Minutes of 2HDM benchmark points meeting on June 23, 2015.

Six groups presented their proposed benchmark points/lines:

1. No et. al., Benchmarks motivated by strong first order phase transition, which prefer relatively large mass splitting between mA and mH.

Benchmark A1 and A2 is at alignment limit, A1 allows A->HZ, A2 allows A->HpmWmp in addition. A1 has overlap with Haber/Oscar and Kling/Su benchmark points.

Benchmark B1 and B2 is for non-alignment case, with mass spectrum similar to A1 and A2. H in the final state could decay to WW and ZZ.

Comment from audience: in B1 and B2 case, could daughter particle H be observed first using inclusive di-boson search before A is discovered through this channel?
Answer from author: in the non-aligned large splitting A-H simplified scenario considered, gg->A->ZH is potentially the dominant production mechanism for H as gluon fusion production is suppressed in a sizable region of parameter space. Given the decay products of H and Z, it is unclear if the inclusive diboson search could easily discover these scenarios.

2. Haber/Stal, 2HDM benchmark lines using Higgs basis parametrization.

Seven benchmark scenarios:
A: h-125, non-alignment, type I has more relaxed parameter region than type II.
B: H-125, type II is very tightly constrained.
C: CP-overlap, mA ~ mh=125 GeV.
D: short cascade: overlap with Su/Kling.
E: long cascade, tends to be suppressed. Br < 5%.
F: opposite sign for bottom Yukawa (Type II) relative to the SM value.
G: MSSM-like.

Comment: We shall discuss how we want to treat the flavor constraints for the light charged Higgs. Latest analysis shows that for Type II 2HDM, mHpm has been constrained to be larger than 485 GeV.

3. Su/Kling, Type II 2HDM benchmark points for exotic Higgs decays

Exotic decay refers to the decay of heavy Higgs into either two light Higgses or one light Higgs with one SM gauge boson. There are five categories: for neutral Higgss, HH type (here and below, H refers to both CP even and CP odd Higgs), HZ type, H+H- type, and H+W- type; for the charge Higgs, HWpm type. Those channels dominate the conventional decays modes (neutral Higgs to gaga, WW, ZZ, bb, tautau and charge Higgs to taunu, cs, tb) once they are kinematically open.

Five benchmark point categories:

BP1: light H with A-> HZ, Hpm->H Wpm. Overlap with No. et. al. A1.
BP2-BP5: light A with H -> AZ, Hpm->AWpm, H->AA, with different kinematic region for mA. Overlap with Haber/Stal D2.1.
BP6-BP8: light Hpm with H->HpmWmp, A->HpmWmp. Overlap with Haber/Stal D2.2, 2.3.
BP9: non-alignment, with A, H, Hpm decay to hSM. Overlap with Haber/Stal A2.1, 2.2.
BP10: H-125, with A-> hZ, Hpm->h Wpm. Overlap with Haber/Stal B2.

Comment: experimentalists prefer benchmark planes (more later).

4. Barducci et. al., SM Higgs decay into a light A: hSM->ZA->Z mumu/Ztautau/Zbb

Two benchmark points for Type I
A: mA=20 GeV
B: mA=65 GeV

Three benchmark points for Type II:
C. mA=6 GeV, below bb threshold.
D. mA=25 GeV
E. mA=63 GeV

on or off-shell Z, could have boosted object.

5. Robens et. al., IDM benchmarks with large MET in the final states (lightest neutral Higgs being the dark matter candidate, assume to be H for now, but should not matter if it is A.)

There are tight constraints from DM searches, mass degeneracy.

Production: EW pair production of H+H- or HA.
Decay: A-> ZH 100% (on-shell or off-shell), Hpm->Wpm H

Benchmark I, II: low scalar mass,
Benchmark III: intermediate mass
BP4-5: high mass with or without degeneracy. The cross section (around 1 fb) would be challenge for experimental searches.

The cross section, Branching fractions and kinematics mainly depend on the mass, not much on the other coupling parameters.

There are complementarity between astro-physics DM searches and collider searches.

There is no H -> gaga and H->WW/ZZ.
For the current analyses, has not studied metastable Hpm.

6. Lopez-Val, Fermiophobic Type I 2HDM with H has no fermion couplings. Non-alignment.

A challenge case for experimental search since H has no couplings to fermions/gluons and very suppressed couplings to WW/ZZ/hh.
Production: HA (around 1.9 fb for 200 GeV mH and 500 GeV mA) or H+H-.
Decay: A-> HZ, Hpm -> H Wpm

However, narrow resonance search for WW and ZZ pair might be of help here.

Main motivation underneath this scenario: let's read it as a warning sign -- the 2HDM, as a representative multi-scalar extension, does include the possibility of rather light, yet very elusive, heavy scalars.

GENERAL COMMENTS:

1. Flavor constraints for the light charged Higgs? Should we consider it assuming 2HDM only particle content, or allow 2HDM to be the Higgs sector of a larger BSM scenario.

2. Maybe we shall take the simplified model approach and consider simple mass spectrum that only allow one type of exotic decay at a time. For example, when consider H/A->AZ/HZ, decouple Hpm. When consider Hpm -> A Wpm, decouple H.

3. Experimentalists would prefer benchmark plane instead of benchmark points/lines.

For decays involve one non-SM Higgs, it could be the mass of the non-SM Higgs (mA, mH, mHpm) versus TB (or other parameter). As for cos(beta-alpha), for simplicity, it could be taken to be 0 alignment or a non-zero value for non-alignment. Other parameters, e.g., m12, could be taken to be a fixed value.

For decays involve two non-SM Higgs, it could be the mass of parent and daughter particle masses. For example, A/H->HZ/AZ, it could be mH versus mA plane (or m versus delta_m plane). Other parameters, for example, tan_beta, could take a few representative points, say, low tan_beta, intermediate tan_beta and high tan_beta.

Experimentalists would like to have plots in those benchmark plane that shows the production cross section, decay branching fraction, and excluded regions by various theoretical and current experimental constraints.

TO DO List:
1. Different group, in particular, No et. al, Haber/Stal, Su/Kling shall work together to merge the common benchmarks.
2. Each group should think how to extend the current benchmark points/lines to benchmark planes.