Higgs Boson Production via Vector Boson Fusion Receives a Stress Test

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PASCOS 2018

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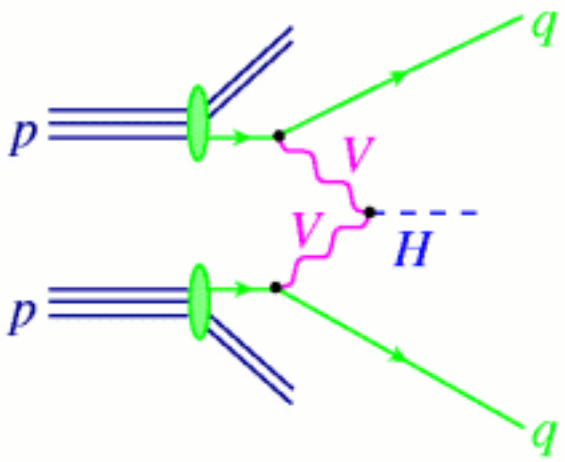
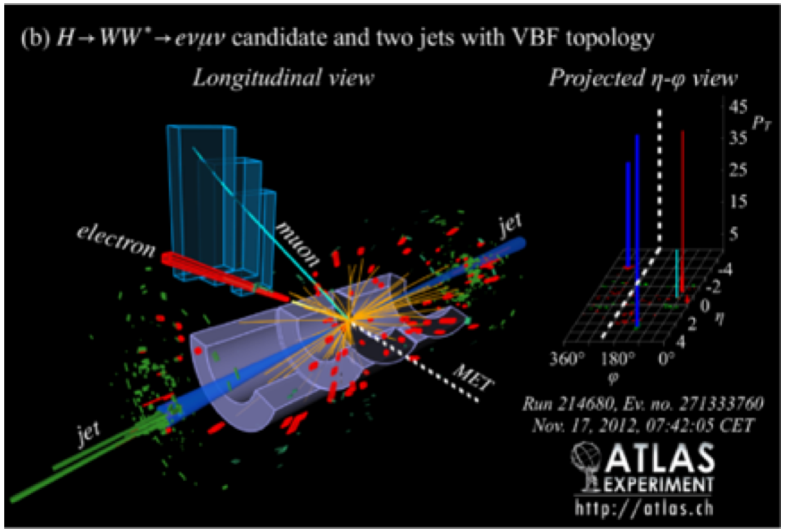
Vector Boson Fusion



- Energetic jets in the forward/backward directions.
- Higgs decays products in central rapidity region.
- Suppressed QCD radiation in central rapidity region.

Vector Boson Fusion



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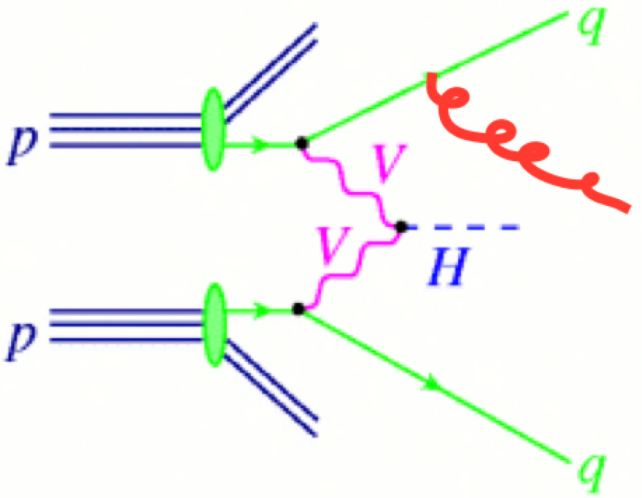
- Higgs decays products in central rapidity region.
- Suppressed QCD radiation in central rapidity region.

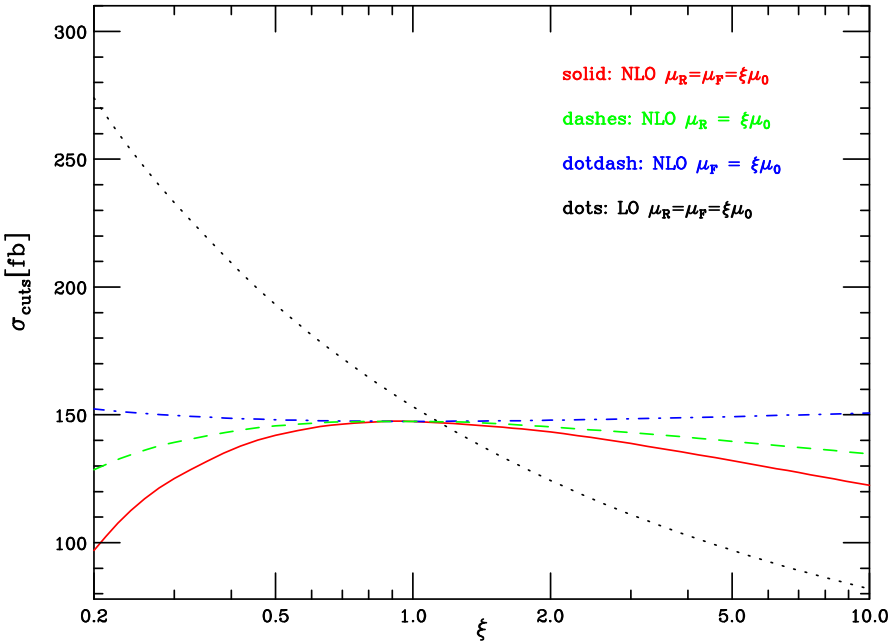
Vector Boson Fusion + Jet



4

H+3 Jets via VBF (only t-channels)

