Predictions and uncertainties

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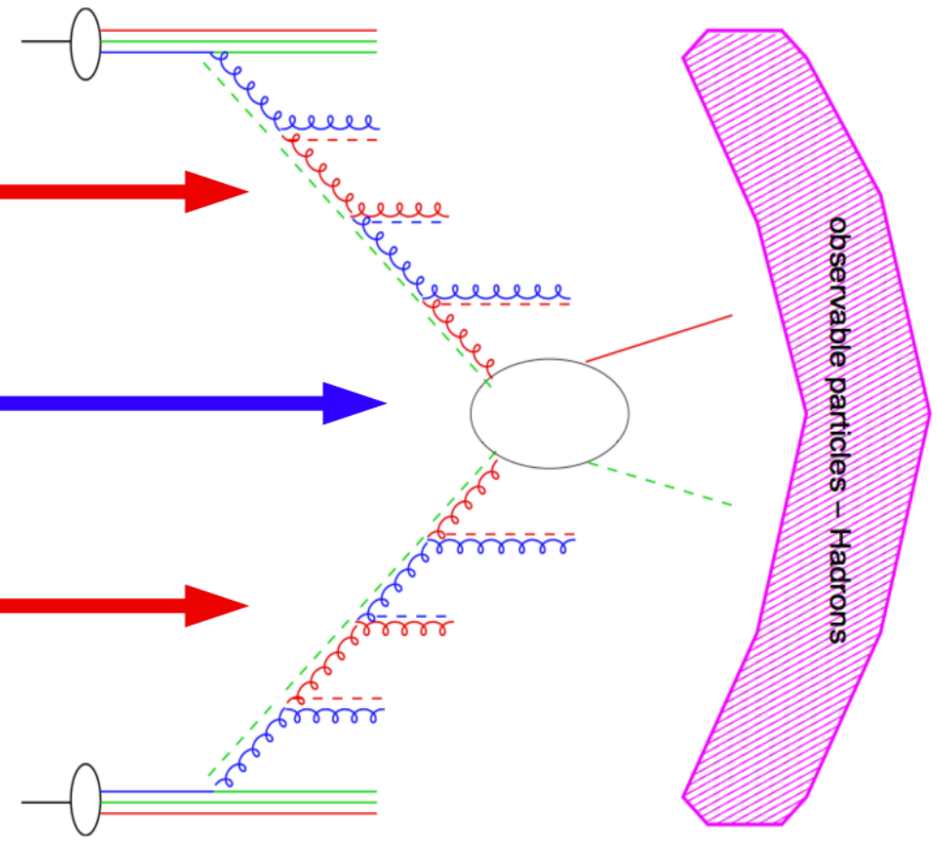
Some thoughts about benchmarking and tuning for precision predictions

Picture of jet production

- General approach to hard scattering processes
  - including higher order parton radiation
    - adding hadronization and fragmentation
- leads to the concept of factorization:

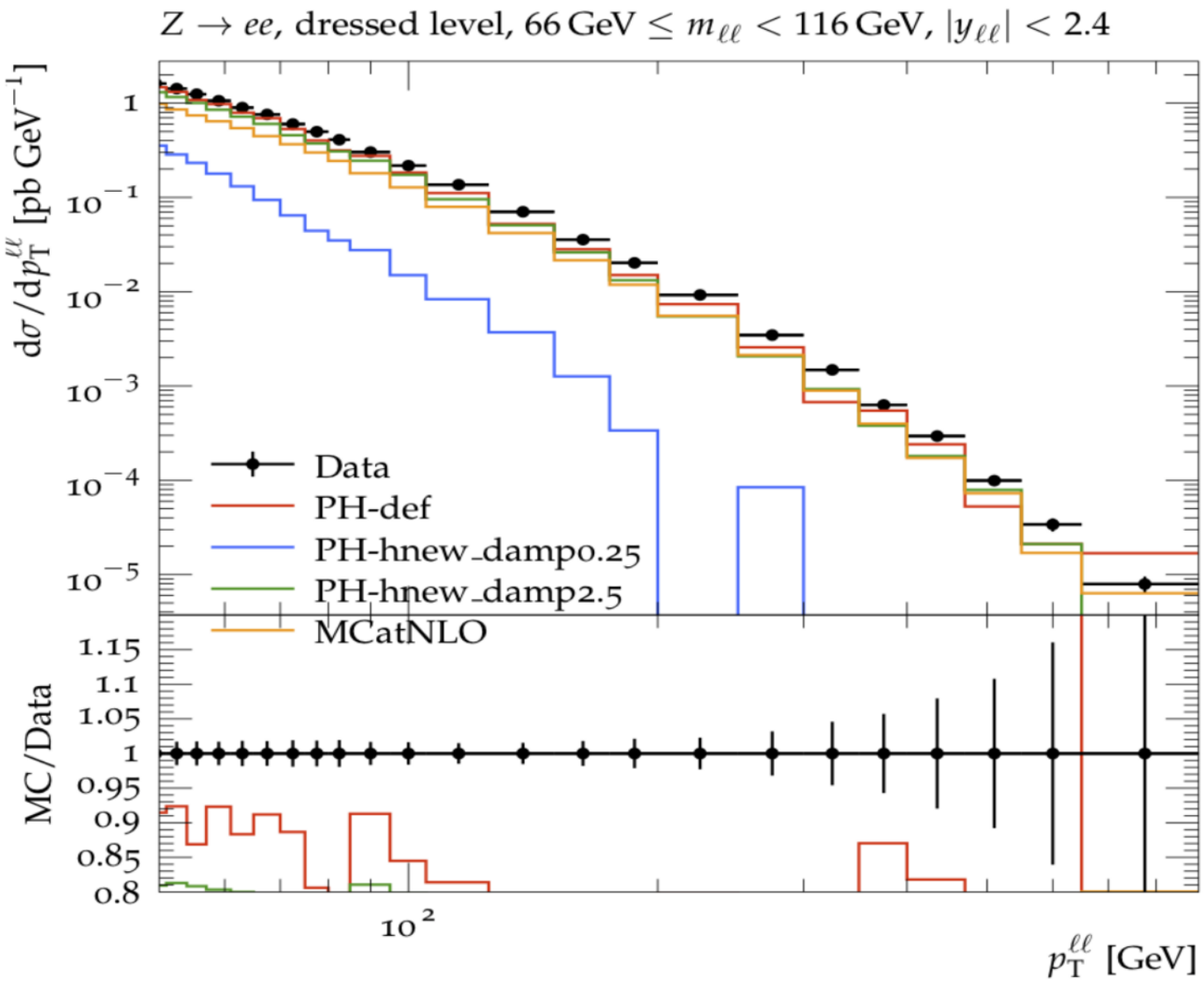
$$\sigma = f(x_1, \mu^2) \otimes \hat{\sigma}(x_1, x_2, \mu^2) \otimes f(x_2, \mu^2)$$



➔factorization ansatz is used in
any calculation (LO,NLO, MC event generators ...)

