HIGGS DECAYS INTO LEPTONS

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• S. Dawson, D. Dicus, and C. Kao, University of Oklahoma Report OKHEP-02-02 (2002); C. Kao and N. Stepanov, Phys. Rev. D **52,** 5025 (1995); C. Kao and V. Barger Phys. Lett. B **424**, 69 (1998).

• Presented at the 31st International Conference on High Energy Physics (ICHEP2002), **Amsterdam, The Netherlands, July 24 - 31, 2002**.

I. Introduction

- It is very promising to search for MSSM Higgs bosons ($\phi^0 = h^0, H^0$, and A^0) via their decays into leptons, $\phi^0 \to \tau^+\tau^-$ and $\mu^+\mu^-$ at the LHC.
- In Model II of two Higgs doublet models and the minimal supersymmetric standard model (MSSM), the $\phi^0 b\bar{b}$ coupling is proportional to $1/\cos\beta$, where $\tan\beta \equiv v_2/v_1$, $v_{1,2}$ are the vacuum expectations values of the Higgs fields.
- The cross section of $gg \to b\bar{b}\phi^0$ is greatly enhanced in hadron collisions by a large $\tan\beta$.
- The contribution from $q\bar{q} \to b\bar{b}\phi^0$ is usually negligible at hadron colliders.

II. Higgs decays into tau leptons

- For $\tan\beta \lesssim 4$, $gg \to \phi^0$ is the dominant source of producing Higgs bosons at the LHC
- For $\tan\beta \gtrsim 7$, $gg \to b\bar{b}\phi^0$ is the major source of producing Higgs bosons at the LHC.
- The discovery channel of MSSM Higgs decays into tau leptons ($\phi^0 \to \tau^+\tau^-$) offers great promise for $\tan\beta \gtrsim 6$ at the LHC for an integrated luminosity (L) of 300 fb^{-1}.

Z. Kunszt and F. Zwirner (1992); CMS Technical Proposal (1994); ATLAS Technical Proposal (1994); E.~Richter-Was et al. (1996); ATLAS Technical Design Report (1999).

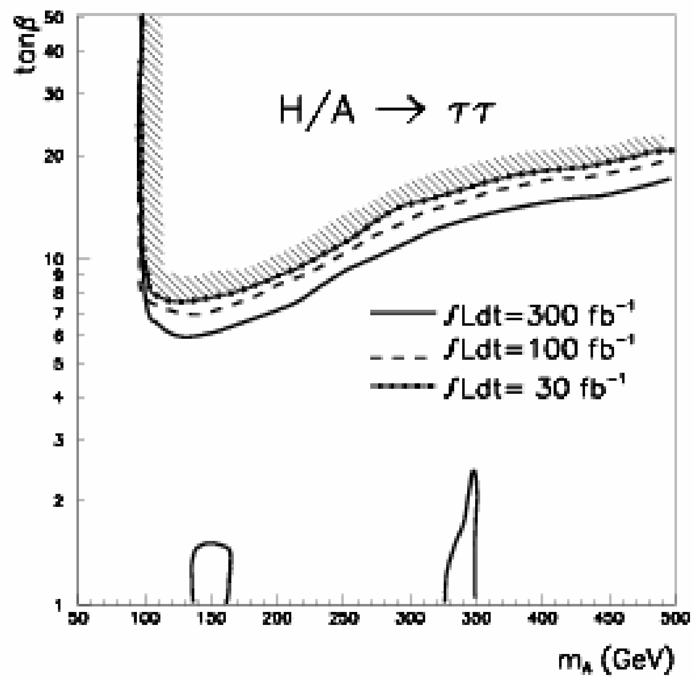


Figure 19-62 For integrated luminosities of 30 fb^{-1}, 100 fb^{-1} and 300 fb^{-1}, 5σ-discovery contour curves for the $H/A \rightarrow \tau\tau$ channel in the (m_A, tanβ) plane.

ATLAS Technical Design Report (1999)

III. Lepton flavor violating Higgs decays

- In the MSSM, radiative corrections via gaugino-sfermion loops can lead to lepton flavor violating Higgs decays with a branching ratio approximately

  $B(h \to \tau\mu) \sim 4\times10^{-4}$ [$\sim 3\sigma$ at the LHC].

- In an E_6-inspired multi-Higgs model with an abelian flavor symmetry, lepton flavor violating effects also arise in Higgs decays $h \to \tau\mu$ that might be observable at the Tevatron and the LHC.

