Matching NLO+PBTMD on inclusive Z and BBar production

2019REF Workshop Pavia Italy

L.I. Estevez, H. Jung, A. Bermudez

OUTLINE

(1) NLO + parton showers

(2) MCatNLO vs POWHEG

(3) Applications

- Z production at LHC
- BBar production at LHC

(4) Conclusions

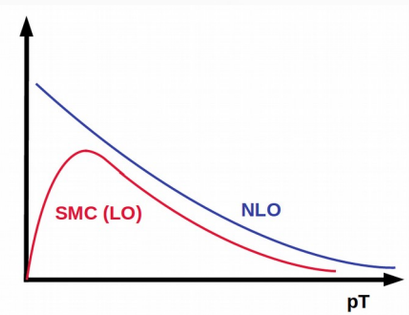
(1) NLO + parton shower

SMC (LO + Shower)

- ✗ Bad description at high pT
- ✗ Less accurate normalization at LO
- ✗ Bigger dependence on factorization and renormalization scales
- ✓ Correct Sudakov suppression at small pT
- ✓ Simulate events at hadron level

NLO

- ✓ Accurate shapes at high pT
- ✓ Normalization at NLO
- ✓ Reduced dependence with factorization and renormalization scales
- ✗ Wrong shapes at small pT
- ✗ Description only at parton level



→ NLO + PS have the best of both approaches

(1) NLO + parton shower

- Interfacing ME generators with PS (Parton Showers)

  - MLM matching [*Mangano*] (Armando's talk)

- **Interfacing NLO calculations with PS**

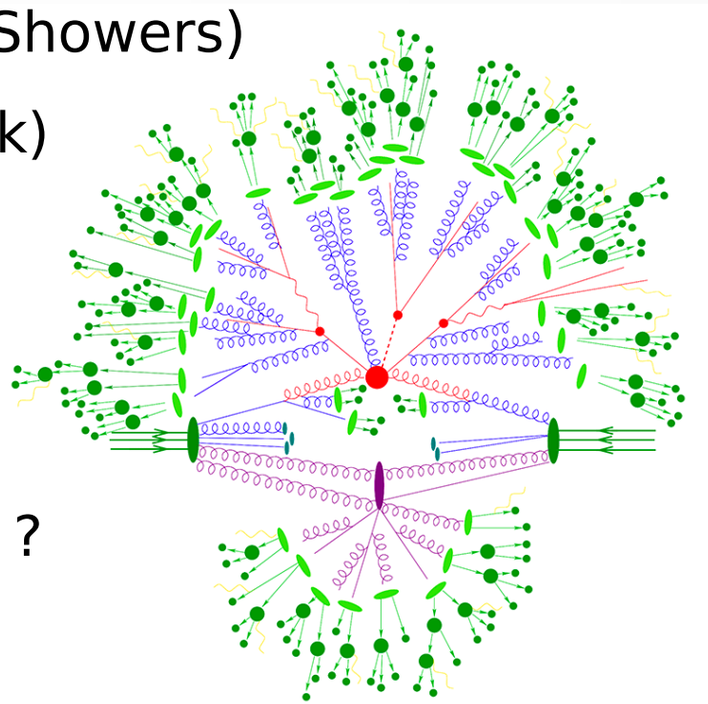
  - **MCatNLO** [*Frixione,Weber*]

  - **POWHEG** [*Nason*]

- Why not to go for **NLO** + **PBTMD** + **HAD** ?

PYTHIA6

CASCADE



(2) MCatNLO vs POWHEG

MCatNLO

- It is dependent on parton shower
- ME obtained using subtraction procedure depends on PS

