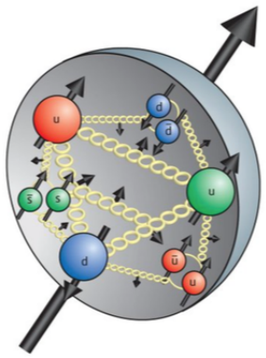






select only
$E_e > 2$ GeV

arXiv:1402.1209v1

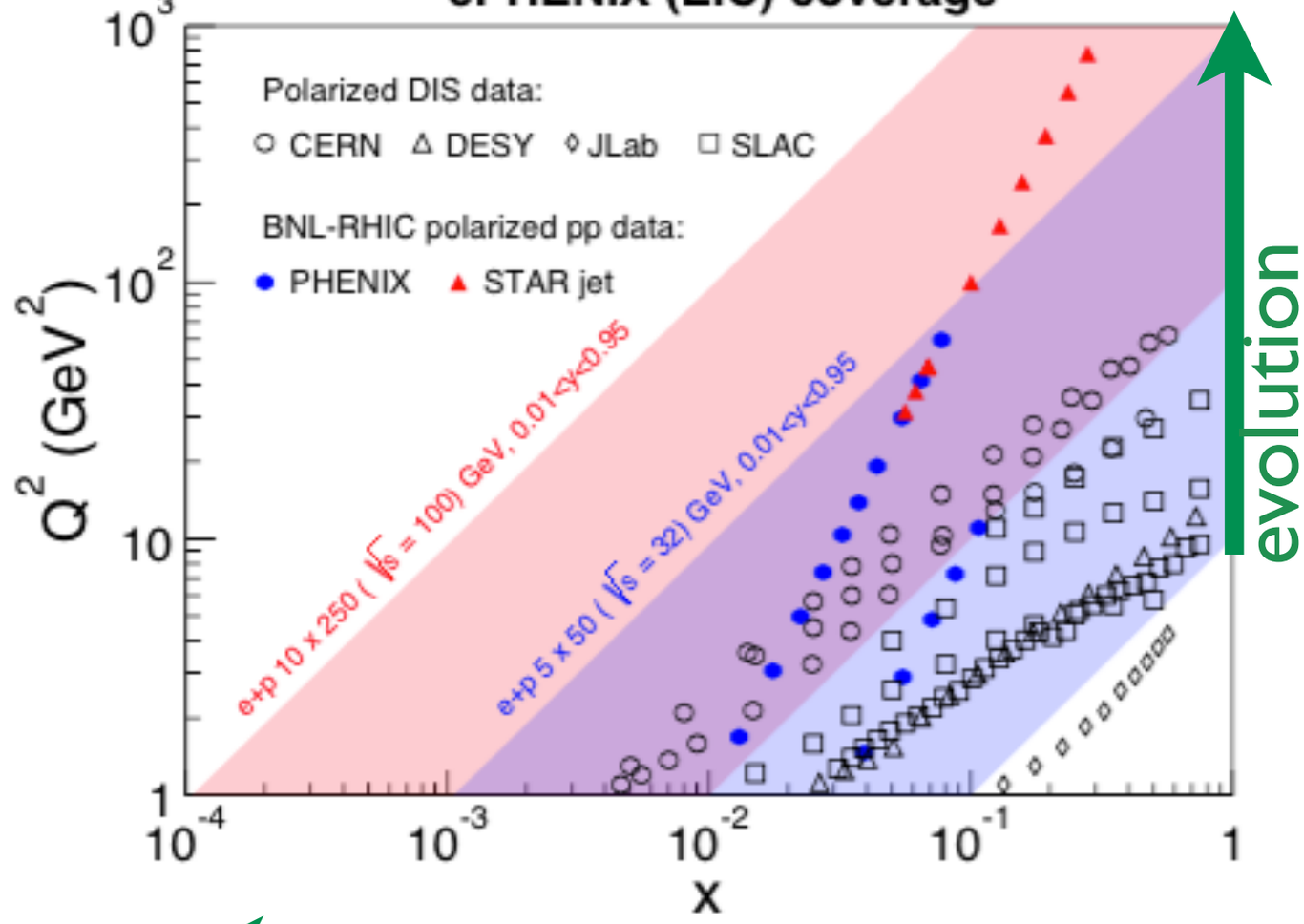


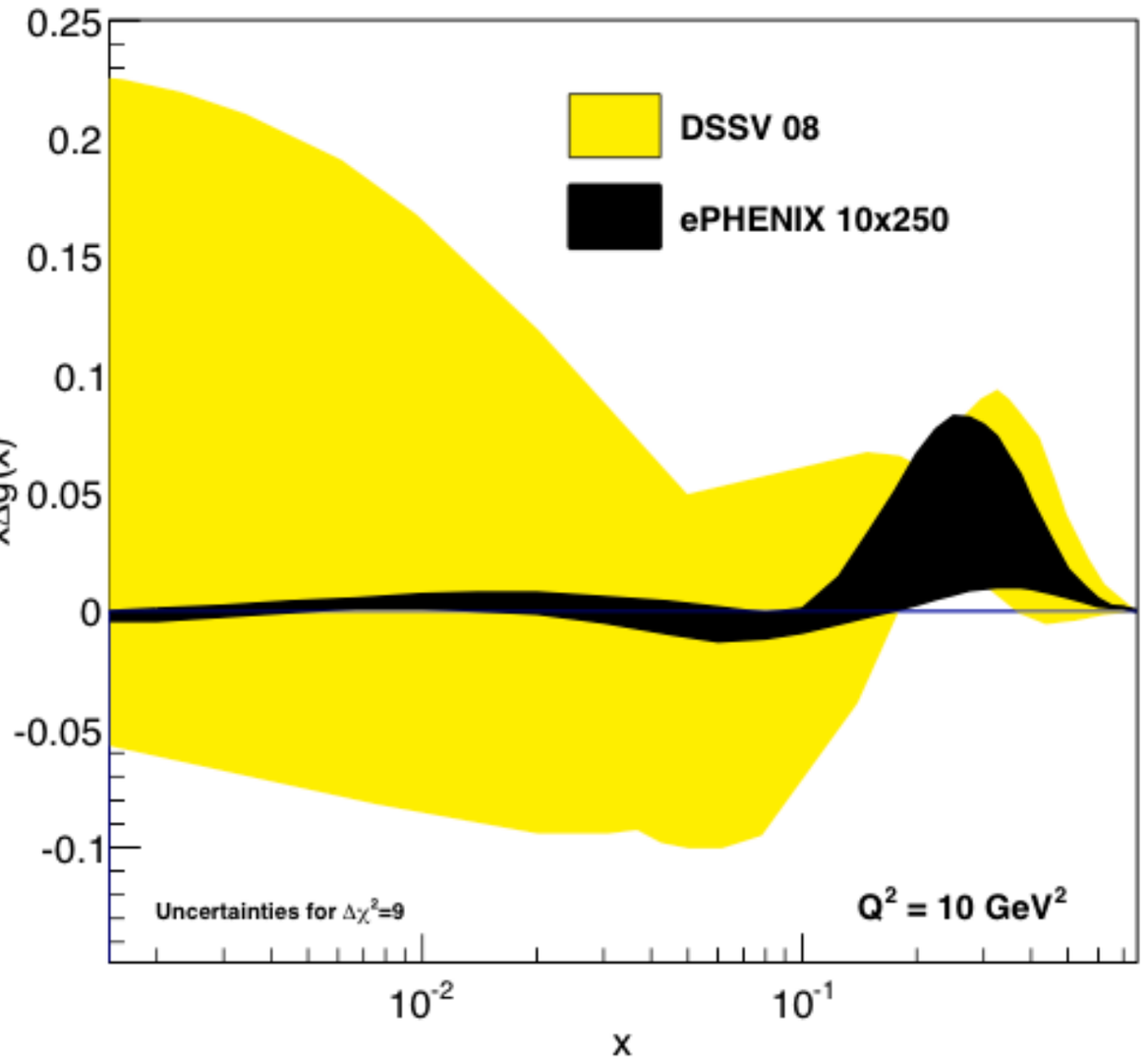
DIS: Longitudinal Proton Spin

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + L_q + \Delta G + L_g$$

PHYTHIA generator and ePHENIX acceptance/efficiencies

10 fb^{-1} at 10GeV×250GeV





