

Higgs as a gluon trigger

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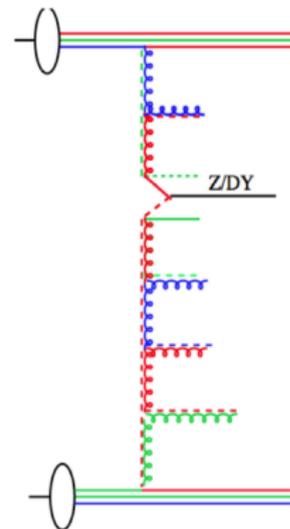
***IIHE Université Libre De Bruxelles**

Low x workshop
Kyoto, Japan, 17 June 2014



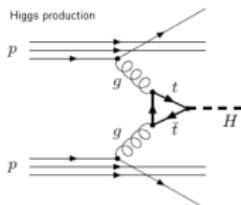
QCD via Drell-Yan process

- All standard electroweak currents couple to quarks (γ, Z_0, W)
 - DY has clean final state and is one of the interesting process to study QCD
 - measure the structure function of quarks
 - study quark induced parton showers
 - measurement of underlying event
- Structure function of gluons, as well as properties of gluon are measured only indirectly via quark
- Is there a way to probe the gluons directly?

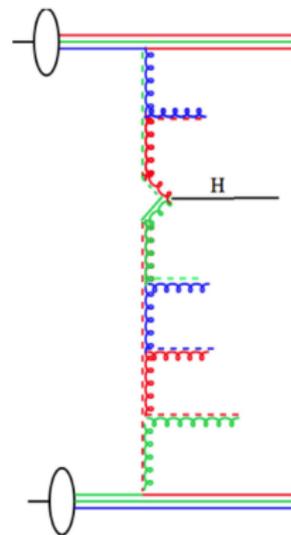


Higgs as a gluon trigger

It is possible due to discovery of the Higgs!
 In heavy top limit, couples directly to gluons



- Color singlet current
- For non-hadronic decays one has access to the same clean final state as in DY processes
- Possibility of directly measuring gluon induced effects!

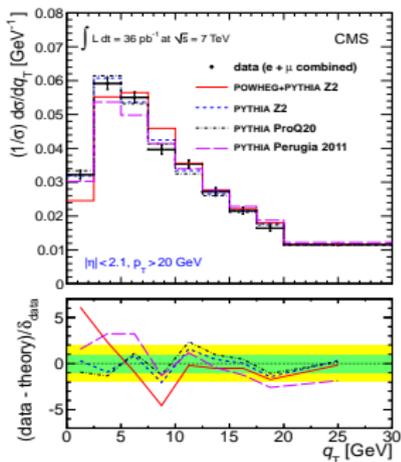


Higgs as a gluon trigger

- Discovery of the Higgs opens up a completely new world for QCD studies:
 - gluon process with color singlet final state at large mass

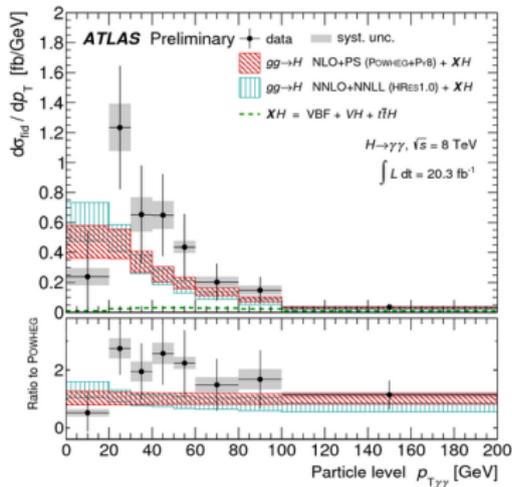
Z production:

Phys. Rev. D 85, 032002 (2012)



Higgs production:

