DM Relic density at one loop - effective coupling approach

Work in progress

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Outline

- Dark matter the standard stuff
- SUSY - non decoupling
- Idea of effective couplings
- Renormalization framework
- Current implementation plan
- How exactly - the technicalities
- Current status of our work
- The future

Yeah! We all know it!

$$\frac{dY}{dx} = \frac{-x\langle\sigma_{\chi\bar{\chi}\to X\bar{X}}v\rangle}{H(m)}\left(Y^2 - Y_{eq}^2\right)$$

$$\Downarrow$$

$$Y_\infty = \frac{3.79(n+1)x_f^{n+1}}{(g_{*s}/g_*^{1/2})m_{\rm pl}m\sigma_0}$$

$$\Downarrow$$

$$\Omega_\chi h^2 \propto \frac{1}{\sigma}$$

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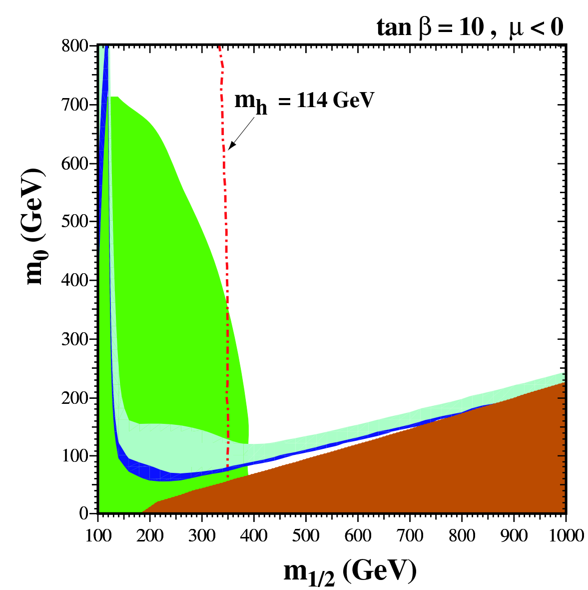
- Precision cosmology
- Percent accuracy with Plank
- Collider interplay



hep-ph/0404175v2

The beauty of broken SUSY

- Unbroken SUSY - equal couplings for the standard and SUSY particles

$$g(e\tilde{e}\tilde{\gamma}) = g(e\,e\gamma)$$

- SUSY breaking $\Rightarrow$ difference between SUSY and SM couplings grows with the SUSY breaking scale
- Same RGE above SUSY breaking scale, SUSY and SM particle decoupling at different scales due to mass hierarchy
- At one loop comparision between two couplings $(Q < m_{\tilde{q}})$

$$\frac{\tilde{\alpha}(Q)}{\alpha(Q)} - 1 = \frac{\alpha(m_{\tilde{q}})}{\alpha(Q)} - 1 = \beta \log \frac{m_{\tilde{q}}}{m_q}, \qquad \mathrm{On-shell}$$

?

Can we use this property of SUSY breaking to perform calculations at one loop?

Renormalization scheme

- -ino -fermion -sfermion process renormalized
- On-shell scheme in the -ino and sfermion sector
- Inputs - Chargino and bino-like neutralino masses in -ino sector

Input parameters	
SM	M_w, M_z α_{em}
-ino	$M_{\chi_1}^{-}, M_{\chi_2}^{-}$ $M_{\chi_i}^{0}$
Other	$\tan\beta$ $M_{\tilde{f}_i}$

- Requires consistant on-shell renormalization scheme
- Renormalization of $\tan\beta$ - simplest not unique, nor the best
- The most bino-like neutralino on-shell, not necessarily LSP

Effective couplings - this work

- A finite set of counter-terms introduced to the bare Lagrangian

$$
\begin{aligned}
\Delta N_{\alpha 1} &\equiv N_{\alpha 1}\left(\frac{\delta g}{g}+\frac{\delta Z_R^{\alpha}}{2}+\frac{\delta t_W}{t_W}\right)+\sum_{\beta\neq\alpha} N_{\beta 1} Z_R^{\alpha\beta} \\
\Delta N_{\alpha 2} &\equiv N_{\alpha 2}\left(\frac{\delta g}{g}+\frac{\delta Z_R^{\alpha}}{2}\right)+\sum_{\beta\neq\alpha} N_{\beta 2} Z_R^{\alpha\beta} \\
\Delta N_{\alpha 3} &\equiv N_{\alpha 3}\left(\frac{\delta g}{g}+\frac{\delta Z_R^{\alpha}}{2}+\frac{1}{2}\frac{\delta M_w^2}{M_w^2}-\frac{\delta\cos\beta}{\cos\beta}\right)+\sum_{\beta\neq\alpha} N_{\beta 3} Z_R^{\alpha\beta} \\
\Delta N_{\alpha 4} &\equiv N_{\alpha 4}\left(\frac{\delta g}{g}+\frac{\delta Z_R^{\alpha}}{2}+\frac{1}{2}\frac{\delta M_w^2}{M_w^2}-\frac{\delta\sin\beta}{\sin\beta}\right)+\sum_{\beta\neq\alpha} N_{\beta 4} Z_R^{\alpha\beta}
\end{aligned}
$$

hep-ph/0207364v2, Guasch, Hollik, Sola

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- Neutralino coupling matrices corrected
- Since -ino sfermion fermion coupling $\propto$ mixing matrix, these are called effective coupling
- Only include all two point correlation functions
- Process dependent corrections

How exactly - the technicalities

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Spectrum generator
(SLHA o/p)

↓

micrOMEGAs

↓

Calchep session
(with modified vertices - NEW!!)

