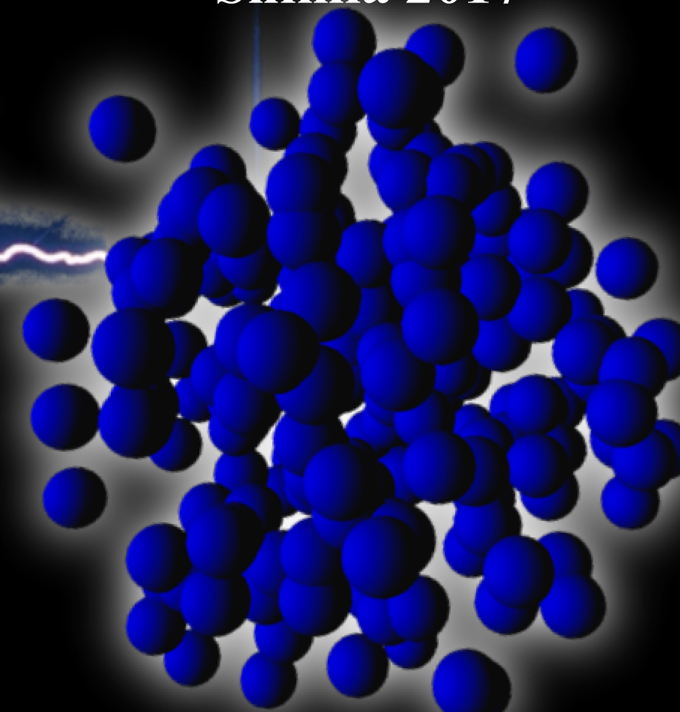
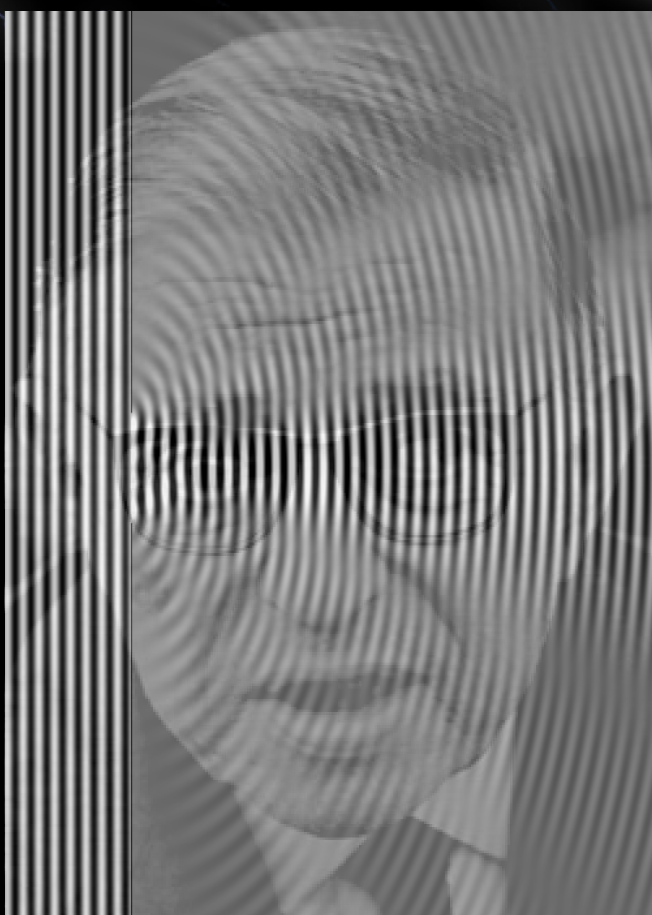
“The Sar*t*re Event Generator”

Tobias Toll

MPI@LHC

Shimla 2017

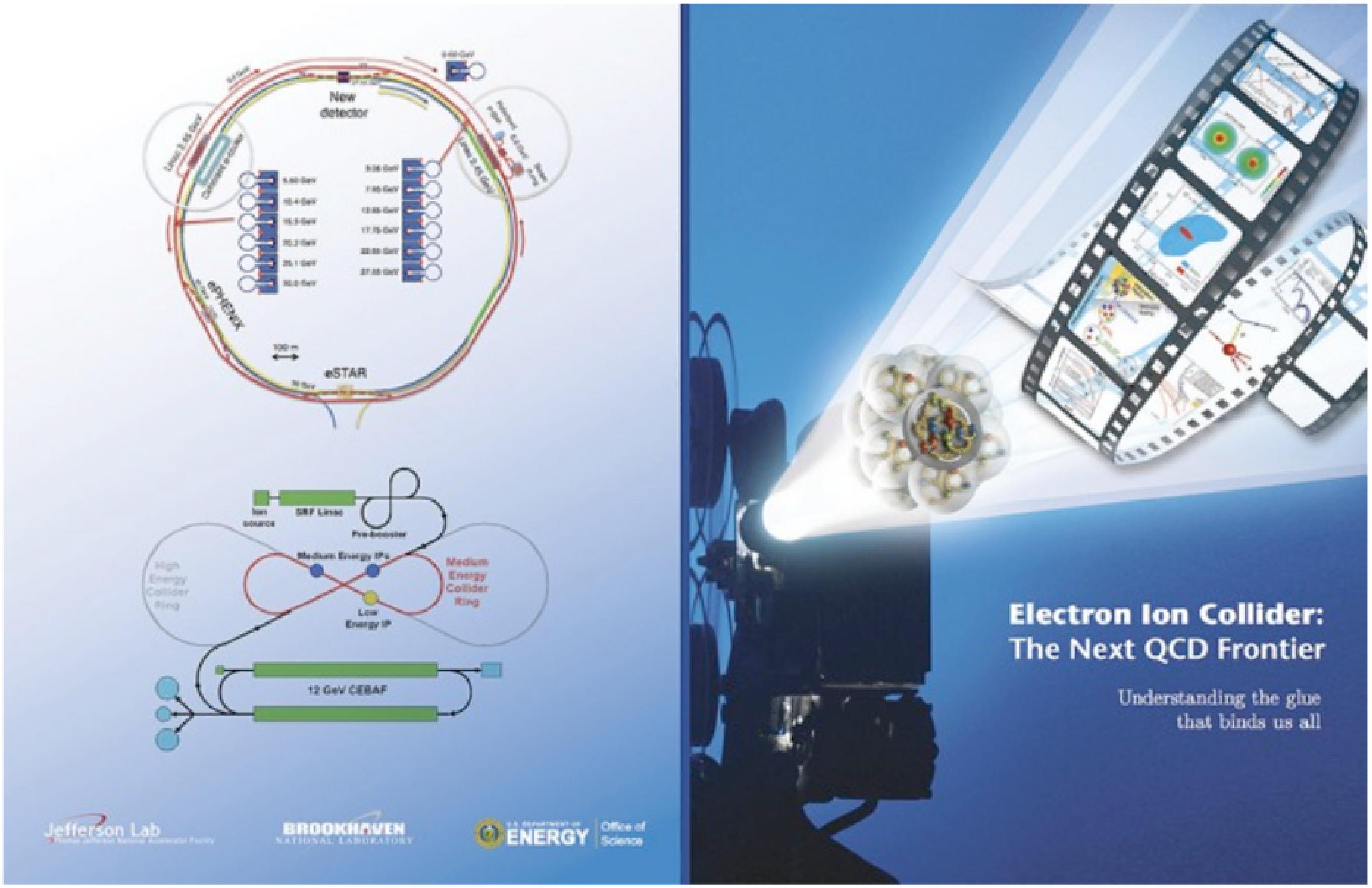




SHIV NADAR UNIVERSITY

The EIC Physics Programme

Eur.Phys.J. A52 (2016) no.9, 268



arXiv:1212.1701

Physics of Strong Colour Fields

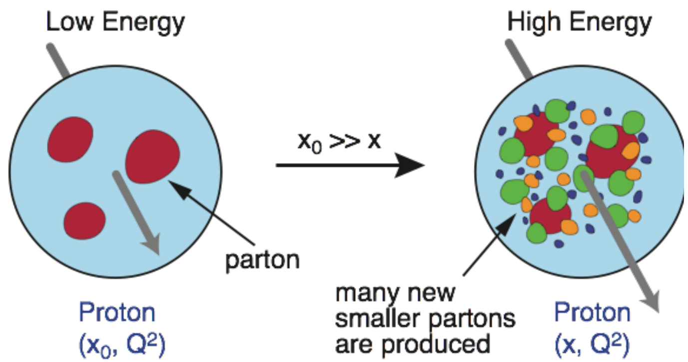
Spin Physics

3D Imaging

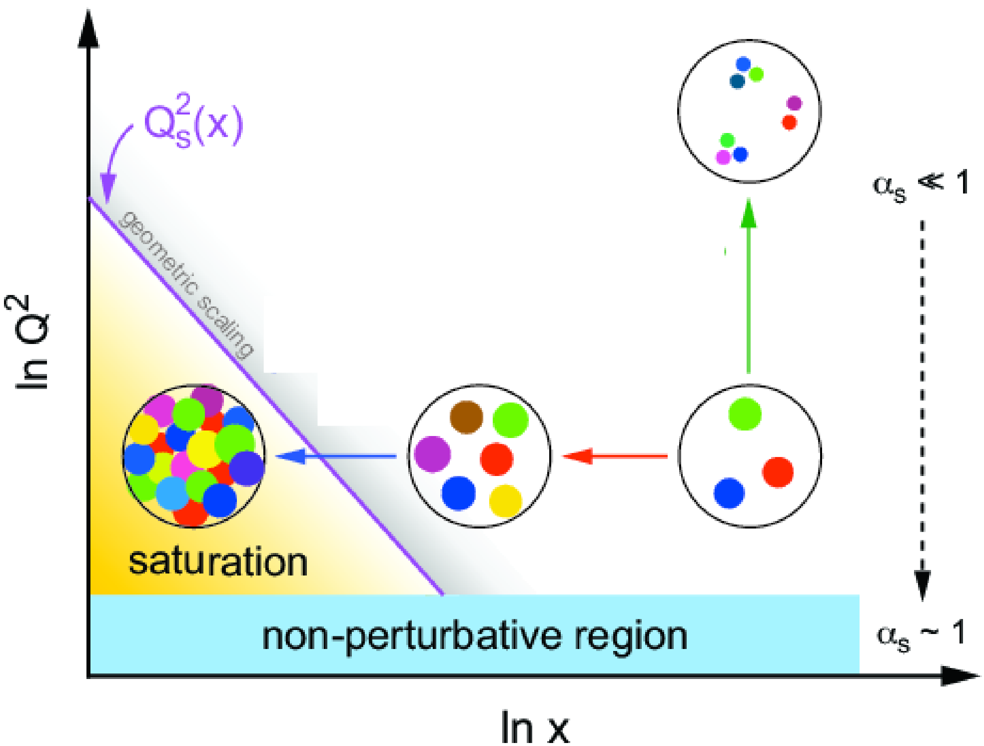
Hadronisation

Electroweak

Saturation at EIC



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



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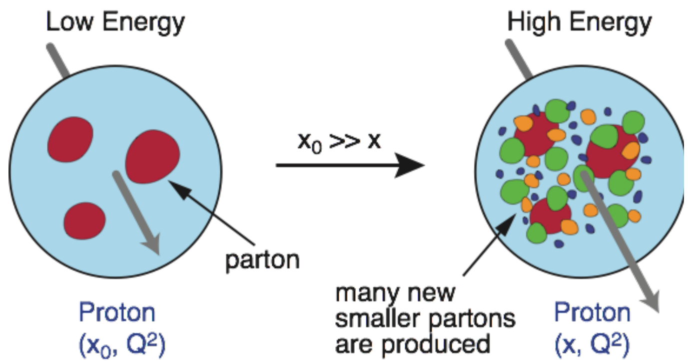
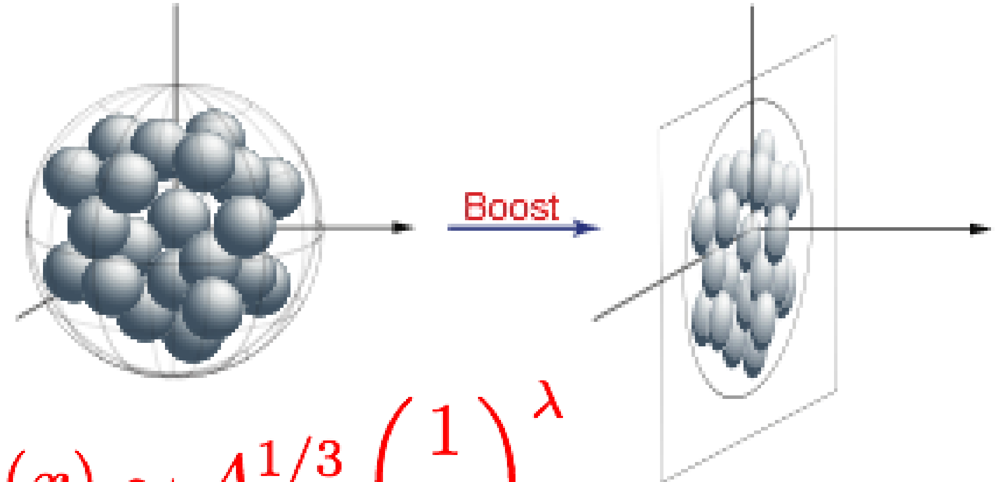
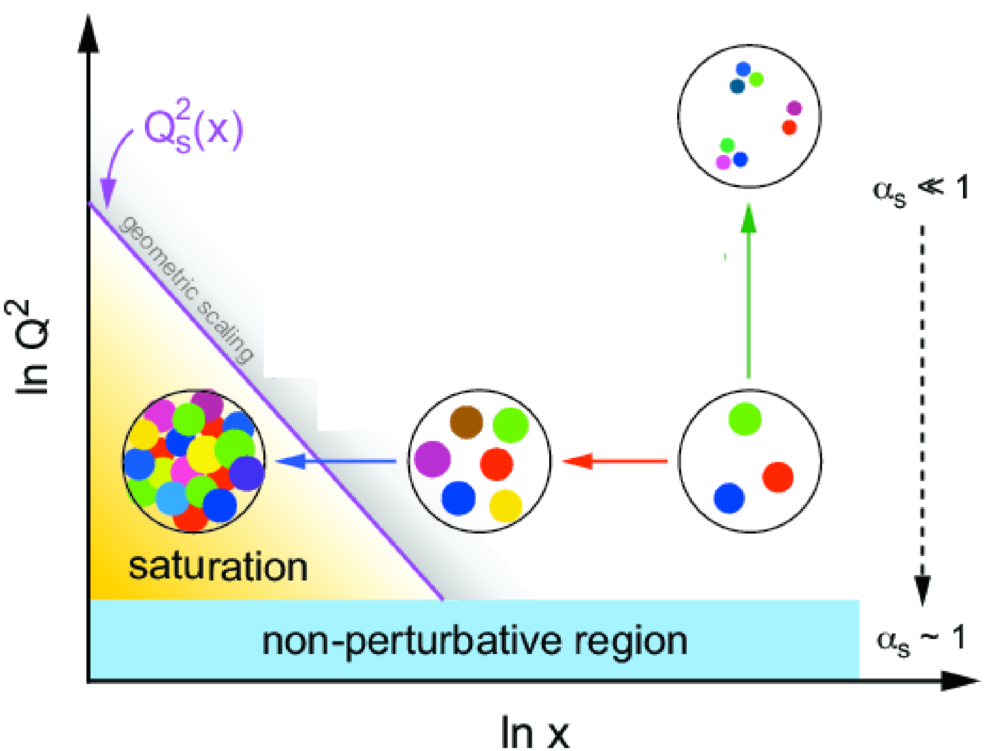
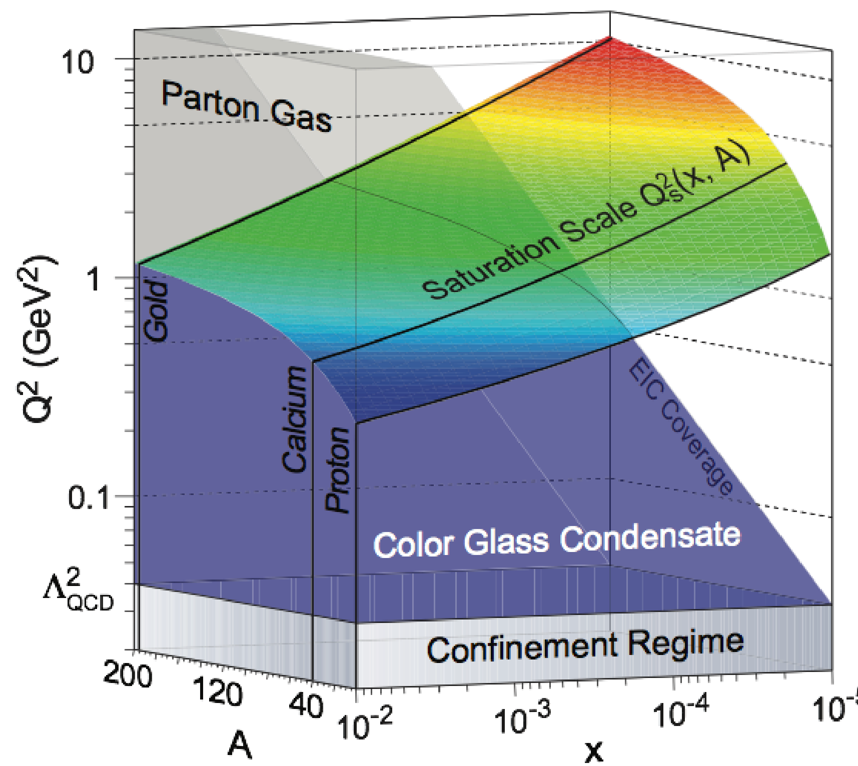




