The Challenges of Focus Point at the LHC and LC

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in collaboration with

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Snowmass, 2005

Focus Point (Hyperbolic Branch) region

H. Baer, C. Chen, F. Paige and X. Tata, Phys.Rev.D52:2746,1995 and Phys.Rev.D53:6241

K. L. Chan, U. Chattopadhyay and P. Nath, Phys.Rev.D58:096004,1998,

J. L. Feng, K. T. Matchev and T. Moroi, Phys.Rev.D61:075005,2000.

The advantages:

- Fine-tuning can be quite low, even for large m_0.
- FP region makes up the largest portion of mSUGRA parameter space, which is still not excluded by WMAP.
- New physics is suppressed, because it is mostly heavy $\Rightarrow$ simple explanation for no NP effects in B physics, electroweak precision measurements, etc.

Mass spectrum:

- Scalars can be in the multi-TeV range.
- Lightest neutralino and chargino are a combination of higgsino and bino, $m_\chi \sim 100$ GeV.

Global reach of LHC in mSUGRA

Tools: CMSJET (Abdullin, Khanov, Stepanov) + ISAJET (Baer, Paige, Protopopescu, Tata).

Pre-cuts:

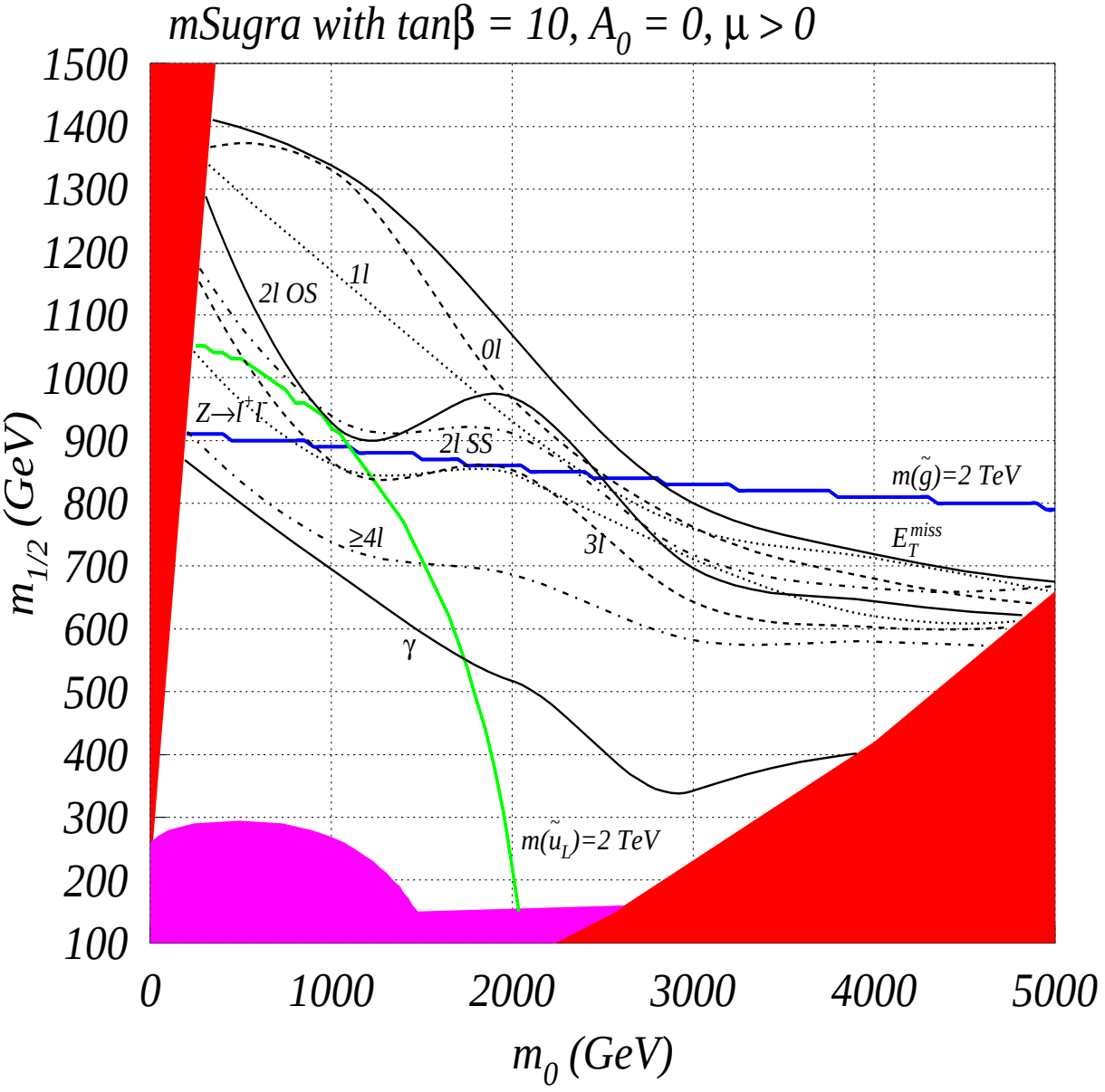
- $E_T^{miss} > 200$ GeV
- at least 2 jets with $p_T^{jet} > 40$ GeV

The cuts are optimized for each point in the mSUGRA parameter space:

S. Abdullin and F. Charles, Nucl.Phys.B547:60-80,1999,

H. Baer, C. Balazs, A. Belyaev, T. K. and X. Tata, JHEP 0306:054,2003.

Variable(s)	Values
N_j	2, 3, 4, ..., 10
E_T^{miss}	200, 300, 400, ..., 1400 GeV
E_T^{j1}	40, 150, ..., 1000 GeV
E_T^{j2}	40, 80, ..., 500 GeV
$\Delta\phi\ (p_T^l, E_T^{miss})$	0, 20 deg.
Circularity	0, 0.2
μ isolation	on, off



LHC reaches in mSUGRA for $\tan\beta = 10$, $\mu > 0$, $m_t = 175$ GeV. Red region is excluded because $\tilde{\tau}_1$ is the LSP (left) or no rEWSB occurs (right). Magenta region is ruled out by LEP2.

H. Baer, C. Balazs, A. Belyaev, T. K. and X. Tata, JHEP 0306:054,2003.

mSUGRA prospects at the LC

Detector simulation: calorimeter cell size $\Delta\eta \times \Delta\phi = 0.05 \times 0.05$, electromagnetic energy resolution $\Delta E_{em}/E_{em} = 0.15/\sqrt{E_{em}} \oplus 0.01$.