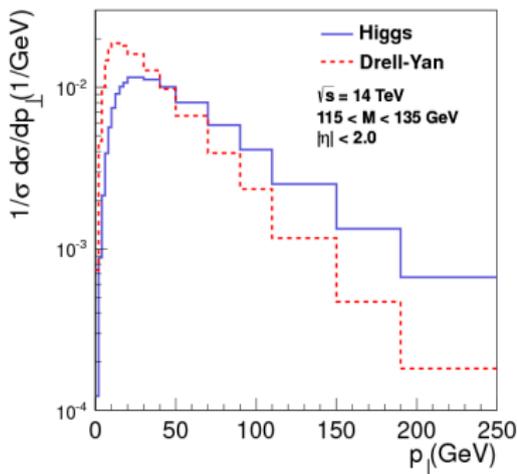
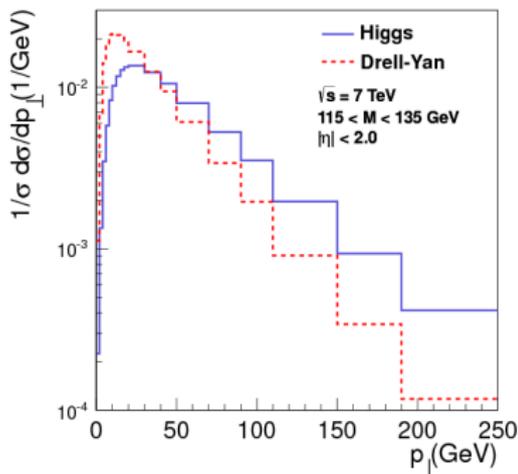
ATLAS-CONF-2013-072



possibility to study QCD with Higgs and DY processes \rightarrow

Higgs as gluon trigger; p_T spectra (inclusive boson production)

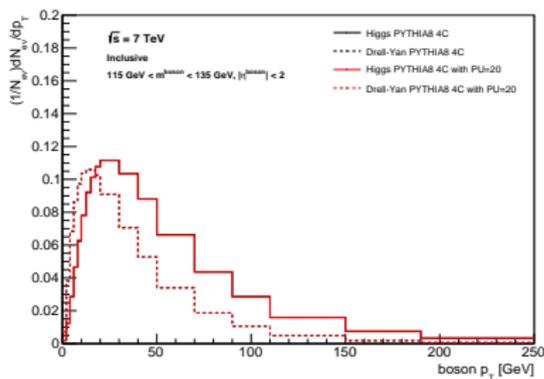
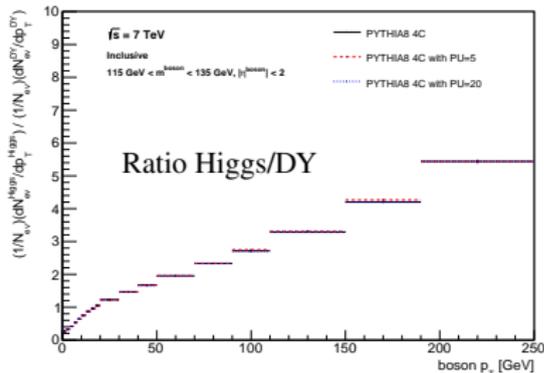
- Start new QCD program with Higgs as gluon trigger
P. Cipriano, S. Dooling, A. Grebenyuk, P. Gunnellini, F. Hautmann, H. Jung, P. Katsas
Phys. Rev. D 88, 097501 (2013)
- comparison with DY production in the same mass range ($115 < M < 135$ GeV)
- comparison p_T spectrum of DY and Higgs \rightarrow difference in soft gluon resummation



- Can we measure QCD processes with small cross section (which require high luminosity)?
- Following pile-up studies are performed (H. Van Haevermaet, DIS2014):
 - look at ratio (Higgs/DY): direct difference in soft gluon vs quark resummation
 - look at subtraction (Higgs - DY): remove PU contributions from UE

p_T spectra (inclusive boson production)

