Detecting Higgs Bosons within Supersymmetric Models

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Outlook of the Talk

MSSM has two Higgs doublets.
After symmetry breaking, there are five Higgs bosons, three neutral Higgs bosons: scalars h^0, H^0 and pseudoscalar A^0
Two free parameters : m_A and $\tan\beta$

We concentrate on Higgs search in three models:

- minimal SUSY model (MSSM)
- minimal supergravity model (SUGRA)
- non-universal Higgs masses within SUGRA

MSSM

Higgs couplings to bottom quark

$$h^0 b \bar{b} \rightarrow \frac{-igm_b \sin\alpha}{2m_W \cos\beta}$$

$$H^0 b \bar{b} \rightarrow \frac{-igm_b \cos\alpha}{2m_W \cos\beta}$$

$$A^0 b \bar{b} \rightarrow \frac{-gm_b}{2m_W} \gamma^5 \tan\beta$$

larger tanβ,
larger coupling

Same coupling hold for $\phi \ell^+ \ell^-$ except $m_b \rightarrow m_\ell$

LHC has great potential to discover $\mu^+ \mu^-$ from neutral Higgs bosons

Direct search

- Direct searches at LHC
  - $pp \to \Phi^0 \to \mu^+\mu^- + X$

    tanβ small $gg \to \Phi^0$ tanβ big $b\bar{b} \to \Phi^0$
  - $pp \to b\Phi^0 \to b\mu^+\mu^- + X$

    $bg \to b\Phi^0$ More promising channel.
  - $pp \to b\bar{b}\Phi^0 \to b\bar{b}\mu^+\mu^- + X$

