The Jet Fragmentation Function in pp and ep Collisions

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Zhong-Bo Kang, Ivan Vitev

POETIC and CTEQ meeting, 11/16/16

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Outline

- Inclusive Jet Production
- The Jet Fragmentation Function in pp
- The Jet Fragmentation Function in ep
- Conclusions

Kang, FR, Vitev `16
Kang, FR, Vitev `16
Kang, FR, Vitev - in preparation

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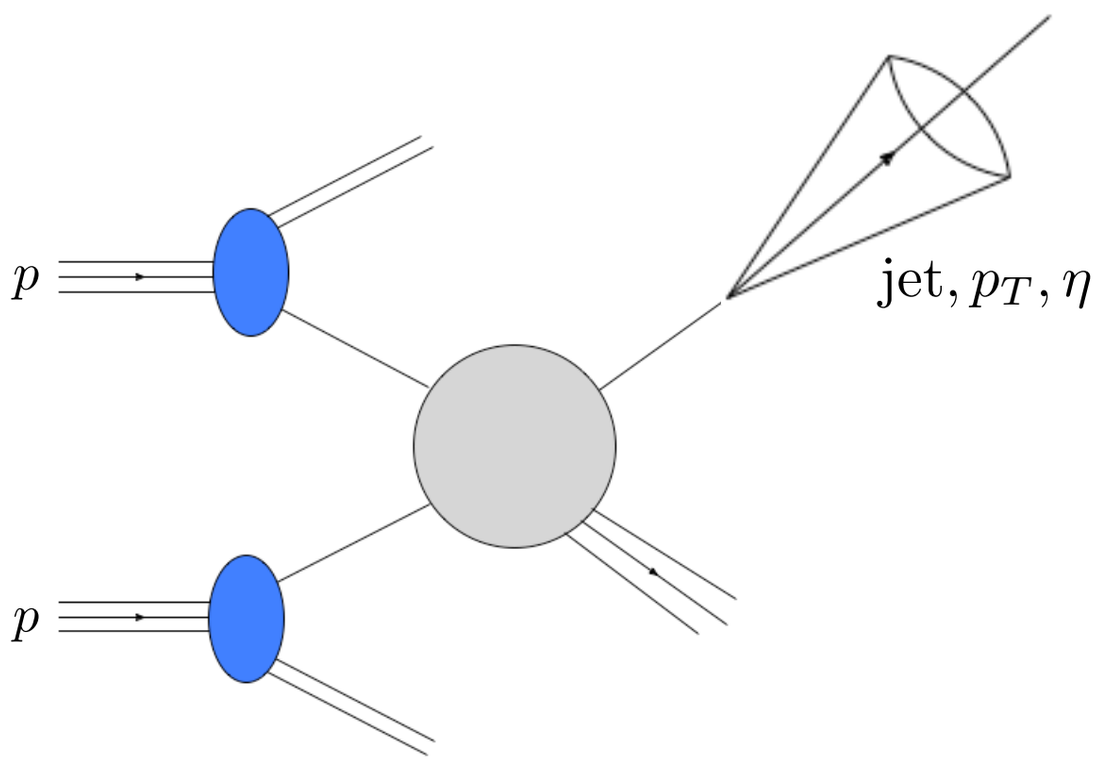
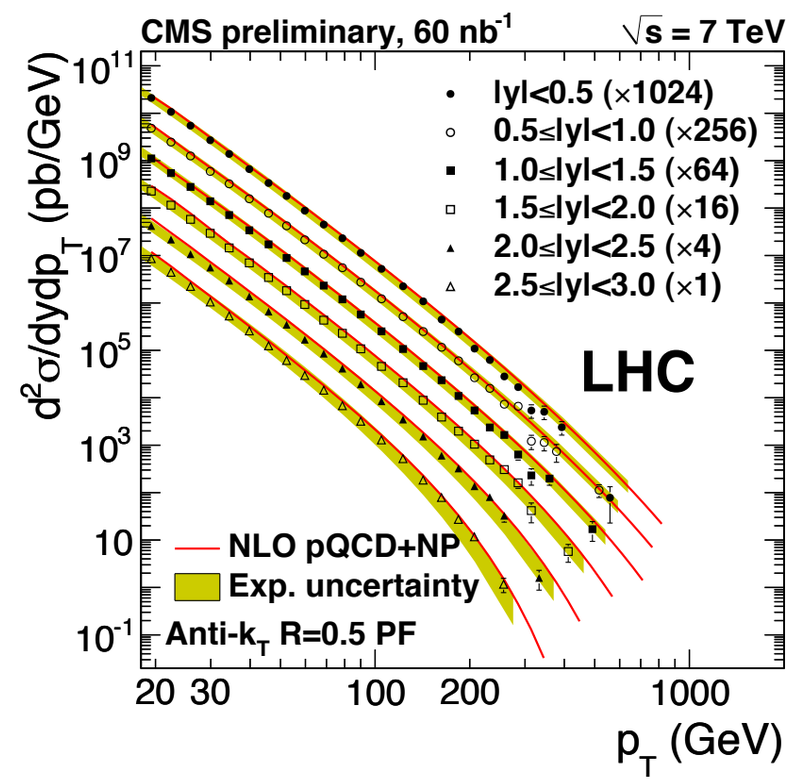
Inclusive Jet Production $pp \to \mathrm{jet}X$

- PDFs are constrained by collider jet data, especially $g(x), \Delta g(x)$
- Determination of α_s
- High p_T jets are a promising observable for the search of BSM physics at the LHC
- Jet quenching studies in AA and eA *see talk by Alberto Accardi and Ivan Vitev*
- Same framework for ee and ep





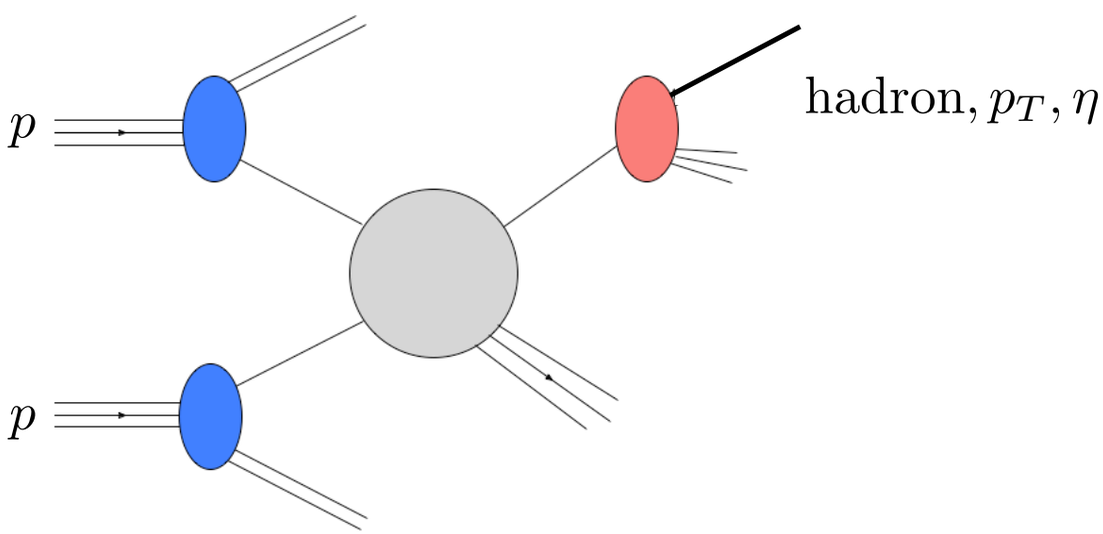
Recall Inclusive Hadron Production $pp \to hX$

Factorization

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

timelike DGLAP for FFs

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



Aversa, Chiappetta, Greco, Guillet `89,
Jäger, Schäfer, Stratmann, Vogelsang `04

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

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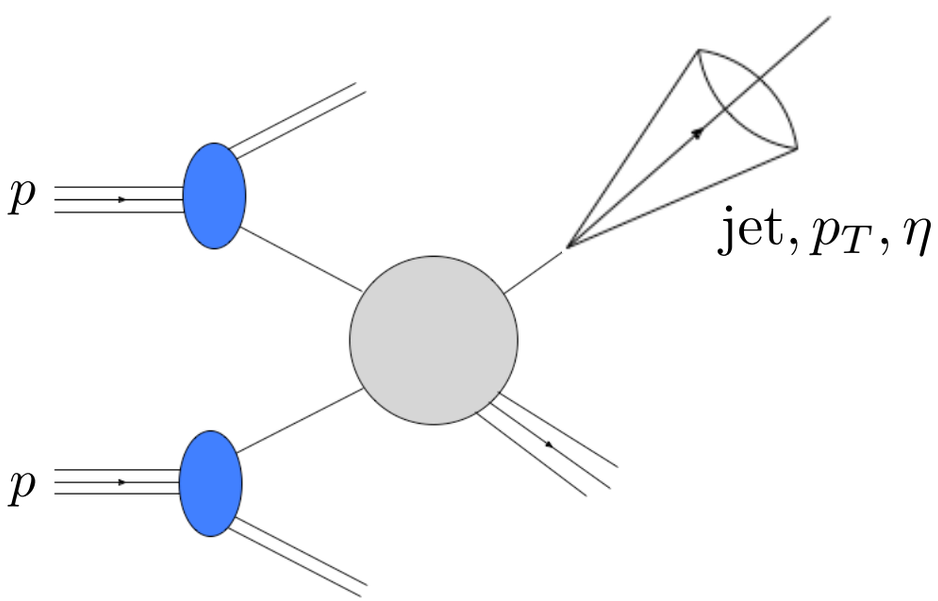
Kang, FR, Vitev `16

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



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

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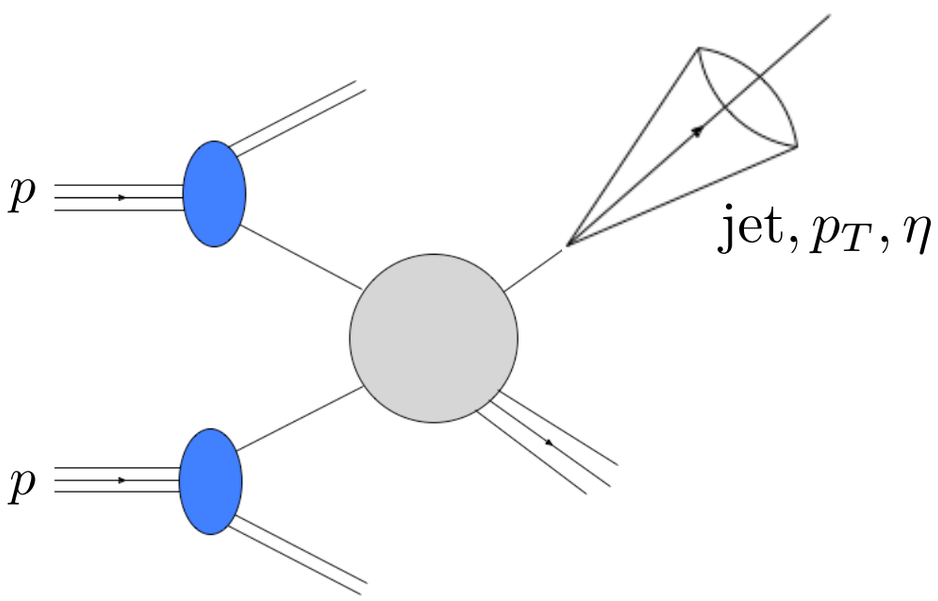
timelike DGLAP for <u>semi-inclusive jet function</u>

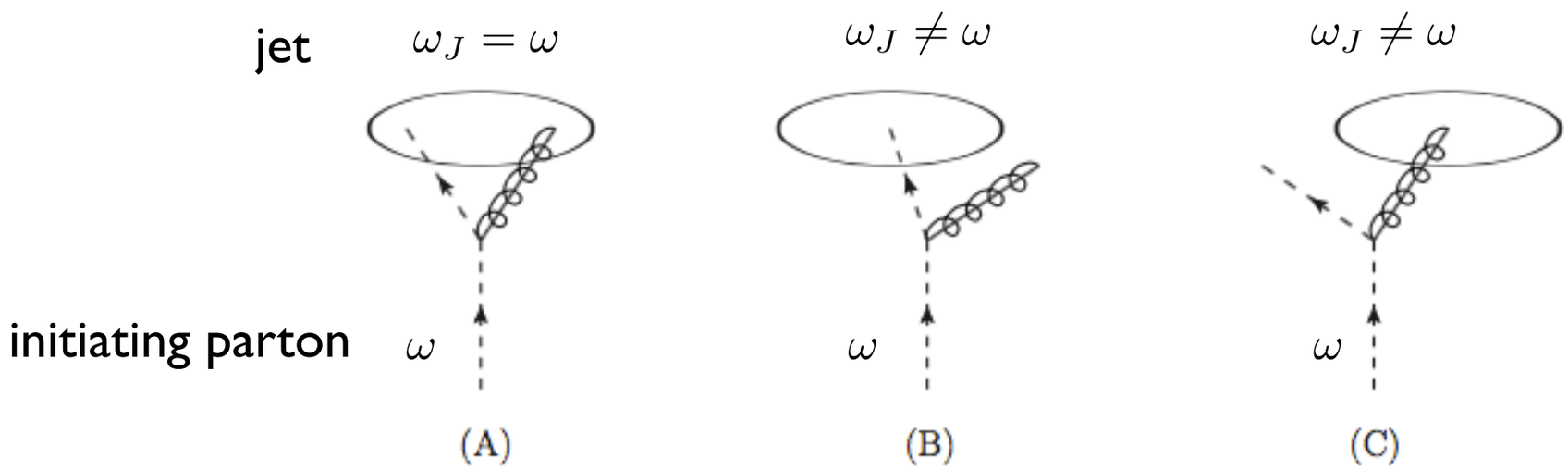
$$\mu\frac{d}{d\mu}J_i(z,\omega_J,\mu) = \frac{\alpha_s(\mu)}{\pi}\sum_j\int_z^1 \frac{dz'}{z'}P_{ji}\left(\frac{z}{z'},\mu\right)J_j(z',\omega_J,\mu)$$