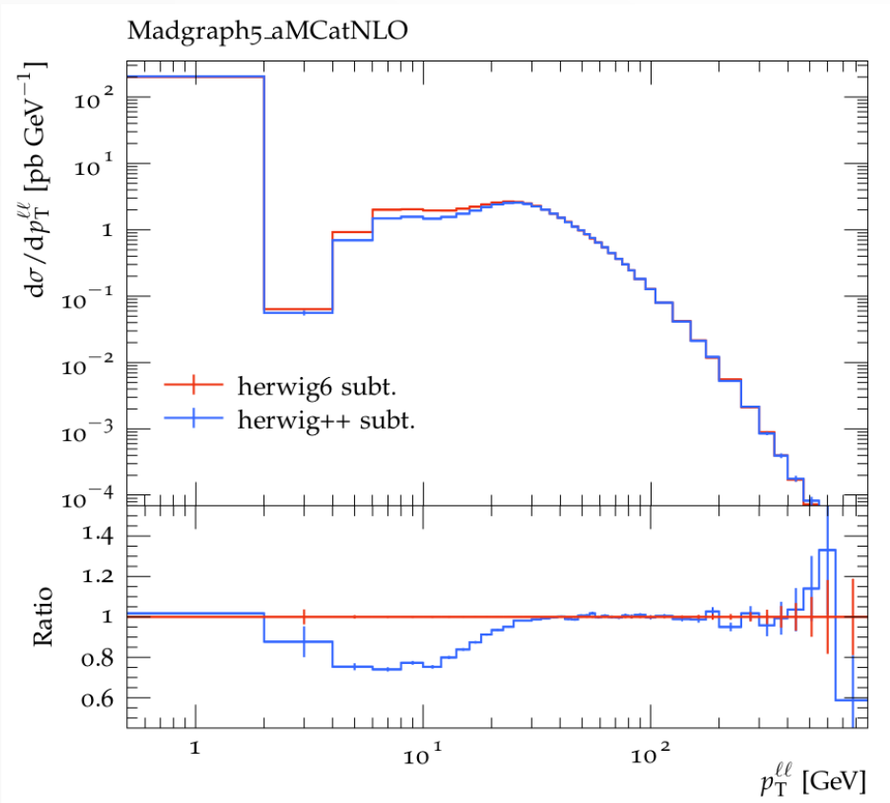
POWHEG

- Independent from any parton shower
- ME obtained using hdamp and ptsqmin parameters

Interface with CASCADE (SMC) for applying PBTMD and TMD shower

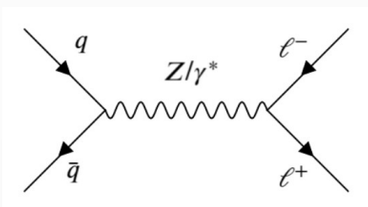
(3) Matching NLO+PBTMD

MCatNLO HERWIG subtraction

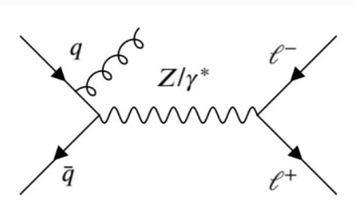


- **Matrix Elements unphysical pT**
- Using **PBset2** for **collinear calculation**
- **NLO accuracy at high pT**, main contribution from Real Emision (RE)
- **No resummation**, LO events going to the first bin (pT = 0)
- Taken from **PhysRevD.100.074027** (Qun talk)

