# An Electron-Ion Collider at RHIC: A detailed study of the nucleus

Matthew A. C. Lamont
BNL

BROOKHAVEN NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY

# Lots of work recently on the physics of e+A collisions

The EIC Science case: a report on the joint BNL/INT/JLab program

## Gluons and the quark sea at high energies: distributions, polarization, tomography

Institute for Nuclear Theory • University of Washington, USA
September 13 to November 19, 2010


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**arXiv:1108.1713**

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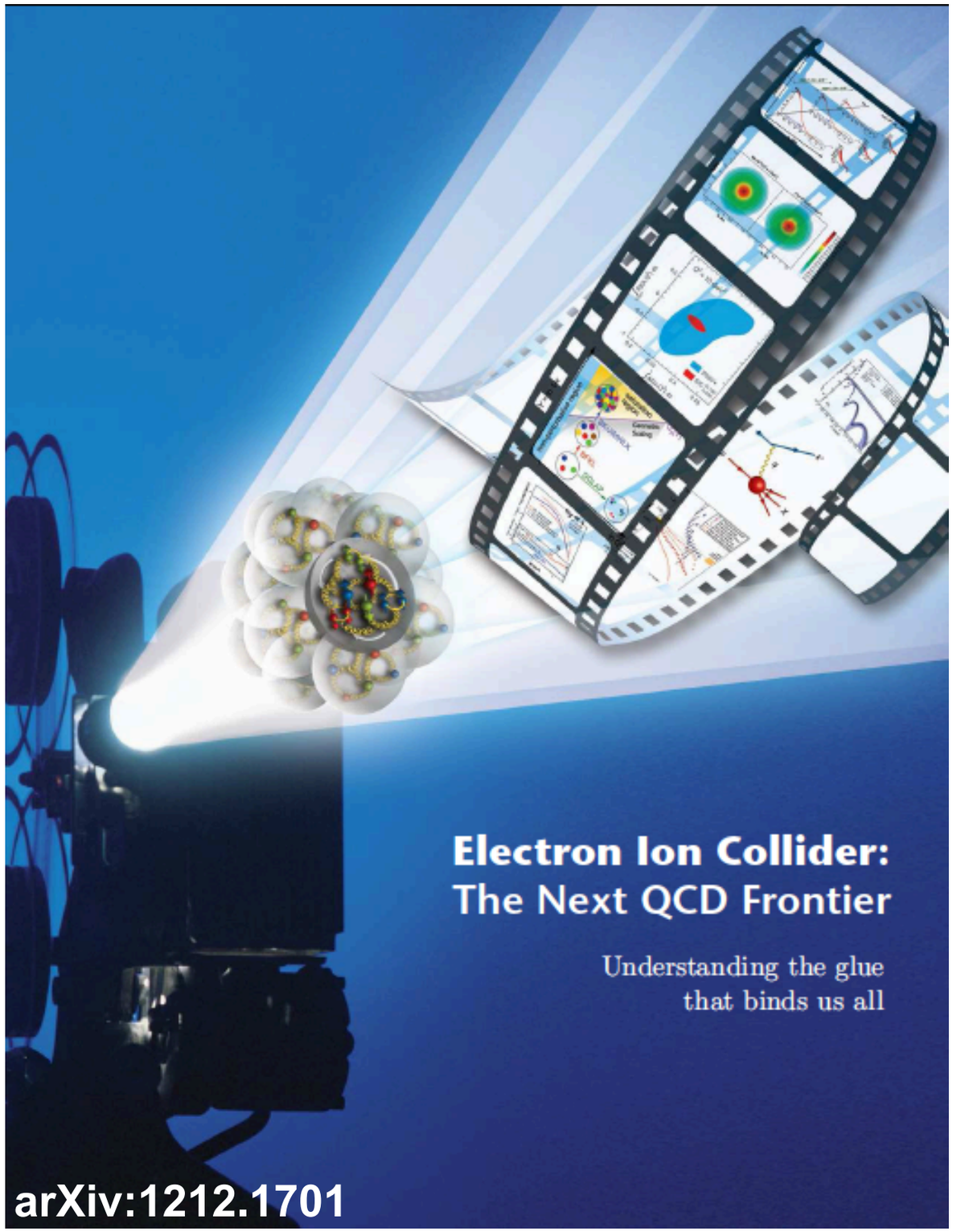
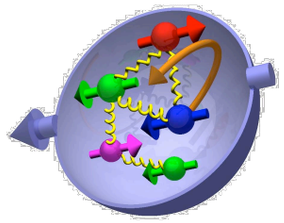



arXiv:1212.1701

# Most compelling physics questions

Spin physics



- What is the polarisation of gluons at small x where they dominate?
- What is the x-dependence and flavour decomposition of the polarised sea?

Determine quark and gluon contributions to the proton spin at last!!

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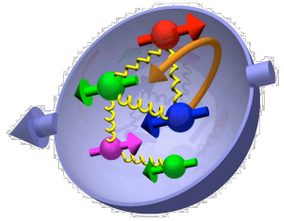

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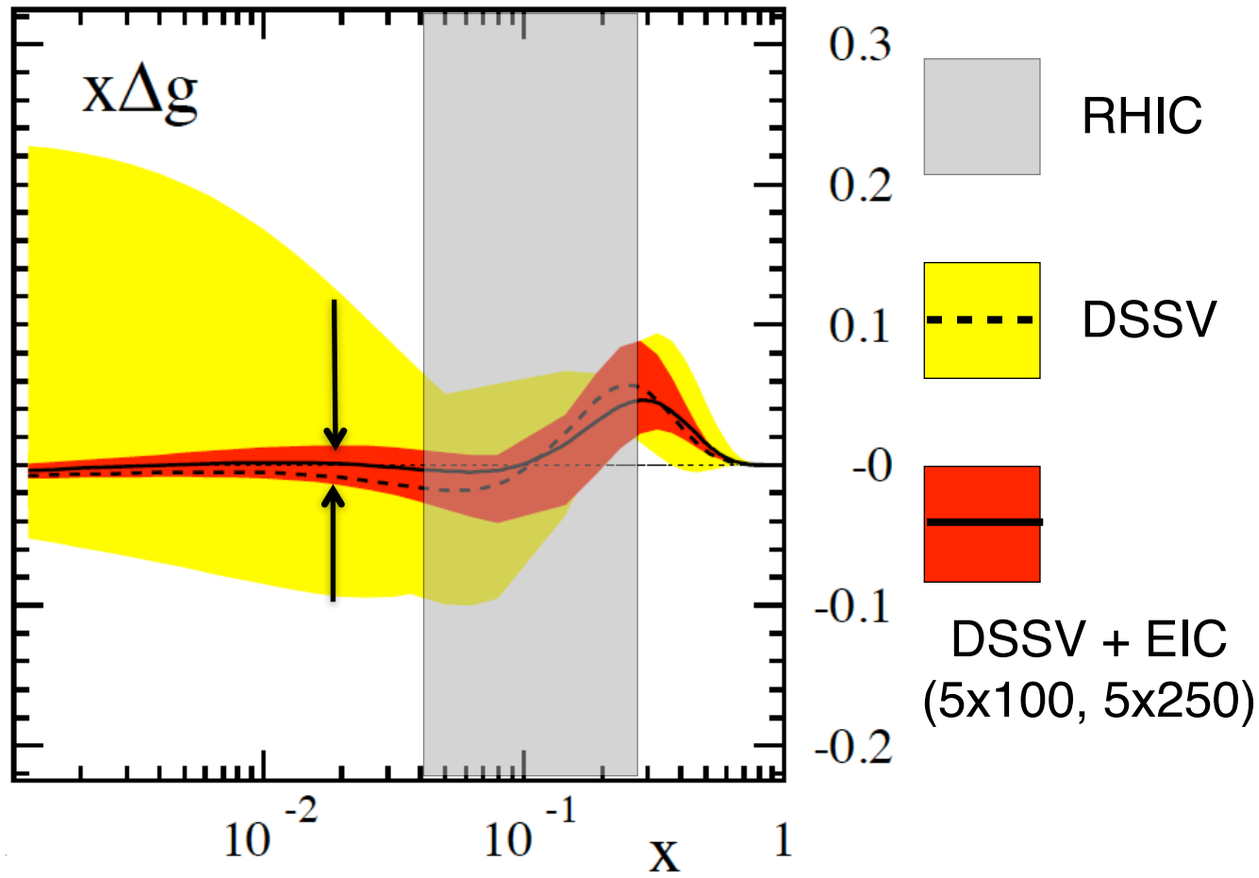

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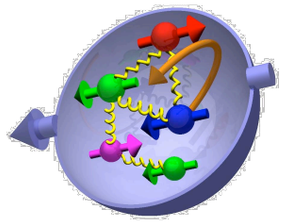

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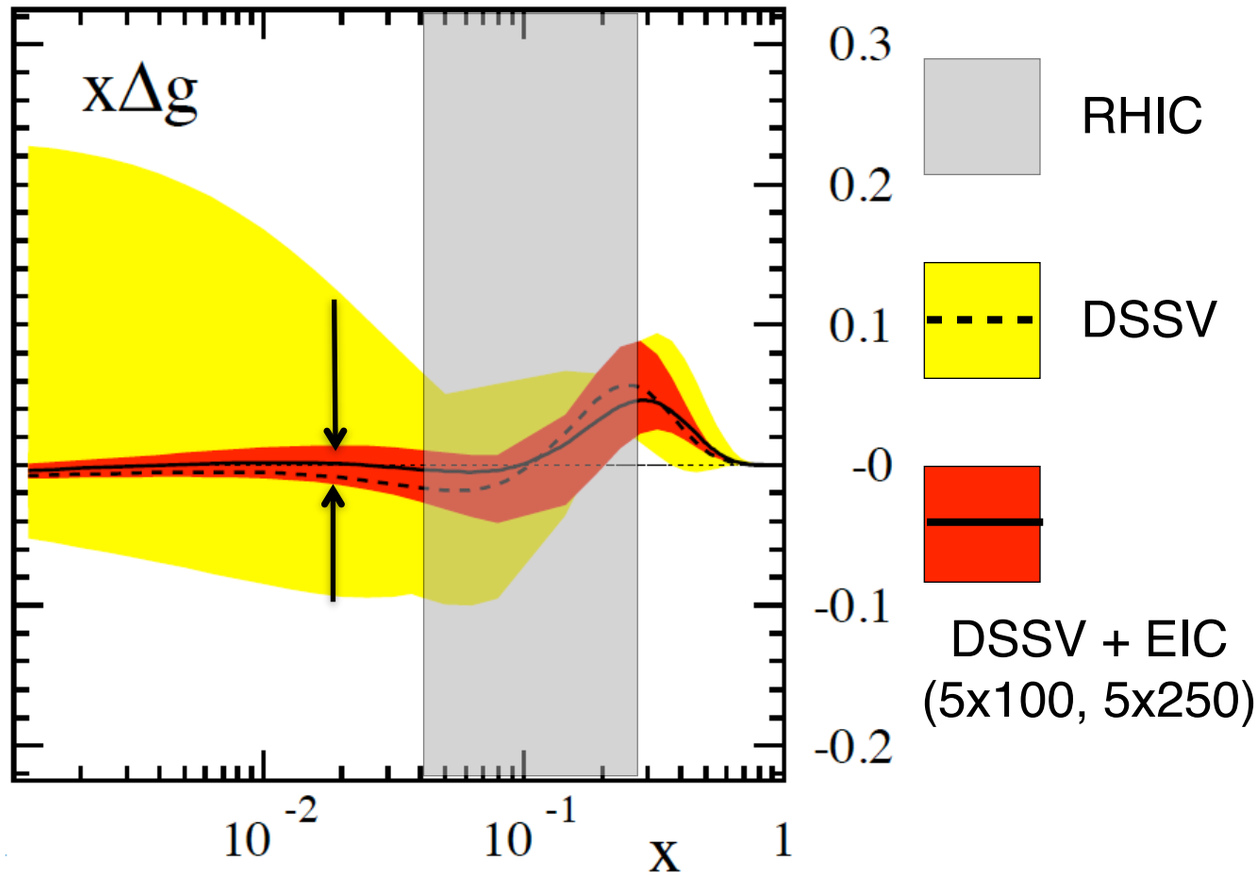
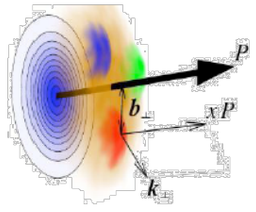



## Imaging




- What is the spatial distribution of quarks/ gluons in nucleons AND nuclei?
- Understand deep aspects of gauge theories revealed by $k_T$ dependent distributions

Possible window to orbital angular momentum

: macl@bnl.gov

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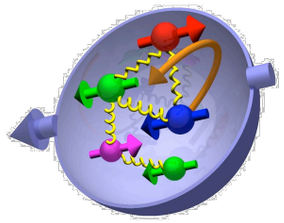

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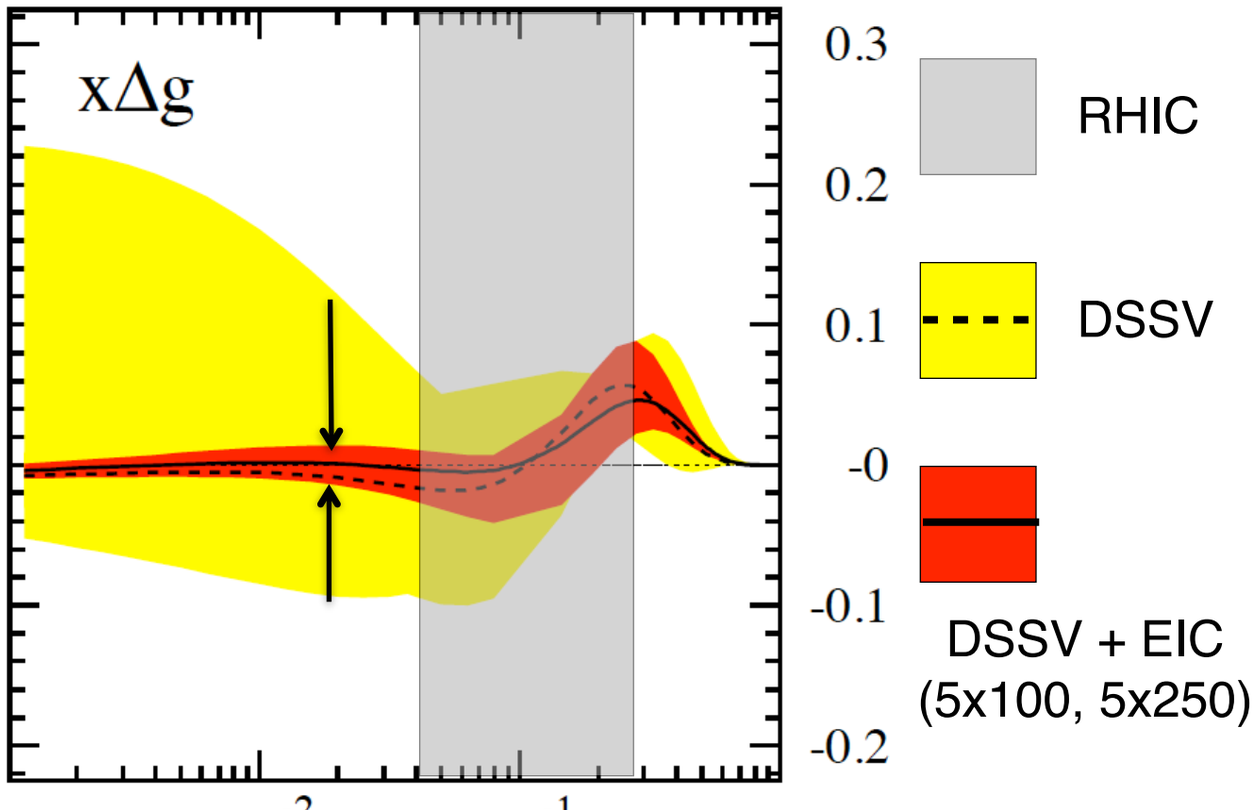


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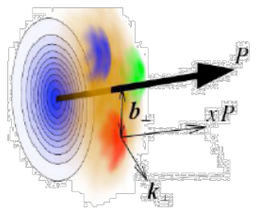


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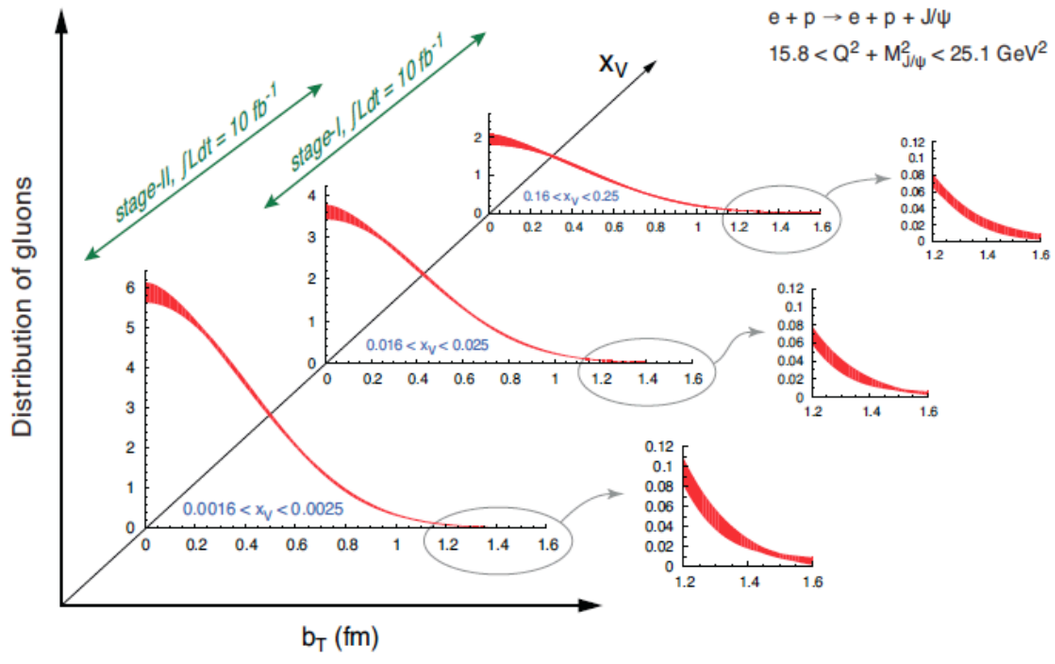


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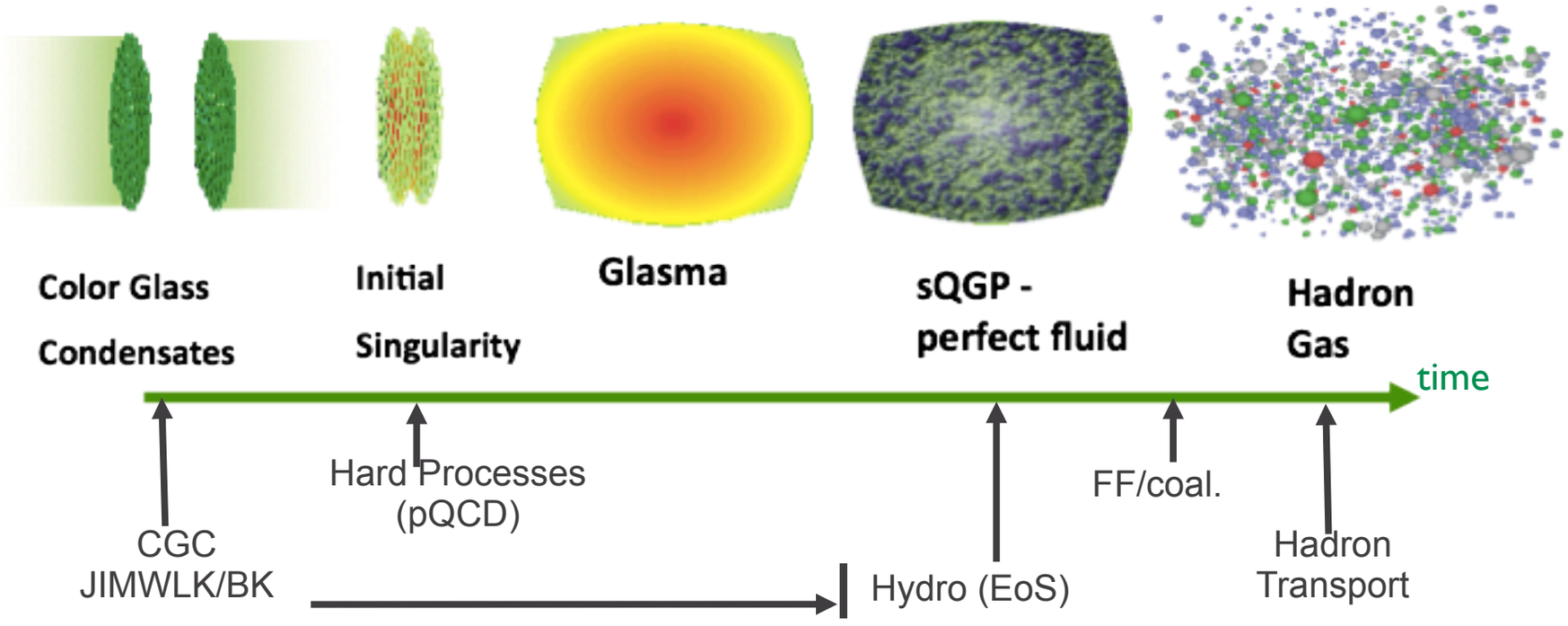
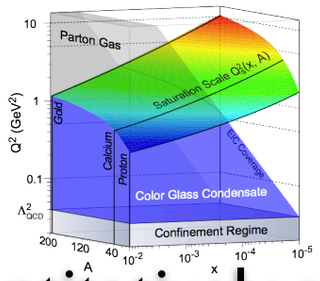
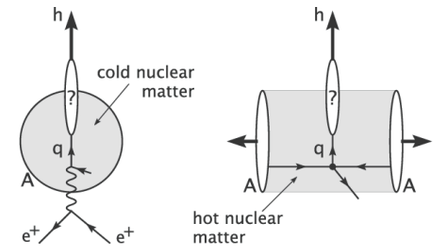



## Strong Colour Fields and Hadronisation

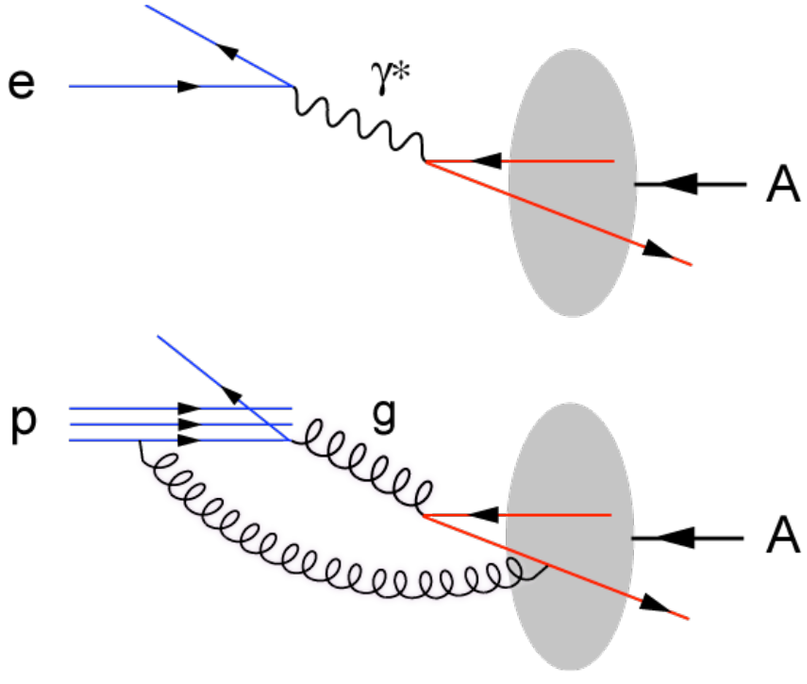



- Quantitatively probe the universality of strong colour fields in A+A, p+A and e+A
- Understand in detail the transition to the non-linear regime of strong gluon fields and the physics of saturation
- What is the spatial distribution of quarks and gluons in nucleu and how much does it fluctuate?
- How do hard probes in e+A interact with the medium?

Currently have no experimental knowledge of gluons in nuclei at small x!!

# Why e+A collisions and not p+A?

- 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
- Issues:
  - ➡ p+A combines initial and final state effects
  - ➡ multiple colour interactions in p+A
  - ➡ p+A lacks the direct access to x, $Q^2$



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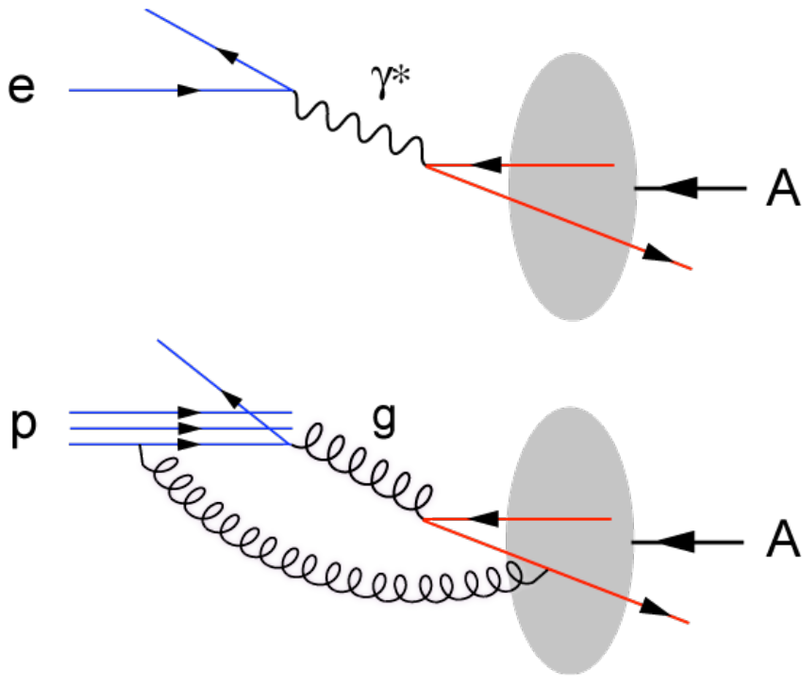


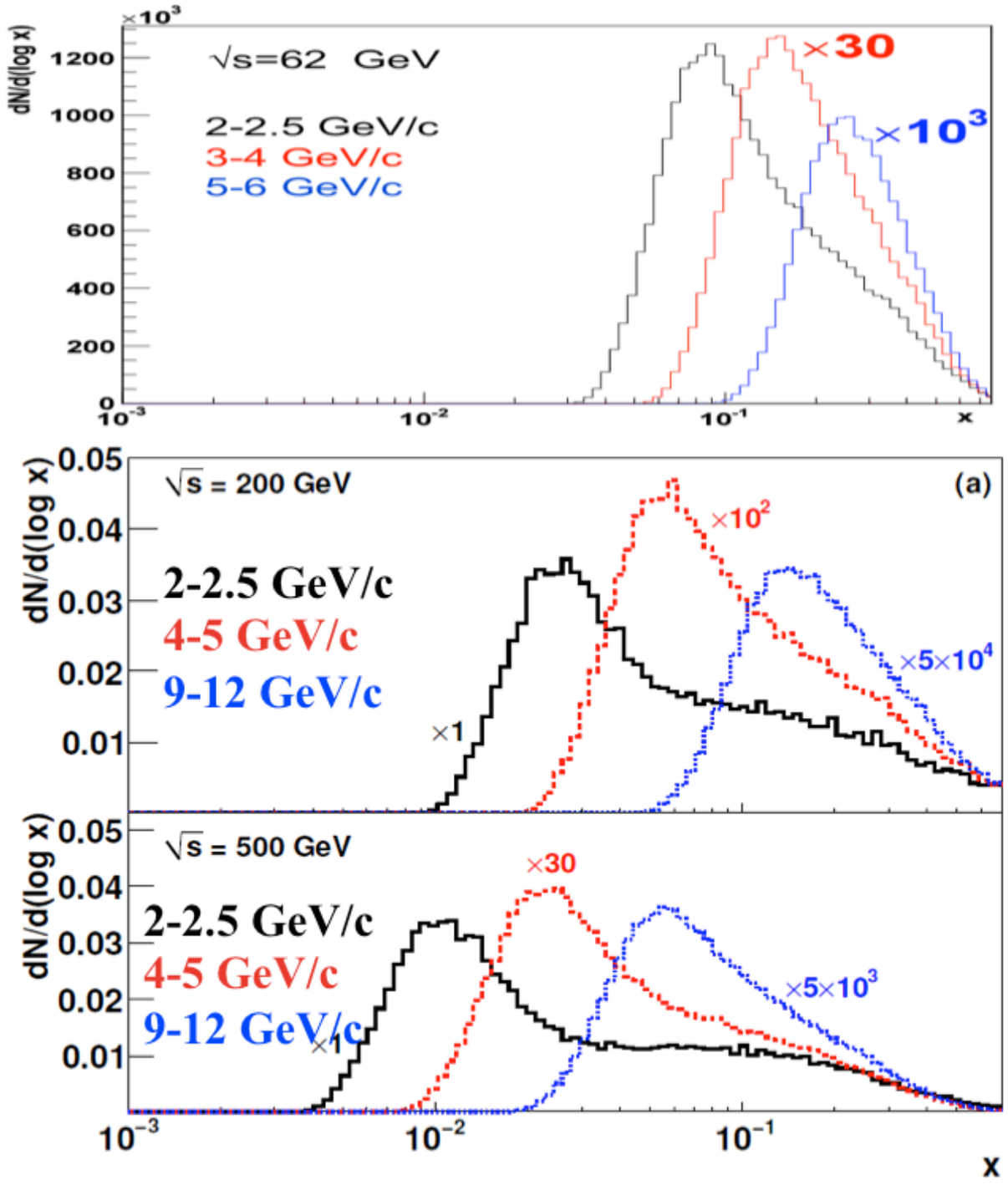


$p_T$ - x correlation in p+p

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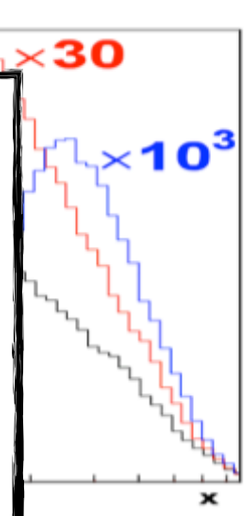
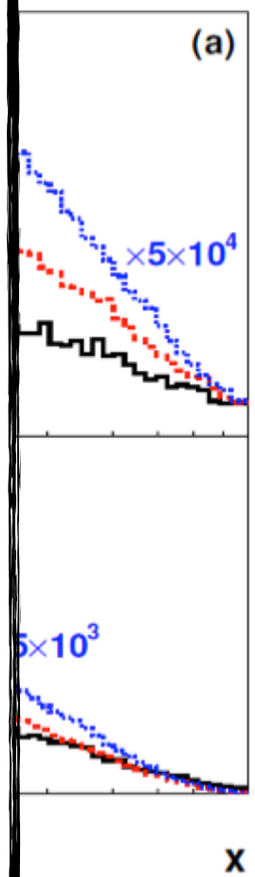
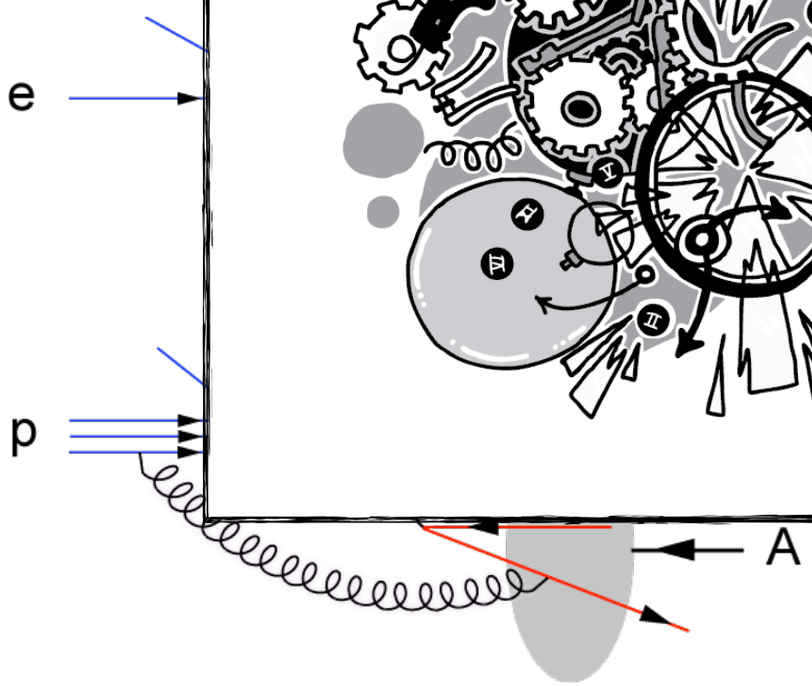
*Scattering of protons on protons*
*is like colliding Swiss watches to find out how they are built.*

R. Feynman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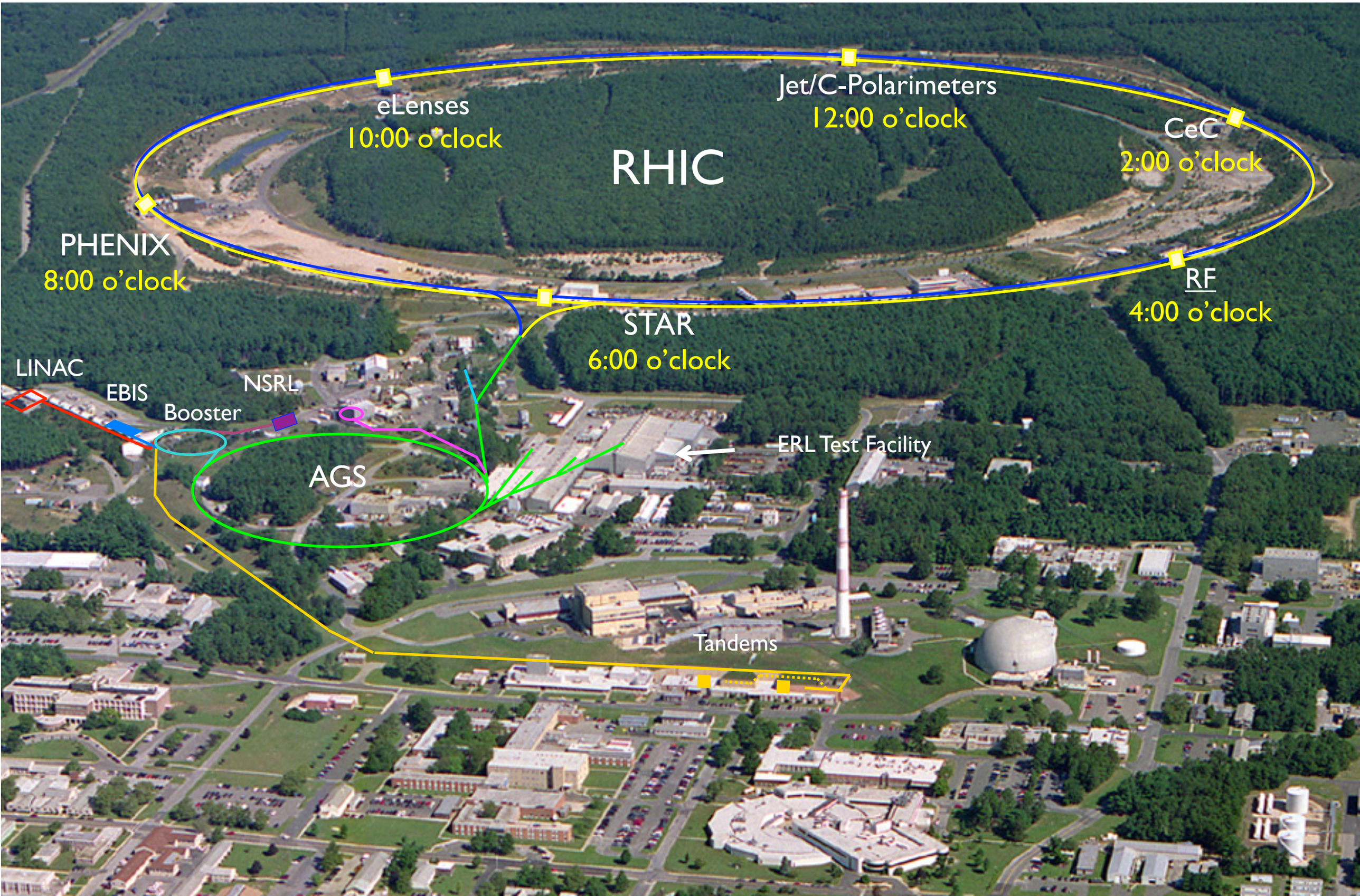
# From RHIC to eRHIC



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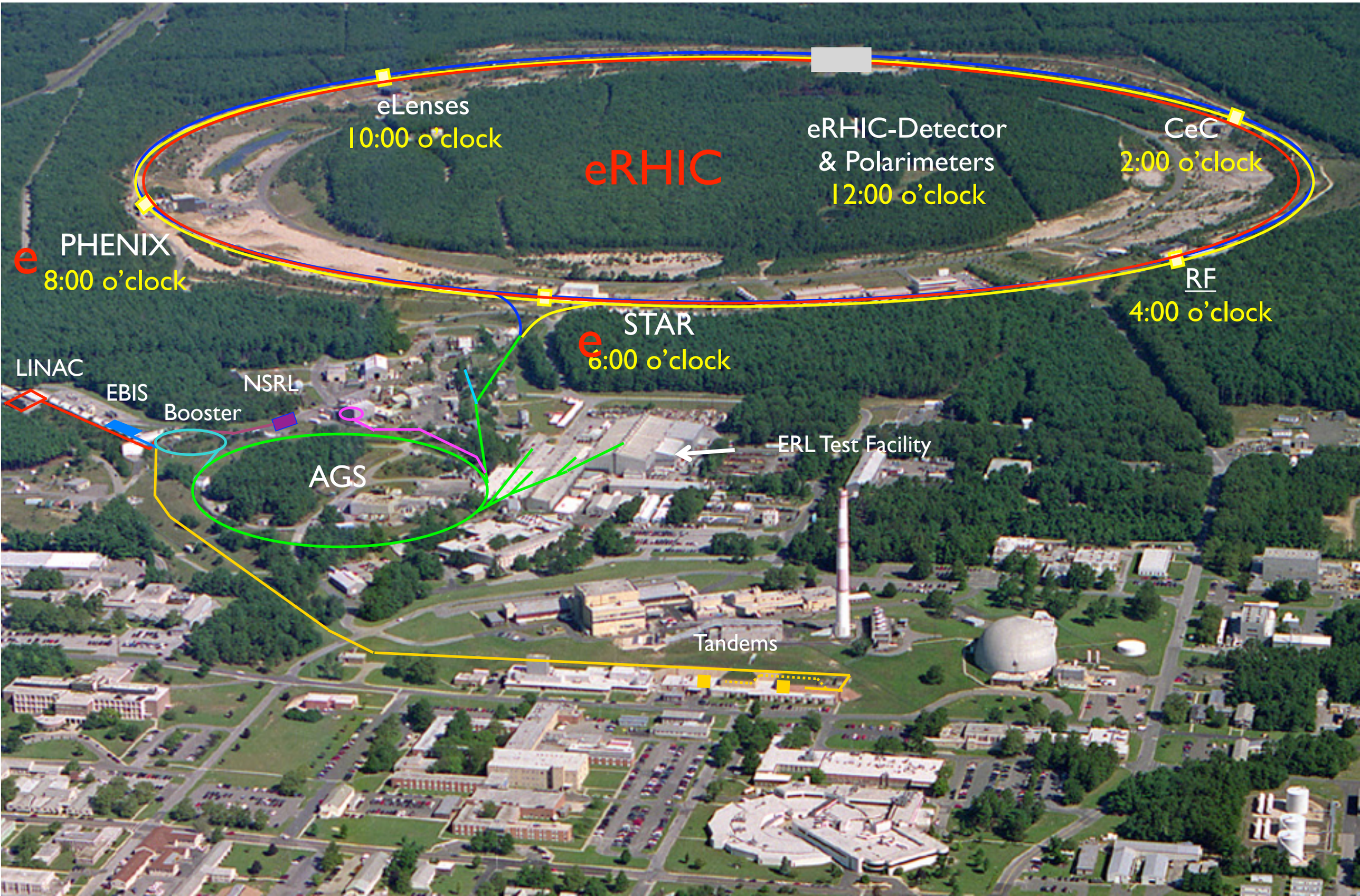
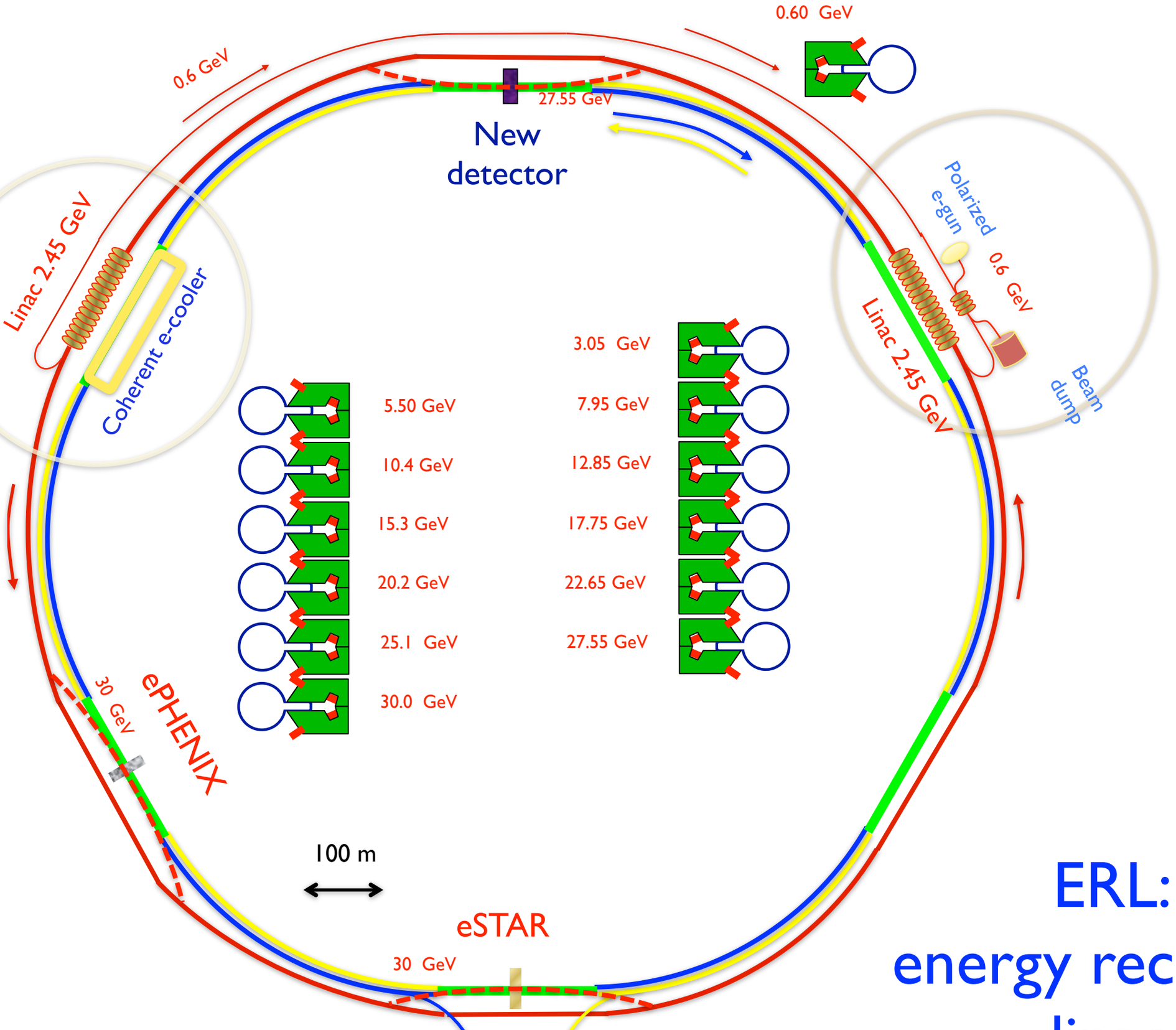


# Electron beam evolution in eRHIC's ERL




ERL:
energy recovery
linac

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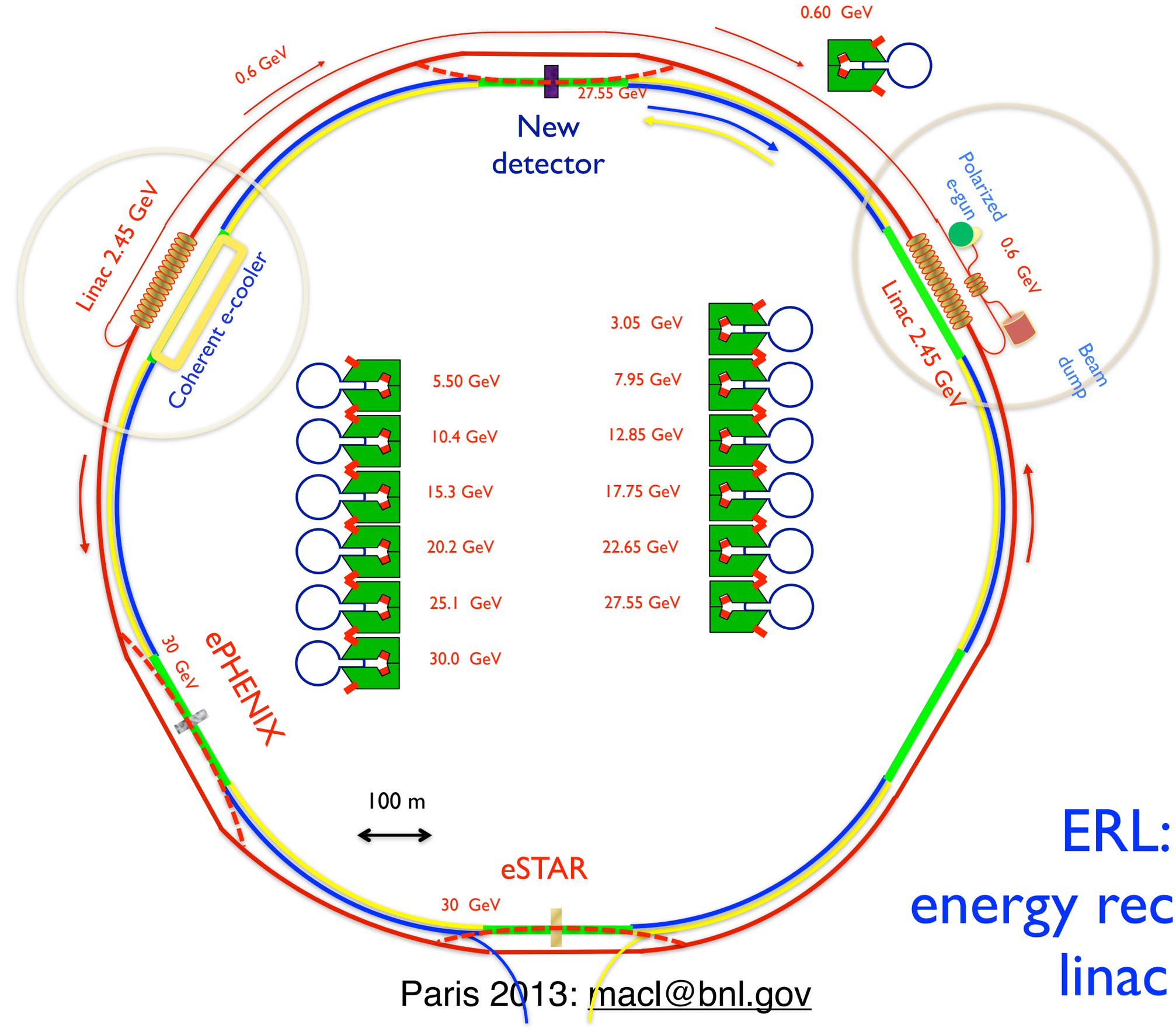


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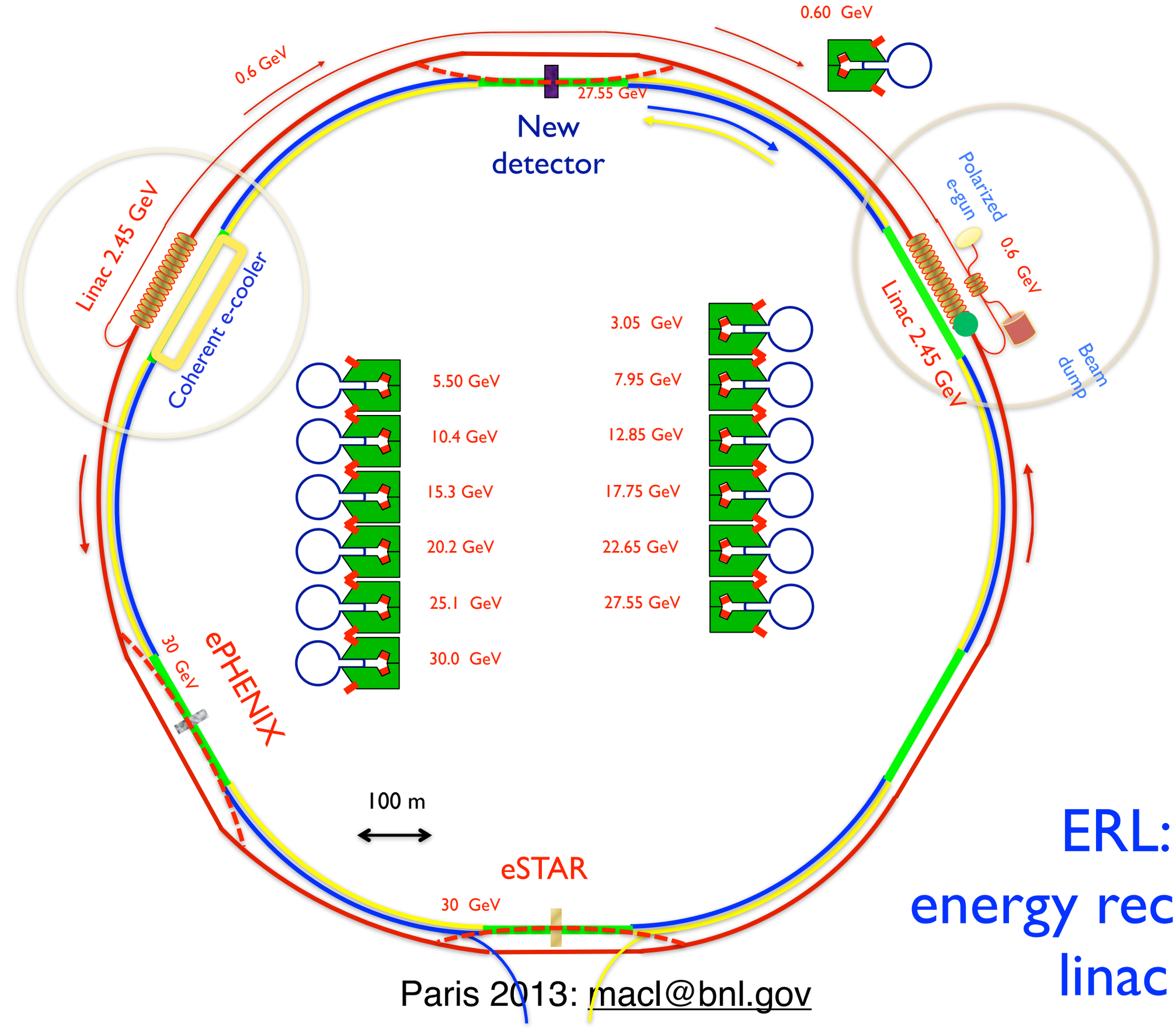


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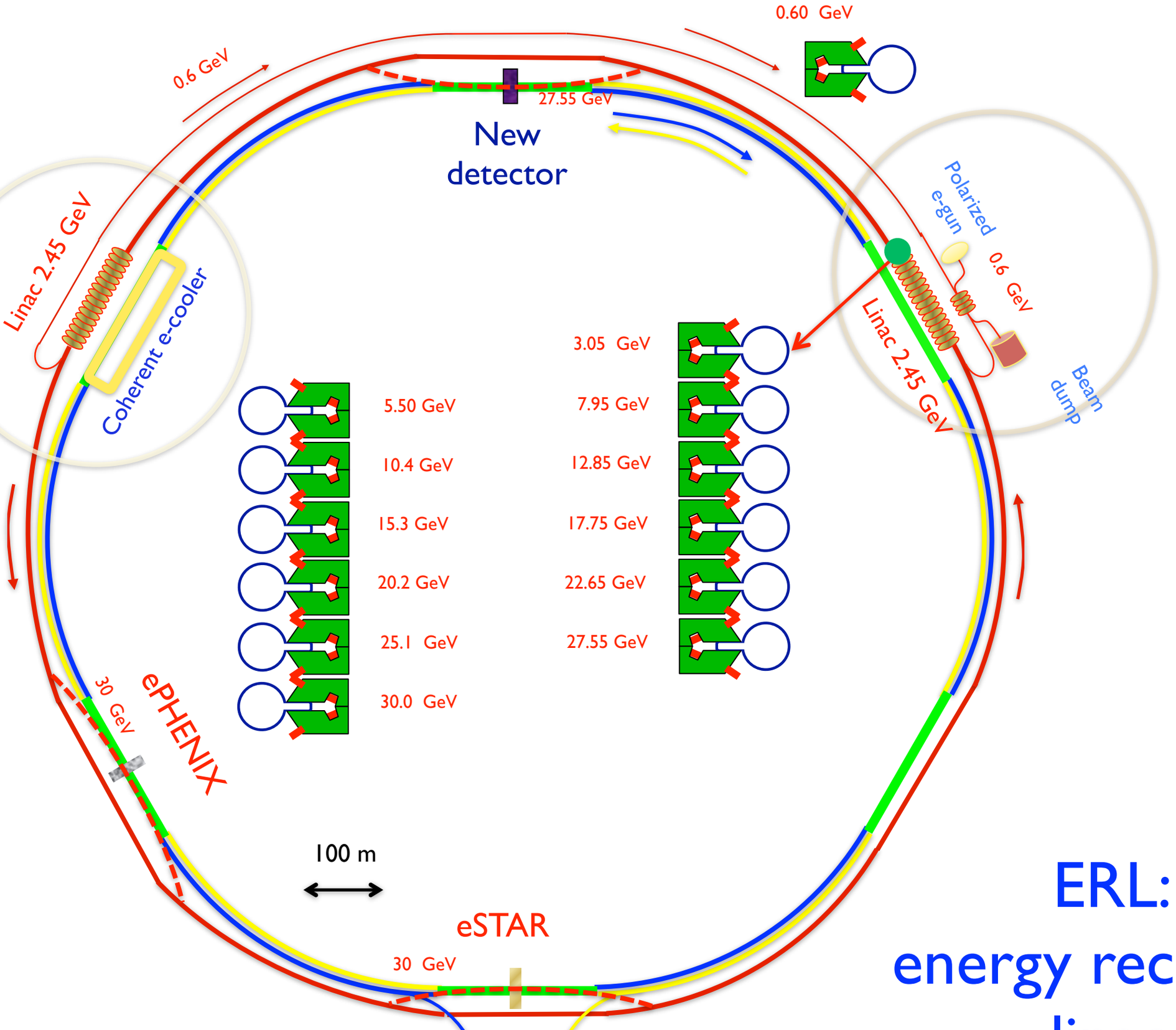


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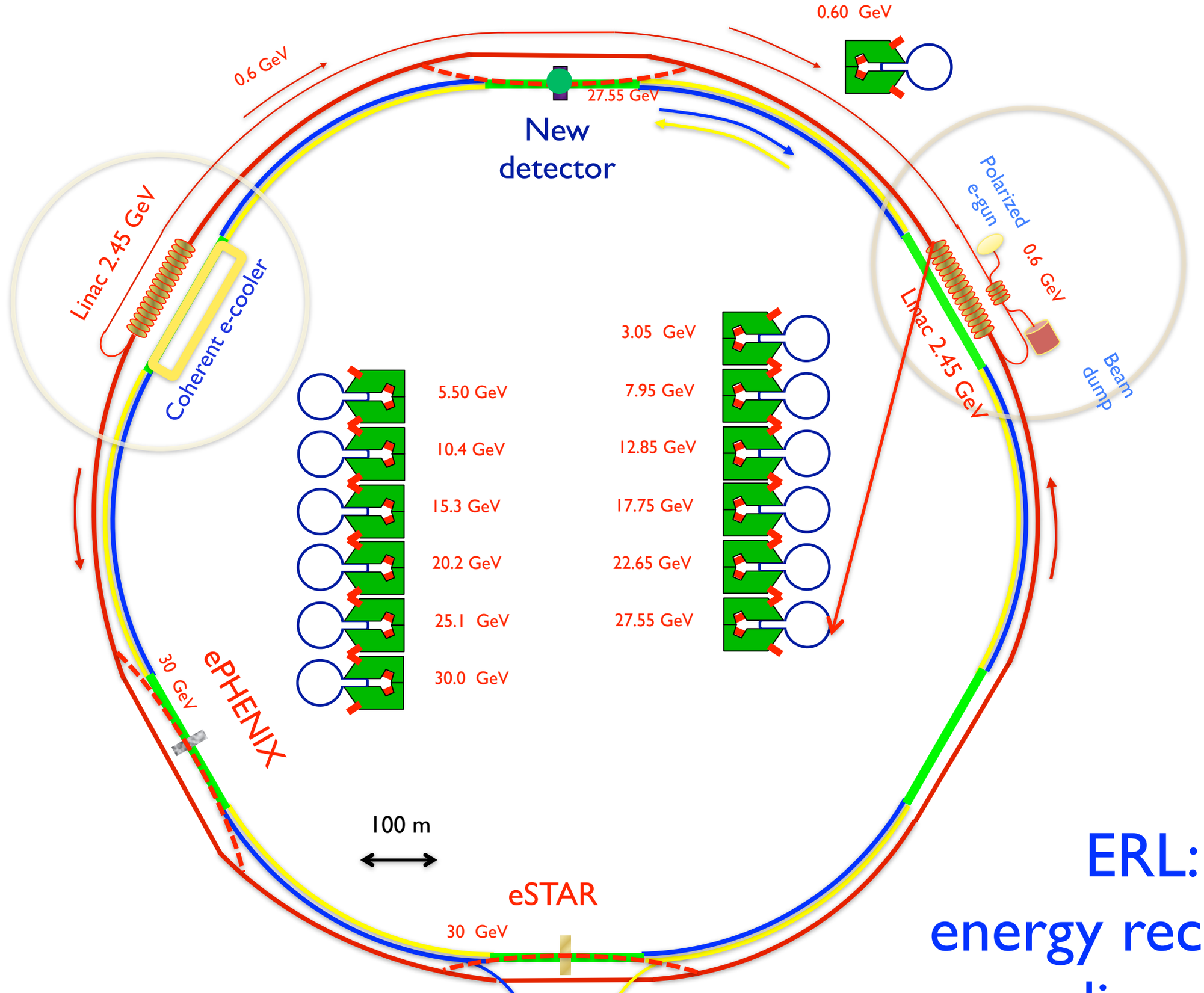


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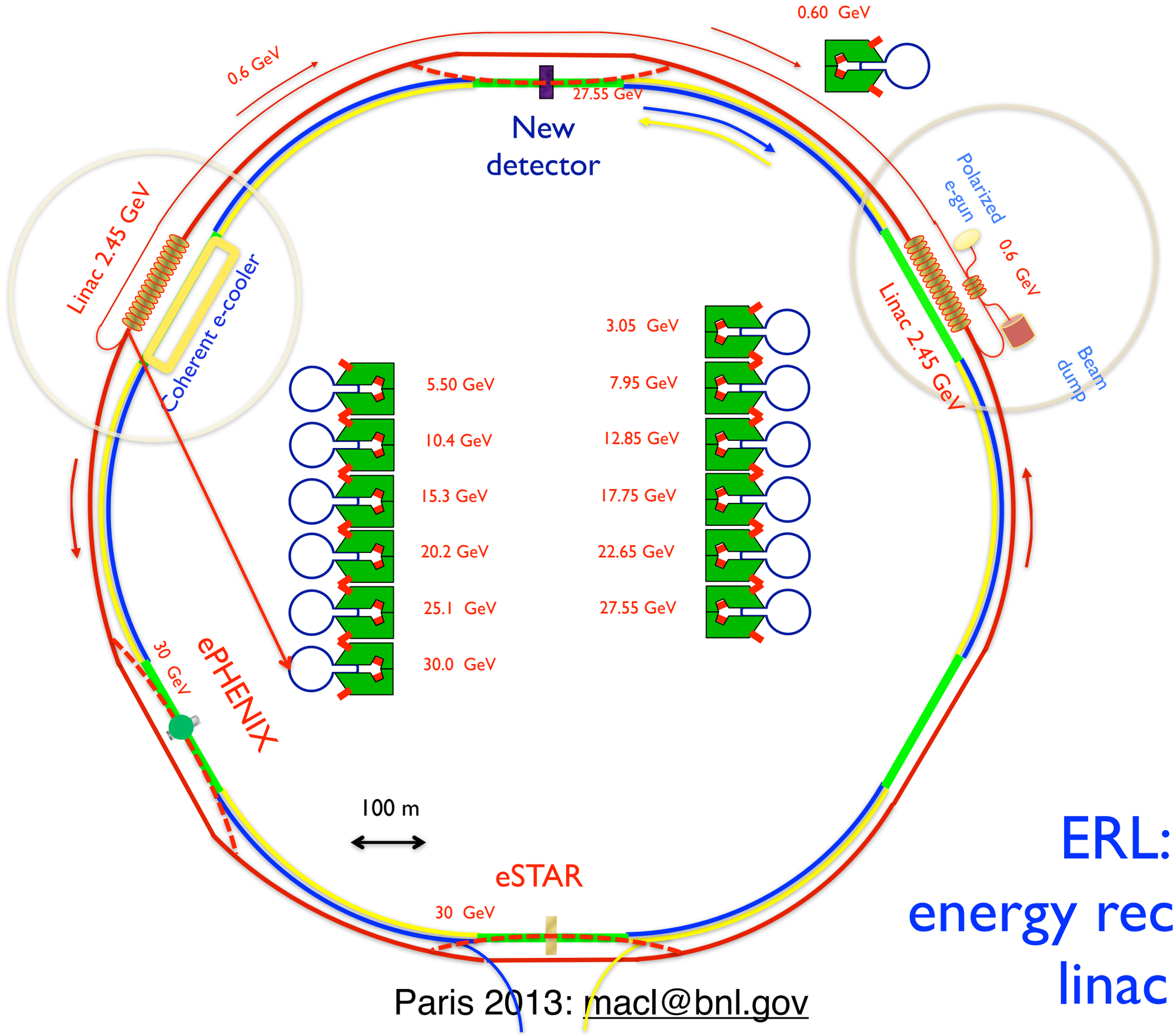