Total Cross Section

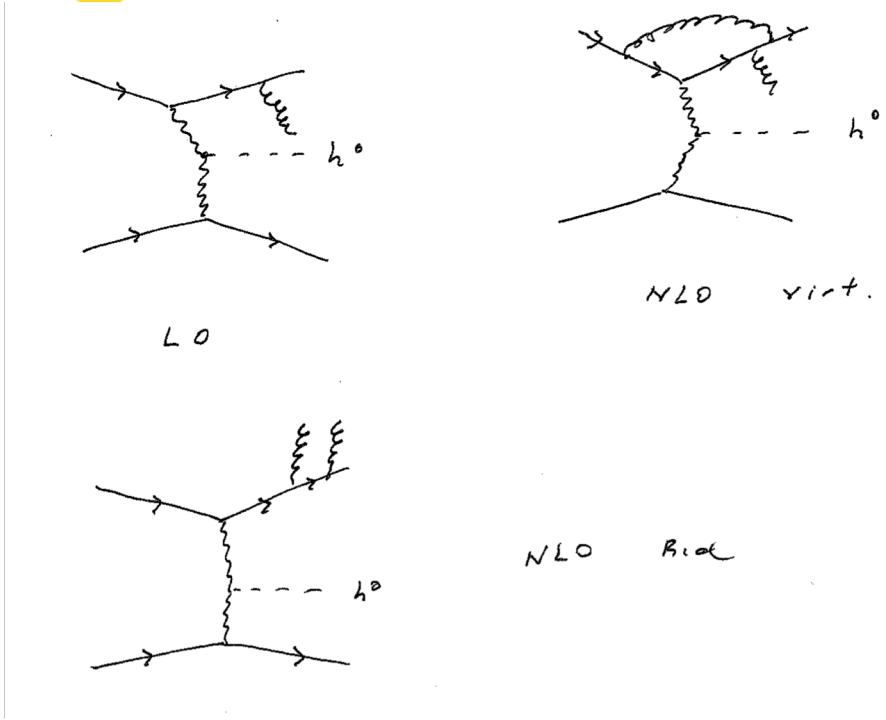


Scale Variations:

- LO: +26% to -19%
- NLO: less than 5%

JHEP 0802 (2008) 076 [arXiv:0710.5621]

H+3 Jets via VBF (only t-channels)

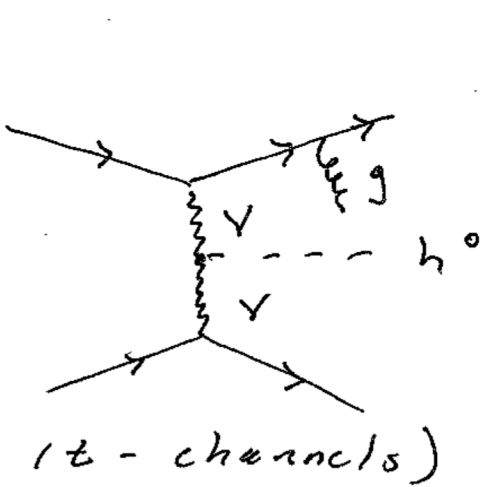


- No pentagon or hexagon diagrams included.
- Approximate as two deeply inelastic scattering processes that exchange a gauge boson.

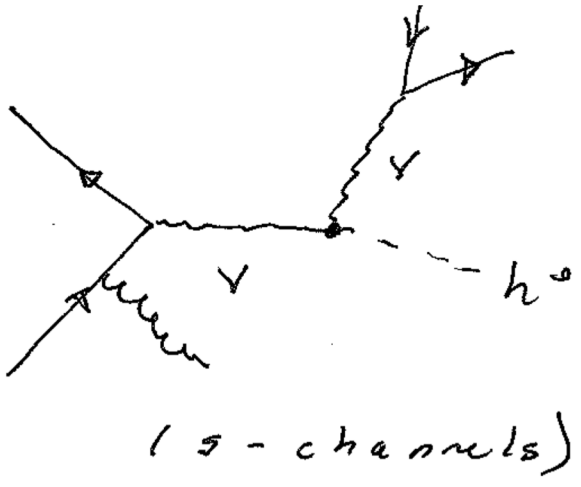
JHEP 0802 (2008) 076 [arXiv:0710.5621]

6

Going for all of it: EW H+3 Jets

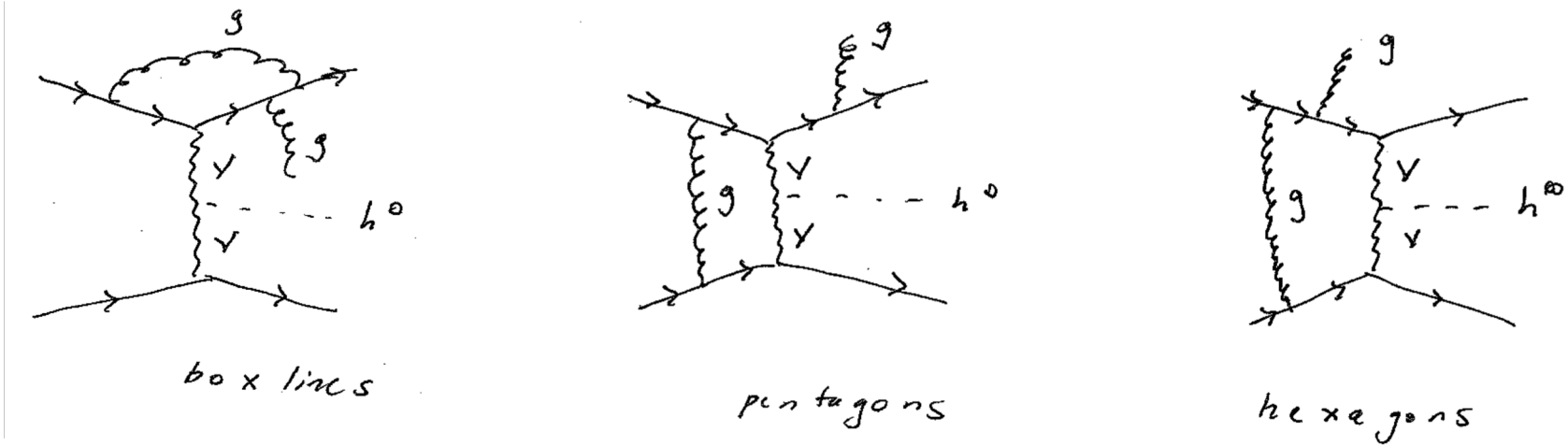


(t - channels)



(s - channels)

