

Studying the glue which binds us all: the physics and status of the polarised electron-ion collider project at BNL (eRHIC)

Talk Outline

The physics of the EIC:

e+p programme:

measuring the spin of the nucleus

e+A programme:

Saturation physics at low-x

Hadronization in nuclear matter

The machine design:

full energy design

medium energy option?

Design of a detector:

work with undergrad students

Project Timeline and goals

Matthew A. C. Lamont
Brookhaven National Lab

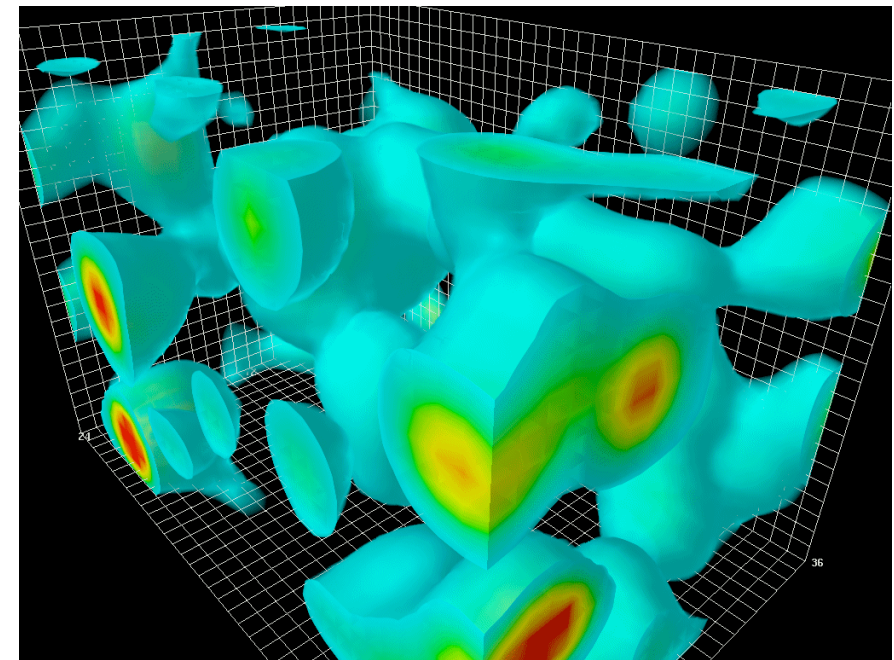
What do we know about gluons?

Glue and the QCD Lagrangian:

$$L_{QCD} = \bar{q}(i\gamma^\mu \partial_\mu - m)q - g(\bar{q}\gamma^\mu T_a q)A_\mu^a - \frac{1}{4}G_{\mu\nu}^a G_a^{\mu\nu}$$

- **Despite the success of QCD in describing the strong interaction, our knowledge of glue is very limited. We know:**

- ➔ Mediators of the strong interaction
- ➔ Determine essential features of QCD
 - ▶ Asymptotic freedom from gluon loops
- ➔ Dominate structure of QCD vacuum (χ SB)
- ➔ Quenched L_{QCD} gets hadron masses correct to $\sim 10\%$

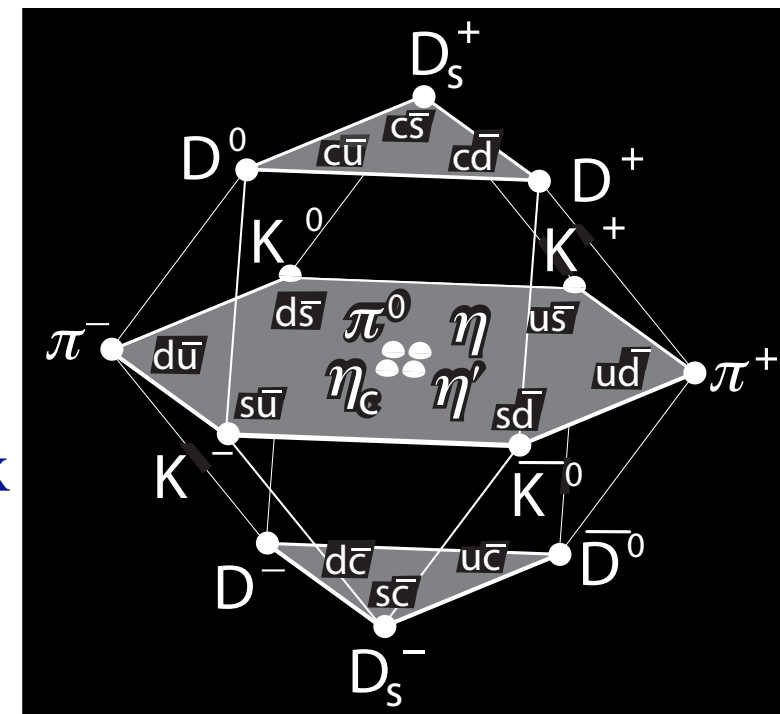


Action ($\sim$ energy) density fluctuations of gluon-fields in QCD vacuum (2.4 x 2.4 x 3.6 fm) (Derek Leinweber)

Glue and the Lagrangian

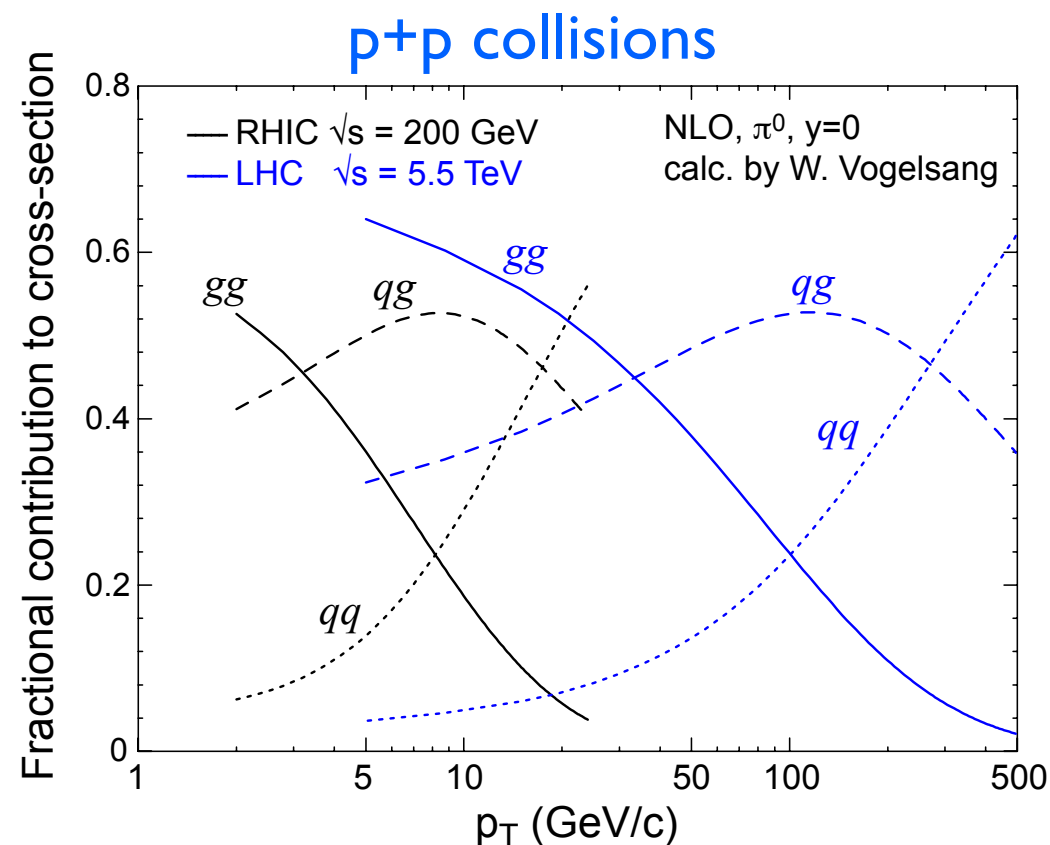
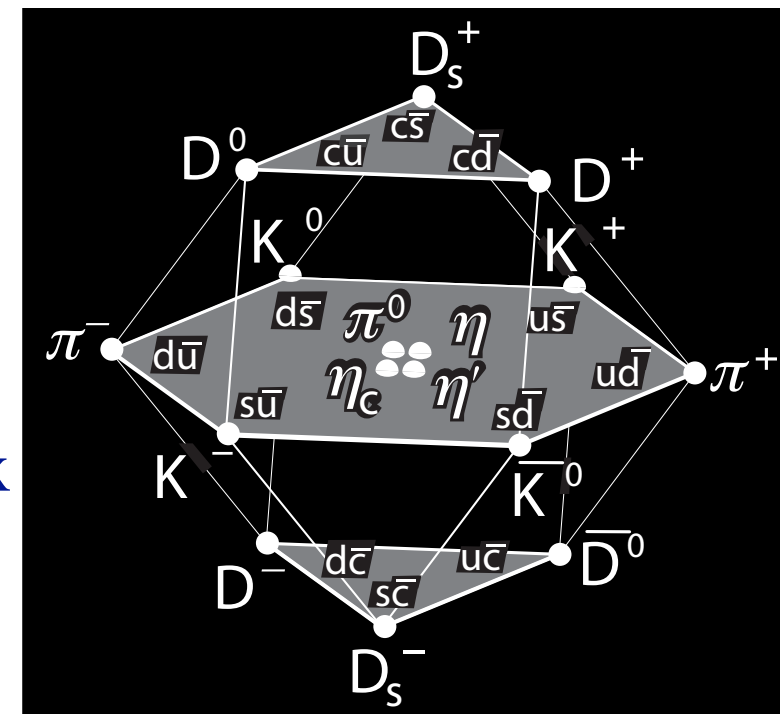
Glue and the Lagrangian

- Hard to “see” glue in the low-energy world
 - ➡ Gluon degrees of freedom “missing” in hadronic spectrum
 - ▶ Constituent Quark Picture?
- From DIS:
 - ➡ Drive the structure of baryonic matter already at medium-x
- Crucial players at RHIC and the LHC
 - ➡ Drive the entropy



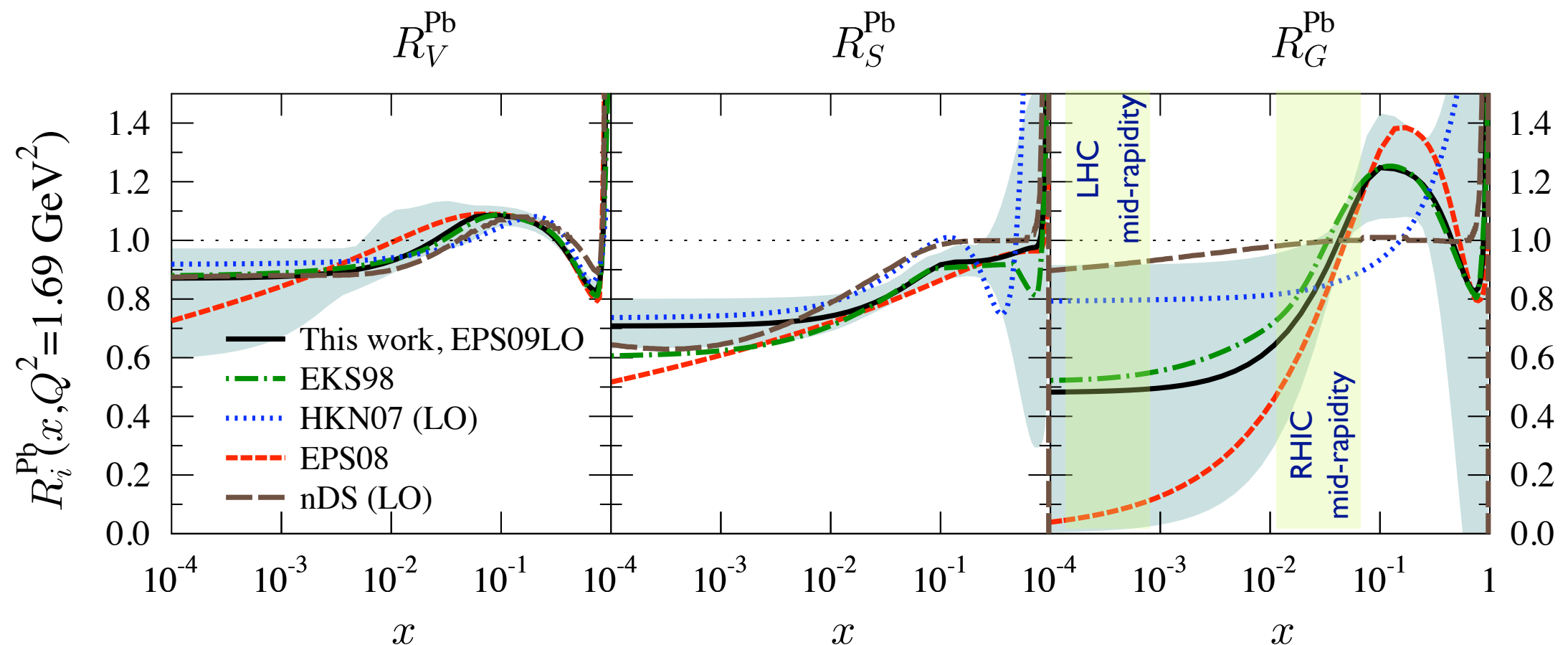
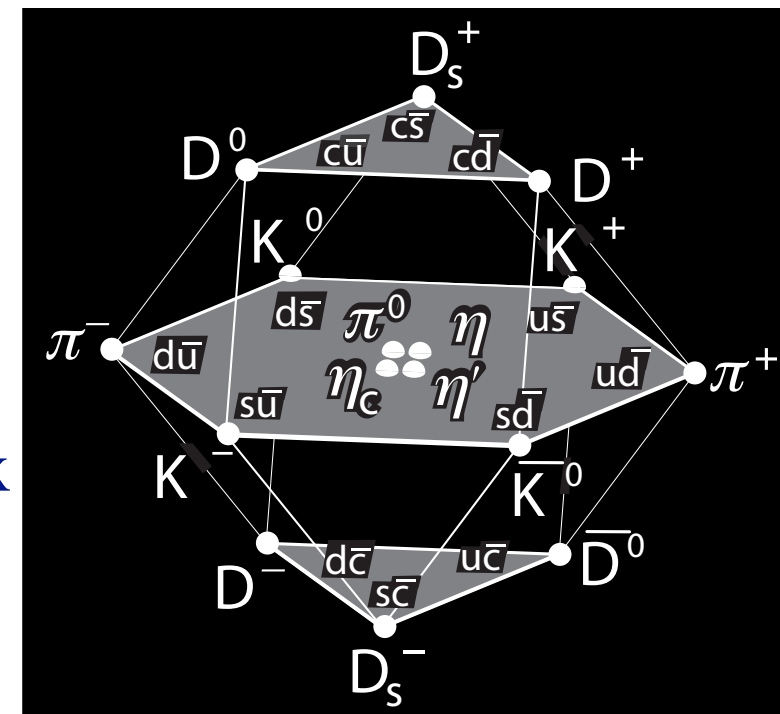
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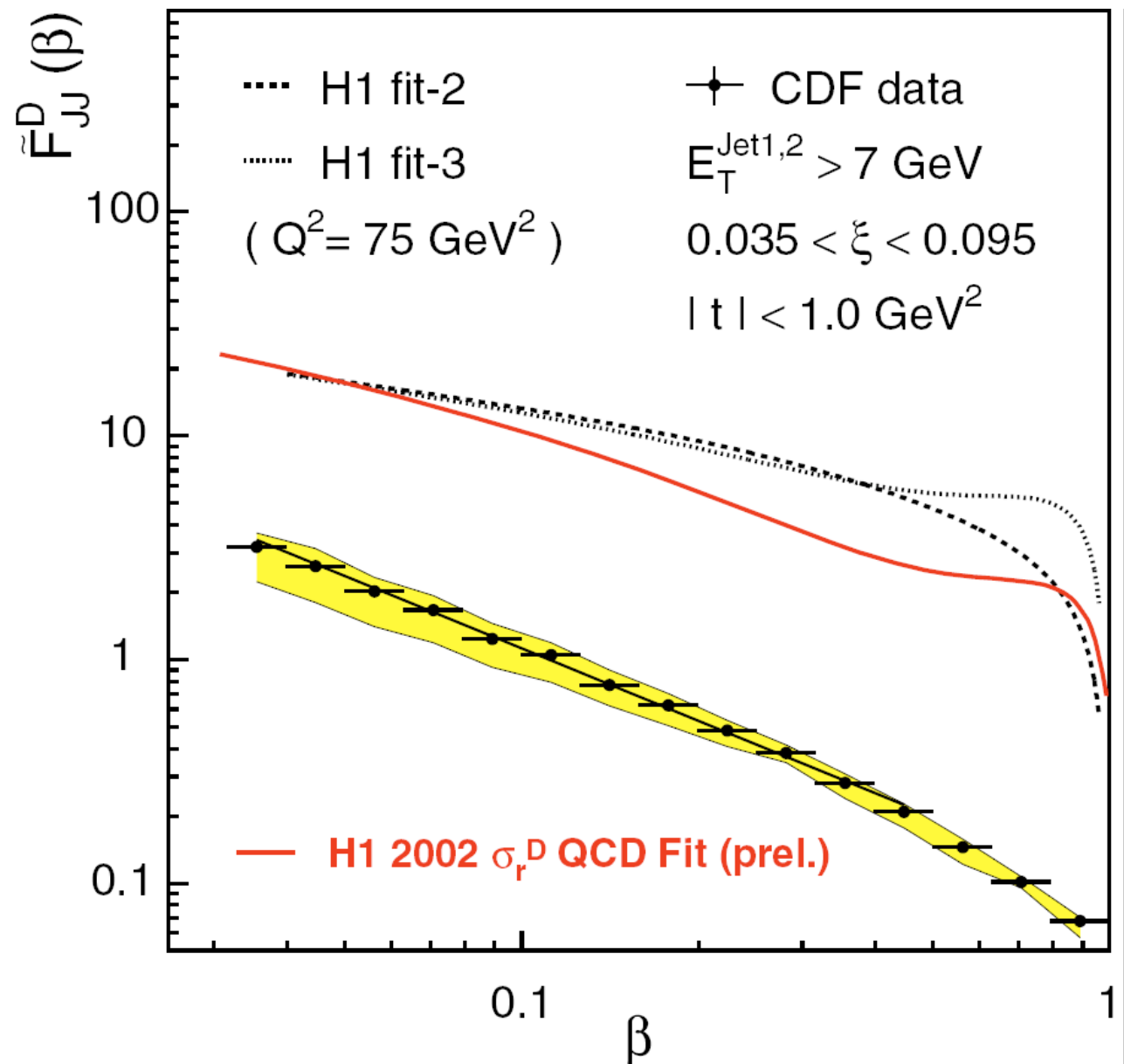
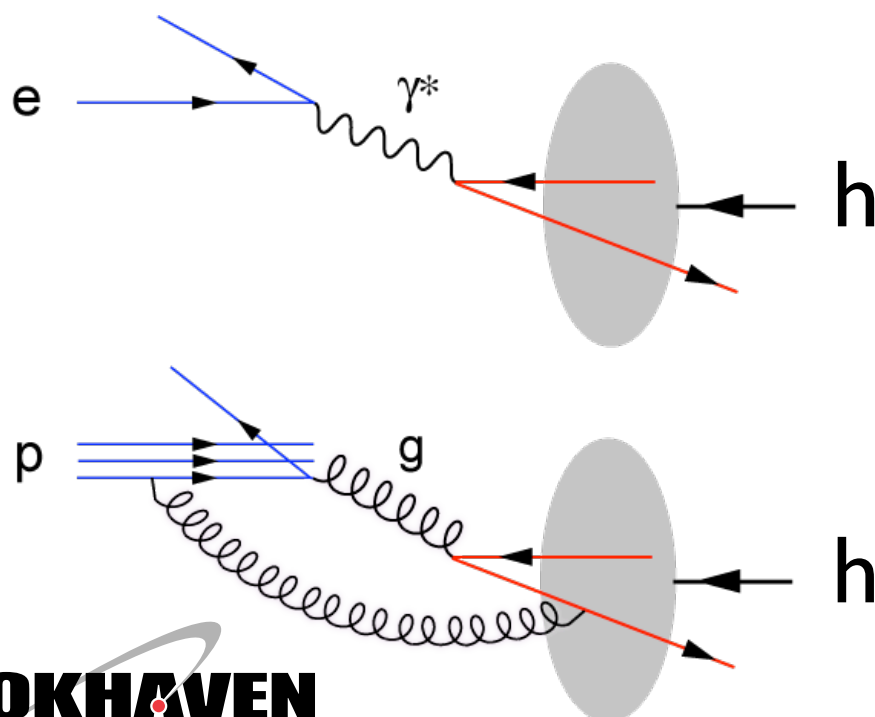


Accessing the glue - $p+h$ vs $e+h$

F. Schilling, hex-ex/0209001

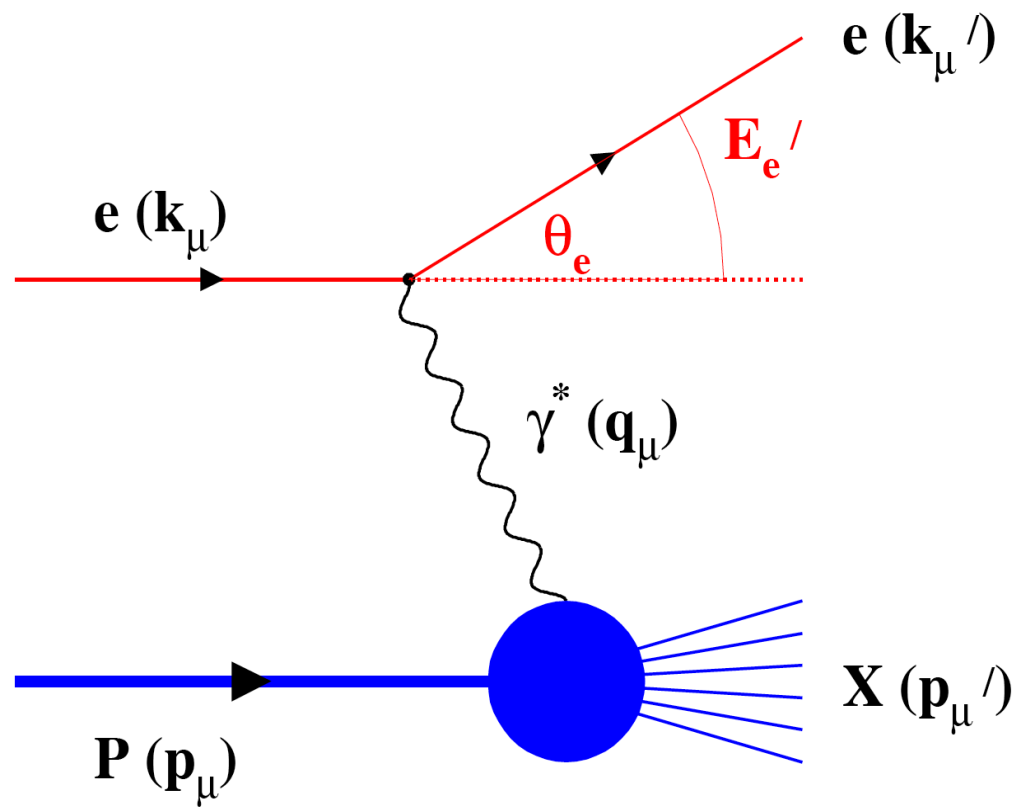
- Both $e+h$ and $p+h$ provide excellent information on properties of gluons in the nuclear wave functions
- Both are complementary and offer the opportunity to perform stringent checks of factorization/universality $\Rightarrow$
- But:

$\Rightarrow$ soft colour interactions between p and h before and after the primary interaction

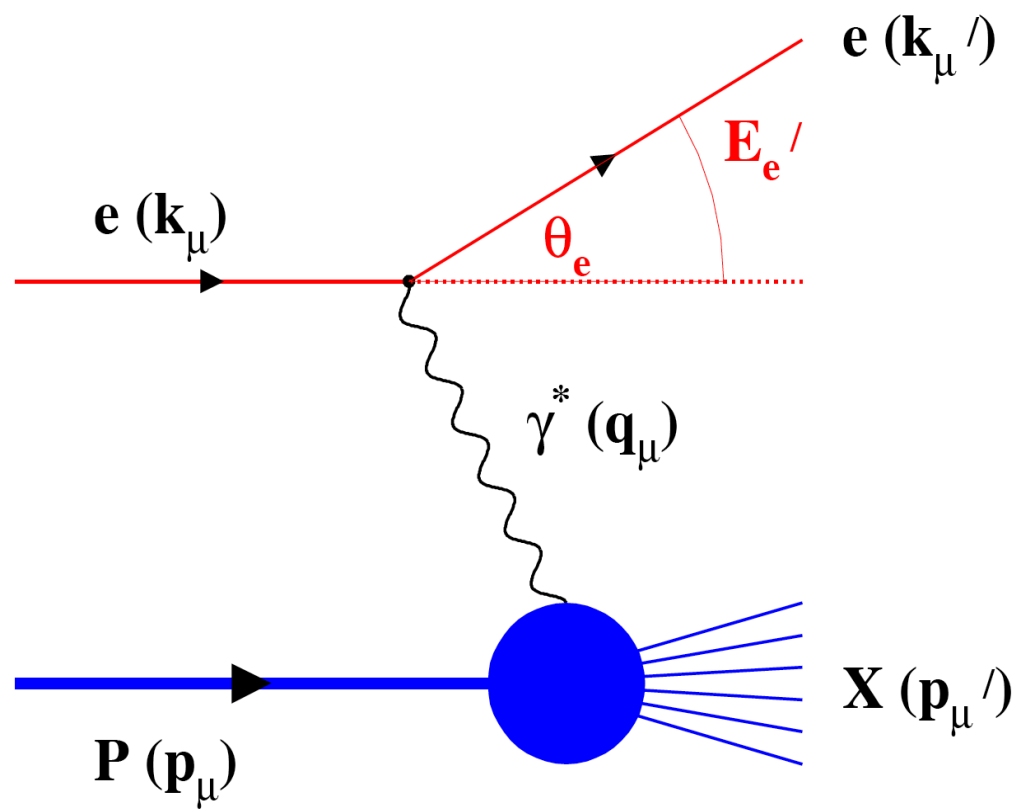


Breakdown of factorization ($e+p$ HERA versus $p+p$ Tevatron) seen for diffractive final states.

DIS Kinematics



DIS Kinematics

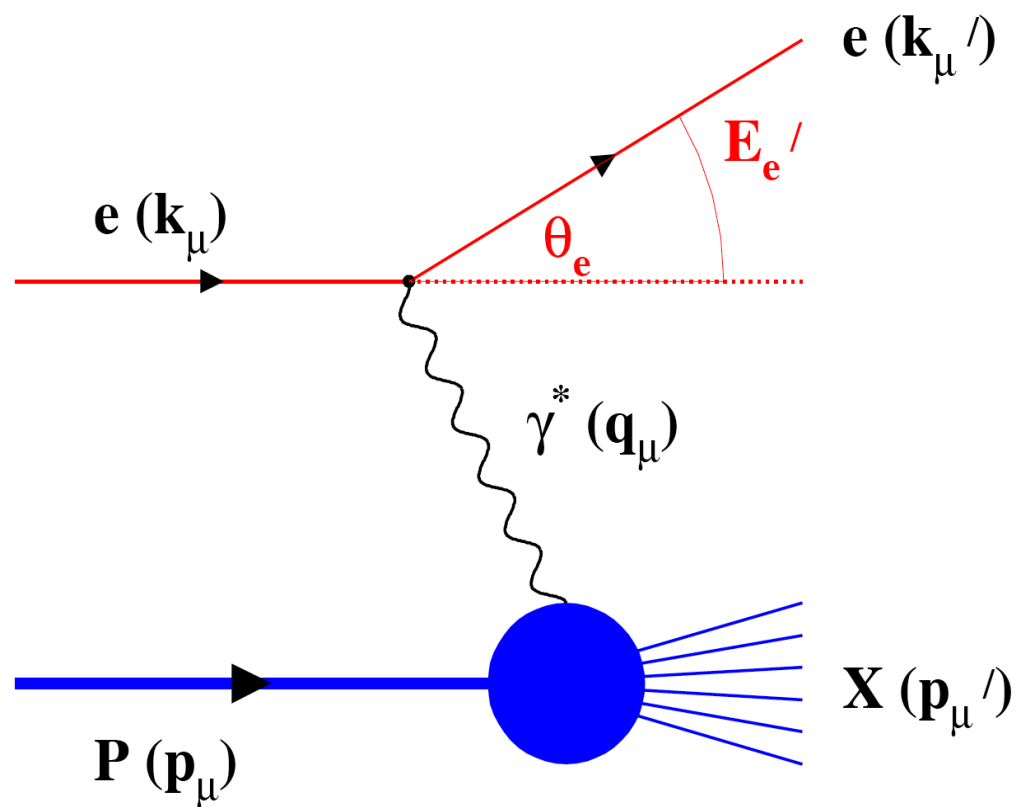


$$Q^2 = -q^2 = -(k_\mu - k'_\mu)^2$$

$$Q^2 = 4E_e E'_e \sin^2\left(\frac{\theta'_e}{2}\right)$$

Measure of
resolution
power or
"Virtuality"

DIS Kinematics



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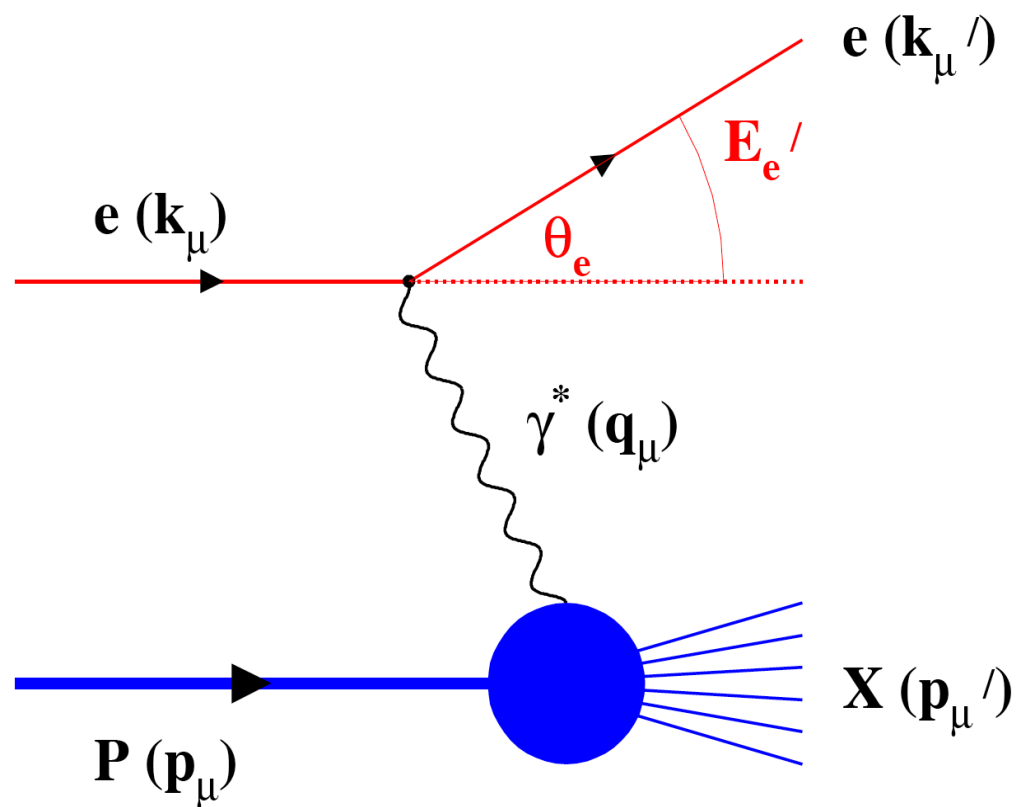
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Measure of inelasticity

DIS Kinematics



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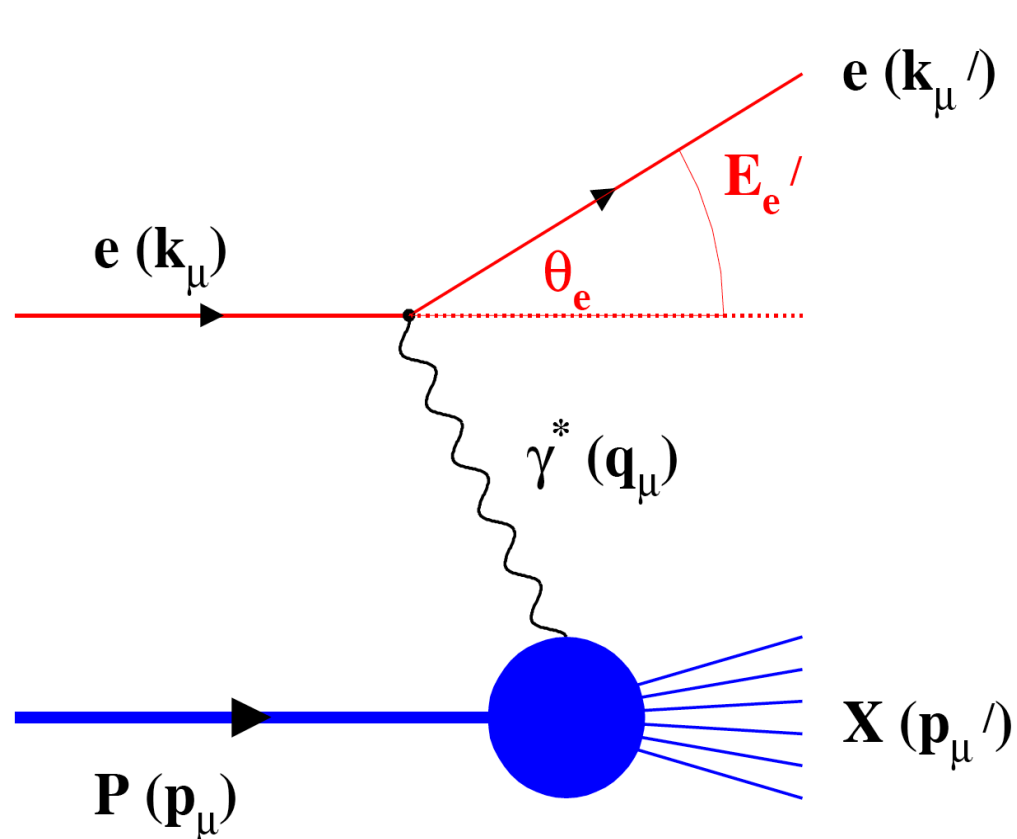
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Measure of inelasticity

$$x = \frac{Q^2}{2pq} = \frac{Q^2}{sy}$$

Measure of momentum fraction of struck quark

DIS Kinematics



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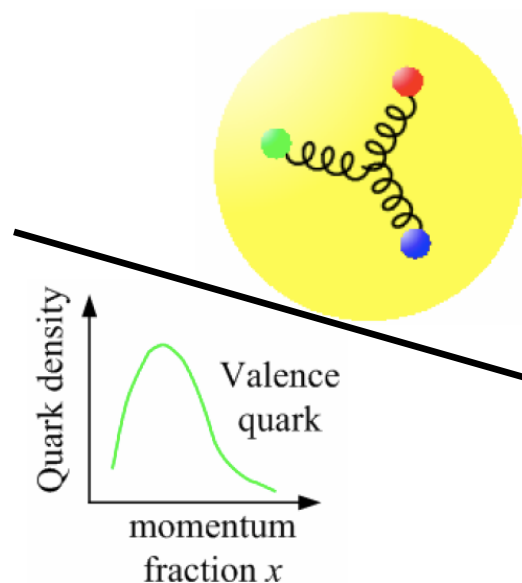
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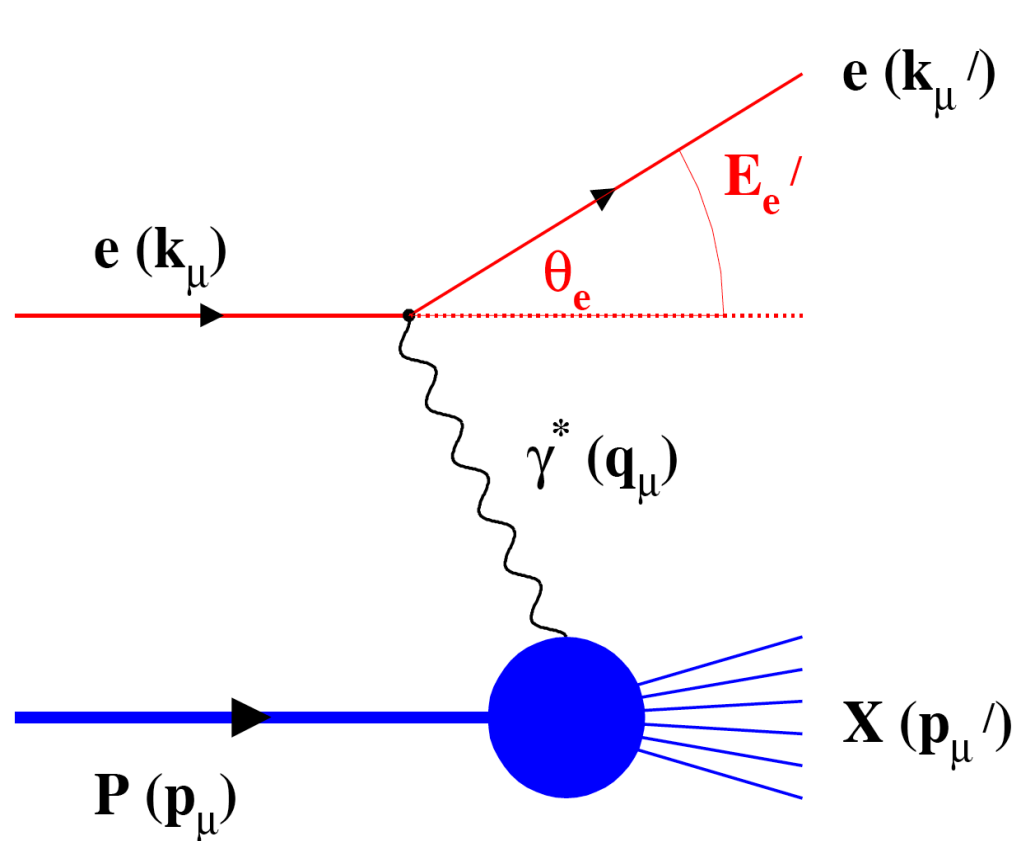
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Increasing resolution
higher Q^2

DIS Kinematics



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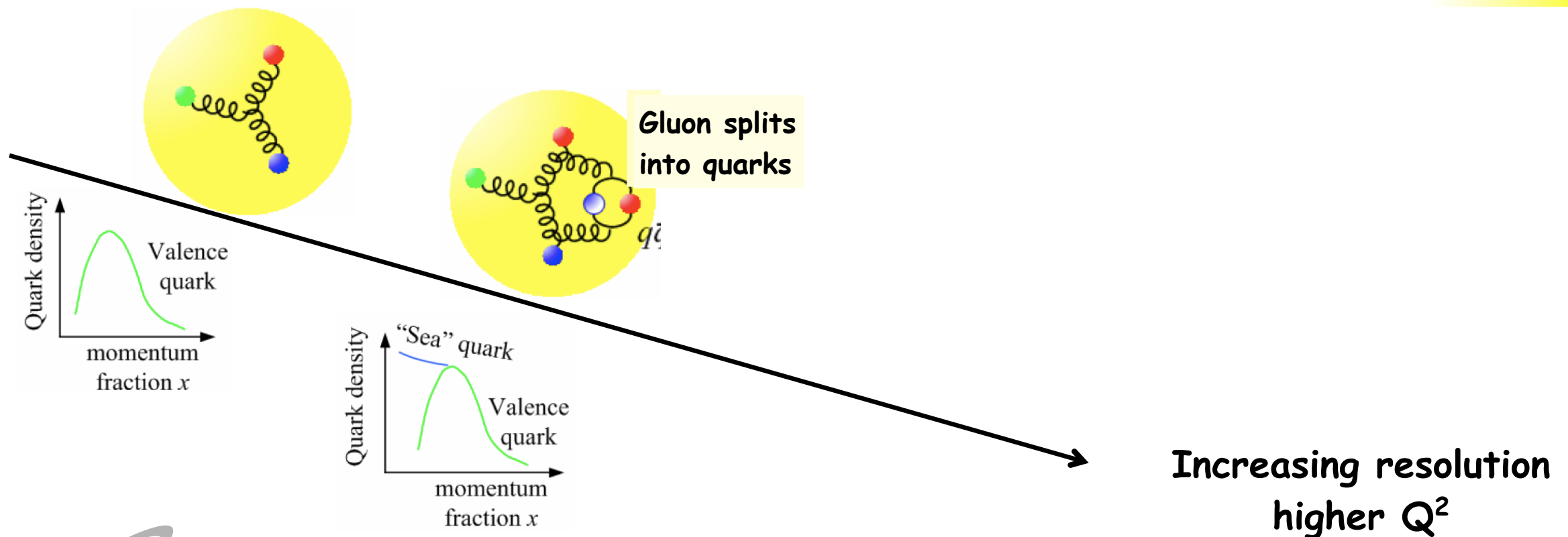
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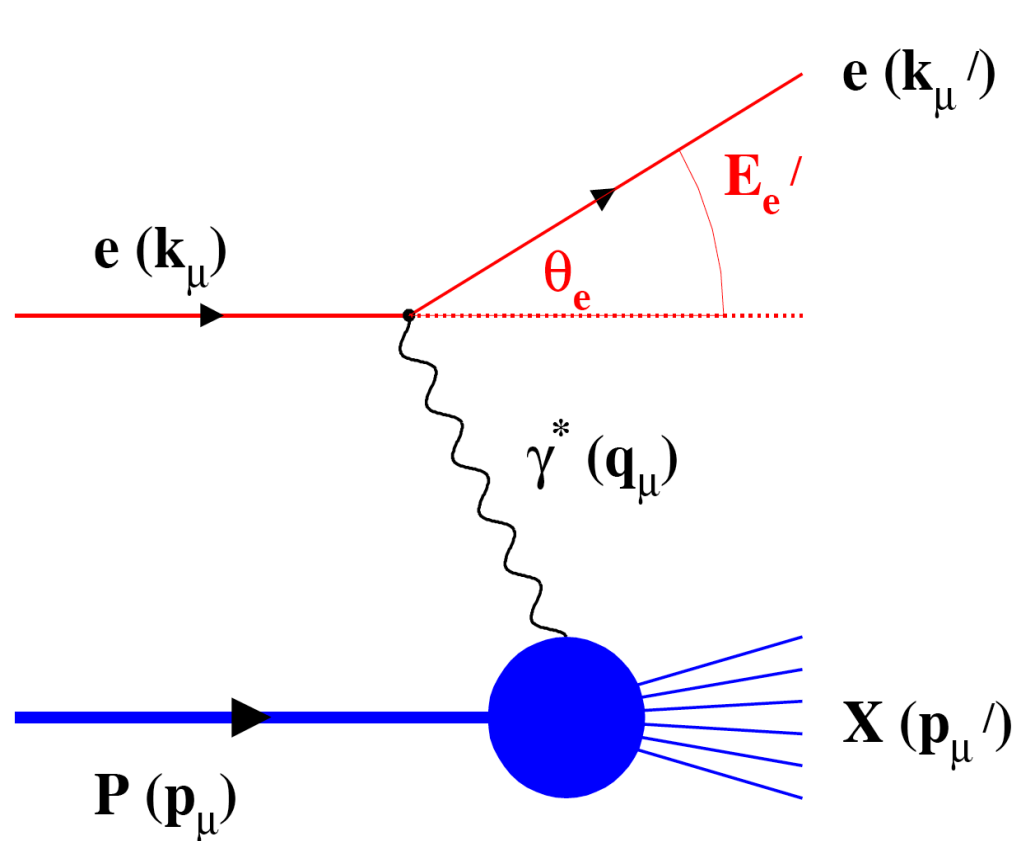
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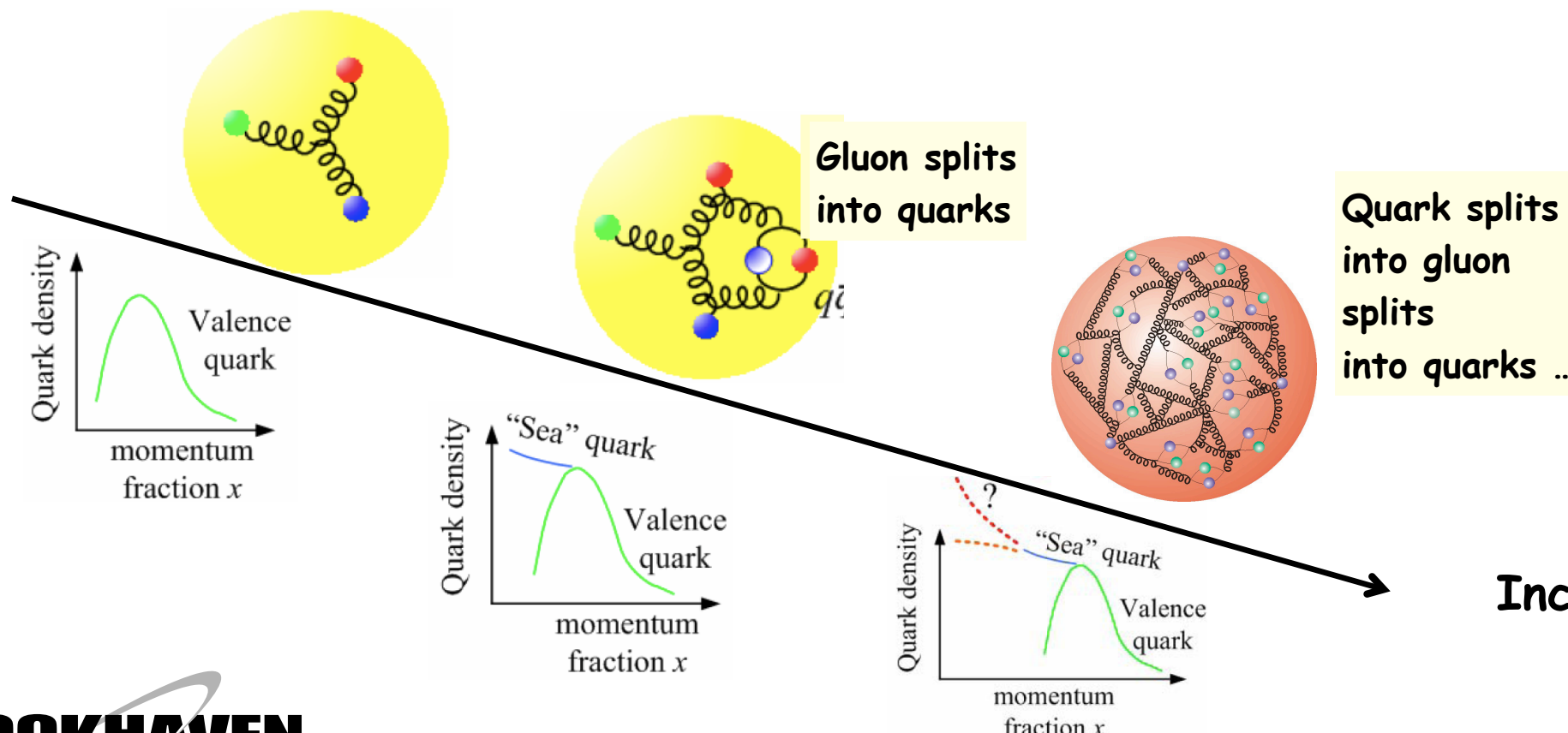
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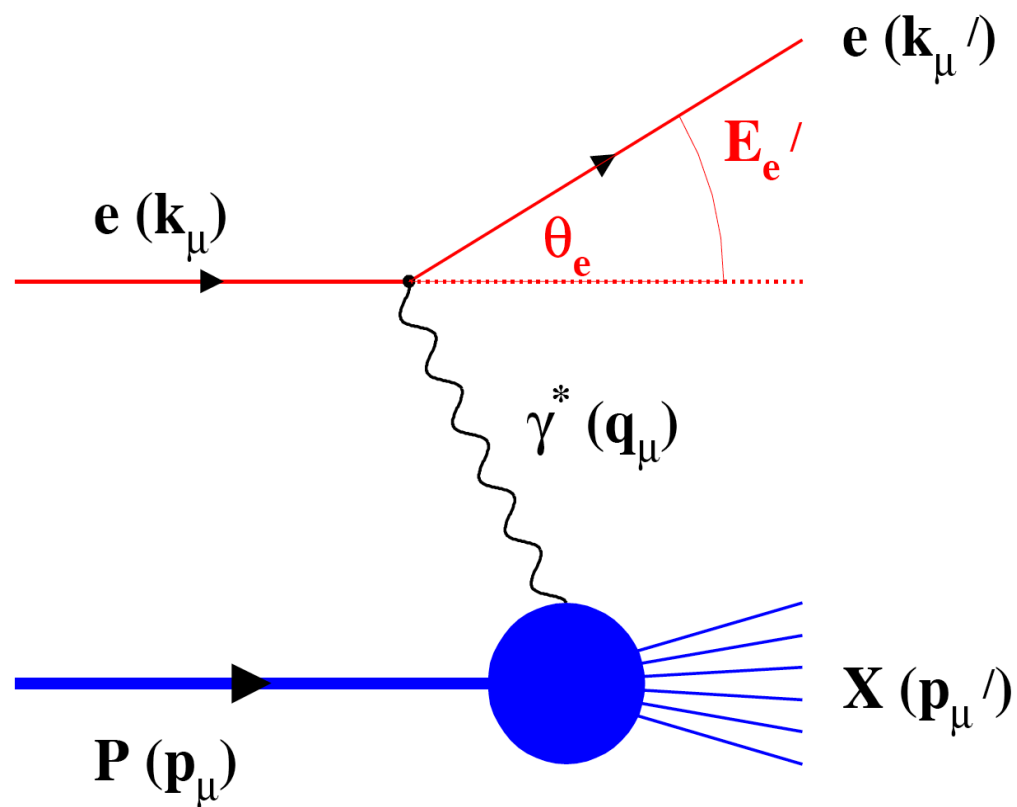
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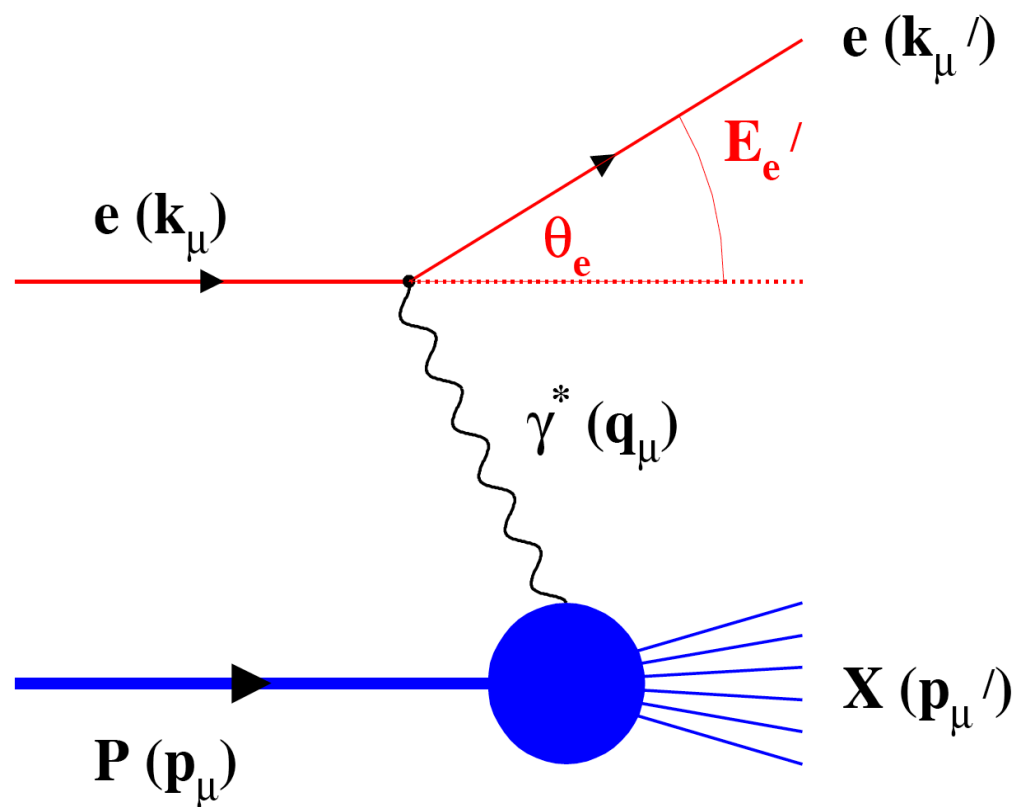
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$$\frac{d^2\sigma^{ep \rightarrow eX}}{dx dQ^2} = \frac{4\pi\alpha_{e.m.}^2}{xQ^4} \left[\left(1 - y + \frac{y^2}{2}\right) F_2(x, Q^2) - \frac{y^2}{2} F_L(x, Q^2) \right]$$

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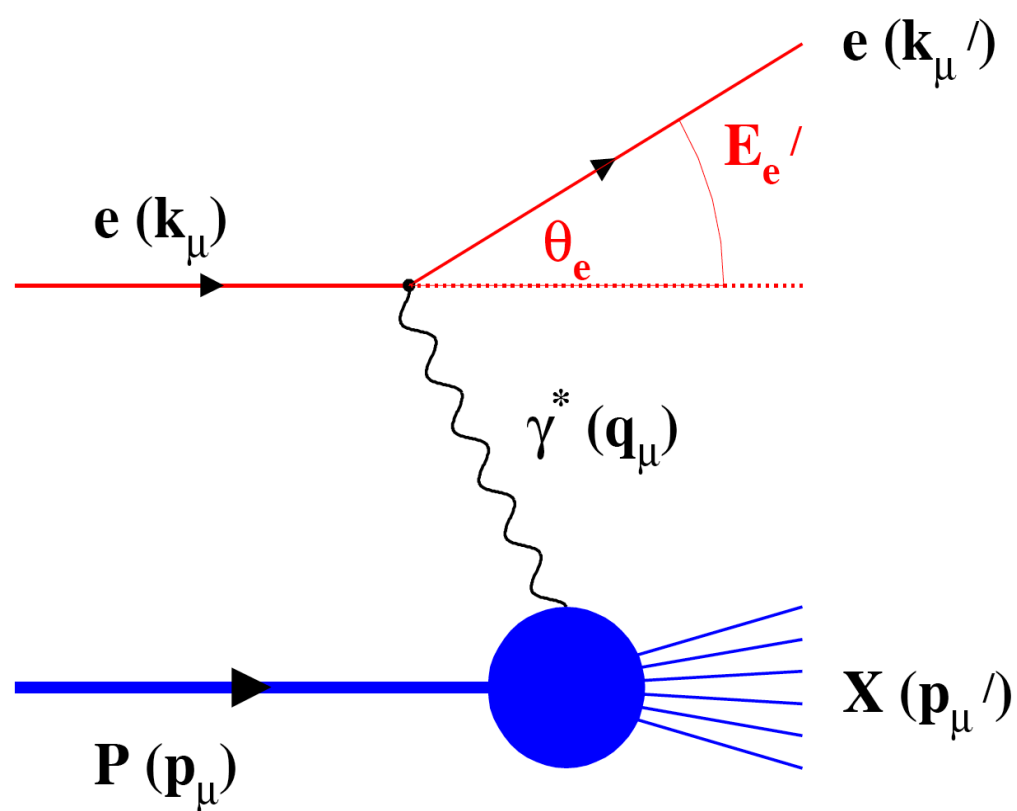
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- *Structure functions:*

➡ $F_2(x, Q^2) \Rightarrow$ q and $\bar{q}$ momentum distributions

➡ $F_L(x, Q^2) \Rightarrow$ gluon momentum distribution

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No direct information on x, Q^2 from p+A collisions !!

e^+p physics programme at eRHIC

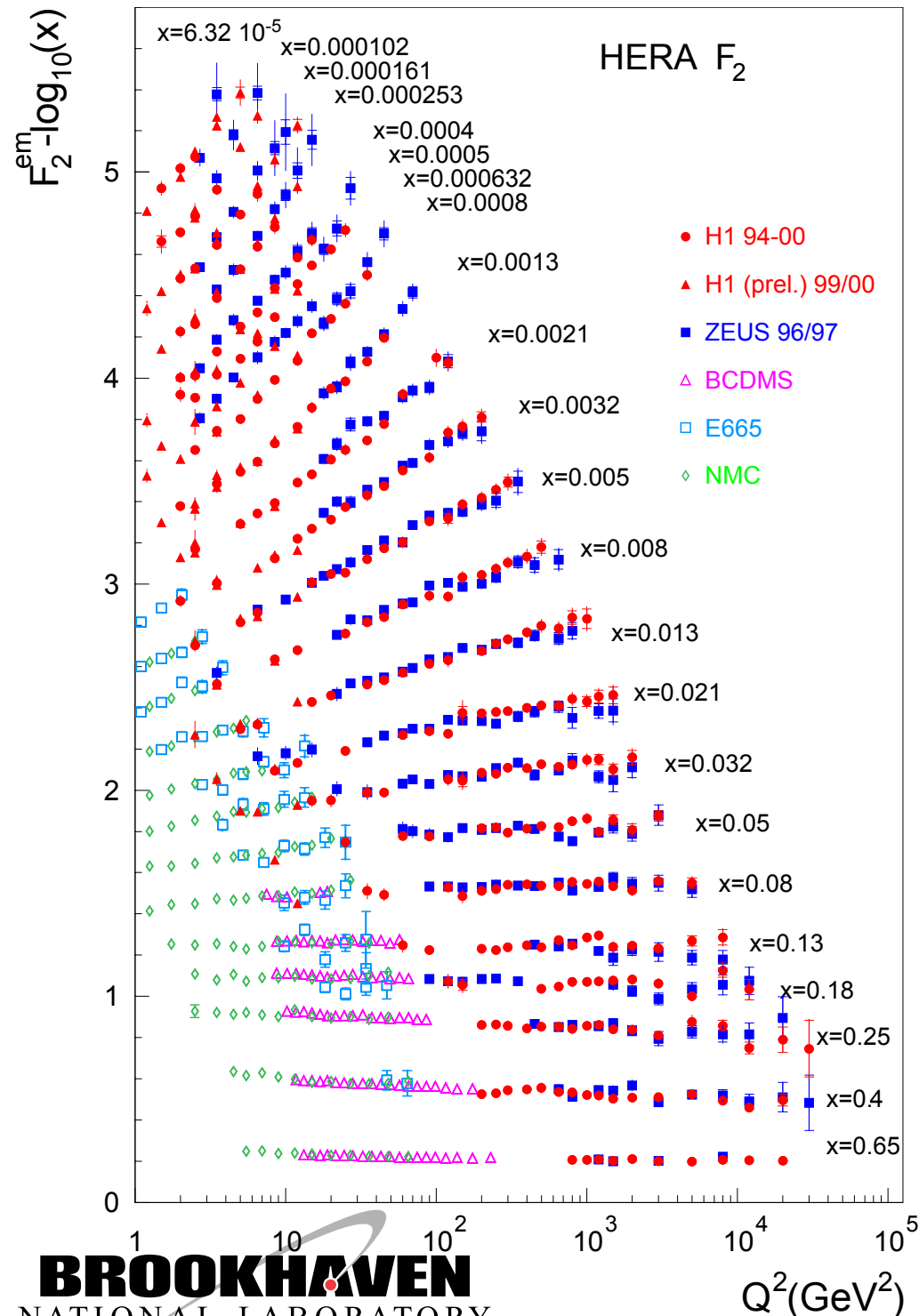
- Precisely image the sea quarks and gluons in the nucleon
 - ➡ How do the gluons and sea quarks contribute to the structure of the nucleon?
 - ➡ What is the spatial distribution of the gluons and sea quarks in the nucleon?
 - ➡ How do hadronic final states form in QCD?

