Charming the Higgs

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based on: *CD, T. Golling, G. Perez, Y. Soreq,*
Phys. Rev. D 89, 033014 [arXiv:1310.7029]

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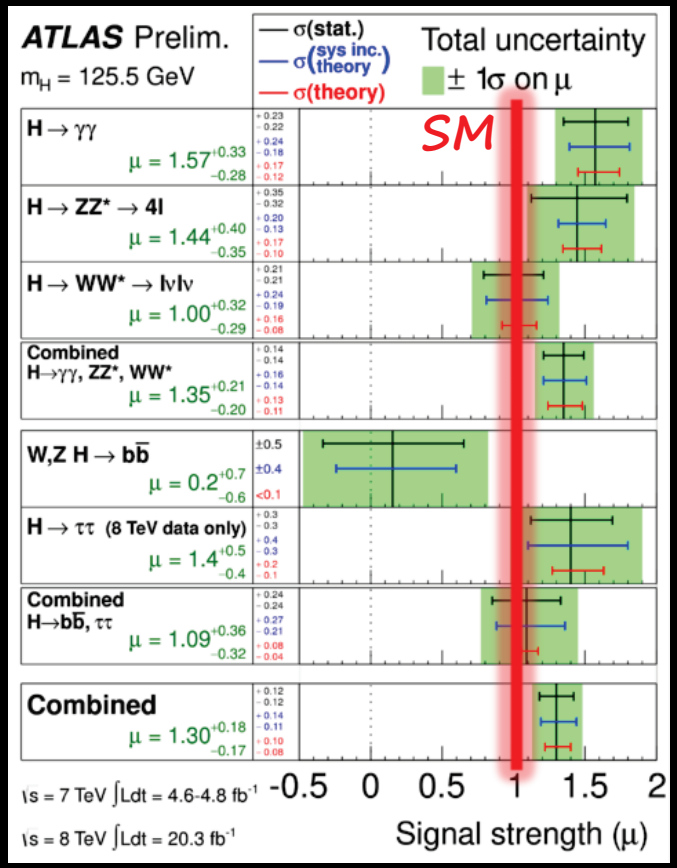
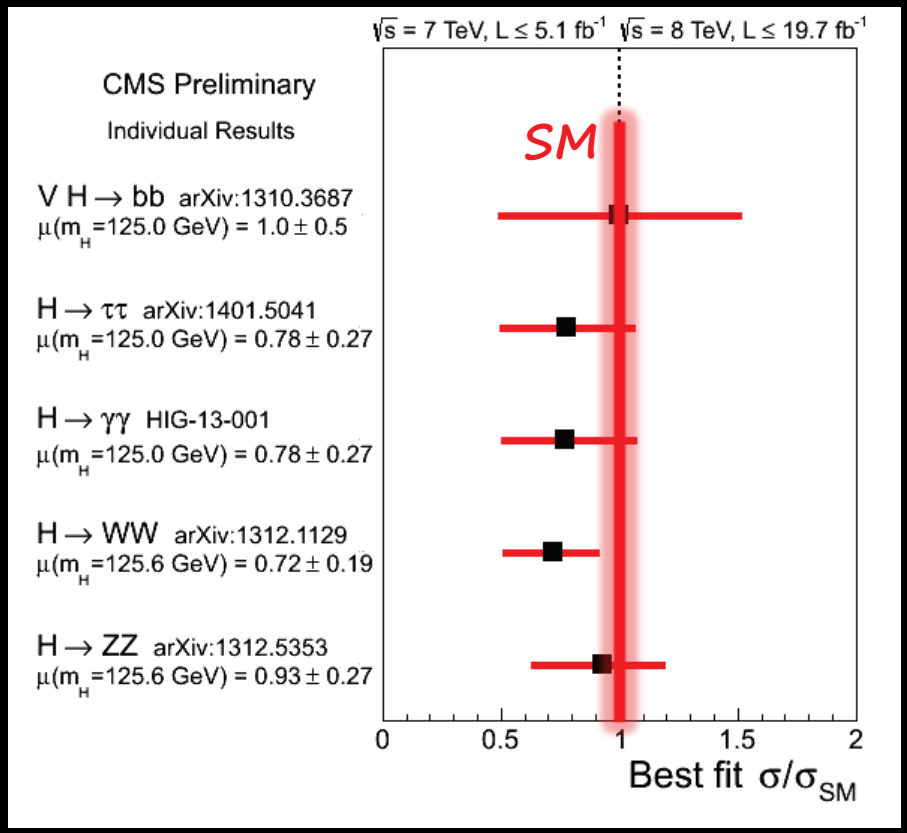
a light Higgs has been found → $W_L W_L \to W_L W_L$ unitary up to E□ TeV
which so far looks like the SM Higgs





