Higgs and Flavour: Experimental Status

Philip Ilten
on behalf of the ATLAS, CMS, and LHCb collaborations

UNIVERSITY OF BIRMINGHAM

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HL-LHC June Workshop
Some Useful Links

- HL-LHC Workshop TWiki page
- WG2 (Higgs) TWiki page
- WG2 conveners: Maria Cepeda, Stefania Gori, Philip Ilten, Marumi Kado, Francesco Riva
- WG4 (Flavour) TWiki page
- WG4 conveners: Jorge Martin Camalich, Alex Cerri, Vladimir Gligorov, Sanda Malvezzi, Jure Zupan
- October 2017 CERN workshop
- April 2018 FNAL workshop
- this June 2018 CERN workshop
- list of WG2 (Higgs) meetings
- list of WG4 (Flavour) meetings
Wishlist Summary

• nice summary by Marianna, et. al. from May meeting
• legend: previous study, 2017 TDR study, to be done/expanded

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<th>ATLAS</th>
<th>CMS</th>
<th>LHCb</th>
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✓✓✓ what about $B^+ \rightarrow K^+ \chi(\mu\mu)$ from LHCb?

• not much new today but things are underway
Yellow Report (YR) Outline

- editors: **Kostas Nikopoulos** (ATLAS), **Alexander Schmidt** (CMS), **Lorenzo Sestini** (LHCb), **Yotam Soreq** (theory)

7 Higgs flavor and rare decays (**WG2**)
   - a) Flavor aspects Yukawa modifications in flavor models (**Bishara**)
   - b) Exclusive Higgs decays (**Soreq**)
   - c) Flavor tagging (charm and strange) (**Schlaffer**)
   - d) LFV decays of the Higgs
   - e) Yukawa constraints from Higgs distributions (**Soreq**)
   - f) CP violation in Higgs couplings ($\tau$, $ttH$) (**Harnik**)

9 Flavor aspects of Higgs (**WG4**)
   - a) Yukawa modifications in flavor models
   - b) Exclusive Higgs decays
   - c) Flavor tagging (charm and strange)
   - d) LFV decays of the Higgs
   - e) Yukawa constraints from Higgs distributions
   - f) CP violation in Higgs couplings ($\tau$, $ttH$)
   - g) Experimental perspective
Higgs to Inclusive Charm
• see talk by Elliot Reynolds for more details
• ATLAS measurement of $ZH \rightarrow \ell\ell cc$: arXiv:1802.04329
• current limit is roughly $100\times$ SM
• projection now available!

arXiv:1802.04329
- no dedicated analysis from CMS
- plan to recast and extrapolate $H \to bb$ results to $H \to cc$
- CMS measurement of boosted $H \to bb$: arXiv:1709.05543
- CMS evidence for $H \to bb$: arXiv:1709.07497
- LHCb measurement of $VH \to c\ell$: LHCb-CONF-2016-006
- current limit is roughly $6400 \times$ SM
- rough projection of $4 \times$ SM
- detailed study underway including $H \to bb$
• jet tagging performance is critical for these measurements
Differential Cross-sections
Distributions

- see talk by Thomas Klijnsma
- $p_T$ spectrum sensitive to couplings (low) and top mass (high)
- rapidity spectrum depends on gluon PDF

![Graphs showing differential cross-section distributions](arXiv:1606.09253)

$\frac{1}{\sigma} \frac{d\sigma}{dp_T,h} / \left( \frac{1}{\sigma} \frac{d\sigma}{dp_T,h} \right)_{SM}$

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<tr>
<th>$\kappa_c$</th>
<th>$\chi^2$</th>
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<td>-10</td>
<td>2.3</td>
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<td>-5</td>
<td>5.99</td>
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<tr>
<td>0</td>
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LHC Run I

HL-LHC

$\Delta \chi^2 = 2.3 \quad \Delta \chi^2 = 5.99$
• $H \rightarrow \gamma\gamma$: arXiv:1802.04146
• $H \rightarrow ZZ$: arXiv:1712.02304
• combined: ATLAS-CONF-2018-002
• projected 5% uncertainty for $\gamma\gamma$, 5 − 10% for $ZZ$, < 5% combined
- $H \rightarrow \gamma\gamma$: CMS-PAS-HIG-17-029
- $H \rightarrow ZZ$: arXiv:1706.09936
- projected 5 – 10% for $ZZ$, no combined but expected $\approx 5\%$
- work on official combined projection underway
- plan to extract $\kappa_b$ and $\kappa_c$ in projection
Lepton Flavour Violation
ATLAS