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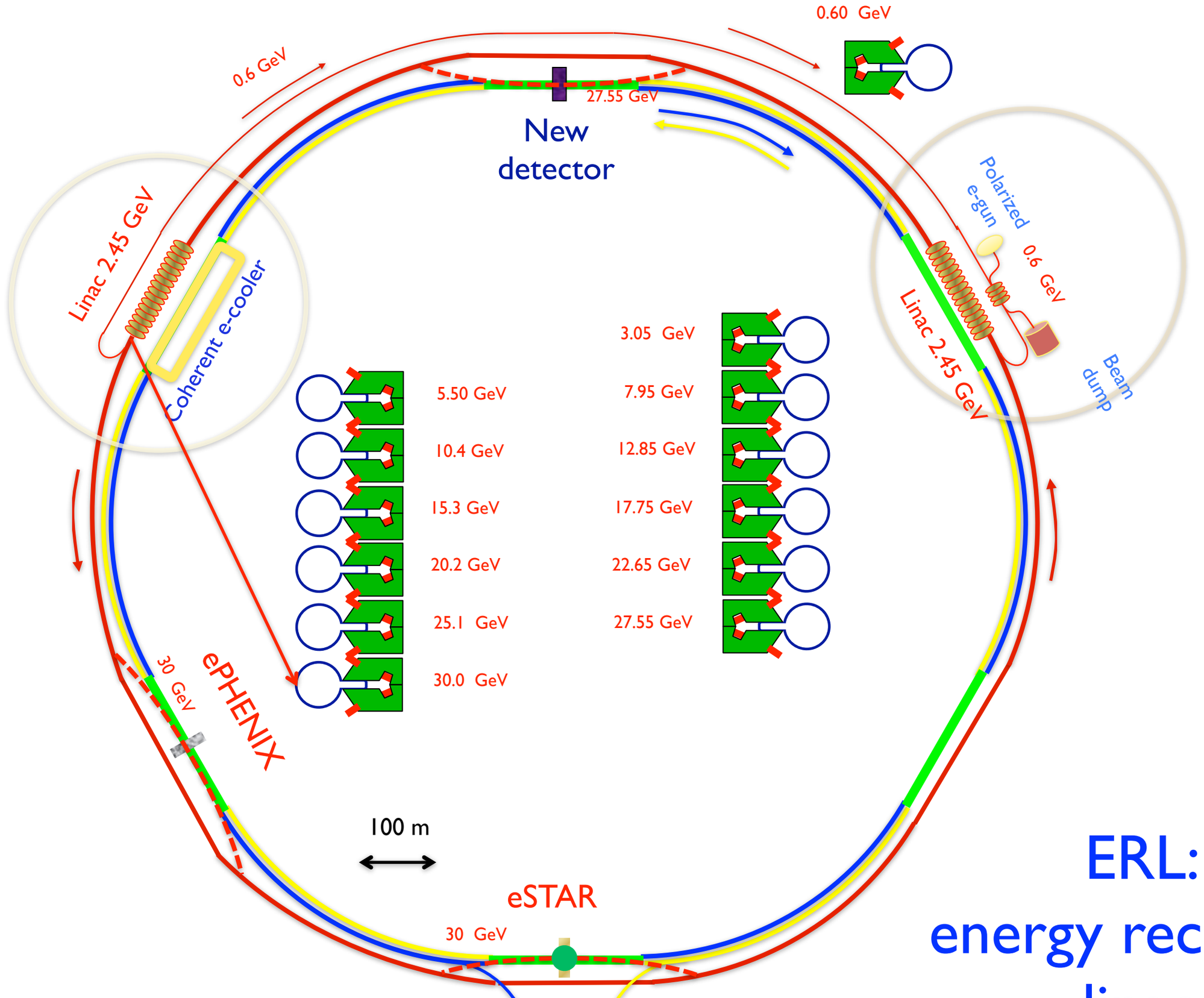


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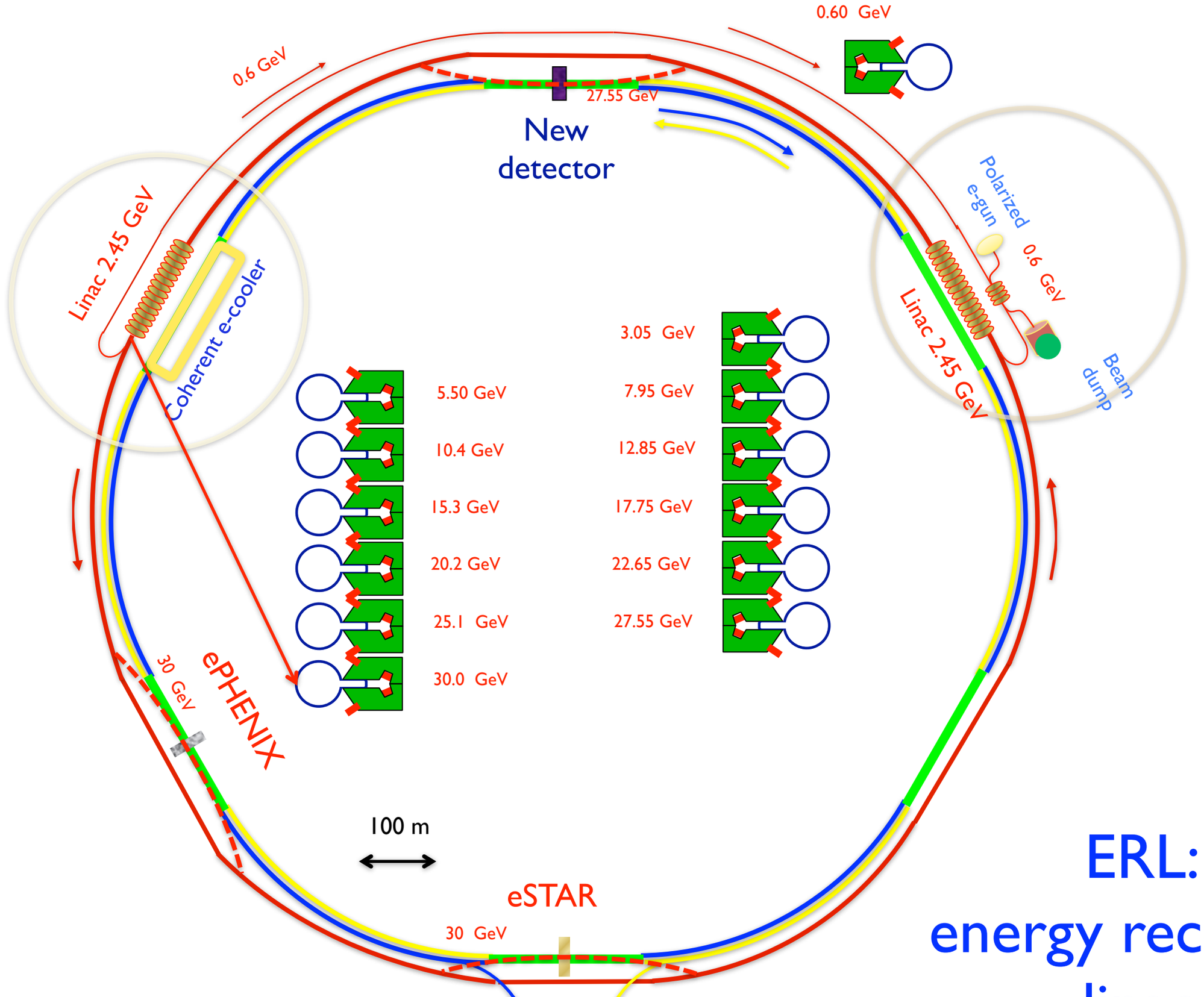


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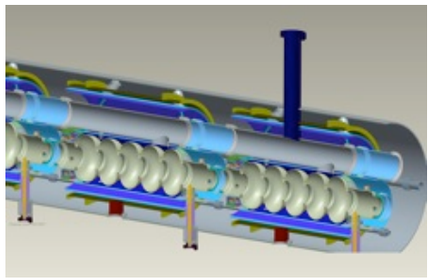
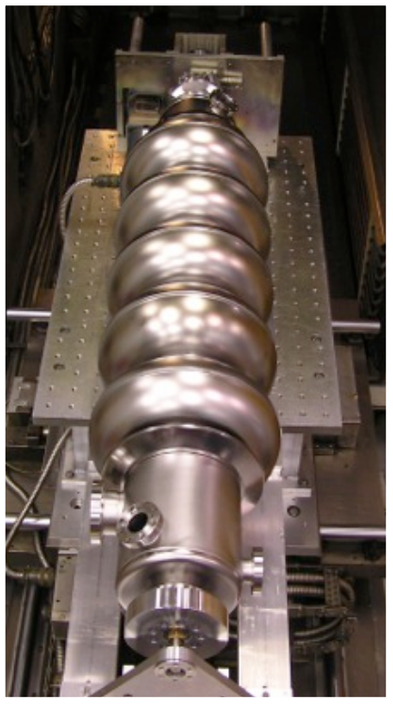
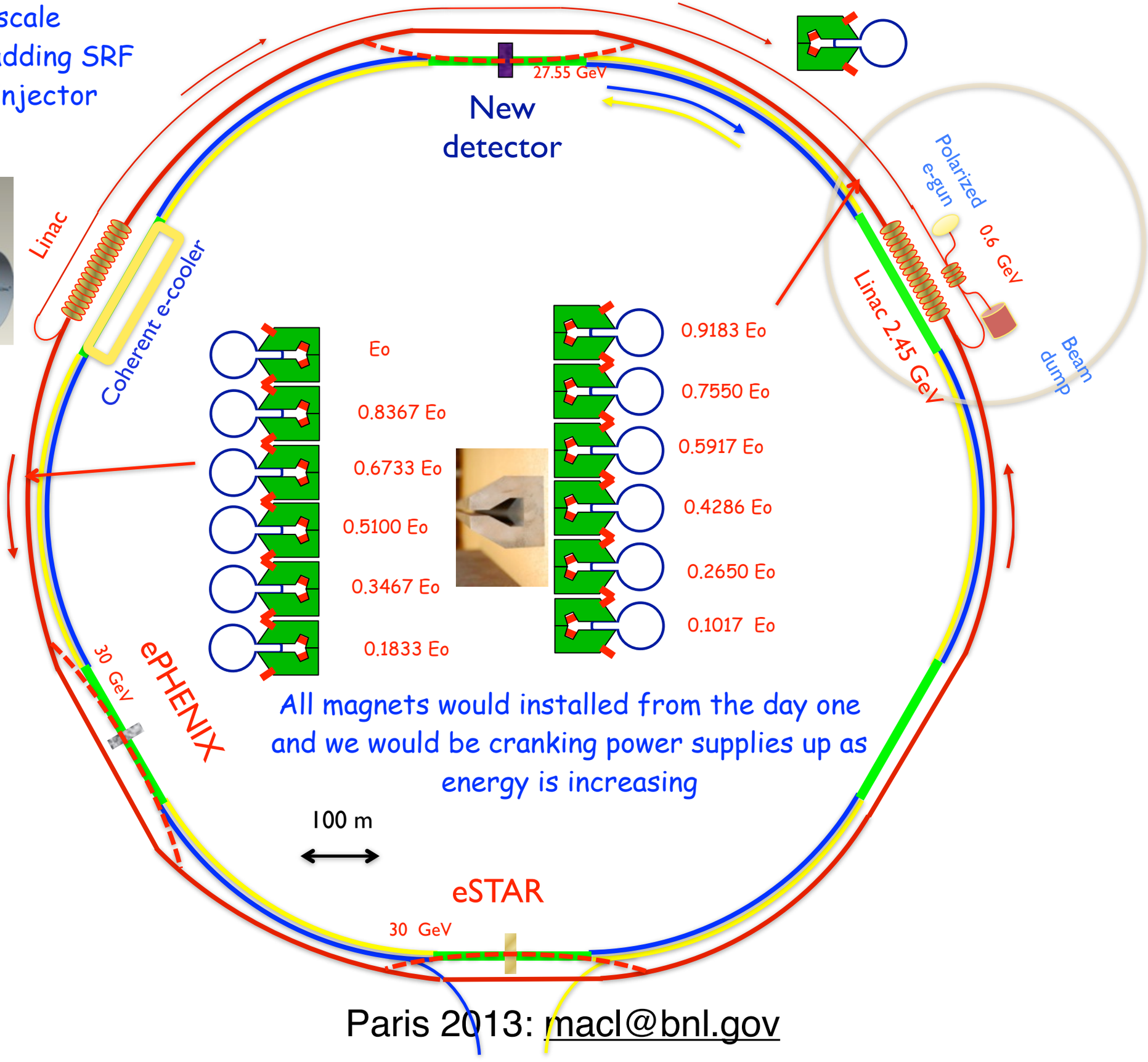
# Staging of eRHIC: $E_e$: 5 to 30 GeV

All energies scale proportionally by adding SRF cavities to the injector





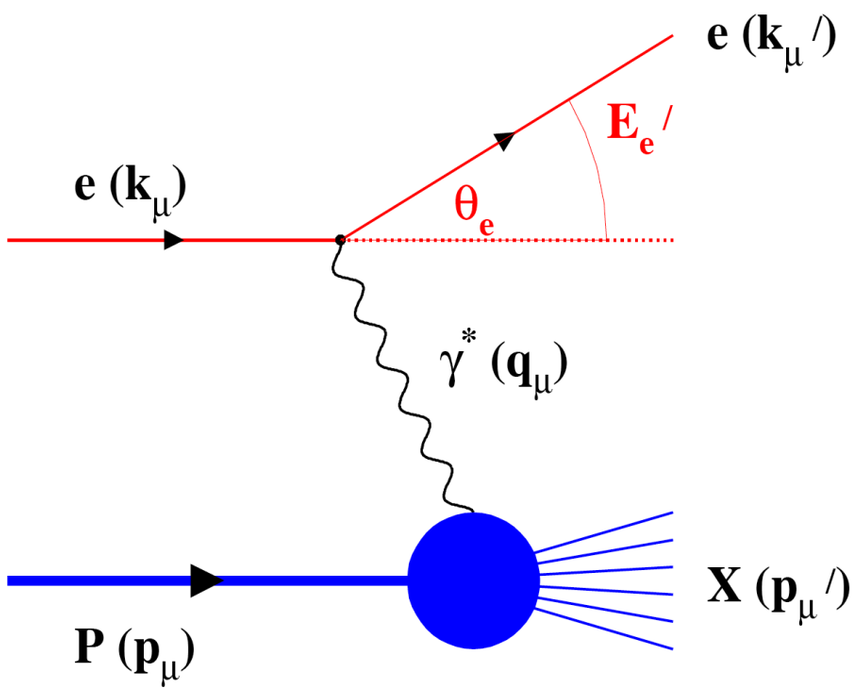



| E/Eo |
|---|
| 0.0200 |
| 0.1017 |
| 0.1833 |
| 0.2650 |
| 0.3467 |
| 0.4283 |
| 0.5100 |
| 0.5917 |
| 0.6733 |
| 0.7550 |
| 0.8367 |
| 0.9183 |
| 1.0000 |

All magnets would installed from the day one and we would be cranking power supplies up as energy is increasing

# DIS Kinematics

e(k) + p(p) → e(k') +X(px)




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

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

Measure of resolution power or "Virtuality"

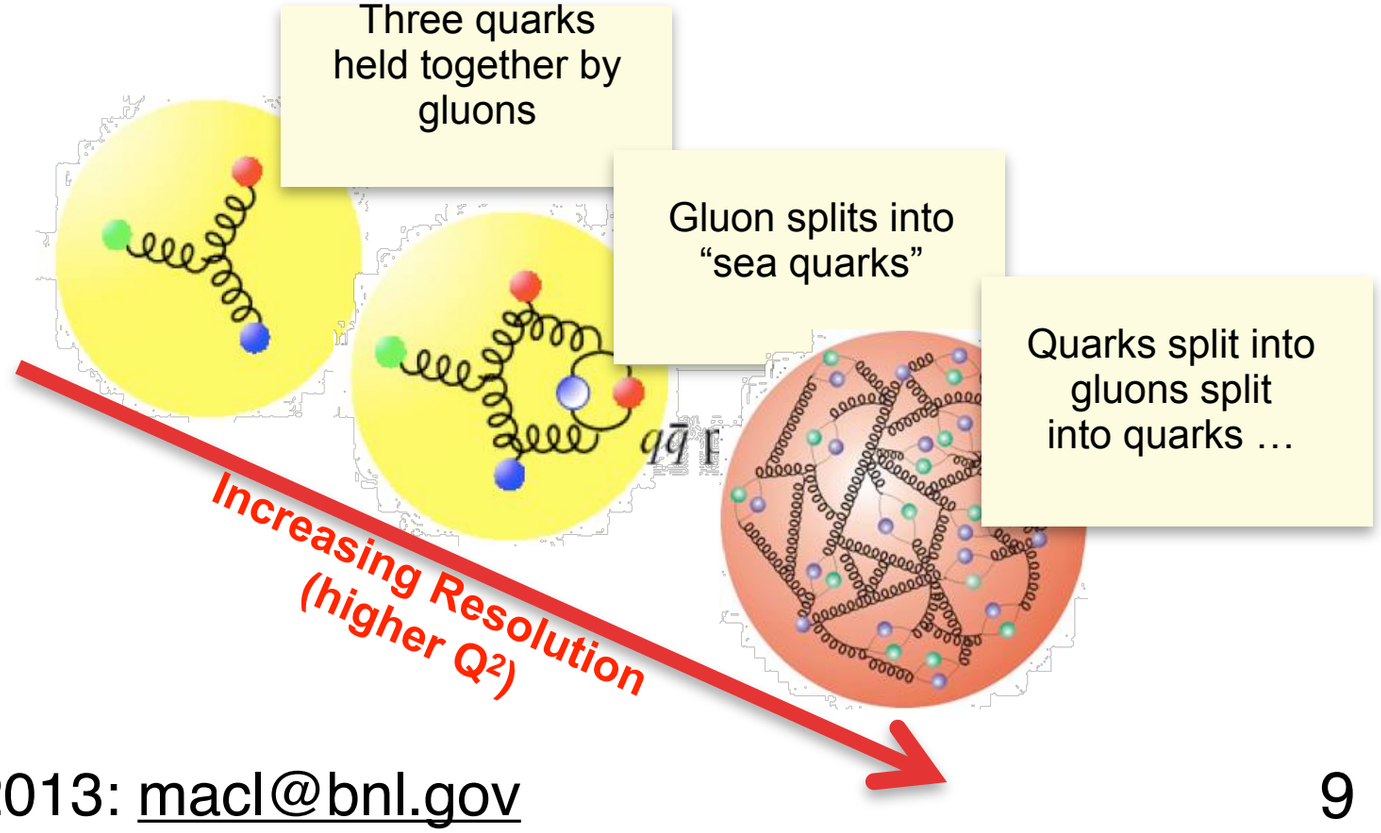
$$y = \frac{pq}{pk} = 1 - \frac{E_{e'}}{E_e} cos^2(\frac{\theta'_e}{2})$$

Measure of inelasticity

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

Measure of momentum fraction of struck quark

Important to note that in order to have different y for the same x and $Q^2$, need to change the beam energies

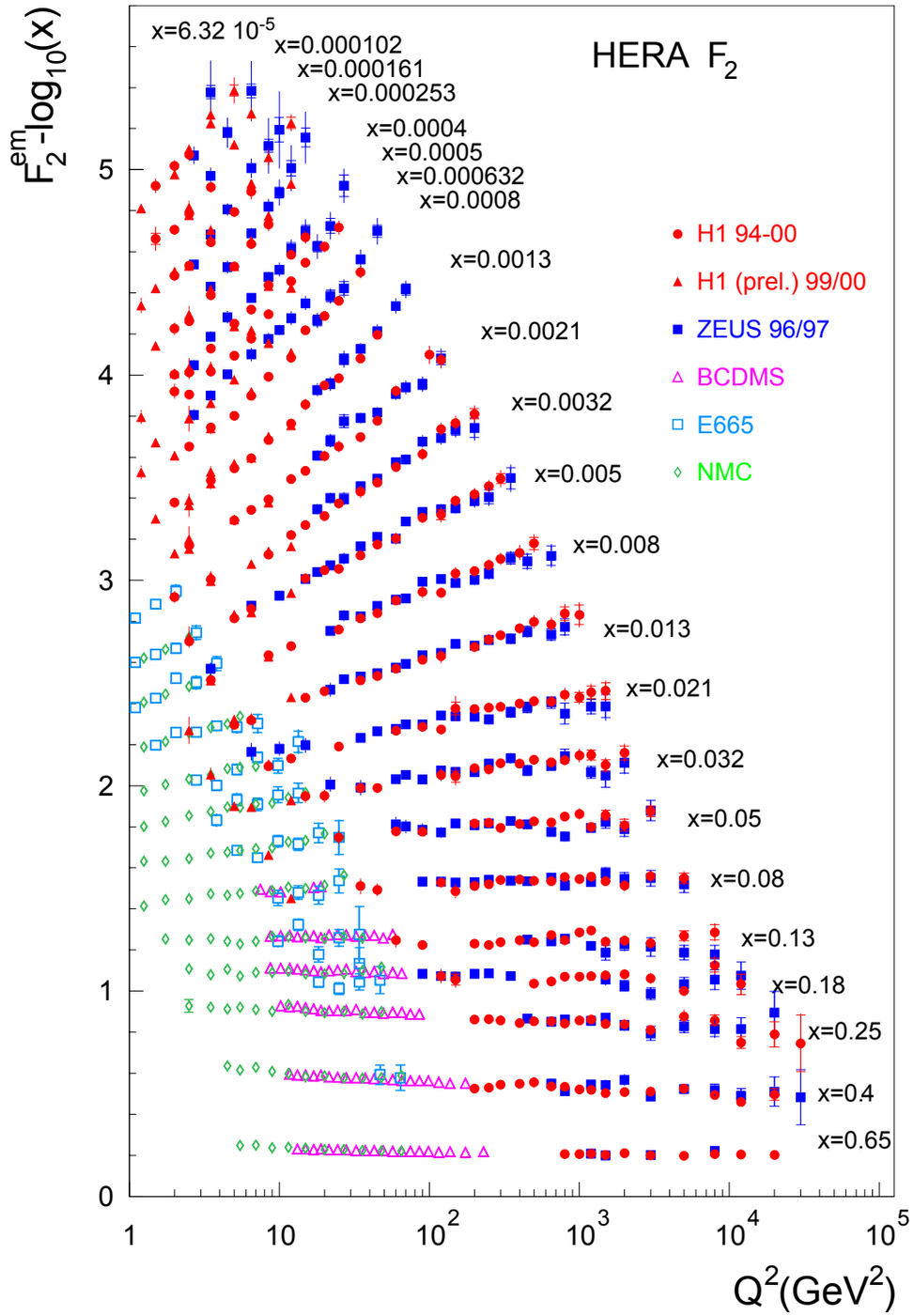


# What did we learn from e+p collisions at HERA?

$$\sigma_r(x,Q^2) = F_2^A(x,Q^2) - \frac{y^2}{Y+} F_L^A(x,Q^2)$$

**quark+anti-quark momentum distributions**

**gluon momentum distribution**



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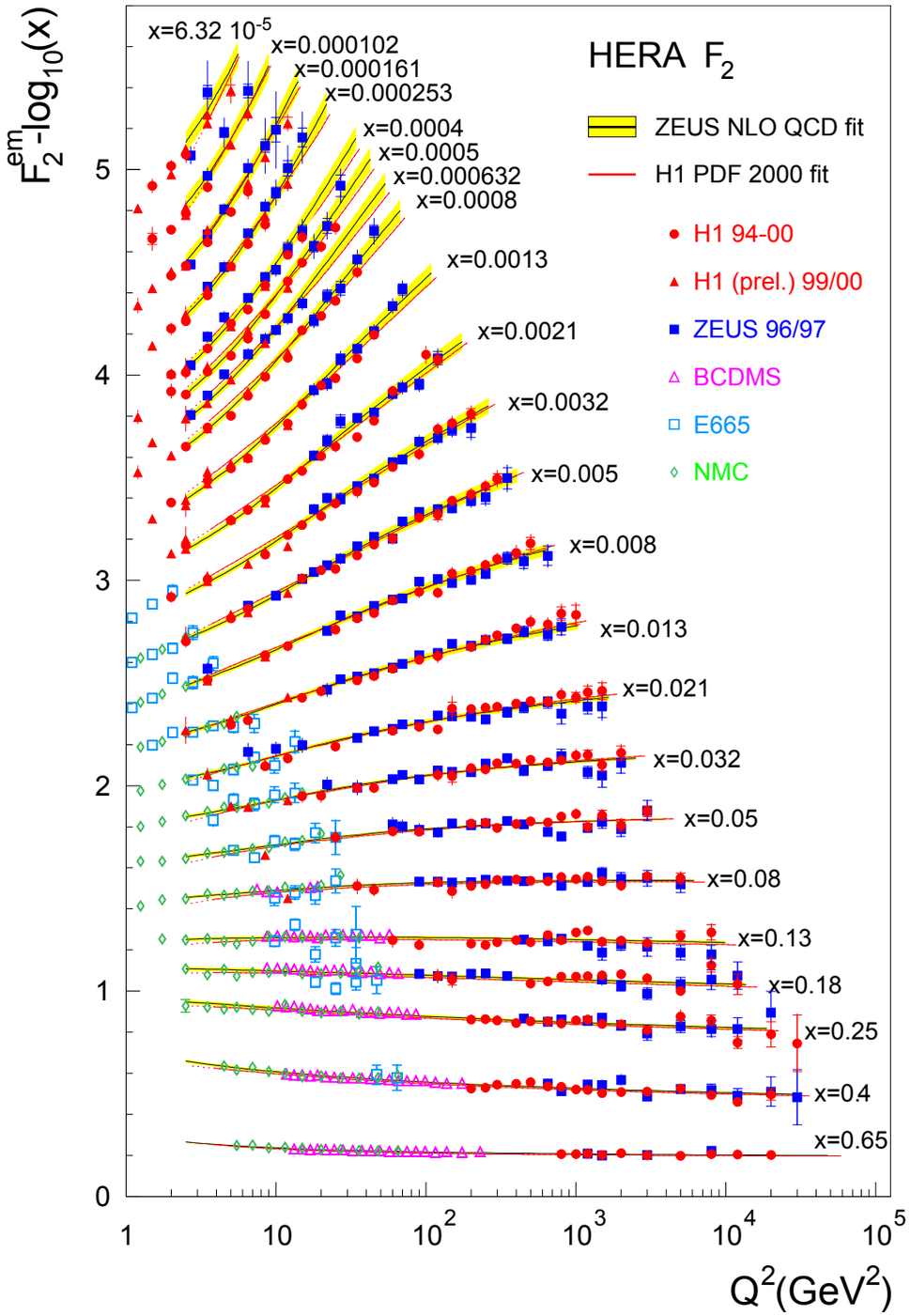


Scaling violation: $dF_2/d\ln Q^2$ and linear DGLAP Evolution $\Rightarrow G(x,Q^2)$

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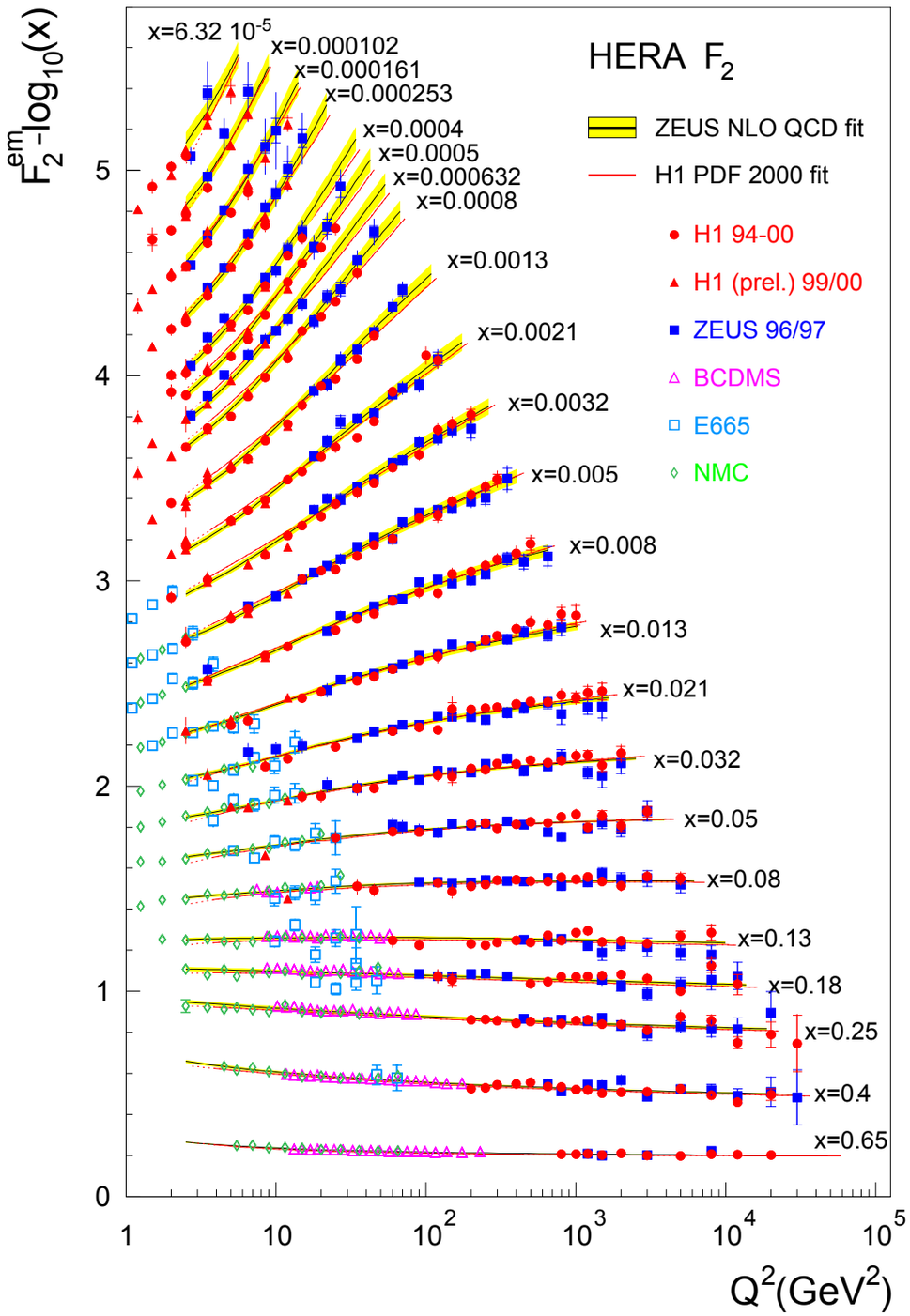


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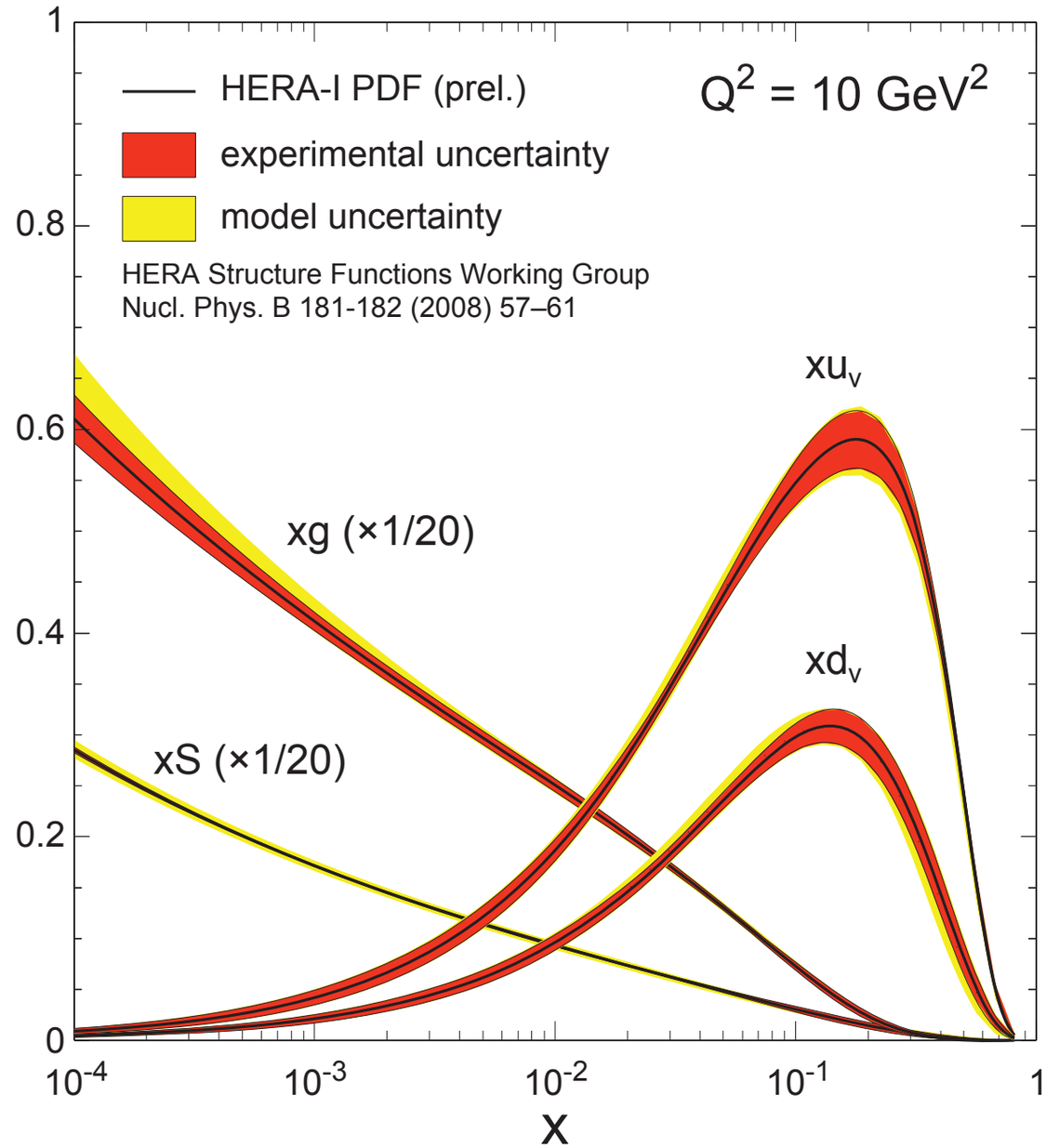

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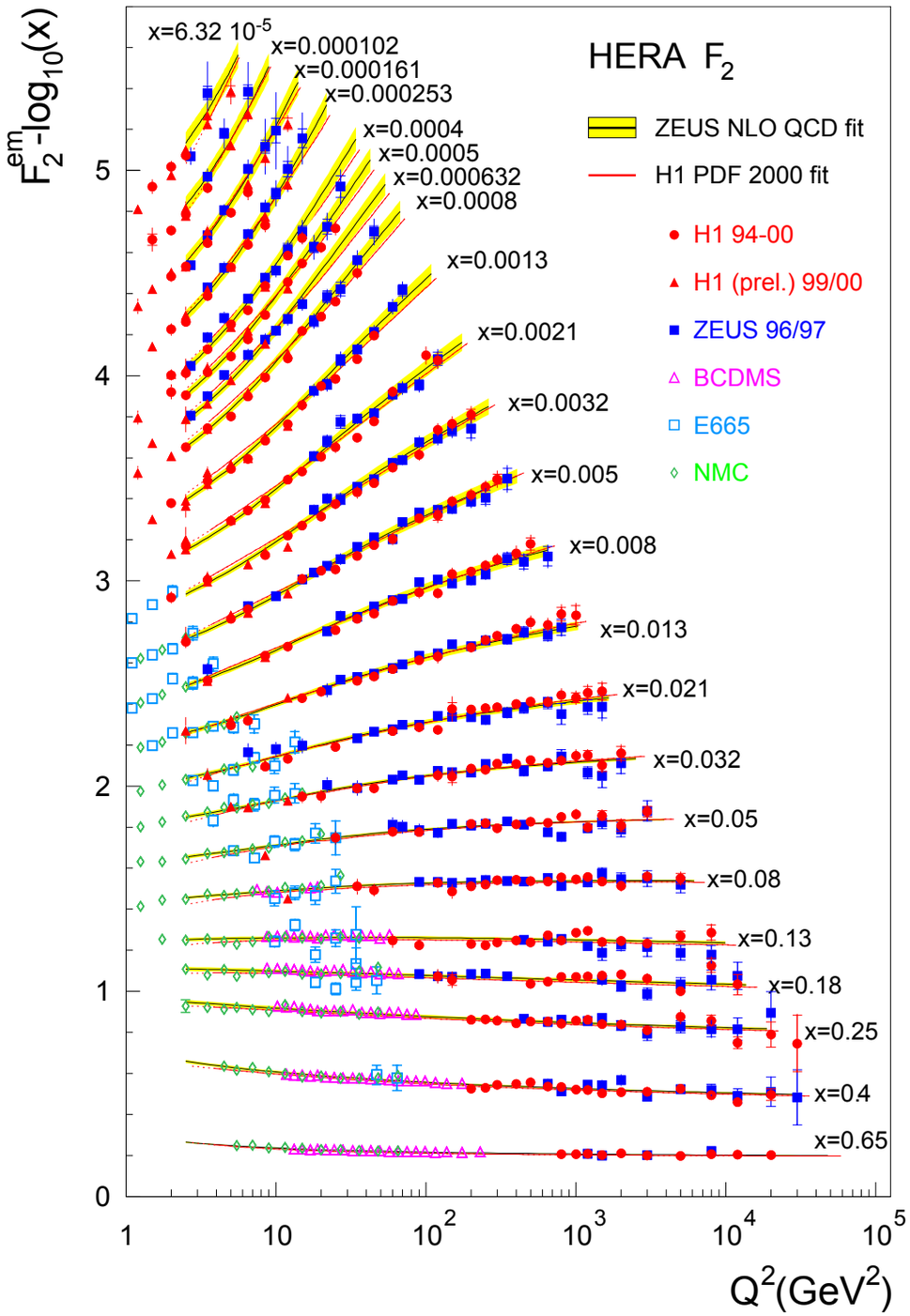


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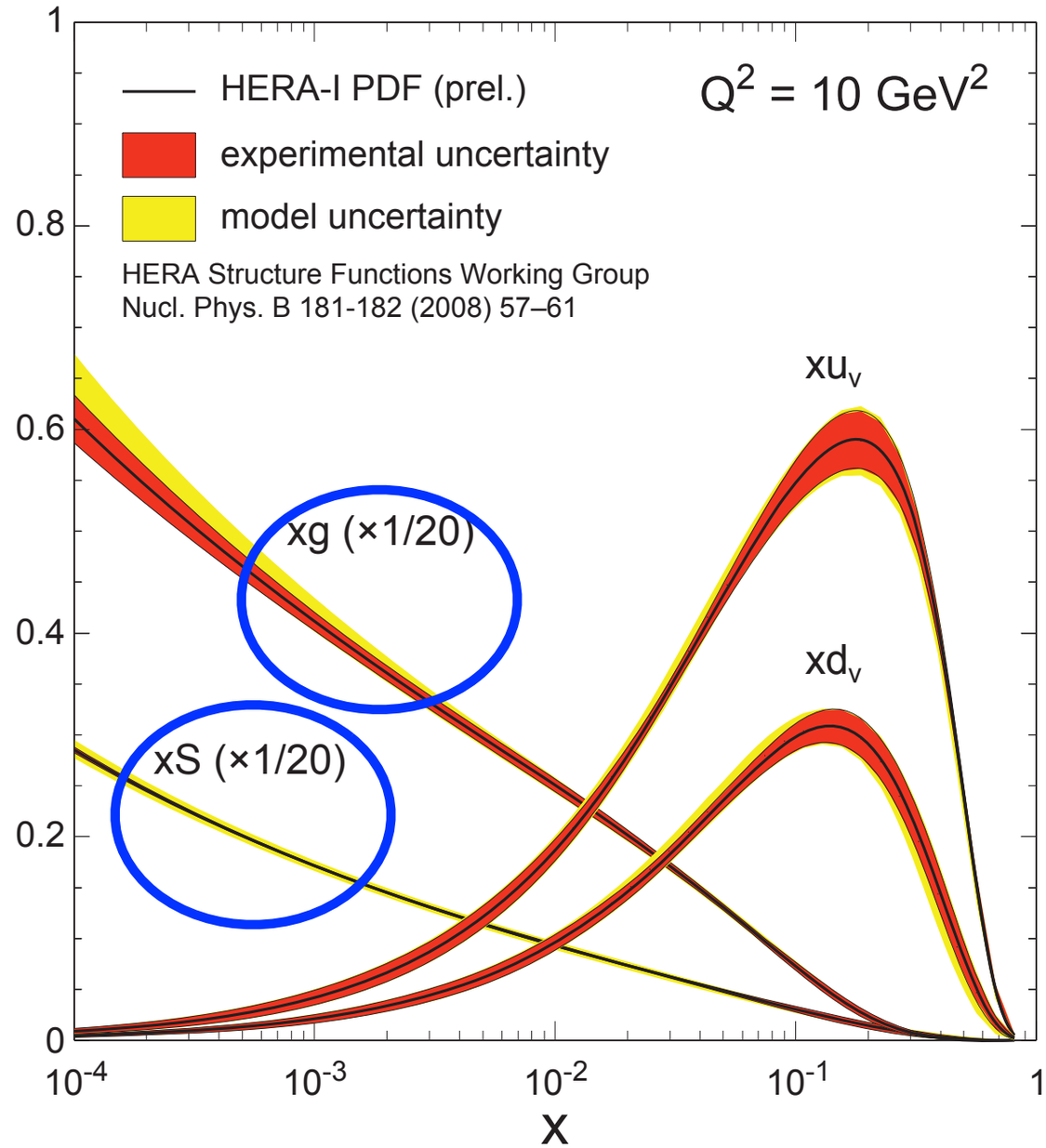

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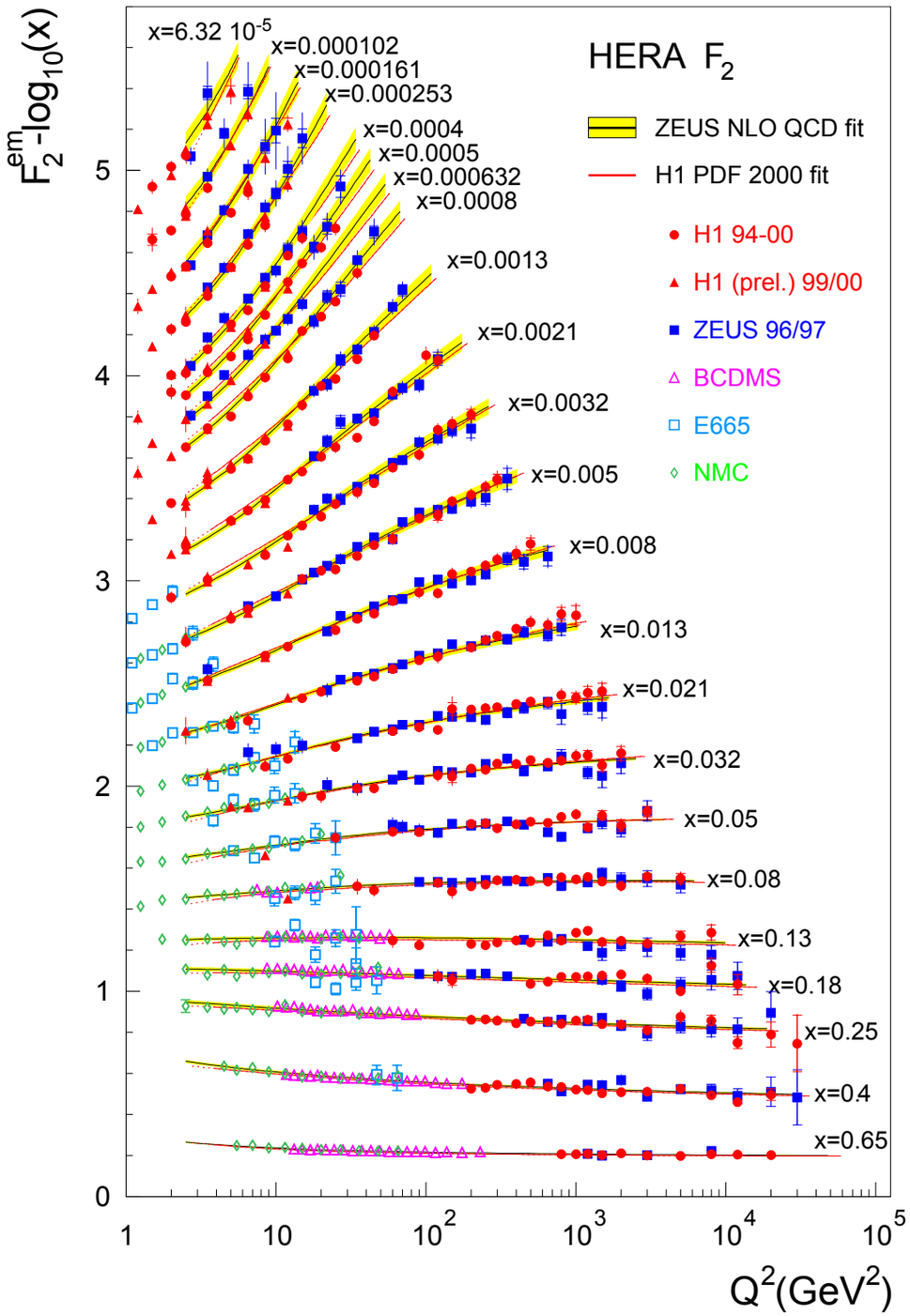


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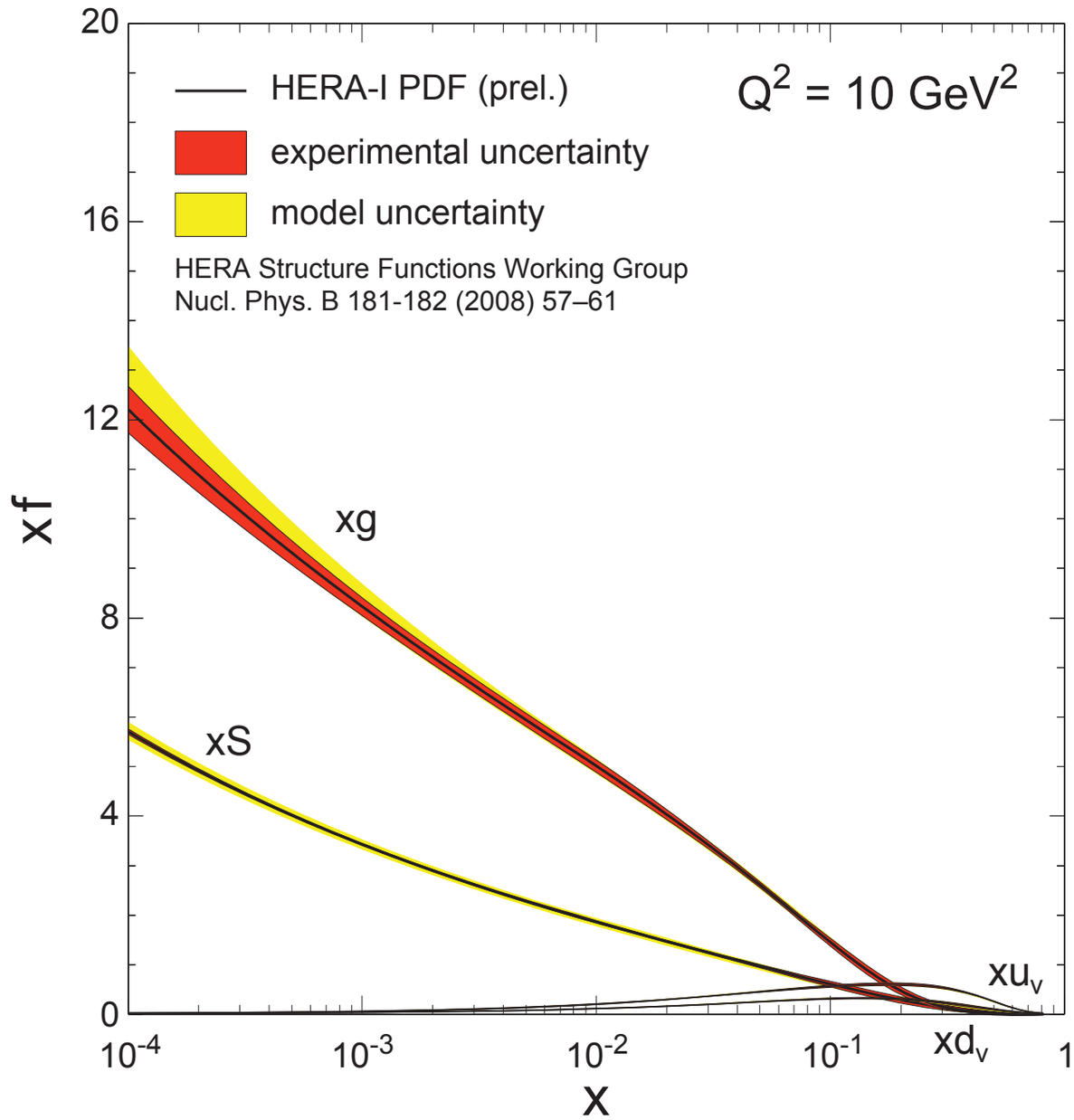
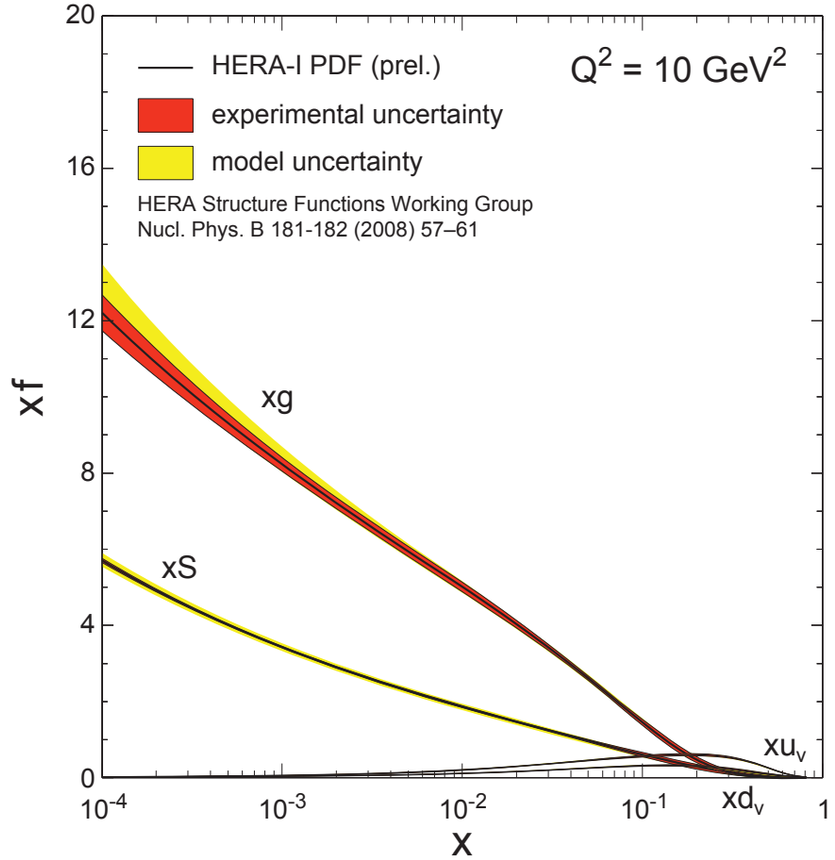
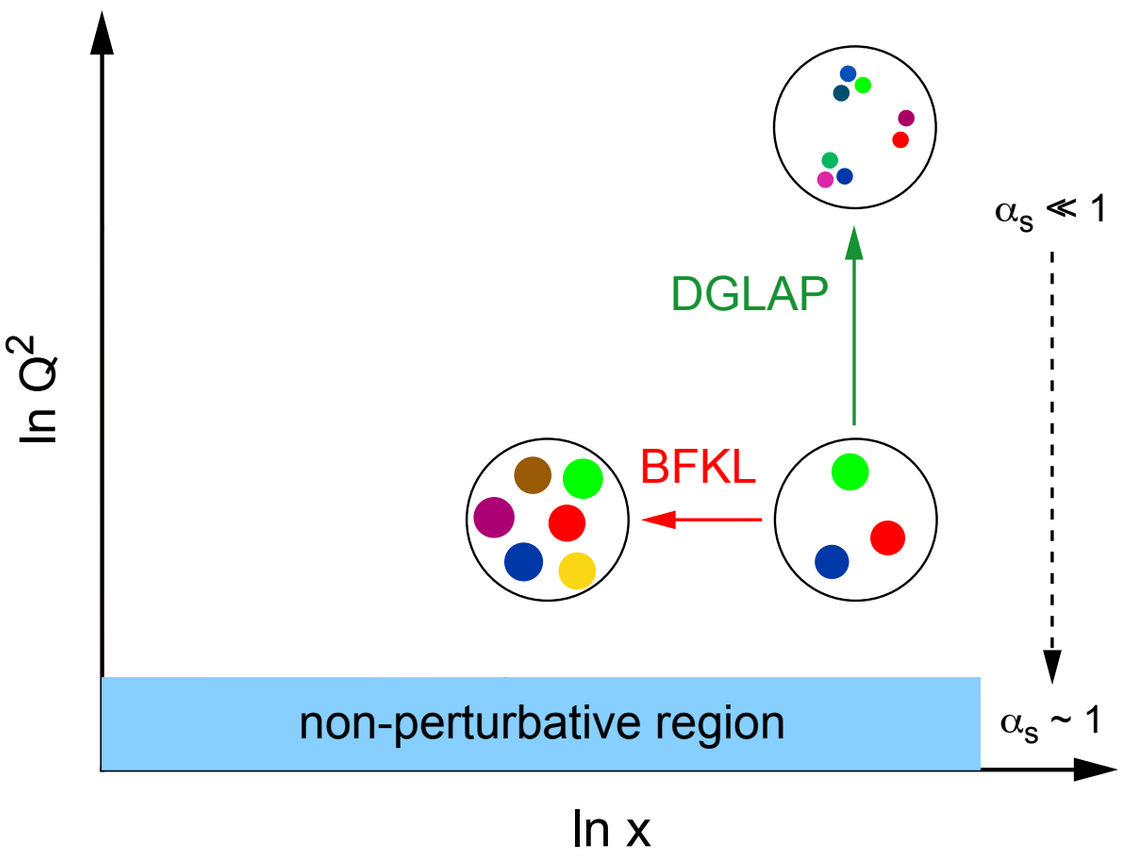


# The structure of matter at small-x

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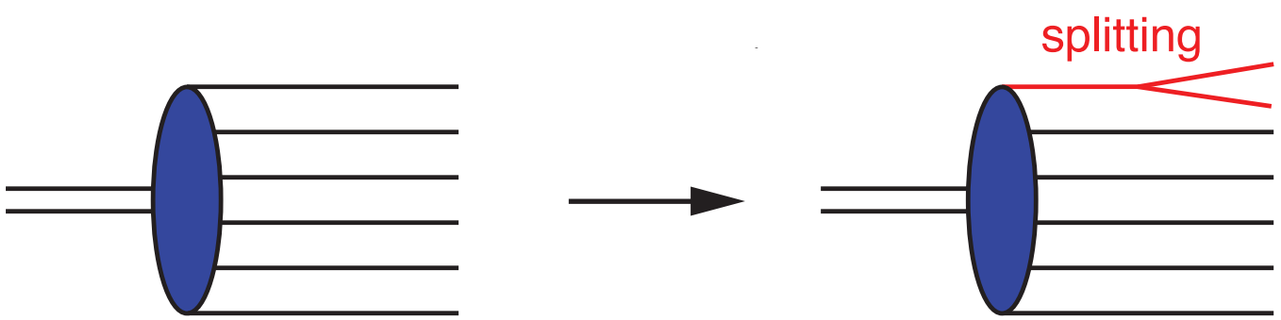
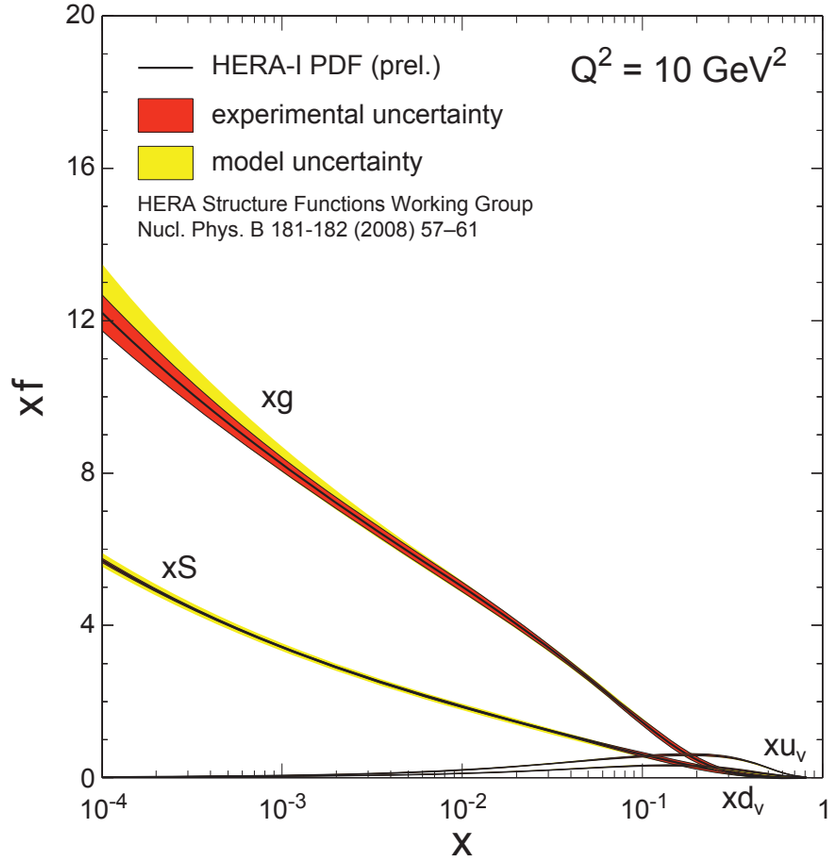
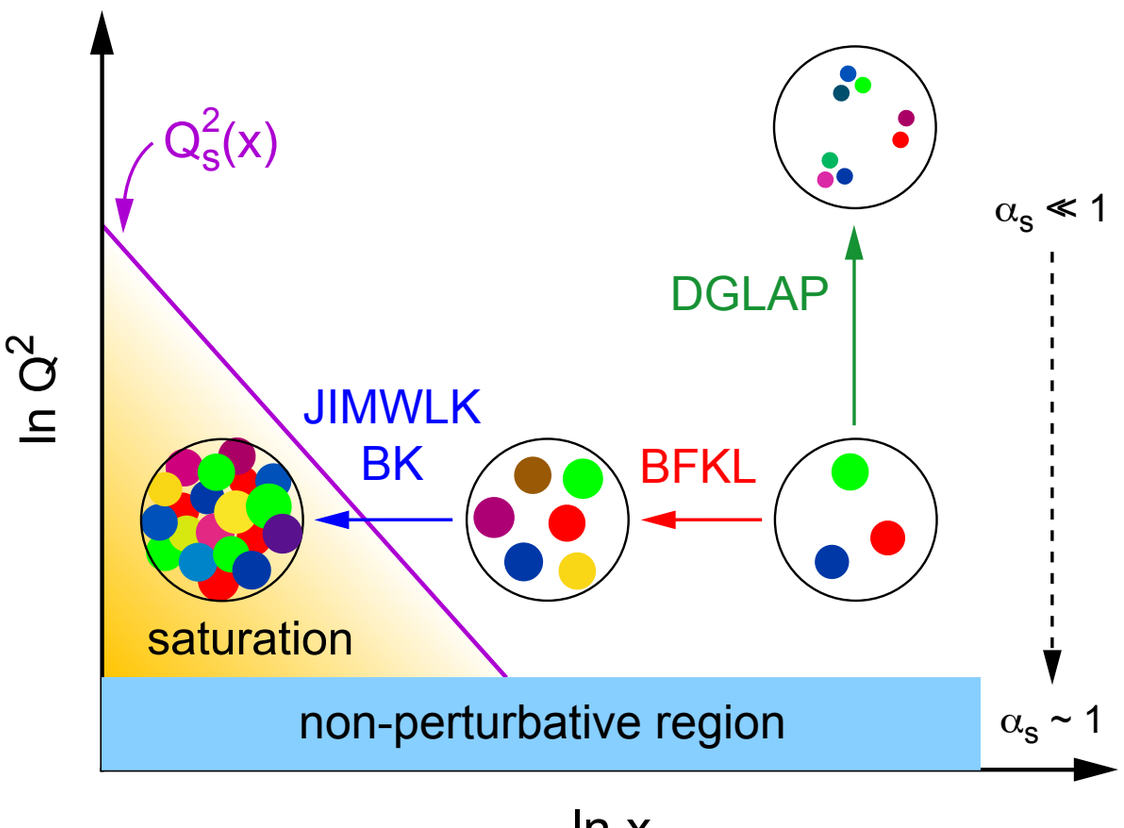


# The structure of matter at small-x




- Gluons dominate the PDFs at small- to intermediate-x ($x < 0.1$)
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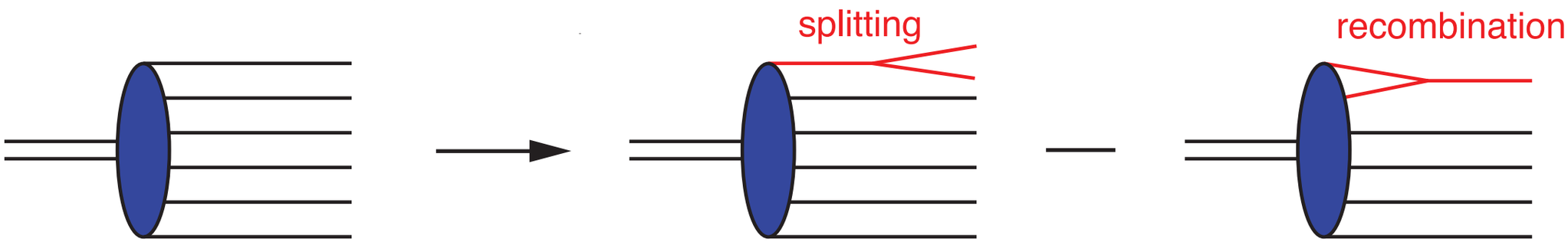
  - ➡ This rise cannot increase forever - limits on the cross-section
    - non-linear pQCD evolution equations provide a natural way to tame this growth and lead to a saturation of gluons, characterised by the saturation scale $Q^2_S(x)$



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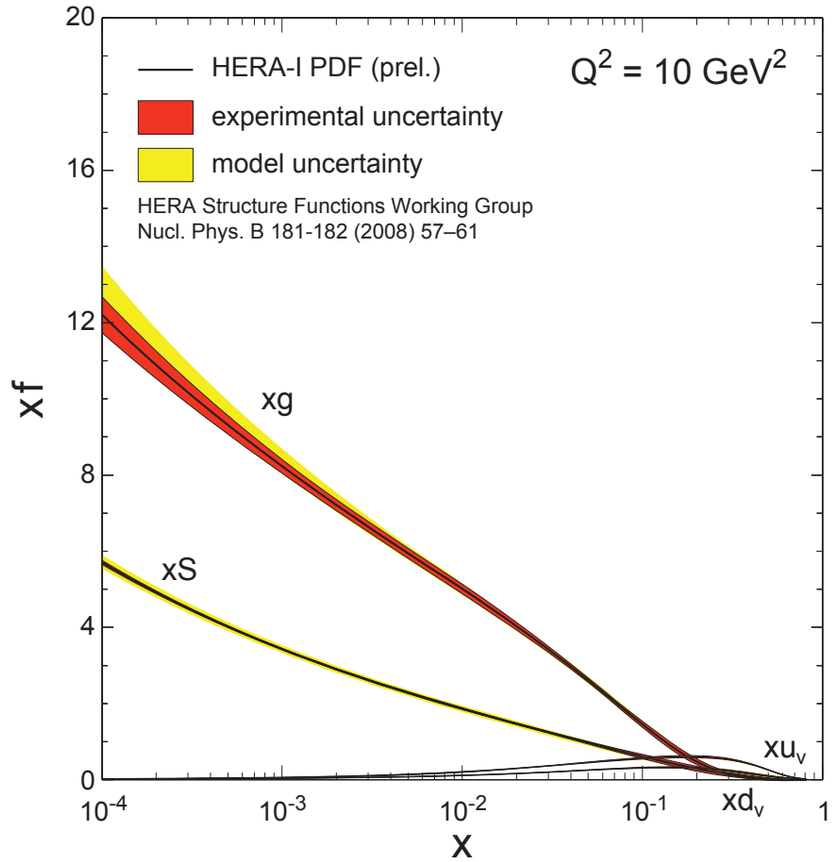


