Status report of BSM working group

- **SUSY**
  1. Understanding SUSY with LHC/LC
  2. Dark Matter?
  3. Testing MSUGRA
  4. SUSY modes involving Higgs
  5. Ideas about 'Hard part'
  6. SUSY? or UED?

- **more ideas (Rizzo)**

1.LHC/LC SUSY study

(Kalinowski-Moortgat-Pick, Kawagoe-Hisano-Nojiri, Polesello)

Aim

LHC(LC) physicists have been thinking about "their own signal"

But, what will we see with $LHC \otimes LC$? (Theorist Question)

Problem:

LARGE HILL between

LHC/LC physicists.

(NO, this is NOT comparison, please!)

SUSY case study is the place to start

SPS 1 project

1. Reconstruction of WEAK SUSY sector

$$\text{LC} \quad \begin{array}{c} \longrightarrow M_1, M_2, \mu \tan\beta + A_\tau, m_{\tilde{l}} \longrightarrow \\ \\ \leftarrow m_{ll} \text{ end points from } \tilde{\chi}_2^0 \text{ and } \tilde{\chi}_4^0 \text{ decays} \leftarrow \end{array} \quad \text{LHC}$$

2. Study STRONG SUSY sector with WEAK SUSY sector inputs.

Ex. $\tilde{g} \to q_i \tilde{q}_i \to qq\tilde{\chi}_2^0$ followed by "known" $\tilde{\chi}_2^0 \to l\tilde{l} \to ll\tilde{\chi}_1^0$

$(\tilde{q}_i = \tilde{q}_1, \tilde{b}_1, \tilde{b}_2)$

Better Acceptance corrections.

Ratio of the events$\to$ Ratio of the branching ratio

LC classic

slepton sectors	$\Delta m_{\tilde{l}} = O(0.1)$ GeV(threshold scan)
stau sector	$\Delta m_{\tilde{\tau}_1} = 0.3$ GeV, $\Delta m_{\tilde{\tau}_2} = 2$ GeV
	$\sigma(\tilde{\tau}\tilde{\tau}) \to \cos\theta_\tau = 0.283 \pm 0.02$
	$\mu \tan\beta + A_\tau = 3778.2 \pm 274.8$ GeV
Ino sector	mass scan and $\sigma(\chi\chi)$ with polarized beam

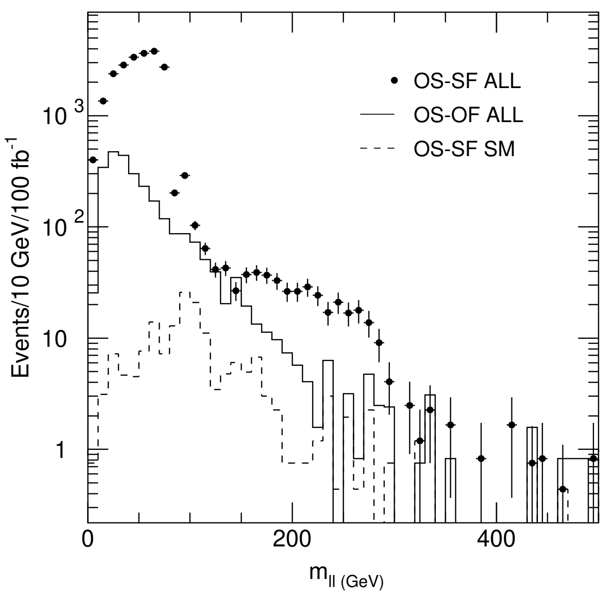
M_1	M_2	μ	$\tan\beta$
99.28 ± 0.3(?)	191.27 ± 3.22	369.93 ± 14.41	not at all (preliminary)

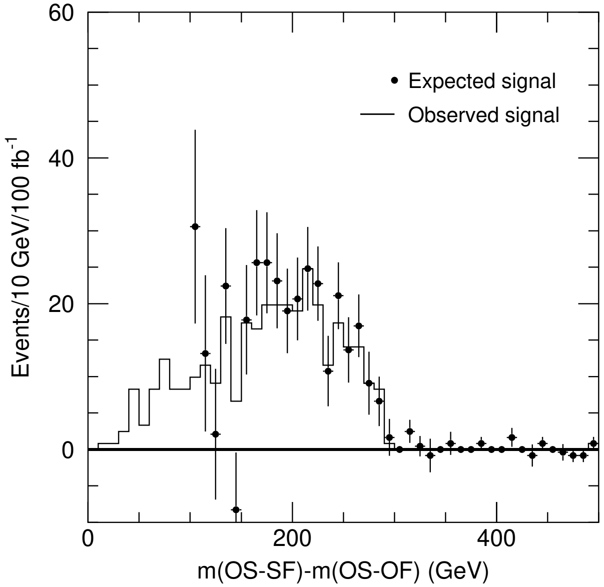
combined with $\tilde{\tau}$ mixing, $\tan\beta \sim 10 \pm 2$

($abs(A_\tau) < 800$ <GeV from symmetry breaking for the point.)

