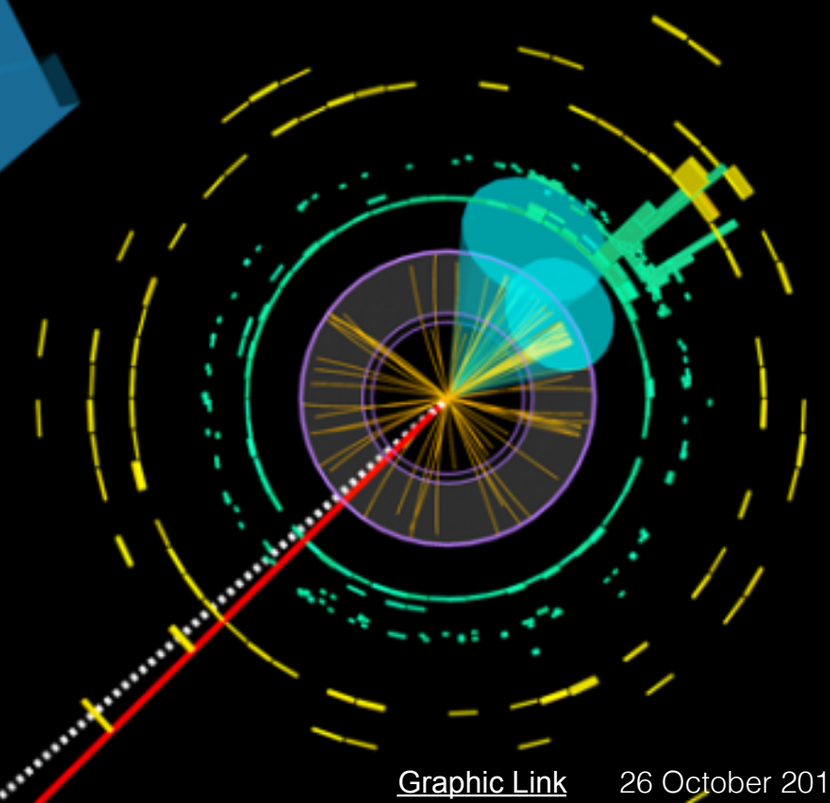
Illuminating the H→bb Discovery at ATLAS with the VBF + photon channel

ATLAS EXPERIMENT

Candidate Event:
$pp \rightarrow H(\rightarrow bb) + W(\rightarrow \mu\nu)$
Run: 338712 Event: 335908183
2017-10-19 23:31:18 CEST

Jacob M. Pasner
US LUA Meeting
Lightning Round Talk
26 October 2018



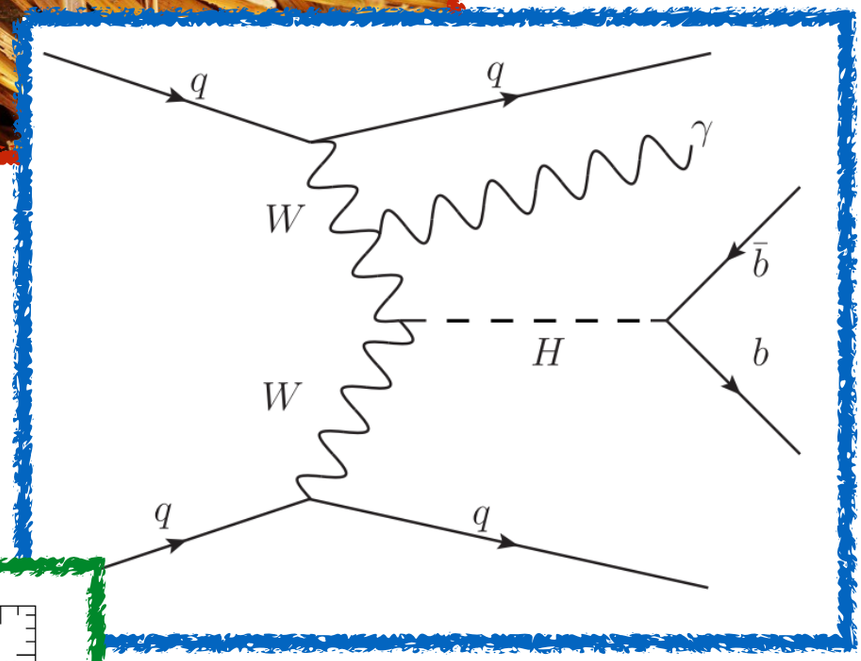
UNIVERSITY OF CALIFORNIA
SANTA CRUZ

Graphic Link 26 October 2018

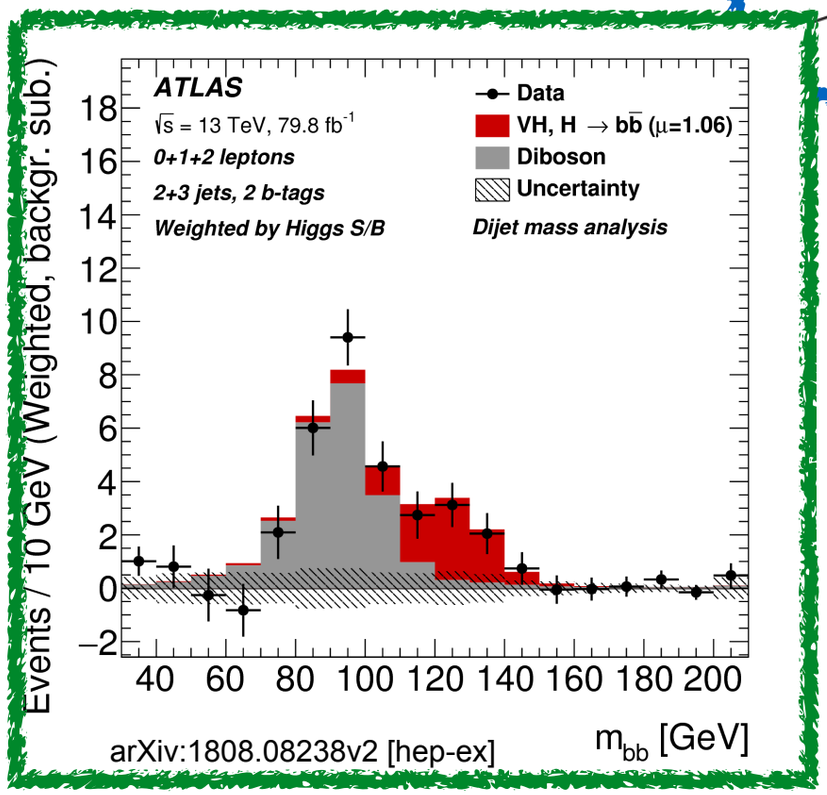
Overview

- What makes **H→bb** so interesting / difficult?

- The **V**ector **B**oson **F**usion + Photon approach.



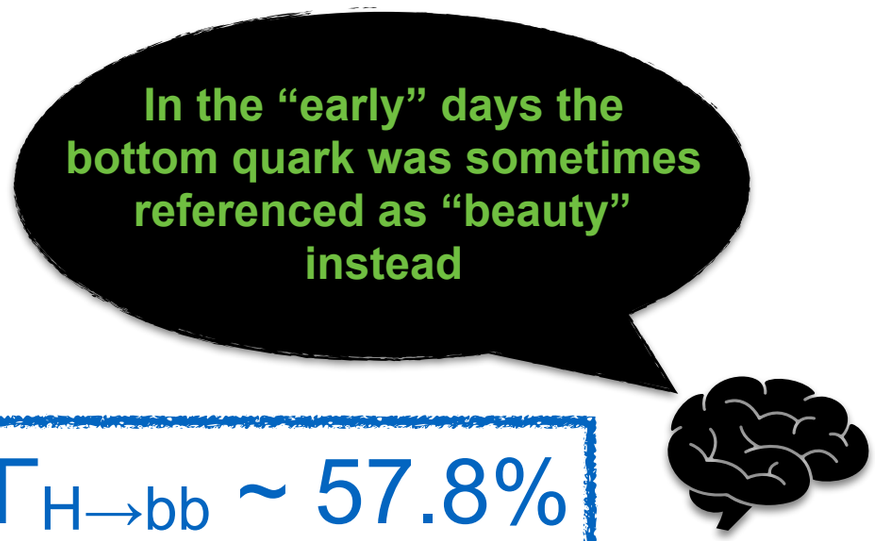
- **H→bb observation** and future for the channel!