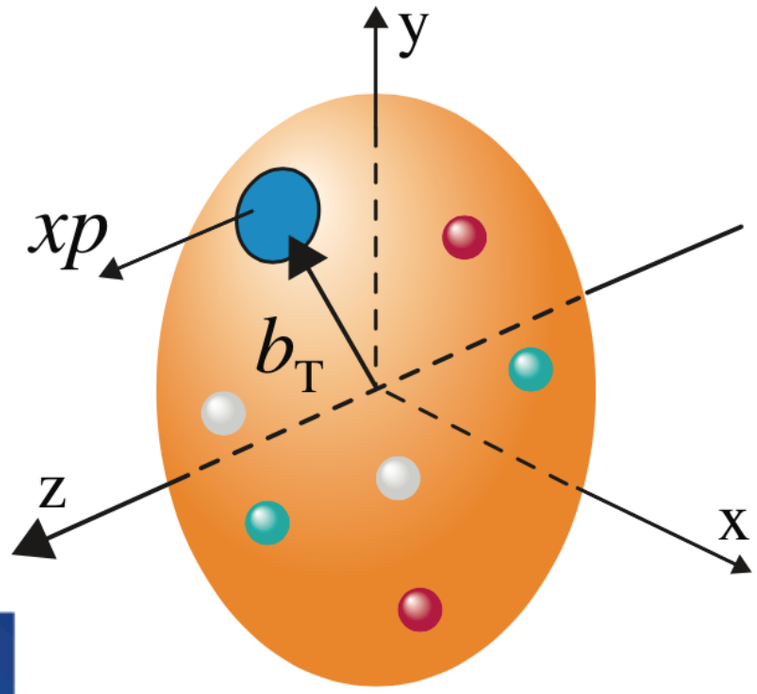
valence to low-x physics

arXiv:1402.1209v1

3D Imaging of Quarks and Gluons

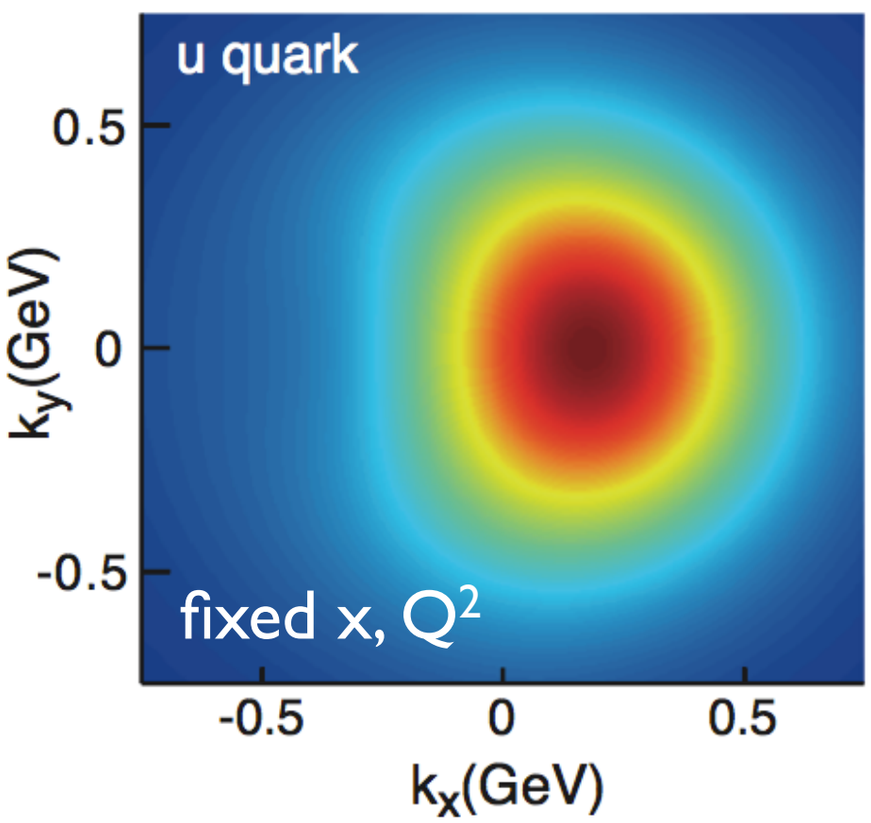
momentum space

$f(x,k_T)$

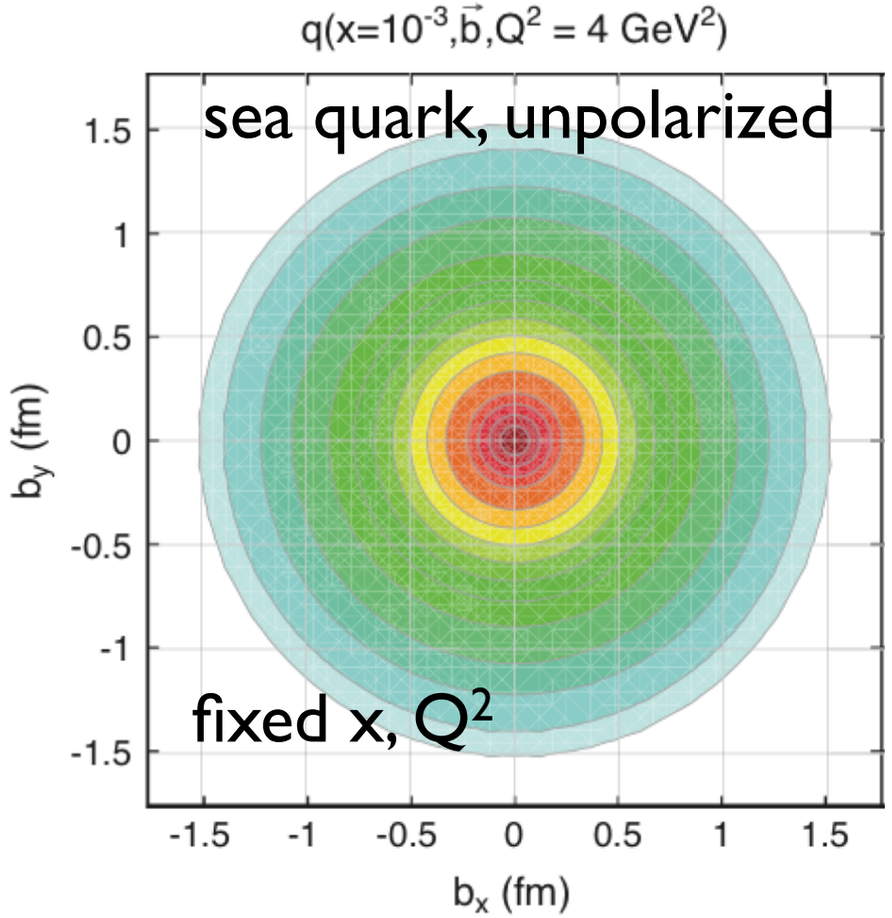


position space

$f(x,b_T)$



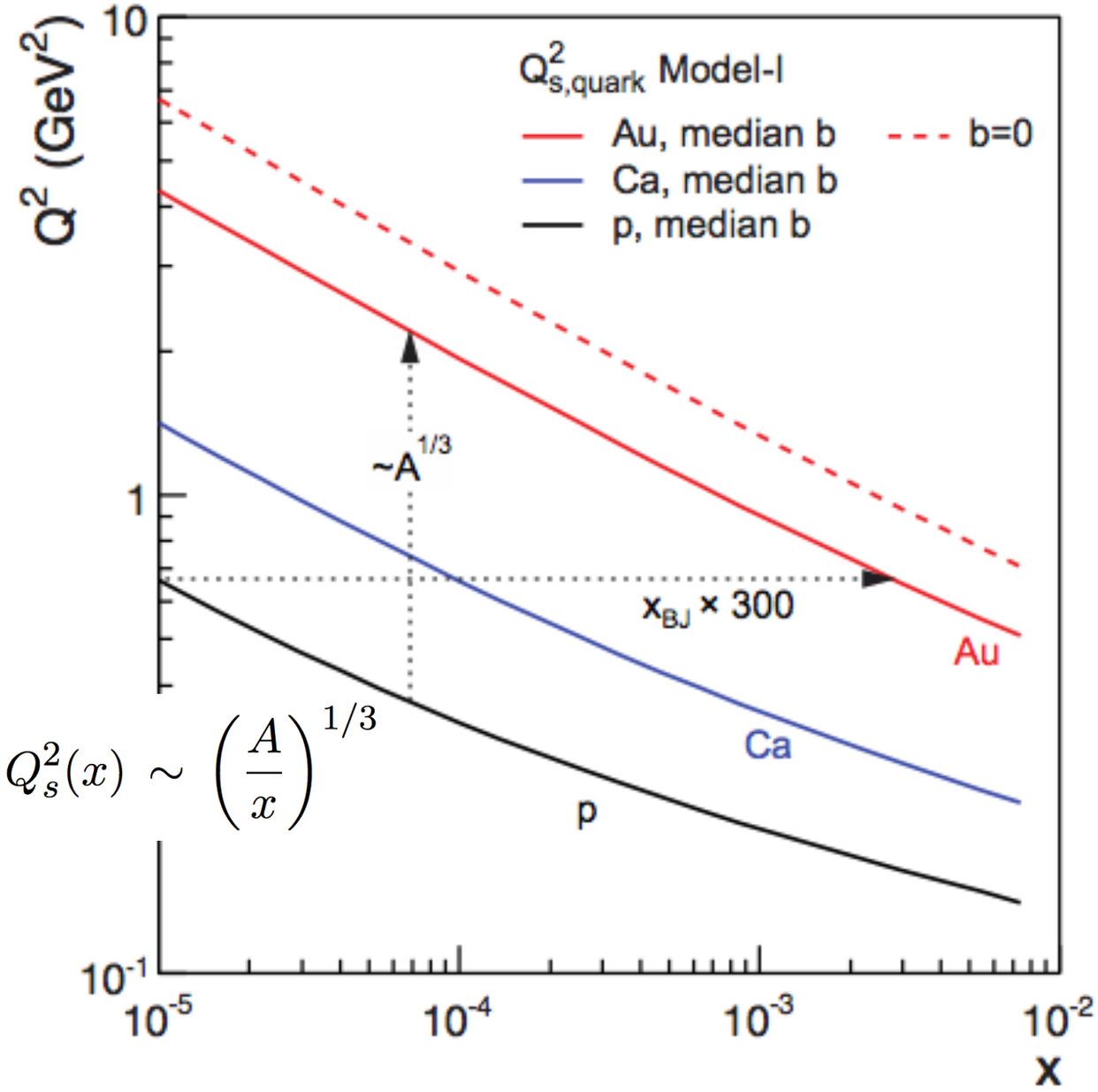
Position r
X
Momentum p
⇩
Orbital motion
of partons

