

Higgs Underproduction @ LHC

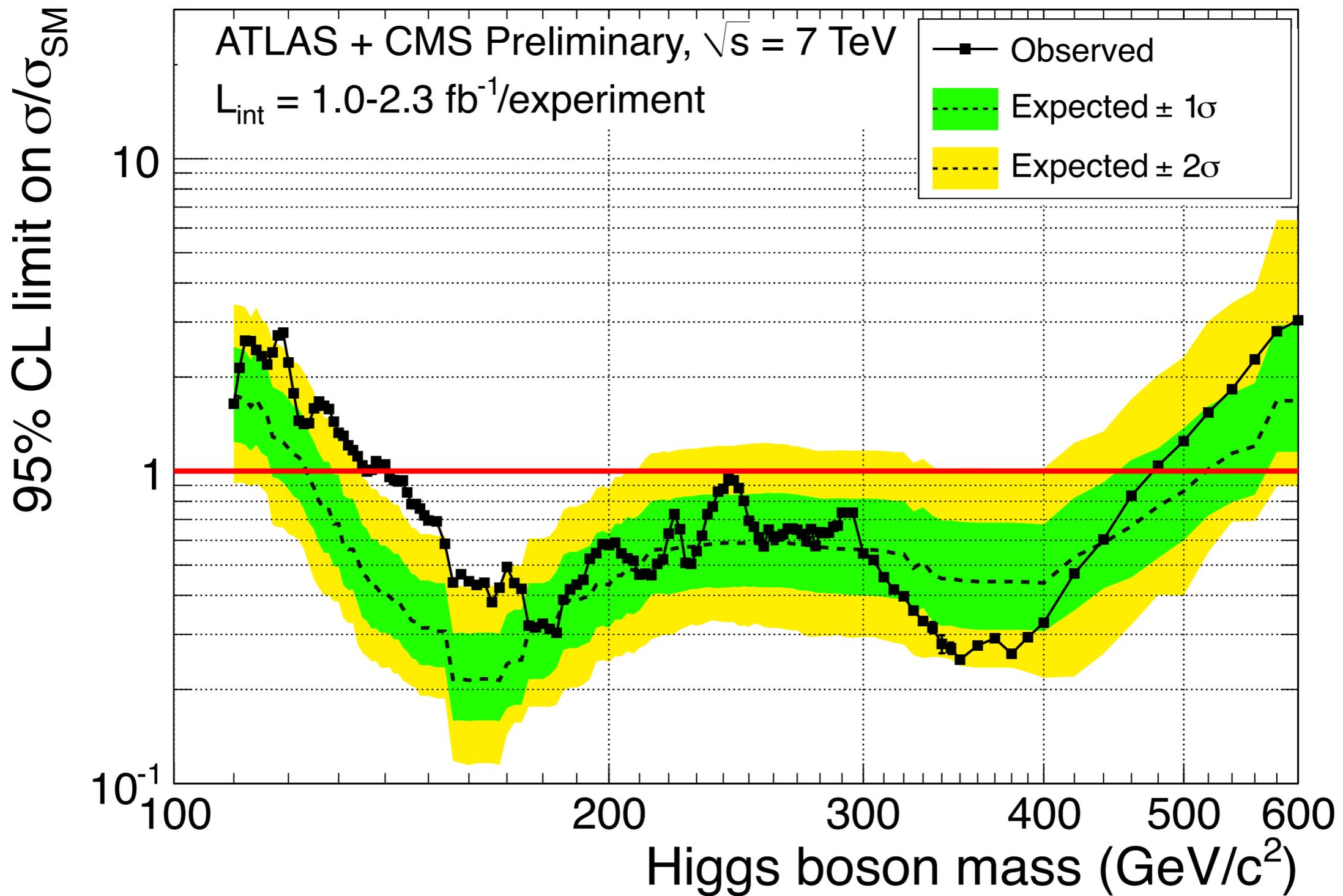
Graham Kribs

University of Oregon

w/ Bogdan Dobrescu & Adam Martin

[1112.2208]

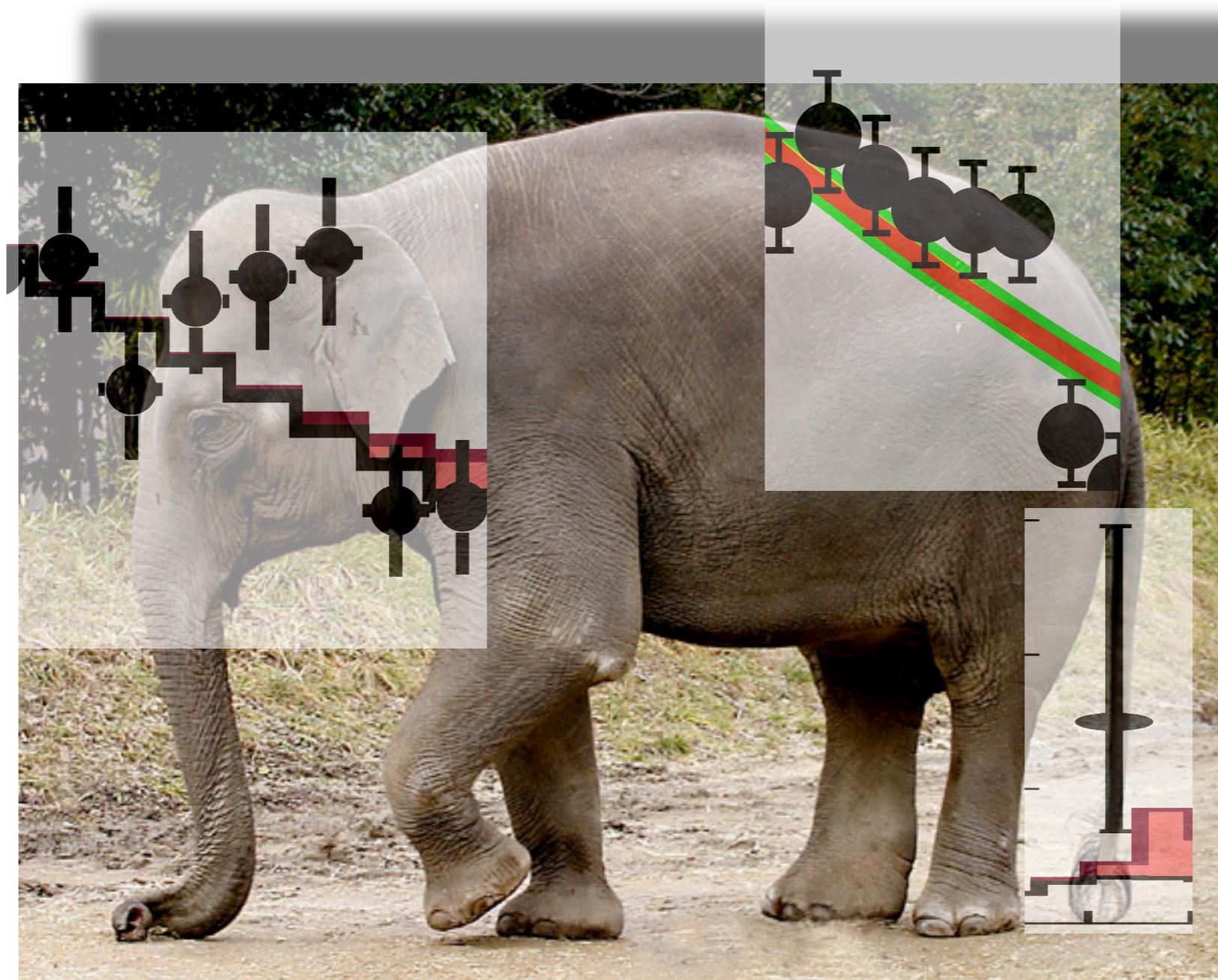
HCP



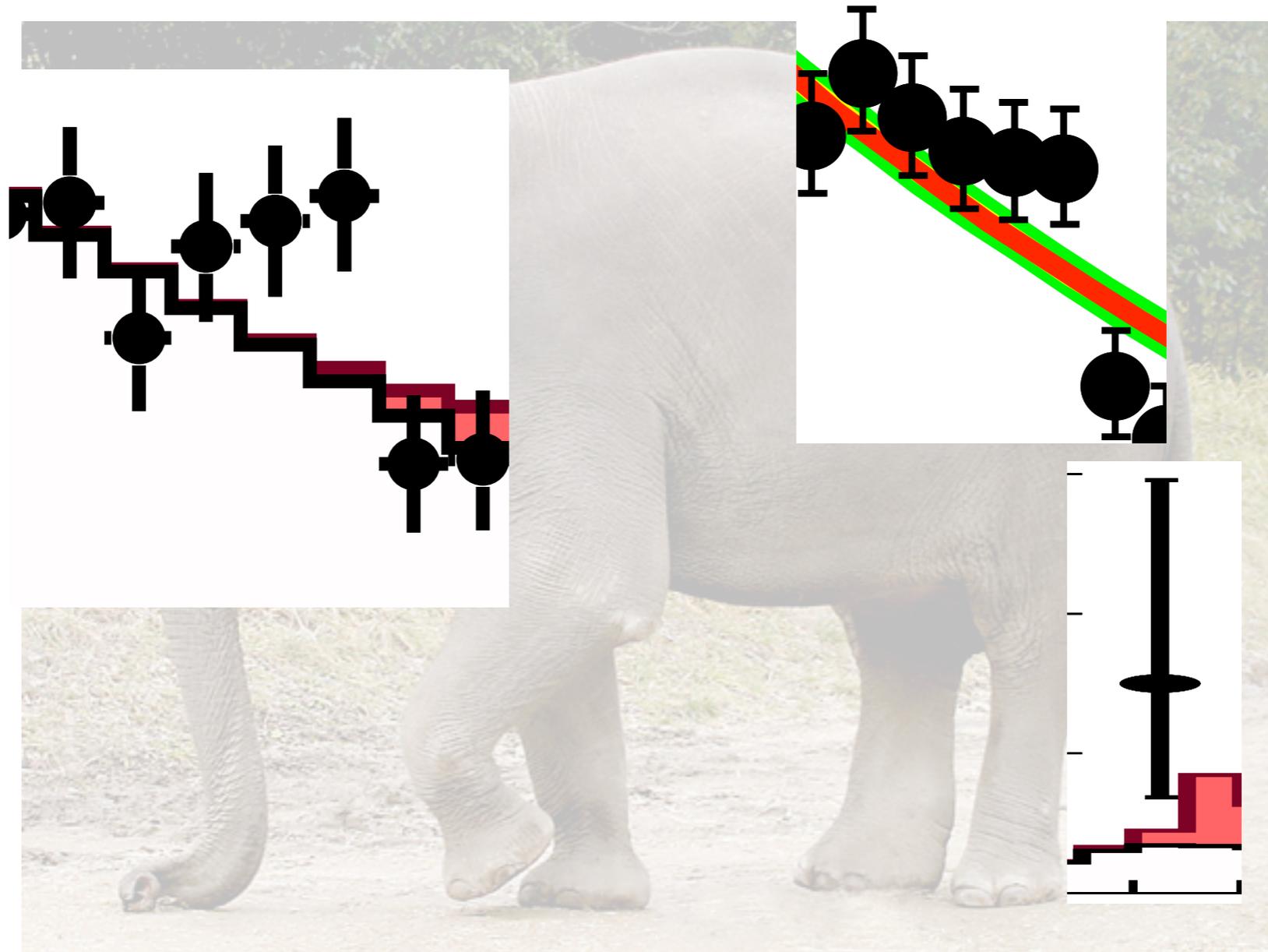
Dec 13...



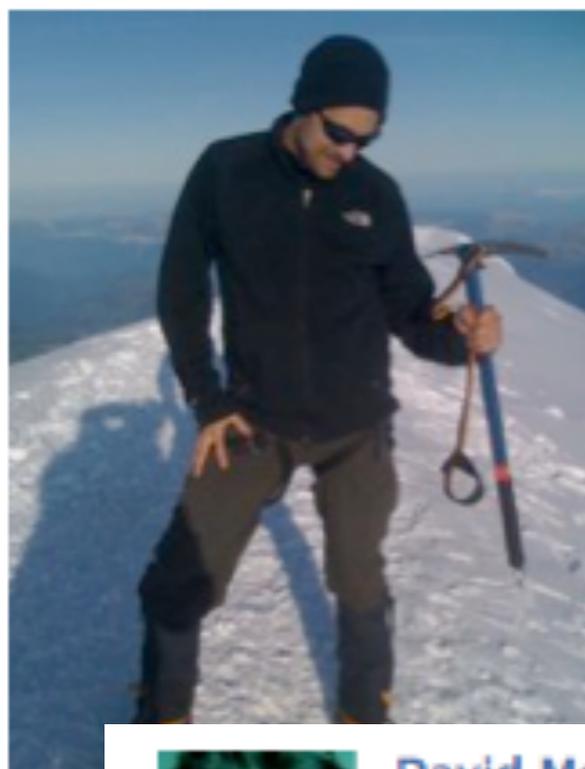
Dec 13...



Dec 13...



What to make of this?



Graham Kribs

♥ Married to Tracy Kribs Born on December 13 Add where you work Add your school Edit Profile



Update Status Add Photo / Video

What's on your mind?



David Morrissey

Happy birthday, and see you tomorrow!

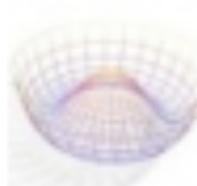
Like · Comment · See Friendship · Monday at 9:25pm



Ann Nelson

Happy Birthday! did you ask for 125 GeV?

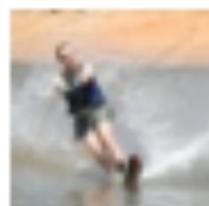
Like · Comment · See Friendship · Tuesday at 5:40am



Kyle Cranmer

Happy birthday, I got you a boson too.

Like · Comment · See Friendship · Tuesday at 1:14pm near New York, NY



John Conway

Your present will have to wait a year, sorry.

Like · Comment · See Friendship · Tuesday at 3:37pm

Hiding the Higgs

Hiding the Higgs



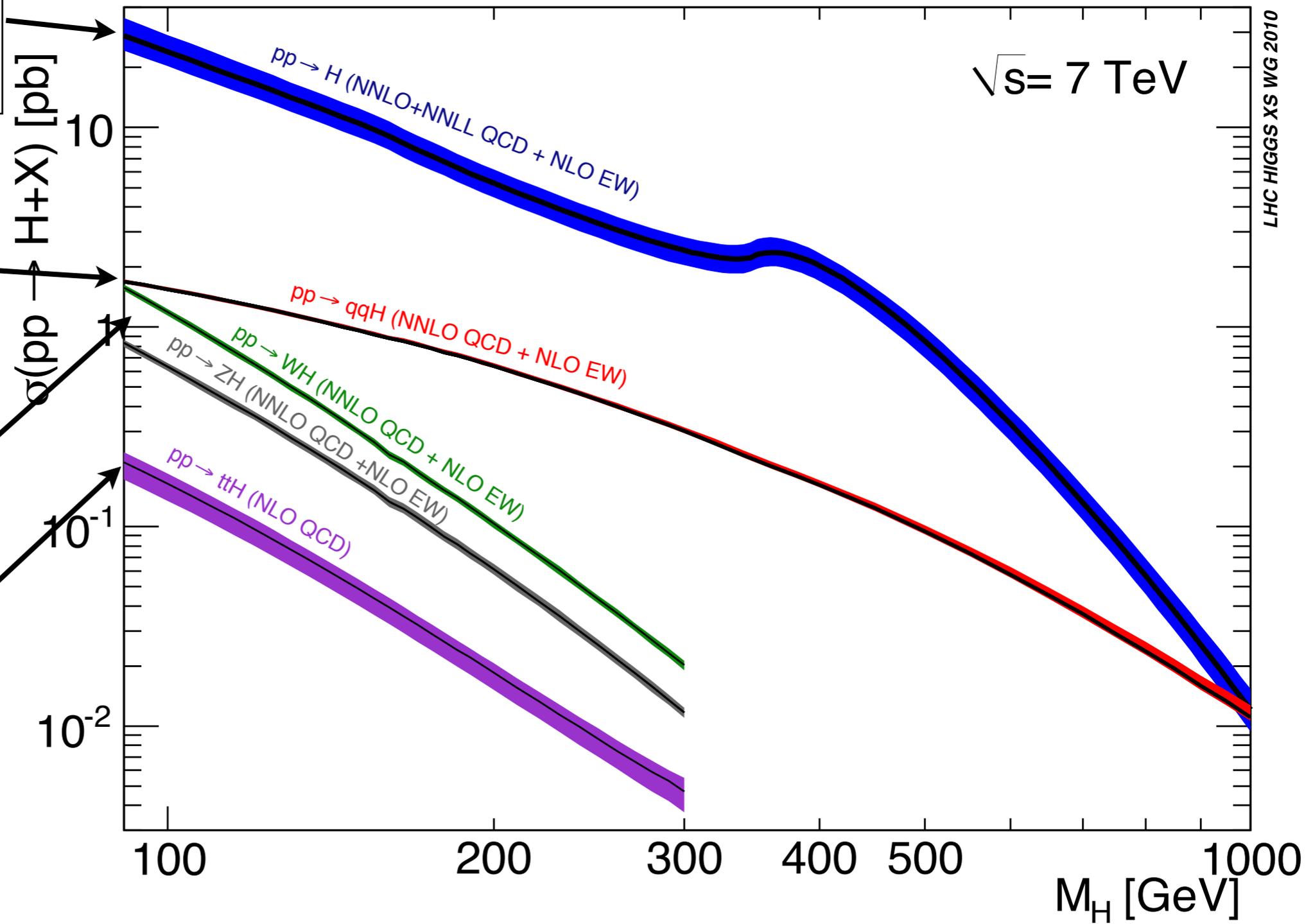
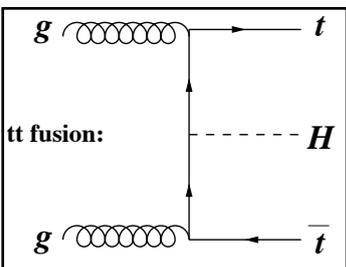
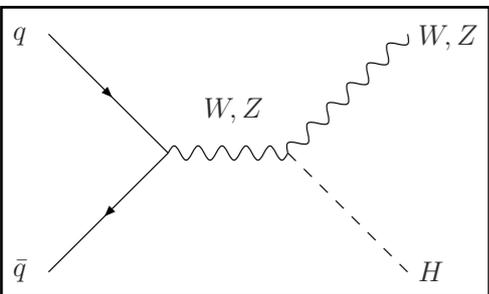
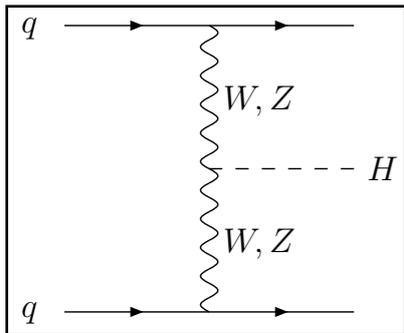
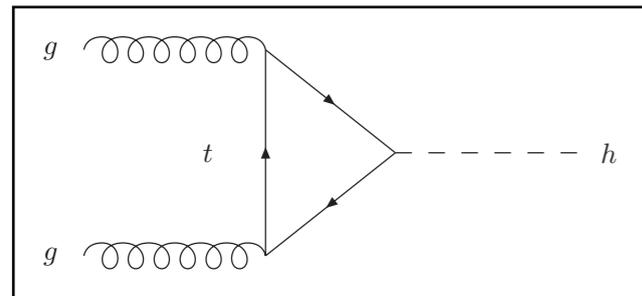
photos.com

How effective can
new physics
hide the Higgs at LHC?

