Supersymmetric Dark Matter and Constraints from LEP

Cosmological Relic Density:

$\Omega h^2 = 0.1 - 0.3$

Phenomenological (LEP) Constraints:

Charginos

Neutralinos

Higgs

b to s γ

sfermions

MSSM vs CMSSM

nUHM vs UHM

Parameters:

M_2, m_0, μ, m_A

$m_1, m_2 \neq m_0$

and are fixed by EWSB.

μ and m_A are independent

Plots: M_2, μ

Parameters:

$m_{1/2}$, m_0, sgn(μ)

$m_1, m_2 = m_0$

μ and m_A are fixed by EWSB

Plots: $m_{1/2}$, m_0

At unification, $M_1 = M_2 = M_3 = M_{1/2}$

Common Parameters: tan β, A

Constraints

- Chargino mass limit

$M_{\chi^\pm} \geq 101 - 102\,\text{GeV}$

Constrains (M_2 and μ)/ $m_{1/2}$

- Higgs mass limit

$M_H \geq 107 - 112\,\text{GeV}$ $\tan\beta = 3$

$103 - 111\,\text{GeV}$ $\tan\beta = 5$

Constrains (m_A, M_2, A)/ $m_{1/2}$ at low $\tan\beta$

- b to s γ

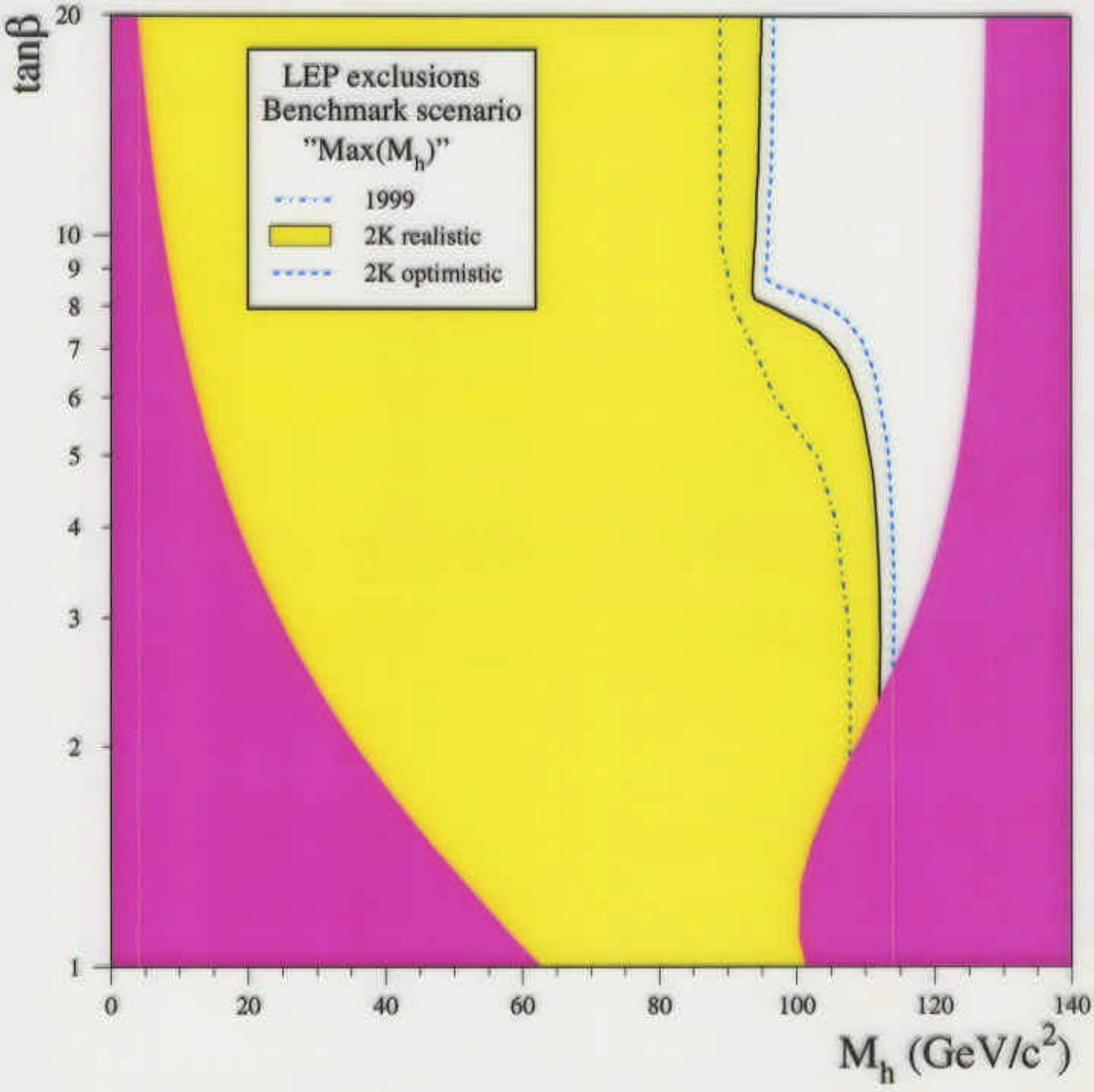
Constrains (m_A)/ $m_{1/2}$ at high $\tan\beta$ and $\mu < 0$

