Detecting Higgs Bosons in B_s Decays and Direct Searches

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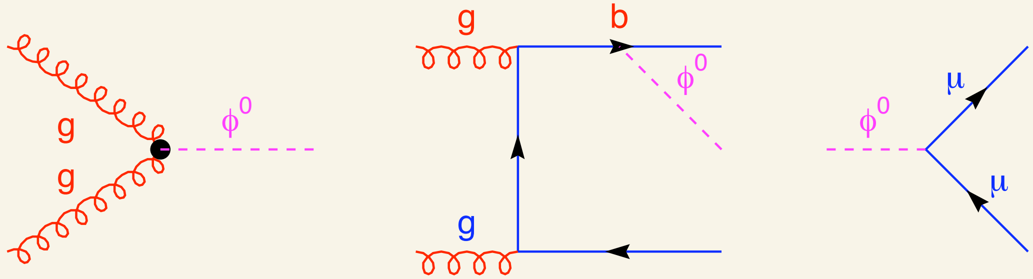
Detecting Higgs Bosons in B_s Decays and Direct Searches

- Based on a recent paper by C. Kao and Y. Wang, Phys. Lett. B **635** (2006) 30.
- Direct search for Higgs bosons at the LHC
  $pp \to b\phi^0 \to b\mu^+\mu^- + X, \phi^0 = H^0, h^0, A^0$
- Indirect search for Higgs bosons in
  $B_s \to \mu^+\mu^-$

The Minimal Supersymmetric Model

- In the minimal supersymmetric standard mode (MSSM), there are two Higgs doublets with vacuum expectation value (VEVs) v_1 and v_2, and five Higgs bosons: two scalars H^0 and h^0, one pseudoscalar A^0, and a pair of singly charged Higgs bosons $H^{\pm}$.
- At the tree level, $m_h \leq M_Z \approx 91$ GeV $< m_H$, with radiative corrections, m_h can be in the range 125 GeV $\leq m_h \leq$ 135 GeV.
- There are only two free parameters in the Higgs sector, often chosen to be m_A and $\tan\beta \equiv v_2/v_1$.

Discovering the Higgs Bosons with Muons



- The A^0 and the H^0 might be observable in a large region of parameter space with $\tan\beta \geq 10$.
- This discovery channel of $\mu^+\mu^-$ will allow precise reconstruction for the Higgs boson masses.
- Kao and Stepanov (1995);
  Barger and Kao (1998);
  Dawson, Dicus and Kao, Phys. Lett. **B545**, 132 (2002).

Cross Section in the MSSM

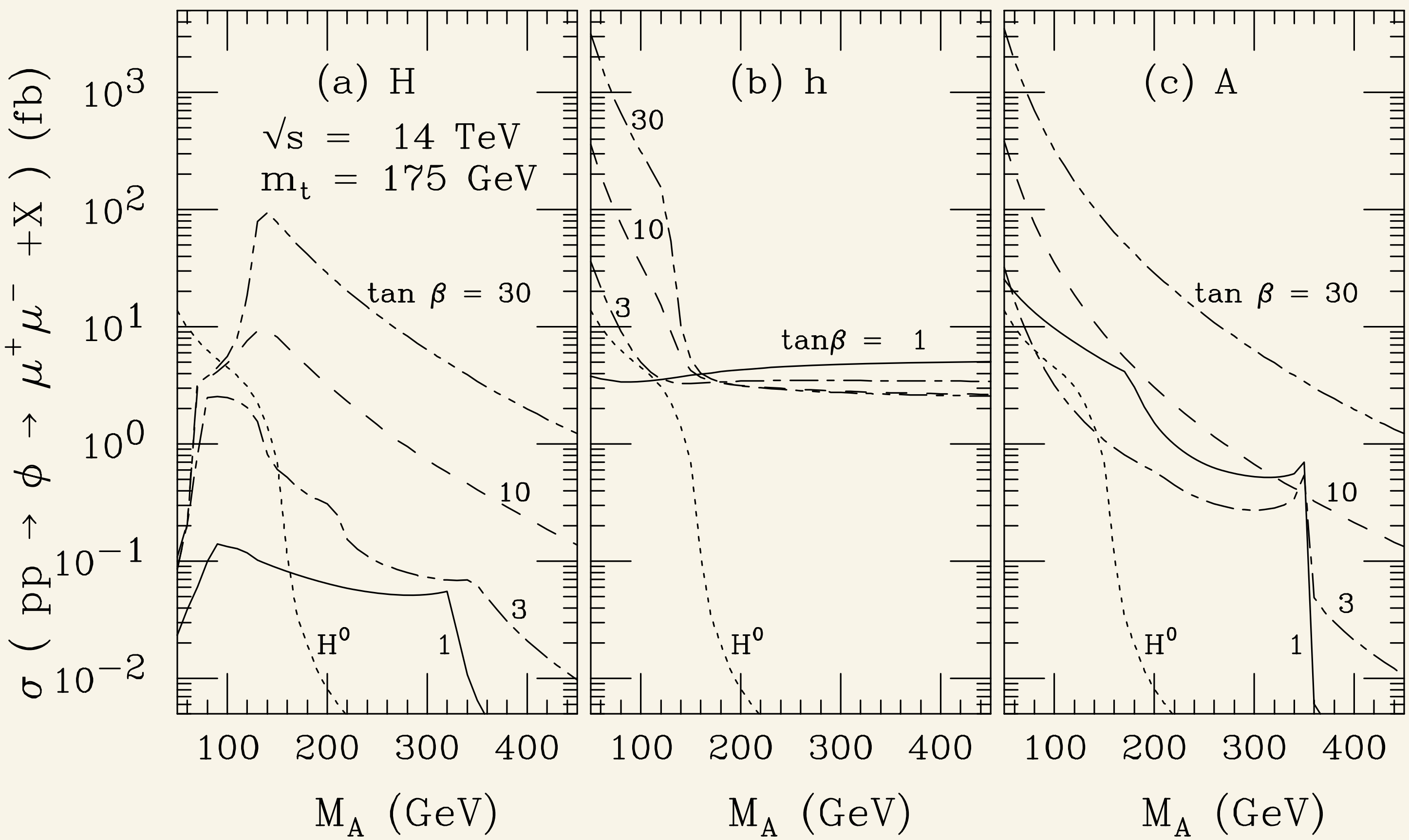
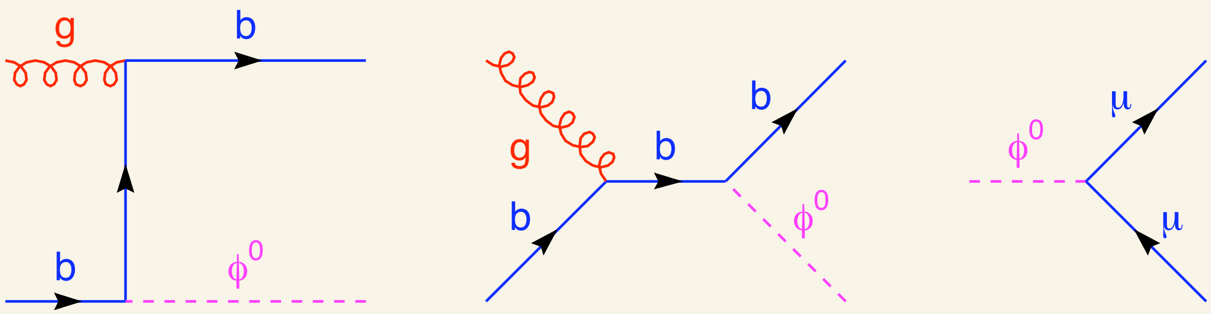