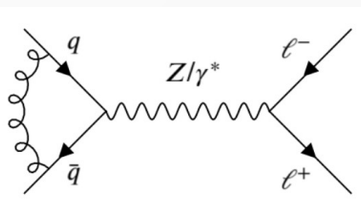
LO



RE

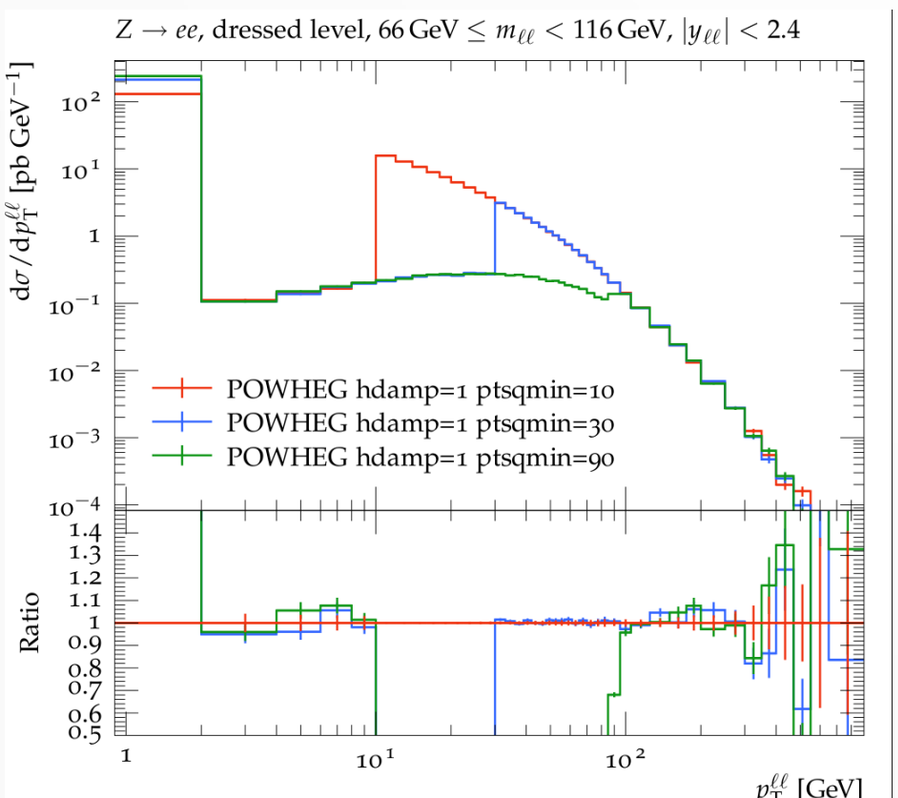


VE

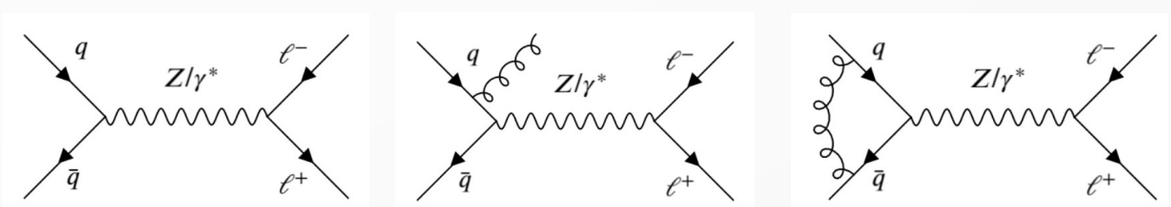


(3) Matching NLO+PBTMD

POWHEG hdamp and ptsqmin

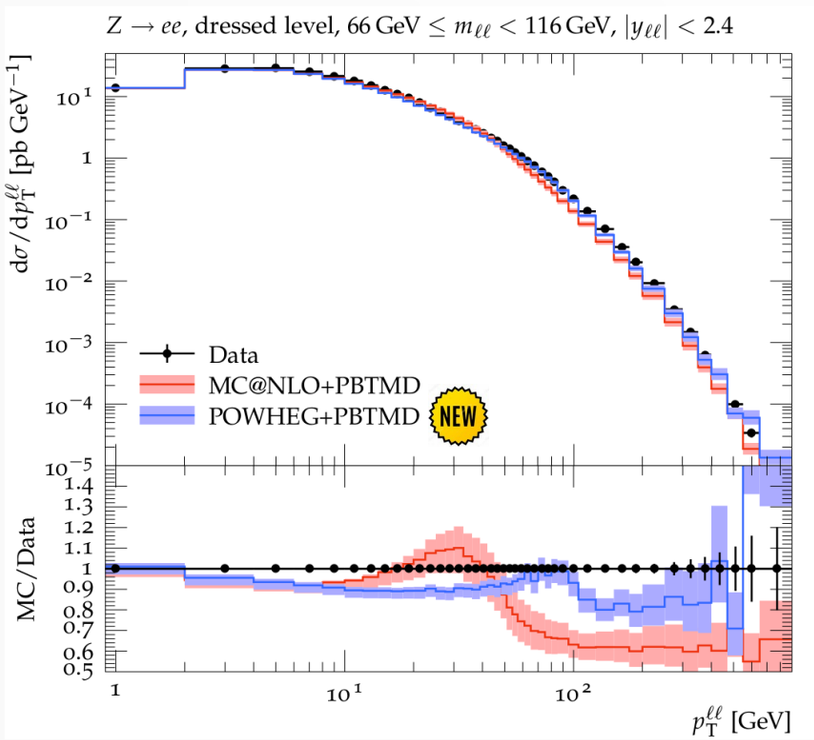


- **Matrix Elements unphysical pT**
- Using **PBset2** for **collinear calculation**
- **NLO accuracy at high pT**, mainly from Real Emission (RE) contribution
- Real Emission for pT > ptsqmin
- **hdamp** define the **damping scale** for suppressing NLO divergences (hdamp = 1 → NLO).
- For Z production hdamp=1 ptsqmin=90