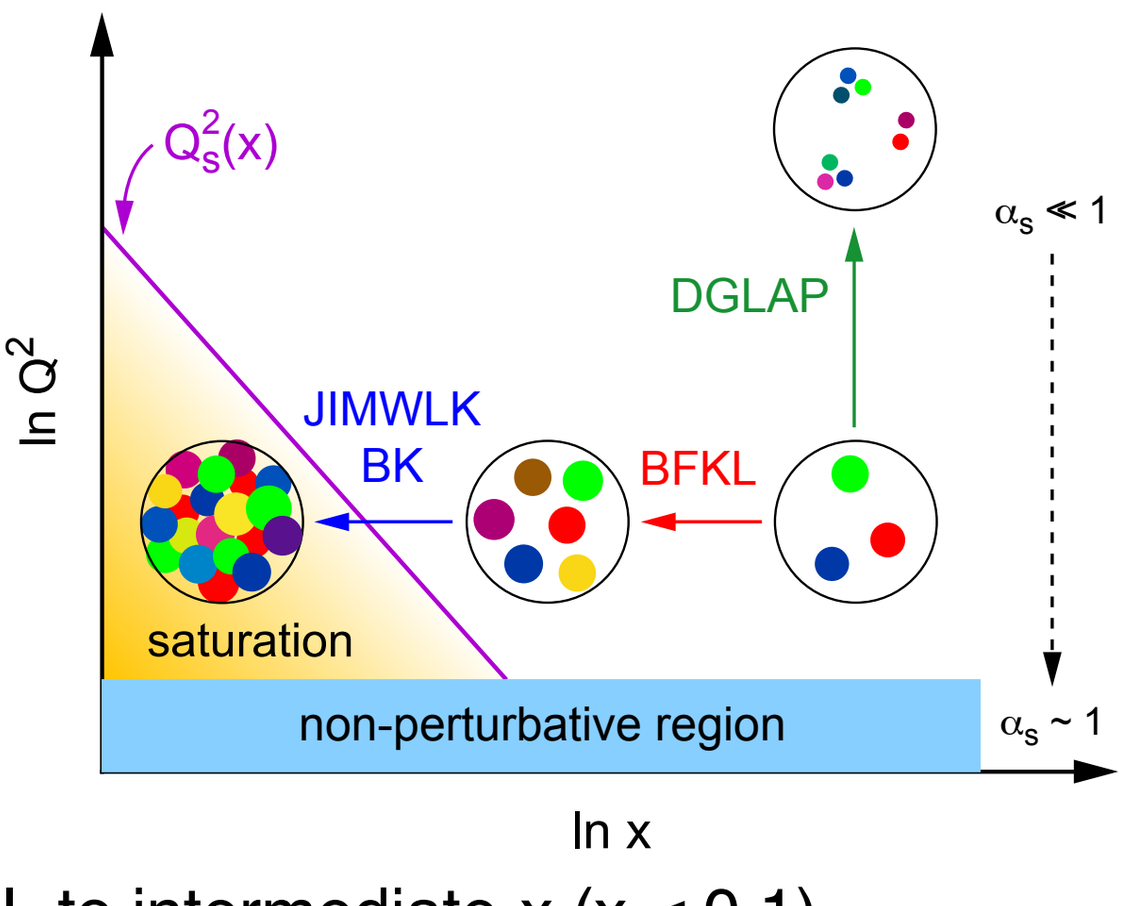


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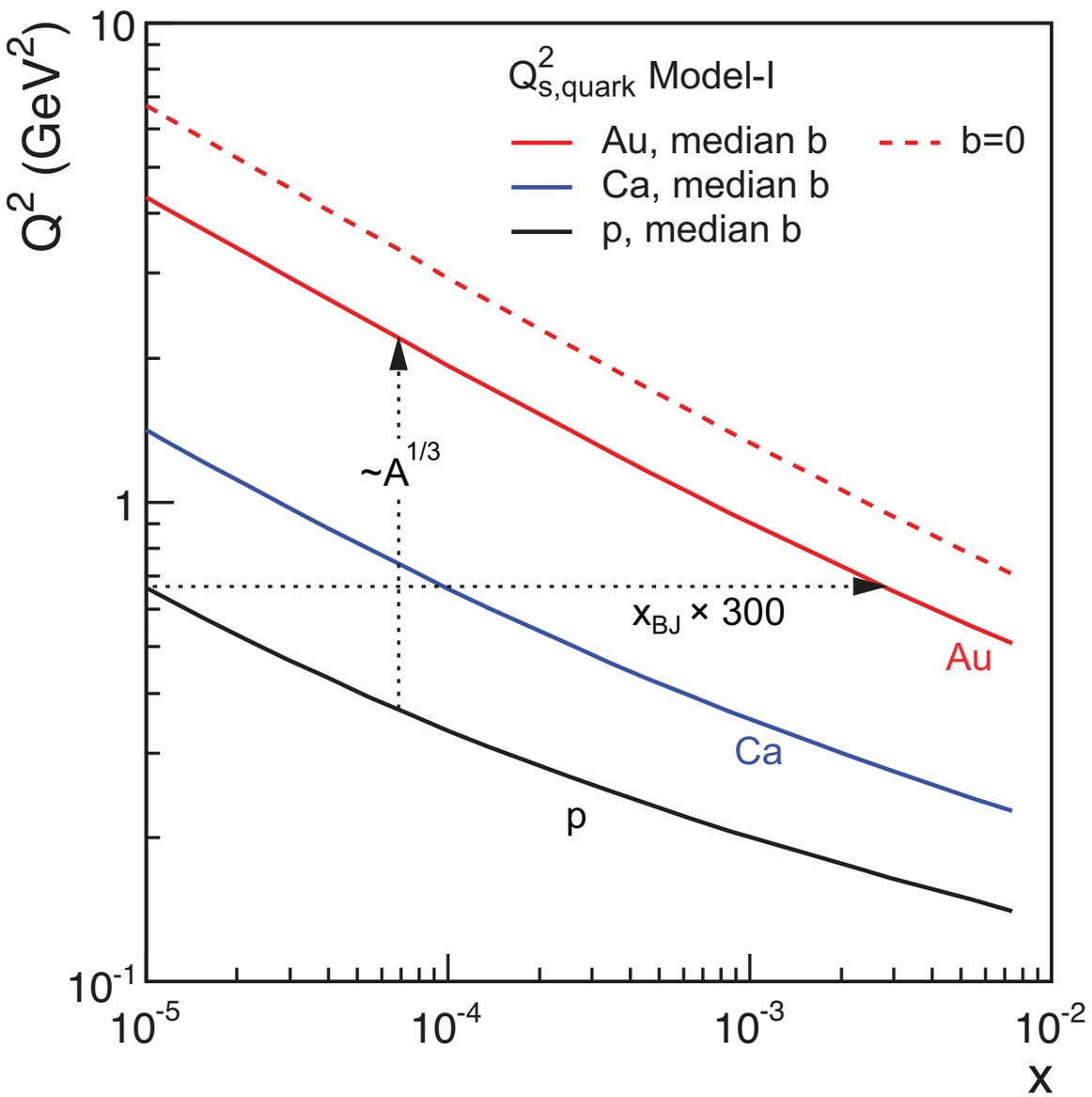
    - ▸ non-linear pQCD evolution equations provide a natural way to tame this growth and lead to a saturation of gluons, characterised by the saturation

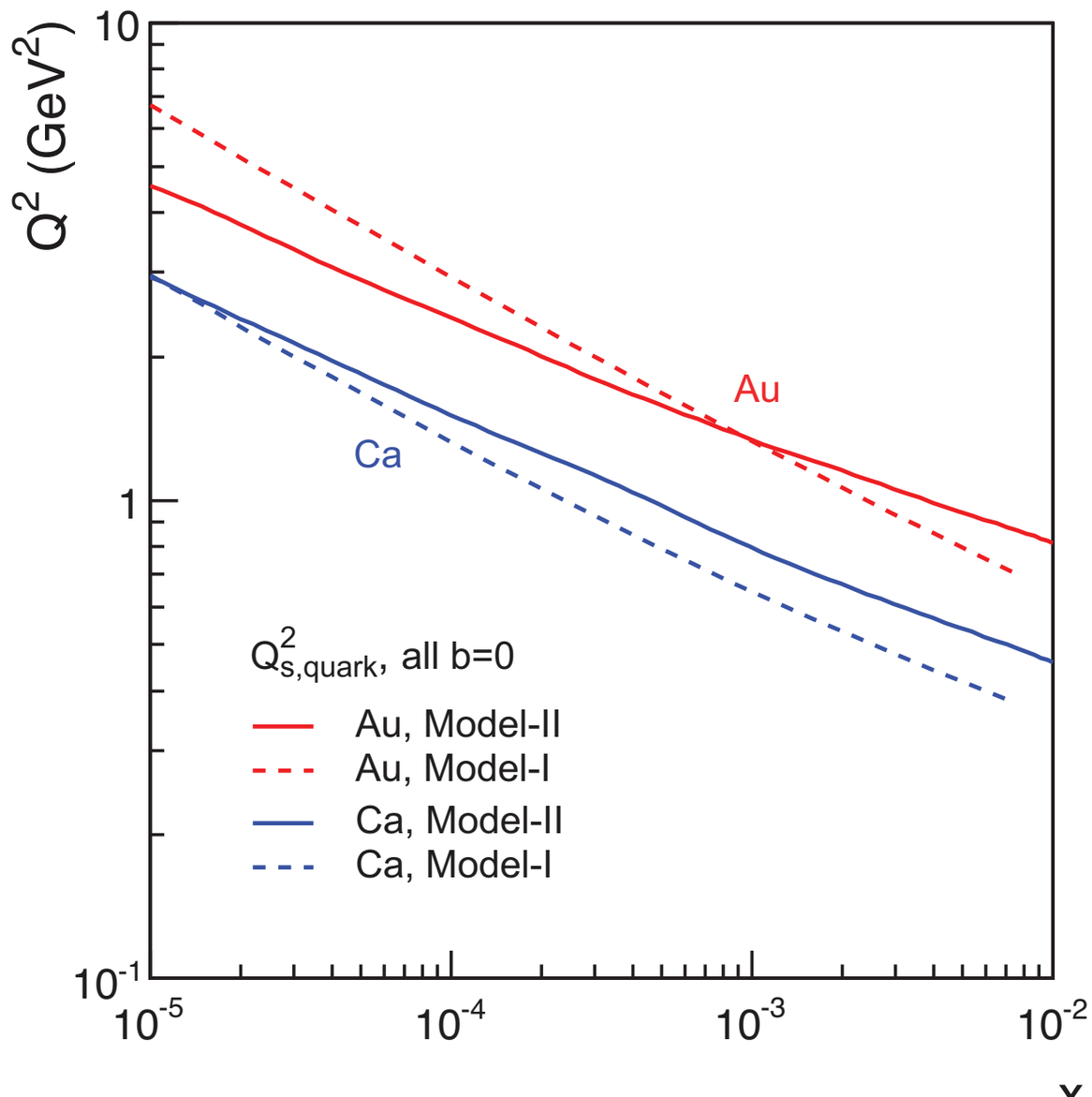
**however - saturation in the gluon density is not observed in the gluon distribution at HERA -> too small an x**

**How can this be observed at eRHIC?**

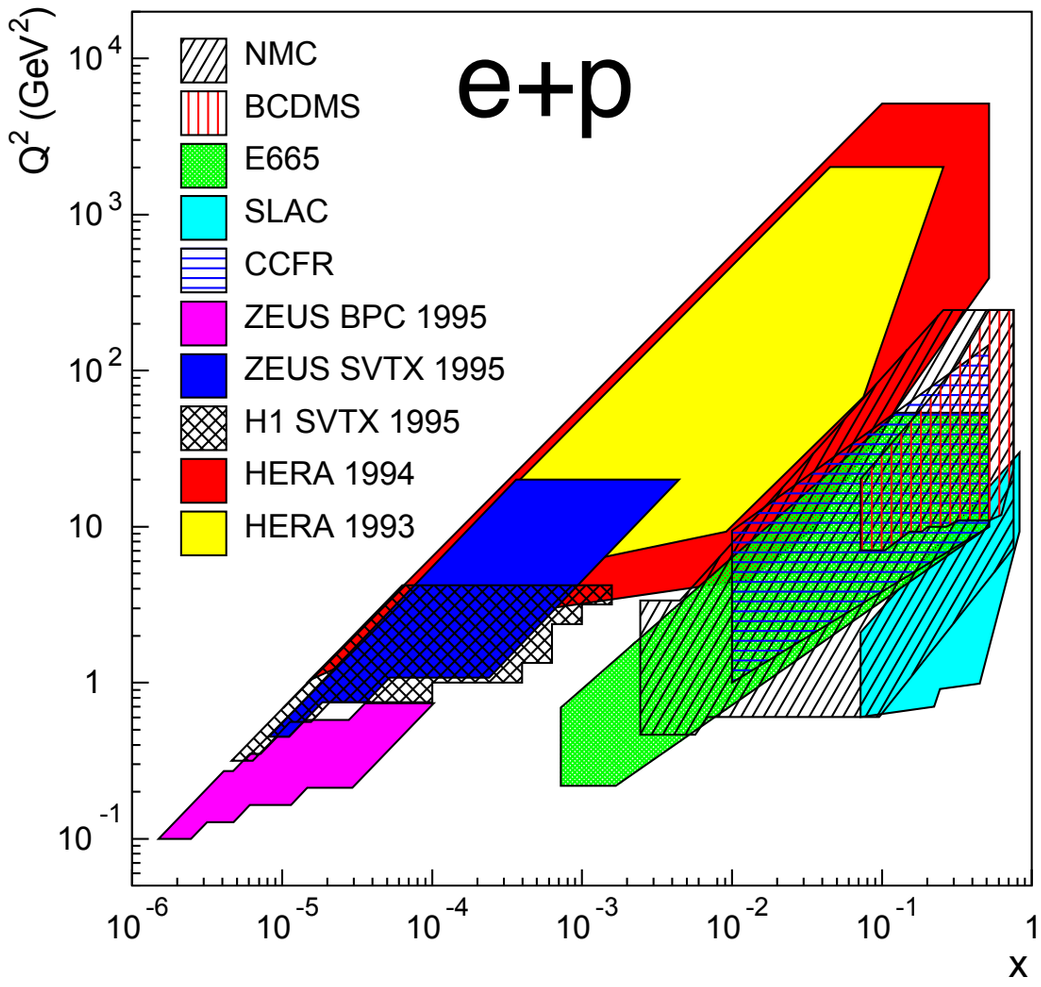
# Nuclear “oomph” effect

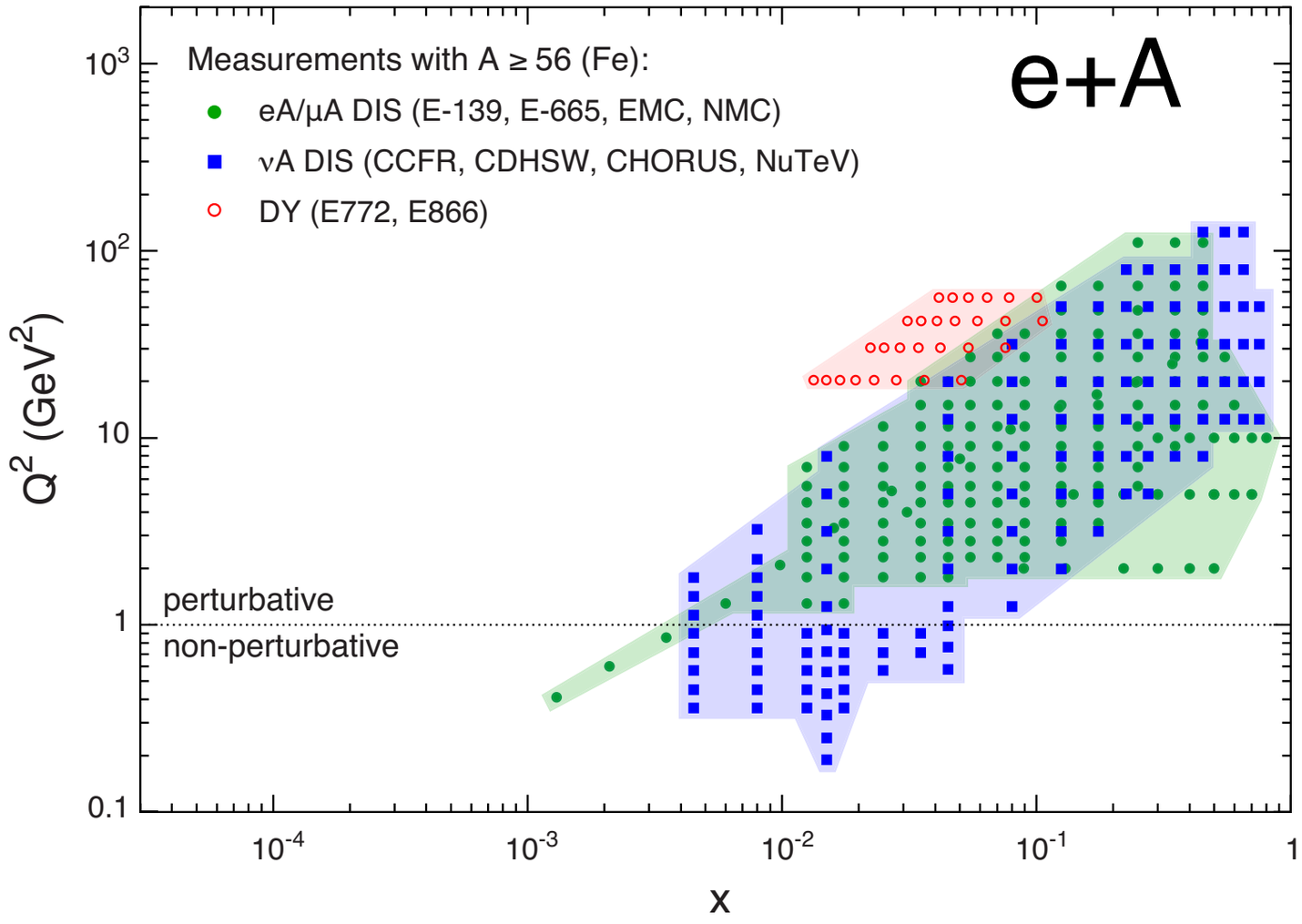
Pocket formula: $Q_s^2(x) \sim A^{1/3} \left(\frac{1}{x}\right)^{\lambda} \sim \left(\frac{A}{x}\right)^{1/3}$



# What do we know about the structure of nuclei?




- e+p data covers large part of phase space
  - ➡ low x and large $Q^2$
- e+A data only a small fraction of this (e+A was a fixed target programme at HERA)
  - ➡ high-medium x and low $Q^2$

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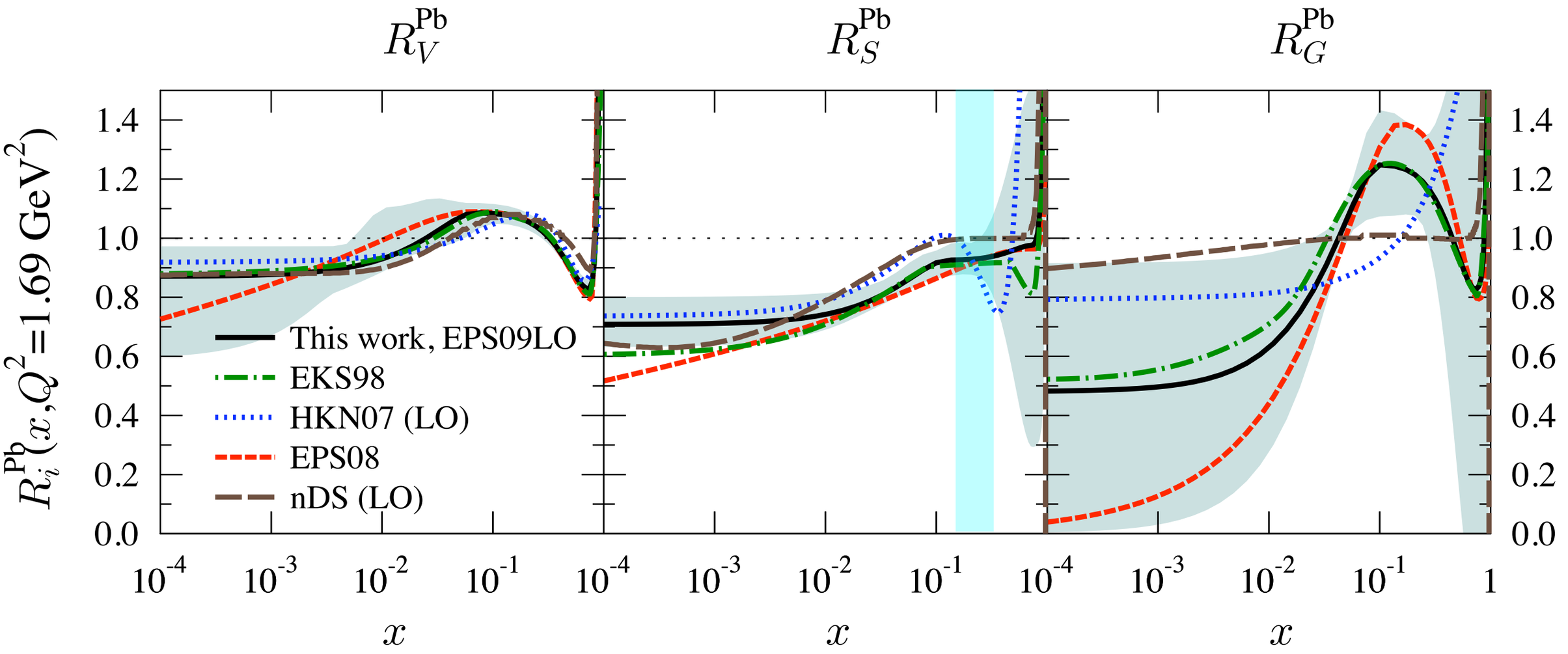


The distribution of valence and sea quarks are relatively well known in nuclei - theories agree well

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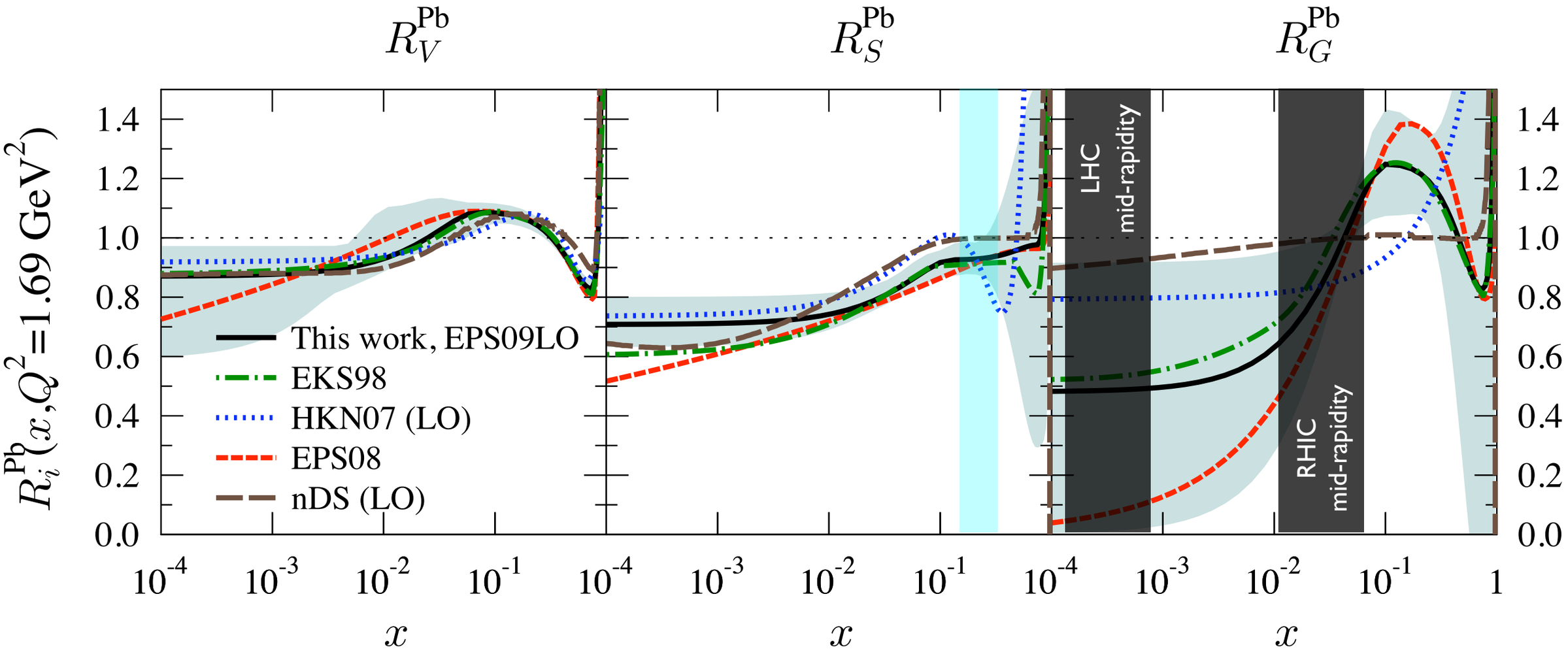


The distribution of valence and sea quarks are relatively well known in nuclei - theories agree well

Large discrepancies exist in the gluon distributions from models for mid-rapidity LHC and forward RHIC rapidities !!

# Phase-space coverage of e+A collisions for an EIC

- Existing data:
  - ➡ Low energy (fixed target)
  - ➡ Low statistics
  - ➡ Mainly light A
- EIC coverage:
  - ➡ Both “low energy” and “high energy” options extend the reach in x-$Q^2$ beyond current data
  - ➡ A coverage extended up to U
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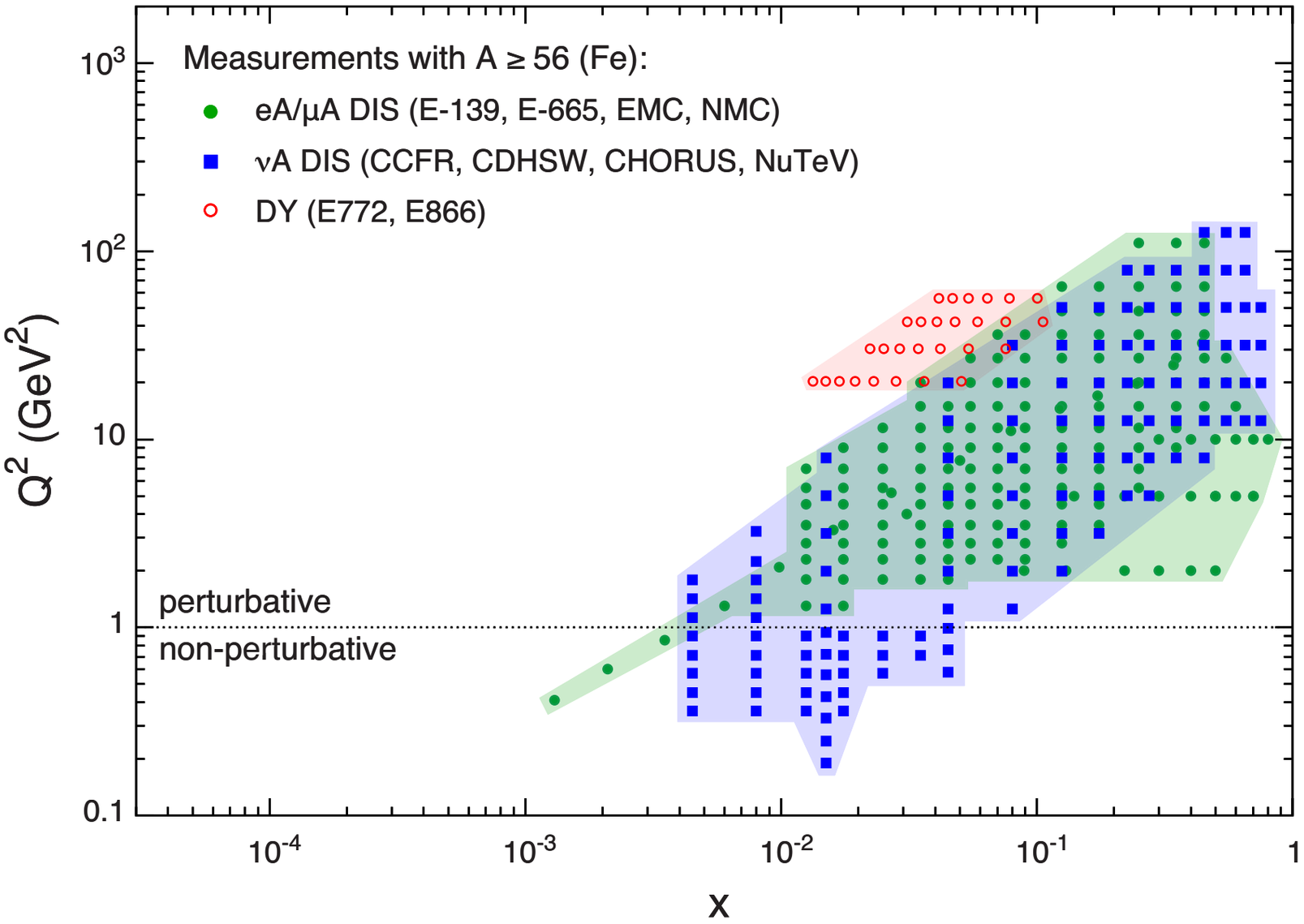

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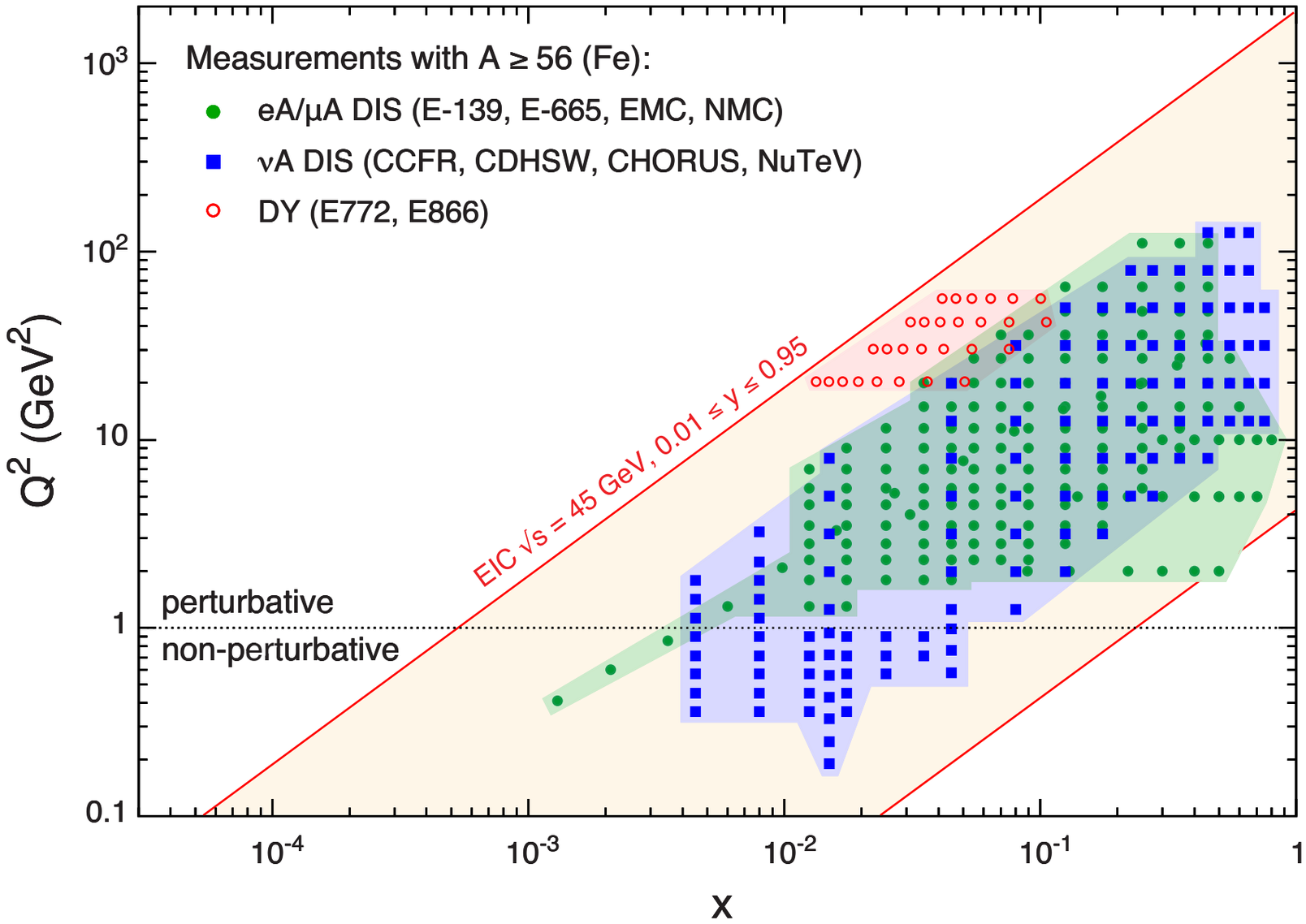

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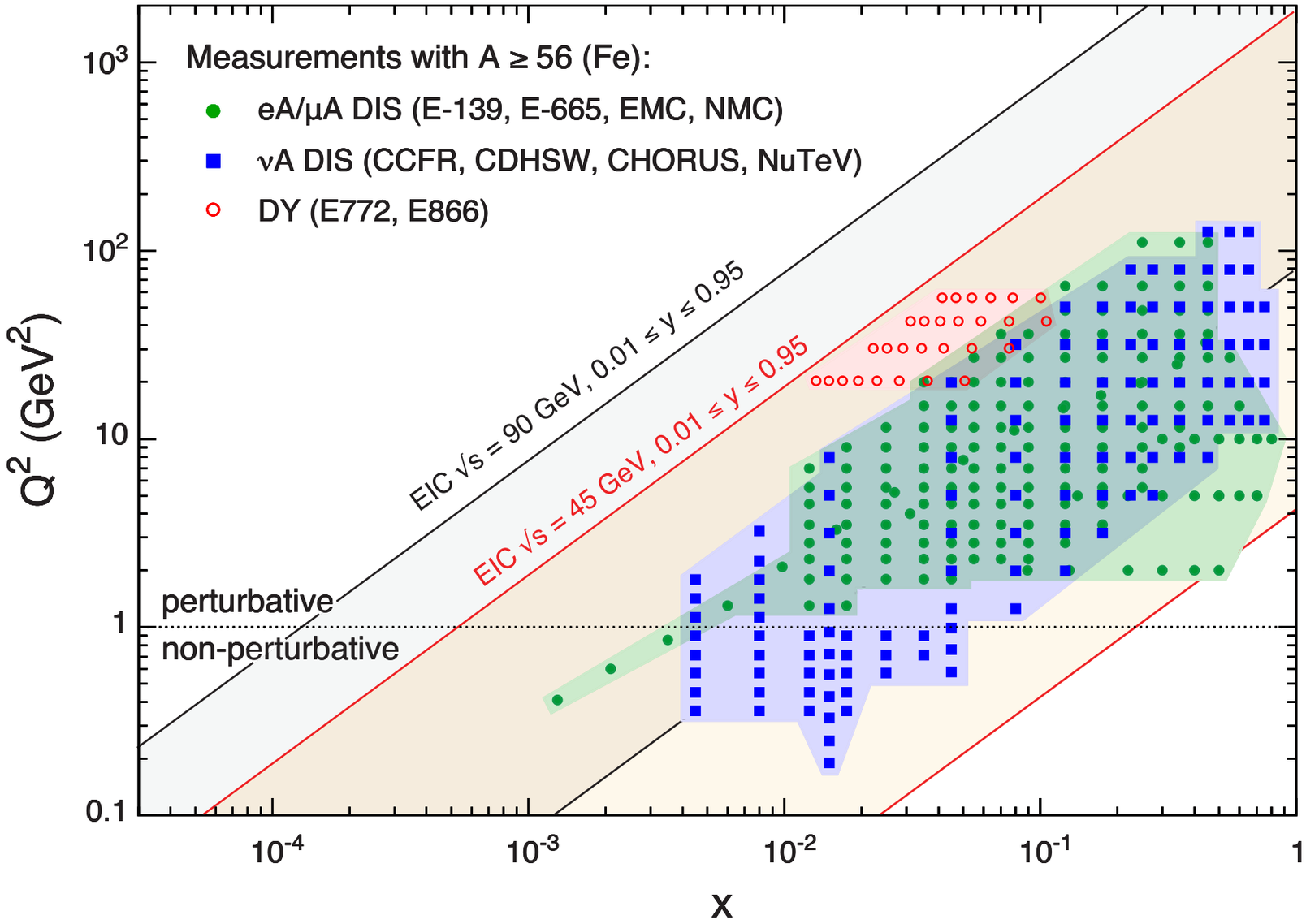

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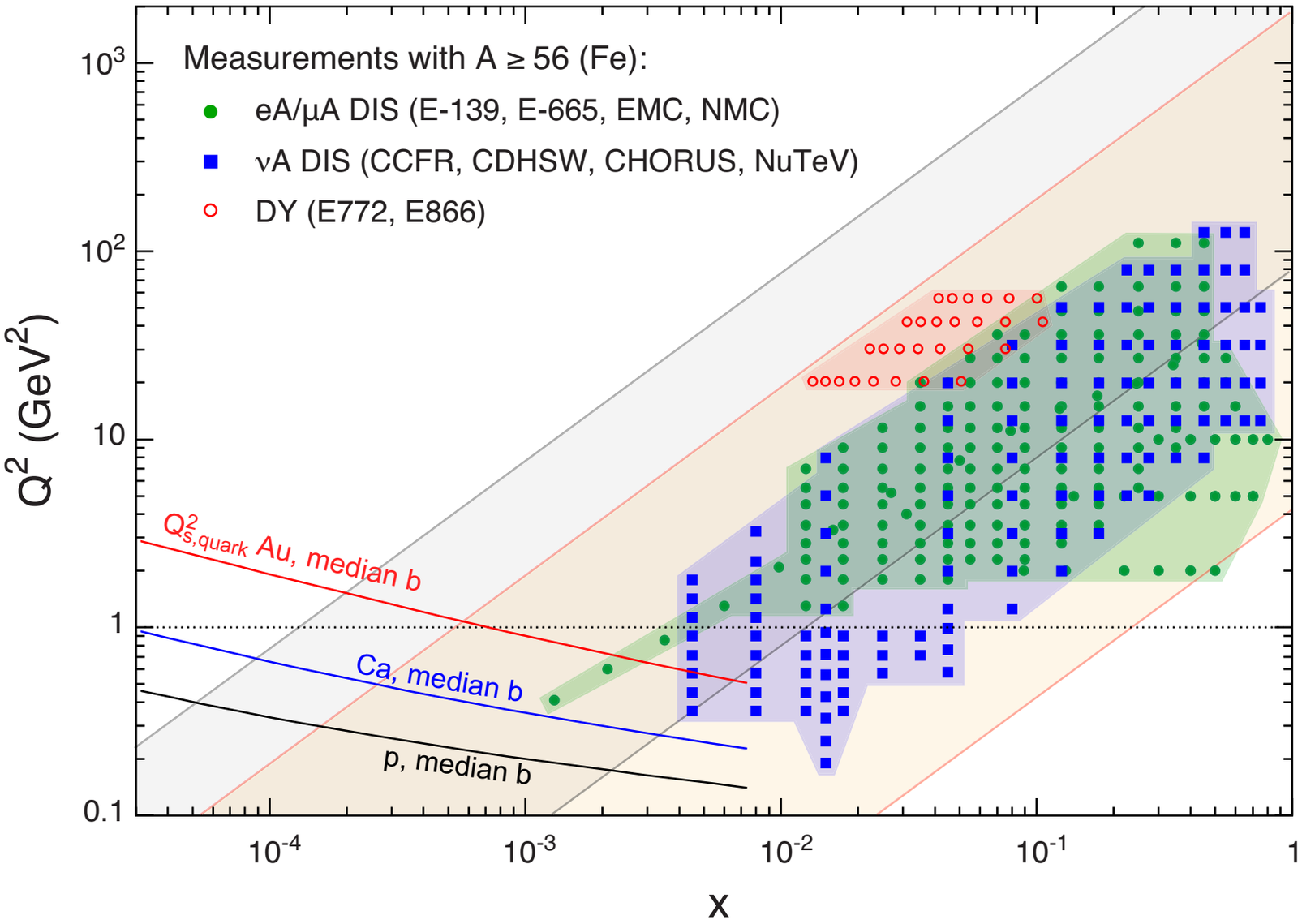


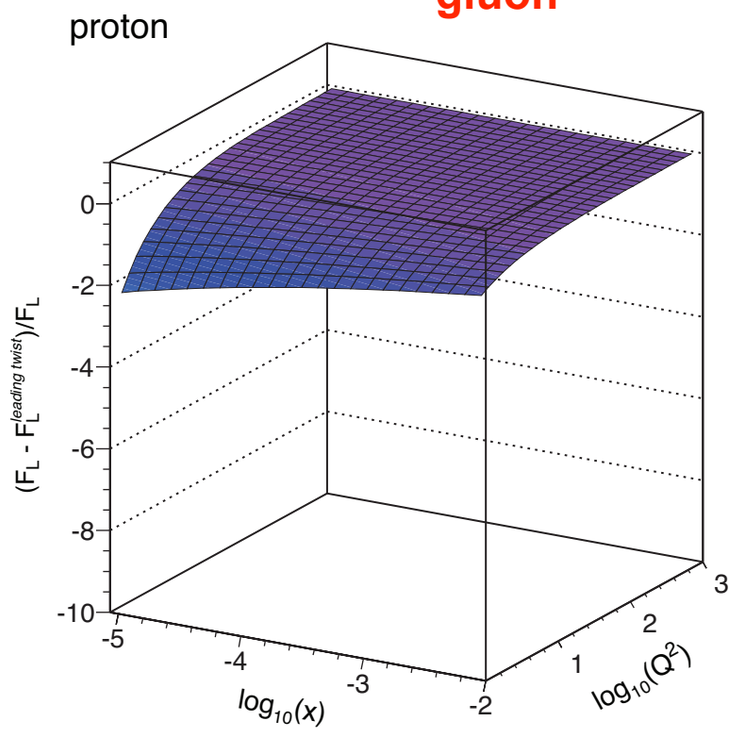
# Saturation effects in the proton and nucleus

$$\frac{d^2\sigma^{eA\to eX}}{dxdQ^2} = \frac{4\pi\alpha^2}{xQ^4}\left[\left(1-y+\frac{y^2}{2}\right)F_2(x,Q^2) - \frac{y^2}{2}F_L(x,Q^2)\right]$$

quark+anti-quark

gluon

## Measure of non-linear effects in the $F_L$ structure function




Dipole model (J. Bartels *et al.*)

- Plotting this distribution coming out of saturation inspired GBW model

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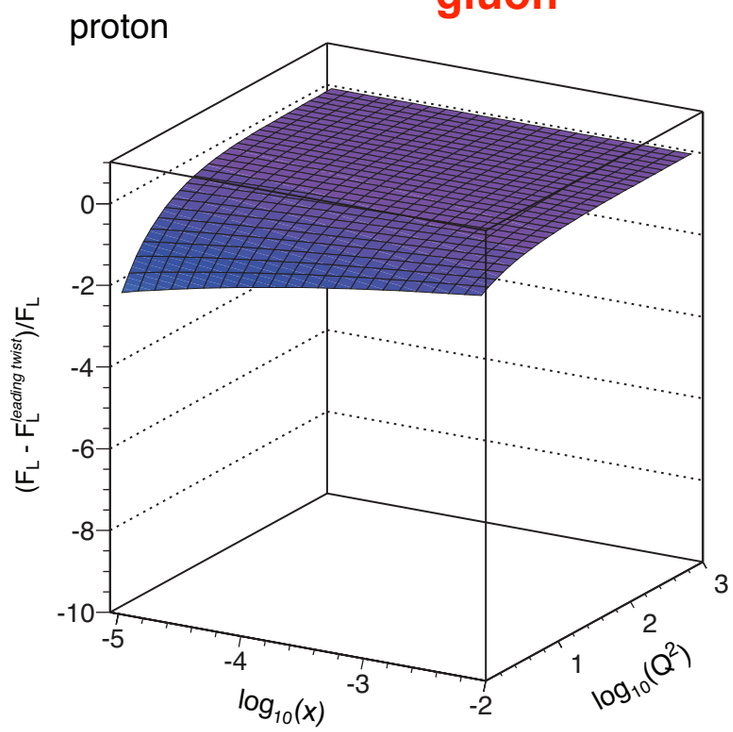


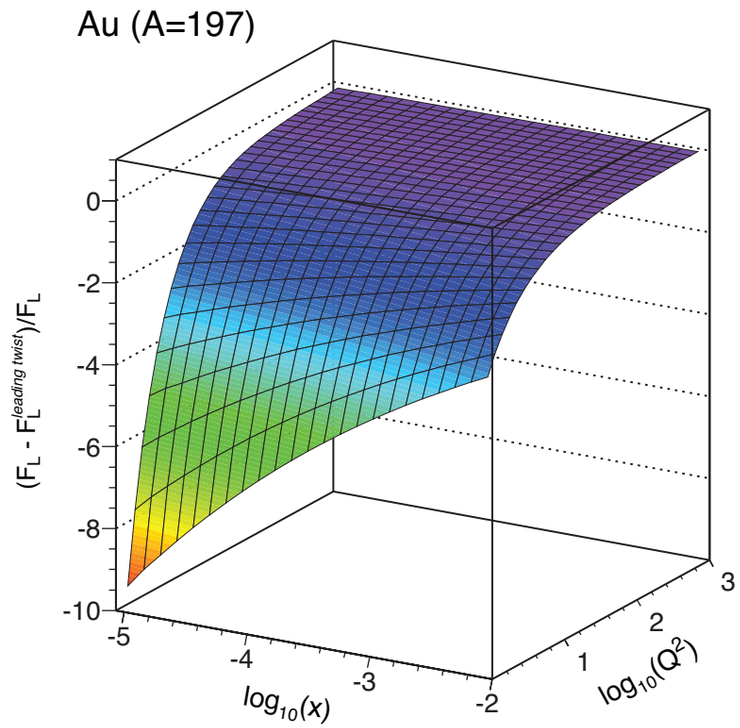


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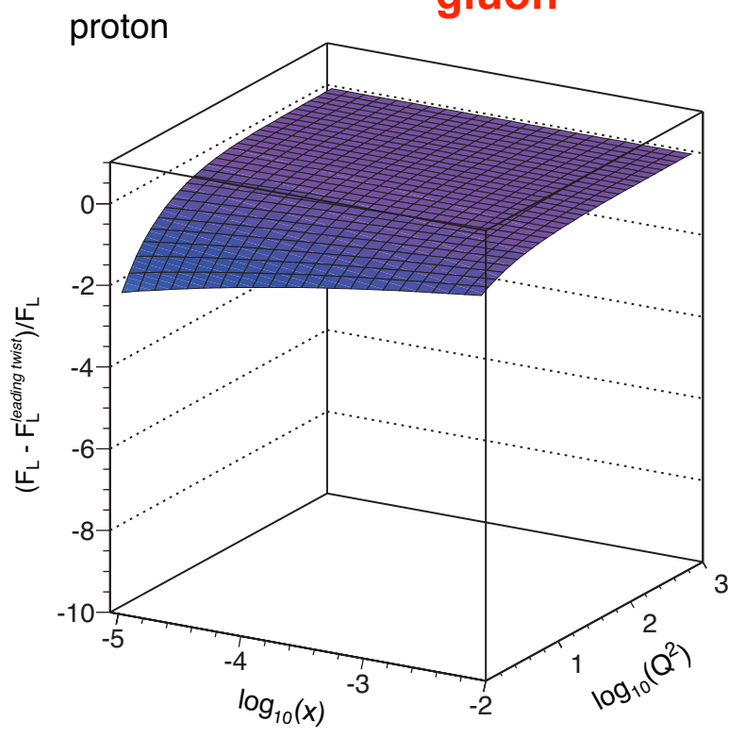


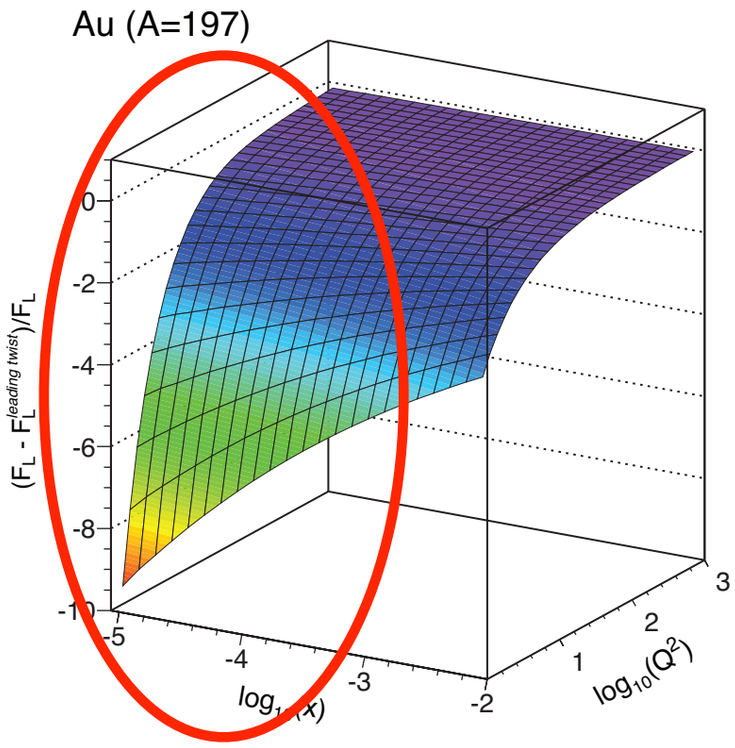


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## Strategies:

slope of $y^2/Y_+$ for different s at fixed x & $Q^2$

## e+Au:

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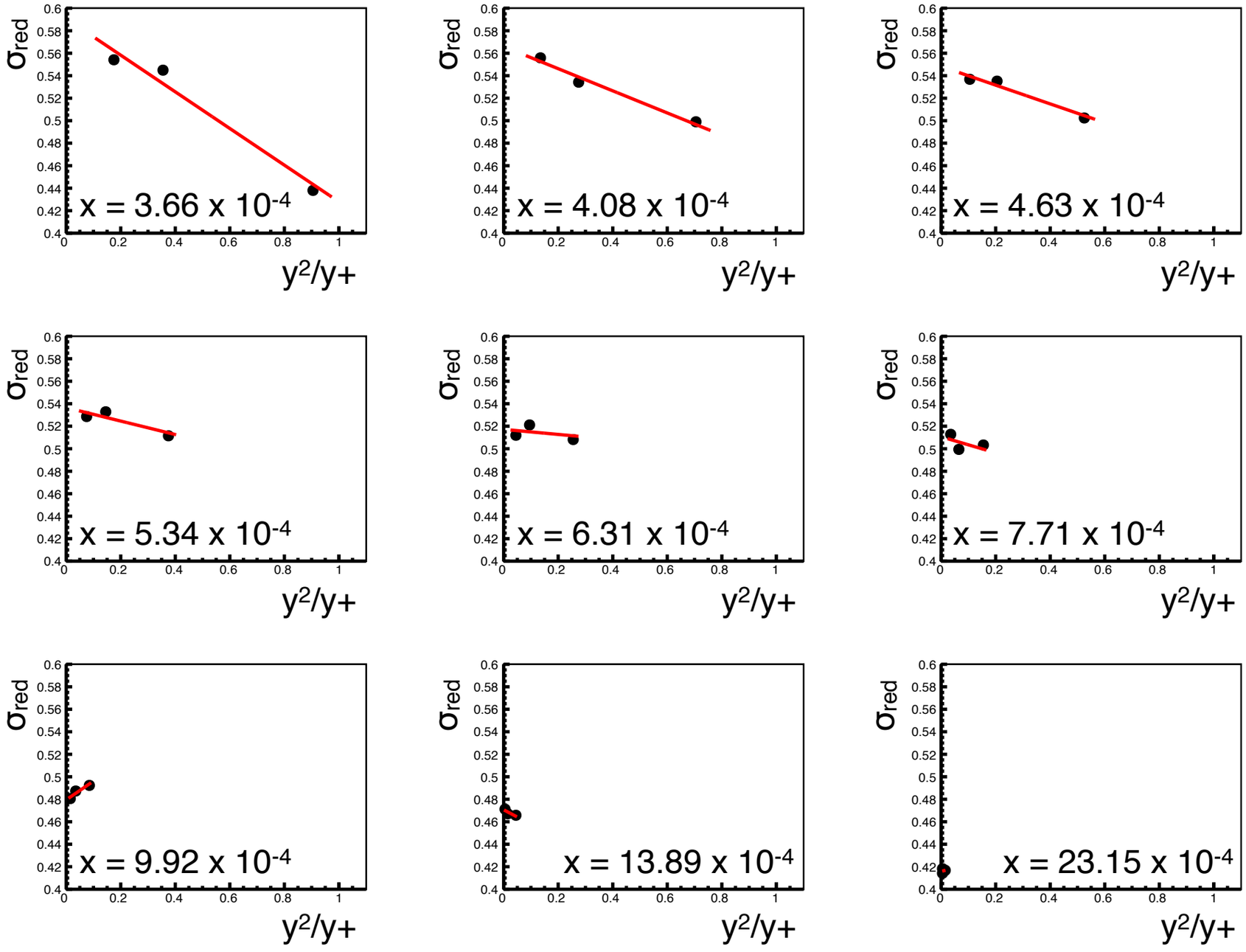
20x100 - A∫Ldt = 4 fb$^{-1}$
running combined
~6 months total running (50% eff)

statistical errors are swamped by the 3% systematic errors

Will be dominated by systematics, but would need a full detector simulation in order to estimate them

$Q^2$ = 1.389 GeV$^2$



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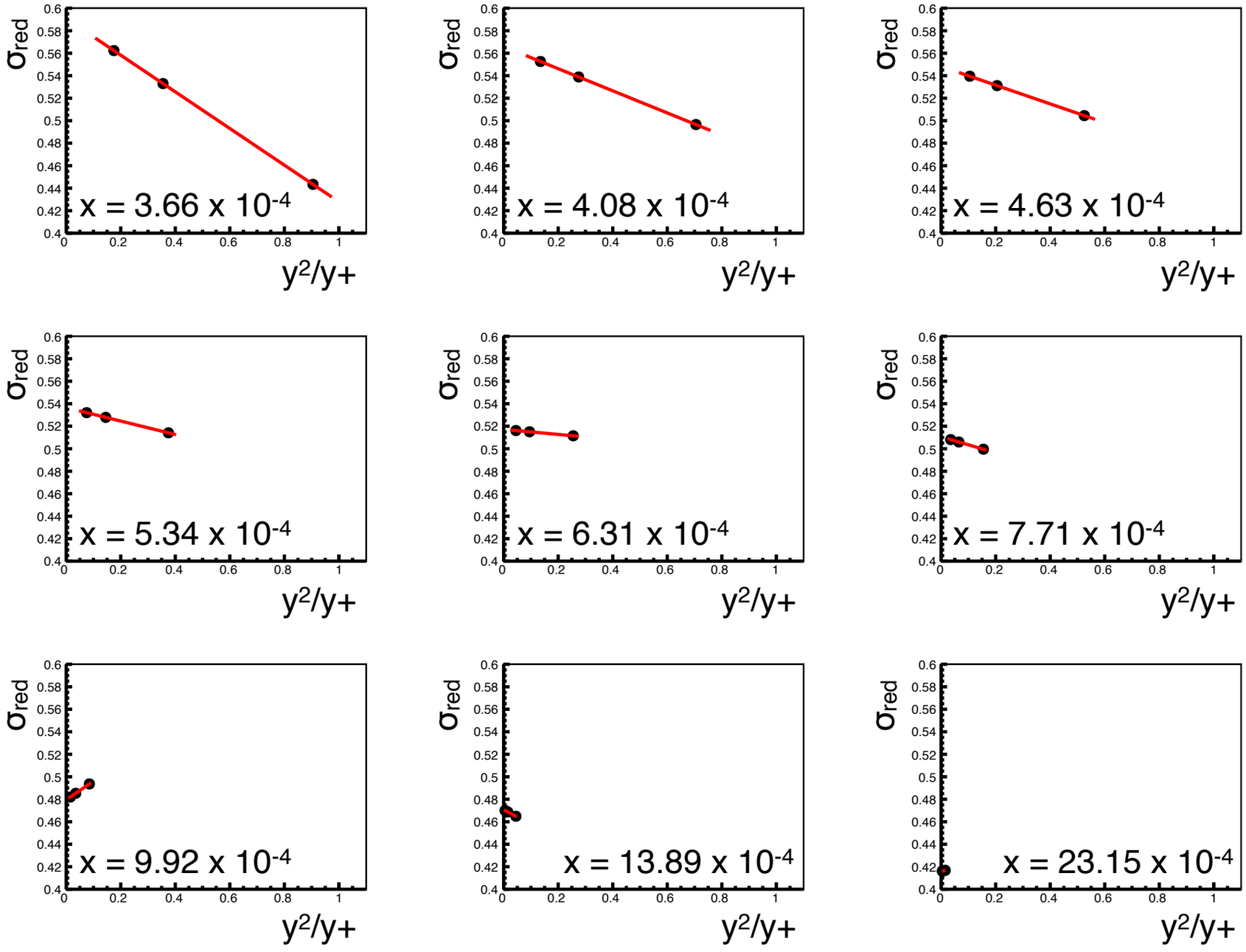

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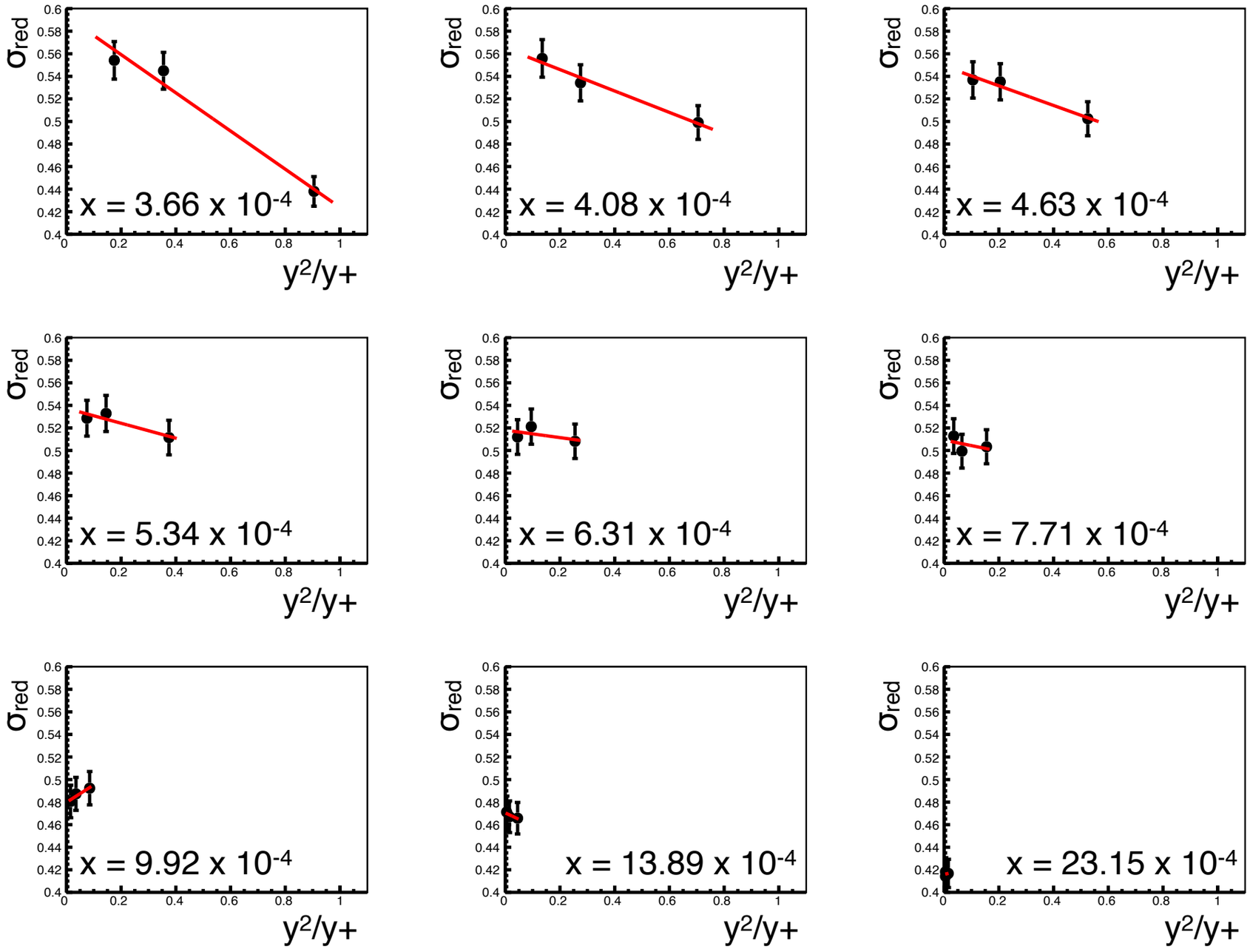

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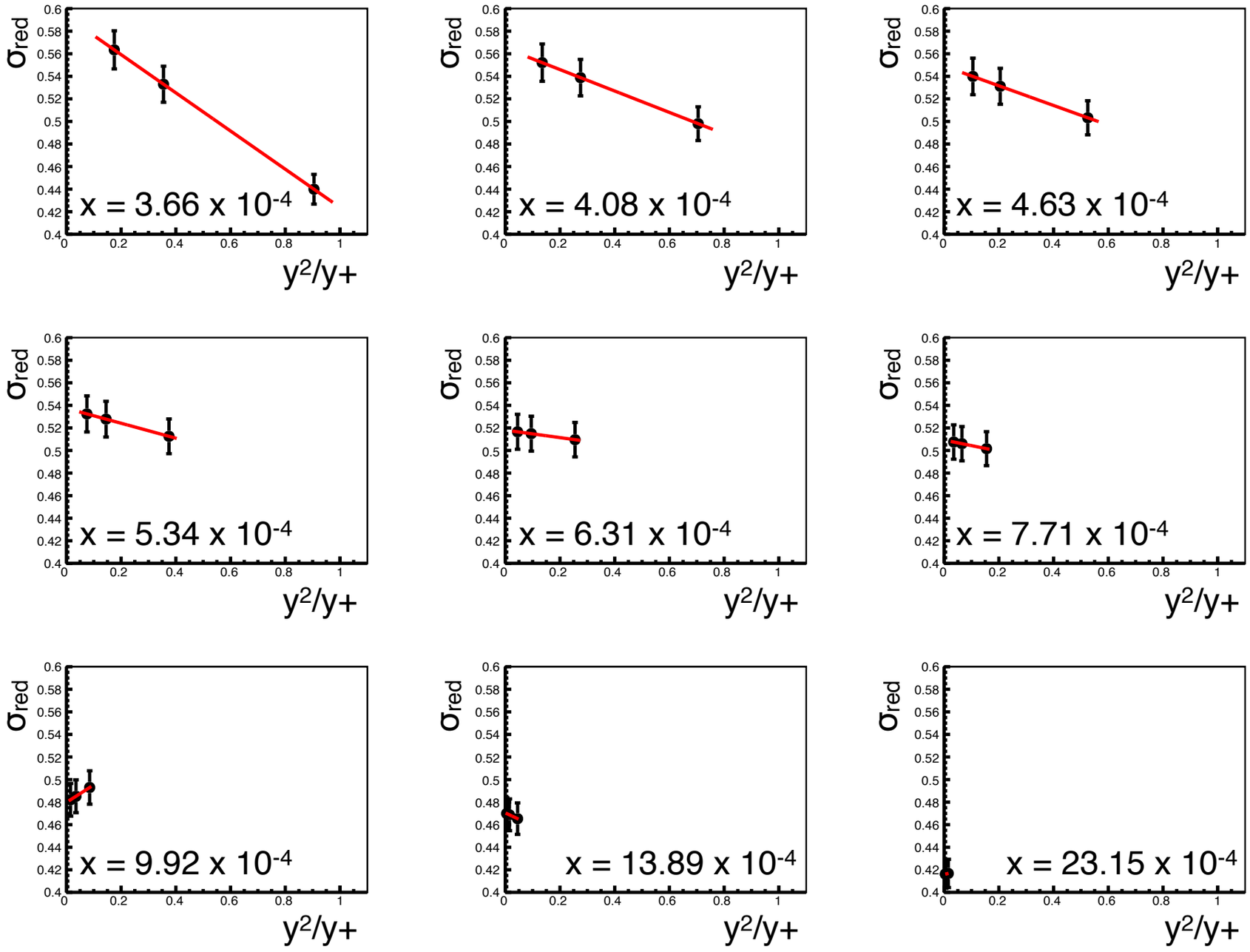