How to measure the glue?

$$\frac{d^2\sigma^{ep\rightarrow eX}}{dx dQ^2} = \frac{4\pi\alpha_{e.m.}^2}{xQ^4} \left[\left(1 - y + \frac{y^2}{2}\right) F_2(x, Q^2) - \frac{y^2}{2} F_L(x, Q^2) \right]$$

**quark+anti-quark
momentum distributions**

**gluon momentum
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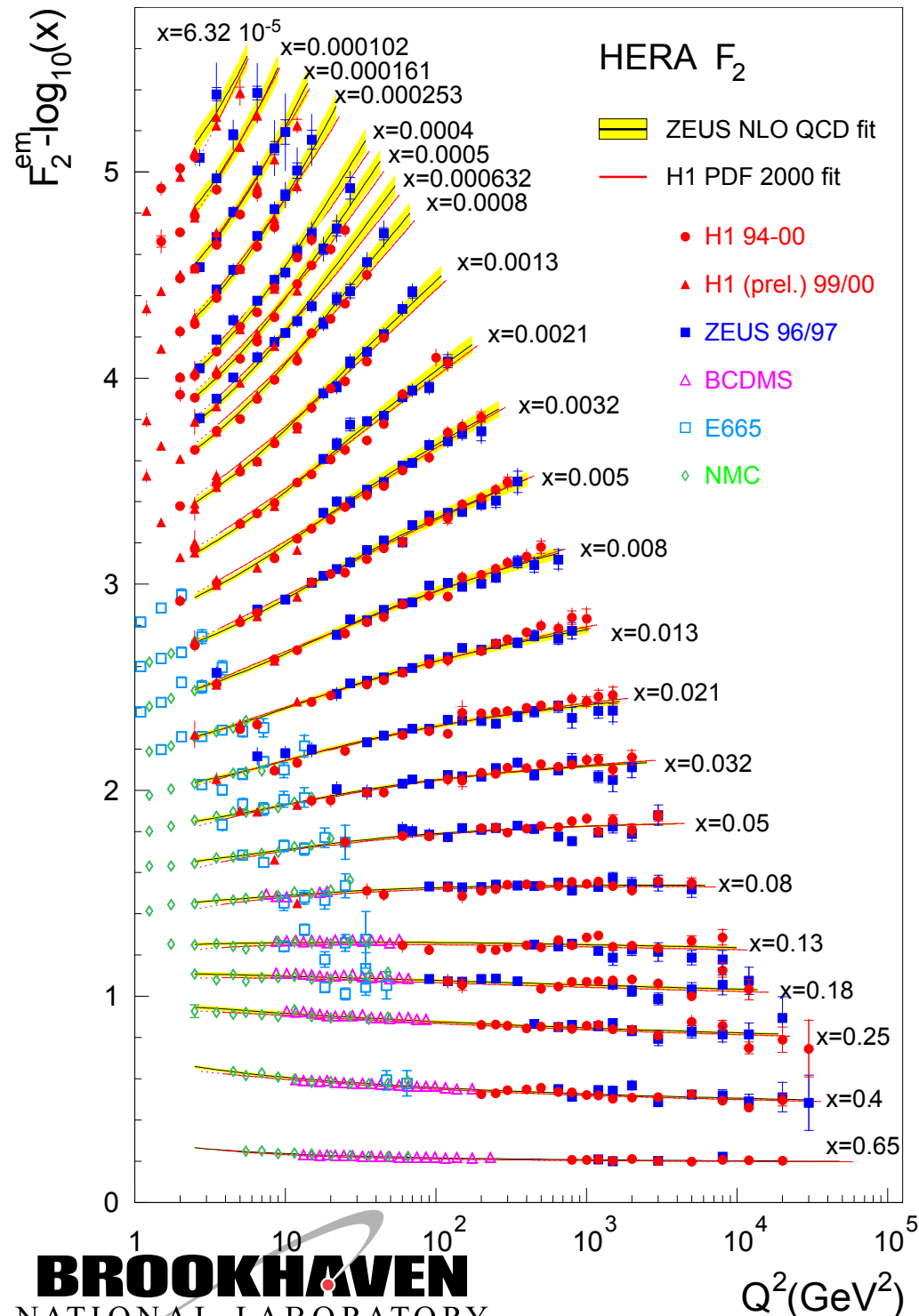


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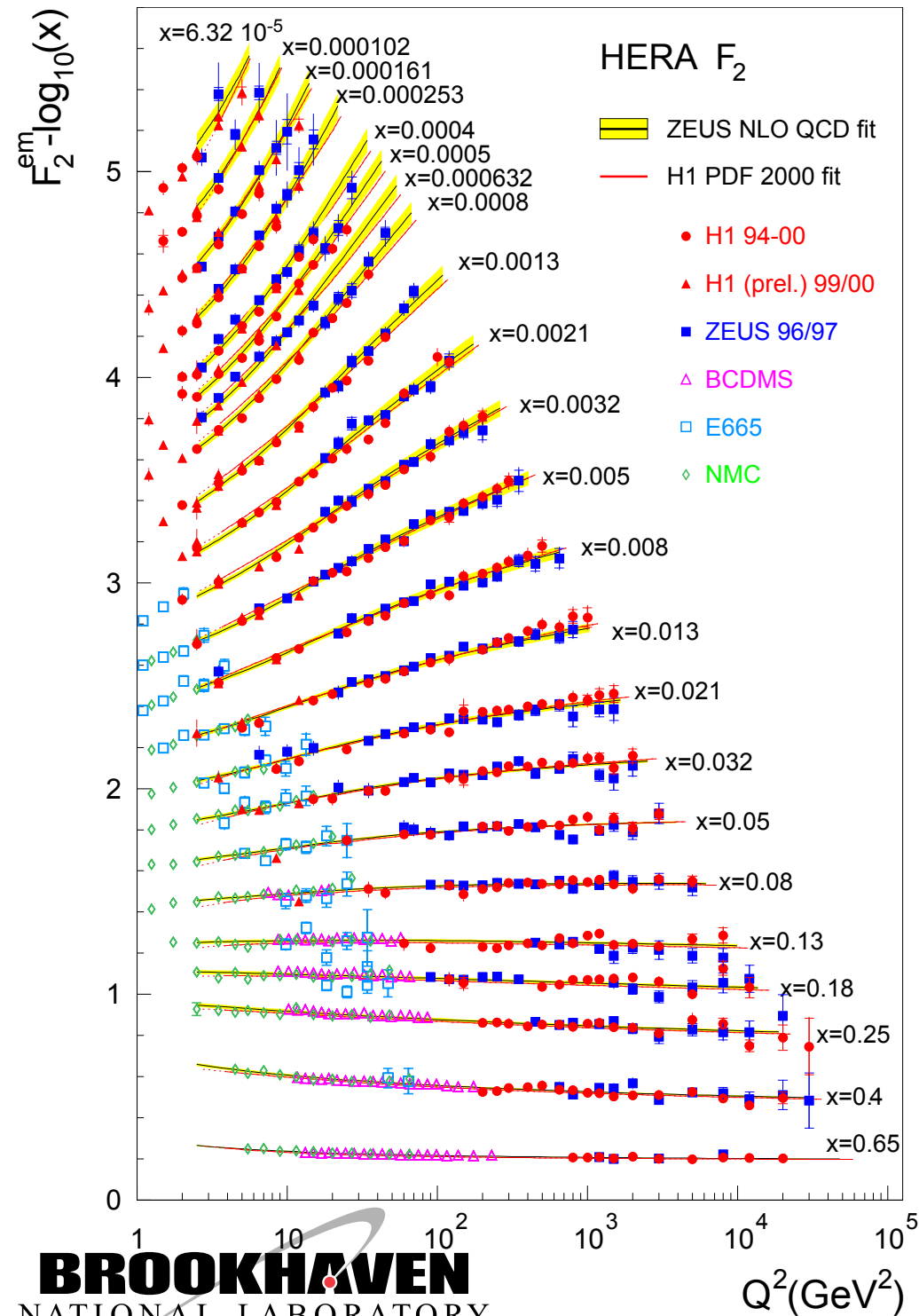
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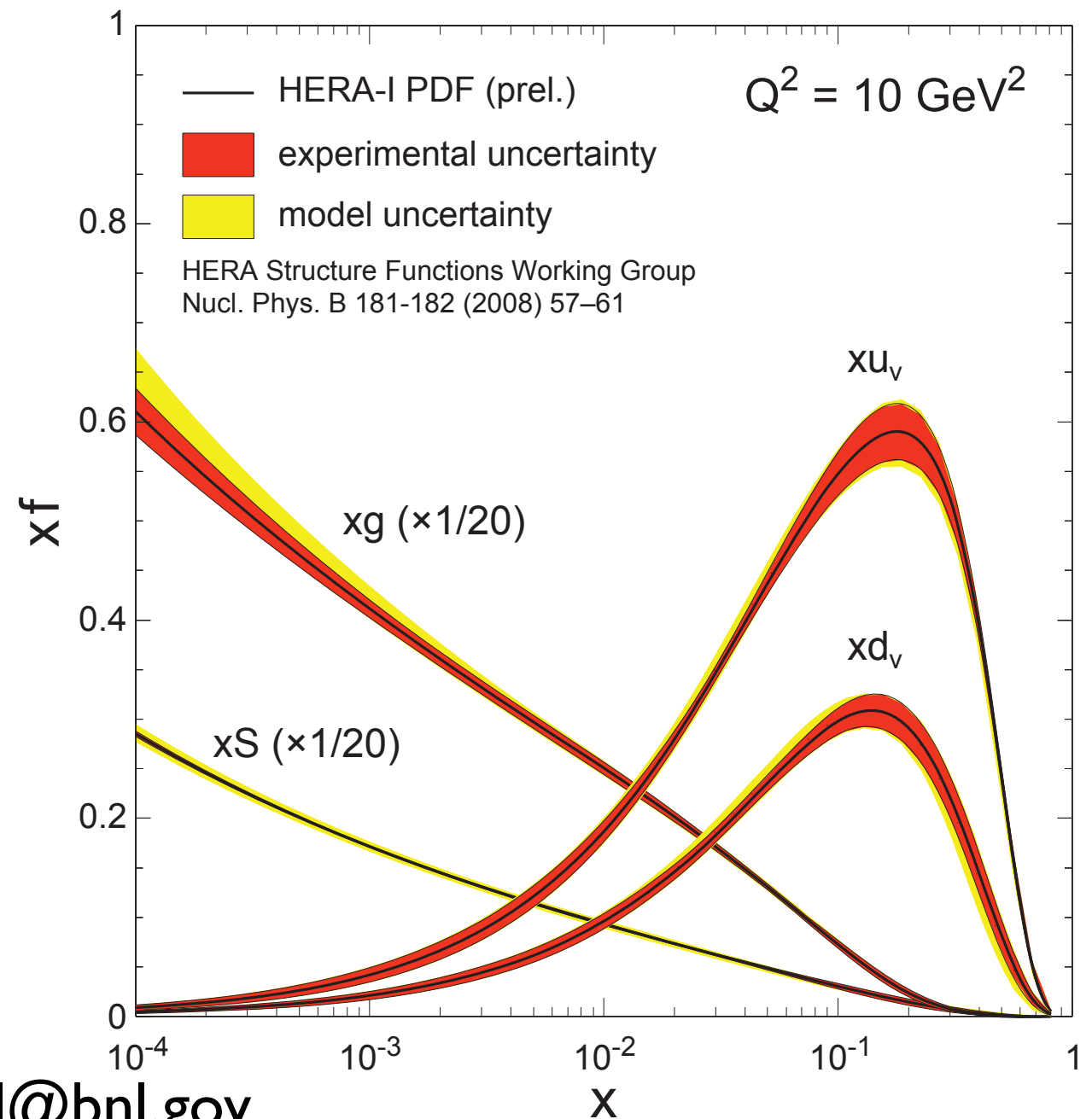


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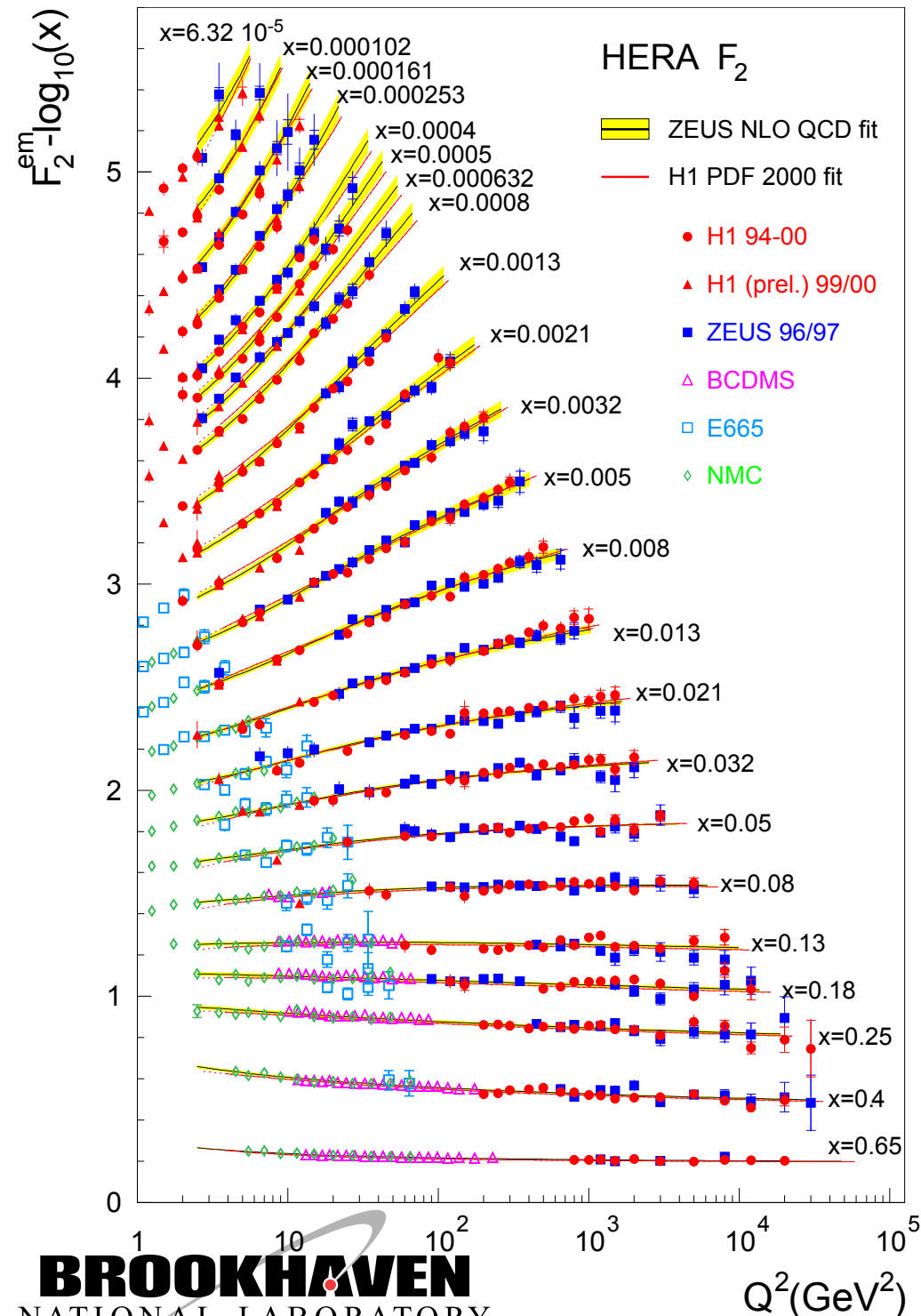


Scaling violation: $dF_2/d\ln Q^2$ and linear DGLAP
Evolution $\Rightarrow G(x, Q^2)$

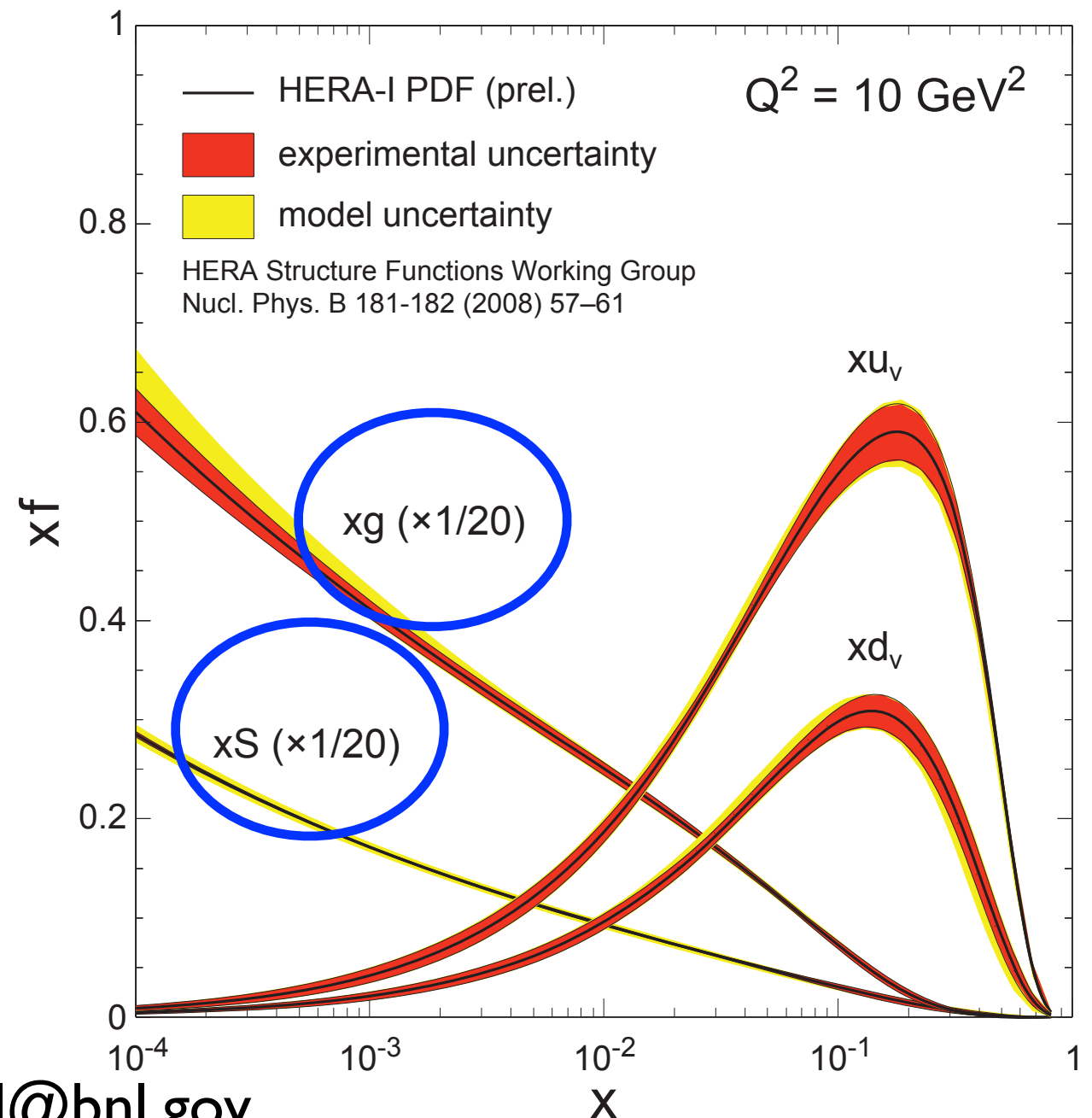


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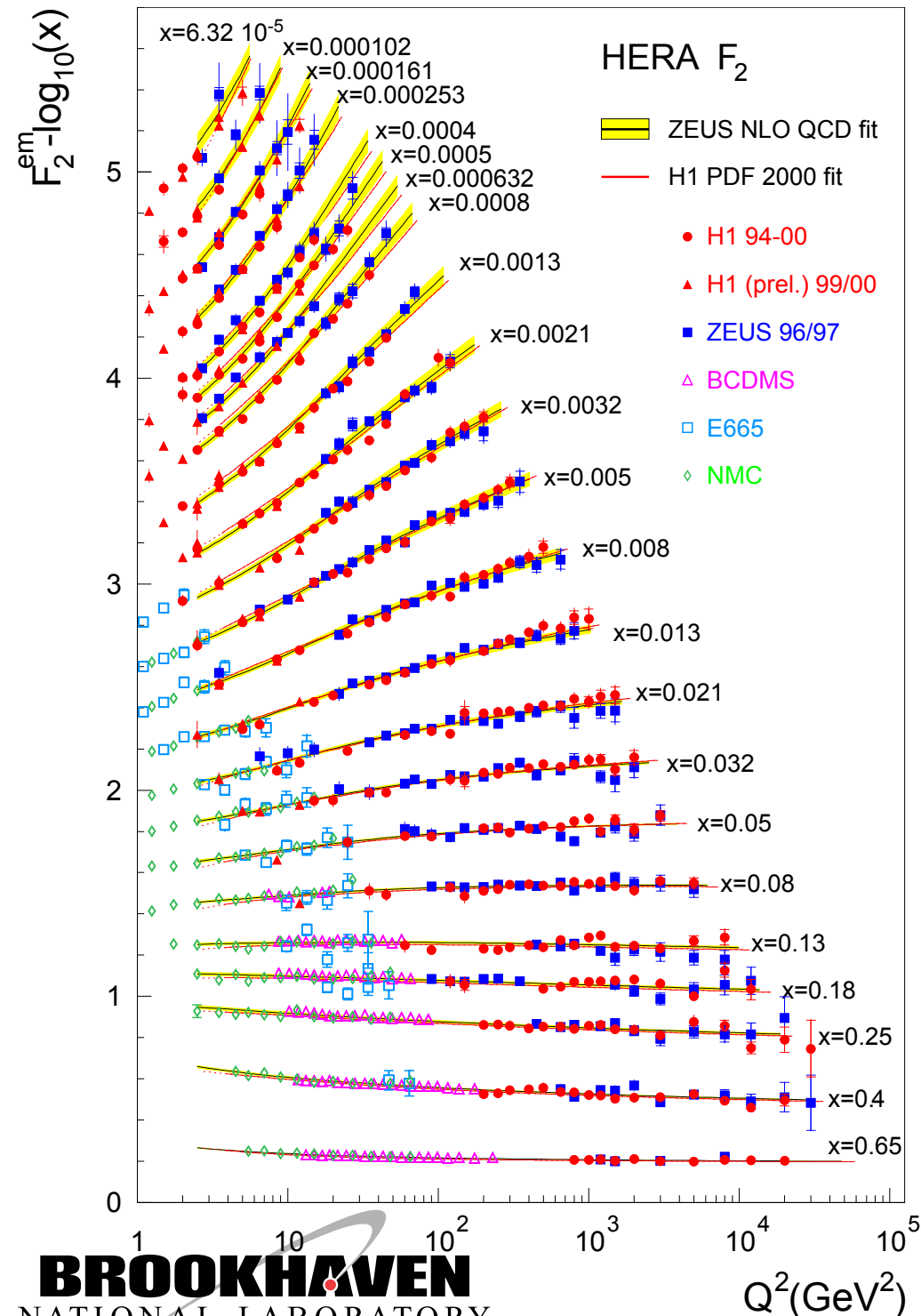


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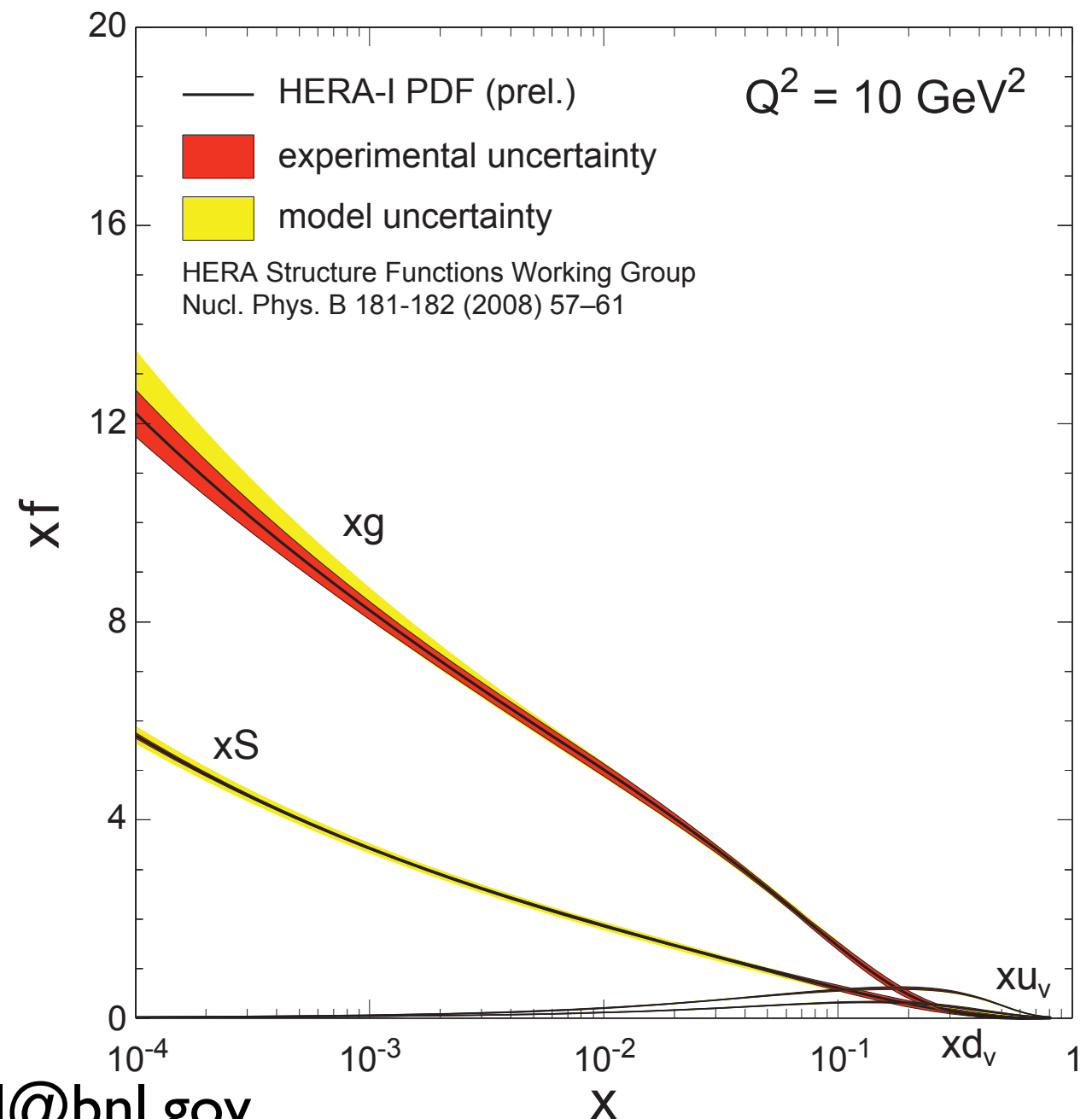


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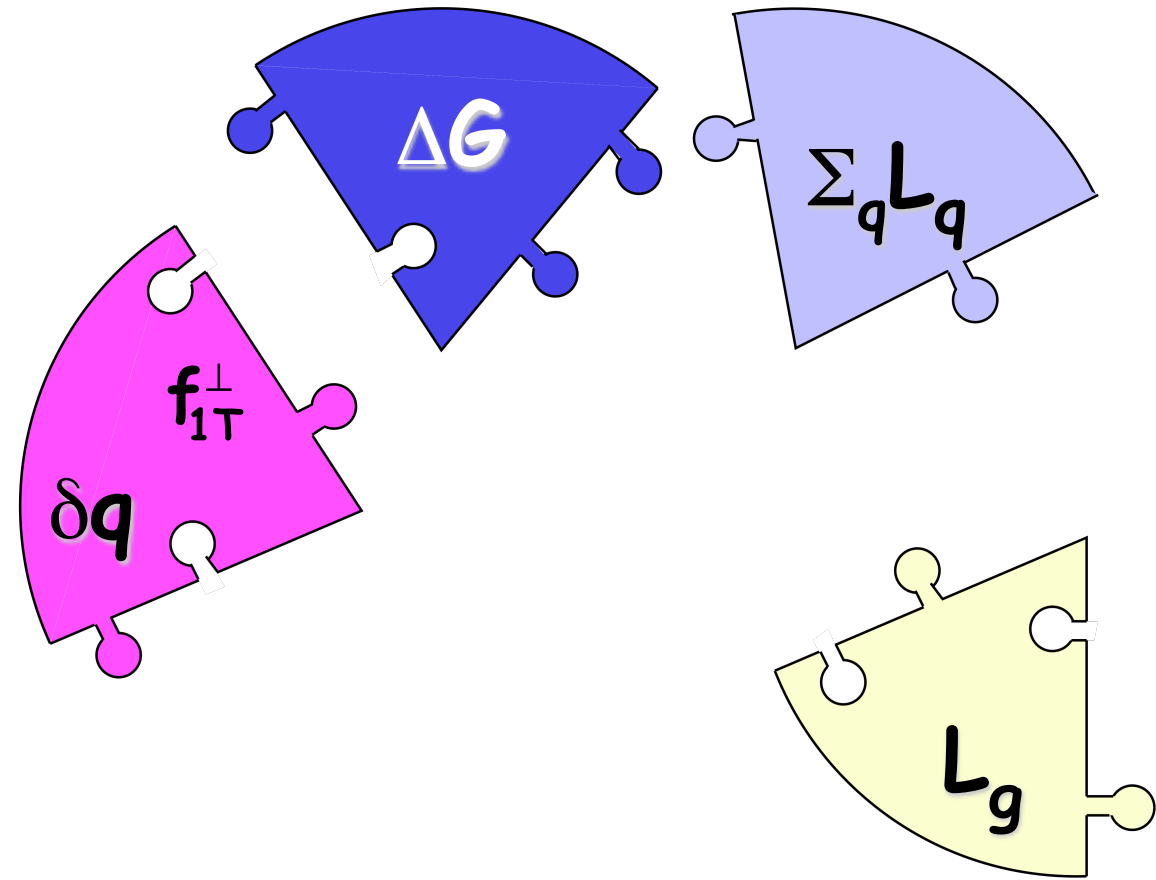


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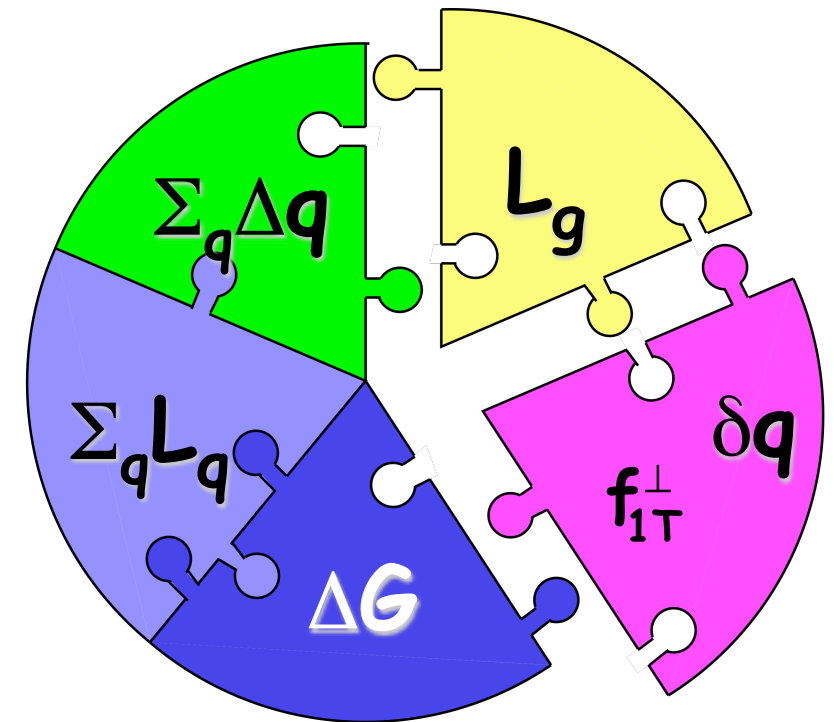
Spin physics at the EIC - the quest for ΔG

- ΔG - Gluon contribution to nucleon spin
- $\Sigma_q \Delta q$ - Quark contribution to nucleon spin
- L_g - Angular momentum of gluons
- $\Sigma_q L_q$ - Angular momentum of quarks
- $f_{1T}^\perp$ - Sivers function
- δq - Transversity



Spin physics at the EIC - the quest for ΔG

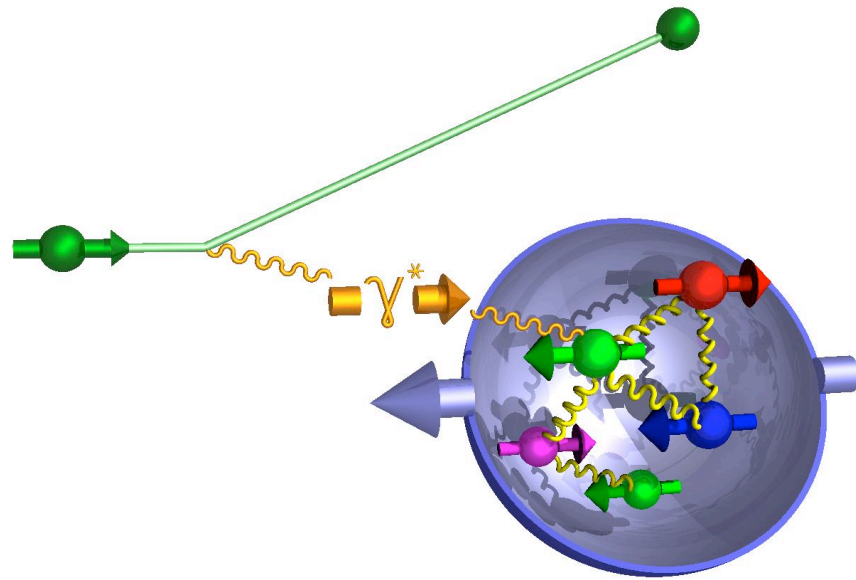
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Helicity sum rule:

$$\frac{1}{2}\hbar = \left\langle P, \frac{1}{2} \left| J_{QCD}^z \right| P, \frac{1}{2} \right\rangle = \underbrace{\sum_q \frac{1}{2} S_q^z}_{\text{total quark spin (u+d+s)}} + \overbrace{S_g^z}^{\text{gluon spin}} + \underbrace{\sum_q L_q^z + L_g^z}_{\text{angular momentum}}$$

How to measure quark polarisations



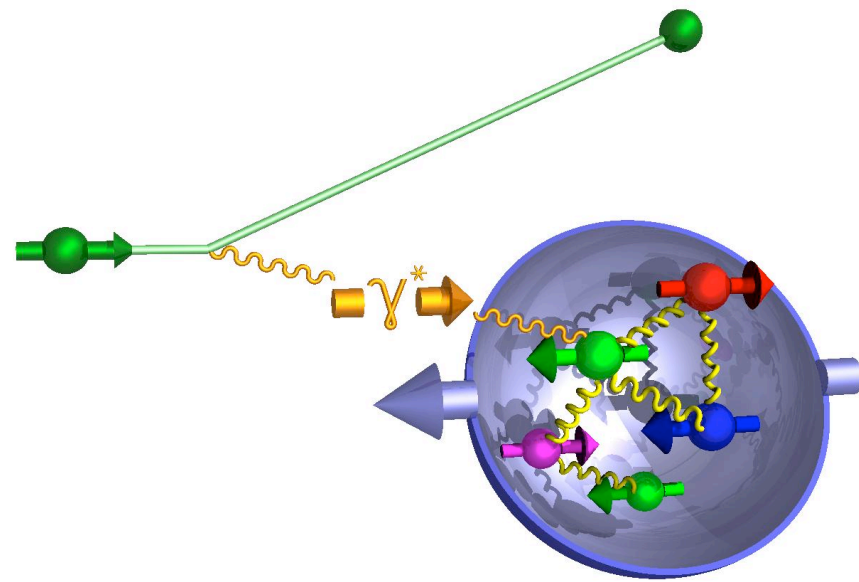
$$\vec{S}_{\gamma^*} + \vec{S}_N = 1/2$$

$$\vec{S}_N = \vec{S}_q$$

$$\sigma_{1/2} \sim q^+(x)$$

Virtual photon γ^* can only couple to quarks of opposite helicity
 Select $q^+(x)$ or $q^-(x)$ by changing the orientation of target nucleon spin or helicity of incident lepton beam: $\Delta q = q^+ - q^-$

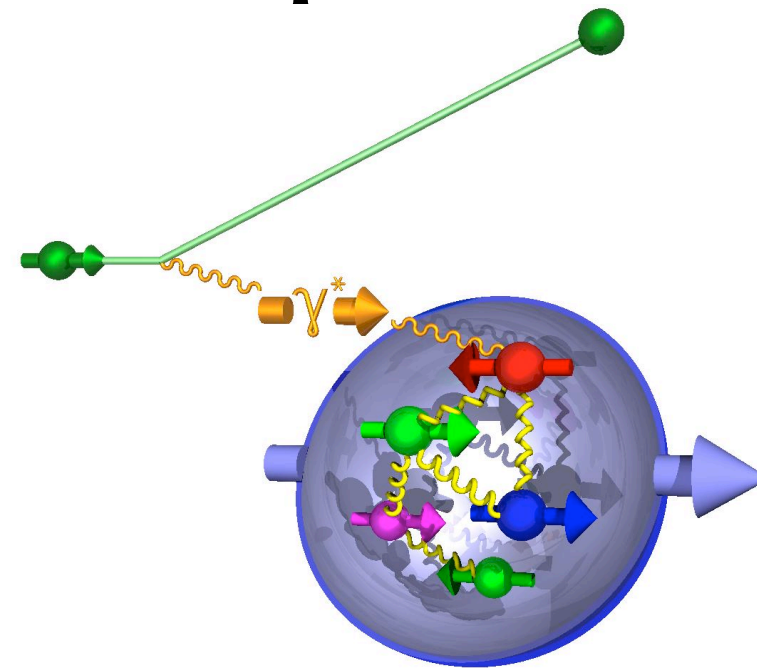
How to measure quark polarisations



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$$\vec{S}_{\gamma^*} + \vec{S}_N = 3/2$$

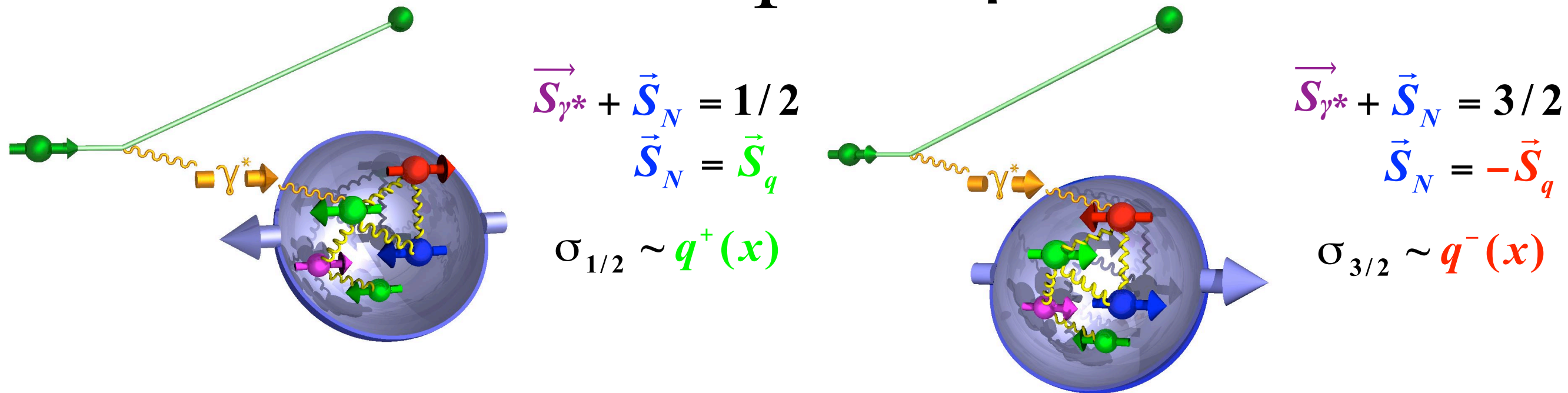
$$\vec{S}_N = -\vec{S}_q$$

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Asymmetry definition:

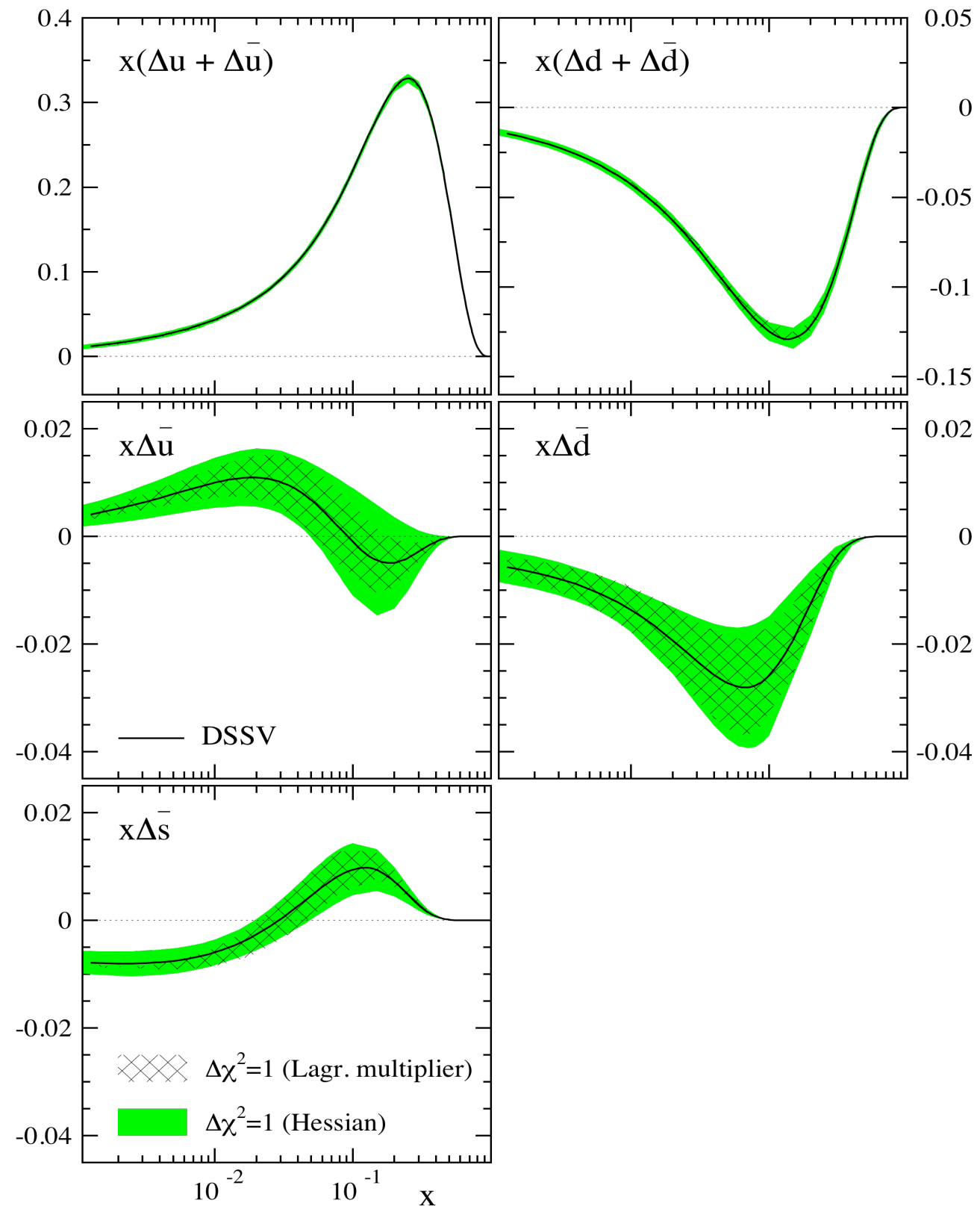
$$A_{\parallel}^{e',h} \sim \frac{\sigma_{1/2}^{e',h} - \sigma_{3/2}^{e',h}}{\sigma_{1/2}^{e',h} + \sigma_{3/2}^{e',h}}$$

$$A_{\parallel}^{e'h} = \frac{1}{\langle P_B P_T \rangle} \frac{N_{e',h}^{\otimes} L^{\otimes} - N_{e',h}^{\otimes} L^{\otimes}}{N_{e',h}^{\otimes} L^{\otimes} + N_{e',h}^{\otimes} L^{\otimes}}$$

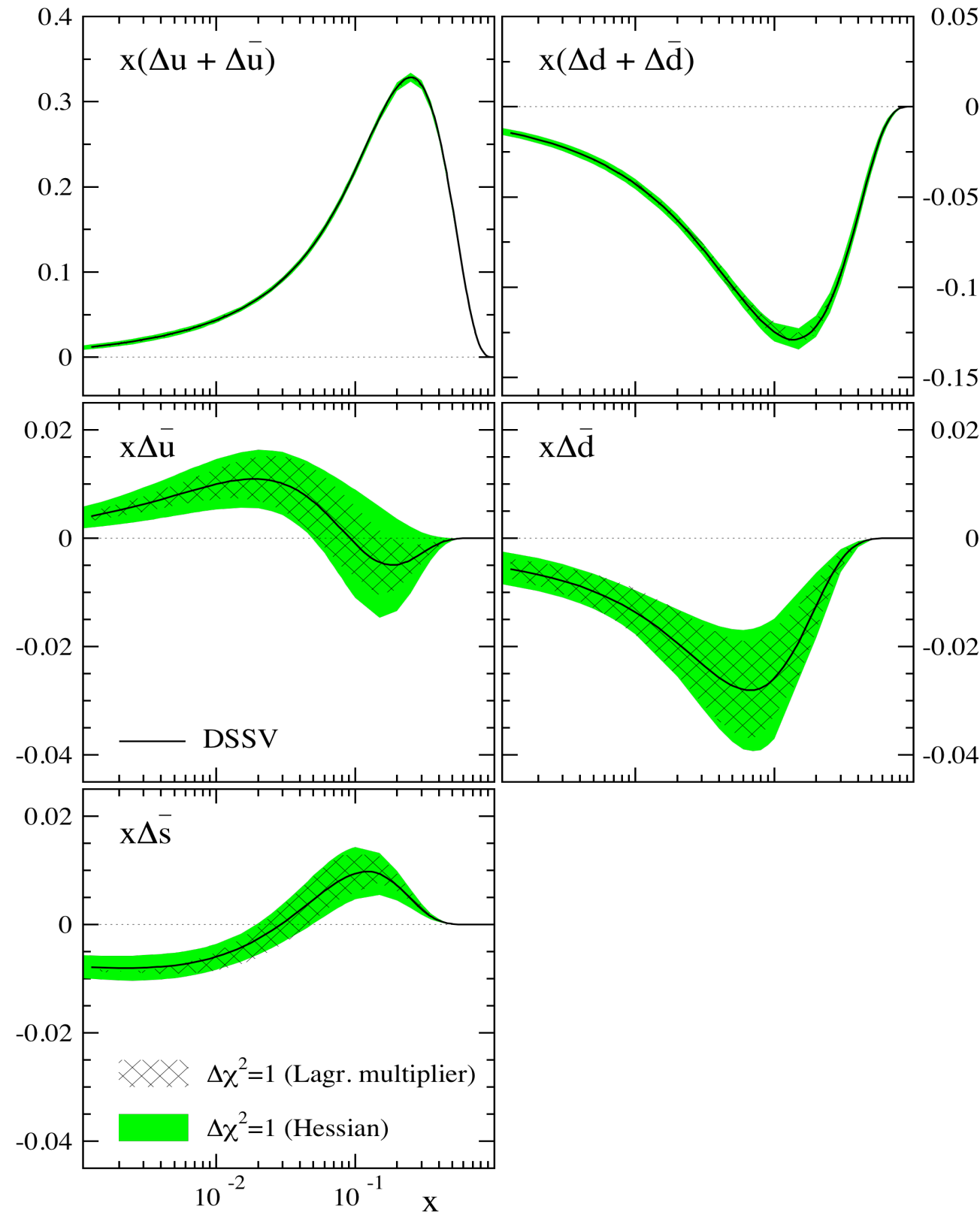
inclusive DIS: only e' info used

semi-inclusive DIS: $e'+h$ info used

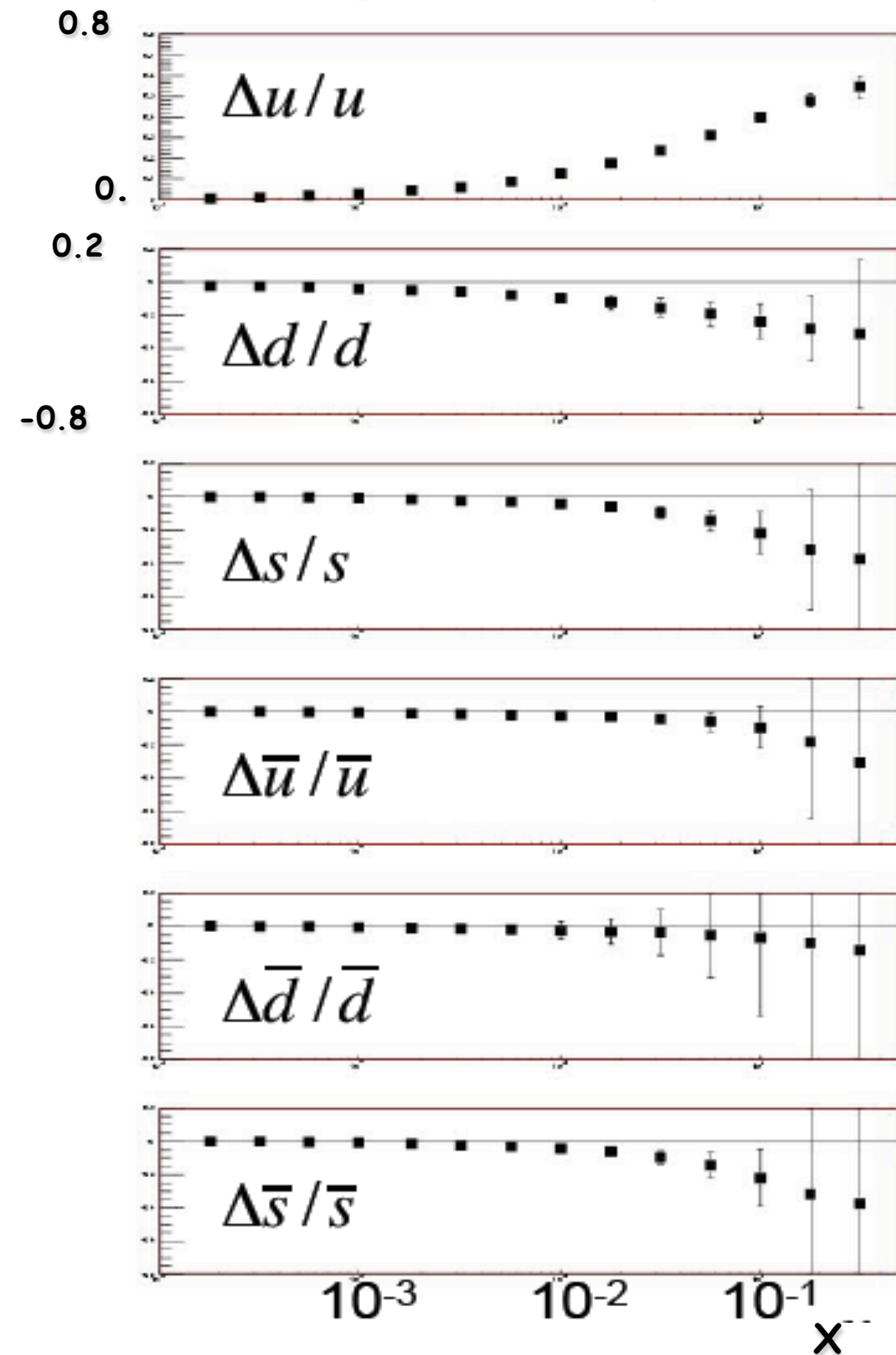
Polarised quark distributions



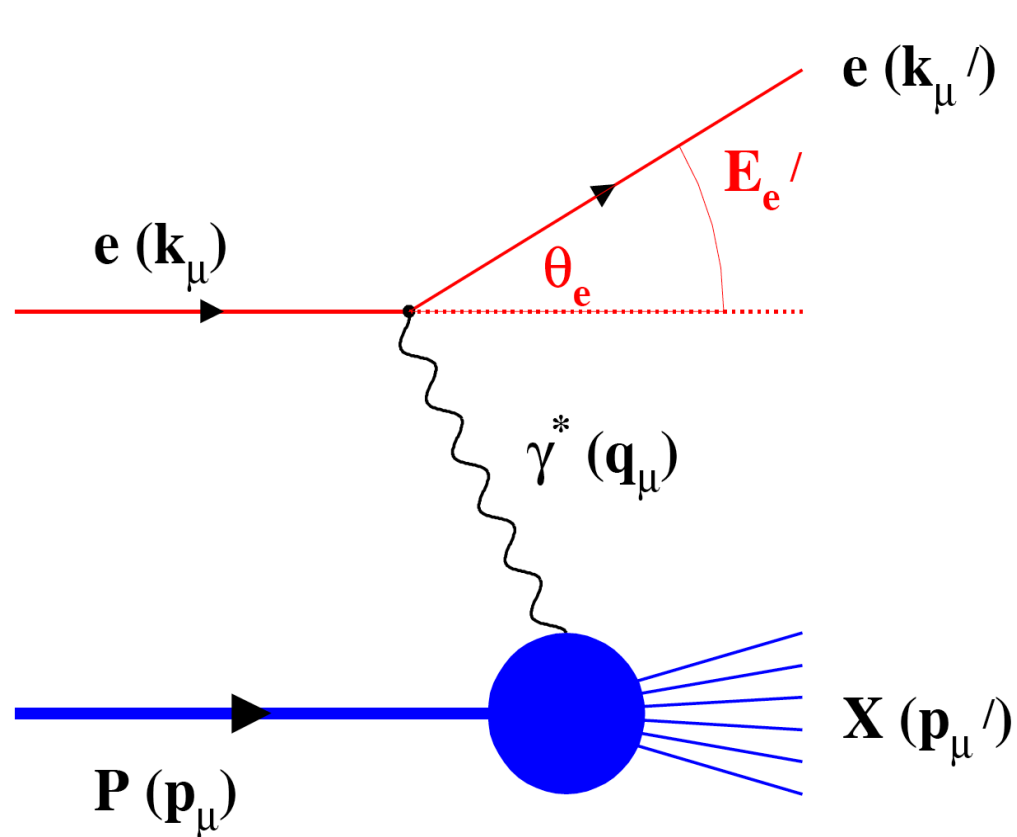
Polarised quark distributions



eRHIC: 10GeV@250GeV at 9 fb⁻¹



Polarised DIS Kinematics



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Measure of
inelasticity

$$x = \frac{Q^2}{2pq} = \frac{Q^2}{sy}$$

Measure of
momentum
fraction of
struck
quark

$$\frac{d^2\sigma}{d\Omega dE'} \sim L_{\mu\nu} W^{\mu\nu}$$

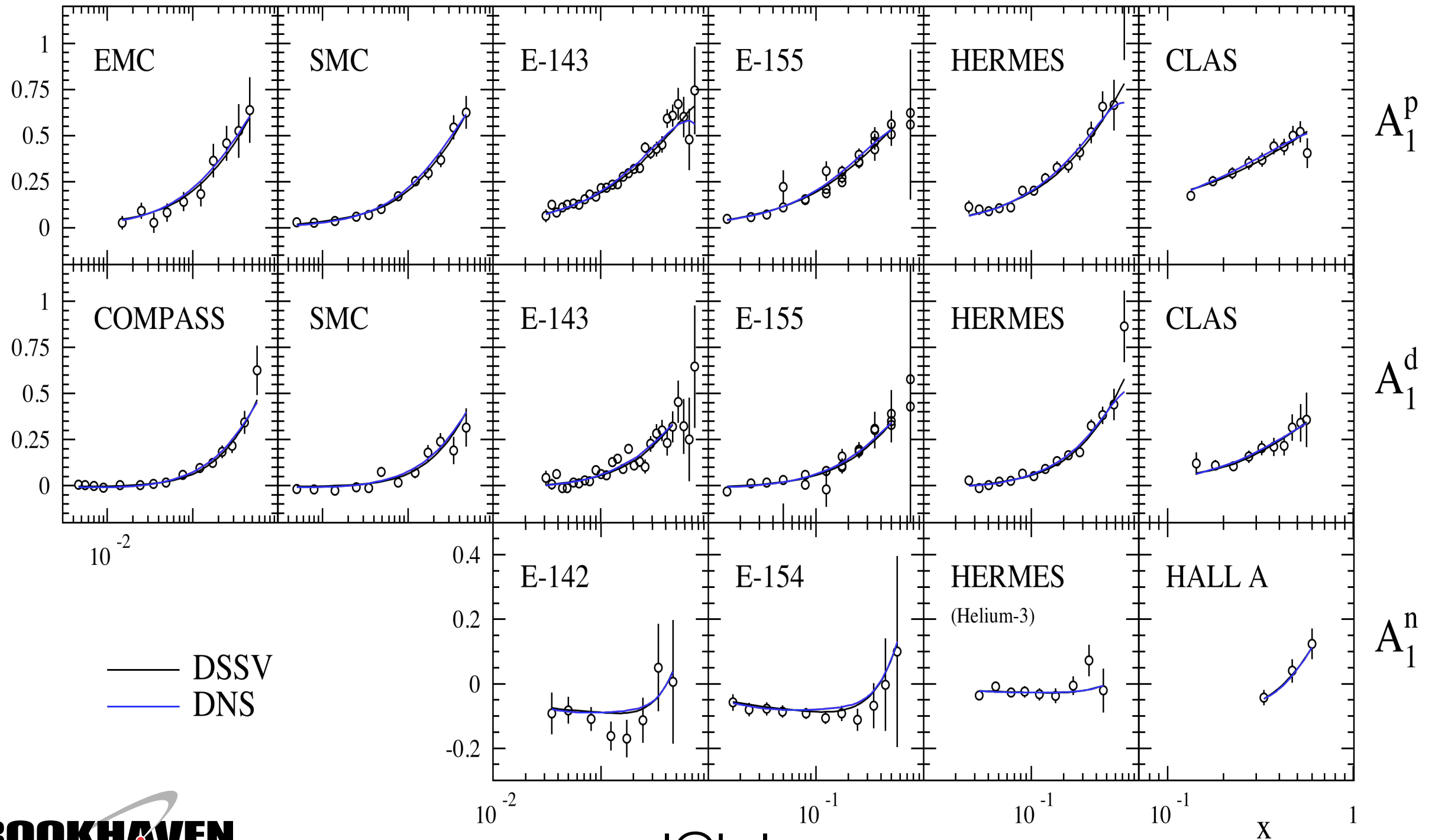
$$W^{\mu\nu} = -g^{\mu\nu} F_1 - \frac{p^\mu p^\nu}{v} F_2 + \frac{i}{v} \varepsilon^{\mu\nu\lambda\sigma} q^\lambda s^\sigma g_1 + \frac{i}{v^2} \varepsilon^{\mu\nu\lambda\sigma} q^\lambda (p \cdot q s^\sigma - s \cdot q p^\sigma) g_2$$

