New Physics

Invitation to Simulation Studies

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Linear Collider Physics Mini-Workshop

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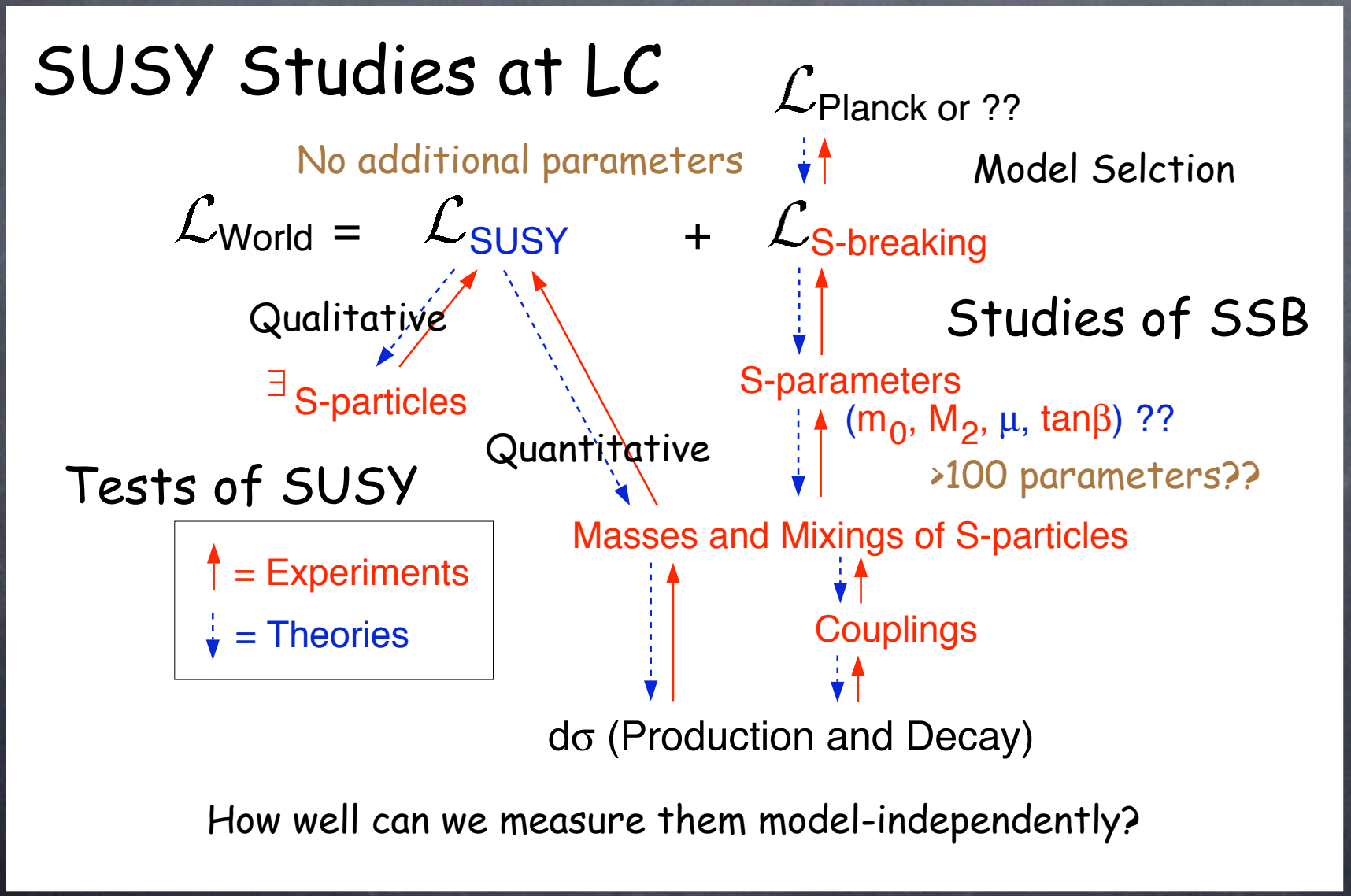
Popular BSM Scenarios

BSM = Extra Dims./Symms.

- In the Case of High Cut-off Scale
  - Supersymmetry (Fermionic Dimensions)
    The most well motivated and studied
  - ???
- In the Case of Low Cut-off Scale
  - Large Extra Dimension (Bosonic Dims.)
  - Extra Symmetries (New Strong Int.?)
    - Little Higgs
    - Techni-Color
    - ???

Supersymmetry
Standard BSM



Sample SSB Scenarios

Need for Super Spectroscopy

	Gravity Mediated	Gauge Mediated	Anomaly Mediated
Gravitino Mass	$M_{SSB}^2/\sqrt{3}M_{pl} \sim TeV$ $(M_{SSB} \sim 10^{10} - 10^{11} GeV)$	$\left(\sqrt{F}/100TeV\right)^2 eV$ $10 < \sqrt{F} < 10^4 TeV$	$\sim 100\ TeV$
Gaugino Mass	$M_i = \left(\frac{\alpha_i}{\alpha_2}\right) M_2$ $M_1 : M_2 : M_3 = 1:2:7$		$M_i = \left(\frac{b_i}{b_2}\right)\left(\frac{\alpha_i}{\alpha_2}\right) M_2$ $M_1 : M_2 : M_3 = 2.8:1:8.3$
Sfermion Mass	$m_{\tilde{f}}^2 = m_0^2 + \sum_i G_{\tilde{f},i} M_i^2$ $m_{\tilde{l}} < m_{\tilde{q}} \quad m_{\tilde{f}_R} < m_{\tilde{f}_L}$	$m_{\tilde{f}}^2 = \sum_i G'_{\tilde{f},i} M_i^2$ $m_{\tilde{l}} << m_{\tilde{q}}$	$m_{\tilde{f}}^2 = m_0^2 + \sum_i 2a_{\tilde{f},i} b_i \left(\frac{\alpha_i}{\alpha_2}\right)^2 M_2^2$ $m_{\tilde{l}_R} \approx m_{\tilde{l}_L}$
LSP	$\tilde{\chi}_1^0 \approx \tilde{B}$	$\tilde{G}$	$\tilde{\chi}_1^0 \approx \tilde{W}$