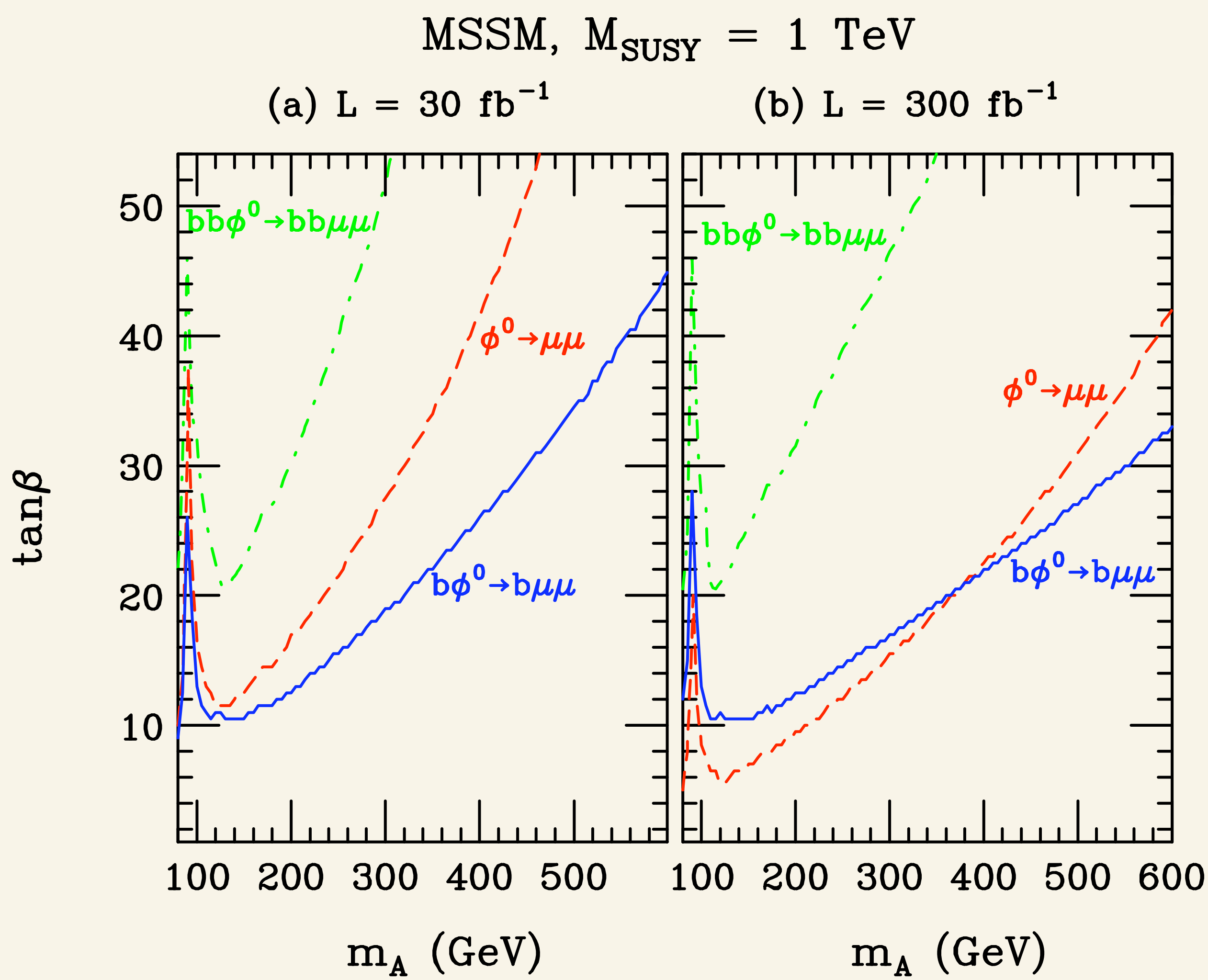
FIG 1/Kao and Stepanov

Discovering Higgs Bosons with Muons and a Bottom Quark



S. Dawson, D. Dicus, C. Kao and R. Malhotra, Phys. Rev. Lett. 92, 241801 (2004). S. Dawson, D. Dicus, and C. Kao, Phys. Lett. B **545**, 132 (2002);
V. Barger and C. Kao, Phys. Lett. B **424**, 69 (1998);
C. Kao and N. Stepanov, Phys. Rev. D **52**, 5025 (1995).