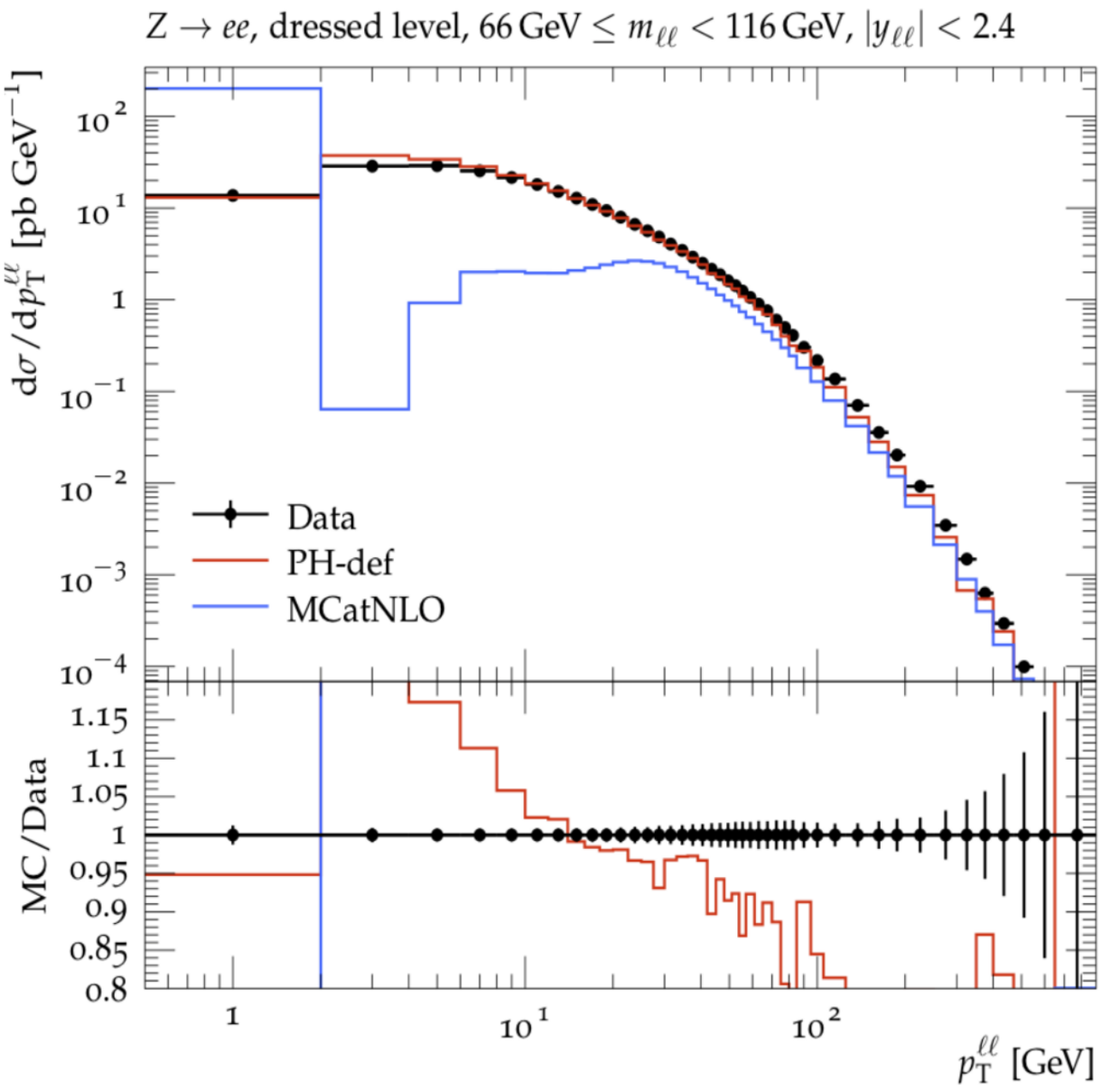
The hard process

- calculations at LO and NLO (in fixed order also to NNLO)
  - what are the predictions in the simplest case: DY at NLO
    - depending on params in NLO calc, huge differences in real emission piece....
      - beyond NLO accuracy :)
        - but wrong !
  - Need clear benchmarks, what is right or wrong !



The parton shower

- Where can parton shower play a role ?
  - inclusive DY p_T spectrum
    - PH includes Sudakov down to small p_T → little room for PS
    - MC@NLO give more space to PS



