Higgs Strahlung in the 2HDM and σ_{WH}/σ_{ZH} as probe of New Physics

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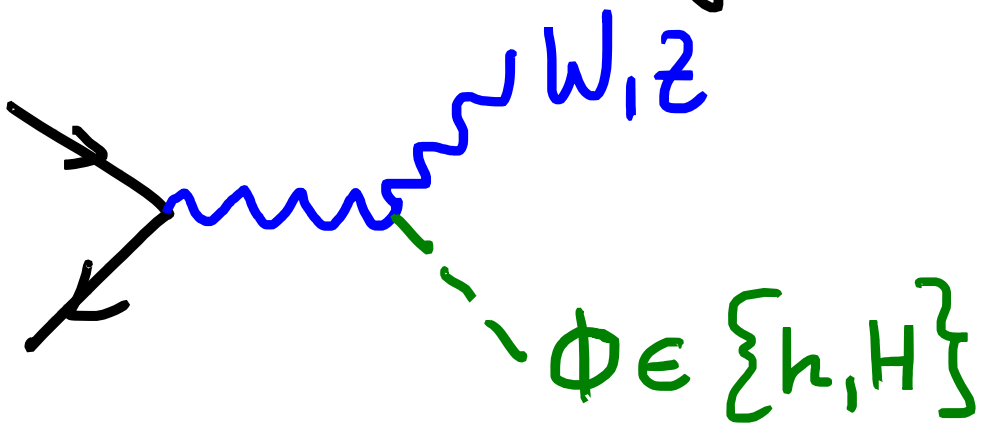
see: RVH, S. Liebler, T. Zirke
arXiv: 1307.8122

Higgs Strahlung in 2HDM

LO:



$$\sigma^{V\Phi}_{2HDM} = \left(g^{\Phi}_{VV}\right)^2 \sigma^{VH}_{SM}$$

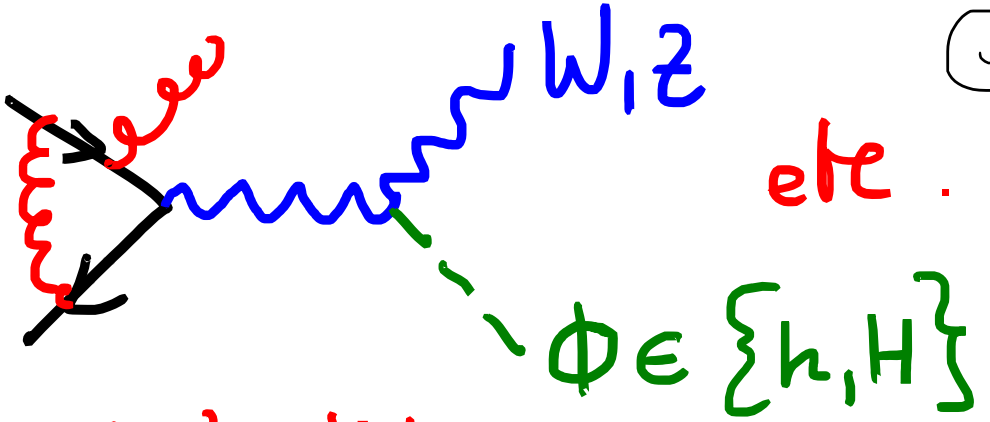
eg. $g^h_{VV} = g^h_{ZZ} = g^h_{WW} = \sin(\beta - \alpha)$

$\rightarrow$ true through NLO QCD !

NNLO

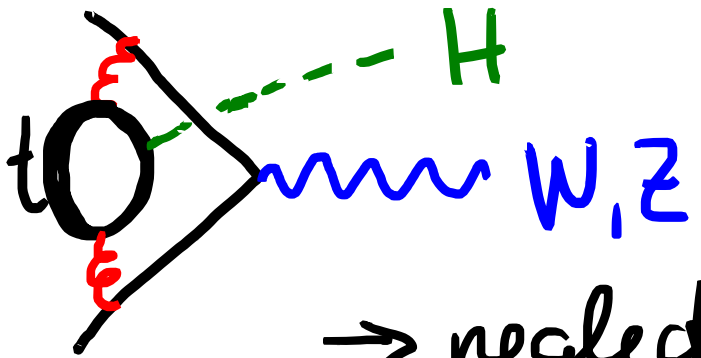
DY-like:

[Brein, Djouadi, RVH '03]



again: $\sigma^{V\Phi}_{2HDM} = \left(g^{\Phi}_{VV}\right)^2 \sigma^{VH}_{SM}$

non DY-like cont's: [Brein, RVH, Wiesemann, Zirke '11]



→ neglect

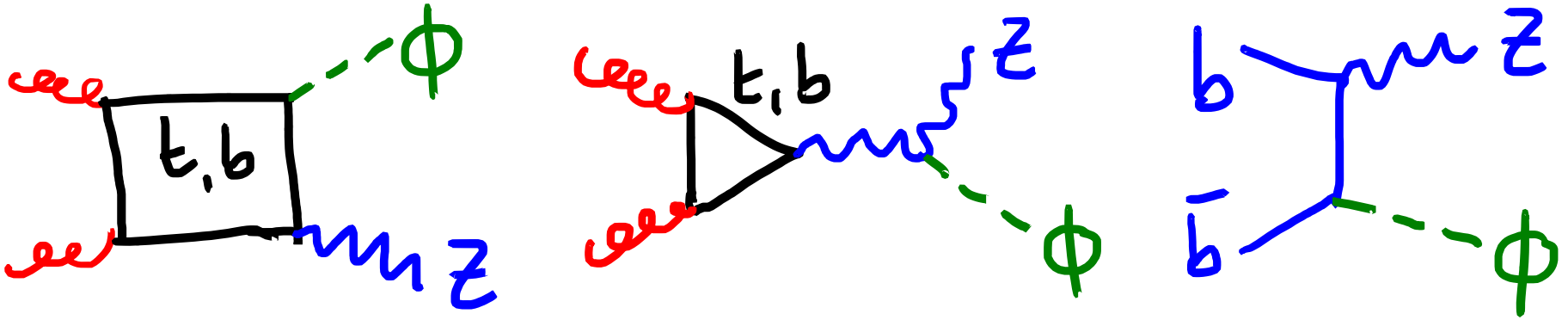
- "same" for WH and ZH
- small (~ 2%)

NNLO $\Rightarrow$ so far:

$$\left(\frac{\sigma^{W\Phi}}{\sigma^{Z\Phi}}\right)_{2HDM} \equiv \underbrace{\left(\frac{g_{VV}^{\Phi}}{g_{VV}^{\Phi}}\right)^2}_{\equiv 1} \left(\frac{\sigma^{WH}}{\sigma^{ZH}}\right)_{SM} !$$

but: additional cont's for ZH!

additional cont's for ZH:

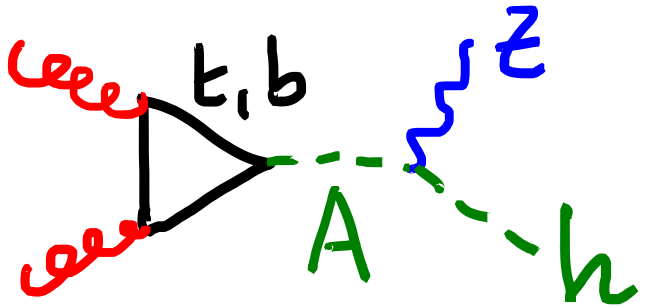


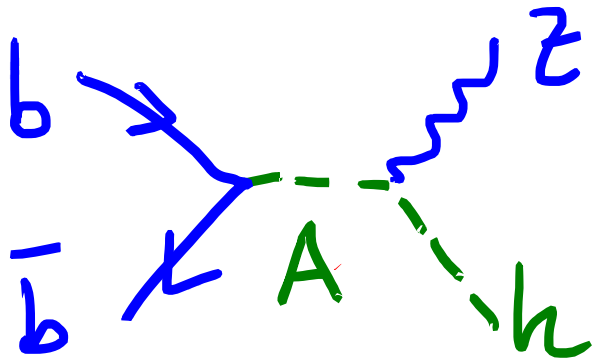
(absent for WH)

→ $\sigma(ZH)$ depends on t,b-Yukawa!

$$\sigma^{Z\Phi}_{2HDM} \neq \left(g^{\Phi}_{VV}\right)^2 \sigma^{ZH}_{SM} \quad !$$

plus: 2HDM-specific 2H forms:

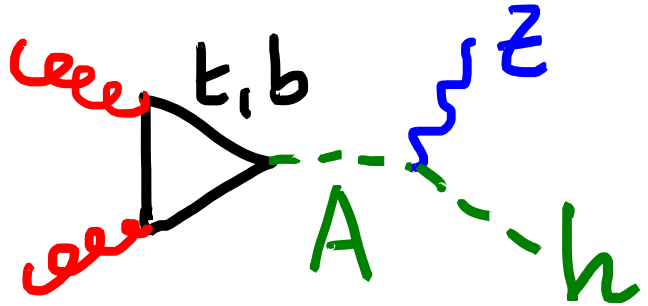




$$\sim \frac{1}{(\hat{s}-m_A^2)^2 + m_A^2 \Gamma_A^2}$$

→ resonant for $m_A > m_Z + m_h$

partonic xsec for



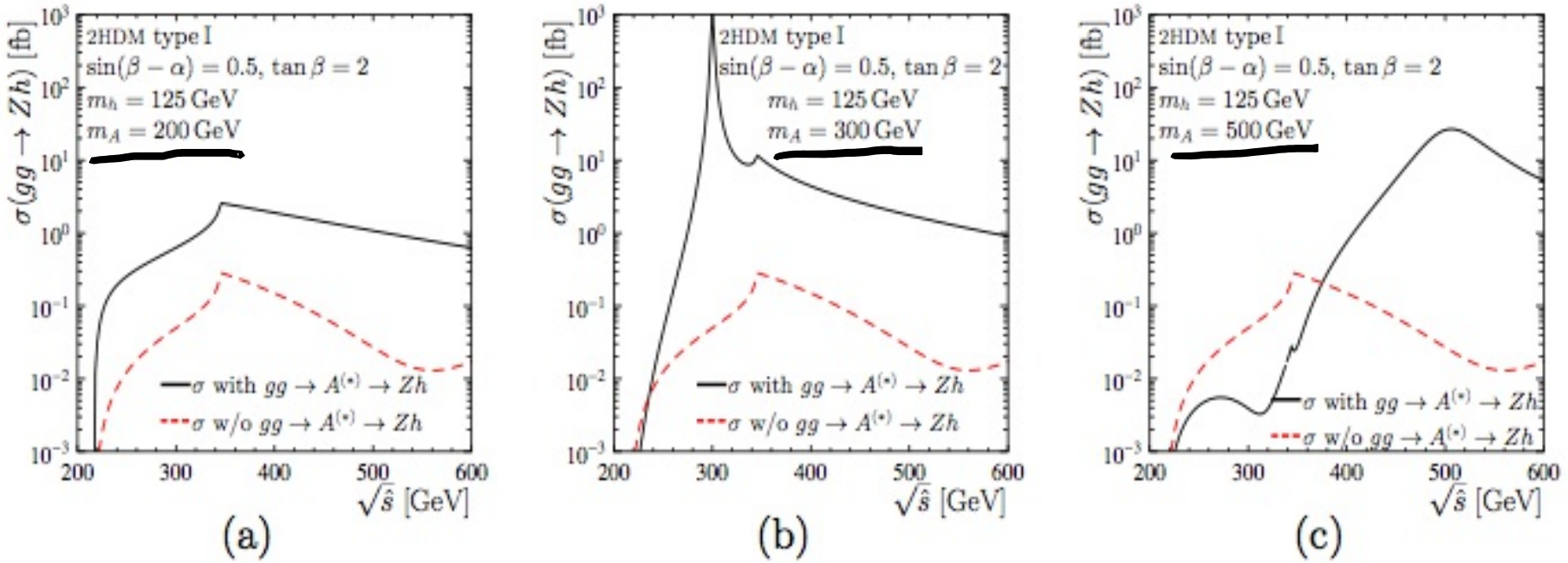


Figure 6. $\sigma(gg \to Zh)$ in fb at the partonic level as a function of $\sqrt{\hat{s}}$ in GeV for $m_h = 125\,\text{GeV}$, $\sin(\beta-\alpha) = 0.5$ and $\tan\beta = 2$. The red/dashed line corresponds to σ without internal pseudoscalar. The black lines show σ with the contribution involving an internal pseudoscalar Higgs for (a) $m_A = 200\,\text{GeV}$, (b) $m_A = 300\,\text{GeV}$ and (c) $m_A = 500\,\text{GeV}$.

