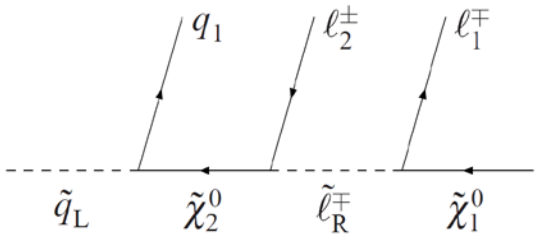
Treatment of the ambiguity in particle assignments

Takanori Kono
University of Hamburg/DESY

Introduction

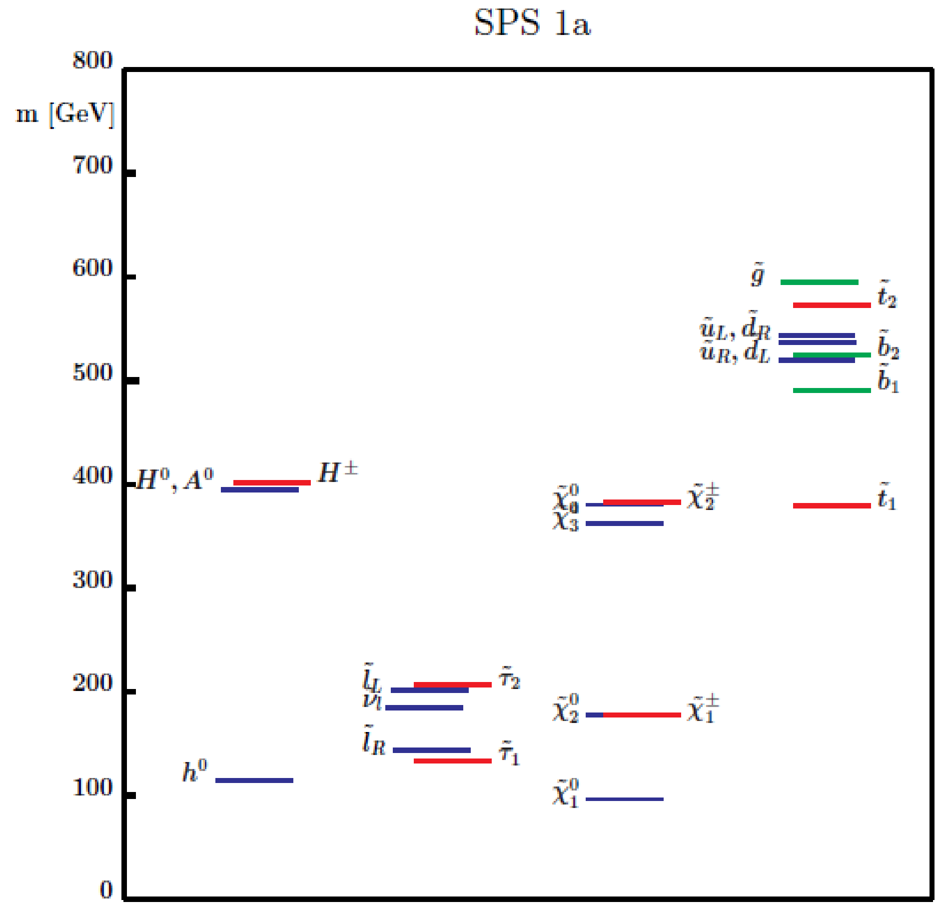
- Extraction of masses of SUSY particles relies on indirect measurements like kinematic edges
  - Kinematic edge depends on the masses of particles involved in the cascade decay
  - Usually make a reasonable assumption on which particles are involved



- Motivation
  - See whether we can extract SUSY parameters without these assumptions
  - Run many fits with different interpretation of particles in the decay chain, and see whether we can get the correct interpretation based on the chi2

Model and input observables

$$m_{1/2} = 250\,\mathrm{GeV}$$
$$m_0 = 100\,\mathrm{GeV}$$
$$A_0 = -100\,\mathrm{GeV}$$
$$\tan\beta = 10$$
$$\mu > 0$$



