Studying the glue which binds us all: the needs and requirements for an e+A collider

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for the EIC Collaboration

Talk Outline

- The role of glue in the World
- How to measure the gluon distributions
- *e*A vs *ep* and the "Nuclear Oomph" factor
- The EIC machine concepts
- Where we are and where we're going

EIC on the web: http://web.mit.edu/eicc
e+A working group: http://www.eic.bnl.gov

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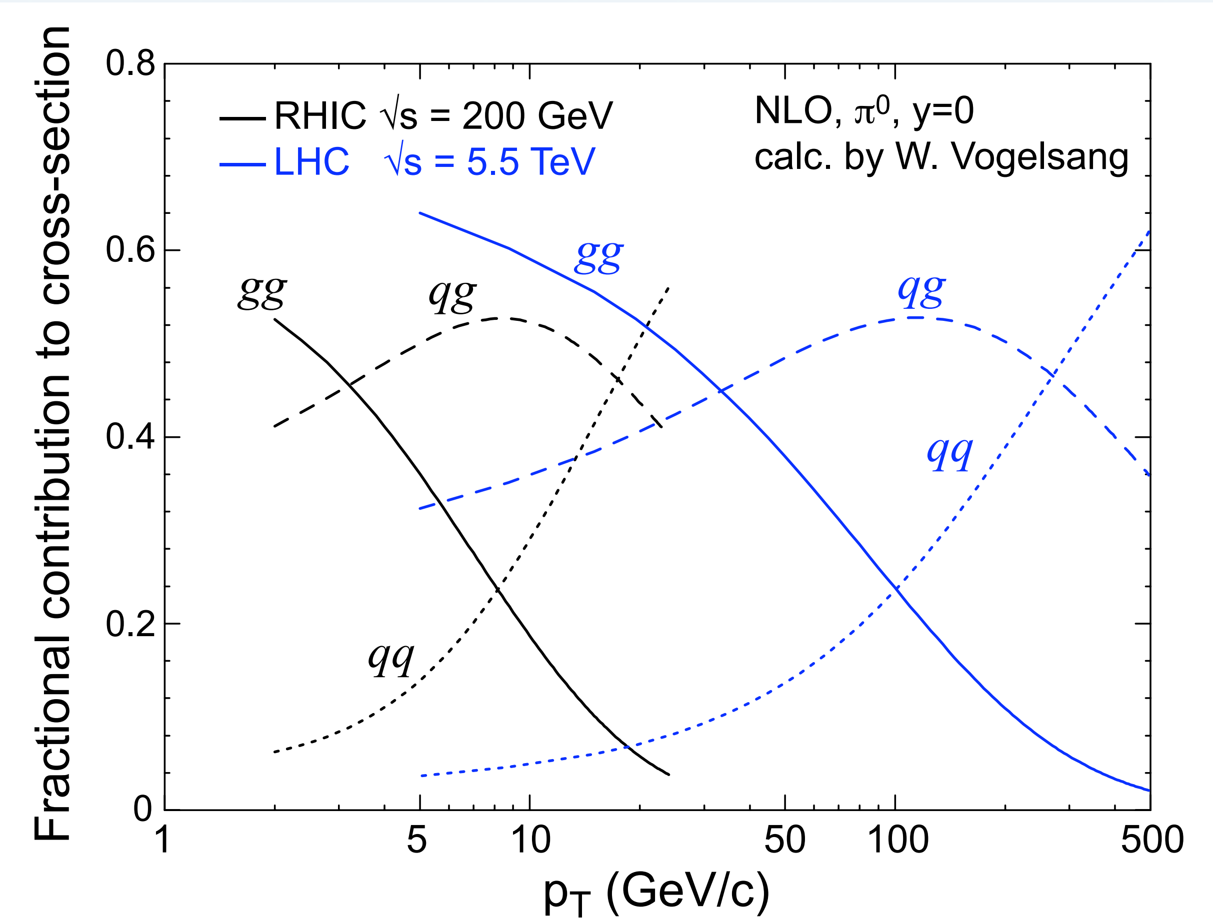
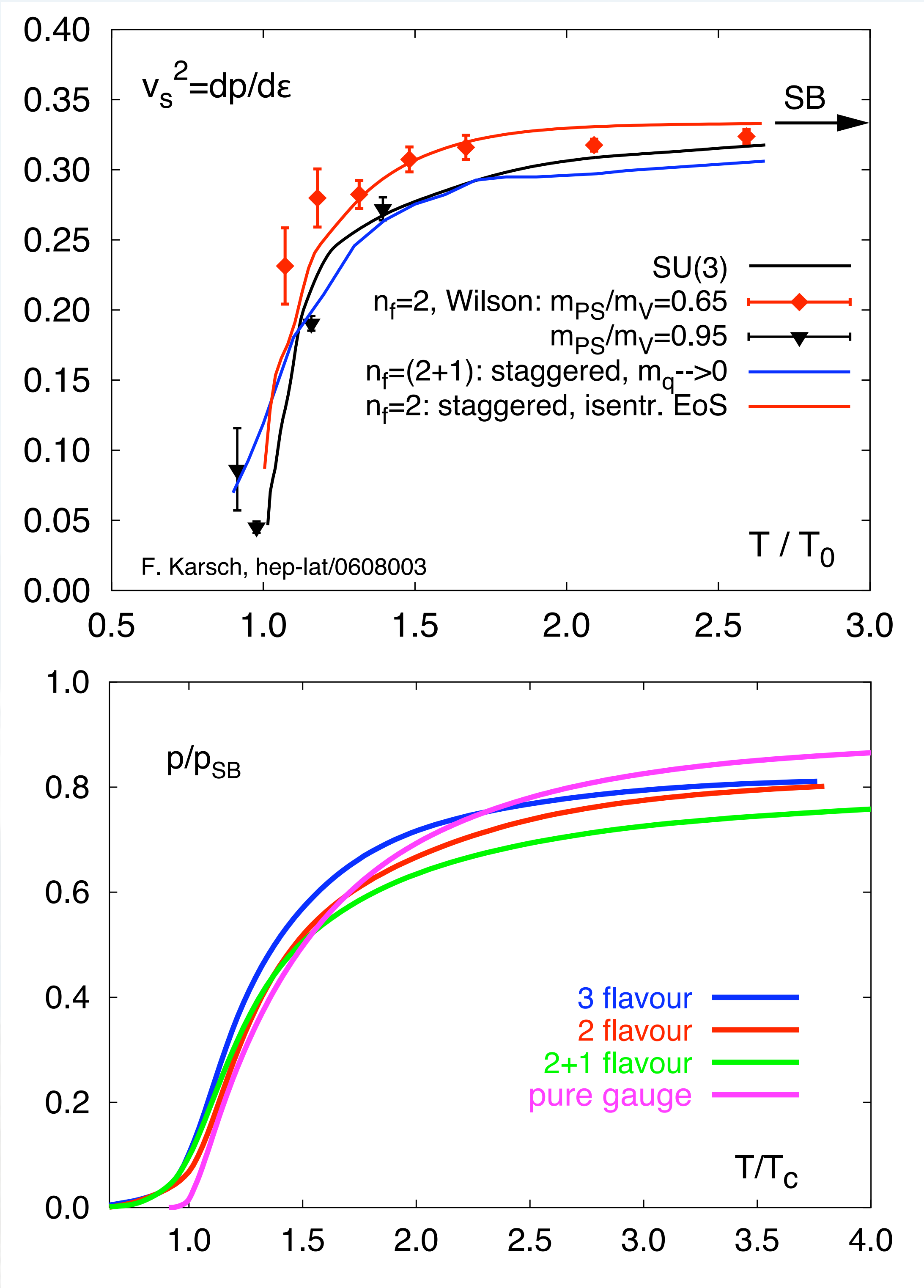
The role of Glue in Heavy-Ion collisions

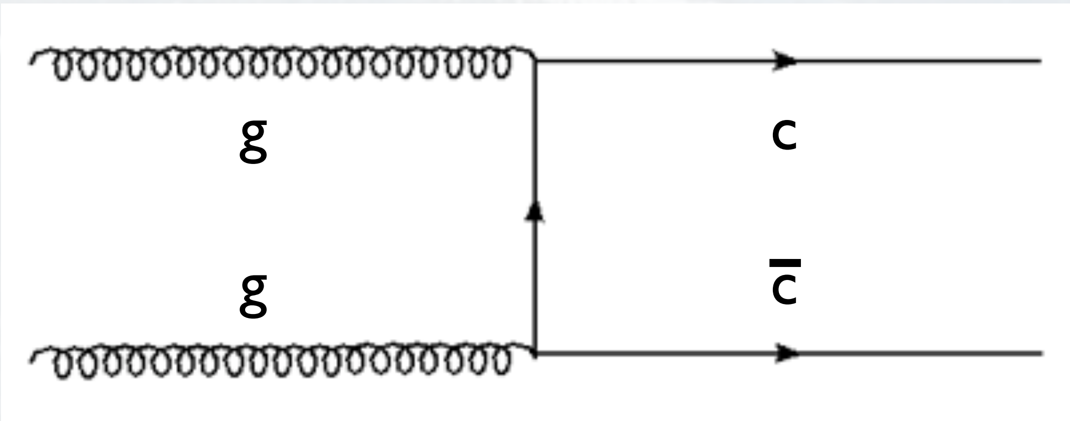
Jets (π^0 production):



Lattice Gauge Theory:



Heavy Flavour Production:

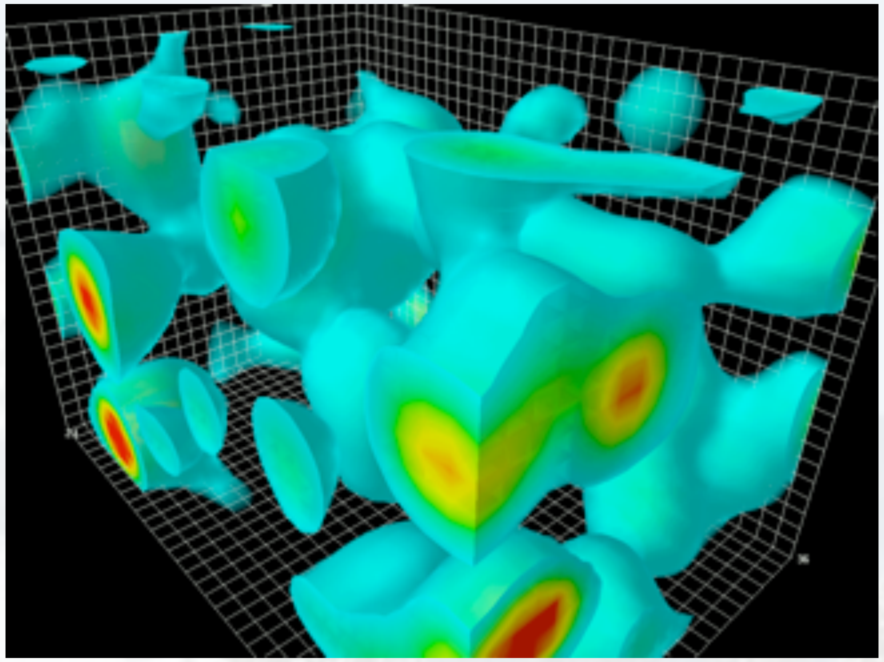


What do we know about gluons?

Glue and the QCD Lagrangian:

$$L_{QCD} = \bar{q}(i\gamma^\mu \partial_\mu - m)q - g(\bar{q}\gamma^\mu T_a q)A^a_\mu - \frac{1}{4}G^a_{\mu\nu}G^{\mu\nu}_a$$

- **>98% of all visible mass due to "emergent" phenomena not evident from Lagrangian**
  - χSB & Colour Confinement
- **Gluons**
  - ➡ Mediators of the strong interaction
  - ➡ Determine essential features of QCD
    - ▸ Asymptotic freedom from gluon loops
  - ➡ Dominate structure of QCD vacuum (χSB)
  - ➡ Quenched L_{QCD} gets hadron masses correct to ~ 10%

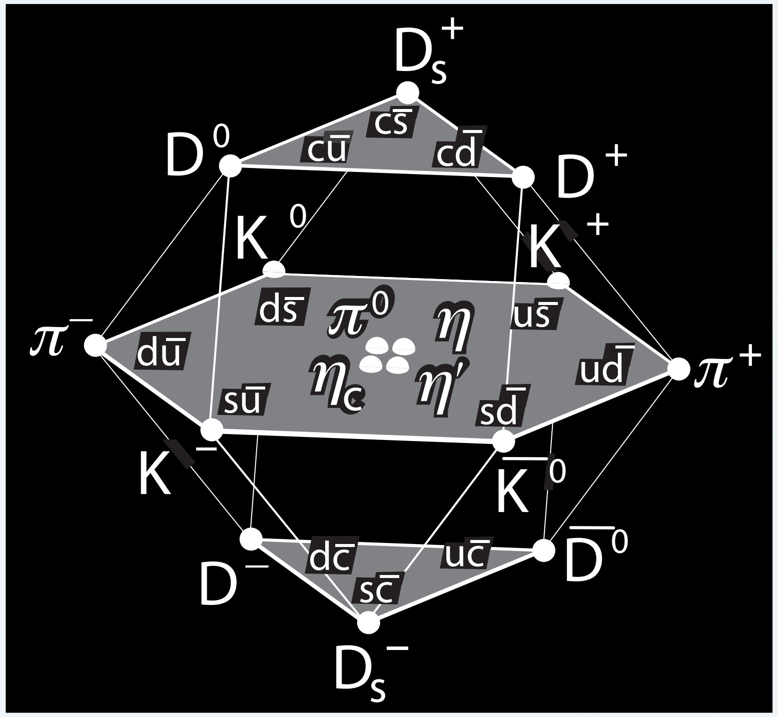


Action (~energy) density fluctuations of gluon-fields in QCD vacuum (2.4 ×2.4× 3.6 fm) (Derek Leinweber)

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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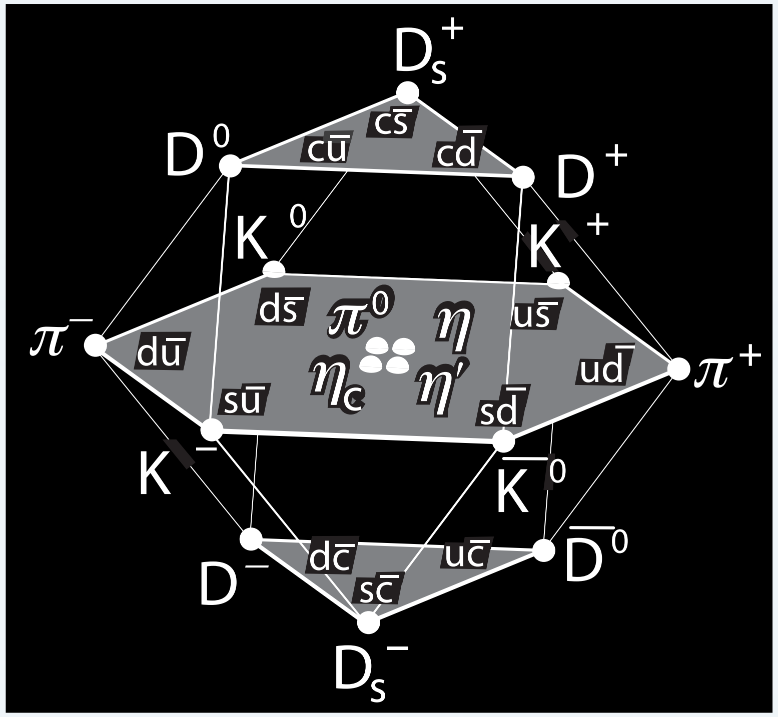

- What is the spatial and momentum distribution of gluons in nuclei/nucleons?
- What are the properties of high-density gluon matter?
- How do quarks and gluons interact as they traverse matter?
- What role do the gluons play in the spin structure of the nucleon?

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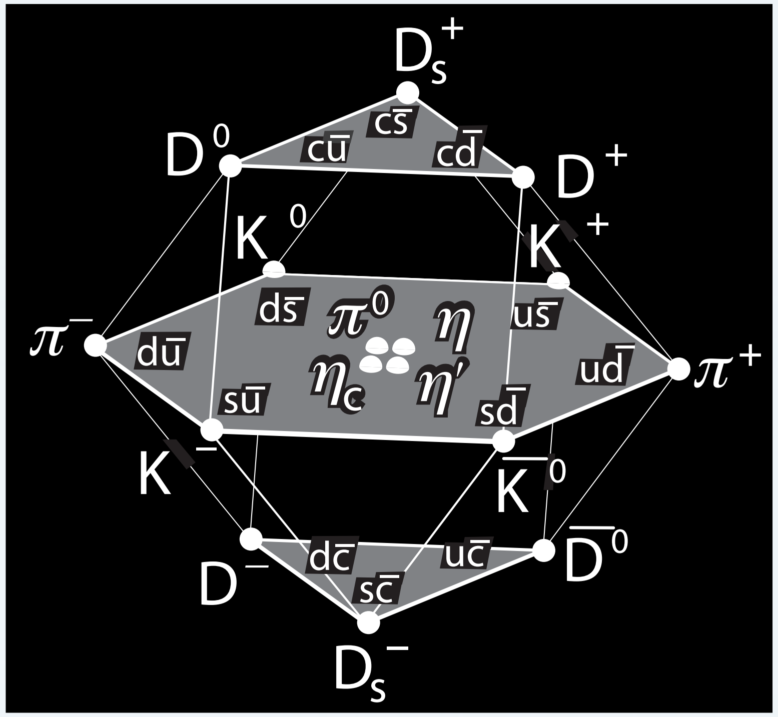

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How do we get to the answers?

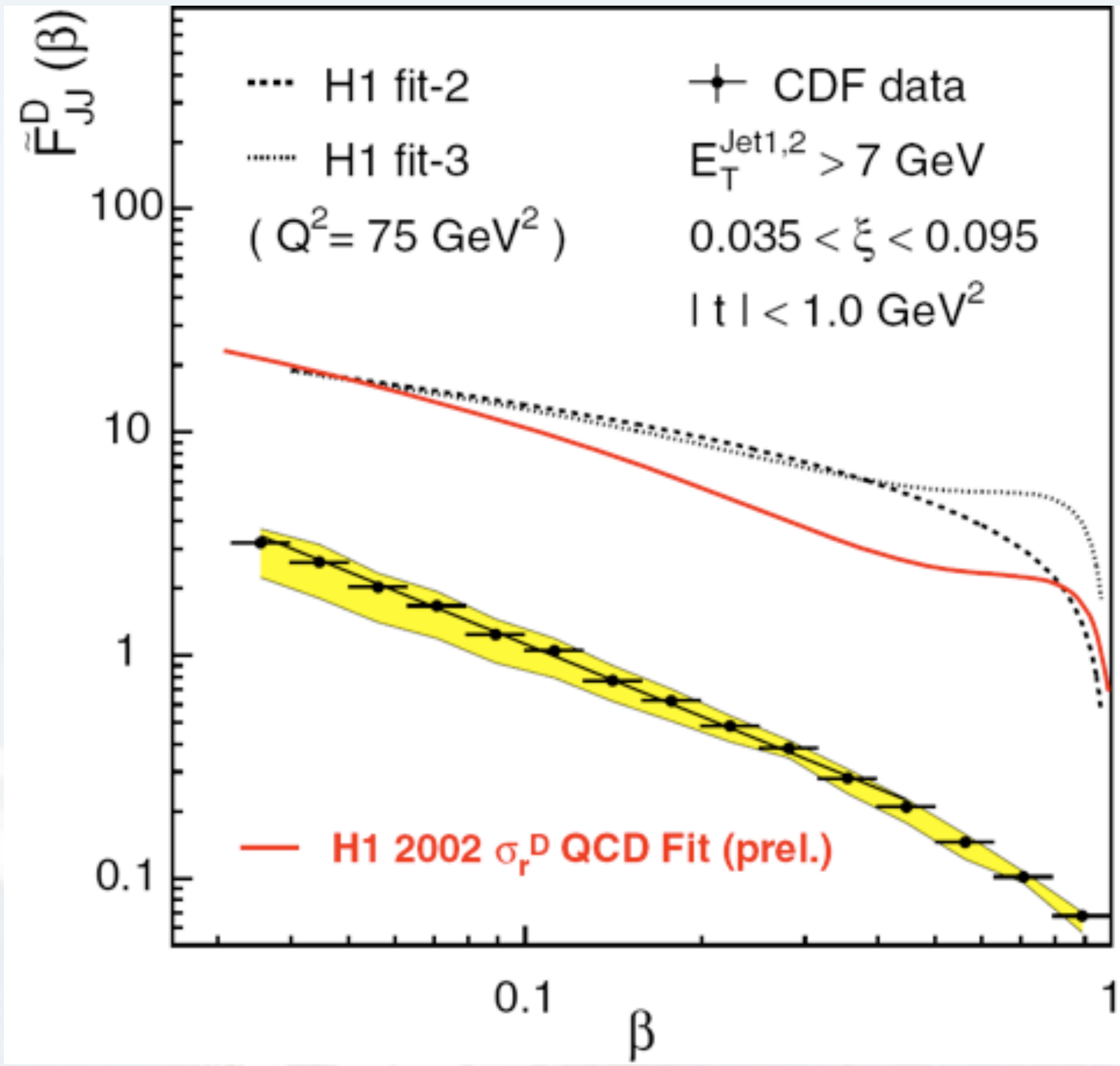
Accessing the Glue - *p*+A vs *e*+A

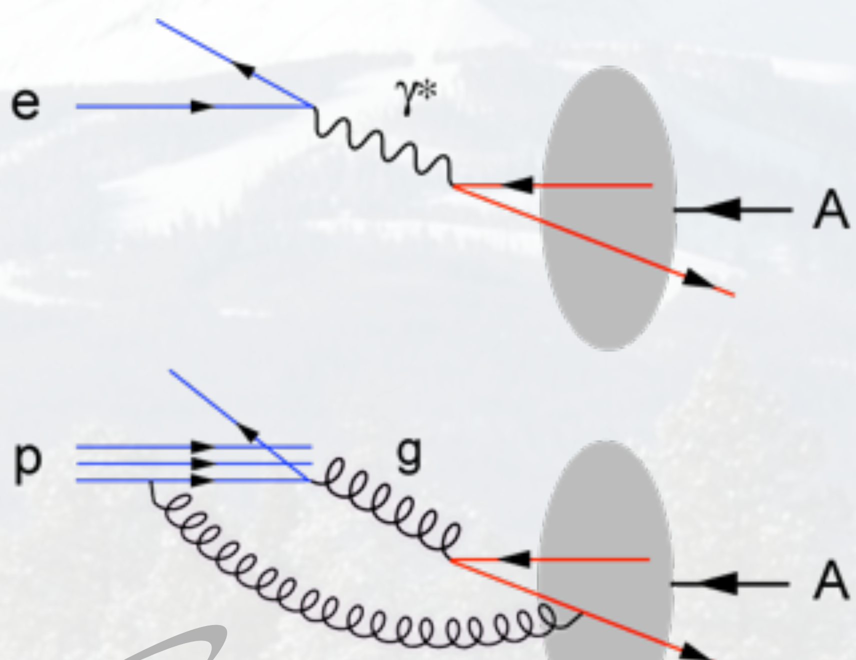
- Both *e*+A and *p*+A provide excellent information on properties of gluons in the nuclear wave functions

- Both are complementary and offer the opportunity to perform stringent checks of factorization/universality ⇒

- But:
  - ➡ soft colour interactions between p and A before and after the primary interaction

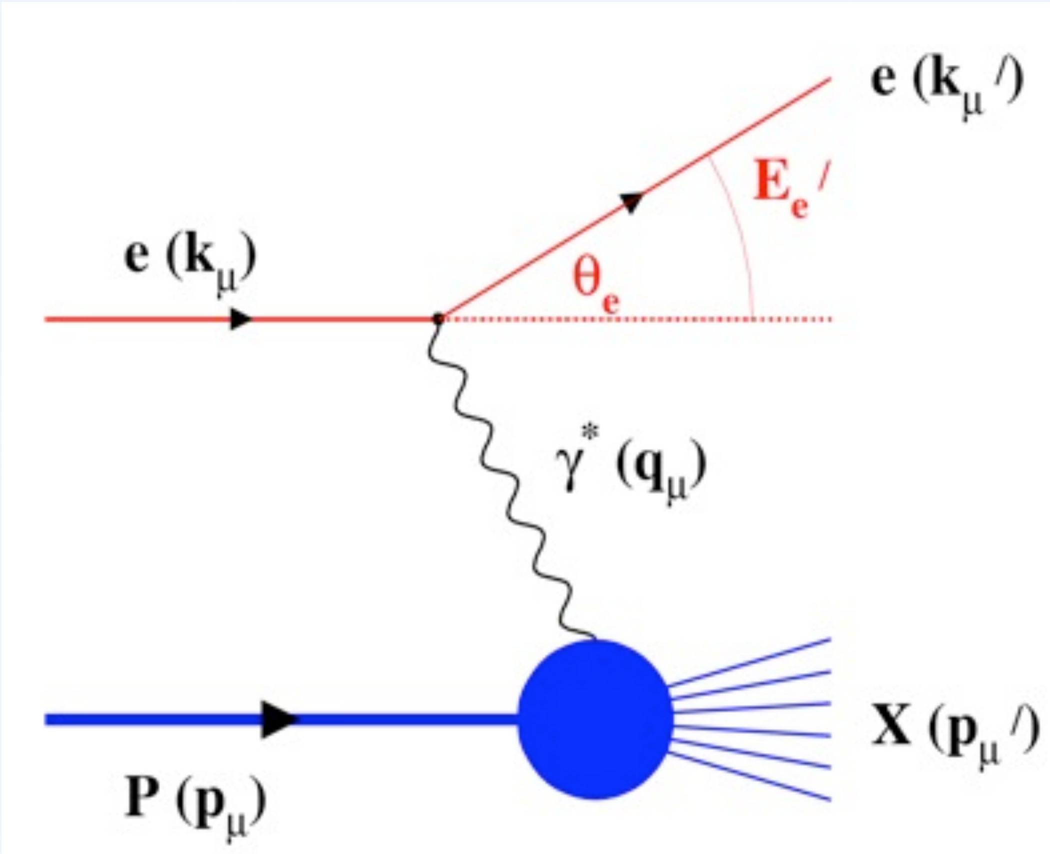
F. Schilling, hep-ex/0209001





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

e+p/A - DIS Kinematics



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

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

Measure of resolution power or "Virtuality"

$$y = \frac{pq}{pk} = 1 - \frac{E_{e'}}{E_e} cos^2(\frac{\theta'_e}{2})$$

Measure of inelasticity

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

Measure of momentum fraction of struck quark

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

- *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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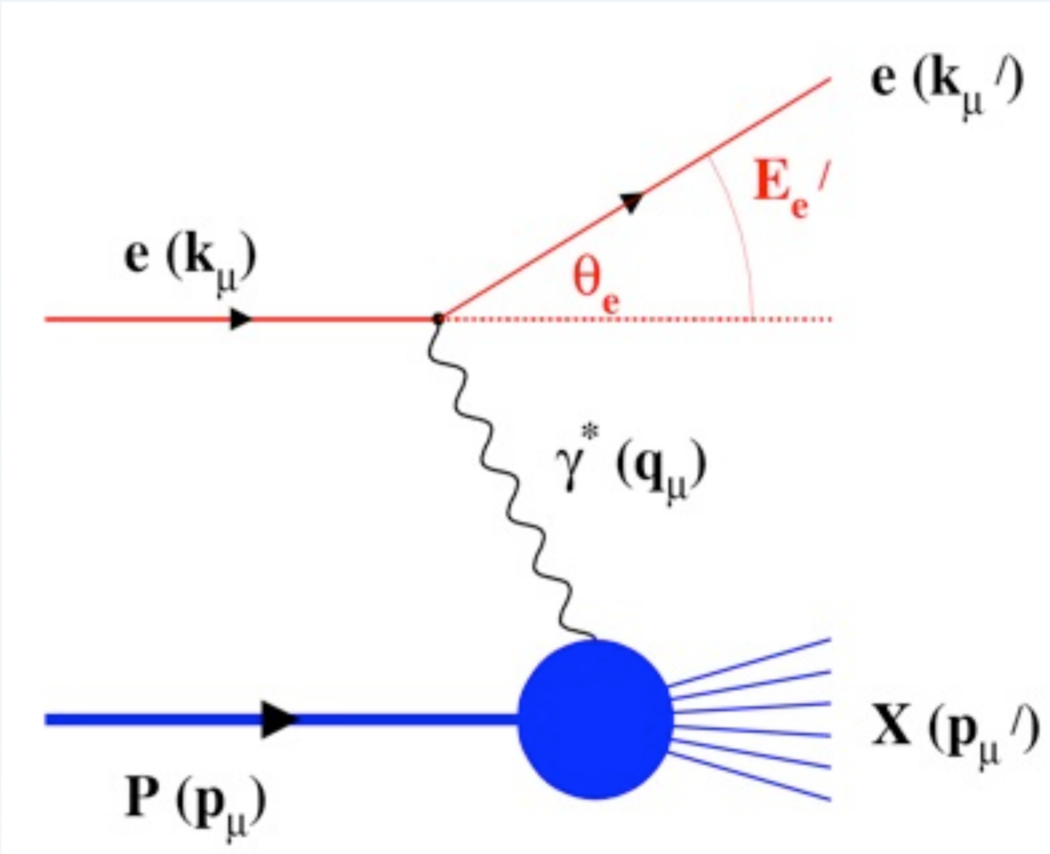

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No direct information on x, Q^2 from p+A colllisions !!

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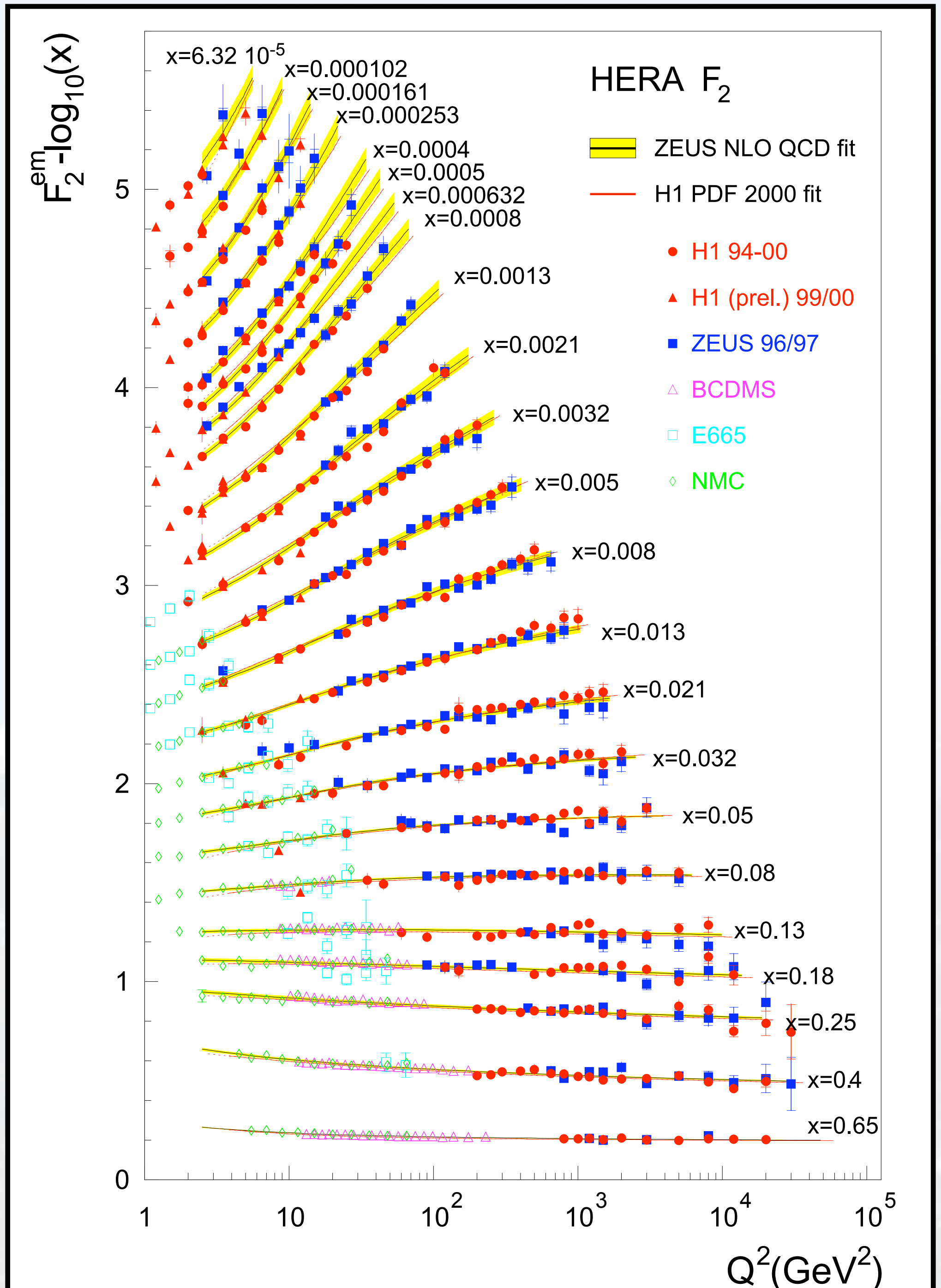

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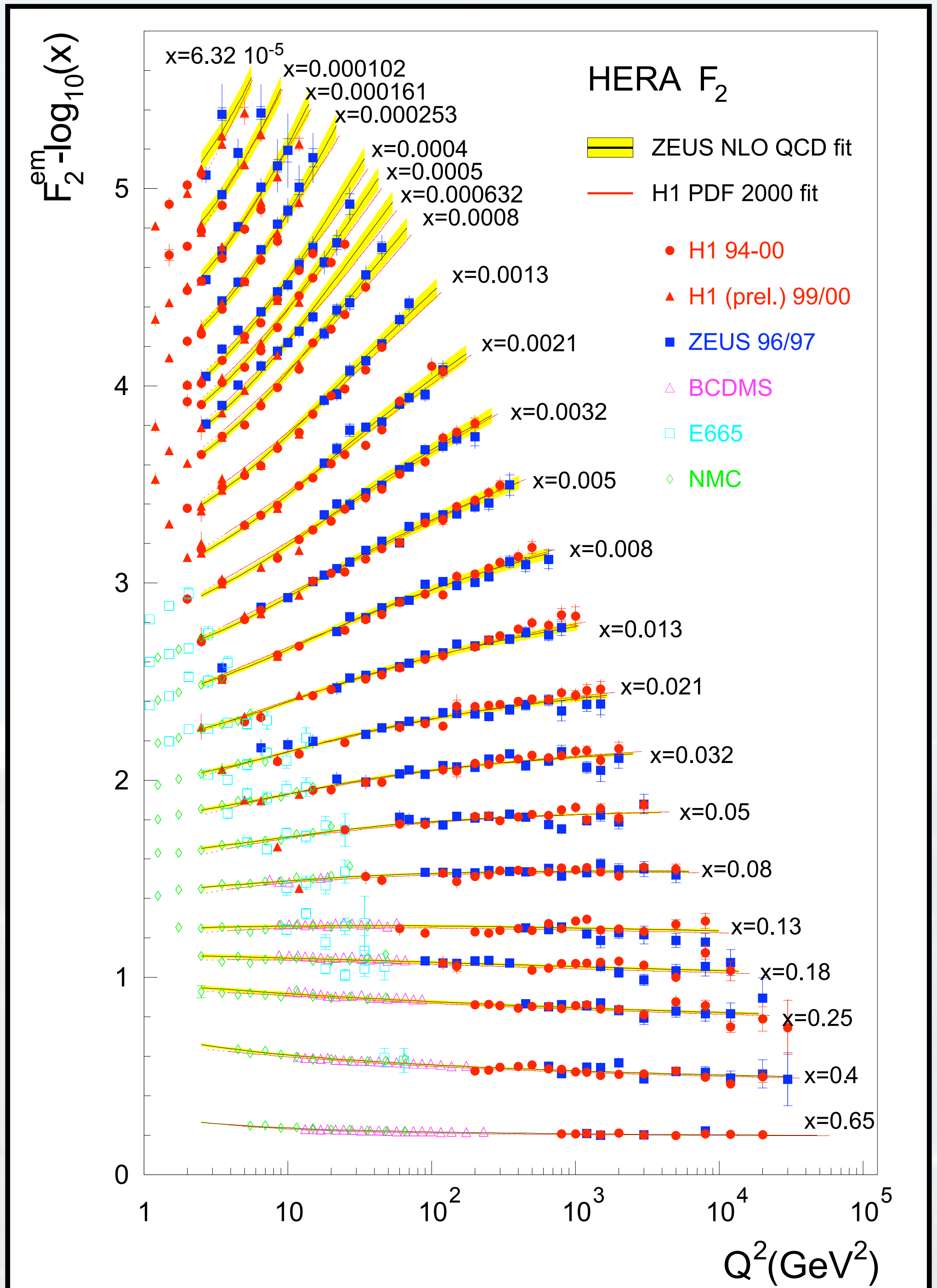

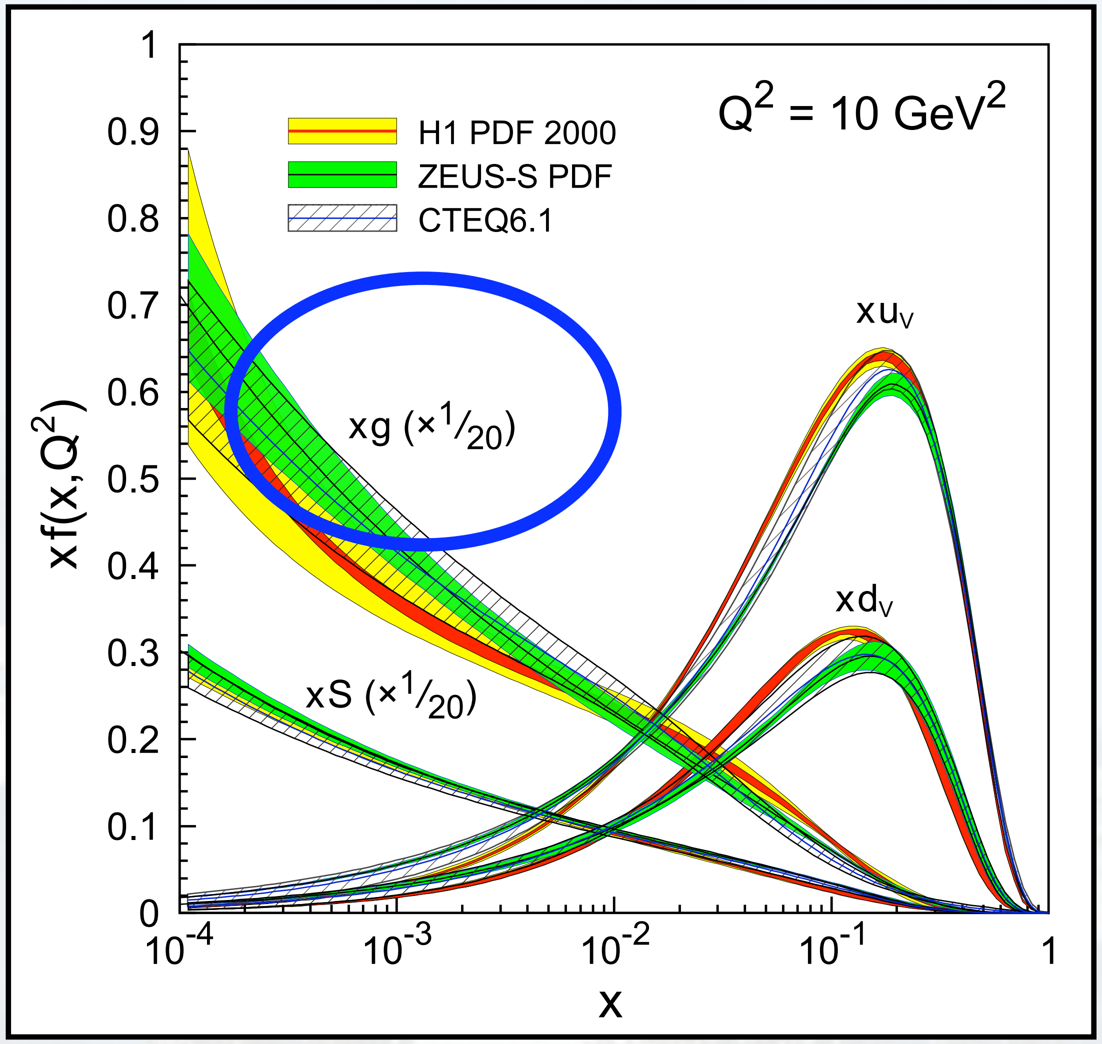

Scaling violation of $dF_2/d\ln Q^2$ and linear DGLAP evolution ⇒ $xG(x,Q^2)$

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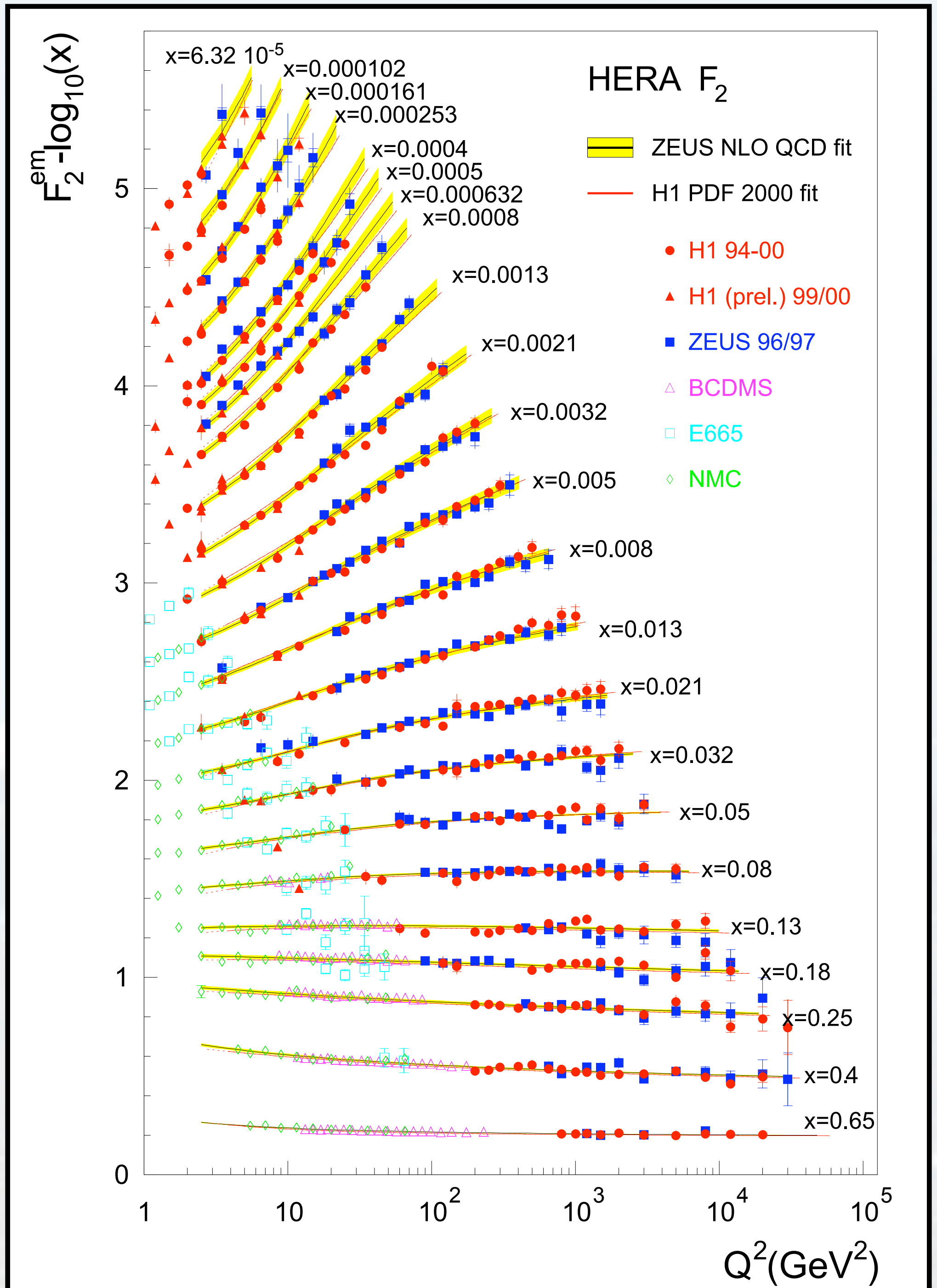
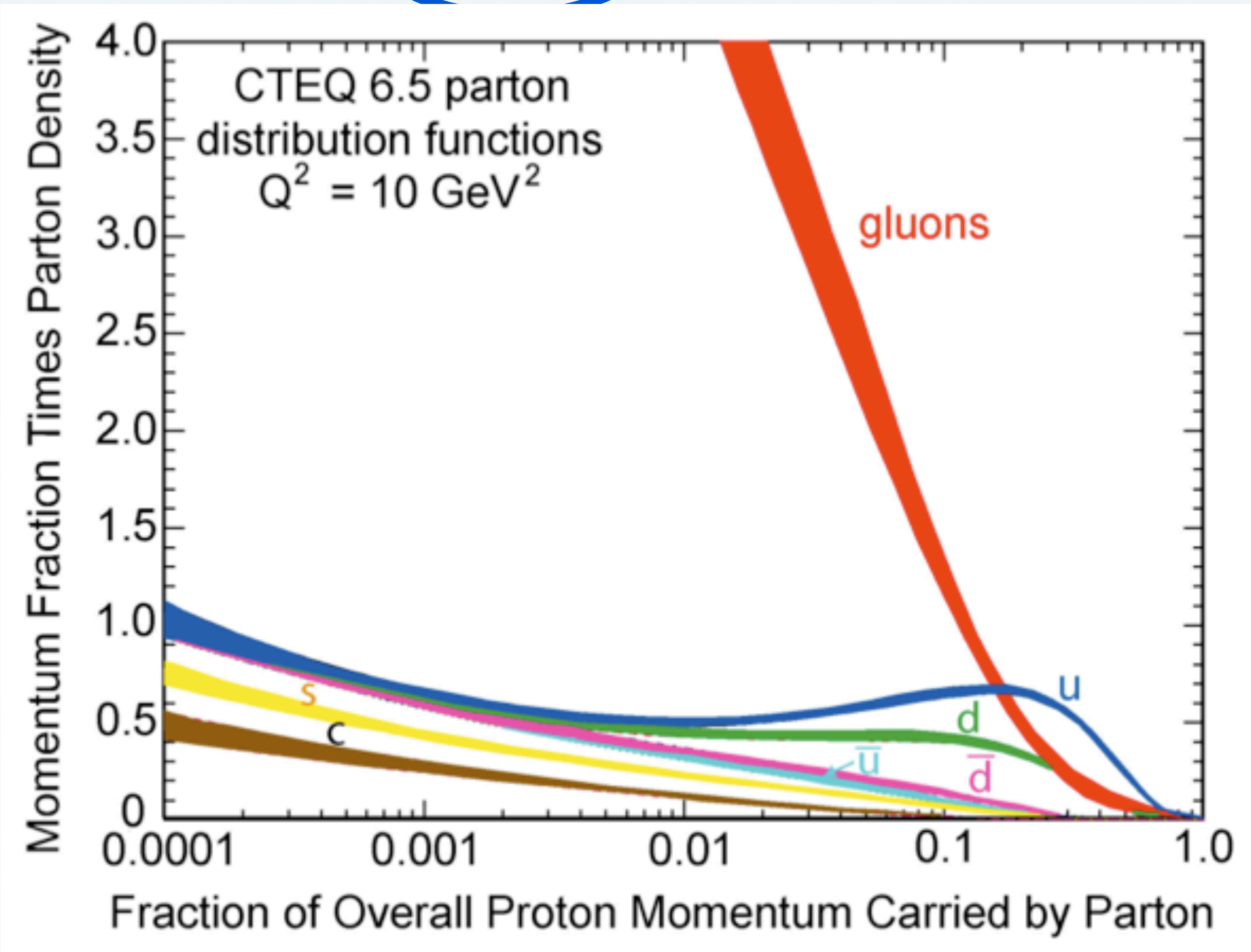


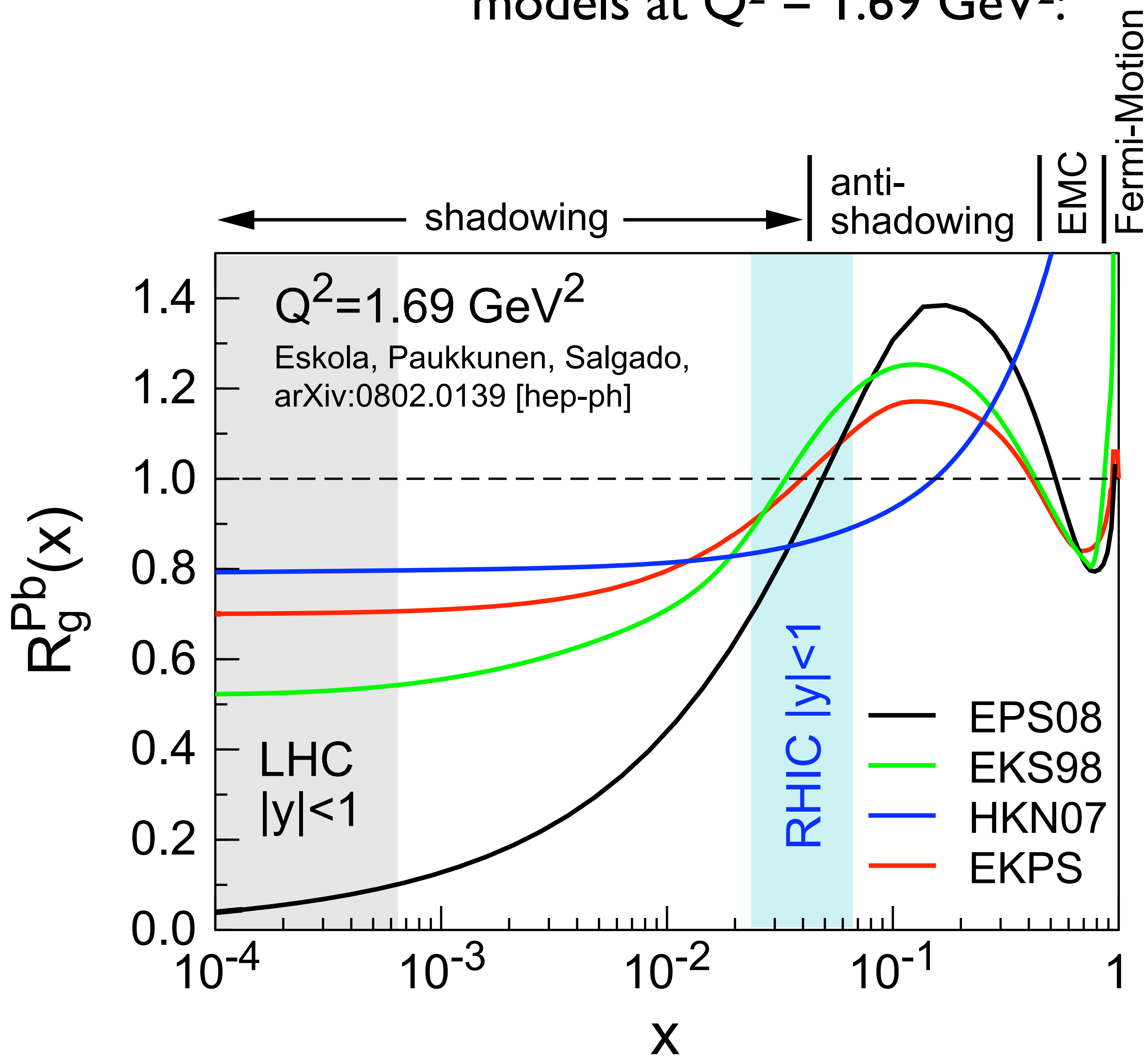


Scaling violation of $dF_2/d\ln Q^2$ and linear DGLAP evolution $\Rightarrow xG(x,Q^2)$

How to Measure the Glue ?

