First studies with SusHi+2HDMC in CMS

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Outline

2HDM has a large parameter space with many phenomenological possibilities.

Theoretical constraints

- Stability, unitarity, perturbativity, CP-conservation.

Experimental constraints

1. We already have one higgs!
   - $m_h = 126 GeV$, CP-even (predominantly)
   - $\sigma \cdot Br$ for several channels
   - ? $\Gamma_h \simeq 4.3 MeV$?
2. We already have constraints on "heavy SM-like resonanse"
3. Oblique electroweak parameters: S, T, U, V, W, X
4. Constraints on $M_{H^\pm}$, light M_A
5. LEP, Tevatron, e.t.c.

Current goal

Constrain 2HDM parameter space with 1 and 2

Tools

2HDMC: Eriksson, Rathsman, Stål [*0902.0851*]

- Implements almost all thinkable constraints
  - Only stability, unitarity and perturbativity applied for now.
- Calculates widthes and branchings for scalars
  - I have some `python` bindings for it

SusHi: Harlander, Lieber, Mantler [*1212.3249*]

- Calculates cross-sections, based on 2HDMC output.
  - Runs on GRID
    (so one can crunch hundreds of thousands of points).

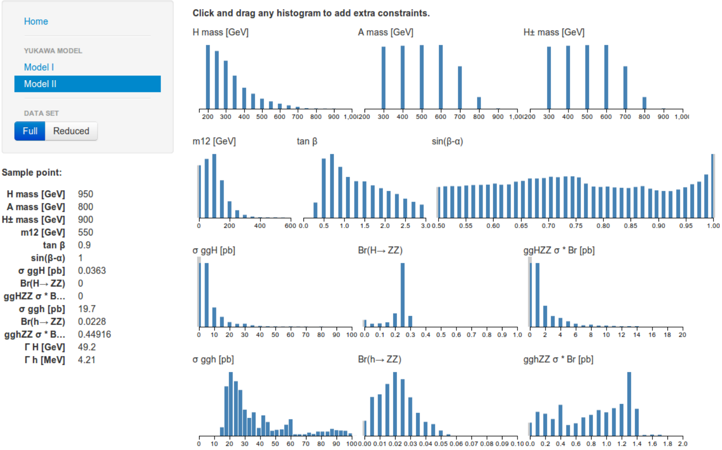
Parameter scans grid

M_h	fixed to 126 GeV
Yukawa	Model I, Model II
$sin(\beta - \alpha)$	0.5 – 1.0, step 0.0125
$tan\beta$	0.1 – 3.0, step 0.2
m_{12}	0 GeV – 600 GeV , step 50 GeV
$M_{H^\pm}$	300 GeV – 1000 GeV , step 100
M_A	300 GeV – 1000 GeV , step 100
M_H	200 GeV – 1000 GeV , step 50

- $\simeq$ 140000 points per Yukawa model, passing the theoretical constraints
- For each point cross-sections for h and H are calculated with SusHi

“2HDM explorer”

- A way to browse the whole scanned parameter space:
  “2HDM explorer”: *http://cern.ch/kkanishc/2HDM/home.shtml*



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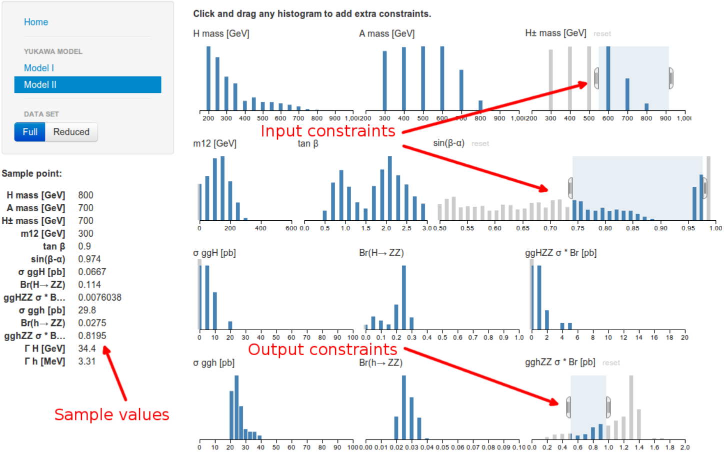

Benchmark points

- As a start – study some specific points in parameter space.
- Like in heavy resonance searches, it seems natural to have M_H as a scanning parameter
- Definition of a "benchmark point":

"Fixed" benchmark points

- Values of M_A, $M_{H^\pm}$, $\tan\beta$, $sin(\beta-\alpha)$ and m_{12} are fixed.
- And we provide σ's and Br's as functions of M_H

"Floating" benchmark points

- Values of M_A, $M_{H^\pm}$, $\tan\beta$, $sin(\beta-\alpha)$ and m_{12} can also be functions of M_H
- And we provide σ's and Br's as functions of M_H

“Fixed” benchmark point example

Model I

M_A	500 GeV
$M_{H^\pm}$	600 GeV
m_{12}	100 GeV
$tan\beta$	0.7
$sin(\beta - \alpha)$	0.95