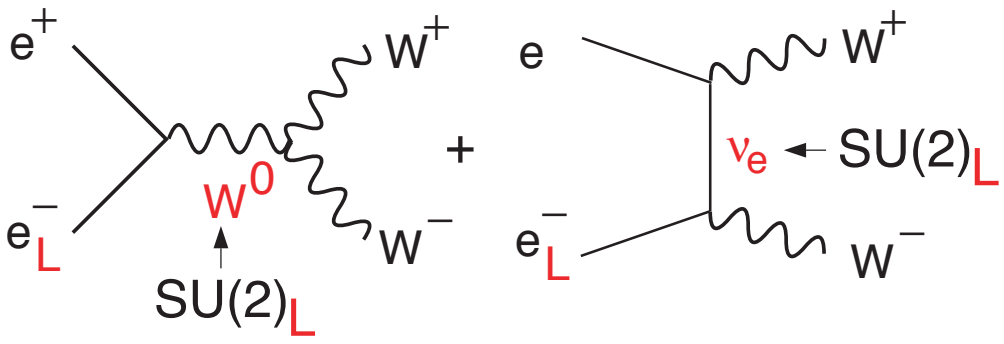
$$\beta_i = -b_i g_i^3/(4\pi)^2$$

$$b_1 = 33/5 \quad b_2 = 1 \quad b_3 = -3$$

More? -> Theorists

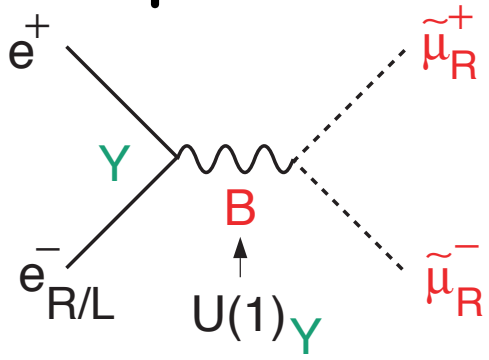
Power of Beam Polarization

W^+W^- (Largest SM BG)



In the symmetry limit, $\sigma_{WW} \to 0$ for e^-_R !

Slepton Pair

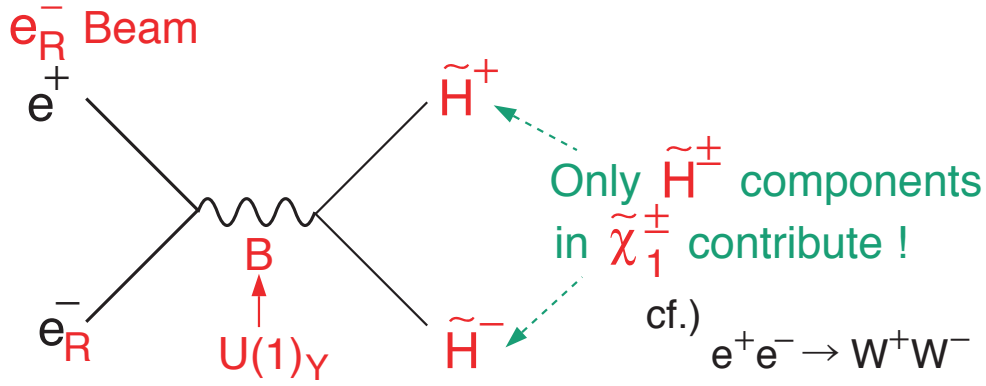


$$\begin{cases} Y_L = -1/2 : e^-_L \\ Y_R = -1 \quad : e^-_R \end{cases}$$

In the symmetry limit, $\sigma_R = 4\,\sigma_L$!

BG Suppression

Chargino Pair



$$\tilde{\chi}^\pm_1 = \bigcirc \cdot \tilde{W}^\pm + \bullet \cdot \tilde{H}^\pm$$

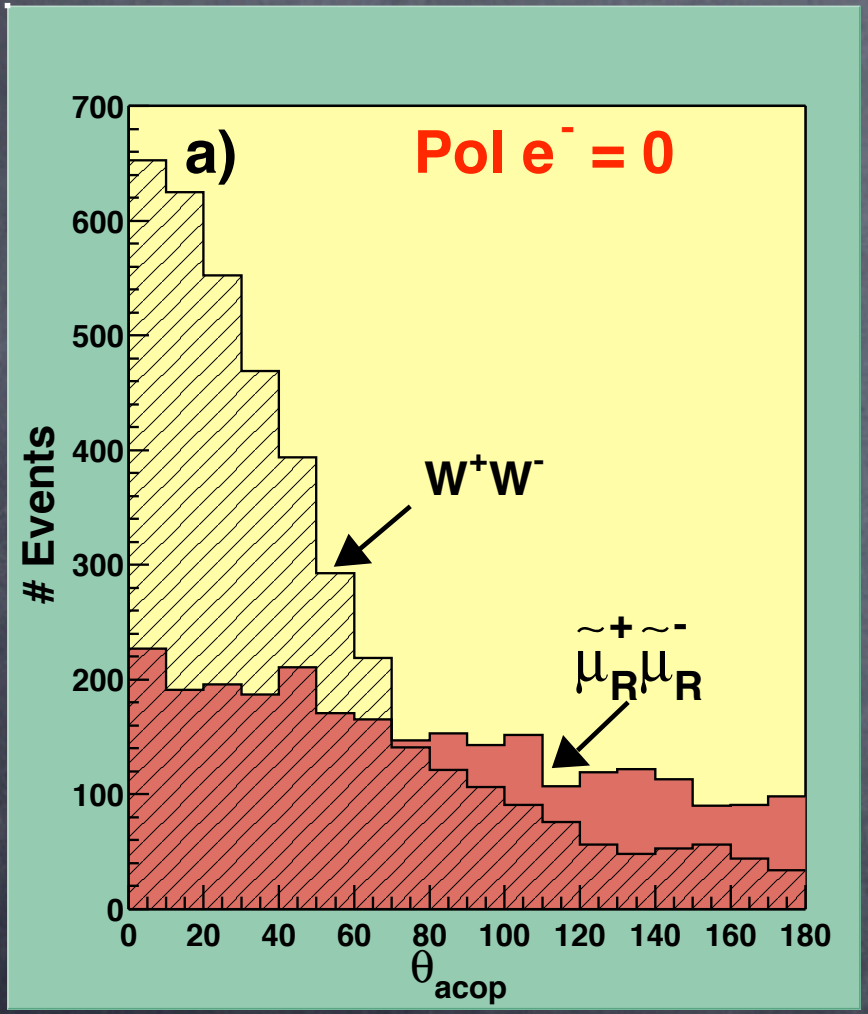
$$\bullet = \langle \tilde{H}^\pm | \tilde{\chi}^\pm_1 \rangle$$

