Associated b-Higgs Production at the LHC

March, 2011

S. Dawson

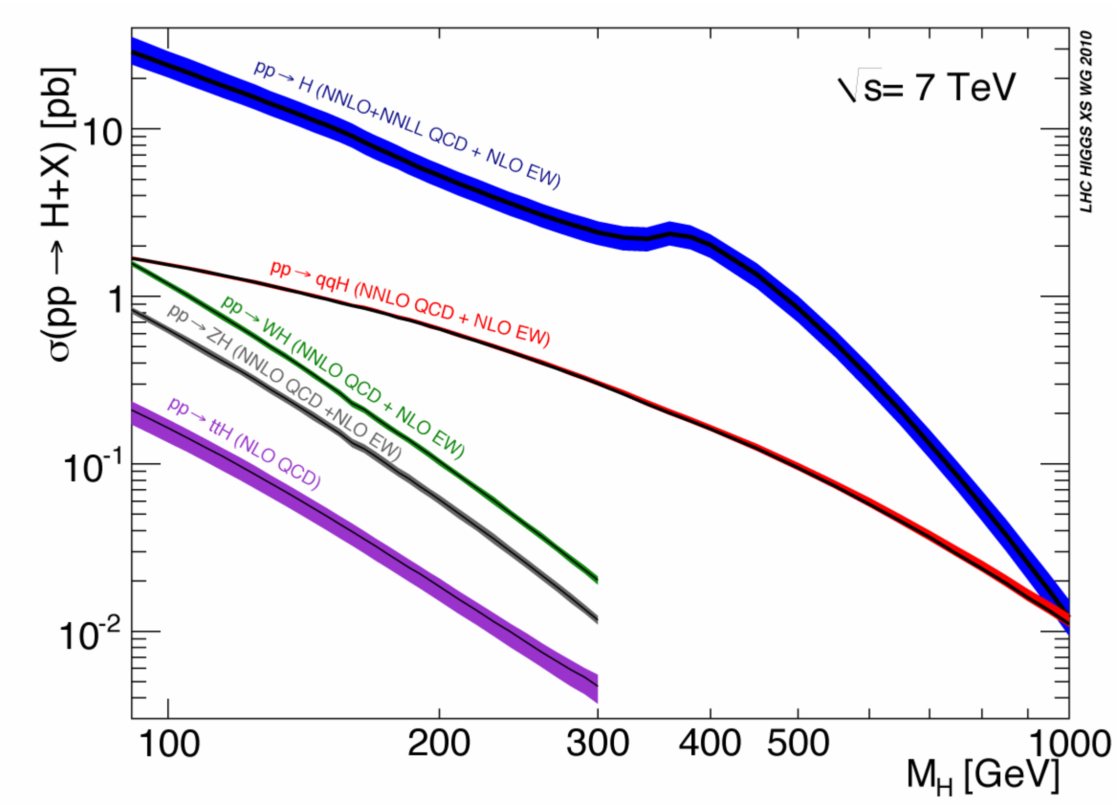
BNL

Dawson & Jackson, Phy. Rev. D77, 015019 (2008)

Dawson, Jackson, Jaiswal, arXiv:1103.xxxx

Dawson, Jaiswal, arXiv:1002.2672

SM Production Mechanisms at LHC



Bands show error estimate (scale + PDF)

All important channels calculated to NLO or NNLO

Production with b's very small in SM

[LHC Higgs Cross Section Working Group]

Higgs in the MSSM

- MSSM has 2 Higgs doublets: H_d and H_u

$$H_d = \begin{pmatrix} \varphi_d^+ \\ \varphi_d^0 \end{pmatrix} \qquad H_u = \begin{pmatrix} \phi_u^0 \\ -\phi_u^- \end{pmatrix}$$

