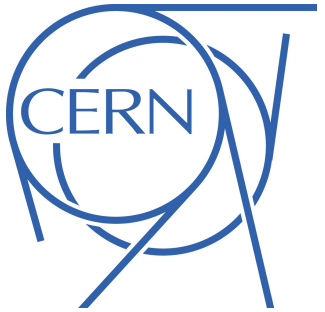
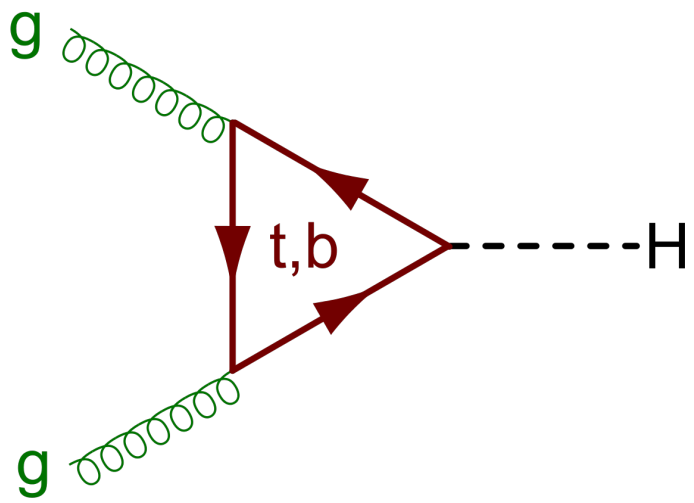


Studies on Associated Higgs Production with Top Quarks in the H→$\gamma\gamma$ Channel