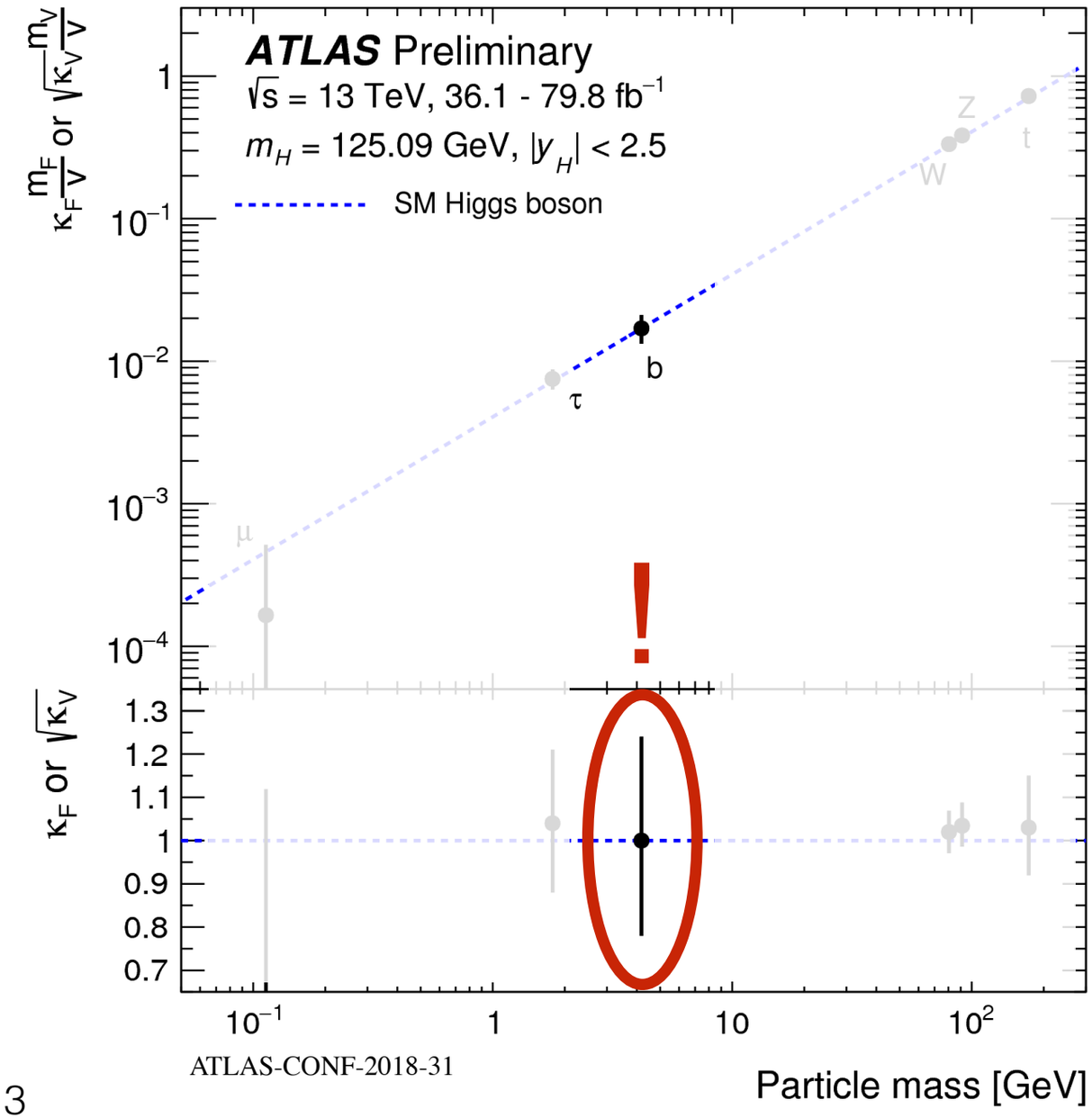
ATLAS EXPERIMENT

H→bb: Why do we care?

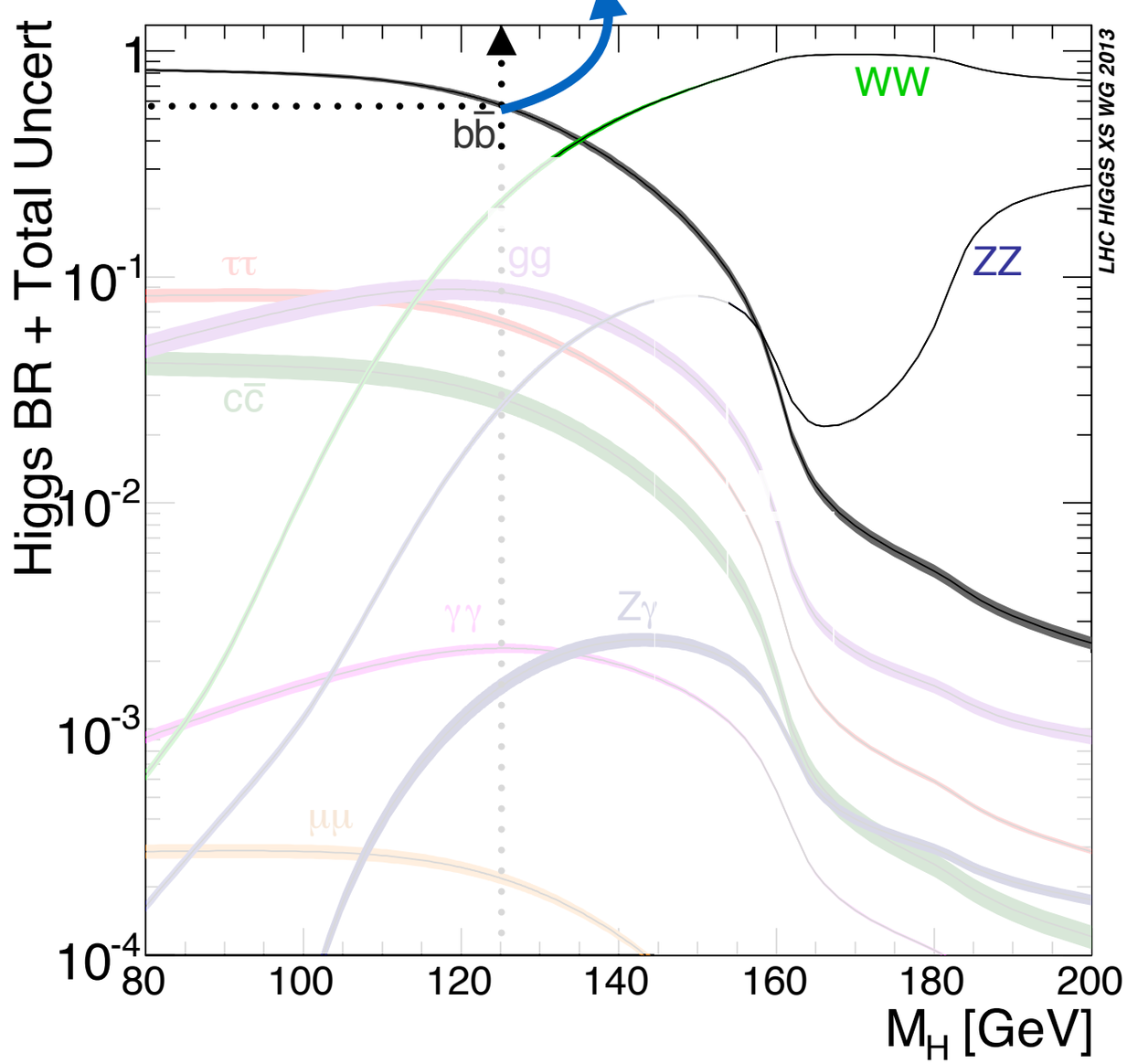
- LHC Run 1 data was not sufficient to measure the coupling between the Higgs boson and bottom quarks, despite it being the largest branching ratio.
  - Measurement of this coupling tests the Higgs properties
- Higgs at high p_T present a region where new physics is accessible via a number of effective field theories



$\Gamma_{H\to bb} \sim 57.8\%$



ATLAS-CONF-2018-31

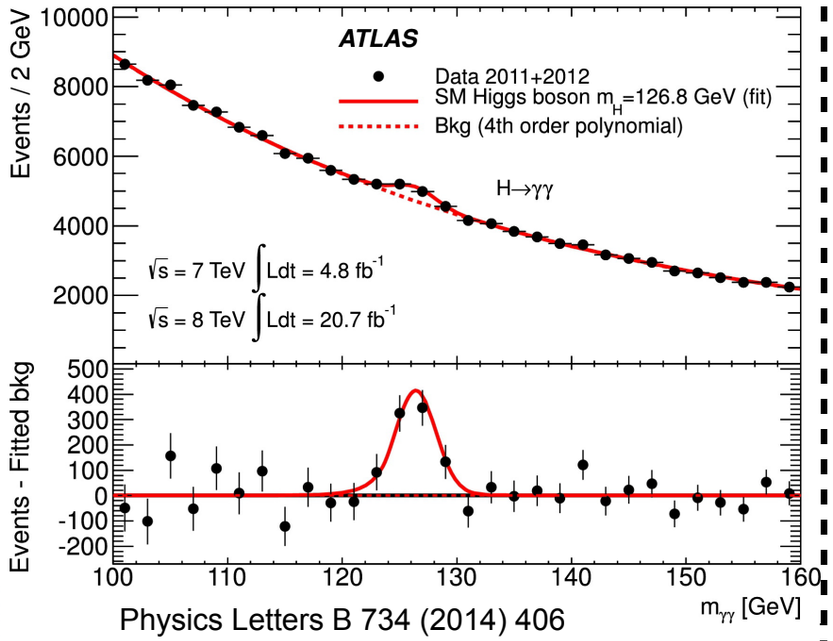


H→bb Challenges

$H \rightarrow \gamma\gamma$

- Low statistics
- Photons have clean signal in detector
- First Higgs observation!

