Higgs as a gluon trigger

- Imagine …
- What is so special on Higgs
- Difference to Drell-Yan at $m_{DY}=125$ GeV
- Is it too crazy ?

Imagine, would could probe gluons directly

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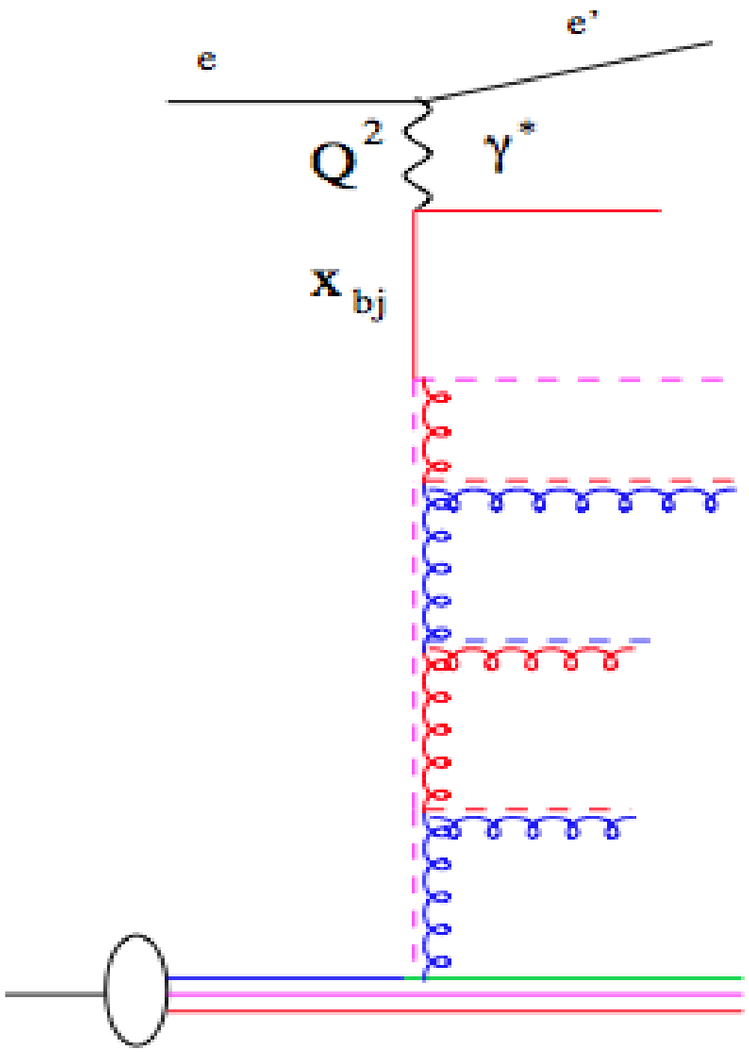

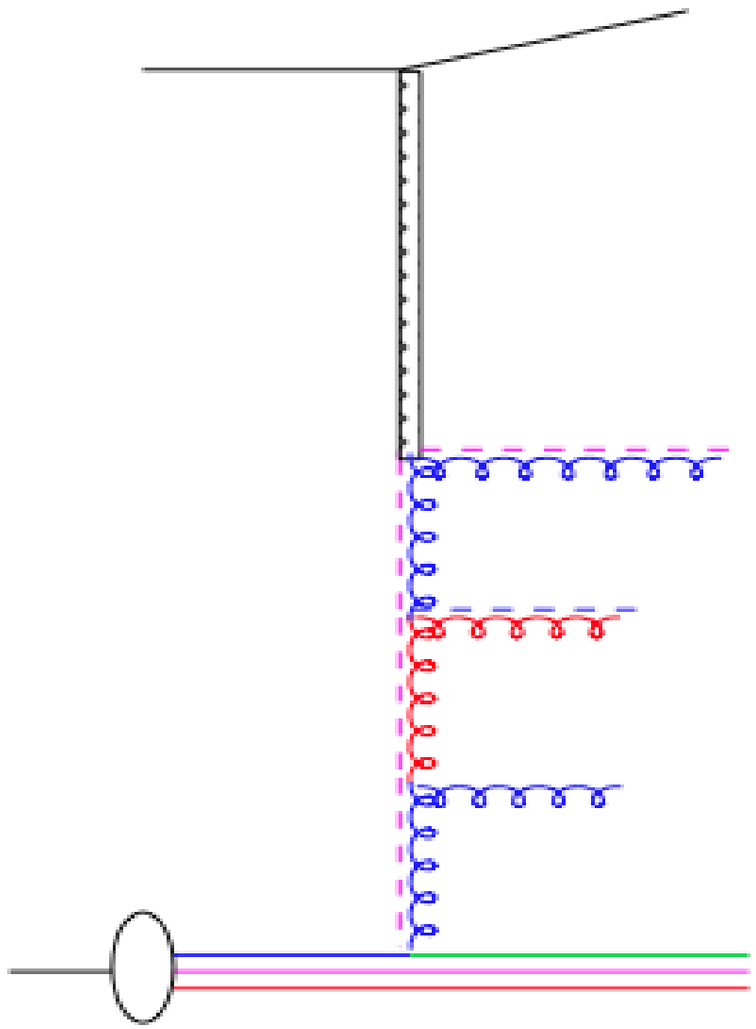

Imagine ...

- all standard electro-weak currents couple to quarks:

  γ, Z_0, W

  - structure function of quarks are well measured in DIS scattering, as well as in DY production
  - structure function of gluons, as well as properties of gluons are measured only indirectly via quark

Imagine ...

