Positron Fraction from Dark Matter Annihilation in the CMSSM

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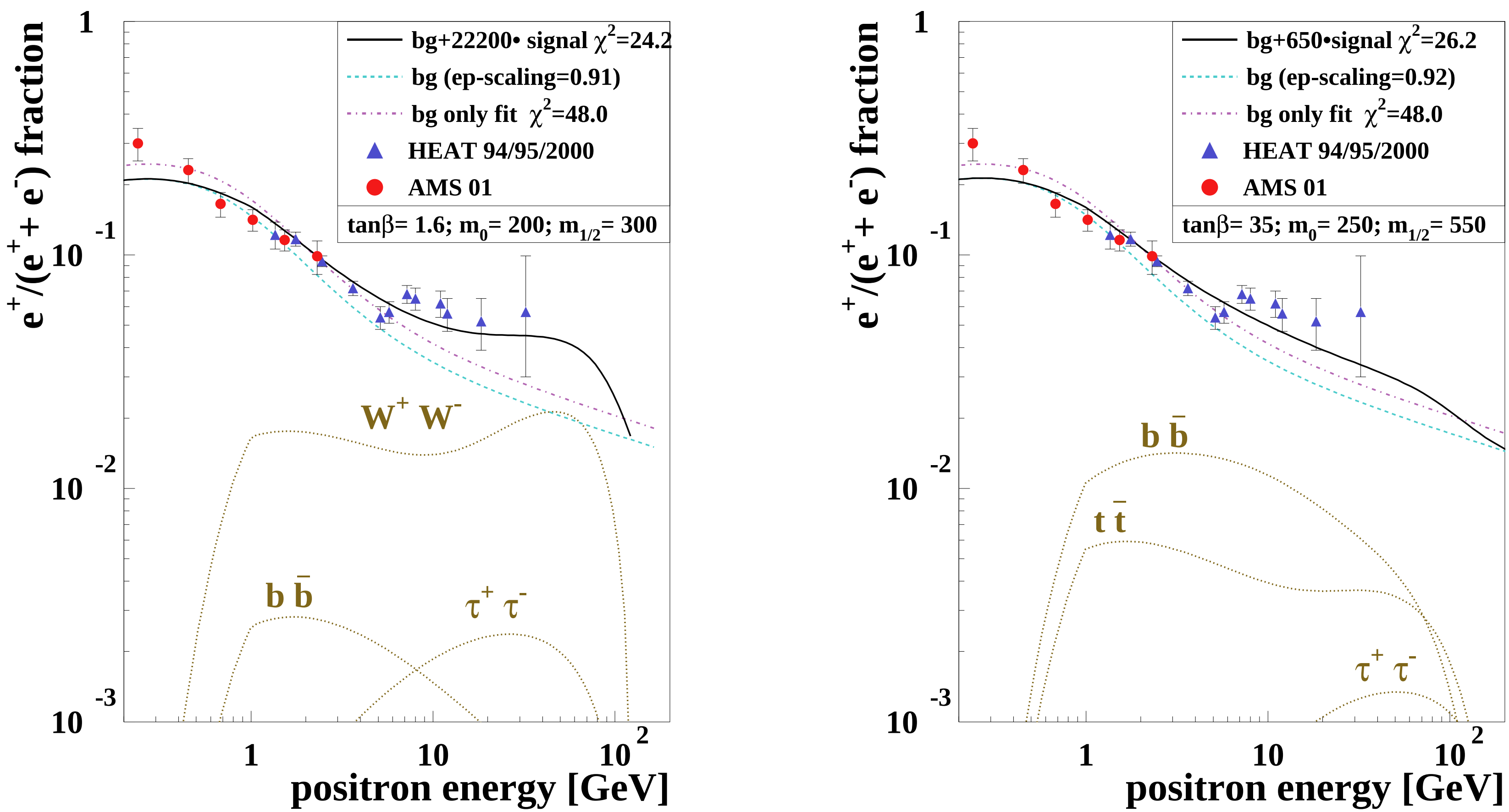
Outline

- CMSSM Constraints
- Positron fraction in the CMSSM Parameter Space
- Comparison with HEAT and AMS data
- Summary

Typical Fits to AMS+HEAT Data vs $\tan\beta$



$\tan\beta = 1.6\ m_\chi^0 = 120\ GeV$ $\qquad$ $\tan\beta = 35\ m_\chi^0 = 230\ GeV$

CMSSM Fitprocedure

Choose the 10 GUT supergravity inspired parameters:
$\mathbf{m_0},\ \mathbf{m_{1/2}}, \alpha_{\mathbf{GUT}},\ \mathbf{M_{GUT}}$
$\mu,\ \mathbf{tan}\beta,\ \mathbf{A(0)},\ \mathbf{Y_t(0)},\ \mathbf{Y_b(0)}, \mathbf{Y_\tau(0)}$

Minimize the Higgs potential in order to determine $\mathrm{M_Z}$

Calculate masses and couplings at low energies by integrating about 30 coupled RGE's and decoupling sparticles at thresholds

calculate $Br(b \to s\gamma)$, a_μ^{SUSY}

Determine the best parameters by minimizing χ^2.

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

$$+\frac{(\mathbf{m_t} - \mathbf{173})^2}{\sigma_{\mathbf{t}}^2} \quad \to \mathbf{Y_t}$$

$$+\frac{(\mathbf{m_b} - \mathbf{4.9})^2}{\sigma_{\mathbf{b}}^2} \quad \to \mathbf{Y_b}$$

$$+\frac{(\mathbf{m_\tau} - \mathbf{1.7771})^2}{\sigma_\tau^2} \quad \to \mathbf{Y_\tau}$$

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

$$+\frac{(Br(b \to s\gamma) - 3.23 * 10^{-4})^2}{\sigma_{bsg}^2}$$

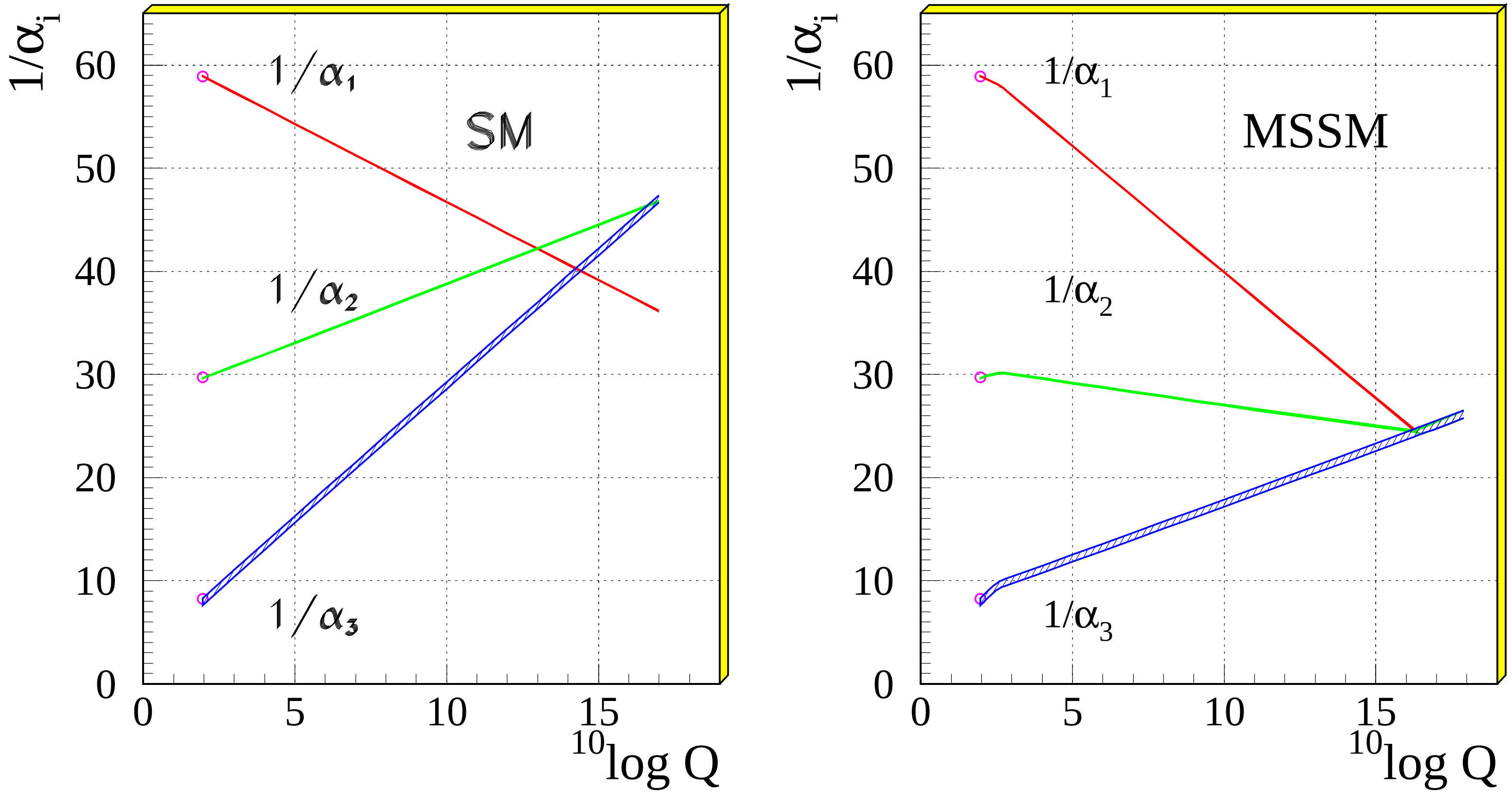
$$+\frac{(a_\mu^{SUSY} - 176 * 10^{-11})^2}{\sigma_{a_\mu}^2}$$