(4) Applications

- Drell Yan/Z production at LHC
  - ATLAS 8 TeV pp → Z/γ* → ee

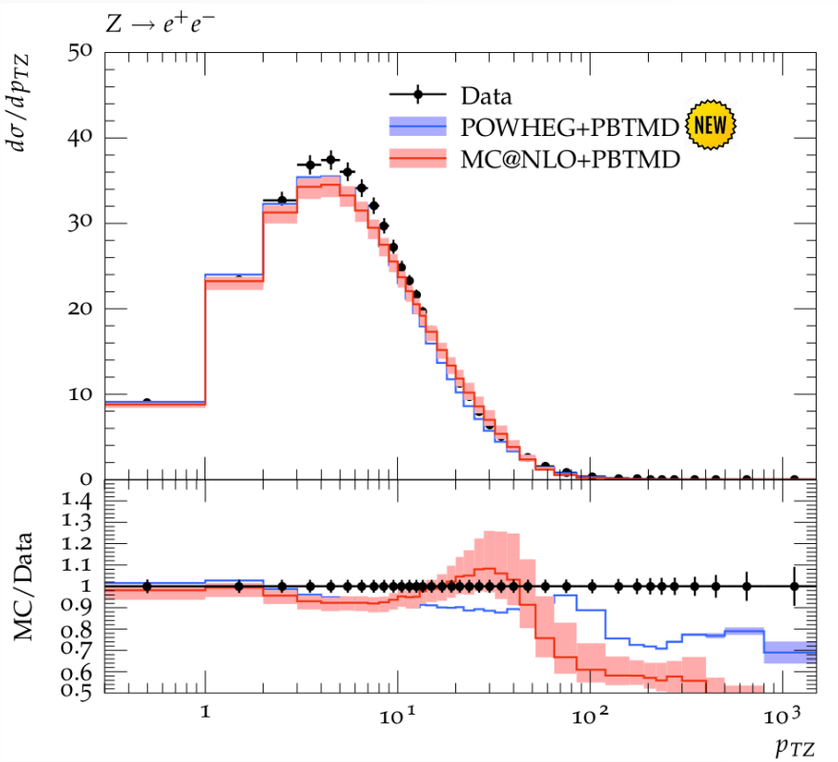


Comparing different NLO calculations

- Using **PBset2** for **collinear calculation**
- PBTMD used: **2018PBTMD-NLO-set2**
- **Scale uncertainty** is **shown** only since **PBTMD uncertainty** much **smaller**.
- Perfect **agreement** at **low pT**
- **Differences** in **matching regions**, and at **high pT** because of different alpha s
- **MCatNLO** prediction from **PhysRevD.100.074027**
- Data from **arXiv:1512.02192**

(4) Applications

- Drell Yan/Z production at LHC
  - CMS 13 TeV pp → Z/γ* → ee

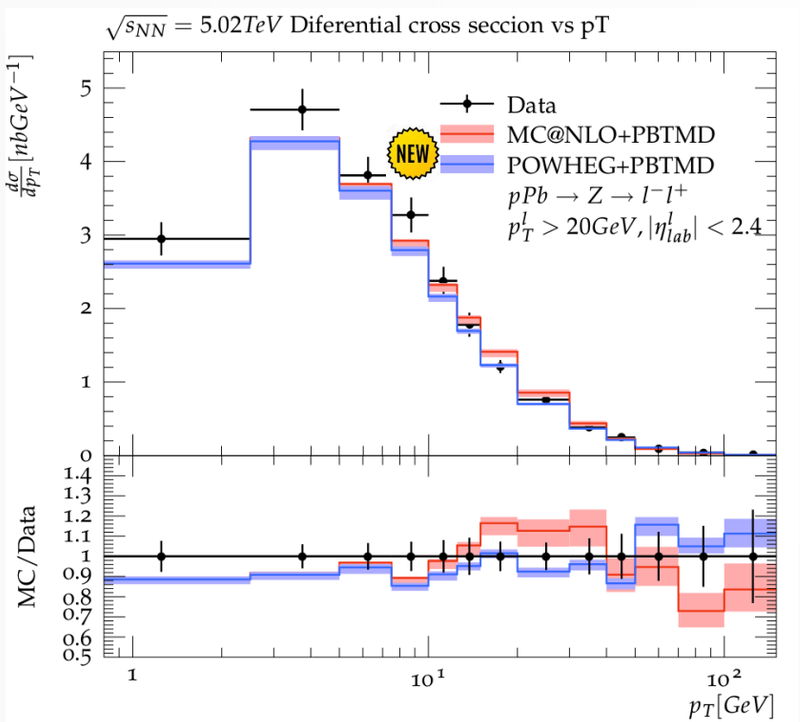


Comparing different NLO calculations

- Using **PBset2** for **collinear calculation**
- PBTMD used : **2018PBTMD-NLO-set2**
- Scale uncertainty is shown (only for MC@NLO)
- Perfect agreement at low pT differences arise at high pT
- CMS 13TeV data has finer binning than ATLAS 8TeV data at low pT
- **McatNLO** prediction from **PhysRevD.100.074027** and **arXiv:1909.04133**
- Data from **arXiv:1909.04133**

