A weak parton shower

Implementation and phenomological studies at 100 TeV

based on JRC and T. Sjöstrand, JHEP 04 (2014) 115 (arXiv:1401.5238 [hep-ph])

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Motivation

- Huge focus on QCD corrections at LHC
- Weak correction scales with energy $\alpha_W \ln^2(E^2/M^2_{W/Z})$
- Emissions of W/Z changes the event structure
  - Fixed number of hard leptons?

The weak parton shower

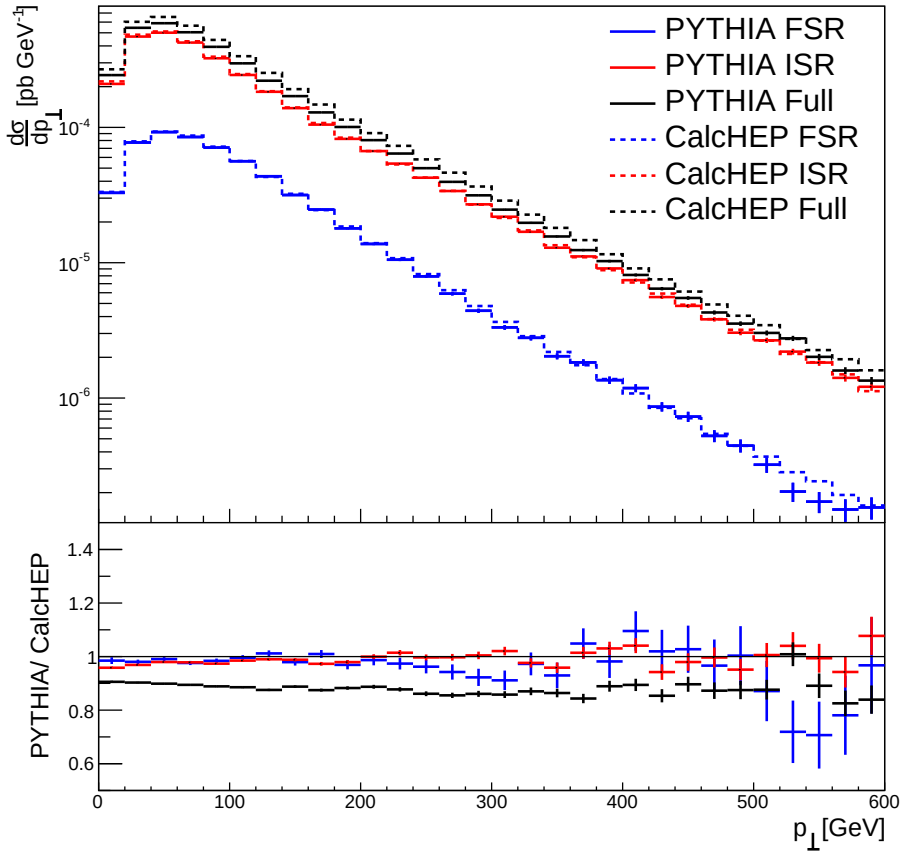
For the ordinary PS, see talk by S. Frixione

What is different for a weak PS

- The W/Z bosons are massive
- The couplings are spin-dependent
  - Keep track of spin throughout the shower
  - Assume spin averaged fermions from hard process
- Flavour change for W emissions
  - Full CKM (except top) is included
  - PDF change for initial state radiation
  - Possible Bloch-Nordsieck violation not accounted for in the shower

