multi-jet merging in the PB method

A. Bermúdez Martínez
F. Hautmann
H. Jung

REF 2019
25^{th} November, 2019

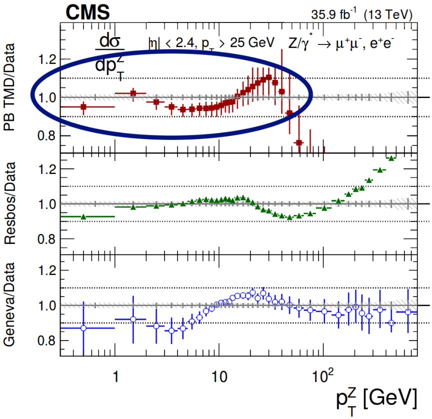
Outline

- PB method and Z p_{T} spectrum
- Multi-jet merging
- Differential jet rate plots
- Application to Z production
- Merging uncertainty
- Summary and conclusions

PB method and Z p_T spectrum

TMDs and PB method

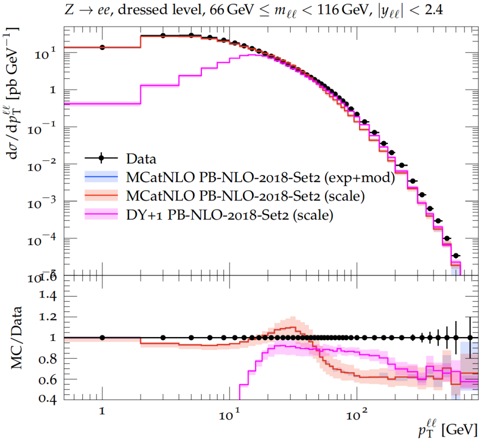
- small momentum transfer very well described → see Qun's talk



arXiv:1909.04133 [hep-ex]
CERN-EP-2019-175

TMDs and PB method

- small momentum transfer very well described → see Qun's talk
- matching to NLO matrix elements achieved → see Qun's talk

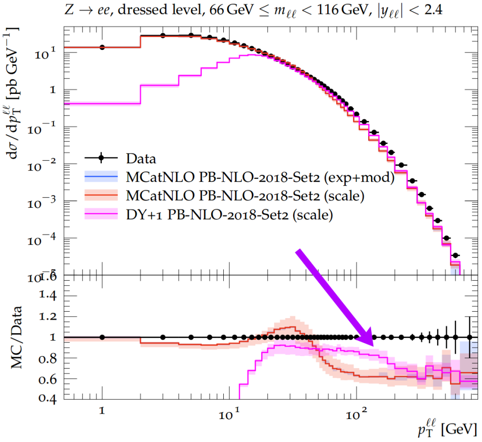


Phys.Rev.D 100, 074027 (2019)

TMDs and PB method

- small momentum transfer very well described → see Qun's talk
- matching to NLO matrix elements achieved → see Qun's talk

→ including higher order corrections at high p_T

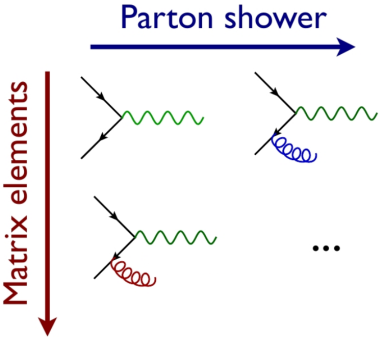


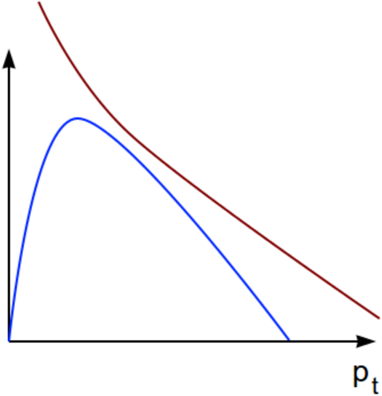
Phys.Rev.D 100, 074027 (2019)

Multi-jet merging

multi-jet merging

- Z production as an example:



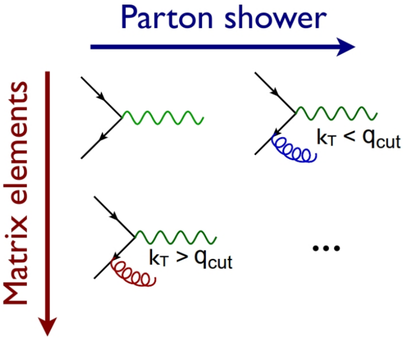


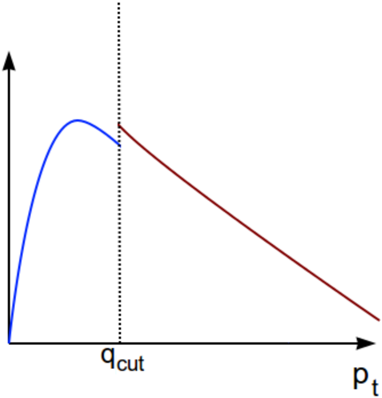
- 1st emission PS: $\mathcal{R}^{PS}(p_t^2) \times \exp\left[-\int_{p_t^2} dp_t'^2 \frac{\mathcal{R}^{PS}(p_t'^2)}{\mathcal{B}}\right]$

- 1st emission ME: $\mathcal{R}(p_t^2)$

multi-jet merging

◦ Z production as an example:



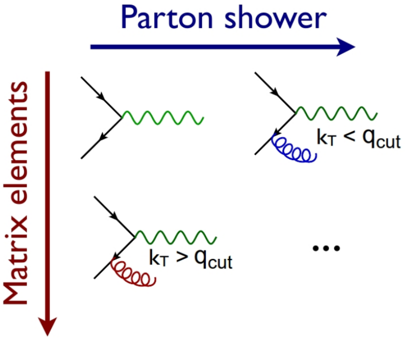


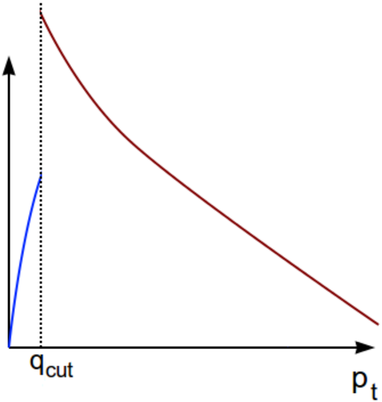
- 1[st] emission PS: $\mathcal{R}^{PS}(p_t^2) \times \exp\left[-\int_{p_t^2} dp_t'^2 \frac{\mathcal{R}^{PS}(p_t'^2)}{\mathcal{B}}\right]$

- 1[st] emission ME: $\mathcal{R}(p_t^2)$

multi-jet merging

◦ Z production as an example:



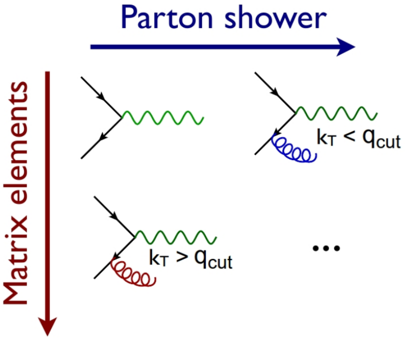


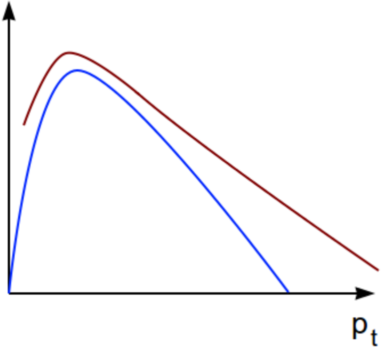
- 1st emission PS: $\mathcal{R}^{PS}(p_t^2) \times \exp\left[-\int_{p_t^2} dp_t'^2 \frac{\mathcal{R}^{PS}(p_t'^2)}{\mathcal{B}}\right]$

- 1st emission ME: $\mathcal{R}(p_t^2)$

multi-jet merging

◦ Z production as an example:

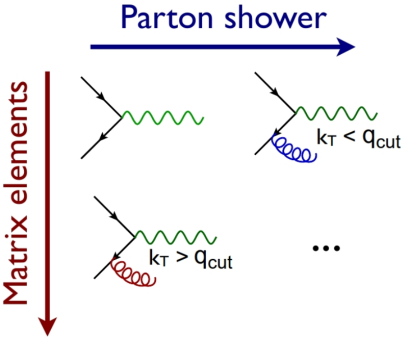


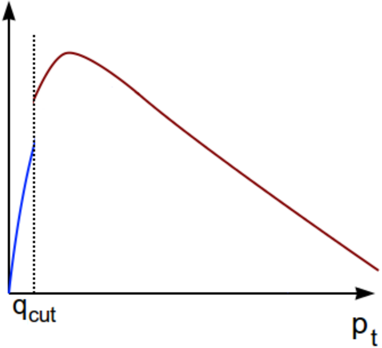


- 1^{st} emission PS: $\mathcal{R}^{PS}(p_t^2) \times \exp\left[-\int_{p_t^2} dp_t'^2 \frac{\mathcal{R}^{PS}(p_t'^2)}{\mathcal{B}}\right]$
- 1^{st} emission ME: $\mathcal{R}(p_t^2) \longrightarrow \mathcal{R}(p_t^2)\times\exp\left[-\int_{p_t^2} dp_t'^2 \frac{\mathcal{R}^{PS}(p_t'^2)}{\mathcal{B}}\right]$

multi-jet merging

◦ Z production as an example:



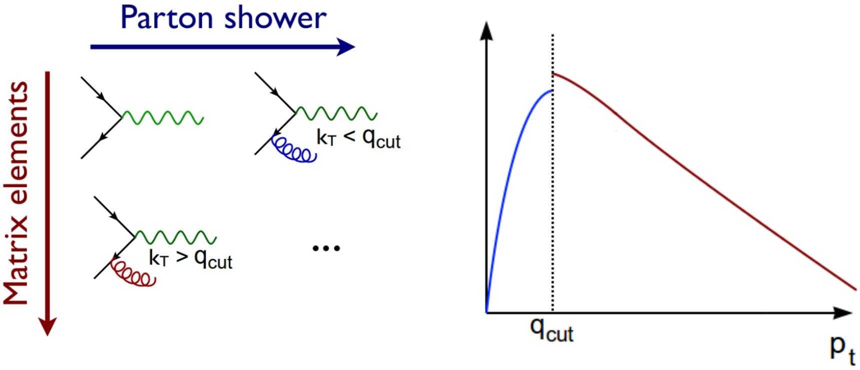


- 1st emission PS: $\mathcal{R}^{PS}(p_t^2) \times \exp\left[-\int_{p_t^2} dp_t'^2 \frac{\mathcal{R}^{PS}(p_t'^2)}{\mathcal{B}}\right]$

- 1st emission ME: $\mathcal{R}(p_t^2) \longrightarrow \mathcal{R}(p_t^2) \times \exp\left[-\int_{p_t^2} dp_t'^2 \frac{\mathcal{R}^{PS}(p_t'^2)}{\mathcal{B}}\right]$

multi-jet merging

◦ Z production as an example:

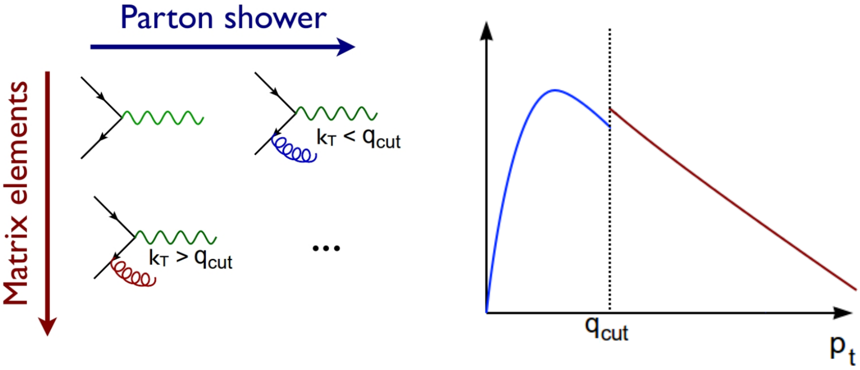


- 1st emission PS: $\mathcal{R}^{PS}(p_t^2) \times \exp\left[-\int_{p_t^2} dp_t'^2 \frac{\mathcal{R}^{PS}(p_t'^2)}{\mathcal{B}}\right]$

