Dynamic color screening in diffractive DIS

MPI@LHC Trieste November 2015

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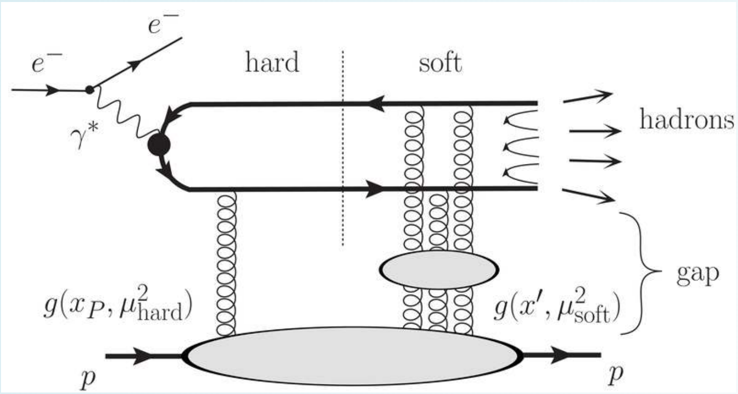
Based on arXiv:1511.06317

Color screening in diffractive DIS

- Color exchange models as alternative to Regge based models
- Start with a inclusive hard process
- Effective color-singlet exchange via additional color exchanges
- Hard process assumed: corresponding non-diffractive
- Kinematics not affected ← Low momentum scales
- Color topology may change → Rearranged strings
  → Large rapidity gaps, forward protons
- Original SCI model
  Random color exchanges, fixed probability.
- Construction principles, not based on amplitudes.

Color screening in diffractive DIS



$$x = \frac{Q^2}{Q^2+W^2}$$

$$x_P = x/\beta$$

$$W^2 = (P+q)^2$$

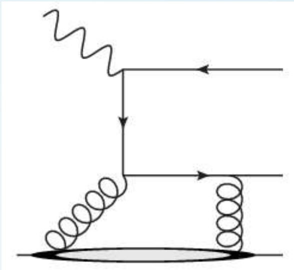
$$\beta = \frac{Q^2}{Q^2+M_X^2}$$

- Amplitude for color screening (pQCD) [hep-ph/0409119], [hep-ph/1005.3399]
- Process described like inclusive, to factorization scale ($\gamma g \to q\bar{q}$)
- Longitudinal momentum x_P carried by first g
- Secondary interaction of partons with proton gluonic field assume factorization
- Soft exchanges do not alter the momentum

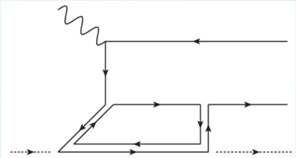
Color screening amplitude

- 1 gluon soft exchange:
  $e^{-ir\cdot k'_\perp} M_1 = i2\pi C_F \alpha_s e^{-ir\cdot k_\perp} \frac{1}{\Delta'^2_\perp} (e^{-ir\cdot \Delta'_\perp} - 1)$

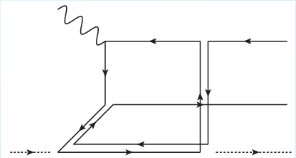
  in cms frame $P' + X$



- Fourier w.r.t. to $\Delta'_\perp$
  $e^{-ir\cdot k'_\perp} M_1 = e^{-ir\cdot k_\perp} i C_F \alpha_s \ln \frac{|b-r|}{|b|}$

