Very forward detector: QCD opportunities

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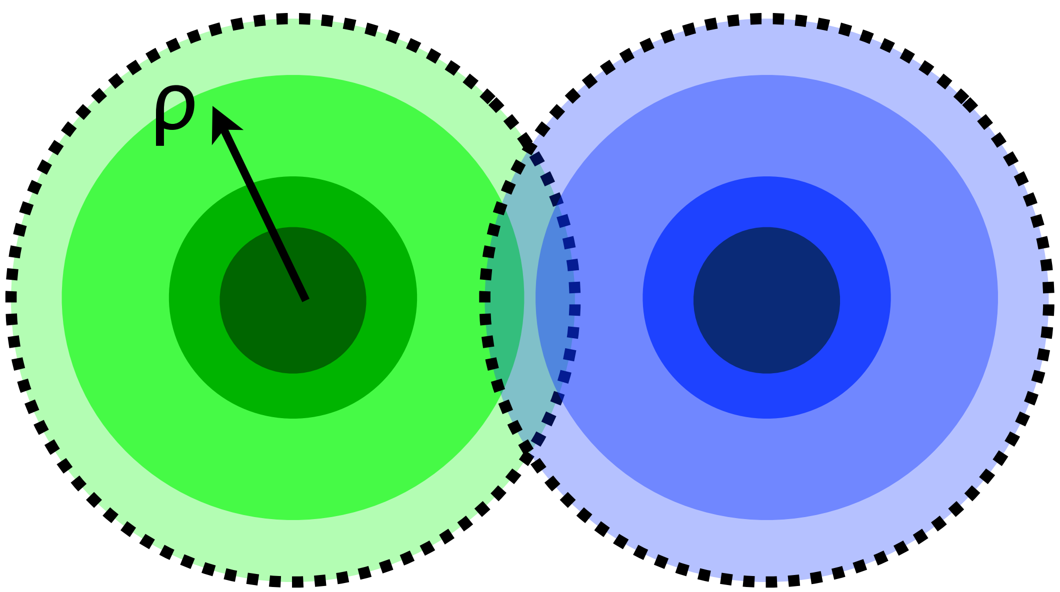
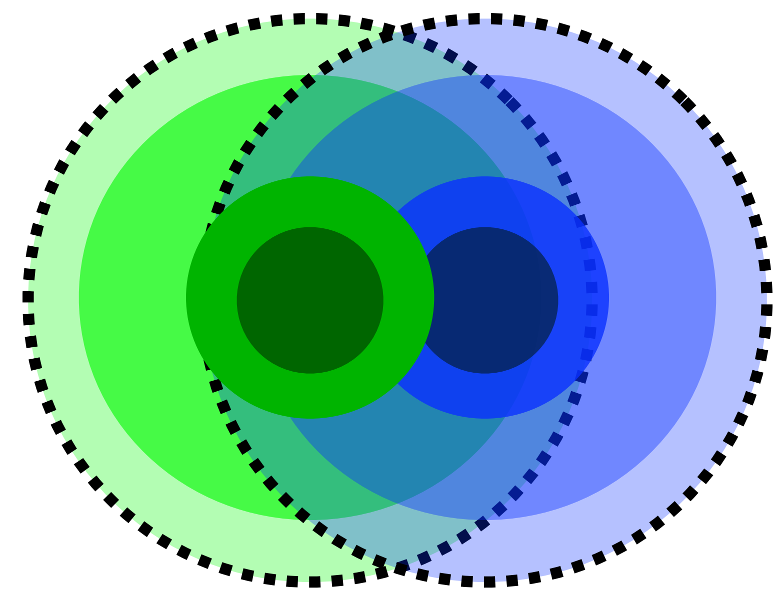
Parton correlations - in diffraction & the nucleon wave function

Reaching $x \sim 10^{-6}$ and $x \sim 1$ ($x_A > 1$)

Probing correlations of partons near nucleon edge (nucleon periphery) in Multi Parton Interactions (MPI)



Peripheral pp - main source of hard diffraction



Central pp

Diffraction with production of two jets.

