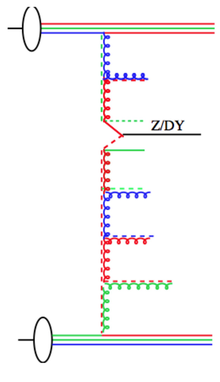
Higgs boson as a gluon trigger: the study of QCD in high pile-up environments

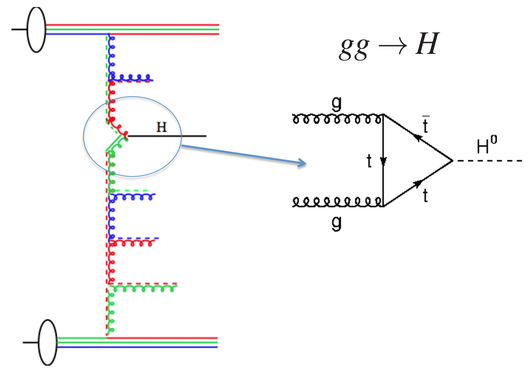
H. Van Haevermaet, P. Cipriano, S. Dooling, A. Grebenyuk, P. Gunnellini, F. Hautmann, H. Jung, P. Katsas

Introduction

Drell-Yan production



- Couples to quarks
- Clean final state, only decay leptons: $q\bar{q} \xrightarrow{\gamma^*/Z^0} l^+l^-$
- Use process to measure quark induced:
  - ➔ structure functions
  - ➔ parton showers
  - ➔ underlying event properties



Higgs production

- Couples to gluons
- Clean final state in H → ZZ → 4l decay channel
- Use process to measure gluon induced:
  - ➔ structure functions
  - ➔ parton showers
  - ➔ underlying event properties

Monte Carlo samples

- ➔ Pythia 8 p-p collisions at √s = 7 TeV with tune 4C
- ➔ invariant mass range of 115 < M < 135 GeV
- ➔ samples with a fixed amount of PU = 5 and PU = 20: add small-p_T QCD process events to the signal event.

- Current accelerators like the LHC operate at very high beam intensities:
  - ➔ collect high statistics, but creates pile-up conditions
  - ➔ can one study QCD in such harsh environments?
- Idea*: use Higgs boson as a gluon trigger: measure difference in soft multi-gluon emissions.

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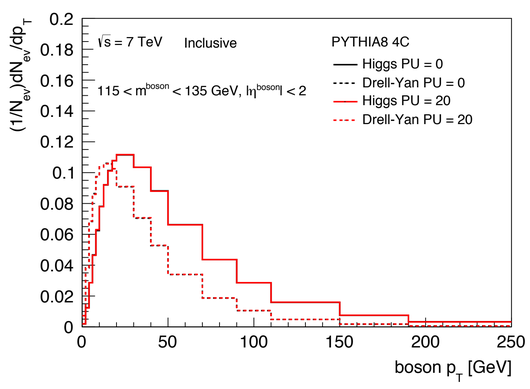
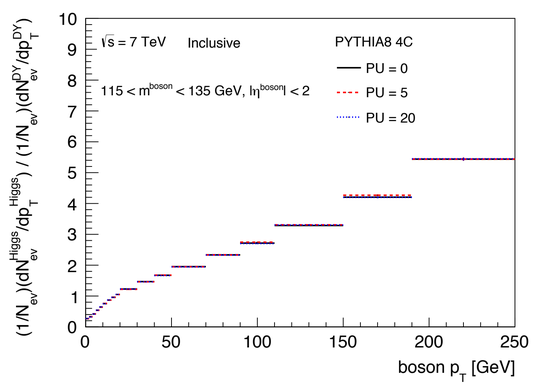
- Is Higgs to Drell-Yan comparison valid in high pile-up environments?
  - ➔ look at ratio (Higgs/DY): sensitive to direct difference in soft gluon versus quark radiation
  - ➔ look at subtraction (Higgs – DY): remove PU contributions from the underlying event.

Transverse momentum spectra





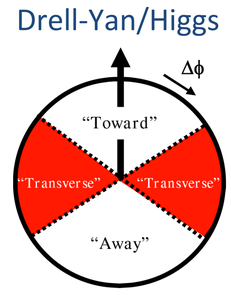
- Inclusive p_T spectra: different due to soft gluon emissions.
- Stable in high pile-up conditions.
- Use ratio to directly quantify the gluon versus quark radiation effects.

Underlying event observables

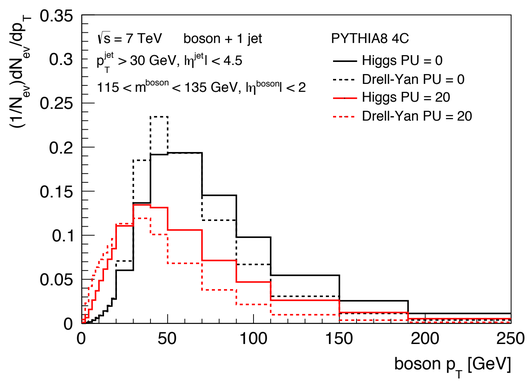
- Charged particle multiplicity and scalar p_T sum in transverse region ($60^o < |\Delta\phi| < 120^o$).
- Clean final state: sensitivity to only initial state radiation (ISR) and multiple parton interactions (MPI).
- When including additional p-p collisions (PU): number of charged particles increases.
- However, when we subtract the UE activity in Drell-Yan process, from the UE in Higgs process, the PU contribution cancels out:

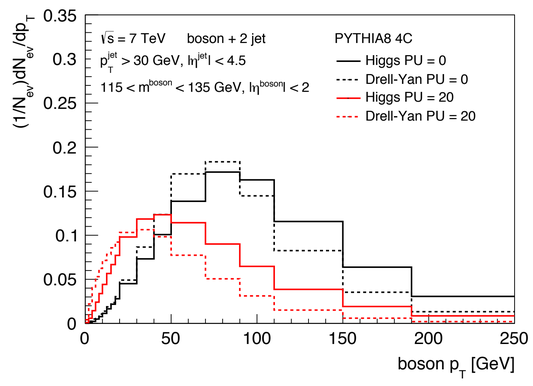
$$\frac{dn}{dp_T}(\mathrm{H}-\mathrm{DY}) = \frac{dn}{dp_T^{\mathrm{H}}} + \frac{dn}{dp_T^{\mathrm{PU}}} - \left(\frac{dn}{dp_T^{\mathrm{DY}}} + \frac{dn}{dp_T^{\mathrm{PU}}}\right)$$

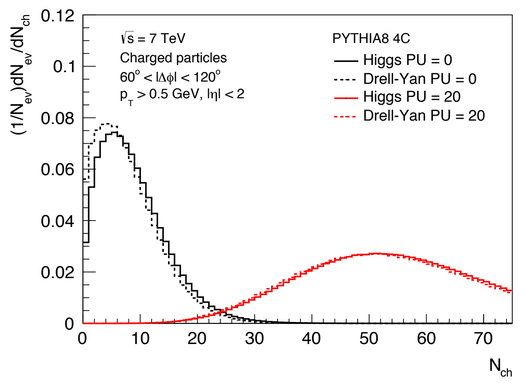
Drell-Yan/Higgs

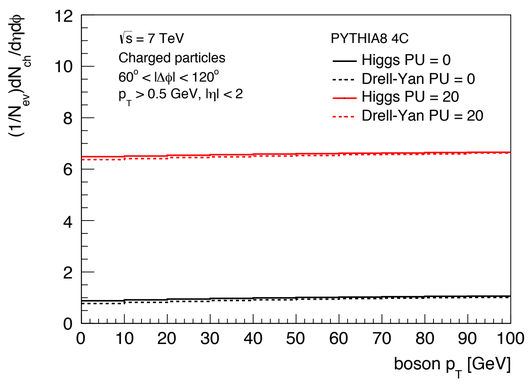


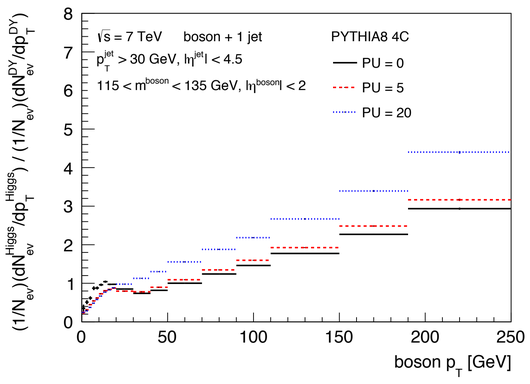
This implies that even in high PU environments one is able to measure small-p_T QCD physics, and one can directly measure gluon versus quark induced ISR.

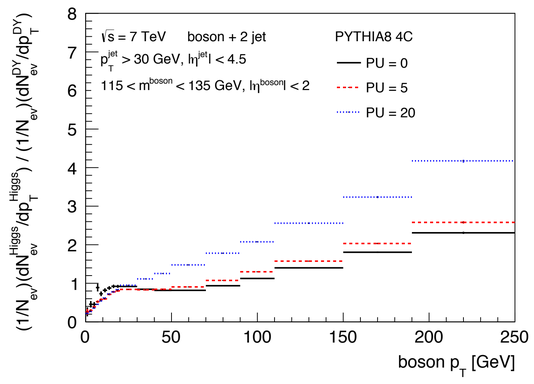


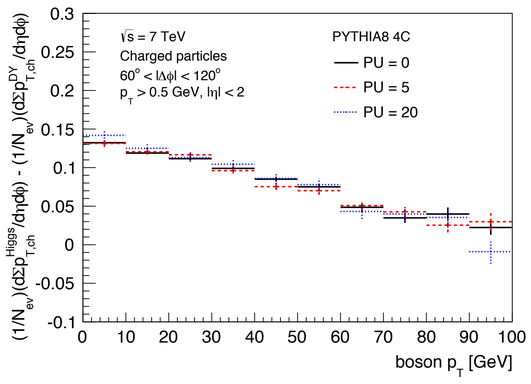


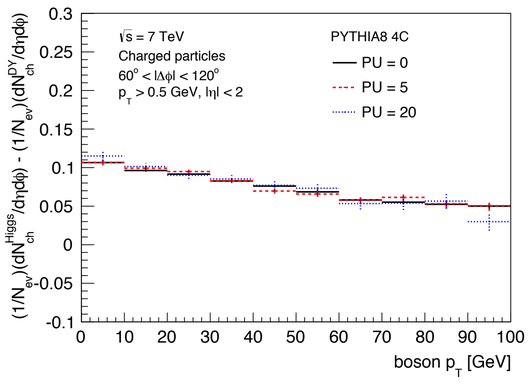












- Boson + jet topologies: sensitive to gluon versus quark emission effects.
- Additional hard jets: p_T balance between the boson and jets.
- Gluon versus quark induced effects less pronounced in p_T spectra.
- When PU events are added:
  - ➔ spectra shift to lower values.
  - ➔ possible jet mismatching.

Summary

- Higgs gg → H production: directly probe gluon physics in clean final state.
- Compared Higgs and Drell-Yan production in same invariant mass range:

➔ The Higgs - DY subtracted underlying event is stable in high pile-up.
➔ One can still access (small-p_T) QCD physics in high pile-up environments.

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