$$\Rightarrow \boxed{R_{WZ\phi} = \frac{\sigma^{W\phi}}{\sigma^{Z\phi}}}$$

depends strongly on 2HDM parameters!

$$\boxed{R_{WZ\phi} \equiv \frac{\sigma^{W\phi}}{\sigma^{Z\phi}}}$$

- SM : NNLO pred. available (vhannlo!)
- experimentally:
  - indep. of ϕ-decay mode
  - b-tagging eff. "cancel" ($\phi \to b\bar{b}$)
  - "indep." of luminosity, ...

→ probe of New Physics ?!

Results for 2HDM: $(m_A < m_h + m_Z)$

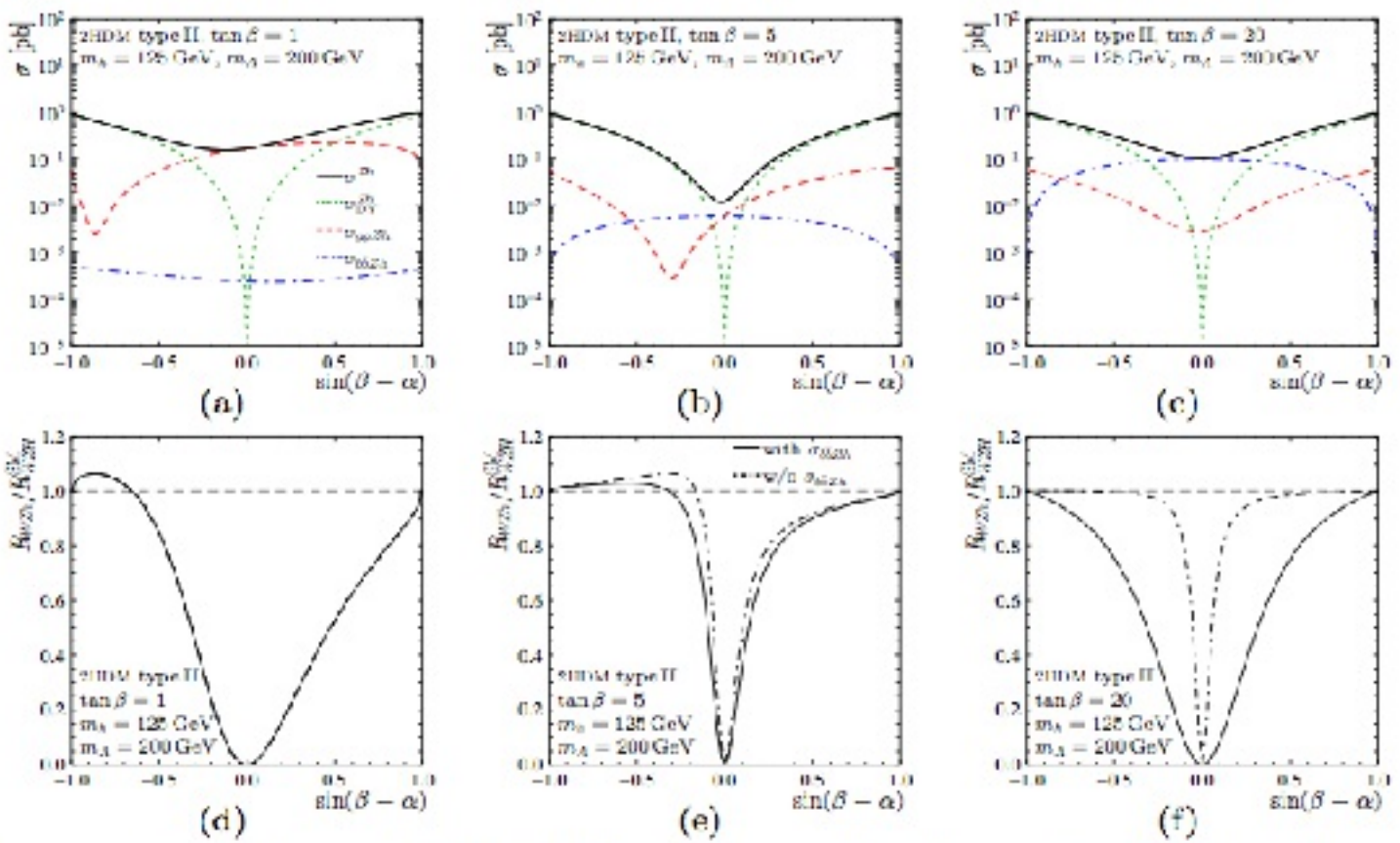
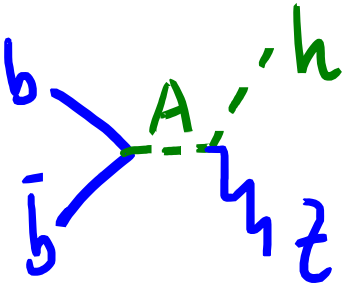
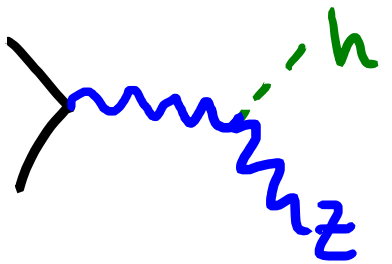