Kaicheng Li

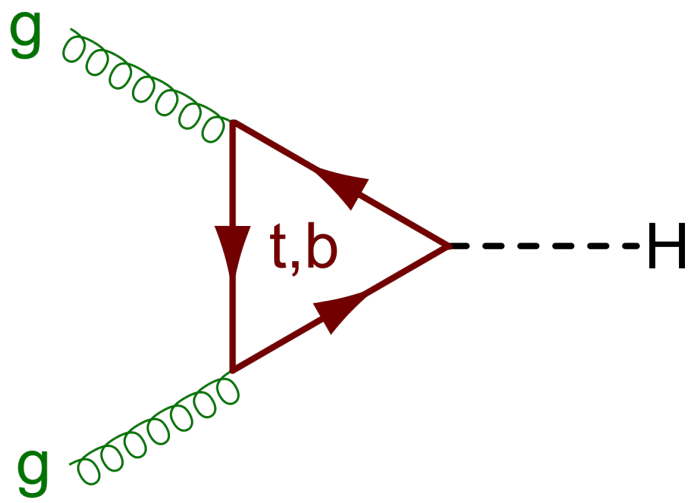
03/26/2015

Higgs Production Modes

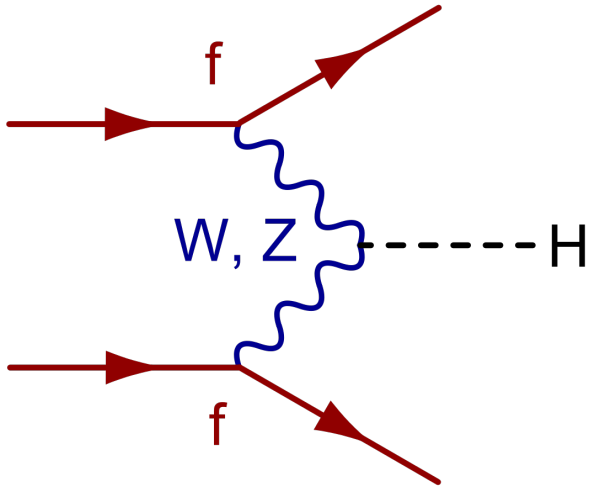


Gluon Gluon Fusion

Higgs Production Modes

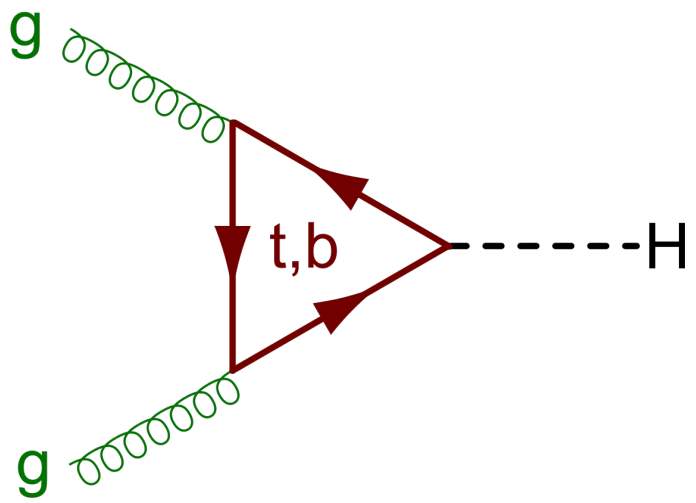


Gluon Gluon Fusion

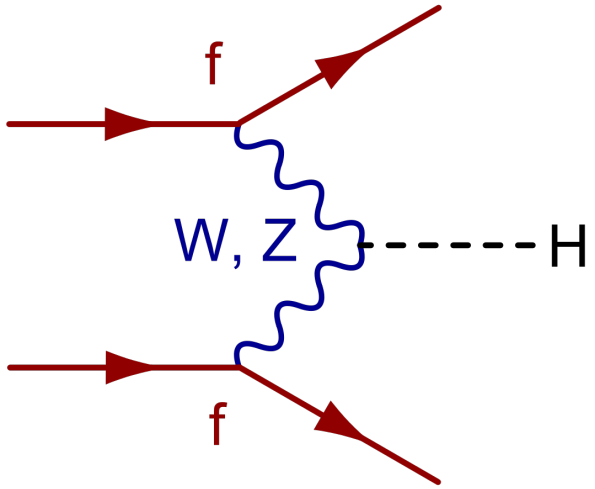


Vector Boson Fusion

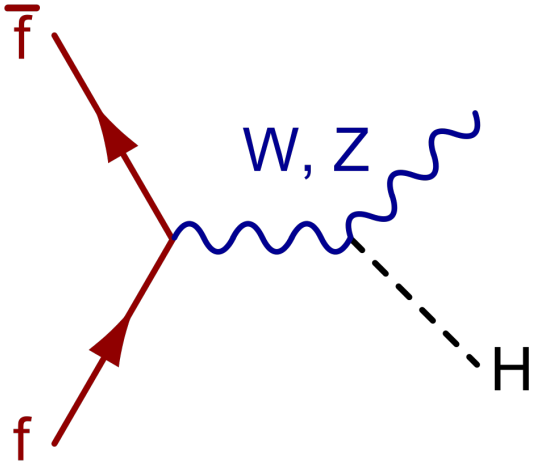
Higgs Production Modes



Gluon Gluon Fusion

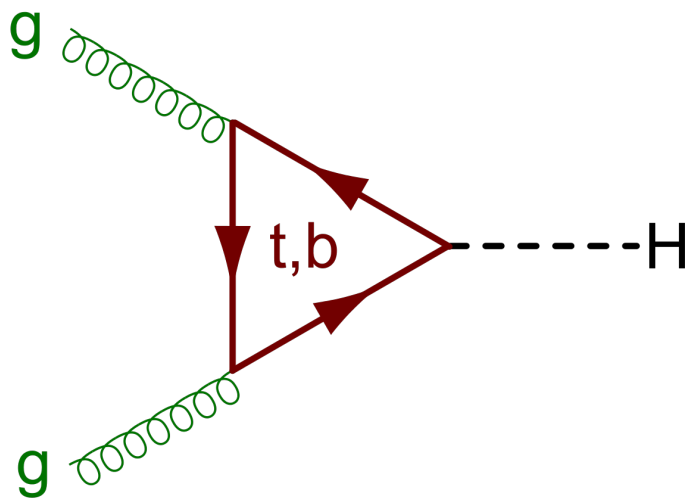


Vector Boson Fusion

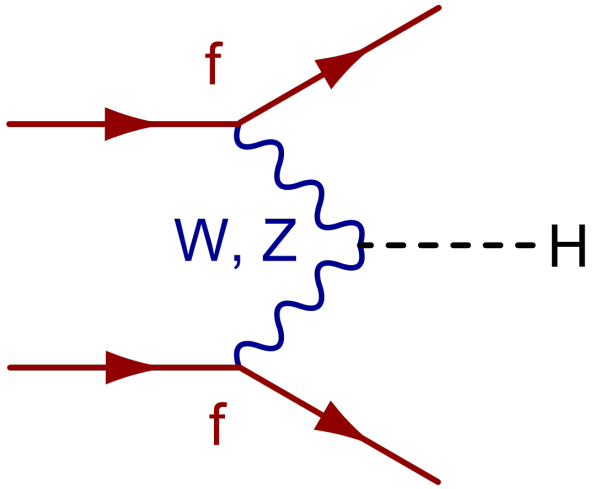


W/Z Associated Production

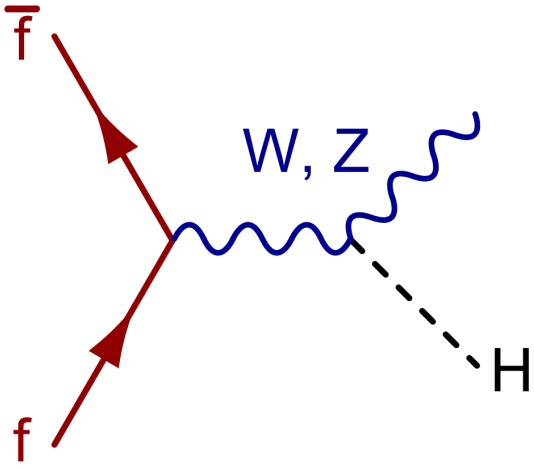
Higgs Production Modes



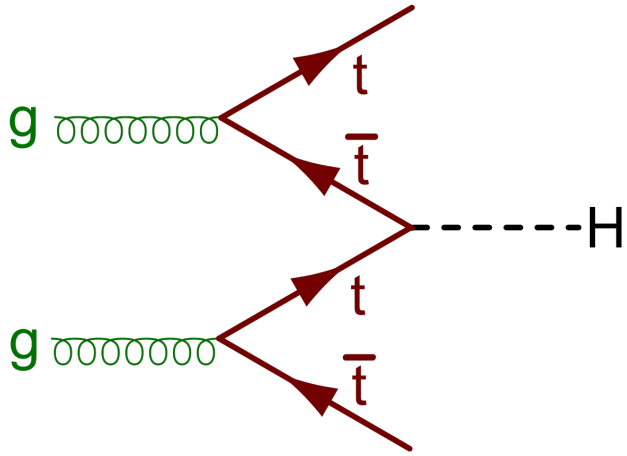
Gluon Gluon Fusion



Vector Boson Fusion

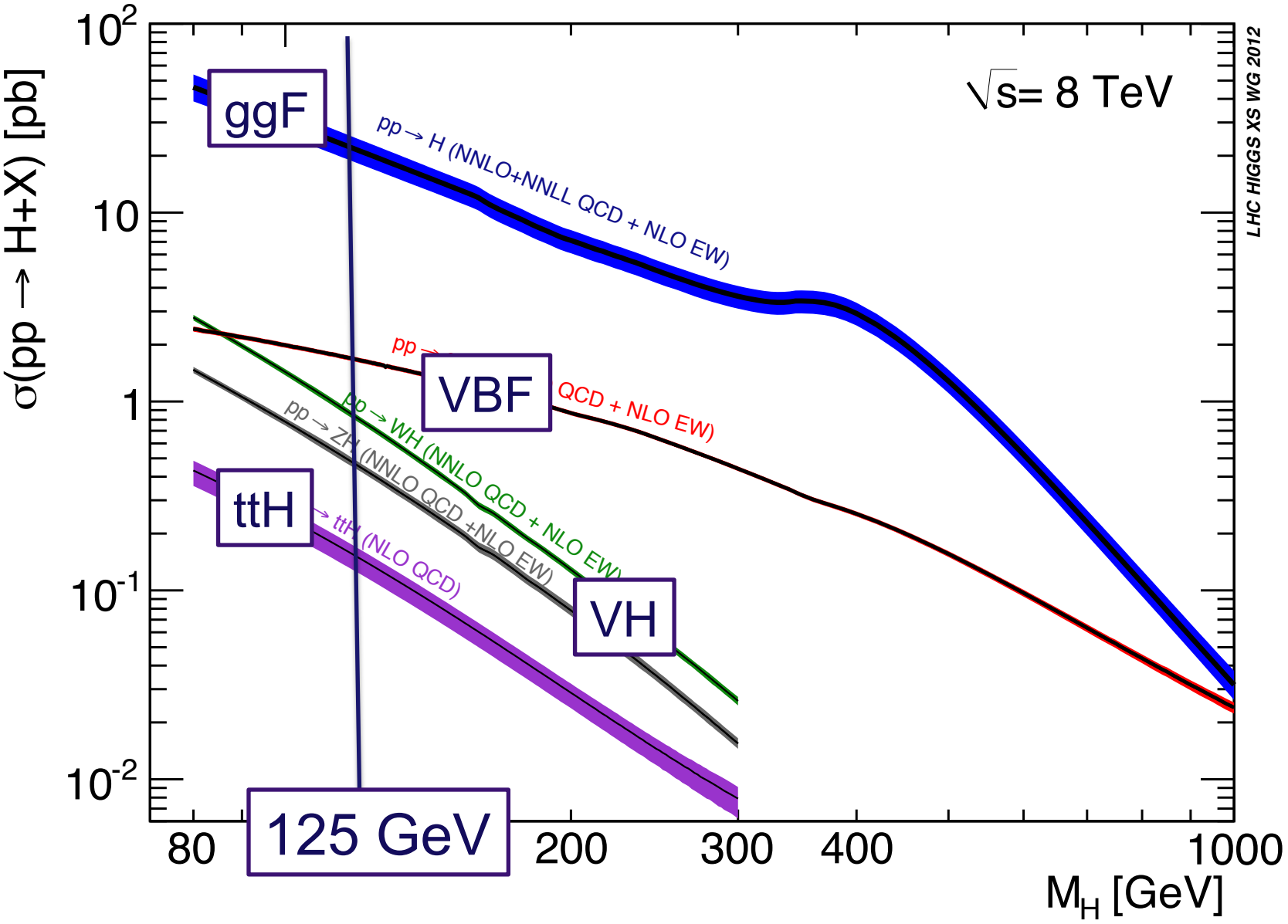


Associated Production with W/Z

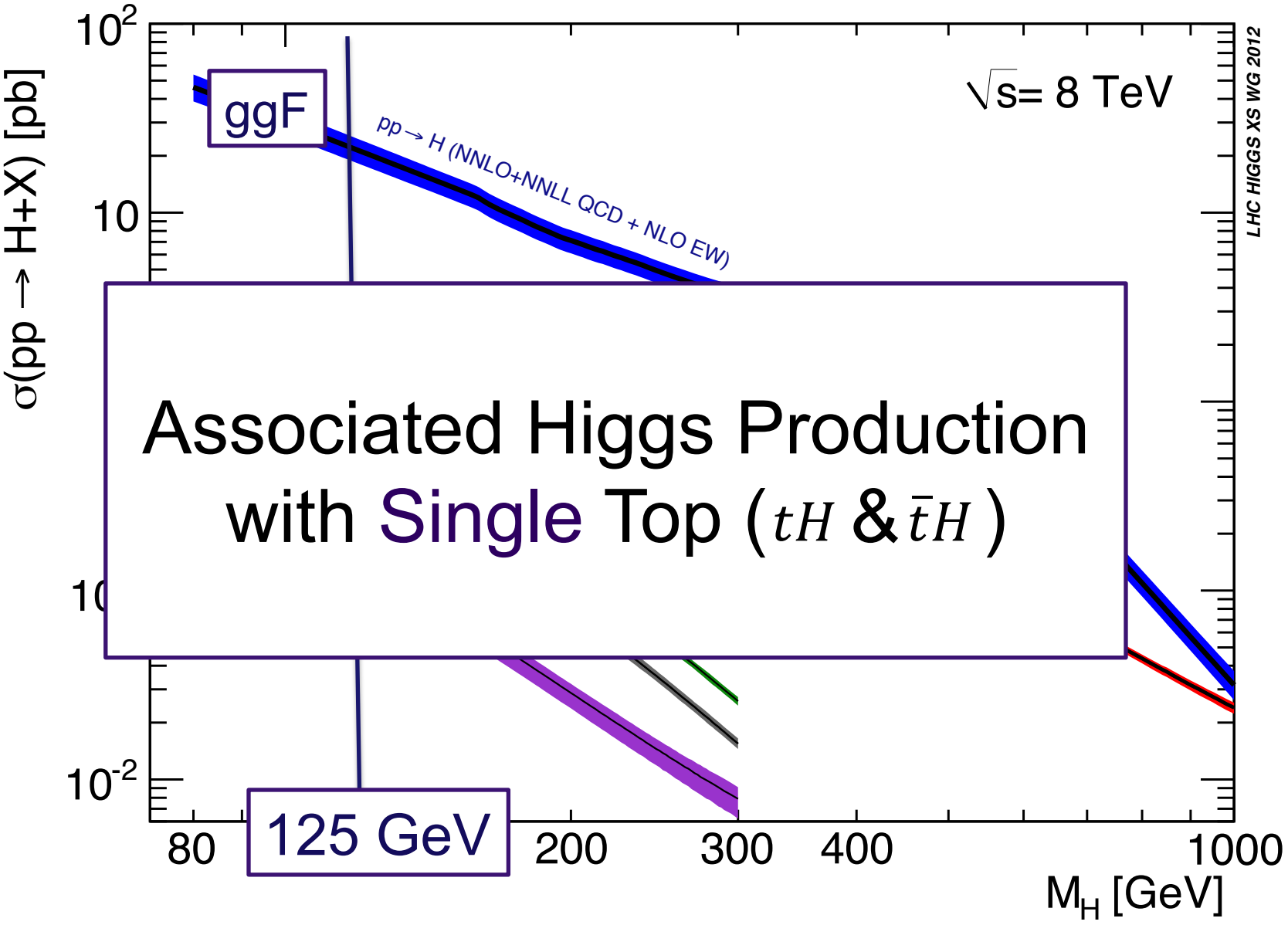


Associated Production with Top Pairs

Higgs Production Modes



Higgs Production Modes



Associated Higgs Production with Single Top (tH & $\bar{t}H$)

