CASCADE - LHE tutorial

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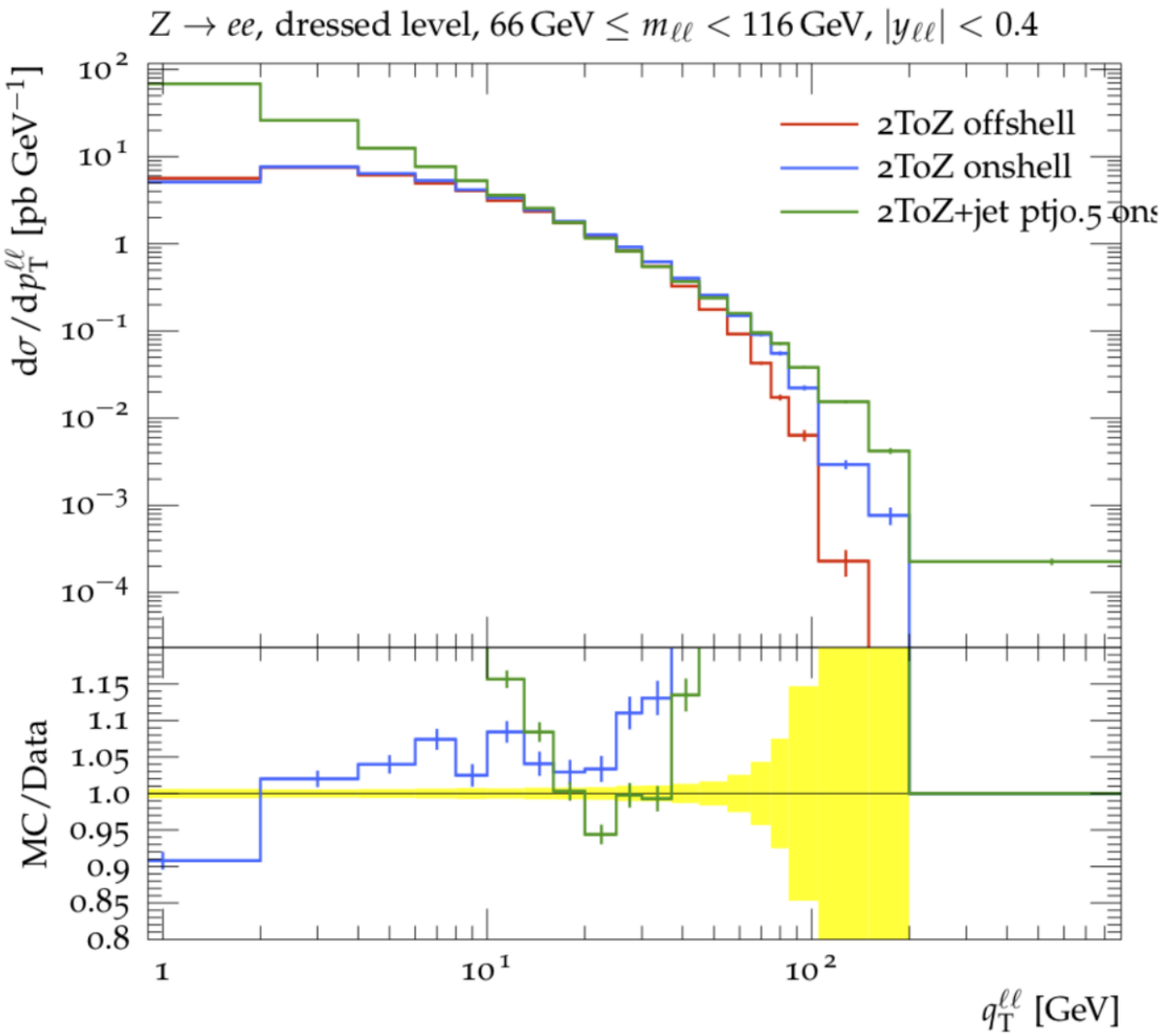
- CASCADE has some in-build processes, mainly for small x physics based on CCFM evolution (this is not the topic of TODAY)
- CASCADE3 (or CASCADE-LHE) can be used for showering collinear and k_t dependent hard processes (via lhe files).
  - collinear processes:
    - k_t is added for both incoming partons according to TMD, preserving the mass of the process ( ), the consequence is modified $x-$ values.
  - off-shell processes:
    - can be showered directly
- after parton shower, events are hadronized and written in form of hepmc file, for further analysis with eg Rivet

