Higgs search in SUSY events

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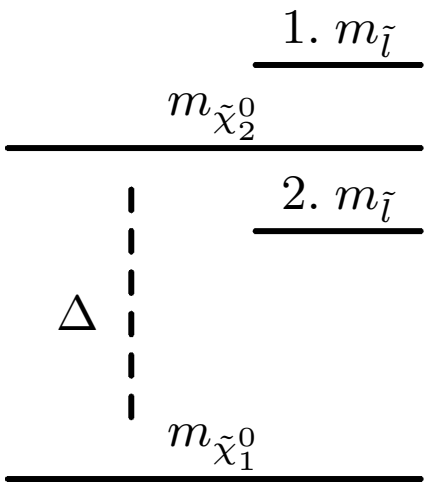
Higgs search



Dominant $\tilde{\chi}_2^0$ decay mode depends on scenario

$\Delta = m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0}$	1. $m_{\tilde{\chi}_2^0} < m_{\tilde{l}}$	2. $m_{\tilde{l}} < m_{\tilde{\chi}_2^0}$
$\Delta > m_h$	$\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 h$	$\tilde{\chi}_2^0 \to \tilde{l}l / \tilde{\chi}_1^0 h$
$m_Z < \Delta < m_h$	$\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 Z$	$\tilde{\chi}_2^0 \to \tilde{l}l$
$\Delta < m_Z$	$\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 ll$	$\tilde{\chi}_2^0 \to \tilde{l}l$

- If open $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 h$ has generally a substantial branching ratio
- A resonance may be reconstructed
- May provide a Higgs discovery mode
- If visible ll channel is still the most powerful for mass measurements
- $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 h / \tilde{\chi}_1^0 Z$ may help to extract informations on $\tan\beta$ and sgnμ

Contents

- Reproducing TDR results:
  - LHCC Point 5
  - $t\bar{t} + jets$ background
- Choice of new point at high $\tan\beta$ with a scan of Minimal SUGRA parameters
- Analysis for this point
- Outlooks

LHCC Point 5: production

(GeV)	TDR	HERE	Δ
$\tilde{g}$	767	785	18
$\tilde{q}_L$	690	695	5
$\tilde{q}_R$	662	668	6
$\tilde{l}$	239	241	2
$\tilde{\chi}_1^0$	122	119	3
$\tilde{\chi}_2^0$	233	229	4
h	93	93	0

