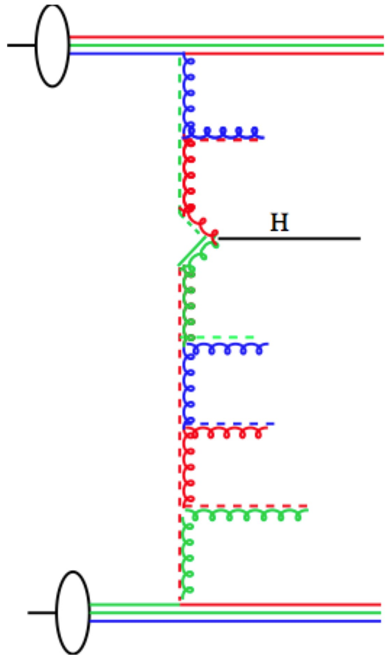
Higgs as a gluon trigger

Study QCD in high pile-up environments



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DIS XXII. Warsaw, 28 April - 2 May 2014

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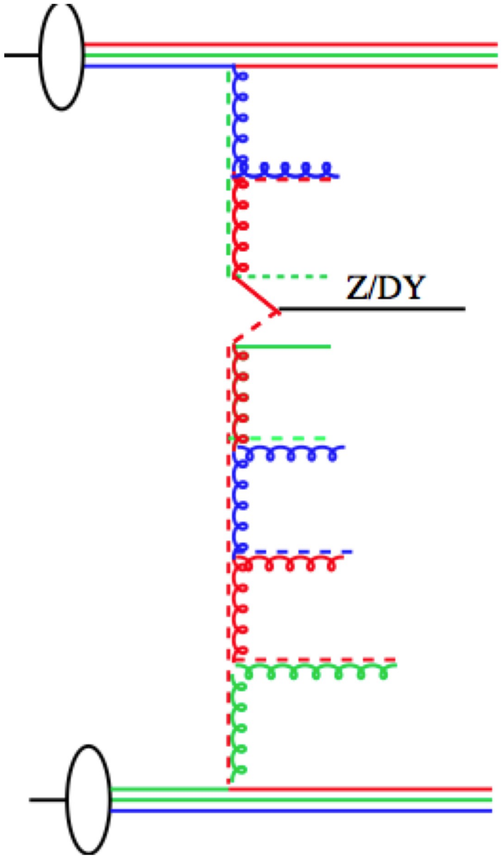
Introduction

- To study QCD one e.g. measures processes in single, very low pile-up (PU), proton – proton collisions, at e.g. the LHC
- One such interesting process is Drell-Yan: all standard electroweak currents couple to quarks

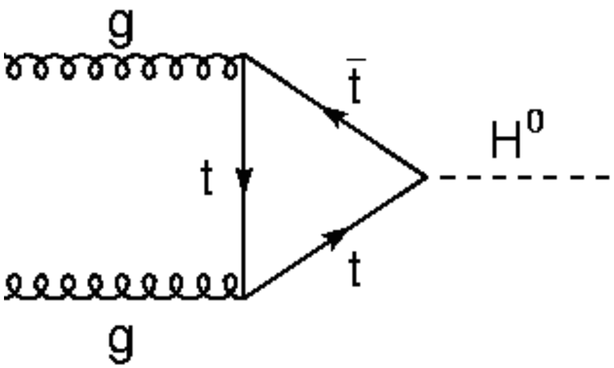
  ➔ measure the structure function of quarks
  ➔ study quark induced parton showers
  ➔ measure underlying event (UE) properties
  ➔ advantage: clean final state

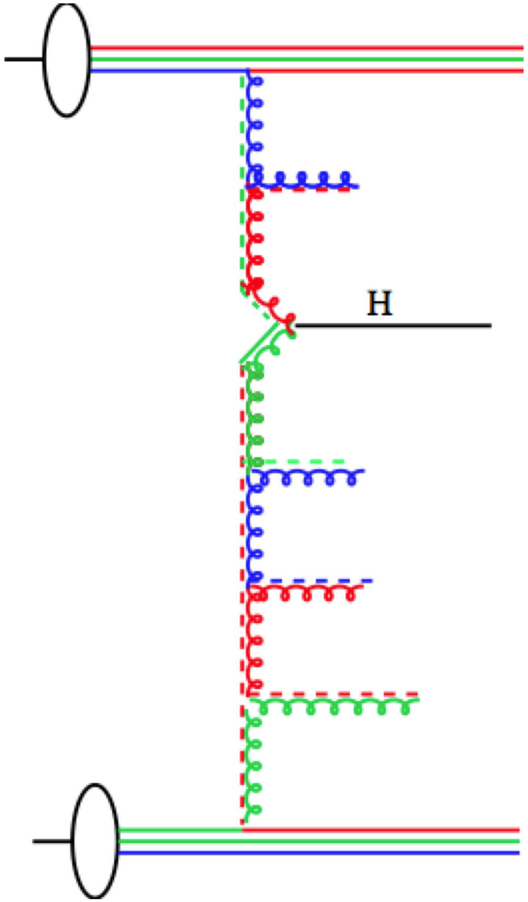


- Properties and structure functions of gluons are then indirectly measured
- Is there a way to probe the gluons directly?

