New Physics at the TeV Scale and Beyond – Summary

Machine and Detector Issues

1. Correlated Beamstrahlung
   – David Strom
2. Implementing Universal Extra Dimensions in COMPHEP
   – Konstantin Matchev
3. Klazu-Klein /Z' Differentiation at LC and LHC
   – Tom Rizzo

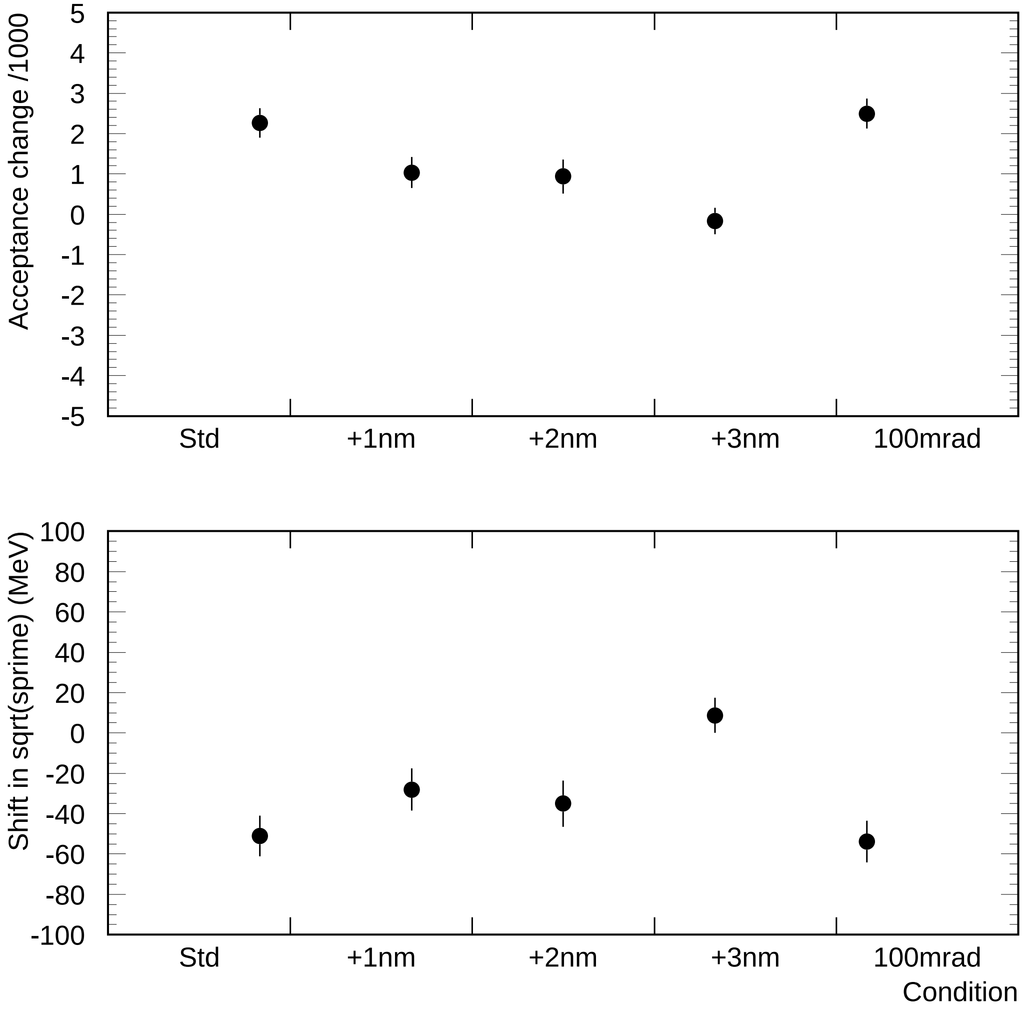
New Theoretical Ideas:

1. Signatures for Brane Kinetic Terms at the LC
   – Tom Rizzo
2. Precision Electroweak Constraints on RS Unified Models
   –Tim Tait
3. Phenomenology of the Little Higgs Model
   – Lian Tao Wang