Usually assumed

$$\sigma_{diff}(2jets+X)=\sigma_{parton-parton}\times f(x_1.p_t)f_{pom}(x_2,p_t)\times \text{Gap surv. prob}$$

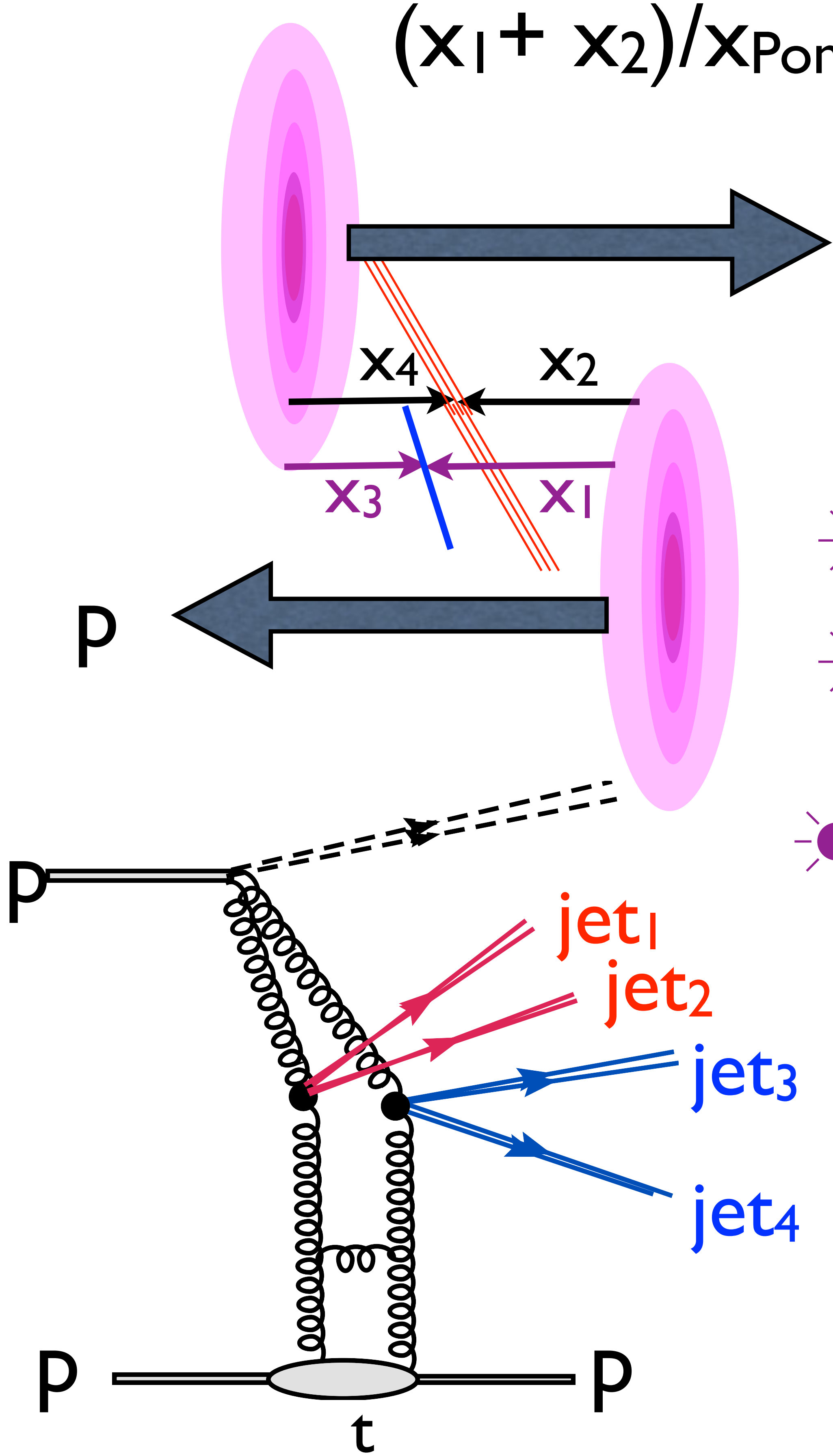
Looking for breaking of soft factorization – universality of the gap survival probability. For example, one may expect that for x_p close to one dominant configuration in a proton interacting with Pomeron are smaller than average, which may lead to an increase of the gap survival probability (large x_p can be reached using a very forward detector (VFD) at much smaller p_t).