What about Higgs production?

- Actually yes! In the heavy top limit, the Higgs boson directly couples to gluons: gg → H



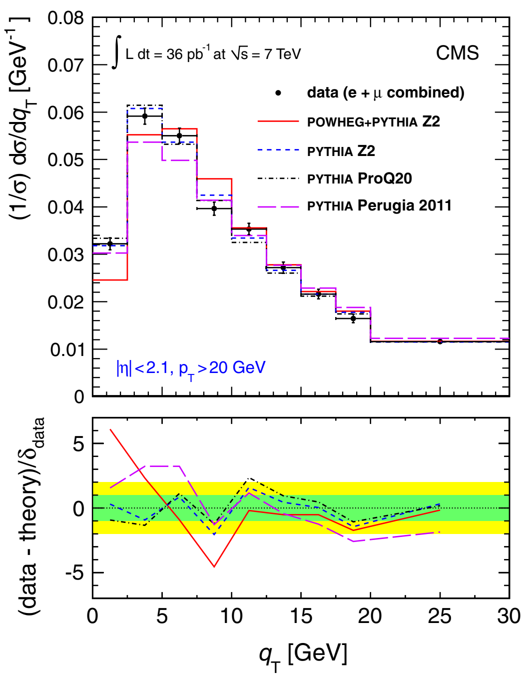


- Color singlet current
- For non-hadronic decays one has access to the same clean final state as in the DY process
- But now we directly measure gluon induced effects

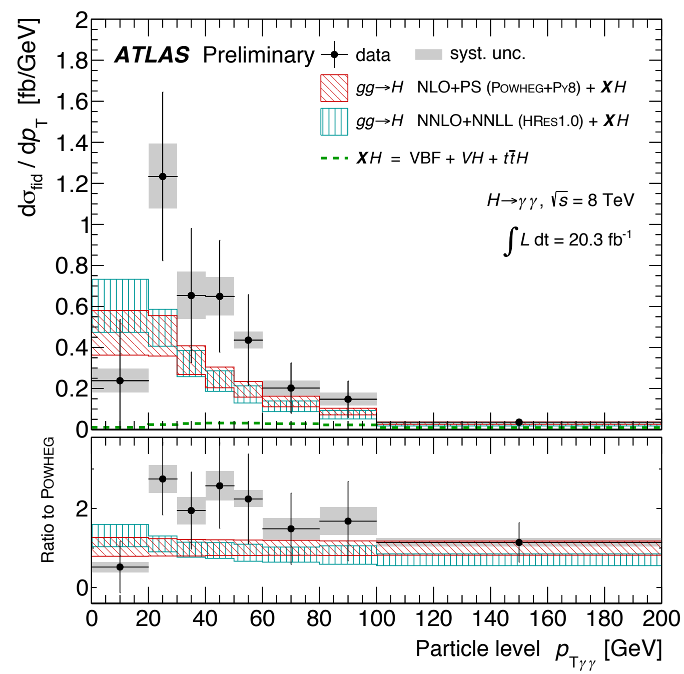
The challenge at high pile-up environments

- Is it possible to study QCD with Higgs and DY processes in current proton-proton colliders?
- Small cross section of the (Higgs) processes:
  ➔ operate at very high pile-up conditions for sufficient statistics
  ➔ differential measurements

Z production: Phys. Rev. D 85, 032002 (2012)