Important for RHIC and LHC:

Ratios of gluon distribution functions for Pb/p versus x from different models at $Q^2 = 1.69\ GeV^2$:



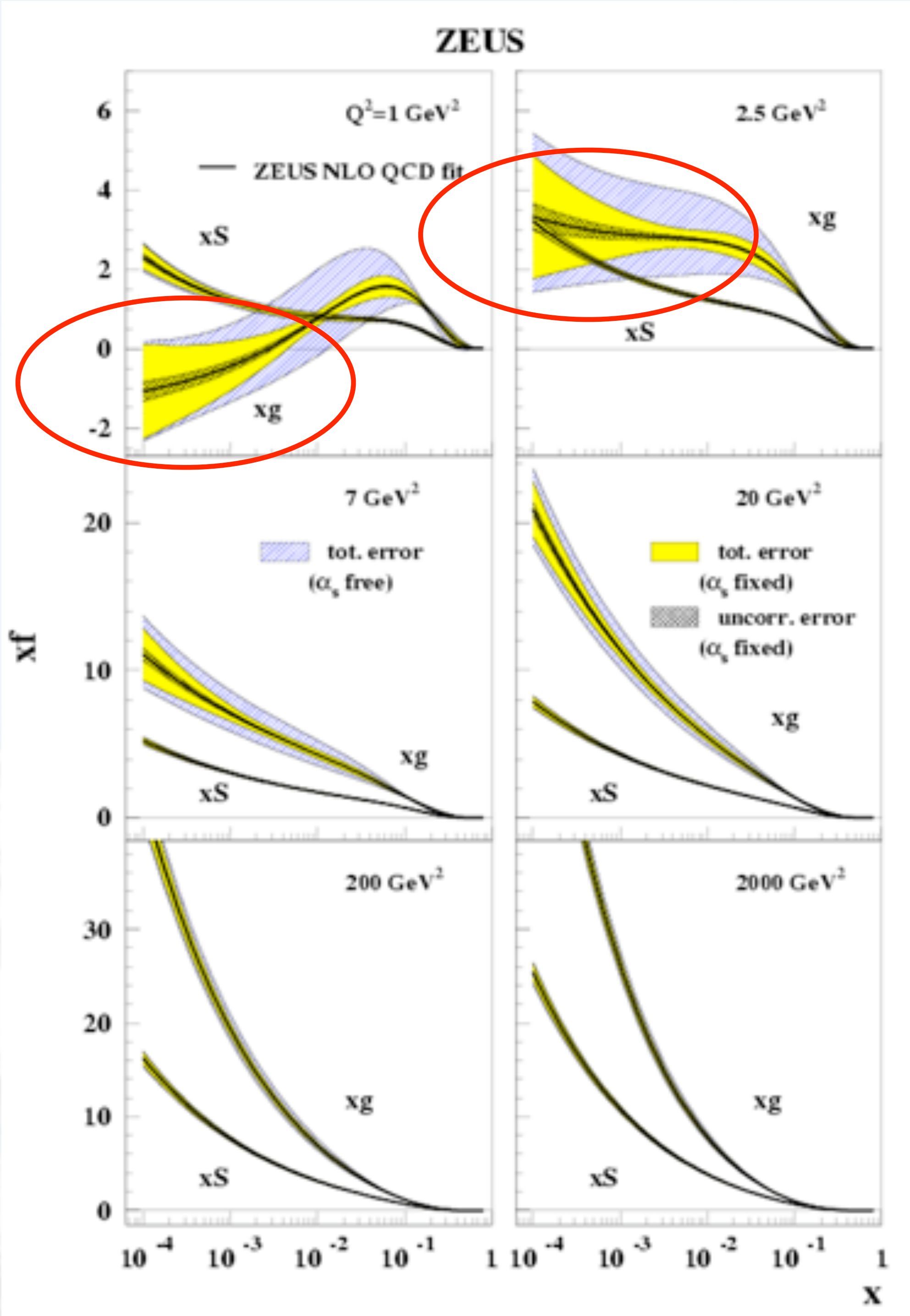
$$R_i^A(x, Q^2) = \frac{f_i^A(x, Q^2)}{A\, f_i^{\text{nucleon}}(x, Q^2)}, \quad f_i = q, \bar{q}, g$$

?

Models agree well for mid-rapidity RHIC, but discrepancies are there for forward RHIC rapidities as well as mid-rapidity at the LHC

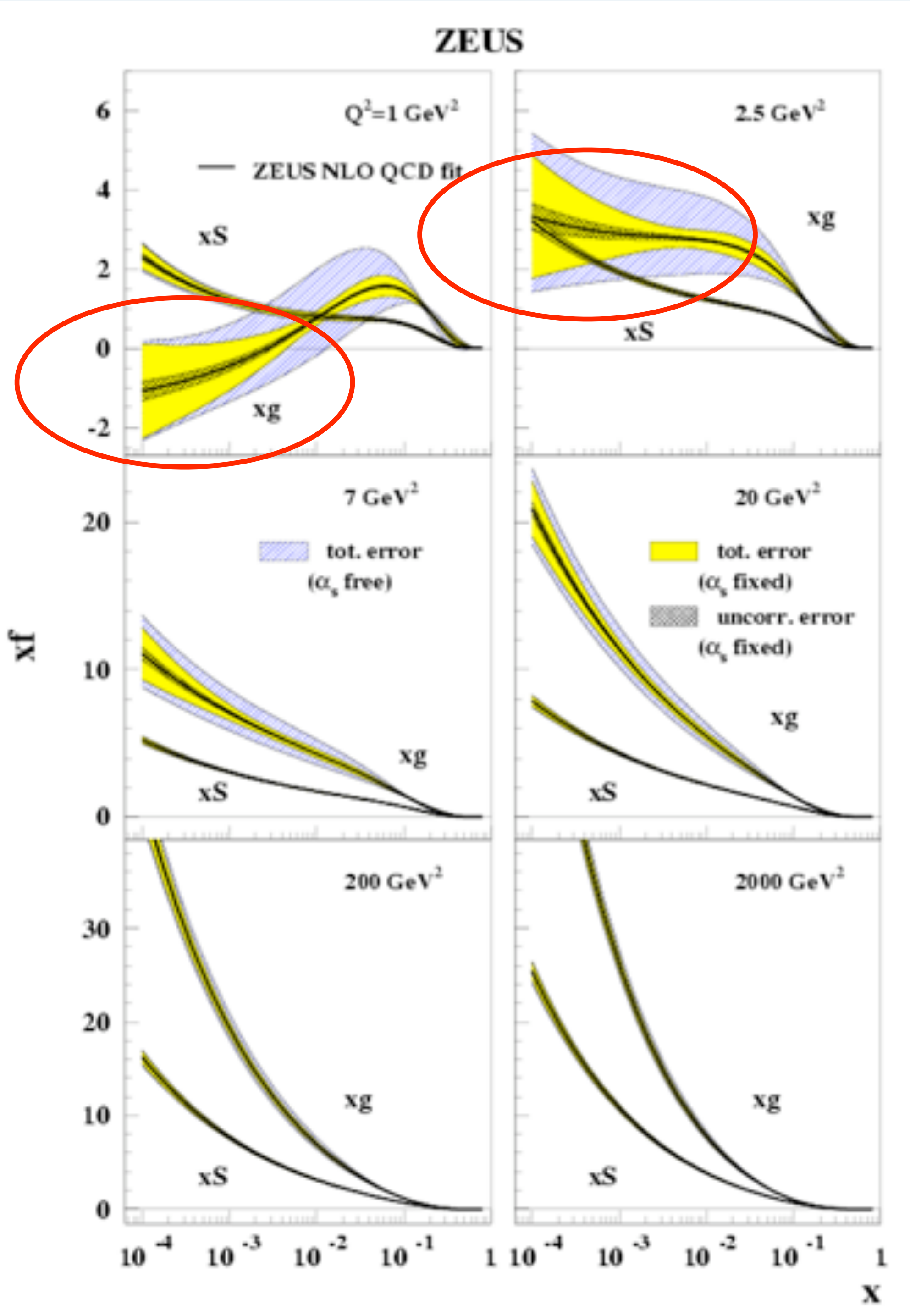
Monday, 13 April 2009

The problem with our current understanding



The problem 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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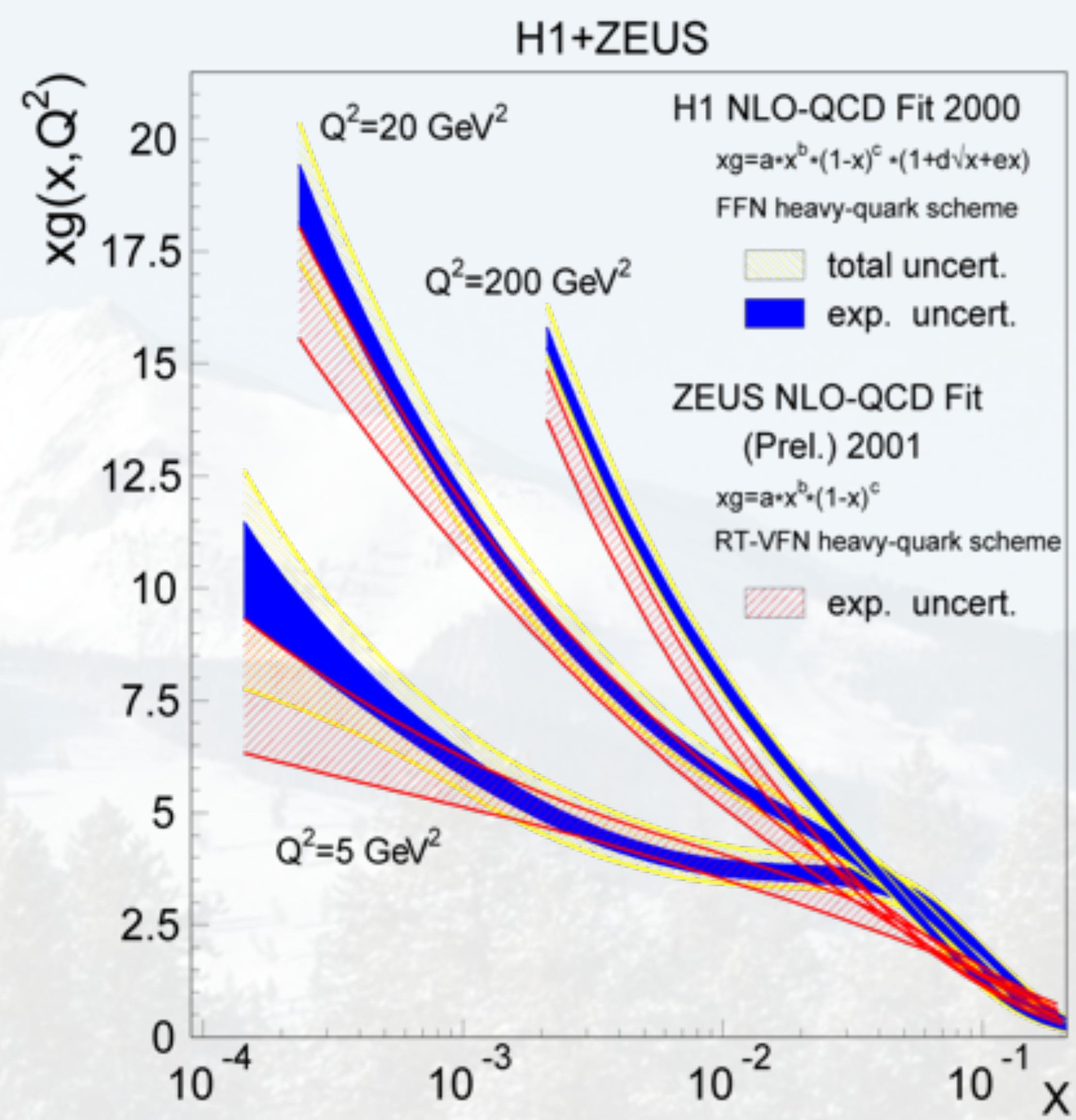
  - ➡ Linear evolution has a built-in high-energy “catastrophe”
  - ➡ *xG* has rapid rise with decreasing *x* (and increasing Q^2) ⇒ violation of Froissart unitarity bound
    - Must have saturation



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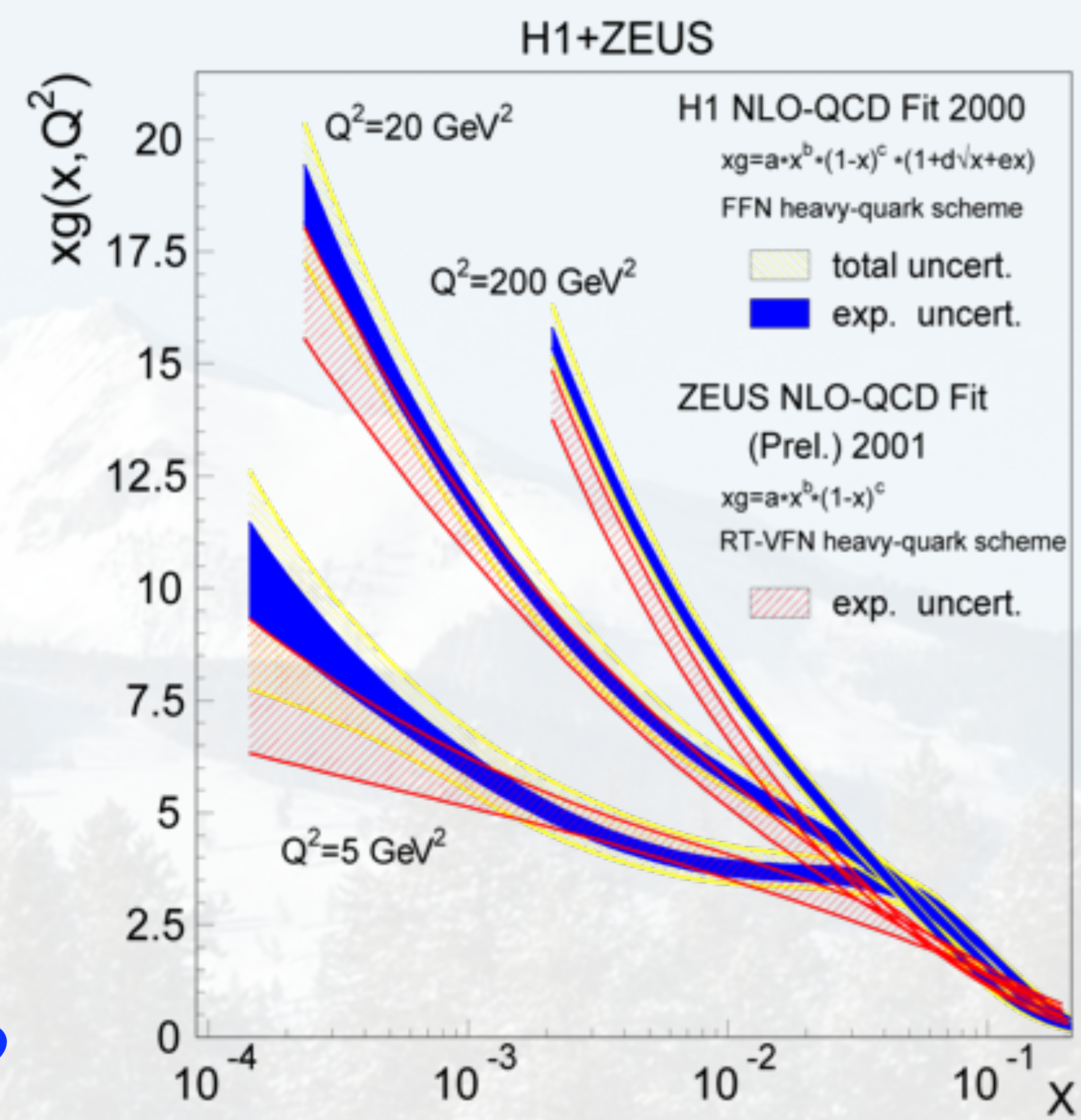
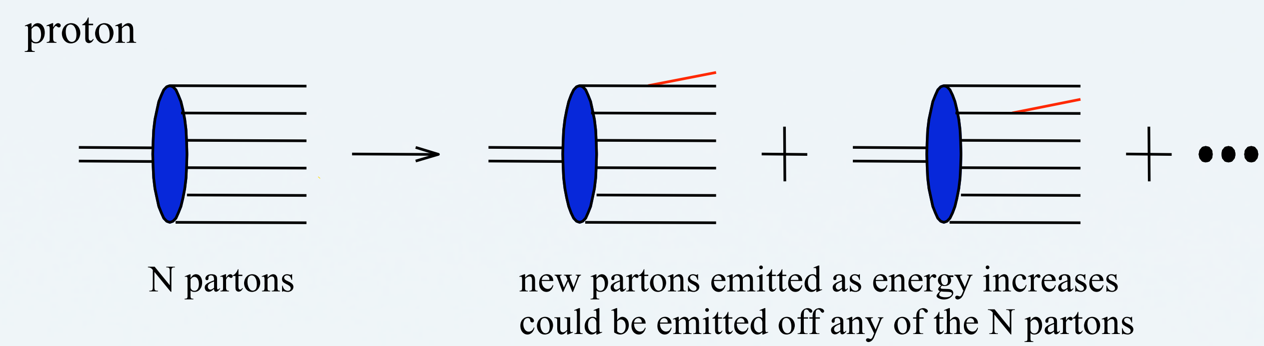


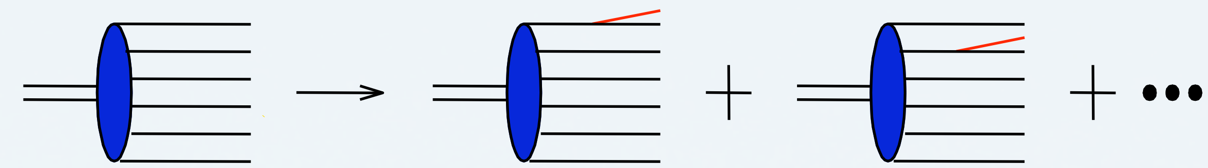
What's the underlying dynamics?

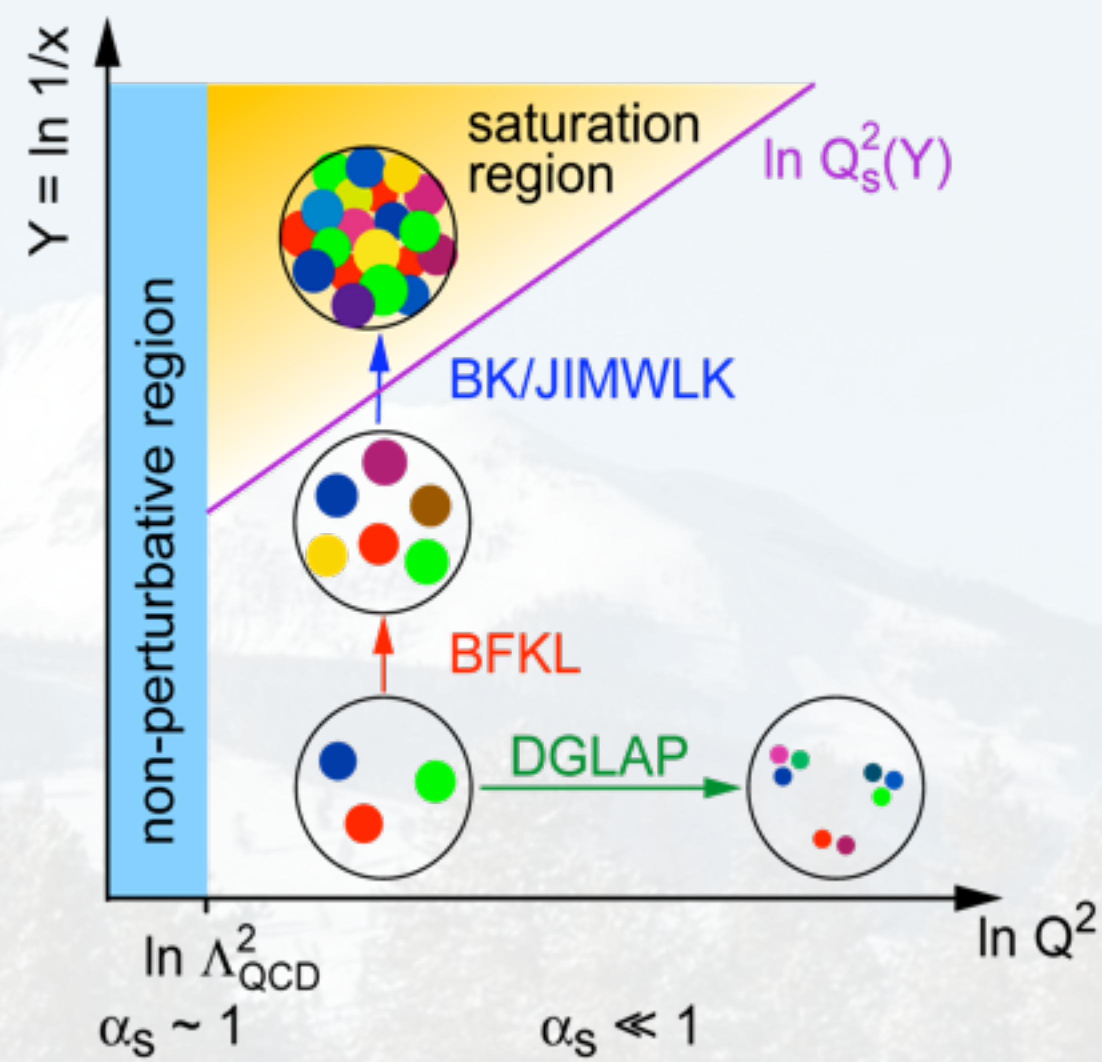
Non-linear QCD - Saturation



Non-linear QCD - Saturation

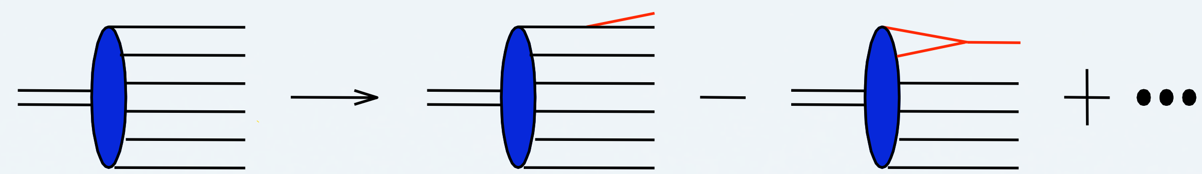
- BFKL: evolution in x
  - ➡ linear
    - explosion in colour field at low-x

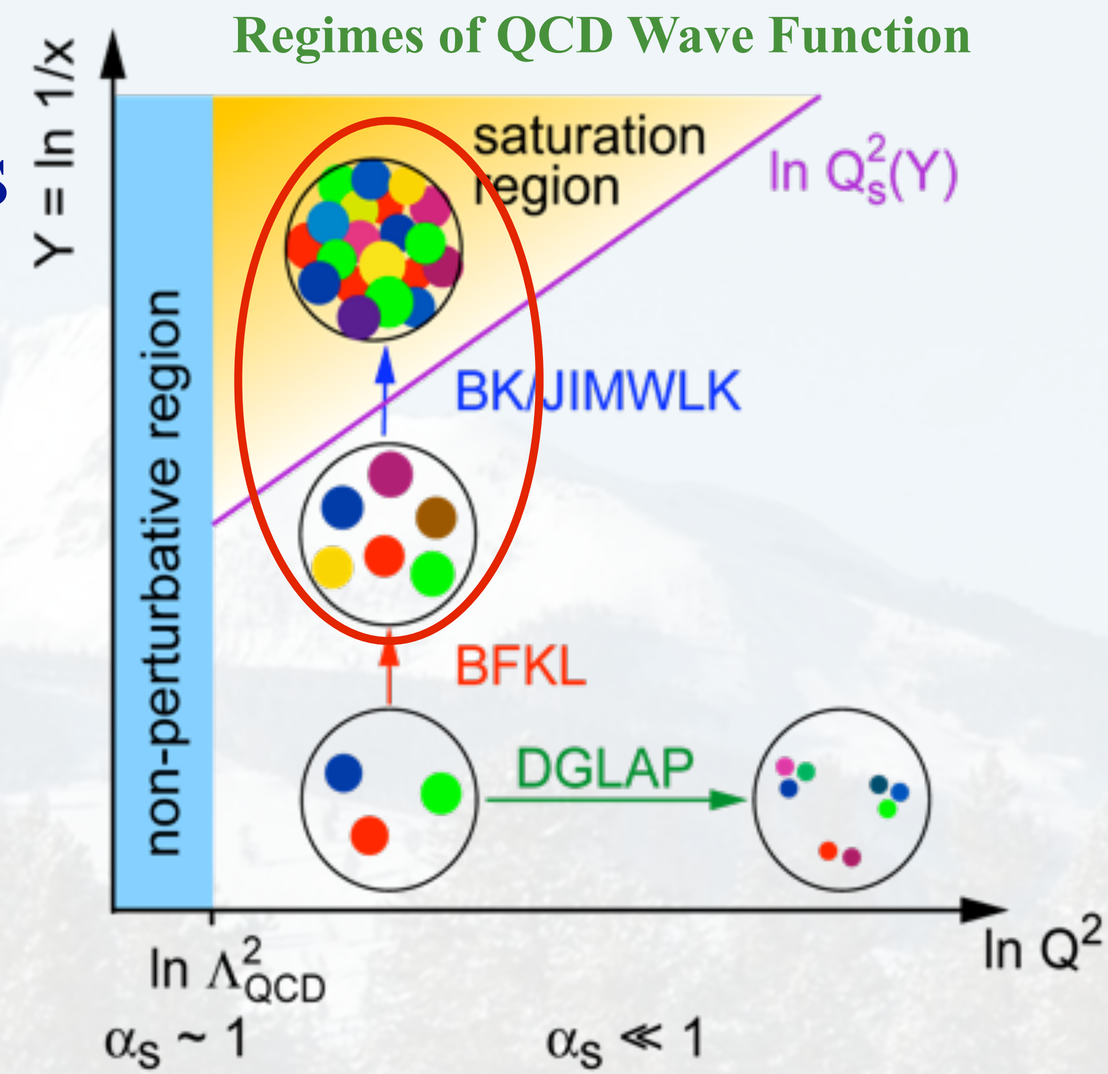




Non-linear QCD - Saturation

- BFKL: evolution in x
  - ➡ linear
    - explosion in colour field at low-x
- Non-linear BK/JIMWLK equations
  - ➡ non-linearity ⇒ saturation
  - ➡ characterised by the saturation scale, $Q_S(x,A)$
  - ➡ arises naturally in the Colour Glass Condensate (CGC) EFT





Why study *e*+A instead of *e*+*p*?

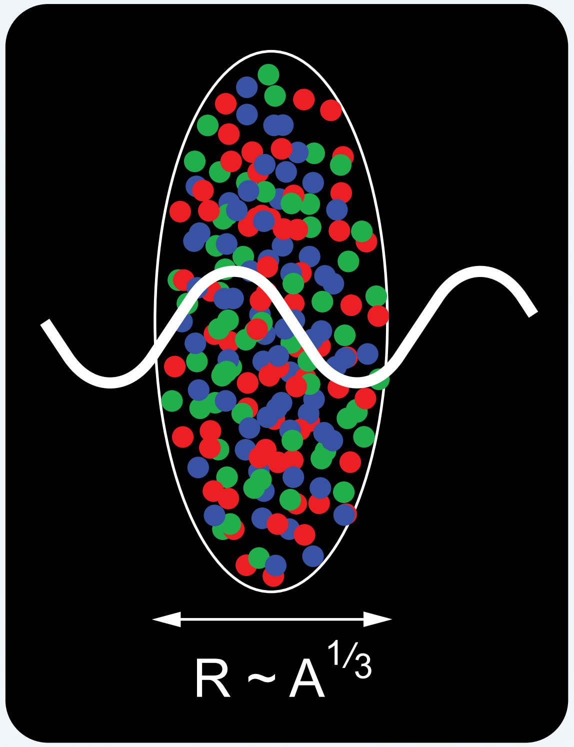
Enhancing Saturation Effects:

Scattering of electrons off nuclei:

Probes interact over distances $L \sim (2m_N x)^{-1}$

For $L > 2\ R_A \sim A^{1/3}$ probe cannot distinguish between nucleons in front or back of nuclei

⇒ Probe interacts *coherently* with all nucleons



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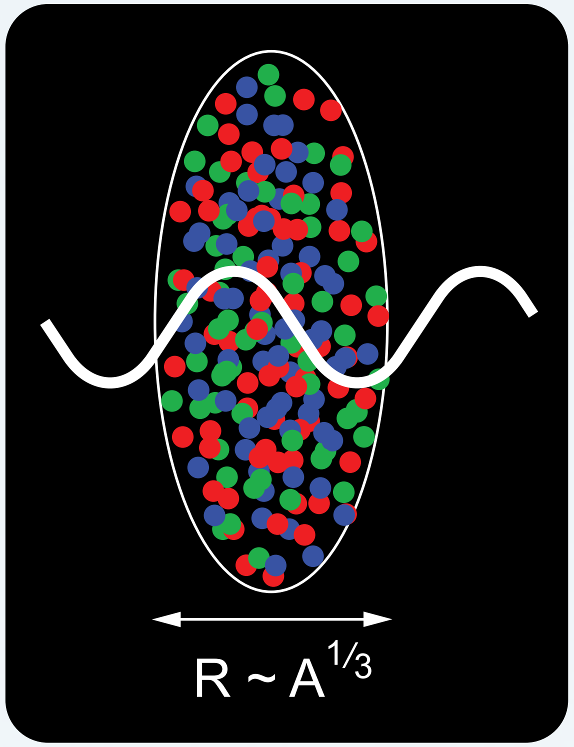

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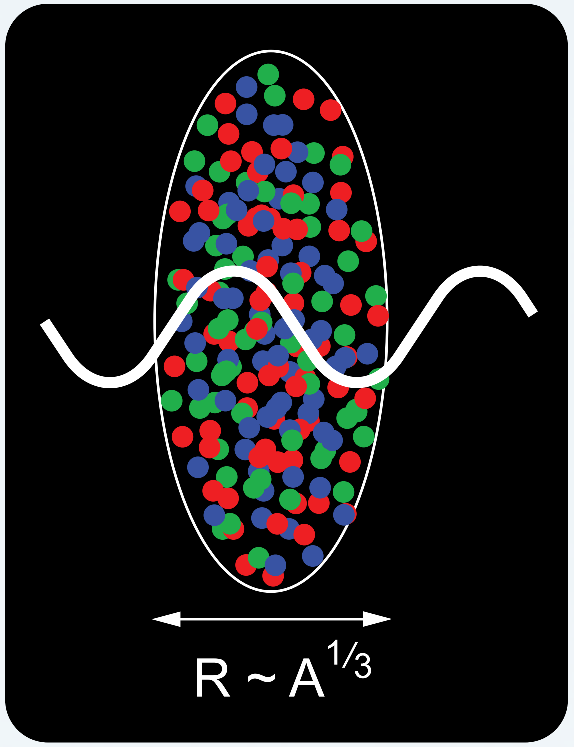

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$$Q_s^2 \propto \frac{\alpha_s xG(x, Q_s^2)}{\pi R_A^2} \qquad \mathrm{HERA:}\ xG \propto \frac{1}{x^{1/3}} \qquad \mathrm{A\ dependence:}\ xG_A \propto A$$

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

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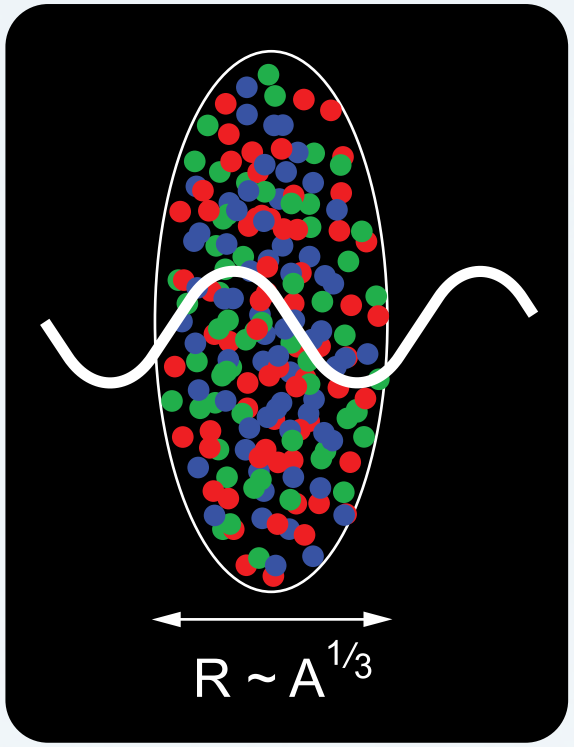

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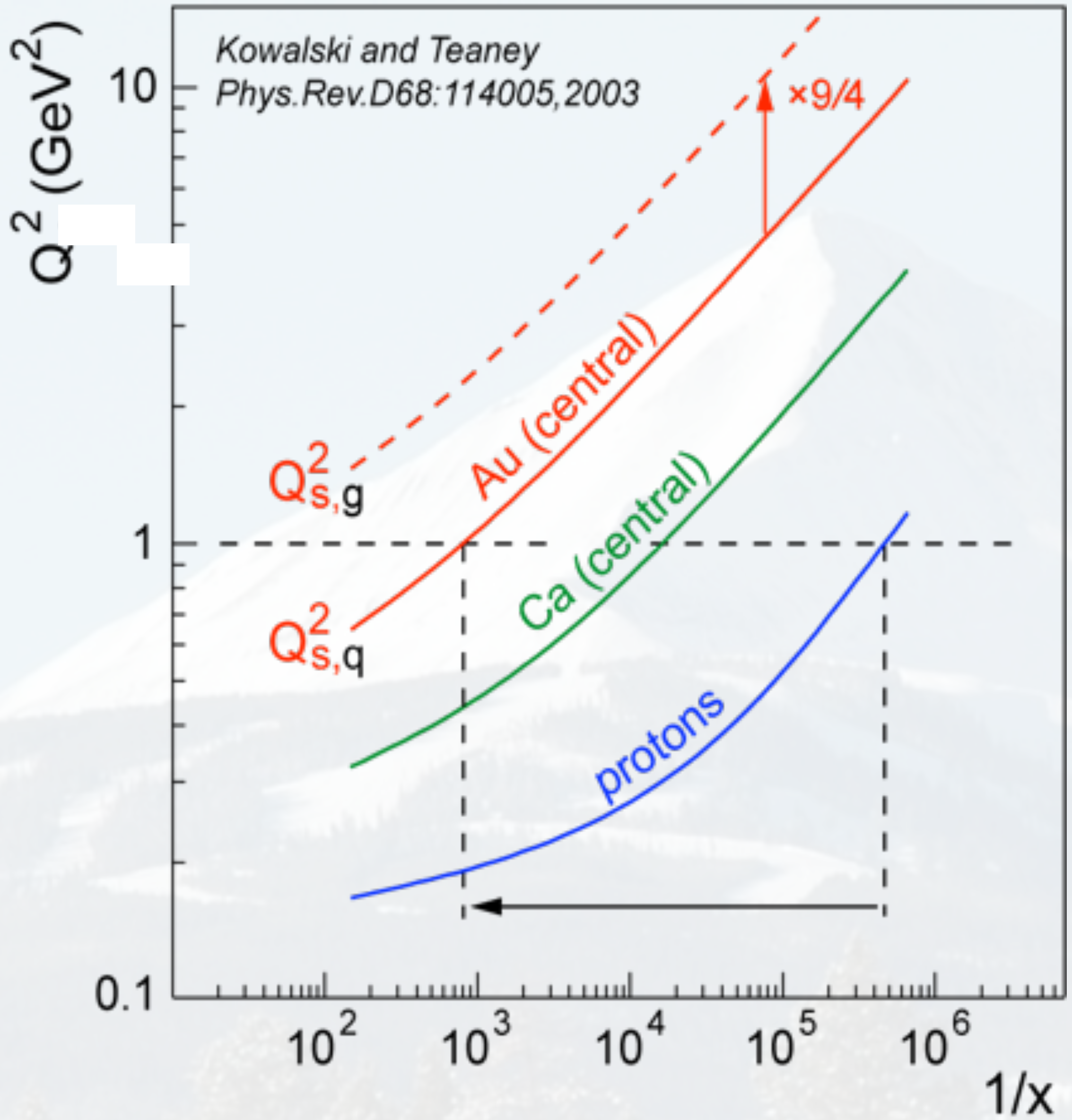
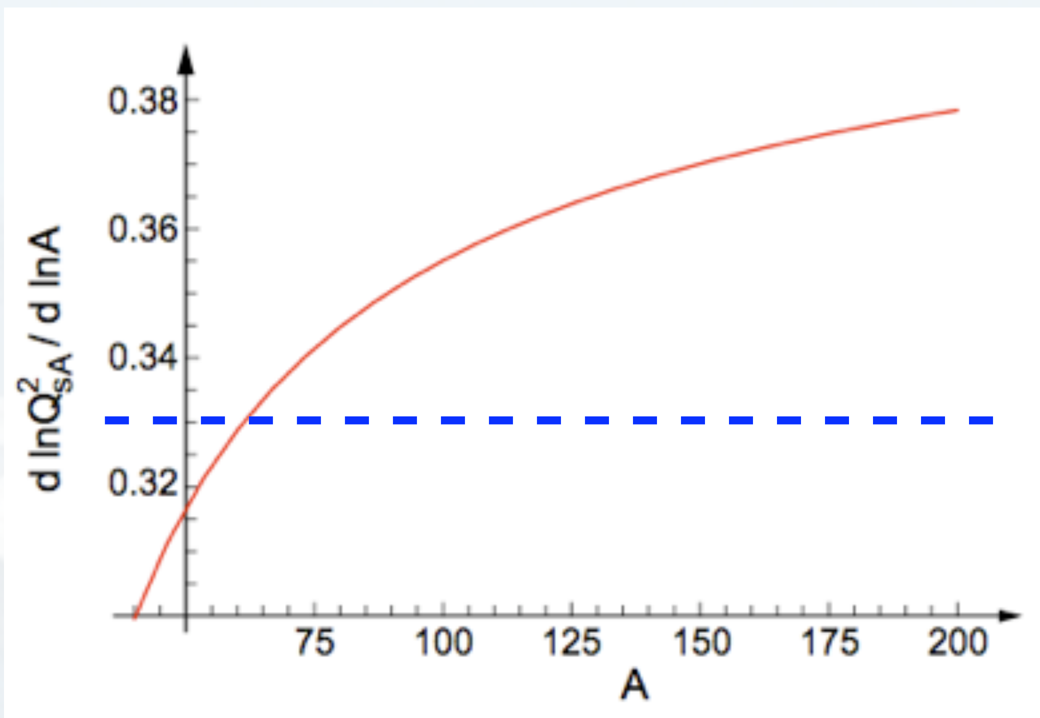
Enhancement of Qs with A: ⇒ non-linear QCD regime reached at significantly lower energy in e+*A* than in *e+p*

The Nuclear "Oomph" factor

More sophisticated analyses ⇒ confirm (exceed) pocket formula

(e.g. Kowalski, Lappi and Venugopalan, PRL 100, 022303 (2008); Armesto et al., PRL 94:022002; Kowalski, Teaney, PRD 68:114005)





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 √s scan)
  - ➡ 2+1 jet rates
  - ➡ Inelastic vector meson production (*e.g.* J/ψ)
  - ➡ Diffractive vector meson production ~ $[xG(x,Q^2)]^2$

Example of Key Measurements:

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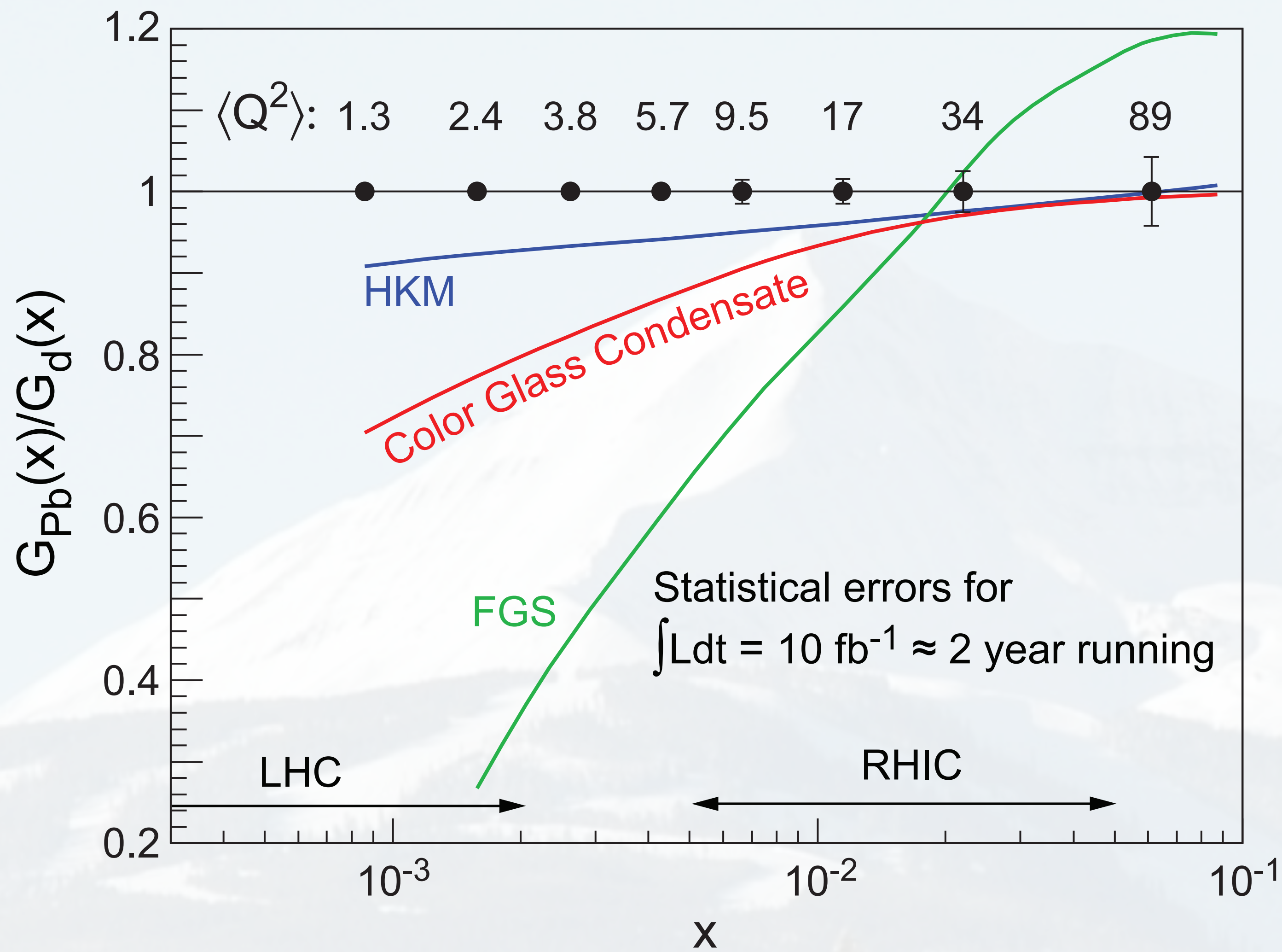

