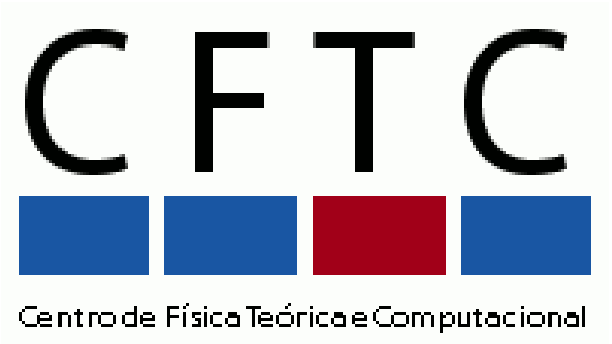


Probing the CP nature of the Higgs couplings in bbh

Harmonia meeting VI – U. Warsaw

Rodrigo Capucha

9 September 2019

Introduction

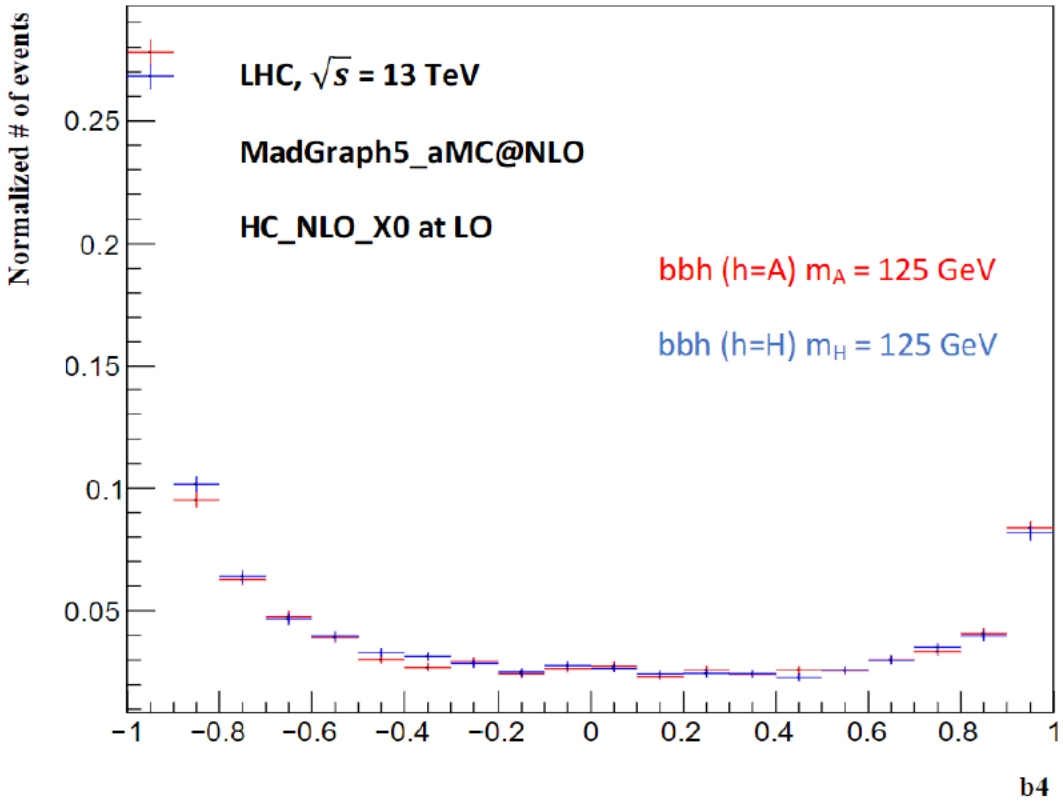
- The potential of tth events to determine the nature of the Higgs couplings to the tops was shown. The objective now is to do the same for the bbh.

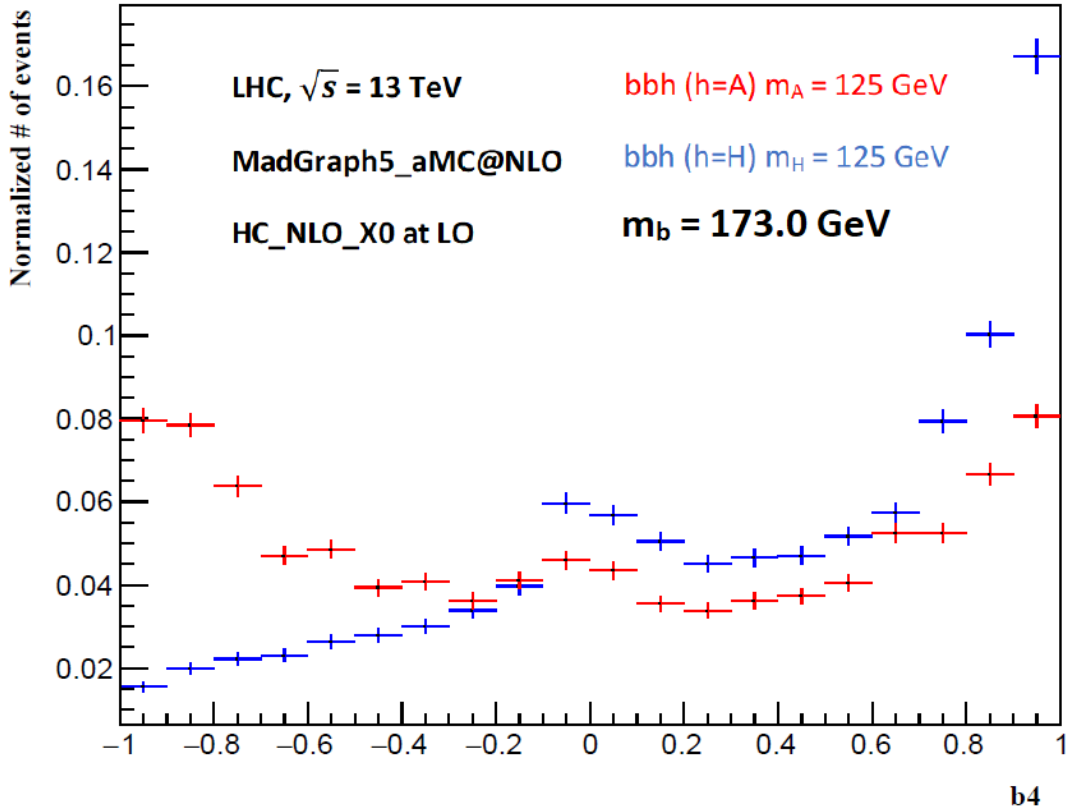
- All events were generated by the **Monte Carlo event generator MadGraph5_aMC@NLO. Two limits** were considered: $\boldsymbol{h}$ **= H** (**CP-even SM Higgs**) and $\boldsymbol{h}$ **= A** (**CP-odd Higgs**), by using the **HC_NLO_X0 model**.