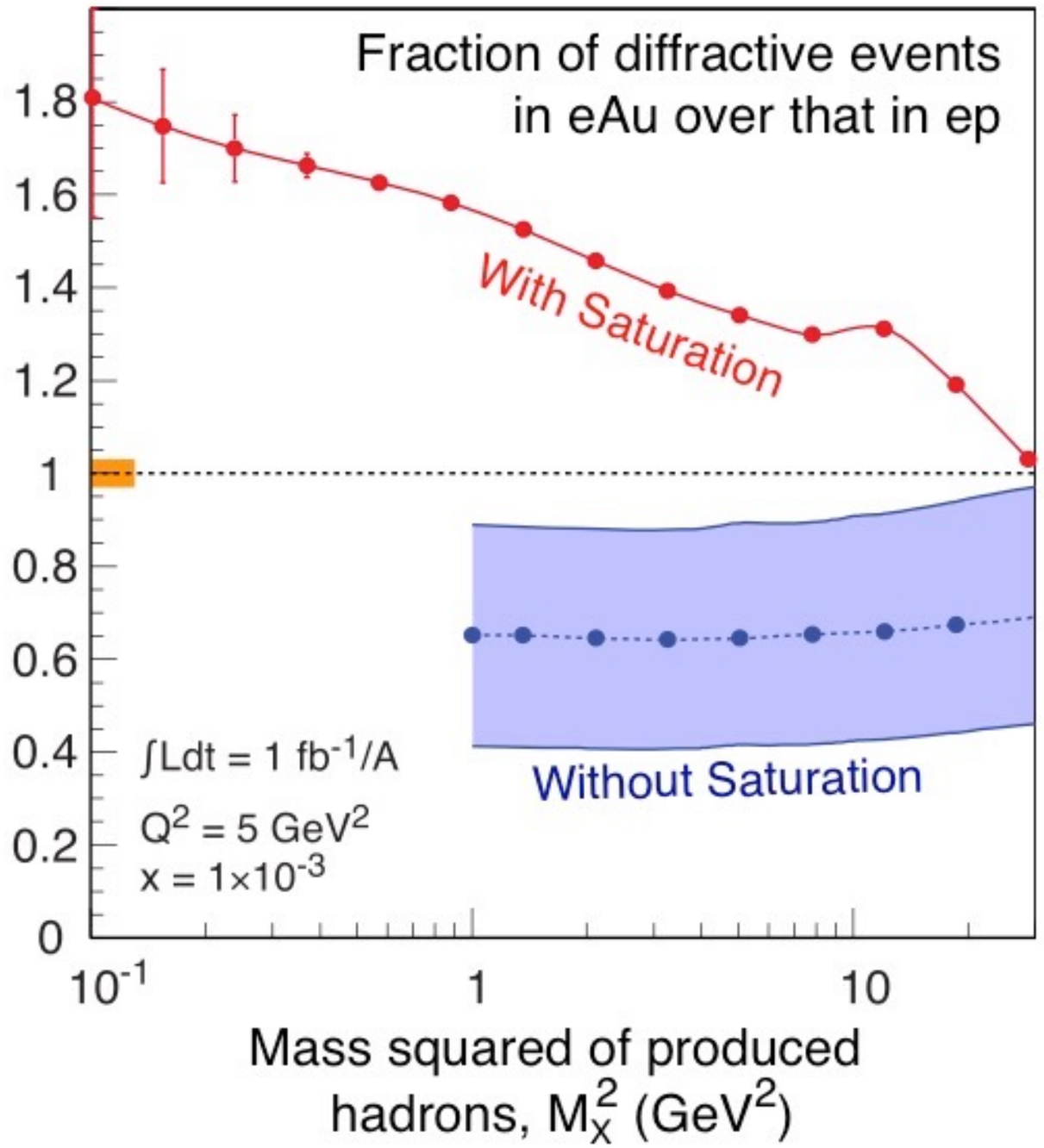


arXiv:1212.1701v3

Gluon Saturation from Diffraction

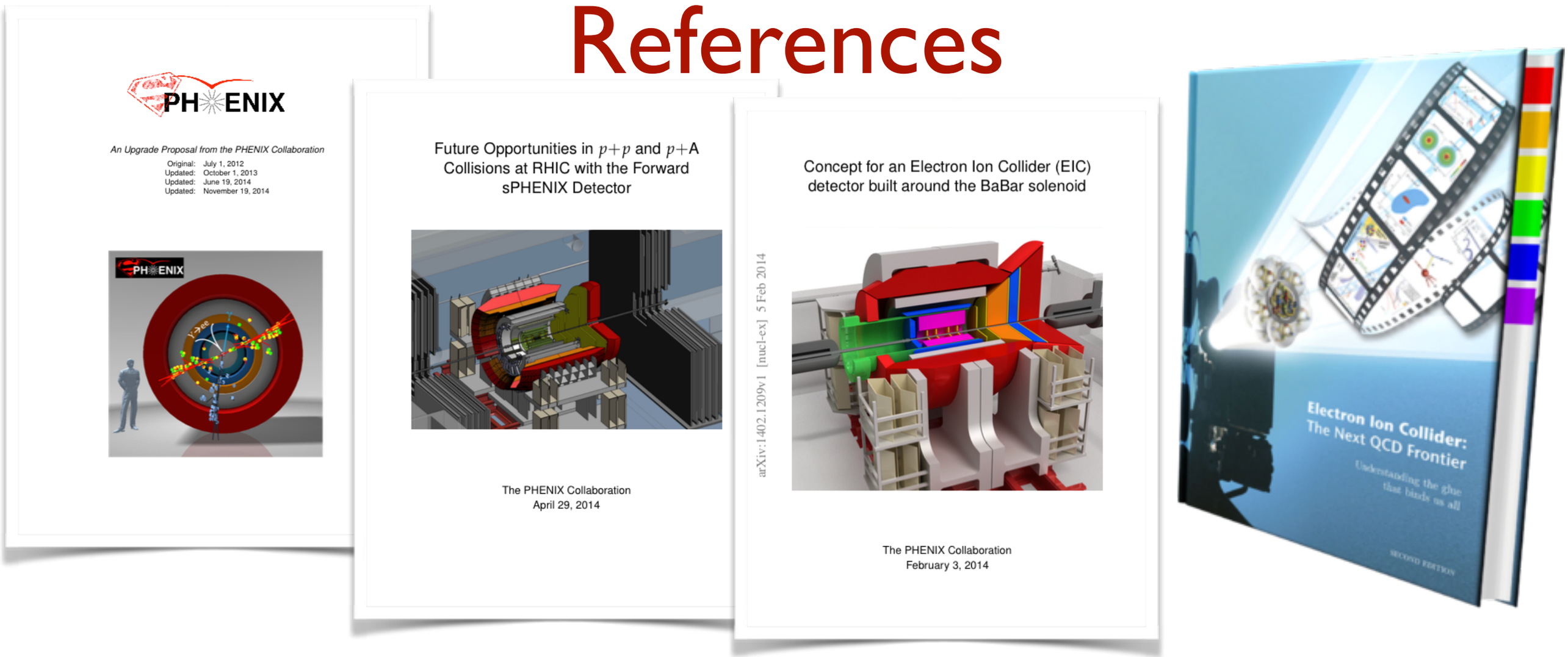
$$\sigma_{\text{diff}} \propto [g(x, Q^2)]^2$$