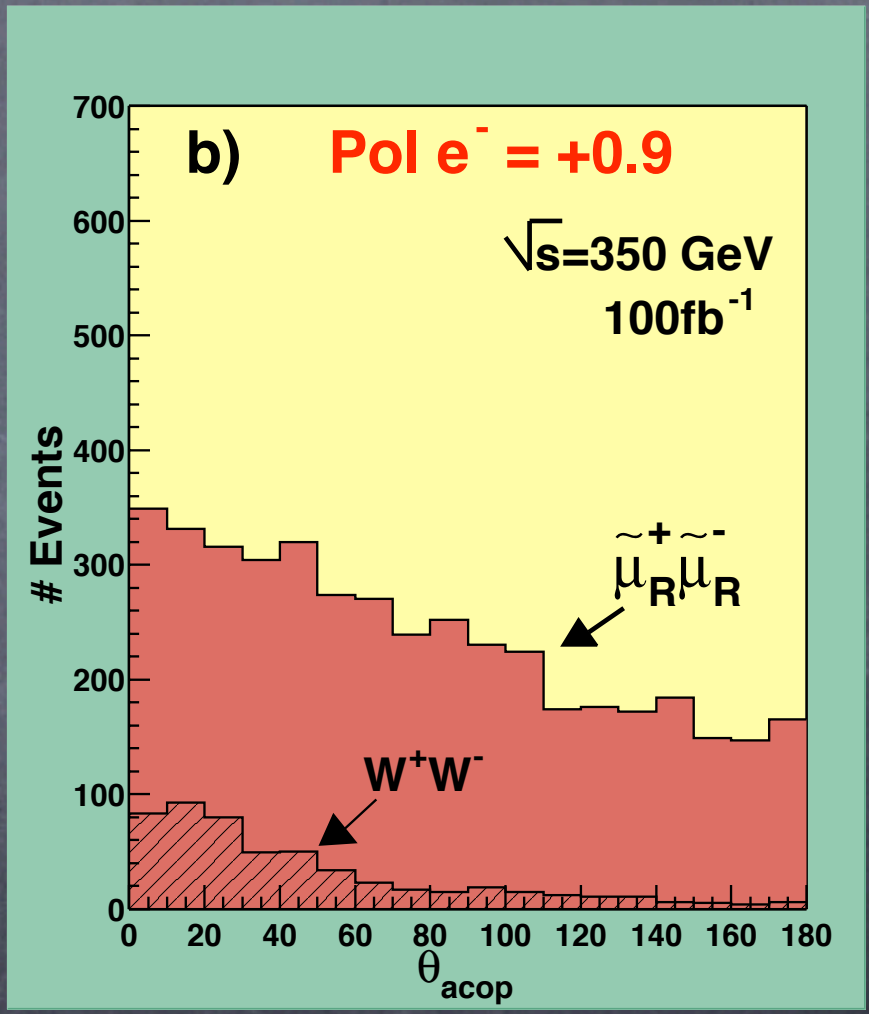
Decomposition

Signal Enhancement

Slepton Studies

Signature = acoplanar Lepton Pair

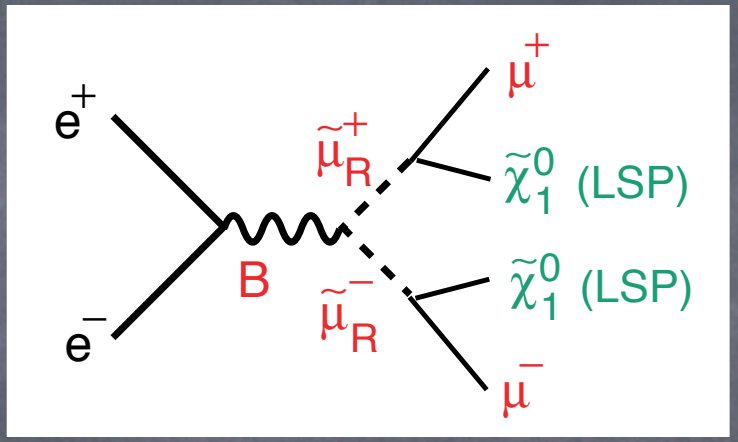


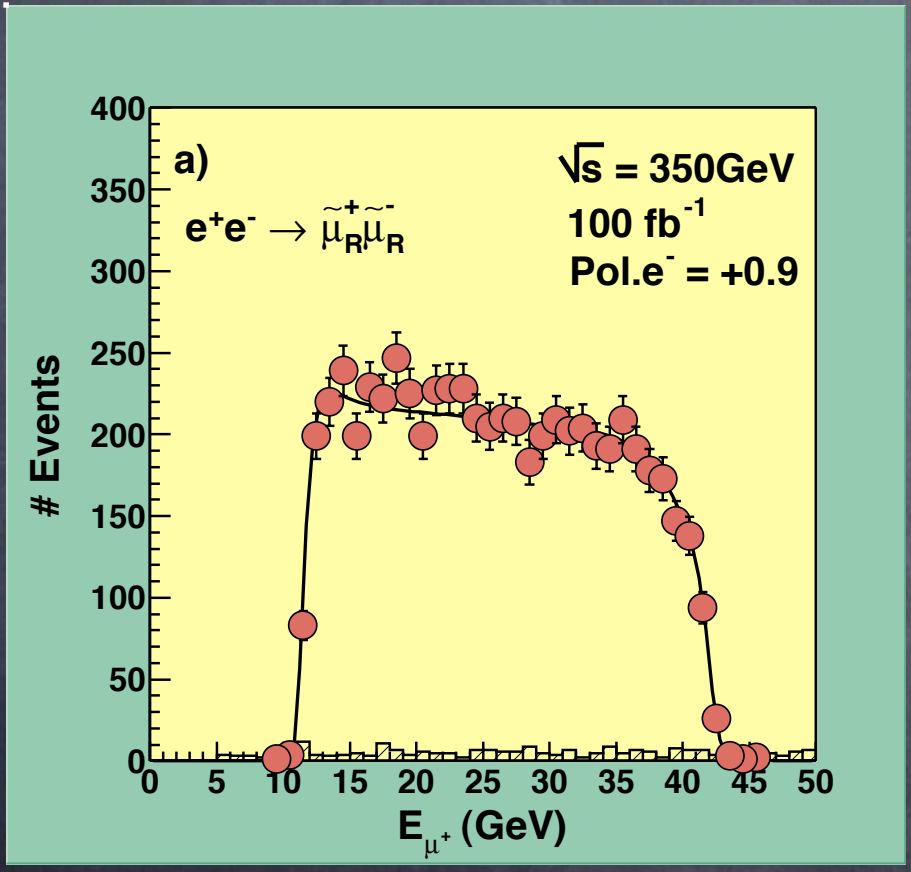


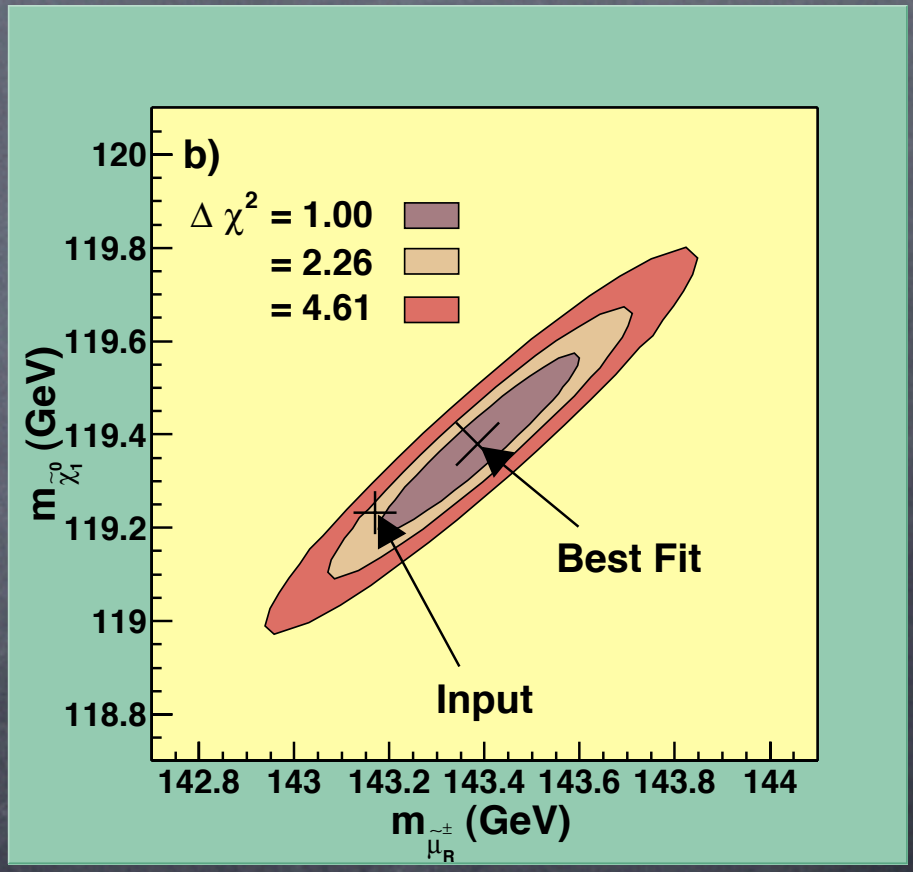
- We can get a very clean sample!