Evidence for correlation of the interaction strength and x_p from centrality dependence of pA collisions for $x_p > 0.3$ at LHC and RHIC (Brian Cole's talk at June meeting)

$$\sigma(x_p=0.6)/\sigma_{tot}(pp)\sim 0.6$$

Consider $pp \to p + X$

$(x_1 + x_2)/x_{Pom}$ distribution change with t



X = 4 jets + Y

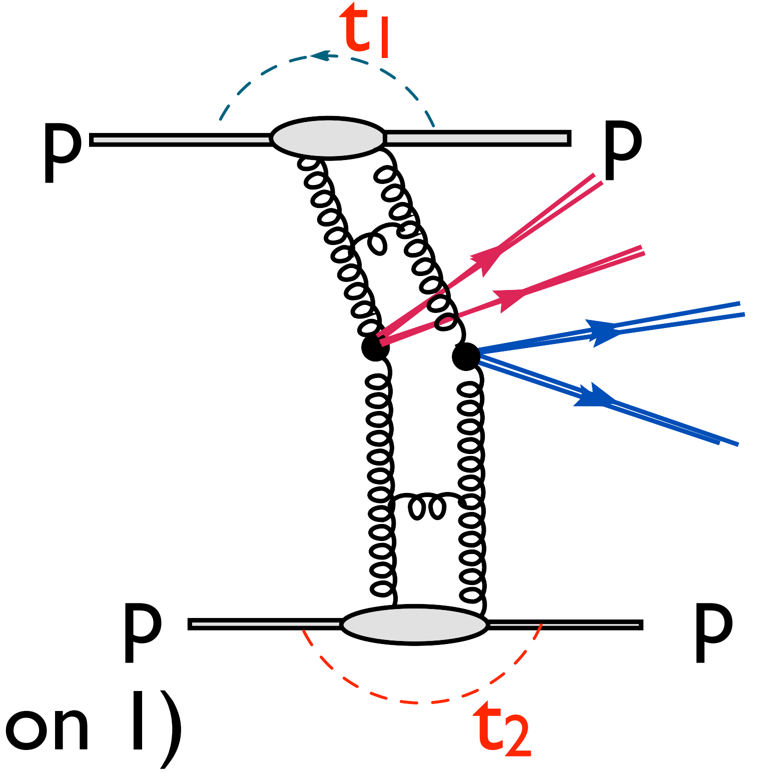
Questions:

- *Is distribution in x_1, x_2 product of two GPDs*
- *Absolute rate - sensitive to transverse size of the "Pomeron" exchange - smaller size - larger cross section*
- Is there dependence on t of *x_1, x_2 distributions:* large t closer to perturbative regime harder spectrum in x_1+x_2
- Large -t > few GeV^2

  Is there a peak near $\delta(x_1+x_2 - x_{Pom})$?