$\Gamma_{H\rightarrow\gamma\gamma}$ ~ 0.227%

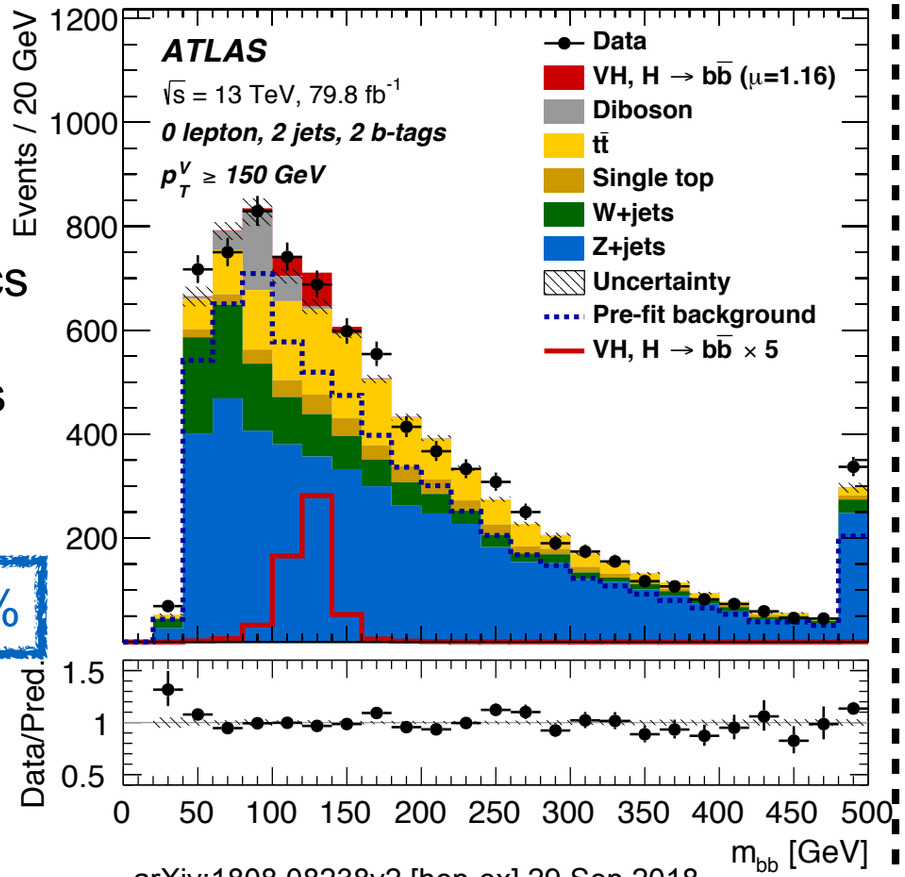


Physics Letters B 734 (2014) 406

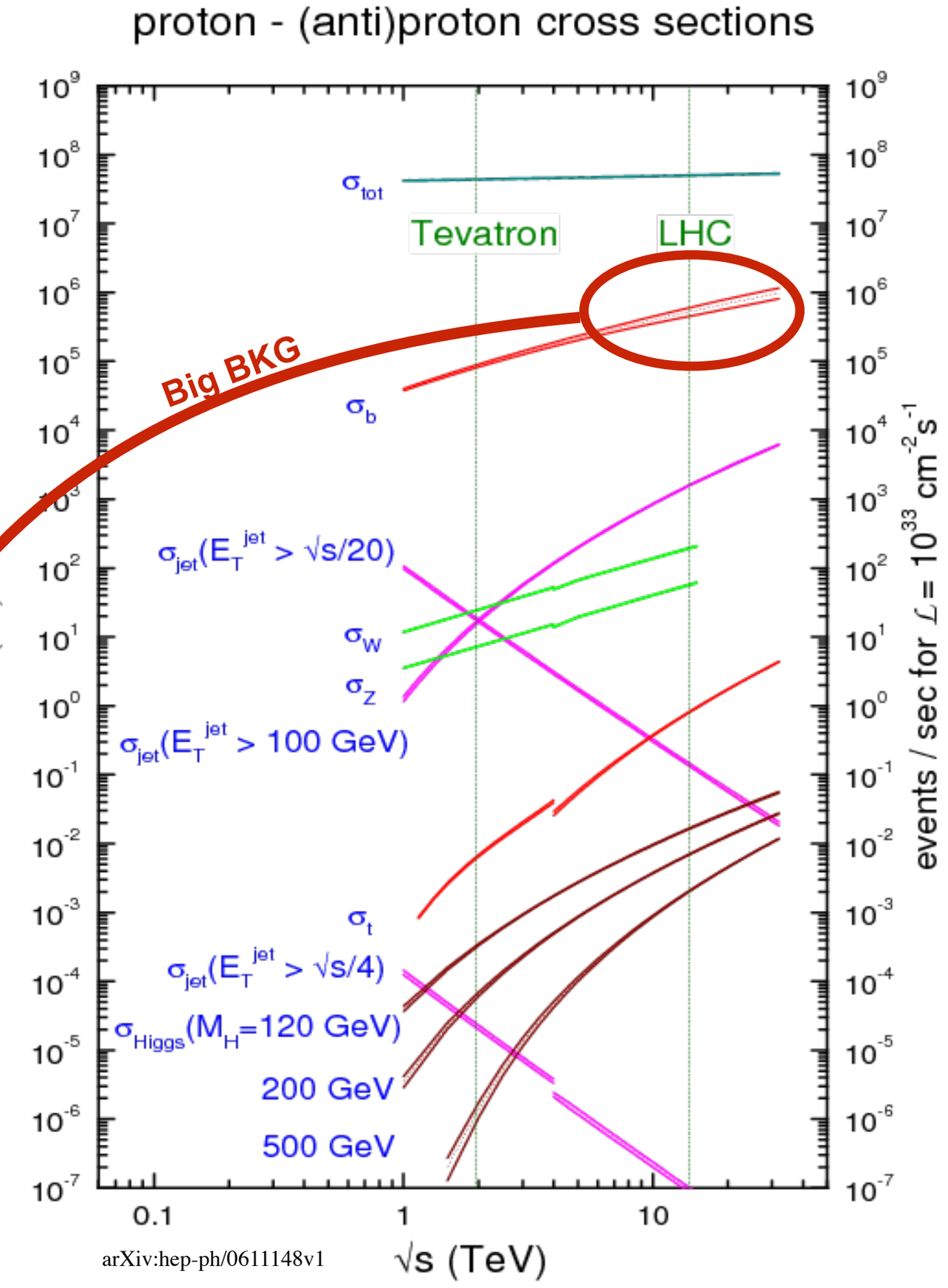
$H \rightarrow b\bar{b}$

- High statistics
- Many backgrounds
- Hard to discover!!!

$\Gamma_{H\rightarrow bb}$ ~ 57.8%



arXiv:1808.08238v2 [hep-ex] 29 Sep 2018

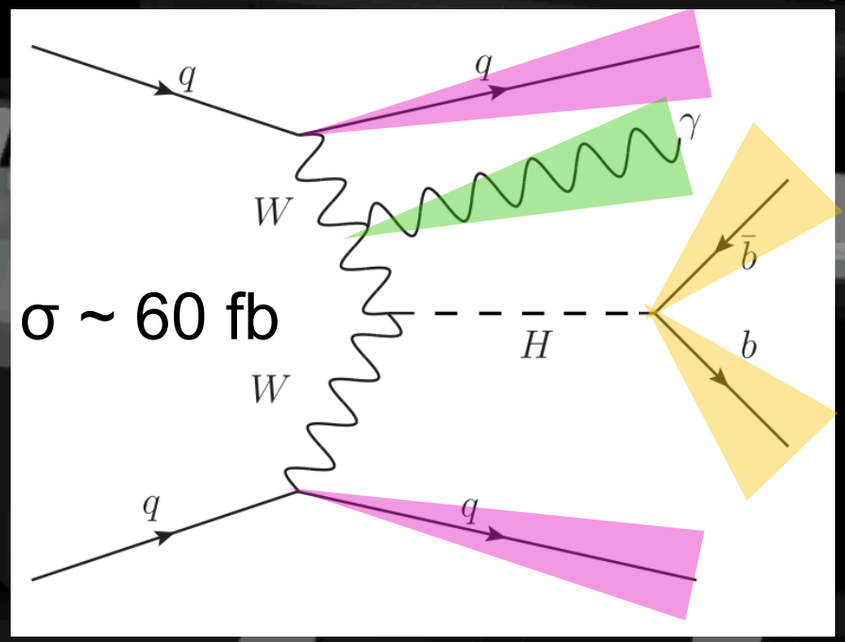


arXiv:hep-ph/0611148v1

Phys. Rev. D 98, 052003

ATLAS EXPERIMENT

VBF + photon example event



μ

Run: 302956
Event: 1228205769
2016-06-29 00:08:58 CEST

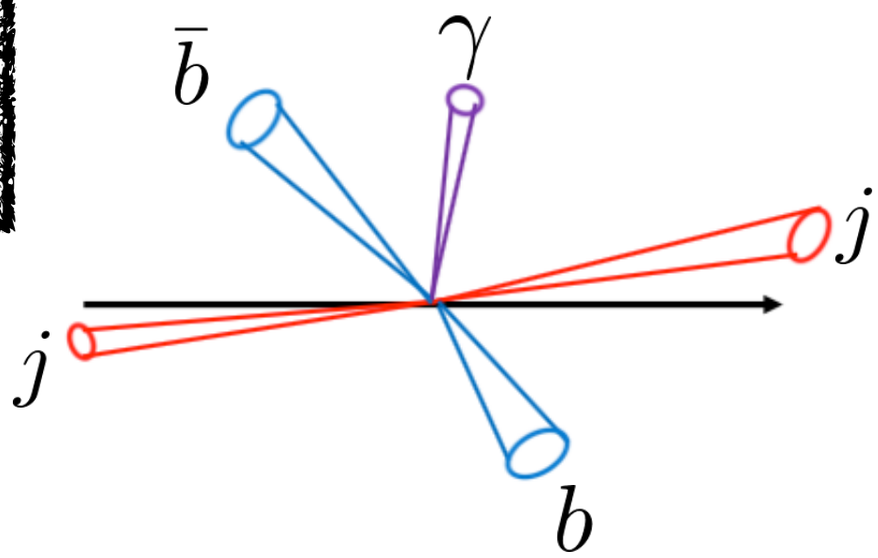
m_{JJ} Enhancement

- m_{JJ} > 800GeV
  - S-channel suppression
  - Reduce Gluon initiated

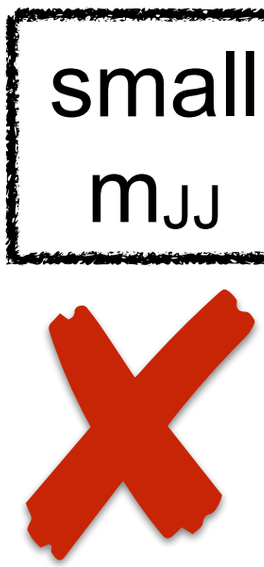
Central Photon Enhancement

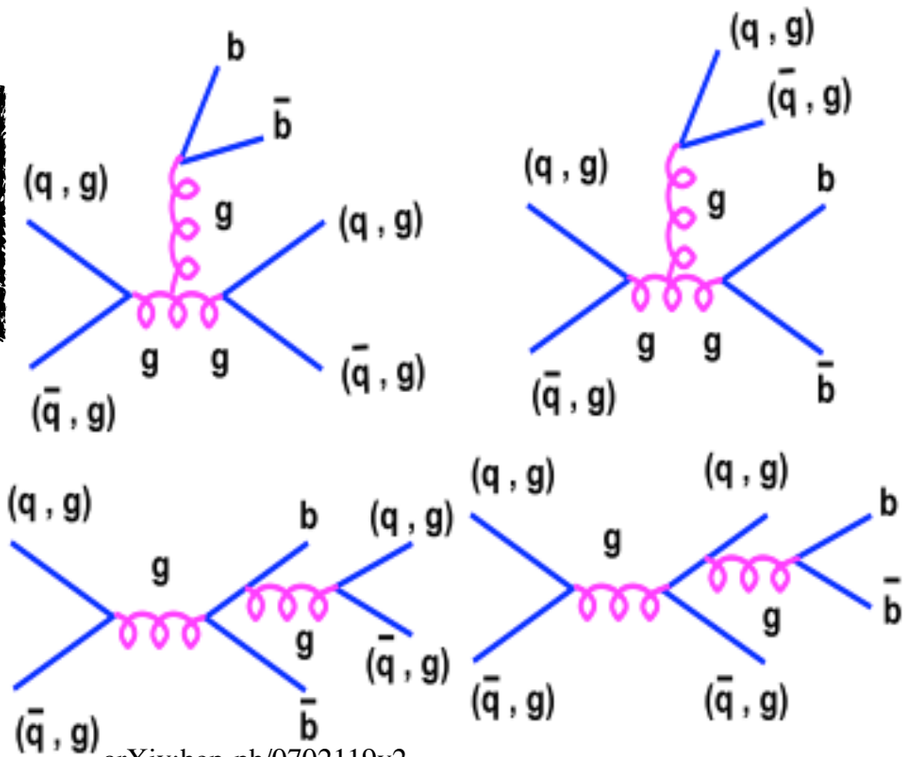
- Remove pure gluon initiated diagrams
- QCD cross section reduction