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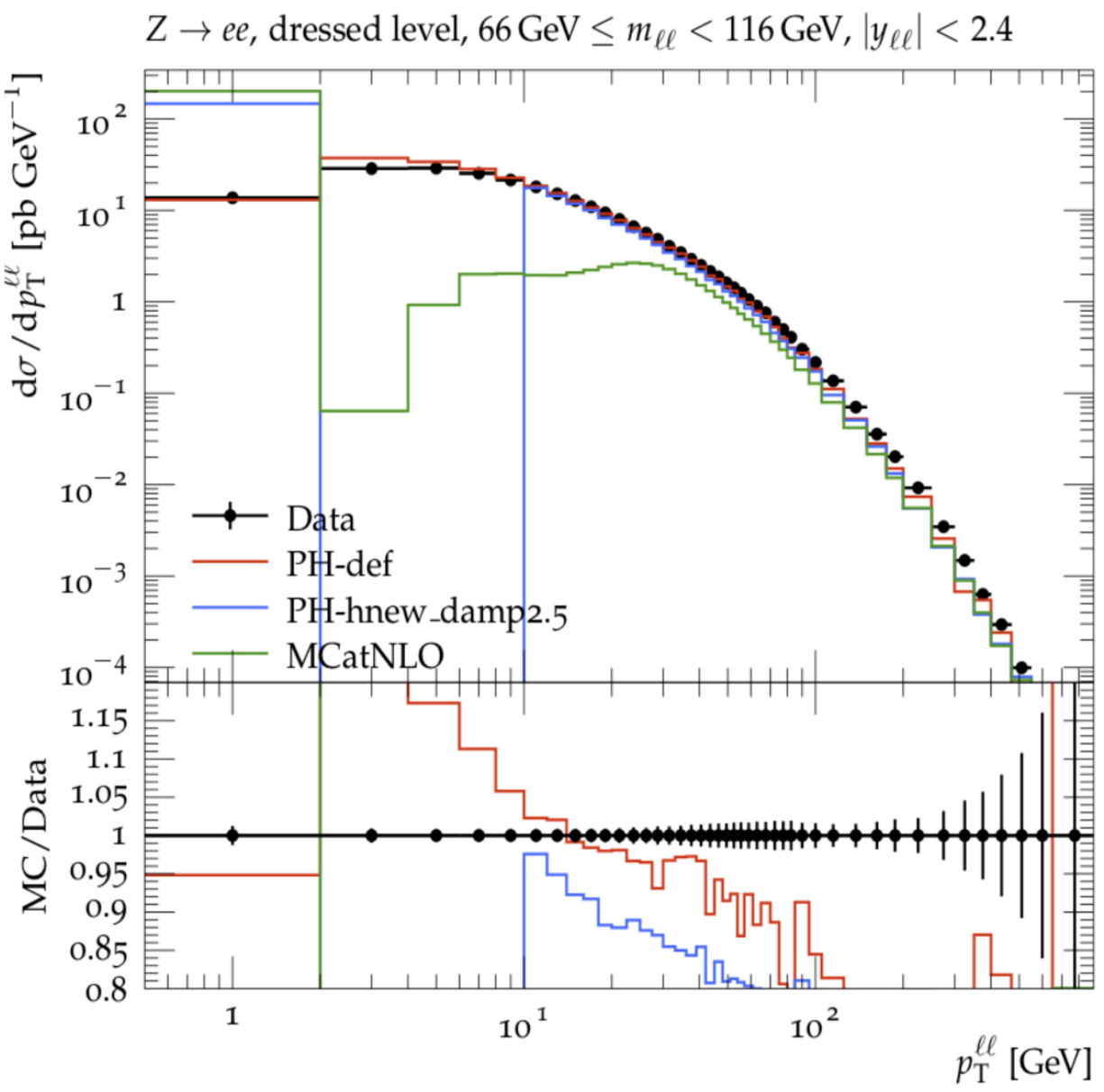
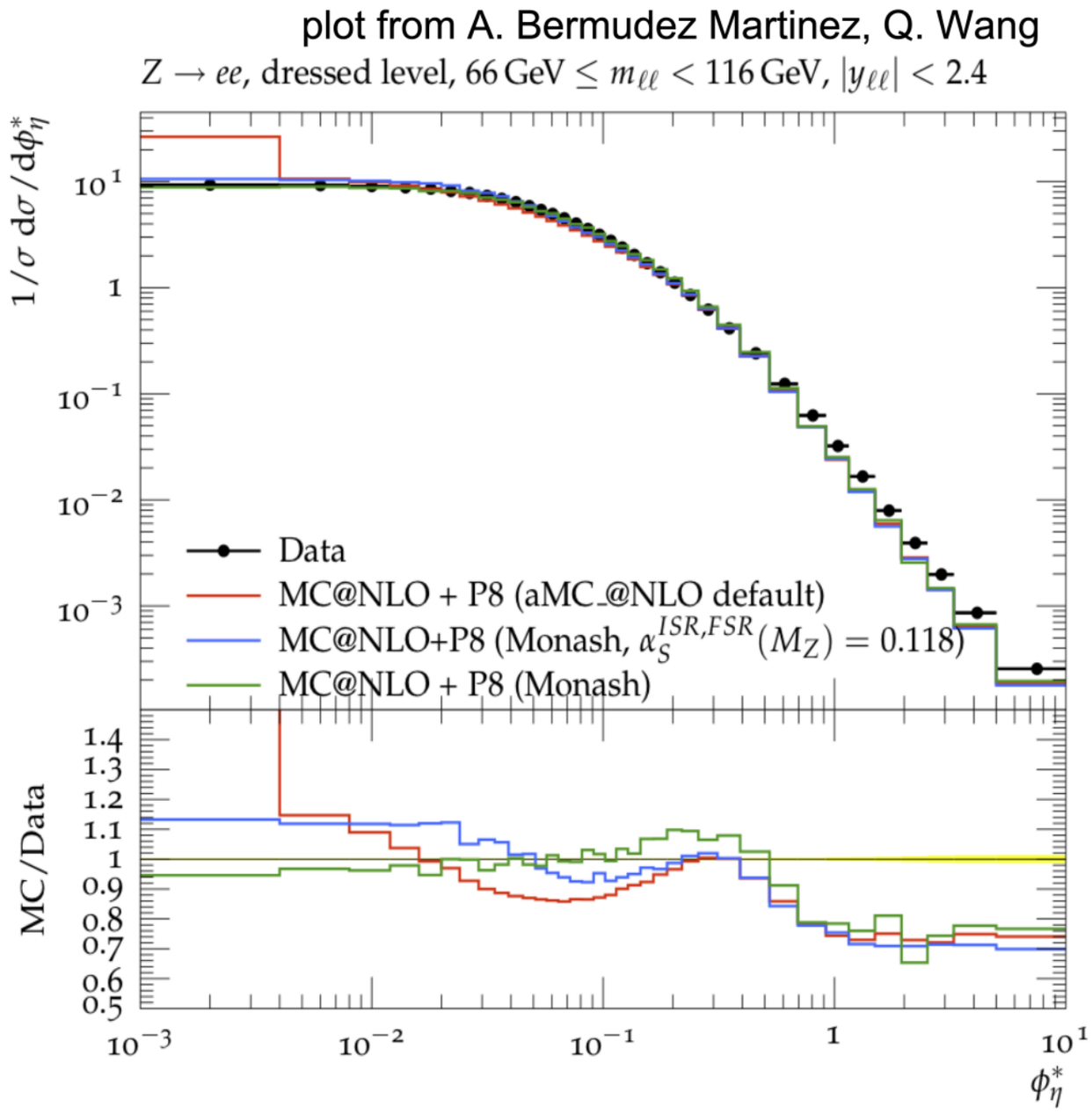