Connections between Linear Collider Physics and Astrophysics and Cosmology

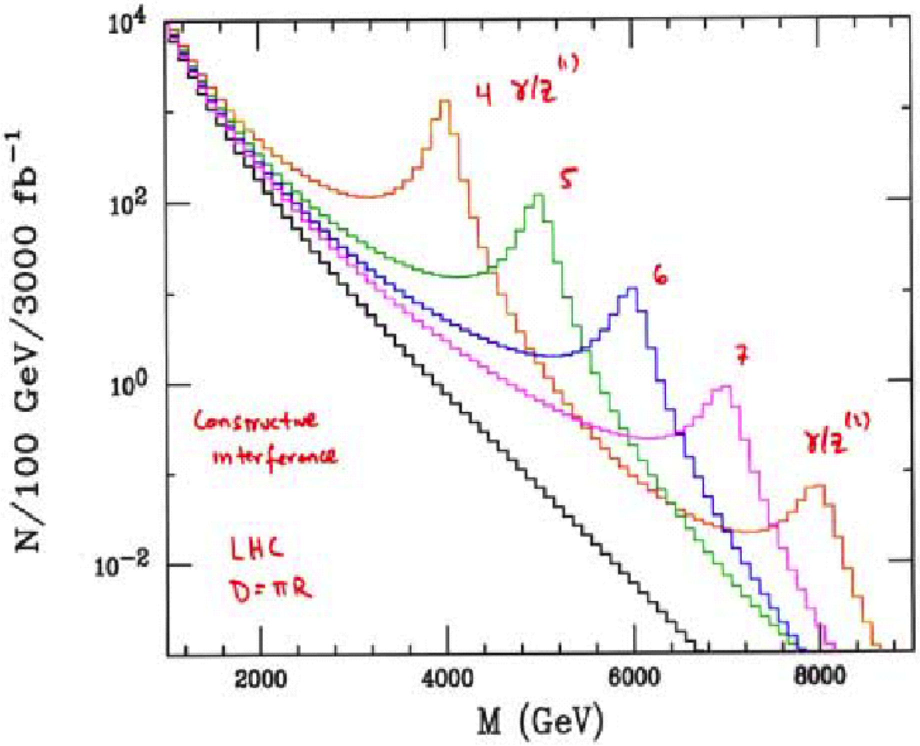
- What do astrophysicists want high-energy physicists to measure?
  Ira Wasserman (Cornell)
- Stau physics and neutralino dark matter
  Bhaskar Dutta (Regina)
- Supersymmetric dark matter and particle searches at accelerators
  Vassilis Spanos (Minnesota)
- How well must we measure the SUSY parameters to predict the neutralino relic density?
  Michael Peskin
- Dark matter candidates from extra dimensions
  Tim Tait

Can't be inferred from acollinearity!

