Influence of the χ_1^0 mass precision on the $A \rightarrow \chi_2^0\chi_2^0$ mass reconstruction

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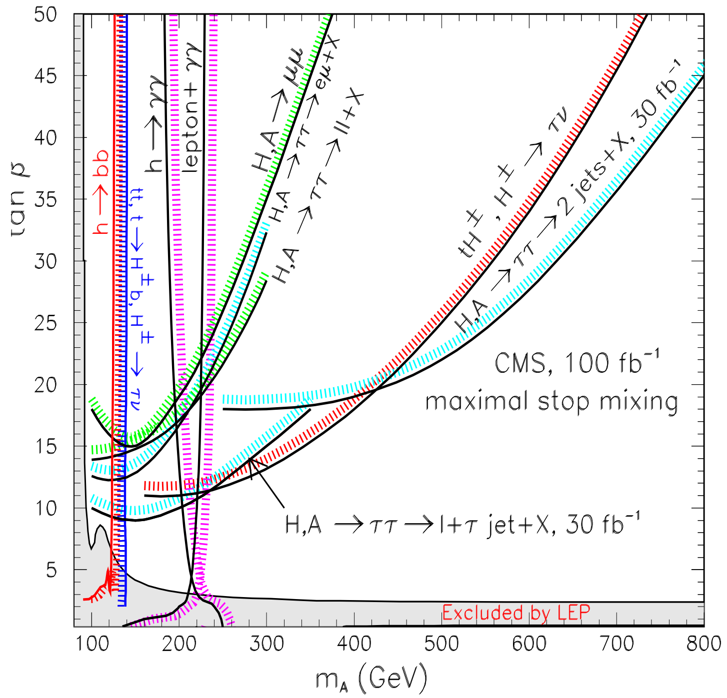
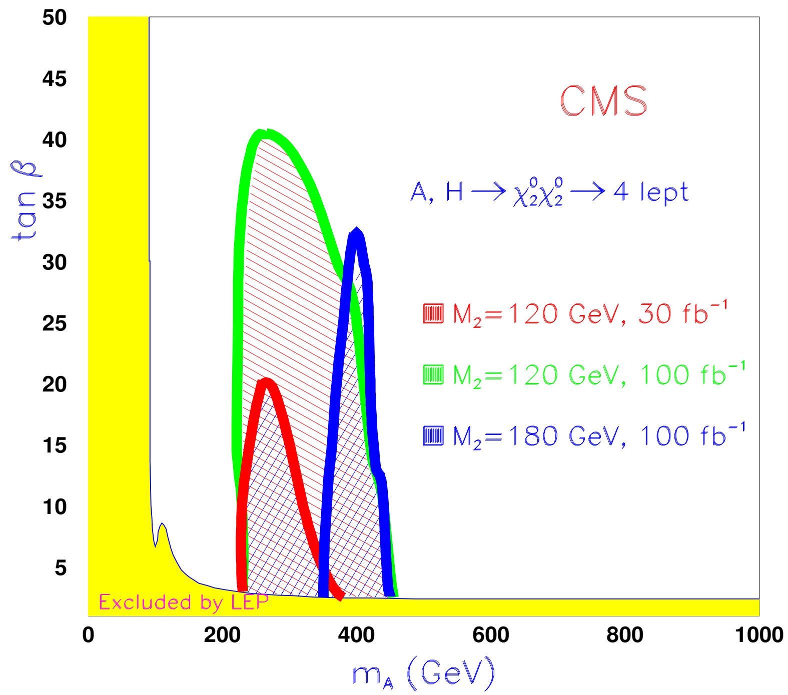
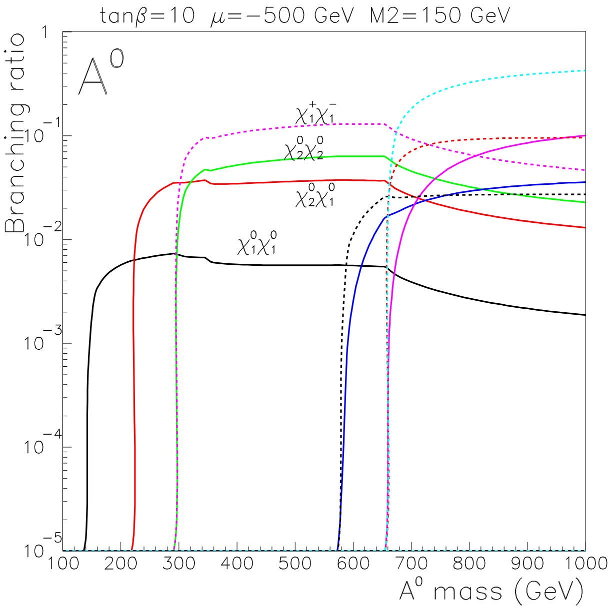
Discovery potential for the MSSM Higgses





Decays to neutralinos and charginos in the MSSM

Example of the decay of the heavy Higgs boson into neutralinos and charginos:



In order to suppress the background, most preferable are the leptonic decay modes of the neutralinos and charginos:

$$\chi_2^0 \to \chi_1^0\, l^+\, l^- \qquad\qquad \chi_1^+ \to \chi_1^0\, l^+\, \nu$$

We therefore consider the channel

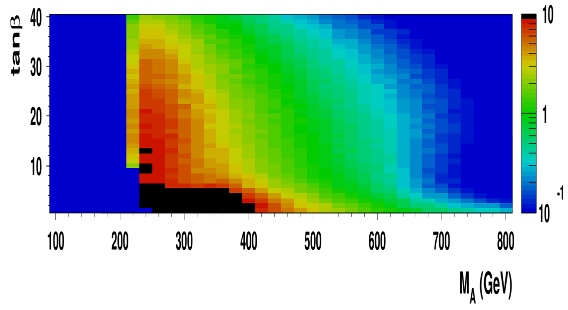
$$A^0, H^0 \to \chi_2^0\, \chi_2^0 \to 4\, l^\pm + X \tag{1}$$

with four isolated leptons (e,μ) in the final state.