LHC classic m_{ll} end point study ($\tilde{\chi}_4^0$)

end point $\leftrightarrow m_{\tilde{\chi}_i^0}$ as the function of $m_{\tilde{l}}, m_{\tilde{\chi}}$



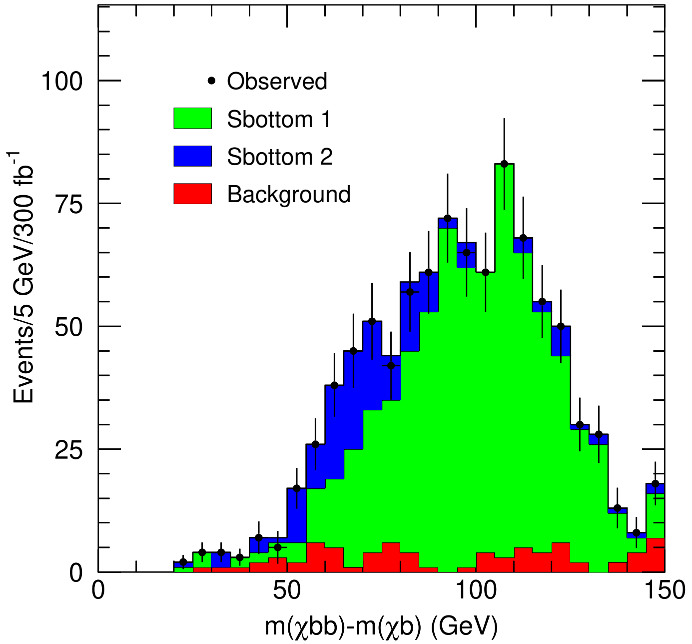


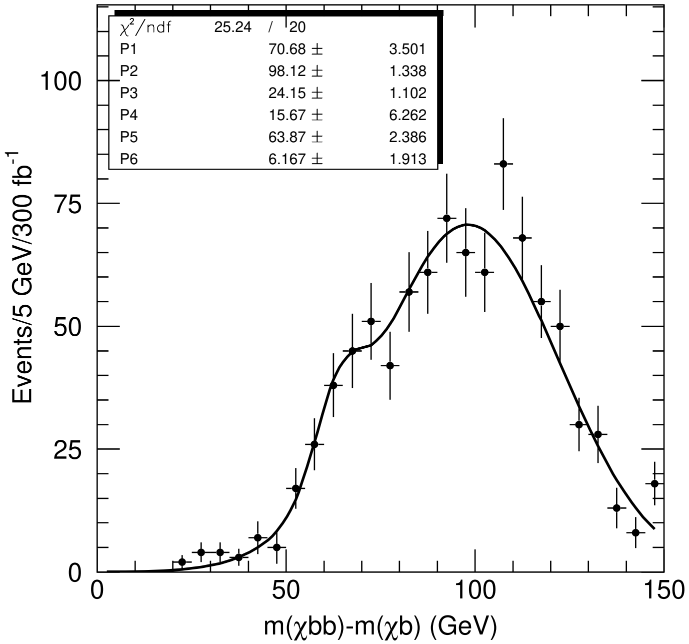
statistical precision of the high end point is 4 GeV.

$\rightarrow \Delta m_{\tilde{\chi}_4^0} \sim 5$ GeV

M_1	M_2	μ	$\tan\beta$
99.22 ± 0.15	191.27 ± 1.14	369.93 ± 1.41(?)	not really
			(preliminary)

Sbottom mass and shape analysis at SPS1($300\ \mathrm{fb}^{-1}$)





Events near m_{ll} end point. $p_{\tilde{\chi}_2^0} = (1 - m_{\tilde{\chi}_1^0}/m_{ll})p_{ll}$

$\Delta m_{\tilde{g}} \sim O(1)$ GeV

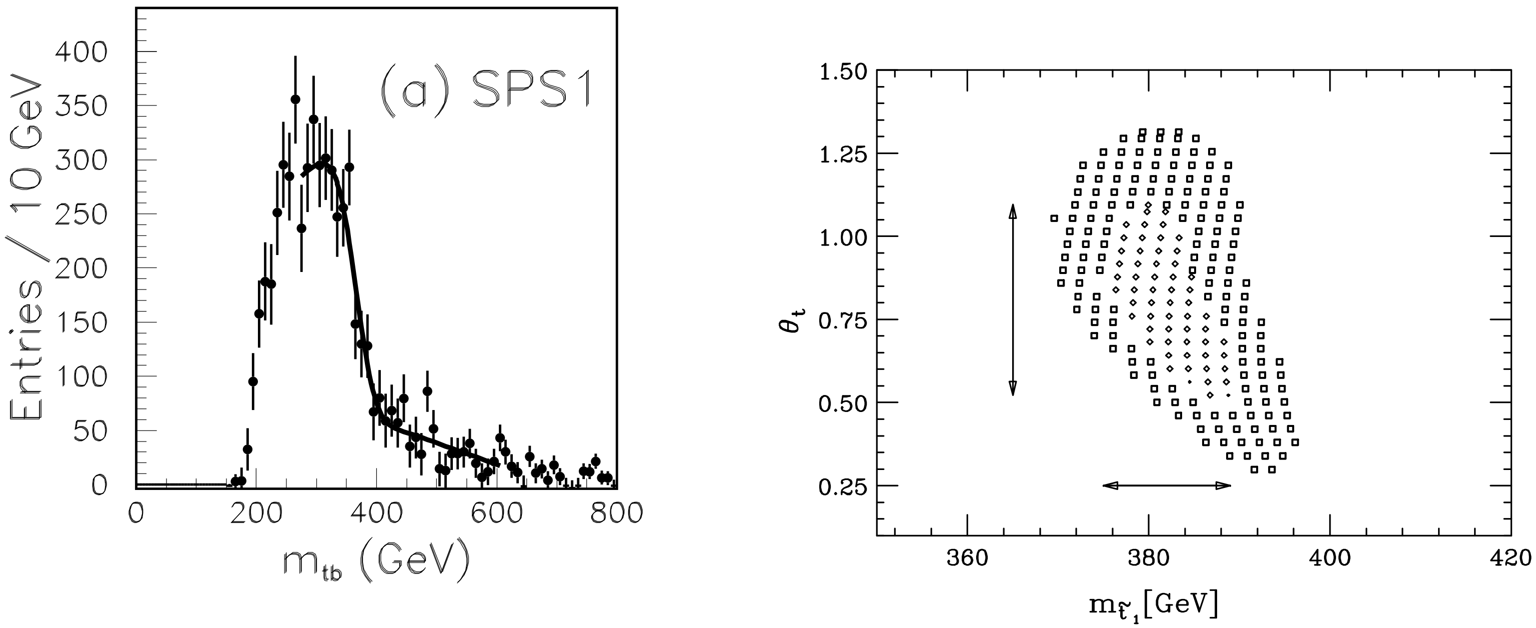
$\Delta(m_{\tilde{g}} - m_{\tilde{b}})$ is 1.3(2.3) GeV.(two peak fit)

$\Delta\theta_b = 0.157$ provided the WEAK SUSY info.

