Uncertainties in the relic density calculations in mSUGRA

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LAPTH/MSU

LC-Cosmology

- Cosmology (relic density of dark matter) strongly constrains SUSY models, in particular, in mSUGRA, points to specific scenarios for SUSY searches at colliders

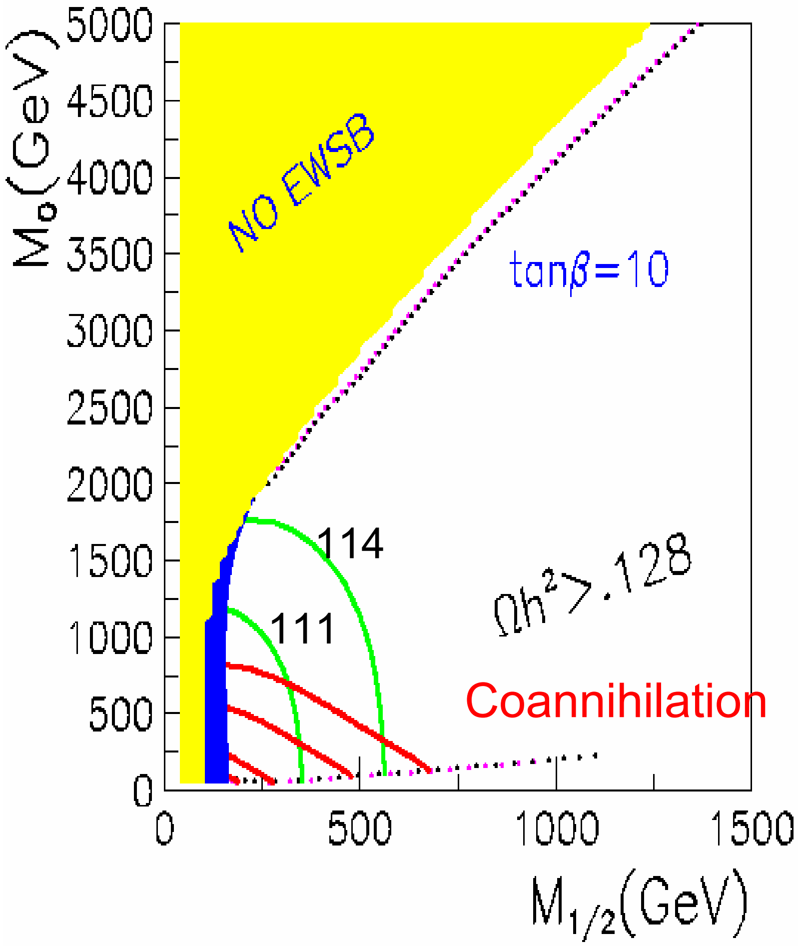
- With WMAP:

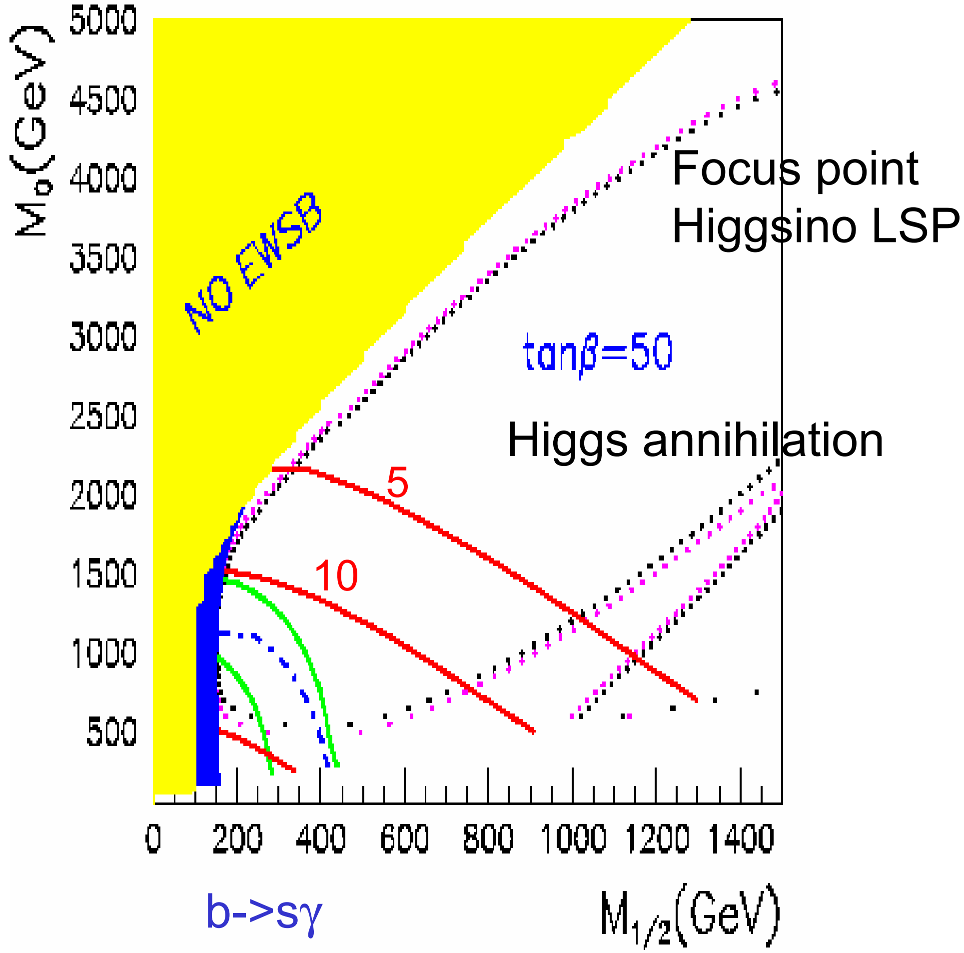
  $.094 < \Omega h^2 < .128$ (2 sigma)