Discovery Potential at the LHC



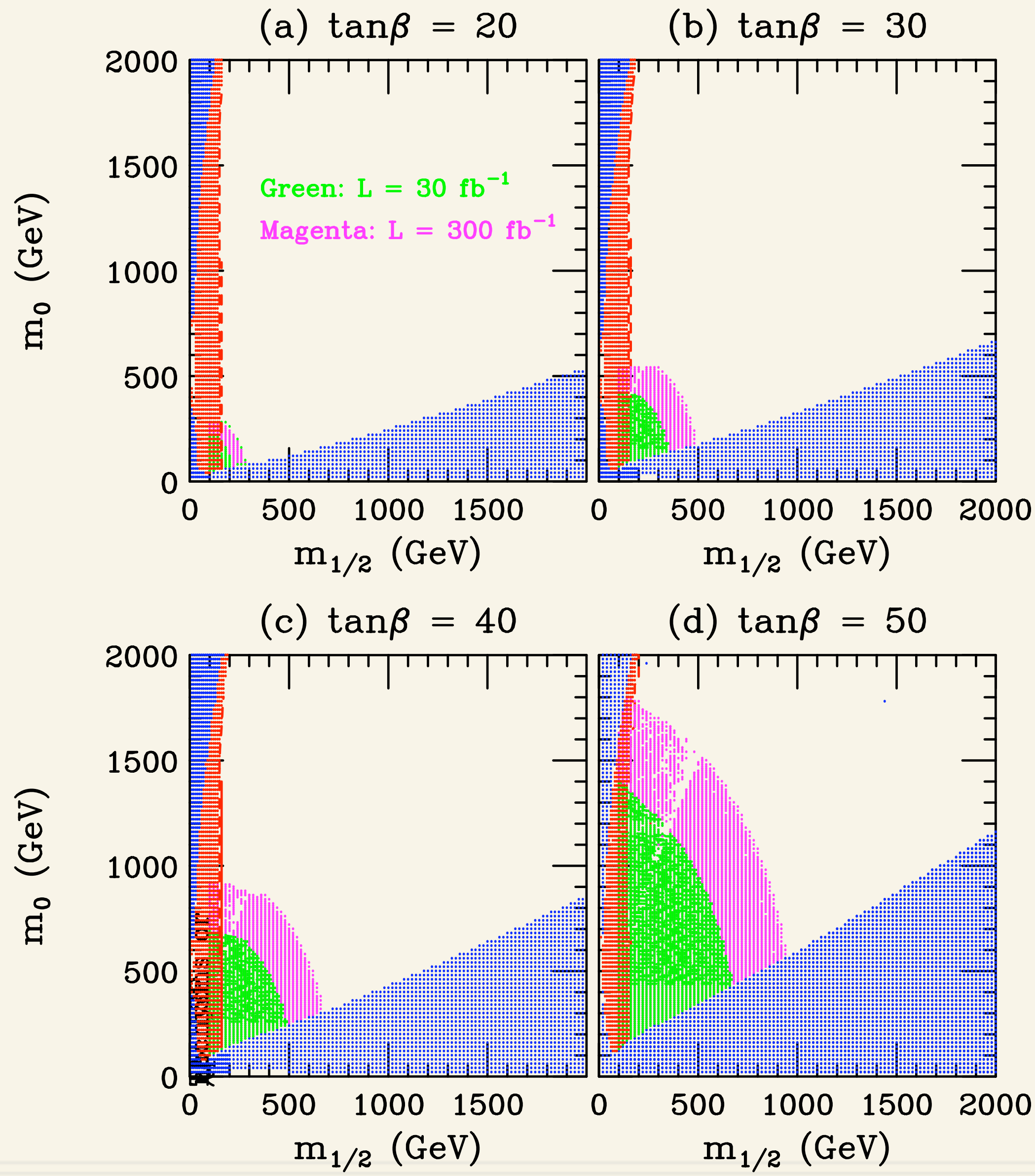
Summary for Higgs Decay into Muons

- The discovery channel of $b\phi^0 \to b\mu^+\mu^-$ offers great promise to discover the A^0 and the H^0 at the LHC for $\tan\beta > 10$, $m_A < 650$ GeV with $L = 30$ fb^{-1}.
- A higher luminosity of 300 fb^{-1} can improve the discovery reach in m_A up to $m_A = 800$ GeV.
- The $b\phi^0$ channel greatly improves the discovery potential beyond the reach of the inclusive channel $pp \to \phi^0 \to \mu^+\mu^- + X$.
- This discovery channel might provide good opportunities to measure important parameters such as the Higgs masses, $\tan\beta$, and Higgs couplings with bottom quarks and leptons.

The Minimal Supergravity Model

- In the minimal supergravity unified model (mSUGRA), it is assumed that SUSY is broken in a hidden sector with SUSY breaking communicated to the observable sector through gravitational interactions, leading to a common scalar mass (m_0), a common gaugino mass ($m_{1/2}$), a common trilinear coupling (A_0), and a bilinear coupling (B_0) at the grand unified scale (M_{GUT}).
- We often choose $m_0, m_{1/2}, A_0, \tan\beta,$ and $\text{sign}(\mu)$ as the 5 free parameters.
- The masses and couplings of SUSY particles are evaluated with renormalization group equations.