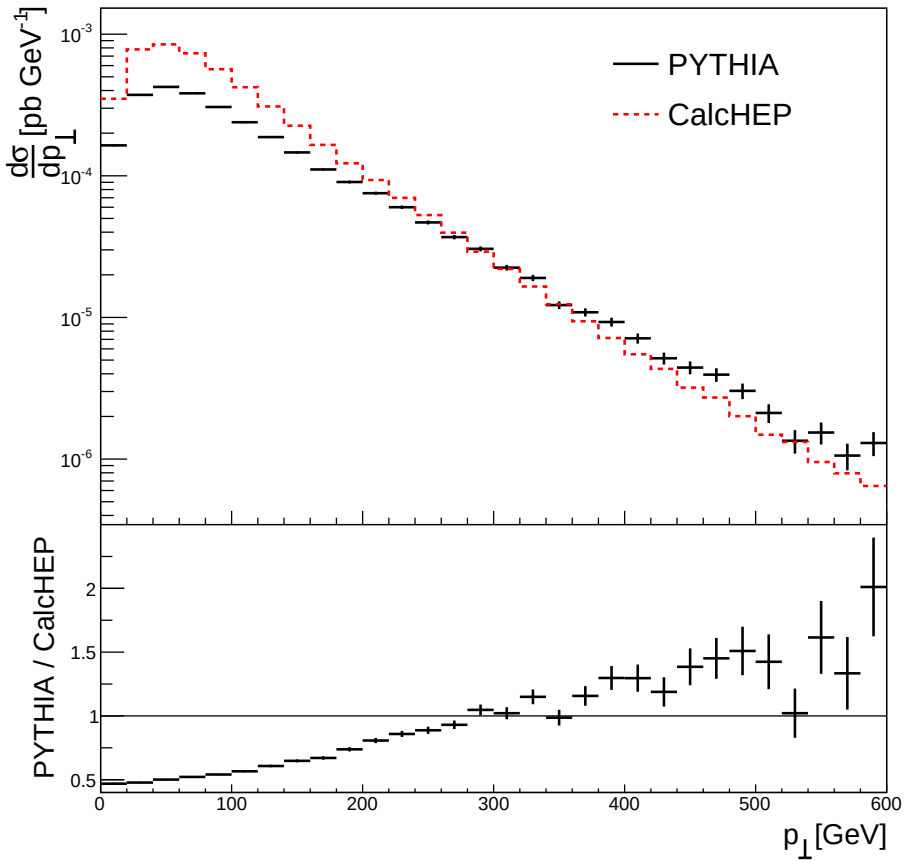
What is different for a weak PS (II)

- The DGLAP splitting kernel ($\frac{1+z^2}{1-z}$) is no longer a good approximation
- But it can still be used as an upper estimate, and later be corrected by the $2 \to 3$ ME



Some caveats

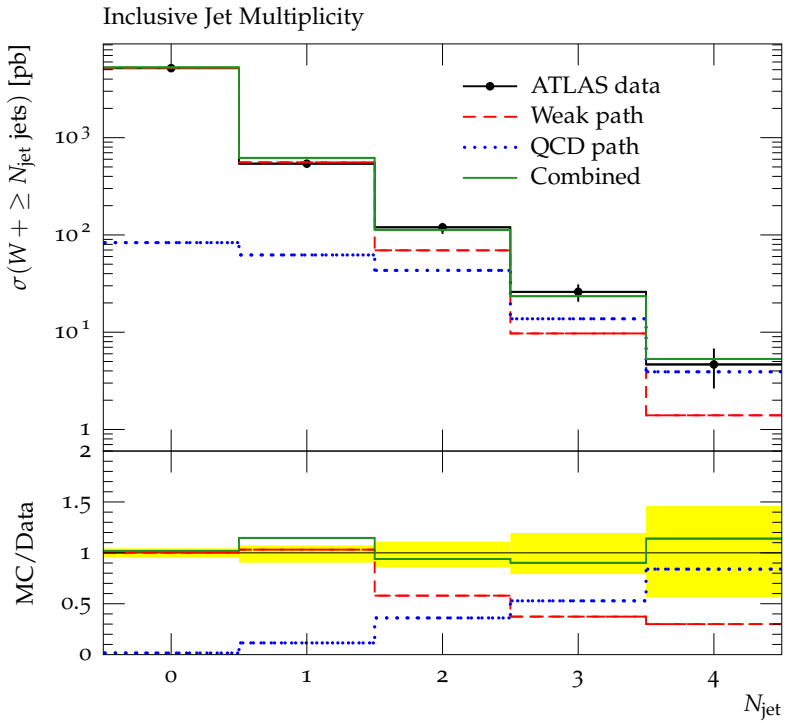
- Works best if hard process is a QCD process
  - The right figure shows $u\bar{u} \to u\bar{d}W^-$ with only EW diagrams, thus worst case scenario
- Radiation only implemented off quarks and leptons (no $Z \to W^+W^-$, ..., no BSM)



