Weak Boson Fusion

Sophy Palmer

Institute of Particle Physics Phenomenology
University of Durham

Annual Meeting of the IOP HEPP Group 2008

Work in collaboration with G Weiglein and T Figy

www.ippp.dur.ac.uk

Outline

1. Introduction
   - The Higgs Sector
   - Weak Boson Fusion
   - Effective Couplings
2. Results
   - Partonic Cross Sections
   - Monte Carlo Results

The MSSM Higgs Sector

- In the MSSM, the Higgs sector has to contain two Higgs doublets, which leads to 5 physical Higgs states:

$$h_0, H_0, A_0, H^+, H^-$$

- The Higgs sector is described by $\tan\beta$ and M_A at tree level
- The masses m_h and m_H are found by diagonalizing the Higgs mass matrix

$$M_H^{2,tree} = \begin{pmatrix} M_A^2 sin^2\beta + M_Z^2 cos^2\beta & -\left(M_A^2 + M_Z^2\right) sin\beta cos\beta \\ -\left(M_A^2 + M_Z^2\right) sin\beta cos\beta & M_A^2 cos^2\beta + M_Z^2 sin^2 \end{pmatrix}$$

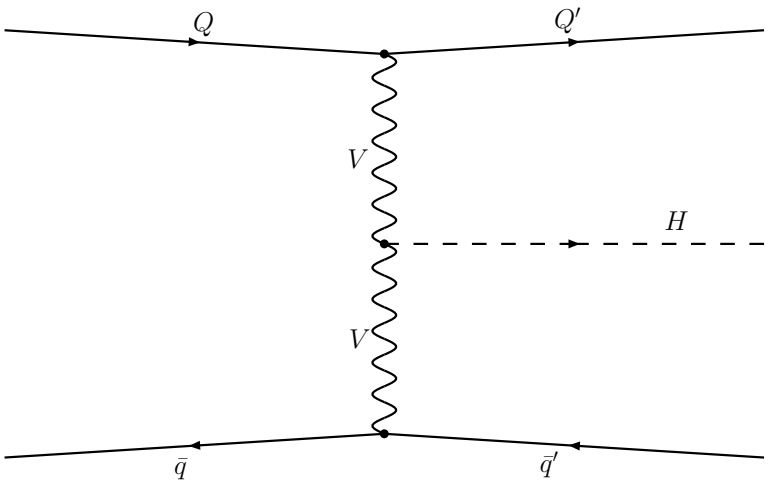
$$\downarrow \textit{diagonalization}, \alpha$$

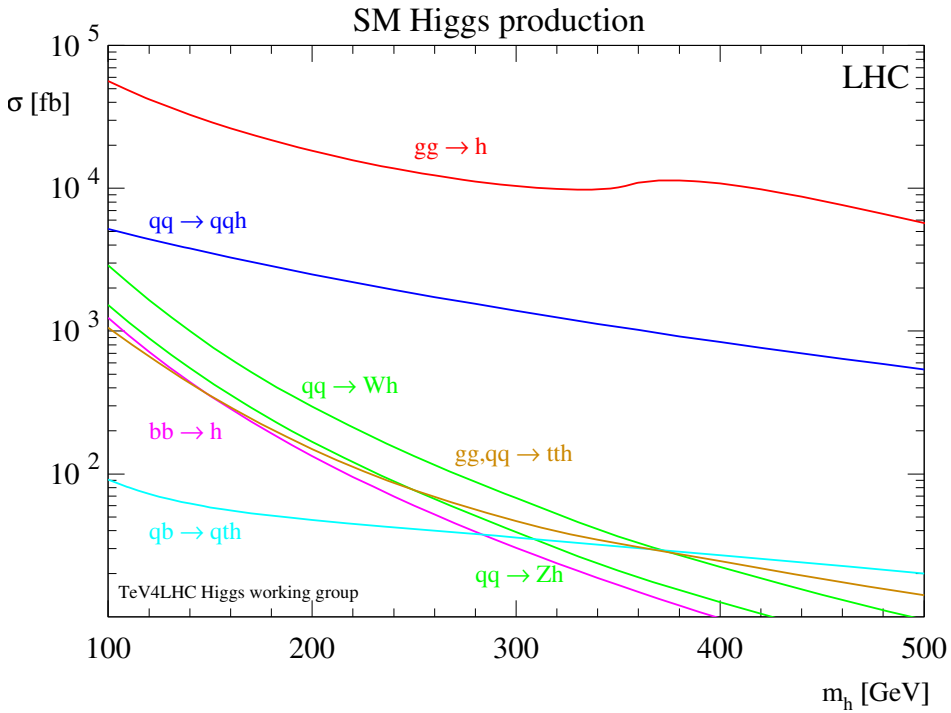
$$M_H^{2,tree} = \begin{pmatrix} m_H^{2,tree} & 0 \\ 0 & m_h^{2,tree} \end{pmatrix}$$