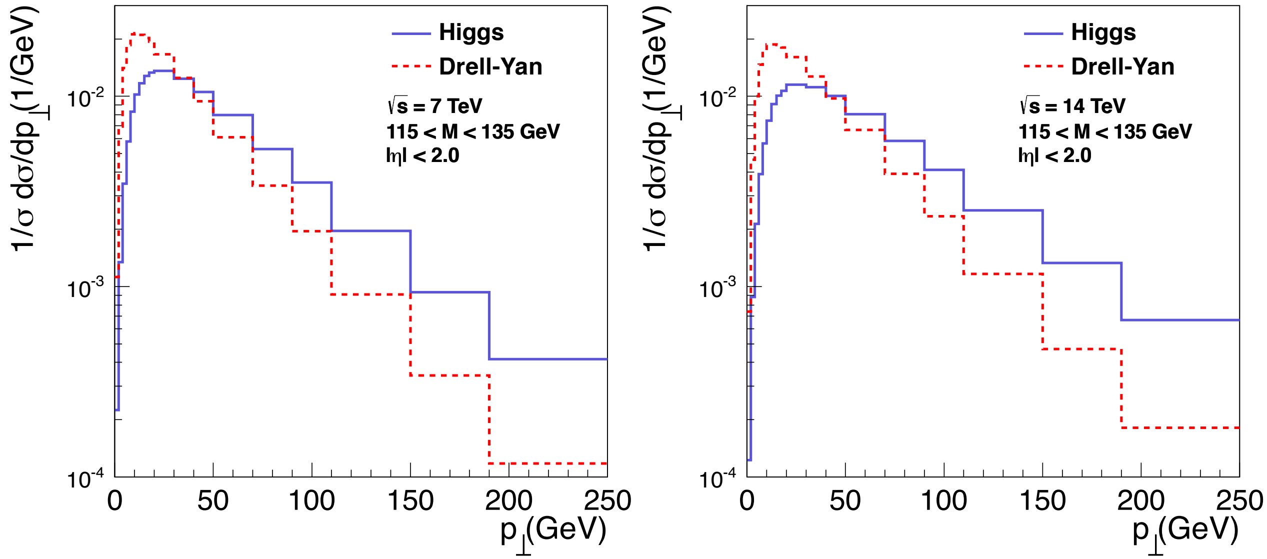


Higgs production: ATLAS-CONF-2013-072



Higgs as a gluon trigger

- Start new QCD program with Higgs as a gluon trigger
  P. Cipriano, S. Dooling, A. Grebenyuk, P. Gunnellini, F. Hautmann, H. Jung, P. Katsas Phys. Rev. D 88, 097501 (2013)
- Compare Higgs and DY production in the same mass range
- Transverse momentum spectrum: difference in soft gluon resummation



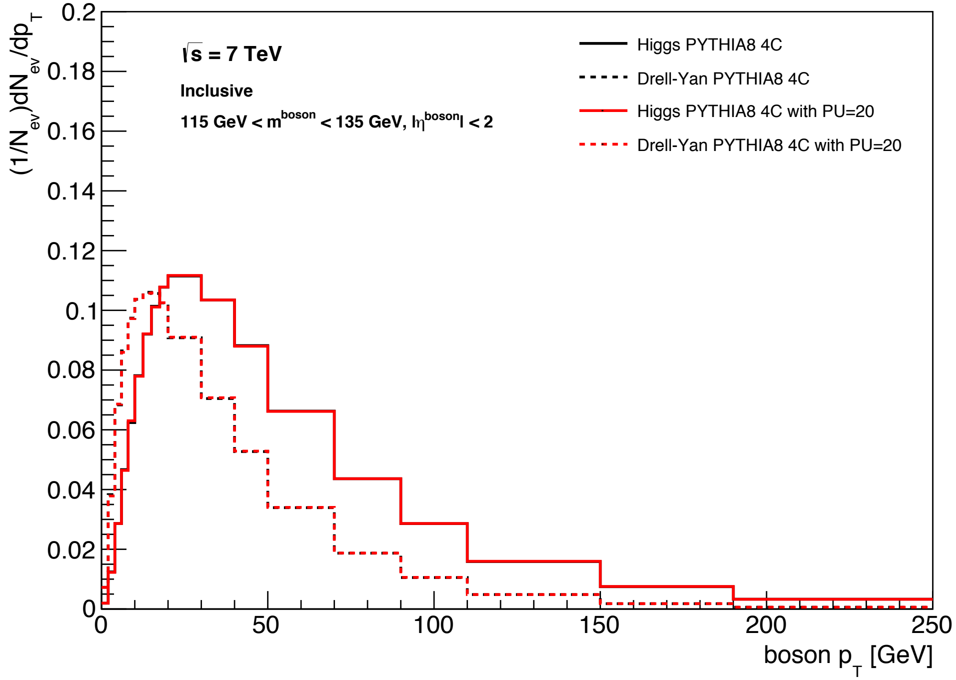
- Perform pile-up studies:
  ➔ look at ratio (Higgs/DY): direct difference in soft gluon vs quark resummation
  ➔ look at subtraction (Higgs - DY): remove PU contributions from UE

Higgs as a gluon trigger: p_T spectra

- Generator pile-up study: standalone Pythia 8.185

  Single Z production and gg -> H production with tune 4C at $\sqrt{s}$ = 7 TeV
  Bosons stable; mass range 115 GeV < M < 135 GeV, |η| < 2
  With No PU; Fixed PU=5; Fixed PU=20; PU processes: Soft QCD (all)

- Look at the inclusive p_T spectra:



By definition p_T spectra are stable with PU

If experimental reconstruction of decay products is precise enough:

➔ can directly probe the gluon

Higgs as a gluon trigger: p_T spectra

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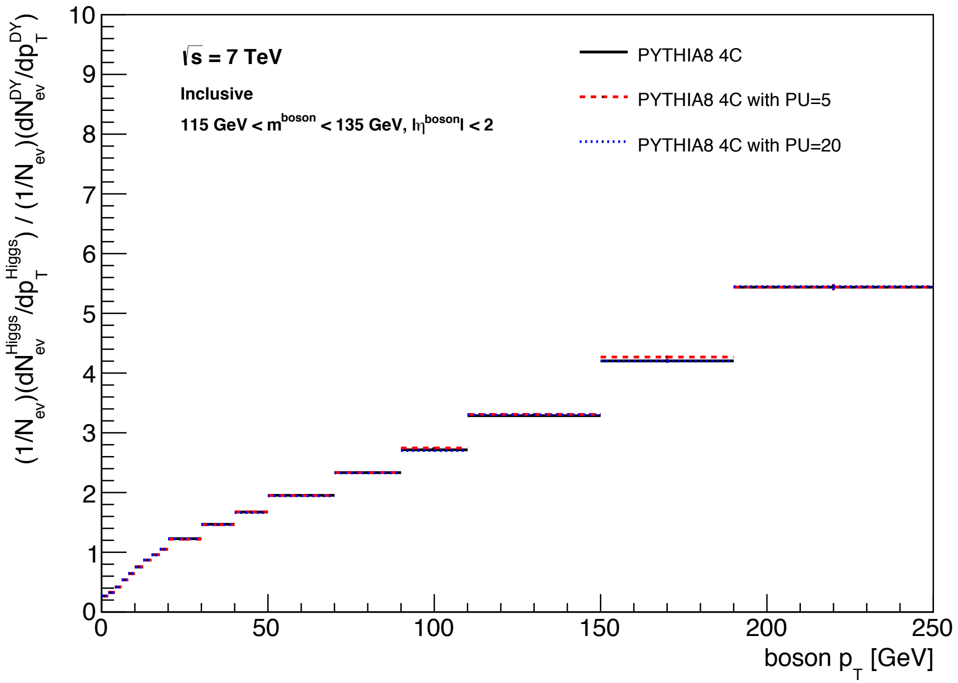