Ciuchini
Degrassi
Gambino
Giudice

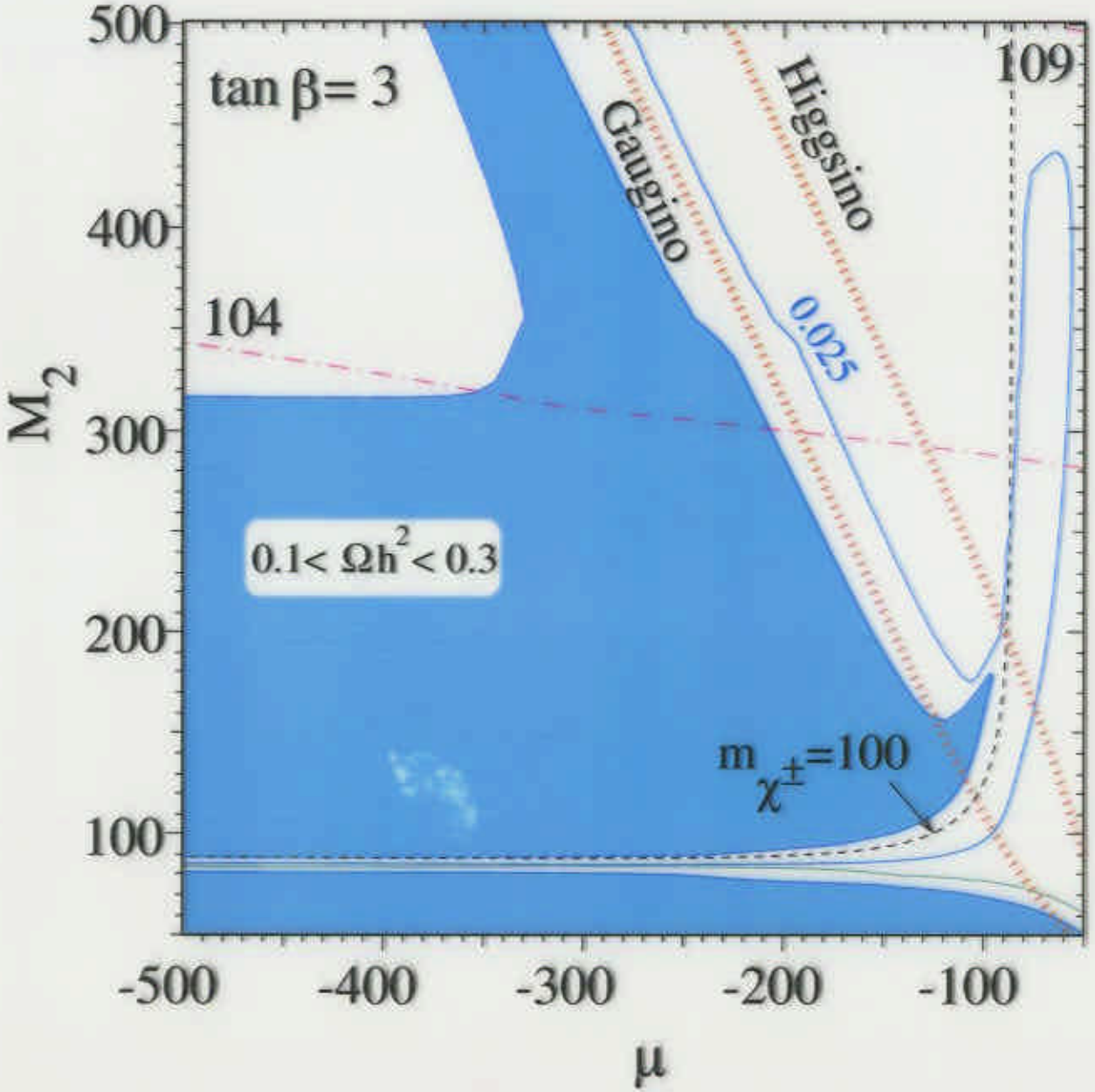
- Also sfermion mass limits from LEP and CDF

$m_{\tilde{f}} \geq 98$ GeV (roughly)

