Global view on the Higgs self-coupling

CLIC meeting

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with

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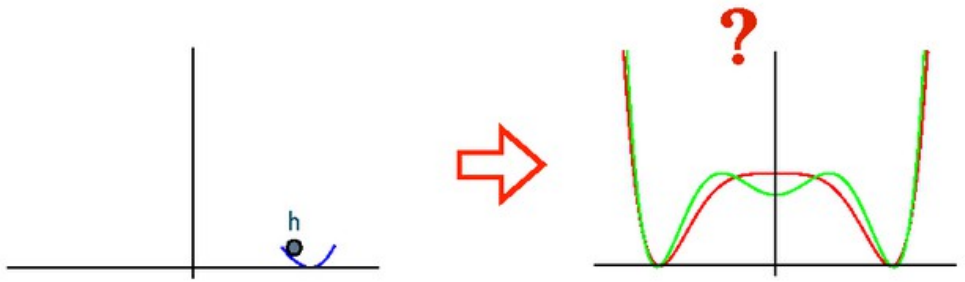
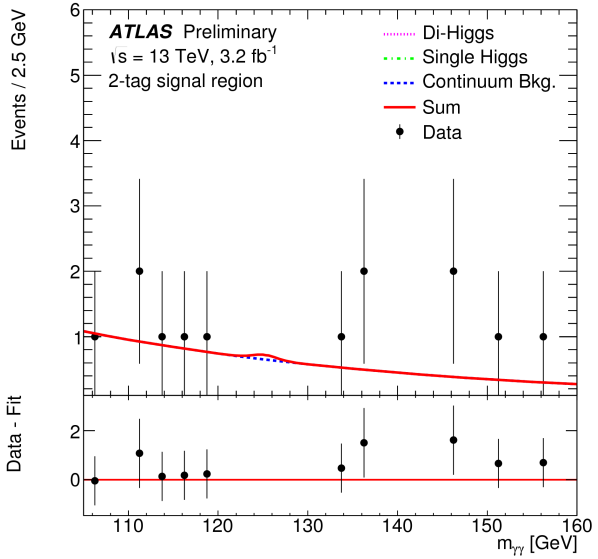
- Structure of the contribution:

  - Discussion of the different ways to probe the trilinear, above and below HH threshold
  - Results of the run below threshold, emphasis on a global analysis
  - Impact of opening the double Higgs production
  - Presentation of the global fit