- PLANCK expects precision of 2%

- LHC will test SUSY Dark Matter hypothesis (can also have some LSP signal from direct detection experiments), with LC and precision measurements of SUSY parameters can one match the precision of the relic density measurement by PLANCK hence consistency check on cosmological model

Constraints on mSUGRA





Mt=170GeV

Mt=172GeV

micrOMEGAs1.3+Softsusy1.8.3

Uncertainties in relic density

- **In the WMAP favoured region, the relic density is very sensitive to**
  - ***ΔM(NLSP-LSP)***
  - μ
  - ***MA-2M*** χ

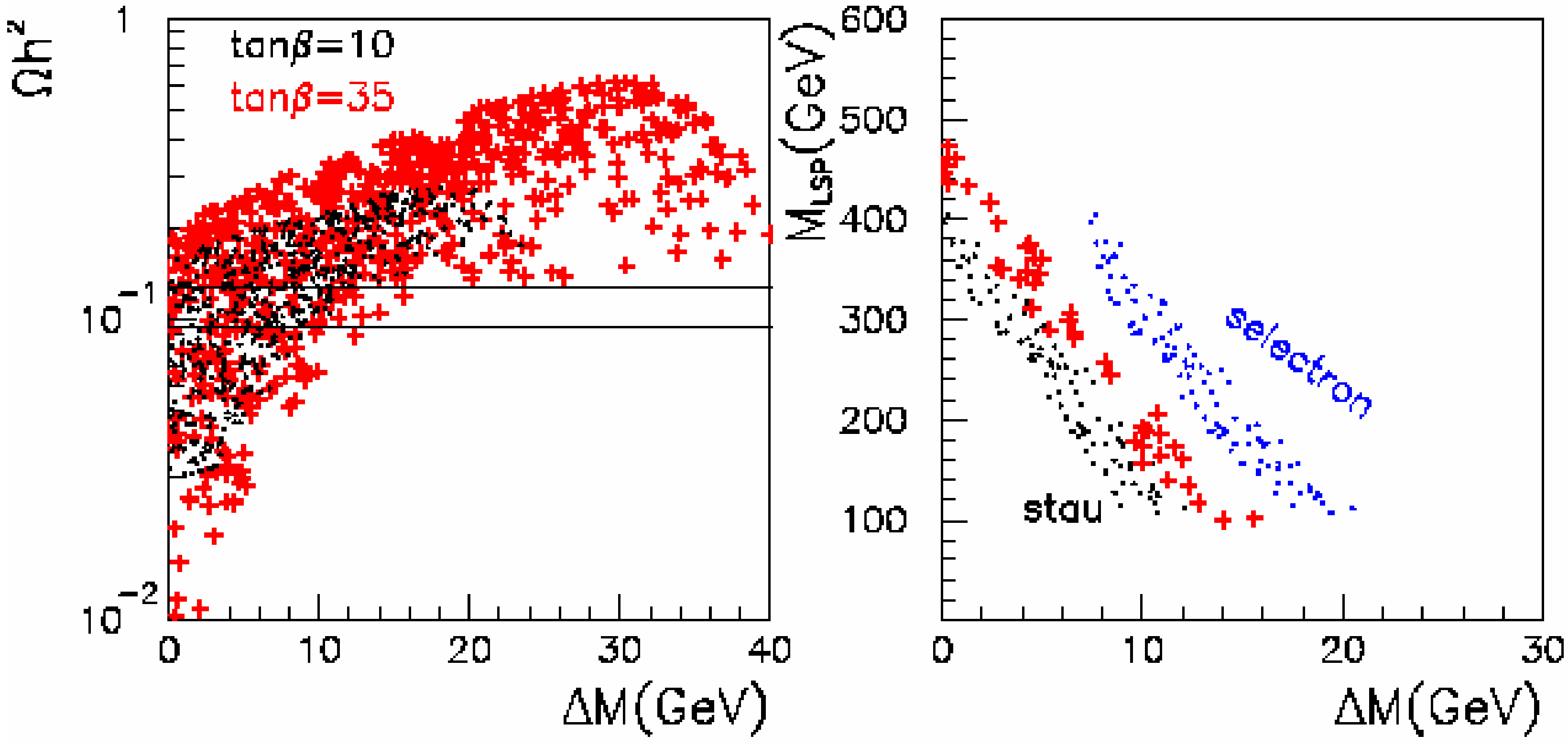
- **How precisely do these parameters need to be measured at LHC+LC colliders to have prediction for Ωh^2 competitive with PLANCK**

