NLO $b \rightarrow s\gamma$, LSP– and Higgs limits in the CMSSM

W. de Boer[a], M. Huber

University Karlsruhe

A. Gladyshev, D. Kazakov

JINR, Dubna

ICHEP2000
Osaka, July 29, 2000

Outline

- Constrained MSSM fits
- $b \rightarrow s\gamma$ in NLO
- Higgs mass predictions in the CMSSM
- LEP LSP– and Higgs limits

[a]Talk at: http://home.cern.ch/~deboerw

CMSSM Fitprocedure

- Choose the 9 GUT parameters:
  α_{GUT}, M_{GUT}, m_0, $m_{1/2}$
  μ, $\tan\beta$, $A(0)$, $Y_t(0)$, $Y_b(0)$
- Minimize the Higgs potential in order to determine M_Z
- Calculate masses and couplings at low energies by integrating about 30 coupled RGE and decoupling sparticles at thresholds
- calculate $Br(b \to s\gamma)$
- Determine the best parameters by minimizing:

$$\chi^2 = \sum_i \frac{(\alpha_i(M_Z) - \alpha_i(MSSM))^2}{\sigma_i^2} \quad \to M_{GUT}, \alpha_{GUT}$$

$$+ \frac{(m_t - 173)^2}{\sigma_t^2} + \frac{(m_b - 4.9)^2}{\sigma_b^2} + \frac{(m_\tau - 1.7771)^2}{\sigma_\tau^2} \quad \to Y_t,\ \to Y_b = Y_\tau,\ \to \tan\beta$$

$$+ \frac{(M_Z - 91.18)^2}{\sigma_Z^2} \quad \to \mu^2$$

$$+ \frac{(Br(b \to s\gamma) - 3.15 * 10^{-4})^2}{\sigma_{bsg}{}^2}$$

$$+ \frac{(\tilde{M} - \tilde{M}_{exp})^2}{\sigma_{\tilde{M}}^2}$$

m_0 and $m_{1/2}$ strongly correlated.

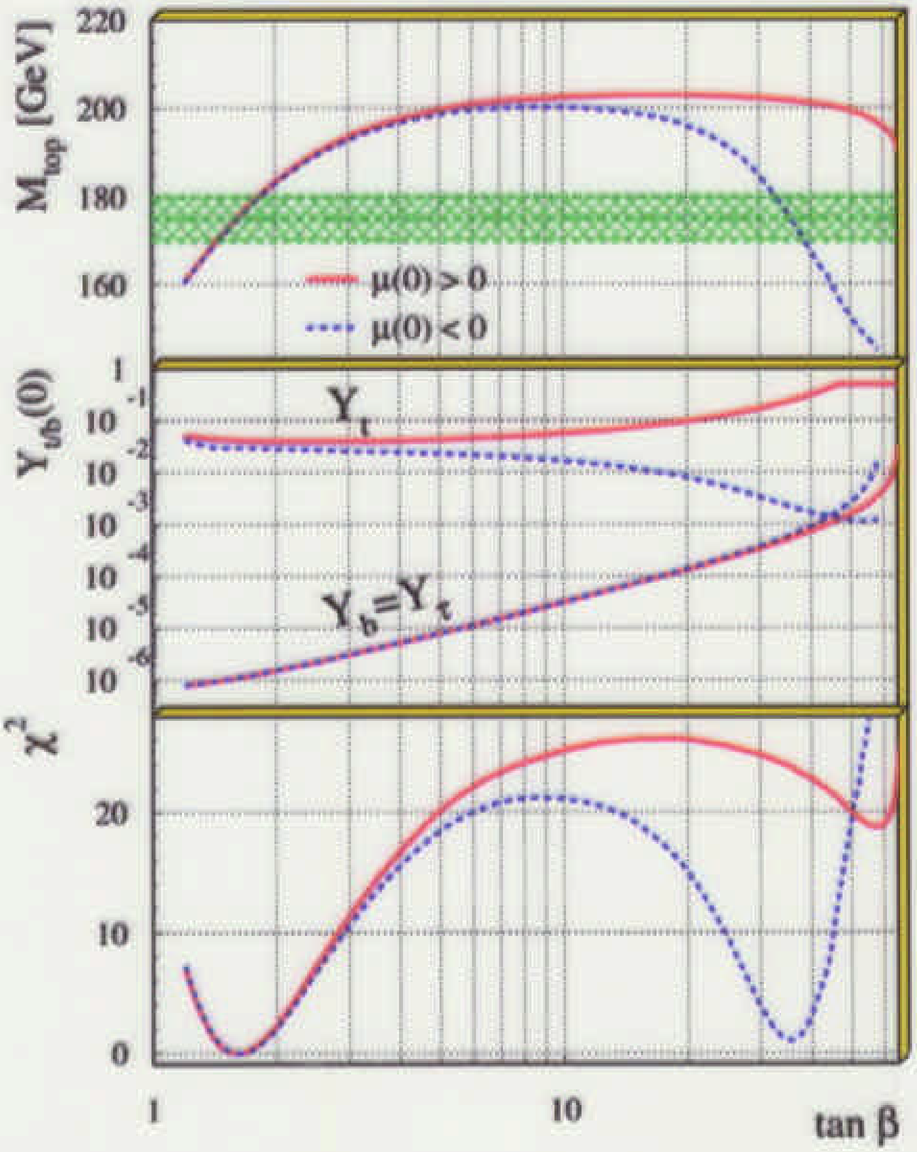
Repeat fits for all pairs of m_0, $m_{1/2}$