Cross sections x BR

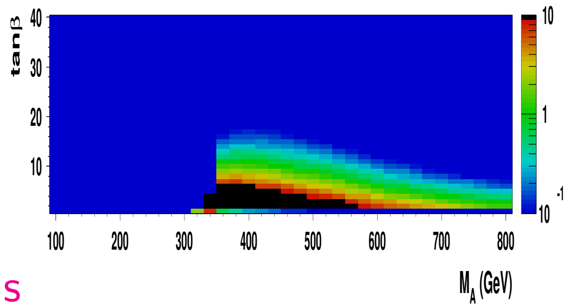
Case 1:

χ_2^0 gaugino-like,
$m_{\tilde{l}} > m_{\chi_2^0}$
$\longrightarrow$ virtual slepton exchange



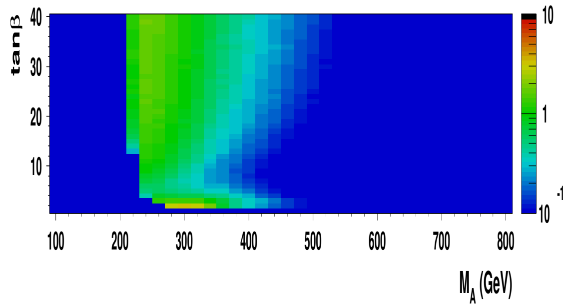
Case 2:

χ_2^0 gaugino-like,
$m_{\tilde{l}} < m_{\chi_2^0}$
$\longrightarrow$ decays into real sleptons



Case 3:

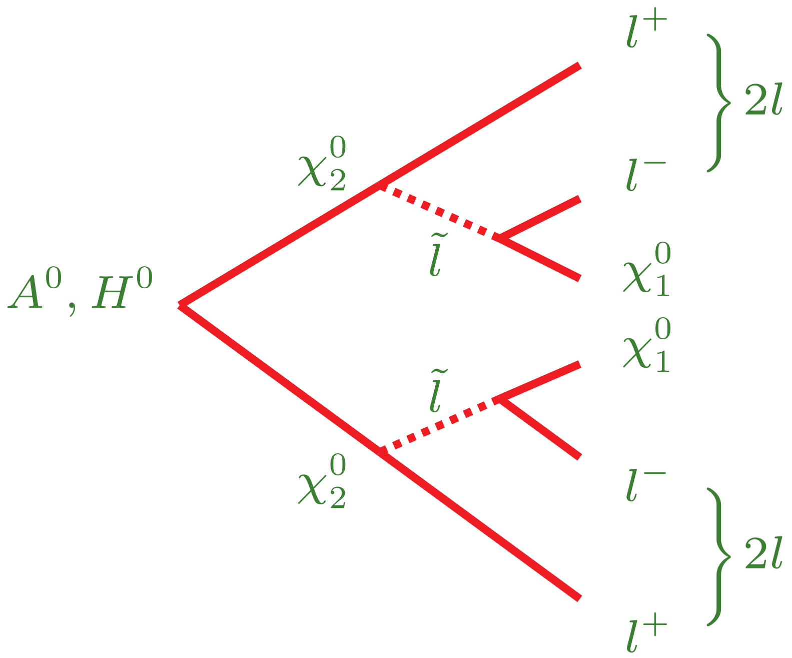
χ_2^0 higgsino-like,
no coupling to sleptons



We will first choose a favourable point in parameter space and look whether we can observe a signal above the background.

Signal and backgrounds considered

- The signal $A^0, H^0 \longrightarrow \chi_2^0\,\chi_2^0 \longrightarrow 4\,l^{\pm}$ is generated with SPYTHIA.
  The signal signature looks like:



- Possible backgrounds that can give four leptons in the final state are:
  - SM : ZZ, $Zb\bar{b}$, $Zc\bar{c}$, $t\bar{t}$, Wtb
  - SUSY : $\tilde{q}/\tilde{g}$, $\tilde{l}\tilde{l}$, $\tilde{\nu}\tilde{\nu}$, $\tilde{q}\tilde{\chi}$, $\tilde{\chi}\tilde{\chi}$

  The backgrounds are generated with PYTHIA 6.136.
- The CMS detector response was generated with the fast simulation package CMSJET .