$F_L \sim \alpha_s\, xG(x,Q^2)$

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

Here:

$\int Ldt = 4/A\ fb^{-1}$ (10+100) GeV

$= 4/A\ fb^{-1}$ (10+50) GeV

$= 2/A\ fb^{-1}$ (5+50) GeV

statistical error only

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

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

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

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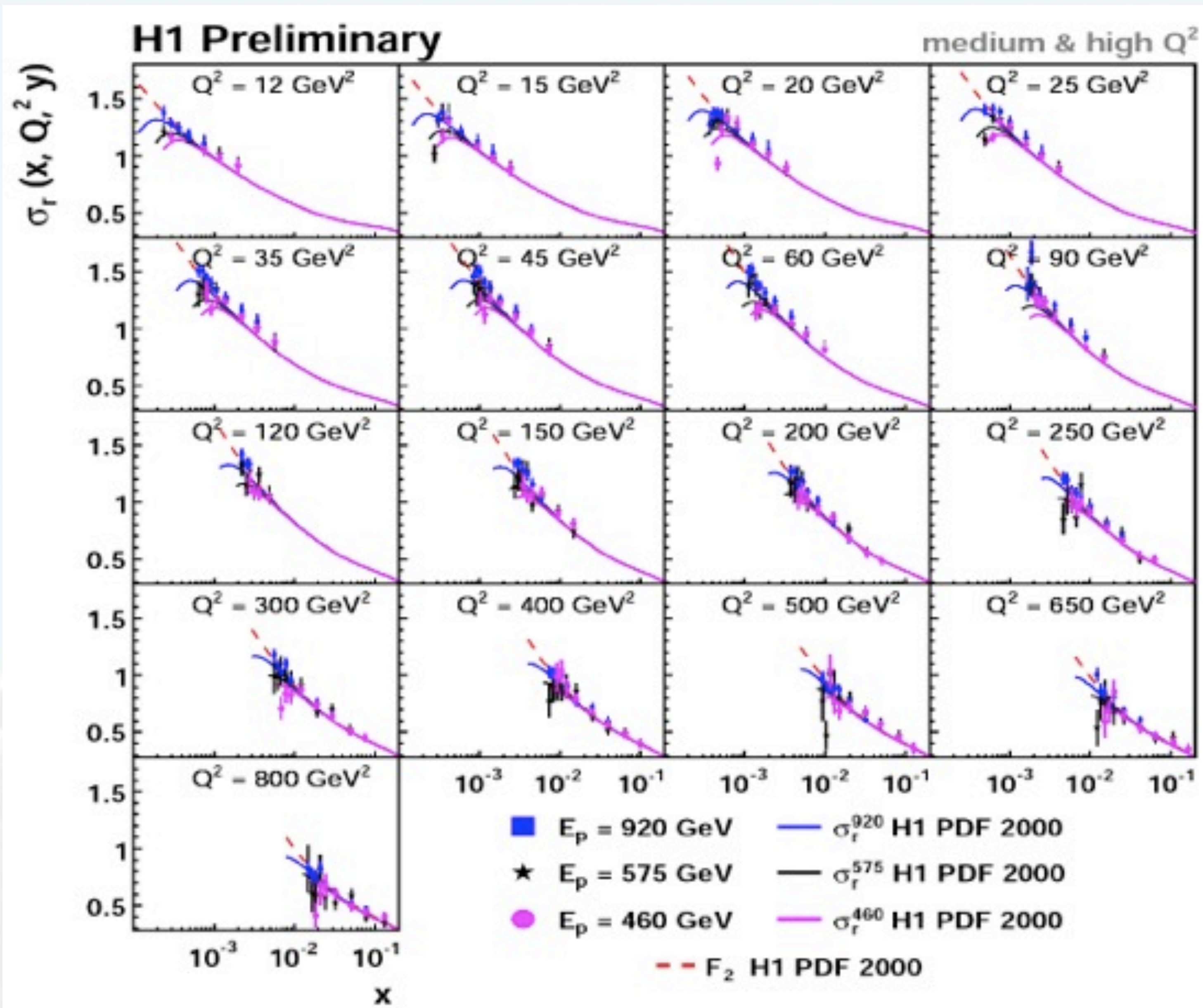

Preliminary F_L measurements

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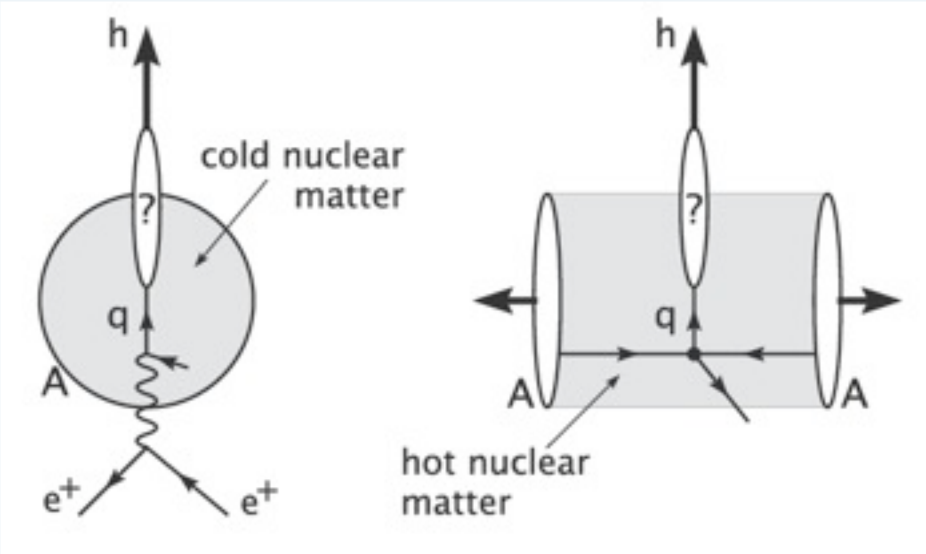
Hadronization and Energy Loss



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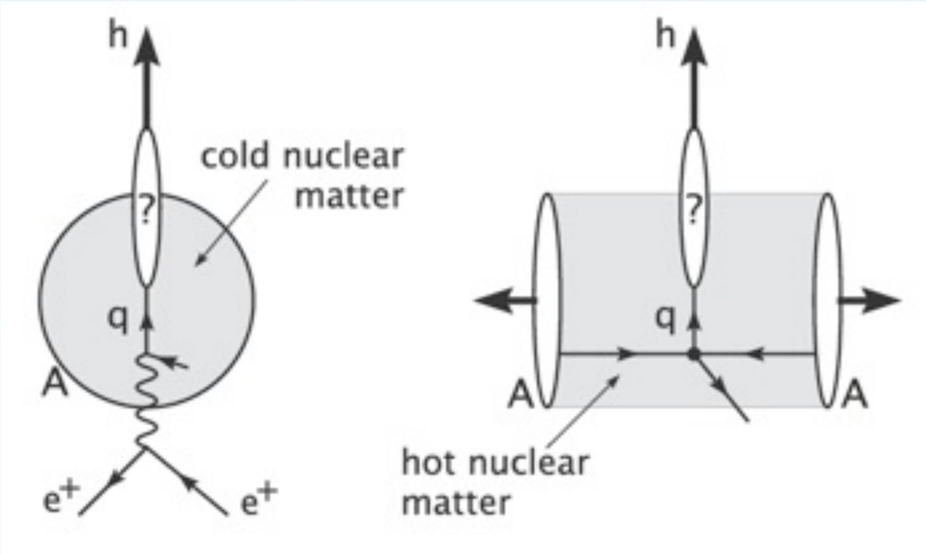

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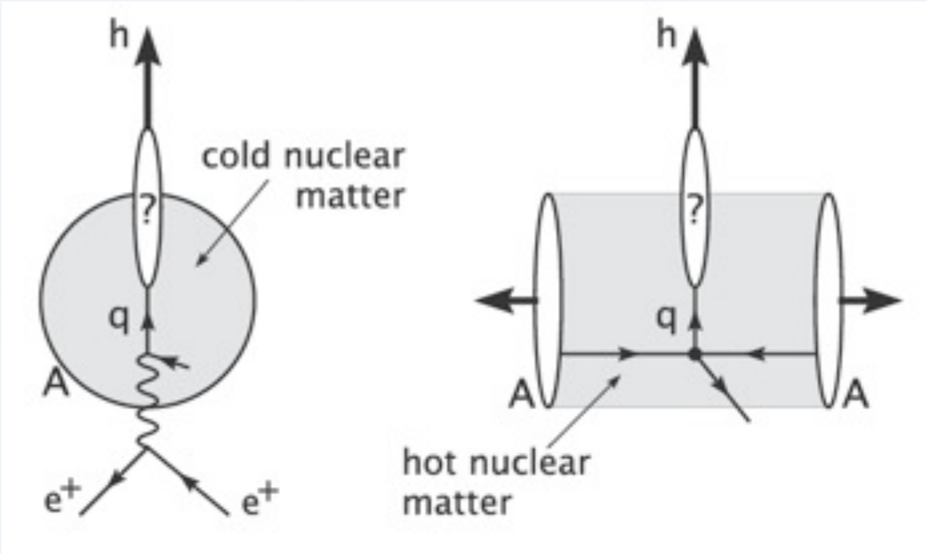

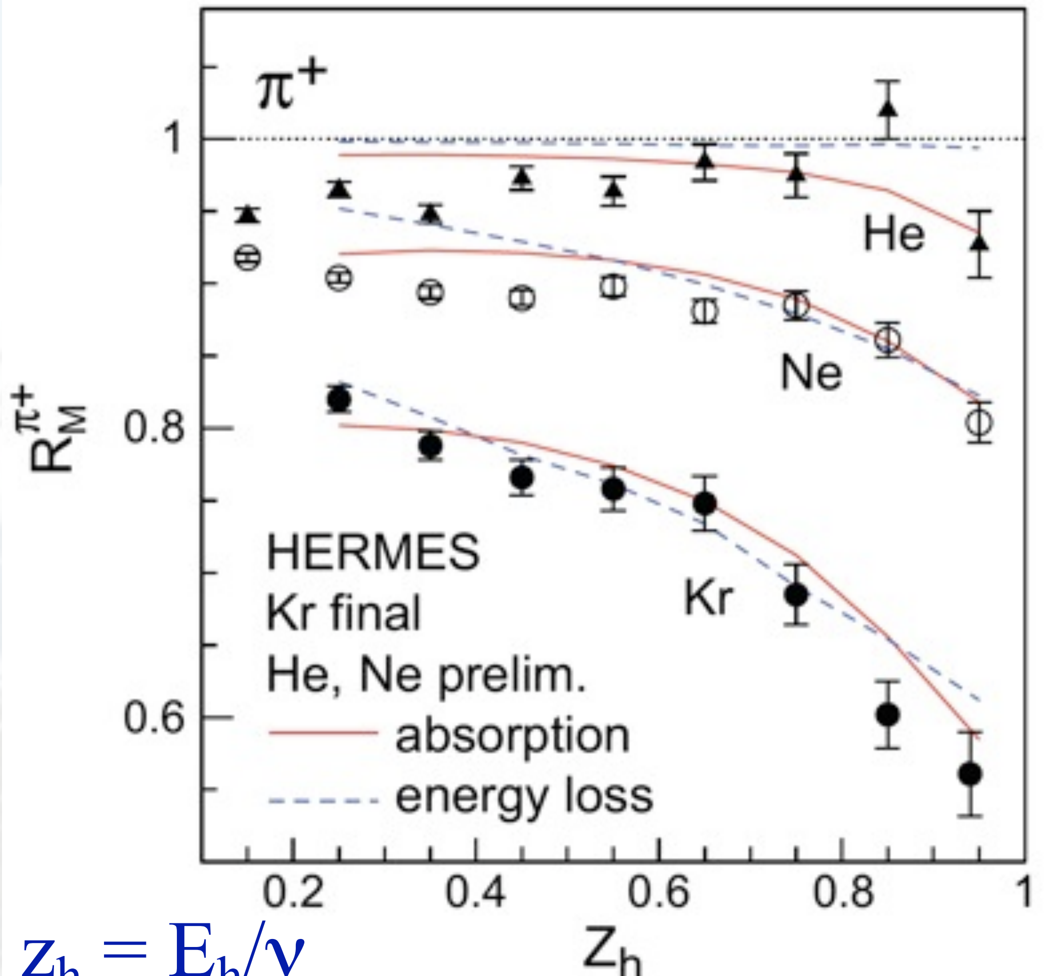

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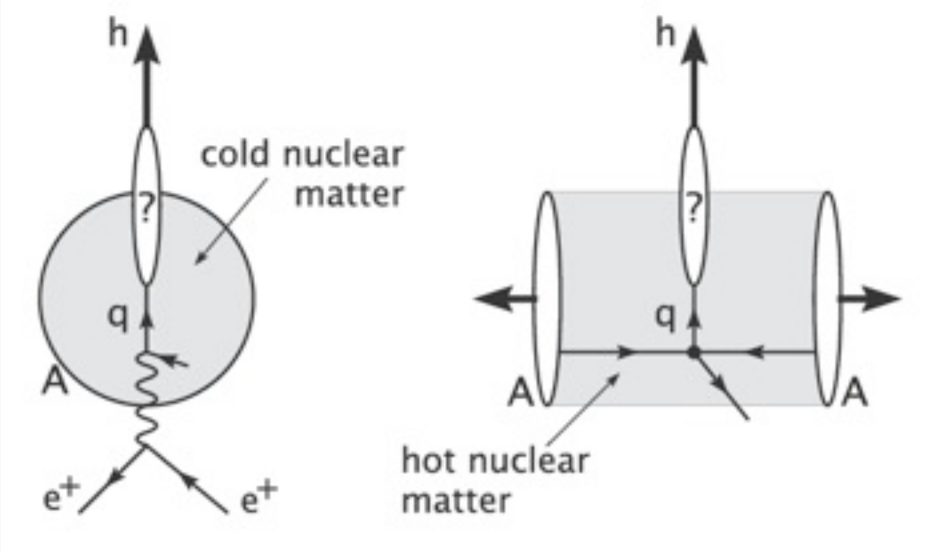
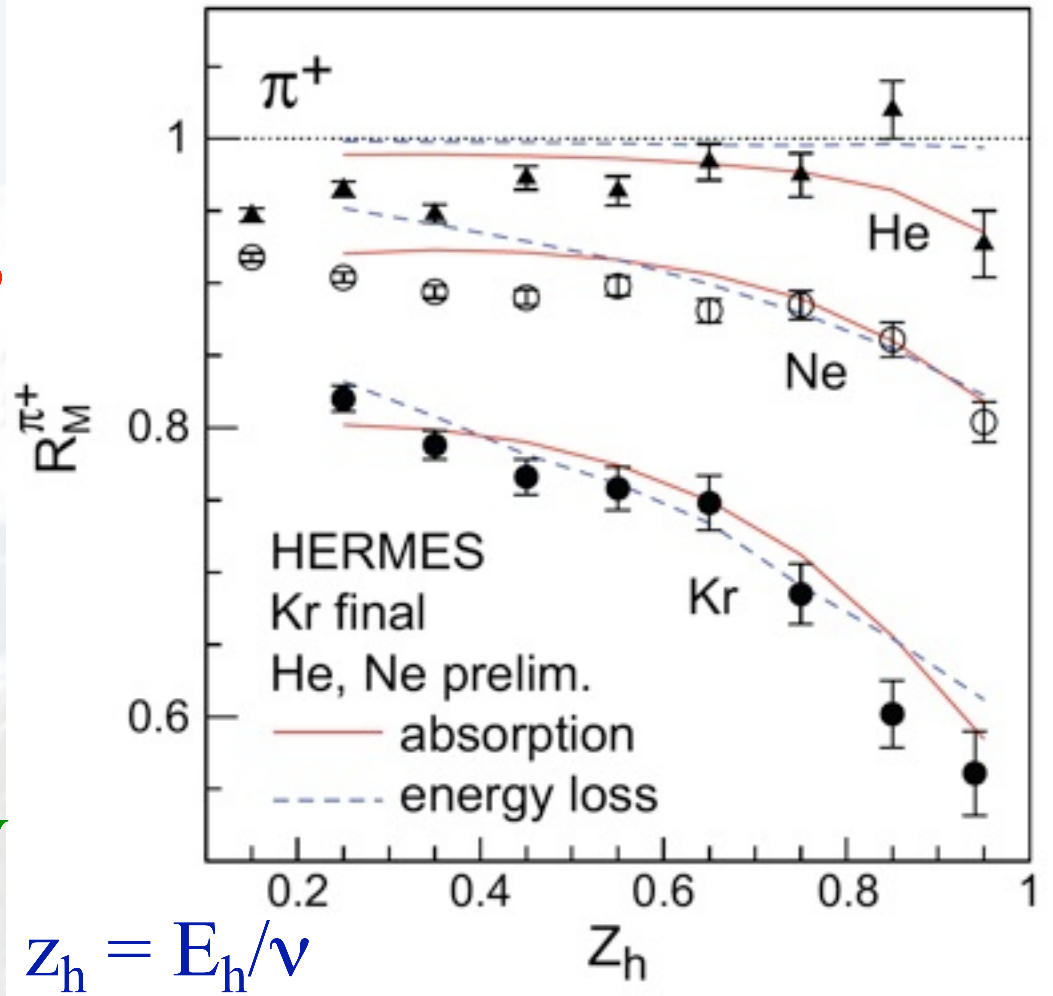


Fundamental question:
When do coloured partons get neutralized?



Parton energy loss vs.
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Energy transfer in lab rest frame:
EIC: $10 < \nu < 1600$ GeV HERMES: 2-25 GeV
EIC: can measure *heavy flavour* energy loss

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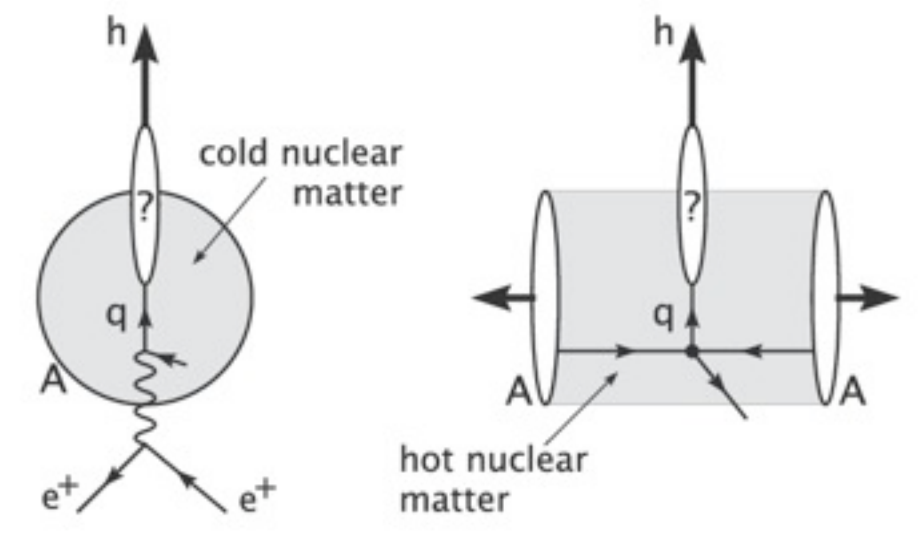

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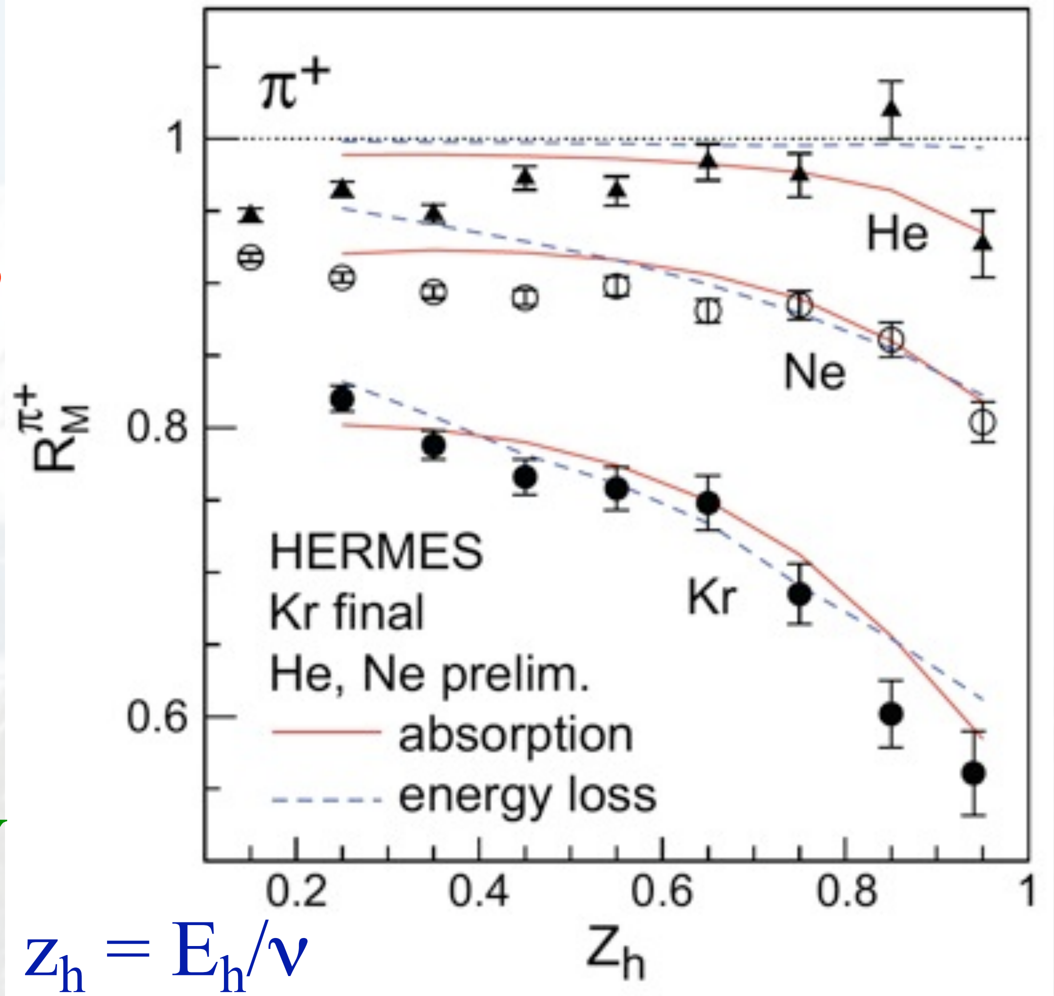

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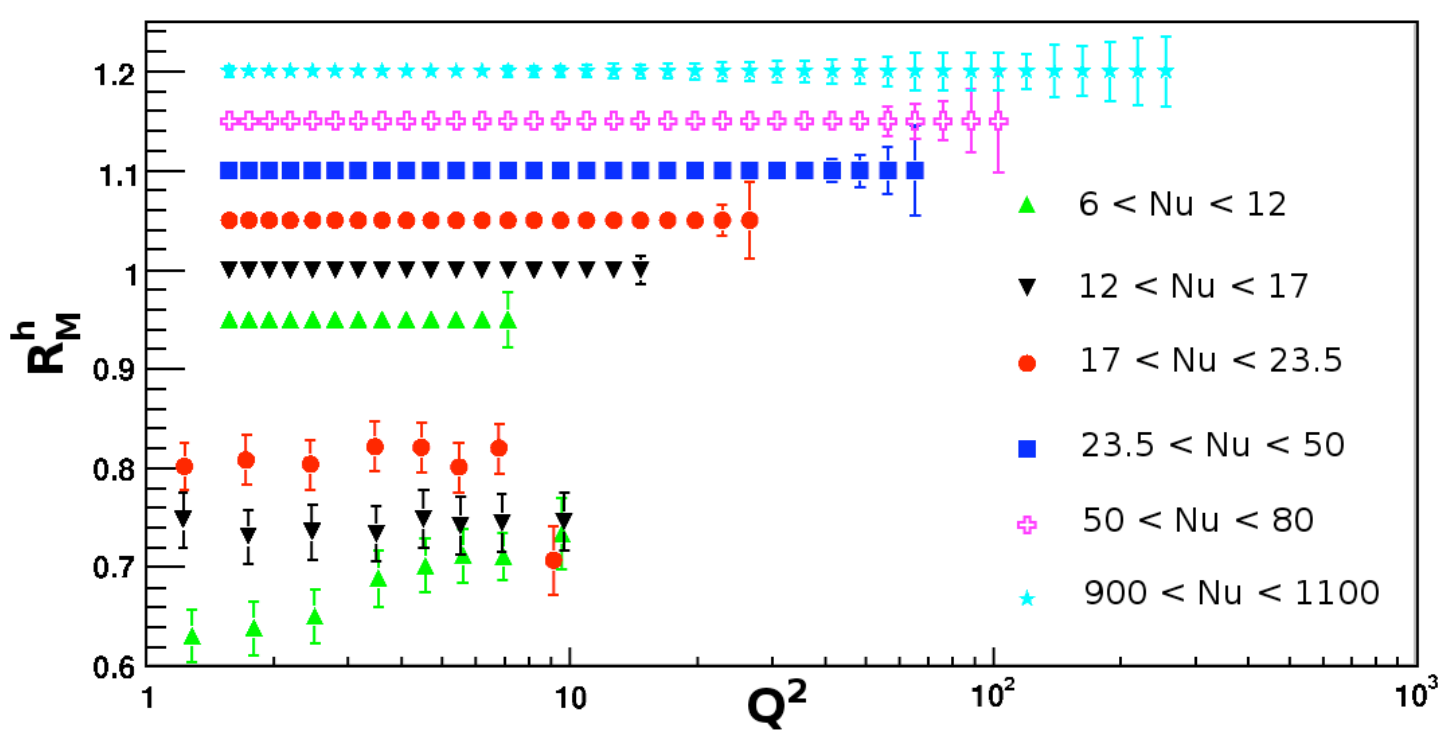

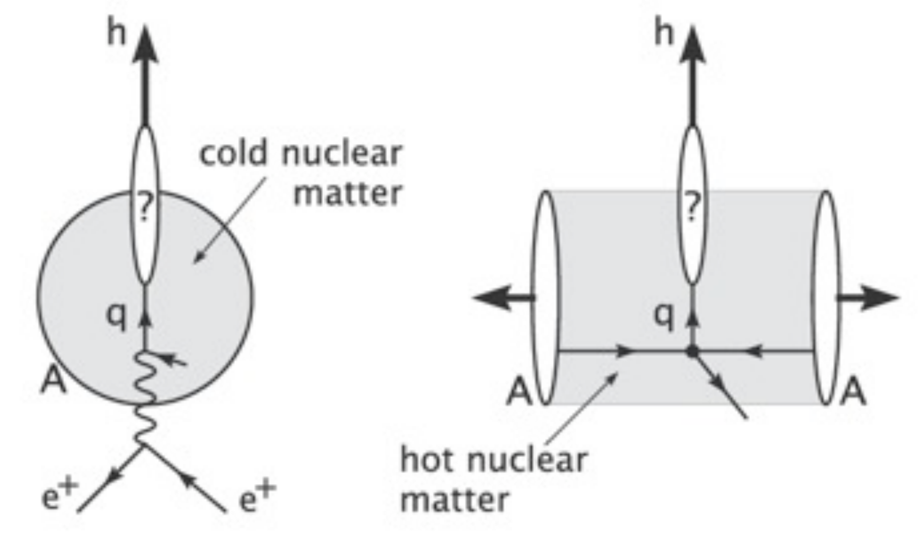

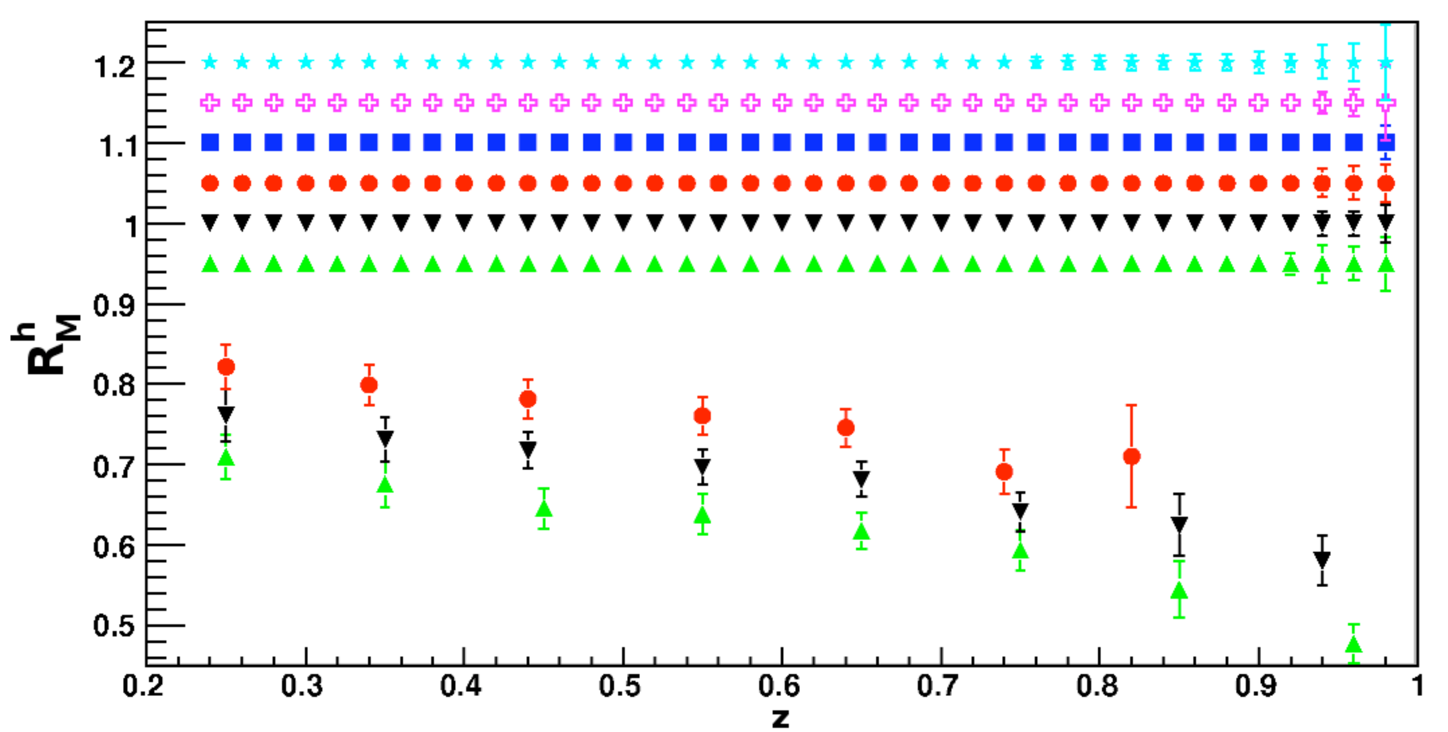

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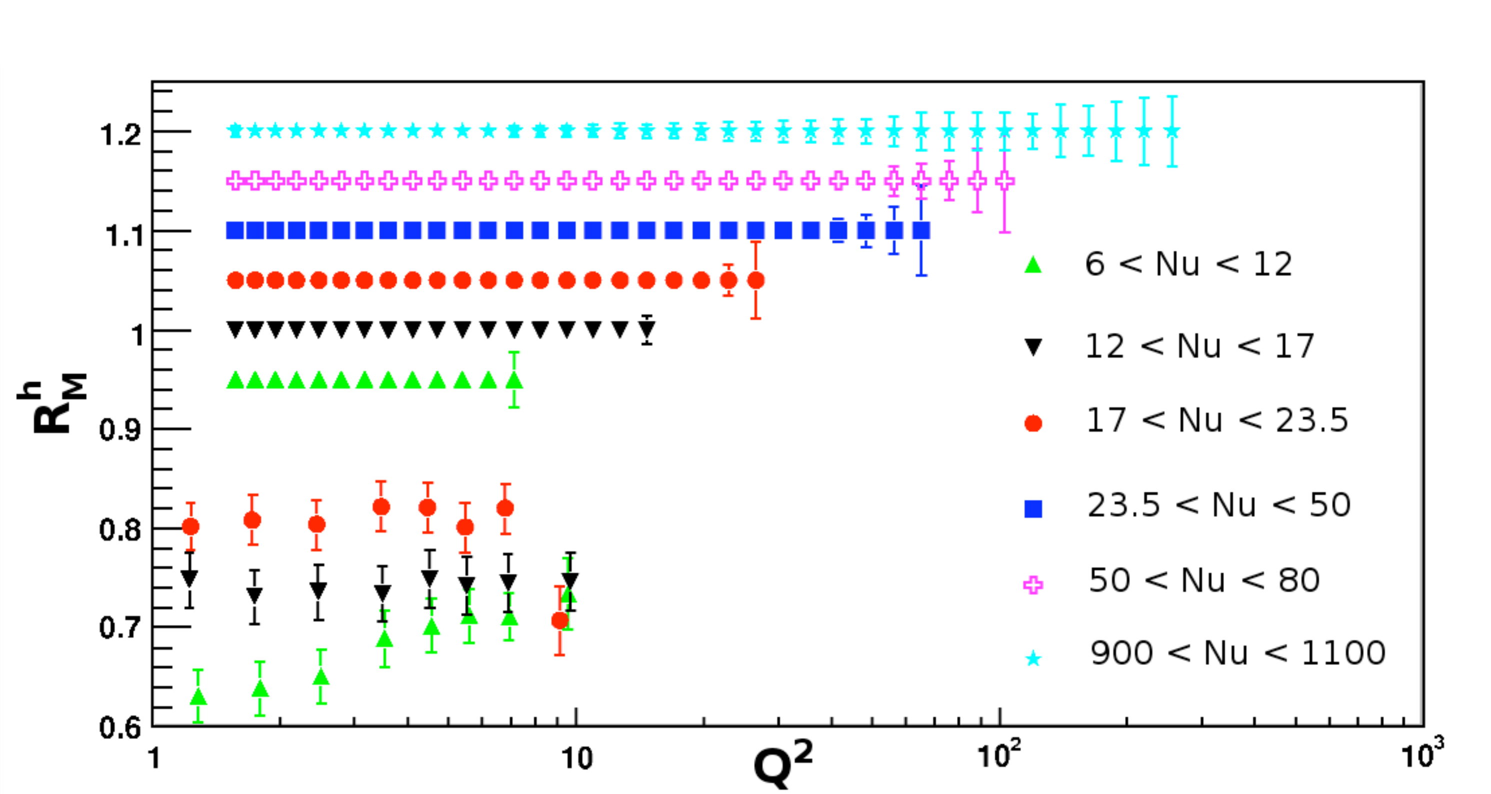

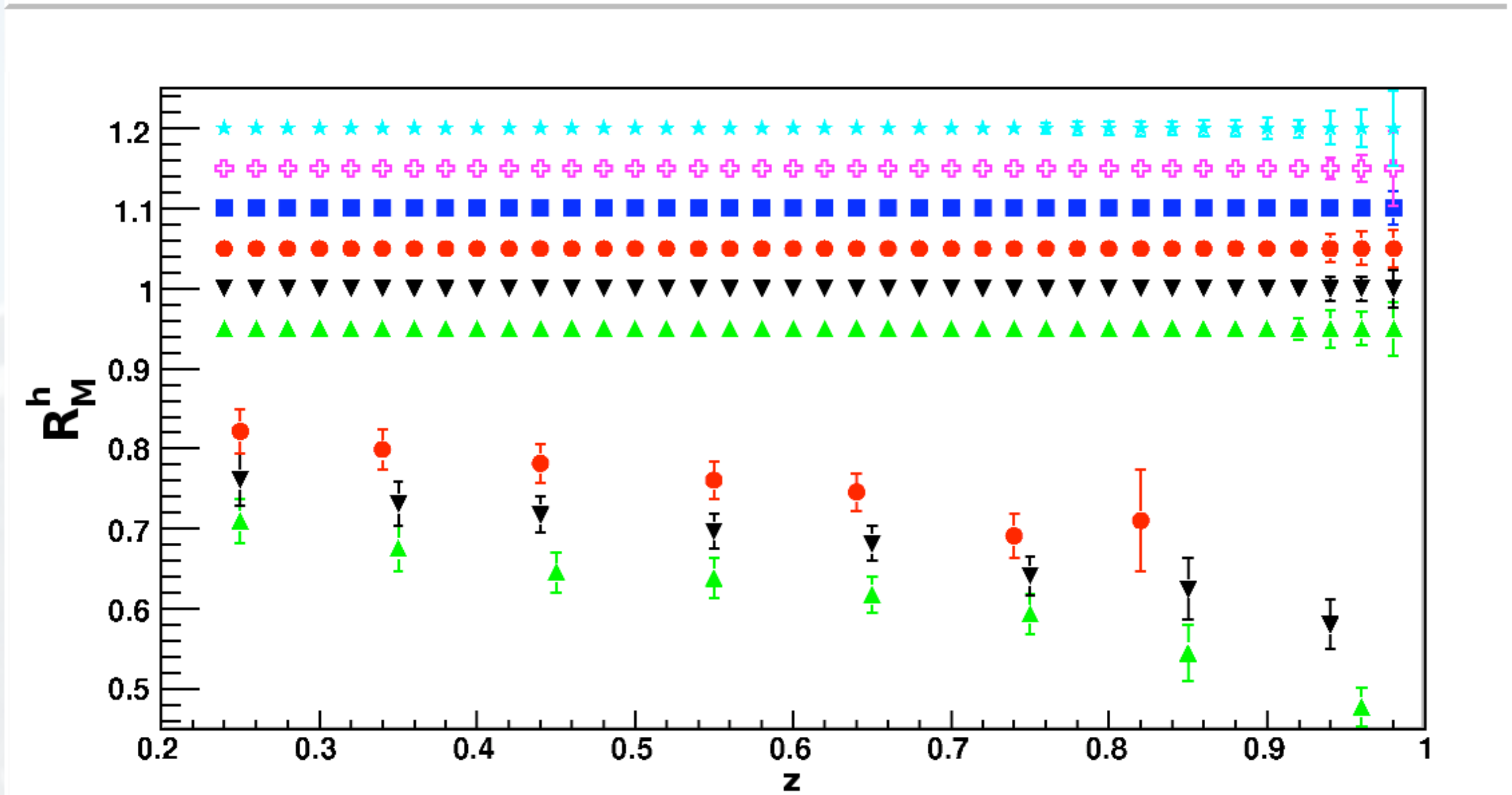

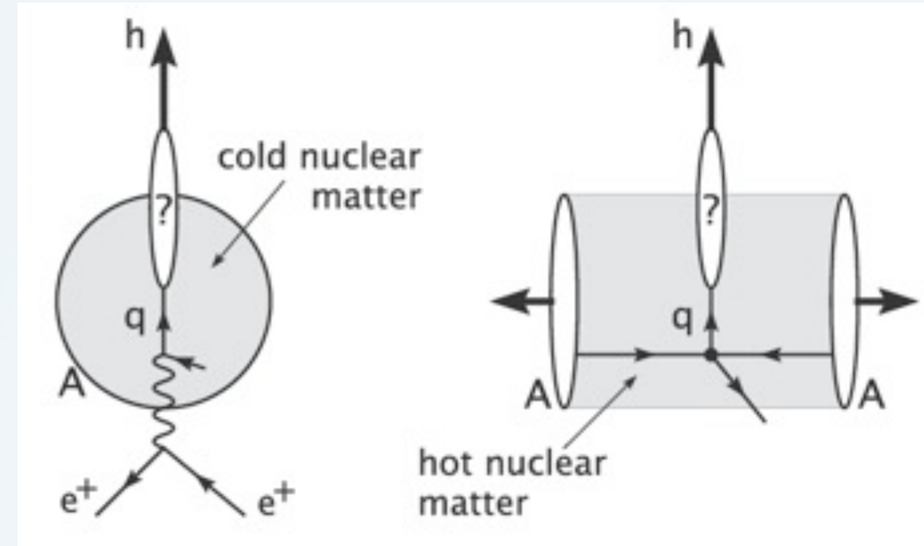

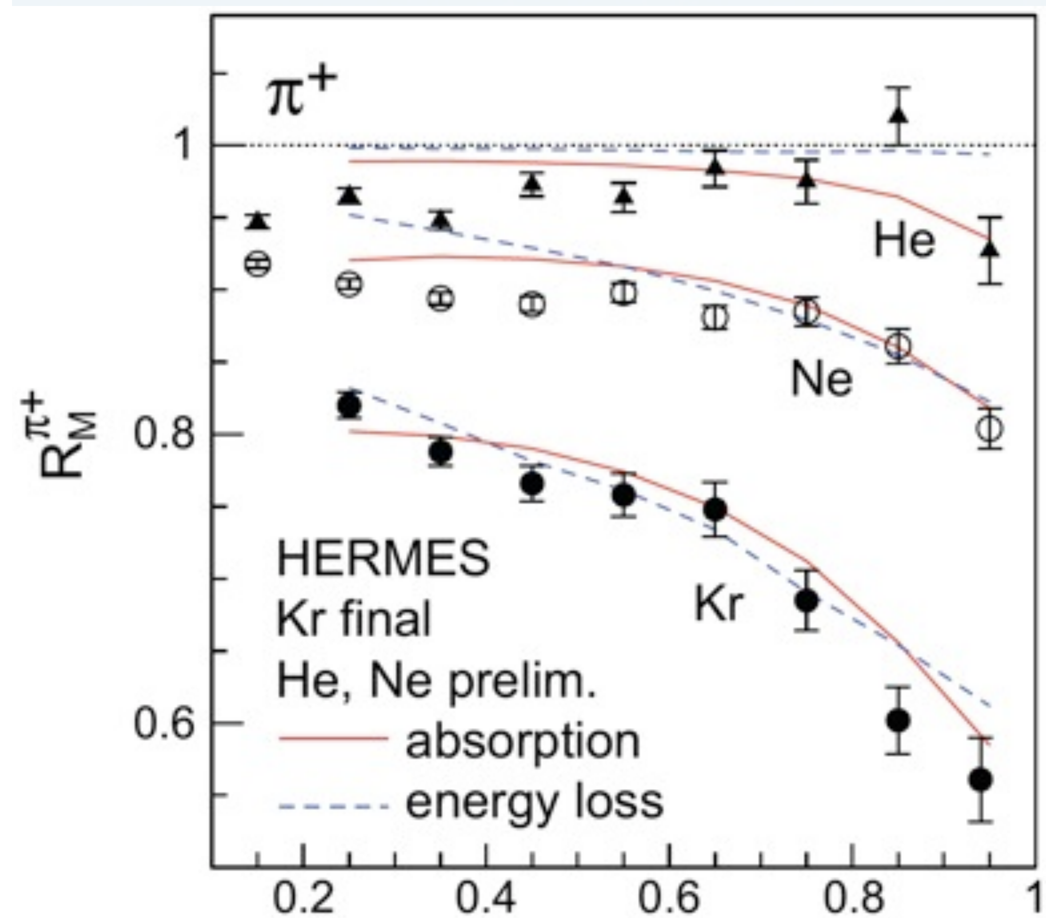

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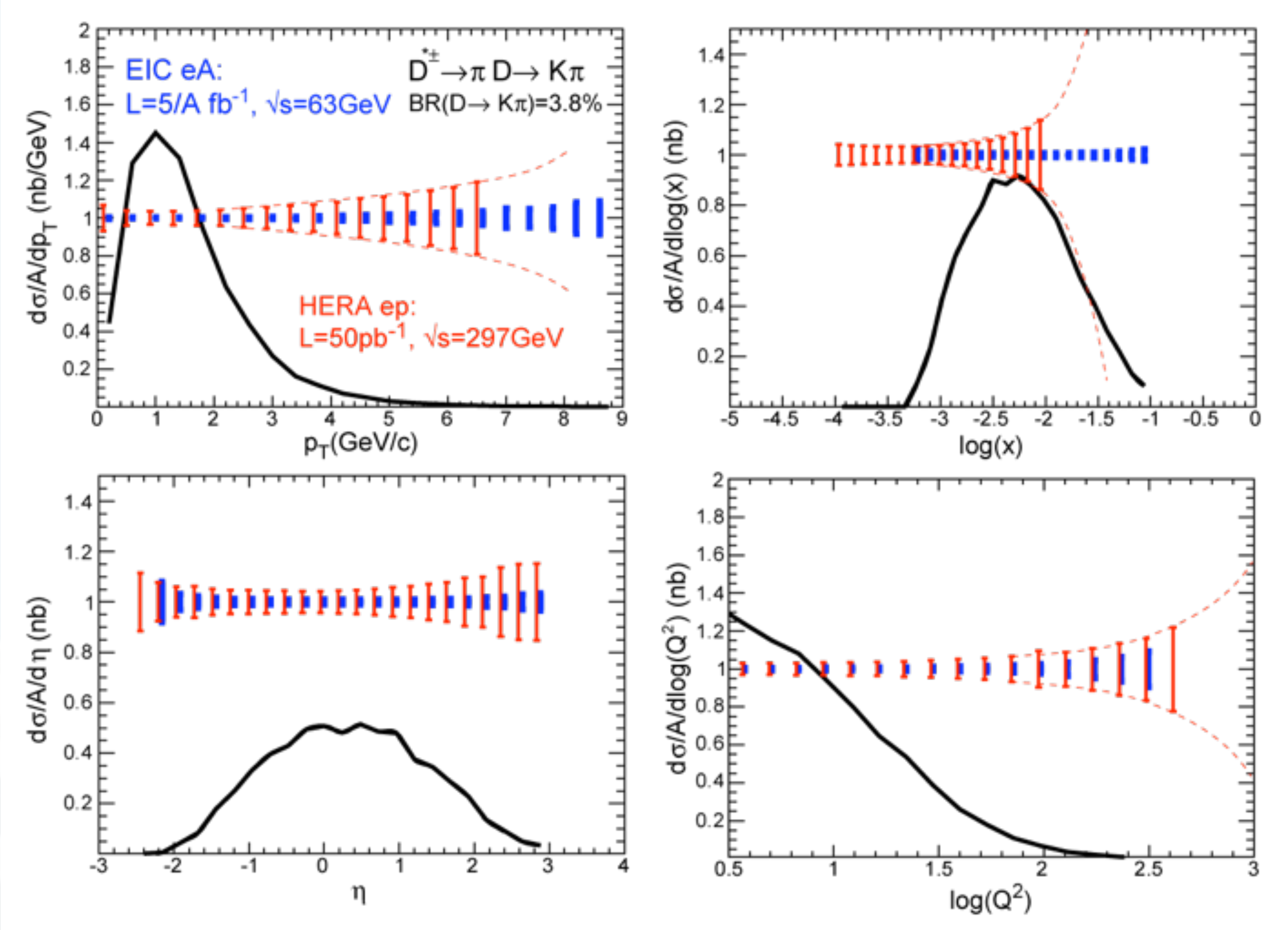
Charm at an EIC



Based on HVQDIS model, J. Smith

- EIC: allows multi-differential measurements of heavy flavour
- covers and extends energy range of SLAC, EMC, HERA, and JLAB allowing for the study of wide range of formation lengths