$$+\frac{(\tilde{M} - \tilde{M}_{lim})^2}{\sigma_{\tilde{M}}^2} \quad for\ \tilde{M} < \tilde{M}_{lim}$$

$$+\chi^2(global\ EW\ precision\ data\ from\ MSSM)$$

m_0 and $m_{1/2}$ strongly correlated. Repeat fits for all pairs of $m_0,\ m_{1/2}, \tan\beta$

Unification of the Coupling Constants in the SM and the minimal MSSM



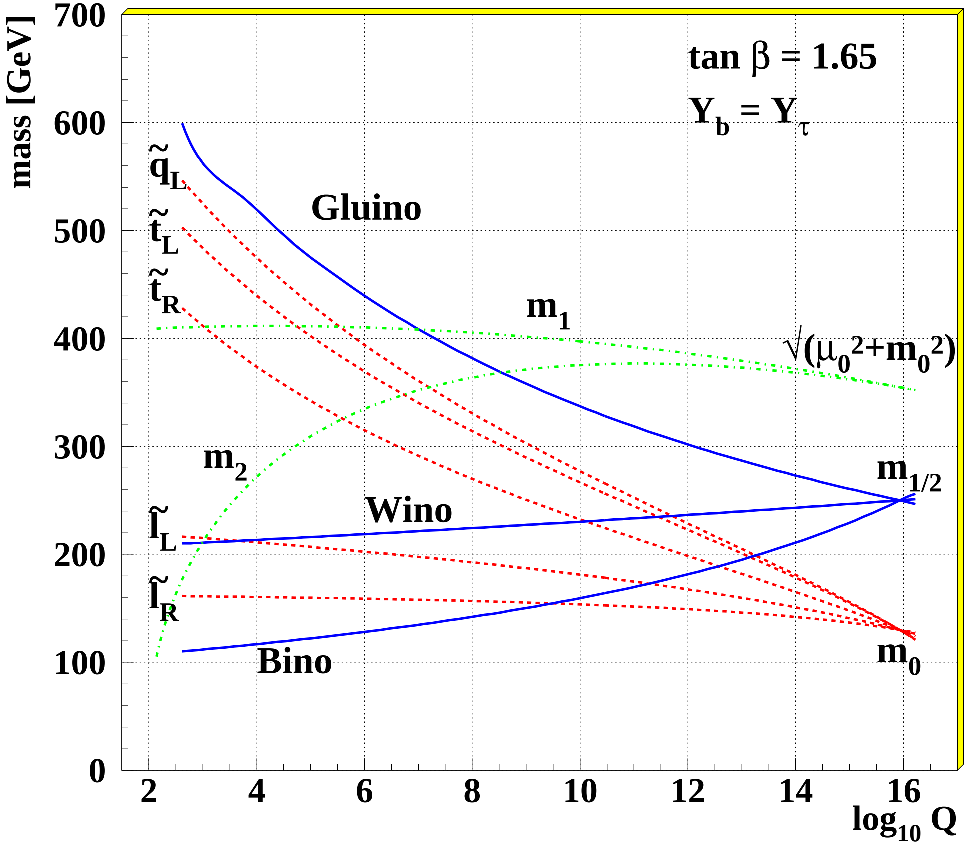
U. Amaldi, W. de Boer, H. Fürstenau, PL B260(1991)

$\alpha_1, \alpha_2, \alpha_3$ **coupling constants of electromagnetic –, weak–, and strong interactions**

$1/\alpha_i \propto \log Q^2$ **due to radiative corrections (LO)**

CMSSM Sparticle Spectrum

From RGE equations:



Characteristic MSSM Features:

Squarks and gluinos heavy through strong rad. corr.

Gaugino from U(1) (=Bino) Lightest Neutral SUSY Particle (LSP) (if $m_{1/2}$ not too large w.r.t. m_0)

Mass m_2 in Higgs potential driven negative by Y_t $\rightarrow$ EWSB (determines μ^2)

Higgs mixing parameter μ usually large compared with $m_{1/2}$

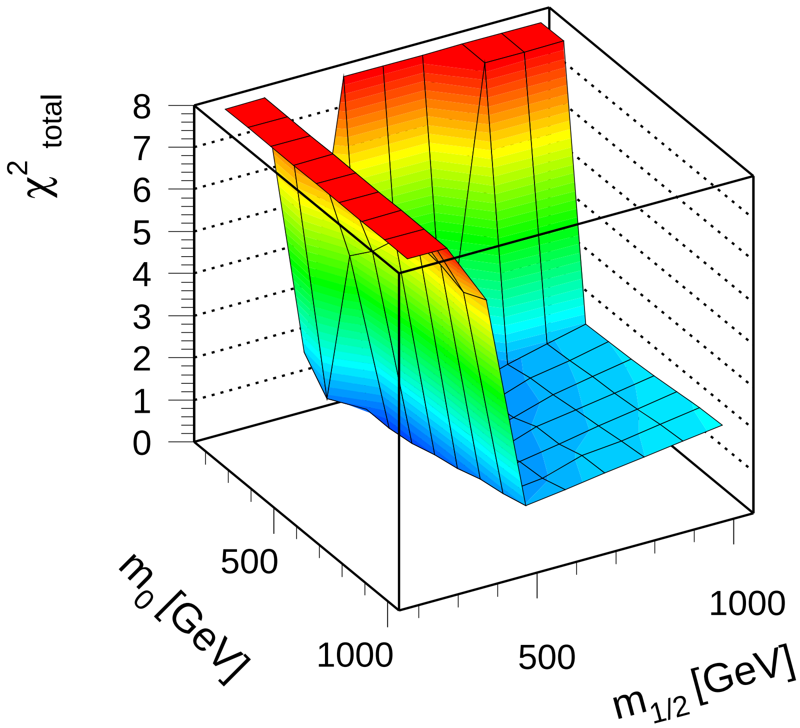
Consequently:

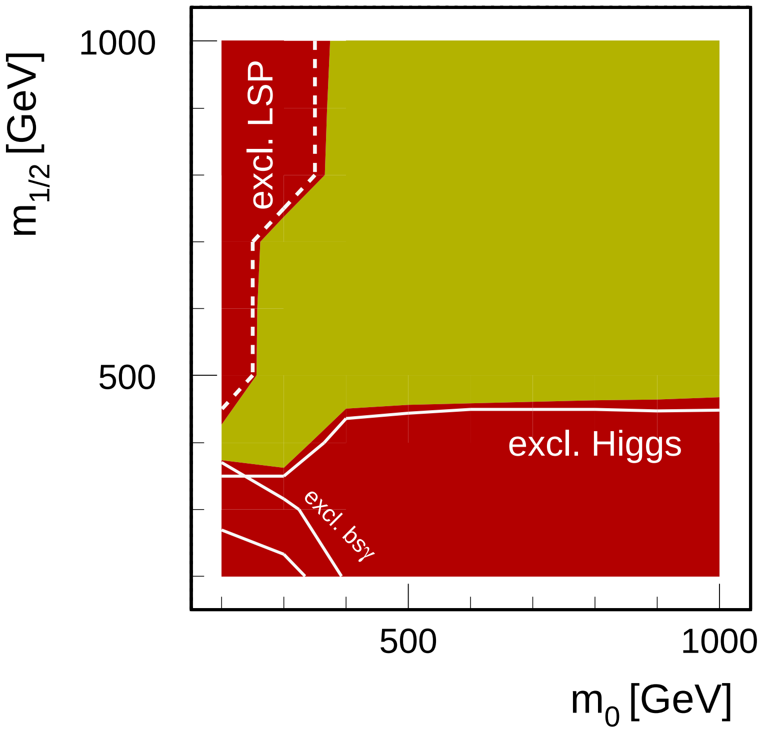
Pseudoscalar Higgs and higgsinos heavy $\rightarrow$

light Higgs SM-higgs-like

LSP bino-like, since no mixing with heavy higgsinos $\rightarrow$ very good dark matter candidate

Allowed Parameter Regions for $\tan\beta = 35$



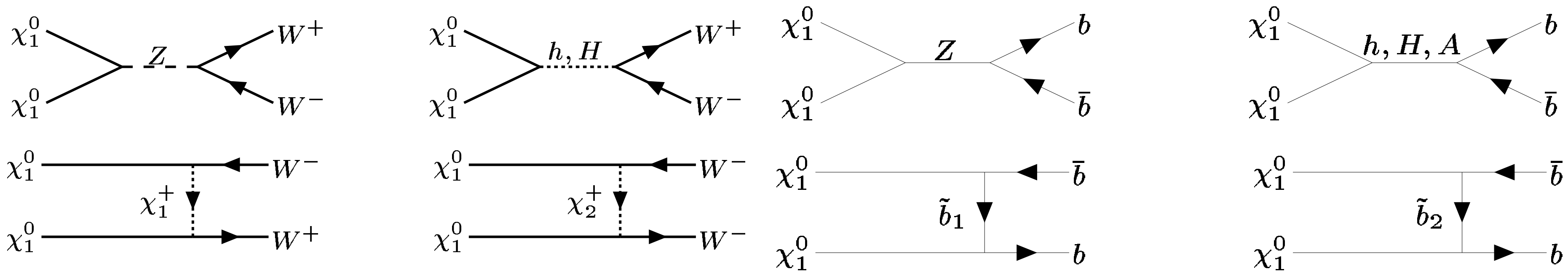


Constraints:Gauge Unification and EWSB

A_0 free! Fit prefers $A_0 > 0$ from $b \to s\gamma$ and $\mu > 0$ from $a_\mu \to$ strong constraint from $M_h > 114\,GeV$ (much less for $A_0 < 0$!!)

Main Diagrams for Neutralino Annihilation

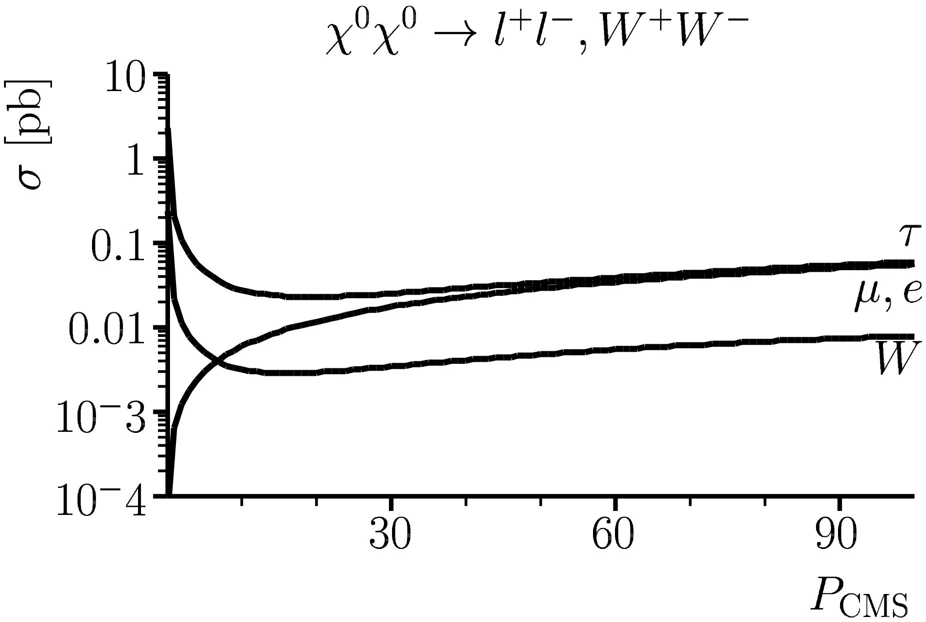
Gauge Bosons | **Fermions**

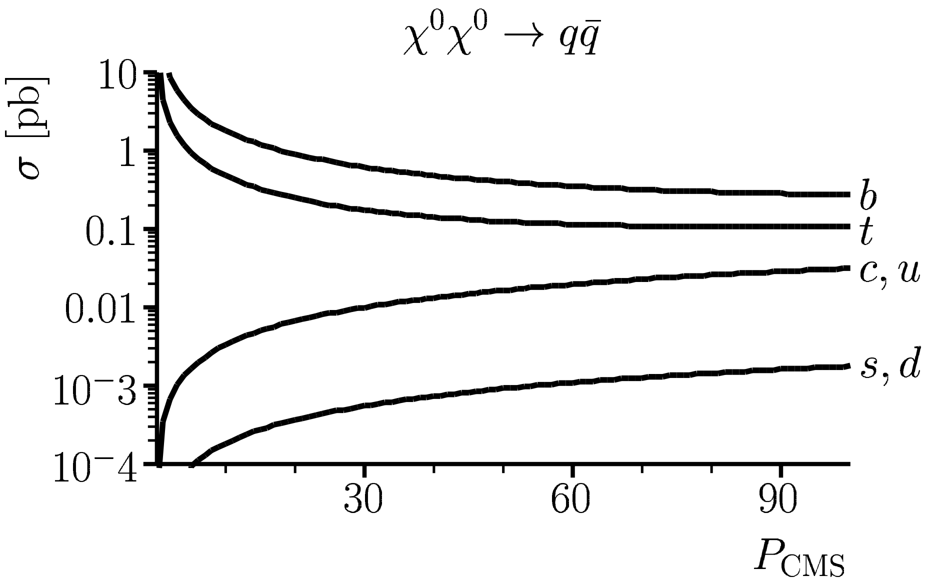


- **Only heavy final states relevant**
- **neutralinos are Majorana particles and fermions $\rightarrow$ Pauli-Principle at zero momentum $\rightarrow$ p-wave $\rightarrow \propto$ fermion mass !)**
- **All x-sections strong function of $\tan\beta$**
- **Interferences (Z-,t-channel) NEGATIVE**
- **Interferences (Higgs-,t-channel) POSITIVE**