Selection Criteria

We can discriminate between the signal and the background by requiring that:

Basic requirements:

- there are four isolated leptons (e/μ) in the final state (no charged particle with $P_T >$ 1.5 GeV in the cone of 0.3 rad around each lepton track)
- Z-veto (dilepton effective mass out of $m_Z\pm$ 10 GeV)

For signal to background optimization:

- P_T hardest lepton $<$ 80 GeV
- 20 Gev $< E_T^{miss} <$ 130 GeV
- E_T hardest jet $<$ 100 GeV
- if necessary (light squark/gluino): only 0,1,2 jets

We now consider the following two sets of MSSM parameters:

Case 1 (virtual sleptons):
$M_2 =$ 120 GeV,
$M_1 =$ 60 GeV,
$\mu =$ -500 GeV,
$M_{\tilde{l}} =$ 250 GeV,
$M_{\tilde{q},\tilde{g}} =$ 1000 GeV

Case 2 (real sleptons):
$M_2 =$ 200 GeV,
$M_1 =$ 100 GeV,
$\mu =$ +350 GeV,
$M_{\tilde{l}} =$ 150 GeV,
$M_{\tilde{q},\tilde{g}} =$ 550 GeV

Case studies (1)

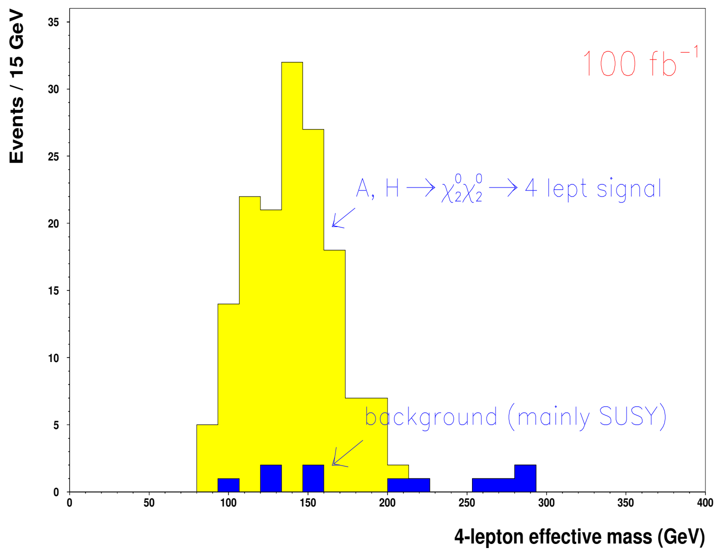
Case 1: $m_{\tilde{l}} > m_{\chi_2^0}$

MSSM parameters: $M_2 = 120$ GeV, $M_1 = 60$ GeV, $\mu =$ -500 GeV, $M_{\tilde{l}} = 250$ GeV, $M_{\tilde{q},\tilde{g}} = 1000$ GeV

Low $\tan\beta$:

$M_A = 350$ GeV

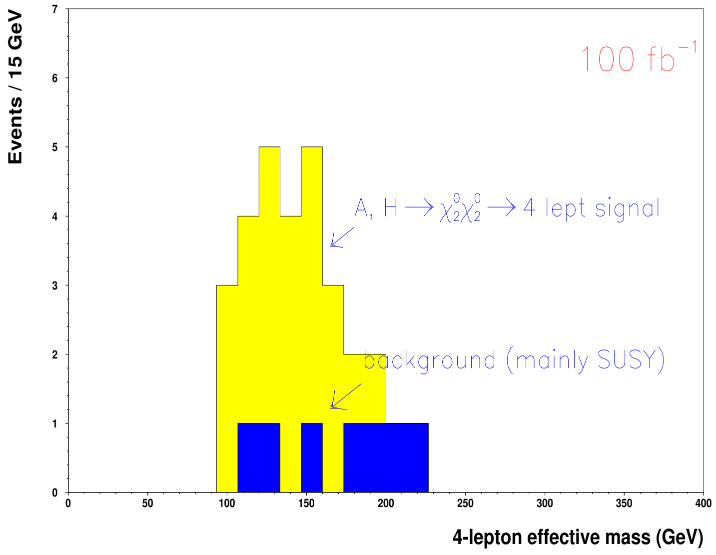
$\tan\beta = 5$



High $\tan\beta$:

$M_A = 350$ GeV

$\tan\beta = 35$



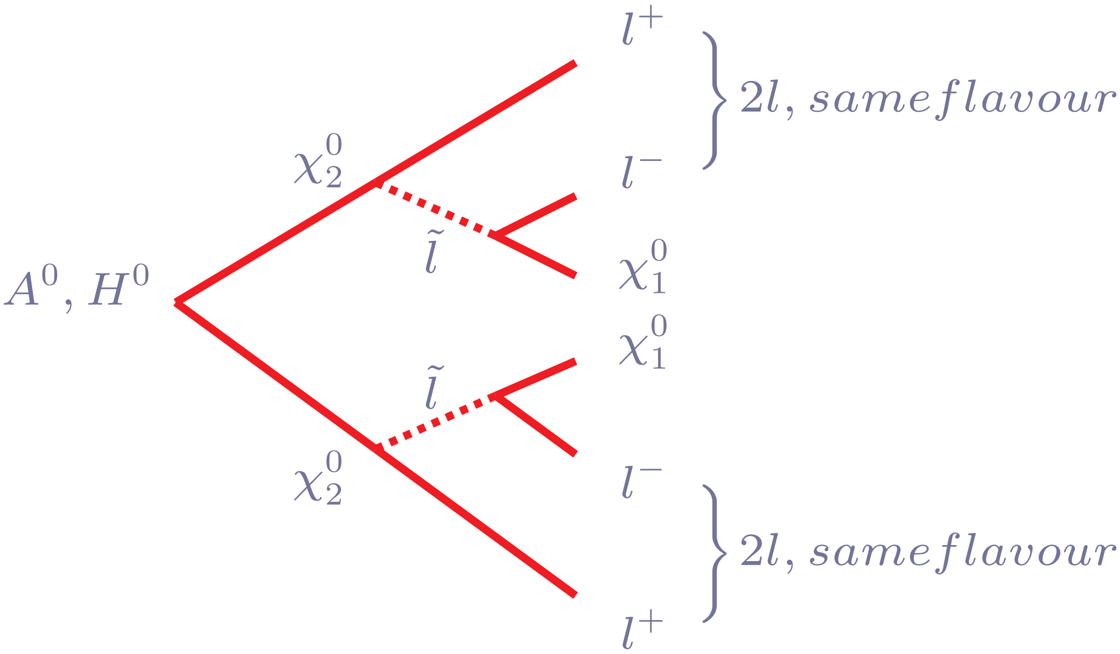
Case 1: M_A = 350 GeV, M_2 = 120 GeV

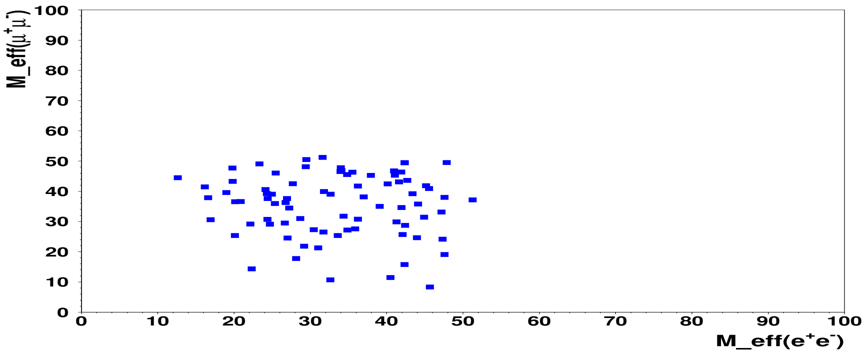
Table 1: Number of events after successive cuts (at 100 fb^{-1}).

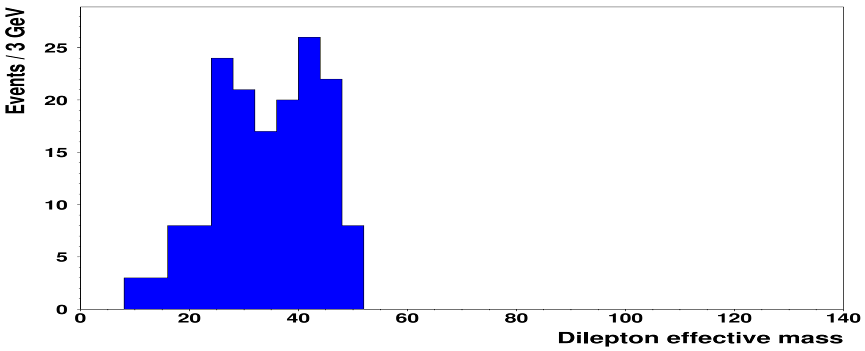
Process	4 isol. lept.	Z-veto	P_T lept. cut	$\not{E}_T$ cut	E_T jet cut	All cuts
$\tilde{q}$, $\tilde{g}$	421	206	60	8	1	1
$\tilde{\nu}$ $\tilde{\nu}$	191	92	20	15	15	11
$\tilde{q}\tilde{\chi}$	41	23	7	0	0	0
$\tilde{\chi}\tilde{\chi}$	40	20	13	5	4	3
tot. SUSY	703	345	102	28	20	15
ZZ	2106	80	79	10	10	2
total bkg.	2809	425	181	38	30	17
H, A signal	320	276	263	212	192	192

The $t\bar{t}$, $Zb\bar{b}$ and $Zc\bar{c}$ backrounds are eliminated through the tight isolation criterium.

Dilepton effective mass spectrum







Case studies (2)

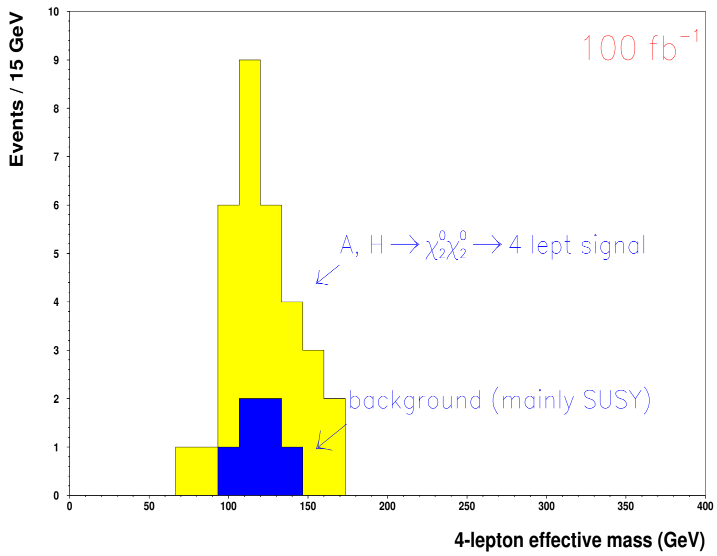
Case 1bis: (heavier $\chi^0/\chi^\pm$, positive μ)

