1. Motivation

* A neutral Higgs boson (spin 0) has been found at the LHC.
* Classify elementary particles by their electric charge and spin:

<table>
<thead>
<tr>
<th>Spin</th>
<th>Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up</td>
<td>$+\frac{1}{2}$</td>
</tr>
<tr>
<td>Down</td>
<td>$-\frac{1}{2}$</td>
</tr>
<tr>
<td>Quark</td>
<td>$-\frac{3}{2}$</td>
</tr>
<tr>
<td>Lepton</td>
<td>$\pm\frac{1}{2}$</td>
</tr>
</tbody>
</table>

• Why not a charged, spin 0 particle, $H^0$?

2. The Two Higgs Doublet Model (2HDM)

* Introduction a second $\tilde{f} = f$ + $\tilde{f}$ to the SM Lagrangian:

$$H_f = \frac{v_f}{\sqrt{2}} f_0 + \frac{i v_f}{\sqrt{2}} \tilde{f}_0 \gamma^0 / \sqrt{2}$$

• Four types of 2HDM (without tree-level flavour changing scalar currents): Type I, II, Lepton-specific, and Flipped.

3. The Three Higgs Doublet Model (3HDM)

* A multi-Higgs doublet model (MHD) has $n$ scalar doublets.
* A MHD has $n-1$ physical charged scalars $H_i$.
* The mass matrix of the charged scalars is diagonalized by the $n \times n$ matrix $U$:

$$
\begin{bmatrix}
H_1 & H_2 & \cdots & H_n \\
H_1^* & H_2^* & \cdots & H_n^* \\
\end{bmatrix} = U \begin{bmatrix}
H_1 & 0 & \cdots & 0 \\
0 & H_2 & \cdots & 0 \\
\end{bmatrix} U^* 
$$

4. LHC and LEP searches for $H^0$

• Top quarks are produced in pairs e.g. $g\rightarrow t\bar{t}$ and then $t\rightarrow Wb$, with $W \rightarrow \ell\nu$ or $\ell\ell$ and $T\rightarrow H^0$.
• $H^0$ decay to fermions with hadronic and leptonic channels captured by the detector.
• Production of charged Higgs pairs from electron-positron collision by exchange of $Z$ or photon.

5. Large BR($H^0 \rightarrow cb$) from Flipped and Democratic 3HDM

$$
\Gamma(H^0 \rightarrow cb) = \frac{g_{uH^0} g_{bH^0} m_2^2}{8 \pi v^2} \Gamma(H^0 \rightarrow \ell\nu) = \frac{g_{uH^0} g_{bH^0} m_2^2}{8 \pi v^2} \Gamma(H^0 \rightarrow \ell\nu) 
$$

• For $m_b > m_c$, the channel $H^0 \rightarrow c\bar{b}$ dominates in all 2HDMs and in 3HDM.
• For $m_b < m_c$, a distinctive signal of $H^0$ from a 3HDM would contain:
  - Large BR($H^0 \rightarrow cb$).

6. BR($t \rightarrow H^0l^\pm$) multiplied by BR($H^0 \rightarrow cb$) in Flipped 3HDM

$$
\text{BR}(t \rightarrow H^0l^\pm) \times \text{BR}(H^0 \rightarrow cb) 
$$

• Current limit on $t \rightarrow H^0b$ for charged Higgs mass 130 GeV are excluded with $\text{BR}(H^0 \rightarrow cb) < 0.01$ at LHC.

7. Conclusion

• Two types of 3HDM (Flipped and Democratic) can have large BR($H^0 \rightarrow cb$).

8. References