(4) Applications

- Drell Yan/Z production at LHC
  - CMS 5.02 TeV pPb → Z/γ* → ee

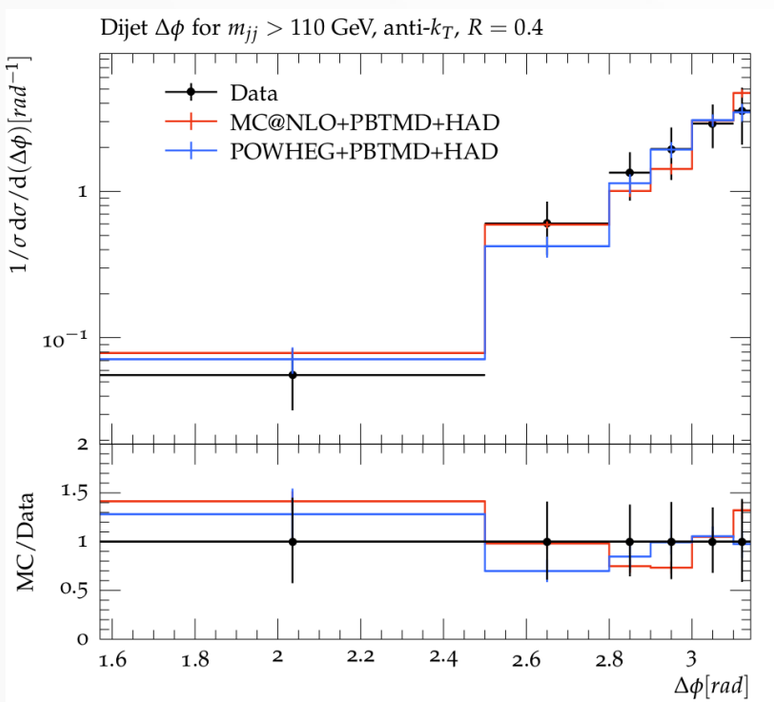


Comparing different NLO calculations

- Using uTMDset2 for collinear calculation
- PBTMD used : 2018PBTMD-NLO-set2
- Scale uncertainty is shown
- Cross section per nucleon
- Agreement at low pT validates the PBTMD
- Data from **j.physletb.2016.05.044**

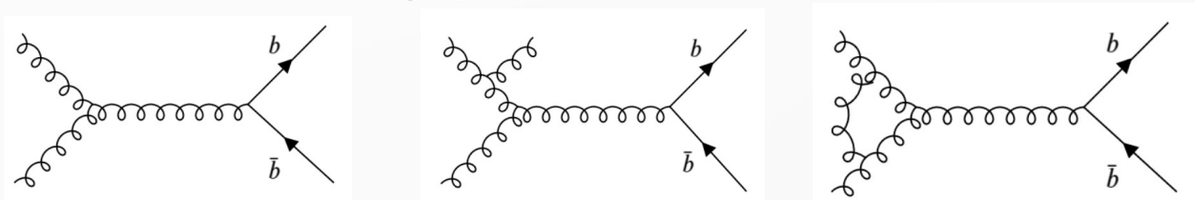
(4) Applications

- BBar production at LHC
  - ATLAS 7 TeV BBar dijets



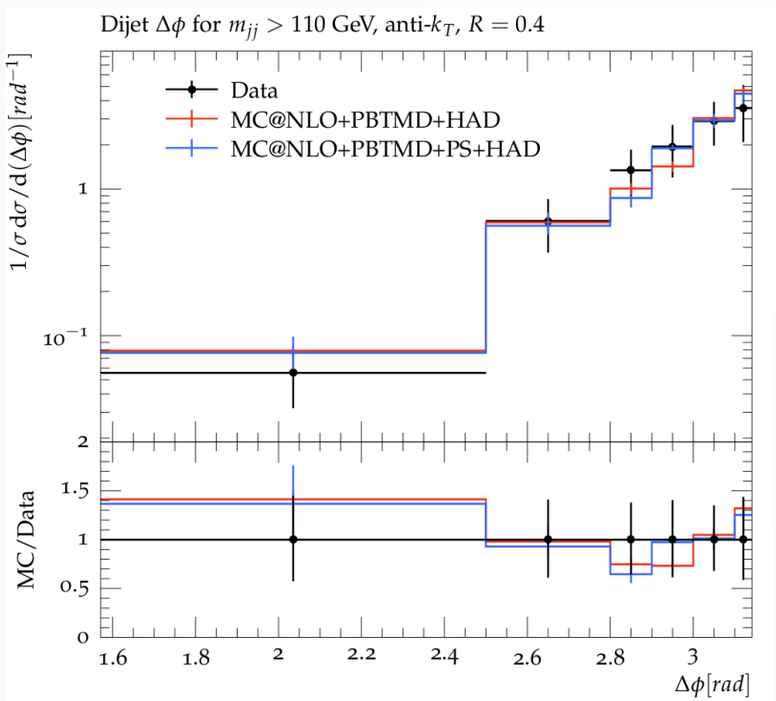
Comparing different NLO calculations

- Using PBset2 for collinear calculation
- PBTMD used : 2018PBTMD-NLO-set2
- Now **Final Color State** at parton level
- Using POWHEG default settings
- PBTMD + HAD describes data
- Good agreement in resummation region (back to back region)
- Data from **Eur.Phys.J. C71 (2011) 1846**



