Threshold Resummation for Longitudinally Polarized Processes

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Outline

- Introduction
- lepton-proton scattering
- W boson production
- Proton-proton collisions
- Conclusions

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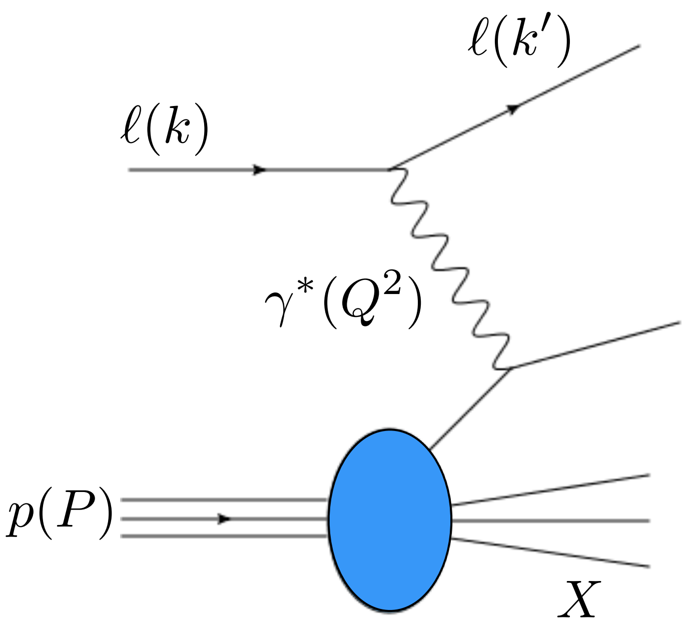
Deep-Inelastic Scattering



Define: $Q^2 \equiv -q^2 = -(k-k')^2$

$$x_B = \frac{Q^2}{2P\cdot q} \qquad y \equiv \frac{P\cdot q}{P\cdot k}$$

Factorized cross section

$$\frac{d^2\sigma}{dx_B dy} = \frac{4\pi\alpha^2}{Q^2}\left[\frac{1+(1-y)^2}{2y}\mathcal{F}_T(x_B,Q^2) + \frac{1-y}{y}\mathcal{F}_L(x_B,Q^2)\right]$$

with structure functions $i = T,\ L$

universal PDF

$$\mathcal{F}_i(x_B,Q^2) = \sum_f \int_{x_B}^1 \frac{dx}{x} f\left(\frac{x_B}{x},\mu^2\right) \mathcal{C}_f^i\left(x,\frac{Q^2}{\mu^2},\alpha_s(\mu^2)\right)$$

hard scattering part

(up to power corrections $1/Q^2$)

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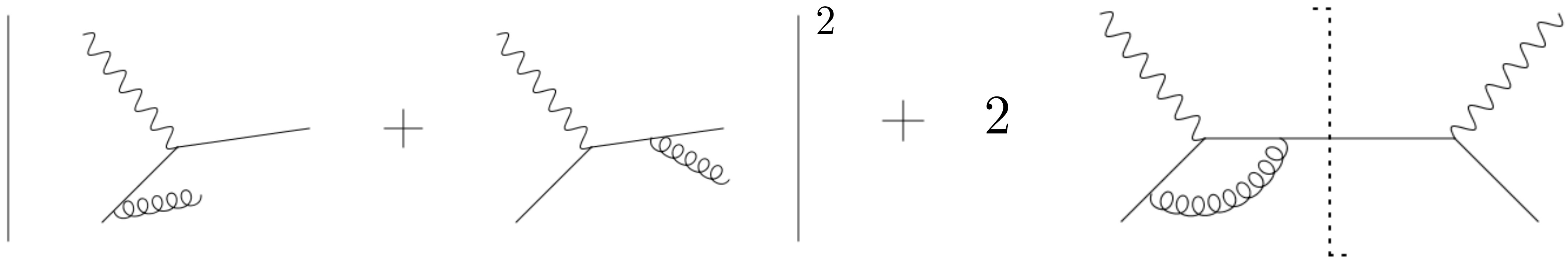
$$\mathcal{F}_i(x_B,Q^2) = \sum_f \int_{x_B}^1 \frac{dx}{x}\, f\left(\frac{x_B}{x},\mu^2\right)\, \mathcal{C}_f^i\left(x, \frac{Q^2}{\mu^2}, \alpha_s(\mu^2)\right)$$

$$\mathcal{C}_f^i = C_f^{i,(0)} + \frac{\alpha_s(\mu^2)}{2\pi} C_f^{i,(1)} + \mathcal{O}(\alpha_s^2)$$

at NLO:



large corrections for $x \to 1$

Altarelli et al. `79; Furmanski, Petronzio `82; de Florian et al. `13

$$C_{q,\mathrm{th}}^{1,(1)}(x) = C_F\left[(1+x^2)\left(\frac{\ln(1-x)}{1-x}\right)_+ - \frac{3}{2}\frac{1}{(1-x)_+} - \left(\frac{9}{2}+\frac{\pi^2}{3}\right)\delta(1-x)\right]$$

spoils perturbative convergence for $x \to 1$ even if $\alpha_s \ll 1$

$\overline{\mathrm{MS}}$ scheme

$$\int_0^1 dz\; h(z)\,[g(z)]_+ \equiv \int_0^1 dz\; [h(z) - h(1)]\; g(z)$$

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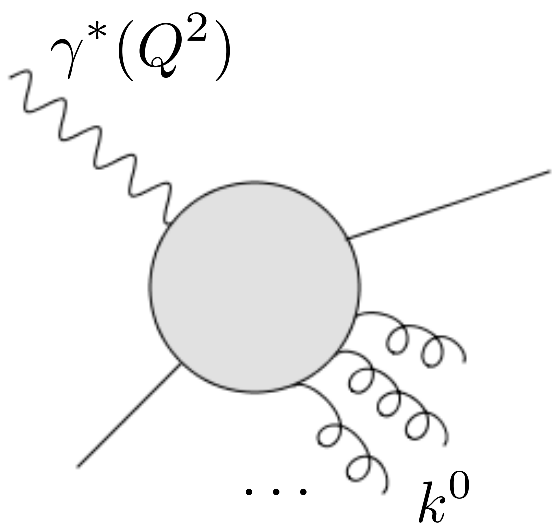
Threshold Logarithms



kth order: $\alpha_s^k \left(\frac{\ln^n(1-x)}{1-x}\right)_+$, with $n \leq 2k-1$

- Partonic threshold $x \to 1$: soft gluon radiation from the LO process $\gamma^* q \to q$
- Origin: suppression of real gluon emission while virtual corrections are allowed
- Logarithms may spoil perturbative series, unless taken into account to all orders

$\longrightarrow$ Threshold resummation

Sterman `81; Catani, Trentadue `89

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Mellin Transform Space

- Structure function

$$\mathcal{F}_1^N(Q^2) = \int dx_B \, x_B^{N-1} \, \mathcal{F}_1(x_B, Q^2)$$
$$= \left(\int_0^1 dx \, x^{N-1} C_f^1 \left(x, Q^2/\mu^2, \alpha_s(\mu^2) \right) \right) \left(\int_0^1 dy \, y^{N-1} f(y, \mu^2) \right)$$

- Threshold logarithms

$$\alpha_s^k \left(\frac{\ln^{2k-1}(1-x)}{1-x} \right)_+ \quad \to \quad \alpha_s^k \ln^{2k} \bar{N}$$

large logarithms in N

$$C_q^{1,(1),N} = C_F \left[\ln^2 \bar{N} + \frac{3}{2} \ln \bar{N} - \frac{9}{2} - \frac{\pi^2}{6} \right]$$

Sterman `81; Catani, Trentadue `89

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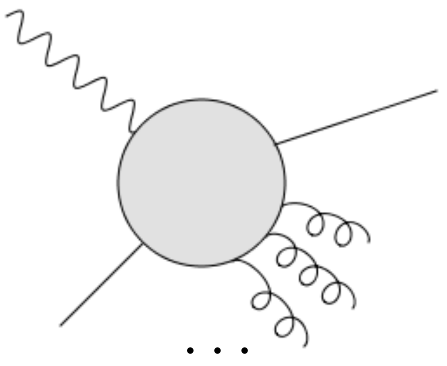
Resummed result



Resummation relies on factorization of

- QCD matrix elements for n-gluon emission in the soft limit
- phase space in Mellin space

in Mellin space: exponentiation of eikonal diagrams

$$C^{1,N}_{q,\mathrm{res}}(Q^2/\mu^2, \alpha_s(\mu^2)) = e_q^2 H_q\left(Q^2/\mu^2, \alpha_s(\mu^2)\right)\ \Delta_q^N(Q^2/\mu^2, \alpha_s(\mu^2))\, J_q^N(Q^2/\mu^2, \alpha_s(\mu^2))$$

where

$$\log \Delta_q^N \equiv \int_0^1 dx \frac{x^N - 1}{1-x} \int_{Q^2}^{(1-x)^2 Q^2} \frac{dk_\perp^2}{k_\perp^2} A_q(\alpha_s(k_\perp^2))$$

$$\log J_q^N \equiv \int_0^1 dx \frac{x^N - 1}{1-x} \left\{ \int_{(1-x)^2 Q^2}^{(1-x) Q^2} \frac{dk_\perp^2}{k_\perp^2} A_q(\alpha_s(k_\perp^2)) + \frac{1}{2} B_q(\alpha_s((1-x)Q^2) \right\}$$

calculable perturbatively

Sterman `81; Gatheral `83; Frenkel, Taylor `84

$\overline{\mathrm{MS}}$ scheme

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Accuracy of Resummation

$$\mathcal{O}(\alpha_s^k) : \qquad C_{kn} \times \alpha_s^k \ln^n \bar{N}, \quad \text{where } n \leq 2k$$

Fixed Order

LO	1					
NLO	$\alpha_s L^2$	$\alpha_s L$	α_s			
NNLO	$\alpha_s^2 L^4$	$\alpha_s^2 L^3$	$\alpha_s^2 L^2$	$\alpha_s^2 L$	α_s^2	
...	...	$\cdots$	...	...	...	
N^kLO	$\alpha_s^k L^{2k}$	$\alpha_s^k L^{2k-1}$	$\alpha_s^k L^{2k-2}$	$\alpha_s^k L^{2k-3}$	$\alpha_s^k L^{2k-4}$	...

Accuracy of Resummation

$$\mathcal{O}(\alpha_s^k): \qquad C_{kn} \times \alpha_s^k \ln^n \bar{N}, \quad \text{where } n \leq 2k$$

Fixed Order →

Resummation ↓

LO	1					
NLO	$\alpha_s L^2$	$\alpha_s L$	α_s			
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...	...	$\cdots$	...	...	...	
N^kLO	$\alpha_s^k L^{2k}$	$\alpha_s^k L^{2k-1}$	$\alpha_s^k L^{2k-2}$	$\alpha_s^k L^{2k-3}$	$\alpha_s^k L^{2k-4}$	...

LL NLL NNLL

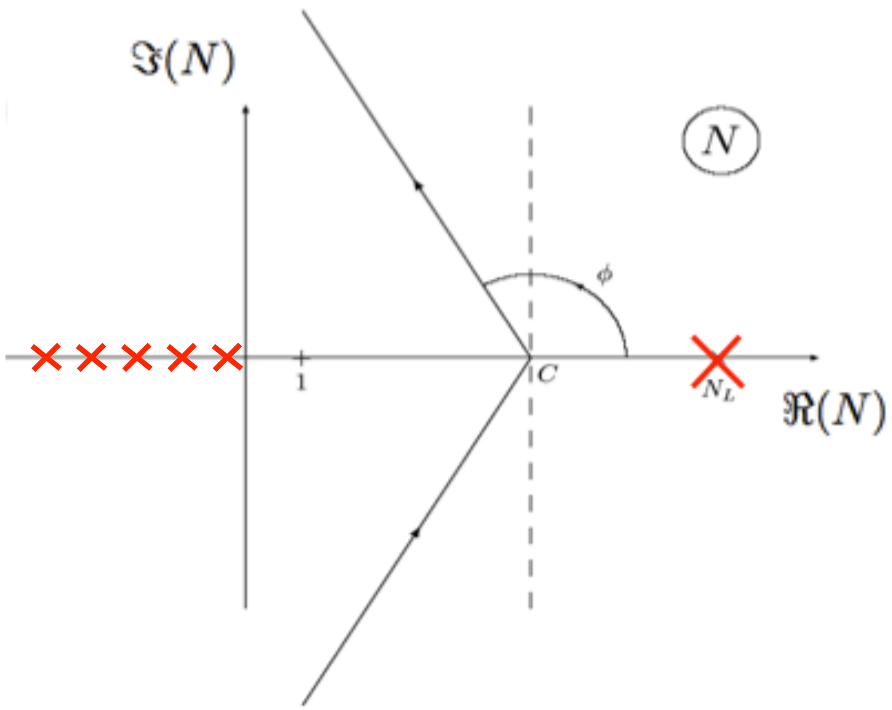
Matching and Minimal Prescription

- Matching procedure (avoiding double counting)

$$d\sigma^{\text{match}} = \left(d\sigma^{\text{resum}} - d\sigma^{\text{resum}}\Big|_{\mathcal{O}(\alpha_s)} \right) + d\sigma^{\text{NLO}}$$

- Inverse Transformation

$$\mathcal{F}_{1,\text{res}}(x_B, Q^2) = \int_{\mathcal{C}_N} \frac{dN}{2\pi i}\, x_B^{-N}\; \mathcal{C}^{1,N}_{q,\text{res}}(Q^2/\mu^2, \alpha_s(\mu^2))\, f^N(\mu^2)$$



Choosing the contour to the left of the Landau pole

Catani, Mangano, Nason, Trentadue `96

- Soft Collinear Effective Theory
  - Detailed studies comparing EFT and traditional treatment
  - Threshold resummation in momentum space
  - So far, threshold resummation using SCET has not been applied to the polarized case

Manohar `03

Becher, Neubert `06

Almeida, Ellis, Lee, Sterman, Sung, Walsh `14

Bonvini, Forte, Ridolfi, Rottoli `14

- Resummed polarized PDFs
  - Similar to the unpolarized case
  - Reduced scale dependence

Sterman, Vogelsang `00

Accardi, Anderle, FR `14

Bonvini, Marzani, Rojo, Rottoli, Ubiali, Ball, Bertone, Carrazza, Hartland `15

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Polarized DIS

Anderle, FR, Vogelsang `13

Spin asymmetry $$A_1(x,Q^2) \approx \frac{g_1(x,Q^2)}{F_1(x,Q^2)}$$

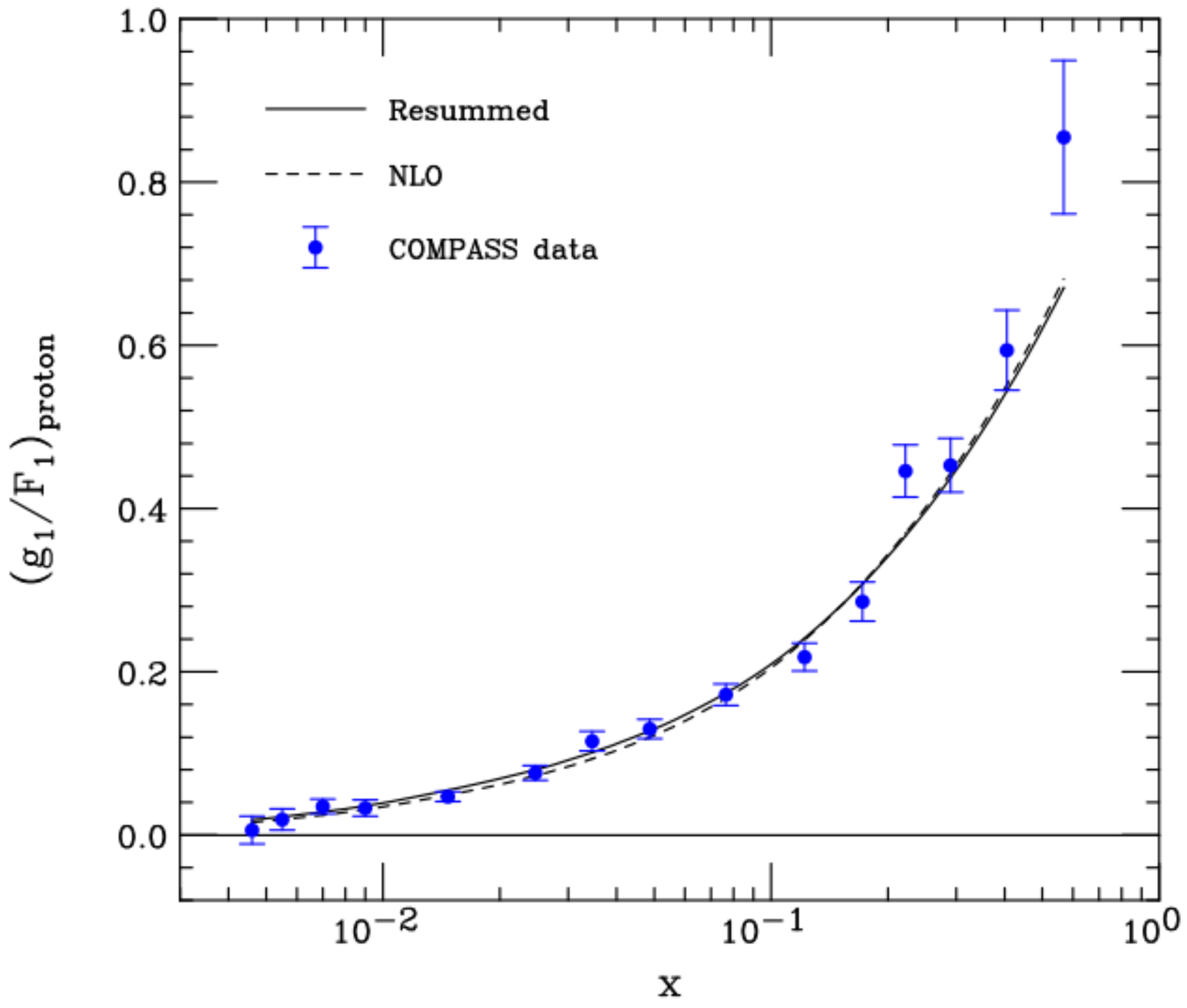
- Same resummed exponent for $g_1(x,Q^2),\ F_1(x,Q^2)$