SUSY Production

$\sigma(TDR) = 19$ pb

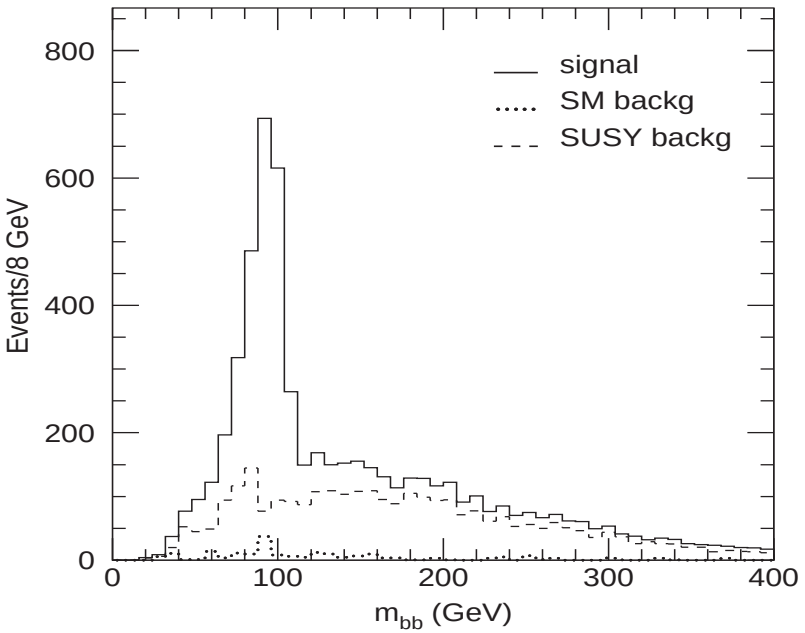
$\sigma(HERE) = 17$ pb

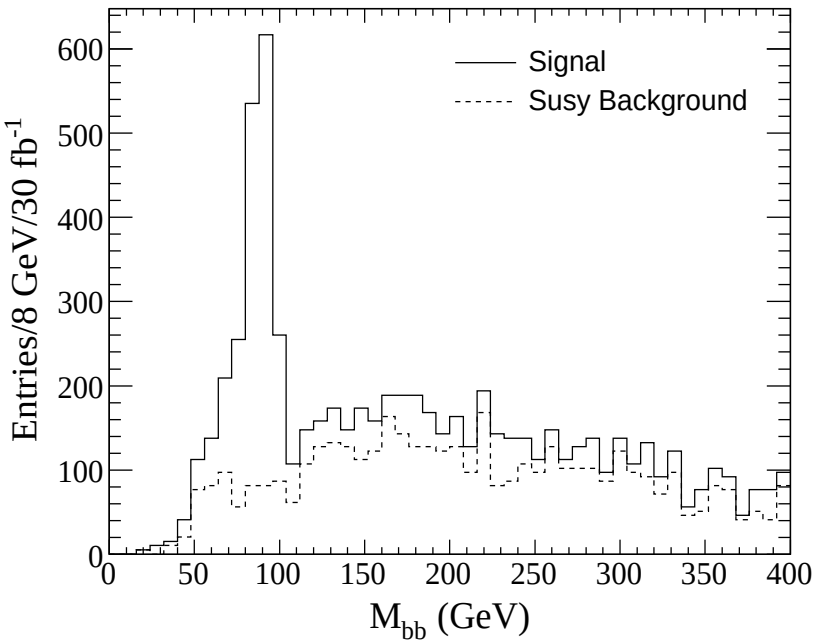
- LHCC Point 5:
  ($m_0 = 100$ GeV, $m_{1/2} = 300$ GeV,
  $A = 300$ GeV, $\tan\beta = 2.1$, $\mu > 0$)
- Generation with PYTHIA 6.3 + CTEQ3L
- About 20% of events contains a light higgs
- Mass spectrum in good agreement
- Heavier squarks and gluinos $\Rightarrow$ smaller cross-section
- Fast simulation study with:
  - b-tagging efficiency: 60%
  - c-rejection: 10
  - jet-rejection: 100

LHCC Point 5: analysis

- Selection cuts:
  - $E_T^{miss} > 300$ GeV
  - 2 *b*-jets with $p_T > 50$ GeV
  - Veto on 3rd jet with $p_T > 50$ GeV
  - 2 *non-b*-jets with $p_T > 100$ GeV
  - Veto on leptons with $p_T > 10$ GeV
  - $|m_{bb} - m_h| < 25$ GeV

30 fb^{-1}	SUSY	SIGNAL	S/B
TDR	2560	1940	3.1
HERE	1980	1480	3.0
HERE (same σ)	2350	1760	3.0

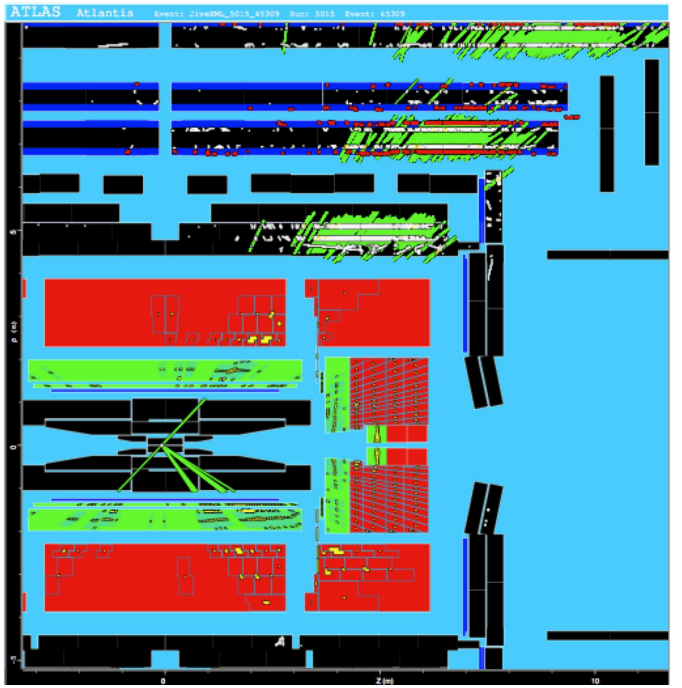




SM background

- Background sources from SM:
  - Irreducibles

$$
\begin{aligned}
t\bar{t} + Nj &\rightarrow b\bar{b} + l\nu + qq \\
t\bar{t} + Nj &\rightarrow b\bar{b} + l\nu + l\nu \\
W + Nj &\rightarrow l\nu + Nj \\
Z + Nj &\rightarrow \nu\nu + Nj \\
Z + Nj &\rightarrow \tau\tau + Nj
\end{aligned}
$$



