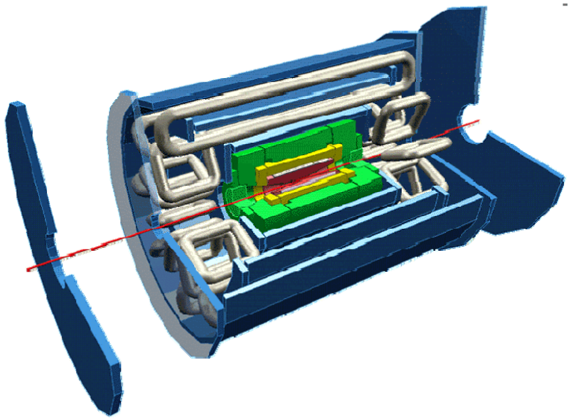
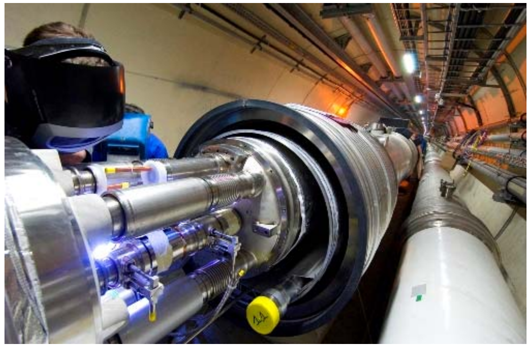
News from ATLAS physics studies

Alan Barr
UCL, London



LHC-ILC : 13 Dec 2005



ATLAS Physics Activities

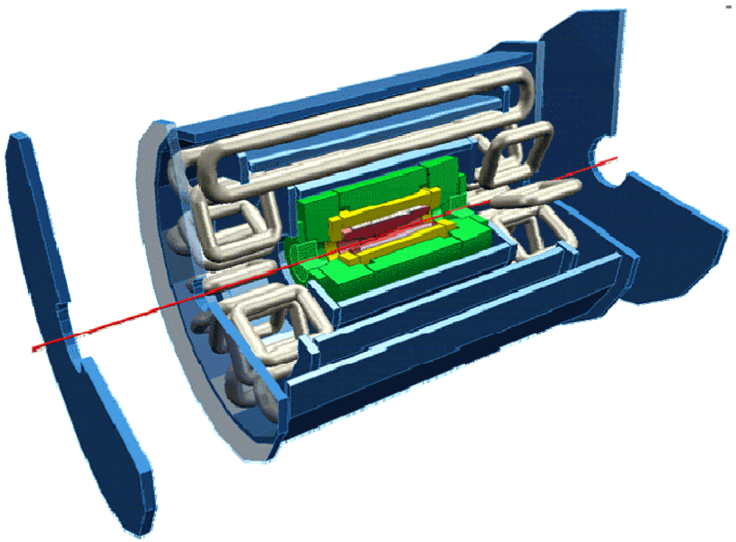
- Currently focused on **commissioning**
  - Measurements with small-luminosity samples
  - 100 pb^{-1} to 10 fb^{-1}
  - What might we be able to see?
- Increase the **realism** of our analyses
  - Better background estimates
  - As-built detector simulation
  - Resolution determination

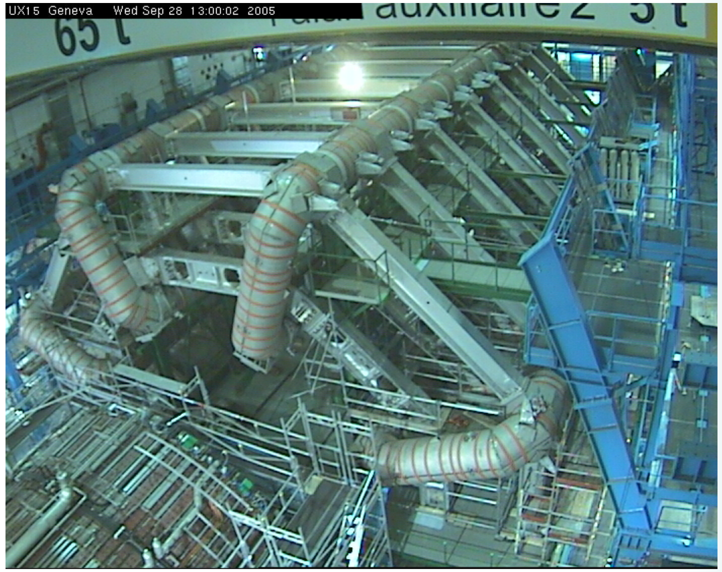
  Motivated by commissioning

No longer an exercise

Real detector commissioning in progress as I speak

Increasing realism (1)





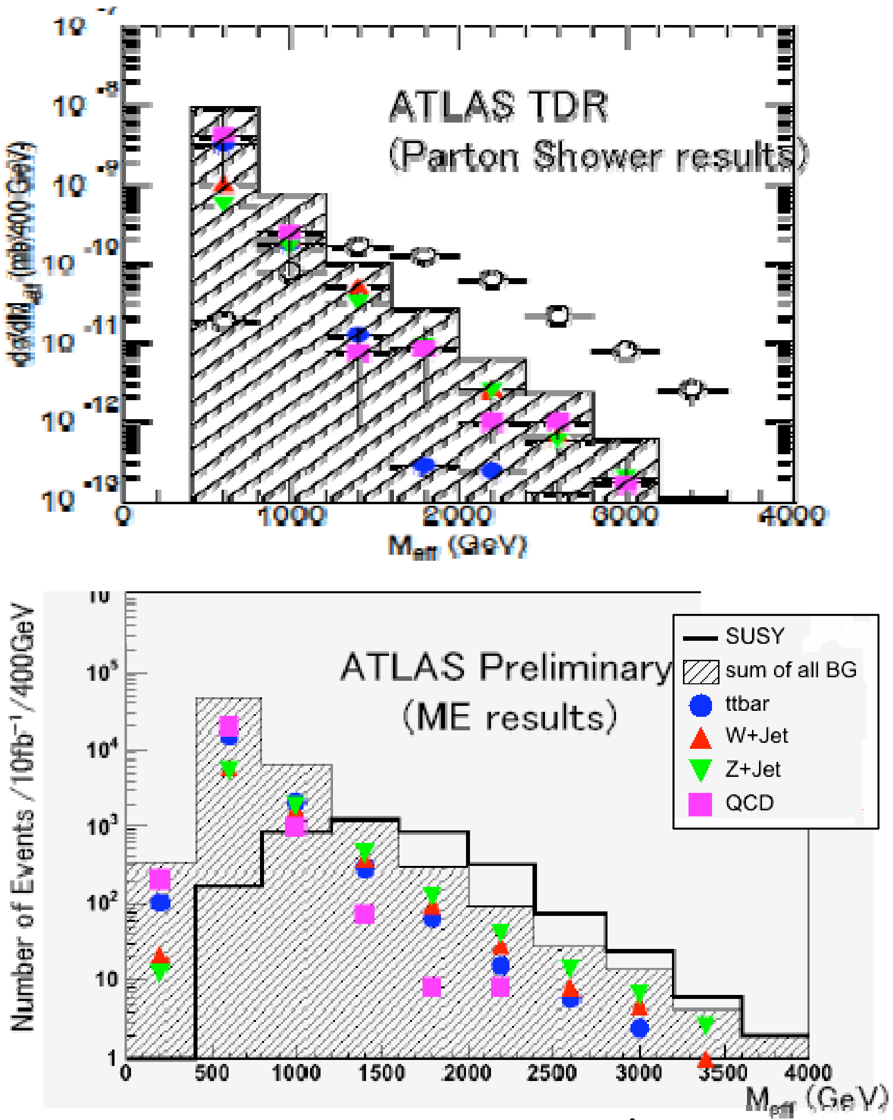
- As-built performance being added to simulations
  - Mis-alignments, dead channels, actual material budget …
- Major effort in progress

Increasing realism (2)

Asai, Sasaki, Tanaka

Have to get SM BG correct
Critical in being able to make discovery

- Some previous predictions made with jets from parton e.g. boson production from parton shower only
  - Or boson + 1 jet in M.E.
  - Cover high k_T region of phase space badly
- Need high k_T jets for SUSY analysis
  - Use newer M.E. Monte Carlos



$M_{eff} \approx$ mass scale

In parallel with commissioning: improved analysis techniques

- Main thrust of this talk is at SUSY:
  - Mass determination
  - Spin determination
  - Flavour measurements
  - Dark-matter sensitive measurements
  - Stable R-hadrons
- N.B. We also have consolidation and progress in:
  - Higgs
  - Parton distributions
  - W mass
  - Top mass
  - …

Things which will be done **after** discovery

Experimental methods for controlling systematic uncertainties

What's being reported?

hep-ph/0410364

Physics Interplay of the LHC and the ILC

The LHC / LC Study Group

Editors:

G. WEIGLEIN[1], T. BARKLOW[2], E. BOOS[3], A. DE ROECK[4], K. DESCH[5], F. GIANOTTI[4], R. GODBOLE[6], J.F. GUNION[7], H.E. HABER[8], S. HEINEMEYER[4], J.L. HEWETT[2], K. KAWAGOE[9], K. MÖNIG[10], M.M. NOJIRI[11], G. POLESELLO[12,4], F. RICHARD[13], S. RIEMANN[10], W.J. STIRLING[1]

- Excellent groundwork done in LHC-ILC doc
  - Chapter 5 = SUSY
  - Masses, Mixings, Couplings, Flavour
- I'm mostly reporting **updates** relative to LHC-ILC doc
  - Improved masses, mixings, couplings + spin, dark matter

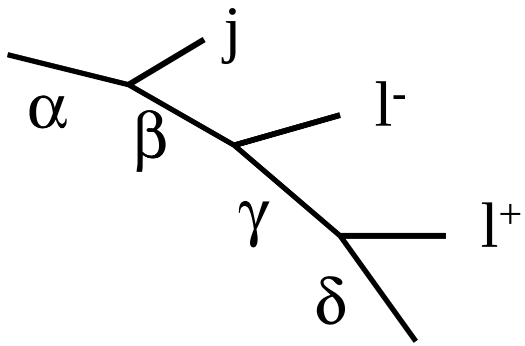
Warning – lots of slides on **edges** follow!
If LSP escapes detection we see kinematic edges rather than mass peaks for new particles

SUSY mass measurements: relevance for ILC

- LHC clearly cannot fully constrain all parameters of mSUGRA
  - However it makes good constraints
    - Particularly good at mass differences [$\mathcal{O}$(1%)]
    - Not so good at mass scales
    - [$\mathcal{O}$(10%) from direct measurements]
    - Mass scale possibly best "measured" from cross-sections
  - Often have >1 interpretation
    - What solution to end-point formula is relevant?
    - Which neutralino was in this decay chain?
    - What was the "chirality" of the slepton " " " ?
    - Was it a 2-body or 3-body decay?
  - Combining constraints is complicated
    - I highlight some analyses which do this well!

Ambiguities in sparticle identification

Lester, Parker, White
hep-ph/0508143



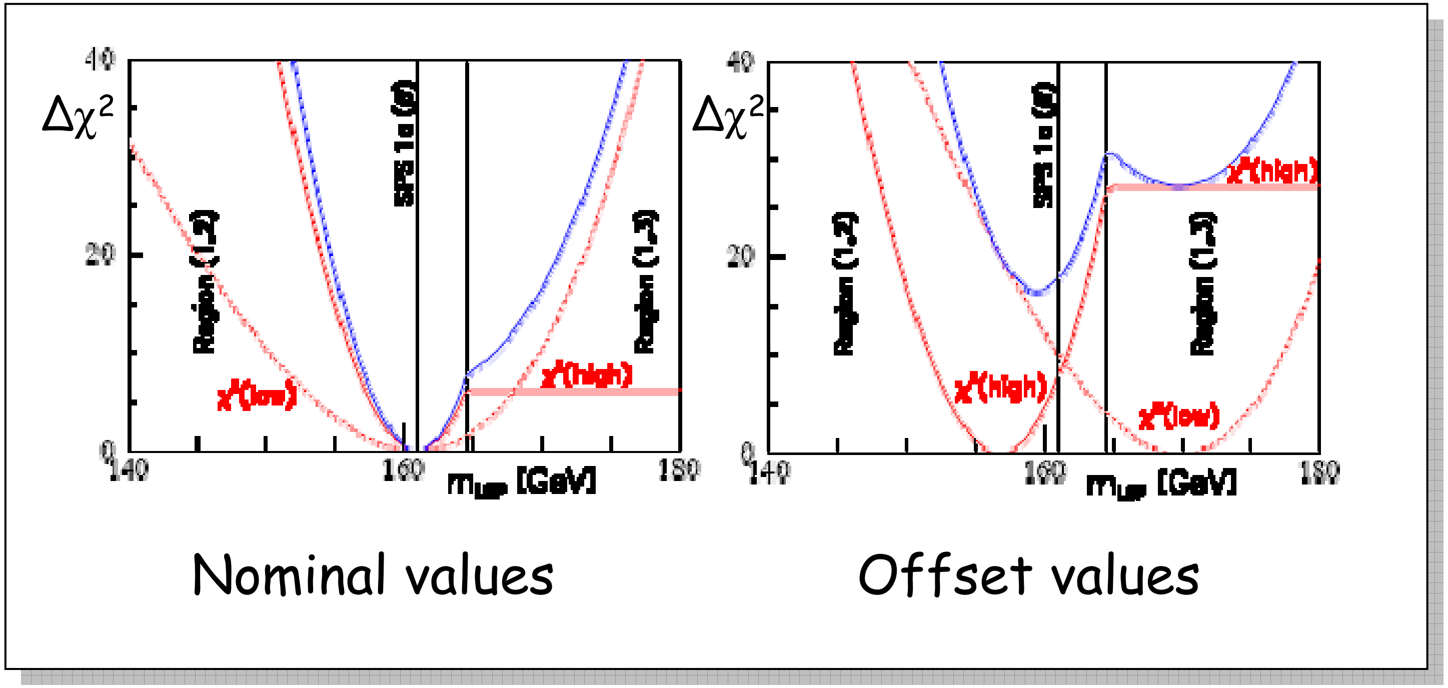
- May not be possible to identify which particles participate in which decay chains
  - Ambiguity in interpreting kinematic edge results