    $gg \to b\bar{b}\Phi^0$

Direct search

One high p_T bottom quark associated with Higgs

Dominant: $pp \rightarrow b\Phi^0 \rightarrow b\mu^+\mu^- + X$

$$bg \rightarrow b\Phi^0 + X \qquad \Phi^0 \rightarrow \mu^+\mu^-$$

Physics background: $bg \rightarrow b\mu^+\mu^-$

$$gg \rightarrow b\bar{b}W^+W^-$$

$$W^\pm \rightarrow \mu^\pm \nu_\mu$$

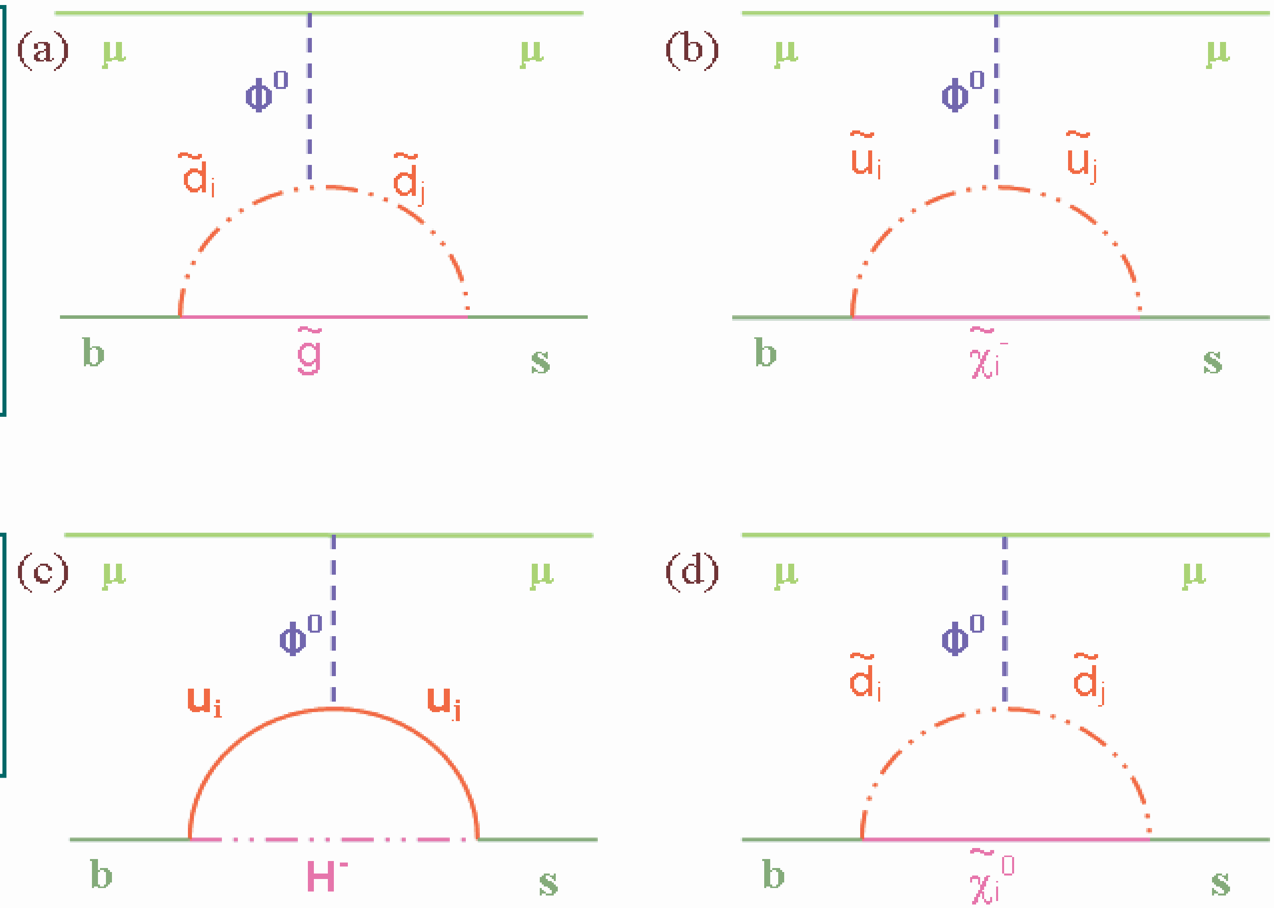
$$q\bar{q} \rightarrow b\bar{b}W^+W^-$$

$bg \rightarrow b\mu^+\nu\mu^-\bar{\nu}$ and $pp \rightarrow j\mu^+\mu^- + X$

Indirect search

➢ **Indirect Search in $B_s \to \mu^+ \mu^-$**

Loop diagrams:
Gluinos,
Charginos
Charged Higgs
Neutrilinos



if tanβ is large, these may give big contributions

Indirect search

$B_s \to \mu^+\mu^-$ Amplitude $\propto \tan^3\beta$, $1/m_A^2$, $1/m_H^2$

Two of $\tan^3\beta$ come from down type squark and lepton Yukawa couplings, the last arises from the offset between Yukawa coupling matrix and mass matrix

SM branching ratio is very small

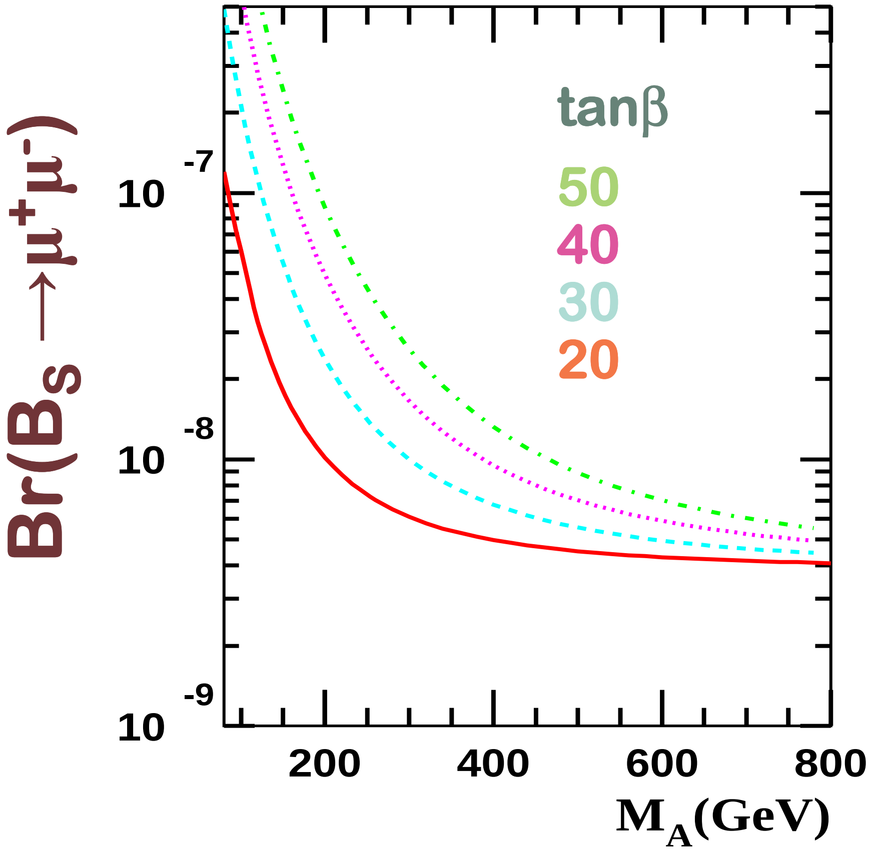
$$BR(B_s \to \mu^+\mu^-) \cong 5.1\times10^{-9}$$