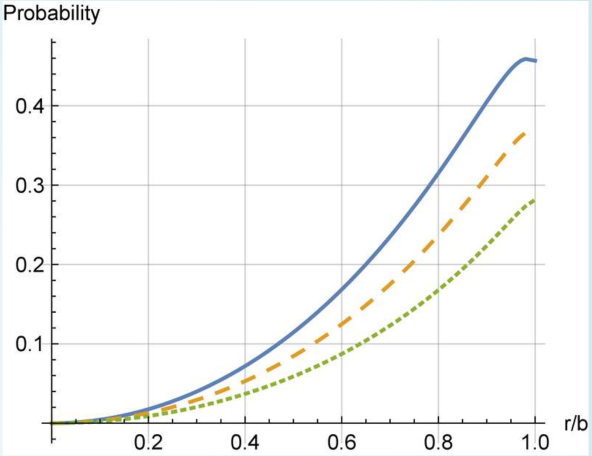


- For M_1, M_2, ... M_∞ gluons, exponentiates (large NC):
  $\mathcal{M} = e^{ir\cdot(k'_\perp - k_\perp)} (1 - e^{iC_F\alpha_s \ln \frac{|b-r|}{|b|}})$



- Requirement for effective color singlet
- Dependence on event kinematics

Probability for screening



- From amplitude to probability
- $M_{\text{diff}}(\mathbf{k}_\perp, \delta_\perp)$
  $\propto \int d^2r d^2b \, M_g(x_{\mathbb{P}}; \mathbf{r}, \mathbf{b}) \, \mathcal{A}_{\text{DCS}}(\mathbf{r}, \mathbf{b}) \, e^{i\mathbf{r}\mathbf{k}_\perp} e^{i\mathbf{b}\delta_\perp}$
- Ratio in impact parameter space
  $\frac{|M_{\text{diff}}(\mathbf{r},\mathbf{b})|^2}{|M_{\text{incl}}(\mathbf{r},\mathbf{b})|^2} = |\mathcal{A}_{\text{DCS}}(\mathbf{r}, \mathbf{b})|^2 \equiv P(\mathbf{r}, \mathbf{b})$
- $P(r/b, \varphi) = \left|1 - \exp\left(iC_F\alpha_s \ln\sqrt{1 + \frac{r^2}{b^2} - 2\frac{r}{b}\cos\varphi}\right)\right|^2$
- Averaged over unobserved angle
  $P(r/b) = \int \frac{d\varphi}{2\pi} P(r/b, \varphi)$
- $P(r/b)$ saturates ~ 0.4
- $P(r/b)$ vanishes for $r/b \to 0$
  $\to$ Color transparency
- α_s essentially a normalization for $P(r/b)$

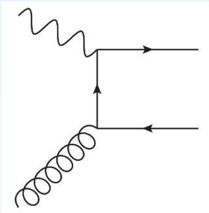
Application in Monte Carlo

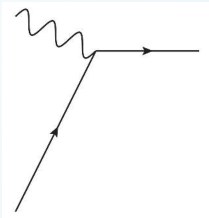
- Color screening dominated by the largest transverse size
- Associate $r \sim 1/k_{\perp\mathrm{min}}$
- Typically $k_{\perp\mathrm{min}} \simeq 1\,\mathrm{GeV}$
  (hard kinematics, $k_\perp$ distributions)
- Small $k_\perp$ from random orientations → introduce regulator $\sim Q_0$
- $b \sim 1/q_\perp$ soft gluon exchange
  $\Lambda_{\mathrm{QCD}} < q_\perp < 1\,\mathrm{GeV}$ (pQCD)
- Results in

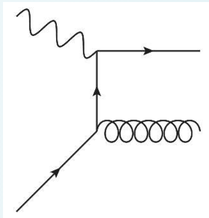
$$\frac{r}{b} = \frac{q_\perp}{\sqrt{k_{\perp\mathrm{min}}^2 + k_{\perp 0}^2}}$$

Application in Monte Carlo

- Different scales Q^2, M_X^2
  (possibly very different)
- Large logs $\frac{M_X^2}{Q^2} = \frac{1}{\beta} - 1$
- Collinear factorization: DGLAP resums $\sim \log Q^2$
- kT-factorization: CCFM evolution for $\sim \log 1/x$
- Cascade: $\gamma g \to q\bar{q}$
  Dominant process in low-x DIS
  CCFM evolution
  Resummation in $1/x$
- Lepto: $\gamma q \to q, \gamma q \to qg, \gamma g \to q\bar{q}$
  DGLAP evolution