$$Q_s^2(x) \sim A^{1/3}\left(\frac{1}{x}\right)^{\lambda}$$





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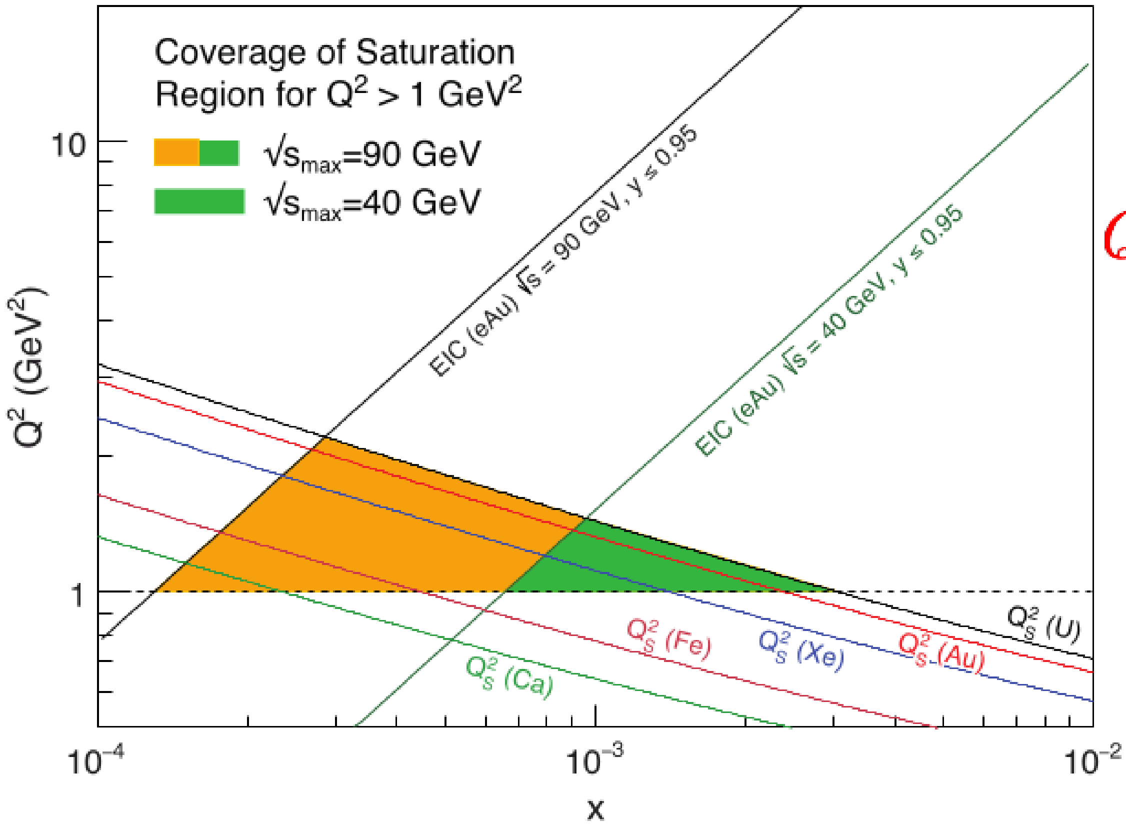
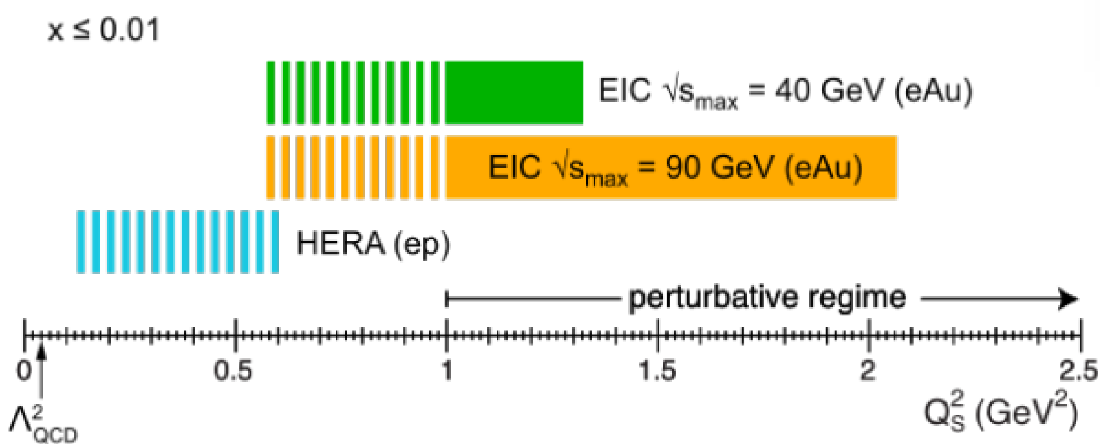
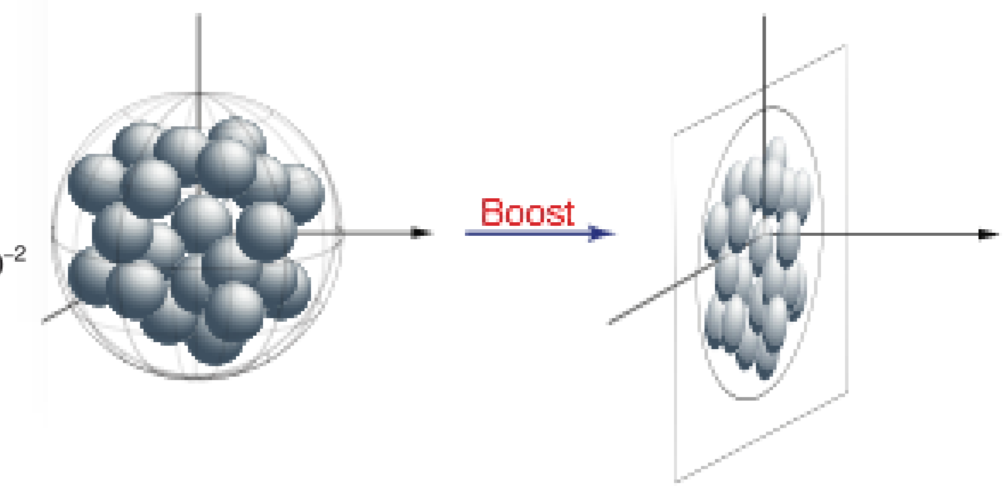
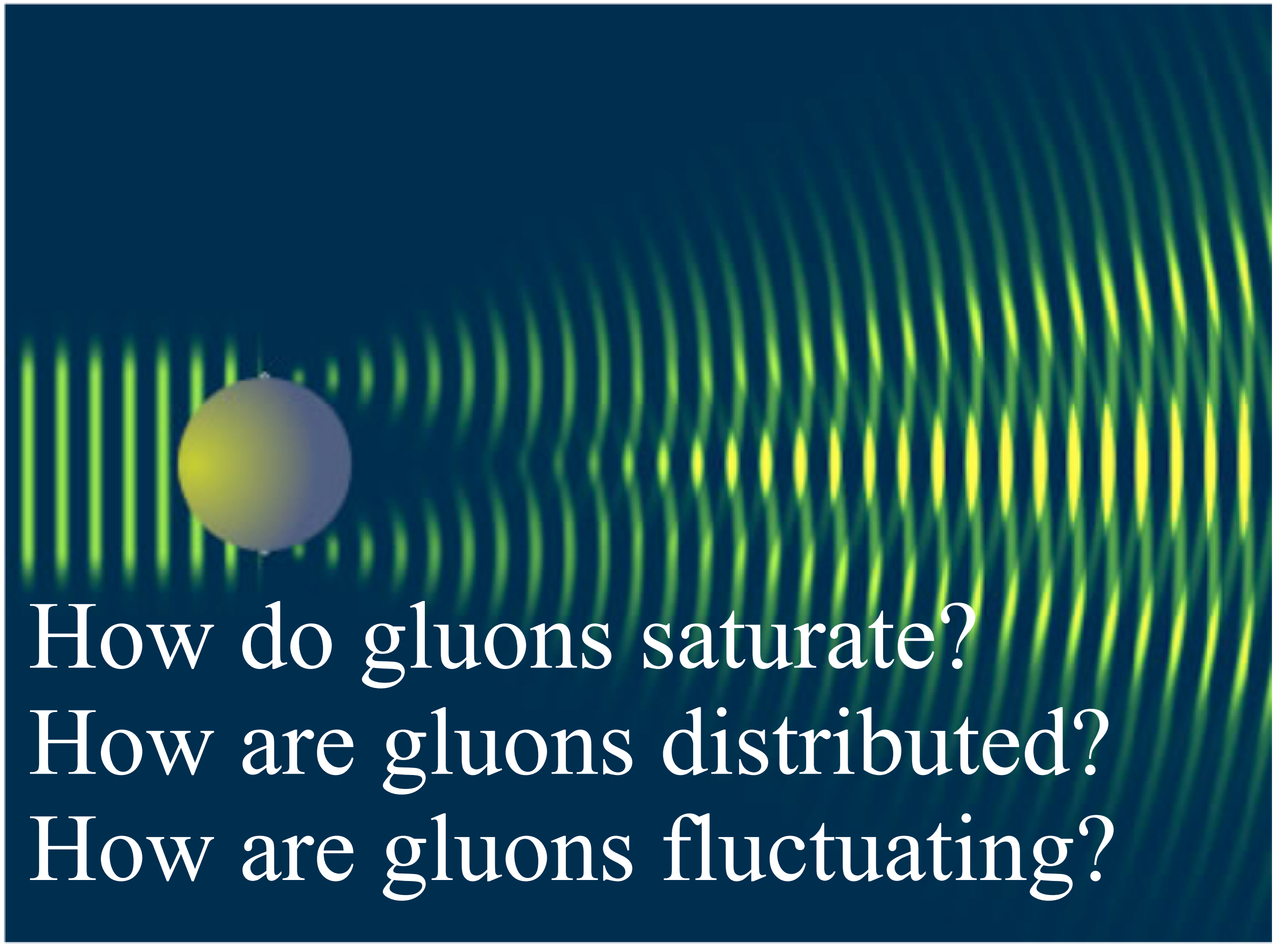


$$Q_s^2(x) \sim A^{1/3}\left(\frac{1}{x}\right)^{\lambda} \sim \left(\frac{A}{x}\right)^{1/3}$$



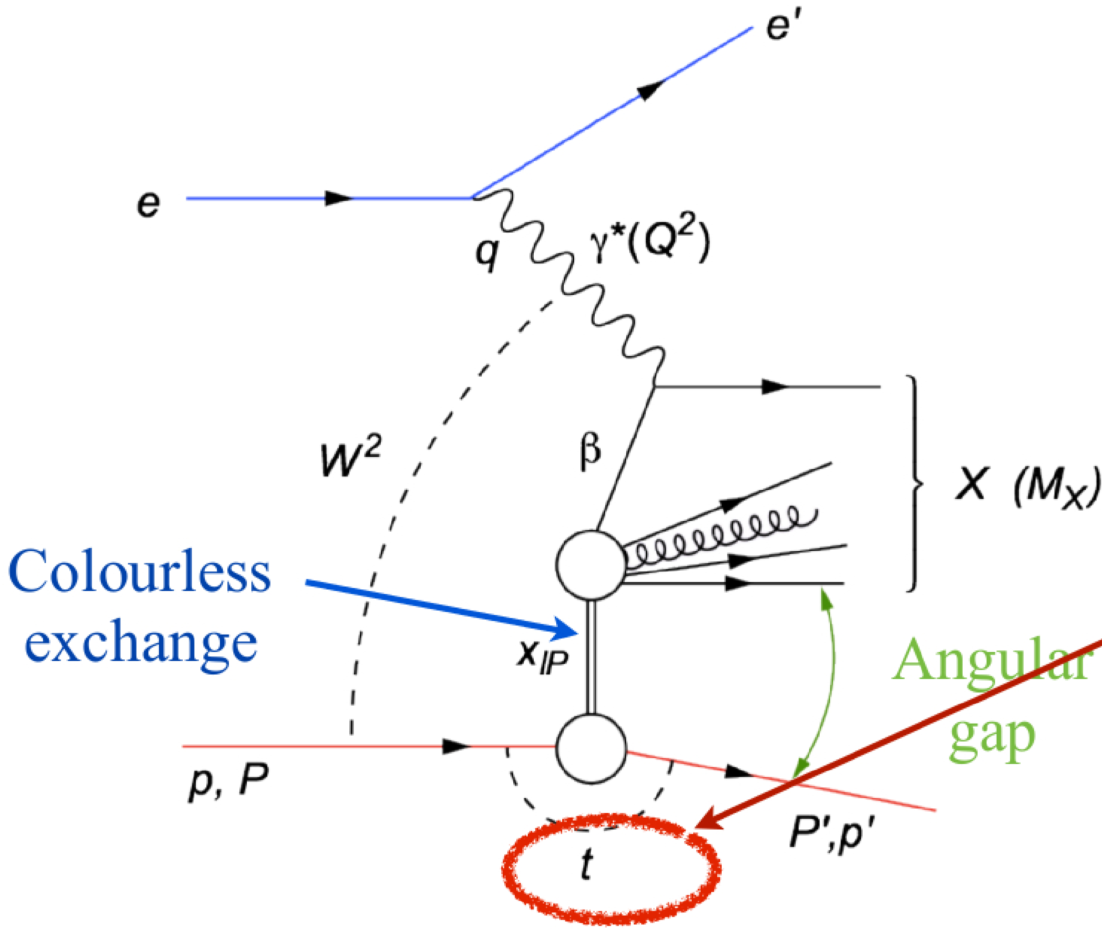


Key Measurements:
Diffractive Processes in eA



In Nuclei and Protons

Diffraction *ep* and *eA*



Another kinematic handle

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

HERA:

Proton collides with electron at CMS energy ~300m_p.
In ~15% of measured collisions proton stays intact!

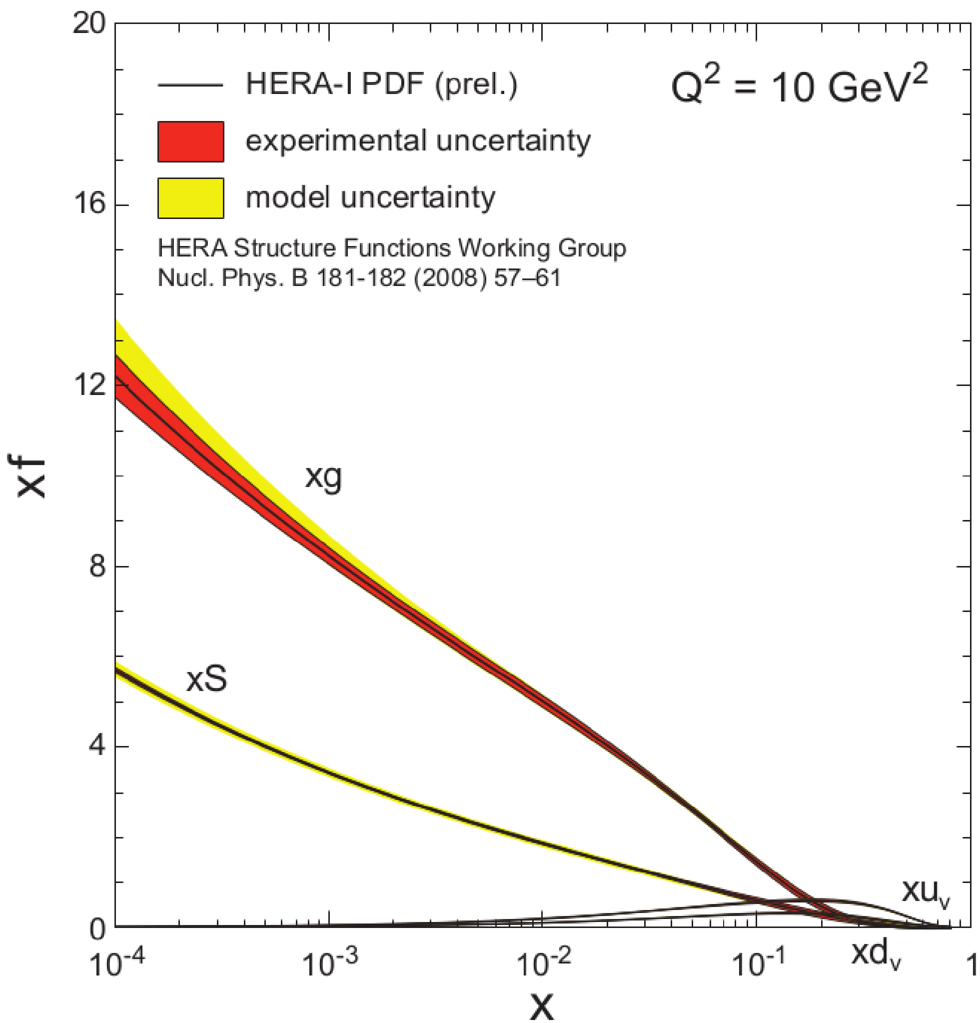
EIC *e*+A:

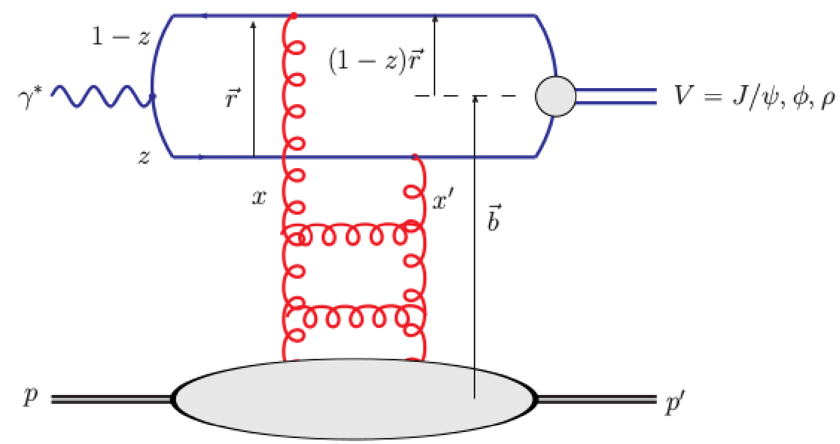
Ion predicted to stay intact in 25%-40% of events w. saturation!