- Need to define regions and processes where PS can/should play role:
  - either rely on PH Sudakov or apply cuts !

The parton shower

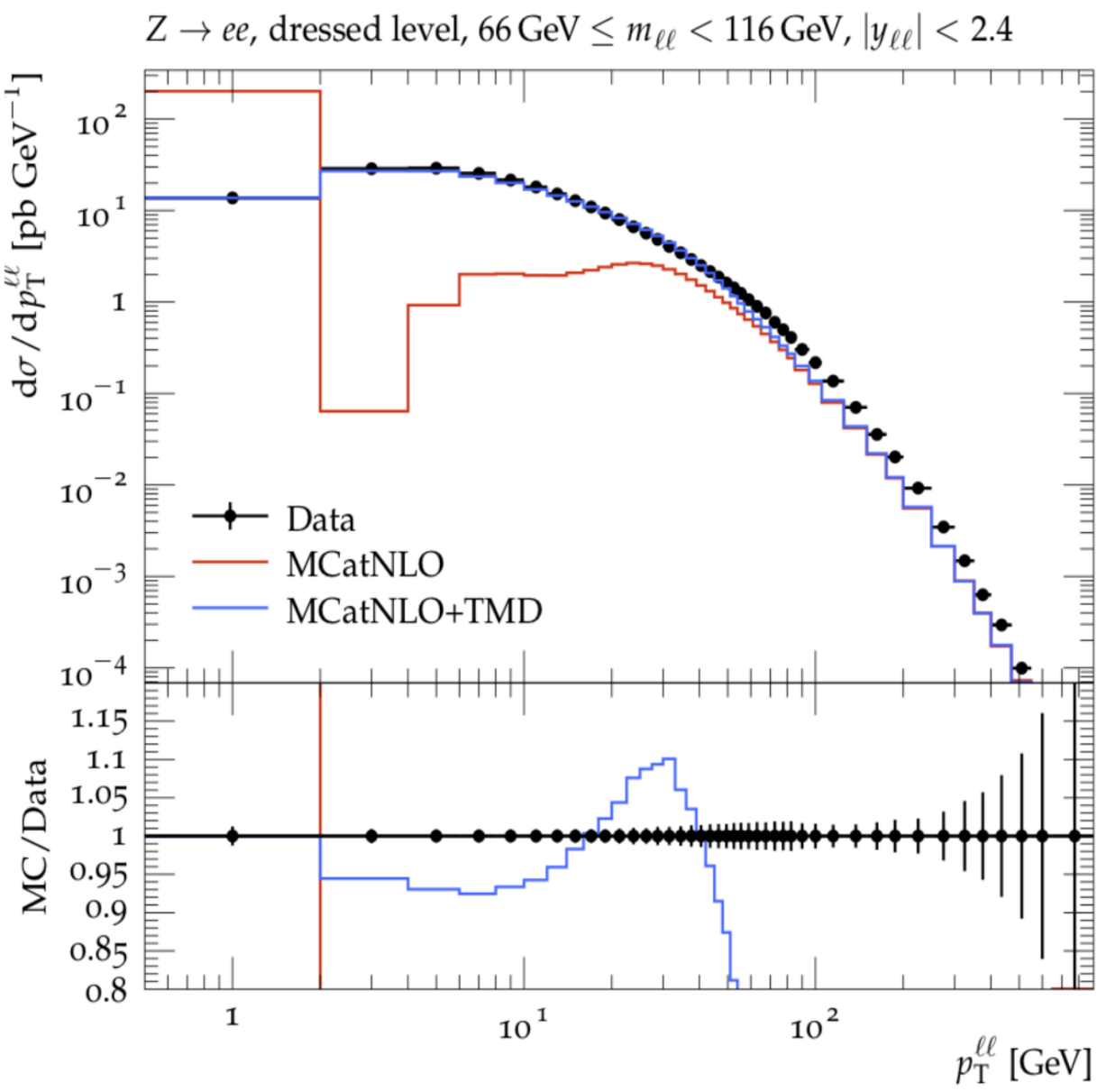
- Where can parton shower play a role ?
  - inclusive DY p_T spectrum
    - MC@NLO give more space to PS
    - sensitivity to PS tunes, α_s etc
- Recommended aMCatNLO gives bad results :)