p-wave suppression at low momentum for light final states

$\sigma \propto m_f^2$ at low neutralino momenta

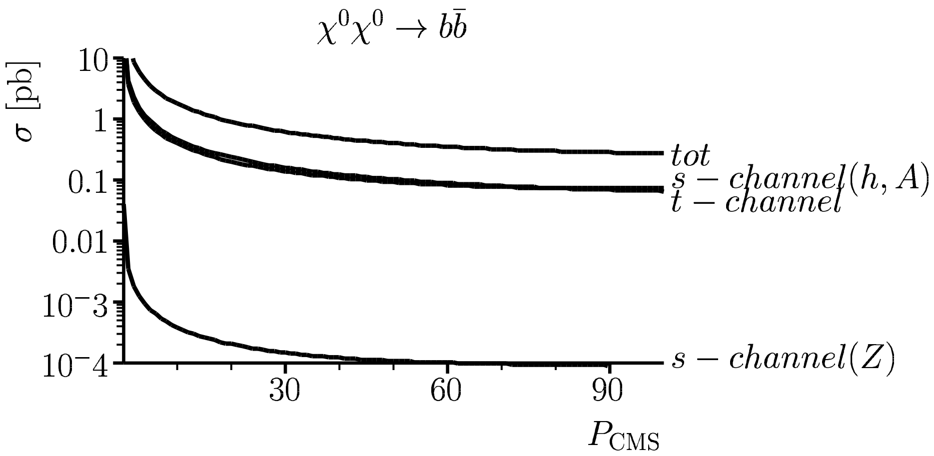


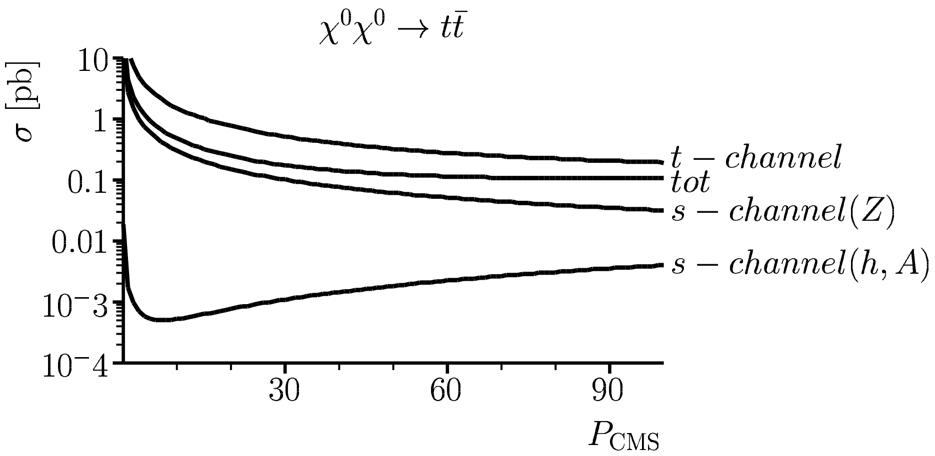


$m_0 = m_{1/2} = 500\,GeV;\ tb = 35\ \mu = 470\,GeV;\ A_t = -1135\,GeV;\ A_b = -1160\,GeV$

s,t-channel Interferences

Higgs large, Z small for $b\bar{b}$ final state **Higgs small, Z large for $t\bar{t}$ final state**





(t-ch, Higgs) Interf. POS , (t-ch, Z) Interf. NEG $\to$

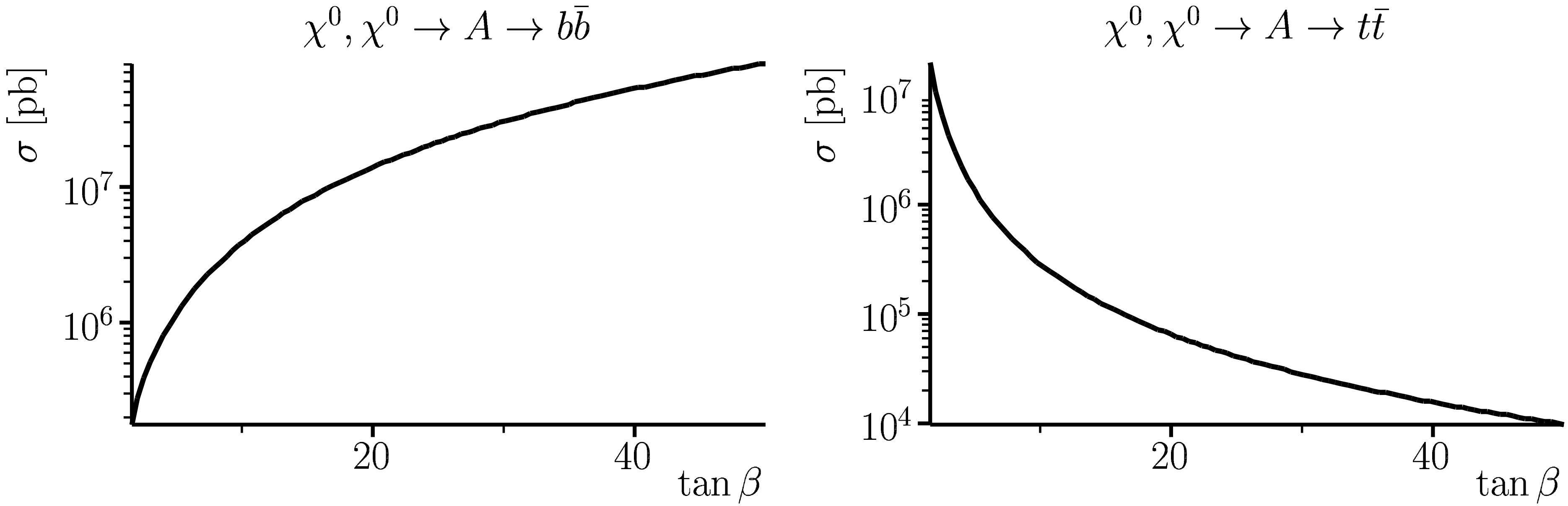
$t\bar{t}$ ($b\bar{b}$) final states suppressed (enhanced) due to interferences!

$b\bar{b}$ final state dominates at large $\tan\beta$

$$m_0 = m_{1/2} = 500 \; tb = 35 \; \mu = 470 \; A_t = -1135 \; A_b = -1160$$

Pseudoscalar Higgs exchange vs $\tan\beta$

$\chi_0\chi_0 \to A \to b\bar{b}$ $\chi_0\chi_0 \to A \to t\bar{t}$



$\chi_0\chi_0 \to A \to b\bar{b}$ **dominates at large** $\tan\beta$**.**

Comparison of X-sections in CalcHEP and darkSUSY

$\langle \sigma v \rangle \left[\frac{\text{cm}^3}{\text{s}} \right]$

$\tan\beta = 35, m_A = 870$ **GeV**, $A_t = -1180, A_b = -1610$ **GeV**

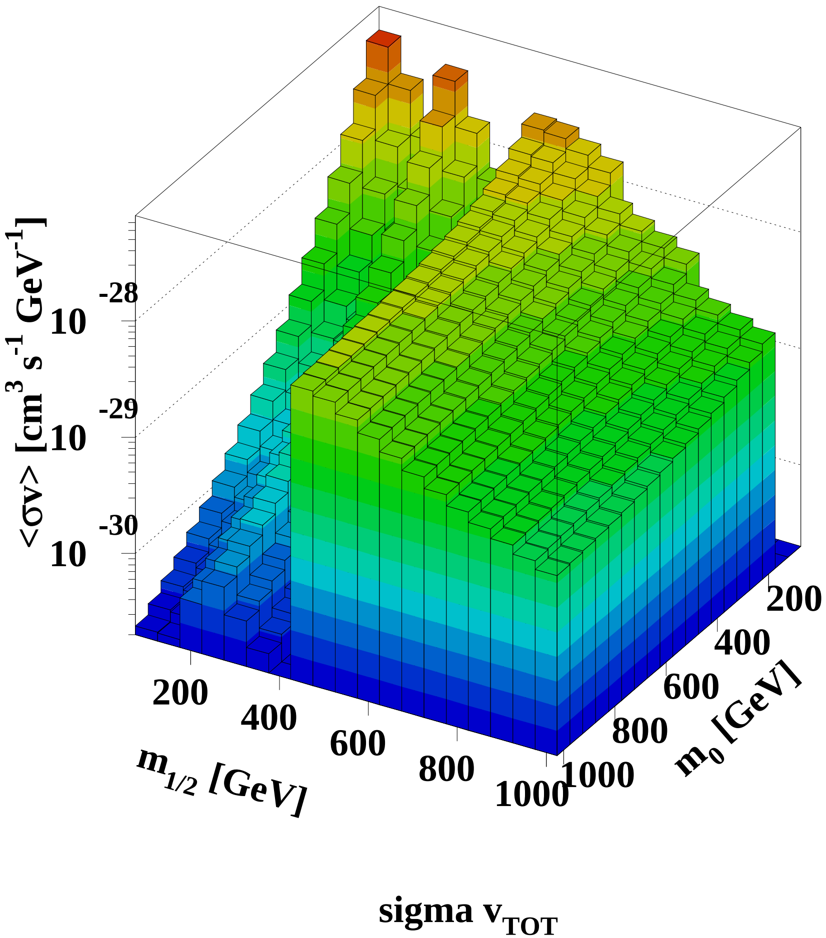
$m_0 = 500$ **GeV**, $m_{1/2} = 500$ **GeV**

