ttHH
at the LHC and beyond

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based on work in collaboration with
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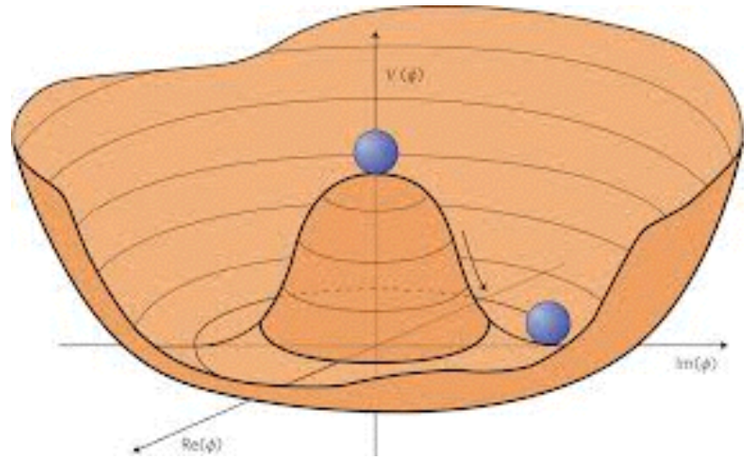
1409.8074

- We have the remnant of elw. symmetry breaking



- Now we want to finally study the mechanism/potential

$$\mathcal{L} = (D_\mu \Phi)^\dagger (D^\mu \Phi) - V(\Phi^\dagger \Phi) \qquad V\left(\Phi^\dagger \Phi\right) = \mu^2 \Phi^\dagger \Phi + \lambda \left(\Phi^\dagger \Phi\right)^2$$

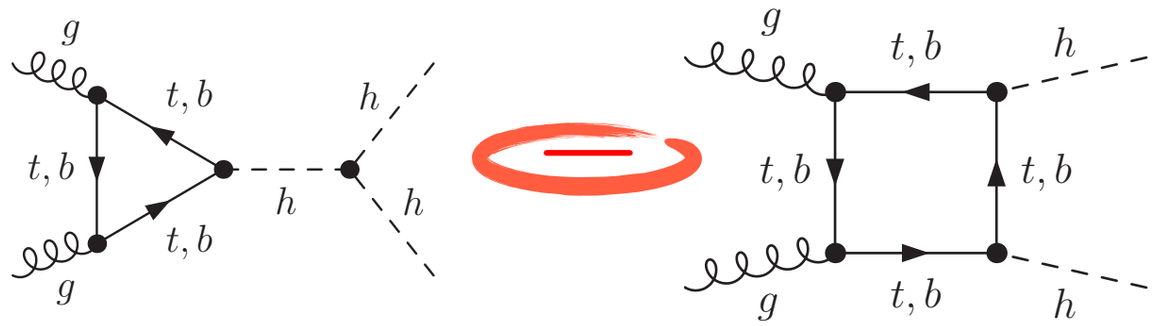
- Studying quartic impossible at envisioned FCs

- Measuring Higgs selfcoupling one of strongest motivations for HL-LHC

- Unless ILC has 1 TeV energy might not outperform LHC

- Interplay between HH and ttHH can be interesting

14 TeV predictions for measurement of Higgs selfcoupling



Due to destructive interference better sensitivity
for selfcouplings smaller than in SM