Mass Measurement

End Point Measurement

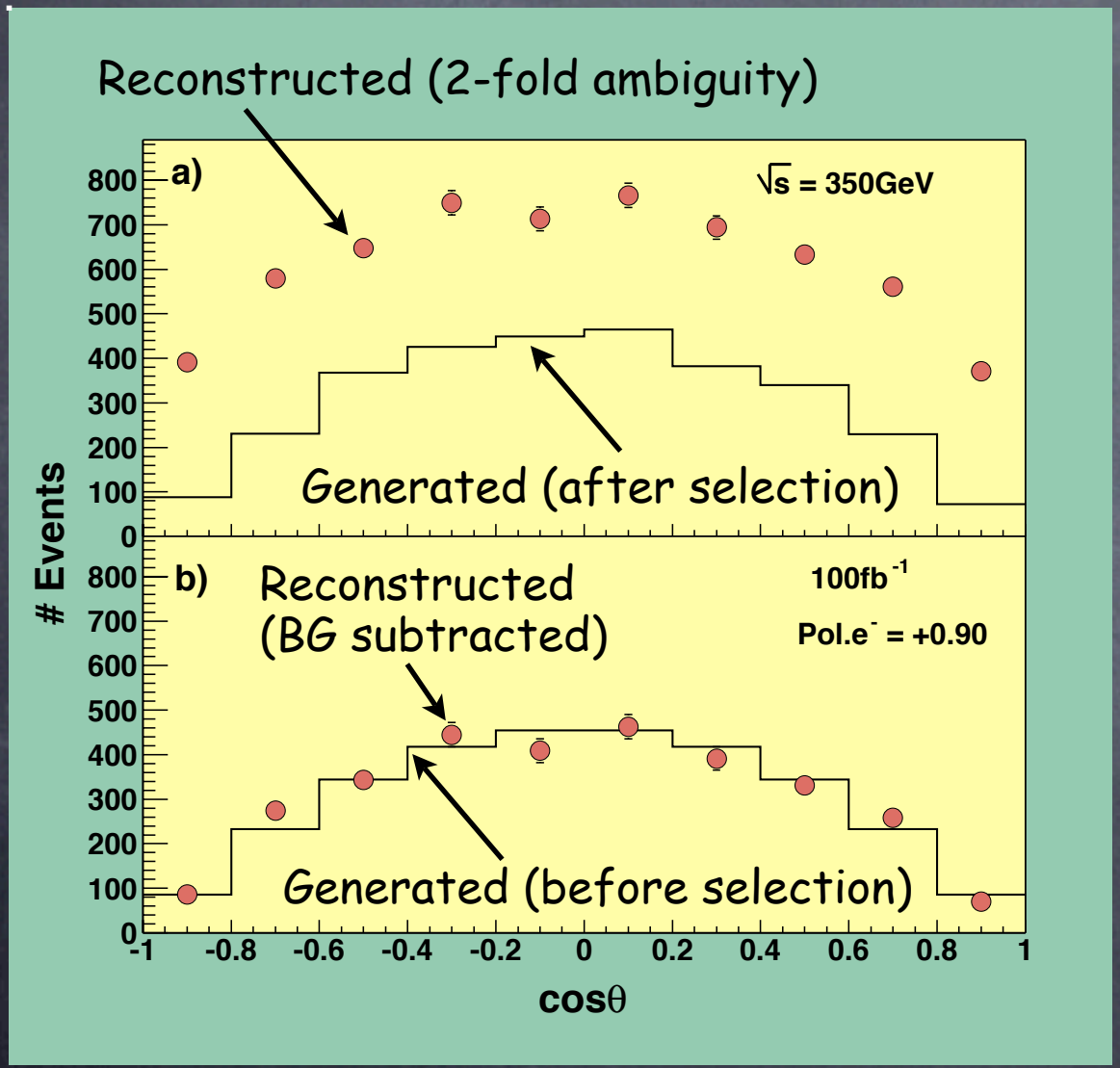






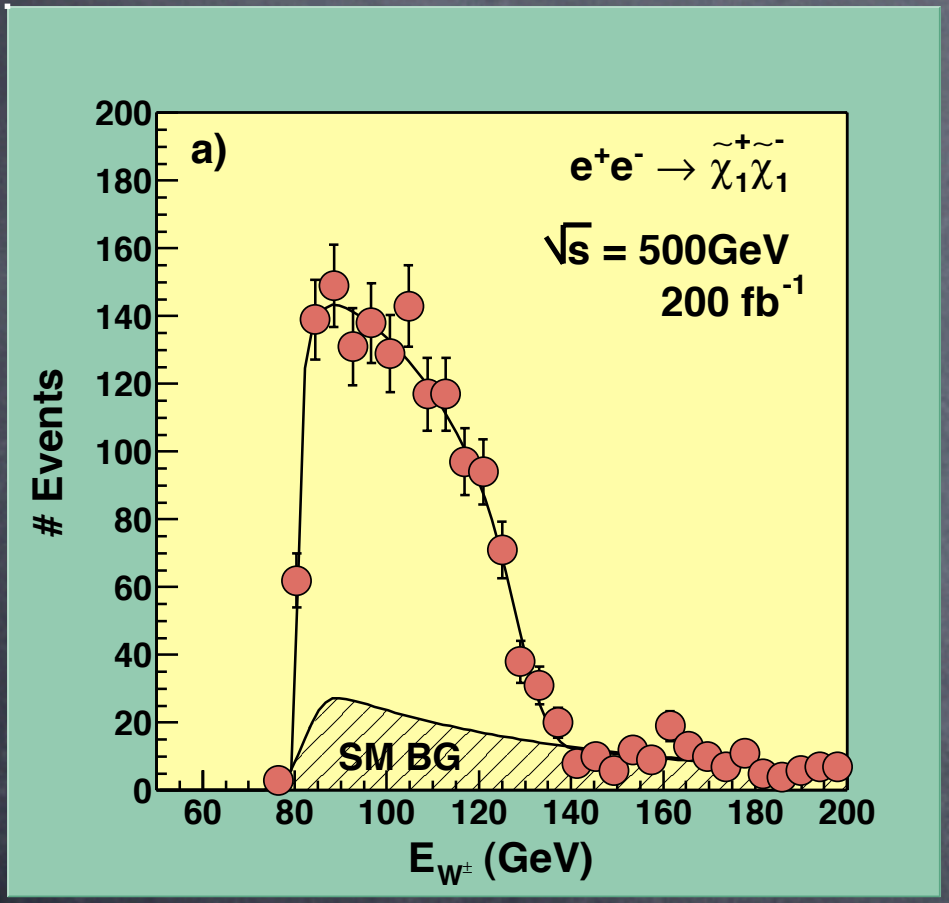
- O(0.1%) measurement is possible!

