Status report 2HDM

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Intro

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- For HIG-14-011 $A \to Zh \to \ell\ell bb$ we had to provide a model-dependent limit in addition to model-independent one ($\sigma * \mathcal{B}$);
- As reference model we used 2HDM (TypeI and TypeII);
  - Not so easy to setup the software and run it, but we eventually managed to do it;
  - Also, running the code and collecting the output in a useful way is not so trivial;
- The work can be used also by other groups
  - and that's why we are here.

Software details

- For cross-sections: `SuShi 1.2.0`
- For BR: `2HDMC 1.6.4`
- plus ancillary code `gsl 1.16`, `LHAPDF 5.9.1`
- Then I have a `perl` script to extract the relevant output from the stdout
- and finally a root macro to build a TTree

Model details: 2HDM parameters

- Type I and Type II (but not Type III or Type IV)
- Physical Basis: $m_h, m_H, m_A, m_H^{\pm}, m_{12}, \tan\beta, \cos(\beta-\alpha), \lambda_6, \lambda_7$
- $m_h = 125.03\ GeV$
- m_A scan $200 - 1200\ GeV$, which step? 10 Gev up to 400, then 50/100?
- m_H scan $200 - 1200\ GeV$, which step?
  - scan independently on m_A and m_H??
- $m_H^{\pm}$? == m_A or == m_H or what?
- m_{12} ?
  - $m_{12} = 0$
  - $m_{12}^2 = m_A^2 \frac{\tan\beta}{1+\tan^2\beta}$ (Z_2 broken as in MSSM) as suggested by Higgs WG[1]
- *continue on next slide*

[1] M.Pelliccioni, High mass BSM Higgs phenomenology, CMS Higgs Workshop, 6/12/13

Model details: cont'ed

- $\tan\beta$ from 0.1 to 10 (or larger range) ? Uniform/non-uniform step?
- $\cos(\beta-\alpha) \in [-1,+1]$: uniform step? Reduced range?
- $-1 < \cos(\beta-\alpha) < +1$, $0 < \beta-\alpha < \pi$
- $\lambda_{6,7} = 0$? no CP-violation at tree-level
- *pdf*: $\mathrm{MSTW2008LO90CL}$, NLO, NNLO Is that ok?
- Renormalization scheme/scale?
- Uncertainties? How?
- Other?

What to store

- Angles
  - $\tan\beta$, α, $\cos(\beta-\alpha)$, $\sin(\beta-\alpha)$
- cross sections
  - ggA/H, bbA/H (NNLO)
- Masses and width
  - A, H, $H^{\pm}$
- BR
  - h, A, H, $H^{\pm}$

Tree structure

Quality

validity
stability
perturbativity
unitarity

Masses

mA
gammaA
mH
gammaH
mHC
gammaHC
m12

Angles

tanbeta
alpha
sinba
cosba

x-sections

ggA
bbA
ggH
bbH

BR (see next slide)

- BRh
- BRA
- BRH
- BRHC

Brancing Ratios

saved as c-struct: `BRh.bb`

h→ BRh
ss
cc
bb
ee
mumu
tautau
gamgam
ZZ
WW
Zgam
gluglu

A→ BRA
ss
cc
bb
tt
ee
mumu
tautau
gamgam
Zgam
gluglu
Zh

H→ BRH
ss
cc
bb
tt
ee
mumu
tautau
gamgam
ZZ
WW
Zgam
gluglu
hh
AA
HCHC
ZA
WHC

$H^{\pm}$ → BRHC
us
ub
cd
cs
cb
td
ts
tb
enue
munumu
taunutau
Wh

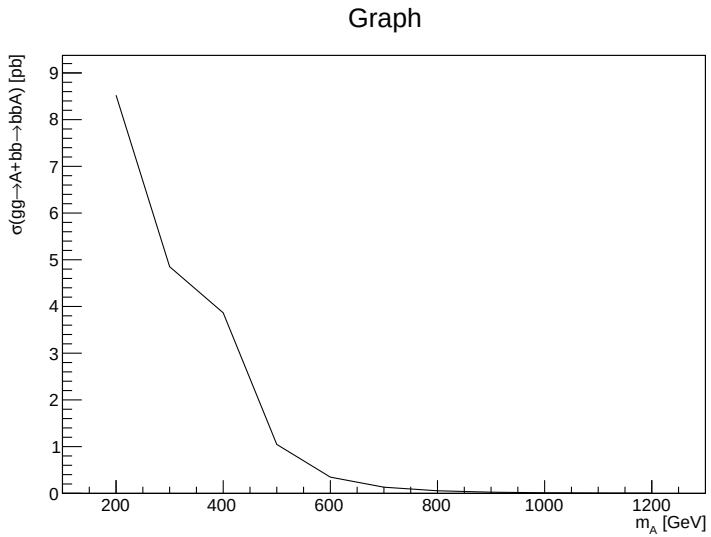
Some BR are forbidden for some A,H,$H^{\pm}$ masses (*eg* →tt, H→hh, . . .)

How to use the tree

The simplest way is to Draw directly from the three the wanted quantities as a function of whatever, then create a TGraph(2D) and fill it with the drawn points, and finally draw the TGraph(2D) according to your need.