By definition p_T spectra are stable with PU

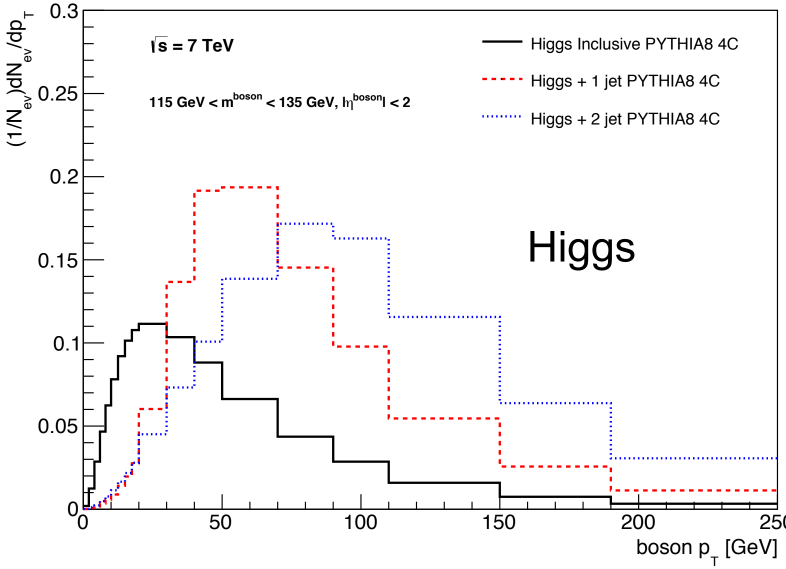
If experimental reconstruction of decay products is precise enough:

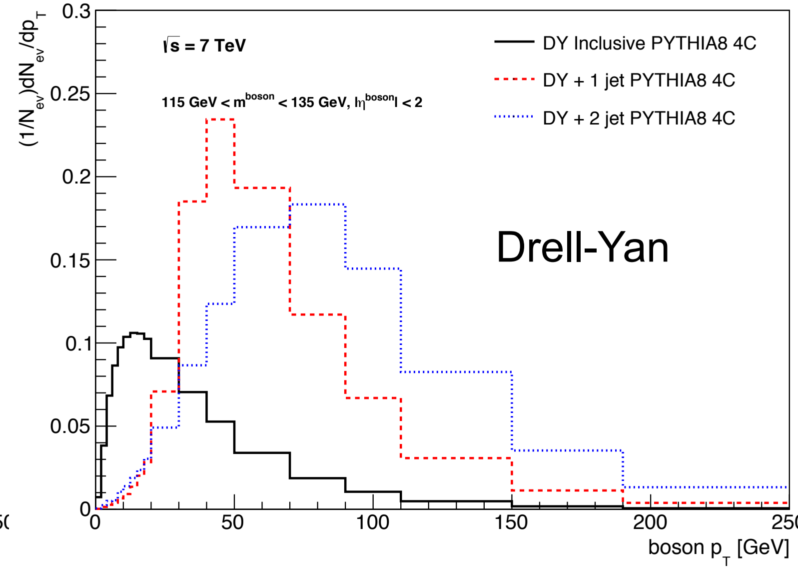
➔ can directly probe the gluon
➔ ratio Higgs/DY quantifies gluon vs quark resummation