Key Measurements in *e*+A

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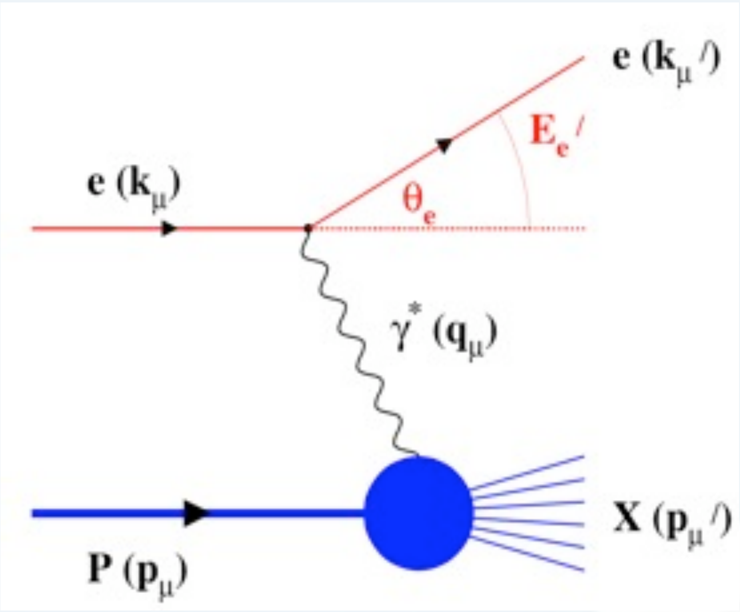
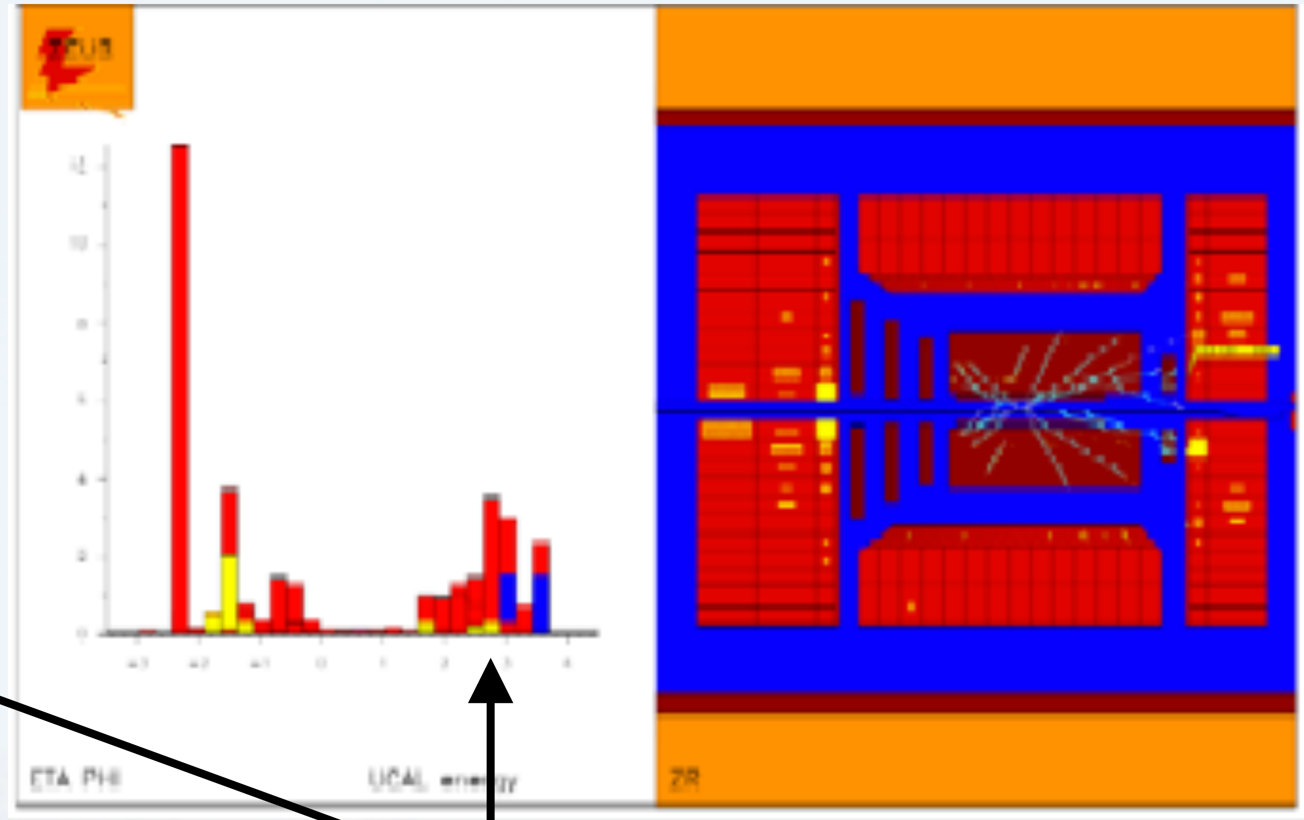
Diffractive Physics in e+A

'Standard DIS event'

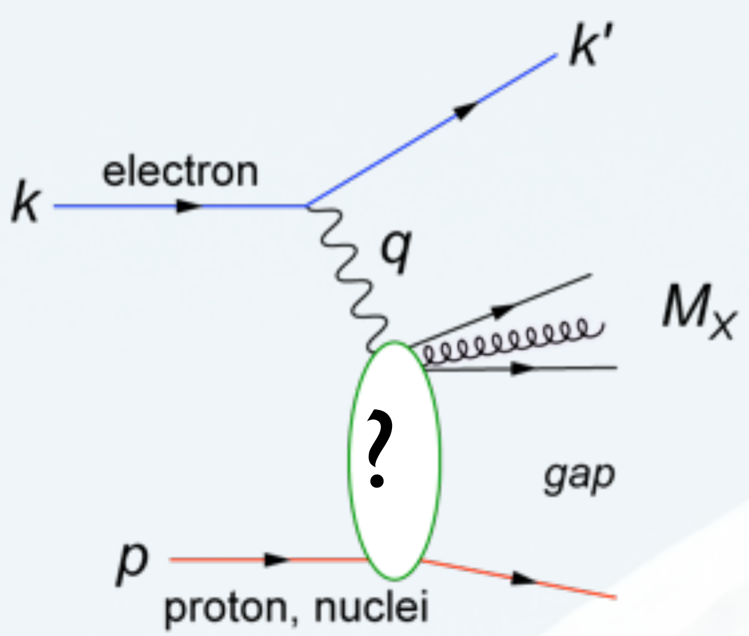


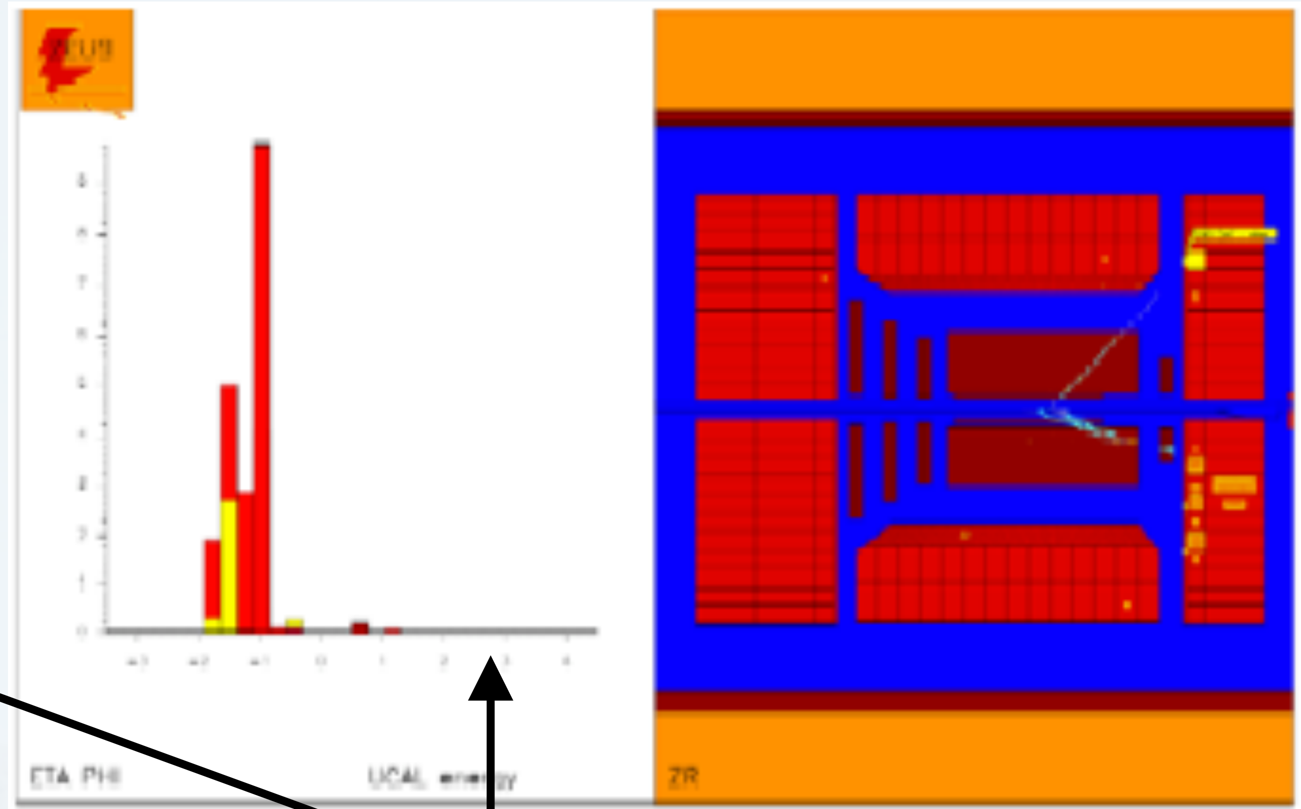


Activity in proton direction

Diffractive Physics in e+A

Diffractive event





Activity in proton direction

- HERA/ep: 15% of all events are hard diffractive
- Diffractive cross-section $\sigma_{diff}/\sigma_{tot}$ in e+A ?
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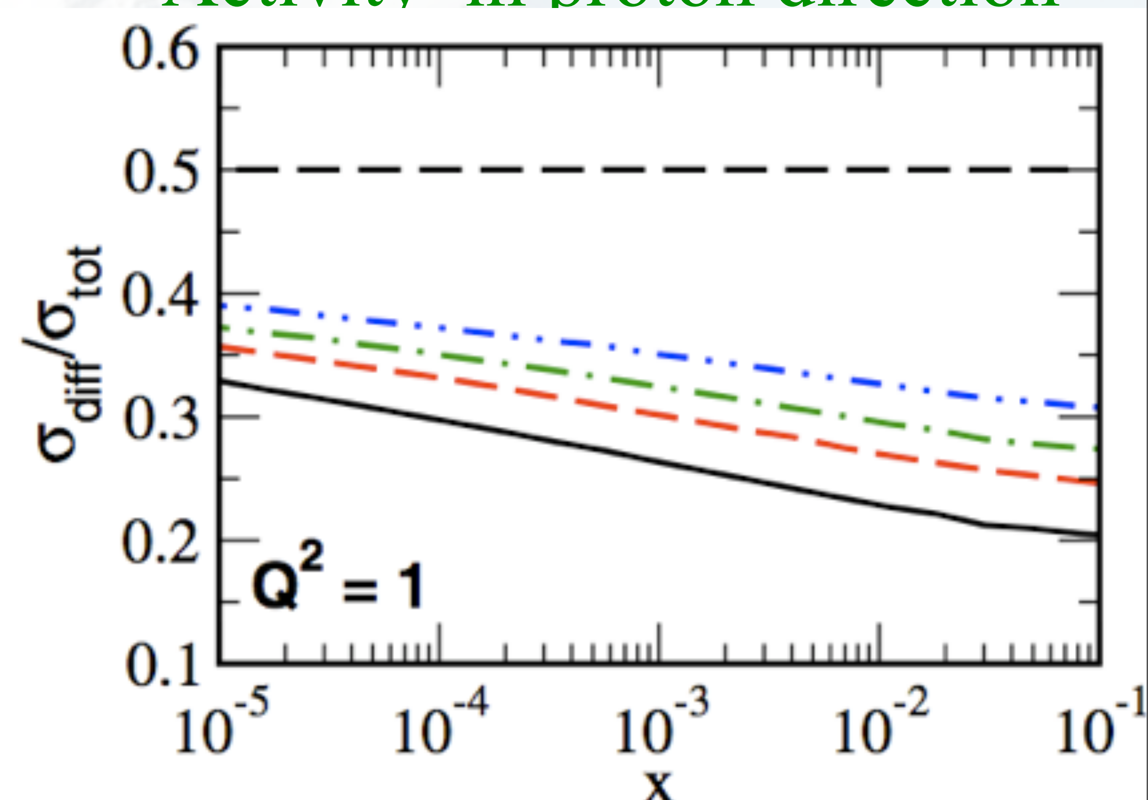

Curves: Kugeratski, Goncalves, Navarra, EPJ C46, 413

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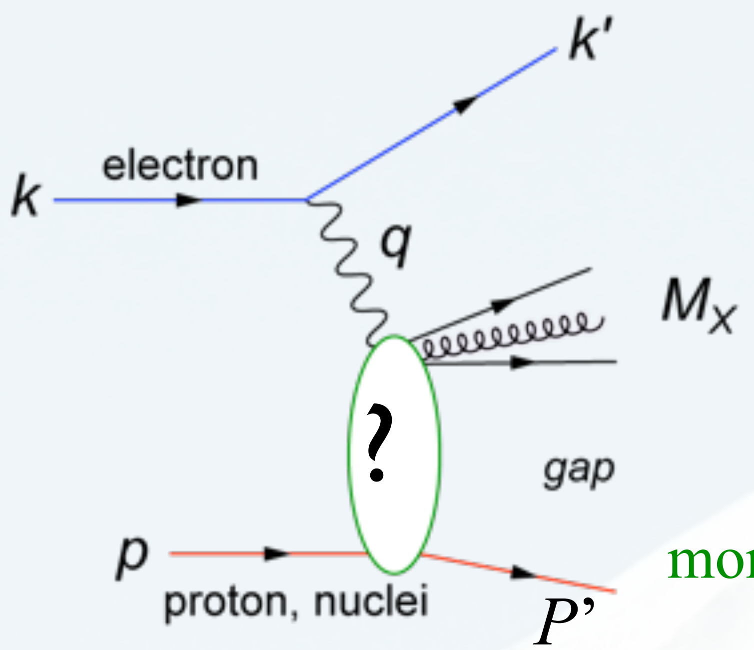
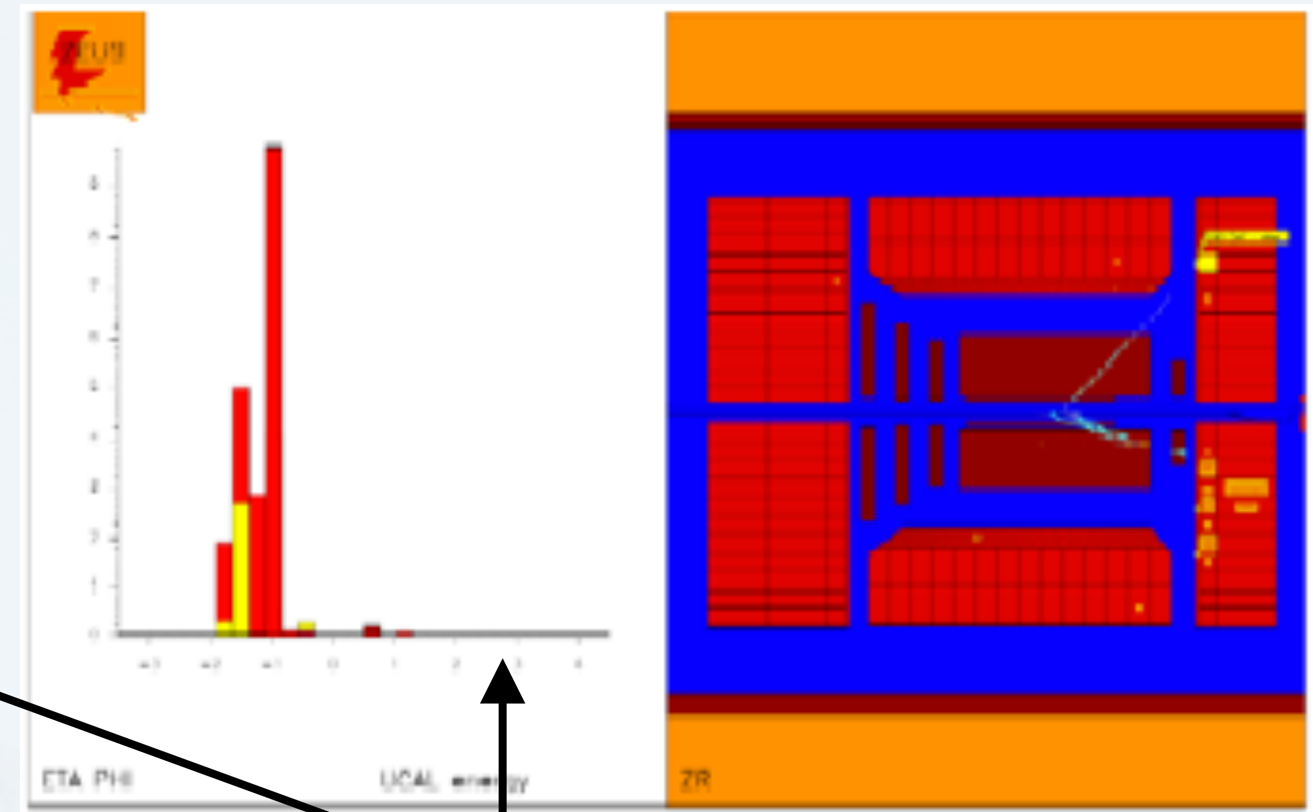


momentum transfer:
$t = (P-P')^2$



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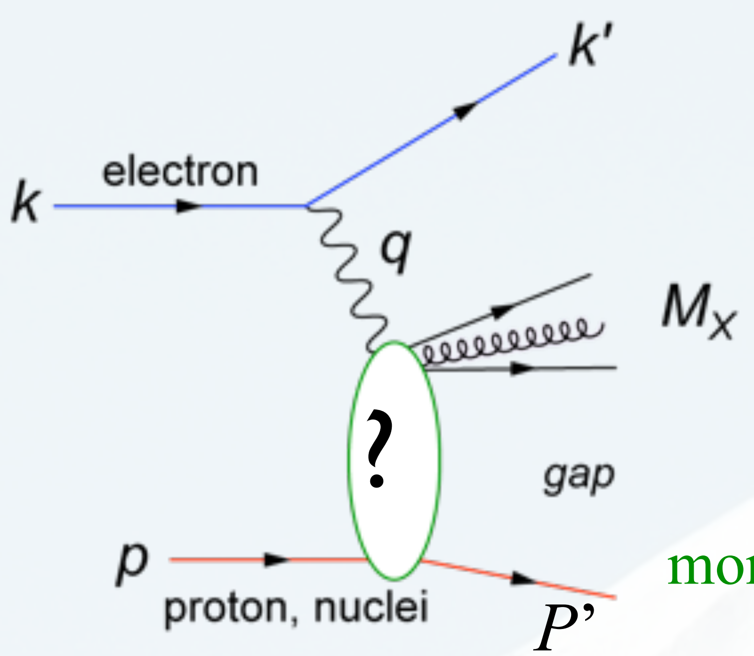

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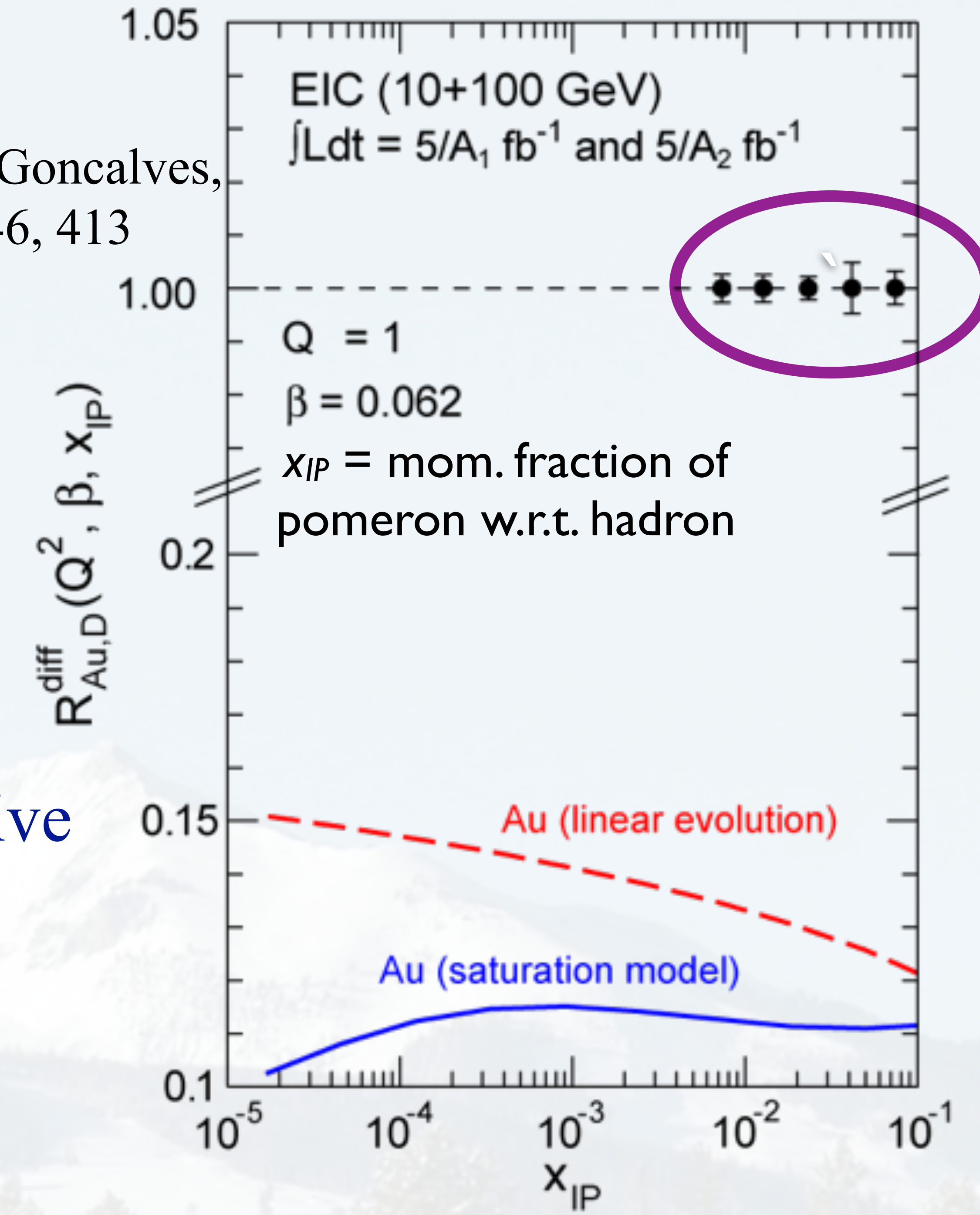

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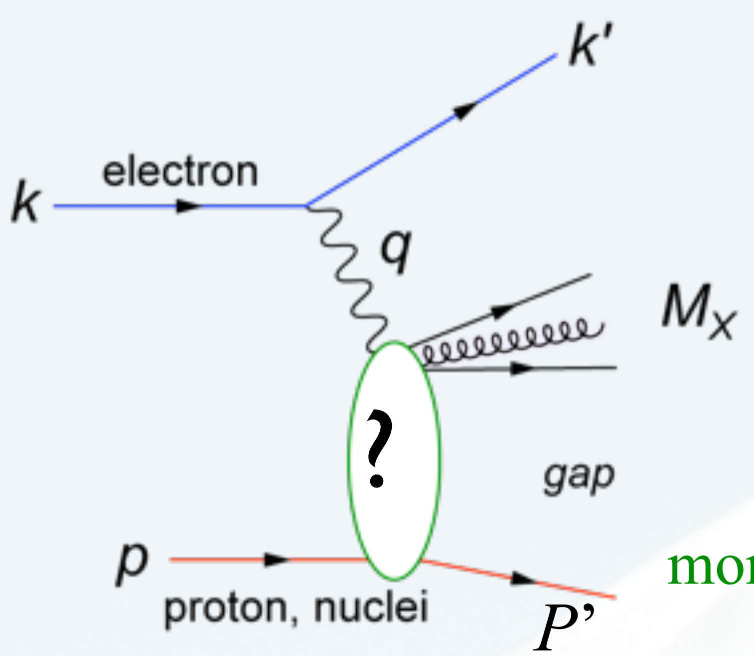

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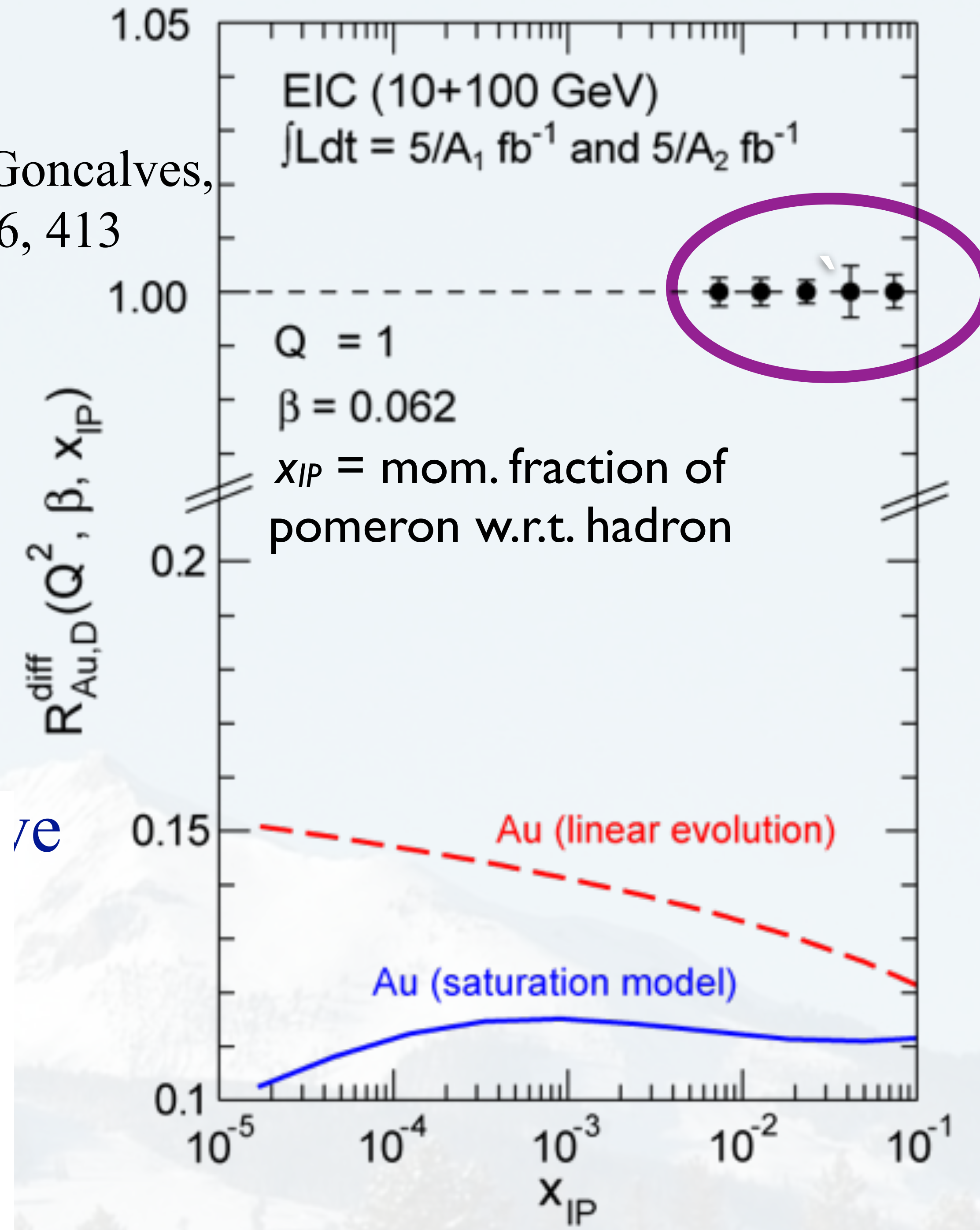

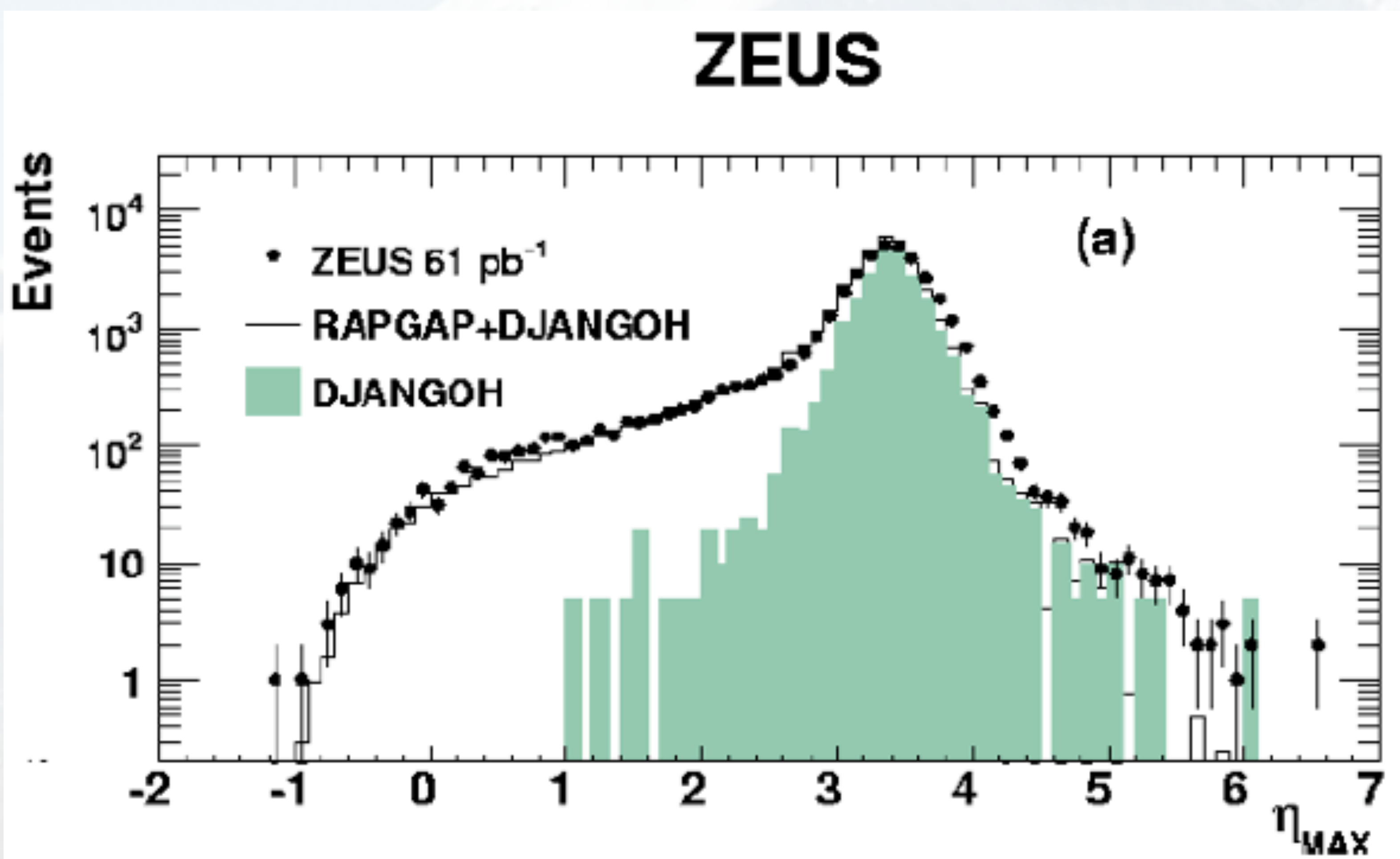

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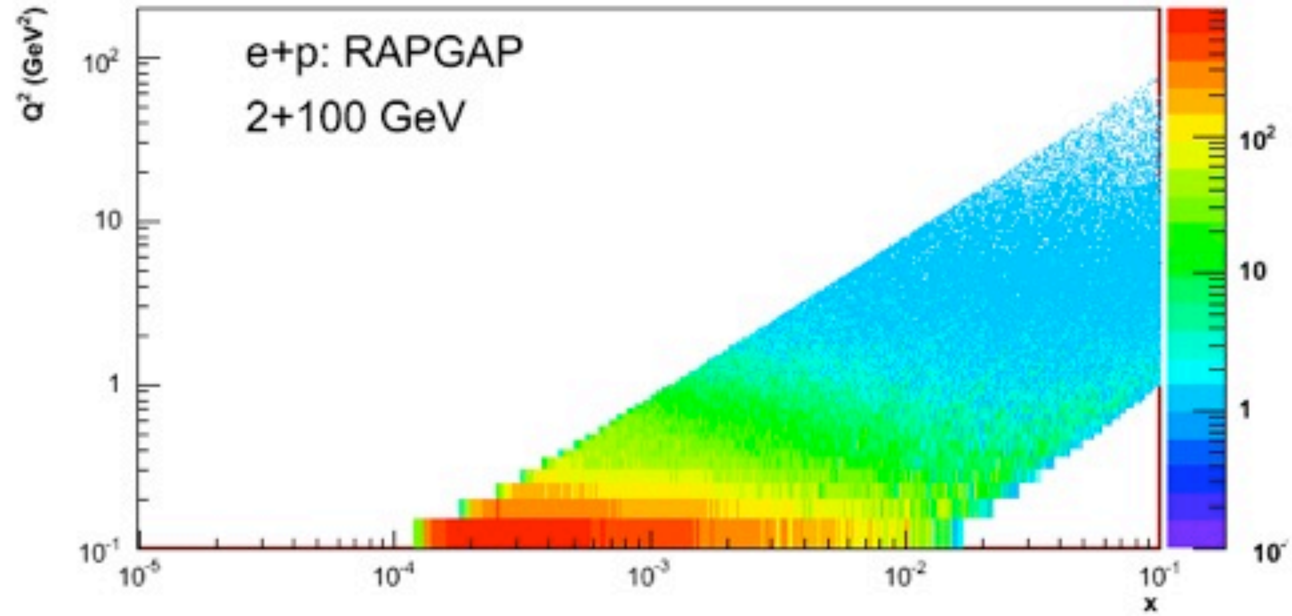
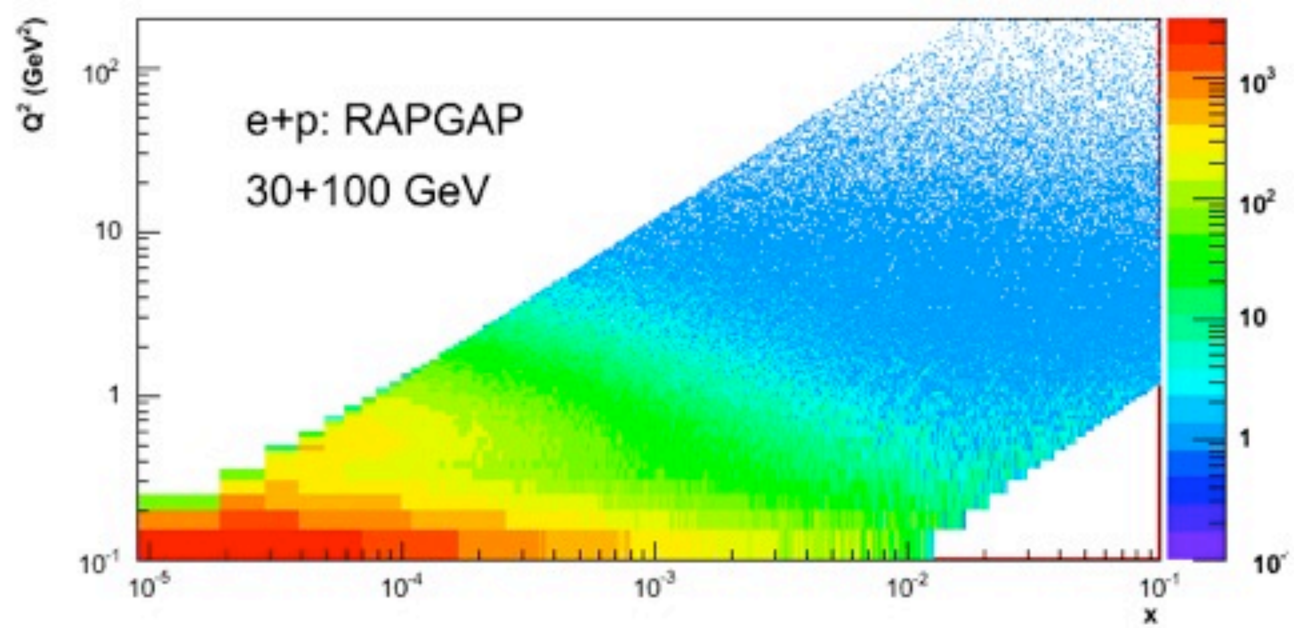
Diffractive Physics at an EIC

Generated 10^6 e+p events using RAPGAP for a variety of proposed EIC energies





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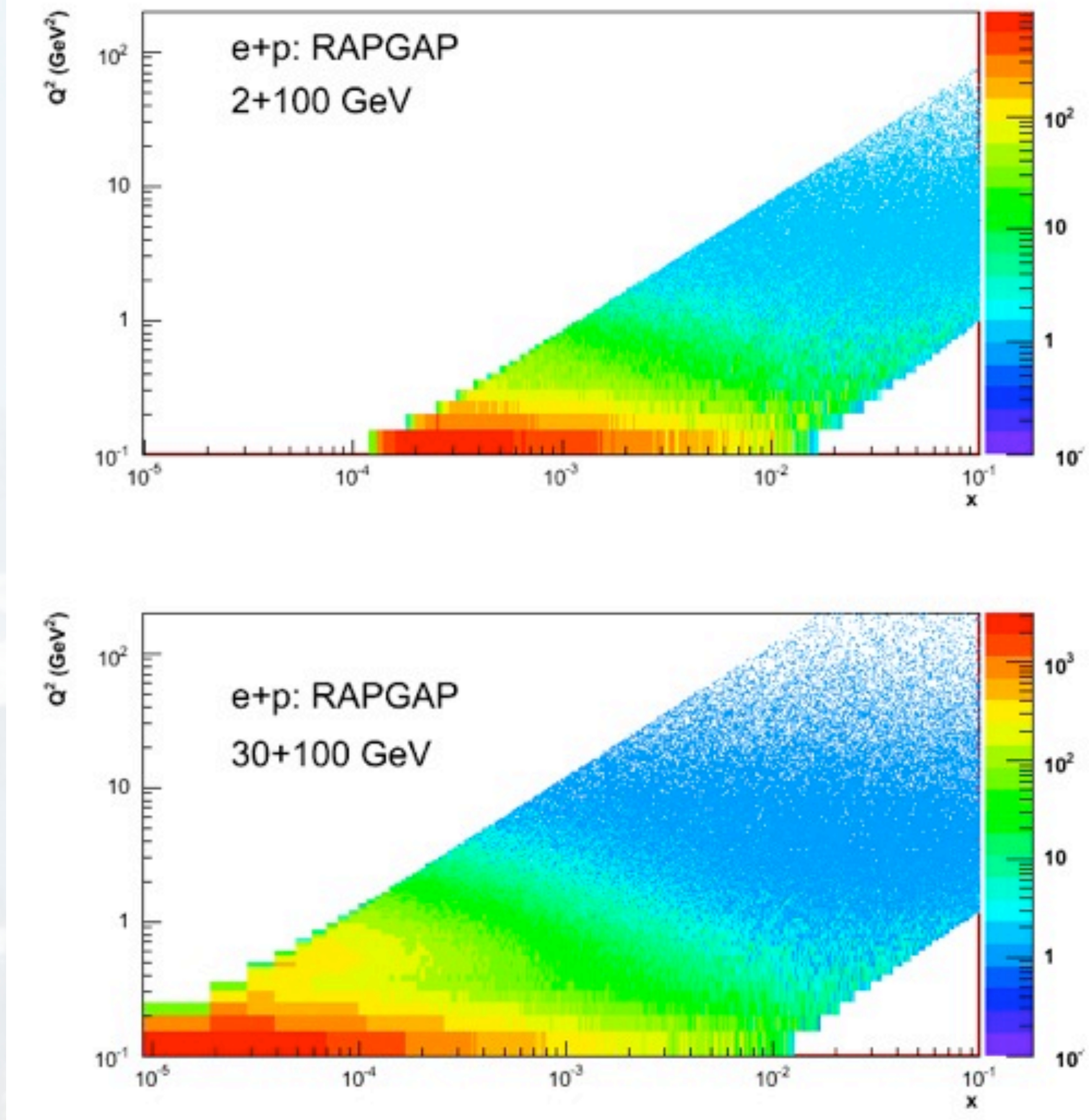

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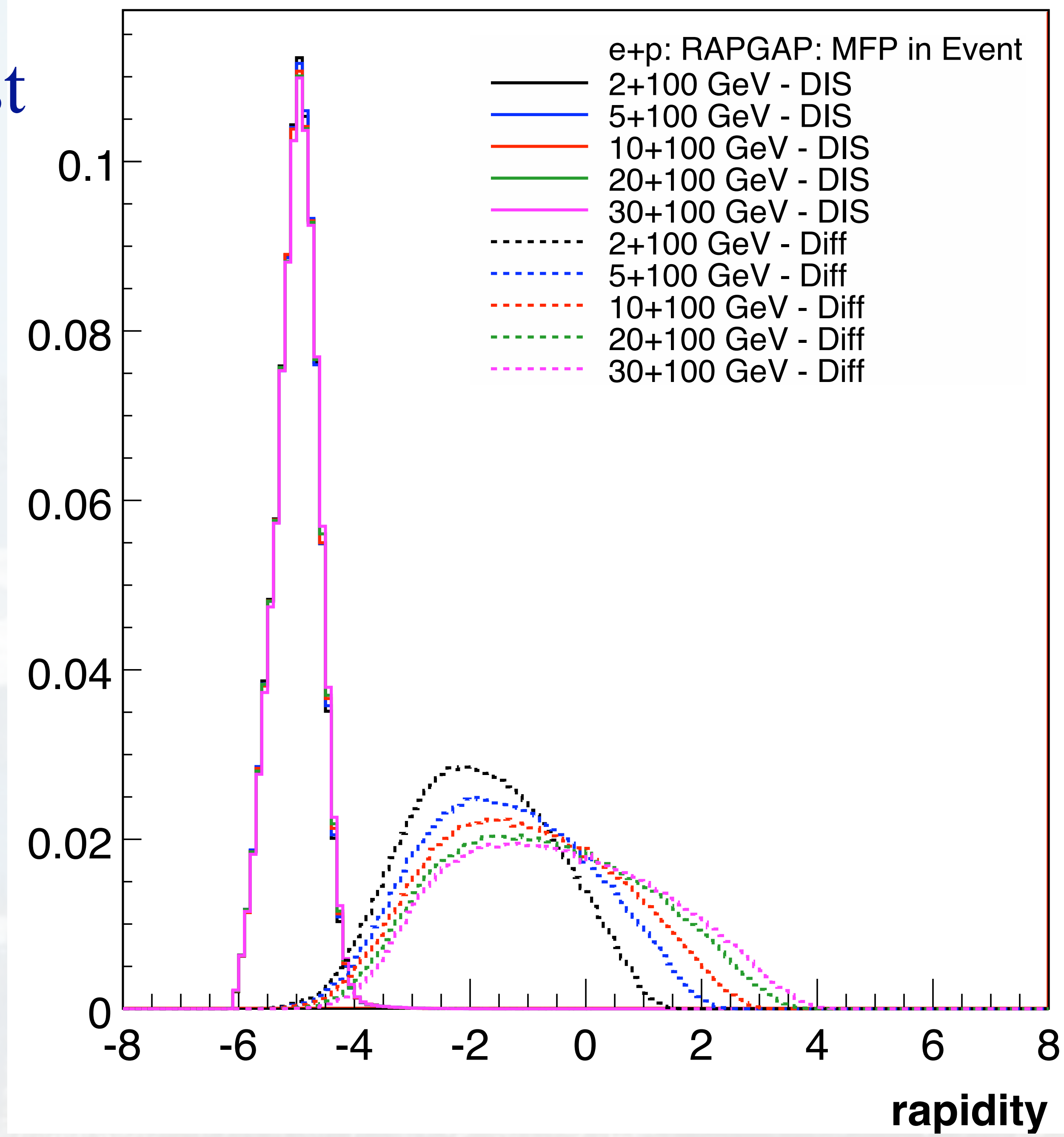

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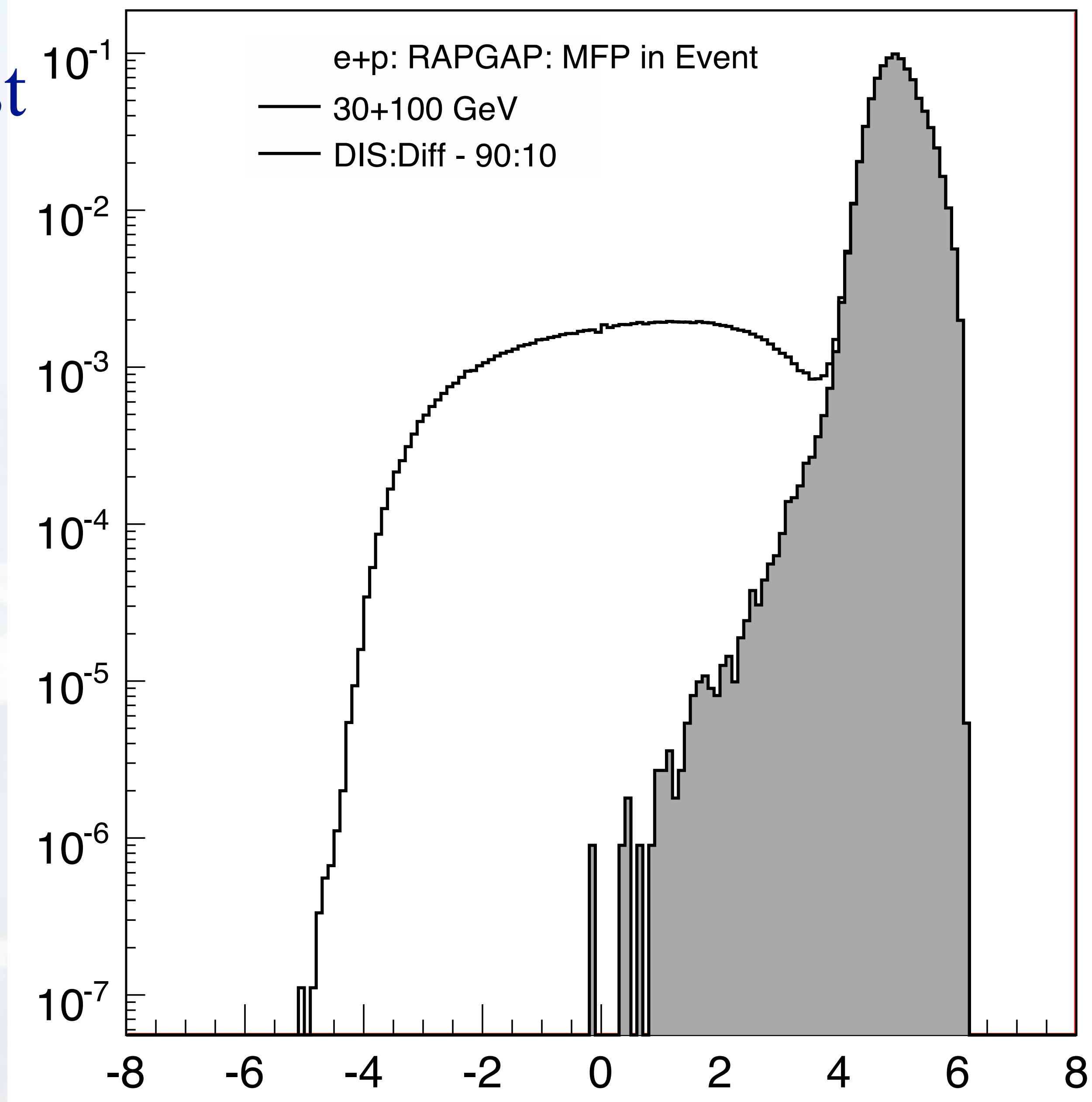

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- Important - plot the efficiency vs purity
  - ➡ Can place a cut in rapidity for ~90% efficiency and ~90% purity !!