$\Delta\overline{Br}(\tilde{b}) = Br(\tilde{g} \to \tilde{b}_2 \to \tilde{\chi}_2^0)/Br(\tilde{g} \to \tilde{b}_1 \to \tilde{\chi}_2^0) = 0.078$(with sys, 3-$\sigma$ effect),

Stop study $\tilde{g} \rightarrow$ **(**$t\tilde{t}$ **or** $b\tilde{b}$**)** $\rightarrow tb\tilde{\chi}_1^{\pm}$

use m_{tb} distribution after side band subtraction
'end point', 'height' and 'total reconstructed tb events'.



stop mass $\Delta m_{\tilde{t}}$ and mixing angle $\Delta\theta_t = 0.287$
(without sys, when all the other errors are ignored.)
Need to sort out weak $m_{\tilde{b}}$ and θ_b dependence.

Big Picture is correct.

(I like this.)

SPS1 is the easiest case.
  all sleptons are within LC reach
  lots of leptons from $\tilde{\chi}_2^0$ decay

How about the other benchmark points?

Certainly need more handles.

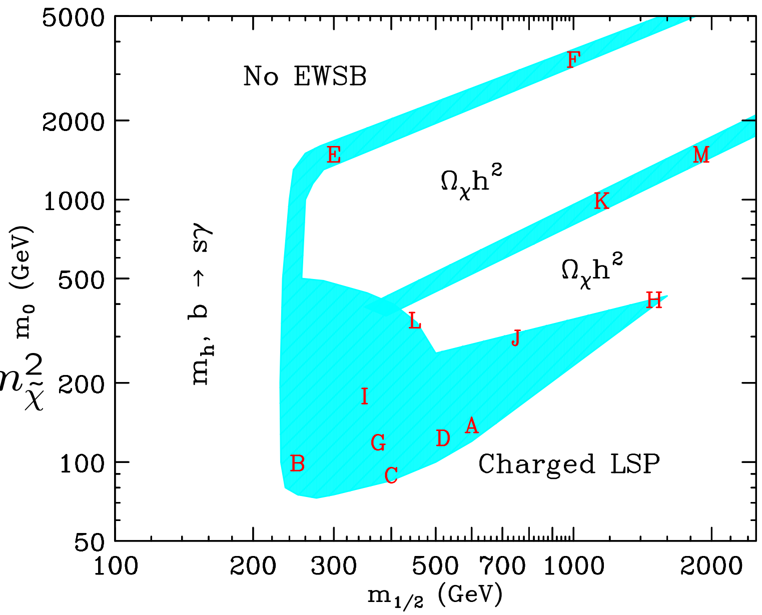
2. Dark matter in MSUGRA and beyond

(I) Light slepton

(II) Stau co-annihilation

(III) Higgs pole

(IV) Higgsino component



Benchmark Study (B,G,I) $\Omega \sim m_{\tilde{l}}^4/m_{\tilde{\chi}}^2$

(Tricomi, Chiorboli, De Roeck)

New Benchmark after WMAP

new dark matter density constraint

(Battaglia, De Roeck, J.Ellis....)

Other models (Balazs)

Can we determine Ω_χ

What is the model independent signal of

$m_{\tilde{\chi}} \sim m_{\tilde{\tau}}$ **or** $2m_{\tilde{\chi}} \sim m_A$**???**

3.Extracting GUT scale parameters?

(B Allanach, S. Kraml, W. Prod)

LHC+LC measurement

$O(1 \sim 5)$ GeV

$\Updownarrow$

2-loop RGE evolution

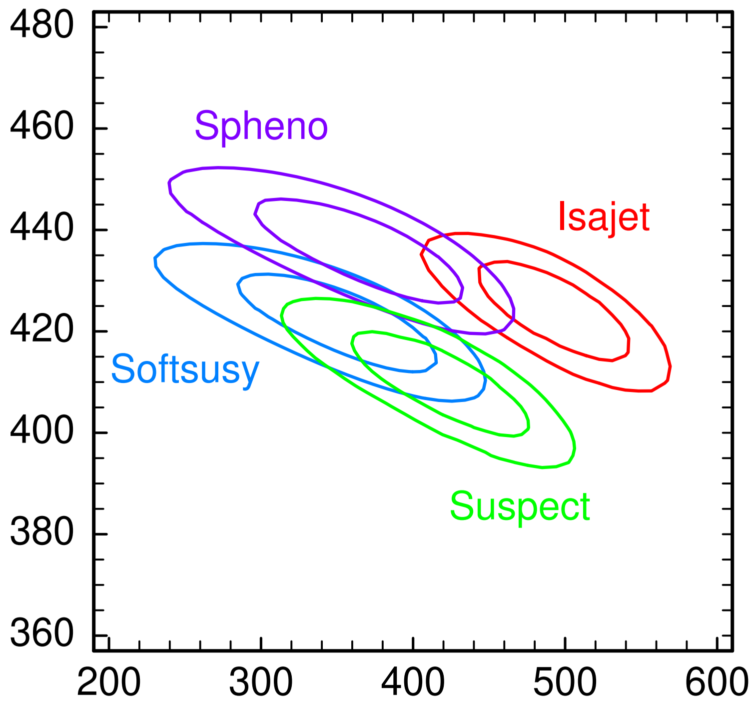
(many independent codes)

$\Updownarrow$

GUT scale parameters

Errors are bigger!!!!