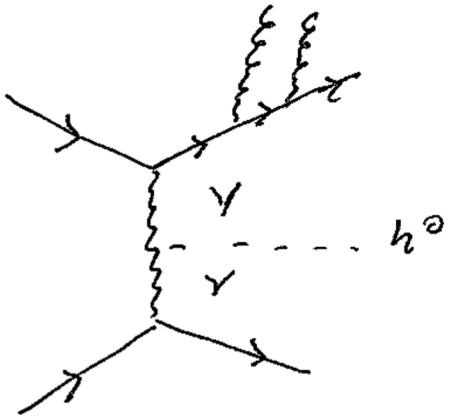
Going for all of it: EW H+3 Jets

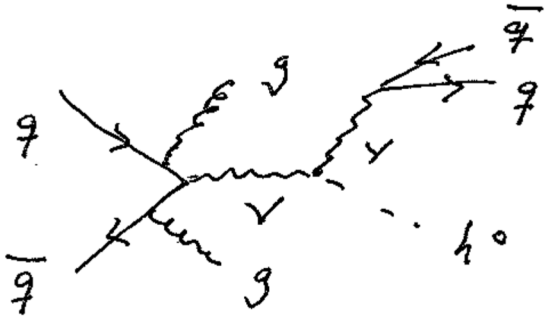


Virtual Corrections

8

Going for all of it: EW H+3 Jets

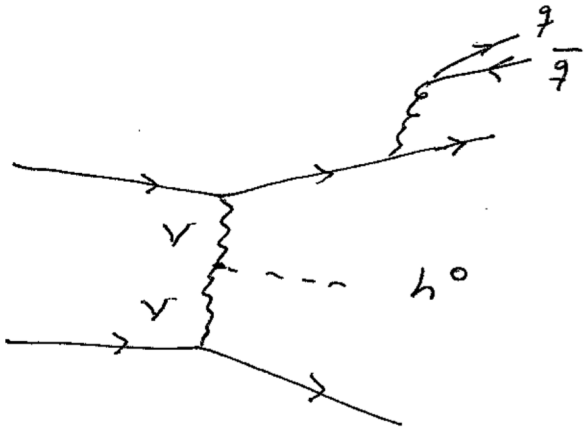


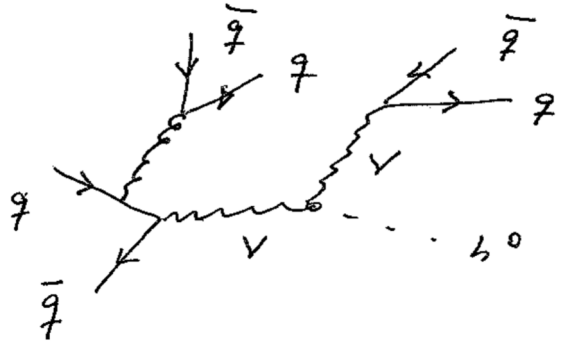


Real Corrections

9

Going for all of it: EW H+3 Jets





10

EW H+3 Jets: Implementation Details

F. Campario, T. M. Figy, S. Platzer, and M. Sjodahl, PRL 111, 211802

- Matchbox [S. Platzer and S. Gieseke, arXiv:1109.6256]
  - Catani-Seymour Dipole subtraction [hep-ph/9605323]
  - Subtractive and POWHEG style matching to parton shower
  - ColorFull [M. Sjodahl, arXiv:1211.2099, http://colorfull.hepforge.org]
- Tensorial Reduction [F. Capanario, arXiv:1105.0920]
- Scalar Loop Integrals: OneLOop [A. van Hameren arXiv:1007.4716]

Stress Testing the VBF Approximation with H+3 Jets

In collaboration with Simon Platzer, Peter Schichtel, Michael Rauch, Malin Sjodahl, and Francisco Campanario.

https://arxiv.org/abs/1802.09955
https://arxiv.org/abs/1308.2932
https://arxiv.org/abs/0710.5621
https://arxiv.org/abs/1610.07922

12

Simulation Tools and Matrix Elements

- Herwig 7 Event Generator (https://herwig.hepforge.org)
- HJETS++ (https://hjets.hepforge.org)
- VBFNLO (https://www.itp.kit.edu/vbfnlo)

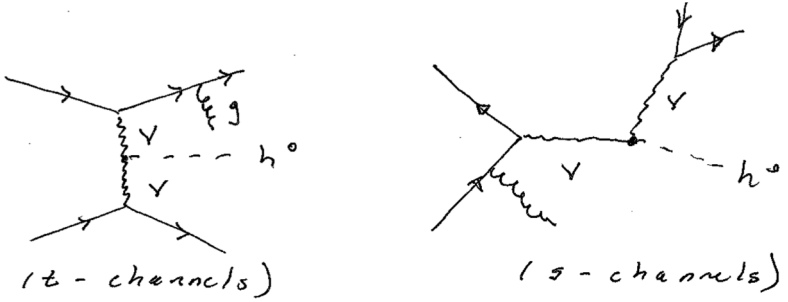
Inclusive Jet Selection Cuts

- (Inclusive cuts) Collider Energy and Cuts used: At least three anti-kt jets with R=0.4