plot from A. Bermudez Martinez, Q. Wang



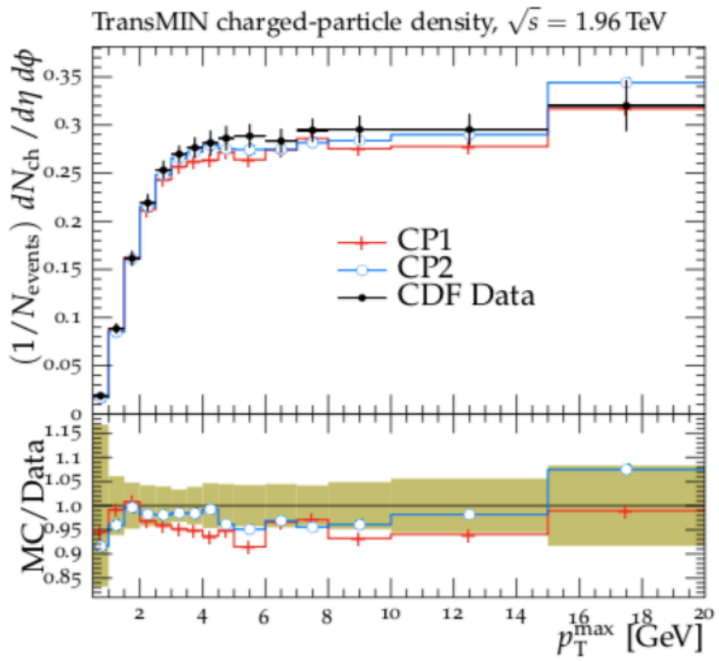
The TMD instead of PS

- Where can parton shower play a role ?
  - inclusive DY p_T spectrum
    - MC@NLO give more space to PS