Require $\Delta R_{jet} < 0.6$, $E_{jet} > 5$ GeV, $|\eta|_{jet} < 2.5$. $E_{lepton} > 5$ GeV, $|\eta|_{lepton} < 2.5$. Lepton is isolated if visible activity within $\Delta R^{iso}_{lepton} = 0.5$ is less than $\max(E_{lepton}/10GeV, 1GeV)$

The parameter space can be split into several regions, requiring different cuts:

1. Selectron pair production (2 OS leptons)
2. Stau pair production (2 hadronic 'tau' jets)
3. $\tilde{Z}^0_1\tilde{Z}^0_2$ production (2 tagged b jets)
4. Chargino pair production (1 lepton + 2 jets)
5. Chargino pair production in the far HB/FP region (1 lepton + 2 jets)

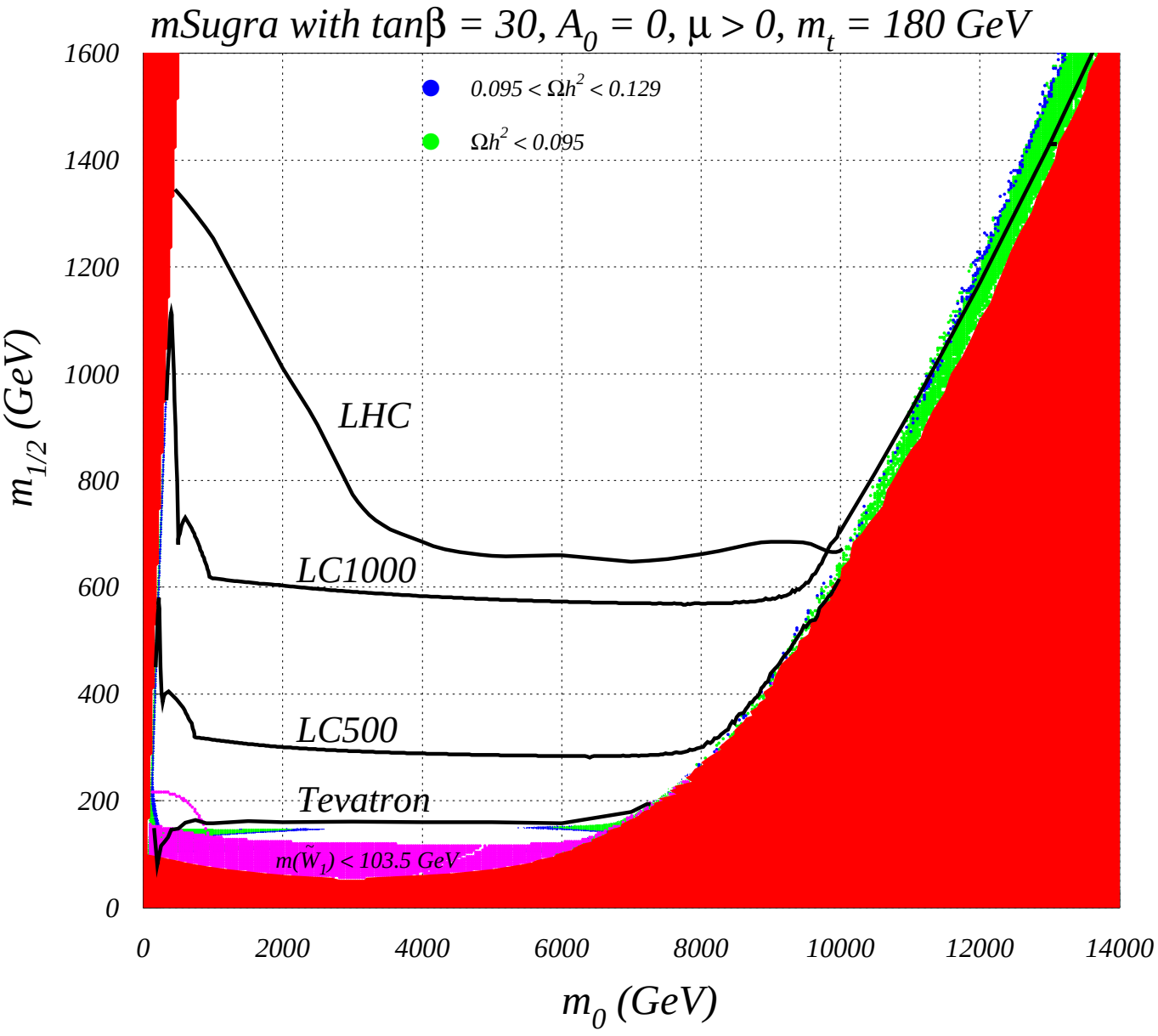
Chargino pair production in the far HB/FP region

Cuts:

- 1 lepton + 2 jets
- 20 GeV $< E_{visible} <$ 100 GeV
- $\cos(\phi_T(j,j)) > -0.6$
- $m(lj_{near}) > 5$ GeV
- $|\cos(\theta(j))| < 0.8$ (both jets)

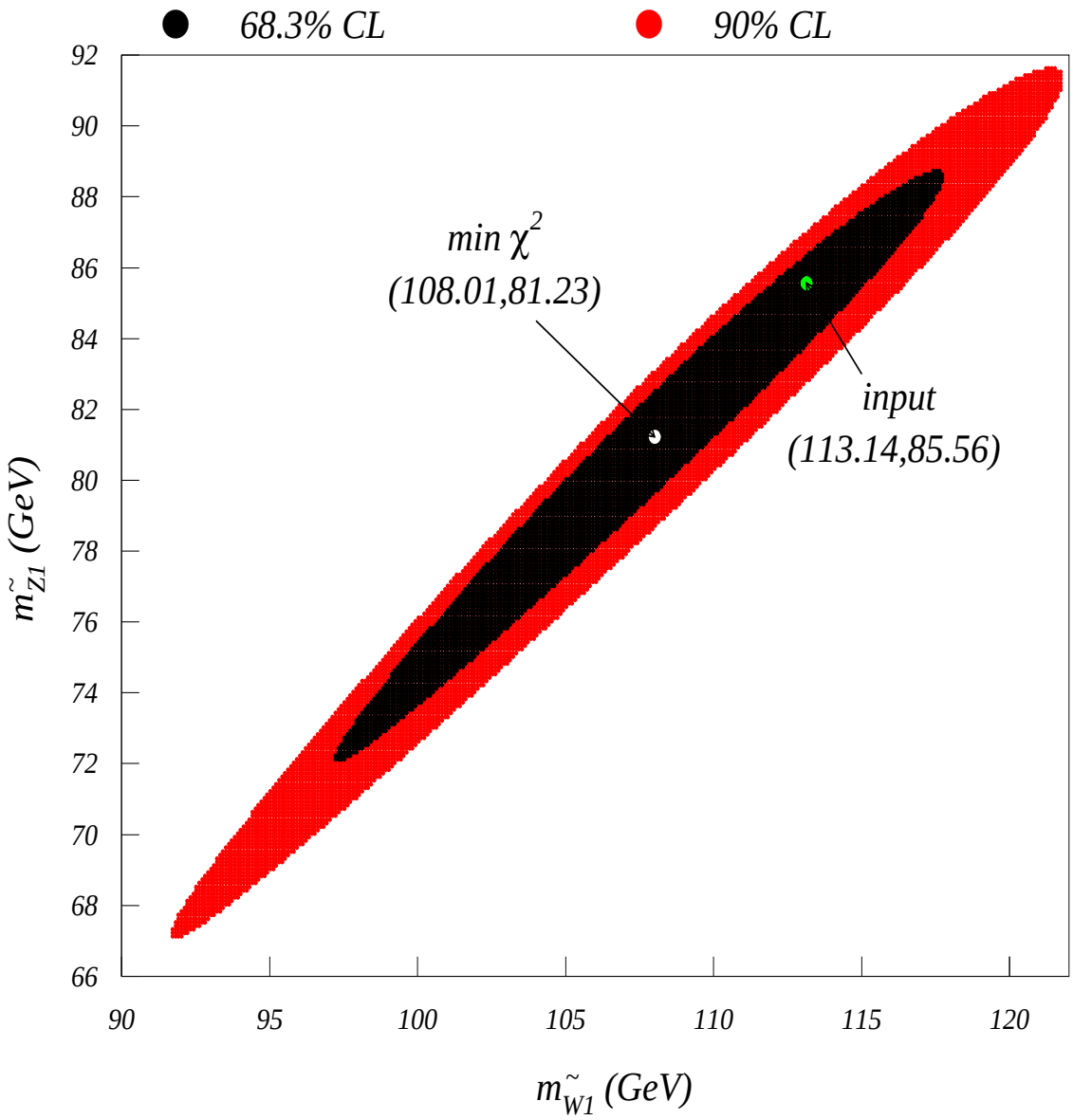
The background was generated with the modified ISAJET 7.69, including all $2 \to 2$ SM processes and $\gamma\gamma \to c\bar{c}, b\bar{b}$ with bremsstrahlung and beamstrahlung.