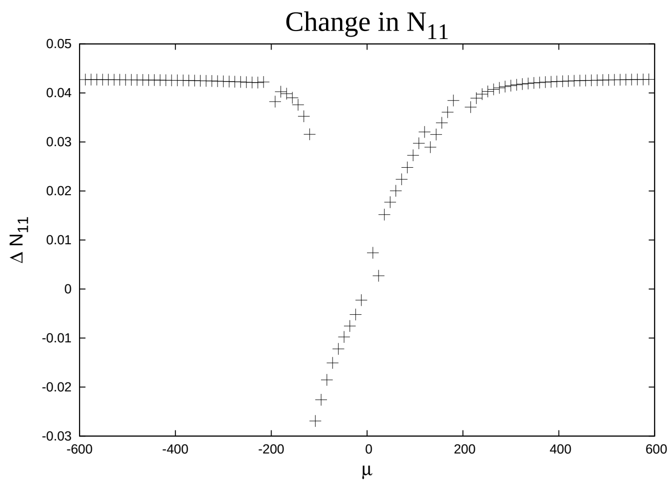
↓

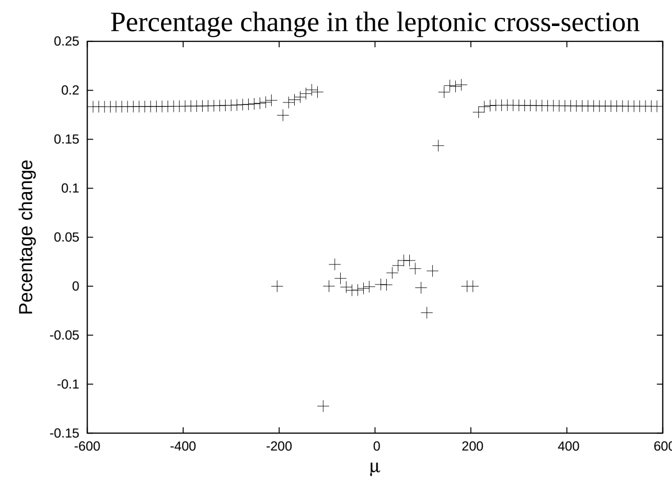
One loop effective vertex calculation
external library (NEW!!)

