Update on W/Z Ratio in Geneva.

Frank Tackmann

Deutsches Elektronen-Synchrotron

EWWG Meeting
CERN, June 20, 2018

[work in collaboration with Simone Alioli and Christian Bauer]

MC Generators in a Nut Shell.

Perturbative

- Partonic calculation

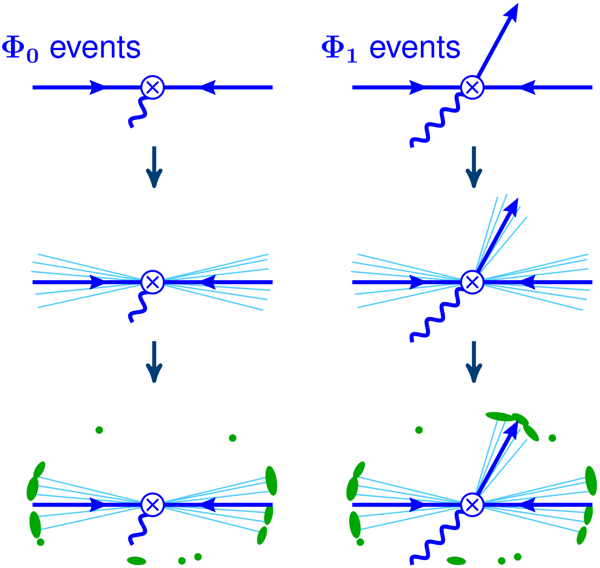
↓

- Parton shower
- Perturbative MPI

↓

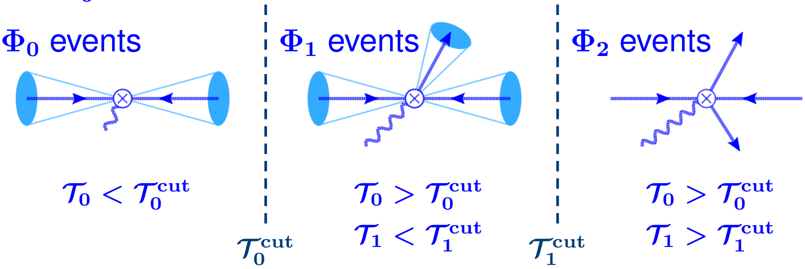
Nonperturbative

- hadronization
- beam remnants
- intrinsic k_T



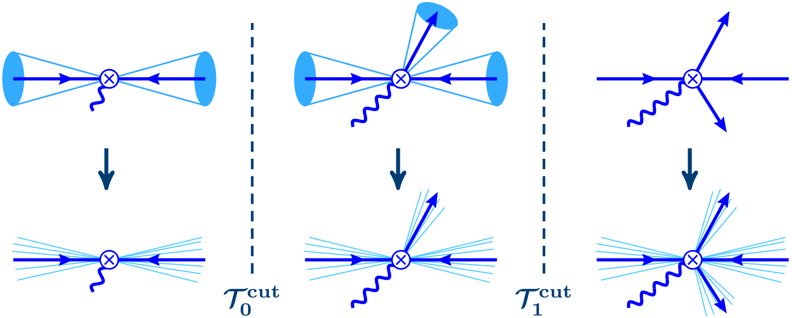
Partonic Calculation.

NNLO_0



- Emissions above (below) $\mathcal{T}_0^{\text{cut}}$ are resolved (unresolved)
  - Partons represent sum over any number of unresolved emissions
  - Want to lower $\mathcal{T}_0^{\text{cut}}$ to resolve more with partonic calculation
- (N)LO+PS merging patches together different (N)LO calculations
- NNLO+PS matching: Contains NLO_1 down to small $\mathcal{T}_0$
  - POWHEG NNLOPS: use MINLO′ to extend POWHEG NLO_1 to small $\mathcal{T}_0^{\text{cut}}$
  - GENEVA: use 0-jettiness subtractions and higher-order resummation

Parton Shower.



Parton shower fills in emissions below $\mathcal{T}_N^{\mathrm{cut}}$

- Provides unresolved emissions that have been integrated over and projected onto partons in partonic calculation
  - Highest partonic multiplicity is showered inclusively (corresponding to $\mathcal{T}_2^{\mathrm{cut}} = \infty$ here)
- MPI is done entirely by shower MCs
  - Currently not included in any partonic calculation
  - Would require to include double-parton scattering

Settings for W and Z.