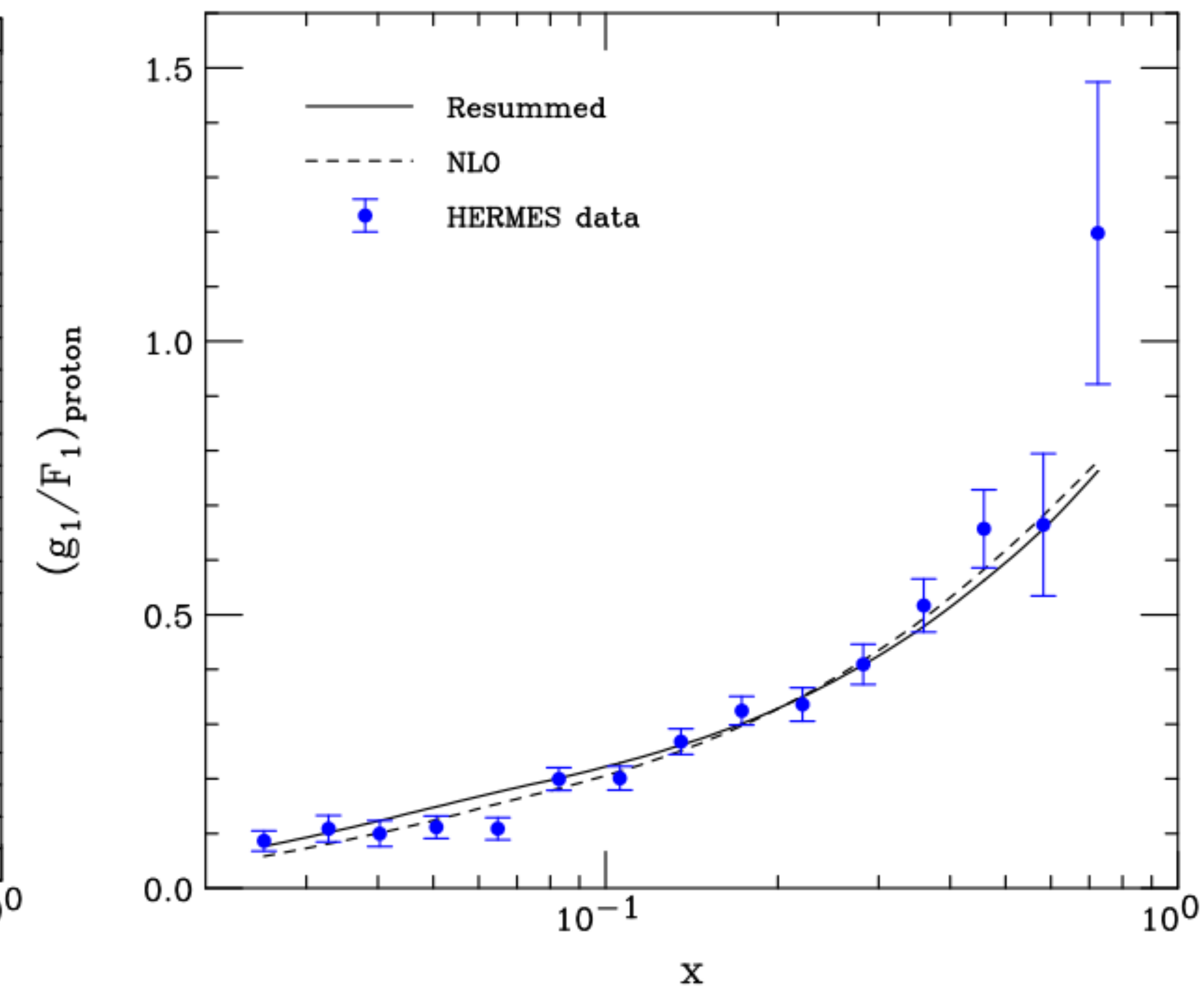
$$\mathcal{C}^{1,N}_{q,\mathrm{res}}(Q^2/\mu^2,\alpha_s(\mu^2)) = e_q^2 H_q\left(Q^2/\mu^2,\alpha_s(\mu^2)\right)\ \Delta_q^N(Q^2/\mu^2,\alpha_s(\mu^2))\, J_q^N(Q^2/\mu^2,\alpha_s(\mu^2))$$

- Convolution with different PDFs
- Matching is different

earlier applications to $g_1^c(x,Q^2)$ and the moments of $g_1(x,Q^2)$
Eynck, Moch `00* *Osipenko, Simula, Melnitchouk `05

Inclusive DIS asymmetries A_1



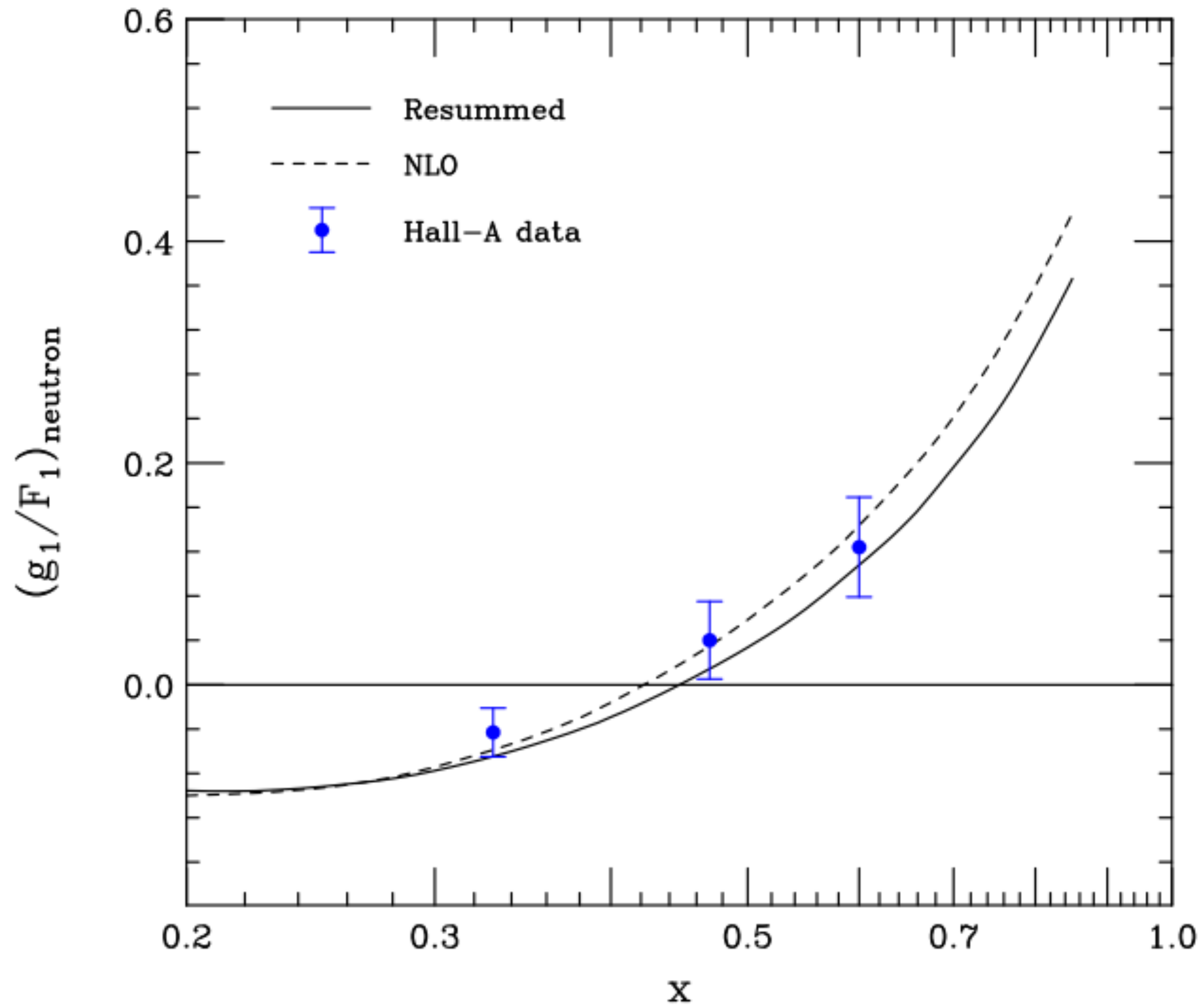


proton target

using MRST'02/DSSV PDFs and DSS FFs

Inclusive neutron DIS asymmetries A_1

sign change at fairly large values of x



neutron target

using MRST'02/DSSV PDFs and DSS FFs

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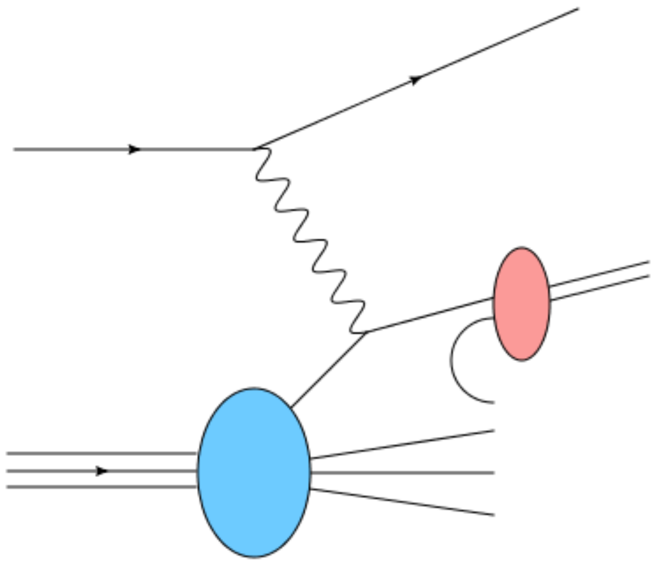
Polarized SIDIS

Longitudinal double-spin asymmetry $\vec{\ell}(k)\vec{p}(P) \to \ell(k')h(P_h)X$



$$A_1^h(x,z,Q^2) \approx \frac{g_1^h(x,z,Q^2)}{F_1^h(x,z,Q^2)}$$

Structure functions: $2F_1^h(x,z,Q^2) = \mathcal{F}_T^h(x,z,Q^2)$

$$2g_1^h(x,z,Q^2) = \sum_{f,f'} \int_x^1 \frac{d\hat{x}}{\hat{x}} \int_z^1 \frac{d\hat{z}}{\hat{z}} \Delta f\left(\frac{x}{\hat{x}},\mu^2\right) D_{f'}^h\left(\frac{z}{\hat{z}},\mu^2\right) \Delta\mathcal{C}_{f'f}\left(\hat{x},\hat{z},\frac{Q^2}{\mu^2},\alpha_s(\mu^2)\right)$$

Polarized SIDIS

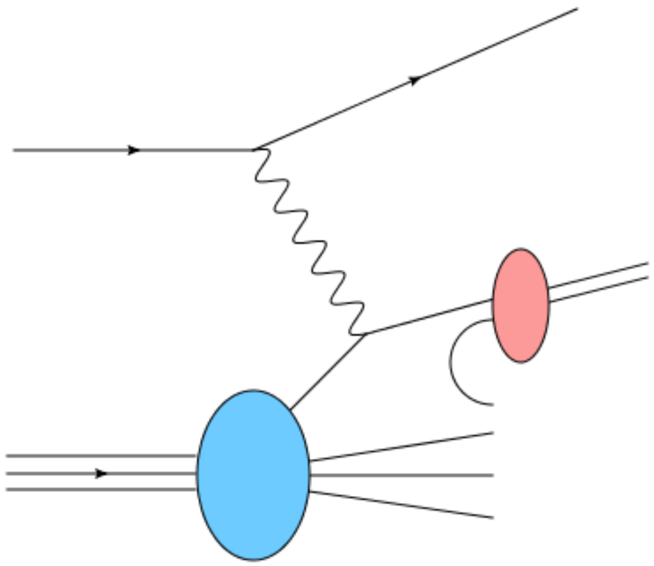
NLO large terms near the partonic threshold $\hat{x},\ \hat{z} \to 1$

$$\Delta C_{qq}^{(1)}(\hat{x},\hat{z}) \sim e_q^2 C_F \left[2\delta(1-\hat{x}) \left(\frac{\ln(1-\hat{z})}{1-\hat{z}}\right)_+ + 2\delta(1-\hat{z}) \left(\frac{\ln(1-\hat{x})}{1-\hat{x}}\right)_+ + \frac{2}{(1-\hat{x})_+(1-\hat{z})_+} - 8\delta(1-\hat{x})\delta(1-\hat{z}) \right]$$

Double Mellin moments

$$\tilde{g}_1^h(N,M,Q^2) \equiv \int_0^1 dx x^{N-1} \int_0^1 dz z^{M-1}\, g_1^h(x,z,Q^2)$$

$$\tilde{C}_{qq}^{(1)}(N,M) \sim e_q^2 C_F \left[-8 + \frac{\pi^2}{3} + \left(\ln \bar{N} + \ln \bar{M}\right)^2 \right]$$



Resummation

$$\Delta \tilde{C}_{qq}^{\rm res}(N,M,\alpha_s(Q^2)) = e_q^2 H_{qq}\left(\alpha_s(Q^2)\right) \exp\left[2\int_{\frac{Q^2}{\bar{N}\bar{M}}}^{Q^2} \frac{dk_\perp^2}{k_\perp^2} A_q\left(\alpha_s(k_\perp^2)\right) \ln\left(\frac{k_\perp}{Q}\sqrt{\bar{N}\bar{M}} \right) \right]$$