F. Paige, ATLAS Susy WG, 05/2006

  - Reducible *QCD events with fake* E_T^{miss} from:
    - Electronic and pile-up noise
    - Fake muons (e.g. from cosmics)
    - Jets in cracks
    - Punchthroughs

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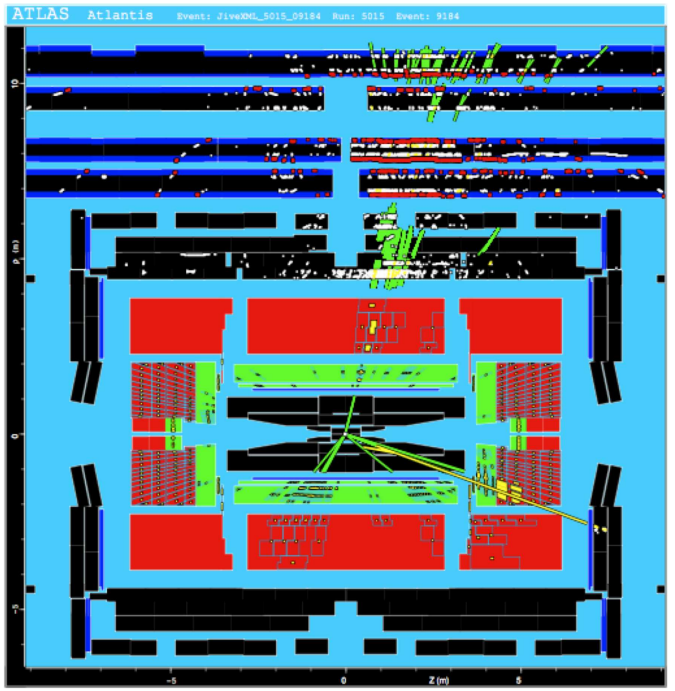

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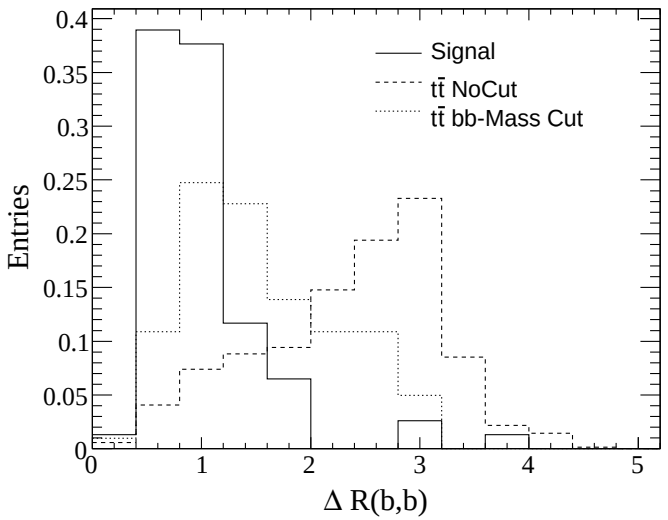
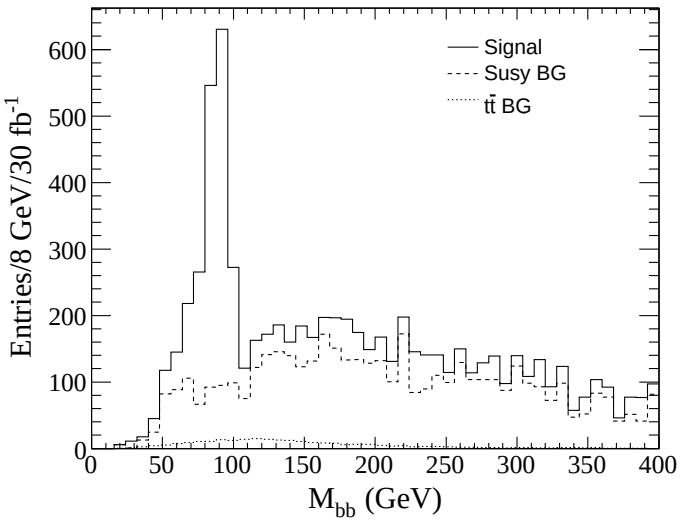
Estimation of $t\bar{t}$ background

- In TDR with Pythia (PS), now using Alpgen+Jimmy (ME+PS)
- $t\bar{t}$ background enhanced by a factor 3.5
- A cut on ΔR_{bb} may be useful to suppress it more