The relevance of the Higgs self-coupling

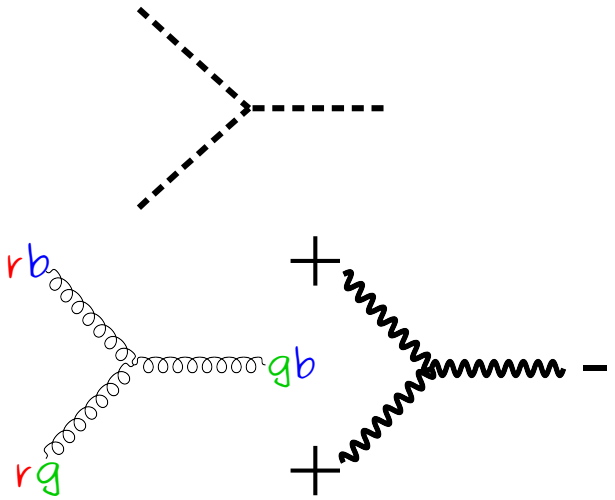


arXiv: 1511.06495

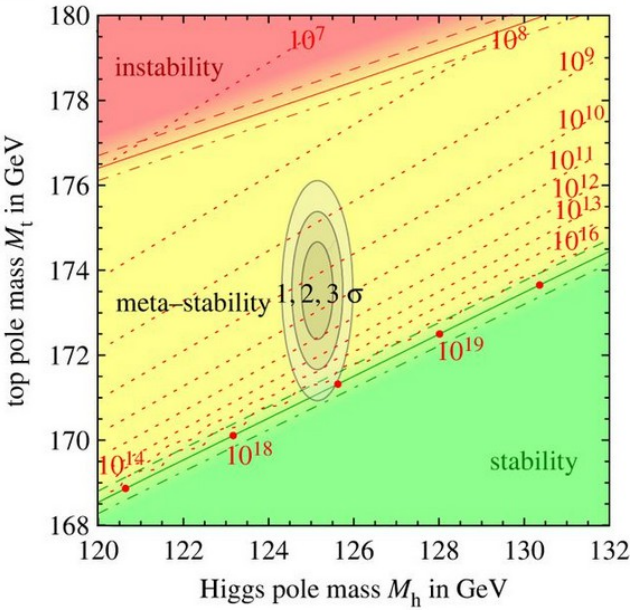


arXiv: 1511.06495

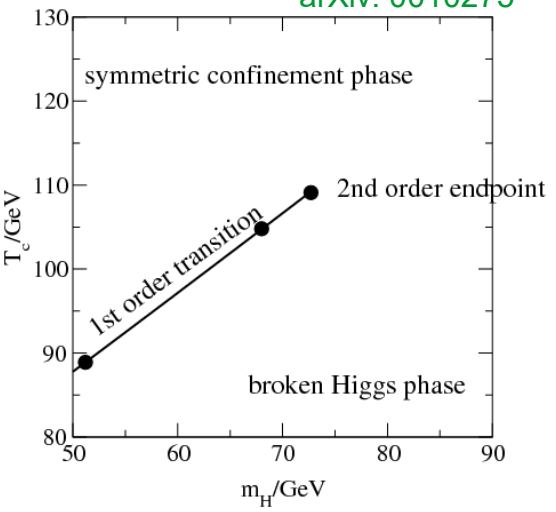
h^3



arXiv: 1205.6497



arXiv: 0010275



Global fit

$$\mathcal{L} \supset \frac{h}{v}\left[\delta c_w \frac{g^2 v^2}{2} W^+_\mu W^{-\mu} + \delta c_z \frac{(g^2+g'^2)v^2}{4} Z_\mu Z^\mu \right.$$
$$+ c_{ww}\frac{g^2}{2} W^+_{\mu\nu} W^{-\mu\nu} + c_{w\Box} g^2 \left(W^-_\mu \partial_\nu W^{+\mu\nu} + \text{h.c.}\right) + \hat{c}_{\gamma\gamma}\frac{e^2}{4\pi^2} A_{\mu\nu}A^{\mu\nu}$$
$$\left. + c_{zz}\frac{g^2+g'^2}{4} Z_{\mu\nu}Z^{\mu\nu} + \hat{c}_{z\gamma}\frac{e\sqrt{g^2+g'^2}}{2\pi^2} Z_{\mu\nu}A^{\mu\nu} + c_{z\Box} g^2 Z_\mu \partial_\nu Z^{\mu\nu} + c_{\gamma\Box} g g' Z_\mu \partial_\nu A^{\mu\nu}\right]$$
$$+ \frac{g_s^2}{48\pi^2}\left(\hat{c}_{gg}\frac{h}{v} + \hat{c}^{(2)}_{gg}\frac{h^2}{2v^2}\right) G_{\mu\nu}G^{\mu\nu} - \sum_f \left[m_f\left(\delta y_f \frac{h}{v} + \delta y_f^{(2)}\frac{h^2}{2v^2}\right)\bar{f}_R f_L + \text{h.c.}\right]$$
$$- (\kappa_\lambda - 1)\lambda_3^{SM} v h^3 \,,$$

7+2+1 independent parameters: $\delta c_z\,,\ c_{zz}\,,\ c_{z\Box}\,,\ \hat{c}_{z\gamma}\,,\ \hat{c}_{\gamma\gamma}\,,\ \hat{c}_{gg}\,, \delta y_t\,,\ \delta y_b\,,\ \delta y_\tau\,,\ \kappa_\lambda\,.$

$$\delta c_w = \delta c_z\,,$$
$$c_{ww} = c_{zz} + 2\frac{g'^2}{\pi^2(g^2+g'^2)}\hat{c}_{z\gamma} + \frac{g'^4}{\pi^2(g^2+g'^2)^2}\hat{c}_{\gamma\gamma}\,,$$
$$c_{w\Box} = \frac{1}{g^2-g'^2}\left[g^2 c_{z\Box} + g'^2 c_{zz} - e^2\frac{g'^2}{\pi^2(g^2+g'^2)}\hat{c}_{\gamma\gamma} - (g^2-g'^2)\frac{g'^2}{\pi^2(g^2+g'^2)}\hat{c}_{z\gamma}\right],$$
$$c_{\gamma\Box} = \frac{1}{g^2-g'^2}\left[2g^2 c_{z\Box} + (g^2+g'^2)\,c_{zz} - \frac{e^2}{\pi^2}\hat{c}_{\gamma\gamma} - \frac{g^2-g'^2}{\pi^2}\hat{c}_{z\gamma}\right],$$
$$\hat{c}^{(2)}_{gg} = \hat{c}_{gg}\,,$$
$$\delta y_f^{(2)} = 3\delta y_f - \delta c_z\,.$$

