Impact of decay chain ambiguities for fits to LHC data

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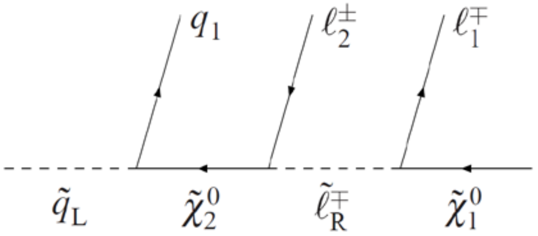
Introduction

- Aim
  - Investigate the impact on the SUSY parameter determination of making a different interpretation of observables, i.e. particle assignments in the cascade decay
  - Can the fit always select the correct interpretation?
  - How does it affect the parameter uncertainty



- Method
  - Perform fits with different interpretation of data
  - First use Markov chain to scan the parameter space quickly to eliminate unrealistic interpretations
  - For interpretations which might give small chi2, perform a toy fit

Model and input observables

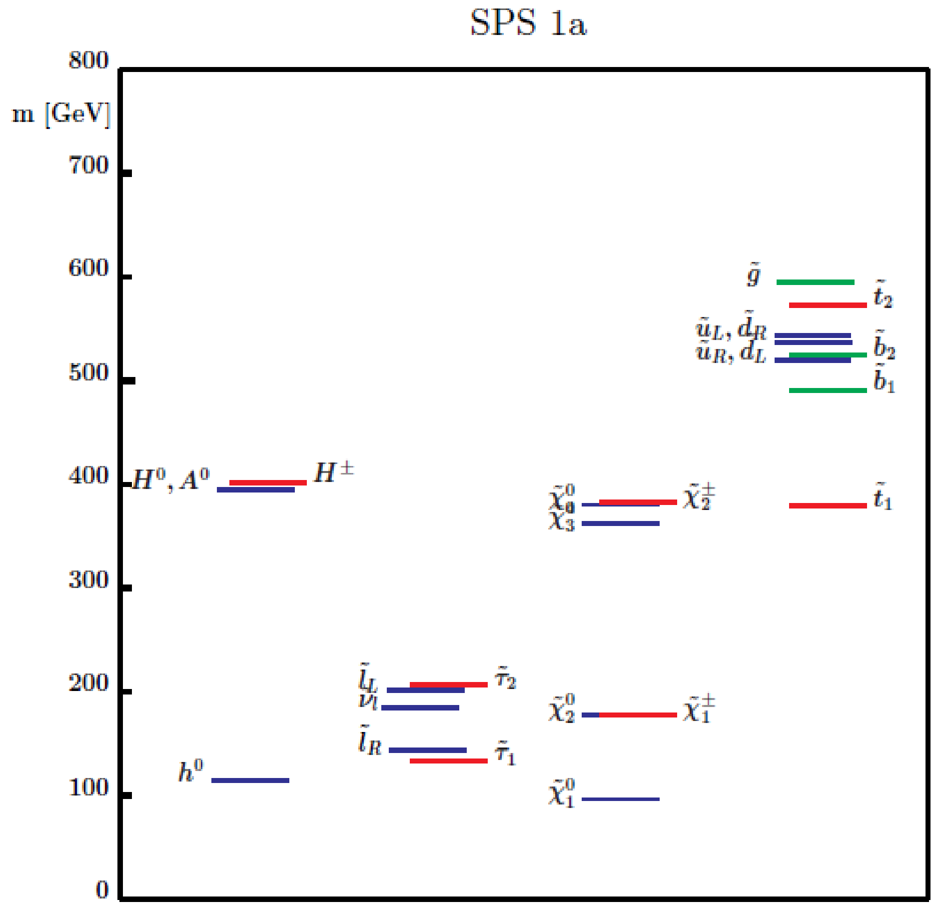
$$m_{1/2} = 250\,\text{GeV}$$

$$m_0 = 100\,\text{GeV}$$

$$A_0 = -100\,\text{GeV}$$

$$\tan\beta = 10$$

$$\mu > 0$$



- Model: mSUGRA
- Data:
  - Measurements expected at LHC (10 fb^{-1})
  - Data generated at SPS1a benchmark point