Large m_{JJ}



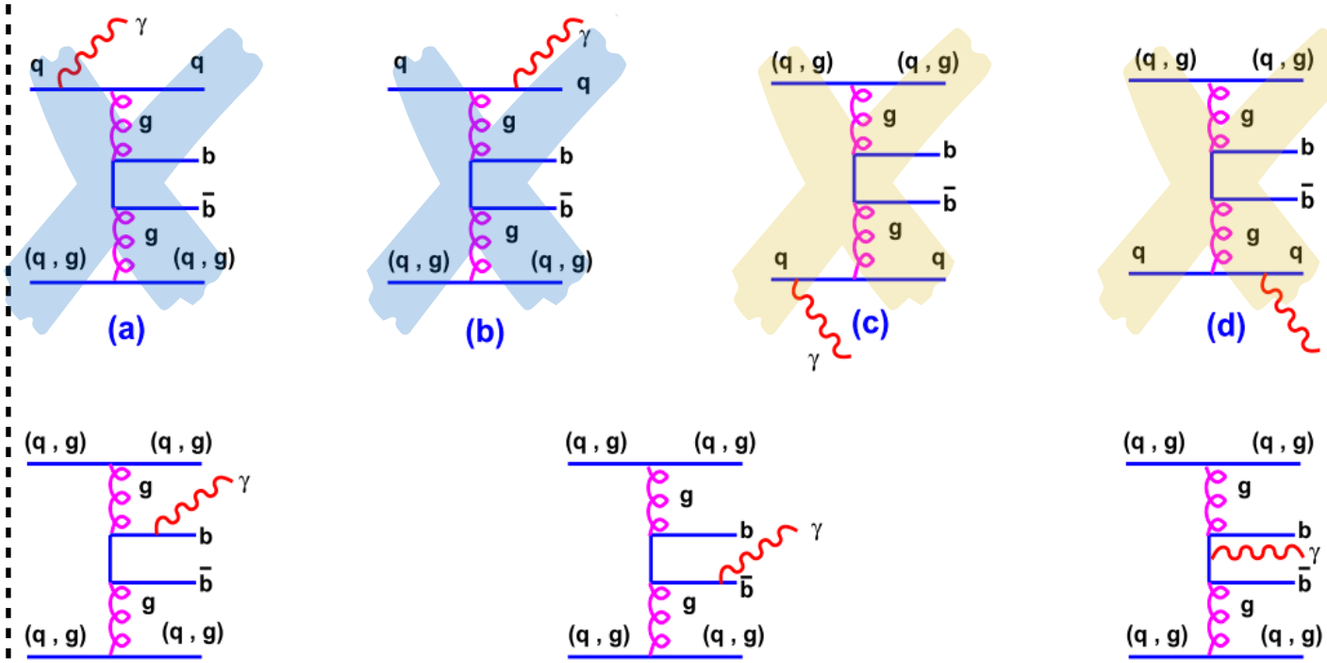
small m_{JJ}





arXiv:hep-ph/0702119v2

INTERFERING DIAGRAMS!



arXiv:hep-ph/0702119v2

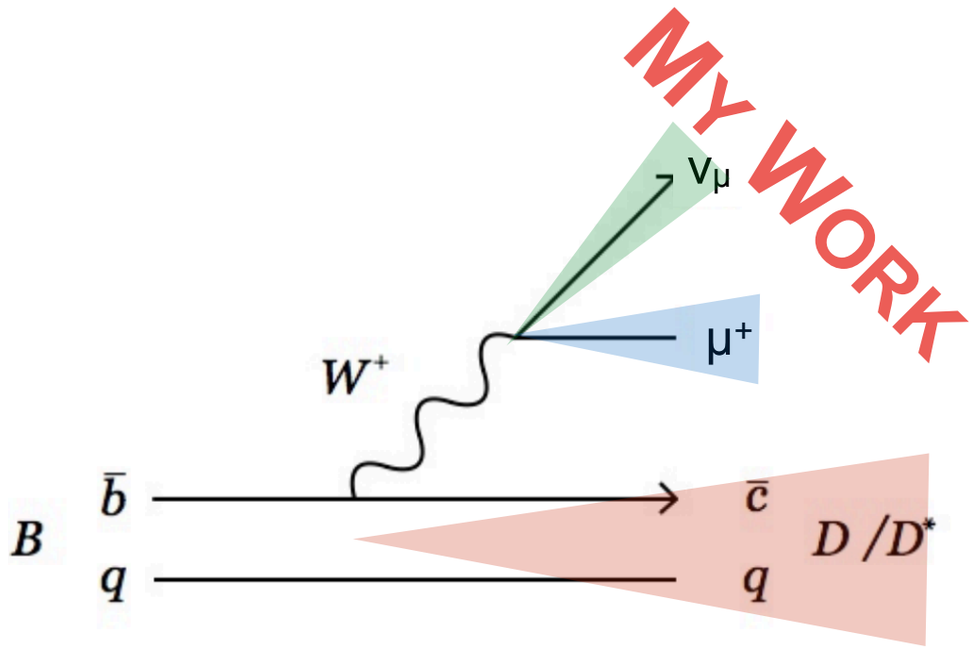
$$\frac{\sigma_{signal}}{\sigma_{background}} \begin{cases} \frac{\sigma\left[H(\to b\bar{b})\gamma jj\right]}{\sigma\left[b\bar{b}\gamma jj\right]} = 0.102(0) \\ \frac{\sigma\left[H(\to b\bar{b})jj\right]}{\sigma\left[b\bar{b}jj\right]} = 0.00309(5) \end{cases}$$

Note: Calculation Only

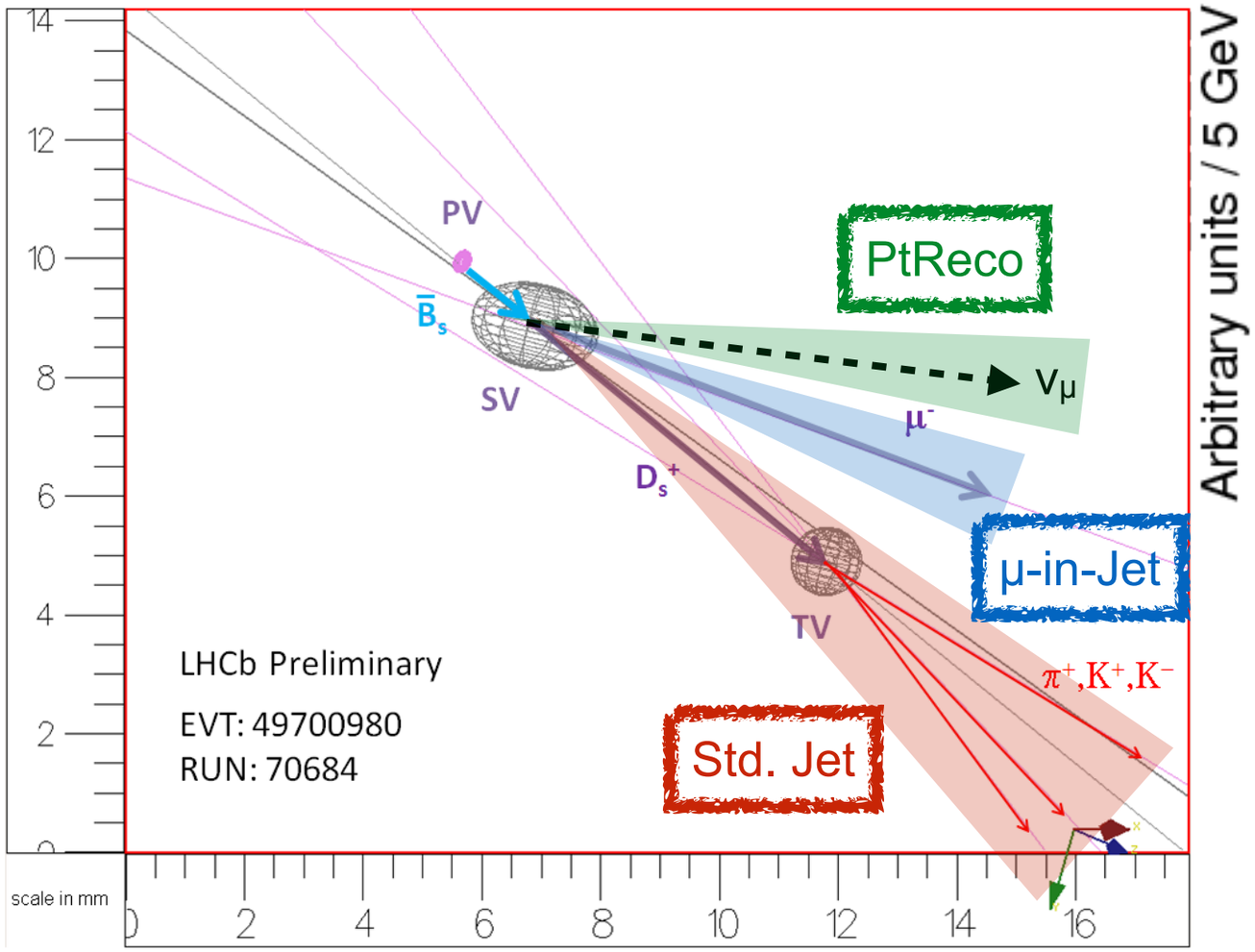
How can we additionally improve the resolution of the Higgs?