reminder: diffractive gluon pdf strong at *x/x_{Pom}* >0.5

Consider reaction (2) $pp \to p\,p + X$



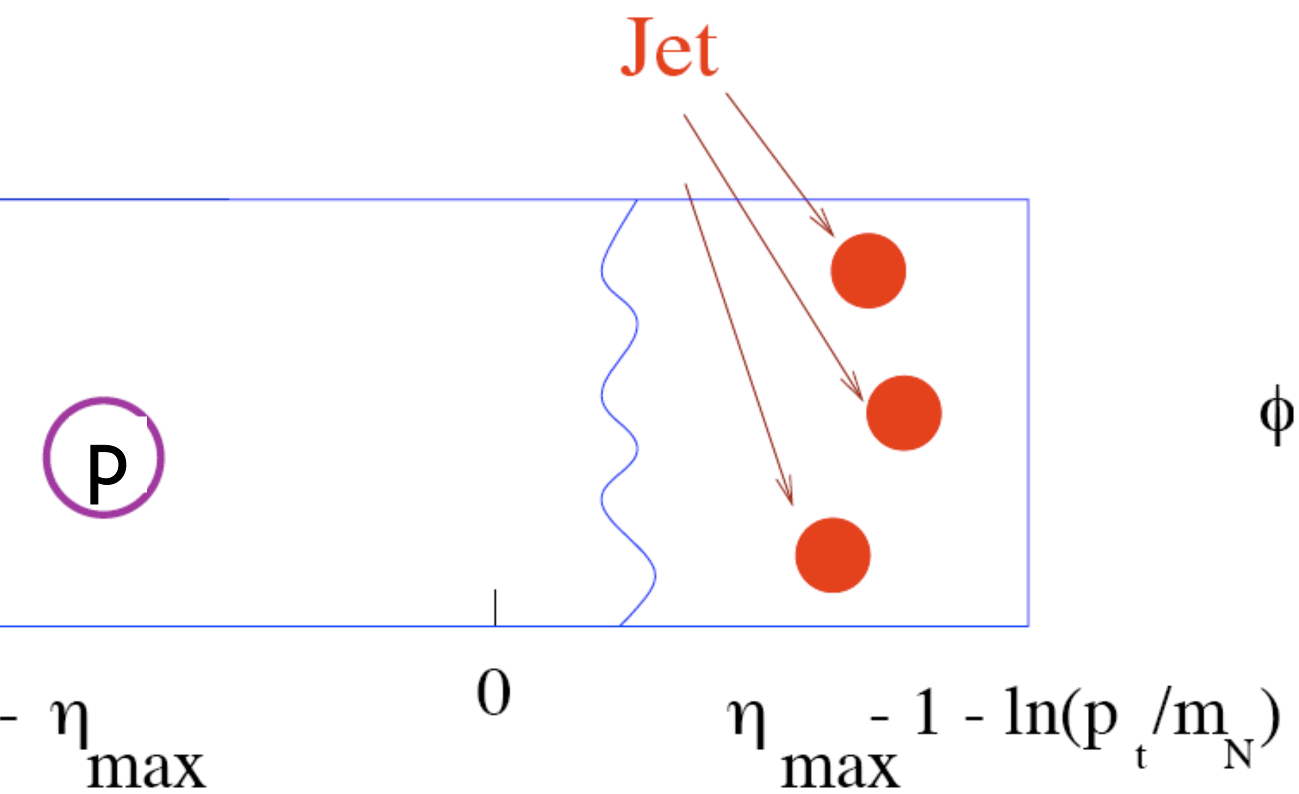
compare with the study of the $pp \to p + X$ (reaction 1)

X=4 jets +Y; 4 jets

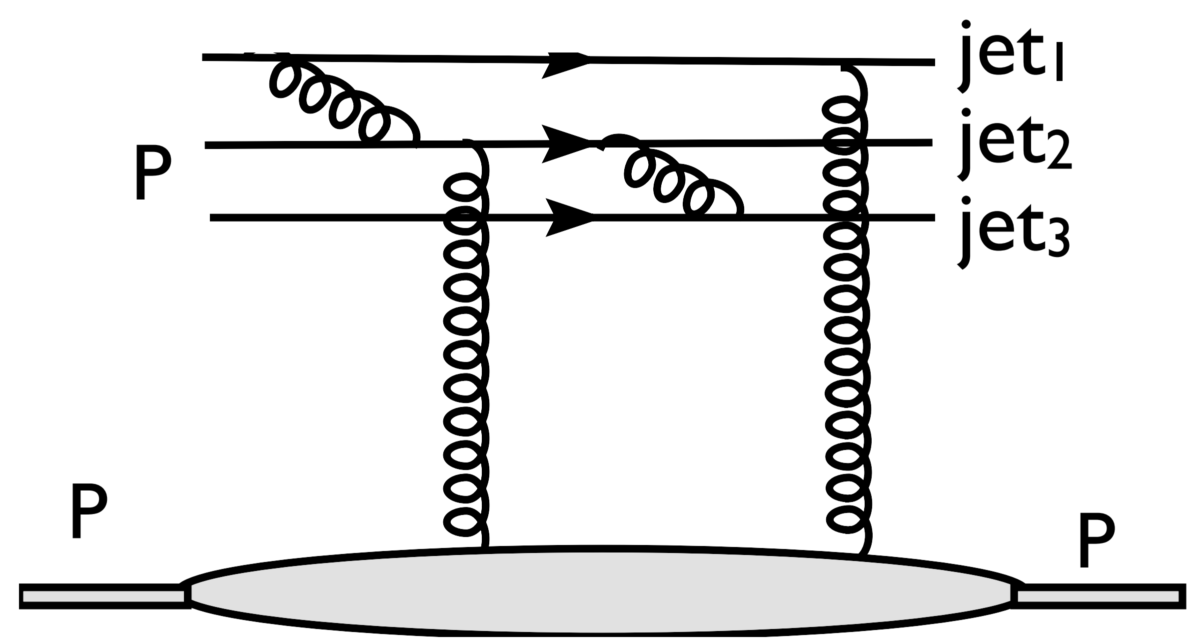
Are double diffractive PDFs the same ?