→ resummation of $\sim(\alpha_s \ln R)^n$

Semi-inclusive jet function in SCET at NLO

- The siJF describes how a parton (q or g) is transformed into a jet with radius R and energy fraction z

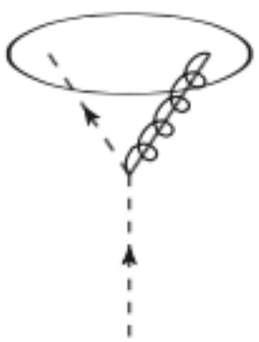


where $z = \omega_J/\omega$

Semi-inclusive jet function in SCET at NLO

$\overline{\mathrm{MS}}$ scheme, $\mathrm{anti\text{-}k_T}$

Leading order $$J_q^{(0)}(z,\omega_J) = \delta(1-z)$$



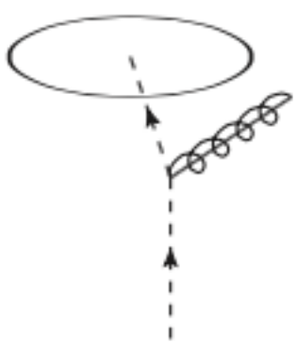
(A)

$$J_q(z,\omega_J) = \delta(1-z)\frac{\alpha_s}{2\pi}C_F\left[\frac{1}{\epsilon^2}+\frac{3}{2\epsilon}+\frac{1}{\epsilon}L+\frac{1}{2}L^2+\frac{3}{2}L+\frac{13}{2}-\frac{3\pi^2}{4}\right]$$

where $$L = \ln\left(\frac{\mu^2}{\omega_J^2\tan^2(R/2)}\right)$$

cf. exclusive jet production

Ellis, Vermilion, Walsh, Hornig, Lee `10



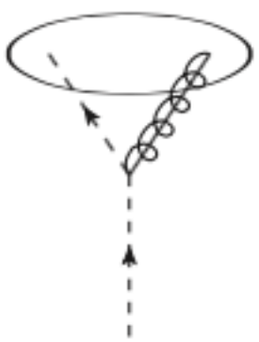
(B)

$$J_q(z,\omega_J) = \frac{\alpha_s}{2\pi}\delta(1-z)\left[-\frac{1}{\epsilon^2}-\frac{1}{\epsilon}L-\frac{1}{2}L^2+\frac{\pi^2}{12}\right] + \frac{\alpha_s}{2\pi}\left[\left(\frac{1}{\epsilon}+L\right)\frac{1+z^2}{(1-z)_+} - 2(1+z^2)\left(\frac{\ln(1-z)}{1-z}\right)_+ - (1-z)\right]$$

Semi-inclusive jet function in SCET at NLO

$\overline{\mathrm{MS}}$ scheme, $\mathrm{anti\text{-}k_T}$

Leading order $\quad J_q^{(0)}(z,\omega_J) = \delta(1-z)$



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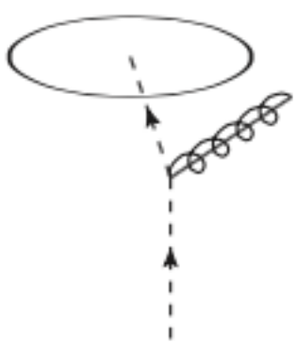

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$\longrightarrow$ only a single logarithmic $\ln R$ remains

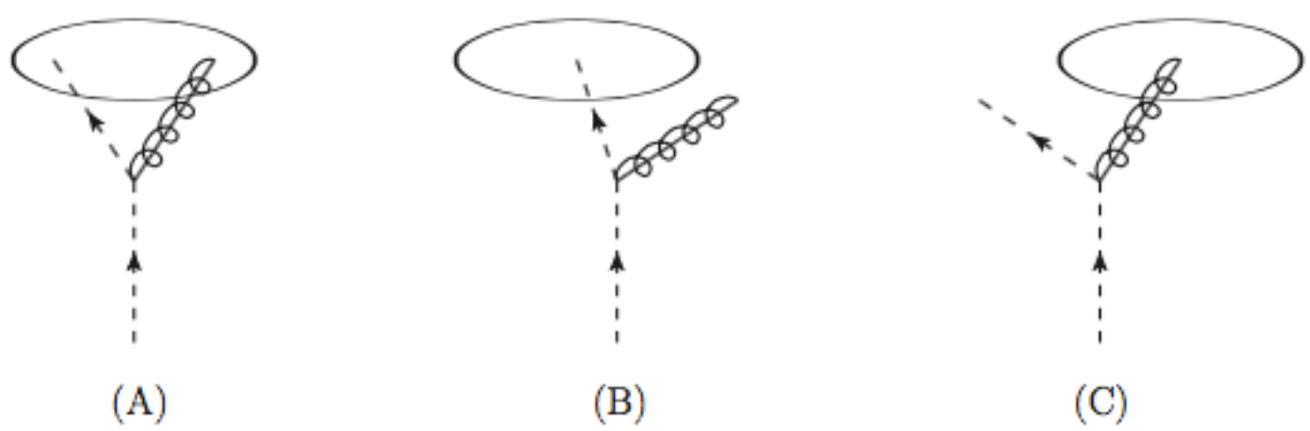
Semi-inclusive jet function in SCET at NLO

$\overline{\mathrm{MS}}$ scheme, $\mathrm{anti\text{-}k_T}$

$$J_q^{(1)}(z,\omega_J) = J_{q\to qg}(z,\omega_J) + J_{q\to q(g)}(z,\omega_J) + J_{q\to (q)g}(z,\omega_J)$$

$$= \frac{\alpha_s}{2\pi}\left(\frac{1}{\epsilon}+L\right)\left[P_{qq}(z)+P_{gq}(z)\right]$$
$$- \frac{\alpha_s}{2\pi}\left\{C_F\left[2\left(1+z^2\right)\left(\frac{\ln(1-z)}{1-z}\right)_+ + (1-z)\right] - \delta(1-z)d_J^{q,\mathrm{alg}}\right.$$
$$\left. + P_{gq}(z)2\ln(1-z) + C_F z\right\}$$

where $d_J^{q,\mathrm{anti\text{-}k_T}} = C_F\left(\frac{13}{2}-\frac{2\pi^2}{3}\right)$



Renormalization and RG evolution

Bare - renormalized semi-inclusive jet function

$$J_{i,\mathrm{bare}}(z,\omega_J) = \sum_j \int_z^1 \frac{dz'}{z'} Z_{ij}\left(\frac{z}{z'},\mu\right) J_j(z',\omega_J,\mu)$$

RG equation

$$\mu\frac{d}{d\mu} J_i(z,\omega_J,\mu) = \sum_j \int_z^1 \frac{dz'}{z'} \gamma_{ij}^J\left(\frac{z}{z'},\mu\right) J_j(z',\omega_J,\mu)$$

Anomalous dimension

$$\gamma_{ij}^J(z,\mu) = -\sum_k \int_z^1 \frac{dz'}{z'} (Z)_{ik}^{-1}\left(\frac{z}{z'},\mu\right) \mu\frac{d}{d\mu} Z_{kj}(z',\mu)$$

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Renormalization and RG evolution

We find

$$\gamma^J_{ij}(z,\mu) = \frac{\alpha_s(\mu)}{\pi} P_{ji}(z)$$

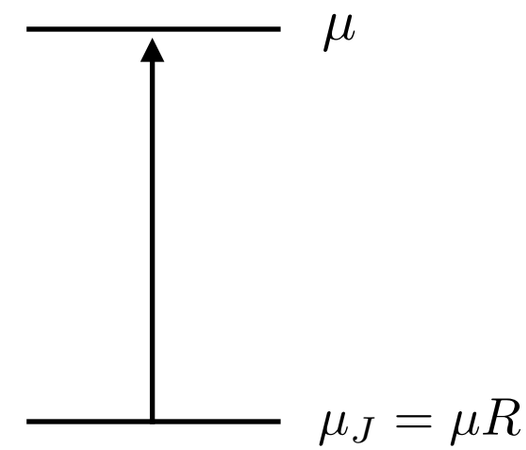
$$\longrightarrow \quad \boxed{\mu \frac{d}{d\mu} J_i(z,\omega_J,\mu) = \frac{\alpha_s(\mu)}{\pi} \sum_j \int_z^1 \frac{dz'}{z'} P_{ji}\left(\frac{z}{z'},\mu\right) J_j(z',\omega_J,\mu)}$$

DGLAP evolution equation like for FFs. Resums single $\ln R$: LL_R, NLL_R

see also
Dasgupta, Dreyer, Salam, Soyez `15, `16

Jet function evolution

$$\frac{d}{d\log\mu^2}\begin{pmatrix} J_S(z,\omega_J,\mu) \\ J_g(z,\omega_J,\mu)\end{pmatrix} = \frac{\alpha_s(\mu)}{2\pi}\begin{pmatrix} P_{qq}(z) & 2N_f P_{gq}(z) \\ P_{qg}(z) & P_{gg}(z)\end{pmatrix} \otimes \begin{pmatrix} J_S(z,\omega_J,\mu) \\ J_g(z,\omega_J,\mu)\end{pmatrix}$$



initial condition contains distributions in $1-z$

where $$J_S(z,\omega_J,\mu) = \sum_{q,\bar{q}} J_q(z,\omega_J,\mu) = 2N_f J_q(z,\omega_J,\mu)$$ (singlet jet function)

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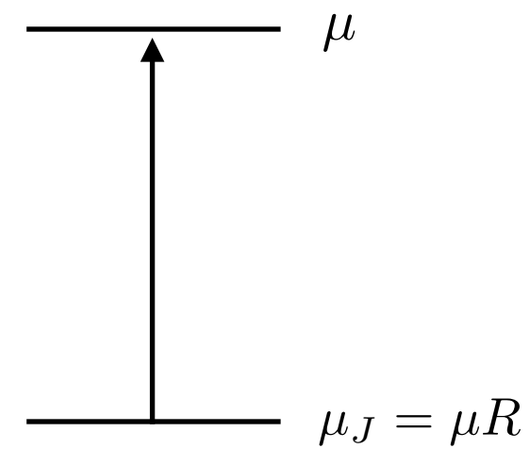

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solve in Mellin space: $$f(N) = \int_0^1 dz\, z^{N-1} f(z)$$

$$(f\otimes g)(N) = f(N)\, g(N)$$

Jet function evolution

solve in Mellin space to LL_R

$$\begin{pmatrix} J_S(N,\omega_J,\mu) \\ J_g(N,\omega_J,\mu) \end{pmatrix} = \left[e_+(N) \left(\frac{\alpha_s(\mu)}{\alpha_s(\mu_J)} \right)^{-r_-(N)} + e_-(N) \left(\frac{\alpha_s(\mu)}{\alpha_s(\mu_J)} \right)^{-r_+(N)} \right] \begin{pmatrix} J_S(N,\omega_J,\mu_J) \\ J_g(N,\omega_J,\mu_J) \end{pmatrix}$$

where $$e_\pm(N) = \frac{1}{r_\pm(N) - r_\mp(N)} \begin{pmatrix} P_{qq}(N) - r_\mp(N) & 2N_f P_{gq}(N) \\ P_{qg}(N) & P_{gg}(N) - r_\mp(N) \end{pmatrix}$$

$$r_\pm(N) = \frac{1}{2\beta_0} \left[P_{qq}(N) + P_{gg}(N) \pm \sqrt{(P_{qq}(N) - P_{gg}(N))^2 + 4P_{qg}(N)P_{gq}(N)} \right]$$