- Model: mSUGRA
- Data:
  - Measurements expected at LHC (10 fb−1)
  - Data generated at SPS1abenchmark point

LHC observables

Observables from:
lhc/fittino.in.lhc_obs10

Pair production of slepton and squarks

$$\tilde{g} \to bb_1 \to bb\tilde{\chi}_2^0$$
$$\to bbl^{\pm}\tilde{l}_R^{\mp} \to bbl^{\pm}l^{\mp}\tilde{\chi}_2^0$$
$$q_L \to q\tilde{\chi}_2^0 \to ql^{\pm}\tilde{l}_1^{\mp} \to ql^{\pm}l^{\mp}\tilde{\chi}_1^0$$
$$q_L \to q\tilde{\chi}_2^0 \to q\tau^{\pm}\tilde{\tau}_1^{\mp} \to q\tau^{\pm}\tau^{\mp}\tilde{\chi}_1^0$$

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

$$\tilde{g} \to t\tilde{t}_1 \to tb\tilde{\chi}_1^{\pm}$$
$$\tilde{g} \to b\tilde{b}_1 \to bW\tilde{t}_1 \to bbW\tilde{\chi}_1^{\pm}$$
$$\tilde{g} \to b\tilde{b}_1 \to tb\tilde{\chi}_1^{\pm}$$

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
$\sqrt{m_{\tilde{\ell}_L}^2 - 2m_{\tilde{\chi}_1^0}^2}$	148.8			1.7
$m_{\tilde{g}} - m_{\tilde{\chi}_1^0}$	507.7		13.7	2.5
$\sqrt{m_{\tilde{q}_R}^2 - 2m_{\tilde{\chi}_1^0}^2}$	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
$m_{\ell q}^{\mathrm{low}}(m_{\tilde{\ell}_R}, m_{\tilde{q}_L}, m_{\tilde{\chi}_2^0})$	318.6	7.6	3.5	0.9
$m_{\ell q}^{\mathrm{high}}(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0}, m_{\tilde{\ell}_R}, m_{\tilde{q}_L})$	396.0	5.2	4.5	1.0
$m_{\ell\ell q}^{\mathrm{thres}}(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0}, m_{\tilde{\ell}_R}, m_{\tilde{q}_L})$	215.6	26.5	4.8	1.6
$m_{\ell\ell b}^{\mathrm{thres}}(m_{\tilde{\chi}_1^0}, m_{\tilde{\chi}_2^0}, m_{\tilde{\ell}_R}, m_{\tilde{b}_1})$	195.9		19.7	3.6
$m_{tb}^{\mathrm{w}}(m_t, m_{\tilde{t}_1}, m_{\tilde{\chi}_1^{\pm}}, m_{\tilde{g}}, m_{\tilde{b}_1})$	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.

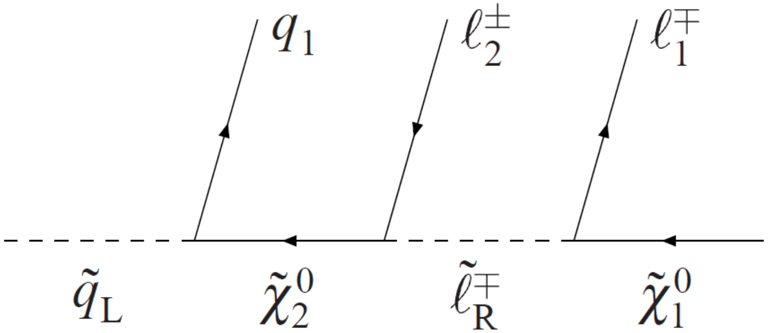
  → 12 combinations
- qll and qtautau final states correlated through the measurement of $\dfrac{Br\left(\tilde{\chi}_2^0 \to \tilde{l}_R l\right) \cdot Br\left(\tilde{l}_R \to \tilde{\chi}_1^0 l\right)}{Br\left(\tilde{\chi}_2^0 \to \tilde{\tau}_1 \tau\right) \cdot Br\left(\tilde{\tau}_1 \to \tilde{\chi}_1^0 \tau\right)}$