- relative rates of (1) and (2) - is gap survival becomes larger for large t?
- would gap survival changes with t_2 when t_1 is already large?

Proton dissociation into three high p_t jets measures high energy color transparency and proton 3 quark wave function - similar process was observed in the pion - nucleus scattering - $\pi A \to$ 2jets + A (good agreement with our predictions)



Lego plot for 3 jet coherent production



pp → leading neutron + 2 jets + p

Analog of $\pi A \to$ 2jets + A better acceptance?

$$\frac{d\sigma(pA \to (jet_1 + jet_2 + jet_3) + A)}{dt \prod_{i=1}^{3} dx_i d^2 p_{ti}} \propto \left[\alpha_s x_A G_A(x_A, p_t^2)\right]^2 \cdot$$

$$\cdot \frac{\phi_N^2(x_1, x_2, x_3)}{\prod_{i=1}^{3} p_i^4} \delta^2(\sum_{i=1}^{3} \vec{p_{ti}} - q_t)\delta(\sum_{i=1}^{3} x_i - 1) G_N^2(t) F_A^2(t),$$

where $t = -q_t^2, x_A = M_{3jet}^2/2s$. Coefficient is also calculable in pQCD. $\phi_N(x_1, x_2, x_3)$ is relevant for calculation of proton decay.

$xG_N(x, Q^2 \sim 100\ GeV^2) \propto x^{-1/2}$ $\Longrightarrow$ $\sigma_{3jet} \propto s$!!!

Rapidity gap events in ultraperipheral pA→ A + J/ψ +Y at large t.
Motivation – can cover larger rapidity gaps and hence study BFKL pomeron energy dependence. in the kinematics where hard scales are present on both ends of the ladder. Also, in AA collisions this process can be used to study propagation of ultra high energy small color dipoles through the nuclear media.

Centrality of collisions

Explore dependence of pA collisions on centrality using a run with lighter nuclei. Would help to investigate how various processes depend on the length of the path in nuclear matter.

Use VFD to build a set of triggers for centrality of pp collisions. One possible trigger activity in the fragmentation regions of two protons. Example of observable: rate of jet production at central rapidities as a function of activity in the fragmentation: no hadron production at large x - more central collisions.

MPI with pp and pA

Study of MPI at large $x_1 + x_2$ – aim correlations of quarks in nucleons (pp).

enhancement of 4→4 as compared to 2 →4
due to larger probability to find two quarks with x=0.3 than one with x=0.6

Comparison of pA and pp to separate longitudinal and transverse correlations, use centrality to measure the strength of soft interaction as a function of $x_1 + x_2$

GPDs allow to measure 3 D distribution of single parton in nucleon.

MPI (pp+pA) : double parton 3D image + global size information

VFD allows to reach x ~ $10^{-6} \div 10^{-7}$

- Black disk limit (limit of 100% absorption) / saturation effects due to the small x effects: in proton - proton/nucleus collisions a parton with given x_1 resolves partons in another nucleon down to $x_2 = 4p_{\perp}^2/x_1 s$