χ is the LSP

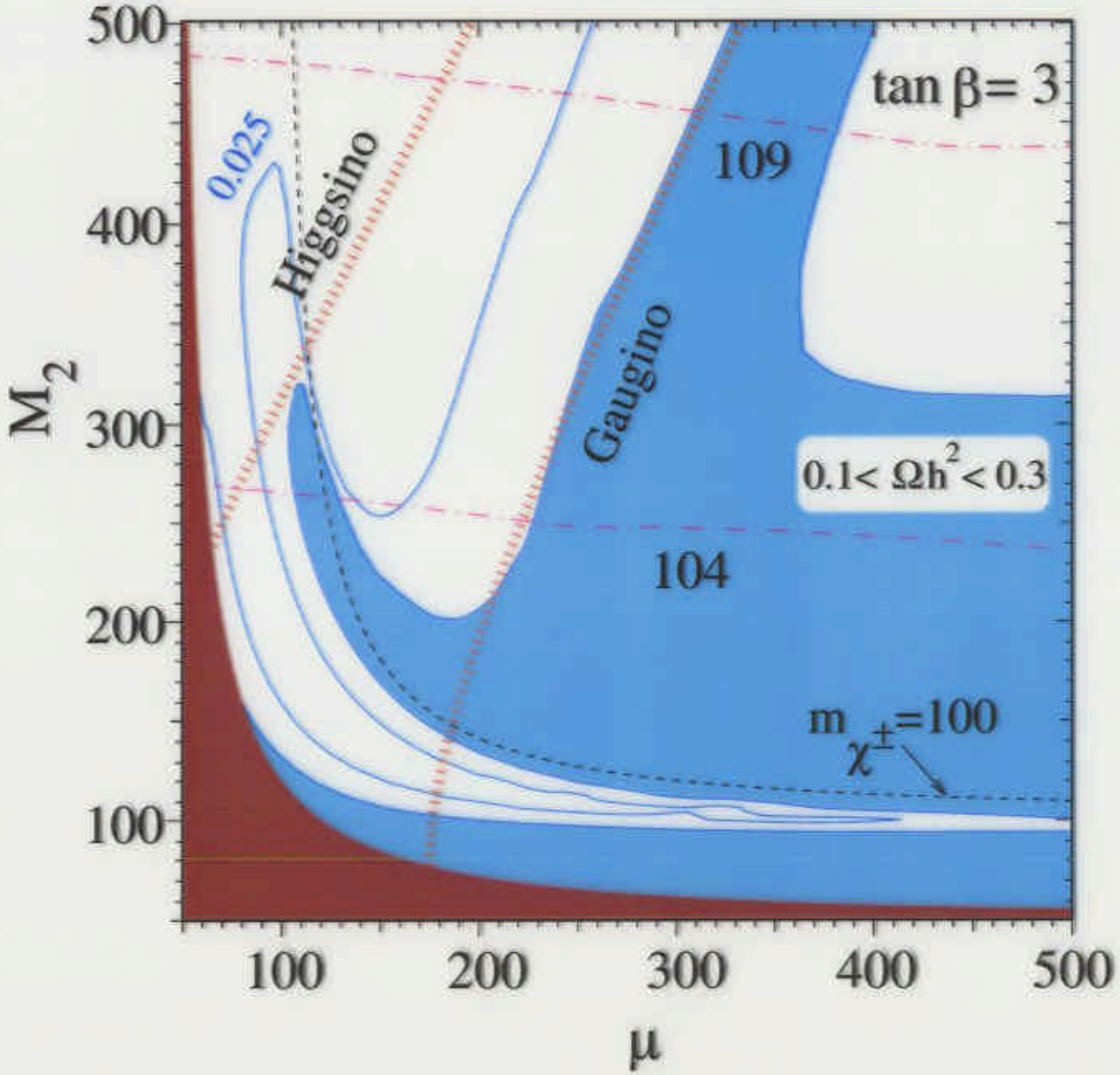

LEP exclusions
Benchmark scenario
"Max(M_h)"
1999
2K realistic
2K optimistic
tanβ
20
10
9
8
7
6
5
4
3
2
1
0
20
40
60
80
100
120
140
M_h (GeV/c^2)

From EFGD



$m_0 = 100$ GeV, $m_A = 1$ TeV

Ellis, Falk
Ganis, Olive
(EFGO)


500
400
300
200
100
M_2
100
200
300
400
500
μ
tan β= 3
0.025
Higgsino
Gaugino
109
104
$0.1< \Omega h^2 < 0.3$
$m_{\chi^\pm}$=100