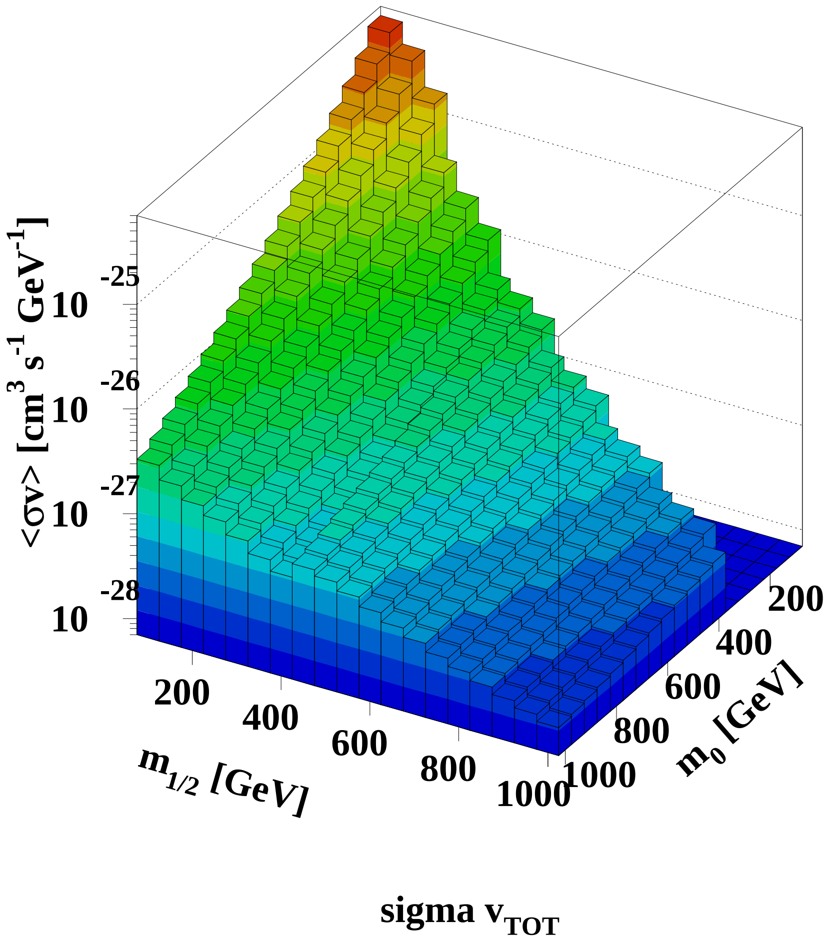
	CalcHEP	darkSUSY
$b\bar{b}$	$8.1 \cdot 10^{-28}$	$8.2 \cdot 10^{-28}$
$t\bar{t}$	$0.8 \cdot 10^{-28}$	$1.6 \cdot 10^{-28}$
$\tau^+\tau^-$	$3.8 \cdot 10^{-29}$	$4.8 \cdot 10^{-29}$
W^+W^-	$2.1 \cdot 10^{-30}$	$2.1 \cdot 10^{-30}$

Feynarts agrees with CalcHEP concerning $t\bar{t}$!