J.L. Diaz-Cruz, hep-ph/0207030 (2002).

IV. Higgs decays into muons

- For $\tan\beta \gtrsim 8$, it might be possible to search for Higgs decays into muons in the MSSM, $pp \to \phi^0 \to \mu^+\mu^- + X$ @LHC with $L = 300\ fb^{-1}$.
- This channel will provide a good opportunity to reconstruct the Higgs masses with high precision.
- Kao and Stepanov (1995); CMS Technical Proposal (1994); E.~Richter-Was et al. (1996); ATLAS Detector and Physics Performance Technical Design Report (1999).
- In the Standard Model, this discovery channel is very challenging at the LHC.
- Plehn and Rainwater (2000); Han and McElrath (2001).

V. The Physics Backgrounds

- For the inclusive final state of $\phi^0 \to \mu^+\mu^-$, the dominant physics background comes from

  $$pp \to Z,\gamma \to \mu^+\mu^- + X.$$

- Additional contributions of physics background come from production of $pp \to t\bar{t}$, $b\bar{b}W^+W^- + X$ and $pp \to jj\mu^+\mu^- + X$, j = g, u, d, s, c, and b. These backgrounds can be reduced by a requirement of minimal missing transverse energy (E_T) and a jet veto.

- Kao and Stepanov (1995).

V. The Physics Backgrounds

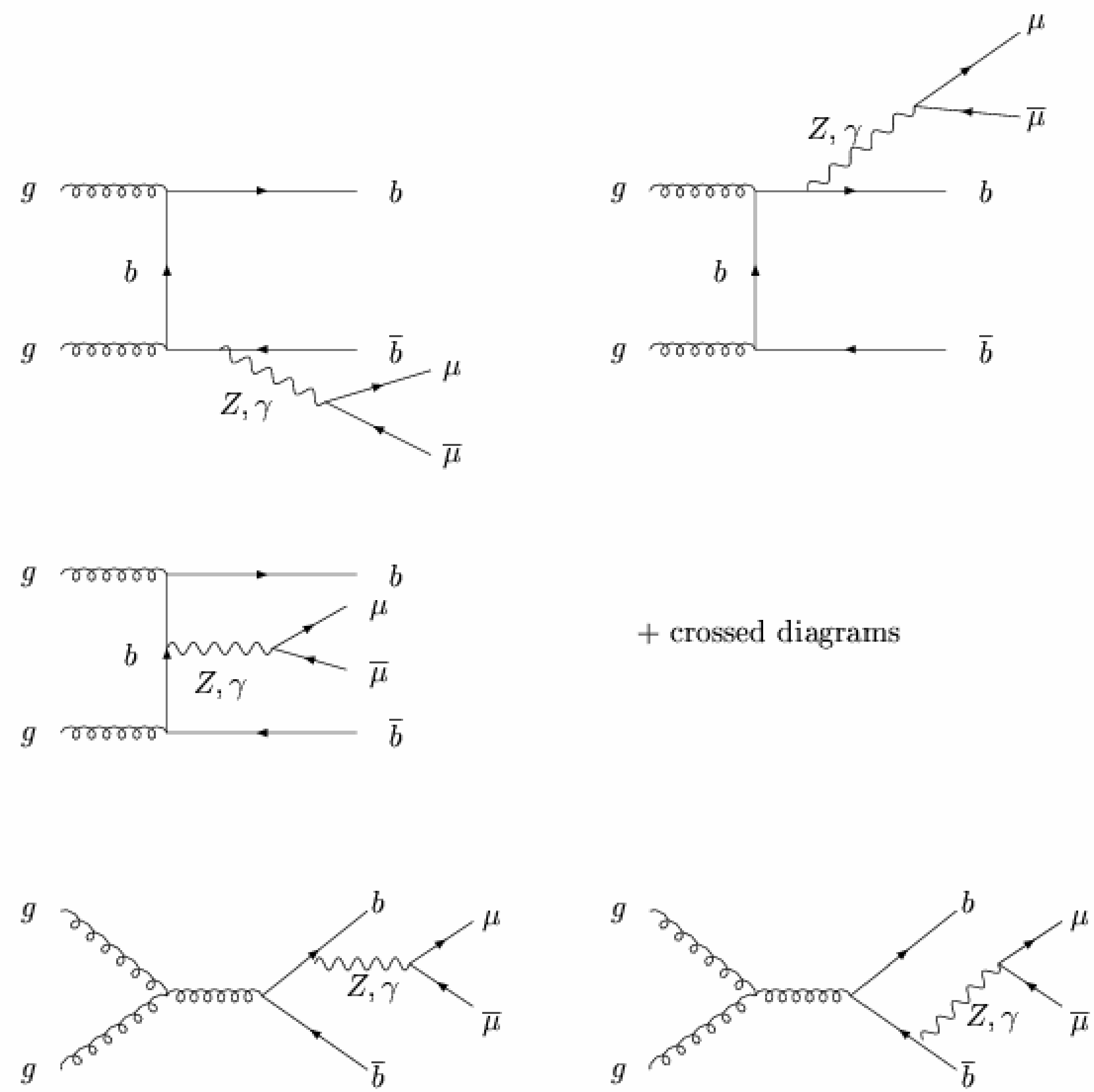
- For the associated final state of $b\bar{b}\phi^0 \to b\bar{b}\mu\mu$, the dominant physics background comes from