EFGO

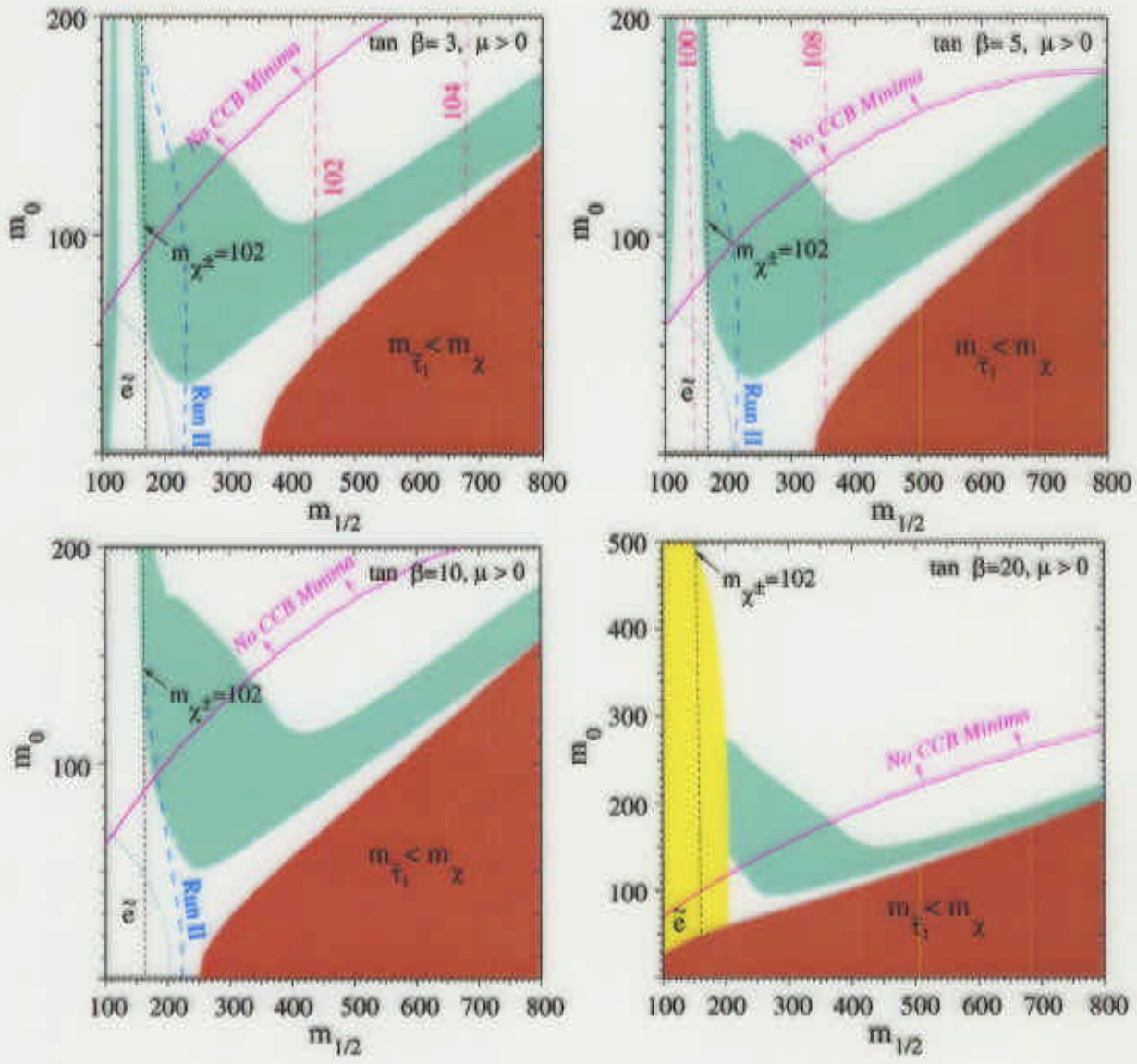
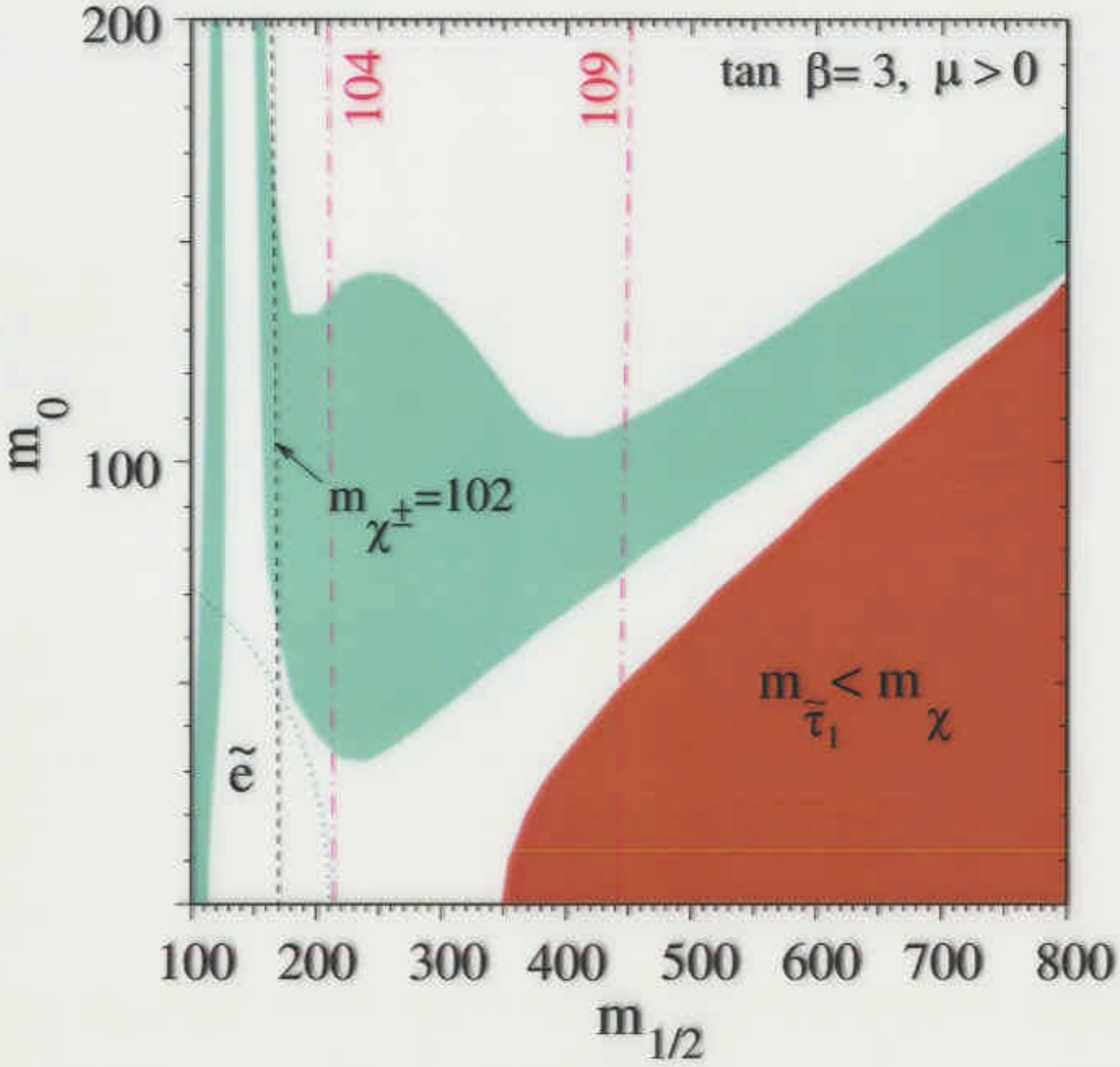
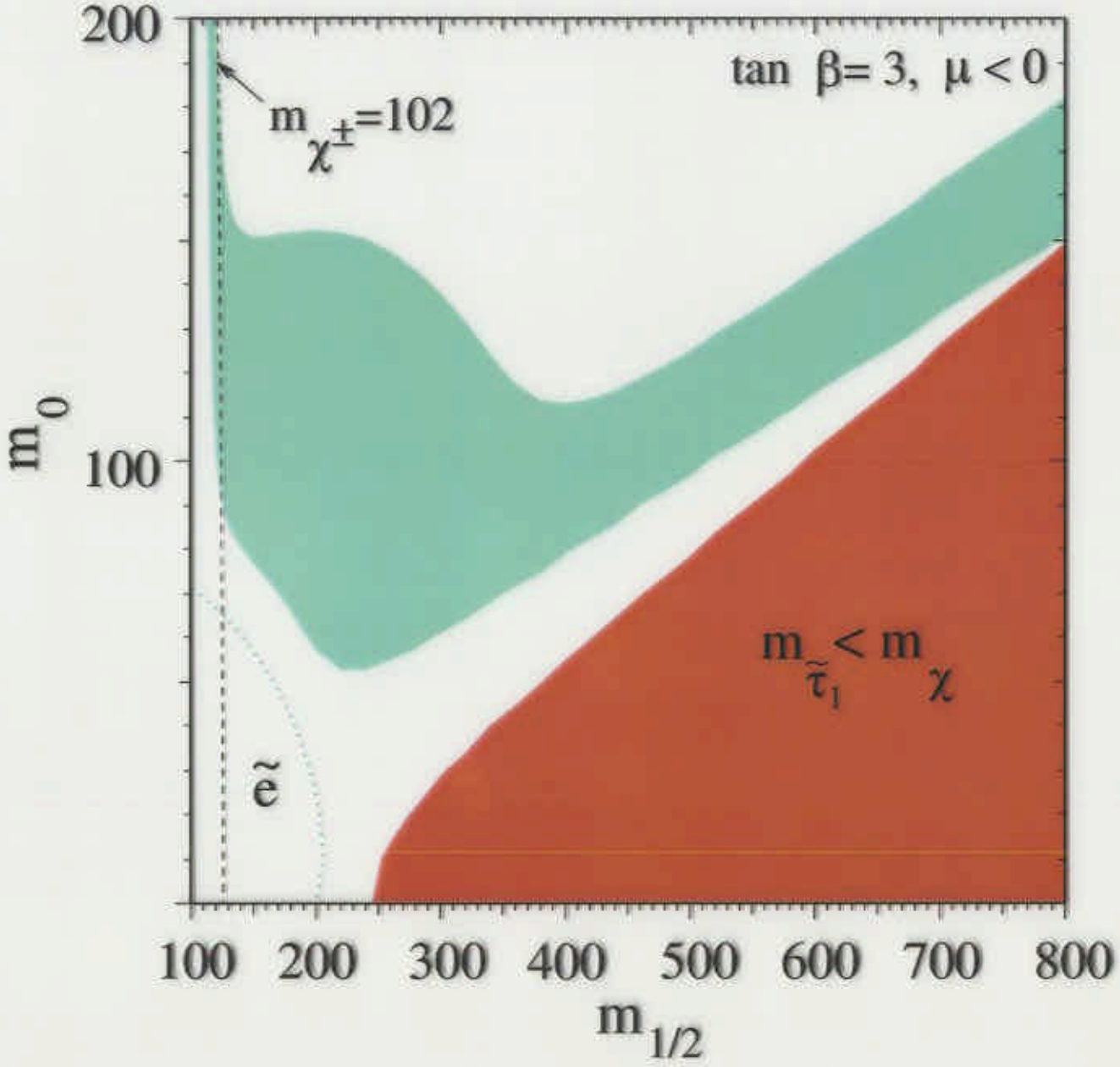


