

Probing a degenerate-scalar scenario in a pseudoscalar dark-matter model

[arXiv:2101.04887]

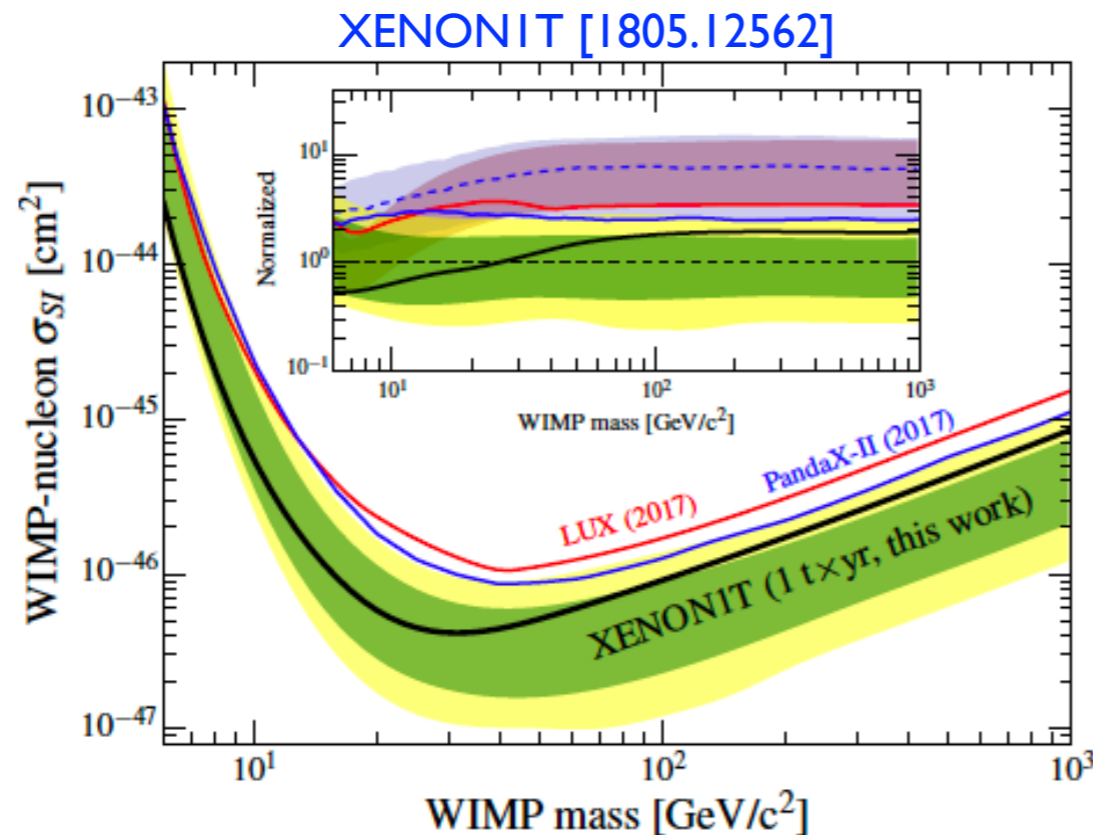
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in collaboration with
G-C. Cho and S.Abe
(Ochanomizu U.)



Strong constraints on WIMP from DM direct detection experiments



How can we avoid such strong constraints ?

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Cancellation Mechanism for Dark-Matter–Nucleon Interaction

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We consider a simple Higgs portal dark-matter model, where the standard model is supplemented with a complex scalar whose imaginary part plays the role of weakly interacting massive particle dark matter (DM). We show that the direct DM detection cross section vanishes at the tree level and zero momentum transfer due to a cancellation by virtue of a softly broken symmetry. This cancellation is operative for any mediator masses. As a result, our electroweak-scale dark matter satisfies all of the phenomenological constraints quite naturally.

Pseudoscalar DM Model

- CxSM : A complex singlet extension of the SM with a softly broken U(1) symmetry

$$V = \frac{m^2}{2}|H|^2 + \frac{\lambda}{4}|H|^4 + \frac{\delta_2}{2}|H|^2|S|^2 + \frac{b_2}{2}|S|^2 + \frac{d_2}{4}|S|^4 + \left(a_1 S + \frac{b_1}{4} S^2 + \text{c.c.} \right)$$

$$H = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ v+h \end{pmatrix}, \quad S = \frac{1}{\sqrt{2}}(v_S + s + i\chi)$$