Focus on **reduction** of Higgs cross section.

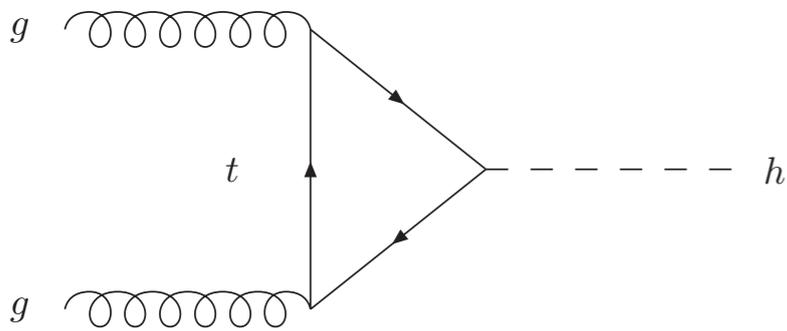
Wide range of Higgs masses
become “re”viable.

σ @ LHC 7 TeV



Gluon Fusion Higgs Production

Gluon Fusion



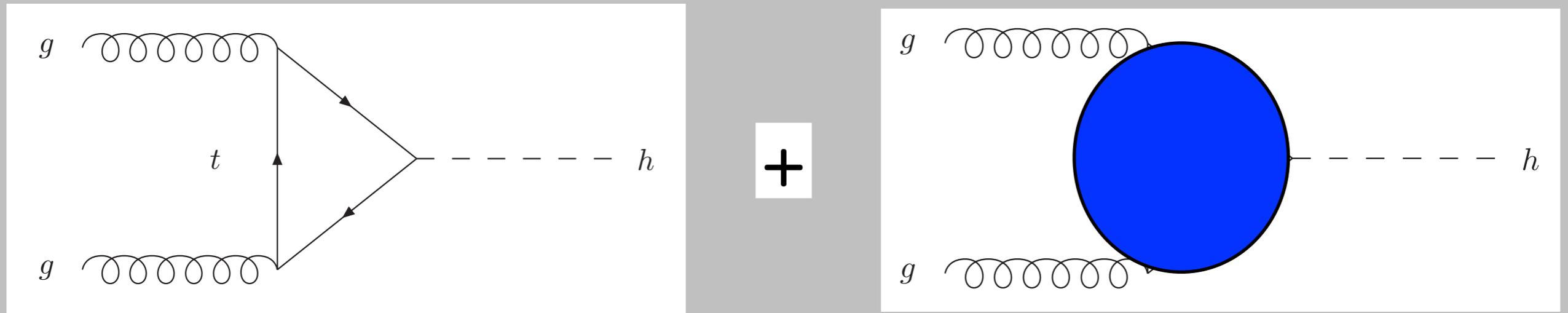
Dominantly top loop.

“Indirect”

- SM tth coupling

- no other loop contributions

Decreasing Production



Many Implementations ...

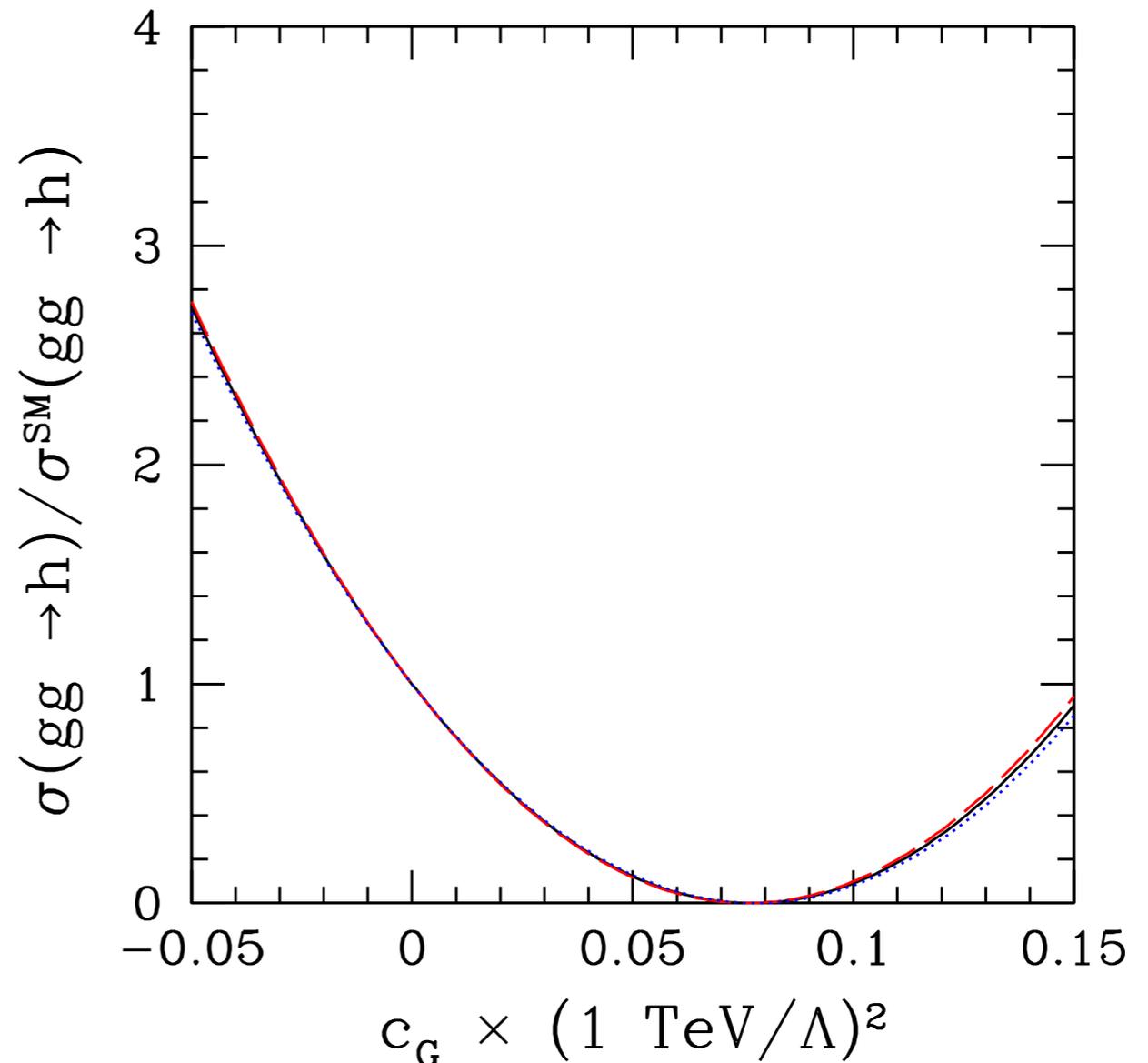
- cutoff operators (Manohar-Wise)
- “fermiophobic” (also affects decays)
- “gluophobic” MSSM (e.g., Djouadi)
- composite Higgs (e.g. Low-Rattazzi-Vechi)

Operators

Manohar & Wise emphasized **one operator**:

$$\delta\mathcal{L} = -\frac{c_G g_3^2}{2\Lambda^2} H^\dagger H G_{\mu\nu}^A G^{A\mu\nu}$$

Completely changes
gluon fusion rate:

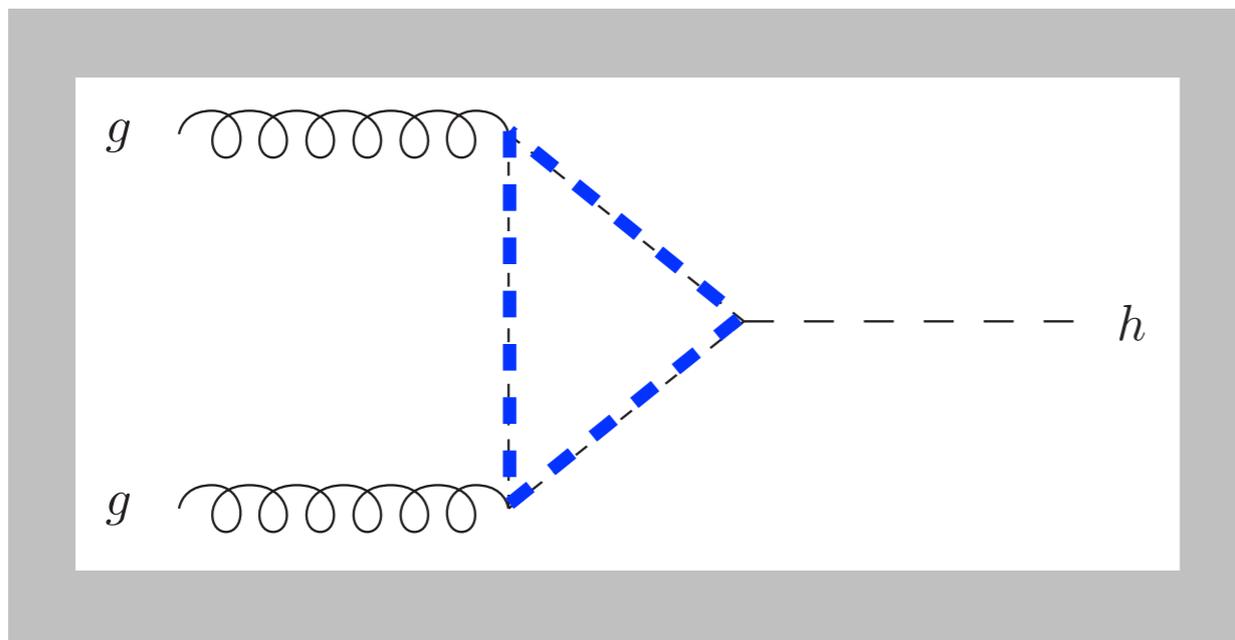


Colored Scalars

What generates this

$$\delta\mathcal{L} = -\frac{c_G g_3^2}{2\Lambda^2} H^\dagger H G_{\mu\nu}^A G^{A\mu\nu}$$

and (virtually) nothing else?



Scalars
transforming
only under QCD.

Class of Models

One or more colored scalars in some representations of QCD.

See also
Y. Bai's talk

Our working example, consider real scalar octet S_a with interactions:

$$\frac{1}{2}(D_\mu S_a)^2 - \frac{1}{2}M_S^2 S_a S^a - \frac{\kappa}{2}H^\dagger H S_a S^a - \frac{\omega_S}{4}(S_a S^a)^2$$

“Higgs portal”

self quartic

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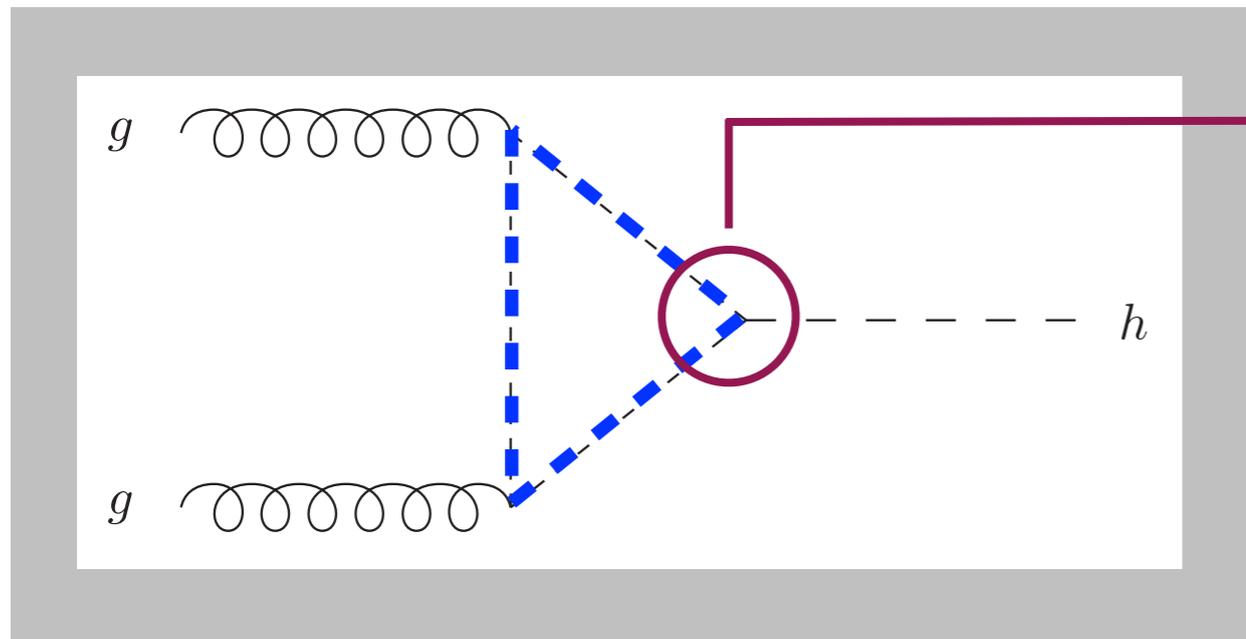
“Higgs portal”

self quartic

Operator Size

$$\delta\mathcal{L} = -\frac{c_G g_3^2}{2\Lambda^2} H^\dagger H G_{\mu\nu}^A G^{A\mu\nu}$$

Loop-induced
size:



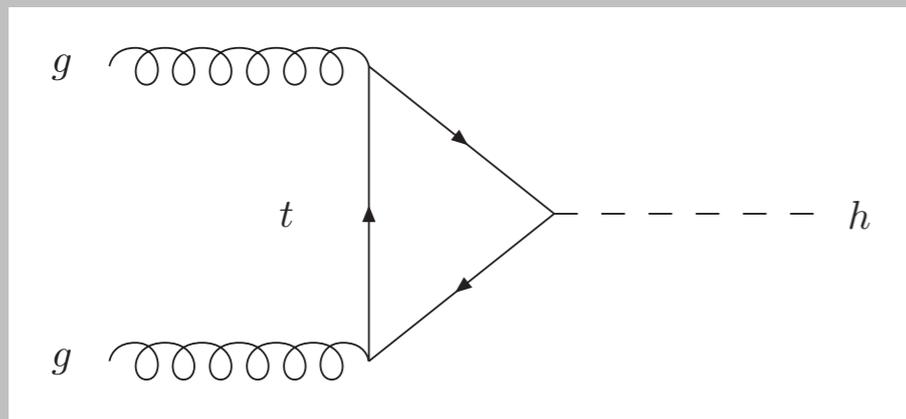
$$\approx \frac{\kappa g^3}{16\pi^2 m_S^2}$$

$$m_S \approx \Lambda / (4\pi) \approx 100 - 300 \text{ GeV}$$

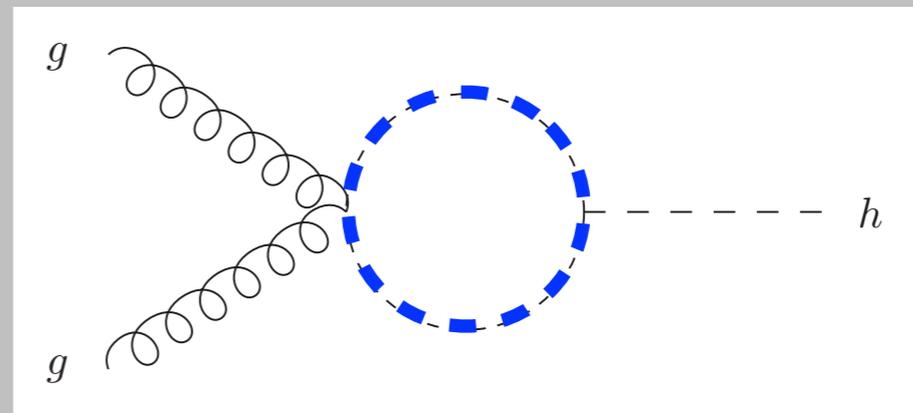
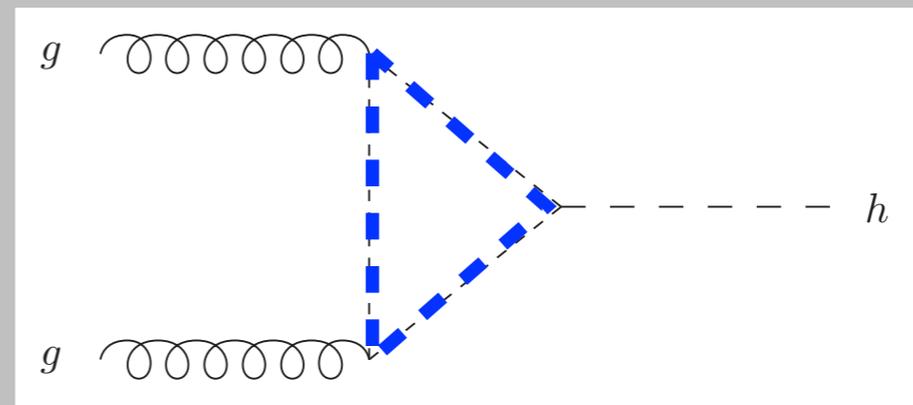
(for $-\kappa \approx 0.3 - 3$)

Higgs Production w/ Scalars

Gluon Fusion



+



Decay width hardly affected since even for light h , rate $h \rightarrow gg$ is small.