see
Vogt `04 (Pegasus),
Anderle, FR, Stratmann `15

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Jet function evolution

solve in Mellin space to LL_R

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see
Vogt `04 (Pegasus),
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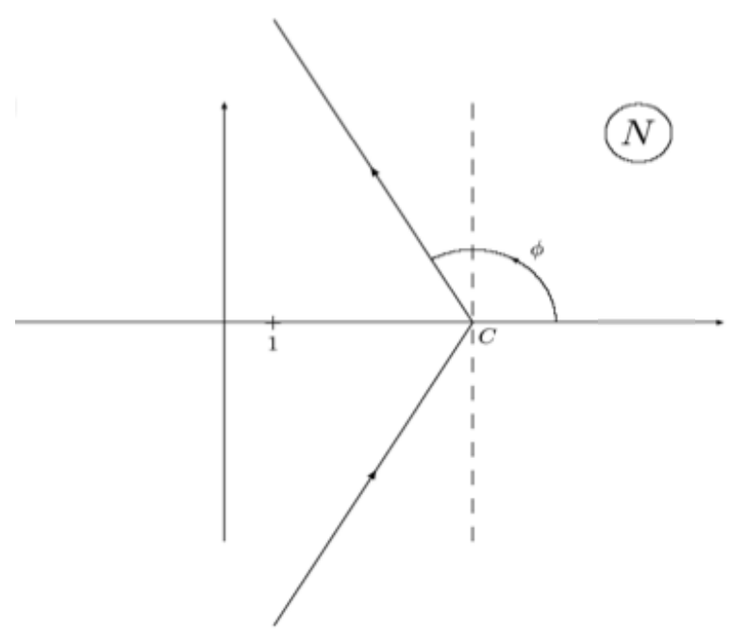
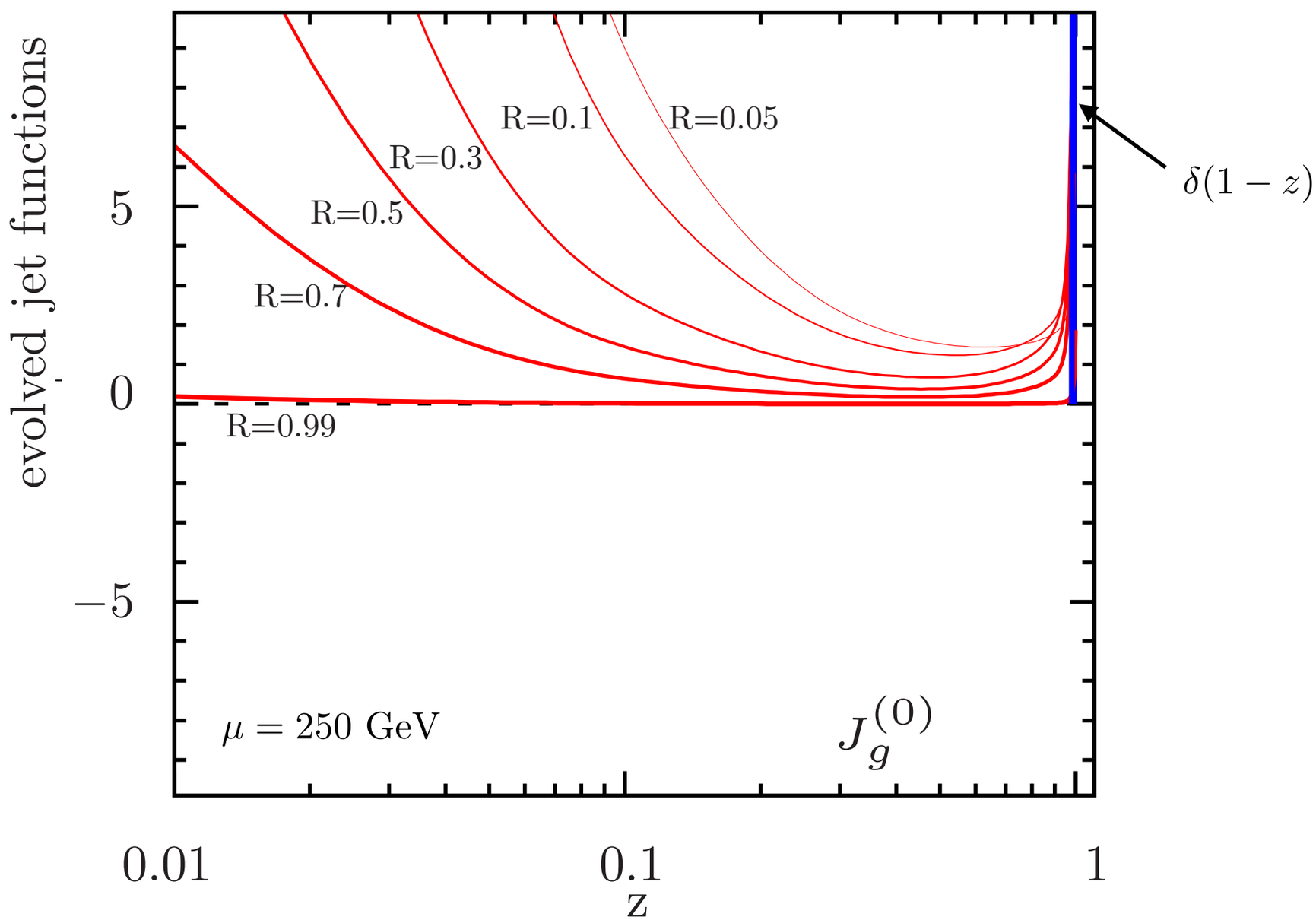
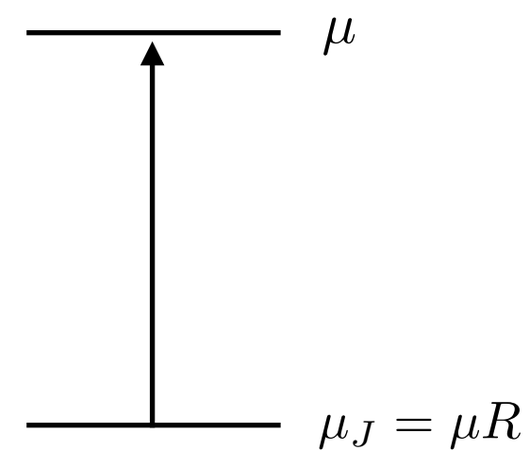
Mellin inverse

$$J_{S,g}(z,\omega_J,\mu) = \frac{1}{2\pi i} \int_{\mathcal{C}_N} dN\, z^{-N} J_{S,g}(N,\omega_J,\mu)$$





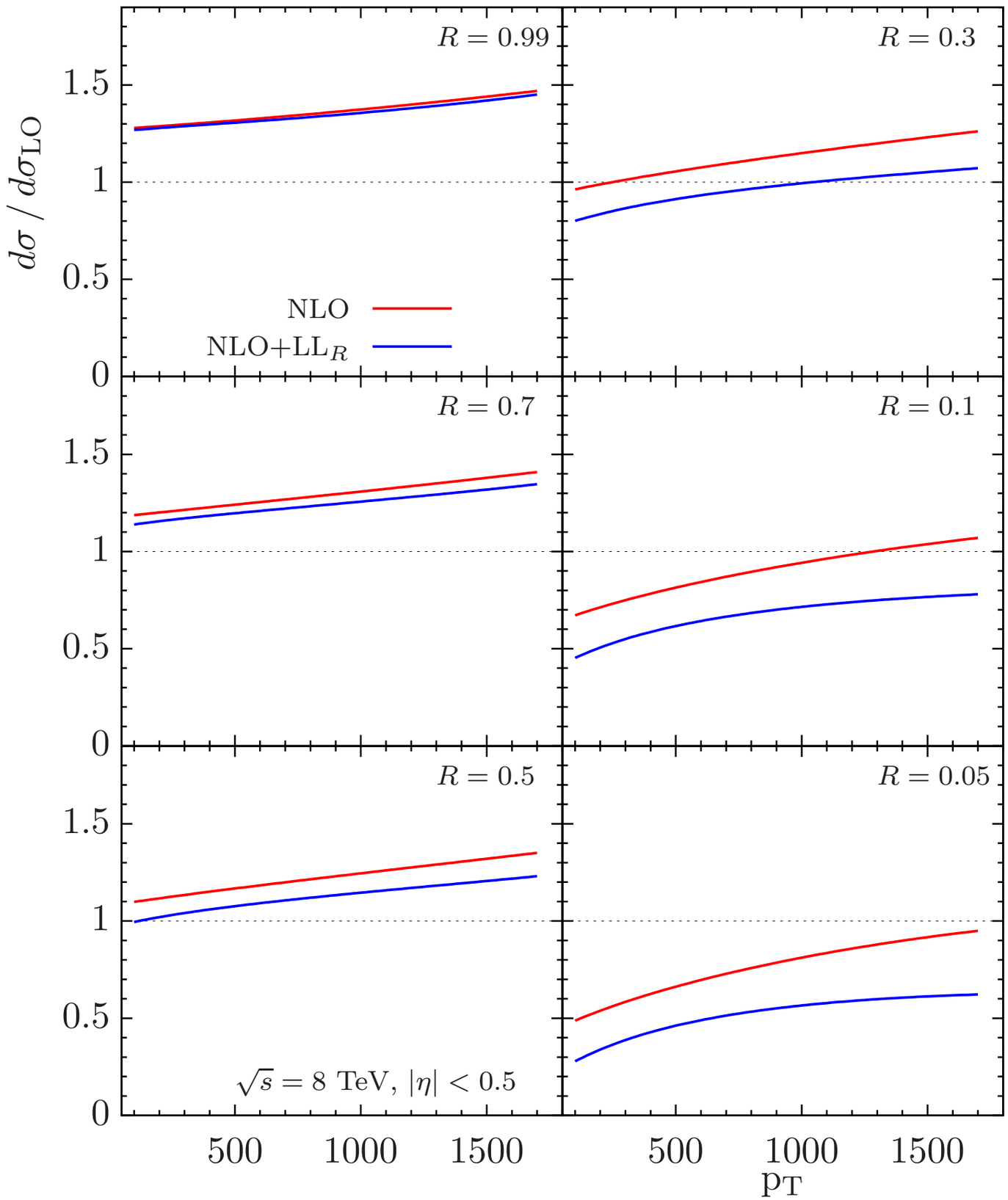
LL_R DGLAP evolution



see
Vogt `04 (Pegasus),
Anderle, FR, Stratmann `15

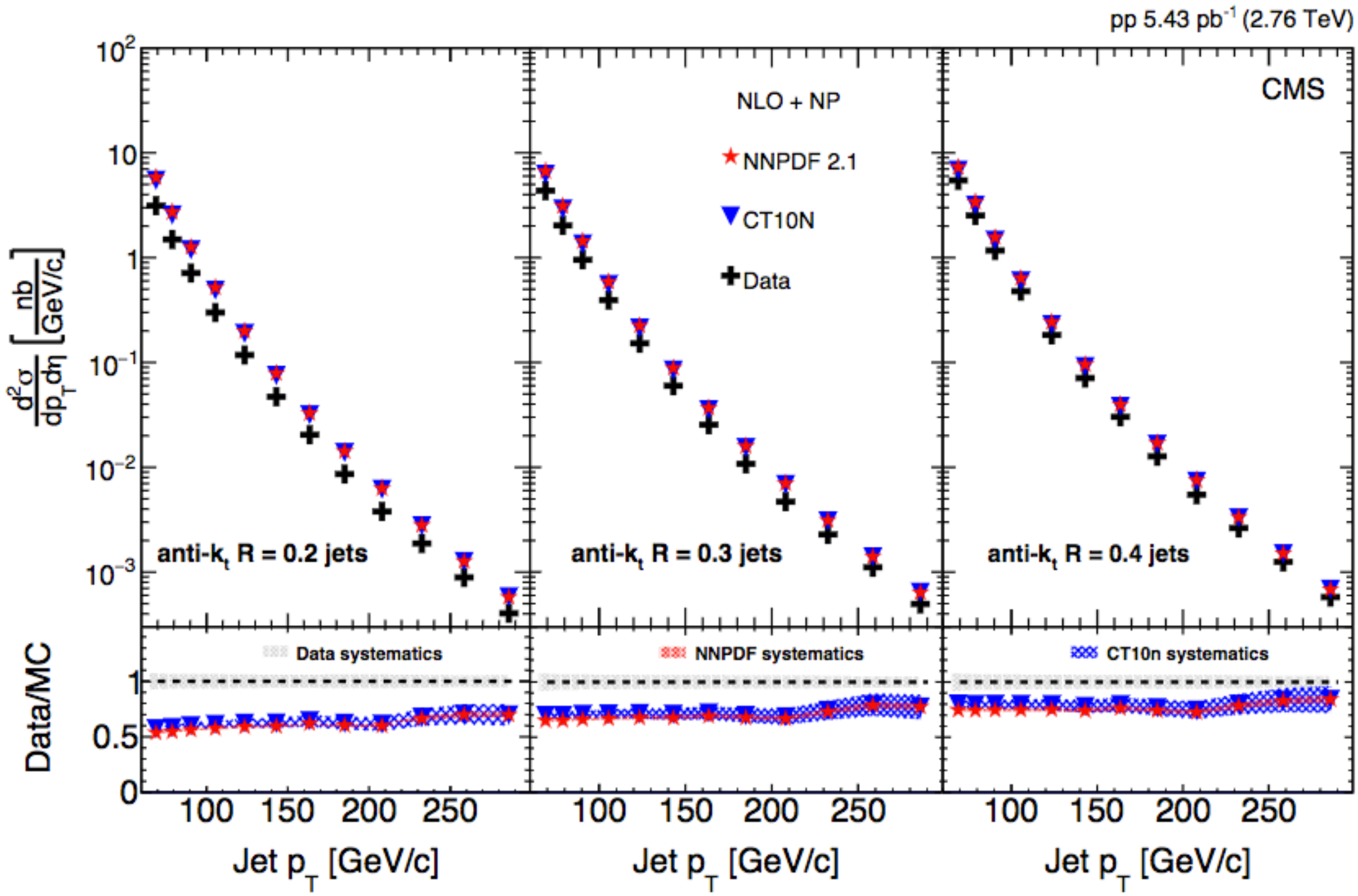
→ Adopt a prescription used for quarkonium fragmentation functions