Name	Hieracrchy
H_1	$m_{\tilde{q}} > m_{\tilde{\chi}_2^0} > m_{\tilde{e}_L} > m_{\tilde{\chi}_1^0}$
H_2	$m_{\tilde{q}} > m_{\tilde{\chi}_3^0} > m_{\tilde{e}_L} > m_{\tilde{\chi}_1^0}$
H_3	$m_{\tilde{q}} > m_{\tilde{\chi}_3^0} > m_{\tilde{e}_L} > m_{\tilde{\chi}_2^0}$
H_4	$m_{\tilde{q}} > m_{\tilde{\chi}_4^0} > m_{\tilde{e}_L} > m_{\tilde{\chi}_1^0}$
H_5	$m_{\tilde{q}} > m_{\tilde{\chi}_4^0} > m_{\tilde{e}_L} > m_{\tilde{\chi}_2^0}$
H_6	$m_{\tilde{q}} > m_{\tilde{\chi}_4^0} > m_{\tilde{e}_L} > m_{\tilde{\chi}_3^0}$
H_7	$m_{\tilde{q}} > m_{\tilde{\chi}_2^0} > m_{\tilde{e}_R} > m_{\tilde{\chi}_1^0}$
H_8	$m_{\tilde{q}} > m_{\tilde{\chi}_3^0} > m_{\tilde{e}_R} > m_{\tilde{\chi}_1^0}$
H_9	$m_{\tilde{q}} > m_{\tilde{\chi}_3^0} > m_{\tilde{e}_R} > m_{\tilde{\chi}_2^0}$
H_{10}	$m_{\tilde{q}} > m_{\tilde{\chi}_4^0} > m_{\tilde{e}_R} > m_{\tilde{\chi}_1^0}$
H_{11}	$m_{\tilde{q}} > m_{\tilde{\chi}_4^0} > m_{\tilde{e}_R} > m_{\tilde{\chi}_2^0}$
H_{12}	$m_{\tilde{q}} > m_{\tilde{\chi}_4^0} > m_{\tilde{e}_R} > m_{\tilde{\chi}_3^0}$

12 different mass hierarchies which lead to qll final state in a series of 2-body decays

- Composite formula for edge positions
  - Multiple interpretations for masses

$$\left(m^{\max}_{ql(\mathrm{low})}, m^{\max}_{ql(\mathrm{high})}\right) = \begin{cases} \left(m^{\max}_{ql_n}, m^{\max}_{ql_f}\right) & \text{for} \quad 2m^2_{\tilde{l}_R} > m^2_{\tilde{\chi}^0_1} + m^2_{\tilde{\chi}^0_2} > 2m_{\tilde{\chi}^0_1}m_{\tilde{\chi}^0_2} \quad (1) \\ \left(m^{\max}_{ql(\mathrm{eq})}, m^{\max}_{ql_f}\right) & \text{for} \quad m^2_{\tilde{\chi}^0_1} + m^2_{\tilde{\chi}^0_2} > 2m^2_{\tilde{l}_R} > 2m_{\tilde{\chi}^0_1}m_{\tilde{\chi}^0_2} \quad (2) \\ \left(m^{\max}_{ql(\mathrm{eq})}, m^{\max}_{ql_n}\right) & \text{for} \quad m^2_{\tilde{\chi}^0_1} + m^2_{\tilde{\chi}^0_2} > 2m_{\tilde{\chi}^0_1}m_{\tilde{\chi}^0_2} > 2m^2_{\tilde{l}_R} \quad (3) \end{cases}$$



Gjelsten, Miller, Osland
hep-ph/0507232

Gjelsten, Miller, Osland
hep-ph/0501033

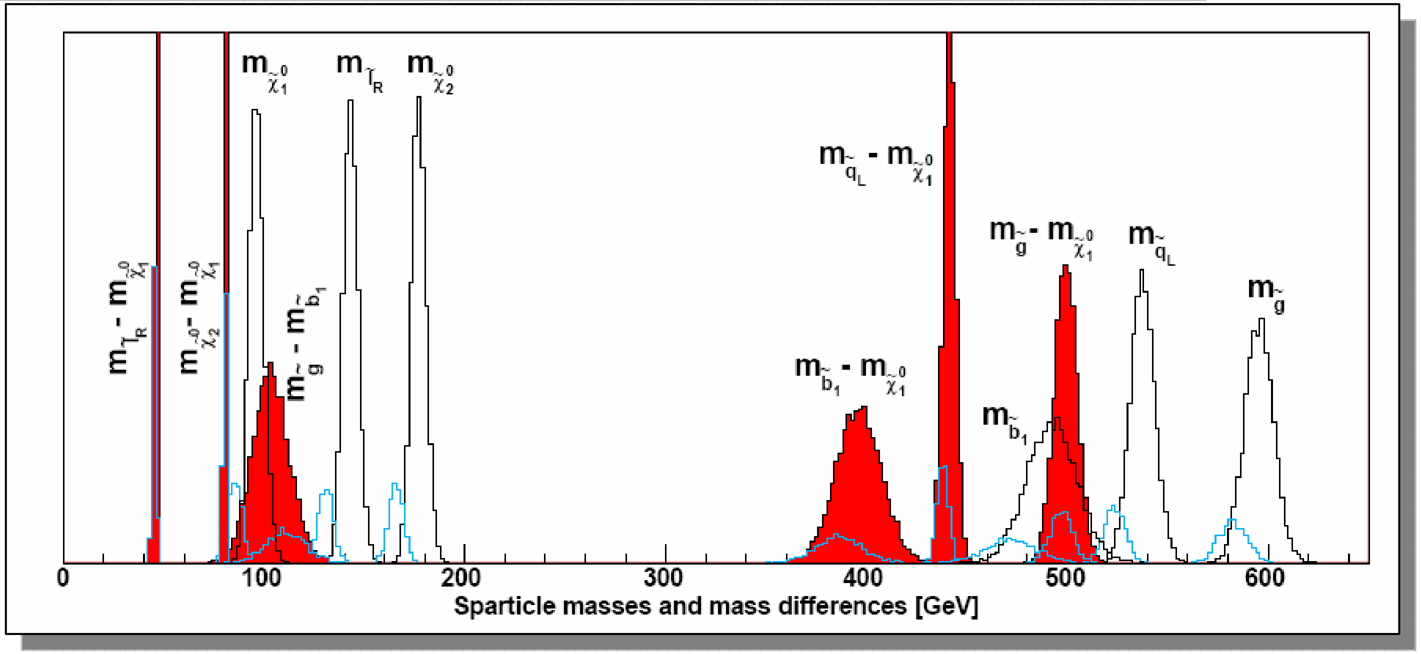
Gluino endpoints

$$\tilde{g} \to \tilde{q}_L q_{\rm n} \to \tilde{\chi}_2^0 q_{\rm f} q_{\rm n} \to \tilde{l}_R l_{\rm n} q_{\rm f} q_{\rm n} \to \tilde{\chi}_1^0 l_{\rm f} l_{\rm n} q_{\rm f} q_{\rm n}$$

$$(m_{qqll}^{\rm max})^2 = \begin{cases} \dfrac{\left(m_{\tilde{g}}^2 - m_{\tilde{q}_L}^2\right)\left(m_{\tilde{q}_L}^2 - m_{\tilde{\chi}_1^0}^2\right)}{m_{\tilde{q}_L}^2} & \text{for} \quad \dfrac{m_{\tilde{g}}}{m_{\tilde{q}_L}} > \dfrac{m_{\tilde{q}_L}}{m_{\tilde{\chi}_2^0}} \dfrac{m_{\tilde{\chi}_2^0}}{m_{\tilde{l}_R}} \dfrac{m_{\tilde{l}_R}}{m_{\tilde{\chi}_1^0}} \quad (1) \\ \dfrac{\left(m_{\tilde{g}}^2 m_{\tilde{\chi}_2^0}^2 - m_{\tilde{q}_L}^2 m_{\tilde{\chi}_1^0}^2\right)\left(m_{\tilde{q}_L}^2 - m_{\tilde{\chi}_2^0}^2\right)}{m_{\tilde{q}_L}^2 m_{\tilde{\chi}_2^0}^2} & \text{for} \quad \dfrac{m_{\tilde{q}_L}}{m_{\tilde{\chi}_2^0}} > \dfrac{m_{\tilde{\chi}_2^0}}{m_{\tilde{l}_R}} \dfrac{m_{\tilde{l}_R}}{m_{\tilde{\chi}_1^0}} \dfrac{m_{\tilde{g}}}{m_{\tilde{q}_L}} \quad (2) \\ \dfrac{\left(m_{\tilde{g}}^2 m_{\tilde{l}_R}^2 - m_{\tilde{\chi}_2^0}^2 m_{\tilde{\chi}_1^0}^2\right)\left(m_{\tilde{\chi}_2^0}^2 - m_{\tilde{l}_R}^2\right)}{m_{\tilde{\chi}_2^0}^2 m_{\tilde{l}_R}^2} & \text{for} \quad \dfrac{m_{\tilde{\chi}_2^0}}{m_{\tilde{l}_R}} > \dfrac{m_{\tilde{l}_R}}{m_{\tilde{\chi}_1^0}} \dfrac{m_{\tilde{g}}}{m_{\tilde{q}_L}} \dfrac{m_{\tilde{q}_L}}{m_{\tilde{\chi}_2^0}} \quad (3) \\ \dfrac{\left(m_{\tilde{g}}^2 - m_{\tilde{l}_R}^2\right)\left(m_{\tilde{l}_R}^2 - m_{\tilde{\chi}_1^0}^2\right)}{m_{\tilde{l}_R}^2} & \text{for} \quad \dfrac{m_{\tilde{l}_R}}{m_{\tilde{\chi}_1^0}} > \dfrac{m_{\tilde{g}}}{m_{\tilde{q}_L}} \dfrac{m_{\tilde{q}_L}}{m_{\tilde{\chi}_2^0}} \dfrac{m_{\tilde{\chi}_2^0}}{m_{\tilde{l}_R}} \quad (4) \\ \left(m_{\tilde{g}} - m_{\tilde{\chi}_1^0}\right)^2 & \text{otherwise} \quad (5) \end{cases}$$

- More end-points available
- Overall more over-constrained system

Masses and mass difference from LHC endpoints



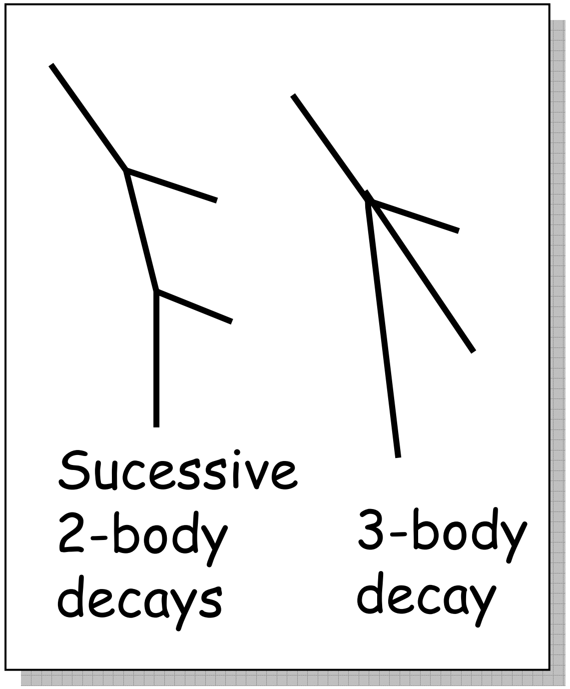
- For SPS1a, combine gluino + standard LHC endpoints
  - Run ensemble of 10,000 "experiments"
  - Plot masses and mass differences (above) for $\Delta\chi^2<1$
- Add ILC "measurement" of LSP
  - Improves mass measurements
  - Removes ambiguities at SPS1a

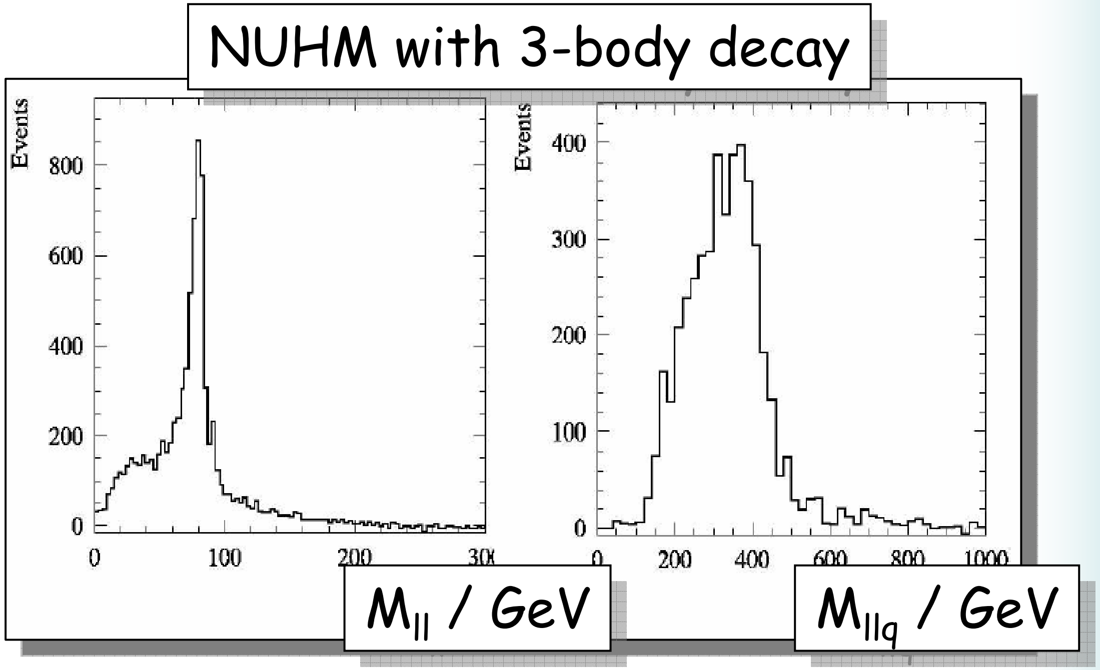
How general is this?