At LHC $x_1 = 0.1, p_{\perp} = 2GeV/c \longrightarrow x_{2min} = 10^{-6}$

Near GZK $x_1 = 0.1, p_{\perp} = 2GeV/c \longrightarrow x_{2min} = 10^{-9}$

implications for GZK protons

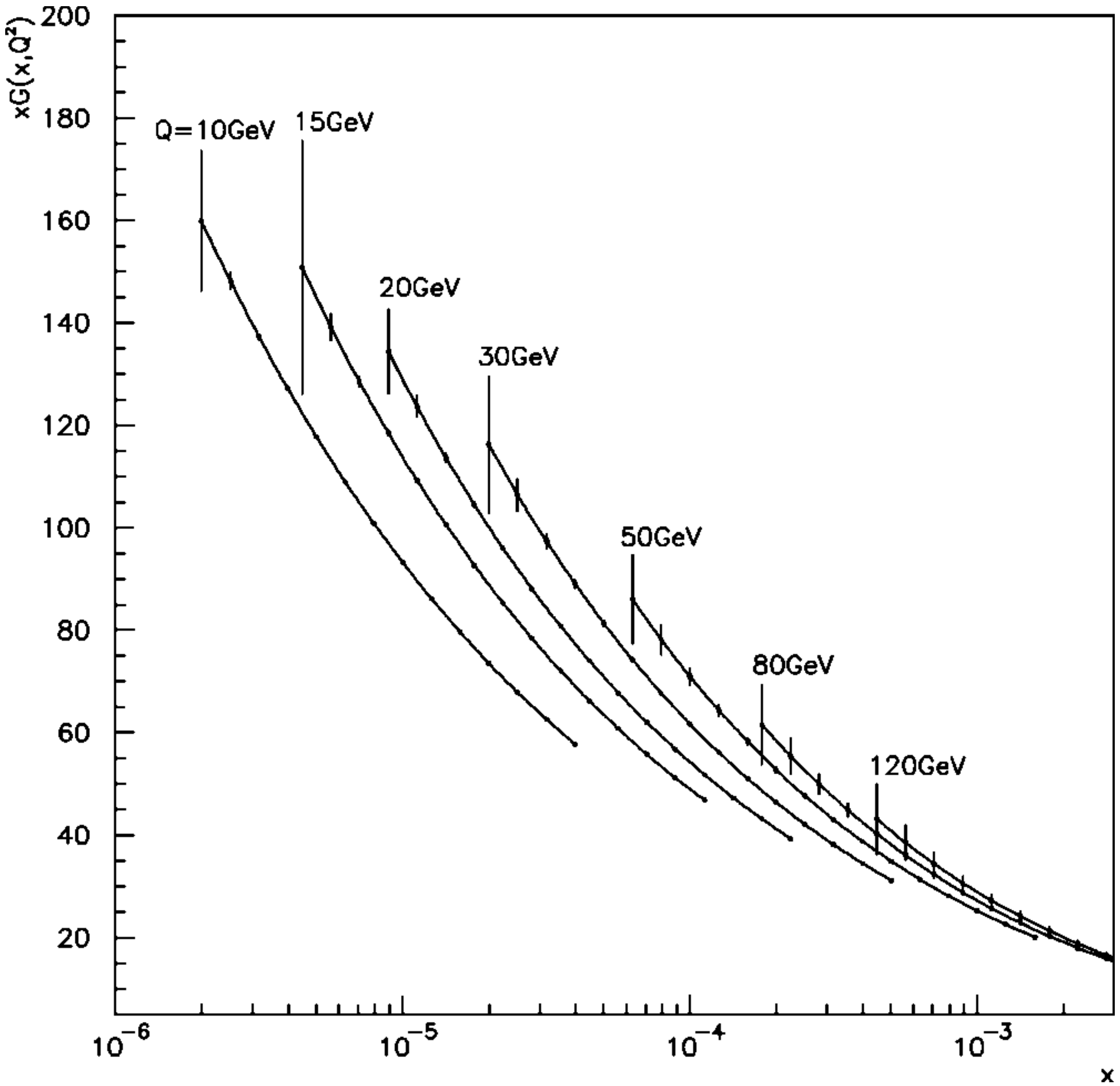


FIG. 3. The gluon momentum distribution with error bars calculated from the jet+ γ cross section and a data sample corresponding to an integrated luminosity of 100 pb^{-1}.