Inclusive World data-set

$$g_1(x, Q^2) = \frac{1}{1 - y/2 - (y^2 \gamma)/4} \left[\frac{Q^4}{8\pi\alpha^2 y} \frac{d^2\sigma_{unpol}}{dx dQ^2} A_{||}(x, Q^2) + \frac{y}{2} \gamma^2 g_2(x, Q^2) \right]$$

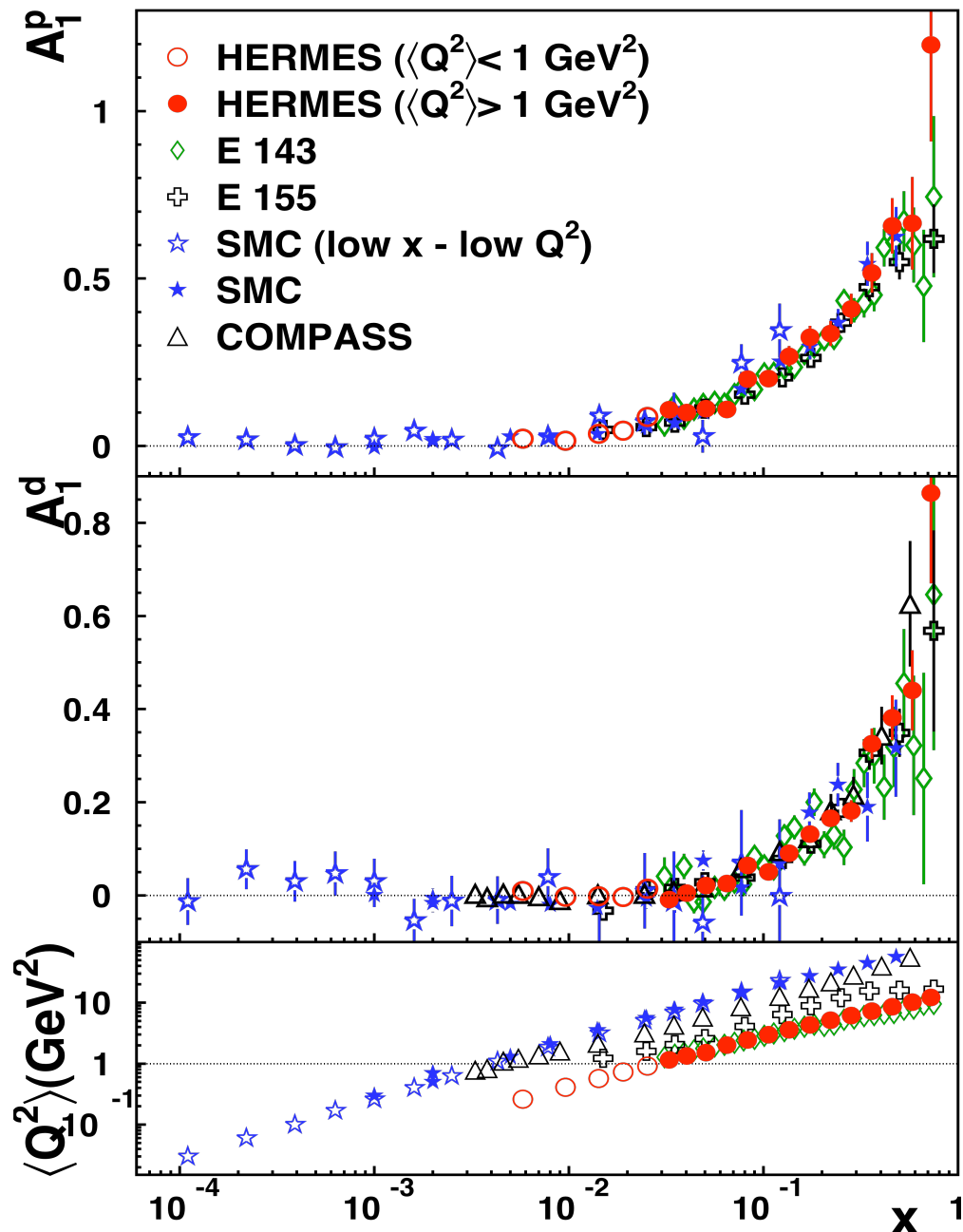
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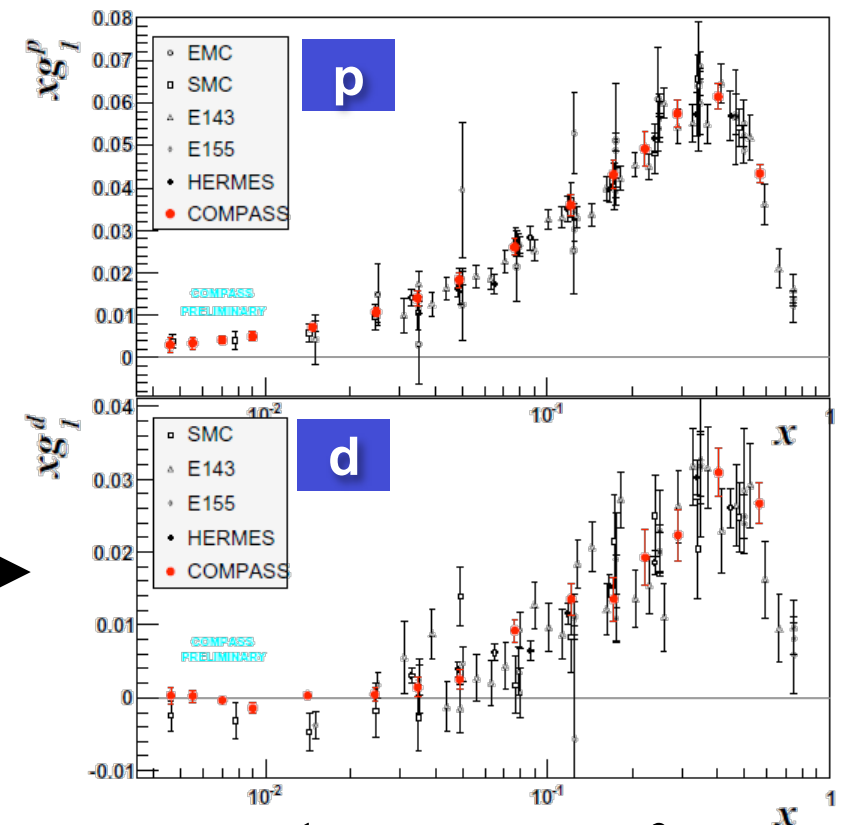
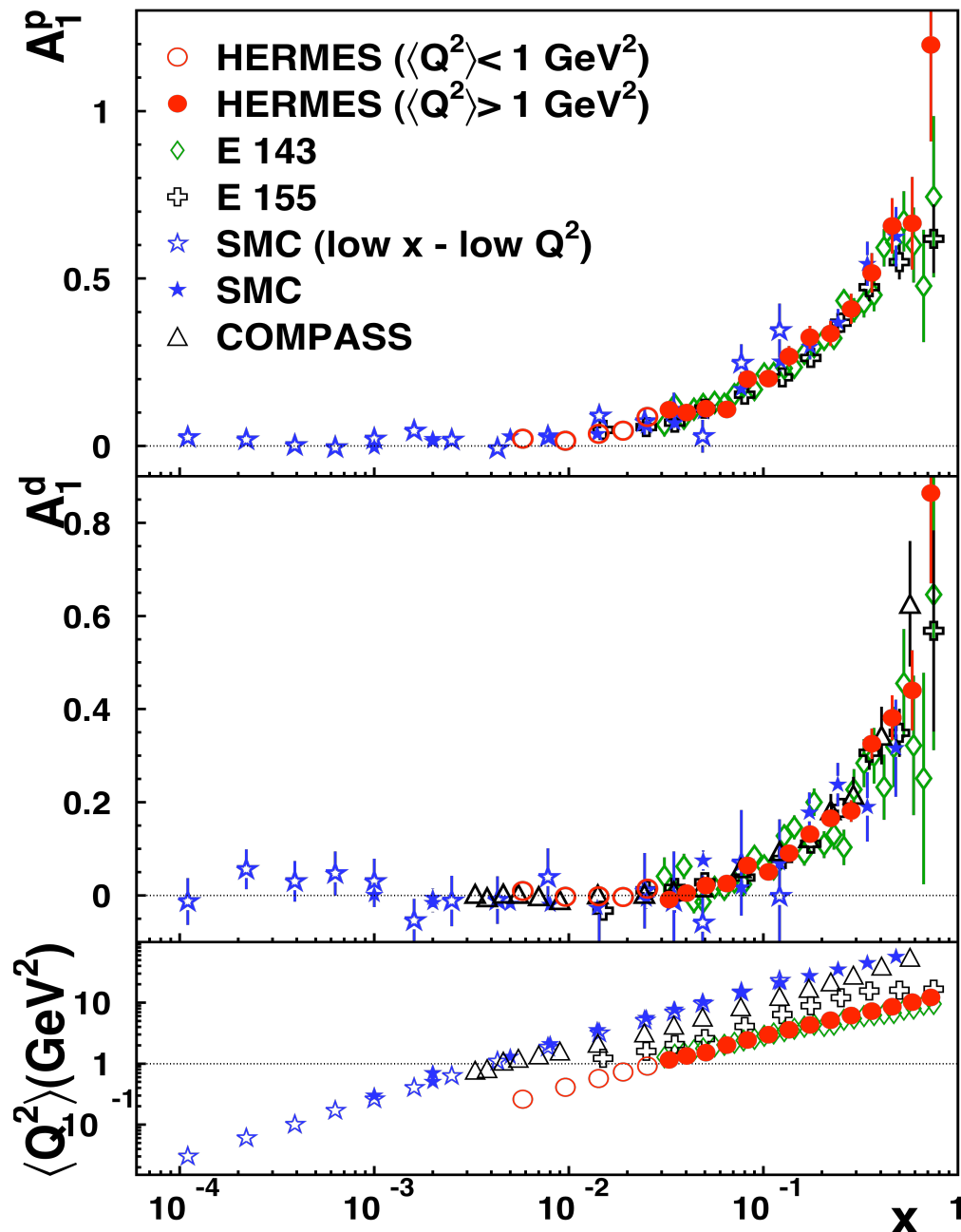
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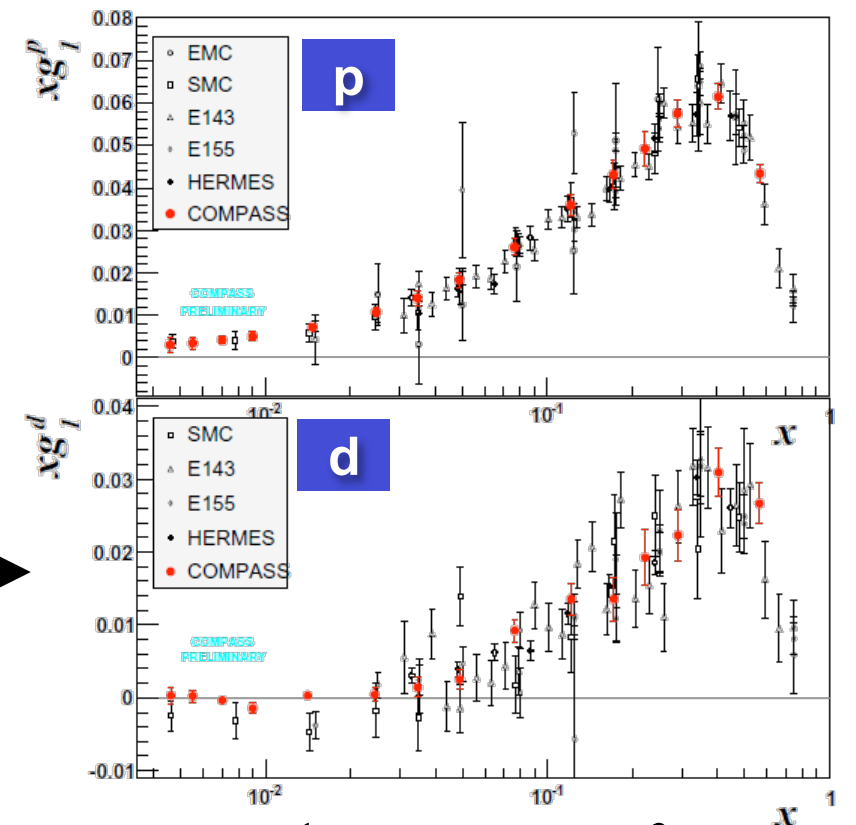
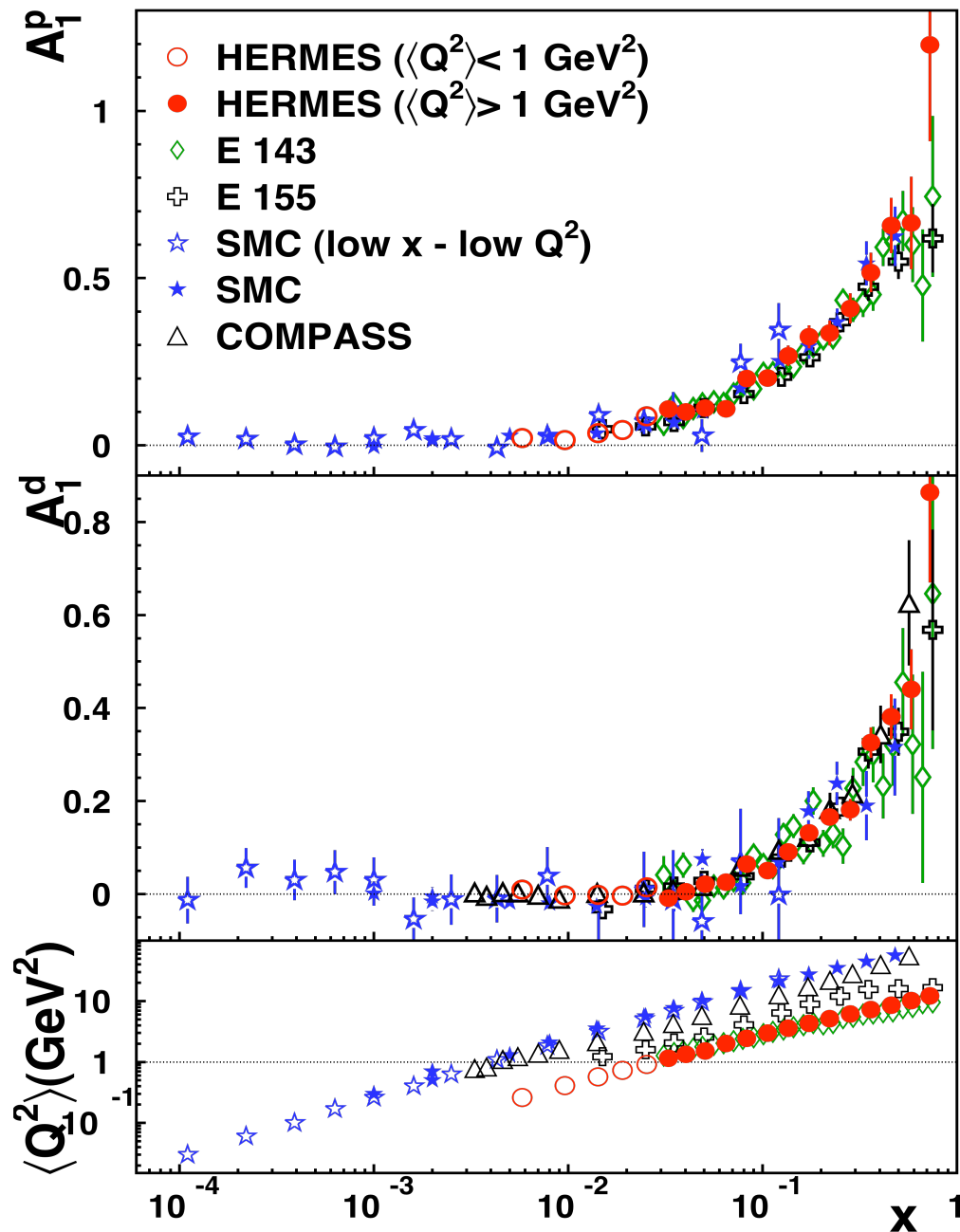
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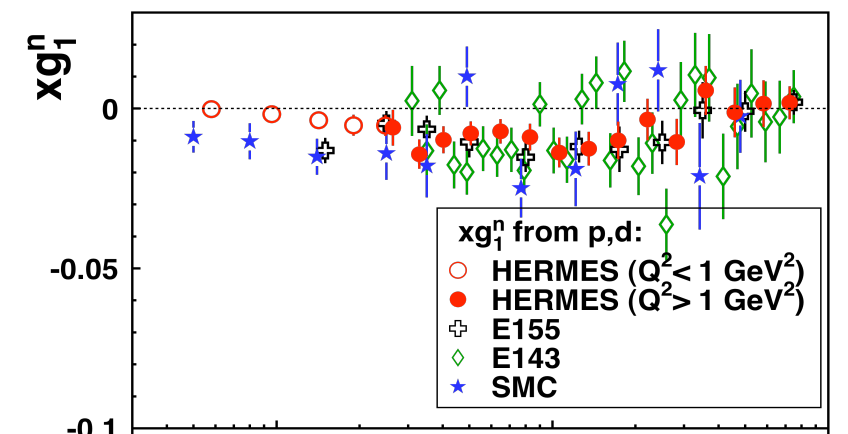
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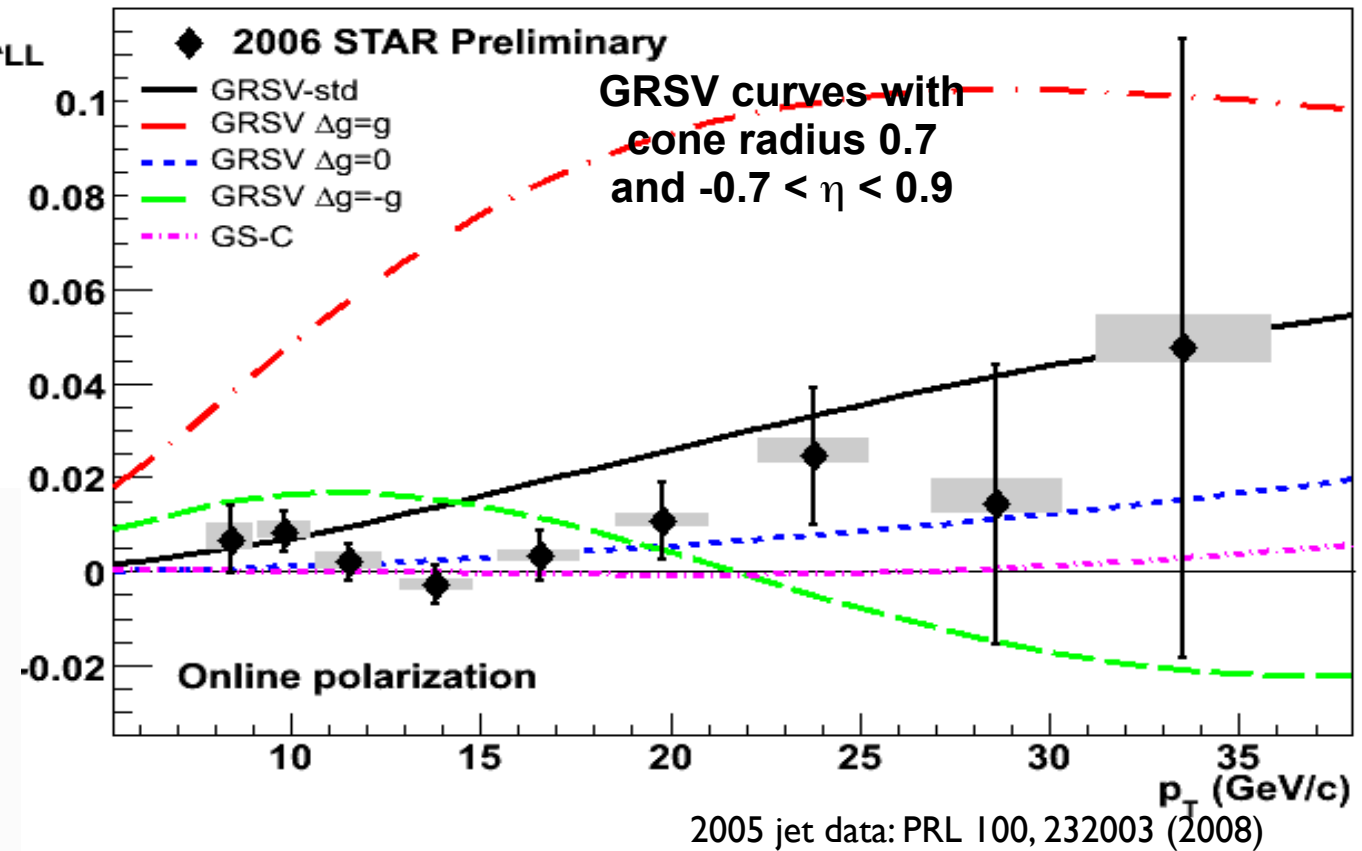
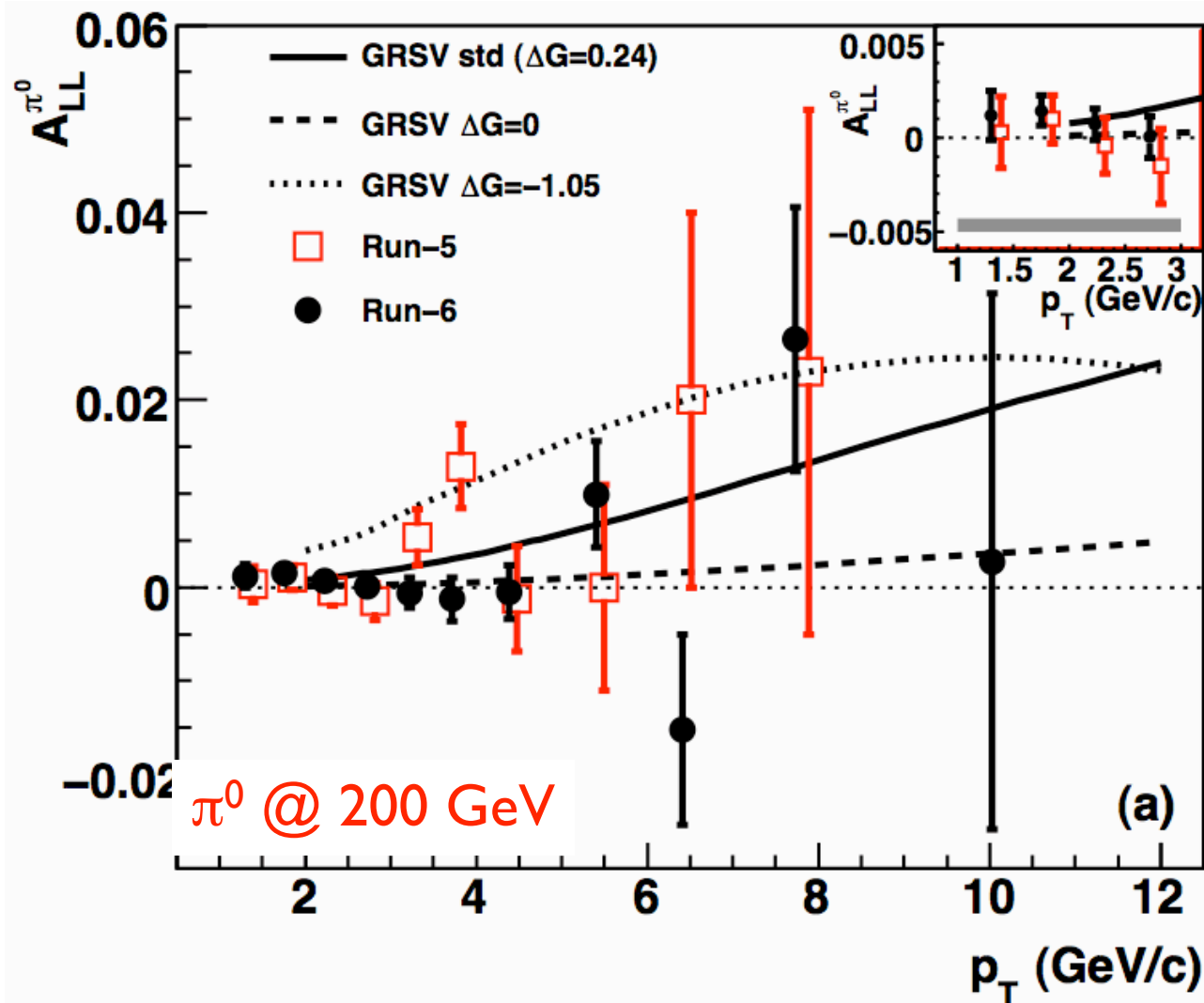
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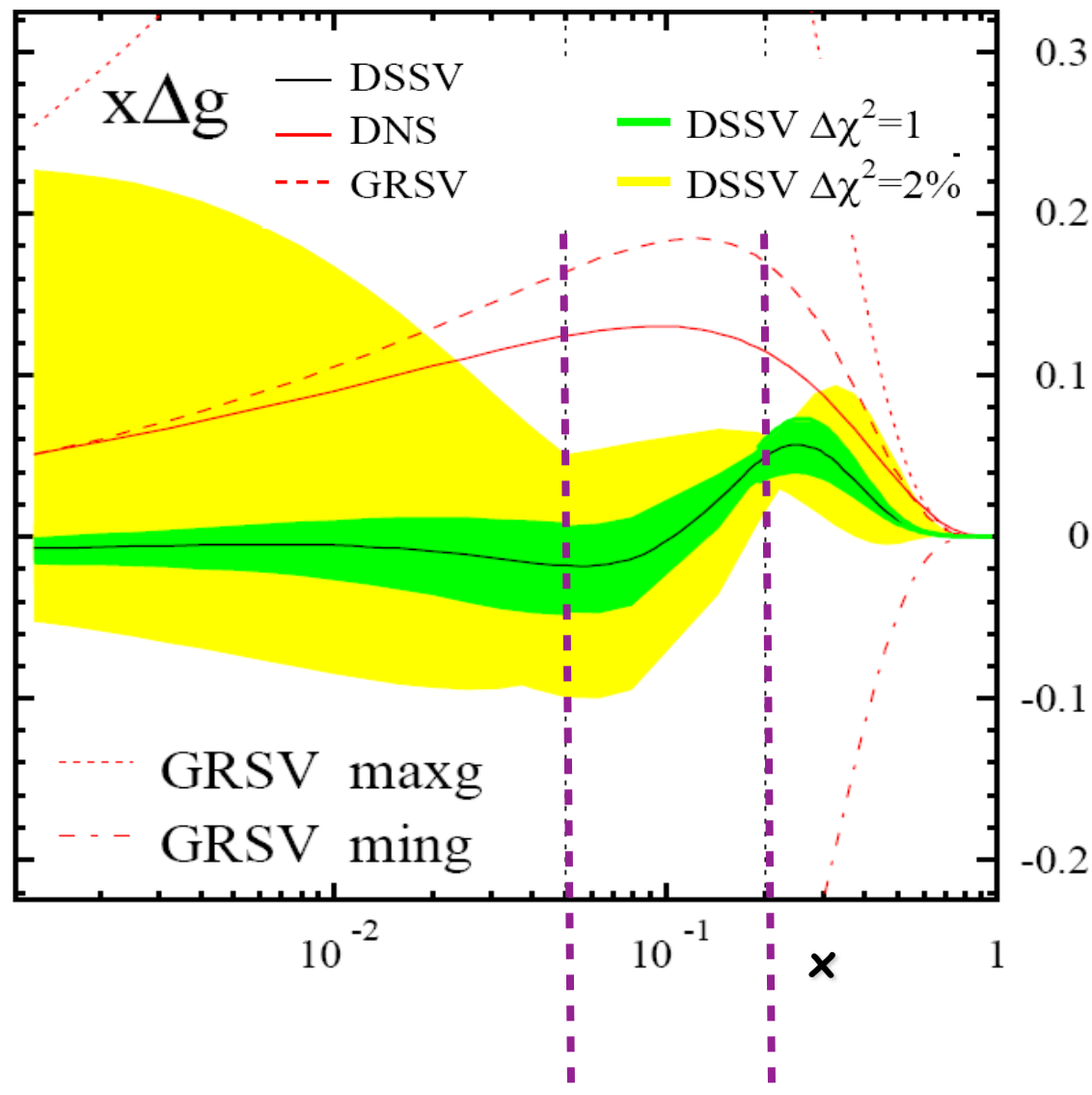
Gluon polarisation - RHIC data



2005: PRD 76, 051106

2006: arXiv:0810.0694

Gluon polarization - World fit



- $\Delta g(x)$ is very small as medium x

➡ best fit has a node at $x \sim 0.1$

➡ large uncertainties at small x

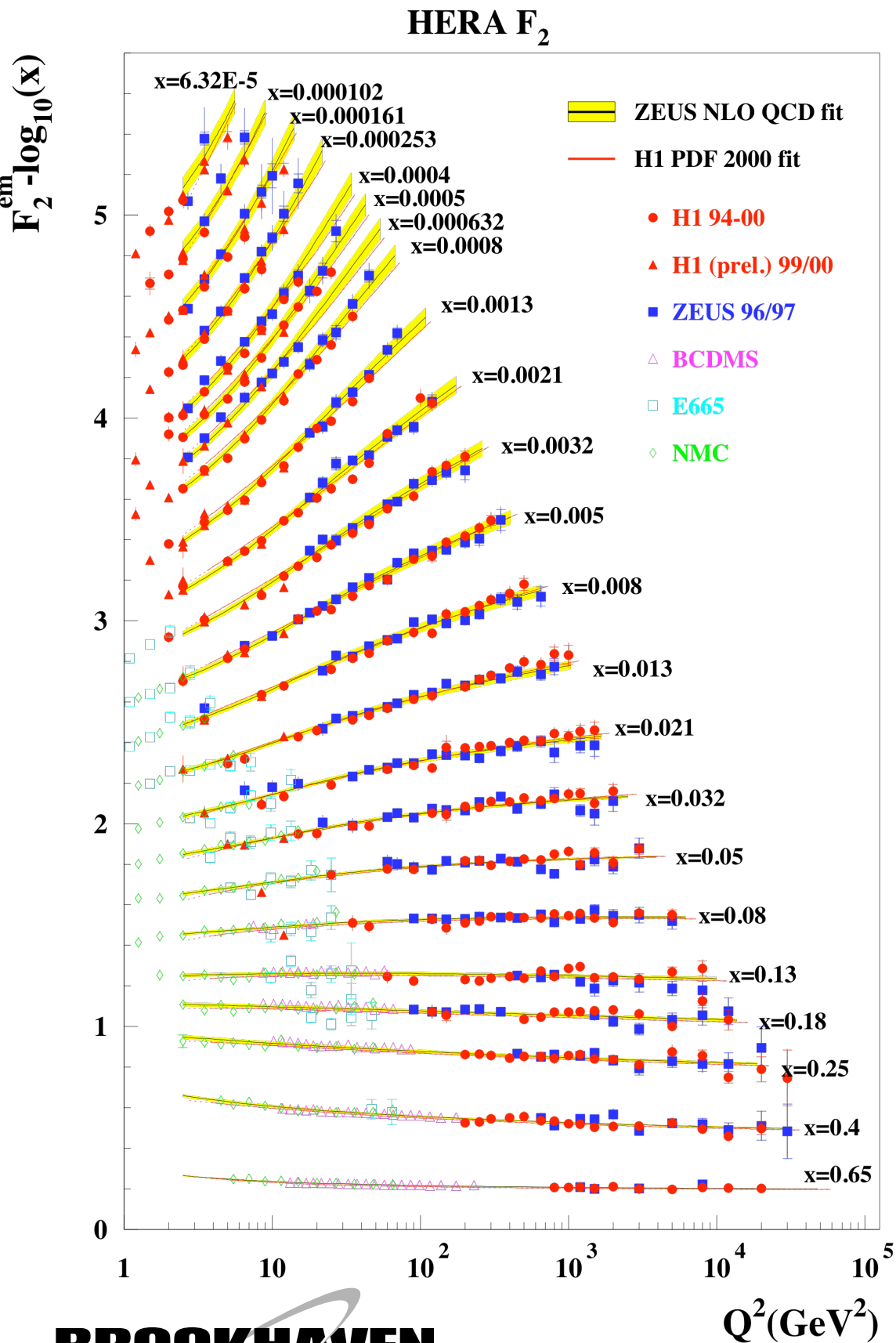
► $\Delta g(x)$ small!!?

$$\int_0^1 \Delta g(x) dx = -0.084 @ 10 \text{ GeV}^2$$

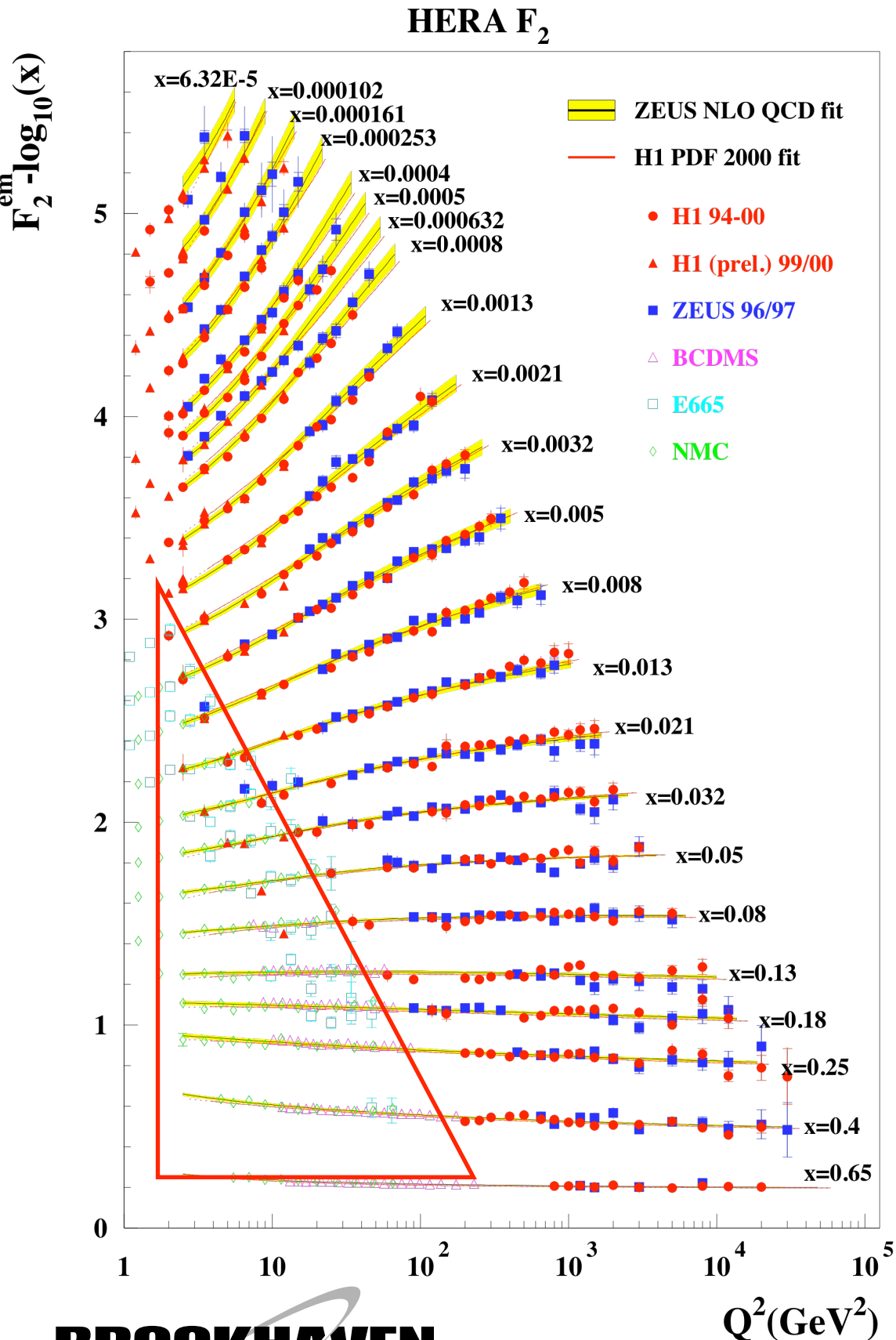
RHIC range: $0.05 < x < 0.2$ (can be changed by extending $\sqrt{s}$ to 64 and 500 GeV)

High x (> 0.2) covered by HERA, JLAB

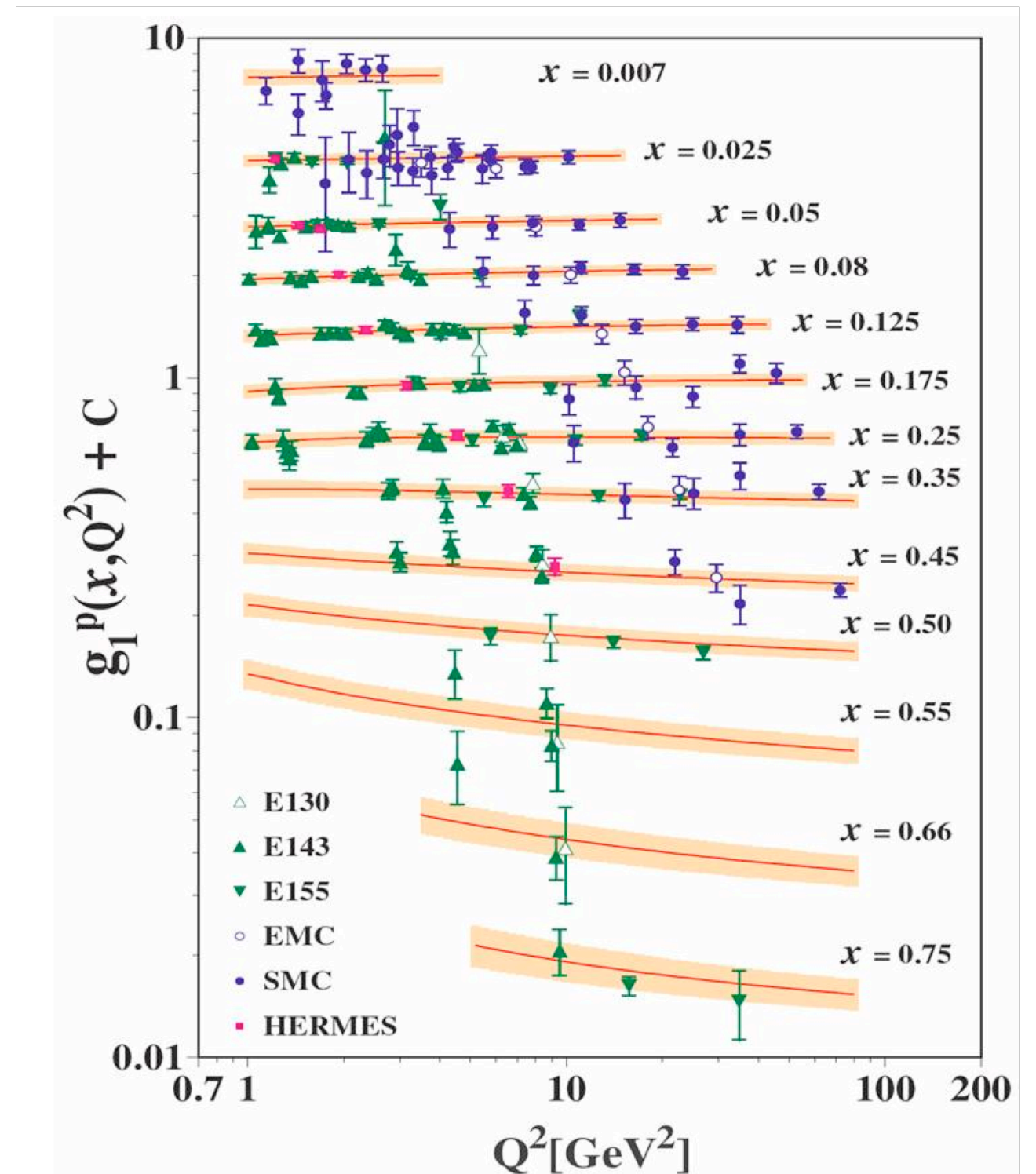
How to measure ΔG at an EIC



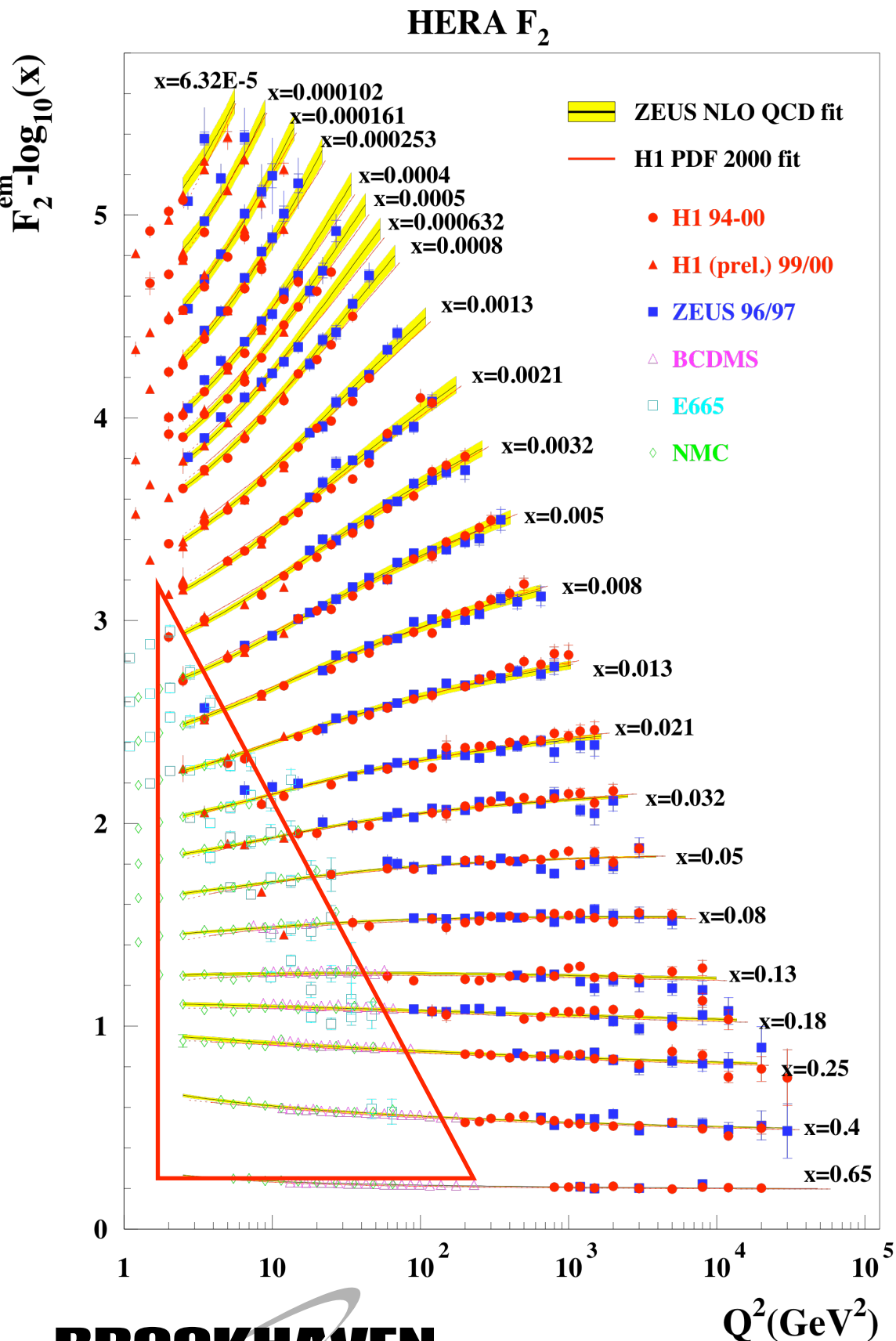
How to measure ΔG at an EIC



● ΔG : Indirect from scaling violation

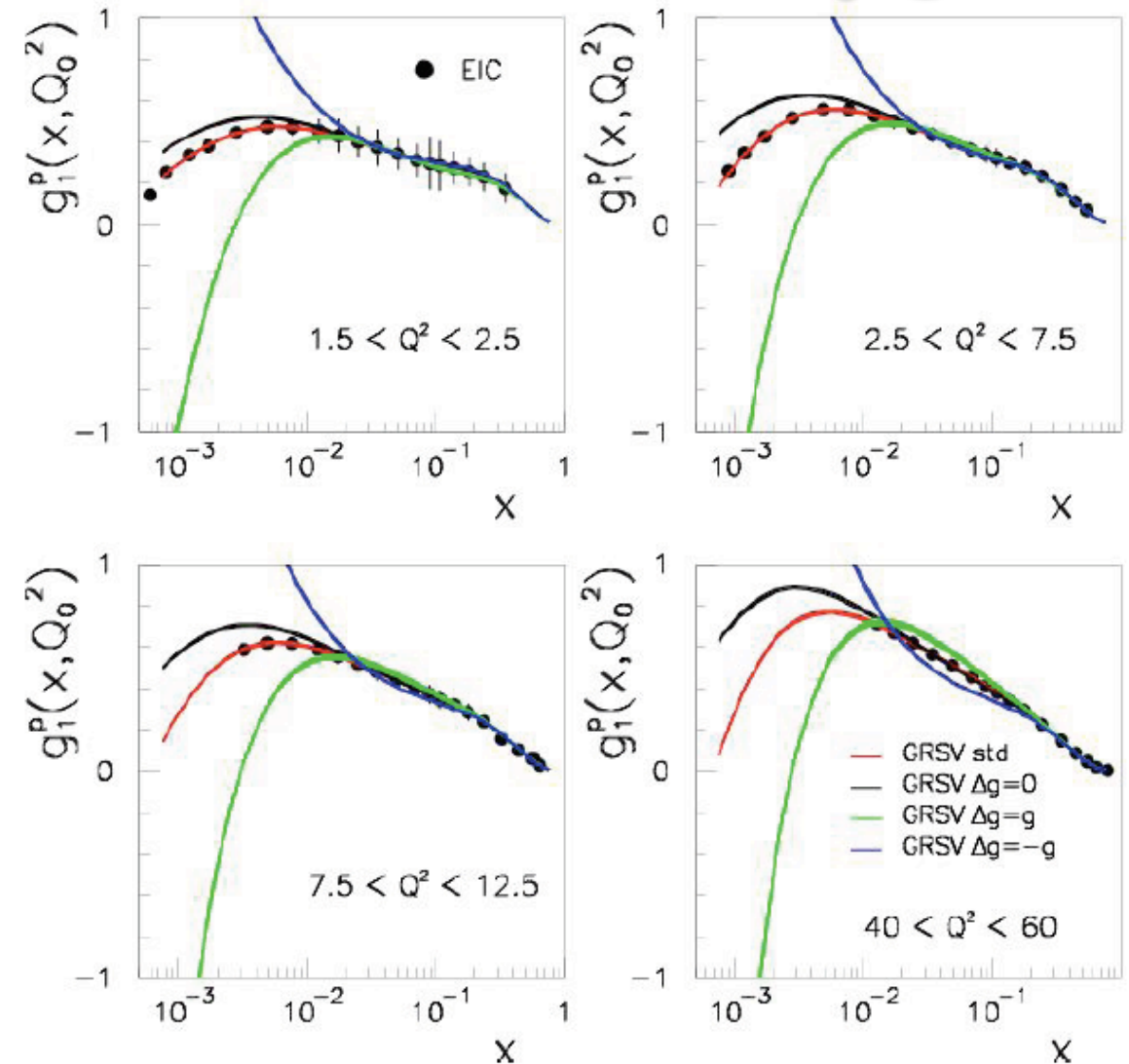


How to measure ΔG at an EIC



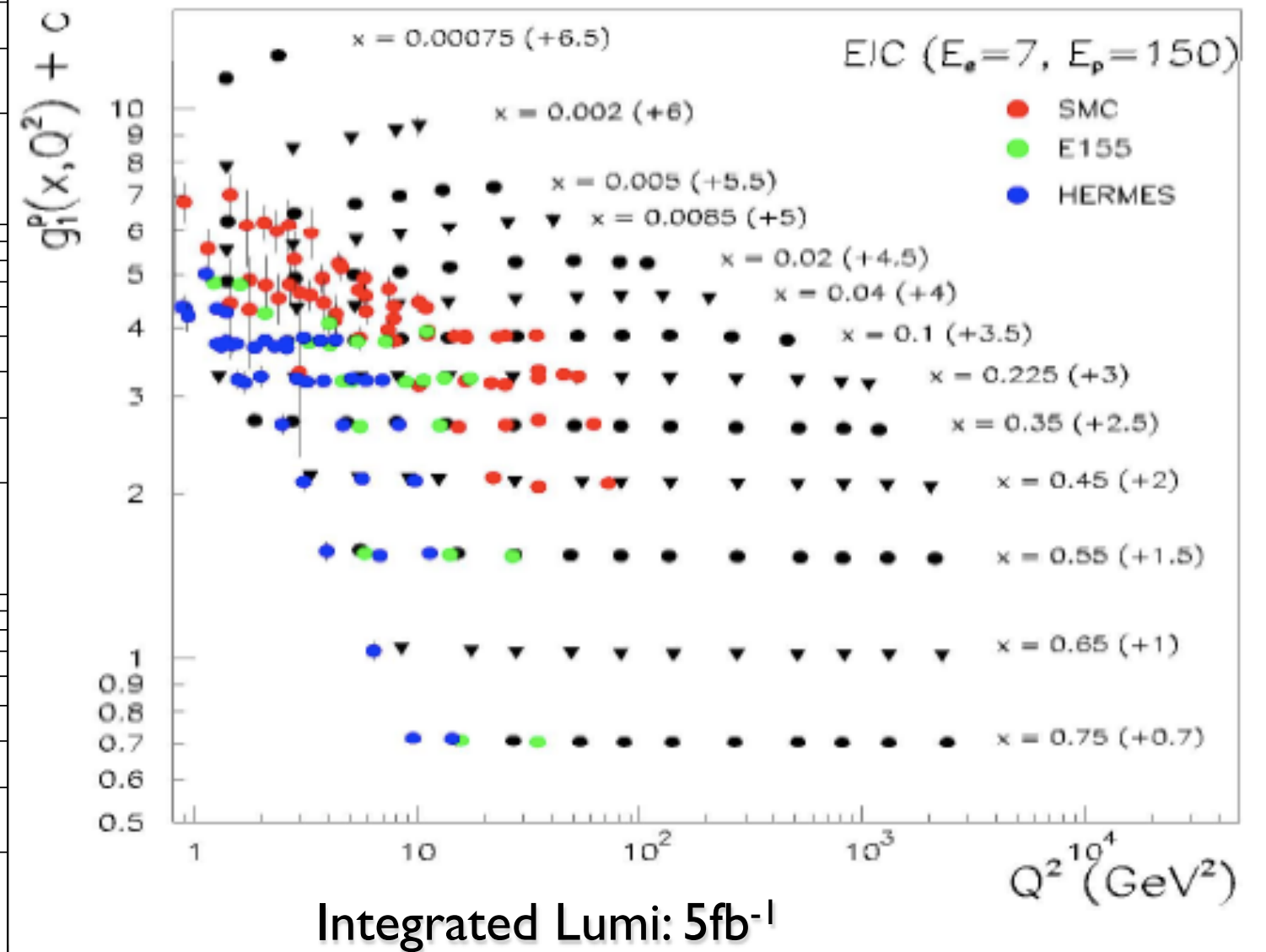
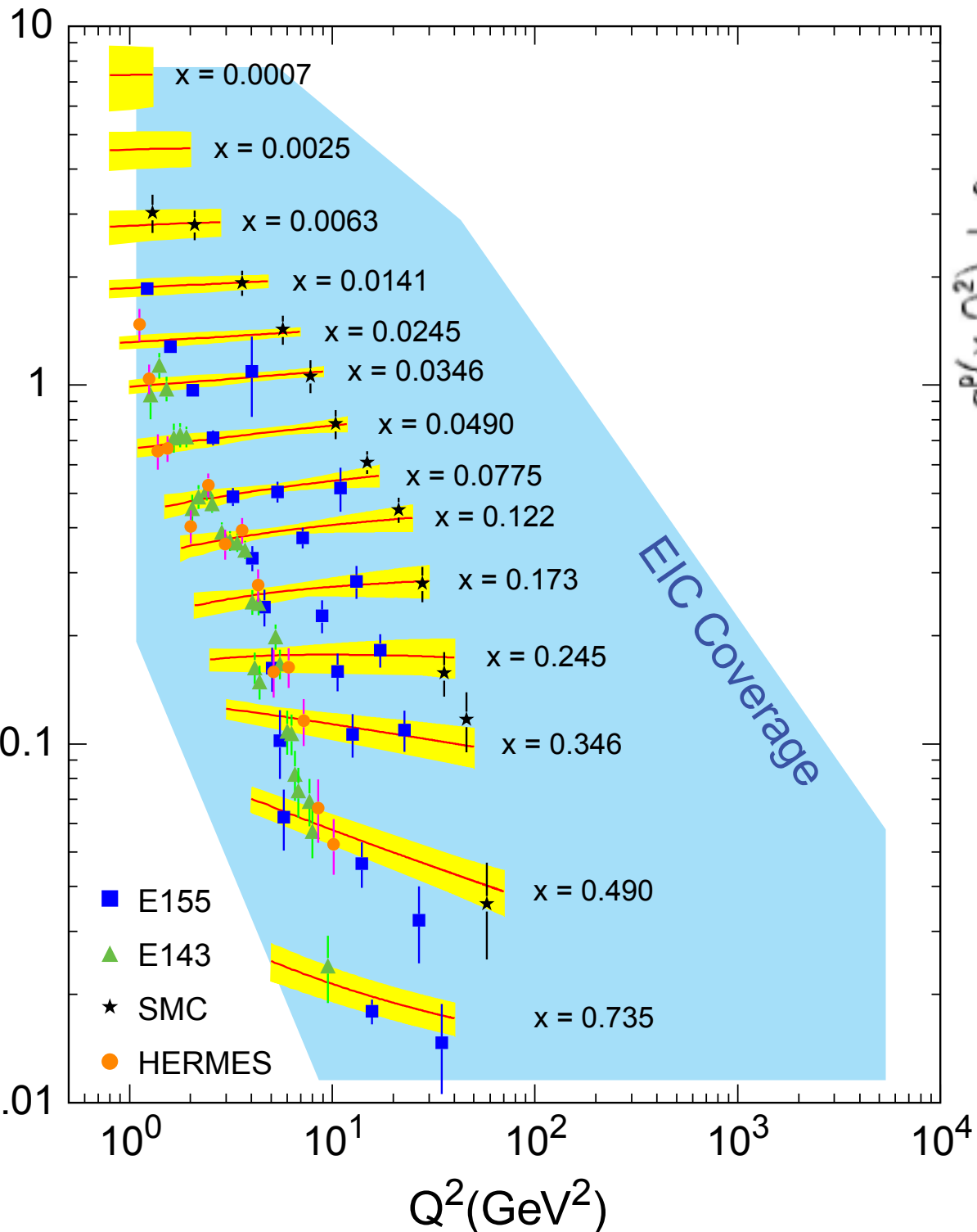
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gI@eRHIC



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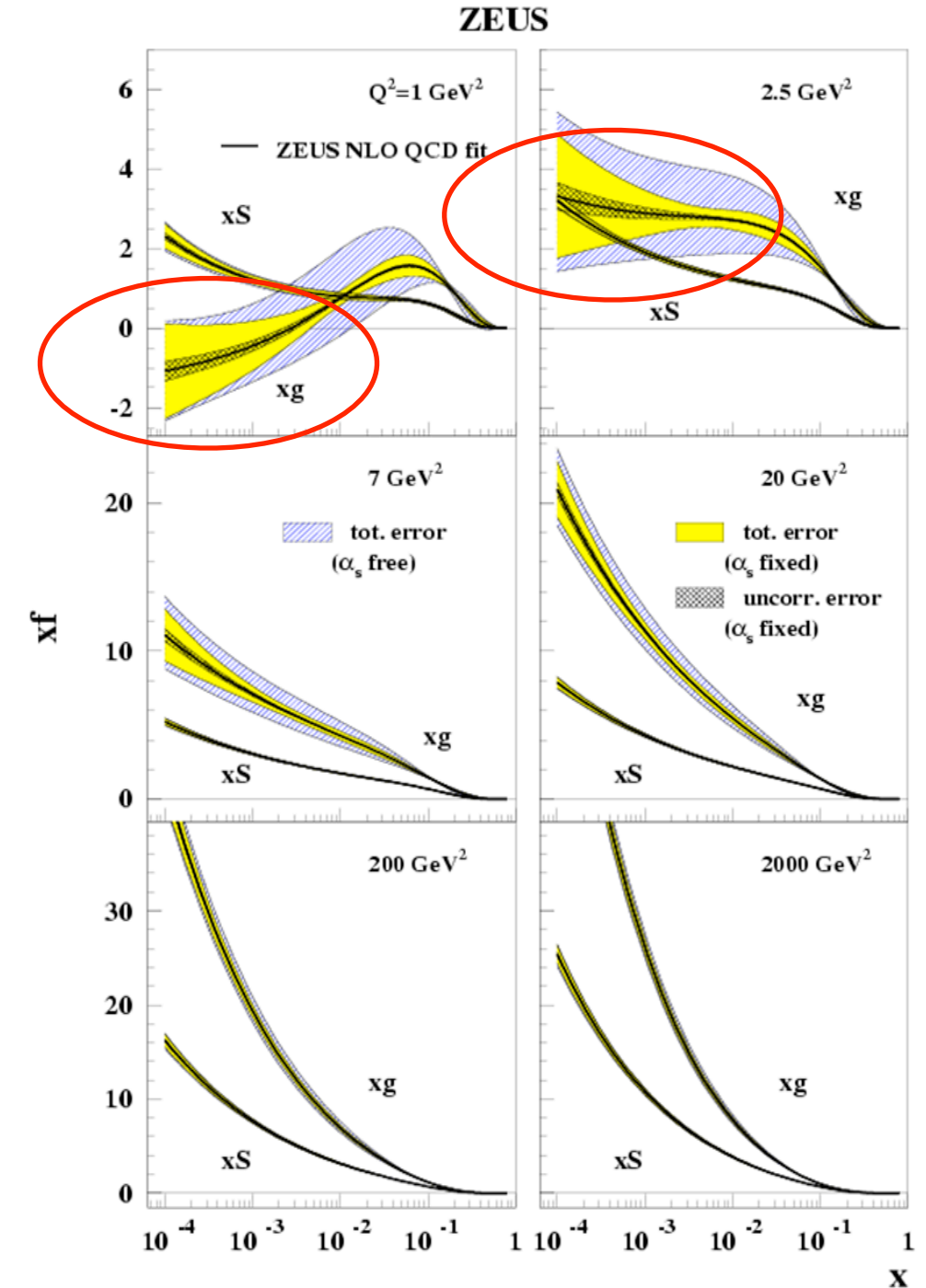
● ΔG : Indirect from scaling violation



$e+A$ physics programme at eRHIC

- Explore the new QCD frontier: strong colour fields in nuclei:
 - ➡ How do the gluons contribute to the structure of the nucleus?
 - ➡ What are the properties of high-density gluon matter
 - ➡ How do fast quarks or gluons interact as they traverse nuclear matter?