  → **Consistency check on cosmological model**

- **What is impact on Ωh^2 of uncertainties in evaluation of sparticle spectra, in particular:**

  - **Mtop dependence in focus point region**
  - **Mb/Mtop dependence in Higgs funnel at large tanβ**

NLSP-LSP mass difference in coannihilation region



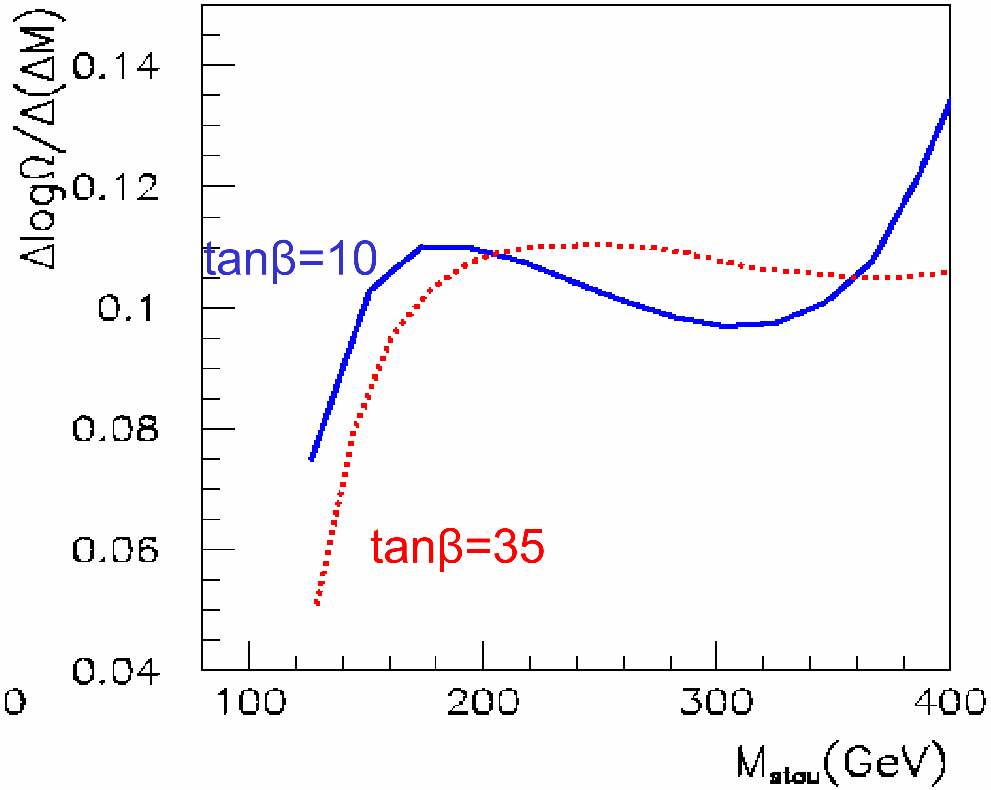
In mass range relevant for LC, typical ΔM(stau χ)= 5-15 GeV, ΔM(eχ)=12-20 GeV

