# Precise predictions for double-Higgs production via vector-boson fusion

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In Collaboration with:
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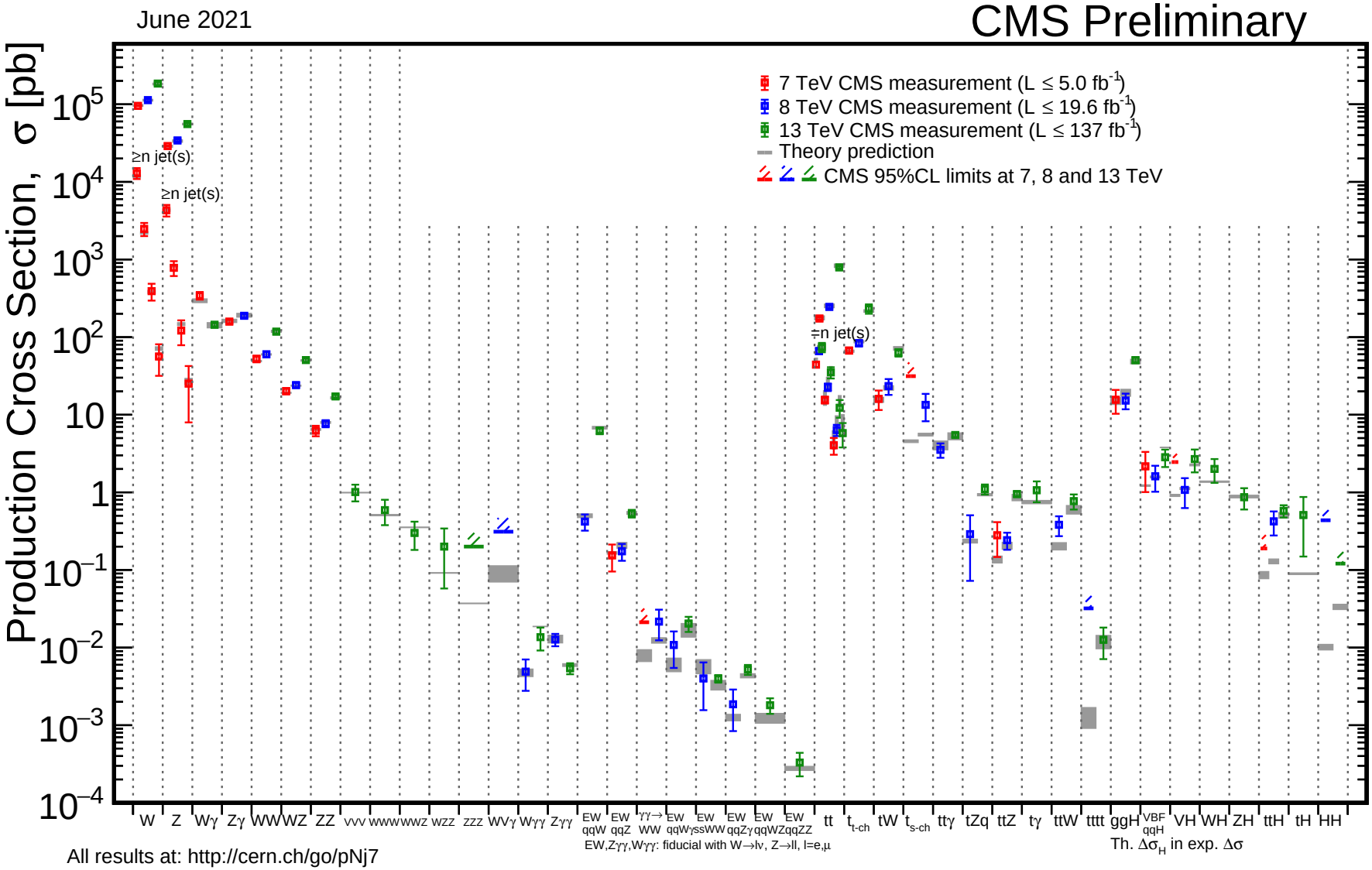
LHC: Great tool to probe fundamental interactions at high energies
$\rightarrow$ Great to measure Higgs bosons