Higher Order Corrections

Boughezal & Petriello calculated higher order corrections in color octet scalar model (inf top mass limit; large logs; incl scalar quartic)

Using their results, we checked that this at most leads to a **shift** in value of κ (up to $\approx 25\%$), but does not change the underproduction result.

Interesting Regimes

1) **Small;**

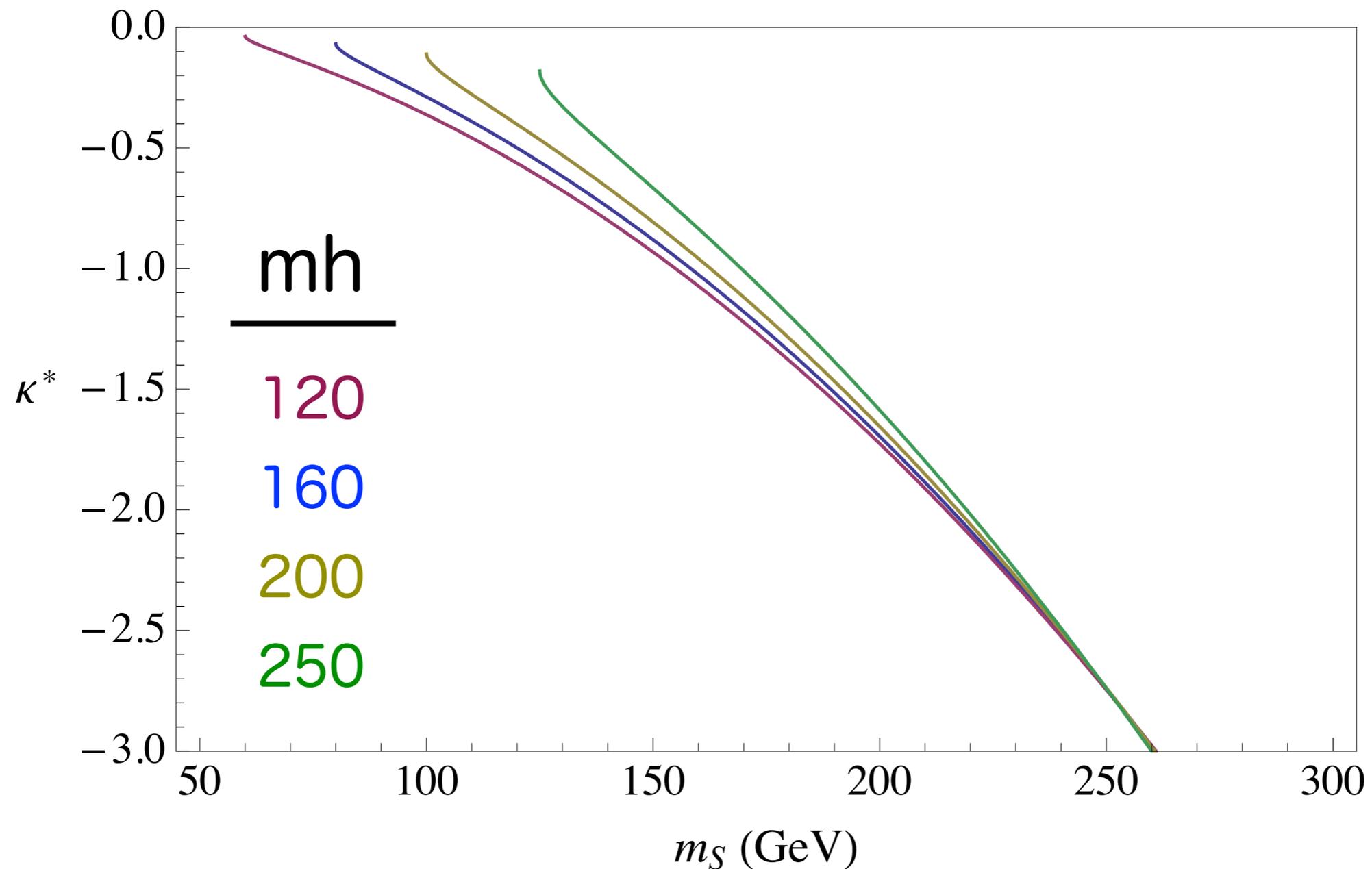
i.e., $SM > \text{gluon fusion} > \text{VBF}$

2) **Really small;**

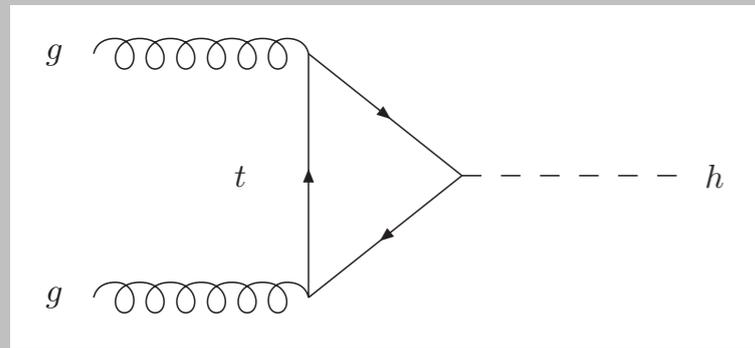
i.e., $\text{gluon fusion} < \text{VBF}$

Total Cancellation

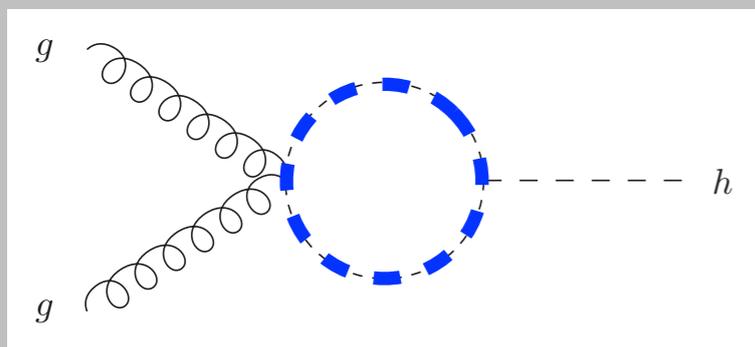
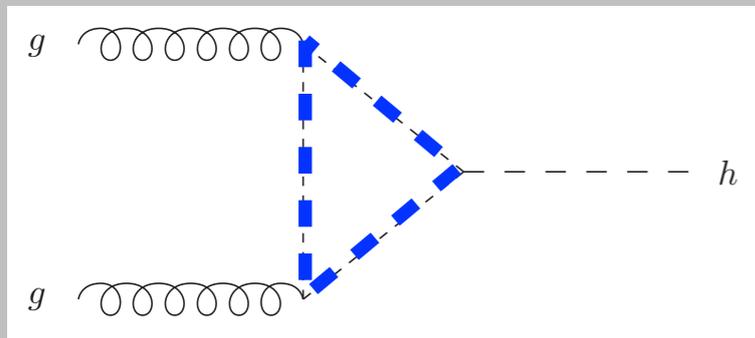
“Critical” size of κ



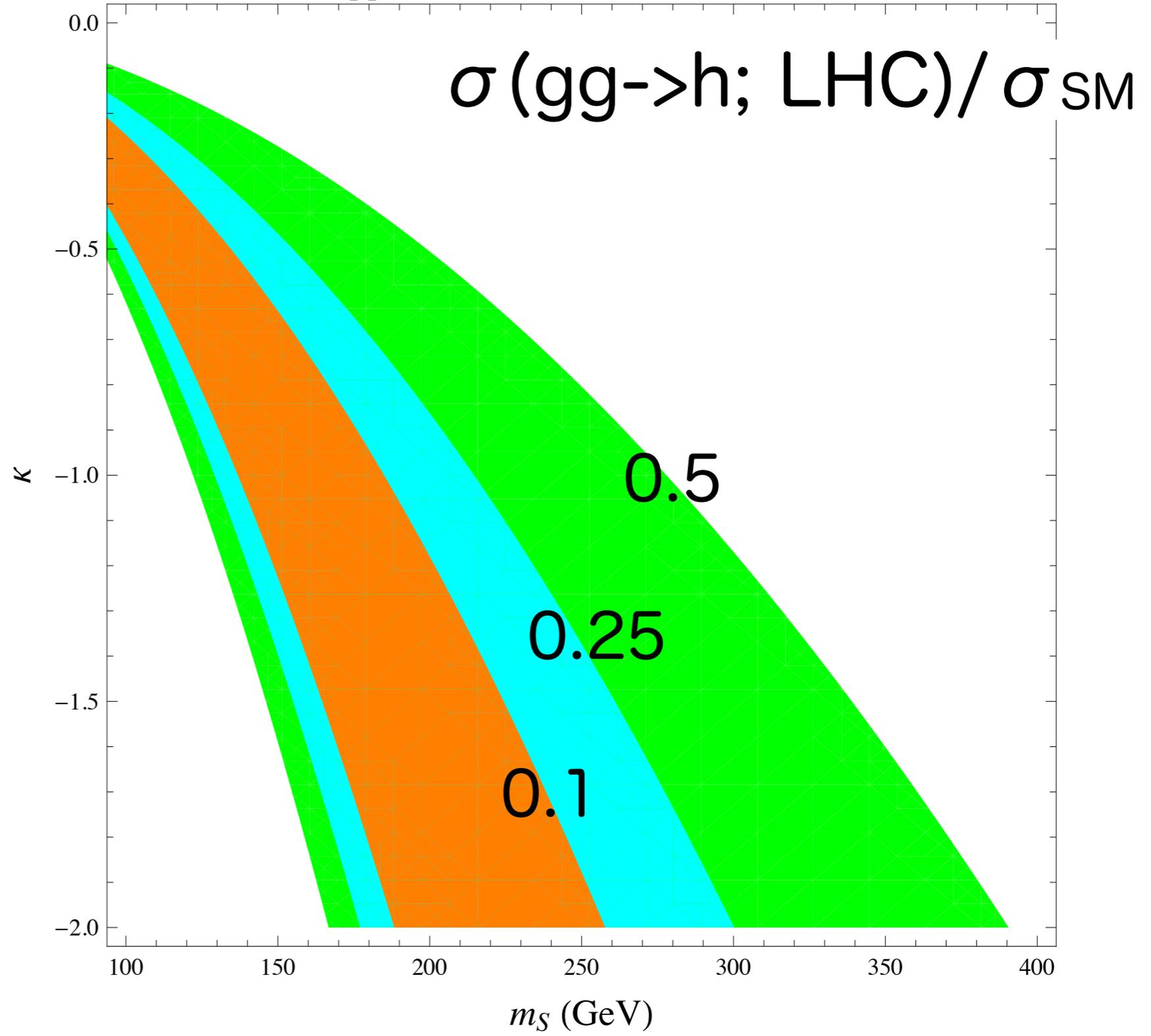
Gluon Fusion Suppression



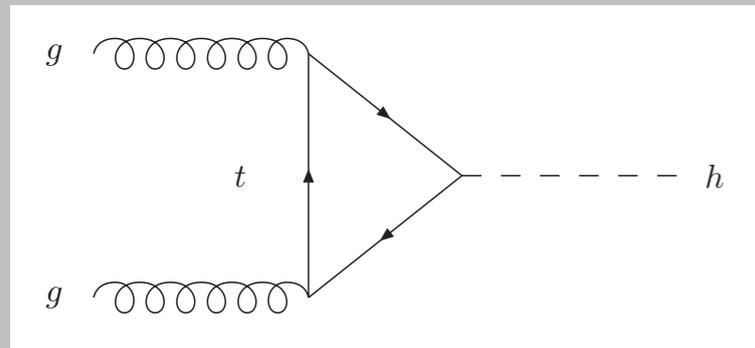
+



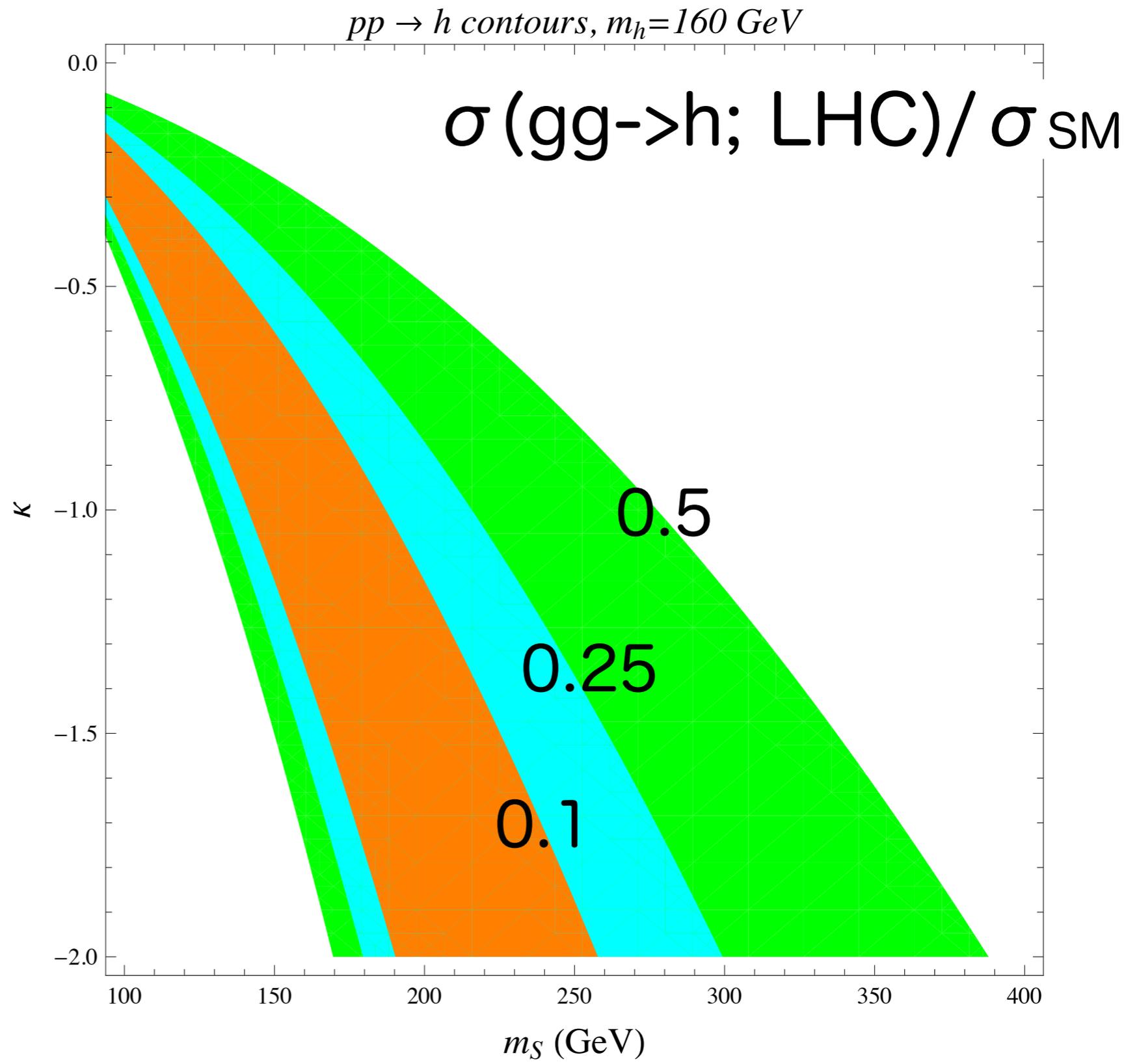
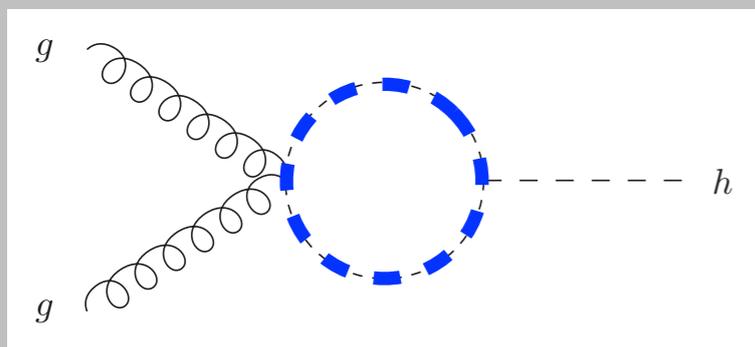
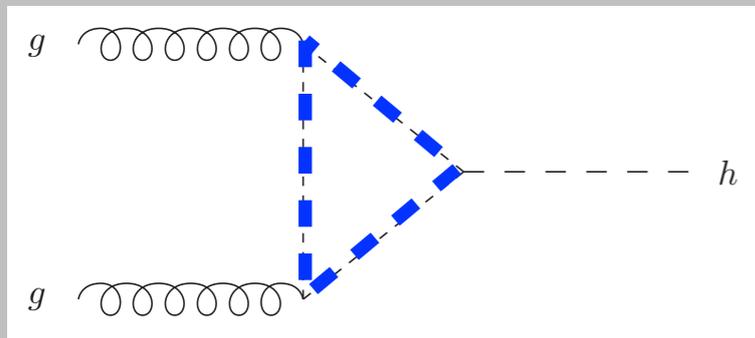
$pp \rightarrow h$ contours, $m_h = 120 \text{ GeV}$