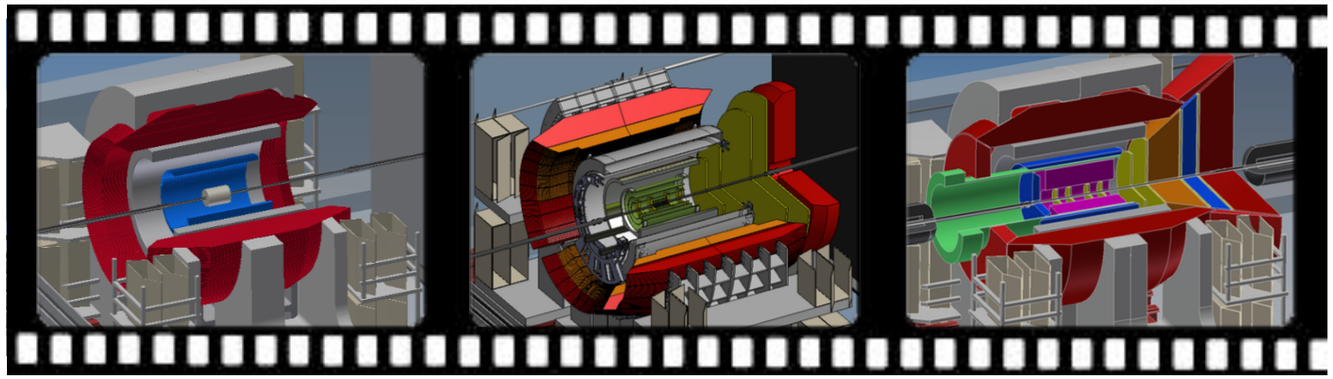
arXiv:1212.1701v3

References



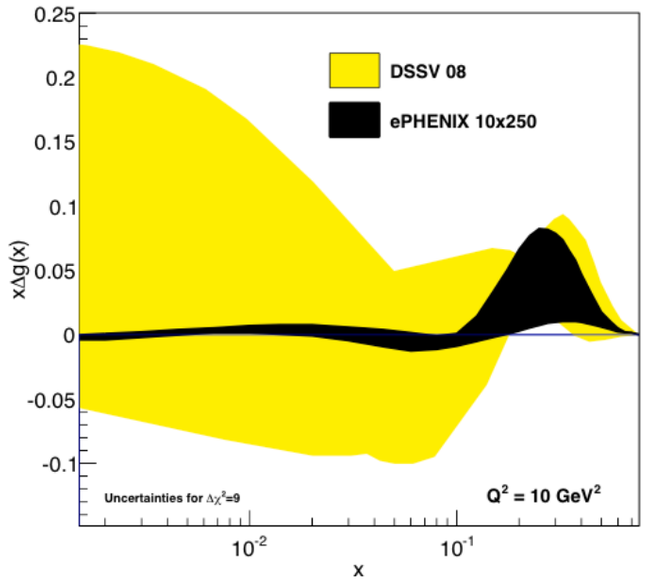
- sPHENIX - An Upgrade Proposal from the PHENIX Collaboration [arXiv:1207.6378v2]
- Future Opportunities in p+p and p+A Collisions at RHIC with the Forward sPHENIX Detector [http://tinyurl.com/lq6e9v3]
- Concept for an Electron Ion Collider (EIC) detector built around the BaBar solenoid [arXiv:1402.1209v1]
- Electron Ion Collider: The Next QCD Frontier [arXiv:1212.1701v3]

Summary



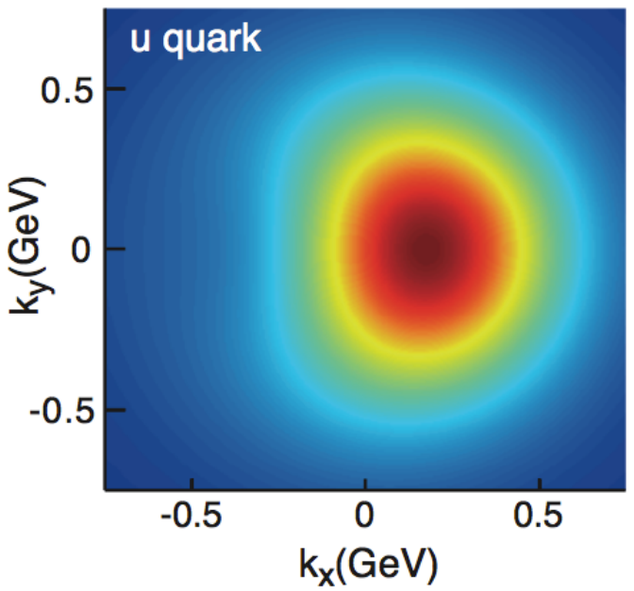
The stages of this detector could make excellent use of the highly intriguing physics potential at RHIC:

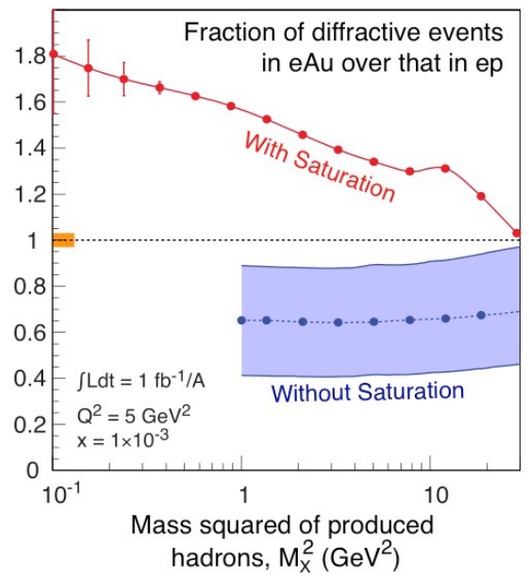
- ❖ Quark Gluon Plasma
- ❖ Effects of hot and cold nuclear matter
- ❖ Transverse spin



and eRHIC (or the MEIC at JLab):

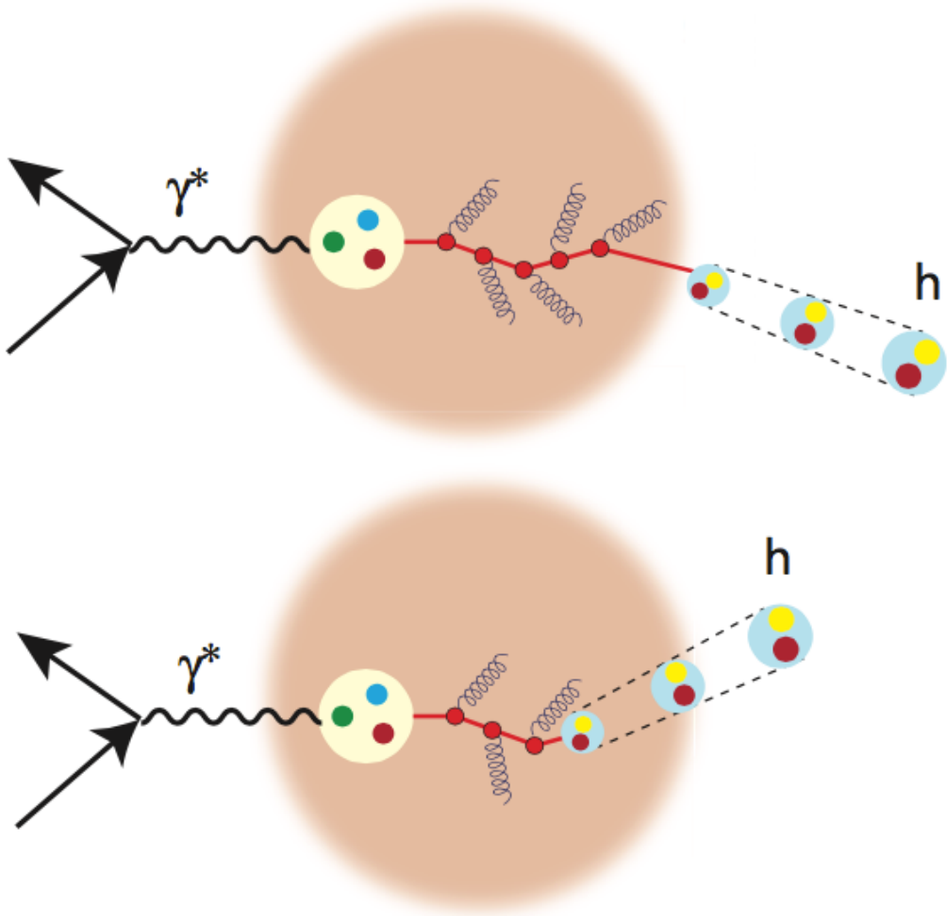
- ❖ Nucleon spin and 3D structure
- ❖ Effects of cold nuclear matter
- ❖ Color Glass Condensate