Figure 9: *The $m_{1/2}, m_0$ plane for $\mu > 0$, $A = -m_{1/2}$ and $\tan\beta =$ (a) 3, (b) 5, (c) 10 and (d) 20. The significances of the curves and shadings are the same as in Fig. 8. The light-shaded region in panel (d) is excluded by the $b \to s\gamma$ constraint. The long dashed curves in panels (a), (b) and (c) represent the anticipated limits from trilepton searches at Run II of the Tevatron [2].*

EF6.0


200
100
m_0
104
109
tan β= 3, μ > 0
$m_{\chi^\pm}$=102
$m_{\tilde{\tau}_1} < m_\chi$
$\tilde{e}$
100 200 300 400 500 600 700 800
$m_{1/2}$

EFqD


200
100
m_0
tan β= 3, μ < 0
$m_{\chi^\pm}$=102
$m_{\tilde{\tau}_1} < m_\chi$
$\tilde{e}$
100 200 300 400 500 600 700 800
$m_{1/2}$

EFGO

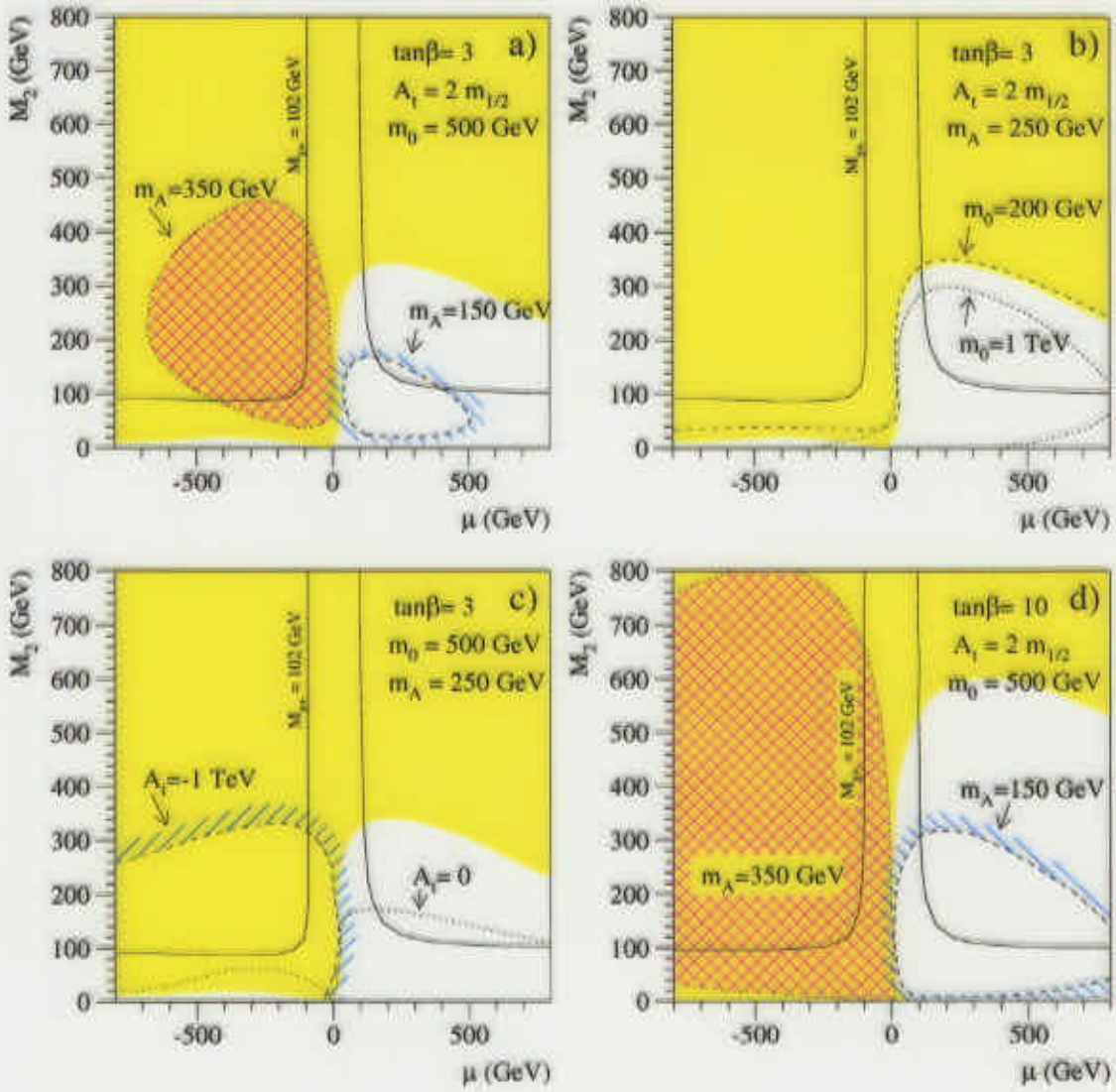


Figure 4: *Constraints on the nUHM parameter space imposed by $\mathcal{B}_{s\gamma}$: domains in the (μ, M_2) plane excluded for* $\tan\beta = 3$ (a,b,c) *and* $\tan\beta = 10$ (d). *In all plots the 'reference' excluded region for $m_A = 250$ GeV, $m_0 = 500$ GeV and the infra-red quasi-fixed-point value $A_0 = 2m_{1/2}$ is shaded, assuming $m_t = 175$ GeV. The effect of varying m_A is shown in panel (a), the effect of varying m_0 is shown in panel (b), the effect of changing the sign of A is shown in panel (c), and panel (d) illustrates the effect of increasing* $\tan\beta$. *Please see the text for further details.*