Low-x physics: problems with our current understanding



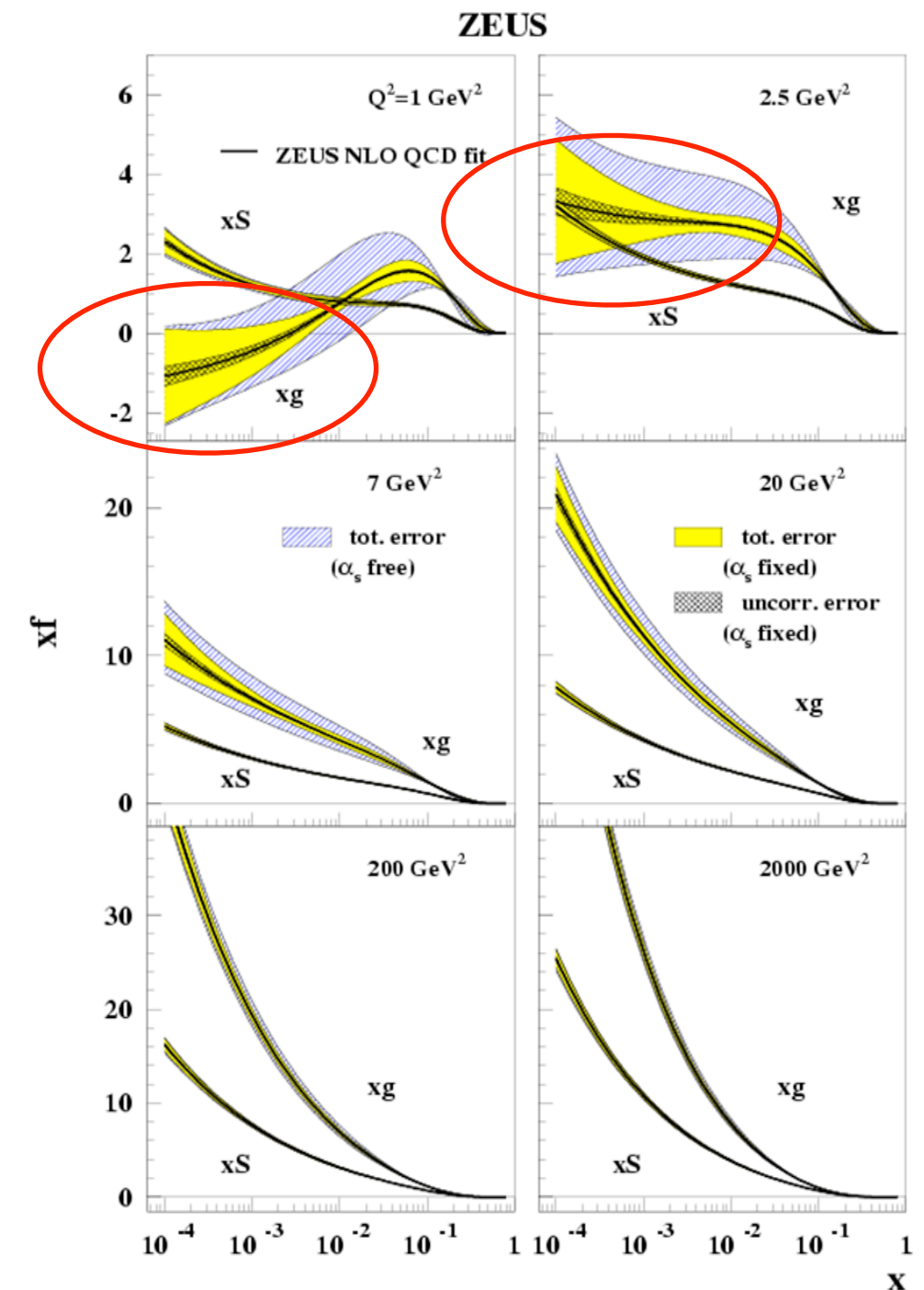
Low-x physics: problems with our current understanding

- Using the Linear DGLAP evolution model:

➔ Weird behaviour of xG at low- x and low Q^2 in HERA data

▶ xG goes negative !!

▶ $xS > xG$, though sea quarks come from gluon splitting ...



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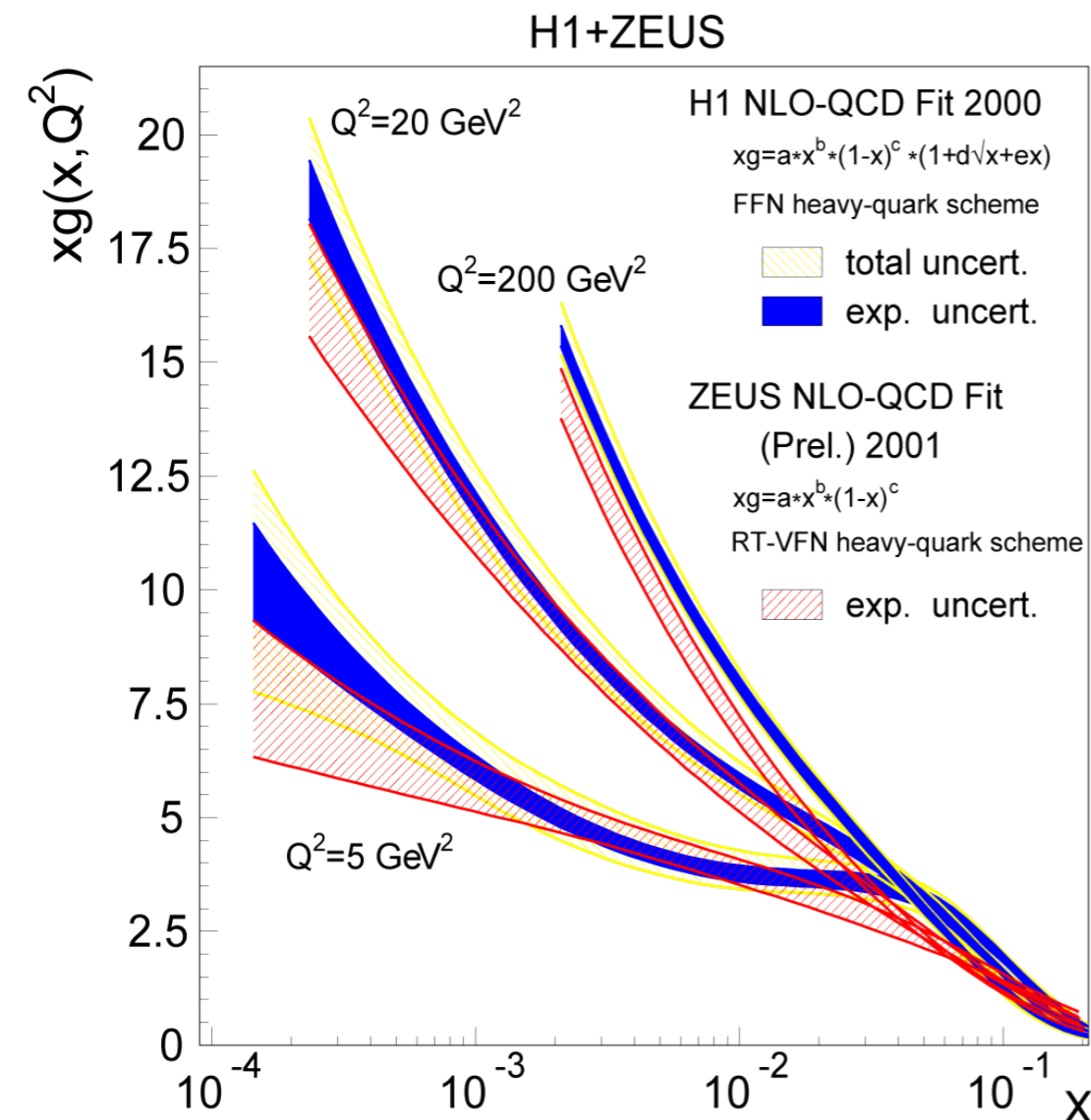
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- More severe

- ➔ Linear evolution has a built-in high-energy “catastrophe”

- ➔ xG has rapid rise with decreasing x (and increasing Q^2) $\Rightarrow$ violation of Froissart unitarity bound

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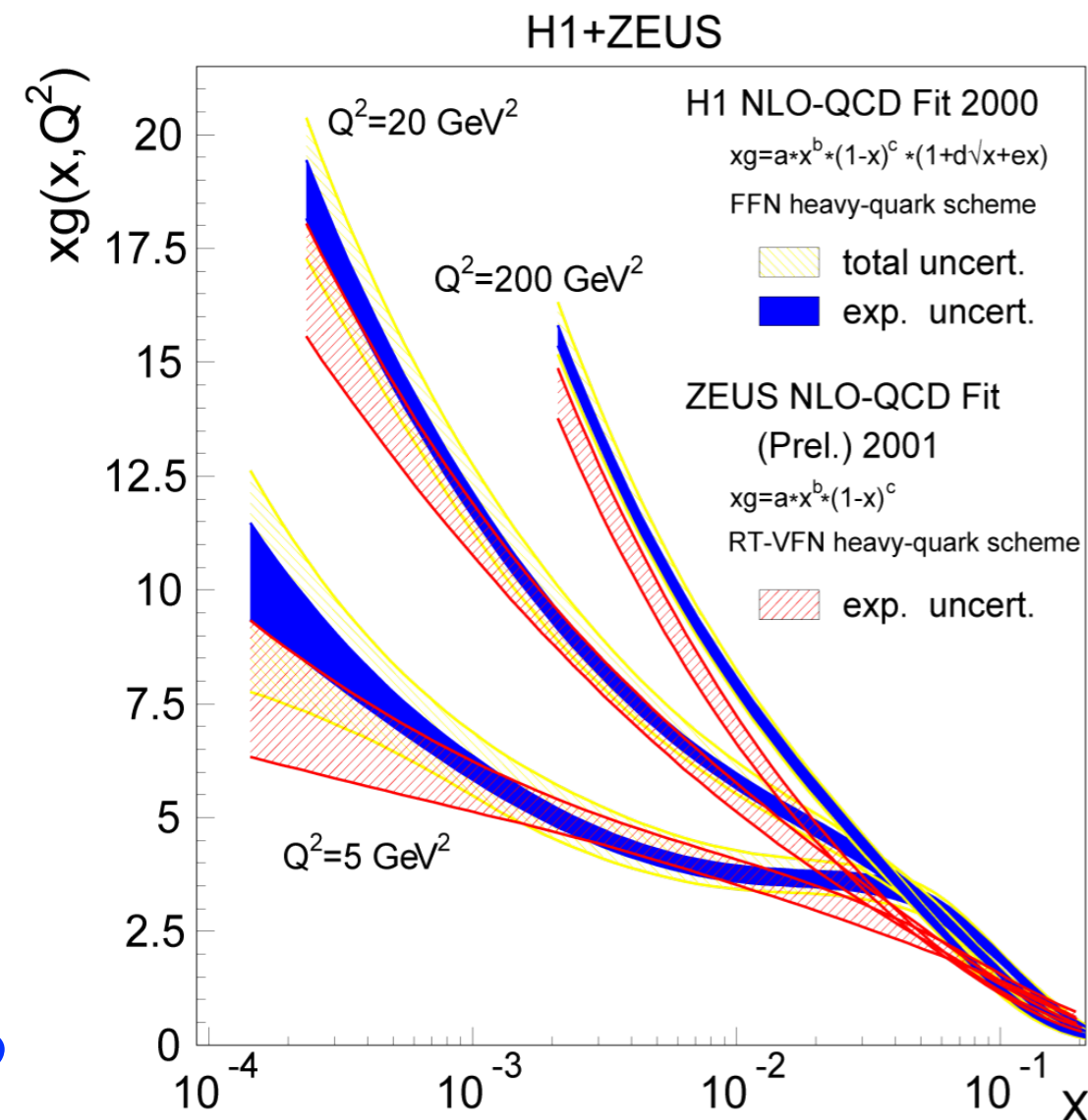
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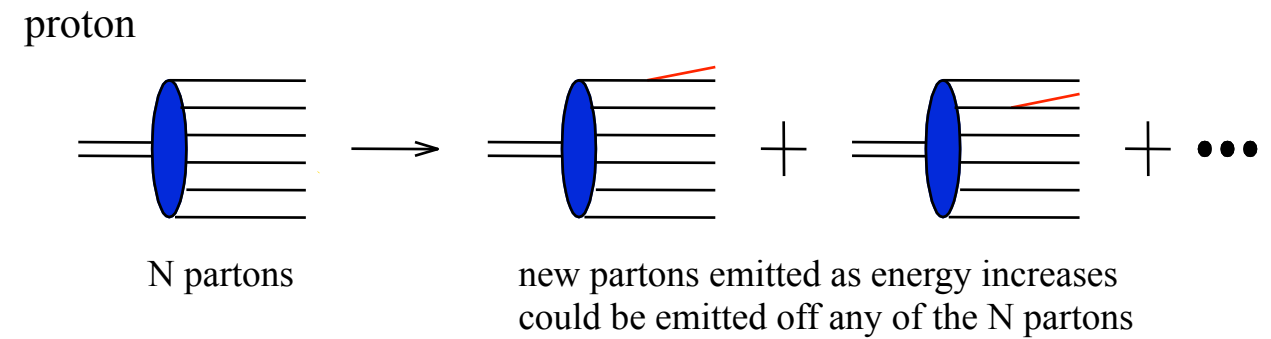
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What's the underlying dynamics?



Non-linear QCD - saturation

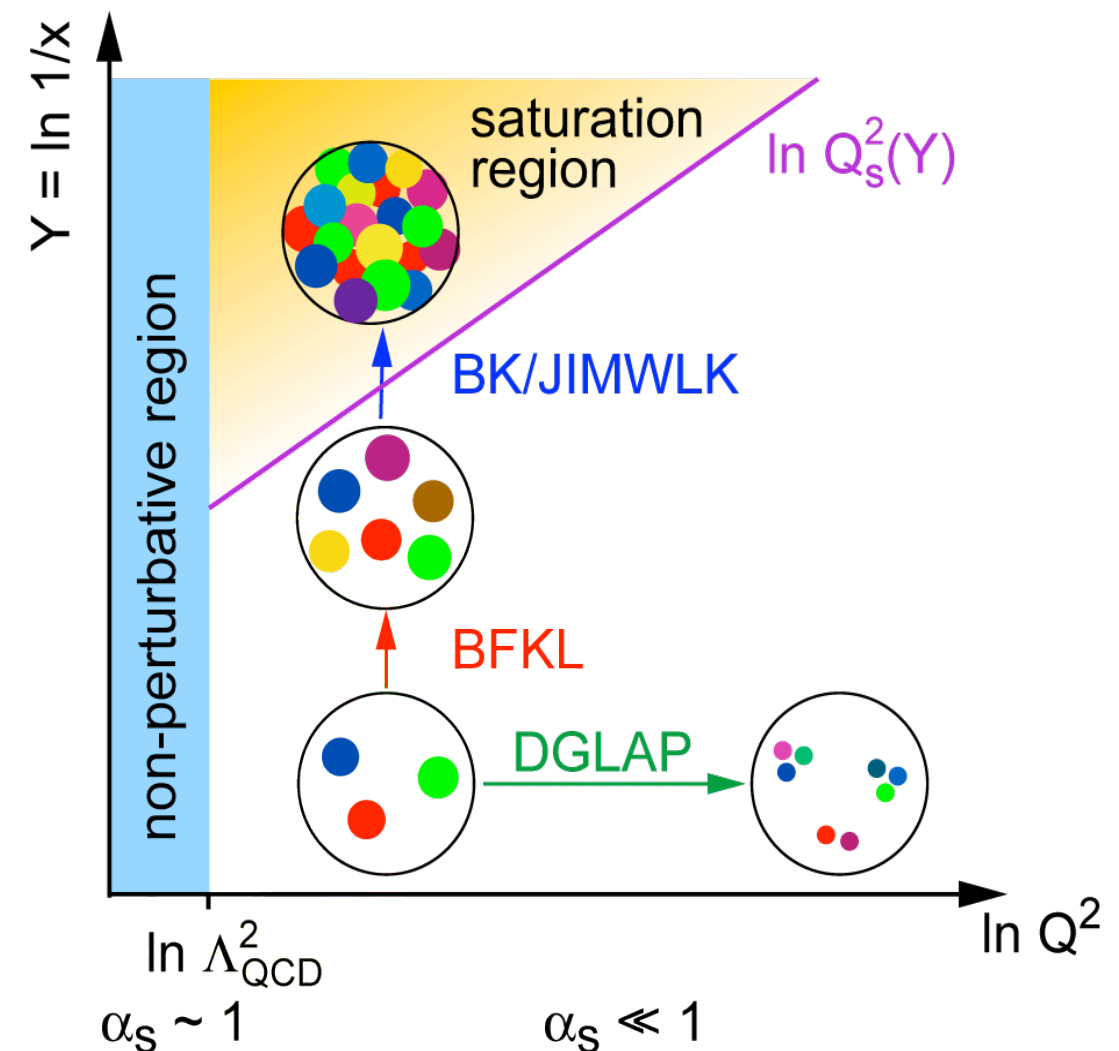
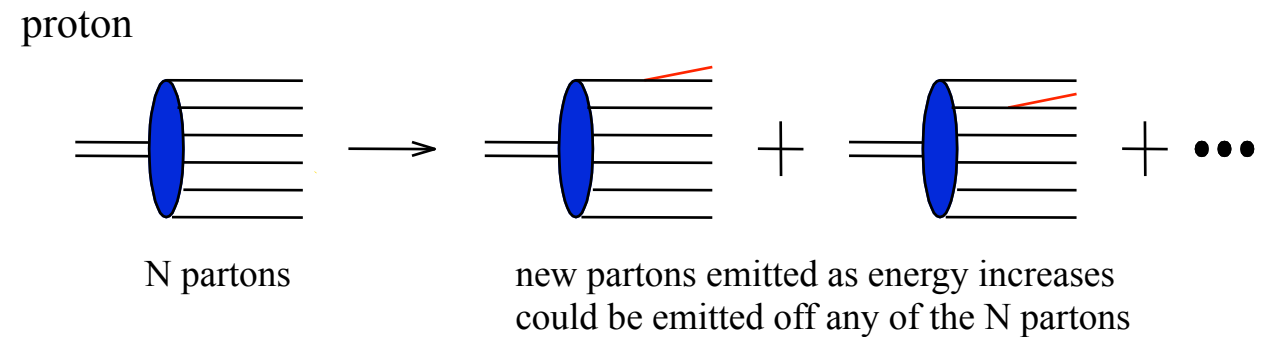


Non-linear QCD - saturation

- **BFKL**: evolution in x

→ linear

► explosion in colour field at low- x



Non-linear QCD - saturation

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➔ linear

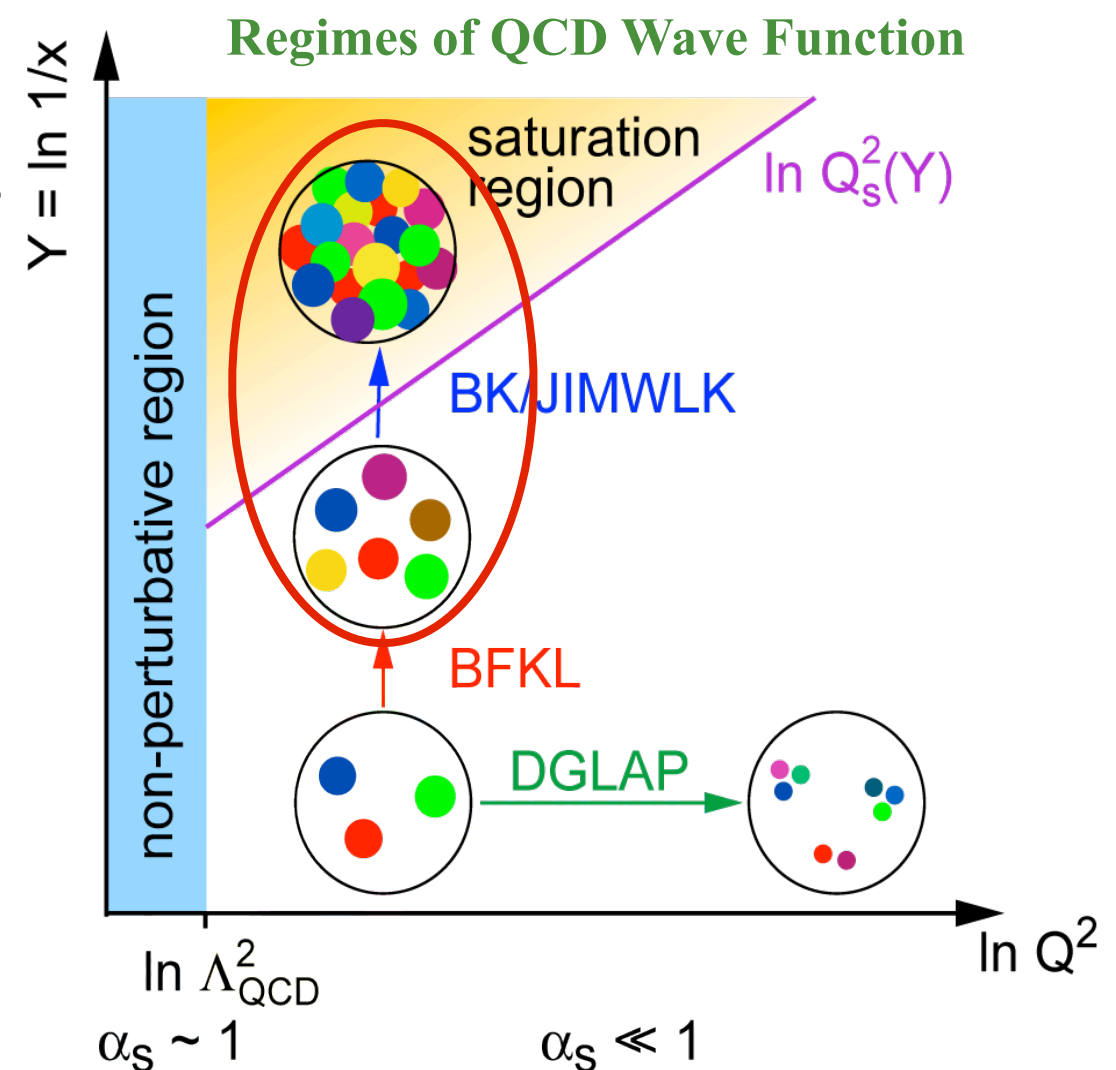
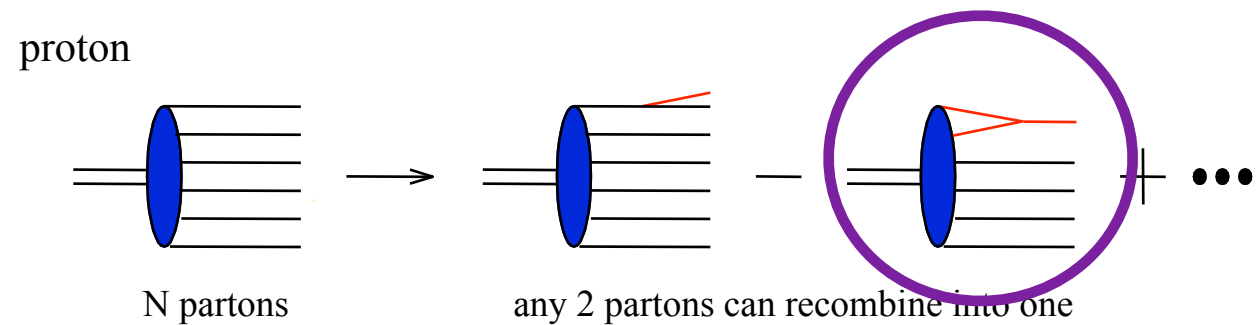
► explosion in colour field at low- x

- Non-linear **BK/JIMWLK** equations

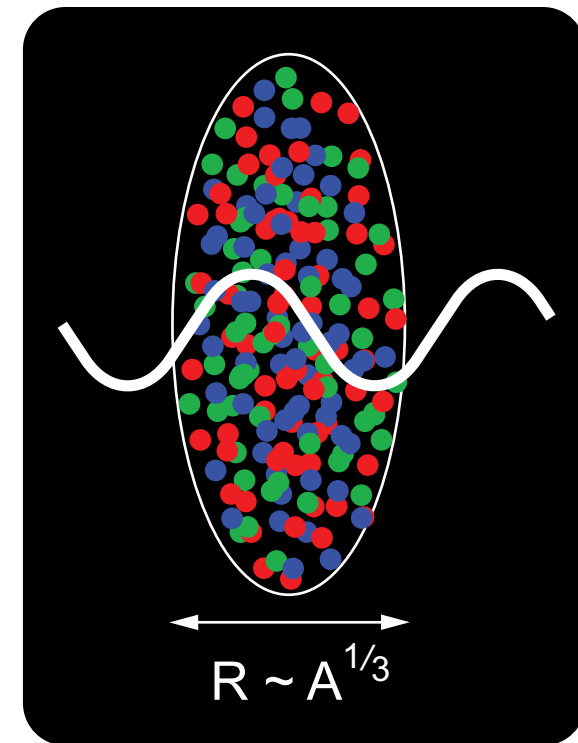
➔ non-linearity $\Rightarrow$ saturation

➔ characterised by the saturation scale, $Q_s(x,A)$

➔ arises naturally in the Colour Glass Condensate (CGC) EFT

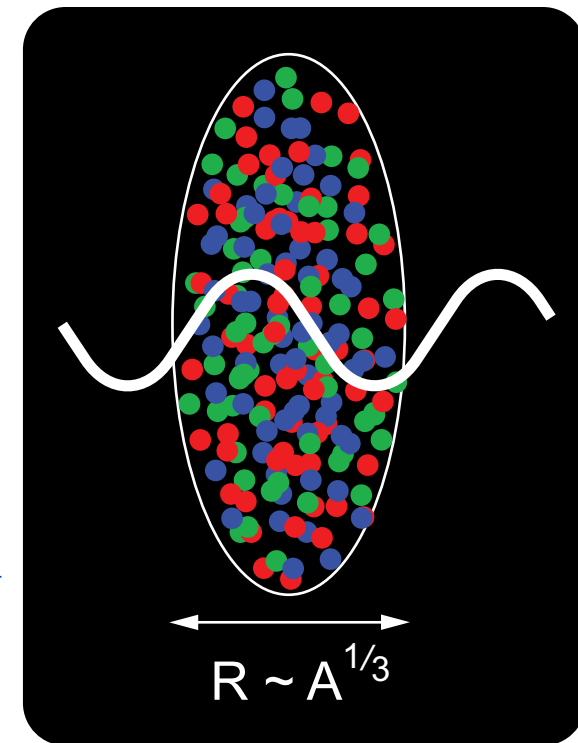


The nuclear enhancement factor



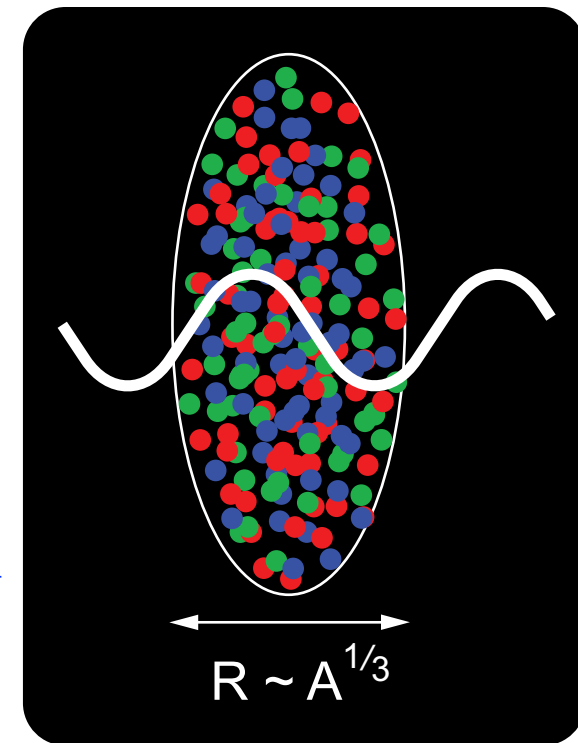
The nuclear enhancement factor

- Enhancing Saturation effects:
 - ➔ Probes interact over distances $L \sim (2m_n x)^{-1}$
 - ➔ For probes where $L > 2R_A (\sim A^{1/3})$, cannot distinguish between nucleons in front or back of the nucleus.
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 - ▶ Probe interacts coherently with all nucleons.
 - ➔ Probes with transverse resolution $1/Q^2 (\ll \Lambda^2_{\text{QCD}}) \sim 1 \text{ fm}^2$ will see large colour charge fluctuations.
 - ▶ This kick experienced in a random walk is the resolution scale.



The nuclear enhancement factor

Simple geometric considerations lead to:

$$Q_s^2 \propto \frac{\alpha_s x G(x, Q_s^2)}{\pi R_A^2} \quad \text{HERA: } xG \propto \frac{1}{x^{1/3}} \quad \text{A dependence: } xG_A \propto A$$

$$\text{Nuclear Enhancement Factor: } (Q_s^A)^2 \approx c Q_0^2 \left(\frac{A}{x} \right)^{1/3}$$

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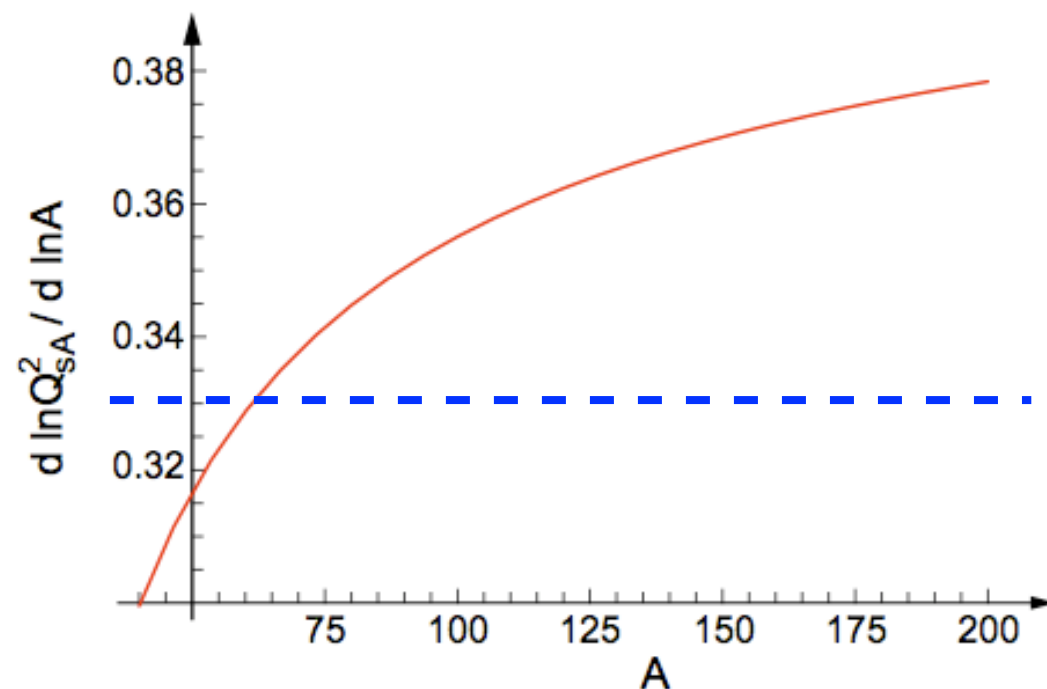
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*Enhancement of Q_s with A : $\Rightarrow$ non-linear QCD regime
reached at significantly lower
energy in $e+A$ than in $e+p$*

The nuclear “oomph factor”

More sophisticated analyses
⇒ confirm (exceed) pocket
formula for high A

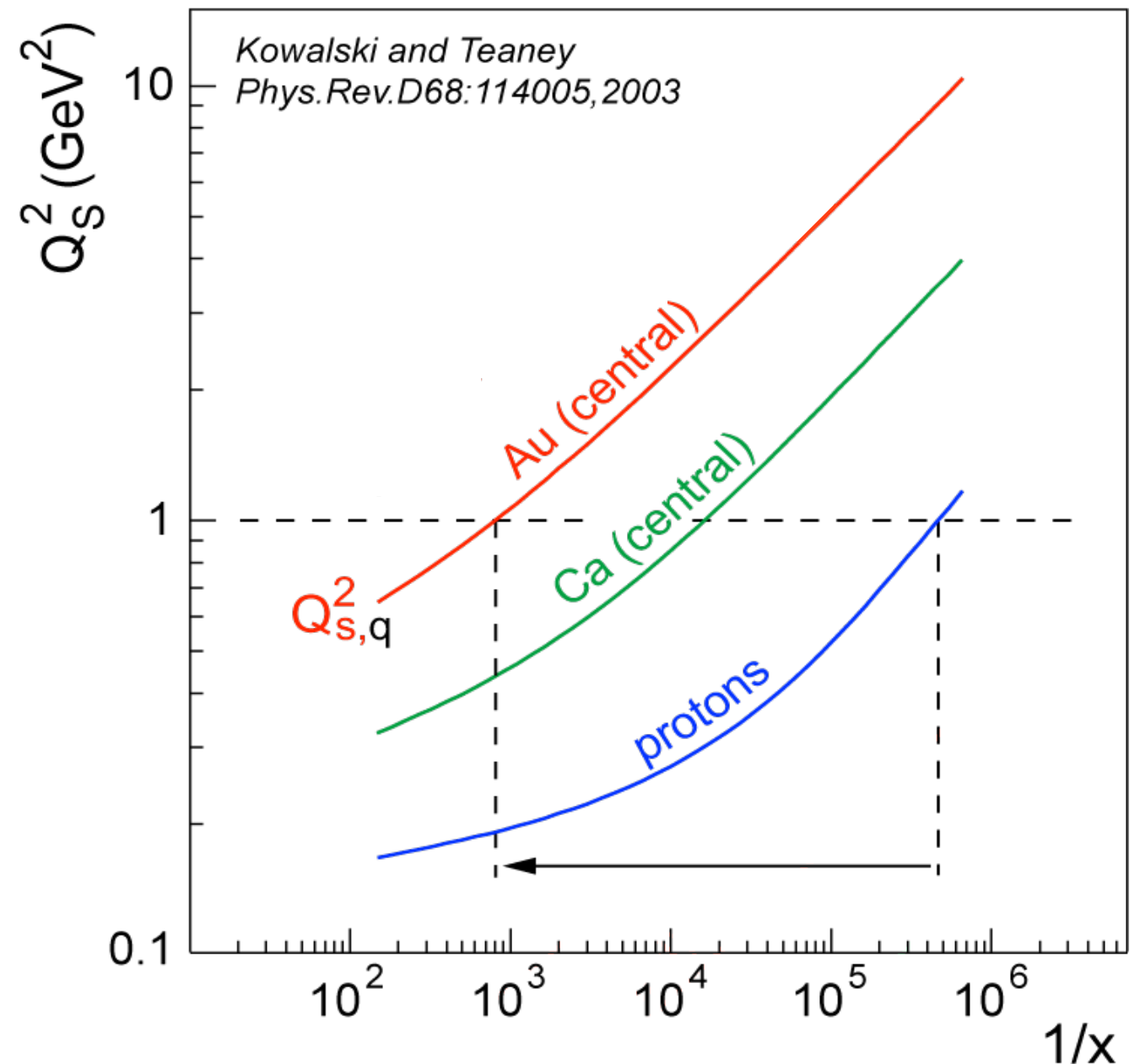
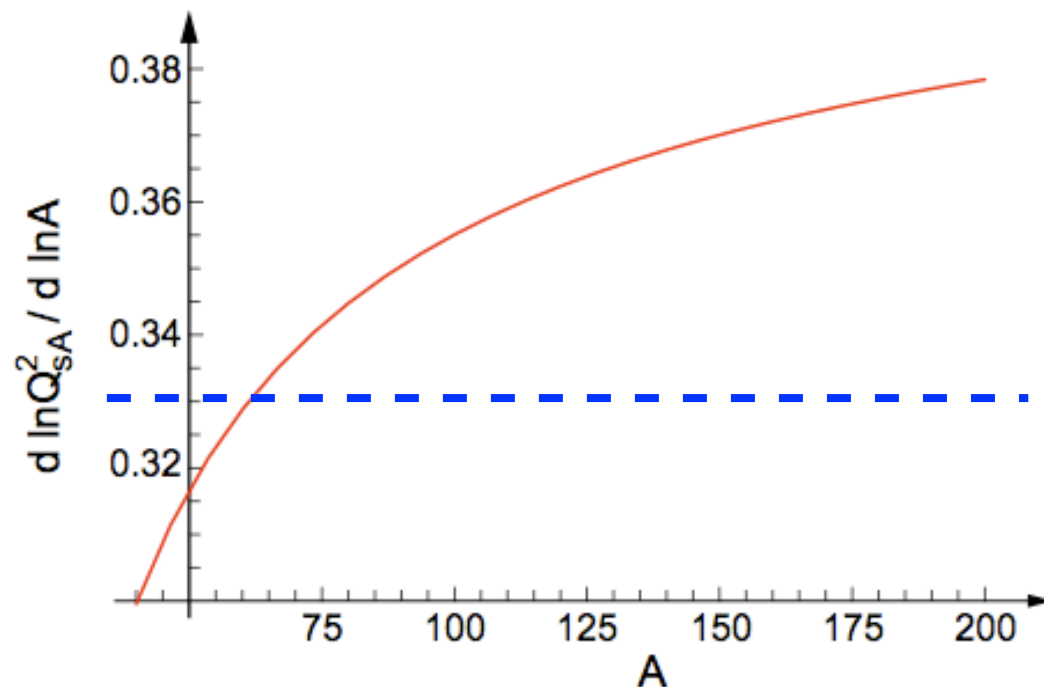
e.g. Kowalski, Lappi and Venugopalan,
PRL 100, 022303 (2008); Armesto et
al., PRL 94:022002; Kowalski, Teaney,
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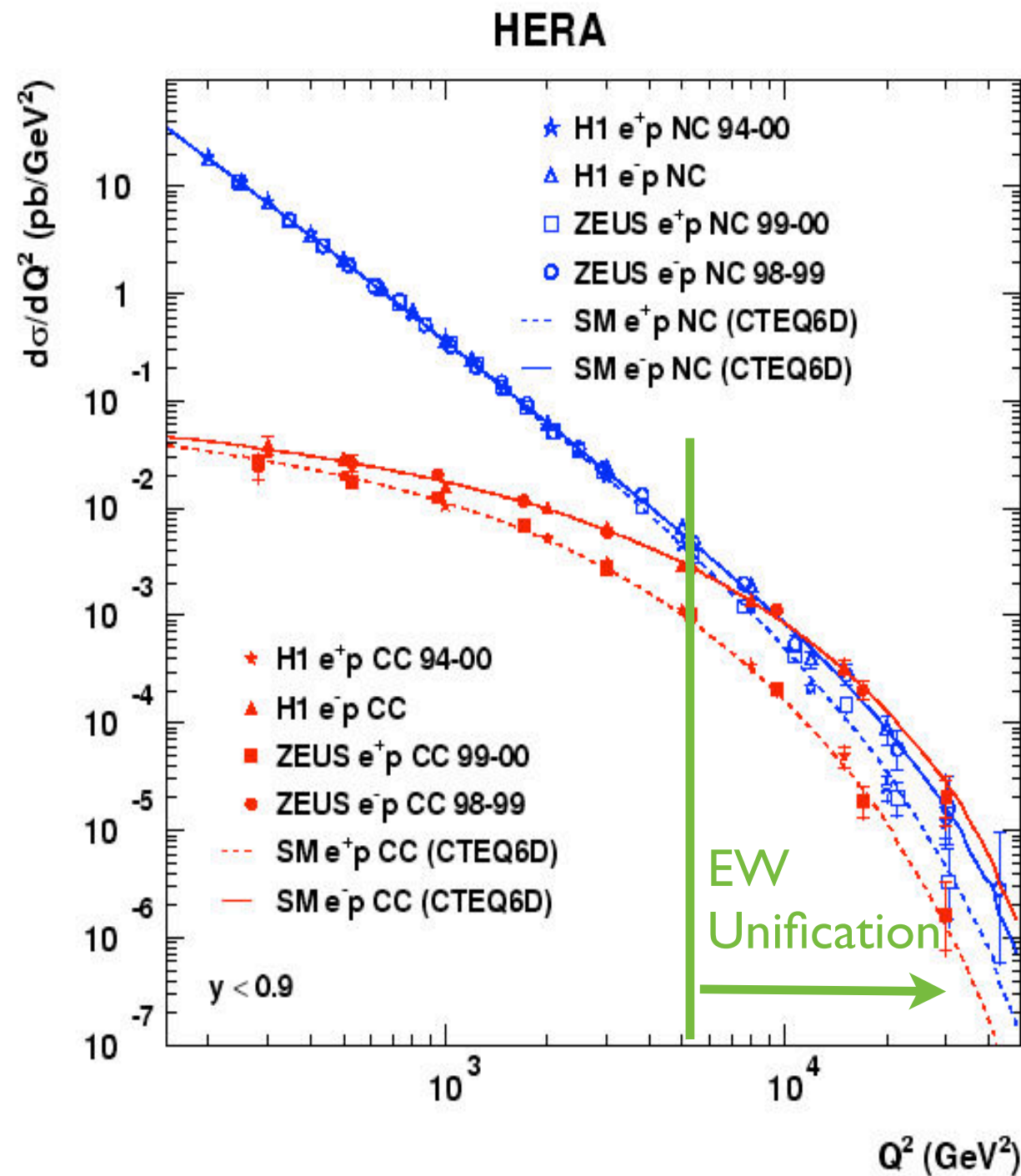
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One would require an energy in e+p
 $\sim 10\text{-}100 \times e+A$ to get to same Q_s^2

EW unification at HERA

- From DIS at HERA:



➡ At small-medium Q^2 , $\sigma(\text{NC}) \gg \sigma(\text{CC})$

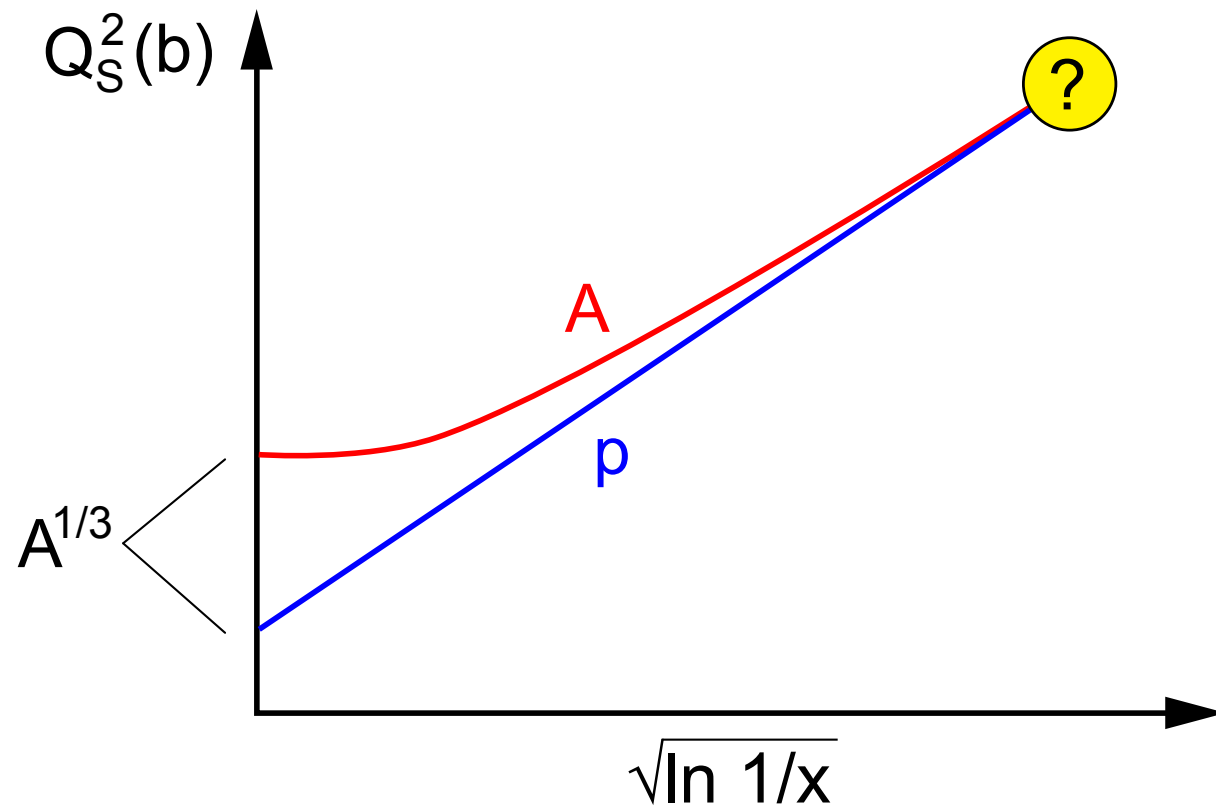
➡ For $Q^2 > M_Z^2$ and M_W^2 , $\sigma(\text{NC}) \sim \sigma(\text{CC})$

► EW Unification

- Already a textbook figure ...

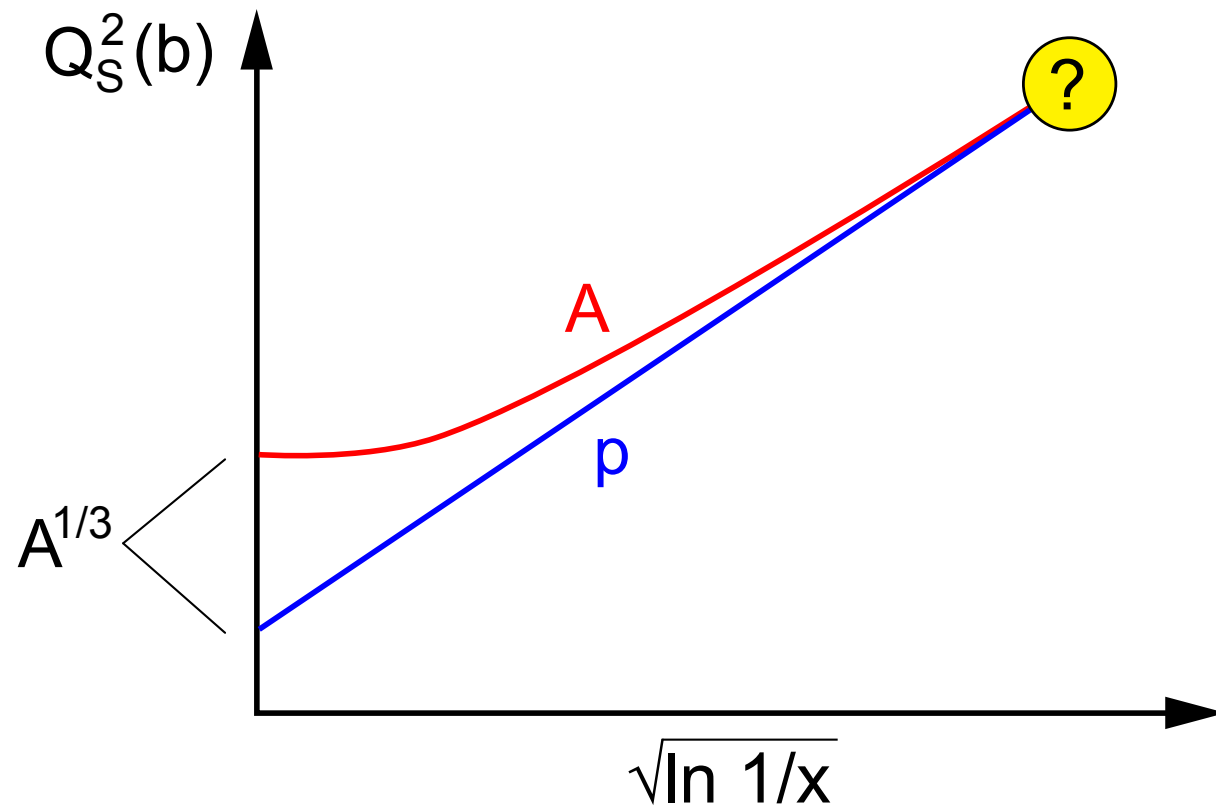
Matter at low-x: A truly universal regime?

What about on the parton scale?