h_1, h_2

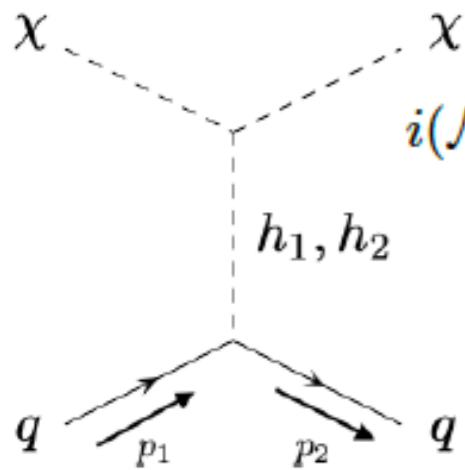
DM

125GeV SM-like Higgs boson

5 free parameters

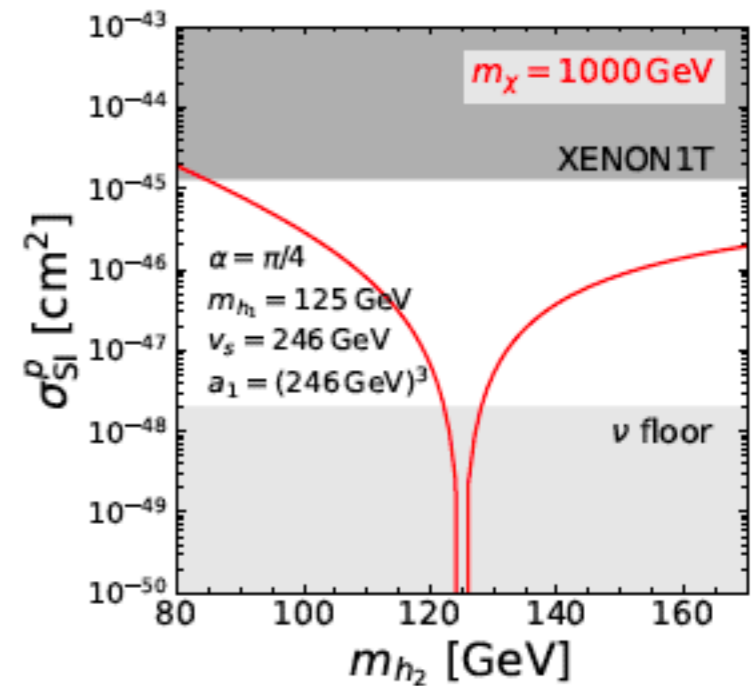
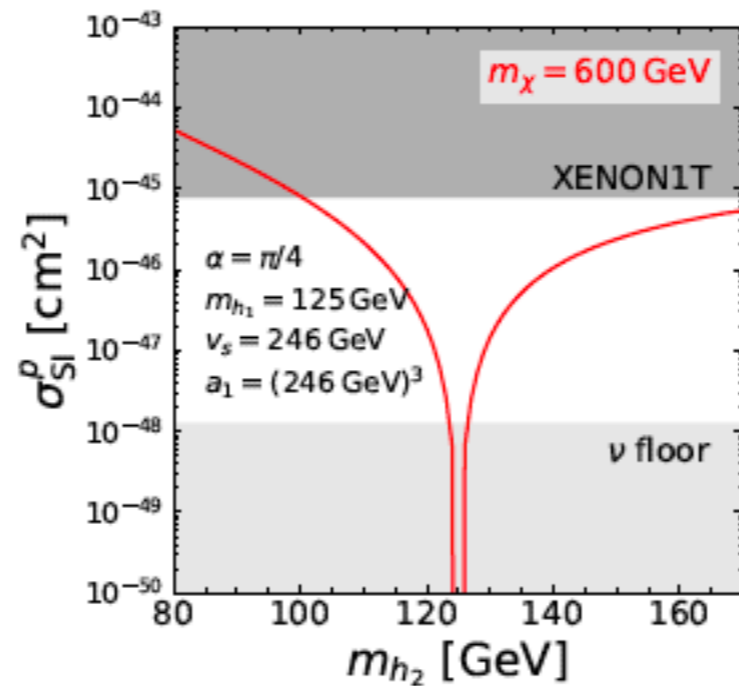
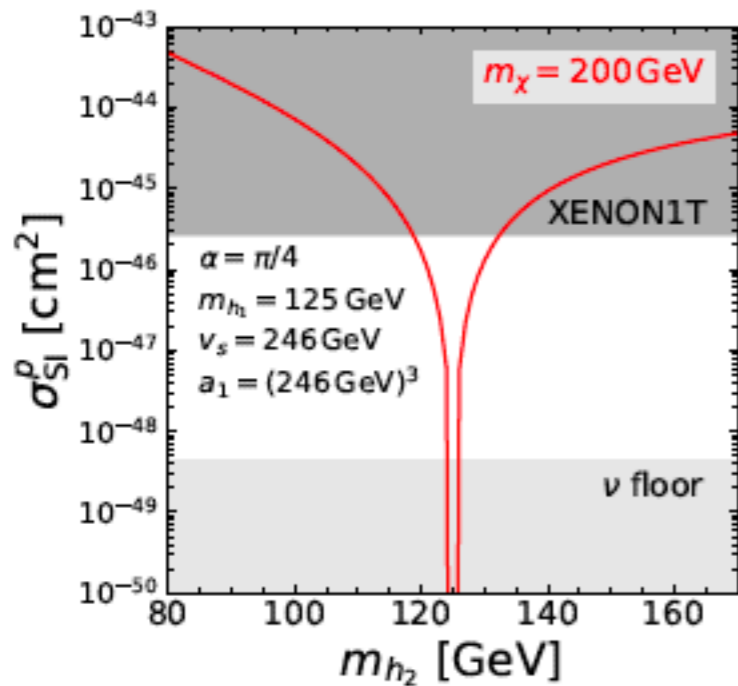
$m_{h_2}, m_\chi, \alpha, a_1, v_S$