$\sim 20 GeV$



	Isajet 7.64	Suspect 2.101	Softsusy 1.71	Spheno 2.0
RGEs	2–loop	2–loop scalars at 1–loop	2–loop	2–loop
VEVs	not running	running (1–loop)		
Yukawa cpl.				
h_t	full 1–loop	full 1–loop	full 1–loop	full 1–loop
h_b	full 1–loop	$bg + \tilde{b}\tilde{g} + \tilde{t}\tilde{\chi}^{\pm}$ loops		full 1–loop
Higgs sector				
tadpoles	3rd gen. (s)fermions	complete 1–loop [1]		2-loop [1,4]
h^0, H^0	1–loop [2]	var. ops.	2–loop [3]	2–loop [5]
SUSY masses				
$\tilde{\chi}^{\pm}, \tilde{\chi}^0$	some corr. for $\tilde{\chi}_1^{\pm}$	1–loop aprox. for ΔM_1, ΔM_2, $\Delta\mu$		full 1–loop
$\tilde{t}$	logs	1–loop approx.	full 1–loop	full 1–loop
$\tilde{b}$	logs	1–loop approx.	full 1–loop	full 1–loop
$\tilde{g}$	all have 1-loop $g\tilde{g} + q\tilde{q}$ re-summed			

[1] Pierce, Bagger, Matchev, Zhang, NPB 491, 3 (1997) [hep-ph/9606211]

[2] M. Bisset, Ph.D.Thesis, Univ. Hawaii, 1995.

[3] Heinemeyer, Hollik, Weiglein, hep-ph/9903404.

[4] Dedes, Slavich, hep-ph/0212132.

[5] Degrassi, Slavich, Zwirner, hep-ph/0105096; Brignole, Degrassi, Slavich, Zwirner, hep-ph/0112177.

Interfacing several generators in one site

http://www.thep.lu.se/~ zeiler/interface.html

	Isajet	Softsusy	Spheno	Suspect	mean	var
Weak						
$\tilde{\chi}_1^0$	96.58	96.43	97.74	97.42	97.04	1.31
$\tilde{\chi}_2^0$	176.79	178.38	183.14	179.76	179.52	6.35
$\tilde{\tau}_1$	133.25	136.29	134.56	135.74	134.96	3.04
Strong						
$\tilde{\chi}_3^0$	360.60	350.46	363.42	351.97	356.86	11.96
$\tilde{g}$	606.63	614.38	592.09	626.42	609.88	34.33
$\tilde{U}_L$	535.68	569.21	562.57	569.64	559.27	33.96
$\tilde{t}_1$	379.44	398.09	396.79	410.17	396.12	30.73

- Diffence comes from the couplings in the loop
  namely 2-loop finite effects + 3-loop RGE

- More problems if there is several scales $m_{SUSY1} \gg m_{SUSY2}...$
  MSUGRA has multiple scales already
  Effective theory RGE, double counting?

- Need to be reduced below expected experimental sensitivity.
  WEAK SUSY $\leftrightarrow$ LC $\leftrightarrow$ $\Delta m < 0.3$ GeV
  STRONG SUSY $\leftrightarrow$ LHC $\leftrightarrow$ $\Delta m < 5$ GeV

4. SUSY(high P_T miss) vs Higgs (low P_T miss)...

has been decoupled (1TeV SUSY? no kidding)

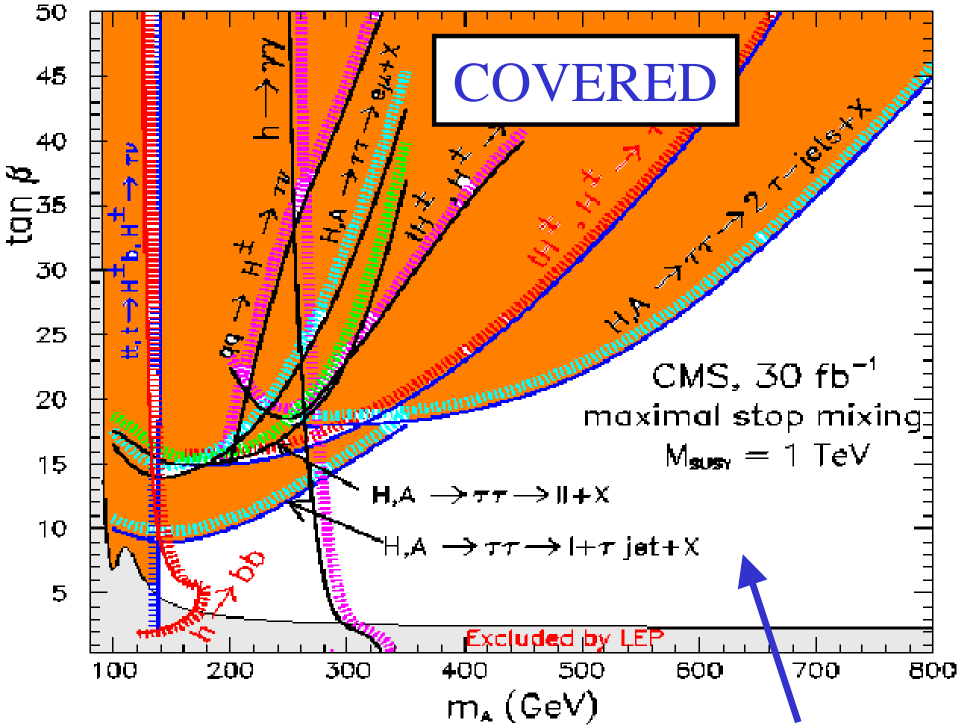
"reasonable attitude" as the first step.