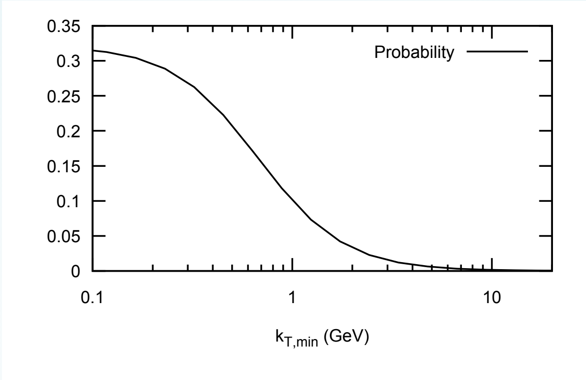
Soft divergence

- For $\gamma g \to q\bar{q}$ from ME → soft divergence
  Energy splitting $z, 1-z$
- Uneven z possibly large x/x_n
- $\gamma g \to q\bar{q}$ only for DDIS $\log 1/z$ not resummed
- Part of σ: $\gamma q \to q$ ME + DGLAP, splitting $g \to q\bar{q}$
  resummation of leading logs in Q^2
- Important at large masses
  $M_X^2 = \frac{m_q^2 + k_\perp^2}{z(1-z)}$
- Interesting for LRG as well:
  Larger p_z → no LRG (despite eff. color singlet)

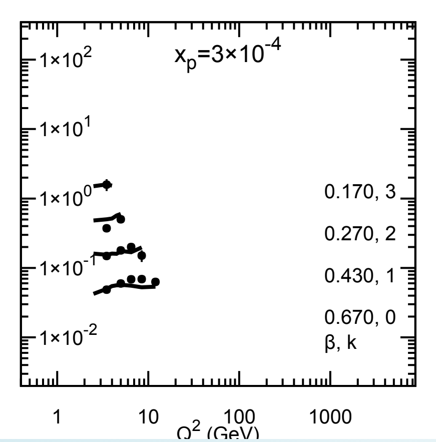
  same true for ISR

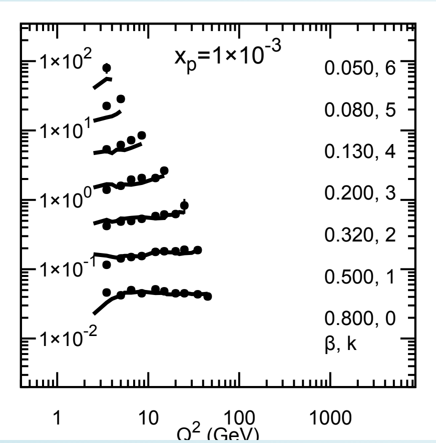
DDIS from Cascade with DCS

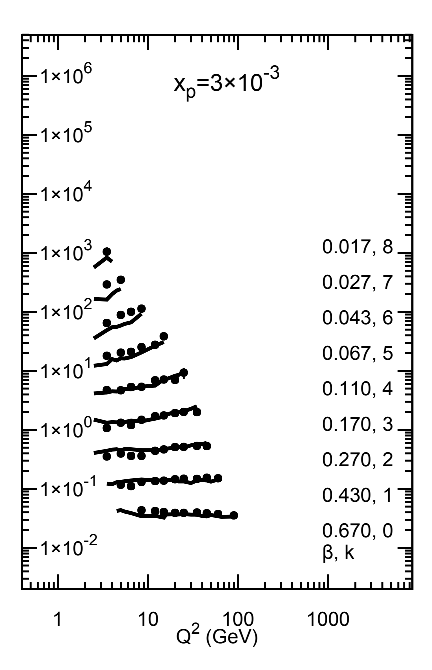
- Attempt to describe data in region:
  $2\,\mathrm{GeV}^2 < Q^2 < 800\,\mathrm{GeV}^2$
  $3 \times 10^{-4} < x_P < 3 \times 10^{-2}$
  $1.7 \times 10^{-3} < \beta < 0.8$
- Color screening, Cascade (CCFM)
- $q_\perp = 0.58\,\mathrm{GeV},\ k_{\perp 0} = 0.72\,\mathrm{GeV}$
- $\Lambda_{\mathrm{QCD}} < q_\perp < k_{\perp 0} < Q_0$