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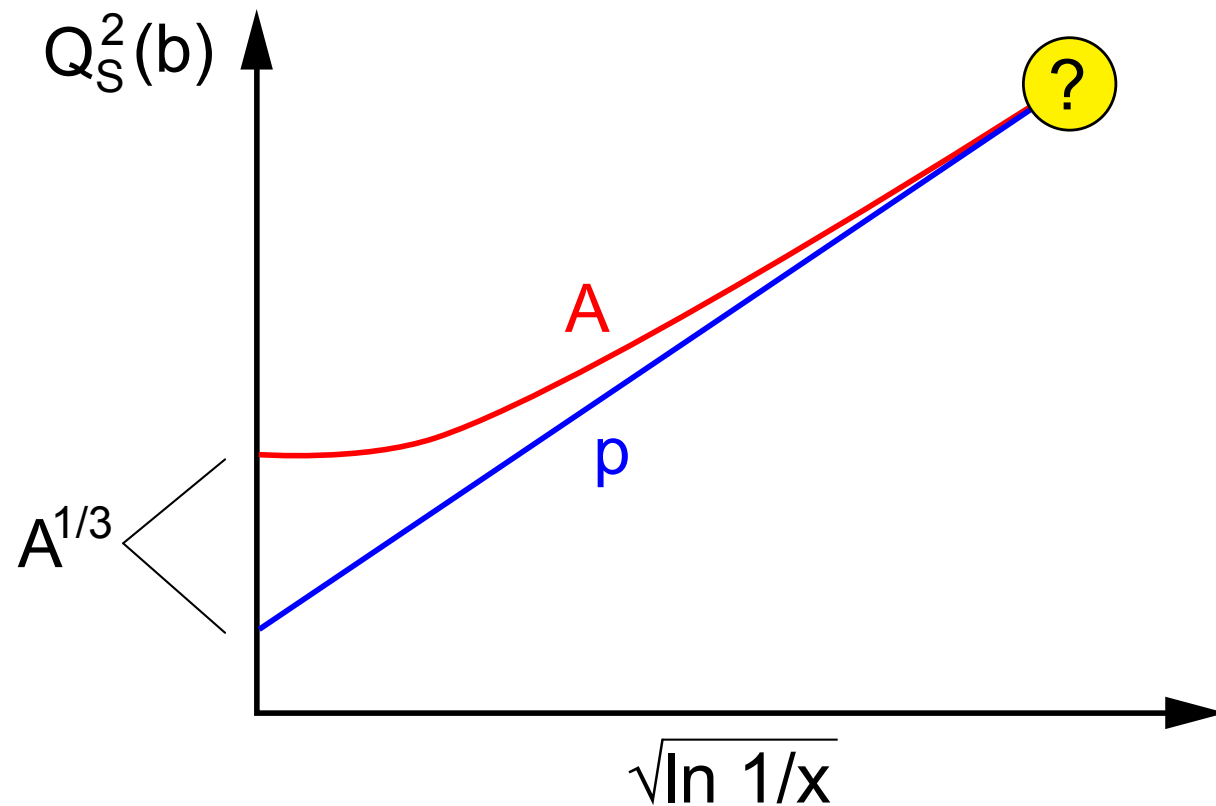


A.H. Mueller, hep-ph/0301109

- Small-x running-coupling BFKL QCD evolution predicts:
 - Q_s approaches universal behaviour for **all** hadrons and nuclei
 - No dependence on A !!
 - Not only functional form $f(Q_s)$ universal, but even Q_s itself becomes universal

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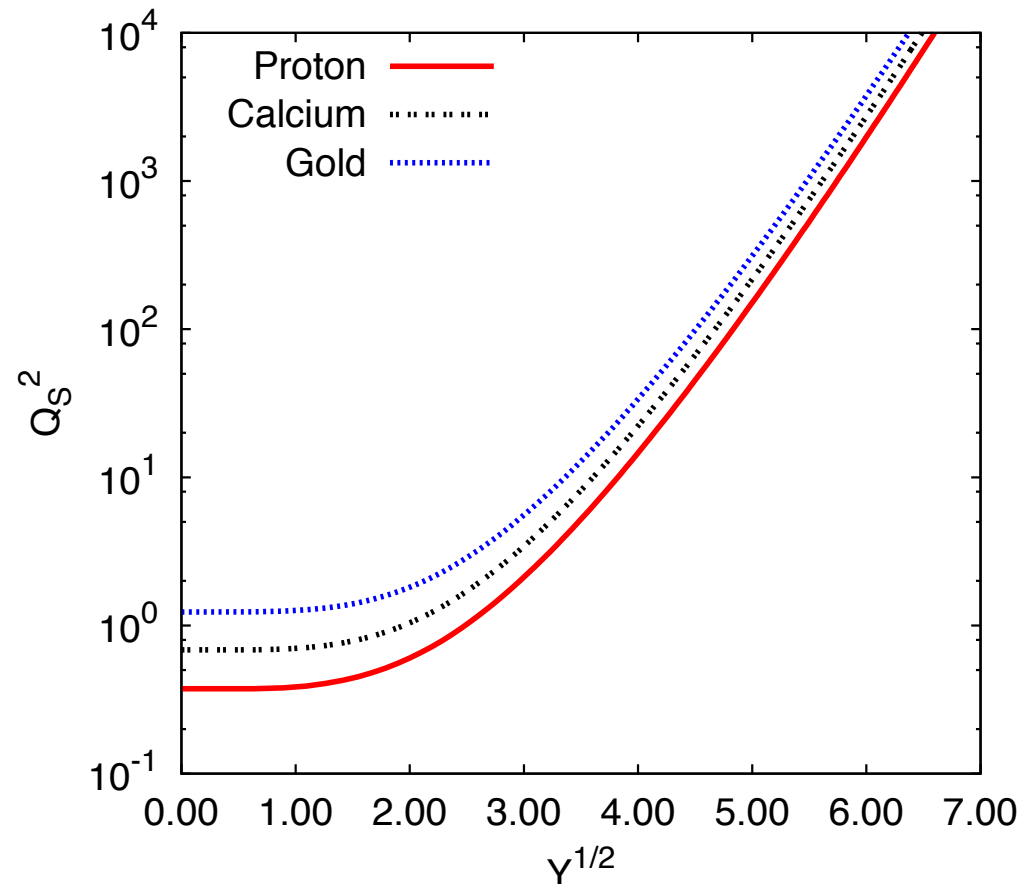
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Radical View:

- ➡ Nuclei and all hadrons have a component of their wave function with the **same** behaviour
- ➡ This is a conjecture! Needs to be tested

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Dusling, Gelis, Lappi and Venugopalan arXiv:0911.2720

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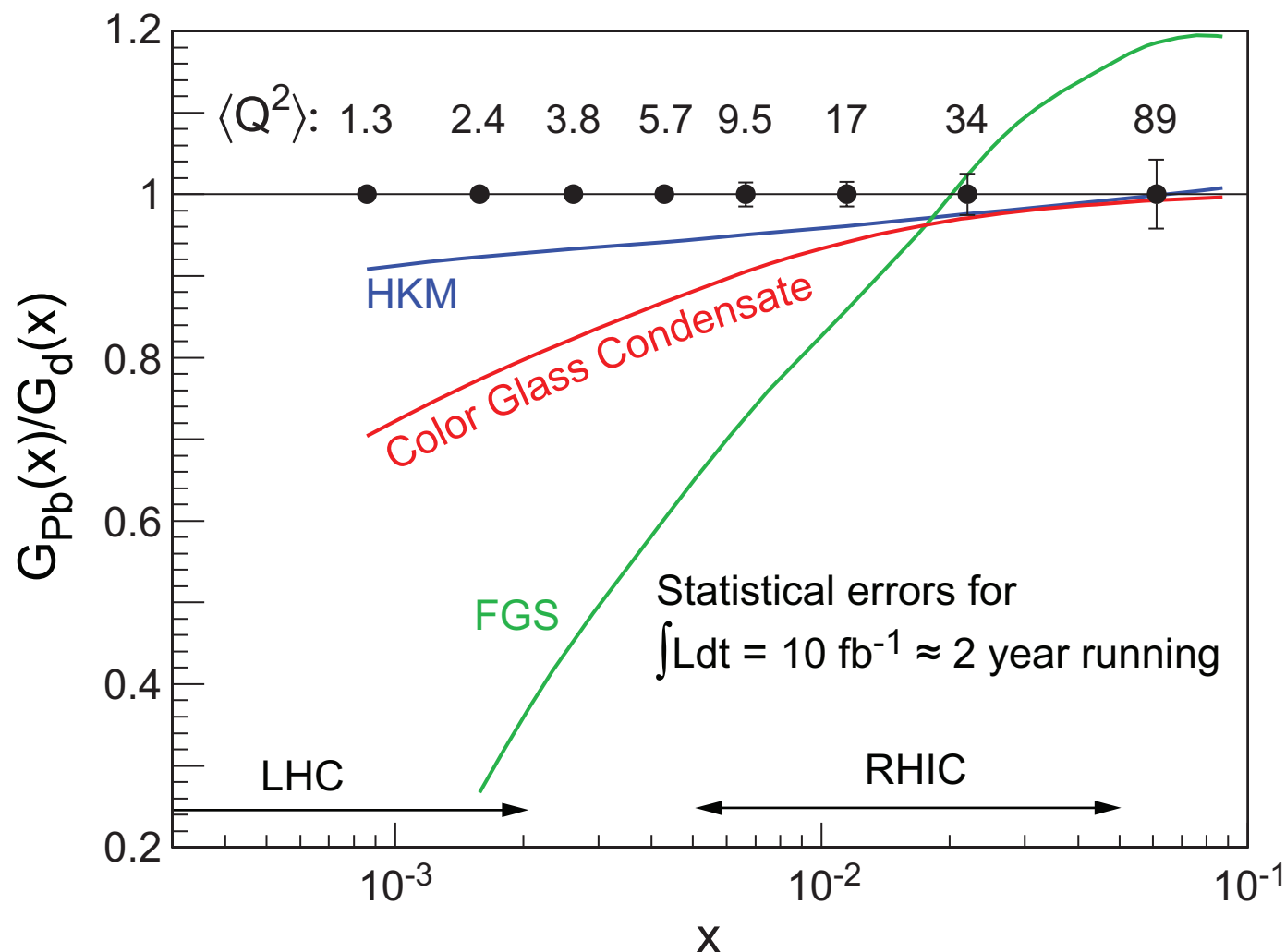
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Key measurements in $e+A$

- ***Momentum* distribution of gluons $xG(x, Q^2)$**
 - ➔ Extract via scaling violation in F_2 : $\delta F_2 / \delta \ln Q^2$
 - ➔ Direct measurement: $F_L \sim xG(x, Q^2)$ (requires $\sqrt{s}$ scan)
 - ➔ 2+1 jet rates
 - ➔ Inelastic vector meson production (e.g. J/ψ)
 - ➔ Diffractive vector meson production $\sim [xG(x, Q^2)]^2$

Example of key measurements: F_L

$$\frac{d^2\sigma^{ep\rightarrow eX}}{dx dQ^2} = \frac{4\pi\alpha_{e.m.}^2}{xQ^4} \left[\left(1 - y + \frac{y^2}{2}\right) F_2(x, Q^2) - \frac{y^2}{2} F_L(x, Q^2) \right]$$



HKM and FGS are "standard" shadowing parameterizations that are evolved with DGLAP

$$F_L \sim \alpha_s xG(x, Q^2)$$

requires $\sqrt{s}$ scan, $Q^2/xs = y$

Here:

$$\begin{aligned} \int L dt &= 4/A \text{ fb}^{-1} \text{ (10+100) GeV} \\ &= 4/A \text{ fb}^{-1} \text{ (10+50) GeV} \\ &= 2/A \text{ fb}^{-1} \text{ (5+50) GeV} \end{aligned}$$

statistical error only

Syst. studies of $F_L(A, x, Q^2)$:

- $xG(x, Q^2)$ with great precision
- Distinguish between models

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- ***Space-time* distributions of gluons in matter**
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 - ➔ Deep Virtual Compton Scattering (DVCS) - $\sigma \sim A^{4/3}$
 - ➔ F_2, F_L for various A and impact parameter dependence

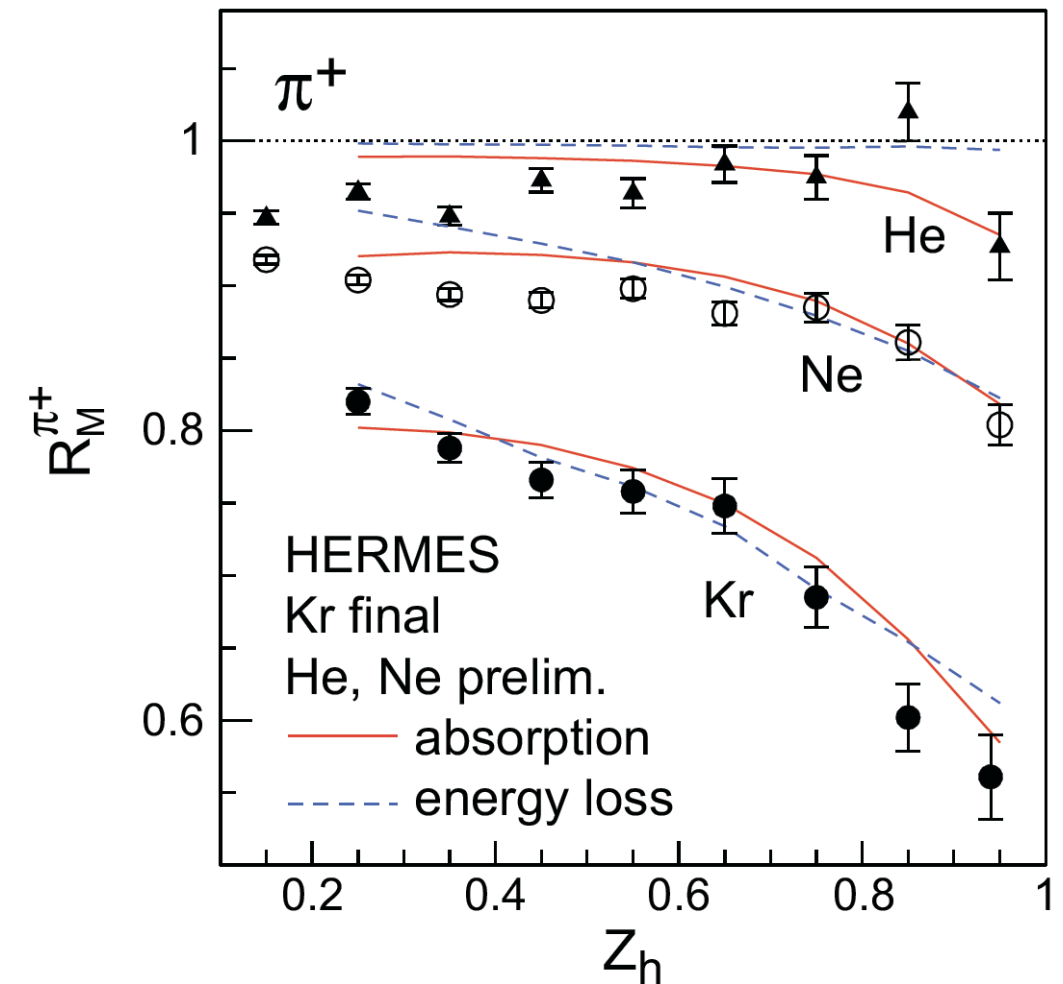
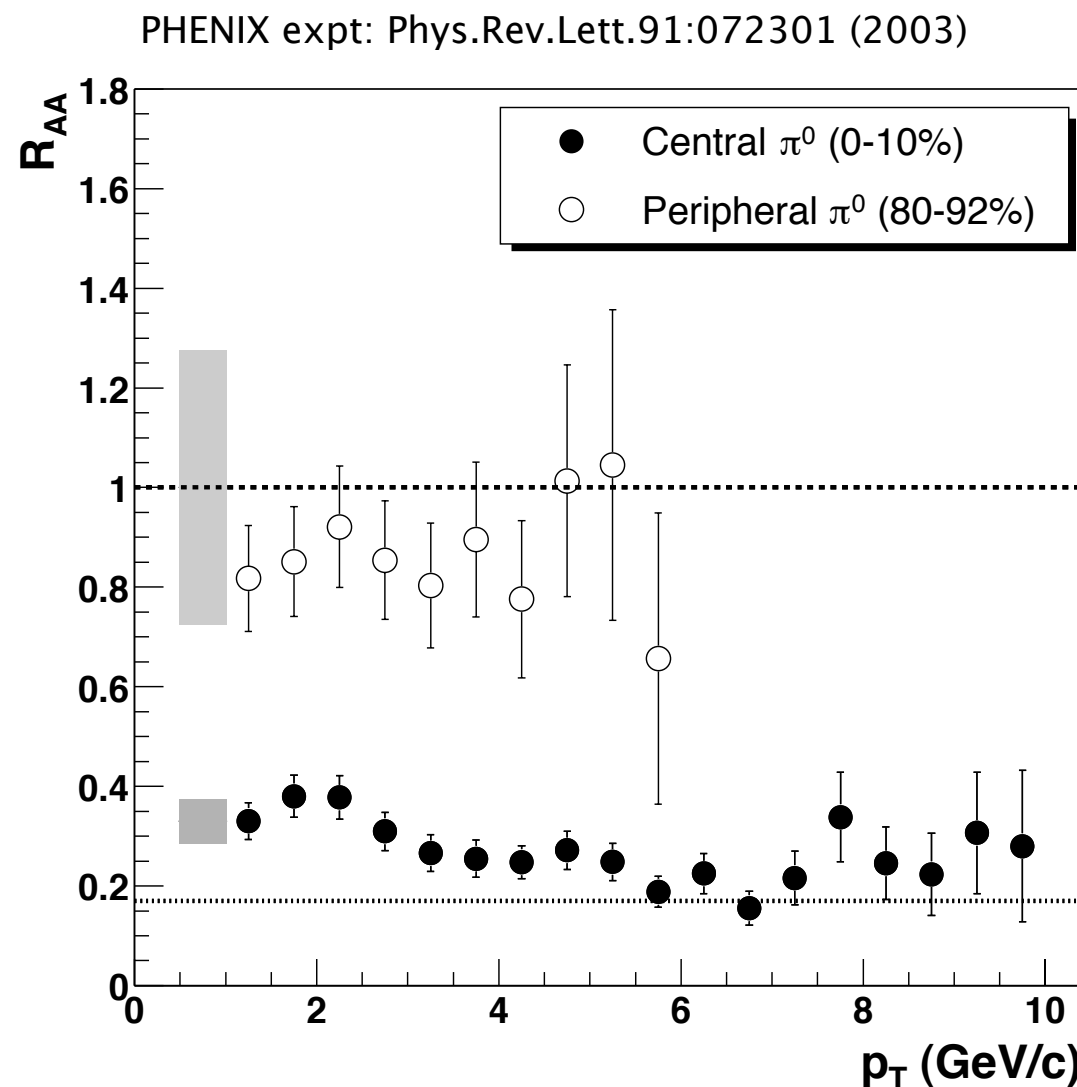
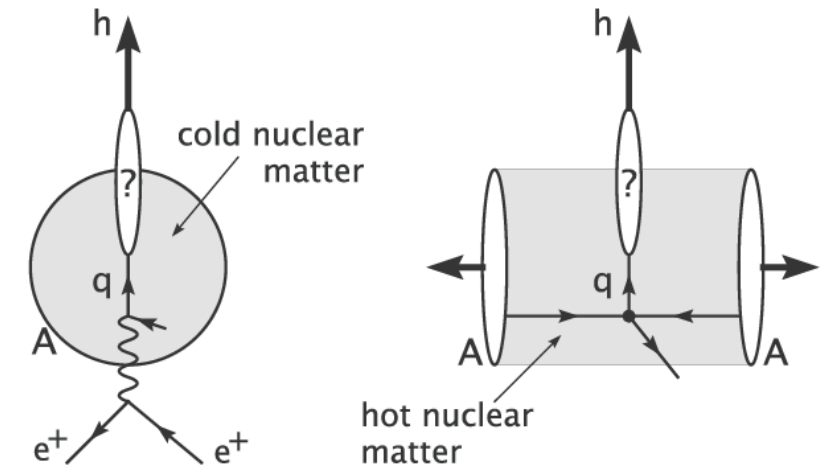
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- **Interaction of fast probes with *gluonic* medium?**
 - ➔ Hadronization, Fragmentation
 - ➔ Energy loss (charm, bottom!)

Interaction of fast probes with a gluonic medium

- nDIS:

- ➔ Clean measurement in 'cold' nuclear matter
- ➔ Suppression of high- p_T hadrons analogous to, but weaker than at RHIC



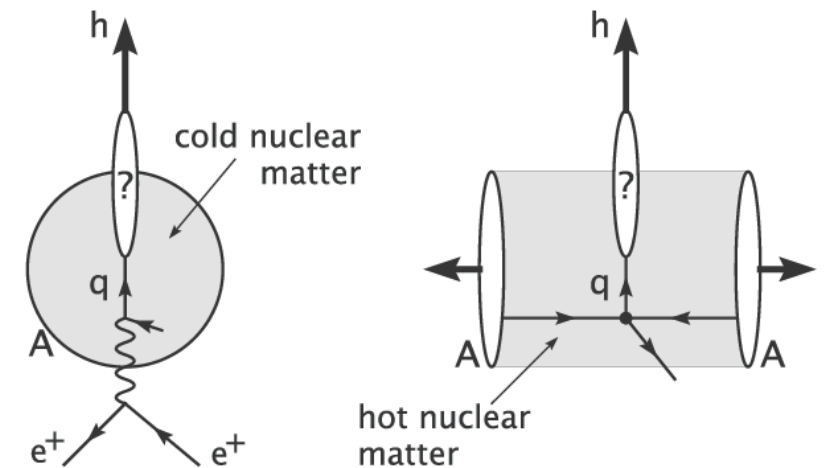
ν = virtual photon energy

$Z_h = E_h/\nu$

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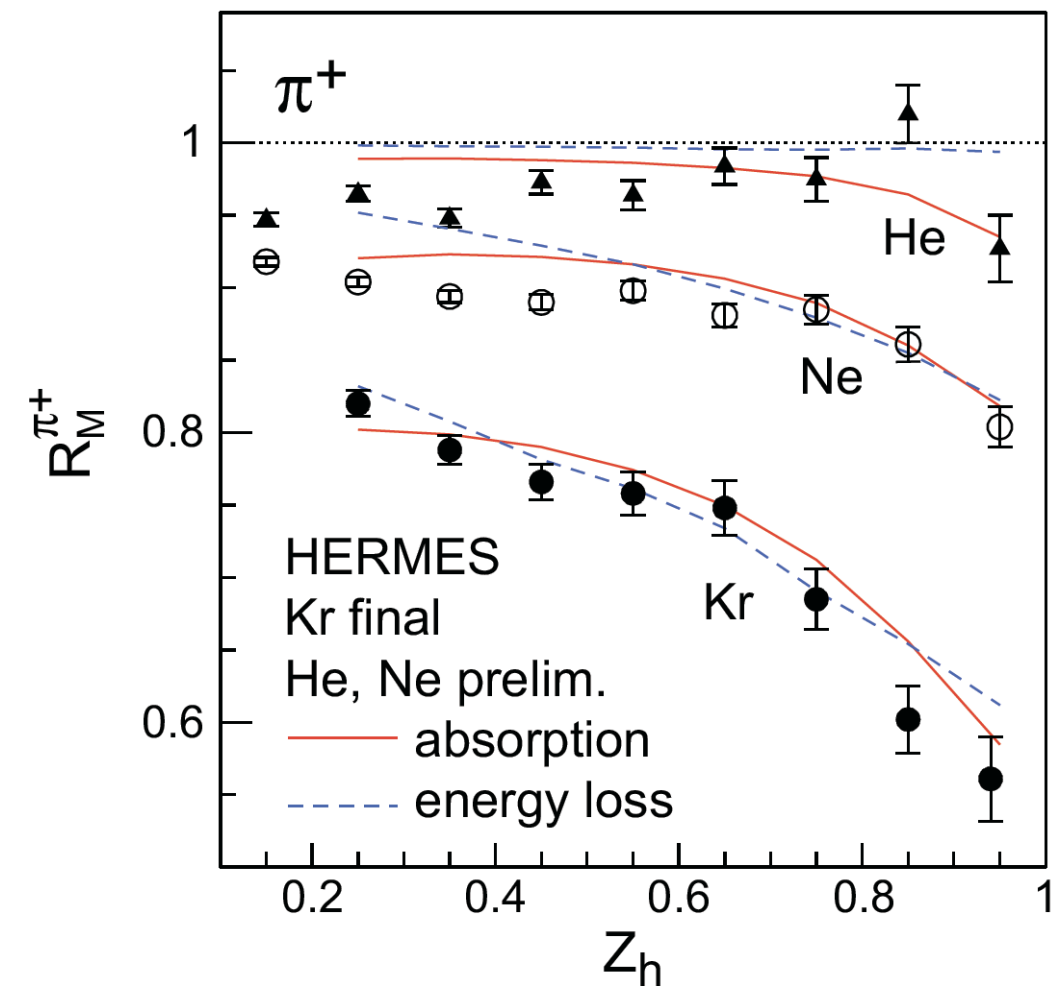
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- Fundamental question:

- When do partons get colour neutralized?

Parton energy loss vs. (pre)hadron absorption



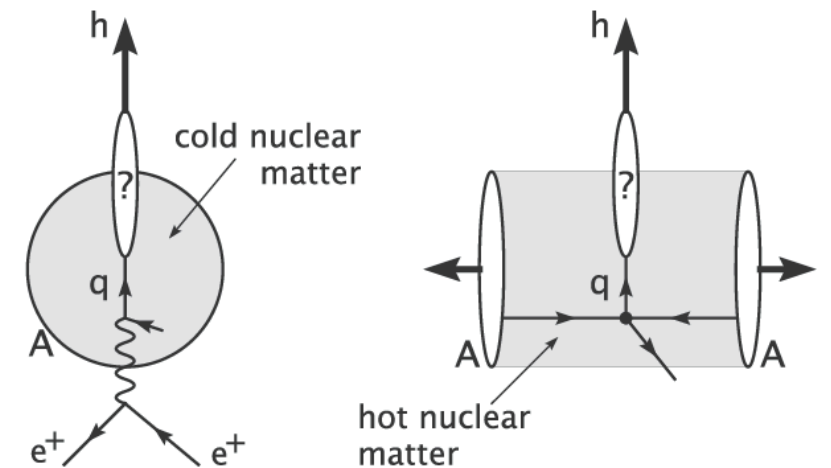
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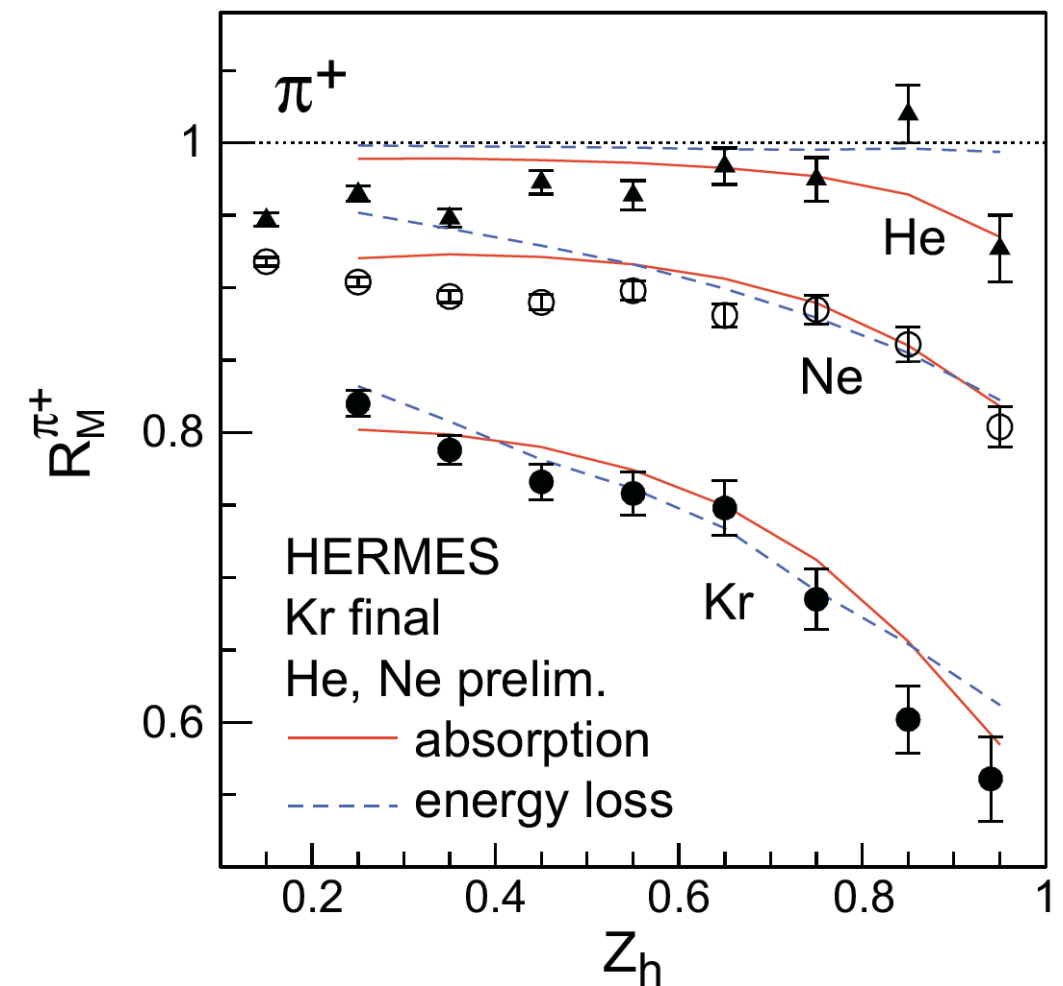
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Energy transfer in lab rest frame:

EIC: $10 < \nu < 1600$ GeV

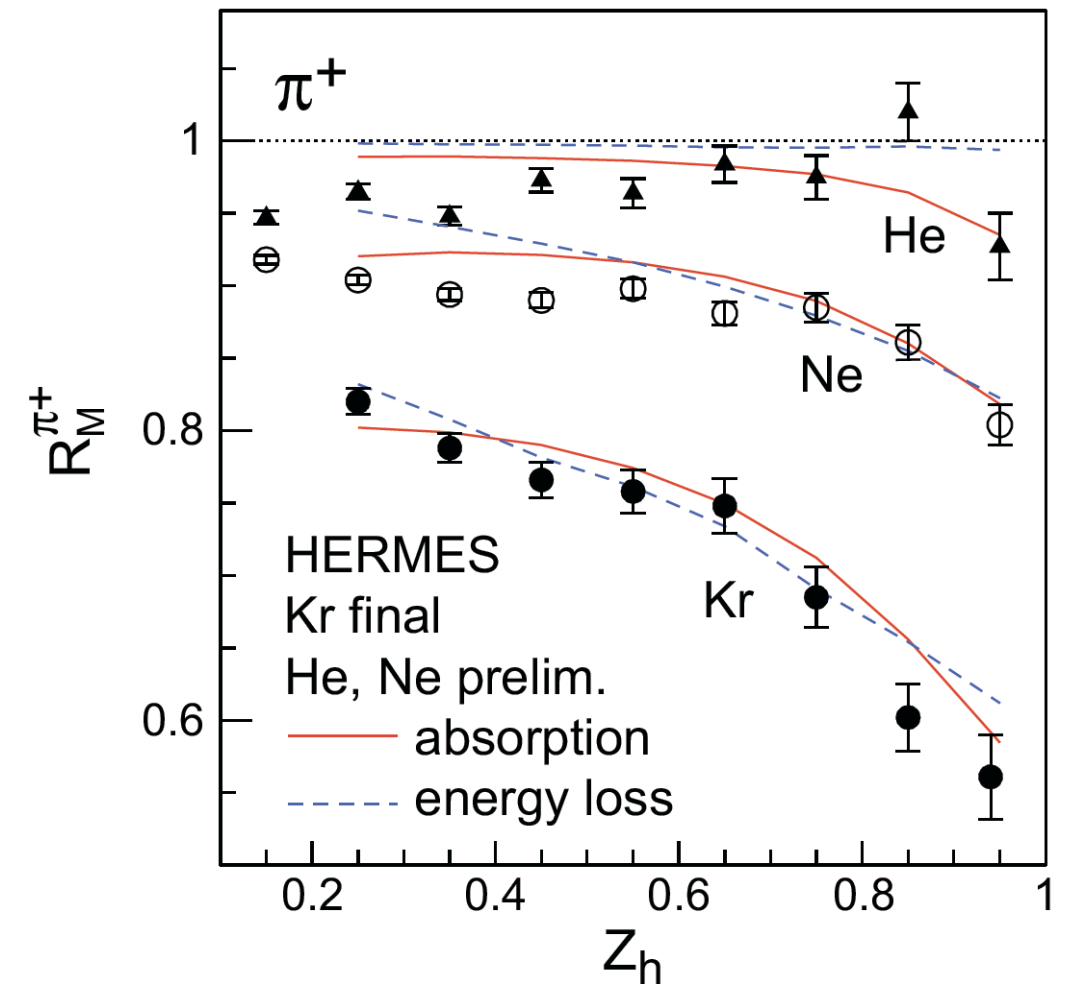
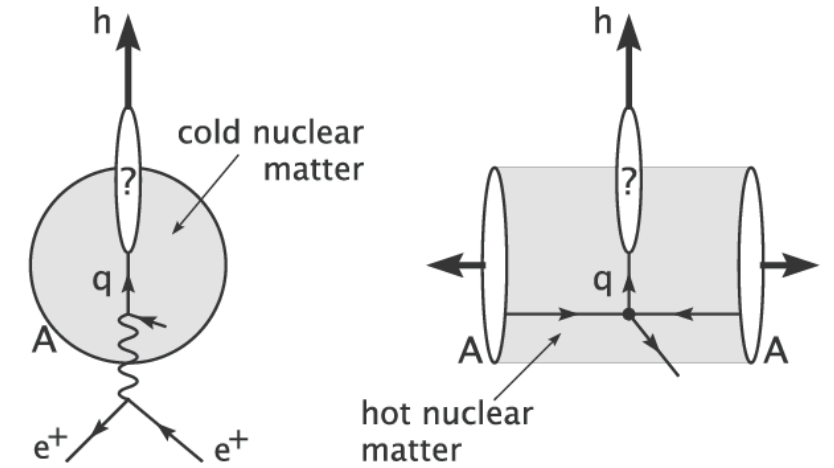
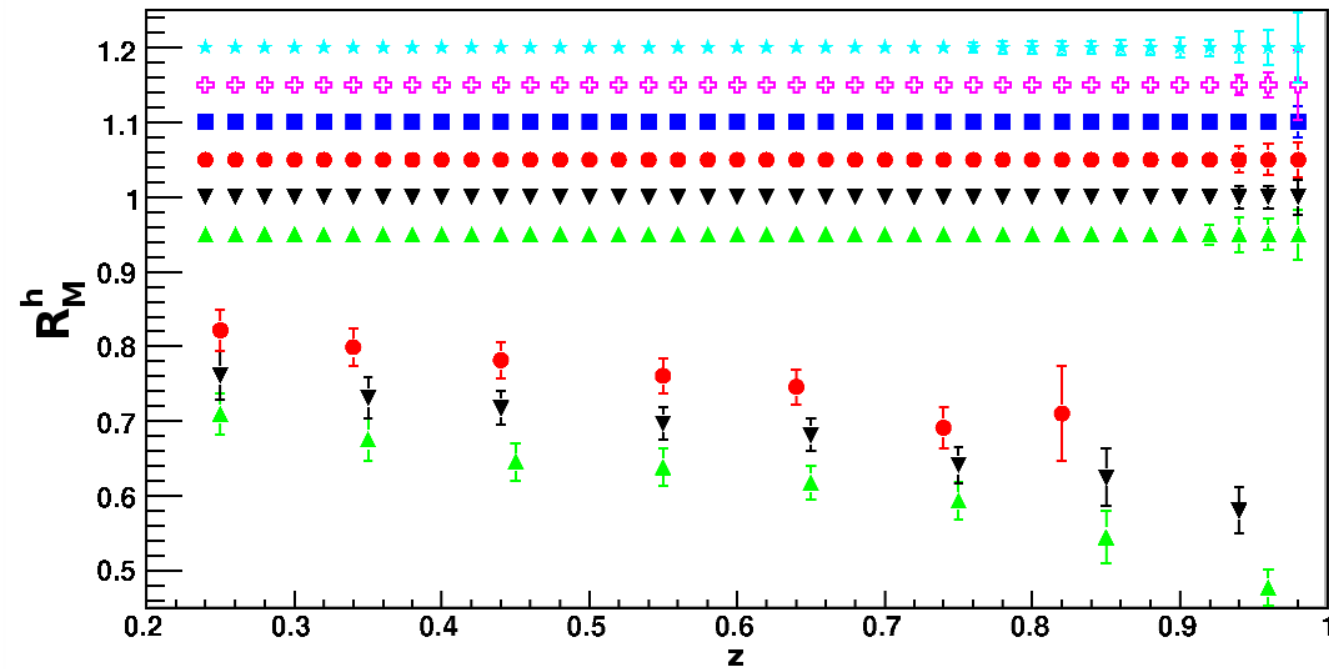
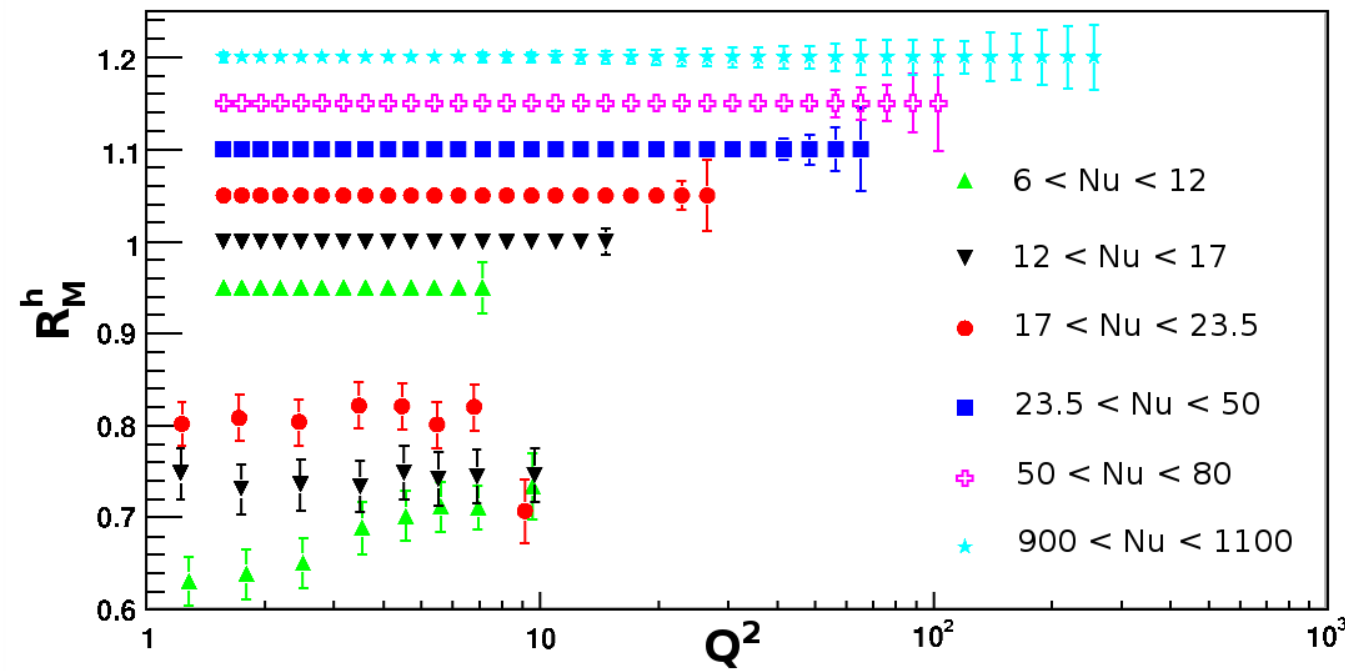
HERMES: 2-25 GeV



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Interaction of fast probes with a gluonic medium



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Key measurements in $e+A$

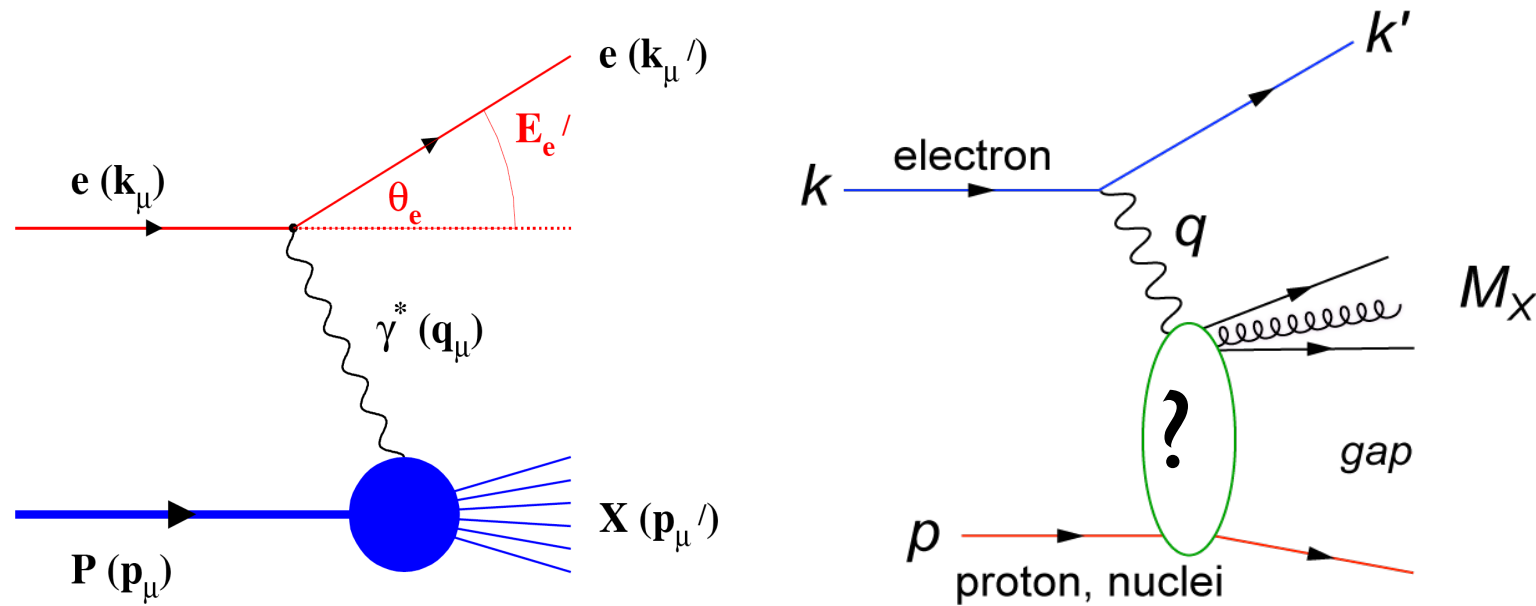
- **Momentum distribution of gluons $xG(x, Q^2)$**
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 - ➔ Direct measurement: $F_L \sim xG(x, Q^2)$ (requires $\sqrt{s}$ scan)
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- **Space-time distributions of gluons in matter**
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 - ➔ Deep Virtual Compton Scattering (DVCS) - $\sigma \sim A^{4/3}$
 - ➔ F_2 , F_L for various A and impact parameter dependence
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 - ➔ Hadronization, Fragmentation
 - ➔ Energy loss (charm!)
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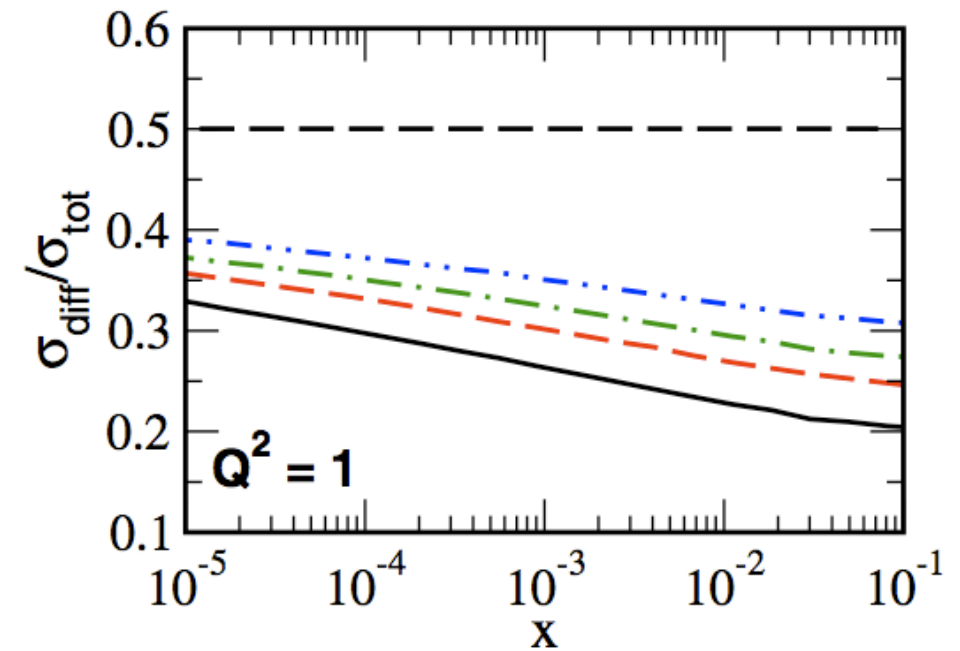
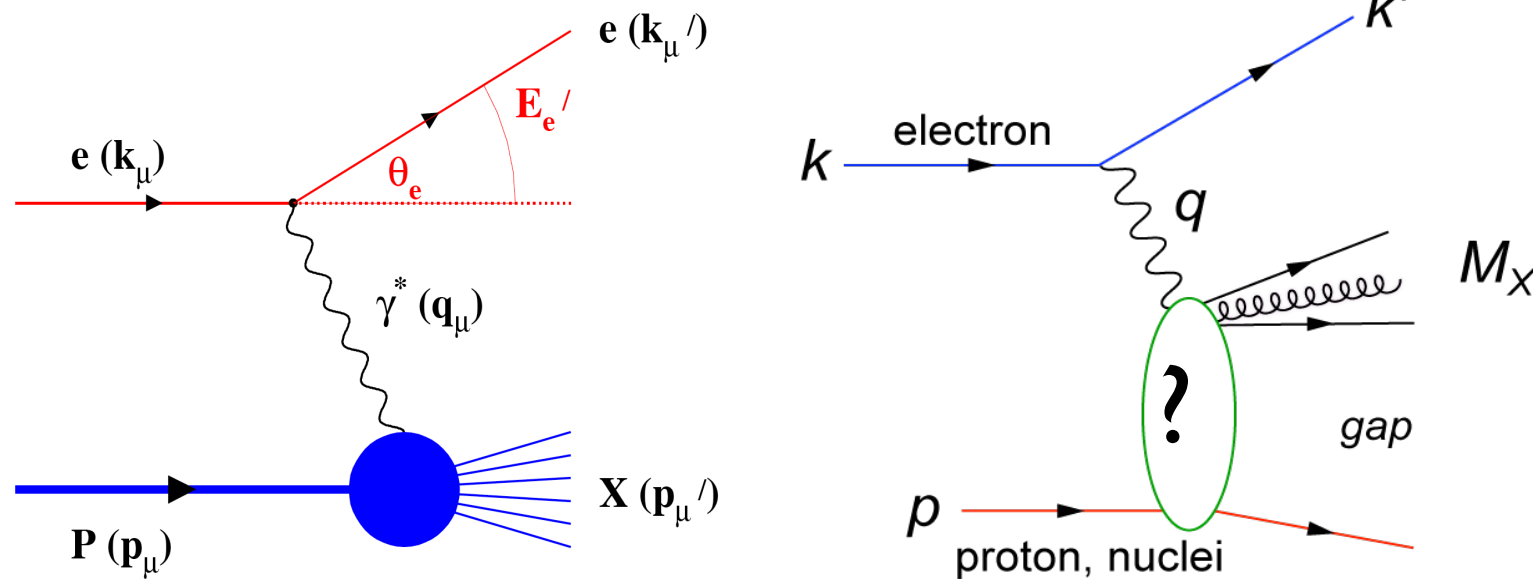
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HERA/ep: 15% of all events are hard diffractive

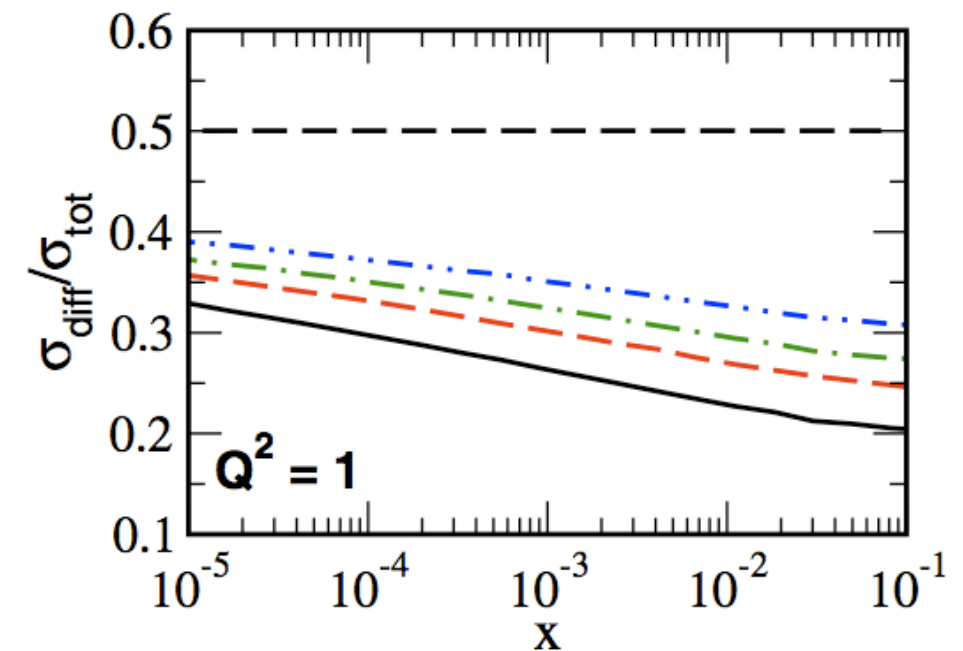
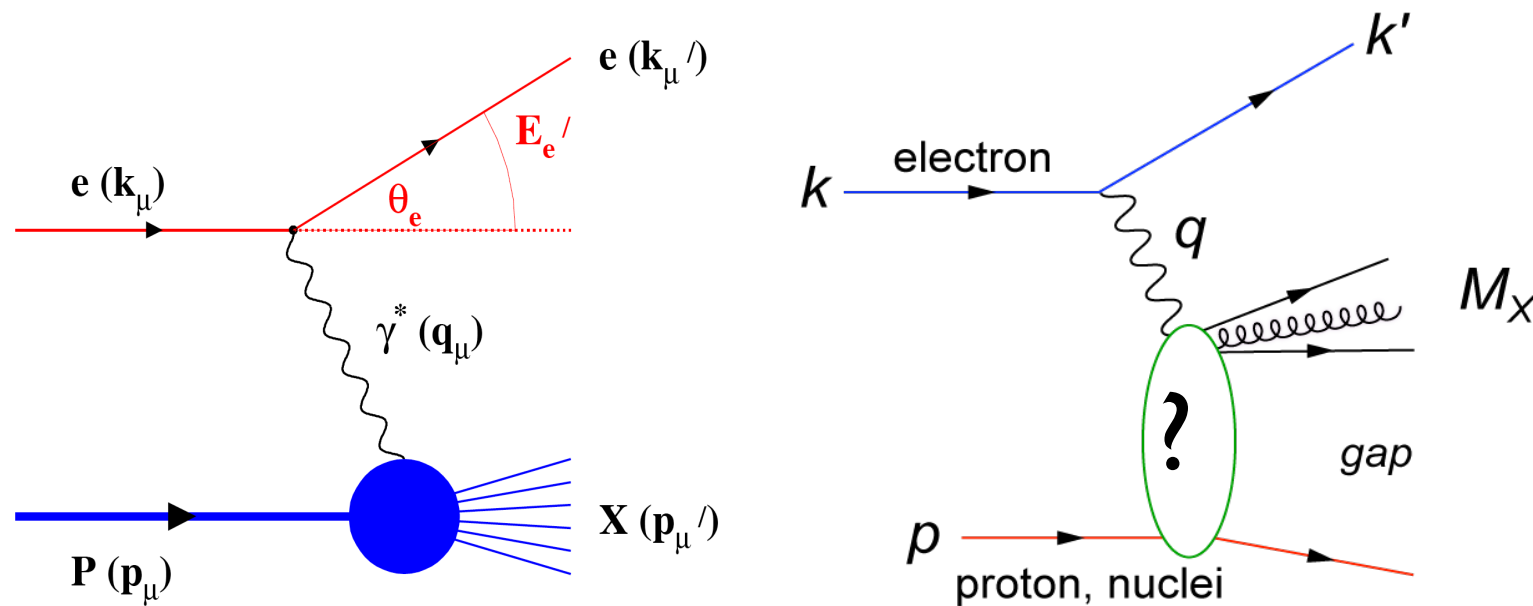
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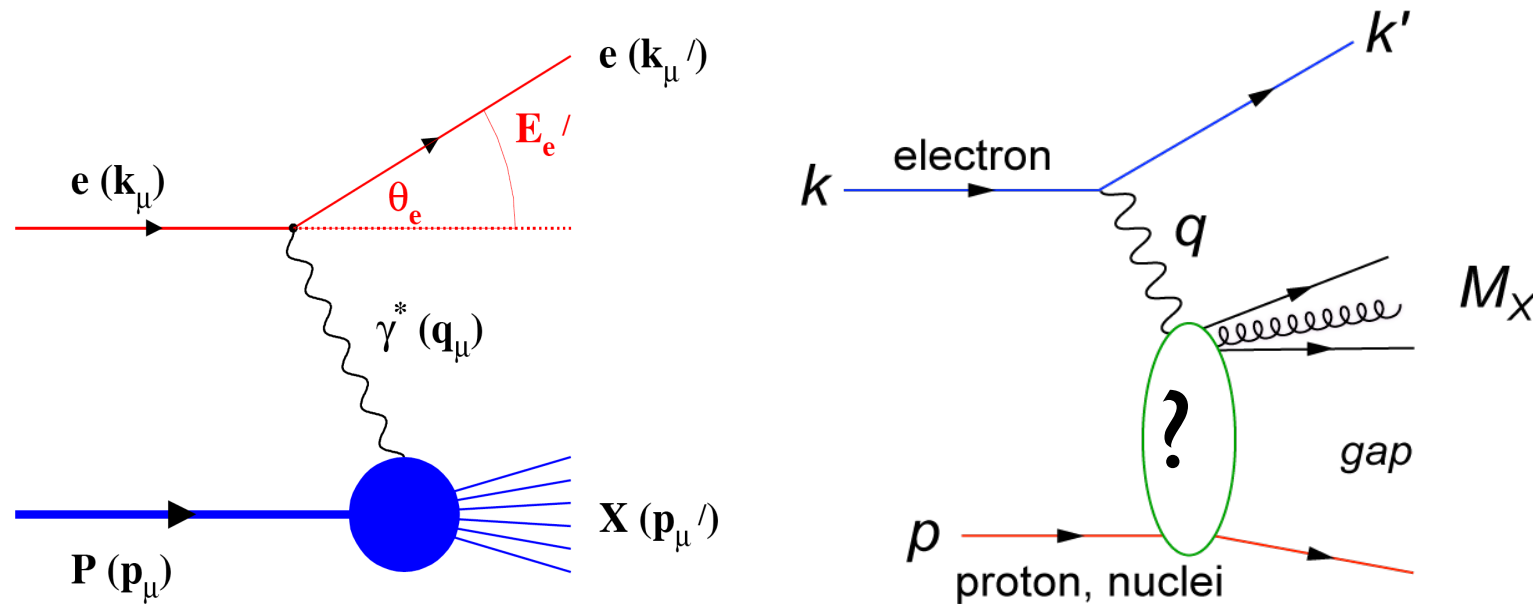
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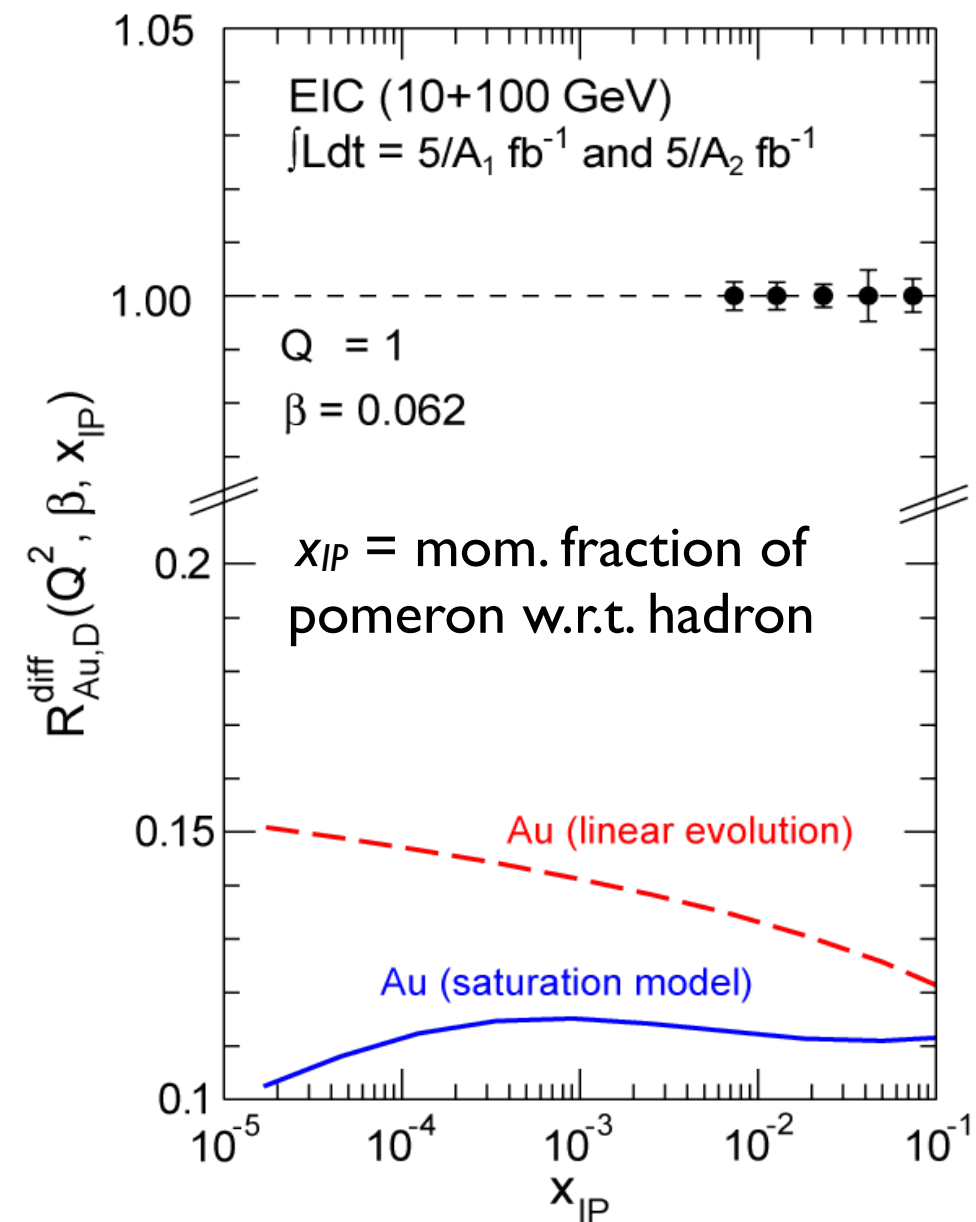
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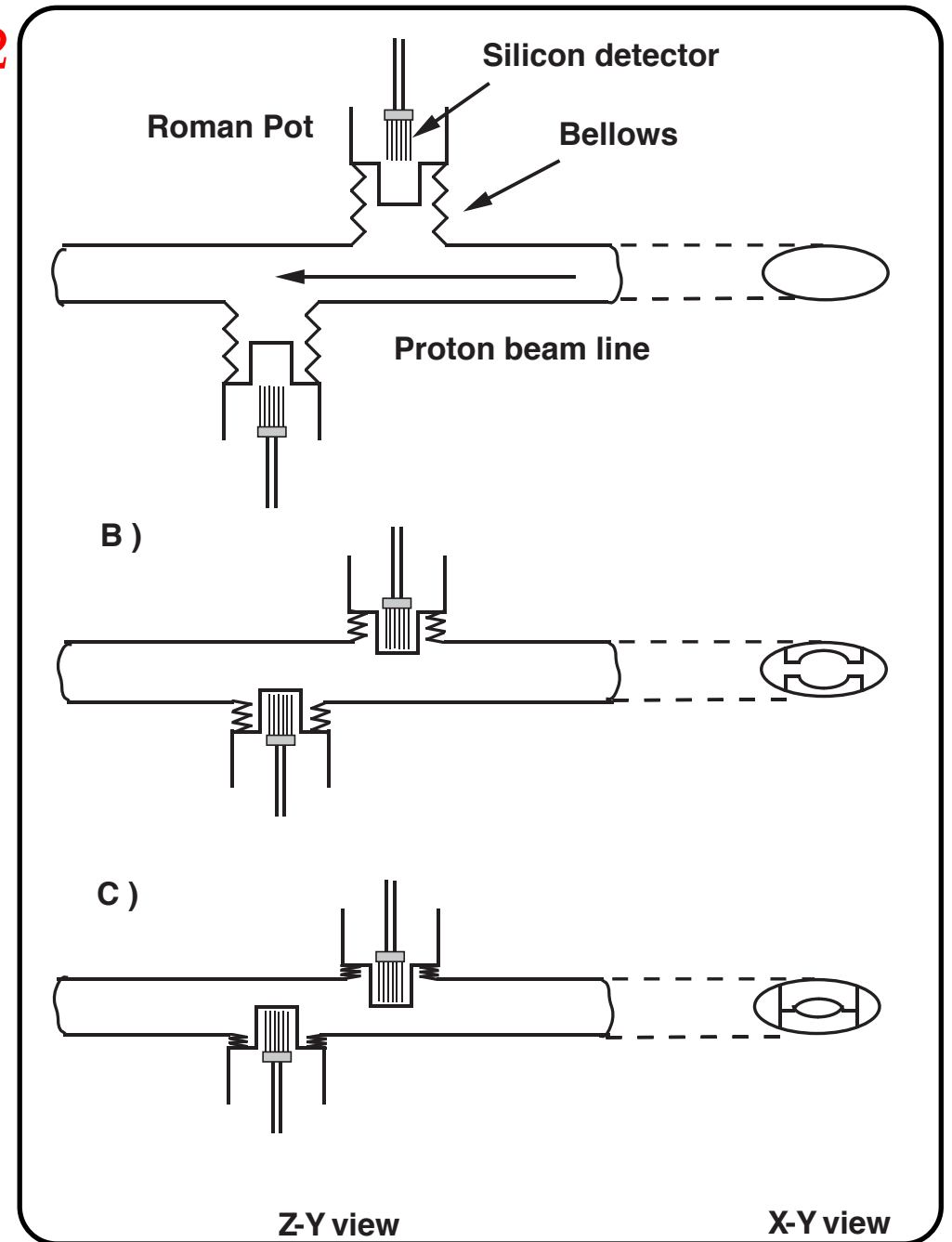
- Diffractive structure functions

Distinguish between **linear evolution** and **saturation** models



How to measure coherent diffraction in e+A ?

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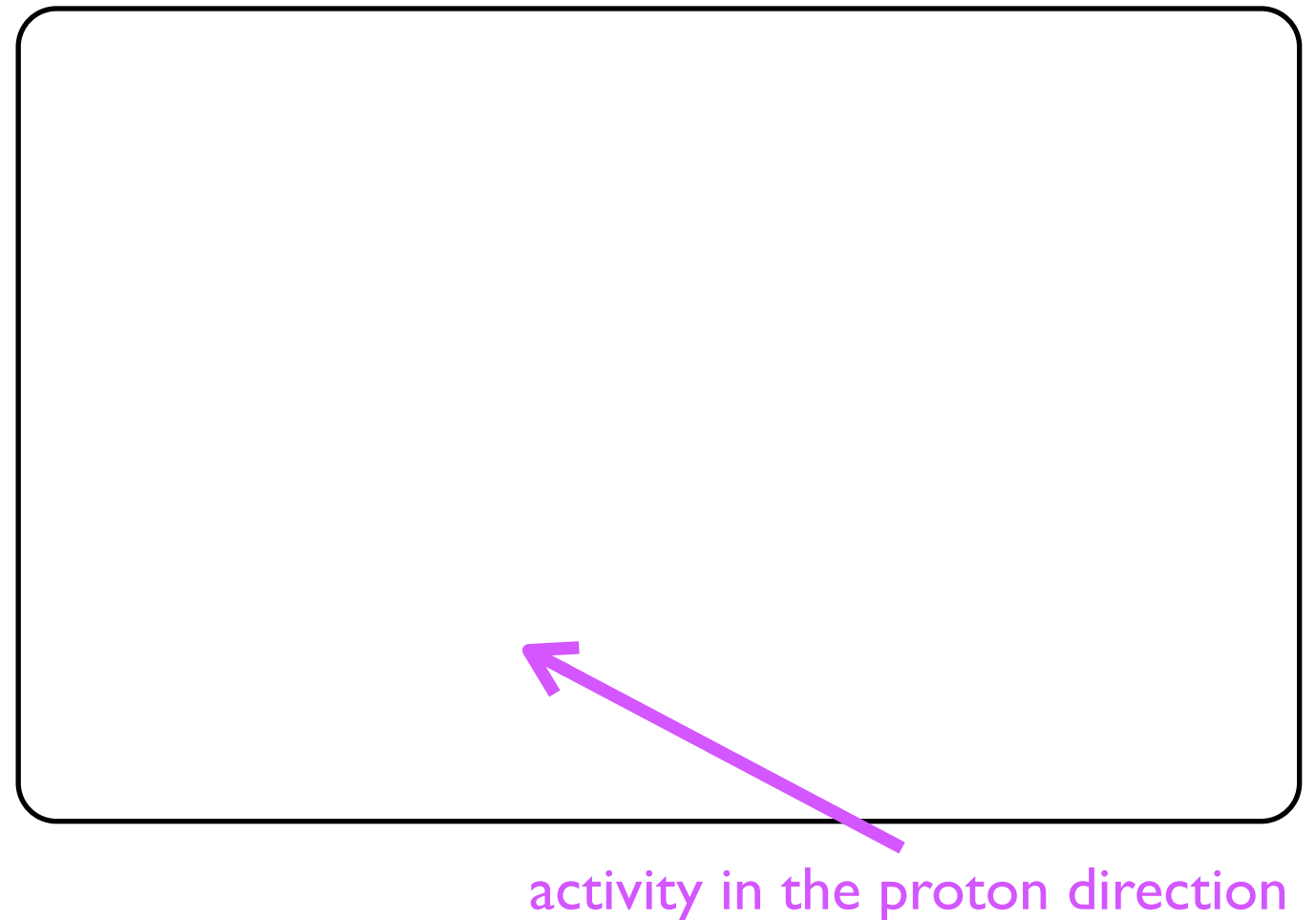
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For large A, nucleus cannot be separated from beam
without breaking up

How else to measure diffraction in $e+A$?