Why diffraction is so great

Diffraction sensitive to gluon momentum distributions²:

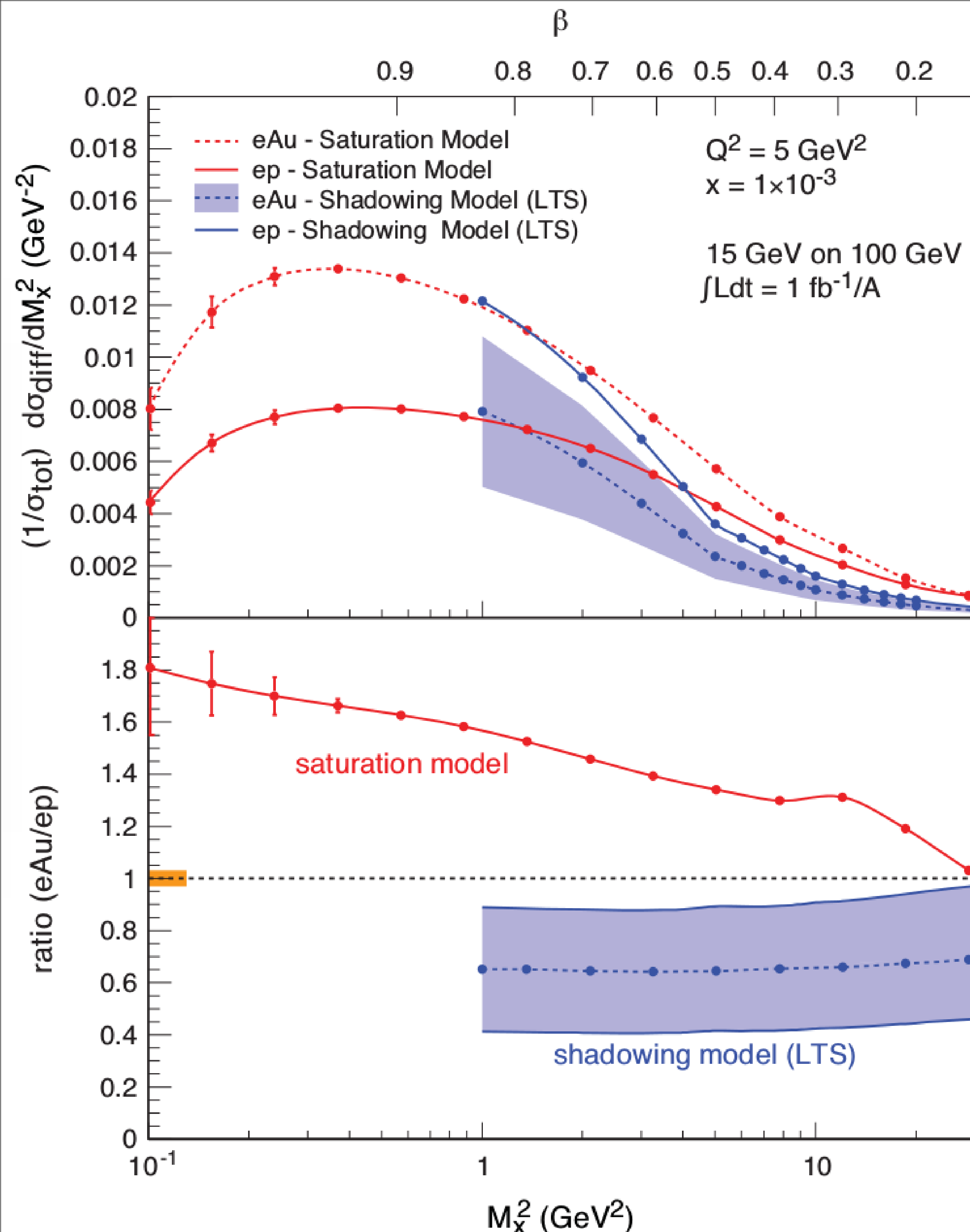
$$\sigma \propto g(x,Q^2)^2$$





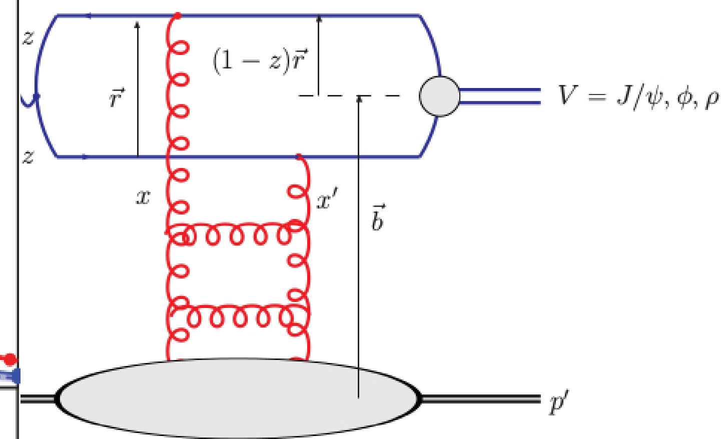
The colourless exchange can be understood as two gluons screening eachother's colour

Sensitive to how the gluon distribution saturates at small x



is so great

mentum distributions[2]:



colourless exchange can

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stribution saturates at

small *x*

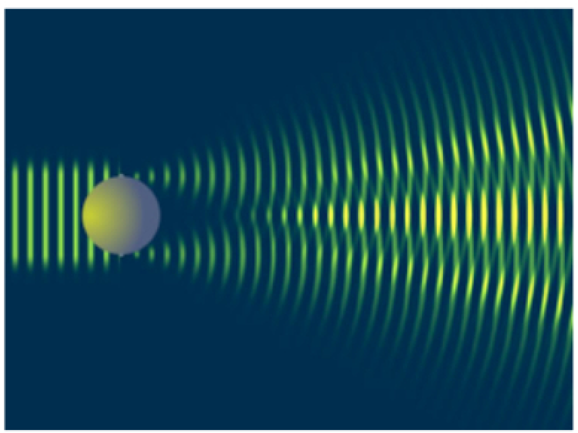
Why diffraction is so great

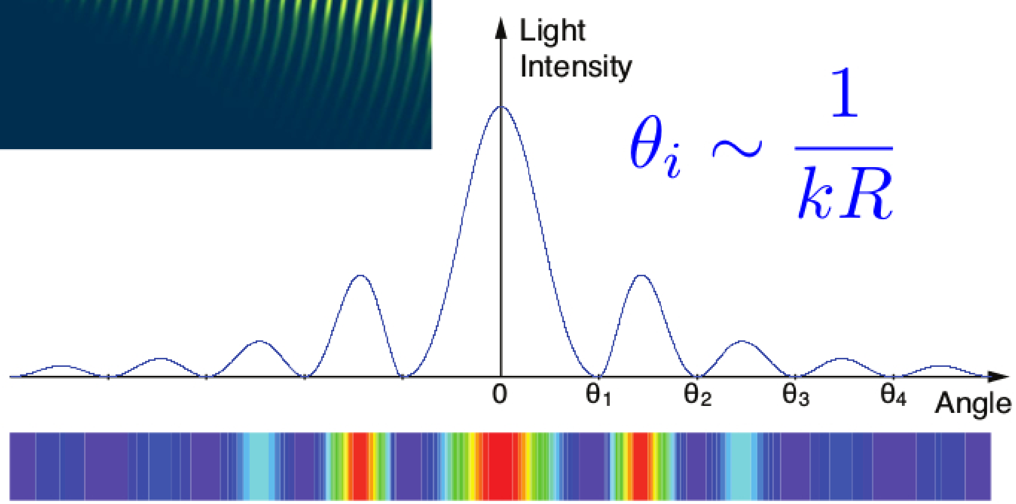
Sensitive to spatial gluon distributions

Light scattering elastically off a circular screen of radius R

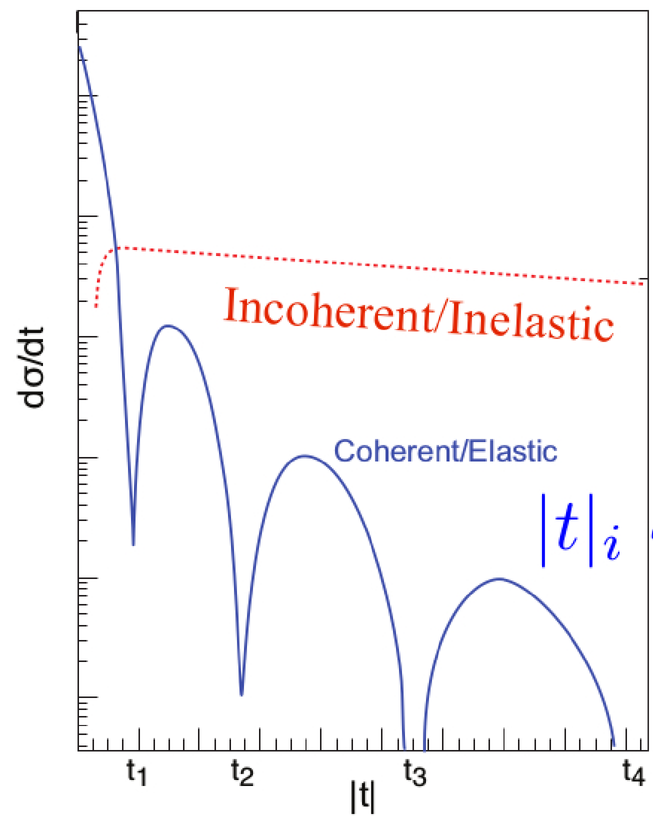
a projectile scattering off a nucleus of radius R
-not a 'black disk', edge effects
-inelastic scattering

t: Fourier conjugate to ion shape



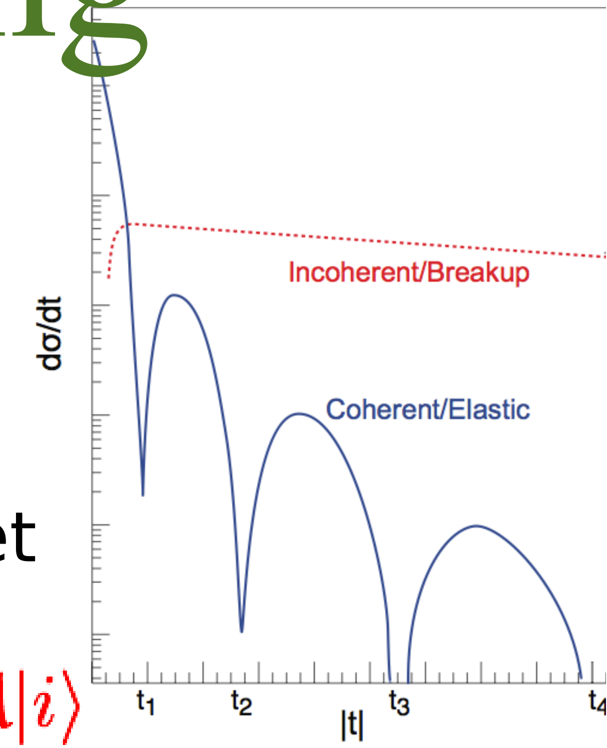


$$\theta_i \sim \frac{1}{kR}$$



$$|t|_i \sim \frac{1}{R^2}$$

Incoherent Scattering



Good, Walker:

nucleus dissociates ($f \neq i$):

$$\sigma_{\text{incoherent}} \propto \sum_{f \neq i} \langle i|\mathcal{A}|f\rangle^\dagger \langle f|\mathcal{A}|i\rangle$$

complete set

$$= \sum_f \langle i|\mathcal{A}|f\rangle^\dagger \langle f|\mathcal{A}|i\rangle - \langle i|\mathcal{A}|i\rangle^\dagger \langle i|\mathcal{A}|i\rangle$$

$$= \langle i\,||\mathcal{A}|^2|\,i\rangle - |\langle i|\mathcal{A}|i\rangle|^2 = \left\langle|\mathcal{A}|^2\right\rangle - |\langle\mathcal{A}\rangle|^2$$

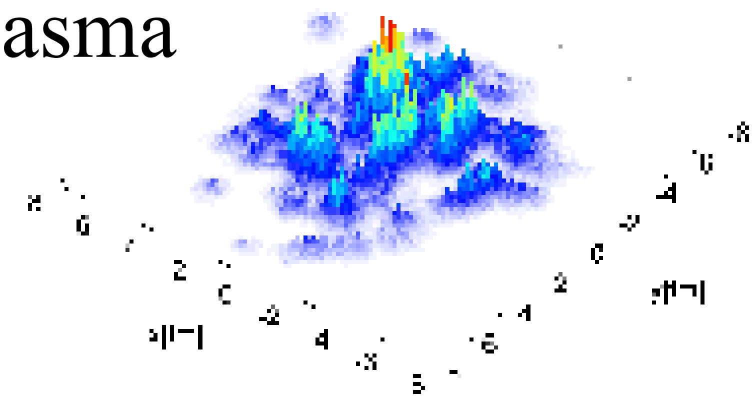
the incoherent CS is the variance of the amplitude!!

$$\frac{d\sigma_{\text{total}}}{dt} = \frac{1}{16\pi}\left\langle|\mathcal{A}|^2\right\rangle \qquad \frac{d\sigma_{\text{coherent}}}{dt} = \frac{1}{16\pi}|\langle\mathcal{A}\rangle|^2$$