Minimal Supergravity Model



$B_s \to \mu^+\mu^-$

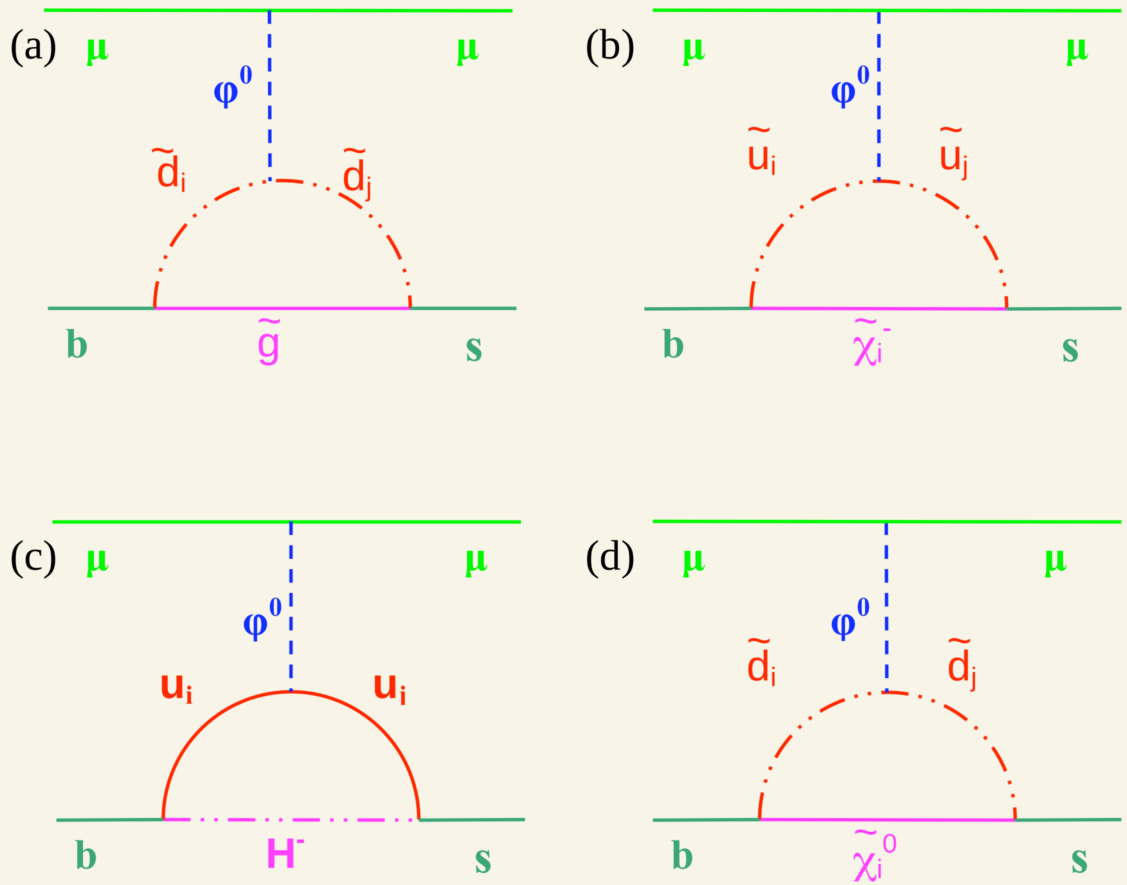
- This rare decay has a small branching fraction in the Standard Model