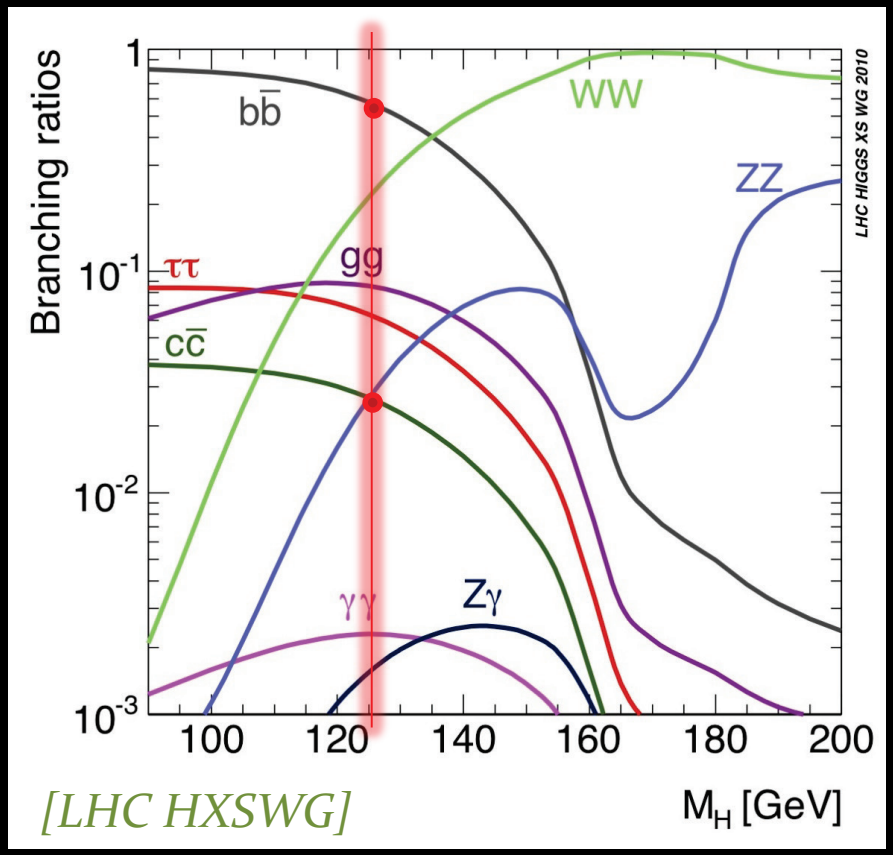
yet, a light Higgs means small couplings (*e.g.* $y_b^{SM}=0.02$)
so there is *a priori* plenty of room for relatively large BSM effects,
for instance in its coupling to fermions.