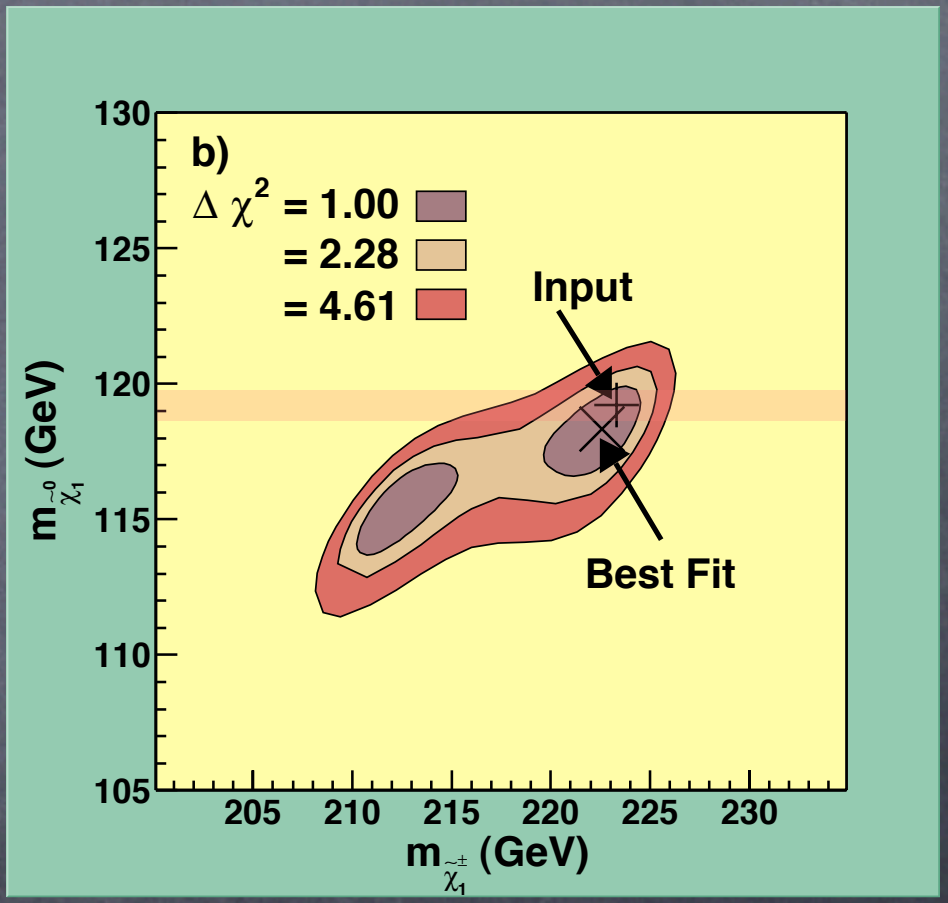
Smuon Spin Measurement



- 2-fold ambiguity
  - wrong solution makes a flat BG
  - easy to subtract
- sin(theta) dist. for J=0 (P-wave)