Large Rapidity Gap Method:

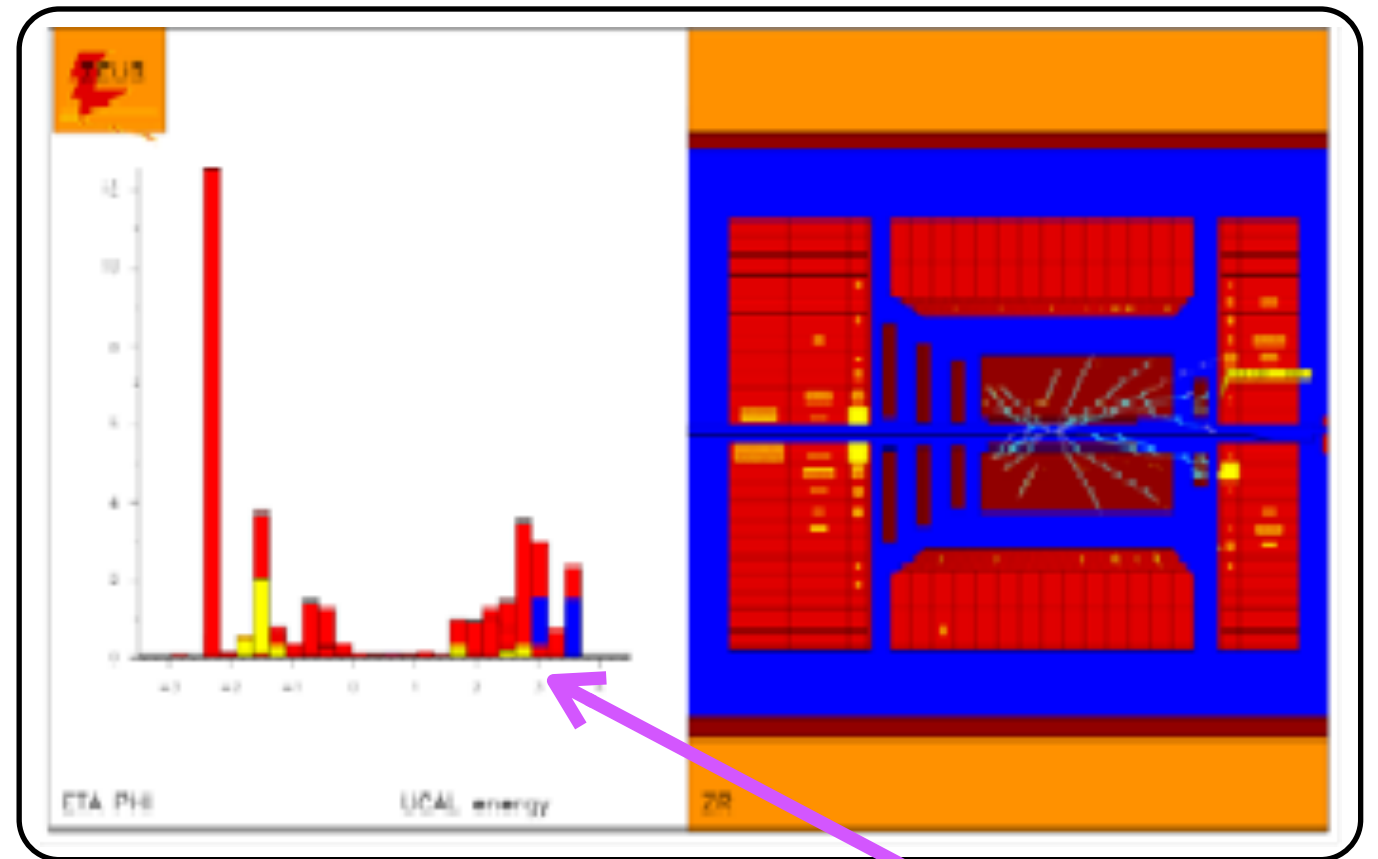
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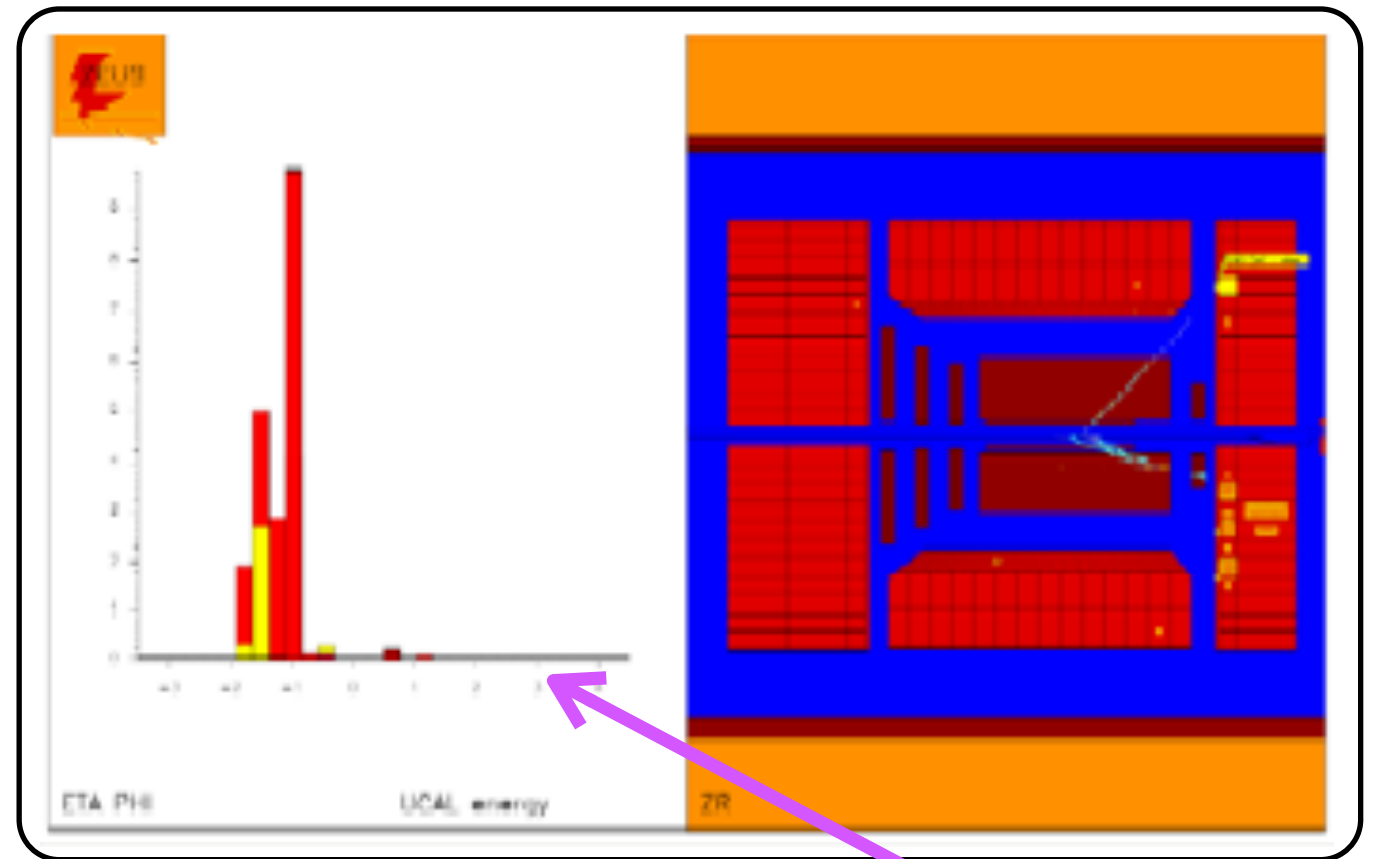


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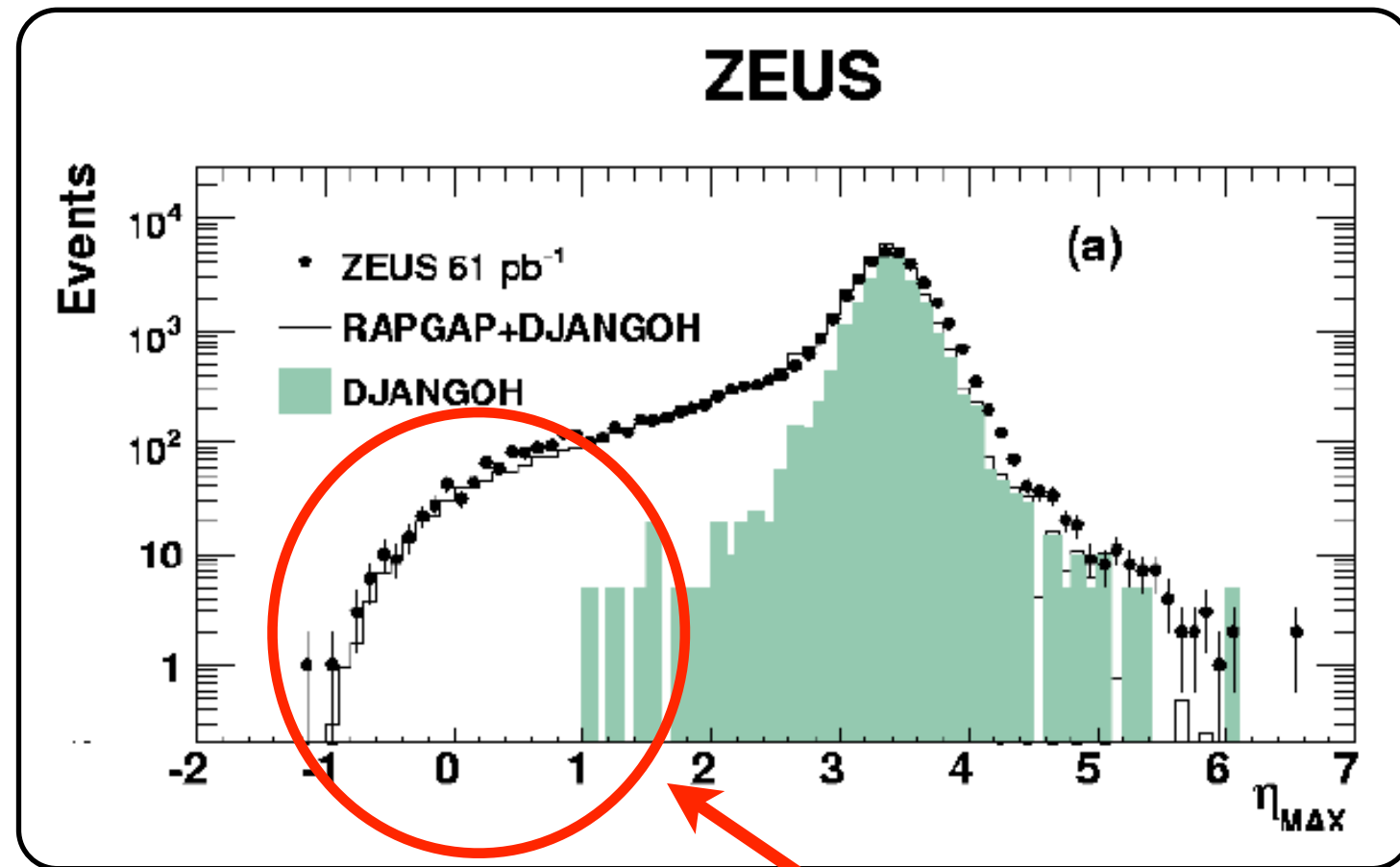


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- At HERA: $\Delta\eta \sim 7 \Rightarrow$ hadronization reduces this to ~ 2.5

- Pros

➡ Lots of statistics

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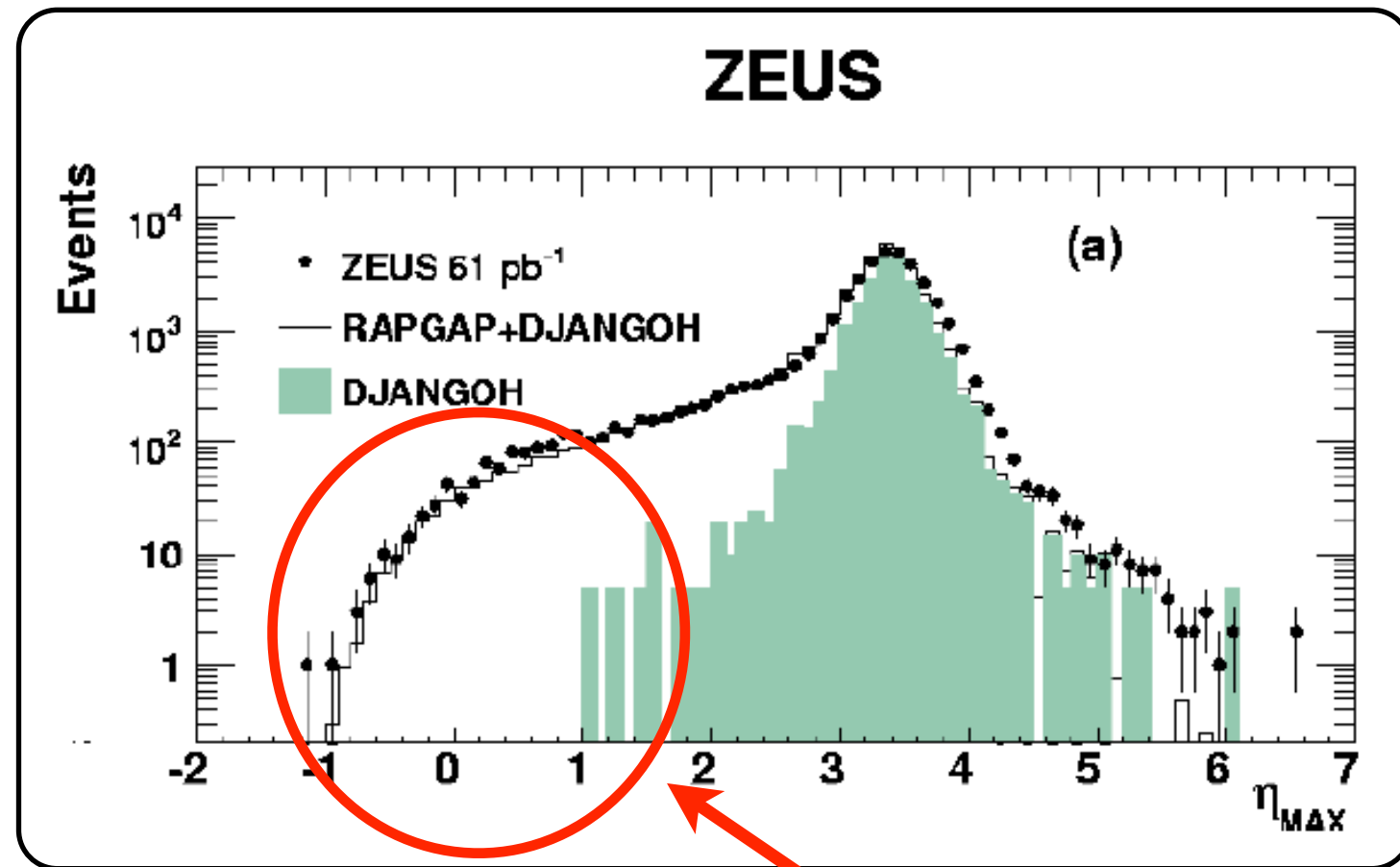
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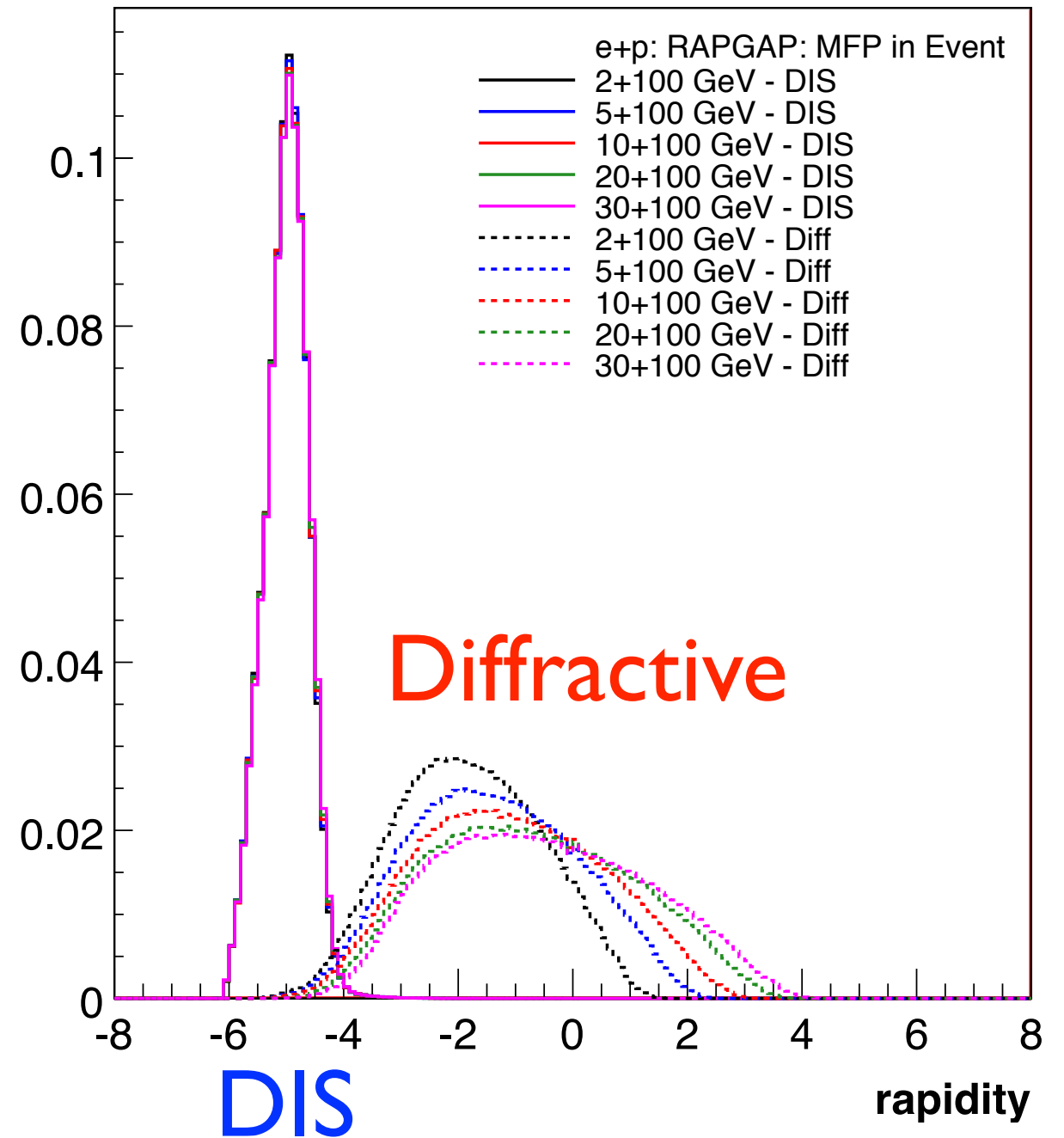
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Can this method be used at an EIC?

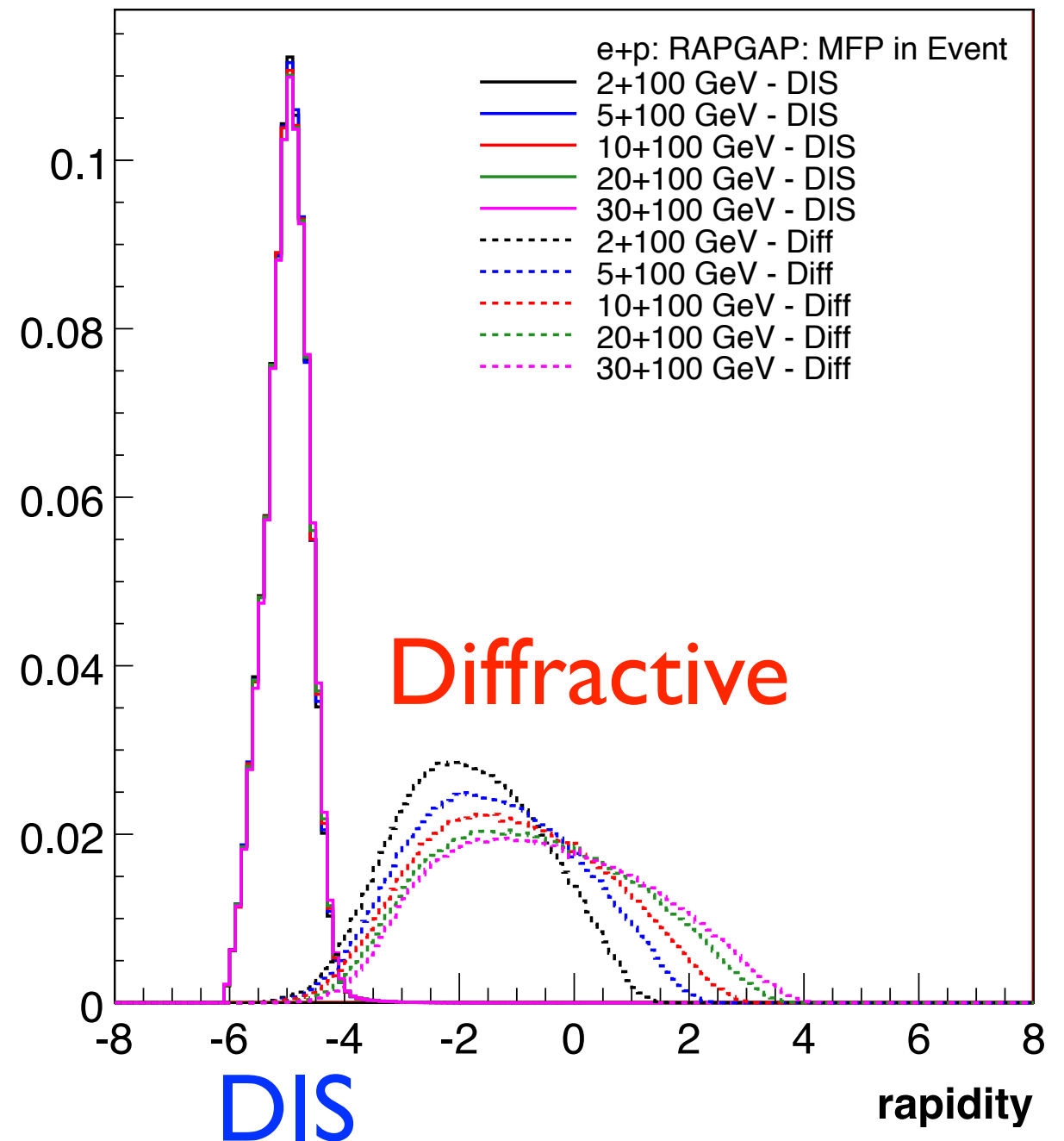
Large rapidity gaps at eRHIC



Large rapidity gaps at eRHIC

- Method:

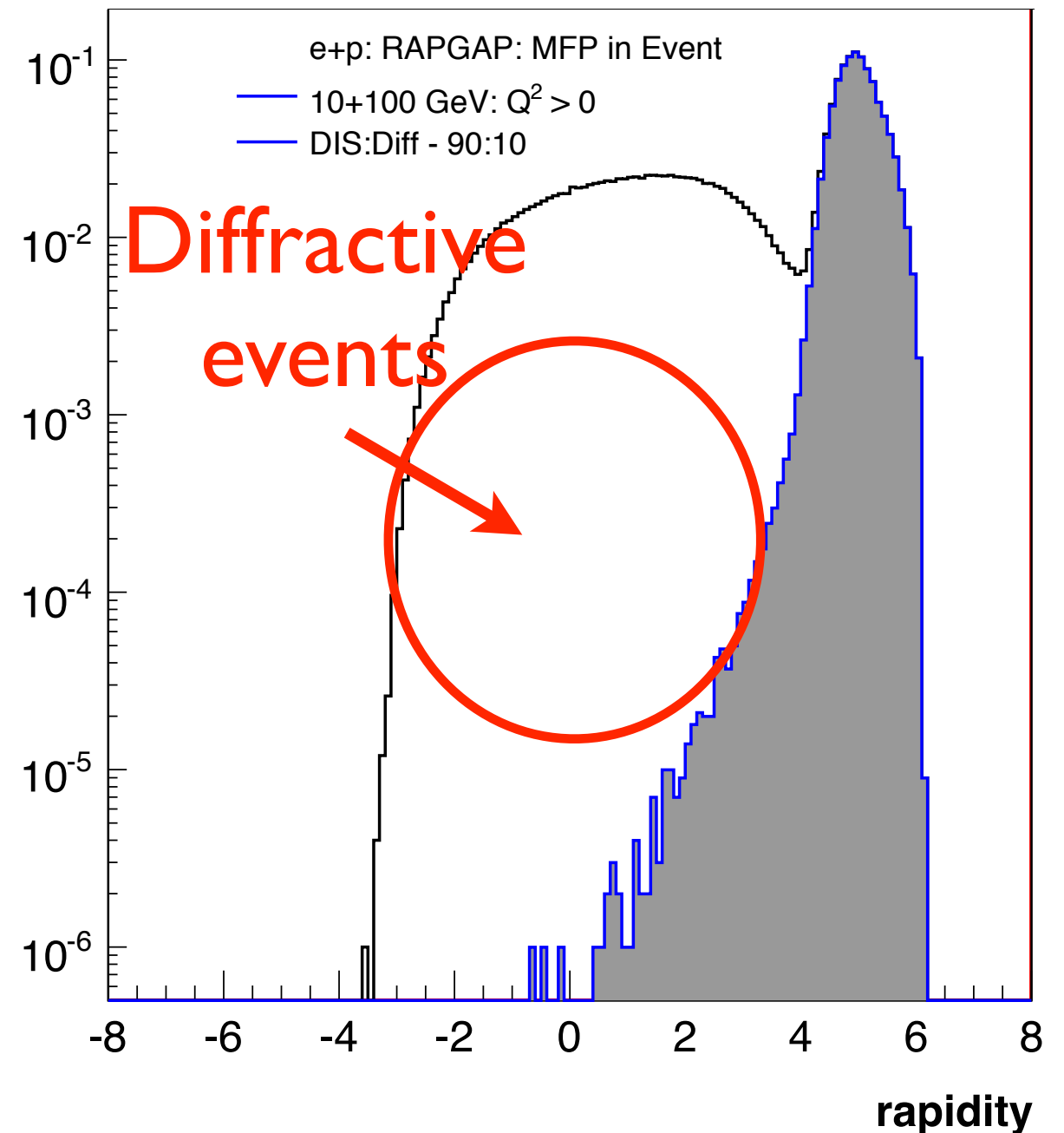
- ➔ Use RAPGAP in diffractive and DIS modes to simulate e+p collisions at EIC energies
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 - ▶ Little change in distributions with increasing energy



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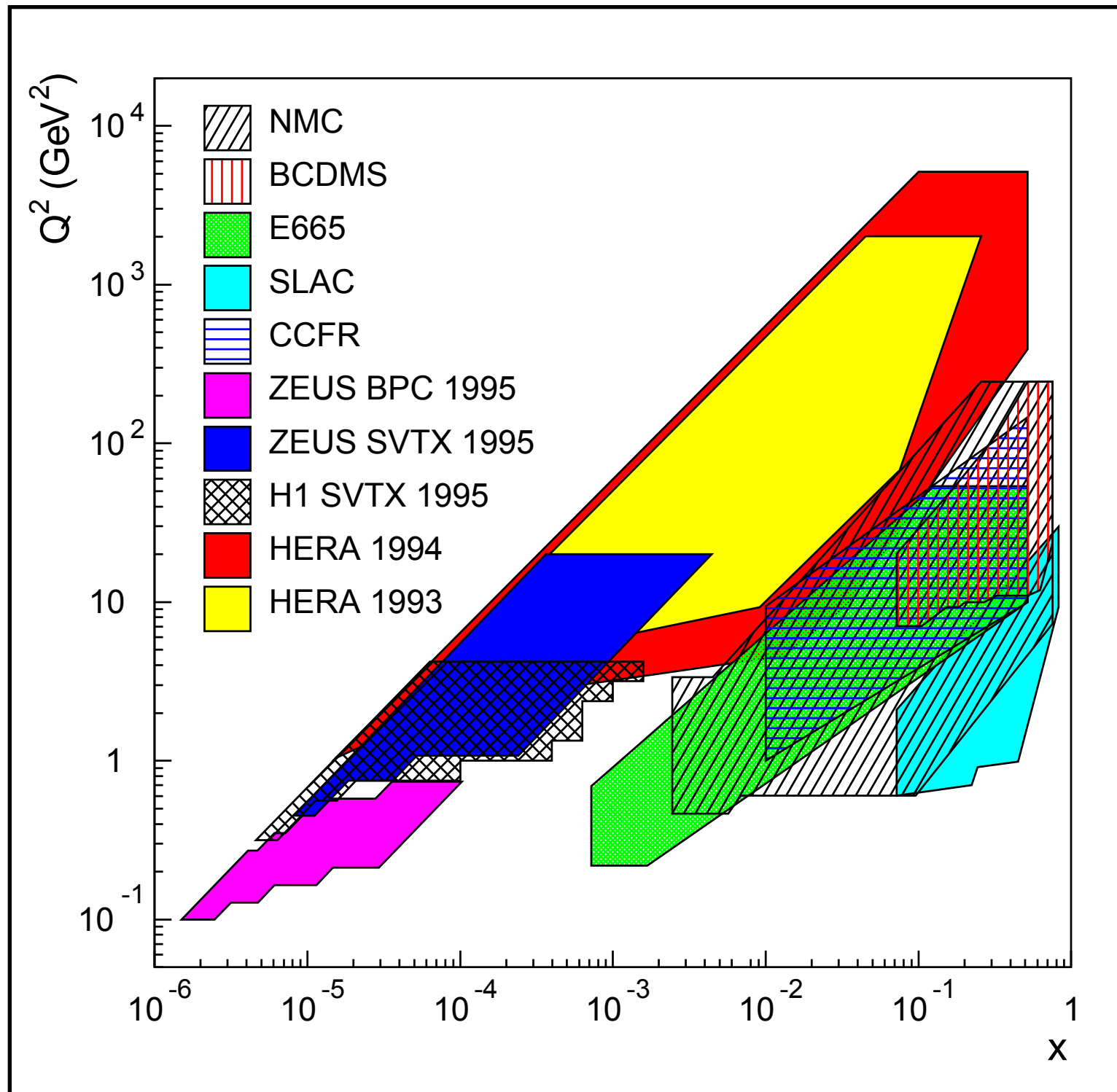
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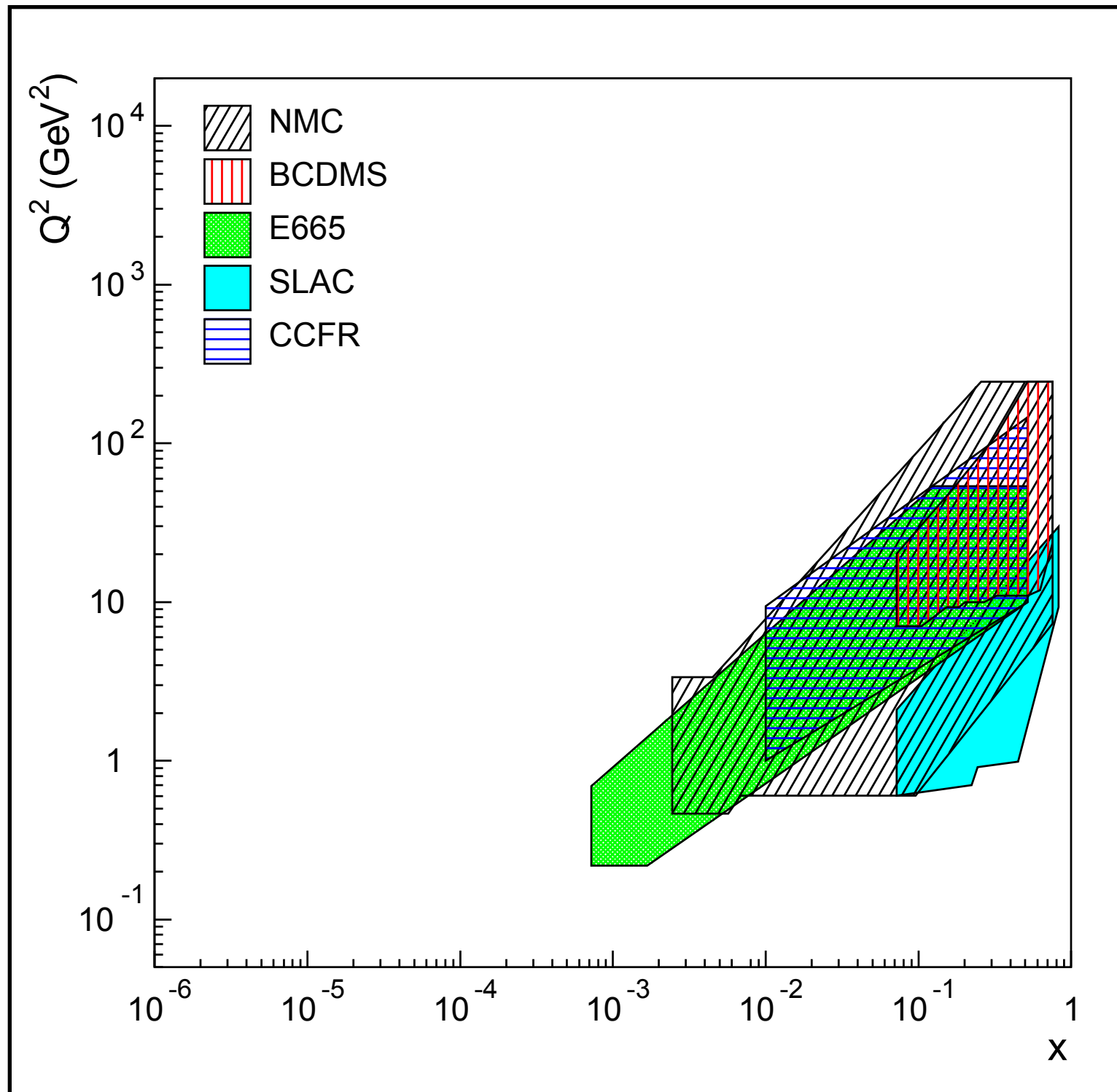


Requirements for an Electron-Ion Collider

Well mapped in $e+p$



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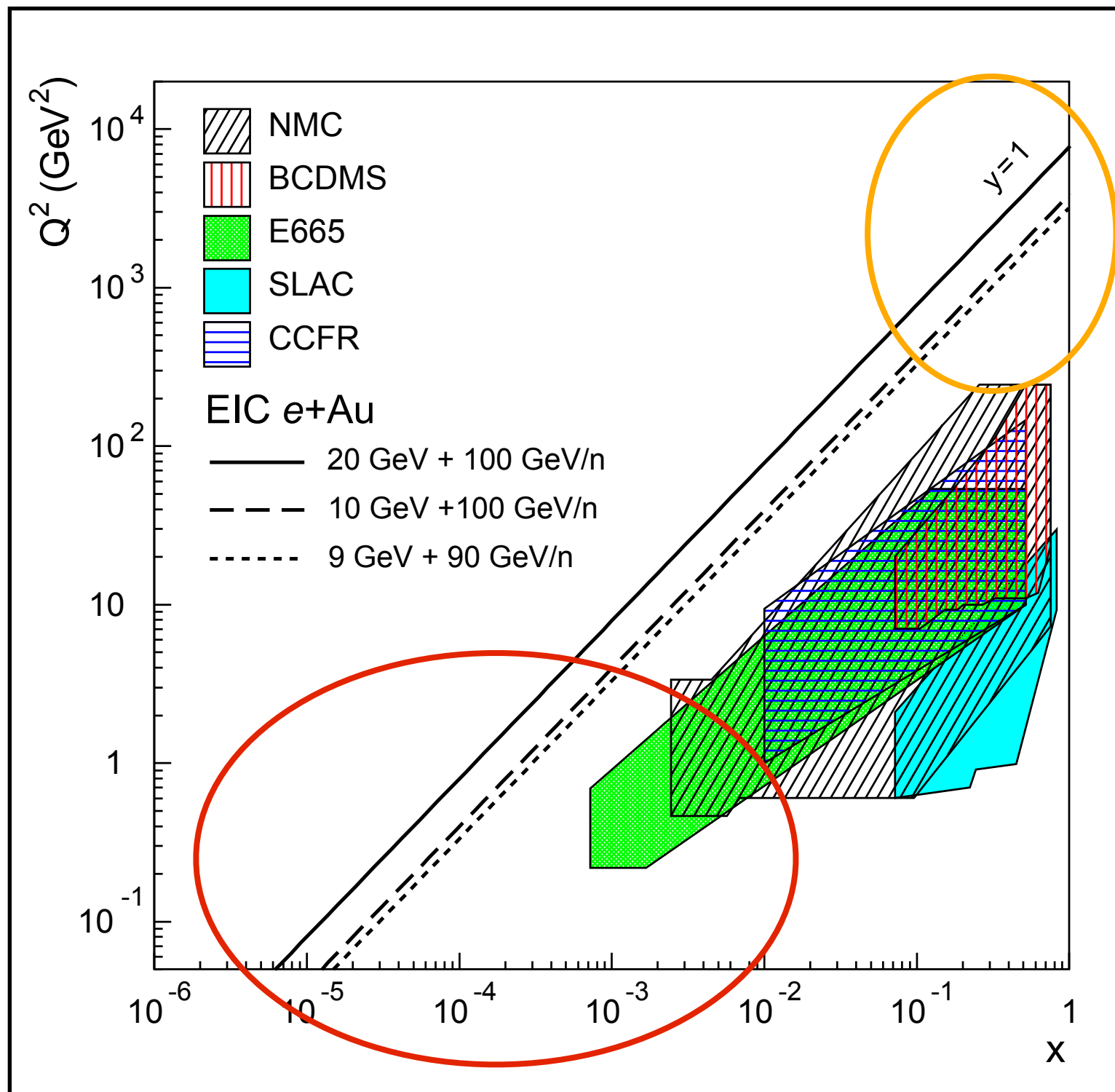


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Not so for $\ell+A$ ($\nu+A$)

- many with small A
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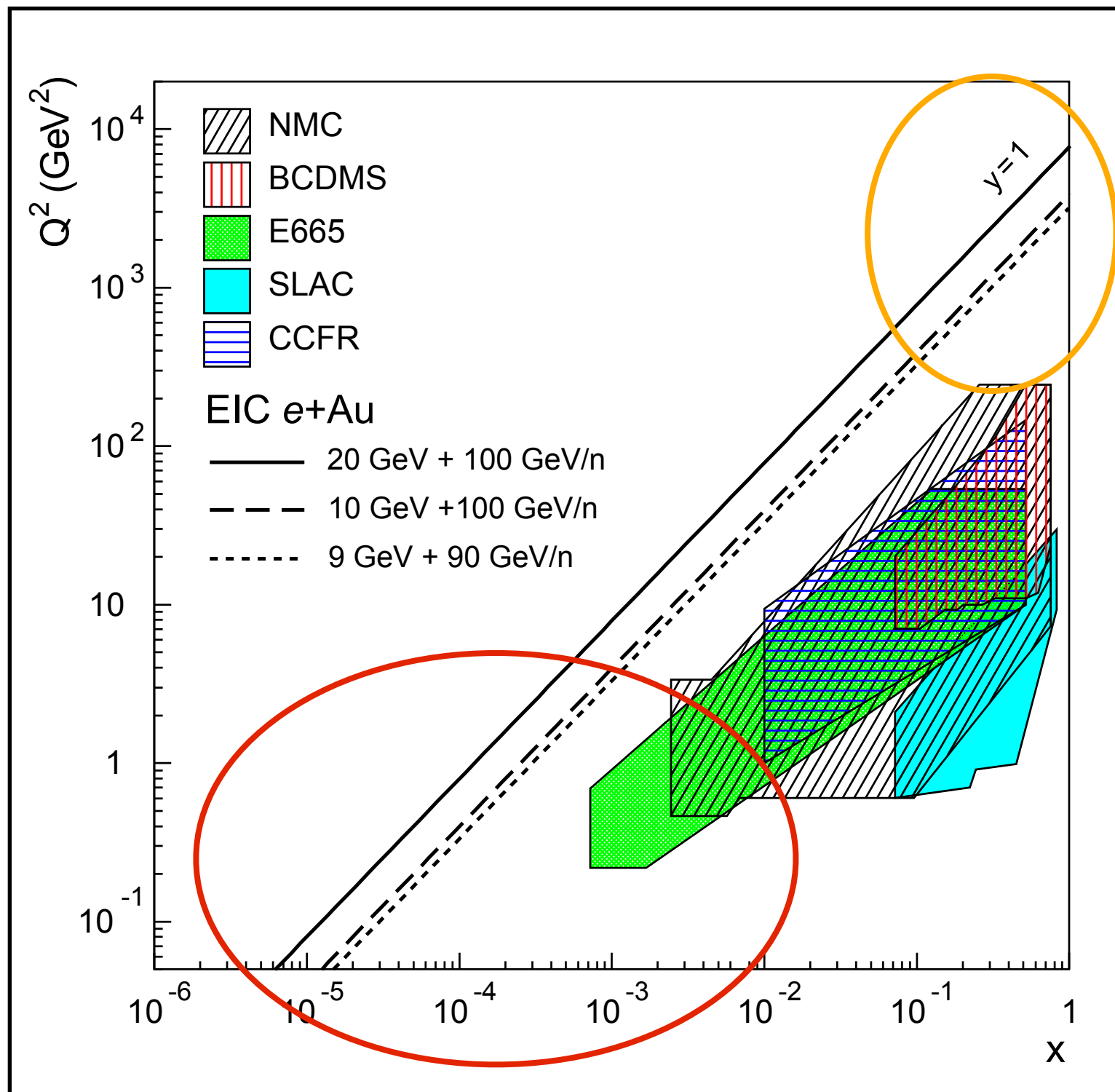
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- $\mathcal{L}(\text{EIC}) > 100 \times \mathcal{L}(\text{HERA})$
- Electrons
 - $E_e = 3 - 20$ GeV
 - polarized
- Hadron Beams
 - $E_A = 100$ GeV
 - $A = p \rightarrow U$
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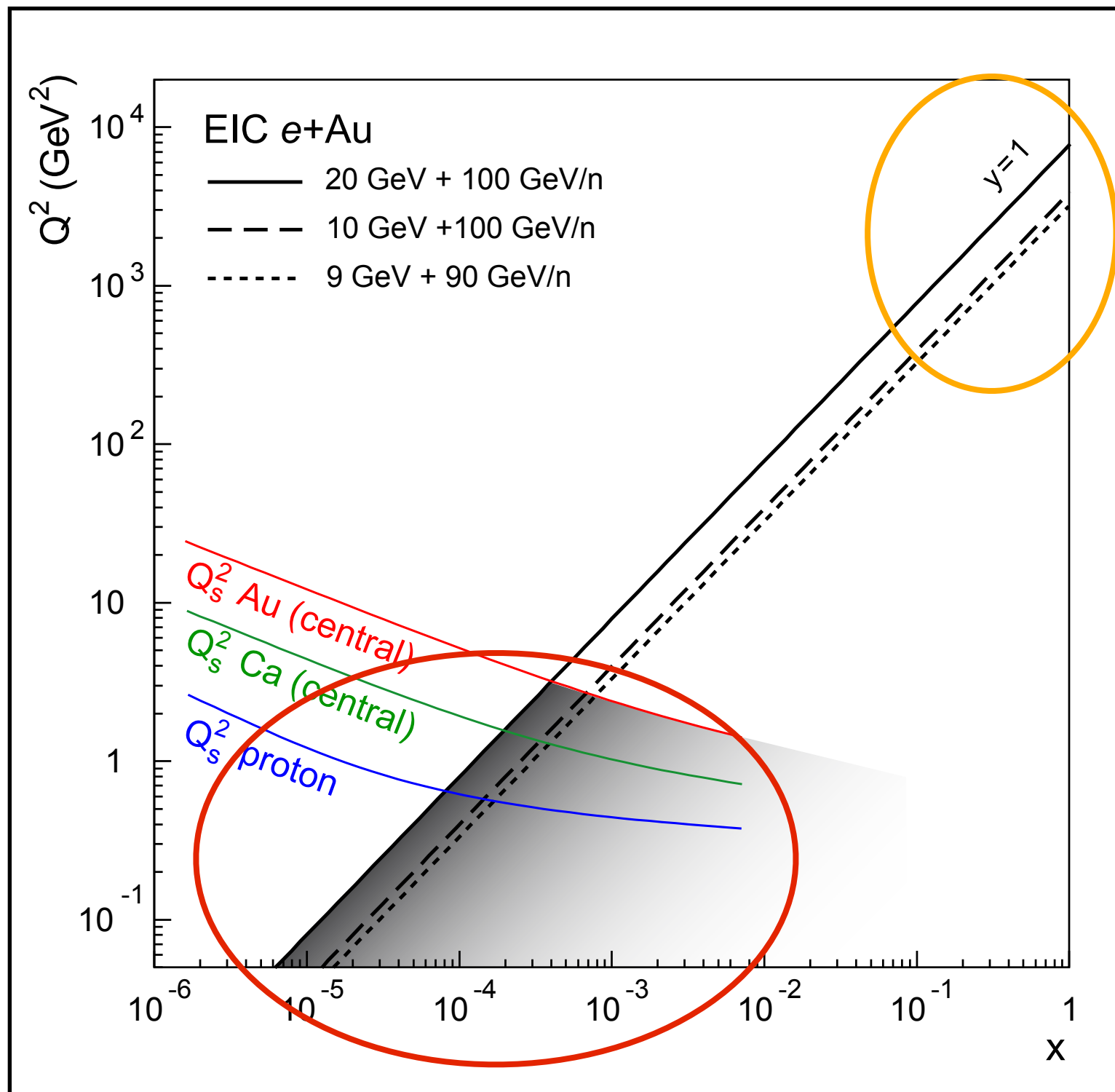
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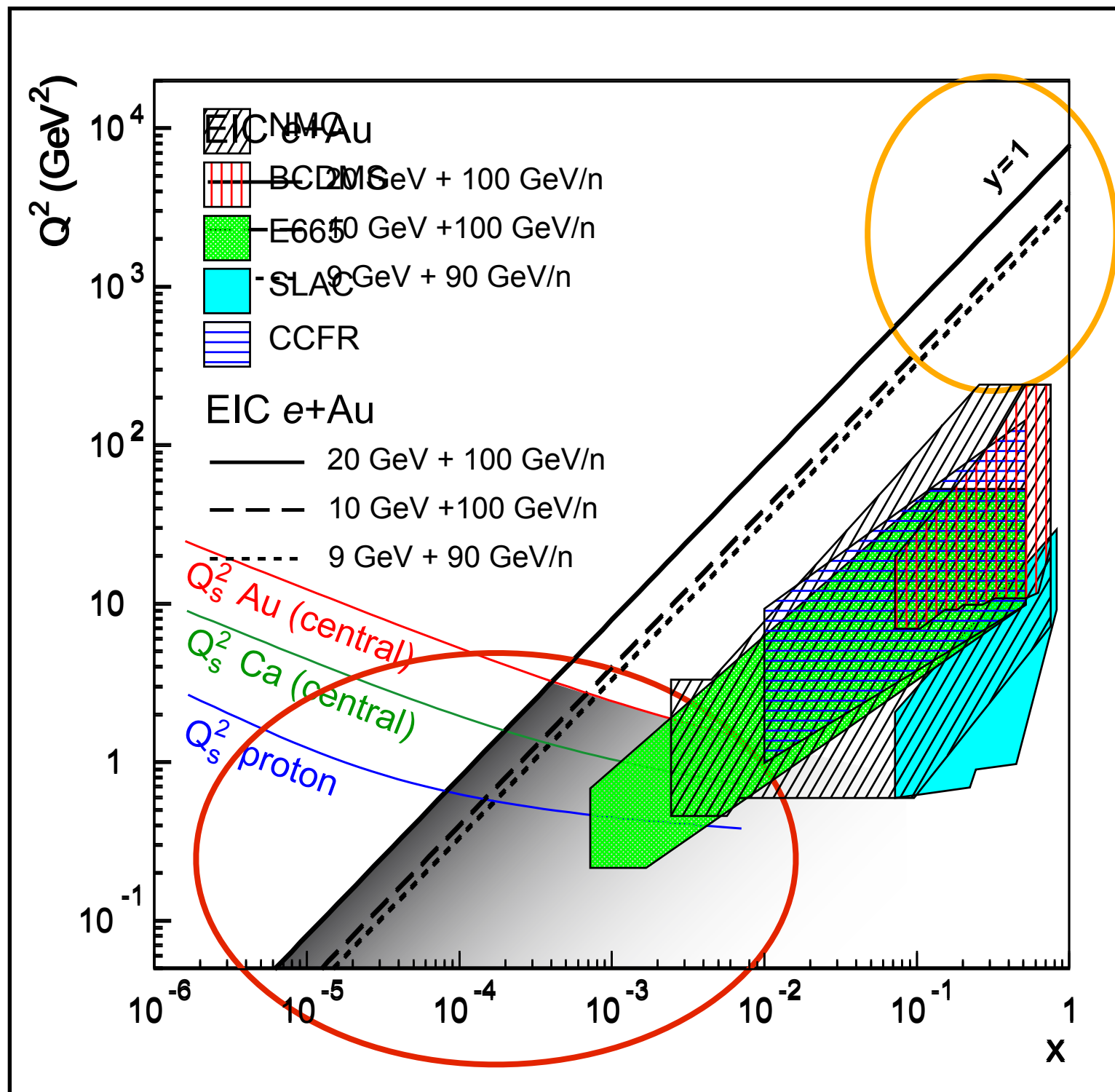
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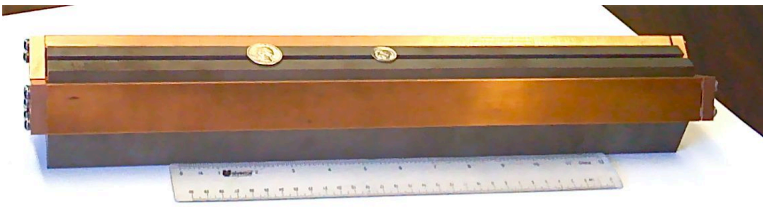
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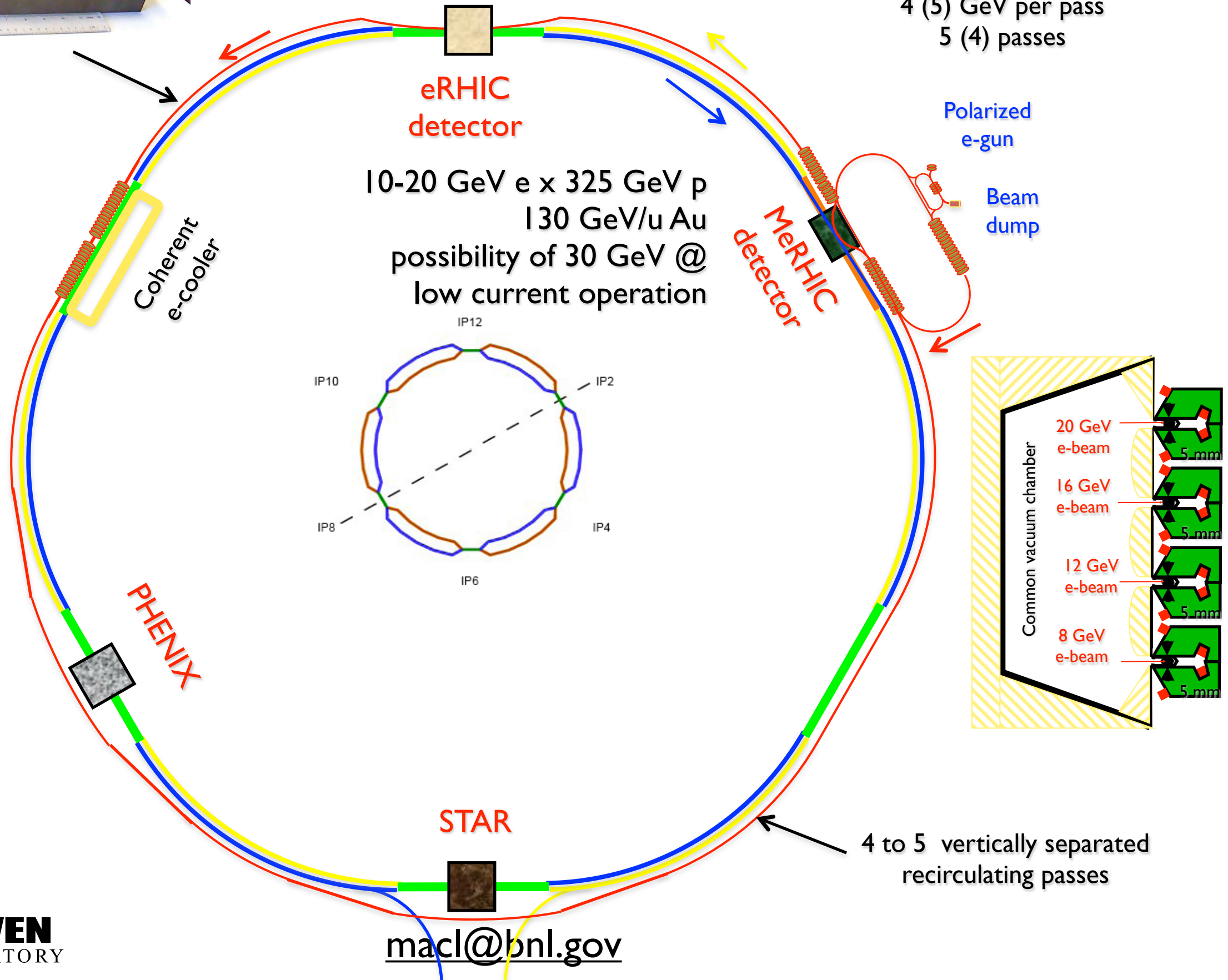
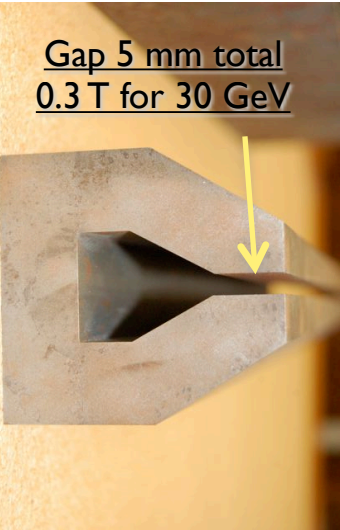
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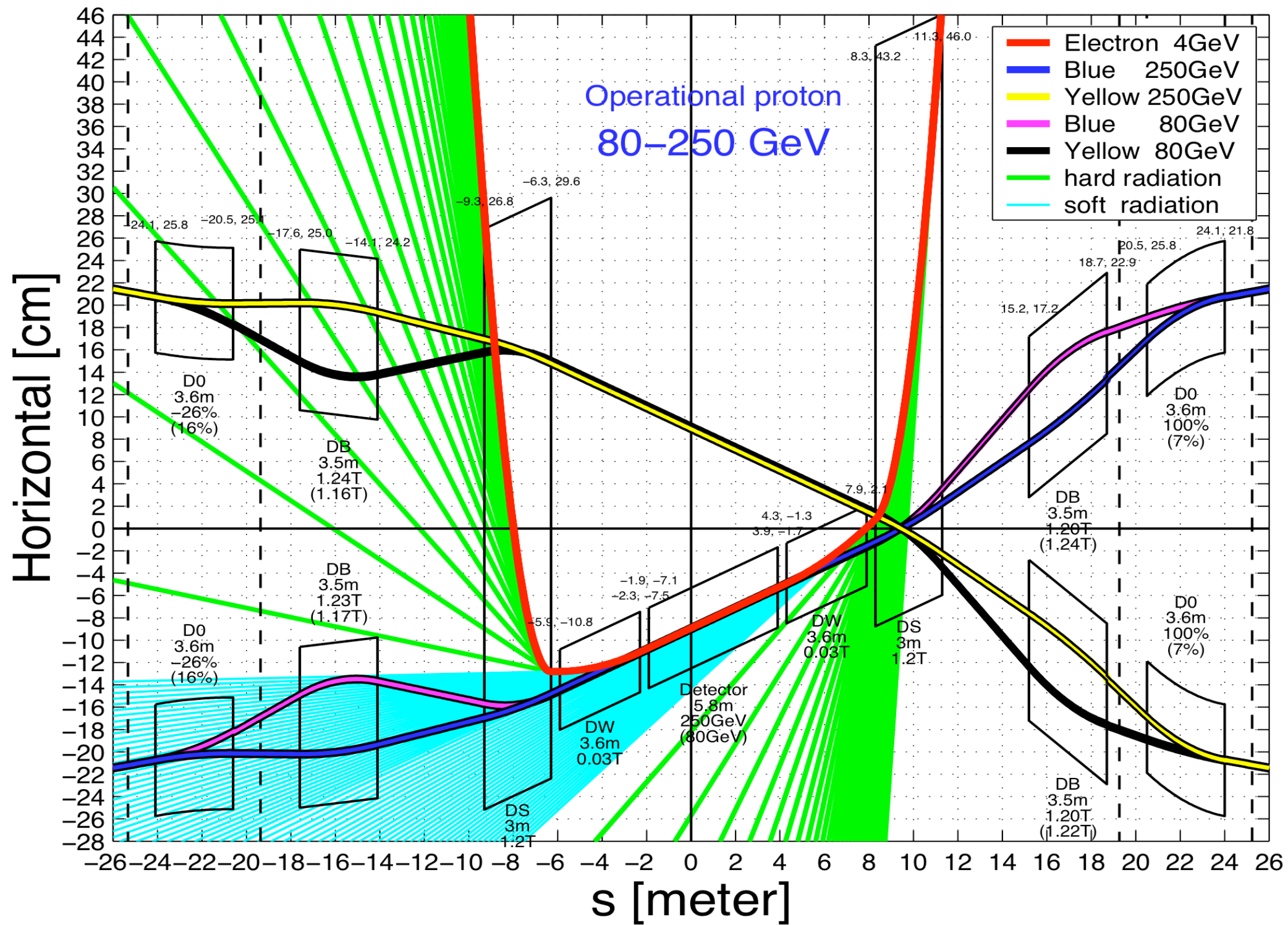
EIC: one solution eRHIC @ BNL