New attempts (Moortgat, Moretti)

- **Higgs decaying into sparticles**
  especially inos, fantastic 4l signal at LHC
  extended reach for small $\tan\beta$ and large m_A

- **Higgs from sparticle(ino) decay.**
  $\tilde{\chi}_2^0$ $\tilde{\chi}_4^0$ decays into higgs once the channel open.
  Not strong discoverly channel but interesting

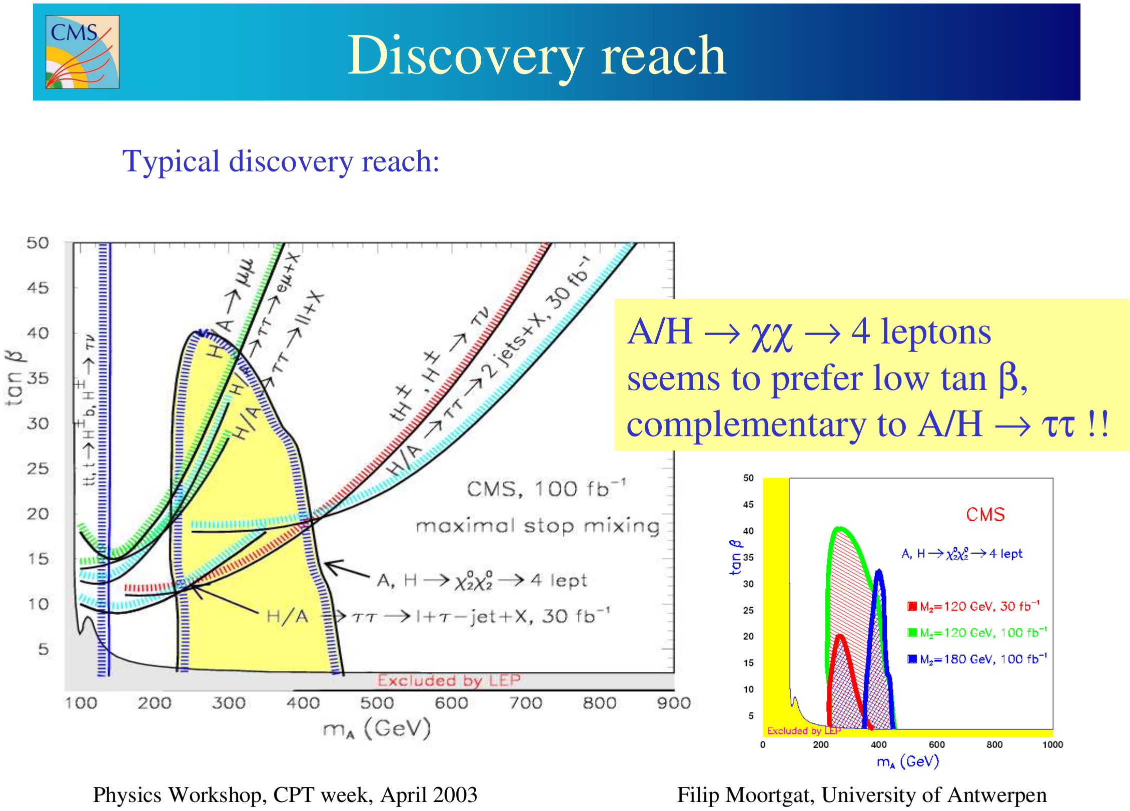
Discovery search



- discovery of the heavy MSSM Higgses limited to upper triangle in m_A – tan β plot
- note: the h^0 can always be found
- problem is that production mechanism (e.g. bbA^0,H^0) needs tan β enhancement

Need new ideas to cover low tanβ - high m_A region …

Higgs decay into SUSY$\rightarrow$ extending discoverly reaches

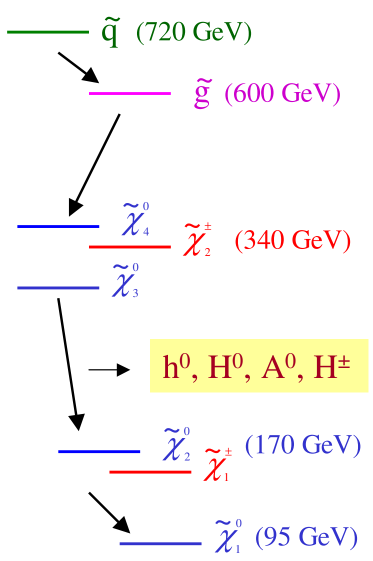


LHC/LC??(if the mass $\tilde{\chi}_2^0$, $\tilde{\chi}_1^0$ is known)

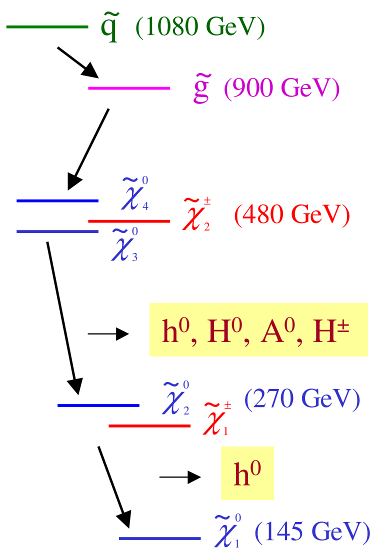
Other cases (like invisible decays?)