Higgs as a gluon trigger: p_T spectra boson + jets

> Look at boson + 1 jet and boson + 2 jet events

Jets: Anti-k_T R=0.5, p_T > 30 GeV, $|\eta|$ < 4.5





> Requiring additional hard jets shifts the spectra towards higher p_T

> p_T balance between boson + jets

> Quark vs gluon induced effects less significant

Higgs as a gluon trigger: p_T spectra boson + jets

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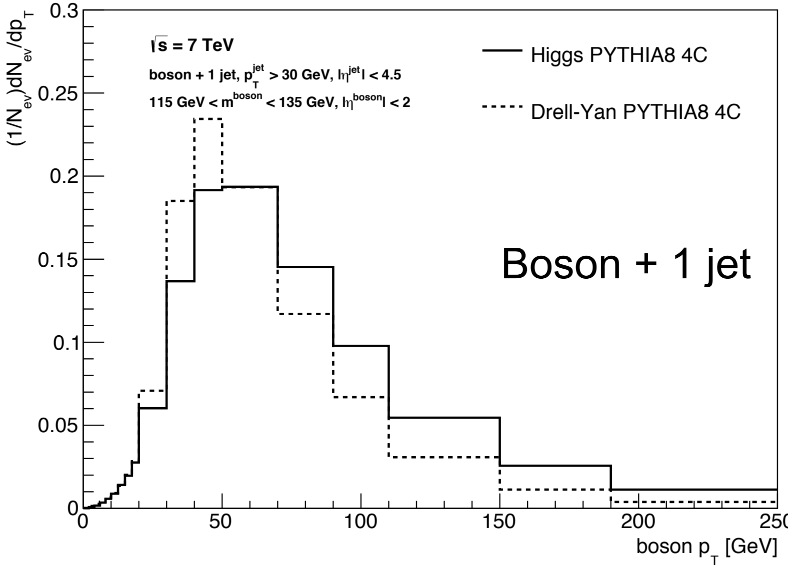
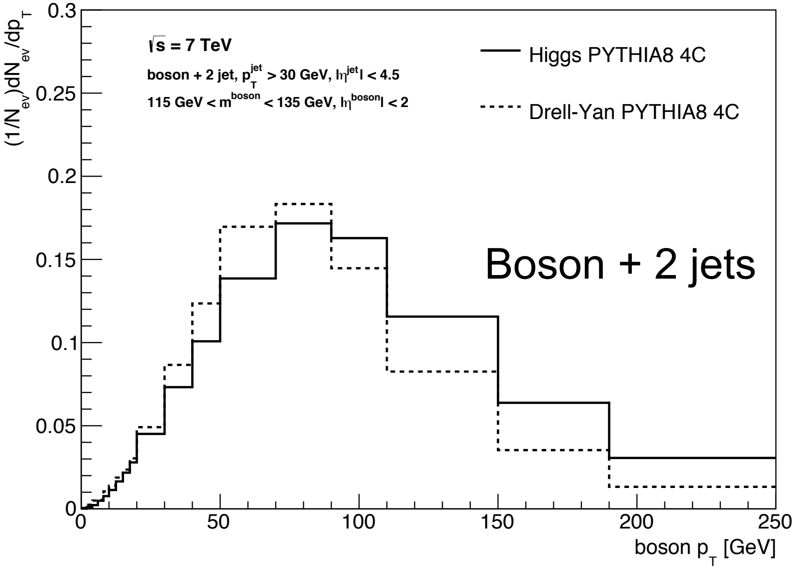


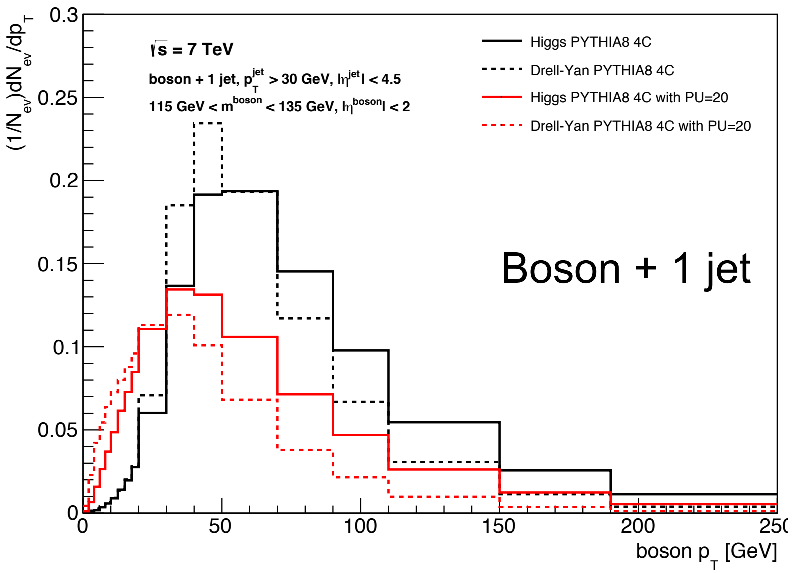


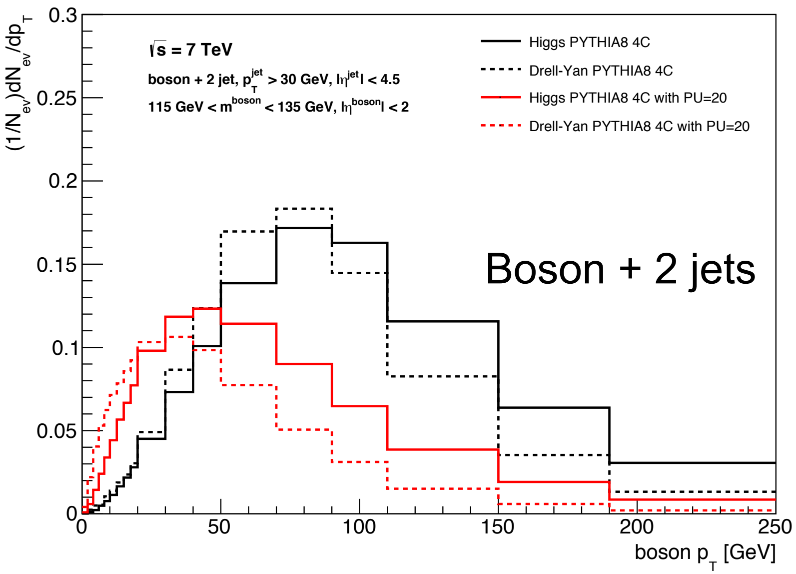
- Requiring additional hard jets shifts the spectra towards higher p_T
- p_T balance between boson + jets
- Difference Higgs vs DY decreases