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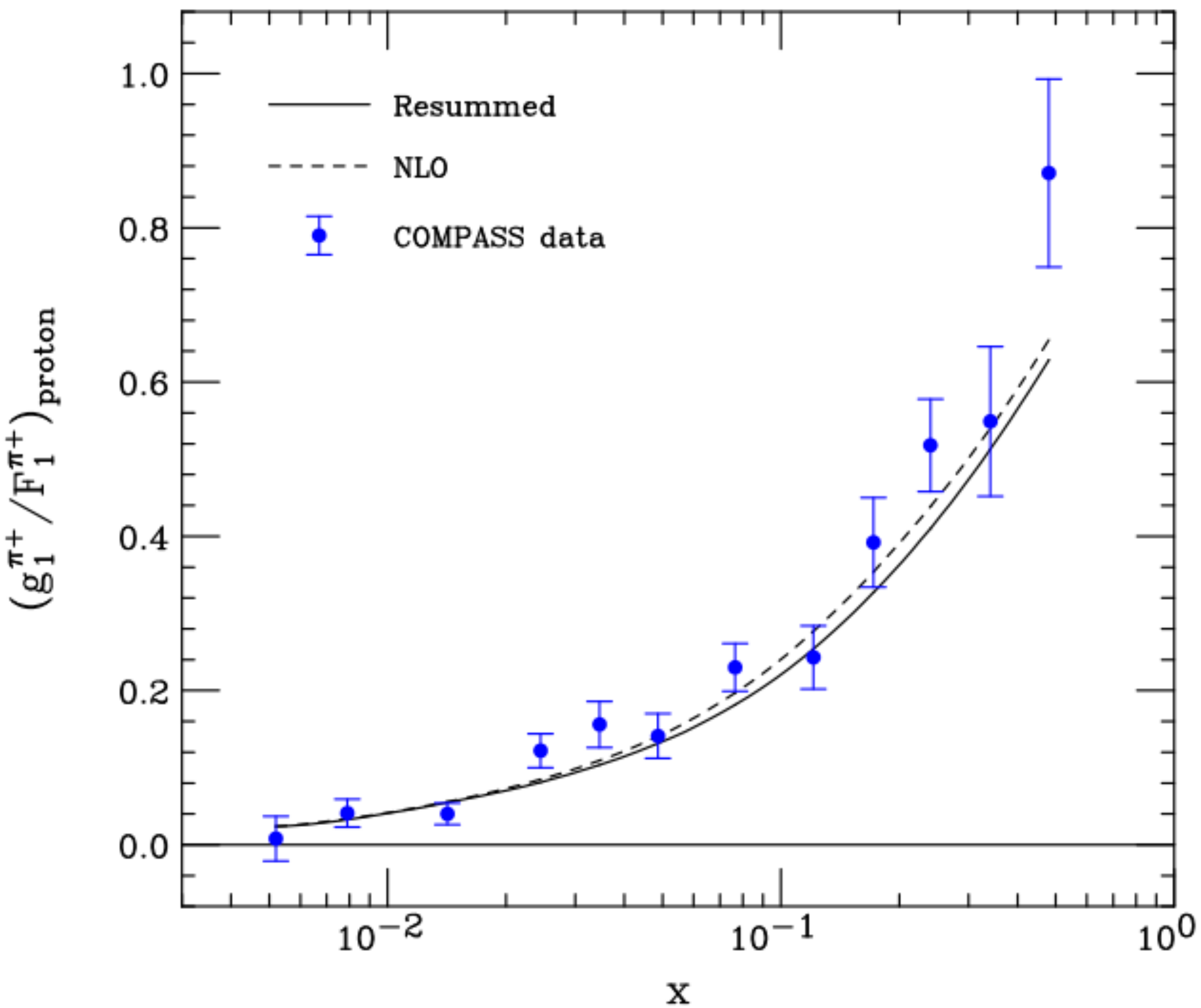
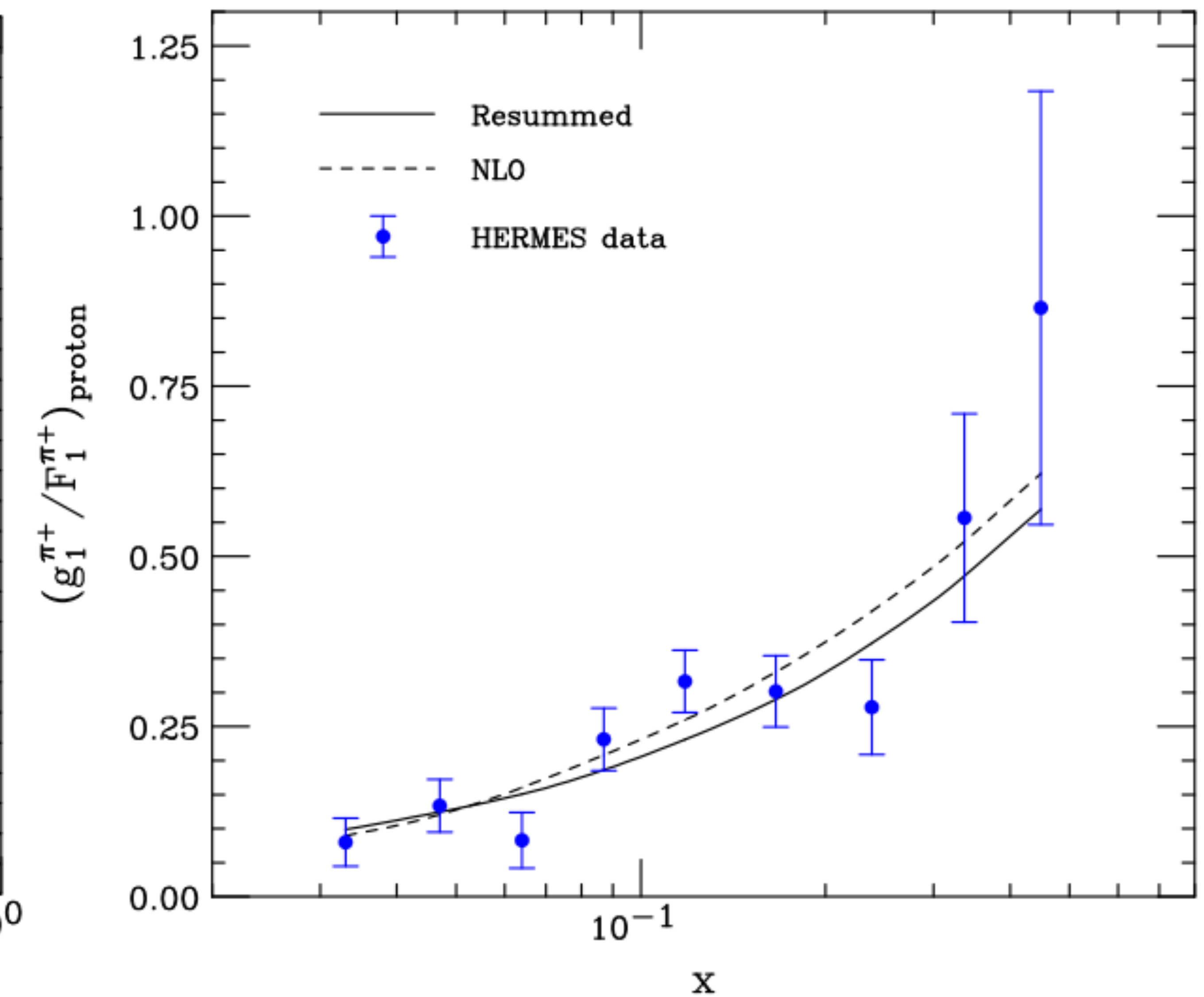
Polarized SIDIS A_1^h





proton target $0.2 < z < 0.8$

using MRST'02/DSSV PDFs and DSS FFs

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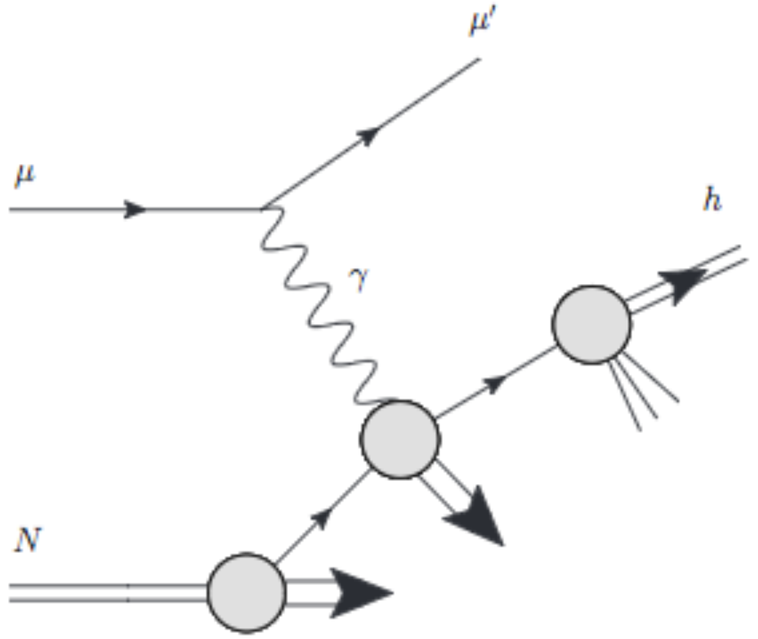
High p_T hadron production at COMPASS

- kinematics such that effectively $\mu N \to \mu' h X$ becomes $\gamma N \to h X$
- directly sensitive to Δg because of direct LO $\gamma g \to q\bar{q}$
- direct and resolved contributions at NLL
- kinematics $x_T = 2p_T/\sqrt{s} \geq 0.2$

de Florian, Pfeuffer, Schäfer, Vogelsang `14
Uebler, Schäfer, Vogelsang `15

$$\frac{p_T^3 d\sigma}{dp_T d\eta} = \sum_{bc} \int_0^1 dx_\ell \int_0^1 dx_n \Delta f_{\gamma/\ell}(x_\ell, \mu_{fi}) \Delta f_{b/N}(x_n, \mu_{fi}) \int_C \frac{dN}{2\pi i} (x^2)^{-N} D_{h/c}^{2N+3}(\mu_{ff}) \Delta\tilde{w}^{2N}_{\gamma b \to cX}(\hat{\eta})$$



where $$\Delta\tilde{w}^N_{\gamma b \to cX}(\hat{\eta}) \equiv 2\int_0^1 d\frac{\hat{s}_4}{\hat{s}} \left(1 - \frac{\hat{s}_4}{\hat{s}}\right)^{N-1} \frac{\hat{x}_T^4 z^2}{8v} \frac{\hat{s} d\Delta\hat{\sigma}_{\gamma b \to cX}}{dv\, dw}$$

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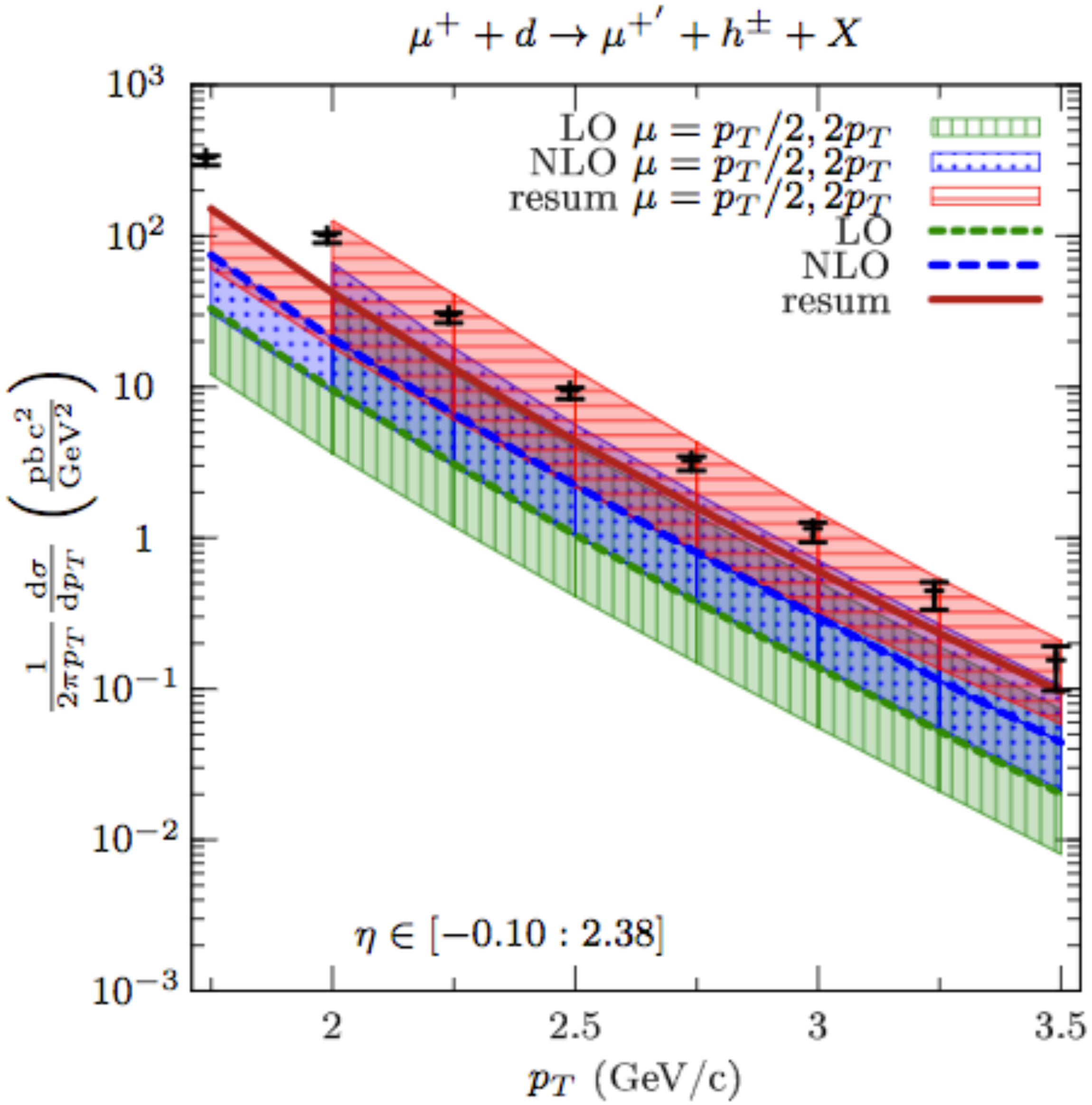
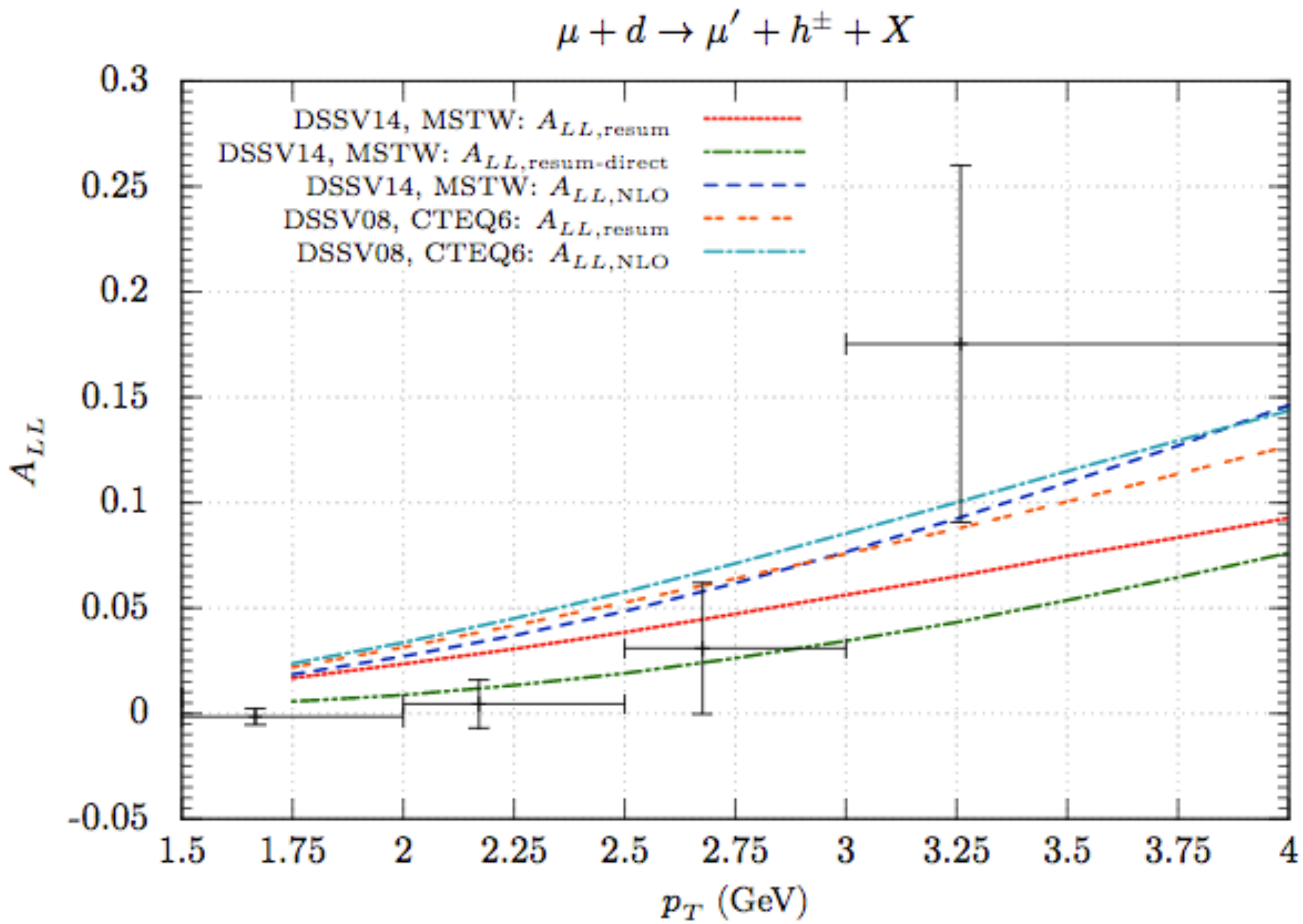


unpolarized cross section



longitudinal spin asymmetry A_{LL}

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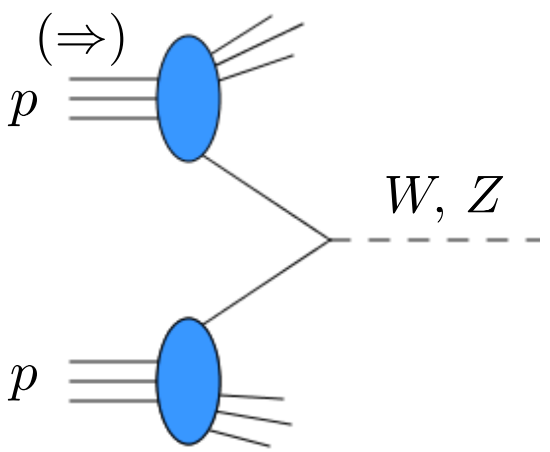
Heavy Gauge Boson Production