- **Parton level distributions** for the same **CP-sensitive variables** used in tth were considered.

- Everything seems similar. What about the results?

bbh results

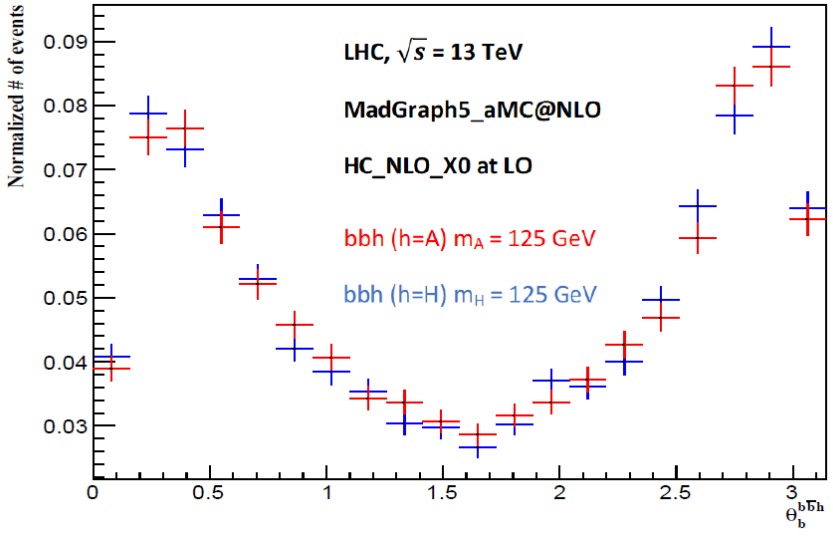


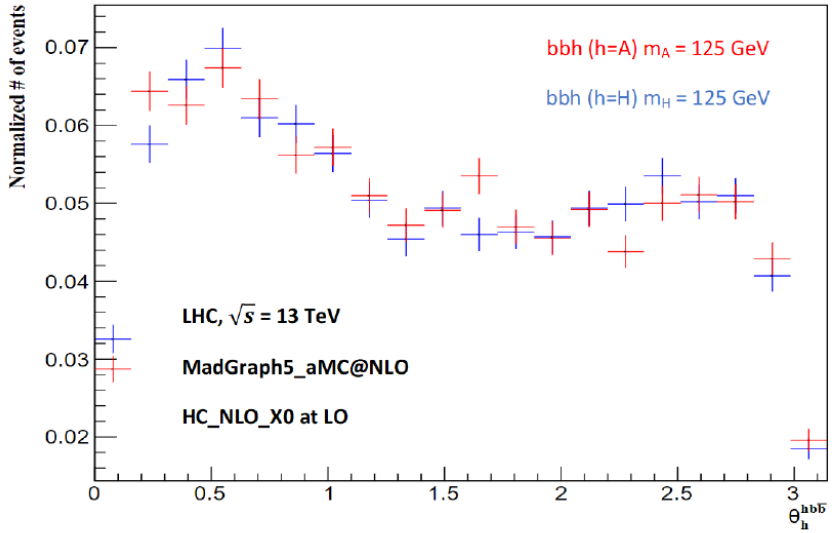


For the bbh the asymmetry vanishes, but when we change the mass of the bottom to the mass of the top we recover the tth asymmetry. The differences between the signals seem to depend on the quark mass.

$$b_4 = \frac{p_b^z p_{\bar{b}}^z}{|\vec{p}_b||\vec{p}_{\bar{b}}|}$$

bbh results


Normalized # of events
LHC, $\sqrt{s}$ = 13 TeV
MadGraph5_aMC@NLO
HC_NLO_X0 at LO
bbh (h=A) m_A = 125 GeV
bbh (h=H) m_H = 125 GeV
$\theta_b^{b\bar{b}h}$