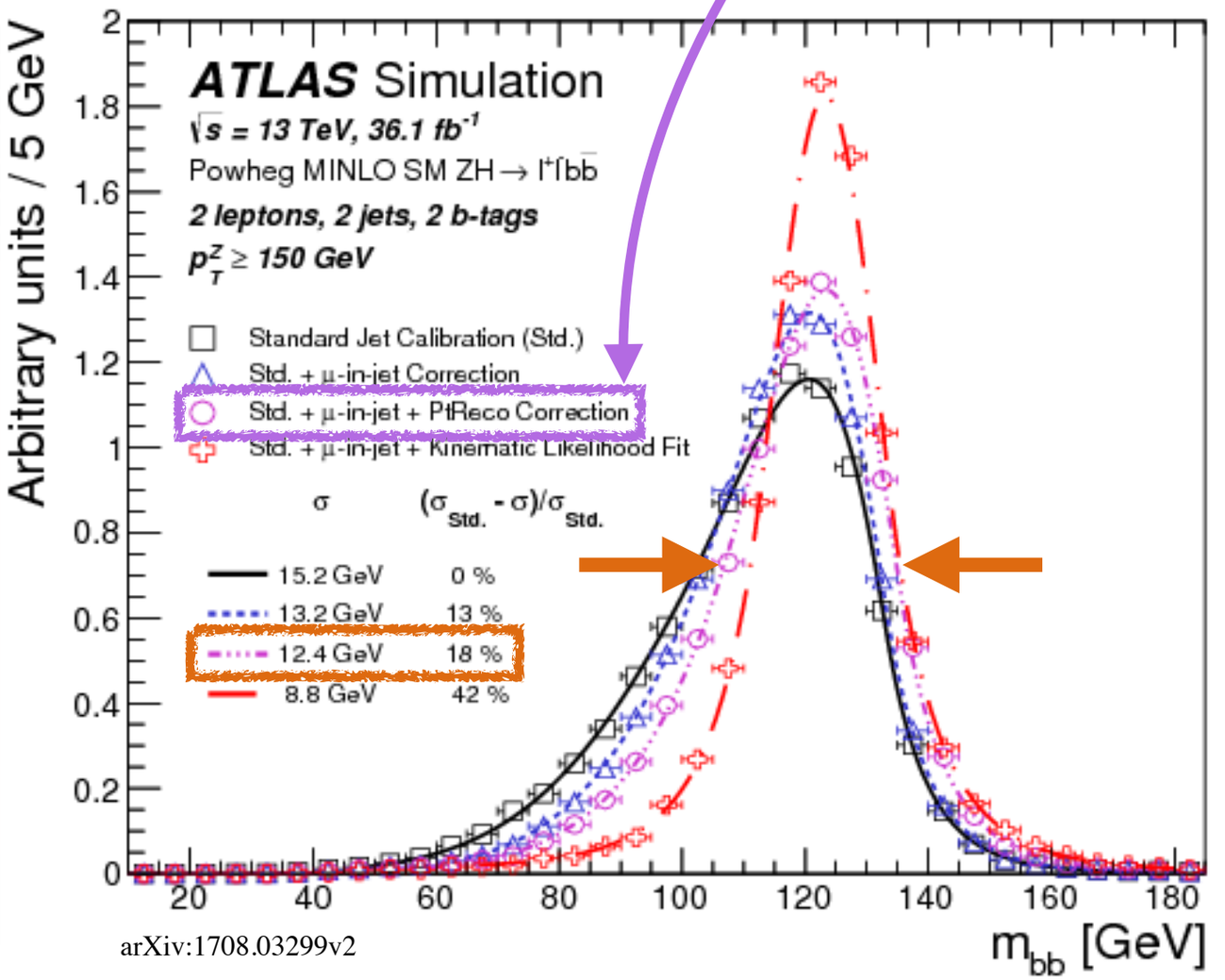
- **μ-in-jet** correction: add nearby muon to b-jet 4 vector
- **PtReco**: MVA trained to correct losses from neutrino
- These corrections take into account errors from semi-leptonic b decays and energy resolution effects

MY WORK



Std. Jet + μ-in-Jet + PtReco



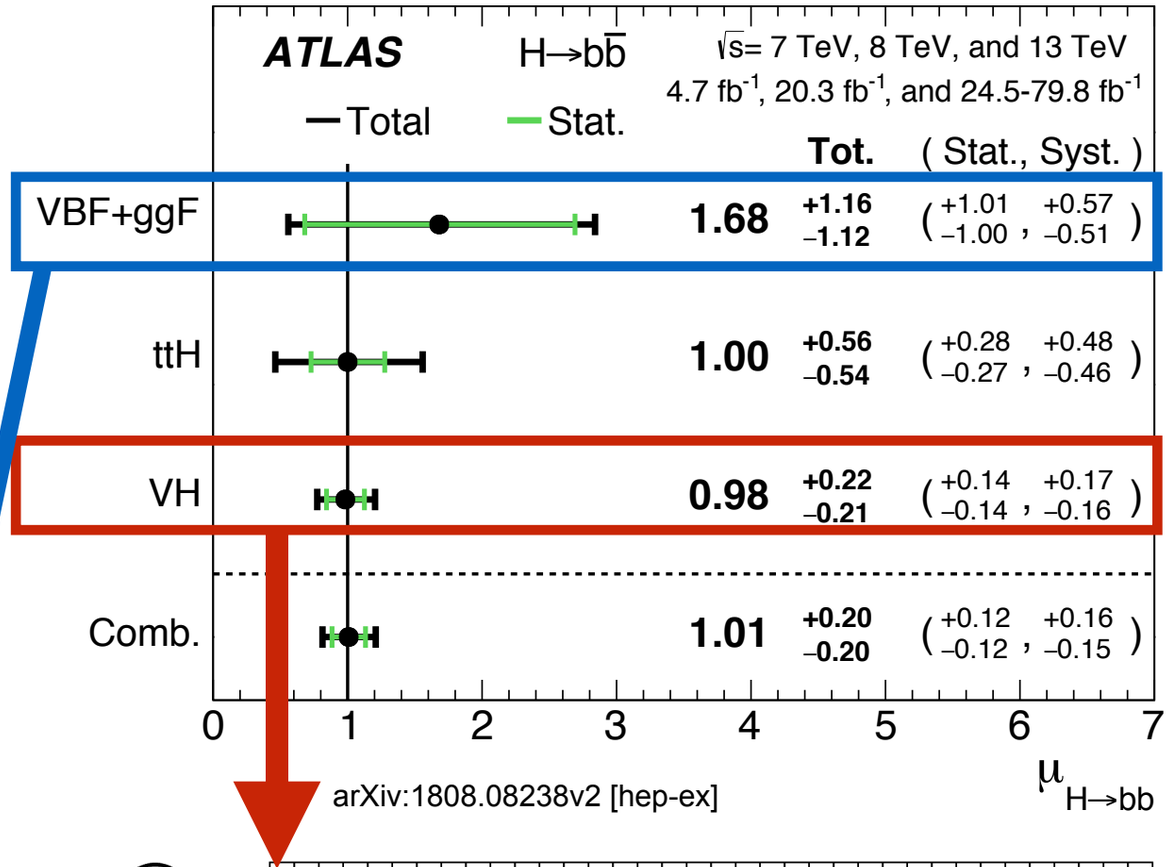


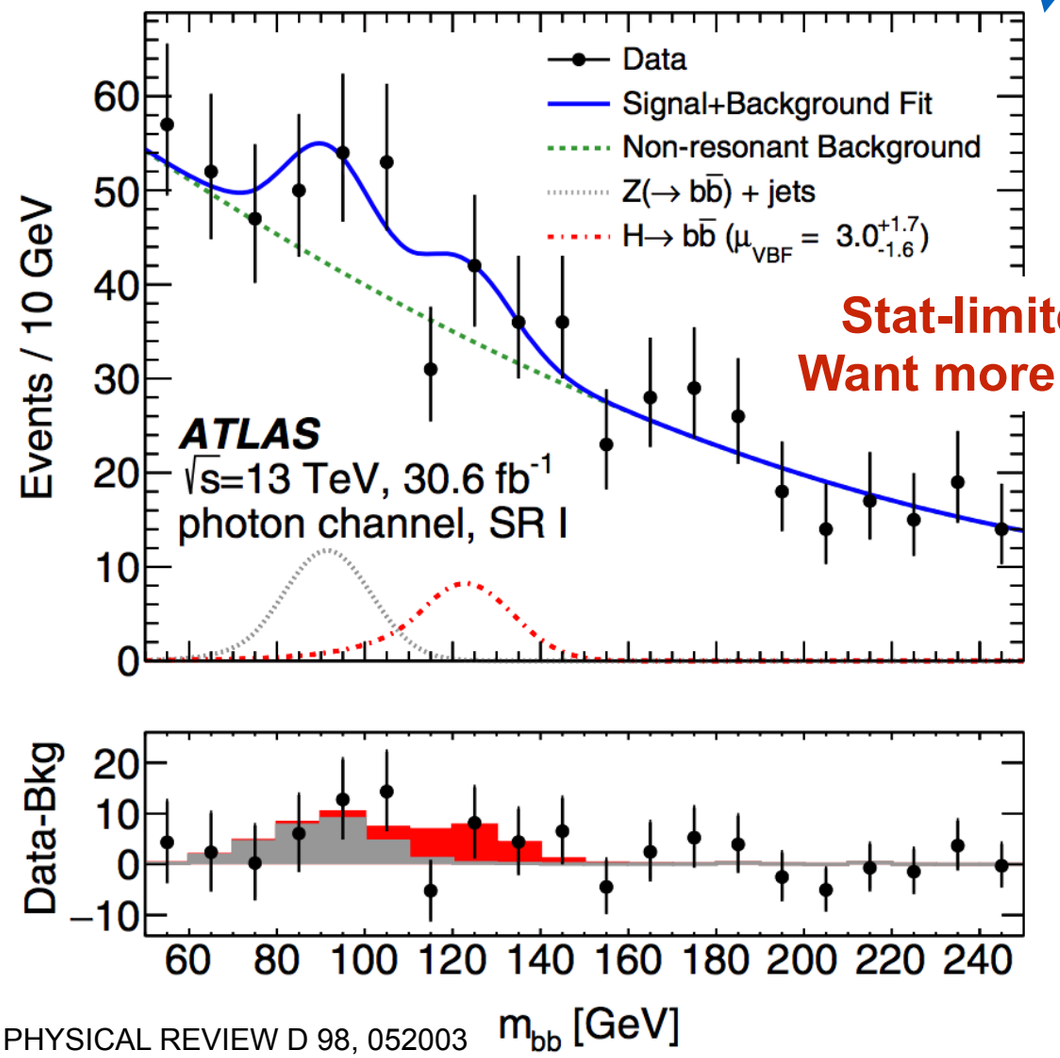
arXiv:1708.03299v2

Link

H→bb Combination

- VBF+photon was stat-limited.
  - Looking forward to more data!
- "By Eye" excess in VH channel!!!
- Combination → **5.4σ** observation