Phenomological studies

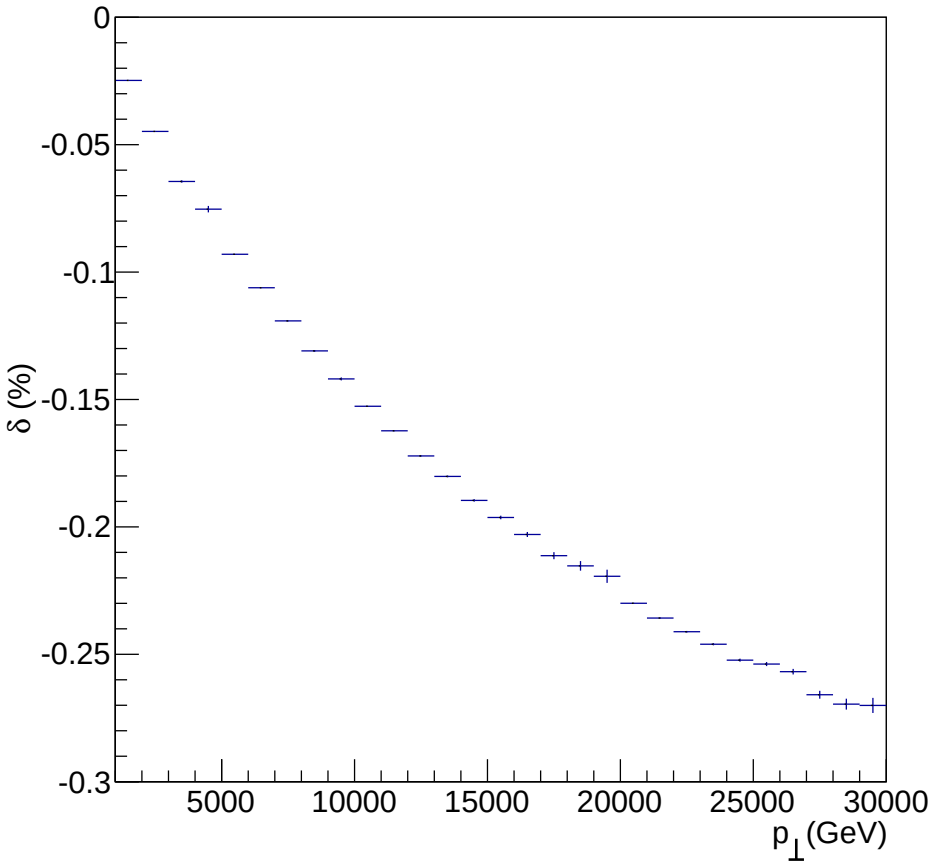
W + jets

- The PS prediction for W + jets is known to not describe data well
- Combine Drell-Yan W production with QCD radiation and $2 \to 2$ hard QCD processes with weak shower
- Double counting avoided by applying cuts in the spirit of the $k_\perp$ jet algorithm
- k-factor applied (normalized to fit first bin)