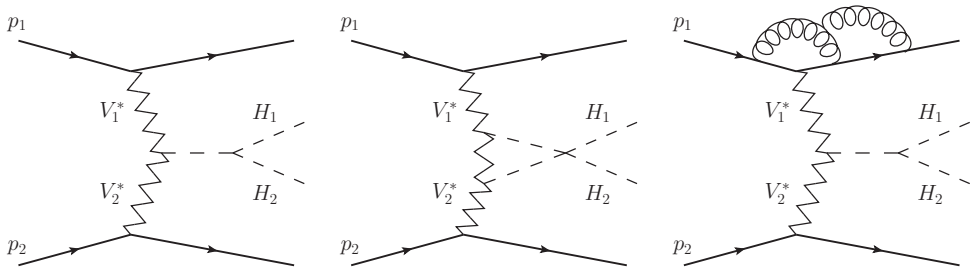

- Main discovery of the LHC!
  $\rightarrow$ no more **hunting**
  $\rightarrow$ focus on the measurements of its properties
  $\rightarrow$ **High-luminosity LHC**




→ **Large variety of Higgs processes ...**
**.. with very different phenomenology!**

# VBF HH at NNLO QCD + NLO EW

→ Higgs self-coupling + extra handle with tagging jets



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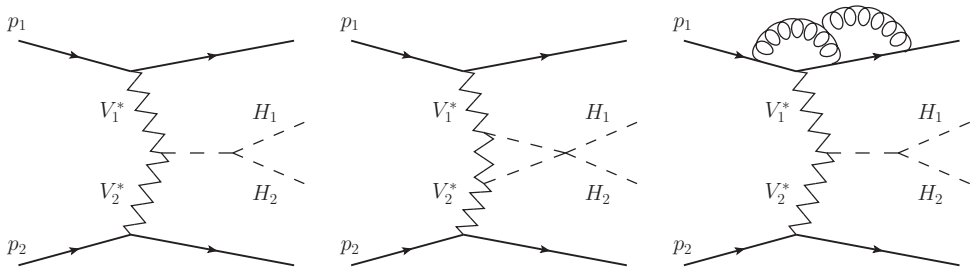


In **[Dreyer, Karlberg, Lang, MP; 2005.13341]**:

- Full NLO QCD + EW (**new**) from MoCaNLO+Recola [Actis et al.; 1605.01090]
- NNLO QCD corrections [Dreyer, Karlberg; 1811.07918] from proVBFHH
- Non-factorisable corrections at NNLO [Dreyer, Karlberg, Tancredi; 2005.11334]

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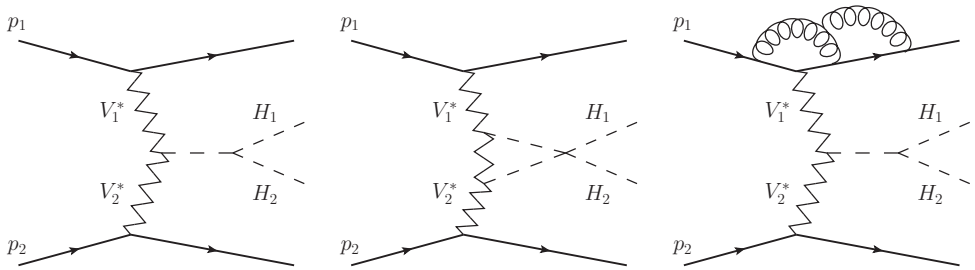


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Already available:

- NLO QCD in VBF approximation [Figy; 0806.2200], [Baglio et al.; 1212.5581]
- NLO QCD + PS [Frederix et al.; 1401.7340]
- N$^3$LO QCD (inclusive) [Dreyer, Karlberg; 1811.07906]