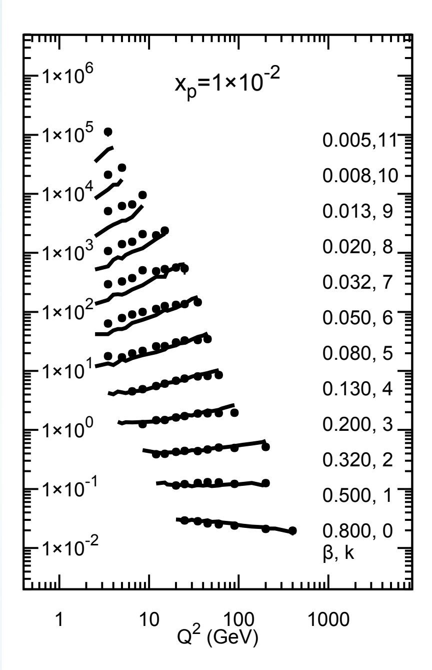


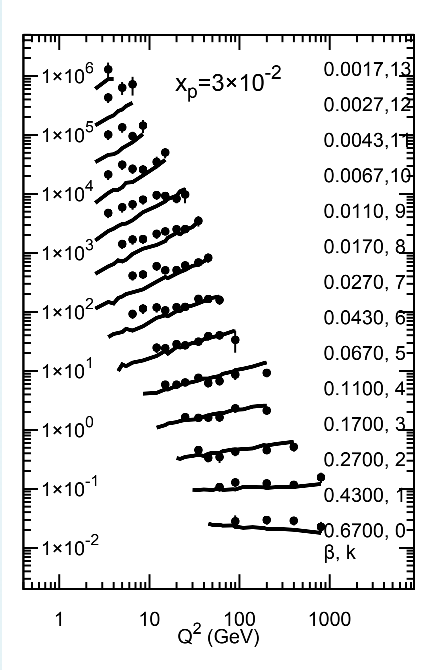
DDIS from Cascade with DCS





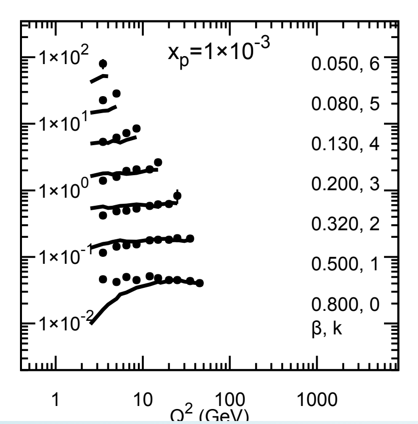


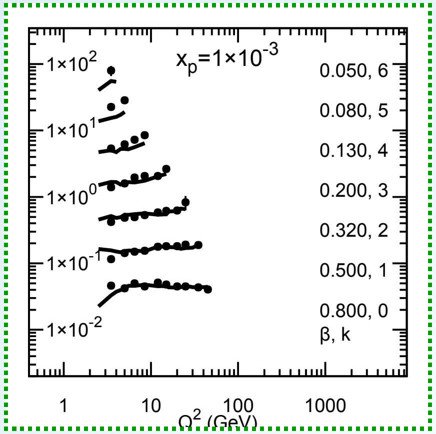


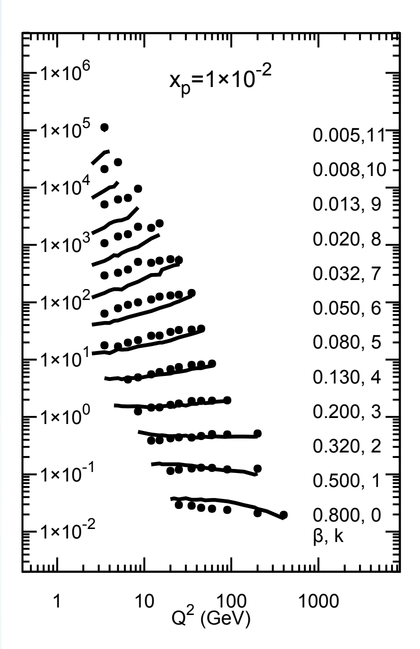


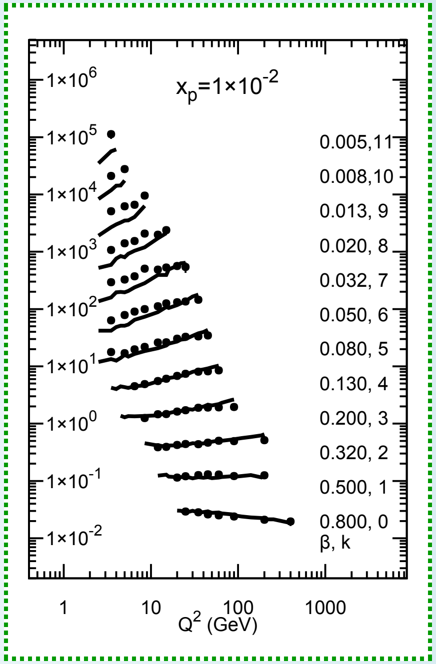
- σ^{diff} defined as forward, proton-like, $M_Y < 1.6\,\text{GeV}$
- Overall, agreement over a wide parameter range.
- Small β, low Q^2: Two different scales.