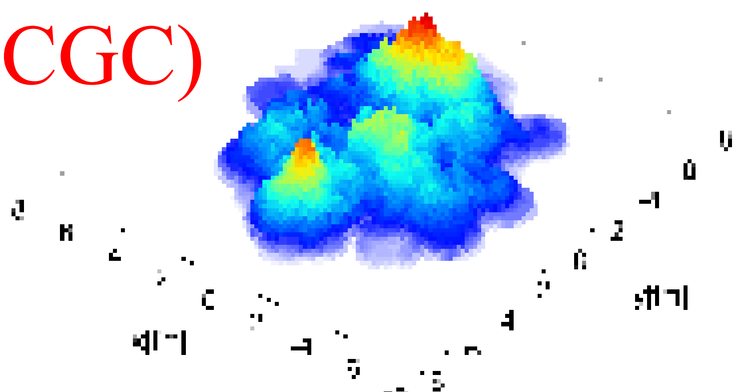
Fluctuations

Schenke, Tribedy, Venugopalan arXiv:1202.6646

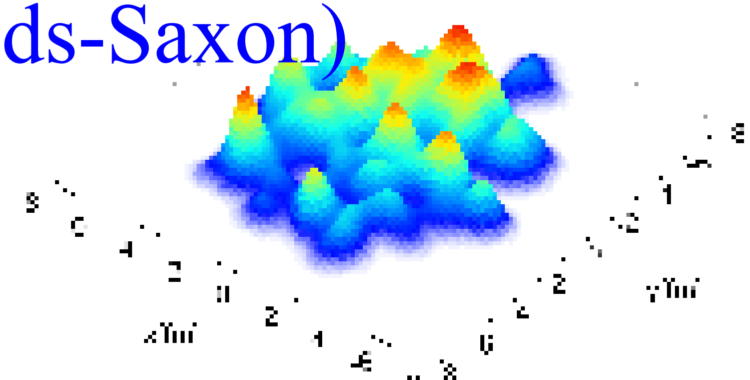
IP-Glasma

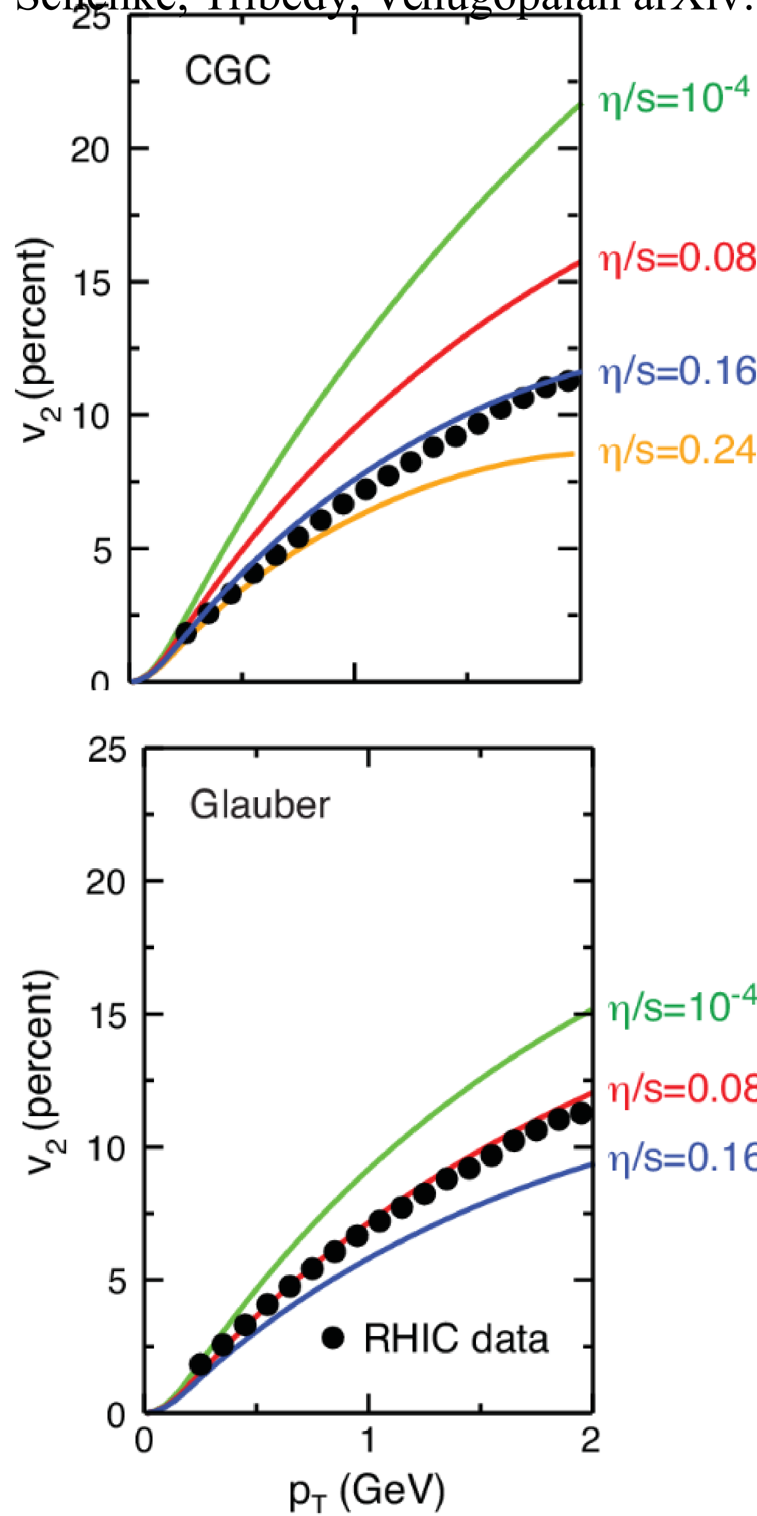


KLN(CGC)

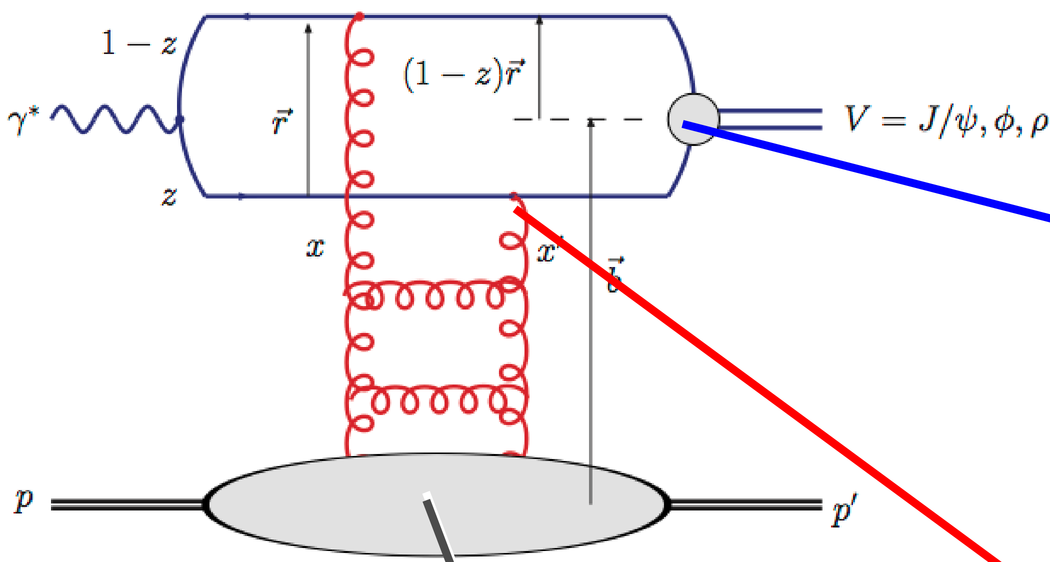


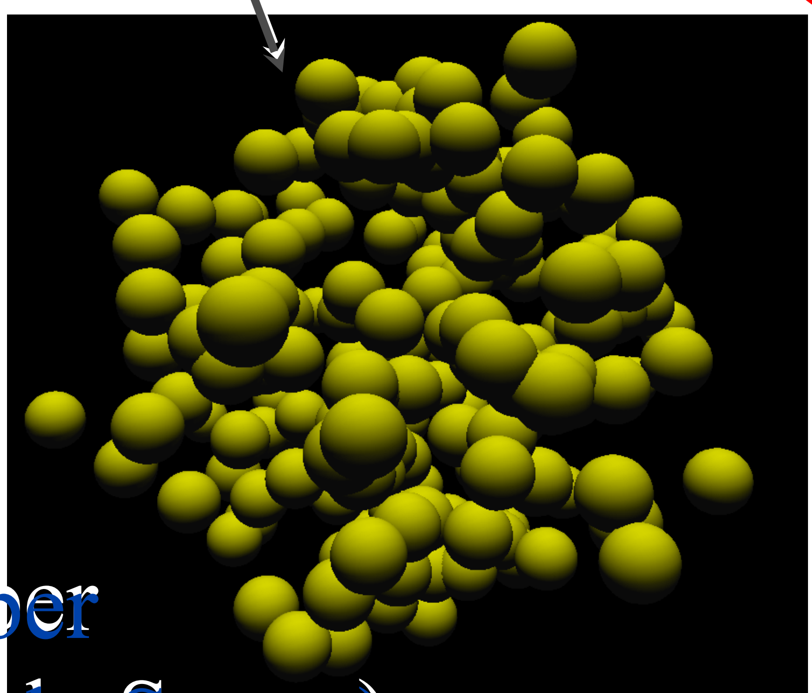
Glauber
(Woods-Saxon)

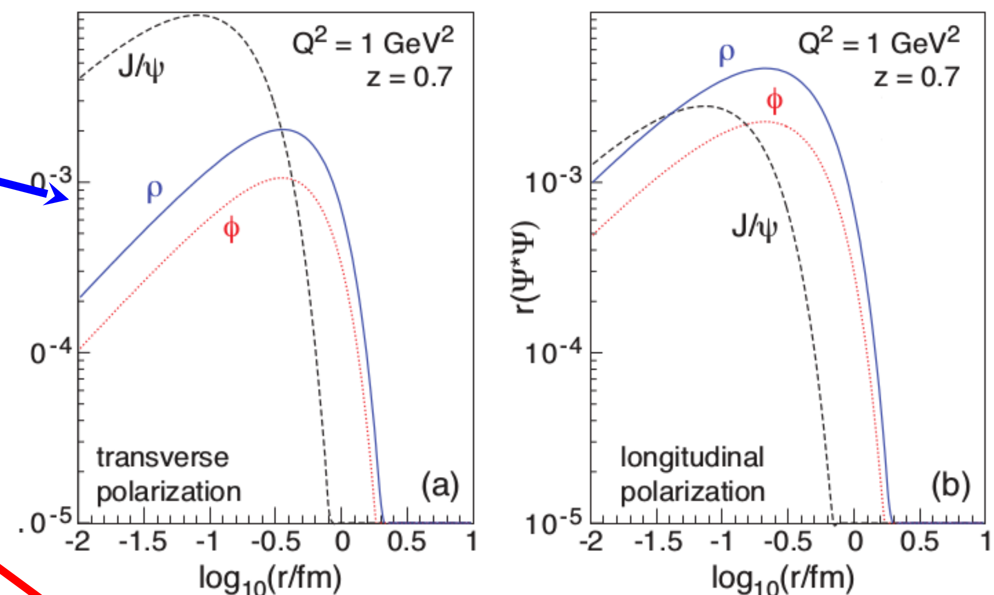


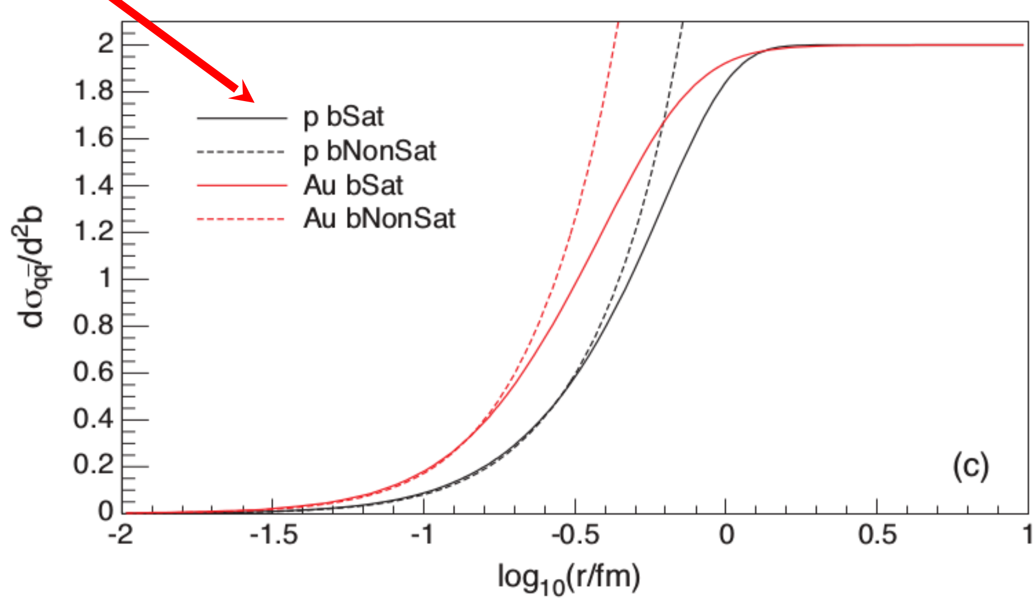


Sar*t*re dipole model with glauber bSat and bNonSat



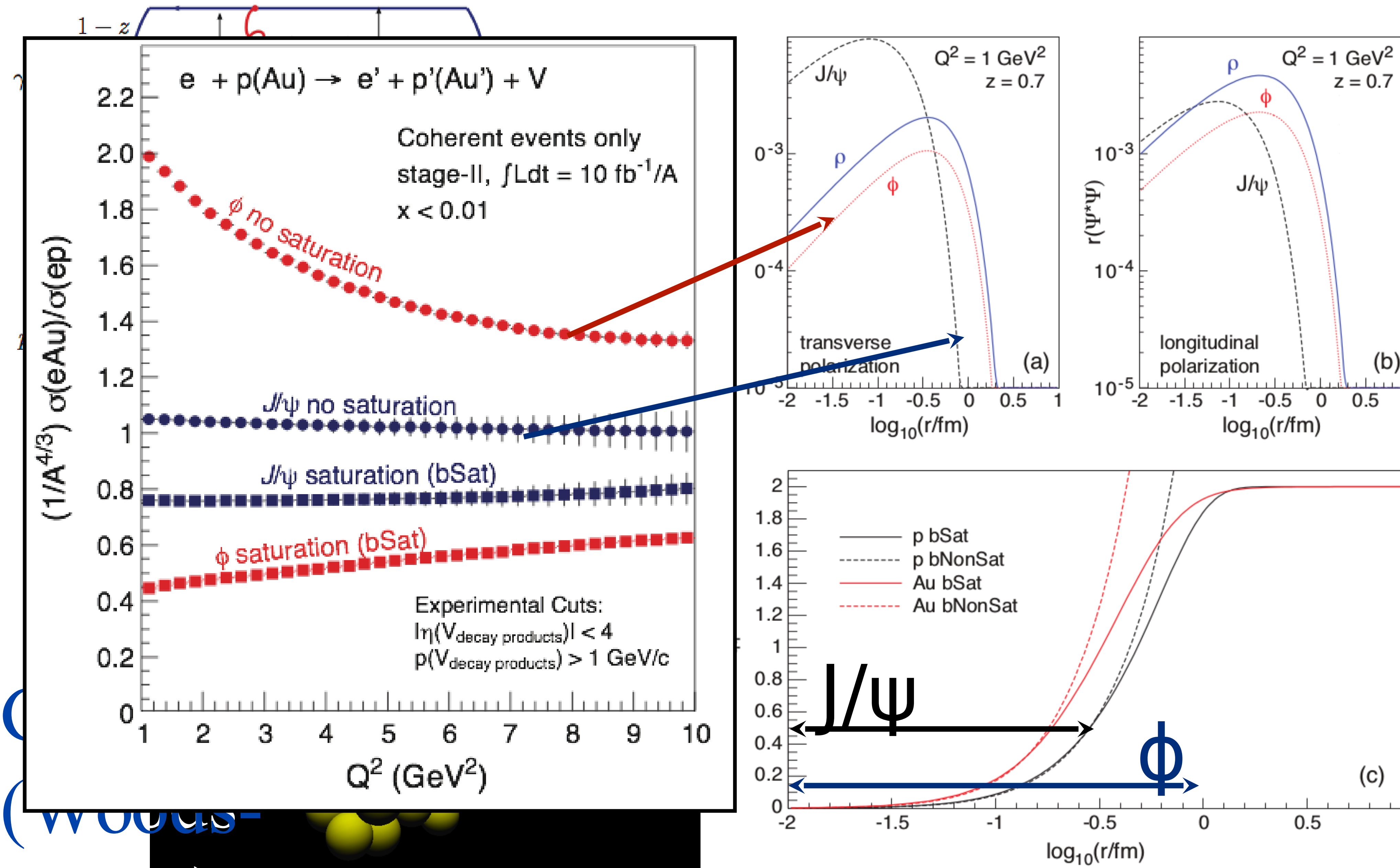






Glauber
(Woods-Saxon)

Sartre dipole model with glauber bSat and bNonSat



(Woods-
Saxon)

