Balazs' Scurrulous Marriage guidance

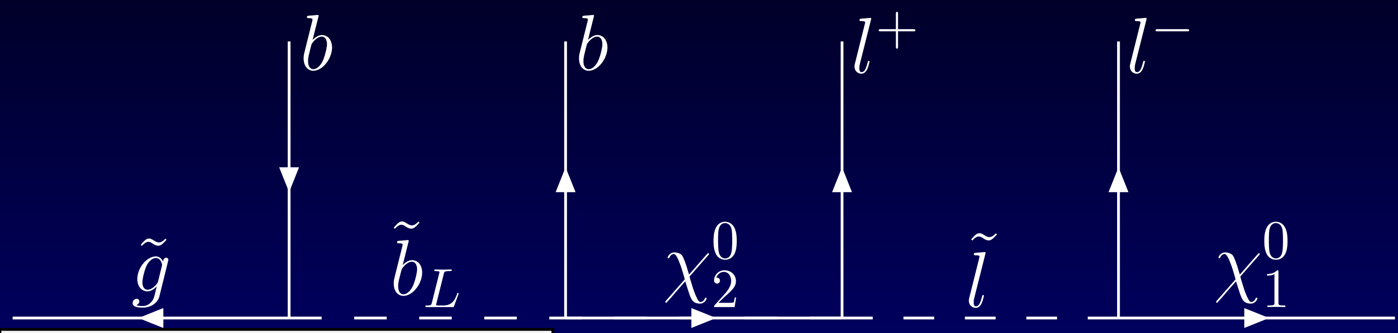
by

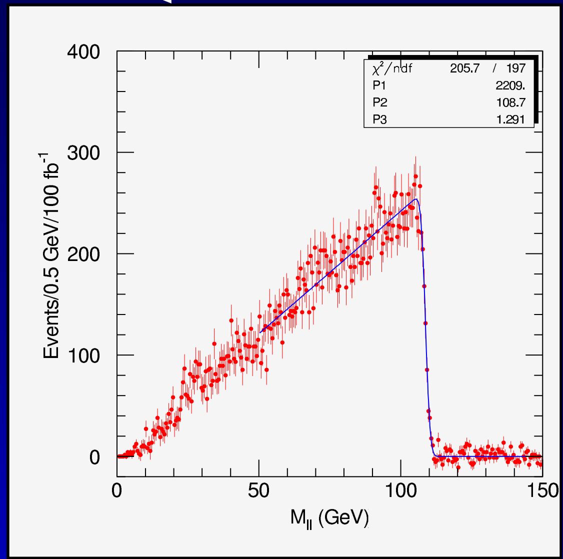
Ben Allanach (DAMTP, Uni of Cambridge)

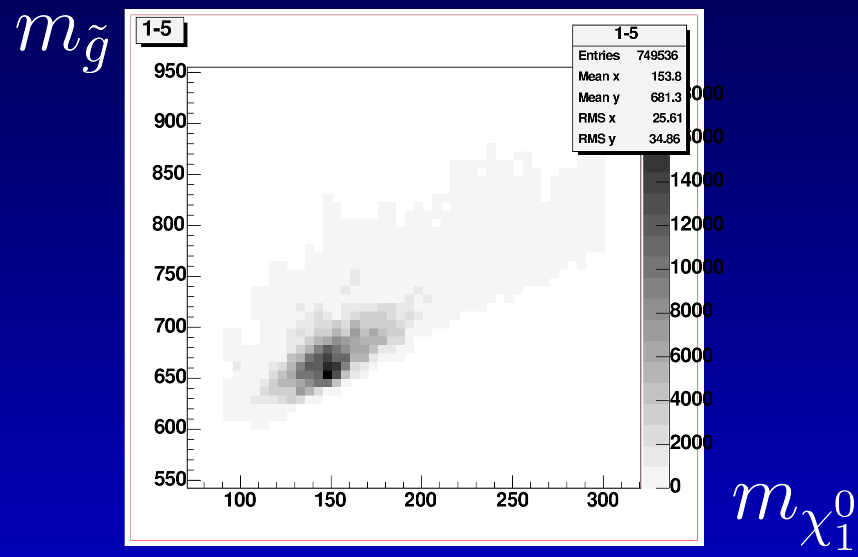
SUSY Theory Summary

- Lot of discussion
- Lot of arguments
- Lot of ideas

Hadronic SUSY Measurements







$\#D = 5(m) + 4(p_{\chi_1^0}) - 5(p^2 = m^2) = 4$ for 1 event.

$\#D = 5(m) + 4n(p_{\chi_1^0}) - 5n(p^2 = m^2) = 5 - n$ for n events, an *overconstrained* system for $n > 5$ [a]

[a] Nojiri, Polesello and Tovey; Lester, Les Houches proceedings 03

Finding $\tilde{g} \to \tilde{b}_1 b \to \tilde{\chi}_2^0 bb \to \tilde{l}_R^{\mp} l_N^{\pm} bb \to \tilde{\chi}_1^0 l_F^{\mp} l_N^{\pm} bb$

Would like a pure sample of events (see C.G. Lester hep-ph/0402295). Taking a look at SPS1a.