Suppression of the DM-quark scattering amplitudes

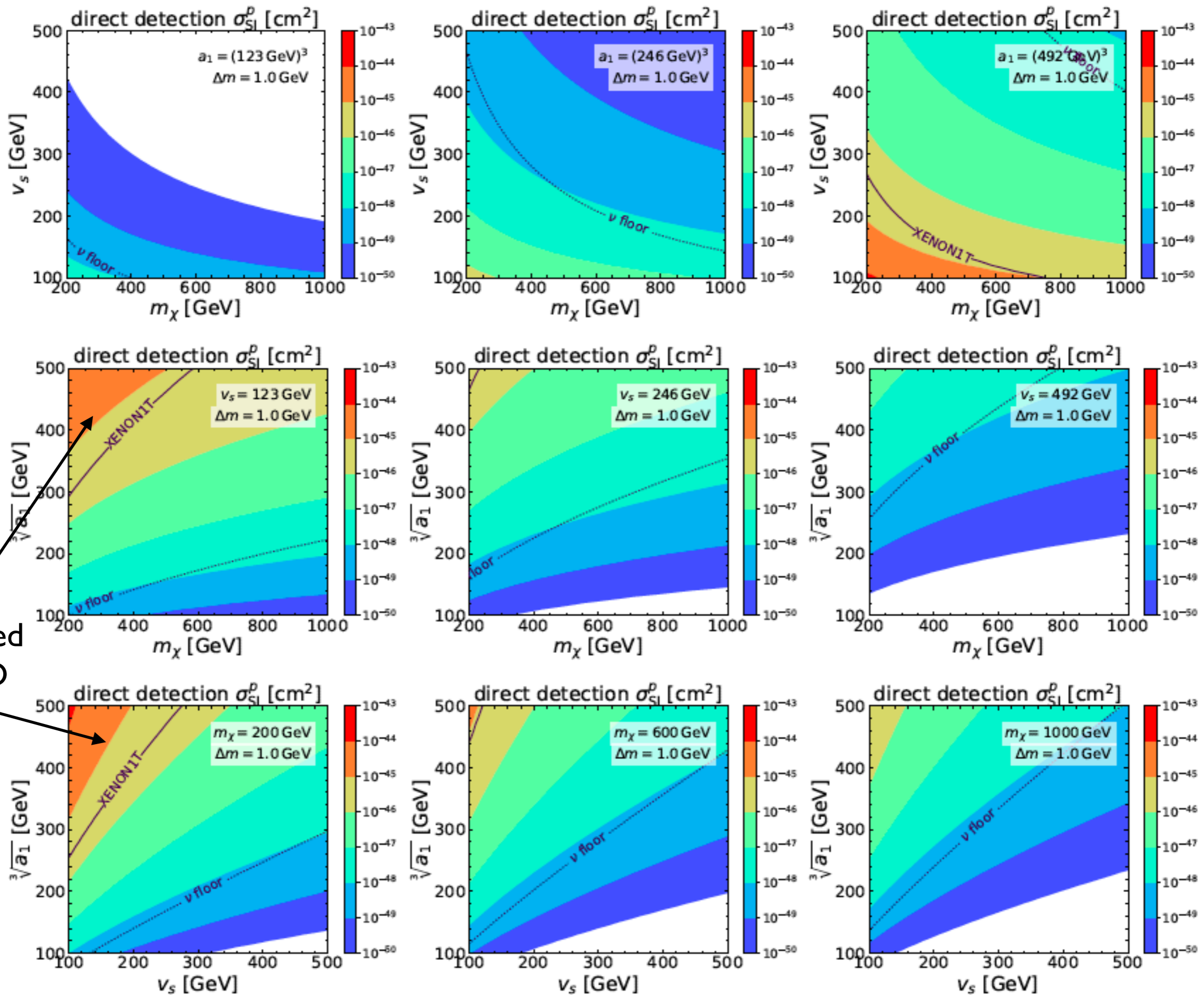


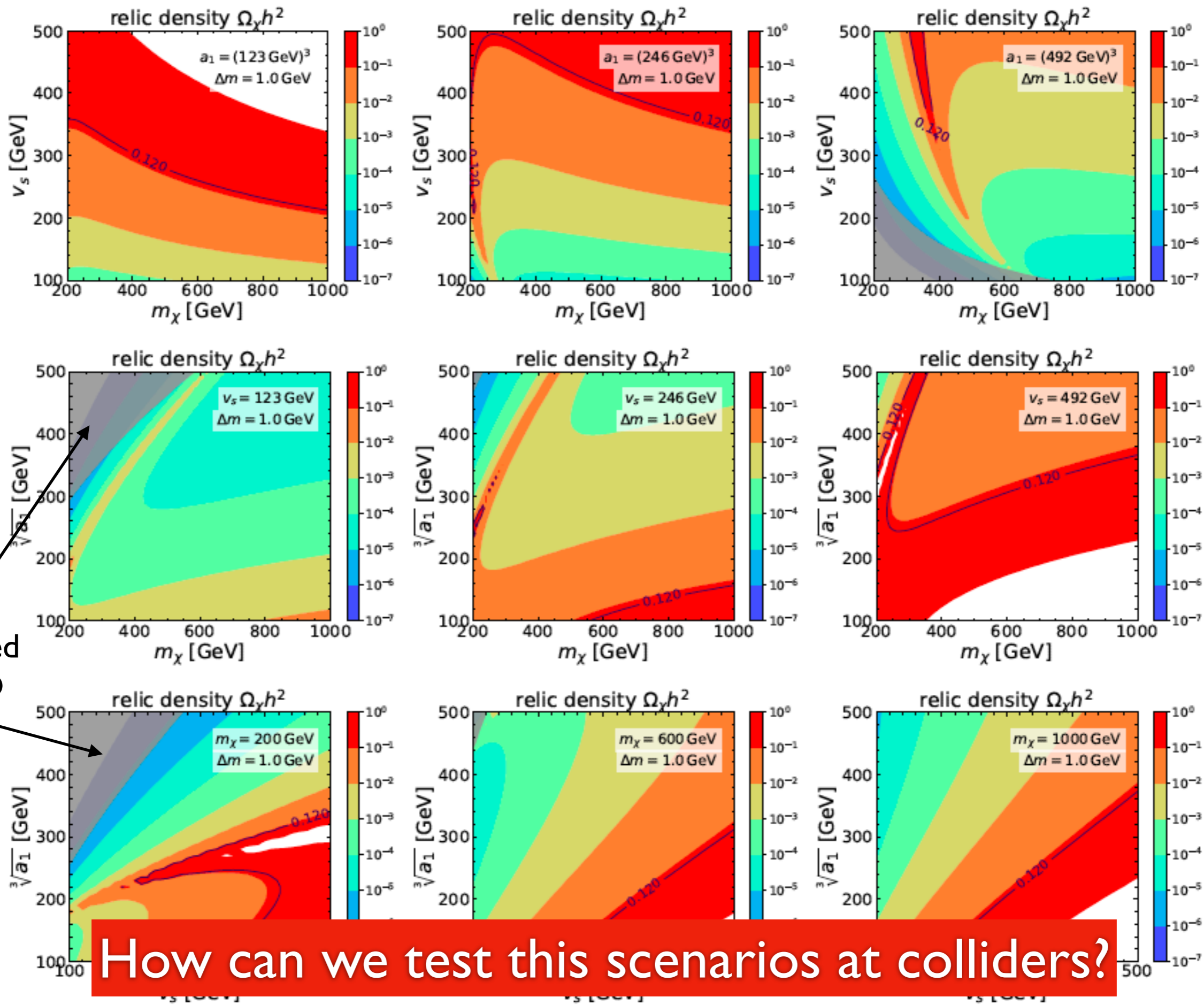
$$i(\mathcal{M}_{h_1} + \mathcal{M}_{h_2}) \simeq i \frac{m_q}{v v_S} \sin \alpha \cos \alpha \bar{u}(p_2) u(p_1)$$

$$\times \frac{1}{m_{h_1}^2 m_{h_2}^2} \left\{ \left(m_{h_2}^2 - m_{h_1}^2 + \frac{\sqrt{2} a_1}{v_S} \frac{m_{h_2}^4 - m_{h_1}^4}{m_{h_1}^2 m_{h_2}^2} \right) t + \frac{\sqrt{2} a_1}{v_S} (m_{h_2}^2 - m_{h_1}^2) \right\}$$



Yes, if the two scalars are nearly degenerate.