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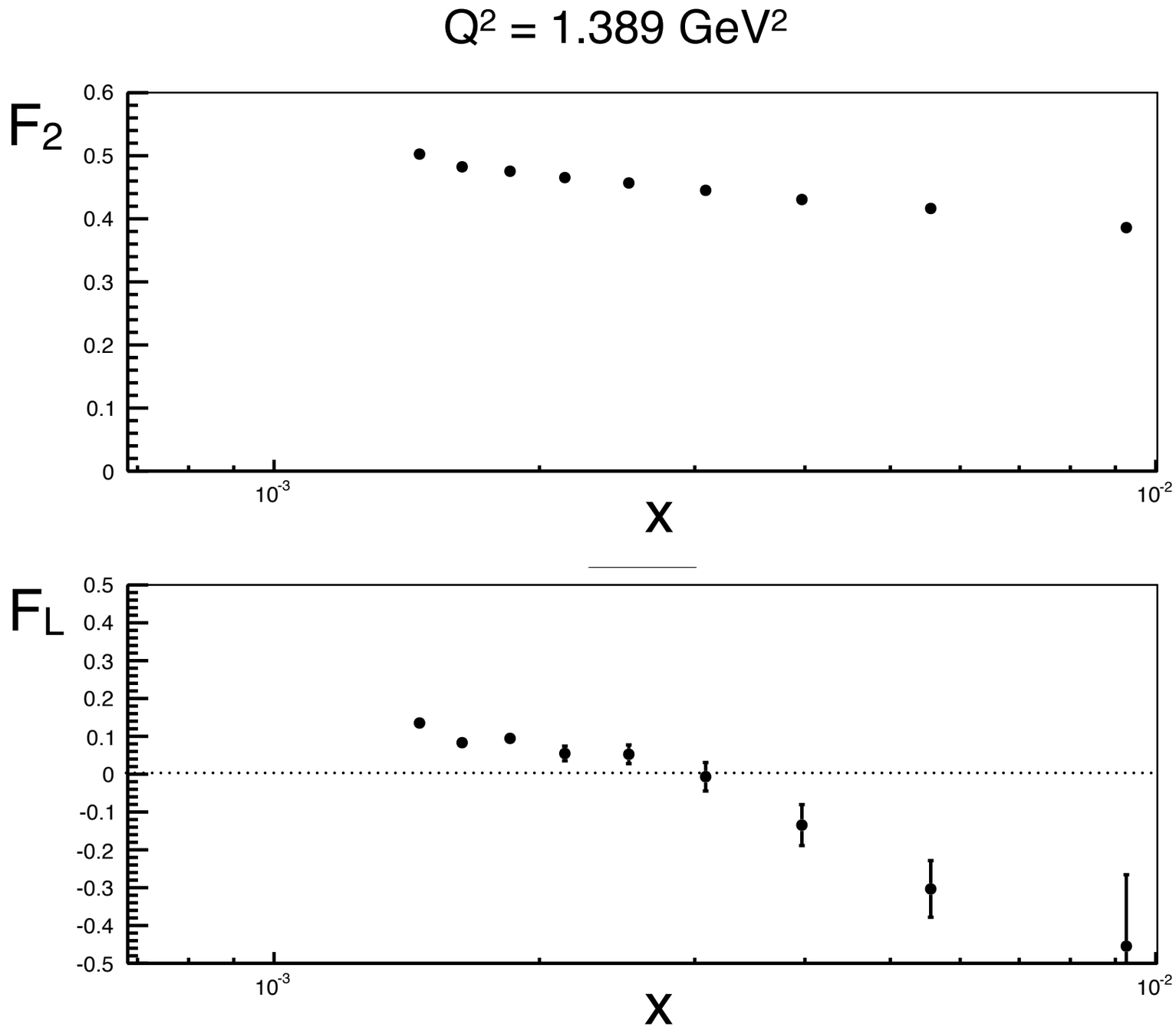

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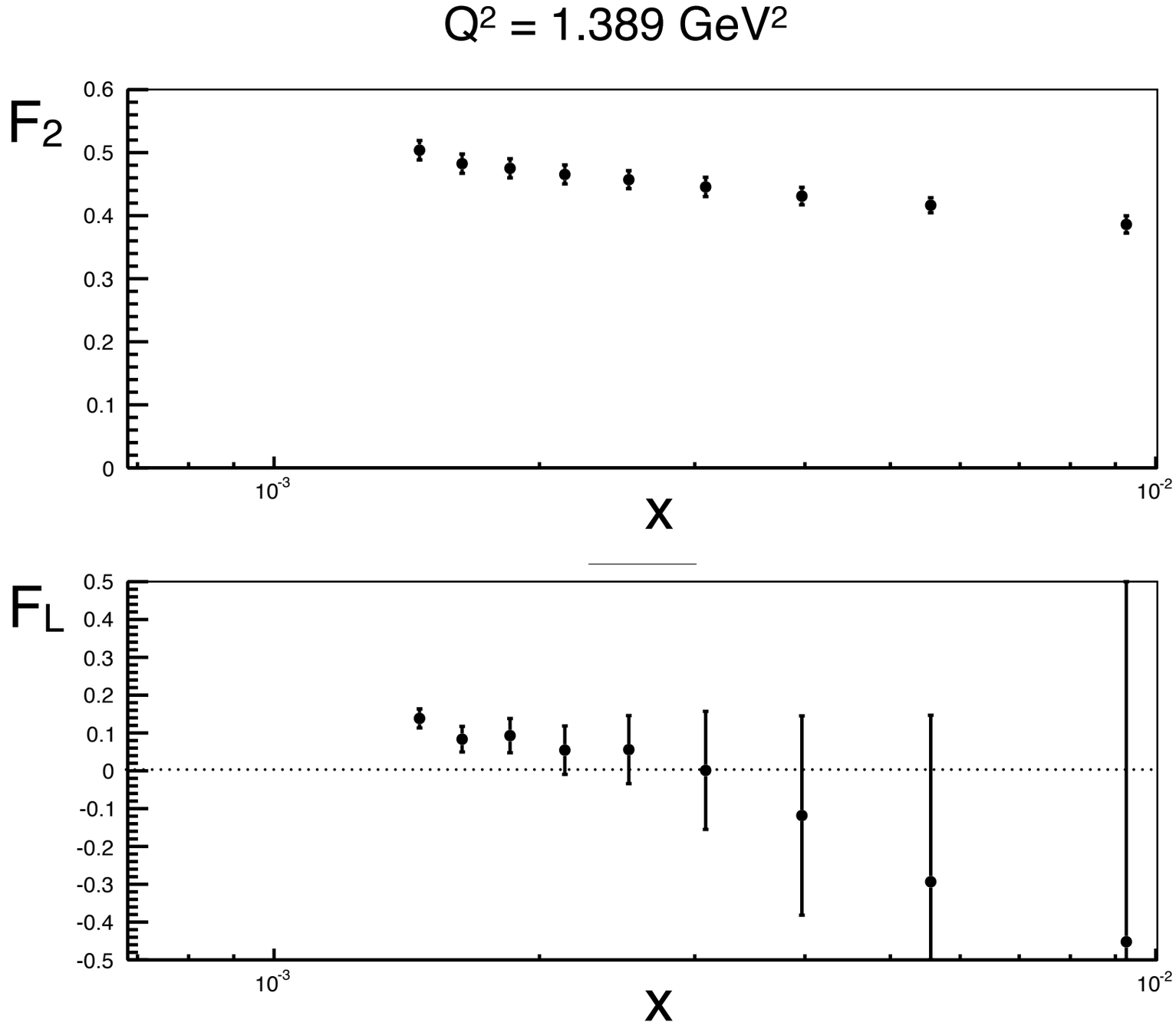

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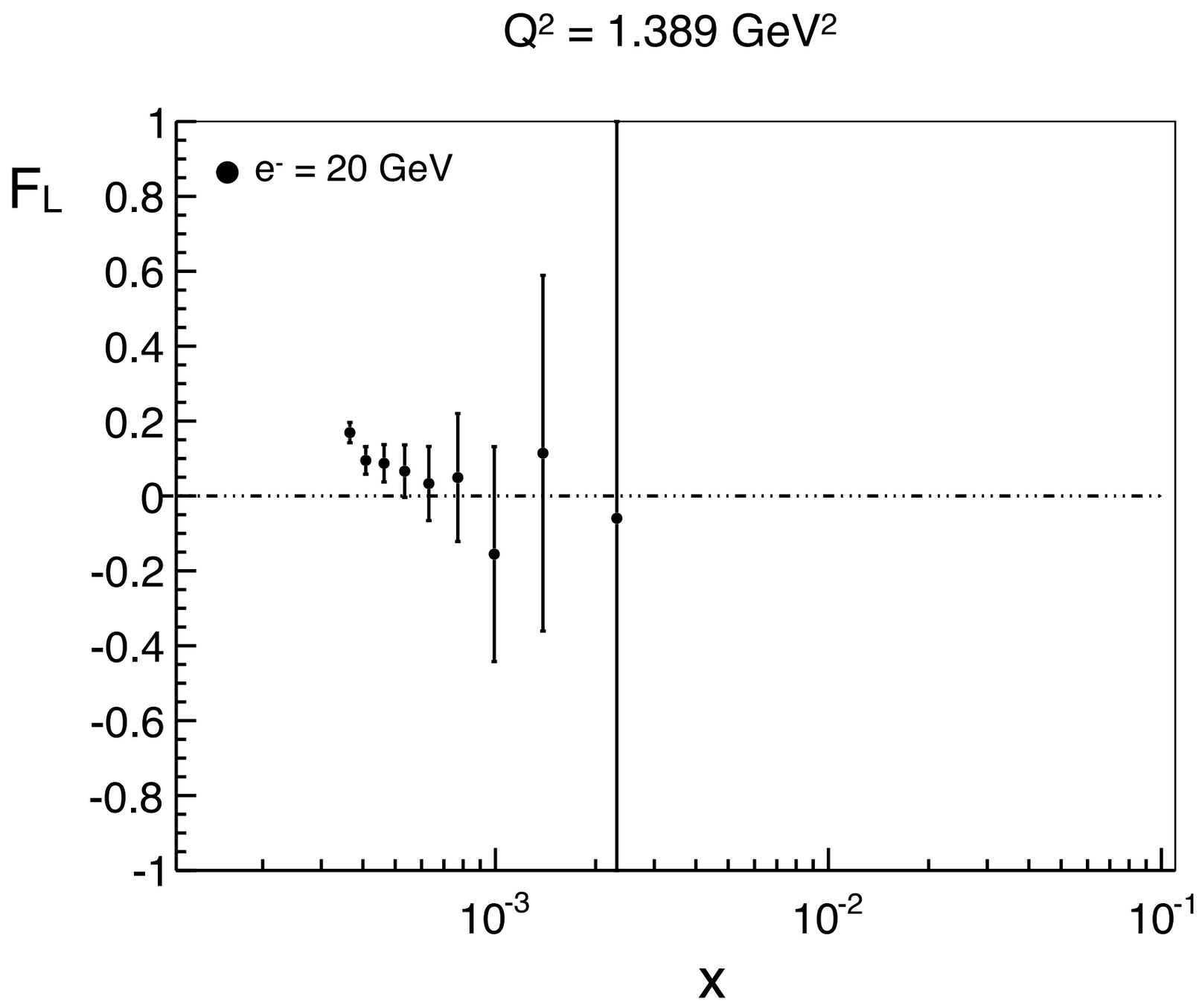

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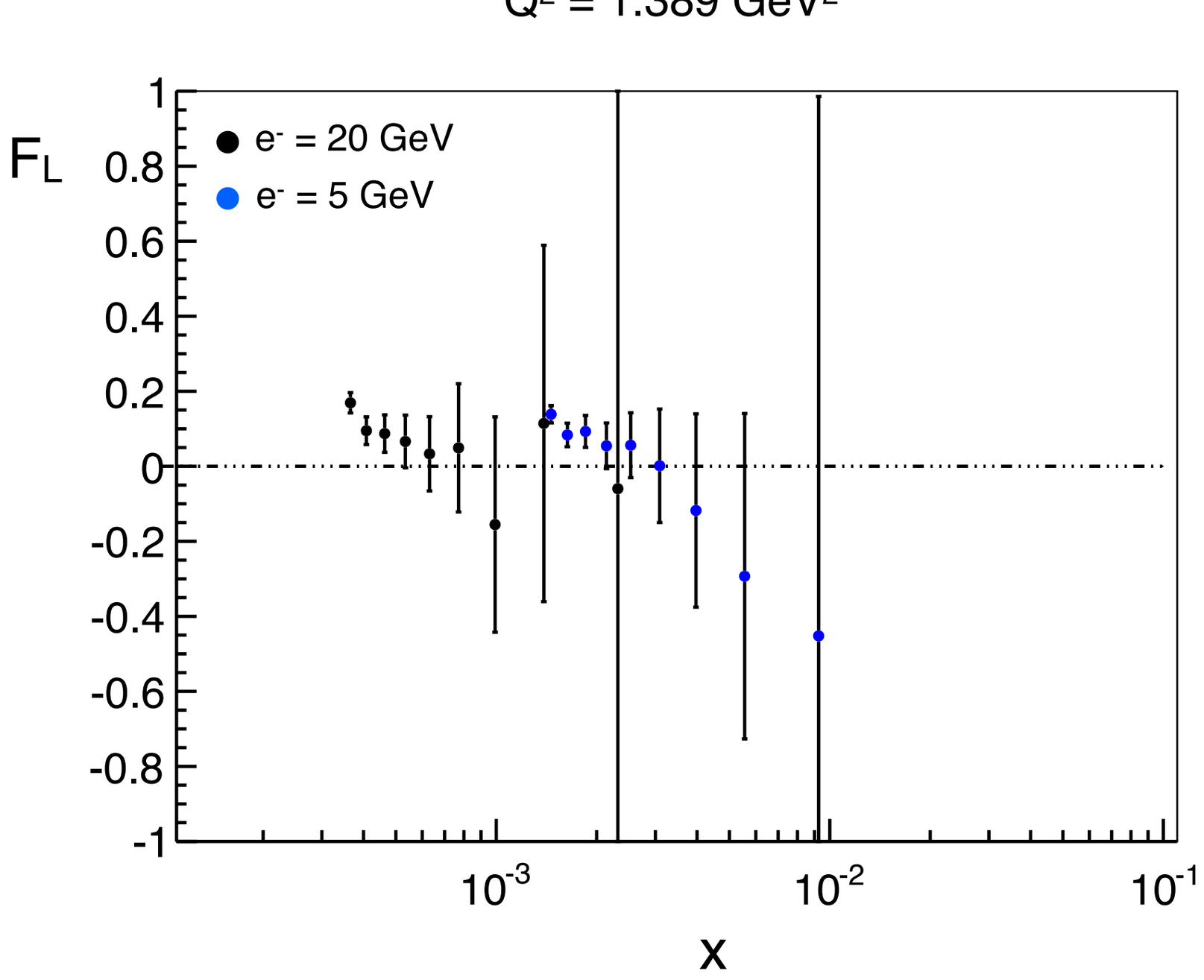

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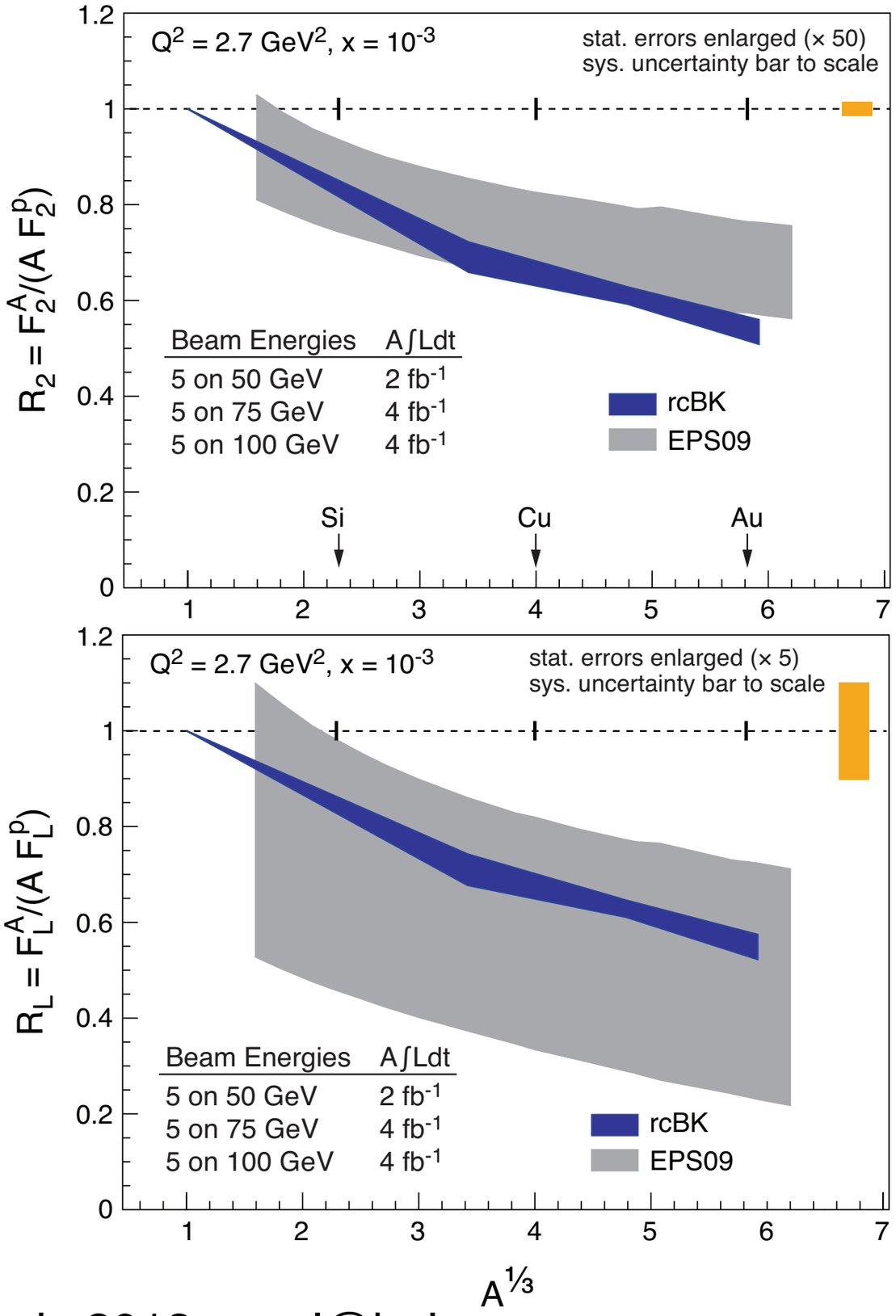

# Work in progress… (H. Paukkunen)

- Take the generated Pseudo-data and include it in a global fit

➡ Only 20x100 and 5x100 included in these plots

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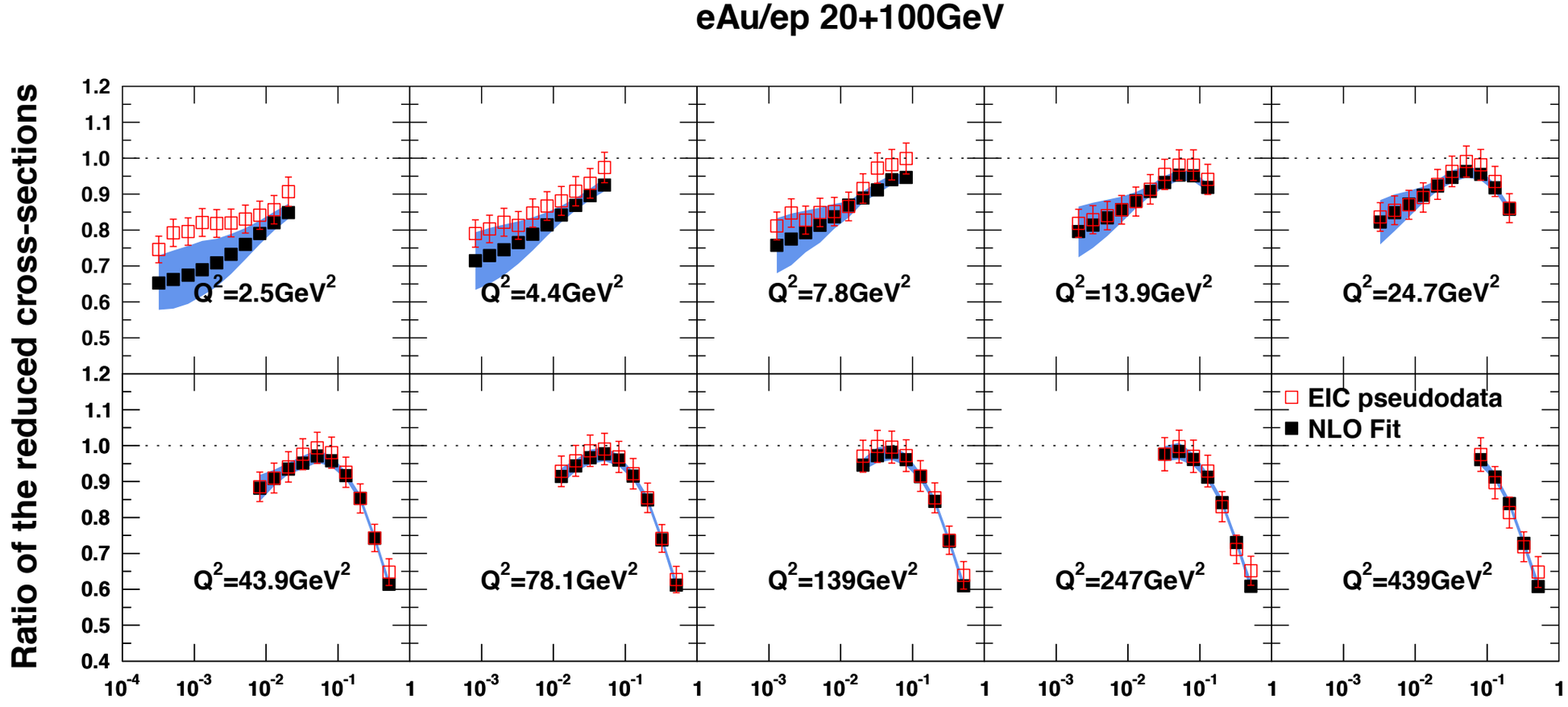

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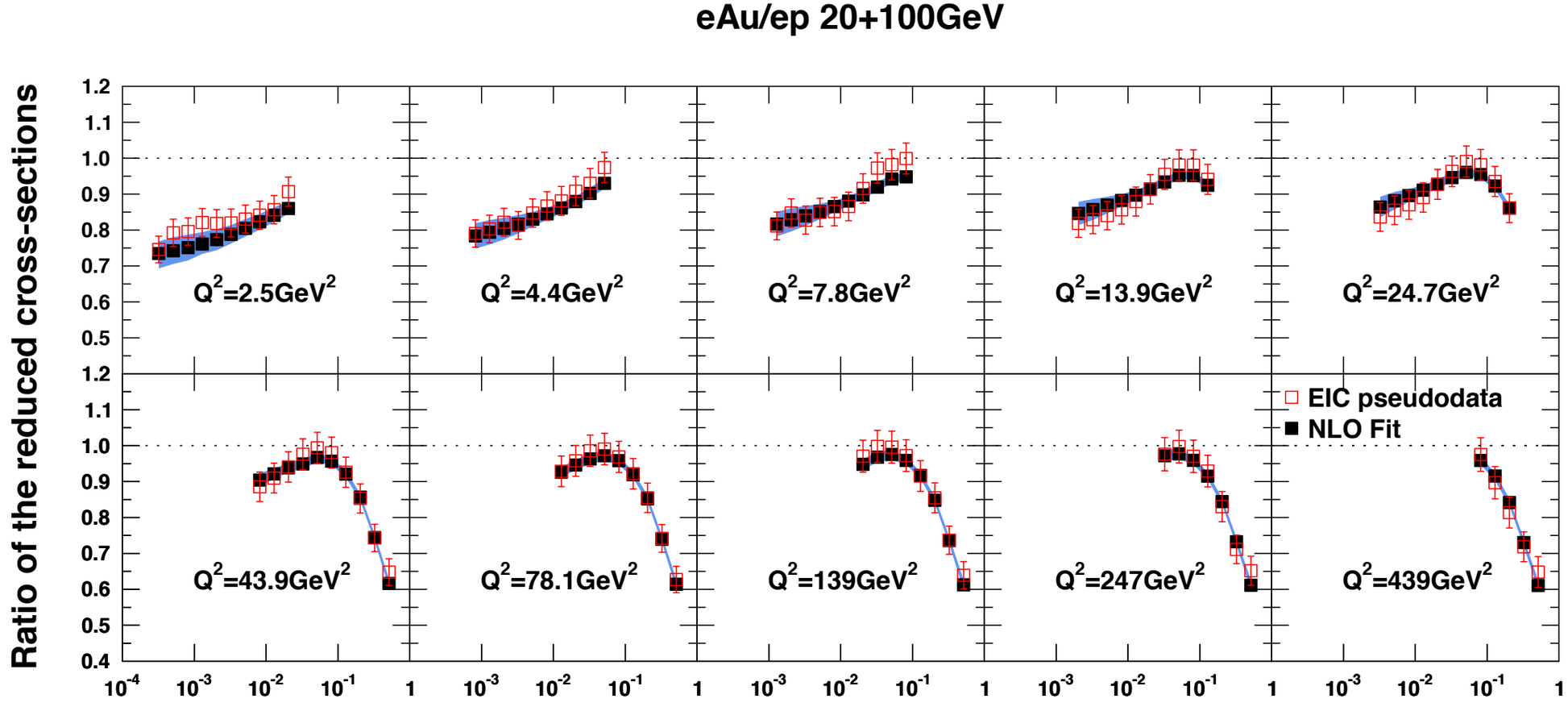

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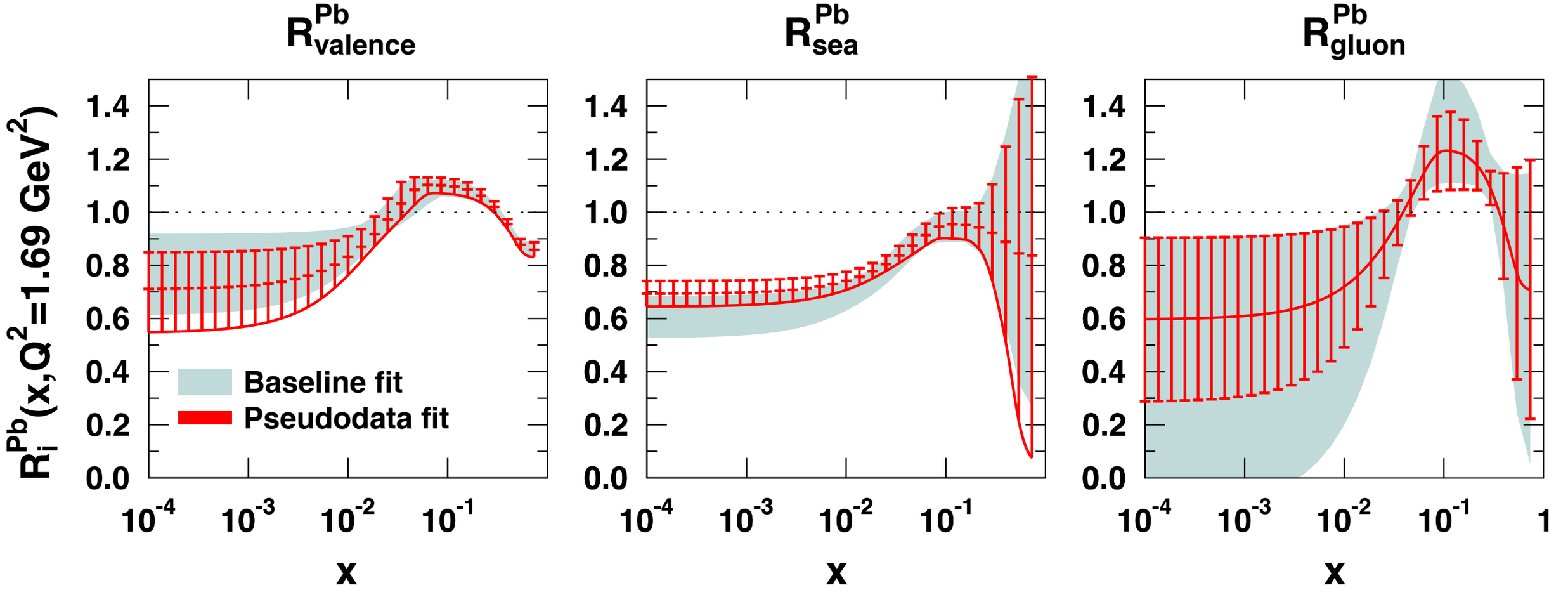
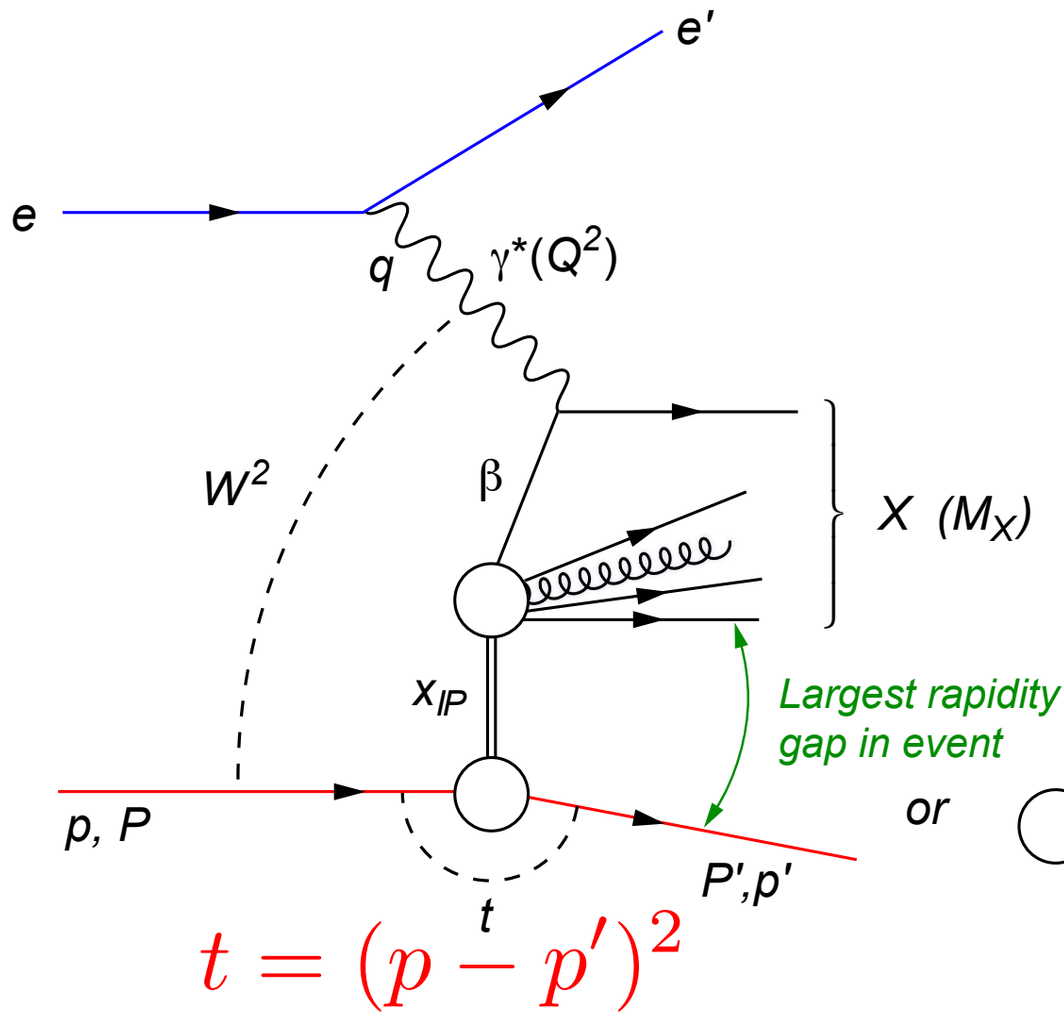


# Exclusive processes in e+A - diffraction




- β is the momentum fraction of the struck parton w.r.t. the Pomeron
- $x_{IP} = x/\beta$: momentum fraction of the exchanged object (Pomeron) w.r.t. the hadron

$$\beta = \frac{x}{x_{I\!P}} = \frac{Q^2}{Q^2 + M_X^2 - t}$$

- Diffraction in e+p:
  - ➡ HERA: 15% of all events are diffractive

- Diffraction in e+A:
  - ➡ Predictions: $\sigma_{diff}/\sigma_{tot}$ in e+A ~25-40%
  - ➡ Coherent diffraction (nuclei intact)
  - ➡ Incoherent diffraction: breakup into nucleons (nucleons intact)

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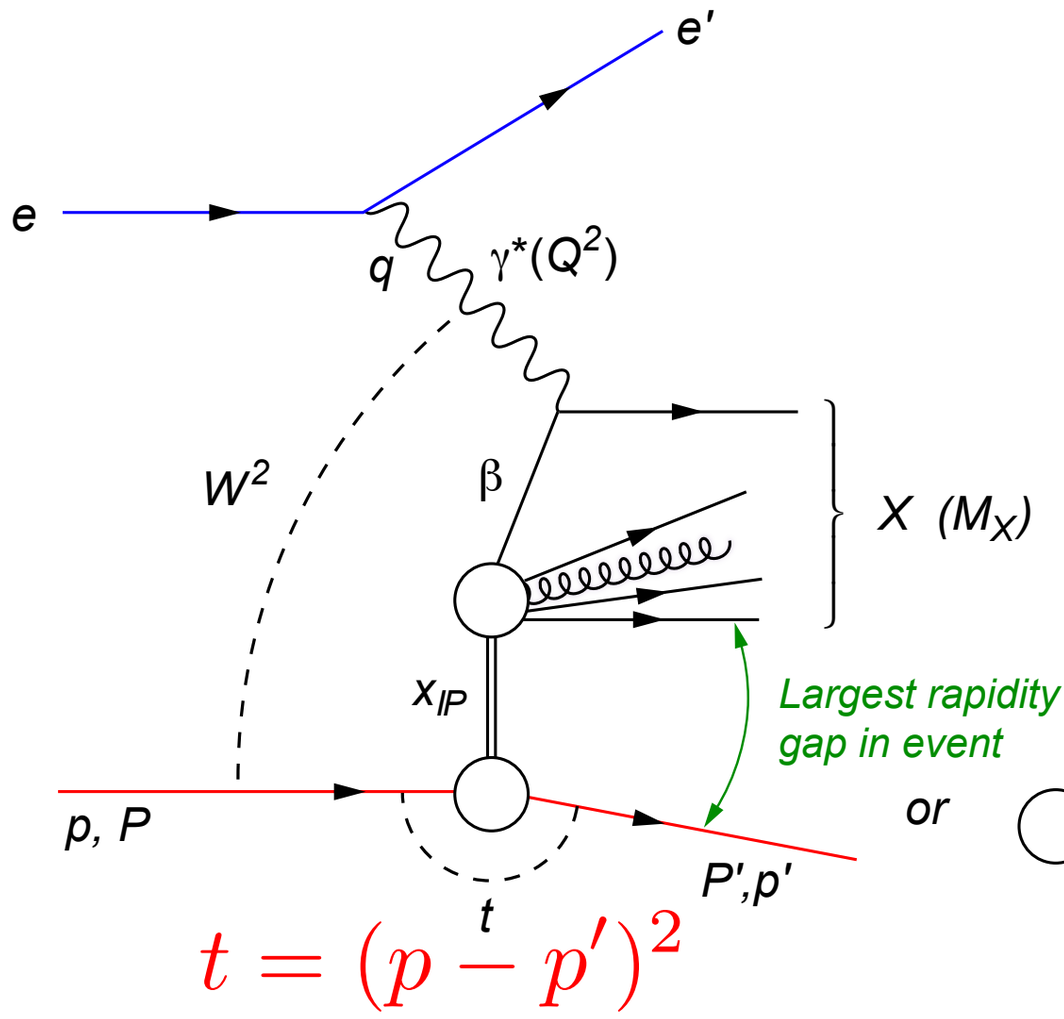


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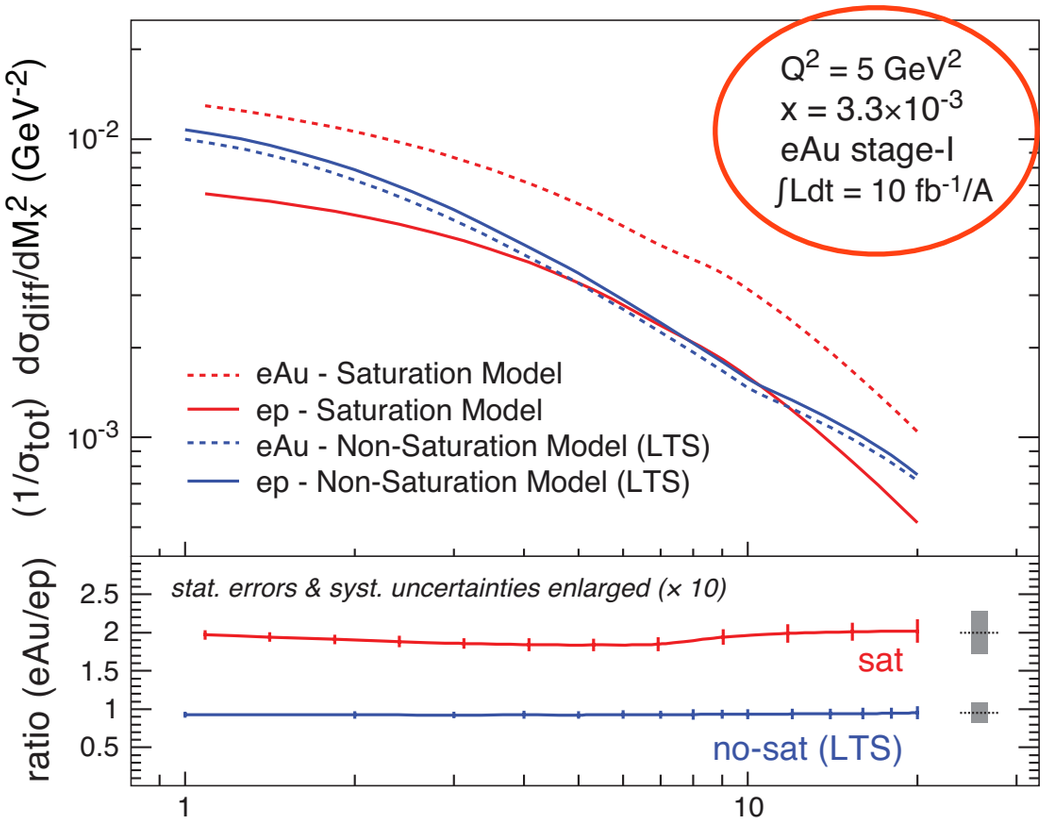
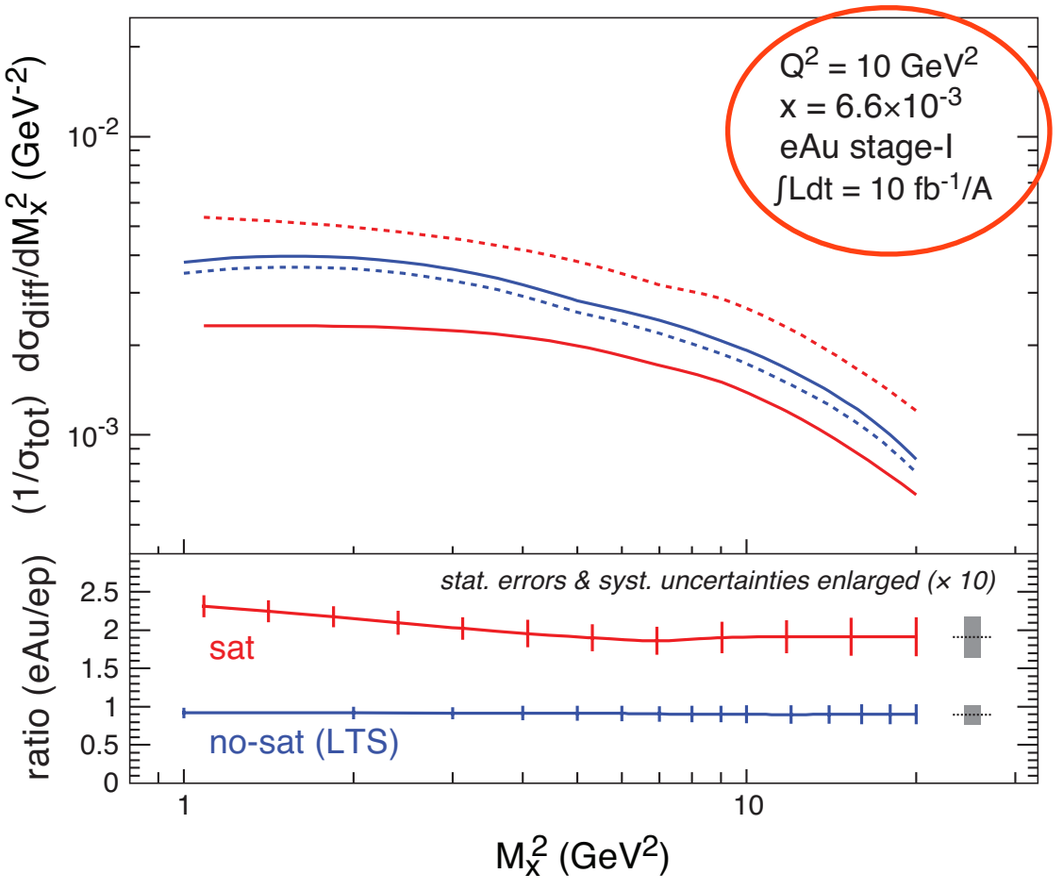
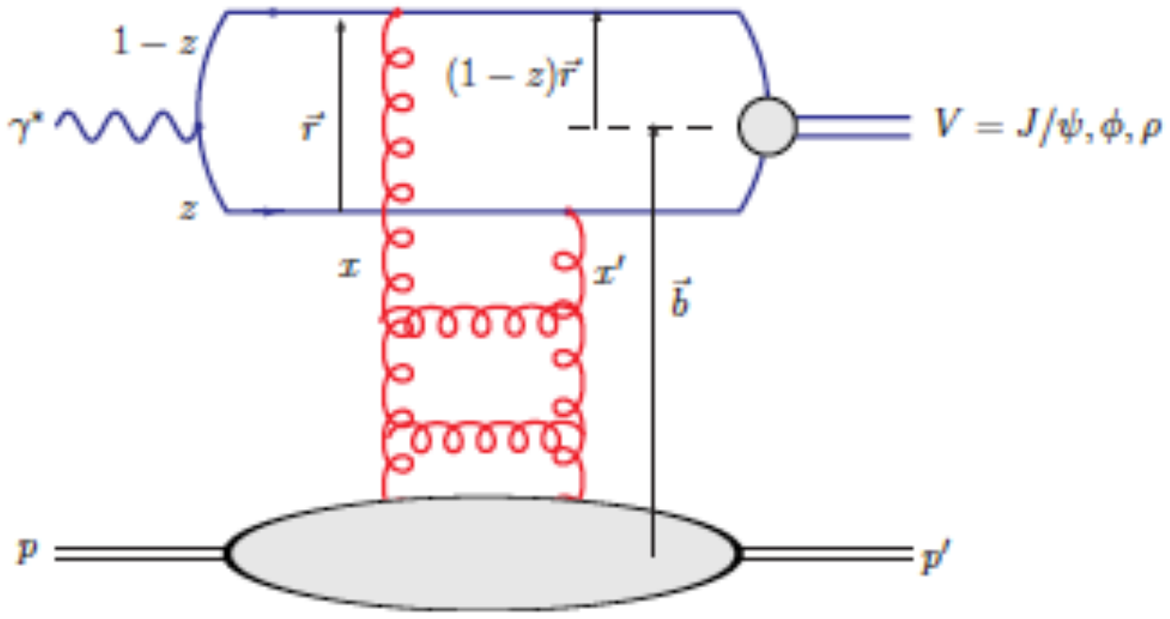
# Day 1: Diffractive Cross-sections



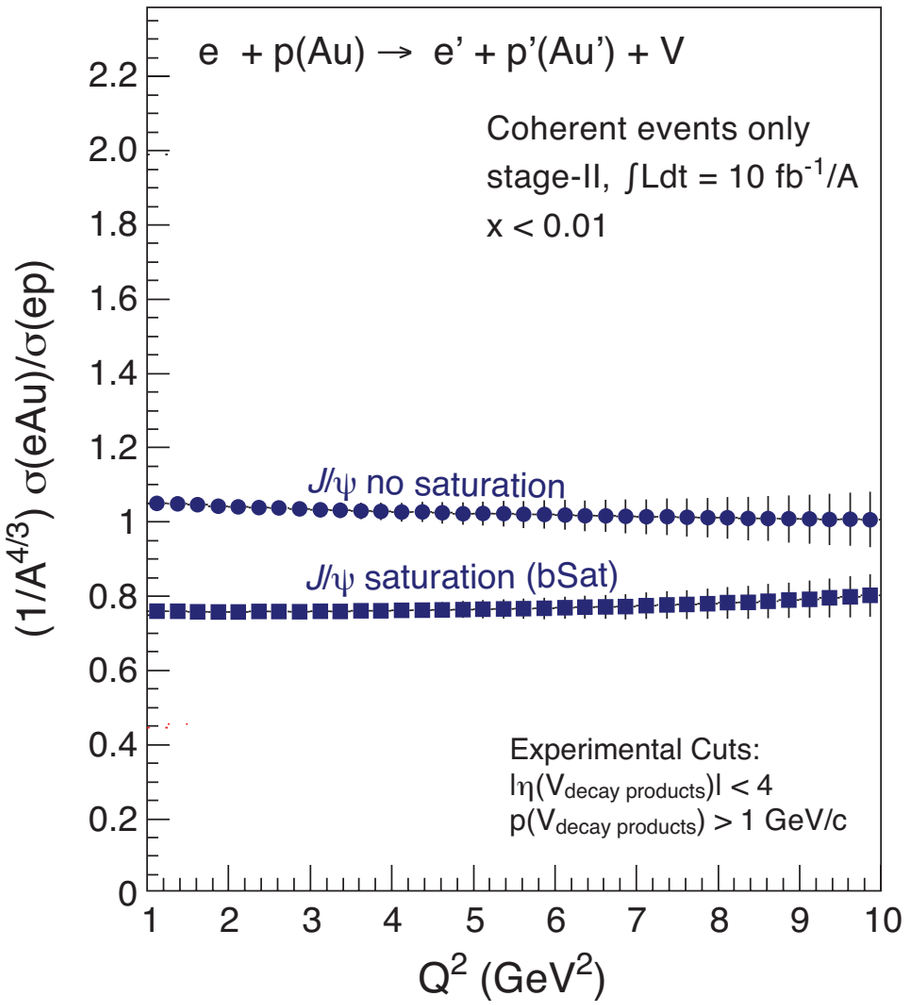




- Ratio of diffractive-to-total cross-section drastically different between saturation (Marquet) and non-saturation (Frankfurt, Guzey, Strikman) models
- Expected experimental error bars (simulated for 10 $fb^{-1}$ of data for a low-energy eRHIC) can distinguish between the two scenarios

# Exclusive vector meson production




$$d\sigma \propto g(x)^2$$




- Exclusive vector meson production is most sensitive to the gluon distribution
  - ➡ colour-neutral exchange of gluons
- J/ψ shows some difference between saturation and no-saturation

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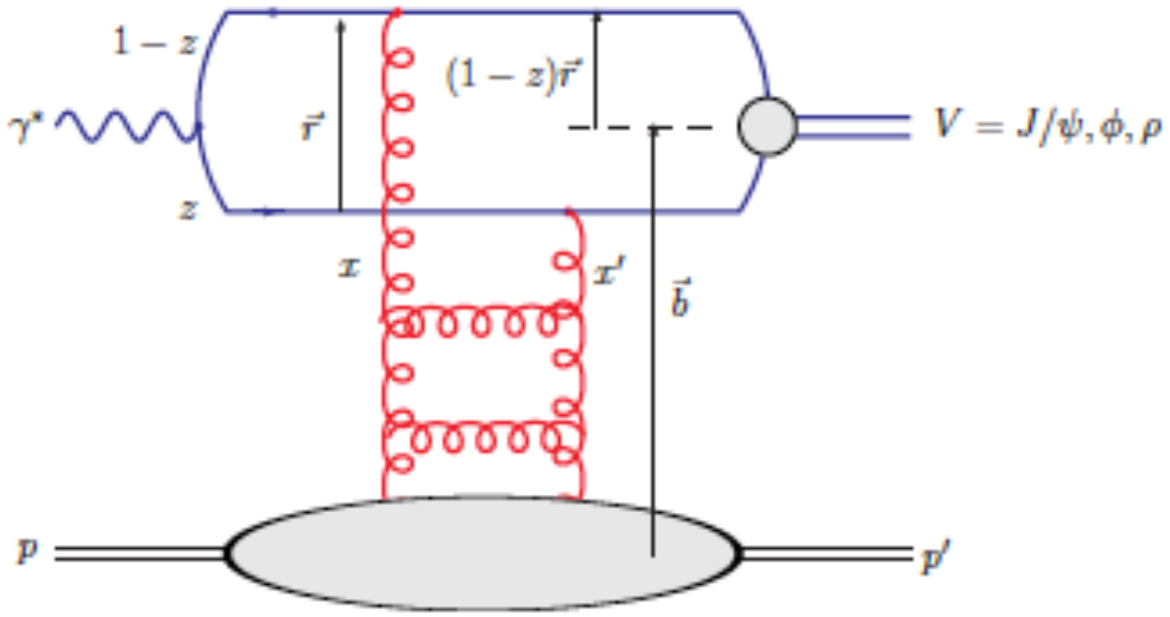


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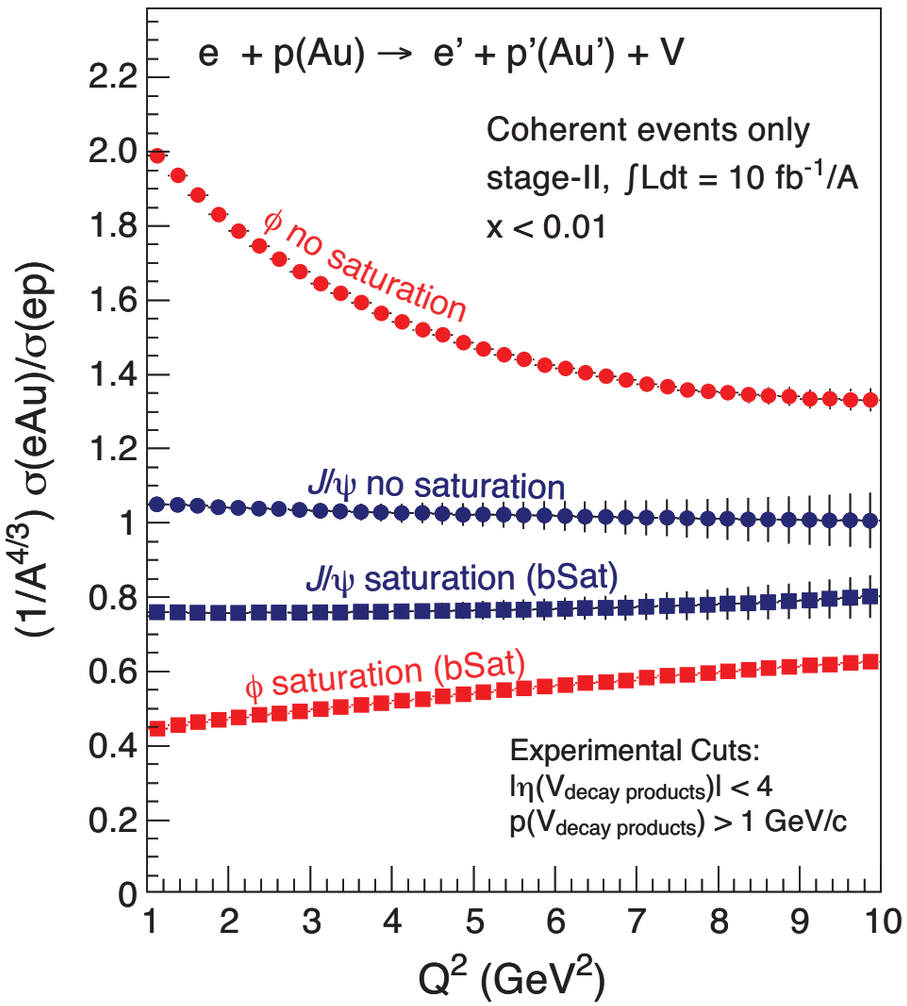
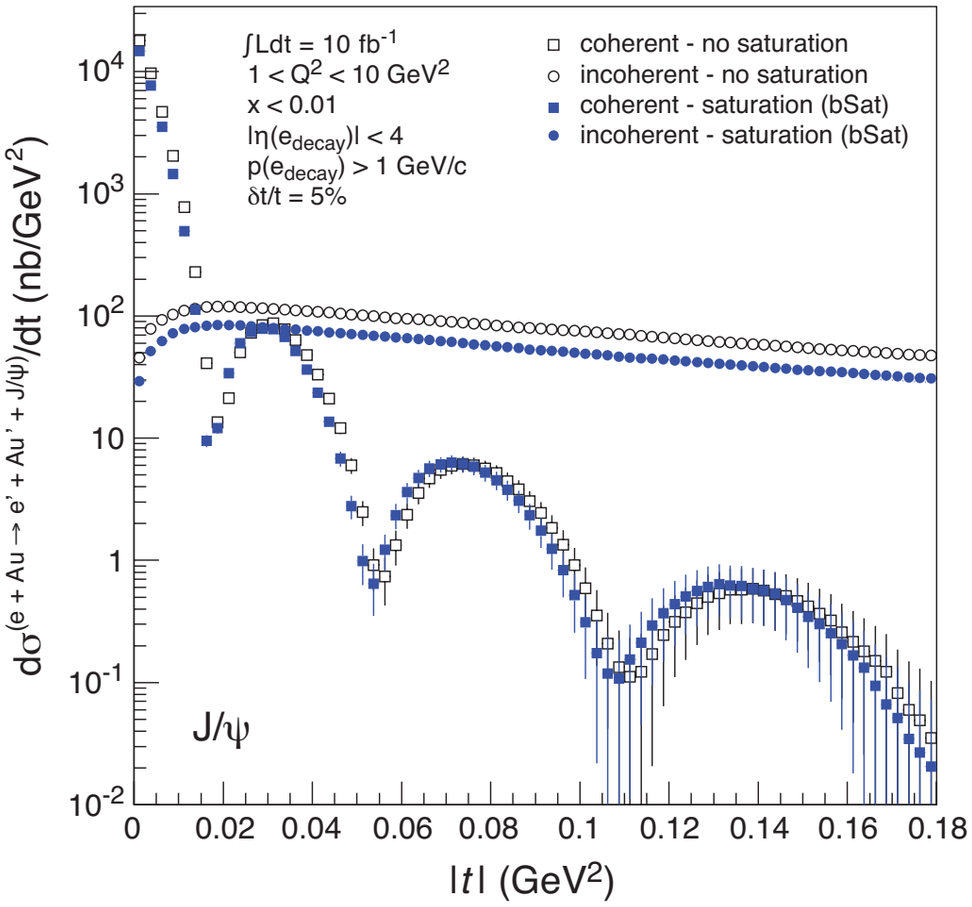
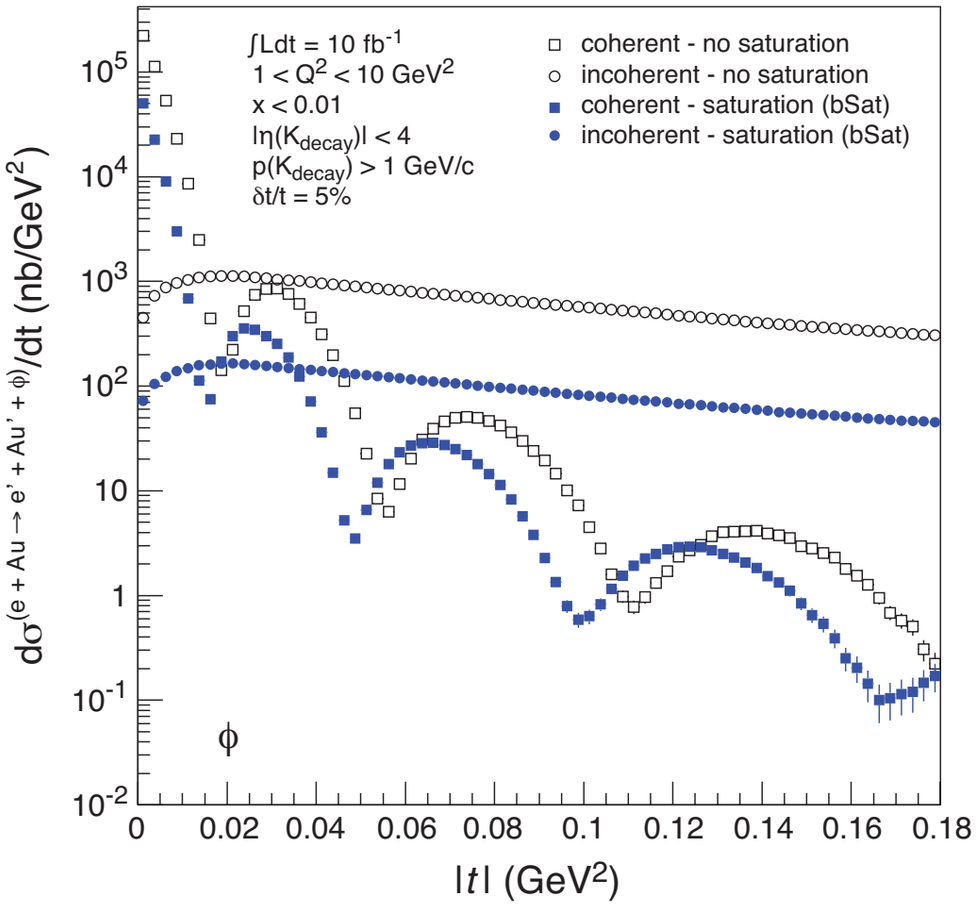



- Exclusive vector meson production is most sensitive to the gluon distribution
  - ➡ colour-neutral exchange of gluons
- J/ψ shows some difference between saturation and no-saturation
- ϕ shows a much larger difference
  - ➡ wave function for ϕ is larger and hence more sensitive to saturation effects

# Exclusive Vector Meson Production in e+A




- Low-t: coherent diffraction dominates - gluon density
- High-t: incoherent diffraction dominates - gluon correlations

➡ Need good breakup detection efficiency to discriminate between the two scenarios

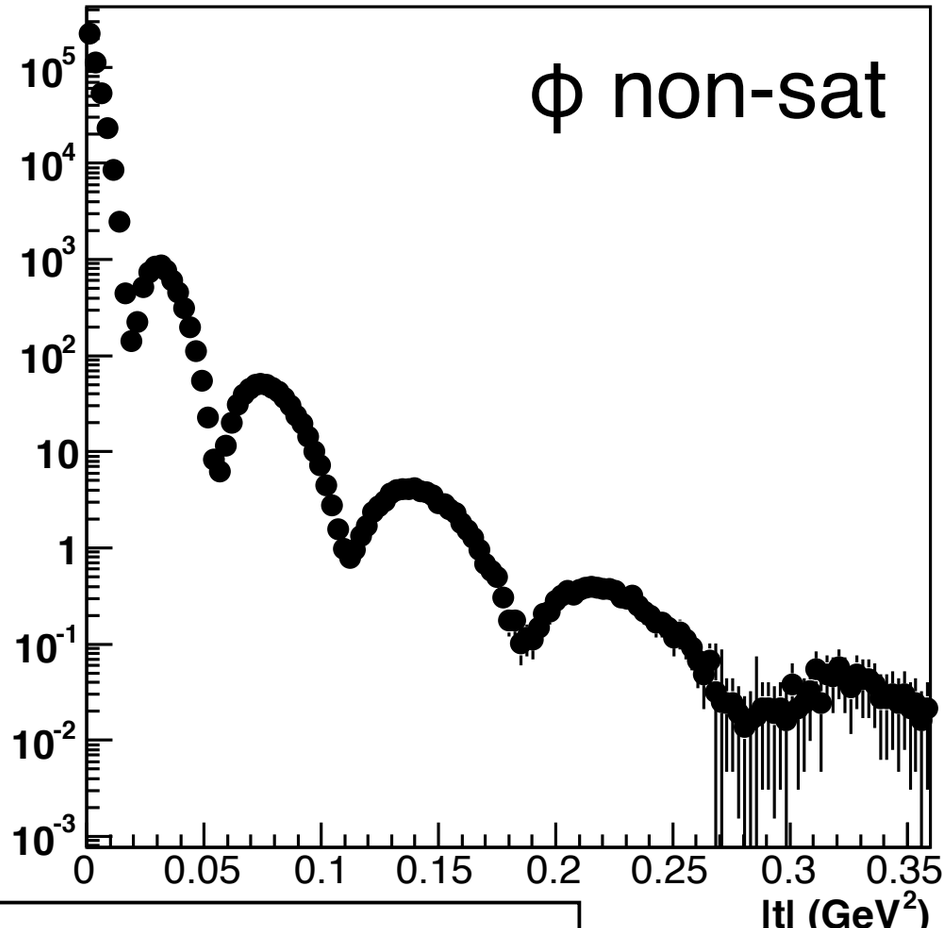
- unlike protons, forward spectrometer won't work for heavy ions
  - measure emitted neutrons in a ZDC
- rapidity gap with absence of break-up fragments sufficient to identify coherent events