$\langle p_T^{Higgs}\rangle / \langle p_T^{DY}\rangle$ inclusive: ~1.52
$\langle p_T^{Higgs}\rangle / \langle p_T^{DY}\rangle$ boson + 1 jet: ~1.17
$\langle p_T^{Higgs}\rangle / \langle p_T^{DY}\rangle$ boson + 2 jet: ~1.16

Higgs as a gluon trigger: p_T spectra boson + jets

- Boson + 1 jet and boson + 2 jet events with fixed PU=20





- Both Higgs and DY spectra shift to lower values (inclusive spectrum)
- Mismatching of leading jets:
  ➔ higher probability that high p_T jets come from independent PU event
- Difference stable when taking ratio?

Higgs as a gluon trigger: p_T spectra boson + jets

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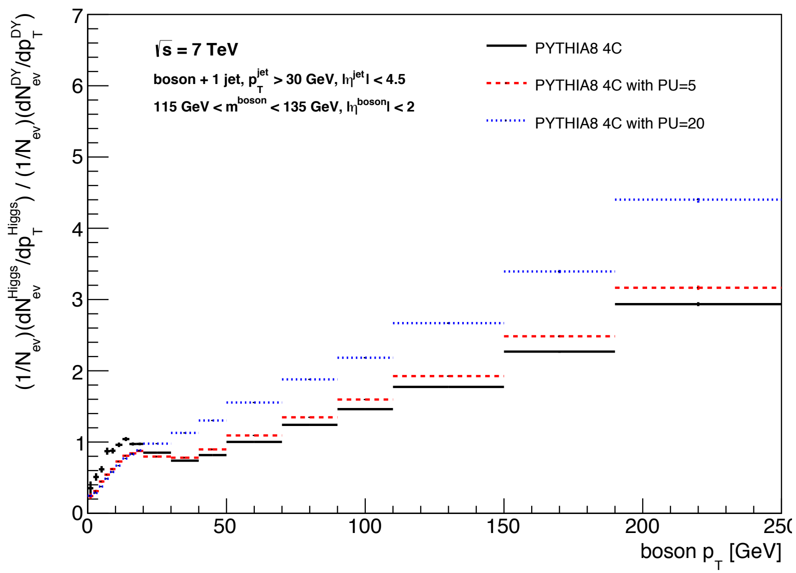
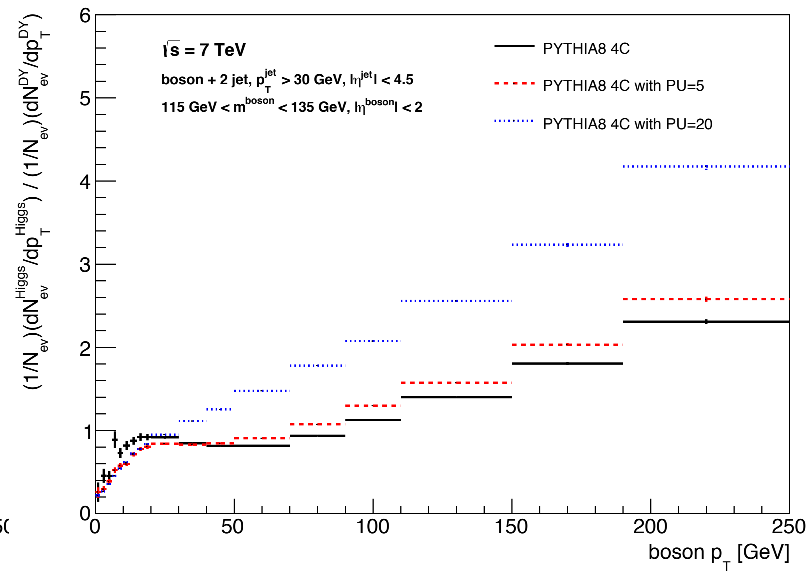
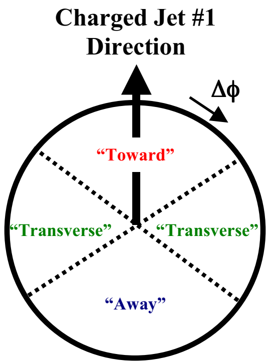