LHC observables

Observables from:
lhc/fittino.in.lhc_obs10

Pair production of slepton and squarks

$$\tilde{g} \to b b_1 \to b b \tilde{\chi}_2^0$$
$$\to b b l^{\pm} \tilde{l}_R^{\mp} \to b b l^{\pm} l^{\mp} \tilde{\chi}_2^0$$
$$q_L \to q \tilde{\chi}_2^0 \to q l^{\pm} \tilde{l}_1^{\mp} \to q l^{\pm} l^{\mp} \tilde{\chi}_1^0$$
$$q_L \to q \tilde{\chi}_2^0 \to q \tau^{\pm} \tilde{\tau}_1^{\mp} \to q \tau^{\pm} \tau^{\mp} \tilde{\chi}_1^0$$

$$b_1 \to b \tilde{\chi}_2^0 \to b l^{\pm} \tilde{l}_1^{\mp} \to b l^{\pm} l^{\mp} \tilde{\chi}_1^0$$

$$\tilde{g} \to t \tilde{t}_1 \to t b \tilde{\chi}_1^{\pm}$$
$$\tilde{g} \to b \tilde{b}_1 \to b W \tilde{t}_1 \to b b W \tilde{\chi}_1^{\pm}$$
$$\tilde{g} \to b \tilde{b}_1 \to t b \tilde{\chi}_1^{\pm}$$

Observable	Nominal Value	1 fb^{-1}	10 fb^{-1}	300 fb^{-1}
m_h	109.6		1.4	0.1
m_t	172.4	1.1	0.05	0.01
$m_{\tilde{\chi}_1^{\pm}}$	180.2			11.4
$\sqrt{m^2_{\tilde{\ell}_L} - 2m^2_{\tilde{\chi}_1^0}}$	148.8			1.7
$m_{\tilde{g}} - m_{\tilde{\chi}_1^0}$	507.7		13.7	2.5
$\sqrt{m^2_{\tilde{q}_R} - 2m^2_{\tilde{\chi}_1^0}}$	531.0	19.6	6.2	1.1
$m_{\tilde{g}} - m_{\tilde{b}_1}$	88.7			1.5
$m_{\tilde{g}} - m_{\tilde{b}_2}$	56.8			2.5
$m_{\ell\ell}^{\max}(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0}, m_{\tilde{\ell}_R})$	80.4	1.7	0.5	0.03
$m_{\ell\ell}^{\max}(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_4^0}, m_{\tilde{\ell}_L})$	280.6		12.6	2.3
$m_{\tau\tau}^{\max}(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0}, m_{\tilde{\tau}_1})$	83.4	12.6	4.0	0.73
$m_{\ell\ell q}^{\max}(m_{\tilde{\chi}_1^0}, m_{\tilde{q}_L}, m_{\tilde{\chi}_2^0})$	452.1	13.9	4.2	1.4
$m_{\ell q}^{\text{low}}(m_{\tilde{\ell}_R}, m_{\tilde{q}_L}, m_{\tilde{\chi}_2^0})$	318.6	7.6	3.5	0.9
$m_{\ell q}^{\text{high}}(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0}, m_{\tilde{\ell}_R}, m_{\tilde{q}_L})$	396.0	5.2	4.5	1.0
$m_{\ell\ell q}^{\text{thres}}(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0}, m_{\tilde{\ell}_R}, m_{\tilde{q}_L})$	215.6	26.5	4.8	1.6
$m_{\ell\ell b}^{\text{thres}}(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0}, m_{\tilde{\ell}_R}, m_{\tilde{b}_1})$	195.9		19.7	3.6
$m_{tb}^{\text{w}}(m_t, m_{\tilde{t}_1}, m_{\tilde{\chi}_1^{\pm}}, m_{\tilde{g}}, m_{\tilde{b}_1})$	359.5	43.0	13.6	2.5
$\frac{\mathcal{B}(\tilde{\chi}_2^0 \to \tilde{\ell}_R \ell) \times \mathcal{B}(\tilde{\ell}_R \to \tilde{\chi}_1^0 \ell)}{\mathcal{B}(\tilde{\chi}_2^0 \to \tilde{\tau}_1 \tau) \times \mathcal{B}(\tilde{\tau}_1 \to \tilde{\chi}_1^0 \tau)}$	0.076	0.009	0.003	0.001
$\frac{\mathcal{B}(\tilde{g} \to \tilde{b}_2 b) \times \mathcal{B}(\tilde{b}_2 \to \tilde{\chi}_2^0 b)}{\mathcal{B}(\tilde{g} \to \tilde{b}_1 b) \times \mathcal{B}(\tilde{b}_1 \to \tilde{\chi}_2^0 b)}$	0.168			0.078