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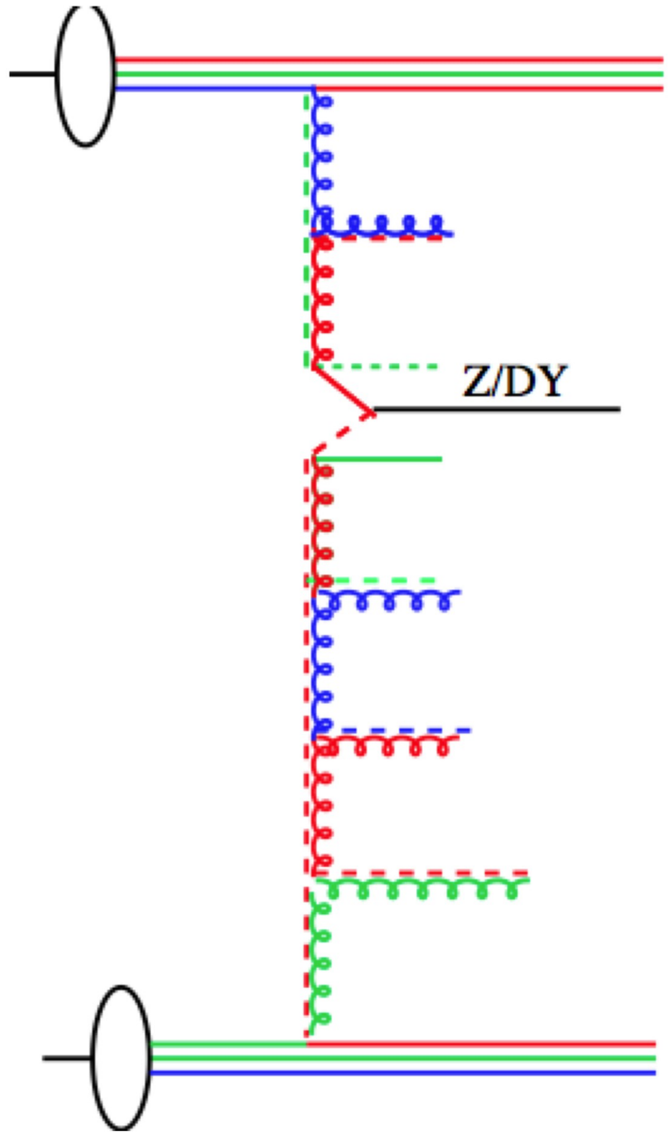
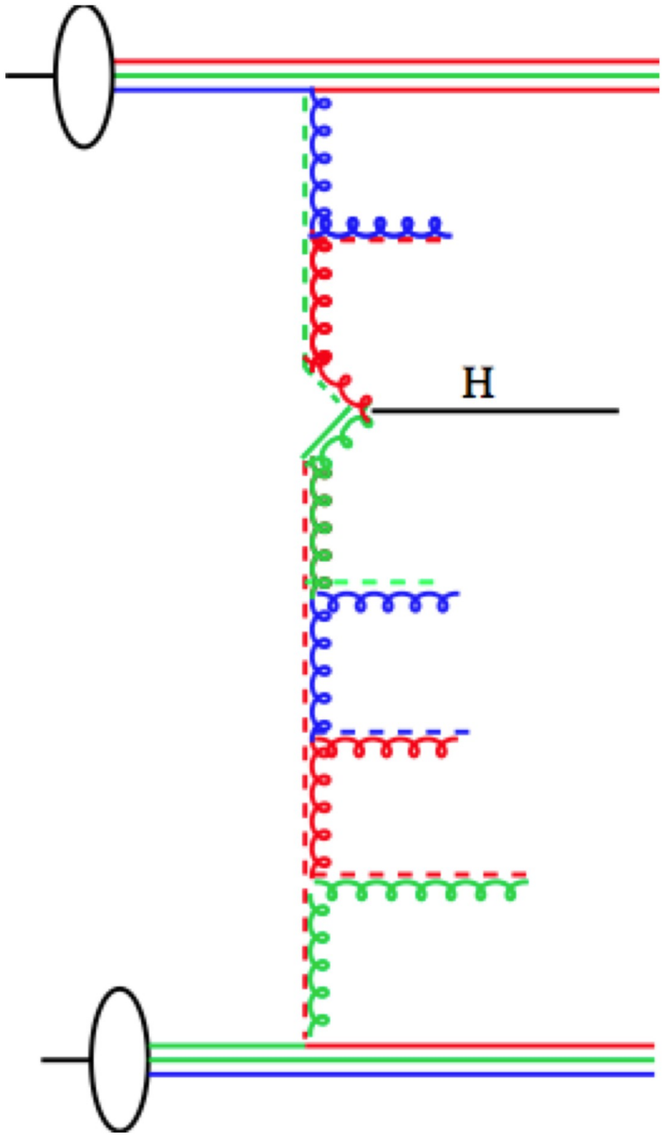
  $\gamma,\ Z_0,\ W$



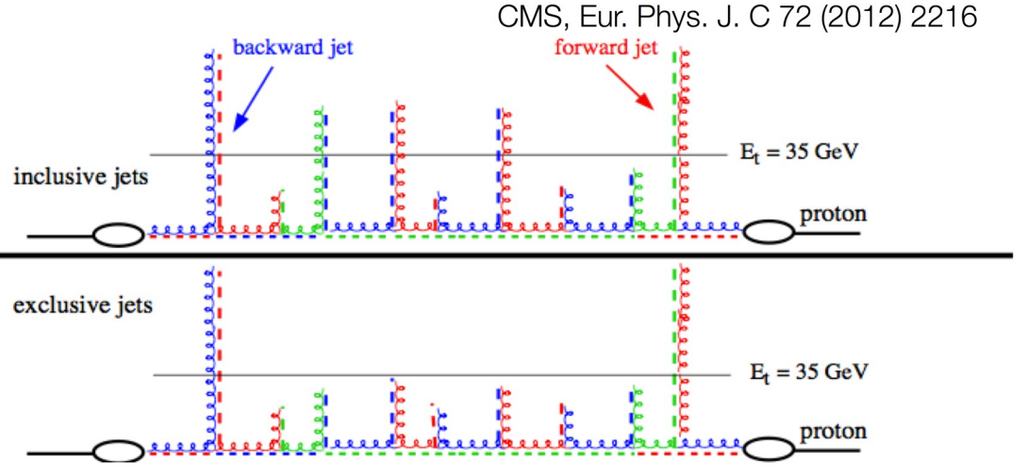
- Higgs is special:
  - in heavy top limit, couples directly to gluons



Challenge in QCD – example

- select (anti-kt) dijets with $p_{t\,min} = 35\ \mathrm{GeV},\ |y| < 4.7$
- plot ratio of exclusive/inclusive xsection (many systematic cancel) as function of rapidity separation Δy between jets
  - for large Δy expect rising xsection due to increased phase space (BFKL effects)
    - this is NOT a search channel, these effect MUST be there if QCD is correct !

CMS, Eur. Phys. J. C 72 (2012) 2216



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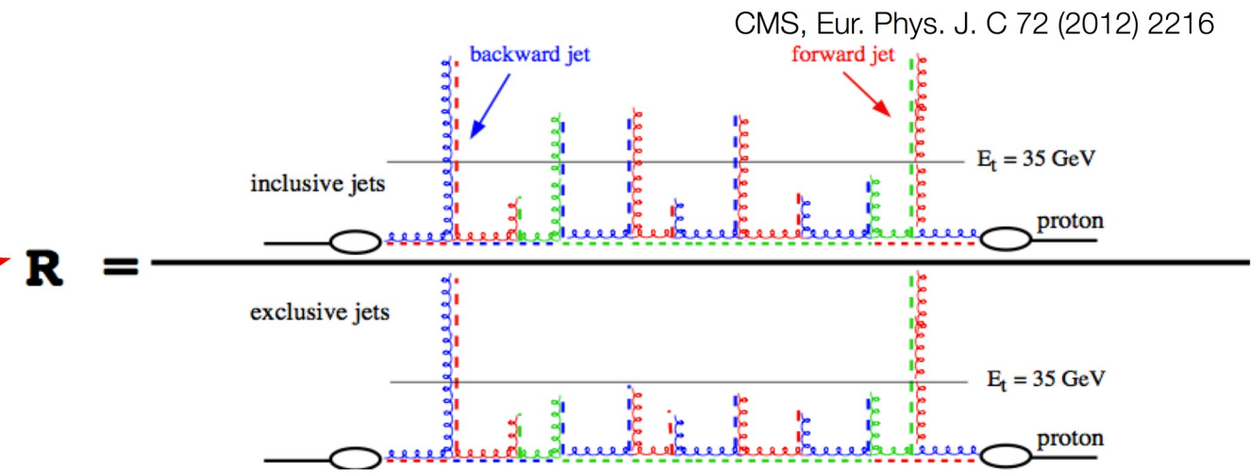
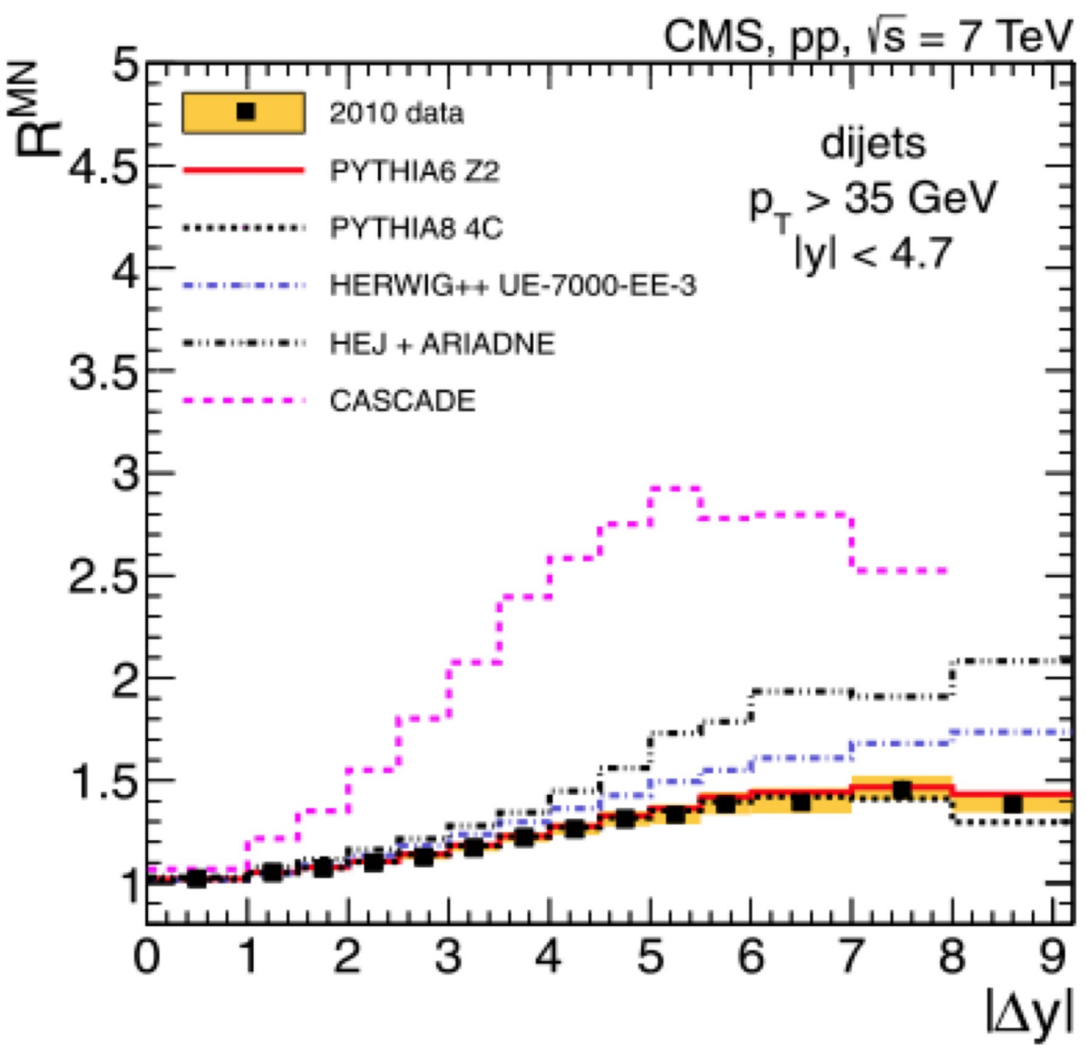