- For the Associated Higgs Production with Top Quark Pairs or Single Top Quark in the diphoton channel, there is a dedicated team from HSG1 ($H \rightarrow \gamma\gamma$) and HSG8 (tH/ttH)..

- I am going to be involved with the tH/ttH($H \rightarrow \gamma\gamma$) analysis during my rest stay at CERN, and hopefully make some contributions.

- Today, I will present my studies on the physics background behind tH/ttH and show sensitivity projectionplots for tH/ttH($H \rightarrow \gamma\gamma$) in Run II.

- At the end, I will report my progress on
  - The HGamma General Classification Tool
  - The Overlap Removal Handler for the HGamma Analysis Framework

Yukawa Interaction

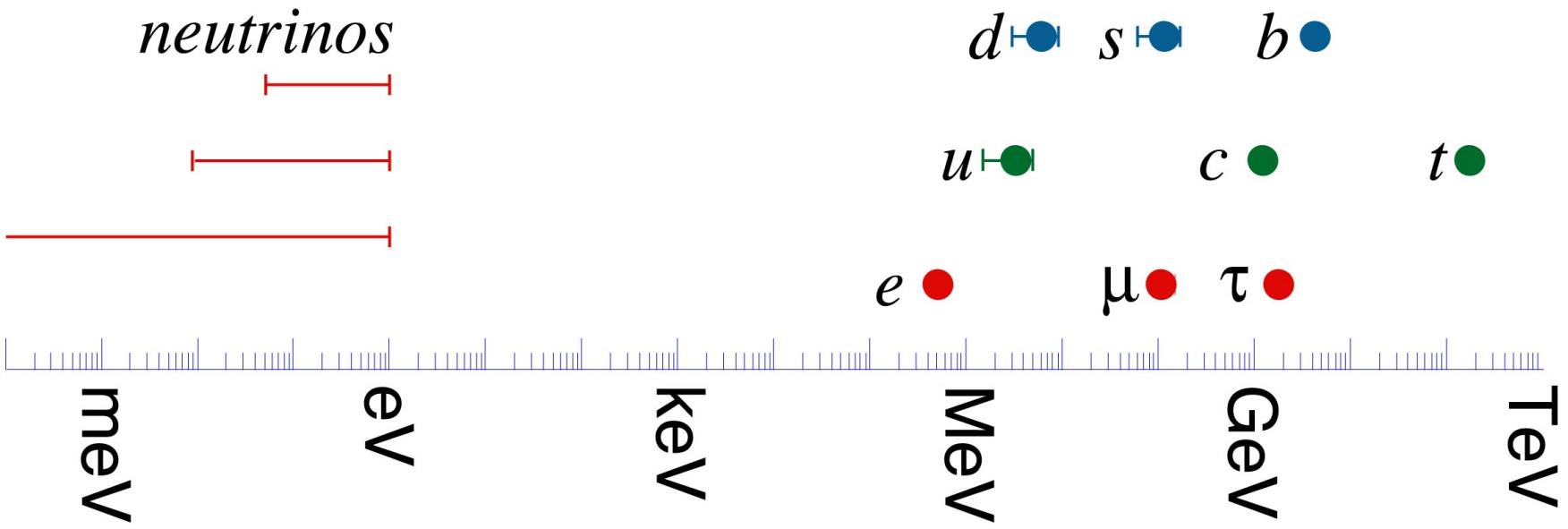
- The Yukawa interaction describes the coupling between the Higgs field and massless quark and lepton fields.

- Through spontaneous symmetry breaking, these fermions acquire a mass proportional to the vacuum expectation value (VEV) of the Higgs field.