Comparison with constant model



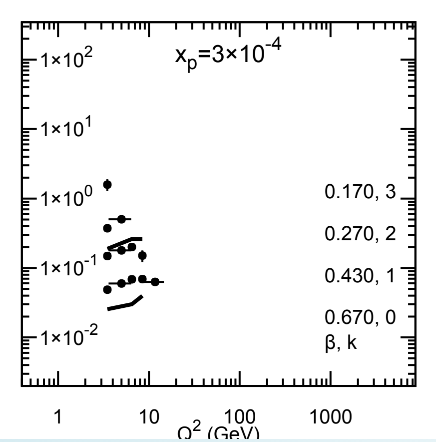


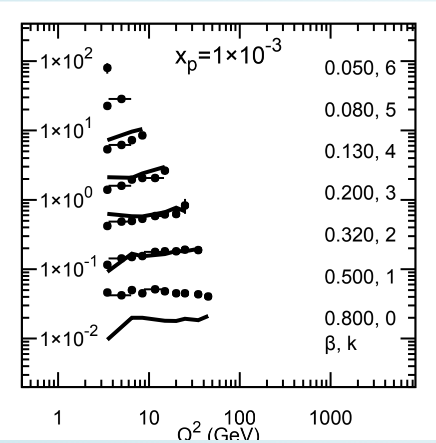


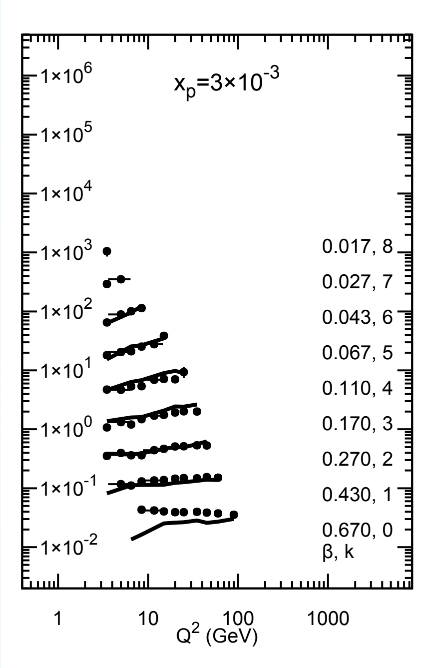


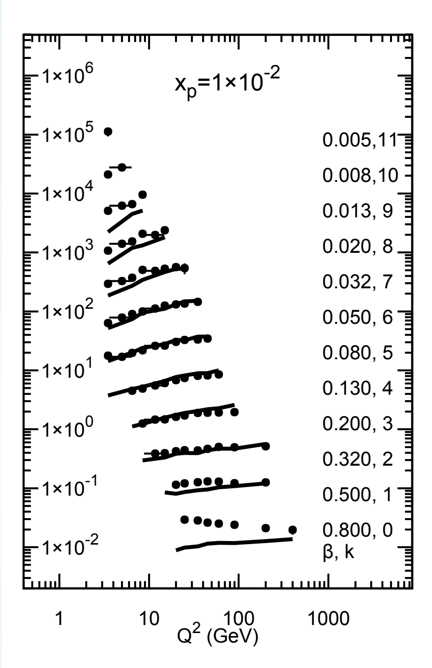
- Dynamic model: Improvement, not full agreement though
- Improvement most noticeable in $\partial\sigma/\partial Q^2$

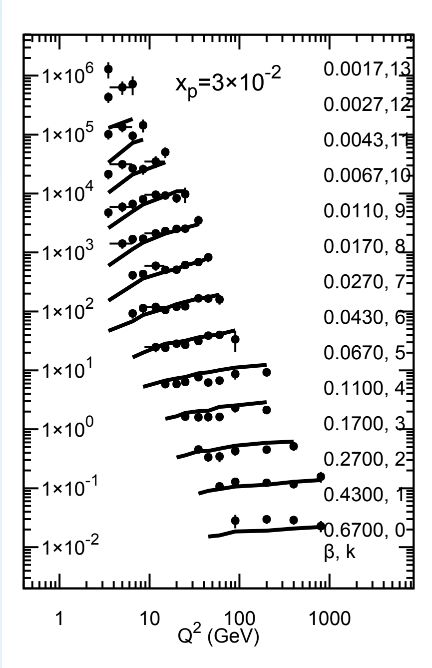
Comparison with Lepto