H. Baer, A. Belyaev, T. K. and X. Tata, JHEP 0402:007,2004.



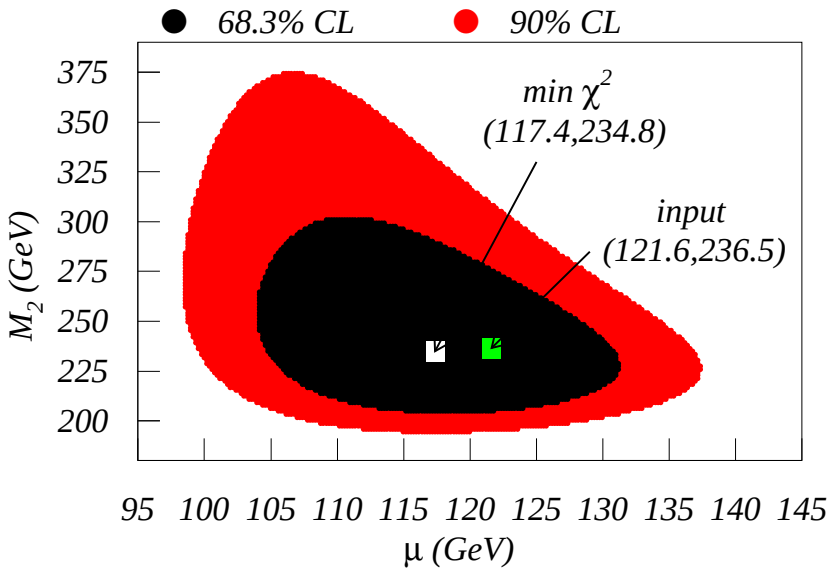
Tevatron, LHC and LC reaches in mSUGRA. Red region is excluded because $\tilde{\tau}_1$ is the LSP (left) or no rEWSB occurs (right). Magenta region is ruled out by LEP2.

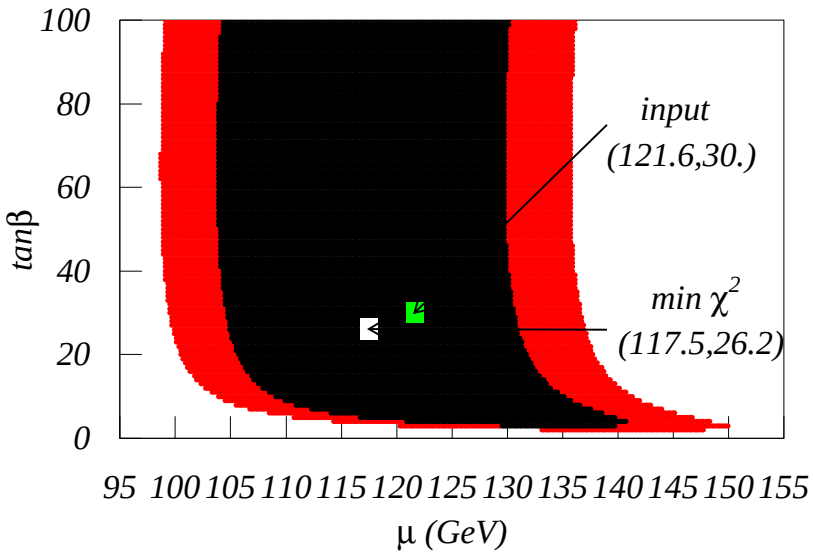
H. Baer, T. K. and X. Tata, JHEP 0406:061,2004.