Matching to hard process: off-shell ME with KaTie

van Hameren, A. CPC, 224, 371, 2018, arXiv 1611.00680

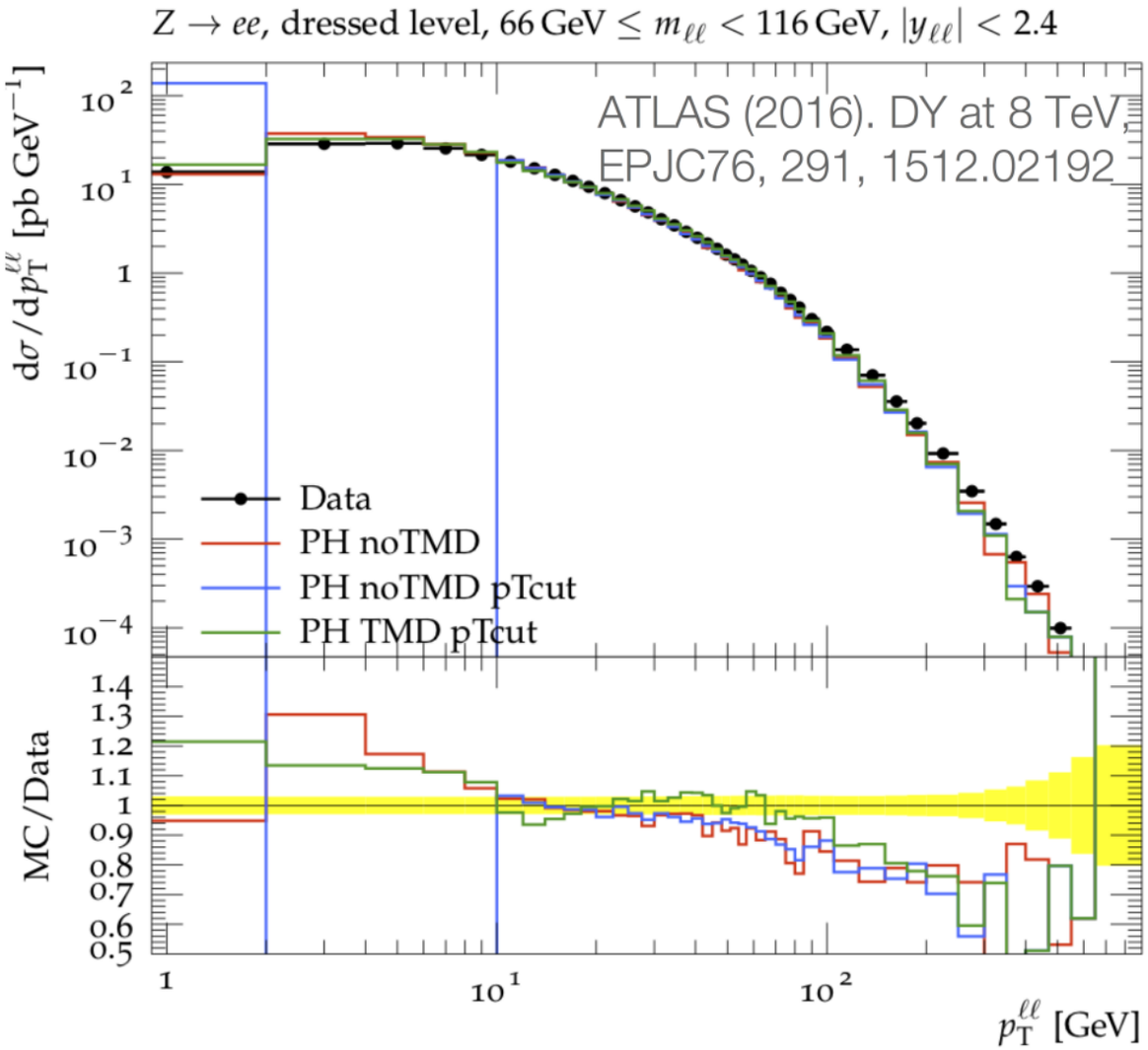
- KaTie (see talk by A. Kusina on Z+jet)
  - off-shell kinematics with TMDs used to calculate hard process
    - no kinematic corrections needed
    - parton shower below scale μ
  - off-shell agrees with on-shell with TMD added (and keeping mass fixed) at small q_T
    - ➔ important check for application with collinear NLO calculation
  - off-shell agrees with $2 \to 2$ on-shell at medium q_T
    - ➔ important check for merging different parton multiplicities



Matching to hard process: POWHEG method

Frixione, S., Nason, P., and Ridolfi, G. (2007). JHEP, 09, 126 arXiv 0707.3088
Frixione, S., Nason, P., and Oleari, C. JHEP, 0711(), 070 arXiv 0709.2092