M_H	200 GeV	300 GeV	400 GeV	500 GeV
$\sigma(ggH)$	7.83 pb	3.68 pb	3.16 pb	Not allowed
$Br(H \to ZZ)$	0.249	0.288	0.126	Not allowed
$\sigma \cdot Br(H \to ZZ)$	1.94 pb	1.06 pb	0.39 pb	Not allowed
Γ_H	0.15 GeV	0.89 GeV	6.1 GeV	Not allowed
$\sigma(ggh)$	38 pb	38 pb	38 pb	Not allowed
$Br(h \to ZZ)$	0.012	0.012	0.012	Not allowed
$\sigma \cdot Br(h \to ZZ)$	0.46 pb	0.46 pb	0.46 pb	Not allowed

“Floating” benchmark point example

Model I

M_A	500 GeV		600 GeV	
$M_{H^\pm}$	600 GeV		700 GeV	
m_{12}	50 GeV	100 GeV		150 GeV
$tan\beta$	0.3		0.5	
$sin(\beta - \alpha)$	0.897			
M_H	200 GeV	300 GeV	400 GeV	500 GeV
$\sigma(ggH)$	47 pb	22.1 pb	5.37 pb	2.29 pb
$Br(H \to ZZ)$	0.23	0.29	0.145	0.112
$\sigma \cdot Br(H \to ZZ)$	10.8 pb	6.45 pb	0.78 pb	0.256 pb
Γ_H	0.15 GeV	1.72 GeV	10.4 GeV	29.3 GeV
$\sigma(ggh)$	107 pb	107 pb	60.9 pb	60.9 pb
$Br(h \to ZZ)$	0.004	0.004	0.0071	0.0071
$\sigma \cdot Br(h \to ZZ)$	0.44 pb	0.44 pb	0.43 pb	0.43 pb

Another "floating" example

Model II

M_A	600 GeV			
$M_{H^\pm}$	700 GeV			
m_{12}	150 GeV	150 GeV	250 GeV	300 GeV
$tan\beta$	1.3	1.7	2.1	2.3
$sin(\beta - \alpha)$	0.526	0.615	0.718	0.731
M_H	200 GeV	300 GeV	400 GeV	500 GeV
$\sigma(ggH)$	1.3 pb	0.568 pb	0.354 pb	0.166 pb
$Br(H \to ZZ)$	0.257	0.3	0.291	0.275
$\sigma \cdot Br(H \to ZZ)$	0.334 pb	0.17 pb	0.103 pb	0.046 pb
Γ_H	1.04 GeV	5.37 GeV	12.9 GeV	28.5 GeV
$\sigma(ggh)$	29 pb	24.7 pb	23.5 pb	22.7 pb
$Br(h \to ZZ)$	0.014	0.015	0.0189	0.0169
$\sigma \cdot Br(h \to ZZ)$	0.4 pb	0.37 pb	0.444 pb	0.383 pb

Moving on...

After one fixes the benchmark point:

1. Obtain kinematic distributions.
2. Do event-by event reweighting of the "SM-like" MC's
3. Redo the exclusion plot (shape analysis with reweighted $M_{2\ell 2q}$ histogram)

Getting distributions (1) from SusHi?

```
Block DISTRIB
 1     3       # distribution : 0 = sigma_total, 1 = dsigma/dpt, 2 = dsigma/dy, 3 = d^2sigma/dy/dpt
               #                 (values for pt and y: 22 and 32)
 2     3       # pt-cut: 0 = no, 1 = pt > ptmin, 2 = pt < ptmax, 3 = ptmin < pt < ptmax
21    30.d0    # minimal pt-value ptmin in GeV
22   100.d0    # maximal pt-value ptmax in GeV
 3     3       # rapidity-cut: 0 = no, 1 = Abs[y] < ymax, 2 = Abs[y] > ymin, 3 = ymin < Abs[y] < ymax
31     0.5d0   # minimal rapidity ymin
32     1.5d0   # maximal rapidity ymax
 4     1       # 0 = rapidity, 1 = pseudorapidity
```

⇑ Is this right?

- Would it be $\int_{30}^{100} dp_\perp \int_{0.5}^{1.5} d\eta \, \frac{d^2\sigma}{dp_\perp d\eta}$?
- Still, looks tedious...

Conclusions/Plans/Discussion

Plans:

- Have whole toolchain ready.
- ? Other channels (already have some data to process).
- ? Cross-checks.

Things to agree on:

- Fix a set of prior constraints that should be imposed.
- Together with "windows" for quantitative values.

  E.g. Can I have $\sigma(gg \to h) \cdot Br(h \to ZZ) \simeq 0.4[pb]$?

  E.g. Can I have $\Gamma_h \simeq 20[MeV]$?
- Benchmark points:
  - Employing M_H as a "scanning parameter" ?
  - Allowing 2HDM parameters to change (slightly) with M_H?