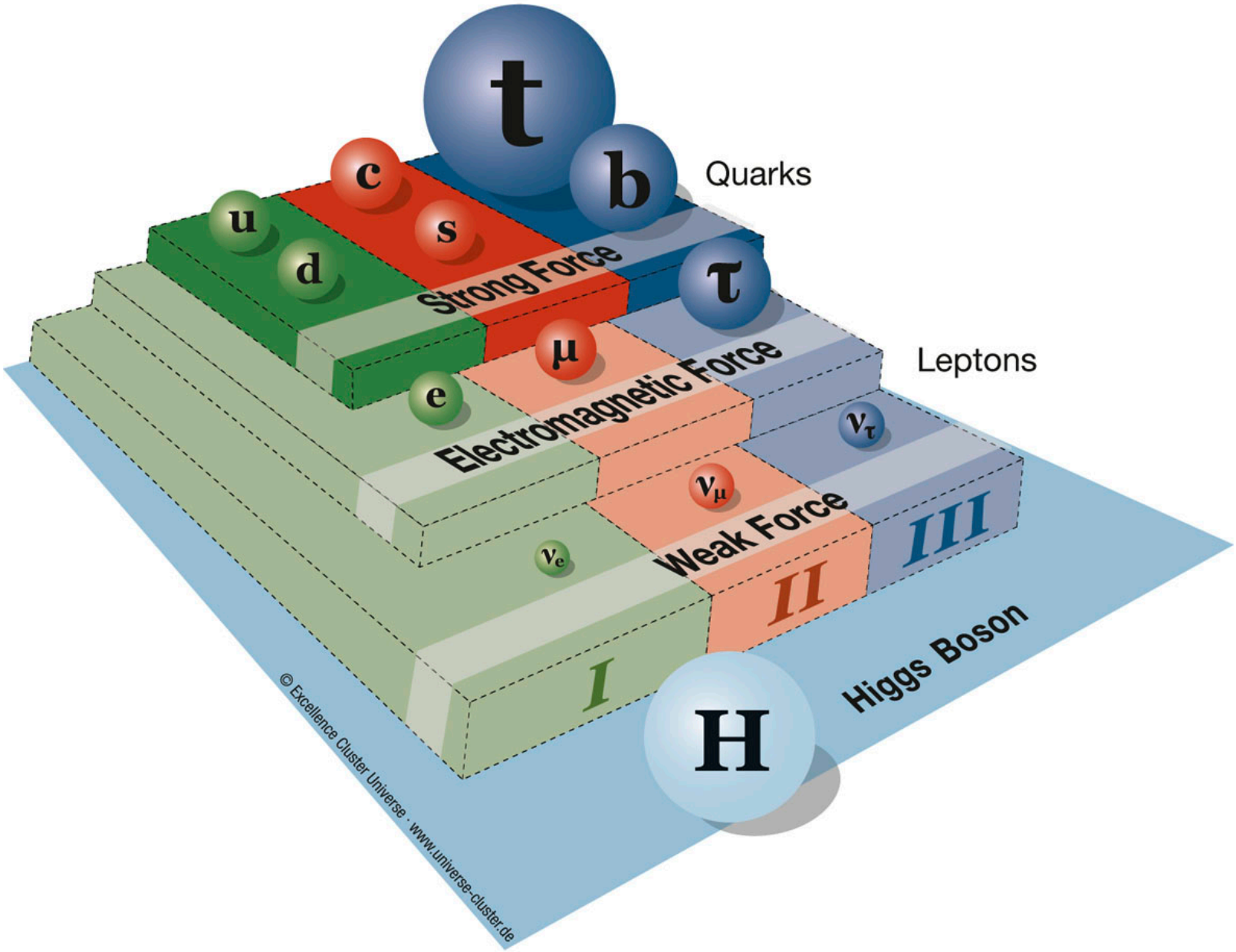
- In the Standard Model, the Yukawa coupling to a fermion is proportional to the mass of the fermion[1]:

$$Y_f = \frac{m_f \cdot \sqrt{2}}{VEV}$$

Top Quark Mass



Top Quark Mass



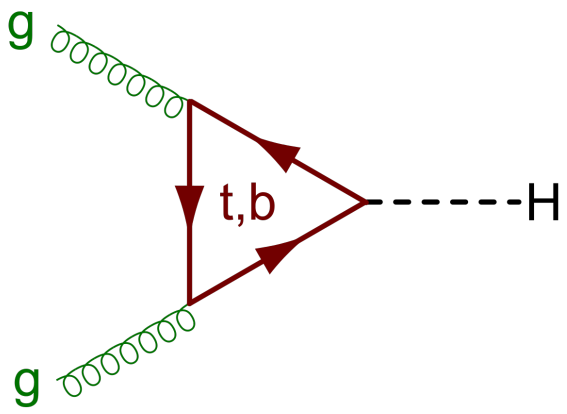
Yukawa Interaction

- Because the top quark is very heavy, its predicted Yukawa coupling to the Higgs boson, Y_t^{SM}, would be very large in comparison to other fermion Yukawa couplings.

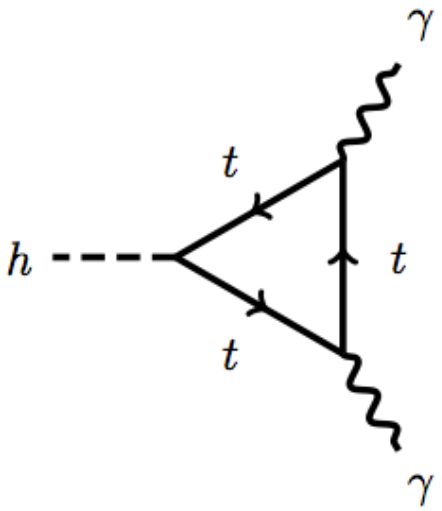
- Hence, the measurement of Y_t is important for understanding Electroweak Symmetry Breaking and testing theories beyond the standard model.

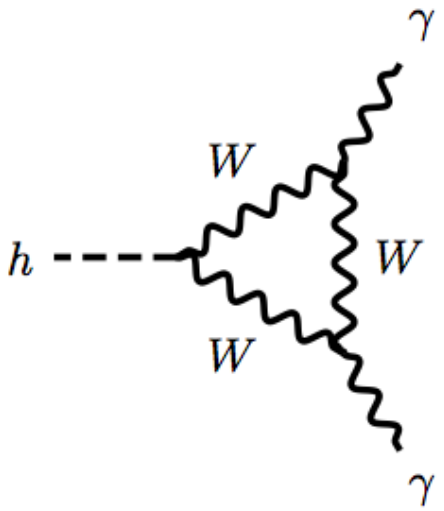
Indirect Measurement of Y_t

- gg→*H*



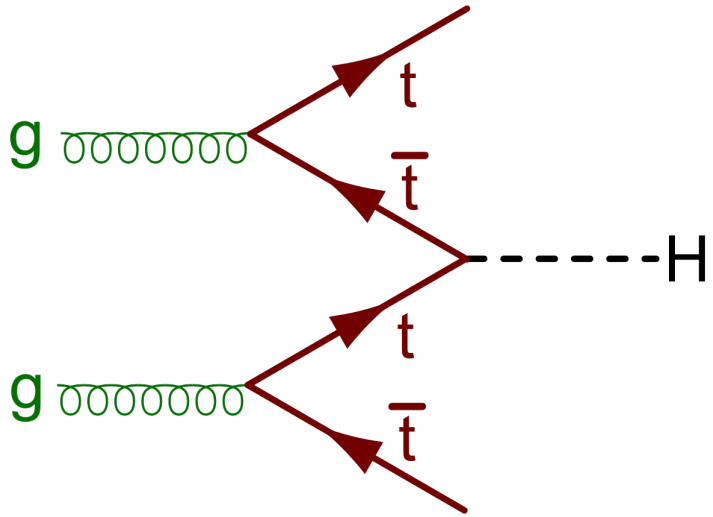
- H→*γγ*





Direct Measurement of Y_t

- Associated Higgs Production with Top Quark Pairs



The production cross section of ttH is proportional to Y_t squared. Thus, ttH can only directly measure the magnitude of Y_t but not the relative sign of Y_t.

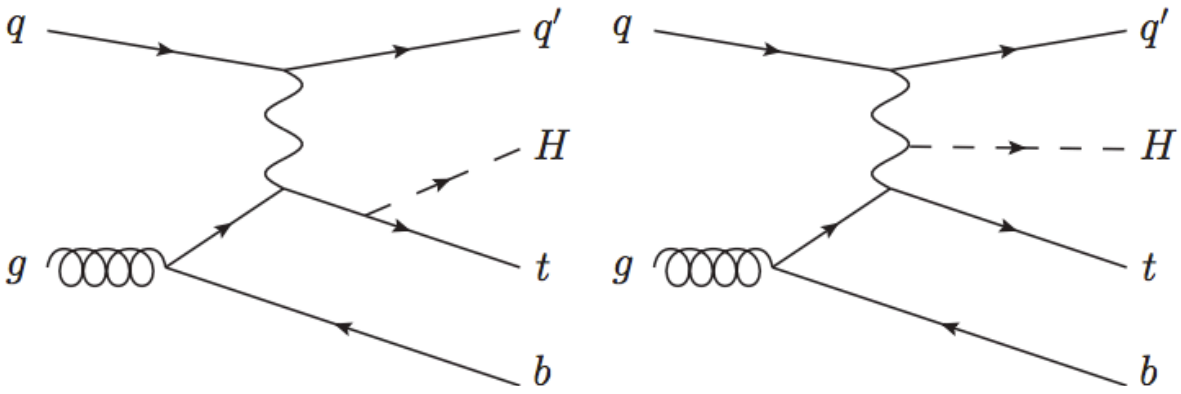
Scale Factor:

$$K_t = \frac{Y_t}{Y_t^{SM}}$$

Direct Measurement of Y_t

- Associated Higgs Production with Single Top Quark

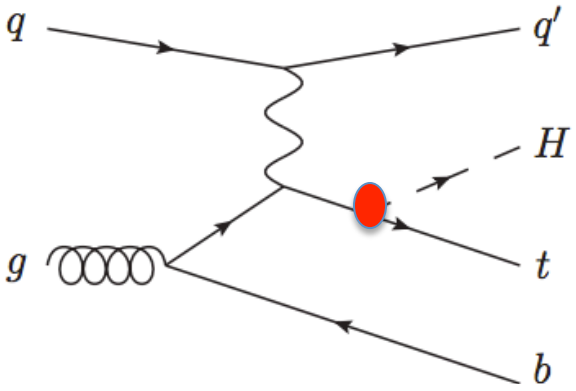
tHqb



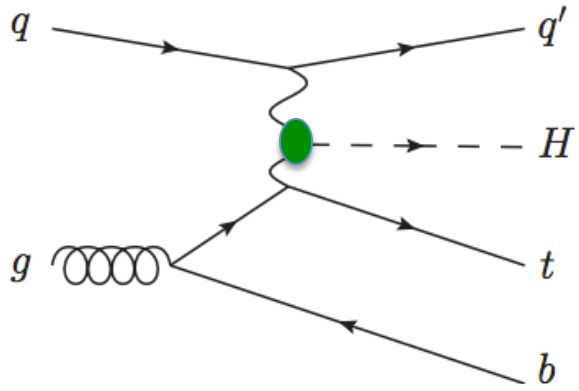
Direct Measurement of Y_t

- Associated Higgs Production with Single Top Quark

tHqb



proportional to Y_t

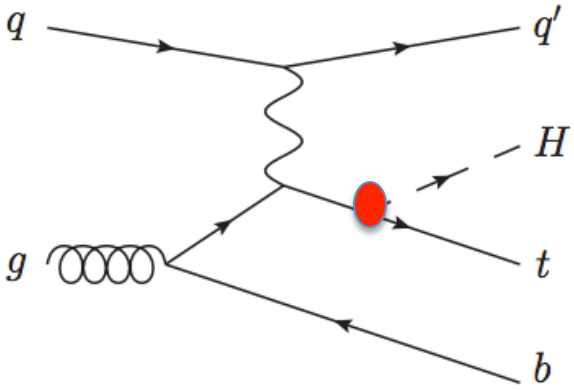


proportional to g_{WWH}

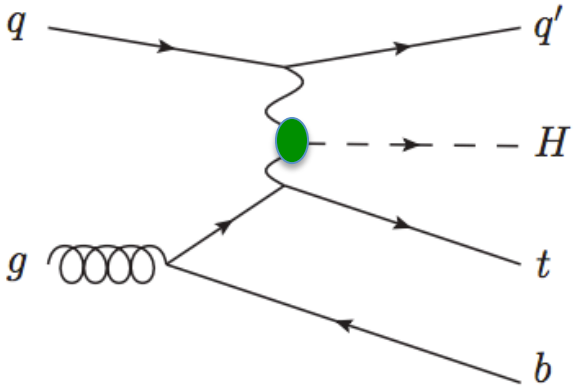
Direct Measurement of Y_t

- Associated Higgs Production with Single Top Quark

tHqb

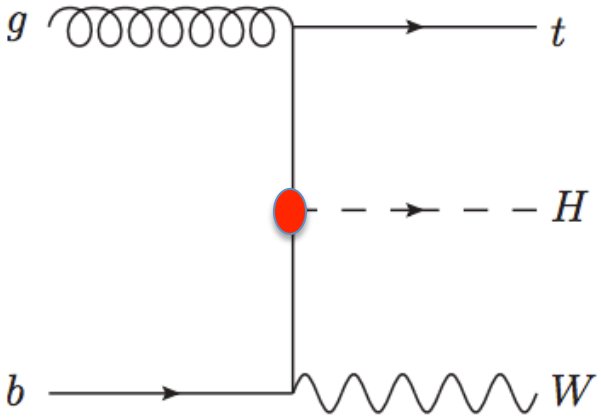


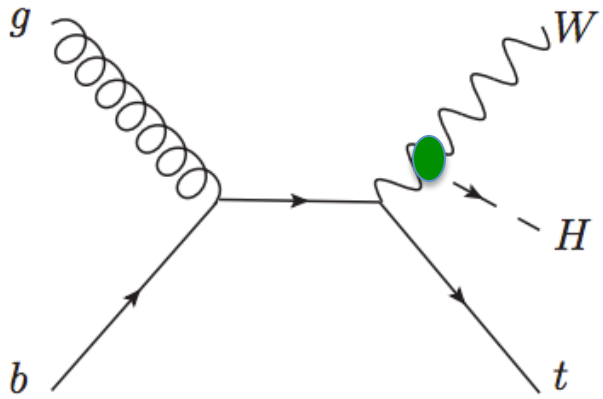
proportional to Y_t



proportional to g_{WWH}

WtH

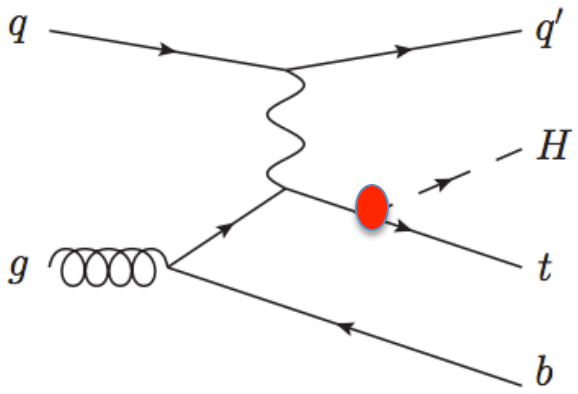


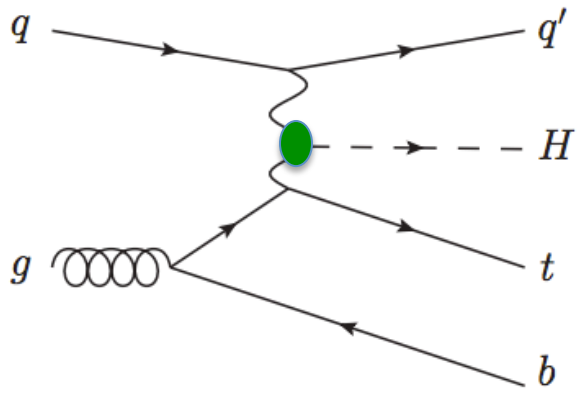


Direct Measurement of Y_t

- Associated Higgs Production with Single Top Quark

tHqb