Gjelsten, Miller, Osland
hep-ph/0501033

$$\tilde{g} \to \tilde{q}_L q_n \to \tilde{\chi}_2^0 q_f q_n \to \tilde{l}_R l_n q_f q_n \to \tilde{\chi}_1^0 l_f l_n q_f q_n$$

Two- or three-body decays?





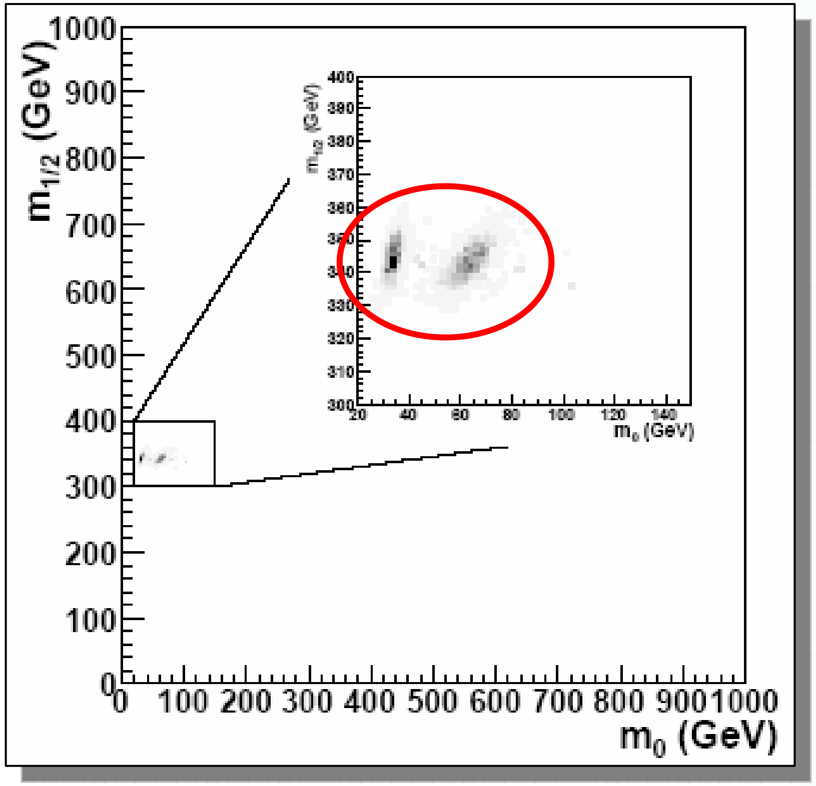
- In some cases (as non-universal higgs model above) it is possible to distinguish 3-body from successive 2-body from *shape* of distributions @ LHC
- **Not** guaranteed
  - Futher ambiguities!

Lester, Parker, White

Lester, Parker, White
hep-ph/0508143

Dealing with ambiguities

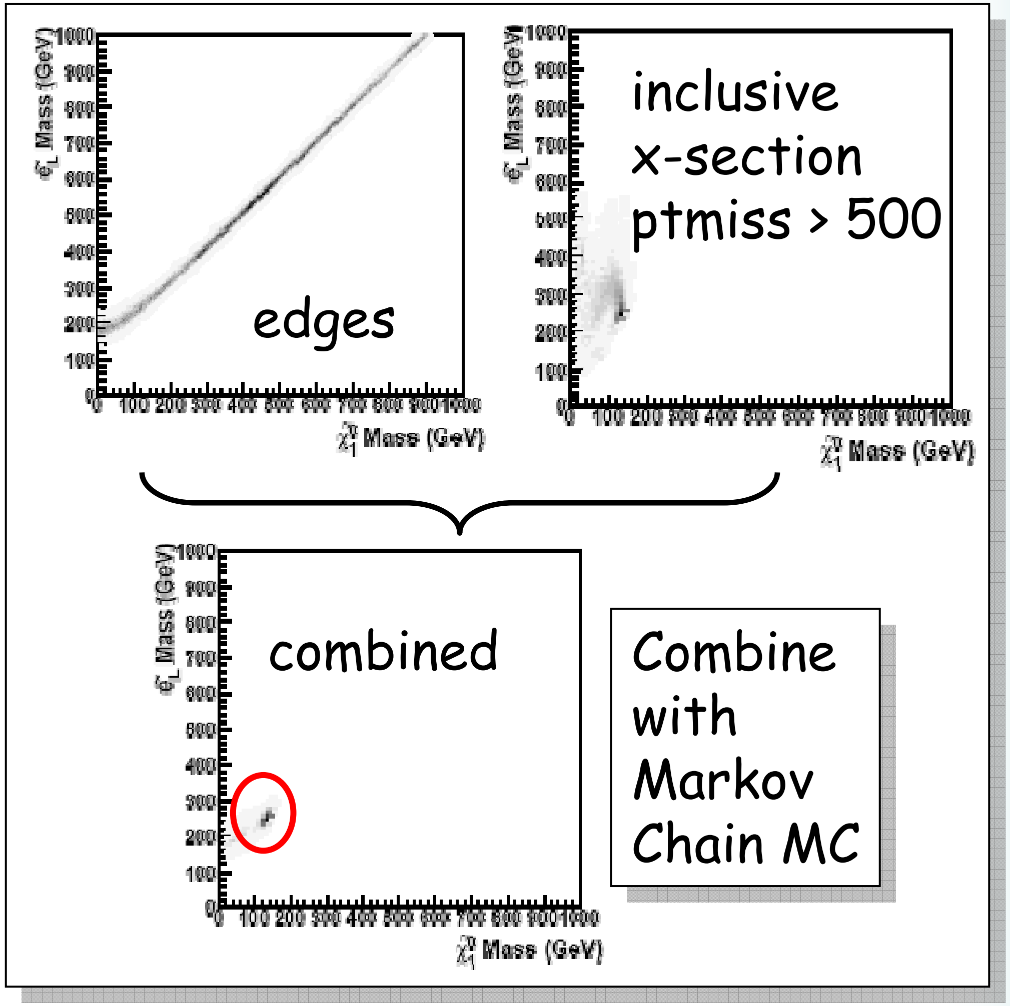
1. Start with experimental observables
   – Kinematic edges etc
2. Use **Markov Chain Monte Carlo** to explore parameter space
   – Fold in ambiguities
3. Parameterise by low-scale or high-scale parameters



- Find **islands** of probability
- Fuller exploration of parameter space

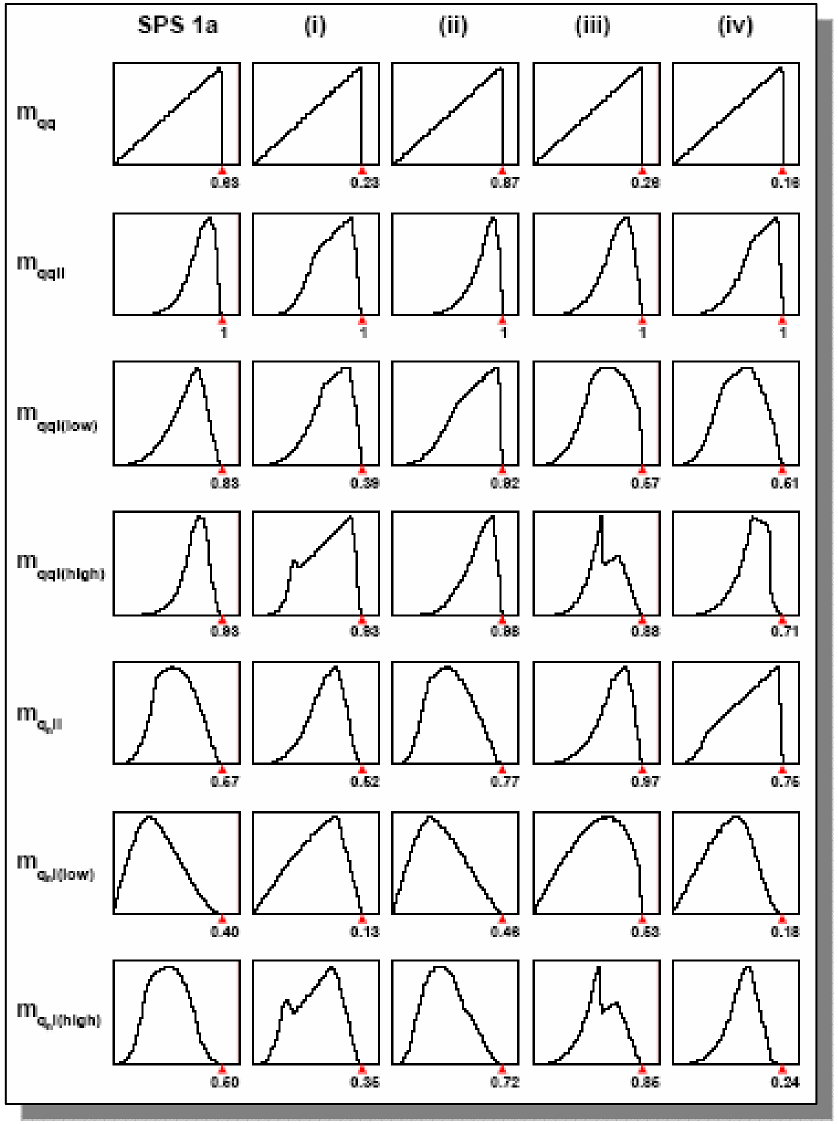
Constraining masses with cross-section information

- Edges best for mass *differences*
  - Formulae contain differences in m^2
  - Overall mass- scale hard at LHC
- X-sec changes rapidly with mass scale
  - Use inclusive variables to constrain mass scale
  - E.g. >500 GeV ptmiss



Lester, Parker, White
hep-ph/0508143

Shapes as well as end-points?



Kinematical edge

Mass spectrum

- First step is to check there is occupancy near end-points
  - Otherwise they can be mis-measured
- Possible also to use shape information directly…

Gjelsten, Miller, Osland
hep-ph/0501033

Likelihood method for mass reconstruction

- Event-by-event likelihood analysis started in:
    - hep-ph/0410160 Kawagoe, Nojiri, Polesello
    - hep-ph/0402295 Lester, Allanach
  - This contains all the experimental information
  - In principle it can give the highest precision
  - Removes problem of how to fit edges
  - Perhaps it can remove some ambiguities?
- Difficult practical issues:
  - Uncertainties in signal and BG must be well know
  - Computationally very expensive
- No real stand-alone workable proof yet

Combining SUSY mass measurements

- LHC mass measurements will **not** be best expressed in the form M(sparticle) = x±y
  - Most of the information (currently) comes from **edges**
    - Cross-sections will also contribute
  - Need to account for **correlations** and **ambiguities**
  - ILC will resolve many ambiguities
  - It is likely that some will remain
- Convergence of a MINUIT fit is not sufficient
  - even with correlations
- Good practice is out there (incl. combined ILC-LHC)
  - Ensembles of experiments
  - Markov Chain Monte Carlo
  - Likelihood analyses

Can LHC-only likelihood analysis reduce/remove ambiguities?

ILC reduces/removes LHC ambiguities for SPS1a
Is this general?

SUSY spin measurements at LHC

Tough, but not impossible!

Spin determination

- Gauntlet thrown down in hep-ph/0205314

Bosonic Supersymmetry? Getting Fooled at the LHC

Hsin-Chia Cheng,[1] Konstantin T. Matchev,[2,3] and Martin Schmaltz[4]

Problem:

"How to distinguish Univ. Ex. Dim. from SUSY at the LHC?"