- Threshold resummed results for $A_L^{W^\pm}$
- Single-spin asymmetries $\vec{p}p \to W^\pm X$
- for the rapidity dependent cross section $\frac{\mathrm{d}\Delta\sigma}{\mathrm{d}\eta}$



Mukherjee, Vogelsang `06

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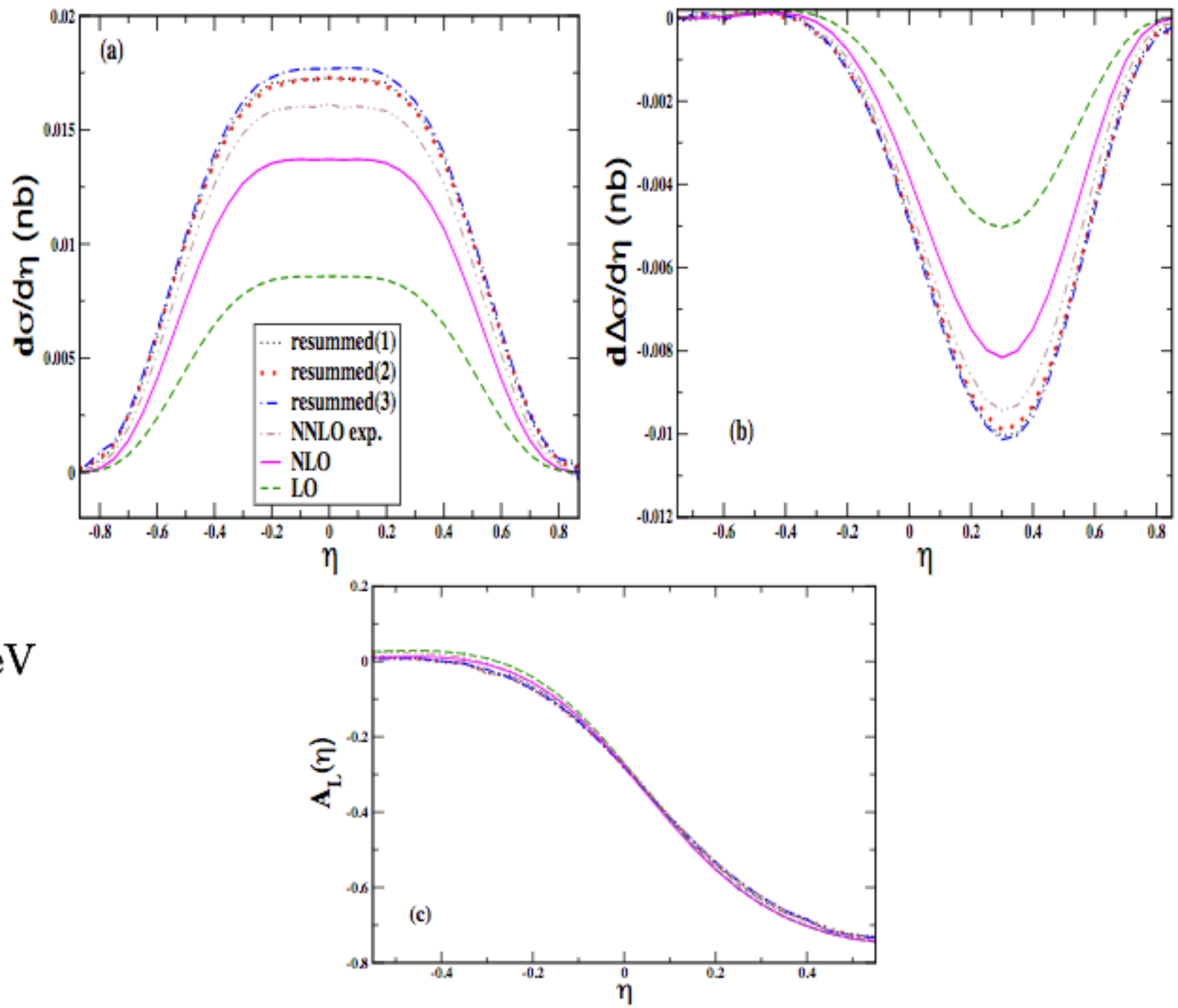
Heavy Gauge Boson Production



RHIC kinema

$\sqrt{s} = 200\ \mathrm{GeV}$

Mukherjee, Vogelsang `06

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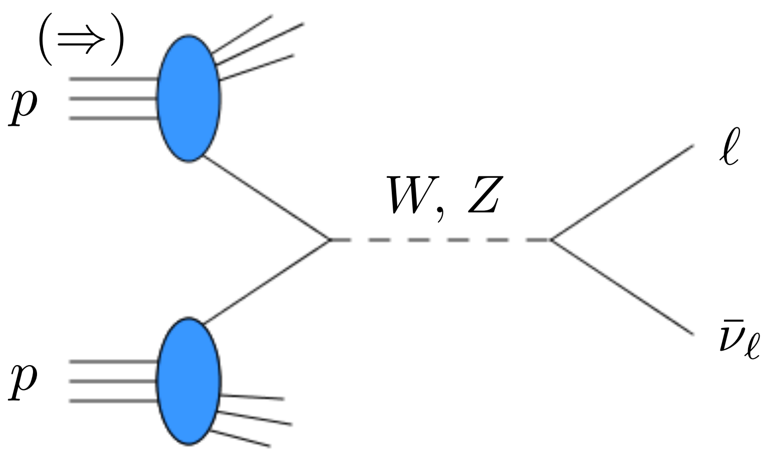
Heavy Gauge Boson Production

- New analytical results at NLO $A_L^{W^\pm}$

  Single-spin asymmetries including the decay

  $\vec{p}p \to W^\pm X \to \ell^\pm X$



- Structure $1 - v = \frac{p_T^\ell}{\sqrt{s}}\,\mathrm{e}^{-\hat{\eta}}$ $\qquad vw = \frac{p_T^\ell}{\sqrt{s}}\,\mathrm{e}^{+\hat{\eta}}$

$$\frac{d\hat{\sigma}^{\mathrm{NLO}}}{dv dw} = \frac{\alpha_s}{2\pi}\left\{\frac{f_{\mathrm{LO}}(v)}{(s-M_W^2)^2+\Gamma^2 M_W^2}\left[A\left(\frac{\ln(1-w)}{1-w}\right)_+ + B(v)\frac{1}{(1-w)_+} + C(v)\delta(1-w)\right]\right.$$

FR, Vogelsang `15

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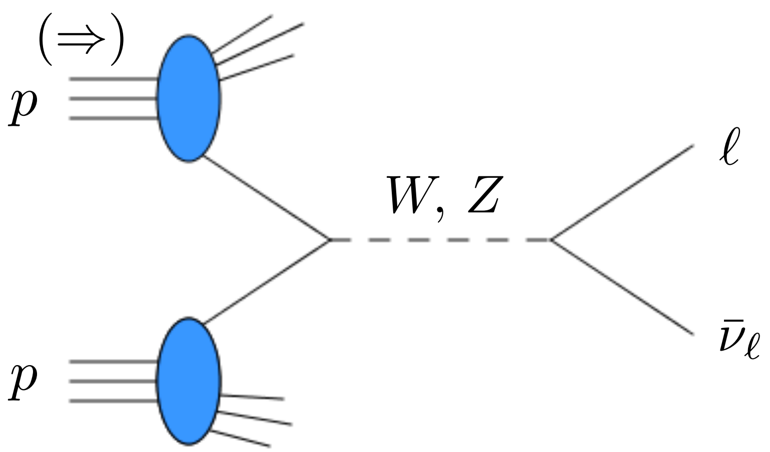
Heavy Gauge Boson Production

- New analytical results at NLO $A_L^{W^\pm}$

  Single-spin asymmetries including the decay

  $\vec{p}p \to W^\pm X \to \ell^\pm X$



- Structure $1 - v = \frac{p_T^\ell}{\sqrt{s}} e^{-\hat{\eta}}$ $vw = \frac{p_T^\ell}{\sqrt{s}} e^{+\hat{\eta}}$

$$\frac{d\hat{\sigma}^{\rm NLO}}{dvdw} = \frac{\alpha_s}{2\pi} \left\{ \frac{f_{\rm LO}(v)}{(s - M_W^2)^2 + \Gamma^2 M_W^2} \left[A \left(\frac{\ln(1-w)}{1-w} \right)_+ + B(v) \frac{1}{(1-w)_+} + C(v)\delta(1-w) \right] \right.$$

$$\left. + \ldots + \frac{\ln\left(\frac{(ws - M_W^2)^2 + \Gamma^2 M_W^2}{M_W^4 + \Gamma^2 M_W^2} \right)}{(ws - M_W^2)^2 + \Gamma^2 M_W^2} + \ldots \right\}$$

FR, Vogelsang `15

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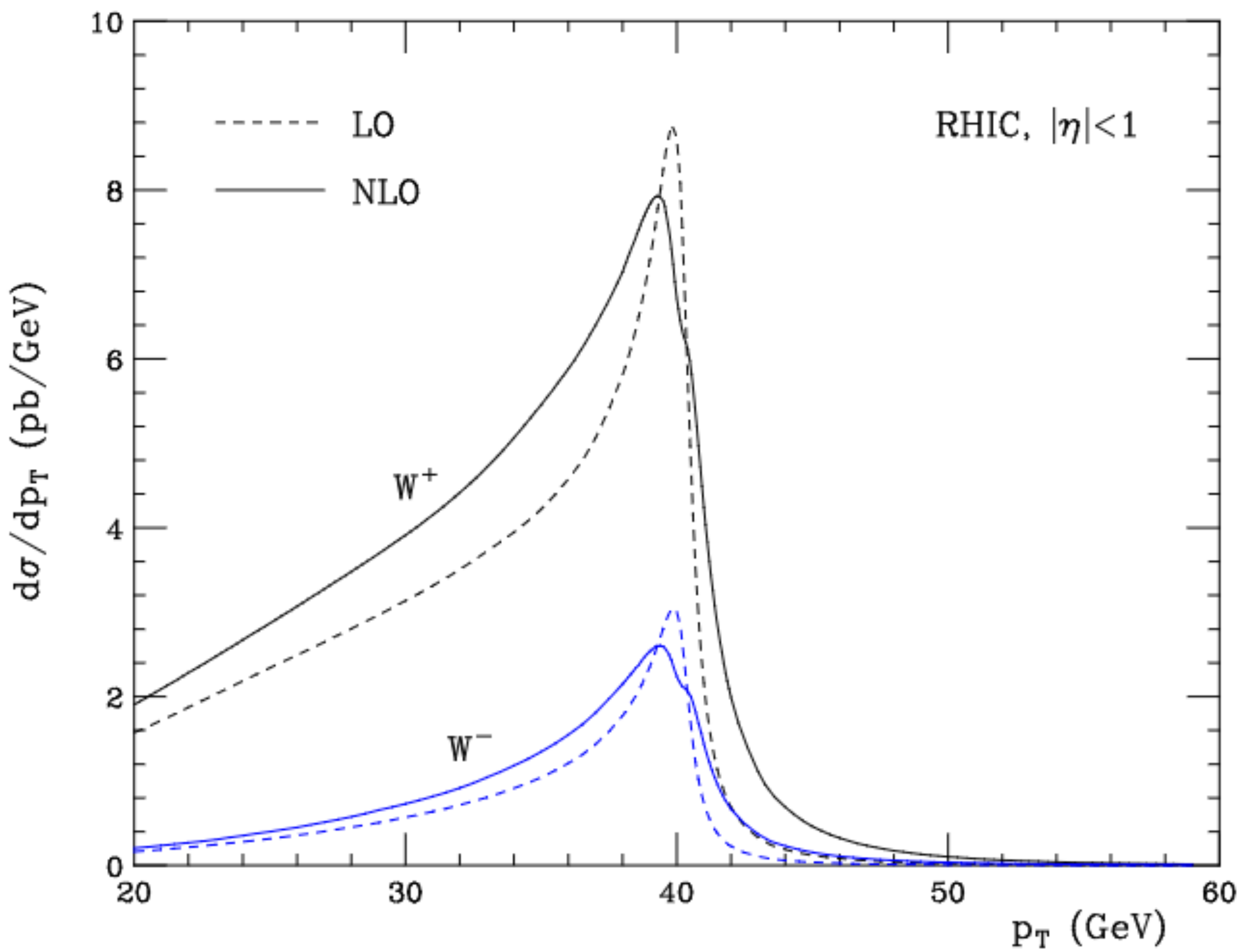
- Analytical results help to understand the structure around $p_T^\ell \sim M_W/2$

  $\longleftrightarrow$ interplay with resummation



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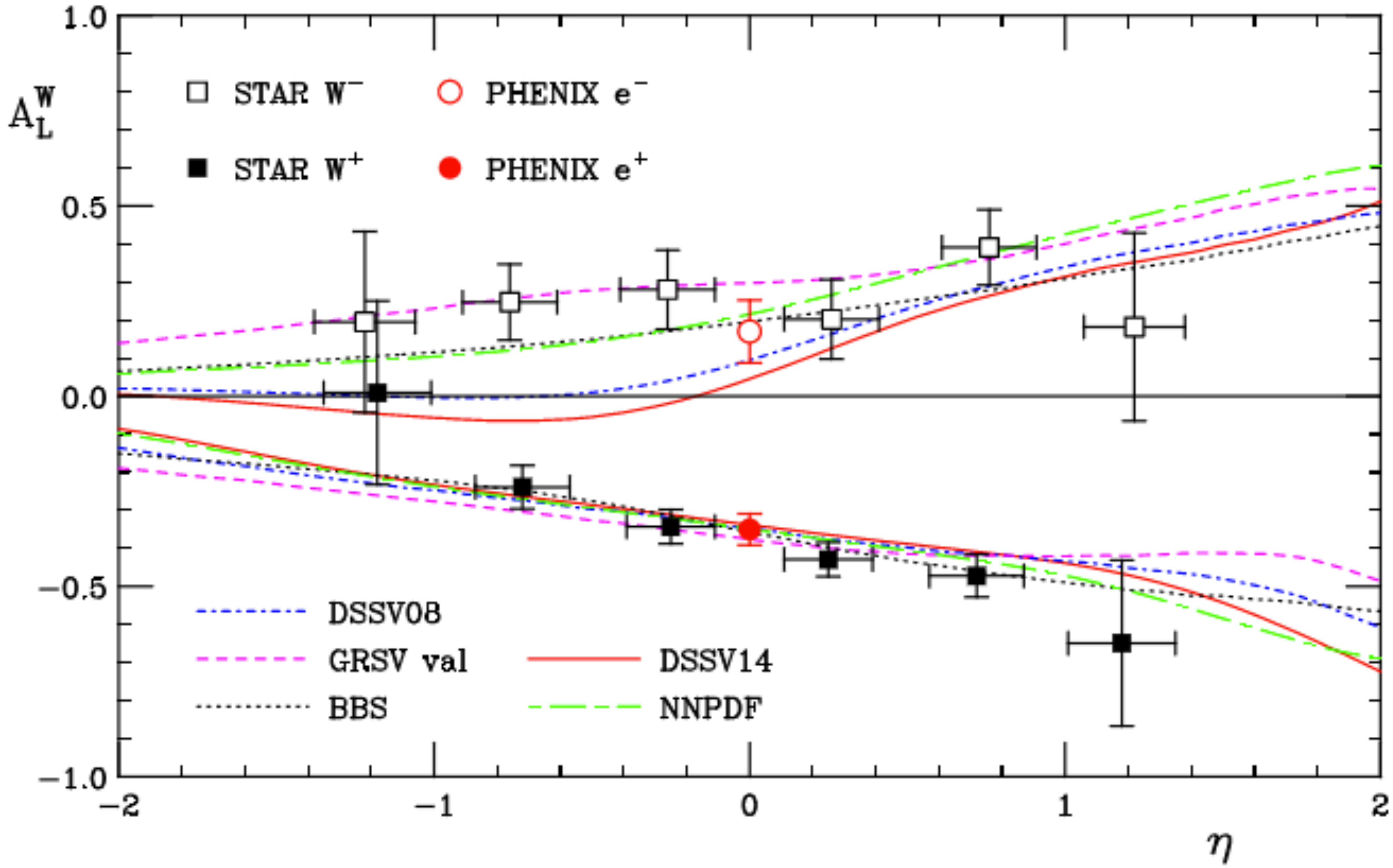
- Analytical results help to understand the structure around $p_T^\ell \sim M_W/2$