Perturbative

- NNLL′+NNLO$_0$ for $\mathcal{T}_0$
- NLL+NLO$_1$ for $\mathcal{T}_1$
- GENEVA bands are from profile scale variations in $\mathcal{T}_0$ resummation (only)
  - Each scale variation treated as correlated between W and Z in their ratio
  - For illustration/information only, not the final word on uncertainty

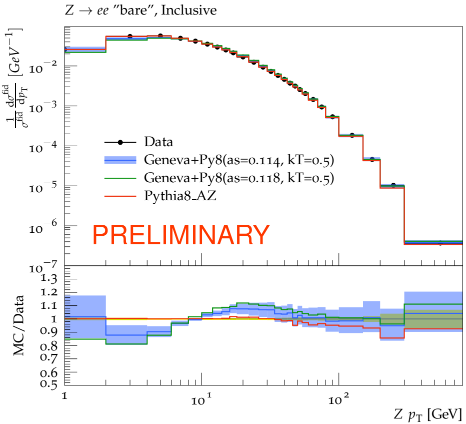
$\alpha_s(m_Z)$ and PDFs (in partonic resummed calculation)

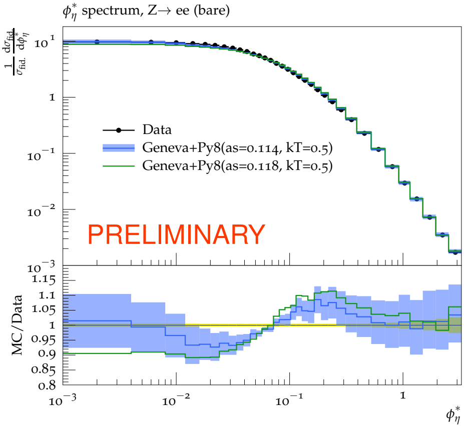
- NNPDF3.1 NNLO, $\alpha_s(m_Z) = 0.114$
- NNPDF3.1 NNLO, $\alpha_s(m_Z) = 0.118$
- CT14 NNLO, $\alpha_s(m_Z) = 0.118$

Pythia8

- Tune 18 (CMS UE tune on top of Monash 2013)
  - primordial (nonperturbative) k_T lowered to 0.5
  - primordial (nonperturbative) k_T at tune value of 1.8
- Compare to plain Pythia8 with AZ tune as proxy
  - Equivalent to what was used in analogous plots in ATLAS m_W paper

α_s Dependence.

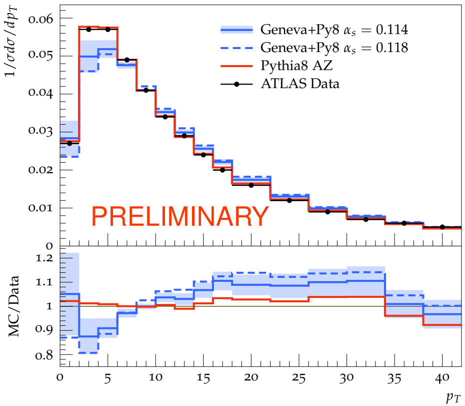




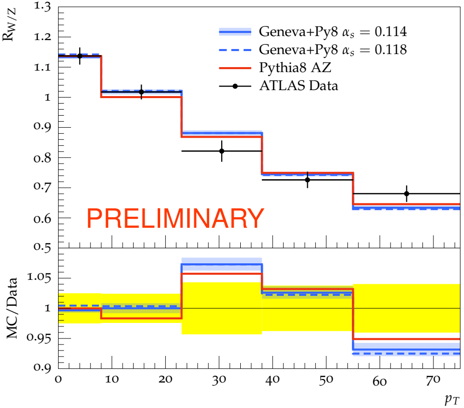
- Agreement within 5-10% (as good as can be expected at this pert. precision)
- Including higher-order resummation, data prefers lower $\alpha_s(m_Z)$
  - Consistent with what is observed in resummed e^+e^- event shapes
  - In contrast to plain Pythia8 AZ, which has much larger α_s in shower

α_s Dependence.

Normalized p_T distribution of Z

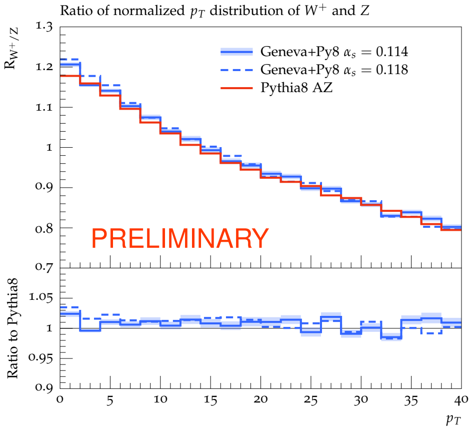


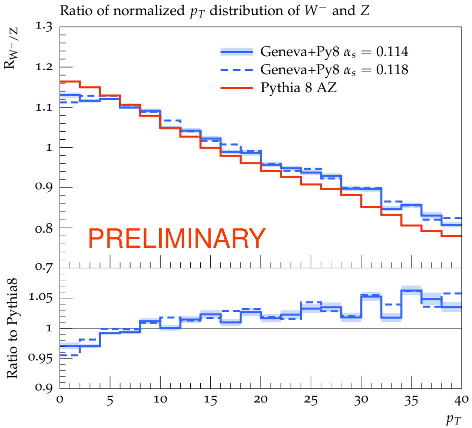
Ratio of normalized p_T distribution of W and Z