Normalized # of events
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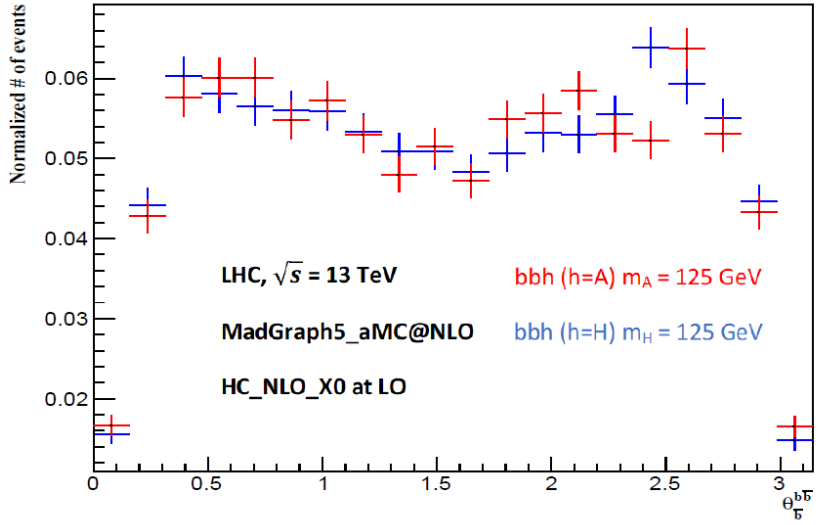
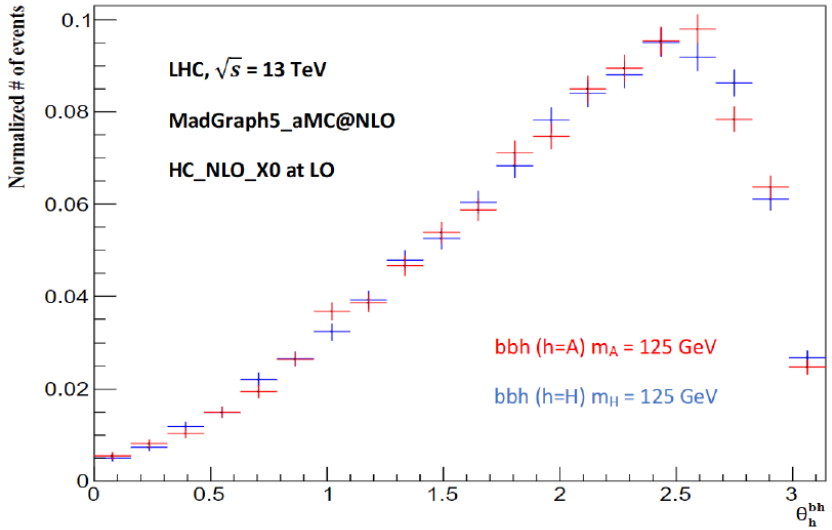
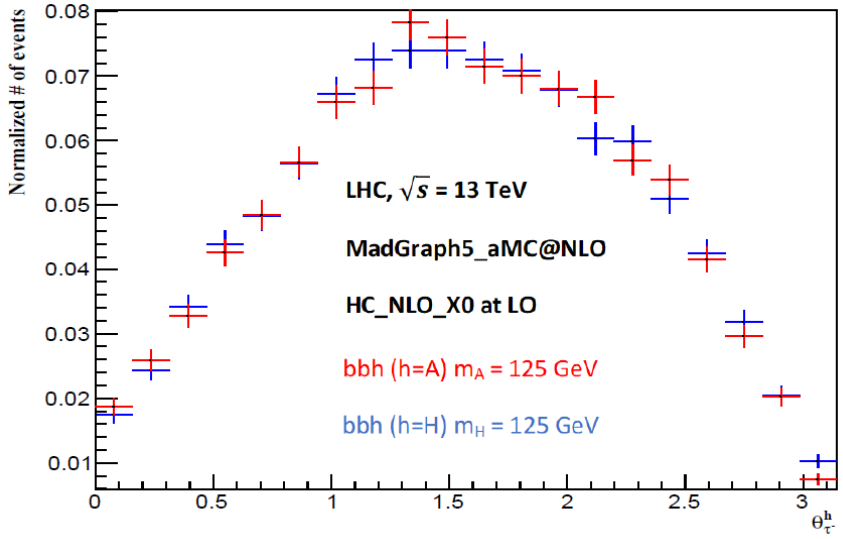
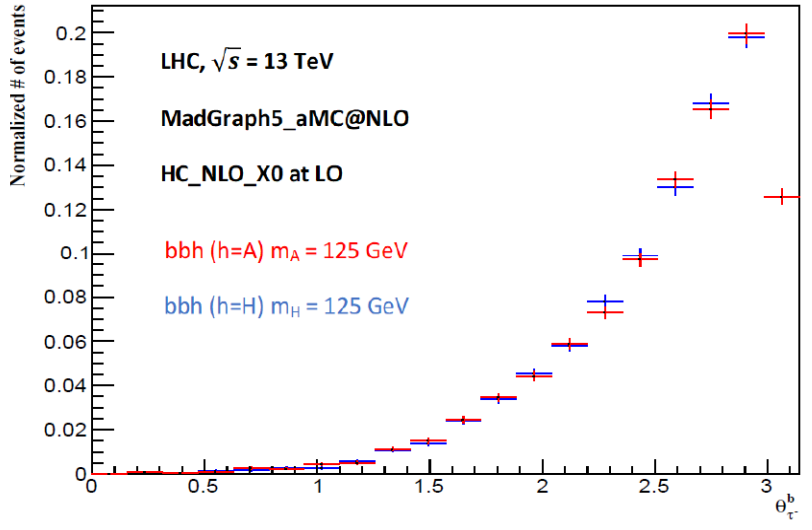
MadGraph5_aMC@NLO
HC_NLO_X0 at LO
$\theta_h^{hb\bar{b}}$