List of interpretations

qll final state $\left(\tilde{\chi}_2^0, \tilde{l}_R, \tilde{\chi}_1^0\right)$

- Change combination of neutralinos involved (x6)
- Right-handed selectron to left-handed (x2)

→ 12 combinations

$q\tau\tau$ final state $\left(\tilde{\chi}_2^0, \tilde{\tau}_1, \tilde{\chi}_1^0\right)$

- Same as above.

→ 12 combinations

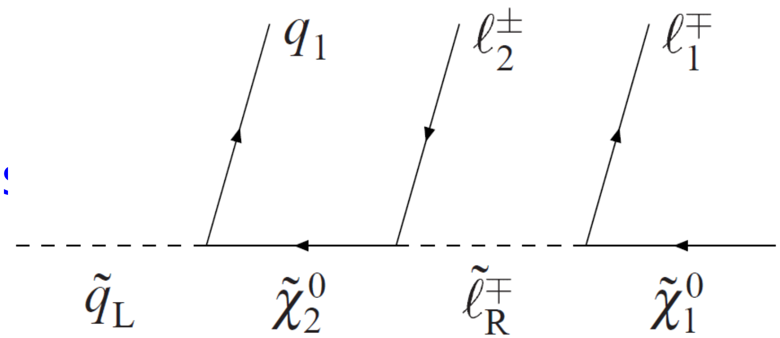
