

SuSy in ATLAS

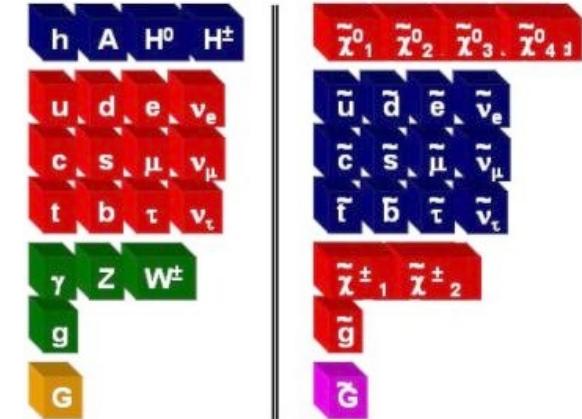
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Franco-Asian Summer School

Some physics questions:

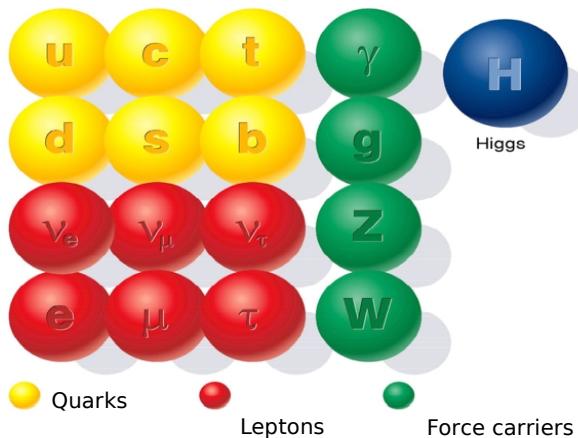
- What is the origin of mass? ← **SuSy**
- Is the Higgs mechanism responsible, or its variants? ← **SuSy**
- What is the origin of matter anti-matter asymmetry? ← **SuSy**
- What are the properties of neutrinos? ← **SuSy**
- Do all the forces, including gravity unify? ← **SuSy**
- What is the nature of dark matter? Dark energy? ← **SuSy LSP**

SM Particles

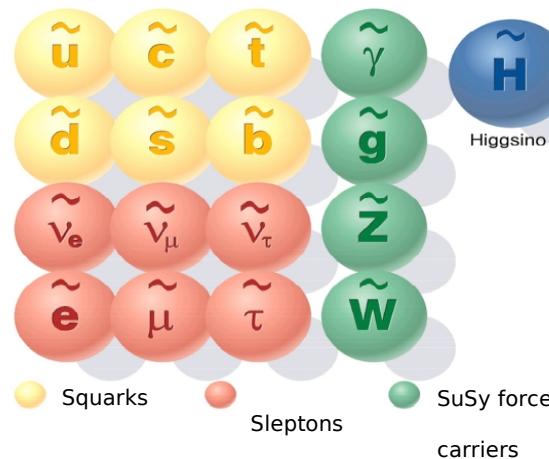


SuperSymmetry (SuSy)

Standard Model

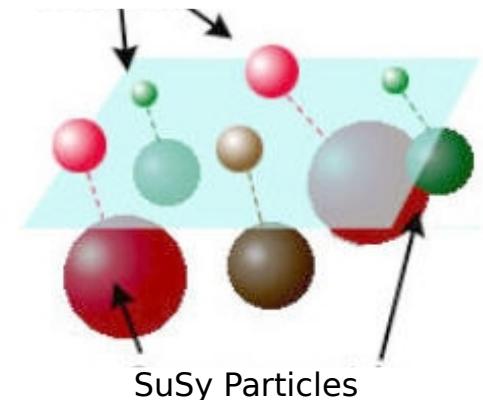


SuSy Model



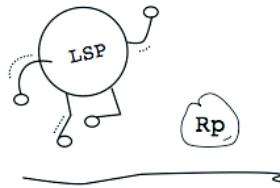
But symmetry must be broken

SM Particles



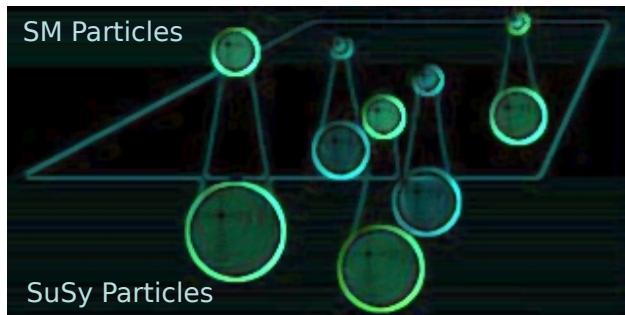
R-Parity

$$R = (-1)^{3B-L+2s} \left\{ \begin{array}{l} (+1) \text{ SM particles} \\ (-1) \text{ SuSy particles} \end{array} \right.$$



R-Parity conserving models !!!