  $\longleftrightarrow$ interplay with resummation

- Polarized results used for global analysis of polarized PDFs



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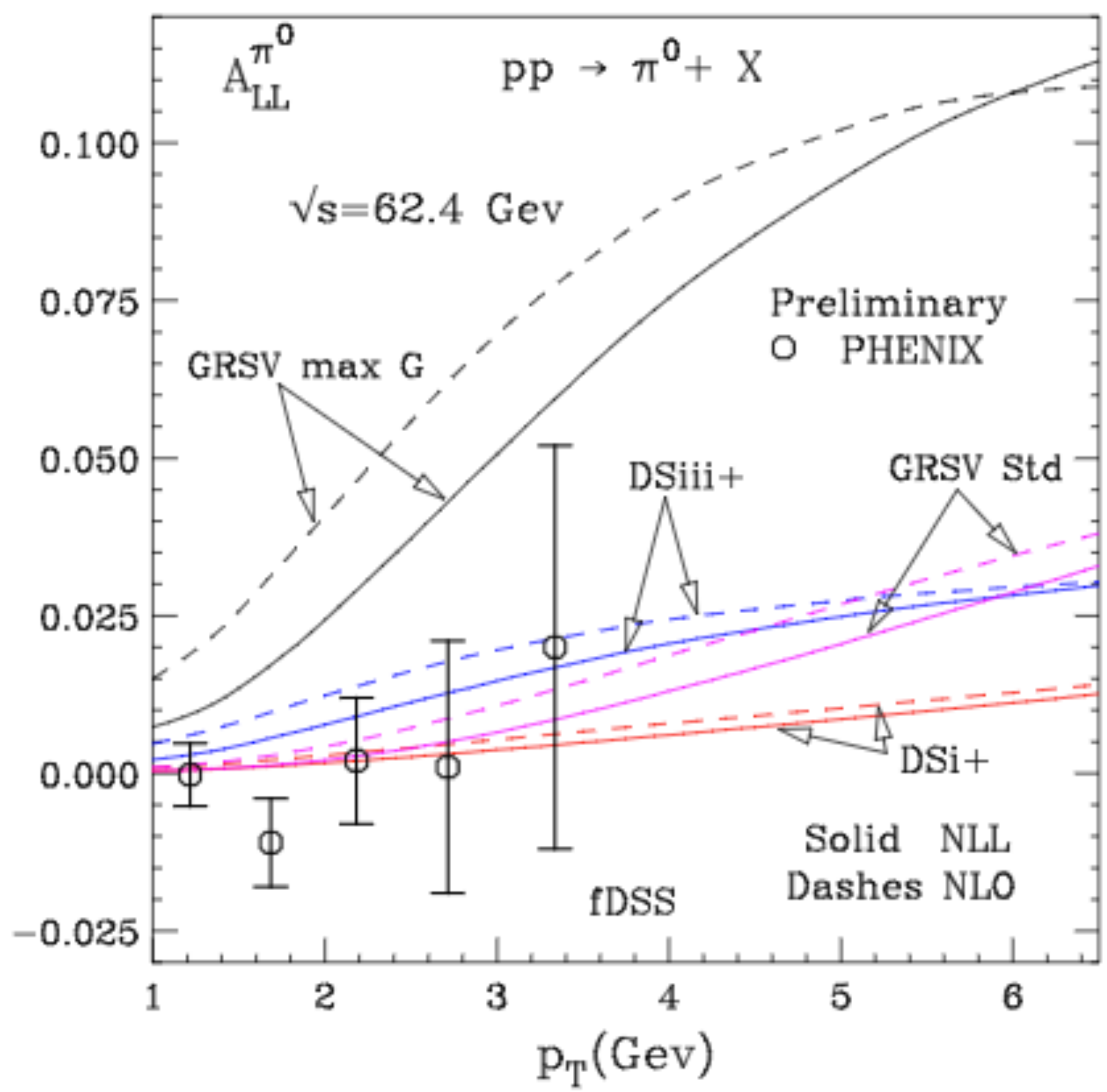
Inclusive hadron and jet production

Rapidity integrated results at NLL

de Florian, Vogelsang `05, de Florian, Vogelsang, Wagner `07, de Florian, Wagner `10

$$\Delta\sigma(N) = \sum_{a,b,c} \Delta f_a(N+1,\mu^2)\,\Delta f_b(N+1,\mu^2)\,D_{h/c}(2N+3,\mu^2)\,\Delta\hat{\sigma}_{ab\to cX}(N)$$

$$\Delta\hat{\sigma}_{ab\to cX}(N) \equiv \int_0^1 d\hat{x}_T^2\,\left(\hat{x}_T^2\right)^{N-1} \int_{\hat{\eta}_-}^{\hat{\eta}_+} d\hat{\eta}\,\frac{\hat{x}_T^4\,\hat{s}}{2}\,\frac{d\Delta\hat{\sigma}_{ab\to cX}(\hat{x}_T^2,\hat{\eta})}{d\hat{x}_T^2 d\hat{\eta}}$$



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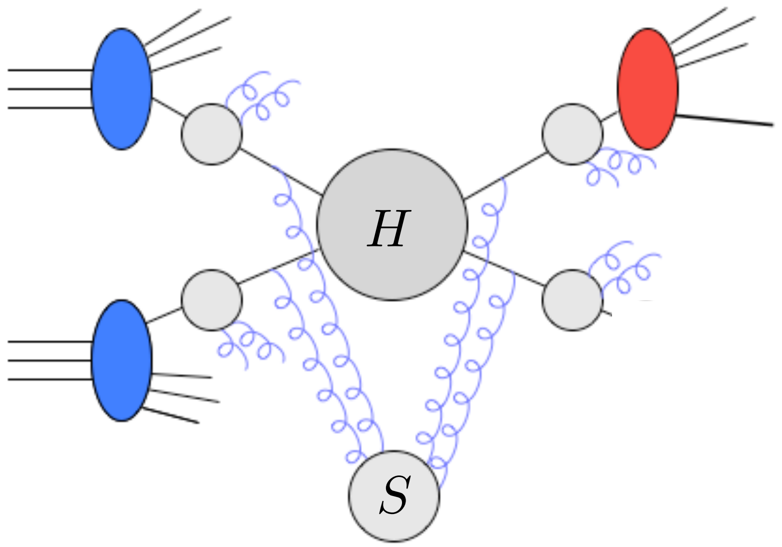
Inclusive hadron production

Hinderer, FR, Sterman, Vogelsang '15,
Hinderer, FR, Sterman, Vogelsang in preparation

Taking into account the rapidity dependence at NNLL



$$\frac{p_T^3 d\sigma}{dp_T d\eta} = \sum_{a,b,c} \int_{x_a^{\min}}^1 dx_a \int_{x_b^{\min}}^1 dx_b \int_x^1 dz_c \frac{\hat{x}_T^4 z_c^2}{8v} \, f_a(x_a,\mu_F) f_b(x_b,\mu_F) D_c^h(z_c,\mu_F) \frac{\hat{s}\, d\hat{\sigma}_{ab\to cX}}{dv dw}$$

$$= \sum_{a,b,c} \int_0^1 dx_a \int_0^1 dx_b f_a(x_a,\mu_F) f_b(x_b,\mu_F) \times \int_{\mathcal{C}} \frac{dN}{2\pi i} (x^2)^{-N} (D_c^h)^{2N+3}(\mu_F)\, \tilde{\omega}^{2N}(v)$$

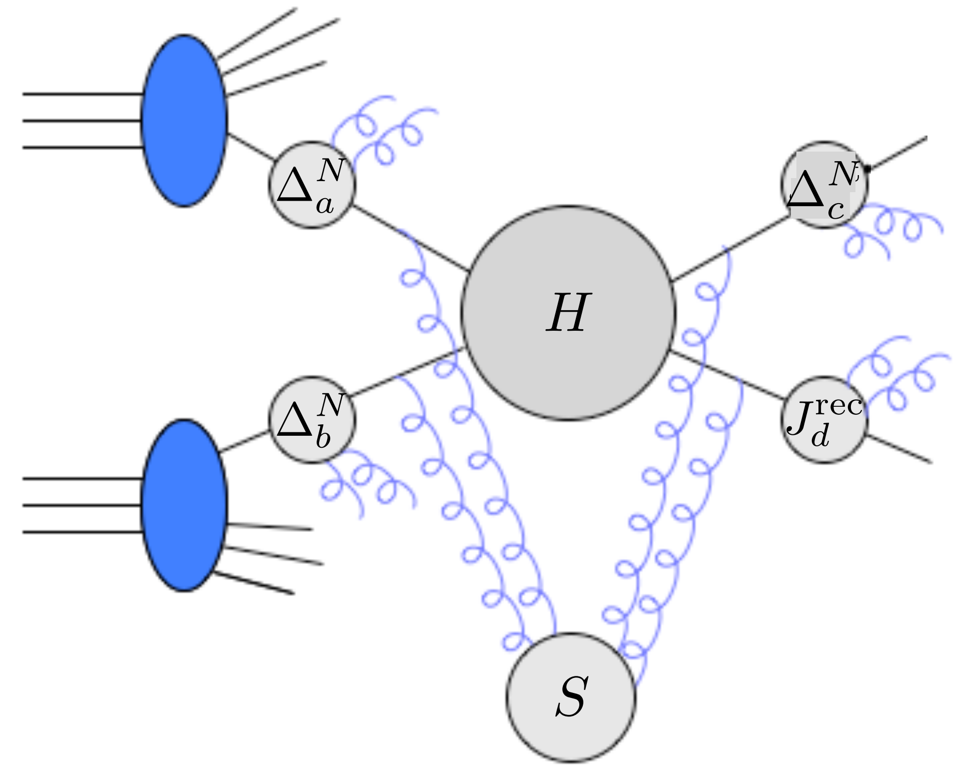
de Florian, Pfeuffer, Schäfer, Vogelsang '14

where

$$\tilde{\omega}^N(v) = 2\int_0^1 d\frac{s_4}{\hat{s}} \left(1 - \frac{s_4}{\hat{s}}\right)^{N-1} \frac{\hat{x}_T^4}{8v} \frac{\hat{s}\, d\hat{\sigma}_{ab\to cX}}{dv dw}$$

Threshold Resummation at NNLL

Refactorization near threshold



recoiling jet (cf. DIS)

observed hadron

$$d\hat{\sigma}^N_{\rm res} = \sum_{abcd=q,\bar{q},g} \Delta_a^{N_a}\, \Delta_b^{N_b}\, \Delta_c^N\, J_d^{\rm recoil,N} \times \mathrm{Tr}\left\{H\mathcal{S}^\dagger S\mathcal{S}\right\}$$

hard function

soft function

as DY but θ dependent

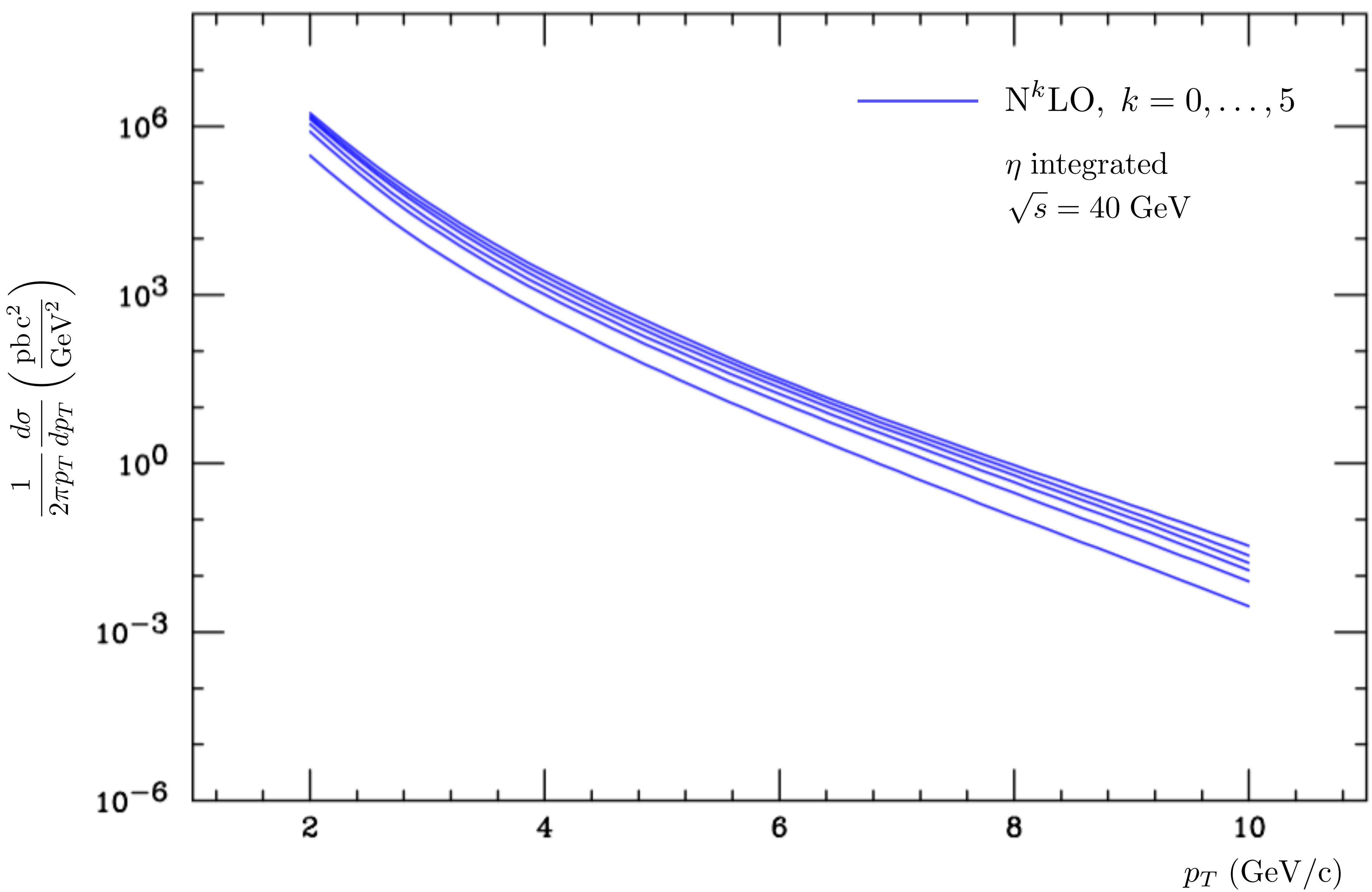
Soft Matrix

$qq' \to qq'$

$$S^{(1)}_{qq'\to qq'} = -\frac{C_F}{2}\left([\ln(1-v)+\ln v]^2 - 2\,\zeta(2)\right) S^{(0)}_{qq'\to qq'} + C_F \ln(1-v)\ln v \begin{pmatrix} 1 & -C_A \\ -C_A & 0 \end{pmatrix}$$