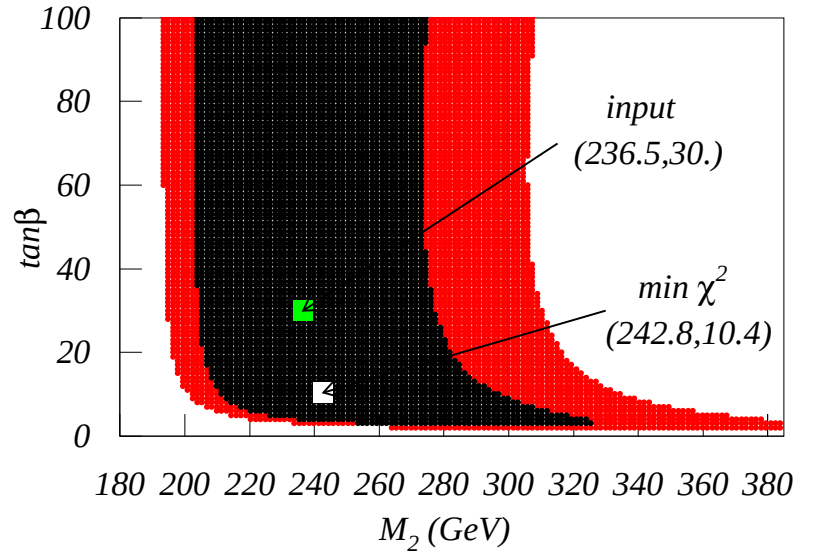


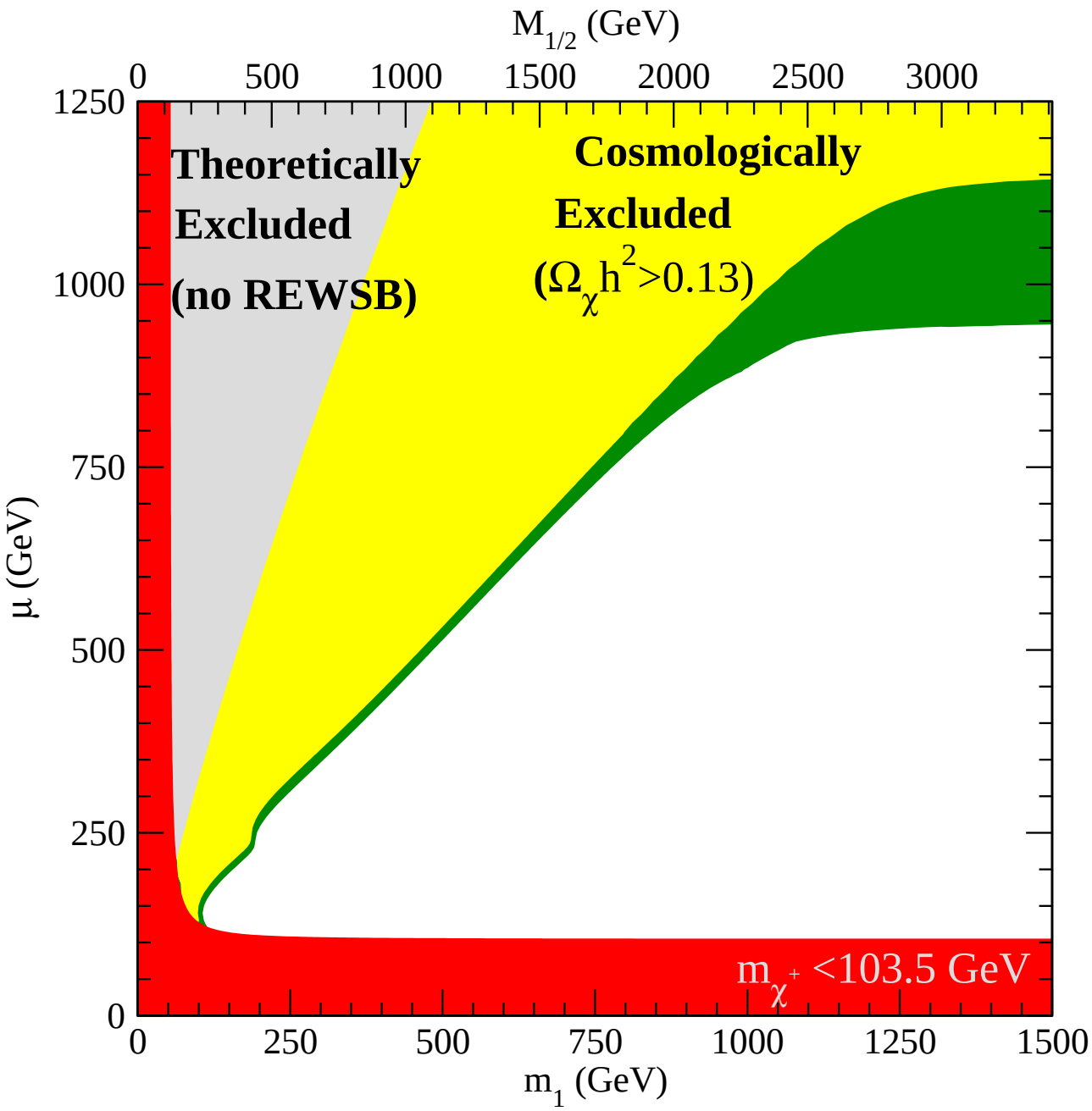
Fits to $m_{\tilde{Z}_1^0}$ and $m_{\tilde{W}_1^\pm}$ for a FP case study $m_0 = 2500$ GeV, $m_{1/2} = 300$ GeV, $\mu > 0$ and $m_t = 175$ GeV.

H. Baer, A. Belyaev, T. K. and X. Tata, JHEP 0402:007,2004.

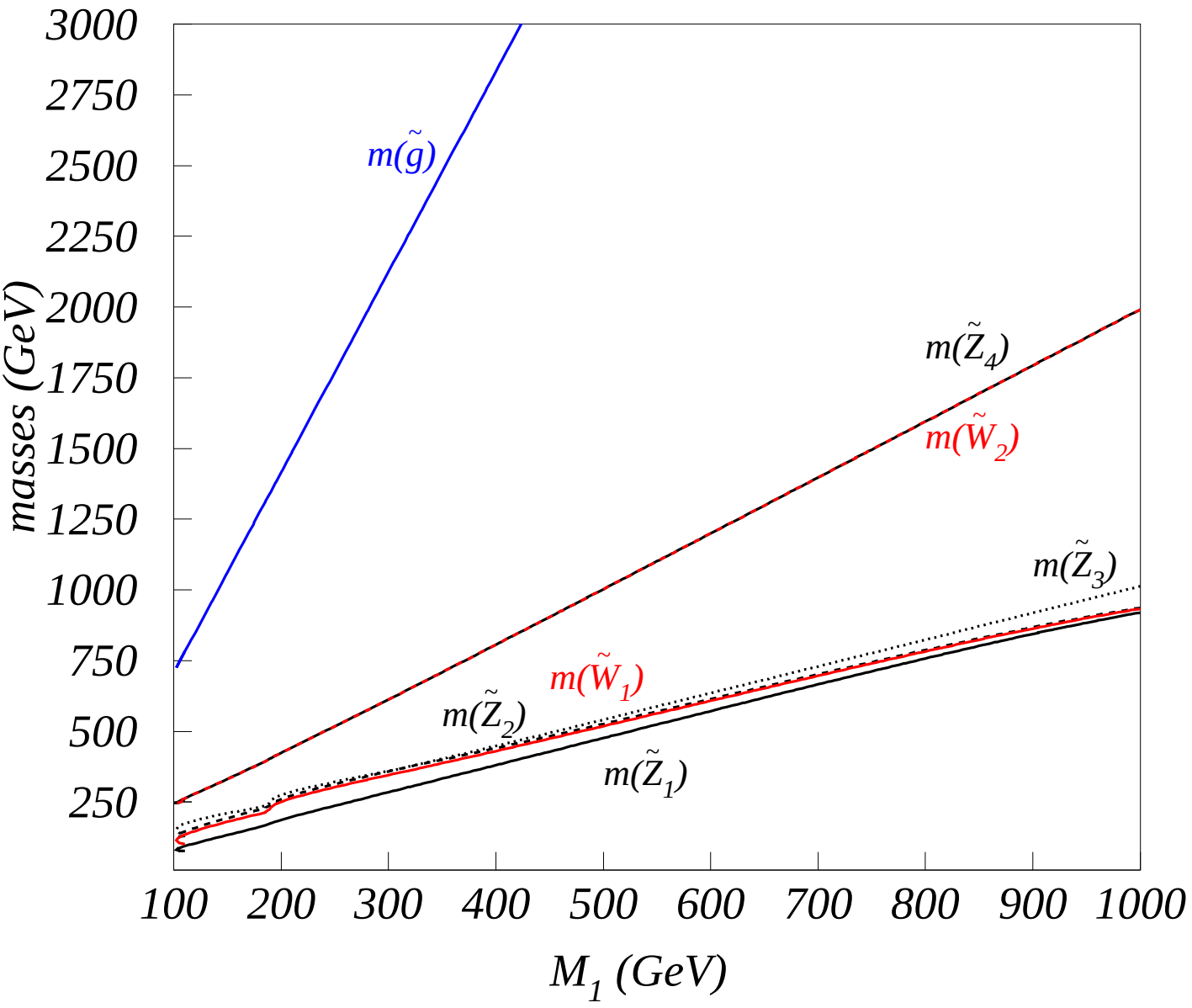

68.3% CL
90% CL
min χ2
(117.4,234.8)
input
(121.6,236.5)
M2 (GeV)
μ (GeV)


input
(121.6,30.)
min χ2
(117.5,26.2)
tanβ
μ (GeV)