EF60

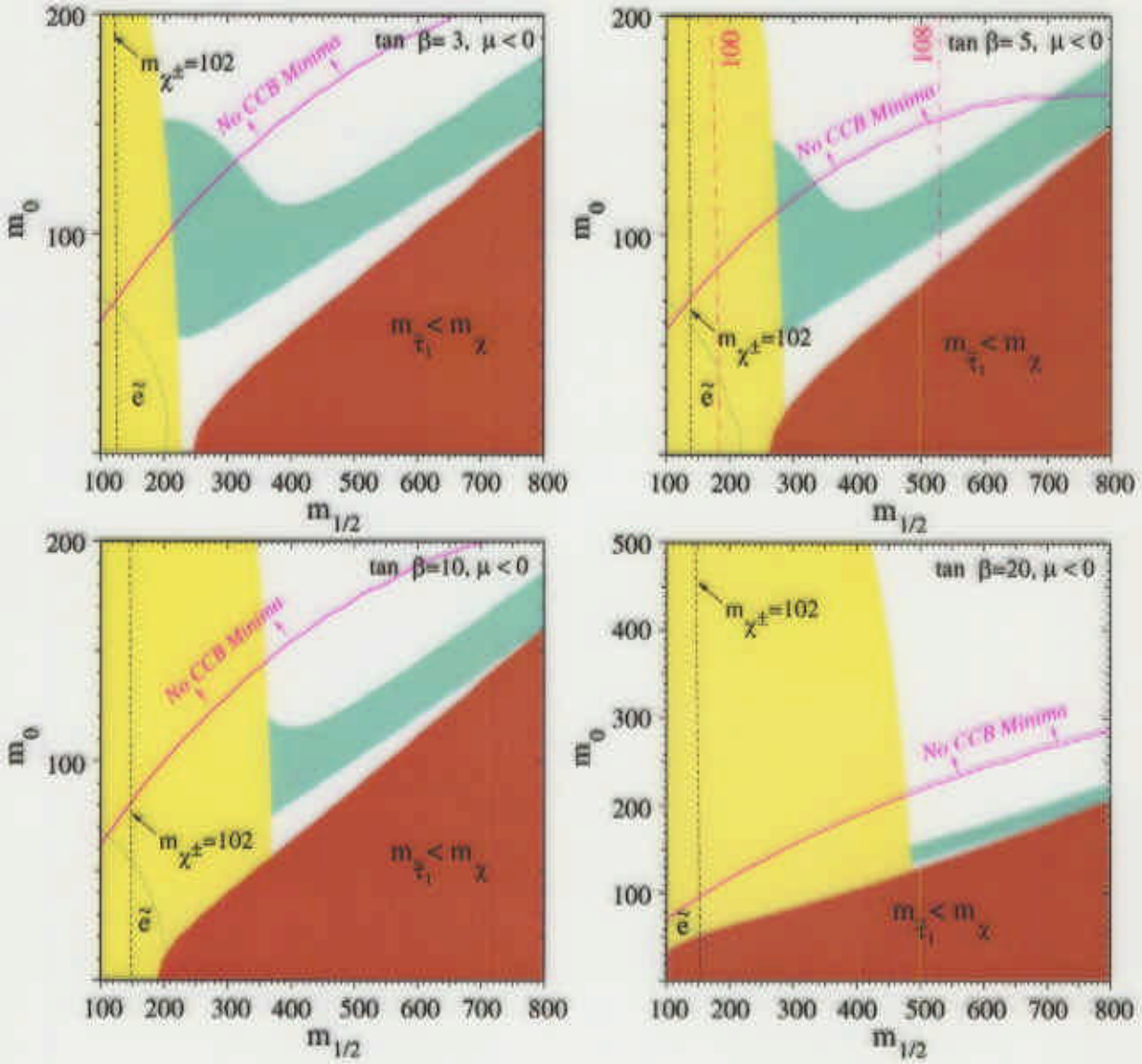


Figure 8: *The $m_{1/2}, m_0$ plane for $\mu < 0$, $A = -m_{1/2}$ so as to minimize the impact of the CCB constraint (indicated by a solid line) and* $\tan\beta$ *= (a) 3, (b) 5, (c) 10 and (d) 20. The region excluded by our $b \to s\gamma$ analysis has light shading. The region allowed by the cosmological constraint $0.1 \leq \Omega_\chi h^2 \leq 0.3$, after including coannihilations, has medium shading. Dotted lines delineate the announced LEP constraint on the $\tilde{e}$ mass and the disallowed region where $m_{\tilde{\tau}_1} < m_\chi$ has dark shading. The contour $m_{\chi^\pm} = 102$ GeV is shown as a near-vertical dashed line in each panel. Also shown as dot-dashed lines are relevant Higgs mass contours.*

EPSO

Limits to m_χ and $\tan\beta$

Lower limits to m_χ

$m_\chi > 50$ GeV

mainly from chargino mass bound

(except at low $\tan\beta$)