Yukawa Unification

$$M_t^2 = (4\pi v)^2\, Y_t\, \frac{\tan\beta^2}{1+\tan\beta^2}$$
$$M_b^2 = (4\pi v)^2\, Y_b\, \frac{1}{1+\tan\beta^2}$$
$$M_\tau^2 = (4\pi v)^2\, Y_\tau\, \frac{1}{1+\tan\beta^2}$$

$Y_b = Y_\tau \rightarrow$

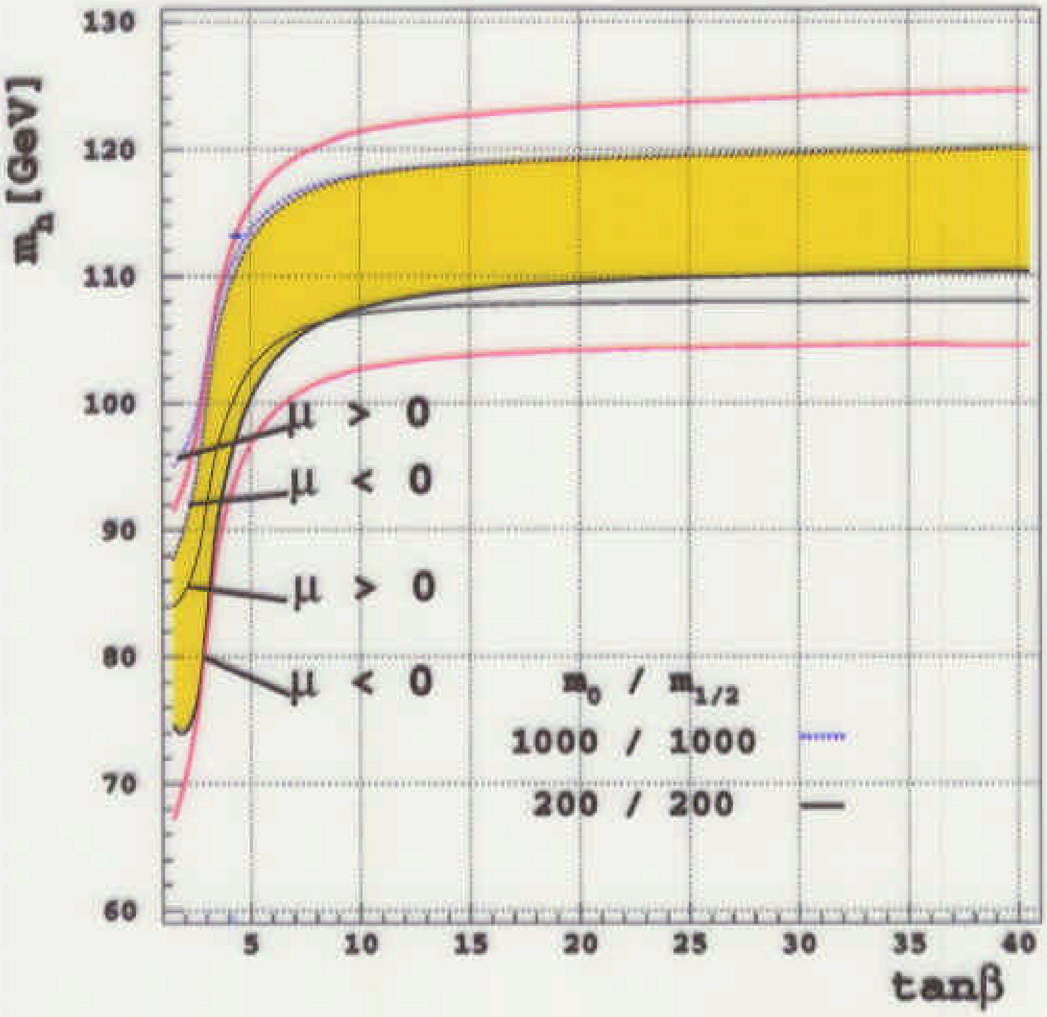
Relation between M_t and $\tan\beta$



Preferred: $\tan\beta = 1.65 \pm 0.3$ or $30 < \tan\beta < 40$

Low $\tan\beta$ scenario excluded by Higgs limit!