relations at dimension 6

$$\delta g_{1,z} = \frac{g'^2}{2(g^2-g'^2)}\left[\hat{c}_{\gamma\gamma}\frac{e^2}{\pi^2} + \hat{c}_{z\gamma}\frac{g^2-g'^2}{\pi^2} - c_{zz}\,(g^2+g'^2) - c_{z\Box}\frac{g^2}{g'^2}\,(g^2+g'^2)\right],$$
$$\delta\kappa_\gamma = -\frac{g^2}{2(g^2+g'^2)}\left[\hat{c}_{\gamma\gamma}\frac{e^2}{\pi^2} + \hat{c}_{z\gamma}\frac{g^2-g'^2}{\pi^2} - c_{zz}(g^2+g'^2)\right],$$

measured in diboson

Analysis

We include in the fit

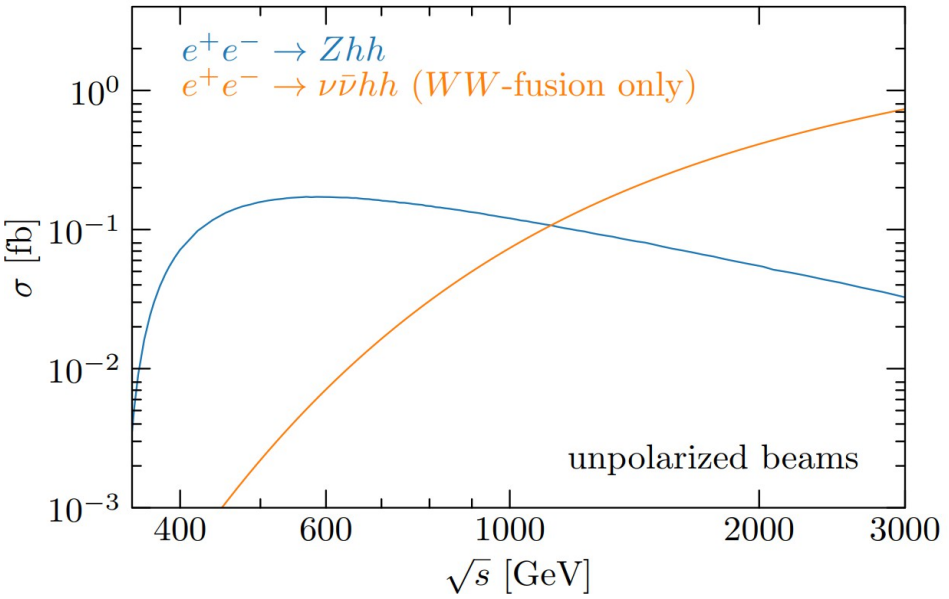
- Higgstrahlung production Zh
- Higgs production through WW fusion
- Higgs decays to: ZZ, WW, γγ, Zγ, gg, bb, cc, ττ, μμ
- Weak boson pair production

- Double Higgstrahlung Zhh
- Weak boson fusion to HH

CLIC specifications from previous study: 1608.07538

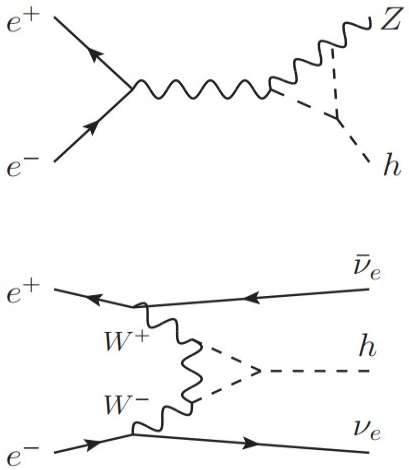
350GeV(0.5/ab), 1.4TeV (1.5/ab), 3TeV (2/ab)