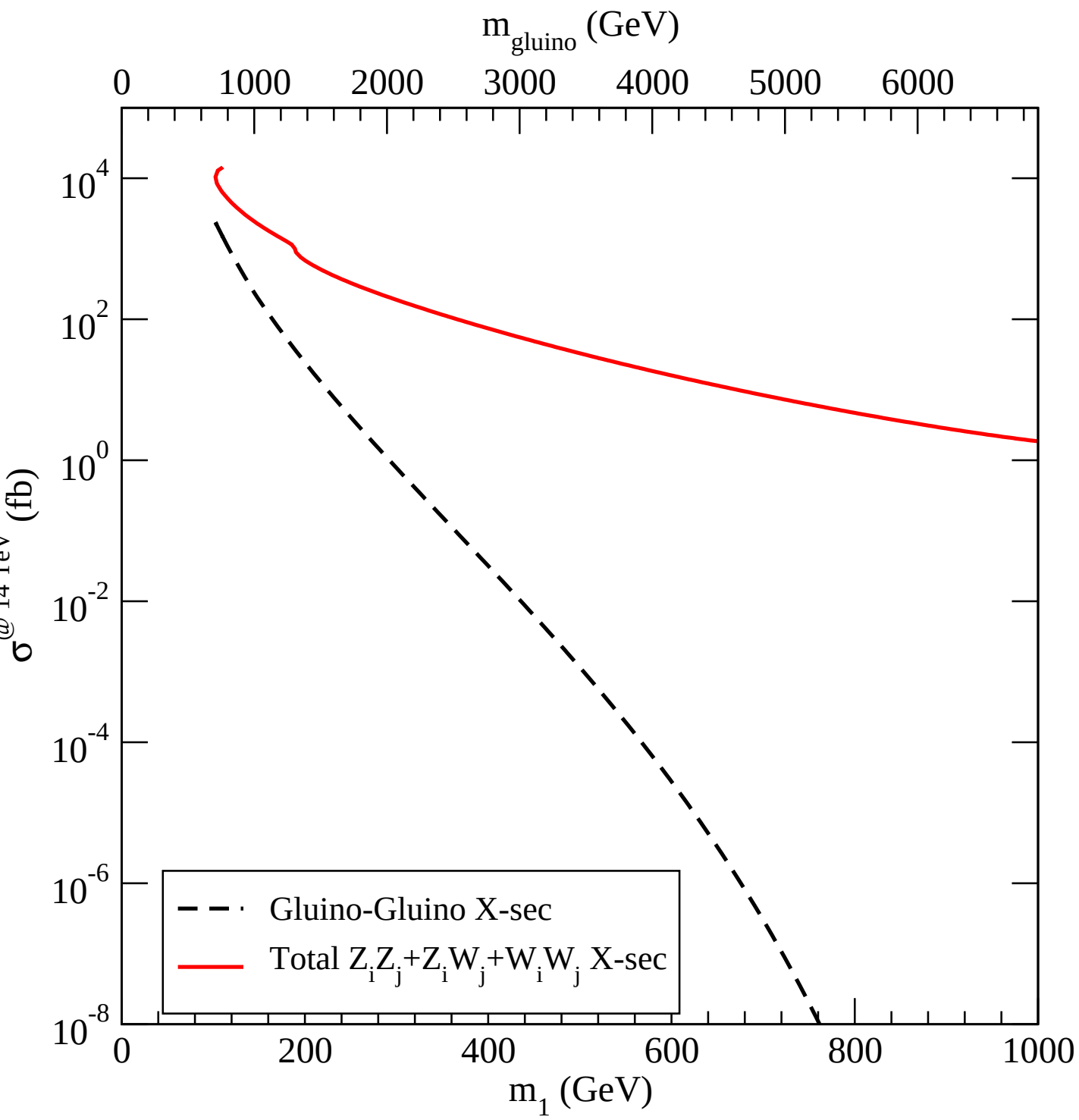

input
(236.5,30.)
min χ2
(242.8,10.4)
tanβ
M2 (GeV)



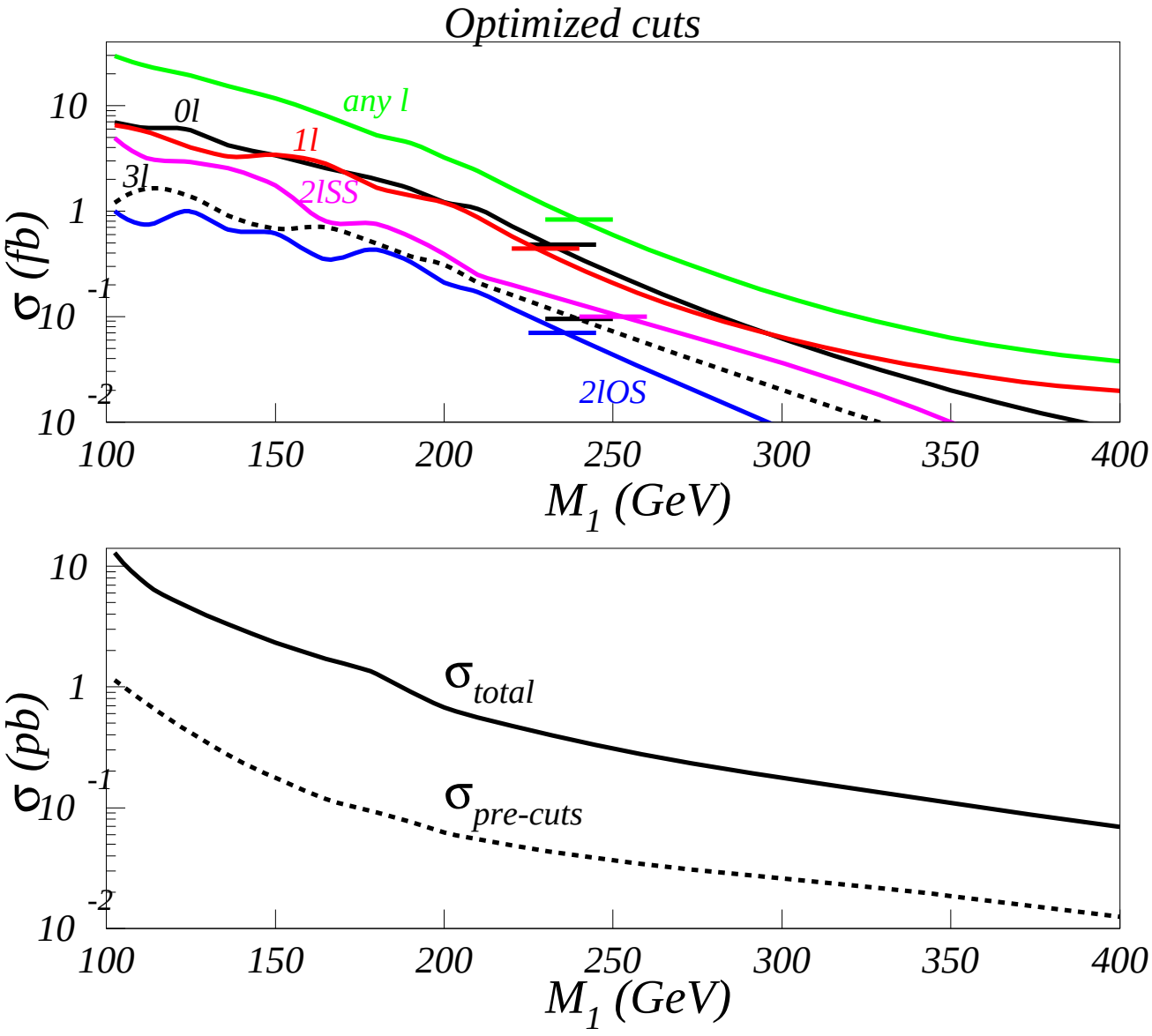
mSUGRA with $\tan\beta = 50$, $A_0 = 0$ and $\mu > 0$, $m_t = 174.3$ GeV.