Scenarios with smaller ΔM allowed but require an additional component for darkmatter

NLSP-LSP mass difference and relic density

In the coannihilation region (**Ωh^2** ≈ .1):

0.15-0.4GeV precision on
Δ M (stau-χ) needed for 2% prediction
of **Ωh^2**



Important to measure precisely mass of stau in coannihilation region:
LC can make precise measurements of sleptons with small ΔM
See studies of Zhang and Martyn (LCWS)

The focus point region

- μ is small, $\tilde{\chi}_1^0, \tilde{\chi}_2^0, \tilde{\chi}_1^+$ are light

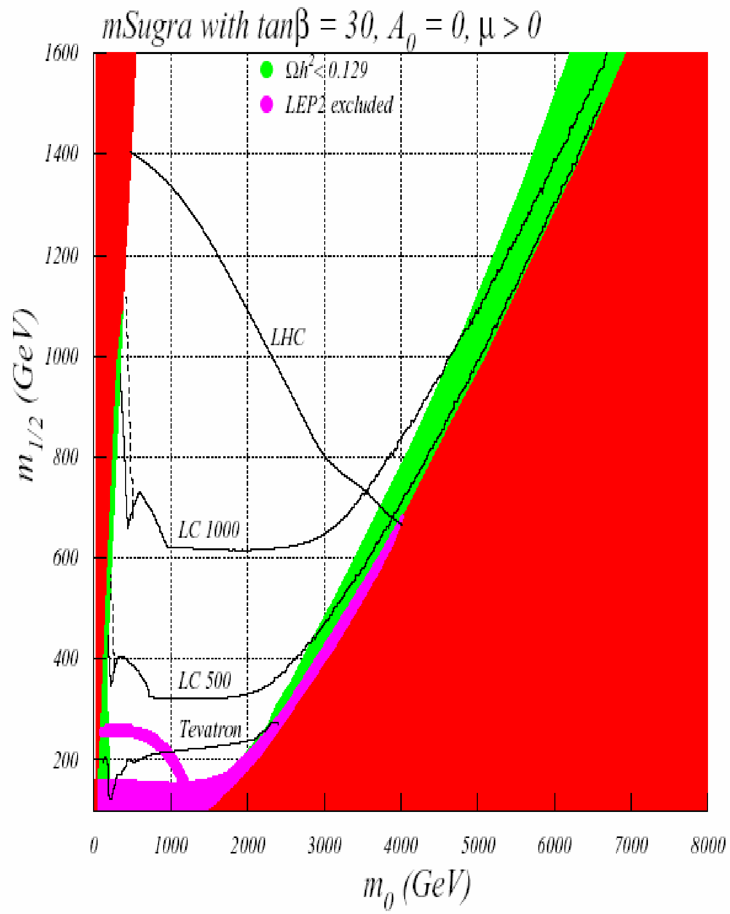
  Efficient annihilation/coannihilation into gauge bosons