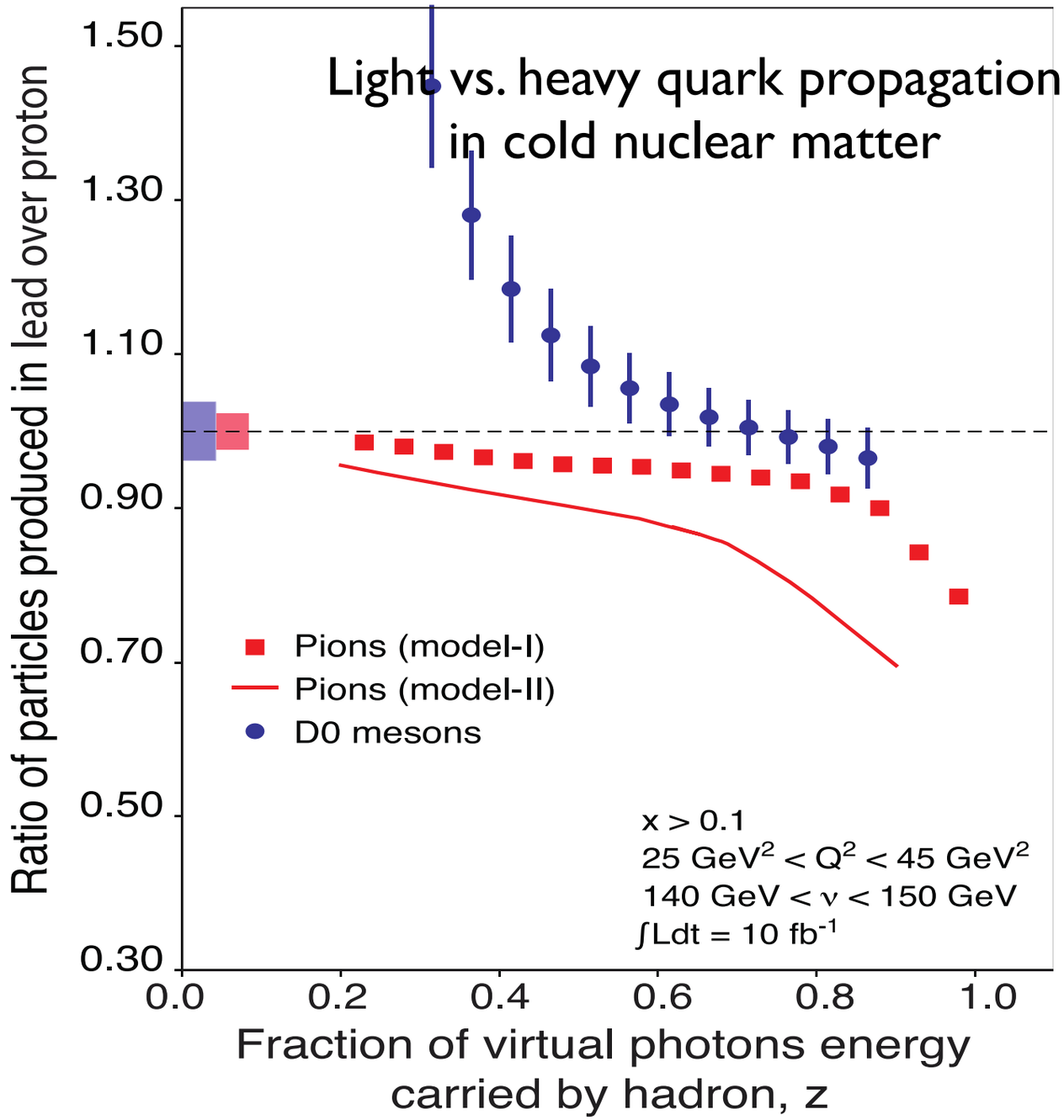


ADDITIONAL SLIDES

Parton Propagation in Nuclei

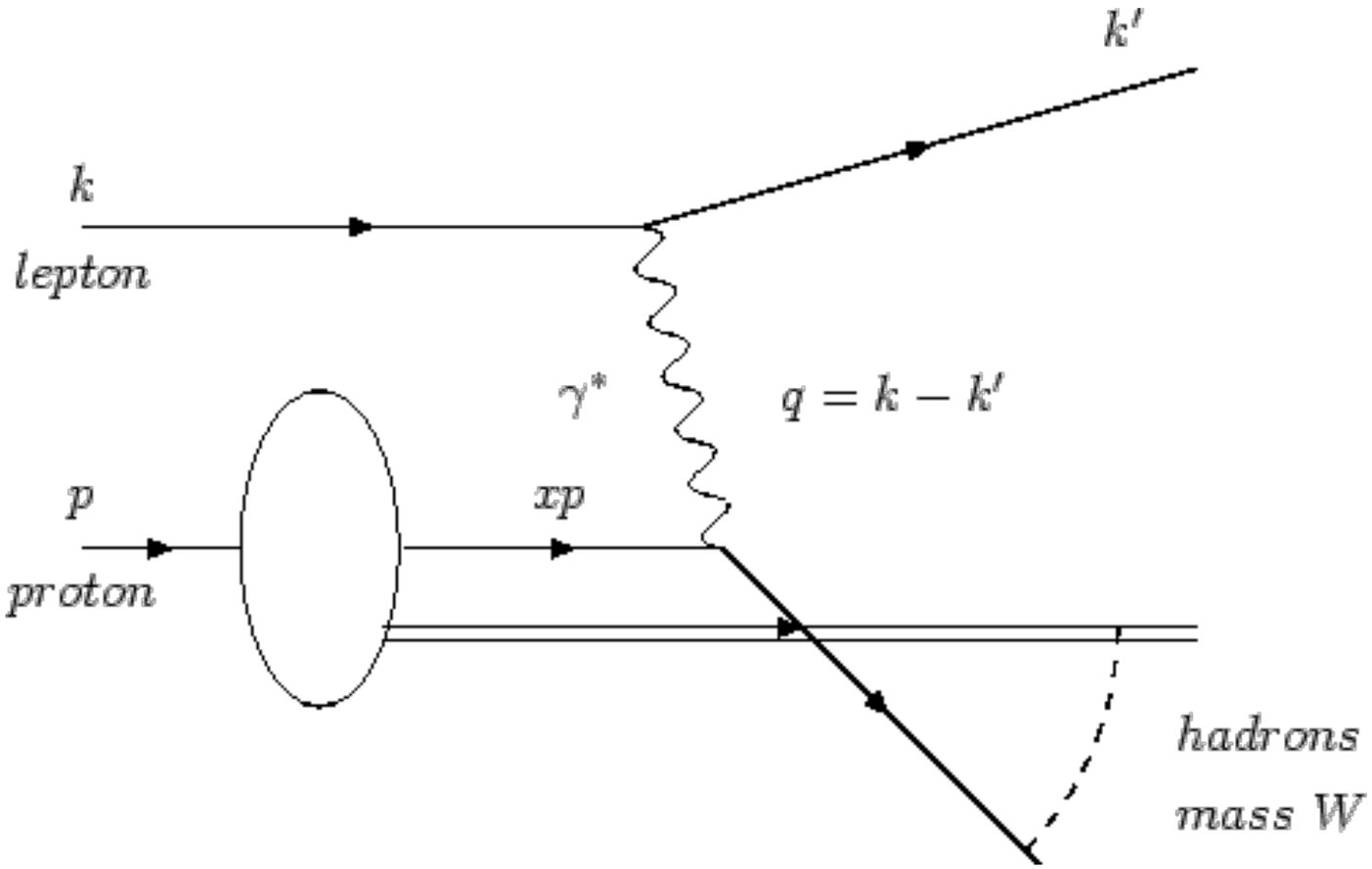


Fragmentation outside vs. inside of cold nuclear matter



arXiv:1212.1701v3

Deep Inelastic Scattering (DIS)



s = collision energy (squared)