$gg \to gg$

$$S^{(1)}_{gg\to gg} = -\frac{C_A}{2}\left([\ln(1-v)+\ln v]^2 - 2\,\zeta(2)\right) S^{(0)}_{gg\to gg} + 3\ln(1-v)\ln v \begin{pmatrix} 5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 5 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 2 & 0 & 0 \\ 0 & 0 & 0 & 0 & 4 & 4 & 8 & 0 \\ 0 & 0 & 0 & 2 & 4 & 4 & 0 & 6 \\ 0 & 0 & 0 & 0 & 8 & 0 & 20 & 12 \\ 0 & 0 & 0 & 0 & 0 & 6 & 12 & 36 \end{pmatrix}$$



preliminary

so far unpolarized only!

using MSTW PDFs and DSS FFs

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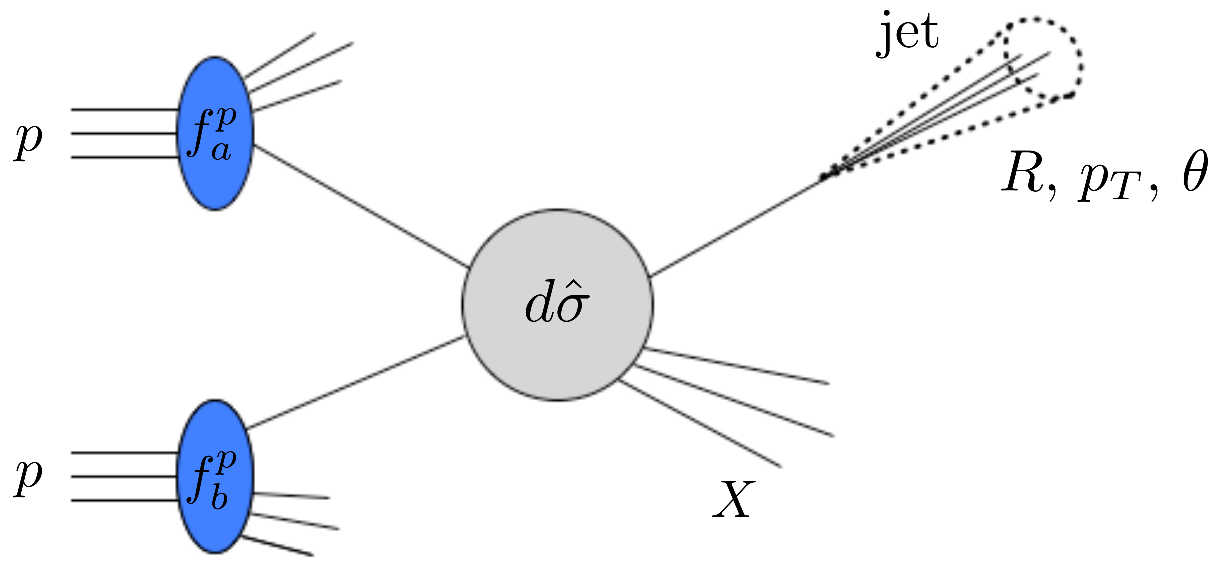
Inclusive jet production

- jet algorithm dependence
- double differential cross section $\frac{d^2\sigma}{dp_T d\theta}$
- Analytical results obtained in the ``Narrow Jet Approximation´´

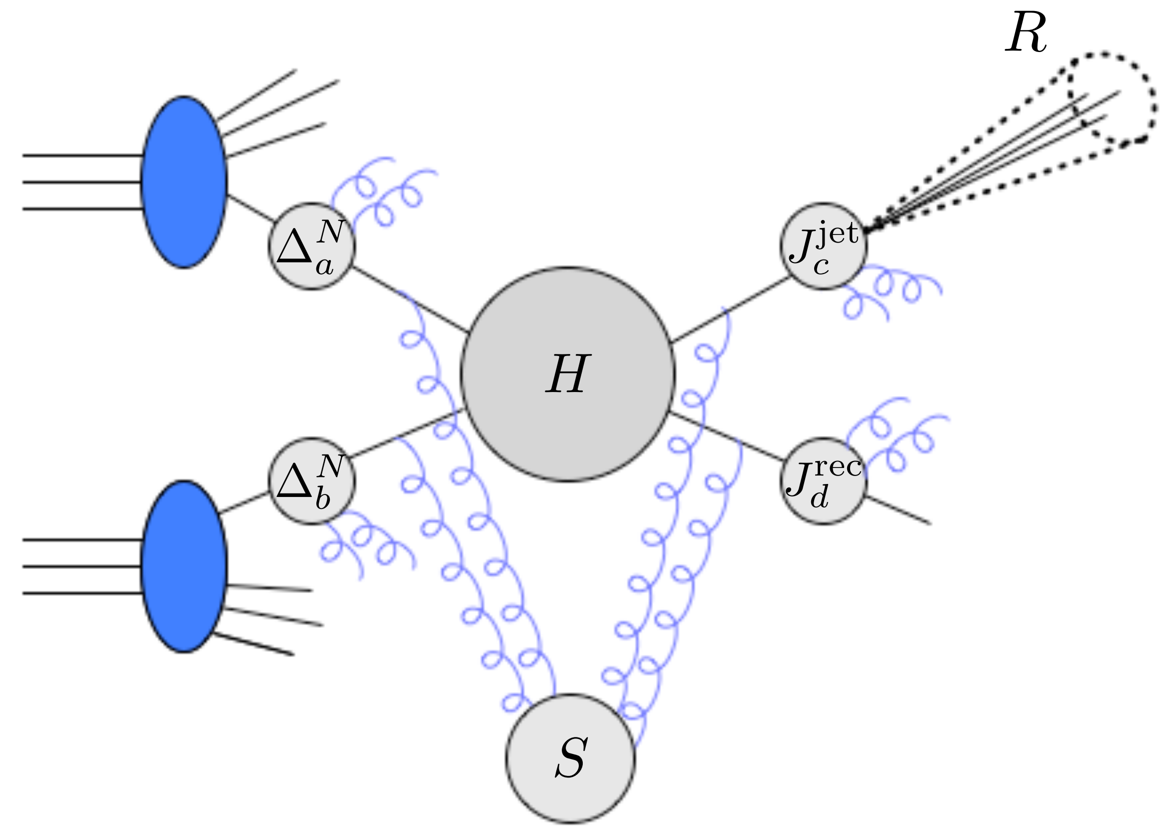
Jäger, Stratmann, Vogelsang '04; Mukherjee, Vogelsang '13

$$\mathcal{A}\log R + \mathcal{B} + \mathcal{O}(R^2)$$



Threshold Resummation at NNLL

Refactorization near threshold



recoiling jet (cf. DIS)

observed jet, R dependence

$$d\hat{\sigma}^N_{\text{res}} = \sum_{abcd=q,\bar{q},g} \Delta_a^{N_a}\,\Delta_b^{N_b}\, J_c^{\text{jet},\text{N}}\, J_d^{\text{recoil},\text{N}} \times \text{Tr}\left\{ H \mathcal{S}^\dagger S \mathcal{S} \right\}$$

hard function

soft function

as DY but θ dependent

de Florian, Hinderer, Mukherjee, FR, Vogelsang `14

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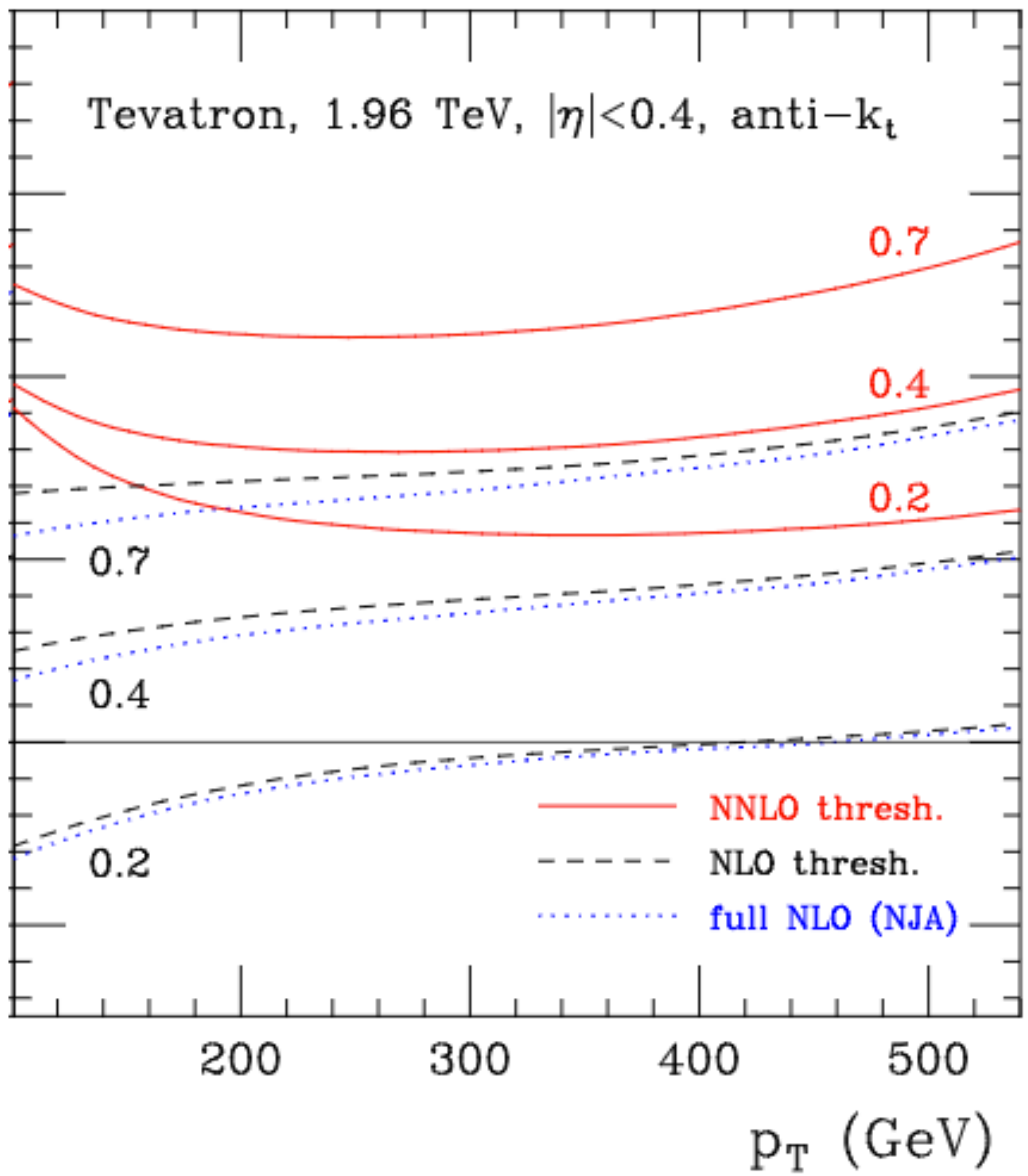
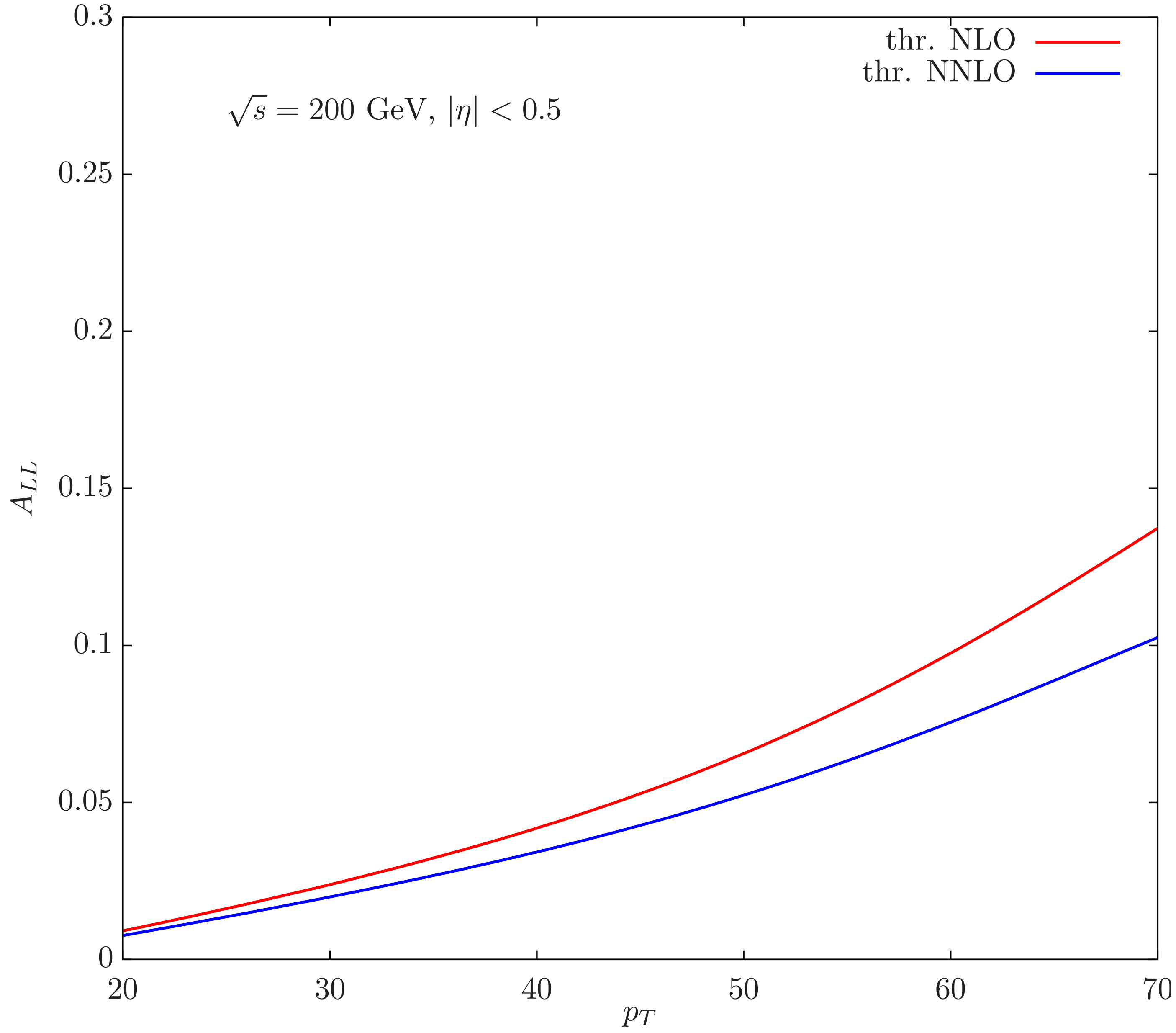
Approximate NNLO results



de Florian, Hinderer, Mukherjee, FR, Vogelsang `14

Approximate NNLO results

RHIC kinematics



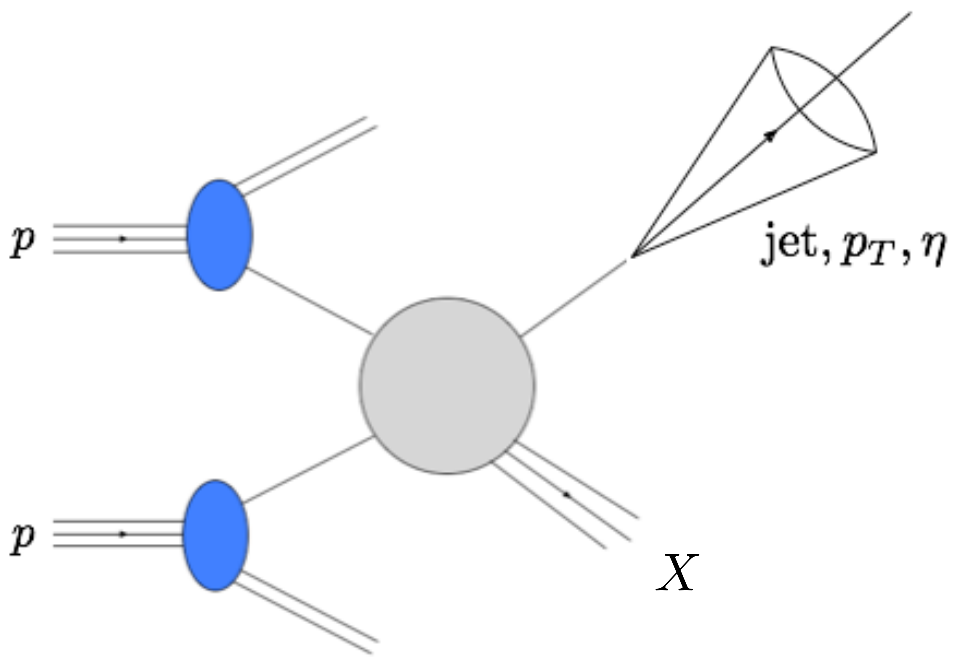
preliminary

- Impact on the extraction of Δg
- Subleading $\ln N/N$ become relevant for the polarized case