- qll and qtautau final states correlated through the measurement of $\dfrac{Br\left(\tilde{\chi}_2^0 \to \tilde{l}_R l\right) \cdot Br\left(\tilde{l}_R \to \tilde{\chi}_1^0 l\right)}{Br\left(\tilde{\chi}_2^0 \to \tilde{\tau}_1 \tau\right) \cdot Br\left(\tilde{\tau}_1 \to \tilde{\chi}_1^0 \tau\right)}$

→ 144 combinations for qll and qtautau

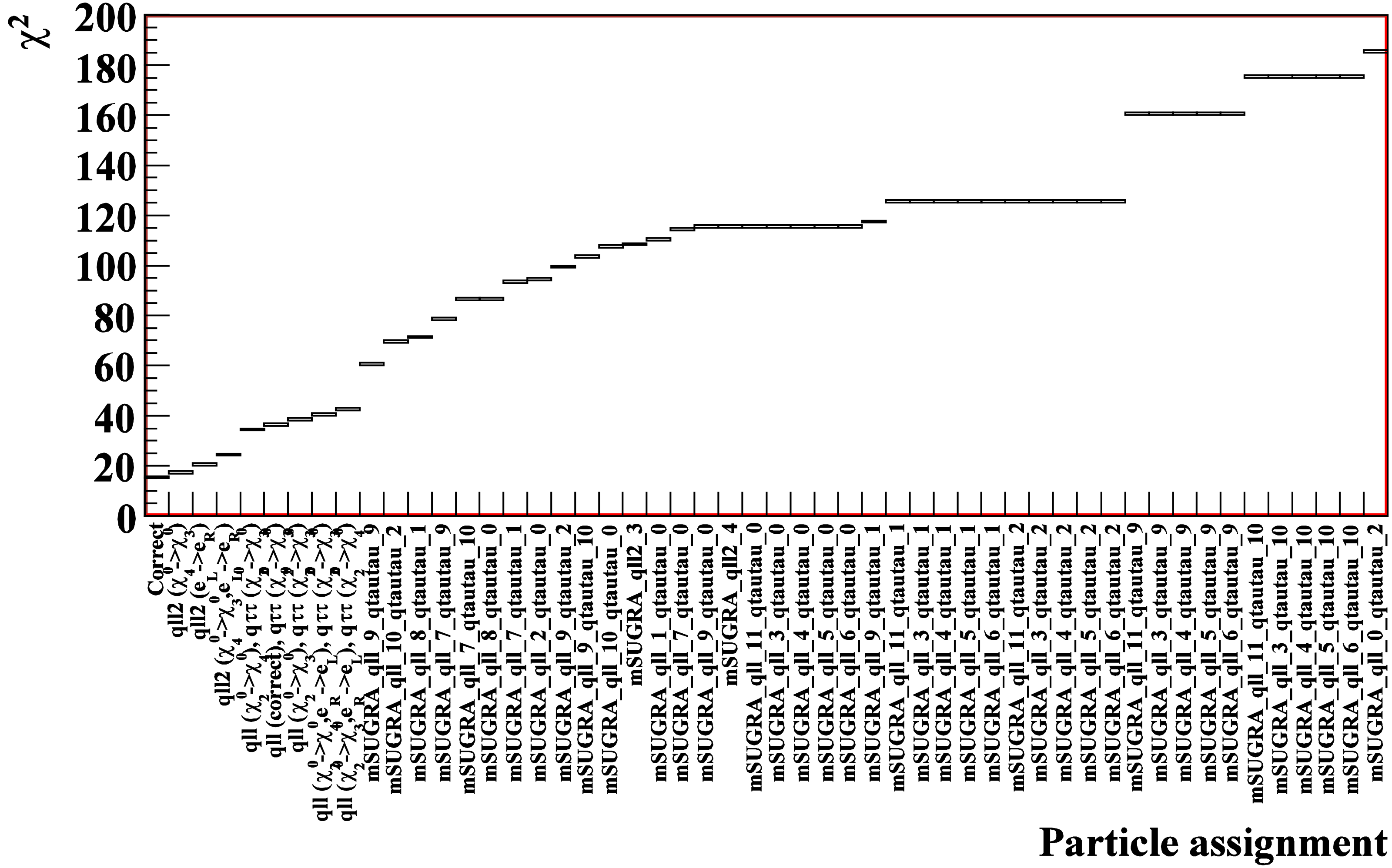
qll final state (2) $\left(\tilde{\chi}_4^0, \tilde{l}_L, \tilde{\chi}_1^0\right)$