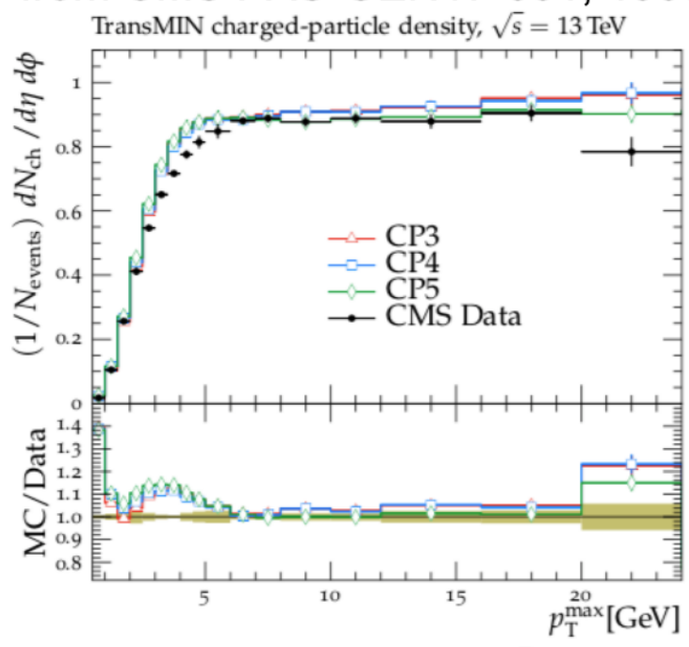


- MC@NLO with TMDs fills nicely the low p_T region (to be discussed separately :)

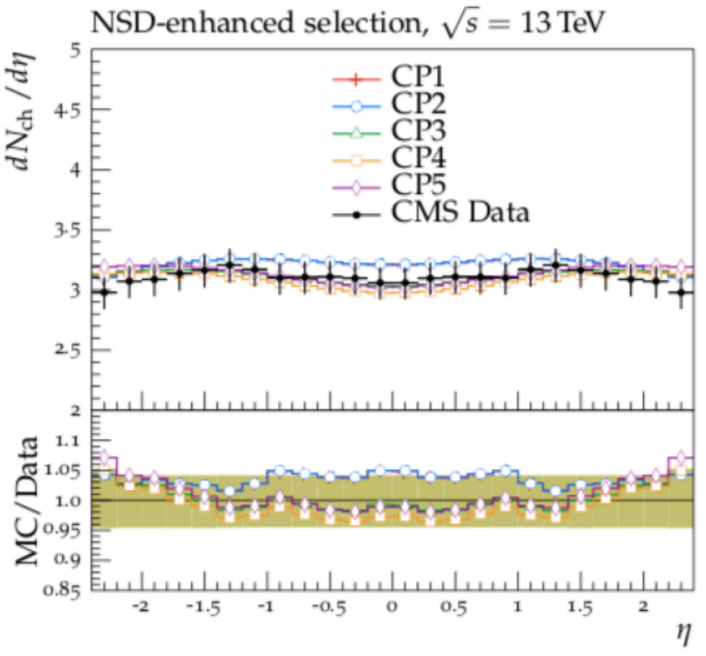
Underlying events and MPI



from CMS PAS-GEN17-001, 1903.12179



- Underlying events in TransMin region
- $dn/d\eta$ distributions, perhaps in bins of p_T