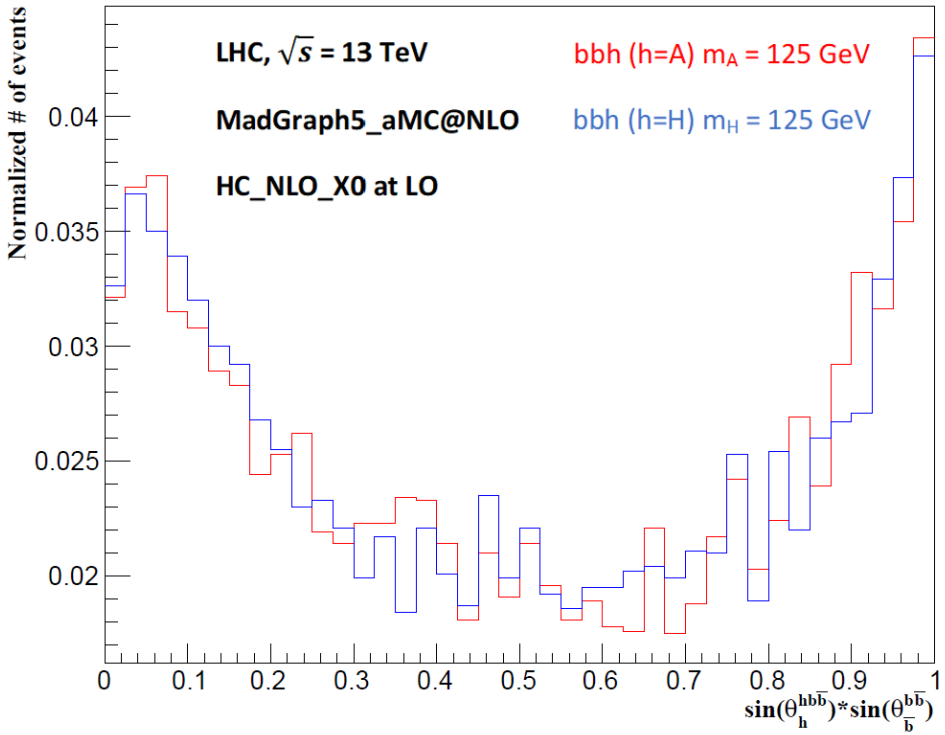

Normalized # of events
LHC, $\sqrt{s}$ = 13 TeV
MadGraph5_aMC@NLO
HC_NLO_X0 at LO
bbh (h=A) m_A = 125 GeV
bbh (h=H) m_H = 125 GeV
$\theta_{\bar{b}}^{b\bar{b}}$

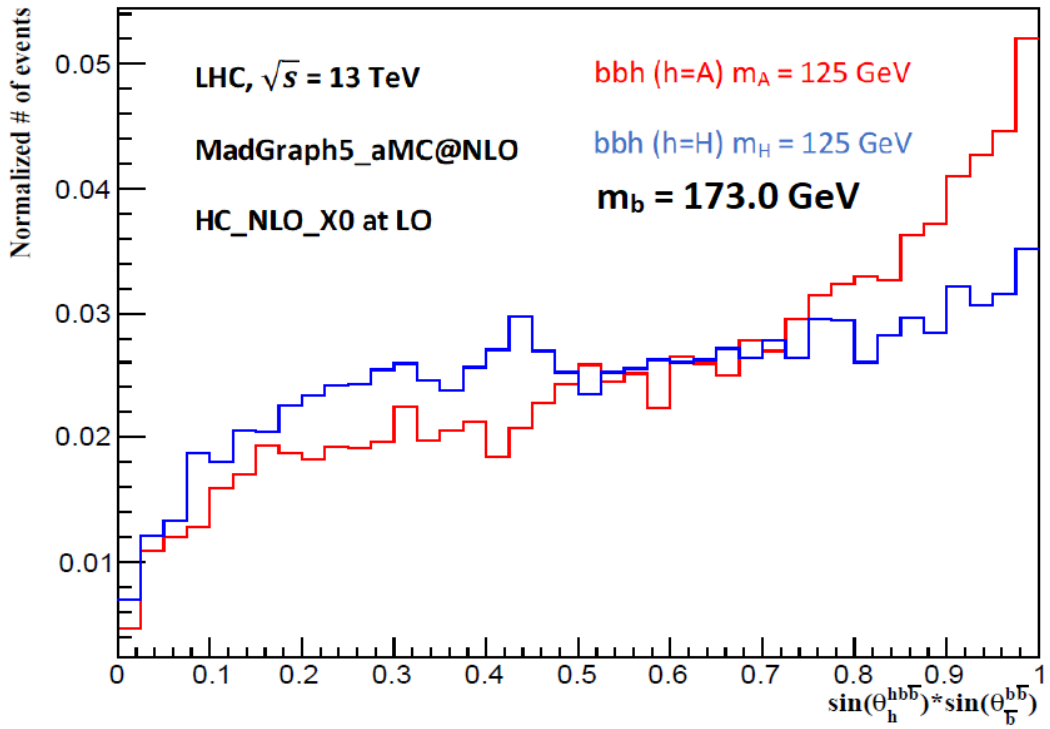

Normalized # of events
LHC, $\sqrt{s}$ = 13 TeV
MadGraph5_aMC@NLO
HC_NLO_X0 at LO
bbh (h=A) m_A = 125 GeV
bbh (h=H) m_H = 125 GeV
θ_h^{bh}


Normalized # of events
LHC, $\sqrt{s}$ = 13 TeV
MadGraph5_aMC@NLO
HC_NLO_X0 at LO
bbh (h=A) m_A = 125 GeV
bbh (h=H) m_H = 125 GeV
$\theta_{\tau^-}^{h}$


Normalized # of events
LHC, $\sqrt{s}$ = 13 TeV
MadGraph5_aMC@NLO
HC_NLO_X0 at LO
bbh (h=A) m_A = 125 GeV
bbh (h=H) m_H = 125 GeV
$\theta_{\tau^-}^{b}$