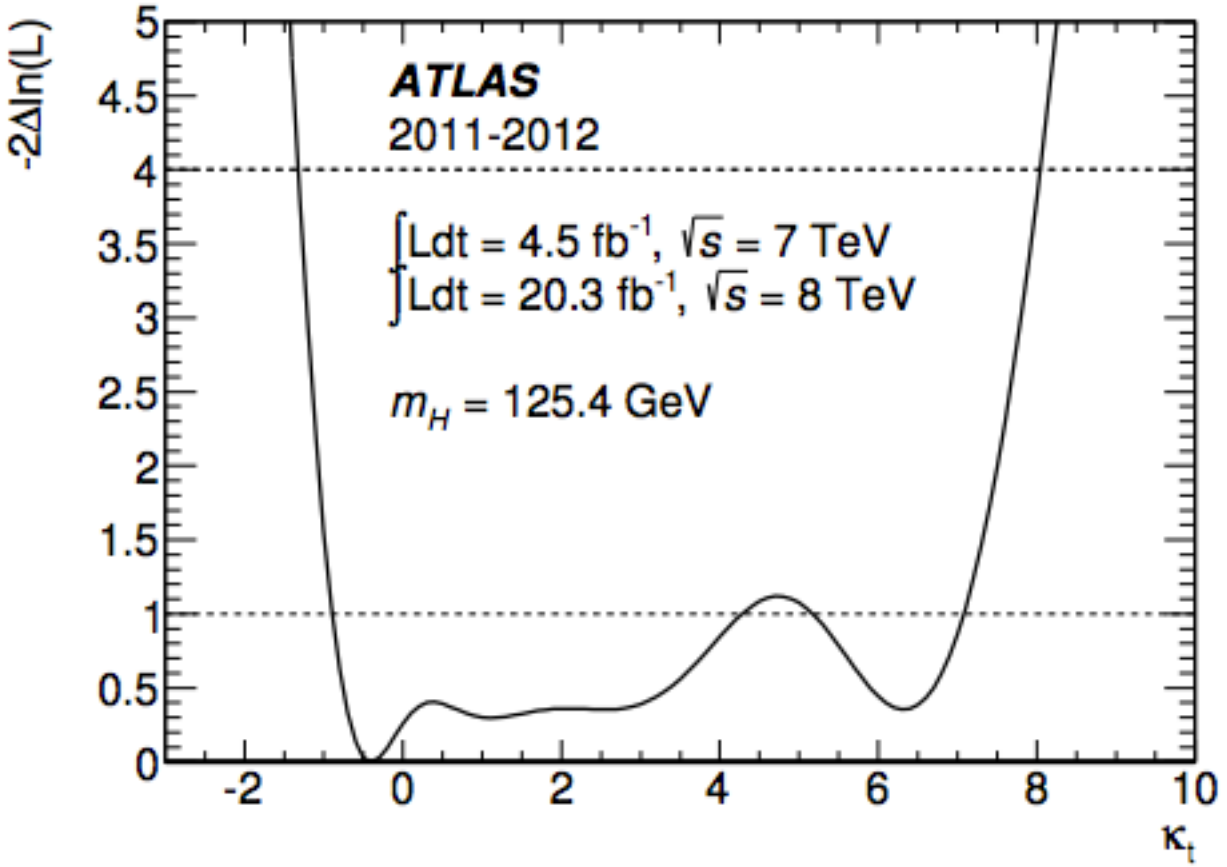


proportional to Y_t

proportional to g_{WWH}

In the Standard Model, Y_t and g_{WWH} are of the same sign, and the two Feynman diagrams destructive interfere with each other.

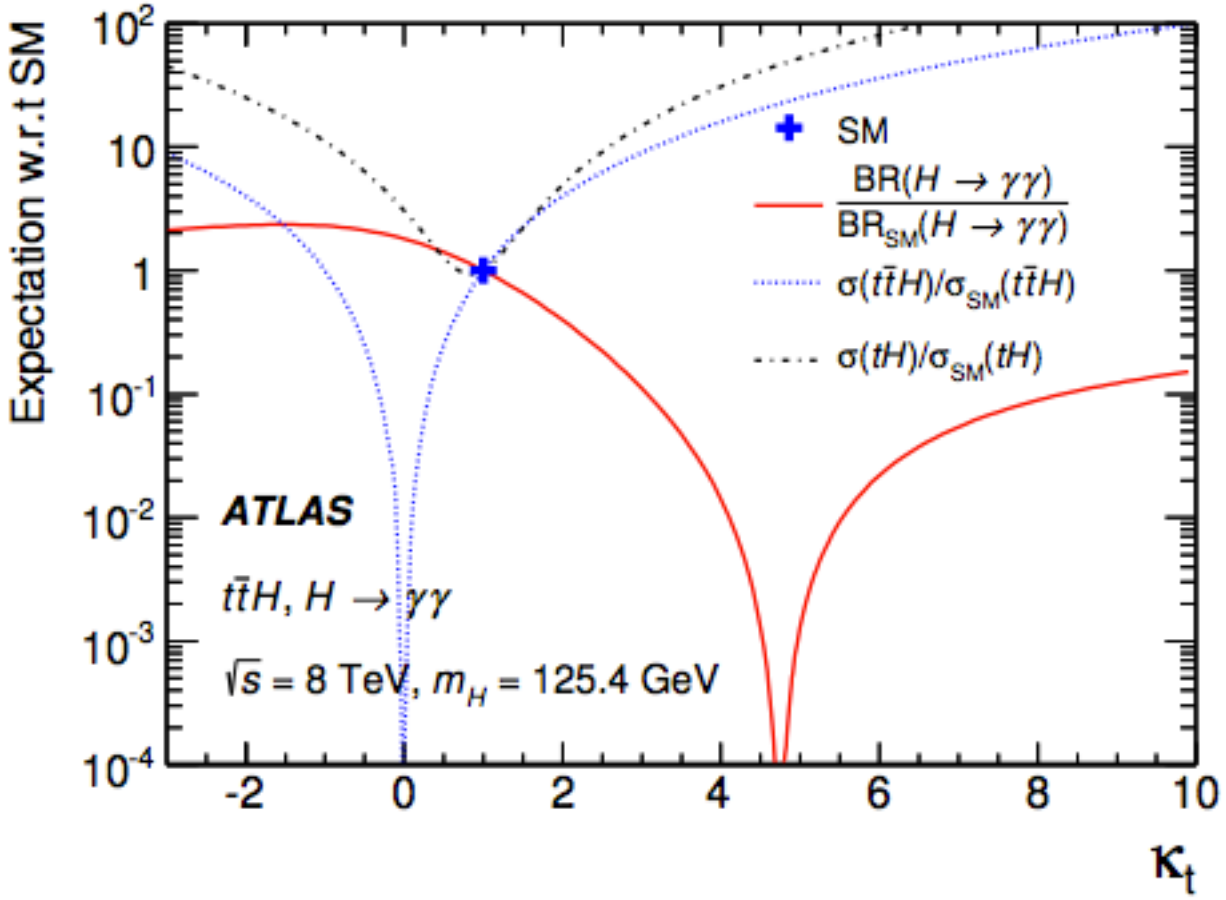
ATLAS tH (H→γγ) Run 1 Results[2]



Negative log-likelihood scan of K_t at m_H = 125.4 GeV.

Scale Factor: $K_t = \frac{Y_t}{Y_t^{SM}}$

ATLAS tH (H→γγ) Run 1 Results[2]



Production cross sections for ttH and tH divided by their SM expectations as a function of κ_t.

Production Cross Section (pb^-1)

	8 TeV	13 TeV	14 TeV
ttH	0.13	0.5027	0.611
tHqb Kt=1	0.018	0.0692	
tHqb Kt=0	0.059		
tHqb Kt=-1	0.197		
tHq Kt=1			0.0882
tHq Kt=0			276
tHq Kt=-1			0.98
WtH Kt=1	0.0047		0.016
WtH Kt=0	0.0073		0.0349
WtH Kt=-1	0.027		0.139
ggF	19.3		49.9
VBF	1.58		4.2
WH	0.705		1.5
ZH	0.415		0.88