Weak Boson Fusion

Weak boson fusion is expected to be the second largest contributor to Higgs Boson production at the LHC

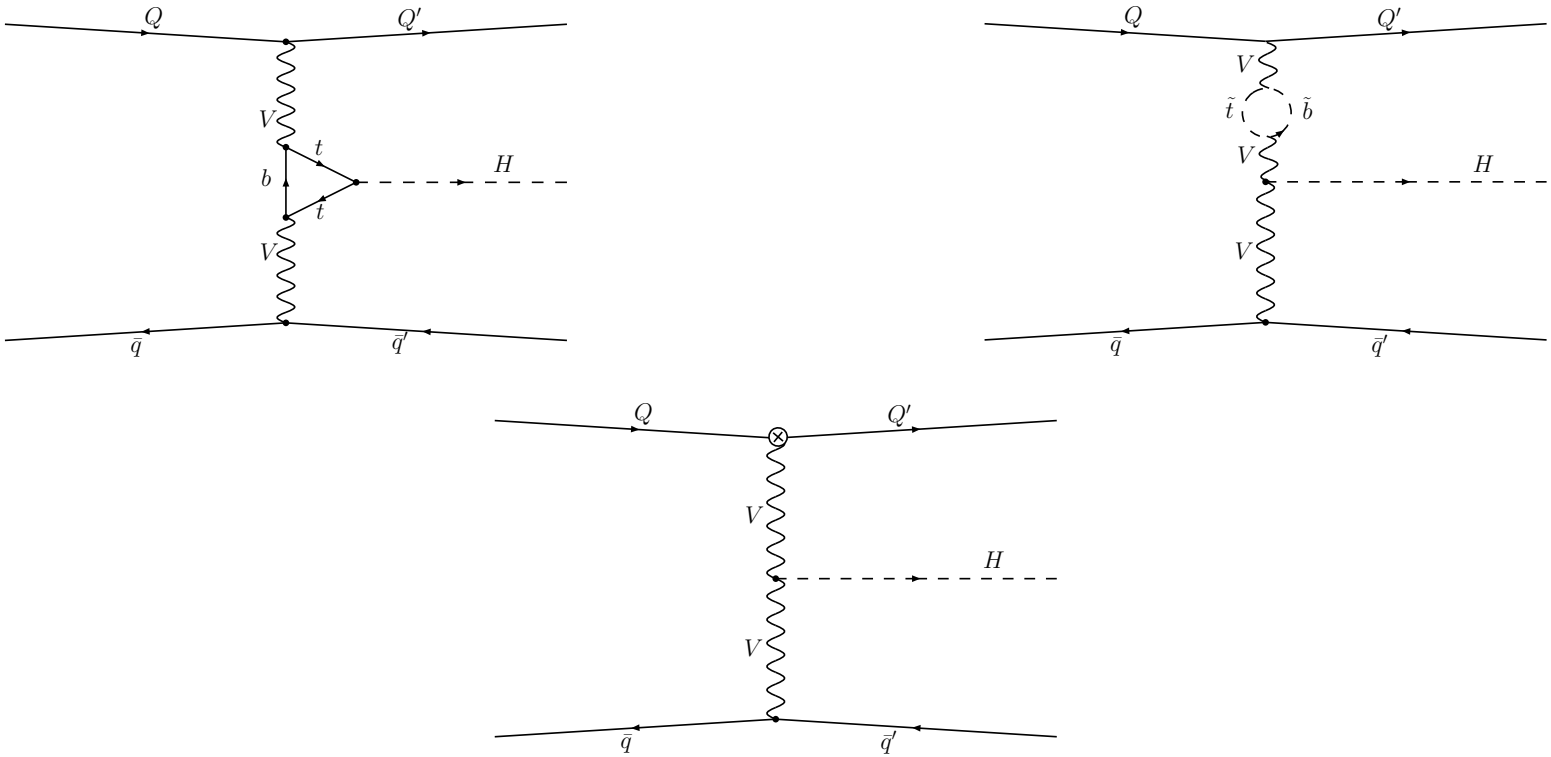
$$Q + \bar{q} \rightarrow Q' + h/H + \bar{q}'$$





From: **hep-ph/0607308**, T Hahn, S Heinemeyer, F Maltoni, G Weiglein, S Willenbrock