  Typically degenerate gauginos lead to $\Omega h^2 < .094$

Sfermions are heavy : difficult for LHC

Potential for LC in gaugino sector

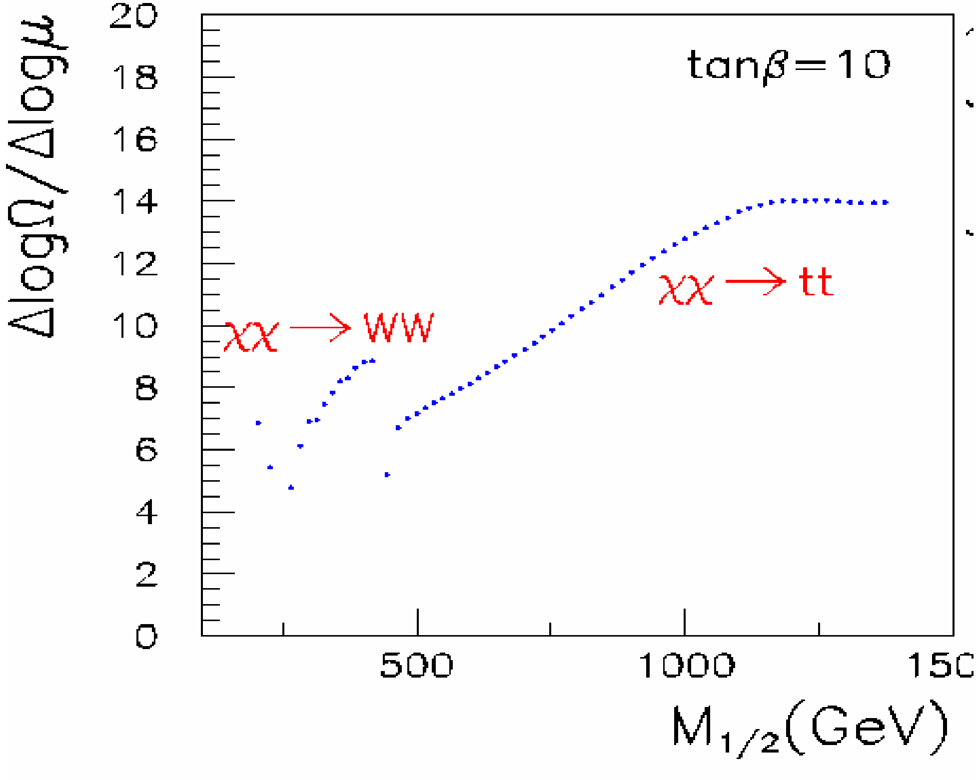
Note:Direct detection experiments have good potential in focus point region



Baer et al , hep-ph/0311351

The focus point region

In the focus point region
($\Omega h^2 \approx .128$):



0.2-0.3% precision on μ necessary for 2% prediction of Ω

Focus point region - observables

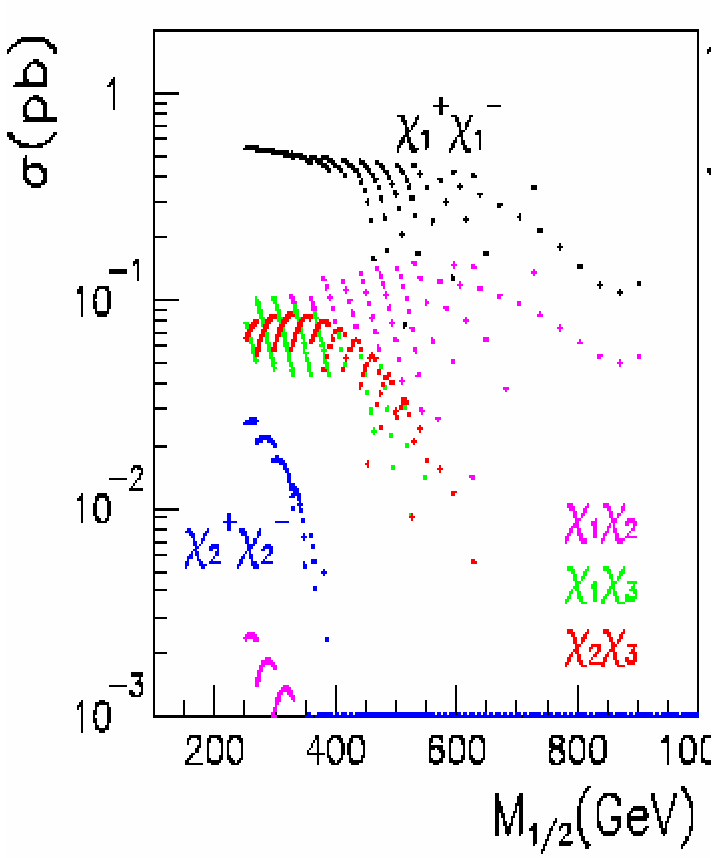
- In region where neutralino annihilate to W+W-/ZZ: typically 3 neutralinos+ chargino are accessible at LC500

What precision can be reached on μ?

For SPS1a combined LHC-LC analysis : %level on μ

`Desch et al hep-ph/0312069`

Here light chargino/neutralino mass depend sensitively on μ: expect good precision already from mass measurement



RGE codes and relic density

- **In general RGE codes get rather good agreement for the sparticle spectra, but difficult regions are the ones interesting for relic density:**
  - **Focus point**
    - **Higgsino/gaugino fraction determines coupling of χ to Z, fermions… and determines main annihilation cross-section ($\chi\chi \rightarrow ff$, WW)**
  - **Large tanβ (mass of Higgs)**
  - **Coannihilation (need precise mass difference)**