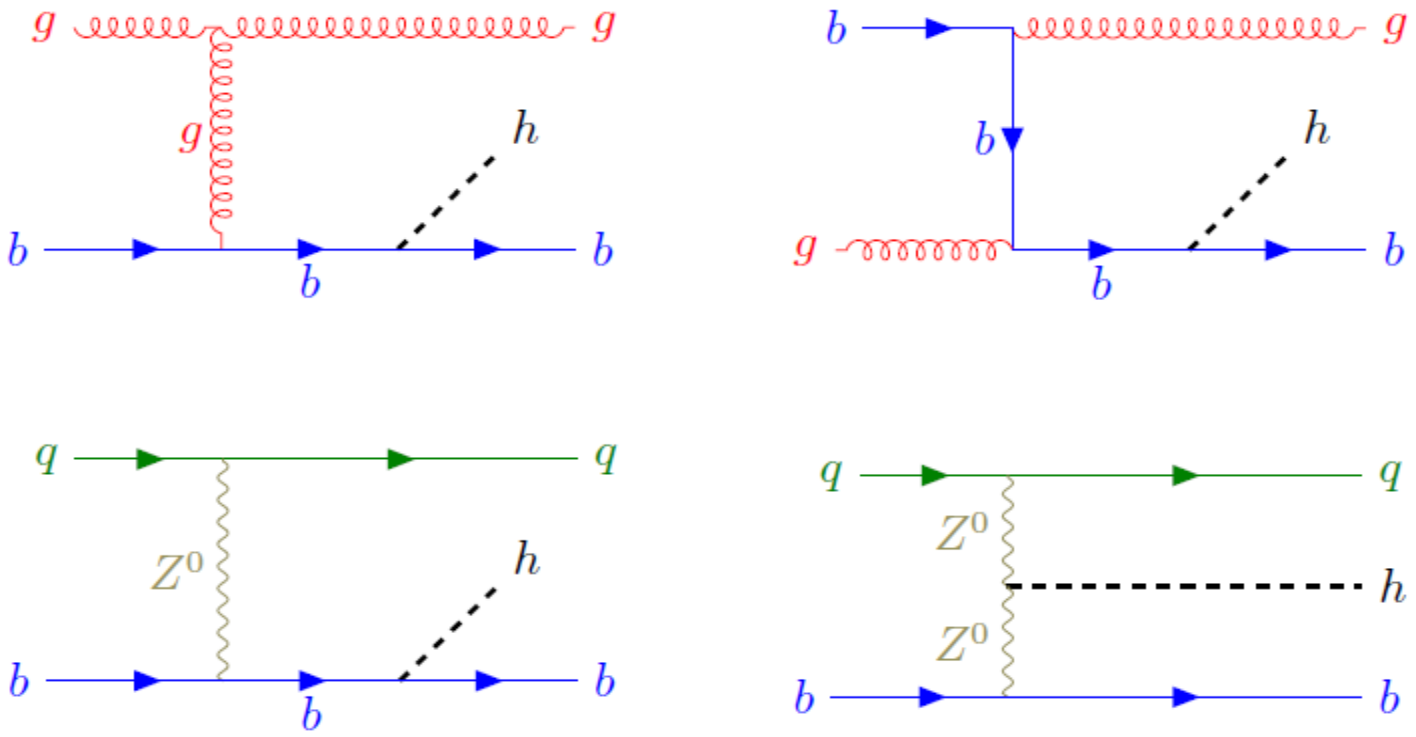
bbh results


LHC, $\sqrt{s}$ = 13 TeV
MadGraph5_aMC@NLO
HC_NLO_X0 at LO
bbh (h=A) m_A = 125 GeV
bbh (h=H) m_H = 125 GeV
Normalized # of events
$\sin(\theta_h^{b\bar{b}})*\sin(\theta_{\bar{b}}^{b\bar{b}})$

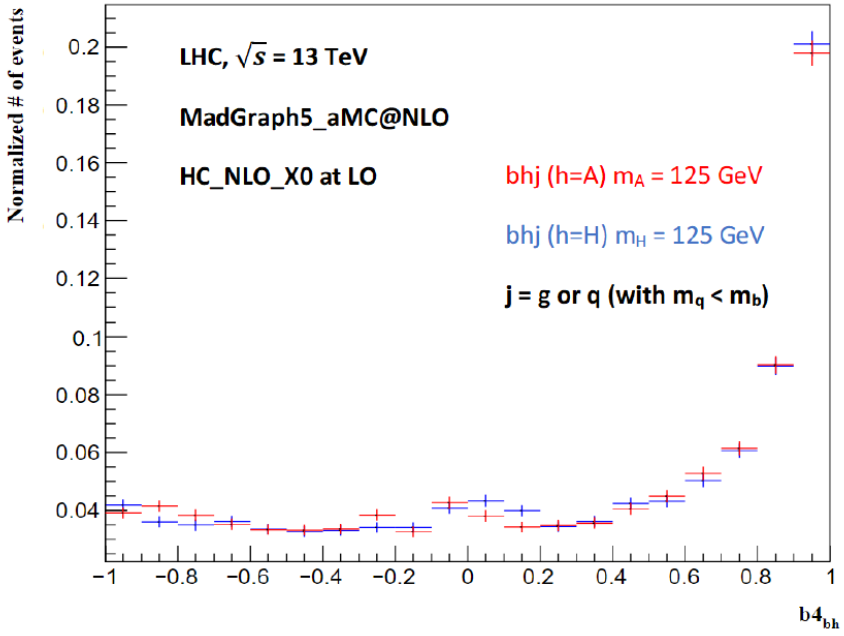

LHC, $\sqrt{s}$ = 13 TeV
MadGraph5_aMC@NLO
HC_NLO_X0 at LO
bbh (h=A) m_A = 125 GeV
bbh (h=H) m_H = 125 GeV
m_b = 173.0 GeV
Normalized # of events
$\sin(\theta_h^{b\bar{b}})*\sin(\theta_{\bar{b}}^{b\bar{b}})$