The Dipole Model for eA

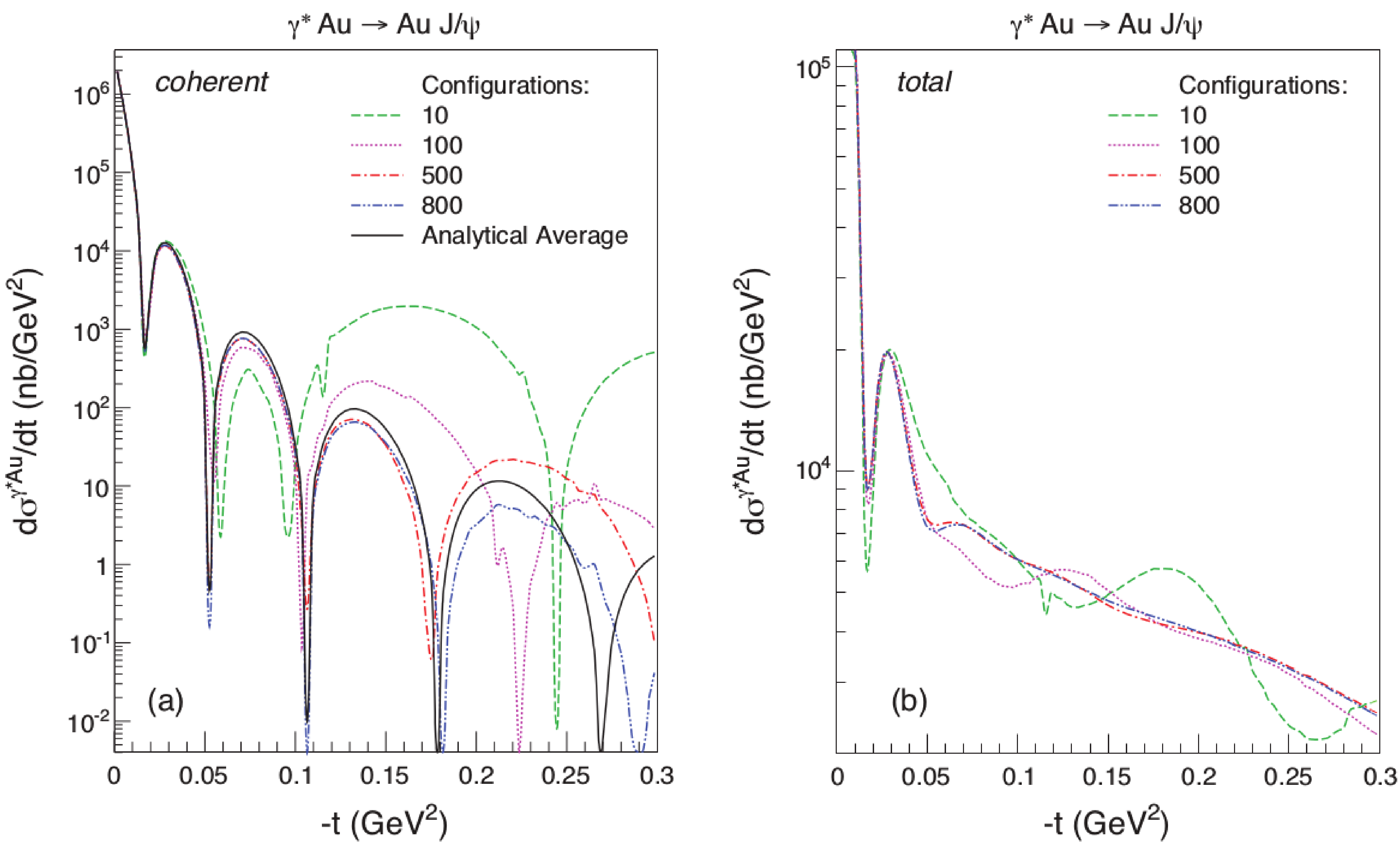
$$\frac{\mathrm{d}\sigma_{q\bar{q}}}{\mathrm{d}^2\boldsymbol{b}} = 2\left[1 - \exp\left(-\frac{\pi^2}{2N_c} r^2 \alpha_S(\mu^2) x g(x,\mu^2) T(b)\right)\right]$$

$$\frac{1}{2}\frac{\mathrm{d}\sigma_{q\bar{q}}^{(A)}}{\mathrm{d}^2\mathbf{b}}(x, r, \mathbf{b}, \Omega) = 1 - \exp\left(-\frac{\pi^2}{2N_C} r^2 \alpha_S(\mu^2) x g(x,\mu^2) \sum_{i=1}^{A} T(|\mathbf{b} - \mathbf{b}_i|)\right)$$

$$\frac{\mathrm{d}\sigma^{\gamma^* \mathrm{A}}}{\mathrm{d}t}(x, Q^2, t) = \frac{1}{16\pi}\frac{1}{C_{\max}} \sum_{i=1}^{C_{\max}} \left|\mathcal{A}(x, Q^2, t, \Omega_i)\right|^2$$

$$\left\langle \frac{\mathrm{d}\sigma_{q\bar{q}}}{\mathrm{d}^2\mathbf{b}} \right\rangle_\Omega = 2\left[1 - \left(1 - \frac{T_A(\mathbf{b})}{2}\sigma_{q\bar{q}}^p\right)^A\right]$$

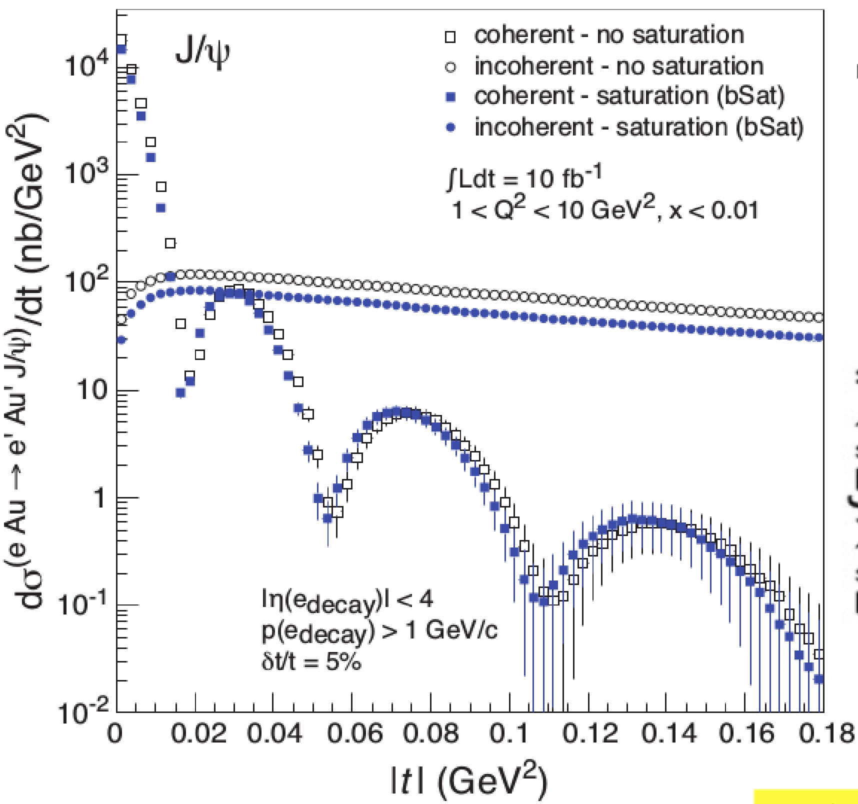
H. Kowalski and D. Teaney, Phys. Rev. D68, 114005 (2003).



400 Configuration means 800 4-D integrals at each point in phase-space, for each nuclear species, vector meson, and dipole model

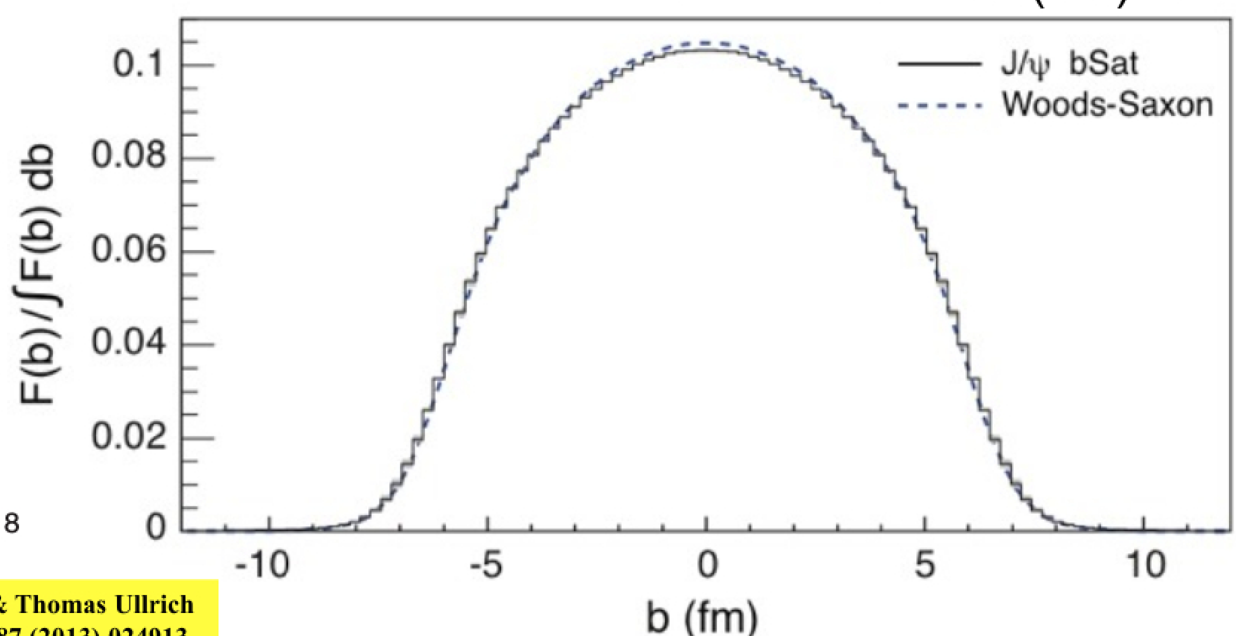
Probing the spatial gluon distribution at EIC

Momentum transfer *t* conjugate to transverse coordinate *b*



$$F(b) \propto \int \mathrm{d}\Delta \Delta J_0(\Delta b) \sqrt{\frac{\mathrm{d}\sigma}{\mathrm{d}t}}$$

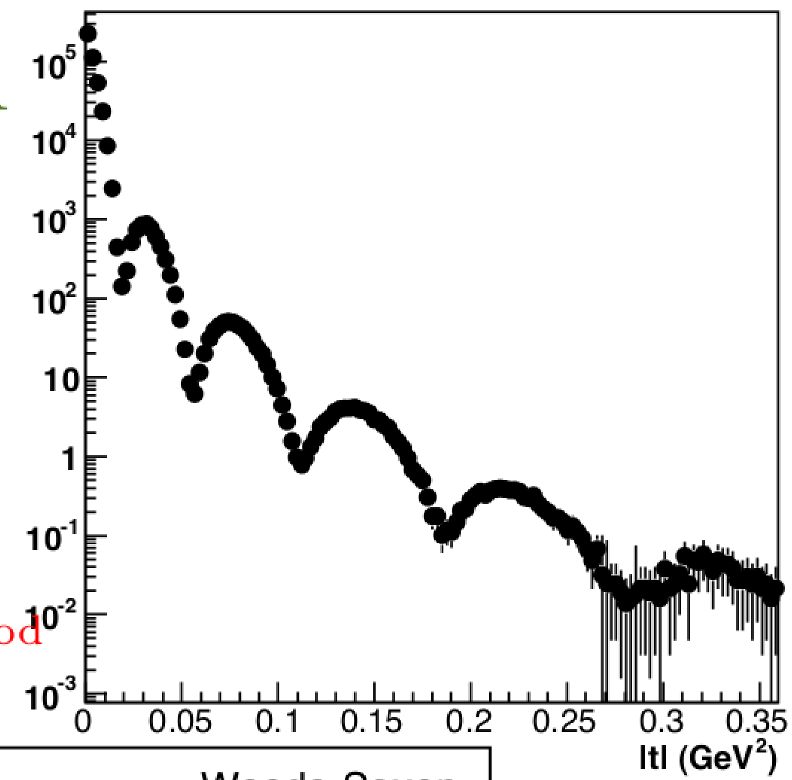
$t = \Delta^2/(1-x) \approx \Delta^2$



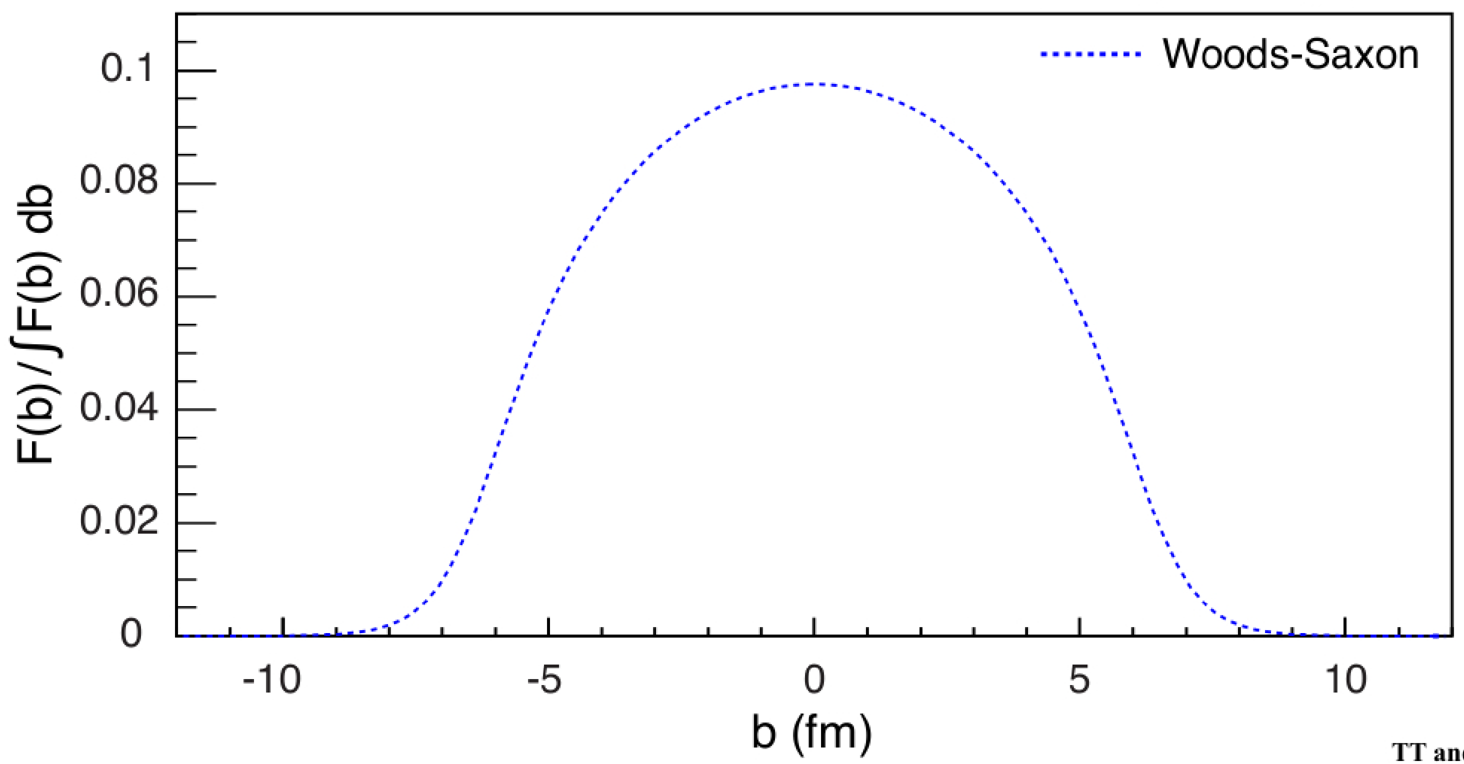
T.T. & Thomas Ullrich
PRC 87 (2013) 024913

EIC will be able to retrieve the spatial gluon distribution with high precision.

Probing the spatial gluon distribution at EIC



$$F(b) = \frac{1}{2\pi}\int_0^\infty \mathrm{d}\Delta\Delta J_0(\Delta b)\sqrt{\frac{\mathrm{d}\sigma_{\mathrm{coherent}}}{\mathrm{d}t}(\Delta)}\Bigg|_{\mathrm{mod}}$$



TT and T. Ullrich,
Phys. Rev. C 87, 024913 (2013)
arXiv:1211.3048

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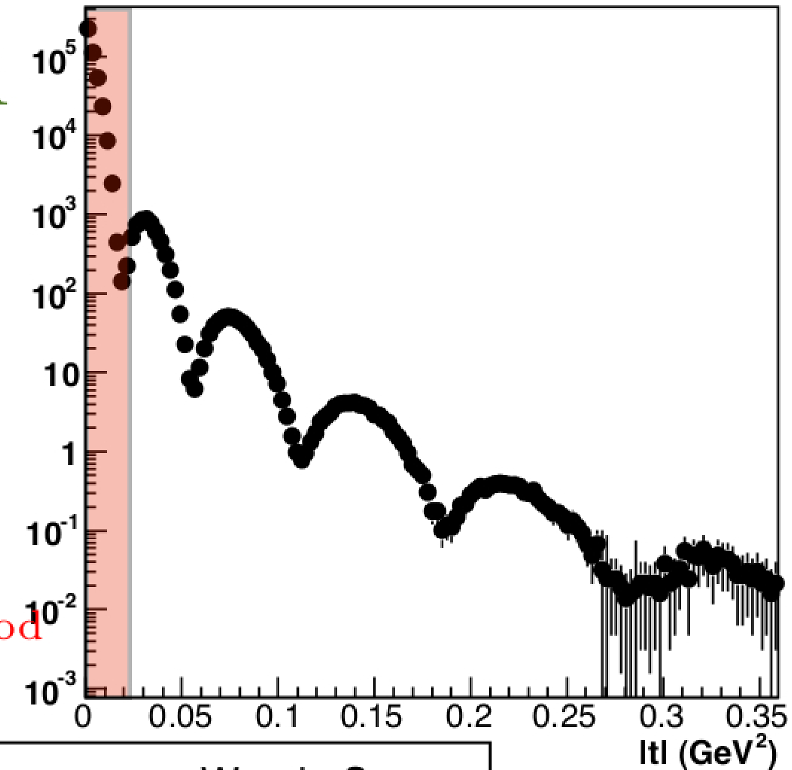