Figure 8. (a-c) $\sigma(pp \to Zh)$ (black/solid), σ_{DY}^{Zh} (green/dotted), $\sigma_{gg\to Zh}$ (red/dashed) and $\sigma_{b\bar{b}Zh}$ (blue/dash-dotted) in pb for $\sqrt{s} = 14\,\mathrm{TeV}$ and $m_h = 125\,\mathrm{GeV}$ as a function of $\sin(\beta - \alpha)$ for type II 2HDM with $m_A = m_{H^0} = m_{H^\pm} = 200\,\mathrm{GeV}$ using (a) $\tan\beta = 1$, (b) $\tan\beta = 5$ and (c) $\tan\beta = 20$; (d-e) the ratio R_{WZh}/R_{WZH}^{SM} for the cases (a-c), respectively with $\sigma_{b\bar{b}Zh}$ (solid) and without (dash-dotted).

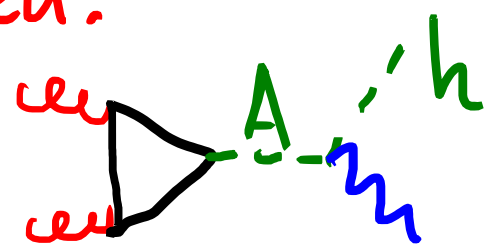
blue:



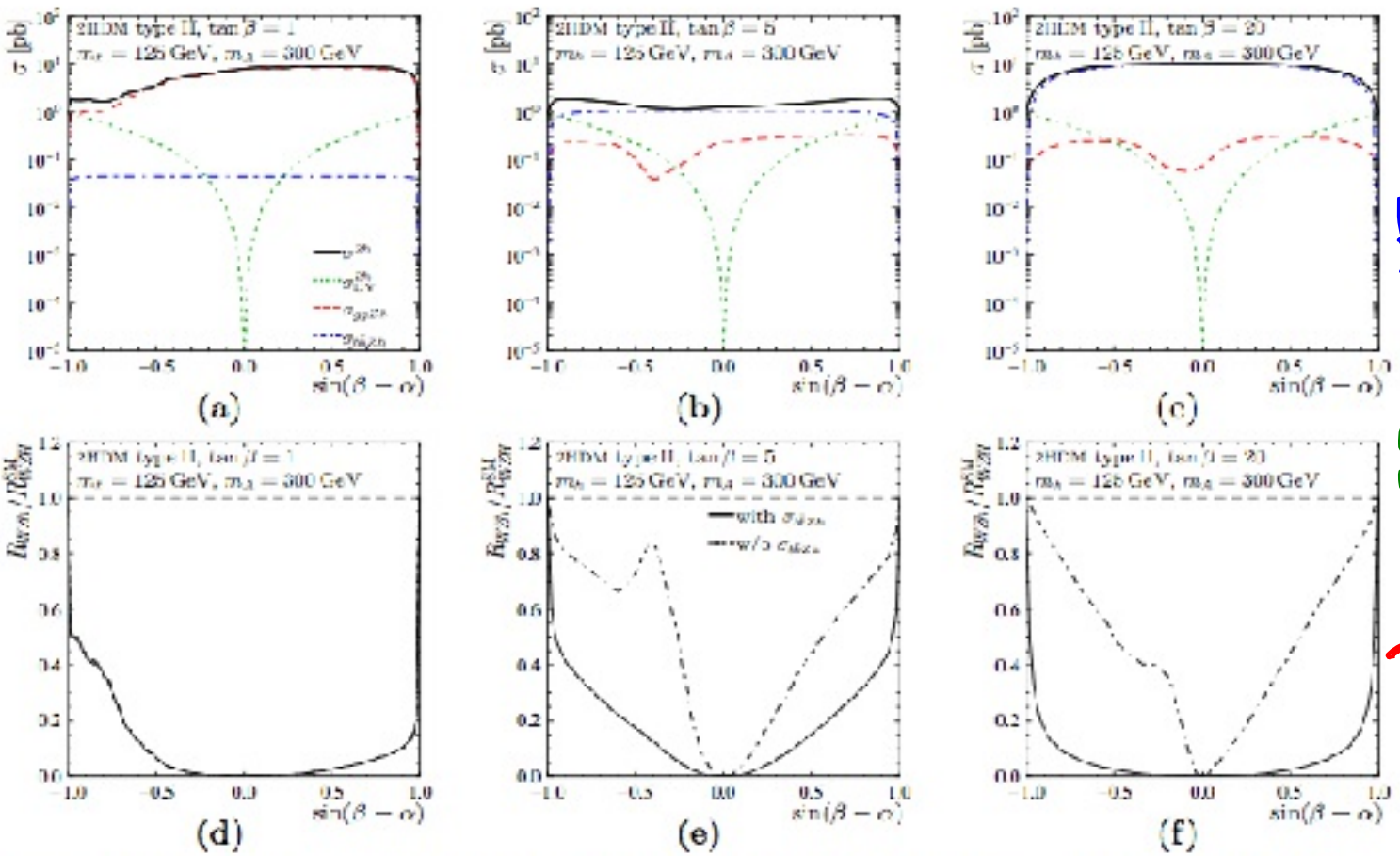
green:



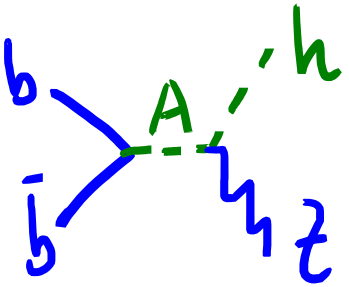
red:



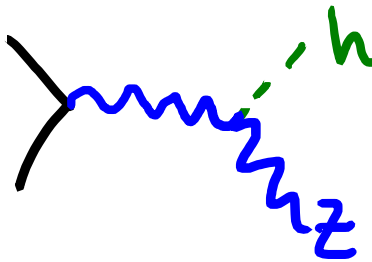
Results for 2HDM: $(m_A > m_h + m_Z)$



blue:



green:



red:

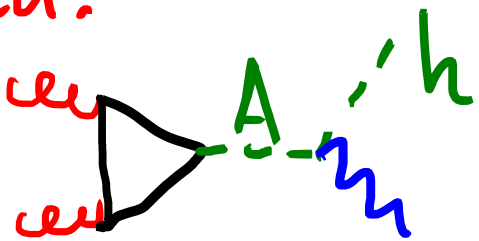


Figure 10. (a-c) $\sigma(pp \to Zh)$ (black/solid), σ^{Zh}_{DY} (green/dotted), $\sigma_{gg,Zh}$ (red/dashed) and $\sigma_{b\bar{b},Zh}$ (blue/dash-dotted) in pb for $\sqrt{s} = 14$ TeV and $m_h = 125$ GeV as a function of $\sin(\beta-\alpha)$ for type II 2HDM with $m_A = m_{H^0} = m_{H^\pm} = 300$ GeV using (a) $\tan\beta = 1$, (b) $\tan\beta = 5$ and (c) $\tan\beta = 20$; (d-e) the ratio R_{WZh}/R^{SM}_{WZH} for the cases (a-c).

Concluding remarks

- σ_{WH}/σ_{ZH} : measurement already possible (even at Tevatron?)
- 2HDM implemented in vh@nnlo (with link to 2HDMC)
  [Eriksson, Rathsman, Stål]
- effects in MSSM expected much smaller (resonant A suppressed)