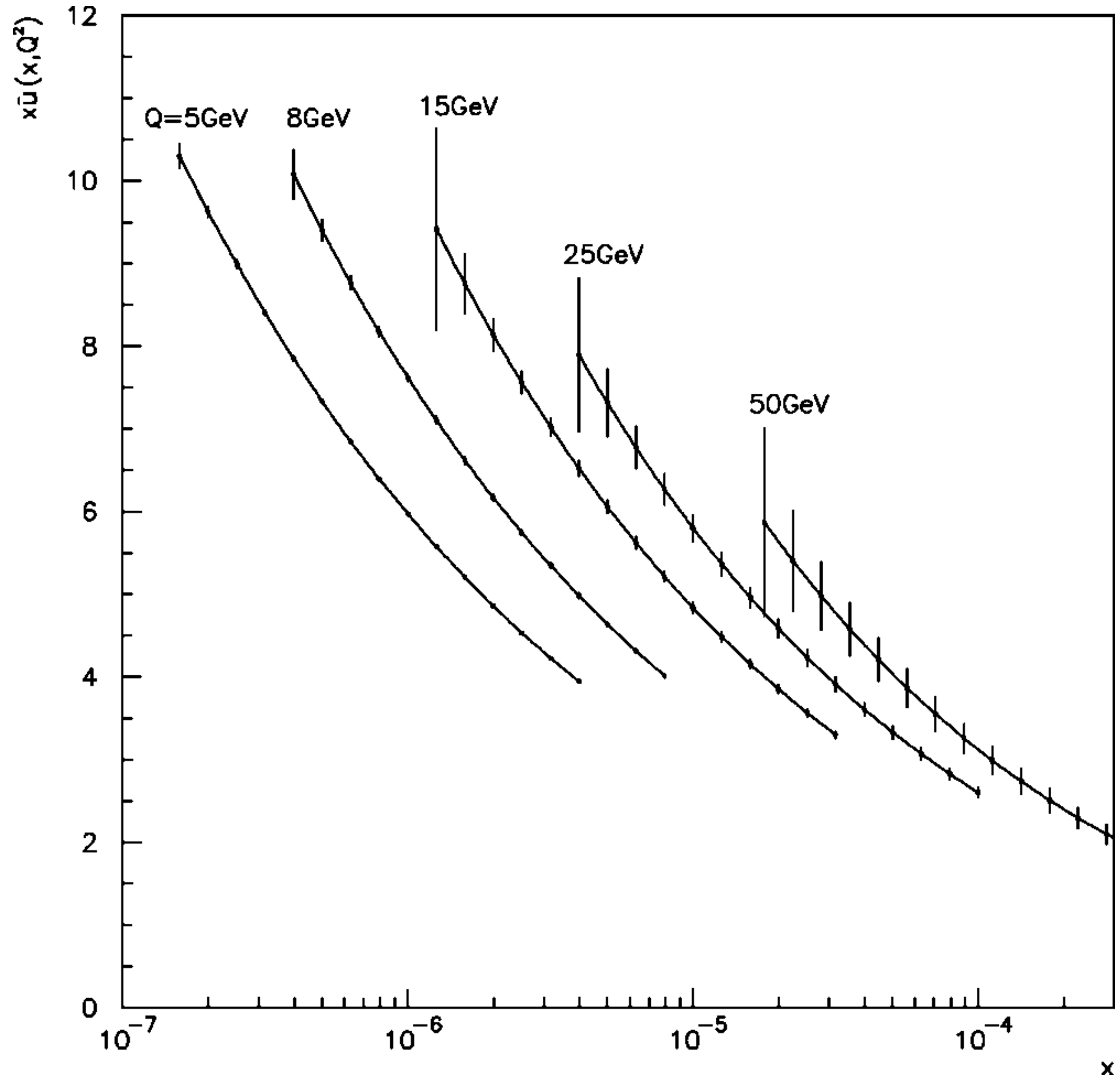


FIG. 5. The $\bar{u}$ antiquark momentum distribution with error bars calculated from the Drell-Yan cross section and a data sample corresponding to an integrated luminosity of 100 pb^{-1}.

Lyndon Alvero, John C. Collins, Mark Strikman, and J. J. Whitmore (1998)

Other applications

Study of the centrality dependence of the leading hadron production in the kinematics where pQCD works for pp collisions and badly violated for pA collisions (so called Brahms effect) . Explore whether the kinematic range where this violation takes place extends to higher transverse momenta

Systematic study of the centrality dependence of hard production extending CMS and ATLAS data using different hard processes including separation of scattering off valence quarks and gluons.

Measurement of superfast quarks (x> 1) in nuclei using VFD. Expected rates should be much higher than for the current detector configurations.

Conclusions

- VFD would allow to explore small x dynamics in a much wider kinematic domain where nonlinear effects are very likely

- Study multiparton 3D structure of nucleons

- New clues to dynamics of diffraction