$$\sqrt{S} = 13 \text{ TeV}$$

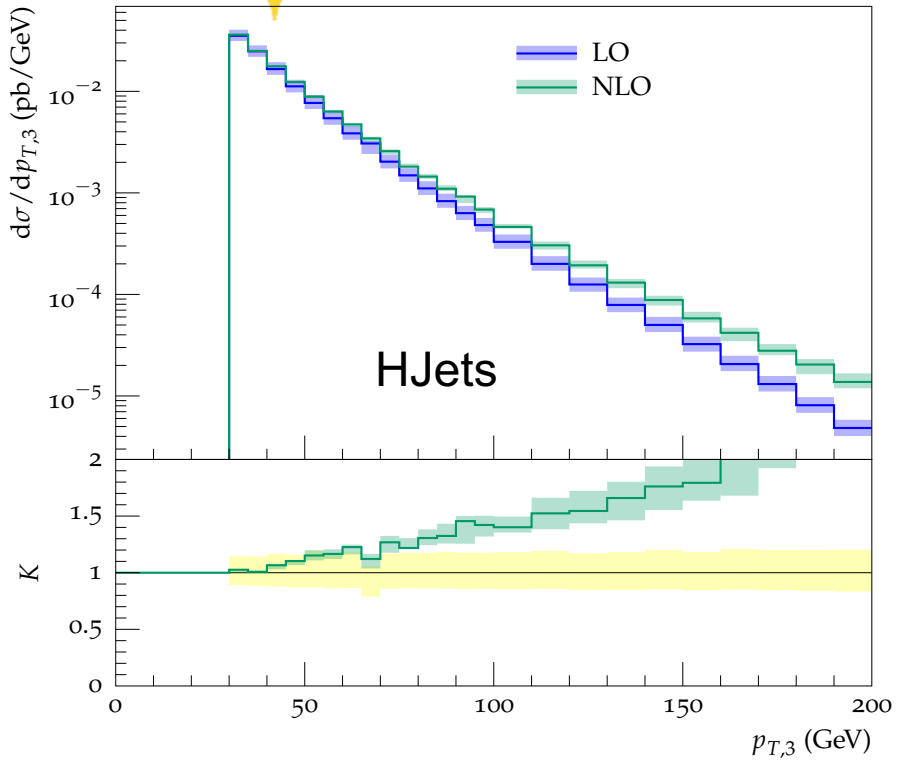
$$p_{Tj} > 30 \text{ GeV} \qquad |y_j| < 4.4$$

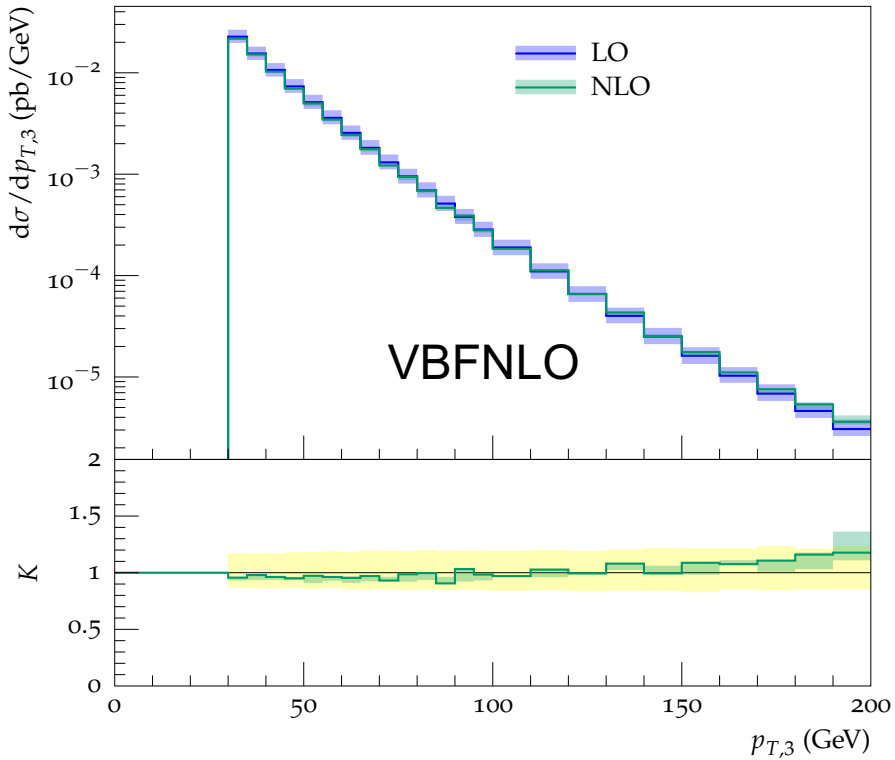
- PDF set: MMHT2014
- Scales: HT(jets)



14

H+ 3 Jets: Inclusive Cuts





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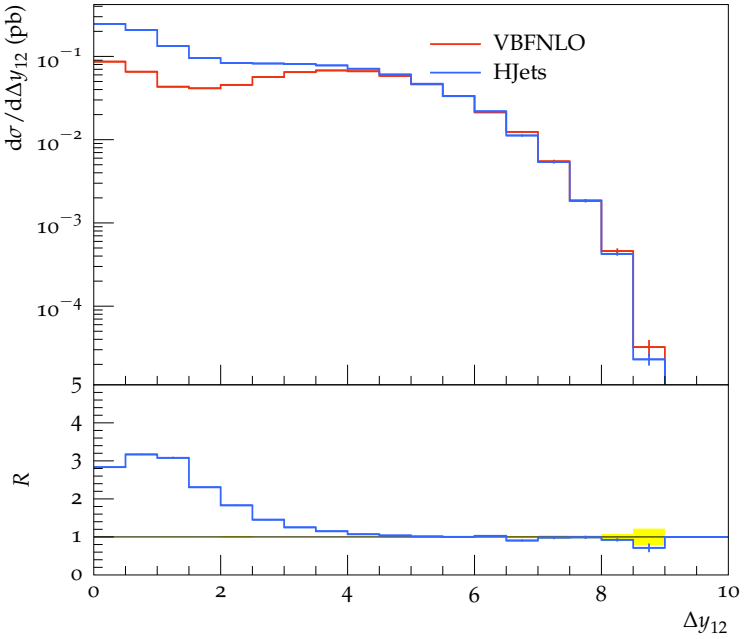
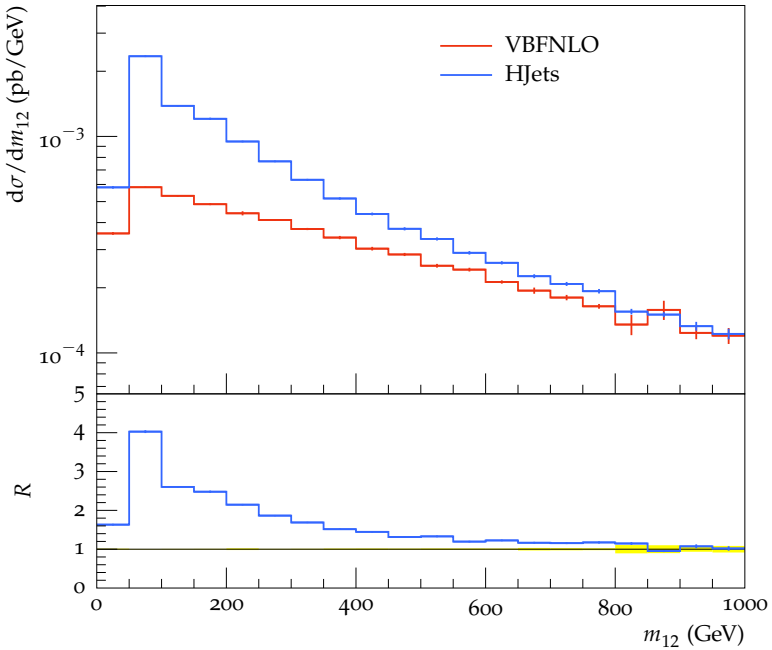
NLO H+3 Jets: VBF Cuts