- Same as above

→ 12 combination:



χ^2 of different fits



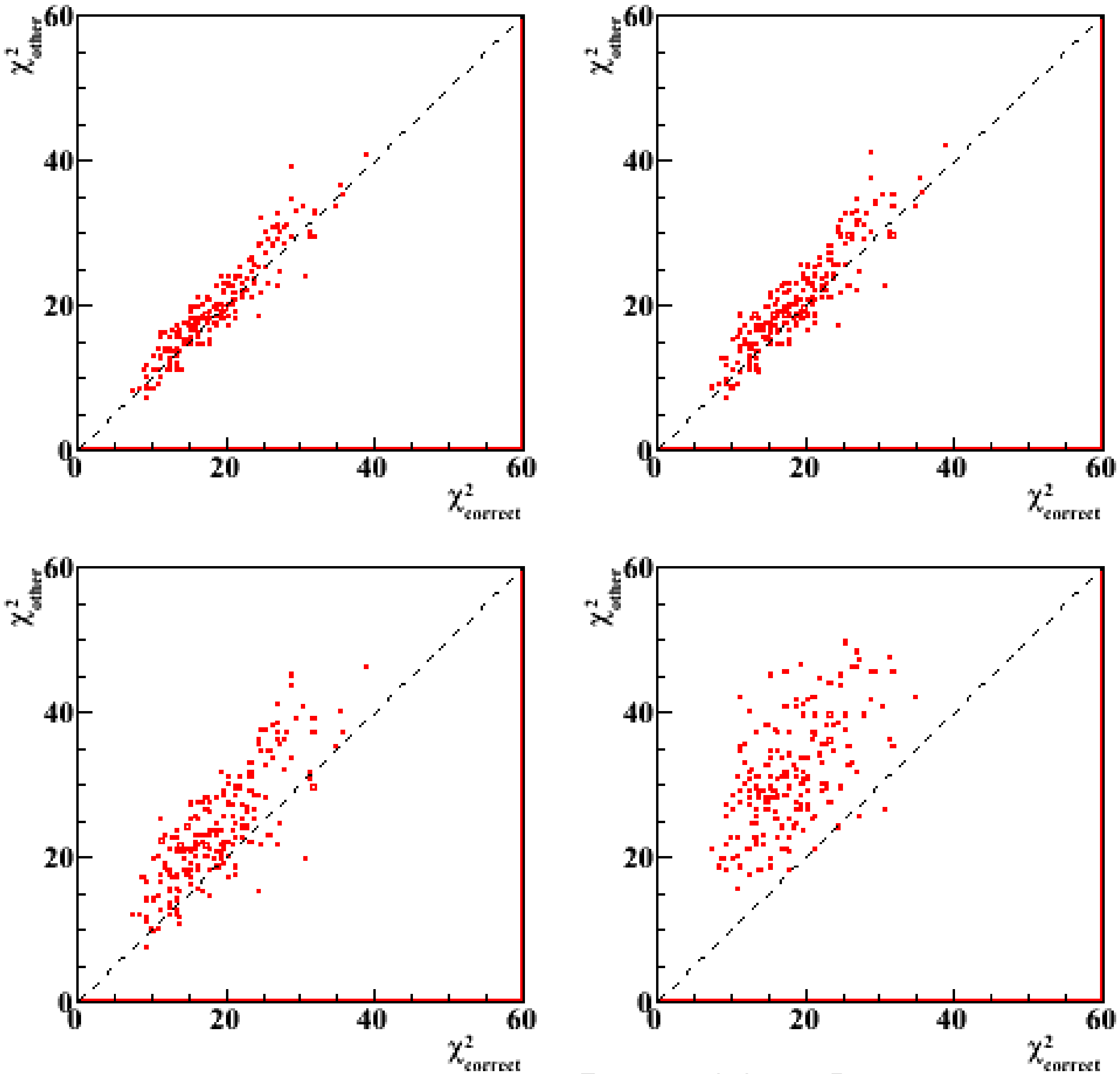
Toy fit

- After pre-selecting interpretations which could give a good fit

- Perform a toy fit
  - Smear observables within their uncertainties and estimate the uncertainty on parameters
  - Consider changing the particle assignment as another degree of freedom and see if it could pin down the correct interpretation