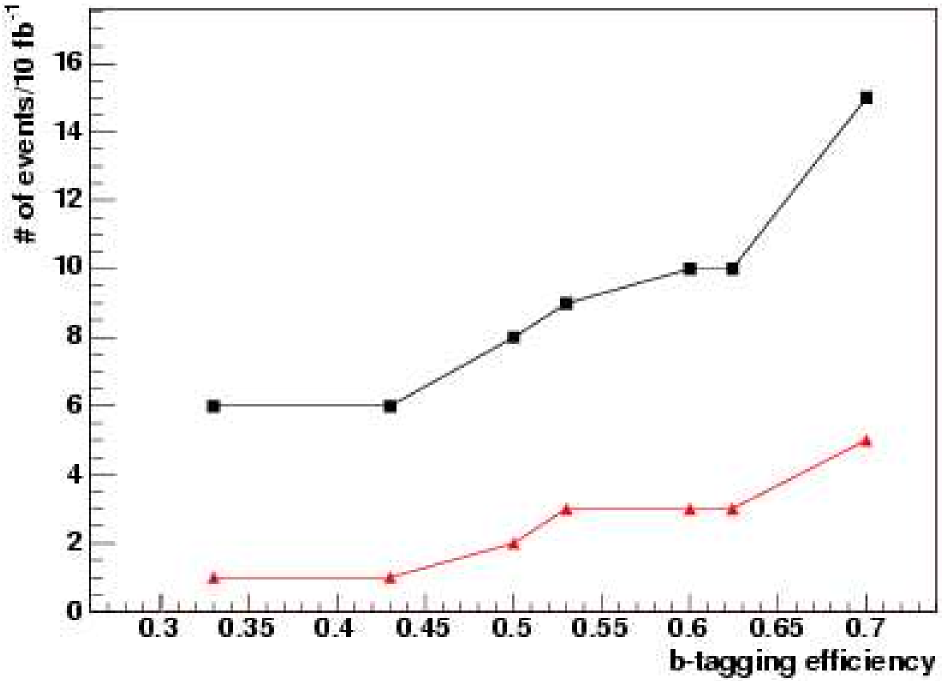


Figure: Correctly identified cascades (black) and misidentifications (red) vs. b-tagging efficiency. Tools: PYTHIA 6.208 and ATLFAST 2.60. p_T parametrization of non b-jet rejection for given b-tagging efficiency is taken from ATLFAST manual.

Main cuts used:

• Two opposite sign, same flavour leptons ($p_T > 30, 20$). • Two b-tagged jets ($p_T > 50$). • One hard jet ($p_T > 150$). • Angle between b-jets ($\cos\theta > 0.4$). • Consistency cuts on m_{ll}, $m_{bl(low)}$, $m_{bl(high)}$, m_{bll}, m_{bb}, $m_{bbl(low)}$, $m_{bbl(high)}$ and m_{bbll}.

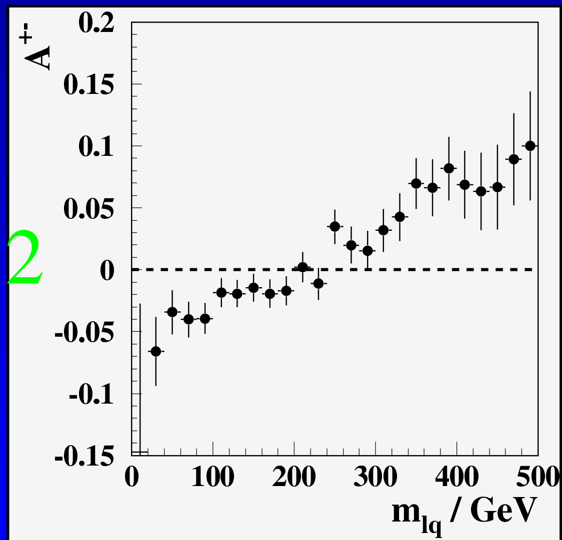
Spins at LHC

Crucial check of SUSY is spin (cf UED). Consider
$\tilde{q}_L \to ql\tilde{l}$: $m \equiv m_{ql}/m_{ql}(max) = \sin\theta/2$

$$\frac{dP(l^+q/l^-\bar{q})}{dm} = 4m^3, \qquad \frac{dP(l^-q/l^+\bar{q})}{dm} = 4m(1-m^2),$$

whereas pure PS is always $2m$. Seems hopeless, since we cannot tag quarks vs anti-quarks (average is PS). pp collider leads to spin-generated lepton charge asymmetry