MSSM parameters: $M_2 = 180$ GeV, $M_1 = 100$ GeV, $\mu = +500$ GeV, $M_{\tilde{l}} = 250$ GeV, $M_{\tilde{q},\tilde{g}} = 1000$ GeV

'Low' M_A:

$M_A = 380$ GeV

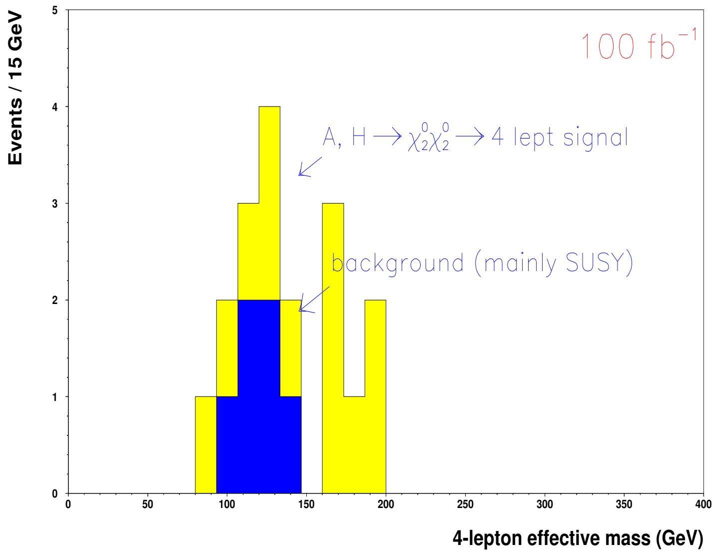
$\tan\beta = 10$



High M_A:

$M_A = 500$ GeV

$\tan\beta = 10$



Case studies (3)

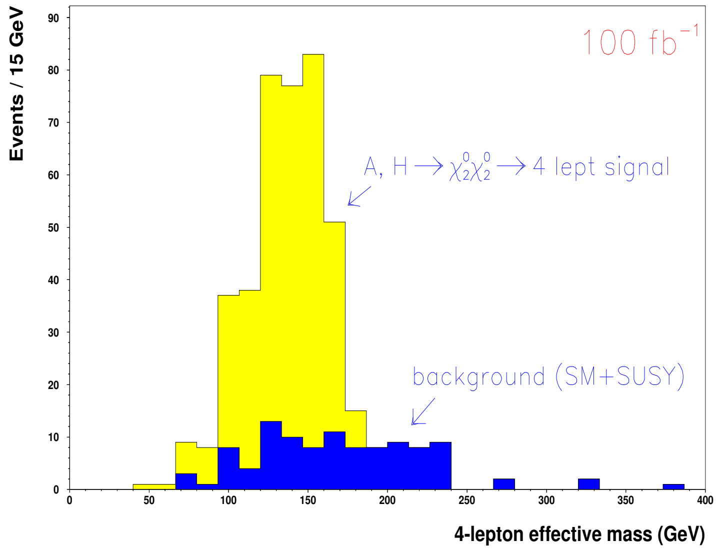
Case 2: $m_{\tilde{l}} < m_{\chi_2^0}$

MSSM parameters: $M_2 = 200$ GeV, $M_1 = 100$ GeV, $\mu = +350$ GeV, $M_{\tilde{l}_L} = 200$ GeV, $M_{\tilde{l}_R} = 150$ GeV, $M_{\tilde{q},\tilde{g}} = 550$ GeV

'Low' M_A:

$M_A = 380$ GeV

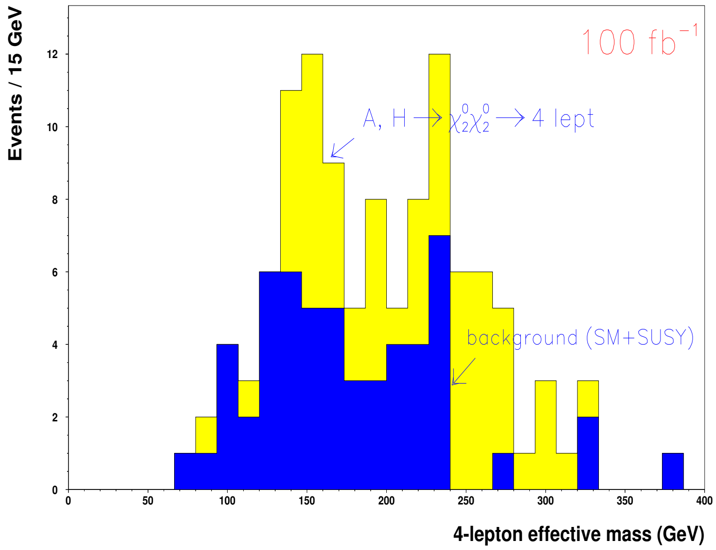
$\tan\beta = 10$



High M_A:

$M_A = 600$ GeV

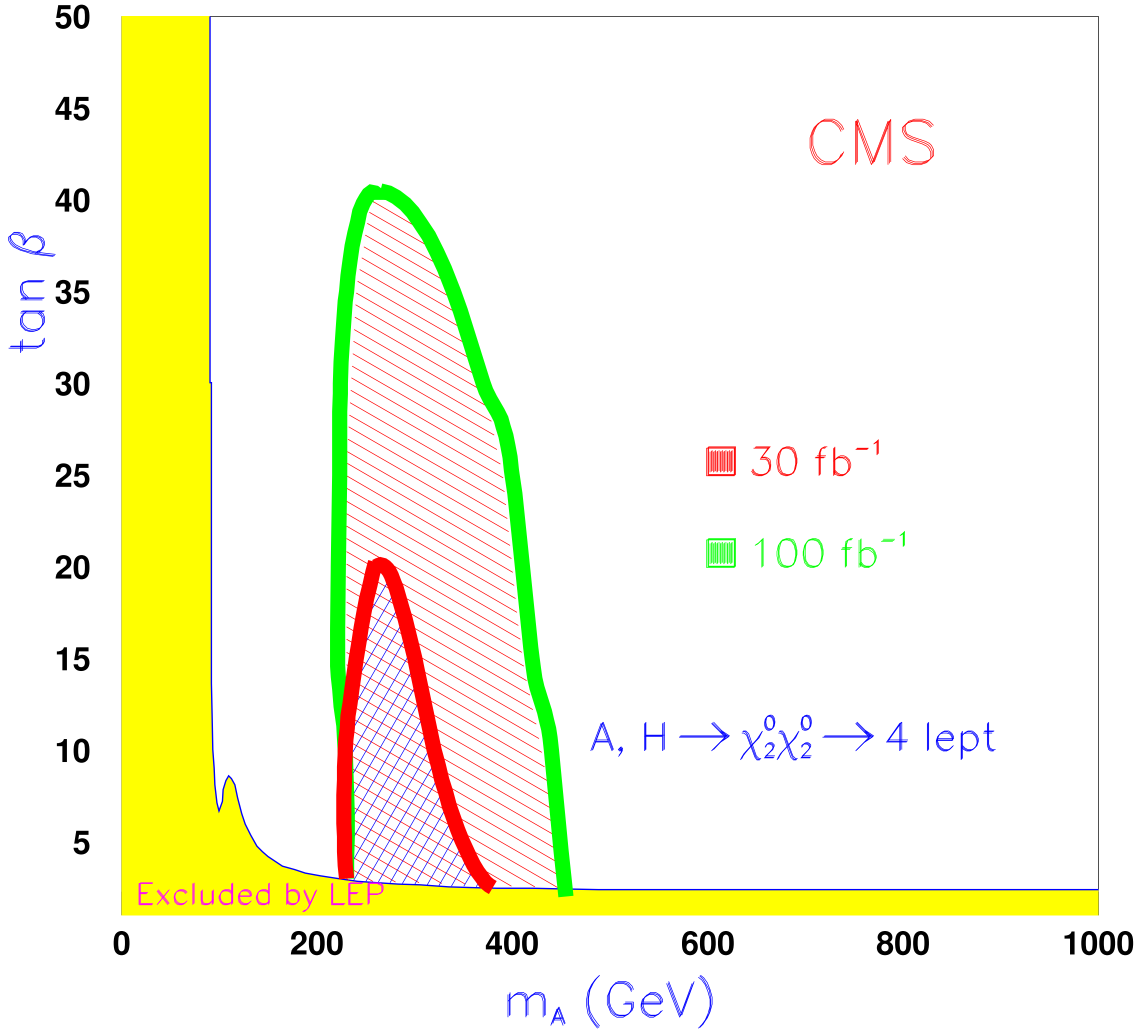
$\tan\beta = 10$



Discovery reach

5σ-discovery contours for case 1:

MSSM parameters: $M_2 = 120$ GeV, $M_1 = 60$ GeV,
$\mu =$ -500 GeV, $M_{\tilde{l}} = 250$ GeV, $M_{\tilde{q},\tilde{g}} = 1000$ GeV



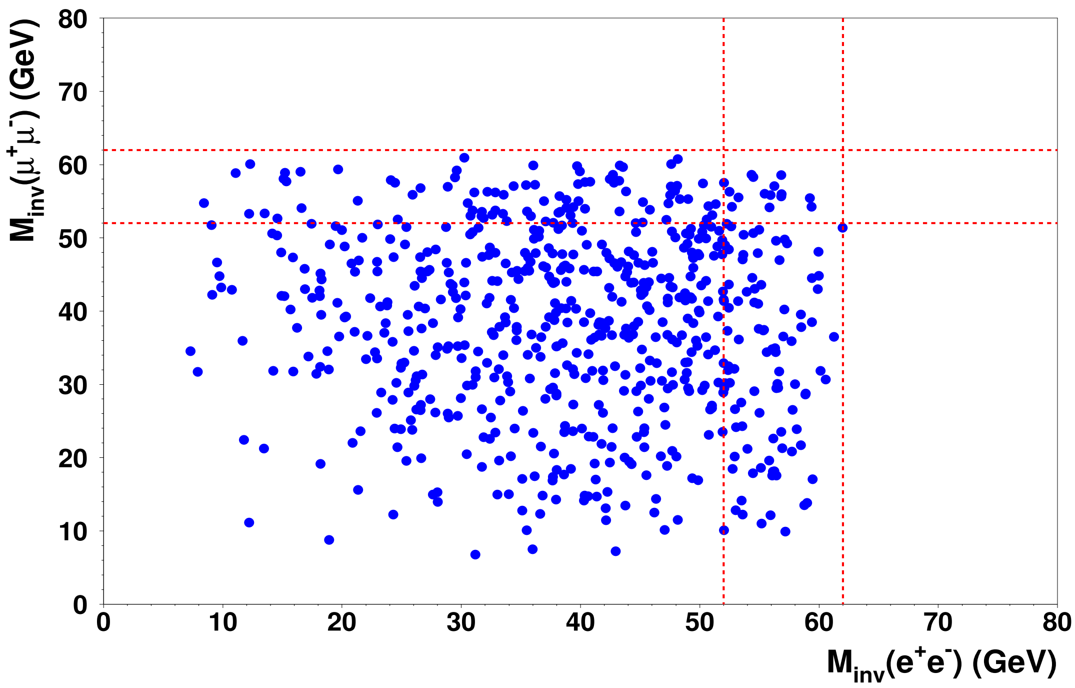
How to reconstuct the Higgs mass?