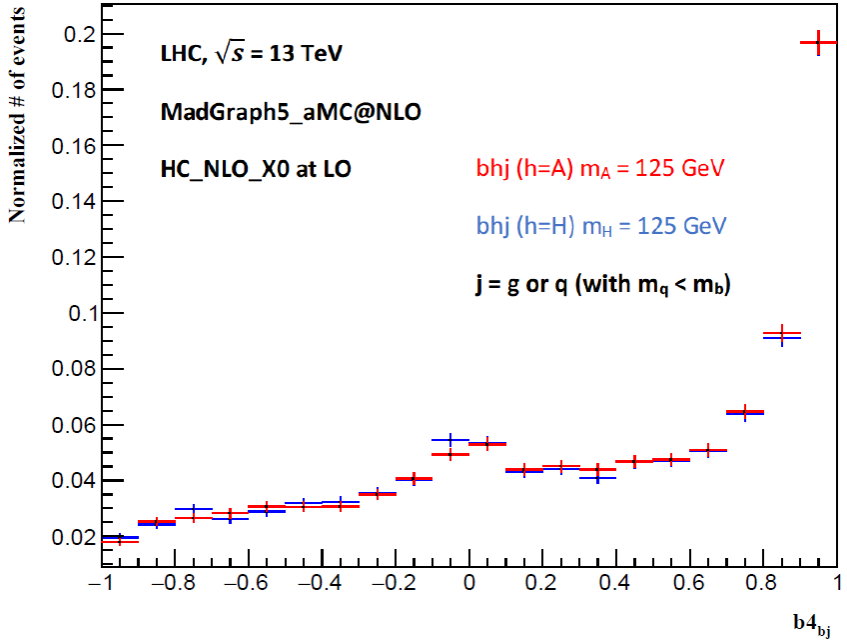
Single bottom and Higgs associated production

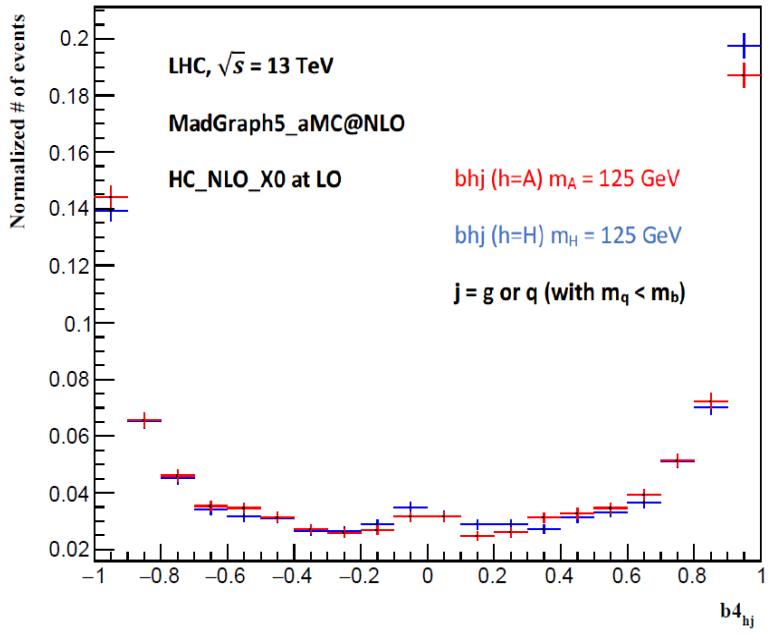
- Besides the bbh, the single b and Higgs was also looked into, since the bbh showed similar behaviours between CP-even and –odd signals.



Single bottom and Higgs associated production







Changing the mass of the b-quark in this case gives very similar distributions.

$$b_{4_{ik}} = \frac{p_i^z p_k^z}{|\vec{p}_i||\vec{p}_k|}$$

bbh vs tth

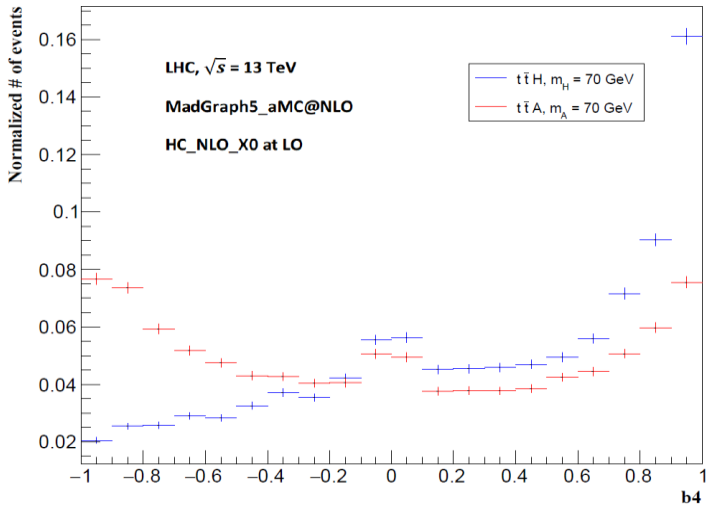
$$\mathcal{L} = \bar{q}(a + ib\gamma_5)qh$$