- 1st emission ME: $\mathcal{R}(p_t^2) \longrightarrow \mathcal{R}(p_t^2)\times\exp\left[-\int_{p_t^2} dp_t'^2 \frac{\mathcal{R}^{PS}(p_t'^2)}{\mathcal{B}}\right]$

multi-jet merging

- Z production as an example:

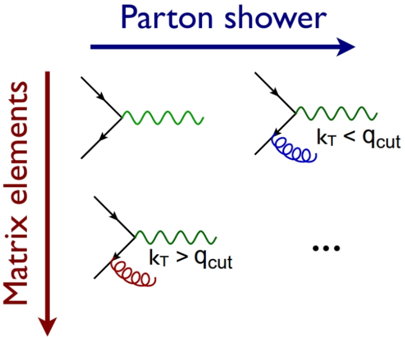


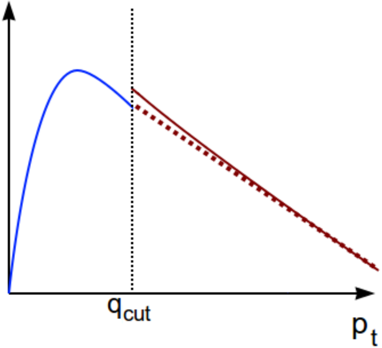
- 1st emission PS: $\mathcal{R}^{PS}(p_t^2) \sim \alpha_s(p_t^2)$

- 1st emission ME: $\mathcal{R}(p_t^2) \sim \alpha_s(\mu^2)$

multi-jet merging

- Z production as an example:





- 1st emission PS: $\mathcal{R}^{PS}(p_t^2) \sim \alpha_s(p_t^2)$

- 1st emission ME: $\mathcal{R}(p_t^2) \quad \rightarrow \mathcal{R}(p_t^2) \times \alpha_s(p_t^2)/\alpha_s(\mu^2)$

MLM merging scheme

- matching partons and jets in physical space
- soft/collinear region suppressed by vetoing events
- reproducing the shower Sudakov

○ merging scale

- separates soft/collinear and hard regions
- chosen value: 20 GeV

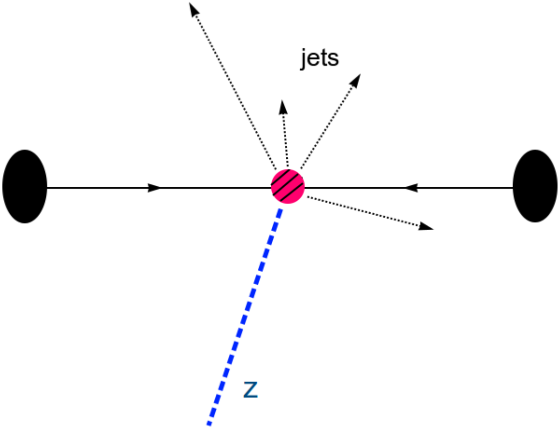
○ matrix elements

- Madgraph LO
- up to 3 partons in the final state
- ME includes α_s reweighting

Differential jet rate plots

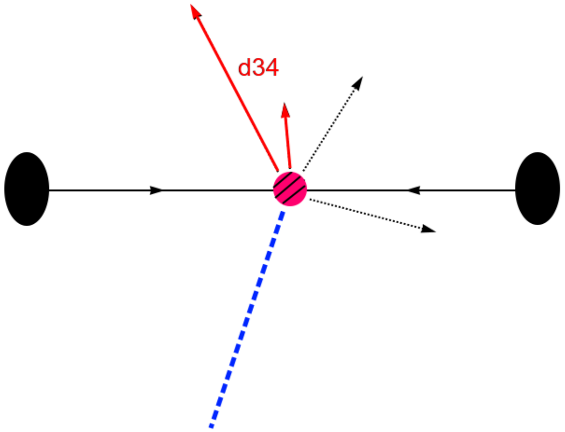
DJR plots

- used to test the merging implementation
- $d_{\mathrm{n,n+1}}$ measures the transition scale from (n+1)-jet to n-jet
- approximately reproduce the merging scale phase space