Upper limits to m_χ

$m_\chi < 300$ GeV (Bino) MSSM

unless $\chi\,\tilde{t}$ degenerate, or pole

$m_\chi < 600$ GeV (Bino) CMSSM

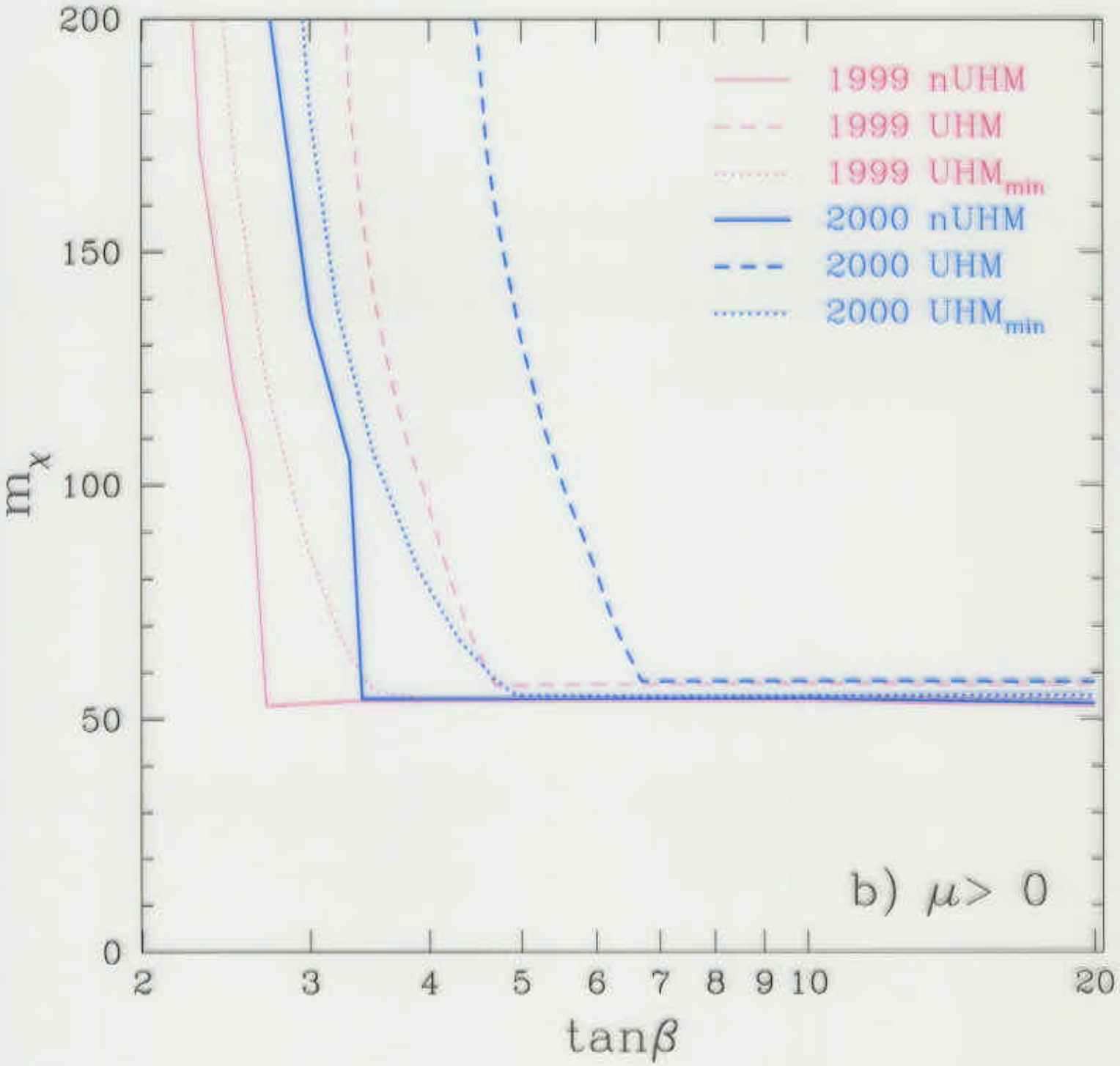
enhanced due to $\chi\,\tilde{\tau}$ co-annihilations