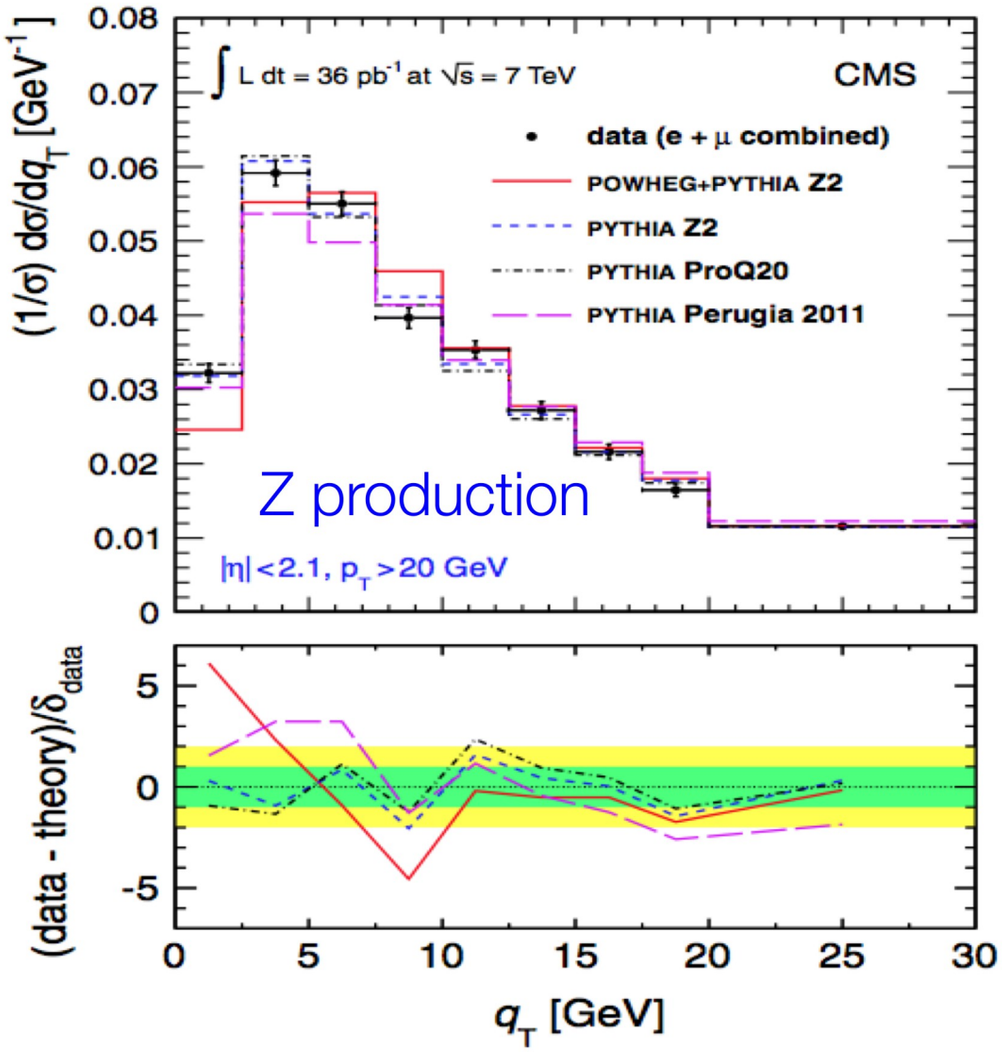
- for large Δy expect rising xsection due to increased phase space (BFKL effects)
  - this is NOT a search channel, these effect MUST be there if QCD is correct !
- BUT .....

QCD options at high luminosity LHC

Until last year, perspectives for QCD studies at HL LHC were rather bad.....