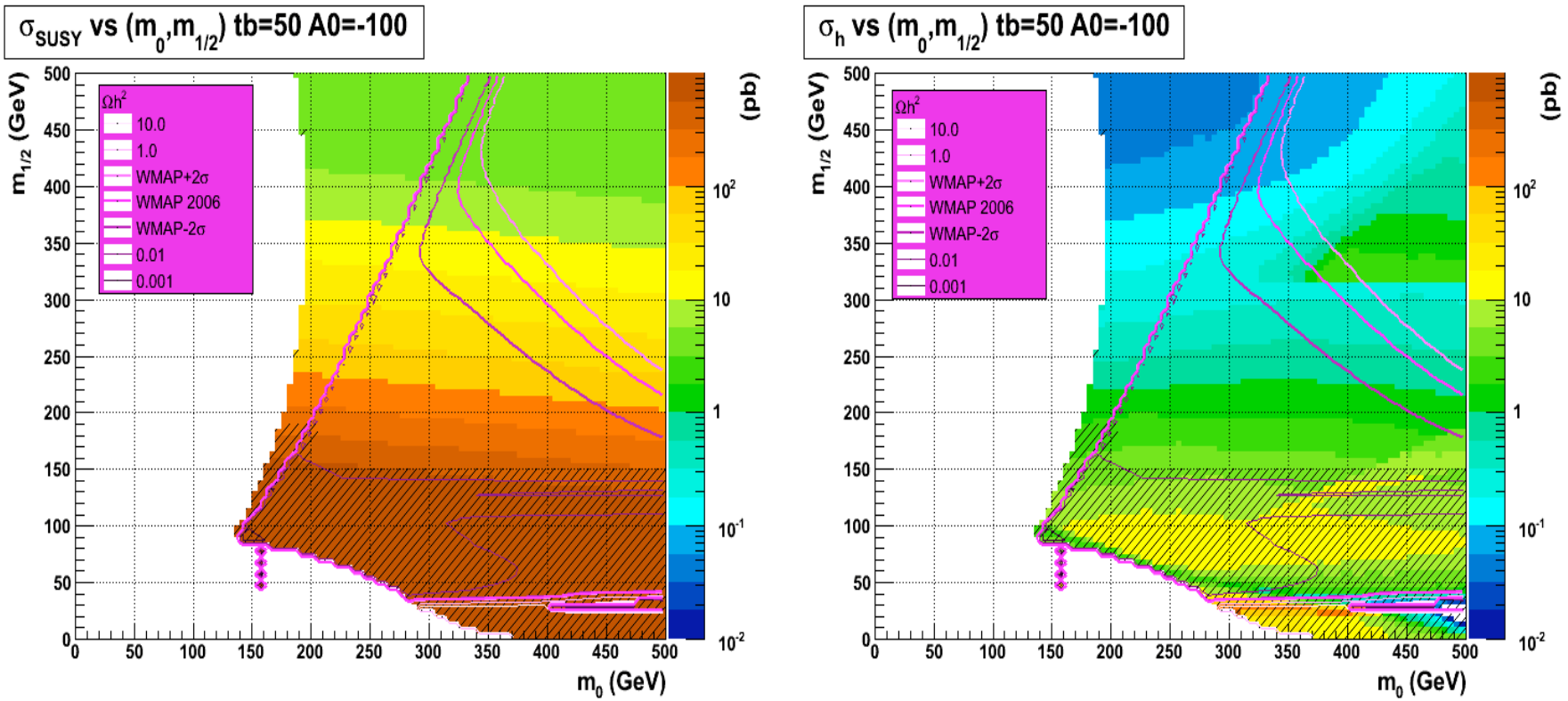
$L = 30$ fb^{-1}	$t\bar{t}$ Pythia (TDR)	$t\bar{t}$ Alpgen (HERE)	Susy $h \to b\bar{b}$ (LHCC 5)
No Cut	10^7	10^7	5×10^5
E_T^{miss} > 300 GeV & 2 b-$jets$ & $\lvert M_{bb} - M_h \rvert$ < 25 GeV	135	640	2240
& 2 hard $jets$ & l veto	40	140	1480
& $\Delta R_{bb} < 2$	-	105	1400





Scan of parameters

- Scan of Minimal SUGRA parameters
- Choice of a new point:
  - Not excluded by LEP
  - Compatible with WMAP observations
  - $m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} > m_h$



New point: topology

- $(\ m_0 = 390\ \text{GeV},\ m_{1/2} = 325\ \text{GeV},\ A = -100\ \text{GeV},\ \tan\beta = 50,\ \mu > 0\ )$
- For large values of $\tan\beta$ there is a non-negligible mixing between the L and R scalar fermions of the third family: $\tilde{\tau}$, $\tilde{b}$ and $\tilde{t}$