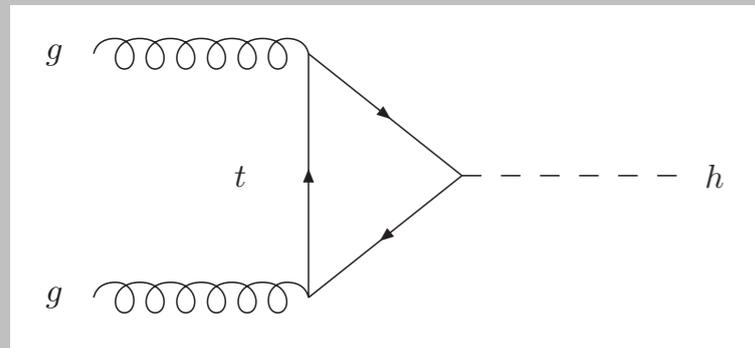
Gluon Fusion Suppression



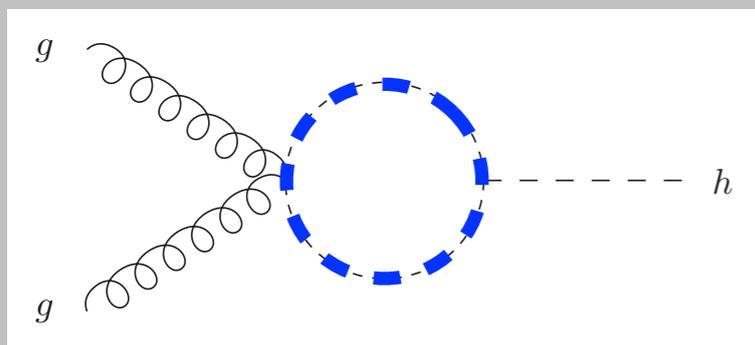
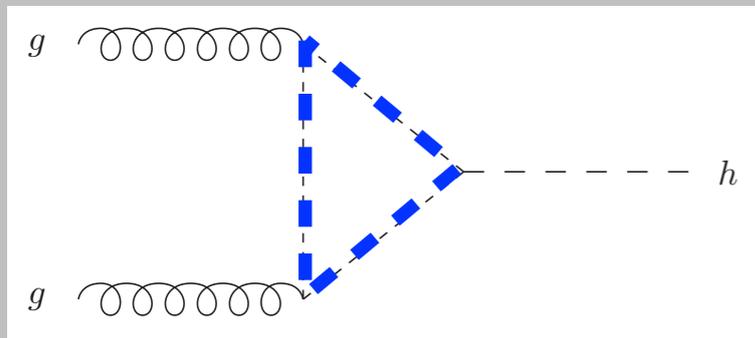
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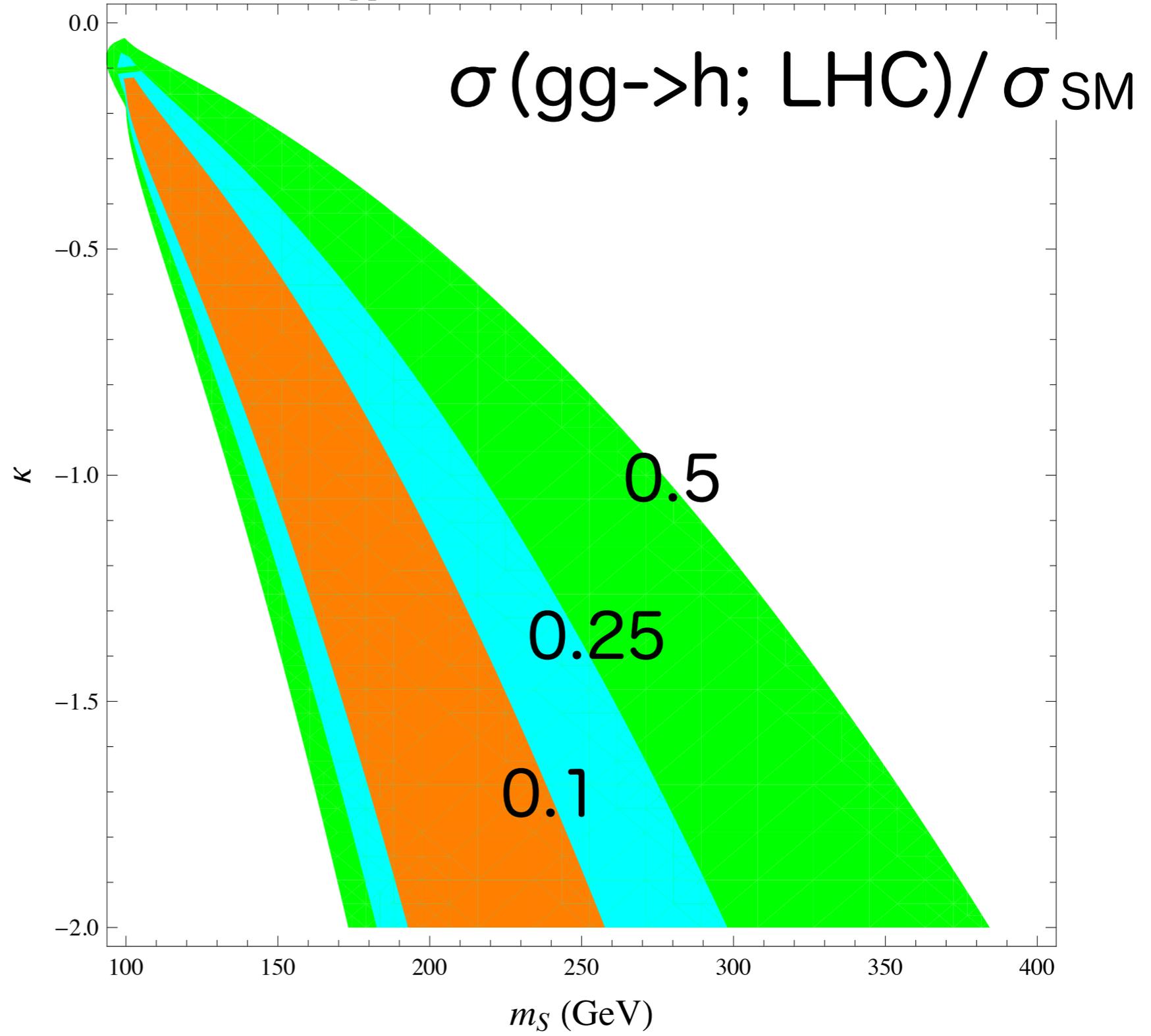
Gluon Fusion Suppression



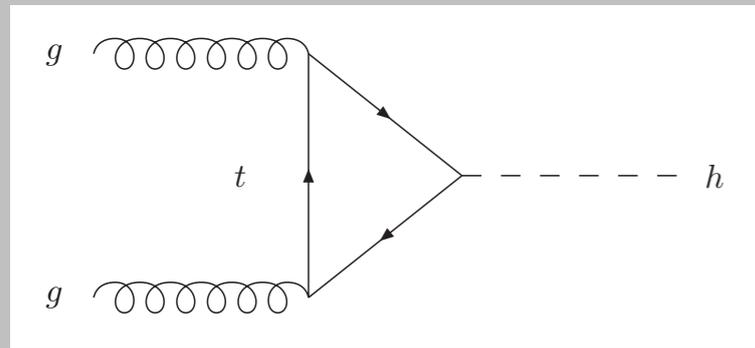
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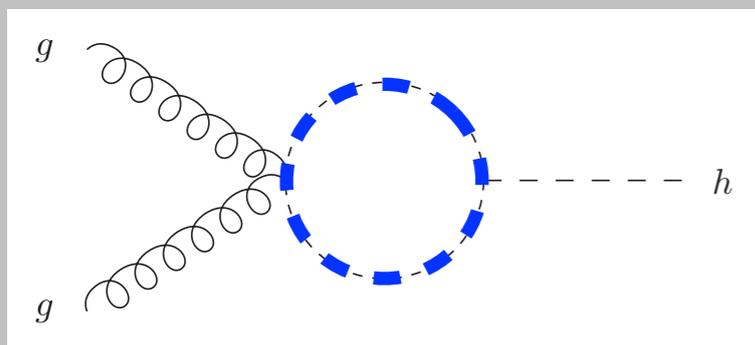
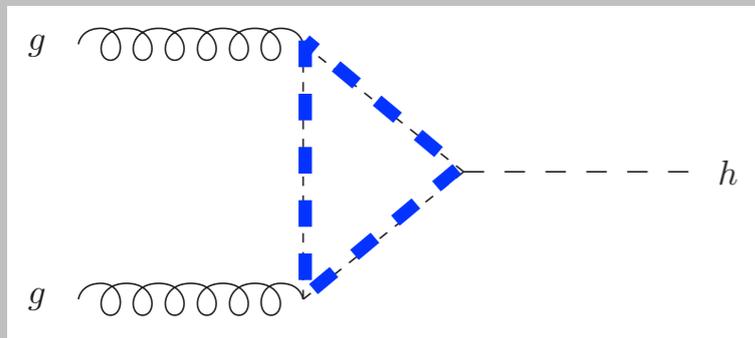
$pp \rightarrow h$ contours, $m_h=200$ GeV



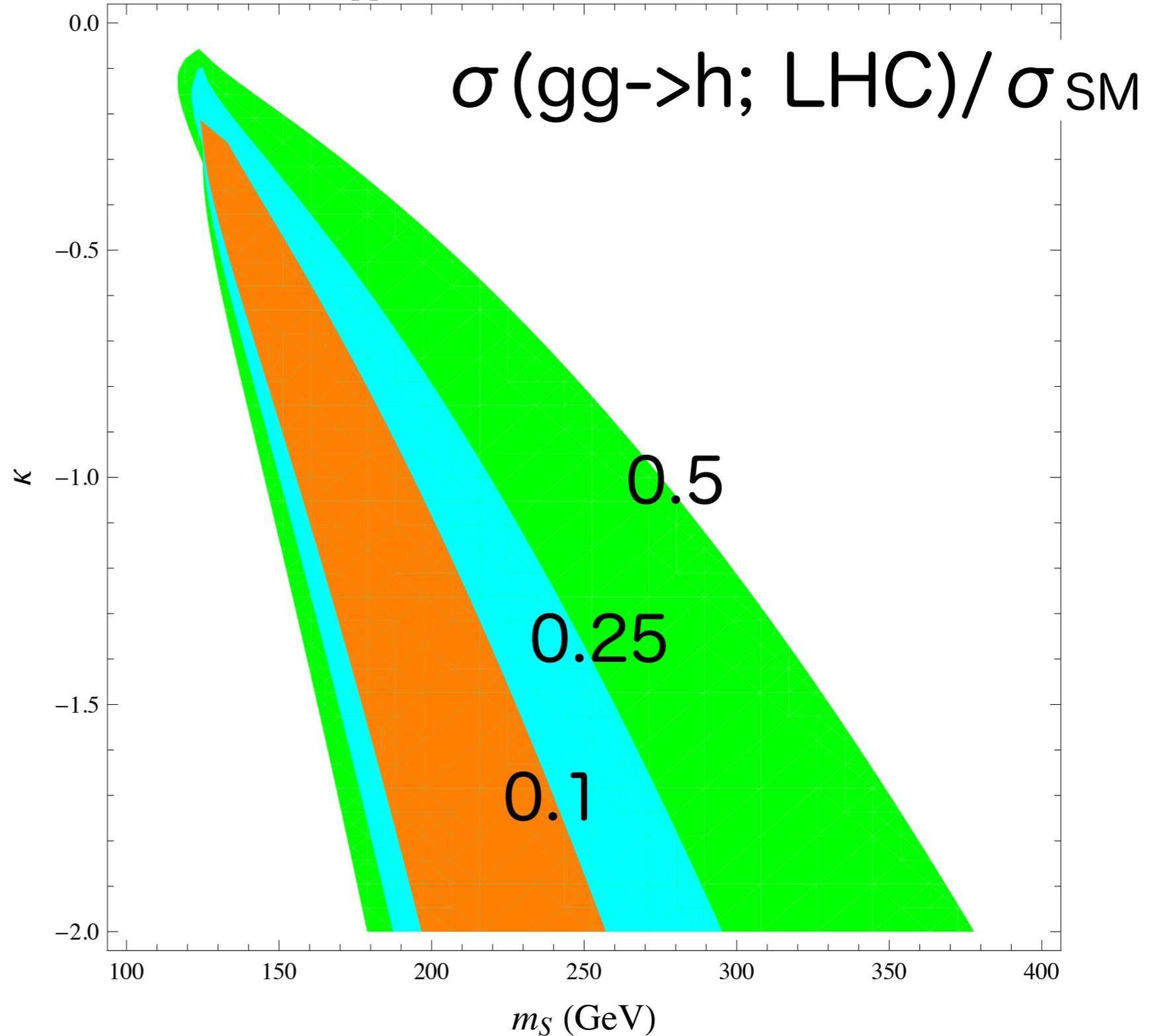
Gluon Fusion Suppression



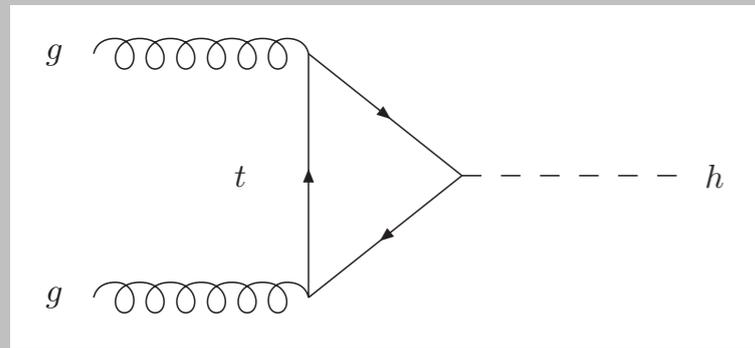
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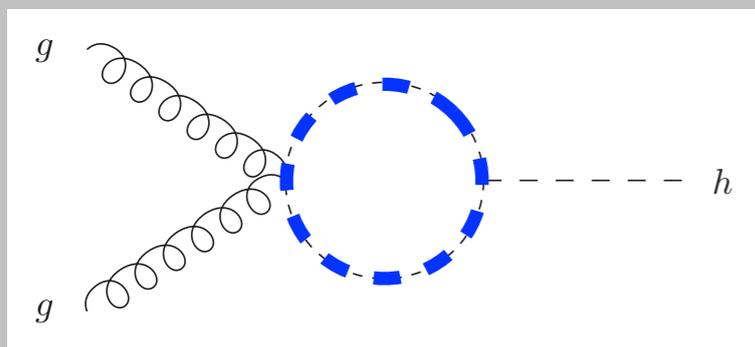
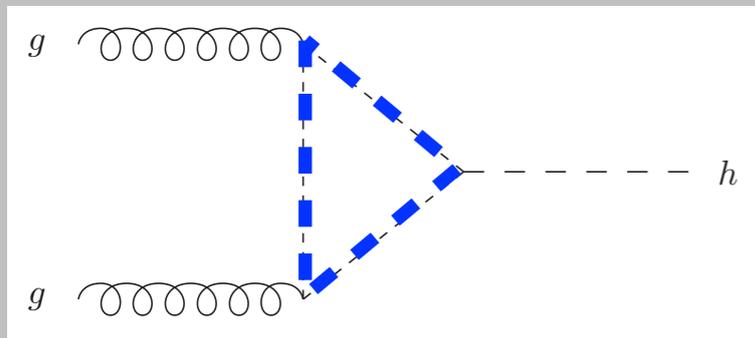
$pp \rightarrow h$ contours, $m_h = 250 \text{ GeV}$