Masses of gluino and gauginos along the $\Omega h^2 = 0.1126^{+0.0161}_{-0.0181}$ line in the FP.



Gluino pair production and total gaugino production cross section along the $\Omega h^2 = 0.1126^{+0.0161}_{-0.0181}$ line in the FP.



Reach of the LHC using optimized cuts of H. Baer *et al.* , JHEP 0306:054,2003

Pre-cuts:

$E_T^{miss} > 200$ GeV

2 jets with $p_T > 40$ GeV

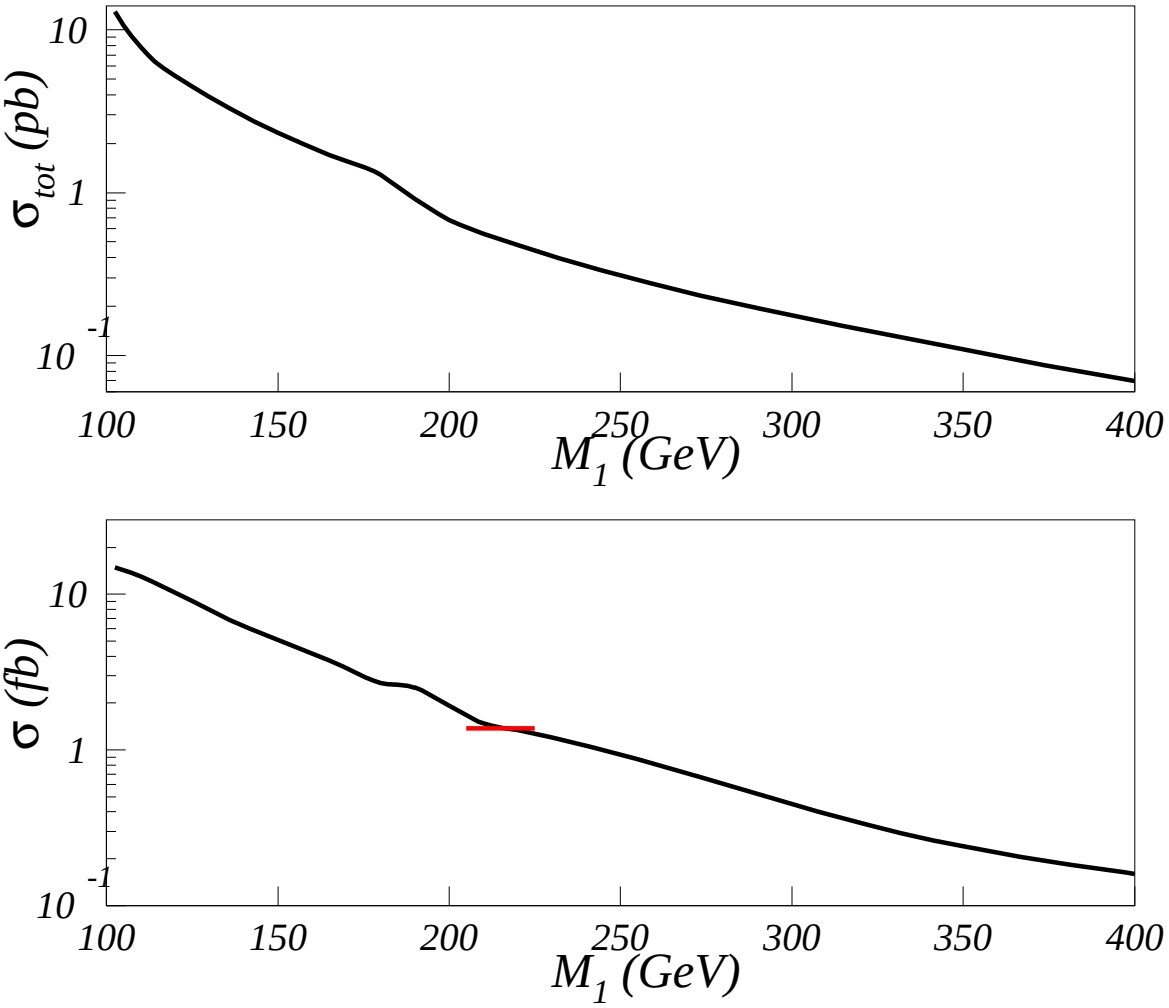
Clean 3-lepton cuts

Dominant 3-lepton backgrounds:
$t\bar{t}$
WZ, ZZ
off-shell $W^*Z^*, W^*\gamma^*$

We require 3 isolated leptons with $p_T > 10$ GeV and $|\eta| < 2.5$. The isolation criterion is $\Sigma E_T^{cell} < 2$ GeV within $\Delta R < 0.6$.

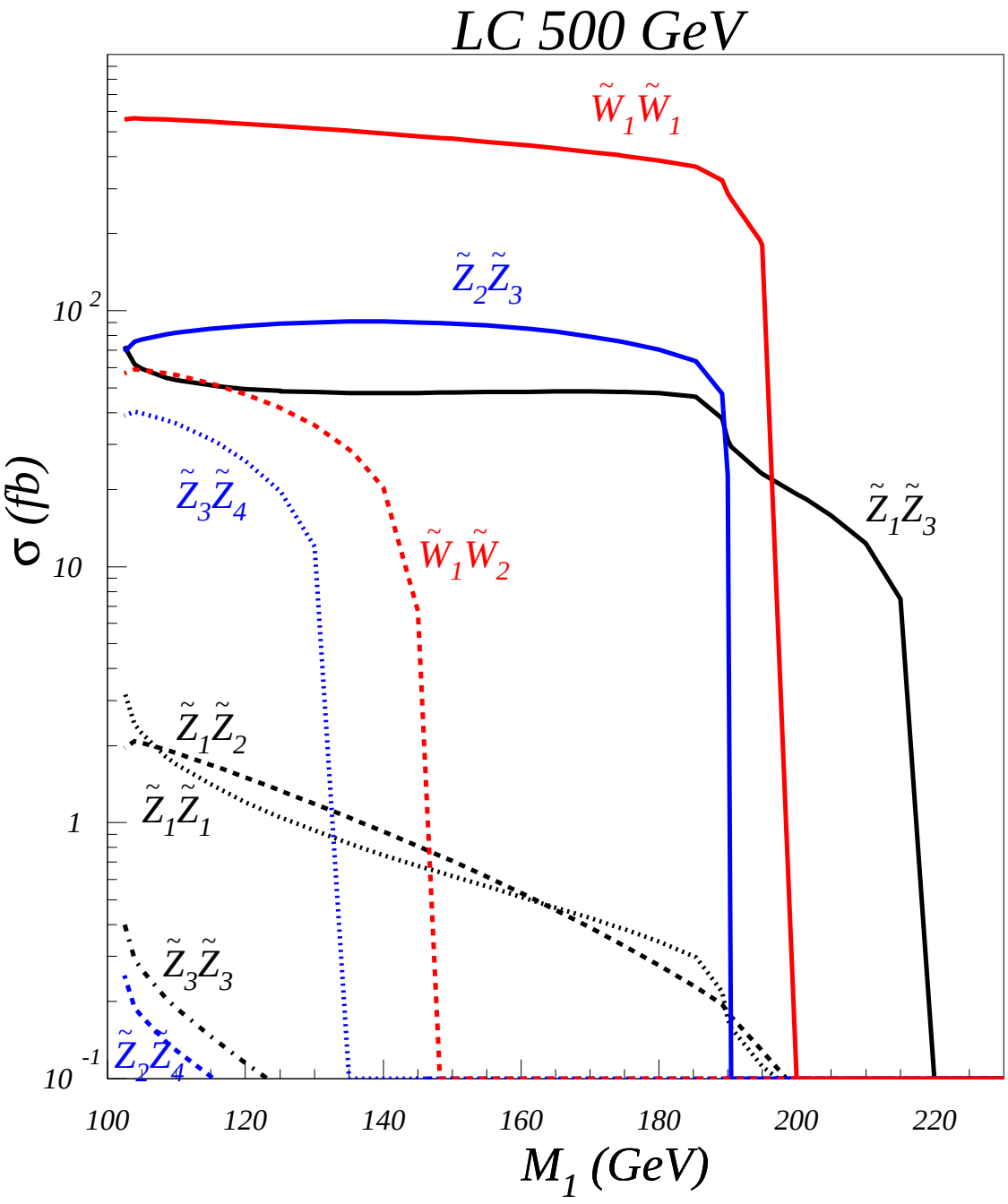
The rest of the cuts (same as SC2 from H. Baer, M. Drees, F. Paige, P. Quintana and X. Tata, Phys.Rev.D61:095007,2000):