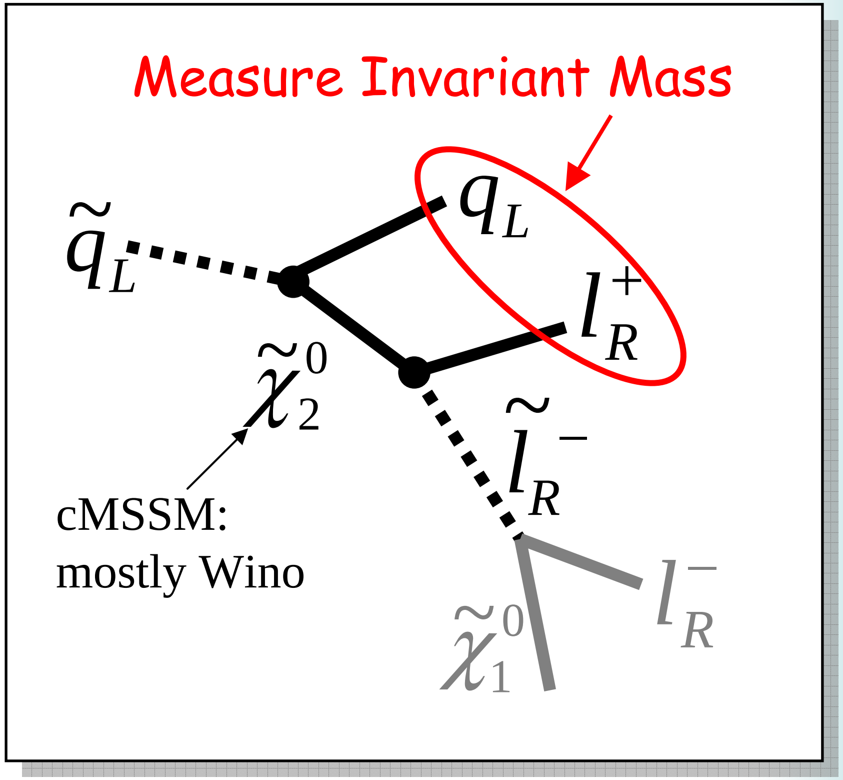
- UED: 2nd KK mode observable if light
- Spin is the ultimate discriminator

- Method 1
  - Charge asymmetry in lepton-quark invariant mass
- Method 2
  - Slepton spin from direct production

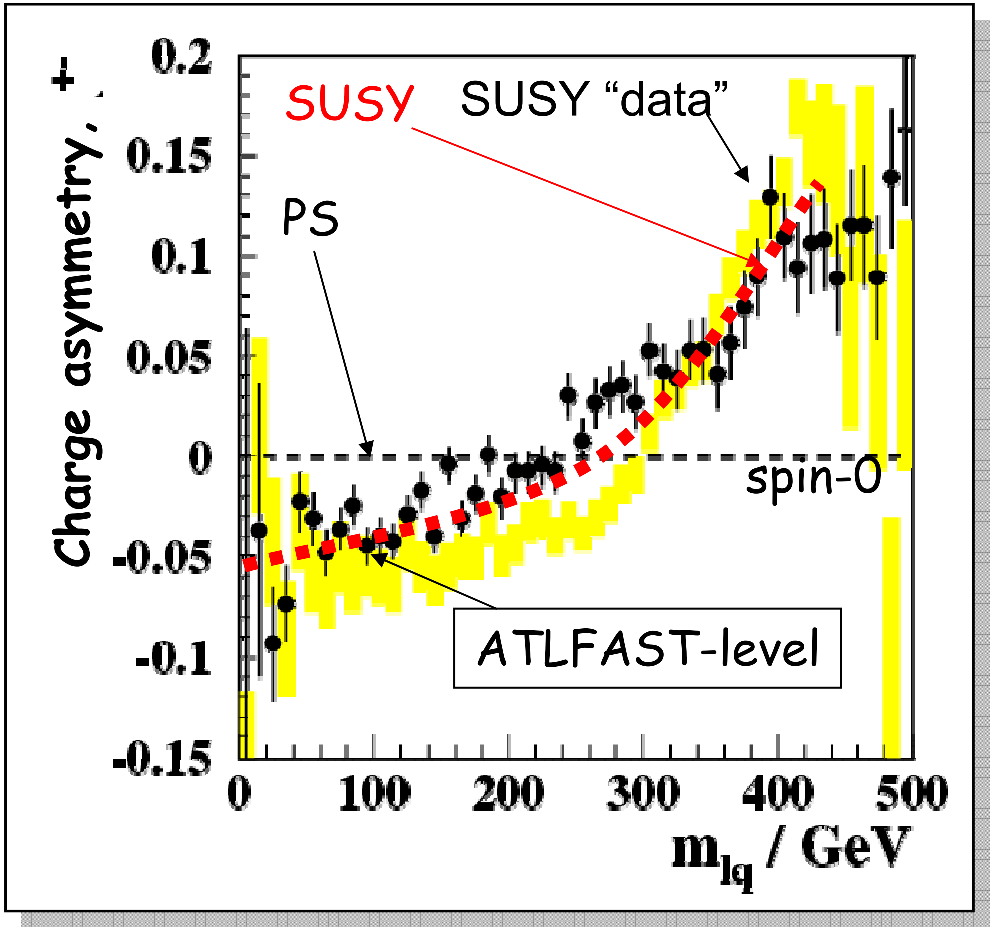
Next step after
1. Discover "SUSY"
2. Measure masses

Analysis 1 : χ_2^0 spin

- Chiral couplings to neutralino-2
- Opposite effect for l^+ vs l^-
  - Charge asymmetry in cascade decays
- Opposite effect for squark vs anti-squark
  - Symmetric production would wash out effect
  - But greater production of squarks relative to anti-squarks @ pp collider



Charge asymmetry

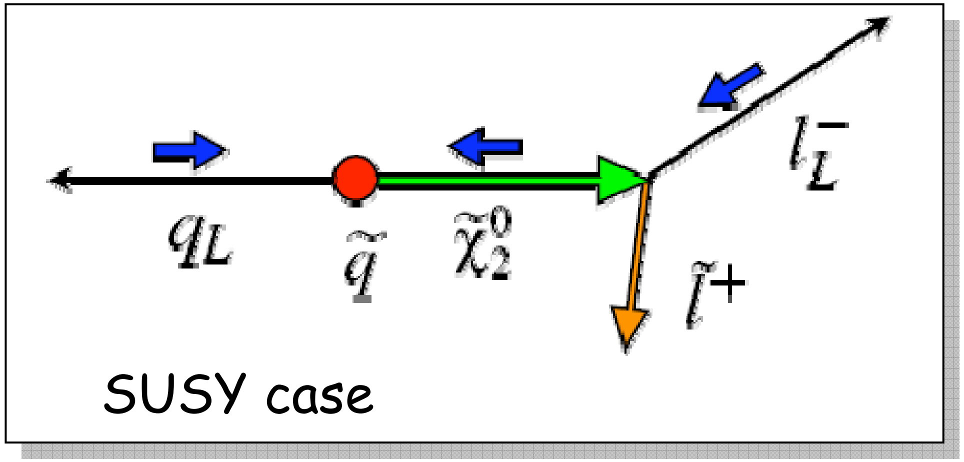


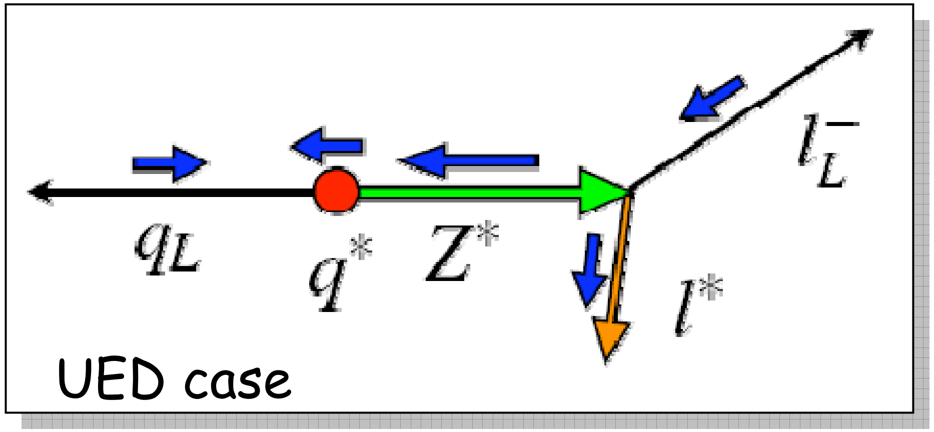
- Demonstration that spin determination is possible @ LHC
- Encouraging… but
  - Relies on presence of particular chain
  - Not a general technique

SUSY vs UED: Helicity structure

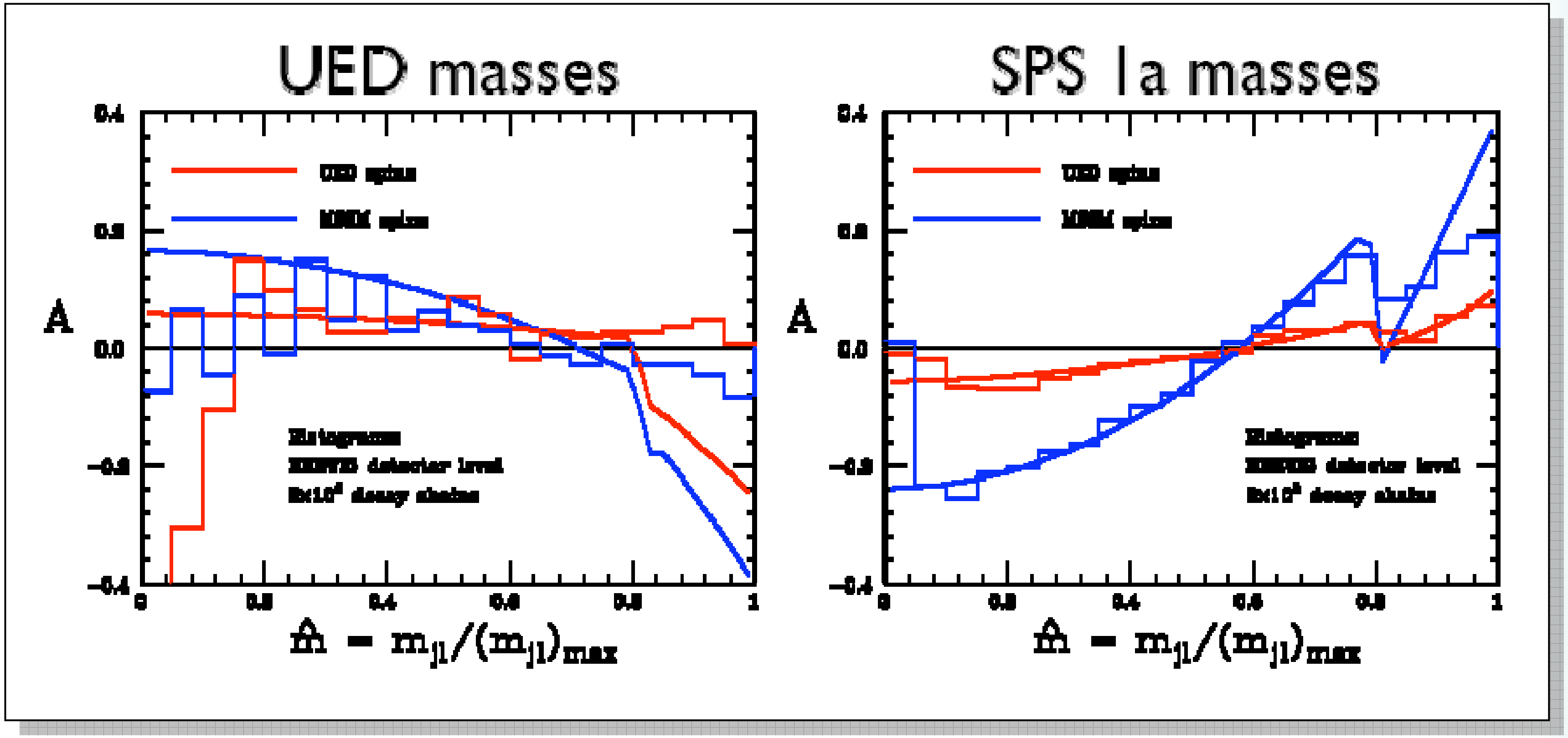
Smillie, Webber
hep-ph/0507170

See also:
Battaglia, Datta, De Roeck, Kong, Matchev
hep-ph/0507284





- Both prefer quark and lepton back-to-back
  - Both favour large (ql^-) invariant mass
- Shape of asymmetry plots similar

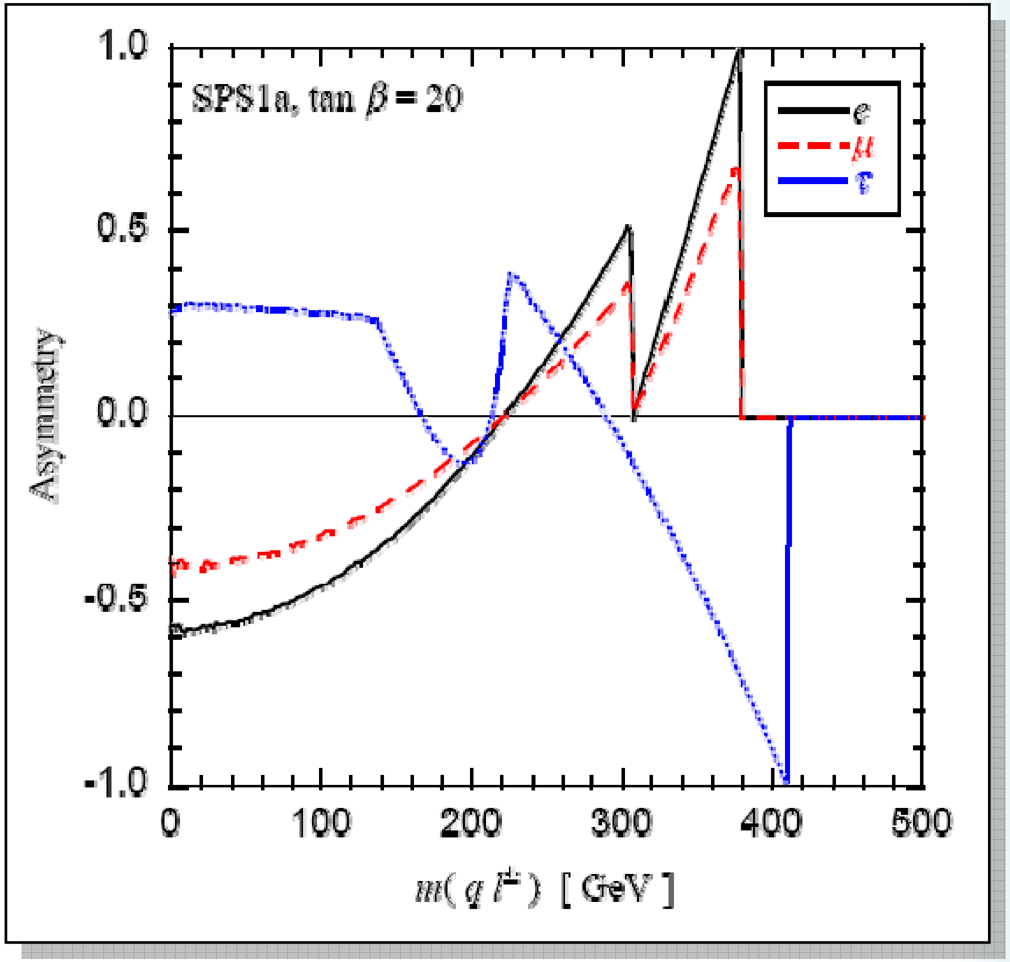


- For UED masses not measureable
  - Near-degenerate masses ➔ little asymmetry
- For SUSY masses, measurable @ SPS1a
  - but shape is similar
  - need to measure size as well as shape of asymmetry