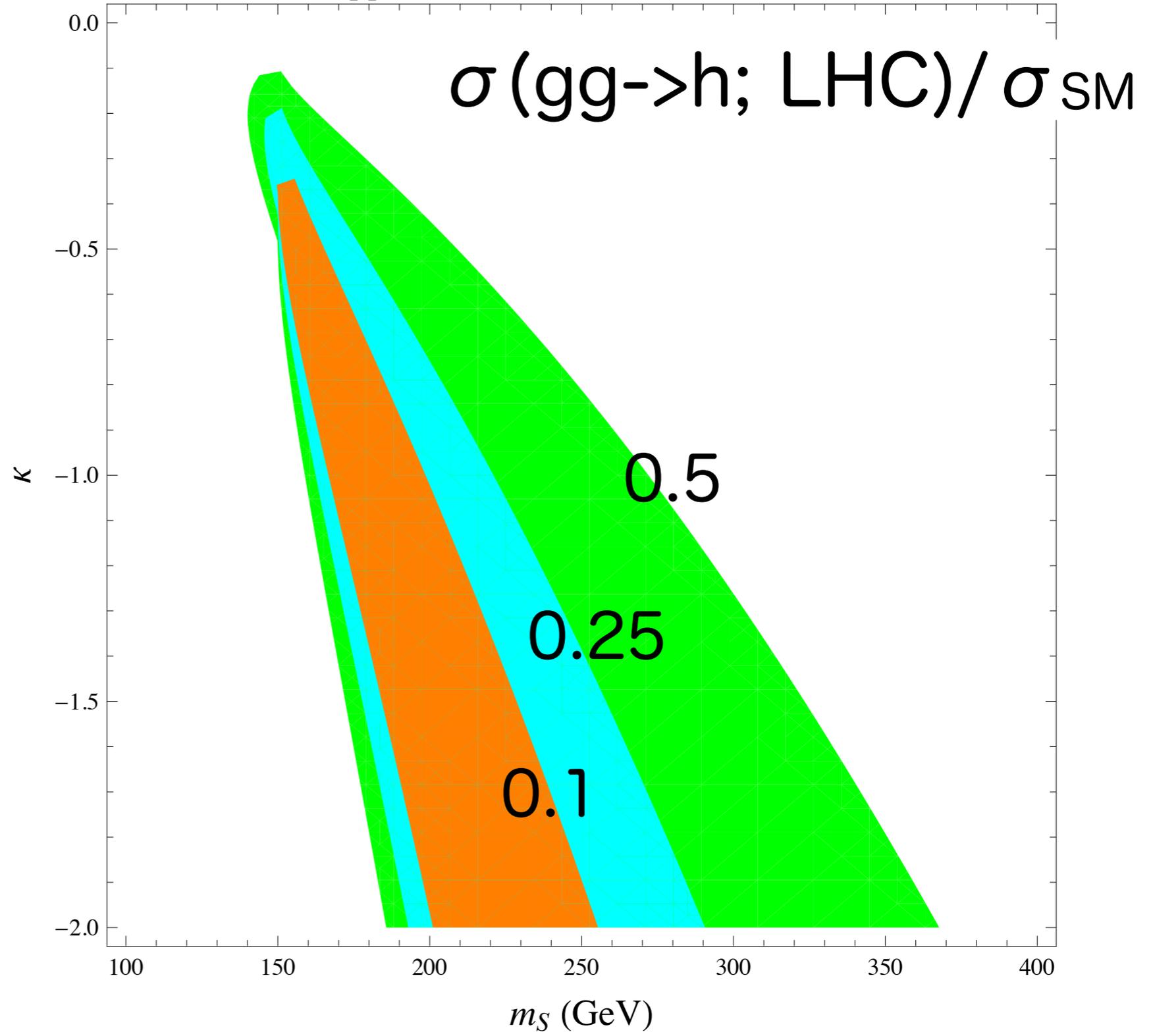
Gluon Fusion Suppression



+



$pp \rightarrow h$ contours, $m_h = 300 \text{ GeV}$



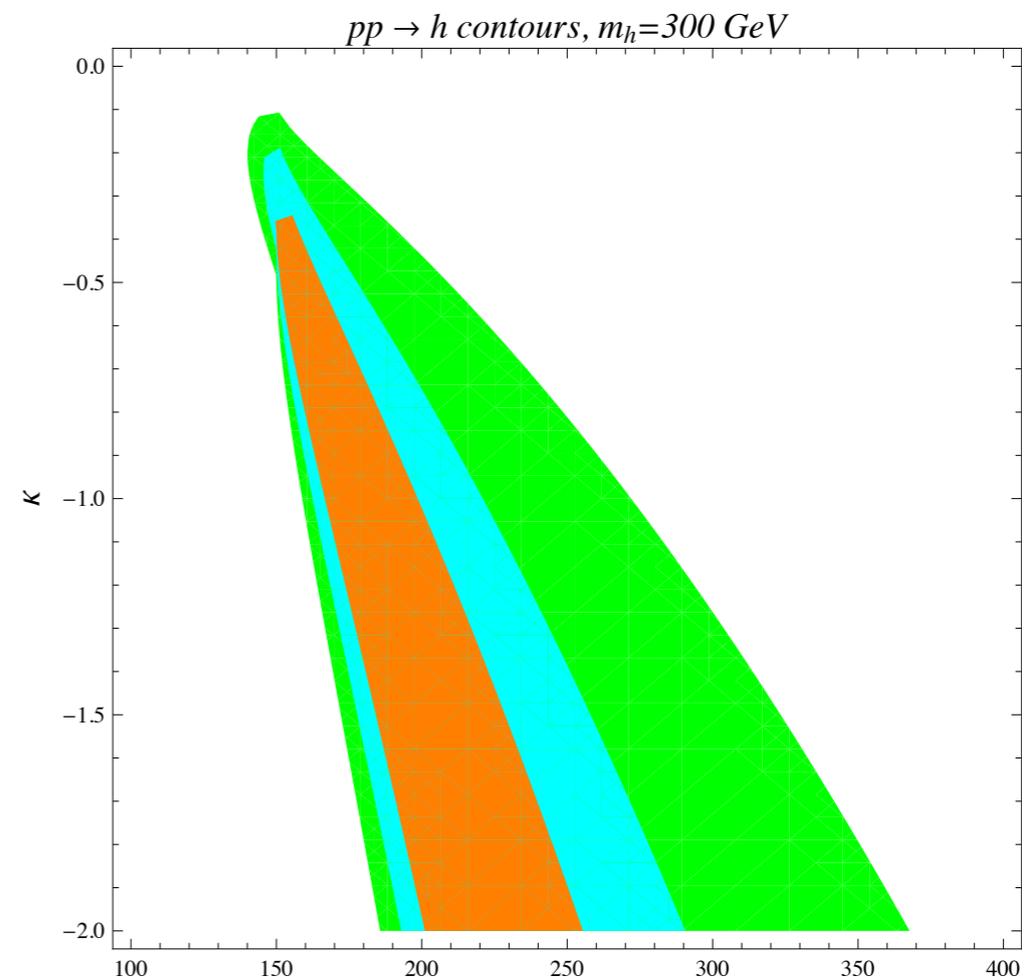
Limits of Applicability

1) $2 m_t < m_h < 2 m_S$

For Higgs heavier than 350 GeV, $h \rightarrow t\bar{t}$ goes on-shell, giving imaginary part to the amplitude.

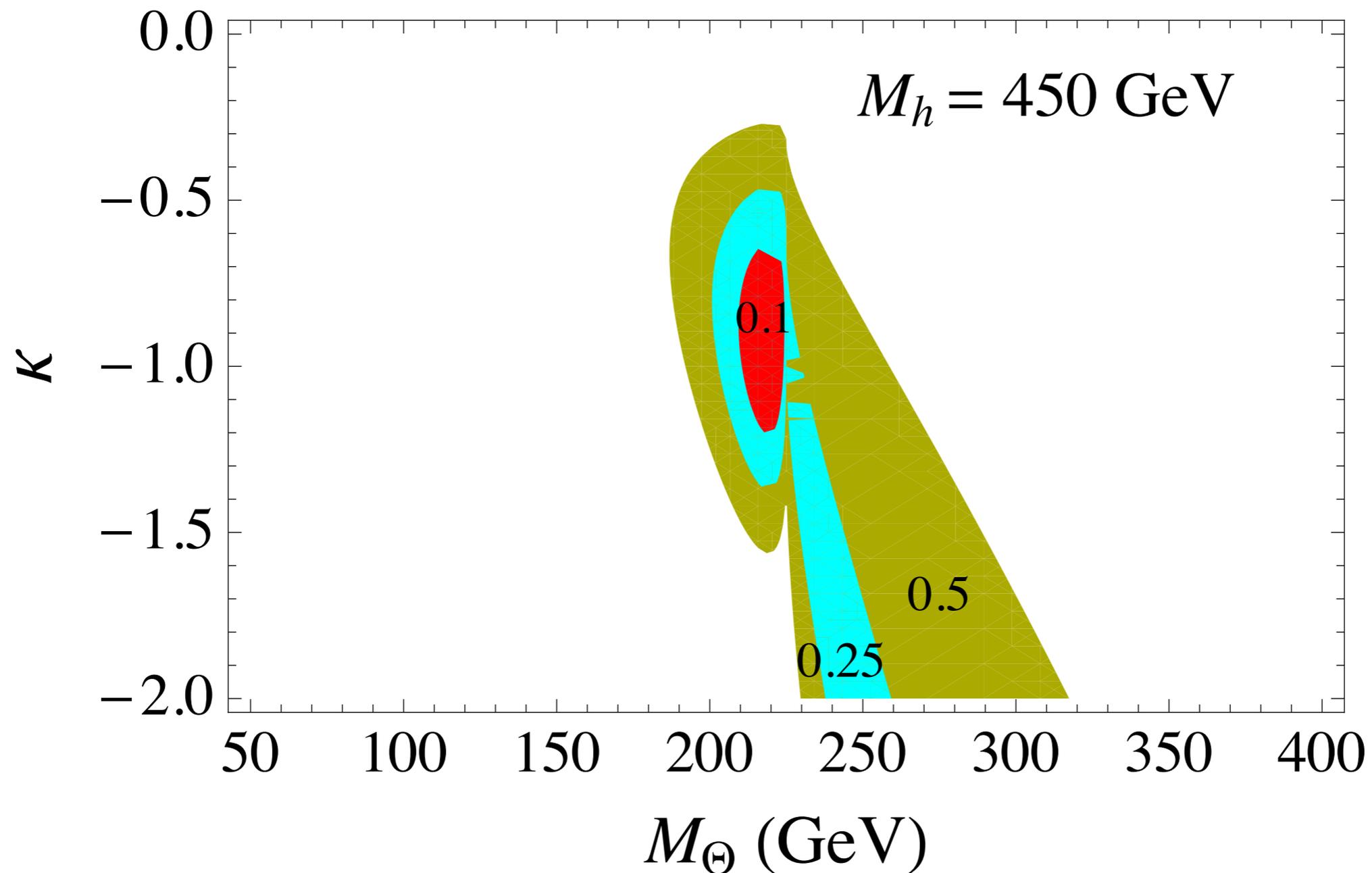
2) $2 m_S < m_h < 2 m_t$

For Higgs heavier than $2 m_S$, decay $h \rightarrow S\bar{S}$ goes on-shell, and again get imaginary part.



Heavy Higgs Also Viable

3) $2 m_t, 2 m_s < m_h$ (real + imag parts cancel)



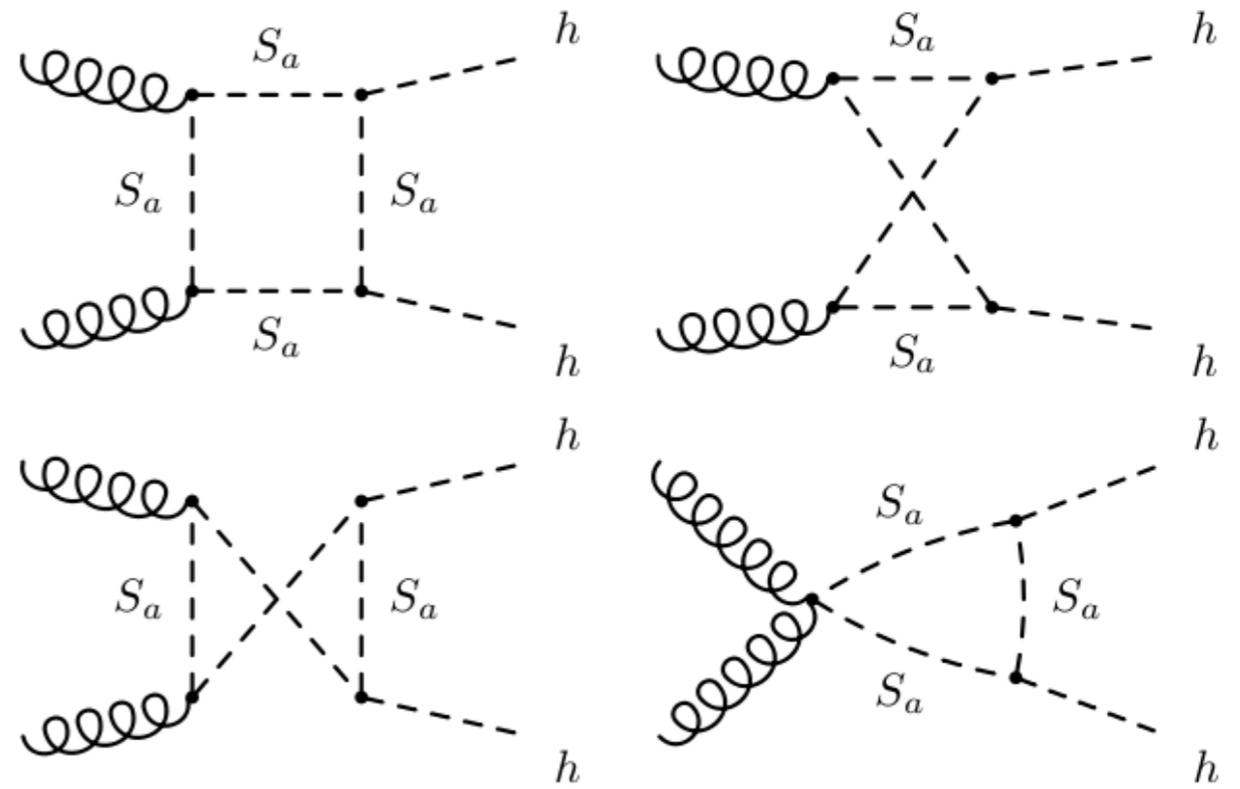
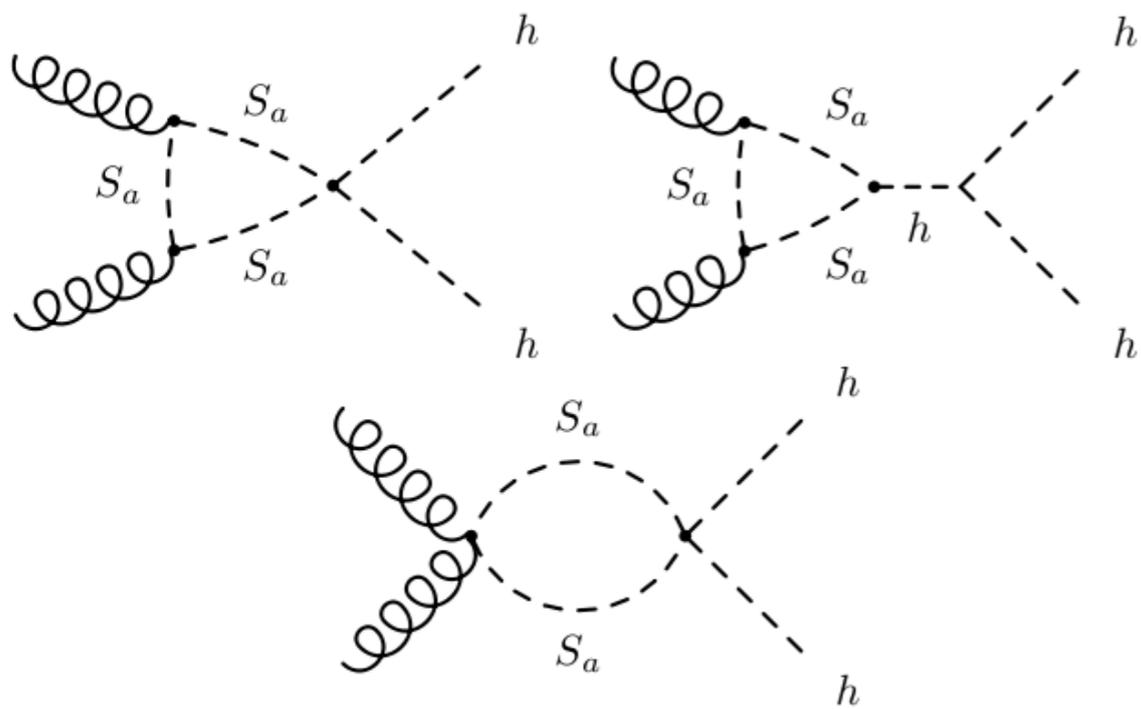
Correlated Effects

Di-Higgs Production

Well known to be correlated with changes to Higgs production (c.f. Pierce, Thaler, Wang)

Some classes of diagrams “still” suppressed; others (boxes) can be significantly enhanced by κ^2 in amplitude.