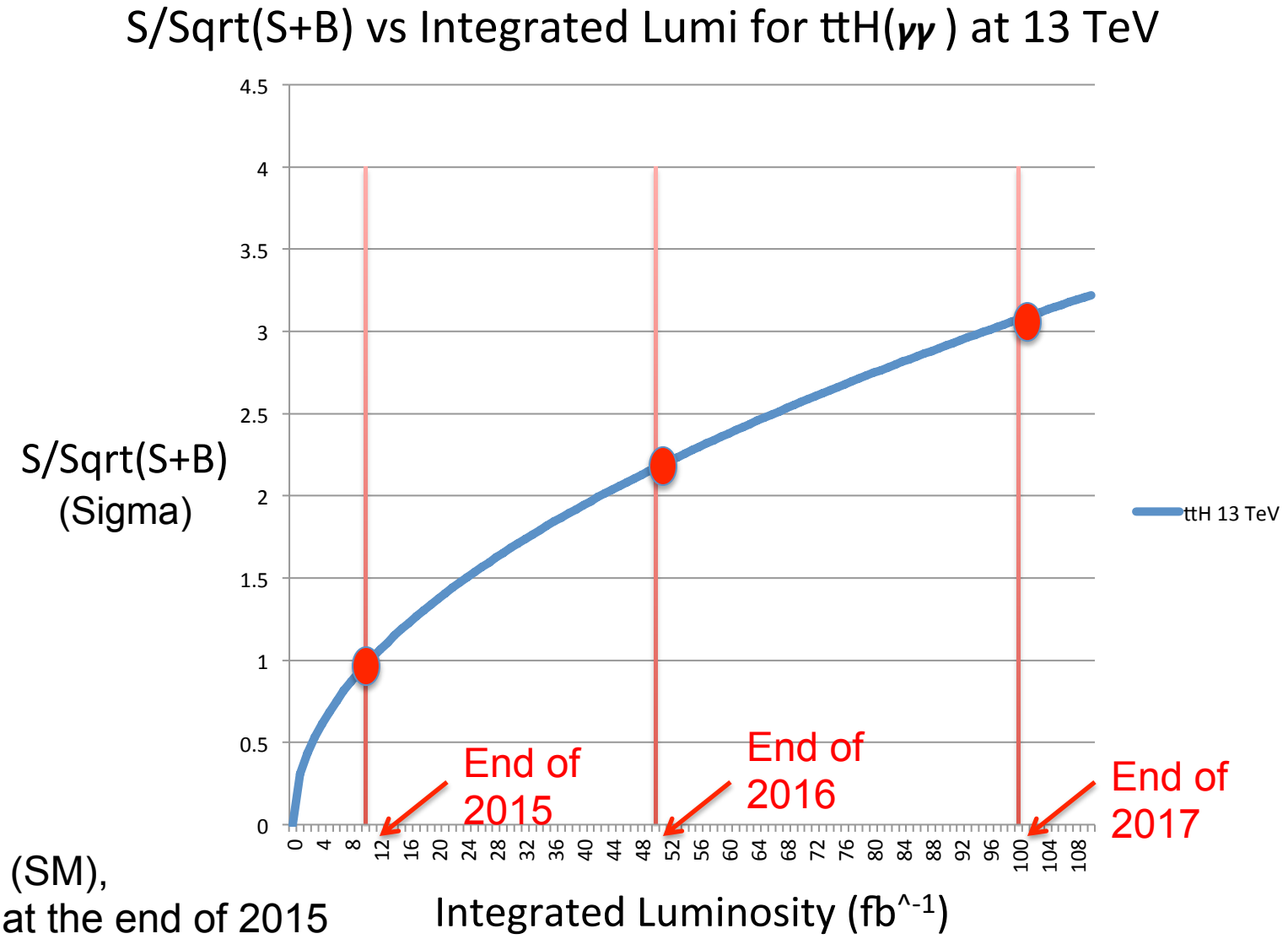
4 Times

11 Times

9 Times

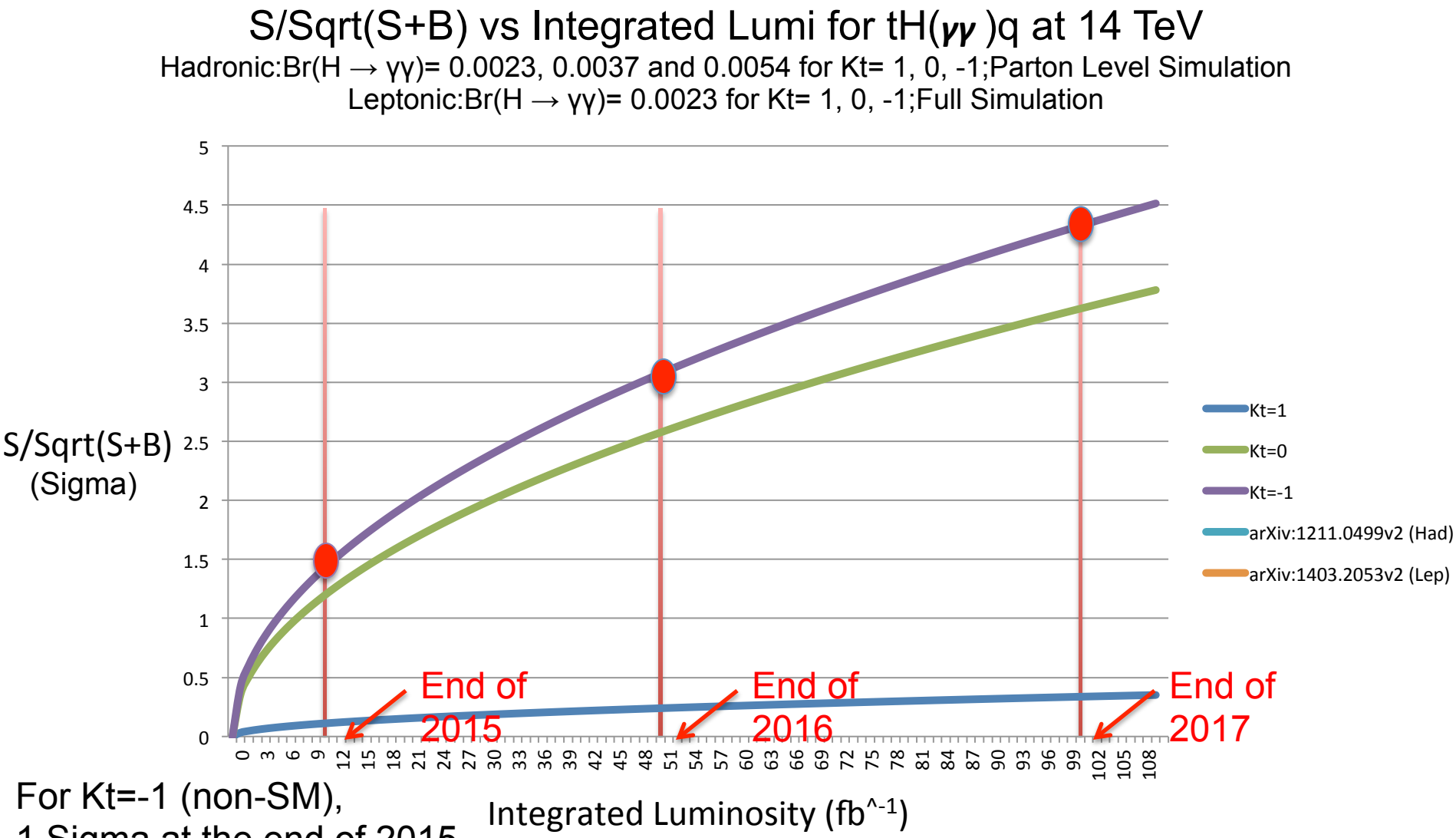
https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CERNYellowReportPageAt1314TeV
ATL-PHYS-PUB-2014-012
arXiv:1211.0499v2
arXiv:1211.3736v2
Update on studies on the search for tH-production at a center-of-mass energy of 13 TeV.pdf

Sensitivity Projection in Run II



For Kt=1 (SM),
1 Sigma at the end of 2015
2 Sigma at the end of 2016
3 Sigma at the end of 2017

Sensitivity Projection in Run II



For Kt=-1 (non-SM),
1 Sigma at the end of 2015
2 Sigma at the end of 2016
3 Sigma at the end of 2017

HGamma Overlap Removal Handler

- The HSG1(H→$\gamma\gamma$) group develops the HGamma Analysis Framework package for Run II analysis.
- The Framework contains many different handler classes and helper functions.
- For example, users can get all good photons by simply calling the Photon Handler. The Photon Handler will calibrate and select photons behind the scene.
- Similarly, the Overlap Removal Handler I am developing will provide users with a method to removal all object overlaps in accordance with the HGamma overlap recommendation.