20 GeV $< m(l\bar{l}) <$ 81 GeV,
65 GeV $< M_T(l', \nu_{l'})$,
$E_T^{miss} > 25$ GeV.

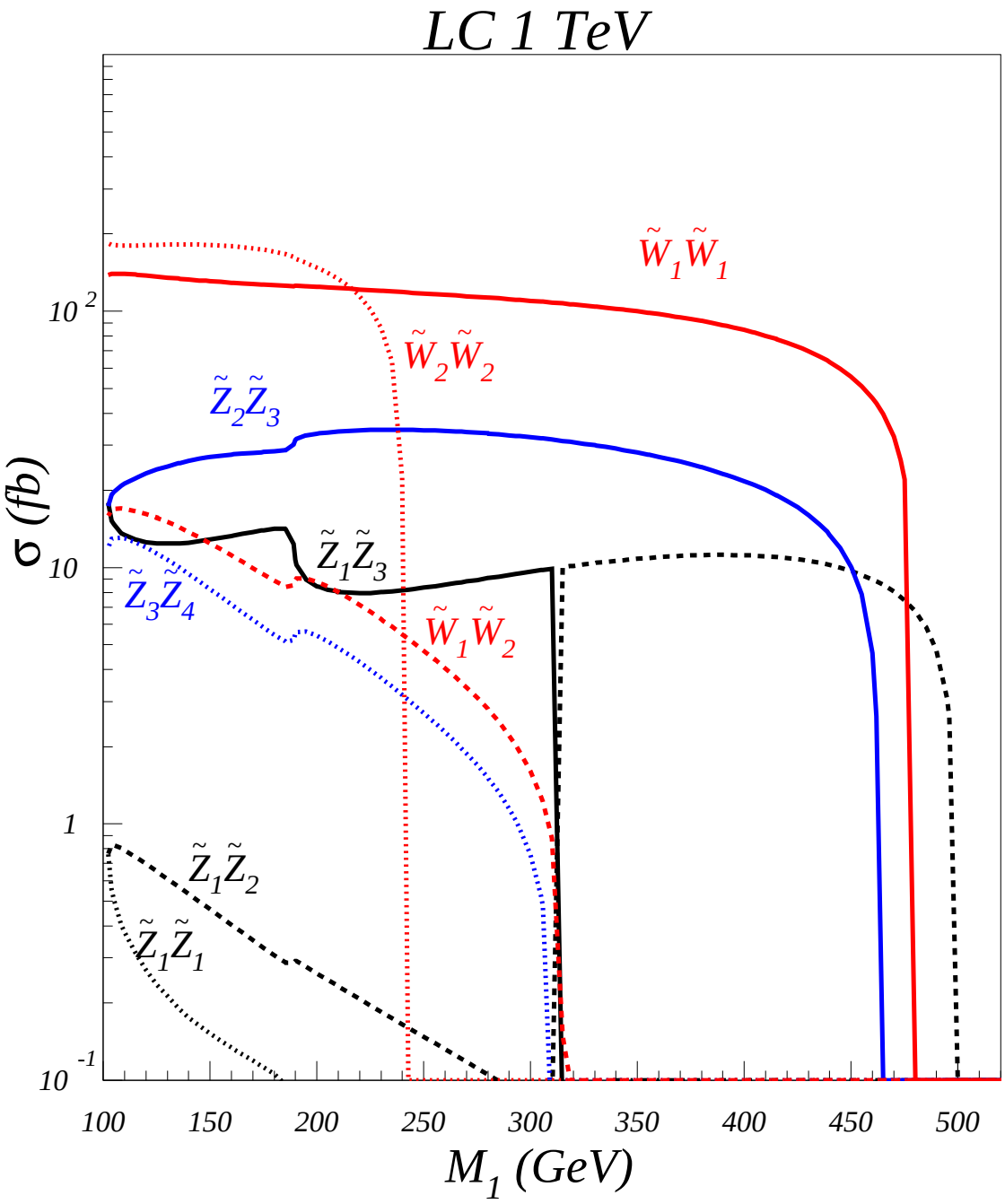


Reach of the LHC along the $\Omega h^2 = 0.1126^{+0.0161}_{-0.0181}$ line in the FP after clean 3-lepton cuts.