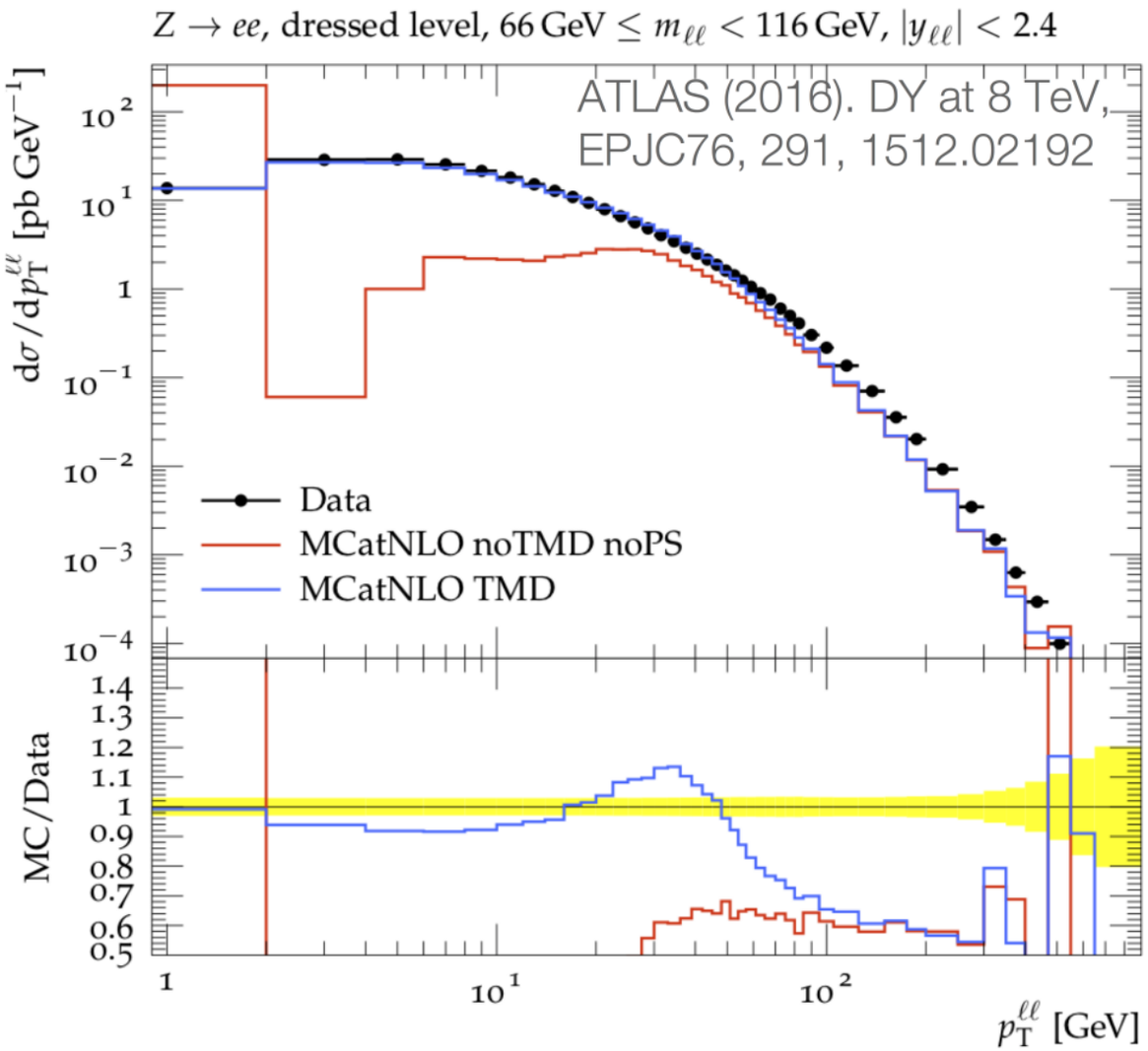
- POWHEG exponentiates real emission (soft part): Sudakov for 1st emission
  - DY-process as example
  - q_T cut applied (`ptsqmin`) to allow for contribution from TMD (and PS)
    - low q_T region filled by TMD + PS
    - large q_T by real emission
  - DY production described reasonably well with TMD + POWHEG with q_T cut
    - TMD fills low q_T part



Matching to hard process: MC@NLO method

Frixione, S. and Webber, B. JHEP, 0206, 029, arXiv hep-ph/0204244
Alwall, J., et al JHEP, 1407, 079 arXiv 1405.0301

- MC@NLO subtracts soft & collinear parts from NLO (added by TMD and shower)
- MC@NLO without shower unphysical
  - DY-process as example
  - low q_T region affected by subtraction of soft & collinear parts
    - to be filled by TMD (+ PS)
  - DY production very well described by TMD with MC@NLO
    - TMD fills low q_T part