Chargino Studies
Mass Measurement

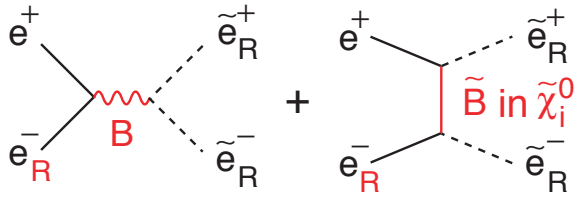




- O(1%) measurement is possible!
  - Need good energy flow resolution

Test of GUT Relation

Global Fit



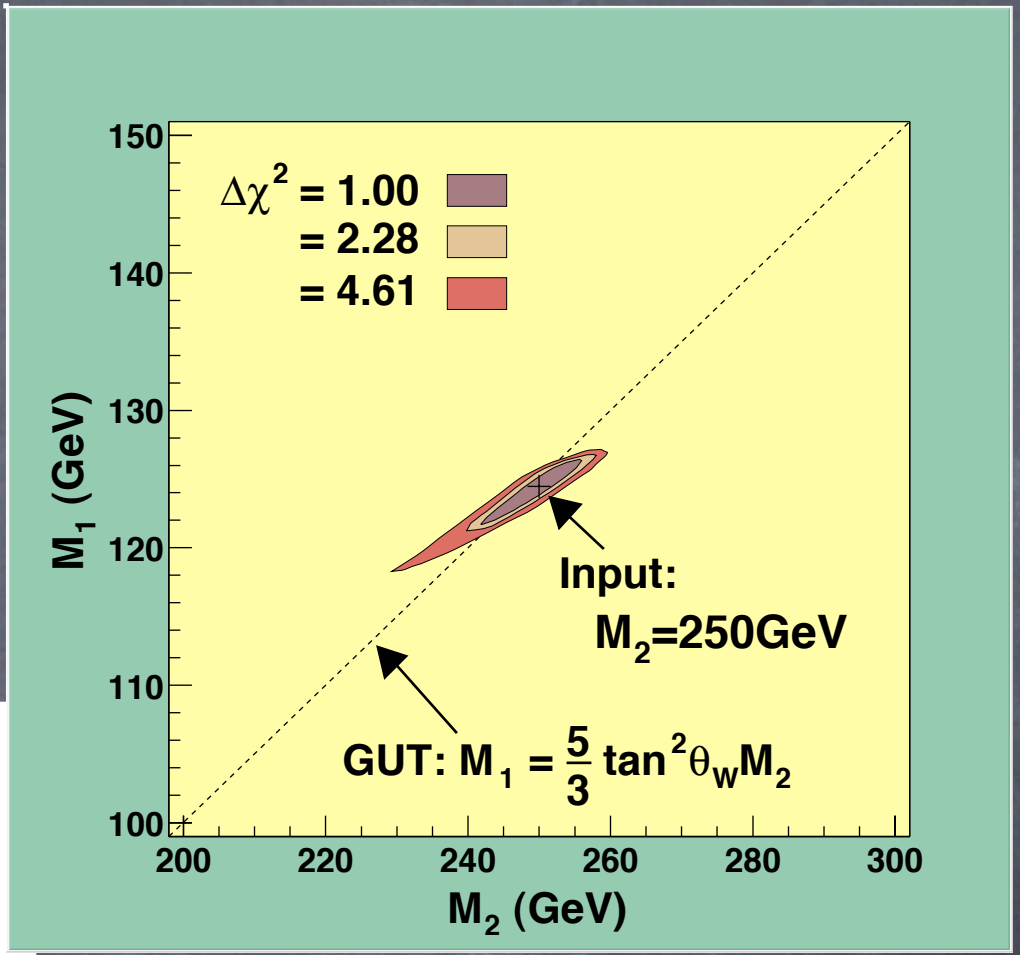
We know

$m_{\tilde{\chi}^0_1}$ = $m_{\tilde{\chi}^\pm_1}$ $\sigma(e^+e^-_R \to \tilde{e}^+_R\tilde{e}^-_R)$ $\sigma(e^+e^-_R \to \tilde{\chi}^+_1\tilde{\chi}^-_1)$

LSP

Mass Matrices $\langle \tilde{B} | \tilde{\chi}^0_1 \rangle$ $\langle \tilde{H}^\pm | \tilde{\chi}^\pm_1 \rangle$

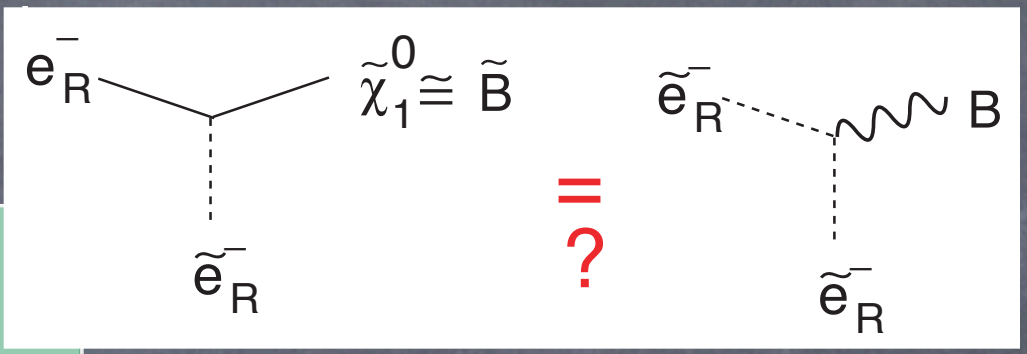
$(M_1, M_2, \mu, \tan\beta)$



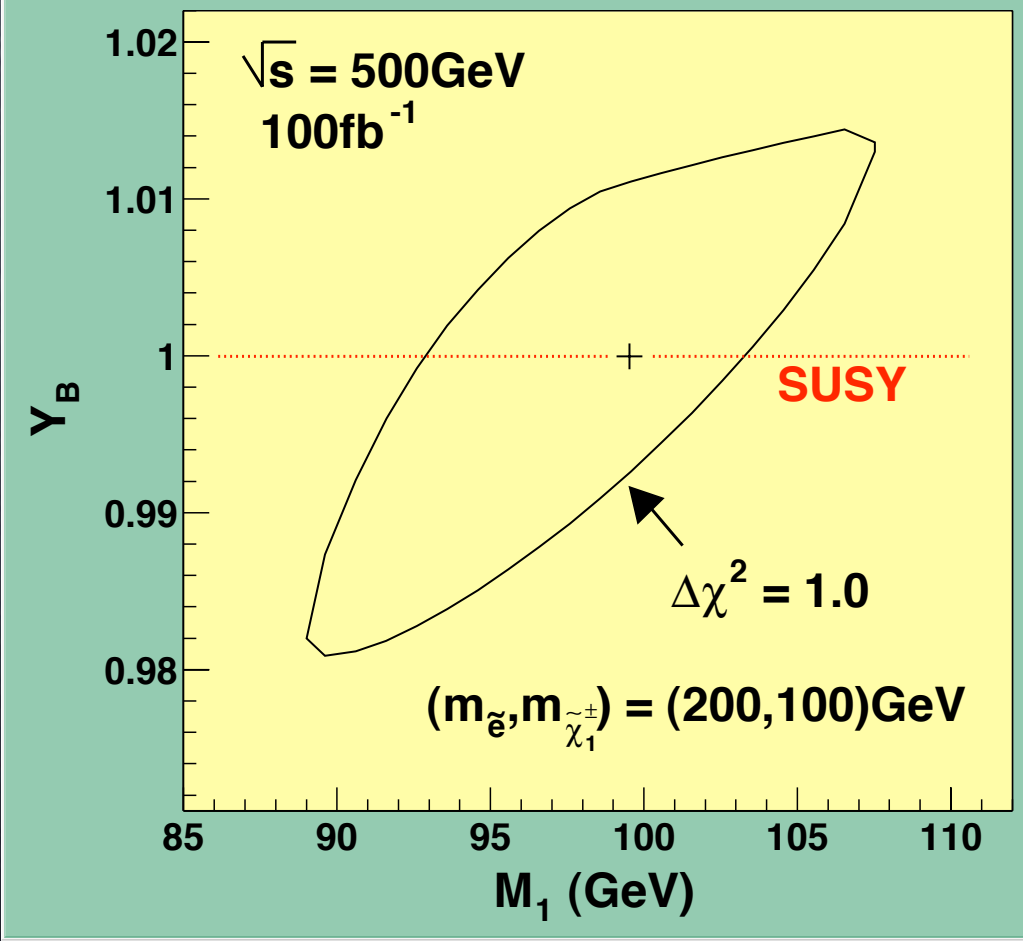
Discriminates AMSB

Beam Polarization Essential!

Quantitative Test of SUSY



Nojiri-KF-Tsukamoto



$$\begin{cases} d\sigma \cong d\sigma(m_{\tilde{e}^\pm_R}, m_{\tilde{\chi}^0_1}, g'_\chi) \\ E_e \text{ distribution (Endpoints)} \end{cases}$$

O(1%) Test of SUSY is possible!