$$pp \to b\bar{b}\, W^+W^- \to b\bar{b}\mu^+\mu^- + \not{E}_T$$

- Additional contributions come from production of $b\bar{b}\mu^+\mu^-$ and $jj\mu^+\mu^-$, j = g, u, d, s, and c.

- We take the b tagging efficiency to be
  $\epsilon_b = 0.6$ (LL = 30 fb^{-1}) or 0.5 (HL = 300 fb^{-1}),
  $\epsilon_c = 0.1$ = probability of c misidentified as b,
  $\epsilon_j = 0.01$ = probability of jets mistagged as b.

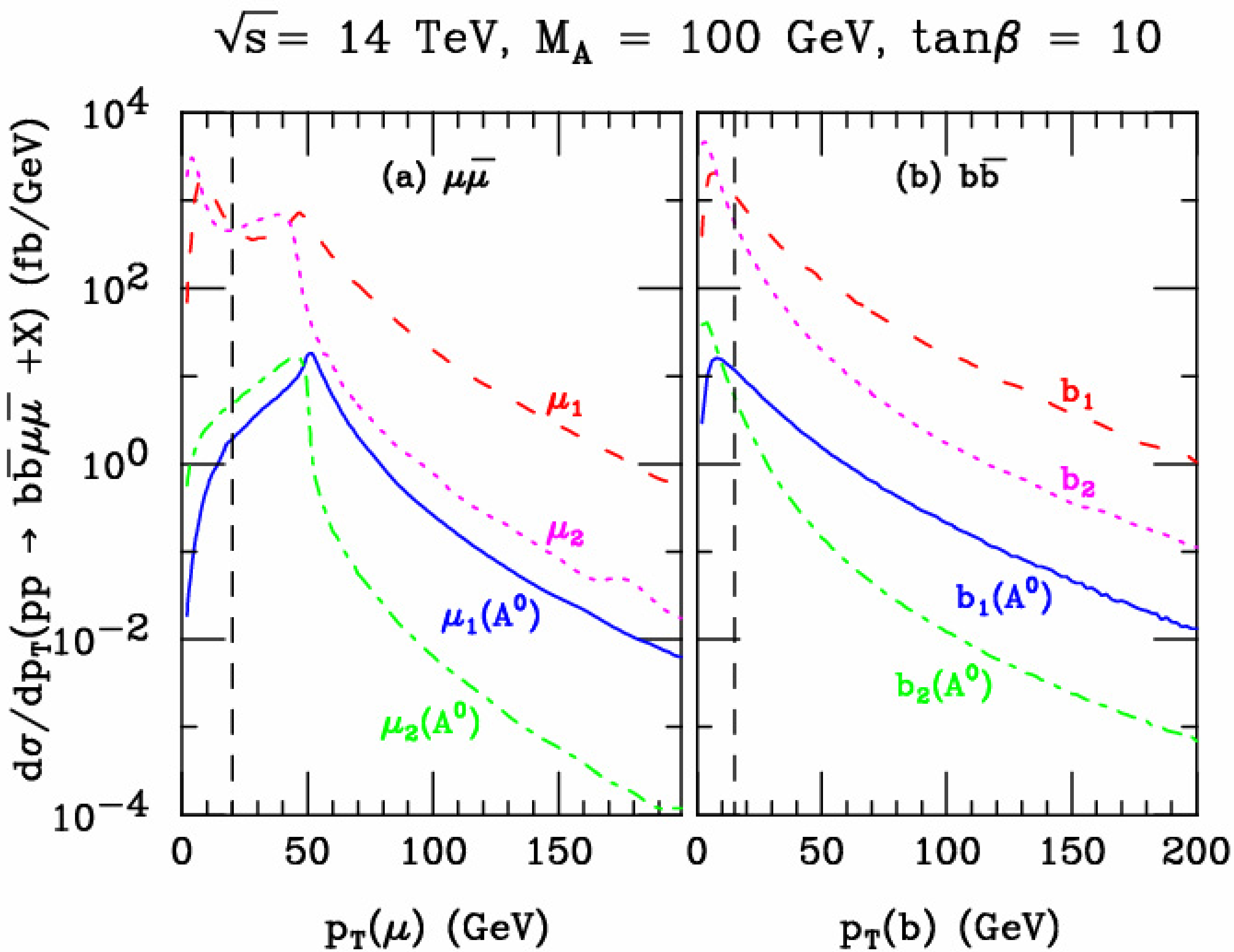
- ATLAS Technical Design Report (1999).