LSP is a good candidate for dark matter



→ Minimal SuperSymmetric Standard Model (MSSM)

$$\mathcal{L}_{MSSM} = \mathcal{L}_{SuSy} + \mathcal{L}_{soft}$$

105 free parameters !!! including mass terms, couplings, mixing angles and CP violation phases



mSugra: 5 free parameters !!!

$M_{1/2}$: Gaugino mass

M_0 : Scalar mass

A_0 : Trilinear gauge coupling

$\tan\beta$: The ratio of the vacuum expectation values of the two Higgs doublets

μ : The sign Higgsino mixing parameter

SuSy (mSugra) discovering potential in ATLAS

- Experimental data: LEP limits on Higgs and SuSy particles
- Theoretical reasons: Electroweak symmetry breaking mechanism
- Cosmological data: compatibility with the cold dark matter in the Universe with relic density of lightest neutralinos



mSugra space parameters regions

- * *Co-annihilation region*: Low M_0 region where de $\chi \tau$ annihilation process forces neutralinos density to be small
- * *Focus-Point region*: High M_0 and low $M_{1/2}$ region where $\chi \chi$ annihilation allows relic neutralinos density
- * *Bulk region*: Low M_0 and low $M_{1/2}$, where SuSy masses are very light
- * *Funnel region*: where the $\chi \chi \rightarrow Z^* \rightarrow H$ resonance yields relic density small

Inclusive SUSY Search

→ “gold-plated” (**jets + E_t^{miss} + n-leptons**)

Many classes of SUSY model predict significant excesses of events in this channel over large areas of parameter space.

<GOAL>

Existence of SUSY!!

SUSY mass scale!!

SUSY production cross-section!!

Need relatively small integrated luminosity GOOD 
Need good understanding of SM at that energy scale (never explored until now!!) Not GOOD 

informations

Signal:

Using mSUGRA model as a benchmark

signatures is governed predominantly by only two parameters $m_0, m_{1/2}$

-> $m_0, m_{1/2}$ determine the M_{SUSY} and σ_{SUSY} of gluinos and squarks

signal events generated every 100 GeV for $m_0, m_{1/2}$

fixed : $\tan(\beta) = (10, 30, 50, 55)$, $\mu > 0$, $A_0 = 0$

Background

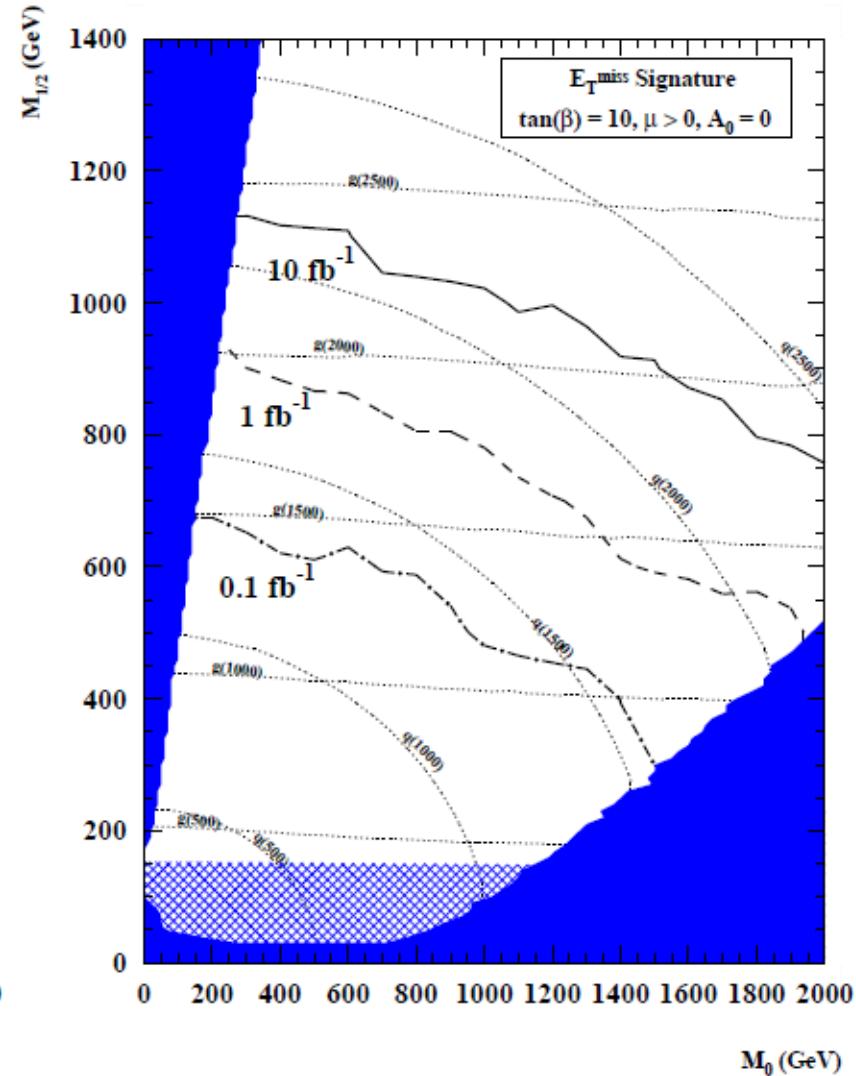
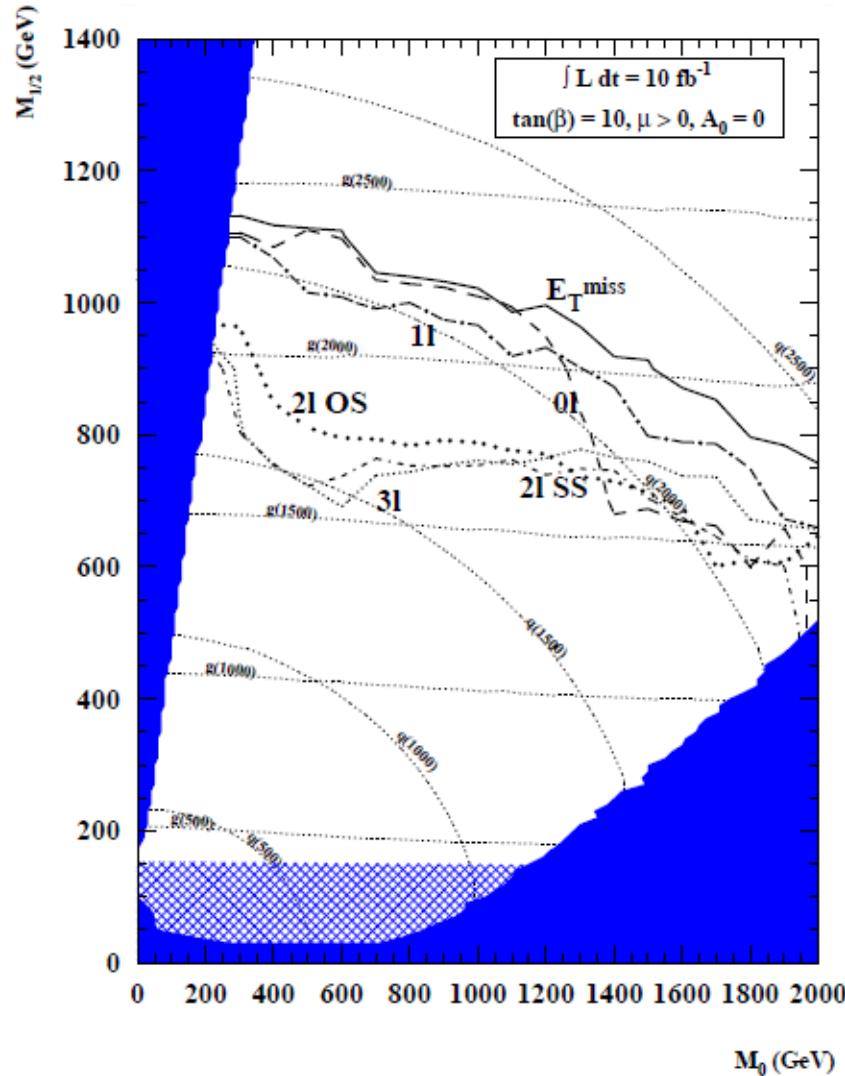
ttbar , W+jet , Z+jet , light quark QCD (10^6 events for each)