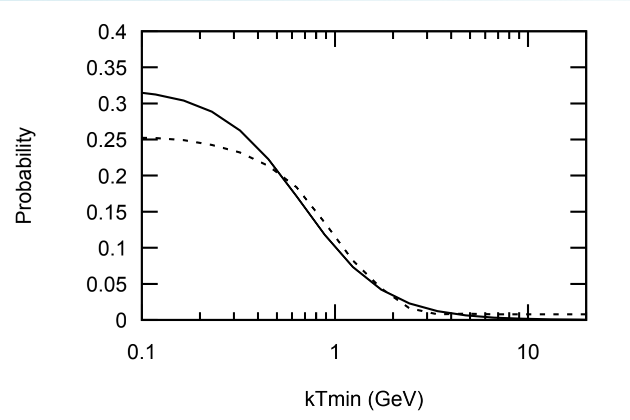


- Lepto (DGLAP)
- $q_\perp = 0.66\,\mathrm{GeV}, k_{\perp 0} = 0.89\,\mathrm{GeV}$
- Overall worse global result
- Better in some areas: Low Q^2 at large x_P
- If dominantly $q\bar{q} \rightarrow$ Large step in x
- Better treated by QED ME + DGLAP parton branching

Overlay free form fit on the model fit

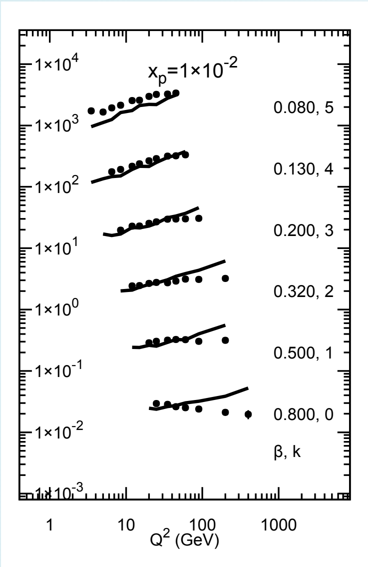
- Assume $P(k_{\perp\min})$ free form, smooth