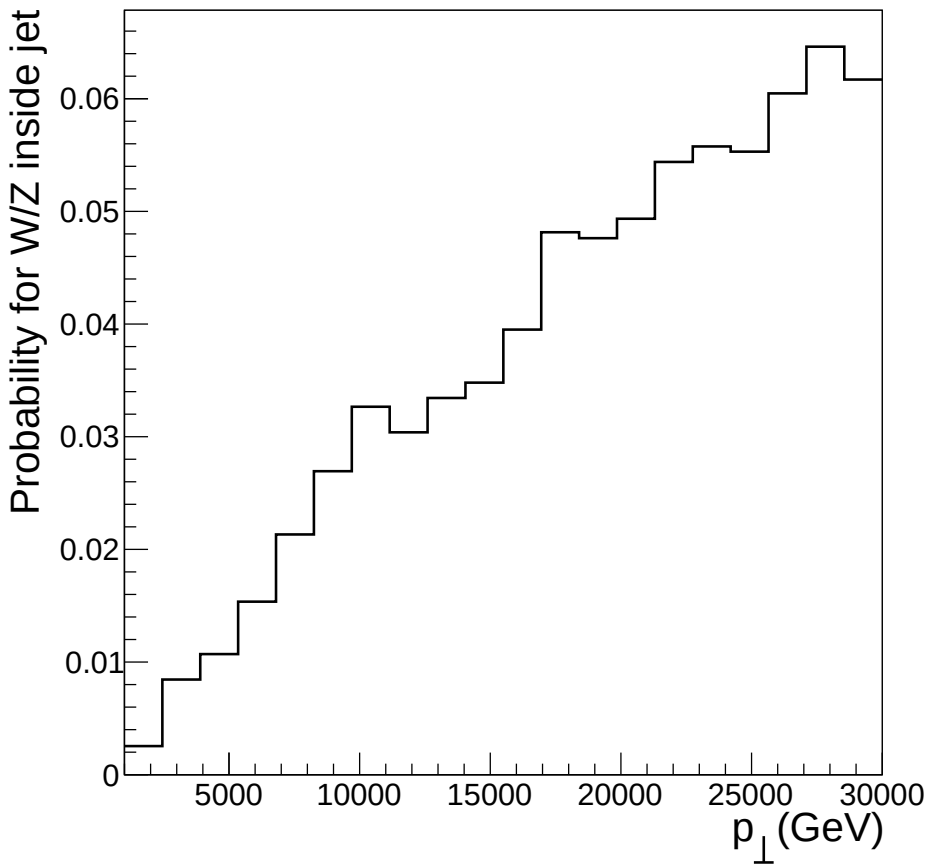
Weak corrections to exclusive di-jet production

- We assume a perfect detector and throw events away if a W/Z is produced: $\delta = -\sigma_{jjW/Z}/\sigma_{jj}$
- Effects becomes large at high jet $p_\perp \Rightarrow$ have to do fully inclusive measurements
- This has also been calculated using ME (e.g. arXiv:1210.0438)