H. Jung, MC uncertainties, LHCEW WG: Jets and EW bosons, 28.May 2019

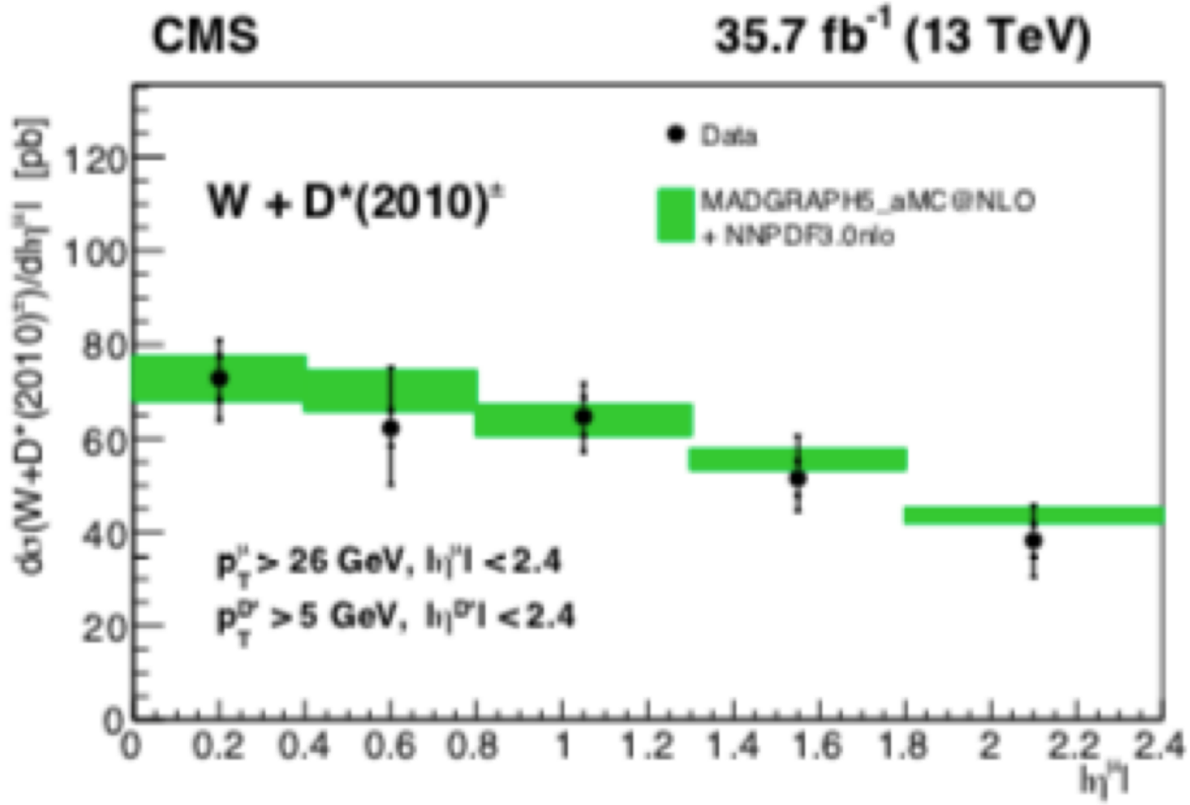
Hadronization

- Hadronziation parameters:
  - charm, beauty
    - uncertainties important for measurements !

CMS-PAS-SMP-17-014,1811.10021

Pseudorapidity $[\lvert\eta^{\mu}\rvert]$	[0,2.4]	[0,0.4]	[0.4,0.8]	[0.8,1.3]	[1.3,1.8]	[1.8,2.4]
Luminosity	±2.5	±2.5	±2.5	±2.5	±2.5	±2.5
Tracking	±2.3	±2.3	±2.3	±2.3	±2.3	±2.3
Branching	±2.4	±2.4	±2.4	±2.4	±2.4	±2.4
Muons	±1.2	±1.2	±1.2	±1.2	±1.2	±1.2
N_{sel} determination	±1.5	±1.5	±1.5	±1.5	±1.5	±1.5
$D^*(2010)^{\pm}$ kinematics	±0.5	±0.5	±0.5	±0.5	±0.5	±0.5
Background normalization	± 0.5	+0.9/−0.8	+1.9/−0.8	+1.4/−0.5	+0.8/−1.0	0.0/−0.6
$\vec{p}_T^{miss}$	+0.7/−0.9	+0.4/−1.2	+1.3/−0.3	+1.1/−1.0	0.0/−2.6	0.0/+1.5
Pileup	+2.0/−1.9	+0.4/−0.5	+2.9/−3.0	+2.0/−1.9	+4.6/−5.1	+2.7/−2.6
Secondary vertex	−1.1	+1.3	−1.2	−1.5	−2.7	−2.5
PDF	±1.2	±1.3	±0.9	±1.4	±1.5	±1.7
Fragmentation	+3.9/−3.2	+3.4/−1.8	+7.4/−5.2	+3.3/−3.0	+2.2/−1.2	+7.4/−5.7
MC statistics	+3.6/−3.3	+8.8/−7.5	+9.0/−11.9	+7.9/−6.8	+9.8/−14.1	+10.1/−8.5
Total	+7.5/−7.0	+10.7/−9.3	+13.2/−14.2	+10.1/−9.3	+12.7/−16.2	+13.8/−12.1

- Fragmentation uncertainty dominant for measurement



What this tells us ?

- Need careful definition of hard scattering process:
  - just aMCatNLO or POWHEG or … is not enough
    - need benchmarking of NLO ME distributions

- Need careful definition, where PS parameters can be adjusted and tuned:
  - where is sensitivity to PS ?

- Need careful definition where intrinsic kt plays a role

- Where do UE and MPI play role, w/o affecting PS and intrinsic kt ?

➔ This Benchmarking & Tuning is important for any precision prediction !

➔ we can/shall do better than what we have, even if it is beyond NLO accuracy :)

Appendix