Bodwin, Chao, Chung, Kim, Lee, Ma `16



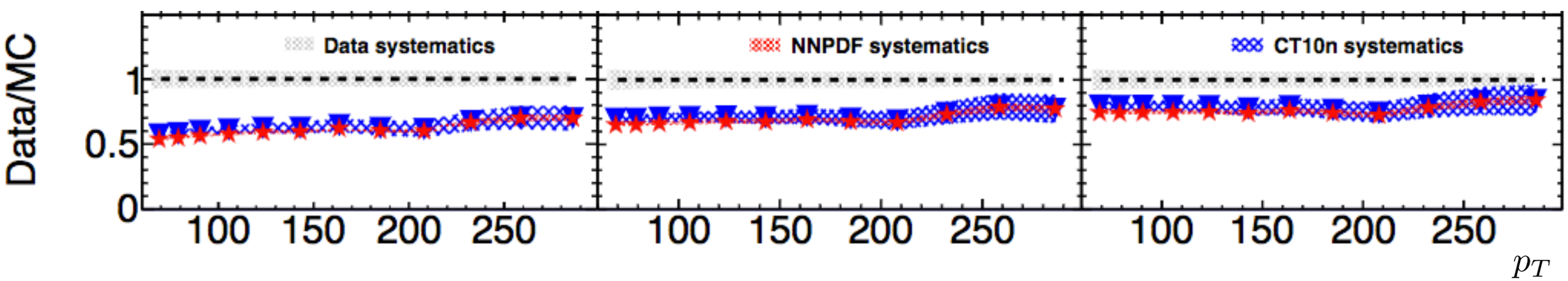
LL_R DGLAP evolution

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



arXiv:1609.05383

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



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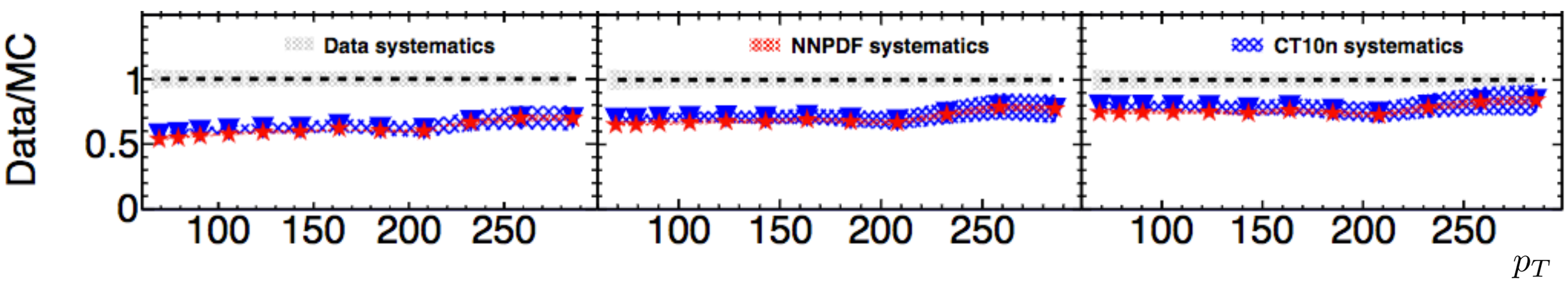
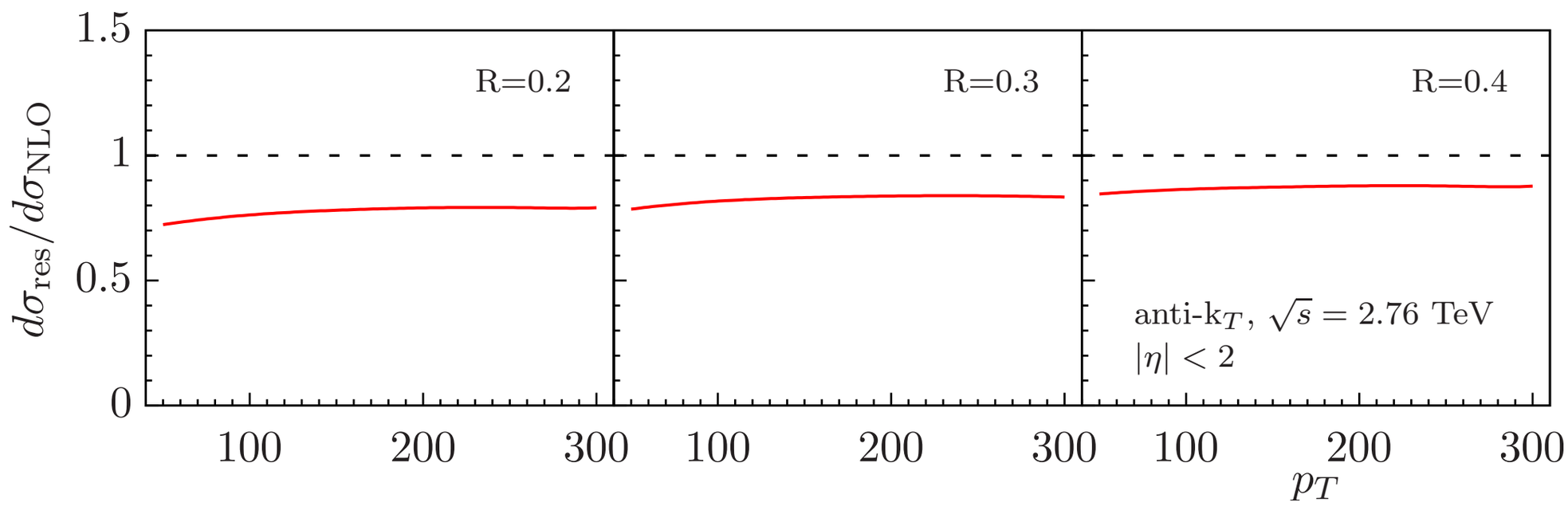
Inclusive Jet Production in SCET $pp \to \mathrm{jet}X$





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- Conclusions

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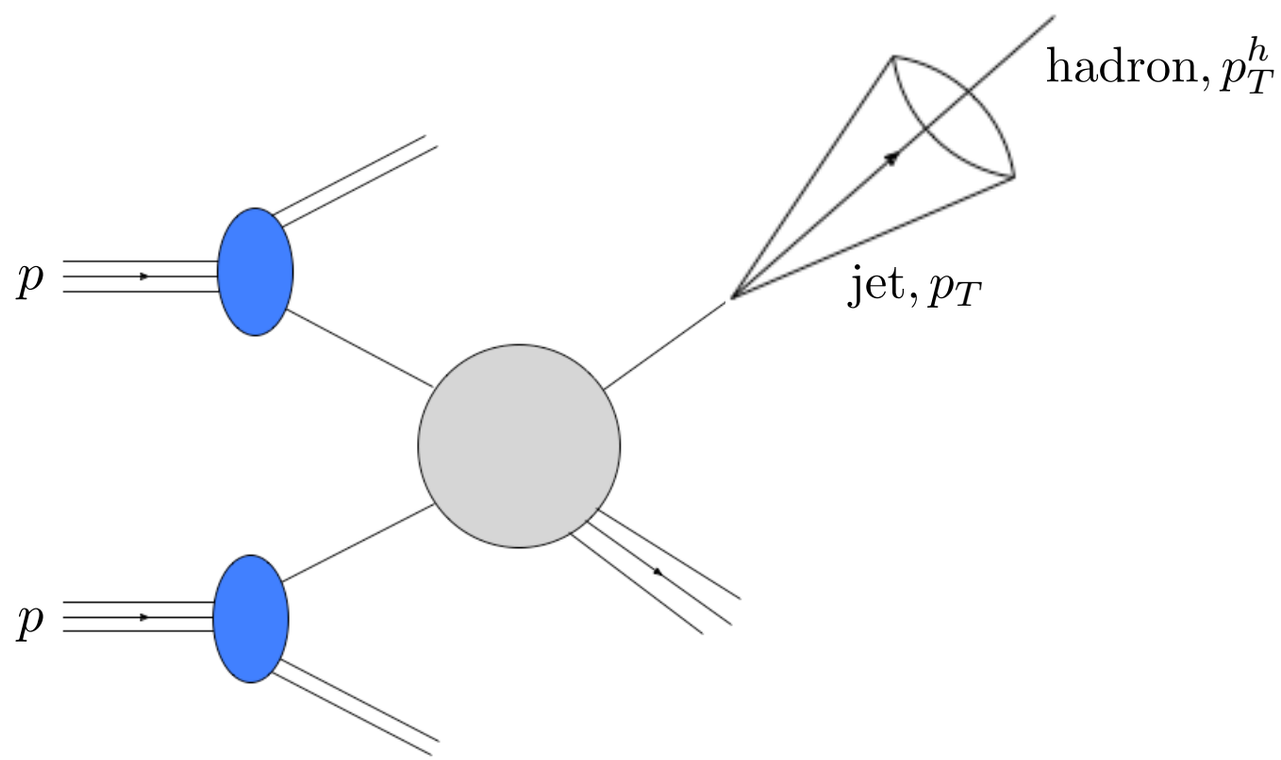
Jet fragmentation function $pp \to (\mathrm{jet}h)X$

- Jet substructure observable studying the distribution of hadrons inside a jet

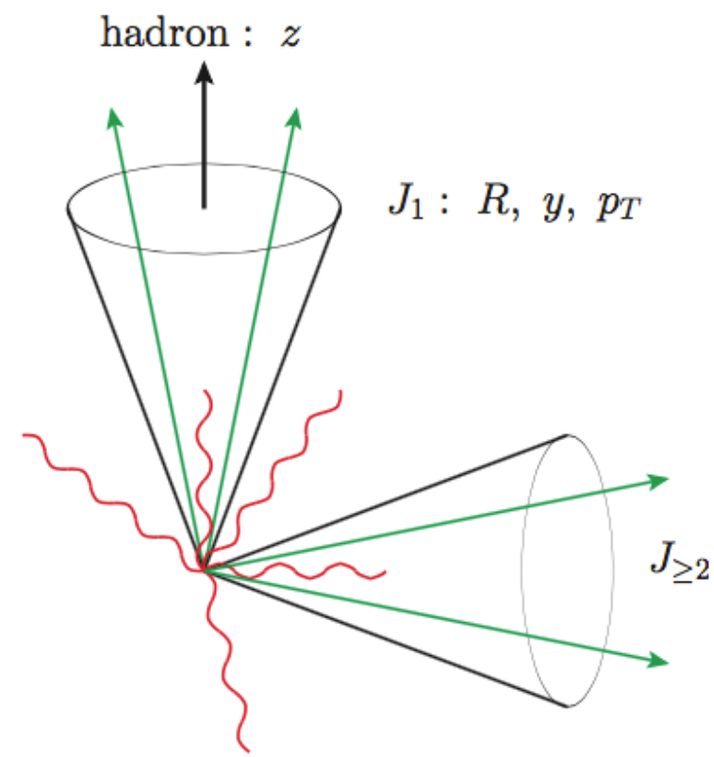
- Provides further constraints for fits of fragmentation functions
- Possible studies include spin correlations and
- Differential probe for the modification of jets in AA and eA *see talk by Ivan Vitev*



Jet fragmentation function

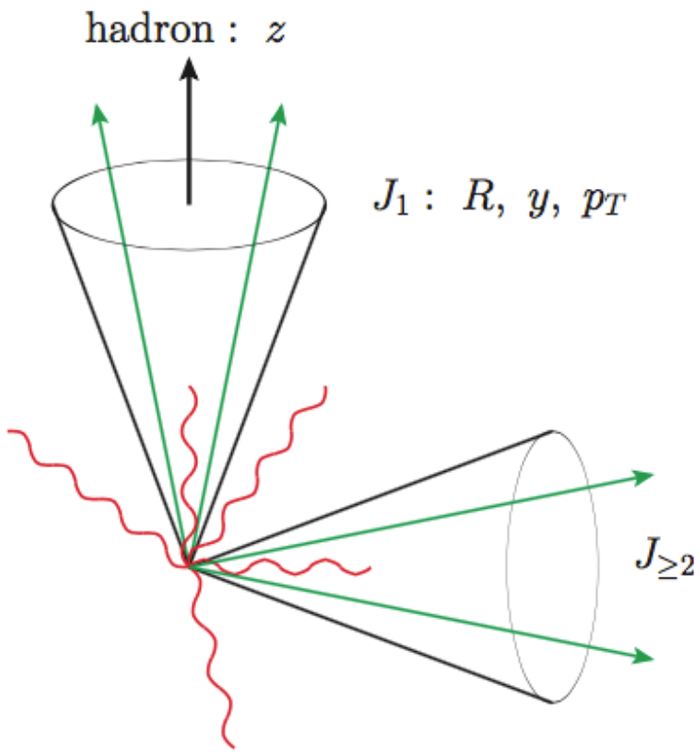
Definition: $$F(z, p_T) = \frac{d\sigma^h}{dy dp_T dz} \Big/ \frac{d\sigma}{dy dp_T}$$

where $$z \equiv p_T^h / p_T$$



It describes the longitudinal momentum distribution of hadrons inside a reconstructed jet

Jet fragmentation function in pp



- Fragmenting jet function studies within SCET

  Procura, Stewart `10; Liu `11; Jain, Procura, Waalewijn `11 and '12; Procura, Waalewijn `12; Bauer, Mereghetti `14; Baumgart, Leibovich, Mehen, Rothstein `14, Chien, Kang, FR, Vitev, Xing `15, Bain, Dai, Hornig, Leibovich, Makris, Mehen `16, Bain, Makris, Mehen `16 …

- Jet fragmentation function studies at NLO for pp

  Arleo, Fontannaz, Guillet, Nguyen `14, Kaufmann, Mukherjee, Vogelsang `15

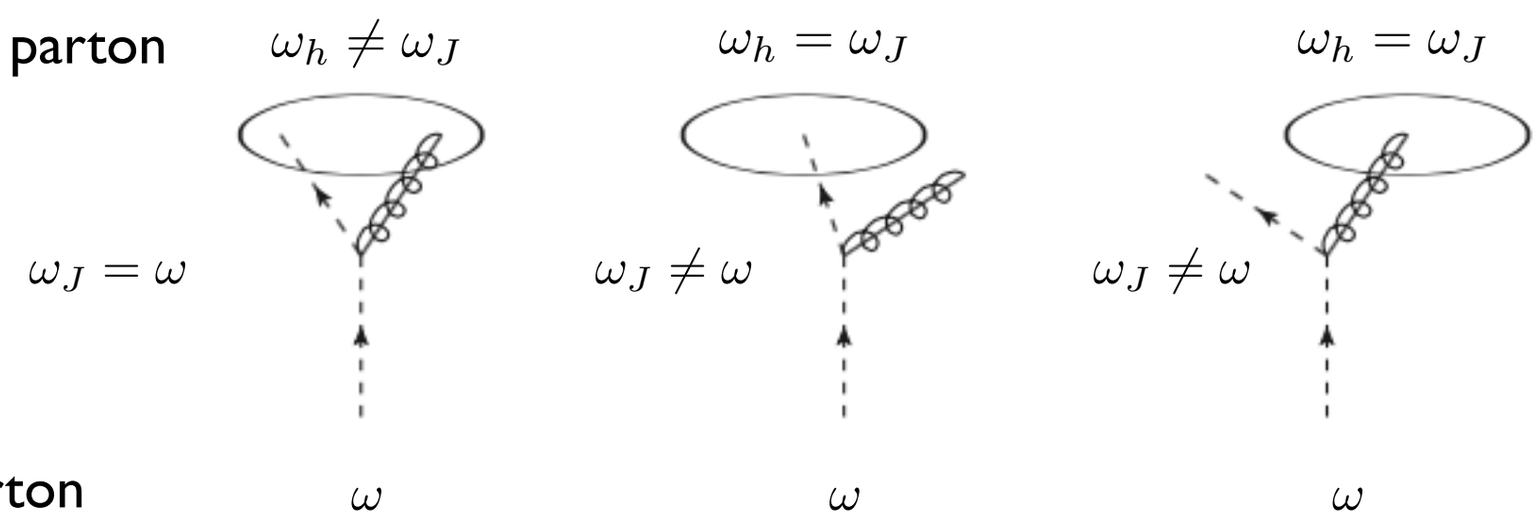
Semi-inclusive fragmenting jet function

$\mathcal{G}_q(z, z_h, \omega_J)$ where $z = \frac{\omega_J}{\omega}, \quad z_h = \frac{\omega_h}{\omega_J}$

Leading-order, e.g. $\mathcal{G}_q^{q,(0)}(z, z_h, \omega_J) = \delta(1-z)\delta(1-z_h)$

NLO

- fragmenting parton
- jet
- initiating parton



Semi-inclusive jet function

quark-quark:

IR

UV

$$\mathcal{G}^q_{q,\mathrm{bare}}(z,z_h,\omega_J,\mu) = \delta(1-z)\delta(1-z_h) + \frac{\alpha_s}{2\pi}\left(-\frac{1}{\epsilon} - L\right)P_{qq}(z_h)\delta(1-z)$$
$$+ \frac{\alpha_s}{2\pi}\left(\frac{1}{\epsilon} + L\right)P_{qq}(z)\delta(1-z_h)$$
$$+ \delta(1-z)\frac{\alpha_s}{2\pi}\left[2C_F(1+z_h^2)\left(\frac{\ln(1-z_h)}{1-z_h}\right)_+ + C_F(1-z_h) + 2P_{qq}(z_h)\ln z_h\right]$$
$$- \delta(1-z_h)\frac{\alpha_s}{2\pi}\left[2C_F(1+z^2)\left(\frac{\ln(1-z)}{1-z}\right)_+ + C_F(1-z)\right],$$

$\overline{\mathrm{MS}}$ scheme, $\mathrm{anti}-k_T$

Renormalization and RG evolution

Bare - renormalized:

$$\mu\frac{d}{d\mu}\mathcal{G}_i^j(z,z_h,\omega_J,\mu)=\sum_j\int_z^1\frac{dz'}{z'}\gamma_{ik}^{\mathcal{G}}\left(\frac{z}{z'},\mu\right)\mathcal{G}_k^j(z',z_h,\omega_J,\mu)$$

where

$$\gamma_{ij}^{\mathcal{G}}(z,\mu)=\frac{\alpha_s(\mu)}{\pi}P_{ji}(z)$$

$$\mu\frac{d}{d\mu}\mathcal{G}_i(z,z_h,\omega_J,\mu)=\frac{\alpha_s(\mu)}{\pi}\sum_j\int_z^1\frac{dz'}{z'}P_{ji}\left(\frac{z}{z'}\right)\mathcal{G}_j(z',z_h,\omega_J,\mu)$$

… same DGLAP RG equations as before, resums $\ln R$

$$\longrightarrow\quad\frac{d}{d\log\mu^2}\begin{pmatrix}\mathcal{G}_S^h(z,z_h,\omega_J,\mu)\\ \mathcal{G}_g^h(z,z_h,\omega_J,\mu)\end{pmatrix}=\frac{\alpha_s(\mu)}{2\pi}\begin{pmatrix}P_{qq}(z) & 2N_fP_{gq}(z)\\ P_{qg}(z) & P_{gg}(z)\end{pmatrix}\otimes\begin{pmatrix}\mathcal{G}_S^h(z,z_h,\omega_J,\mu)\\ \mathcal{G}_g^h(z,z_h,\omega_J,\mu)\end{pmatrix}$$

+ non-singlet evolution

Matching

- onto standard collinear fragmentation functions

$$\mathcal{G}_i^h(z, z_h, \omega_J, \mu) = \sum_j \int_{z_h}^1 \frac{dz_h'}{z_h'} \mathcal{J}_{ij}\left(z, z_h', \omega_J, \mu\right) D_j^h\left(\frac{z_h}{z_h'}, \mu\right)$$

FFs:

$$D_i^j(z,\mu) = \delta_{ij}\delta(1-z) + \frac{\alpha_s}{2\pi} P_{ji}(z)\left(-\frac{1}{\epsilon}\right)$$

$$\begin{aligned}\mathcal{J}_{qq}(z, z_h, \omega_J, \mu) = \delta(1-z)\delta(1-z_h) + \frac{\alpha_s}{2\pi}\Bigg\{ & L\left[P_{qq}(z)\delta(1-z_h) - P_{qq}(z_h)\delta(1-z)\right] \\ & + \delta(1-z)\left[2C_F(1+z_h^2)\left(\frac{\ln(1-z_h)}{1-z_h}\right)_+ + C_F(1-z_h) + \mathcal{I}_{qq}^{\rm alg}(z_h)\right] \\ & - \delta(1-z_h)\left[2C_F(1+z^2)\left(\frac{\ln(1-z)}{1-z}\right)_+ + C_F(1-z)\right]\Bigg\},\end{aligned}$$

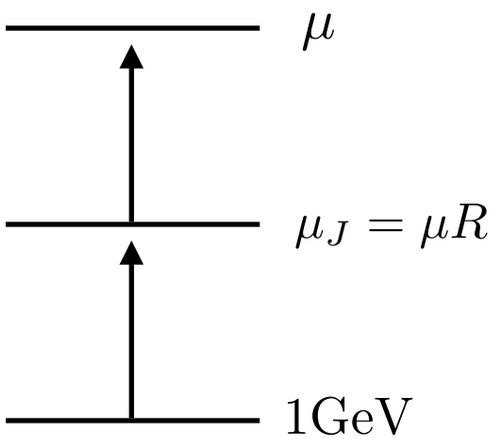
$\overline{\rm MS}$ scheme, $\mathrm{anti}{-}k_T$

⟶ Full agreement with standard pQCD result *Kaufmann, Mukherjee, Vogelsang `15*

Matching

- onto standard collinear fragmentation functions

$$\mathcal{G}_i^h(z, z_h, \omega_J, \mu) = \sum_j \int_{z_h}^1 \frac{dz_h'}{z_h'} \mathcal{J}_{ij}\left(z, z_h', \omega_J, \mu\right) D_j^h\left(\frac{z_h}{z_h'}, \mu\right)$$



FFs:

$$D_i^j(z, \mu) = \delta_{ij}\delta(1-z) + \frac{\alpha_s}{2\pi} P_{ji}(z)\left(-\frac{1}{\epsilon}\right)$$

… 2 DGLAPs now

$$\begin{aligned}\mathcal{J}_{qq}(z, z_h, \omega_J, \mu) = \delta(1-z)\delta(1-z_h) + \frac{\alpha_s}{2\pi}\Bigg\{ & L\left[P_{qq}(z)\delta(1-z_h) - P_{qq}(z_h)\delta(1-z)\right] \\ & + \delta(1-z)\left[2C_F(1+z_h^2)\left(\frac{\ln(1-z_h)}{1-z_h}\right)_+ + C_F(1-z_h) + \mathcal{I}_{qq}^{\text{alg}}(z_h)\right] \\ & - \delta(1-z_h)\left[2C_F(1+z^2)\left(\frac{\ln(1-z)}{1-z}\right)_+ + C_F(1-z)\right]\Bigg\},\end{aligned}$$

$\overline{\text{MS}}$ scheme, $\text{anti}-k_T$

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Matching

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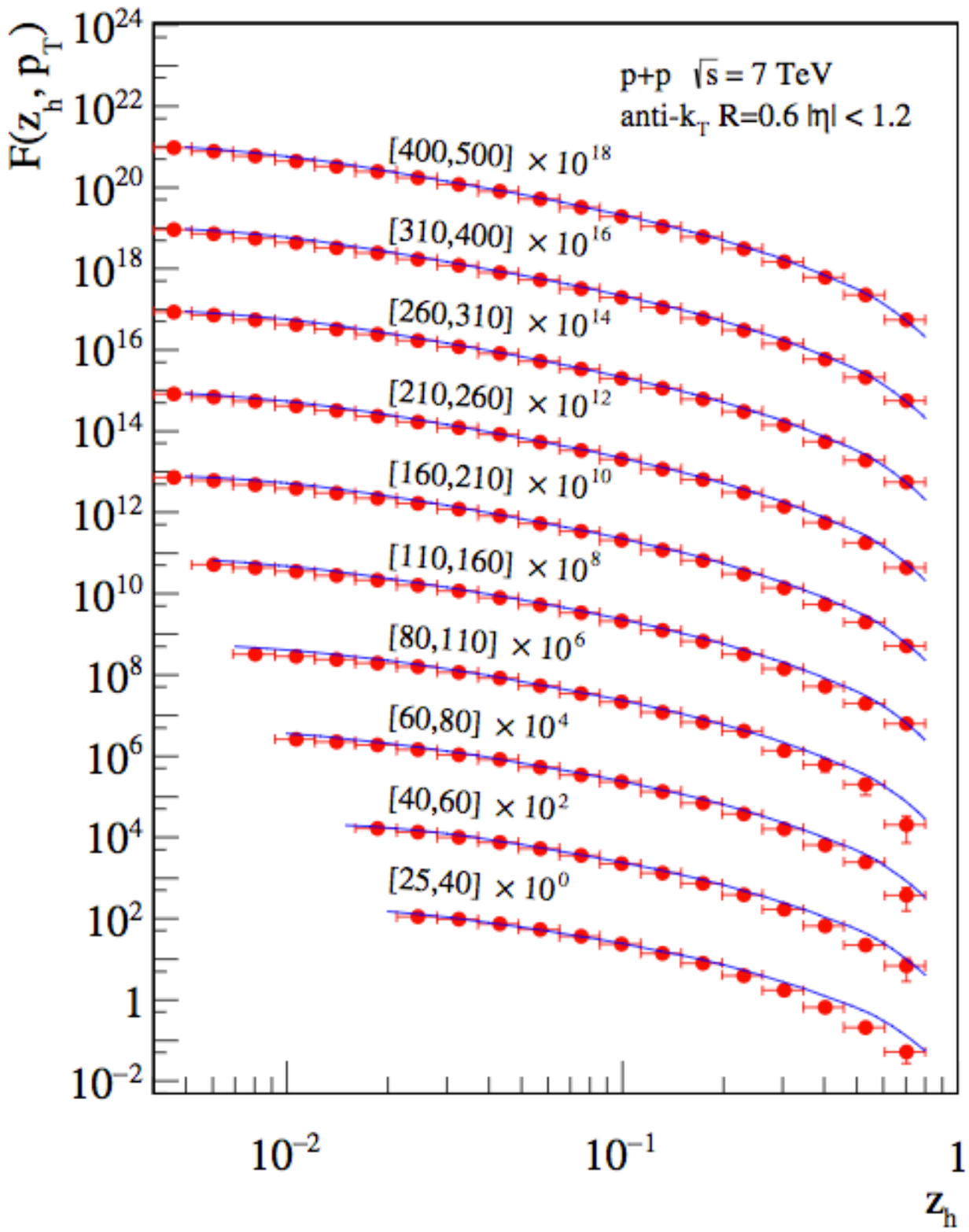
$$\mathcal{G}_i^h(z, z_h, \omega_J, \mu) = \sum_j \int_{z_h}^1 \frac{dz_h'}{z_h'} \mathcal{J}_{ij}\left(z, z_h', \omega_J, \mu\right) D_j^h\left(\frac{z_h}{z_h'}, \mu\right)$$