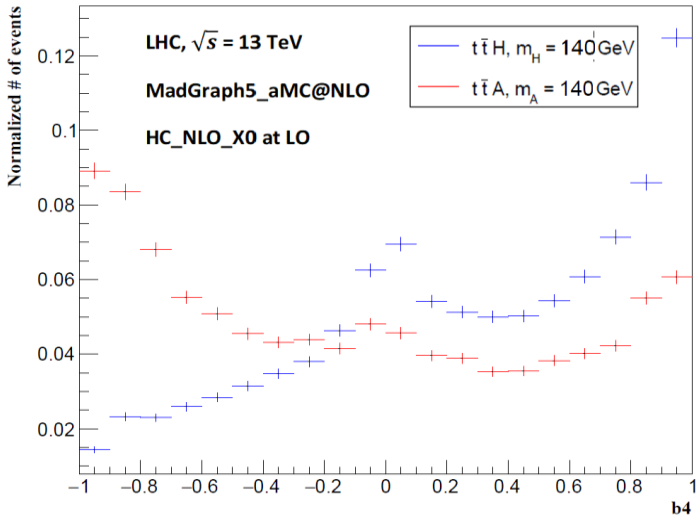
- The cross section of a $q\bar{q}h$ process is proportional to both $(a^2 + b^2)$ and $(a^2 - b^2)m_q^2$, so the **sensitivity to the coupling components depends on m_q^2.**

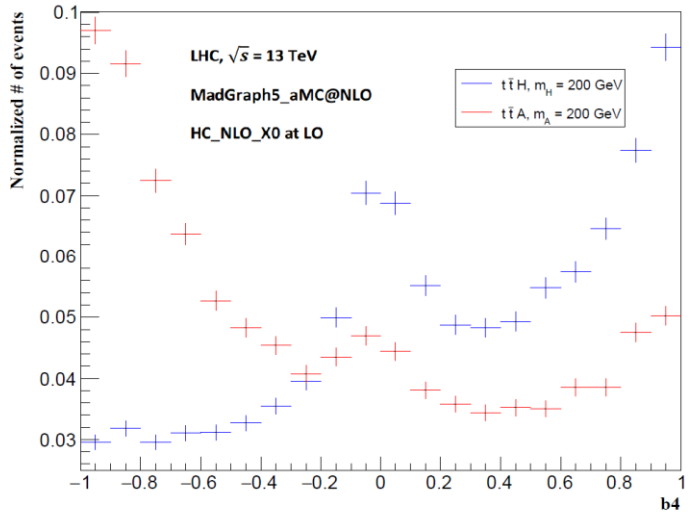
- **For the tops significant differences are found** between the pure CP-even and -odd hypotheses, allowing to determine the Higgs eventual pseudoscalar components at the LHC for the studied observables. **For the b-quarks the differences are too small to be seen** because $m_t^2 >> m_b^2$.

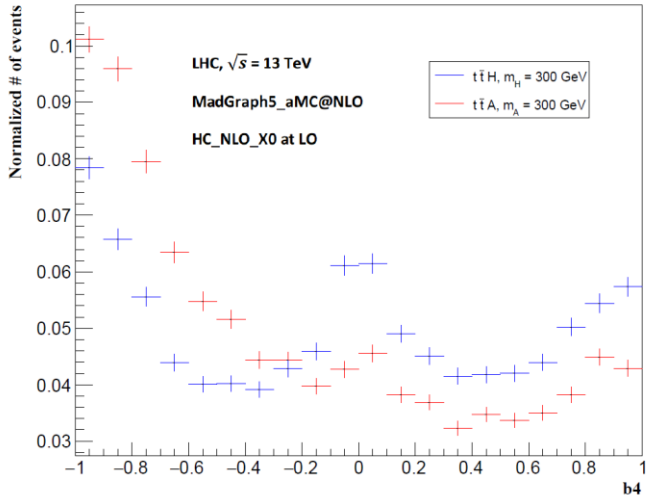
Back to the tth!

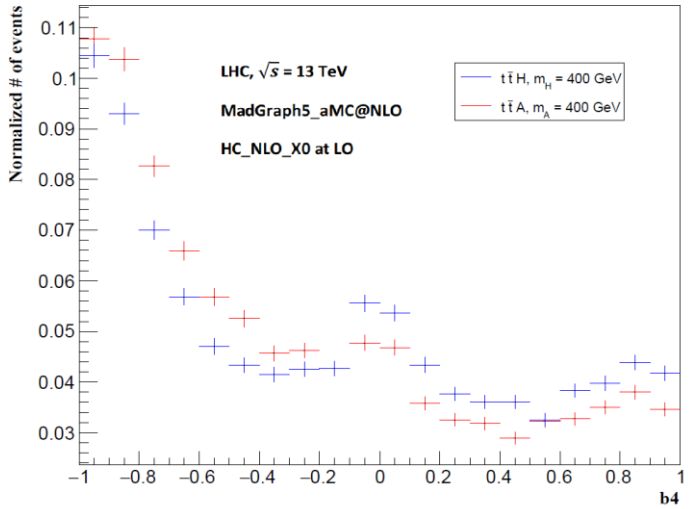
We are now investigating the scenario of $t\bar{t}h$ with scalar masses either below or above 125 GeV.