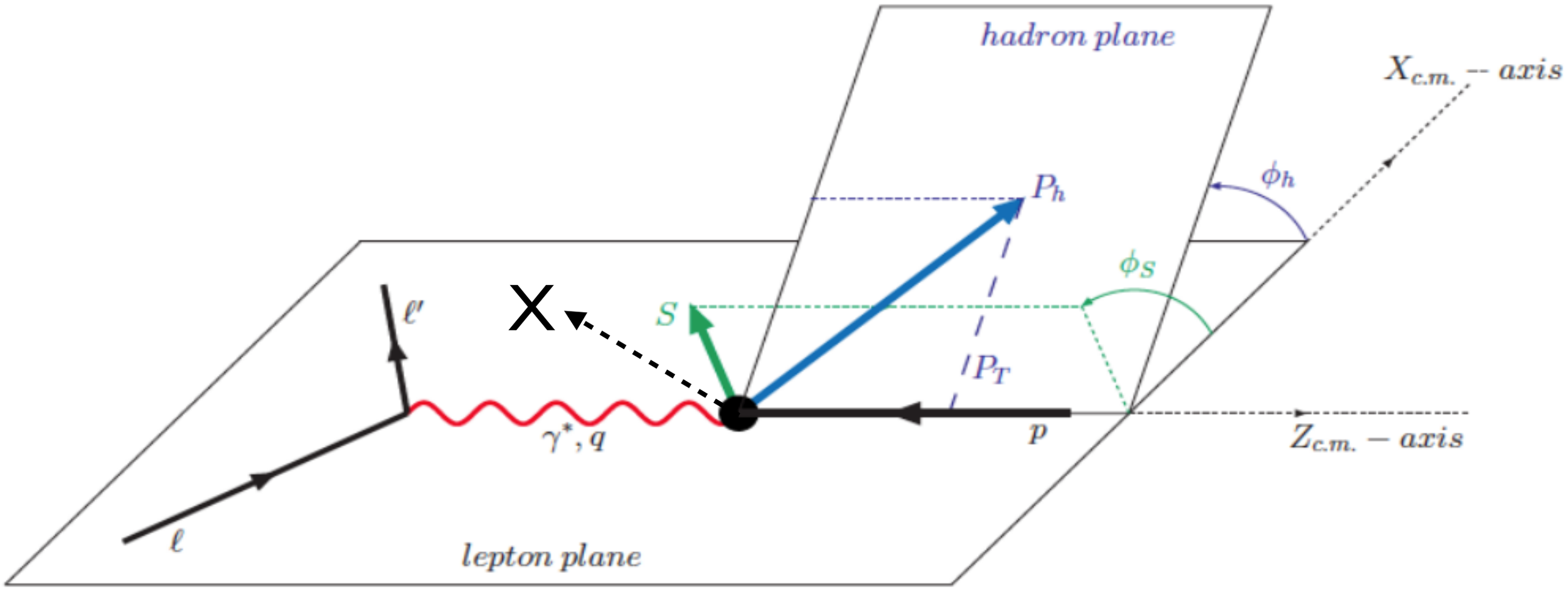
$Q^2 = -q^2 = -(k - k')$ = momentum transfer / resolution

x = momentum fraction of struck quark

$y = (q\ p) / (k\ p)$ = inelasticity

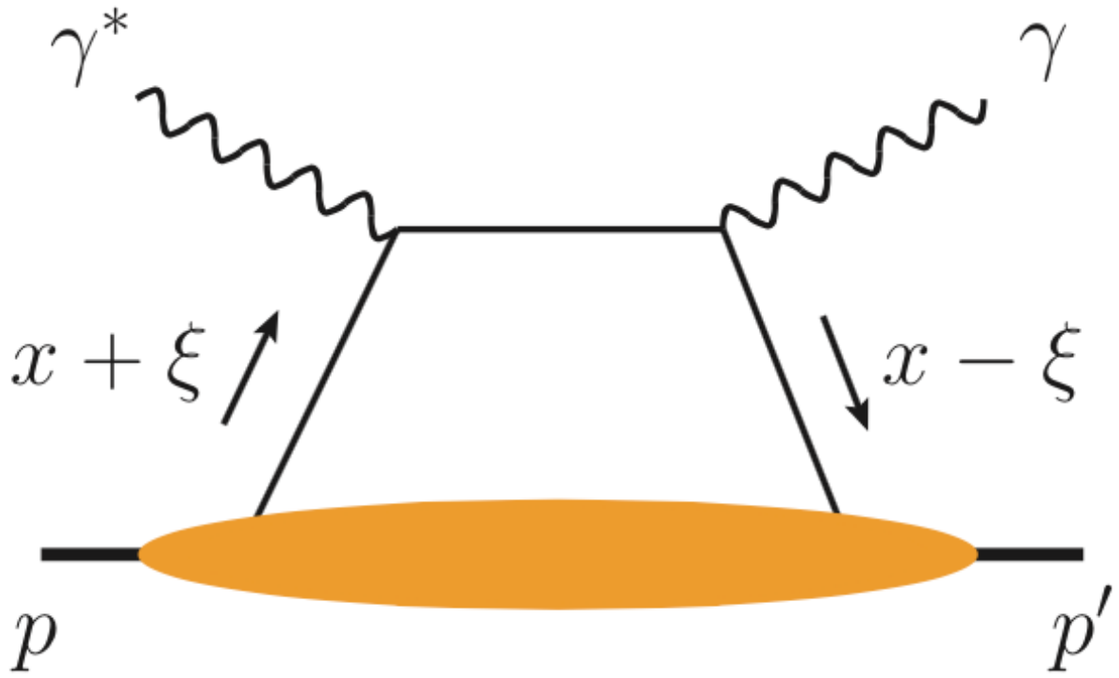
Relation: $Q^2 = s\ x\ y$

Semi-inclusive DIS

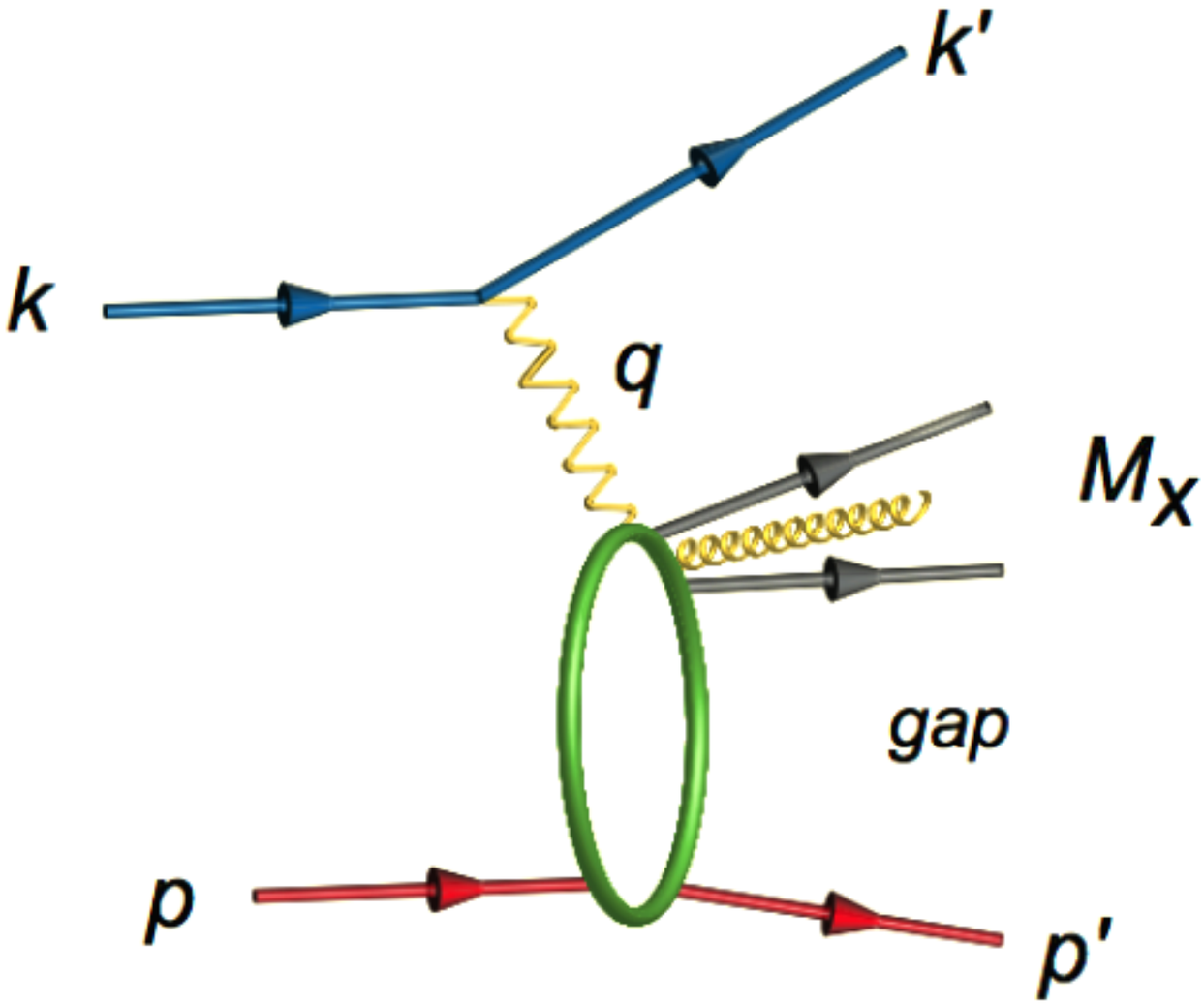


Exclusive DIS

Deeply Virtual Compton Scattering (DVCS)