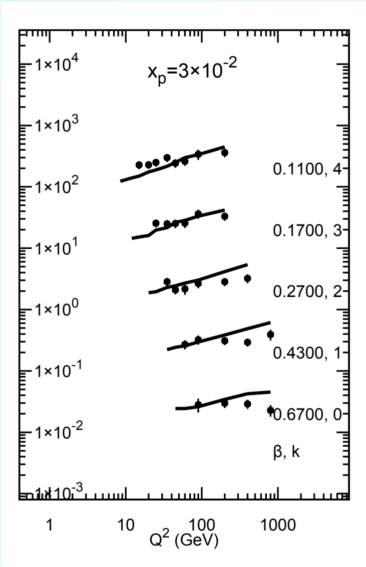
$$\min_{P(k_\perp)} \left\{ \sum_{Q^2,\beta,x_P} \frac{(\sigma(Q^2,\beta,x_P) - \sigma^{\exp}(Q^2,\beta,x_P))^2}{\mathrm{Var}(\sigma^{\exp}(Q^2,\beta,x_P))} + \sum \left(\alpha k_\perp \frac{\partial P}{\partial k_\perp} \right)^2 \right\}$$

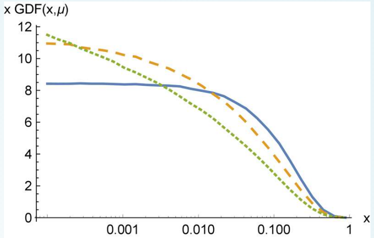


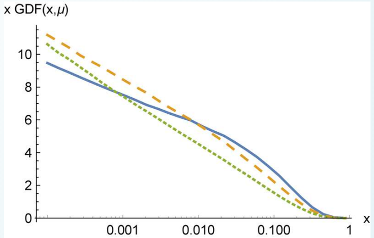
- Very similar result as screening model
- A posteriori reassuring