Higgs mass vs $\tan\beta$



RGE improv. two loop by M. Carena, M. Quirós and C. Wagner

4.1 113.3

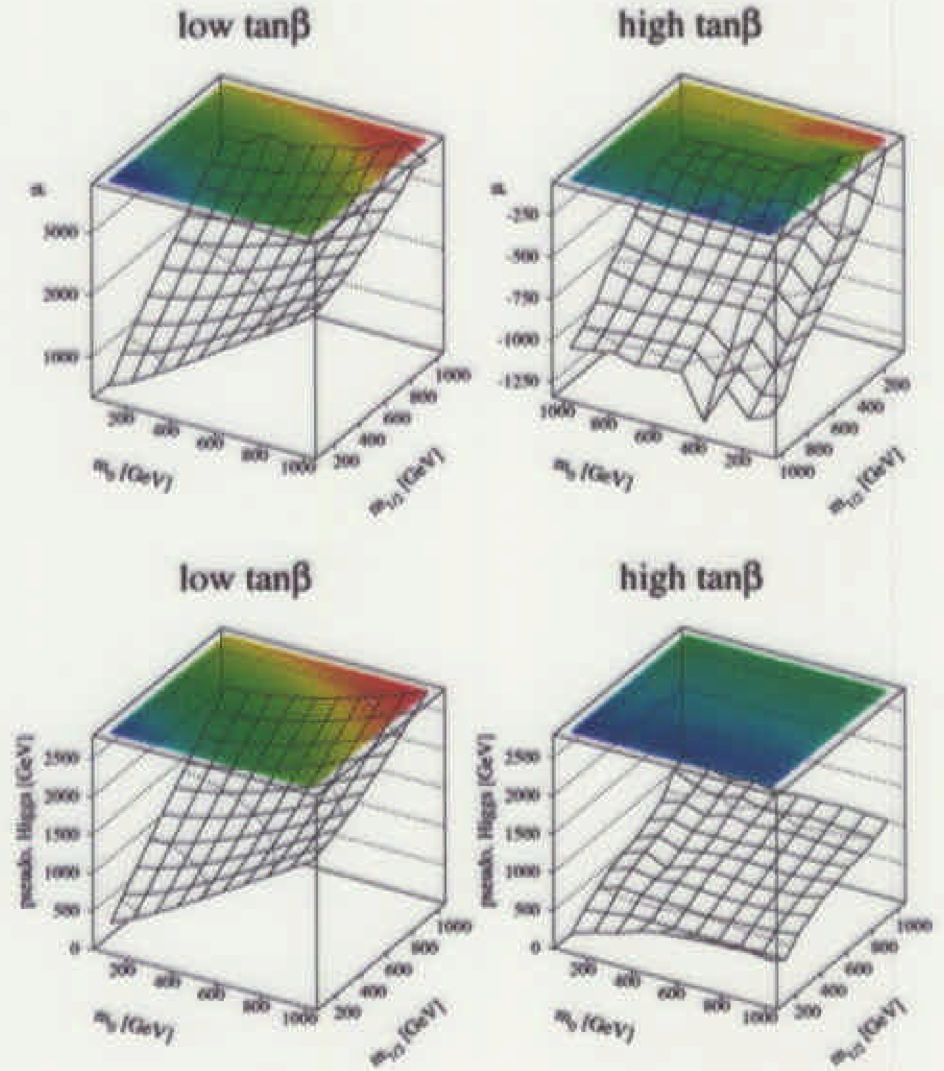
$\tan\beta \leq$ **3.3 excluded by Higgs limit of 107.9 GeV!**

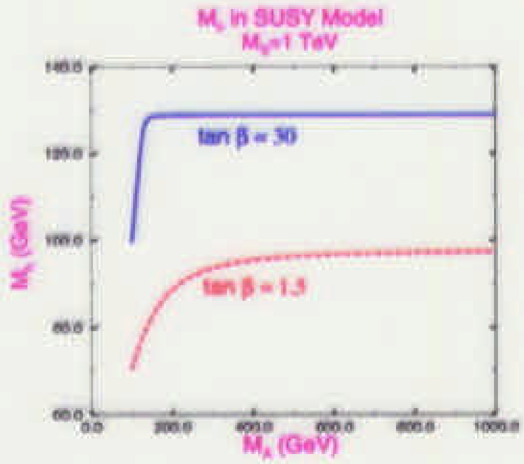
Large $\tan\beta$: $105 < m_h < 125$ **GeV**

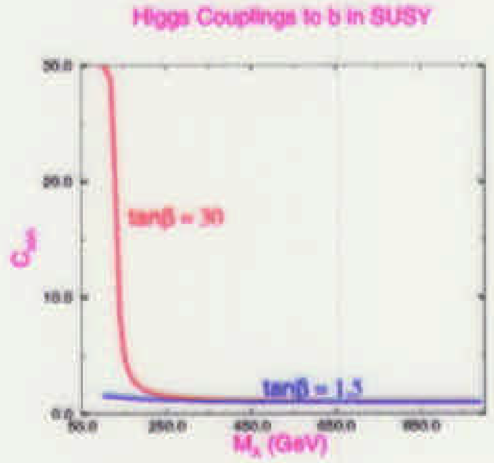
For $m_t = 175\text{GeV}$: $110 < m_h < 120$ **GeV**

or $m_h = 115 \pm 3\,\text{(stopmass)} \pm 1.5\,\text{(stopmixing)} \pm 2\,\text{(theory)}$ GeV.
$(\sigma = interval/\sqrt{12})$

Pseudoscalar Higgs heavy by EWSB







For large m_A → MSSM Higgs SM-like! (Dawson hep-ph/9712464)

$b \to s\gamma$

- **New measurements:**

BELLE : $(3.34 \pm 0.50 ^{+0.34}_{-0.26} {}^{+0.38}_{-0.28}) \cdot 10^{-4}$

CLEO (LP99, Stanford):

