AN EXCLUSIVE WINDOW ONTO HIGGS YUKAWA COUPLINGS

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(C. Delaunay, T. Golling, G. Perez and YS - 1310.7029)
Current searches for Higgs Yukawas focus mainly on top, bottom and leptons.

What about Higgs couplings to light quarks?
Indirect bounds on light-quark Yukawas from current Higgs data (naive $\chi^2$):

$$y_u/y_b^{SM} < 0.98(1.3) \quad y_d/y_b^{SM} < 0.93(1.4)$$
$$y_s/y_b^{SM} < 0.70(1.4) \quad y_c/y_b^{SM} < 0.70(1.4)$$

@ 95% CL

Can even be larger than the SM bottom Yukawa!

Leads to interesting Higgs phenomenology
INTRODUCTION

- Challenges for probing light-quark ($u,d,s,c$) Yukawas:
  - The SM-Higgs branching ratios are tiny
  - Huge QCD background
  - Flavor tagging - only charm is possible

Looks almost hopeless, at least in the inclusive rates.

c-tagging
ATLAS-CONF-2013-068
Delaunay, Golling, Perez, YS
1306.5770
EXCLUSIVE DECAYS

$h \rightarrow MV$

vector meson

$\gamma W Z$

work in progress

Bodwin, Petriello, Stoynev, Velasco
1306.5770

$h \rightarrow J/\psi \gamma \rightarrow y_c$

$\phi \gamma \rightarrow y_s$

$h \rightarrow \rho \gamma, \omega \gamma \rightarrow y_d, y_u$

Small branching ratio, BUT reduced QCD background!
Direct:

\[ \propto y_s f_\perp \langle 1 / u \bar{u} \rangle \]
light-cone distribution amplitude (LCDA)

Indirect:

\[ \propto f_\phi \]

\[ \Gamma(\phi \rightarrow e^+ e^-) \]

Main sensitivity to Yukawa due to interference!
RESULTING RATES

\[
\frac{\text{BR}_{h \to \phi \gamma}}{\text{BR}_{h \to b \bar{b}}} = \frac{\kappa_\gamma [(3.0 \pm 0.13) \kappa_\gamma - 0.78 \bar{\kappa}_s]}{0.57 \bar{\kappa}_b^2} \times 10^{-6} \pm \mathcal{O}(20\%)
\]

can be improved
(both theoretically and experimentally)

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\bar{\kappa}_q \equiv y_q / y_b^{\text{SM}} \quad \kappa_\gamma^{\text{SM}} = 1
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\[ \frac{\text{BR}_{h \rightarrow \rho\gamma}}{\text{BR}_{h \rightarrow b\bar{b}}} = \frac{\kappa_\gamma [(1.9 \pm 0.15)\kappa_\gamma - 0.24\bar{\kappa}_u - 0.12\bar{\kappa}_d]}{0.57\bar{\kappa}_b^2} \times 10^{-5} \]

\[ \frac{\text{BR}_{h \rightarrow \omega\gamma}}{\text{BR}_{h \rightarrow b\bar{b}}} = \frac{\kappa_\gamma [(1.6 \pm 0.17)\kappa_\gamma - 0.59\bar{\kappa}_u - 0.29\bar{\kappa}_d]}{0.57\bar{\kappa}_b^2} \times 10^{-6} \]
FUTURE EXPERIMENTAL PROSPECTS

- Focus on future hadron colliders

- $h \rightarrow \phi \gamma$ as an example:
  - 70-75% of the $\phi$ decays products fall in the central region ($\eta < 2.4$).

- 3σ sensitivity with 3000 fb$^{-1}$:

<table>
<thead>
<tr>
<th>$\sqrt{s}$ [TeV]</th>
<th>$\bar{\kappa}_S &gt; (&lt;)$</th>
<th>$\bar{\kappa}_S^{\text{stat.}} &gt; (&lt;)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>0.39 (-0.97)</td>
<td>0.27 (-0.81)</td>
</tr>
<tr>
<td>33</td>
<td>0.36 (-0.94)</td>
<td>0.22 (-0.75)</td>
</tr>
<tr>
<td>100</td>
<td>0.34 (-0.90)</td>
<td>0.13 (-0.63)</td>
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factor 6 from the SM
• Probing the Higgs Yukawa of the first two generations via inclusive rates and flavor tagging may only be possible for charm.

• Rare Higgs decays to a photon and a vector meson can explore the structure of the Higgs Yukawa of the first two generations.

• Exclusive decays can also be used to probe off-diagonal Higgs couplings and CP-violation.

Bhattacharya, Datta, London, 1407.0695
BACKUP SLIDES