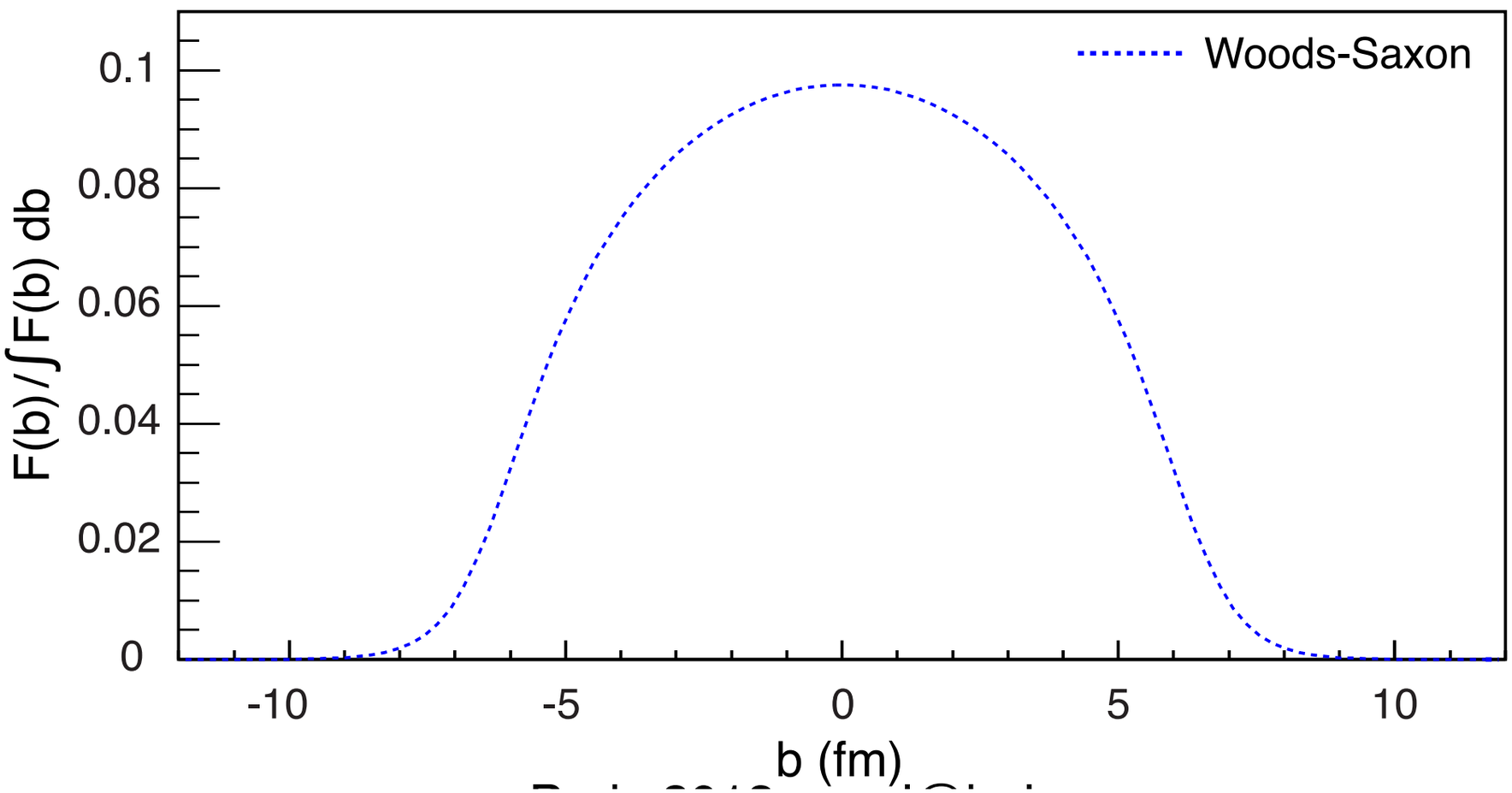
# Finding the source…

- Take the dσ/dt distribution and perform a Fourier Transform to extract the b-distribution of the gluons

$$F(b) \sim \frac{1}{2\pi} \int_0^\infty d\Delta\, \Delta\, J_0(\Delta b) \sqrt{\frac{d\sigma}{dt}}$$

t = $\Delta^2/(1-x) \approx \Delta^2$ (for small x)



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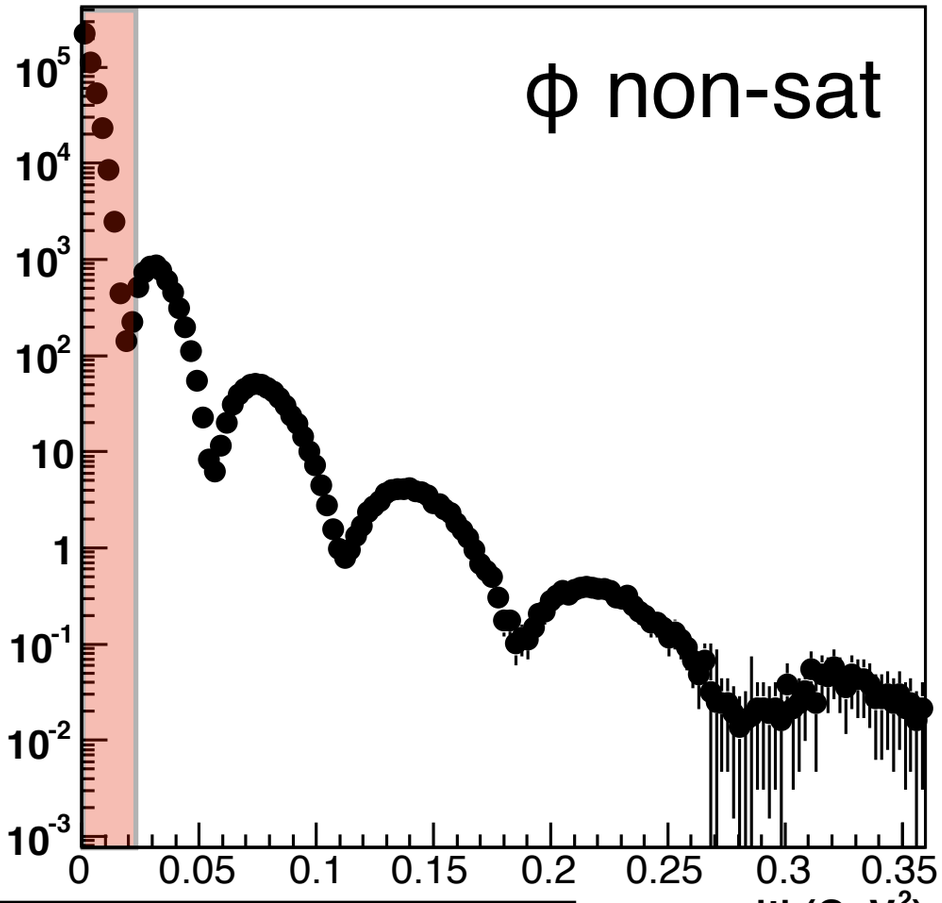


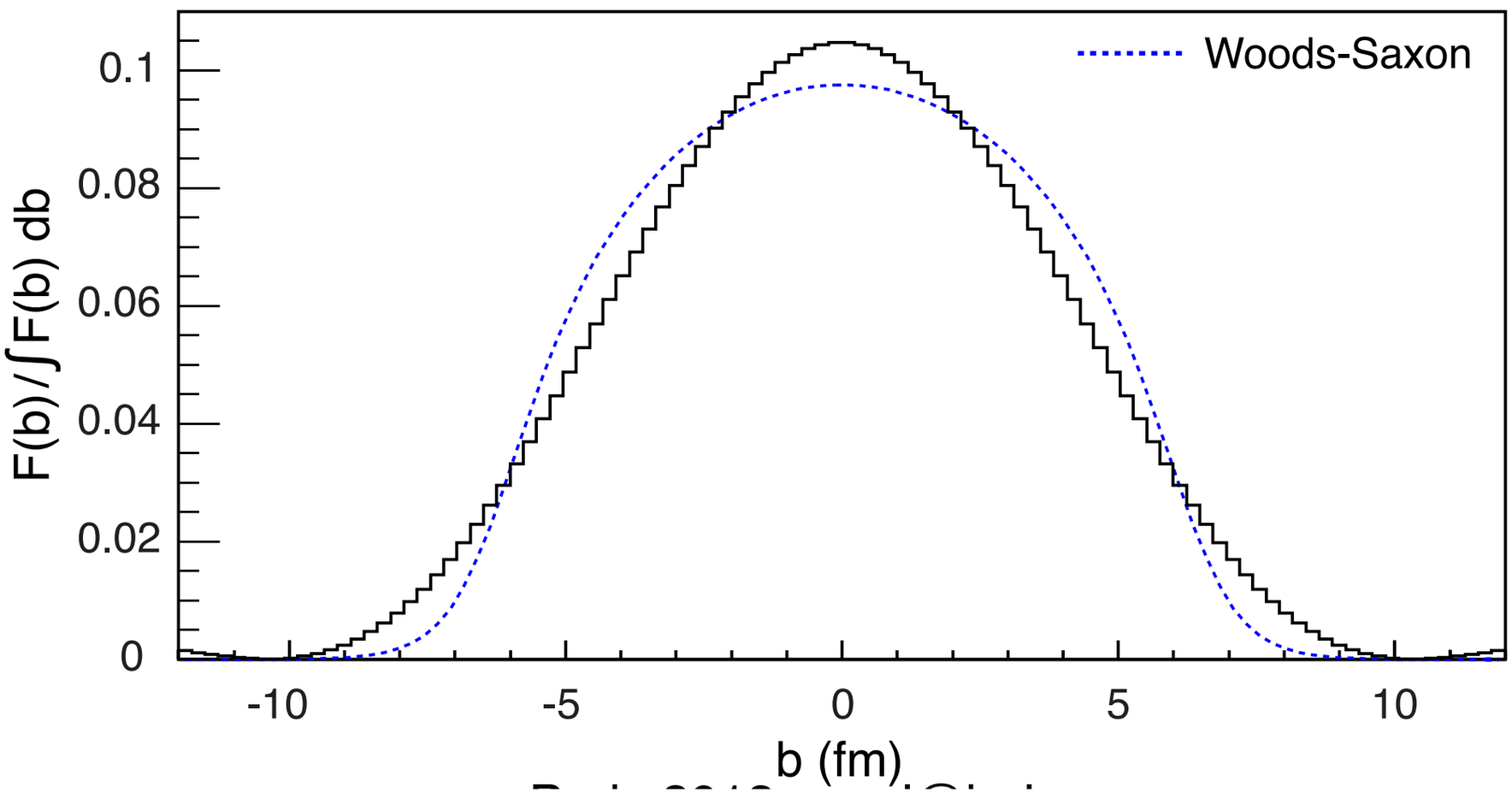

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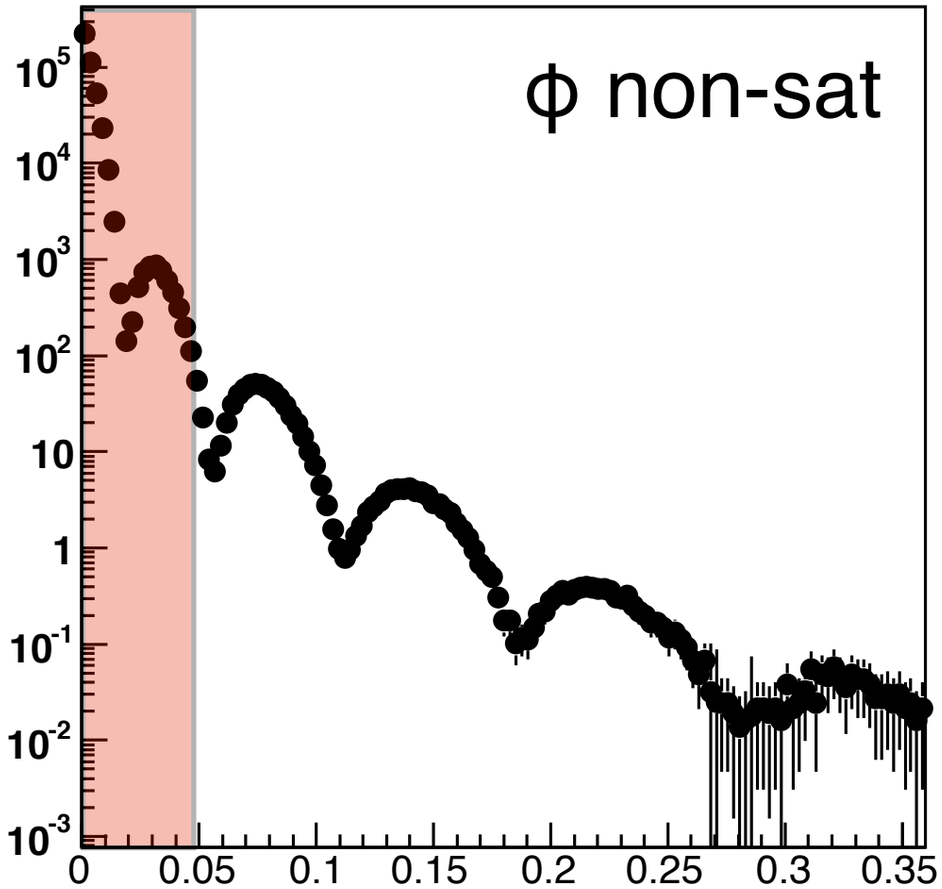


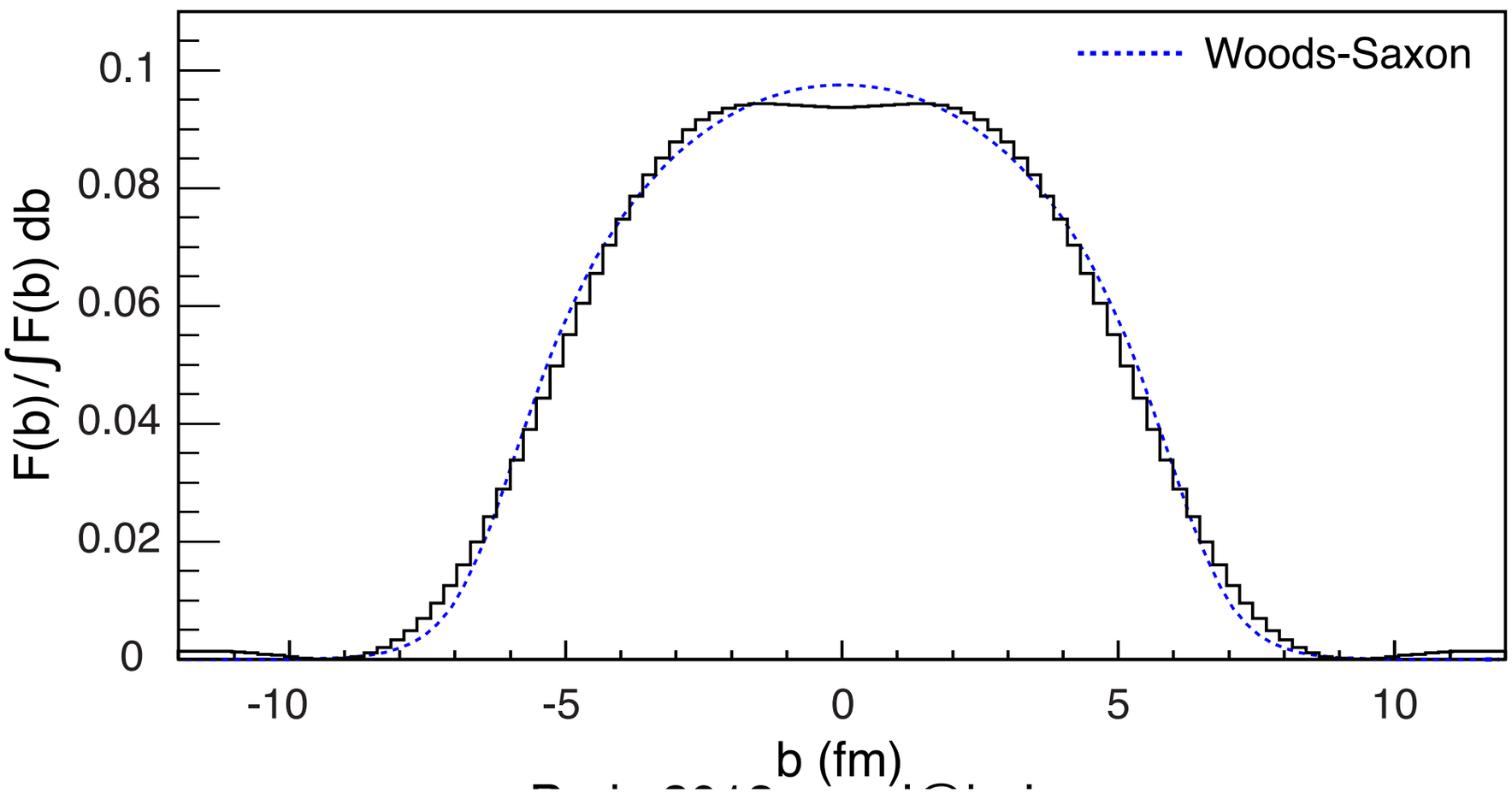

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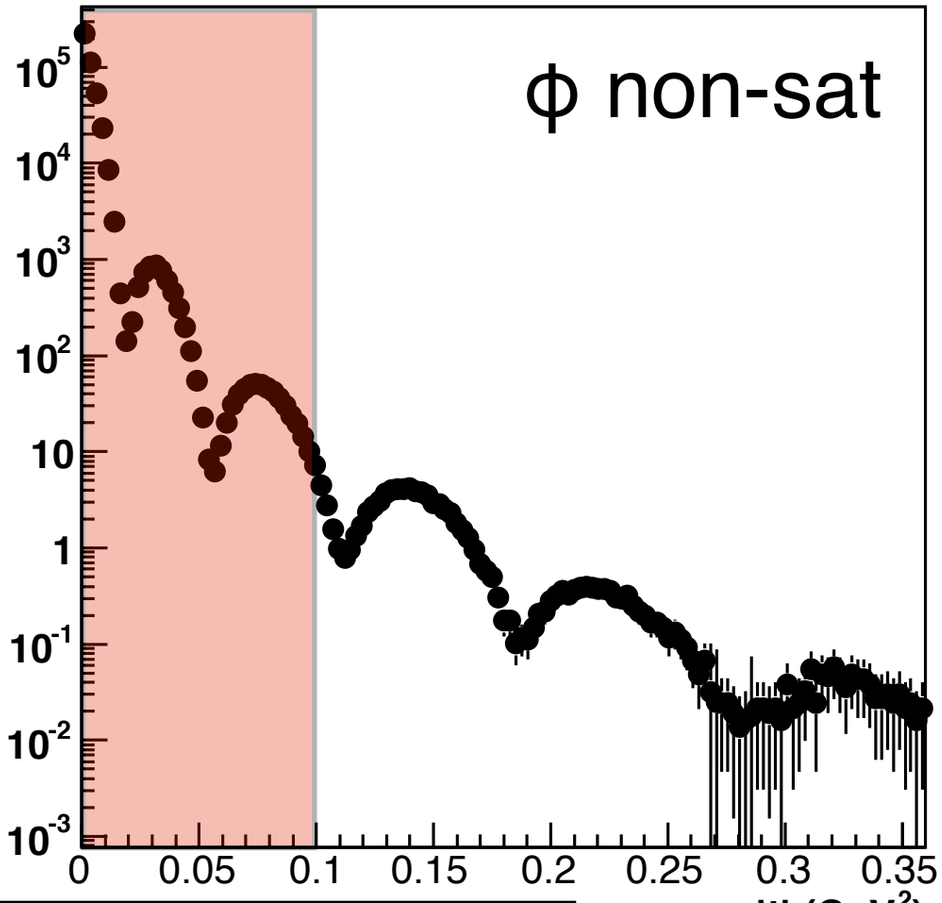


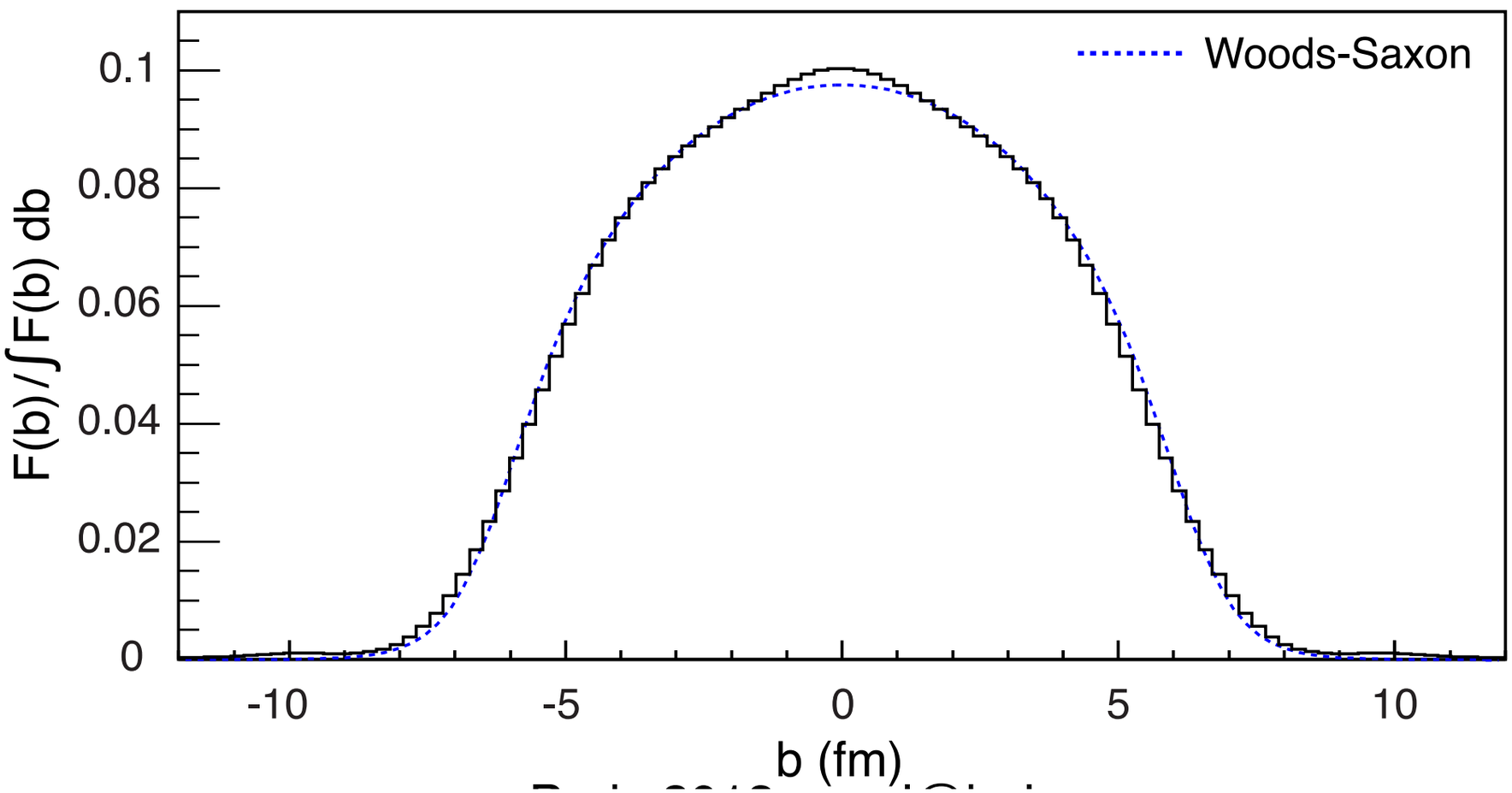

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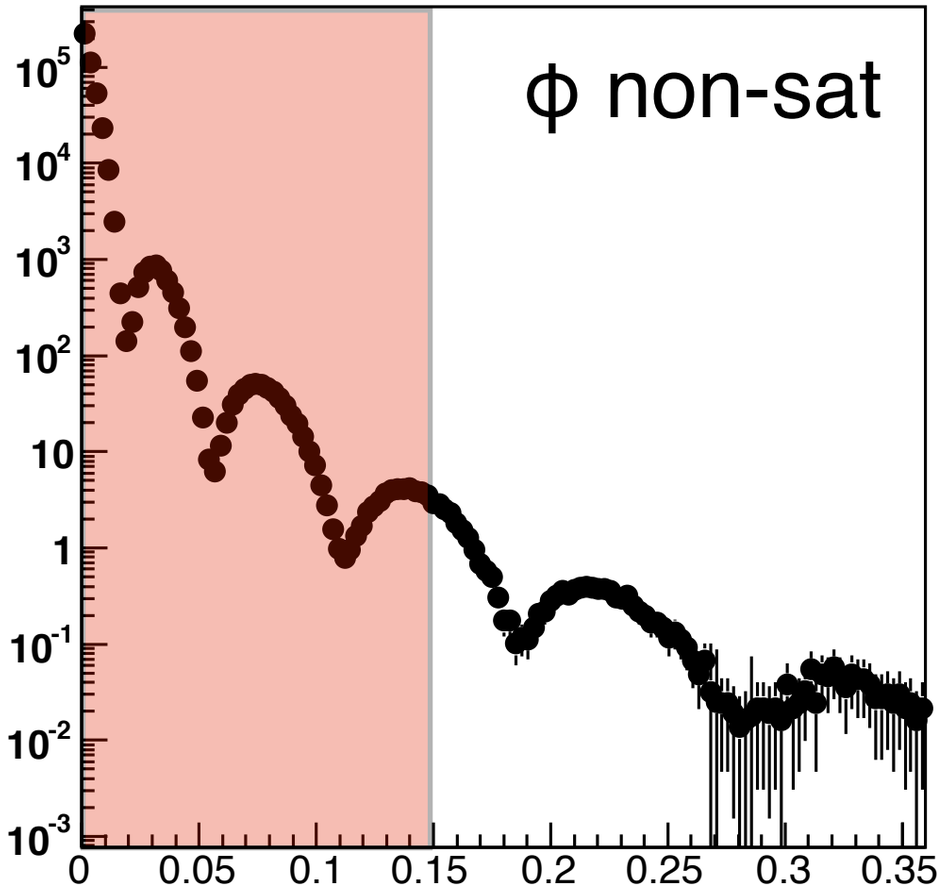


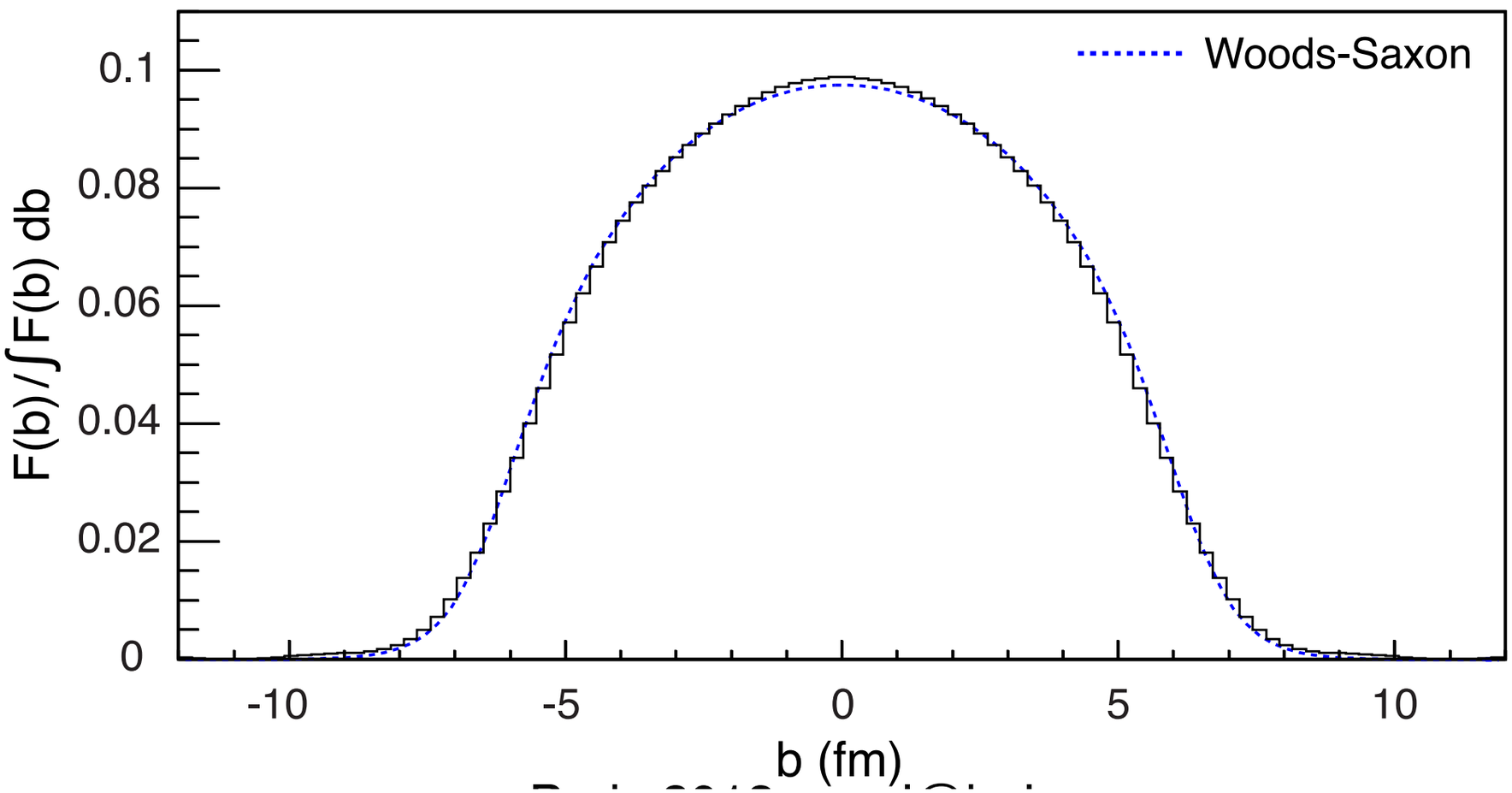

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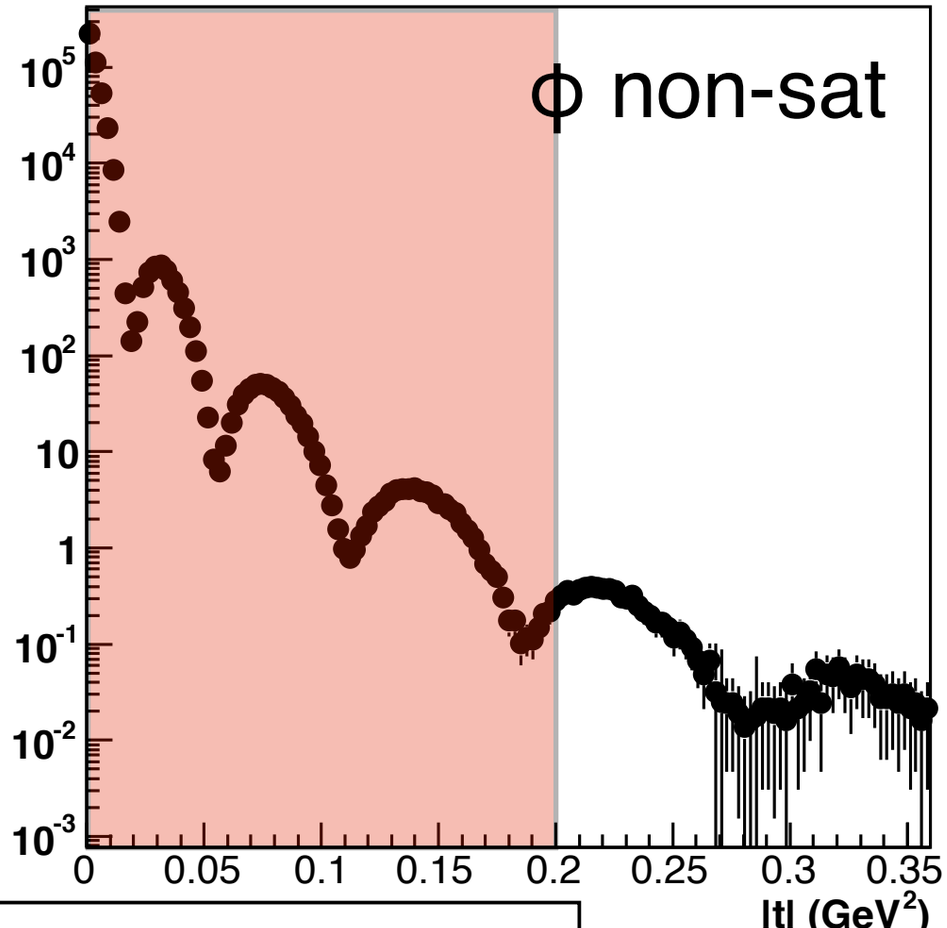


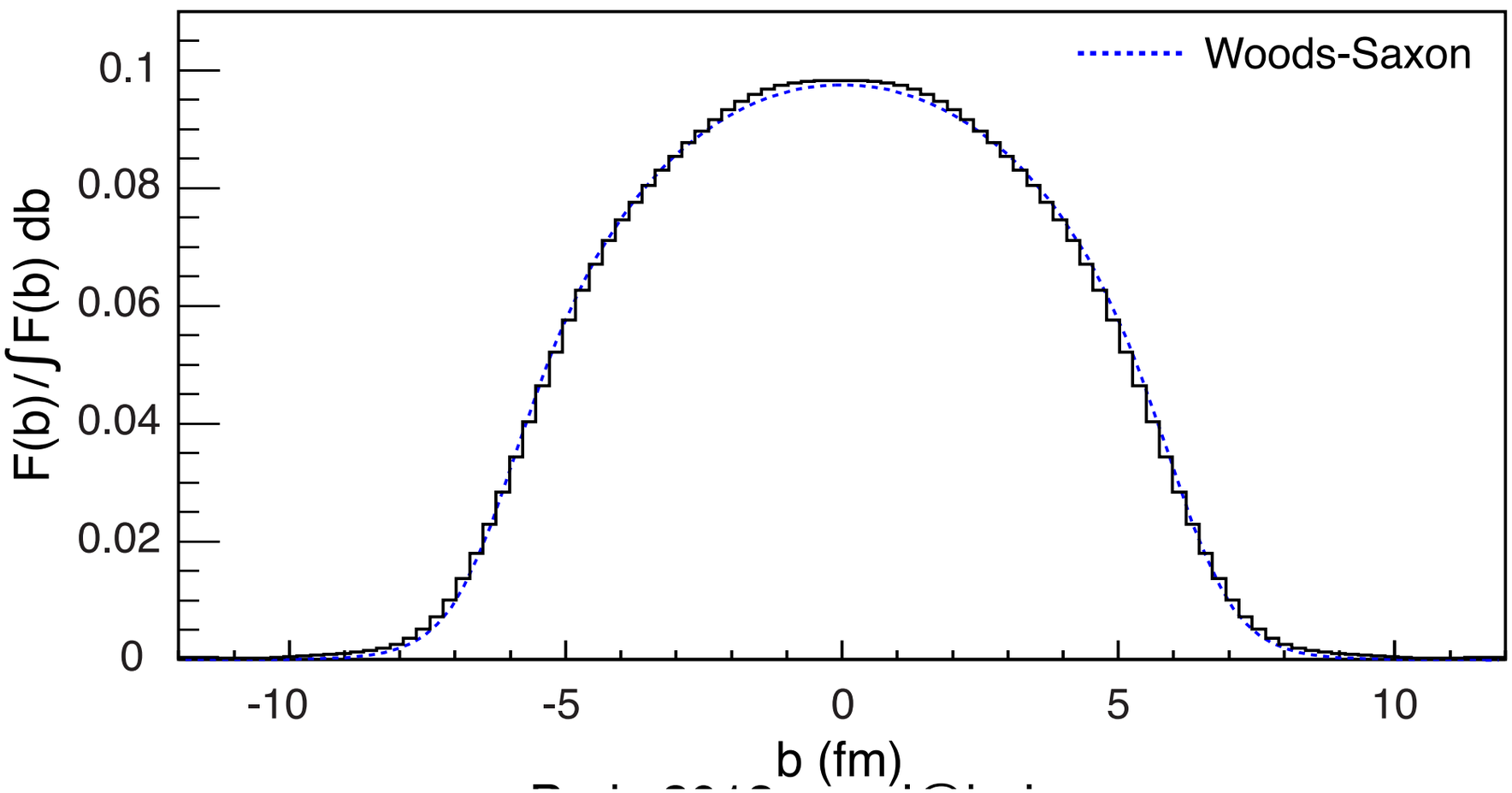

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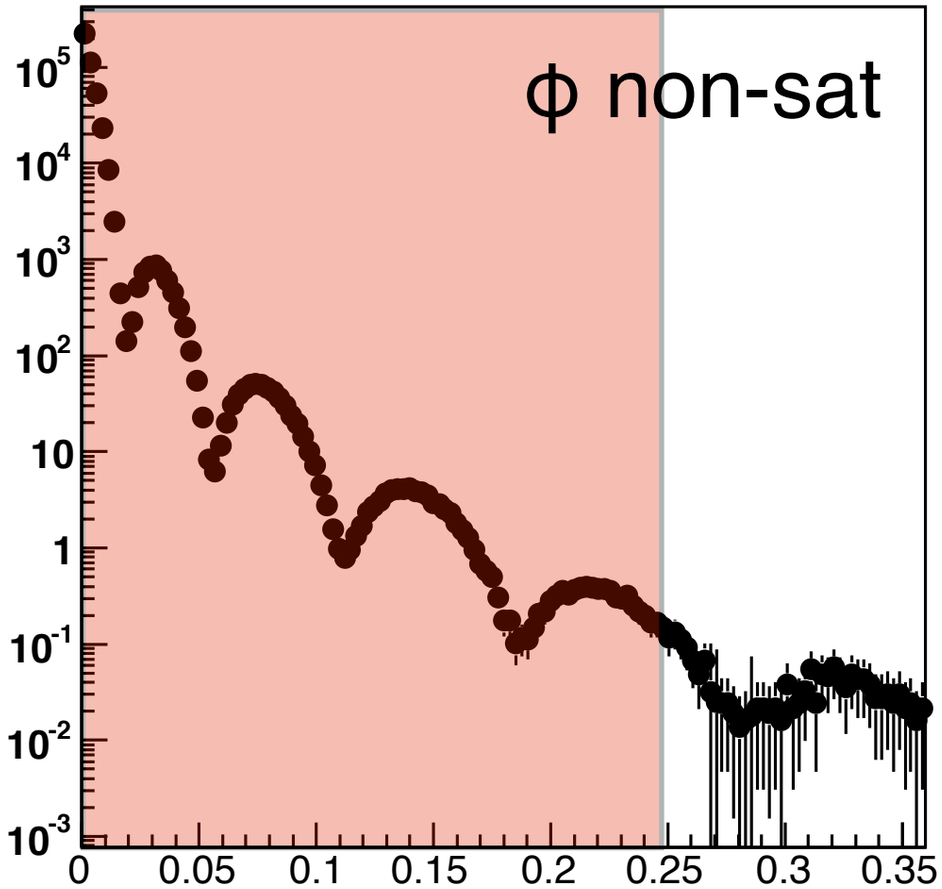


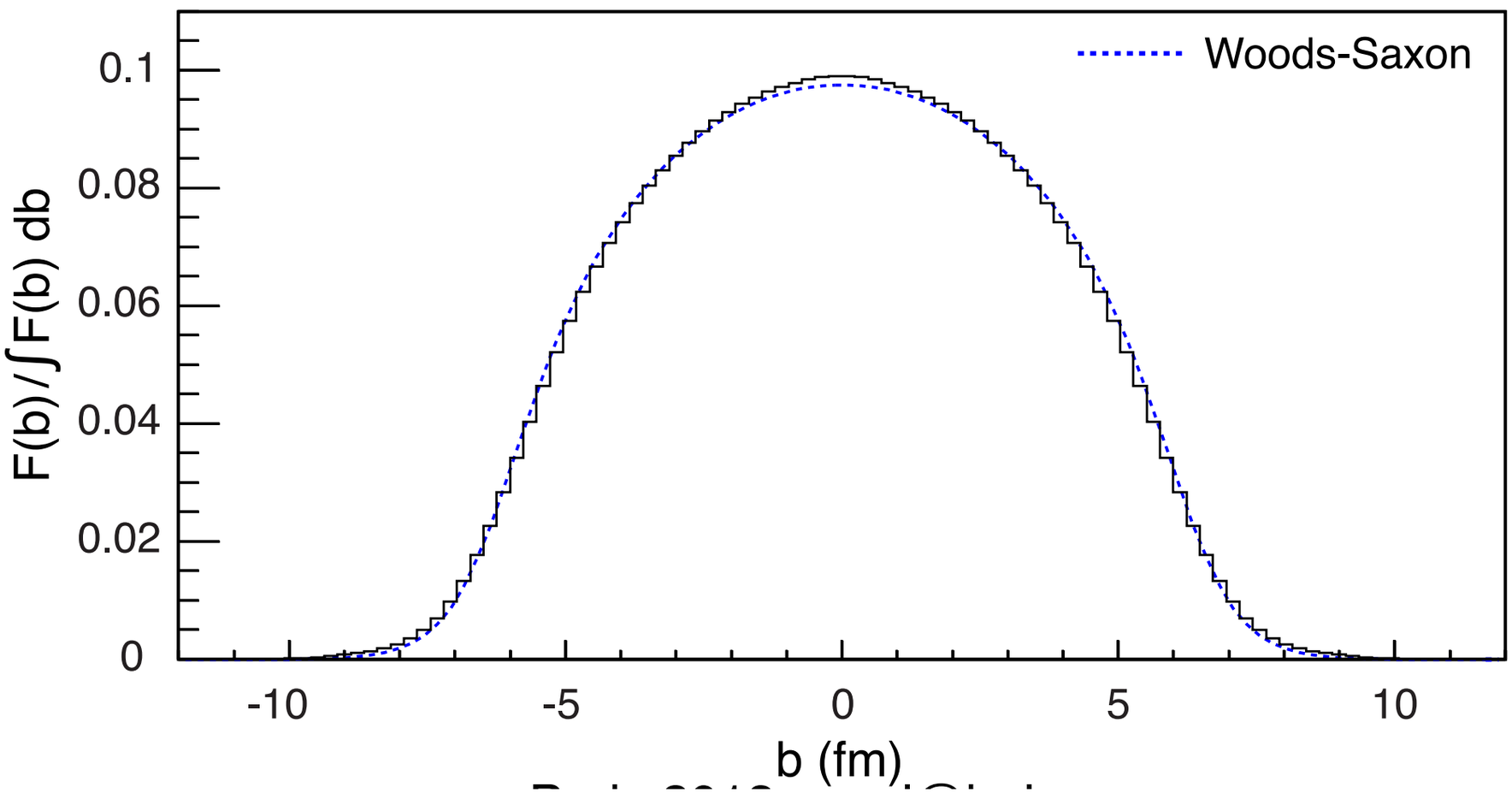

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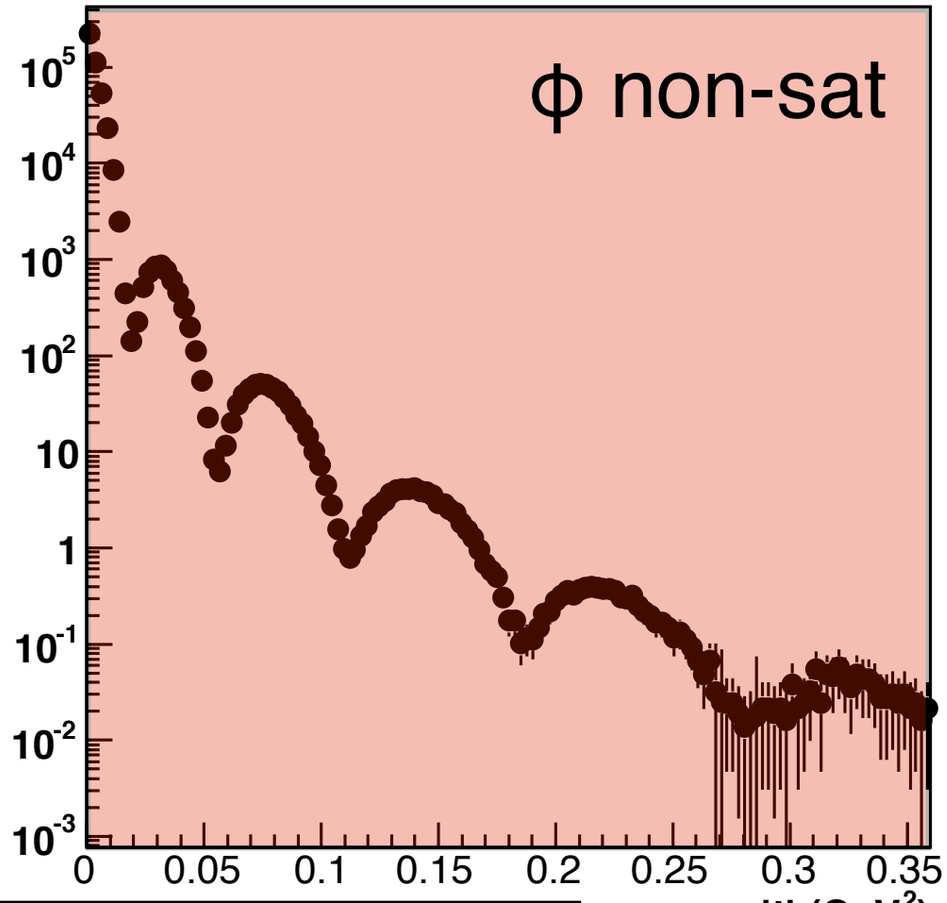
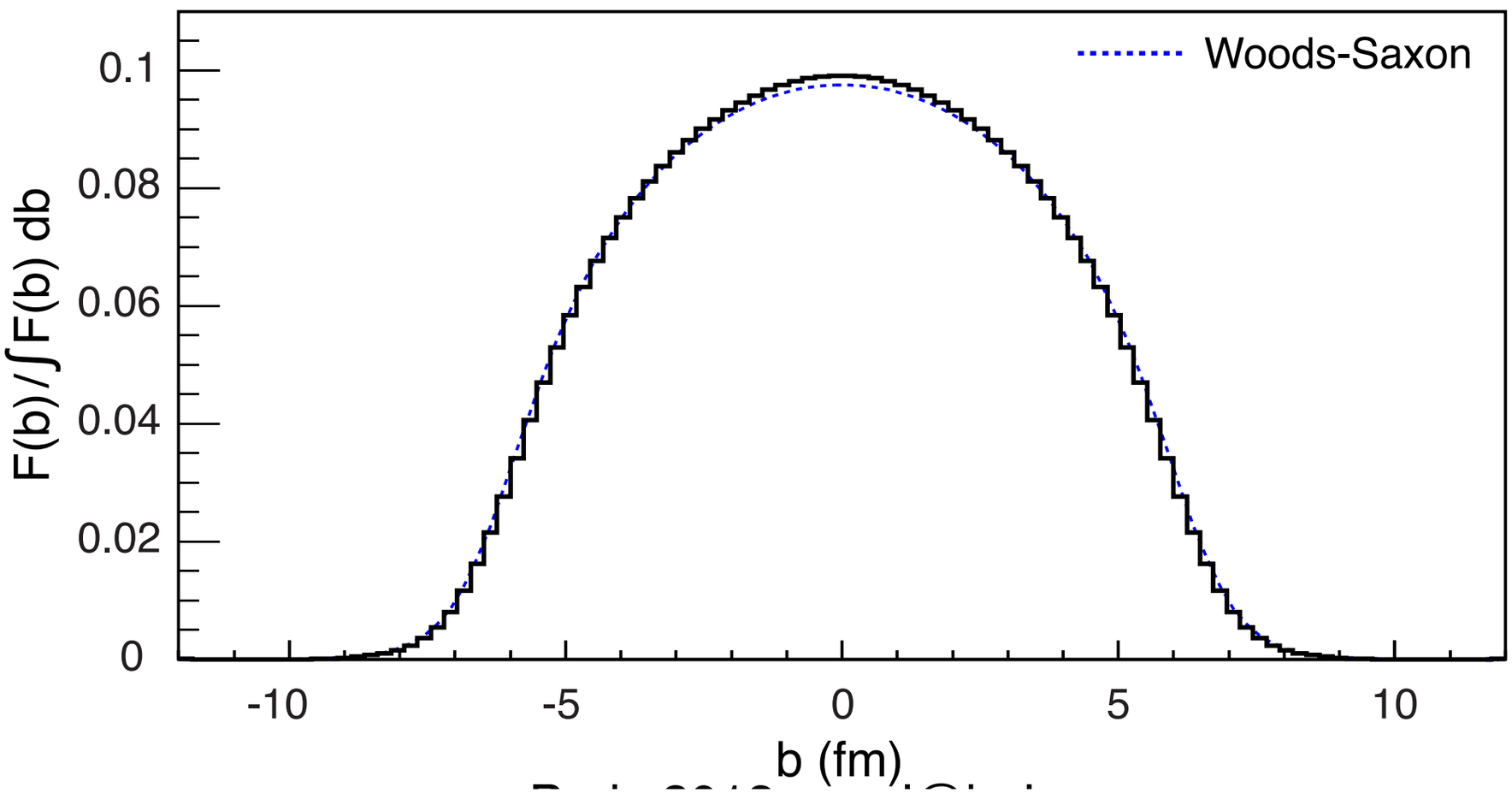
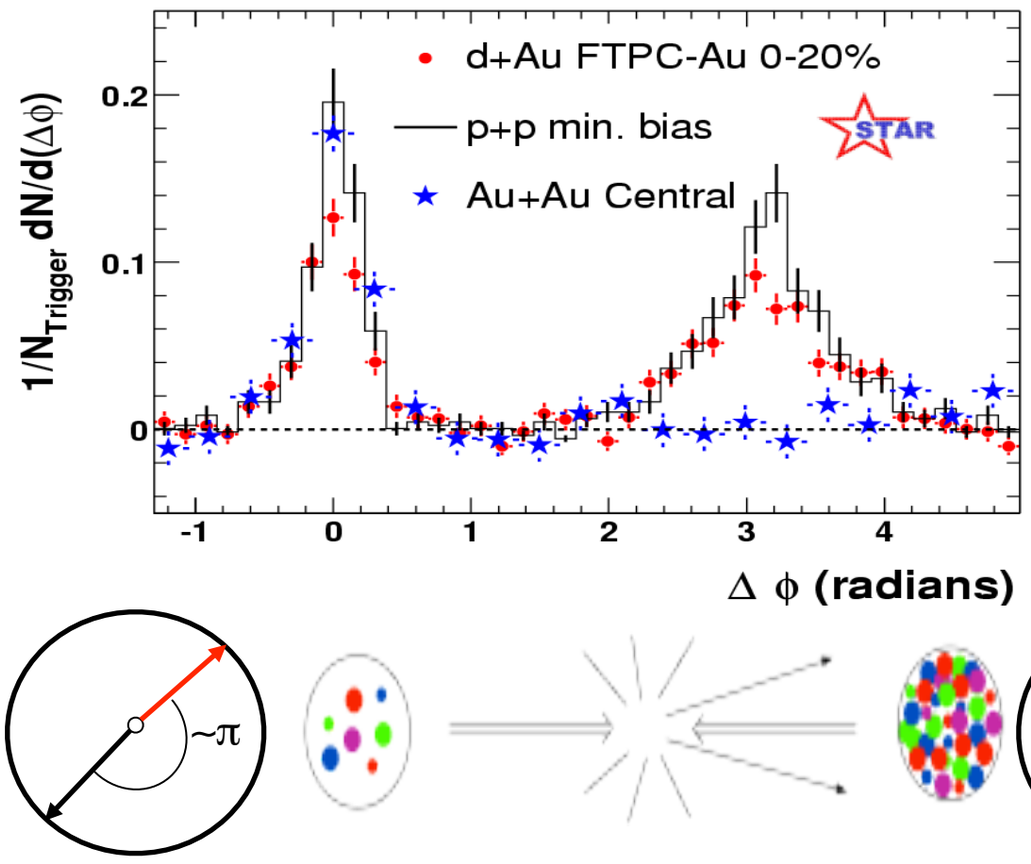


# di-hadron correlations in d+A

comparisons between d+Au → $h_1$ $h_2$ X (or p +Au → $h_1$ $h_2$ X ) and p+p → $h_1$ $h_2$ X




- At y=0, suppression of away-side jet is observed in A+A collisions
- No suppression in p+p or d+A

➡ x ~ $10^{-2}$

$$x_A = \frac{k_1 e^{-y_1} + k_2 e^{-y_2}}{\sqrt{s}} << 1$$

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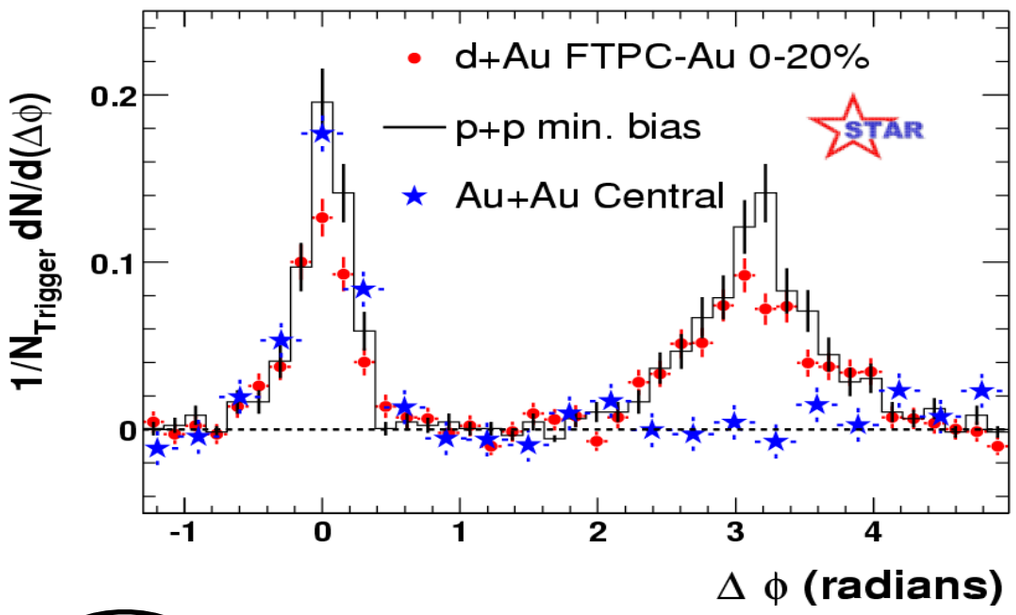


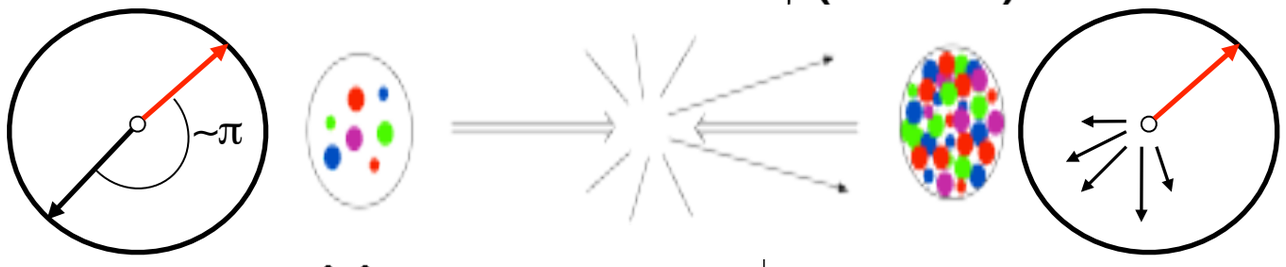


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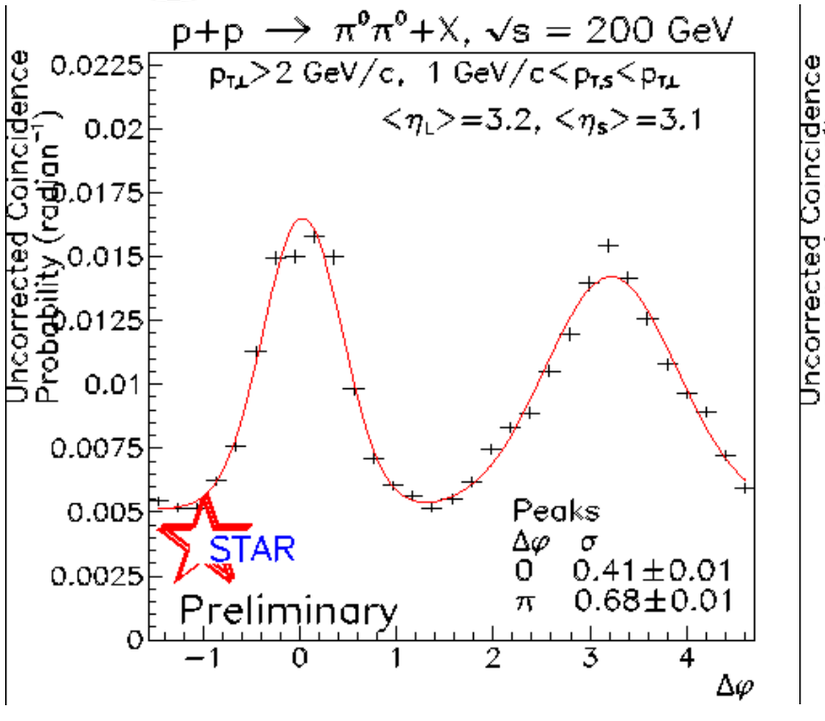
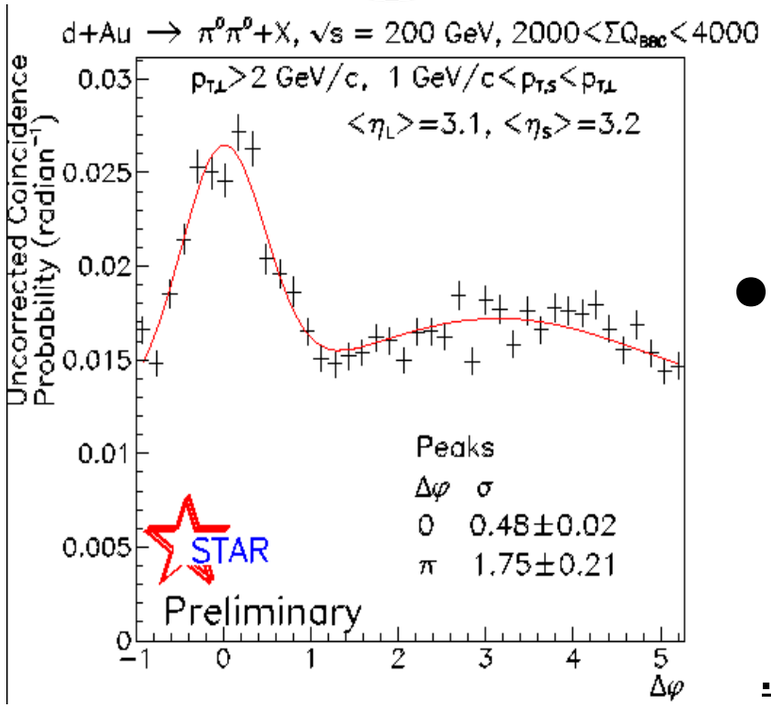
- However, at forward rapidities (y ~ 3.1), an away-side suppression is observed in d+Au
- Away-side peak also much wider in d+Au compared to p+p

➡ x ~ $10^{-3}$



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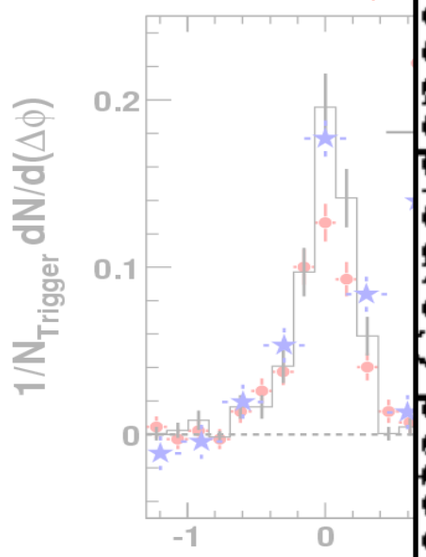


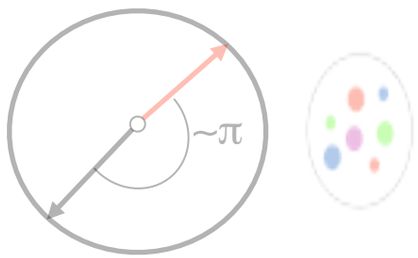




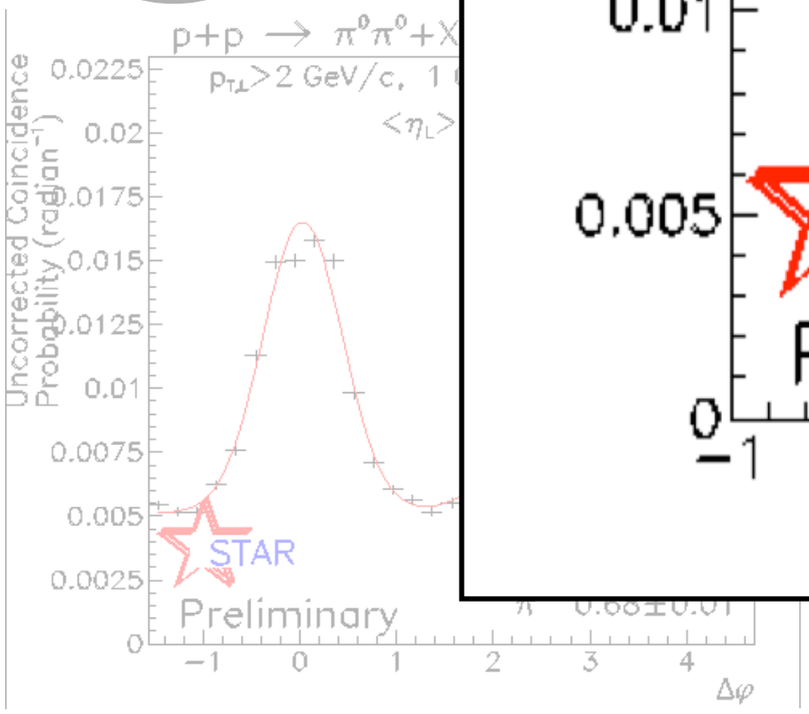


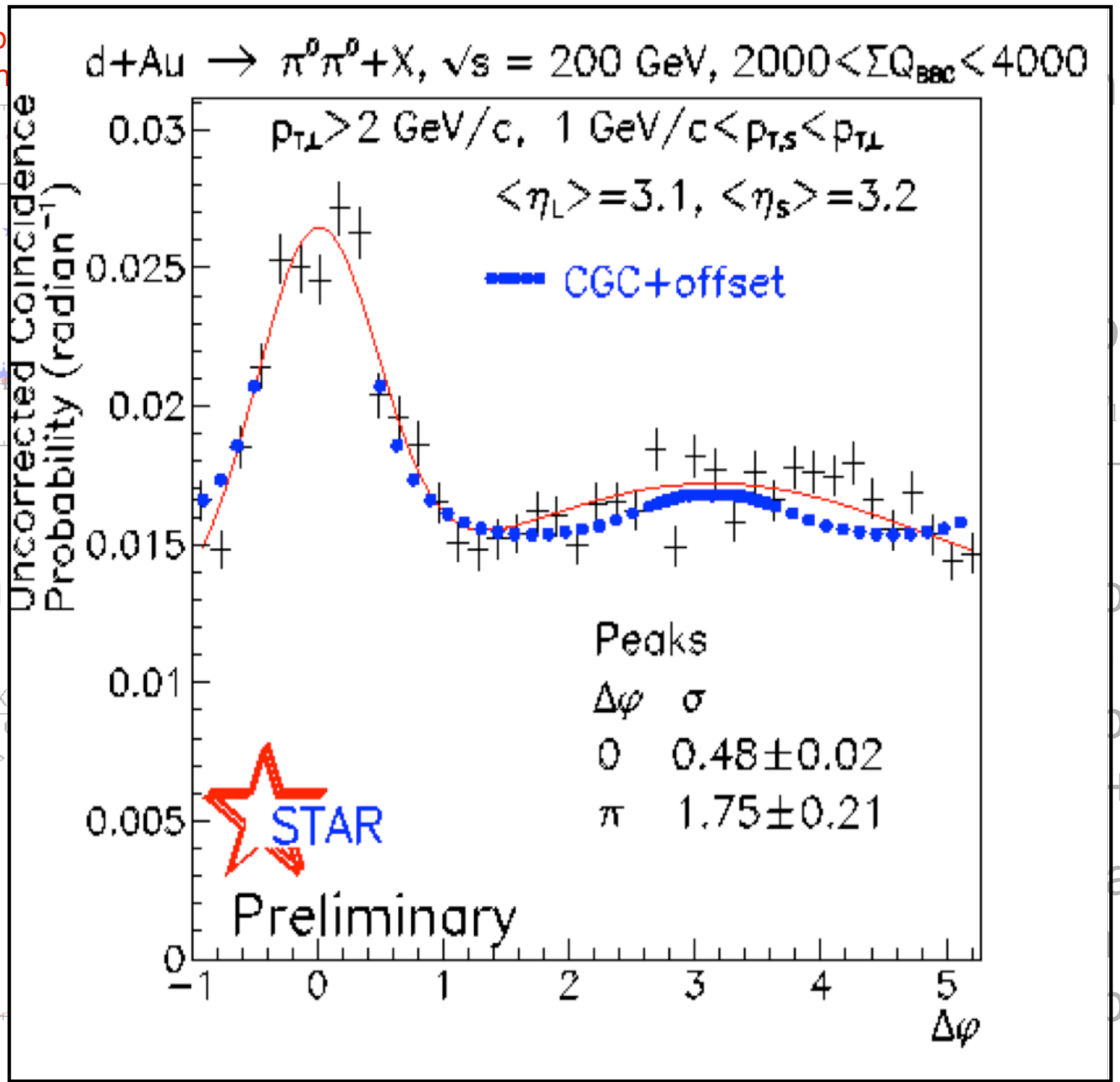


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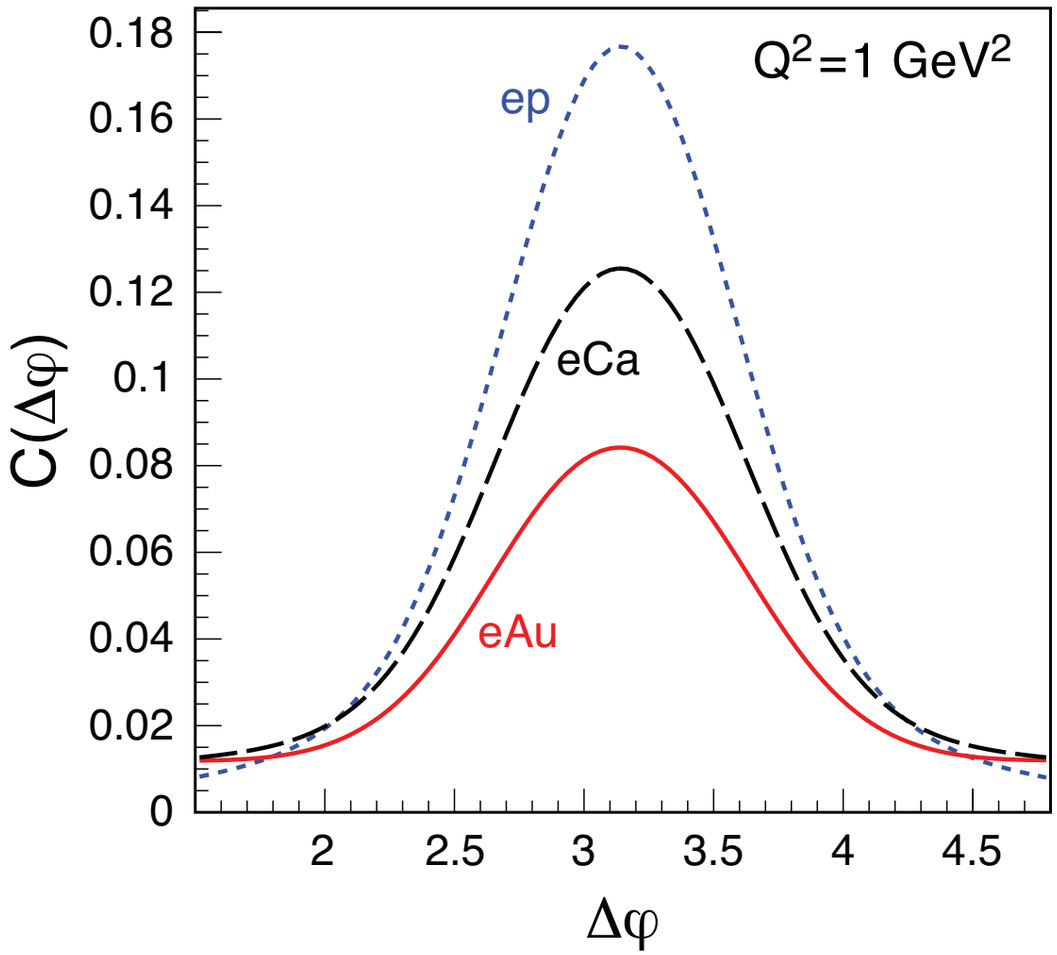