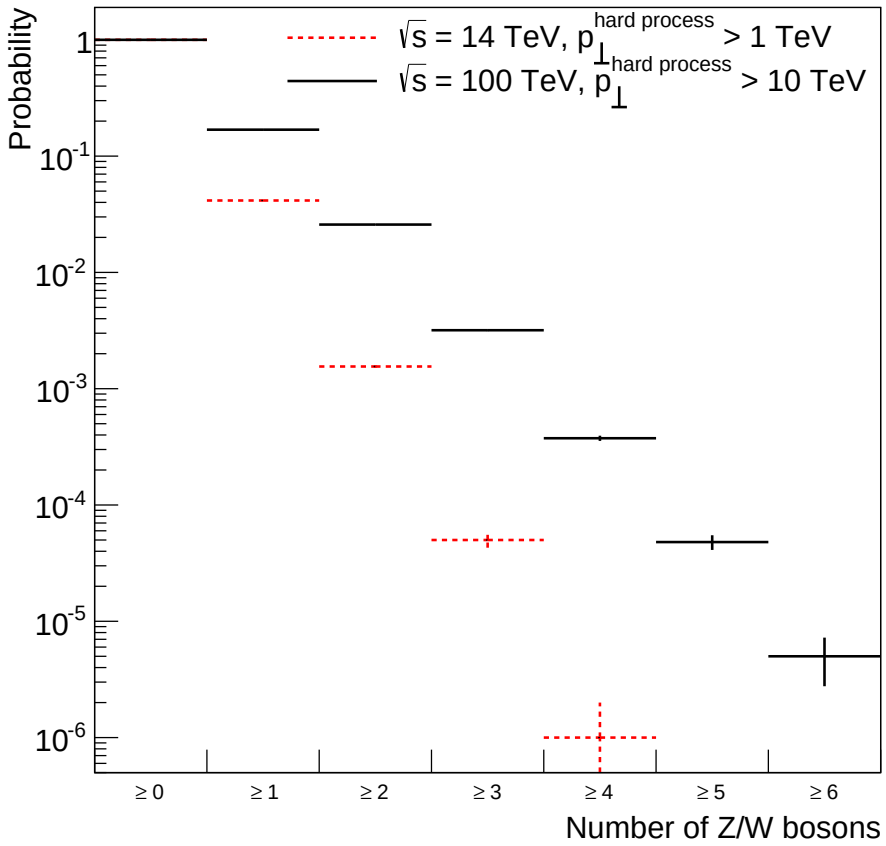
Weak bosons inside jets

- Look for W/Z inside high $p_\perp$ jets:
  - $k_\perp$-jet algorithm with $R = 0.4$
  - W and Z participating in jet clustering
  - Remove isolated W and Z jets
- How problematic is this background for top identification?



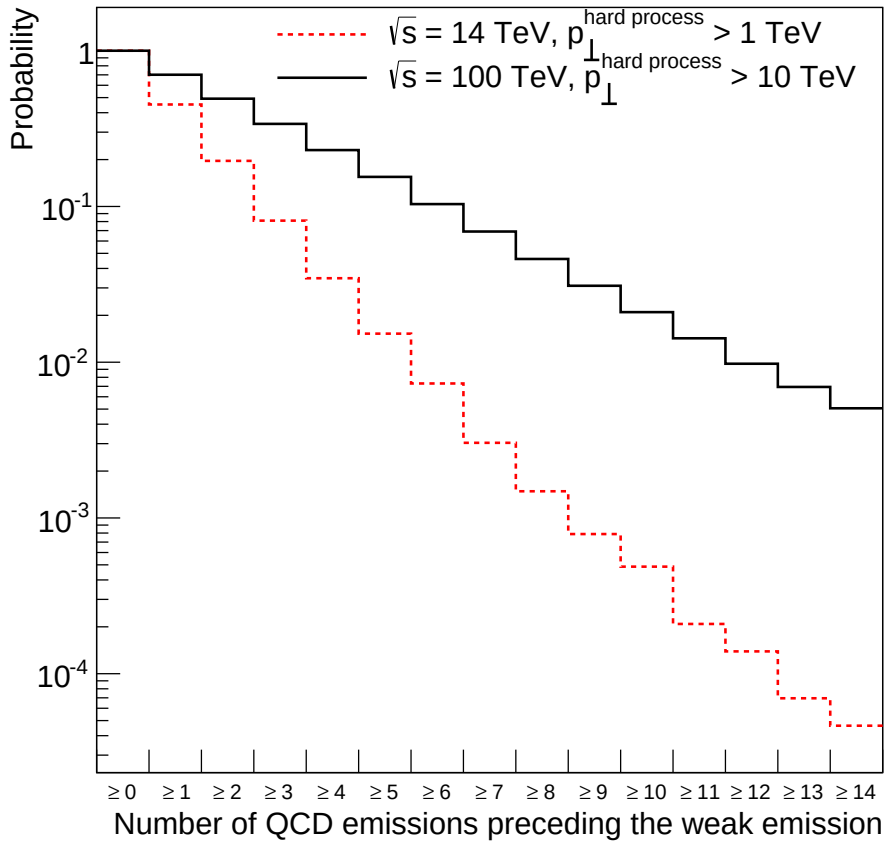
Multiple weak emissions

- Simple to extend to multiple emissions
- (Remember radiation from gauge bosons not included)
- σ_{n+1}/σ_n goes from 17 % for n = 0 down to 8 % for n = 5