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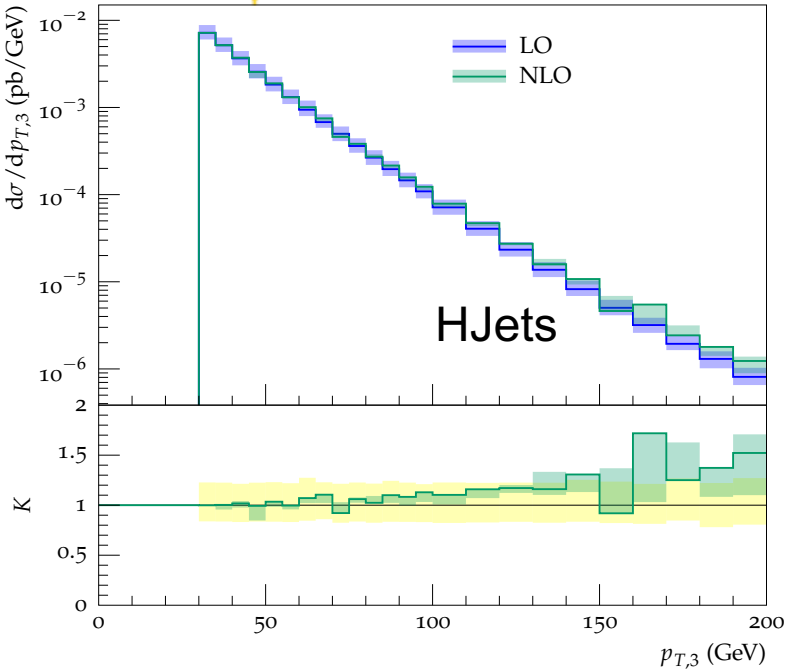
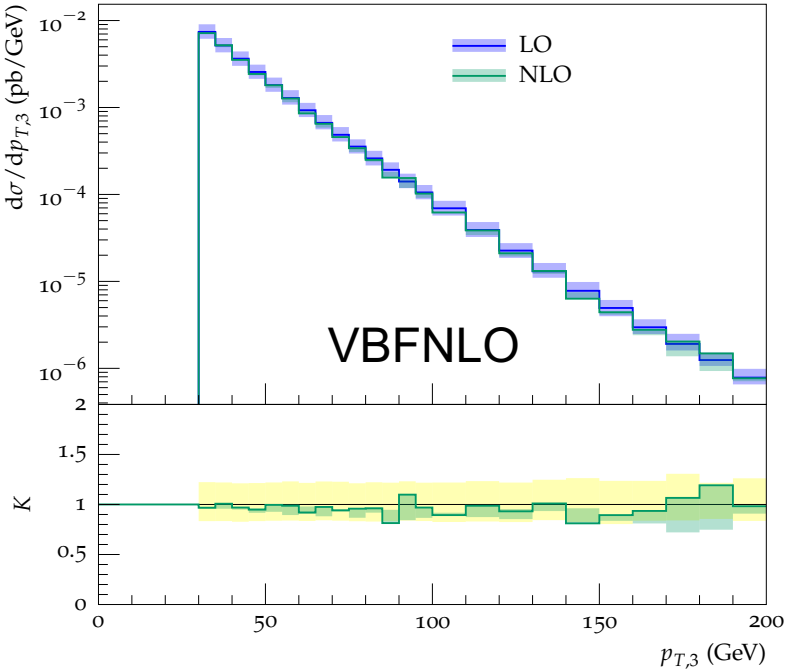
H+ 3 Jets: VBF cuts





(VBF Cuts) $m_{12} > 600$ GeV $\Delta y_{12} = |y_1 - y_2| > 3$

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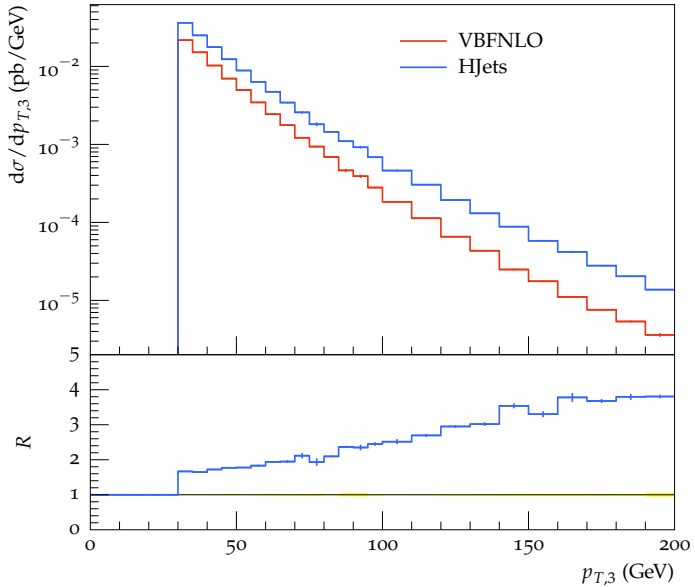
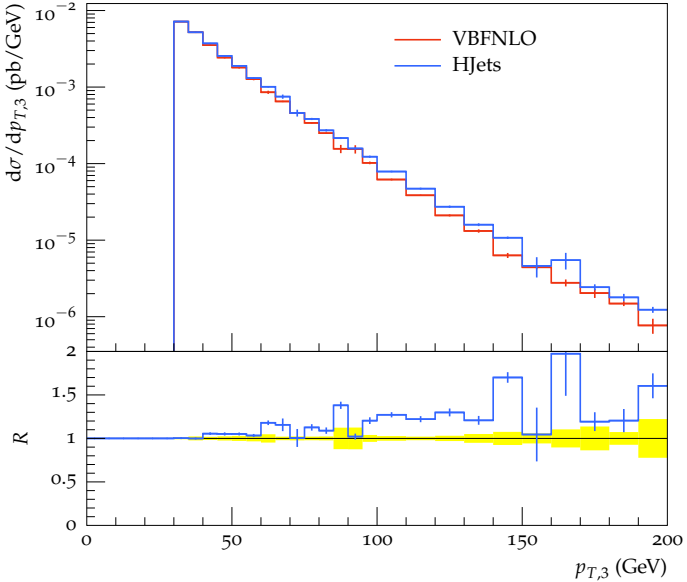
NLO H+3 Jets