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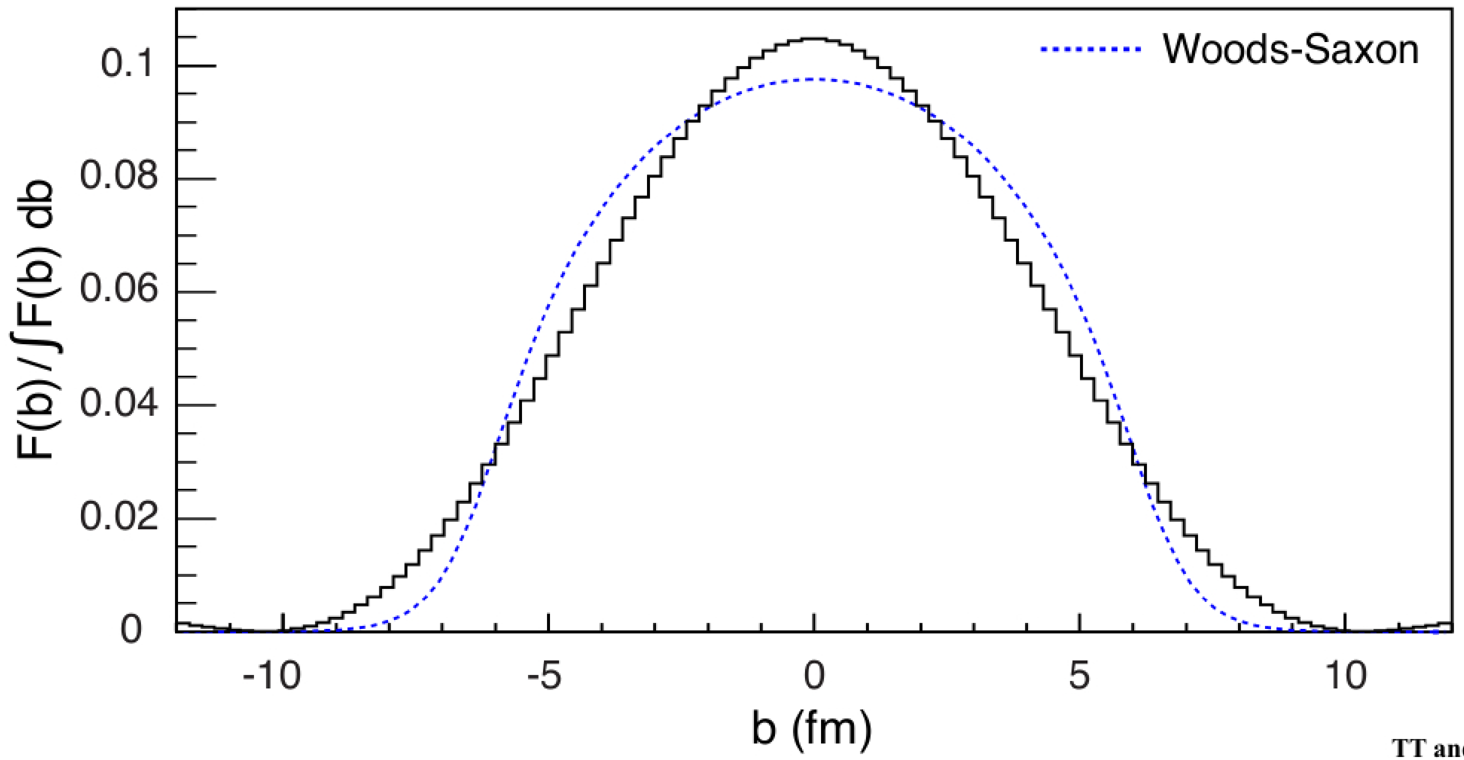

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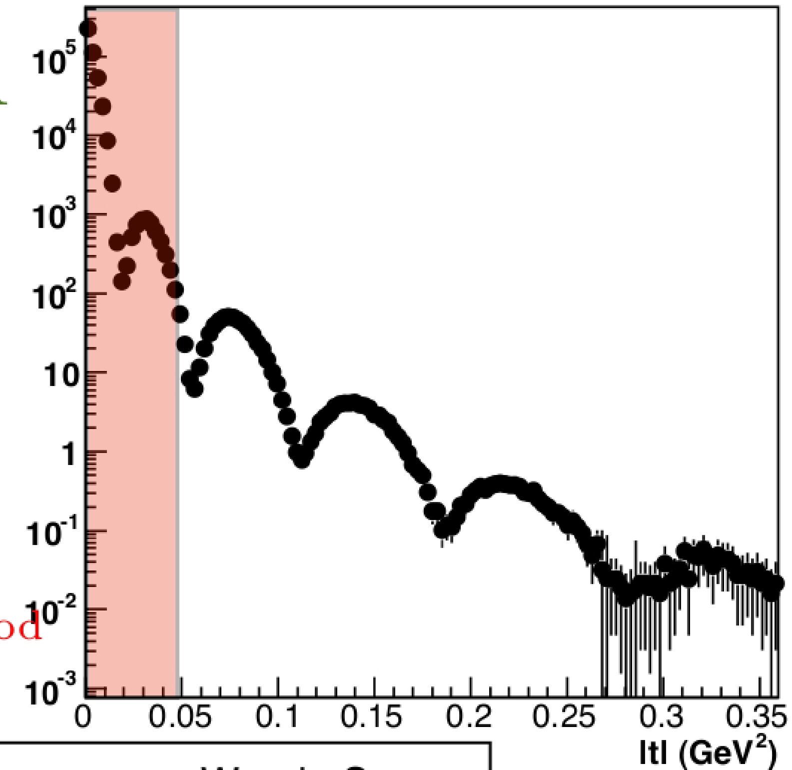

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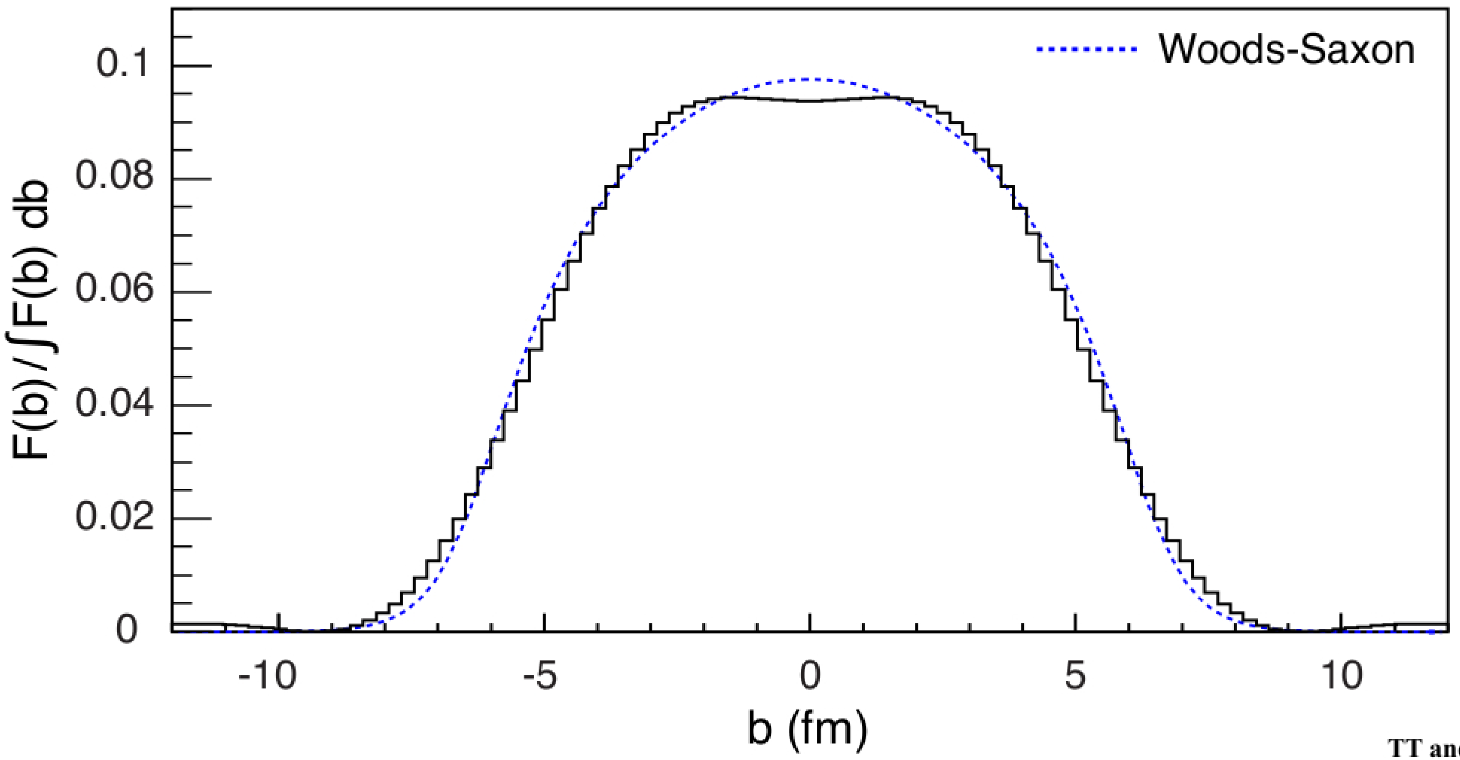

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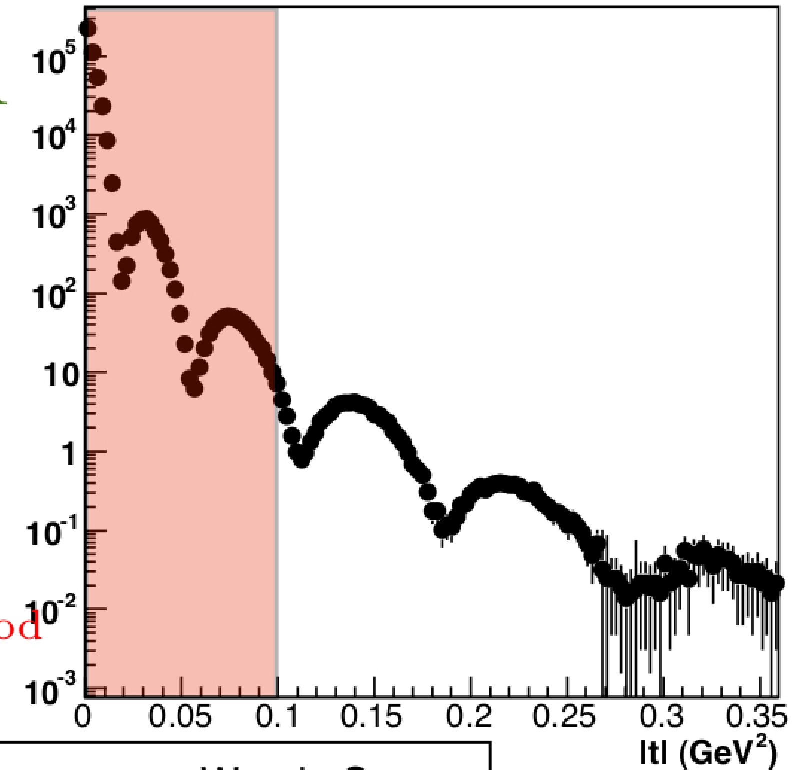

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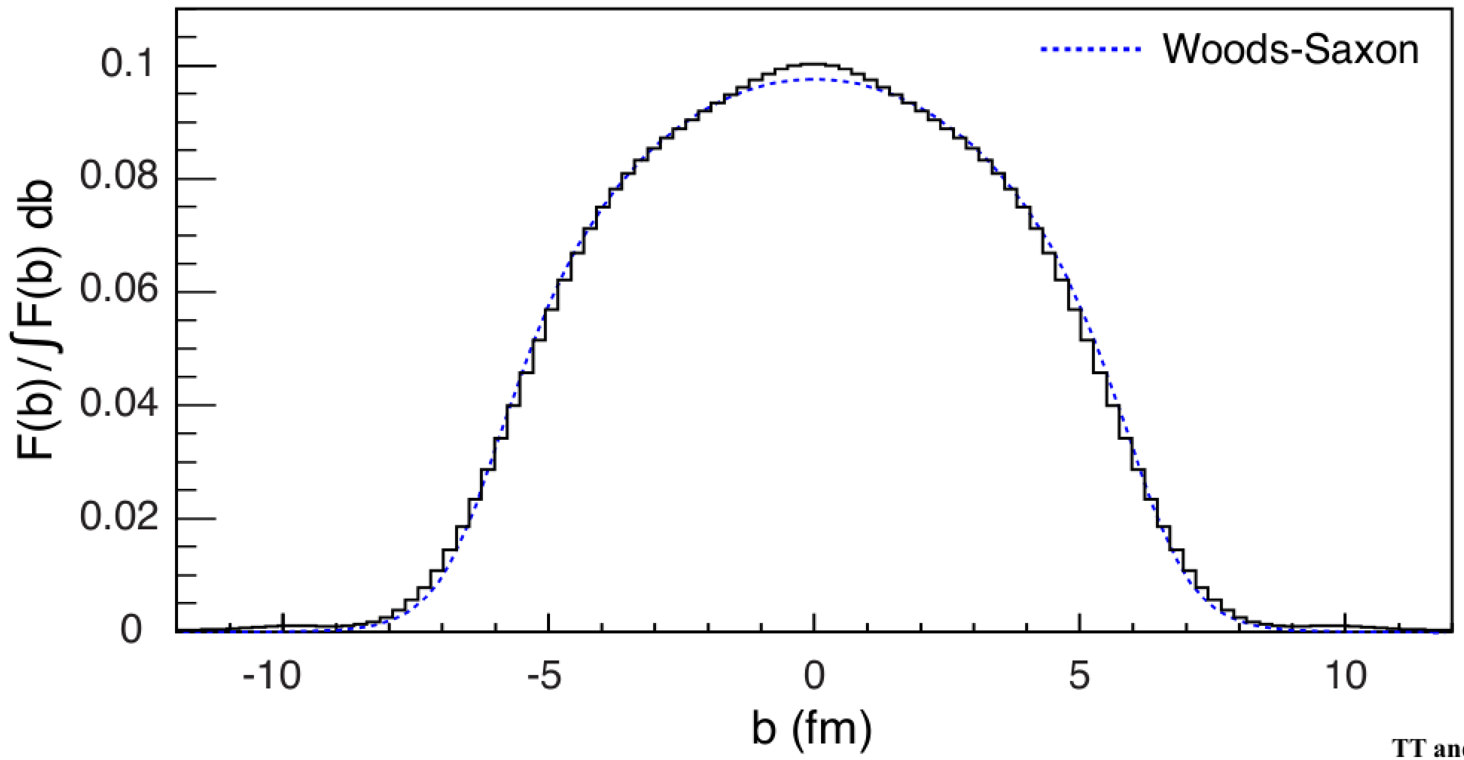

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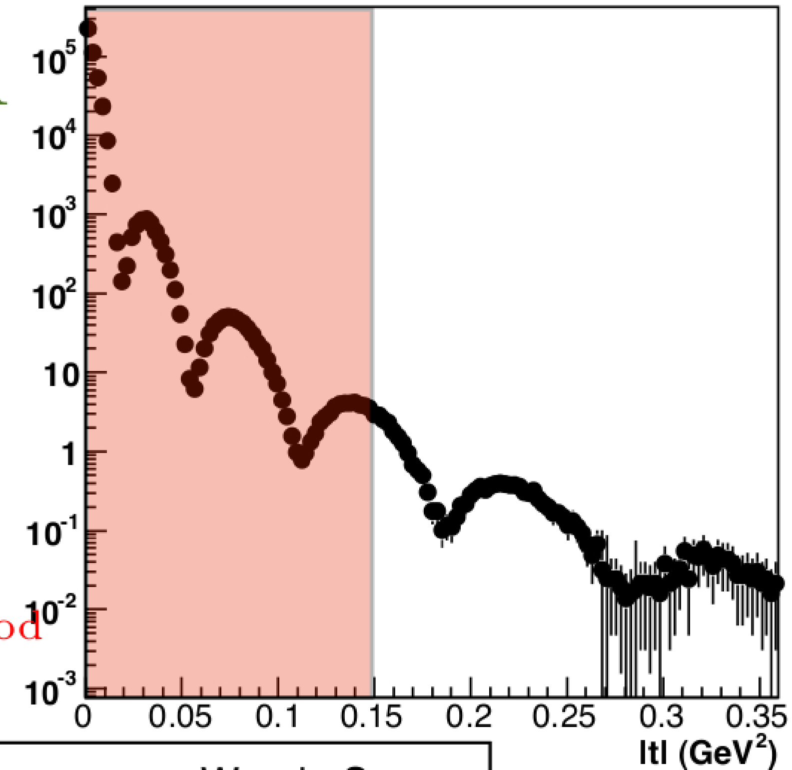