Neutralino Annihilation X-sections

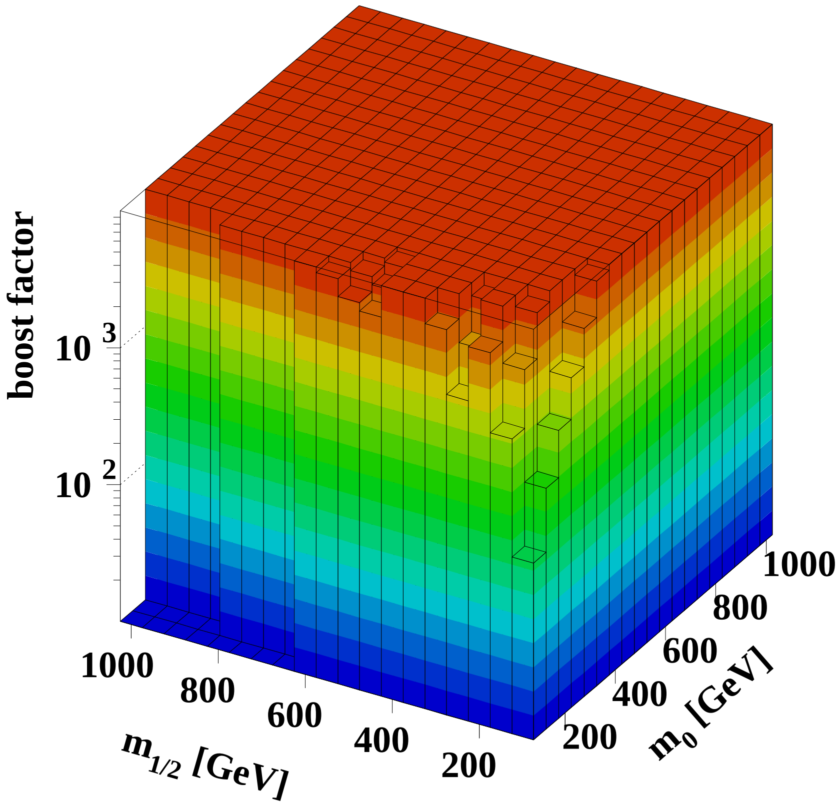
$\tan\beta = 1.6$ $\tan\beta = 35$



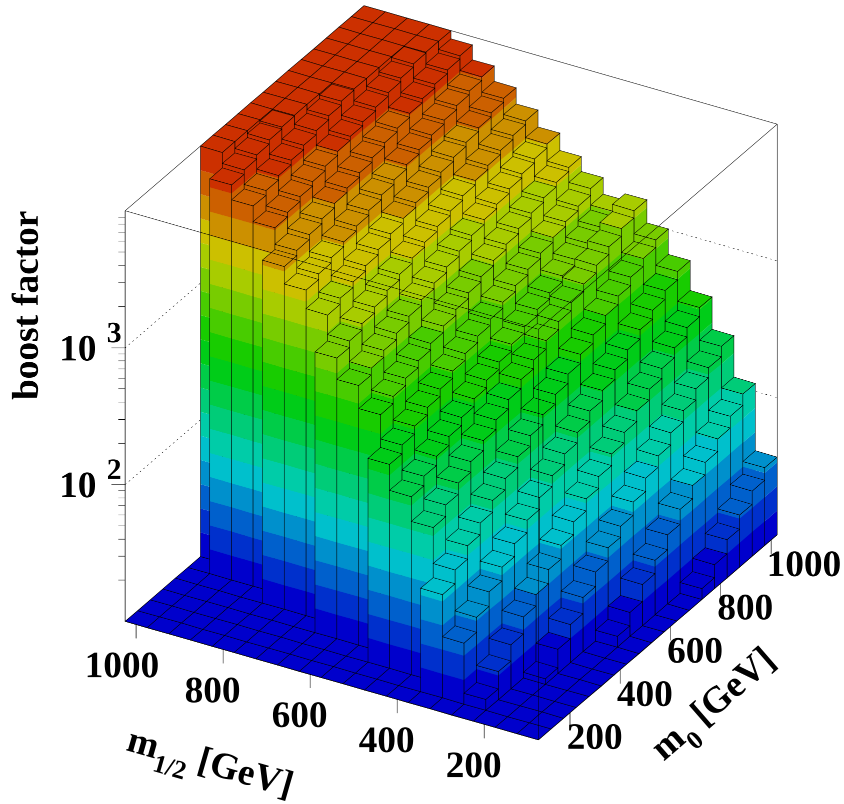


Boost factor for AMS and HEAT Data

$\tan\beta = 1.6$ $\tan\beta = 35$



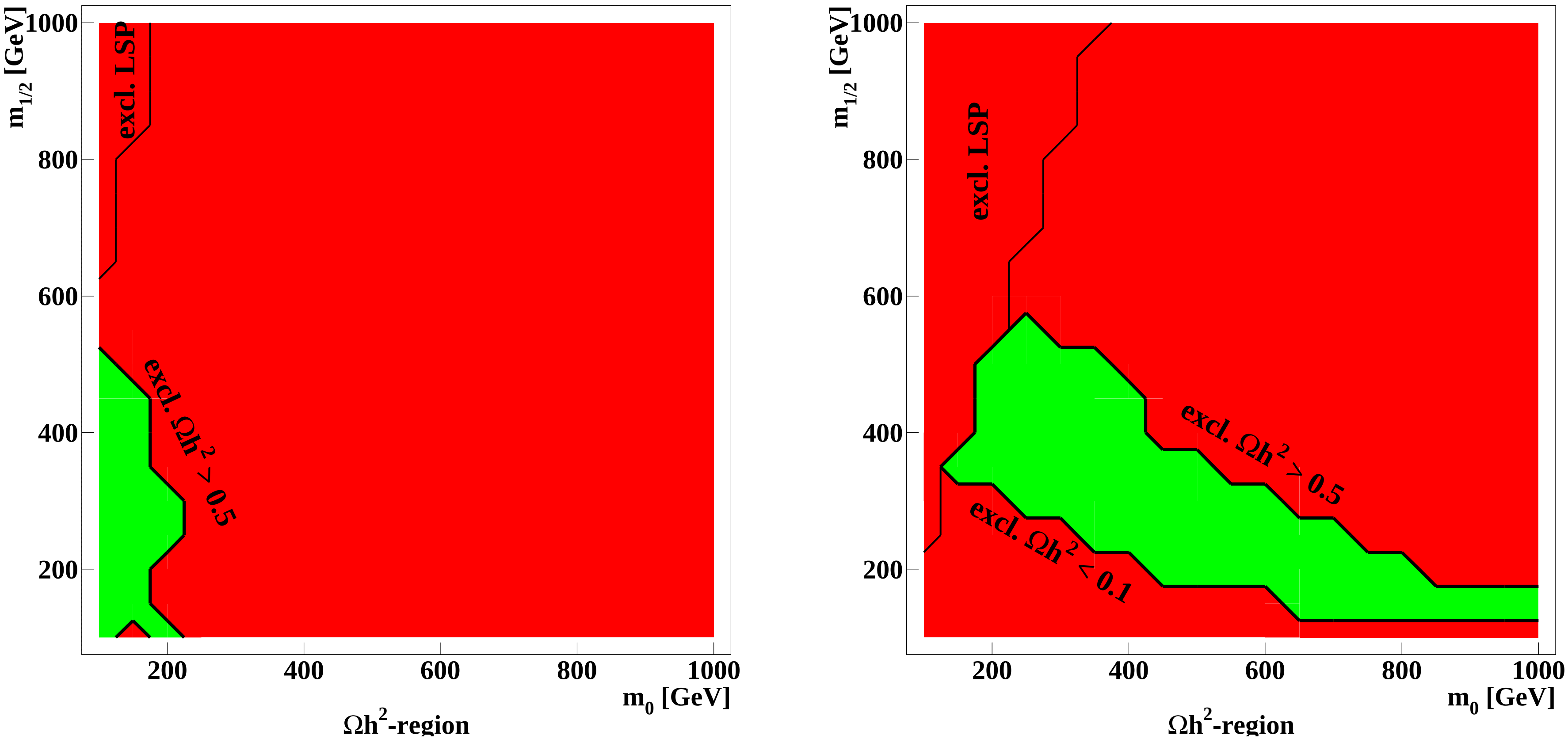
boost-factor (best fit)



boost-factor (best fit)

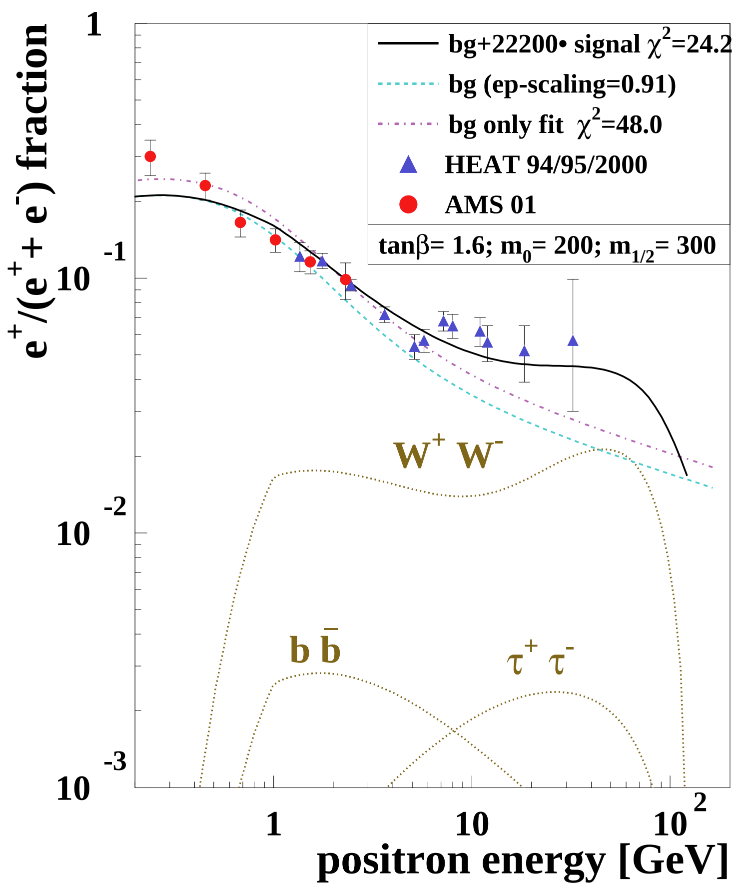
Dark Matter $\Omega h^2 = 0.3 \pm 0.2$ (from DarkSusy)