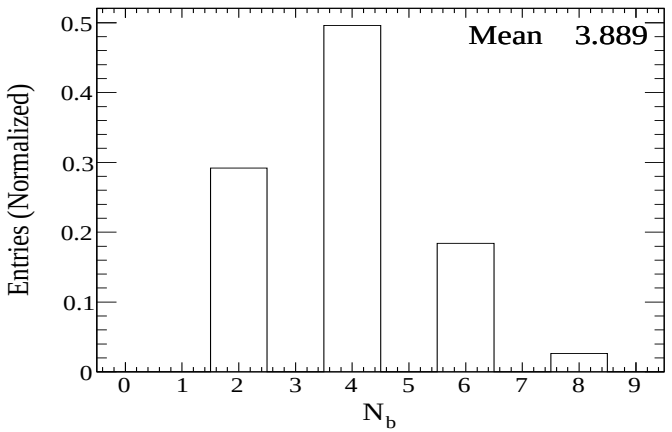
$\Rightarrow$ Significant splitting between $m_{\tilde{b}_1}$ and $m_{\tilde{b}_2}$, enhancing $BR(\tilde{g} \to \tilde{b}_1 b)$ with respect to the light flavours

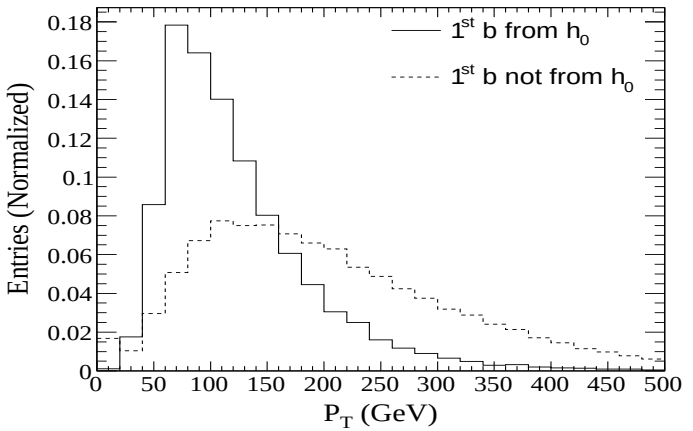
$\Rightarrow$ Lots of b's in the SUSY events

$\Rightarrow$ Combinatorial background makes the discovery more challenging

$$\tilde{g} \to \tilde{b}_1 b_2 \to \tilde{\chi}_2^0 b_1 b_2 \to \tilde{\chi}_1^0 h b_1 b_2 \to \tilde{\chi}_1^0 b_1^h b_2^h b_1 b_2$$

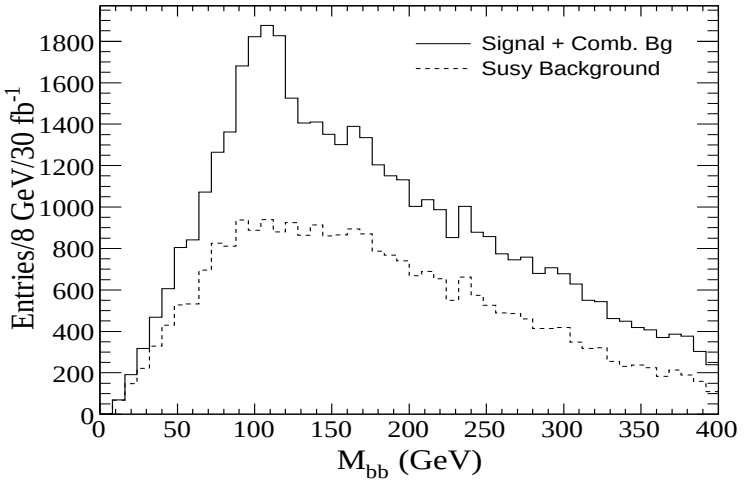
Since $m(\tilde{b}_1) - m(\tilde{\chi}_2^0) \gg m(h) \Rightarrow P_T(b_1) \gg P_T(b_1^h)$