Goto, Kawagoe, Nojiri
hep-ph/0406317

Lepton non-universality

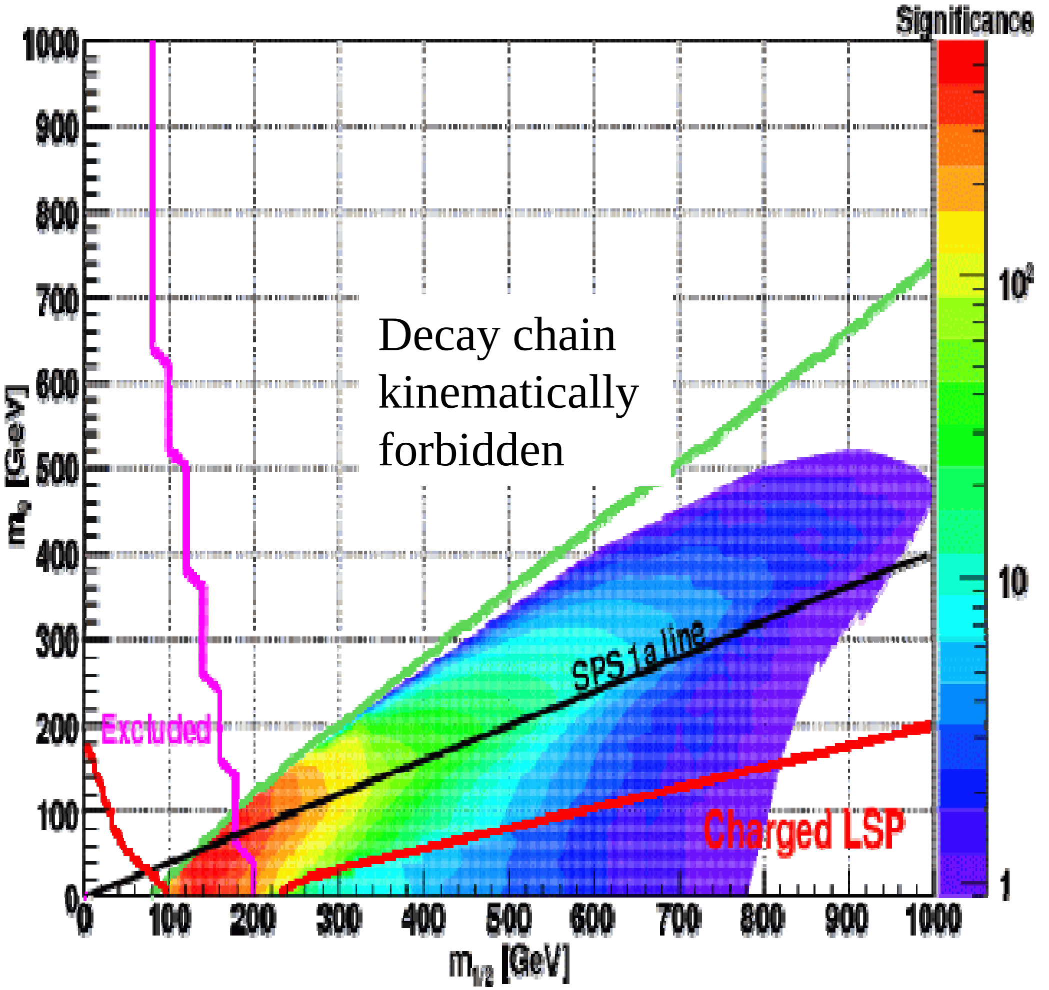
- Lepton Yukawa's lead to differences in slepton mixing
  - Mixing measurable in this decay chain
- Not easy, but there is sensitivity at e.g. SPS1a
  - Biggest effect for taus – but they are the most difficult experimentally



Range of Validity

Allanach & Mahmoudi
To appear in proceedings
Les Houches 05

- Limits:
  - Decay chain must exist
  - Sparticles must be fairly light
- Relatively small area of validity
  - ~ red + orange areas in plot after cuts



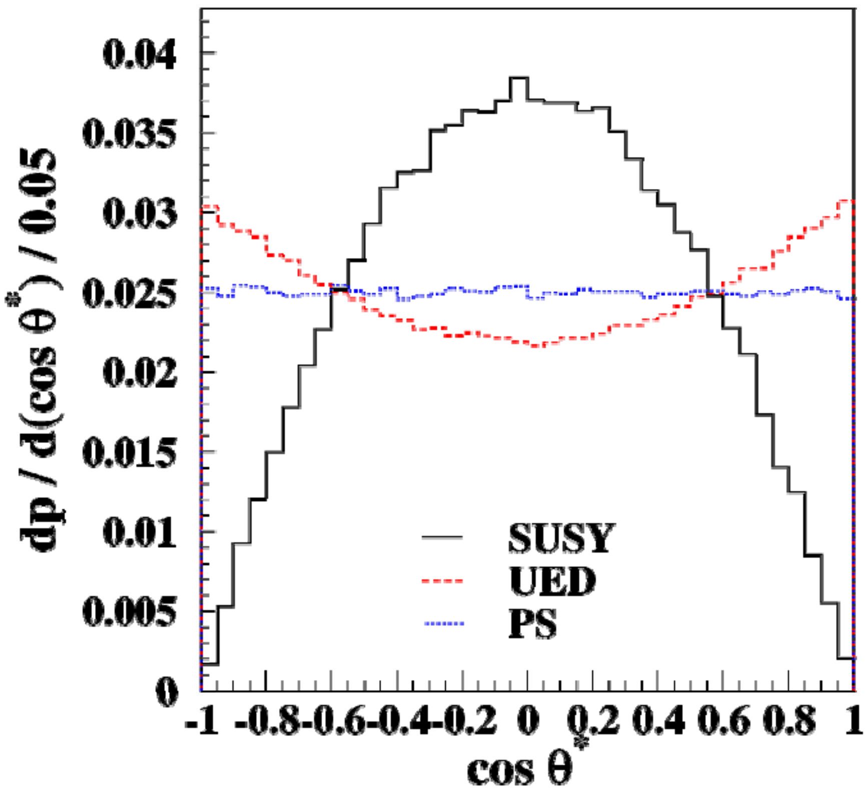
Spin Significance at the parton level – no cuts etc

Summary of neutralino-2 spin

- Workable in some regions of parameter space
  - But those regions are not very large
- Can give slepton mixing information
  - Lepton non-universality
- Works best when sparticles non-degenerate (SUSY-like)
  - Not workable when masses are near-degenerate (UED-like)
- Similar shape for UED and SUSY
  - Size of asymmetry must be experimentally measured, not simply shape

Method 2: Angular distributions in direct slepton pair production

Normalised cross-sections



SUSY : qq ➔ slepton pair

$$\left(\frac{d\sigma}{d\cos\theta^*}\right)_{SUSY} \propto 1 - \cos^2\theta^*$$

UED : qq ➔ KK lepton pair

$$\left(\frac{d\sigma}{d\cos\theta^*}\right)_{UED} \propto 1 + \left(\frac{E_{\ell_1}^2 - M_{\ell_1}^2}{E_{\ell_1}^2 + M_{\ell_1}^2}\right)\cos^2\theta^*$$

Phase Space :

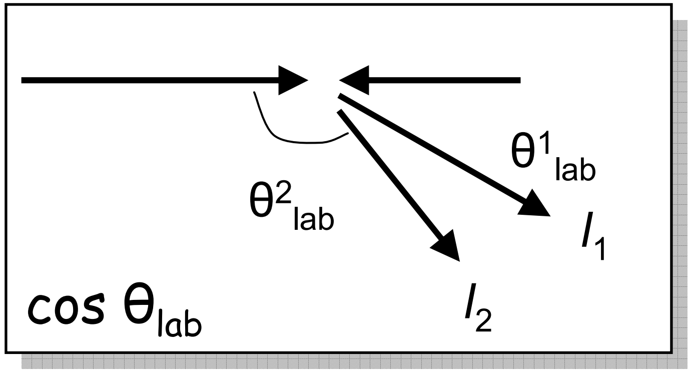
$$\left(\frac{d\sigma}{d\cos\theta^*}\right)_{PS} \propto \text{constant}$$

AJB hep-ph/0511115

Sensitive variables?

AJB hep-ph/0511115

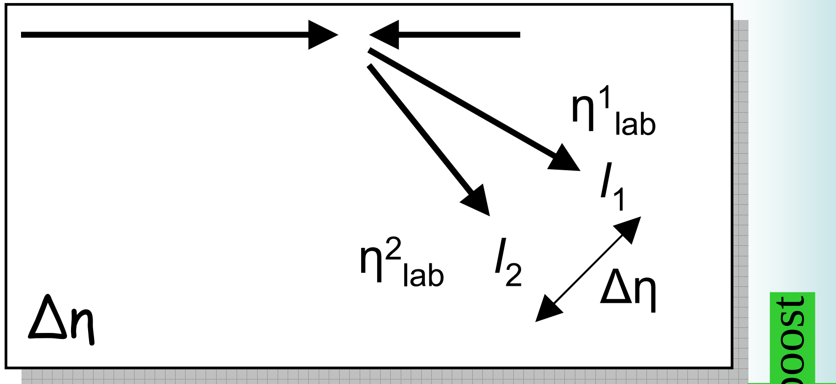
- cos θ_{lab}
  - **Good for linear e^+e^- collider**
  - Not boost invariant
    - Missing energy means Z boost not known @ LHC
    - Not sensitive @ LHC

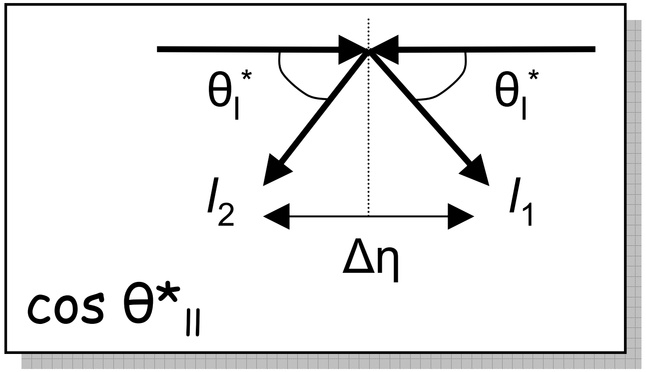


- cos θ_{ll}^*
  - 1-D function of Δη:

$$\cos\theta_{ll}^* = \cos(2\tan^{-1} e^{-\frac{1}{2}\Delta\eta}) = \tanh(\tfrac{1}{2}\Delta\eta)$$

  - Boost invariant
  - Interpretation as **angle** in boosted frame
  - Easier to compare with theory