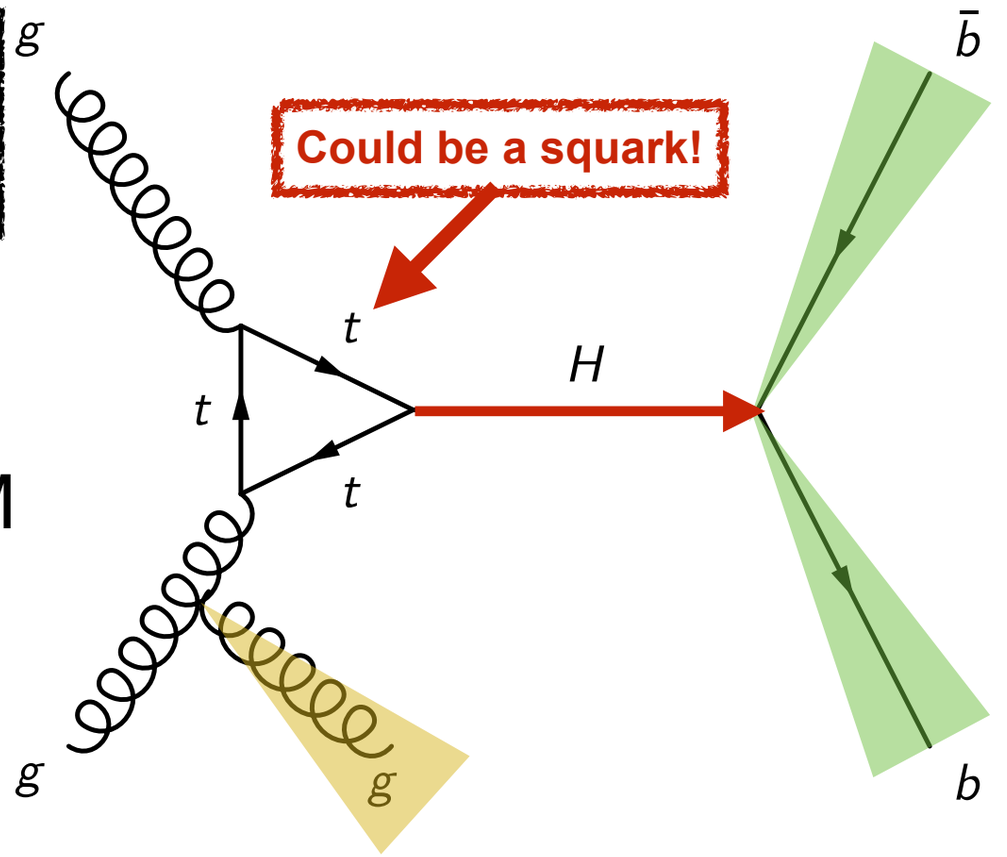
Stat-limited!
Want more data

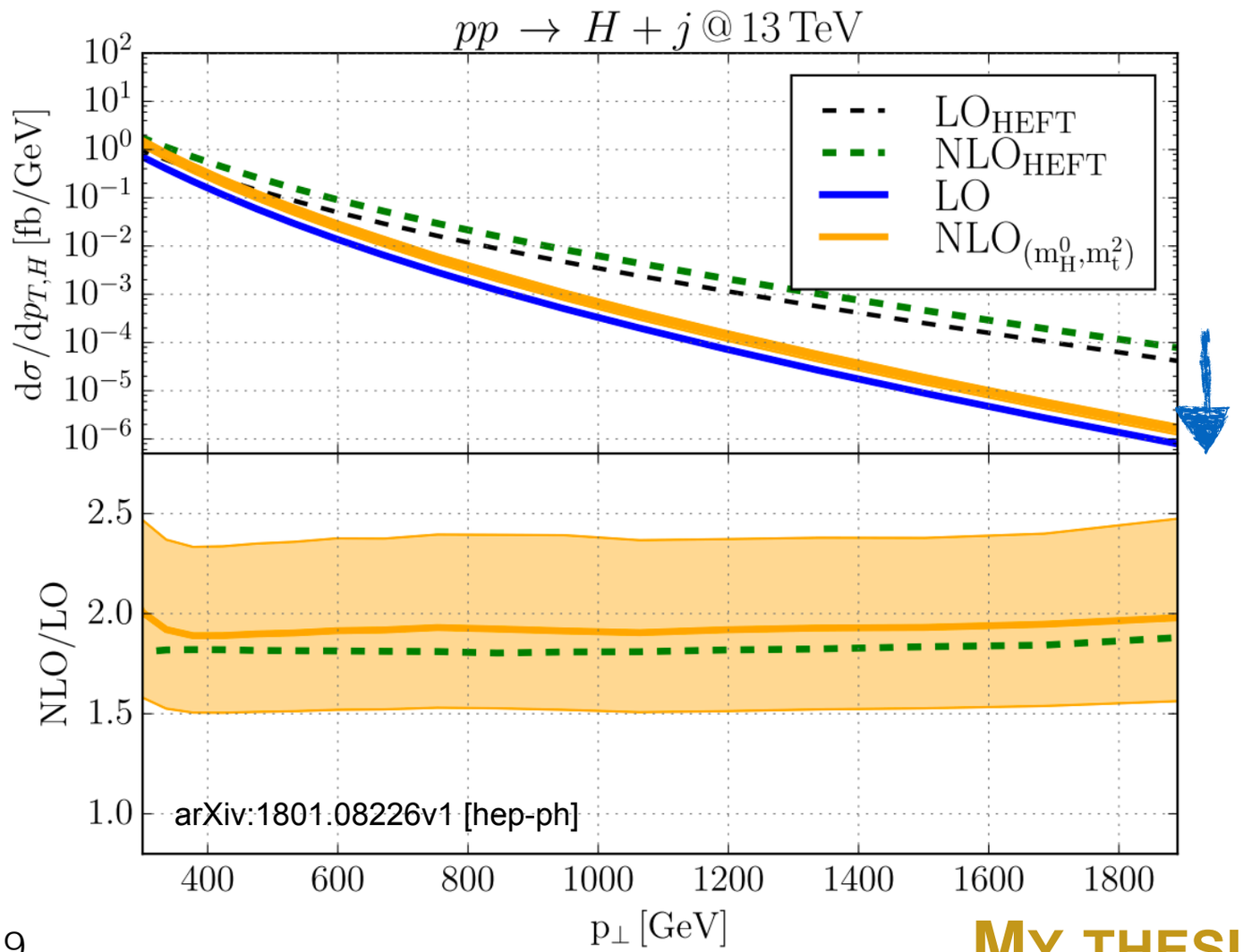
PHYSICAL REVIEW D 98, 052003

arXiv:1808.08238v2 [hep-ex]

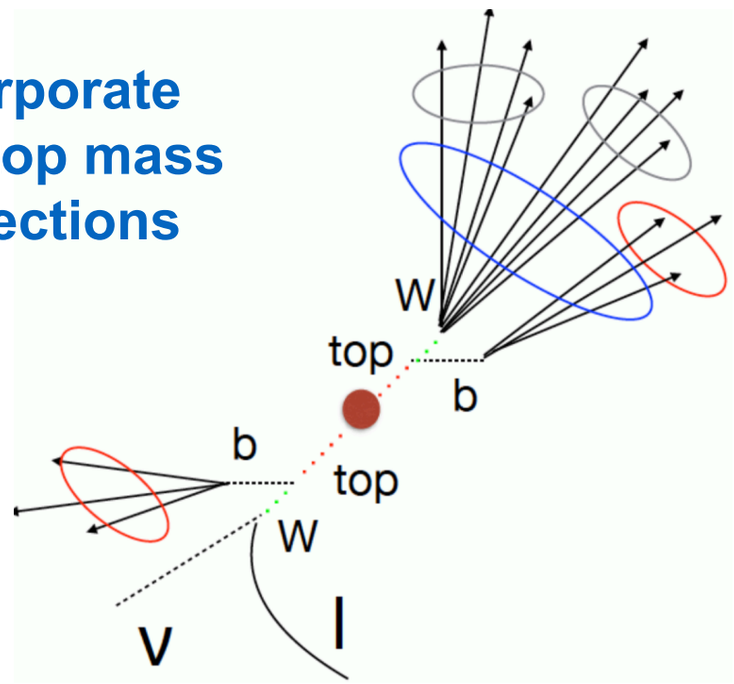
What's next? Boosted H→bb!

- Initial State Radiation boost allows probing of **BSM physics** in ggF initiated top loop
- Look for **finite top mass corrections** to SM
- Benefits from past work with b-jet energy corrections
- QCD and ttbar bkg challenge





incorporate finite top mass corrections



MY THESIS IS BASED ON THIS

Conclusion

Results: The H→bb channel has profited from multiple innovative analyses resulting in a 5.4σ observation

Innovation: Continue to explore this Higgs decay mode and push for better resolution at higher energies

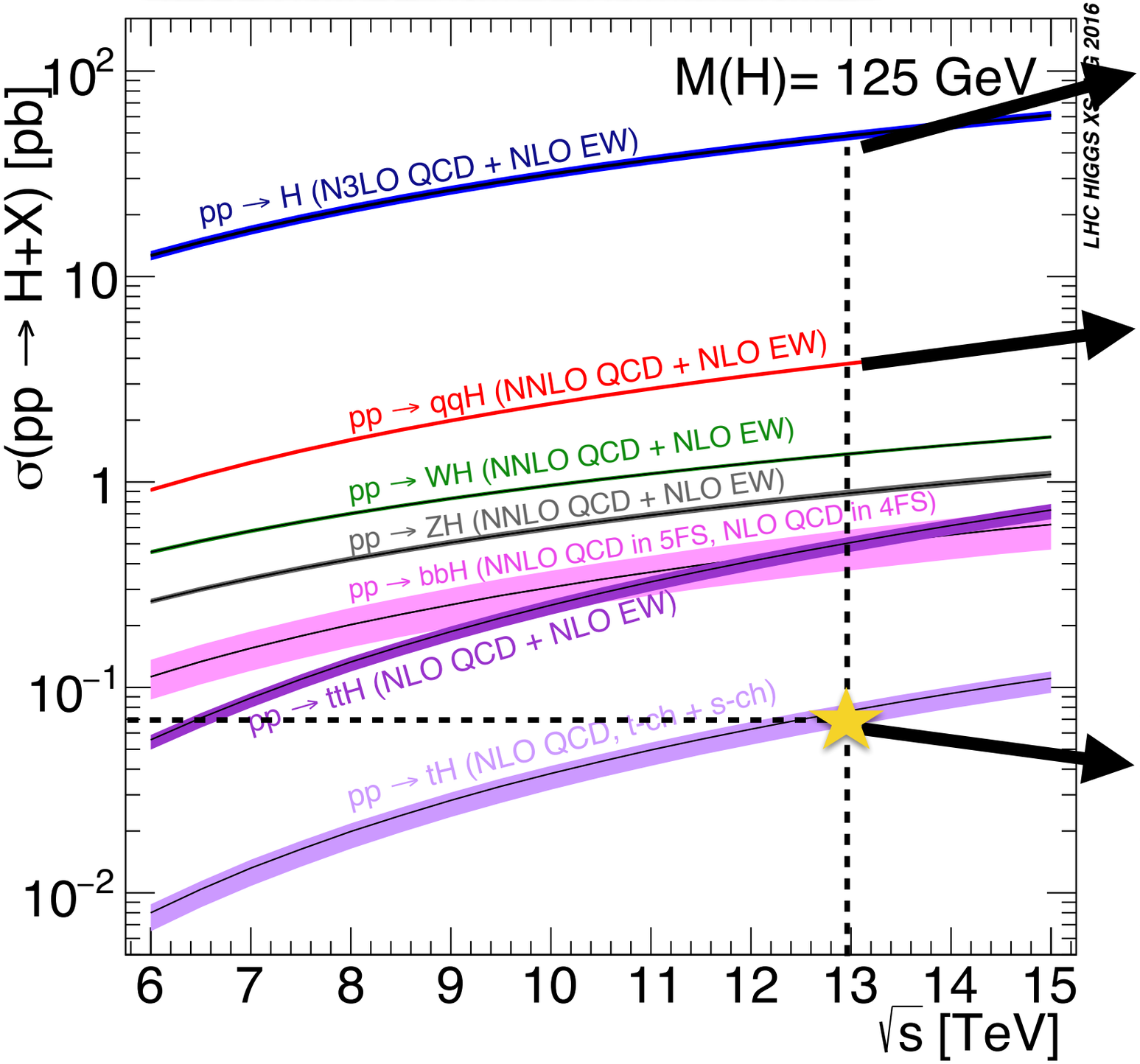
- Inner Tracker upgrade - larger η & better res.
- High Granularity Timing Detector upgrade - better res.
- Jet substructure Multi-Variate Analysis Techniques