Barr, hep-ph/0405052

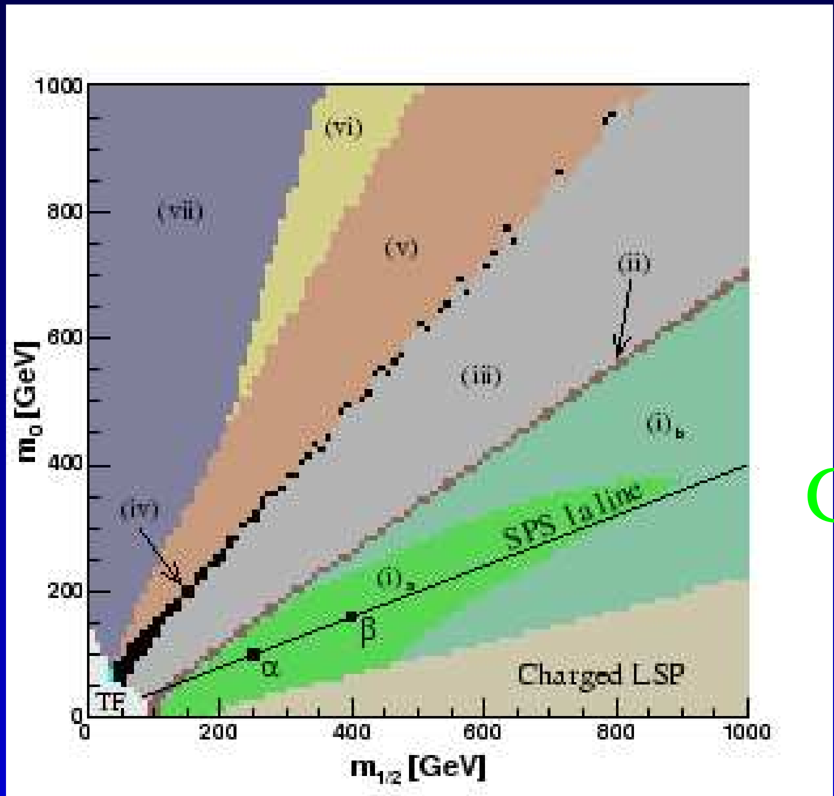


$$A^{+-} = \frac{m_{jl^+} - m_{jl^-}}{m_{jl^+} + m_{jl^-}}$$

$$\mathcal{L} = 150pb^{-1}$$

Region of Validity of Barr Method

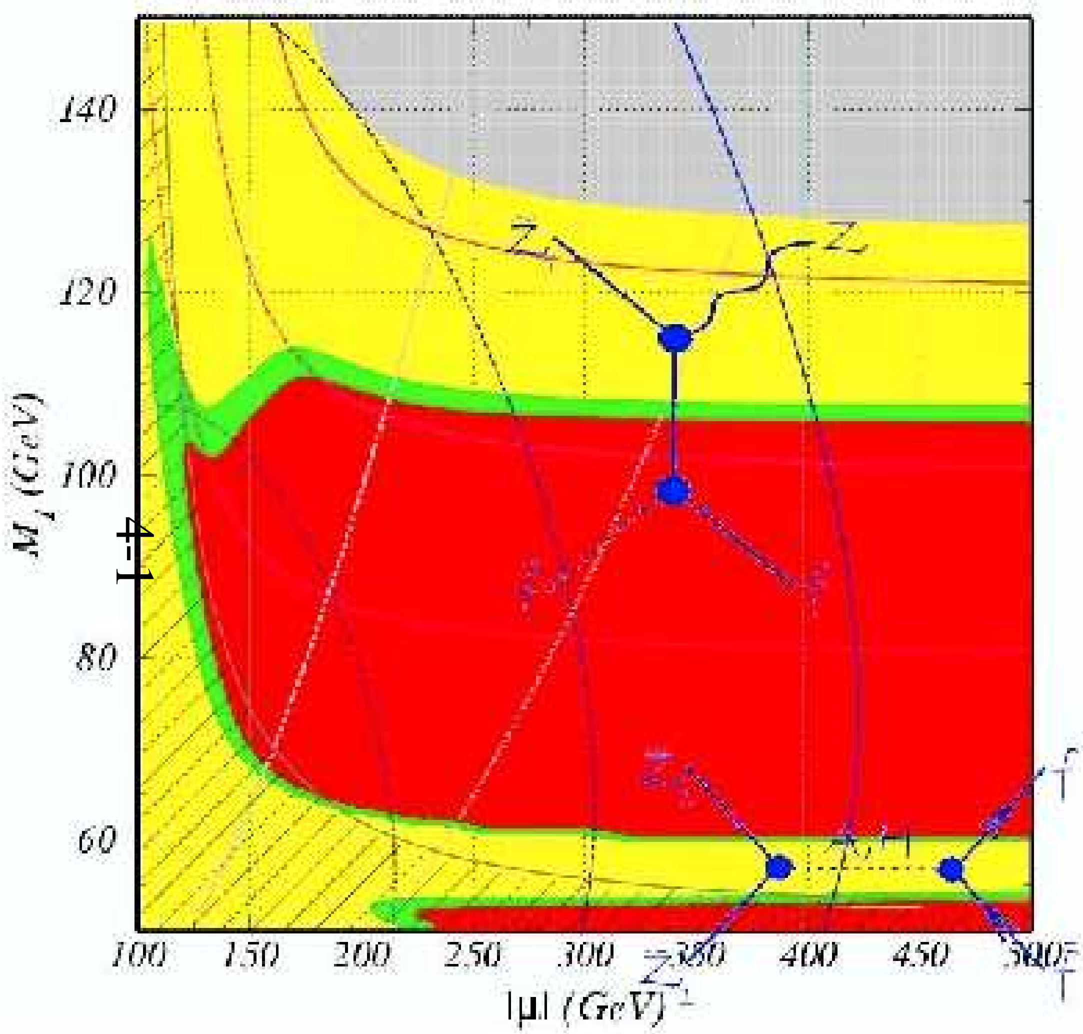
Where can one determine spins via Barr method: necessary conditions: $\#\tilde{q} - \#\bar{\tilde{q}} \neq 0$ and chain exists:



Gjelsten *et al*, hep-ph/0410303

Allanach, Mahmoudi

Electroweak baryogenesis, dark matter and a light $\tilde{t}_1$



Balázs, Carena, Menon, Morrissey, Wagner 2004

Allanach, Balázs, Galanti, Ghosh, Godbole, Guchait, Lari, Schumacher, Shepherd, Sopczak, Zhukovarena ...

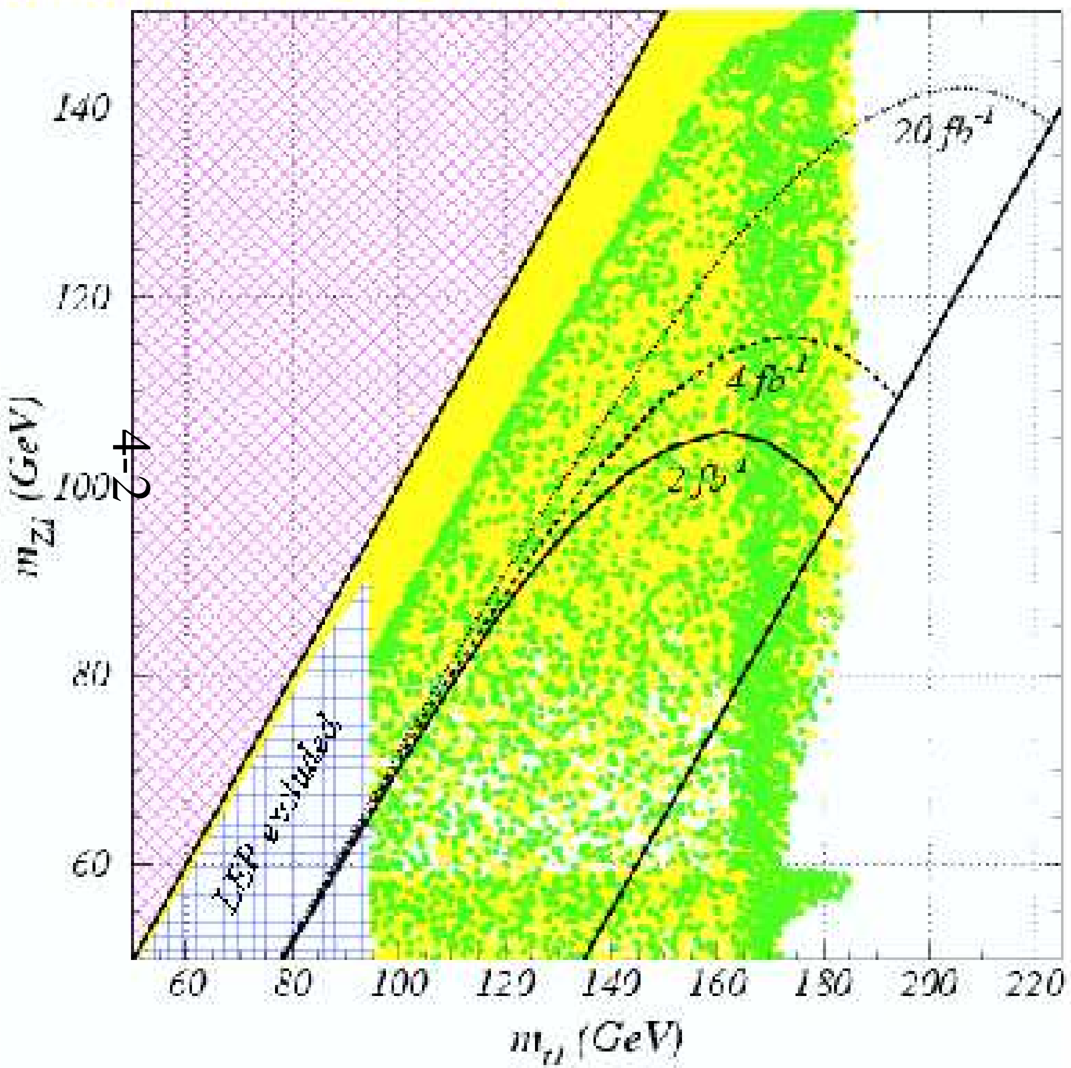
- Baryon asymmetry and dark matter can simultaneously be generated in the MSSM : green band → Ω_{CDM} consistent with WMAP at $2\,\sigma$