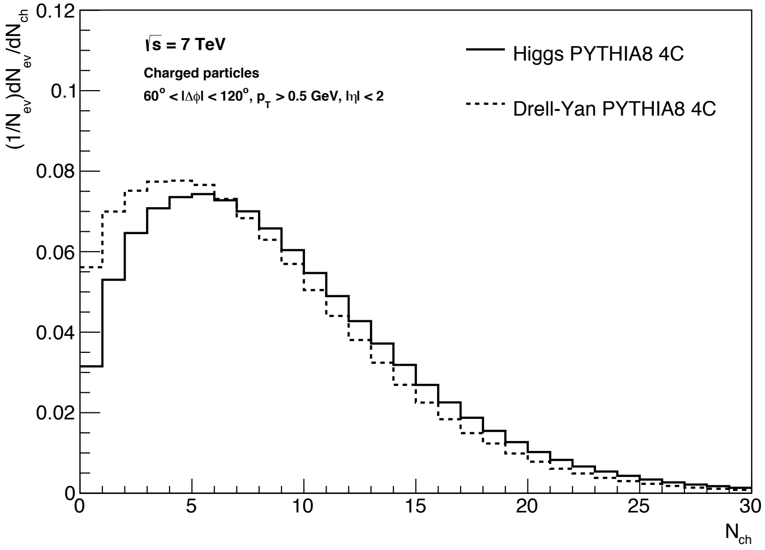


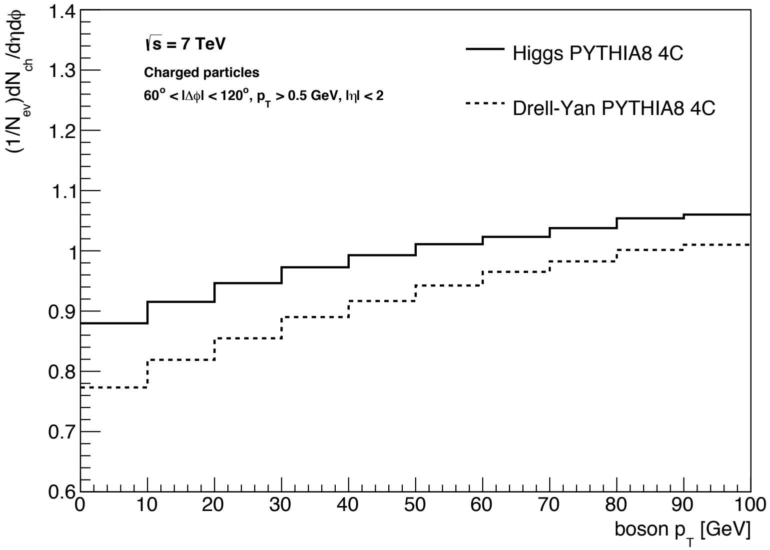
- Ratio not stable due to difference in hardness of inclusive spectra
  ➔ fraction of jet mismatching not the same
- Very low PU runs stay important to study QCD

The underlying event in high pile-up environments

- UE studies typically measure the number of charged particles (or Σp_T) in the transverse plane
- As function of the hard scale in the event
- Compare UE of Higgs vs DY production
  ➔ clean final state ➔ only initial state radiation (ISR) + MPI
- Can one perform UE studies in high PU environments?