$$\phi_d^0 = \frac{1}{\sqrt{2}}\left(v_1 + h_d^0\right)$$

$$\phi_u^0 = \frac{1}{\sqrt{2}}\left(v_2 + h_u^0\right)$$

$\tan\beta = v_1/v_2$

- Physical CP-Even Higgs bosons

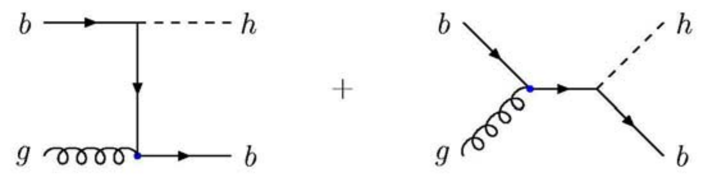
$$\begin{pmatrix} h^0 \\ H^0 \end{pmatrix} = \begin{pmatrix} c_\alpha & -s_\alpha \\ s_\alpha & c_\alpha \end{pmatrix} \begin{pmatrix} h_u{}^0 \\ h_d{}^0 \end{pmatrix}$$

- Pseudoscalar, A^0, and two charged Higgs, $H^\pm$

Higgs coupling to b's enhanced for large tan β

Higgs + b Production

5 Flavor number
PDF scheme

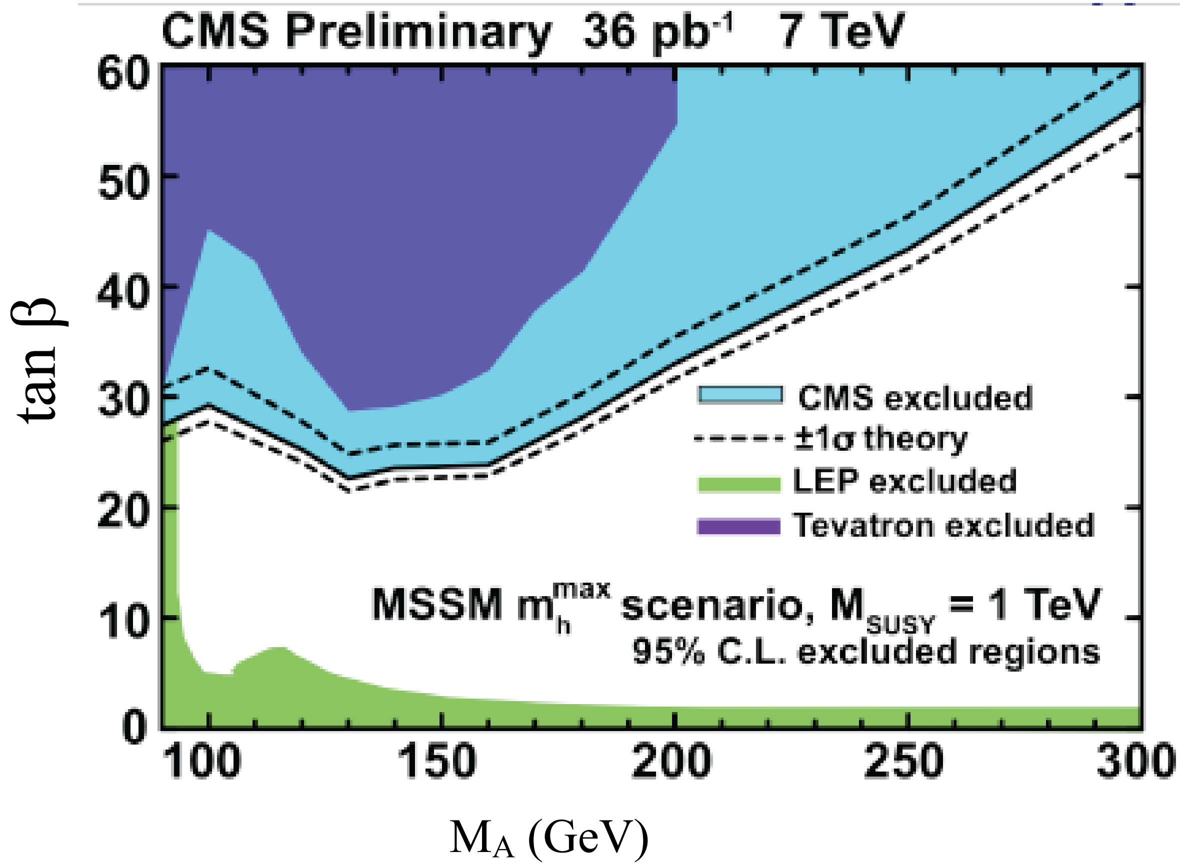


4 Flavor number
PDF scheme

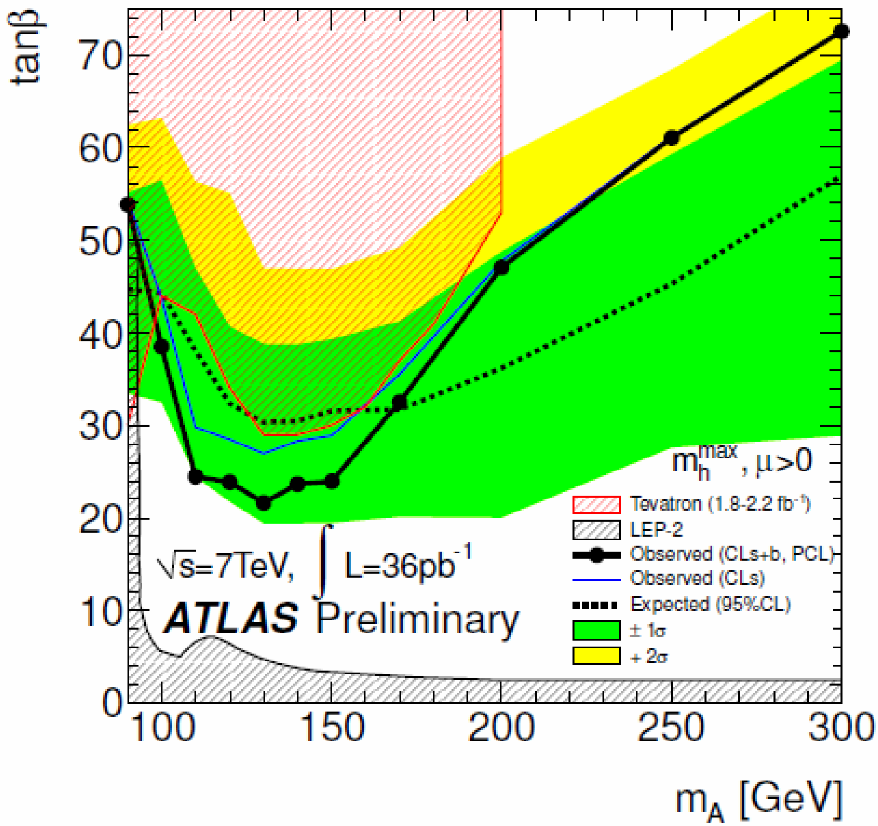
Schemes represent different orderings of perturbation theory

NLO QCD Corrections well known in both schemes

CMS: $h \to \tau^+\tau^-$



ATLAS Limit: $h \rightarrow \tau^+\tau^-$



Higgs Couplings to Fermions

- At tree level, H_d couples to charge -1/3 quarks, and H_u couples to charge 2/3 quarks

$$L = -\lambda_b \overline{\psi}_L H_d b_R - \lambda_t \overline{\psi}_L H_u t_R + hc \qquad \psi_L = \begin{pmatrix} t_L \\ b_L \end{pmatrix}$$

- Since up and down quark sectors are diagonalized independently, Higgs interactions are flavor diagonal

- Trilinear couplings couple both Higgs to charge -1/3 and charge 2/3 squarks

$$L = \tilde{t}_L^* \lambda_t \left(A_t H_u - \mu^* H_d \right) \tilde{t}_R + \tilde{b}_L^* \lambda_b \left(A_b H_d - \mu^* H_u \right) \tilde{b}_R + h.c.$$

Couples "wrong" Higgs

Effective Lagrangian Approach

- No tree level $H_u b\bar{b}$ coupling in MSSM, but it arises at 1-loop

$$L_{eff} = -\lambda_b \bar{b}_R \left(\phi_d^0 + \frac{\Delta m_b}{\tan\beta} \phi_u^{0*} \right) b_L + hc$$

- At tree level, $m_b = \lambda_b v_1/\sqrt{2}$
- At one loop: $m_b \equiv \lambda_b v_1 (1+ \Delta m_b)/\sqrt{2}$
- Yukawa coupling shifted:

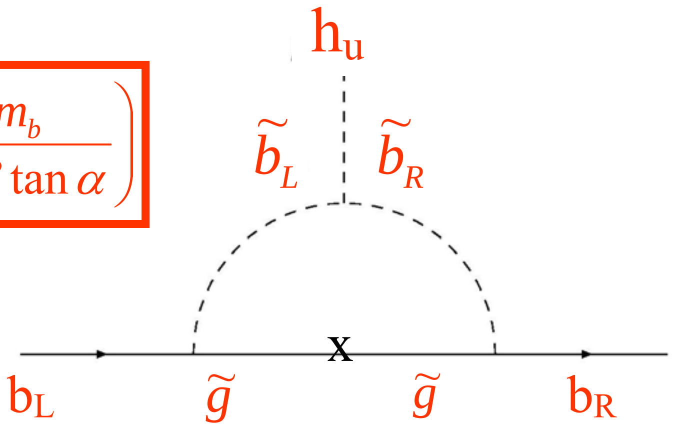
$$L_{eff} = \frac{m_b}{v_{SM}} \left(\frac{1}{1+\Delta m_b} \right) \left(-\frac{\sin\alpha}{\cos\beta} \right) \left(1 - \frac{\Delta m_b}{\tan\beta \tan\alpha} \right) \bar{b} b h^0$$

Define Effective Yukawa Couplings

$$\Delta m_b = \frac{2\alpha_s}{3\pi} m_{\tilde{g}} \mu I(m_{\tilde{b}_1}, m_{\tilde{b}_2}, m_{\tilde{g}})$$

Assumes $M_h << M_{SUSY}$

$$g_{hbb} \equiv \frac{m_b}{v_{SM}} \left(\frac{1}{1+\Delta m_b} \right) \left(-\frac{\sin\alpha}{\cos\beta} \right) \left(1 - \frac{\Delta m_b}{\tan\beta \tan\alpha} \right)$$



Effective Lagrangian approach neglects momentum dependence of 3-pt function

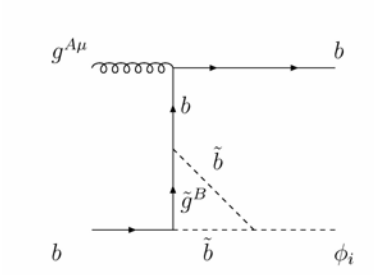
Calculate SUSY QCD Corrections to bg→bh

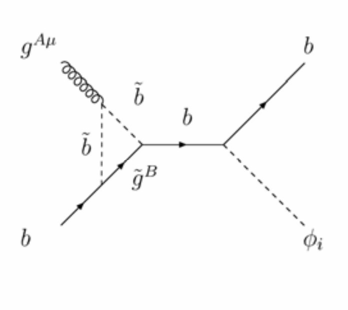
- Approach 1: “Improved Born Approximation”

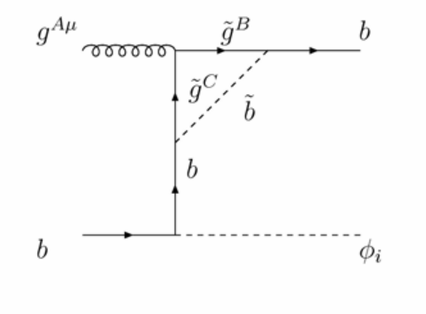
$$g_{hbb} \equiv \frac{m_b}{v_{SM}}\left(\frac{1}{1+\Delta m_b}\right)\left(-\frac{\sin\alpha}{\cos\beta}\right)\left(1-\frac{\Delta m_b}{\tan\beta\tan\alpha}\right)$$

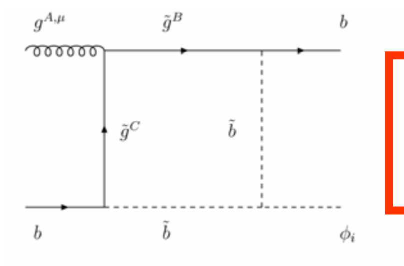
$$\sigma_{IBA} = \left(\frac{g_{hbb}}{g_{hbb}^{SM}}\right)^2 \sigma_{LO}$$