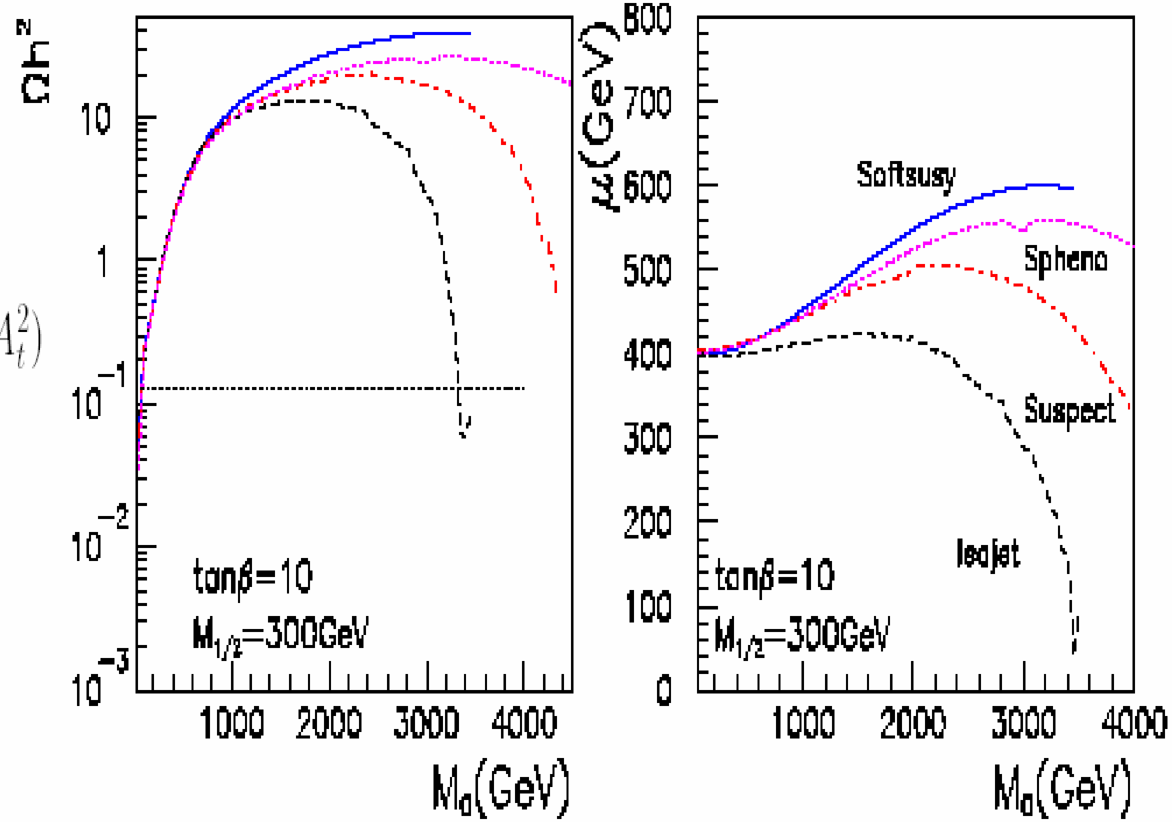
Influence of RGE code on relic density
Focus point region

Running of $m^2_{H_2}$ very sensitive to top Yukawa

$$\frac{m^2_{H_2}}{dt} \approx \frac{3}{8\pi^2} h_t (m^2_{\tilde{Q}} + m^2_{\tilde{U}} + m^2_{H_2} + A^2_t)$$

μ parameter also sensitive to top Yukawa

$$\mu^2 = \frac{\overline{m}^2_{H_1} - \overline{m}^2_{H_2} \tan^2\beta}{\tan^2\beta - 1} - \frac{1}{2} M^2_Z$$