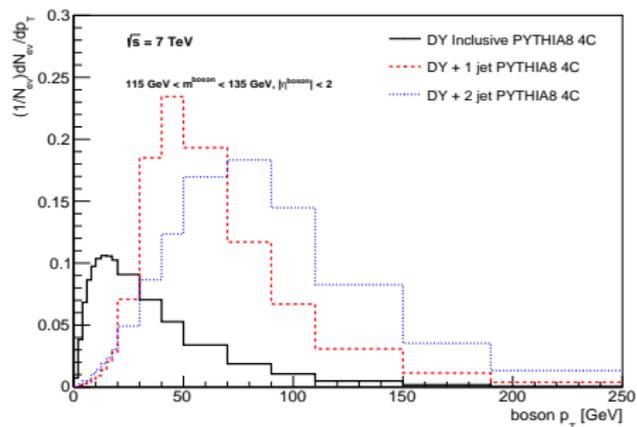
Pile-up studies on generator level:

Single Z production and $gg \rightarrow H$ production with tune 4C at $\sqrt{s} = 7 \text{ TeV}$ Bosons stable; mass range $115 \text{ GeV} < M < 135 \text{ GeV}$, $|\eta| < 2$
With No PU; Fixed PU= 5; Fixed PU= 20;
PU processes: Soft QCD (all)By definition p_T spectra are stable with PUIf experimental reconstruction of decay products is precise enough
→ can directly probe the gluon

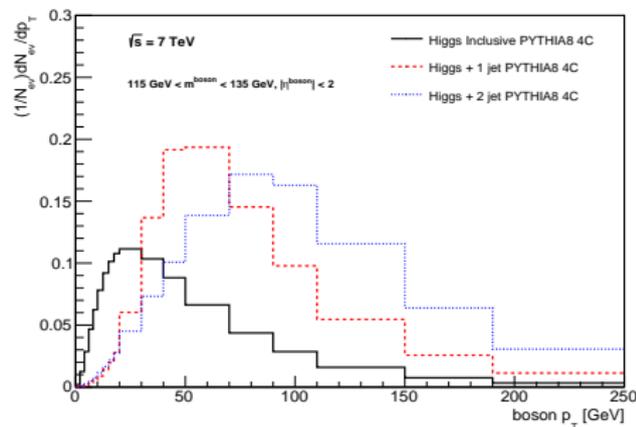
→ ratio Higgs/DY quantifies gluon vs quark resummation

p_T spectra (boson + jets)

DY inclusive; DY + 1 jet; DY + 2 jets:



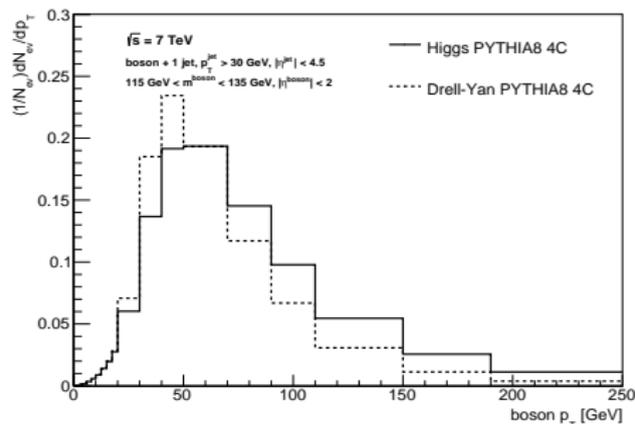
Higgs inclusive; Higgs + 1 jet; Higgs + 2 jets:



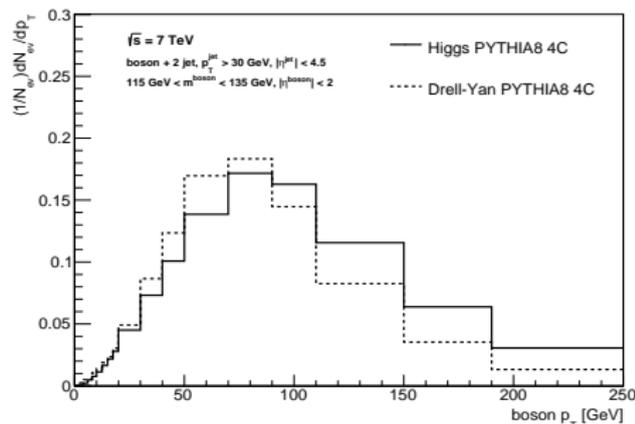
- Requiring additional hard jets shifts the spectra towards higher p_T
- p_T balance between boson + jets
- Quark vs gluon induced effects less significant

p_T spectra (boson + jets)