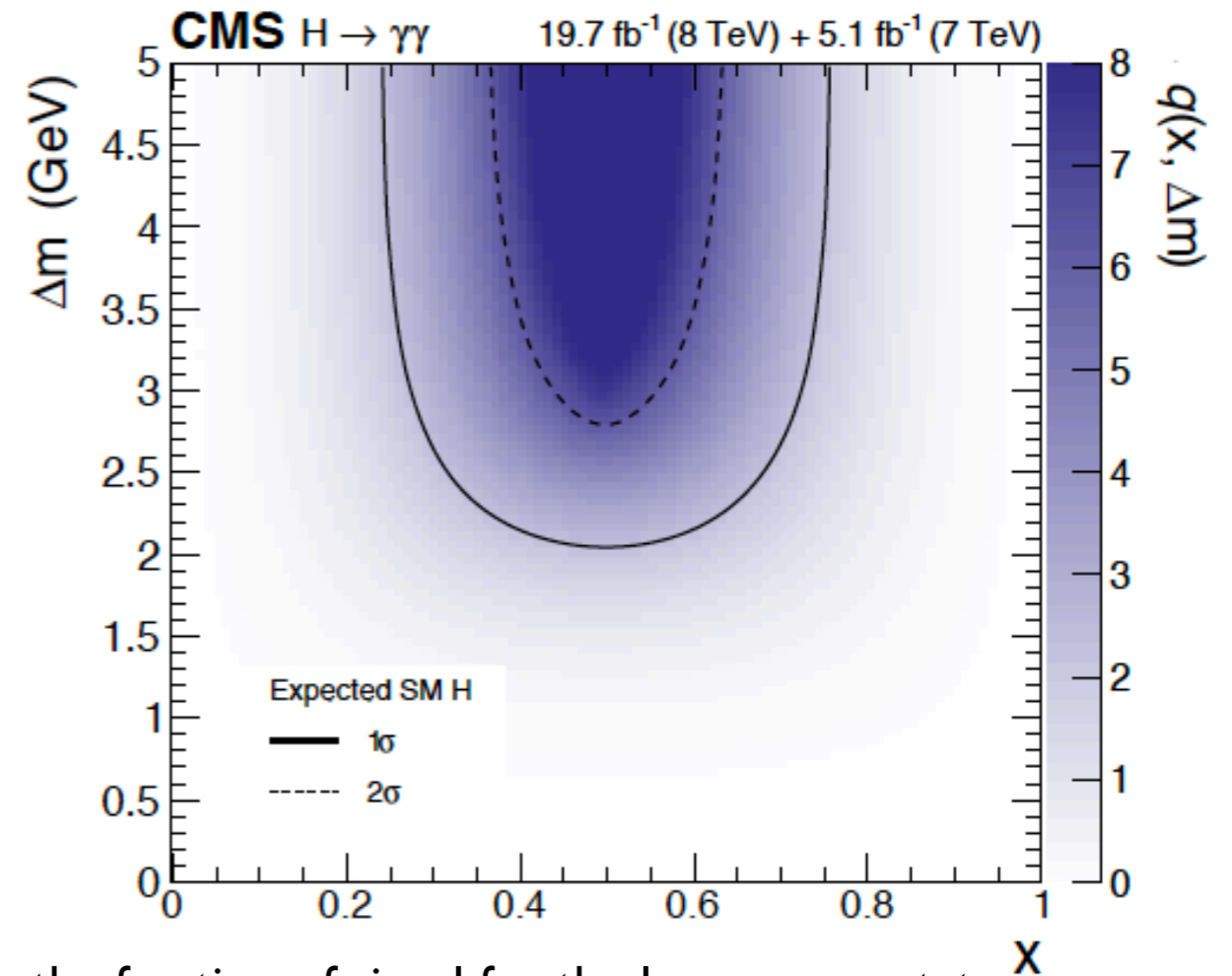
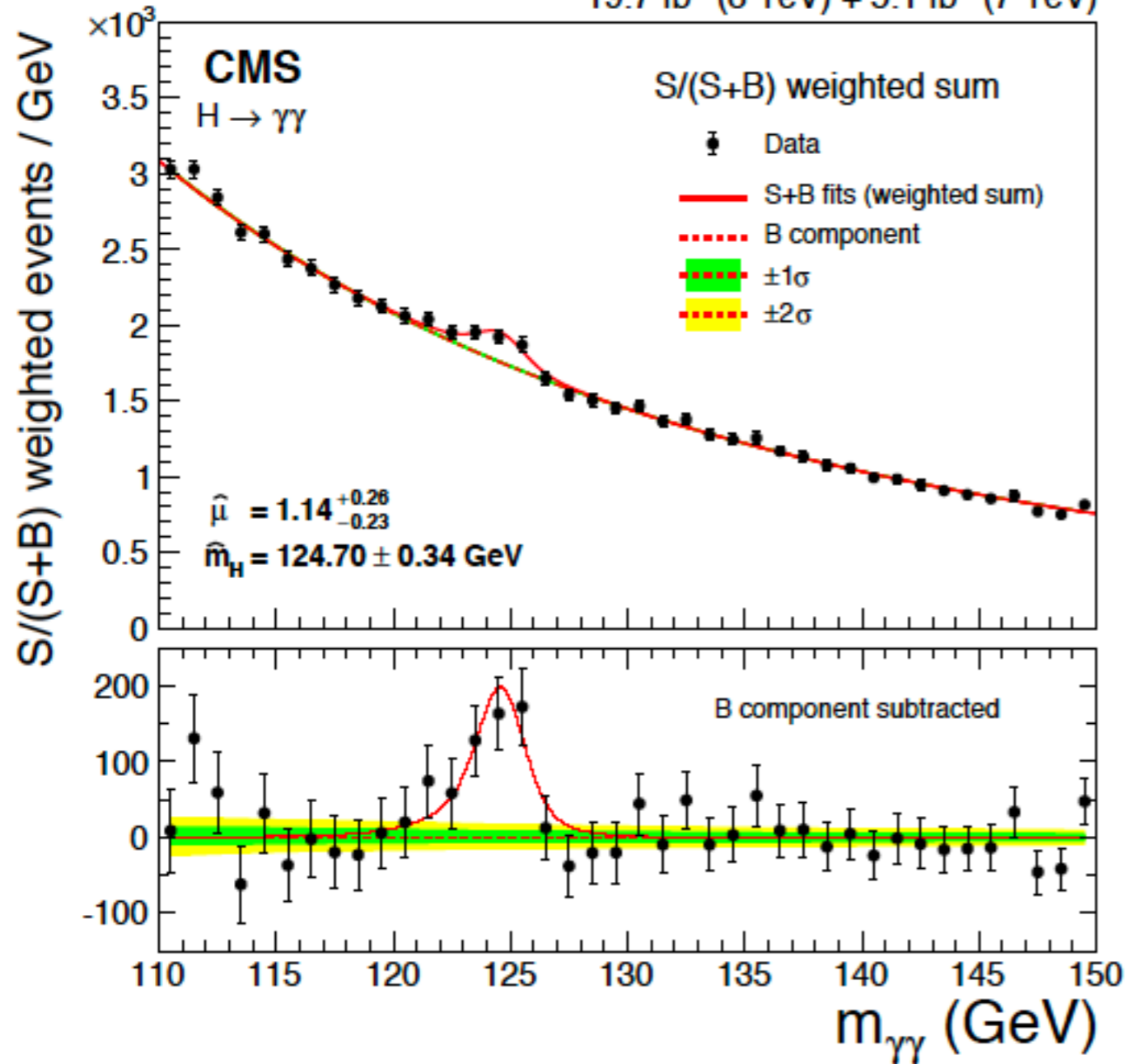