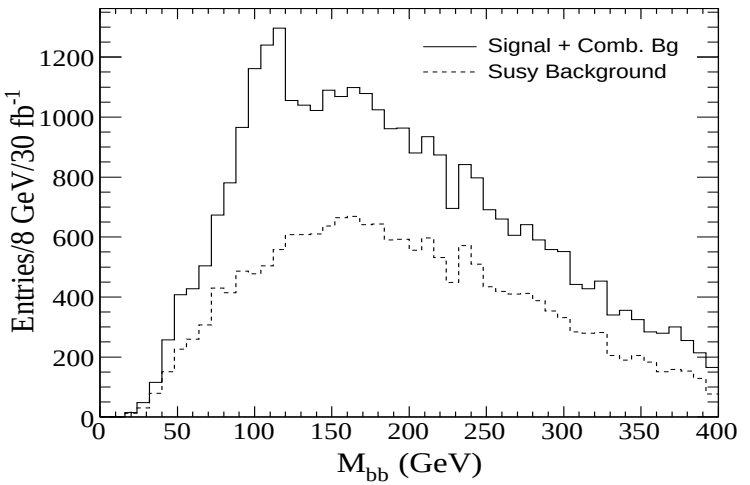




New point: analysis

- $E_T^{miss} > 200$ GeV
- $|m_{bb} - m_h| < 25$ GeV
- Fig. on top: take the two hardest *b*-jets
- Fig. on bottom: take 2^{nd} and 3^{rd} *b*-jets and ask for $p_T^b > 50$ GeV
- Try to find out correlations to remove the uncertainty on the choice of b-jets





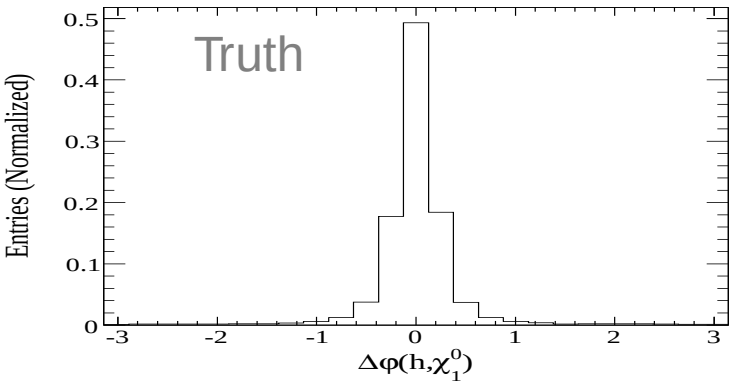
30 fb^{-1}	**SUSY**	**SIGNAL**	**S/B**
b1 & b2	10510	2400	0.29
b2 & b3	6710	1680	0.33

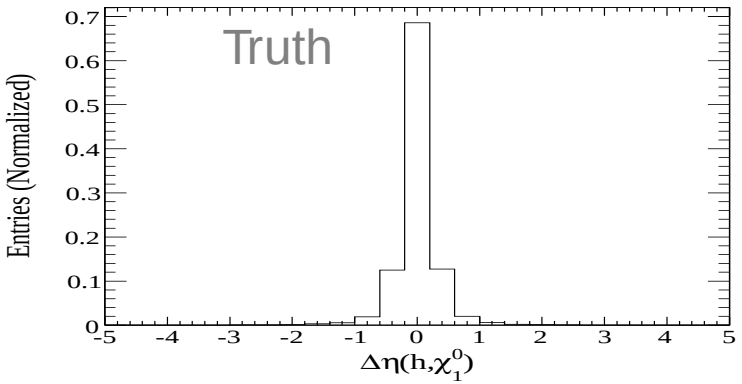
Correlation studies

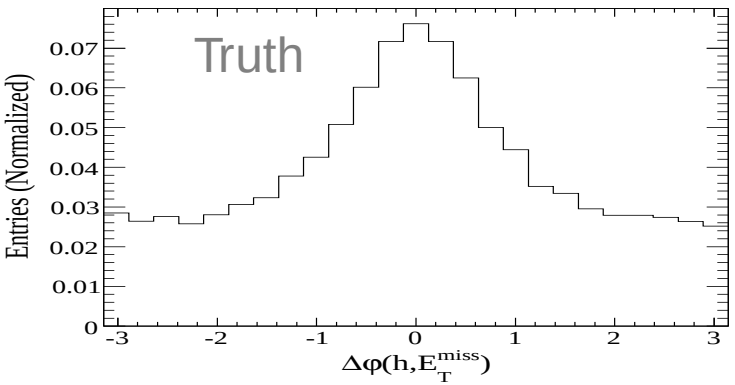
- h is produced by $\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 h$
- $m(\tilde{\chi}_2^0) \sim m(\tilde{\chi}_1^0) + m(h)$