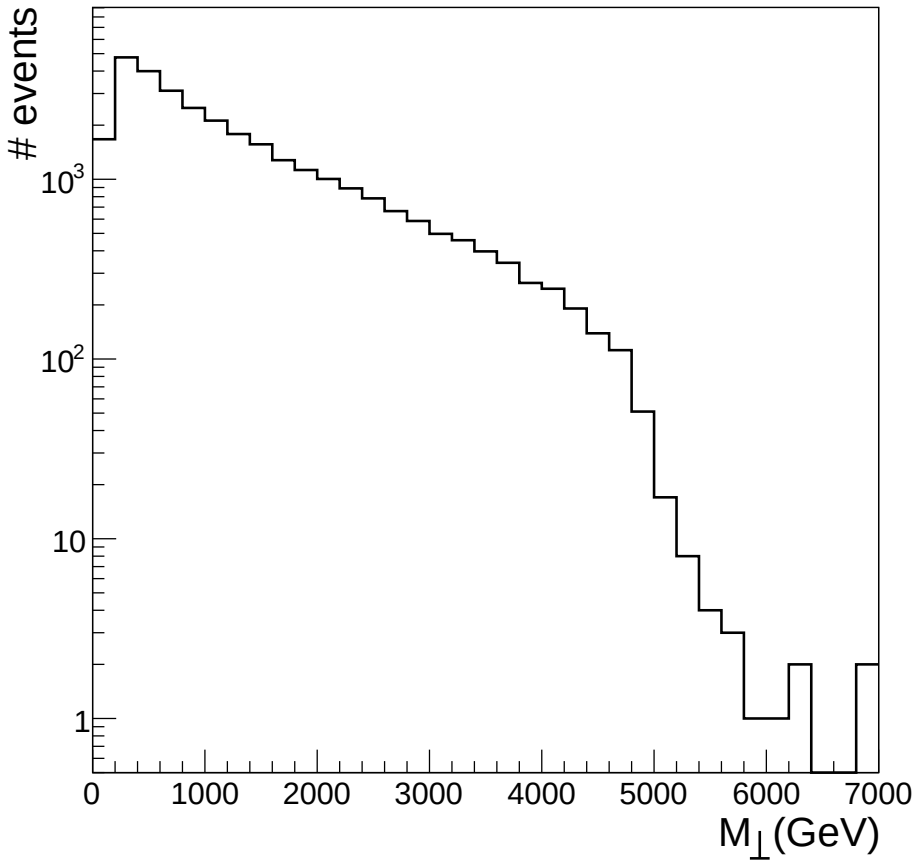
Competition between QCD and weak emissions

- Need to include up to 11 emissions, to only miss 1 %
  $\Rightarrow$ Does this become problematic for merging techniques?



Mono Z

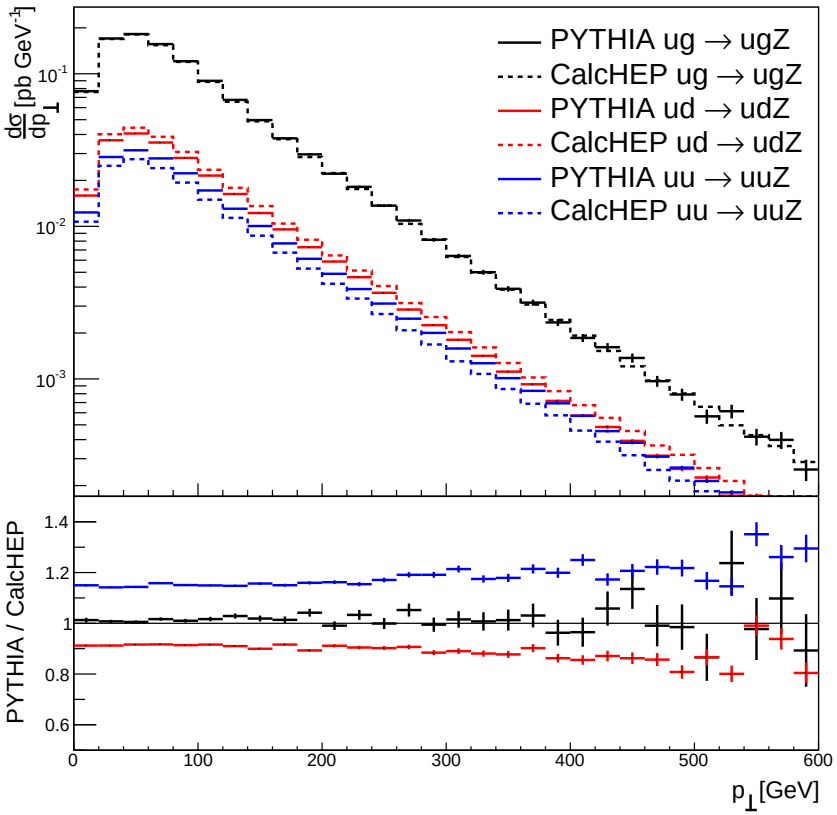
- Similar to mono jet searches, just searching for Z bosons instead
- Also possibility for WIMPs to radiate Z in FSR - any use?
  - Simple study of $Z' \to \nu\bar{\nu} \to \nu\bar{\nu}Z$, with M(Z') = 5 TeV
- (Weak radiation for BSM particles not yet implemented)