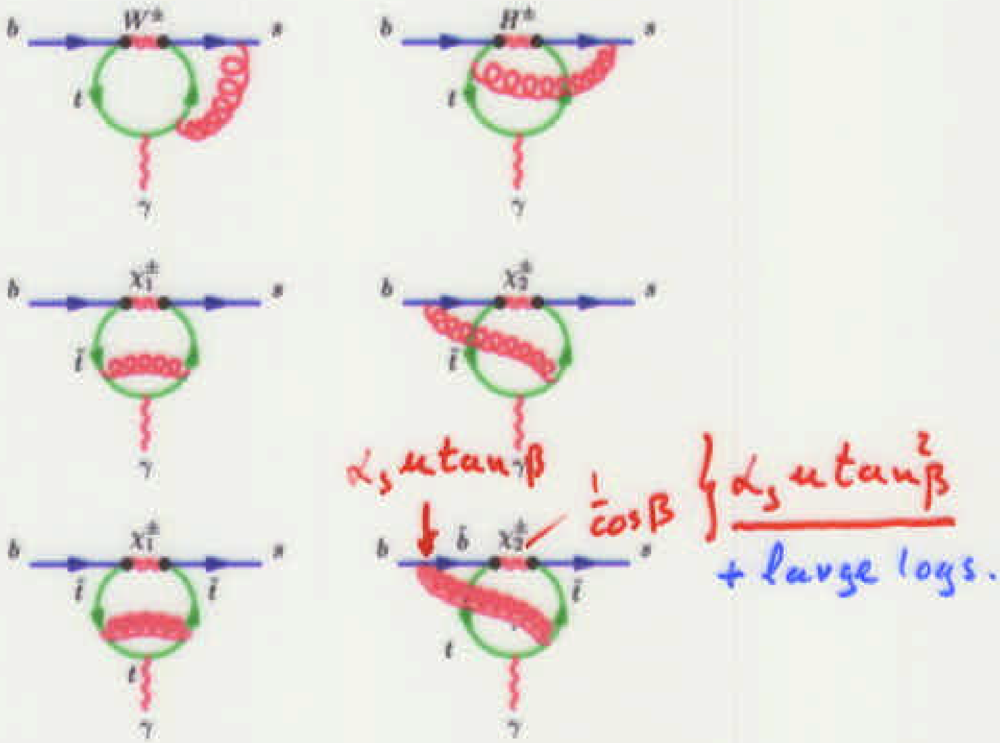
$$\mathrm{BR}(b \to s\gamma) = (3.15 \pm 0.35 \pm 0.32 \pm 0.26) \cdot 10^{-4}$$

ALEPH (PL B429 (1998) 169):

$$\mathrm{BR}(b \to s\gamma) = (3.11 \pm 0.80 \pm 0.72) \cdot 10^{-4}$$

- **New NLO calculations (QCD corrections):**

Chetyrkin, Misiak, Münz, Ciuchini, Degrassi, Gambino, Giudice....



NLO contribution for Chargino Ampl. $\propto \alpha_s \mu \tan^2\beta$
For large $\tan\beta$ NLO chargino contributions very large!
Preferred sign of μ now SAME as sign required for $b-\tau$ unification.

$\mathrm{b} \rightarrow \mathrm{s}\gamma$ NLO Approximations

Paper for SUSY NLO at high $\tan\beta$: M. Ciuchini, G. Degrassi, P. Gambino, G.F. Giudice, Nucl. Phys. B 534 (1998) 3-20.
However: it assumes that only one stop constibution dominates, i.e. a large stop splitting with one stop heavier than the other.
This does not hold , if the SUSY scale is well above the top mass!
Then the stop1 and stop2 have similar masses and the mixing angle is moderate.
This is a problem! Complete calculations under way, including both stops and their mixing.
Present presentation gives only qualitative features, which are nevertheless very interesting, since they show that with the preferred opposite sign of μ in NLO, the whole large $\tan\beta$ scenario is allowed again.

$$\delta^x C_7^{eff}(\mu_W) = \underbrace{\delta^x C_7^{(0)eff}(\mu_W)}_{\text{LO}} + \underbrace{\frac{\alpha_s(\mu_W)}{4\pi}\delta^x C_7^{(1)eff}(\mu_W)}_{\text{NLO}}$$