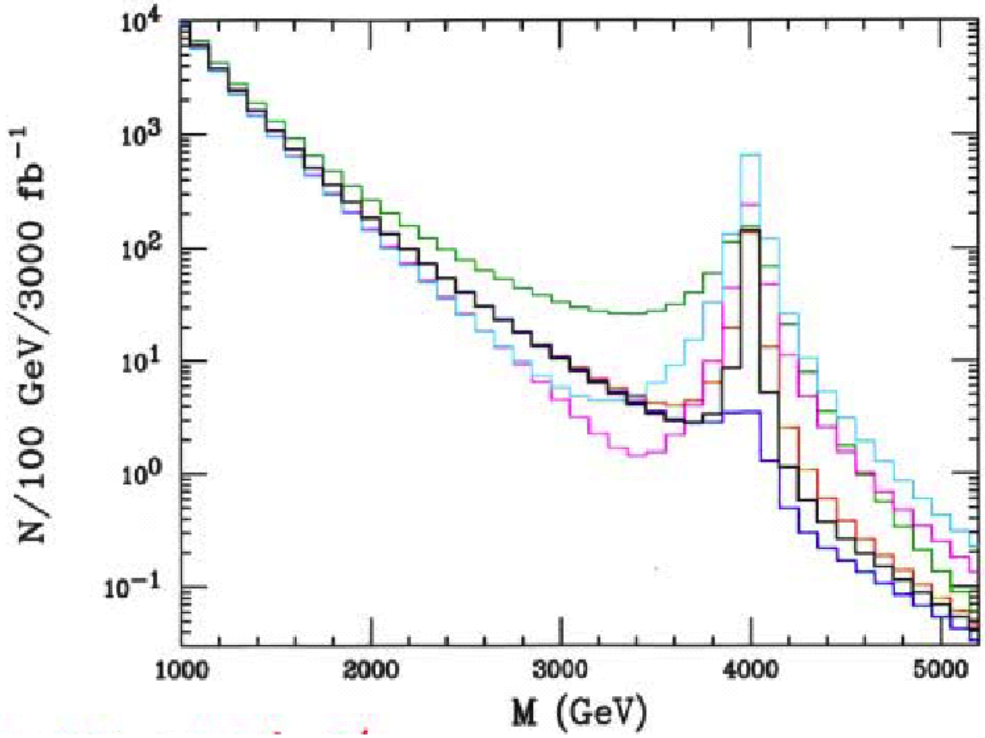


Bottom line: few 10^{-3} effects in Acceptance

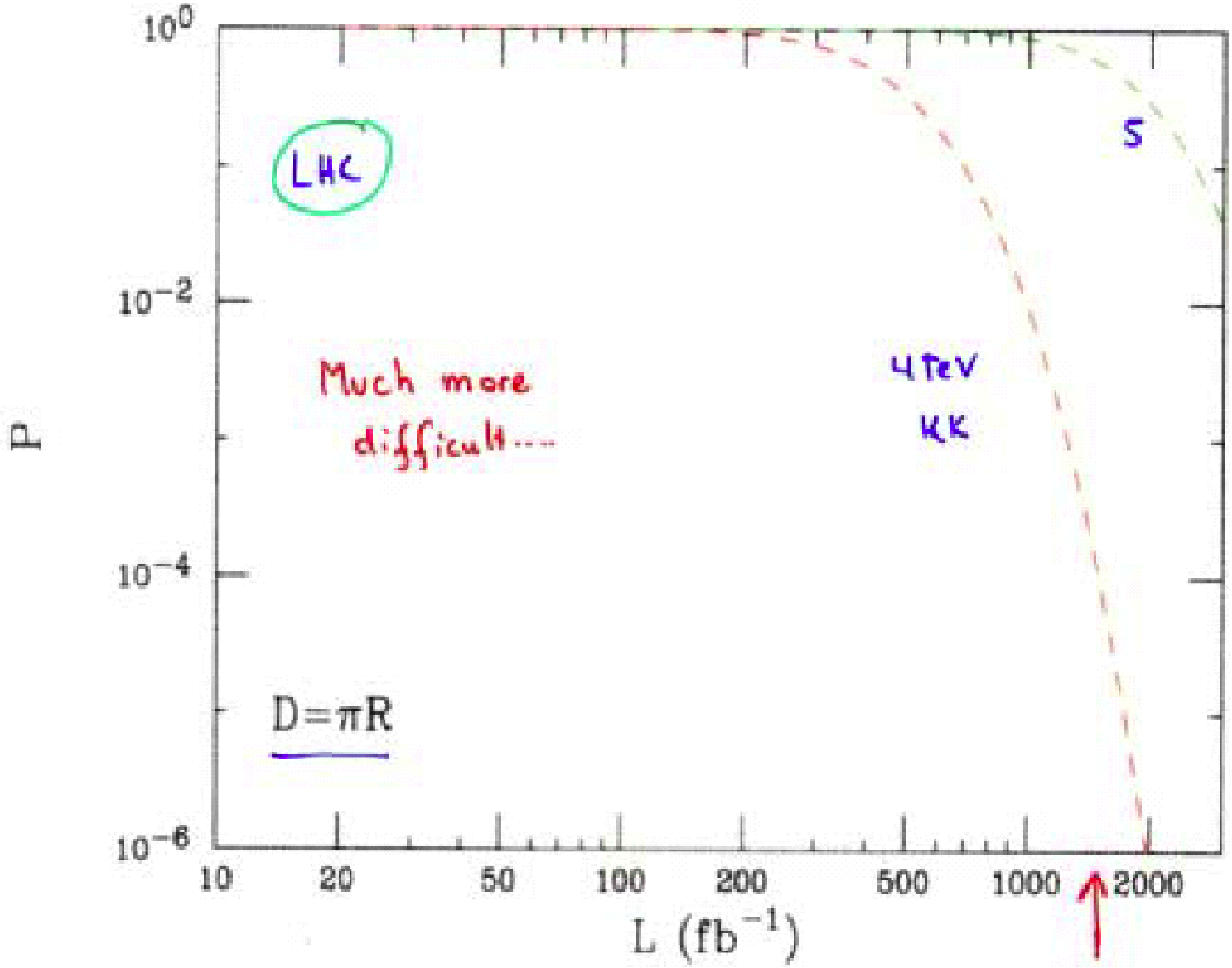
Klazu-Klein /Z' Differentiation at LC and LHC – Tom Rizzo



KK gauge resonance, $D = \pi R$ (quarks and leptons localized at opposite fixed points)