$$\mathrm{B}(B_s \to \mu^+\mu^-) = 3.4 \times 10^{-9}$$

- The current experimental upper limit from CDF and D0 is

$$\mathrm{B}(B_s \to \mu^+\mu^-) < 0.8 \times 10^{-7}$$

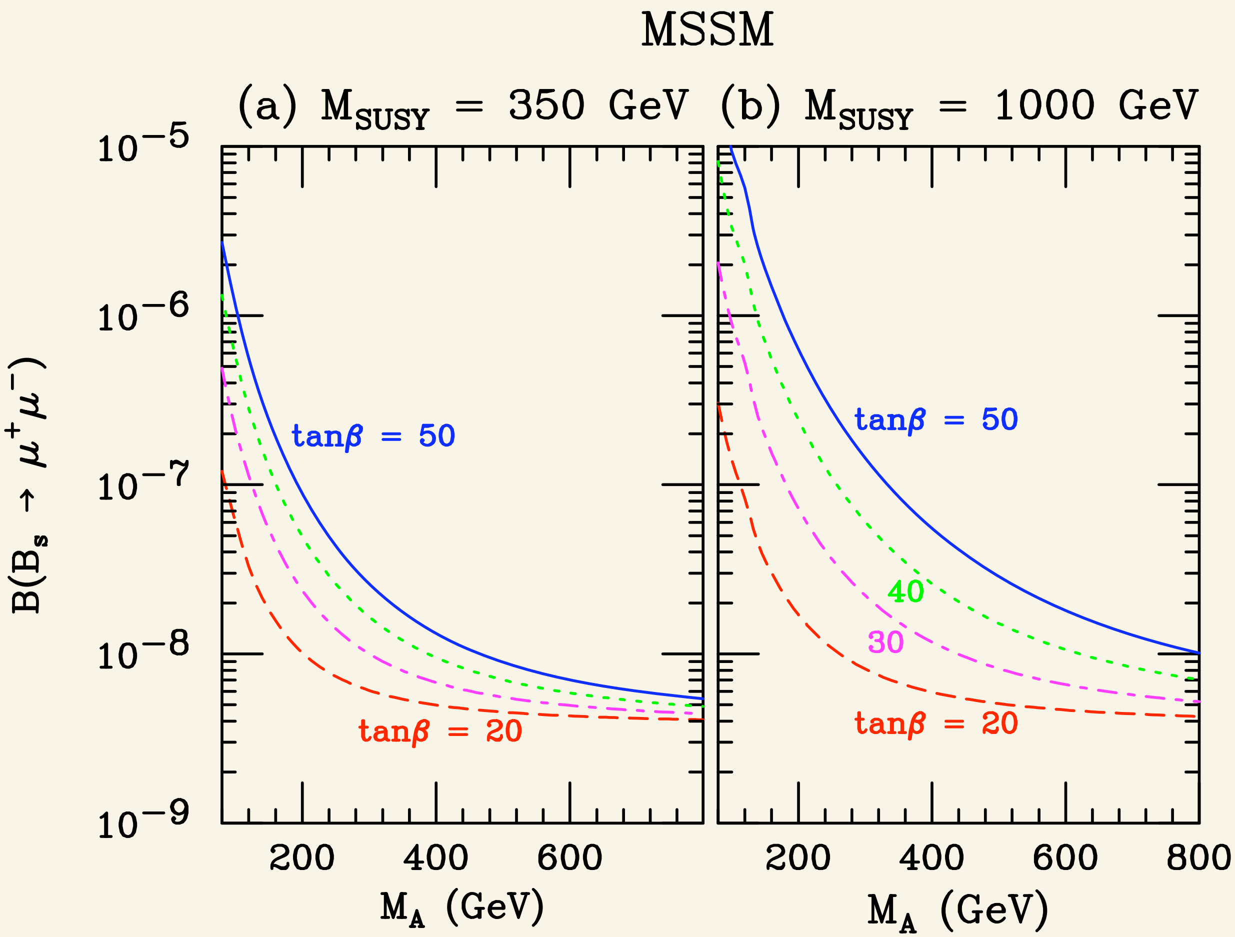
Feynman Diagrams



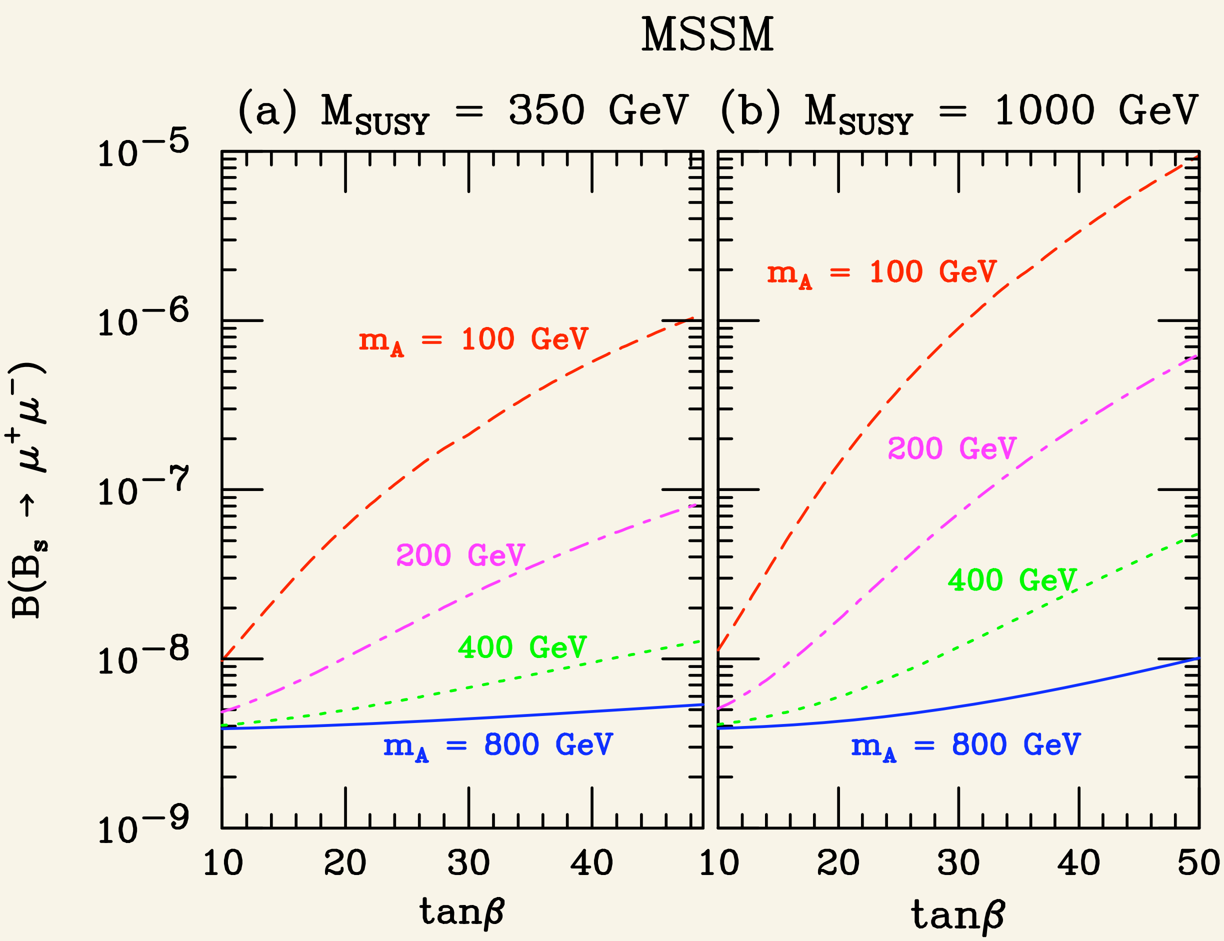
Recent Studies

- Mizukoshi, Tata and Wang (2002).
- Babu and Kolda (2000).
- Arnowitt, Dutta, Kamon and Tanaka (2002); Bobeth, Ewerth, Kruger and Urban (2002); Buras, Chankowski, Rosiek and Slawianowska (2002); Kane, Kolda and Lennon (2003; Dedes and Pilaftsis (2002); Dedes (2003); Dedes and Huffma (2004).
- Ellis, Olive and Spanos (2005); Ellis, Olive, Santoso and Spanos (2006).
- Isidori and Paradisi (2006).
- Carena, Menon, Noriega-Papaqui, Szynkman and Wagner (2006).