Scenarios

Scenario 1 (big cascades)

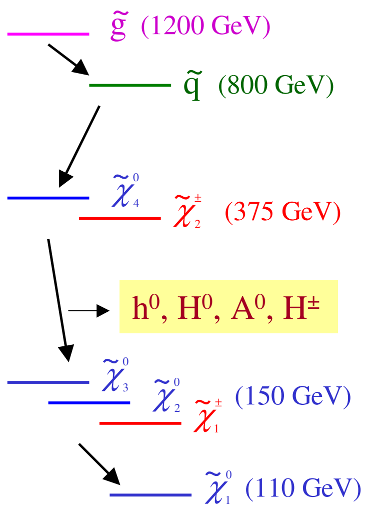


Scenario 2 (little + big cascades)

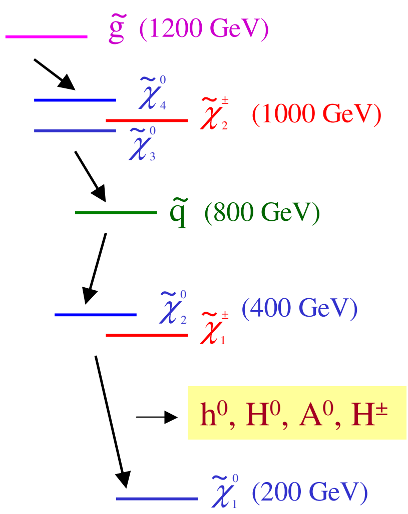


Scenarios (cont'd)

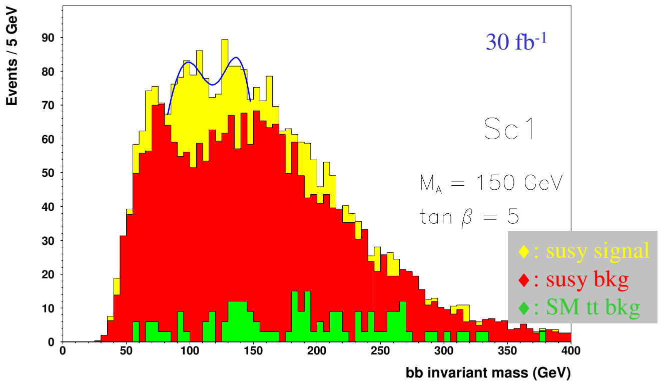
Scenario 3 (big cascades)



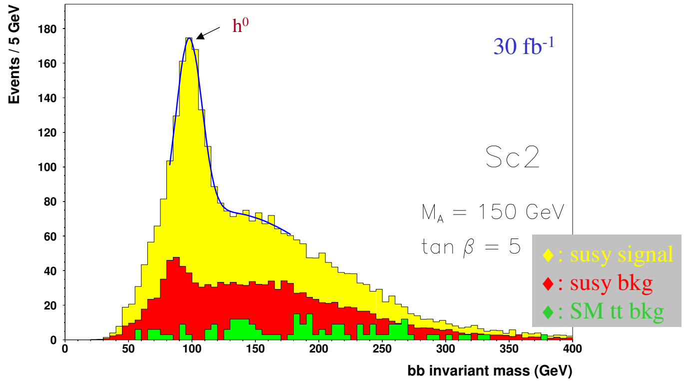
Scenario 4 (little cascades)



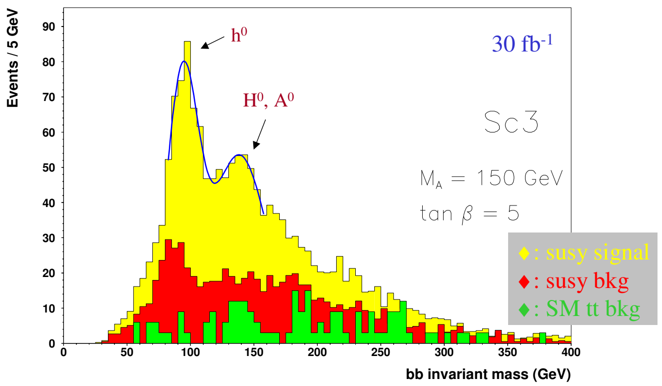
Results: scenario 1



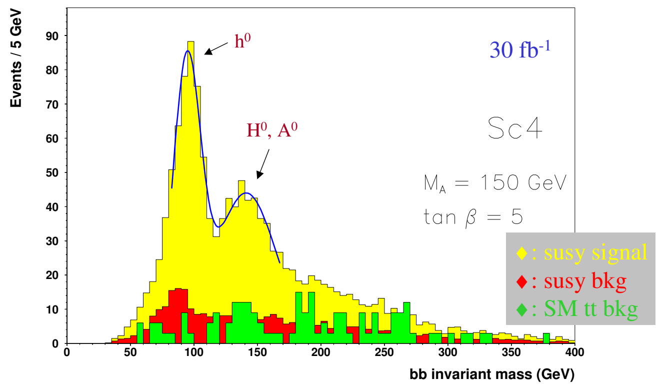
Results: scenario 2



Results: scenario 3



Results: scenario 4



More on Higgs from SUSY decays

- Parent reconstruction? $\tilde{\chi}_4^0$
- Relative height of higgs peaks?$\longrightarrow$ BR??(take ratios!)
- charged Higgs
- LHC/LC $\tilde{\chi}_1^0$, $\tilde{\chi}_2^0$ and $\tilde{l}$ masses.