Balázs, Carena, Wagner 2004

- EWBG requires a light $m_{\tilde{t}_1} \lesssim m_t$
- $\tilde{t}_1 \tilde{Z}_1$ coannihilation lowers $\Omega_{\tilde{Z}_1}$ where $m_{\tilde{t}_1} \sim m_{\tilde{Z}_1}$ → small mass gap
- Annihilation via h^0, A^0 resonances lowers Ω_{CDM} for $2\,m_{\tilde{Z}_1} \sim m_{H^0(A^0)}$

Electroweak baryogenesis, dark matter and a light $\tilde{t}_1$

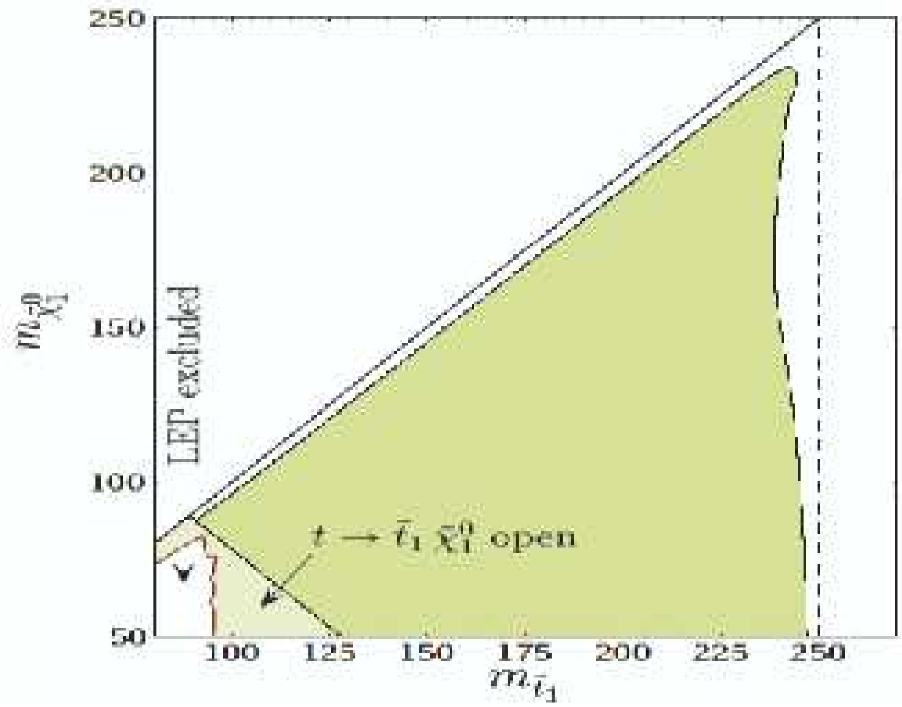
- When $\tilde{t}_1 \to c\tilde{Z}_1$ is dominant for $m_{\tilde{t}_1} - m_{\tilde{Z}_1} \lesssim 30$ GeV triggering is difficult at the Tevatron