Effic: frac of Diff events out of all Diff events

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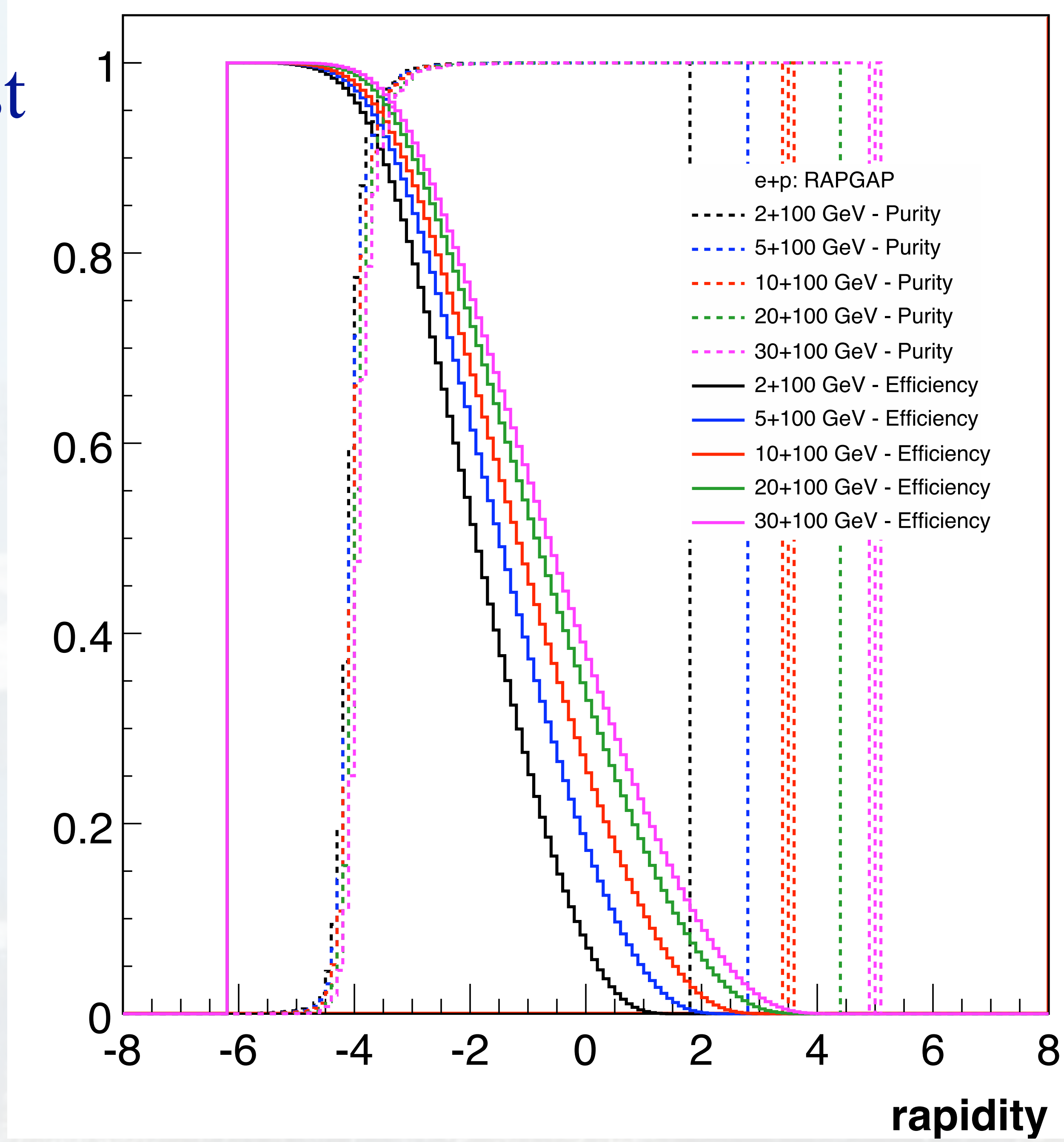

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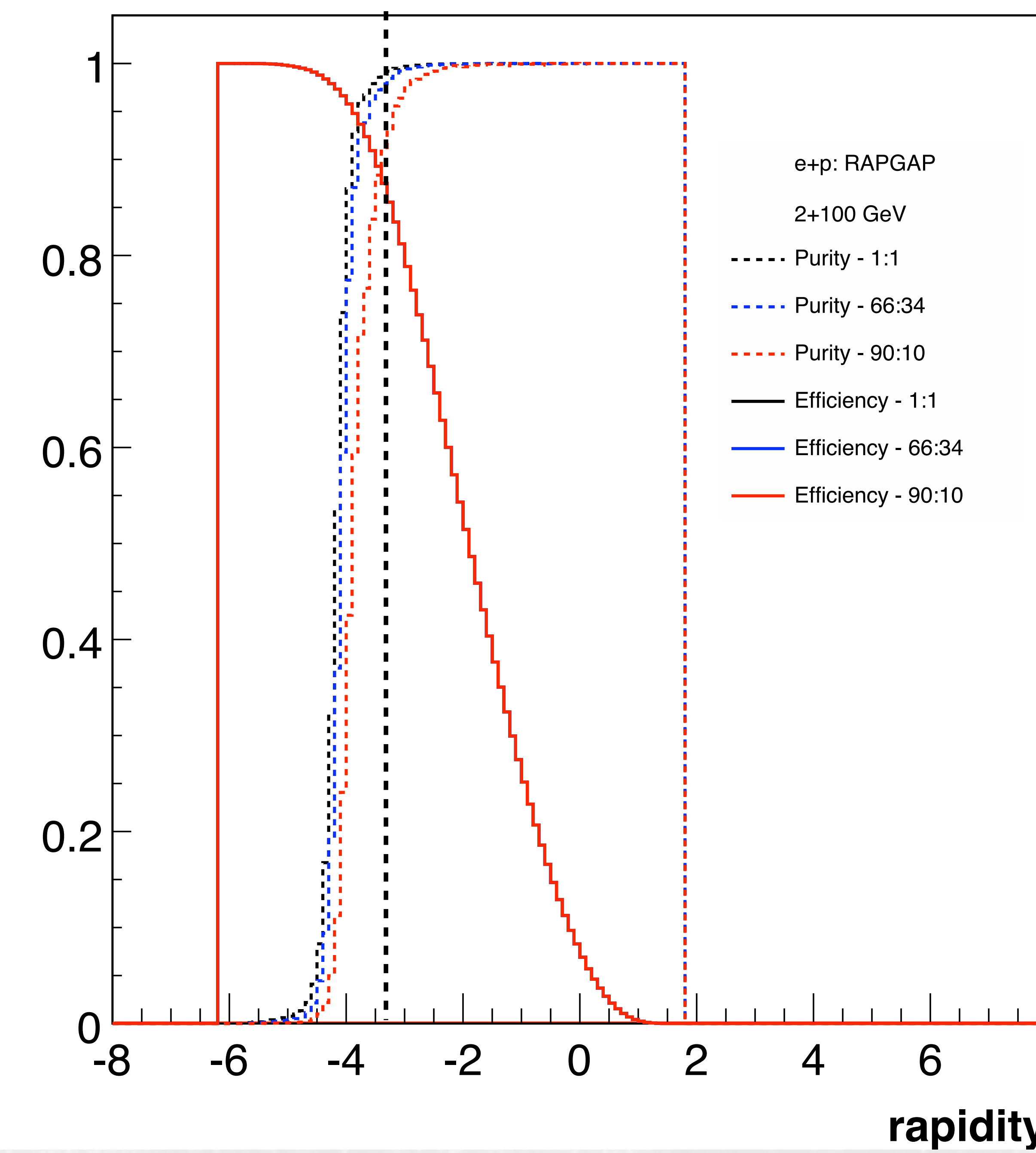

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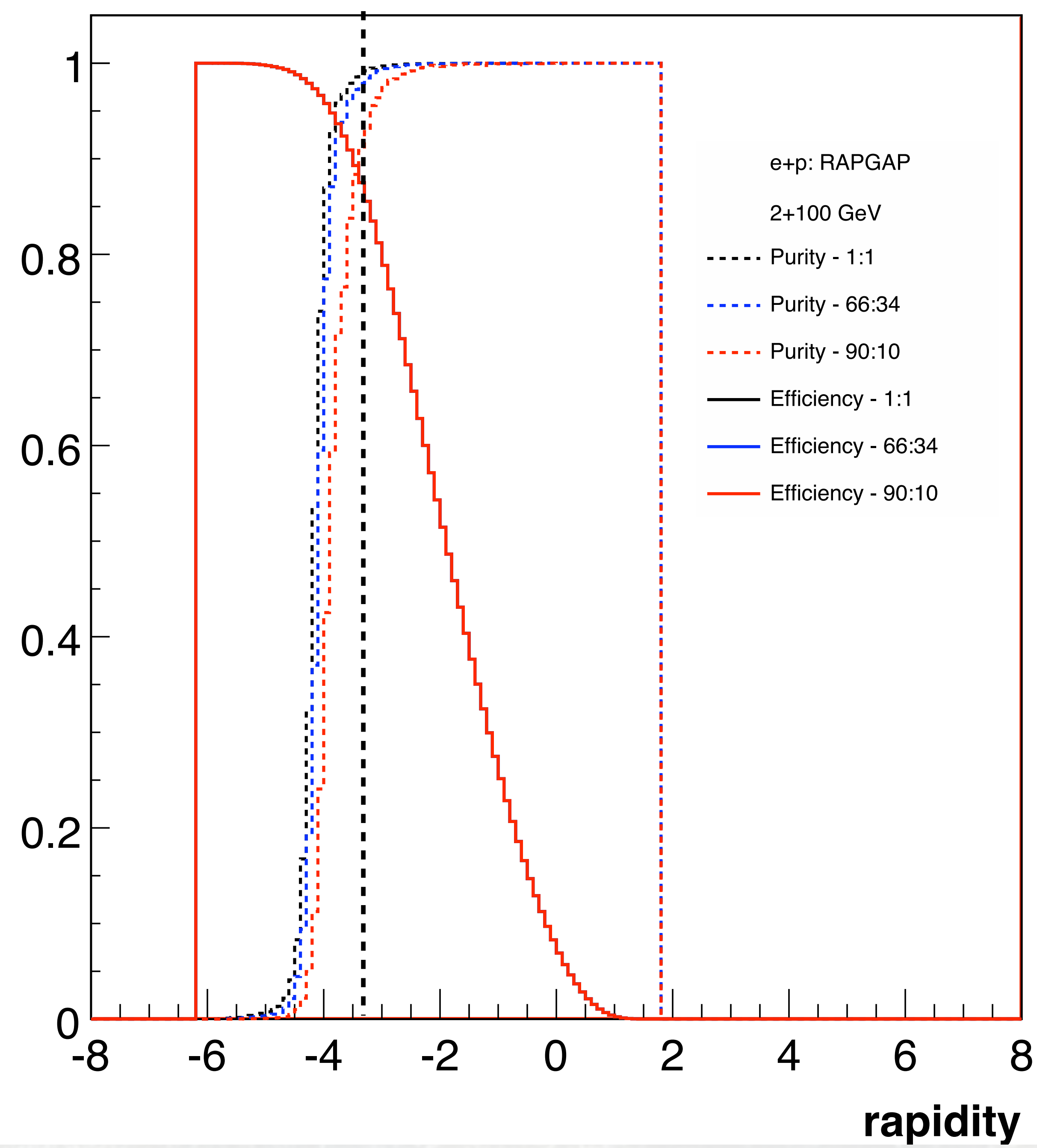

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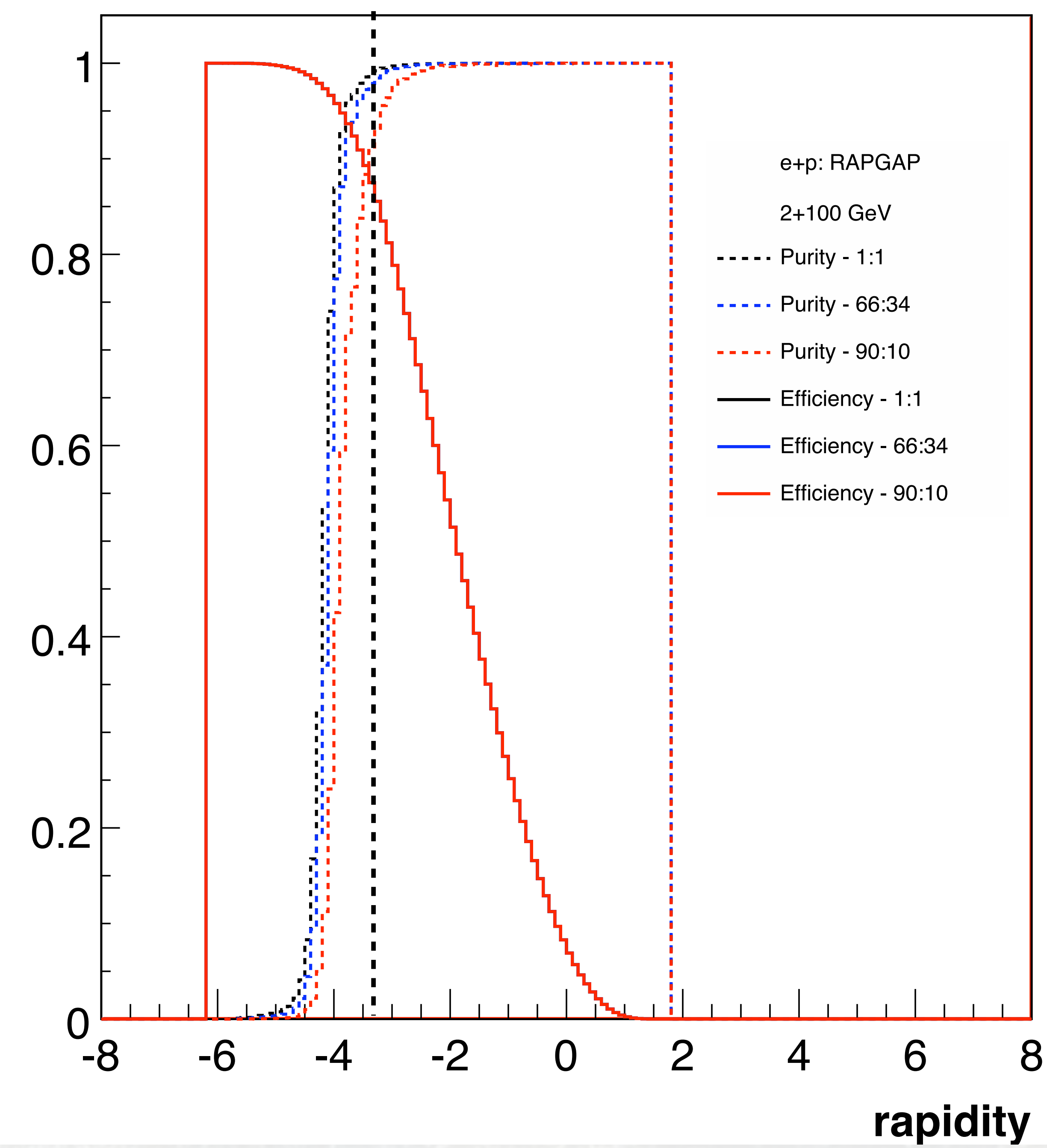

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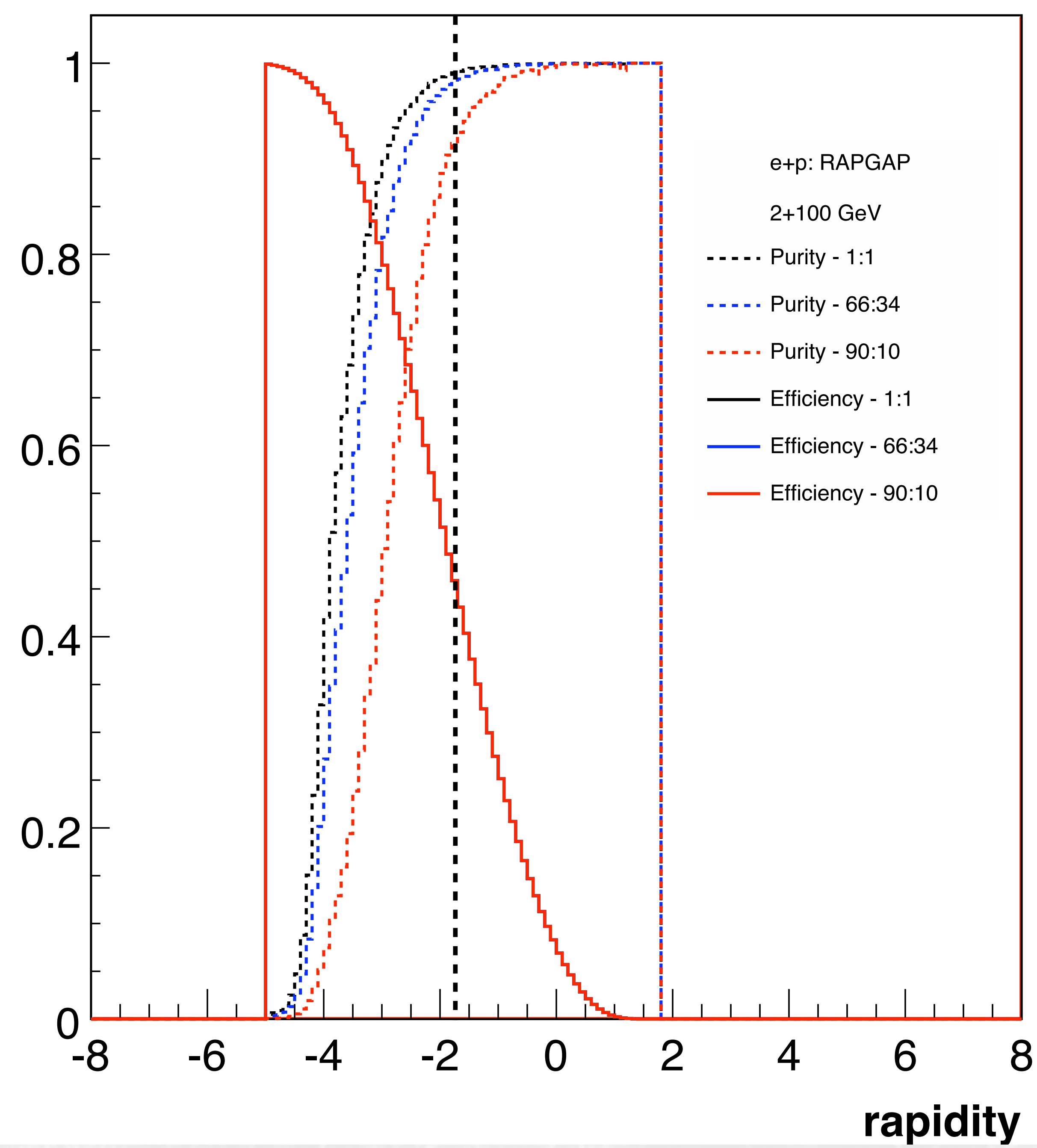

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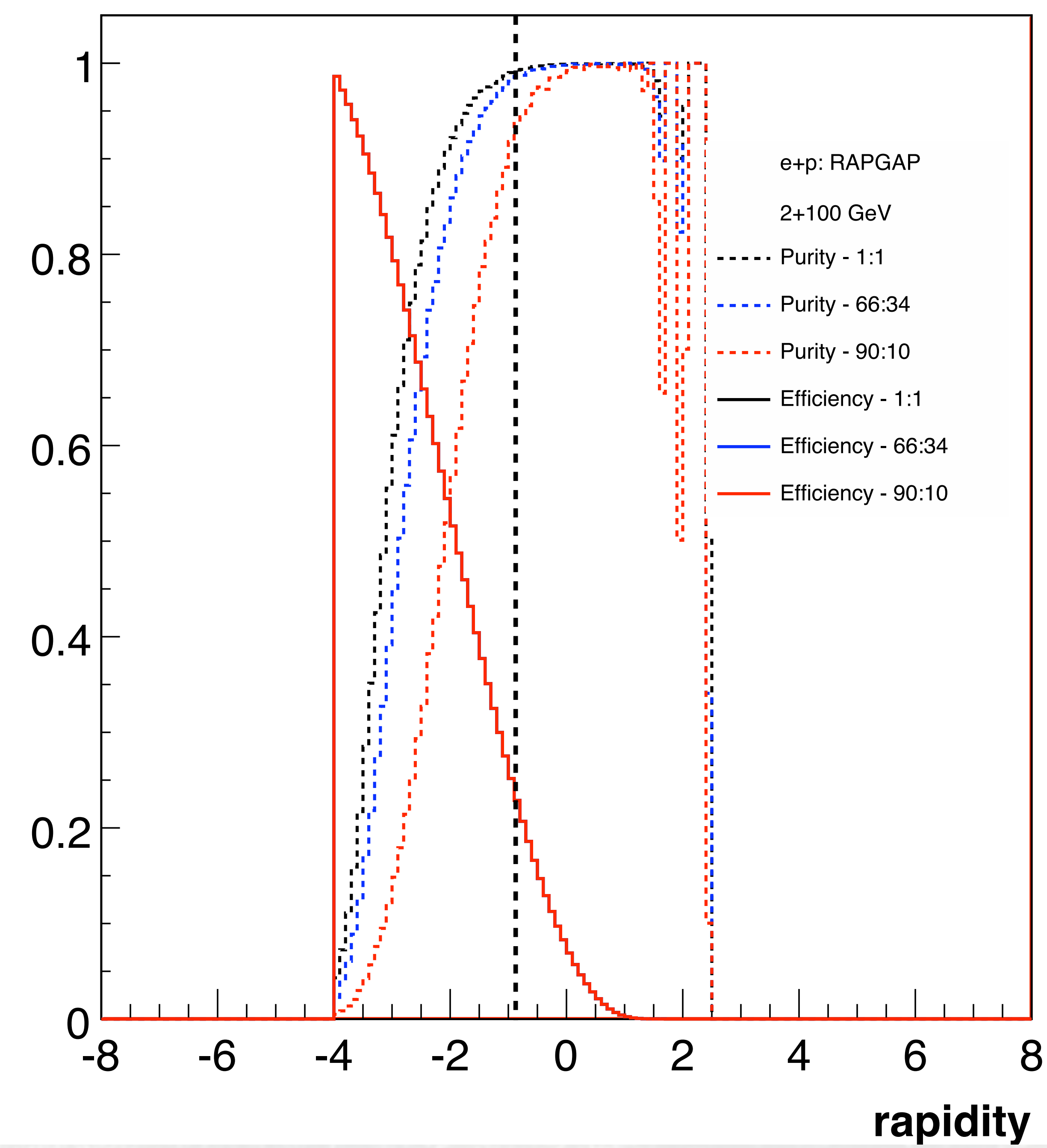

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- When designing a detector, it is essential to be as hermetic as possible !!!

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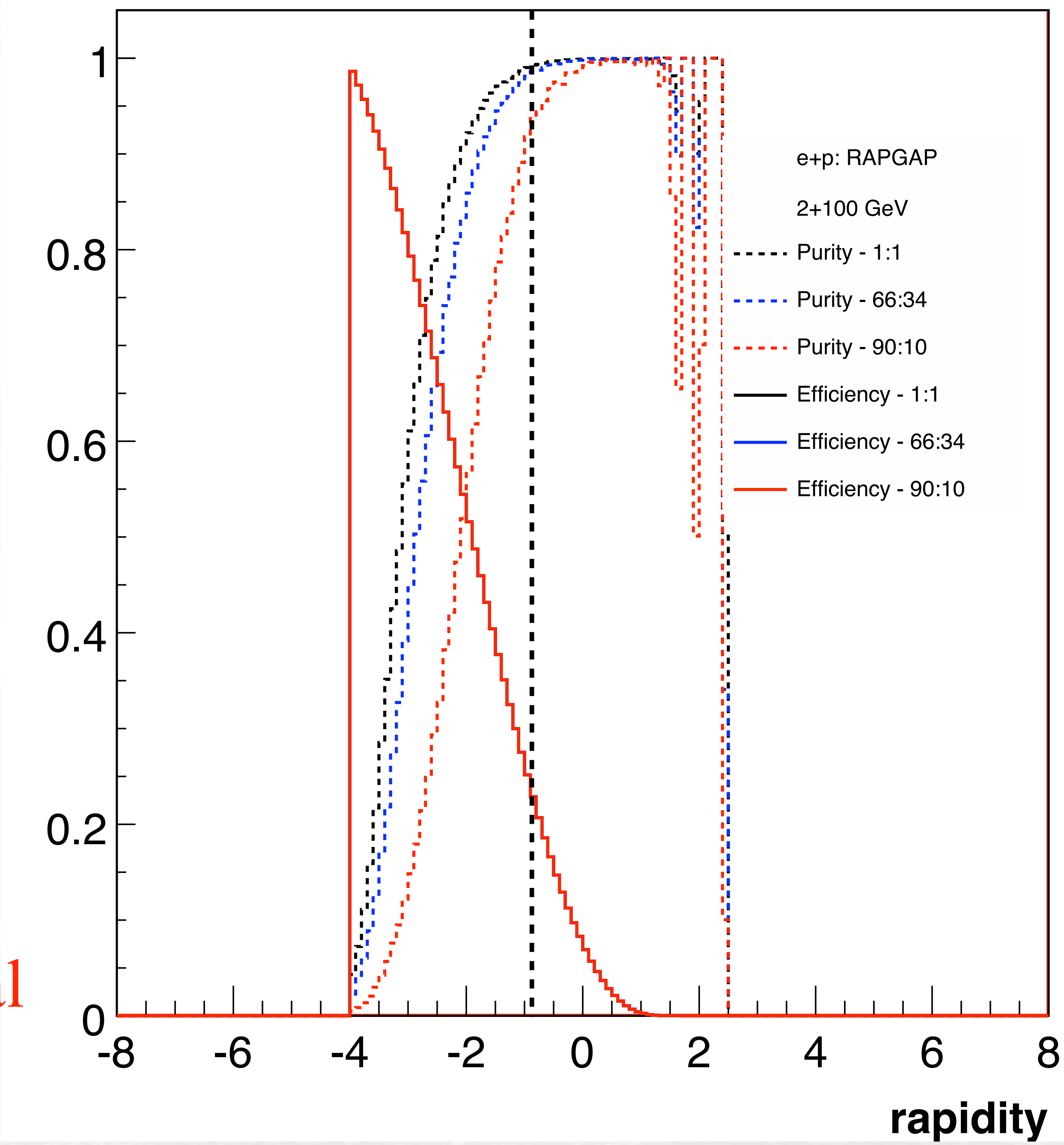
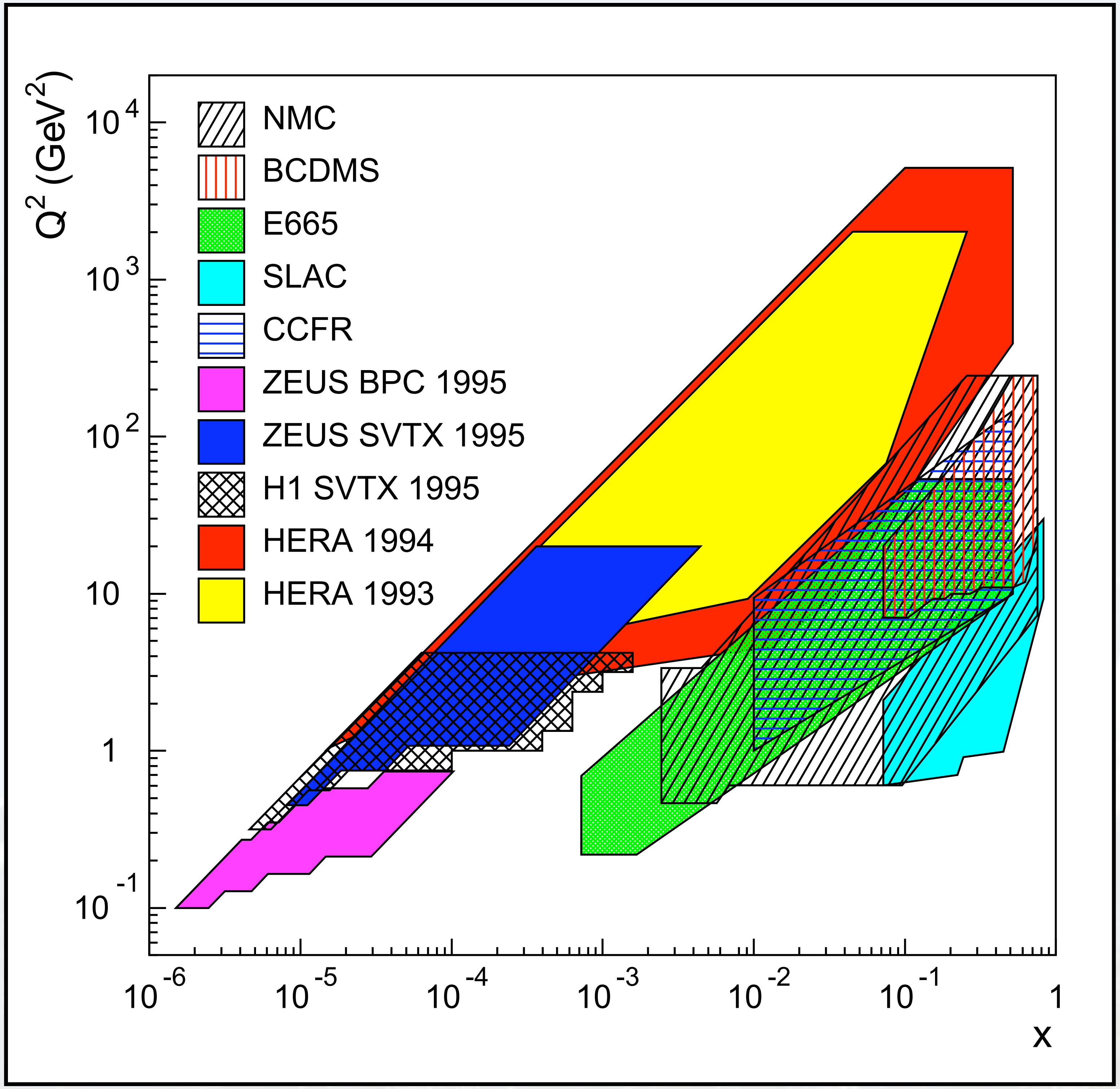


Requirements for an Electron Ion Collider



Well mapped in *e+p*

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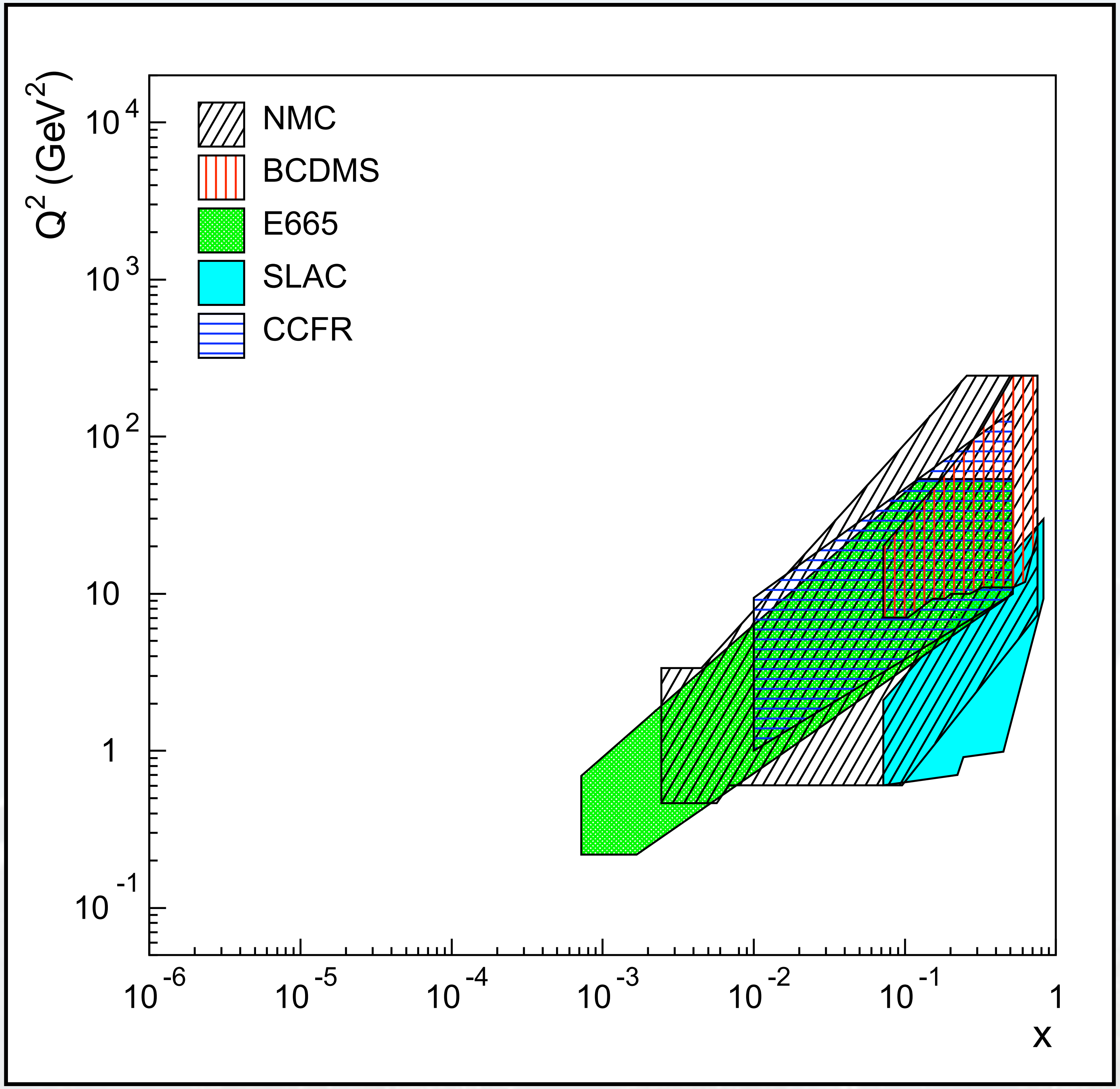
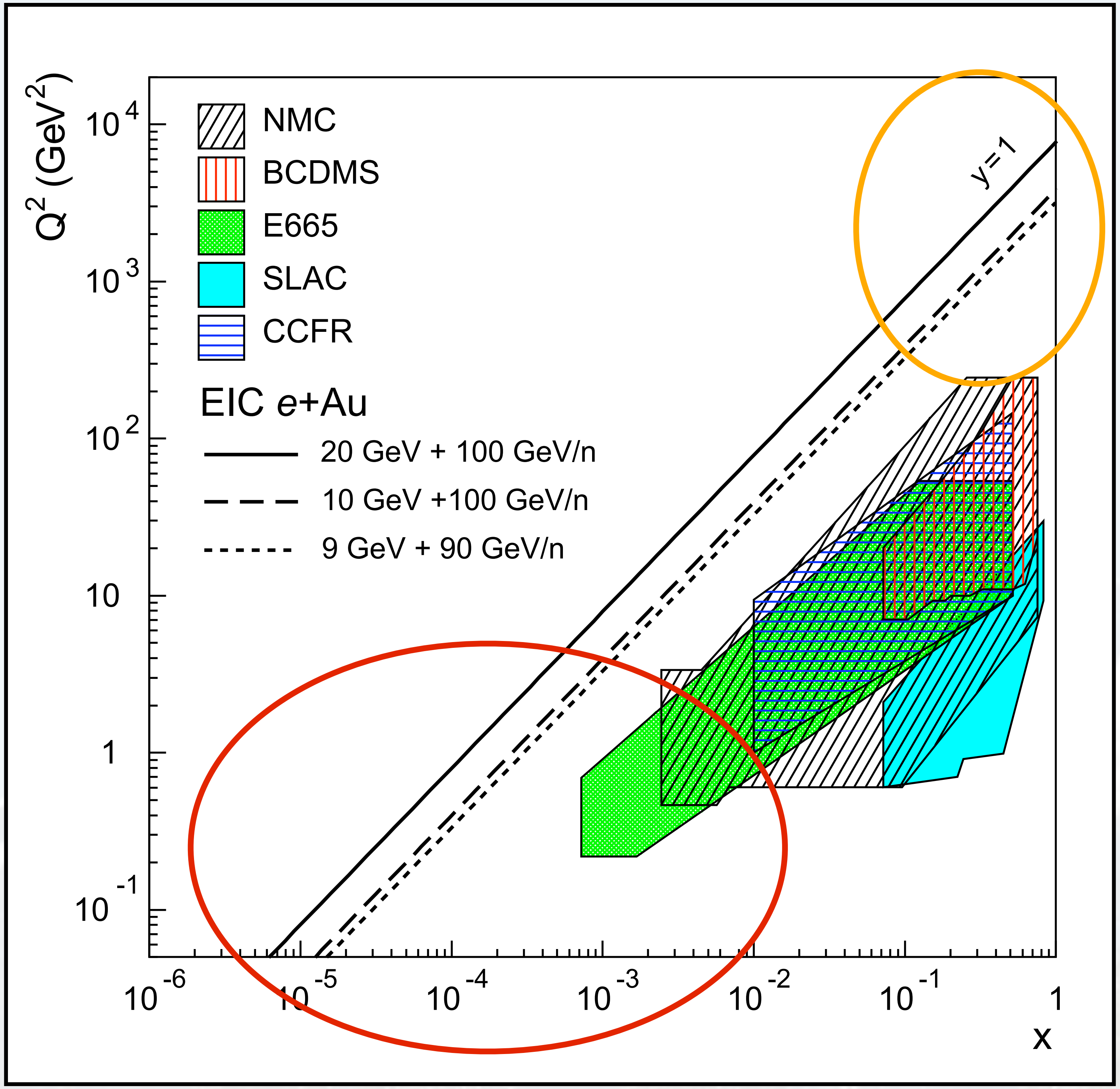


Well mapped in *e+p*

Not so for ℓ+A (ν+A)

- many with small A
- low statistics

Requirements for an Electron Ion Collider



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Electron Ion Collider:

- $\mathcal{L}$(EIC) > 100 × $\mathcal{L}$(HERA)
- Electrons
  - E_e = 3 - 20 GeV
  - polarized
- Hadron Beams
  - E_A = 100 GeV
  - A = p → U
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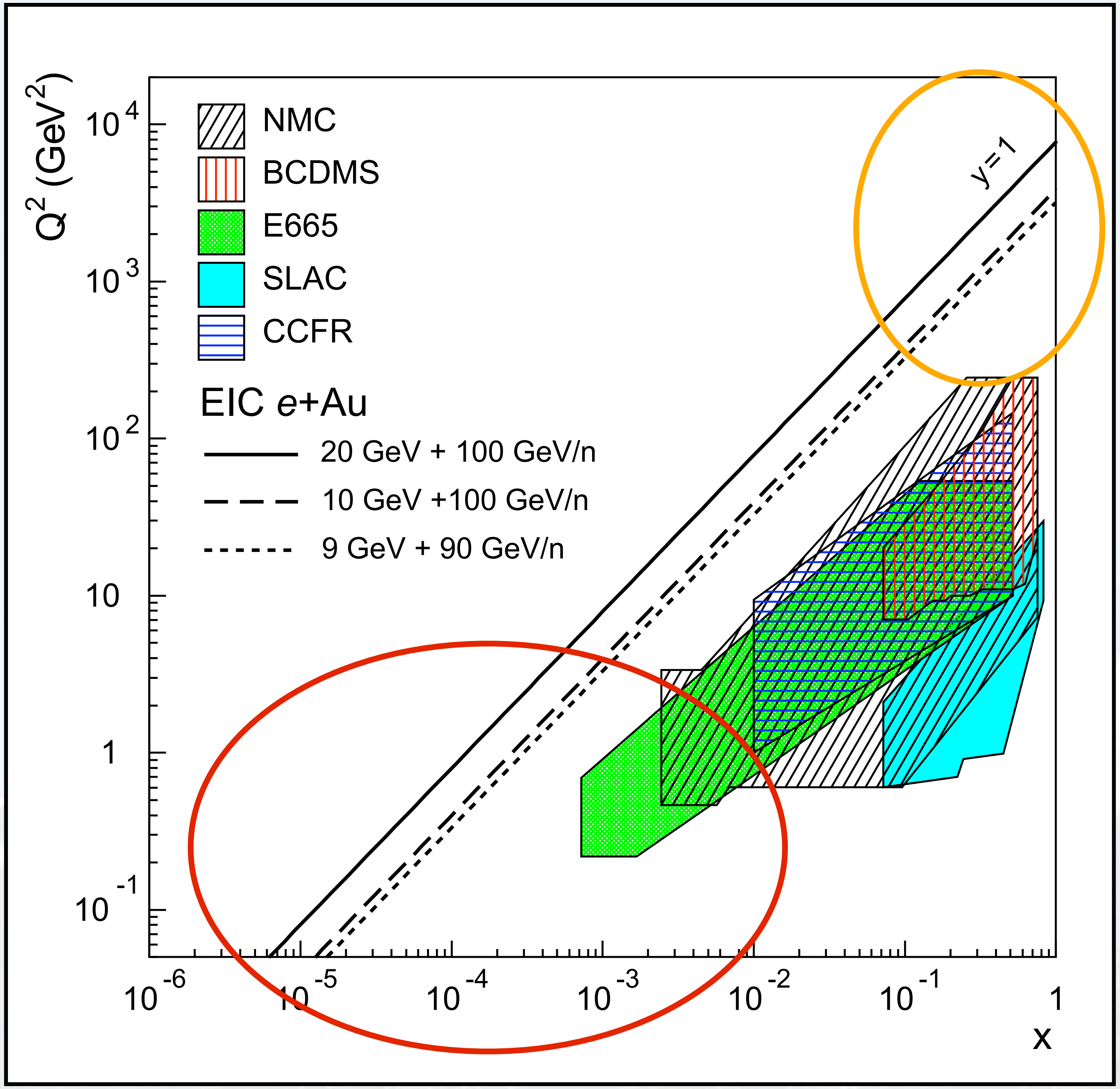

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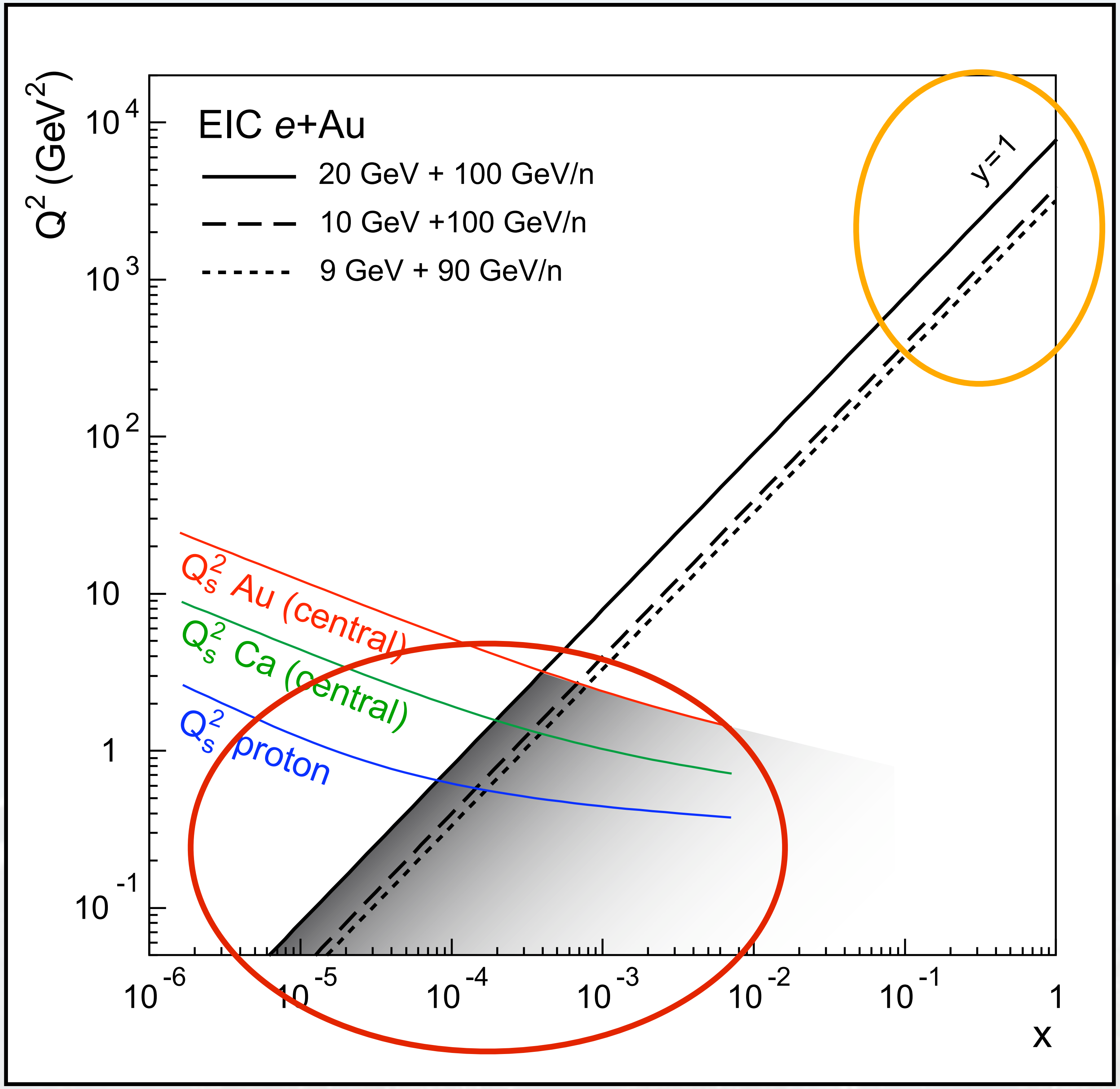