g
b
$\bar{b}$
Z, γ
μ
$\bar{\mu}$
+ crossed diagrams

VI. The Acceptance Cuts

- Our acceptance cuts are chosen to be consistent with the experimental cuts proposed for each event at the LHC as follows.
- (i) We require 2 isolated muons with $p_T(\mu) > 20$ GeV, [10 GeV for $m_\phi < 100$ GeV] and $|\eta(\mu)| < 2.5$.
- (ii) All jets are required to have $p_T(j) > 15$ GeV (LL) or 30 GeV (HL) and $|\eta(j)| < 2.5$. We apply jet veto for the inclusive mode $pp \to \phi^0 \to \mu^+\mu^- + X$.
- (iii) To reduce the background from $b\bar{b}WW$ ($t\bar{t}$), we require $\not{E}_T < 20$ GeV (LL) or 40 GeV (HL).

- Only 5%-10% of the $bb\mu\mu$ and $jj\mu\mu$ events survive the requirement of $p_T(b,j) > 15$ GeV.


√s = 14 TeV, M_A = 100 GeV, tanβ = 10
dσ/dp_T(pp → bb̄μμ̄ +X) (fb/GeV)
(a) μμ̄
(b) bb̄
μ1
μ2
μ1(A0)
μ2(A0)
b1
b2
b1(A0)
b2(A0)
10^4
10^2
10^0
10^−2
10^−4
0
50
100
150
200
pT(μ) (GeV)
pT(b) (GeV)