This talk = implications of an enhanced $hc\bar{c}$ coupling

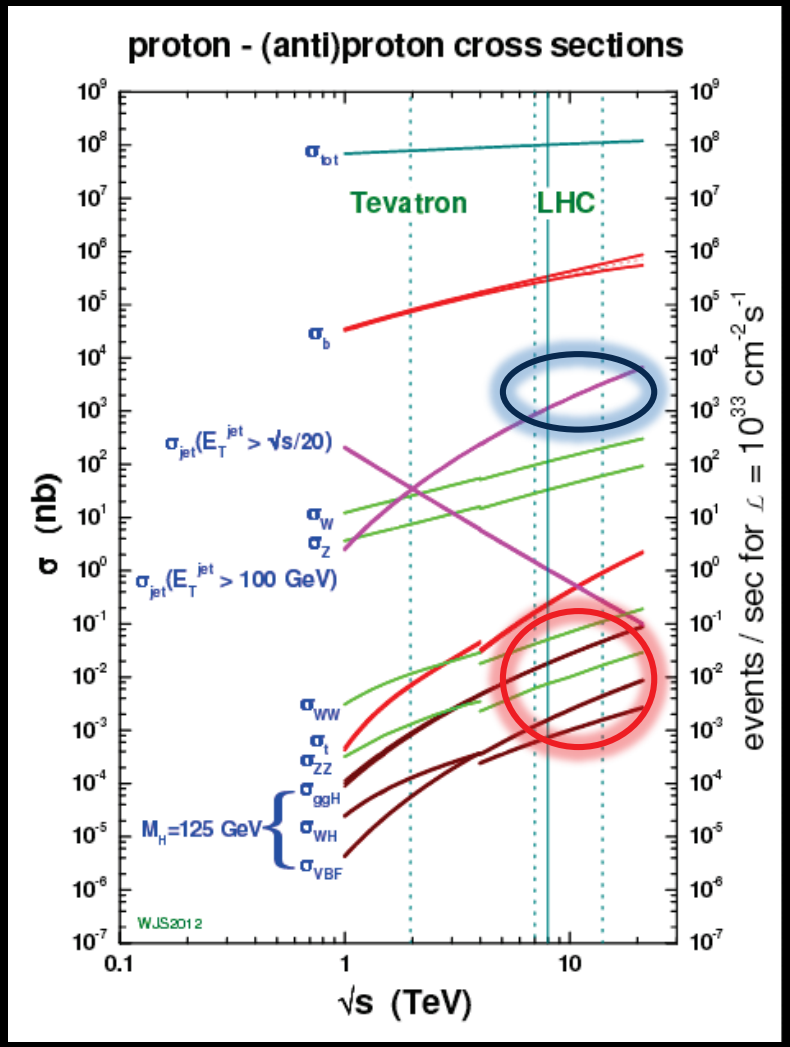
→ "charming the Higgs"

Common lore: $H \to cc$ *within the SM* is not visible @LHC:

- $\mathrm{BR}(H \to cc) \sim \frac{m_c^2}{m_b^2}\ \mathrm{BR}(H \to bb) \sim 1/16 \times 60\% \sim 4\%$
- hard to resolve charm jets
  → huge QCD dijet bkg



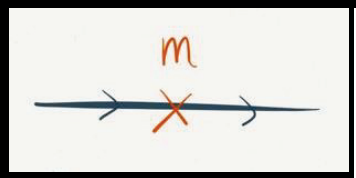
[LHC HXSWG]



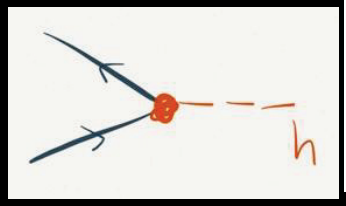
but there is hope as:

- *Hcc* cpl. could be significantly larger due to BSM physics:

$$\mathcal{L}_{\rm EFT} \supset \lambda^u_{ij}\bar{Q}_i\tilde{H}U_j + \frac{g^u_{ij}}{\Lambda^2}\bar{Q}_i\tilde{H}U_j\left(H^\dagger H\right) + \text{h.c.}$$



$$= \frac{v}{\sqrt{2}}\left(\lambda^u_{ij} + g^u_{ij}\frac{v^2}{2\Lambda^2}\right),$$



$$= \frac{1}{\sqrt{2}}\left(\lambda^u_{ij} + 3g^u_{ij}\frac{v^2}{2\Lambda^2}\right).$$

$$\Lambda \simeq \frac{44\,\text{TeV}}{\sqrt{c_c - 1}}\,.$$

Hcc enhancement

yet, modulo an accidental cancellation of o(1/few)

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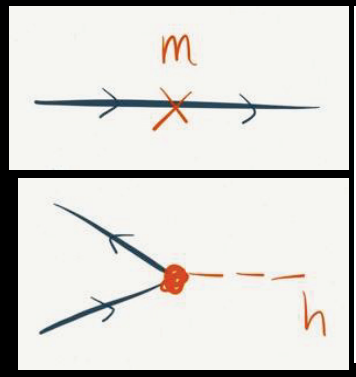

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- a method was recently put forward to tag c-jets at the LHC