Balázs, Carena, Wagner 2004

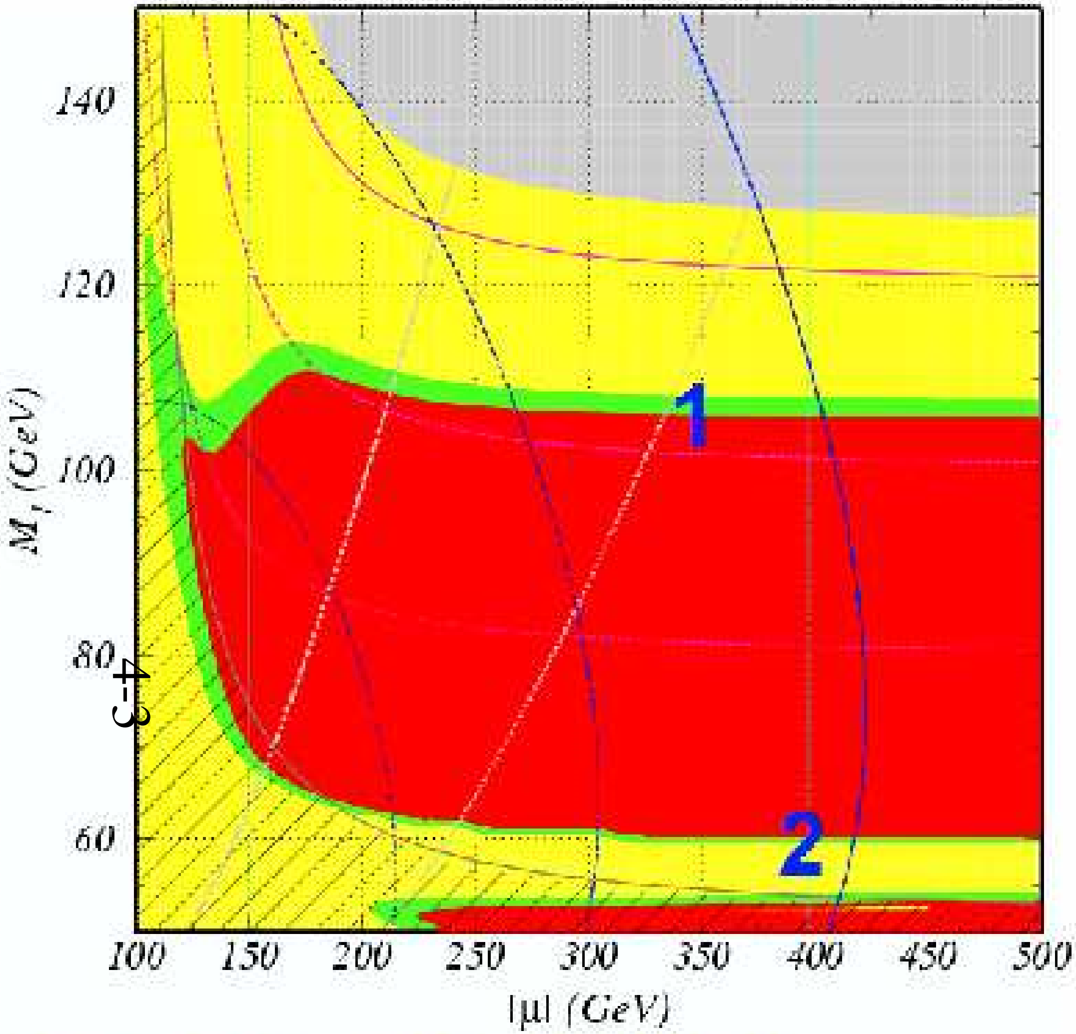
4-2

- Study for the LHC ?
- The ILC extends the LEP region covering the full interesting para.spac



Freitas, Milstene, Carena, Finch, Sopczak, Nowak 2005

Electroweak baryogenesis, dark matter and a light $\tilde{t}_1$



1 $\{|\mu|, M_1\} = \{350, 110\}$ GeV
Arg(μ) optional ($\tilde{t}_1 \tilde{Z}_1$ coann. insensitive to it)

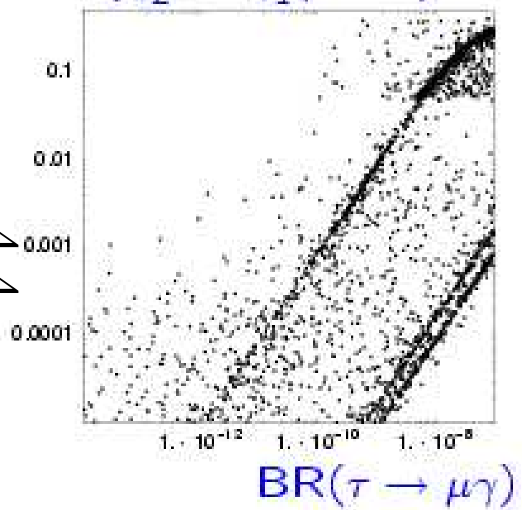
2 $\{|\mu|, M_1\} = \{400, 60\}$ GeV
in Tevatron / LHC reach (resonance ann.)