  → 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

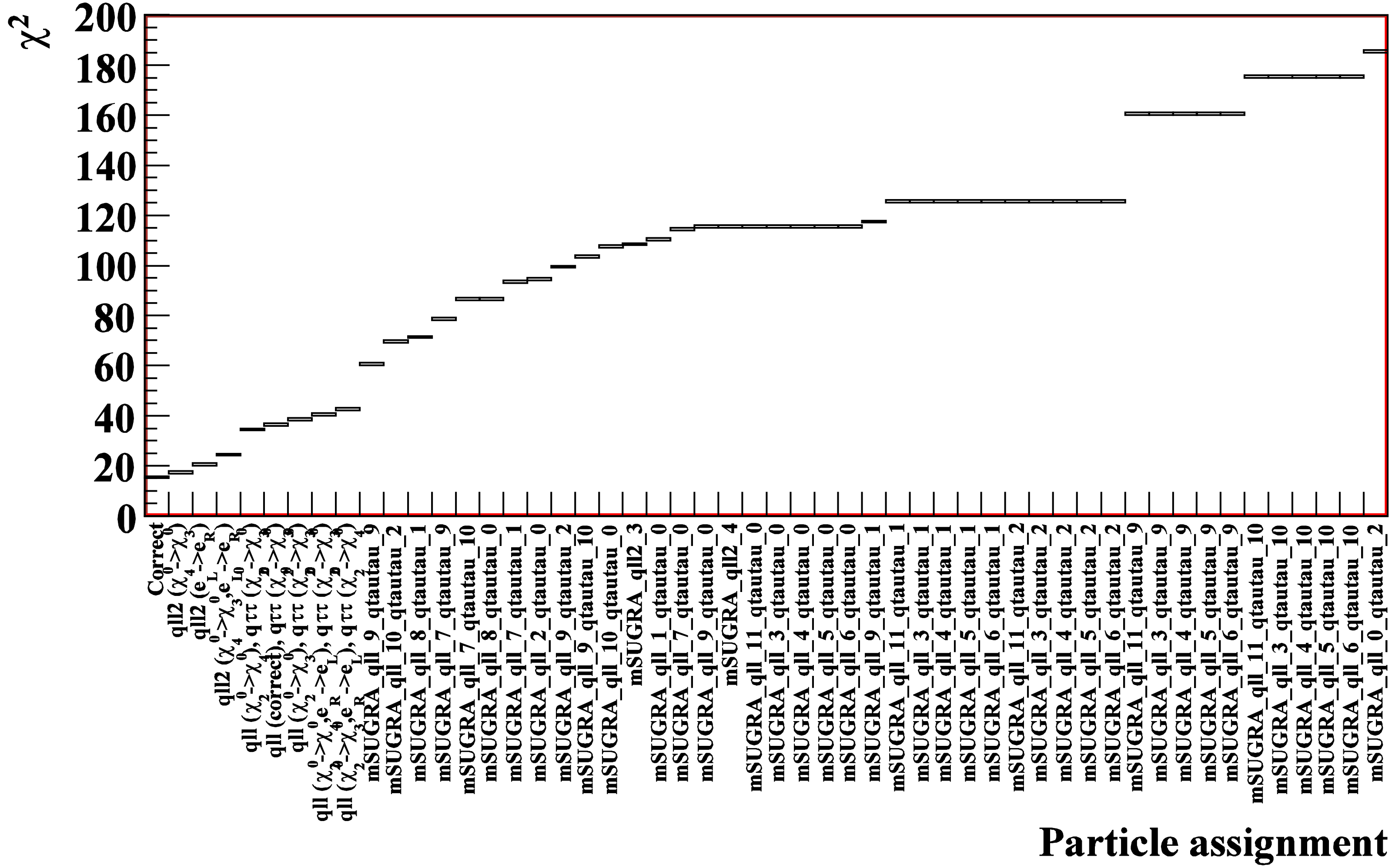
  → 12 combination:



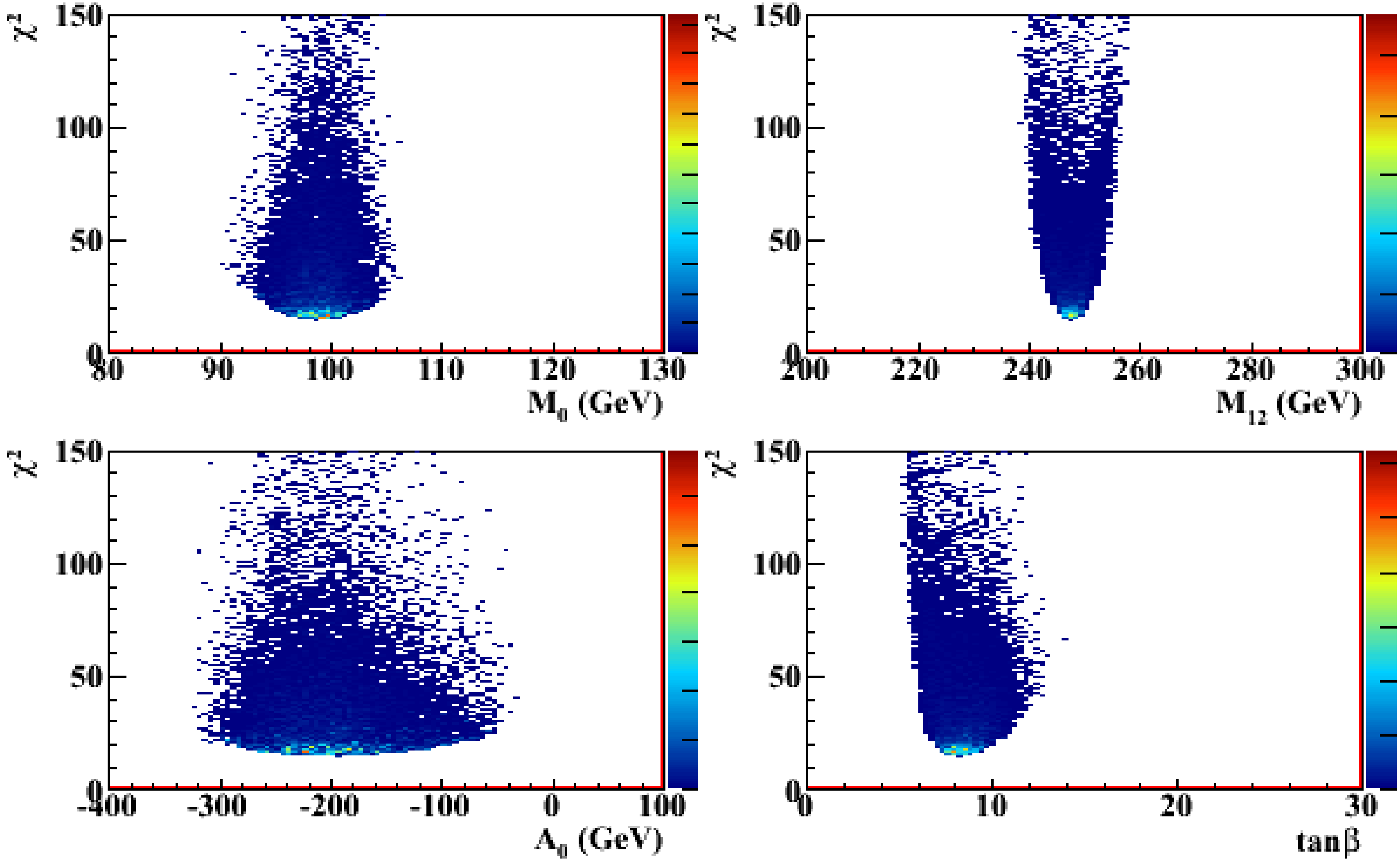
Fit with Markov chain

- Tried 144+12=156 fits with different interpretation of observed data
  - Done by modifying the fittino input file
  - For example, m_{ll} edge calculation would be done using different particle masses
  - Try these combinations blindly without thinking whether a particular interpretation is physically sensible or not
- Run the fit using Markov chain to get results quickly
  - Takes a few hours for each setting
  - 52 out of 156 cases, had chi2=100 M, probably mass hierarchy was unphysical