Experimental upper limit (CDF)

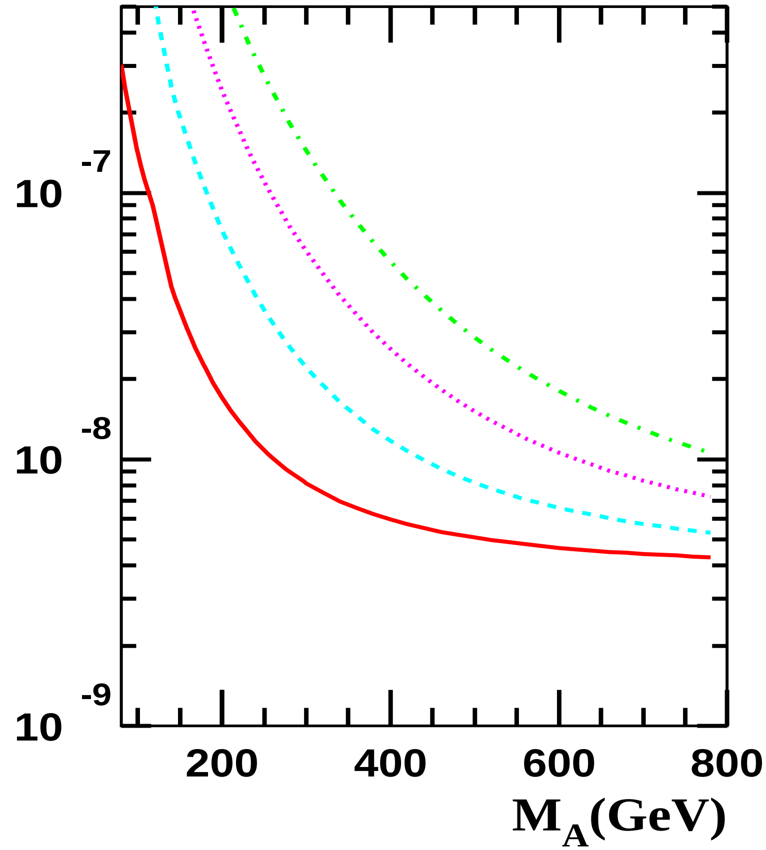
$$BR(B_s \to \mu^+\mu^-) < 1.5\times10^{-7}$$

Good channel to discover a muon pair from Higgs.