Branching Fraction versus m_A

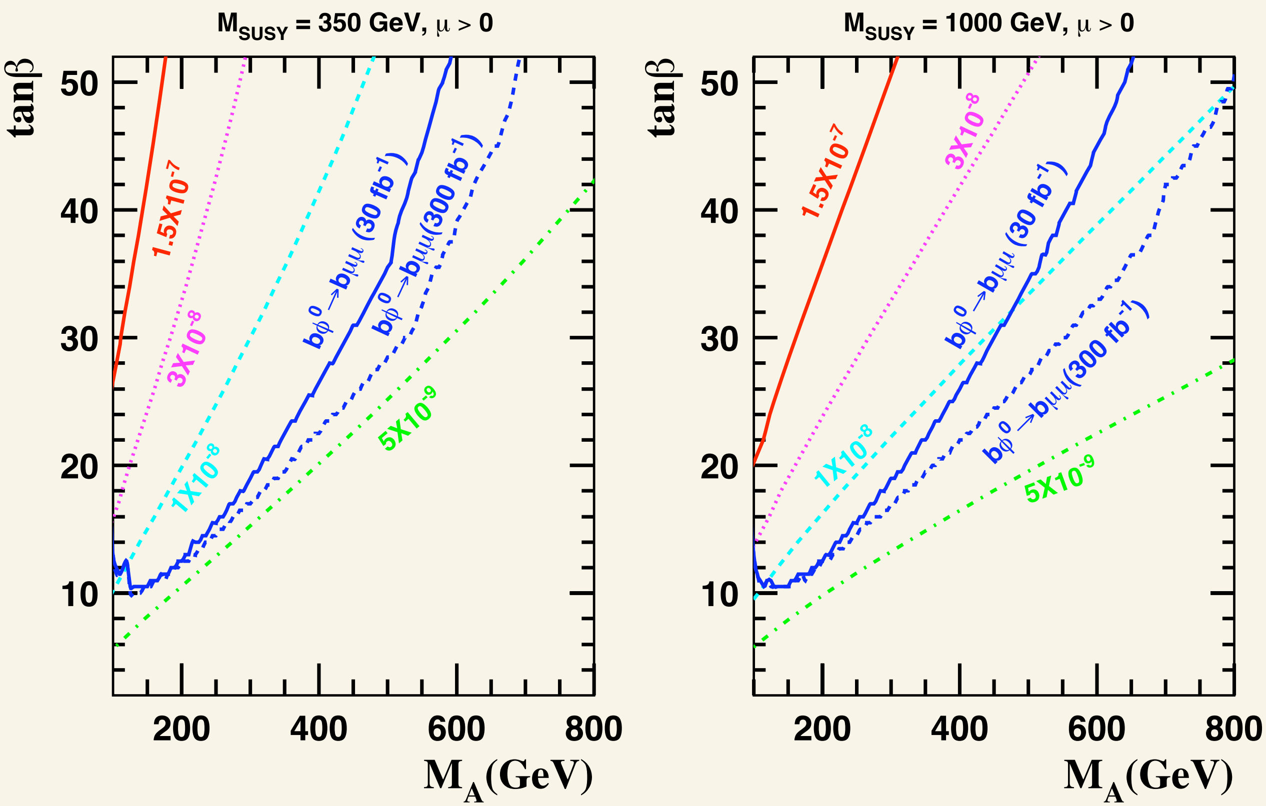


Branching Fraction versus tan(b)

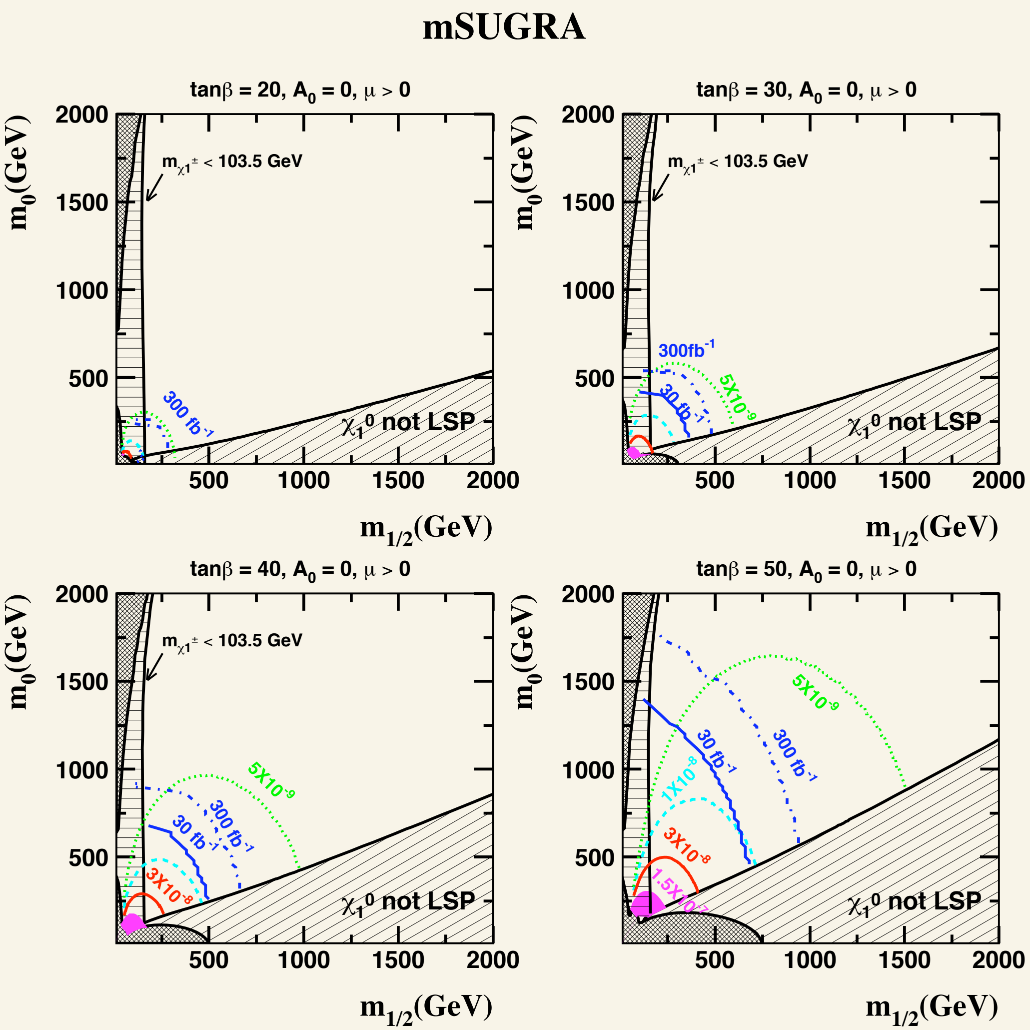


Minimal Supersymmetric Model

MSSM



Minimal Supergravity Model



Non-universal Supergravity Models

- Supergravity models with non-universal Higgs boson masses (NUHM SUGRA) give more interesting rates.
- The Higgs masses at M_{GUT} are chosen to be