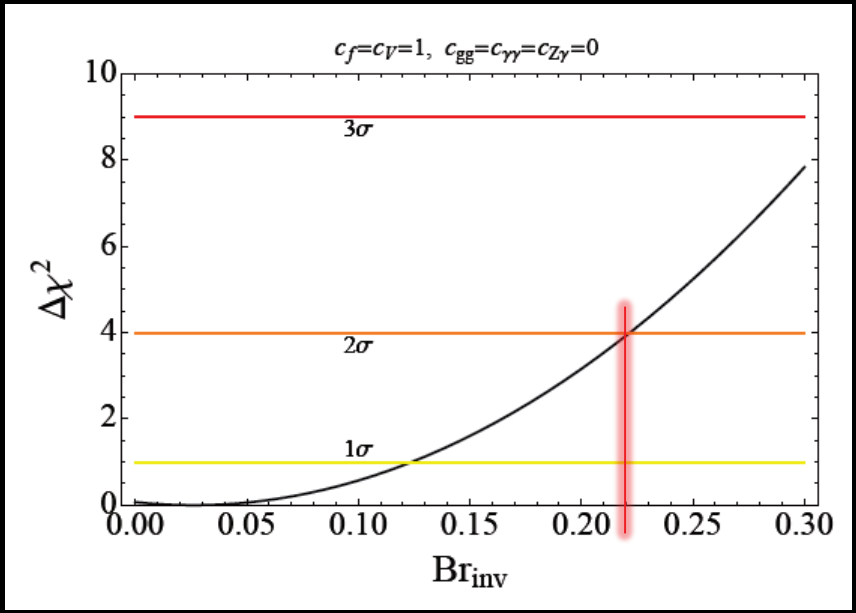
[ATLAS-CONF-2013-068]

medium working point: 20% efficiency w/ 1/5, 1/140, 1/10 rejection for b,QCD,τ-jets

(*loose* point: 95% efficiency w/out significant rejection power for fakes.)

What's the sensitivity to larger charm coupling in Higgs data?

- indirectly constrained through the invisible width:



[Falkowski-Riva-Urbano '13]

if all other "visible/tagged" couplings set to their SM values:

$Br_{inv} \lesssim 22\%$ @95%CL

adding a new physics (>0) source of ggh: $Br_{inv} \lesssim 50\%$ @95%CL

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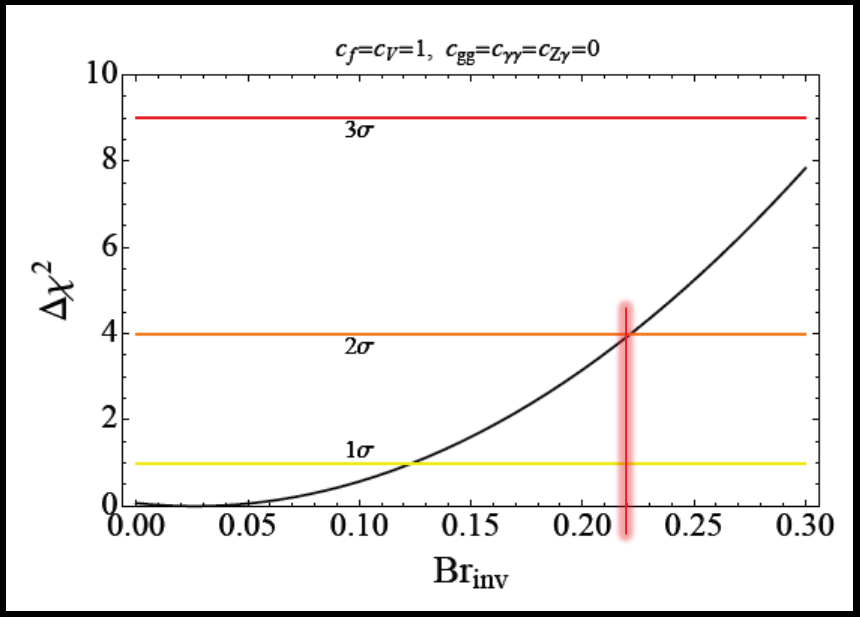