Optimization of Cuts

- * MET :Missing Et
- * Pt(1) :Pt of hardest jet
- * Pt(2) :Pt of second hardest jet
- * Scalar sum of Pt of jets in event
- * $M_{\text{eff}} = \text{MET} + \sum \text{Pt}(i)$:Effective mass
- * Nj :Number of jets in event
- * Pt(lep) :Pt of isolated leptons (if any)

Discovery potential

Significance Variable $S_f = S/\sqrt{B}$



LEFT : $5\sigma(S_f=5)$ discovery potential in the $(M_0 M_{1/2})$ -plane for mSUGURA models assuming 10 fb^{-1} integrated luminosity.
 $E_T^{\text{miss}}, 0l, 1l, 2l(\text{OS}), 2l(\text{SS}), 3l$ are shown here

RIGHT : $5\sigma(S_f=5)$ discovery potential of E_T^{miss} channel in the $(M_0 M_{1/2})$ -plane for mSUGURA models assuming $0.1\text{fb}^{-1}, 1\text{fb}^{-1}, 10\text{fb}^{-1}$ integrated luminosity.

Results from Inclusive Search

→ Discovery potential

E_t^{miss} has greatest discovery potential ,covering q^\sim, g^\sim masses up 2TeV

Performance of 6 channels ($E_t^{\text{miss}}, 0l, 1l, 2l\text{OS}, 2l\text{SS}, 3l$) are similar

→ SUSY mass scale

precisions of $M_{\text{SUSY}}^{\text{eff}}$

< 20% (<60%) for mSUGRA (constrained MSSM) for 10fb⁻¹

< 10% (<30%) for mSUGRA (constrained MSSM) for 100fb⁻¹

-> see [backup slides](#)

→ SUSY cross-section

precisions of cross-section

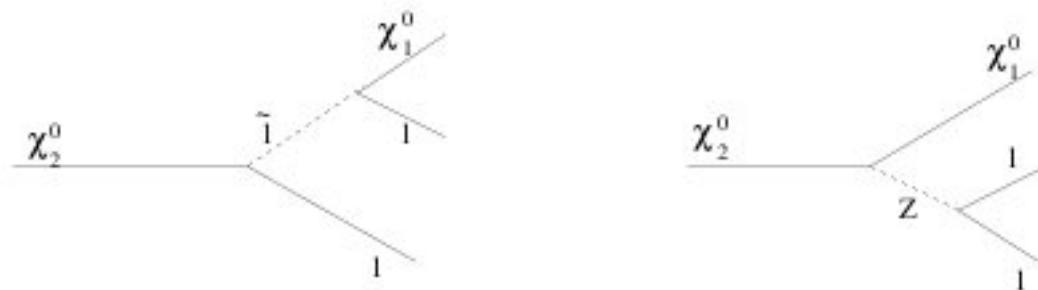
< 30% (<80%) for mSUGRA (constrained MSSM) for 100 fb⁻¹

-> see [backup slides](#)

Exclusive SuSy searches

One « golden channel » : Di-leptonic edge reconstruction
Signature : 2 isolated leptons

Feynman diagram of a neutralino leptonic decay :



Example of a decay chain in mSUGRA :

$$\tilde{g} \rightarrow j_1 \tilde{q} \rightarrow \tilde{\chi}_2^0 j_1 j_2 \rightarrow \tilde{l} l_1 j_1 j_2 \rightarrow \tilde{\chi}_1^0 l_1 l_2 j_1 j_2$$