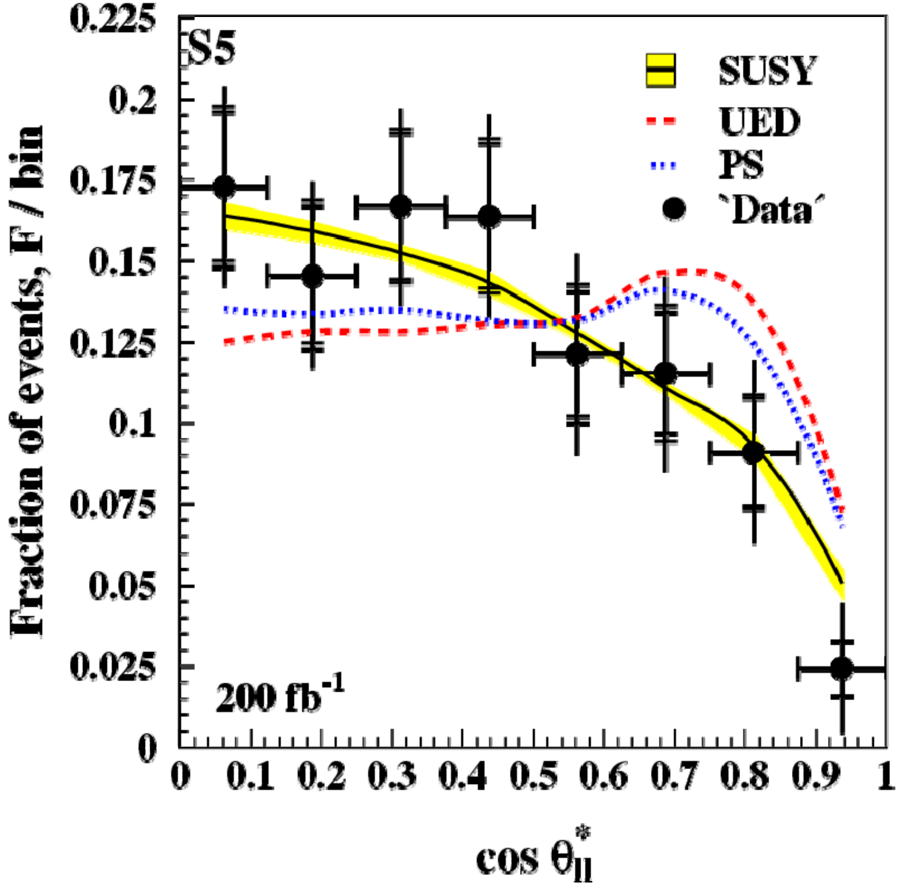




N.B. ignore azimuthal angle

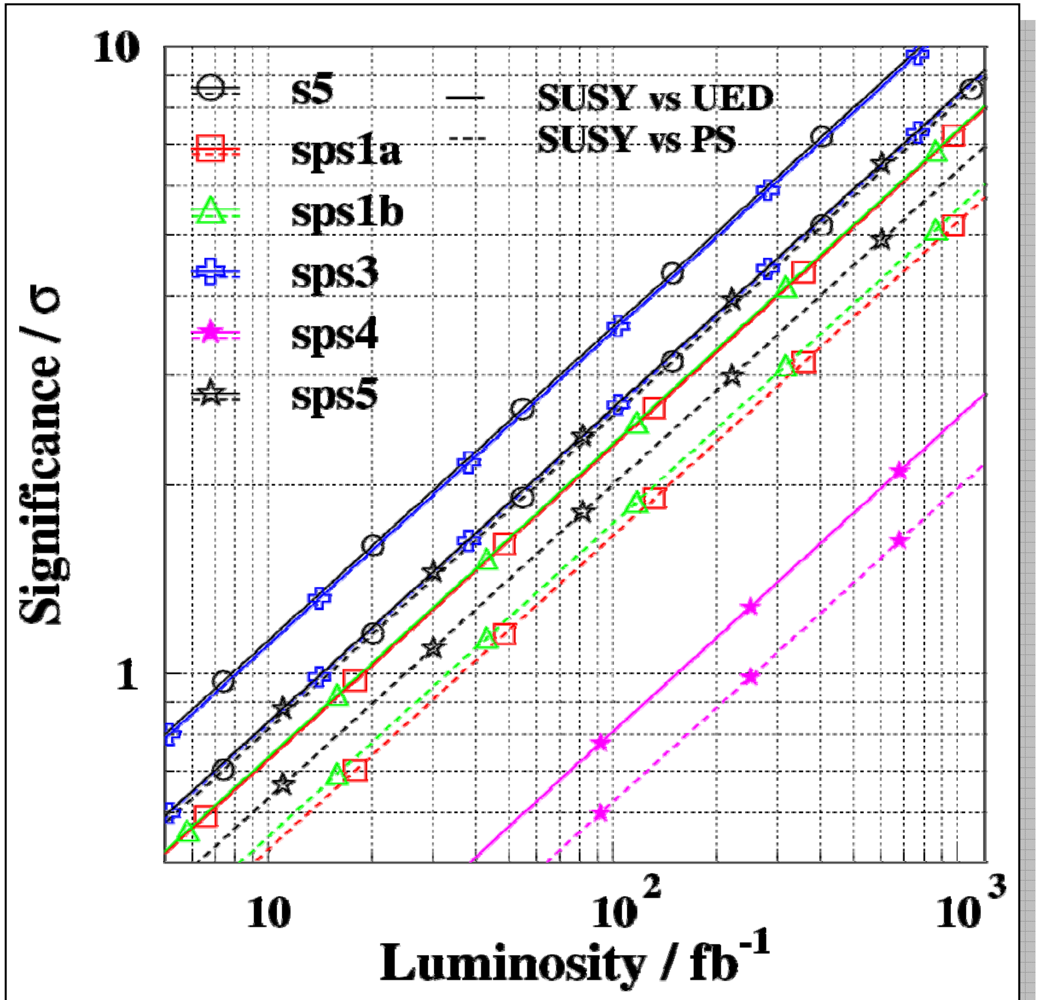
Slepton spin – LHC pt 5

- Statistically measurable
- Relatively large luminosity required
- Study of systematics in progress
  - SM background determination
  - SUSY BG determination
  - Experimental systematics
- No show-stoppers so far



"Data" = inclusive SUSY after cuts

Snowmass points



Statistical significance of spin measurement
LHC design luminosity ≈ 100 fb^{-1} / year

SPS1a, SPS1b, SPS5
mSUGRA "Bulk" points
Good sensitivity

SPS3 sensitive
Co-annihilation point
(stau-1 close to LSP)
Signal from *left*-sleptons

SPS4 – non-universal cMSSM
Larger mass LSP
Softer leptons
Signal lost in WW background

Analysis fails in "focus point" region (SPS2). No surprise:
Sleptons > 1TeV ➔ no xsection

Summary of slepton spin

- A more general method than lepton charge asymmetry
  - Works at various SPS points
- Sensitive when both:
  1. sleptons are light
     1. → reasonable x-sec
  2. slepton-LSP mass difference is > m_W
     (for either slepton) → separate from WW
- Possible extensions
  - Clean environment for measuring slepton pair production **cross-section**
    - Very useful constraint esp. if mass scale can be independently measured

Finding stable R-hadrons

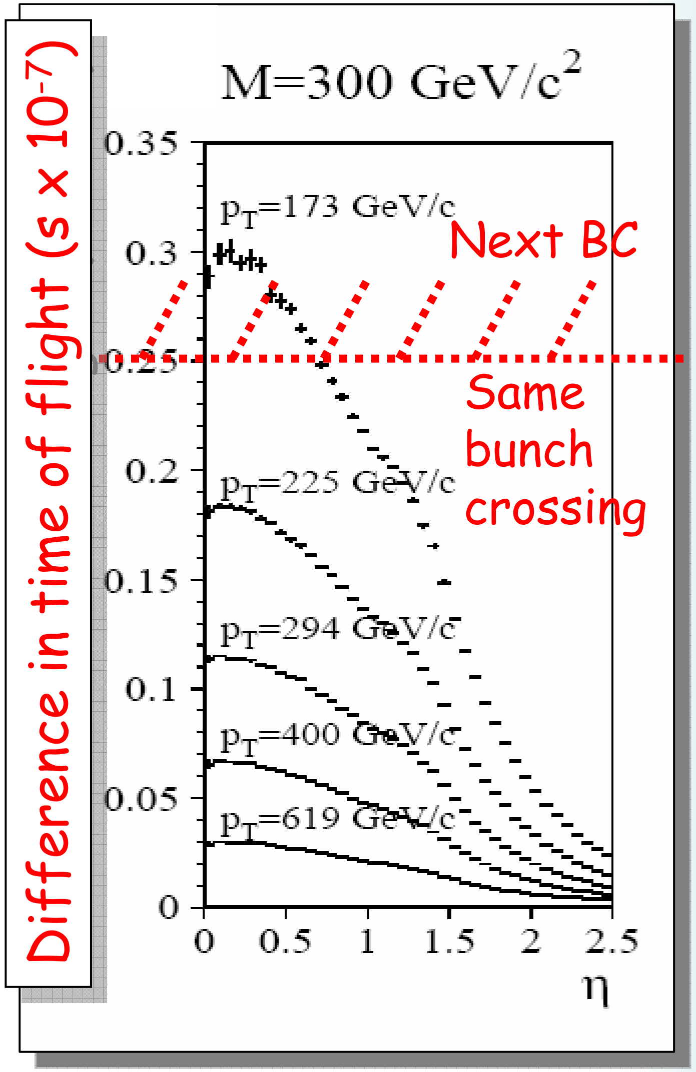
- Heavy hadrons from:
  - Hadronised stable gluinos
    - **Gluino** (n)LSP from split susy, GMSB …
  - New conserved QN
  - Kinematic supression of decays
- Production:
  - Gluino pair, squark pair, or one of each
    - Study looks at gg➔gluino gluino only
- Lightest states:
  - R-mesons
    - Charged or neutral in approximately equal numbers
- Interactions
  - R-meson ➔ R-baryon
  - Charge change (neutral ⇔ charged)

Kraan
hep-ph/0404001

Kraan, Hansen, Nevski
hep-ph/0511014

LHC characteristics: R-hadrons

- Signatures:
  1. High P_T tracks (charged hadrons)
  2. High ionisation in tracker (slow, charged)
  3. Characteristic energy deposition in calorimeters
  4. Large time-of-flight (muon chambers)
- Trigger:
  1. Calorimeter: etsum or etmiss
  2. Time-of-flight in muon system
- Overall high selection efficiency
  - Reach up to mass of 1.8 TeV at 30 fb^{-1}



Kraan, Hansen, Nevski

Polesello, Nojiri, Tovey

Constraining MSSM dark matter

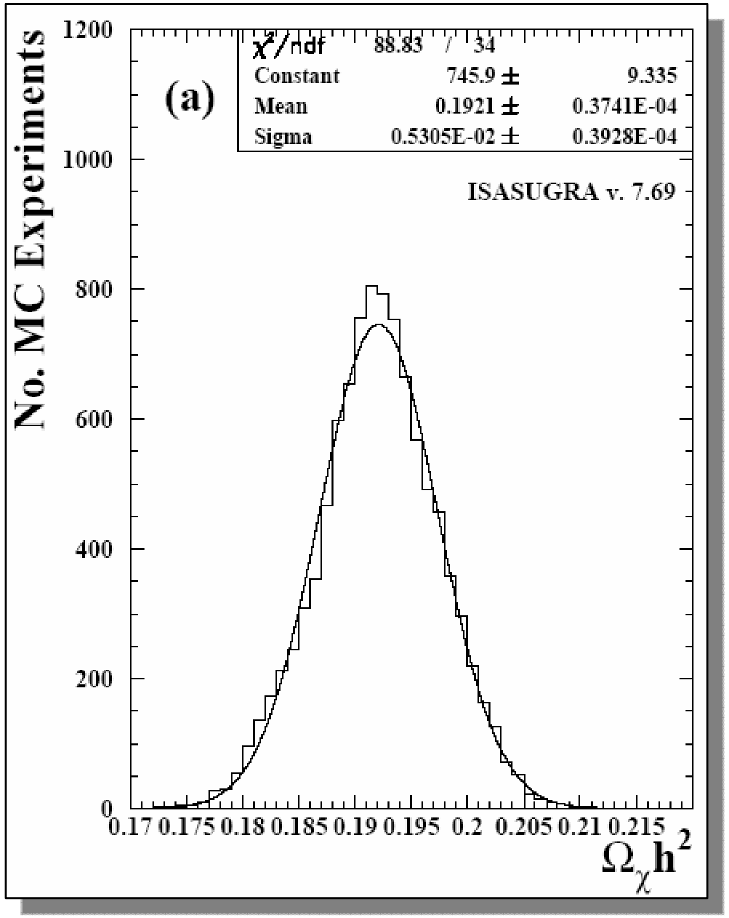
- We expect/hope to observe particles stable on detector time-scales
  - Are these the major contributors to the cosmological CDM?
  - What can we say about the expected relic-abundance

N.B. this necessarily comes after we:

1. Find "supersymmetry"
2. Make inclusive measurements → prove there is a WIMP
3. Make excusive measurements → find out about sparticle masses
4. Measure B.R.s and decays

Dark matter constraints in mSUGRA

- Restrict to mSUGRA
  - "Over-constrain" masses
- Small uncertainty on expected relic density
- Realistic?
  - Probably too restrictive



Important to look at unconstrained MSSM

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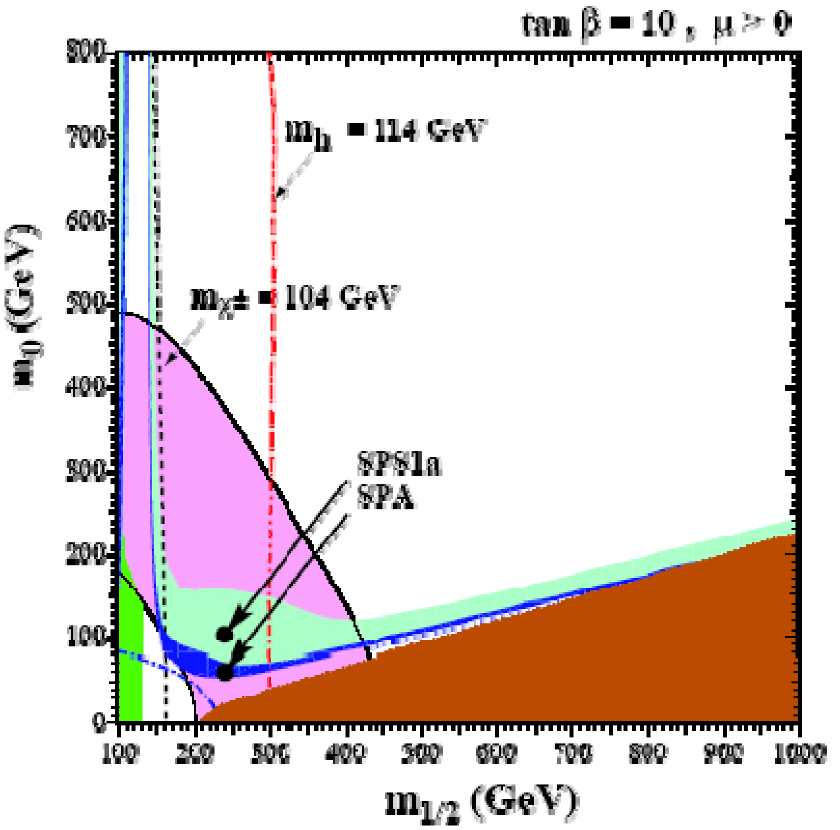
Full MSSM : Required quantities

1. Neutralino masses
   - Use as inputs to gaugino & higgsino content of LSP
2. Lightest stau mass
   - Is stau-coannihilation important?
3. Heavy Higgs boson masses
   - Is Higgs co-annihilation important?