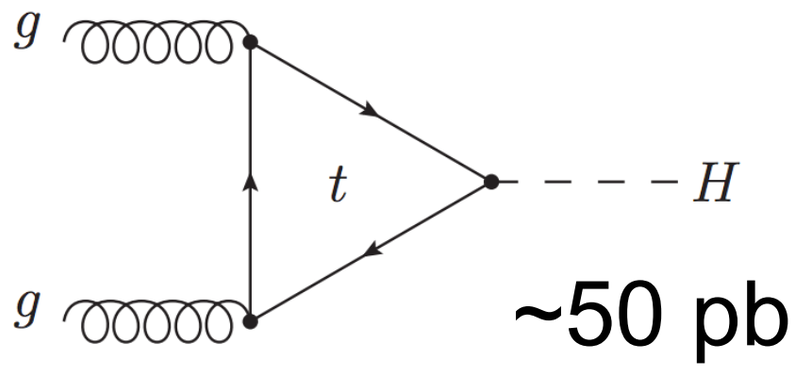
Future Goals: Constrain Higgs couplings and collaborate with theorists to explore the possibility for BSM physics

Backup

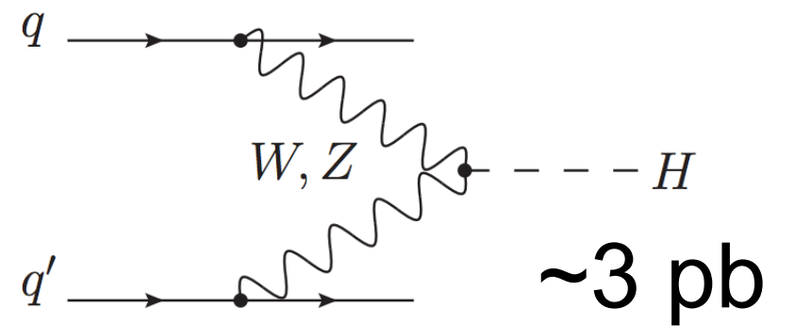
Why VBF?

- Better Triggering
- Unique Final State
- Innovative bkg reduction

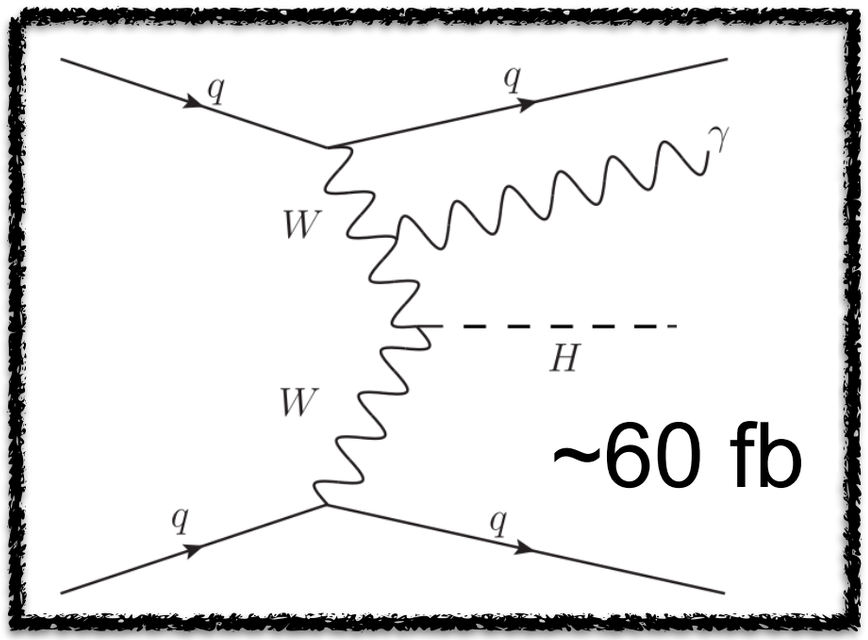




~50 pb



~3 pb



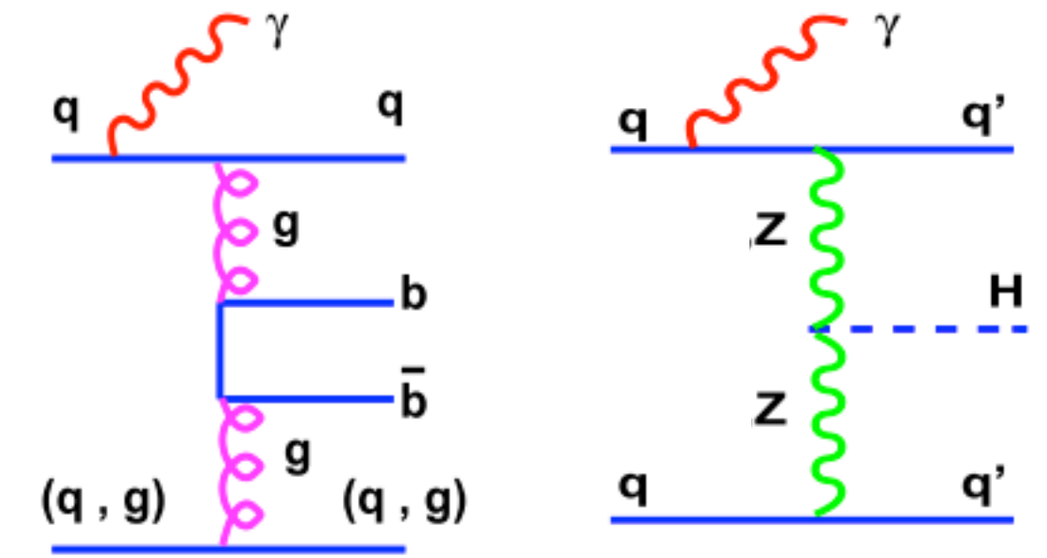
~60 fb

Selection Decisions

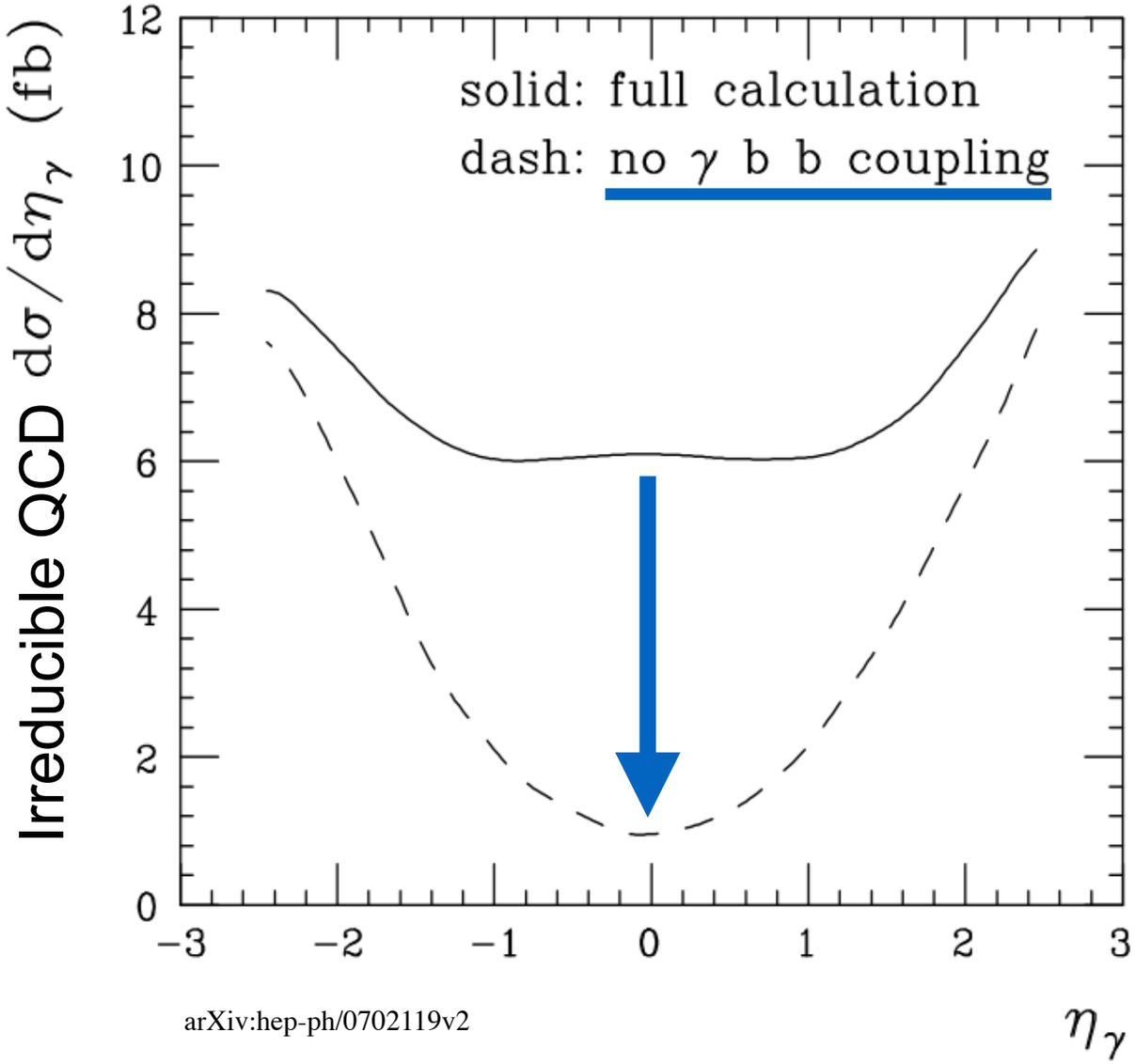
Selection	Requirement
Derivation	HIGG5D3
Trigger	HLT_g25_medium_L1EM22VHI_4j35_0eta490_invm700
Event quality (data only)	pass GRL no Tile, LAr, SCT and Core error
Primary Vertex	At least one primary vertex
Photon	$\geq$ 1 photon E_T >30 GeV
Jets	$\geq$ 4 jets (p_T > 40 GeV, $\mid \eta \mid$< 4.5) $\geq$ 2 jets in $\mid \eta \mid$< 2.5 (central jets)
Higgs signal jet (BB)	two central jets with highest MV2c10 weights
VBF jets (JJ)	pair of non-signal jets with highest invariant mass
b-jets	2 b-tagged jets (tagged on the BB pair with MV2c10 at 77% fixed cut working point)
m_{JJ}	$m_{JJ} > 800$ GeV
$p_T(BB)$	$p_T(BB) > 80$ GeV