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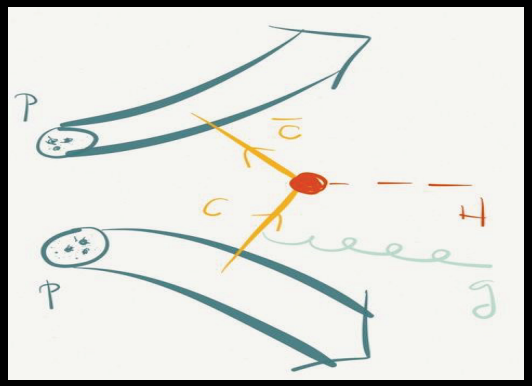
[Falkowski-Riva-Urbano '13]

- charm fusion opens up as a significant H prod. mechanism



@NLO: $\sigma_{cc} \approx 0.003\ \sigma_{gg}$ in the SM

~20% increase* in $\sigma_{pp\to h}$ if Hcc 4 times larger

** effect in charm loop is largely subdominant*

What's the sensitivity to larger charm coupling in Higgs data?

we perform a global Higgs fit within the EFT framework*:

$$\mathcal{L} = \frac{1}{2}\partial_\mu h\,\partial^\mu h - \frac{1}{2}m_h^2 h^2 - c_3\frac{1}{6}\left(\frac{3m_h^2}{v}\right)h^3 + \dots$$

$$+ m_W^2\, W_\mu^+ W^{-\mu}\left(1 + 2c_W\frac{h}{v} + \dots\right) + \frac{1}{2}m_Z^2\, Z_\mu Z^\mu\left(1 + 2c_Z\frac{h}{v} + \dots\right)$$

$$- \sum_{\psi=u,d,l} m_{\psi^{(i)}}\,\bar{\psi}^{(i)}\psi^{(i)}\left(1 + c_\psi\frac{h}{v} + \dots\right) + \dots$$

$$\mathcal{L}_{(2)} = -\frac{h}{4v}\left[2c_{WW}W^\dagger_{\mu\nu}W^{\mu\nu} + c_{ZZ}Z_{\mu\nu}Z^{\mu\nu} + 2c_{Z\gamma}A_{\mu\nu}Z^{\mu\nu} + c_{\gamma\gamma}A_{\mu\nu}A^{\mu\nu} - c_{gg}G^a_{\mu\nu}G^{a,\mu\nu}\right],$$

$SU(2)_V$ custodial symmetry, h = custodial singlet, $c_Z = c_W = c_V$

*we follow fit procedure of *[Falkowski-Riva-Urbano '13]*

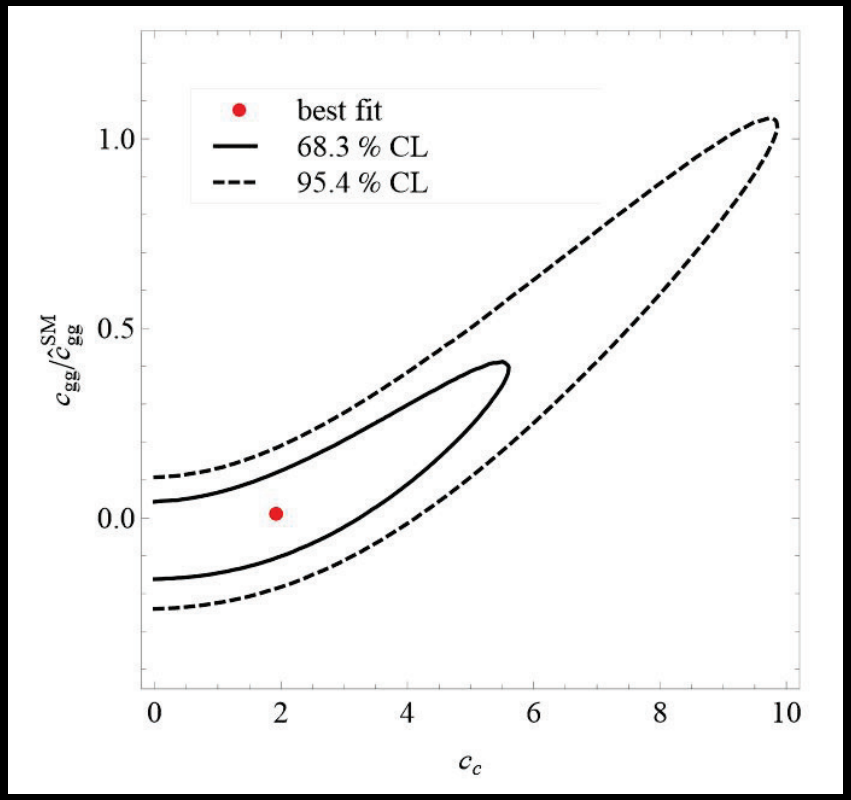
What's the sensitivity to larger charm coupling in Higgs data?