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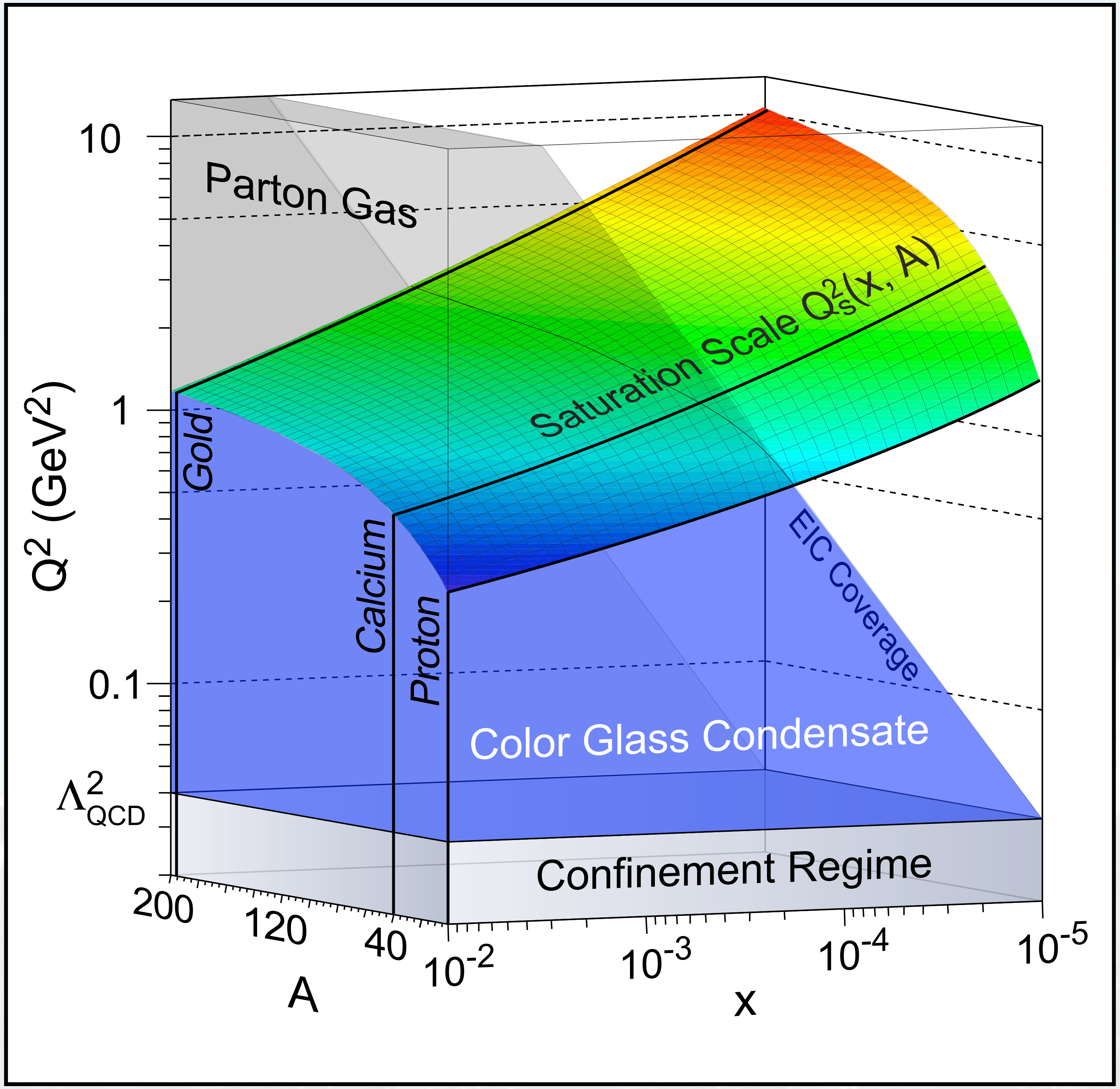

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EIC Collider concepts

*e*RHIC (RHIC/BNL):

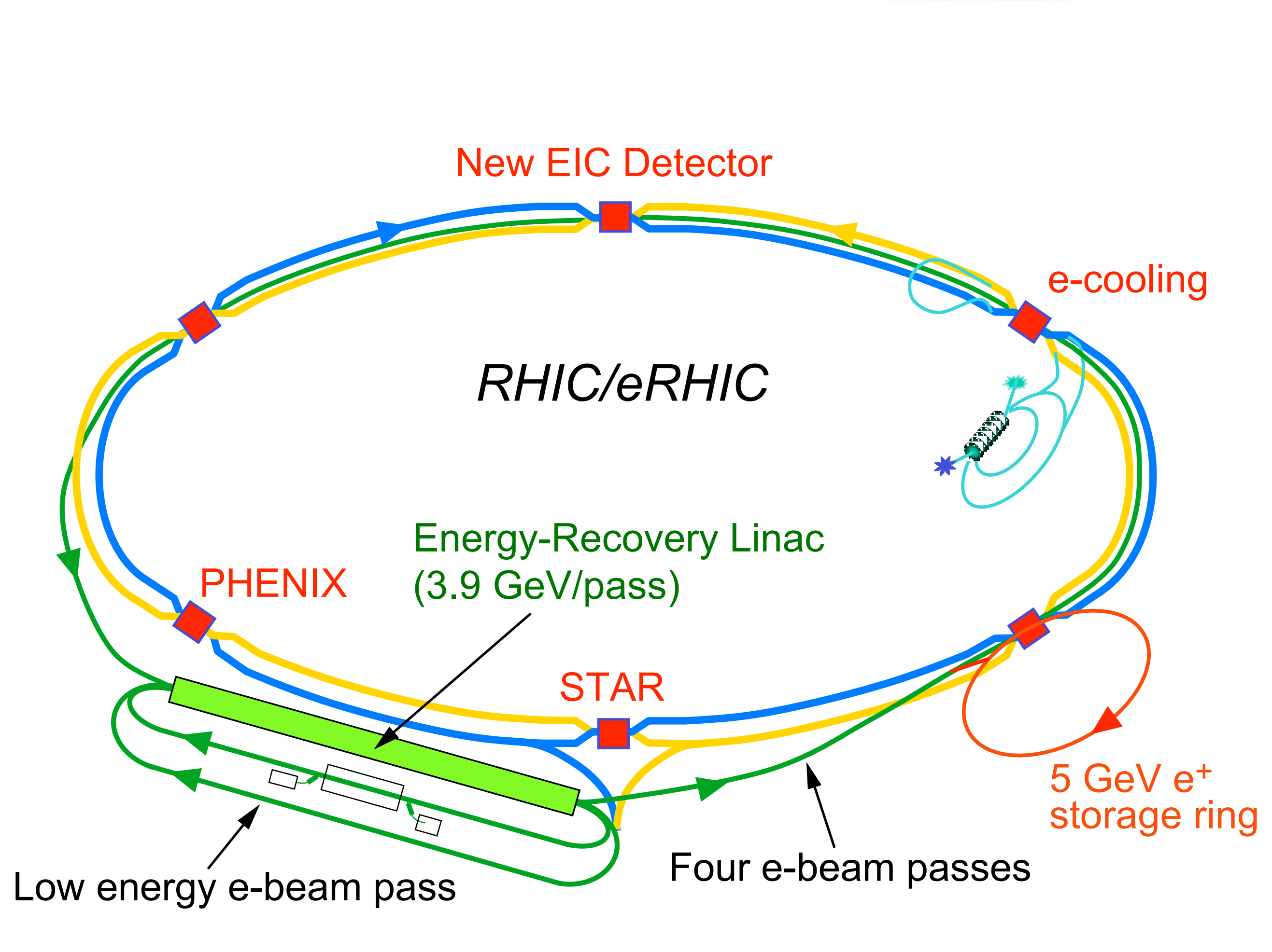
Add Energy Recovery Linac

$E_e = 10\ (20)$ GeV

$E_A = 100$ GeV (up to U)

$\sqrt{s_{eN}} = 63\ (90)$ GeV

L_{eAu} (peak)/n ~ $2.9 \cdot 10^{33}\ cm^{-2}\ s^{-1}$



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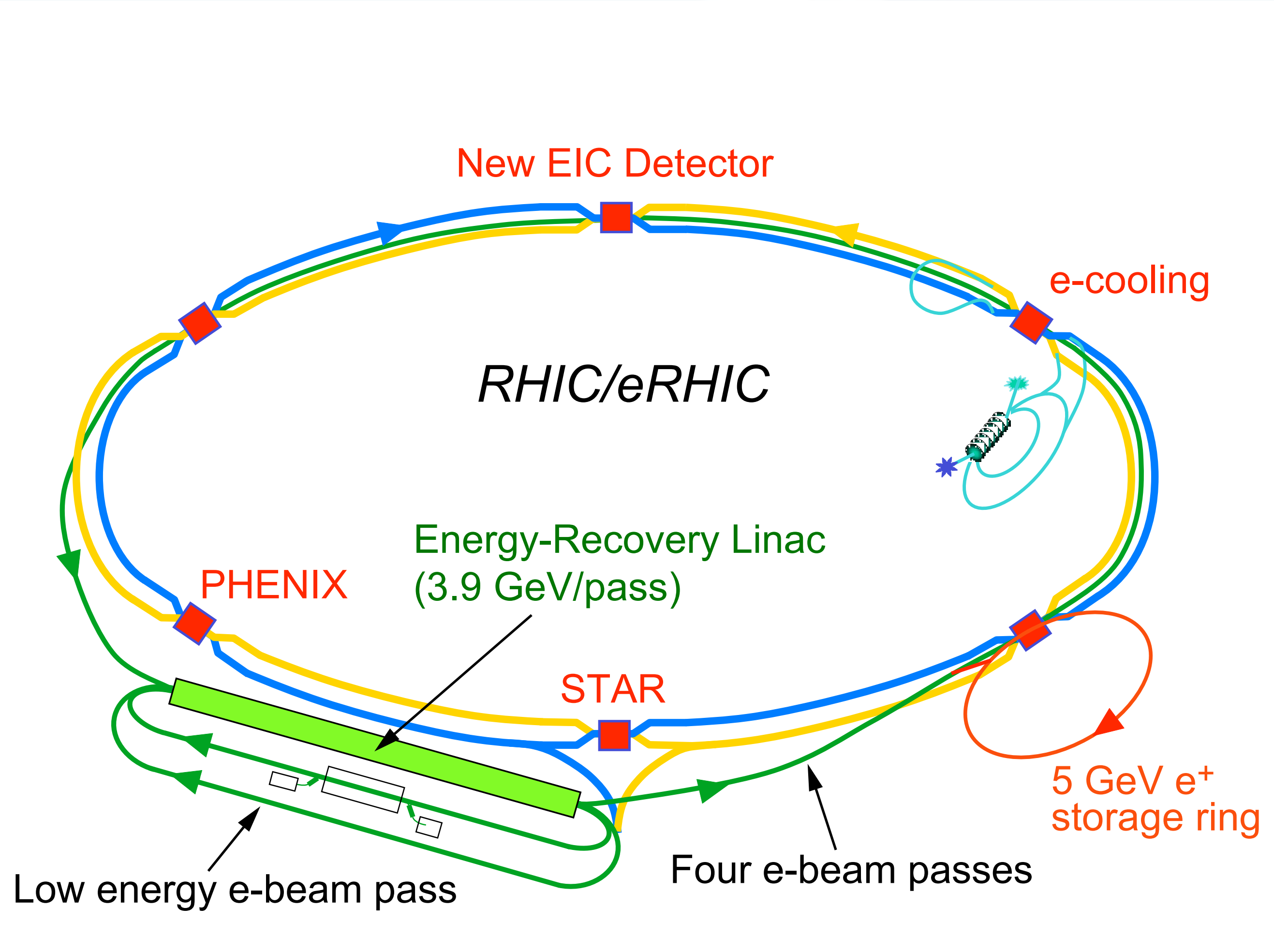


ELIC (CEBAF/JLAB):

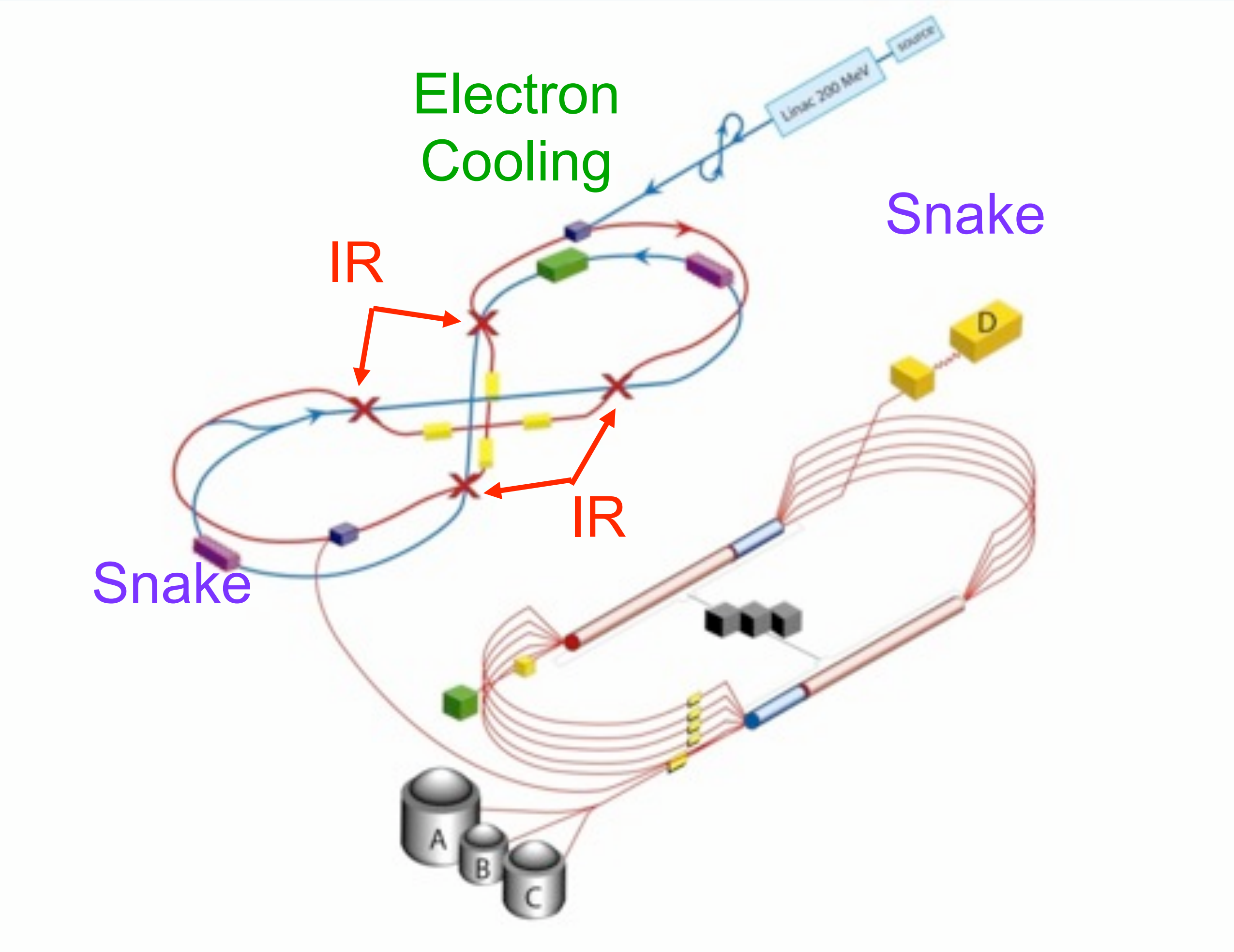
Add hadron machine

$E_e = 9$ GeV

$E_A = 90$ GeV (up to Au)

$\sqrt{s_{eN}} = 57$ GeV

L_{eAu} (peak)/n ~ $1.6 \cdot 10^{35}$ cm^{-2} s^{-1}



Monday, 13 April 2009

Staged Approach to an EIC (MEeIC)

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- Q) Is it possible to build an EIC in stages
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  - ➡ Must be low cost ~$100m

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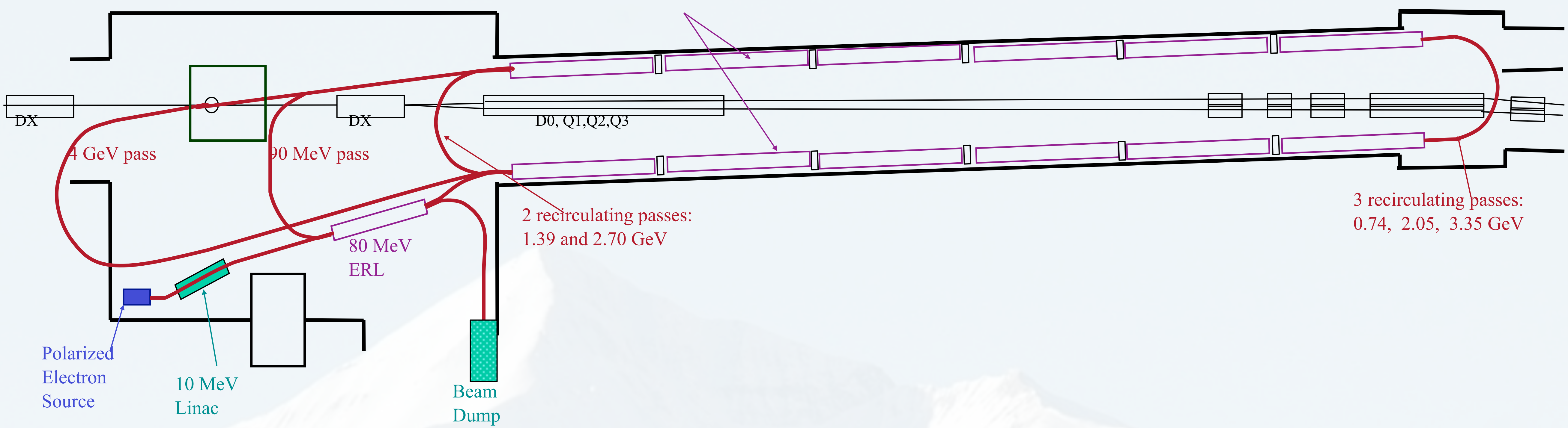

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  - ➡ requires some (small) tunnel reconstruction

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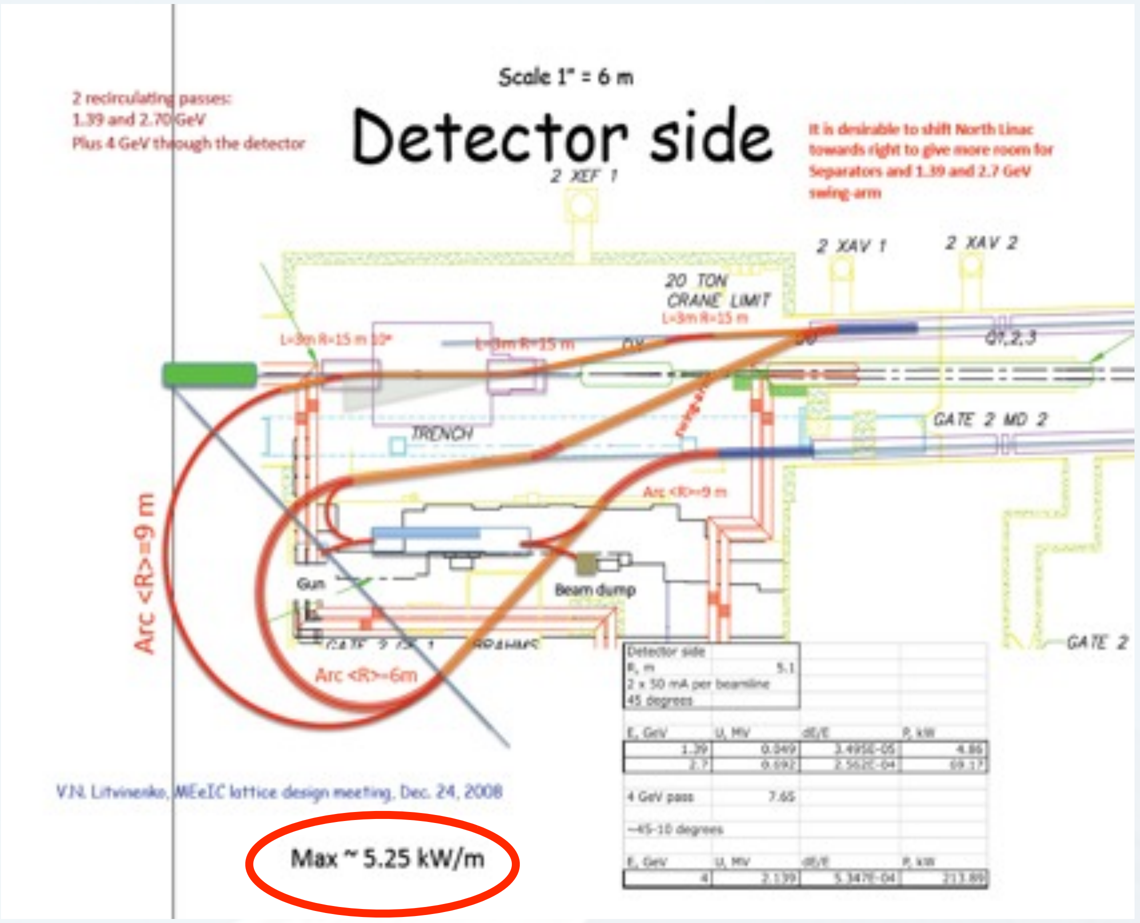

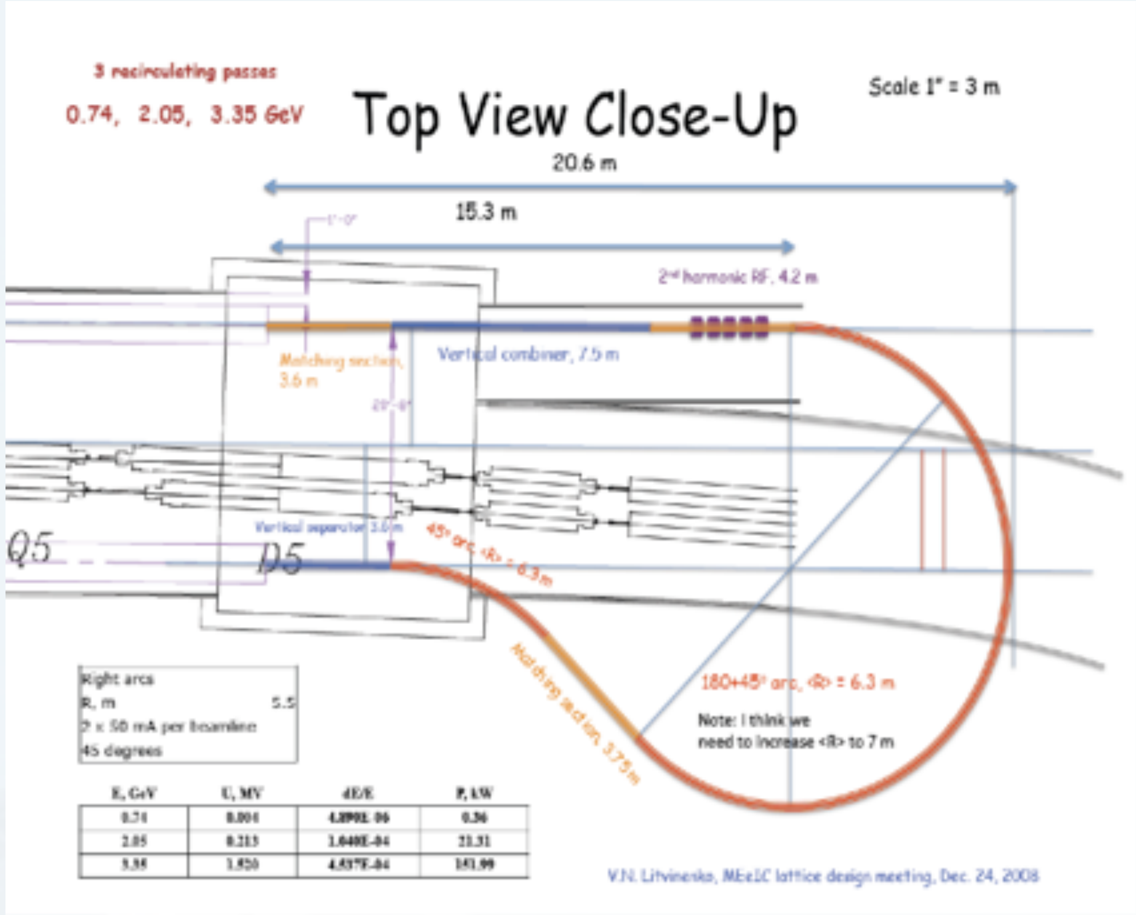

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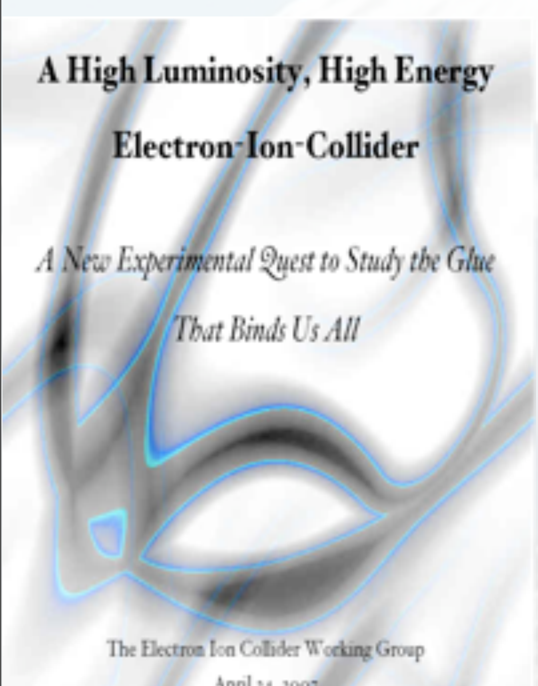
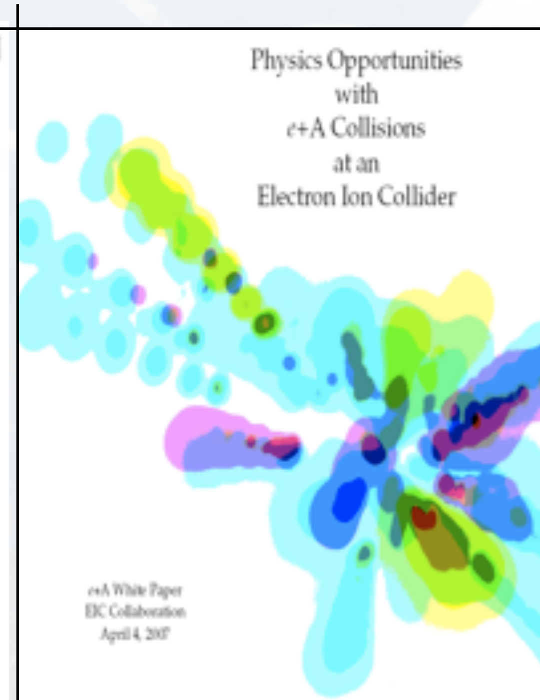
Status of the EIC Project:

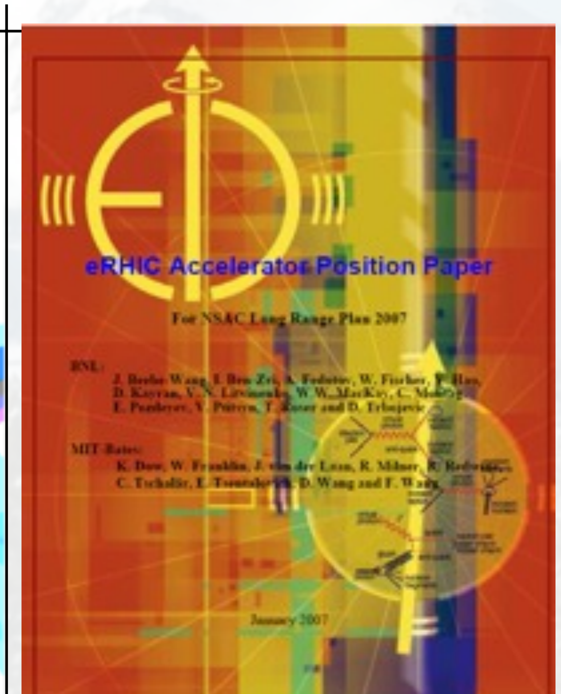
Available at:

- NSAC LRP2007 home page
- Rutgers Town Meeting page
- **http://web.mit.edu/eicc**

- 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
- ELIC ZDR Draft







What is happening now

- EIC "Collaboration" formed in 2007
  - ➡ Bi-Annual collaboration meetings
    - Last meeting, 11th - 13th December, 2008, LBNL
    - Next meeting, May 2009, GSI
- INT
  - ➡ Week long workshop - October 2009
  - ➡ 3-month programme just approved - Autumn 2010
- e+A working group
  - ➡ Convenors: T. Ullrich, D. Morrison, R. Venugopalan, V. Guzey
  - ➡ bi-weekly meetings at BNL + phone bridge
    - http://www.eic.bnl.gov/ for details (and previous seminars)

What is happening now - eA notes

In the process of composing eA "EIC notes" linking theory, experiment and simulations on distinct topics

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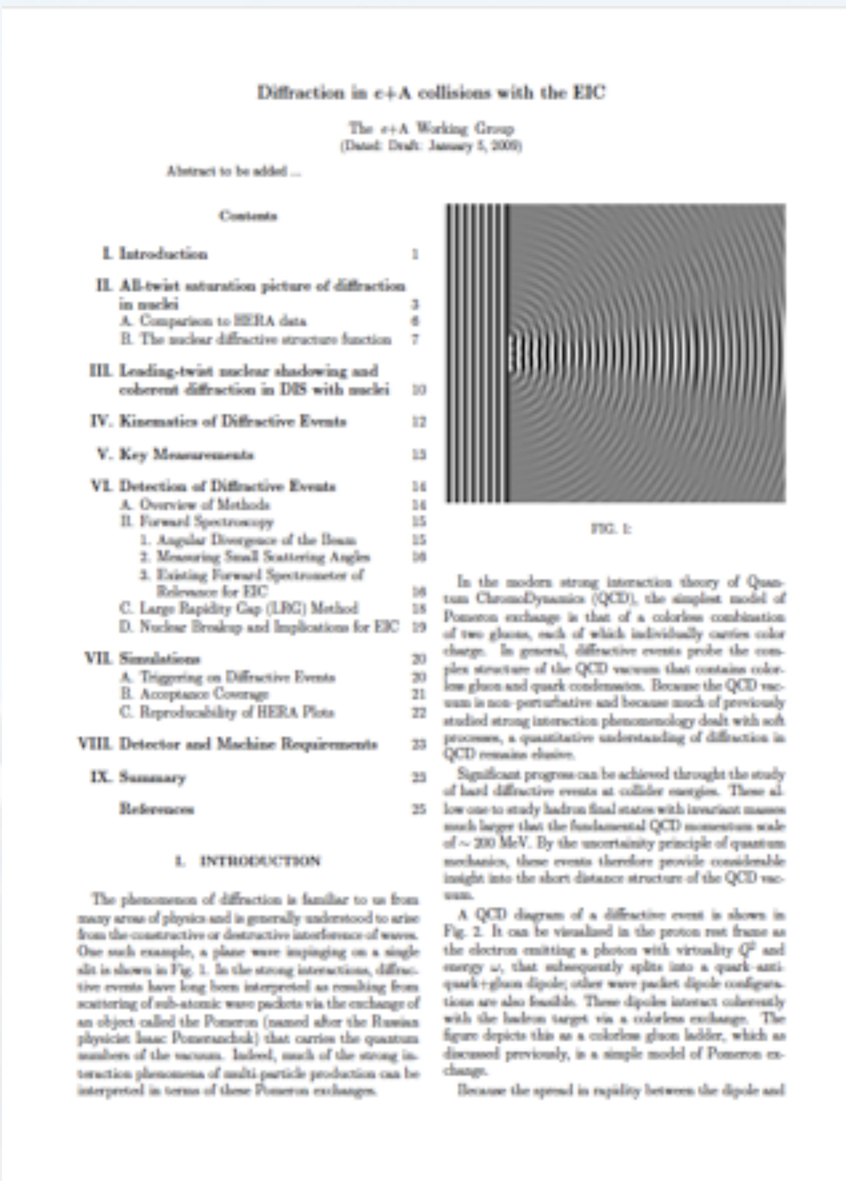
Diffraction



Diffraction in e+A collisions with the EIC

The e+A Working Group
(Dated: Draft: January 5, 2009)

Abstract to be added ...

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FIG. 1:

In the modern strong interaction theory of Quantum ChromoDynamics (QCD), the simplest model of Pomeron exchange is that of a colorless combination of two gluons, each of which individually carries color charge. In general, diffractive events probe the complex structure of the QCD vacuum that contains colorless gluon and quark condensates. Because the QCD vacuum is non-perturbative and because much of previously studied strong interaction phenomenology dealt with soft processes, a quantitative understanding of diffraction in QCD remains elusive.

Significant progress can be achieved throught the study of hard diffractive events at collider energies. These allow one to study hadron final states with invariant masses much larger that the fundamental QCD momentum scale of ~ 200 MeV. By the uncertainity principle of quantum mechanics, these events therefore provide considerable insight into the short distance structure of the QCD vacuum.

A QCD diagram of a diffractive event is shown in Fig. 2. It can be visualized in the proton rest frame as the electron emitting a photon with virtuality Q^2 and energy ω, that subsequently splits into a quark-anti-quark+gluon dipole; other wave packet dipole configurations are also feasible. These dipoles interact coherently with the hadron target via a colorless exchange. The figure depicts this as a colorless gluon ladder, which as discussed previously, is a simple model of Pomeron exchange.

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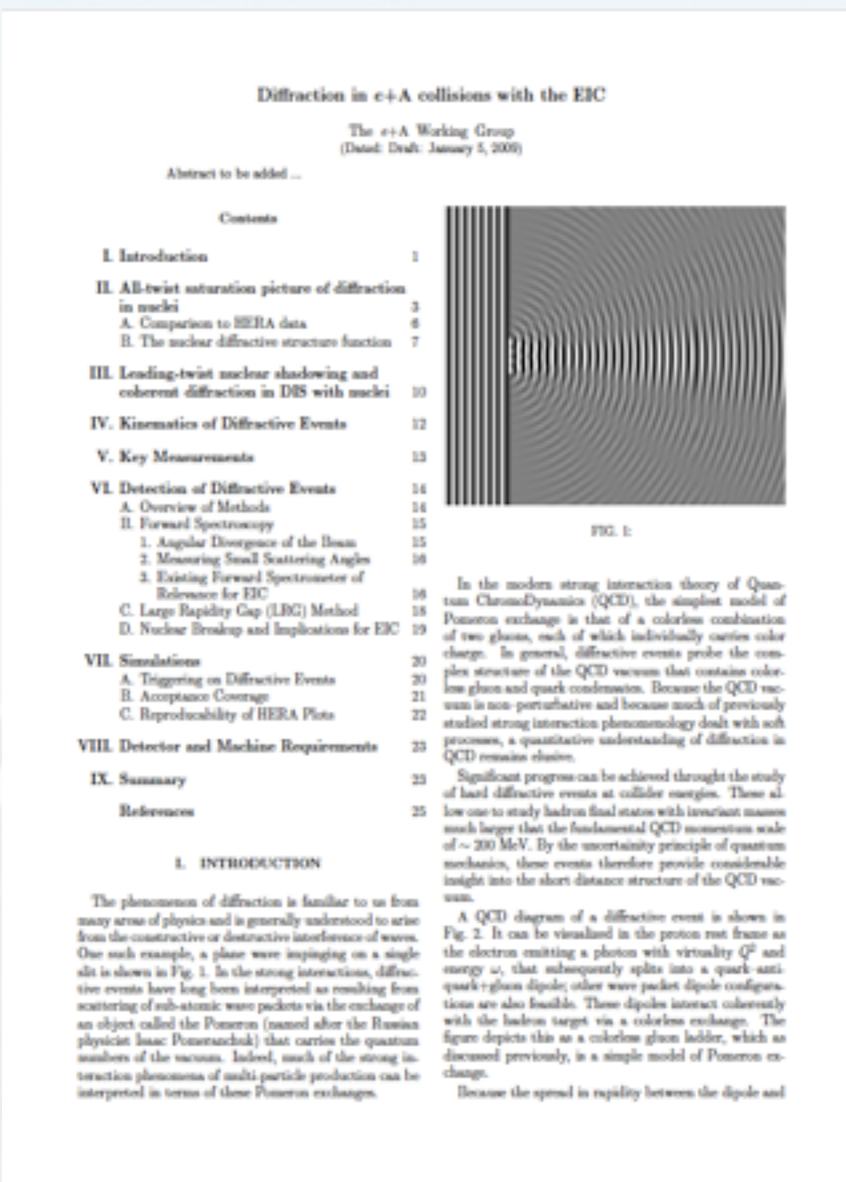

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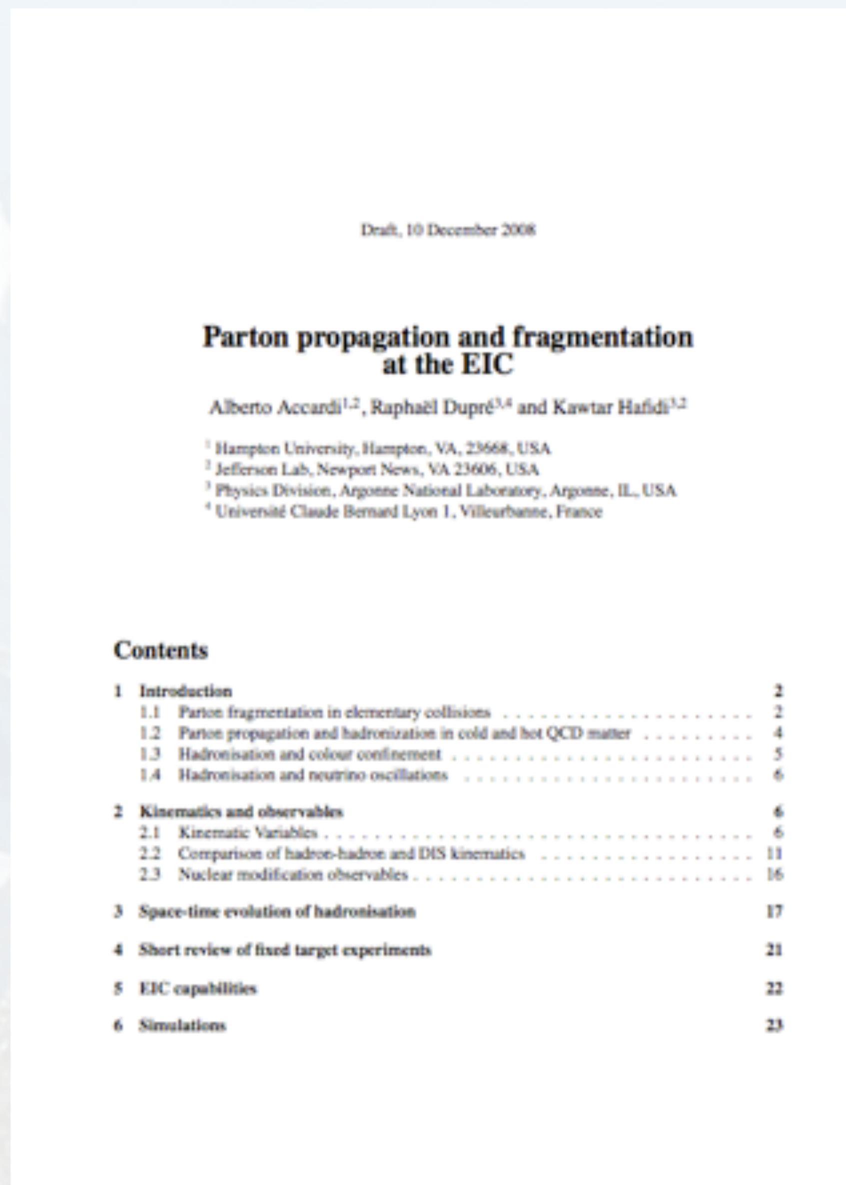

Draft, 10 December 2008

Parton propagation and fragmentation at the EIC

Alberto Accardi[1,2], Raphaël Dupré[3,4] and Kawtar Hafidi[3,2]

[1] Hampton University, Hampton, VA, 23668, USA
[2] Jefferson Lab, Newport News, VA 23606, USA
[3] Physics Division, Argonne National Laboratory, Argonne, IL, USA
[4] Université Claude Bernard Lyon 1, Villeurbanne, France

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1.4 Hadronisation and neutrino oscillations 6

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The e+A Working Group
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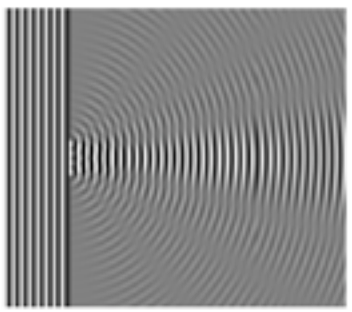

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Jets

Jet measurements in future e+A colliders

The EIC e+A working group
November 2008

Abstract

In this note, we describe the measurements that one can perform at the future EIC colliders based on jets in the final state. We put emphasis on observables that are unique to the heavy-ion case and provide valuable information on the structure of the nucleus.