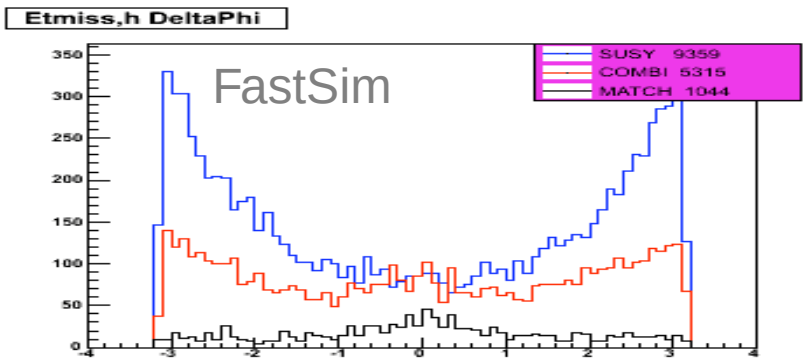
$\Rightarrow$ Strong correlation between higgs and neutralino directions

- The correlation is mantained also comparing higgs and $\vec{E}_T^{miss}$





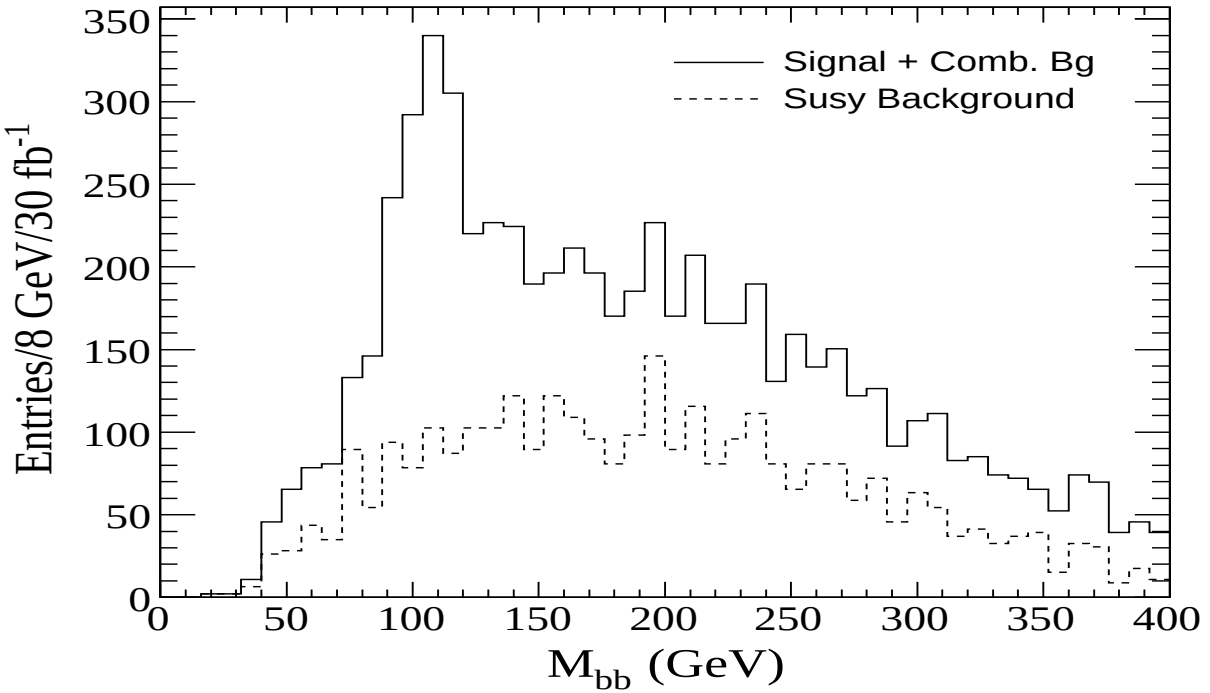




Correlation studies

Ask for $|\Delta\varphi(h, \vec{E}_T^{miss})| < 1$:

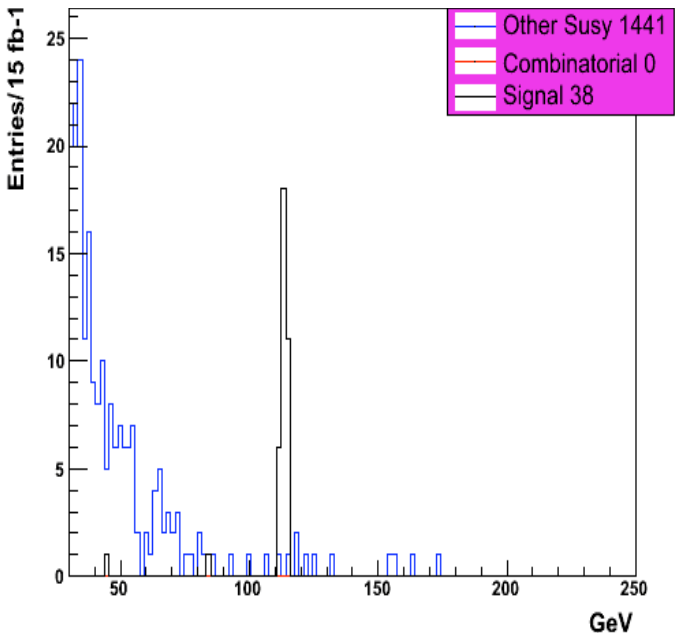
$30\ \text{fb}^{-1}$	**SUSY**	**SIGNAL**	**S/B**
Before $\Delta\varphi$ cut	6710	1680	0.33
After $\Delta\varphi$ cut	2090	870	0.72