Gap 5 mm total
0.3 T for 30 GeV

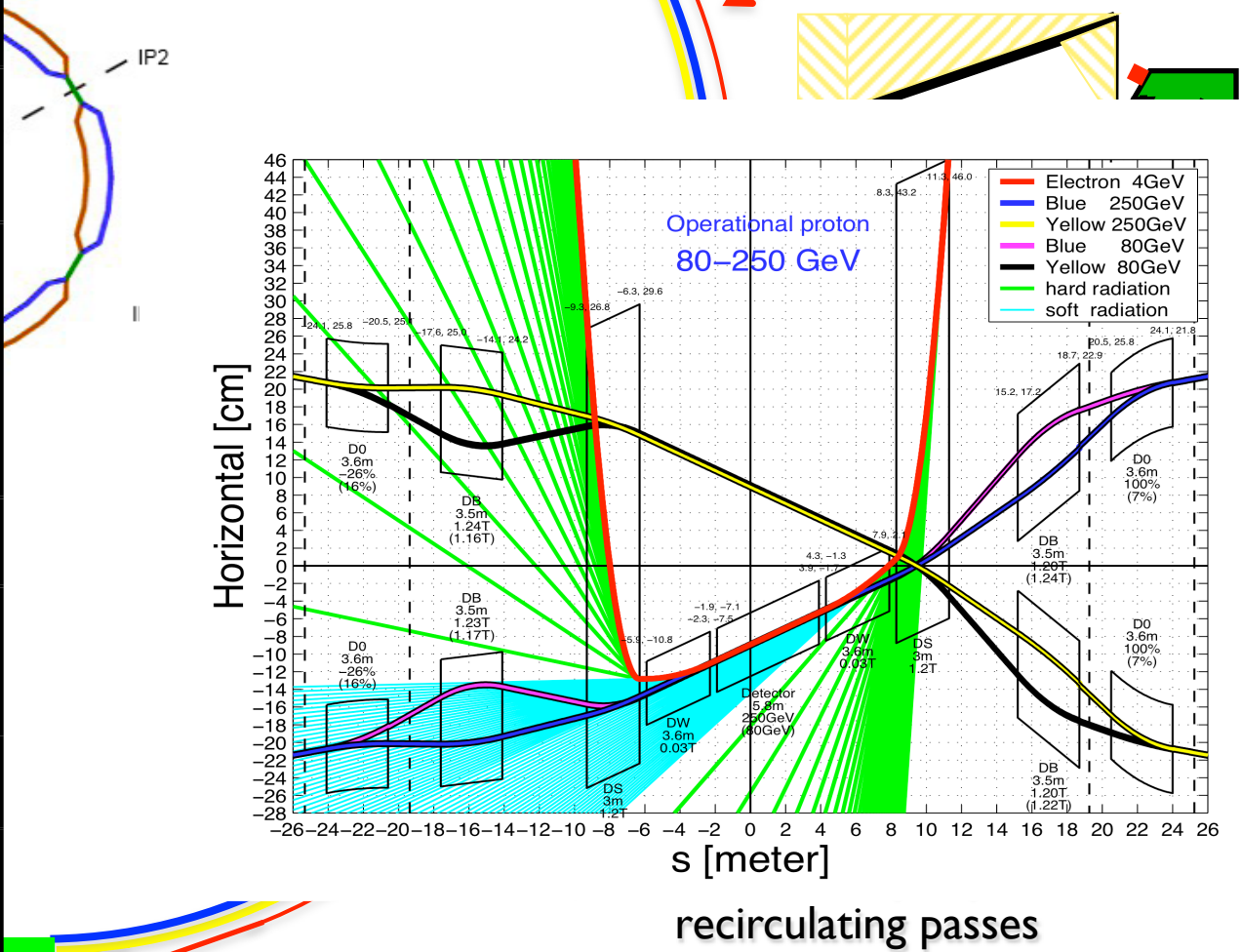
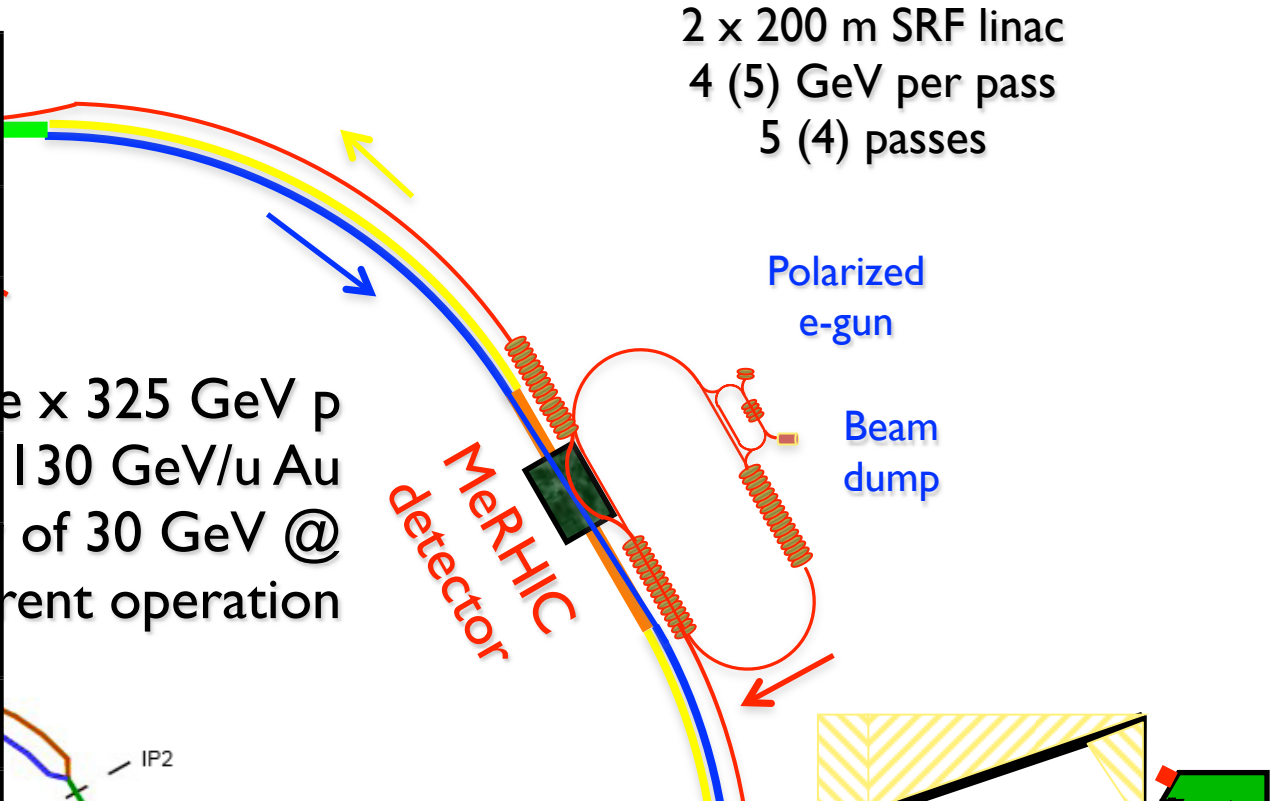


EIC: one solution eRHIC @ BNL



EIC: one solution eRHIC @ BNL

	MeRHIC		eRHIC with CeC	
	p (A)	e	p (A)	e
Energy, GeV	250 (100)	4	325 (125)	20 <30>
Number of bunches	111		166	
Bunch intensity (u) , 10 ¹¹	2.0	0.31	2.0 (3)	0.24
Bunch charge, nC	32	5	32	4
Beam current, mA	320	50	420	50 <10>
Normalized emittance, 1e-6 m, 95% for p / rms for e	15	73	1.2	25
Polarization, %	70	80	70	80
rms bunch length, cm	20	0.2	4.9	0.2
β*, cm	50	50	25	25
Luminosity, x 10 ³³ , cm ⁻² s ⁻¹	0.1 -> 1 with CeC		2.8	



Detector requirements from physics

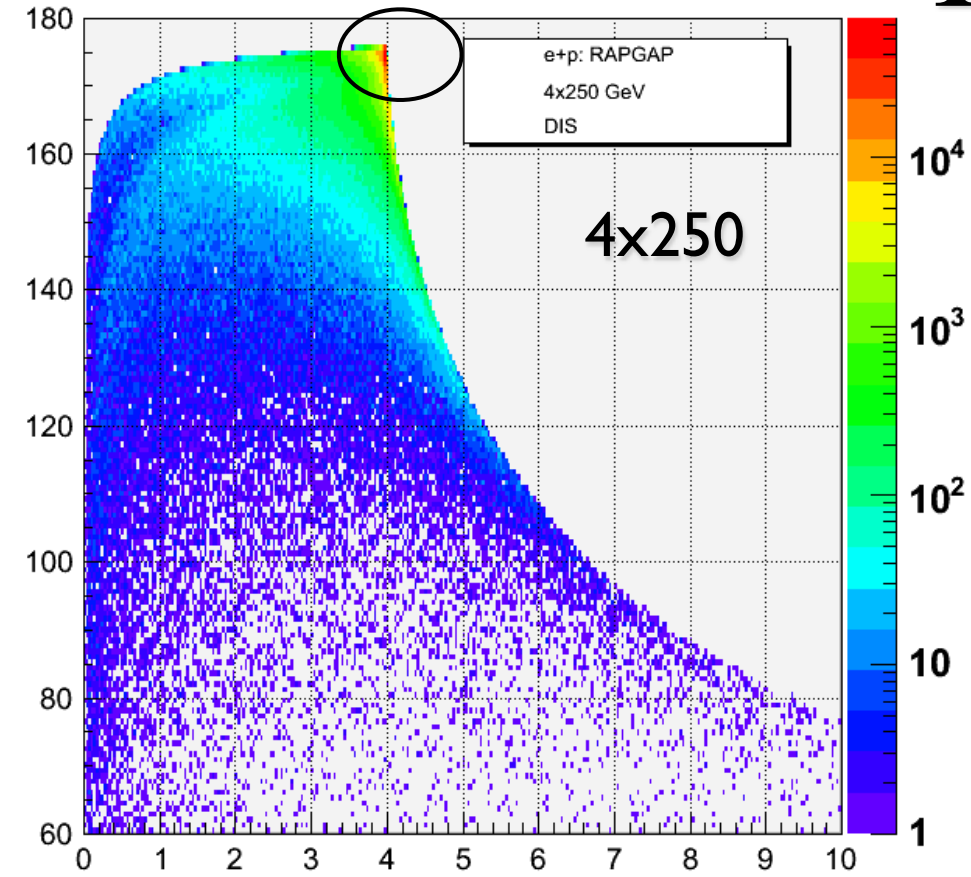
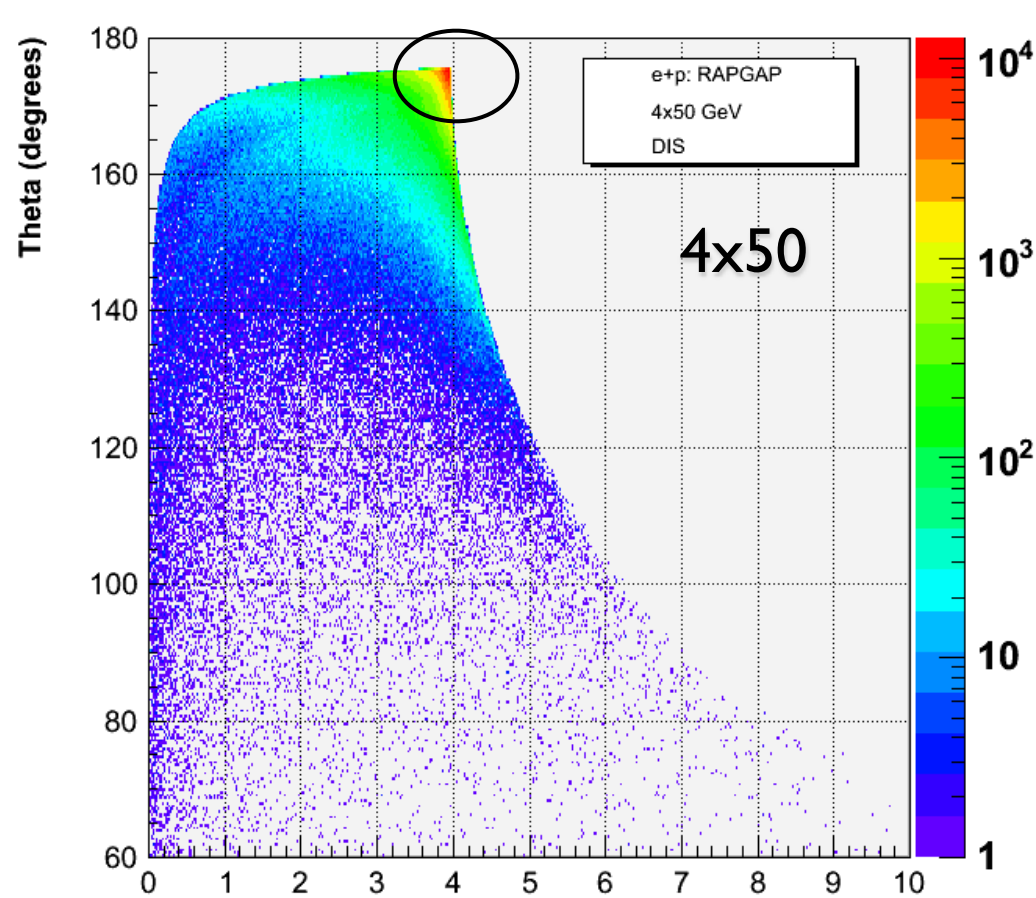
- e+p physics
 - ➔ Need the same detector for inclusive ($ep \rightarrow e'X$), semi-inclusive ($ep \rightarrow e'X + \text{hadrons}$) and exclusive ($ep \rightarrow e'p+\pi$) reactions
 - ▶ Need to have a large acceptance (*both* mid- and forward-rapidity)
 - ▶ Crucial to have particle identification
 - e, π , K, p, n over wide momentum range and scattering angles
 - Excellent secondary vertex resolution (charm)
 - ▶ Small systematic uncertainty for e/p polarisation measurements
 - ▶ Small systematic uncertainty for luminosity measurements
- e+A physics
 - ➔ Most requirements similar to e+p guidelines
 - ➔ Additional complication arises from the need to tag the struck nucleus in exclusive and diffractive reactions
- Also, important to have the same detector for all energies
 - ➔ Reduce systematic errors

Simulations

- Initial simulations performed using the RAPGAP simulation code in both **DIS** and **diffractive** mode
- No detector information involved in these simulations
 - ➔ **importantly, no magnetic field**
- Detector geometry implemented in Geant 3, code about ready to run simulations through and make trees out of them
 - ➔ **Also run PYTHIA with radiative corrections**
- **Anyone can apply for an EIC account at BNL and have access to the simulations**

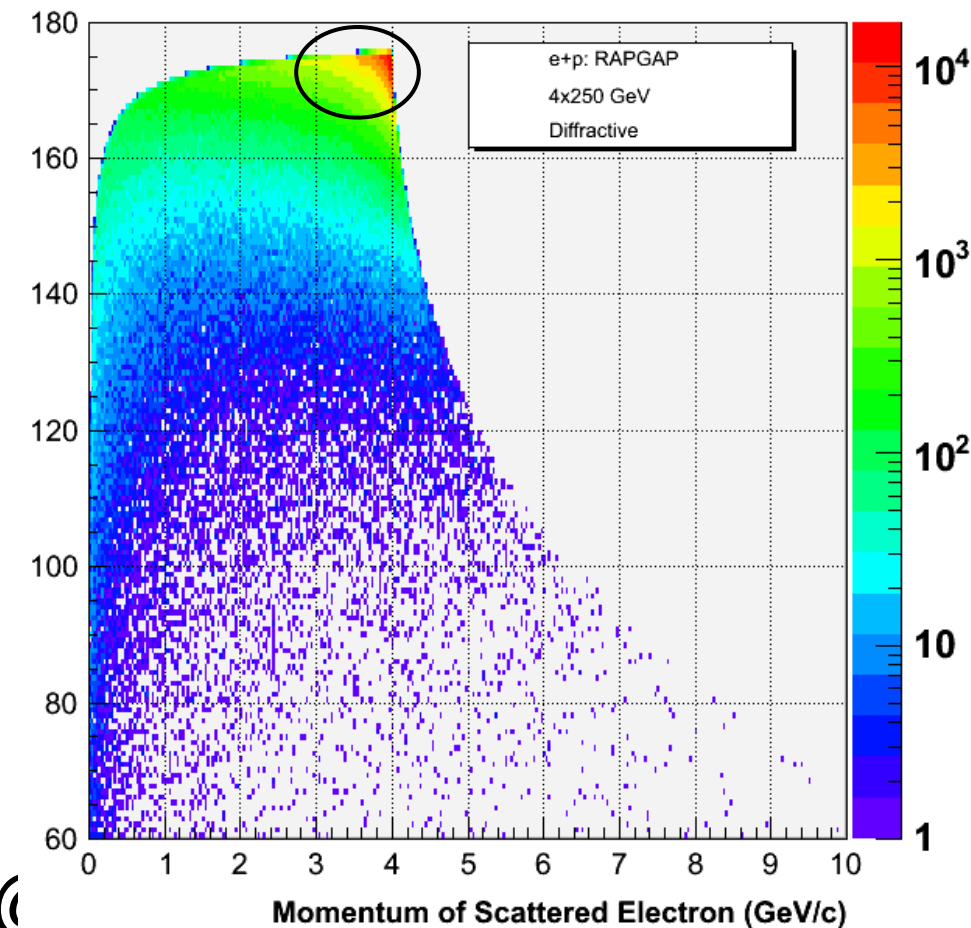
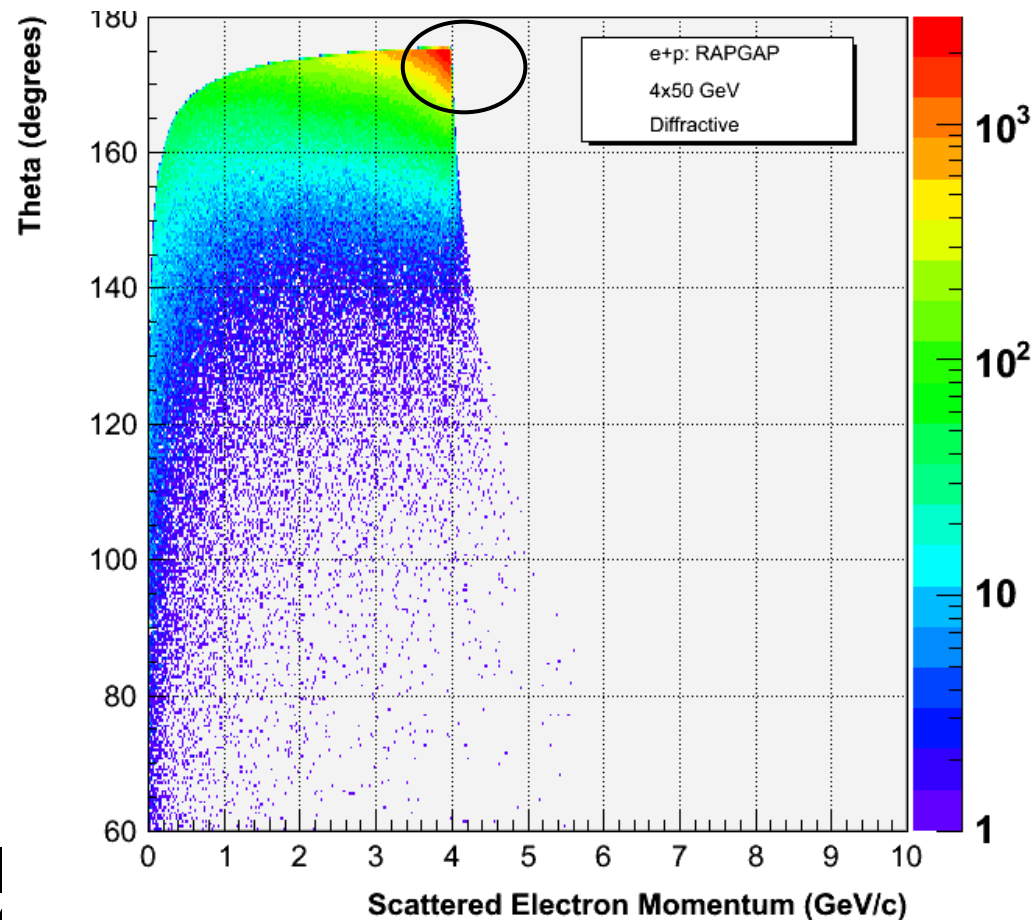
Event kinematics: scattered lepton

D
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S



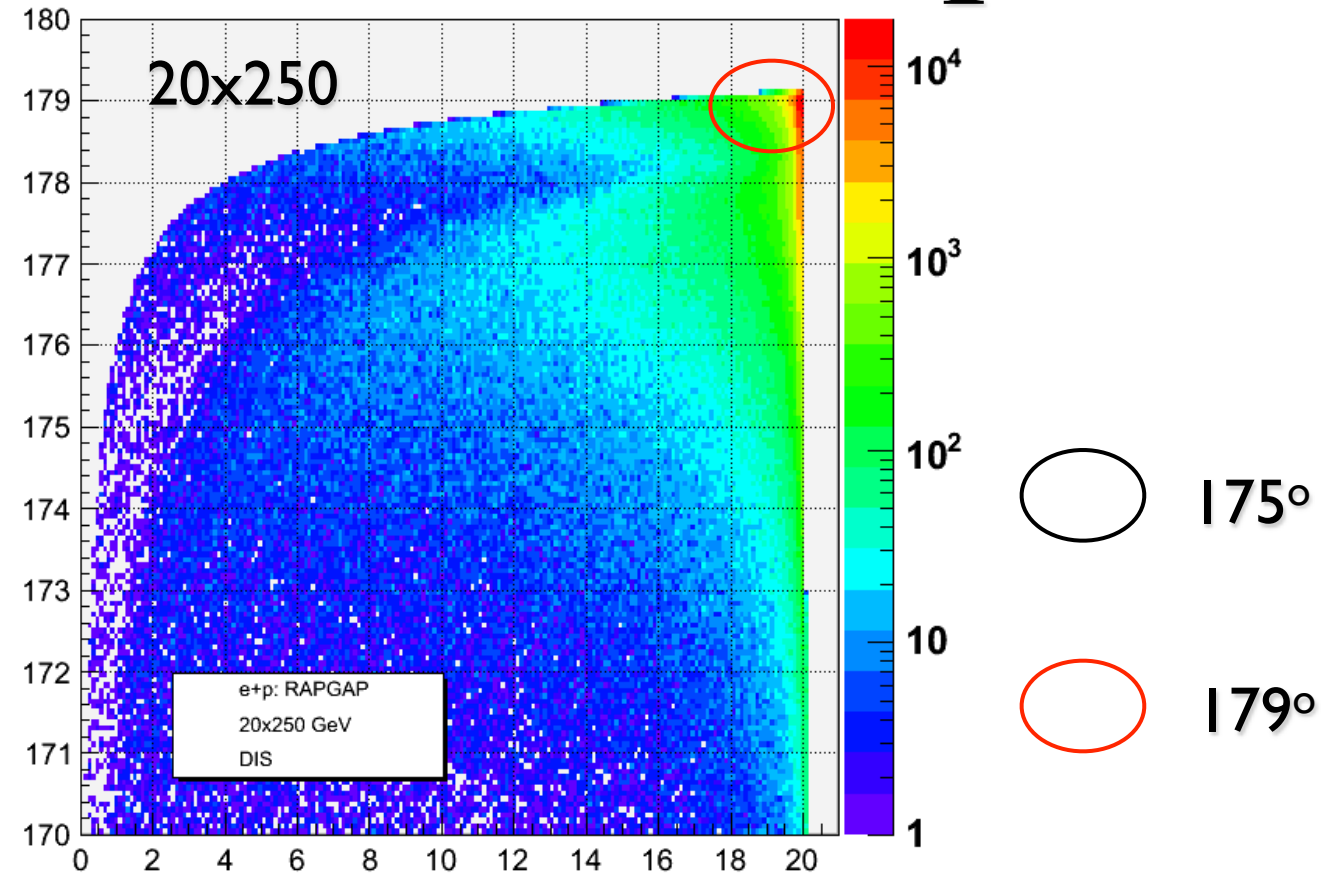
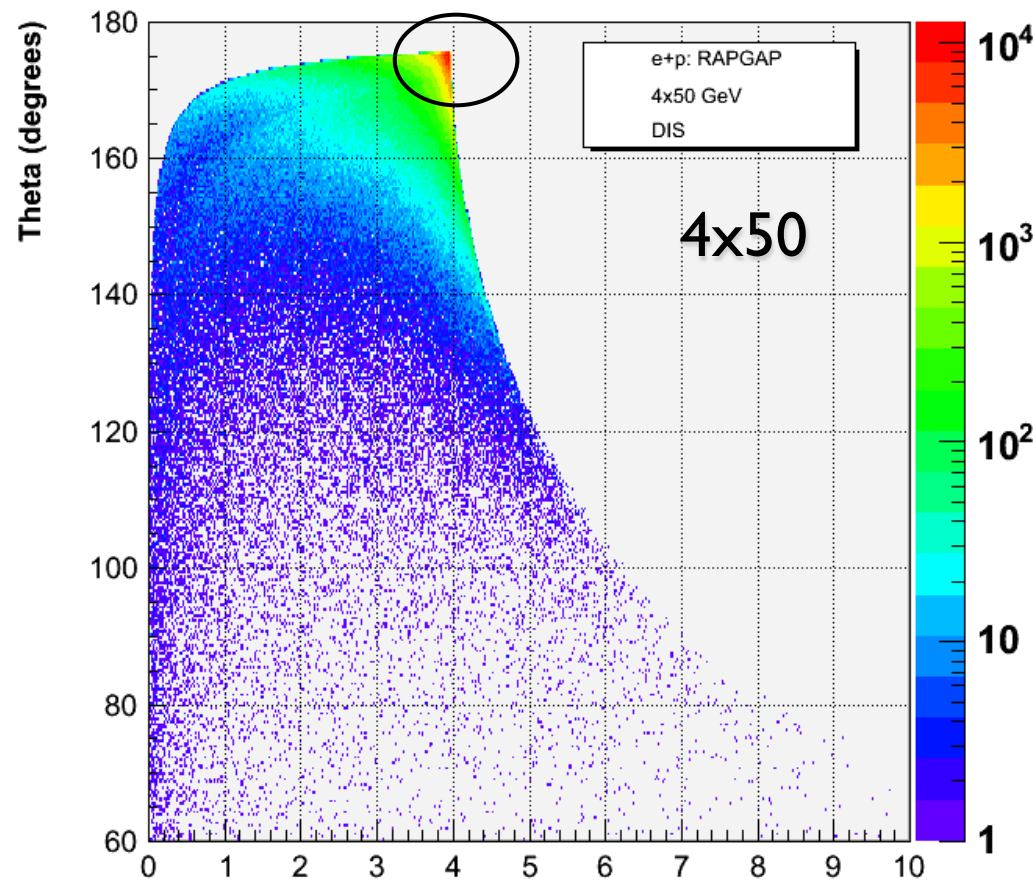
○ 175°

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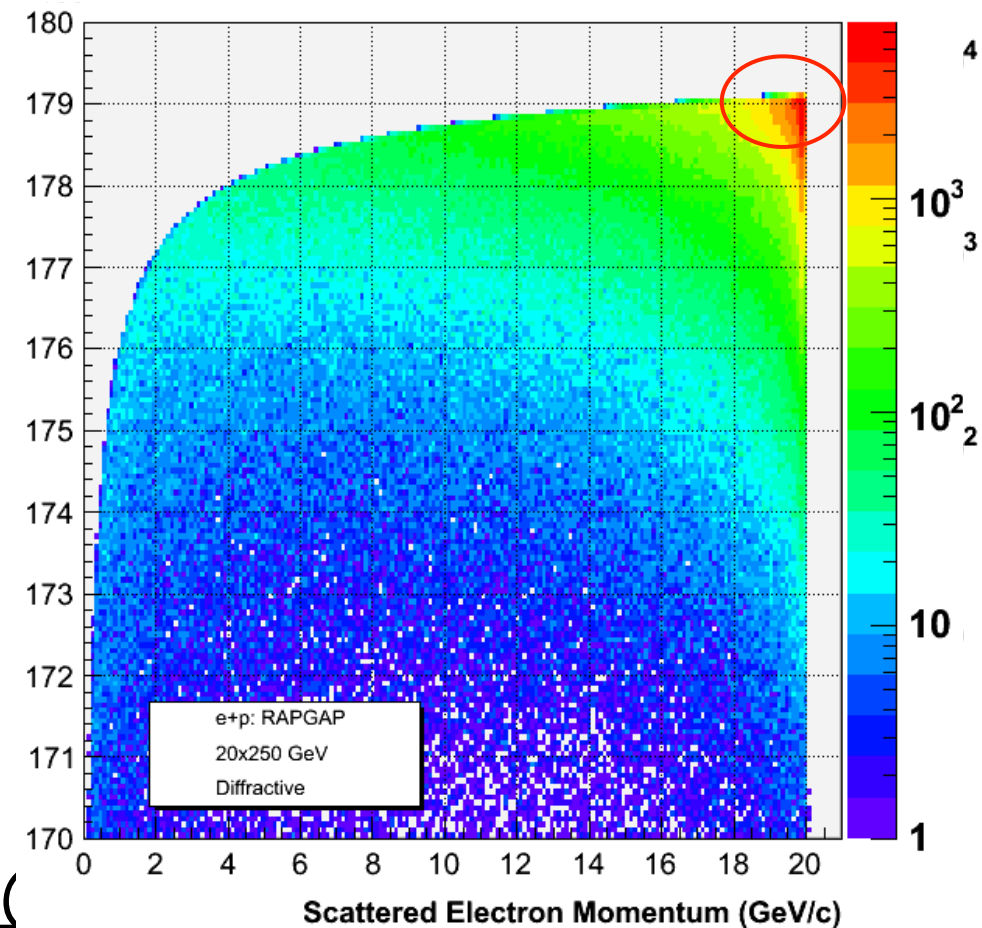
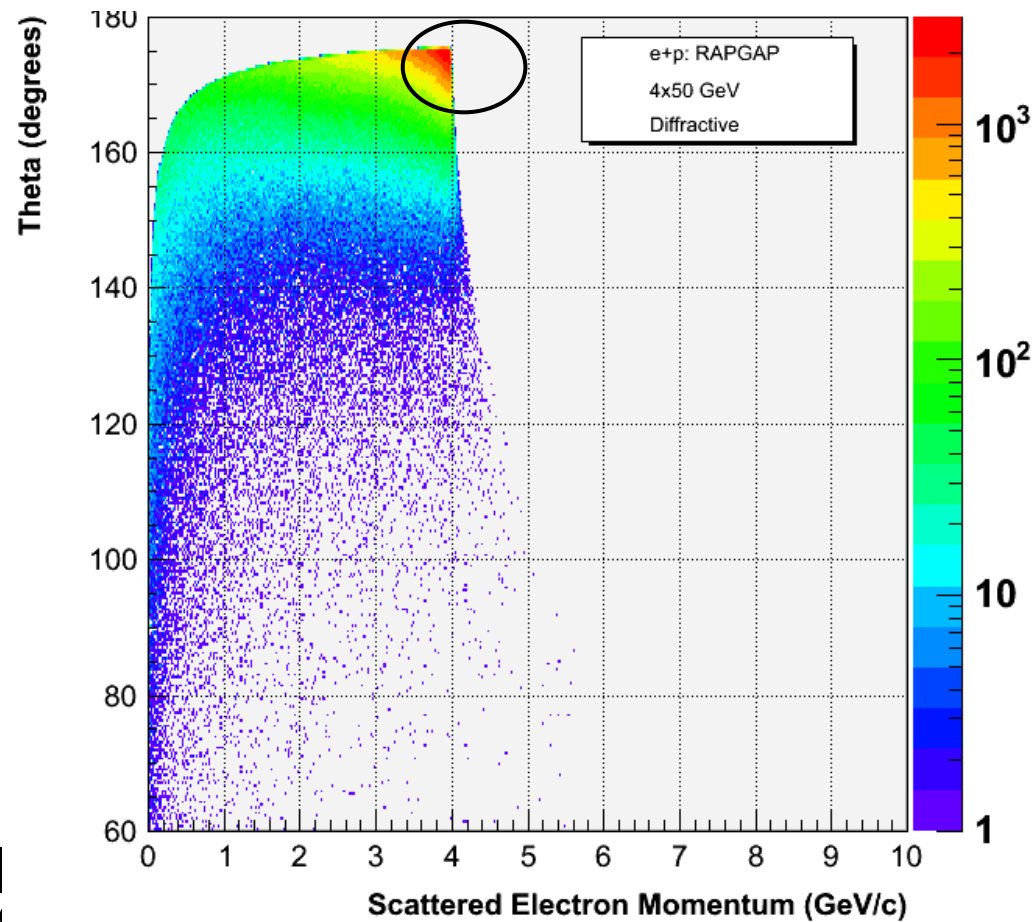
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DIS



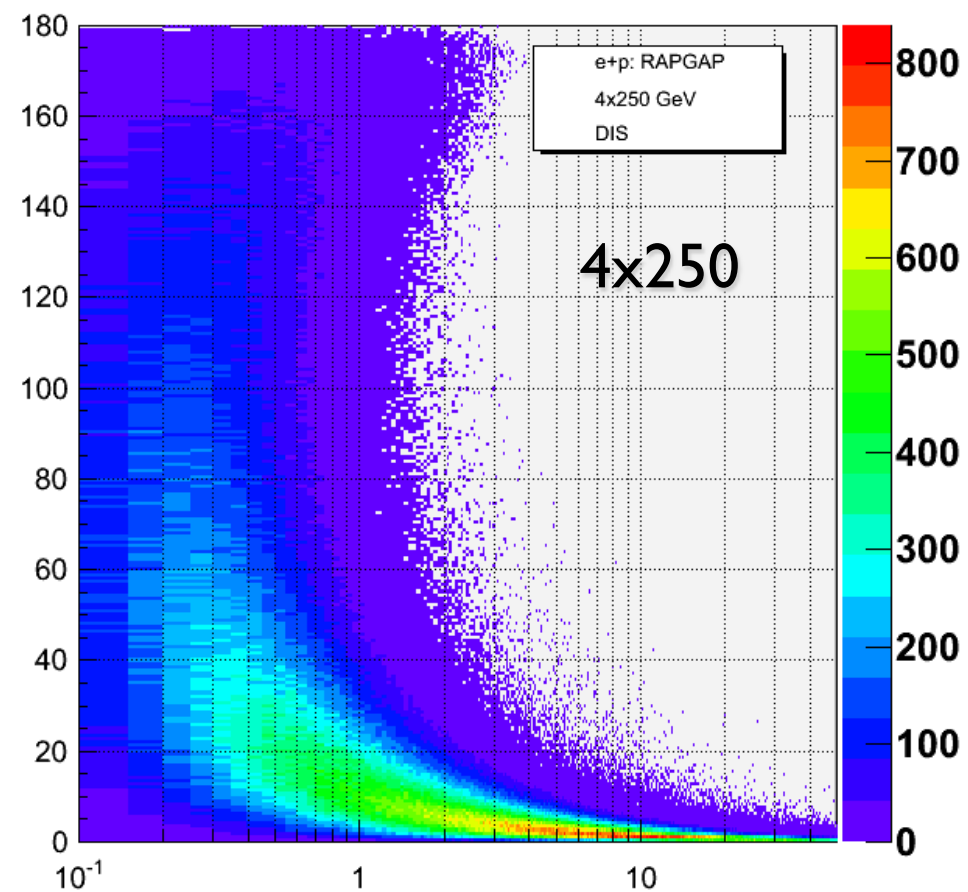
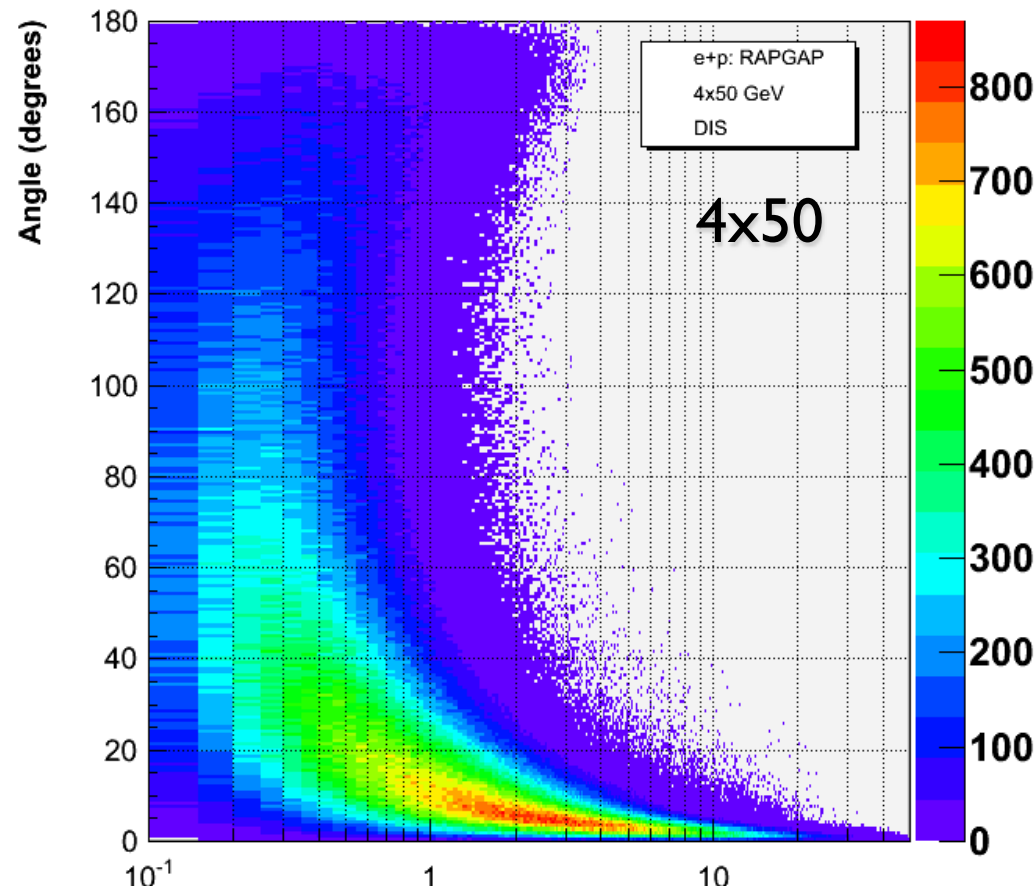
○ 175°
○ 179°

DIFFRACTIVE



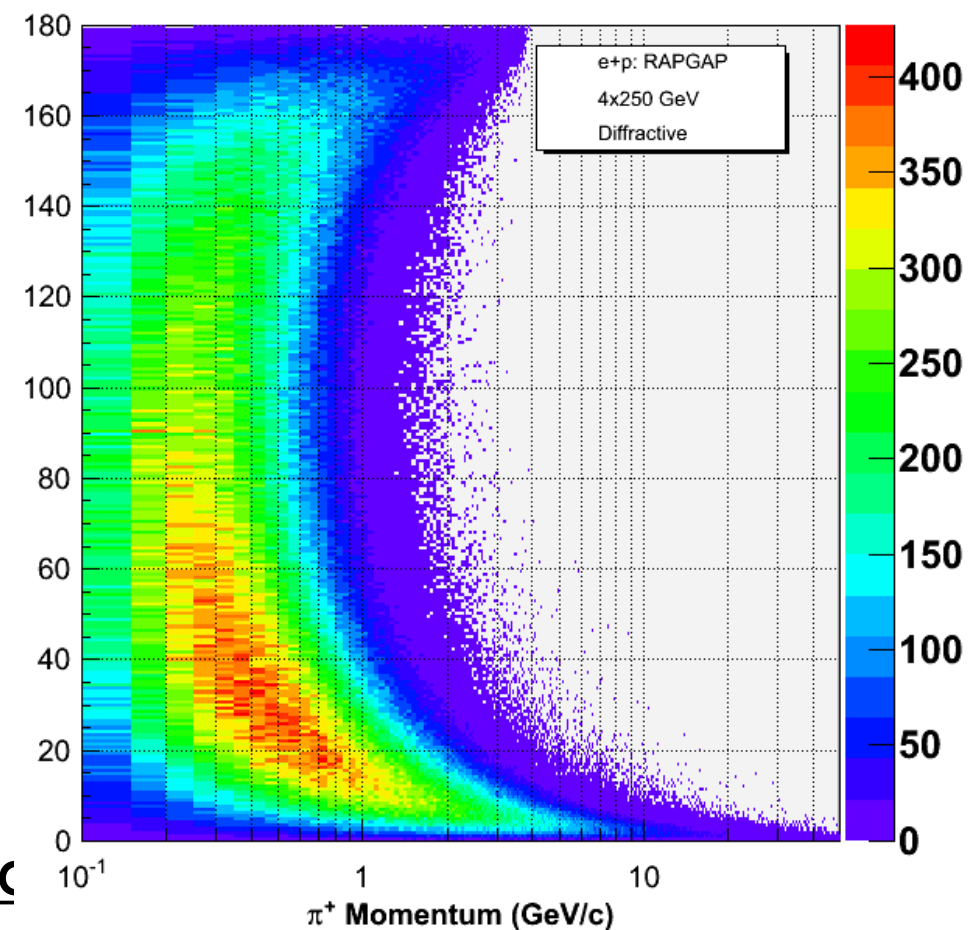
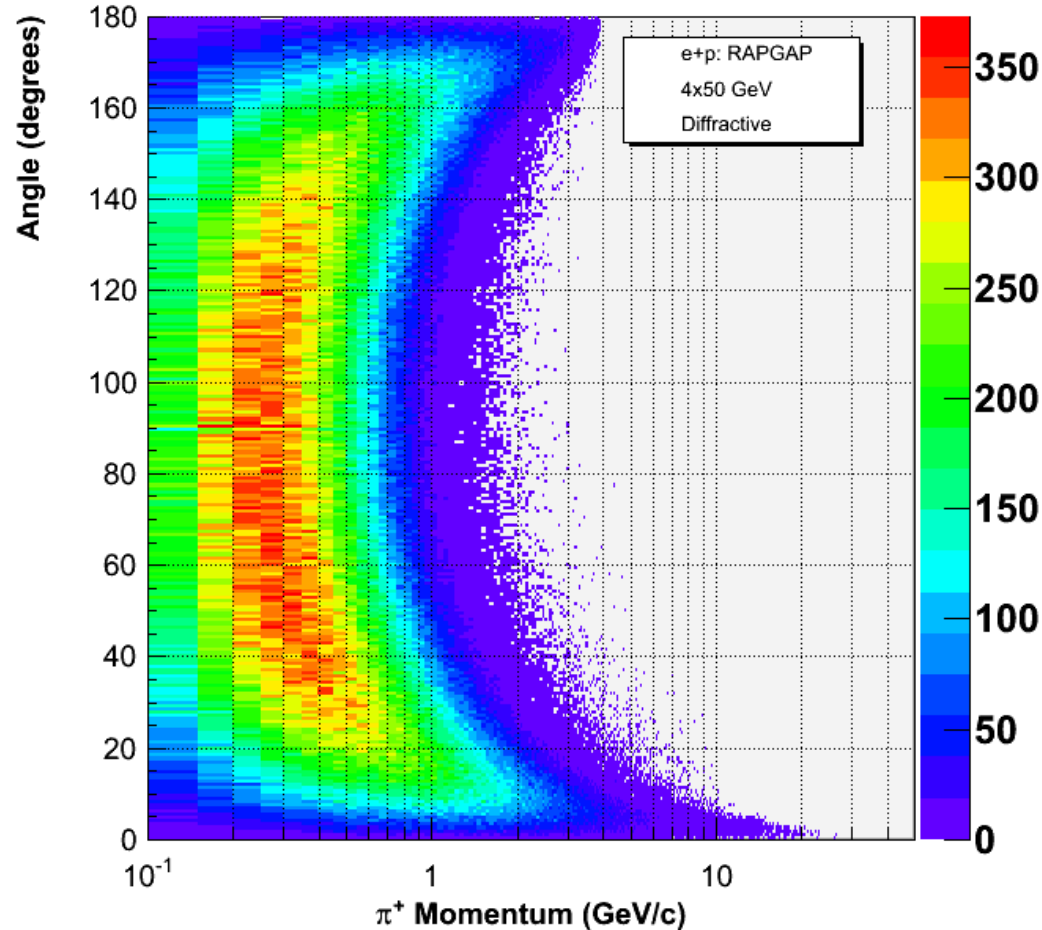
Event kinematics: produced hadrons (π^+)

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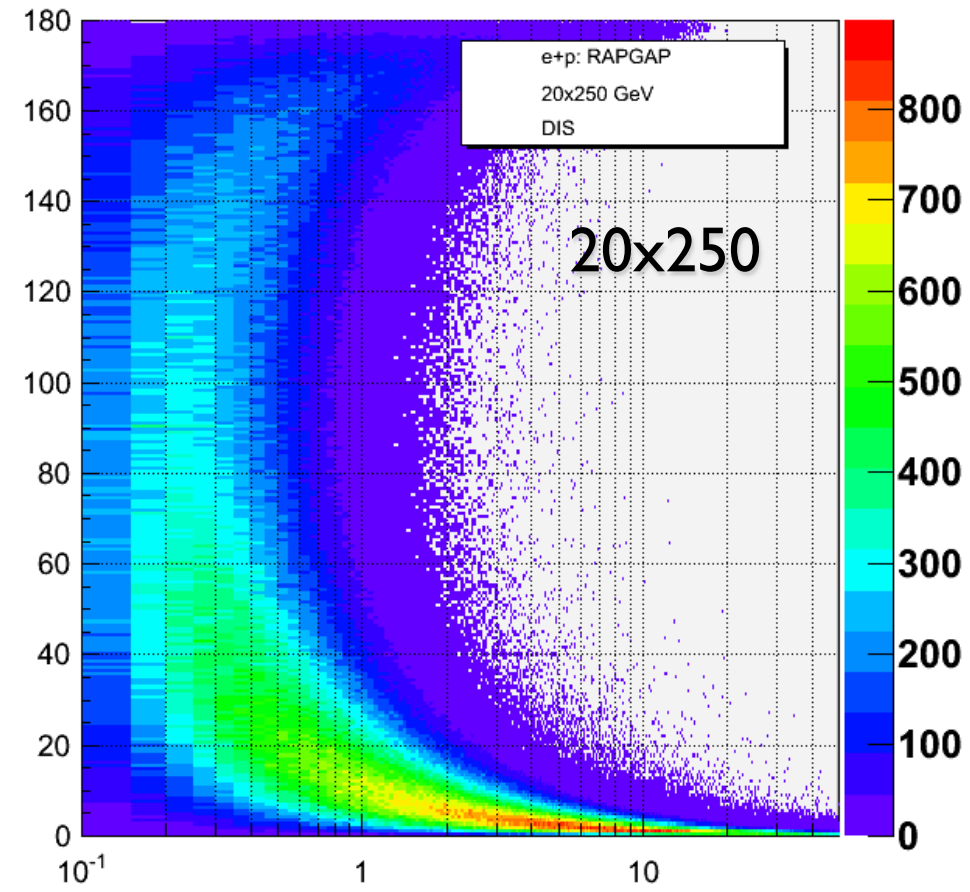
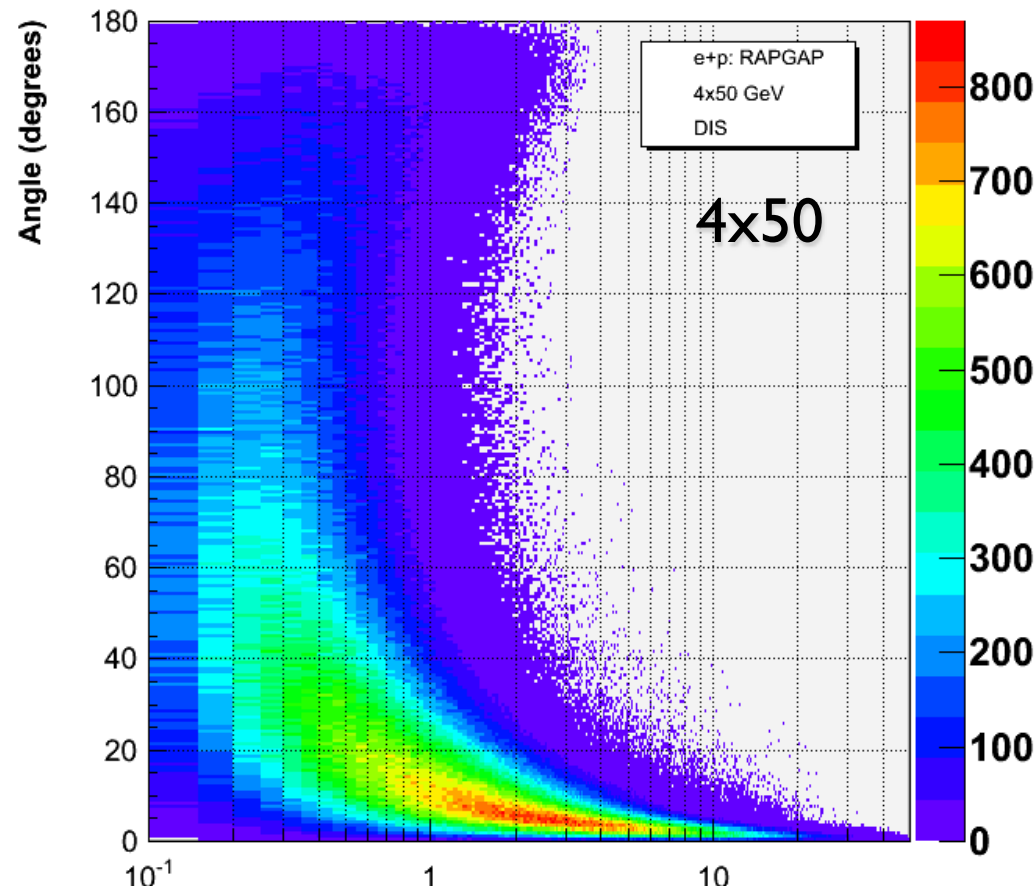
DIS:
small
theta
important

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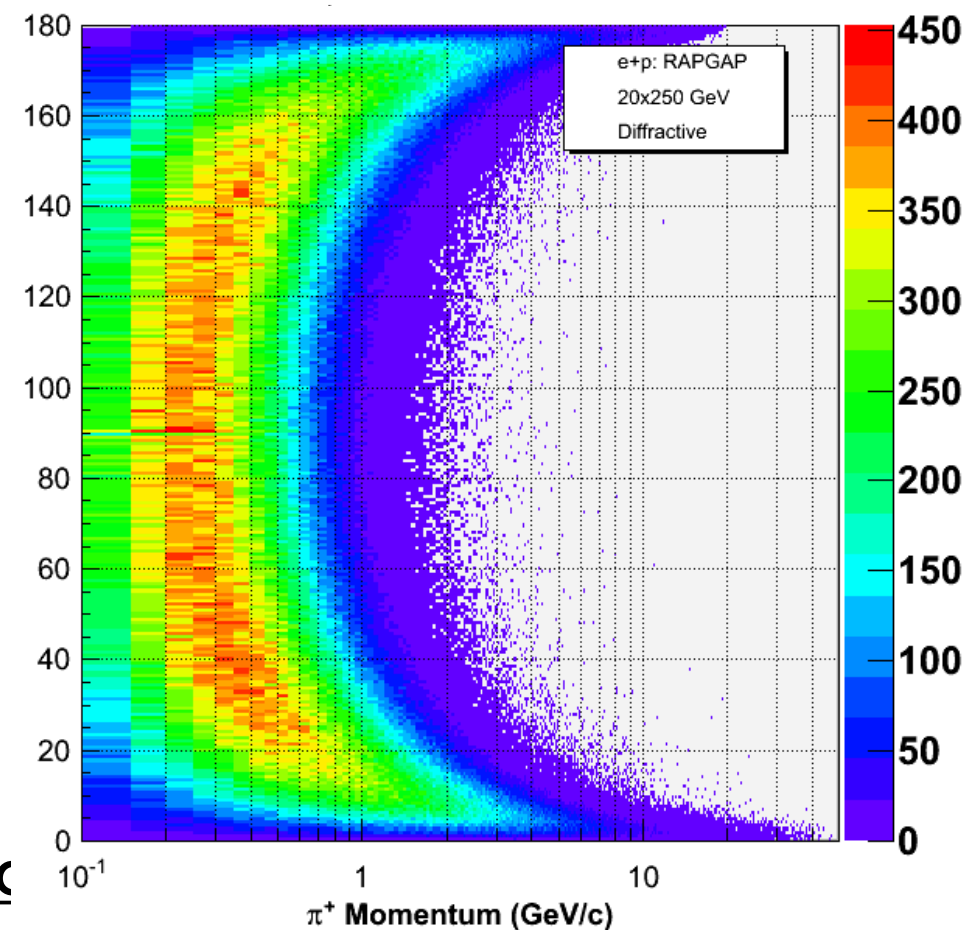
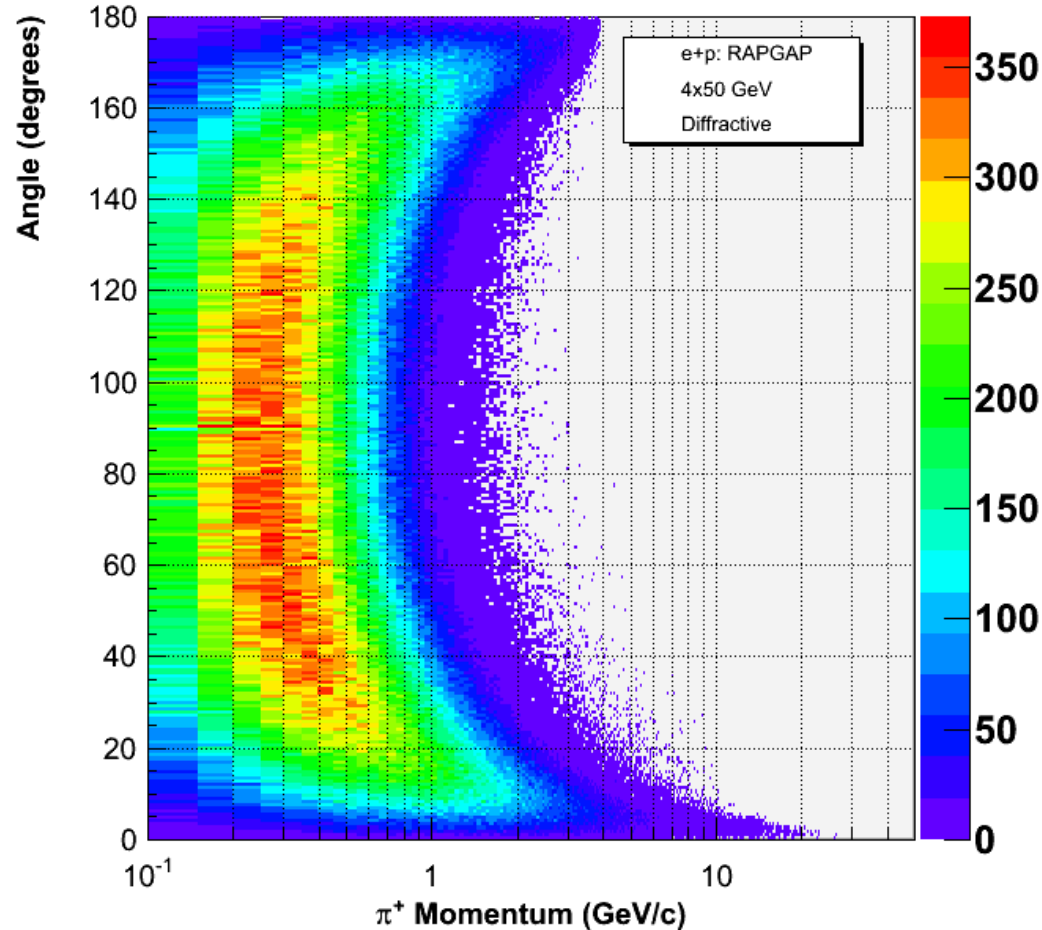
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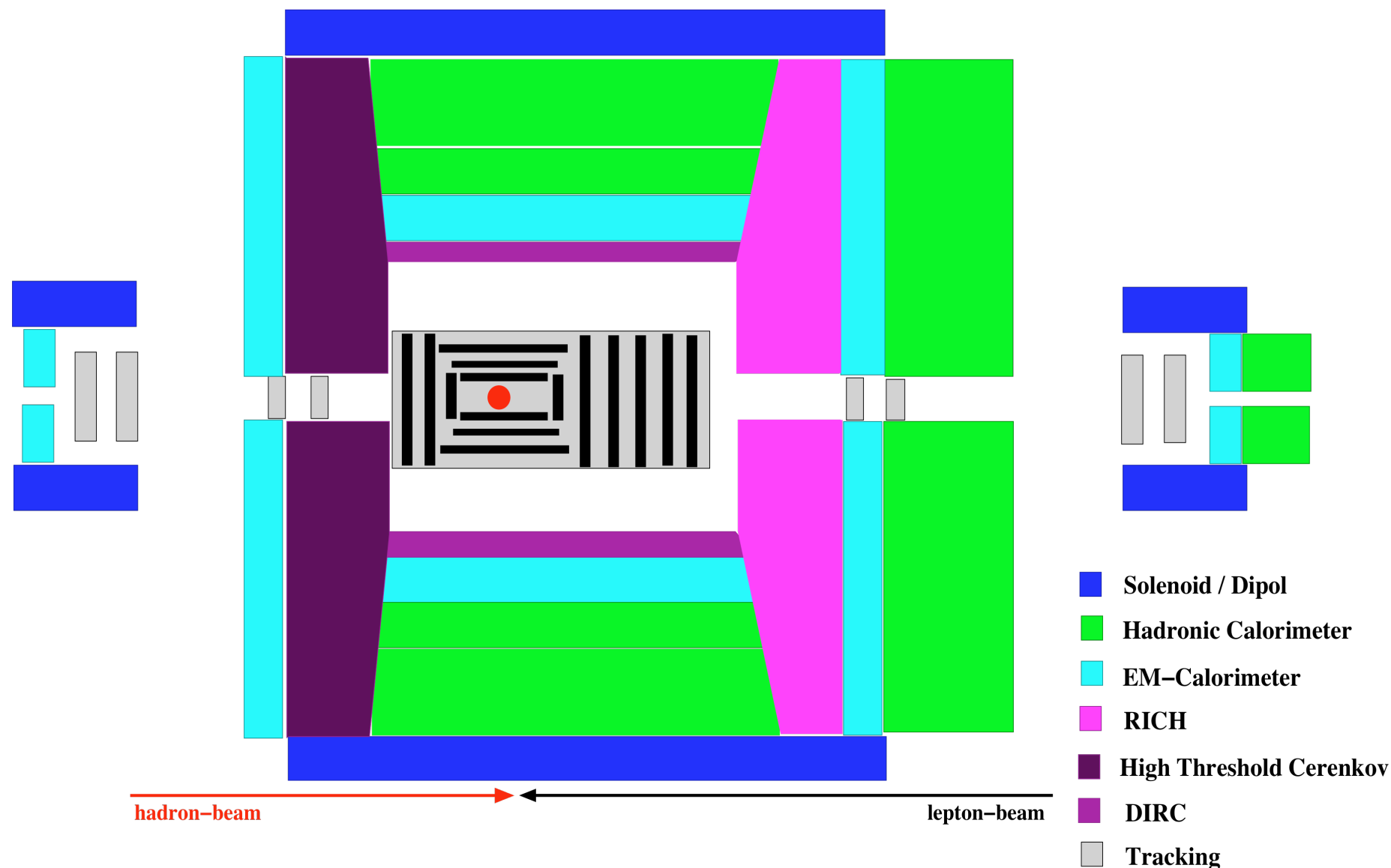