Dominguez, Xiao and Yuan (2012)

- At small-x, multi-gluon distributions are as important as single-gluon distributions and they contribute to di-hadron correlations

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- The d+Au RHIC data is therefore subject to many uncertainties

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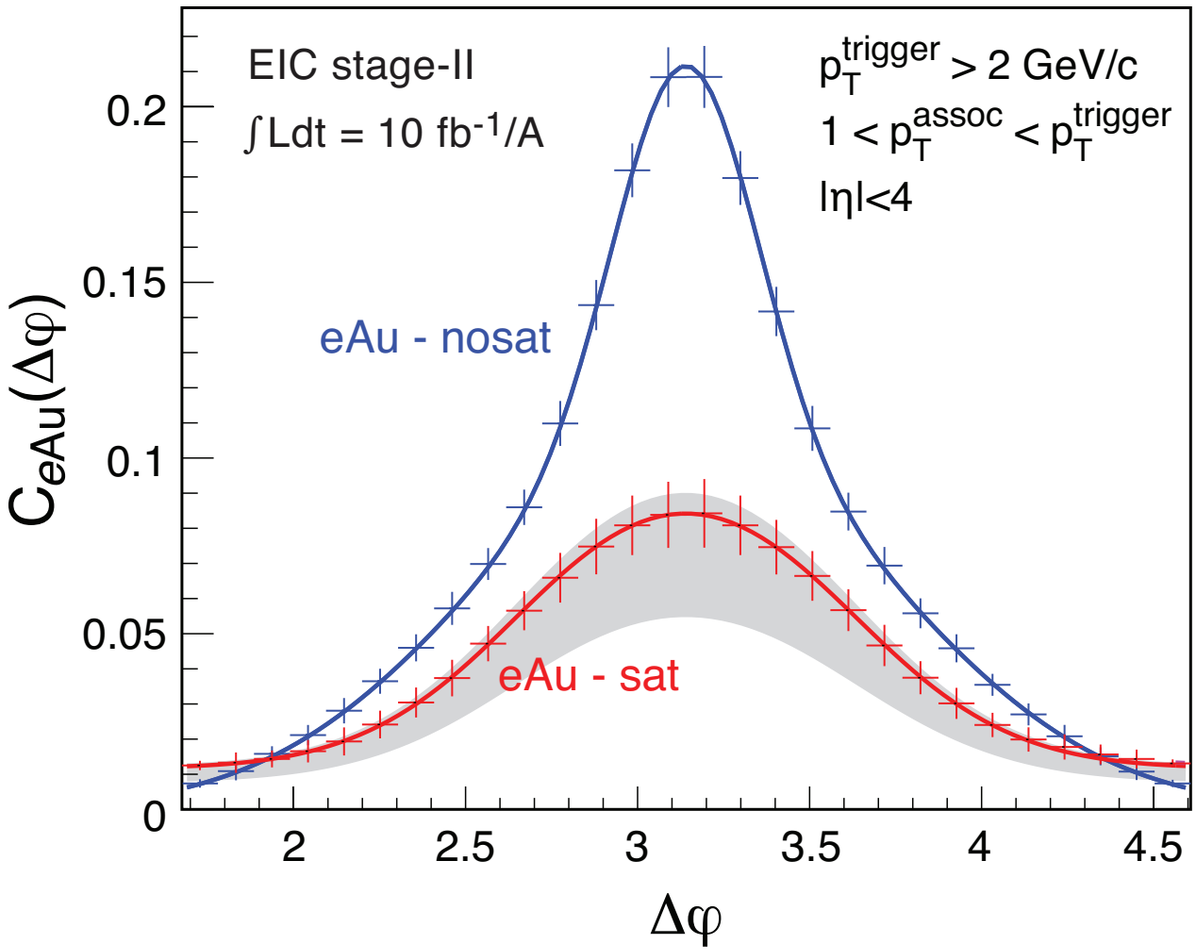


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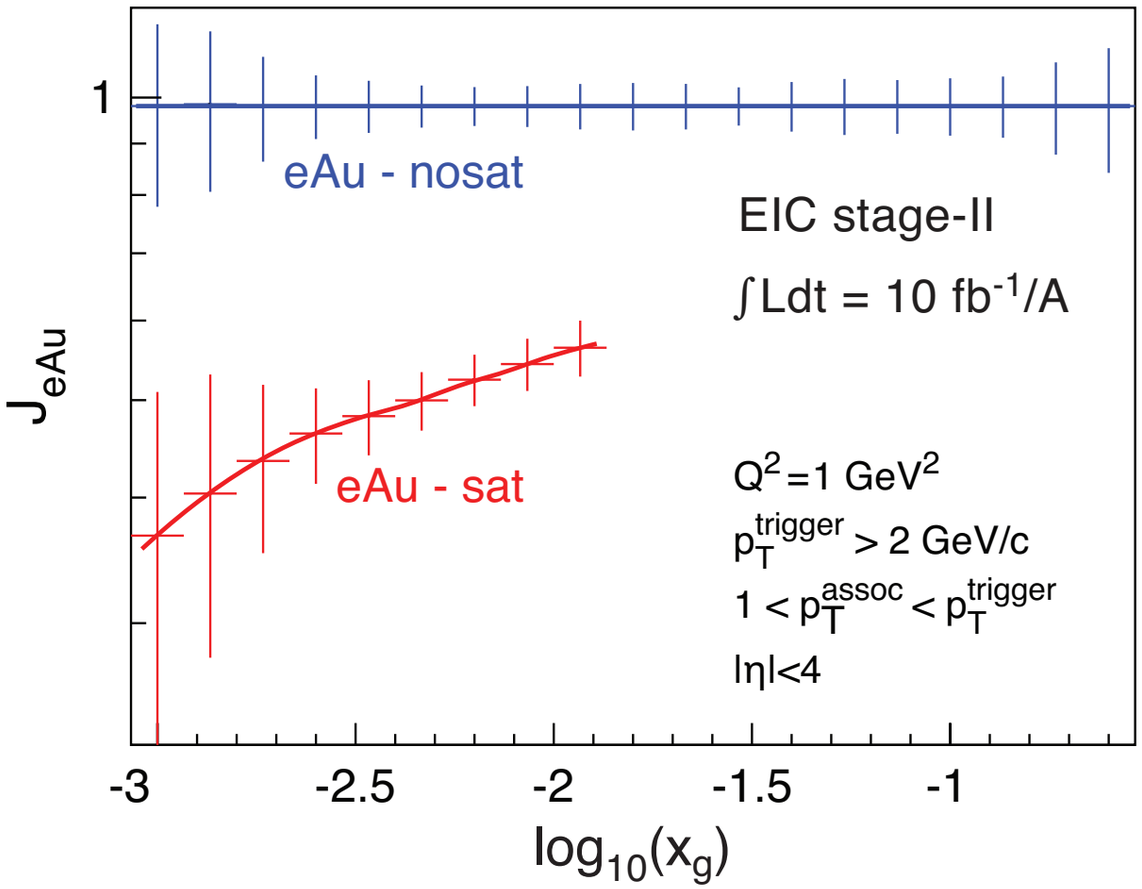
# di-hadron Correlations - relative yields

- PHENIX measured $J_{dAu}$ - relative yield of di-hadrons produced in d+Au compared to p+p collisions

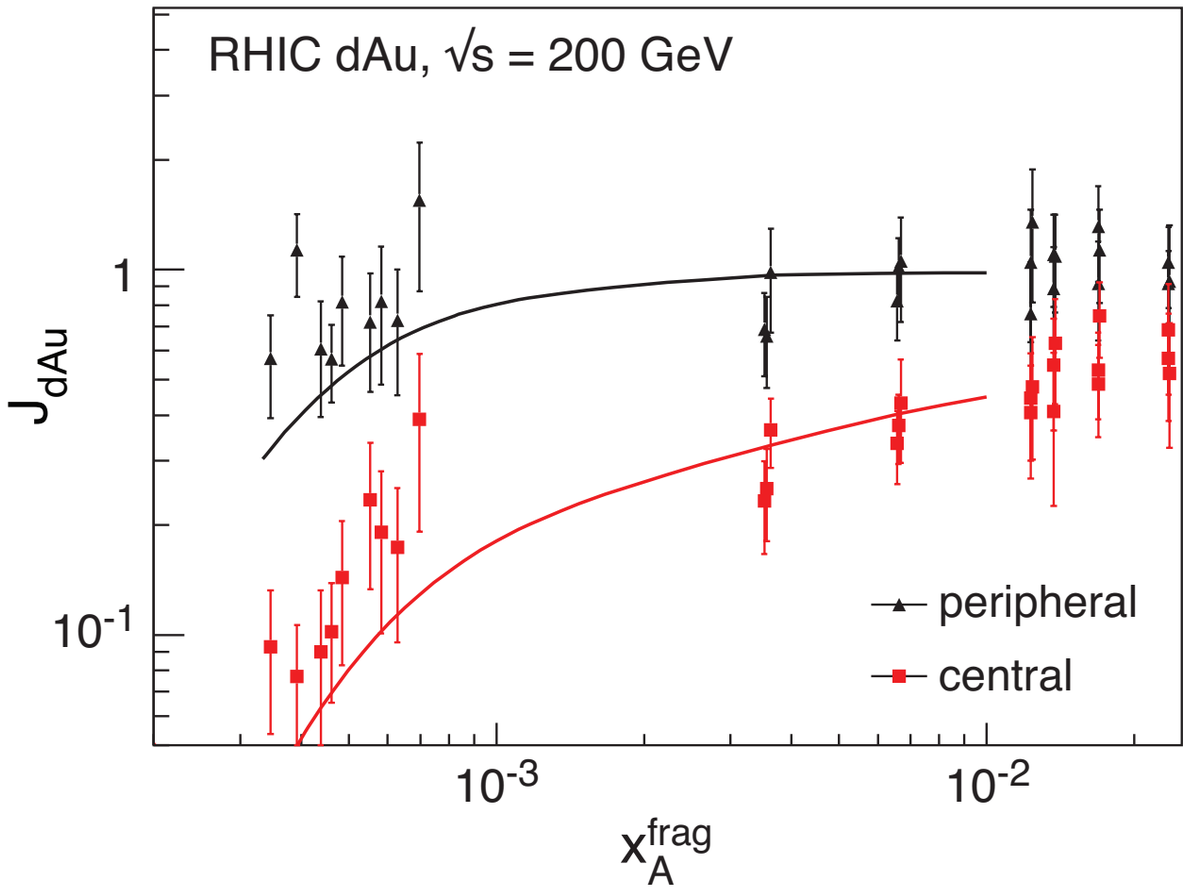
➡ Suppression in central events compared to peripheral as a function of $x_A^{frag}$

  - Curves come from saturation model

- Can perform the same measurement in e+A collisions




forward-forward mid-forward




A. Adare et al., Phys. Rev. Lett. 107, 172301 (2011)

# Summary and Conclusions

- The e+A physics programme at an EIC will give us an unprecedented opportunity to study gluons in nuclei
  - ➡ Low-x: Measure the properties of gluons where saturation is the dominant governing phenomena
  - ➡ Higher-x: Understand how fast partons interact as they traverse nuclear matter and provide new insight into hadronization
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- The INT programme in the Autumn of 2010 allowed us to formulate the observables in terms of golden and silver measurements
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# Summary and Conclusions

- The e+A physics programme at an EIC will give us an unprecedented opportunity to study gluons in nuclei
  - ➡ Low-x: Measure the properties of gluons where saturation is the dominant governing phenomena
  - ➡ Higher-x: Understand how fast partons interact as they traverse nuclear matter and provide new insight into hadronization

**entire science programme is uniquely tied to a future high-energy electron-ion collider never been measured before & never without**

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# BACKUP

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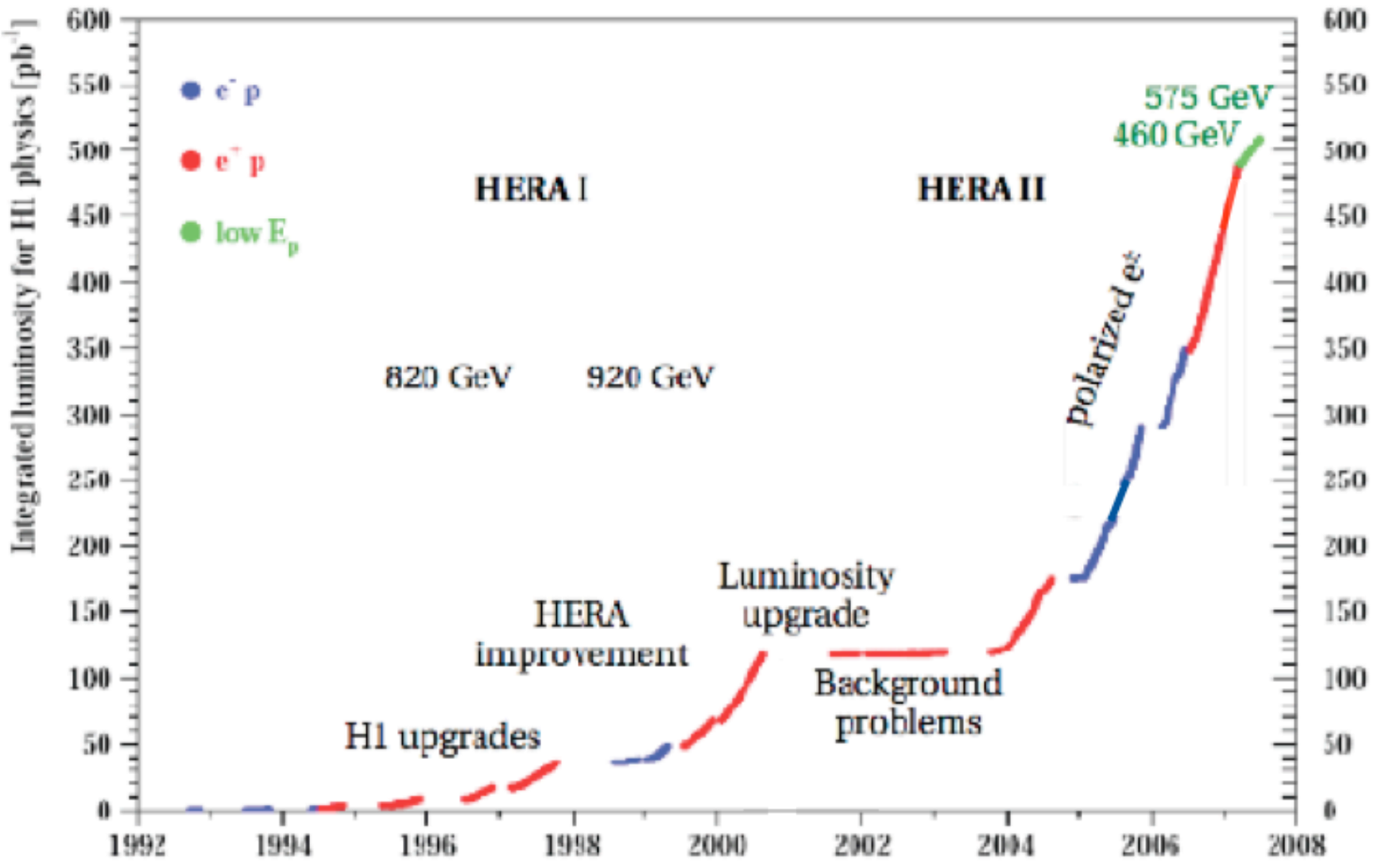

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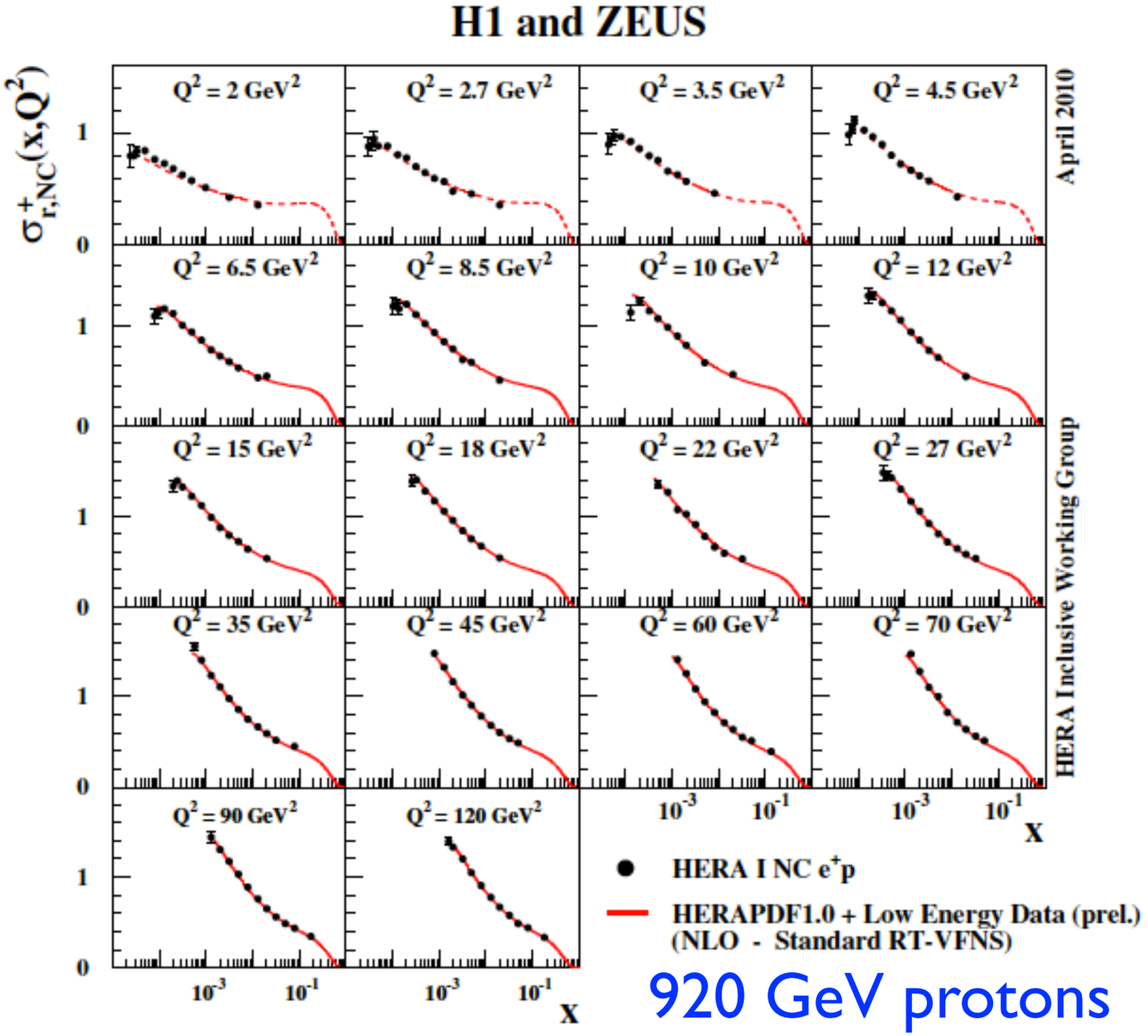


920 GeV protons

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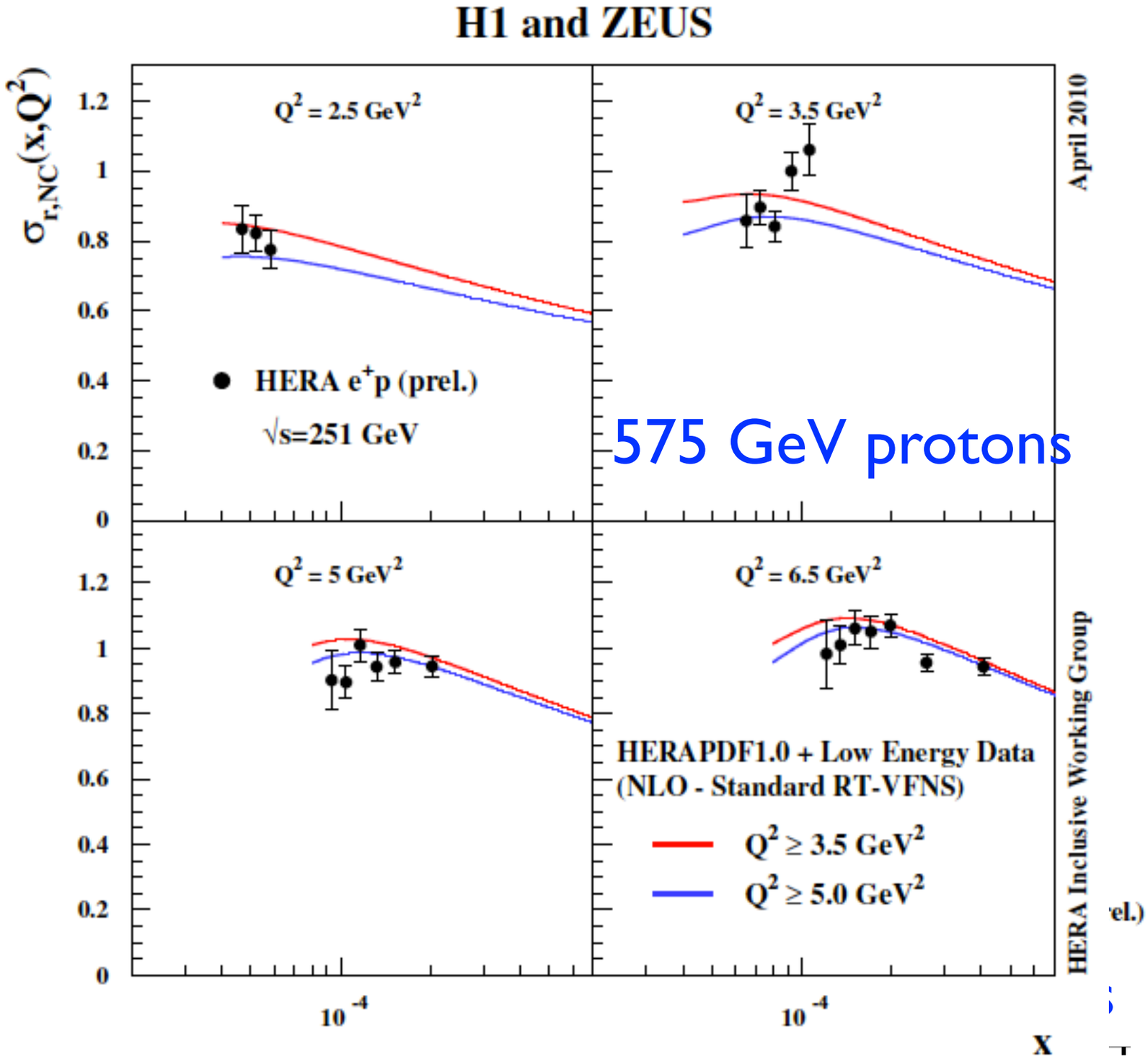

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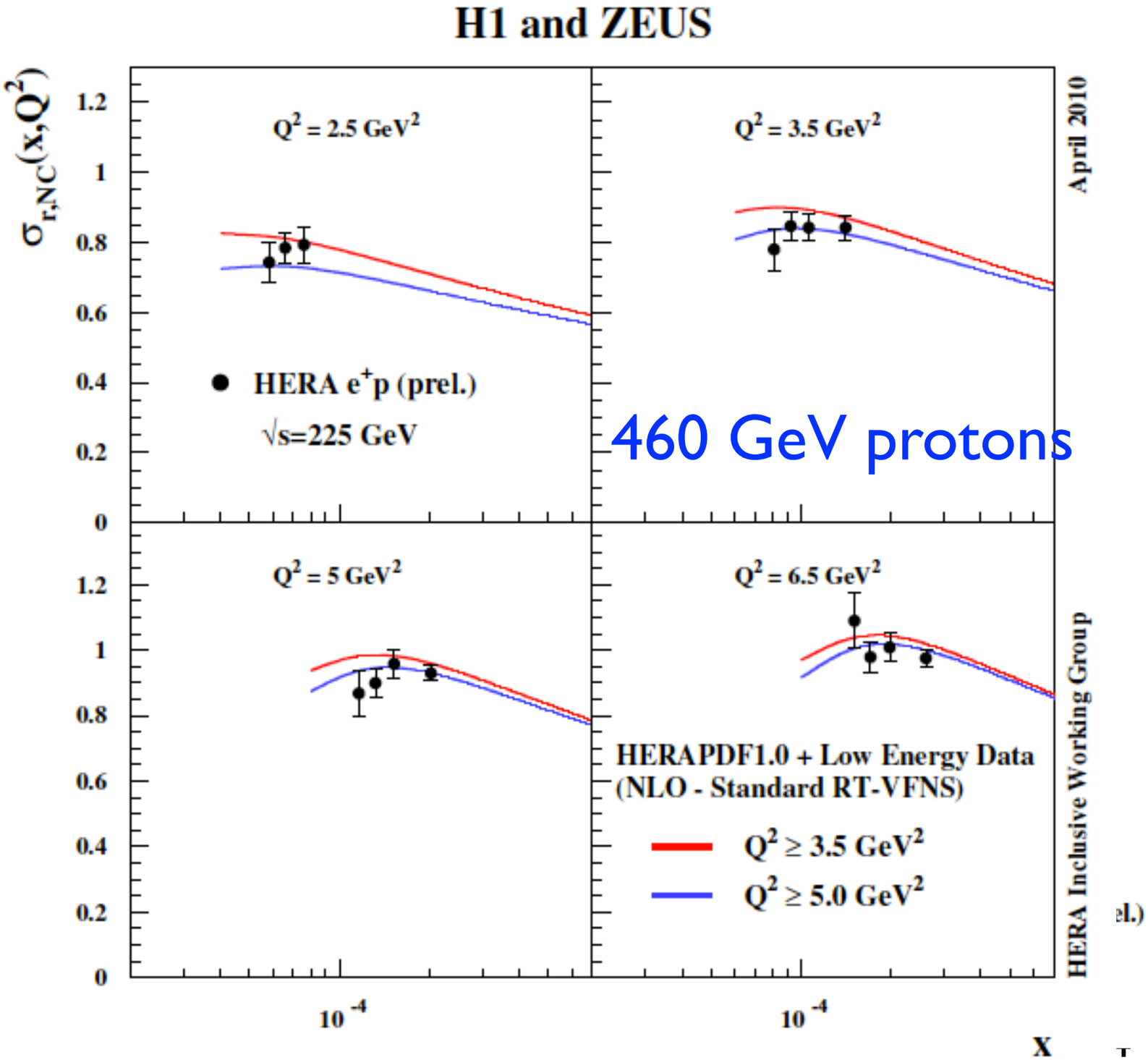

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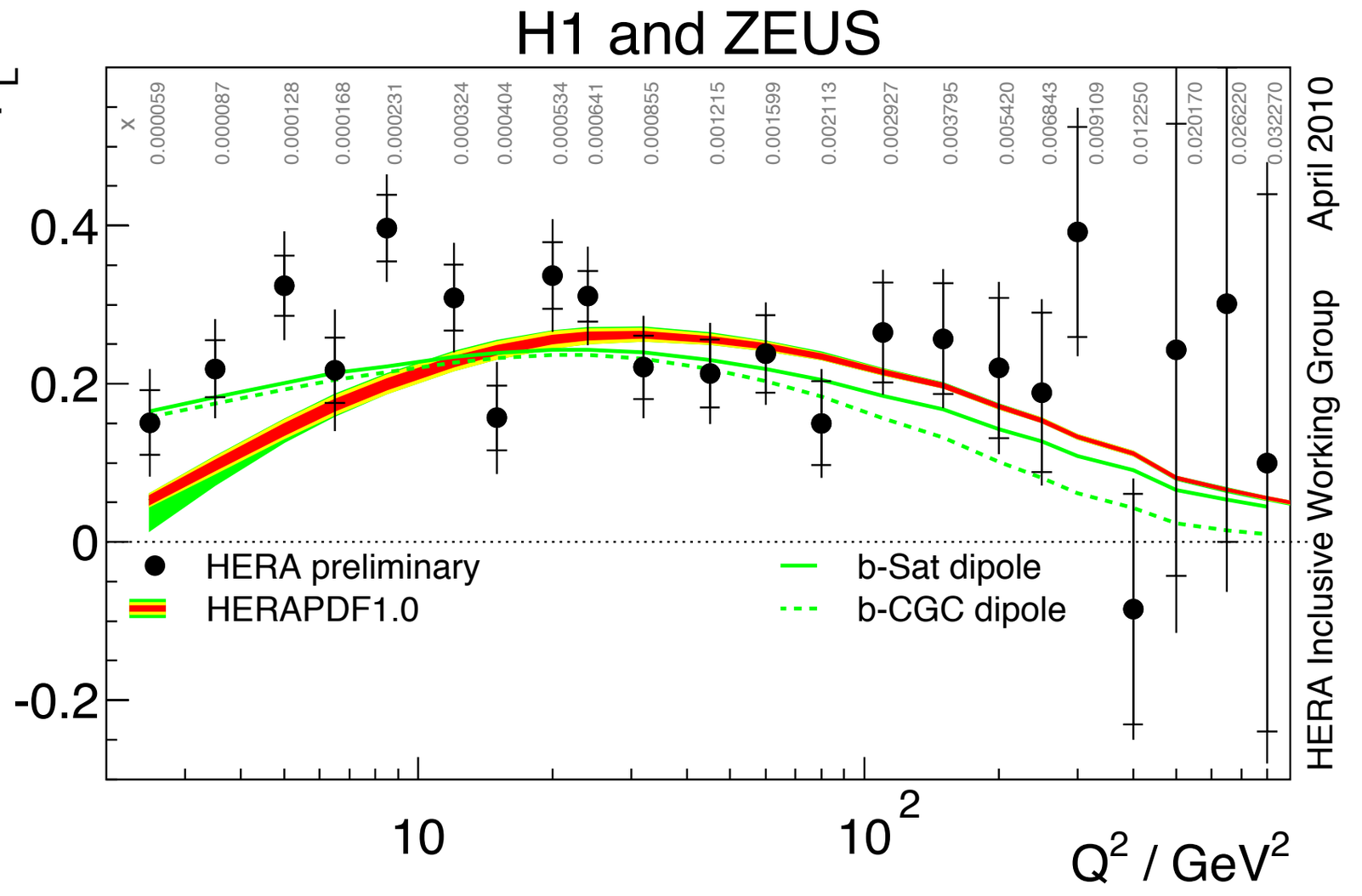

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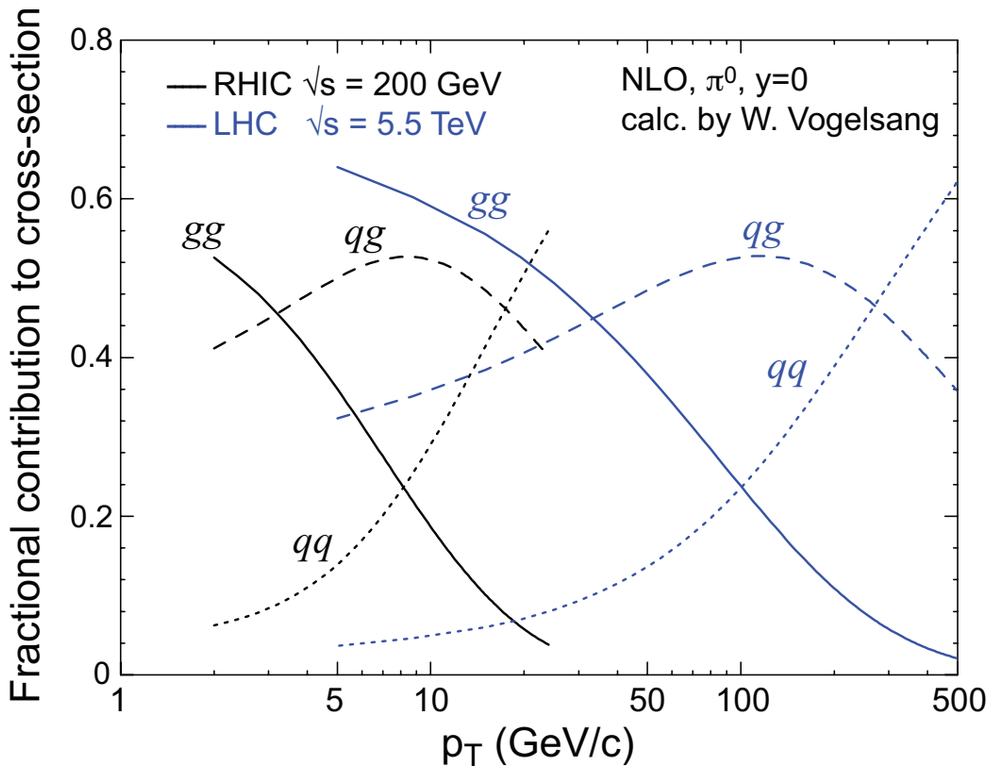

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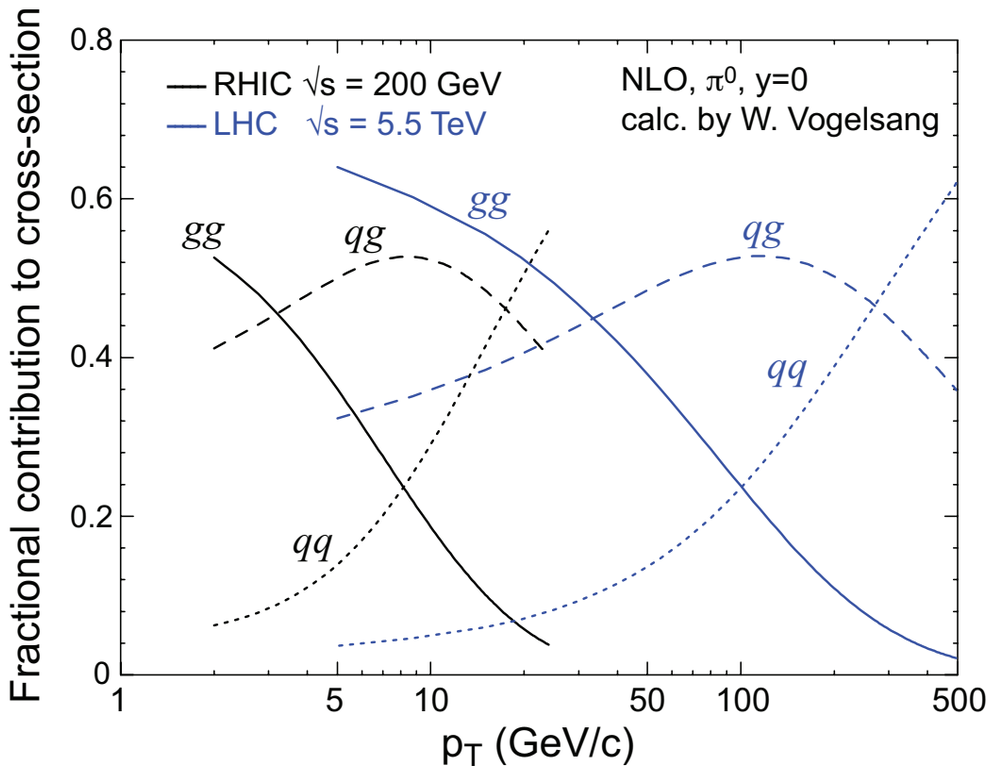


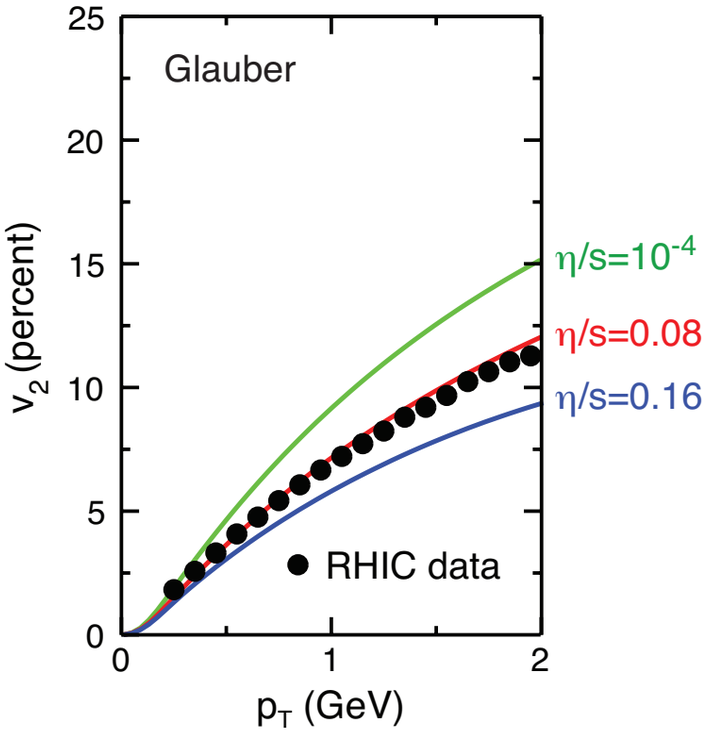


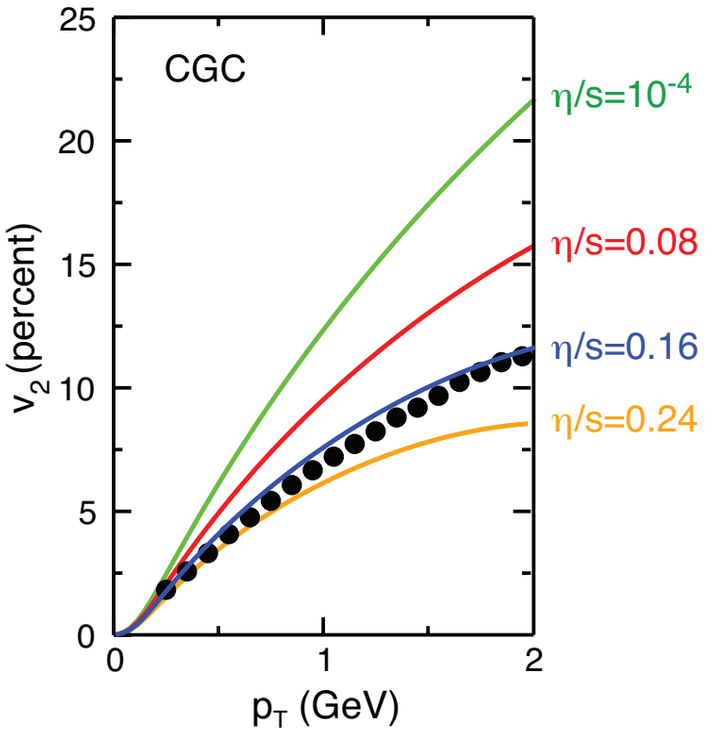

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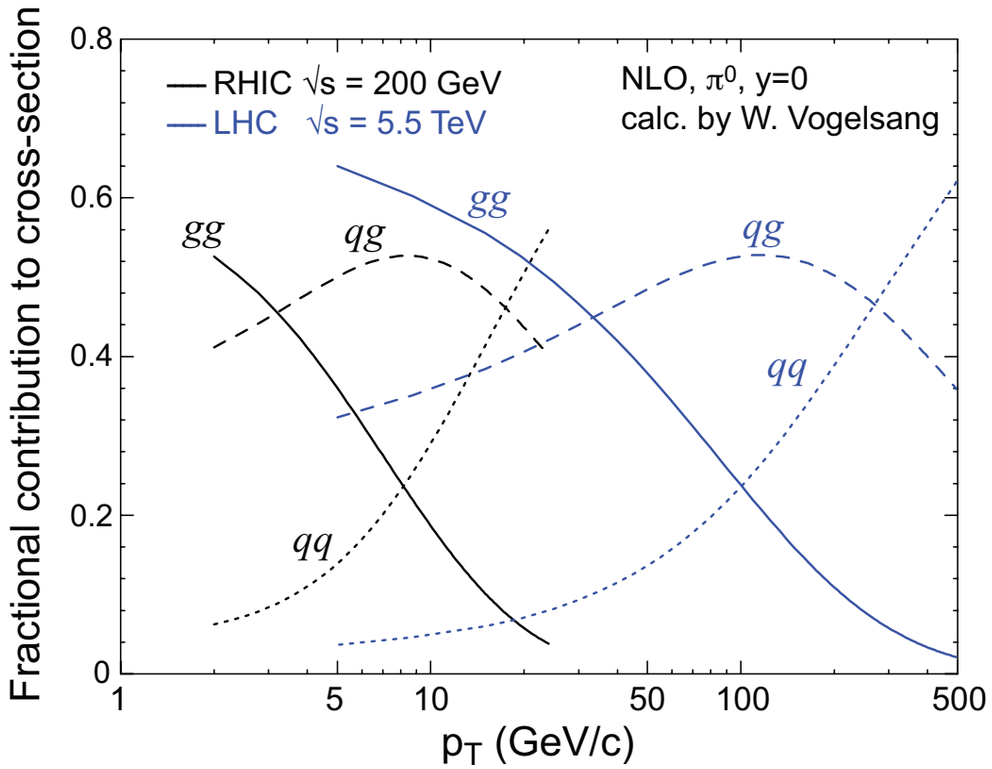


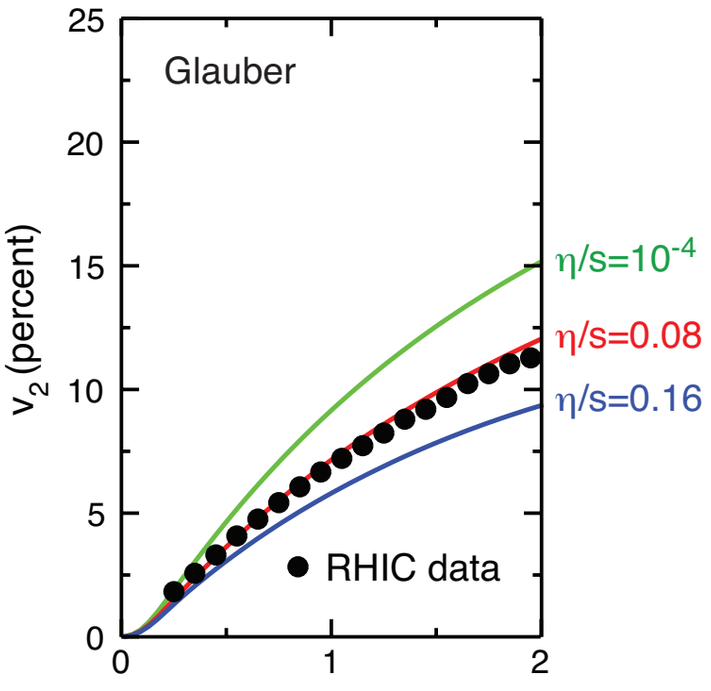


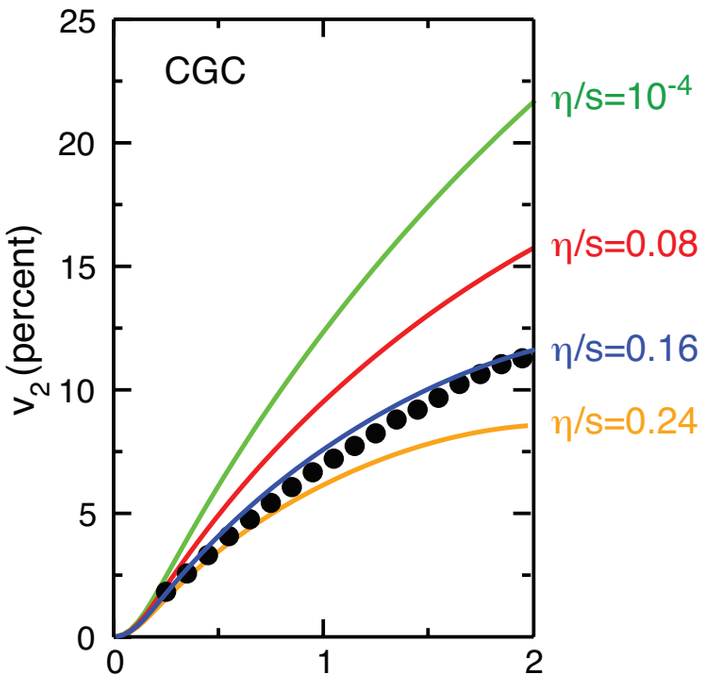


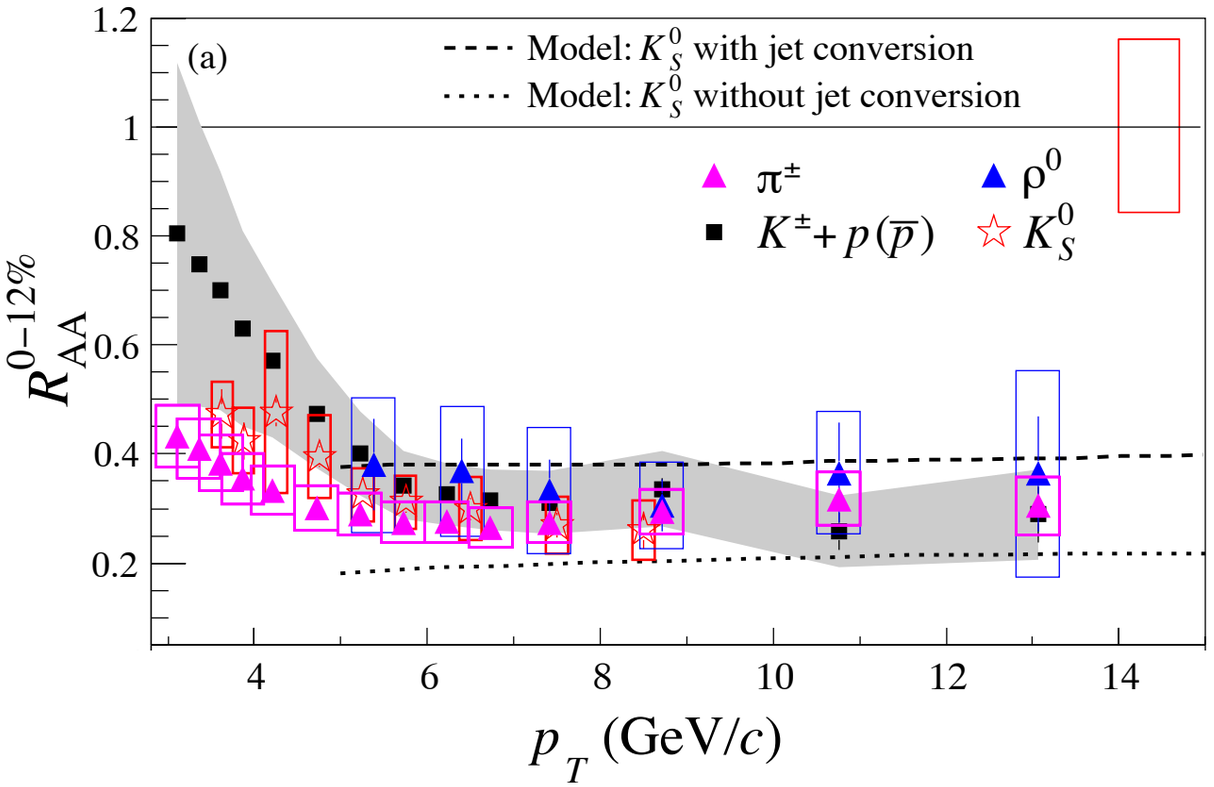

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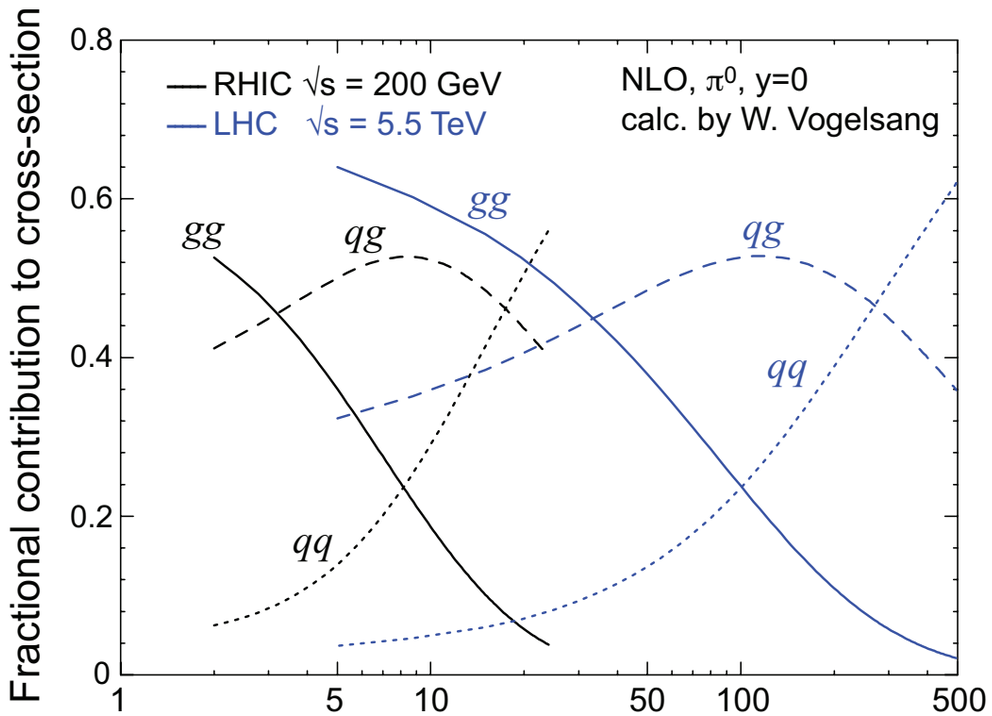
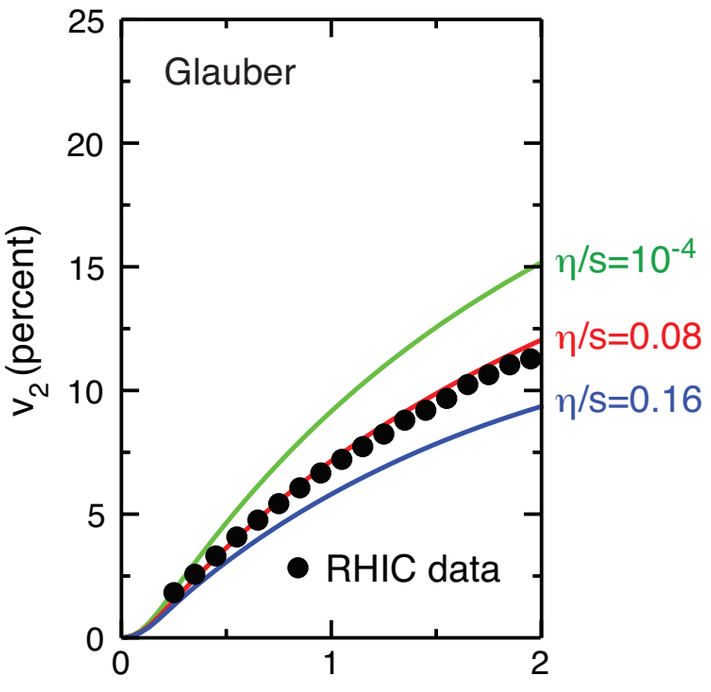
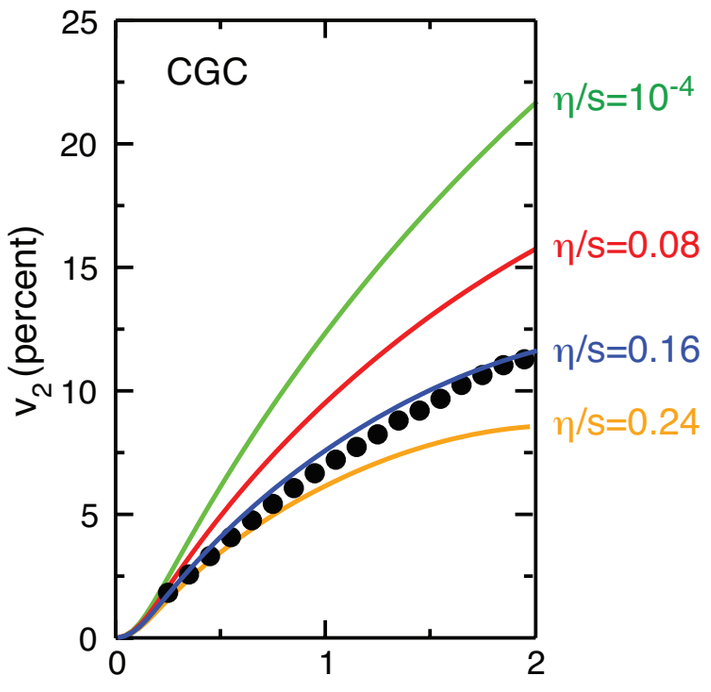
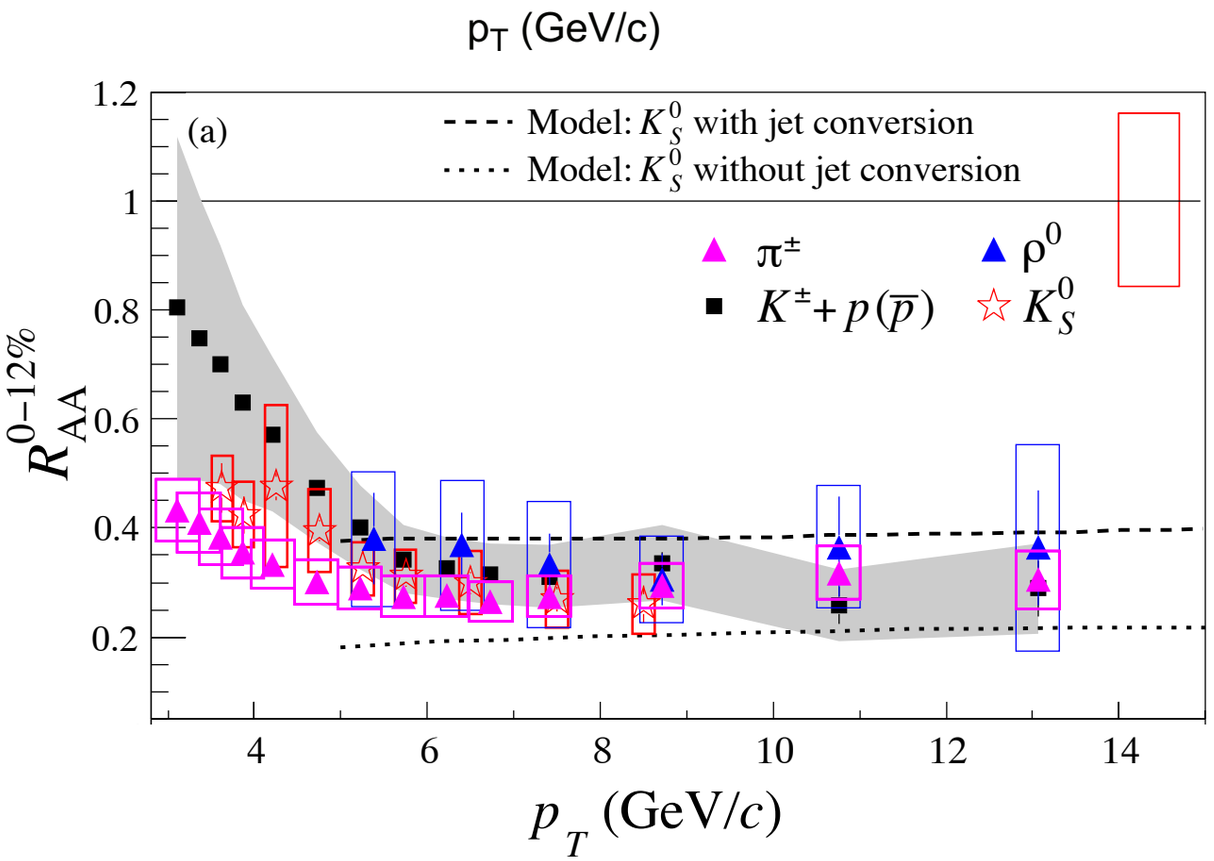
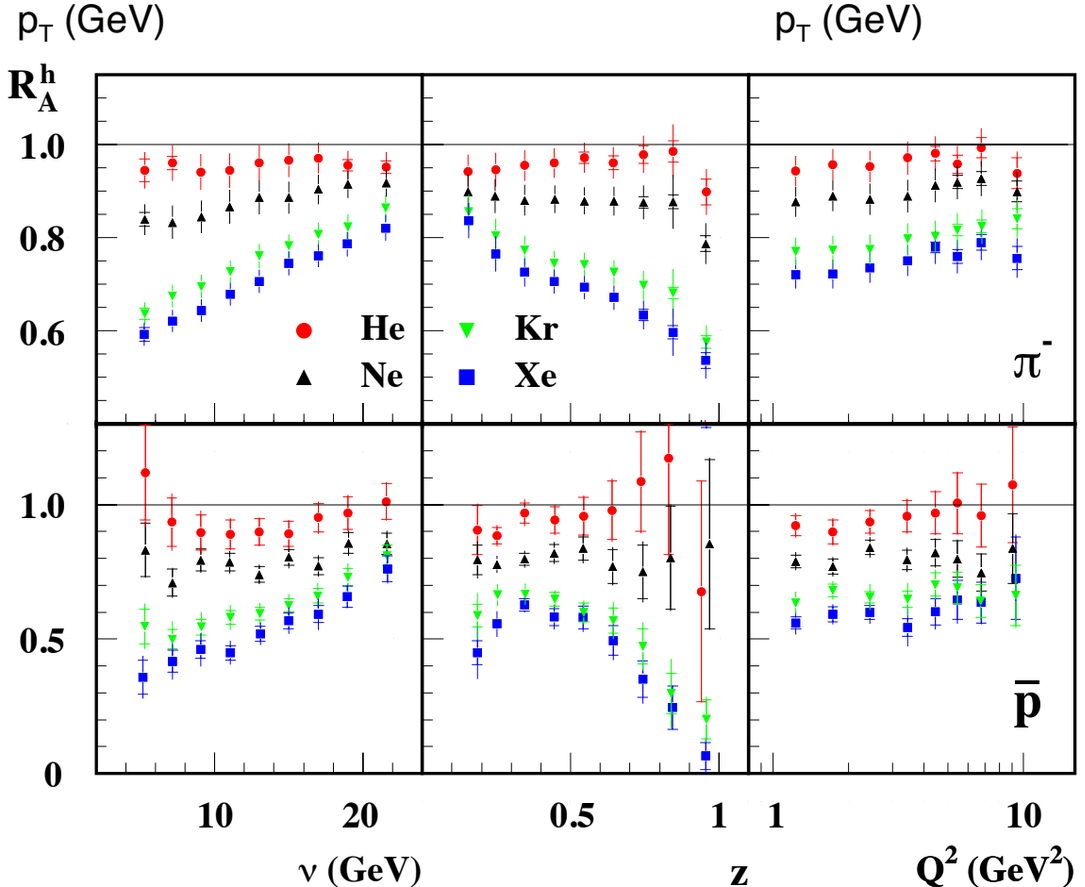


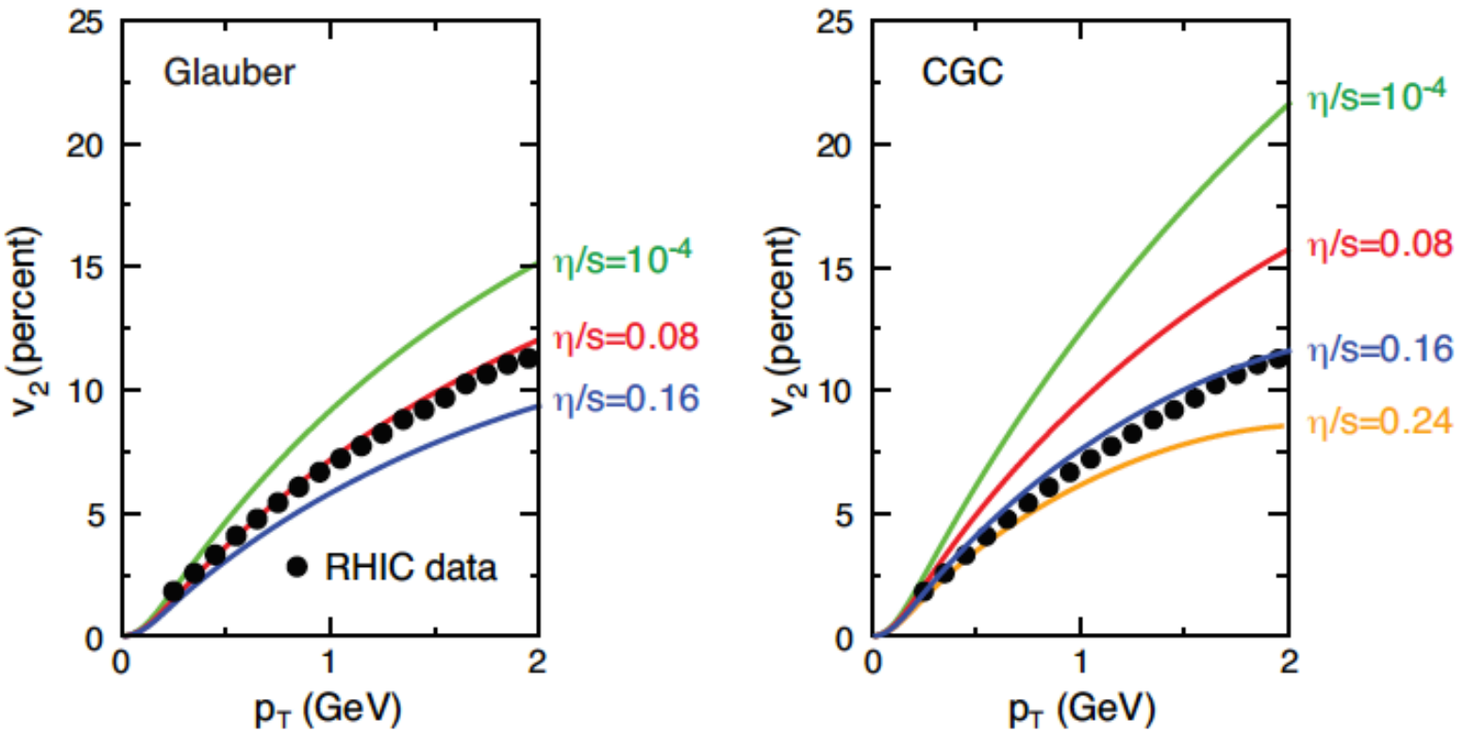



# Importance of the knowledge of the initial conditions




- A comparison of data and theoretical predictions using viscous hydro for $v_2^h(p_T)$ with Glauber initial conditions (left) and KLN CGC (right)
- The different assumptions in the initial conditions lead to a factor of 2 difference in the extracted η/s
- Figure adapted from: M. Luzum and P. Romatschke, Phys. Rev. C79, 039903 (2009)

# Fundamental questions addressed via e+A collisions

- What is the role of strong gluon fields, parton saturation effects, and collective gluon excitations in nuclei?