Inclusive Jet Production in SCET $pp \to \mathrm{jet}X$

Kang, FR, Vitev `16, `16

$$\frac{d\sigma^{pp\to \mathrm{jet}X}}{dp_T d\eta} = \frac{2p_T}{s}\sum_{a,b,c}\int_{x_a^{\min}}^1 \frac{dx_a}{x_a} f_a(x_a,\mu)\int_{x_b^{\min}}^1 \frac{dx_b}{x_b} f_b(x_b,\mu) \int_{z_c^{\min}}^1 \frac{dz_c}{z_c^2}\frac{d\hat{\sigma}^c_{ab}(\hat{s},\hat{p}_T,\hat{\eta},\mu)}{dvdz} J_c(z_c,\omega_J,\mu)$$



"semi-inclusive jet function" in SCET

Also applicable to jet A_{LL}

see also:

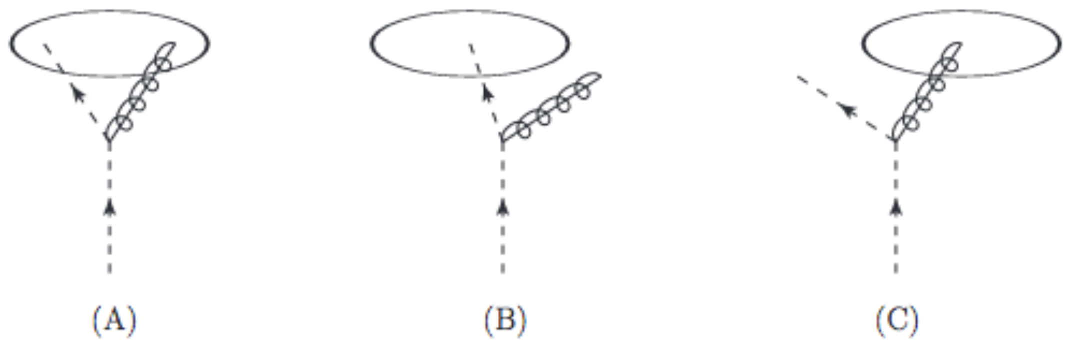
Jäger, Stratmann, Vogelsang `04, Mukherjee, Vogelsang `12, Kaufmann, Mukherjee, Vogelsang `15, Dasgupta, Dreyer, Salam, Soyez `14, `16

Inclusive Jet Production in SCET $pp \to \text{jet}X$

Kang, FR, Vitev `16, `16

$$\frac{d\sigma^{pp\to \text{jet}X}}{dp_T d\eta} = \frac{2p_T}{s}\sum_{a,b,c}\int_{x_a^{\min}}^1 \frac{dx_a}{x_a} f_a(x_a,\mu)\int_{x_b^{\min}}^1 \frac{dx_b}{x_b} f_b(x_b,\mu)\int_{z_c^{\min}}^1 \frac{dz_c}{z_c^2}\frac{d\hat\sigma_{ab}^c(\hat s,\hat p_T,\hat\eta,\mu)}{dvdz} J_c(z_c,\omega_J,\mu)$$

Definition similar to FFs
but perturbatively calculable:



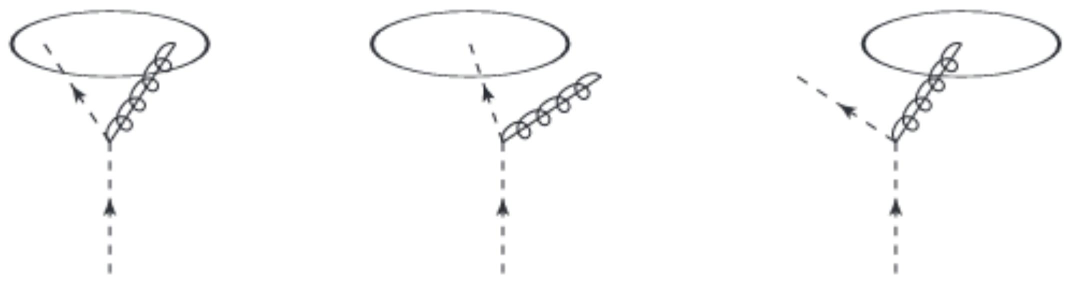
Jet cross section at NLO: $d\sigma \sim \mathcal{A}\ln R + \mathcal{B} + \mathcal{O}(R^2)$

Inclusive Jet Production in SCET $pp \to \mathrm{jet}X$

Kang, FR, Vitev `16, `16

$$\frac{d\sigma^{pp\to\mathrm{jet}X}}{dp_T d\eta} = \frac{2p_T}{s}\sum_{a,b,c}\int_{x_a^{\min}}^{1}\frac{dx_a}{x_a}f_a(x_a,\mu)\int_{x_b^{\min}}^{1}\frac{dx_b}{x_b}f_b(x_b,\mu)\int_{z_c^{\min}}^{1}\frac{dz_c}{z_c^2}\frac{d\hat{\sigma}_{ab}^{c}(\hat{s},\hat{p}_T,\hat{\eta},\mu)}{dvdz}J_c(z_c,\omega_J,\mu)$$

Definition similar to FFs
but perturbatively calculable:



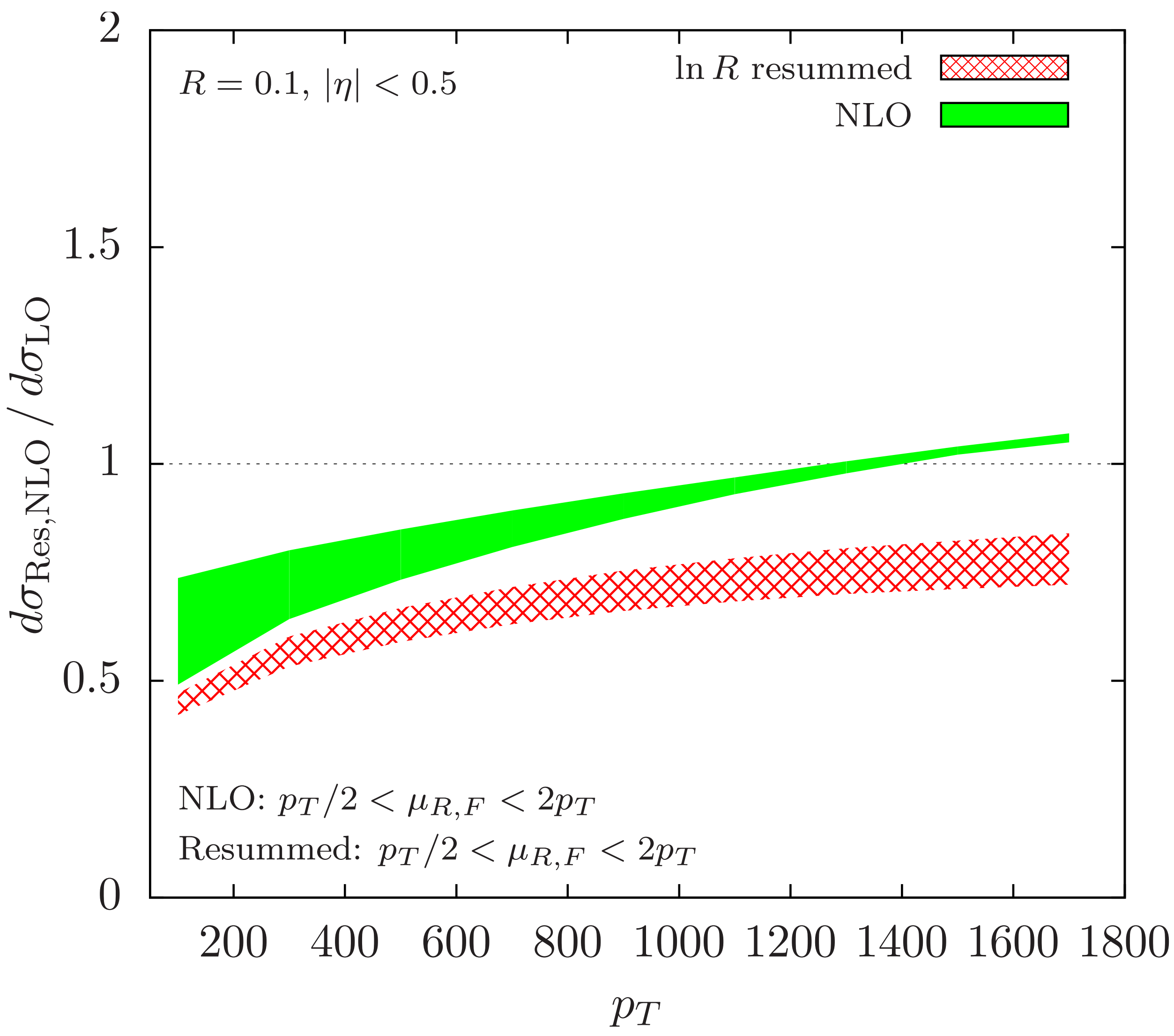
Follows standard timelike DGLAP

$$\mu\frac{d}{d\mu}J_i(z,\omega_J,\mu) = \frac{\alpha_s(\mu)}{\pi}\sum_j\int_z^1\frac{dz'}{z'}P_{ji}\left(\frac{z}{z'},\mu\right)J_j(z',\omega_J,\mu)$$

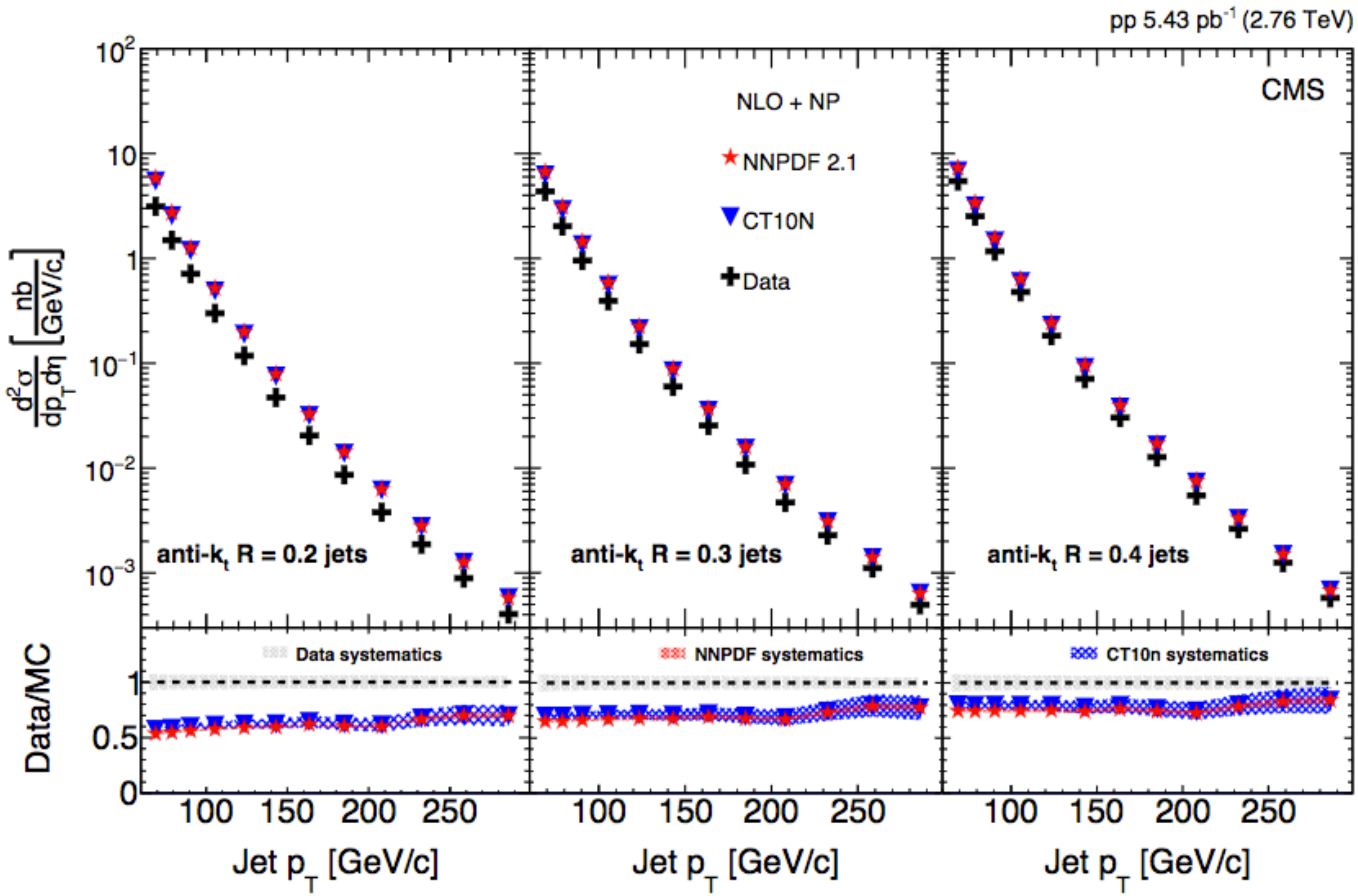
→ resummation of single logarithms $\ln R$, i.e. $\mathrm{NLO}+\mathrm{NLL}_R$

Inclusive Jet Production in SCET $pp \to \text{jet}X$

Kang, FR, Vitev `16, `16



Inclusive Jet Production in SCET $pp \to \text{jet} X$



arXiv:1609.05383

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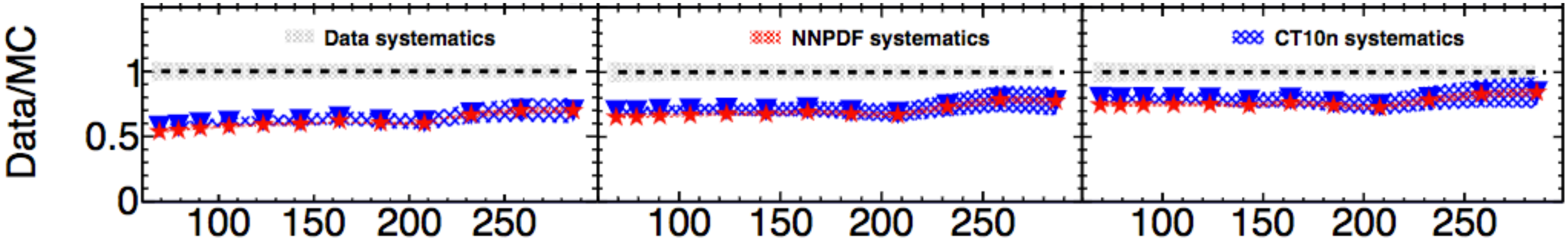
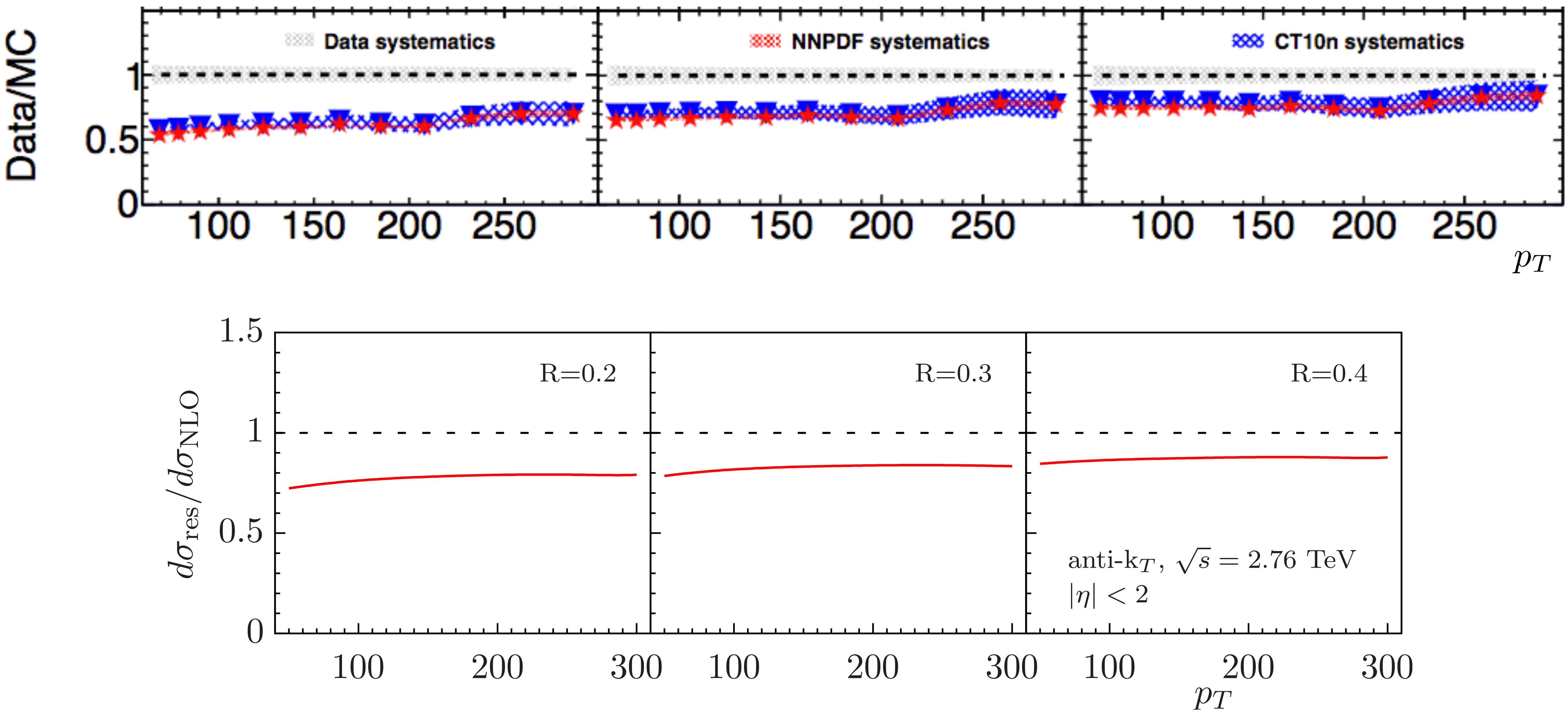
Inclusive Jet Production in SCET $pp \to \text{jet}X$



arXiv:1609.05383

Inclusive Jet Production in SCET $pp \to \mathrm{jet}X$

Kang, FR, Vitev `16, `16



arXiv:1609.05383

Outline

- Introduction
- lepton-proton scattering
- W boson production
- Proton-proton collisions
- Conclusions