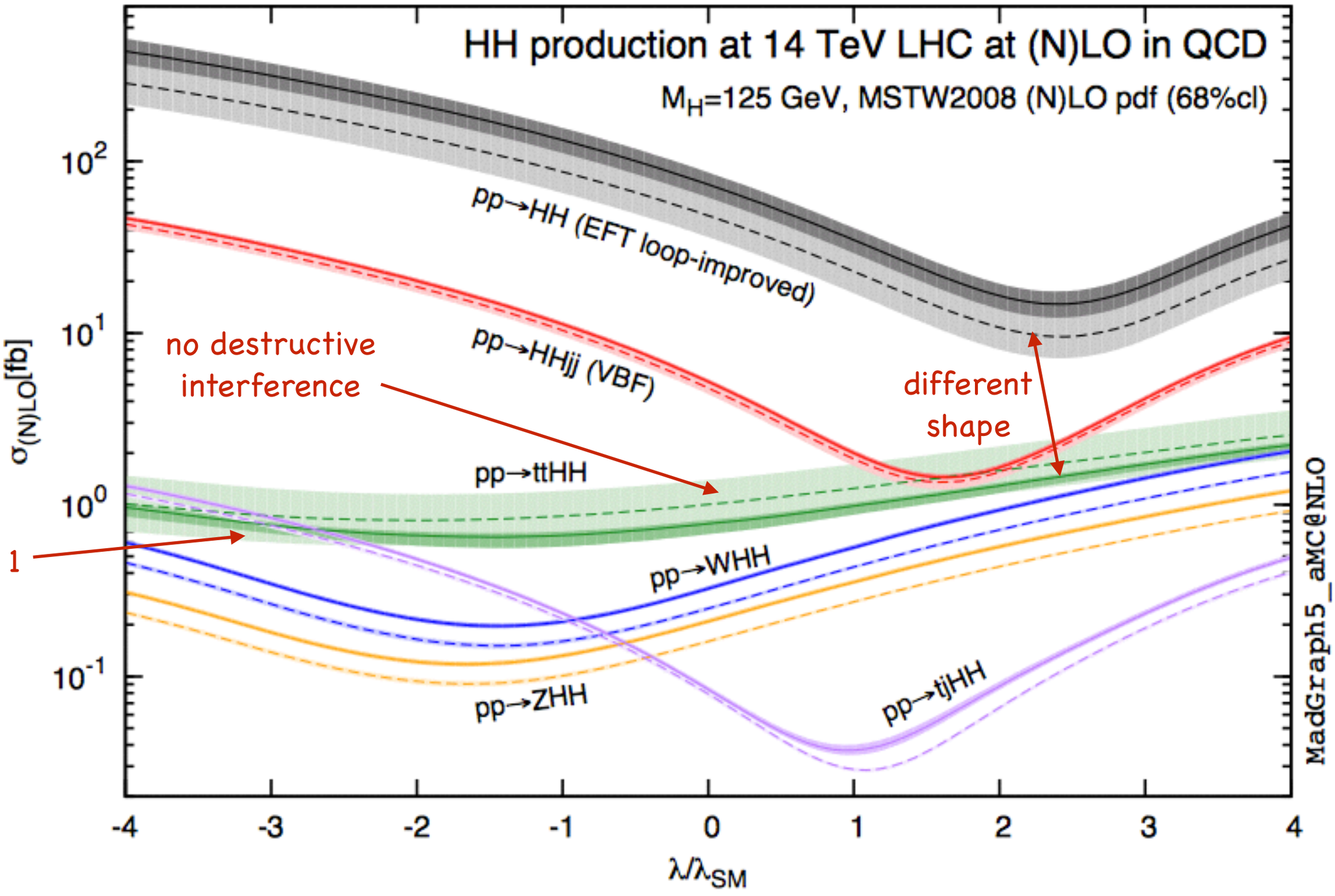
$b\bar{b}\gamma\gamma$: Prospects for 14 TeV dire...

process	ATLAS		CMS
SM HH→bbγγ	8.4± 0.1		9.9
bbγγ	9.7 ± 1.5	γγ+jets	8.5
ccγγ, bbγj, bbjj, jjγγ	24.1 ± 2.2	γ+jets, jets	7.4
top background	3.4 ± 2.2		1.1
ttH(γγ)	6.1 ± 0.5		1.5
Z(bb)H(γγ)	2.7 ± 0.1		3.3
bbH(γγ)	1.2 ± 0.1		0.8
Total background	47.1 ± 3.5		22.6
S/√B (barrel+endcap)	1.2		
S/√B (split barrel and endcap)	1.3		

Will need combination with $b\bar{b}\tau^+\tau^-$, $b\bar{b}W^+W^-$ and $b\bar{b}b\bar{b}$

Higgs selfcoupling in ttHH

[Frederix et al. PLB 732 (2014)]