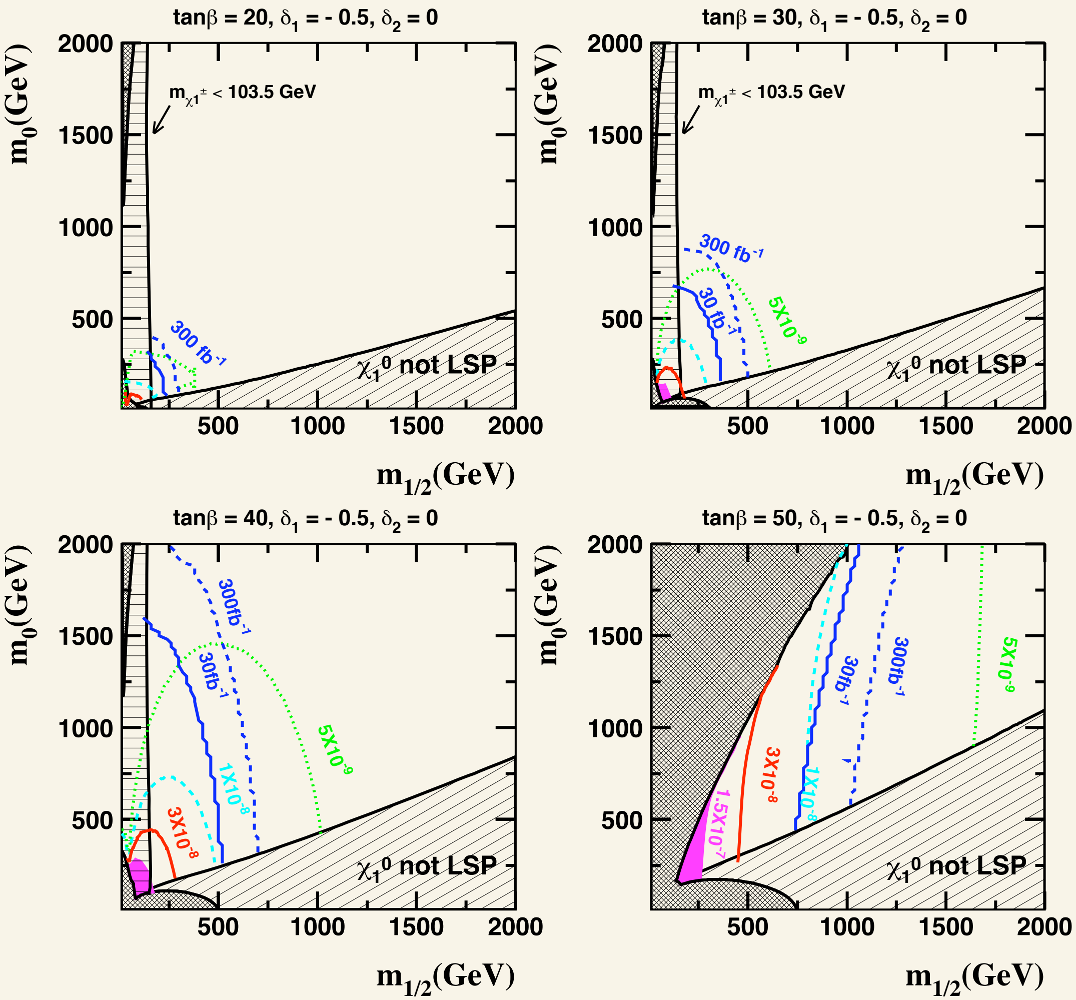
$$m^2_{H_i}(\mathrm{GUT}) = (1+\delta_i)m_0^2, i = 1, 2.$$

- In our NUHM SUGRA cases, m_A and m_H are smaller than those in the mSUGRA model for the same values of m_0 and $m_{1/2}$.
- Consequently, both

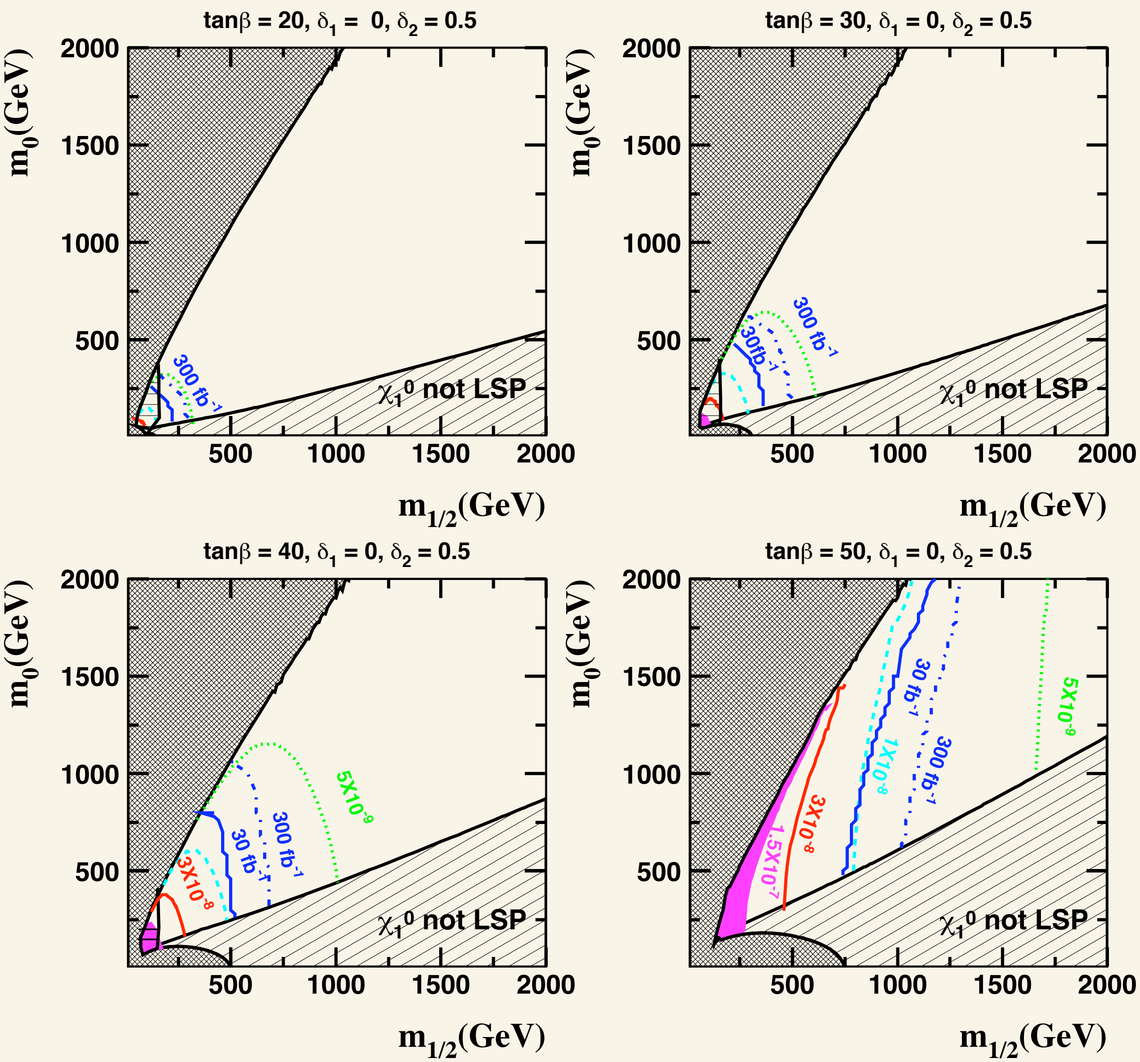
$$b\phi^0 \to b\mu^+\mu^- \text{ and } B_s \to \mu^+\mu^-$$