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2 Jet reconstruction in DIS 2
3 Gluon distribution from 2+1 jets 2
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3.2 Extraction of the gluon distribution 6
3.3 Simulations and expected statistical errors 8
3.4 Systematic errors 8

1

Summary

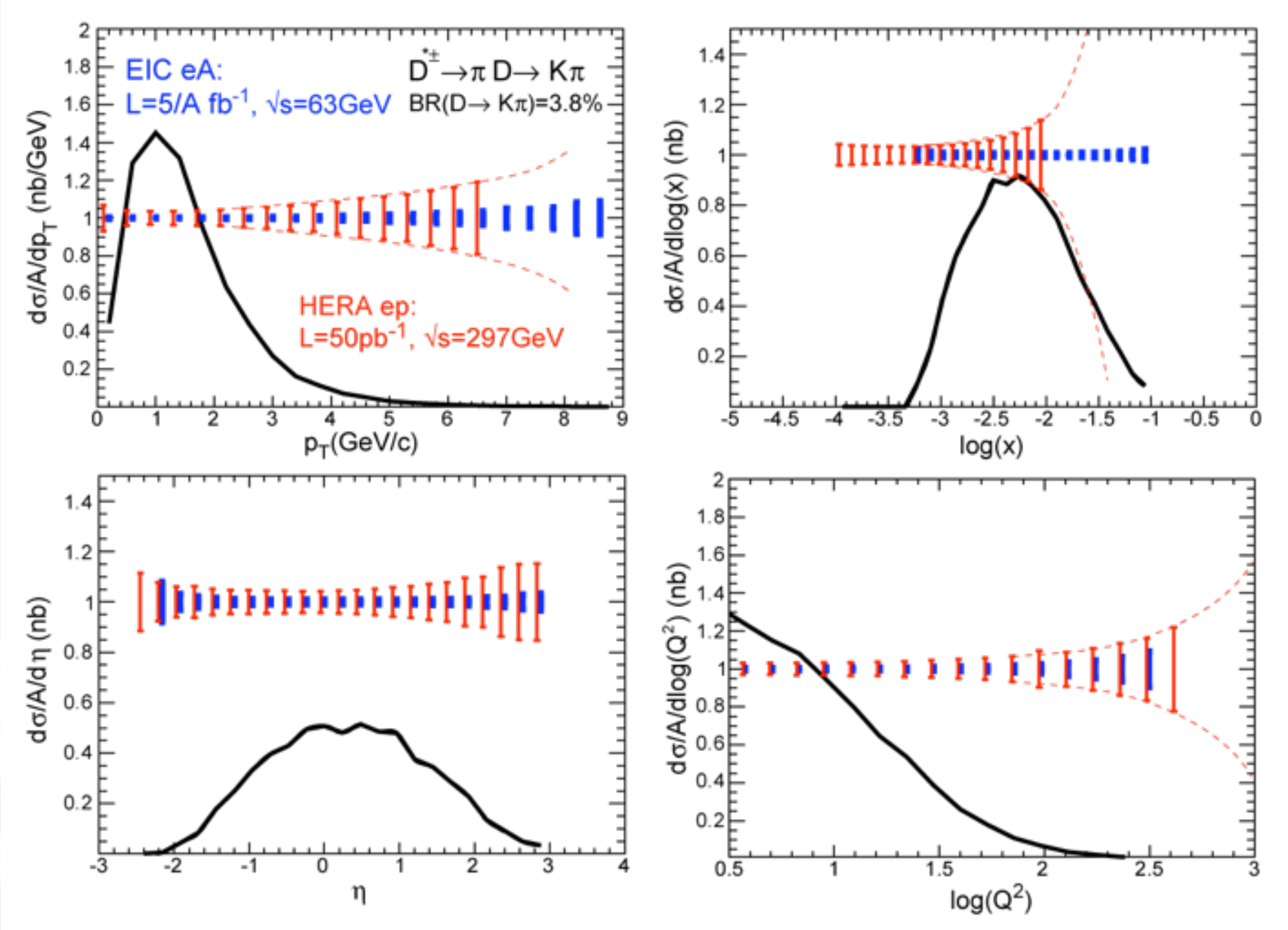
An EIC presents a unique opportunity in high energy nuclear physics and precision QCD physics

e+A	Polarized e+p
◆ Study the Physics of Strong Colour Fields • Establish (or not) the existence of the saturation regime • Explore non-linear QCD • Measure momentum & space-time of glue ◆ Study the nature of colour singlet excitations (Pomerons) ◆ Test and study the limits of universality (eA vs. pA)	◆ Precisely image the sea-quarks and gluons to determine the spin, flavour and spatial structure of the nucleon

- Embraced by NSAC in Long Range PLan
  - Recommendation of $30M for R&D over next 5 years
- EIC Long Term Goal - start construction in next decade
- Possibility of Staged Approach
  - Cheap (no civil construction costs)
  - Early time-scale for realisation (operation by ~2016)
  - Cons - lower energy and luminosity than full design

BACKUP SLIDES

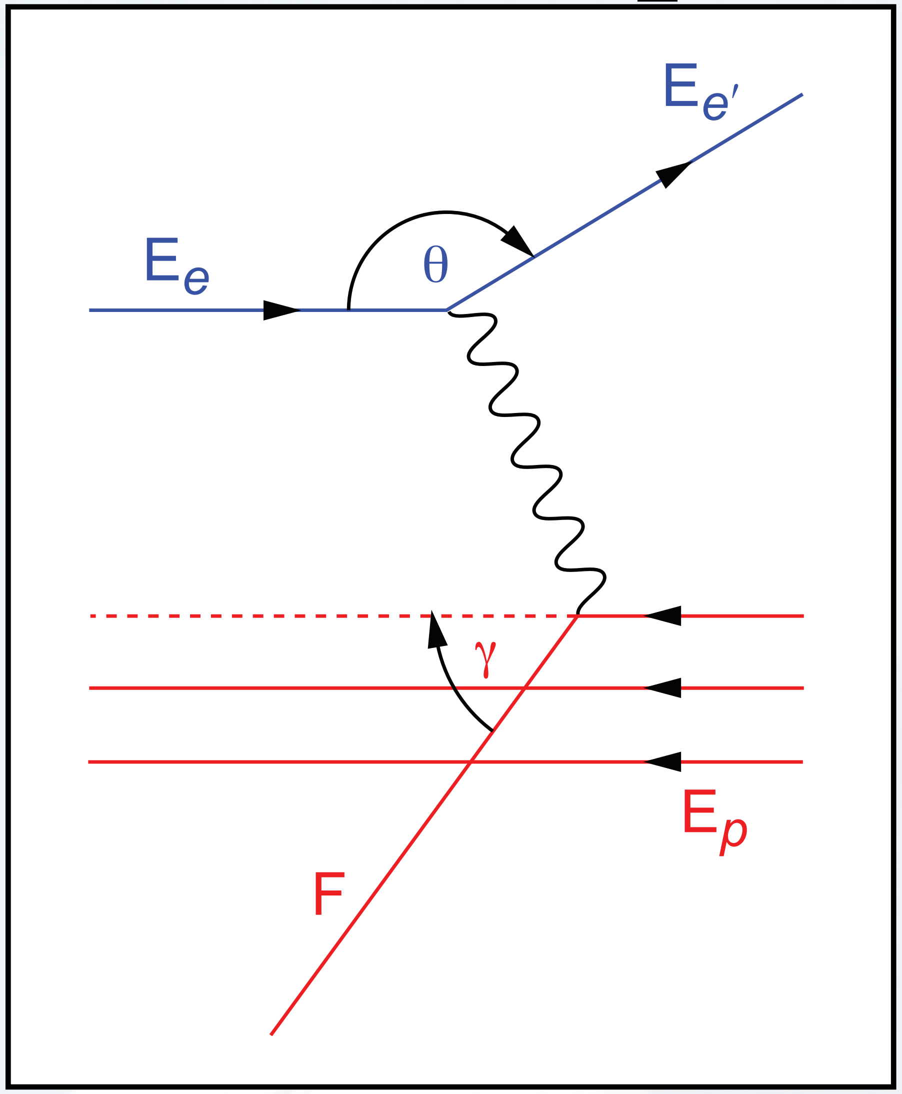
Charm at an EIC

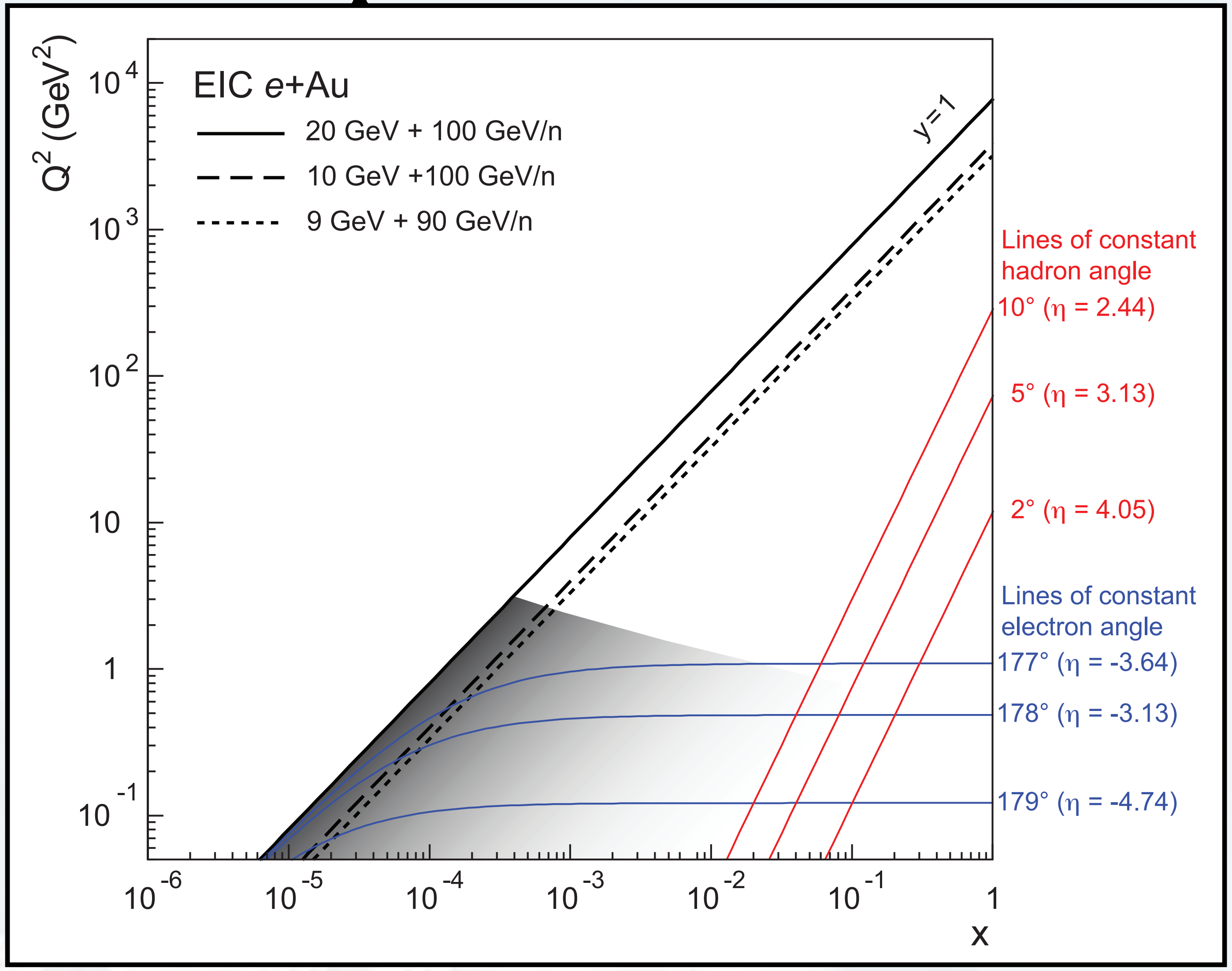


Based on HVQDIS model, J. Smith

- EIC: allows multi-differential measurements of heavy flavour
- covers and extends energy range of SLAC, EMC, HERA, and JLAB allowing for the study of wide range of formation lengths

Experimental Aspects





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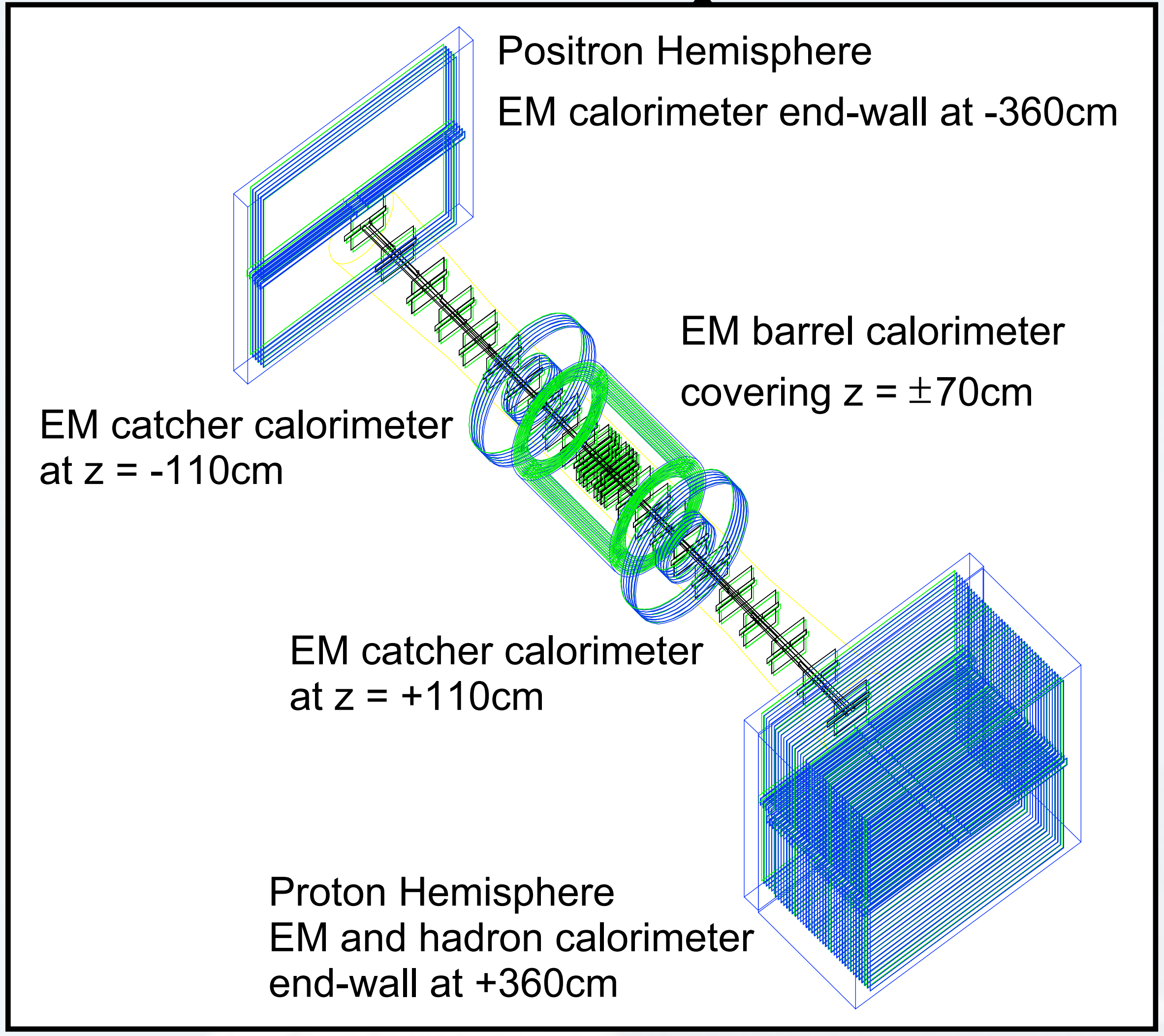
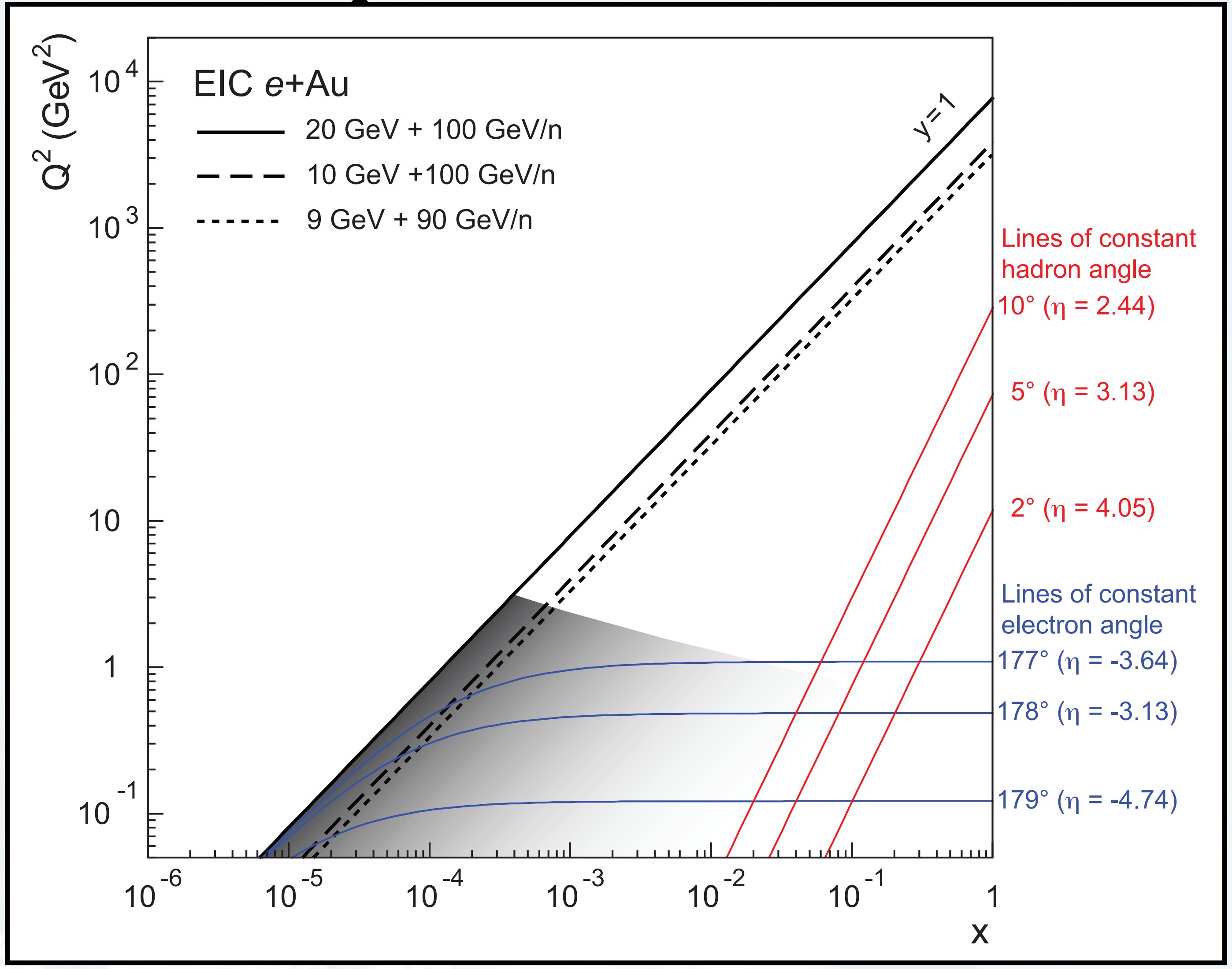


I. Abt, A. Caldwell, X. Liu, J. Sutiak, hep-ex 0407053

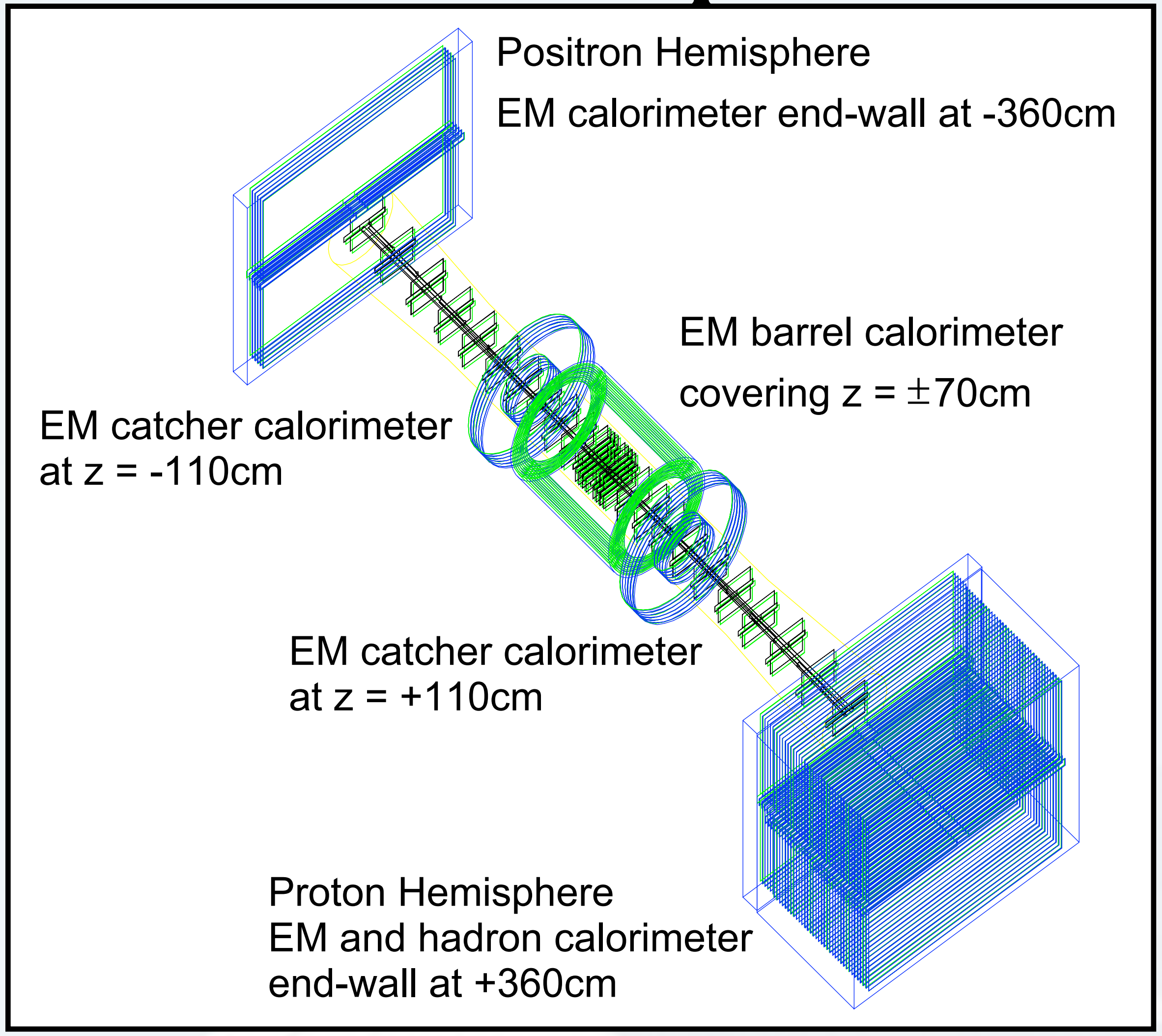


Concepts:

(a) Focus on the rear/forward acceptance and thus on low-*x* / high-*x* physics

- compact system of tracking and central electromagnetic calorimetry inside a magnetic dipole field and calorimetric end-walls outside

Experimental Aspects



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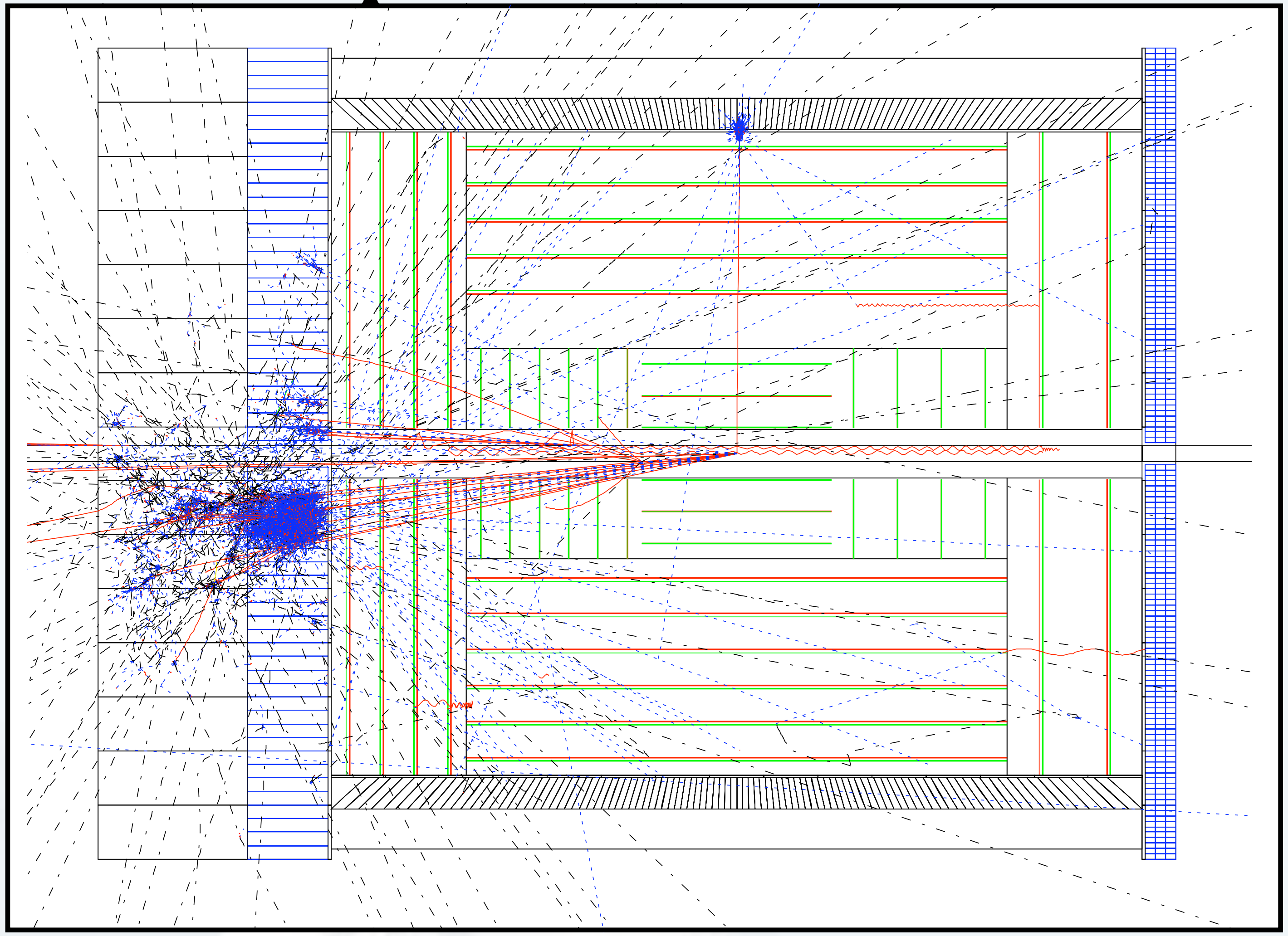


J. Pasukonis, B.Surrow, physics/0608290

Concepts:

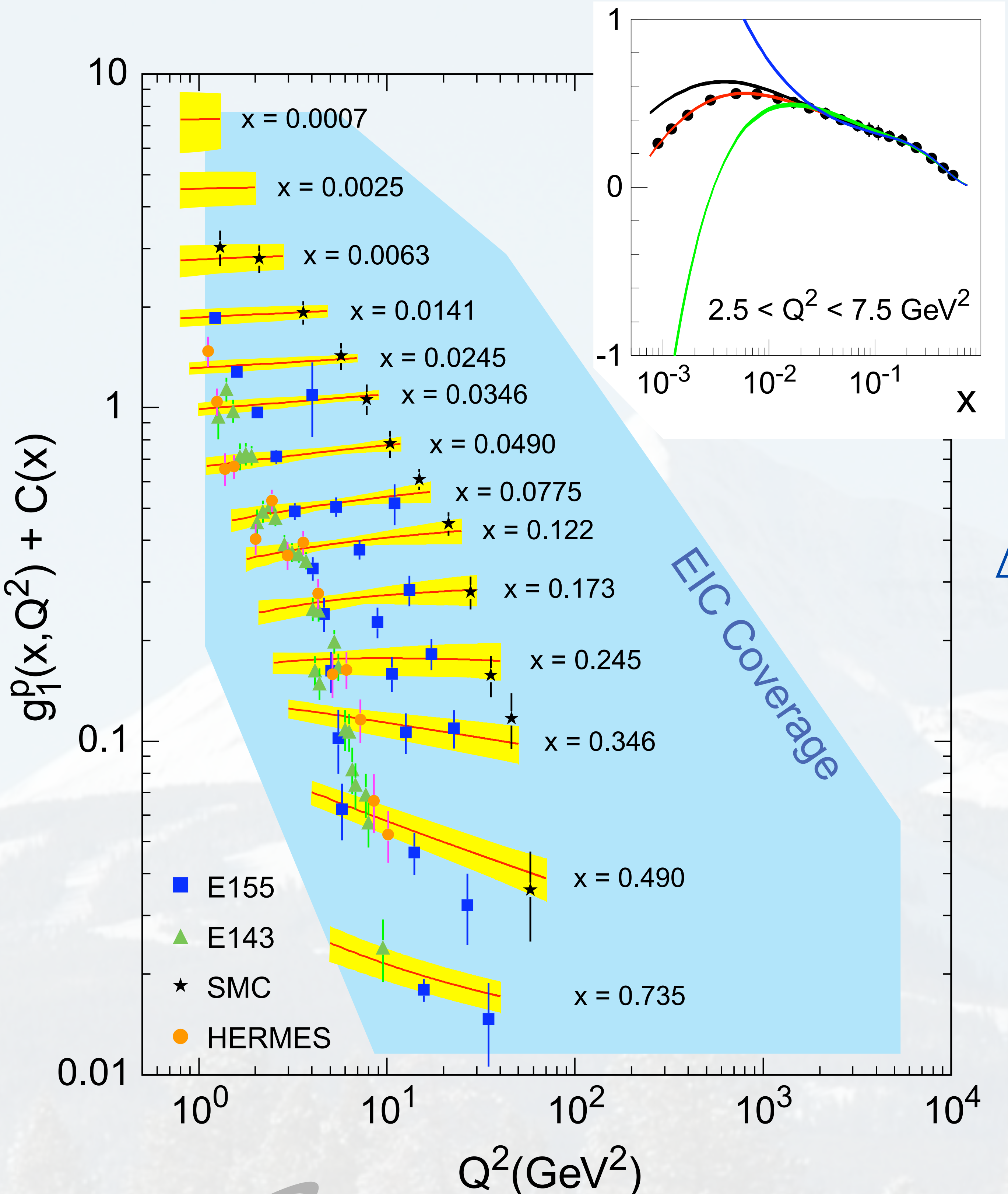
(a) Focus on the rear/forward acceptance and thus on low-x / high-x physics

- compact system of tracking and central electromagnetic calorimetry inside a magnetic dipole field and calorimetric end-walls outside

(b) Focus on a wide acceptance detector system similar to HERA experiments

- allow for the maximum possible Q^2 range.

EIC as an $e+\vec{p}$ machine - The Quest for ΔG



Spin Structure of the Proton

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

quark contribution $\Delta\Sigma \approx 0.3$

gluon contribution $\Delta G \approx 1 \pm 1$?

ΔG: a "quotable" property of the proton (like mass, charge)

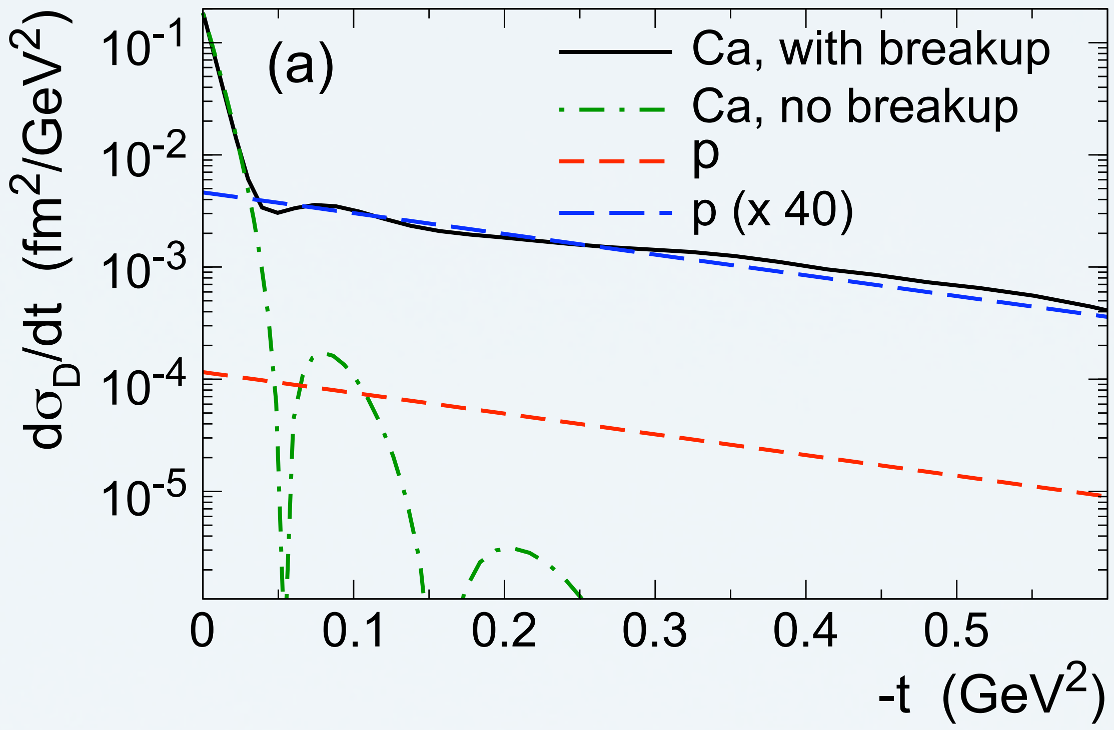
Measure through scaling violation:

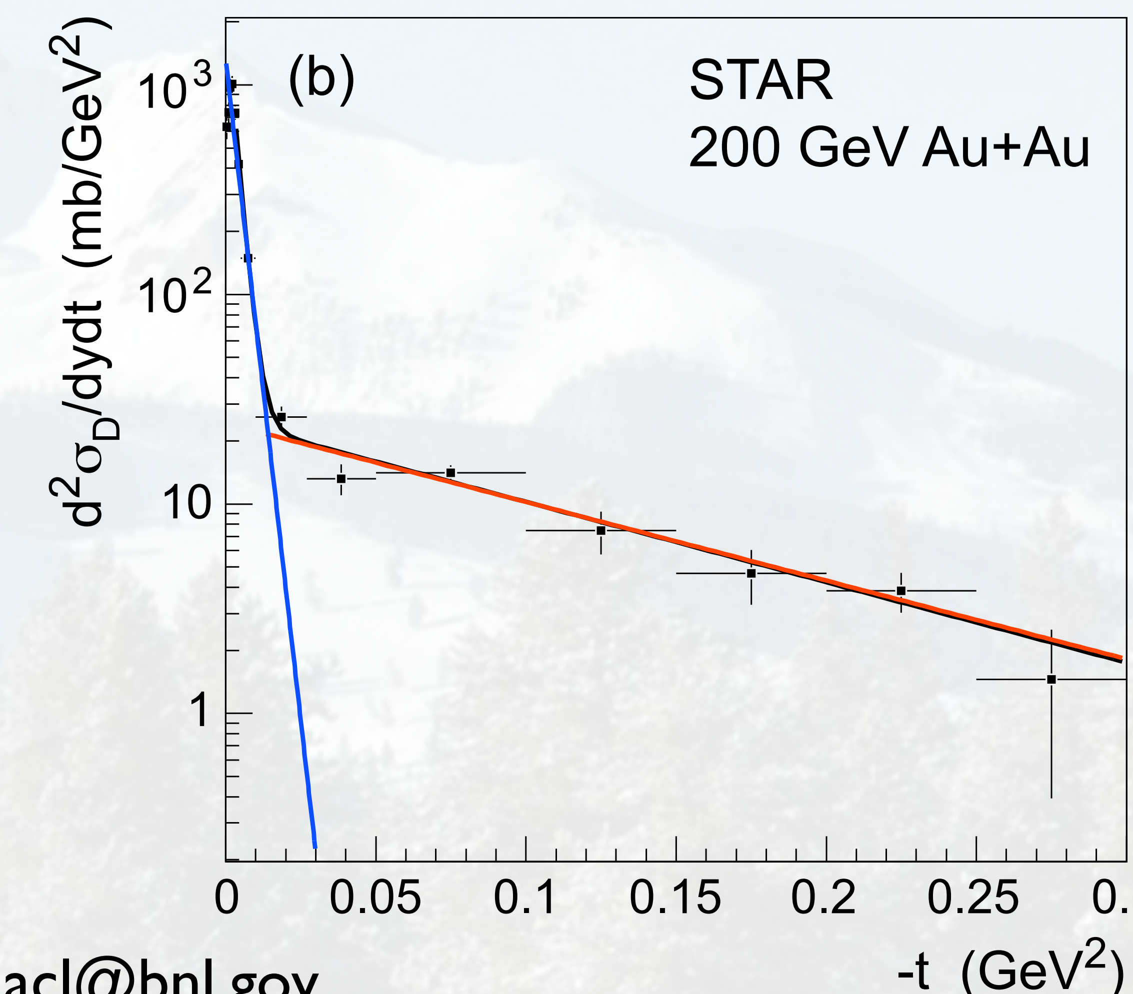
$$\frac{dg_1}{d\log(Q^2)} \propto -\Delta g(x,Q^2)$$

$$\Delta G = \int_{x=0}^{x=1} \Delta g(x,Q^2)dx$$

Superb sensitivity to ΔG at small x!

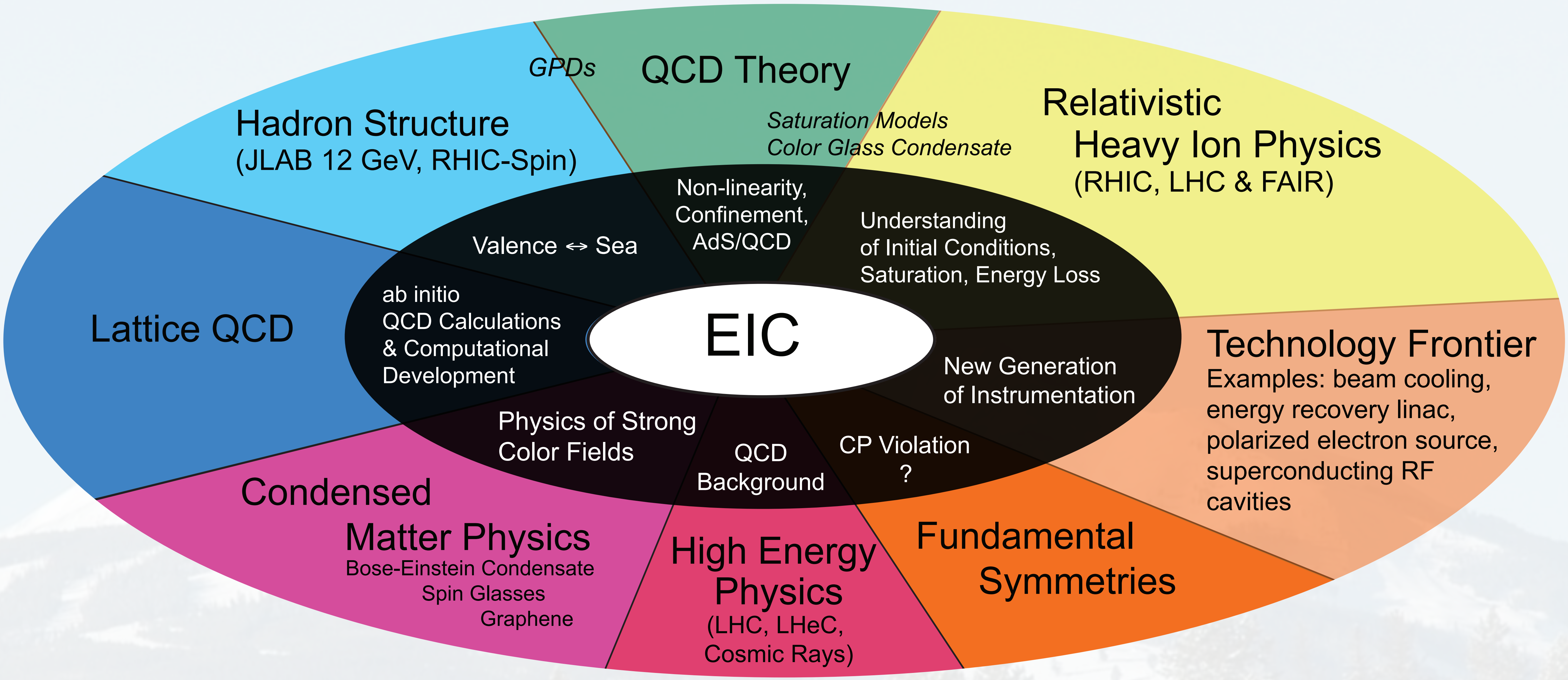
t dependence on Diffractive Physics





t dependence on Diffractive Physics

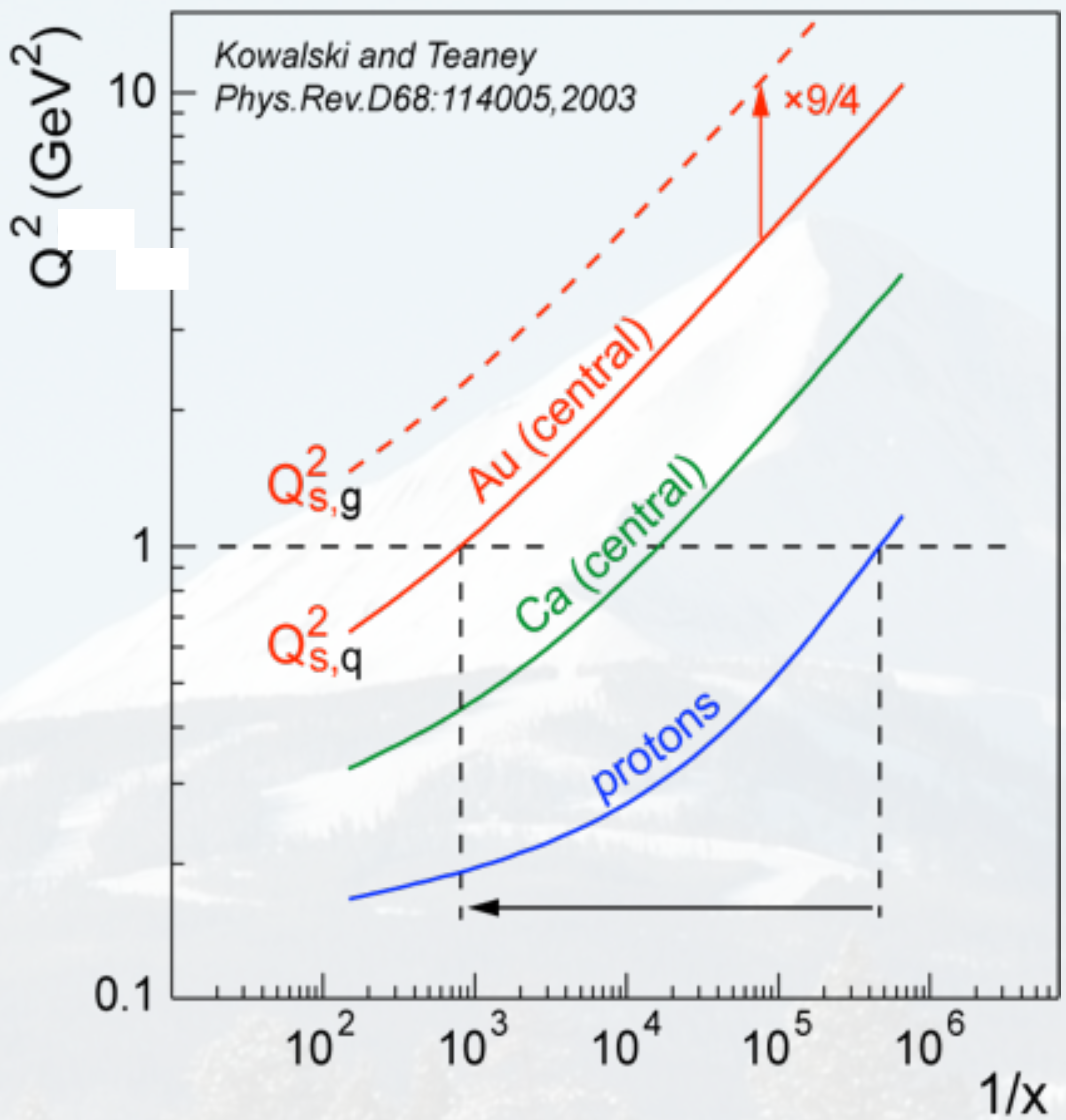
Connection to other fields

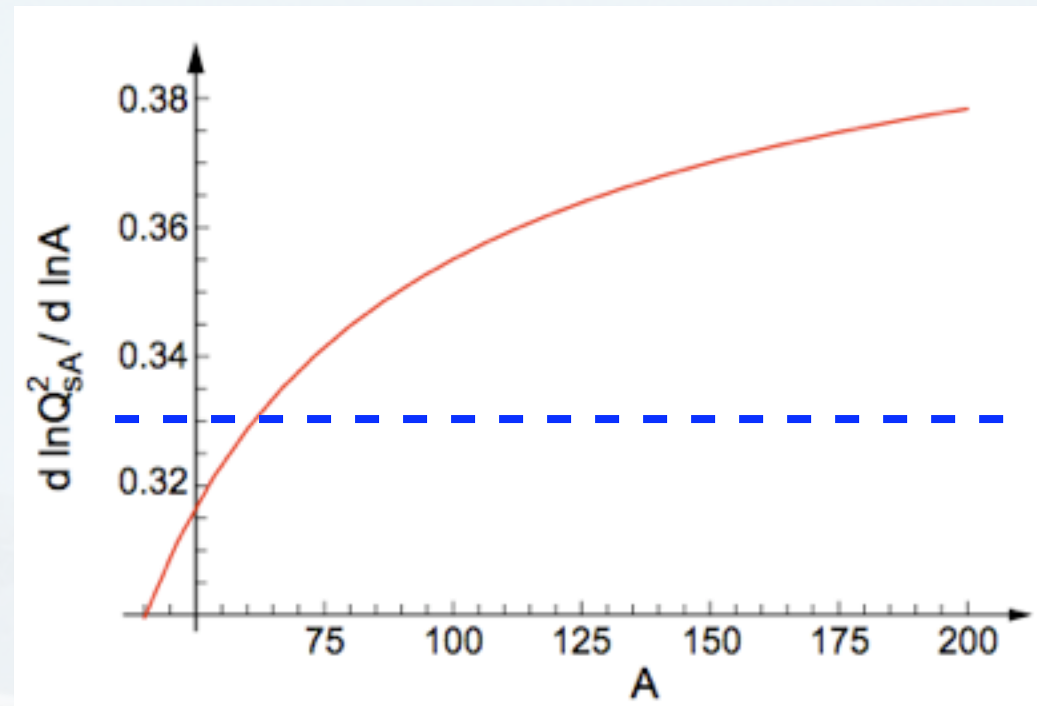


The Nuclear "Oomph" factor

More sophisticated analyses ⇒ confirm (exceed) pocket formula

(e.g. Kowalski, Lappi and Venugopalan, PRL 100, 022303 (2008); Armesto et al., PRL 94:022002; Kowalski, Teaney, PRD 68:114005)





Models need to use realistic b-dependence for nuclei and nucleons

⇒ b = 0 for proton ≠ b_{med}

The Nuclear "Oomph" factor

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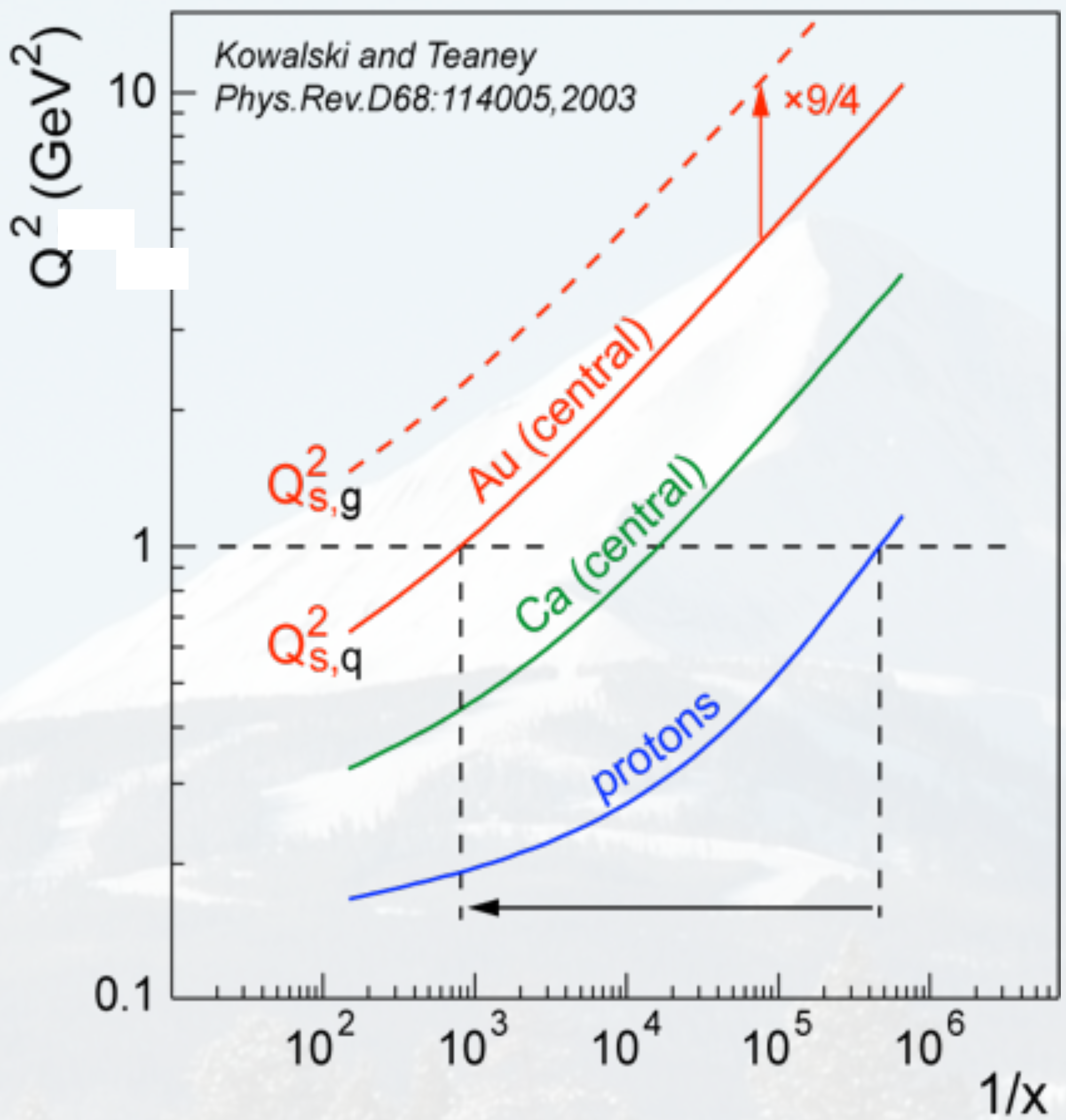
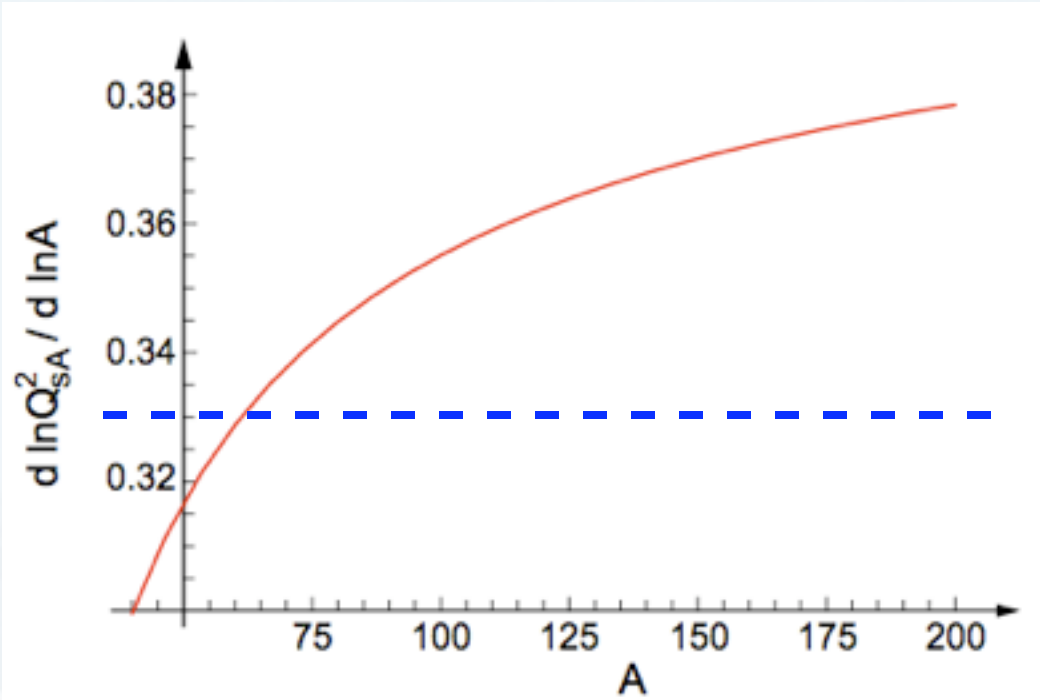
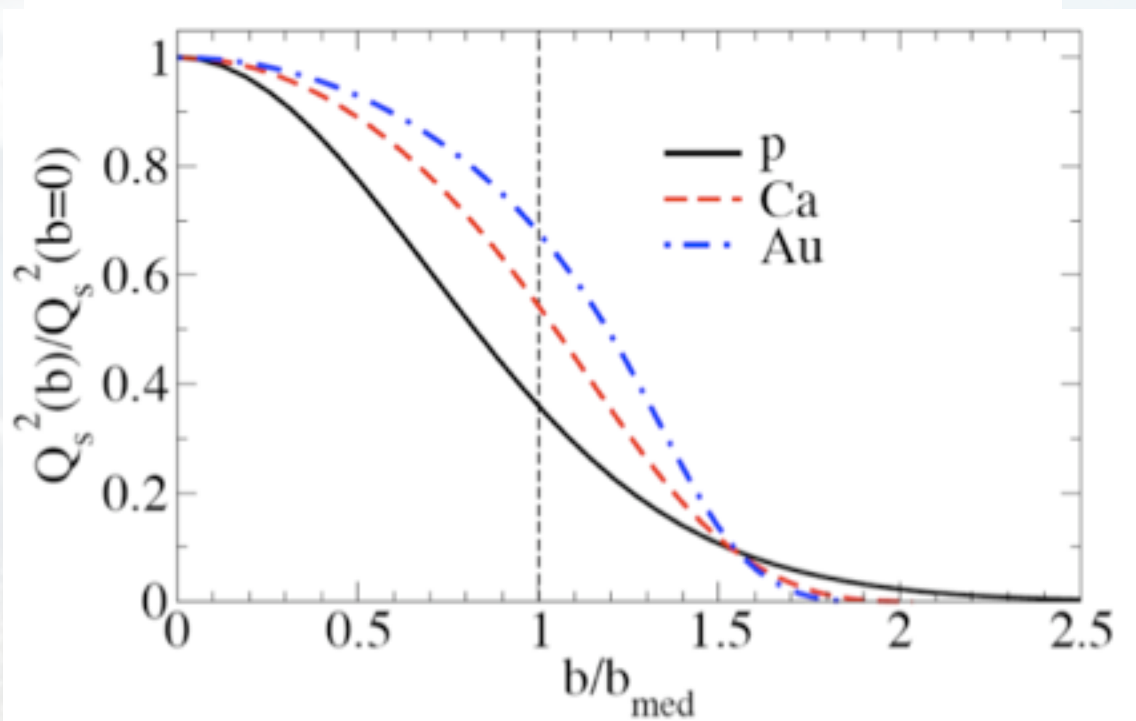
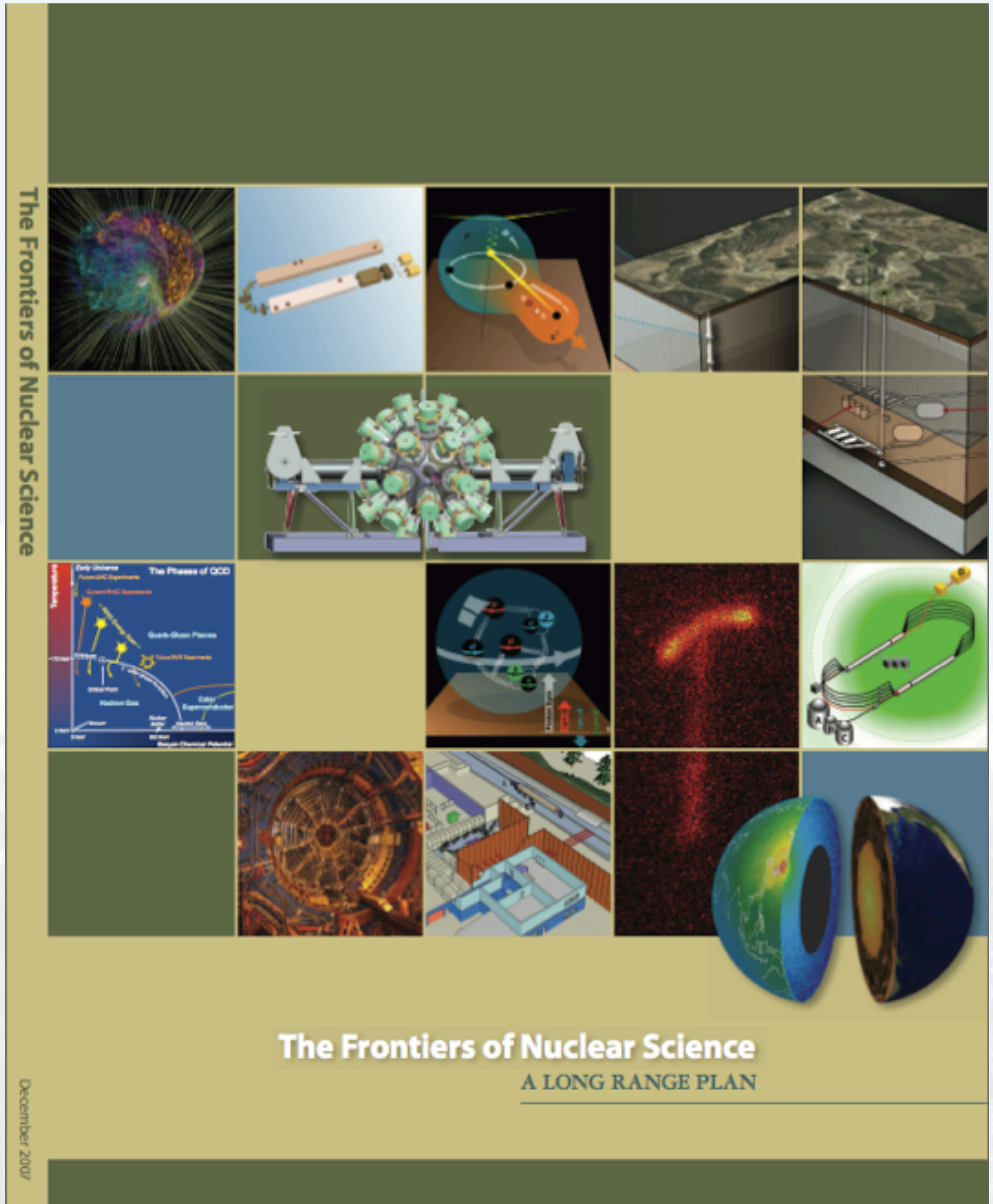






2007 NSAC Long Range Plan



2007 NSAC Long Range Plan

FURTHER INTO THE FUTURE

Gluons and their interactions are critical to QCD. But their properties and dynamics in matter remain largely unexplored. Recent theoretical breakthroughs and experimental results suggest that both nucleons and nuclei, when viewed at high energies, appear as dense systems of gluons, creating fields whose intensity may be the strongest allowed in nature. The emerging science of this universal gluonic matter drives the development of a next-generation facility, the high-luminosity Electron-Ion Collider (EIC). The EIC's ability to collide high-energy electron beams with high-energy ion beams will provide access to those regions in the nucleon and nuclei where their structure is dominated by gluons. Moreover, polarized beams in the EIC will give unprecedented access to the spatial and spin structure of gluons in the proton.