UGDF dependence



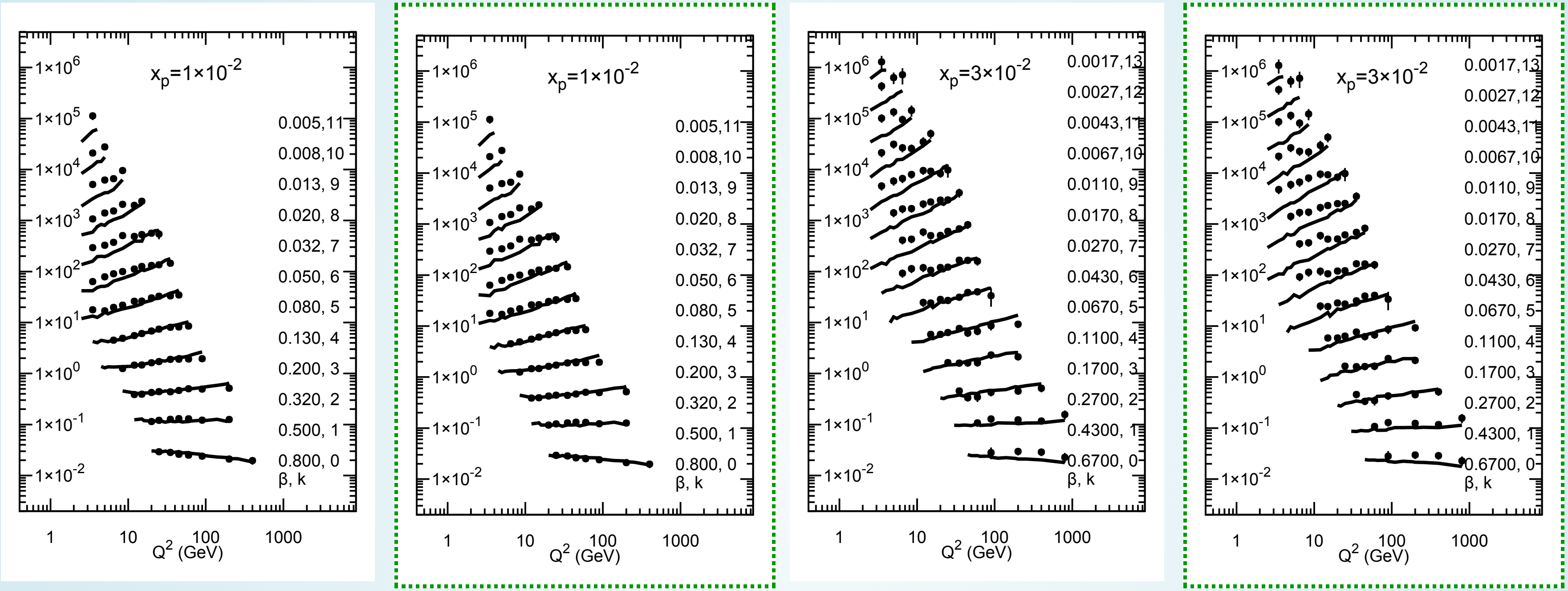






- Substantial dependence, $d\sigma/dQ^2$
- Constrain standard PDF from diffractive data?

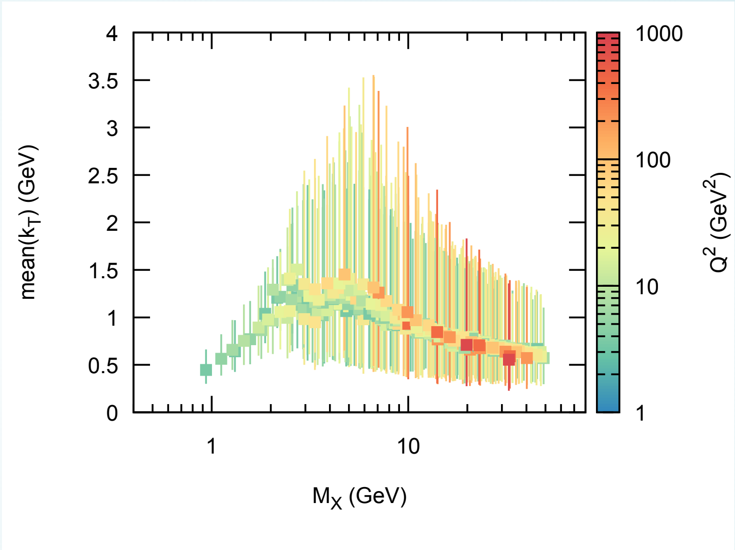
Large rapidity gap



- Forward small-mass vs. LRG
- Require: $\Delta\eta > 2$
- Gap observable sensitive to radiation pattern.
- Both $\sigma^D_{r,\mathrm{FWD}}$ and $\sigma^D_{r,\mathrm{LRG}}$ similar

Distribution in $k_\perp$

- $P(k_\perp, \ldots)$
- $k_\perp \sim \mathcal{N}(\ln k_\perp)$
- PC of variation in M_X
- Prediction from parton evolution
- Previous study: $m_q^{\text{eff}}(\beta, Q^2)$ for dressed up quark, free parameter
- Difference DGLAP / CCFM



Conclusions and outlook

- Novel implementation of color screening for DDIS
- Based on semisoft gluon exchanges, saturates, vanish at small size
- Event based dynamics ($k_{\perp\mathrm{min}}$)
- Use low-x CCFM evolution for improved description at small β
- $\sigma^D_{r,\mathrm{FWD}}$ and $\sigma^D_{r,\mathrm{LRG}}$, compared with HERA data
- Correlation of $\langle k_\perp \rangle$ with M_X^2
- Future: Deviation at large x_P, low Q^2, low β