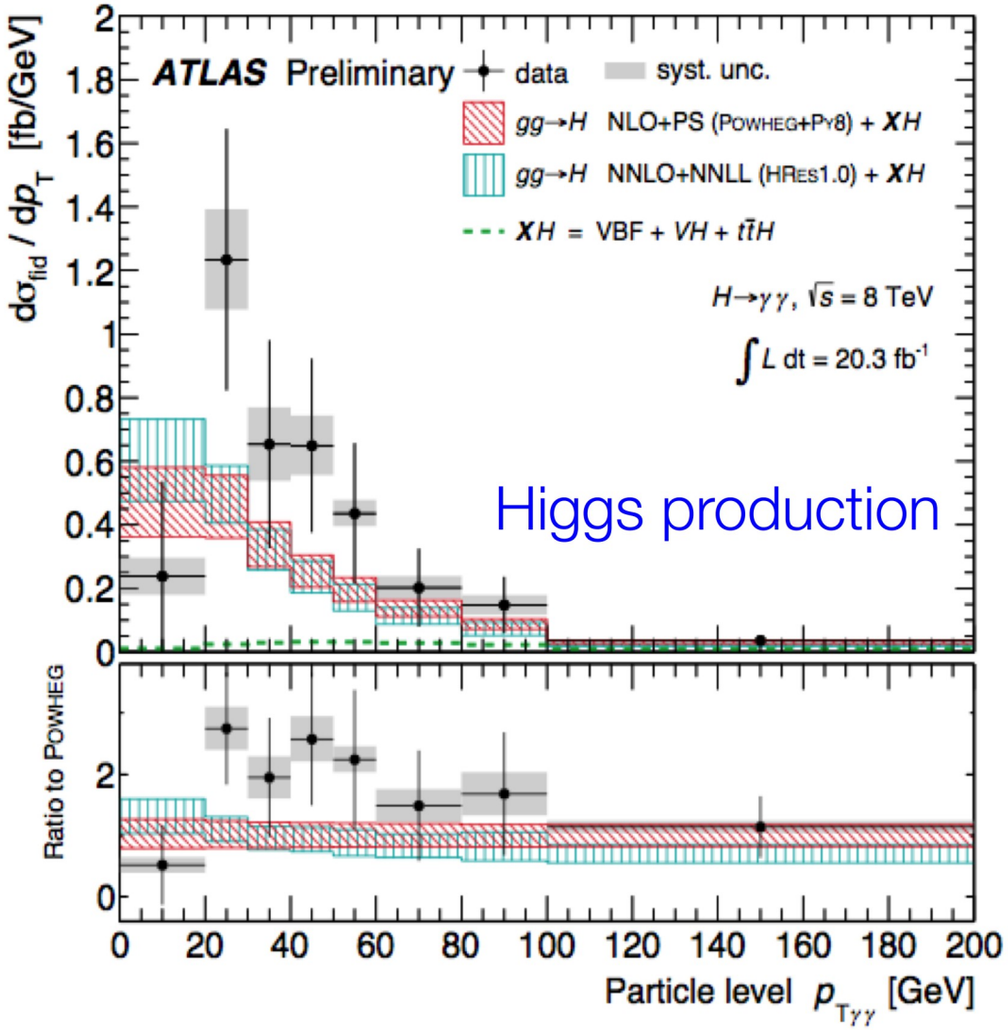
- **BUT now, with Higgs, we have a new and exciting result, which opens up a completely new world for QCD studies:**
  - **gluon process with color singlet final state at large masses:**

CMS Coll., PRD 85, 032002 (2012)



Z production

Differential cross sections of the higgs boson measured in the diphoton decay channel using 8 TeV pp collisions. ATLAS-CONF-2013-072,

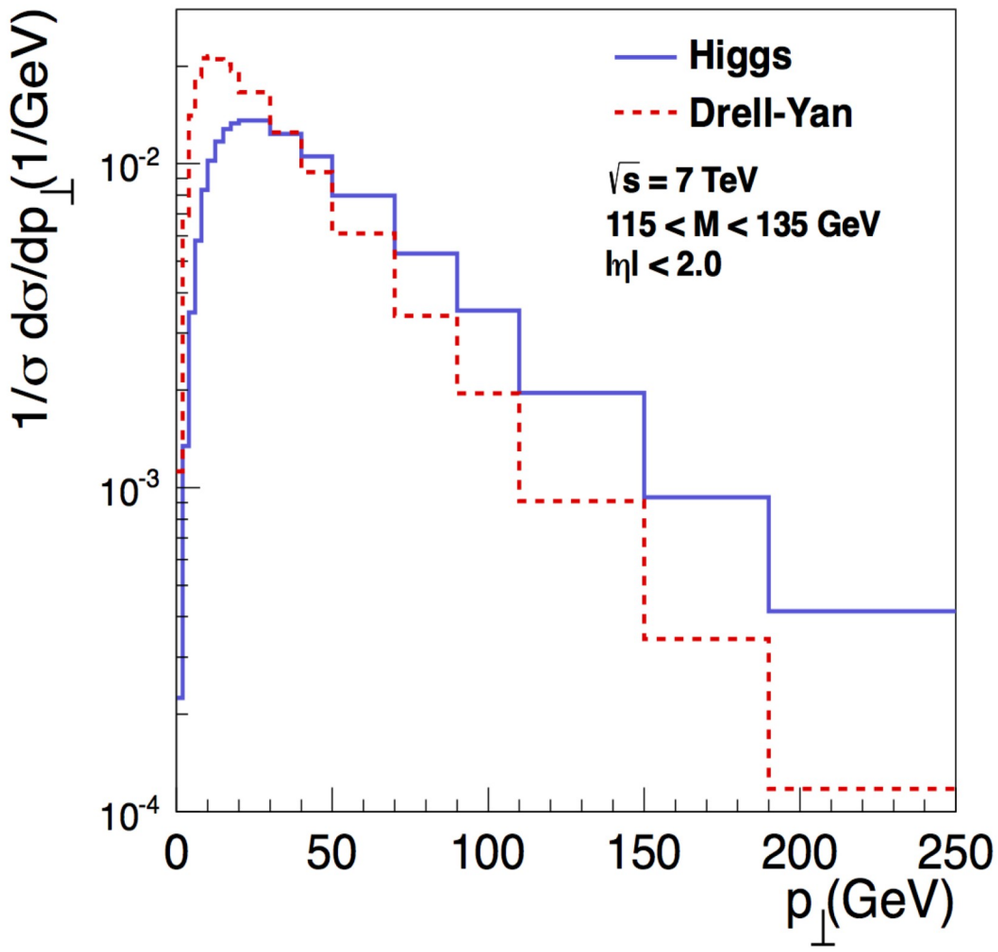


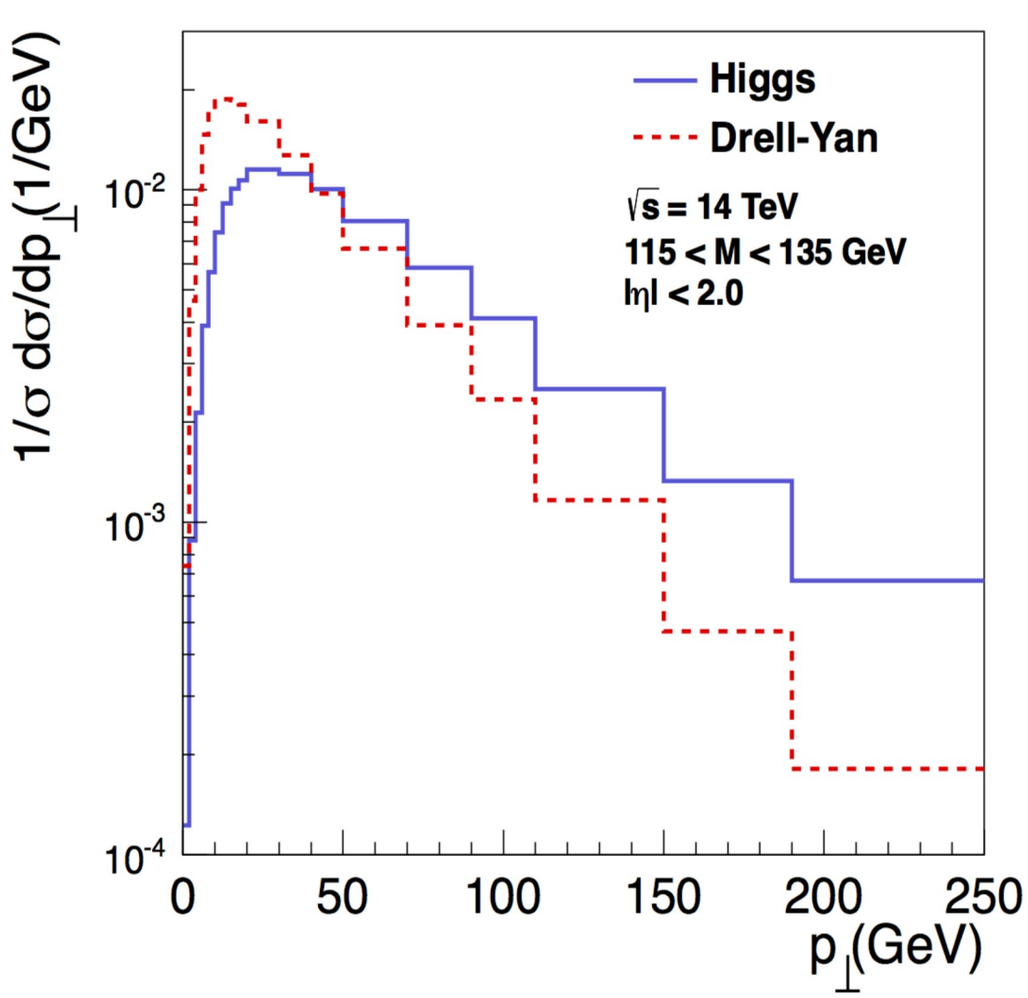
Higgs production

Higgs as a gluon trigger

- **Start new QCD program with Higgs as gluon trigger (arXiv:1308.1655)**
  P. Cipriano, S. Dooling, A. Grebenyuk, P. Gunnellini, F. Hautmann, H. Jung, P. Katsas
  - comparison with DY production at same mass range
  - p_T spectrum of DY and Higgs:

    difference in soft gluon resummation:





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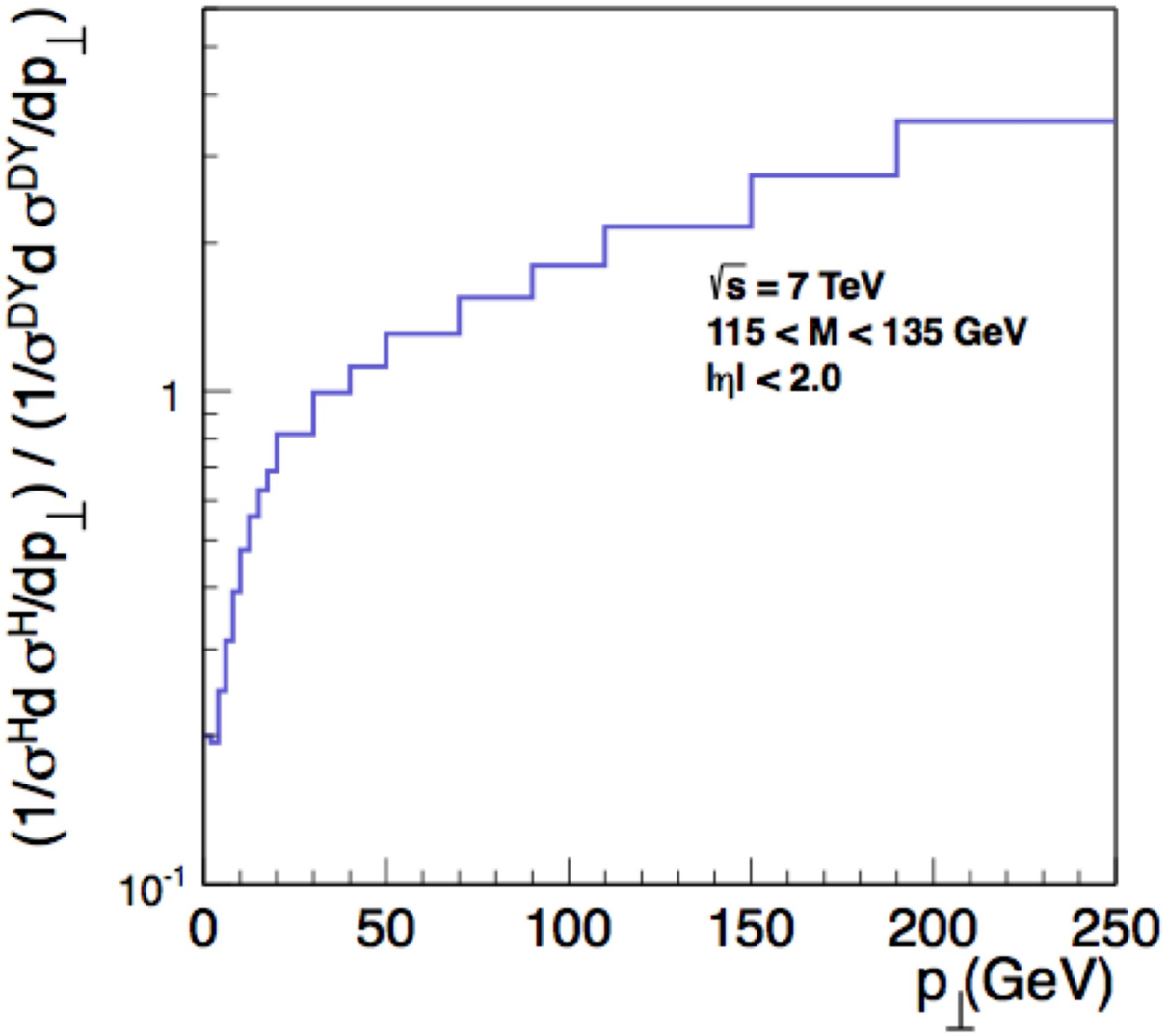
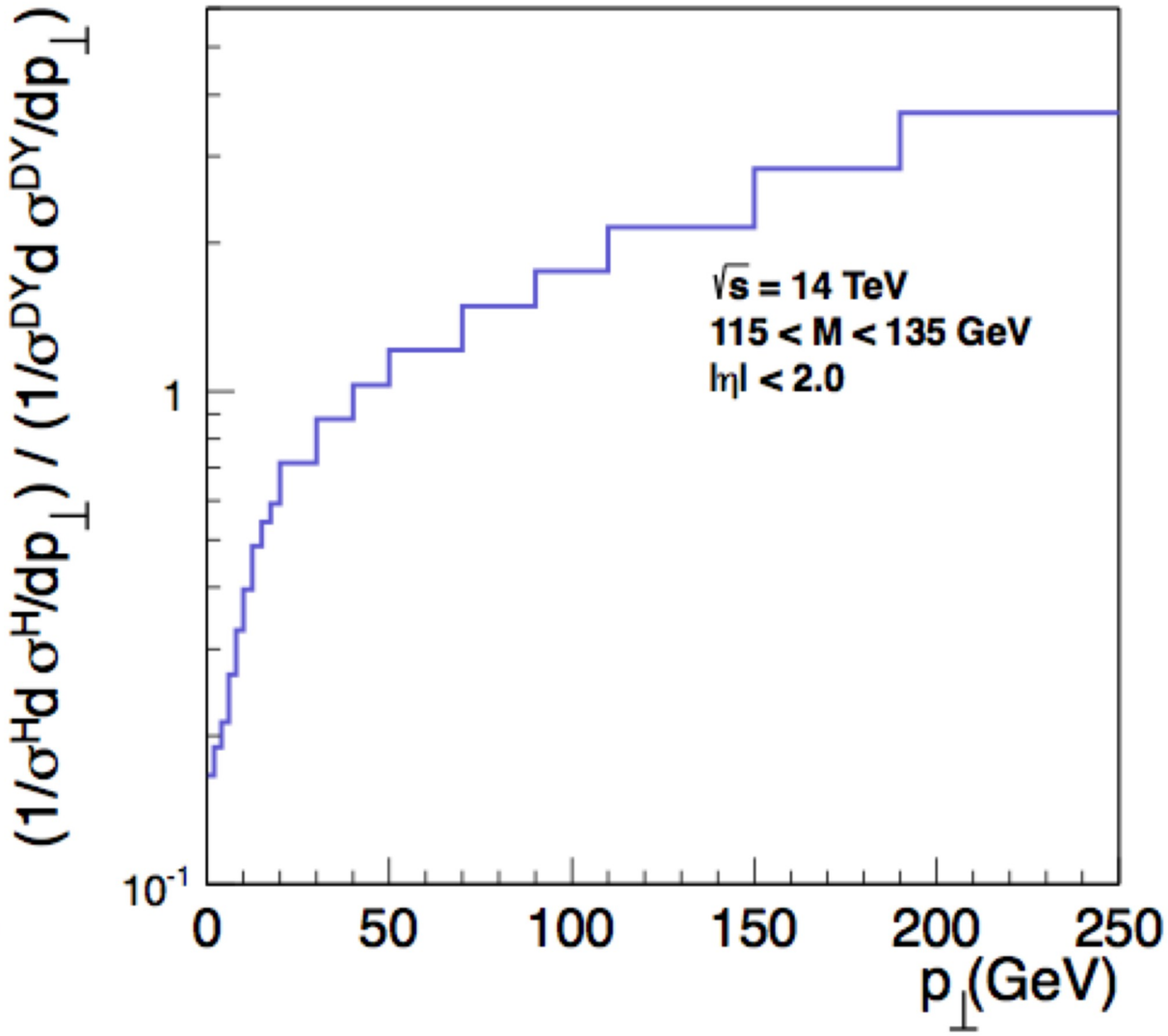
  - **plot ratio of Higgs/DY xsections at $m{=}125\,GeV$ at fixed rapidity**
    → pdf dependence cancel