Supersymmetry
A Lot More to Do

Non-standard Event Signatures
- Difficult Corners of Parameter Space
- Other SSB Scenarios: GMSB, AMSB, ..., ??
- R-parity violation

Spectroscopy at Higher E (Cascade Decays)
- Mass Measurements (Endpoint/Threshold Scan)
- Determination of Low Scale Parameters

CP Phases

High Scale Physics (SSB Mechanisms)

Combined Analyses with Higgs Sector

Large Extra Dimensions

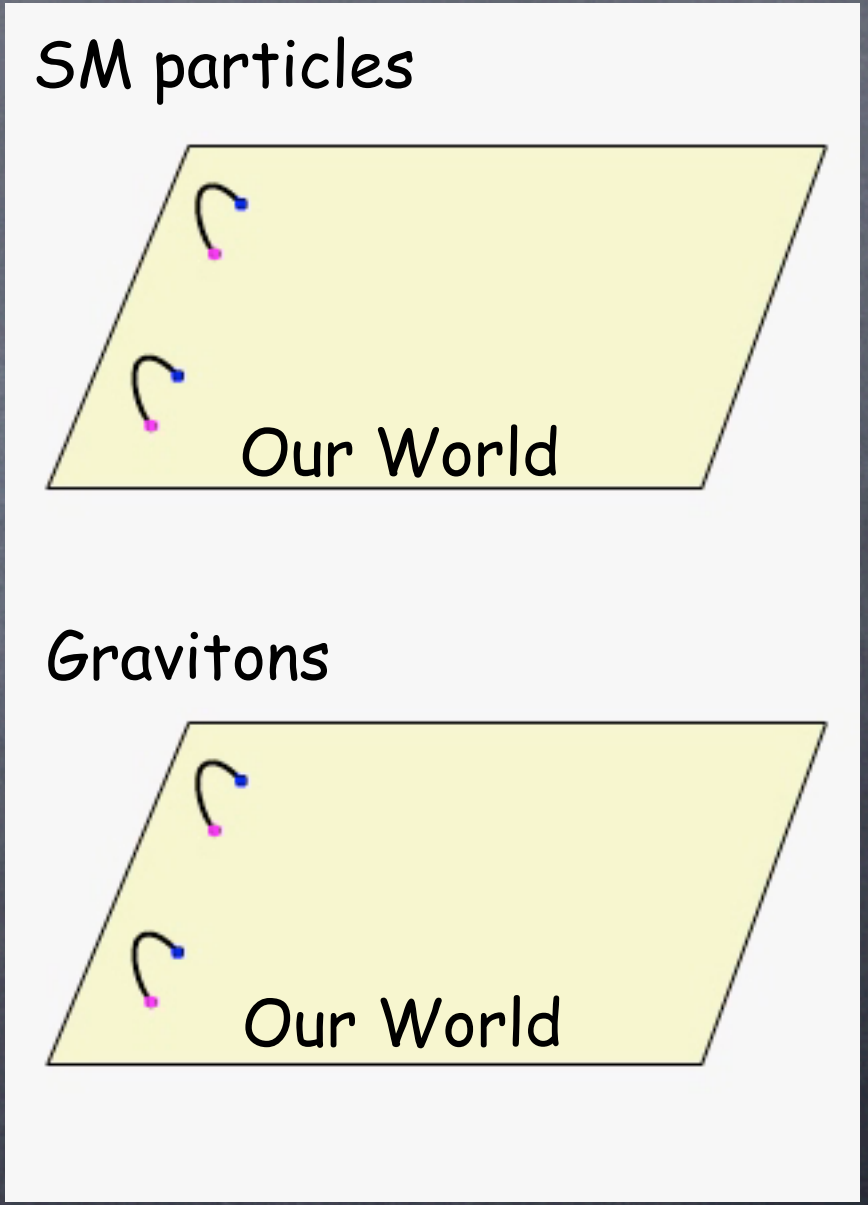
Brane World Scenario

Our World = Brane

All the SM particles live on the brane!

Gravitons live in the bulk!

--> may leave the brane and disappear from our world!



Large Extra Dimensions

- How to Decide Nature of Extra Dimensions
  - Size and Shape (Topology)
  - Non-commutative Geometry?
- Possible Probes
  - Quantum Gravity Effects (KK Modes)?
  - Classical Gravity Effects (Black Holes)?
  - String Effects (Regge, Winding Modes)?

Size and Shape

$$e^+e^- \rightarrow \gamma G$$

KK Gravitons
-> Missing E

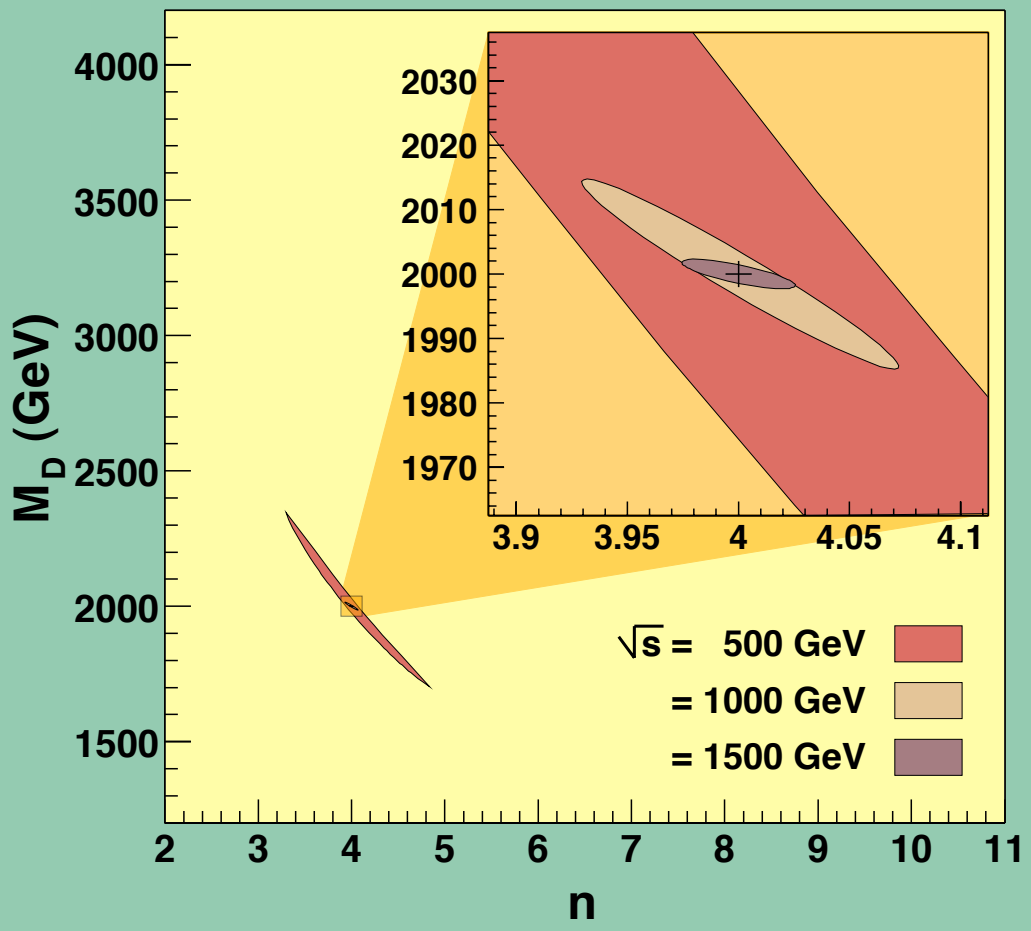
Single Photon Event

Angular Distribution
--> Spin of G (J=2 if KKG)