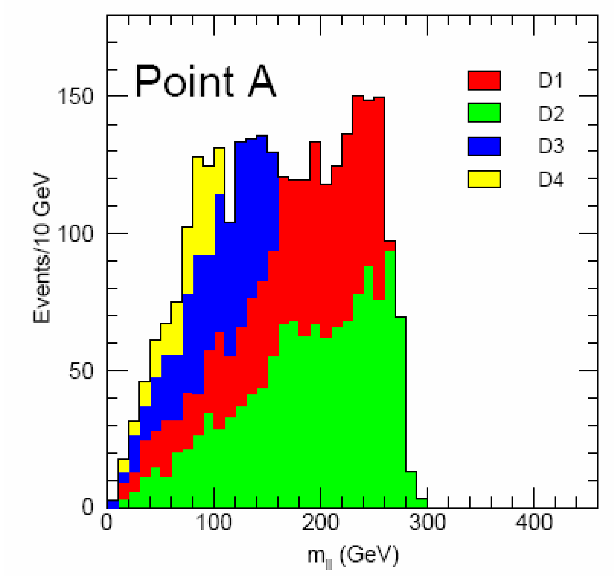


Try SPA point - similar to SPS 1a

Neutralino inputs to dark matter

Polesello
sn-atlas-2004-041

- χ_1^0 and χ_2^0 as above
- χ_4^0, χ_2^+ from other end-points
  - If light enough, edges visible
  - Ambiguities in interpretation still need to be investigated



Heavy gaugino➔slepton
➔light gaugino
(signal only)

$\tilde{\chi}_4^0 \; q$
$\quad \hookrightarrow \tilde{\ell}_R^{\pm} \; \ell^{\mp}$
$\qquad \hookrightarrow \tilde{\chi}_1^0 \; \ell^{\pm}$ [D1]

$\tilde{\chi}_4^0 \; q$
$\quad \hookrightarrow \tilde{\ell}_L^{\pm} \; \ell^{\mp}$
$\qquad \hookrightarrow \tilde{\chi}_1^0 \; \ell^{\pm}$ [D2]
$\qquad \hookrightarrow \tilde{\chi}_2^0 \; \ell^{\pm}$ [D3]

$\tilde{\chi}_2^{\pm} \; q'$
$\quad \hookrightarrow \tilde{\nu}_\ell \; \ell^{\pm}$
$\qquad \hookrightarrow \tilde{\chi}_1^{\pm} \; \ell^{\mp}$ [D4]

$\therefore$ 3 masses + input tan β perhaps from higgs sector?

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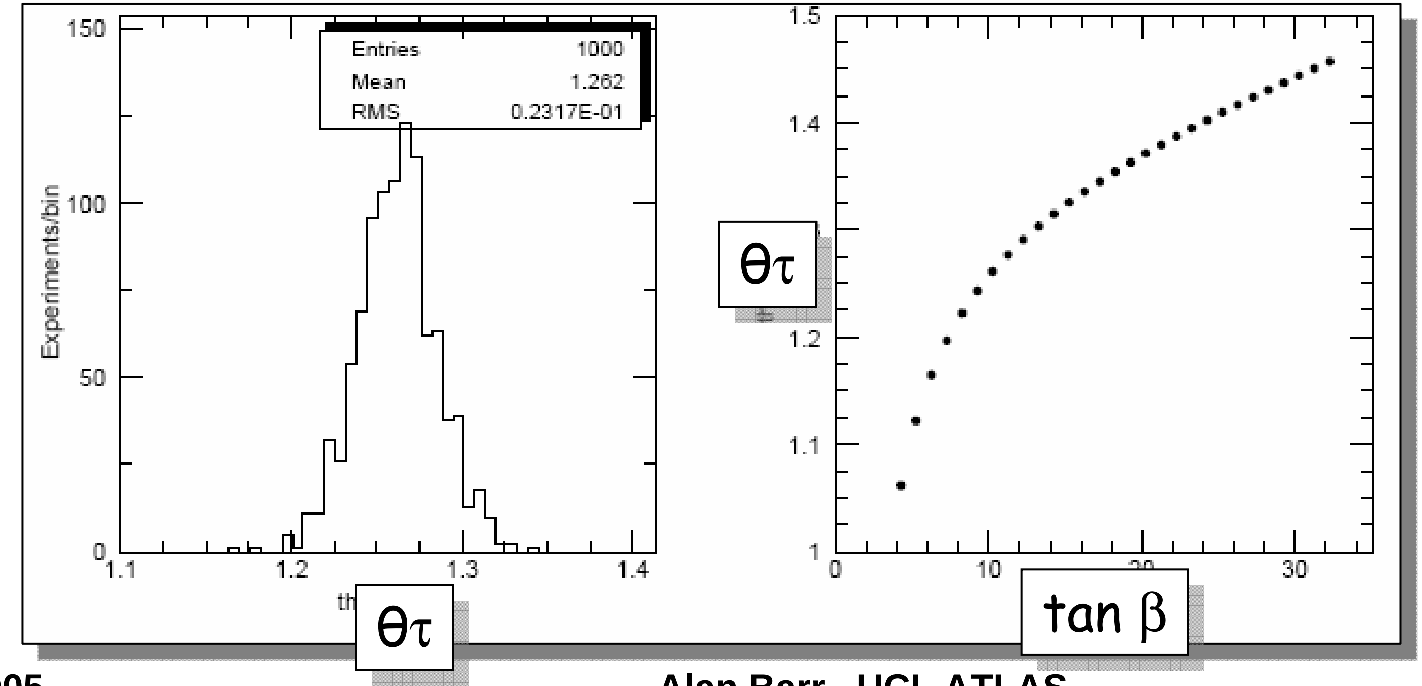
τ mass and mixing

- stau$_1$ mass from kinematical edges
- Mixing angle from
  - Ratio of branching ratios (with netrualino mixing maxtrix as input)
  - Charge asymmetry?
- Need one other parameter
  - τ_2 mass (perhaps from direct pair production?)



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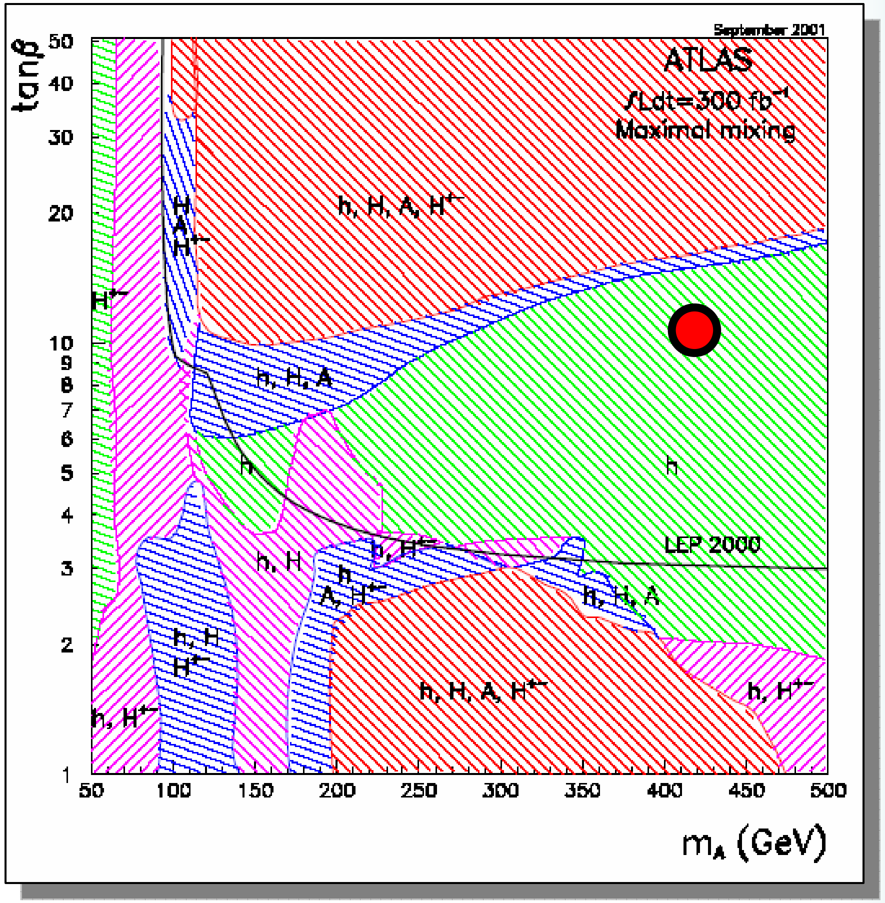
Higgs constraints

- Large area where heavy higgses not detectable in decays to SM particles
  - Including SPA point (425,10)
- Decays into SUSY particle pairs under investigation
- Null results might be enough
  - "the H/A are too heavy to put you in a Higgs focus region"



Discoverable higgs' in decays ➔ SM

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Dark matter prelim. results

- Early study suggests ATLAS might achieve at SPA1

$$\Omega_\chi h^2 = 0.108 \pm 0.01(stat + sys)^{+0.00}_{-0.002}(M(A))^{+0.001}_{-0.011}(\tan\beta)^{+0.002}_{-0.005}(m(\tilde{\tau}_2))$$

- Good (but not at WMAP precision)
- Dosen't prove that WIMPs are cosmologically stable
  - Direct search needed
- Still need to ensure we can measure:
  - τ_2 mass
  - H/A masses
  - tan β

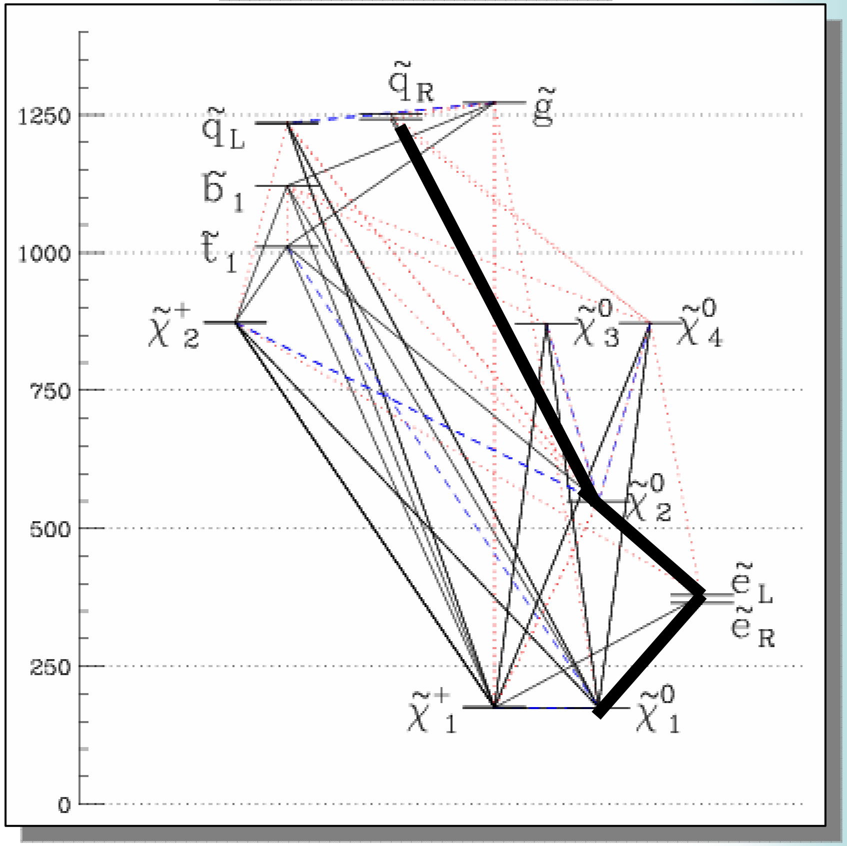
Input from ILC will surely help

- LHC experimental studies required at other points

Most difficult SUSY case for the LHC?

- In LHC-ILC document Gunion suggests
  - Baryonic R-parity violation
    - LSP → c,d,s so no vertex tags
  - + degenerate wino LSP
    - With mass in range where soft pions are produced in chargino-1 decay
- I think we might be able to crack that one:
  - **If** there are cascades from squarks via neutralinos and leptons
  - similar to mSUGRA RPV case (see e.g. hep-ph/0102173)

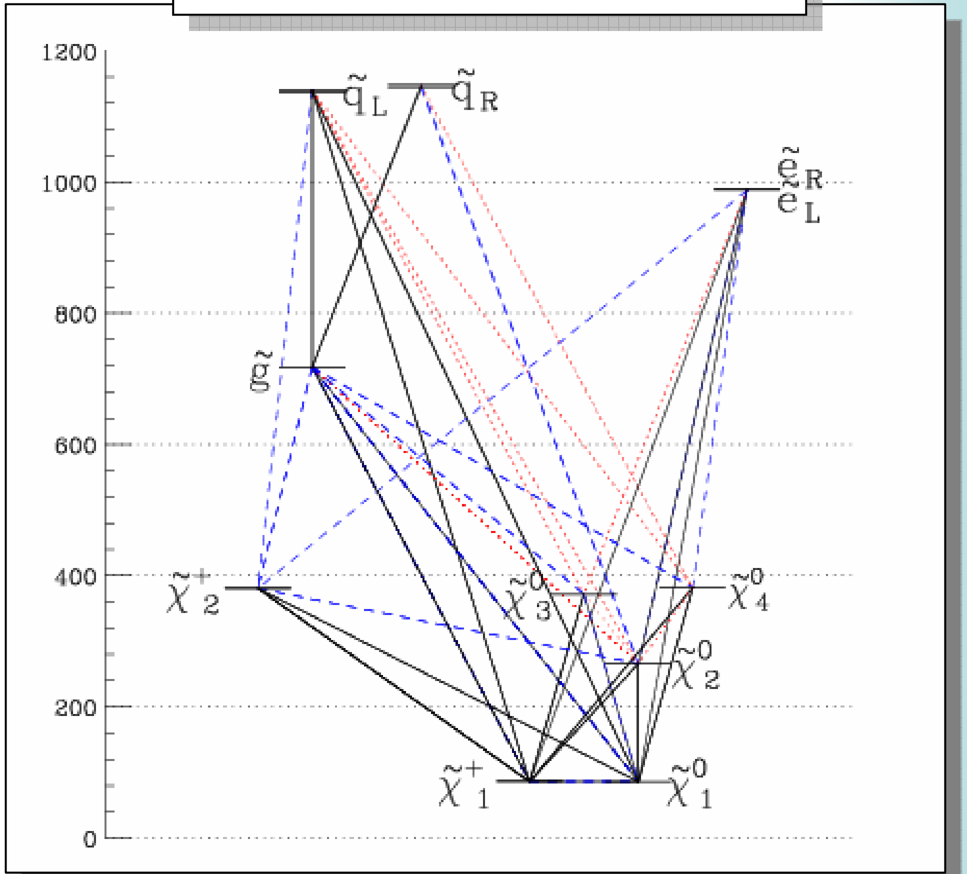
Snowmass pt9



Toughest back-street corner of MSSM?