SM and MSSM Corrections to WBF



- Third generation quarks (and squarks in the MSSM) are included in the loop diagrams
- The programs FeynArts, FormCalc, LoopTools and FeynHiggs have been used

*Programs available at **www.feynarts.de** and **www.feynhiggs.de***

WBF - Status

- In the Standard Model, next to leading order QCD corrections are known and have been implemented in Monte Carlo codes such as vbfnlo

  (see, for instance **hep-ph/0407066**, T Figy, C Oleari, D Zeppenfeld)

- The QCD corrections to weak boson fusion are relatively small, so electroweak corrections could be important
- Recently, the full one-loop corrections in the Standard Model have been calculated

  (e.g. **hep-ph/0710.4749**, M Ciccolini, A Denner, S Dittmaier)

- Relevant interference effects have been calculated

  (e.g. **hep-ph/0709.3513**, J Andersen, T Binoth, G Heinrich, J Smillie; **hep-ph/0801.4231**, A Bredenstein, K Hagiwara, B Jäger)

Effective Couplings

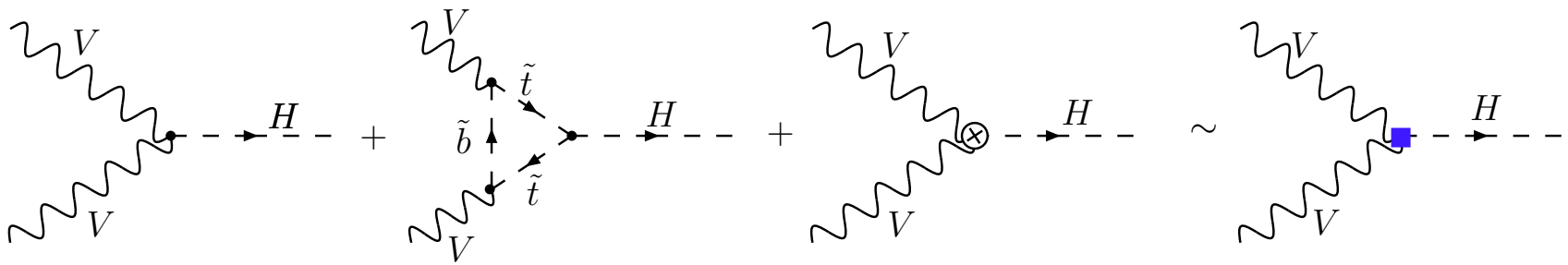
- The most general HVV coupling is:

$$T^{\mu\nu}(q_1,q_2) = a_1(q_1,q_2)\,g^{\mu\nu} + a_2(q_1,q_2)\left(q_1 \bullet q_2 g^{\mu\nu} - q_2^{\mu} q_1^{\nu}\right) + a_3(q_1,q_2)\,\epsilon^{\mu\nu\rho\sigma} q_{1\sigma} q_{2\rho}$$

- At tree level

$$a_1^{SM} = \frac{ieM_W}{sin(\theta_W)}; \quad a_1^{MSSM} = \frac{ieM_W}{sin(\theta_W)} sin(\beta-\alpha); \quad a_2 = 0; \quad a_3 = 0;$$

- New physics (e.g. a heavy particle loop) can be represented by the effective coupling $T^{\mu\nu}$