- Approach 2: $O(\alpha_s^2)$ NLO calculation
  - Use g_{hbb} as above, so subtract off double counting
  - Include all contributions from squark/gluino loops









Many contributions not included in IBA

Analytic Results

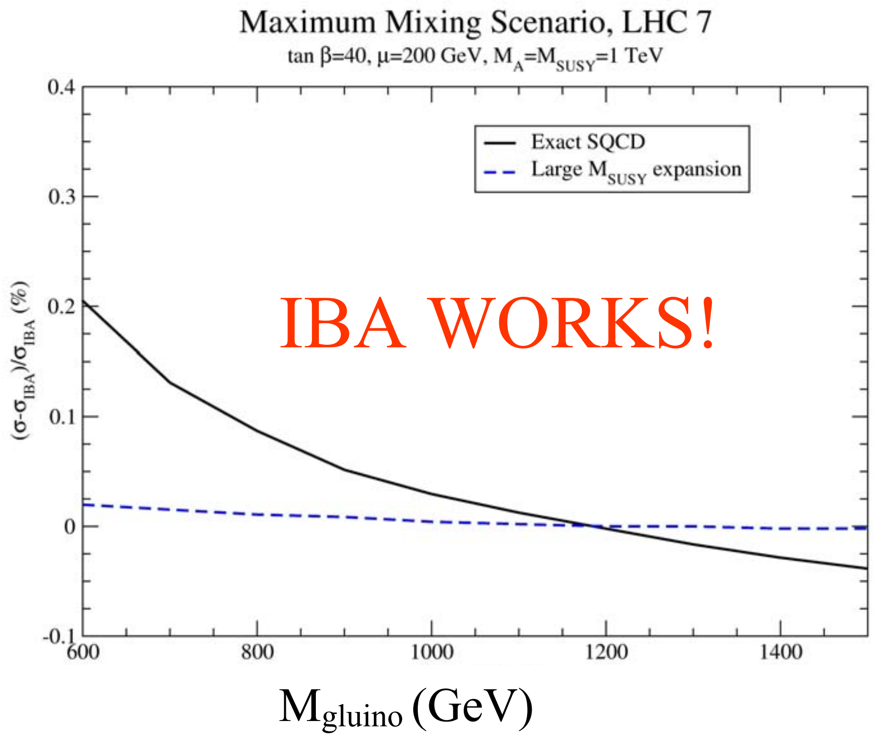
- New calculation includes:
  - $m_b \tan\beta$ enhanced terms
  - Analytic results for small and large b-squark mixing in large M_{SUSY} limit
  - Example: Large mixing, b-squarks almost degenerate, $\sin 2\theta_b \sim 1$

$$\left|A(bg \to bh\right|^2 = \left|A(bg \to bh\right|_{IBA}^{2} \underbrace{\left(1 + 2\left(\frac{\delta g_{bbh}^{(2)}}{g_{bbh}}\right)\right) + 2\frac{M_h^2}{M_S^2}\delta\kappa}$$