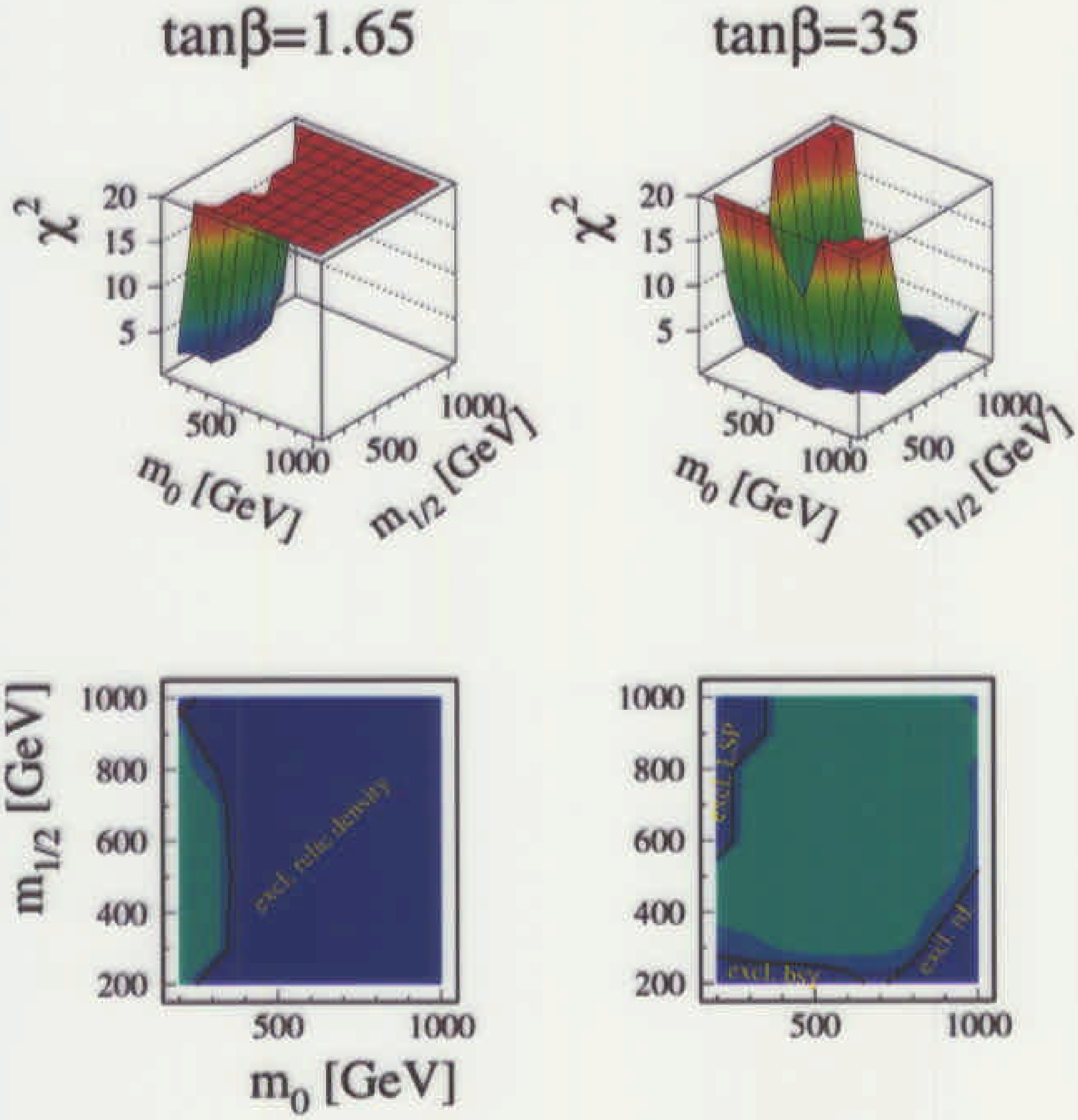
$$\underbrace{\delta^x C_7^{(0)eff}(\mu_W)}_{\text{LO}} \approx \sum_{j=1,2} [K_j\,(x_1 + x_2\cos\theta_t + x_3\sin\theta_t)]$$

$\cos\theta_t$: *heavy stop* $\sin\theta_t$: *light stop*

$$\underbrace{\delta^x C_7^{(1)eff}(\mu_W)}_{\text{NLO}} \approx \sum_{j=1,2} [K_j\,(a\sin\theta_t + b\sin\theta_t + c\sin\theta_t)]$$