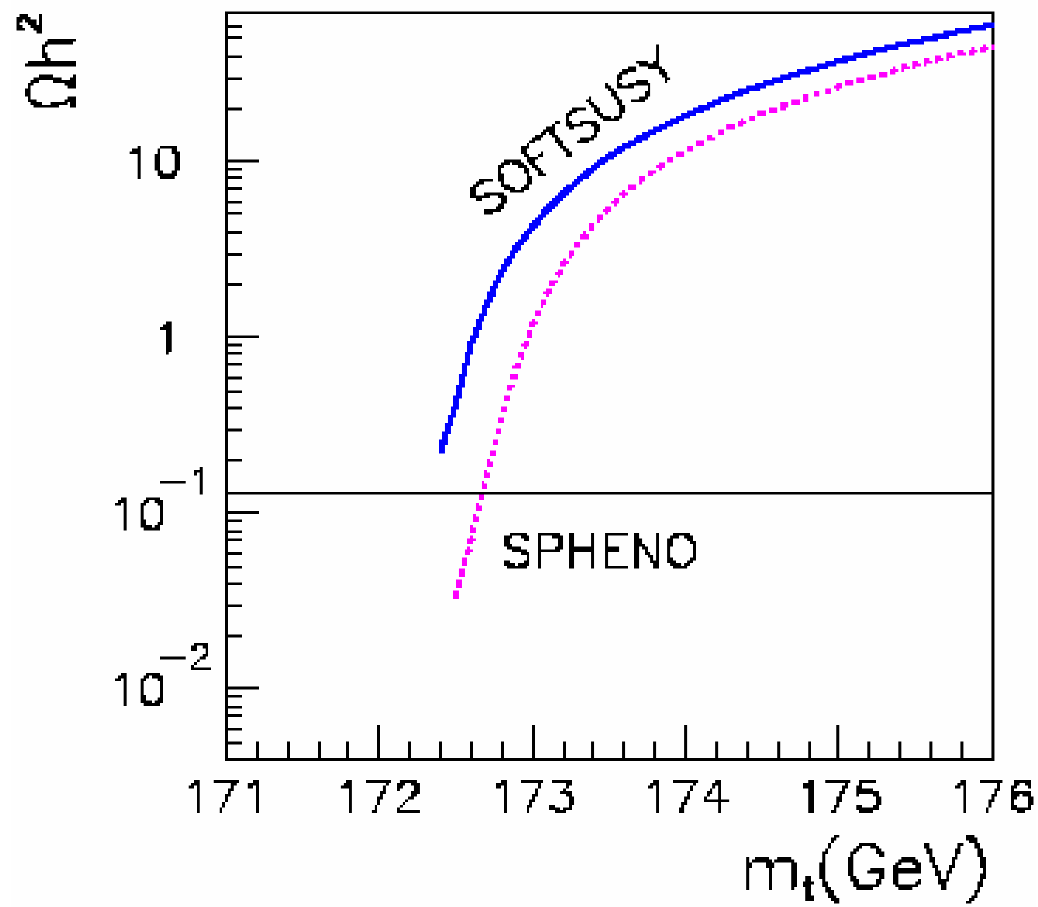
Focus point in mSUGRA: mtop dependence

Strong dependence on mt

With expected precision from hadron Collider (Δmt=1-2GeV)
→one order of magnitude change in Ωh^2

With expected precision from LC Δmt=0.1GeV still large corrections to Ωh^2 (up to 100%)

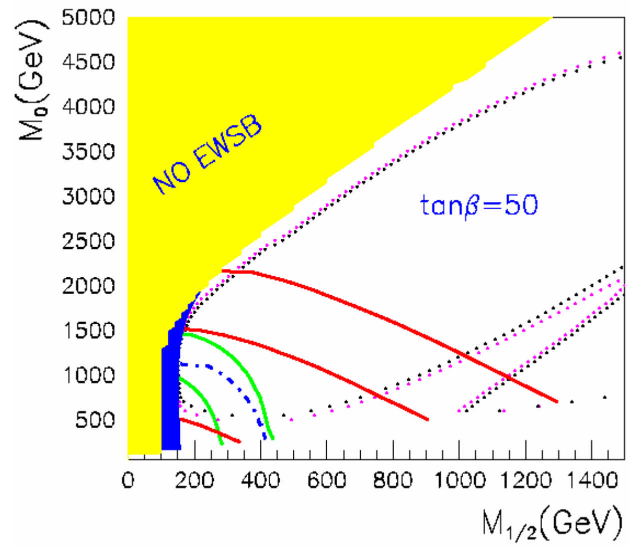
Need to improve on theoretical predictions