Inclusive Cuts



VBF Cuts



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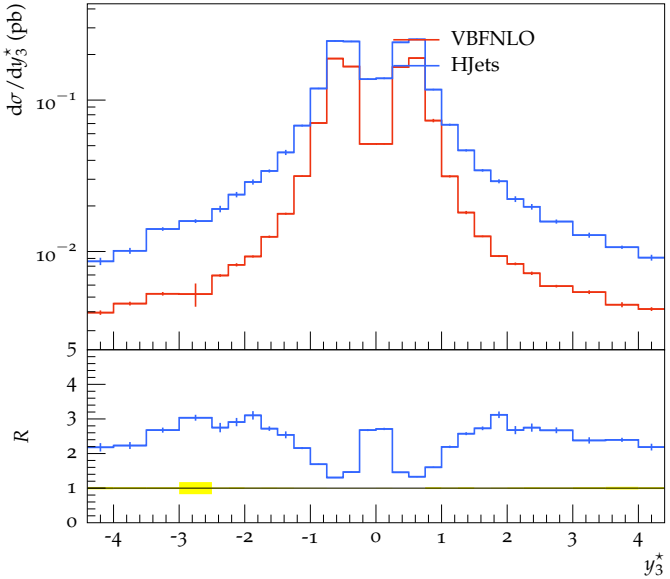
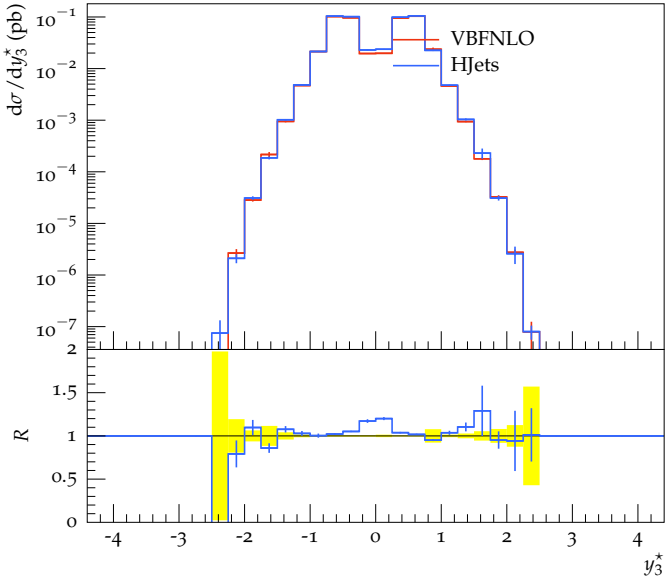
NLO H+3 Jets

Inclusive Cuts



VBF Cuts



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VBF Cuts and Resonant Cuts

VBF Cuts:

$$m_{12} = \sqrt{(p_1 + p_2)^2},$$

$$m_{12} > m_{12}^{\text{cut}} \in \{0, 100, 200, 300, 400, 500, 600\} \text{ GeV}$$

$$\Delta y_{12} > \Delta^{\text{cut}} y_{12} \in \{0, 1, 2, 3\} \qquad \Delta y_{12} = |y_1 - y_2|$$

Res. Veto:

$$m_V - \delta m_V < m_{jets} < m_V + \delta m_V$$

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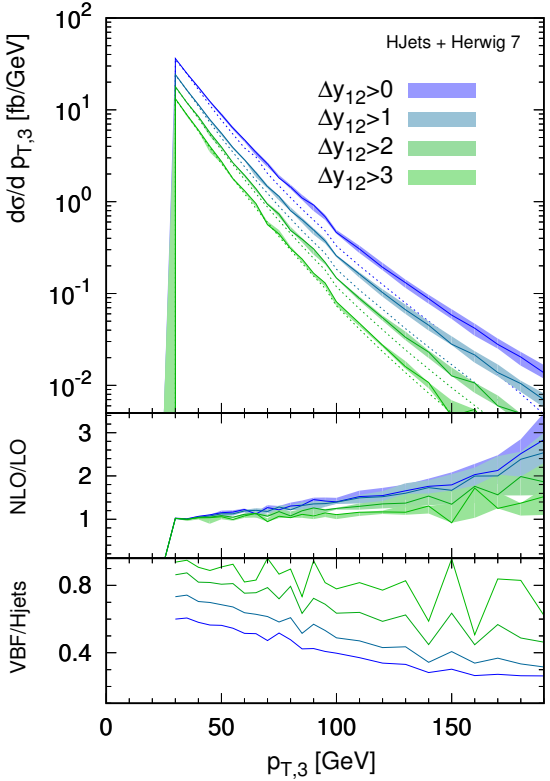
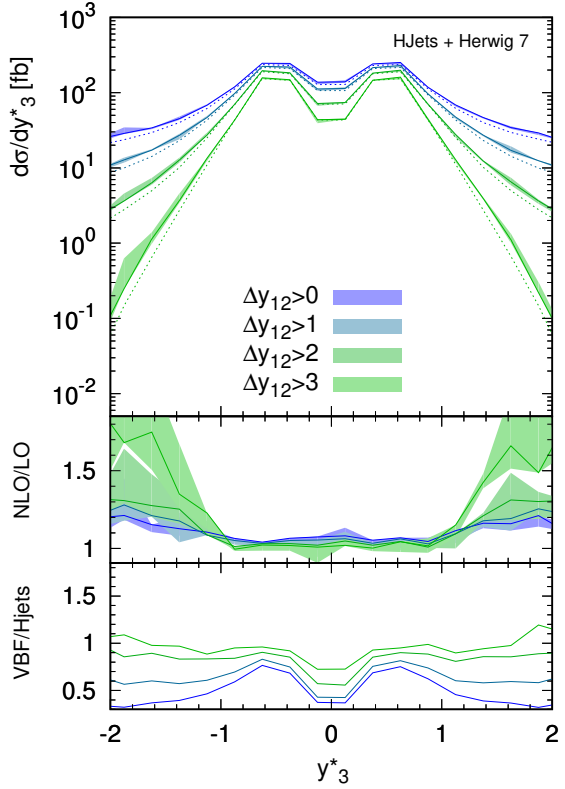
Transverse Momentum of the Third Jet