$\sin\theta_t$: *only light stop in NLO*

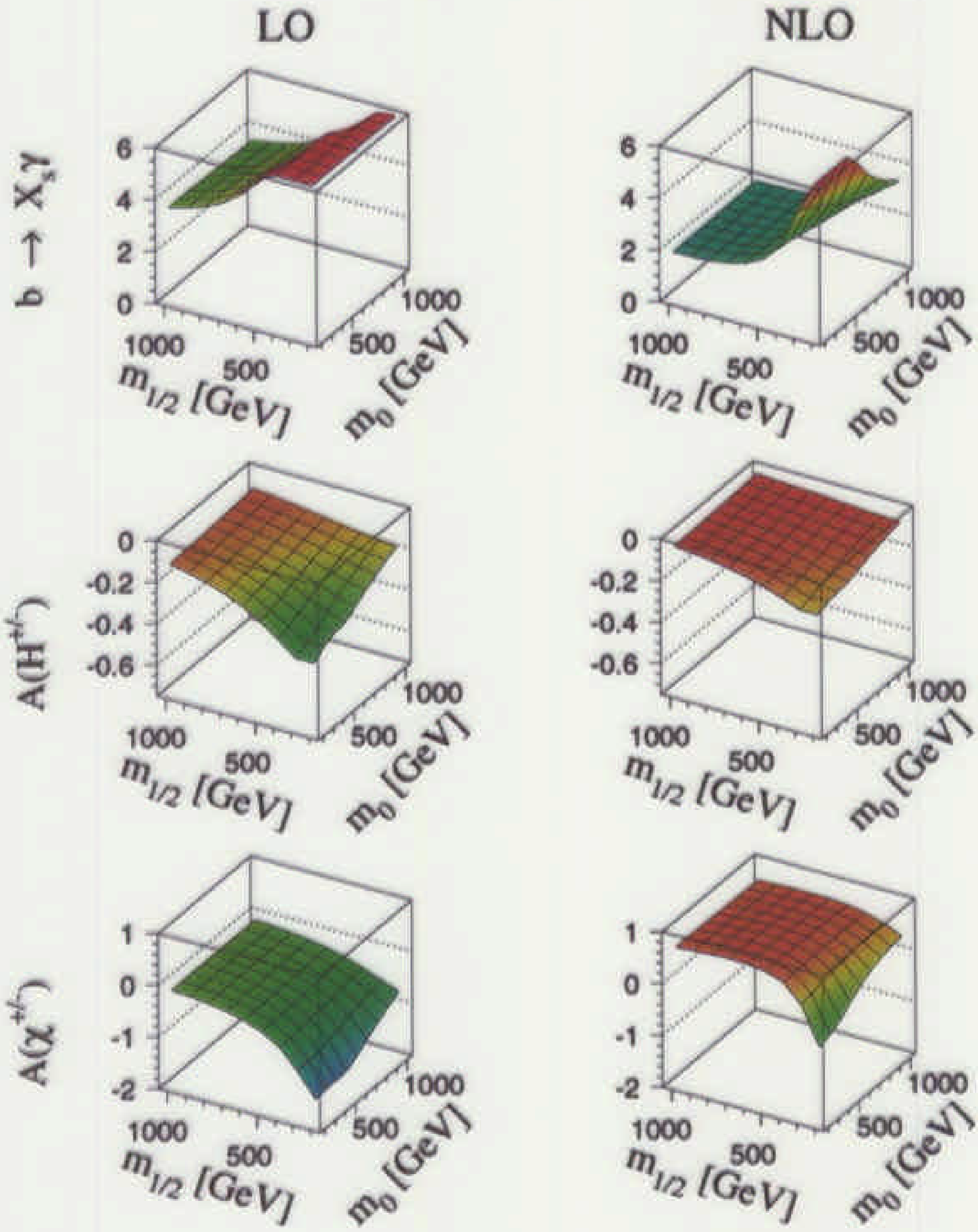
Allowed Parameter Regions in NLO $b \to s\gamma$