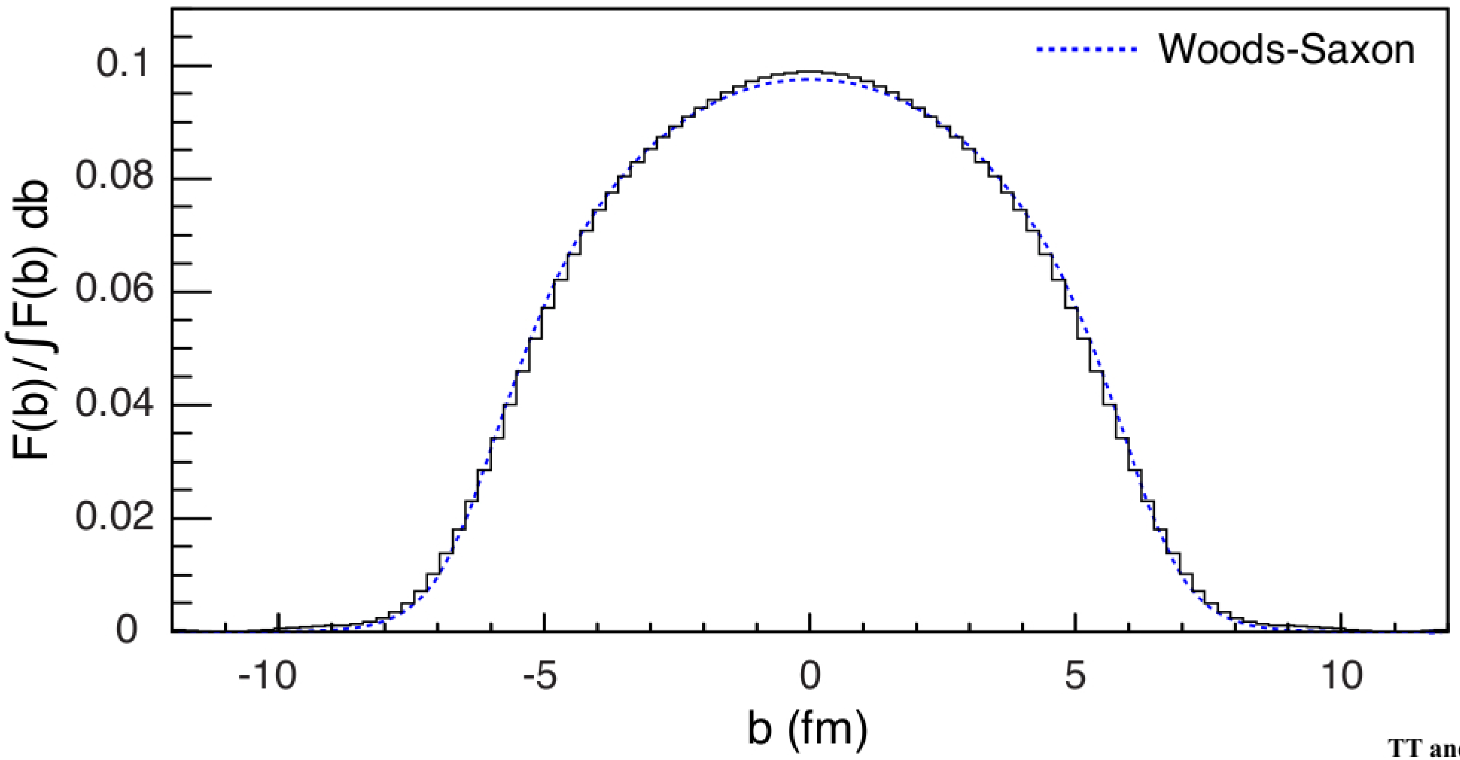

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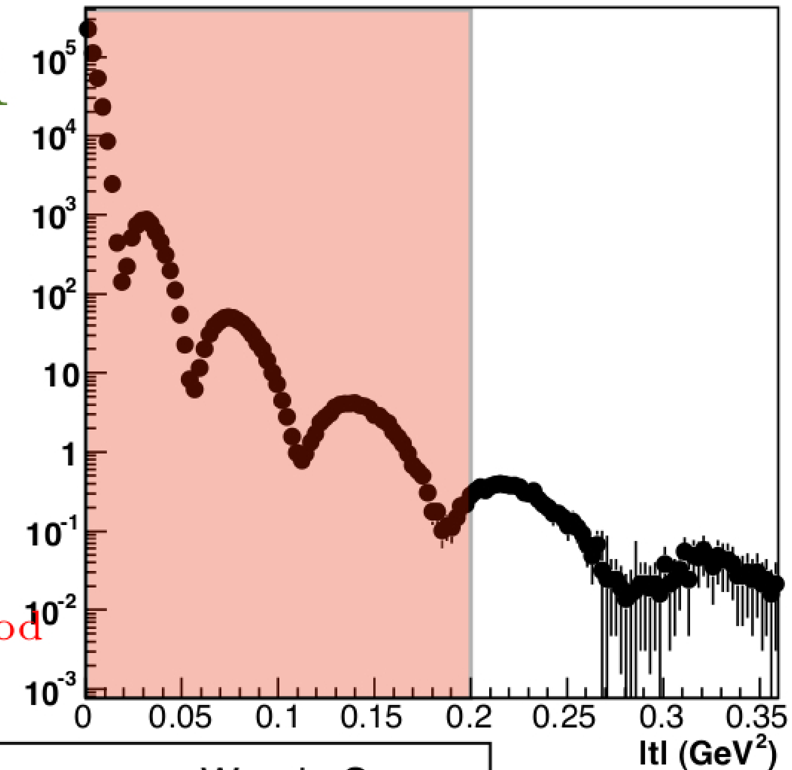

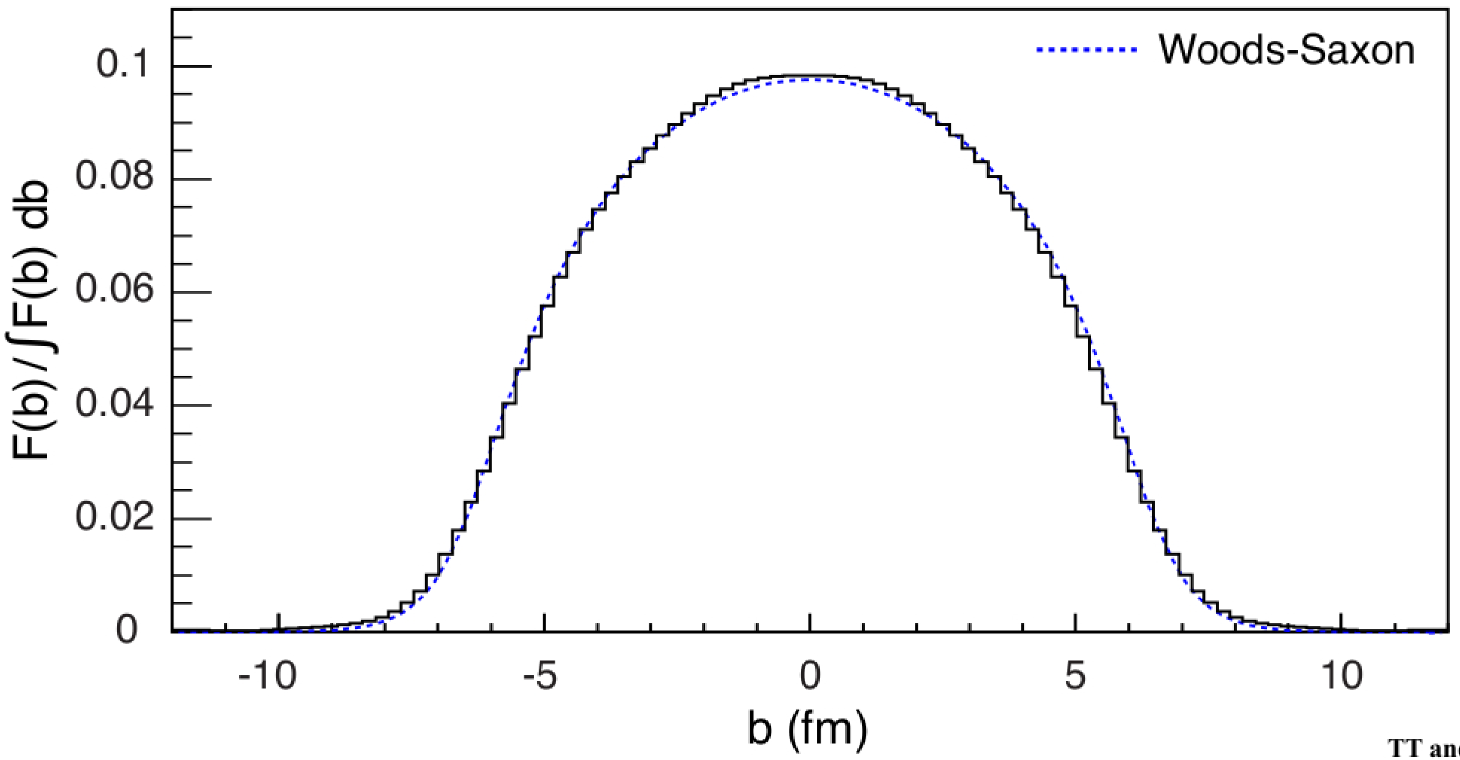

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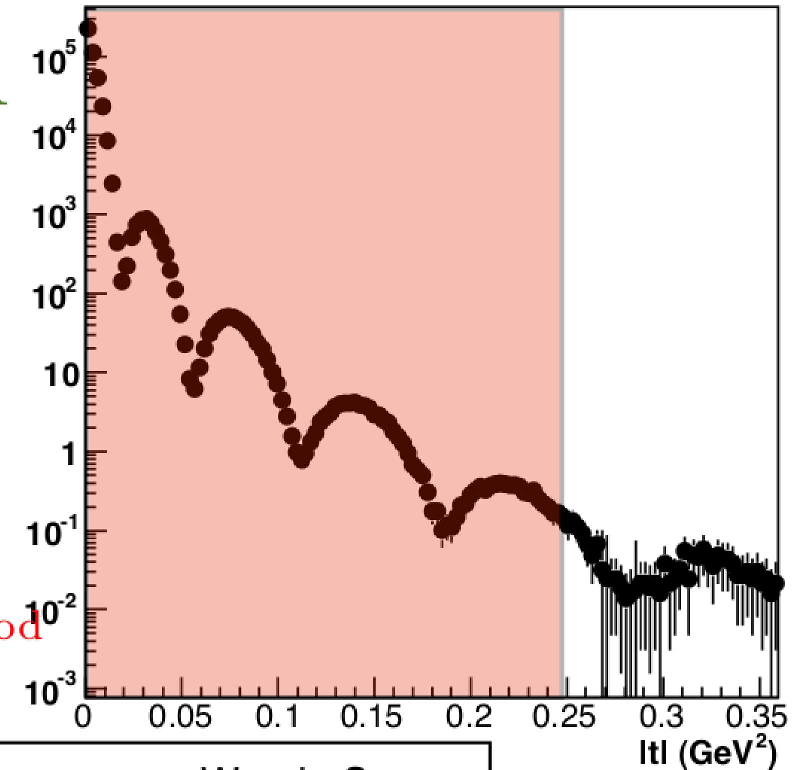

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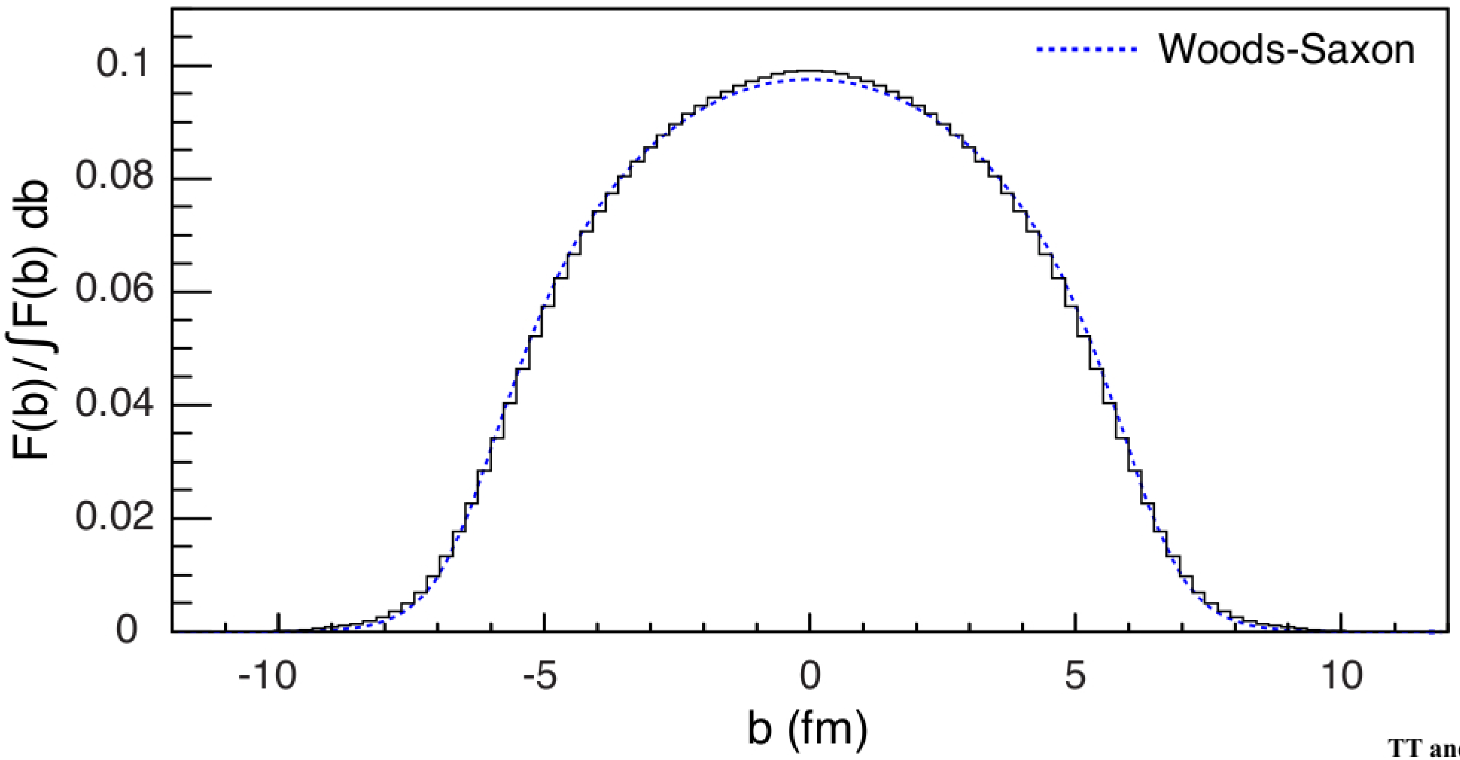

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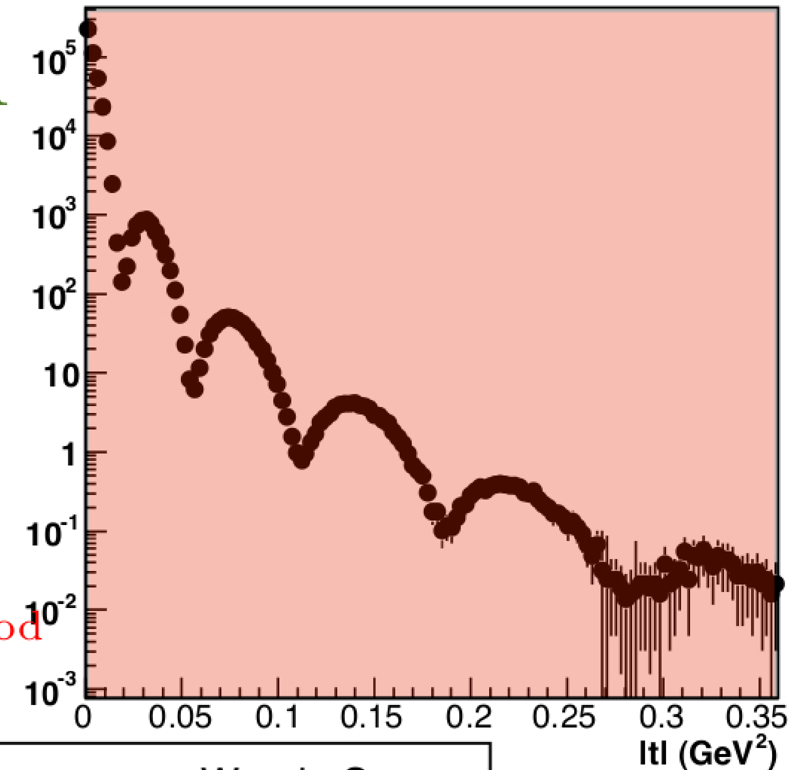