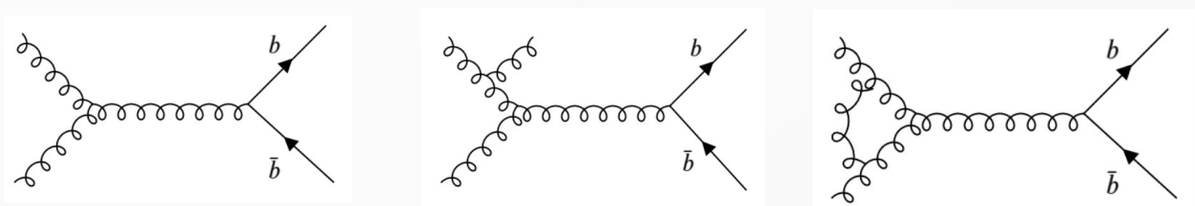
(4) Applications

- BBar production at LHC
  - ATLAS 7 TeV BBar dijets



NLO+PBTMD+PS+HAD

- Using PBset2 for collinear calculation
- PBTMD used : 2018PBTMD-NLO-set2
- Small effect from TMD shower in resummation region
- Main effect is from TMD kt distribution

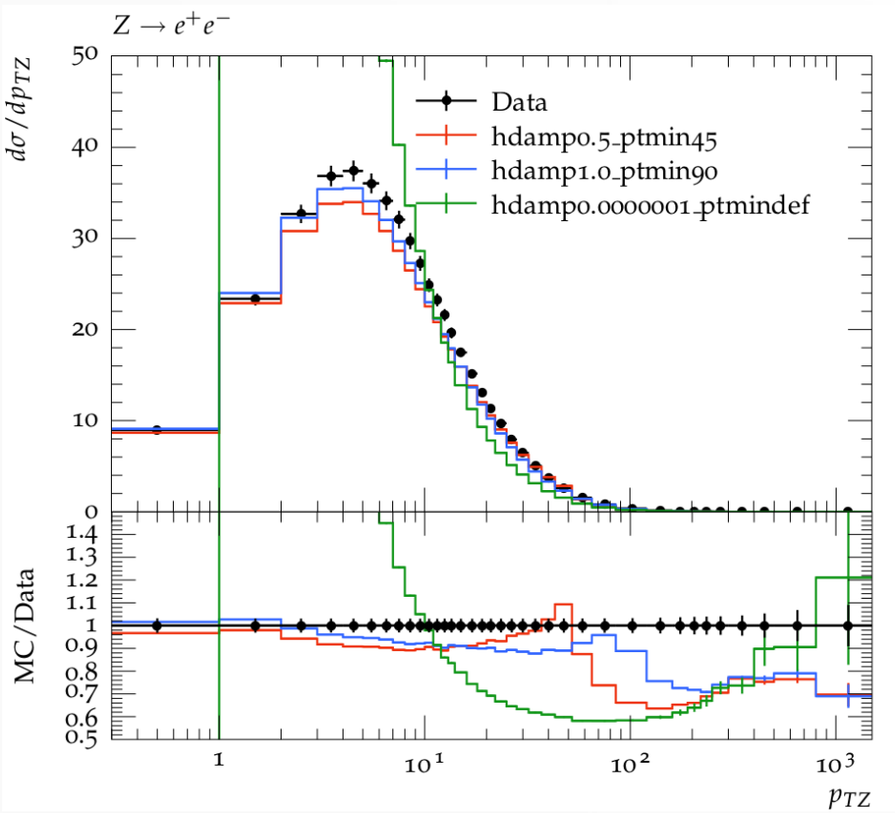


(5) Conclusions

- Good description of color neutral and color final state with NLO + PBTMD:
  - DY at different energies
  - BBar dijets
- Very small uncertainty (<<1%) in low pT (resummation) from PBTMD (not shown here but in **PhysRevD.100.074027**).
- Scale uncertainty dominates at resummation region (coming from ME)
- Very good agreement at low pT with different NLO approaches
- TMD parton shower applied to BBar jets production

BACK UP

- POWHEG hdamp and ptsqmin



POWHEG real emission :

$$D\frac{\overline{\mathcal{B}}}{\mathcal{B}}\mathcal{R}(p_t^2)\exp\left[-\int_{p_t^2} dp_t'^2 \frac{D\mathcal{R}(p_t'^2)}{\mathcal{B}}\right] + (1-D)\mathcal{R}(p_t^2),$$