- Agreement within 5-10% (as good as can be expected at this pert. precision)
- Including higher-order resummation, data prefers lower $\alpha_s(m_Z)$
  - Consistent with what is observed in resummed e^+e^- event shapes
  - In contrast to plain Pythia8 AZ, which has much larger α_s in shower
- Largely drops out in ratio (as expected)
  - Slope with lower $\alpha_s(m_Z)$ slightly closer to Pythia8 AZ

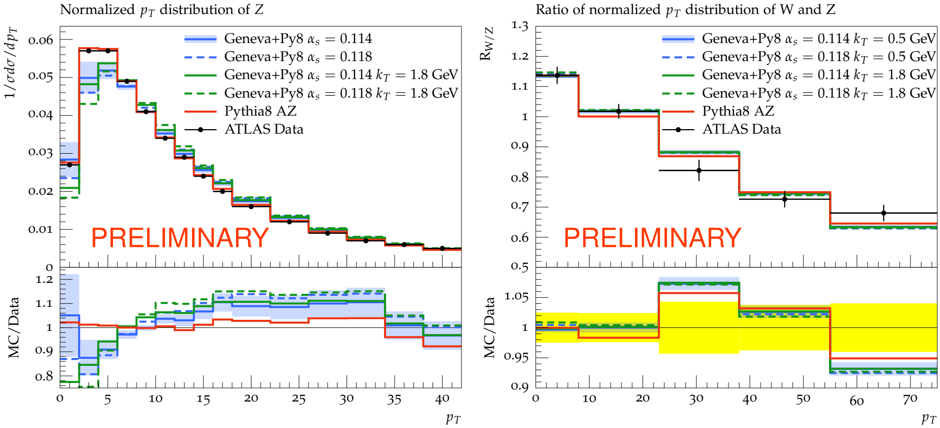
α_s Dependence.





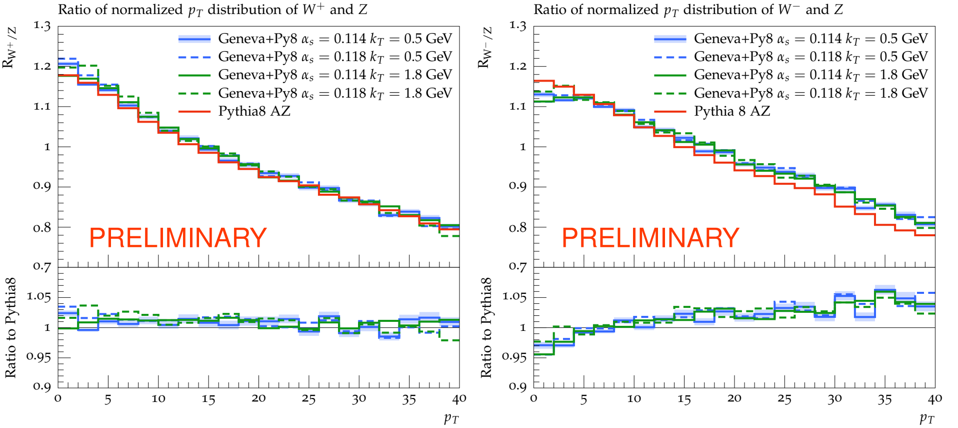
- Agreement within 5-10% (as good as can be expected at this pert. precision)
- Including higher-order resummation, data prefers lower $\alpha_s(m_Z)$
  - Consistent with what is observed in resummed e^+e^- event shapes
  - In contrast to plain Pythia8 AZ, which has much larger α_s in shower

Primordial k_T Dependence.



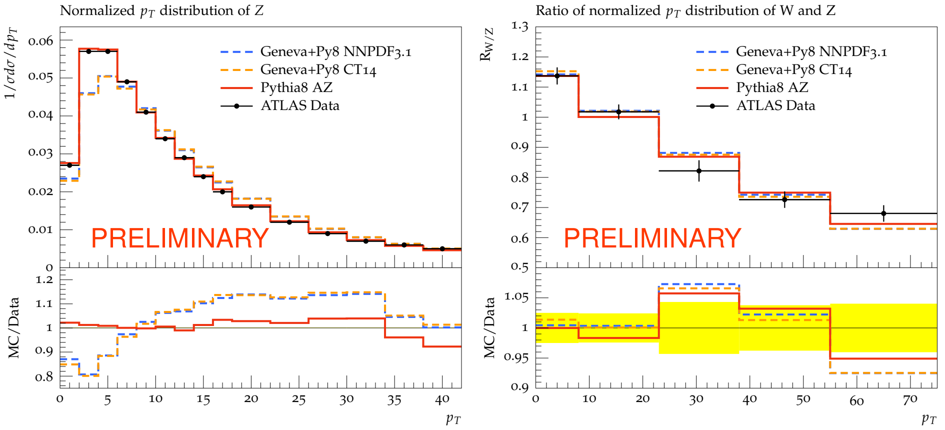
- Sizeable impact at small p_T
- Cancels out in ratio (as expected)
  - However cannot be the full story, since a priori could also be flavor dependent, which is then less likely to cancel

Primordial k_T Dependence.