  ➡ Can we complete the discovery of the gluon saturation (CGC) regime, tantalising hints of which have been observed at HERA, RHIC and the LHC?

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  - Accomplishing the discovery of a new regime of QCD would have a profound impact on our understanding of strong interactions.

- Can we experimentally find evidence of non-linear QCD dynamics in high-energy scattering off nuclei?

  ➡ One of the main predictions of saturation is the x-dependence of DIS cross-sections and structure functions is described by non-linear evolution equations.

  - Discovery of the saturation regime would not be complete without unambiguous experimental evidence in favour of these non-linear equations

# Fundamental questions addressed via e+A collisions

- What is the momentum distribution of gluons and sea quarks in nuclei?
  What is the spatial distribution of gluons and sea quarks in nuclei?

  ➡ The physics of multiple re-scatterings at larger-x, along with parton saturation (if found) would allow us to reconstruct the momentum and impact parameter distributions of gluons and sea quarks in nuclei.

    - At small-x, the transverse momentum distribution may allow us to identify the saturation scale, $Q_s$.

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  - At small-x, the transverse momentum distribution may allow us to identify the saturation scale, $Q_s$.

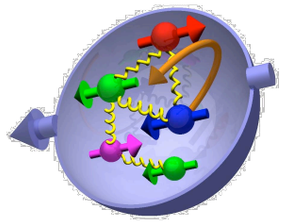
- Are there strong colour (quark and gluon density) fluctuations inside a large nucleus? How does the nucleus respond to the propagation of a colour charge through it?

  ➡ Our understanding of the spatial and momentum-space distributions of quarks and gluons would not be complete without understanding their fluctuations.

  - The typical size of colour fluctuations can be measured by sending a quark probe through the nucleus.
  - The conversion of the quark probe into a hadron my be affected by the nuclear environment, giving us a better understanding of the process.

# Most compelling physics questions

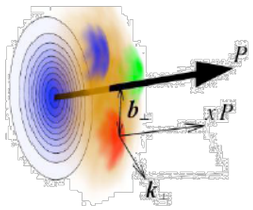
## Spin physics



- What is the polarisation of gluons at small x where they dominate?
- What is the x-dependence and flavour decomposition of the polarised sea?

Determine quark and gluon contributions to the proton spin at last!!

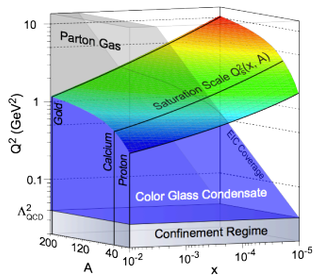
## Imaging

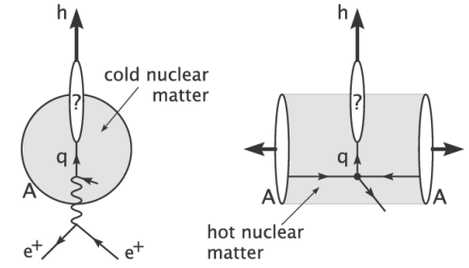



- What is the spatial distribution of quarks/ gluons in nucleons AND nuclei?
- Understand deep aspects of gauge theories revealed by $k_T$ dependent distributions

Possible window to orbital angular momentum

## Strong Colour Fields and Hadronisation

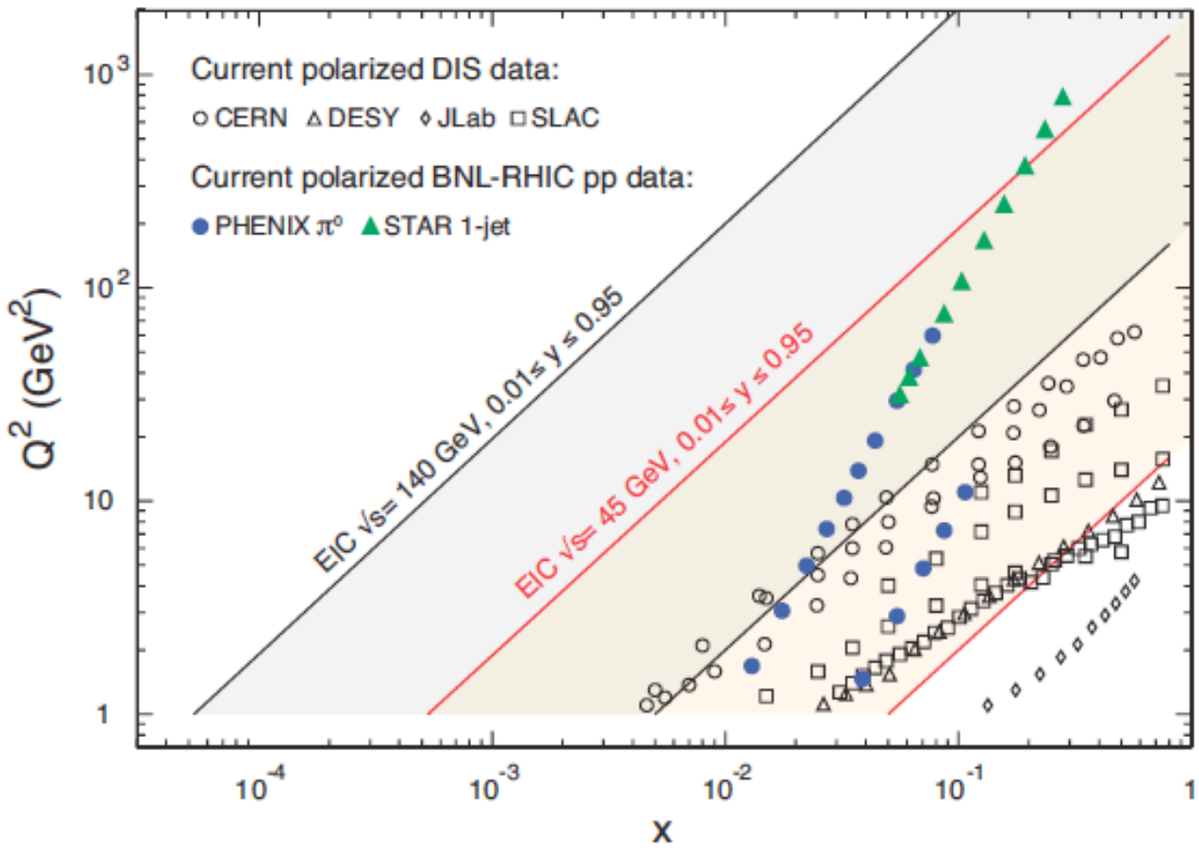


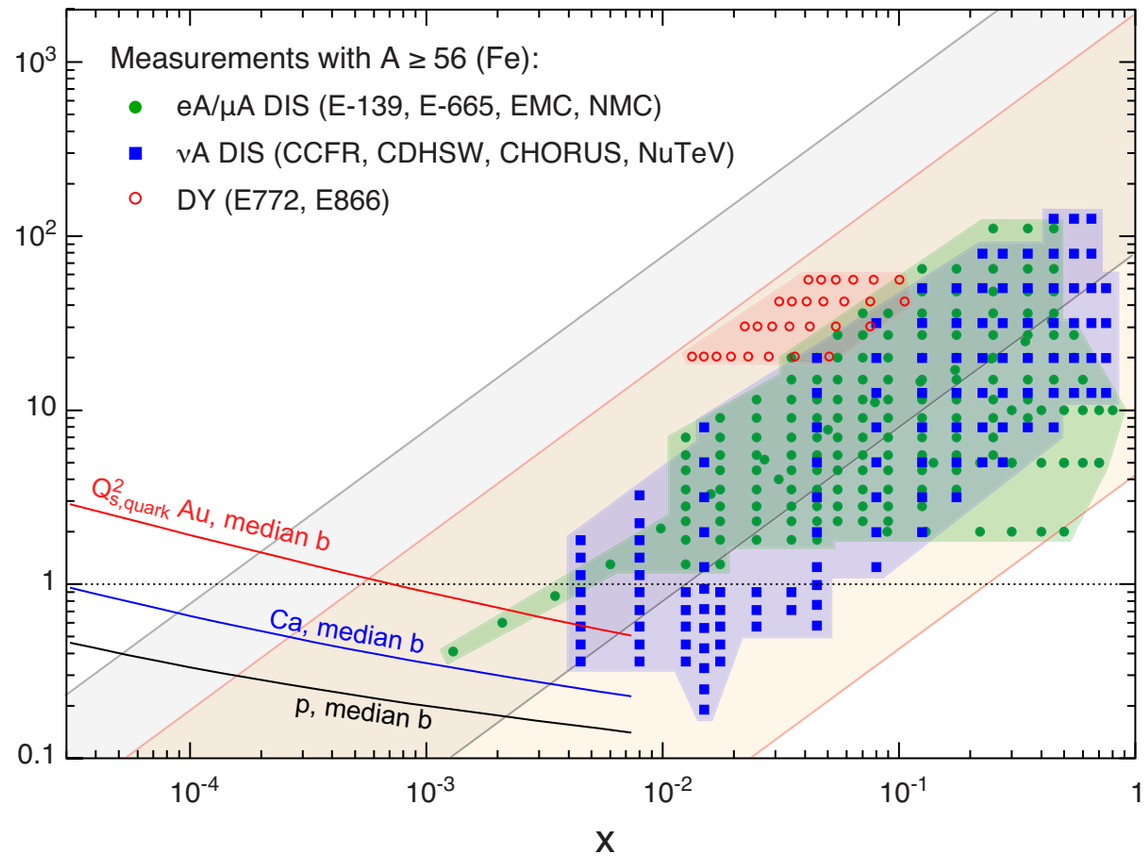




- Quantitatively probe the universality of strong colour fields in A+A, p+A and e+A
- Understand in detail the transition to the non-linear regime of strong gluon fields and the physics of saturation
- How do hard probes in e+A interact with the medium?

Currently have no experimental knowledge of gluons in nuclei at small x!!

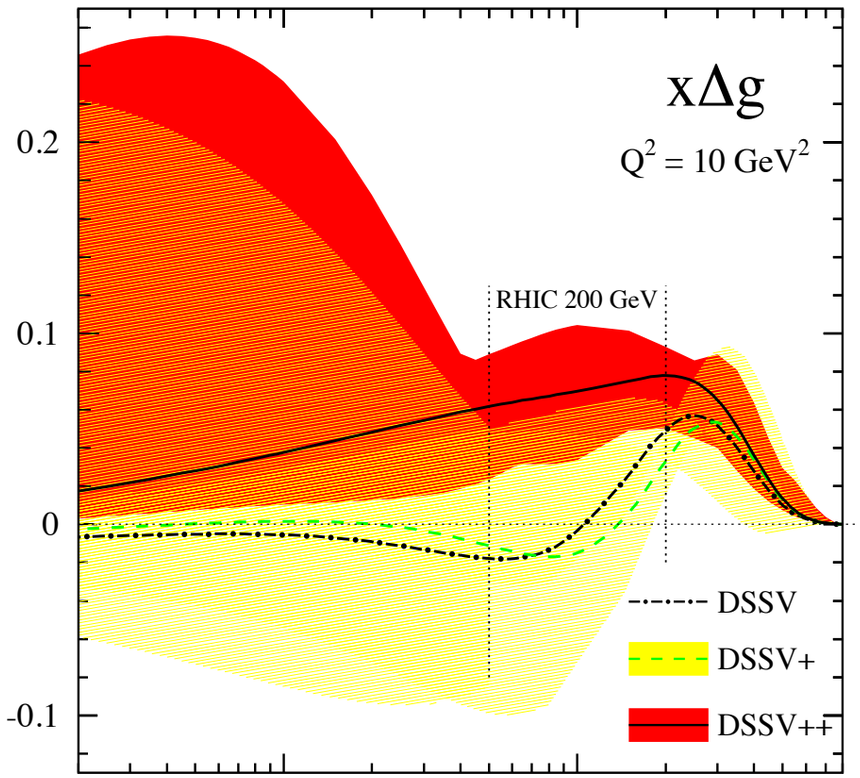
# Extension of x,$Q^2$ coverage with an EIC




- Increase reach in x by a factor of 100 in both polarised e+p and e+A - into the range where gluons dominate
  - ➡ e+p: constrain the helicity sum rules?
  - ➡ e+A: saturation effects become visible?
- Increase in $Q^2$ coverage
  - ➡ study scaling violations

# Constraining Δg(x) at RHIC, EIC




$$\int_{0.05}^{0.2} \Delta g(x) = 0.1 \pm^{0.06}_{0.07}$$

- RHIC data can constrain Δg(x) down to a few x $10^{-2}$
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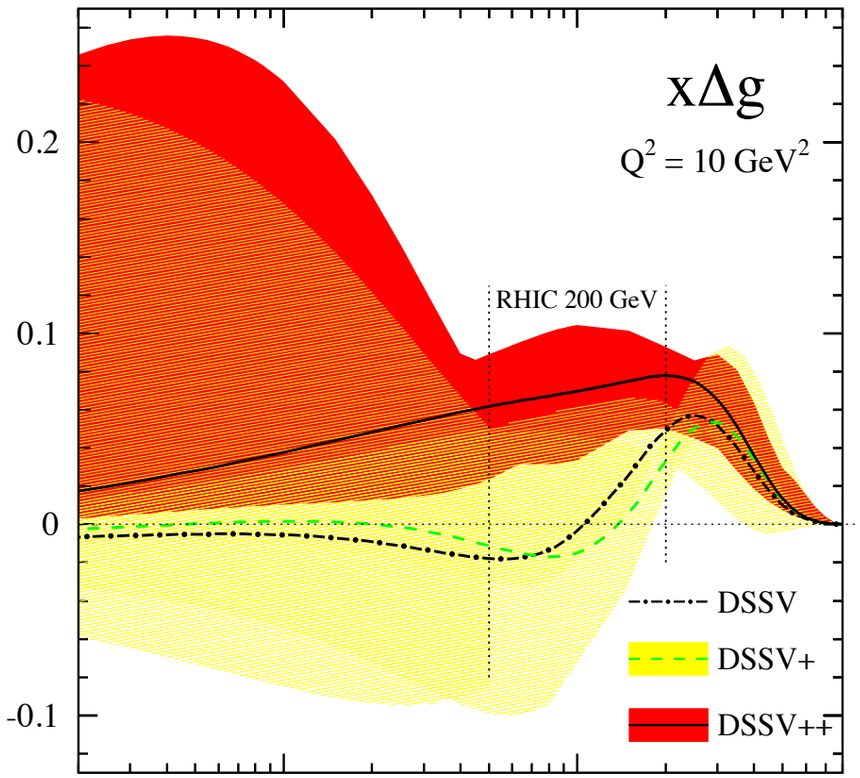


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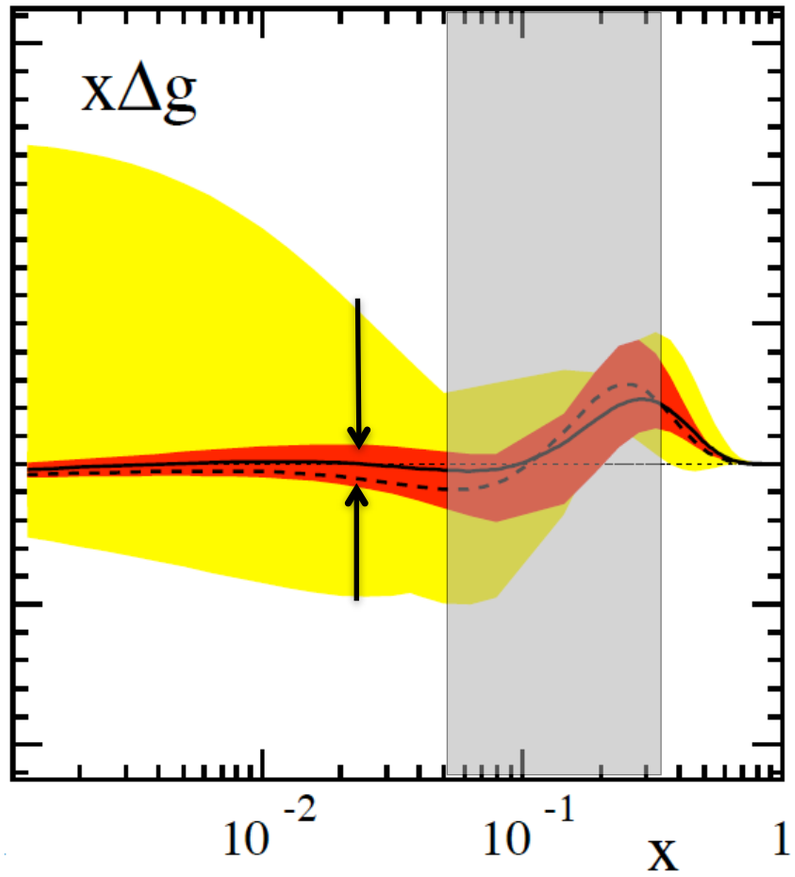
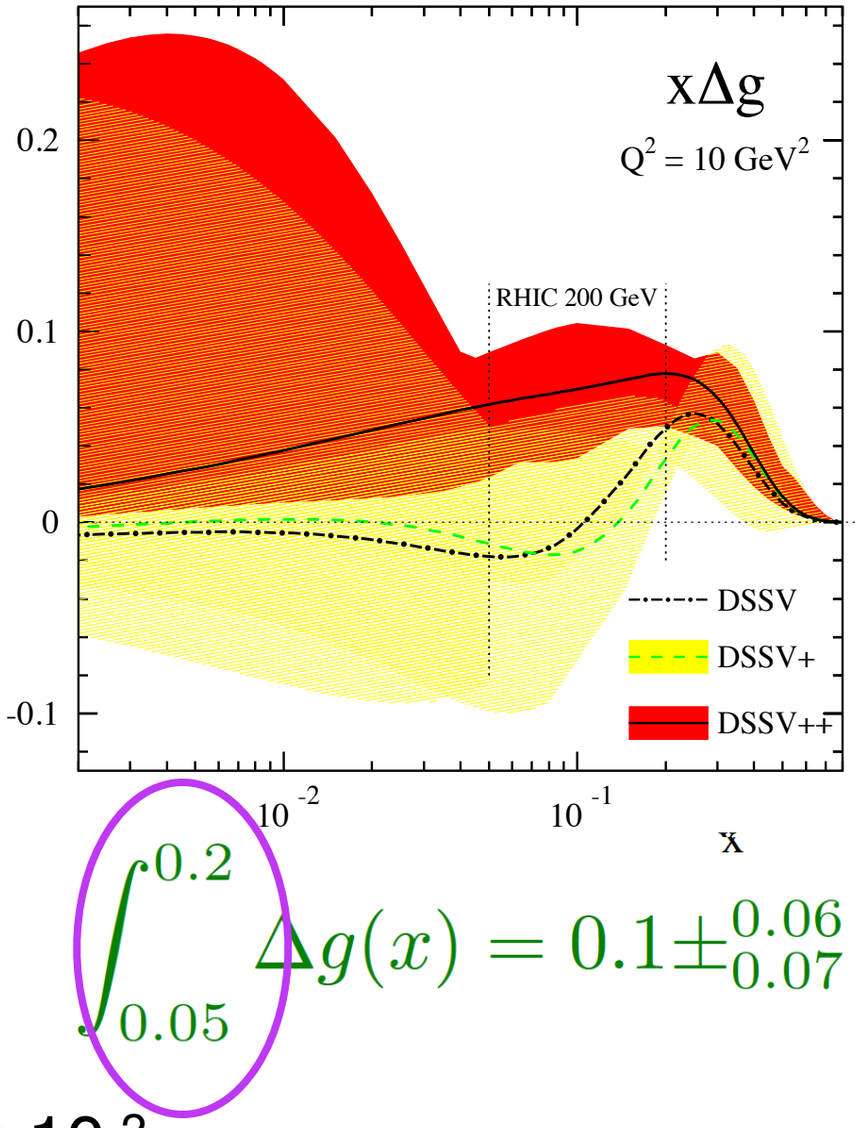



RHIC coverage

DSSV

DSSV + EIC
(5x100, 5x250)

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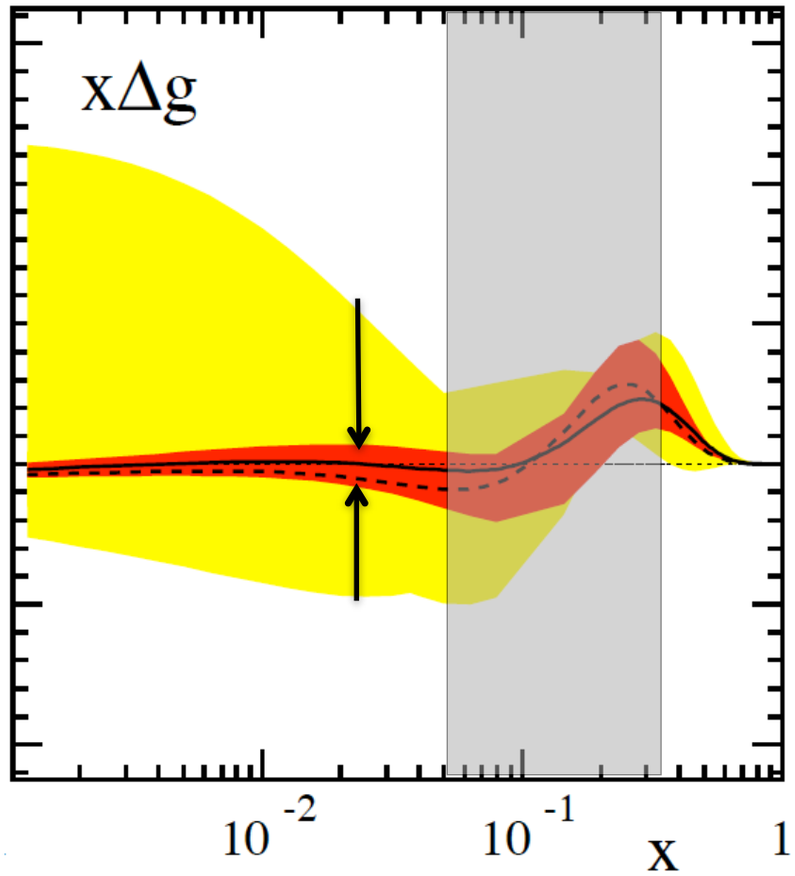


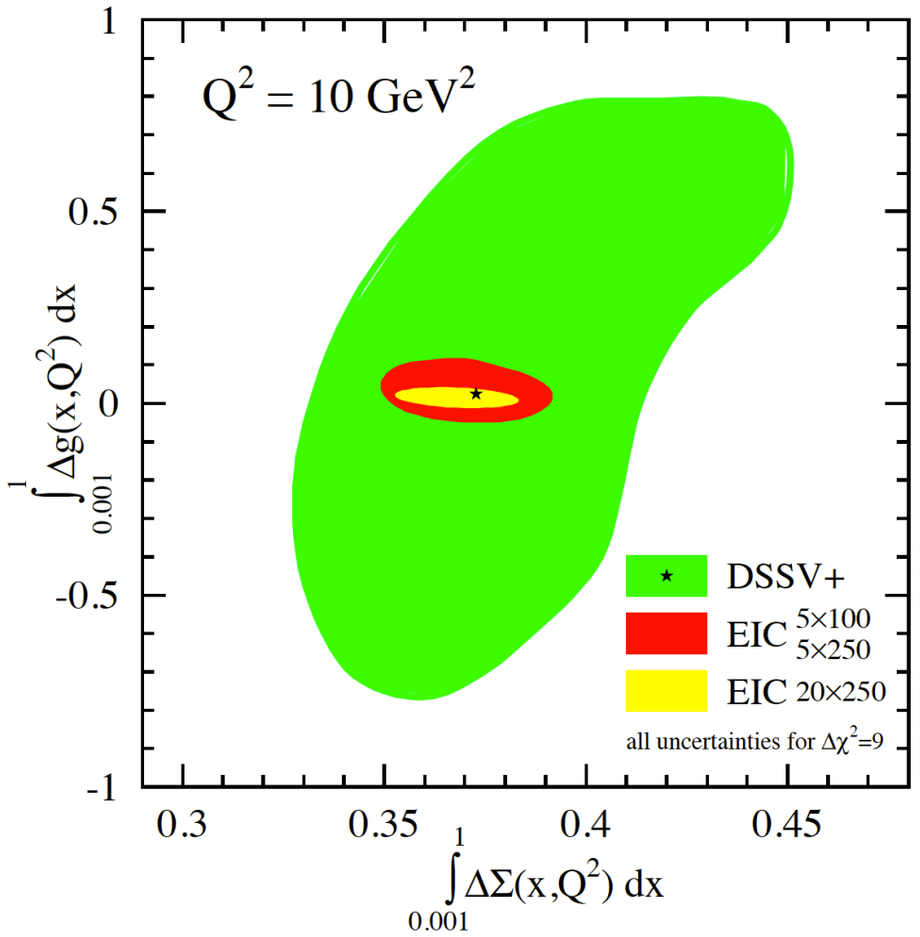


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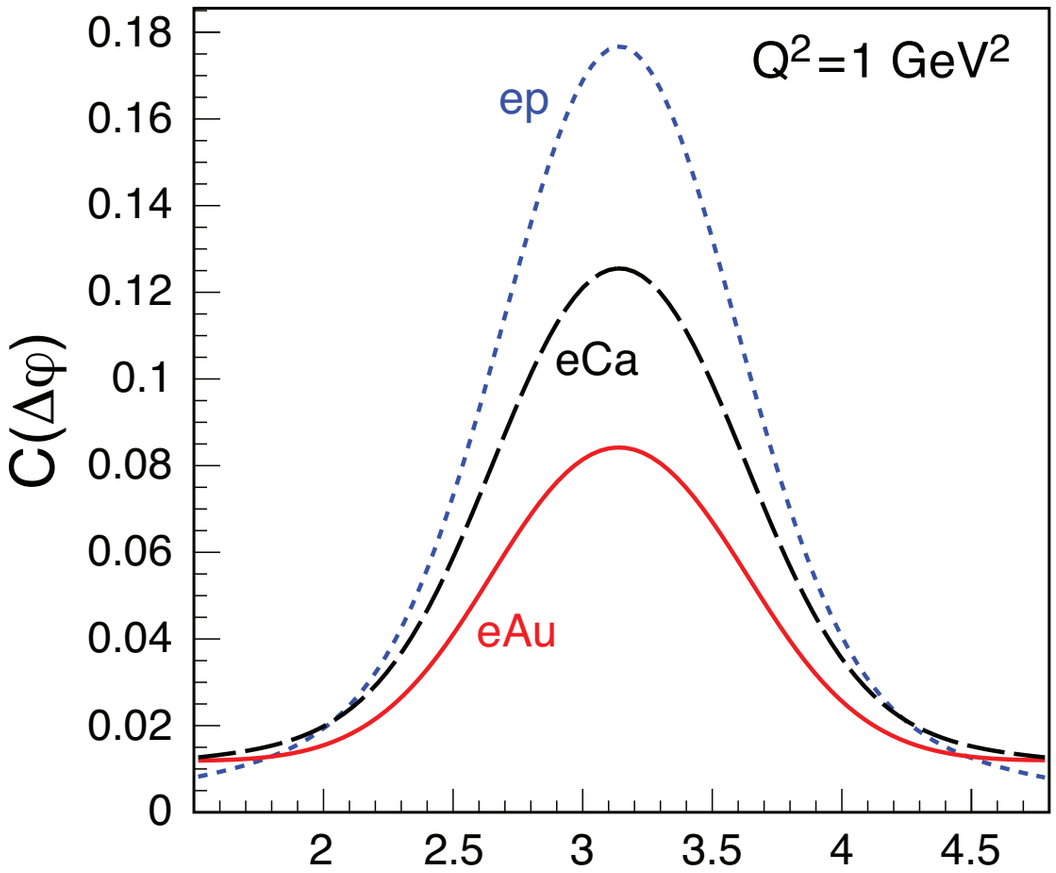
# SIDIS in e+A → di-hadron correlations




Xiao, Yuang et al (private communication)

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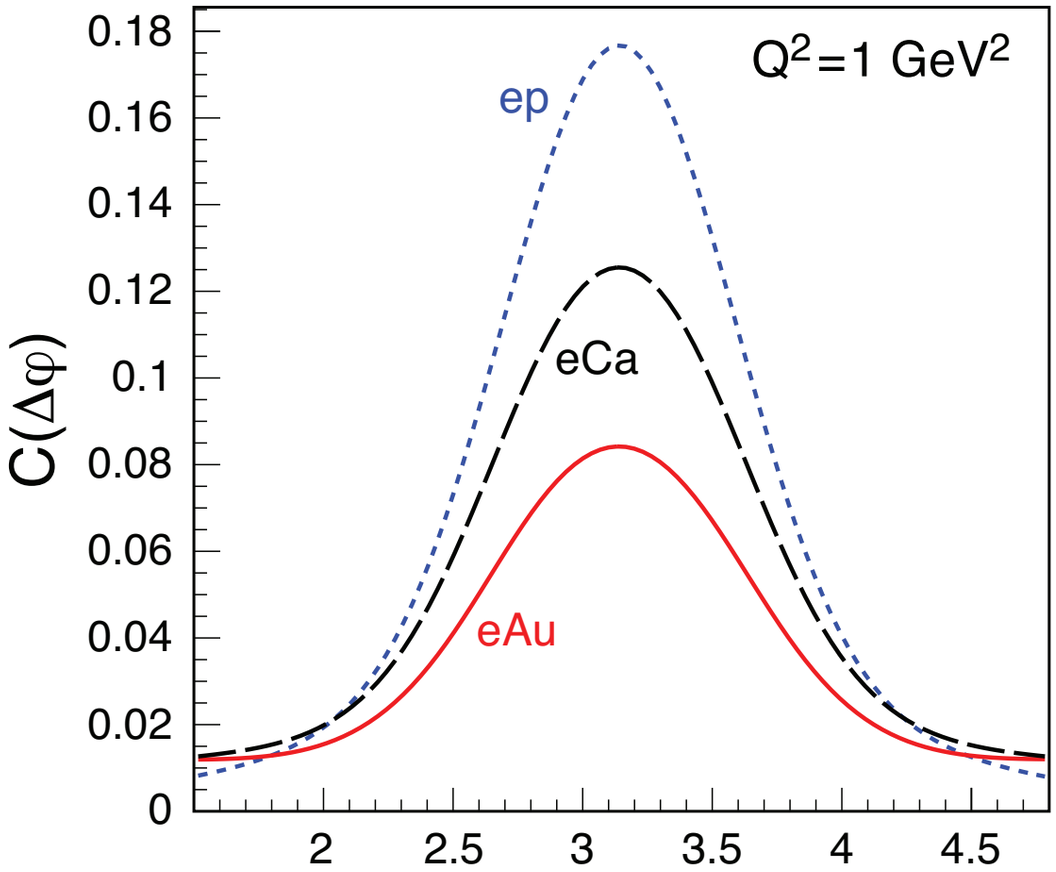


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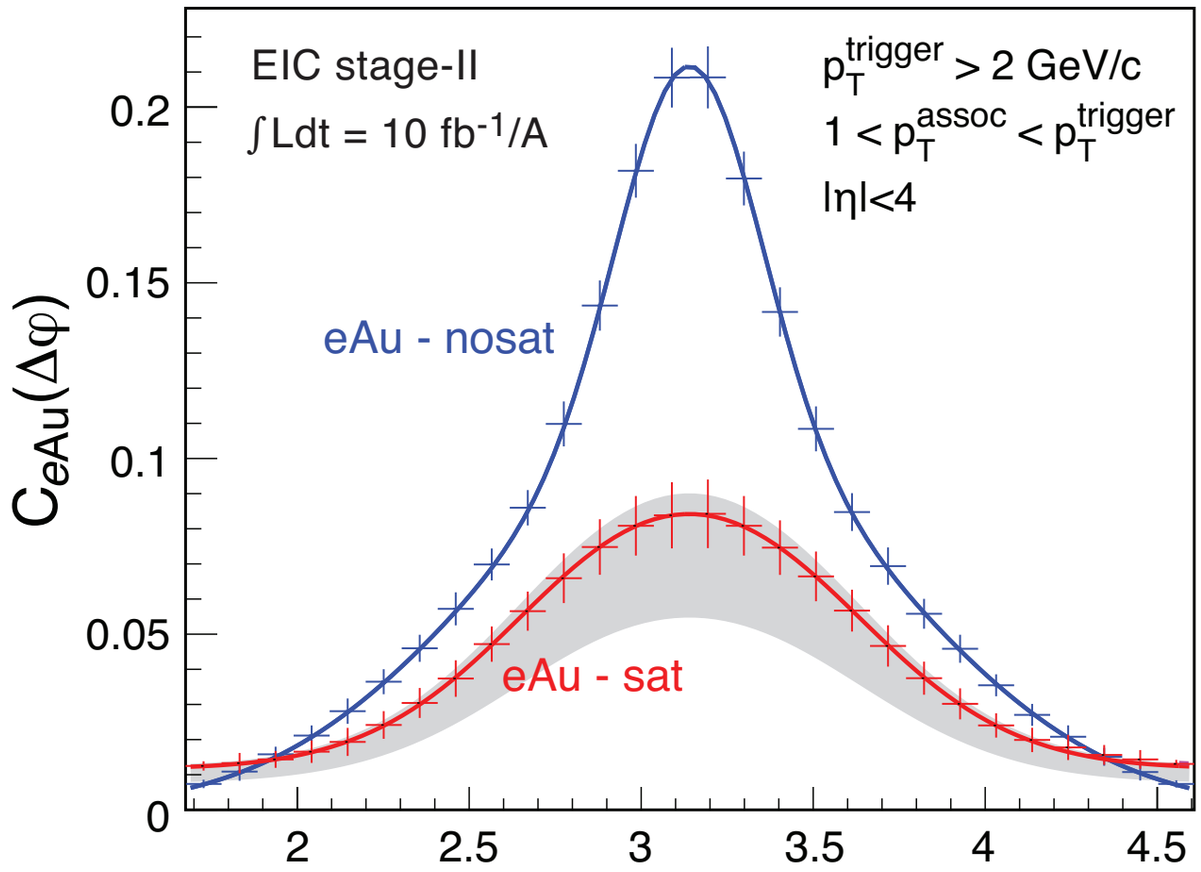
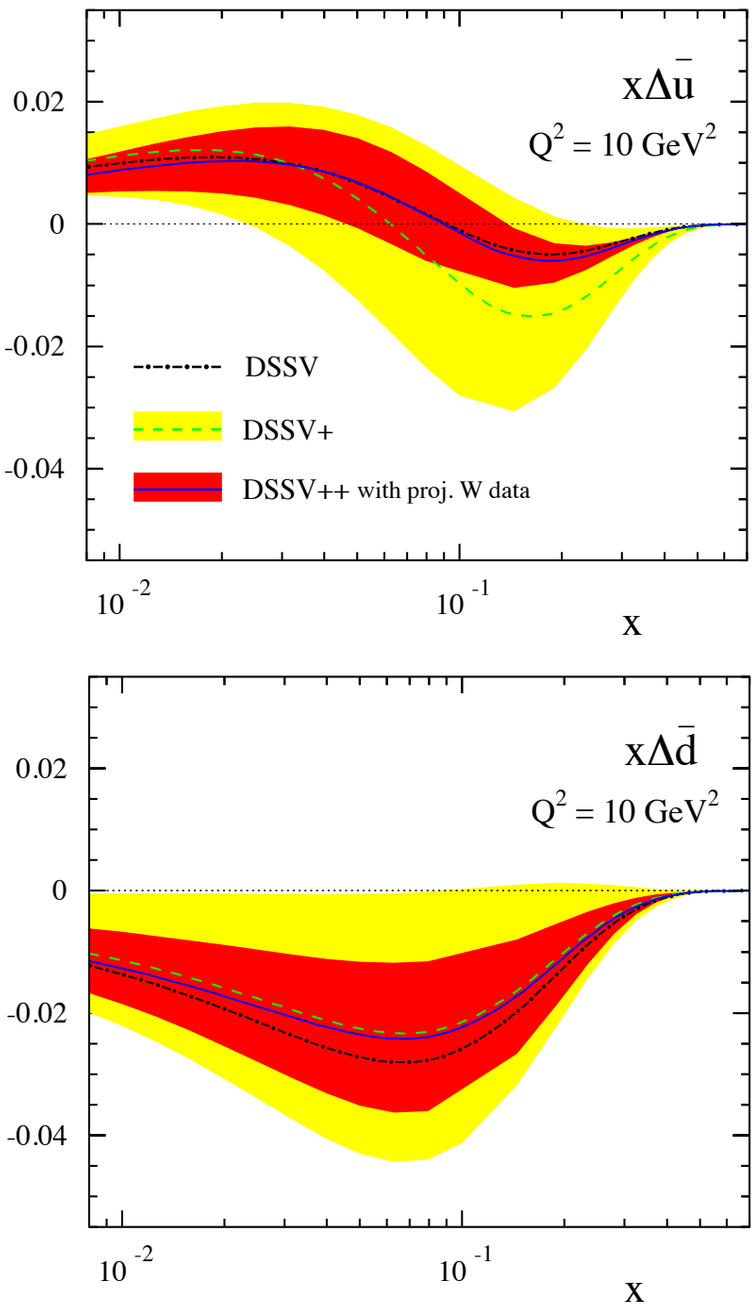



- Predictions from a saturation model show an ordered attenuation of the away-side with increasing nuclear mass
- Simulations (PYTHIA + DPMJETIII) for e+Au show that the sat/no-sat scenarios can be distinguished within errors

➡ Gives a handle on multi-gluon distributions

# SIDIS in e+p → flavour-separated helicity PDFs

- SIDIS measurements with identified π, k lead to much reduced uncertainties in the flavour-separated helicity PDFs as in Δg(x)



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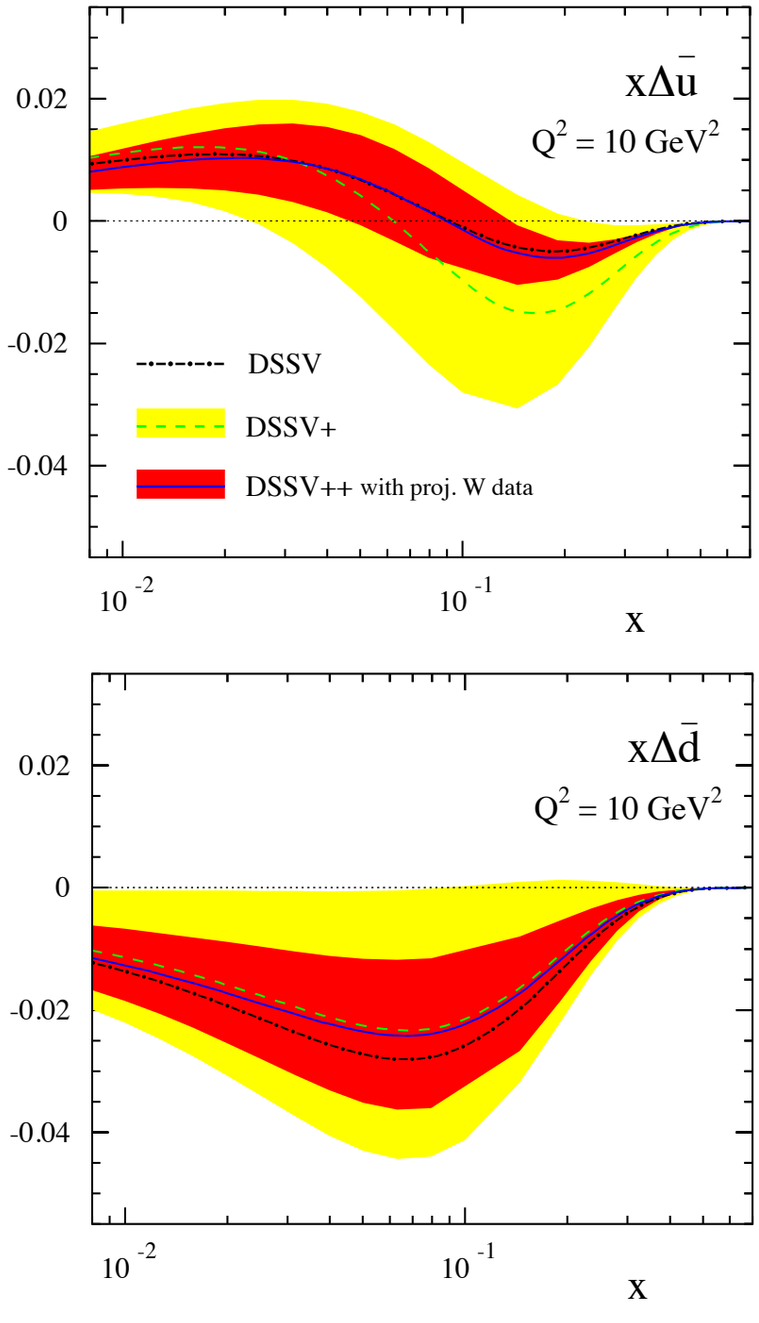
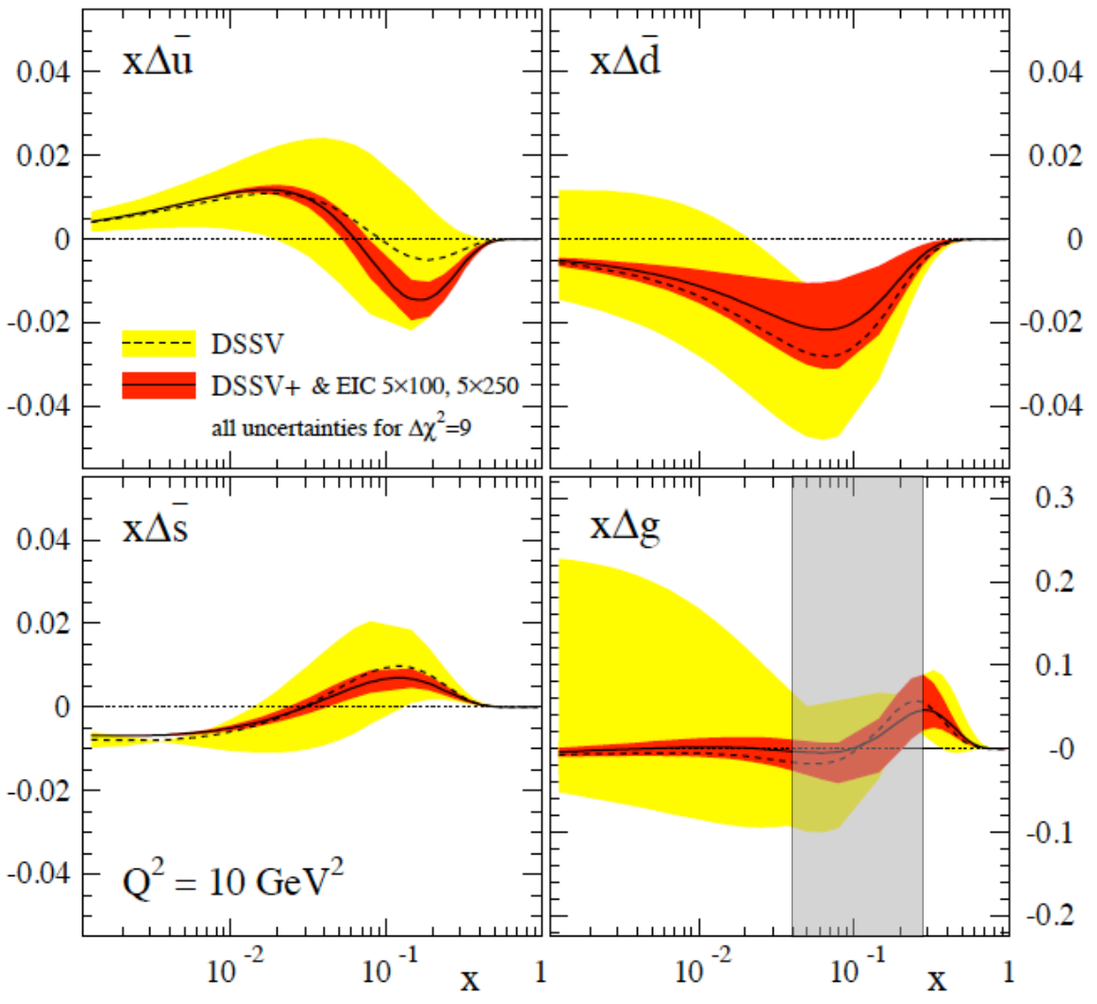



RHIC to eRHIC

smaller x; need integral from 0 to 1 for spin sum rule

Δs(s̄) cannot be accessed at existing facilities




DSSV

DSSV + EIC (5x100, 5x250)

RHIC coverage

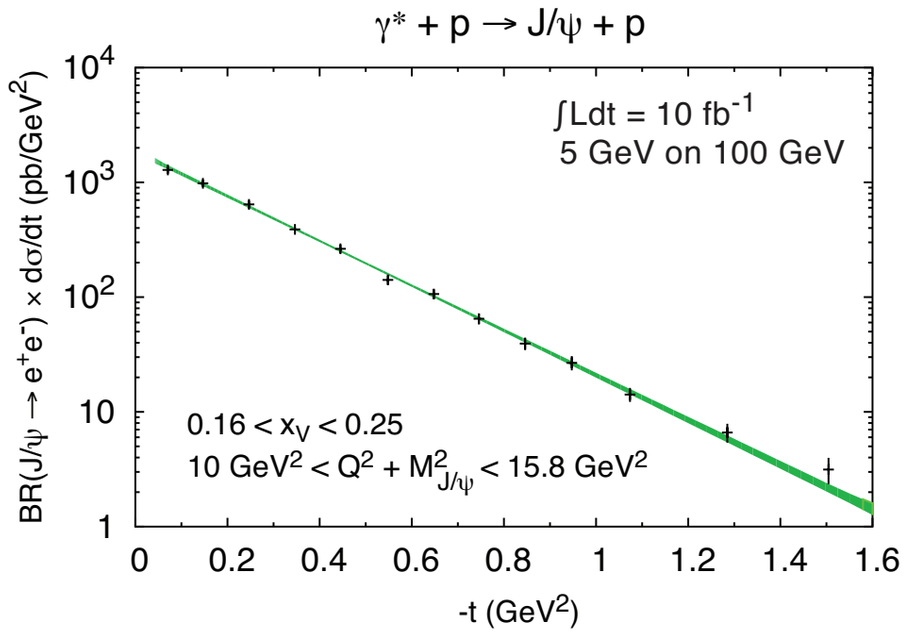
# Imaging in e+p

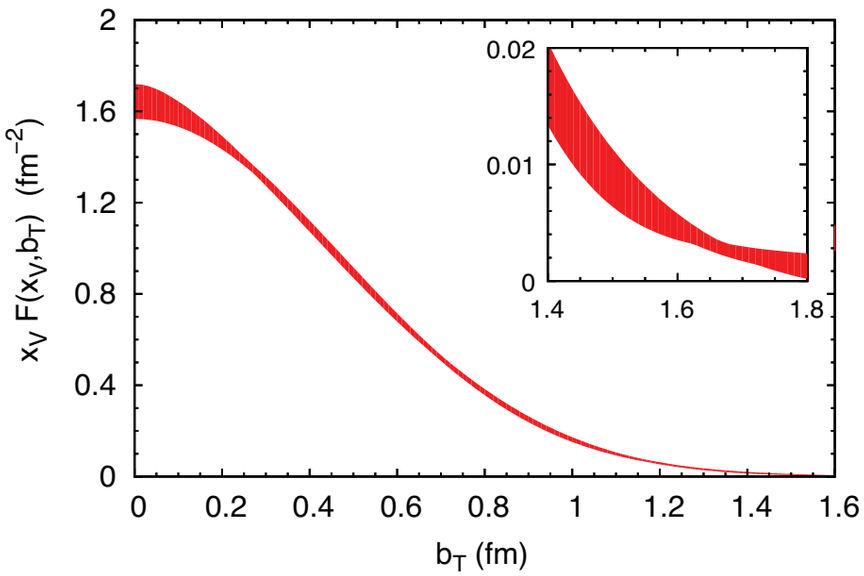
- As with e+A, exclusive measurements can be used to image momentum space (TMDs) or position space (GPDs)

- Fine binning in (x,$Q^2$,t) space

  ➡ Small statistical error bars in ~ 1 years running

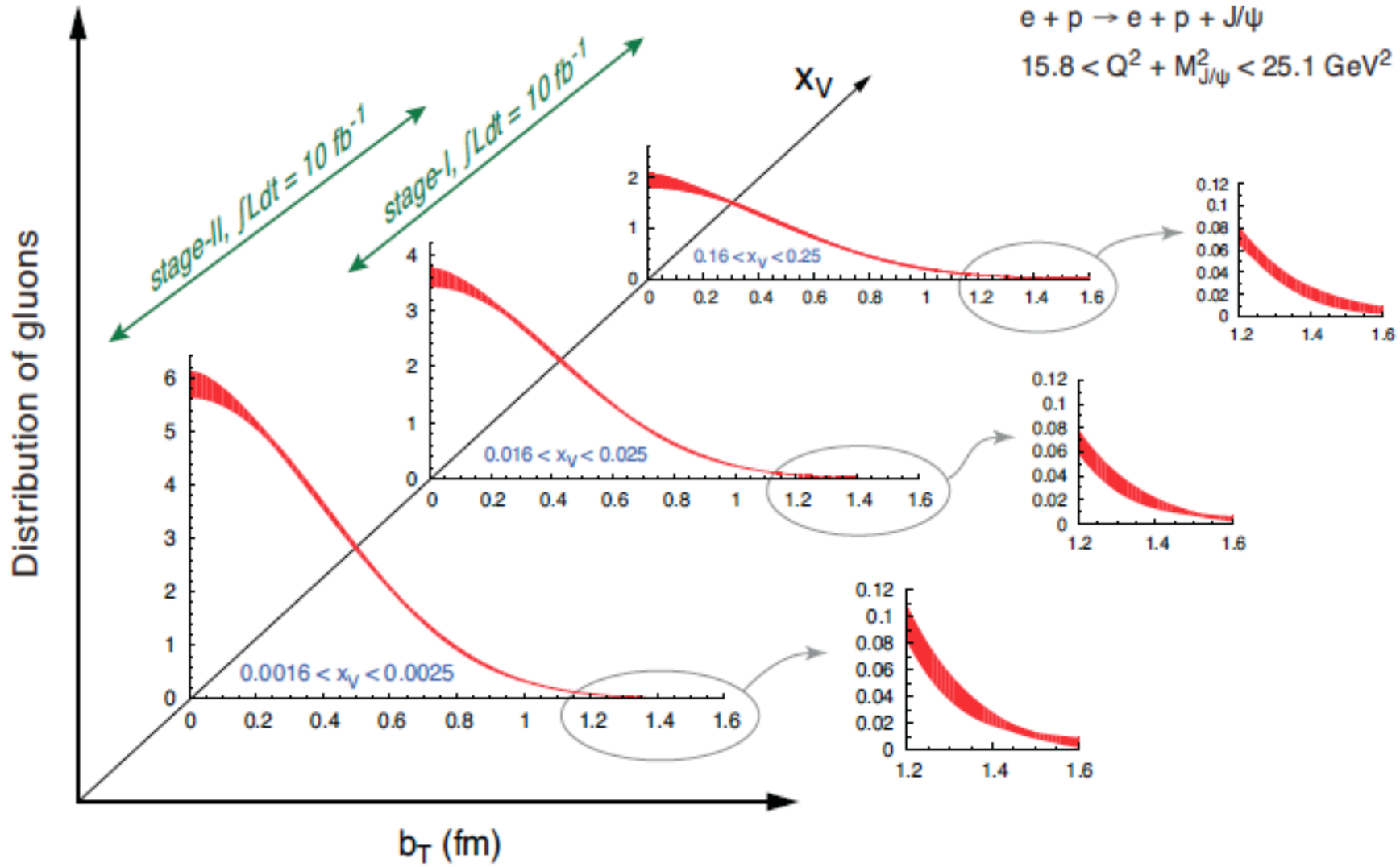
- Fourier transform the momentum distribution to get the b-dependent gluon distribution



# Imaging in e+p

- As with e+A, exclusive measurements can be used to image momentum space (TMDs) or position space (GPDs)
- Map out the x-dependence of the gluon distribution



# Summary and Conclusions

- Both the e+A the e+p physics programmes at an EIC will give us a unique opportunity for precision studies of gluons in nuclei and nucleons
- e+A:
  - ➡ Low-x: Measure the properties of gluons where saturation is the dominant governing phenomena
  - ➡ Higher-x: Understand how fast partons interact as they traverse nuclear matter and provide new insight into hadronization
- e+p:
  - ➡ Constrain $\Delta g(x)$ at small x along with the flavour-separated helicity PDFs
  - ➡ Imaging of the spatial and momentum gluon distributions in nucleons

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**entire science program uniquely tied to a future high-energy electron-ion collider**

**never been measured before & never without**

# EIC White Paper

- 2010: Ten week INT programme on “Gluons and the quark sea at high energies”

  ➡ 550 page proceedings on the ArXiv: http://arxiv.org/abs/1108.1713

- 2012: White paper released to community

  ➡ ~150 page document, recently released to the community

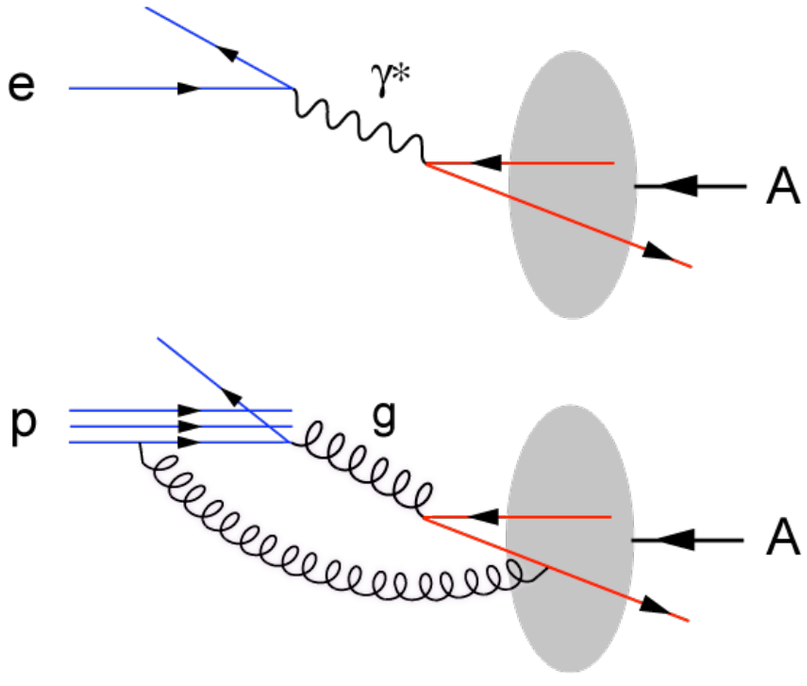
  ➡ http://www.bnl.gov/rhic/eicrev/ch/ch-files/c1-c6.pdf

    - Simulations and other tasks identified in INT programme were performed for this document and presented in this talk

- Community input and comments requested by October 31st

# Why *e*+A collisions and not $p$+A?

- $e$+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
- Issues:
  - ➡ p+A combines initial and final state effects
  - ➡ multiple colour interactions in p+A
  - ➡ p+A lacks the direct access to x, $Q^2$



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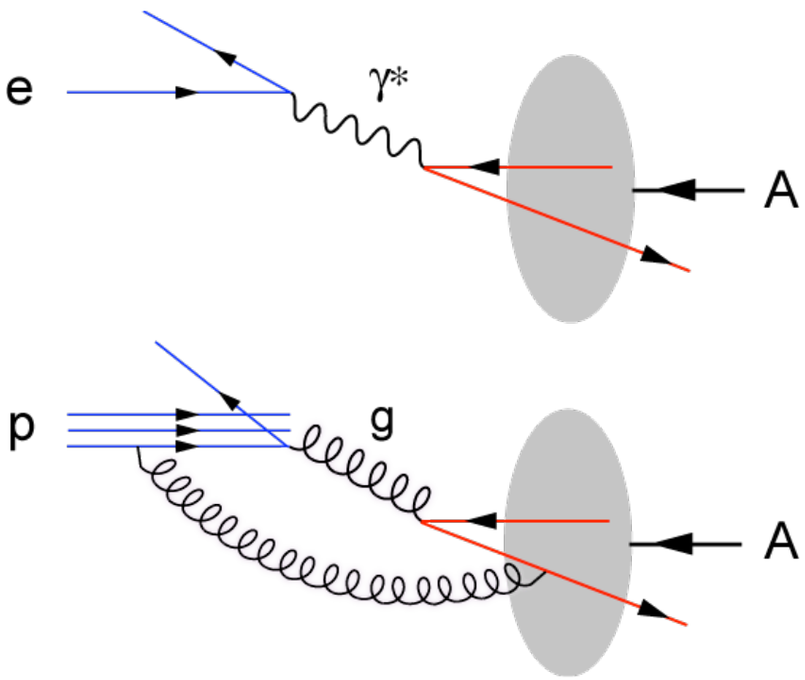
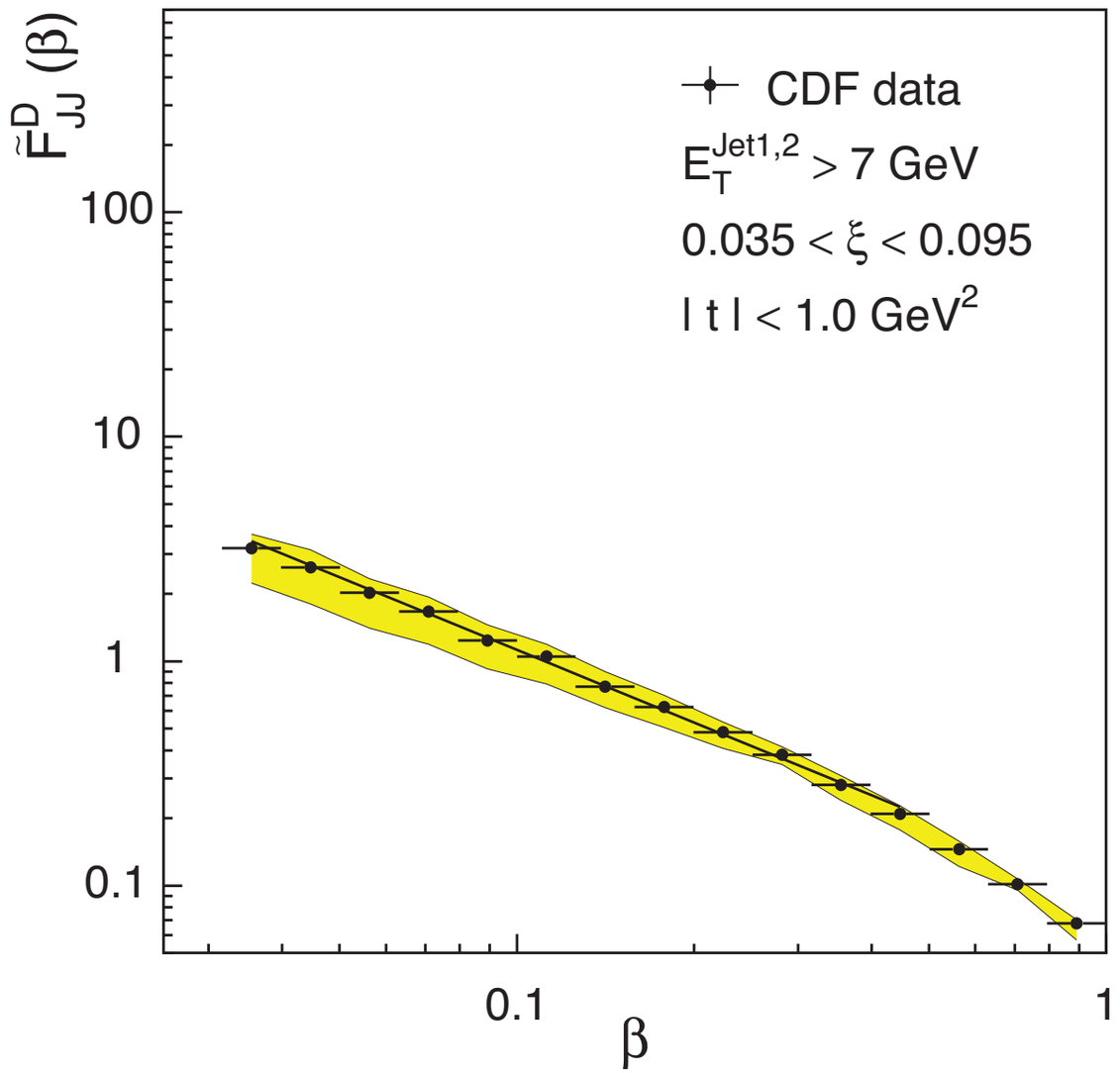



F. Schilling, hep-ex/0209001



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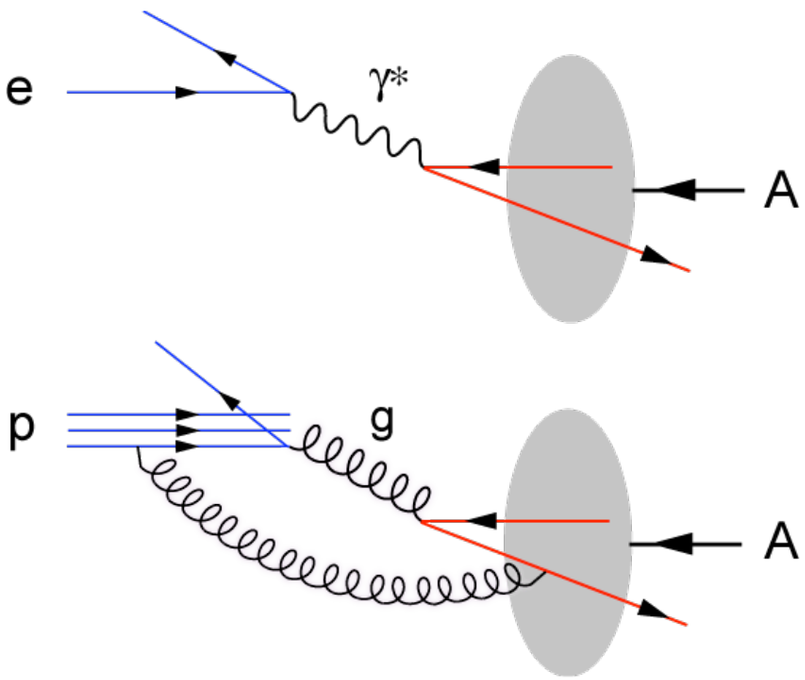