- at the hard scale

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

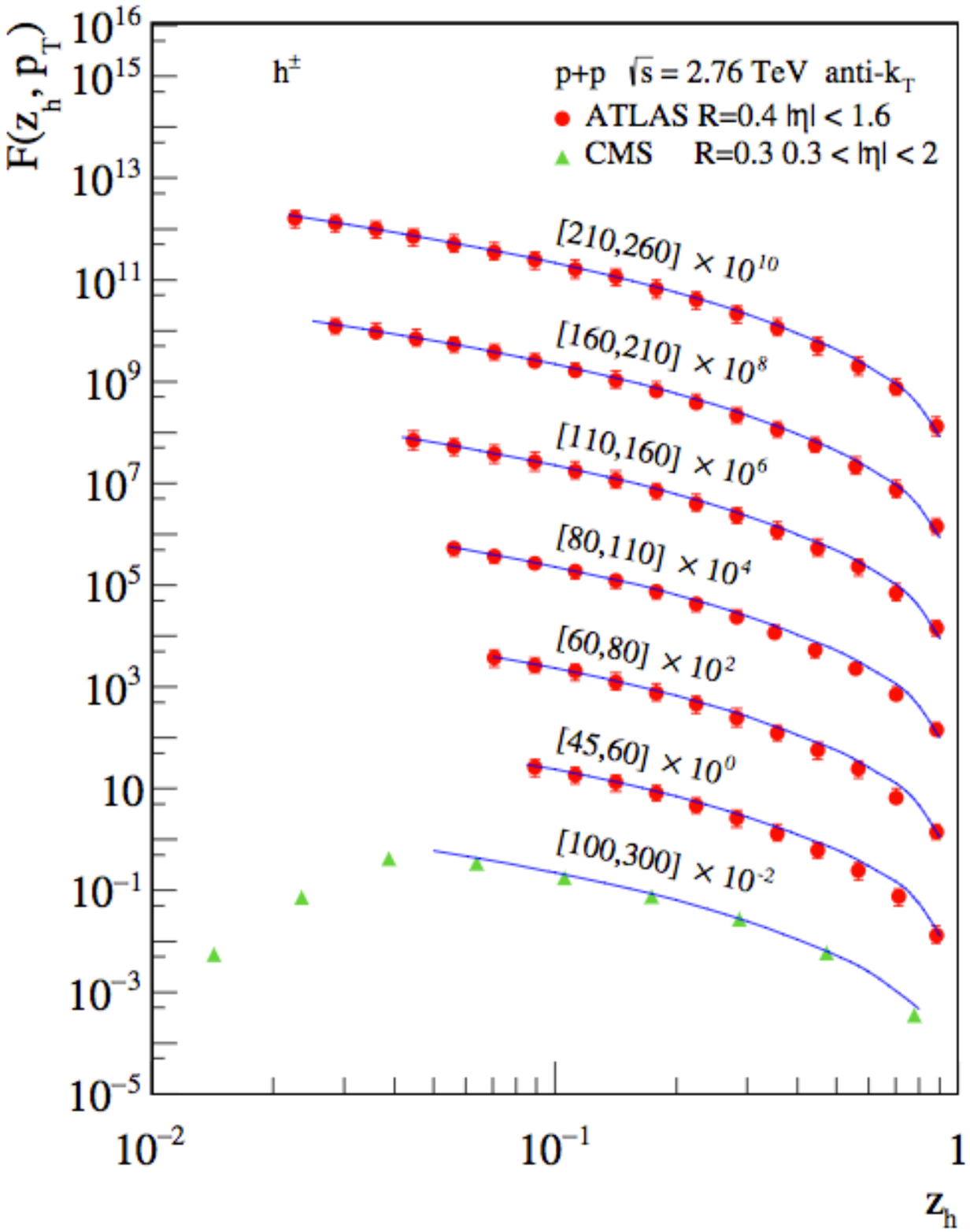


Comparison to ATLAS data at $\sqrt{s} = 7\,\mathrm{TeV}$

Light charged hadrons $h = \pi + K + p$

Using DSS FFs

de Florian, Sassot, Stratmann - '07

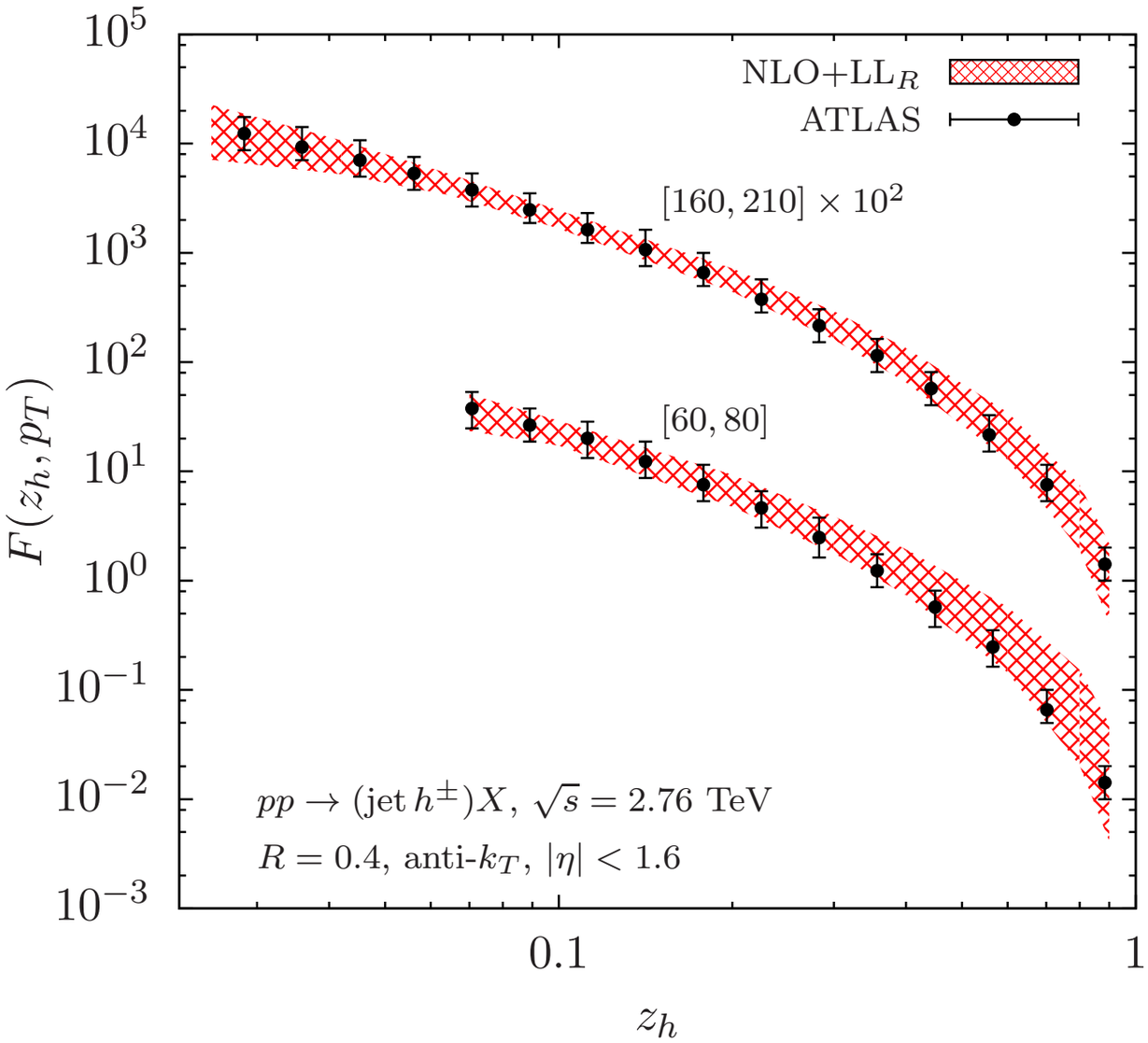


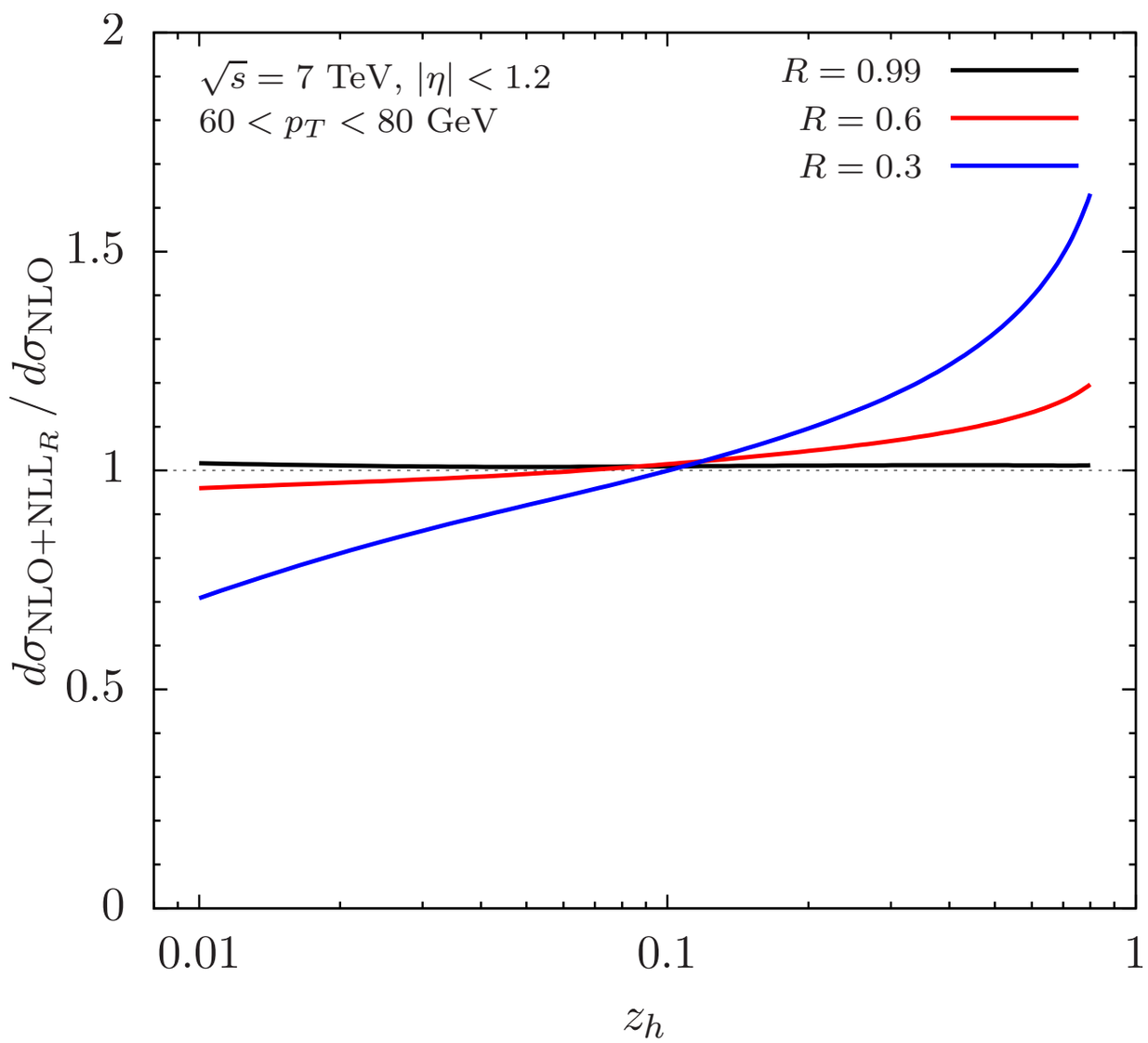
Comparison to ATLAS and CMS data at $\sqrt{s} = 2.76\,\mathrm{TeV}$

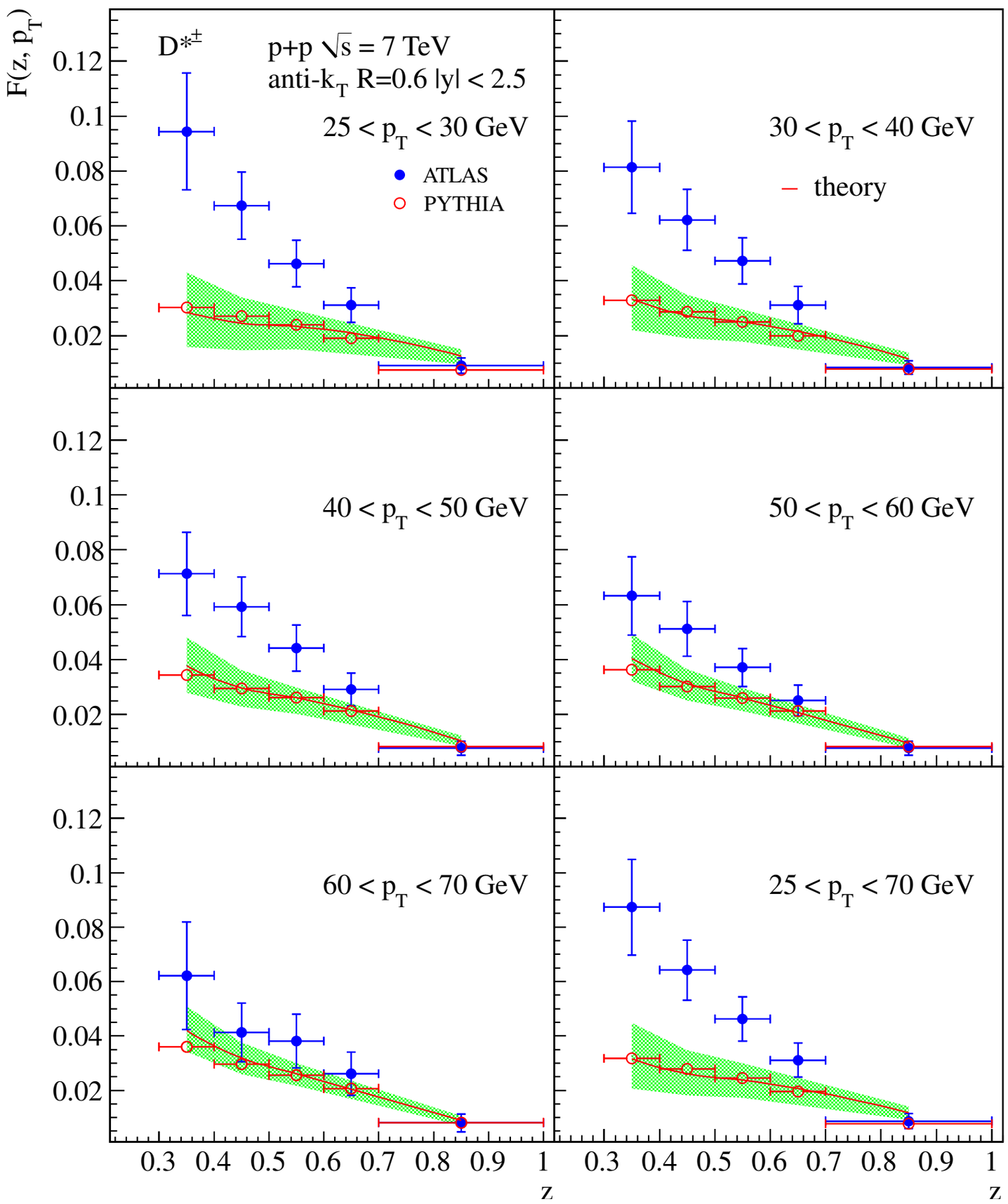
Light charged hadrons $h = \pi + K + p$

Using DSS FFs

de Florian, Sassot, Stratmann - '07


NLO+LL$_R$
ATLAS
$[160, 210] \times 10^2$
$[60, 80]$
$pp \to (\text{jet}\, h^{\pm})X$, $\sqrt{s} = 2.76$ TeV
$R = 0.4$, anti-k_T, $|\eta| < 1.6$
$F(z_h, p_T)$
z_h


$\sqrt{s} = 7$ TeV, $|\eta| < 1.2$
$60 < p_T < 80$ GeV
$R = 0.99$
$R = 0.6$
$R = 0.3$
$d\sigma_{\text{NLO+NLL}_R} / d\sigma_{\text{NLO}}$
z_h



D-meson
jet fragmentation function

Comparison to ATLAS data
and PYTHIA simulations
at $\sqrt{s} = 7\,\mathrm{TeV}$

Using FFs from
Kneesch, Kniehl, Kramer, Schienbein - '08

ZMVNFS, $e^+e^- \to DX$
$\mu,\ \mu_J,\ \mu_{\mathcal{G}} \gg m_Q$

Chien, Kang, FR, Vitev, Xing `15 (exclusive FJF)

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Outline

- Inclusive Jet Production
- The Jet Fragmentation Function in pp
- The Jet Fragmentation Function in ep
- Conclusions

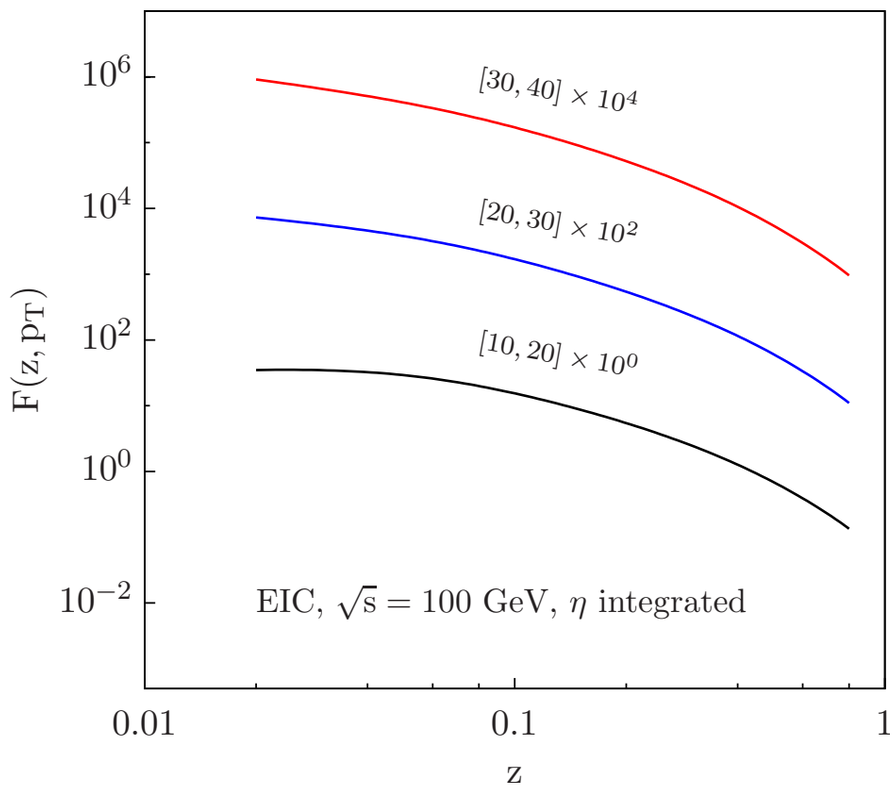
Kang, FR, Vitev `16
Kang, FR, Vitev `16
Kang, FR, Vitev - in preparation