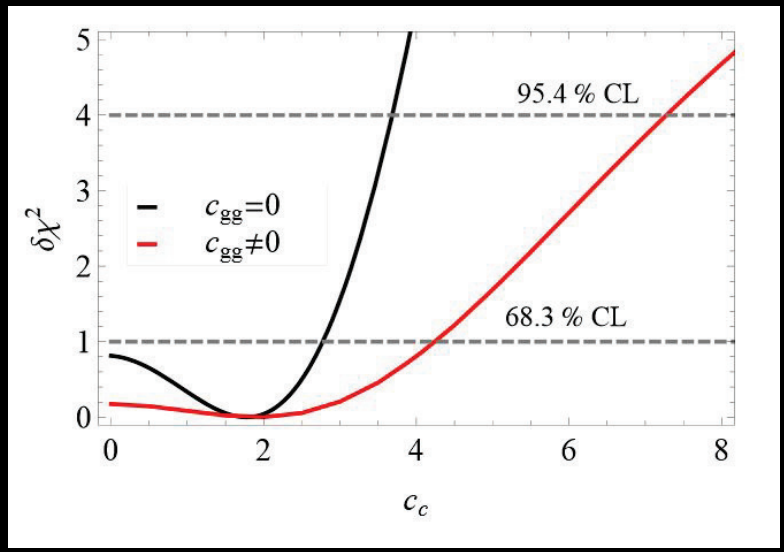
we perform a global Higgs fit within the EFT framework*:

only allowing c_c to float: $c_c \lesssim 4$ @2σ

allowing a new physics source in ggh: $c_c \lesssim 7$ @2σ

a fairly large coupling allowed by Higgs data





*we assume similar cut efficiencies for cc and gg fusion

This yields significant change $(V)H\to bb$ channel:

BR($H\to bb$) is significantly suppressed:

$$\frac{\mathrm{BR}_{h\to b\bar{b}}}{\mathrm{BR}^{\mathrm{SM}}_{h\to b\bar{b}}} = \left[1+(|c_c|^2-1)\mathrm{BR}^{\mathrm{SM}}_{h\to c\bar{c}} + \left(\left|\frac{c_{gg}}{\hat{c}^{\mathrm{SM}}_{gg}}+1\right|^2-1\right)\mathrm{BR}^{\mathrm{SM}}_{h\to gg}\right]^{-1}$$

$\approx$ 70% (40%)

with $c_{gg}>0$

but most charm fusion events rejected after VH-enriching cuts:

$\rightarrow$ $\mu_{bb} \approx 0.74\ (0.40)$ @8TeV

with $c_{gg}>0$

large part of bb signal expected @ATLAS/CMS could be lost!

in the benefit of charm...

now, one can use charm tagging technique to capture $H \to cc$:

build cc-enriched bb signal = *"charming the Higgs"*:

$$\mu_{b\bar{b}+c\bar{c}} \equiv \frac{\sigma_{pp\to h}\left(\epsilon_b^2 \mathrm{BR}_{h\to b\bar{b}} + \epsilon_c^2 \mathrm{BR}_{h\to c\bar{c}}\right)}{\sigma_{pp\to h}^{\mathrm{SM}}\left(\epsilon_b^2 \mathrm{BR}_{h\to b\bar{b}}^{\mathrm{SM}} + \epsilon_c^2 \mathrm{BR}_{h\to c\bar{c}}^{\mathrm{SM}}\right)}$$

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assume ATLAS' *medium working point* w/ ε_c=20% efficiency, and ε_b=70% for b-tagging efficiency:

→ $\mu_{bb+cc} \approx 0.78\ (0.49)$

only marginal fraction of lost signal recovered

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assume instead a prospective ε_c=40% c-tagging efficiency:

→ $\mu_{bb+cc} \approx 0.9\ (0.75)$

large fraction recovered, almost back to bb SM rate!

Conclusions

- the observed Higgs boson appeared Standard so far.
- yet, there is still room for significant BSM corrections
  even for new dynamics >~TeV scale