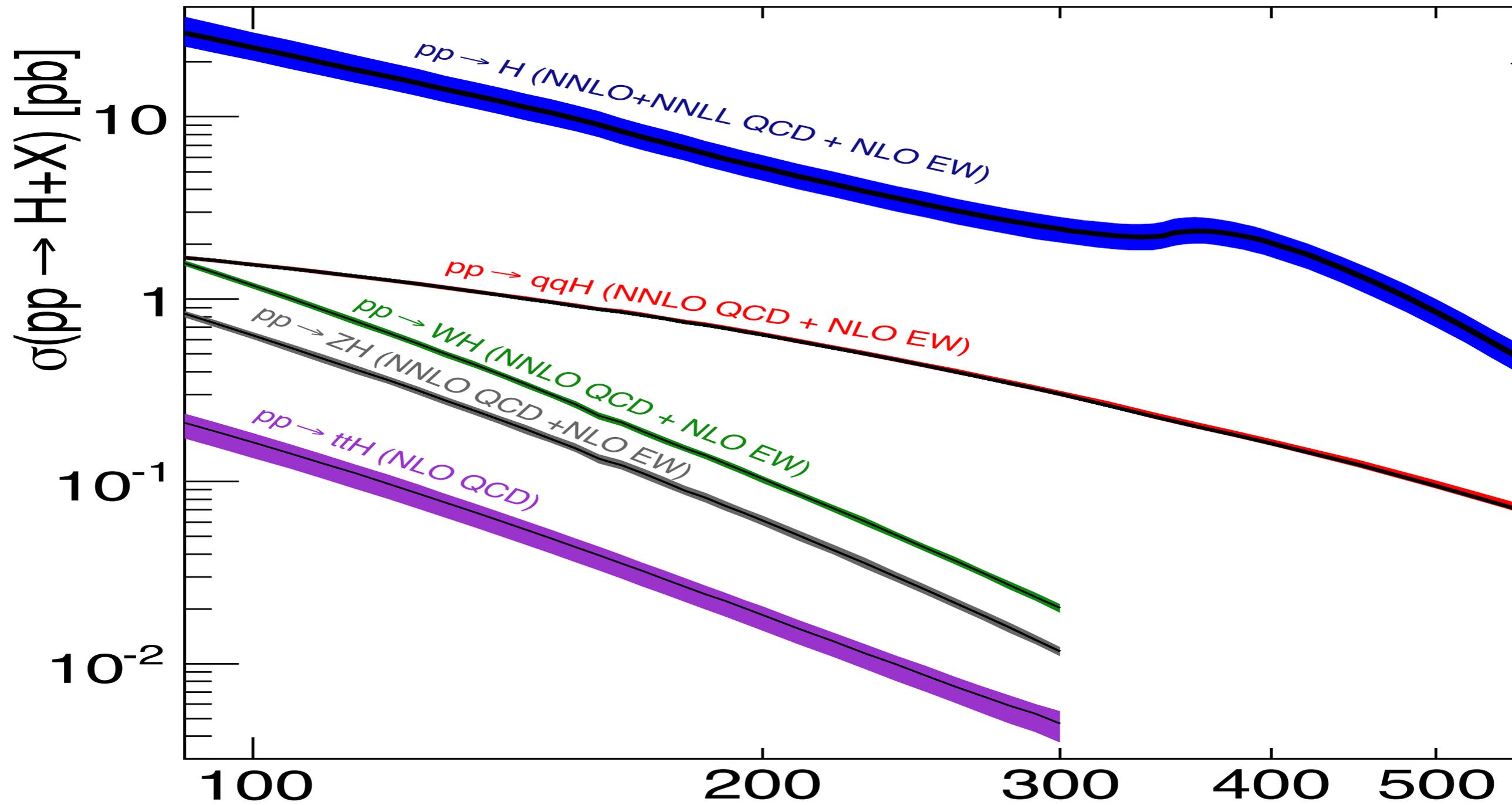
Di-Higgs Production



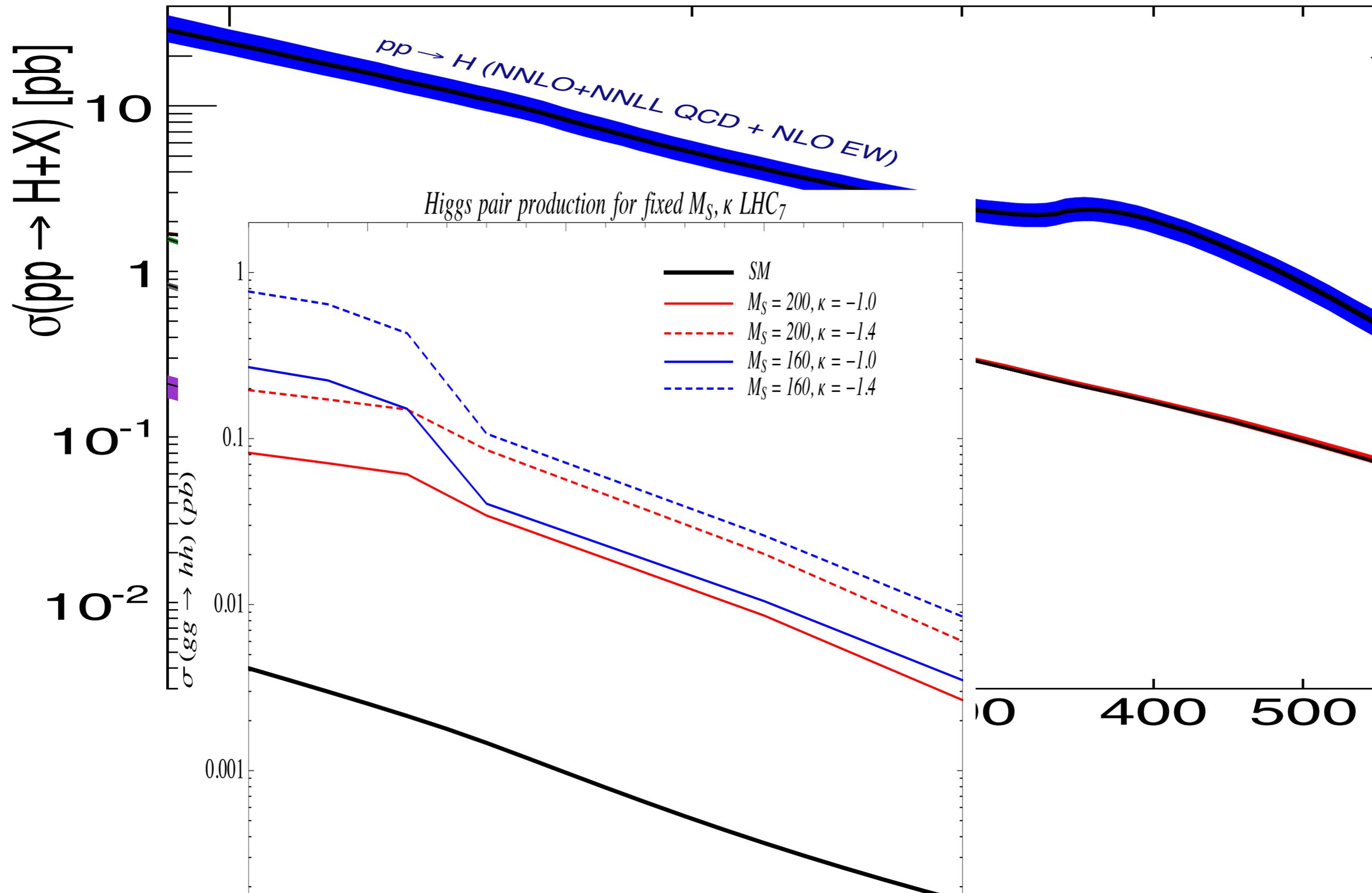
$$|\mathcal{A}|^2 \approx \kappa^2$$

$$|\mathcal{A}|^2 \approx \kappa^4$$

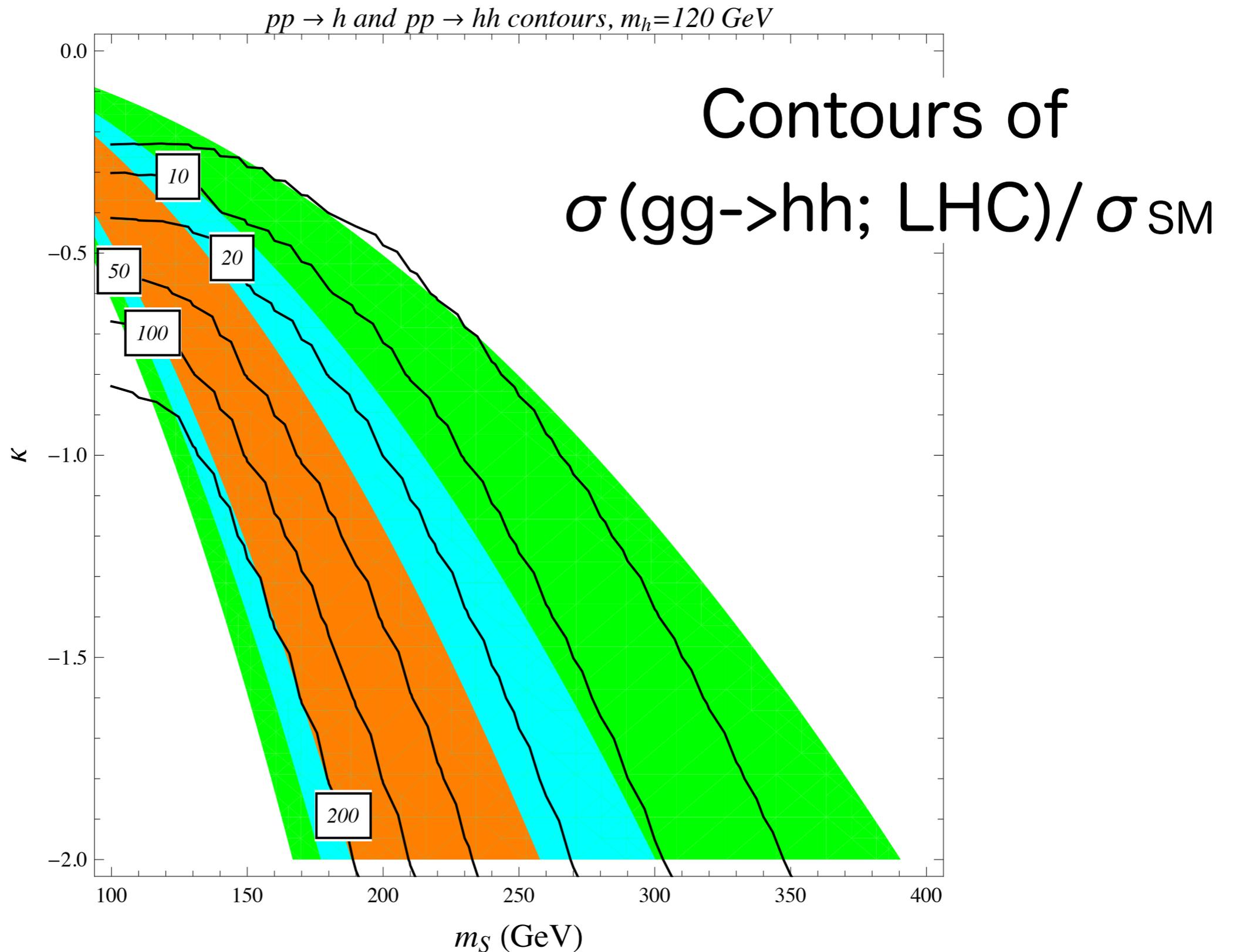
$\sigma(h) \dots$



$\sigma(h)$ versus $\sigma(hh)$

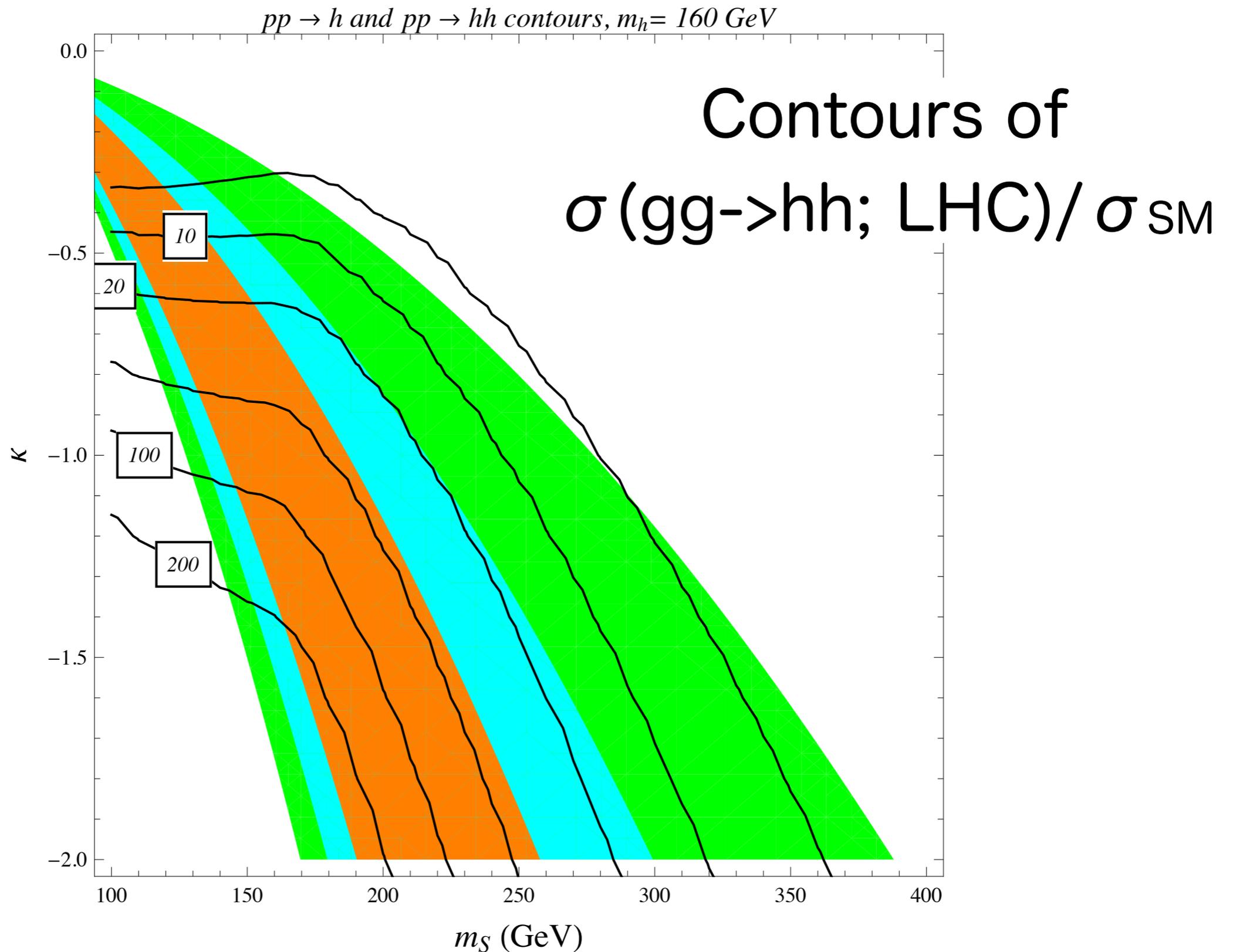


Simult. Di-Higgs Enhancement

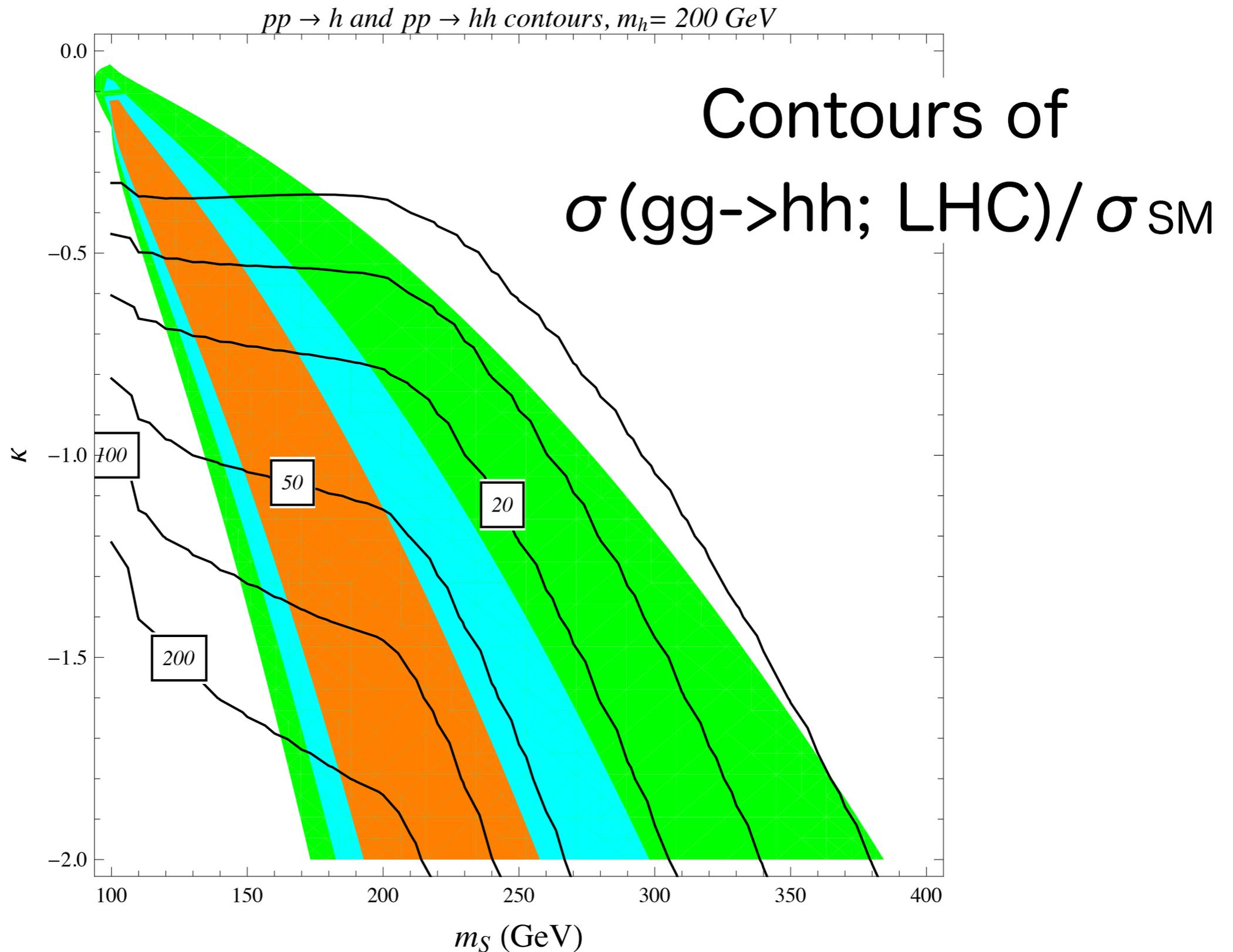


Dobrescu,
Martin,
GK
[to appear]