Conclusion

- Explained the implementation of a weak shower within PYTHIA (fully implemented since public version 8.183, with some small bug fixes in 8.185)
- Weak corrections need to be included in events with high $E_\perp$
  - And we need to consider more inclusive observables
- The studies shown are more to highlight some of the possible changes coming from weak radiation - more detailed studies will be needed

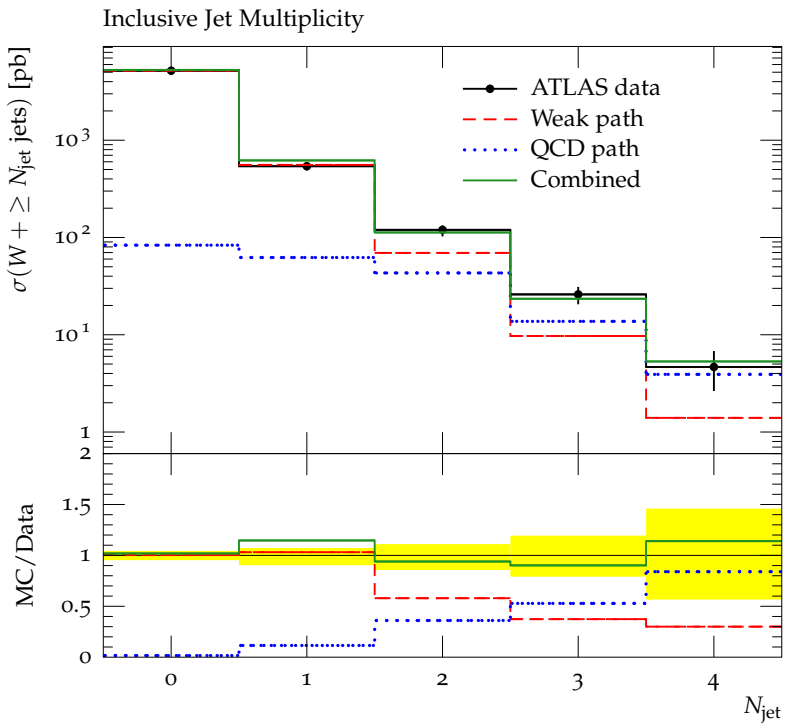
t-channel validation



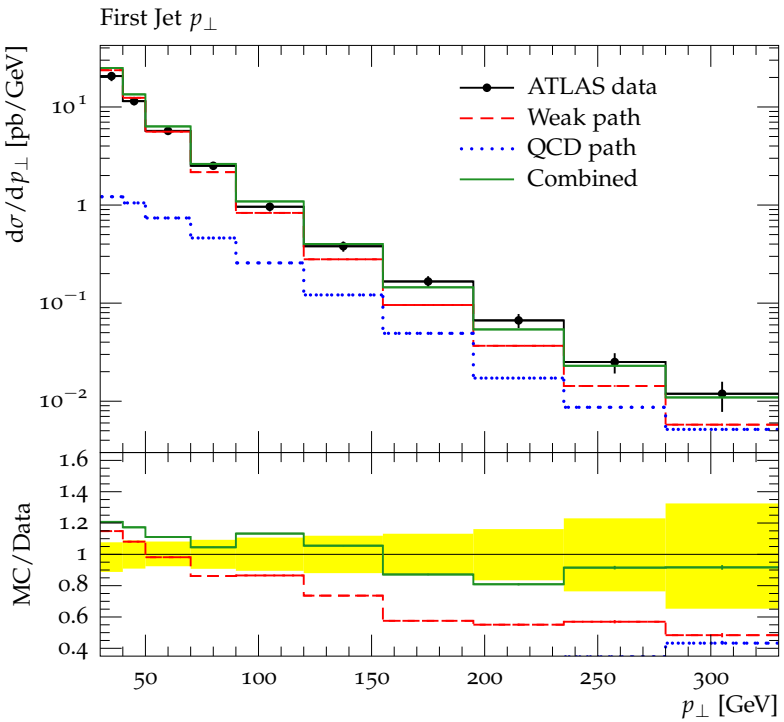
- Comparison of t-channel processes between PYTHIA and CalcHEP
- $p_\perp(u) > 100$ GeV, $M(u,u) > 150$ GeV and fixed scales at m_Z
- PS is not always an overestimate of the ME.