See 1704.02333, 1711.03978 for details



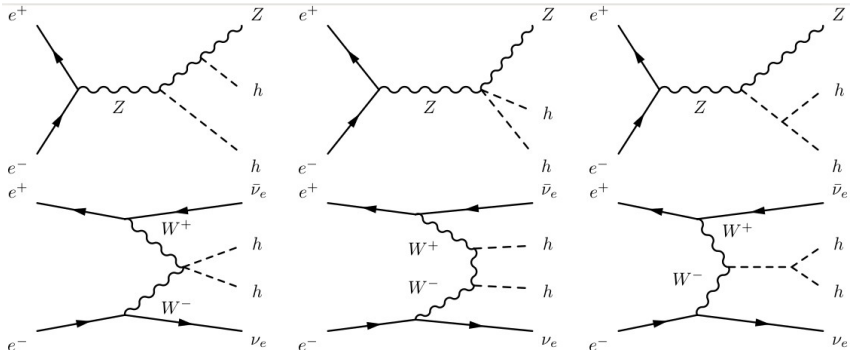
350GeV run

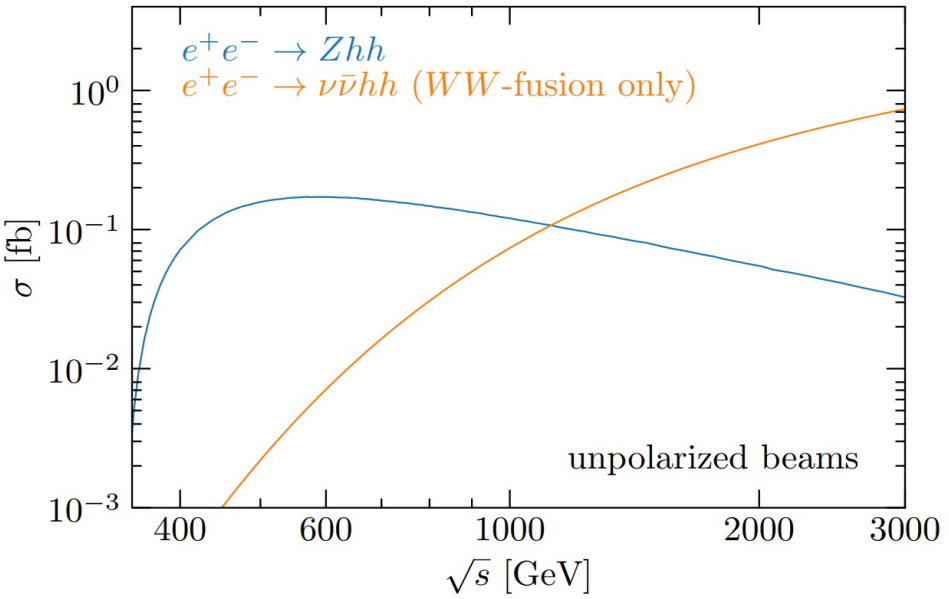
below HH threshold



1.4 & 3 TeV run

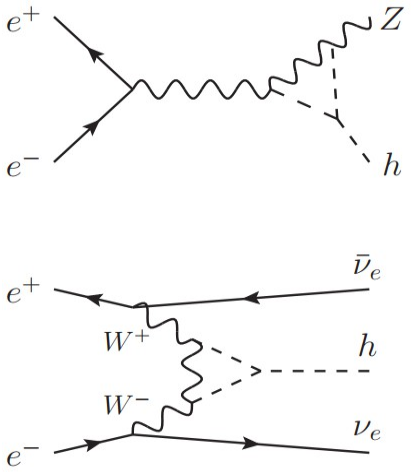
above HH threshold





350GeV run

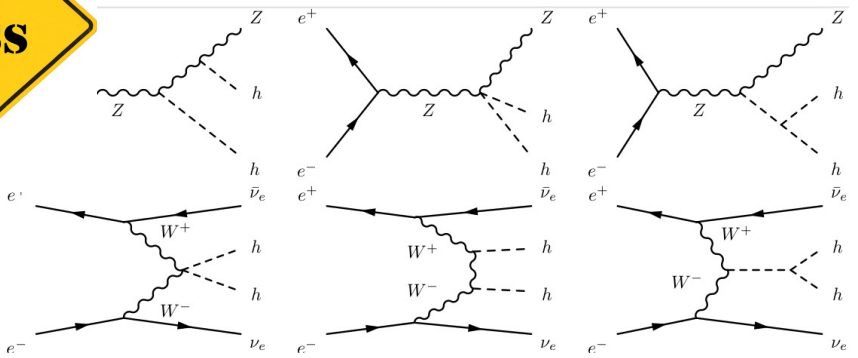