Boson + 1 jet:



Boson + 2 jets:



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

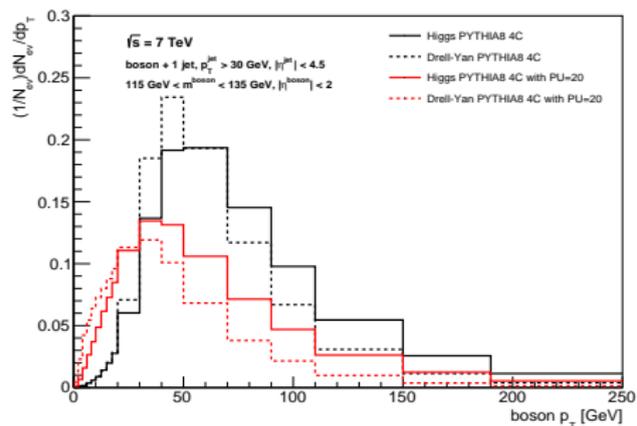
$$\langle p_T^{\text{Higgs}} \rangle / \langle p_T^{\text{DY}} \rangle \text{ inclusive: } 1.52$$

$$\langle p_T^{\text{Higgs}} \rangle / \langle p_T^{\text{DY}} \rangle \text{ boson + 1 jet: } 1.17$$

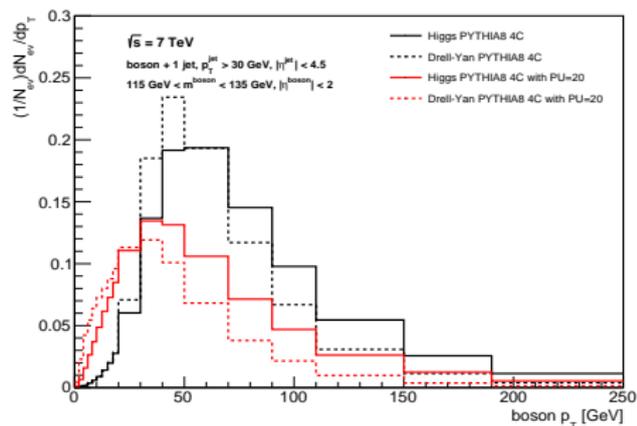
$$\langle p_T^{\text{Higgs}} \rangle / \langle p_T^{\text{DY}} \rangle \text{ boson + 2 jet: } 1.16$$

p_T spectra (boson + jets)

Boson + 1 jet:



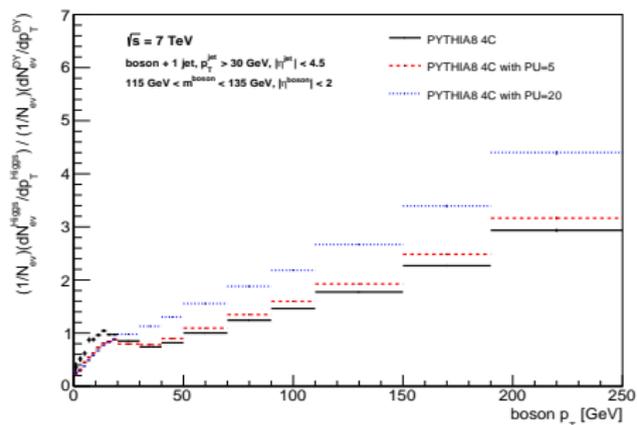
Boson + 2 jets:



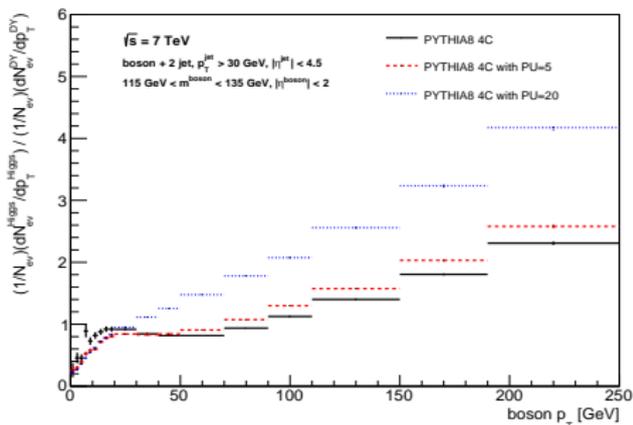
- Both Higgs and DY spectra shift to lower values (as for inclusive spectrum)
- Mismatching of leading jets \rightarrow higher probability that high p_T jets come from independent PU event
- Difference stable when taking ratio?

p_T spectra (boson + jets)

Boson + 1 jet:



Boson + 2 jets:

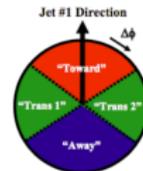


- Ratio not stable due to difference in hardness of the inclusive spectra → fraction of jet mismatching not the same
- Very low PU runs stay important to study QCD (especially for jets measured in the full CMS acceptance)

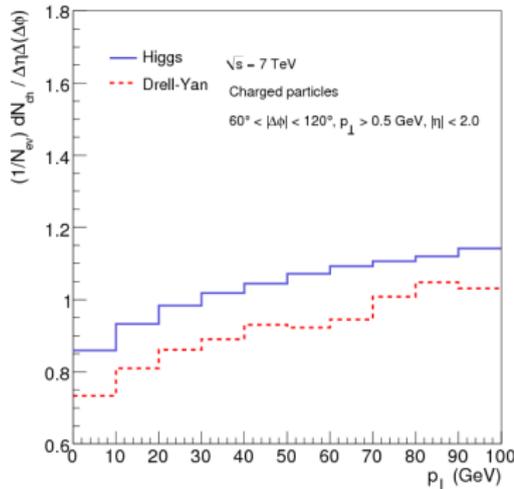
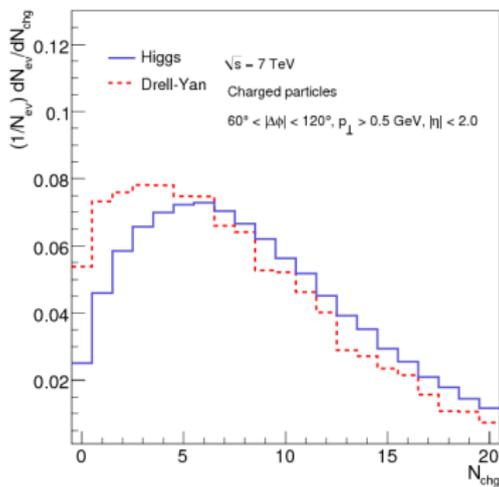
Underlying event studies

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Studies of number of charged particles (or $\sum p_T$) in the azimuthal region transverse to the boson axis



- comparison with DY production in the same mass range ($115 < M < 135$ GeV)
- underlying events in **DY** and **Higgs** → difference in quark vs gluon induced process