$b \to s\gamma$ Amplitudes

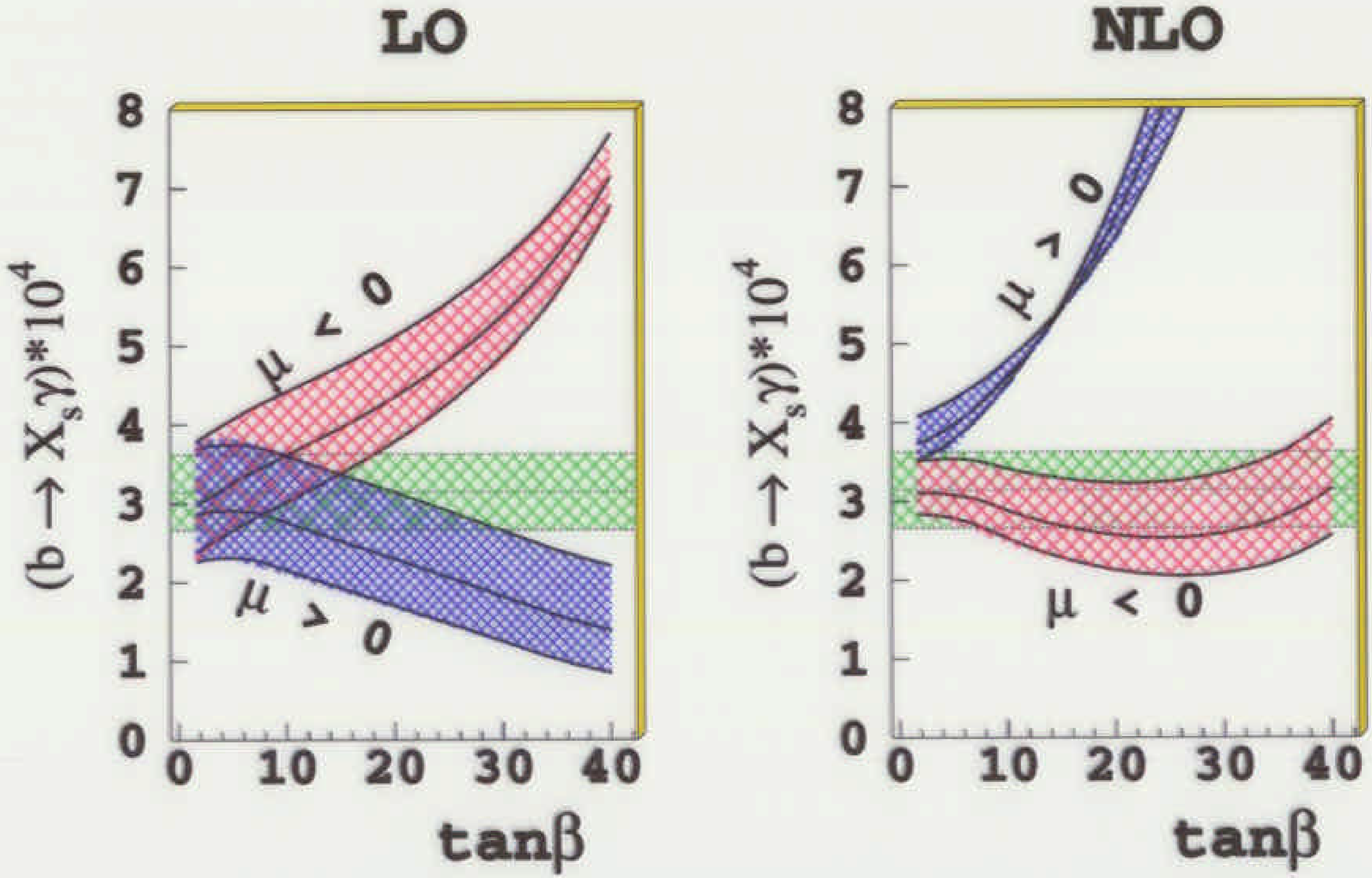
x10²

$\tan\beta = 35, \mu < 0$



SM amplitude : −0.57 [10⁻²)

$b \to s\gamma$ versus $\tan\beta$



Dark Matter discovered?

R. Bernabei et al., Phys. Lett. B480 (2000) 21

Search for WIMP annual modulation signature: results from DAMA/NaI-3 and DAMA/NaI-4 and the global combined analysis

R. Bernabei[a], P. Belli[a], R. Cerulli[a], F. Montecchia[a], M. Amato[b], G. Ignesti[b], A. Incicchitti[b], D. Prosperi[b], C.J. Dai[c], H.L. He[c], H.H. Kuang[c], J.M. Ma[c]

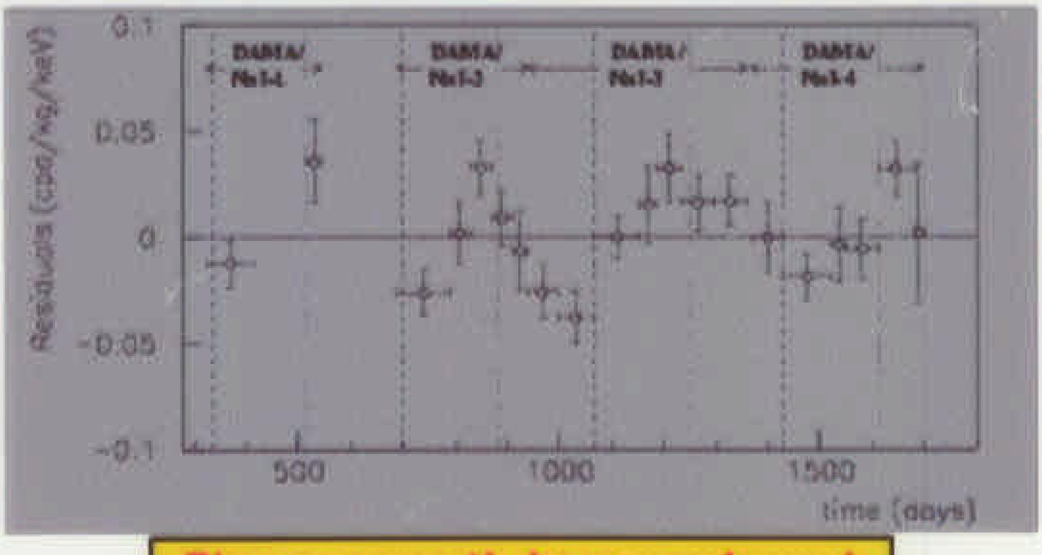
[a] *Dip. di Fisica, Universita' di Roma "Tor Vergata" and INFN, sez. Roma2, I-00133 Rome, Italy*
[b] *Dip. di Fisica, Universita' di Roma "La Sapienza" and INFN, sez. Roma, I-00185 Rome, Italy*
[c] *IHEP, Chinese Academy, P.O. Box 918/3, Beijing 100039, China*

Abstract

The data, collected by the ≃ 100 kg NaI(Tl) DAMA set-up at the Gran Sasso National Laboratory of I.N.F.N. during two further yearly cycles (DAMA/NaI-3 and DAMA/NaI-4; statistics of 38475 kg·day), have been analysed in terms of WIMP annual modulation signature. The results agree with those previously achieved. The cumulative analysis of all the available data (DAMA/NaI-1 to 4; statistics of 57986 kg·day) favours the possible presence of a WIMP with $M_w = (52^{+10}_{-8})$ GeV and $\xi\sigma_p = (7.2^{+0.4}_{-0.9}) \cdot 10^{-6}$ pb at 4 σ C.L., when standard astrophysical assumptions are considered. The allowed mass extends up to 105 GeV (1 σ) when the uncertainty on the mean value of the local velocity v_0 is taken into account and up to 132 GeV (1 σ) in case a possible bulk halo rotation is also considered. Moreover, the allowed regions extend to lower $\xi\sigma_p$ values when the limit achieved in DAMA/NaI-0 is included in the cumulative analysis (favouring e.g., in case of standard assumptions, $M_w = (44^{+12}_{-9})$ GeV and $\xi\sigma_p = (5.4 \pm 1.0) \cdot 10^{-6}$ pb at ≃ 4 σ C.L.). The regions in the $\xi\sigma_p$ versus M_w plane allowed for the possible signal at 3 σ C.L. are given.

$M_{WIMP} = 52^{+10}_{-8}$ GeV
from recoil spectrum

DAMA discovered annual modulation signal?!