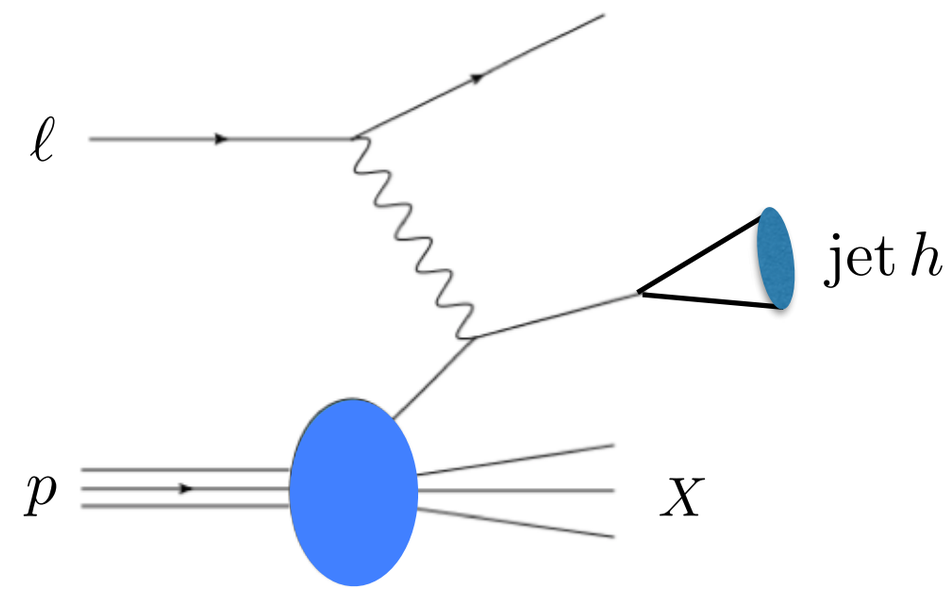
The Jet Fragmentation Function in ep

- Jet substructure observable for the EIC
- Especially interesting for eA *see talk by Alberto Accardi and Ivan Vitev*
- Possible to look at high-p_T jets at the EIC without observing the scattered lepton

$$\ell p \to (\text{jet } h) + X$$

see also Kang, Metz, Qiu, Zhou `11, Hinderer, Schlegel, Vogelsang '15
Abelof, Boughezal, Liu, Petriello `16





see talk by Brian Page

The Jet Fragmentation Function in ep

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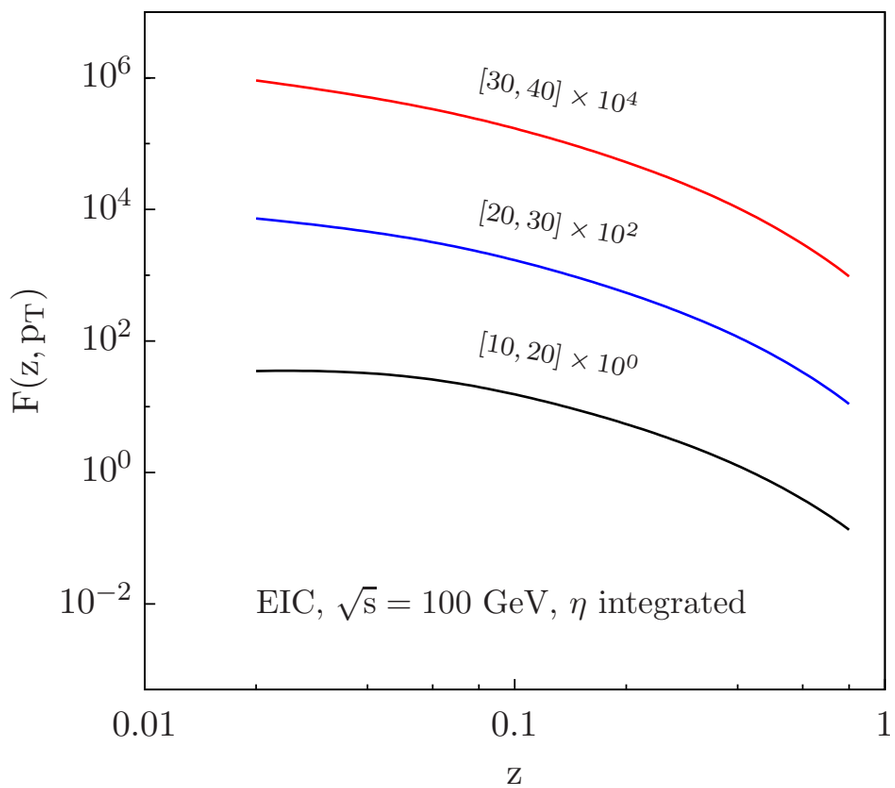
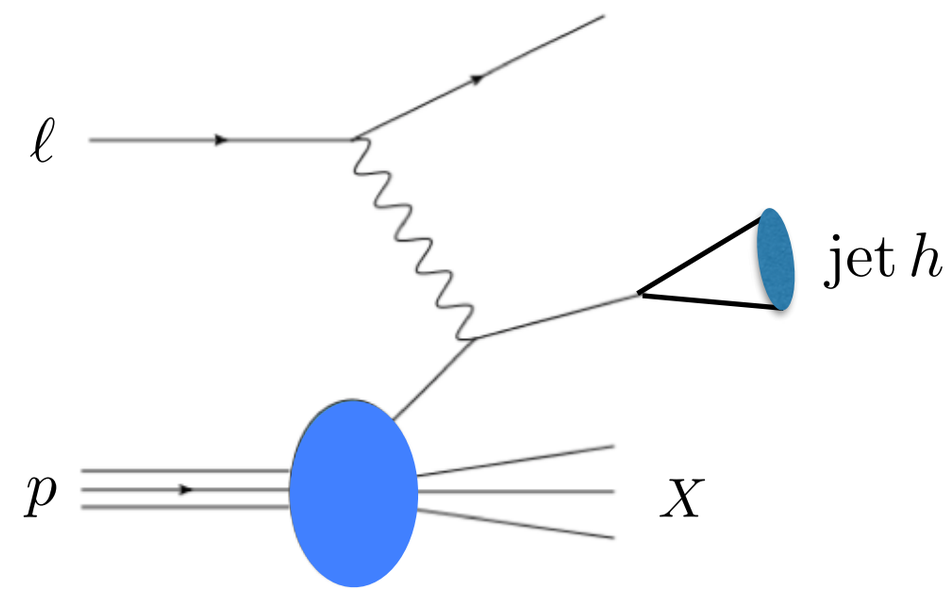




see talk by Brian Page

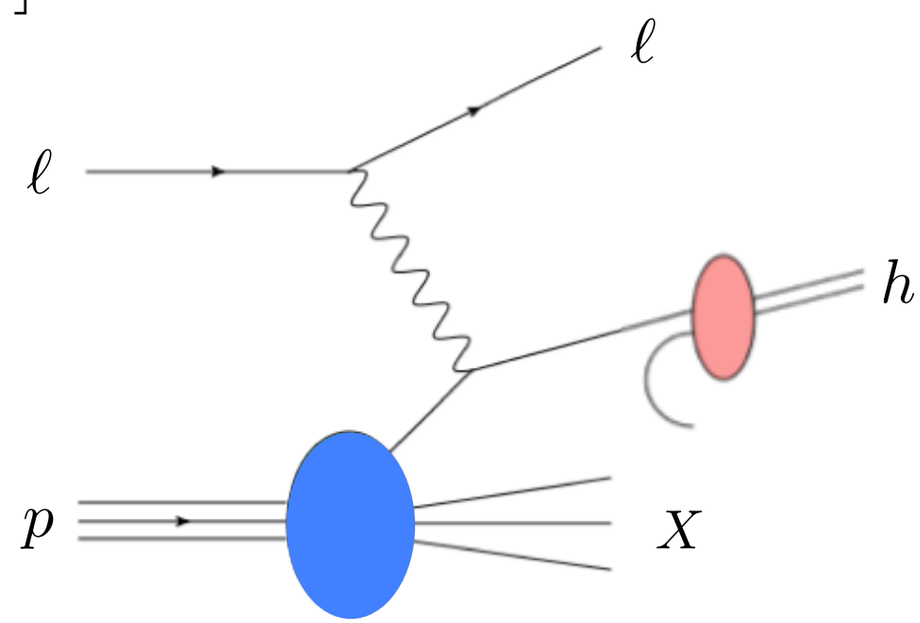
- Instead, we can also measure jets analogous to Semi-Inclusive DIS

Recall Semi-Inclusive DIS

Cross section for $\ell p \to \ell h X$

$$\frac{d^3\sigma^h}{dxdydz} = \frac{4\pi\alpha^2}{Q^2}\left[\frac{1+(1-y)^2}{2y}\,\mathcal{F}_T^h(x,z,Q^2) + \frac{1-y}{y}\,\mathcal{F}_L^h(x,z,Q^2)\right]$$

where $x \equiv \frac{Q^2}{2P\cdot q}$ $y \equiv \frac{P\cdot q}{P\cdot k}$ $z \equiv \frac{P\cdot P_h}{P\cdot q}$



Structure functions

$$\mathcal{F}_i^h(x,z,Q^2) = \sum_{f,f'}\int_x^1 \frac{dx'}{x'}\int_z^1 \frac{dz'}{z'} f\left(\frac{x}{x'},\mu^2\right) D_{f'}^h\left(\frac{z}{z'},\mu^2\right) \mathcal{C}_{f'f}^i\left(x',z',\frac{Q^2}{\mu^2}\right)$$

where e.g. $\mathcal{C}_{qq}^{T,(0)}\left(x',z',\frac{Q^2}{\mu^2}\right) = \delta(1-x')\delta(1-z')$

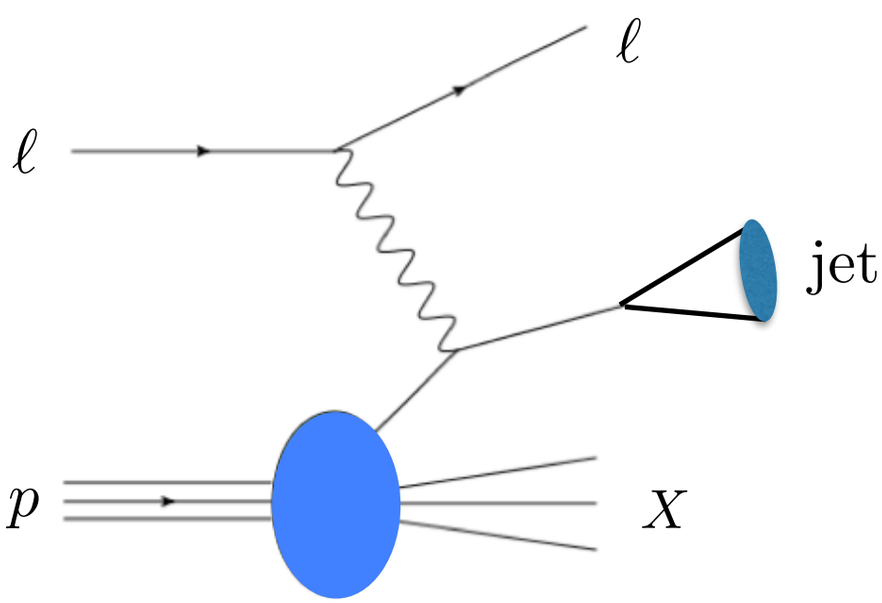
Semi-Inclusive Jet Cross Sections

Promote to semi-inclusive jet cross sections

$\ell p \to \ell \,\mathrm{jet}\, X$

siJF

$$\mathcal{F}_i^{\mathrm{jet}}(x, z_J, Q^2) = \sum_{f,f'} \int_x^1 \frac{dx'}{x'} \int_{z_J}^1 \frac{dz'}{z'} f\left(\frac{x}{x'}, \mu^2\right) \boxed{J_{f'}\left(\frac{z_J}{z'}, \omega_J, \mu^2\right)} \mathcal{C}^i_{f'f}\left(x', z', \frac{Q^2}{\mu^2}\right)$$