A) complete reconstruction

By selecting dilepton pairs that have an invariant mass near the kinematical endpoint, one can recontsruct the four-momentum of the χ_2^0:

$$\vec{p}_{\chi_2^0} = \left(1 + \frac{M_{\chi_1^0}}{M_{ll}}\right) \vec{p}_{ll}$$
$$M_{\chi_2^0} = M_{\chi_2^0} + M_{ll}$$

The Higgs mass can then be calculated as the invariant mass of the two χ_1^0's.

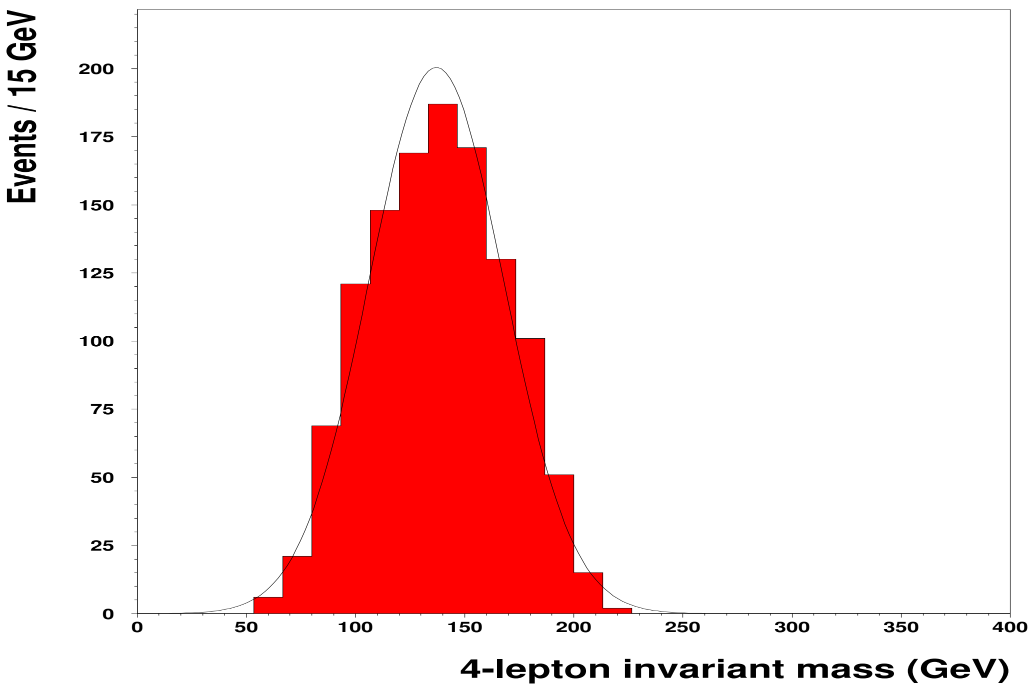


Problem: very poor statistics, even after 600 fb^{-1}.
Only useful in a few very favourable points in the MSSM parameter space ...

B) fitting the 4 lepton invariant mass with the Monte Carlo distribution

A first excercise for case 1, using PYTHIA 6.152.

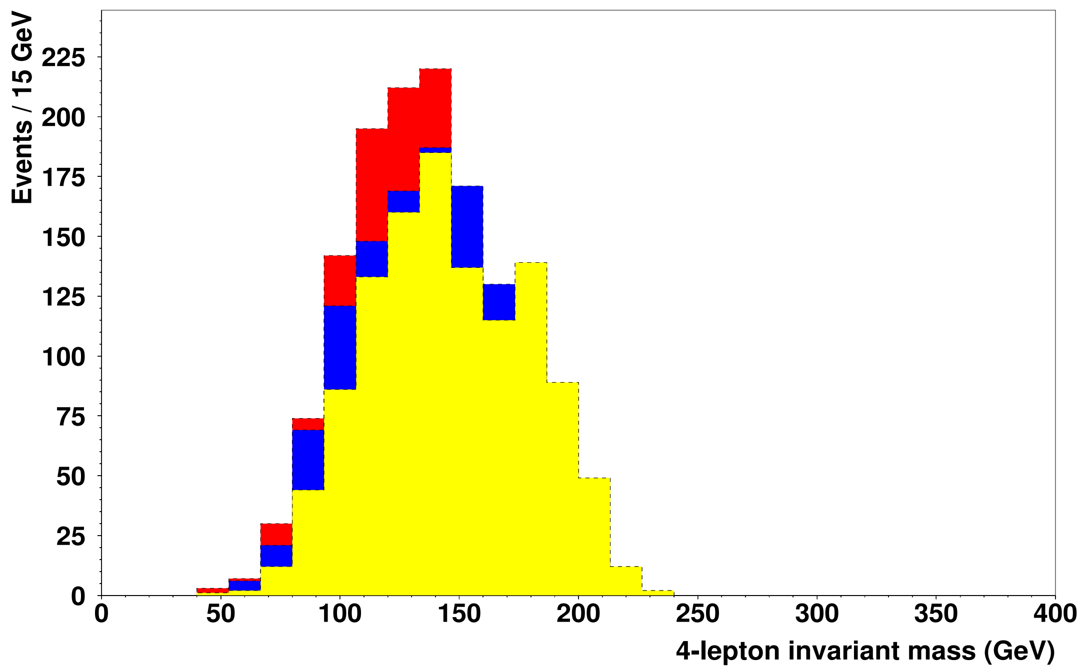
WARNING: preliminary results !!