Higgs decay channels other than bb

- b's are produced copiously...
- Can we look for other decays?
  - $h \to \tau\tau \sim 6\%$ but neutrinos make it difficult to reconstruct the invariant mass (and $\tau\tau$ susy bg $\sim 2 \times h \to \tau\tau$ events)
  - $h \to \gamma\gamma \sim 1.5\ 10^{-3}$ but few energetic photons produced in susy events
  - Background only from reducible QCD events

$\Rightarrow$ $\sigma(h) \times 30\ \text{fb}^{-1} \times 1.5\ 10^{-3} \sim 90$ events if $\sigma(h) \sim 2$ pb

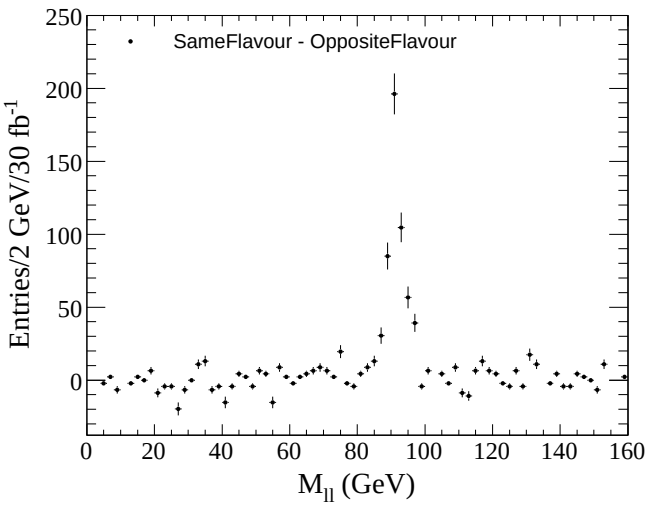


Susy $h \to \gamma\gamma$ ($L = 30\ \text{fb}^{-1}$)	Events
No Cut	76
$E_T^{miss} > 200$ GeV & $P_T(\gamma) > 25$ GeV	40
Photon identification	32

Outlooks

- Deeper look at the event topology
  - $\tilde{q}$'s and $\tilde{g}$'s are produced in opposite direction in xy plane
  - Two distinct half-plane for each cascade
  - This effect may be partially washed out by the fact that these particle are very massive

- Can we extract mass measurements?
  - At this point the $\tilde{\chi}_2^0 \rightarrow \tilde{l}l$ is closed
  - The h resonance can be the starting point to reconstruct mass edges (m_{hq}, m_{hqq},...)
  - The measure of the production ratio of h and Z gives informations about $\tan\beta$ and sgnμ



Outlooks

Mass reconstruction method as in Kawagoe, Nojiri, Polesello, hep-ph/0410160

$$\tilde{g} \rightarrow \tilde{b}_1 b_1 \rightarrow \tilde{\chi}_2^0 b_1 b_2 \rightarrow \tilde{\chi}_1^0 h b_1 b_2$$

$$\begin{aligned} m(\tilde{g})^2 &= (p(\tilde{\chi}_1^0) + p(h) + p(b_1) + p(b_2))^2 \\ m(\tilde{b}_1)^2 &= (p(\tilde{\chi}_1^0) + p(h) + p(b_2))^2 \\ m(\tilde{\chi}_2^0)^2 &= (p(\tilde{\chi}_1^0) + p(h))^2 \\ m(\tilde{\chi}_1^0)^2 &= p(\tilde{\chi}_1^0)^2 \end{aligned}$$

- After N events:
  - 4 unknown masses + $N \times 4$ unknown parameters
  - $N \times 4$ constraints

$\Rightarrow$ Underconstrained system

$\Rightarrow$ One step longer chain needed to have one more constraint and solve the system ideally with $N = 4$ events

$\Rightarrow$ Or use the fact that $\vec{p}(\tilde{\chi}_1^0) = k \times \hat{p}(h)$ (only two unknow parameters)