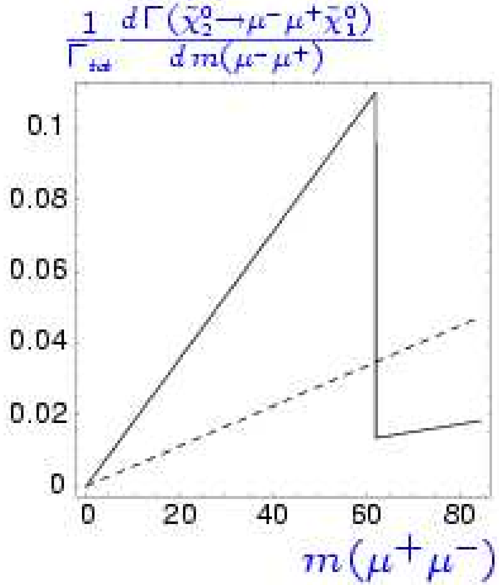
- Strategy initiated at Houches to explore collider phenomenology
- 'Bemchmark' point selection
  - 1 & 2 + modified SPS1a (Arg$(\mu) \neq 0$)
- Arg$(\mu) = 0$
  - is Arg(μ) important at collider ?
  - to study (by standard tools) :
    — 3 & 4 - body decays of $\tilde{t}_1$
    — Higgs sector ($gg \to H$, ...)
    — ATLFast events (available ?)
- Arg$(\mu) \neq 0$
  - Validate tools with phases
  - Generate events with PYTHIA ?
  - Compare to Arg$\mu = 0$ case

Lepton Flavour Violation @ LHC

A. De Roeck, D. Ghosh, W. Porod, A. Raklev, L. Ruruar

Idea: Seesaw mechanism $\Rightarrow$ off-diagonal elements for $M_{\tilde{L}}^2$, A_l, $M_{\tilde{L}}^2$.
$\Rightarrow \tilde{\chi}_2^0 \to \mu\tilde{\tau}_i \to \mu\,\tau\tilde{\chi}_1^0$, $\tilde{\chi}_2^0 \to \mu\tilde{\tau}_i \to \mu^+\mu^-\tilde{\chi}_1^0$





Variations around SPS1a'

$\Leftarrow$ maximal **LFV** compatible with $\tau \to \mu\gamma$

Questions:

1) Can LFV be large enough to yield measurable structures in m_{ll}^2 (relative heights in the right figure)
2) Impact on slepton mass measurements
3) What can be learned about the off-diagonal elements

Direct Calculation of 2 → 6 amplitudes in SUSY

- Motivations:
  - Theory : Study case for ME calculation w/ large nber of final state particles
  - Expt : Study case for systematic uncertainty on a SUSY signal modeling
- SUSY Process: $q\bar{q} / gg \rightarrow \tilde{g}\tilde{g} \rightarrow \tilde{b}_1 \bar{b} \bar{\tilde{b}}_1 b \rightarrow 4b + 2\tilde{\chi}_1^0$
  - No existing such 2 → 6 SUSY calculations available so far
- Aim:
  - Compare b-quarks/$E_T$miss angles/energy correlations in full ME wrt stepwise calculations based on BRs
- Tools:
  - Full ME calculation:
    - Using a modified version of FormCalc — DONE
    - Reminder PH-SP up to 2 → 3
  - LHA interface between PS generators & ME (P. Richardson)
    - Setup and tests based on simple 2 → 2 case: D-Y — DONE
    - Need to generate P_i for 2 → 6 PH-SP (hack piece from MCFM) — TO BE TESTED
  - To do list:
    - Compare Form ME+Pythia/Herwig, PS, …, SHERPA — TO DO
    - Evaluate signal modeling systematics (accept/ε) → D0 analysis — TO DO

(A. Deandrea, F. Mahmoudi, T. Millet, S. Muanza)

CPX scenario

Light higgs $M(H_1) < 50$GeV allowed by LEP if have CP violating phases.
H_1ZZ coupling suppressed $H_1H^{+/-}W^{-/+}$ coupling enhanced (sum rule).

2 possible channels to investigate:

$$pp \rightarrow t\,\bar{t}\,(X)\,;\;\; t \rightarrow b\,H^+ ,\;\; H^+ \rightarrow W\,H_1\,,\; H_1 \rightarrow b\,\bar{b}$$
$$\bar{t} \rightarrow \bar{b}\,W$$

BR $(H^+ \rightarrow W\,H_1)$ large. Large cross section (O(10) pb)

Interest in first (Schumacher, Godbole et al.) and second sessions in above channel.

2nd channel.

$$pp \rightarrow H^+\,H_1\,(X)\;;\; H^+ \rightarrow W\,H_1\,;\; H_1 \rightarrow b\,\bar{b}$$

Interest 2nd session: Claire Shepherd, Dilip Ghosh, Stefano Moretti

Way to get information on spin of $\tilde{\chi}$ and/or CP violation?

- crew: S. Hesselbach, S. Kraml, F. Moortgat, G. Moortgat-Pick, A. Raklev, S. Rindani

- look at the chains like: $\tilde{q} \to q\tilde{\chi}^0_2 \to q\ell_1\tilde{\ell} \to q\ell_2\tilde{\chi}^0_1$

- distributions of ℓ reflect spin of $\tilde{\chi}$

- triple product between $q\ell_1\ell_2$ observable at LHC?
  effects from spin of $\tilde{\chi}$
  effects from CP violation in triple product asymmetry $\to \phi$ dependence
  distinction between ℓ_1 and ℓ_2 'far/near' from event-to-event basis
  averaged by other processes from $\bar{q}$?