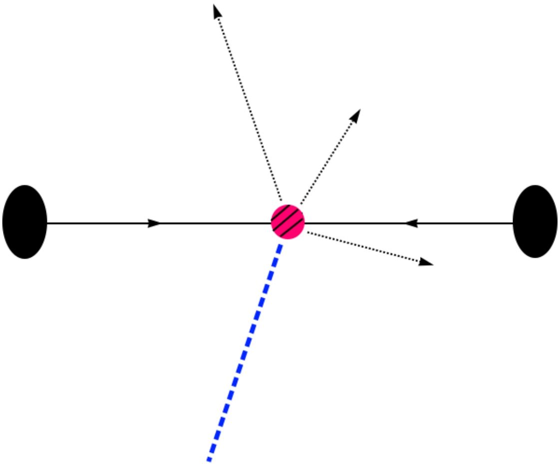
DJR plots

- used to test the merging implementation
- $d_{\mathrm{n,n+1}}$ measures the transition scale from (n+1)-jet to n-jet
- approximately reproduce the merging scale phase space



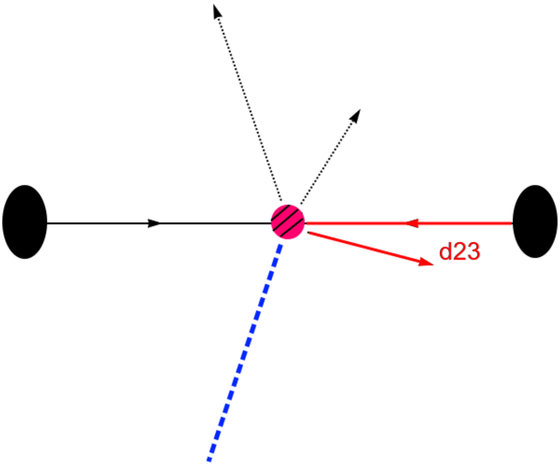
DJR plots

- used to test the merging implementation
- $d_{n,n+1}$ measures the transition scale from (n+1)-jet to n-jet
- approximately reproduce the merging scale phase space



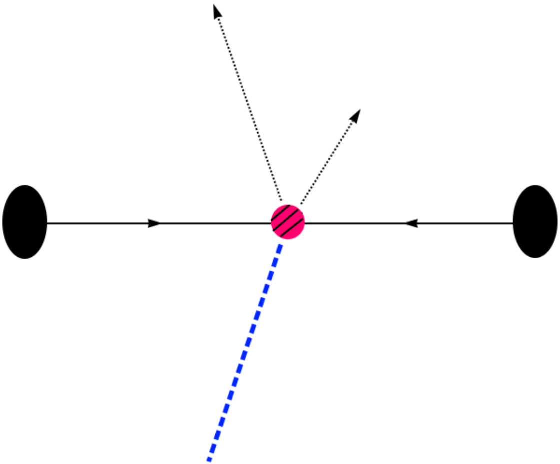
DJR plots

- used to test the merging implementation
- $d_{n,n+1}$ measures the transition scale from (n+1)-jet to n-jet
- approximately reproduce the merging scale phase space



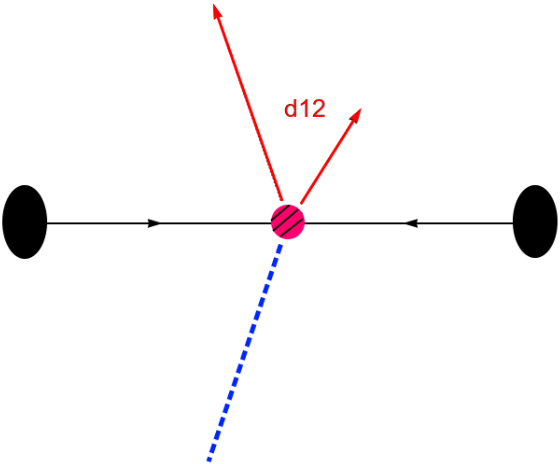
DJR plots

- used to test the merging implementation
- $d_{n,n+1}$ measures the transition scale from (n+1)-jet to n-jet
- approximately reproduce the merging scale phase space