No Res. Veto





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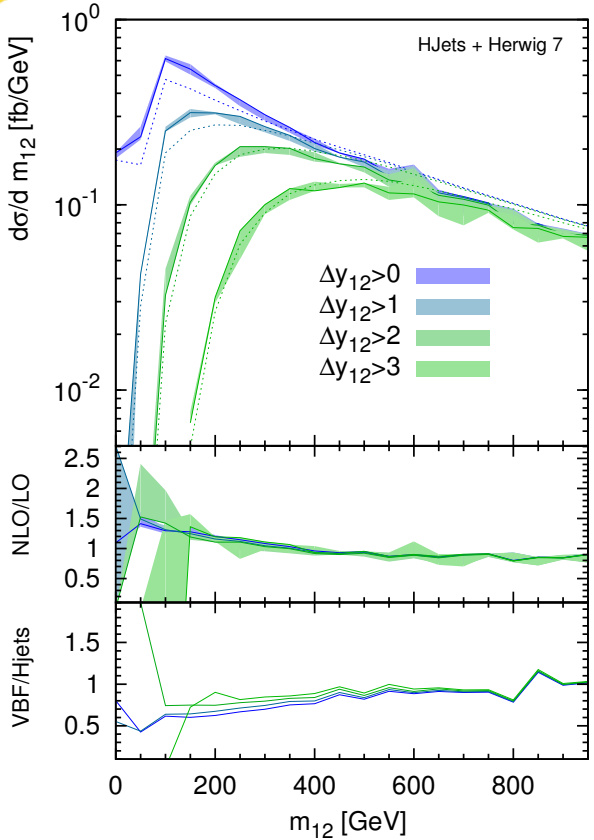
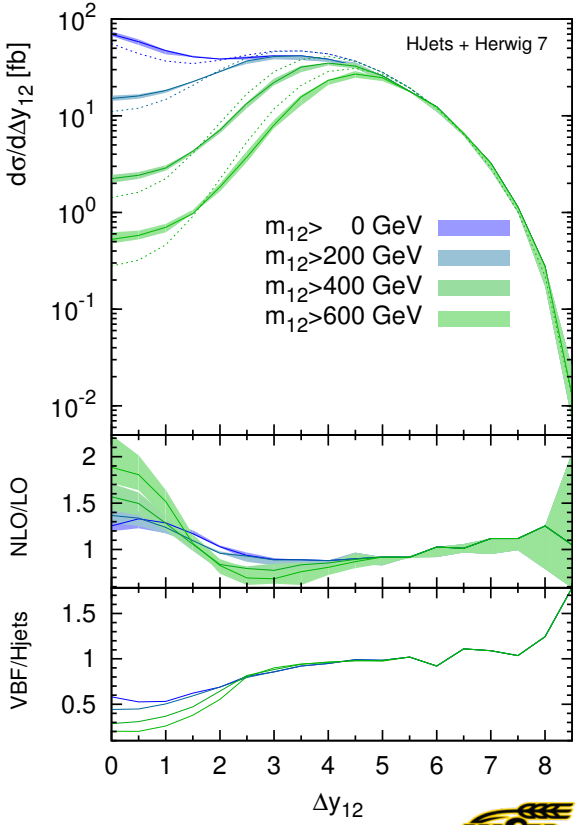
Di-jet invariant mass and rapidity gap

Res. Veto





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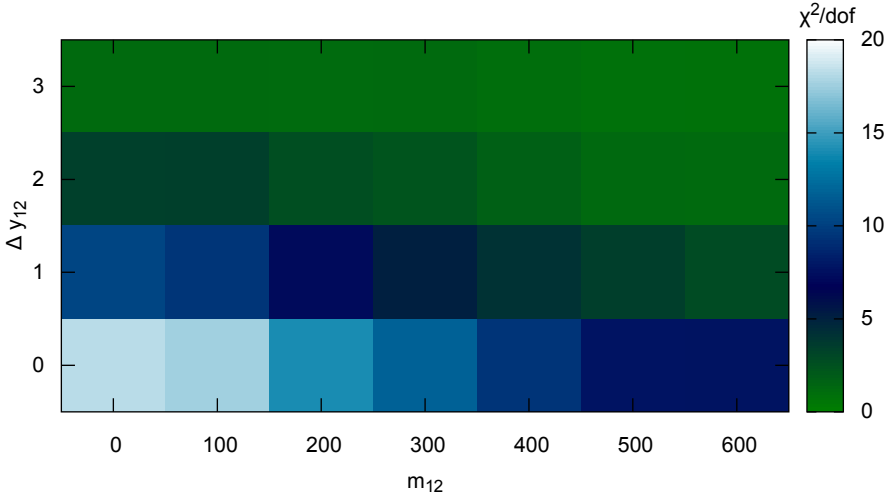
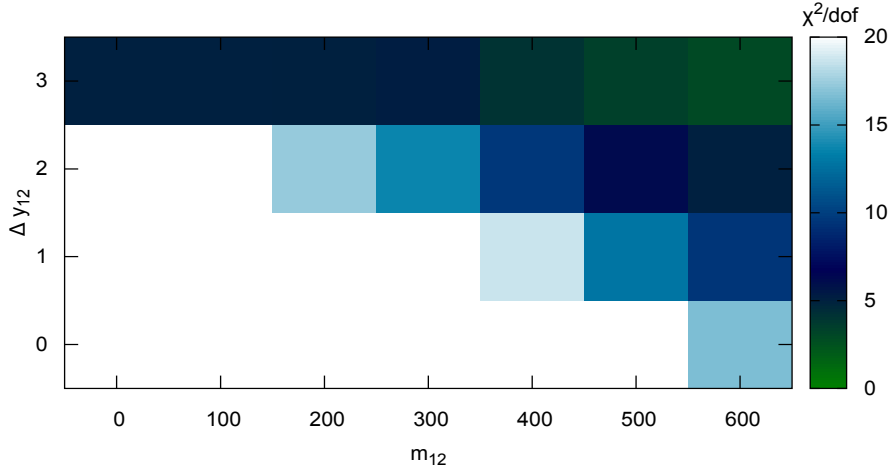
The Chi-Squared Test