will be able to cover regions of the parameter space with larger values of m_0 and $m_{1/2}$.

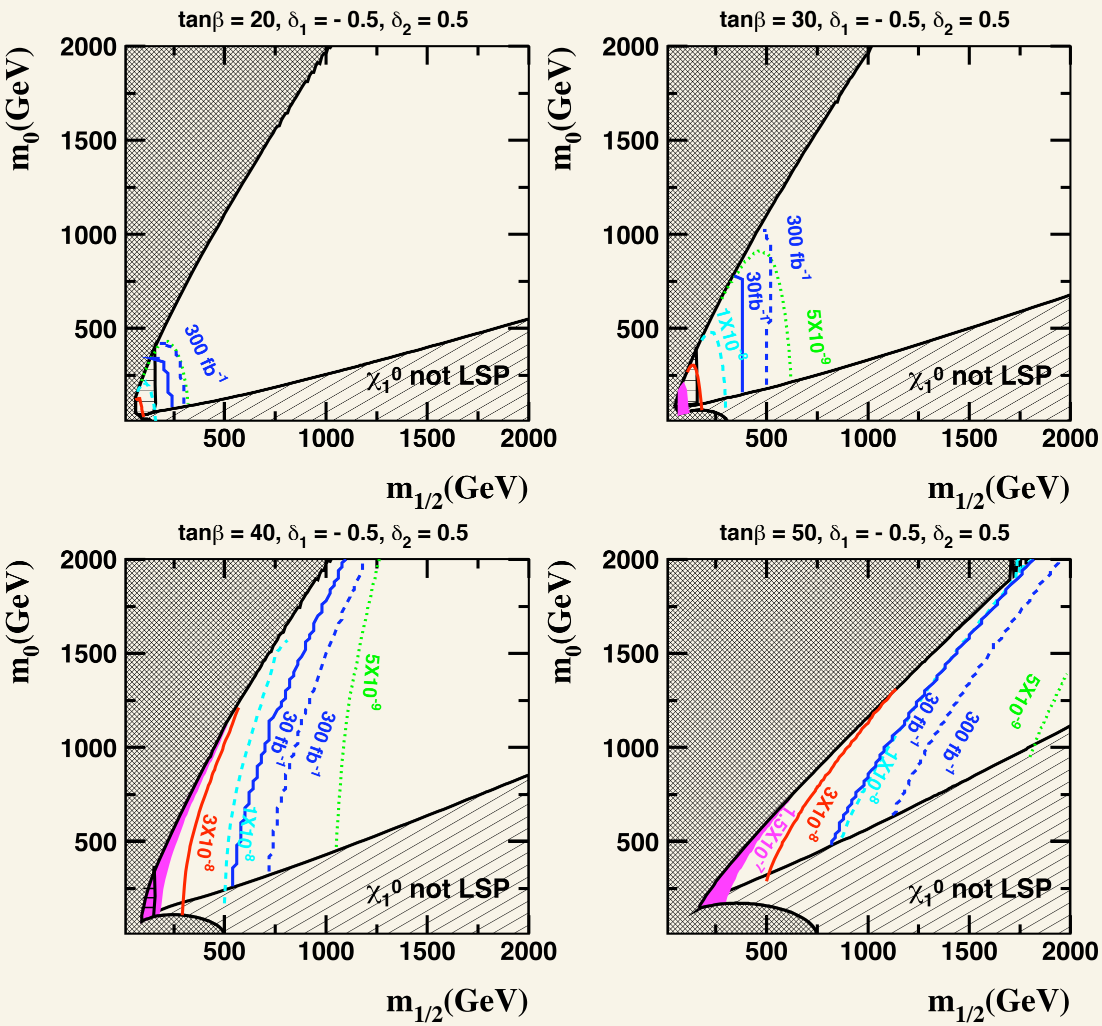
NUHM SUGRA Case I



NUHM SUGRA Case II



NUHM SUGRA Case III



Summary

(a) The contours for $B(B_s \to \mu^+\mu^-) = 1 \times 10^{-8}$ in the parameter space are very close to the 5σ contours for $pp \to b\phi^0 \to b\mu^+\mu^- + X$, at the LHC with $L = 30$ fb^{-1}.

(b) The regions covered by $B(B_s \to \mu^+\mu^-) \geq 5 \times 10^{-9}$ and the discovery region for $b\phi^0 \to b\mu^+\mu^-$ with 300 fb^{-1} are complementary in the mSUGRA parameter space.

(c) in SUGRA models with nonuniversal Higgs masses, a discovery for $B(B_s \to \mu^+\mu^-) \simeq 5 \times 10^{-9}$ at the LHC will cover regions of the parameter space beyond the direct search for $pp \to b\phi^0 \to b\mu^+\mu^- + X$, with $L = 300$ fb^{-1}.