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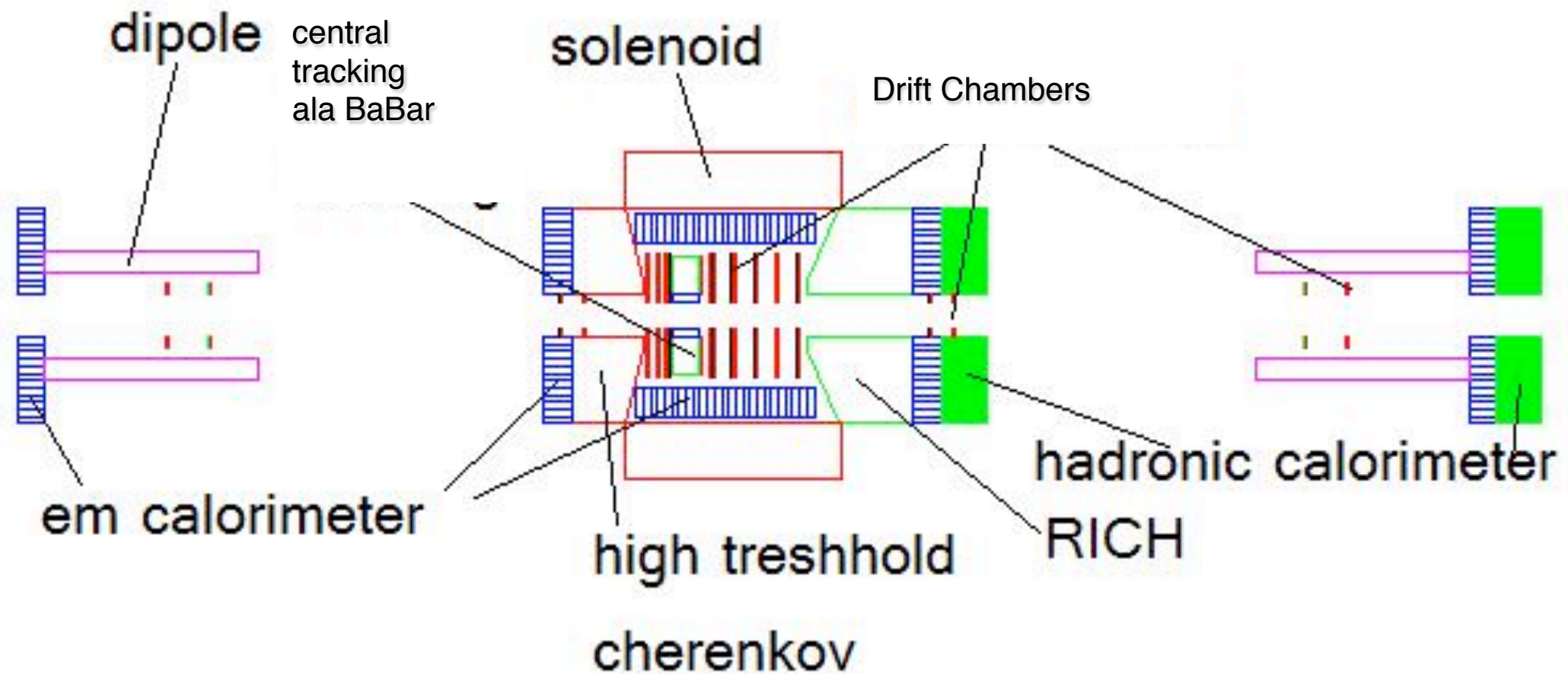


First attempt at detector design



- Dipoles need to have good forward momentum resolution
 - Solenoid has no magnetic field for $r \rightarrow 0$
- RICH, DIRC for hadron pid
- High threshold Cherenkov → fast trigger for scattered lepton
- Radiation length very critical → low lepton energies

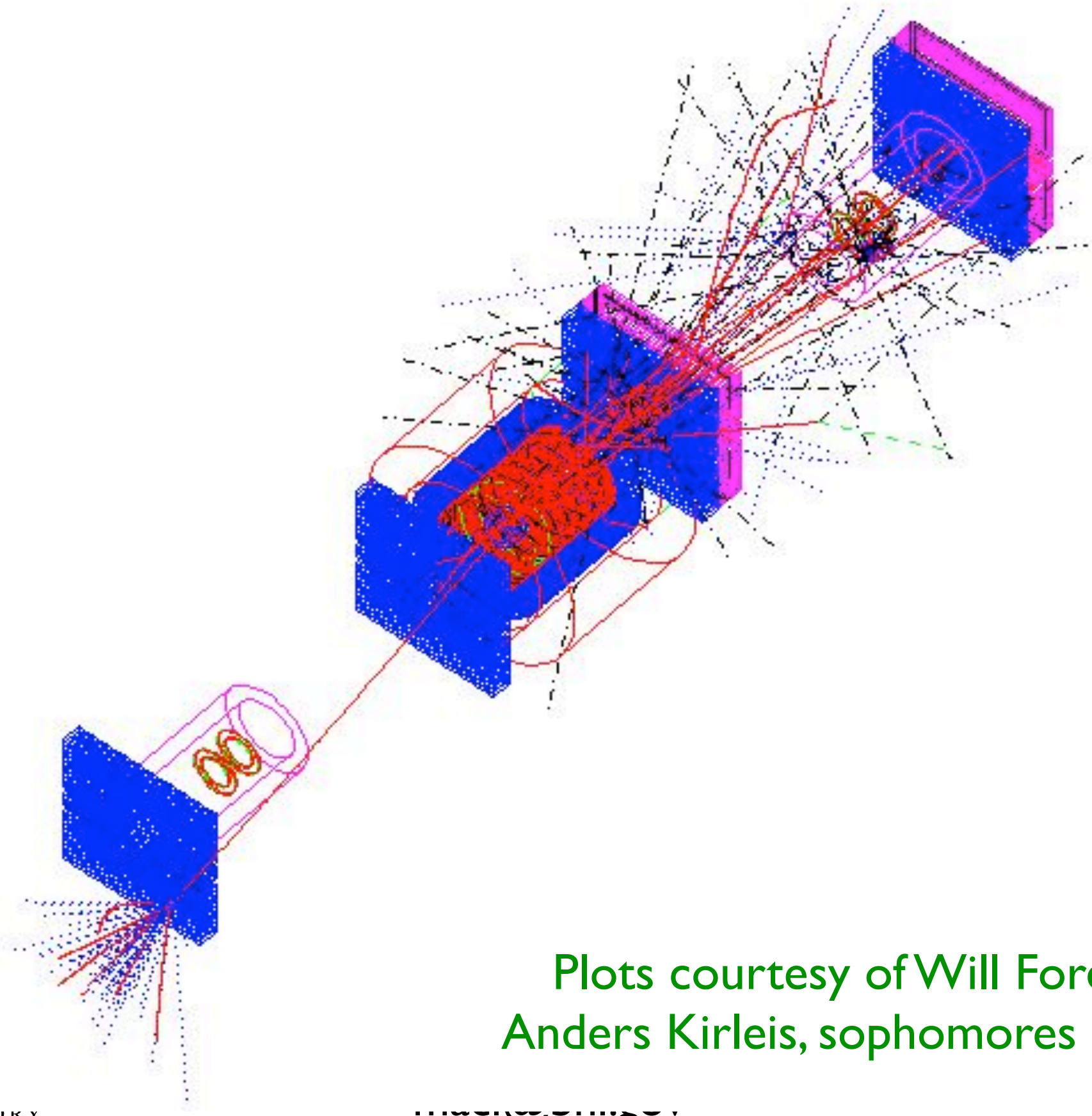
MeRHIC detector in Geant 3



DIRC is present but not seen
due to position of cut

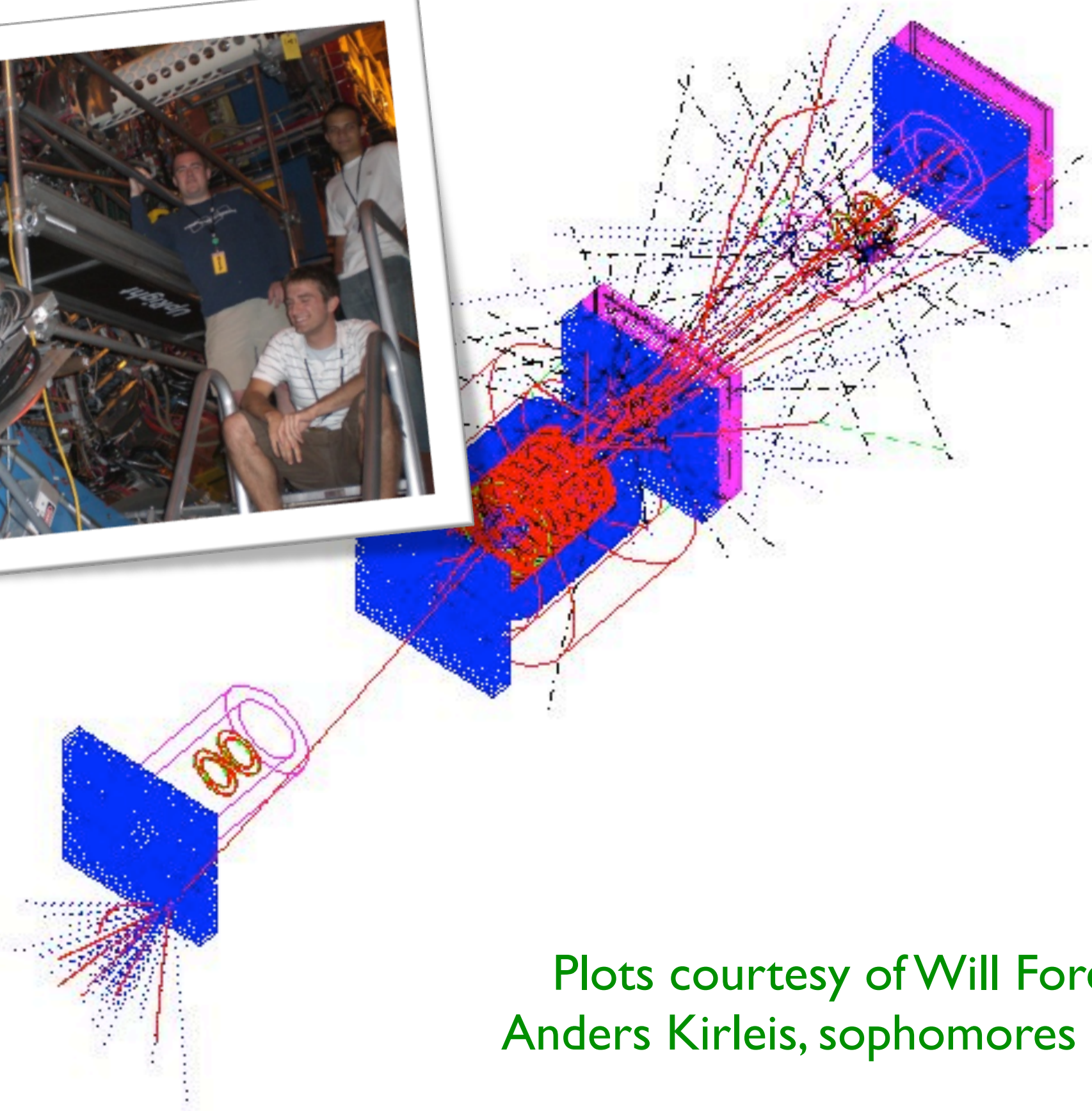
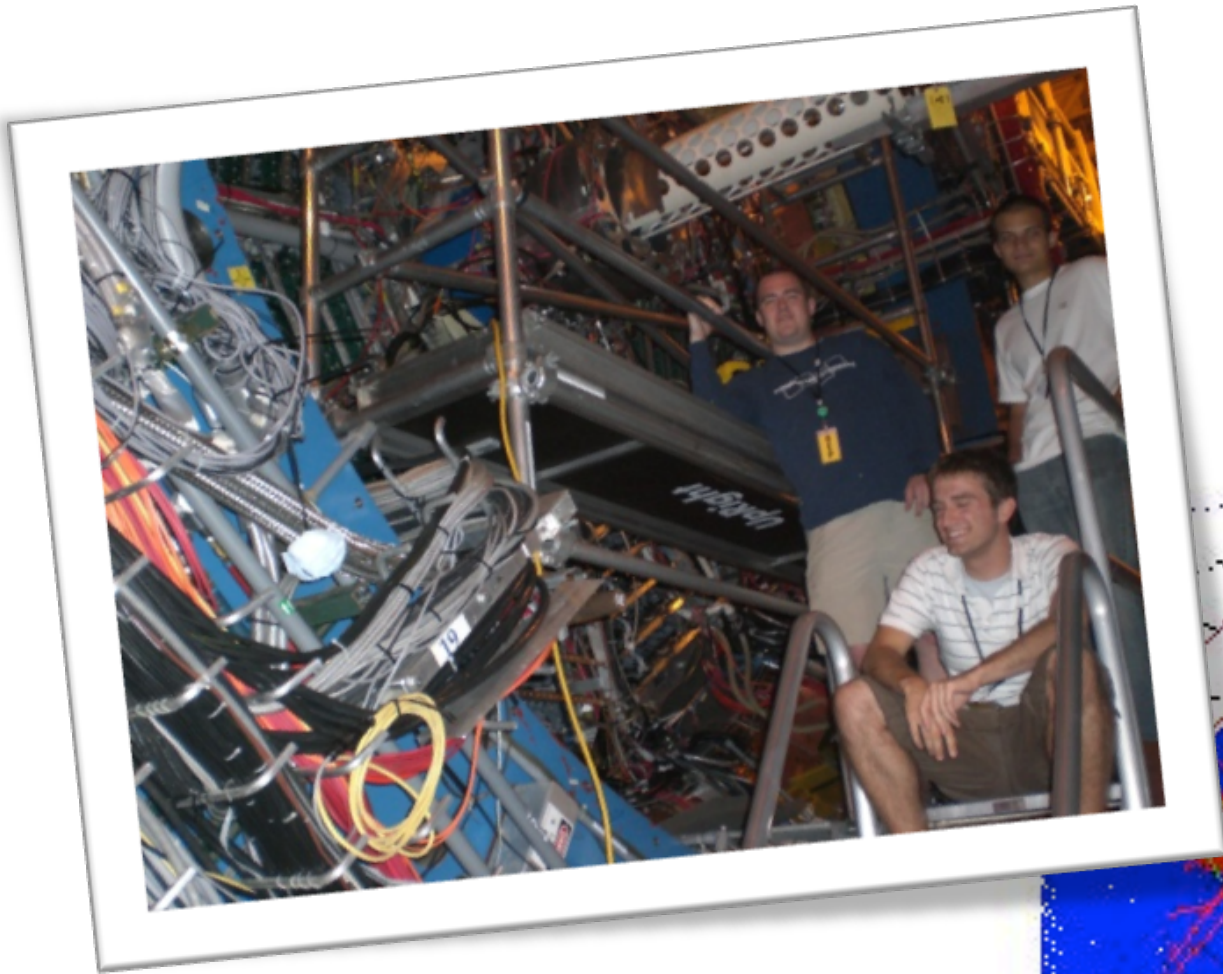
- Note - no hadronic barrel calorimeter due to height restrictions at IP2

MeRHIC detector in Geant 3



Plots courtesy of Will Foreman and
Anders Kirleis, sophomores at SUNY-SB

MeRHIC detector in Geant 3



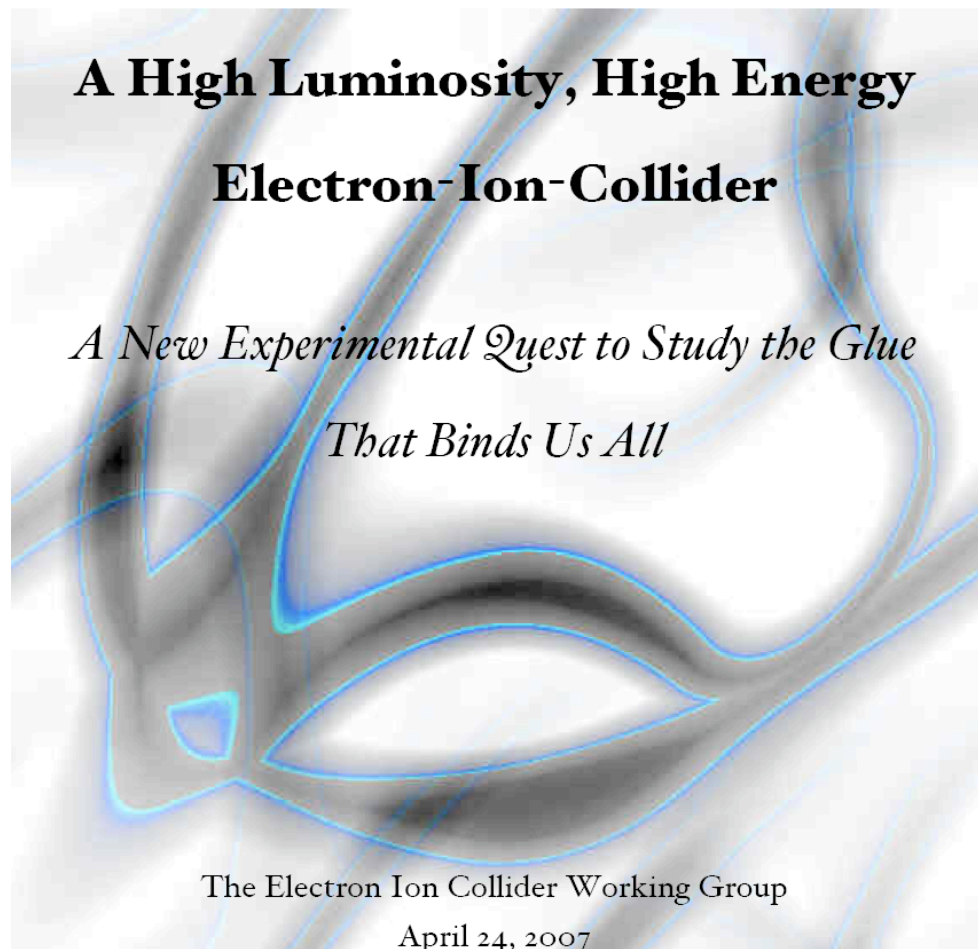
Plots courtesy of Will Foreman and
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What is happening now?

- EIC “Collaboration” formed in 2007
 - ➔ Bi-Annual collaboration meetings
 - ▶ Next meeting, 10th - 12th January, 2010, SUNY-SB
 - ➔ Week long INT workshop - Autumn 2009
 - ➔ 3-month INT programme - Autumn 2010
- Physics working Groups
 - ➔ e+A, e+p, detector design
- BNL Task Force
 - ➔ <http://www.eic.bnl.gov/> and <https://wiki.bnl.gov/eic> for details
 - ➔ Current focus of work - understanding diffraction in e+A physics
 - ▶ How do we measure diffractive events? ⇒ detector design
- 3 summer students from SUNY-SB working on both detector design and theoretical issues
 - ➔ Have continued working through the semester on a “research for credit” scheme and we have gained 2 more students!!

Status of the EIC project:

The Electron Ion Collider (EIC) White Paper



Status of the EIC project:

Available at:

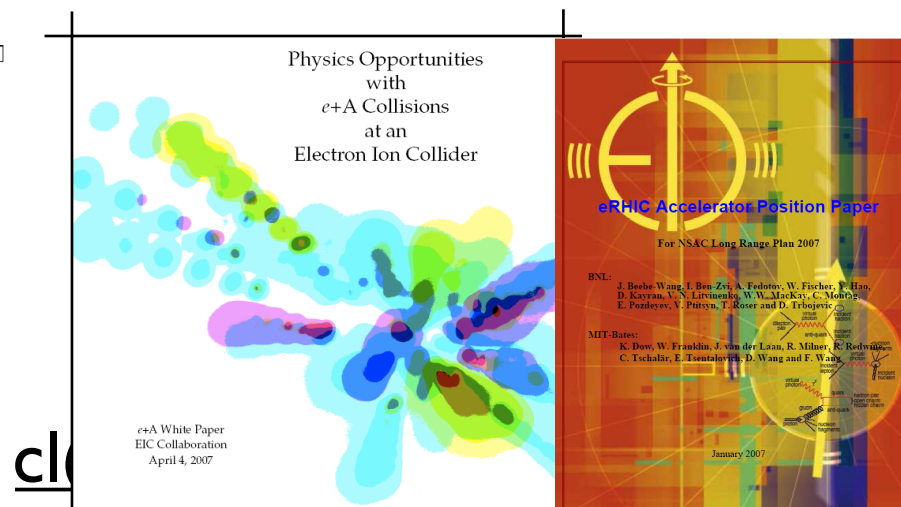
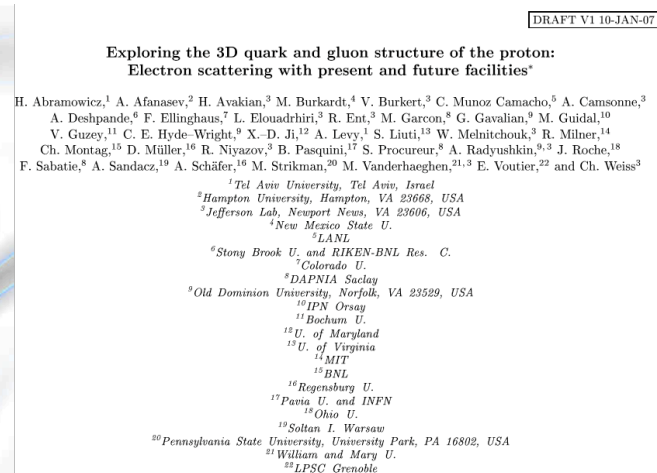
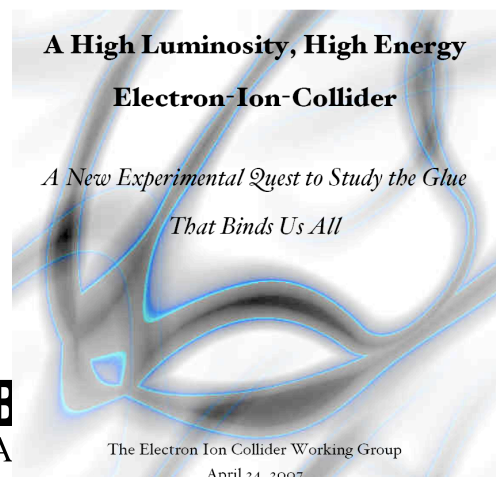
- NSAC LRP2007 home page
- Rutgers Town Meeting page
- <http://www.eic.bnl.gov>
- <https://wiki.bnl.gov/eic>

The Electron Ion Collider (EIC) White Paper

The GPD/DVCS White Paper

Position Paper: e+A physics at an Electron Ion Collider

The eRHIC machine: Accelerator position paper



2007 NSAC Long Range Plan

“We recommend the allocation of resources to develop accelerator and detector technology necessary to lay the foundation for a polarized Electron-Ion Collider. The EIC would explore the new QCD frontier of strong colour fields in nuclei and precisely image the gluons in the proton.”

The Frontiers of Nuclear Science
A LONG RANGE PLAN

Summary

An EIC presents a unique opportunity in high energy nuclear physics and precision QCD physics

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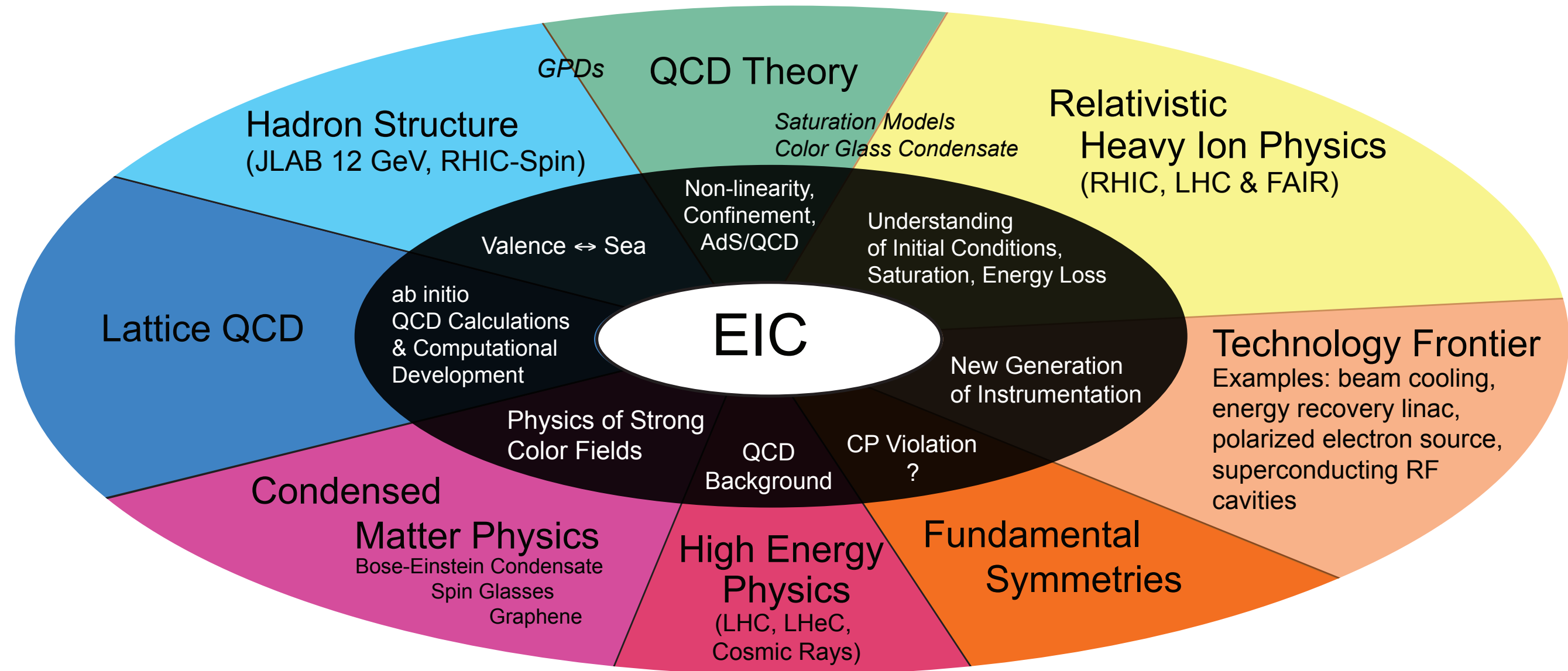
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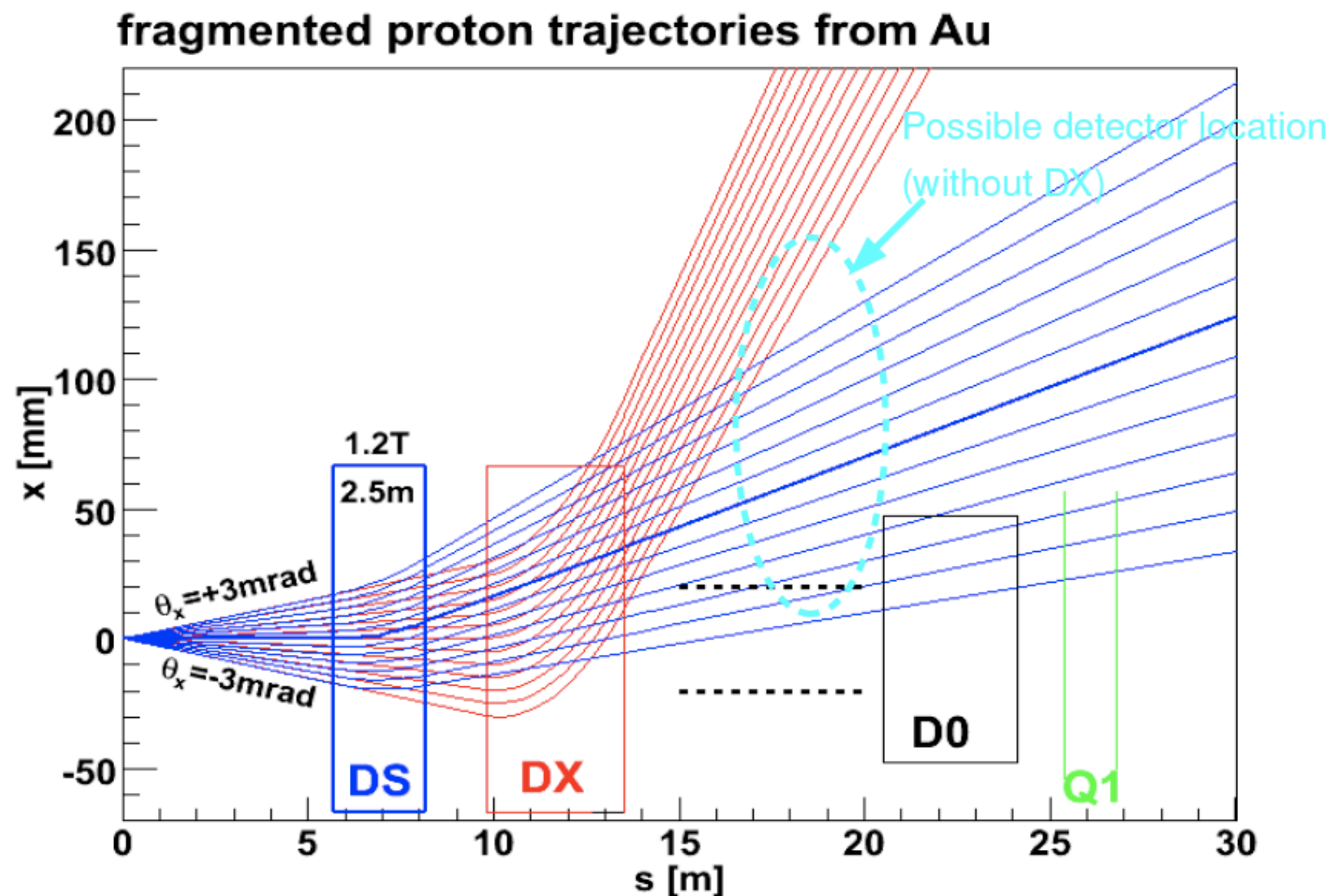
- Embraced by NSAC in Long Range PPlan
 - Recommendation of \$30M for R&D over next 5 years
- EIC Long Term Goal - start construction in next decade
- Possibility of Staged Approach
 - Cheap (less civil construction costs)
 - Early time-scale for realisation (operation by ~2016)

Connection to other fields



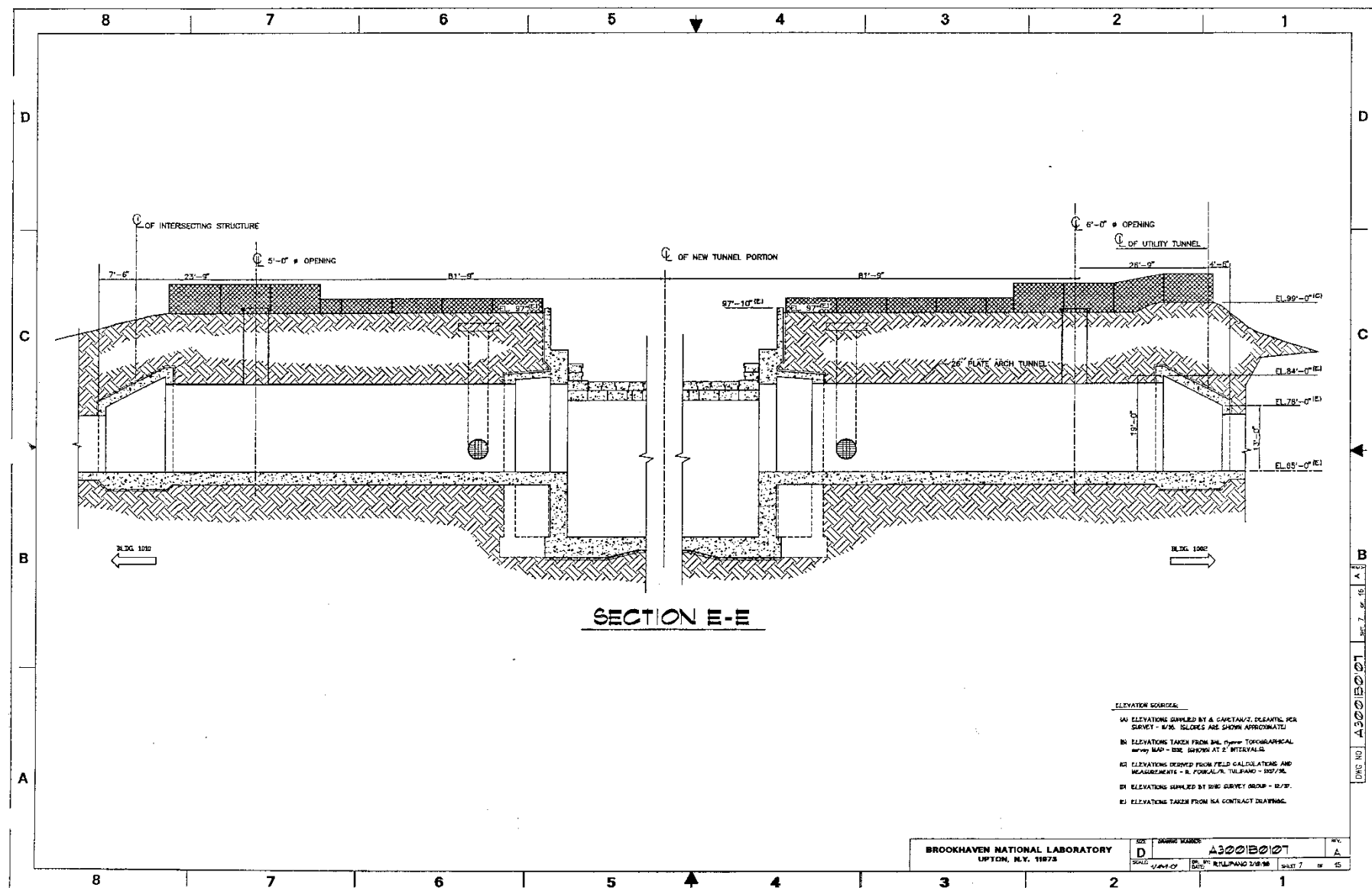
Detection from hadron beam

- Tagging from Au fragments and p/n in e+p collisions
 - ➡ suppress incoherent scattering / ensure exclusivity
 - ▶ neutrons are detected in the **Z**ero **D**egree **C**alorimeter
 - ▶ protons use magnetic rigidity (Au:p = 2.5:1)
 - ➡ DX magnet disturbs p tagging

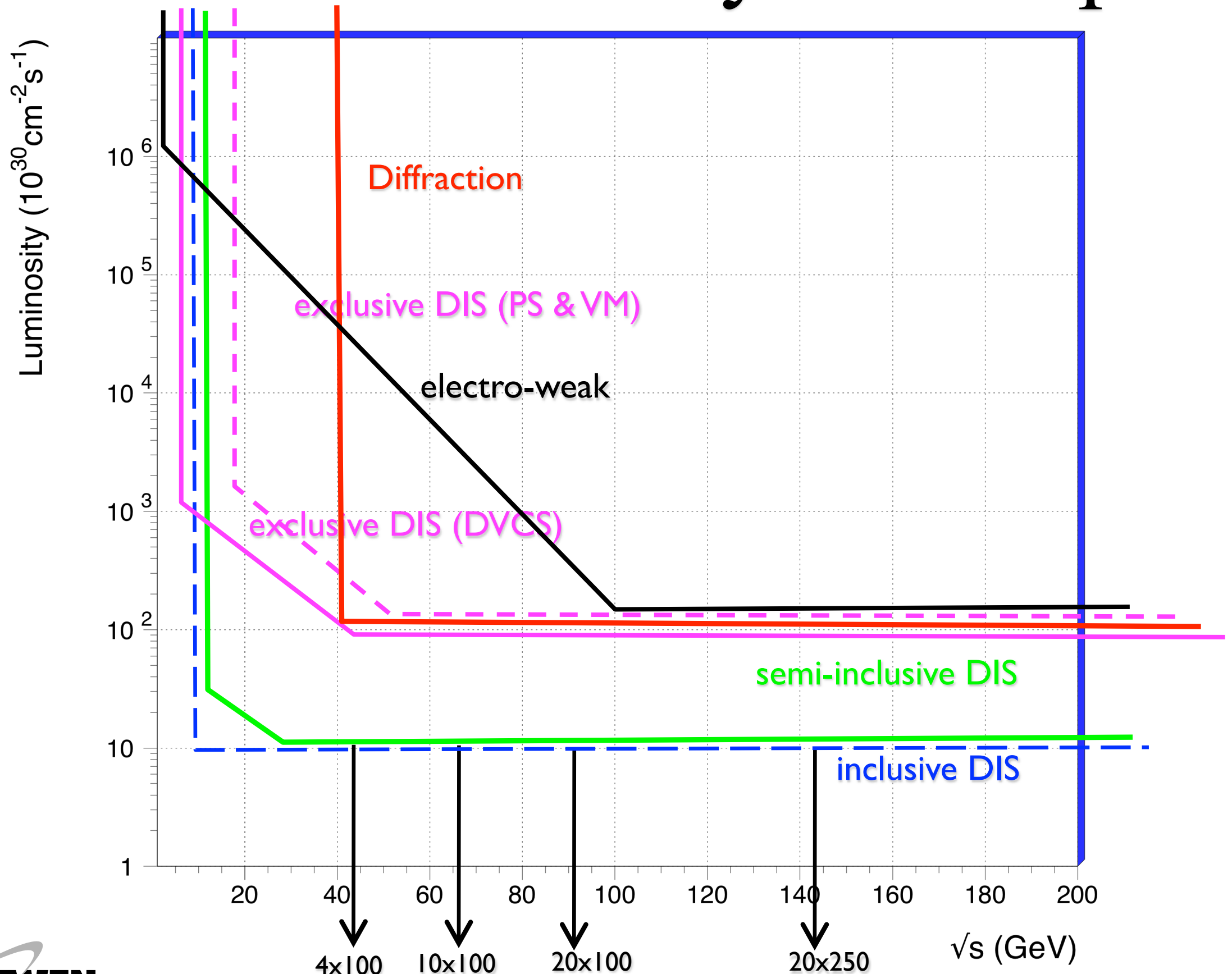


What about 12 o'clock instead of 2

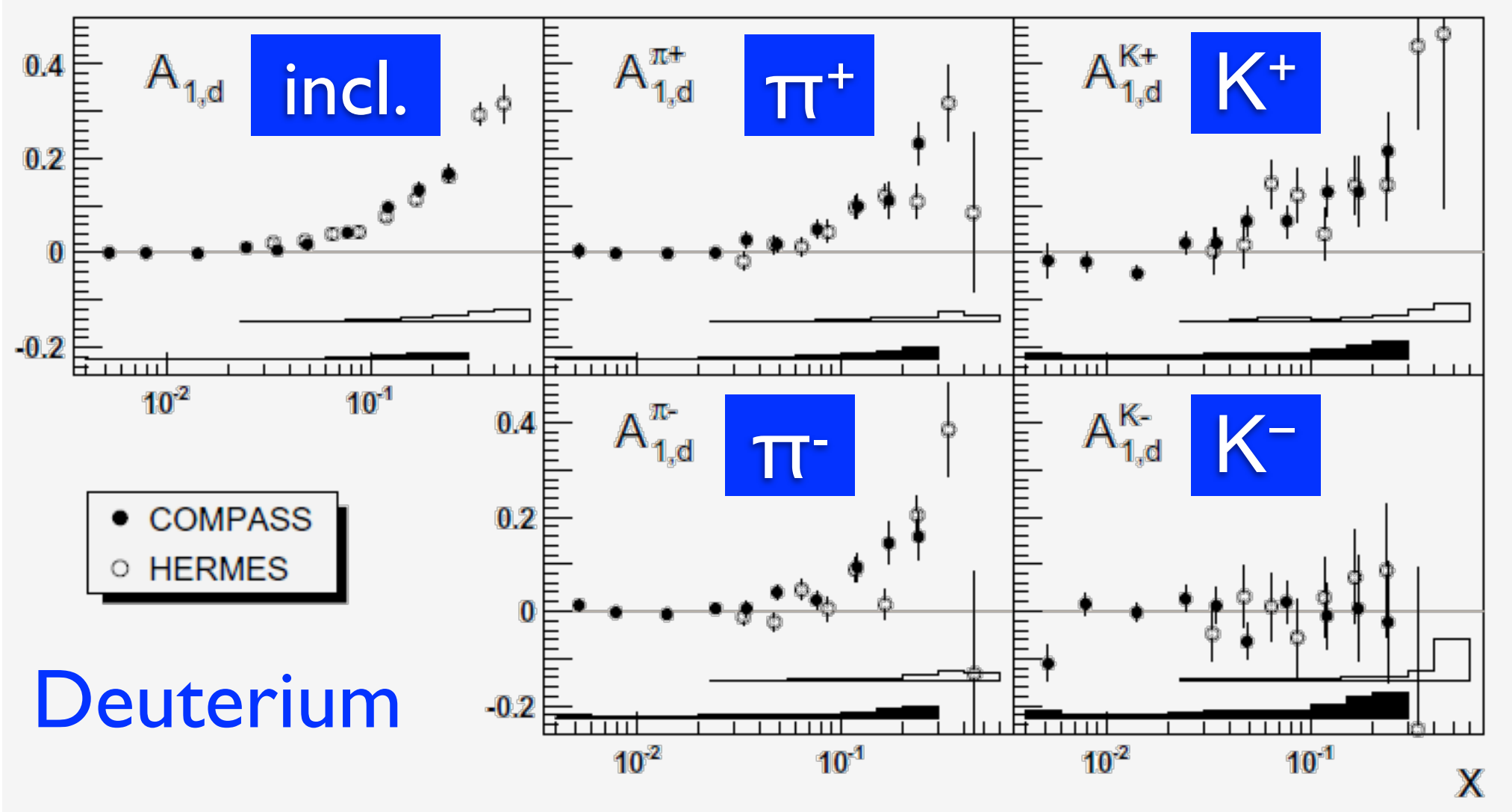
- Detector cost savings
 - ➔ Fully staged detector from MeRHIC to eRHIC
 - ▶ Vertical space much greater
 - ▶ Need to buy magnets only once
 - ▶ Can stage detector components (e.g. hadronic calorimeter)
 - ▶ No moving of components



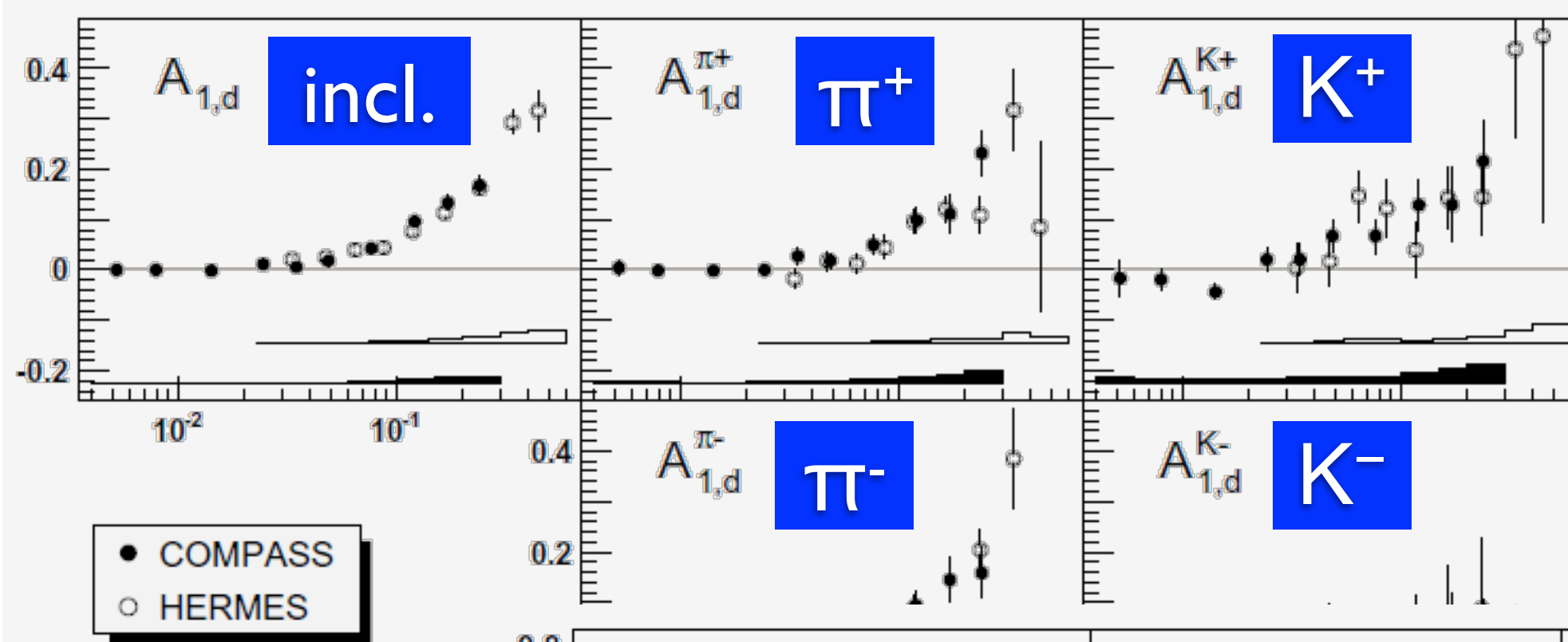
The $\sqrt{s}$ vs. luminosity landscape



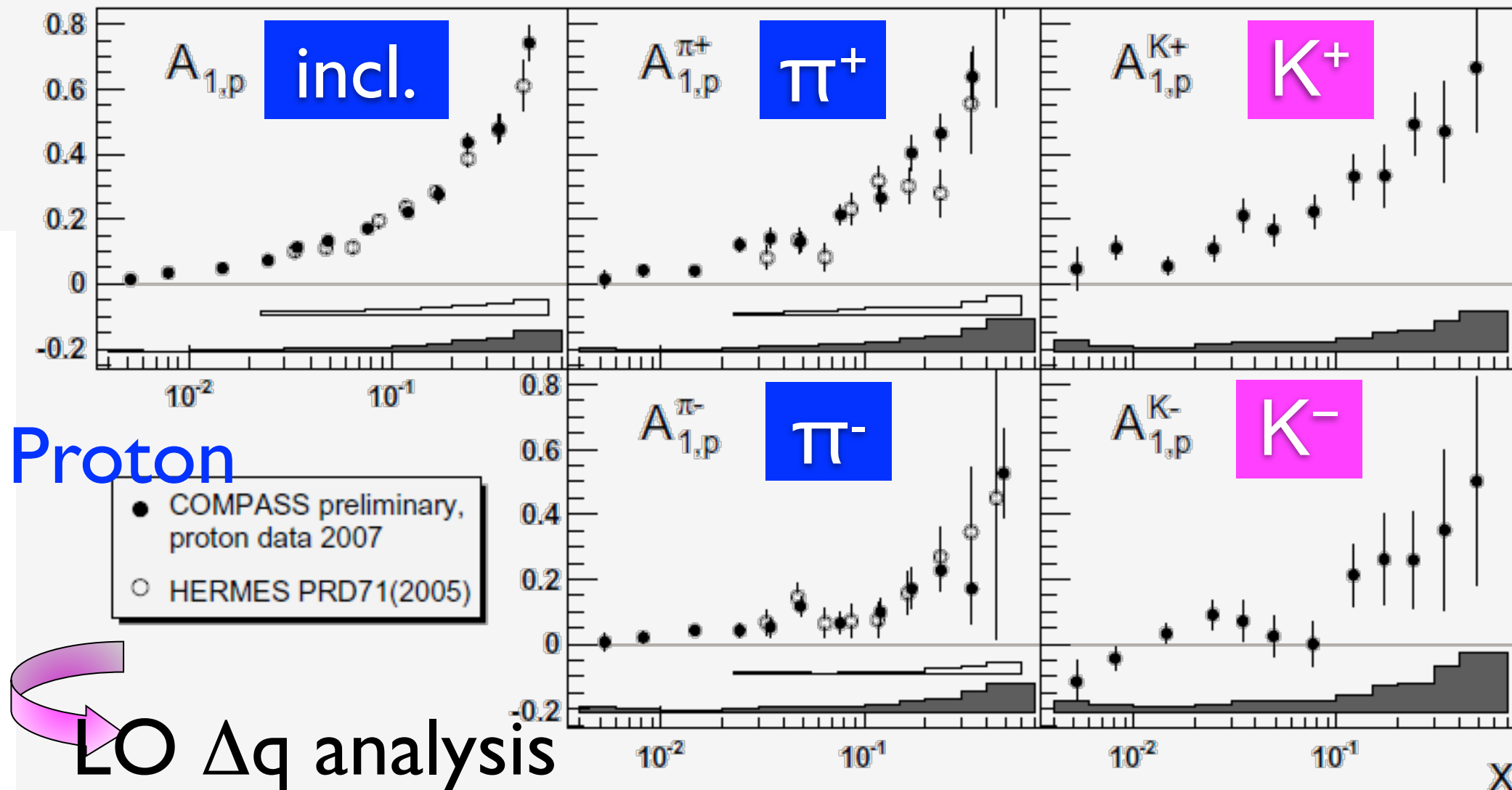
Compass a lot of new results



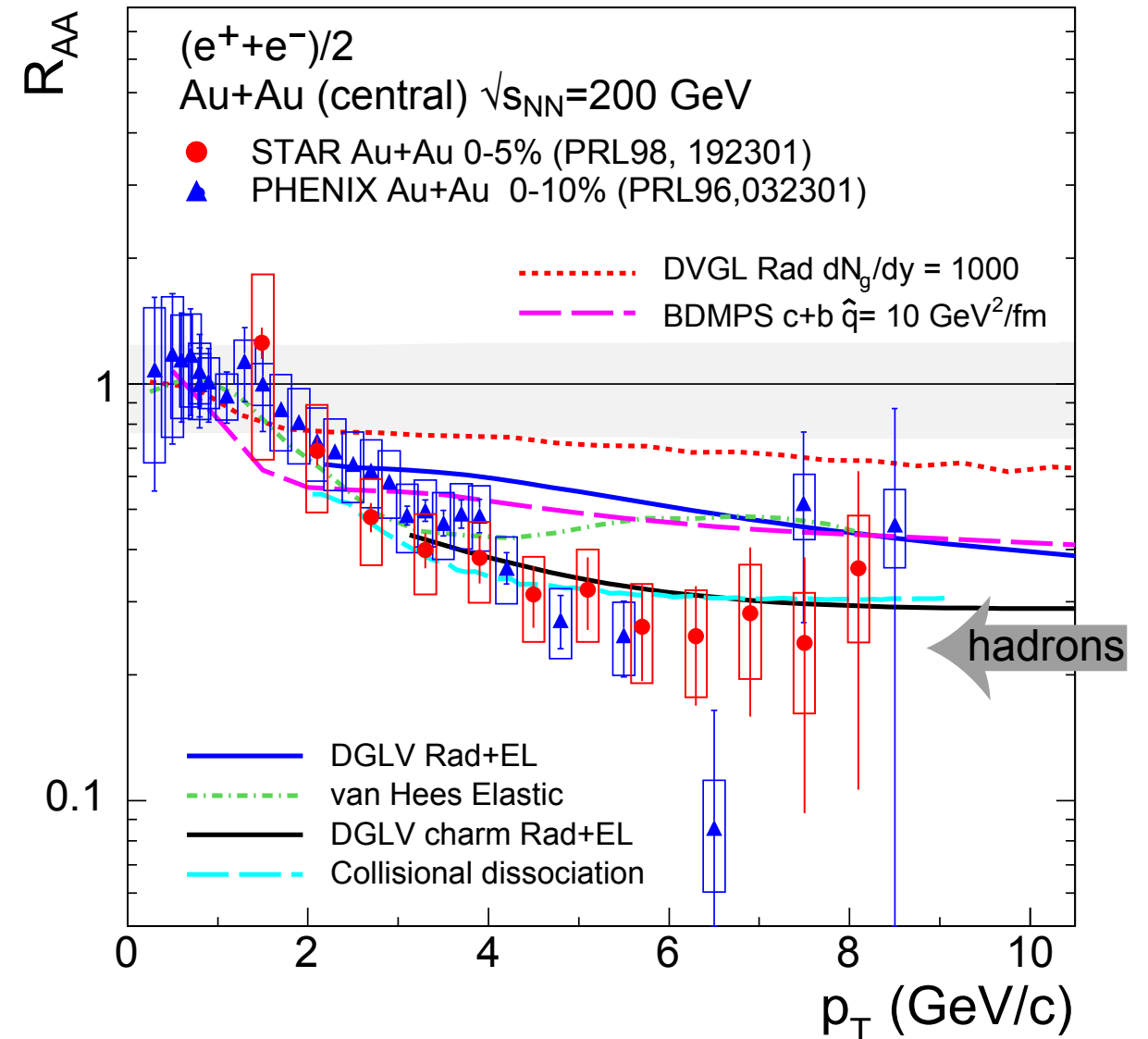
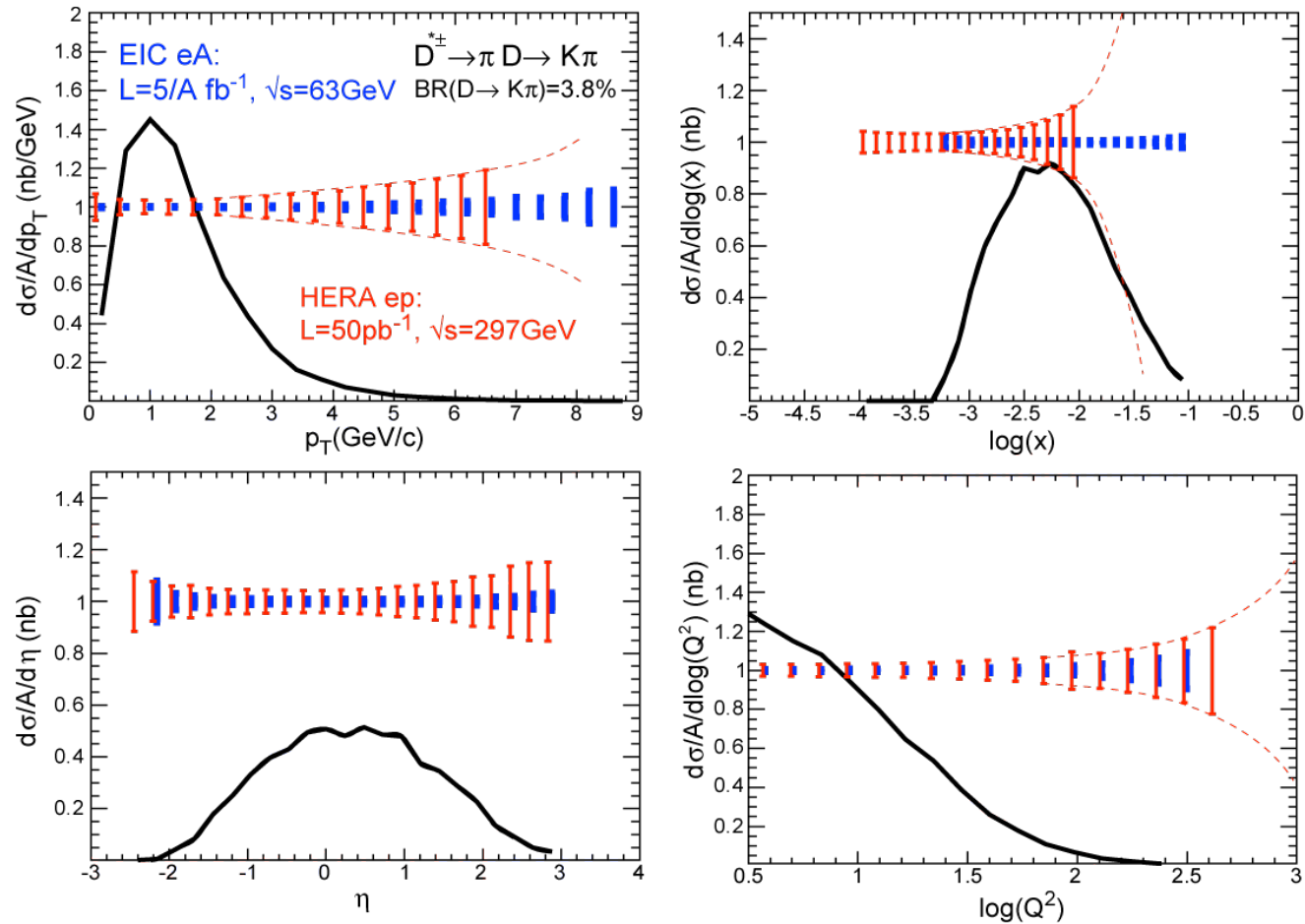
Compass a lot of new results



Deuteron



Charm at eRHIC



- eRHIC allows **multi-differential measurements** of heavy flavour
- covers and **extends energy range** of previous experiments, allowing for **the study of a wide range of formation lengths**