Single H or 2 near mass-degenerate H ?

CMS [1407.0558]

19.7 fb⁻¹ (8 TeV) + 5.1 fb⁻¹ (7 TeV)

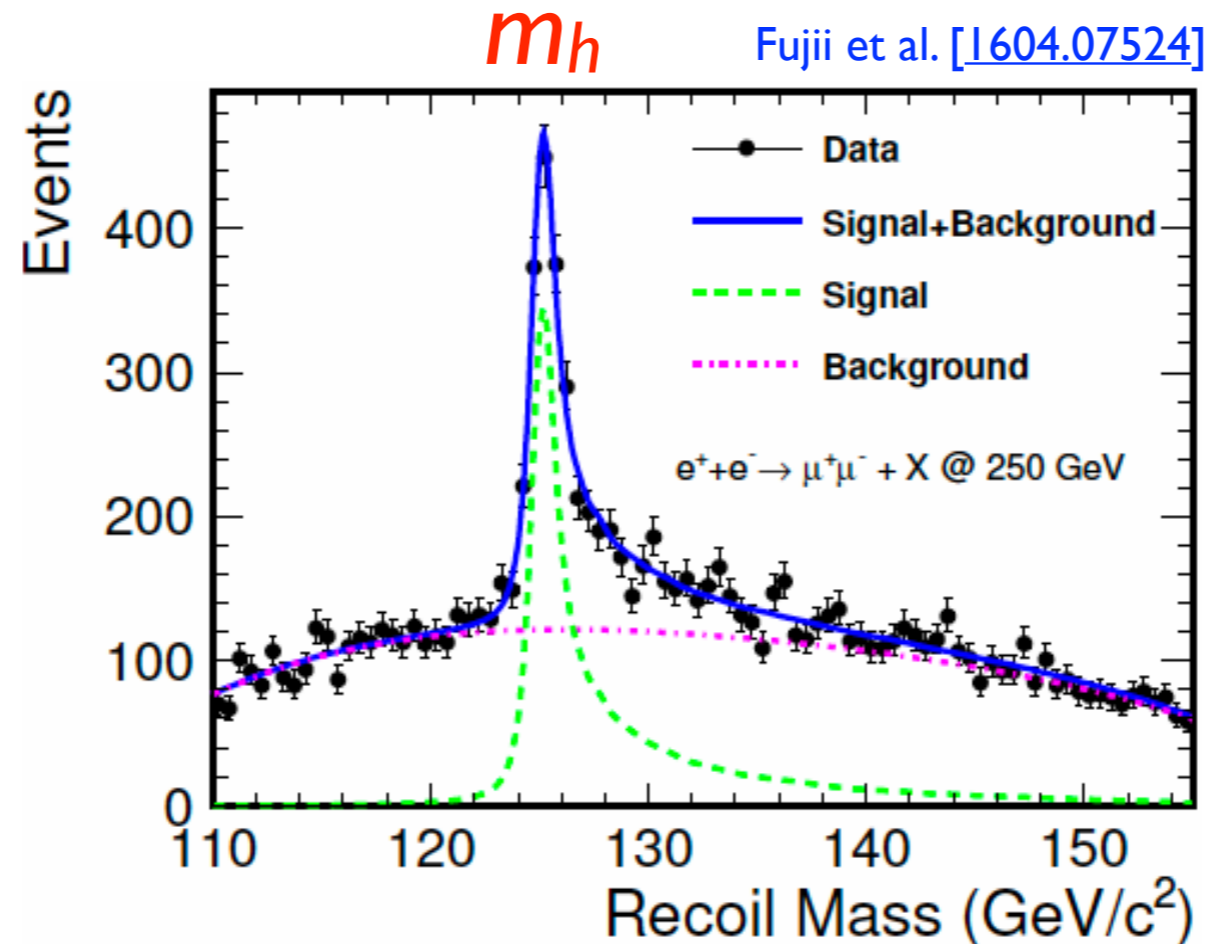


the fraction of signal for the lower mass state

At the LHC, two near mass-degenerate Higgs