Higgs as a gluon trigger – UE studies

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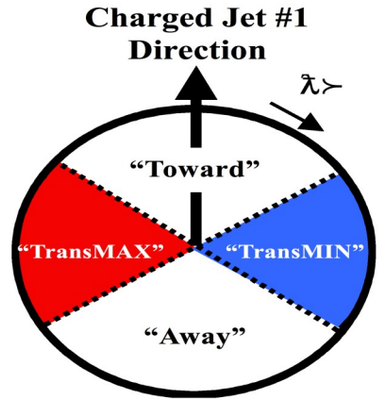
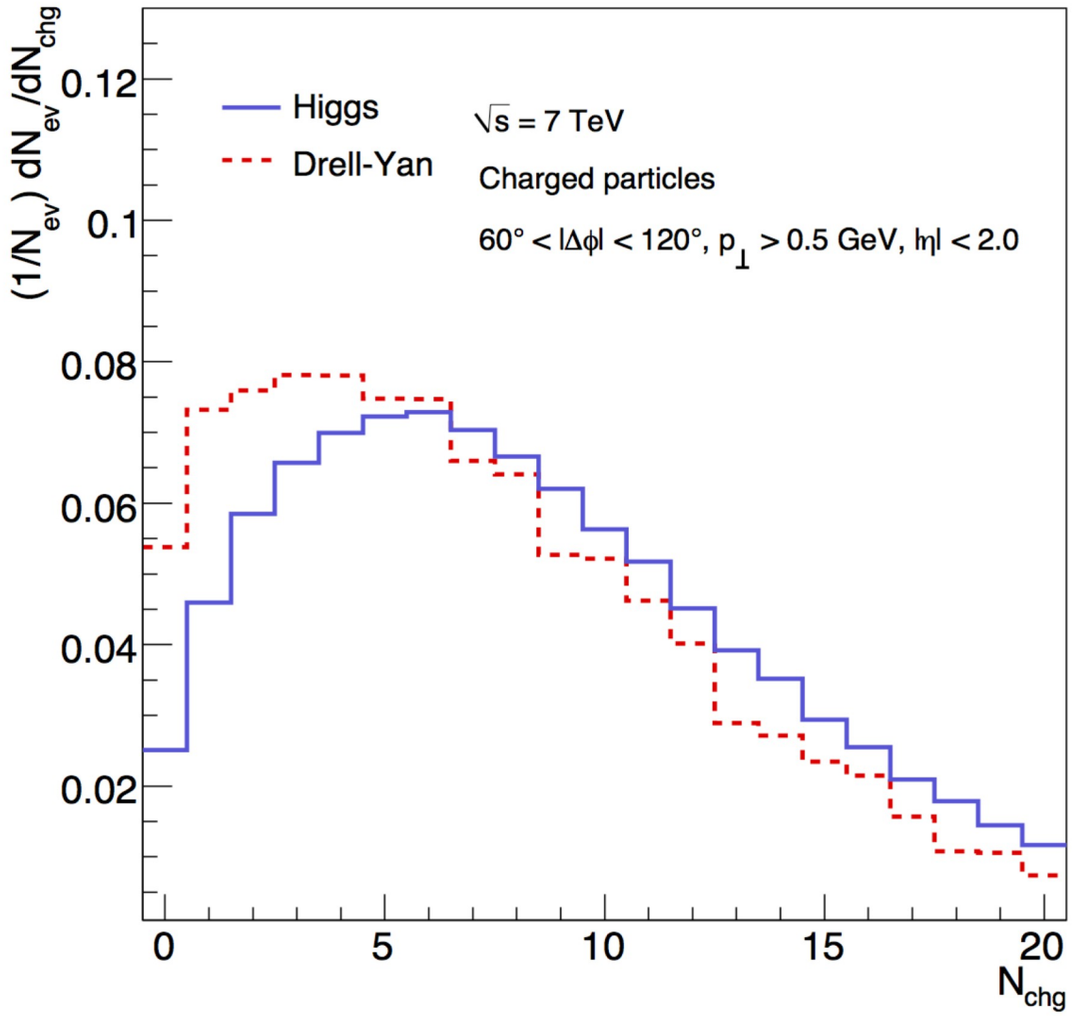
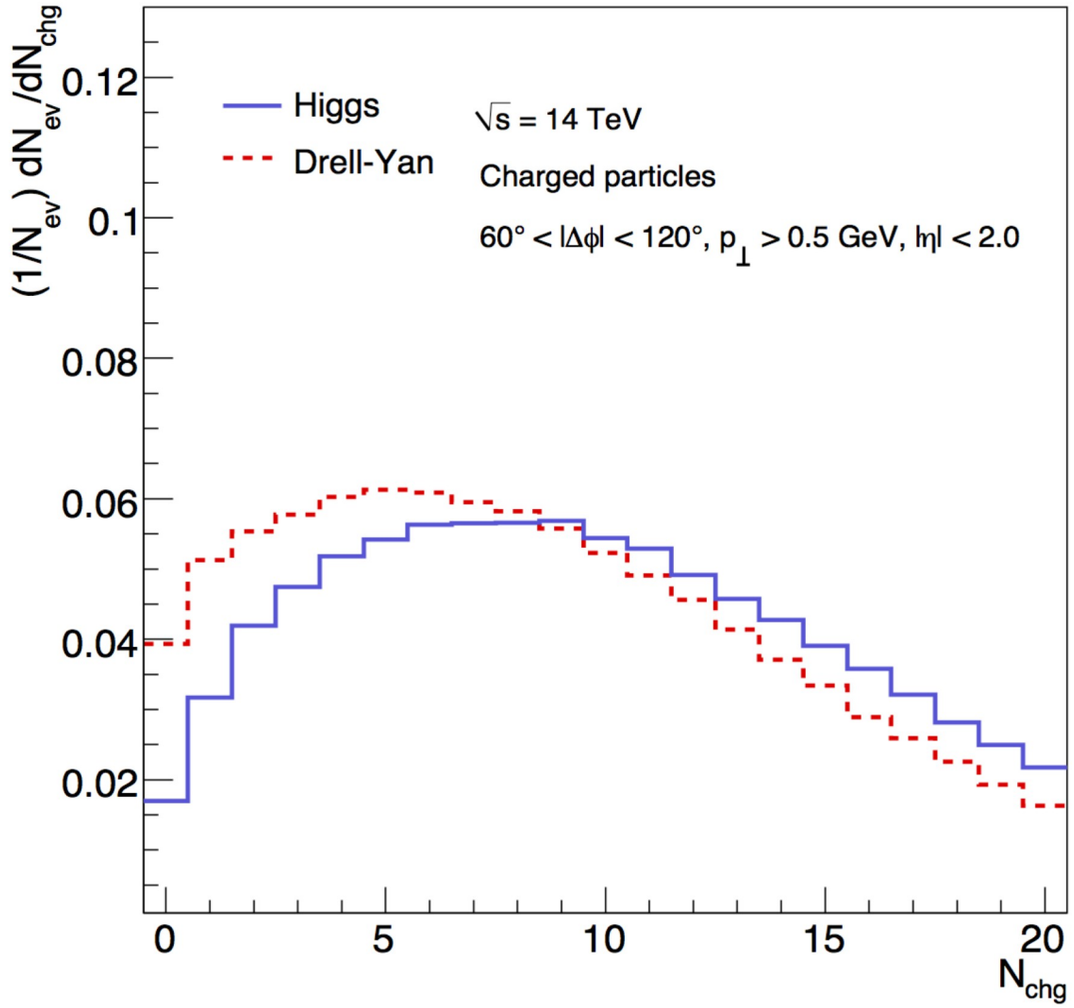
  - comparison with DY production as same mass range
  - underlying events in DY and Higgs:
    difference in quark vrs gluon induced process