- **Really** tough experimental case would be:
  - Like Gunion scenario
    - Wino LSP
    - Baryon RPV
  - + **heavy sleptons**
    - No cascade decays through leptons
  - + **squarks near gluino mass**
    - So gluino is **not** stable
- Signature is jets!
- Could gluino decays to heavy quarks still be used?
  - Make sure the b-tagging efficiency is good!

AMSB Point d'Aix + RPV



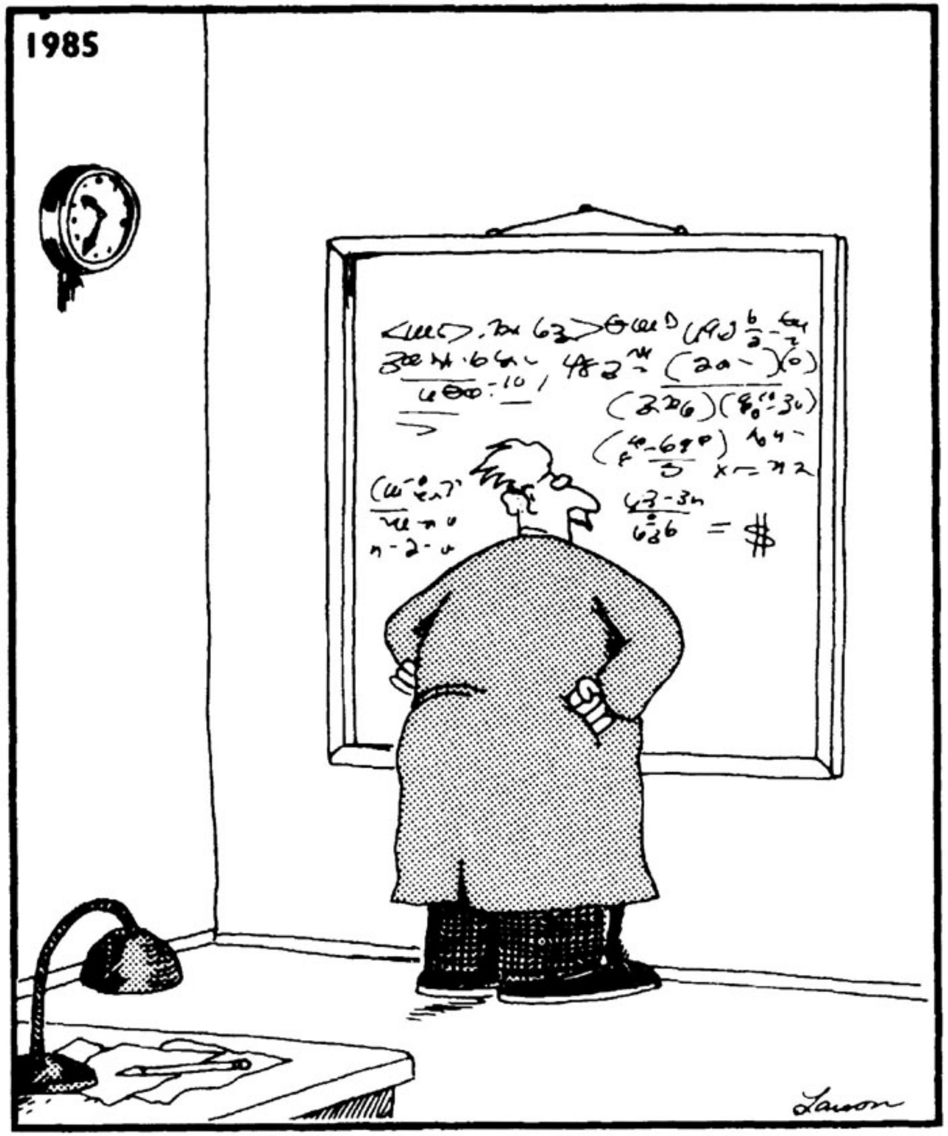
Scale up masses for extra misery!

Observations

- "Competition" is healthy!
  - Mass analysis @ ILC improved LHC techniques
  - Spin determination at LHC was spurred on by:
    1. Theoretical model (UED) showing importance of spin
    2. Studies showing that it e^+e^- colliders are capable of such measurements
- Effect of ILC studies has already been to improve LHC analyses and reach
  - New analyses developed
  - Better understand LHC limits
  - Synergy already apparent here!

ILC definitely will improve **precision**
Q: How well can the ILC cover the **gaps** where the LHC isn't sensitive?

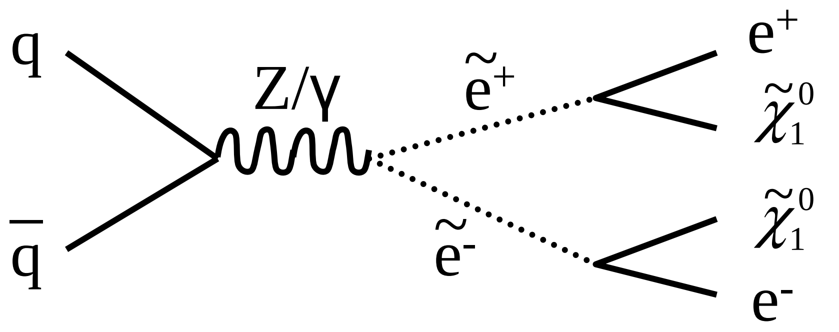
Back-up slides



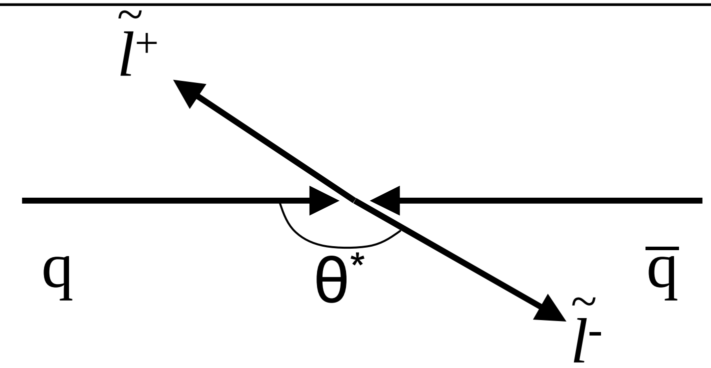
Einstein discovers that time is actually money.

Analysis 2 : Direct slepton spin determination

- Sleptons easier than squarks
- Lower cross-section
- But s-channel production dominates
  - Gauge boson fusion to slepton pair important at higher slepton masses

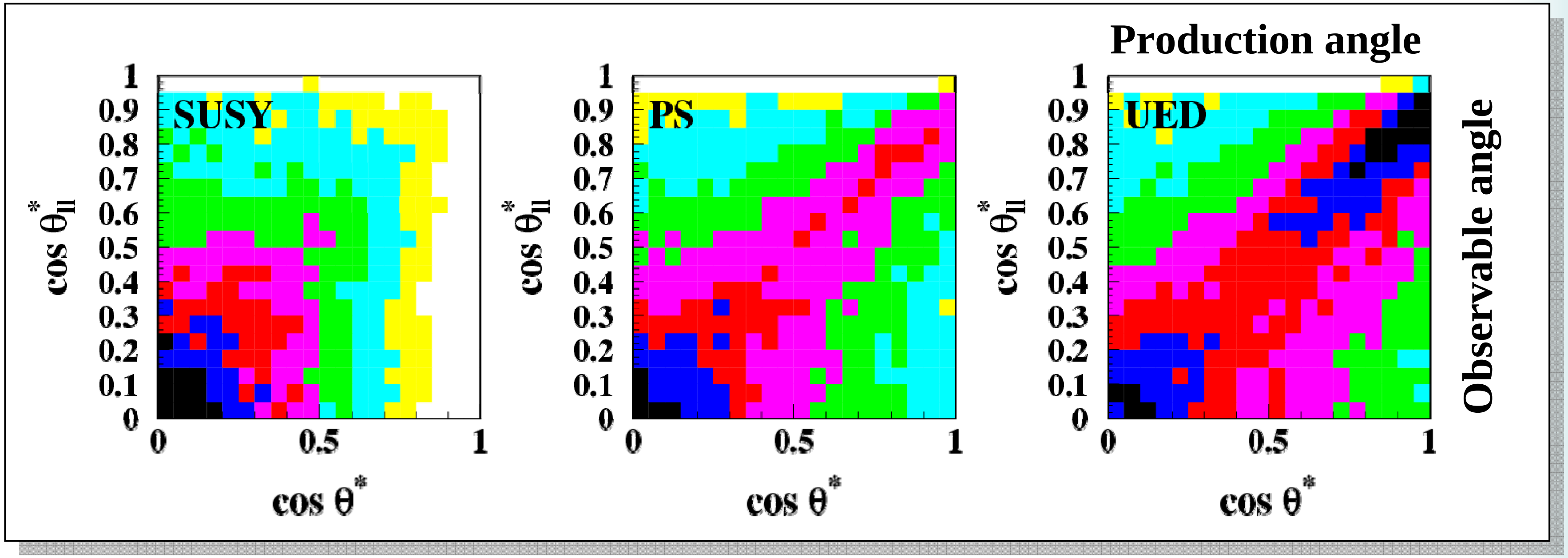


S-channel spin-1 process

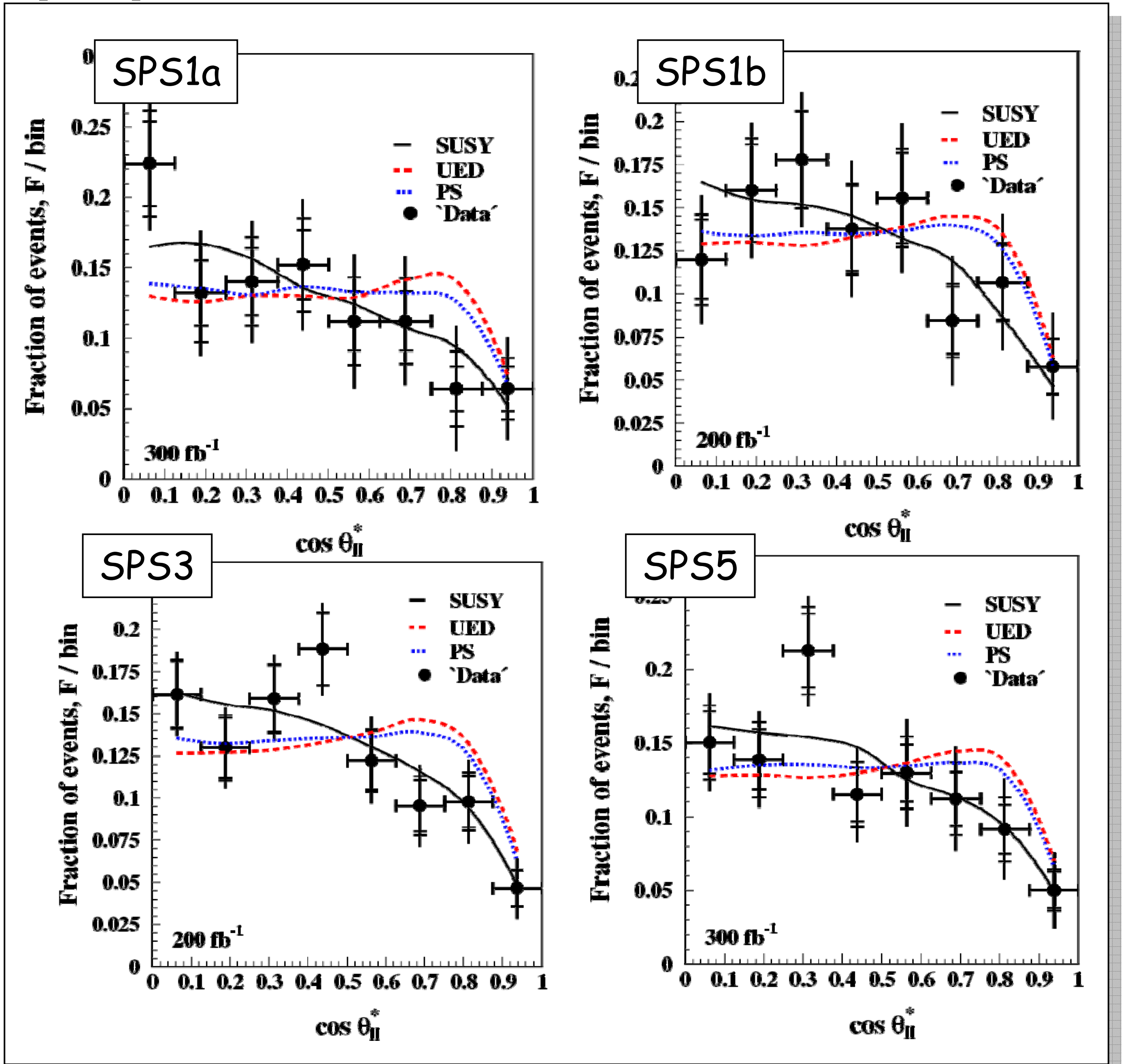


Anglular dependence in CMF

slepton ⇔ lepton correlations



- Slepton/KK lepton production angle not measurable
- Lepton *inherits* from boost of slepton parent
  - Good correlation in plots above
- Observable cos θ^*_{ll} smaller for SUSY than UED



Similar results at various SPS points

200-300 fb^{-1}

Includes stat error from SM and SUSY BG subtraction

No systematic uncertainty in backgrounds