June

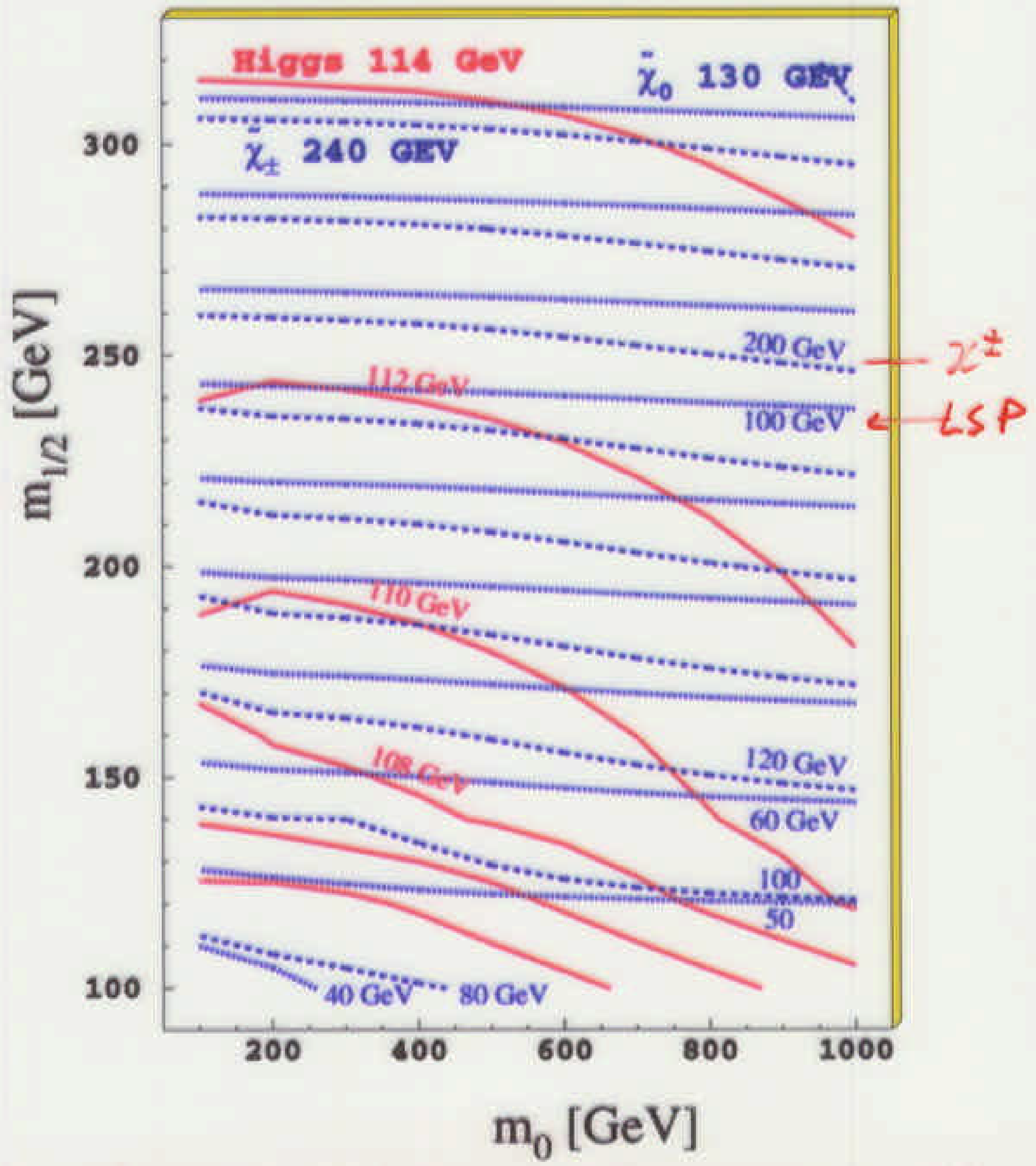
Phase correct! June maximum!

Is it the LSP?

Expected MSSM cross section much smaller!

Mass of 44^{12}_{-9} GeV hardly compatible with LEP

Large $\tan\beta$



Chargino $\geq$ 100 GeV $\rightarrow$ LSP mass $\geq$ 50 GeV

Summary

- NLO $b \to s\gamma$ have large terms $\propto \alpha_s \tan^2\beta$ (+ logs), which can change sign of chargino amplitude
  $\Rightarrow$
  Now same sign of μ as for Yukawa unification allowed $\Rightarrow$ NO Constraints from $b \to s\gamma$ in CMSSM with present uncertainties, especially if large uncertainties from missing higher orders are taken into account.
- Present SM Higgs limit of (113.3) 107.9 GeV excludes $\tan\beta < 3.3$, so low $\tan\beta$ CMSSM scenario excluded!
- For high (4.1) $\tan\beta$: $105 < m_h < 125$ GeV

  Uncertainties (estimated by $\sigma = interval/\sqrt{12}$) from following sources: :

$$m_h = 115 \pm 3\,(stopmass) \pm 1.5\,(stopmixing)$$

$$\pm 2\,(theory) \pm 5\,(topmass)\ \mathrm{GeV}.$$

- If DAMA results imply LSP of 52^{+10}_{-8} GeV, then it is at border of parameter space allowed by LEP. Will be settled by present LEP data taking. ???