below HH threshold



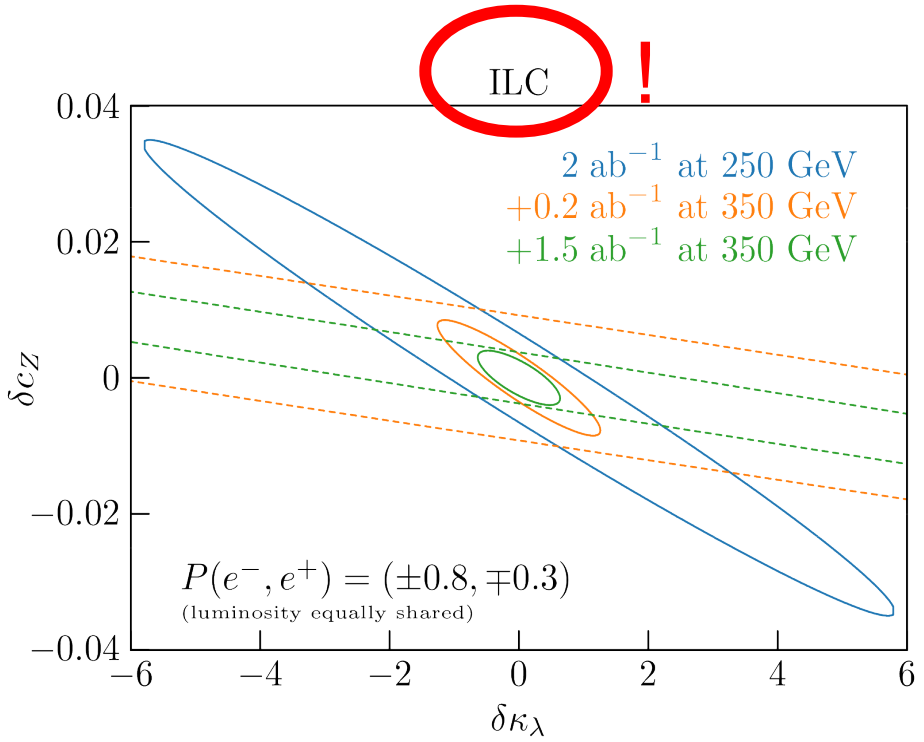
380GeV run

1.4 & 3 TeV run

above HH threshold



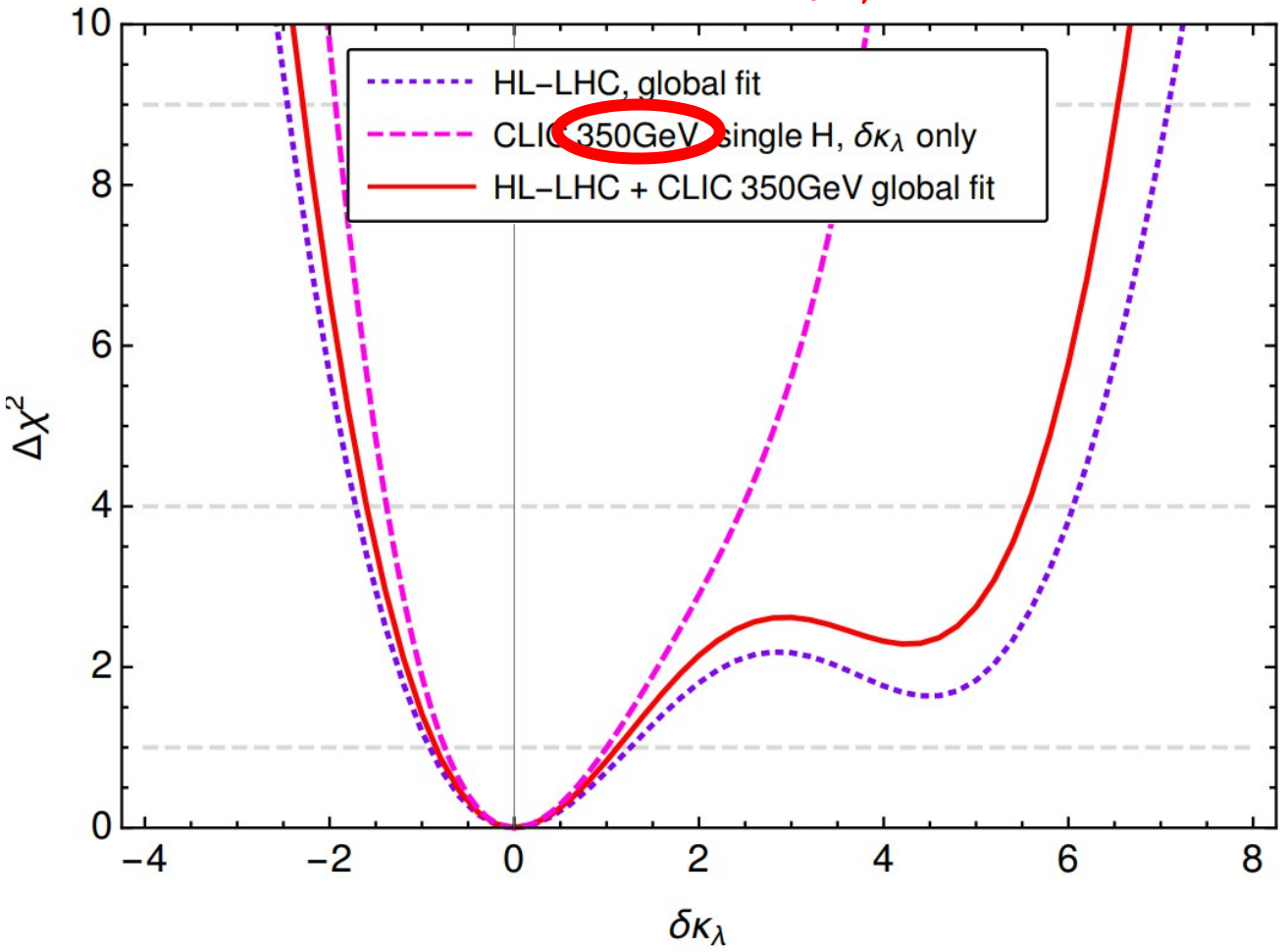
A low energy run



- Large degeneracy with a single run
- Loops of Higgses deform the spectrum in a nontrivial way as the momentum transfer crosses different thresholds.