# Double Higgs production via VBF at the LHC

$$pp \to HHjj$$

- LO at $\mathcal{O}\left(\alpha^4\right)$
  In addition to VBF contributions: $pp \to VHH \to HHjj$
  (Higgs-Strahlung contributions)
  $\to pp \to HHjj = \text{VBF} + VHH$

$$K_{\text{full/VBF}} = \frac{d\sigma_{\text{LO}}^{\text{full}}}{d\sigma_{\text{LO}}^{\text{VBF}}}$$

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- NLO EW at $\mathcal{O}\left(\alpha^4\right)$
  all real photon corrections and virtual diagrams included
  photon-induced contributions neglected

$$\sigma_{\text{NNLO QCD}\times\text{NLO EW}} = \sigma_{\text{NNLO QCD}} \left(1 + \frac{\delta_{\text{NLO EW}}^{\text{full}}}{\sigma_{\text{LO}}^{\text{full}}}\right)$$

$\rightarrow$ as in the Higgs cross-section working-group report for VBF

# Set-up

## Input:

- LHC at $\sqrt{s} = 14\,\text{TeV}$
- PDF: NNPDF31_nnlo_as_0118_luxqed [NNPDF; 1712.07053]
- $\mu = \sqrt{\frac{M_H}{2}\sqrt{\left(\frac{M_H}{2}\right)^2 + p_{T,HH}^2}}$

## Event selection:

- $p_{T,j} > 25\,\text{GeV}$ and $|y_j| < 4.5$
- $m_{j_1 j_2} > 600\,\text{GeV}$ and $|y_{j_1} - y_{j_2}| > 4.5$
- No cuts on the Higgs bosons