Example 1D: (Example 2D next slide)

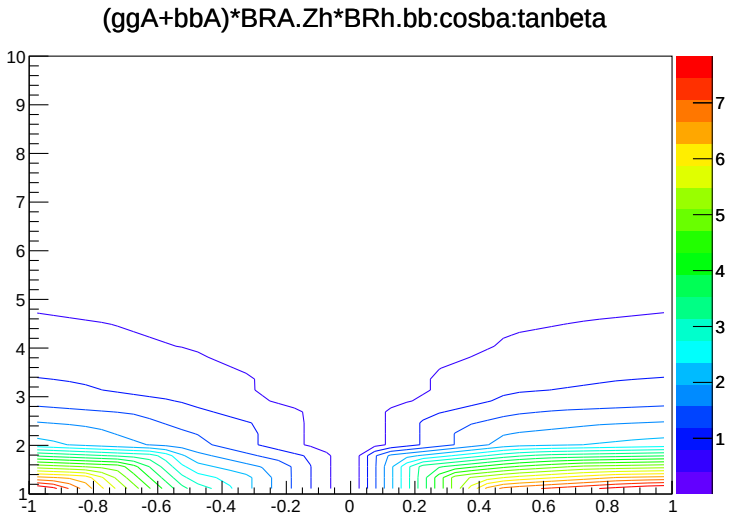
```
Tree2HDM.Draw("ggA+bbA:mA")
TGraph *gr=new TGraph(Tree2HDM.GetSelectedRows(),
    Tree2HDM.GetV2(),
    Tree2HDM.GetV1())
gr->GetYaxis()->SetTitle("#sigma(gg#rightarrowA+bb#rightarrowbbA) [pb]")
gr->GetXaxis()->SetTitle("m_{A} [GeV]")
gr->Draw("al")
```

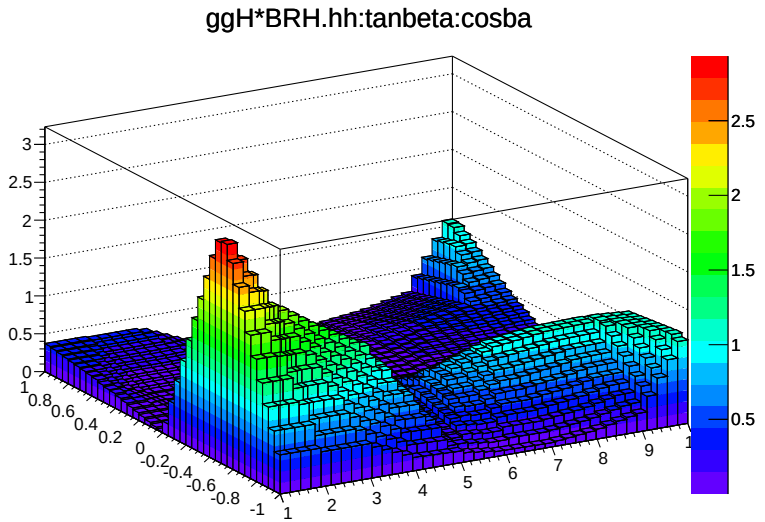


How to use the tree II

Example 2D (I have a simple macro for this);

```
Tree2HDM.Draw("(ggA+bbA)*BRA.Zh*BRh.bb:tanbeta:cosba")
TGraph2D *gr2=new TGraph2D(Tree2HDM.GetSelectedRows(),
    Tree2HDM.GetV2(), Tree2HDM.GetV3(), Tree2HDM.GetV1())
gr2->Draw("lego2")
gr2->GetXaxis()->SetTitle("#tan#beta")
gr2->GetYaxis()->SetTitle("#cos(#beta-#alpha)")
gr2->GetZaxis()->SetTitle(
    "#sigma(pp#rightarrowA)*BR(A#rightarrowZh)*BR(h#rightarrowbb)")
gr2->Draw(...)
```





Status and timescale

- System is set-up
  - I can produce the tree scanning mA, mH, tanBeta, and Cos(Beta-Alpha)
  - Debugging is done
- I'm producing some test tree to distribute for test and feedback;
- Need to define all remaining issues before full production;
  - Now, it takes about 1' (on single CPU) per point (mA, mH, tanBeta, cos(Beta-Alpha));
  - I should have no problem with CPU using out T2_LNL farm;
  - Anyhow, the number of points to be generated is $n_{points} = n_{m_A} \times n_{m_H} \times n_{\tan\beta} \times n_{\cos(\beta-\alpha)}$, so it can be HUGE
- Once all is defined, depending on the total number of points, the trees can be ready in days-week.
- In parallel, document all in a TWiki page.
- Feedback welcome!

Test TTrees and macro

In my `afs` public area: `slacapra/public/2HDM`

- `parameter_2HDM_ty1_mA300_mH300.root`
  2HDM TypeI, mA=mH=300 GeV, $-1 < \cos(\beta - \alpha) < 1$ (5 points), $0.1 < \tan\beta < 10$ (10 points);
- `parameter_2HDM_ty1_mA200-1200_mH200-1200.root`
  2HDM TypeI, $200 < m_A < 1200$ *GeV* (10 points), $200 < m_H < 1200$ *GeV* (10 points), $\cos(\beta - \alpha) = 0.1$, $\tan\beta = 1$;
- `plot.C`
  a simple macro to draw a 1D or 2D `TGraph`.