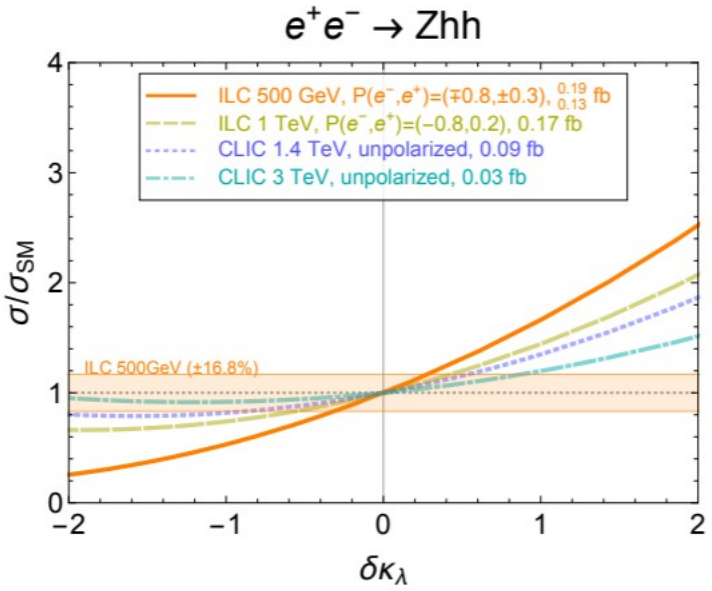
A low energy run

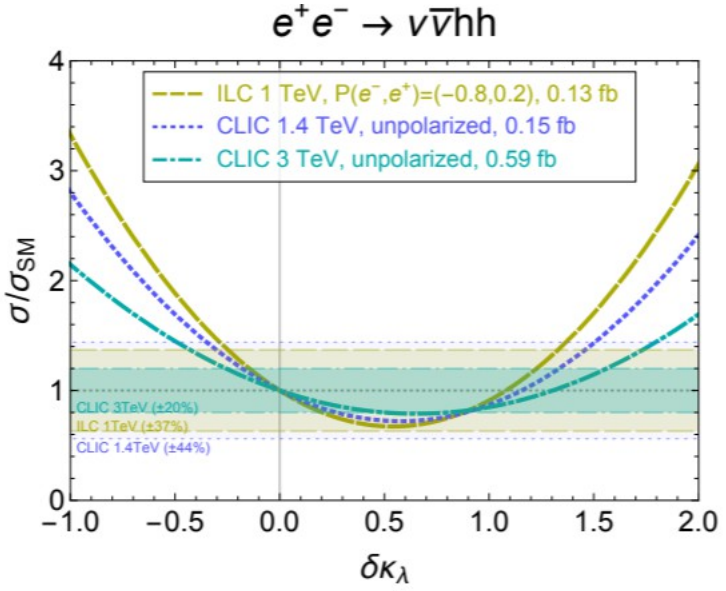
0.5/ab at 350GeV



- Loop effects in single Higgs production better than HL-LHC, in exclusive fit
- Flat directions worsen constraints if a global fit is considered