- Initial values of parameters taken from the Markov chain result

χ^2 correlations

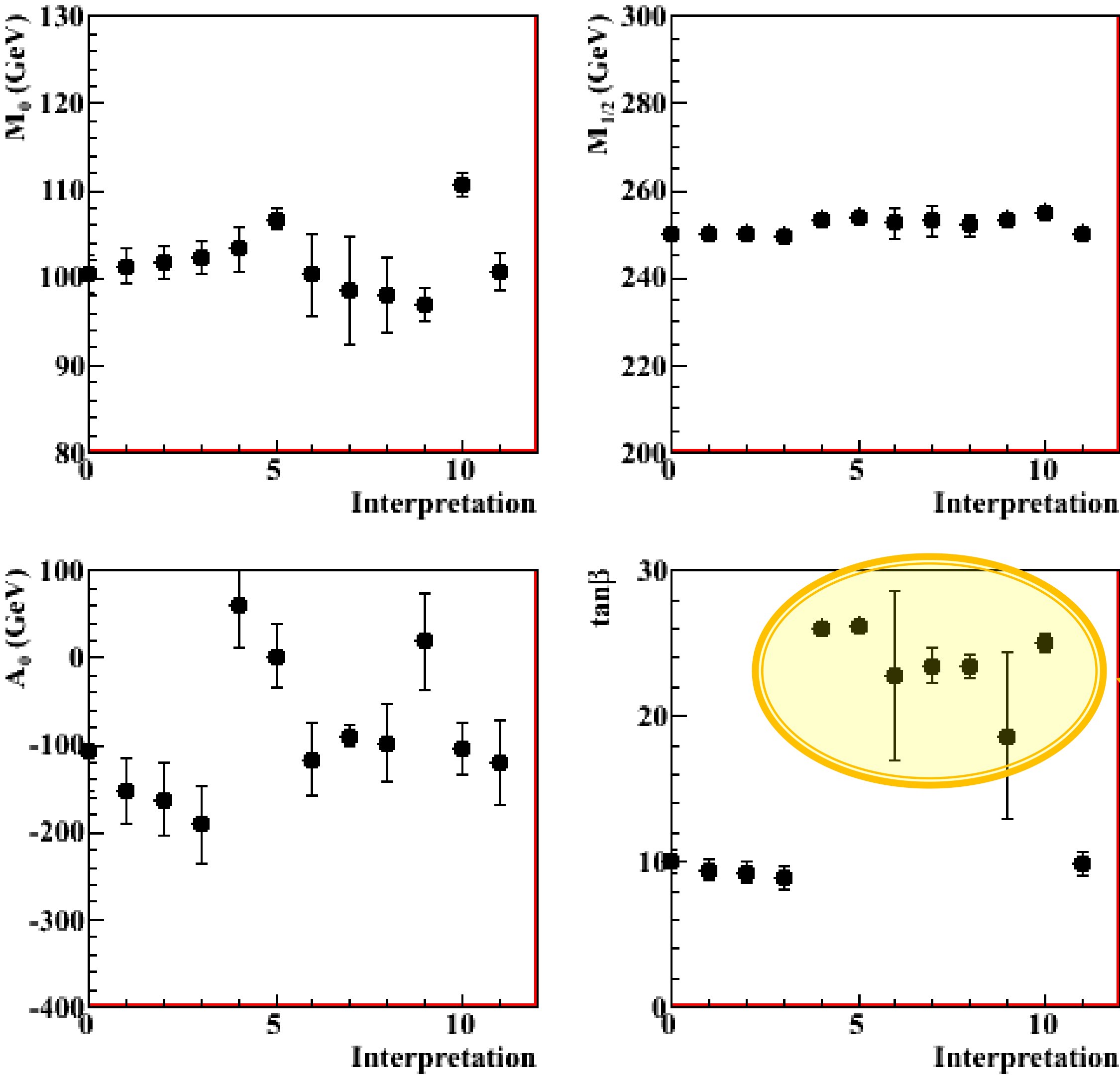


χ2 correlation between the correct interpretation and 4 best other interpretations

Results of the fit (198 smeared points)

	No. of times getting the best χ^2 among all	No. of times getting the best χ^2 wrt. the correct model
Correct assignment	135	---
qll2, $\chi_4 \rightarrow \chi_3$	40	60
qll2, $e_L \rightarrow e_R$	13	50
qll2, $\chi_4 \rightarrow \chi_3$, $e_L \rightarrow e_R$	5	28
qll, $\chi_2 \rightarrow \chi_4$; q$\tau\tau$, $\chi_2 \rightarrow \chi_3$	0	2
q$\tau\tau$, $\chi_2 \rightarrow \chi_3$	0	1
qll, $\chi_2 \rightarrow \chi_3$; q$\tau\tau$, $\chi_2 \rightarrow \chi_3$	0	3
qll, $\chi_2 \rightarrow \chi_{4,}$ $e_R \rightarrow e_L$; q$\tau\tau$, $\chi_2 \rightarrow \chi_3$	2	4
qll, $\chi_2 \rightarrow \chi_{3,}$ $e_R \rightarrow e_L$; q$\tau\tau$, $\chi_2 \rightarrow \chi_3$	2	3
Model 9	1	1
Model 10	0	0