VVH Coupling and Azimuthal Angles

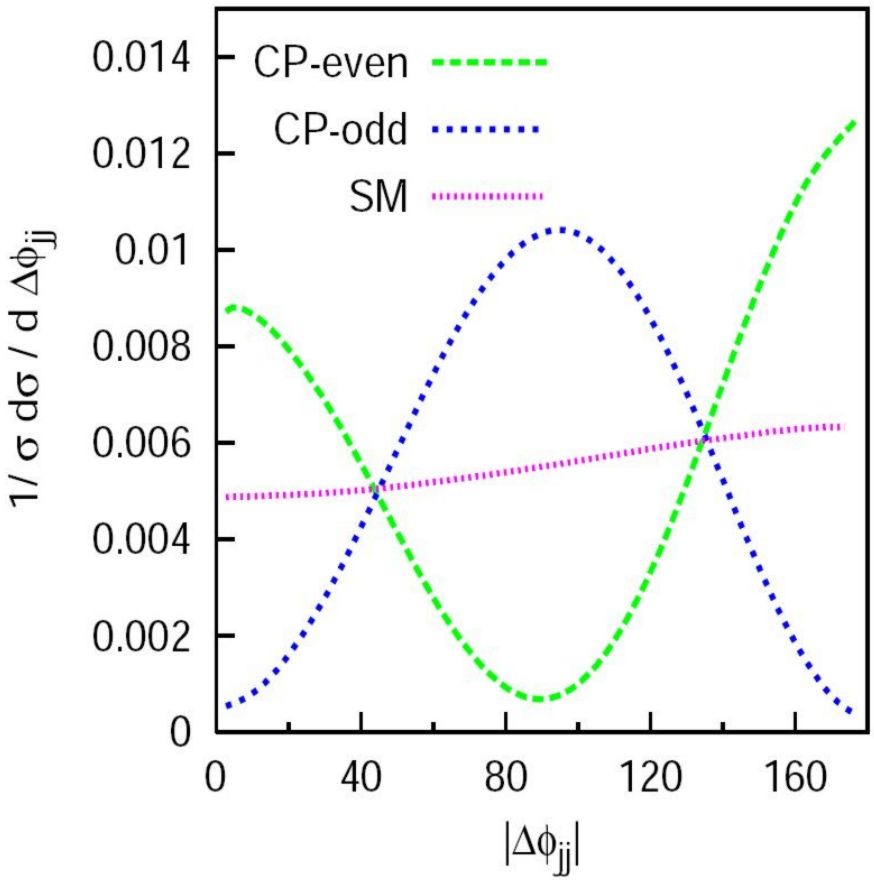


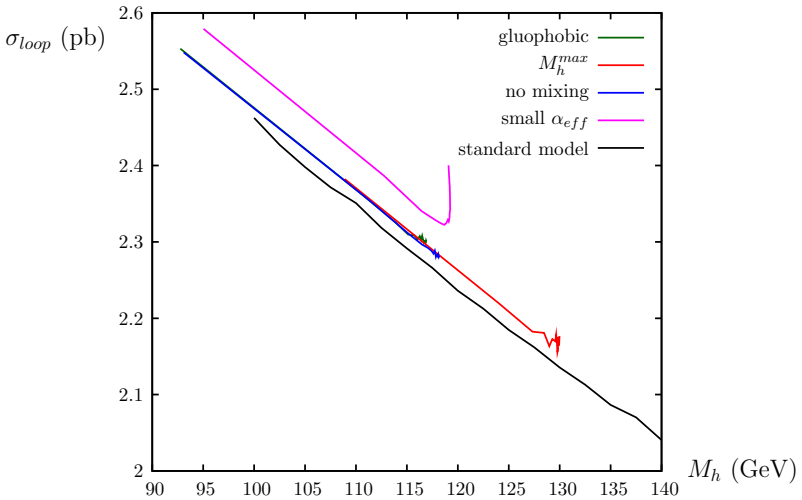
Figure from: **hep-ph/0609075**, Hankele, G Klamke, D Zeppenfeld, T Figy

The LHC will (hopefully) provide information about

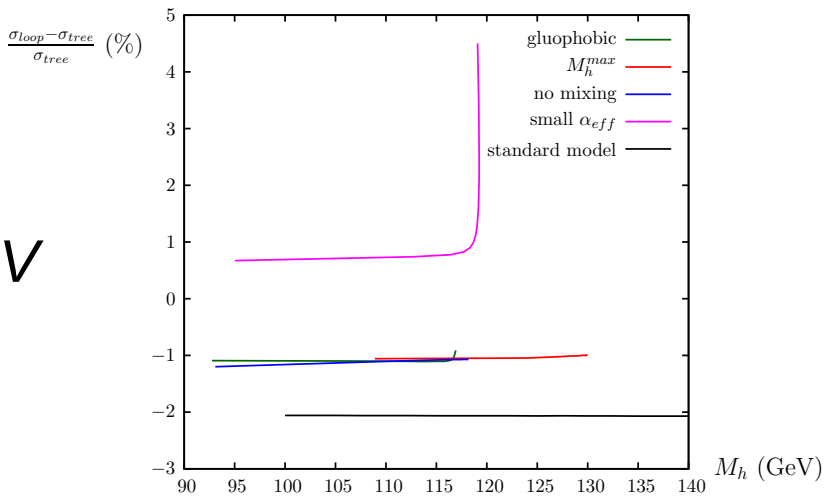
- Strength of the HVV coupling
- Tensor structure of the HVV coupling

Partonic Cross Section

- Partonic cross sections have been calculated for the process: u + d $\longrightarrow$ d + H + u

