The Supersymmetric Higgs bounds at the Tevatron and LHC

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Electroweak Interactions and Unified Theories

(based on: J.B. and A. Djouadi, JHEP 1103 (2011) 055 [arXiv:1012.0530]
J.B. and A. Djouadi, arXiv:1012.2748)

Introduction

Minimal Supersymmetric Standard Model (MSSM)

Promising extension of the Standard Model (SM) which protects Higgs mass from SM quadratically divergent corrections $\delta M_H \sim \frac{m_t^2 \Lambda^2}{8\pi} \Rightarrow \frac{m_t^2 M_{\rm SUSY}^2}{8\pi}$

Higgs spectrum

- Anomalies cancellation requires 2 Higgs doublets ; Higgs spectrum after electroweak symmetry breaking:

$$\text{2 CP-even } h,\ H, \text{ 1 CP-odd } A, \text{ 1 charged } H^{\pm} \text{ Higgses}$$

$$\text{2 vev } v_1,\ v_2, \text{ new parameter } \tan\beta = \frac{v_1}{v_2}$$

- In MSSM benchmark scenarios, $h(H)$ SM–like, $H(h)$ A–like
  $\Rightarrow \Phi = A,\ H(h)$ with same mass, same couplings, same production and decays

Calculation overview for Higgses production

Central cross section

- b–processes dominant at relevant $\tan\beta > 10$:
  only b–loop in gg fusion, $b\bar{b}$ fusion comes into the game
- SUSY Δ_b contribution to $\Phi b\bar{b}$–coupling neglected (cancel out in $\sigma \times \mathrm{BR}$)
- Numerical results presented with $\tan\beta = 1 \Rightarrow$ multiply by $2\tan^2\beta$ for actual value

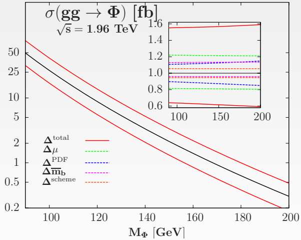
Standard QCD theoretical uncertainties

- scale variation $\frac{1}{\kappa}\mu_0 \leq \mu_R, \mu_F \leq \kappa\mu_0$, μ_0 as central scale
- PDF+$\Delta^{\mathrm{exp+th}}\alpha_S$ uncertainties (equivalent to MSTW PDF4LHC recommandation)
- m_b uncertainties: $\Delta\overline{m}_b$, m_b renormalisation scheme, m_b impact on PDFs

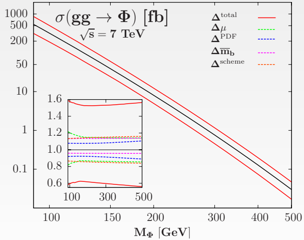
MSSM $gg \to \phi$ production

- Calculation done at NLO only (no b–loop NNLO calculation available)
  [M. Spira et al, Nucl. Phys. B 453 (1995)]
- Central scale $\mu_0 = \frac{1}{2} M_H$, scale variation with $\kappa = 2$
- m_b uncertainties important (mainly m_b renormalisation scheme)

Tevatron: $\sim +58\%, -40\%$.



lHC: $\sim +53\%, -38\%$

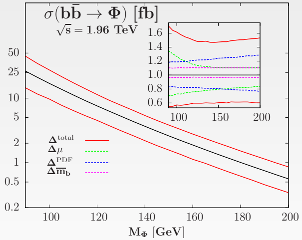


MSSM $b\bar{b} \to \phi$ production

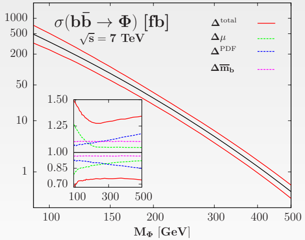
- Process known at NNLO, central scale $\mu_0 = \frac{1}{4} M_H$

  [R. Harlander and W. Kilgore, Phys. Rev. D 68 (2003) 013001]
- Scale variation with $\Rightarrow \kappa = 3$ (include m_b renormalisation scheme)