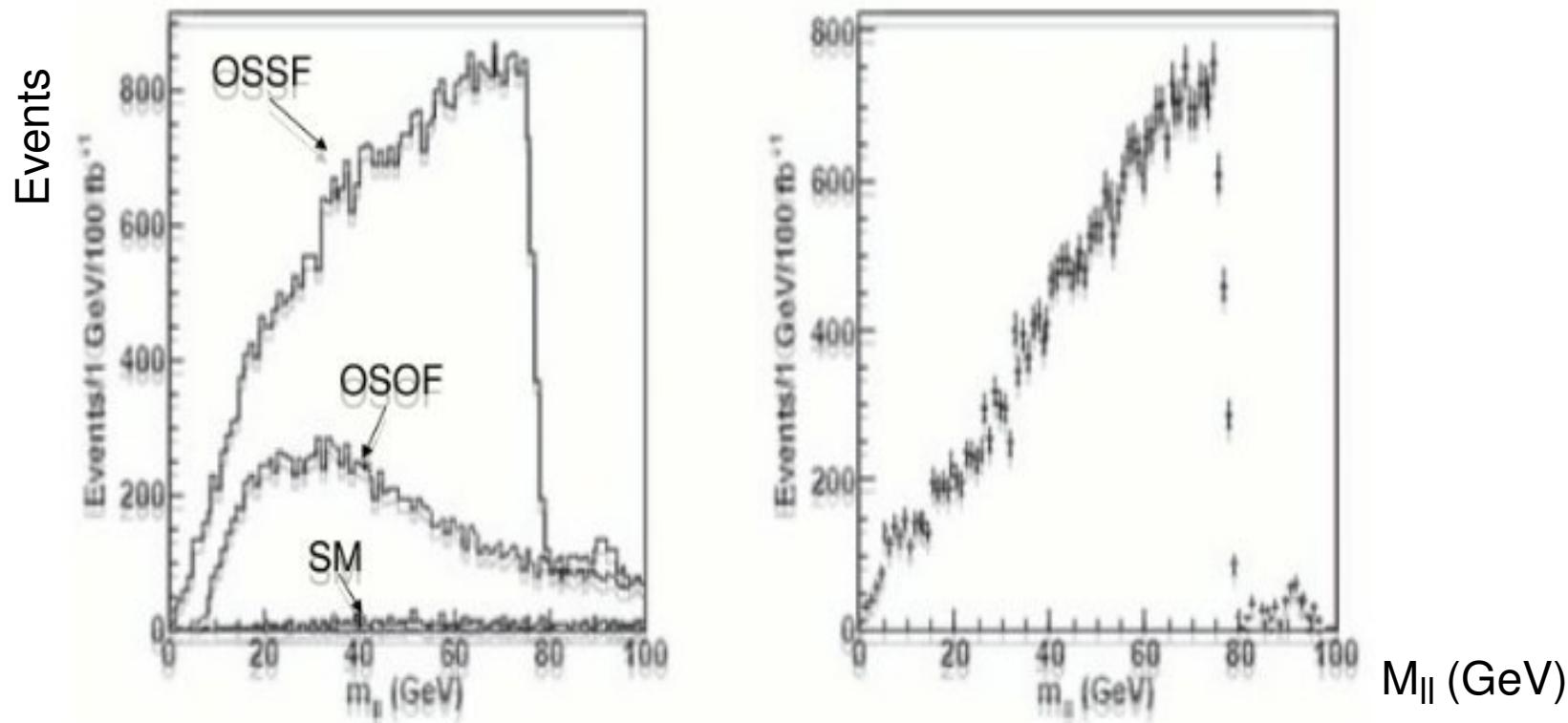
What is the basic signature of the decay chain ?

Results for the Bulk region

- 4 jets, the three hardest satisfying :
 $P_{T,1} > 150\text{GeV}$, $P_{T,2} > 100\text{GeV}$, $P_{T,3} > 50\text{GeV}$
- $E_T > \max(100\text{GeV}, 0.2 M_{\text{eff}})$
- $M_{\text{eff}} = E_T + \sum P_{T,i} > 600 \text{ GeV}$
- *Two isolated Opposite Sign Same Flavour (OSSF) leptons (e, μ) with $P_{T,l1} > 20\text{GeV}$ and $P_{T,l2} > 10\text{GeV}$*
and

What are the Backgrounds ?

- SM contribution is relevant
- Others processes with no correlation between the two leptons : OSOF (Opposite Sign Opposite Flavour)



Signal and Background plots

At the left, OSSF, OSOF and SM contribution

At the right, flavour substraction OSSF-OSOF



In this channel, we can expect precise constraints on differences in masses between s-particles, with a minimal integrated luminosity of 100 fb^{-1}