bosons with $\Delta m < 3$ GeV can not be distinguished from the single-state Higgs boson (SM).

How about at the ILC?

Recoil mass at the ILC



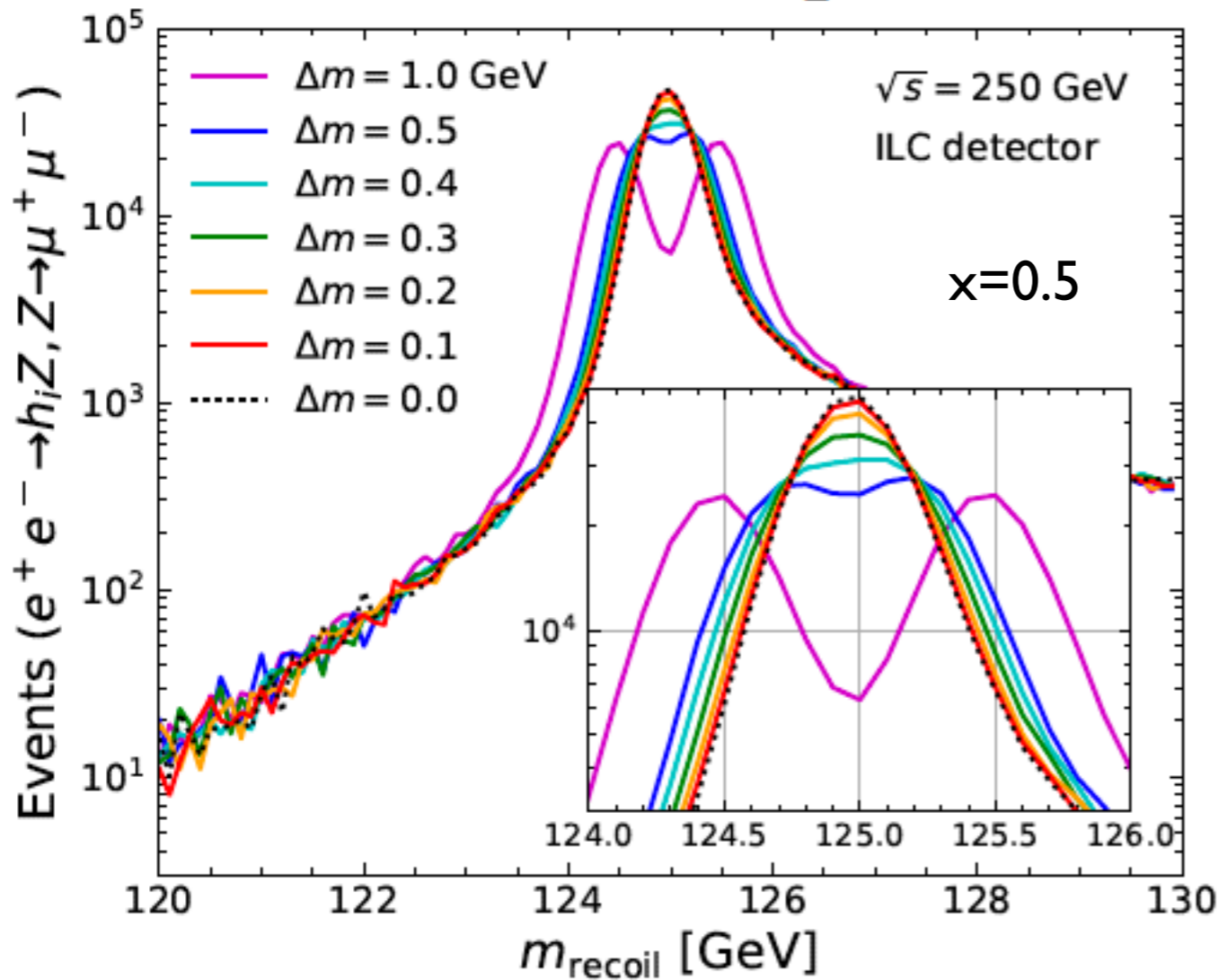
$\Delta m_H \sim 0.04 \text{ GeV}$
@250/fb