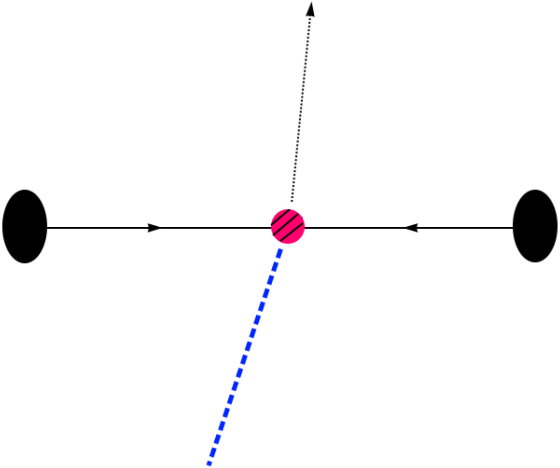
DJR plots

- used to test the merging implementation
- $d_{\mathrm{n,n+1}}$ measures the transition scale from (n+1)-jet to n-jet
- approximately reproduce the merging scale phase space



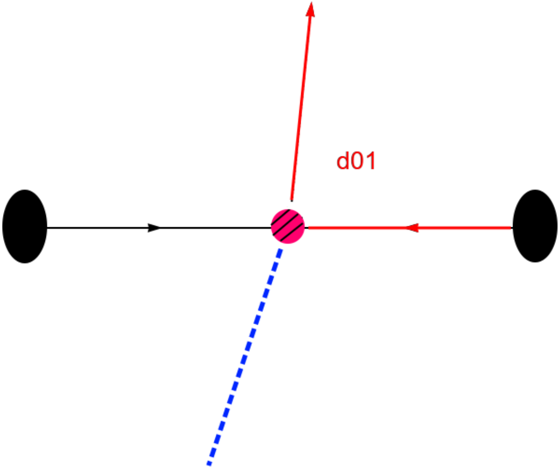
DJR plots

- used to test the merging implementation
- $d_{\mathrm{n,n+1}}$ measures the transition scale from (n+1)-jet to n-jet
- approximately reproduce the merging scale phase space



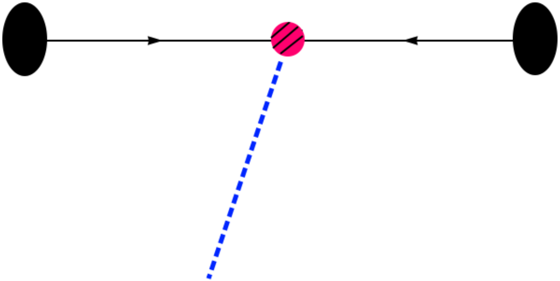
DJR plots

- used to test the merging implementation
- $d_{n,n+1}$ measures the transition scale from (n+1)-jet to n-jet
- approximately reproduce the merging scale phase space



DJR plots

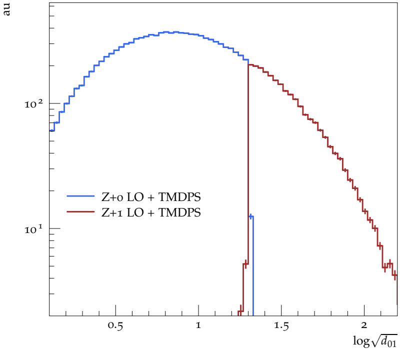
- used to test the merging implementation
- $d_{\mathrm{n,n+1}}$ measures the transition scale from (n+1)-jet to n-jet
- approximately reproduce the merging scale phase space
- $d_{\mathrm{n,n+1}} \rightarrow$ scale in the k_{T} clustering algorithm



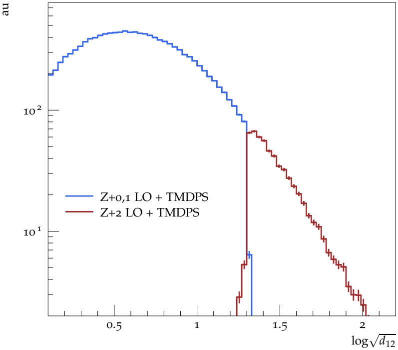
DJR plots

- used to test the merging implementation
- $d_{\mathrm{n,n+1}}$ measures the transition scale from (n+1)-jet to n-jet
- approximately reproduce the merging scale phase space