Higgs selfcoupling in ttHH

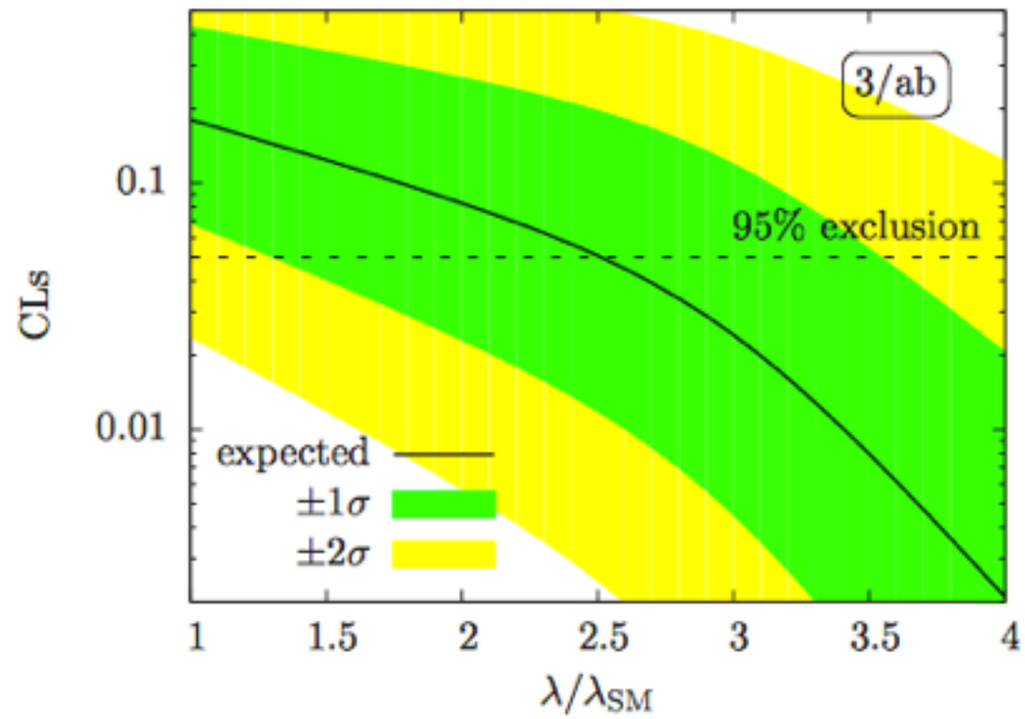
[Englert, Krauss, MS, Thompson]

[Liu, Zhang]

	signal		backgrounds					
	$\xi = 1$	$\xi = 4$	$t\bar{t}b\bar{b}b\bar{b}$	$t\bar{t}h b\bar{b}$	$t\bar{t}hZ$	$t\bar{t}Zb\bar{b}$	$t\bar{t}ZZ$	$Wb\bar{b}b\bar{b}$
trigger	0.10	0.23	4.75	1.38	0.64	1.37	1.36×10^{-2}	1.33
jet cuts	7.40×10^{-2}	0.17	1.44	0.76	0.40	0.65	8.74×10^{-3}	7.46×10^{-2}
5 b tags	1.23×10^{-2}	2.83×10^{-2}	4.46×10^{-2}	6.19×10^{-2}	7.24×10^{-3}	4.43×10^{-2}	1.25×10^{-3}	5.35×10^{-4}
$2\times h\to b\bar{b}$	7.33×10^{-3}	1.69×10^{-2}	1.59×10^{-2}	2.71×10^{-2}	3.41×10^{-3}	1.56×10^{-2}	4.28×10^{-4}	$<1\times10^{-4}$
lep./had. t	5.04×10^{-3}	1.12×10^{-2}	9.50×10^{-3}	1.66×10^{-2}	2.29×10^{-3}	9.42×10^{-3}	2.69×10^{-4}	$<1\times10^{-4}$
lep. t only	2.33×10^{-3}	5.29×10^{-3}	5.03×10^{-3}	9.36×10^{-3}	1.14×10^{-3}	4.90×10^{-3}	1.39×10^{-4}	$<1\times10^{-4}$
had. t only	2.71×10^{-3}	5.93×10^{-3}	4.47×10^{-3}	7.20×10^{-3}	1.16×10^{-3}	4.44×10^{-3}	1.30×10^{-4}	$<1\times10^{-4}$
6 b tags	2.21×10^{-3}	4.97×10^{-3}	3.80×10^{-3}	8.01×10^{-3}	9.57×10^{-4}	5.10×10^{-3}	1.86×10^{-4}	$<1\times10^{-4}$
$2\times h\to b\bar{b}$	1.81×10^{-3}	5.94×10^{-3}	2.01×10^{-3}	5.47×10^{-3}	6.60×10^{-4}	3.28×10^{-3}	1.11×10^{-4}	$<1\times10^{-4}$