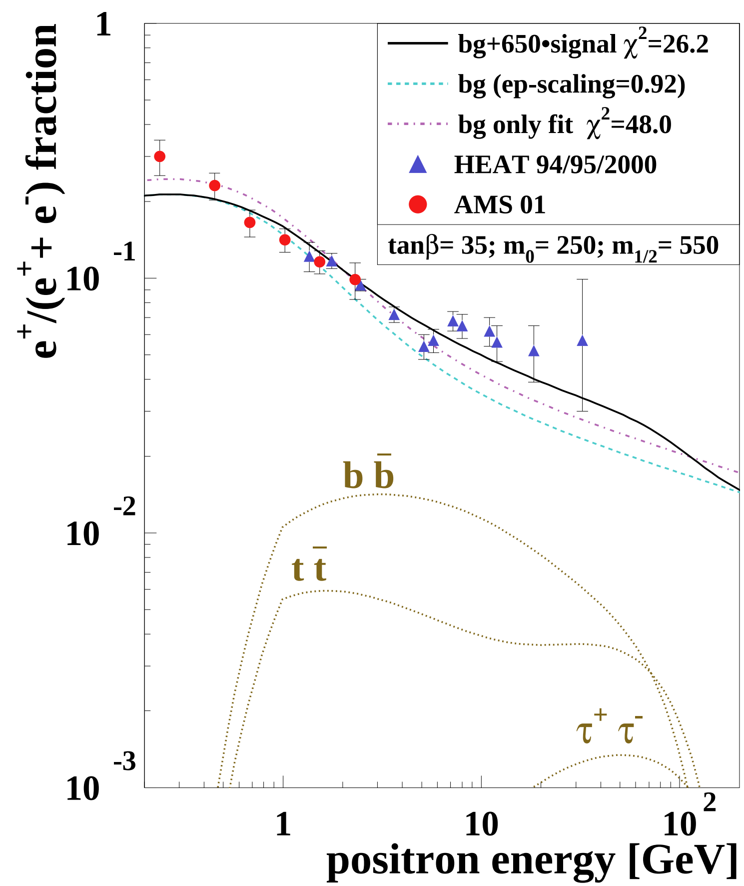
$\tan\beta = 1.6$ $\tan\beta = 35$



Green regions preferred by Boomerang and SN Ia

Typical Fits to AMS+HEAT Data vs $\tan\beta$

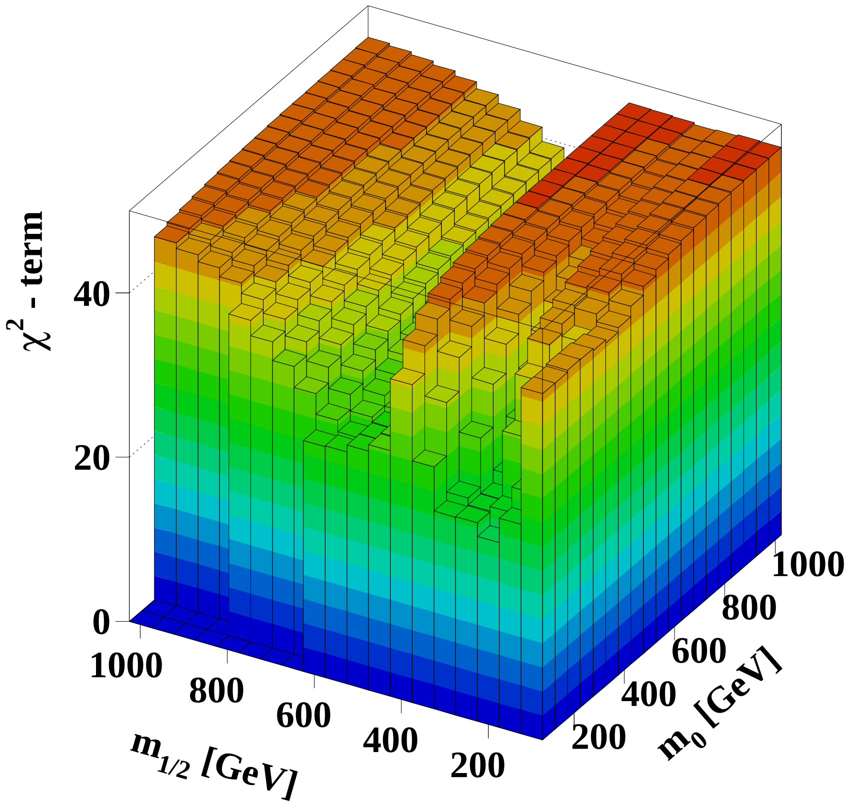




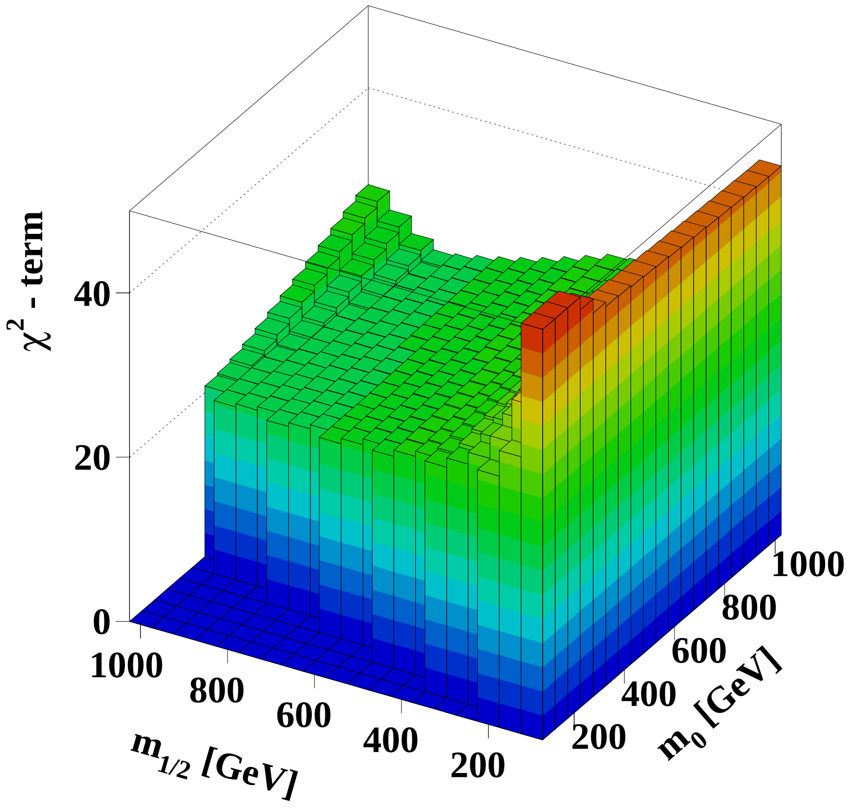
$\tan\beta = 1.6 \; m^0_\chi = 120 \; GeV$ $\qquad$ $\tan\beta = 35 \; m^0_\chi = 230 \; GeV$