→ DJR plots smooth



d01



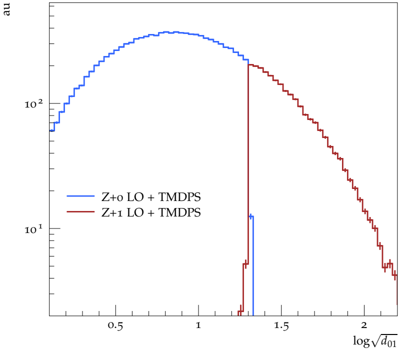
d12

DJR plots

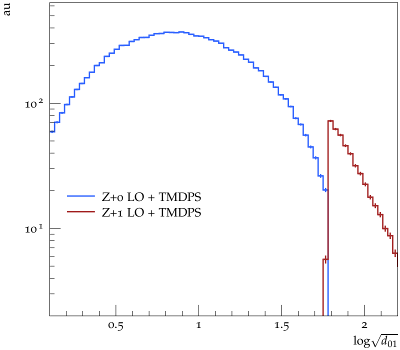
- used to test the merging implementation
- $d_{\mathrm{n,n+1}}$ measures the transition scale from (n+1)-jet to n-jet
- approximately reproduce the merging scale phase space

→ DJR plots smooth

- merging scale qcut $\sim 1/5 \times Q$



qcut = 20 GeV

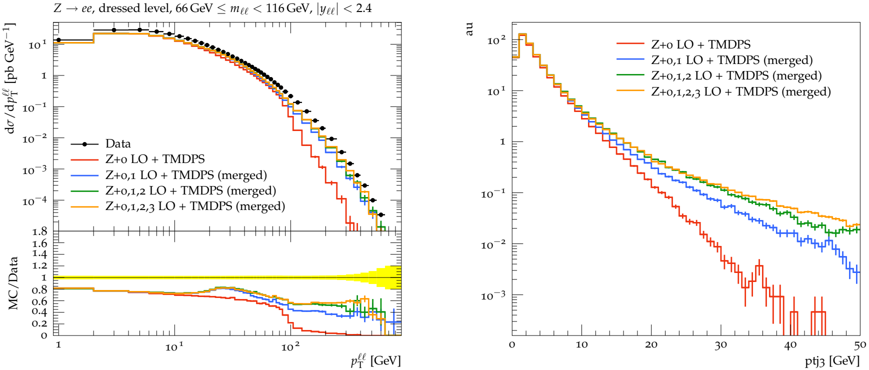


qcut = 60 GeV

Application to Z production

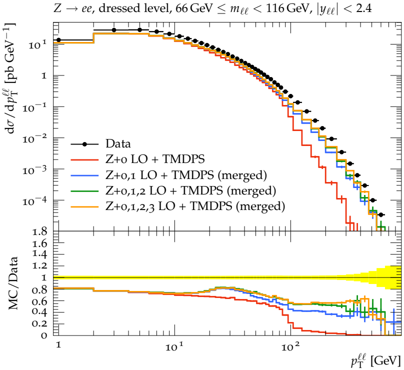
Z and third jet p_T spectra

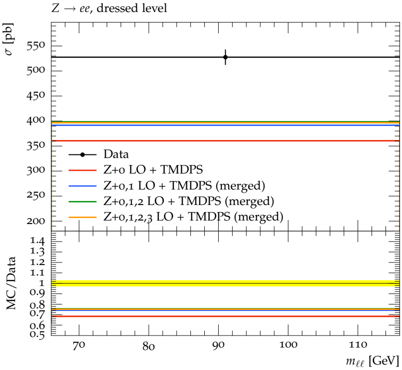
- corrections improve significantly high p_T tail
- higher corrections become gradually important
- p_T of the third jet is smooth



Z and third jet p_T spectra

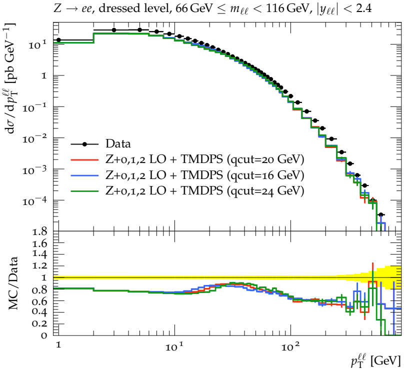
- corrections improve significantly high p_T tail
- higher corrections become gradually important
- p_T of the third jet is smooth
- change in the LO cross section $\sim 8\%$