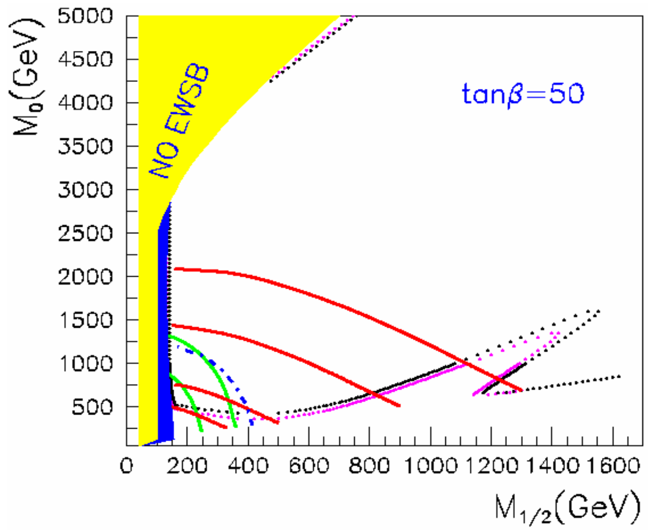
M0=3.3TeV
M1/2=300GeV

Heavy Higgs annihilation

- **Most of Heavy Higgs annihilation region at large tanβ is not accessible to LC500.**
- **Even at low M1/2, important contribution from heavy Higgs exchange as well as slepton exchange**
  - **What are relevant parameters and how precisely should they be measured to get precise estimate of relic density (MA≈300-400GeV)**



Mt=172



Mt=175

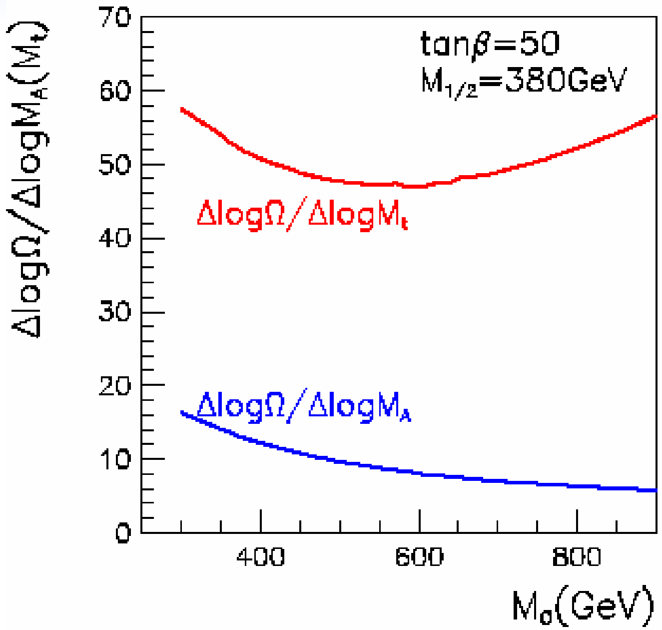
MA dependence

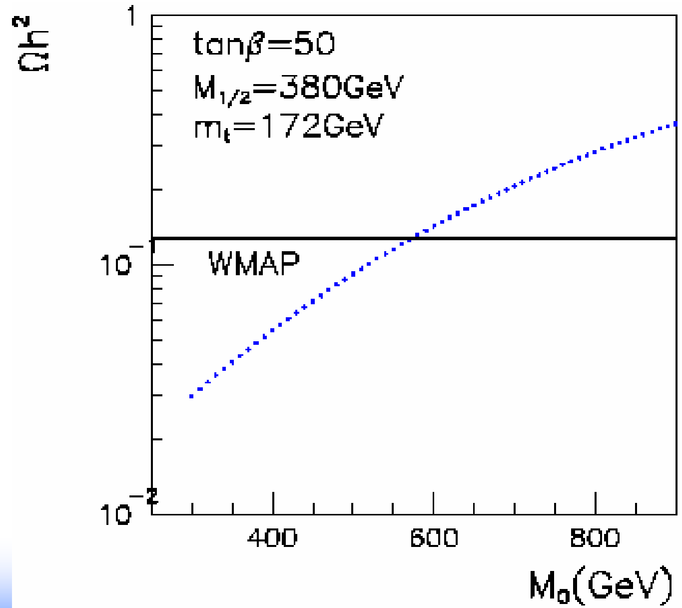
.2% (1GeV) precision on MA needed for
2% prediction of Ωh^2

Within mSUGRA also strong dependence
on top quark mass

With expected precision from LC
(Δmt =.1GeV) can predict Ωh^2 with
2-3% precision

Only weak dependence on μ and on mb
(not the case for heavier Higgs)





G. Bélanger

Summary

- **Precision measurement of NLSP-LSP mass difference at LC essential to be competitive with PLANCK precision on relic density in coannihilation region**
- **In focus point region, need high precision determination of μ .**
- **At large $\tan\beta$ need high precision determination of MA.**
- **To go back to origin of supersymmetry breaking mechanism, high-precision determination of mt is needed in focus point region (also improvement in precision in RGE) and in heavy Higgs annihilation region**