χ^2 contr. for AMS+HEAT Data vs $\tan\beta$

$\tan\beta = 1.6$ $\tan\beta = 35$

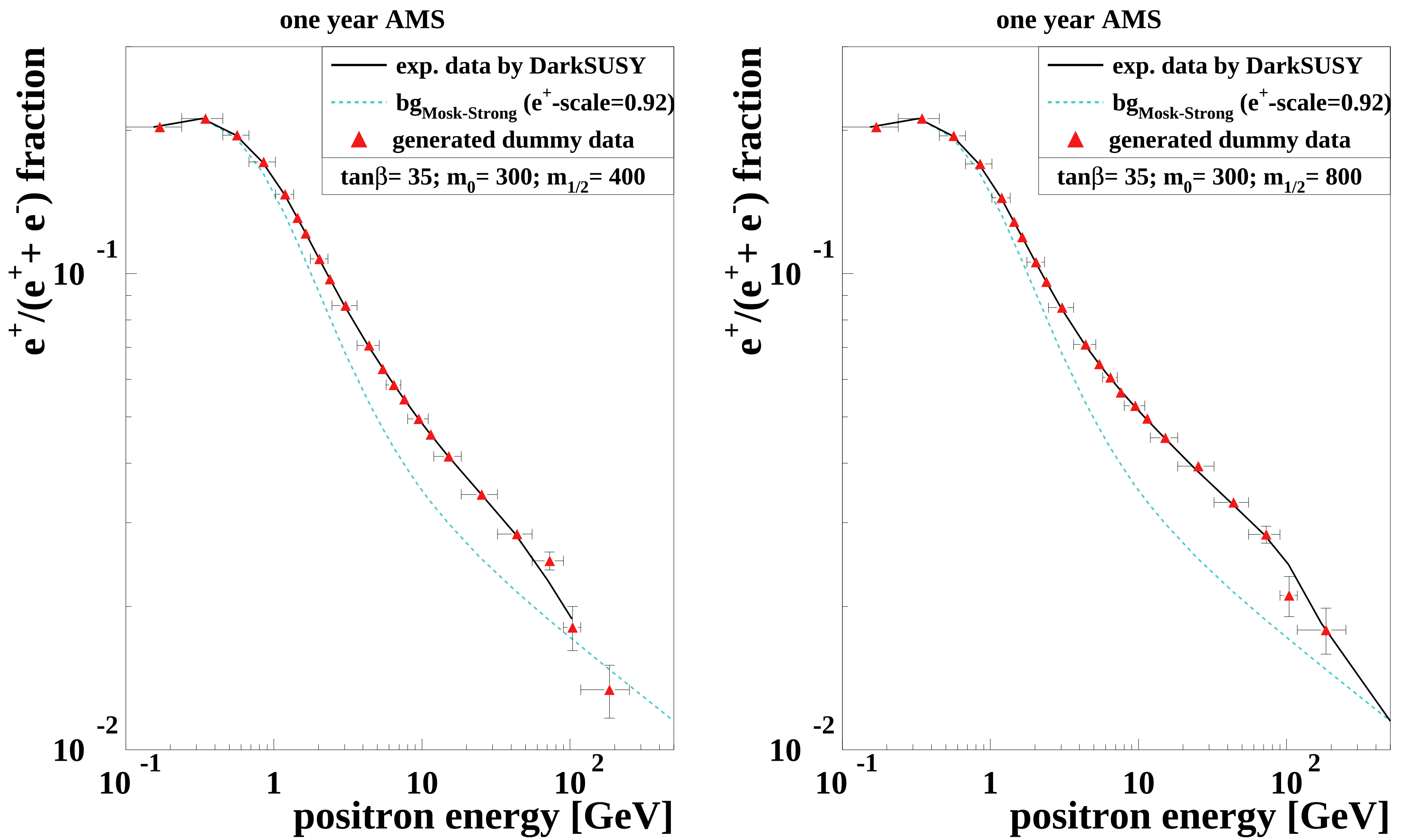


χ^2 - term



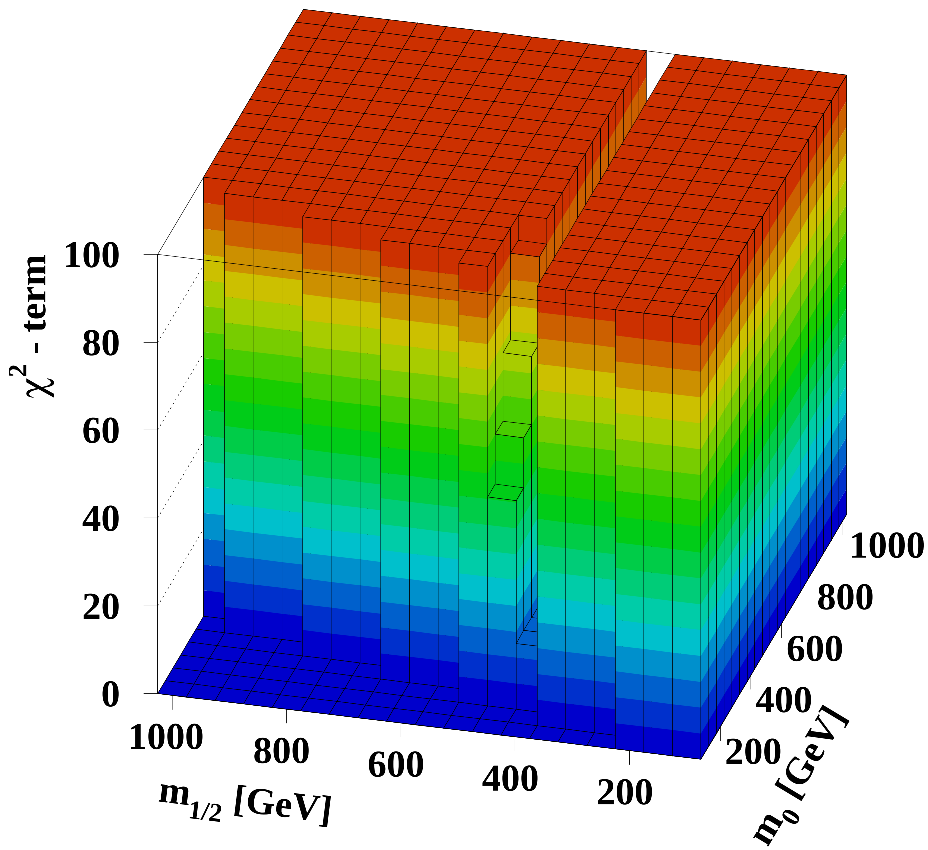
χ^2 - term

Possible AMS-02 Data in 2006

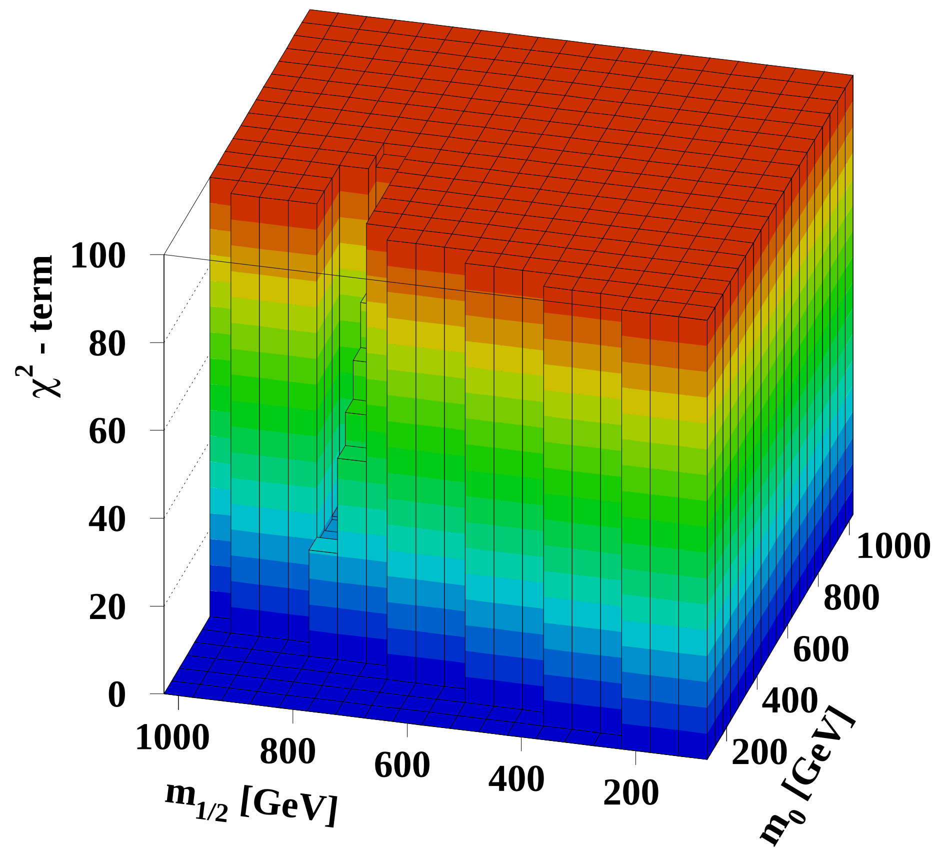


$\tan\beta = 35 \; m_\chi^0 = 160\;GeV$ $\qquad m_\chi^0 = 320\;GeV$

Possible χ^2 after one year AMS-02



χ^2 - term



χ^2 - term

Summary

Low values of ($\tan\beta < 4.3$) excluded by LEP Higgs Limit of 114 GeV

At larger values of $\tan\beta$ $b\bar{b}$ DOMINANT FINAL STATE

$b\bar{b}$ FINAL STATE has orders of magnitude larger x-section than W^+W^- final states and also larger than $t\bar{t}$ final states for $\tan\beta > 5$

$b\bar{b}$ FINAL STATE fits the AMS+HEAT data as well as the W^+W^- final states

Supersymmetry is an excellent candidate to explain the cold Dark Matter in the universe. Its signal could be the positrons and antiprotons from neutralino annihilation into $b\bar{b}$ final states