- search by ATLAS for $H \rightarrow \tau\mu$: arXiv:1508.03372
- with 20 fb$^{-1}$ of data $\mathcal{B}(H \rightarrow \tau\mu) < 1.85\%$
- no current plans for projections arXiv:1508.03372
- search by CMS for $H \rightarrow \tau\mu$ and $H \rightarrow \tau e$ arXiv:1712.07173
- search by CMS for $H \rightarrow e\mu$ and $H \rightarrow e\tau$ : arXiv:1607.03561
- projections of results underway

arXiv:1607.03561

$\tau e \rightarrow 95\%$ CL limit on $\mathcal{B}(H \rightarrow e\tau)$:
- Observed: $0.69\%$ (obs.)
- Expected: $0.75\%$ (exp.)

$\tau e \rightarrow H$
- Observed: $2.88\%$ (obs.)
- Expected: $3.55\%$ (exp.)

$\mu \tau$, 0 Jets
- Observed: $1.51\%$ (obs.)
- Expected: $0.75\%$ (exp.)

$\mu \tau$, 1 Jet
- Observed: $3.68\%$ (obs.)
- Expected: $2.31\%$ (exp.)

$\mu \tau$, 2 Jets
- Observed: $2.22\%$ (obs.)
- Expected: $2.07\%$ (exp.)

$\mu \tau$, 0 Jets
- Observed: $2.22\%$ (obs.)
- Expected: $2.07\%$ (exp.)

Higgs and Flavour: Experimental Status

Ilten
Rare Decays
Rare Decays

$H \rightarrow J/\psi \gamma$

- search by ATLAS for $H/Z \rightarrow Q\bar{Q}\gamma$: arXiv:1501.03276
- projections by ATLAS for HL-LHC: ATL-PHYS-PUB-2015-043
- no plans for CMS or LHCb projections

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<tr>
<th>$\mathcal{B}(H \rightarrow J\psi\gamma)$</th>
<th>$\mathcal{B}(Z \rightarrow J/\psi\gamma)$</th>
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<tr>
<td>SM  $2.9 \times 10^{-6}$</td>
<td>8.0 $\times 10^{-8}$</td>
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<tr>
<td>Run 1   $1.5 \times 10^{-3}$</td>
<td>2.6 $\times 10^{-6}$</td>
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<tr>
<td>HL-LHC  $4.4 \times 10^{-5}$</td>
<td>4.4 $\times 10^{-7}$</td>
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Rare Decays

$H \rightarrow \phi \gamma$ and $H \rightarrow \rho \gamma$

- search by ATLAS for $H/Z \rightarrow \rho/\phi \gamma$: arXiv:1712.02758
- ATLAS projections are underway
- no plans for CMS or LHCb projections

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<td>$1.0 \times 10^{-8}$</td>
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<tr>
<td>Run 2</td>
<td>$4.8 \times 10^{-4}$</td>
<td>$9.0 \times 10^{-7}$</td>
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<tr>
<td>SM</td>
<td>$1.7 \times 10^{-5}$</td>
<td>$4.2 \times 10^{-8}$</td>
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<tr>
<td>Run 2</td>
<td>$8.8 \times 10^{-4}$</td>
<td>$2.5 \times 10^{-5}$</td>
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Conclusions
Outlook and Plans

- Higgs to inclusive charm projections planned by ATLAS, CMS, and LHCb
  - ATLAS projections already available!
  - what about $c$-tagging performance benchmarks?
- Yukawa constraints from differential distributions planned by CMS
- lepton flavour violation projection from CMS underway
- exclusive $H \rightarrow J/\psi\gamma$ projection available from ATLAS
- $H \rightarrow \rho\gamma$ and $H \rightarrow \phi\gamma$ projections underway by ATLAS
- $H \rightarrow \mu\mu$ studies already available from ATLAS and CMS TDRs
- CP violation from $H \rightarrow \tau\tau$ planned by CMS using simulation