Tevatron: $\sim +50\%, -40\%$



lHC: $\sim +40\%, -30\%$



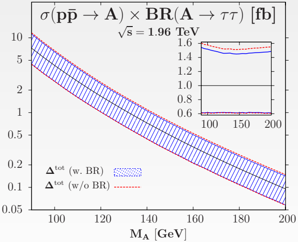
Combinaison of the two channels and with Higgs decay

Add the decay $A \to \tau^+\tau^-$ and combining the two production channels together

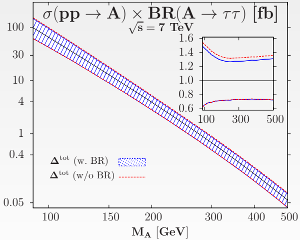
Addition of production channels weighted according to their importance

m_b–uncertainties between production and decay anti-correlated: nearly vanish during the combinaison

Tevatron: $\sim +50\%, -39\%$



lHC: $\sim +35\%, -30\%$

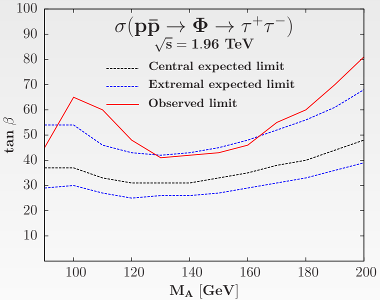


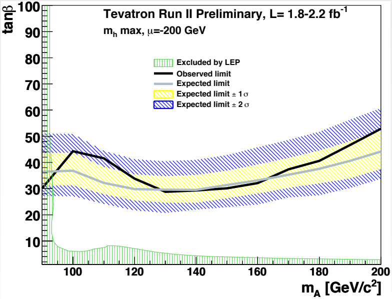
Limits on the MSSM parameter space

$p\bar{p} \to \Phi \to \tau\tau$ gives limits on the $\tan\beta - M_A$ parameter space

- Some parametric uncertainties (Δm_b, etc..) cancel out in $\sigma \times \mathrm{BR}$
- Limits model dependent (Δ_b^{SUSY}) cancel out in $\sigma \times \mathrm{BR}$

Theoretical uncertainties extremely important:





[arXiv:1003.3363v3]

With theoretical uncertainties, $\tan\beta > 45$ **excluded**

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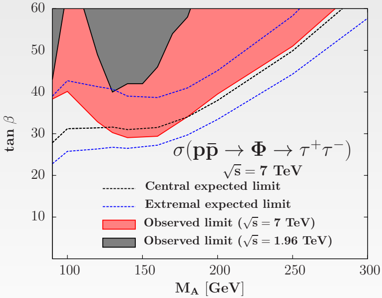

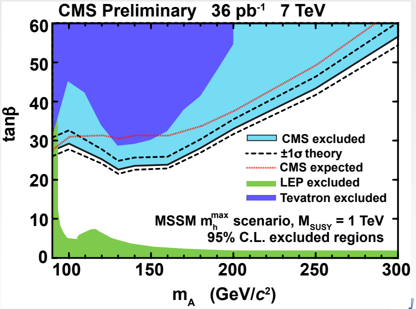

[CMS PAS HIG-10-002]

With theoretical uncertainties, $\tan\beta > 29$ **excluded**

Summary and conclusion

Higgs production in the MSSM:

- The Higgs mechanism is a key point in the understanding of the electroweak symmetry breaking, hence a quest of utmost importance for particle physics
- Higgs production enhanced in the MSSM: more chances to find the elusive particle
- **Theoretical uncertainties have to be included ; ours reopen a large part of the $\tan\beta - \mathbf{M_A}$ parameter space excluded by CDF/D0**
- At the lHC it opens a small part of the parameter space excluded by CMS (see their theory uncertainty)

Scale uncertainty in $b\bar{b}$ fusion

Two reasons why use $\kappa = 3$ for scale variation interval:

- Put in the calculation the renormalisation scheme uncertainty on m_b
- Process unstable against scale variation: use the compromise of $\kappa = 3$ with the restriction $\frac{1}{\kappa} \leq \frac{\mu_R}{\mu_F} \leq \kappa$ (see also LHCHXSWG, arXiv:1101.0593)