$\rightarrow$ Exclusive cuts to ensure reliable VBF approximation

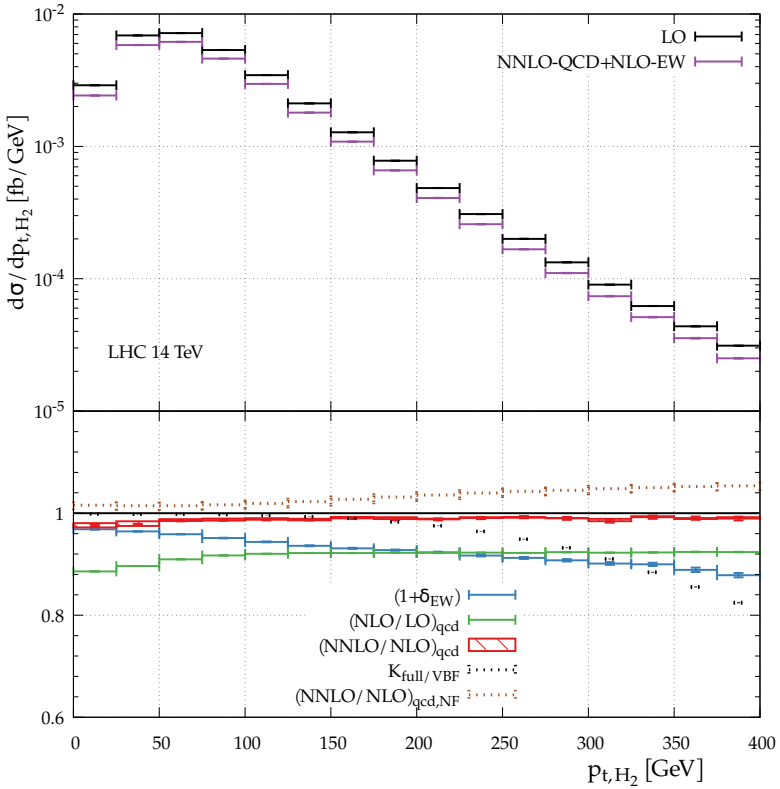
# Cross sections

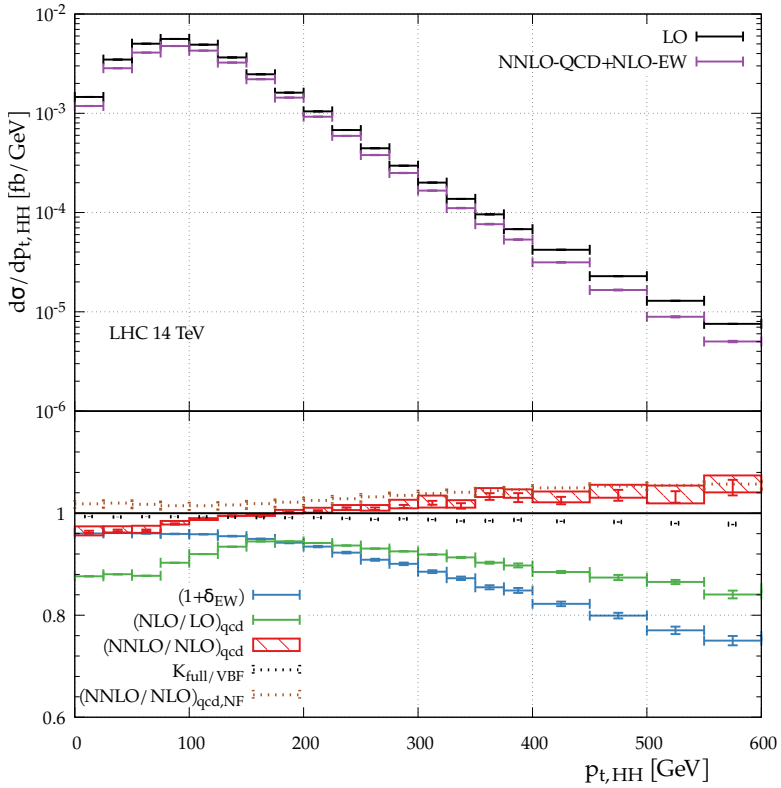
| $\sigma_{\text{LO}}^{\text{full}}$ | $\delta_{\text{NLO QCD}}^{\text{full}}$ | $\delta_{\text{NNLO QCD}}^{\text{VBF}}$ | $\delta_{\text{NLO EW}}^{\text{full}}$ | $\sigma_{\text{NNLO QCD}\times\text{NLO EW}}$ [fb] |
|---|---|---|---|---|
| $0.78444(9)^{+0.0825}_{-0.0694}$ | $-0.07110(13)$ | $-0.0115(5)$ | $-0.0476(2)$ | $0.6684(5)^{+0.002}_{-0.0004}$ |
| $^{+10.5\%}_{-8.8\%}$ | $-9.1\%$ | $-1.5\%$ | $-6.1\%$ | $-14.8\%^{+0.3\%}_{-0.06\%}$ |

- Non-factorisable corrections: 0.01237(2) *i.e.* +1.7%
- NLO EW corrections of the order of NLO QCD and larger than NNLO QCD
  → Typical size of EW corrections
  ( −5% for VBF [Ciccolini, Denner, Dittmaier; 0710.4749])
  → As opposed to intrinsic large EW corrections in VBS