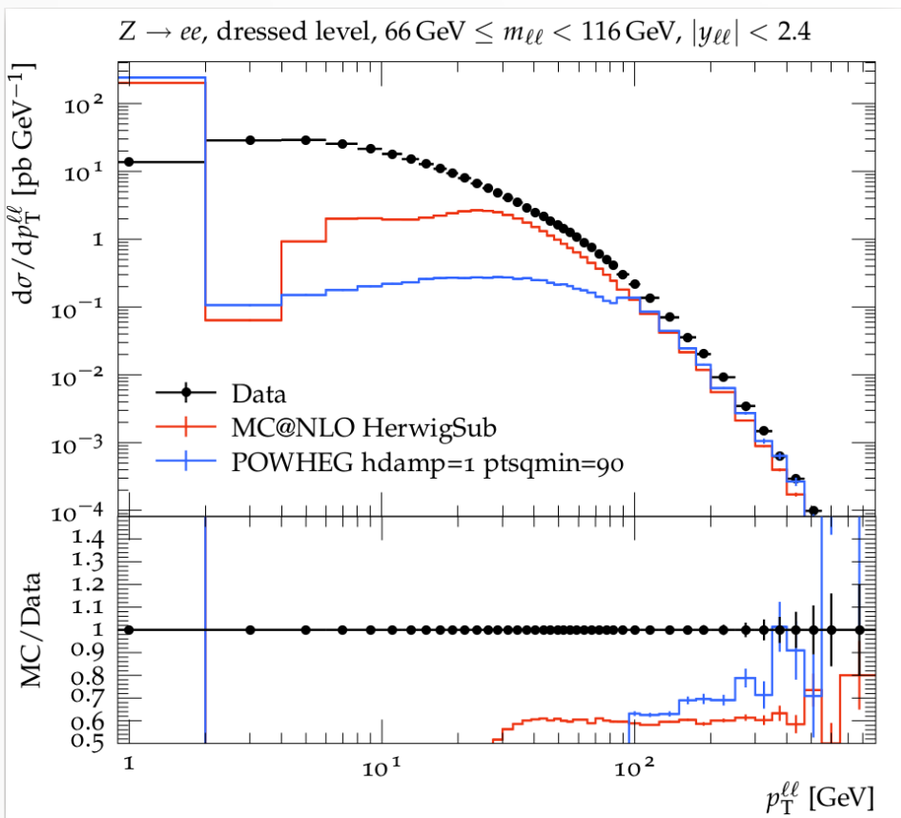
$$D(p_t^2; h) = \frac{h^2 M_Z^2}{h^2 M_Z^2 + p_t^2}$$

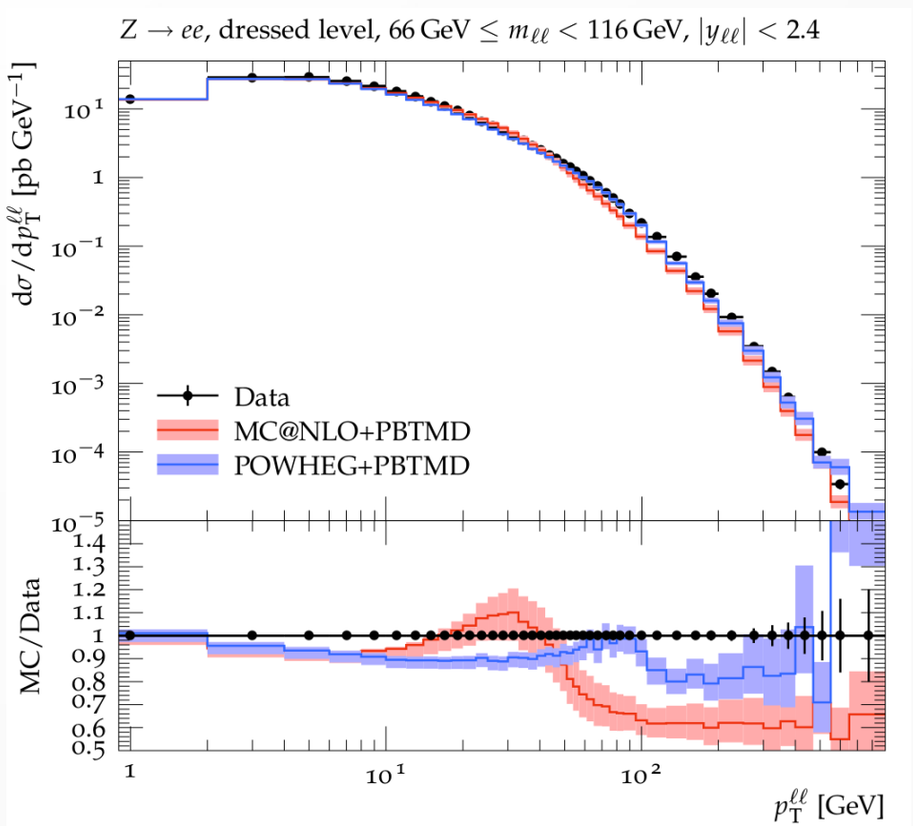
ptsqmin
hdamp → h

- If h→ 0 then POWHEG NLO limit
- If h→ inf then maximal Sudakov suppression
- Choosing h=1 and ptsqmin = 90 there is a balance since damping and suppression of real emission happens around same scale (Mz).