Hard Diffractive Scattering

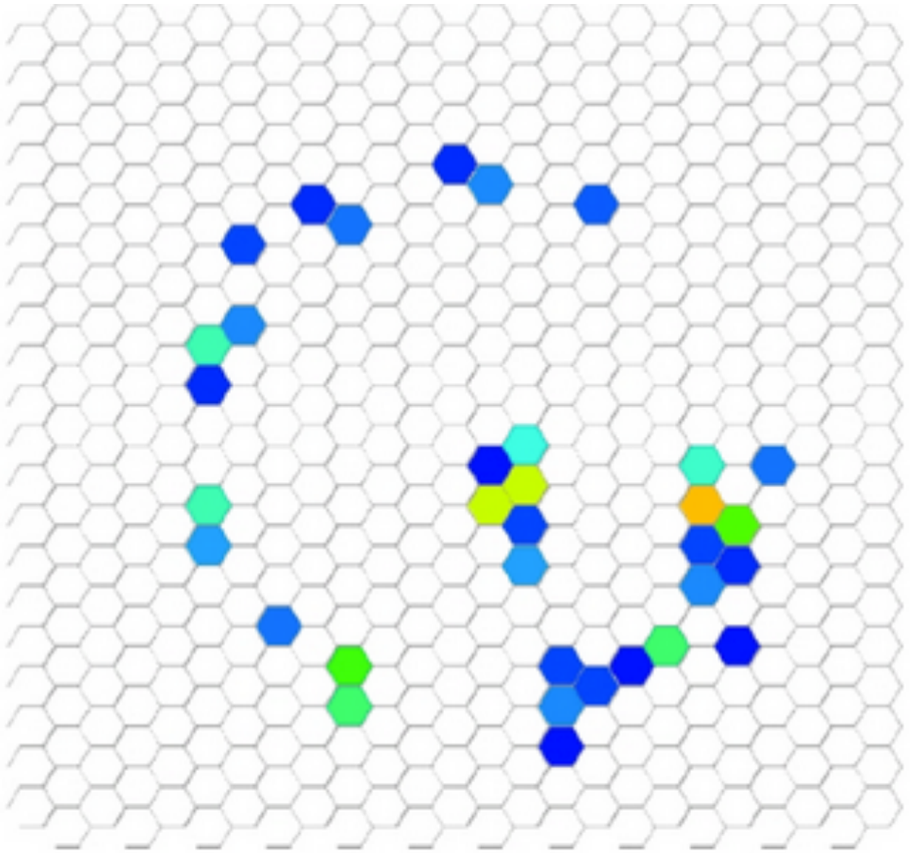


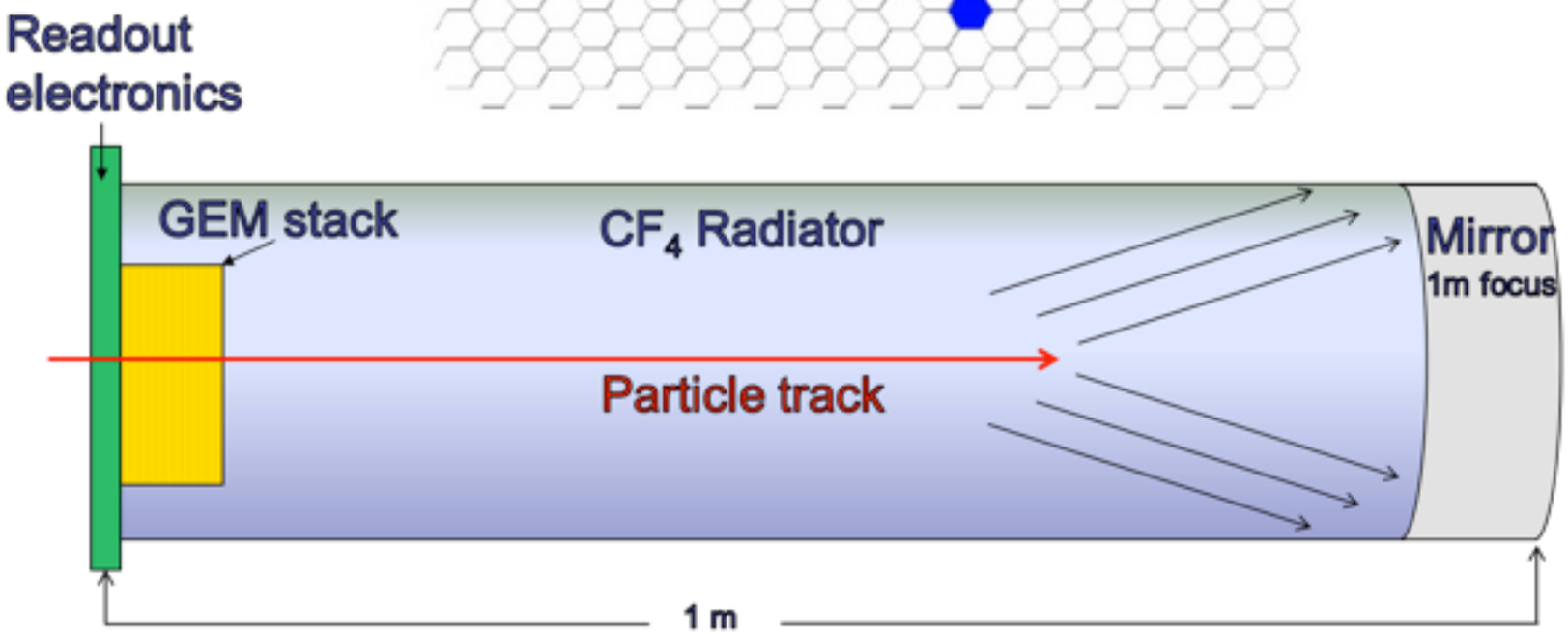
$M_x^2 = (p - p' + k - k')^2$

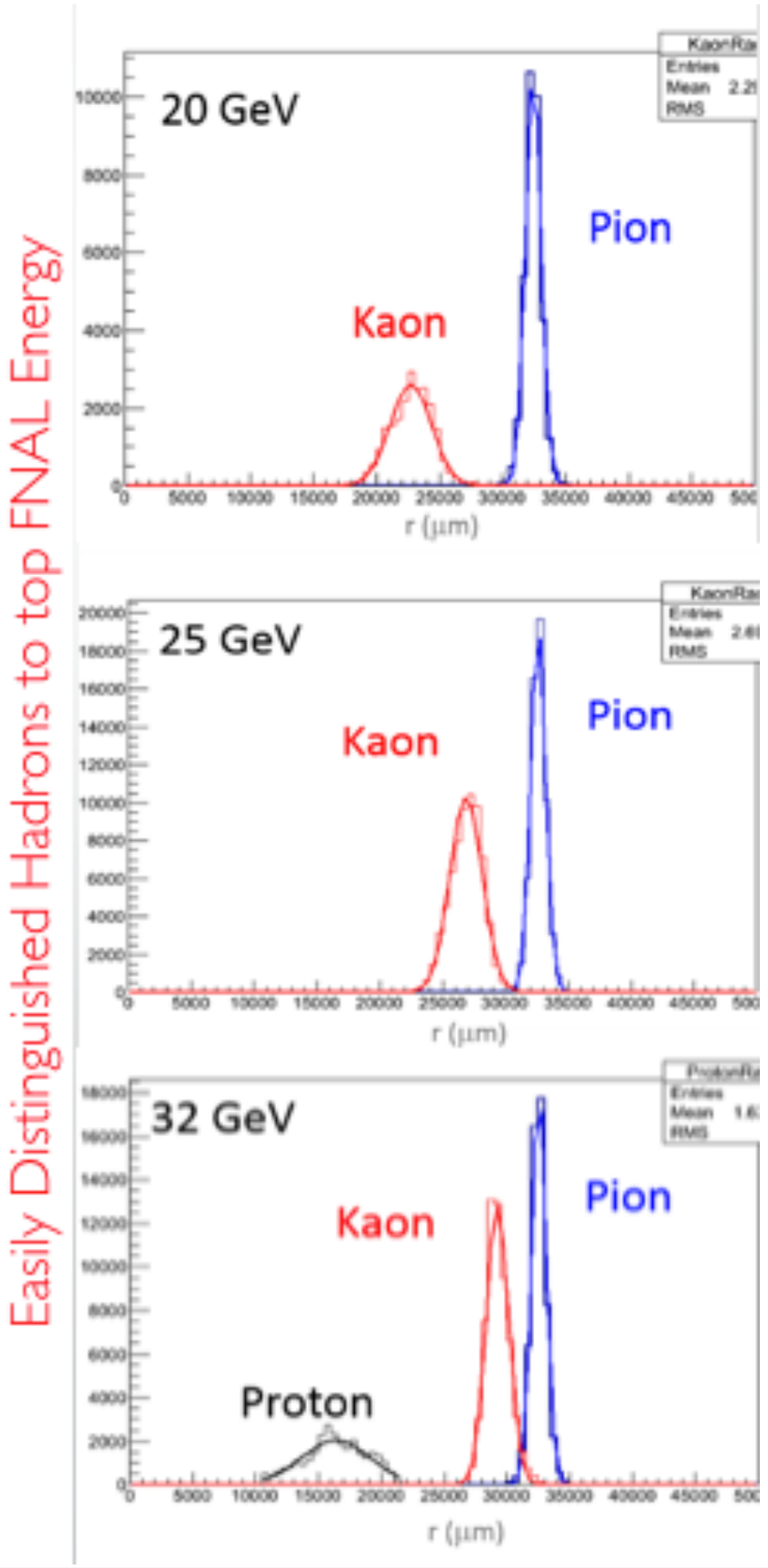
$t \quad = - (p - p')^2$