MSSM

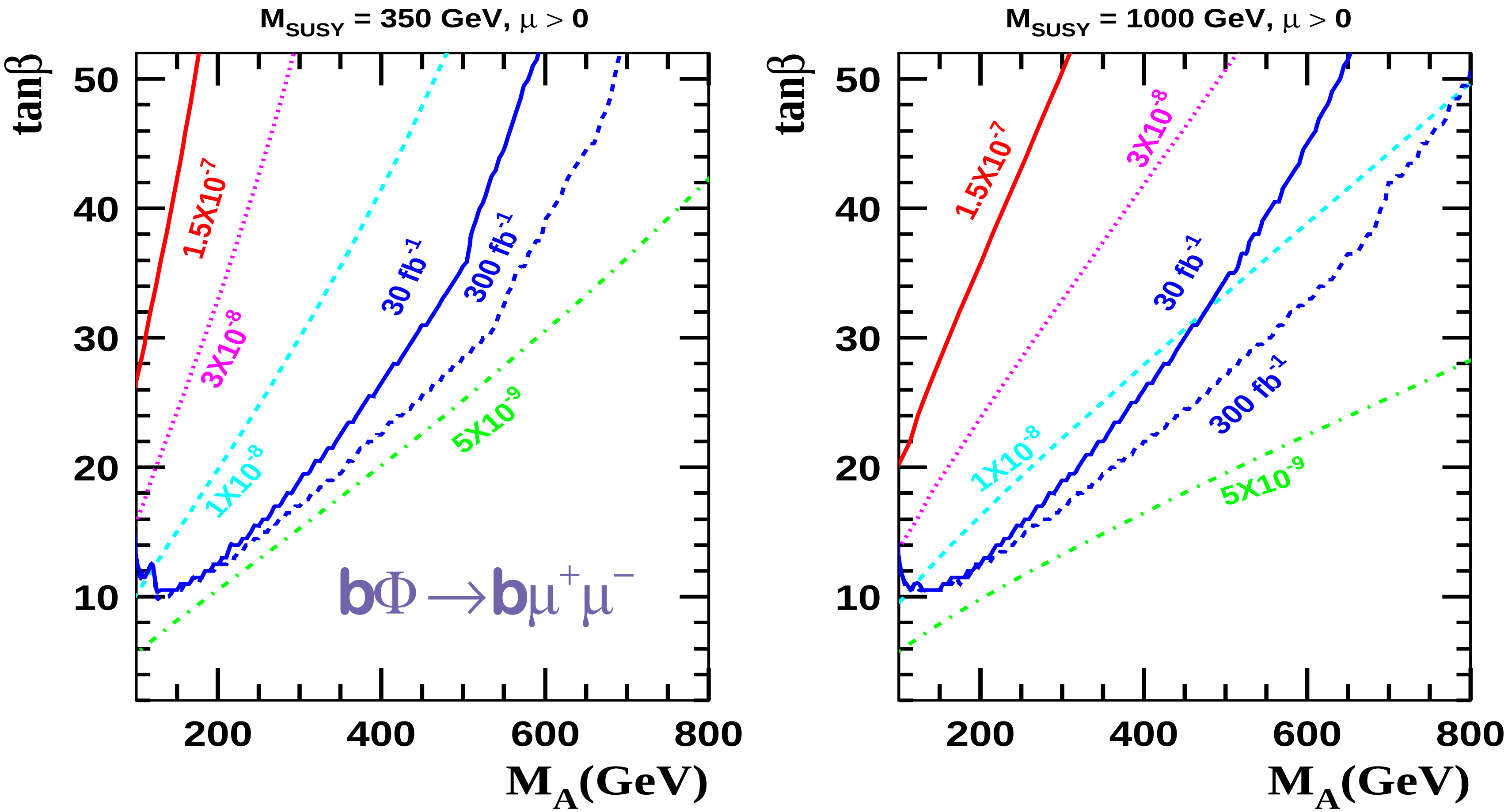


M_{SUSY} = 350 GeV



M_{SUSY} = 1000 GeV

MSSM



bϕ 5σ contour is larger than B_s in 3×10^{-8}

$m_{SUSY} = -A_f$

bϕ 5σ contour is close to B_s in 1×10^{-8}

mSUGRA

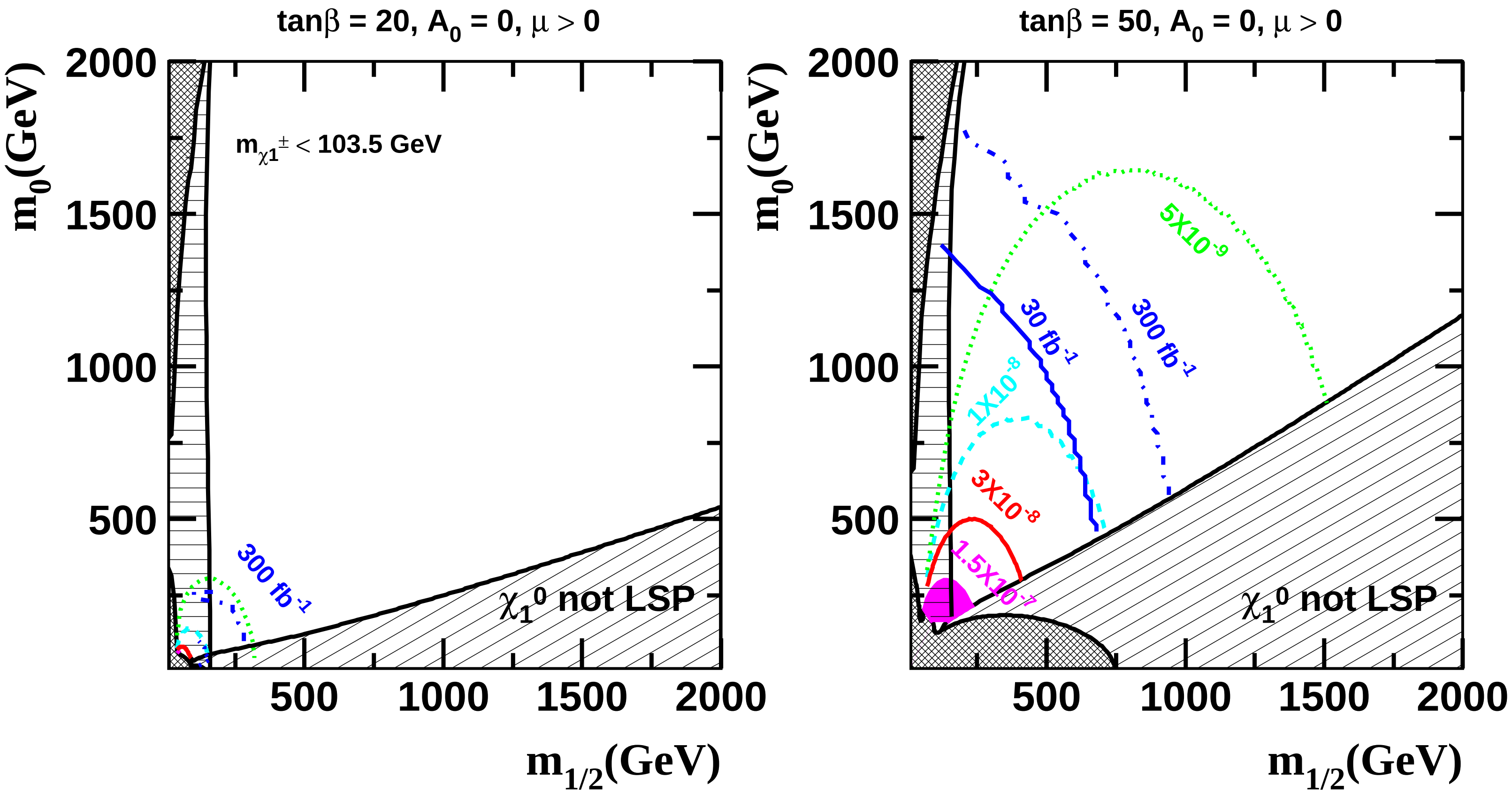
SUSY is broken in hidden sector and communicated to observable sector by gravitational interactions

Parameters:

- common scalar mass m_0
- gaugino mass $m_{1/2}$
- Trilinear coupling A_0
- sign of (μ)
- Ratio of Higgs vacuum expectation value $\tan\beta$

$$m_0,\quad m_{1/2},\quad A_0,\quad \tan\beta,\quad \mathrm{sgn}(\mu)$$

mSUGRA



Large tanβ does greatly increase the detecting region

tanβ ≥ 50, Br($B_S \to \mu\mu$) ≥ 5×10^{-9} is complementary with bφ →bμμ at L = 300 fb-1