Photon Enhancement

- WW over ZZ
- Require Central Photon
- No fully gluon channel



arXiv:hep-ph/0702119v2



arXiv:hep-ph/0702119v2

$\sqrt{s} = 14TeV$	$p_{\mathrm{T}}^{\gamma,cut}$	$m_H = 120$ GeV
$\sigma[H(\to b\bar{b})\gamma jj]$	20 GeV	3.59(7) fb
	30 GeV	2.62(3) fb
$\sigma[b\bar{b}\gamma jj]$	20 GeV	33.5(1) fb
	30 GeV	25.7(1) fb
$\sigma[H(\to b\bar{b})jj]$		320(1) fb
$\sigma[b\bar{b}jj]$		103.4(2) pb

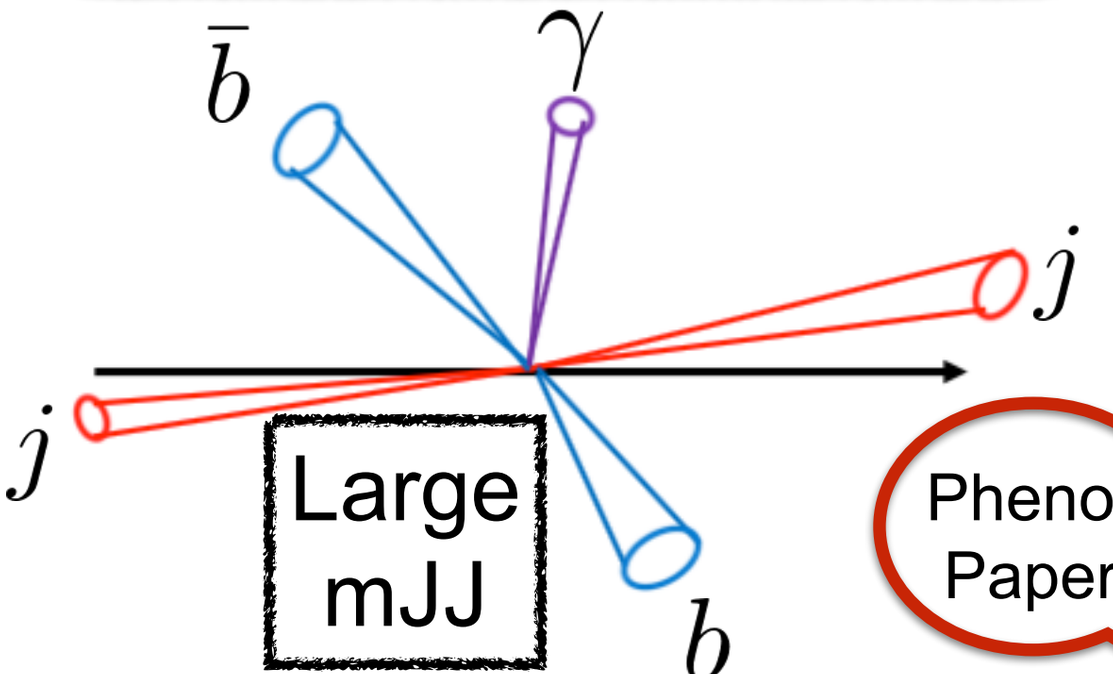
arXiv:hep-ph/0702119v2

$$\frac{\sigma\left[H(\to b\bar{b})\gamma jj\right]}{\sigma\left[b\bar{b}\gamma jj\right]} = 0.102(0)$$

$$\frac{\sigma\left[H(\to b\bar{b})jj\right]}{\sigma\left[b\bar{b}jj\right]} = 0.00309(5)$$

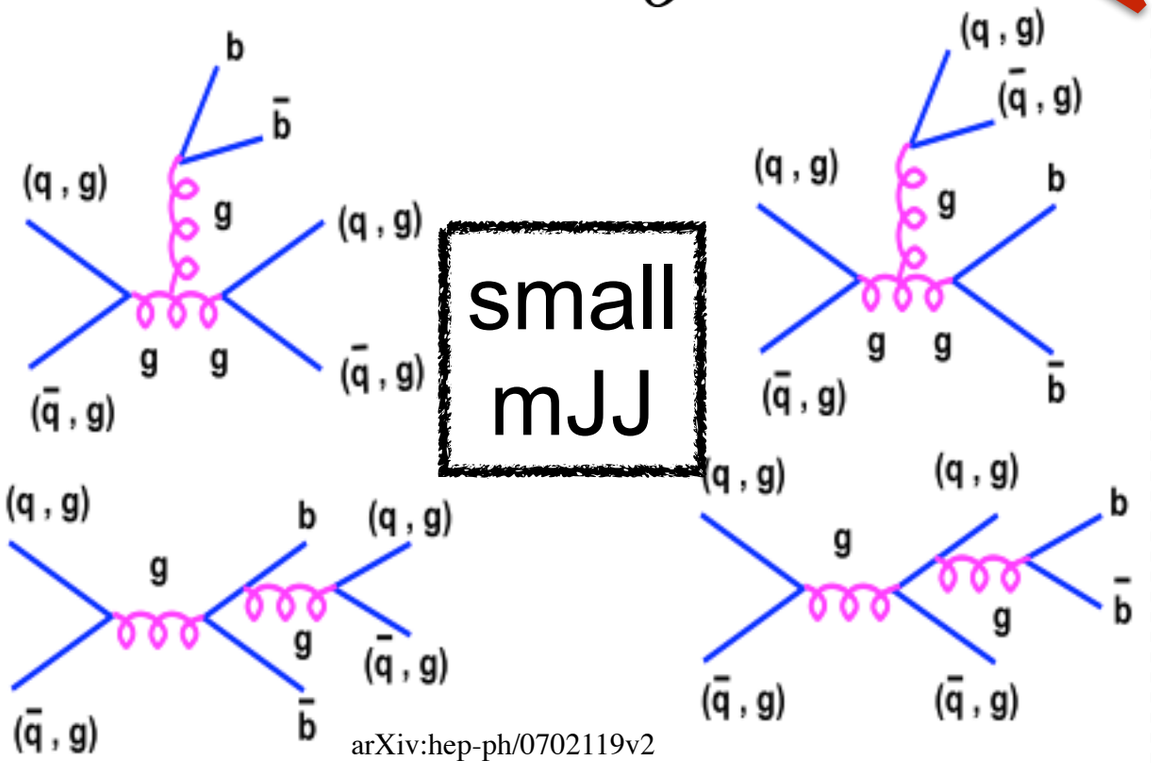
mJJ Enhancement

- Background suppression
  - S-channel
  - Gluon initiated



Large mJJ

Pheno. Paper



small mJJ

arXiv:hep-ph/0702119v2

Suppression Tally

Note: Parton level with kinematic cuts

sub-processes	σ_i (pb)	σ_i/σ	σ_i^γ (fb)	$\sigma_i^\gamma/\sigma^\gamma$
$gq \to b\bar{b}\,gq\,(\gamma)$	57.2(1)	55.3 %	17.3(1)	51.6 %
$gg \to b\bar{b}\,gg\,(\gamma)$	25.2(1)	24.4 %	3.93(3)	11.7 %
$qq' \to b\bar{b}\,qq'\,(\gamma)$	7.76(3)	7.5 %	4.04(2)	12.1 %
$qq \to b\bar{b}\,qq\,(\gamma)$	6.52(2)	6.3 %	4.49(3)	13.4 %
$q\bar{q}' \to b\bar{b}\,q\bar{q}'\,(\gamma)$	4.60(2)	4.4 %	2.28(2)	6.8 %
$q\bar{q} \to b\bar{b}\,q\bar{q}\,(\gamma)$	2.13(2)	2.1 %	1.21(2)	3.6 %
$gg \to b\bar{b}\,q\bar{q}\,(\gamma)$	0.0332(7)	0.03 %	0.124(3)	0.37 %
$q\bar{q} \to b\bar{b}\,gg\,(\gamma)$	0.0137(2)	0.01 %	0.094(2)	0.28 %
$q\bar{q} \to b\bar{b}\,q'\bar{q}'\,(\gamma)$	0.000080(3)	00007 %	0.00080(8)	0.002 %

arXiv:hep-ph/0702119v2

sub-processes	σ_i^γ[no b rad] (fb)	σ_i^γ[no b rad]/σ^γ[no b rad]
$gq \to b\bar{b}\,gq\gamma$	8.19(6)	47.8 %
$gg \to b\bar{b}\,gg\gamma$	0	0 %
$qq' \to b\bar{b}\,qq'\gamma$	2.80(2)	16.4 %
$qq \to b\bar{b}\,qq\gamma$	3.49(3)	20.4 %
$q\bar{q}' \to b\bar{b}\,q\bar{q}'\gamma$	1.57(2)	9.2 %
$q\bar{q} \to b\bar{b}\,q\bar{q}\gamma$	0.87(1)	5.1 %
$gg \to b\bar{b}\,q\bar{q}\gamma$	0.10(2)	0.6%
$q\bar{q} \to b\bar{b}\,gg\gamma$	0.096(2)	0.6 %
$q\bar{q} \to b\bar{b}\,q'\bar{q}'\gamma$	0.0009(1)	0.005 %