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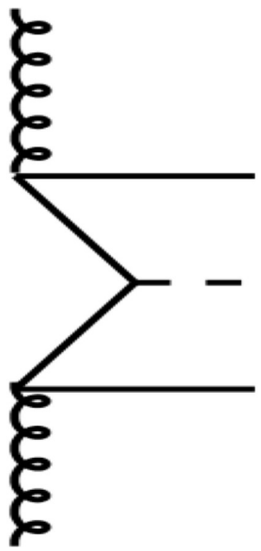
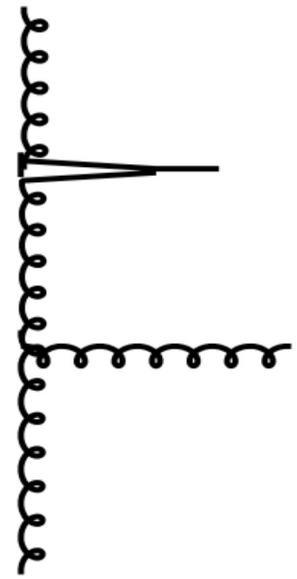
  P. Cipriano, S. Dooling, A. Grebenyuk, P. Gunnellini, F. Hautmann, H. Jung, P. Katsas
  - comparison with DY production as same mass range
  - jet + DY / Higgs: in rest-frame see effect of quark vrs gluon propagator → angular distribution

Drell Yan



Higgs



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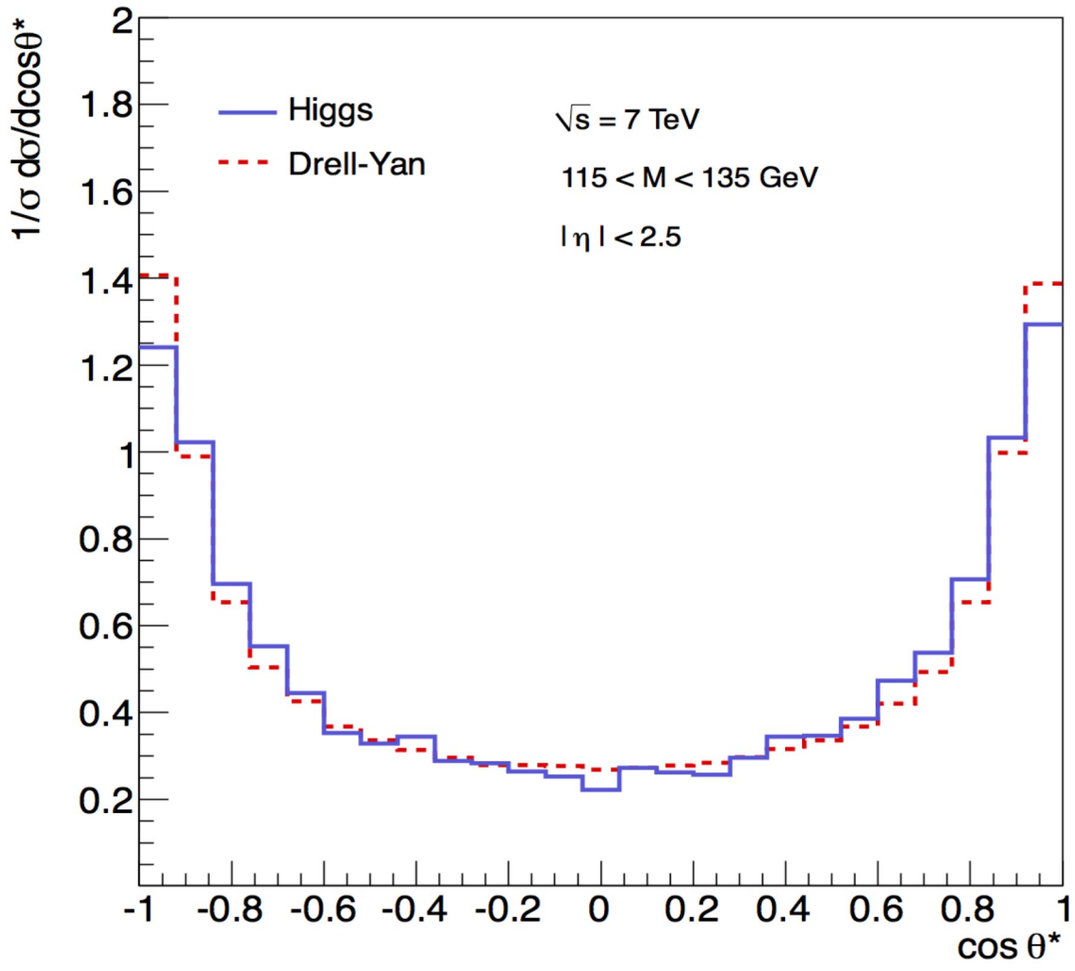
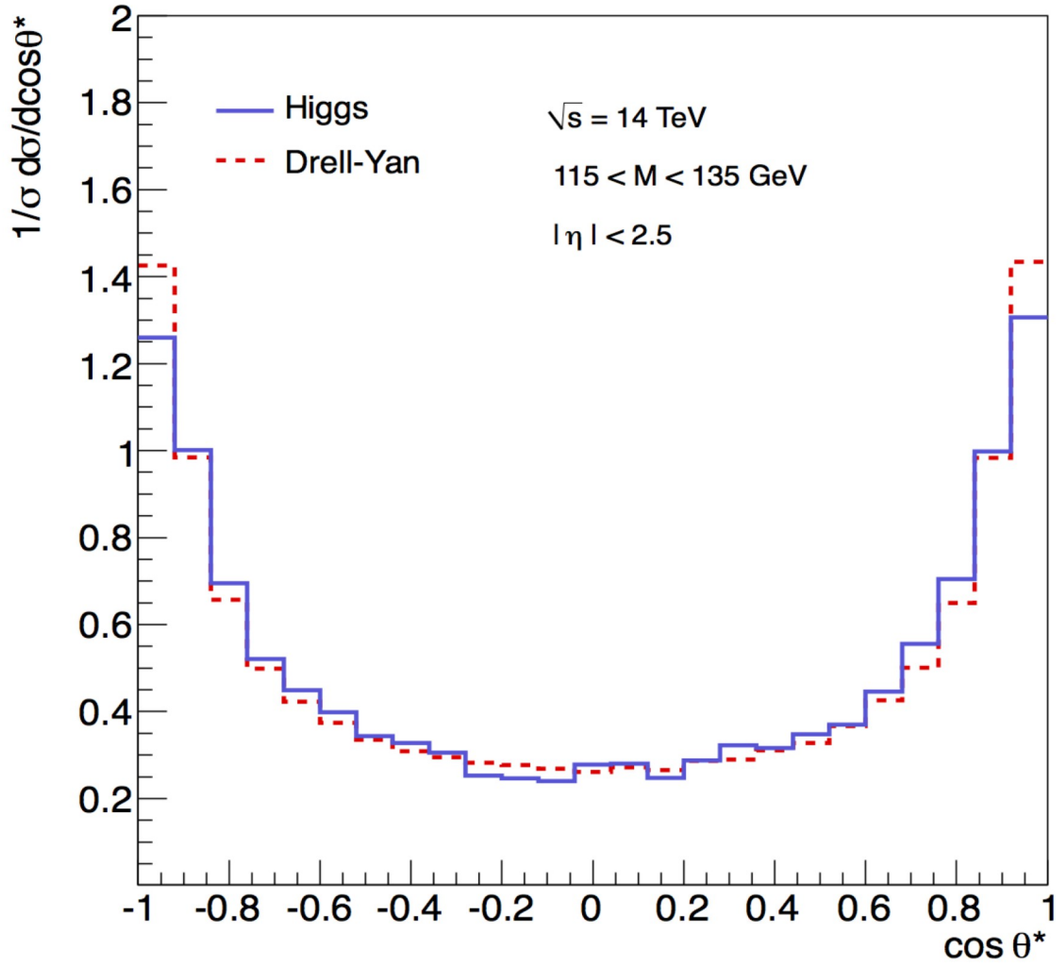
  - jet + DY / Higgs: in rest-frame sensitivity to spin-coupling to gluons - vanishing effect of quark vrs gluon propagator