Conclusions

- Spin asymmetries can have sizeable corrections from threshold resummation
- Reduction of scale uncertainty
- Subleading $\ln N/N$ corrections can be relevant
- Resummed polarized PDFs
- SCET can provide new insights
- include $\ln R$ resummation for jet observables

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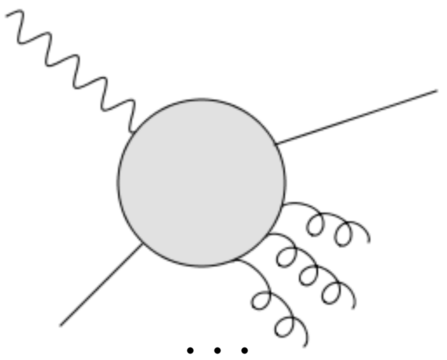
Resummed result



$$\Delta_q^N \sim \exp\left\{h_q^{(1)}(\lambda)\ln\bar{N} + h_q^{(2)}\left(\lambda, \frac{\mu_R}{Q}, \frac{\mu_F}{Q}\right) + \alpha_s(\mu_R)\, h_q^{(3)}\left(\lambda, \frac{\mu_R}{Q}, \frac{\mu_F}{Q}\right)\right\}$$

LL NLL NNLL

$$\lambda = \alpha_s(\mu_R^2) b_0 \ln \bar{N}$$

$$h^{(1)}(\lambda) = \frac{A_q^{(1)}}{2\pi b_0 \lambda}[2\lambda + (1-2\lambda)\ln(1-2\lambda)]$$

$$h^{(2)} = \dots$$

$$h^{(3)} = \dots$$

Catani, Mangano, Nason, Trentadue `96; Vogt `01

$\overline{\mathrm{MS}}$ scheme

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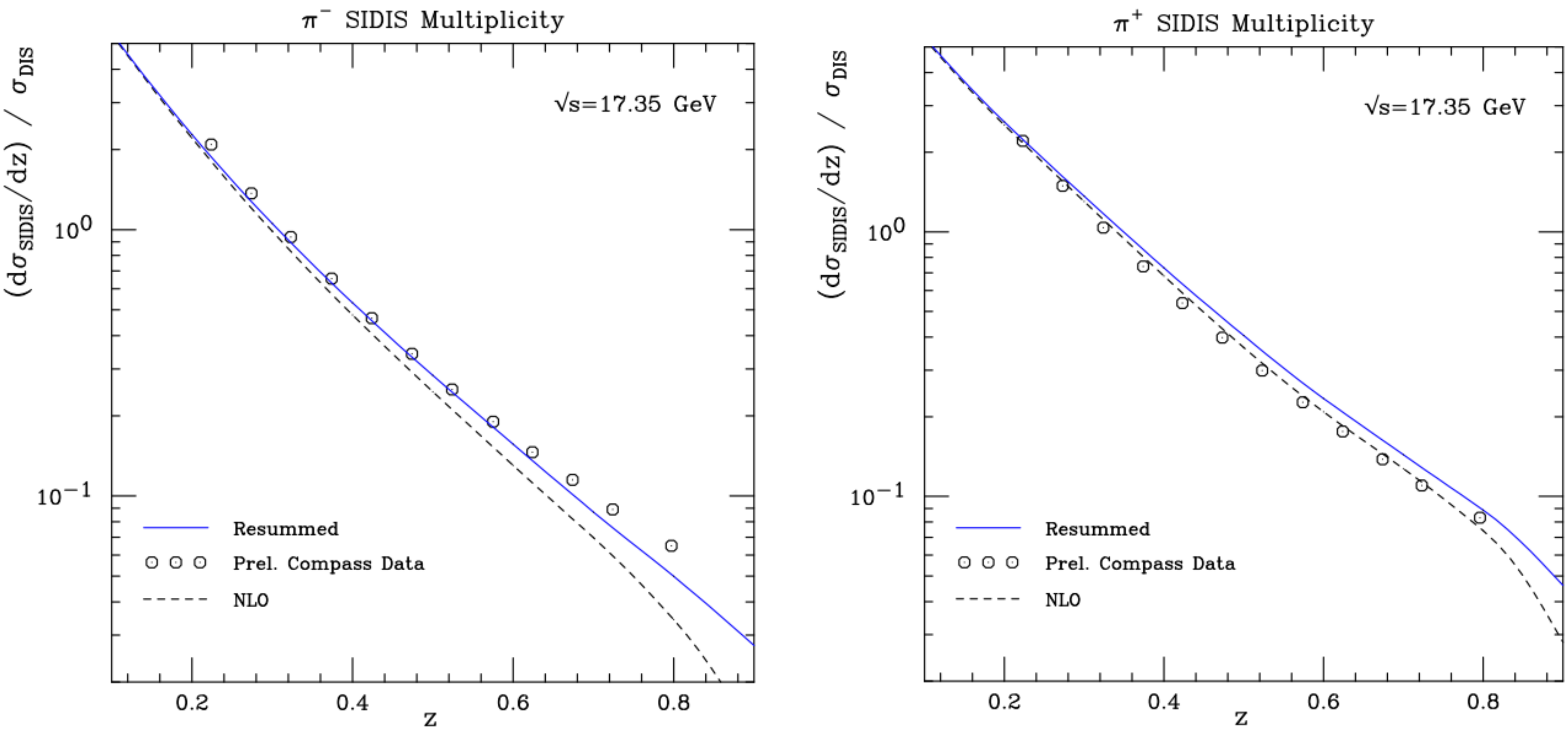
SIDIS $\pi^{\pm}$ multiplicities,
COMPASS data

$0.041 < x < 0.7 \quad Q^2 > 1\,\mathrm{GeV}^2$

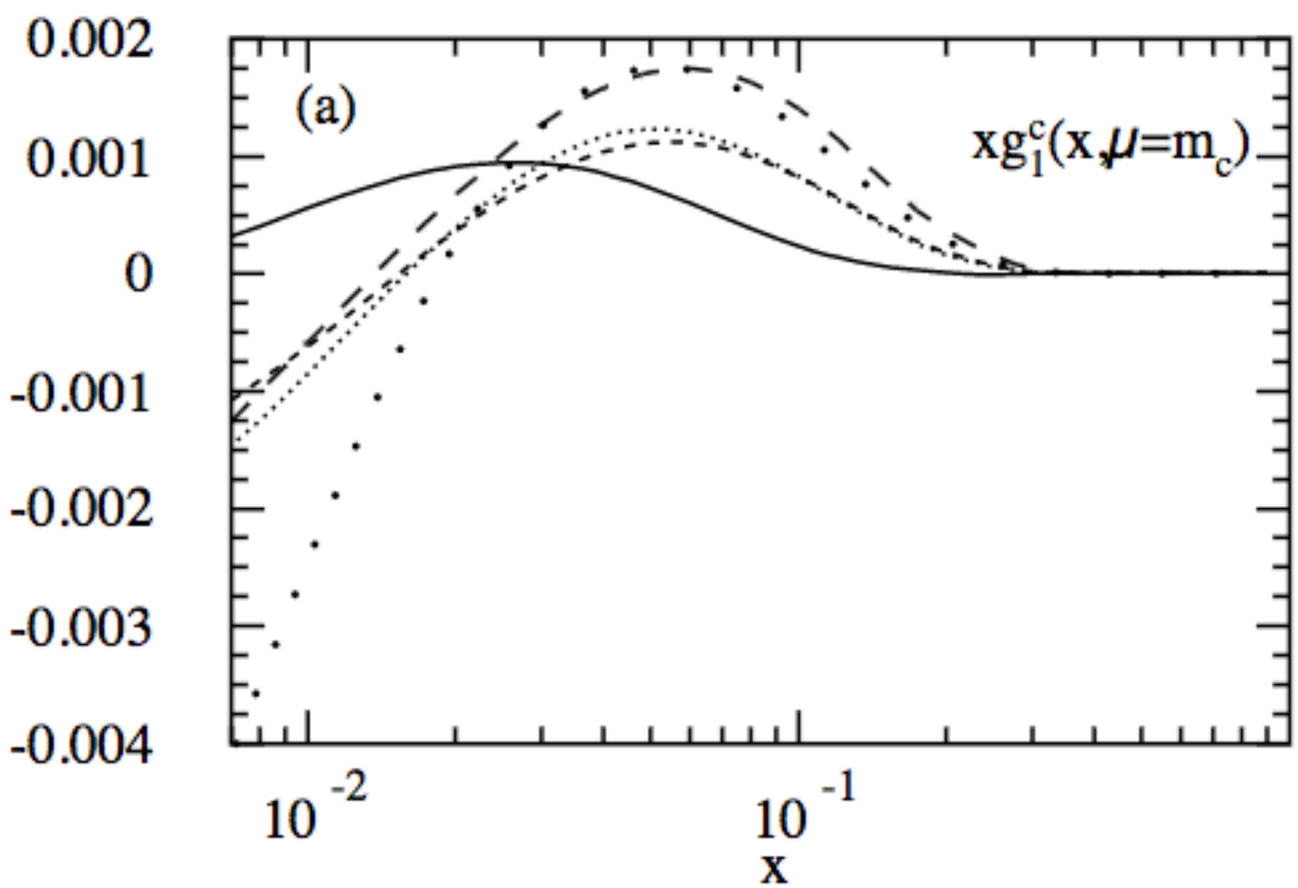
$0.1 < y < 0.9 \quad W^2 > 7\,\mathrm{GeV}^2$



using MSTW'08 PDFs and DSS FFs

Polarized charm structure function

LO, NLO, NNLO using Gehrmann, Stirling `96 PDFs



Eynck, Moch `00

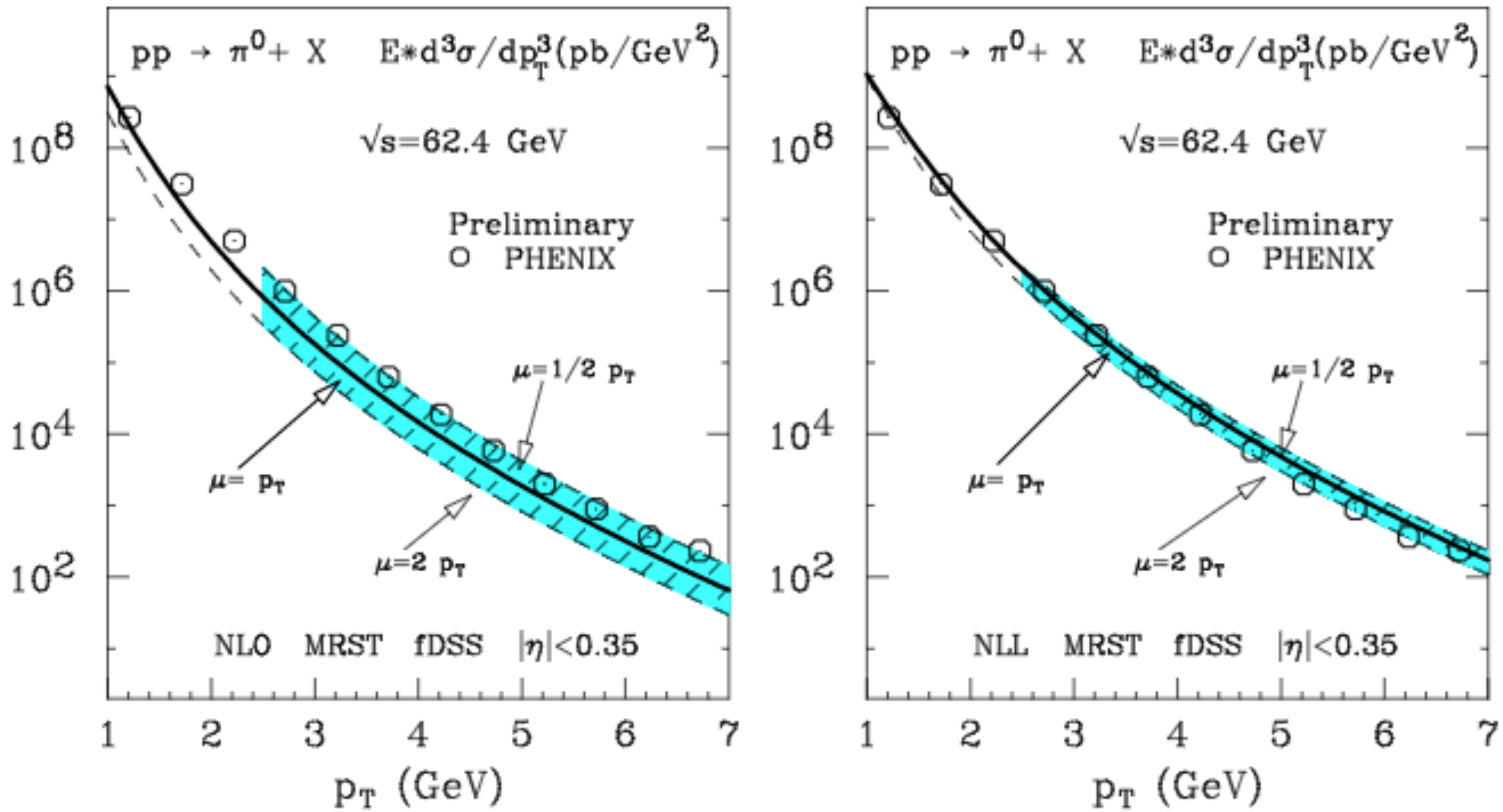
Inclusive hadron and jet production

Rapidity integrated results at NLL

de Florian, Vogelsang `05, de Florian, Vogelsang, Wagner `07, de Florian, Wagner `10

$$\Delta\sigma(N) = \sum_{a,b,c} \Delta f_a(N+1,\mu^2)\,\Delta f_b(N+1,\mu^2)\,D_{h/c}(2N+3,\mu^2)\,\Delta\hat{\sigma}_{ab\to cX}(N)$$

$$\Delta\hat{\sigma}_{ab\to cX}(N) \equiv \int_0^1 d\hat{x}_T^2\,\left(\hat{x}_T^2\right)^{N-1} \int_{\hat{\eta}_-}^{\hat{\eta}_+} d\hat{\eta}\,\frac{\hat{x}_T^4\,\hat{s}}{2}\,\frac{d\Delta\hat{\sigma}_{ab\to cX}(\hat{x}_T^2,\hat{\eta})}{d\hat{x}_T^2\,d\hat{\eta}}$$



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