“Hard part”

Theorists have to provide agressive ideas constantly

- motivate the improved analysis

- full simulation(recent ATLAS activities)
  Ex. τ polarization

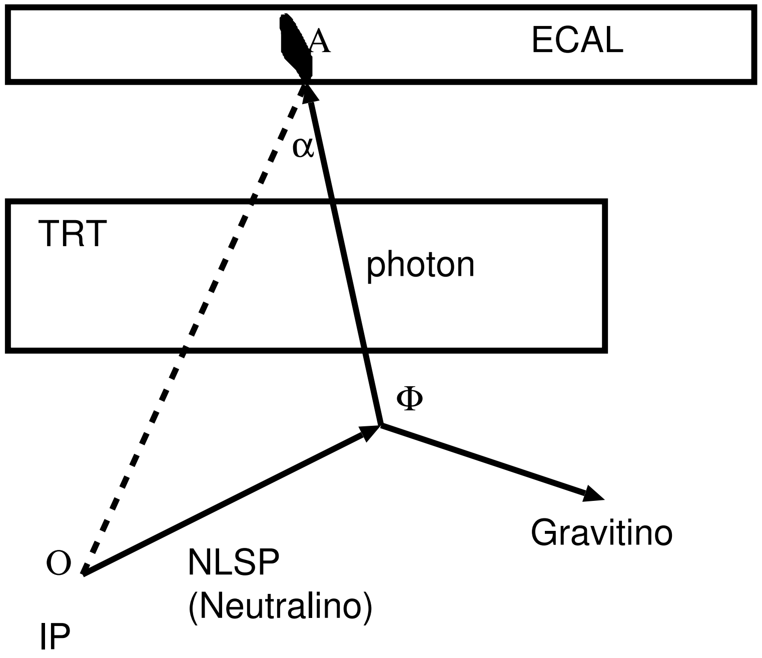
- interplay of several detector components

ONLY 5 years left....

Example:(Kawagoe-Kobayashi-Nojiri-Ochi, Prieur, Polesello)
Gauge mediation: $\tilde{\chi}_1^0 \to \tilde{G}\gamma$

$$c\tau_{\tilde{\chi}} \propto \left(\frac{100\mathrm{GeV}}{m_\chi}\right)^5 \left(\frac{\sqrt{F_0}}{100\mathrm{TeV}}\right)^2 \times 10^{-2}\mathrm{cm} \tag{1}$$

F_0: "fundamental" SUSY scale

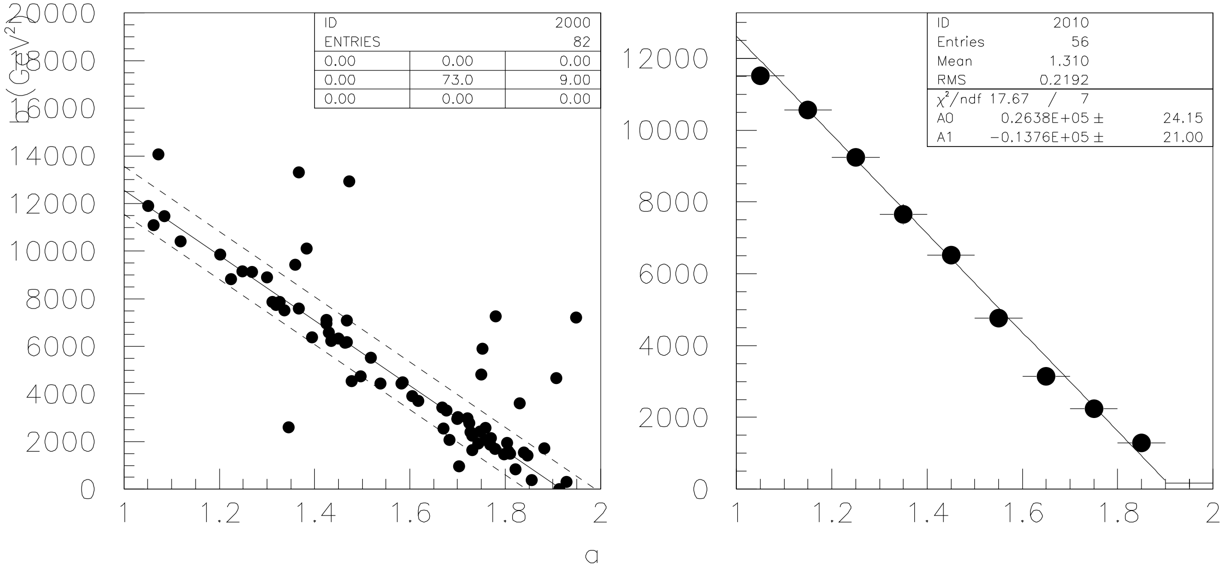


- **time delay at ECAL**
  possible to have $\Delta t \sim 1$ ns resolution at ECAS

- **A photon point back to the decay position. (not IP)**
  TRT converted photon
  (probability O(1)%)
  $\to$ improved $\Delta\phi_\gamma$

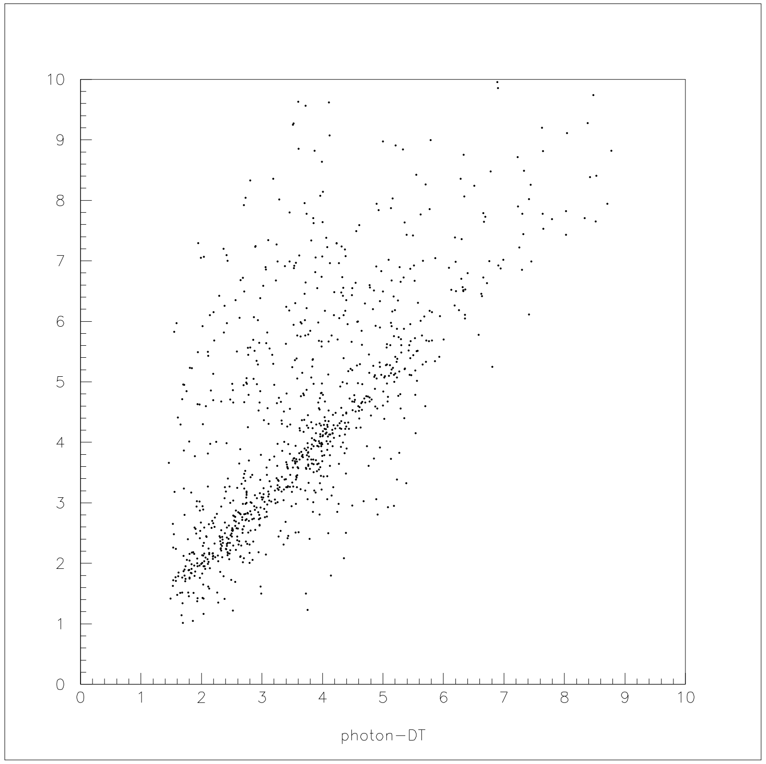
Follow the cascade decay $\tilde{l} \to l\tilde{\chi} \to \gamma\tilde{G}$.
$p_l \to$ one more constrant of neutralino direction.