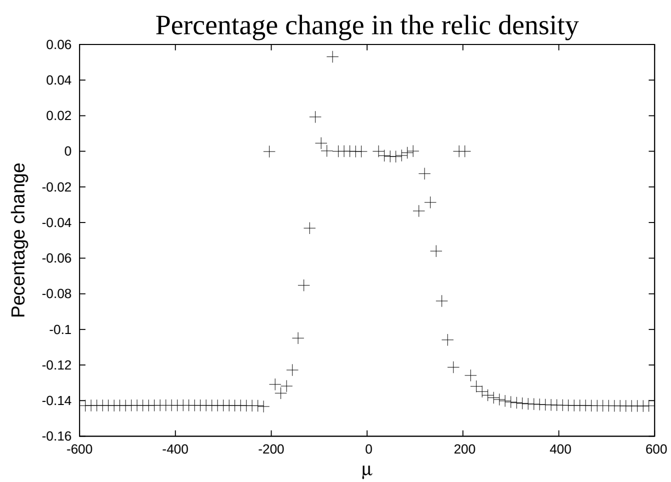
↓

Relic density at one loop

First results

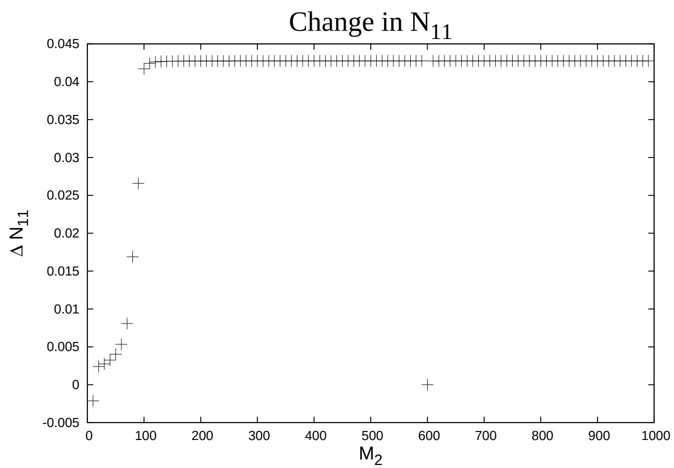


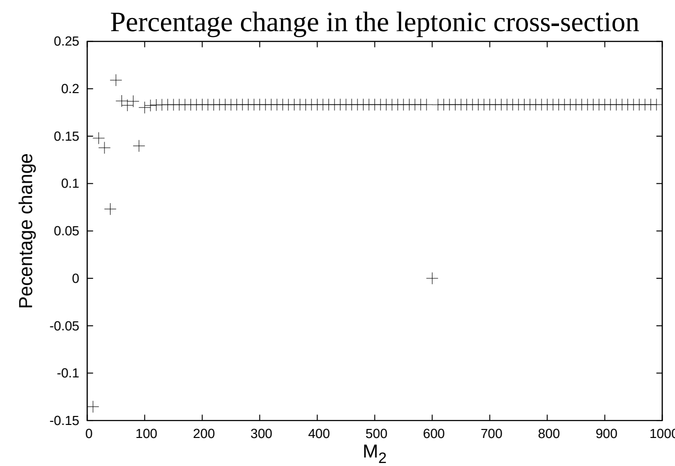


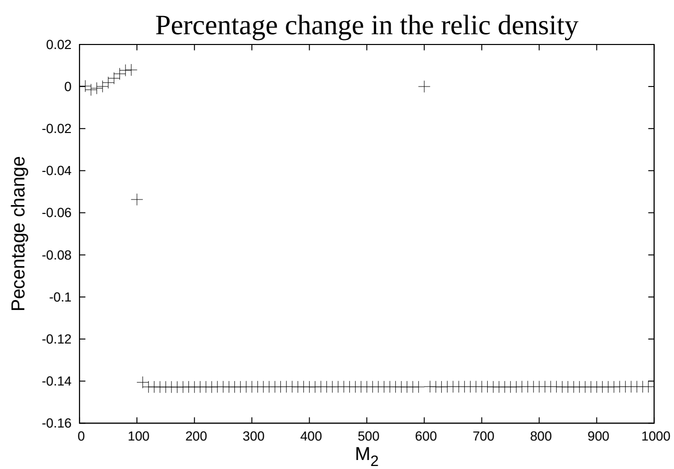


- EWSB scenario $\mu = -600$, $M_2 = 200$, $M_1 = 90$, $\tan\beta = 5$, $A_f = 0$
- Dominant leptonic channel annihilation
- Rich structure associated with the nature of LSP

First results







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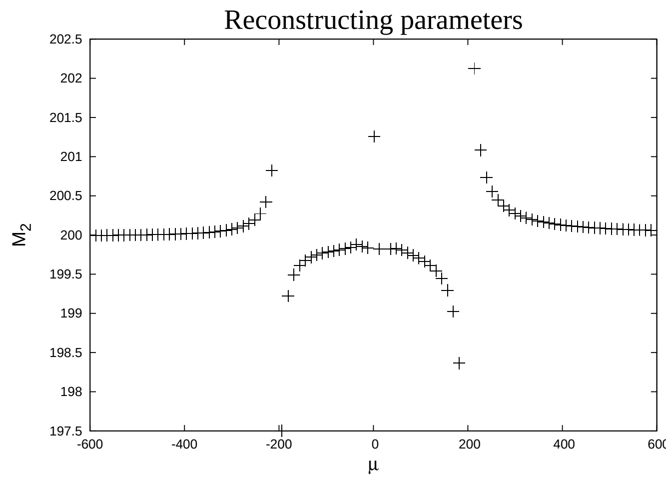
Future Plans

- Effective couplings - process dependent in MSSM
- Need to include the higgs -ino -ino couplings as well
- No known way to find effective coupling for this vertex so far
- A comparision to full one loop relic density calculations necessary
- Effect of initial and final state radiation

We expect the final results in near future . . .

Back - up

Reconstruction of parameters



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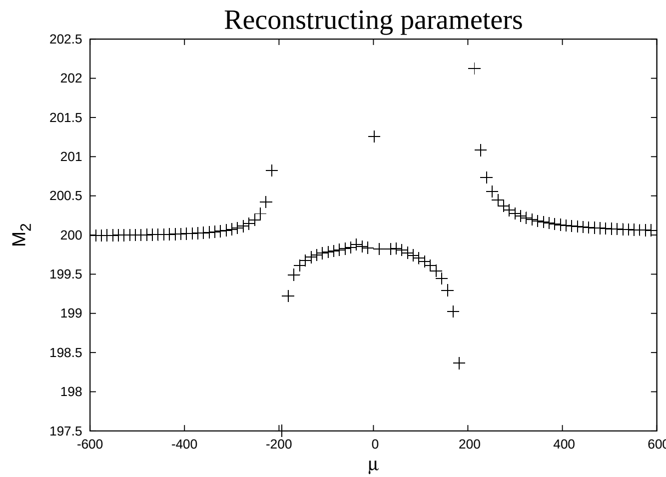

- SLHA accord not gauge invariant
- Threshold corrections to masses but MSSM parameters in $\overline{DR}$
- Higgsino - wino nature of $\tilde{\chi}^+$ determined by couplings
- M_1 extracted via bino-like neutralino