Non-universal SUGRA

At GUT scale, Higgs masses are not universal

$$m_{H_i}^2(\mathrm{GUT}) = (1+\delta_i)m_0^2$$

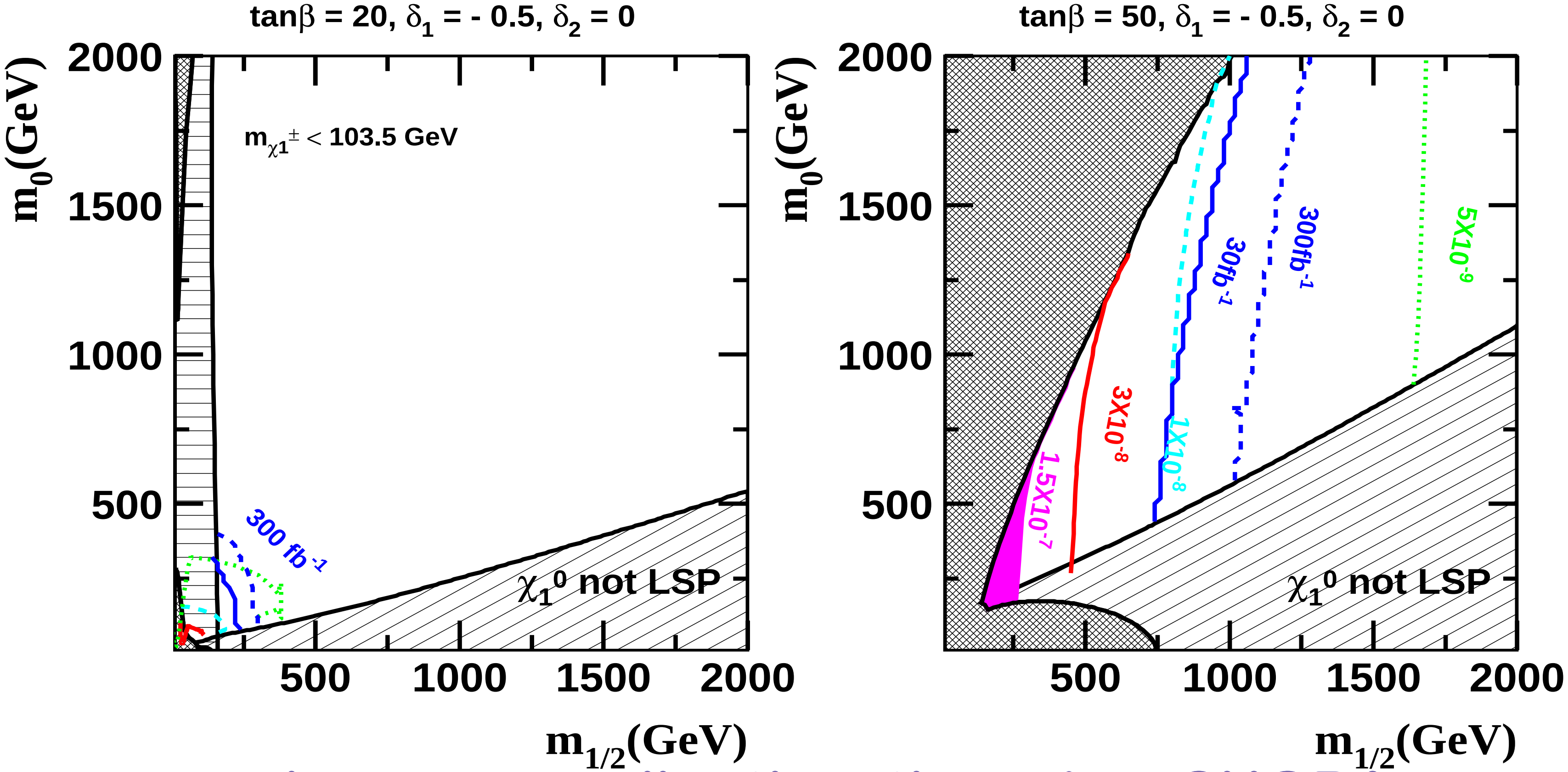
Non-universal Higgs masses at the GUT scale affect weak-scale Higgs masses significantly.