Conclusion

SuSy is great
We just have to find it



Back-up

Mass scale & cross-section measurement

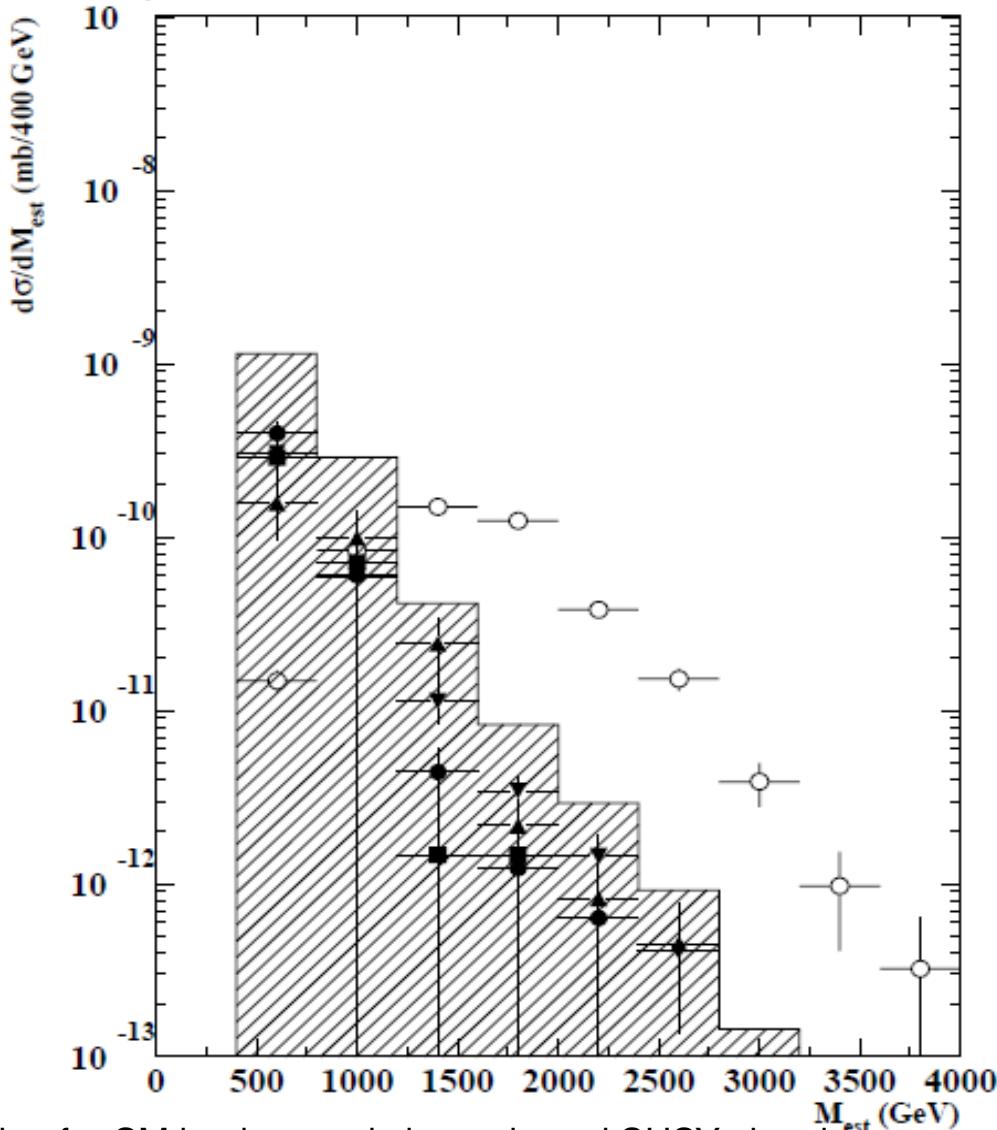
$$M_{\text{est}} = \sum_i |P_T(i)| + E_t^{\text{miss}}$$

we can estimate:

$M_{\text{SUSY}}^{\text{eff}}$ <- from mean of SUSY signal distribution

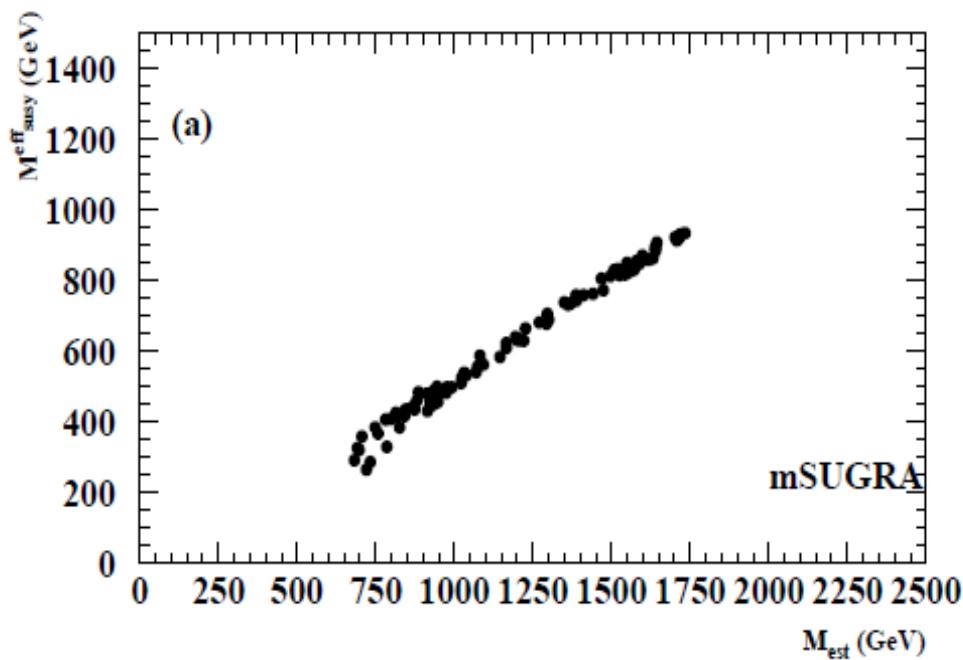
σ_{SUSY} <- from fitted normalization of the SUSY signal distribution

...next slide



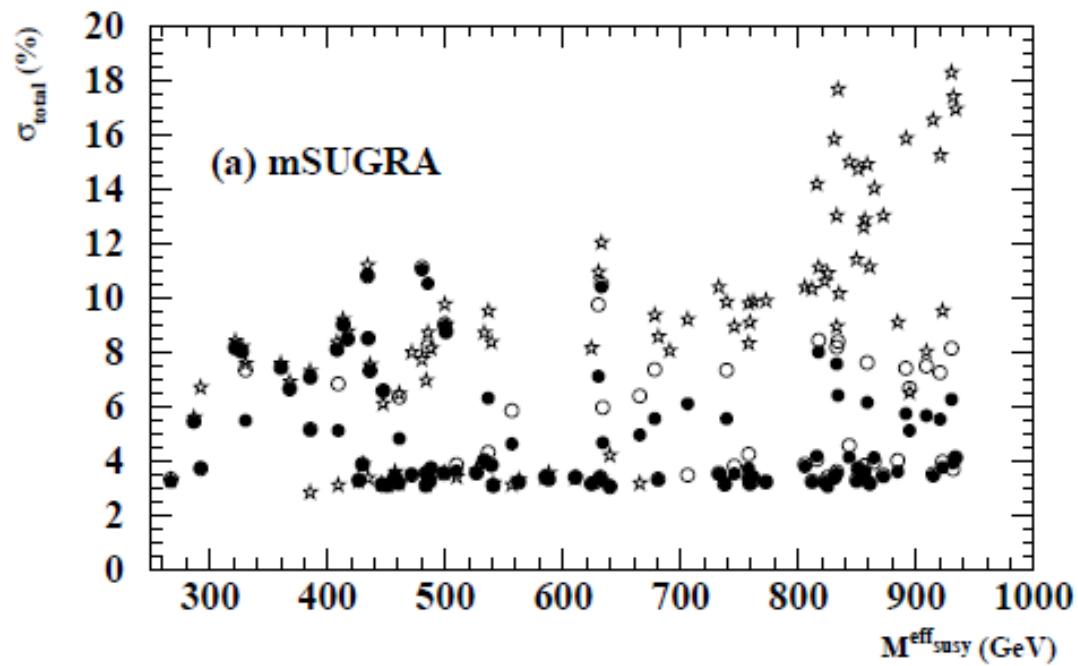
M_{est} distribution for SM background channels and SUSY signal
($m_0=100\text{GeV}$, $m_{1/2}=300\text{GeV}$, $A_0=300\text{GeV}$, $\mu>0$, $\tan(\beta)=2.1$)
●:ttbar,▲:W+jet,▼:Z+jet,■:QCD,○:SUSY,hatched:SM total