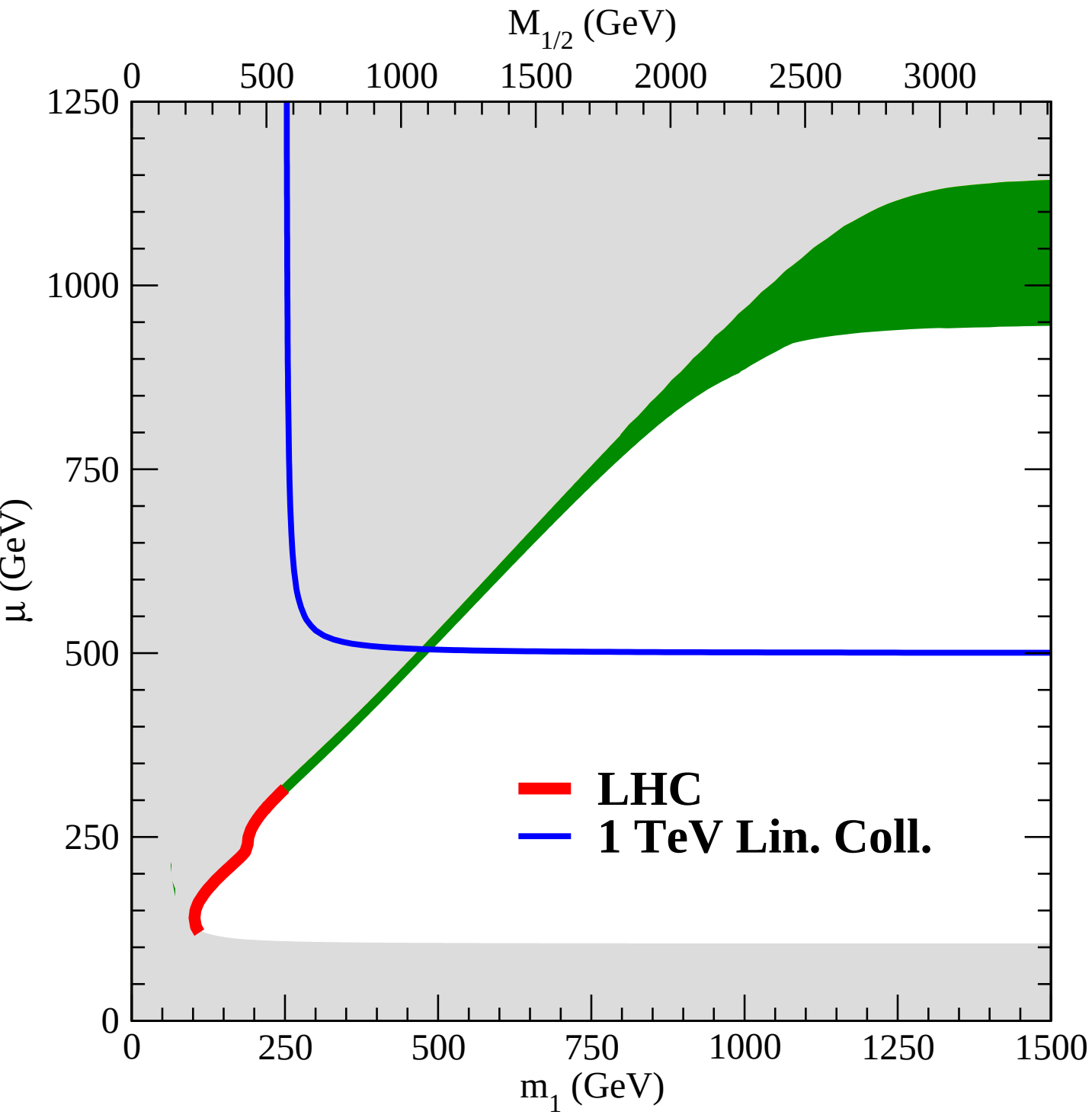
H. Baer, T. K., S. Profumo and P. Ullio, hep-ph/0507282.



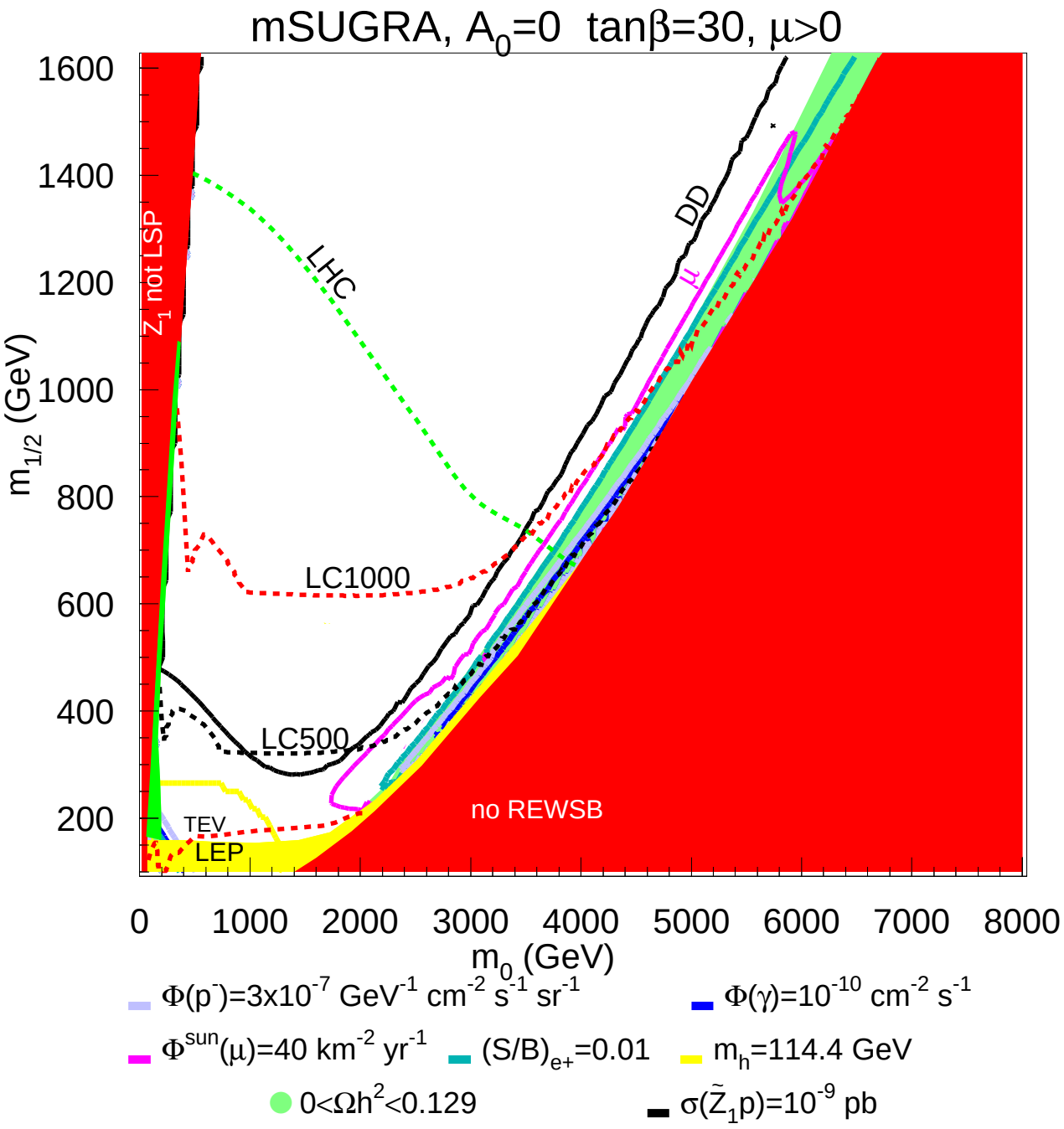
Gaugino production cross sections at a 500 GeV LC along the $\Omega h^2 = 0.1126^{+0.0161}_{-0.0181}$ line in the FP.



Gaugino production cross sections at a 1 TeV LC along the $\Omega h^2 = 0.1126^{+0.0161}_{-0.0181}$ line in the FP.



The reaches of LHC and LC in $M_1 - \mu$ plane for $\tan\beta = 50$, $A_0 = 0$, $\mu > 0$, $m_t = 174.3$ GeV.



A plot of the reach of direct, indirect and collider searches for neutralino dark matter in the m_0 *vs.* $m_{1/2}$ plane, for $A_0 = 0$, $\tan\beta = 30$, $\mu > 0$ and $m_t = 175$ GeV.

Conclusions

• HB/FP region is still a viable and attractive option in mSUGRA.

• If scalars are taken to be 'unnaturally' heavy, FP represents a challenge to the LHC. However, the prospects of a 1 TeV LC are encouraging in this scenario.

• FP will be covered by the future DM detection experiments. However, the case for the LC becomes even stronger if DM particles are detected.