GUT Scale		
$\delta_1 < 0,$	m_{H_1}	decreases
$\delta_2 > 0,$	m_{H_2}	increases

Weak Scale	
m_A	smaller
m_H	smaller

Non-universal SUGRA

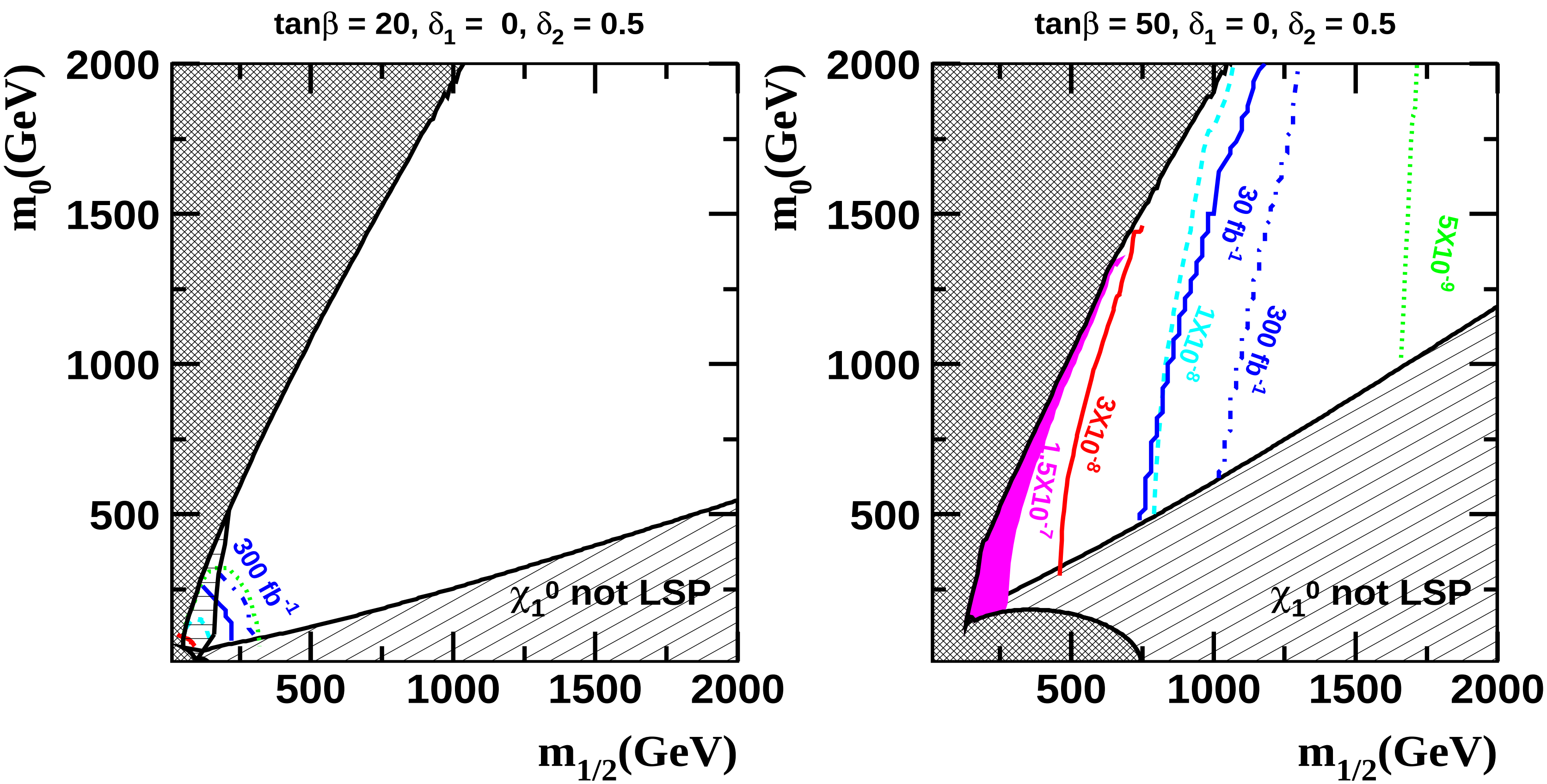
➢ **case I** $\delta_1 = -0.5, \quad \delta_2 = 0$



m_A and m_H are smaller than those in mSUGRA
Both $b\phi \to b\mu\mu$ and $B_s \to \mu\mu$ will cover larger region.

Non-universal SUGRA

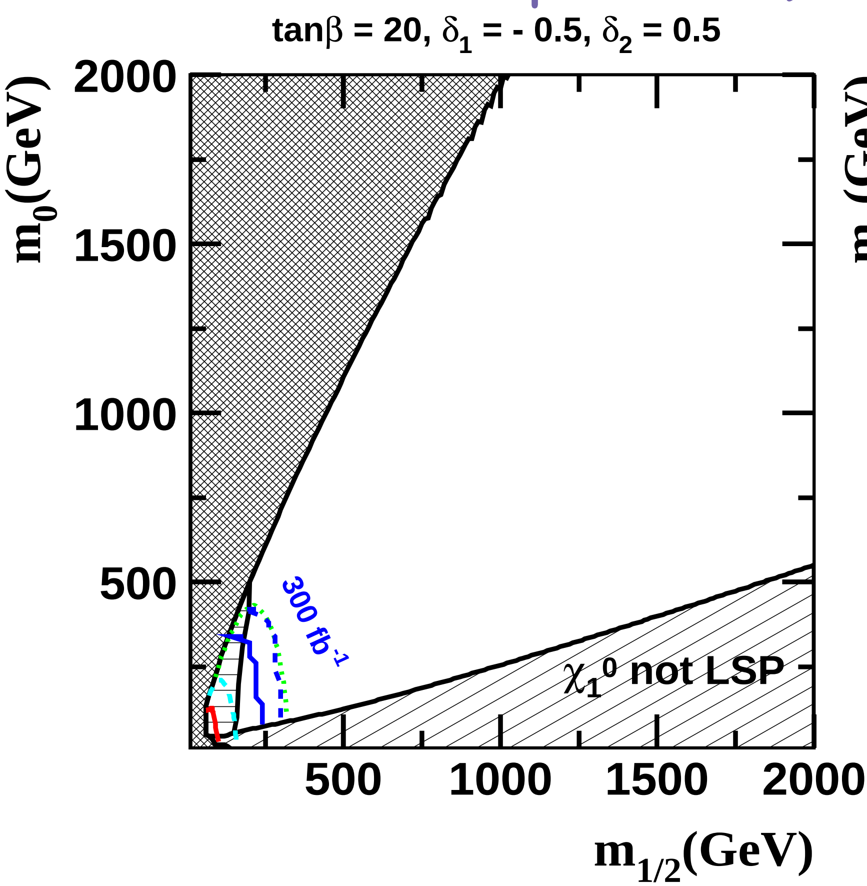
- **case II** $\delta_1 = 0, \quad \delta_2 = 0.5$