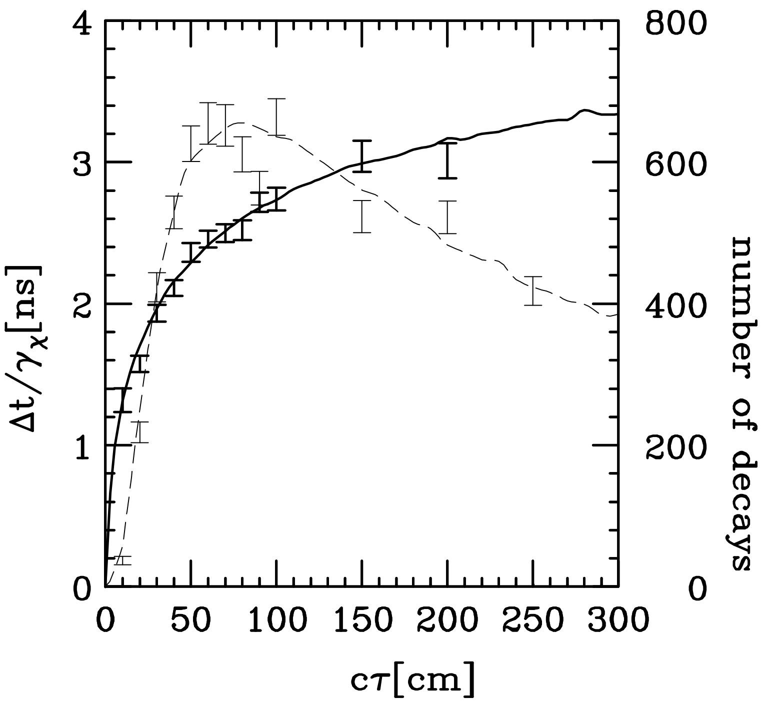
section:$m^2_{\tilde{l}}$
slope:$m^2_{\tilde{\chi}}$



O(1)GeV mass errors for $c\tau = 100$cm, 10 fb^{-1} at point G1 of ATLAS TDR.

$m_{\tilde{l}}$ and $m_{\tilde{\chi}} \rightarrow$ decay point and time
$\rightarrow$ life time measurement (F_0 measurement)





6. Fake SUSY

Universal Extra Dim(SUSY)

all particles are in the bulk

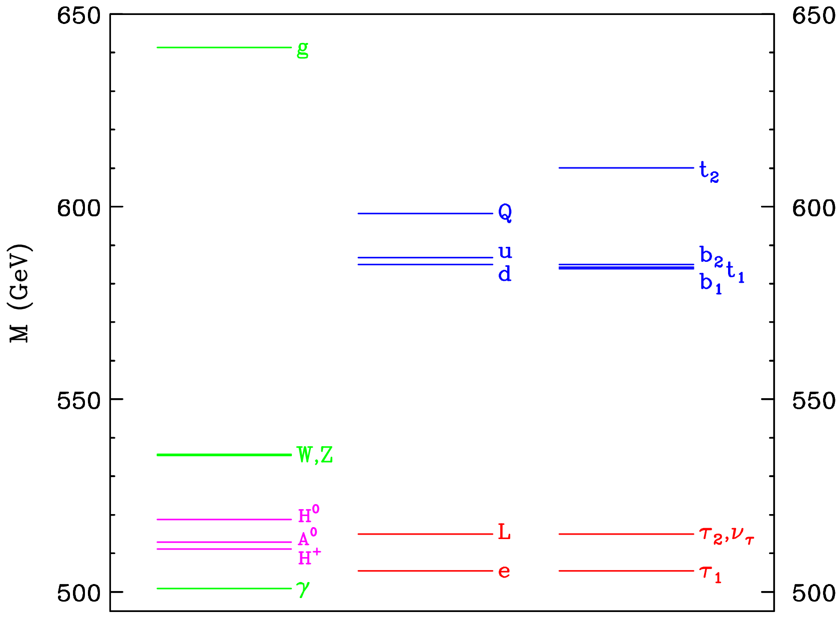
Conserved KK number

$$m_n^2 = an^2 + m^2 \tag{2}$$

radiative mass splitting

fake SUSY?

Decay pattern is SUSY like.



Feasibility of the search (especially at LHC)

mass splitting is too small $\rightarrow$

jet p_T, lepton p_T?
M_{eff}, P_T^{miss} cut
do not work

Need Systematic LHC study.

(Roeck-Matchev,Tovey, Nojiri, Polesello, ...)

" the discovery reach of SUSY for degenerated case"

background investigation, optimized cut

(Some study by Roeck at CLIC already, generator?)

Choose SUSY points with various mass splitting.

$\Delta(m_{\tilde{g}} - m_{\tilde{\chi}}) = 150, 200, 250, 300$ GeV. for $m_{\tilde{g}} = 600$ GeV