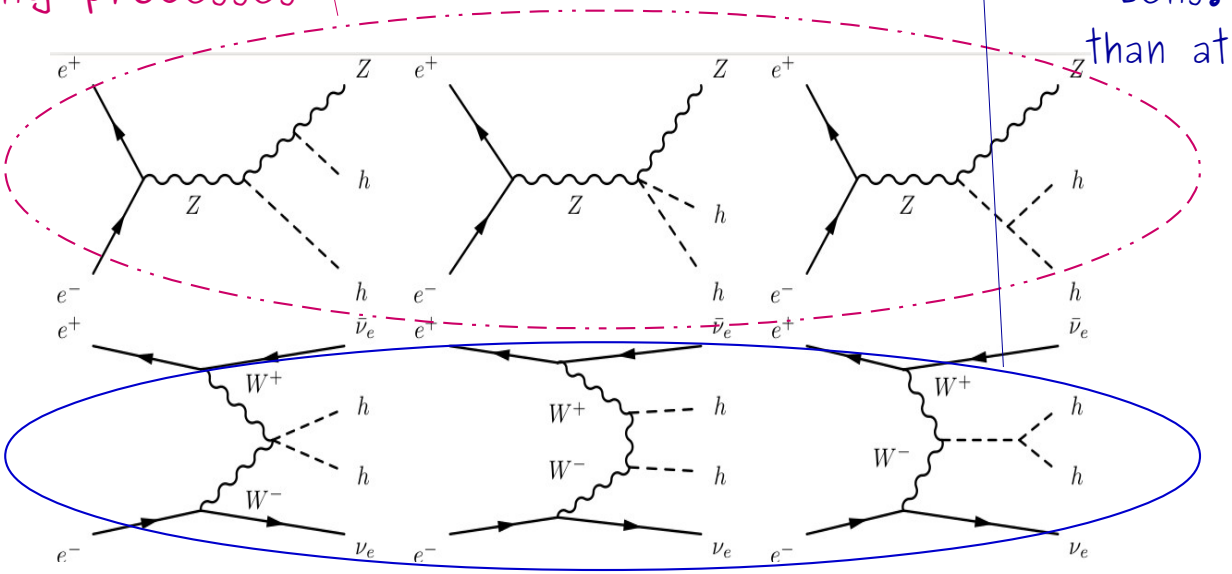
High energy run



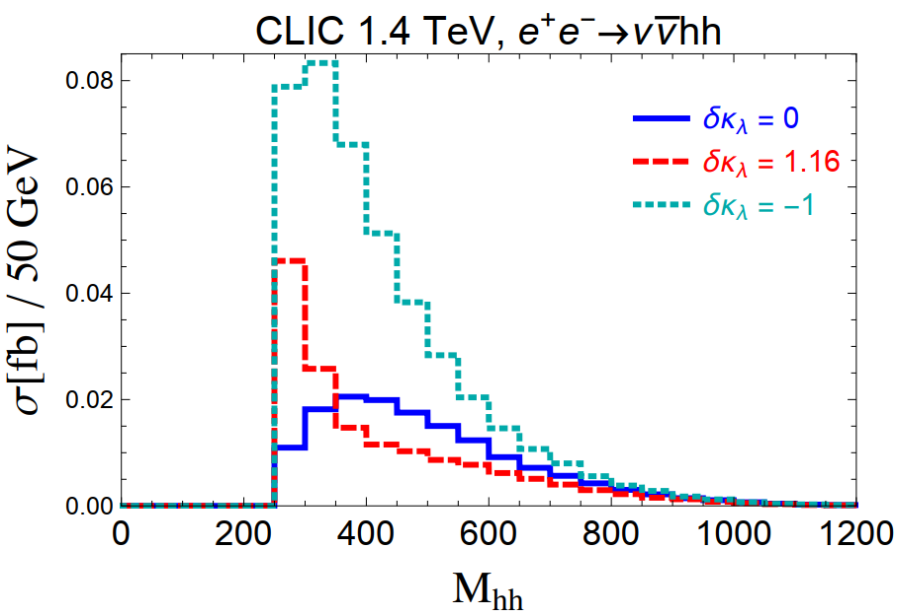


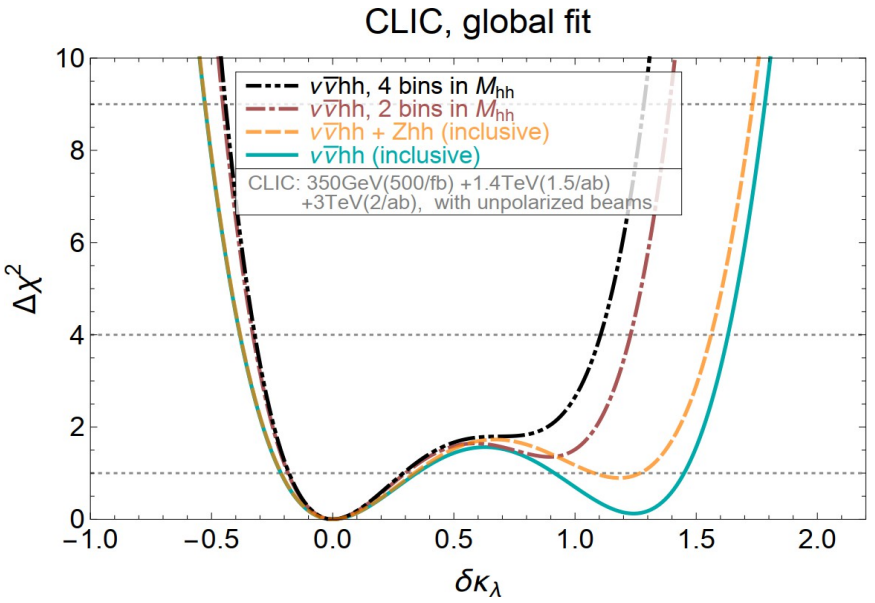
- Low sensitivity on trilinear in Zhh production due to Large uninteresting processes

- Low sens. due to destructive Interference.
- Sens. at 3TeV smaller than at 1.4TeV!



High energy run

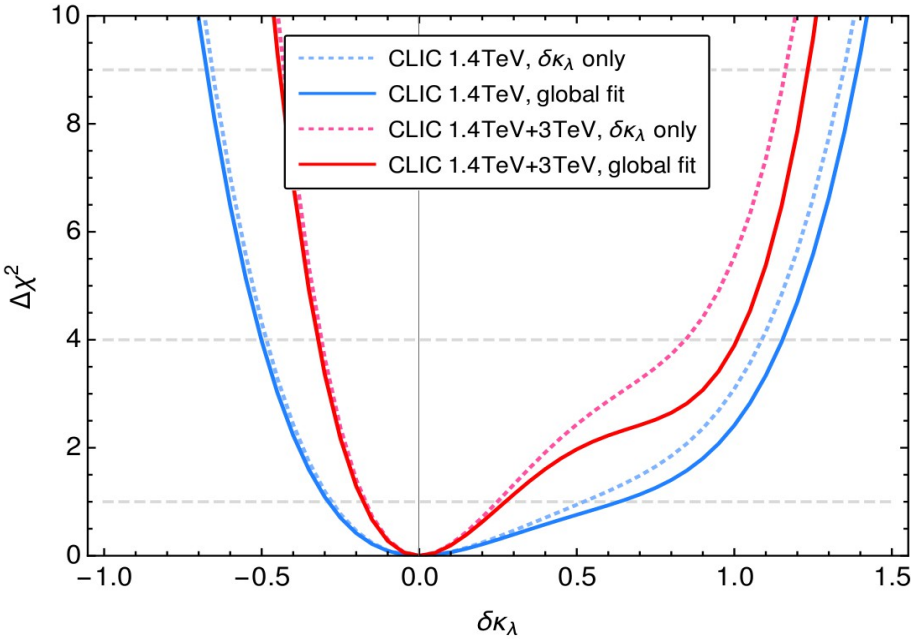




- High sensitivity on trilinear on the spectrum near threshold
- (simple) differential information resolves degenerate minima

Global fit

350GeV(0.5/ab), 1.4TeV (1.5/ab), 3TeV (2/ab)



	$\Delta\chi^2 = 1$	$\Delta\chi^2 = 4$
1.4 TeV, exclusive	$[-0.29,\ 0.52]$	$[-0.49,\ 1.09]$
1.4 TeV, global	$[-0.29,\ 0.63]$	$[-0.50,\ 1.15]$
1.4 + 3 TeV, exclusive	$[-0.18,\ 0.24]$	$[-0.31,\ 0.84]$
1.4 + 3 TeV, global	$[-0.18,\ 0.27]$	$[-0.32,\ 1.01]$

- 1.4TeV fit dominated by (differential) VFB. Single Higgs observables strong enough to close any flat direction.
- 3TeV does not help much: decrease in cross section and sensitivity. Limiting factor is precision on single Higgs couplings.

To be done:

- Luminosities to be changed to

  380GeV(1/ab), 1.5TeV (2/ab), 3TeV (5/ab)

The 380GeV run might imply qualitative changes, yet to be studied.