Corrections to IBA:$O(1/M_{SUSY}^2)$

  - $\delta\kappa$ term not rescaling of LO

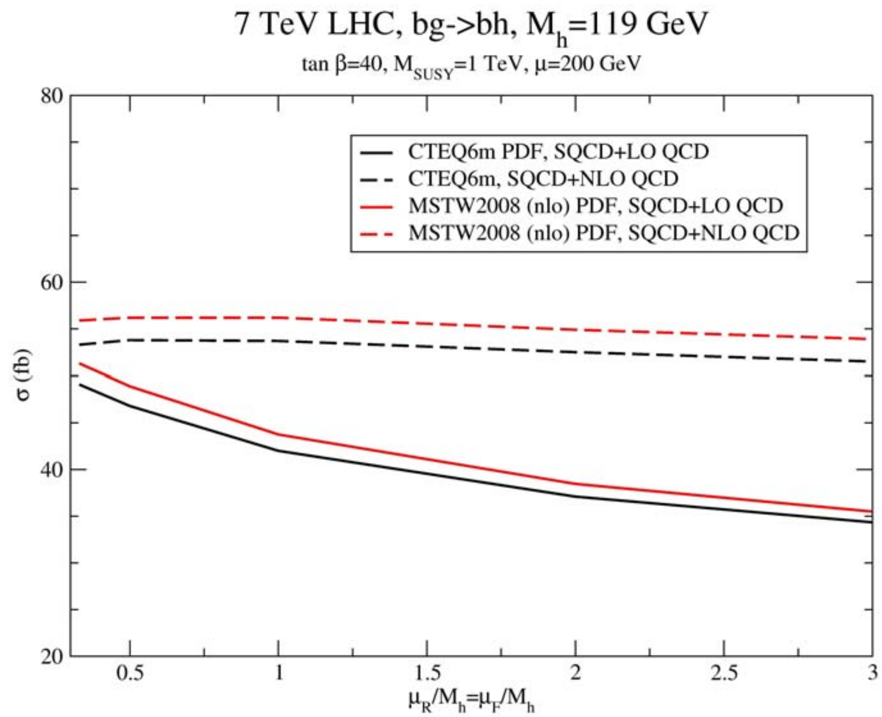
% deviation
from IBA



Deviations from IBA only for light (~200 -400 GeV) squarks and gluinos (excluded by LHC)

Dawson, Jackson, Jaiswal arXiv:1103.xxxx [hep-ph]

PDF/Scale Uncertainties



Scale variation ~2%, PDF set variation ~ 5%

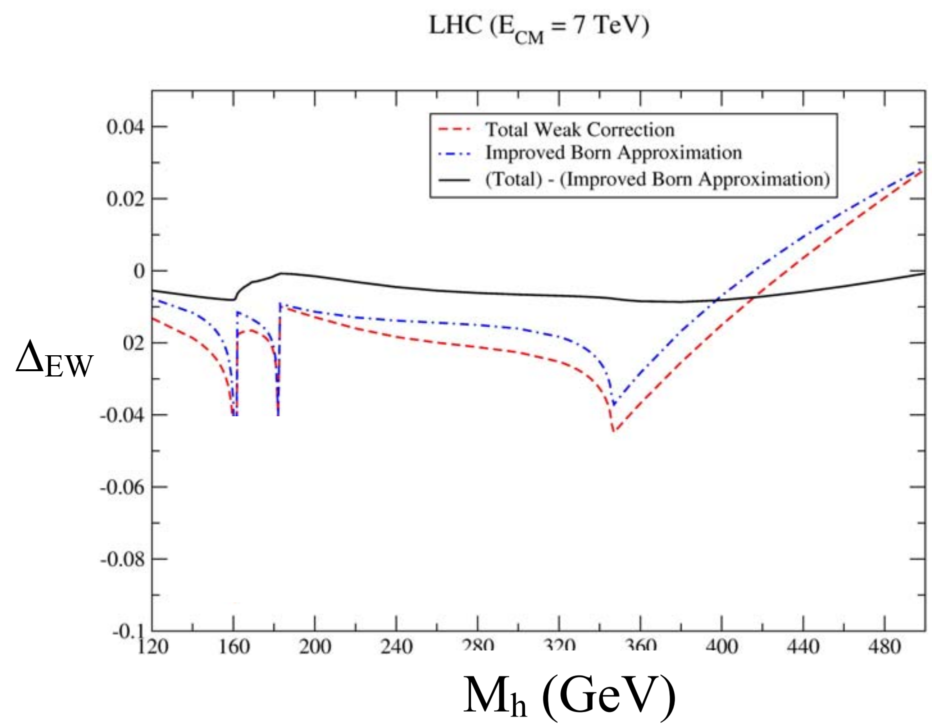
Dawson, Jackson, Jaiswal arXiv:1103.xxxx [hep-ph]

Standard Model: EW Corrections to pp → b h

$$\sigma(pp \to bh) = \sigma_0 \left(1 + \Delta_{QCD} + \Delta_{EW} + \Delta_{SQCD}\right)$$

For $M_h \sim 400$ GeV corrections 2-4%

IBA captures weak corrections accurately



Dawson, Jaiswal [arXiv:1002.2672]

Conclusions

- For heavy squarks and gluinos, SQCD loop effects well approximated by effective Lagrangian approach
  - SQCD effects are large! But contained in Δm_b
- Scale/PDF uncertainties ~ 2-5%