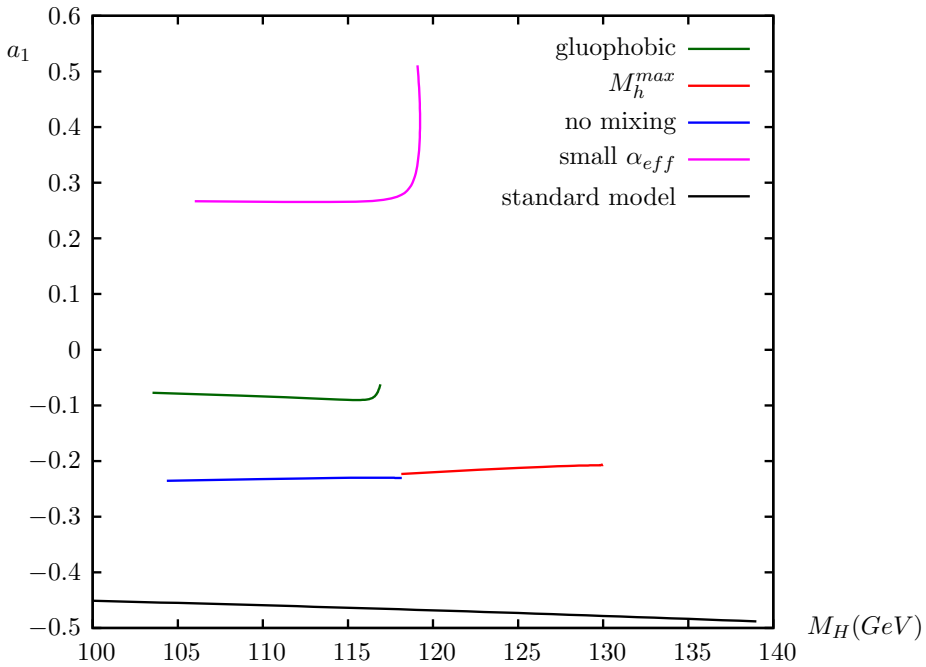


$$\sqrt{\hat{s}} = 1TeV$$

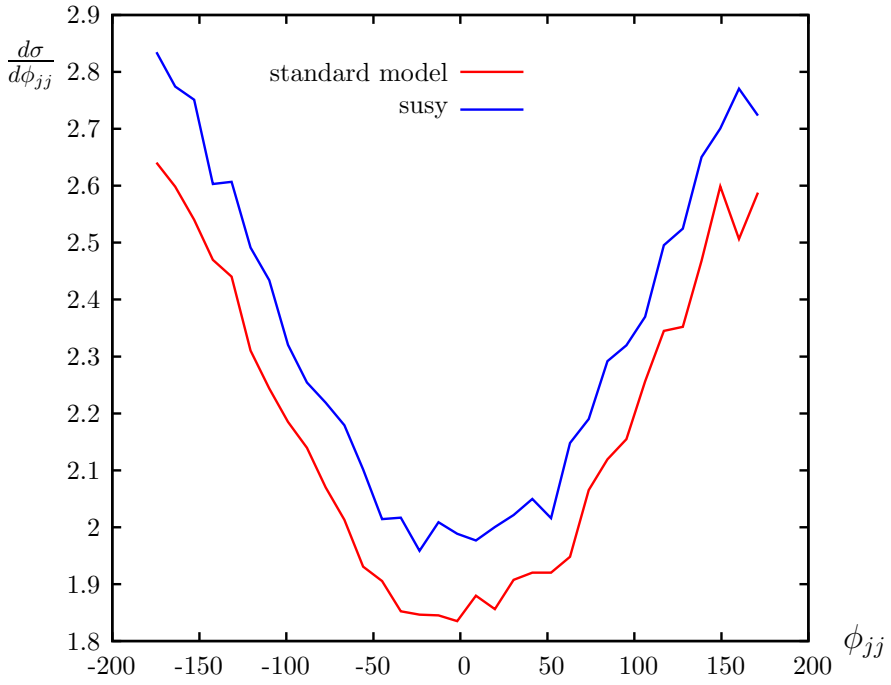


- For the MSSM, M_A is fixed at 500 GeV and tan β is varied
- The partonic cross section is $\sim$ 2 - 2.5 pb, with loop corrections at the percent level for certain benchmarks

Monte Carlo



For the MSSM, M_A = 500 GeV and tan β is varied between 2 and 42



NLO result, small α_{eff} scenario
tan β = 5
M_A = 500 GeV, M_h = 115 GeV

Summary

- Weak boson fusion provides
  - Higgs discovery method
  - Study of electroweak symmetry breaking
  - Possible indication of BSM physics
- By calculating the form factors of the effective $T^{\mu\nu}$ coupling, Monte Carlo code can be used to calculate distributions for BSM scenarios
- MSSM cross sections are slightly enhanced compared to SM cross sections (more detailed parameter scans are in progress)