Lower limits to $\tan\beta$

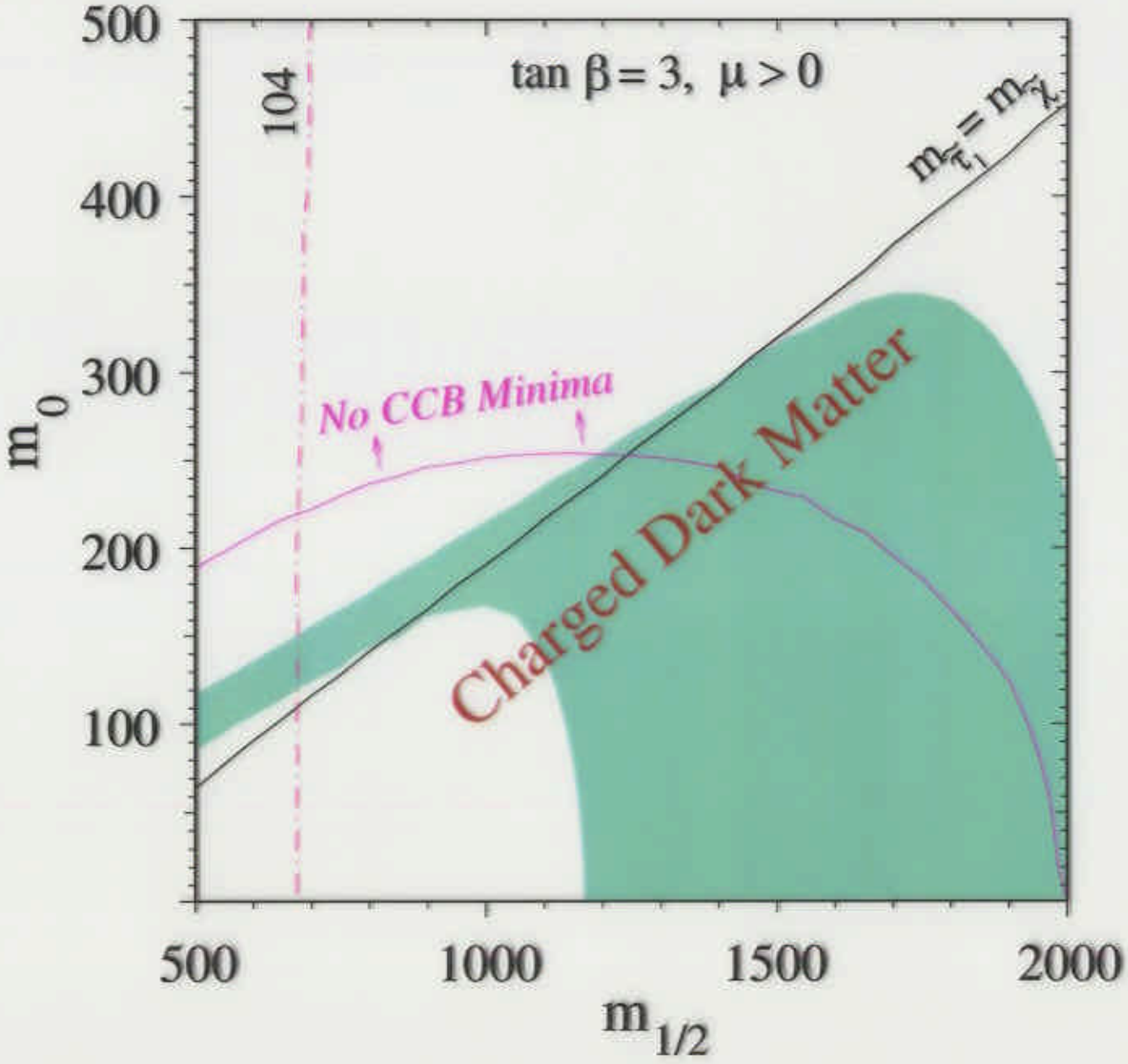
$\tan\beta > 1.8 - 2.1$ MSSM

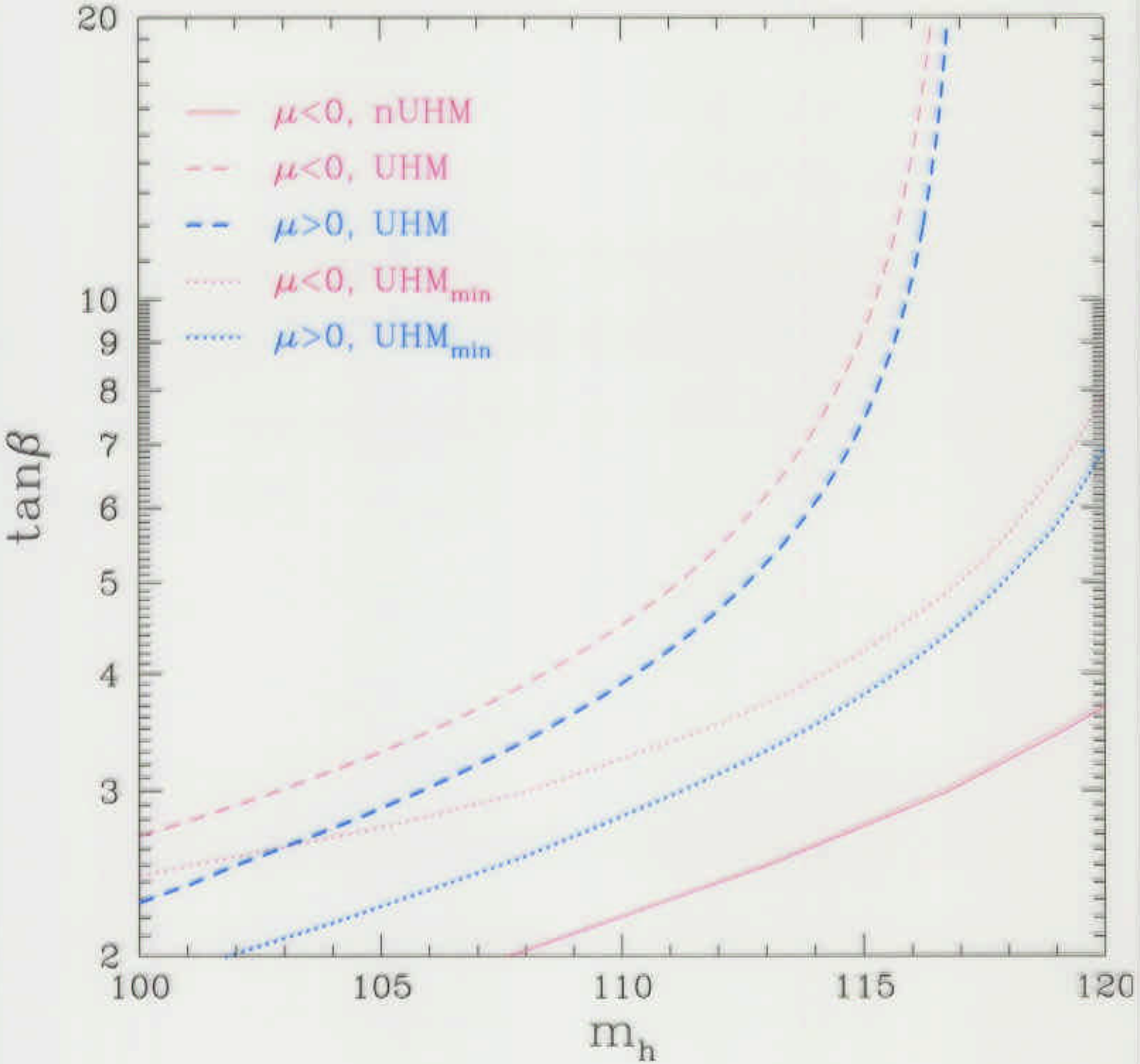
$\tan\beta > 2.2 - 2.7$ CMSSM $\mu > 0$

$\tan\beta > 2.7 - 3.1$ CMSSM $\mu < 0$


200
150
100
50
0
m_χ
1999 nUHM
1999 UHM
1999 UHM$_{min}$
2000 nUHM
2000 UHM
2000 UHM$_{min}$
b) $\mu > 0$
2
3
4
5
6
7
8
9
10
20
tanβ

FF60


500
400
300
200
100
m_0
104
tan β = 3, μ > 0
$m_{\tilde{\tau}_1} = m_{\tilde{\chi}_1^0}$
No CCB Minima
Charged Dark Matter
500
1000
1500
2000
$m_{1/2}$


20
10
9
8
7
6
5
4
3
2
tanβ
100
105
110
115
120
m_h
μ<0, nUHM
μ<0, UHM
μ>0, UHM
μ<0, UHM_min
μ>0, UHM_min