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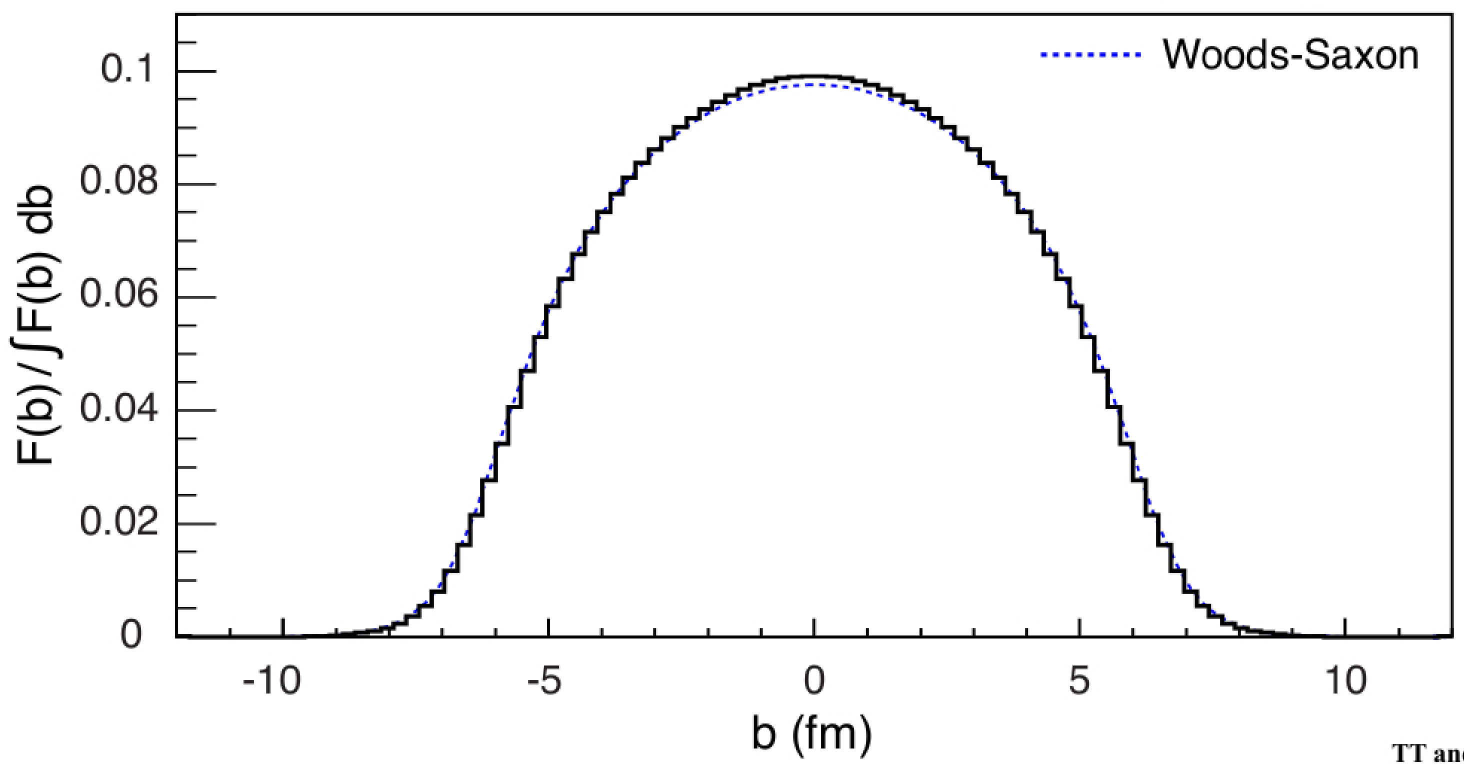

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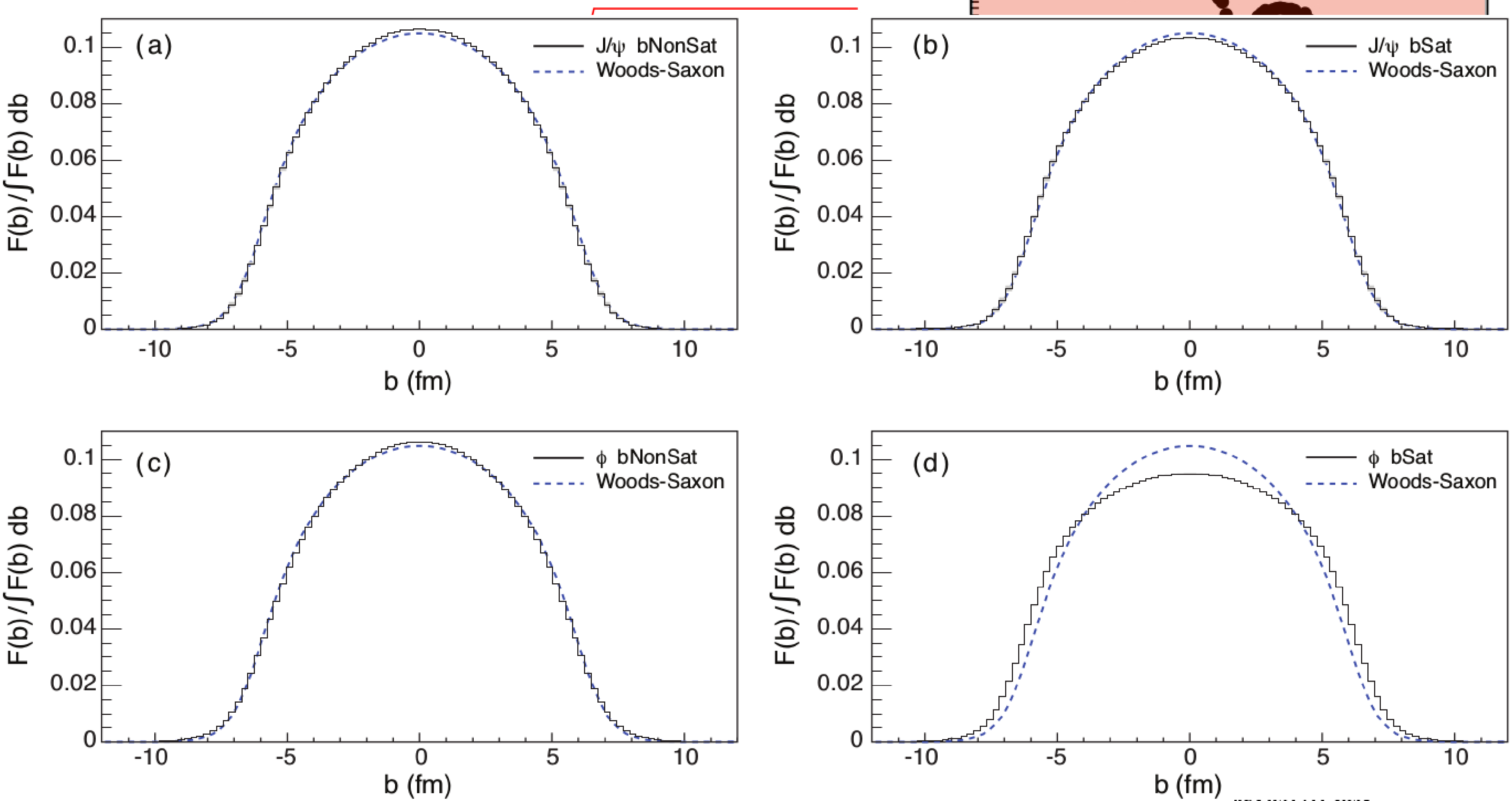
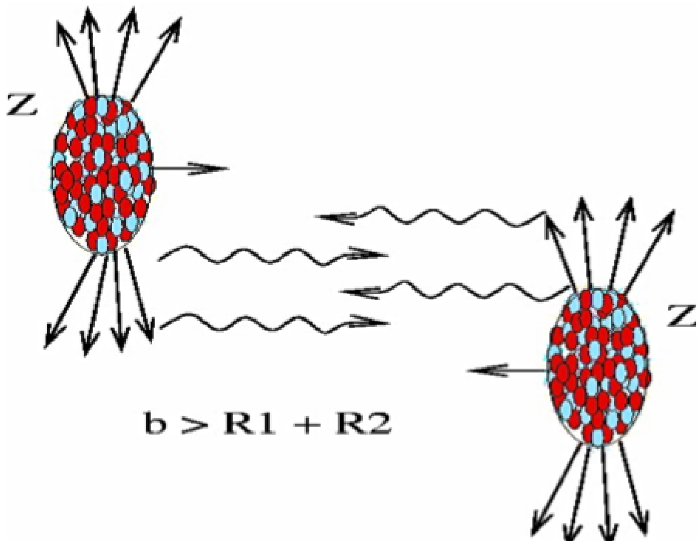


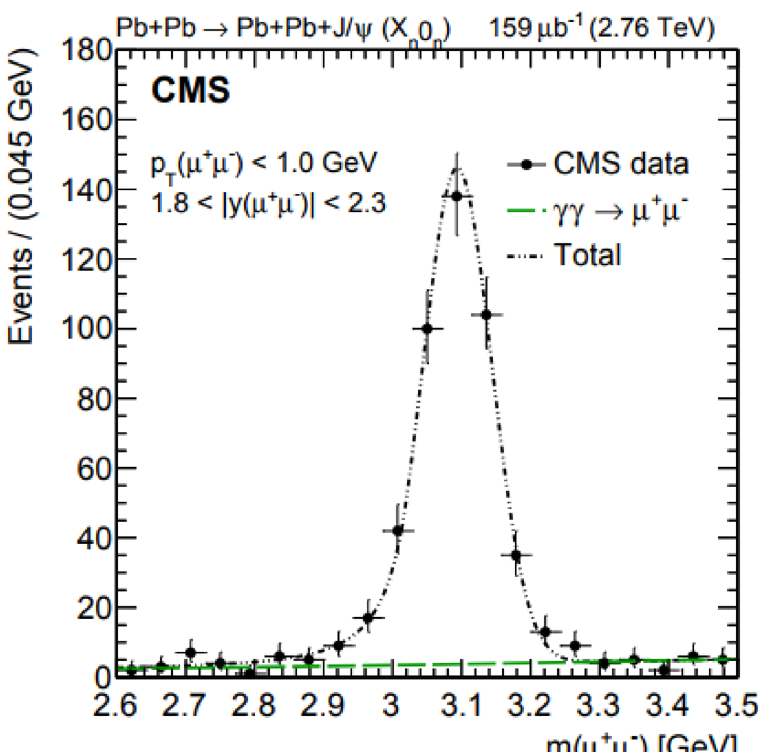
arXiv:1211.3048

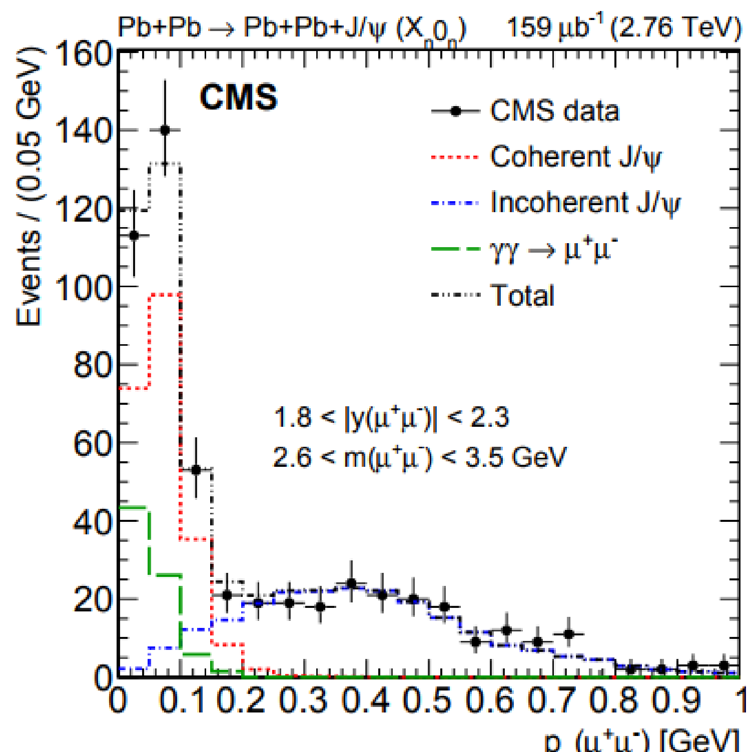
Ultra Peripheral Collisions



When nuclei interact at large impactparameter, electro-magnetic interaction dominate.
This is similar to electron-nucleus interaction:
UPC is a testing groundfor EIC!
Only available measurement to test dipole model extention to nuclei.

$$1 - \mathcal{N}^{(A)}(x, \mathbf{r}, \mathbf{b}) = \prod_{i=1}^{A} \left(1 - \mathcal{N}^{(p)}(x, \mathbf{r}, |\mathbf{b} - \mathbf{b}_i|)\right)$$



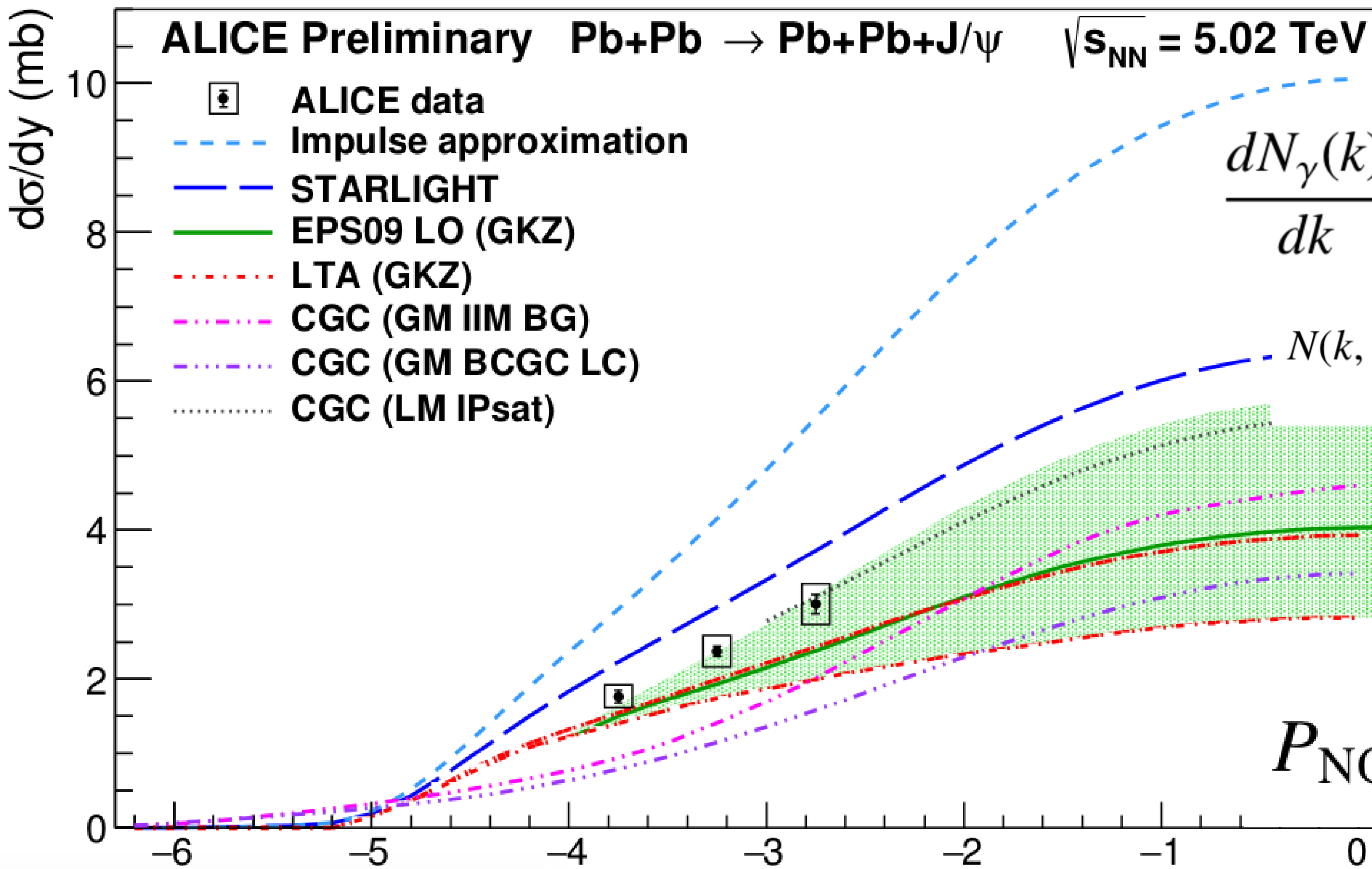


CMS Collaboration
Physics Letters B
Volume 772,
10 September 2017,
Pages 489-511

Ultra Peripheral Collisions

Include Photon Flux a'la StarLight:

$$\frac{\mathrm{d}\sigma}{\mathrm{d}t}(AA \to AAJ/\psi) = 2\int_0^\infty \mathrm{d}k \frac{\mathrm{d}N_\gamma(k)}{\mathrm{d}k}\frac{\mathrm{d}\sigma}{\mathrm{d}t}(\gamma^* A \to J/\psi)$$



$$\frac{dN_\gamma(k)}{dk} = \int d^2b P_{\mathrm{NOHAD}}(\vec{b})N(k,\vec{b})$$

$$N(k,b) = \frac{Z^2\alpha}{\pi^2}\frac{k}{(\hbar c)^2}\frac{1}{\gamma^2}\left[K_1^2(x) + \frac{1}{\gamma^2}K_0^2(x)\right]$$

$$P_{\mathrm{NOHAD}}(\vec{b}) = e^{-\sigma_{\mathrm{NN}}T_{\mathrm{AA}}(\vec{b})}$$

$$\sigma = (33.73+0.2838\ln^2(r)+13.67r^{-0.412}-7.77r^{-0.5626})\mathrm{mb}$$

Klein, Nystrand, Seger, Gorbunov, and Butterworth, Comput.Phys.Commun. 212 (2017) 258-268

Ongoing Work

Currently Performing a new fit for the Dipole Model parameters, to take into account the combined HERA data. There are some tensions that needs to be resolved.

After that, create incoherent lookup table with new parameters: CPU heavy

Next subversion of Sartre to include UPC for exclusive diffraction, both coherent and incoherent processes.

Sartre 2 will simulate inclusive diffraction