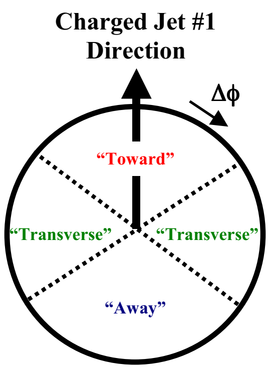




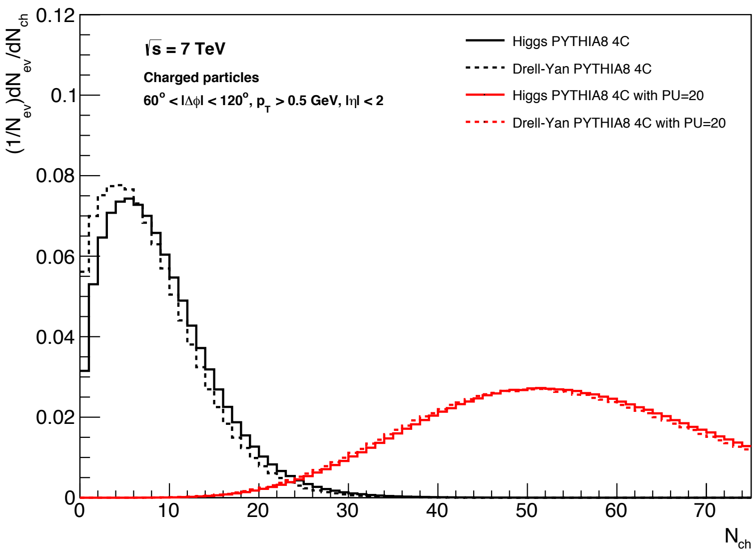


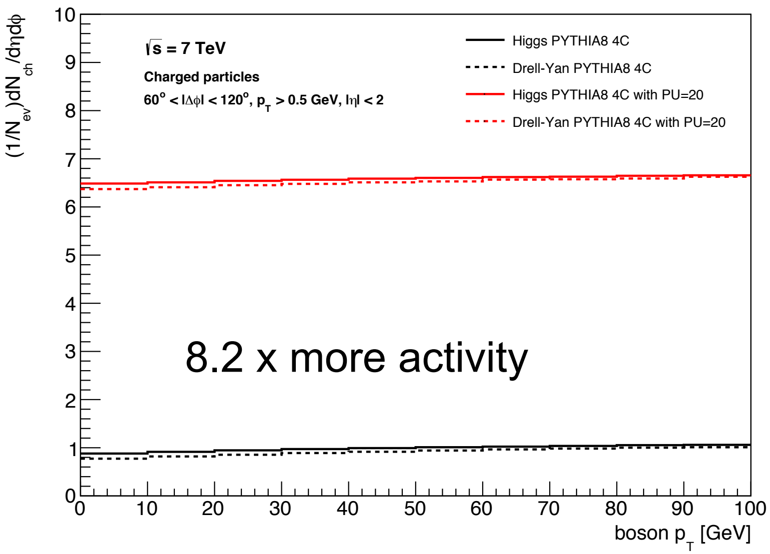
The underlying event in high pile-up environments

- UE studies typically measure the number of charged particles (or Σp_T) in the transverse plane
- Activity scales with number of additional PU events
- But one can subtract PU contribution:



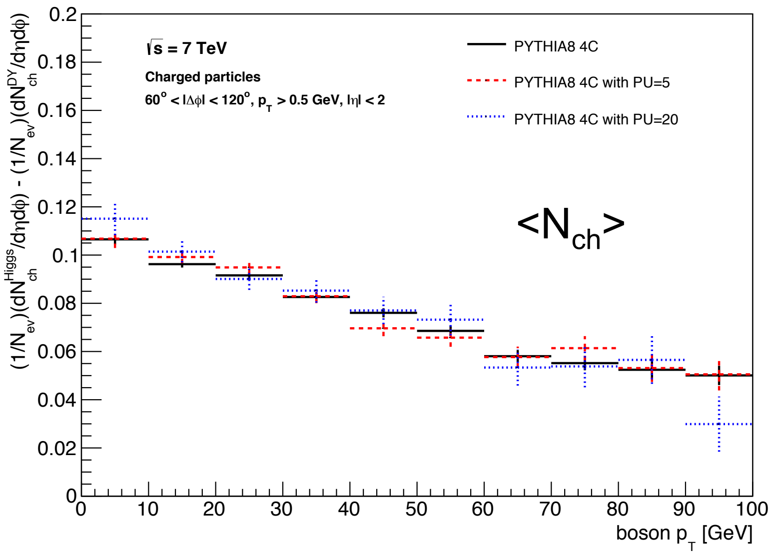
$$\frac{dn}{dp_t}(H - DY) = \frac{dn}{dp_t}_H + \frac{dn}{dp_t}_{pileup} - \left(\frac{dn}{dp_t}_{DY} + \frac{dn}{dp_t}_{pileup}\right)$$

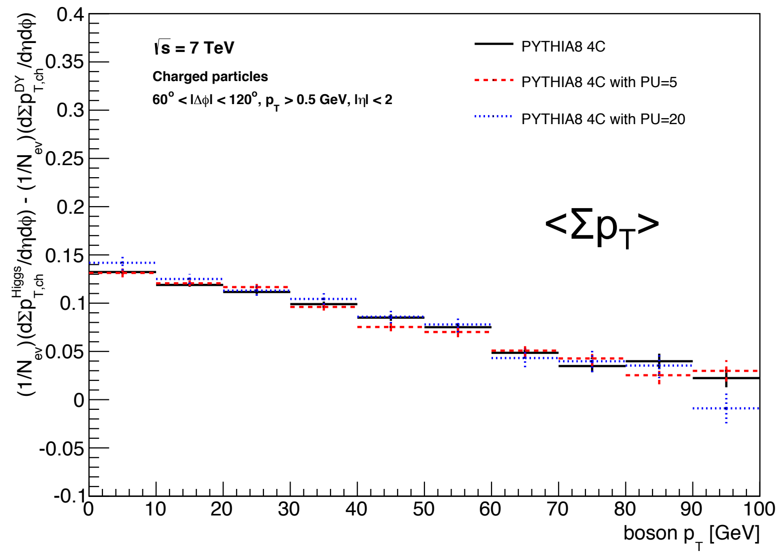




The underlying event in high pile-up environments

- After substraction of activity in DY from activity in Higgs production:





- PU contribution cancels
- Probe directly difference of quark vs gluon induced UE activity (ISR)!

Conclusions

- Higgs production measurement provides new perspectives for challenging QCD studies
  - ➔ only electroweak current that couples to gluons
  - ➔ color singlet state: no complications from final state effects
- Novel method: compare Higgs – DY in same mass & rapidity range:
  - ➔ direct comparison of quark vs gluon induced processes
- Presented preliminary generator studies:
  - ➔ ratios of inclusive, boson + 1 jet & boson + 2 jet p_T spectra:
    - inclusive spectrum sensitive to soft gluon resummation
    - boson + jet events suffer from PU effects
  - ➔ underlying event activity in subtraction Higgs – DY:
    - $\langle N_{ch} \rangle$ & $\langle \Sigma p_T \rangle$ in transverse regions stable with PU
  - ➔ with Higgs – DY comparison, we can still measure the UE in high PU!
- Comparison of Higgs – DY processes allows interesting and challenging QCD measurements at high luminosity