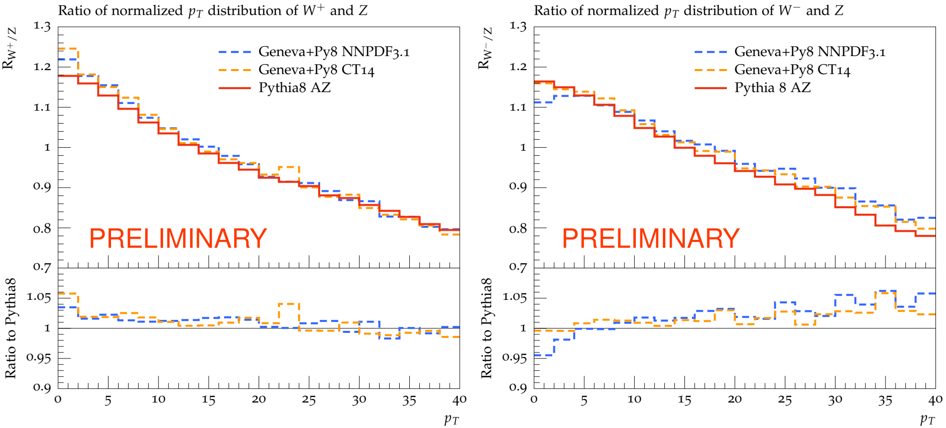
- Sizeable impact at small p_T
- Cancels out in ratio (as expected)
  - However cannot be the full story, since a priori could also be flavor dependent, which is then less likely to cancel

PDF Dependence.



- Essentially no effect on (normalized) p_T spectrum (as expected)
  - Also the case for MMHT2014 (not shown)
  - Except at very small p_T, which is also expected since PDF is effectively evaluated at $\mu \simeq p_T$

PDF Dependence.



- Essentially no effect on (normalized) p_T spectrum (as expected)
  - Also the case for MMHT2014 (not shown)
  - Except at very small p_T, which is also expected since PDF is effectively evaluated at $\mu \simeq p_T$

Outlook.

Immediate Future

- v1.0-rc3 imminent (improvements under the hood, bugfixes, more user-friendly running)
- W production will be available publicly in v1.0

Further plans

- Further improve underlying perturbative description
- Proper Pythia8 tune for Geneva+Pythia8
- Possibly QED/EWK corrections
  (at least “easy-to-include” ones, depending on demand)

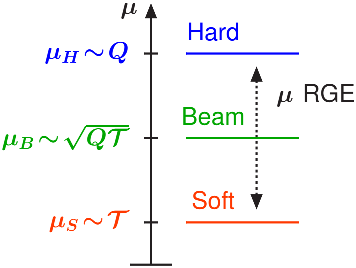
Backup Slides

GENEVA Uses N-Jettiness as Resolution Variable.

Resummation Structure for $\mathcal{T}_0$

$$\frac{d\sigma^{(0)}}{d\mathcal{T}_0} = H(Q, \mu_H) \times B(Q\mathcal{T}_0, \mu_B)^2 \otimes S(\mathcal{T}_0, \mu_S) \otimes U_{\text{total}}(\mathcal{T}_0; \mu_H, \mu_B, \mu_S)$$

$$\ln^2 \frac{\mathcal{T}_0}{Q} = 2\ln^2 \frac{Q}{\mu} - \ln^2 \frac{\mathcal{T}_0 Q}{\mu^2} + 2\ln^2 \frac{\mathcal{T}_0}{\mu}$$



- RGE resums logarithms of ratios of scales

$$\ln^n(\mu_B^2/\mu_H^2)\,, \qquad \ln^n(\mu_S^2/\mu_B^2)\,, \qquad \ln^n(\mu_S/\mu_H)$$

  - Logarithms $\ln^n(\mathcal{T}_0/Q)$ are resummed by canonical scale choices

$$\mu_H = Q\,, \qquad \mu_B = \sqrt{\mathcal{T}_0 Q}\,, \qquad \mu_S = \mathcal{T}_0$$

  - Resummation is turned off by taking

$$\mu_S = \mu_B = \mu_H = \mu_{\text{FO}} = Q$$

  - Uncertainties are estimated by using profile scale variations