  [Biedermann, Denner, MP; 1611.02951]
- Measurable at the High-luminosity LHC

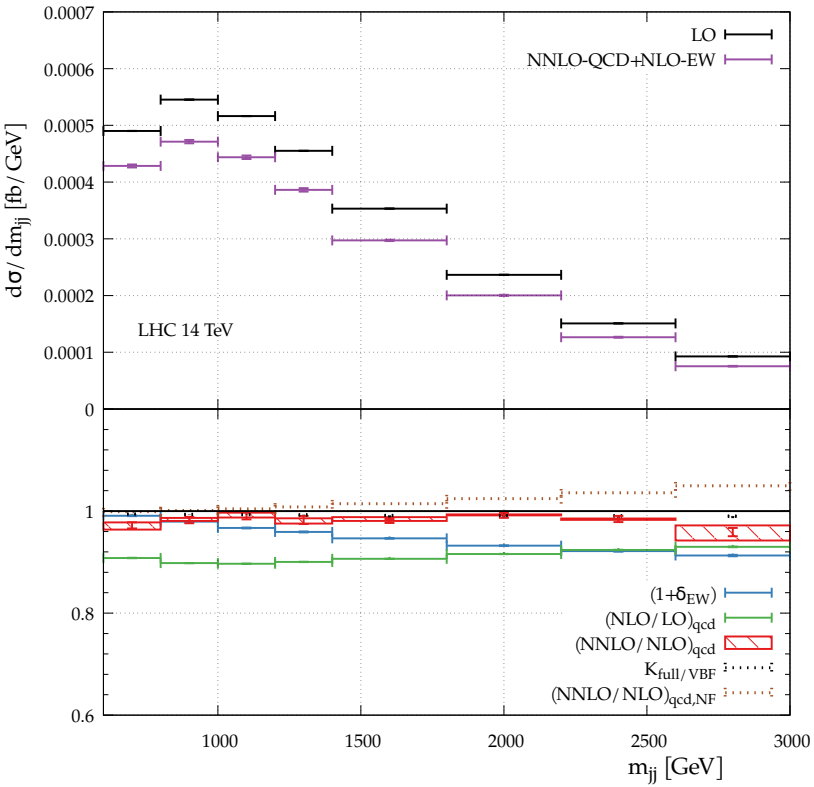
# Differential distributions (1)

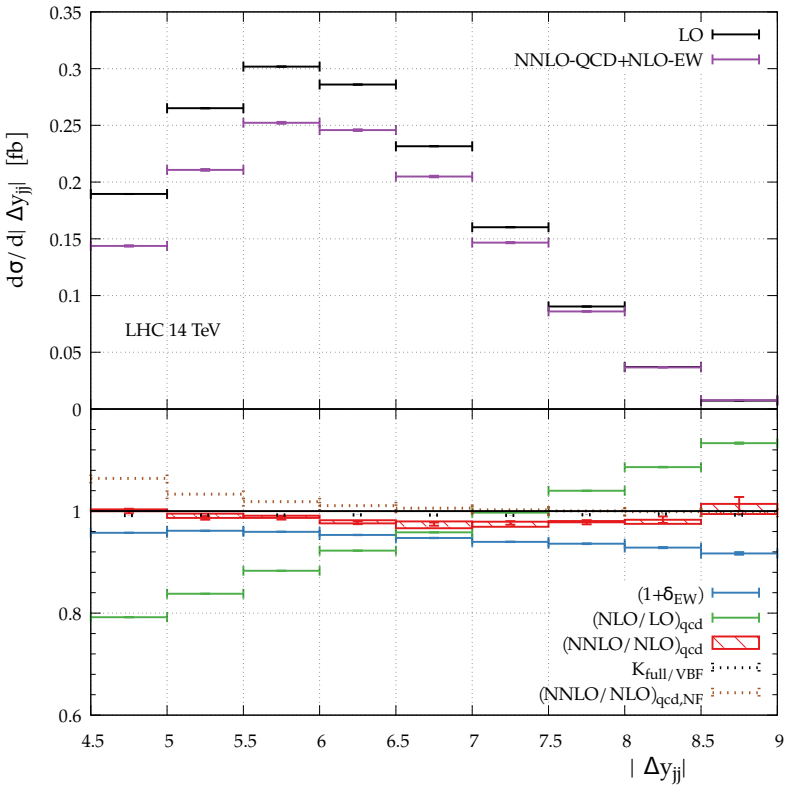



- Effect of VBF approximation up to 20%
- EW Sudakov logarithms in tails of distributions: $-25\%$

# Differential distributions (2)




- Important distributions for VBF: $m_{jj}$ and $|\Delta y_{jj}|$
- Corrections at the level of 10/20%
- More distributions in [Dreyer, Karlberg, Lang, MP; 2005.13341]

# Summary

**NNLO QCD + NLO EW for VBF HH**
**[Dreyer, Karlberg, Lang, MP; 2005.13341]**

- State of the art predictions at fixed order
- Quantifies VBF approximation
- NLO EW corrections of the order of the QCD ones

Thank you