$=$ momentum transfer

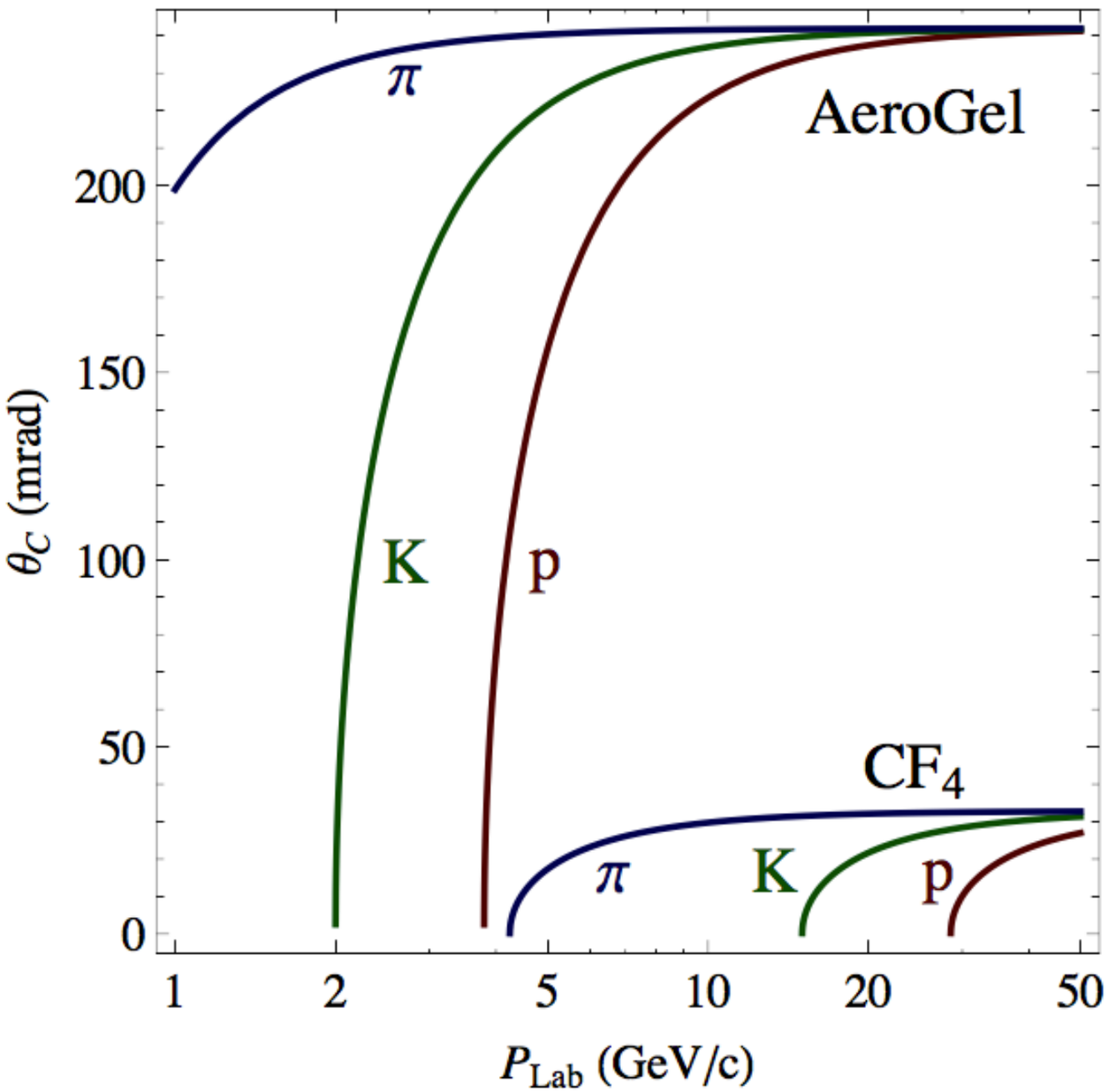
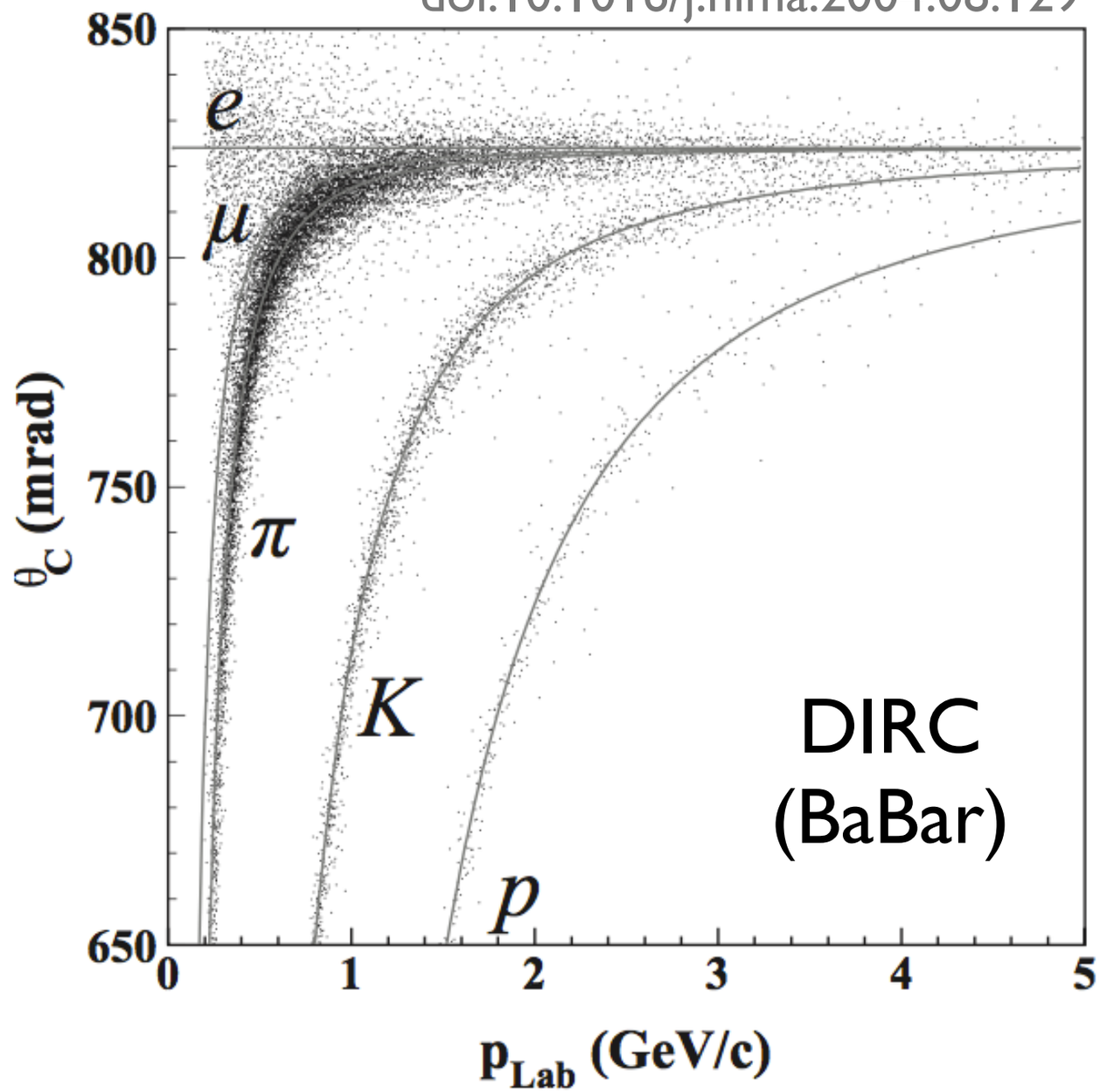
EIC R&D: Gas RICH







Hadron ID Performance for EIC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