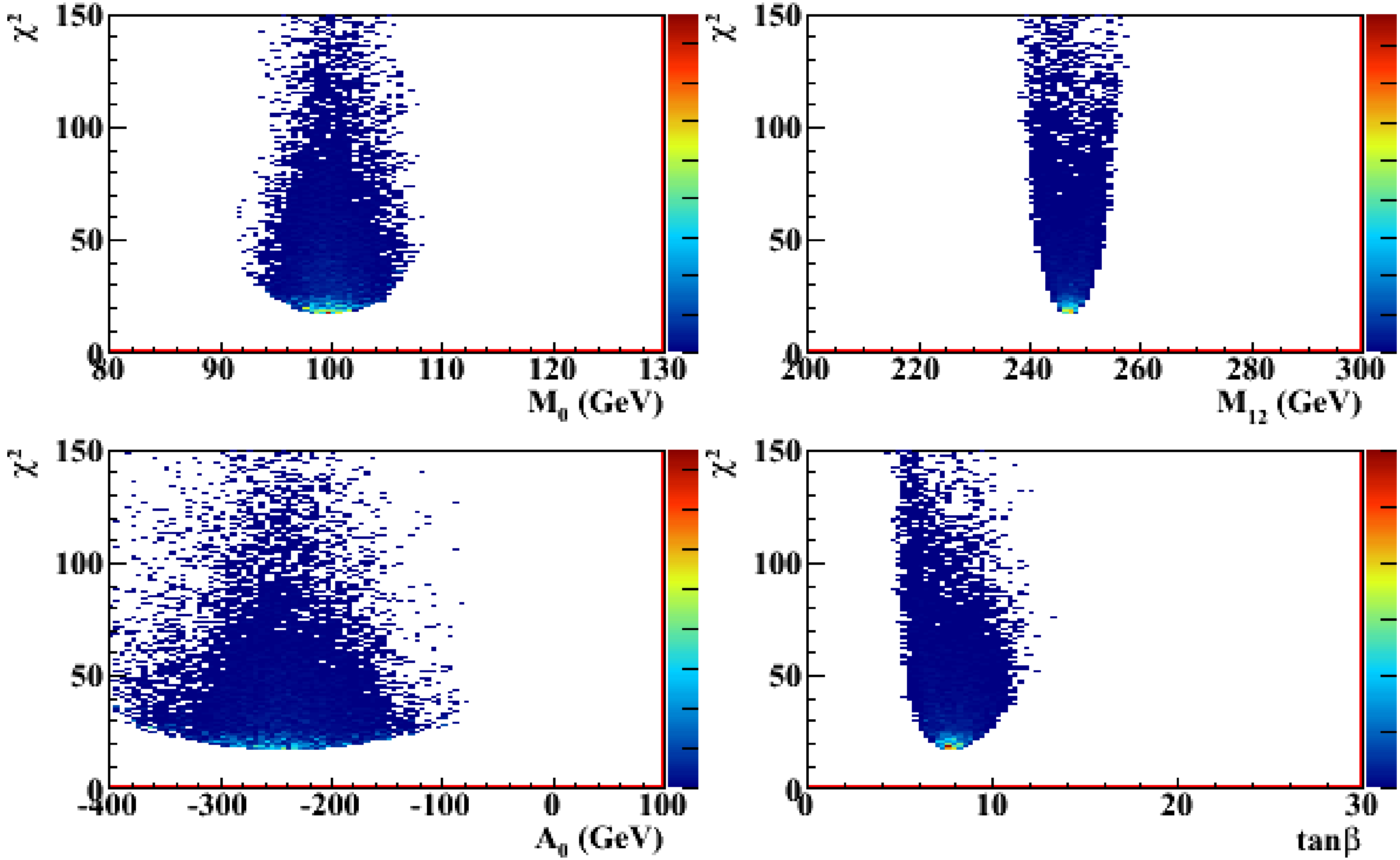
χ^2 of different fits



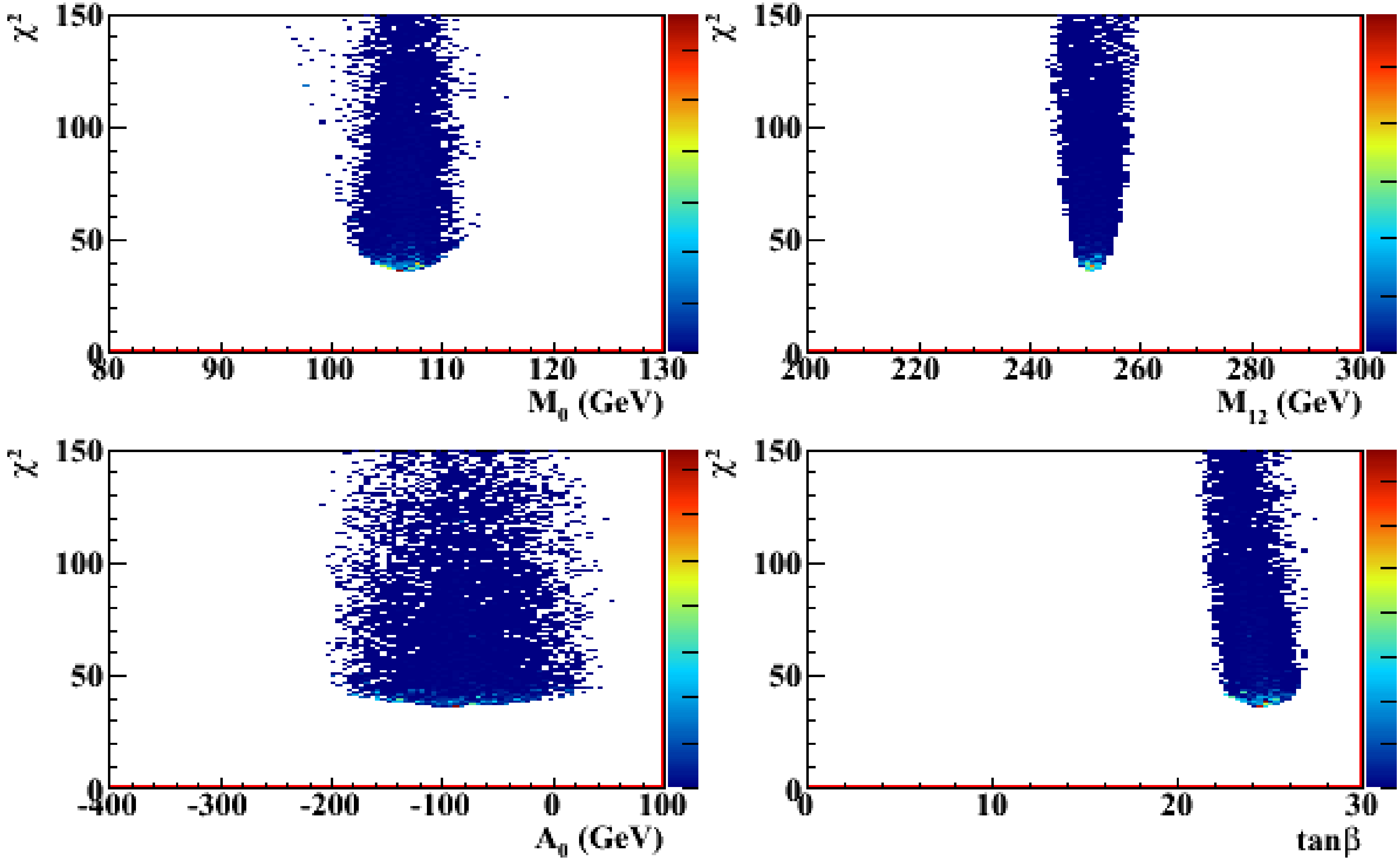
Correct assignment



qll2 ($\chi^0_4 \rightarrow \chi^0_3$)



qll (correct), qtautau ($\chi^0_2 \rightarrow \chi^0_3$)