Mass scale measurement



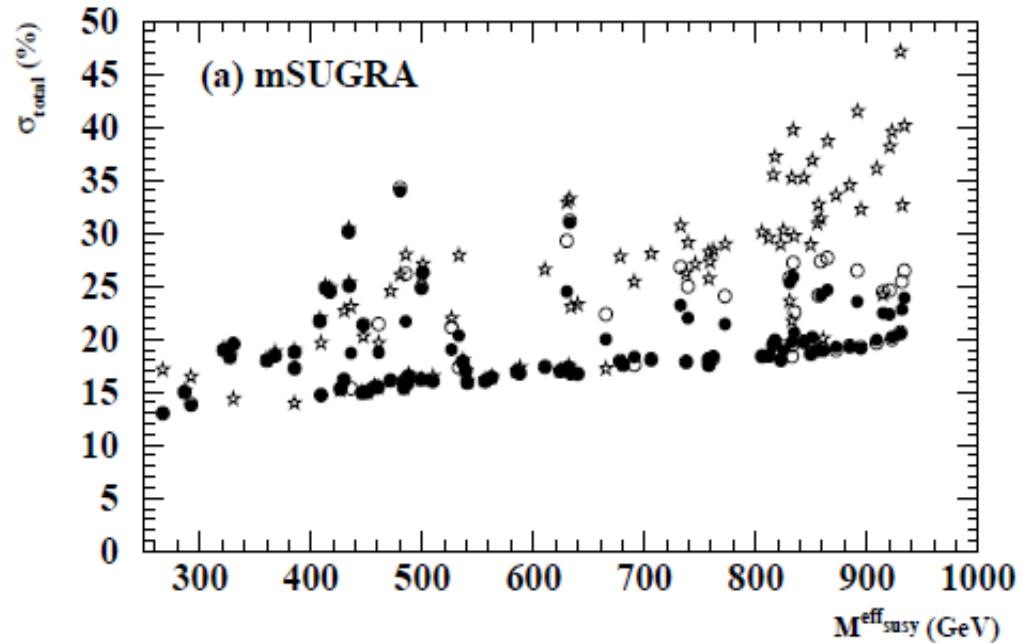
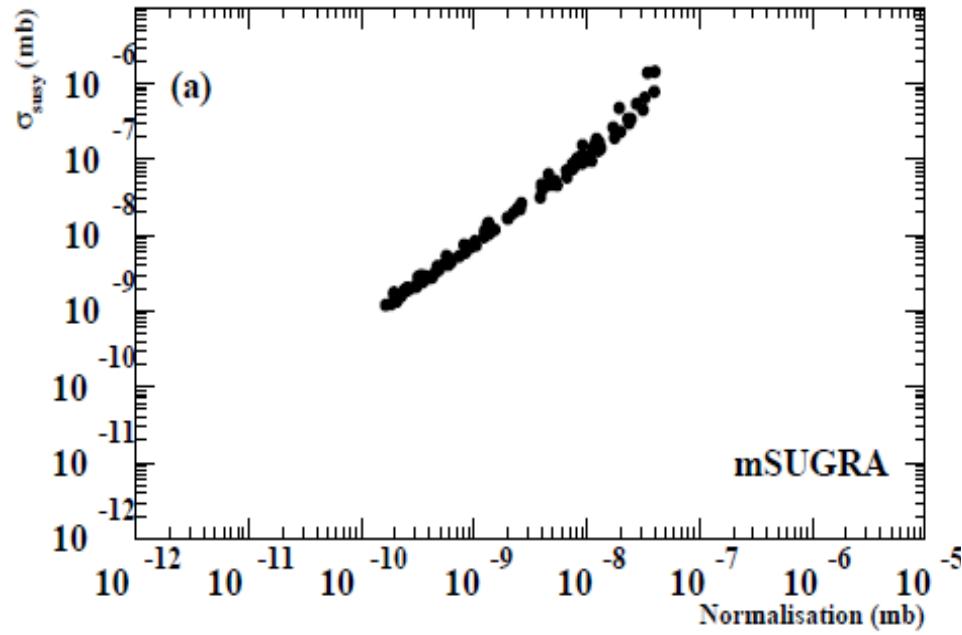
Reration of the effective SUSY mass scale $M_{\text{SUSY}}^{\text{eff}}$ and M_{est} for 100 random mSUGRA models.

We can estimate $M_{\text{SUSY}}^{\text{eff}}$ from figure above.



SUSY mass scale
precisions of $M_{\text{SUSY}}^{\text{eff}}$
< 20% for mSUGRA for 10fb^{-1}
< 10% for mSUGRA for 100fb^{-1}

cross-section measurement



The total SUSY particle production cross-section σ_{SUSY} plotted against the fitted area under the signal distribution for 100 random mSUGURA models.

precisions of cross-section
 $< 30\%$ for mSUGRA for 100 fb^{-1}

We can estimate σ_{SUSY} from figure above.