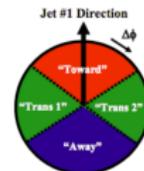


→ higher multiplicity for the Higgs case from gluon cascade

Underlying event studies; pile-up

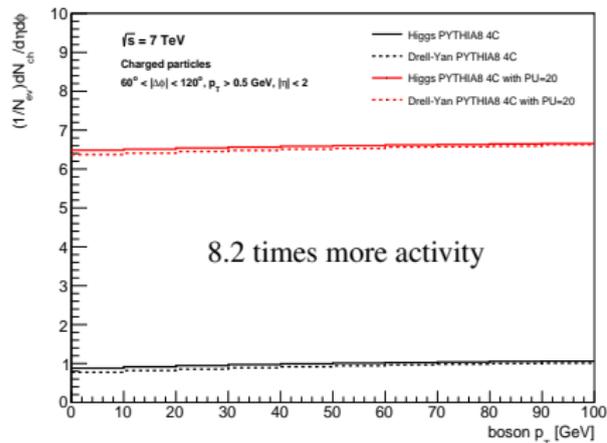
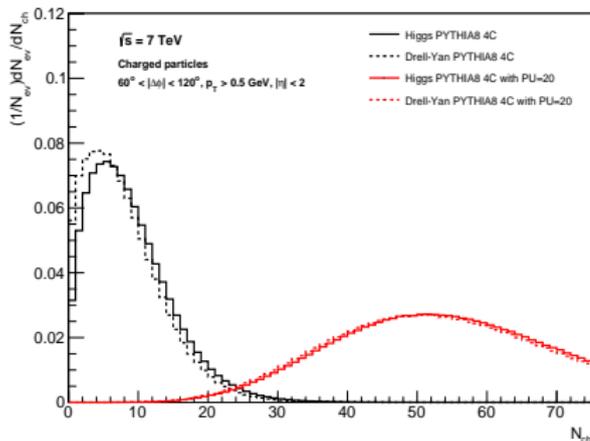
Studies of number of charged particles (or $\sum p_T$) in the azimuthal region transverse to the boson axis

Activity scales with number of additional PU events



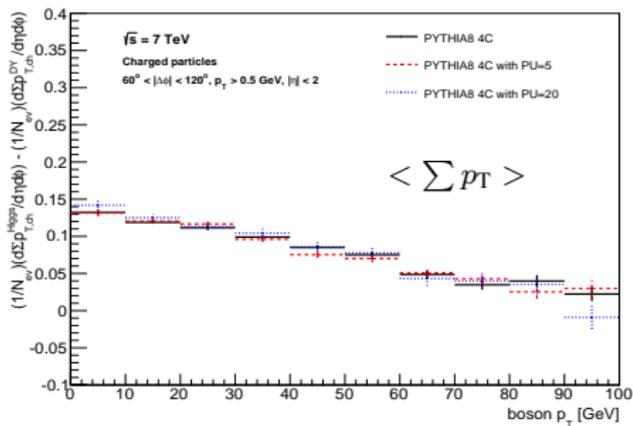
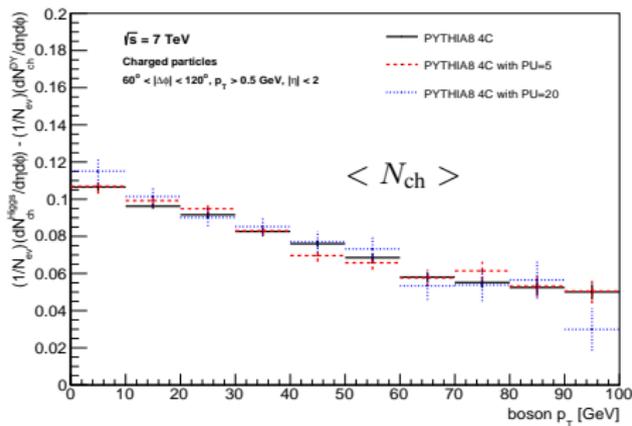
- PU can be subtracted:

$$\frac{dn}{dp_T}(\text{H-DY}) = \frac{dn}{dp_{T\text{H}}} + \frac{dn}{dp_{T\text{pileup}}} - \left(\frac{dn}{dp_{T\text{DY}}} + \frac{dn}{dp_{T\text{pileup}}} \right)$$



p_T spectra (boson + jets)

After subtraction of activity in DY from activity in Higgs production:



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

Summary

- Higgs production measurement provides new perspectives for challenging QCD studies
 - Higgs is the only electroweak current which couples to gluon
 - color single state → no complications from final state effects
- New proposal to compare Higgs - DY in the same mass and rapidity range
- Preliminary generated studies are presented:
 - ratios of inclusive, boson+ 1 jet, boson + 2 jets p_T spectra
 - inclusive spectrum sensitive to soft gluon resummation
 - boson + jet events suffer from PU effects
 - underlying event activity in subtraction Higgs - DY:
 - $\langle N_{\text{ch}} \rangle$ and $\langle \sum p_T \rangle$ 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



Back up slides



DPS fraction in data