Simult. Di-Higgs Enhancement

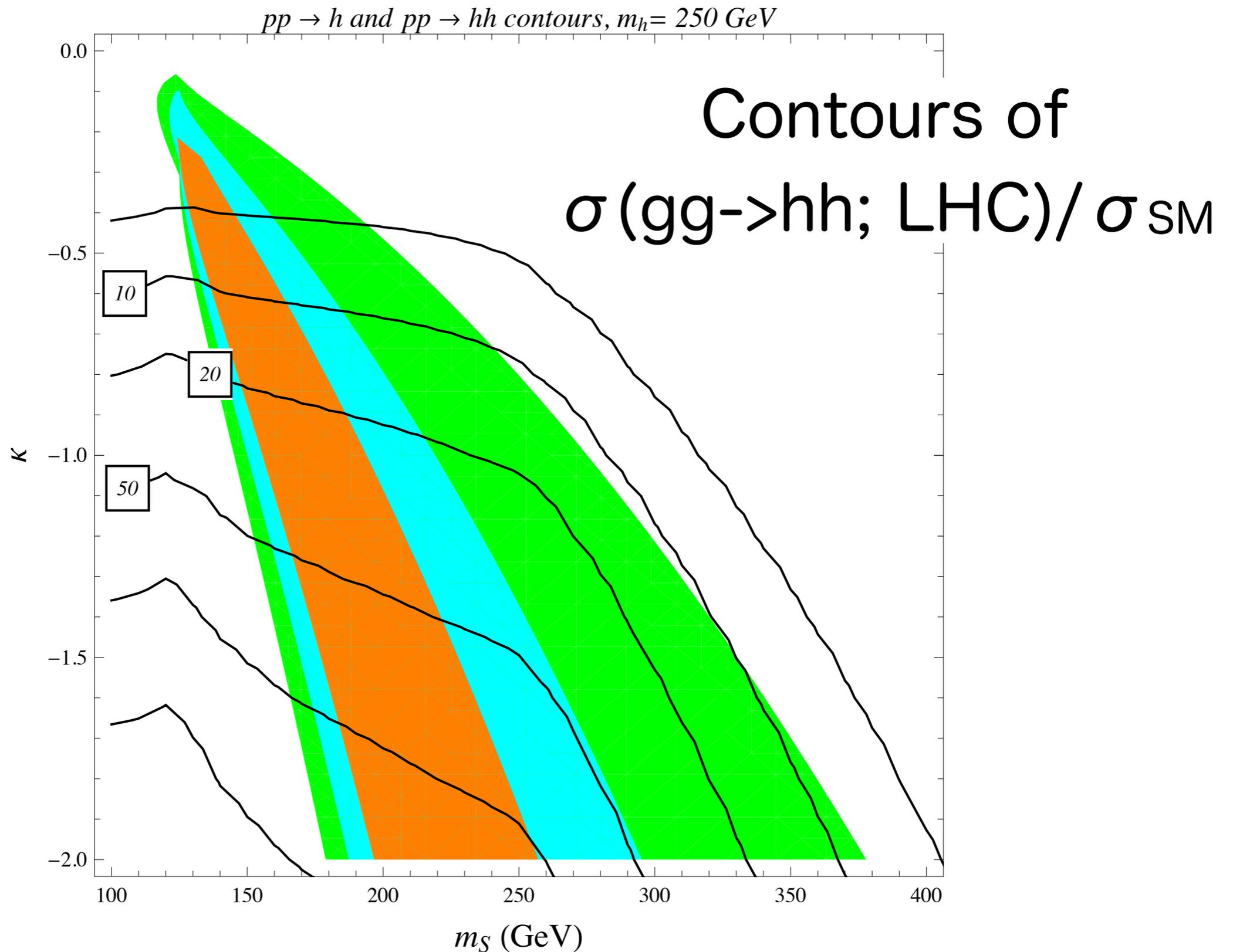


Simult. Di-Higgs Enhancement

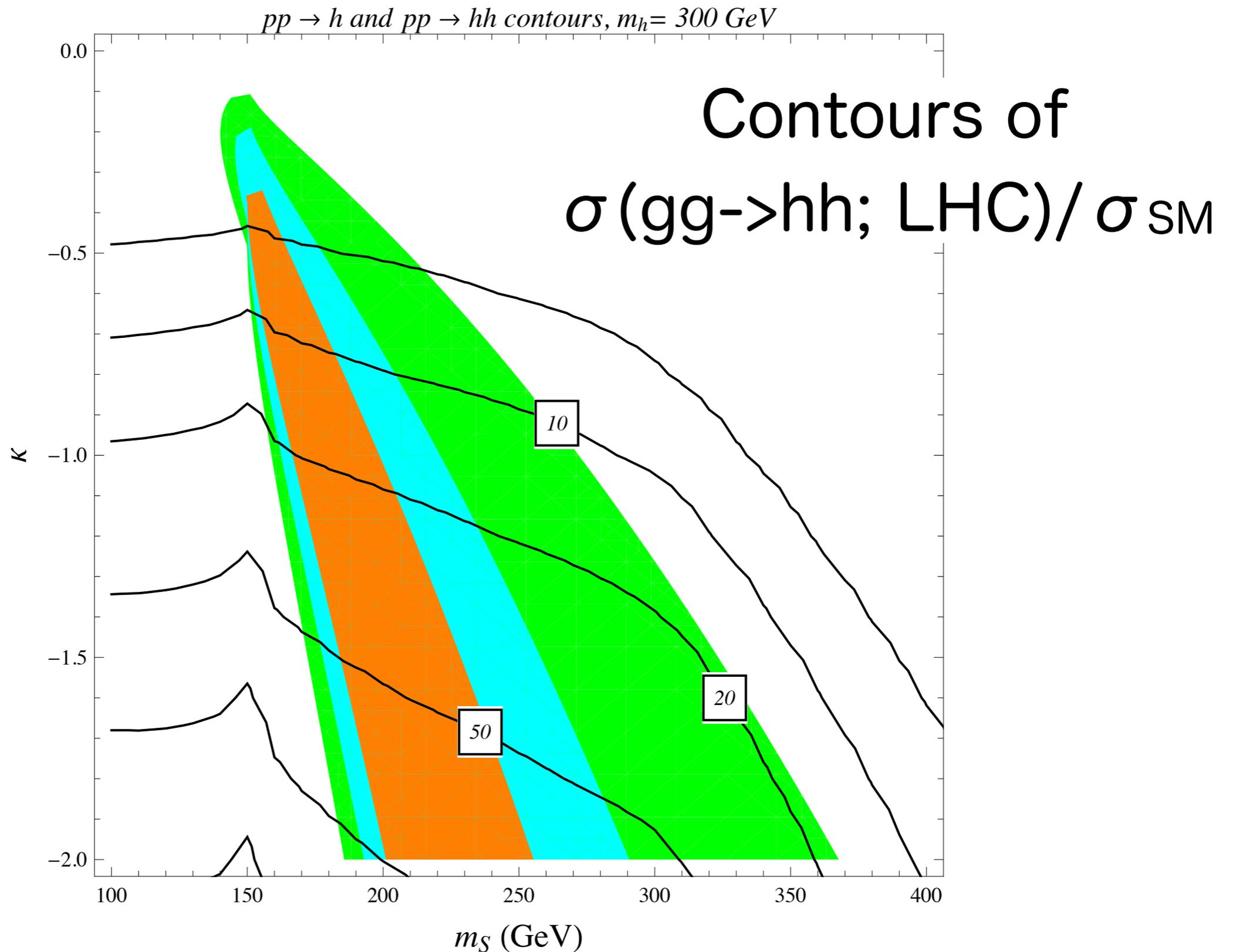


Dobrescu,
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[to appear]

Simult. Di-Higgs Enhancement



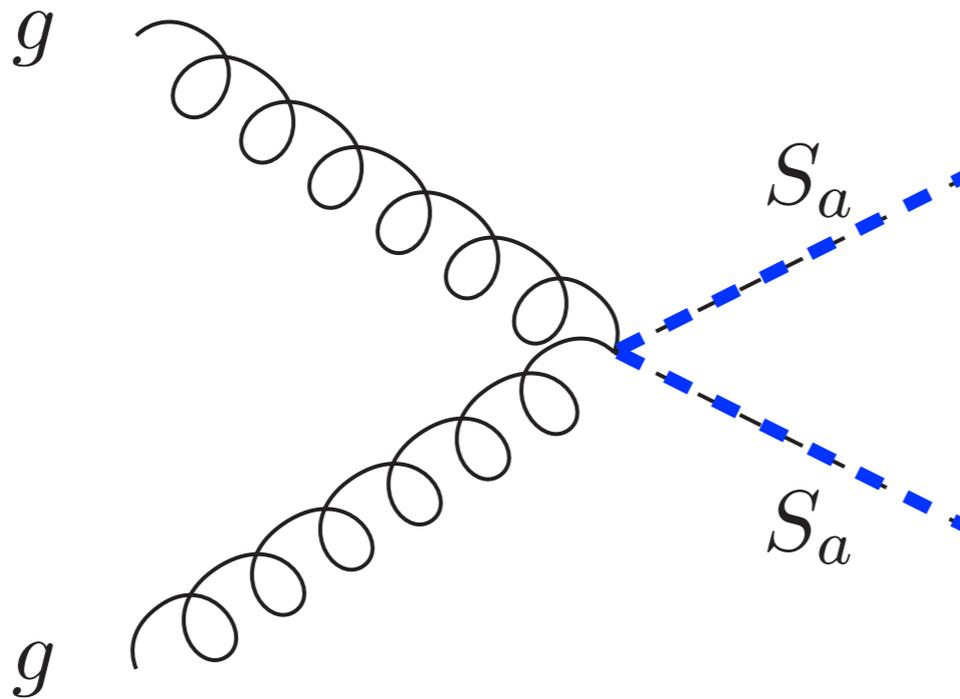
Simult. Di-Higgs Enhancement



Dobrescu,
Martin,
GK
[to appear]

Octet Production

One of several diagrams:



Huge cross section ...

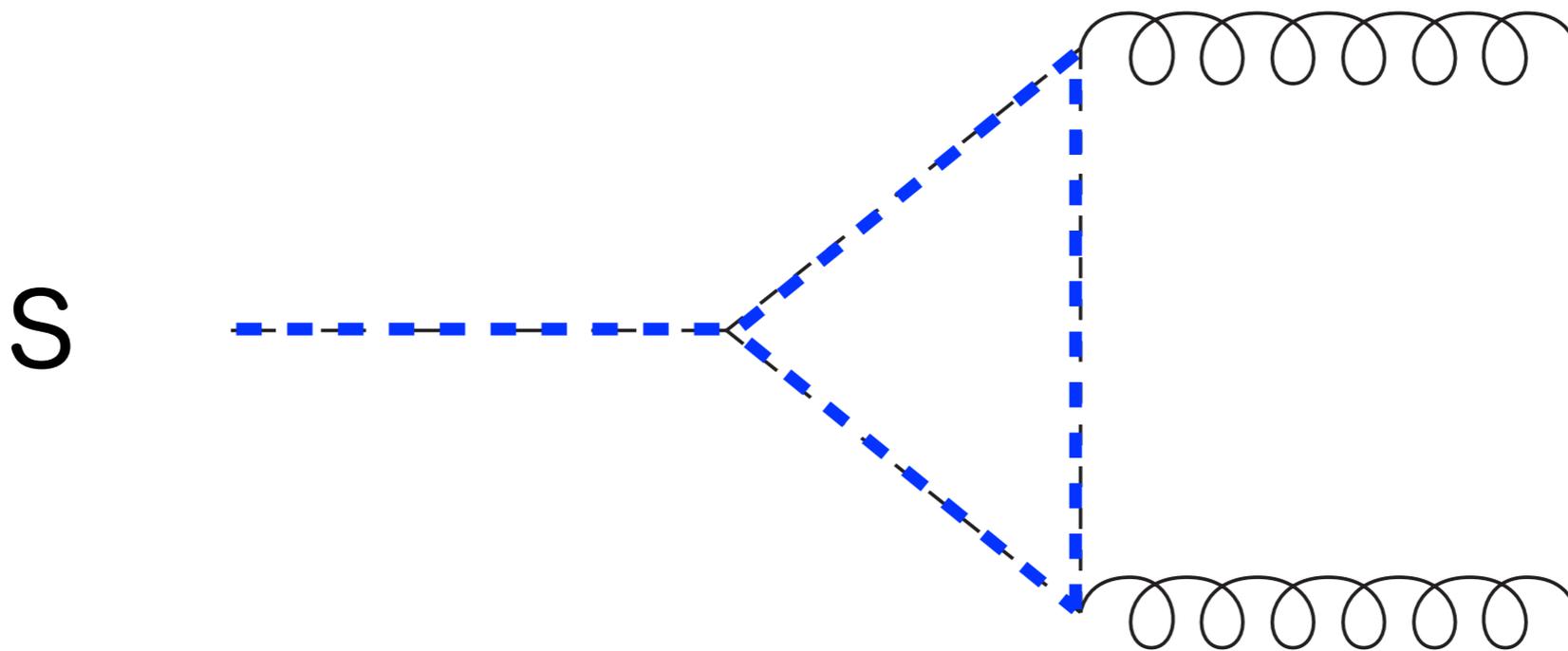
but what do you look for?

Octet Decay

Break Z_2 ($S \rightarrow -S$) through:

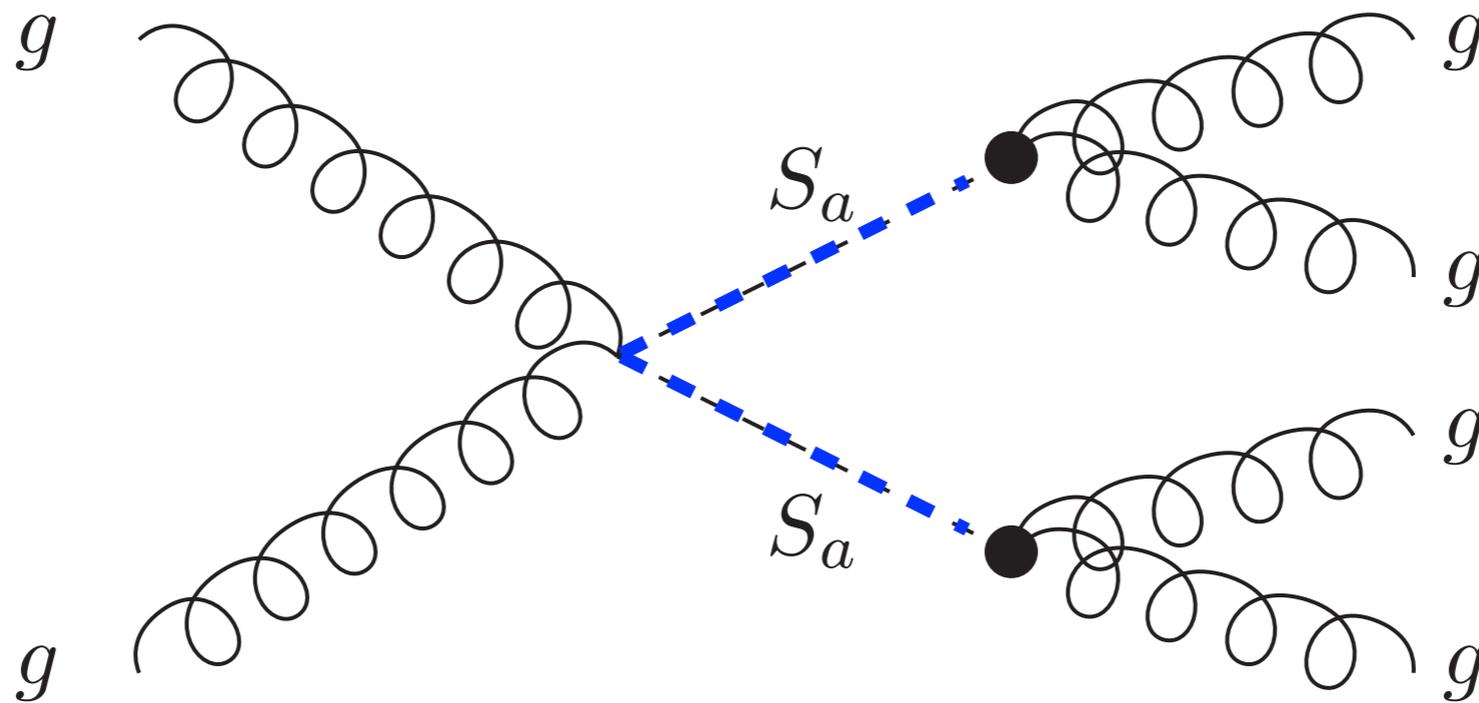
$$\lambda_S d^{abc} S_a S_b S_c,$$

leads to decay into two gluons:



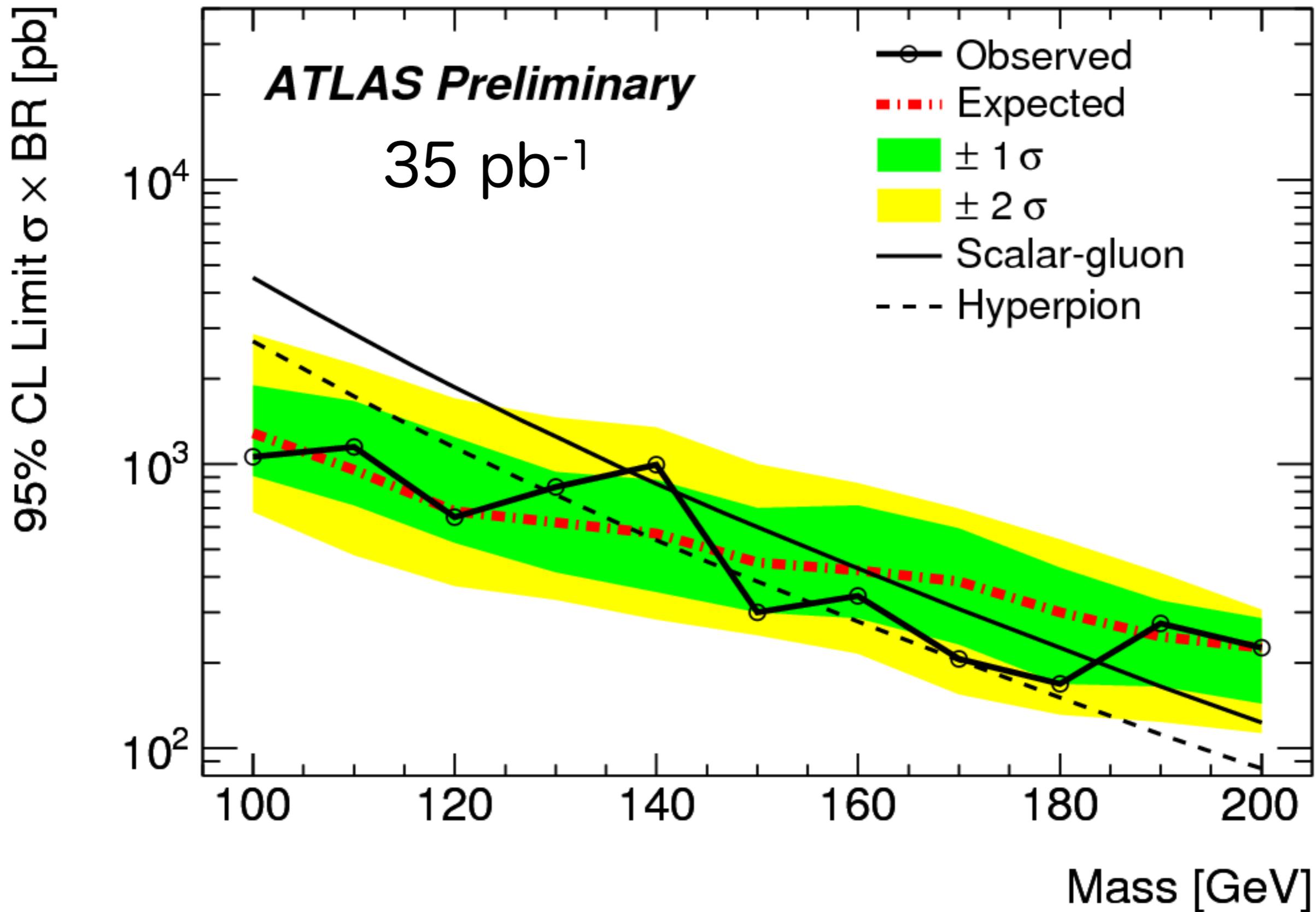
Octet Production

Four jet production

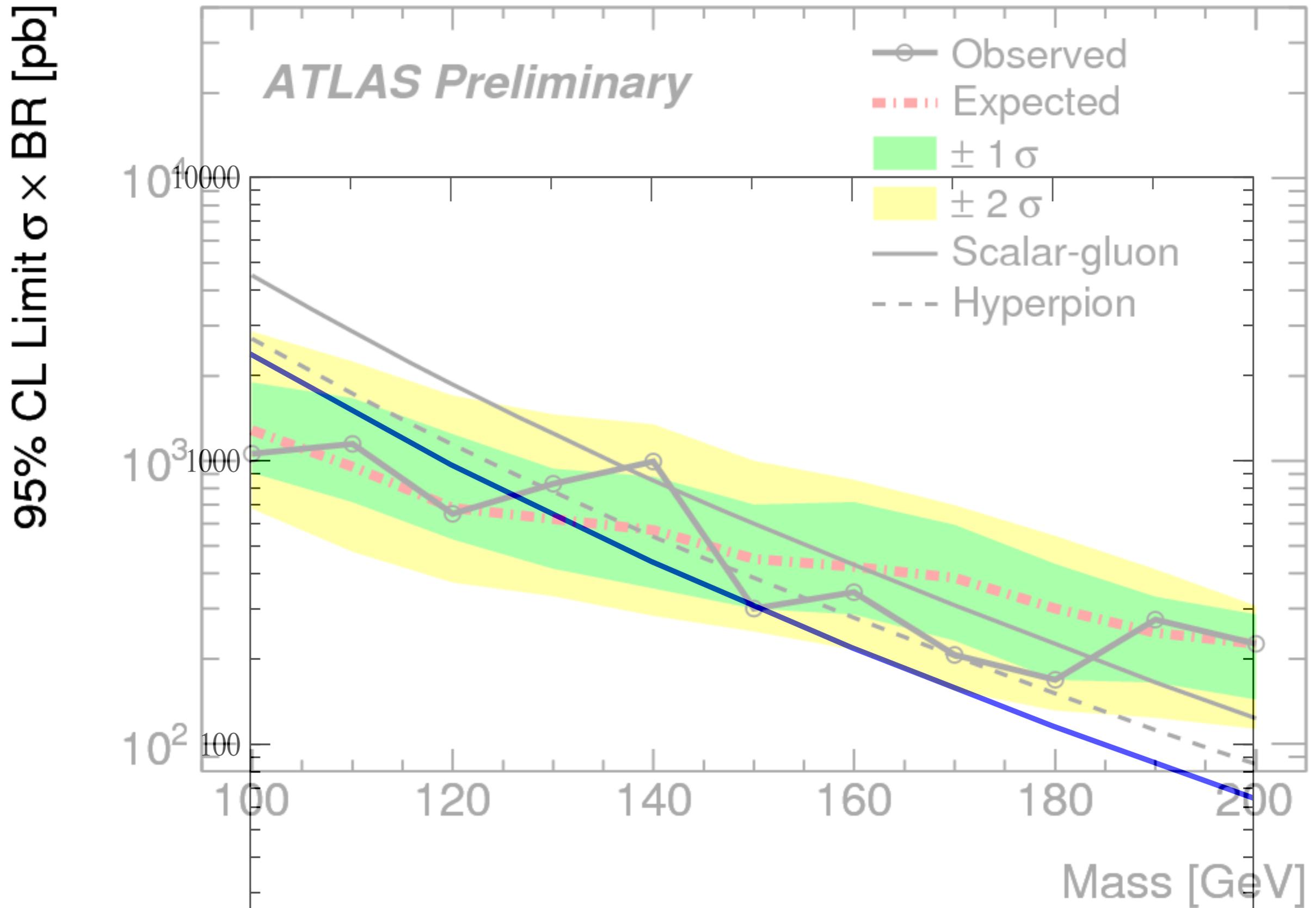


with S_a invariant mass among two pairs.

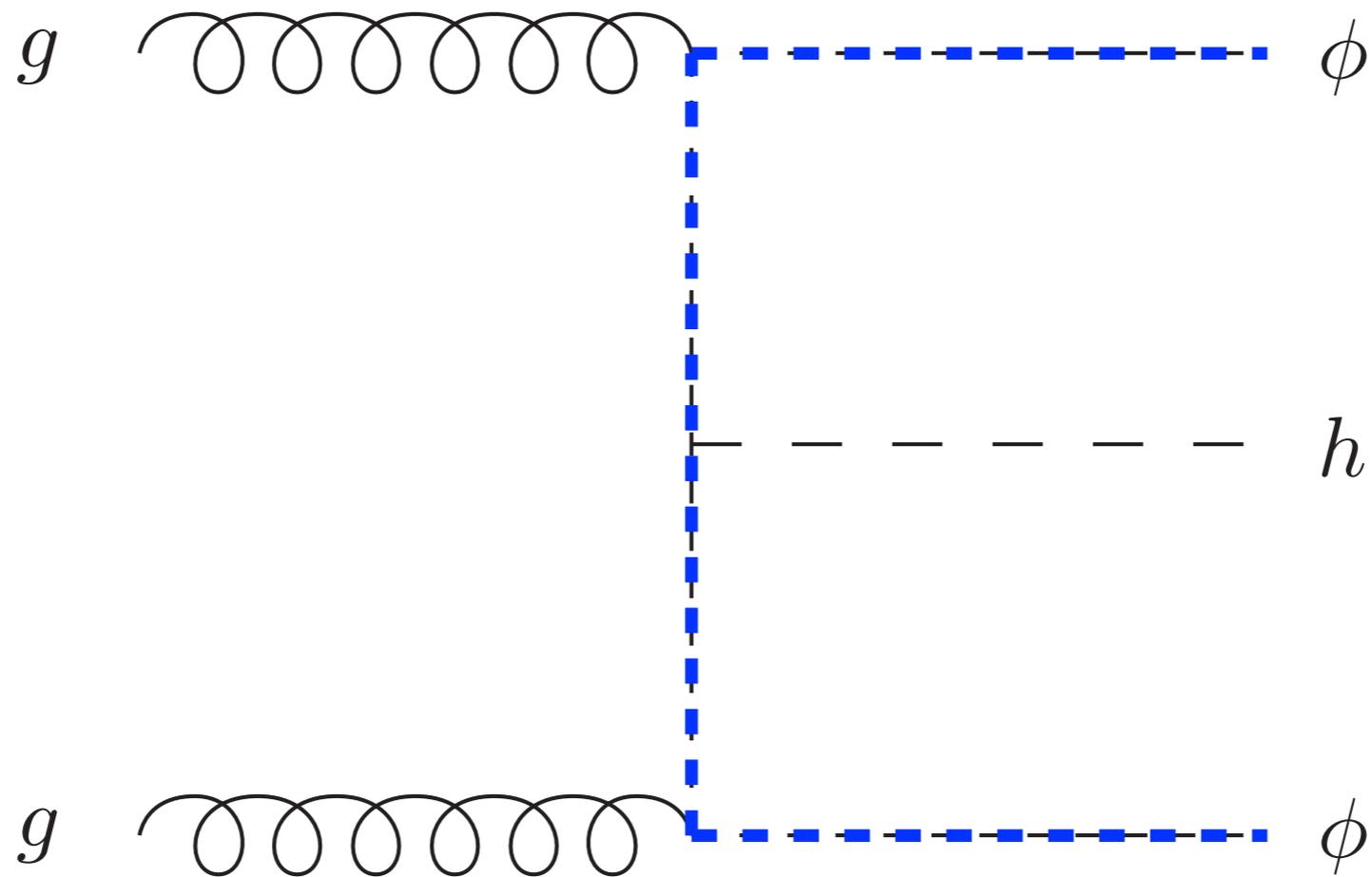
Bounds on 4-jet Signal



Bound on Real Scalar Color Octet



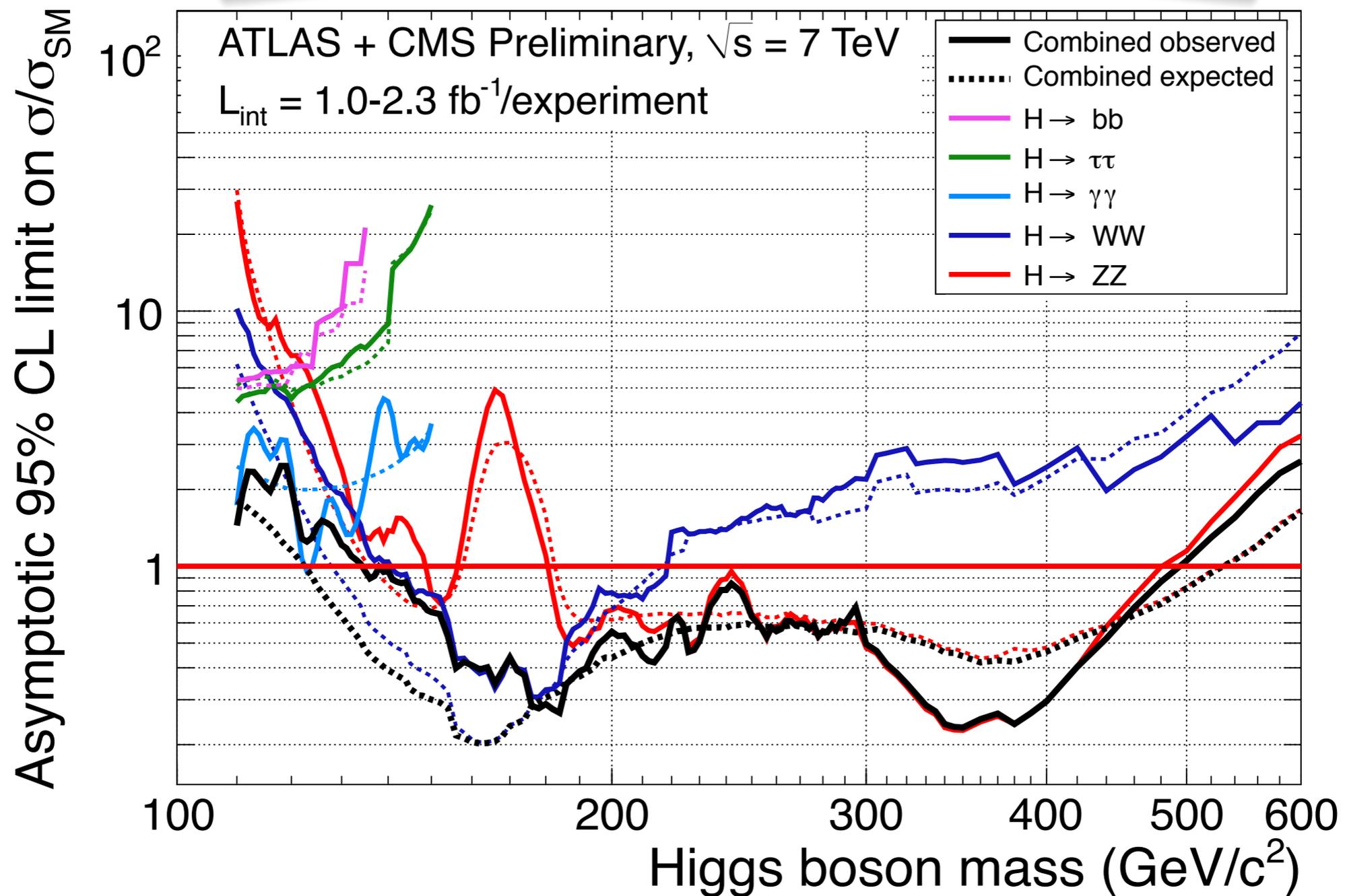
New Higgs Production Mode



Important when scalars light?

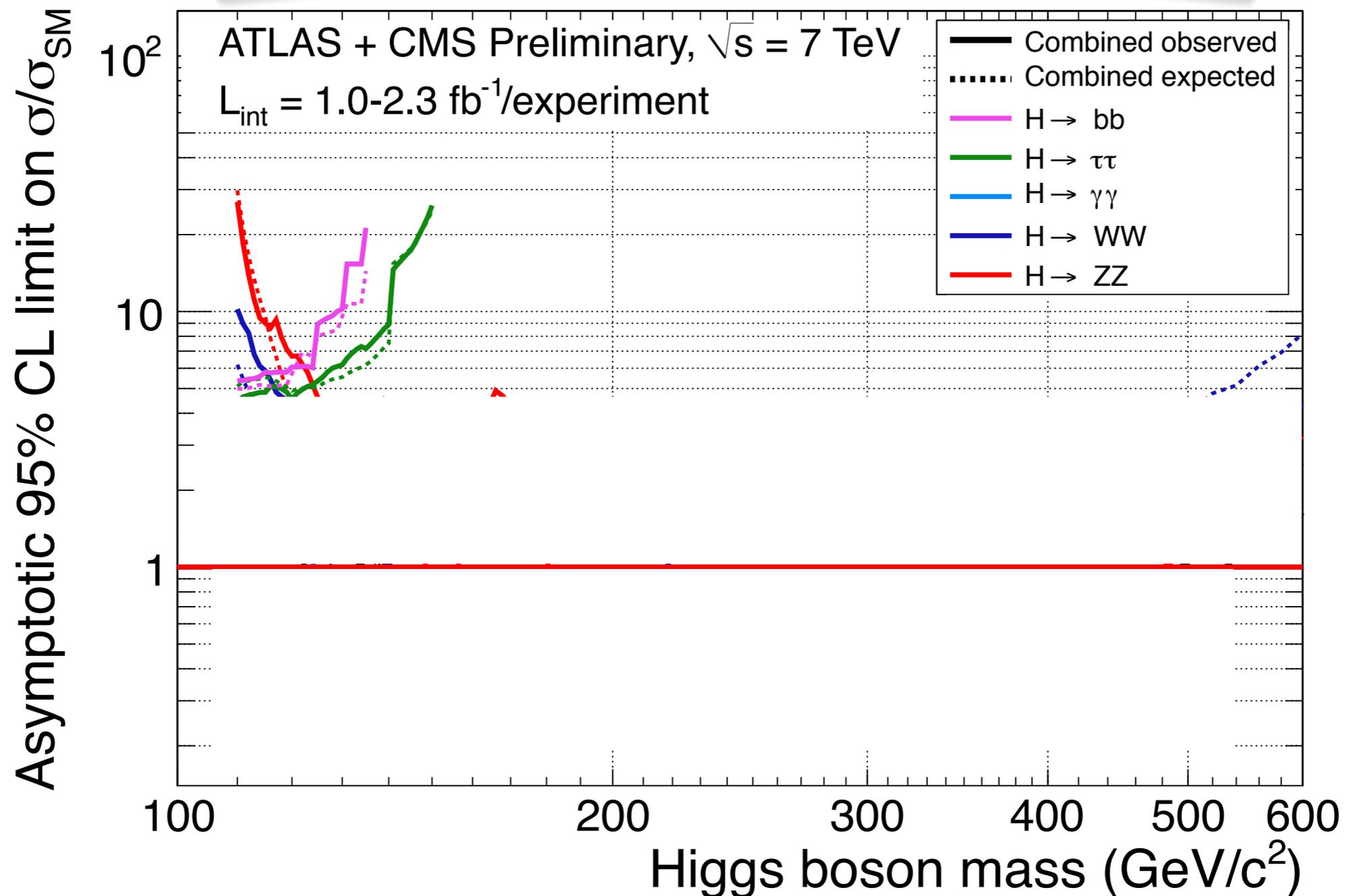
Impact on LHC Searches

SM



Impact on LHC Searches

SM + Colored Scalars



Summary

One particle can effectively hide any mass Higgs from the LHC.

Whole class of models of colored scalars; concrete example -- color octets -- viable!

Di-Higgs cross section generically large; 5-100 times SM.

Caution -- (over-)optimized search strategies?