$$M_{\text{rec}}^2 = (\sqrt{s} - E_{1+1-})^2 - |\vec{p}_{1+1-}|^2$$

Precise measurement of the Higgs boson mass

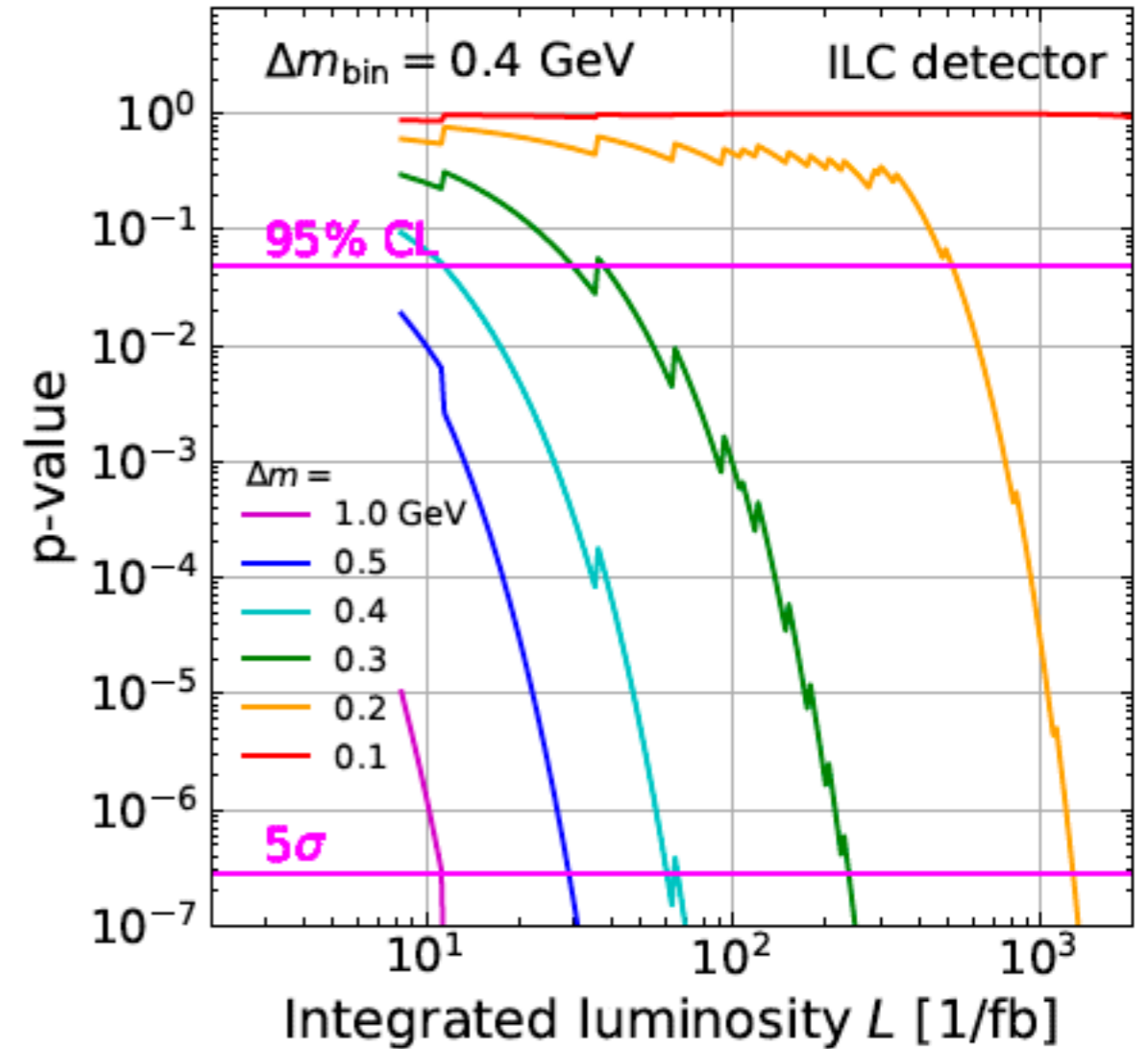
2 near mass-degenerate Higgs bosons

$$m_{h_{1,2}} = \left(125 \pm \frac{\Delta m}{2}\right) \text{ GeV}.$$



$$\chi^2 = \sum_{i=1}^N \frac{(n^i - n_{\text{SM}}^i)^2}{n_{\text{SM}}^i}$$

$e^+e^- \rightarrow h_i Z, Z \rightarrow \mu^+ \mu^-$ @ILC250



We can explore two near mass-degenerate Higgs boson at the ILC if $\Delta m > 0.2 \text{ GeV}$.

Summary

- CxSM is one of the simplest extensions of the SM, which contains an additional Higgs boson and a DM candidate.
- If $m_{h1} \sim m_{h2}$, we can avoid strong constraints from DM direct detection experiments due to the suppression of the DM-nucleon scattering amplitudes.
- Such a degenerate-scalar scenario can be tested at the ILC by using the recoil mass technique.