What is new there ?

- Comparison of DY and Higgs allows direct comparison of quark vrs gluon induced process
  - with DY we can go to the same mass as with Higgs
    - comparing DY and Higgs at fixed y: pdf dependence cancels
  - advantage is: color singlet final state
    - no issue with color flow from initial to final state as in ttbar, bbar or jet processes
  - pile-up is no issue: by comparing DY and Higgs, pile-up drops out:

$$\frac{dn}{dp_t}(H-DY) = \frac{dn}{dp_{t\,H}} + \frac{dn}{dp_{t\,pileup}} - \left(\frac{dn}{dp_{t\,DY}} + \frac{dn}{dp_{t\,pileup}}\right)$$

  - dito for UE contribution: isolate directly initial state effects
  - can even measure jet at low transverse momenta

Challenge in QCD – another example

- Higgs + jet production
  - as fct of Δy jet multiplicity must increase
  - similar to dijet case
- Measure at fixed $m = 125\,GeV$

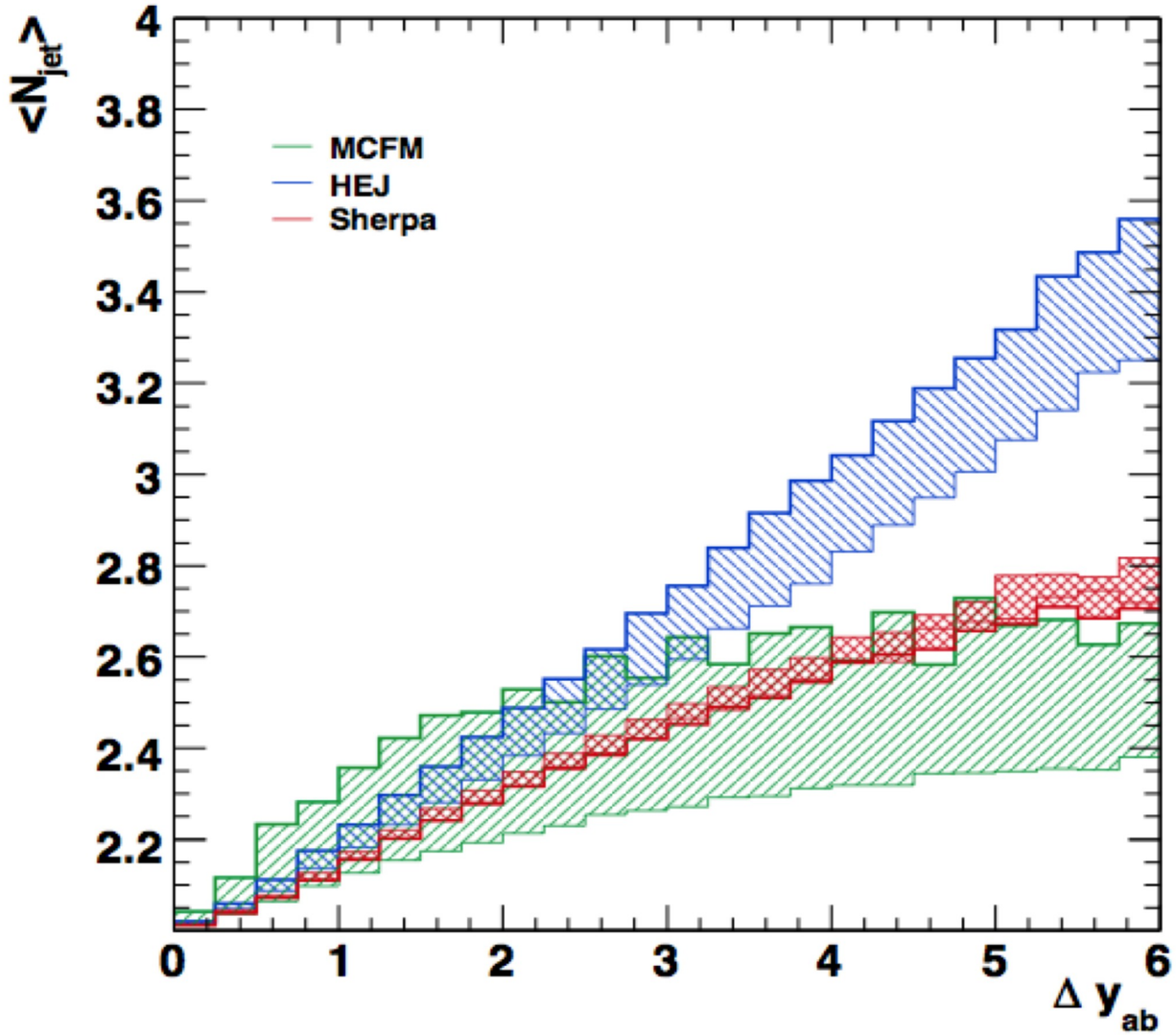
$$\frac{dn}{d\Delta y}_{Higgs} - \frac{dn}{d\Delta y}_{DY}$$

- pileup and UE effects cancel
- isolate gluon contribution

High Energy Description of Processes with Multiple Hard Jets
Jeppe R. Andersen. Jennifer M. Smillie.
Nucl.Phys.Proc.Suppl. 205-206 (2010) 205-210, 1007.4449

$$pp \to h + 2 \text{ jets } (+ \text{ n jets})$$

$$\sqrt{s} = 10 \text{ TeV}, \; p_T > 40 \text{ GeV}$$



A word on x-sections

- need a clean channel:
  - $h \to \gamma\gamma$ is difficult since fit to signal and background needed in each bin
  - $h \to ZZ \to 4l$ is clean bu has small x-section: ca 20 evts in 20 fb^{-1}
  - use also other channels: $h \to WW$
- really high luminosity is needed, but then one can measure to low p_t

- can one use instead χ_c and J/ψ or χ_b and Υ ?
  - in principle yes,
    - but difficulties in description of production mechanism
    - mass is low, evolution is less important
    - nit really in weak coupling limit

Conclusion

- Higgs measurement offers new perspectives for challenging QCD measurements
- Higgs is the only electroweak current which couples to gluons
- advantage since color singlet state has no complications from final state effects
- Higgs – DY comparison at $m = 125\,GeV$ removes most of background:
  - pdf dependence drops at fixed y
  - UE and pileup background drops out in difference or ratios
- Higgs allows interesting and challenging QCD measurements at high luminosity