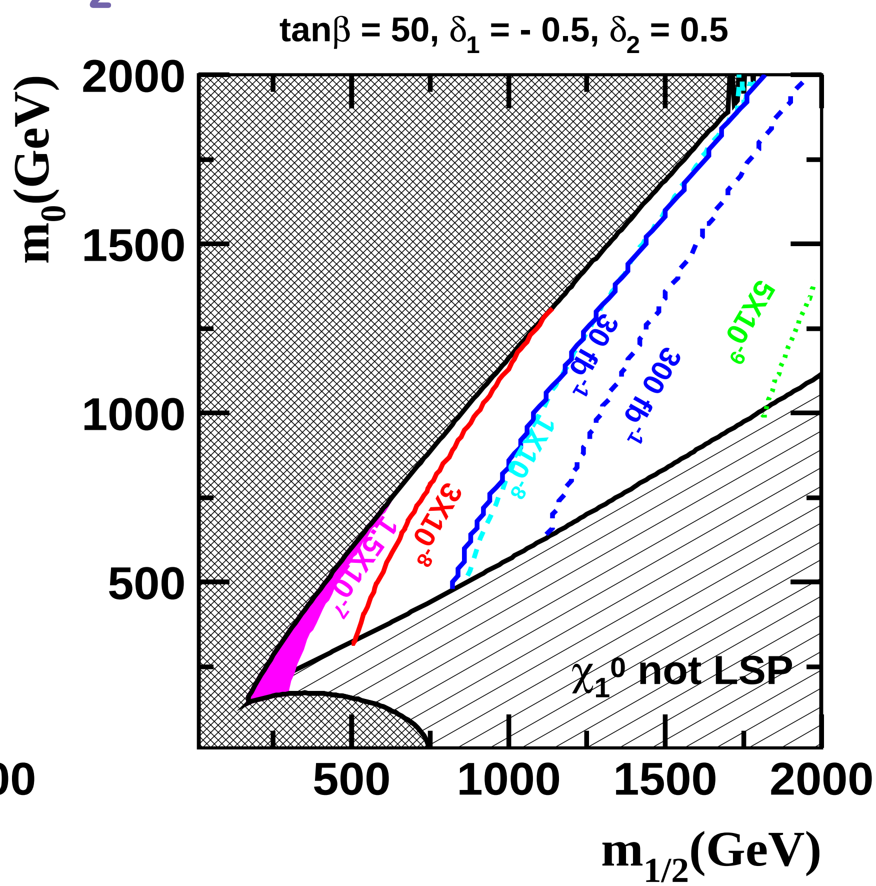


$\tan\beta \geq 50$, $b\phi \to b\mu\mu$ at $L = 30\ fb^{-1}$ is comparable with $Br(B_s \to \mu\mu) \geq 1x10^{-8}$

Non-universal SUGRA

- **case III** $\delta_1 = -0.5, \quad \delta_2 = 0.5$





theoretically favored region shrinks with δ_2=0.5 .

Conclusion

- In SUSY models, muon pair discovery channels offer great promise for detecting Higgs, in both direct and indirect searches.
- large $\tan\beta$ does enhance the Higgs boson detection dramatically.
- In MSSM, if $M_{SUSY} \sim 1$ TeV, $b\phi \to b\mu\mu$ at L = 30 fb-1 is comparable with $Br(B_S \to \mu\mu) \geq 1x10^{-8}$, $M_{SUSY} \sim 350$ GeV $b\phi \to b\mu\mu$ becomes more promising than $B_S \to \mu\mu$
- If $\tan\beta \geq 50$, $Br(B_S \to \mu\mu) \geq 5\times10^{-9}$ is complementary with $b\phi \to b\mu\mu$ at $L = 300\ fb^{-1}$ in mSUGRA, but in non-universal SUGRA, $Br(B_S \to \mu\mu) \geq 5\times10^{-9}$ is beyond the region of $b\phi \to b\mu\mu$ at $L = 300\ fb^{-1}$