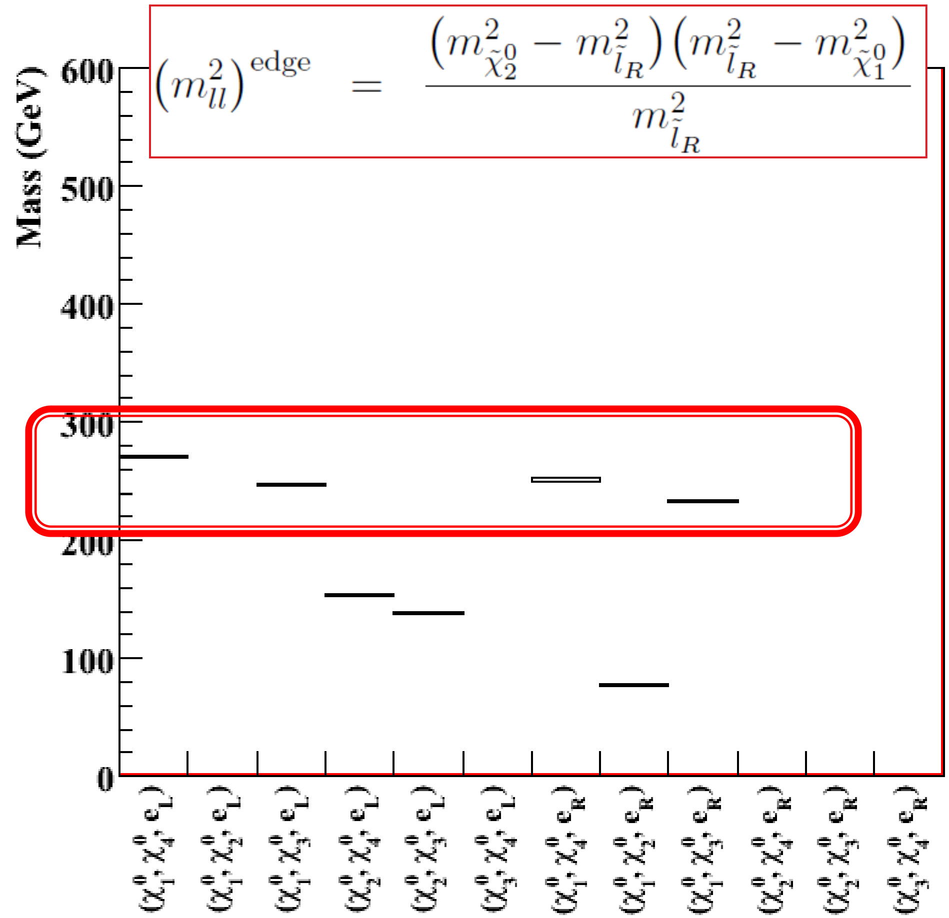
qll final state (2)

There is only one edge measurement (m_{ll}) used in the fit

All these combinations give not too big chi2

In what I'm doing now, I don't check whether we the decay is allowed or not

It would be nice if we could also take that into account (e.g. expected number of events)



Summary

- Tried different interpretation of particles involved in the cascade decay
  - The lowest chi2 was found for the correct interpretation
  - Fit failed for 52 cases out of 156
- Different interpretation of qll(2) final state
  - Only one mass edge used as an input
  - Several interpretations would predict similar values, therefore give rather low chi2
- Different interpretation of qll final state
  - Many kinematic edges are used in the fit which makes it more difficult to have low chi2 with a wrong interpretation
  - Fitted parameters may differ a lot from the true value (especially $\tan\beta$ and A_0)

Mass edges with different particles