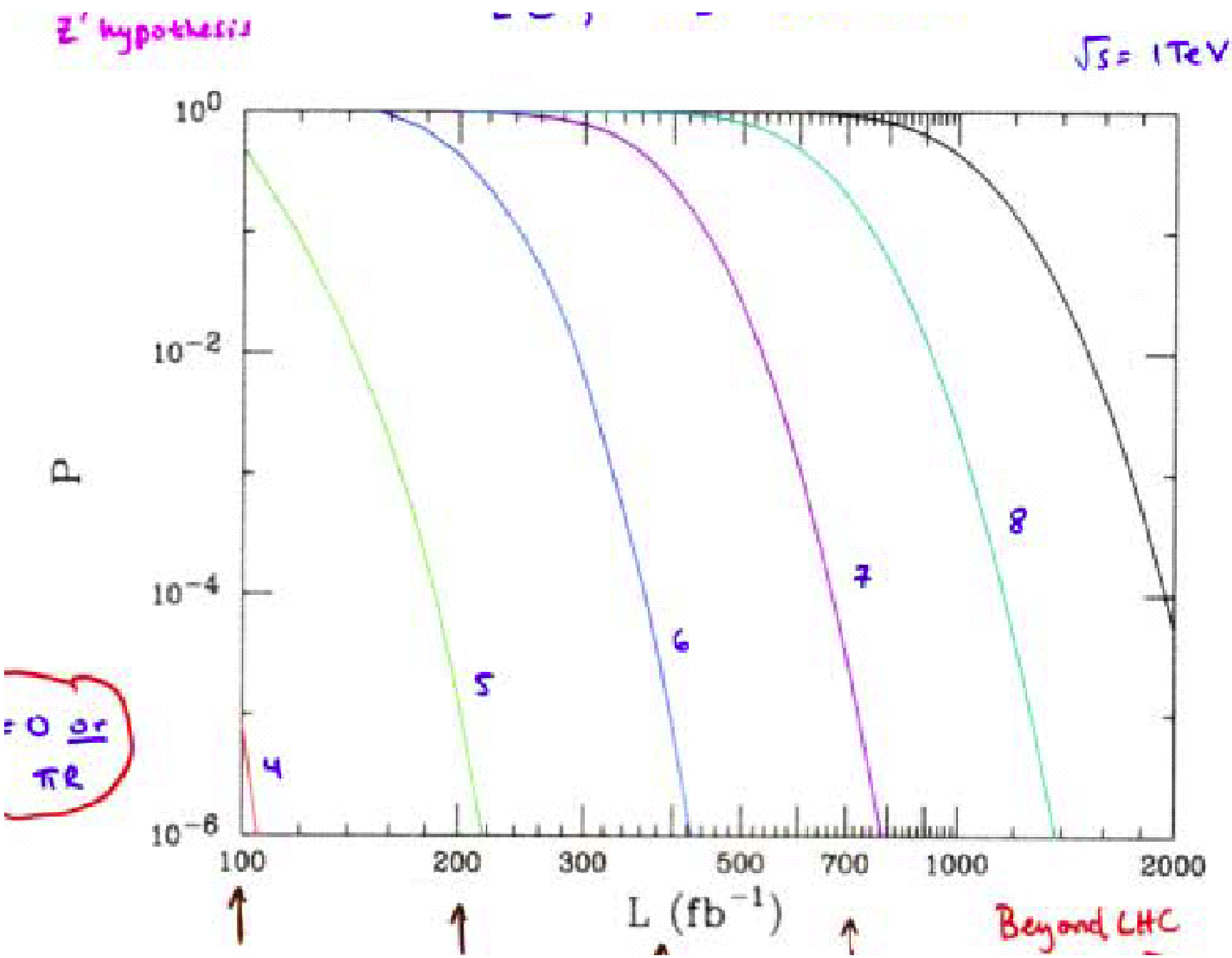


Some Z' models at the LHC 10,000 considered



Fit probability LHC

Rizzo



Fit probability at an 1.0 TeV LC

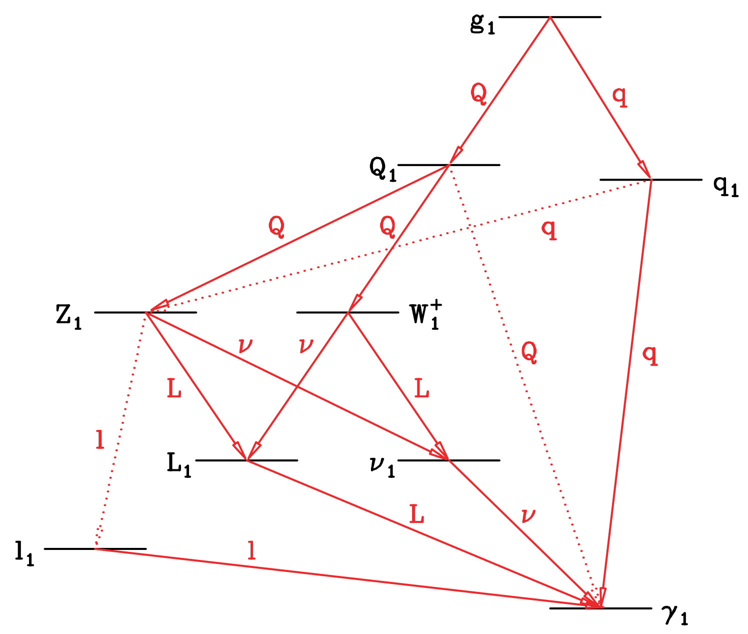
Rizzo

Implementing Universal Extra Dimensions COMPHEP –Konstantin Matchev (AKA Bosonic Supersymmetry)

- Allow all particles to propagate in extra dimension (Circle with opposite points identified, avoids right handed couplings)
- Spectrum of KK excitations:

$$m_n^2 = (\frac{n}{R})^2 + m_0^2 + \text{rad.corr.}$$

- Rich spectrum with many leptonic decays
- LC studies need radiative corrections...