CASCADE steering file

```
&CASCADE_input
! NrEvents = -1                                  ! Nr of events to process
NrEvents = 10000                                 ! Nr of events to process
Process_Id = -1                                  ! Read LHE file
!Hadronisation = 1                               ! Hadronisation on (=1)
Hadronisation = 0                                ! Hadronisation on (=1)
SpaceShower = 1                                  ! Space-like Parton Shower
SpaceShowerOrderAlphas=2                         ! Order alphas in Space Shower
TimeShower = 1                                   ! Time-like Parton Shower
ScaleTimeShower = 4                              ! Scale choice for Time-like Shower
!                                                  1: 2(m^2_1t+m^2_2t)
!                                                  2: shat
!                                                  3: 2(m^2_1+m^2_2)
!                                                  4: 2*scalup (from lhe file)
!ScaleFactorFinalShower = 1.                     ! scale factor for
!                                                  Final State Parton Shower
PartonEvolution = 2                              ! type of parton evolution
!                                                  in Space-like Shower
!                                                  1: CCFM
!                                                  2: full all flavor TMD evolution
```

CASCADE steering file

```
! EnergyShareRemnant = 4                    ! energy sharing in proton remnant
!                                             1: (a+1)(1-z)**a <z>=1/(a+2)=1/3
!                                             2: (a+1)(1-z)**a
!                                                 <z>=1/(a+2)=mq/(mq+mQ
!                                             3: N/(z(1-1/z-c/(1-z))**2)
!                                                c=(mq/mQ)**2
!                                             4: PYZDIS: KFL1=1
PartonDensity = 102200                      ! use TMDlib: PB-TMDNLO-set2
! PartonDensity = 101201                     ! use TMDlib: PB-TMDNLO-set1
  ! TMDDensityPath= './share'                ! Path to TMD density
  !                                            for internal files
  lheInput = 'KaTie-Zj-7TeV.lhe'            ! LHE input file
  lheHasOnShellPartons = 0                  ! = 0 LHE file has
  !                                              off-shell parton configuration
  lheReweightTMD = 0                        ! Reweight with new TMD
  !                                            given in PartonDensity
  lheScale = 0                              ! Scale defintion for TMD
  !                                            0: use scalup
  !                                            1: use shat
  ! lheWeightId = 0                         ! use weight Id = ...
  !                                            as weight for LHE file
  &End
```

CASCADE3 – tutorial: getting started

- all CASCADE lhe files and steering files are under:

```
/afs/desy.de/user/j/jung/scratch/ref2018/cascade3/local/share/cascade/LHE
```

- Instructions to run CASCADE with Rivet for the event analysis and plot production:

```
export HEPMCOUT=/tmp/$(whoami)/myfile.hepmc
mkfifo $HEPMCOUT

cascade < steeringXXXX.txt > mycascade.out &
rivet -a LHCB_2014_I1262703 $HEPMCOUT

rivet-mkhtml -o myresults Rivet.yoda:"Title=CAS-LHE"
```

- on your laptop:

```
scp -rp
schoolXX@naf.school01.desy.de:/afs/desy.de/user/s/school90/public/myresults .
firefox myresults/index.html
```

CASCADE3 – tutorial: KaTie

- run CASCADE-LHE with Zj-LHE file with LHCb Rivet plugin for $Z+j$ configuration at 7 TeV (`LHCB_2014_I1262703`).
  - use KaTie LHE file (done in KaTie tutorial), together with Rivet for analysis.
    - edit steering file `steering-KaTie.txt`
    - copy lhe file to your directory and gunzip it
    - pure LHE configuration (no TMD, no parton shower, no hadronization)
    - use initial state parton shower and hadronization

CASCADE3 – tutorial: POWHEG

- run CASCADE-LHE with Zj-LHE file with LHCb Rivet plugin for $Z+j$ configuration at 7 TeV (`LHCB_2014_I1262703`).
  - use POWHEG LHE file (provided) for $Z+j$ configuration
    - edit steering file `steering-DY-PH-7TeV.txt`
    - copy lhe file to your directory and gunzip it
    - pure LHE configuration
    - with TMD (but without parton shower)
    - with TMD and parton shower
    - check the differences when LO or NLO splitting functions in the initial state partons shower are used
  - compare the results from the different runs

CASCADE3 – tutorial: POWHEG - MC@NLO

- run CASCADE-LHE for DY production with POWHEG with different ptsqmin cuts and aMCatNLO files, use Rivet plugin `ATLAS_2015_I1408516` (8 TeV) for DY production:
  - edit steering file `steering-DY-XX-8TeV.txt`
  - copy lhe file to your directory and gunzip it
  - run without TMD and PS
  - run with TMD
  - include parton shower from TMDs

CASCADE3 – tutorial: Questions, requests