VII. The Discovery Potential at the LHC

- To study the discovery potential of

  $pp \to b\bar{b}\phi^0 \to b\bar{b}\mu^+\mu^- + X$

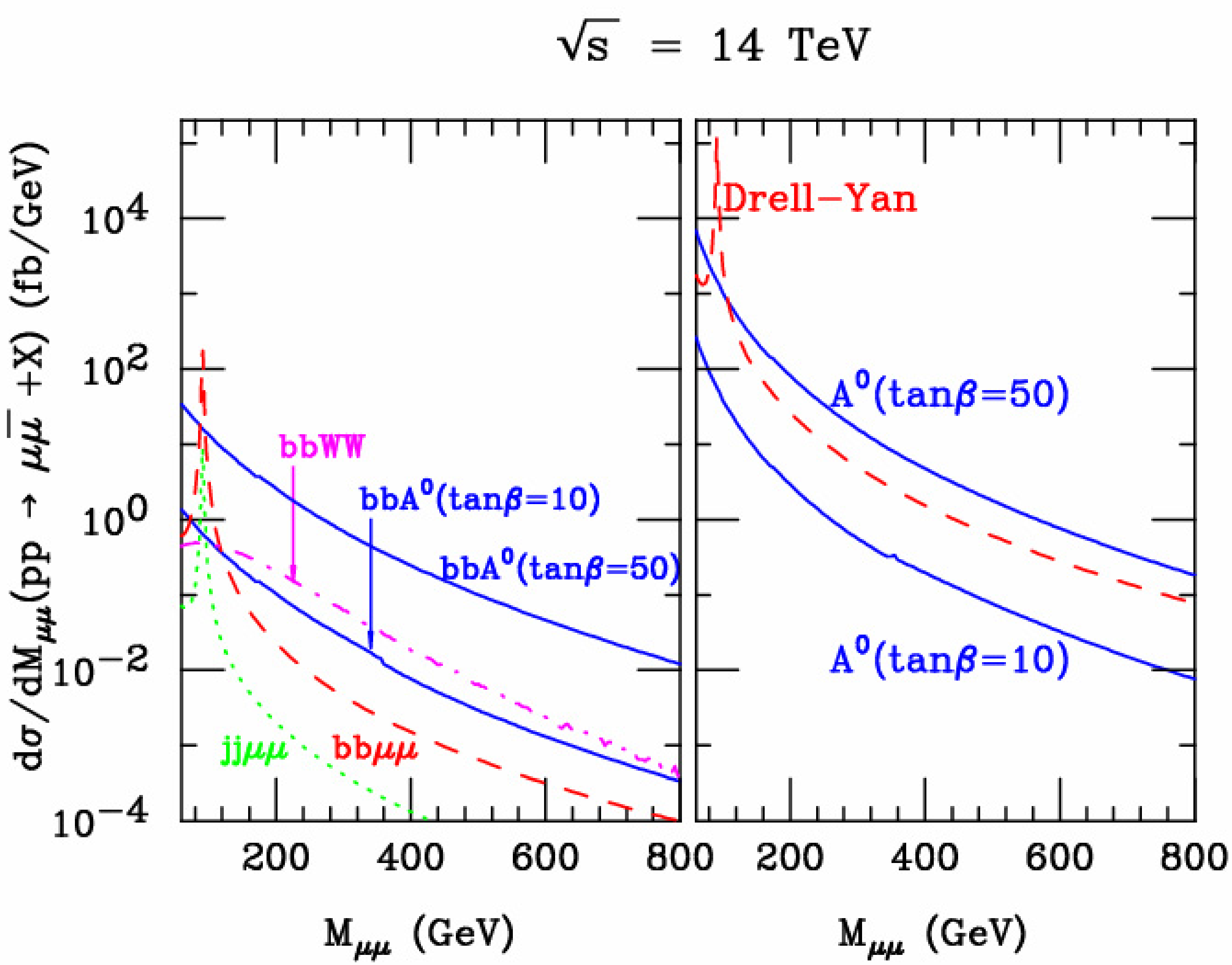
  we calculate the SM background from

  $pp \to b\bar{b}\mu^+\mu^- + X$ and

  $pp \to b\bar{b}W^+W^- \to b\bar{b}\,\mu^+\mu^- + X$

  in the mass window of $m_\phi \pm \Delta M_{\mu\mu}$.

- $\Delta M_{\mu\mu} = 1.64\,[(\Gamma_\phi/2.36)^2 + \sigma_m{}^2]^{1/2}$,
- Γ_ϕ is the width of the Higgs boson, and
- σ_m = the muon mass resolution $\simeq 0.02\, m_\phi$.