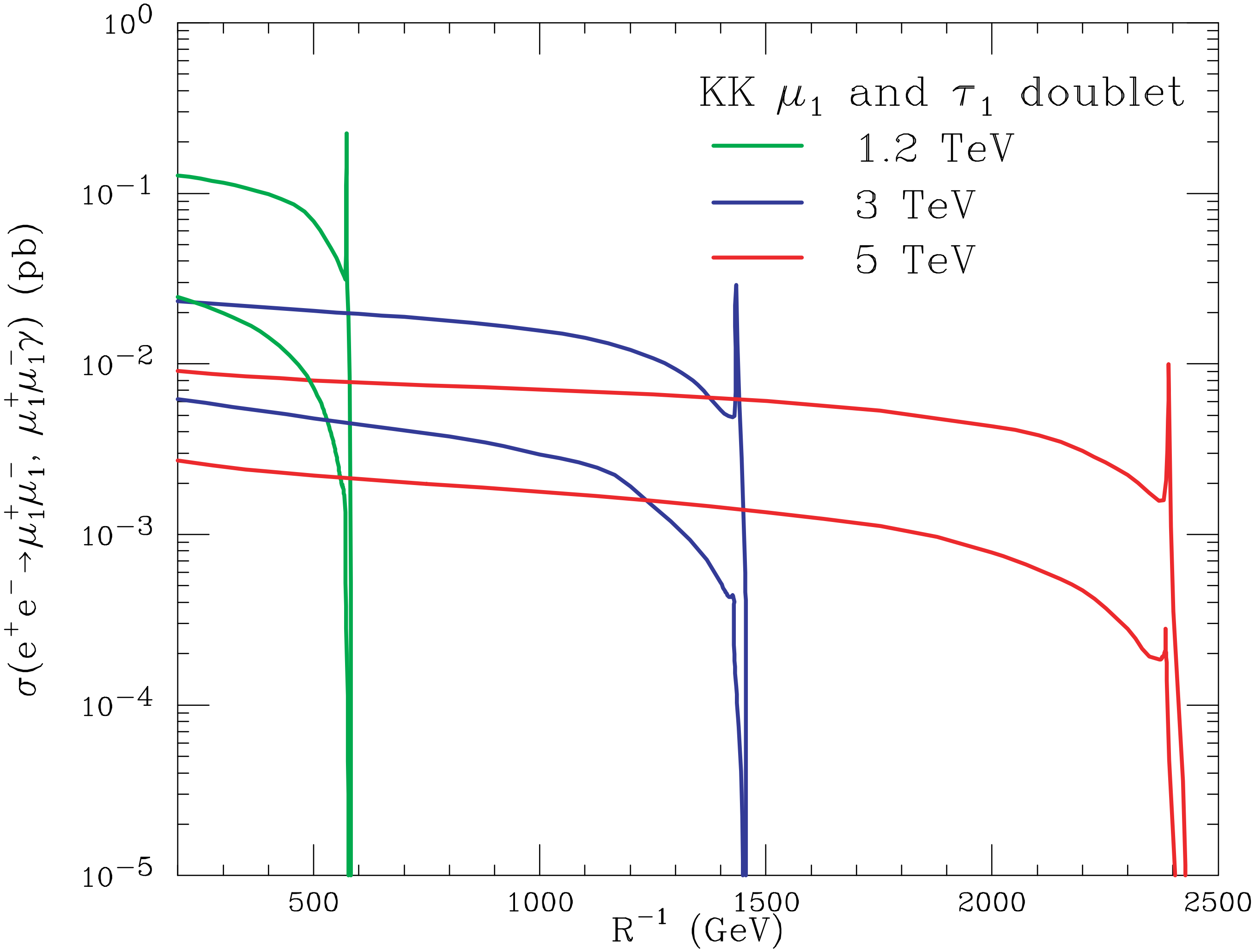


Spectroscopy of super-partners

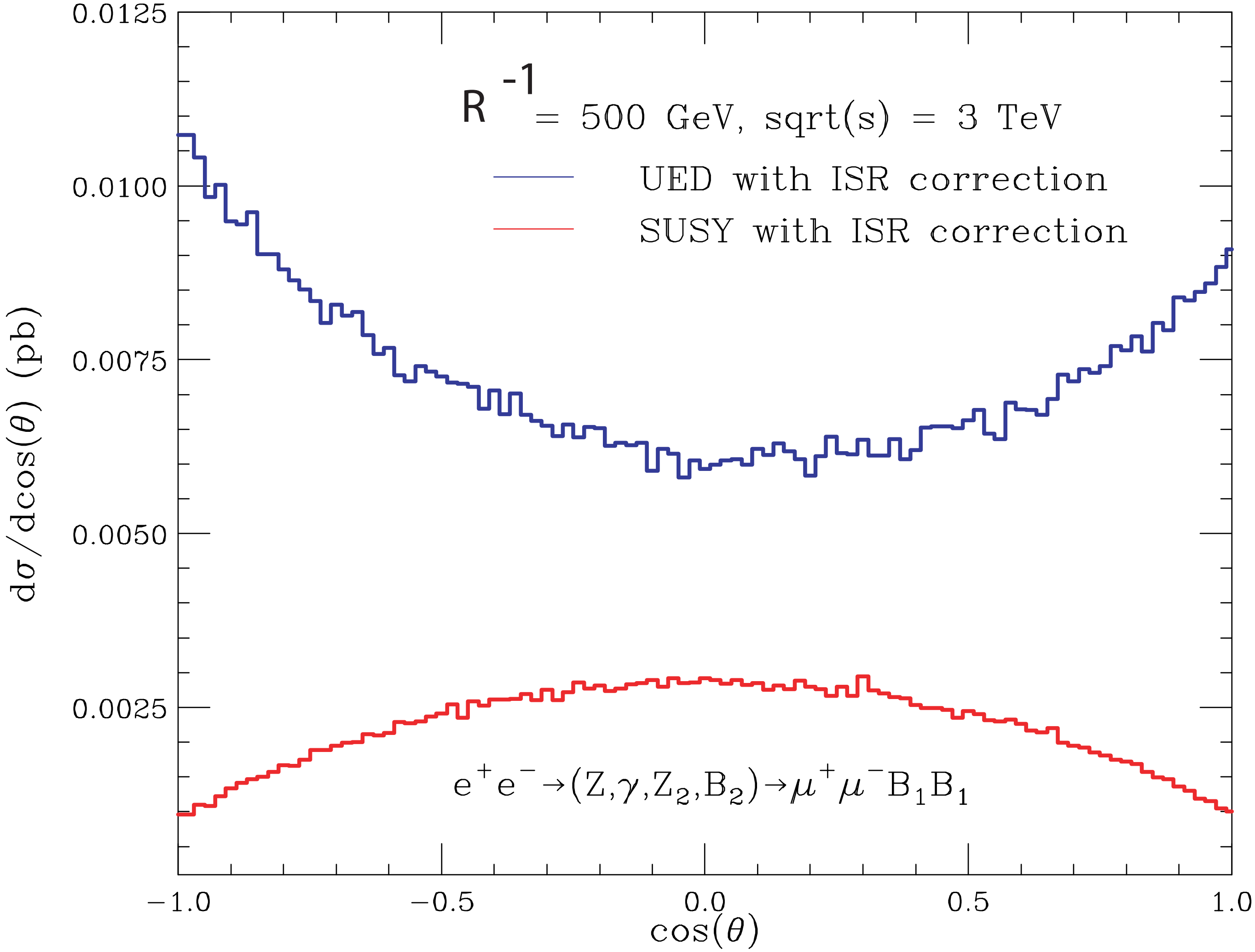
with Cheng and Shmaltz: hep-ph/0204432, hep-ph/0205314

with Cheng and Feng: hep-ph/0207125

UED resonances in e^+e^- – Matchev:



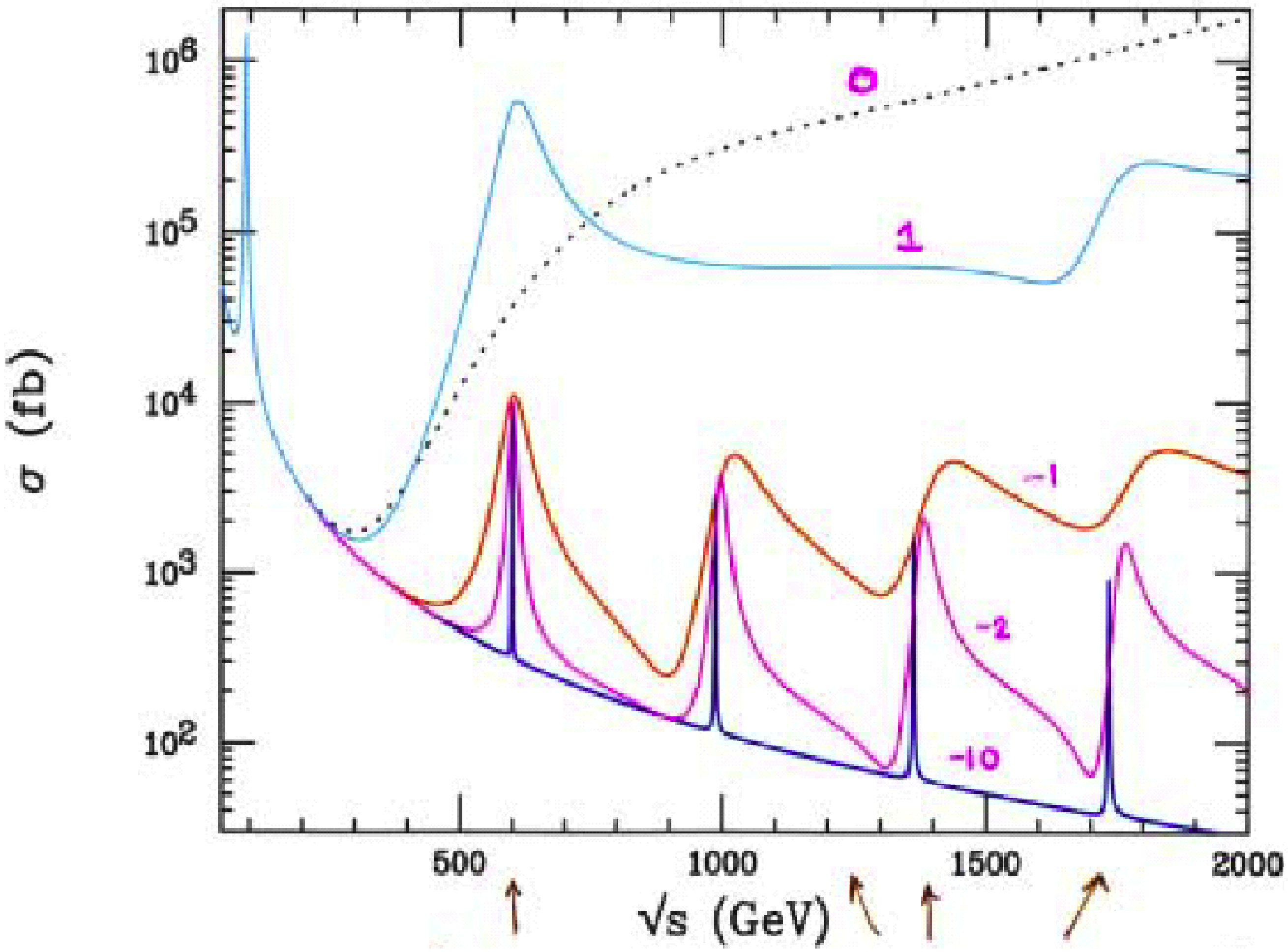
UED versus SUSY using COMPHEP



Signatures for Brane Kinetic Terms at the LC – Tom Rizzo

- Kinetic terms are naturally generated in
  - Orbifold theories (see Universal Extra Dimensions)
  - Models where matter exists on m boundaries
- Two models consistent with present experimental constraints considered:
  - gauge boson in bulk in RS
  - gravity in the bulk in RS
- Kinetic terms alter spacing of KK states and reduces couplings

Example of change in KK resonances with kinetic term parameter



Need to look for bumps in s' distribution

Precision Electroweak Constraints on RS Unified Models–Tim Tait

hep-ph/0305188, PRD67:096006 (2003)