Fitting the 4-lepton invariant mass with m_A

Consider the case of $M_1 = 60$ GeV, $M_2 = 120$ GeV, $m_{\tilde{l}} = 250$ GeV, $\mu =$ -500 GeV.

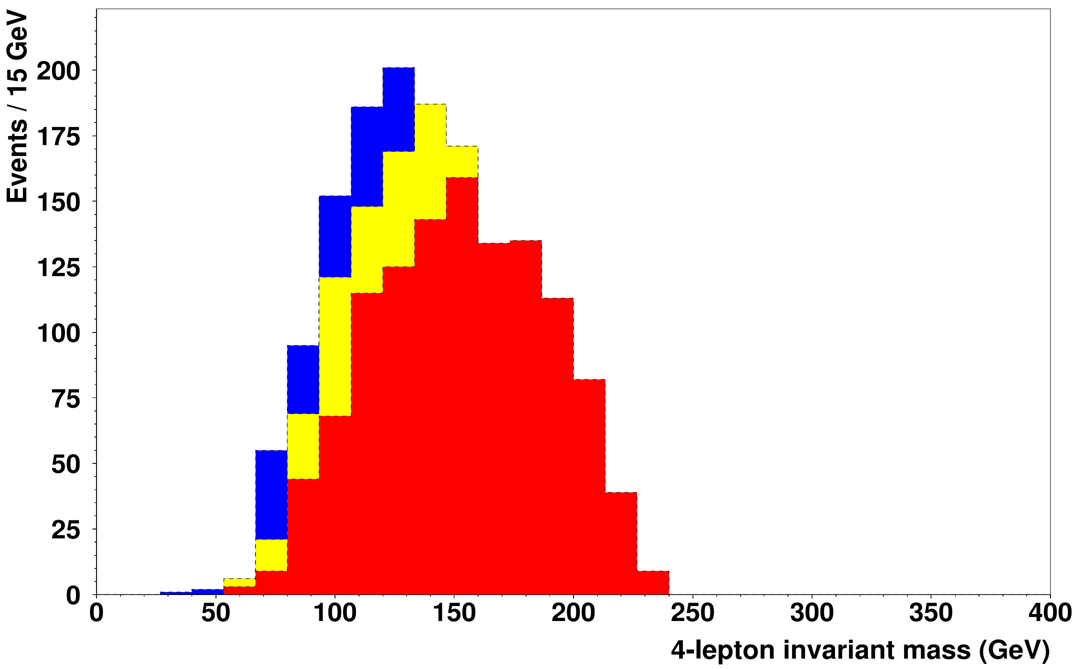
$$
\begin{array}{llcl}
m_A = 330\,GeV & \rightarrow & & -8\,GeV \\
m_A = 340\,GeV & \rightarrow & & -4\,GeV \\
m_A = 350\,GeV & \rightarrow & < M_{llll} > = & 137\,GeV \\
m_A = 360\,GeV & \rightarrow & & +4\,GeV \\
m_A = 370\,GeV & \rightarrow & & +8\,GeV
\end{array}
$$



Effect of M_1 on the 4-lepton invariant mass

Assuming that $M_2 - M_1$ is constant (well measured), there is still a large effect when varying M_1:

$$
\begin{array}{llrl}
M_1 = 50\,GeV & \rightarrow & & +17\,GeV \\
M_1 = 55\,GeV & \rightarrow & & +5\,GeV \\
M_1 = 60\,GeV & \rightarrow & < M_{llll} > = & 137\,GeV \\
M_1 = 65\,GeV & \rightarrow & & -4\,GeV \\
M_1 = 70\,GeV & \rightarrow & & -15\,GeV
\end{array}
$$



4-lepton distribution is more sensitive to M_1 than to m_A!!

Conclusions

- The channel $H^0, A^0 \longrightarrow \chi_2^0\chi_2^0 \longrightarrow 4\,l$ may be observed in the low and intermediate $\tan\beta$ region of MSSM parameter space, if neutralinos and sleptons are light enough. This region is largely complementary to the reach of the $H^0, A^0 \longrightarrow \tau\tau$ channel.

- A direct reconstruction of the Higgs mass seems very difficult due to very poor statistics, even after 600 fb^{-1}.

- A determination of m_A by comparing the 4-lepton invariant mass distribution with MC is possible. However, the distribution is more sensitive to $m_{\chi_1^0}$ than to m_A!!

  A percent level accuracy on the LSP mass would be needed to eliminate this source of error in the determination of the Higgs mass.