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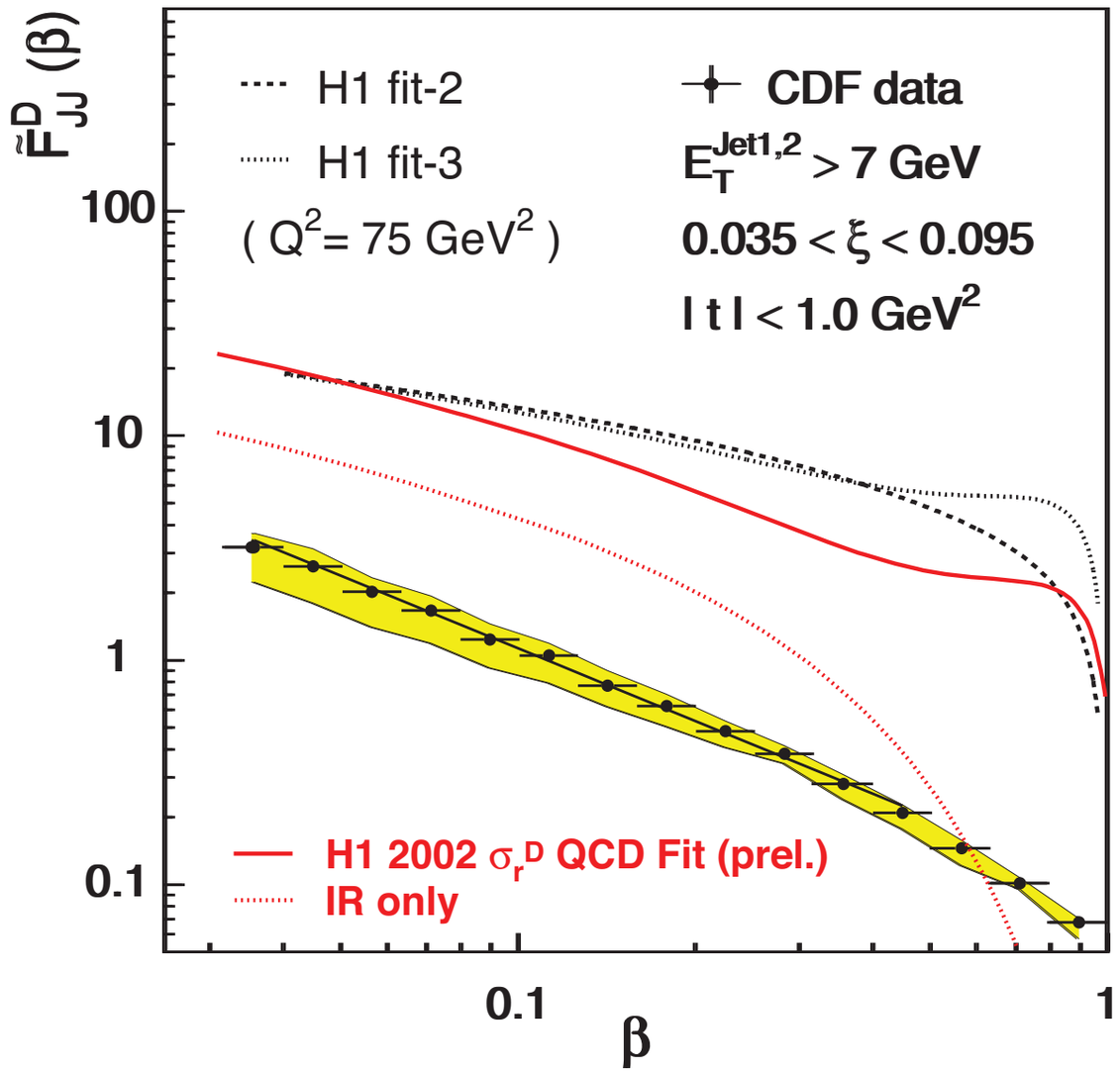


Breakdown of factorization (*e*+*p* HERA versus *p*+*p* Tevatron) observed for di-jets produced in diffractive collisions

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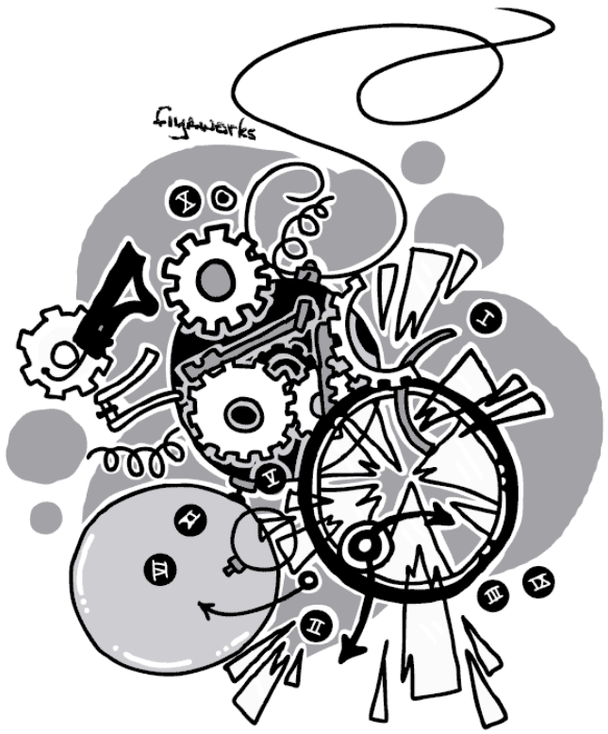
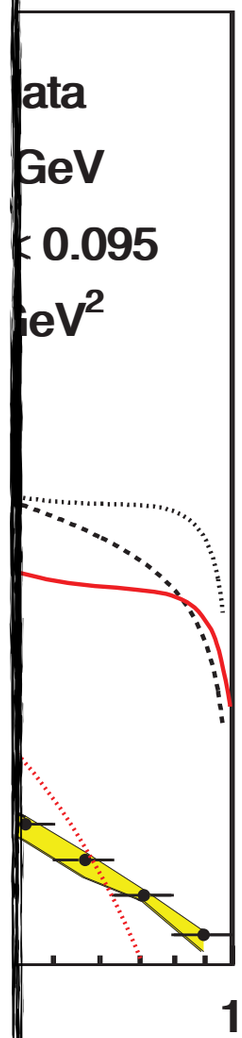
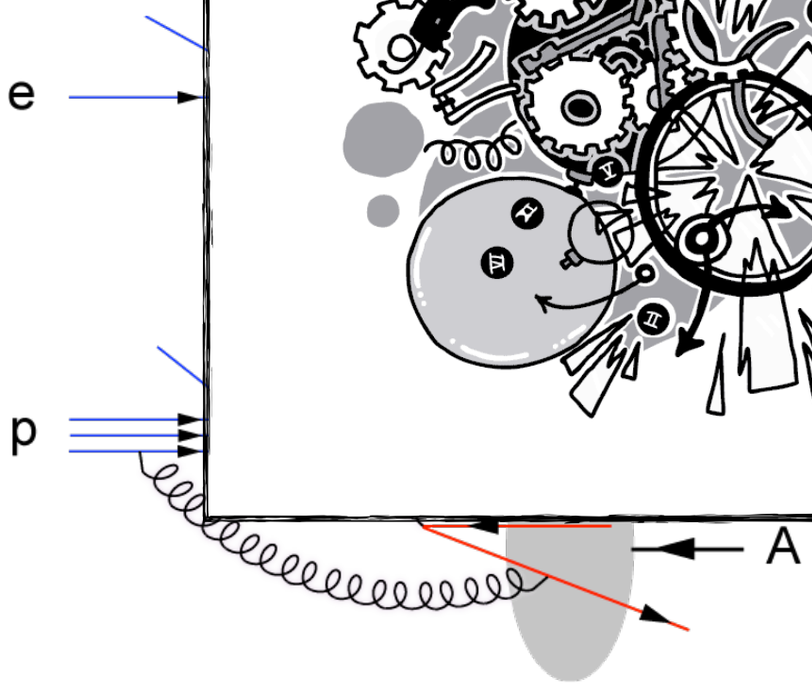
F. Schilling, hep-ex/0209001

*Scattering of protons on protons*
*is like colliding Swiss watches to find out how they are built.*



R. Feynman




+*p* HERA
for di-jets
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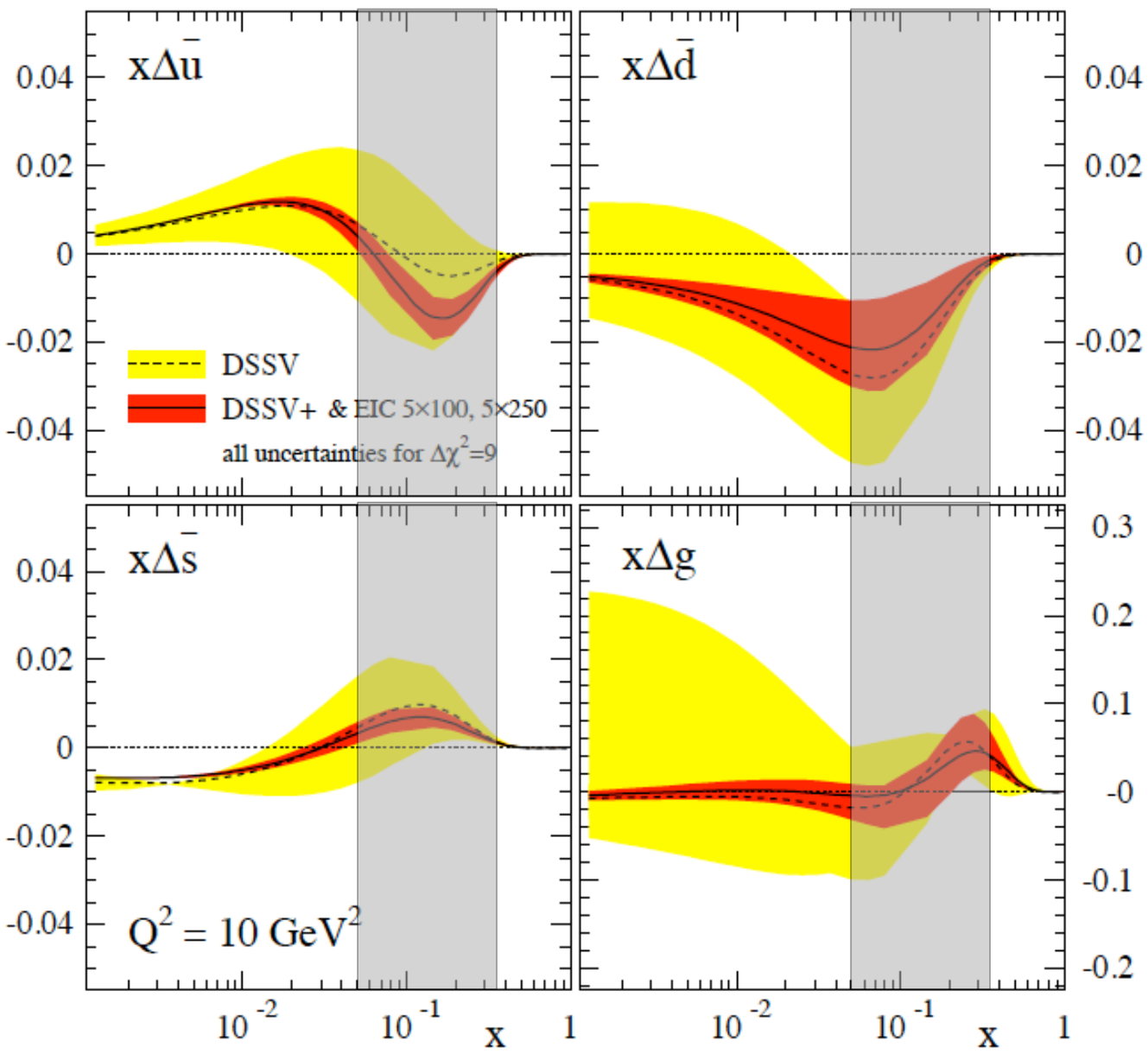


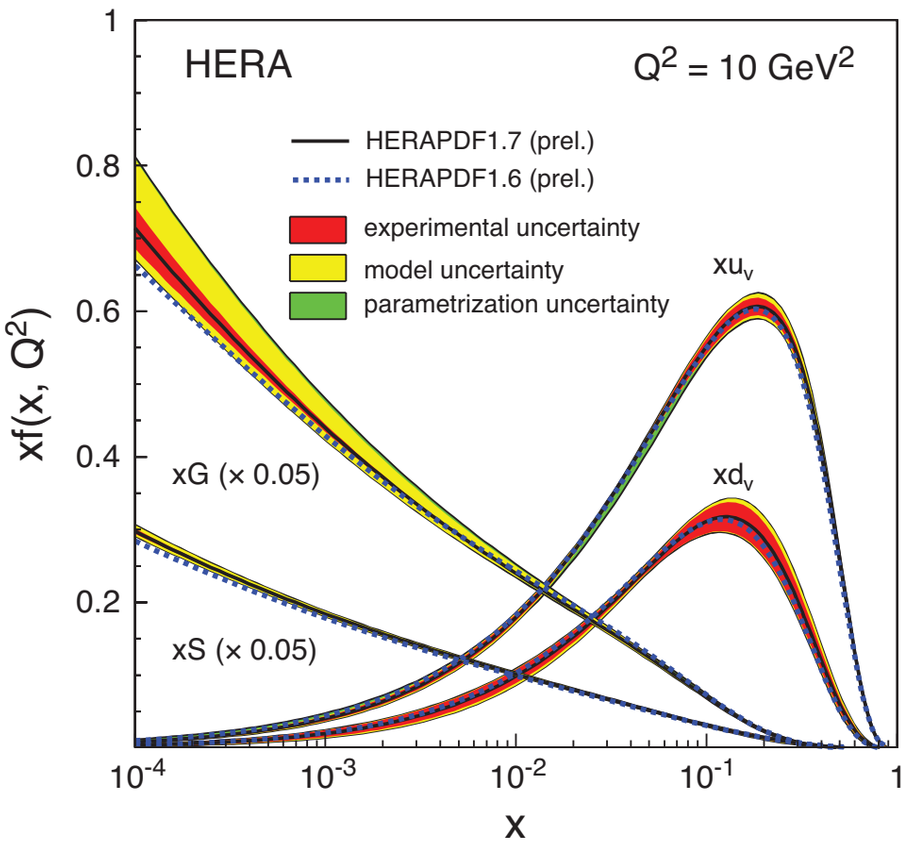

RHIC coverage

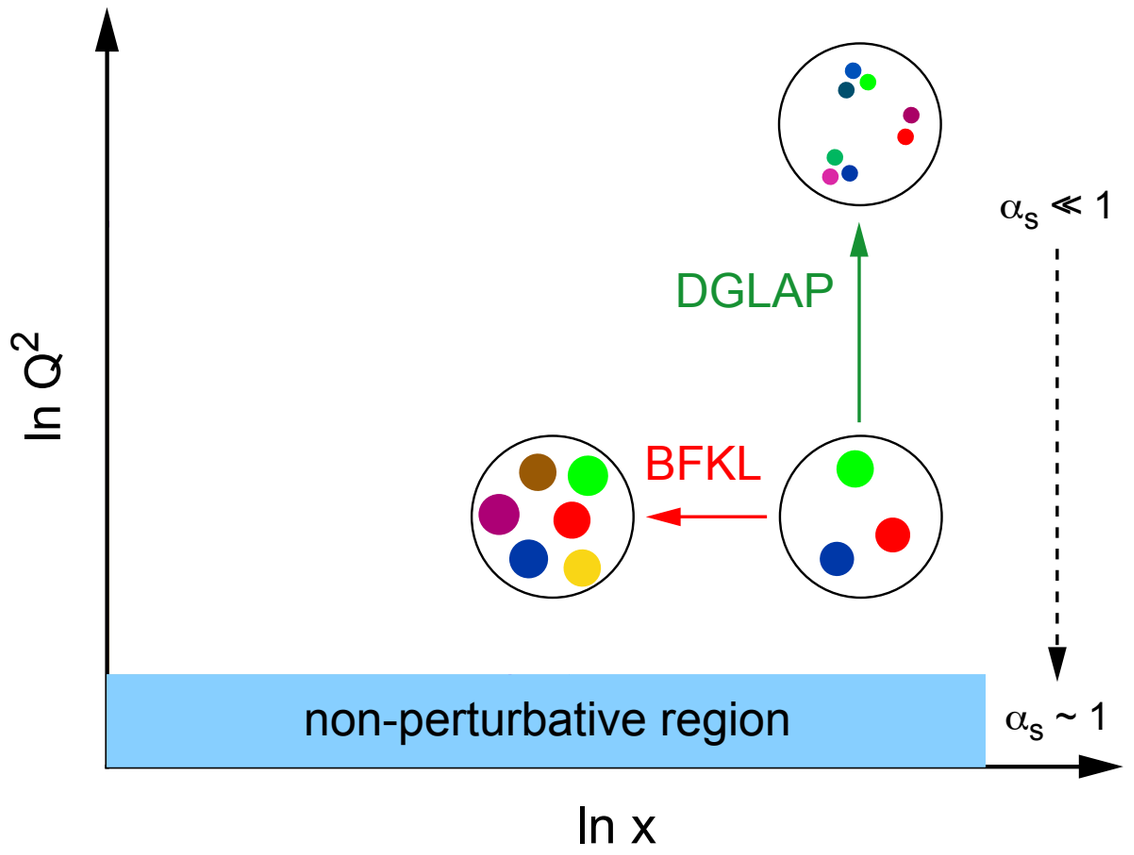
DSSV

DSSV + EIC (5x100, 5x250)

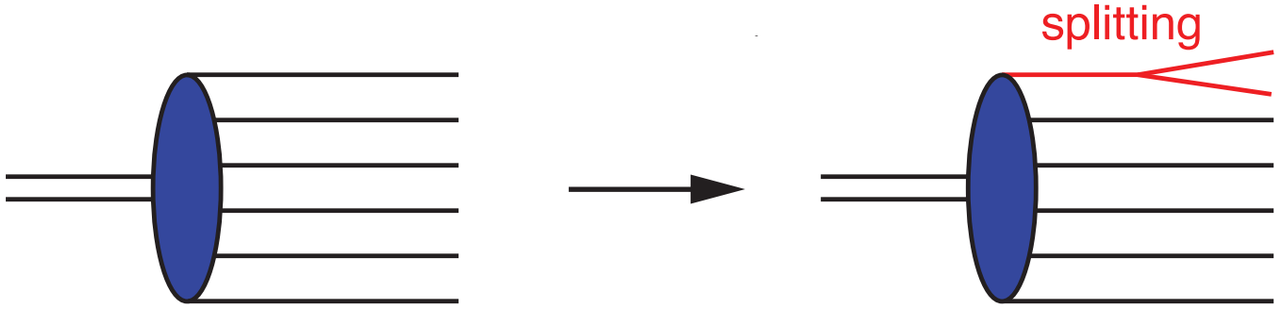
all uncertainties for $\Delta\chi^2=9$

# The structure of matter at small-x




- Gluons dominate the PDFs at small- to intermediate-x ($x < 0.1$)
  - ➡ Rapid rise in gluons described naturally by linear pQCD evolution equations



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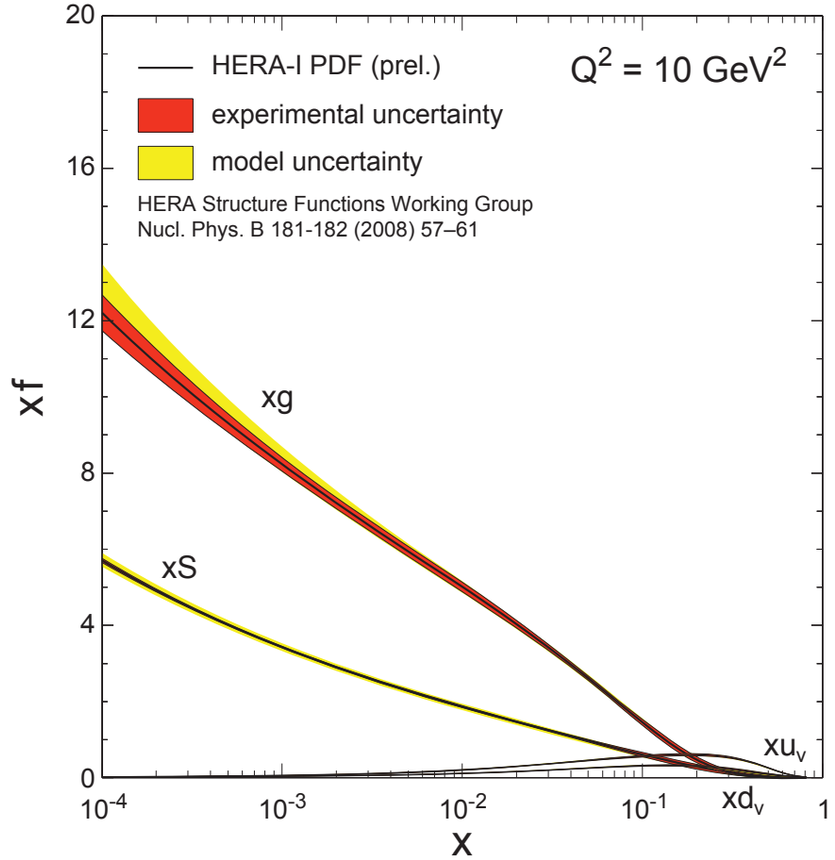


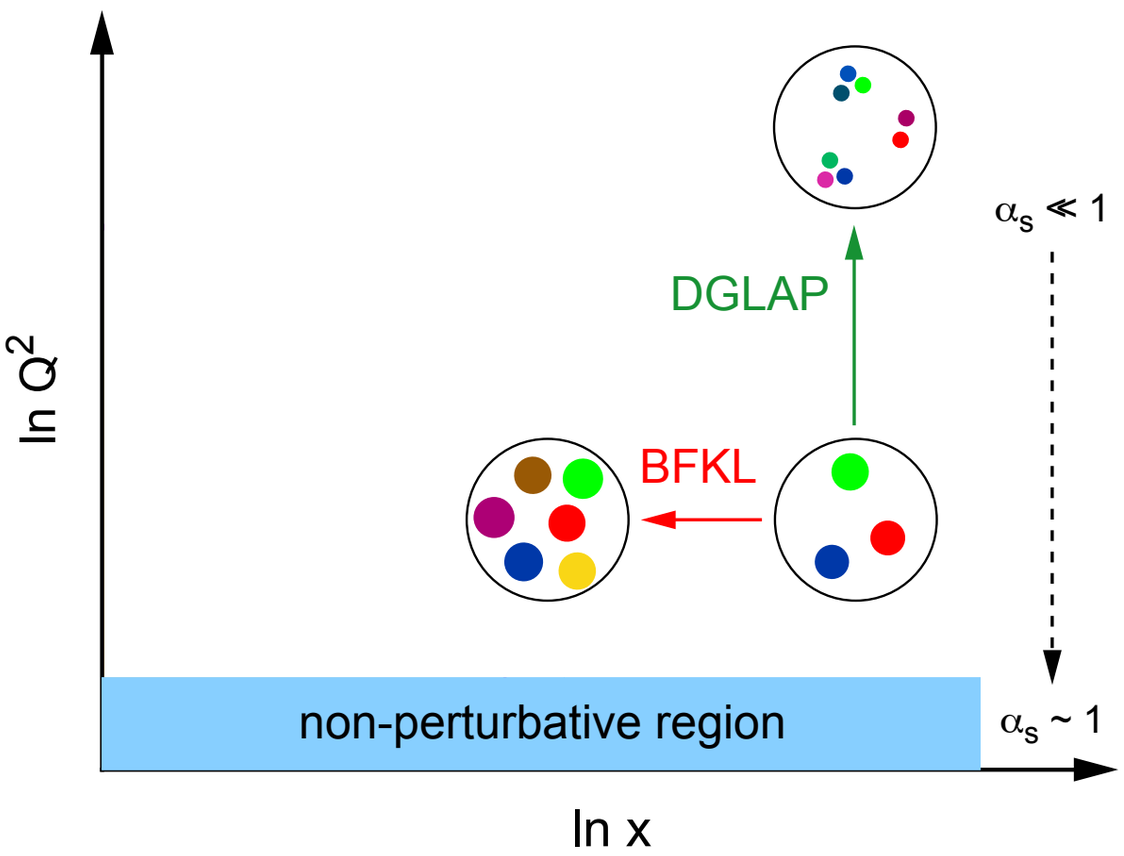


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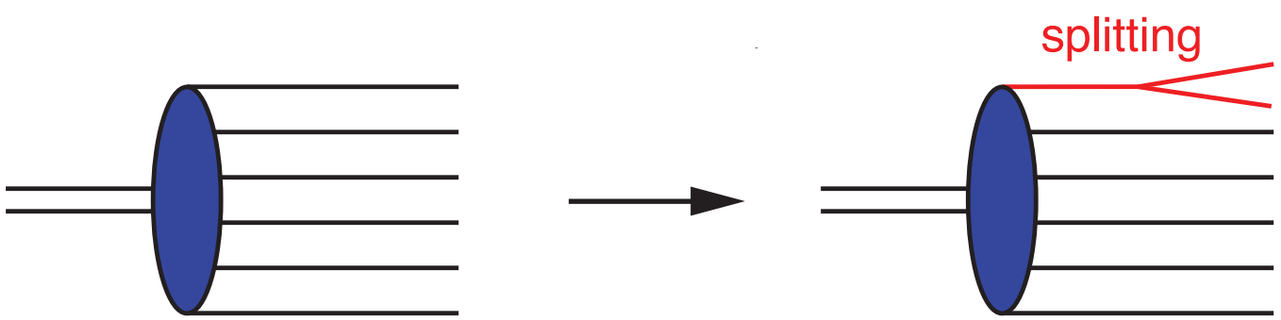

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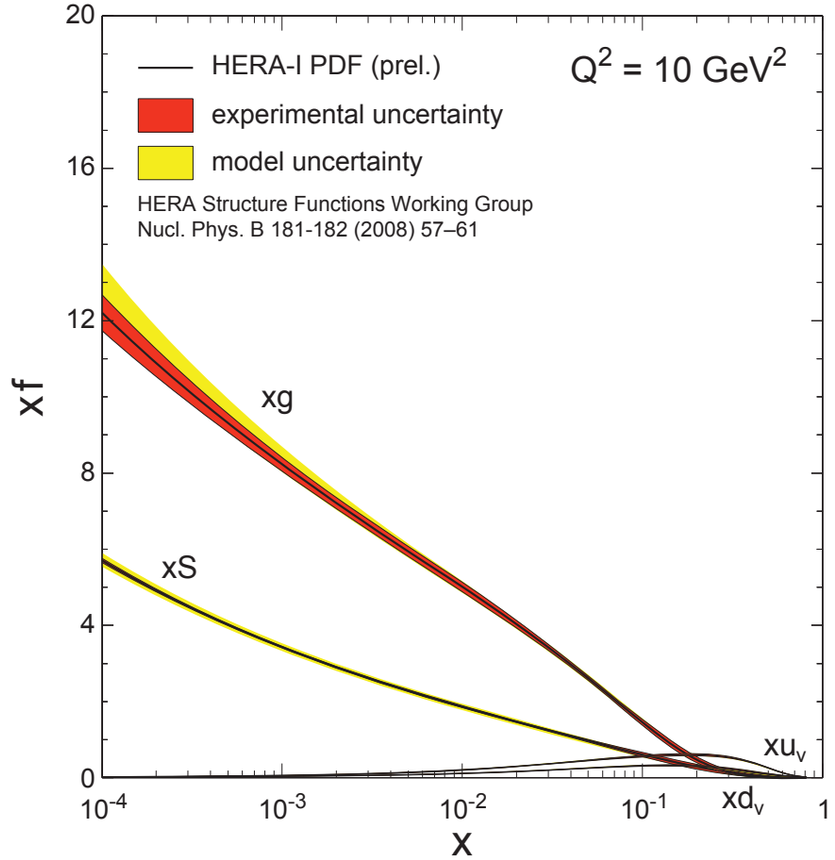
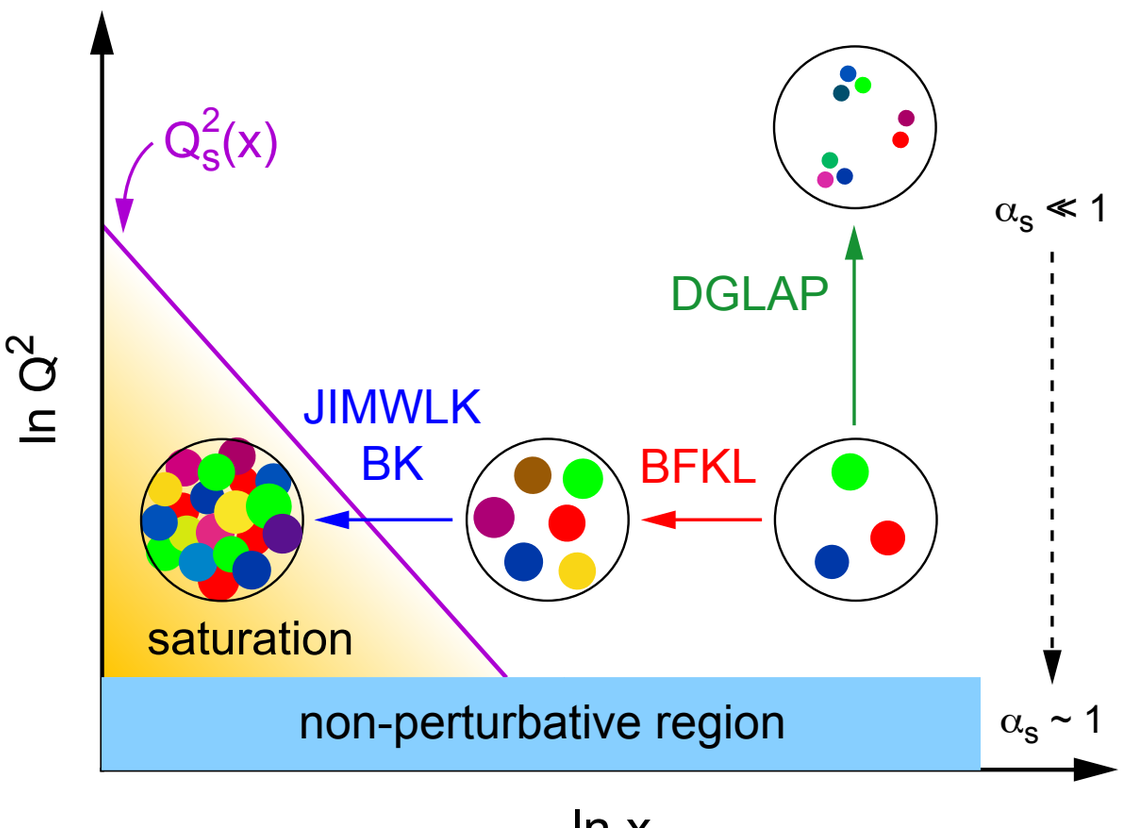
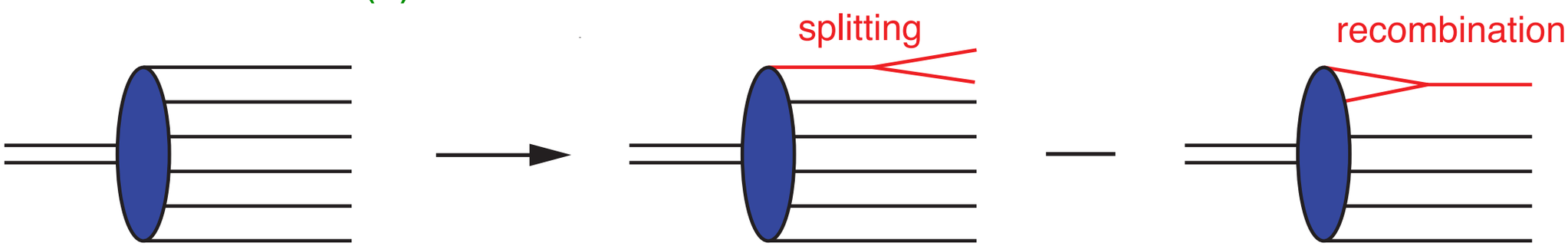


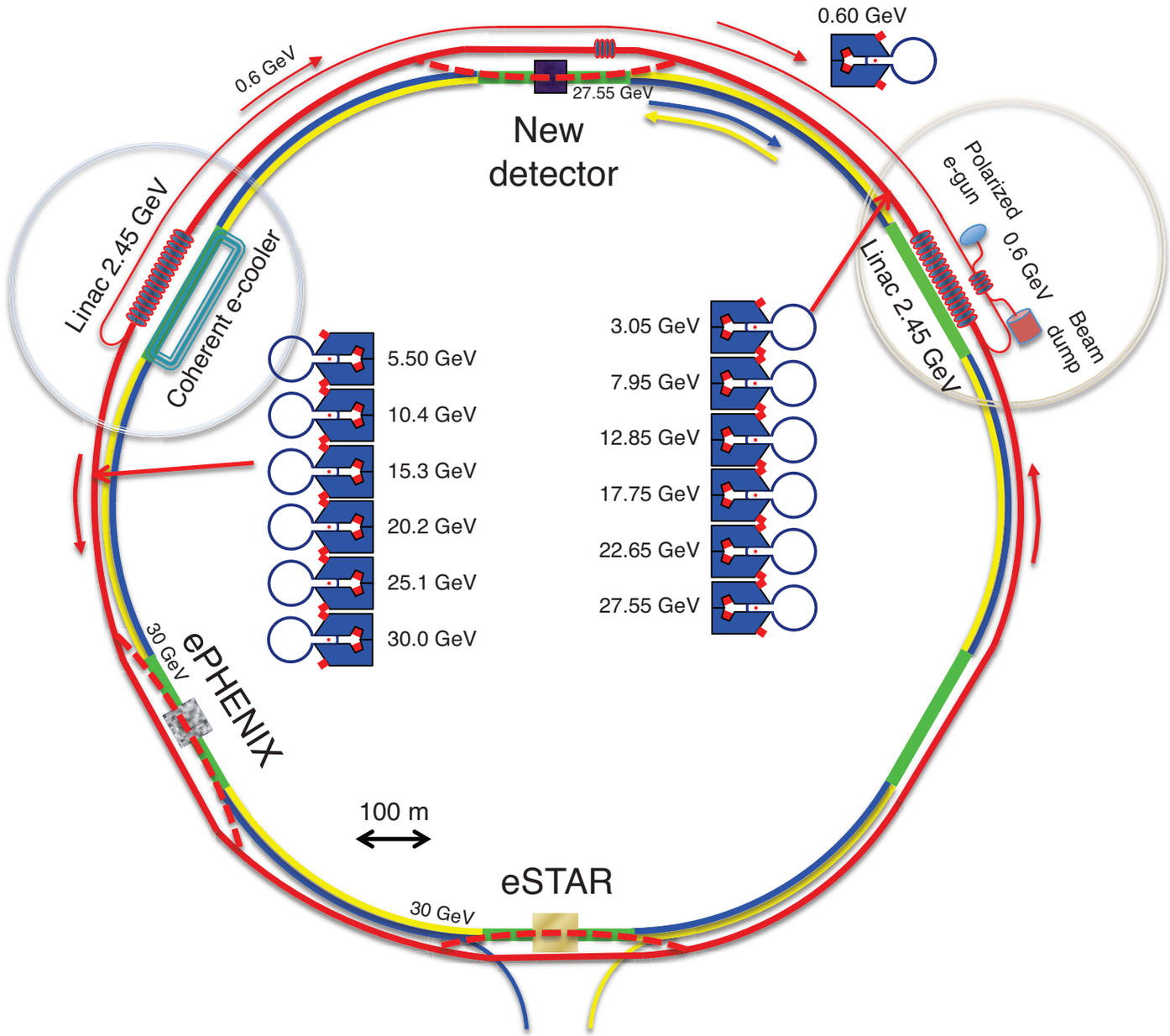




- Gluons dominate the PDFs at small- to intermediate-x ($x < 0.1$)
  - ➡ Rapid rise in gluons described naturally by linear pQCD evolution equations
  - ➡ This rise cannot increase forever - limits on the cross-section
    - non-linear pQCD evolution equations provide a natural way to tame this growth and lead to a saturation of gluons, characterised by the saturation scale $Q^2_S(x)$



# The eRHIC project

- eRHIC:
  - ➡ Utilises the RHIC ion beams
  - ➡ Two 2.45 GeV Energy Recovery Linacs (ERLs) accelerate the $e^-$ beam
    - ▸ 6 separate rings accelerate the $e^-$ up to a maximum energy of 30 GeV
  - ➡ 2-stage approach
    - ▸ Stage 1: $e^-$ 5-10 GeV
    - ▸ Stage 2: $e^-$ 20-30 GeV
  - ➡ Space for new detector at IP12
    - ▸ Possibilities for collisions in current STAR and PHENIX IPs



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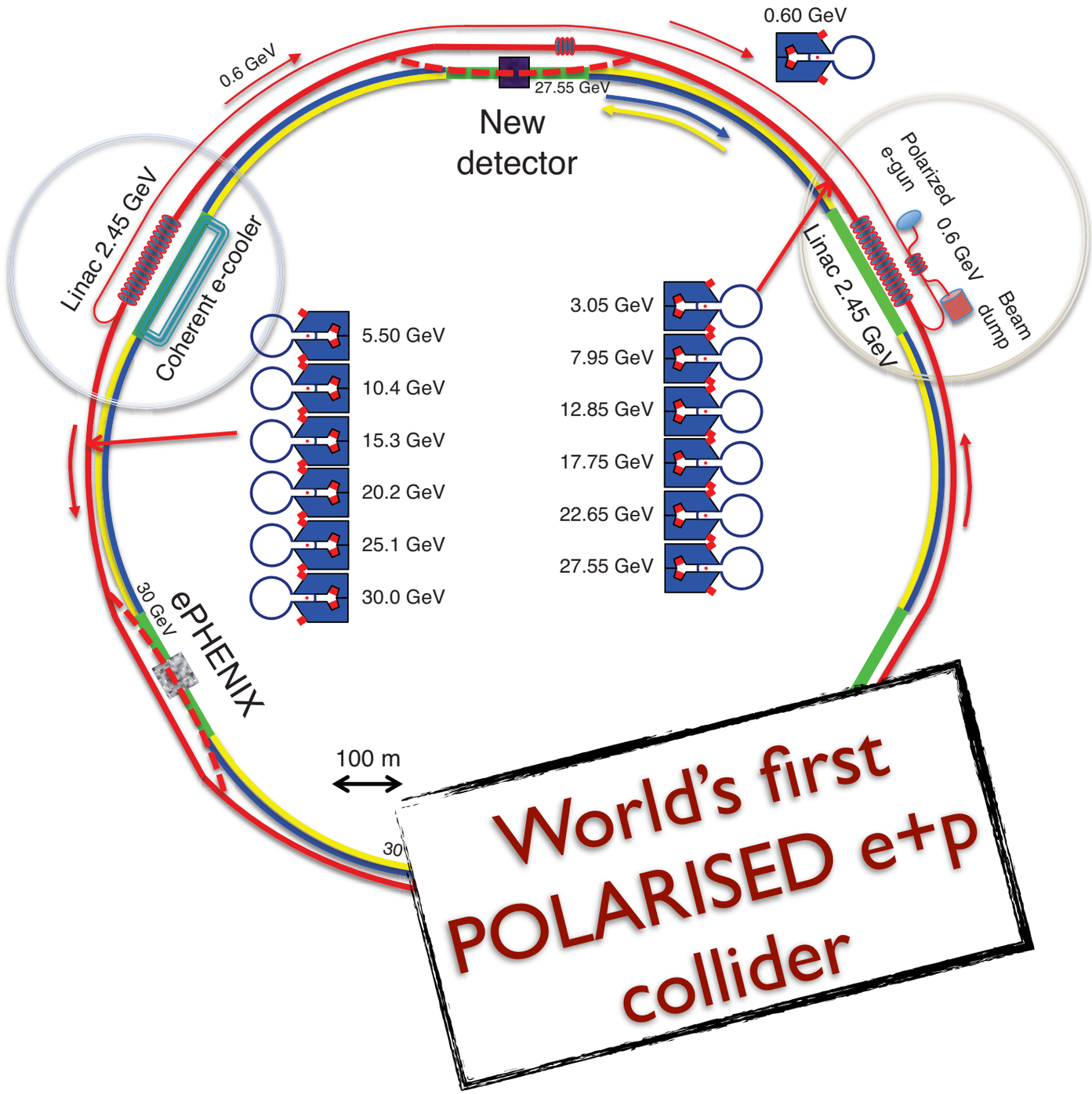

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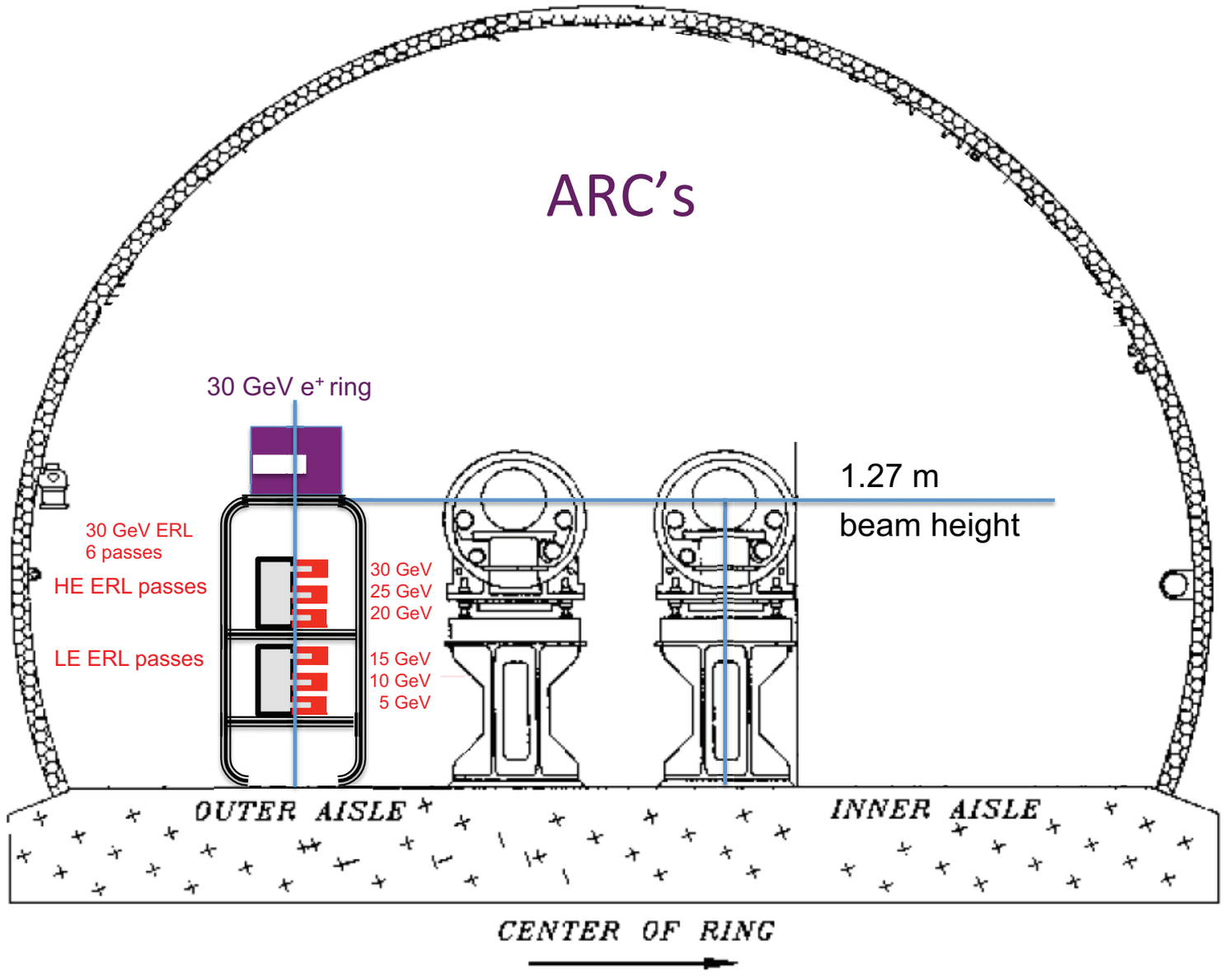
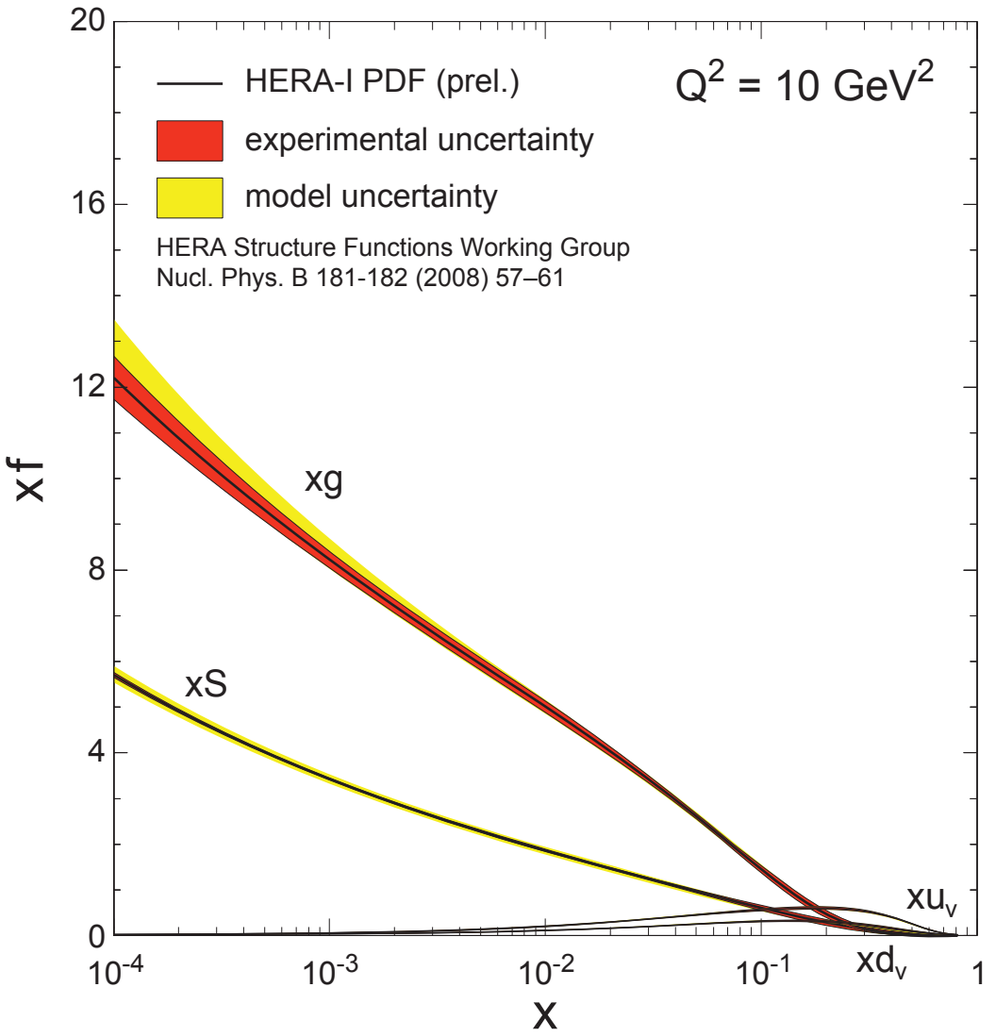


# (Very) Brief Recap of Saturation at an EIC



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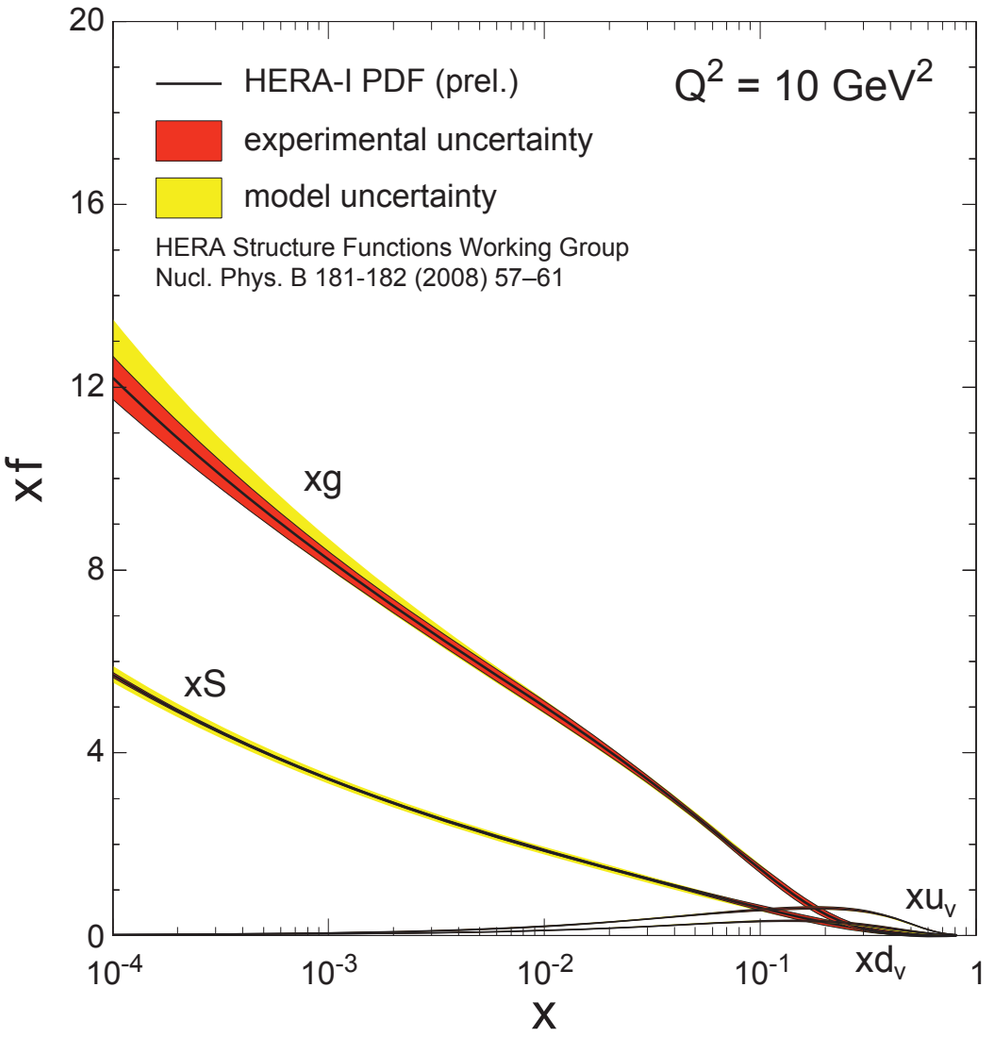


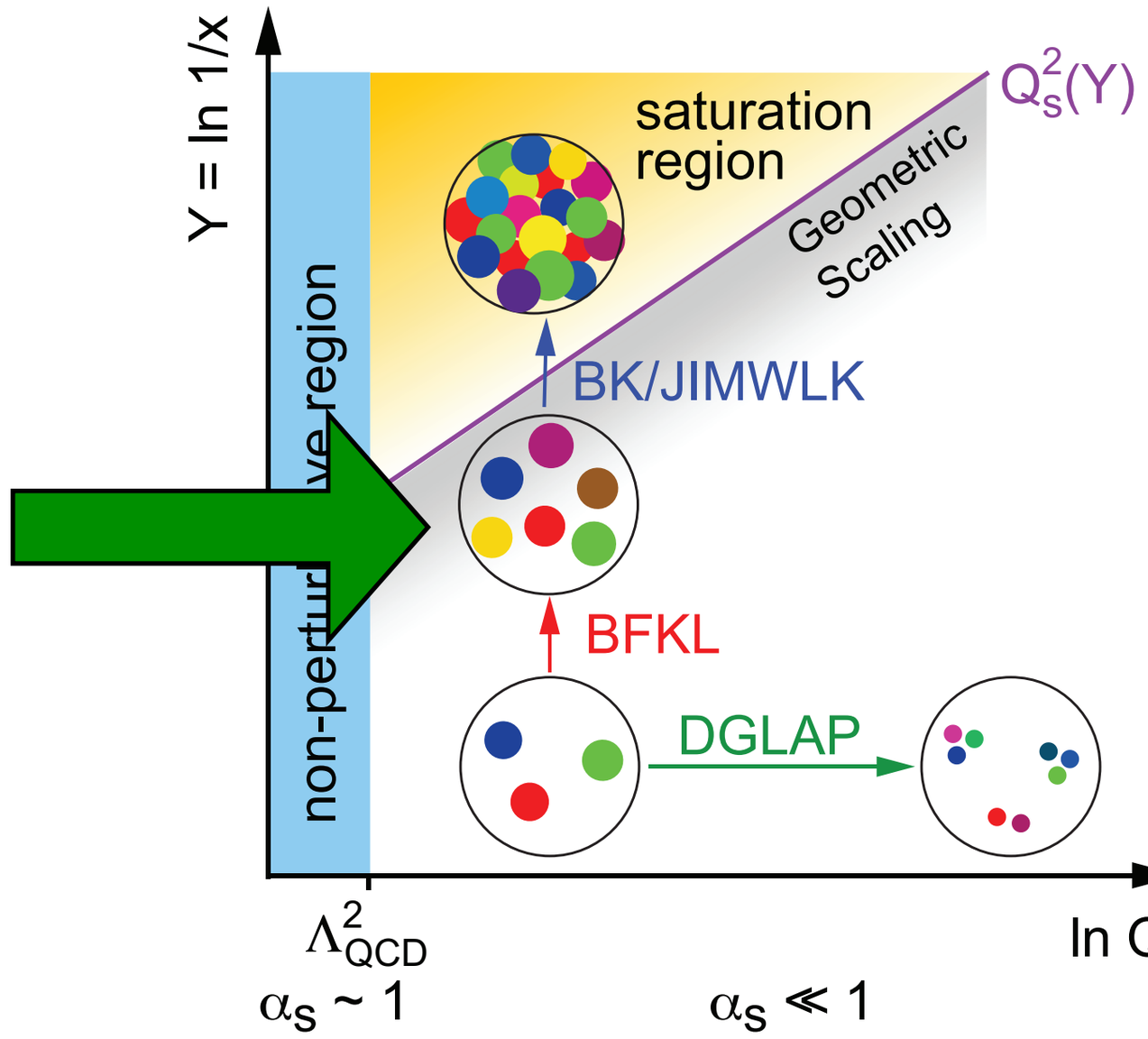


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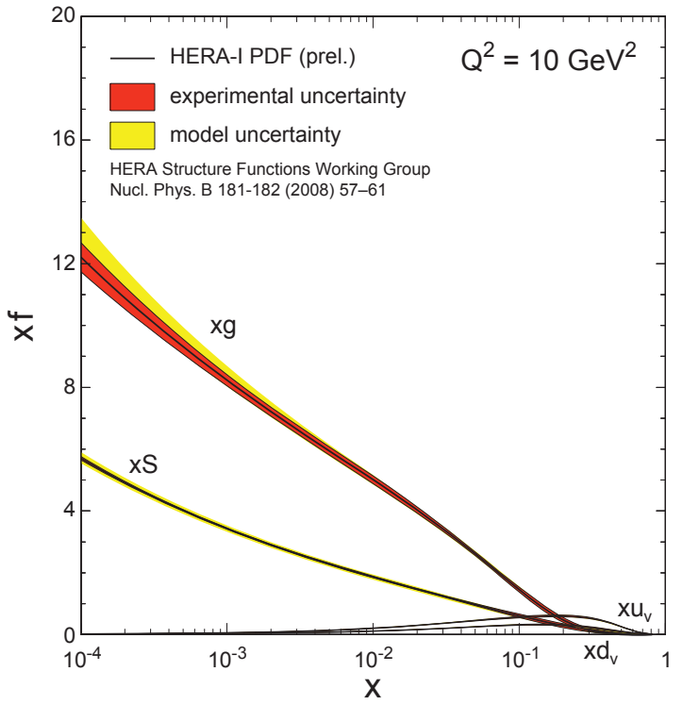
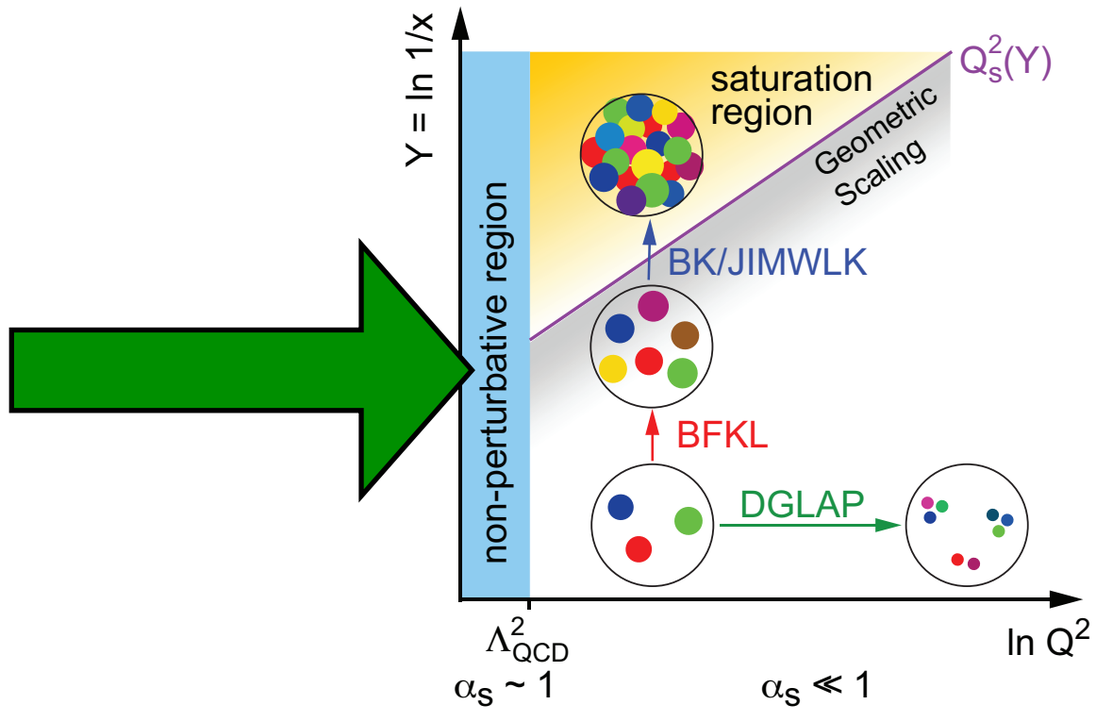
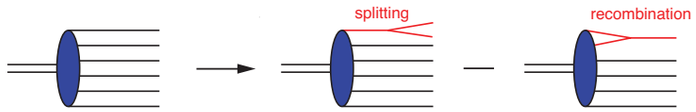
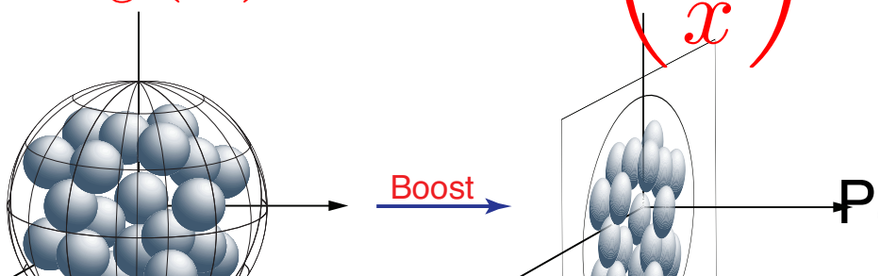



$$Q_s^2(x) \sim A^{1/3} \left(\frac{1}{x}\right)^{\lambda}$$



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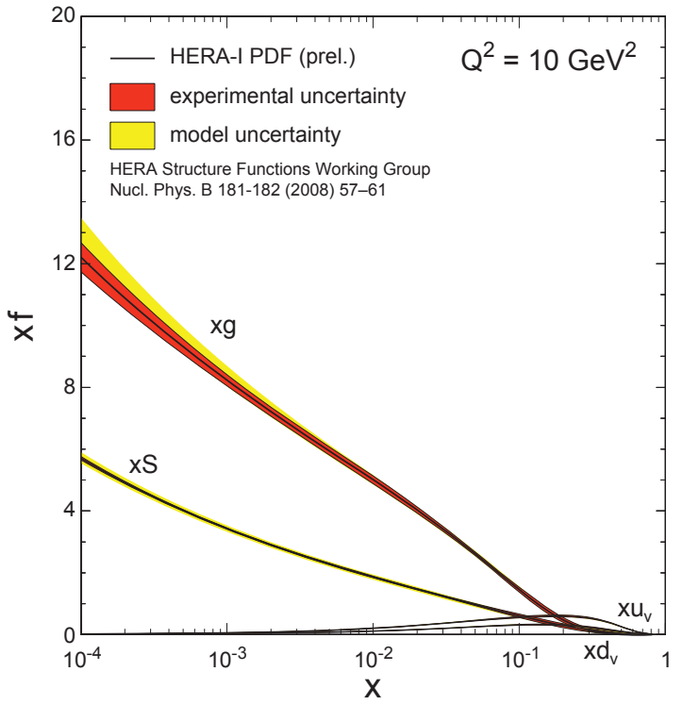


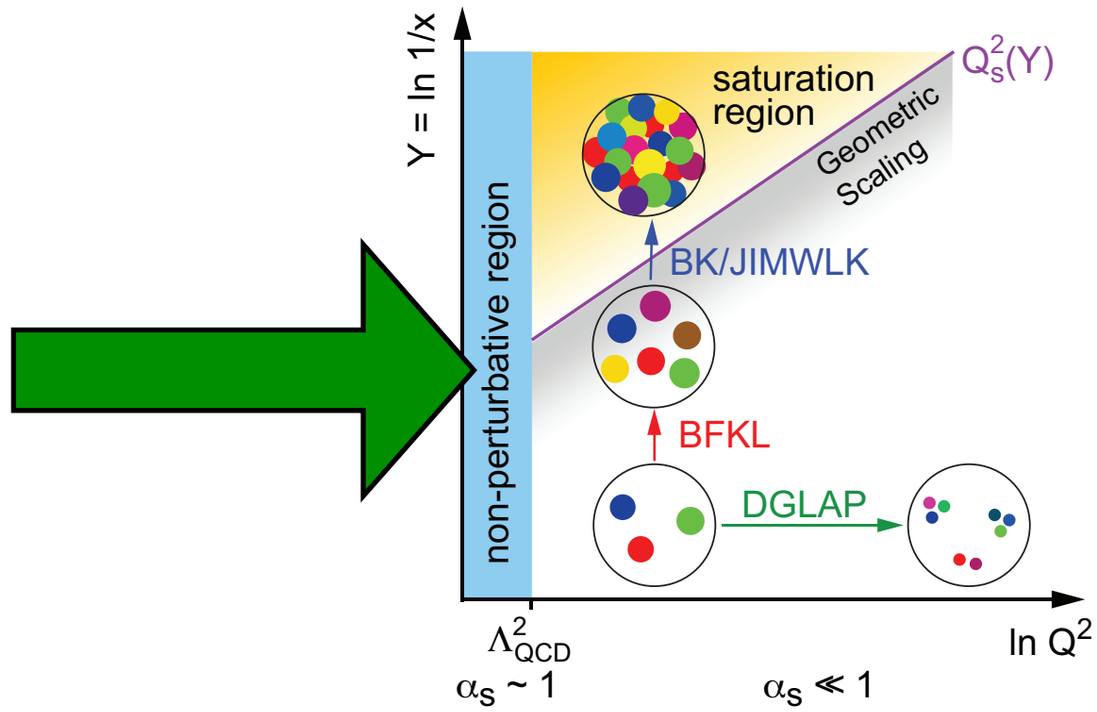


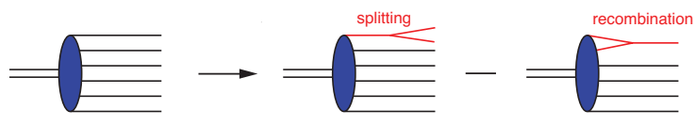


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