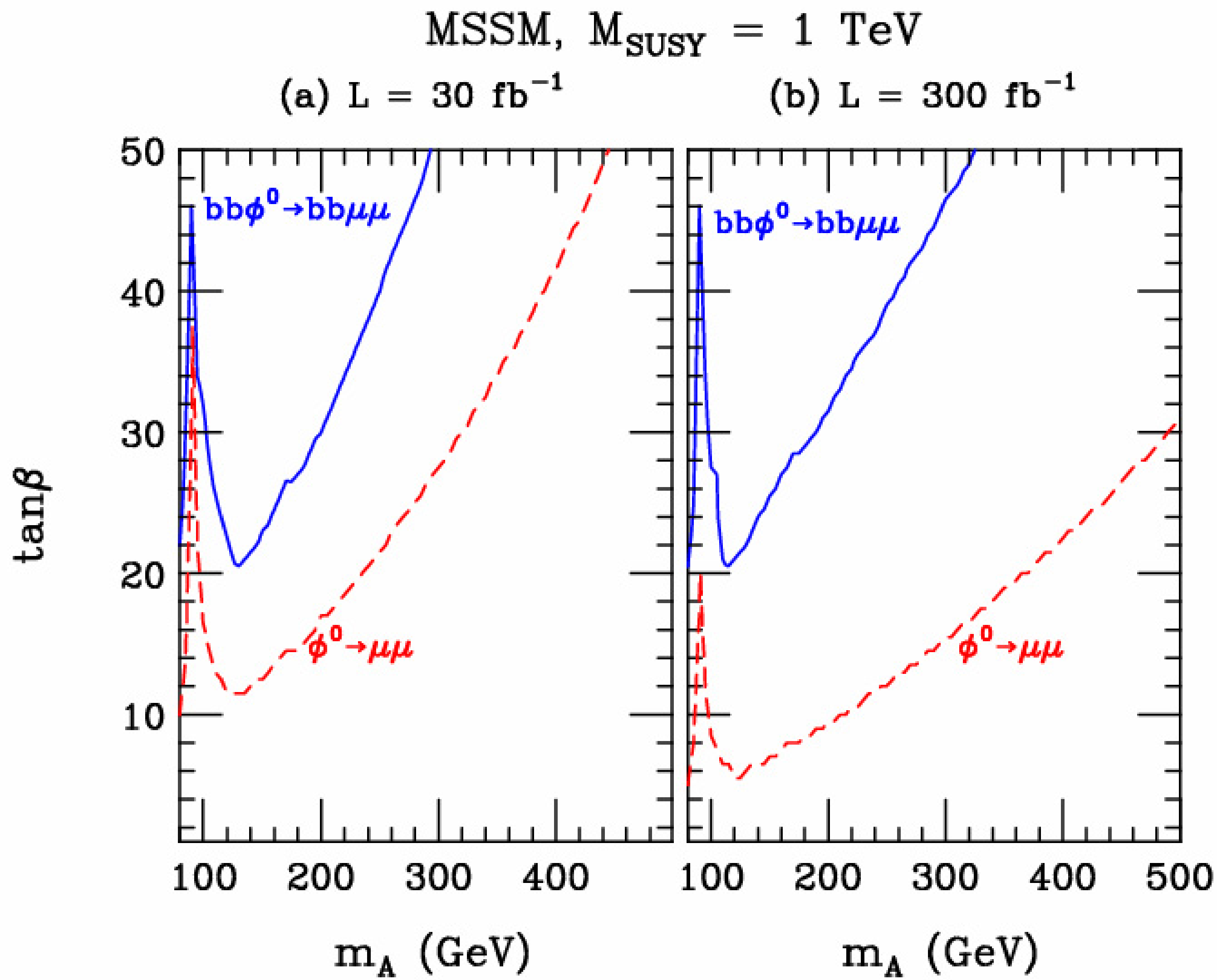
√s = 14 TeV
dσ/dM_μμ(pp → μμ̄ +X) (fb/GeV)
10^4
10^2
10^0
10^-2
10^-4
bbWW
bbA^0(tanβ=10)
bbA^0(tanβ=50)
jjμμ
bbμμ
Drell−Yan
A^0(tanβ=50)
A^0(tanβ=10)
200
400
600
800
M_μμ (GeV)
M_μμ (GeV)

VIII. Conclusions

- The muon pair discovery mode is a very promising channel to search for the neutral Higgs bosons of minimal supersymmetry.
- This channel provides a good opportunity to reconstruct masses for neutral Higgs bosons with high precision at the LHC.
- The inclusive final state of $\phi^0 \to \mu^+\mu^-$ is very promising to search for the A^0 and the H^0 for $\tan\beta \gtrsim 10$ and $m_A \lesssim 450$ GeV with $L = 30\ fb^{-1}$, and the discovery reach is greatly improved with a higher luminosity $L = 300\ fb^{-1}$ at the LHC.

VIII. Conclusions

- The associated final state of $b\bar{b}\phi^0 \rightarrow b\bar{b}\mu+\mu-$ offers great promise to discover the A^0 and the H^0 for $\tan\beta \gtrsim 20$ and $mA \lesssim 300$ GeV with an integrated luminosity of 30 fb^{-1} at the LHC.
- A higher luminosity of 300 fb^{-1} can only improves the discovery reach slighly in m_A, because the harder p_T cut on the b quarks reduces the Higgs cross section while larger missing E_T slightly increases the background from bbW^+W^- ($t\bar{t}$).
- This discovery channel has simple production mechanism and could provide a good opportunity to measure $\tan\beta$ and the $b\bar{b}\phi^0$ couplings.



MSSM, M_SUSY = 1 TeV
(a) L = 30 fb^-1
(b) L = 300 fb^-1
tanβ
bbφ^0→bbμμ
φ^0→μμ
bbφ^0→bbμμ
φ^0→μμ
50
40
30
20
10
100
200
300
400
100
200
300
400
500
m_A (GeV)
m_A (GeV)