BACK UP

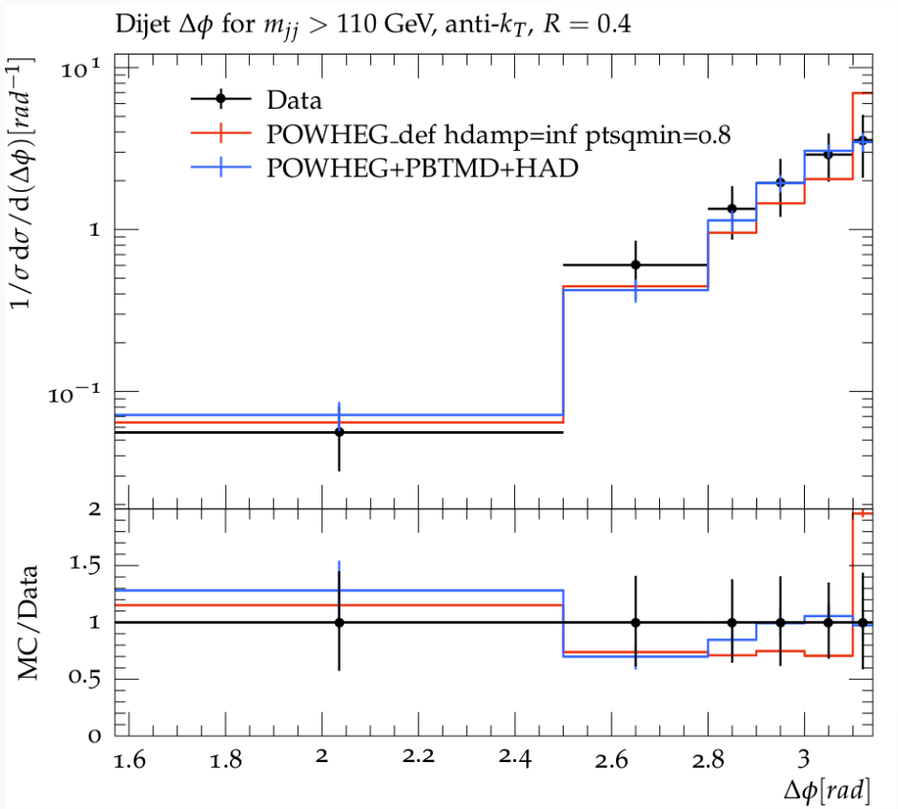
- ME and NLO+PBTMD with McatNLO and POWHEG

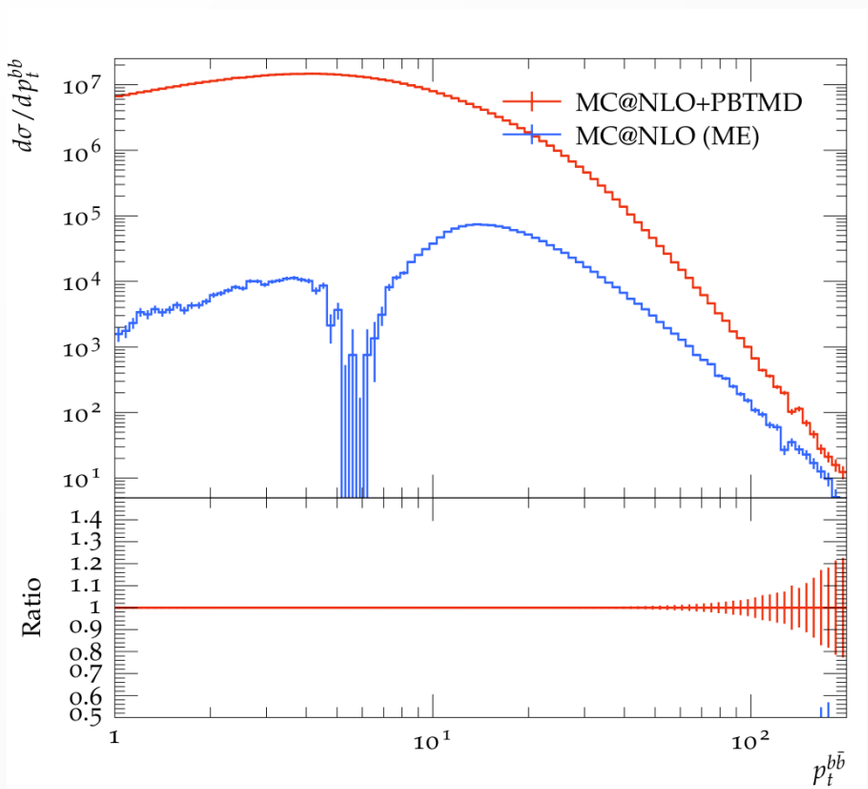




BACK UP

- ME vs NLO+PBTMD+HAD and pT of bbar system





BACK UP

- POWHEG pT and phi*