- steps: a) first kinematical approach to observables and kinematics
  b) sum about all related processes
  c) study effects from spin and/or CP phases

Diphotons

Non-minimal study: D Ghosh *et al* of a non-minimal composite Higgs model (Mathcev *et al*)

- $H \longrightarrow aa \longrightarrow 4\gamma$. $M_H \sim 140$ GeV
- $m_a < 1$ GeV $\Rightarrow$ soft γ's can't be reconstructed
- $\sigma\times$BR $\sim \mathcal{O}(30)$ pb^{-1}
- Looks like a 2γ signal: relevant for BSM benchmark study (Ferrag et al)

Distinguishing between MSSM and NMSSM by combined LHC and ILC analyses

G. Moortgat-Pick, S. Hesselbach, F. Franke, H. Fraas, hep-ph/0502036

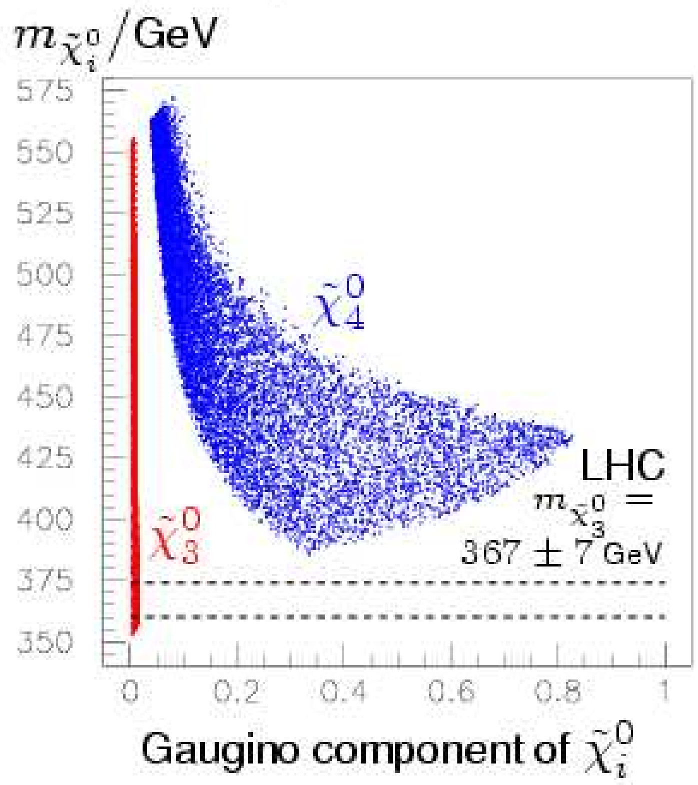
- Assume: No model identification via Higgs or neutralino/chargino measurements at ILC
- Start with NMSSM scenario:
  $M_1 = 360$ GeV, $M_2 = 147$ GeV, $\tan\beta = 10$, $x = 915$ GeV, $\lambda = 0.5$, $\kappa = 0.2$
- Measured at ILC ($\sqrt{s} = 500$ GeV): $m_{\tilde{\chi}_1^\pm}$, $m_{\tilde{\chi}_{1,2}^0}$, $\sigma(e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^-, \tilde{\chi}_1^0\tilde{\chi}_2^0)$

  $\longrightarrow$ Consistent with MSSM $\longrightarrow$ Reconstruction of M_1, M_2, μ, $\tan\beta$

  $\longrightarrow$ Predictions:

  $m_{\tilde{\chi}_3^0} = [352, 555]$ GeV $\longrightarrow$ pure higgsino
  $m_{\tilde{\chi}_4^0} = [386, 573]$ GeV $\longrightarrow$ larger gaugino comp.
  $m_{\tilde{\chi}_2^\pm} = [450, 600]$ GeV

  $\Longrightarrow$ $\tilde{\chi}_3^0$ not accessible at LHC



- However: $\tilde{\chi}_3^0$ in underlying NMSSM scenario has large gaugino component

  $\longrightarrow$ visible at LHC $\longrightarrow$ inconsistency
- Motivation for ILC$_{650}^{\mathcal{L}=1/3}$

  $\longrightarrow$ determination of underlying model

Splitting Extended SUSY in Intersecting Branes

Karim BENAKLI,
with **I. Antoniadis, A. Delgado, M. Quirós, M. Tuckmantel**

Abstract

- SUSY? because it is there in string models.
- Intersecting brane models lead generically to extended SUSY in the gauge sector.
- Simple SUSY breaking scenario predicts strong hierarchy between scalar and sfermion soft masses: Split SUSY
- Models are compatible with gauge unification and neutralino as dark matter.
- At low energy SM + two Higgs doublets + at 1.1 TeV neutralinos and charginos: a case for CLIC?

Conclusion

- Thought goats weren’t a problem but they got noisier and a lot closer!