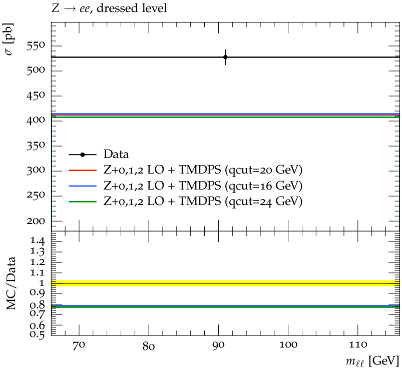




Merging uncertainty

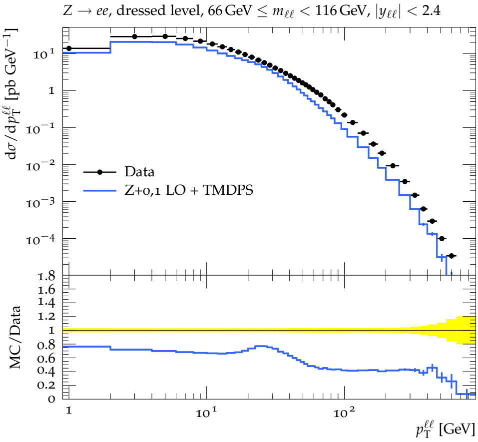
- merging scale variation
- effects around the merging scale
- 20% qcut variation $\Rightarrow\sim$ 5% variation in Z p_T spectrum
- no important effect in the inclusive cross section





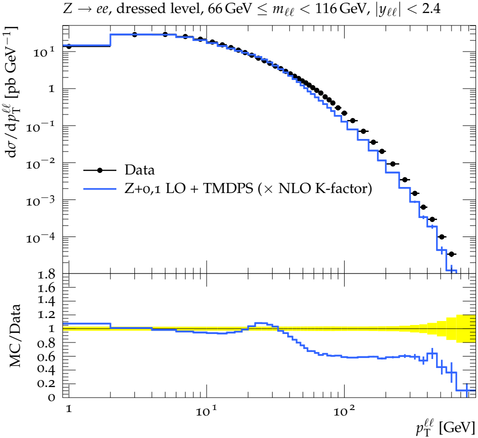
LO merging and MC@NLO matching comparison

- take Z + 0,1 merged prediction



LO merging and MC@NLO matching comparison

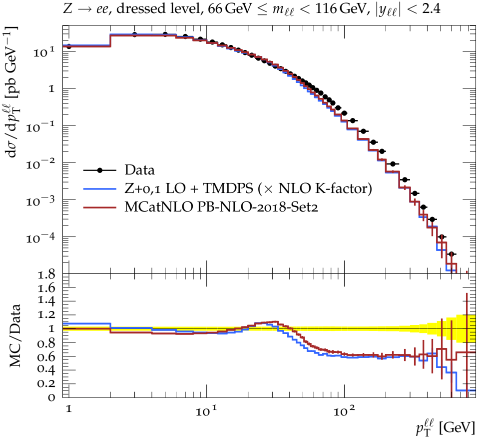
- take Z + 0,1 merged prediction
- apply NLO K-factor



LO merging and MC@NLO matching comparison

- take Z + 0,1 merged prediction
- apply NLO K-factor
- compare to MC@NLO prediction (Phys.Rev.D 100, 074027 (2019))

$\longrightarrow$ very good agreement is achieved!



Summary

◦ MLM style multi-jet merging has been applied to PB-TMD events for the first time

◦ Z + up to 3 partons has been merged giving an increasingly good agreement with the data

◦ smooth DJR as well as exclusive jet p_T

◦ 20% `qcut` variation $\Rightarrow \sim$ 5% variation in Z p_T spectrum

◦ Z + 1 LO + TMDPS ($\times$ K-factor) is in very good agreement with the MC@NLO PBTMD result

Outlook

◦ application to off-shell matrix elements events

◦ extension to NLO multi-jet merging