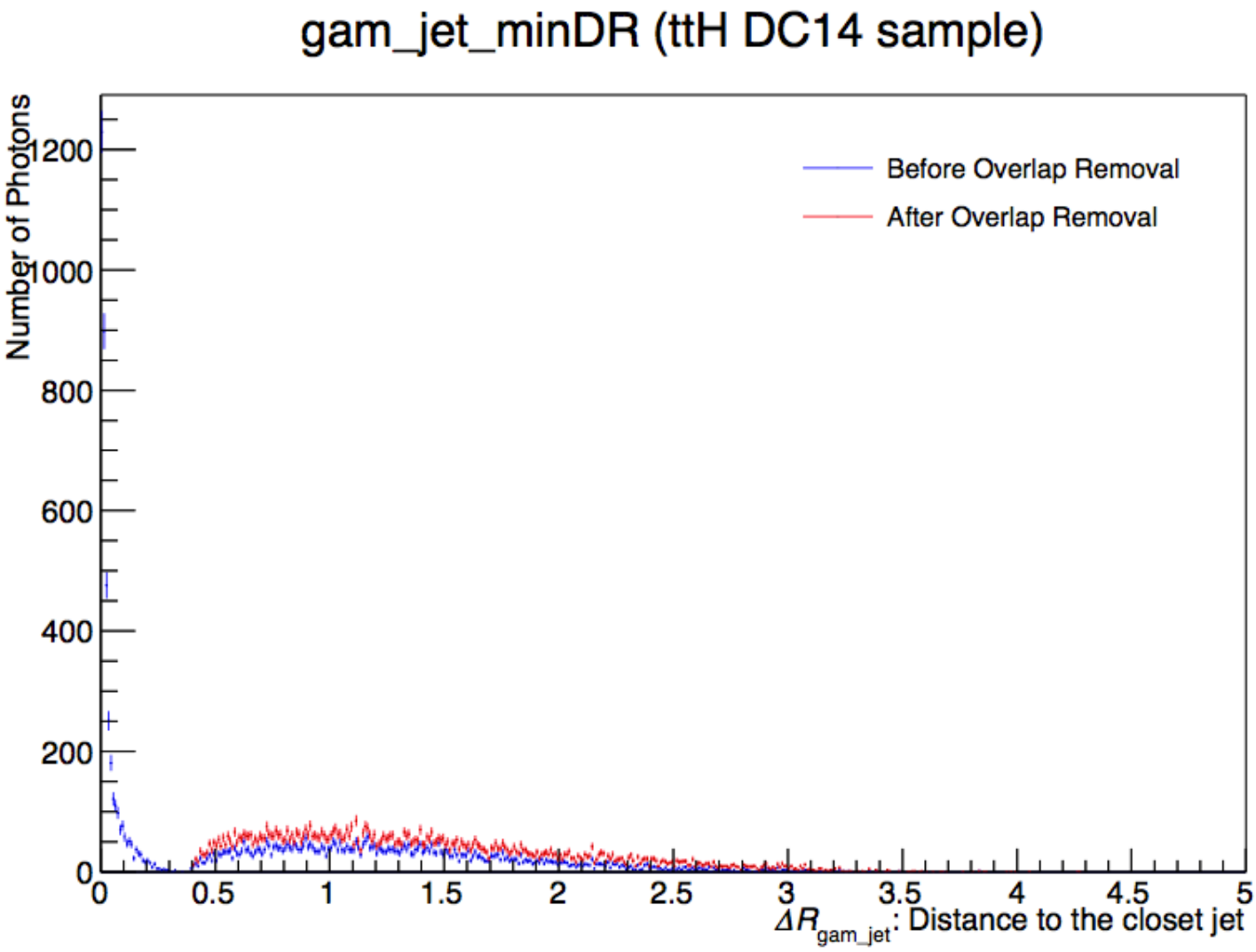
HGamma Overlap Removal Handler

- The first version of the Overlap Removal Handler along with an example code is finished and has been uploaded to the HGamma Sandbox for testing.
- Next week, I will present the first version at the HGamma xAOD meeting and we will decide the detailed configurations of the handler.
- Afterwards, the Overlap Removal Handler will be migrated from the Hgamma Sandbox to the Hgamma Analysis Framework.

https://svnweb.cern.ch/trac/atlasoff/browser/PhysicsAnalysis/HiggsPhys/Run2/HGamma/xAOD/HgammaSandbox/trunk/Root/OverlapRemovalHandler.cxx

HGamma Overlap Removal Handler

Validation Plot Example



Hgamma General Classification Tool

Details in Final Talk

Acknowledgements

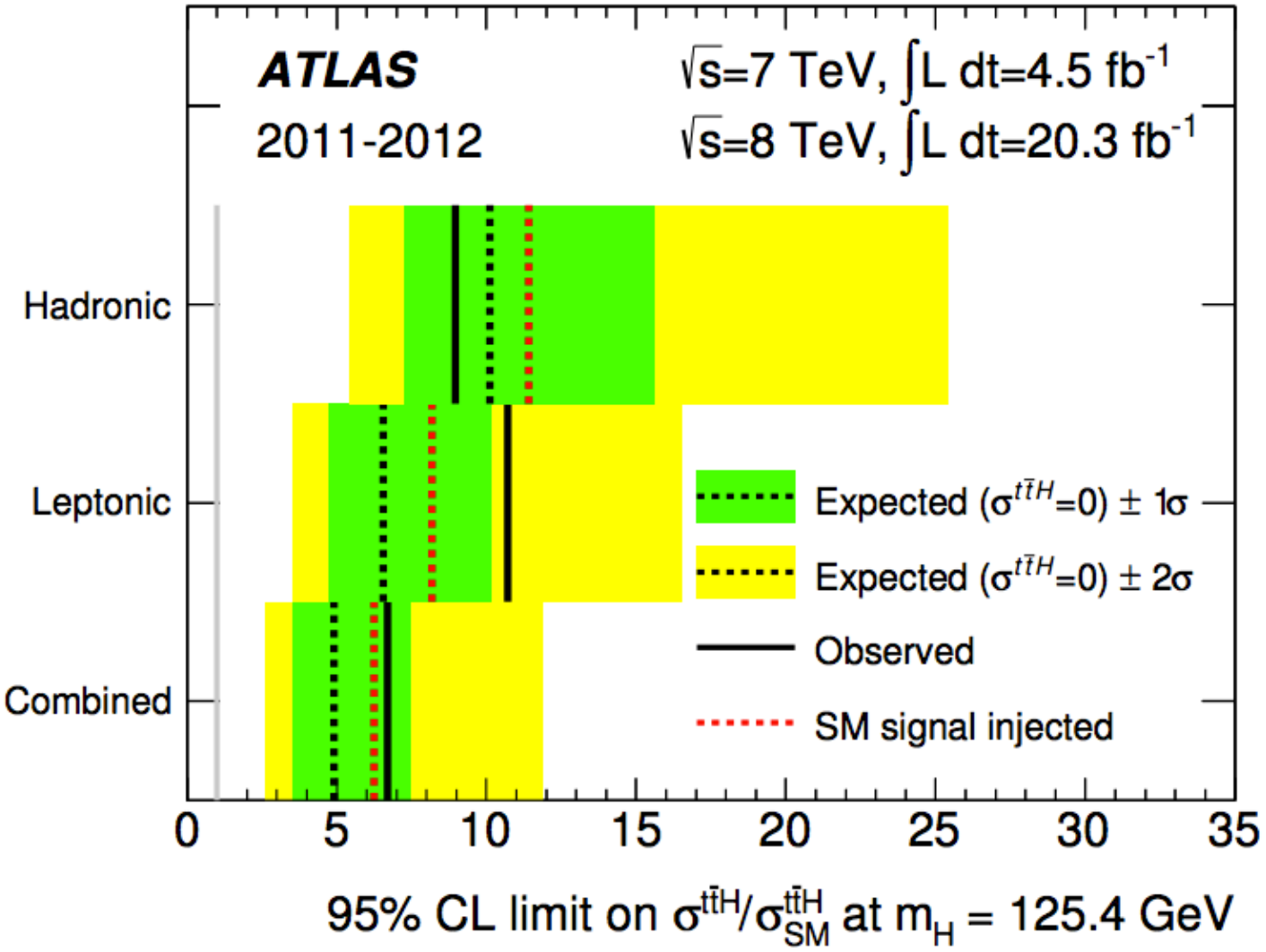
Thanks Magda, Prof.Jean, Steve,Prof.Neal and Prof.Schwartz.

Reference

[1] A. Quadt, Top Quark Physics at Hadron Colliders, DOI 10.1007/978-3-540-71060-8
[2] ATLAS Collaboration, arXiv:1409.3122

BACK UP

ATLAS ttH (H→γγ) Run 1 Results



An upper limit at 95% confidence level of **6.7** times the SM cross section times BR(H → γγ) is observed.