$$\chi^2 = \frac{1}{N_{\text{bins}}} \sum_{\text{bins } i} \frac{(\sigma_{i,\text{HJets}} - \sigma_{i,\text{VBF}})^2}{\max\left(\delta_\mu \sigma_i^2, \delta_{\text{stat}} \sigma_i^2\right)} \,,$$

$p_{T,3}, y_3^\star, y_h^\star, \Delta y_{h,12}, \Delta\phi_{h,12}$, and m_{123}



Res. Veto



No Res. Veto

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Conclusions

- For the first time H+3 jets at NLO in the VBF approximation has been stress-tested for a variety of VBF cuts.
- We have implemented a resonance veto on HVj events in order to perform a fair comparison between VBFNLO and HJETS.
- We find that the rapidity gap cut alone gives a good approximation where a ditag mass cut alone does not.

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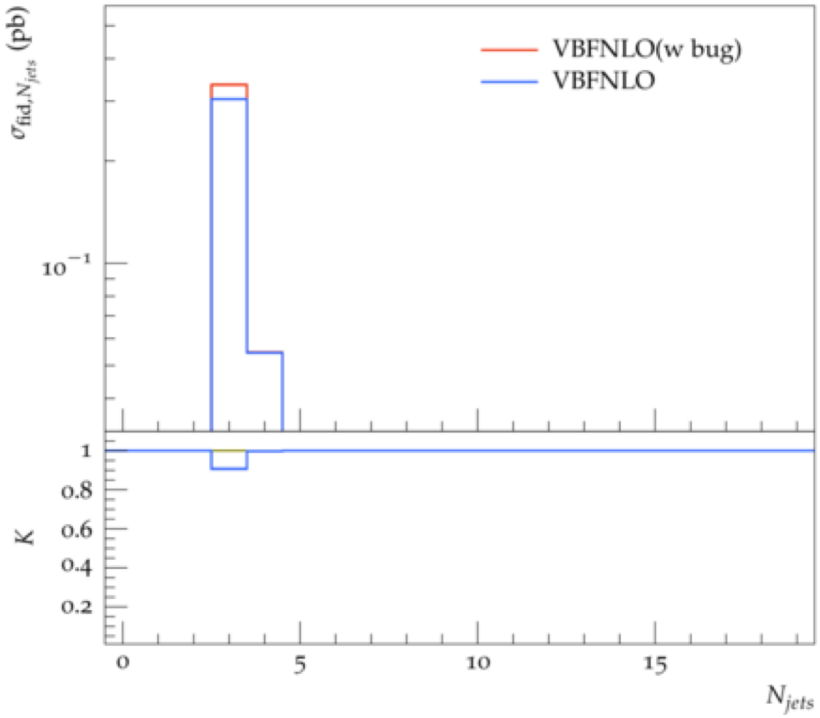
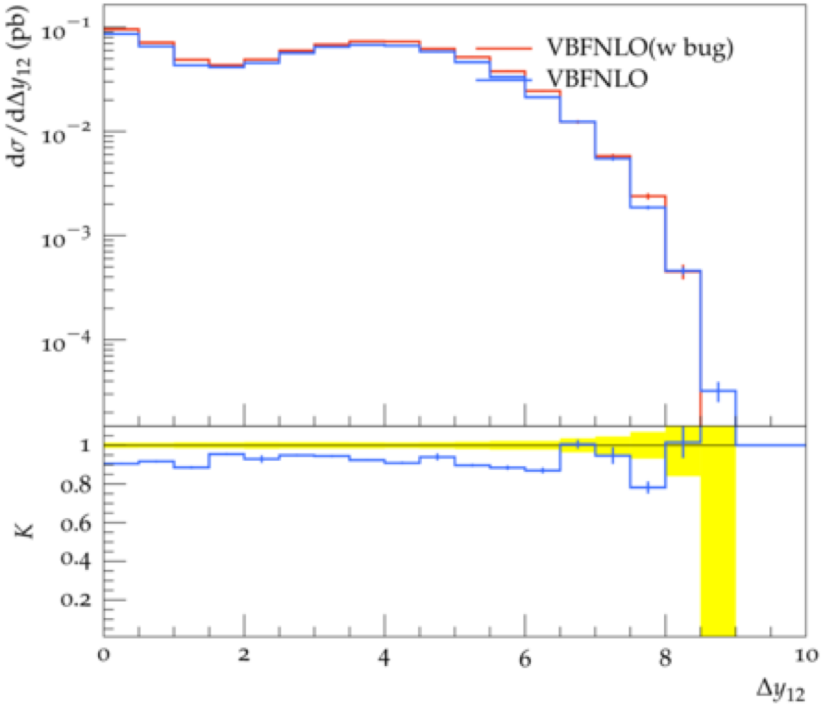
Auxiliary Slides

Thanks to Juan for the notification and to Michael Rauch for helping me isolate the bug!
https://arxiv.org/abs/1802.02445





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