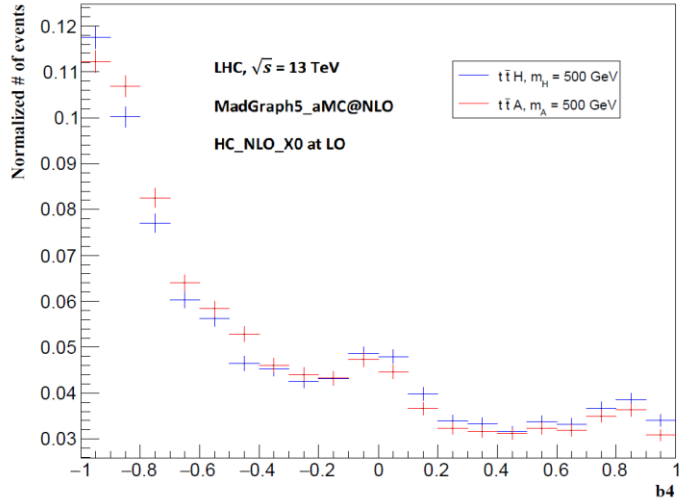




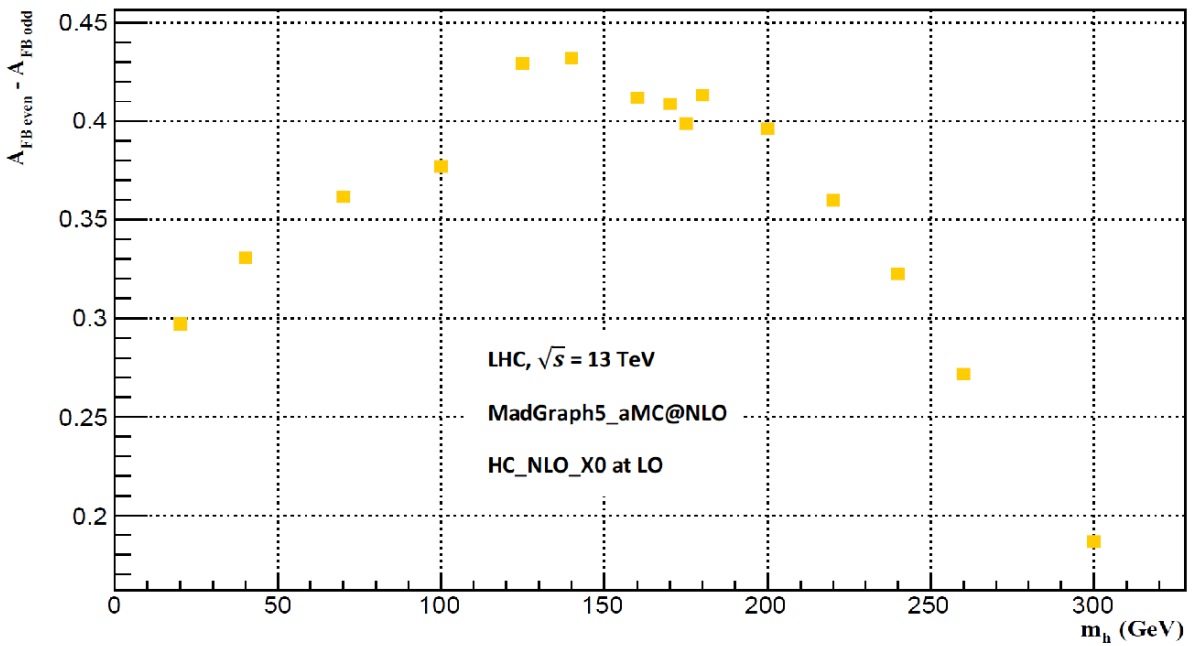


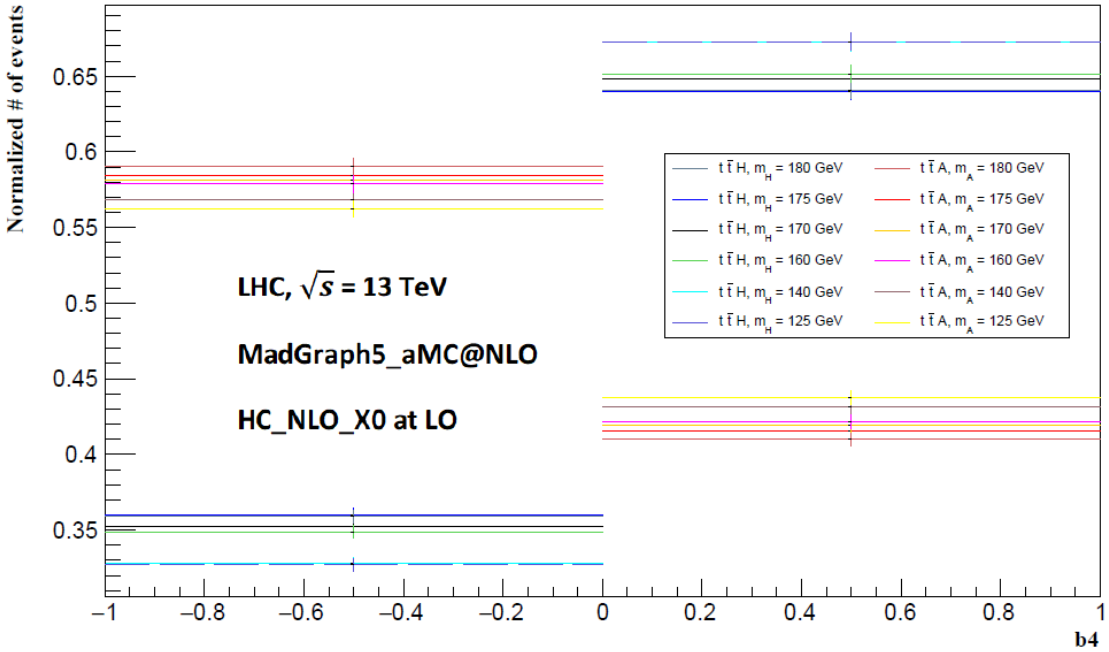






Back to the tth!





The asymmetry also changes for the mass of the scalar!

$$A_{FB} = \frac{\sigma_Y(x > x') - \sigma_Y(x < x')}{\sigma_Y(x > x') + \sigma_Y(x < x')}$$

The Work Group

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- Yang Qin – University of Manchester

- António Onofre – University of Minho