Semi-Inclusive Jet Cross Sections

Promote to semi-inclusive jet cross sections

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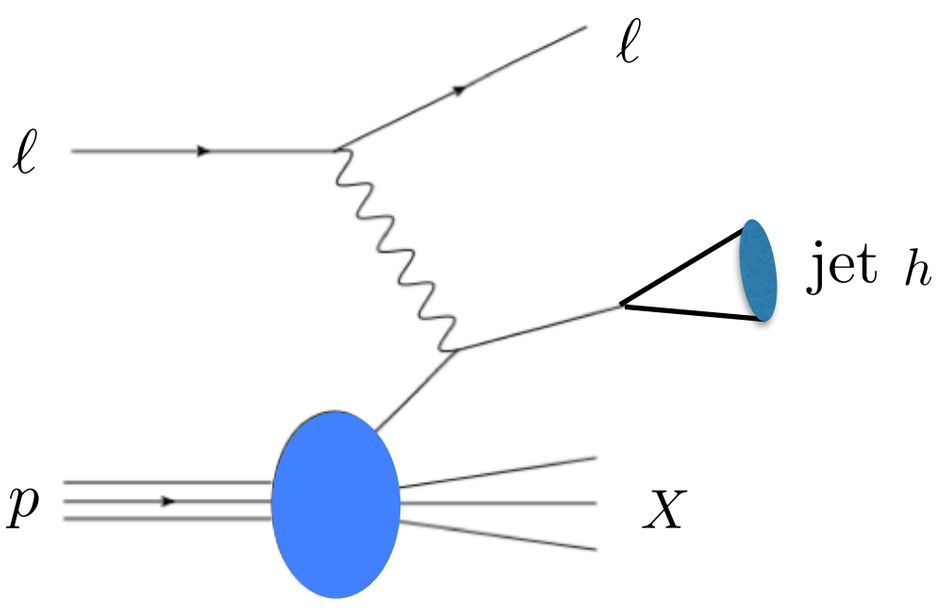
siJF

$$\mathcal{F}_i^{\mathrm{jet}}(x, z_J, Q^2) = \sum_{f,f'} \int_x^1 \frac{dx'}{x'} \int_{z_J}^1 \frac{dz'}{z'} f\left(\frac{x}{x'}, \mu^2\right) \boxed{J_{f'}\left(\frac{z_J}{z'}, \omega_J, \mu^2\right)} \mathcal{C}^i_{f'f}\left(x', z', \frac{Q^2}{\mu^2}\right)$$

$\ell p \to \ell\,(\mathrm{jet}\, h) X$

siFJF

$$\mathcal{F}_i^{\mathrm{jet}\,h}(x, z_J, z_h, Q^2) = \sum_{f,f'} \int_x^1 \frac{dx'}{x'} \int_{z_J}^1 \frac{dz'}{z'} f\left(\frac{x}{x'}, \mu^2\right) \boxed{\mathcal{G}^h_{f'}\left(\frac{z_J}{z'}, z_h, \omega_J, \mu^2\right)} \mathcal{C}^i_{f'f}\left(x', z', \frac{Q^2}{\mu^2}\right)$$



Semi-Inclusive Jet Cross Sections

$\ell p \to \ell \,\mathrm{jet}\, X$

siJF

$$\mathcal{F}_i^{\mathrm{jet}}(x, z_J, Q^2) = \sum_{f,f'} \int_x^1 \frac{dx'}{x'} \int_{z_J}^1 \frac{dz'}{z'} f\left(\frac{x}{x'}, \mu^2\right) \boxed{J_{f'}\left(\frac{z_J}{z'}, \omega_J, \mu^2\right)} \mathcal{C}^i_{f'f}\left(x', z', \frac{Q^2}{\mu^2}\right)$$

- Differential in z_J
- Fixed order issues

LO: $\mathcal{C}^{T,(0)}_{qq}\left(x', z', \frac{Q^2}{\mu^2}\right) = \delta(1-x')\delta(1-z')$ $\qquad J_q^{(0)}(z, \omega_J) = \delta(1-z)$

NLO: singular functions in both $J_{f'}$ and $\mathcal{C}^i_{f'f}$

- directly sensitive to the resummation of $\ln R$

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Semi-Inclusive Jet Cross Sections

$\ell p \to \ell \,\mathrm{jet}\, X$

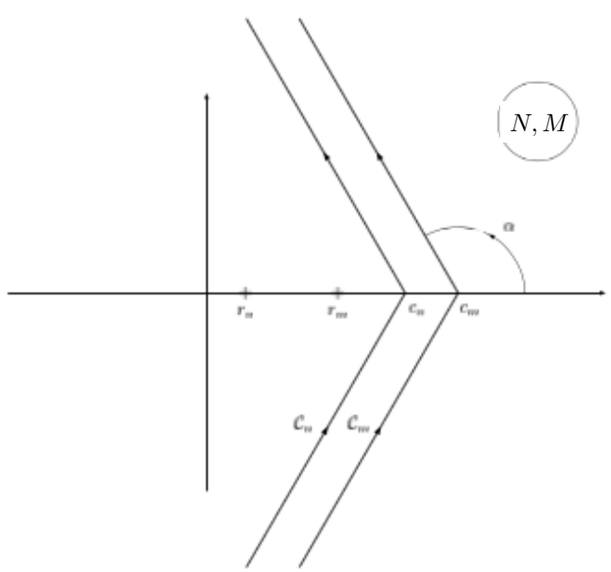
siJF

$$\mathcal{F}_i^{\mathrm{jet}}(x, z_J, Q^2) = \sum_{f,f'} \int_x^1 \frac{dx'}{x'} \int_{z_J}^1 \frac{dz'}{z'} f\left(\frac{x}{x'}, \mu^2\right) \boxed{J_{f'}\left(\frac{z_J}{z'}, \omega_J, \mu^2\right)} \mathcal{C}^i_{f'f}\left(x', z', \frac{Q^2}{\mu^2}\right)$$

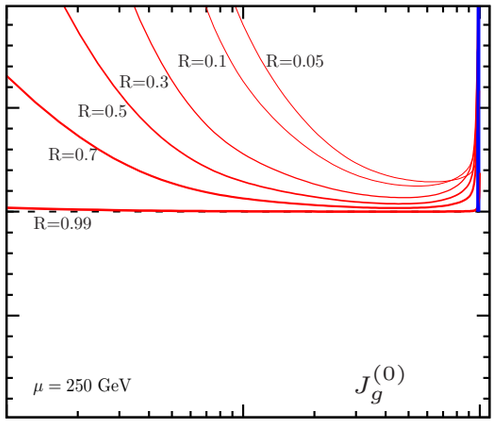
- Double Mellin transform and include $\ln R$ resummation

Stratmann, Vogelsang `01, Anderle, FR, Vogelsang `12

$$\int_0^1 dx\, x^{N-1} \int_0^1 dz_J\, z_J^{M-1} \mathcal{F}_i^{\mathrm{jet}}(x, z_J, Q^2) = \sum_{f,f'} f(N, \mu^2)\, J_{f'}(M, \omega_J, \mu^2)\, \mathcal{C}^i_{f'f}(N, M, \mu^2)$$

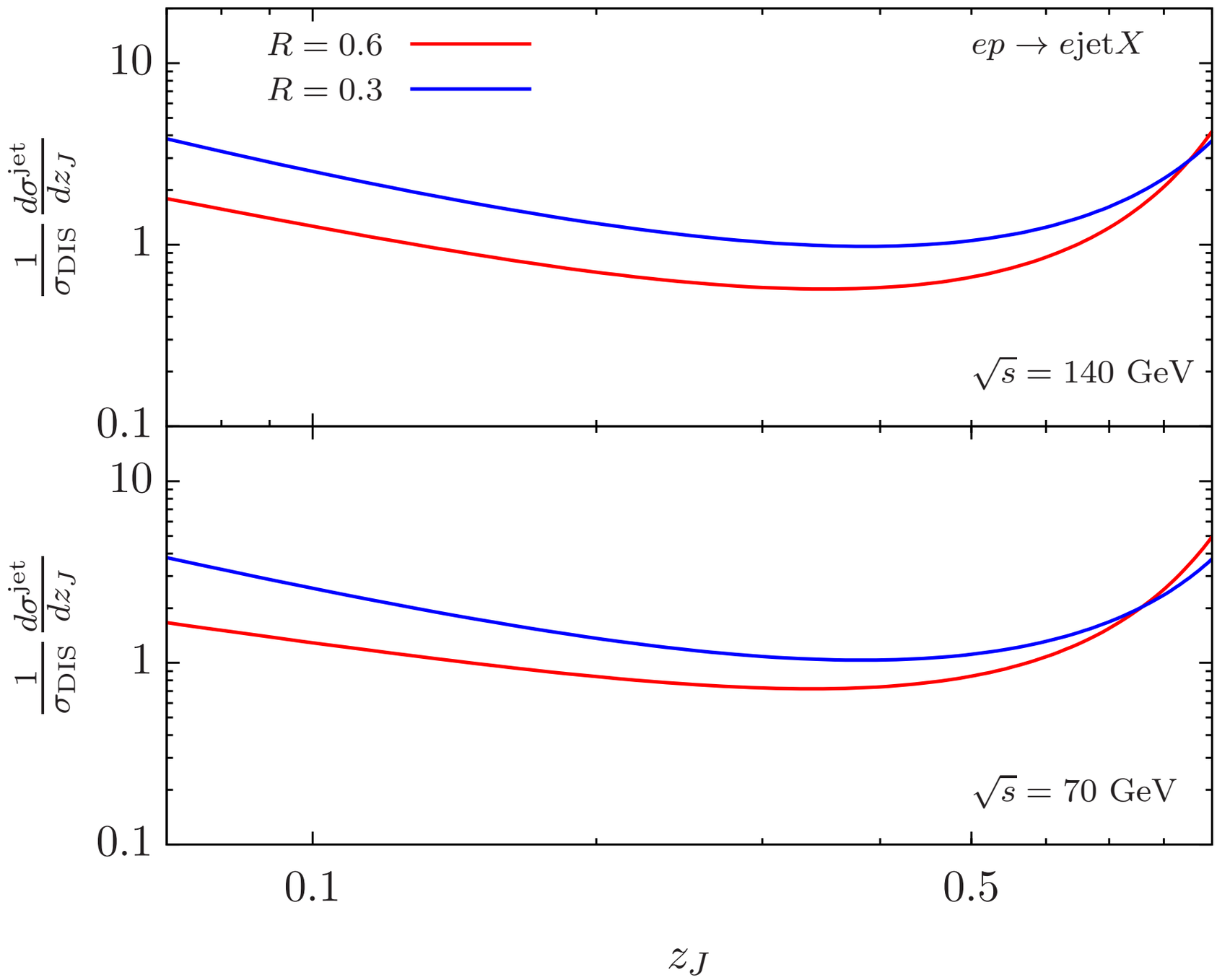


use evolved siJF:



Semi-Inclusive Jet Cross Sections

$\ell p \to \ell \, \mathrm{jet}\, X$



$Q > 1/R$ GeV

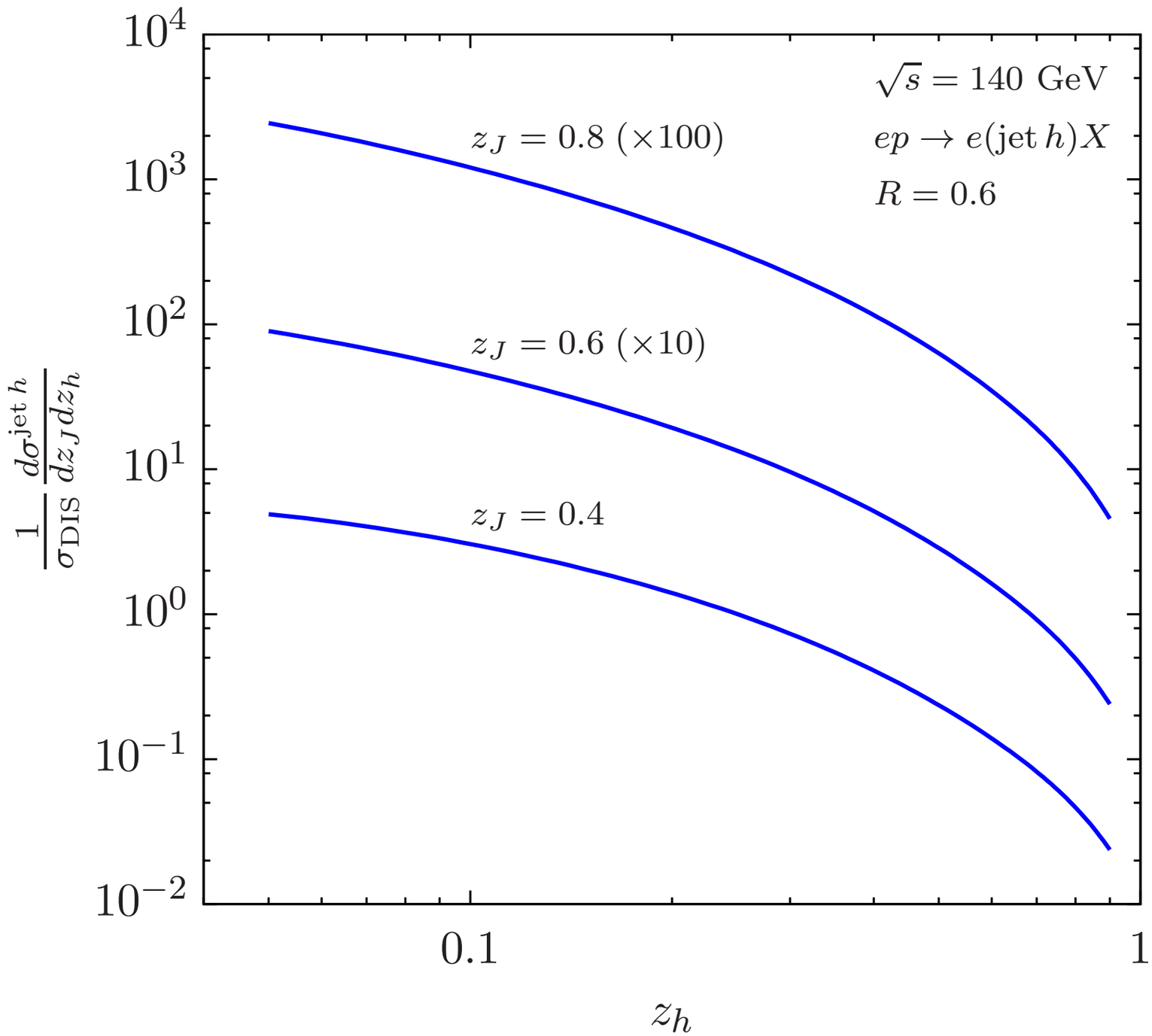
$0.1 < x_B < 0.9$

$W > 3$ GeV

$0.05 < y < 0.95$

Semi-Inclusive Jet Cross Sections

$\ell p \to \ell\,(\text{jet}\,h)X$



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Kang, FR, Vitev `16
Kang, FR, Vitev `16
Kang, FR, Vitev - in preparation

Conclusions

- Inclusive jet observables in SCET
- $\ln R$ resummation at NLL
- Application to both pp and ep collisions

- Extension to other jet substructure observables
- More detailed studies needed for jet production at the EIC

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