- Signal rate too small for inventive reconstruction
- Though Backgrounds for 5+ b-tags already small
- 13-22 signal event with 3000 ifb

$$\lambda \lesssim 2.51\ \lambda_{\rm SM} \text{ at } 95\%\ \text{CLs.}$$



Higgs selfcoupling in ttHH

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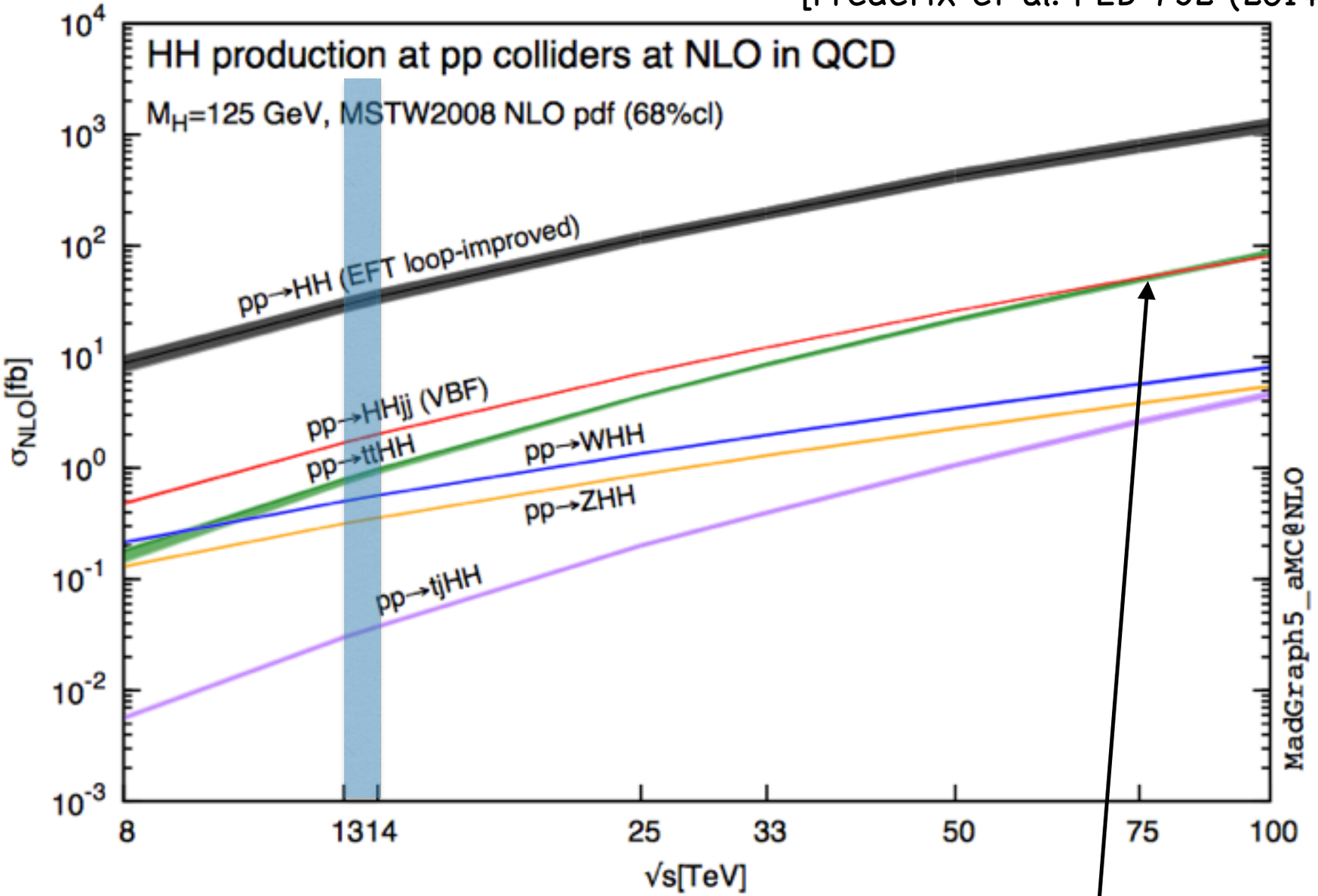

ttHH cross section grows over-proportionally compared to other channels

Summary

ttHH possibly viable already at 14 TeV HL-LHC

ttHH can be more sensitive for enhance selfcouplings
(complementary to HH final state)

Signal cross section at 100 TeV grows a lot,
backgrounds need testing