An EIC with polarized beams has been embraced by the U.S. nuclear science community as embodying the vision for reaching the next QCD frontier. EIC would provide unique capabilities for the study of QCD well beyond those available at existing facilities worldwide and complementary to those planned for the next generation of accelerators in Europe and Asia. While significant progress has been made in developing concepts for an EIC, many open questions remain. Realization of an EIC will require advancements in accelerator science and technology, and detector research and development. The nuclear science community has recognized the importance of this future facility and makes the following recommendation.

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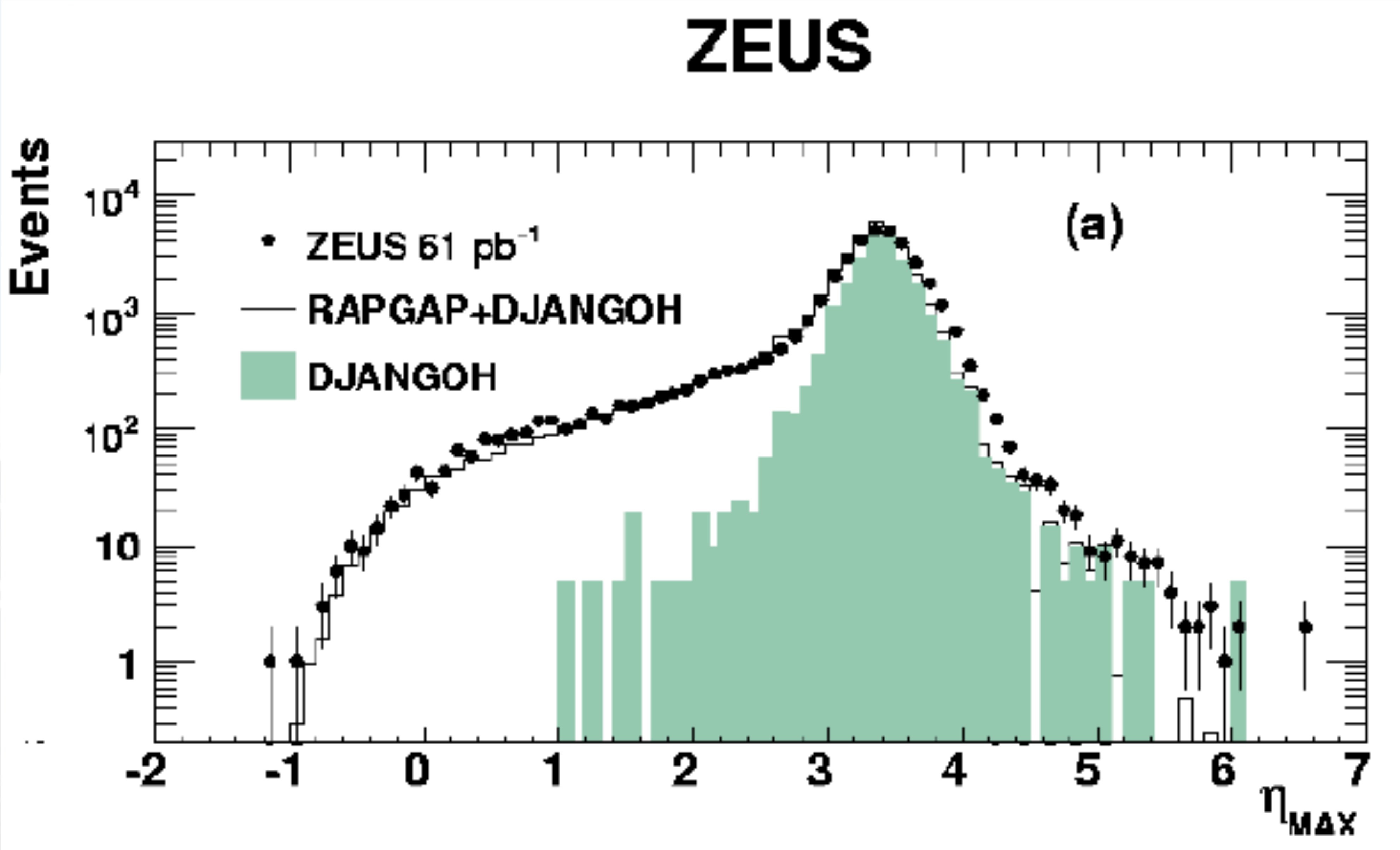
We recommend the allocation of resources to develop accelerator and detector technology necessary to lay the foundation for a polarized Electron-Ion Collider. The EIC would explore the new QCD frontier of strong color fields in nuclei and precisely image the gluons in the proton.

Diffractive Physics in e+A

- How to measure diffraction in e+A?
  - ➡ Use HERA method of Large Rapidity Gaps
  - ➡ Ideal gap of ~7.7 at HERA units reduced to 3-4 due to spread from hadronisation



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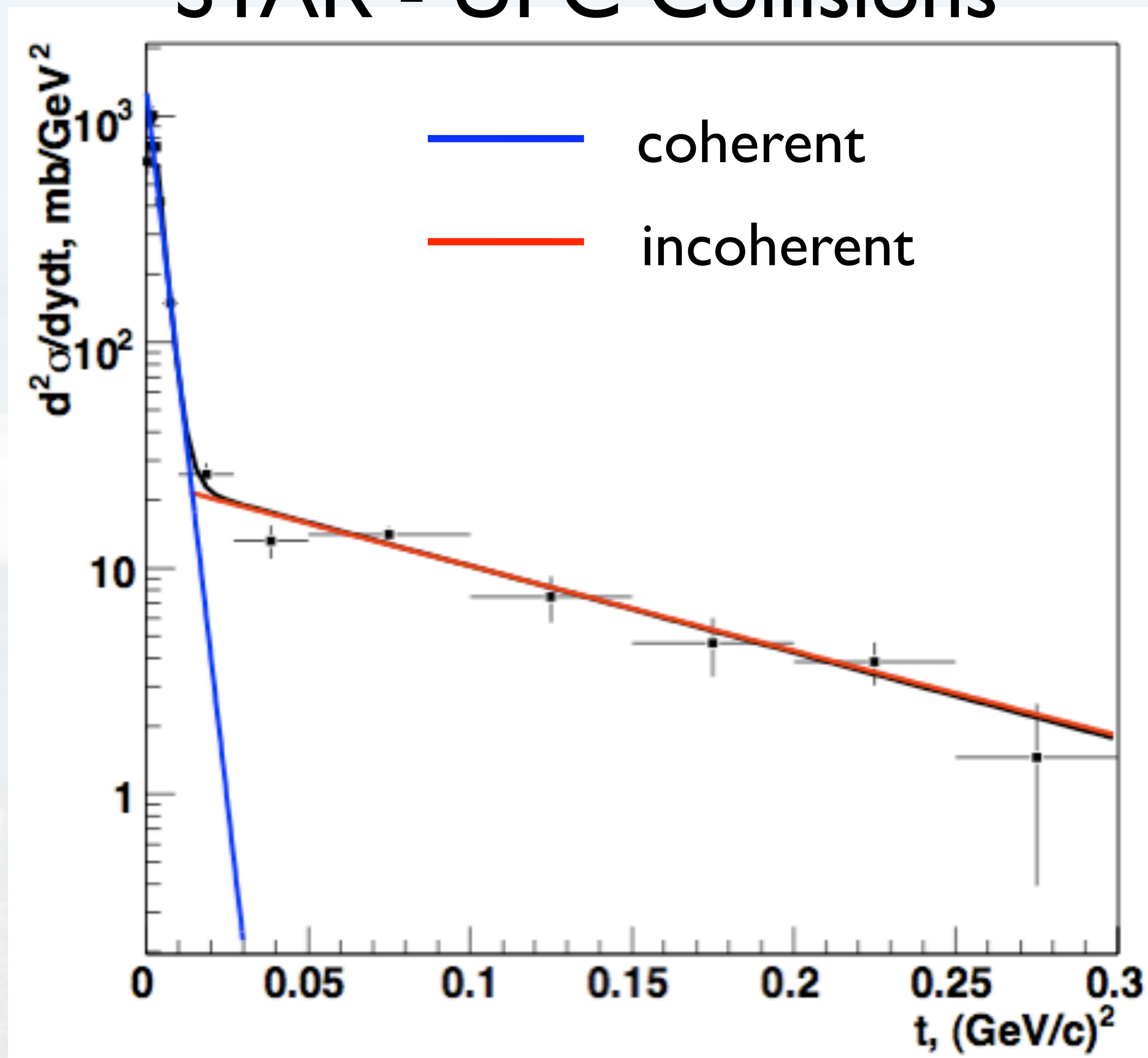
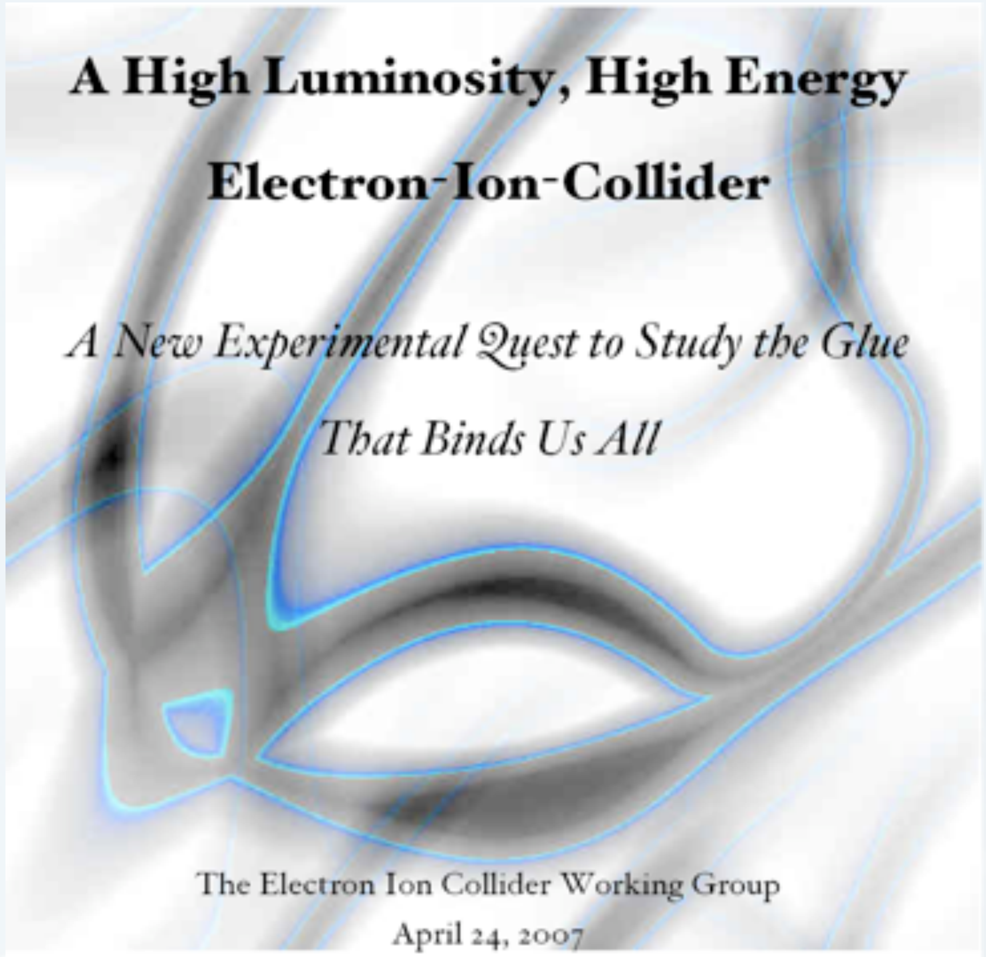
- Issues with measuring diffractive physics in e+A:
  - ➡ *t* required for nucleus to break-up is small (~ 30 MeV/c^2)
  - ➡ *t* required for nucleus to be measured in detector >> 30 MeV/c^2
  - ➡ To measure *t* dependence, must measure exclusive diffraction (e.g. vector mesons - $t \sim p_T^2$)

STAR - UPC Collisions



Status of the EIC Project:


A High Luminosity, High Energy
Electron-Ion-Collider
A New Experimental Quest to Study the Glue That Binds Us All
The Electron Ion Collider Working Group
April 24, 2007

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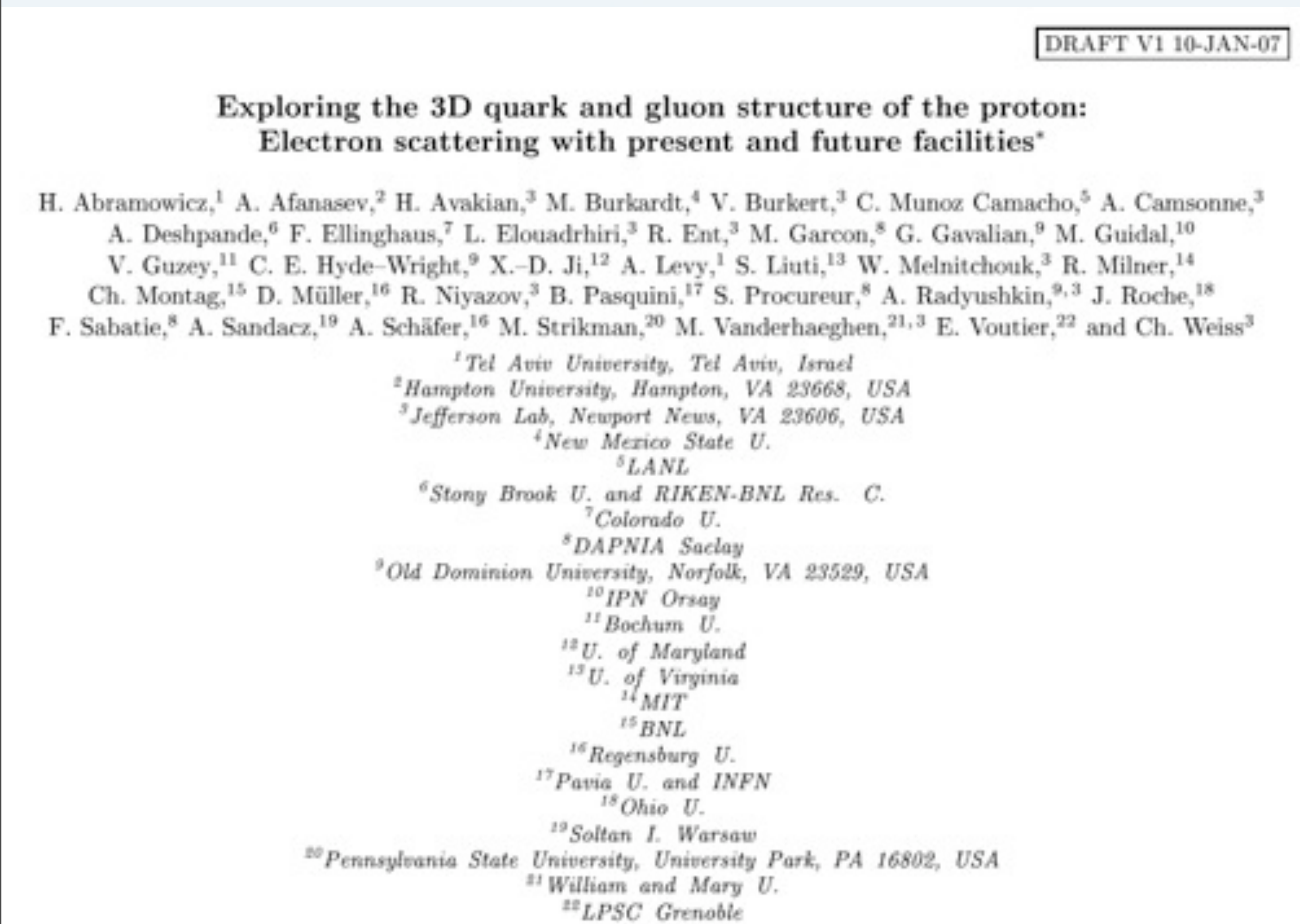

DRAFT V1 10-JAN-07

Exploring the 3D quark and gluon structure of the proton: Electron scattering with present and future facilities*

H. Abramowicz,[1] A. Afanasev,[2] H. Avakian,[3] M. Burkardt,[4] V. Burkert,[3] C. Munoz Camacho,[5] A. Camsonne,[3] A. Deshpande,[6] F. Ellinghaus,[7] L. Elouadrhiri,[3] R. Ent,[3] M. Garcon,[8] G. Gavalian,[9] M. Guidal,[10] V. Guzey,[11] C. E. Hyde-Wright,[9] X.-D. Ji,[12] A. Levy,[1] S. Liuti,[13] W. Melnitchouk,[3] R. Milner,[14] Ch. Montag,[15] D. Müller,[16] R. Niyazov,[3] B. Pasquini,[17] S. Procureur,[8] A. Radyushkin,[9,3] J. Roche,[18] F. Sabatie,[8] A. Sandacz,[19] A. Schäfer,[16] M. Strikman,[20] M. Vanderhaeghen,[21,3] E. Voutier,[22] and Ch. Weiss[3]

[1]*Tel Aviv University, Tel Aviv, Israel*
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[4]*New Mexico State U.*
[5]*LANL*
[6]*Stony Brook U. and RIKEN-BNL Res. C.*
[7]*Colorado U.*
[8]*DAPNIA Saclay*
[9]*Old Dominion University, Norfolk, VA 23529, USA*
[10]*IPN Orsay*
[11]*Bochum U.*
[12]*U. of Maryland*
[13]*U. of Virginia*
[14]*MIT*
[15]*BNL*
[16]*Regensburg U.*
[17]*Pavia U. and INFN*
[18]*Ohio U.*
[19]*Soltan I. Warsaw*
[20]*Pennsylvania State University, University Park, PA 16802, USA*
[21]*William and Mary U.*
[22]*LPSC Grenoble*

- The Electron Ion Collider (EIC) White Paper
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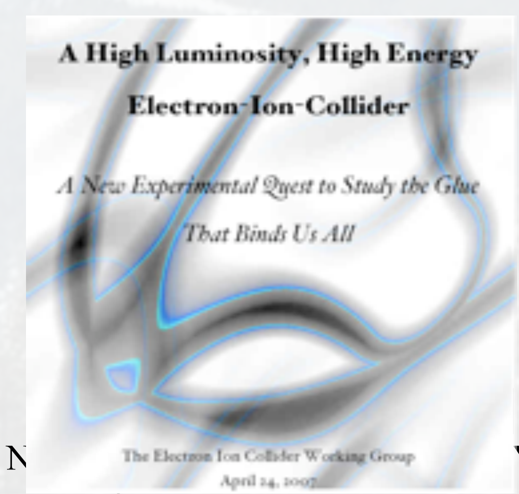
- ELIC ZDR Draft



A High Luminosity, High Energy Electron-Ion-Collider

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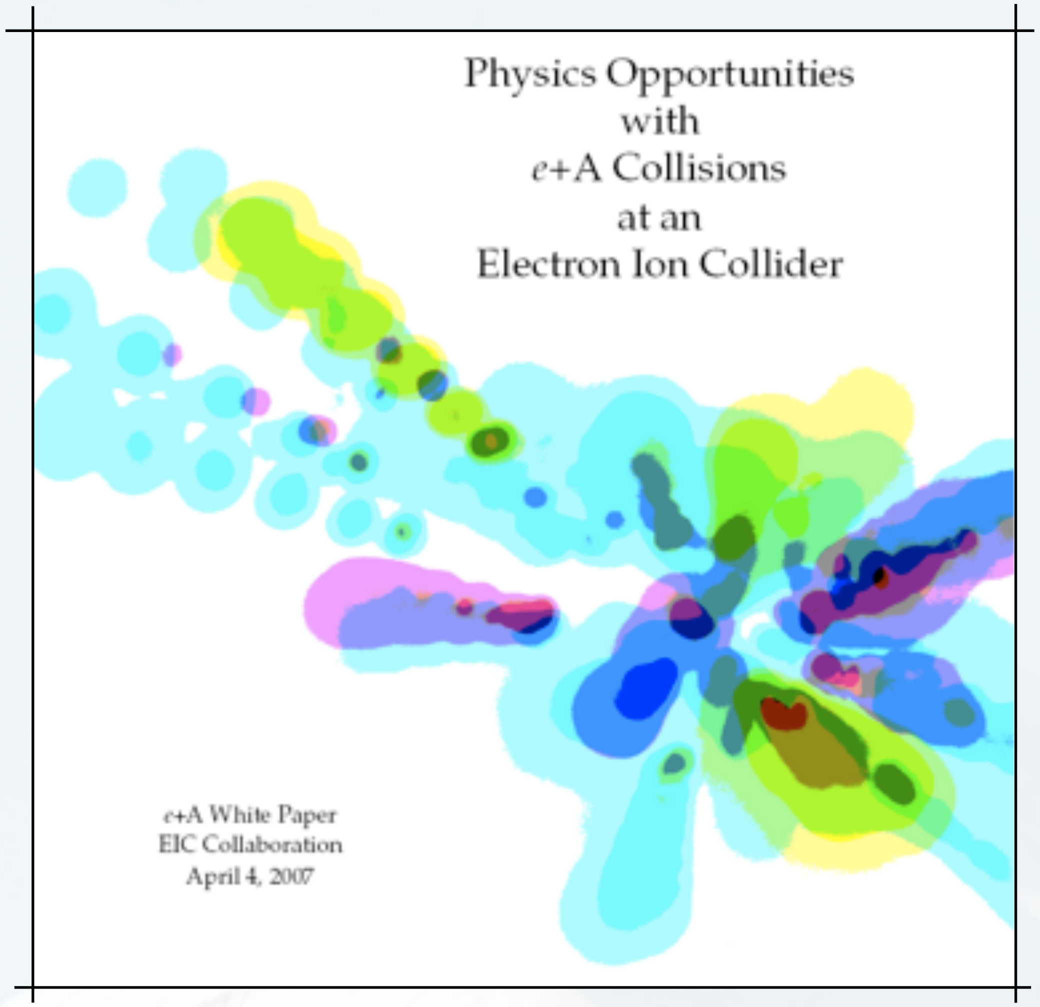

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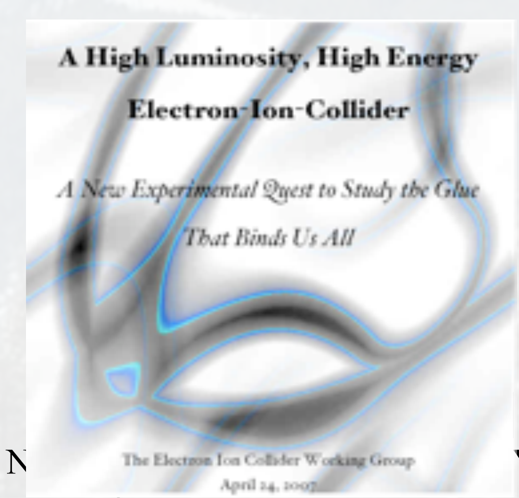

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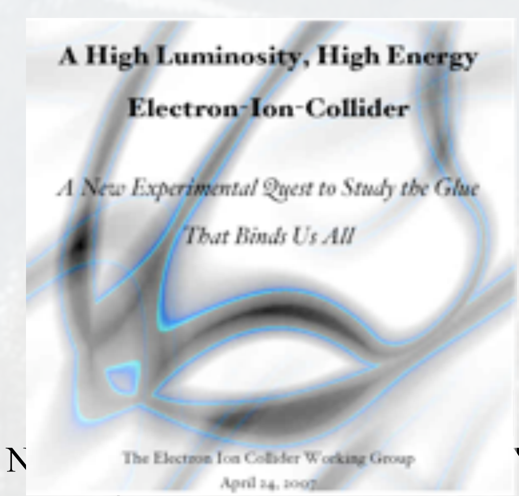

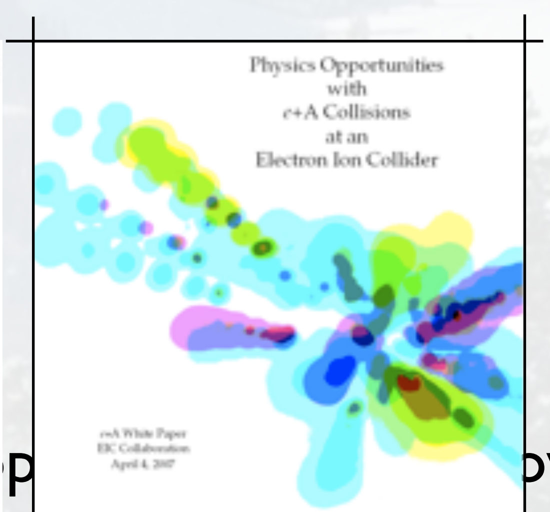

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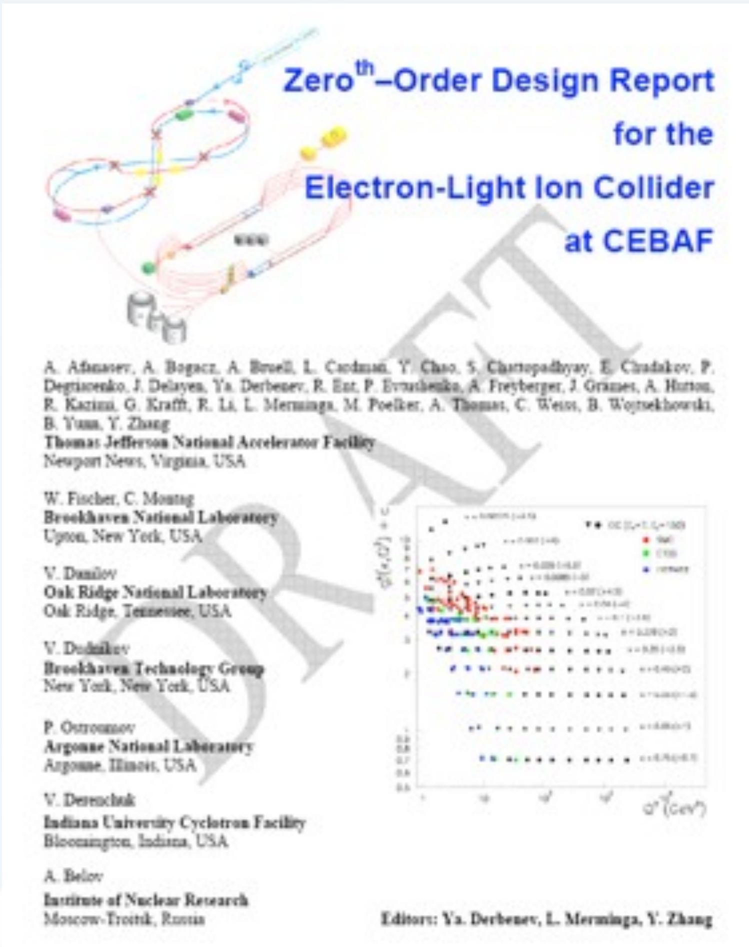

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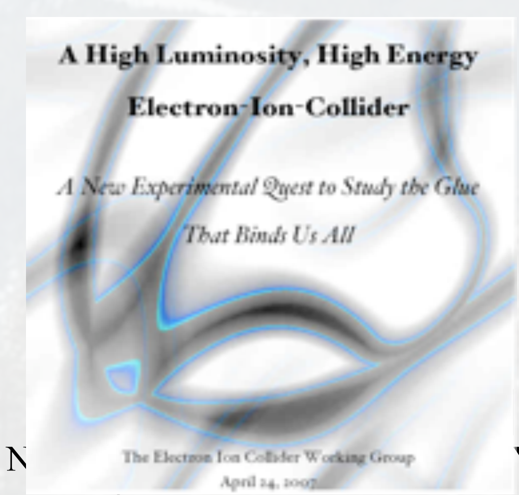

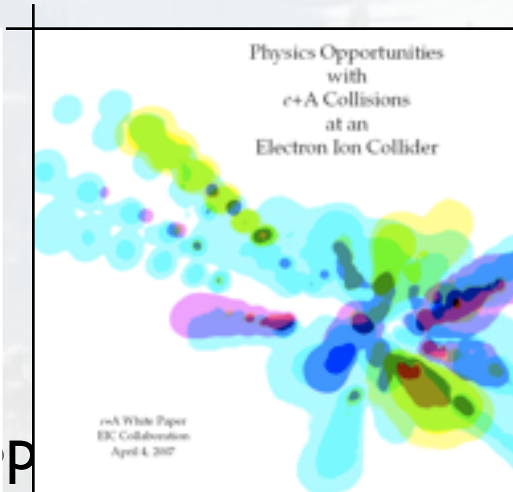

Monday, 13 April 2009

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Available at:

- NSAC LRP2007 home page
- Rutgers Town Meeting page
- **http://web.mit.edu/eicc**

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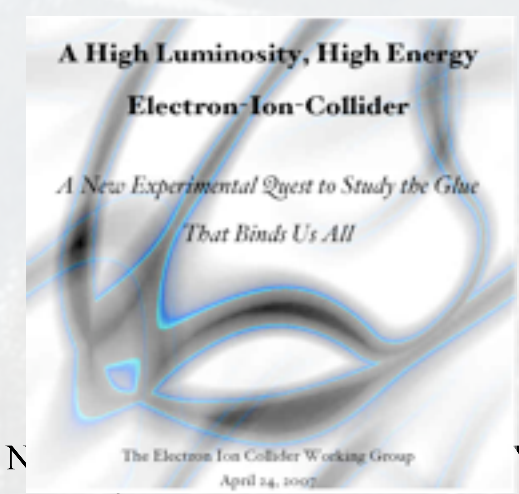
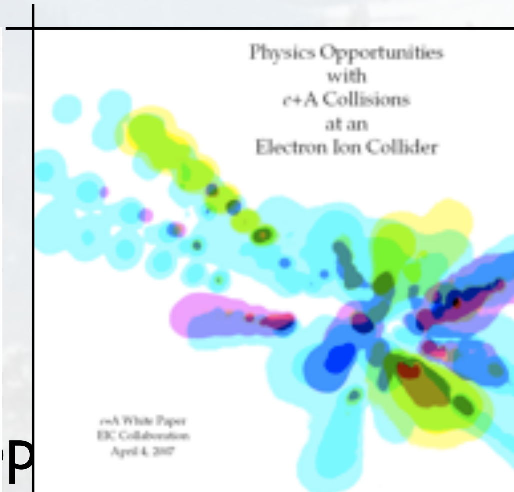
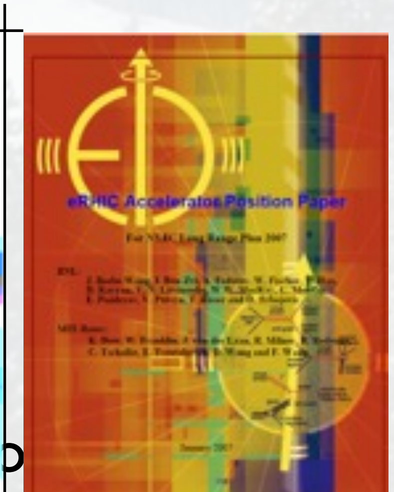






ACCELERATOR BACKUP SLIDES

MEEIC parameters for e-p collisions

	not cooled		pre-cooled		high energy cooling	
	p	e	p	e	p	e
Energy, GeV	**250**	**4**	**250**	**4**	**250**	**4**
Number of bunches	**111**		**111**		**111**	
Bunch intensity, 10^{11}	**2.0**	**0.31**	**2.0**	**0.31**	**2.0**	**0.31**
Bunch charge, nC	**32**	**5**	**32**	**5**	**32**	**5**
Normalized emittance, 1e-6 m, 95% for p / rms for e	**15**	**73**	**6**	**29**	**1.5**	**7.3**
rms emittance, nm	**9.4**	**9.4**	**3.8**	**3.8**	**0.94**	**0.94**
beta*, cm	**50**	**50**	**50**	**50**	**50**	**50**
rms bunch length, cm	**20**	**0.2**	**20**	**0.2**	**5**	**0.2**
beam-beam for p /disruption for e	**1.5e-3**	**3.1**	**3.8e-3**	**7.7**	**0.015**	**7.7**
Peak Luminosity, 1e32, $cm^{-2}s^{-1}$	**0.93**		**2.3**		**9.3**	

Staging of eRHIC: Energy Reach and Luminosity

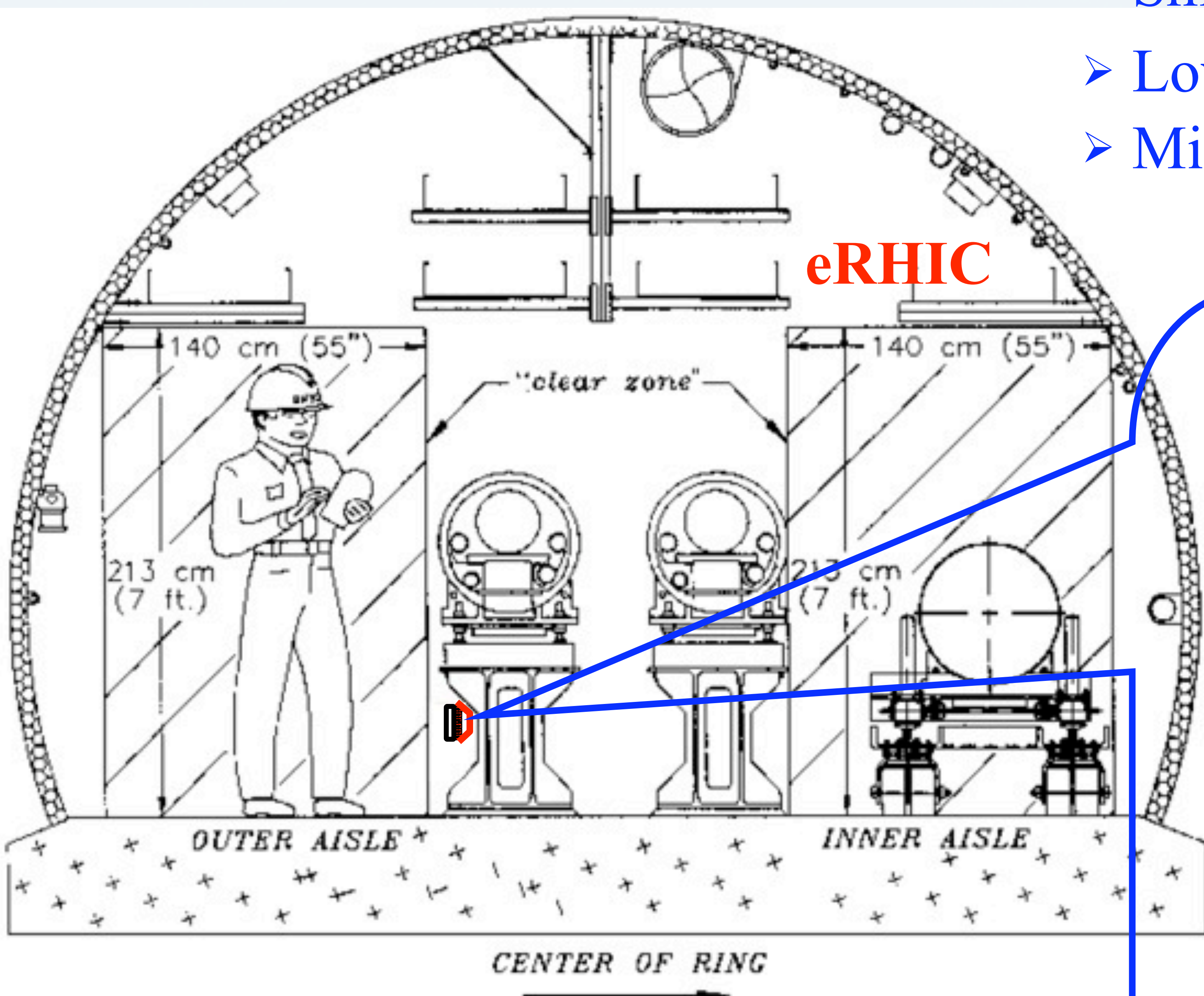
- **MEIC**: Medium Energy Electron-Ion Collider
  - Both Accelerator and Detector are located at IP2 of RHIC
  - 2 or 4 GeV e^- x 250 GeV p (45 or 63 GeV c.m.), L ~ 10^{32}-10^{33} cm^{-2} sec^{-1}
- **eRHIC, High energy and luminosity phase,** inside RHIC tunnel

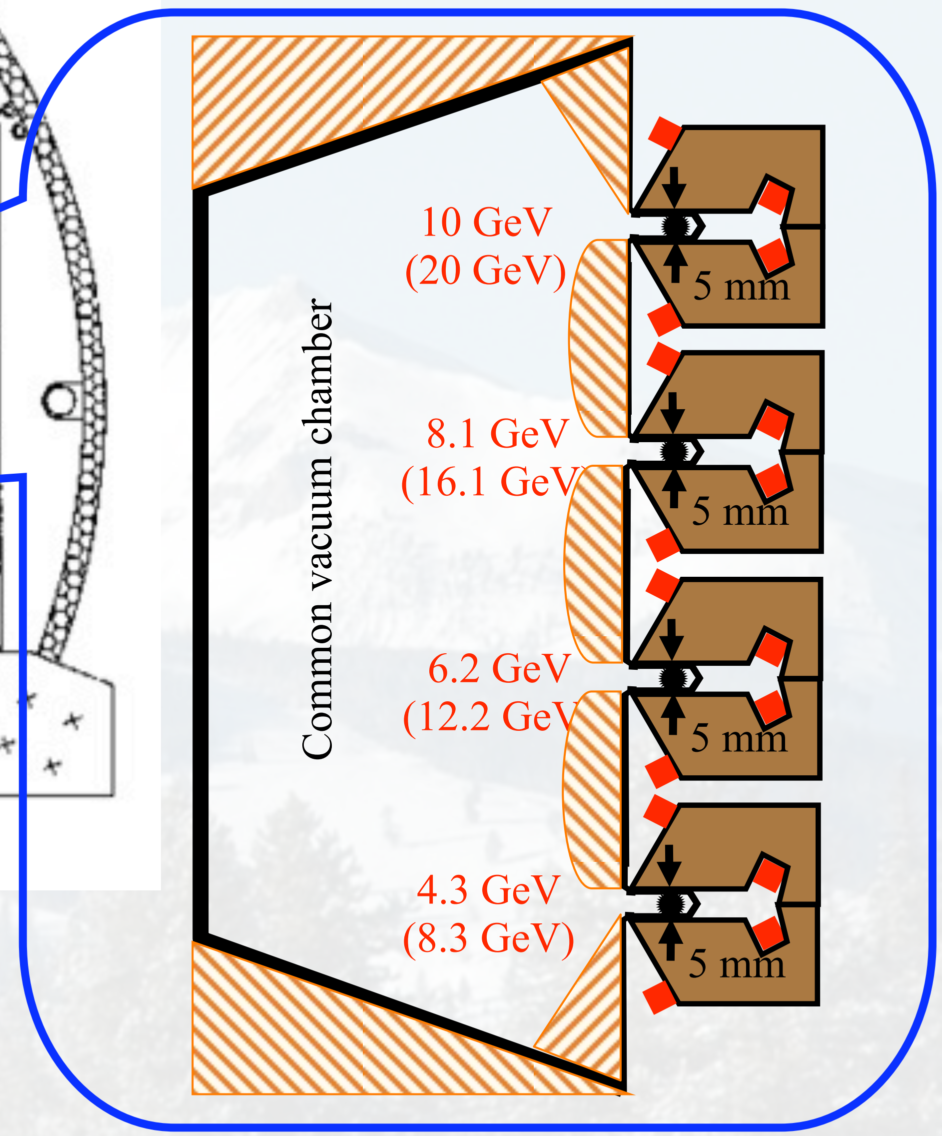
  Full energy, nominal luminosity ,
  - Polarized 20 GeV e^- x 325 GeV p (160 GeV c.m), L ~ 10^{33}-10^{34} cm^{-2} sec^{-1}
  - 30 GeV e x 120 GeV/n Au (120 GeV c.m.), ~1/5 of full luminosity
  - and 20 GeV e x 120 GeV/n Au (120 GeV c.m.), full liminosity
- **eRHIC, 10 GeV elevated luminosity phase,** inside RHIC tunnel

  Higher luminosity at reduced energy, can be added if needed
  - Polarized 10 GeV e^- x 325 GeV p, L ~ 10^{35} cm^{-2} sec^{-1}
  - Smaller improvements (3-4 fold) in e-Ion collisions

eRHIC R&D - Recirculation Passes

- Separate recirculation loops
- Small aperture magnets
- Low current, low power consumption
- Minimized cost





Development of prototype magnets is underway (BNL LDRD, V.N.Litvinenko)