Energy Distribution
--> #extra dims. (n) and fundamental scale (M_D)

$$m_{Pl}^2 \sim M_D^{(2+n)} R^n$$

Odagiri



- But So Far No Serious Simulation Studies in ACFA LCWG

Be Prepared for Unexpected

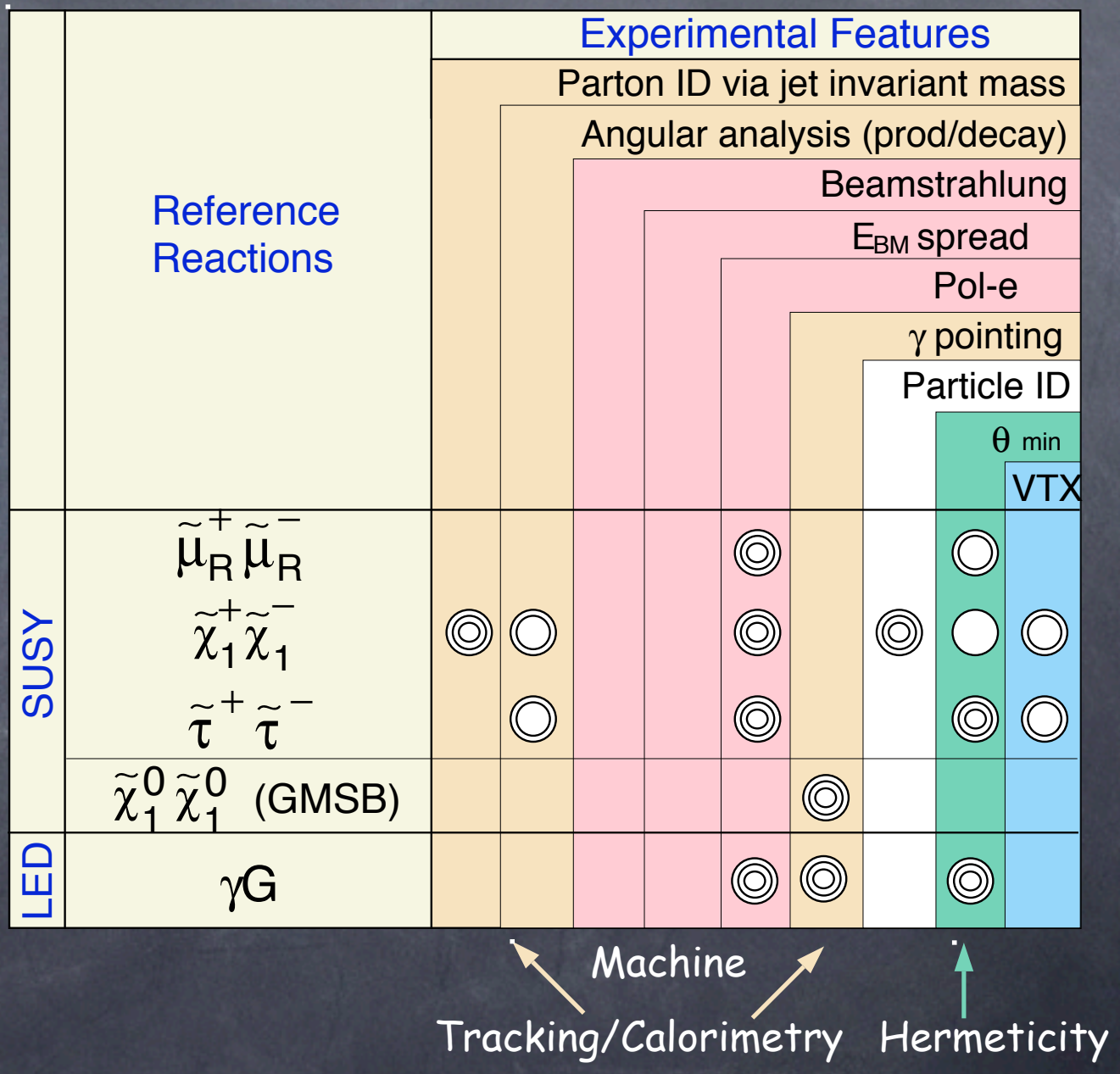
Is Our Detector Good Enough?

- Hermeticity
- Energy Flow Resolution
- Vertex Tagging
- Time Stamping
- Photon Vertex (Off-vertex Photon)
- Heavy Long-lived Particles?
- Polarization (e+?, Transverse Pol.?)

Example of Score Sheet

Sample reference reactions and relevant experimental features in relation to performance requirements on machine and detector

Need to study them with beam induced Background



Feed Back to Machine and Detector Designs

- Beam Polarization (e^+?, Transverse Pol.?)
- Beamstrahlung and Beam Energy Spread
- Parton ID by Jet Invariant Mass
- Angular Analysis (Production/Decay)
- Endpoint Measurements
- Threshold Scan
- Photon Pointing
- Slow Track Trigger
- Minimum Veto Angle
- Vertex Tagging (c/b/tau)

LHC + LC or LHC x LC

Essentiality

- Higgs
  - Discovery --> LHC
  - Yukawa and Self Couplings --> LC
- Supersymmetry
  - Super Spectroscopy
    - Colored Sparticles --> LHC
    - Colorless Sparticles --> LC
- Large Extra Dimensions
  - Black Hole --> LHC
  - Size and Shape --> LC

Summary

- Past Simulation Studies in ACFA LCWG
  - Mostly SUSY in Phase I (Ecm<500GeV)
    - A lot more to do even within SUSY:
      - Higher E (cascade decays), Different Scenarios, CP Phases, Extrapolation to High Scale, Global Analyses Incl. Higgs Sector, ...
- Large Extra Dimensions
  - Size and Shape? Non-commutiative?
  - Stringy Effects?
- Extra Symmetires
  - Little Higgs?
- ???? --> Ideas and Man Power Wanted!