Fitted parameters

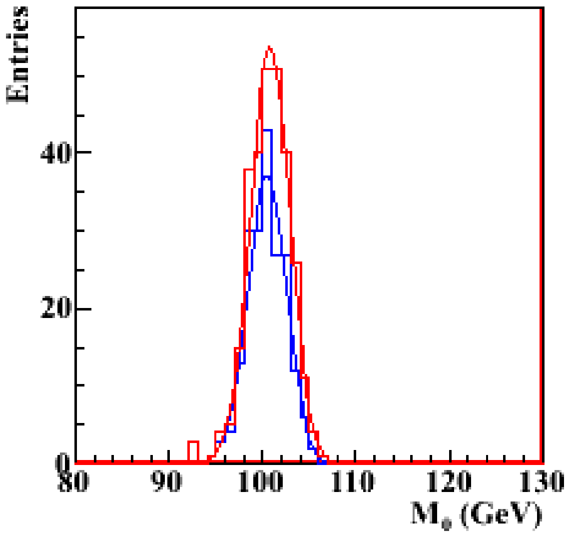


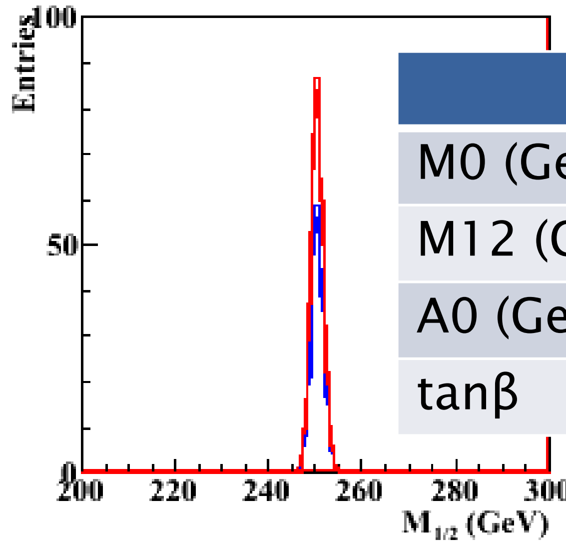
Fitted parameters for various interpretations.

- Obtain similar values in all cases except for tanβ
- Uncertainty on A0 is rather large and fluctuates

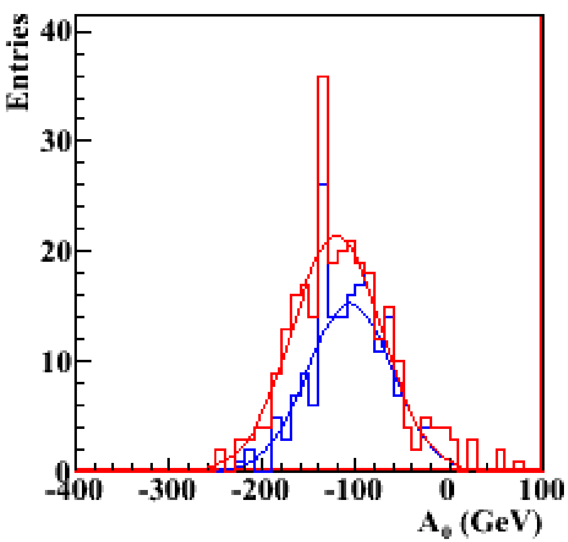
Changing simultaneously the particle assignments in qll and qττ final states

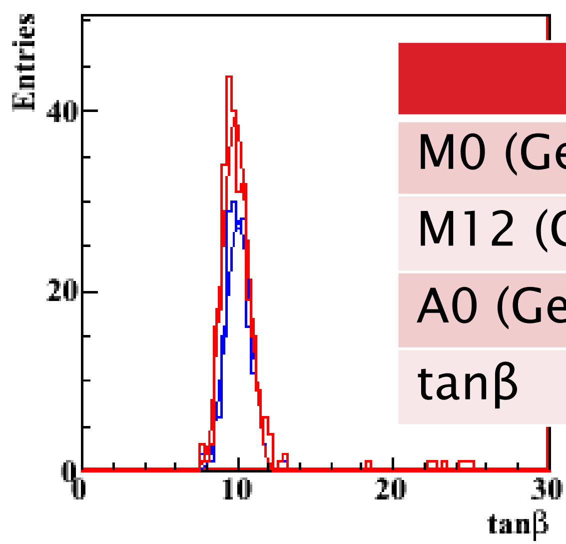
Parameter uncertainty





	Mean	Error
M0 (GeV)	100.0	2.1
M12 (GeV)	250.4	1.4
A0 (GeV)	−106	44
tanβ	10.04	0.78





	Mean	Error
M0 (GeV)	100.0	2.1
M12 (GeV)	250.3	1.4
A0 (GeV)	−120	48
tanβ	9.84	0.79

Results from taking the best χ^2

Some ideas on next steps

- Would be interesting to see when these ambiguities become important
  - So far, tried mSUGRA with many LHC observables (10 fb^{-1})
  - Try with less LHC observables expected with 1 fb^{-1}
  - MSSM18 fit with LE+few LHC observables

- Implementation into fittino
  - I have a few scripts to generate fittino input file with different interpretations observables
  - However, the whole process takes a few weeks
    - submitting MC jobs → analyze → submit ToyFit jobs → analyze
  - Shall we include these scripts/macros to fittino?

Summary

- The decay chain ambiguities on mSUGRA fit to LHC observables were investigated
  - Vary the assumptions on neutralino and slepton involved in the cascade decay
  - Scan parameter space for each interpretation with Markov chain method
  - Toy fit for detailed evaluation for few interpretations
- Only a few interpretations would give the lowest χ^2 compared to the correct one
  - Small increase on the parameter uncertainty
- Will redo the analysis with latest software