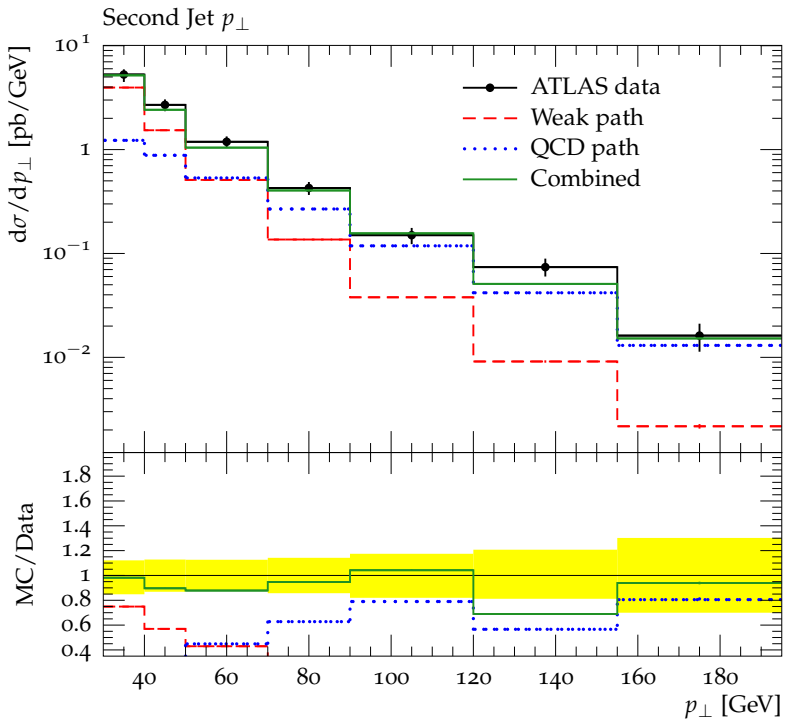
W + jets

- W + jets is notoriously known for being difficult to describe data for pure PS approaches
- Combine Drell-yan W production with QCD radiation and $2 \to 2$ hard QCD processes with weak shower
- Double counting avoided by applying cuts in the spirit of the $k_\perp$ jet algorithm



W + jets


First Jet $p_\perp$
ATLAS data
Weak path
QCD path
Combined
$d\sigma/dp_\perp$ [pb/GeV]
MC/Data
$p_\perp$ [GeV]


Second Jet $p_\perp$
ATLAS data
Weak path
QCD path
Combined
$d\sigma/dp_\perp$ [pb/GeV]
MC/Data
$p_\perp$ [GeV]

W + jets

- The φ-angle between the two jets is not that well described by PYTHIA.
- It shows the limitation of the PS approach.