- In Randall-Sundrum models have AdS_5 with curvature $k \sim M_{Pl}$.
- Curvature red-shifts Higgs VEV from M_{pl} on UV-brane to M_W on IR (TeV)-brane.
- To solve hierarchy problem only Higgs must be on TeV-brane
- In this approach fermions are allowed in the bulk and unification of gauge couplings in a "GUT" is possible

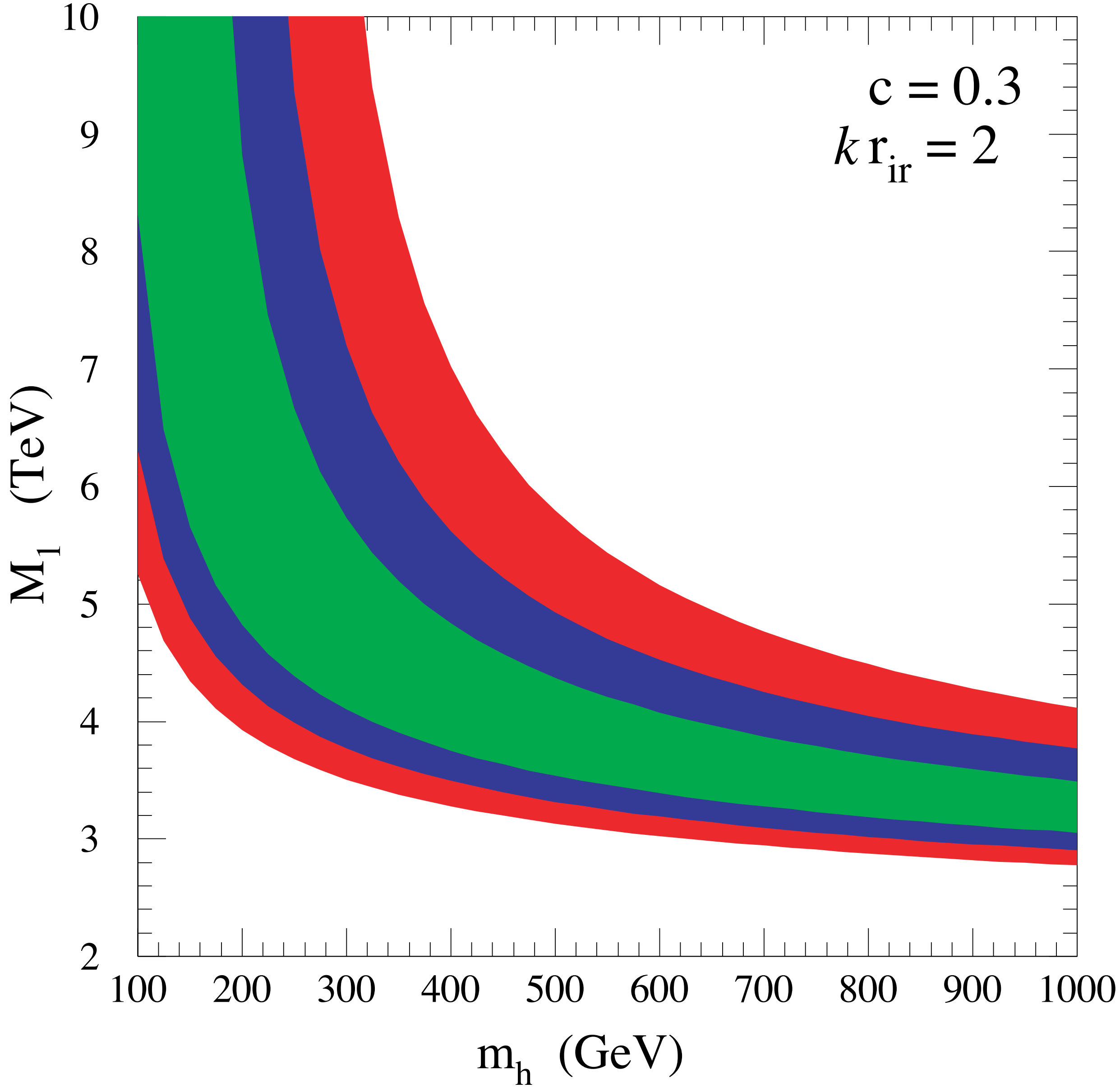
First allowed KK resonance verus Higgs mass, includes precision electroweak constraints

Green 1 σ

Bule 2 σ

Red 3 σ

Note: Higgs mass can be large in these models



Phenomenology of the Little Higgs Model
– Lian Tao Wang

- Little Higgs Model allow for a naturally light Higgs boson while introducing new particles at the scale

$$f \sim TeV$$

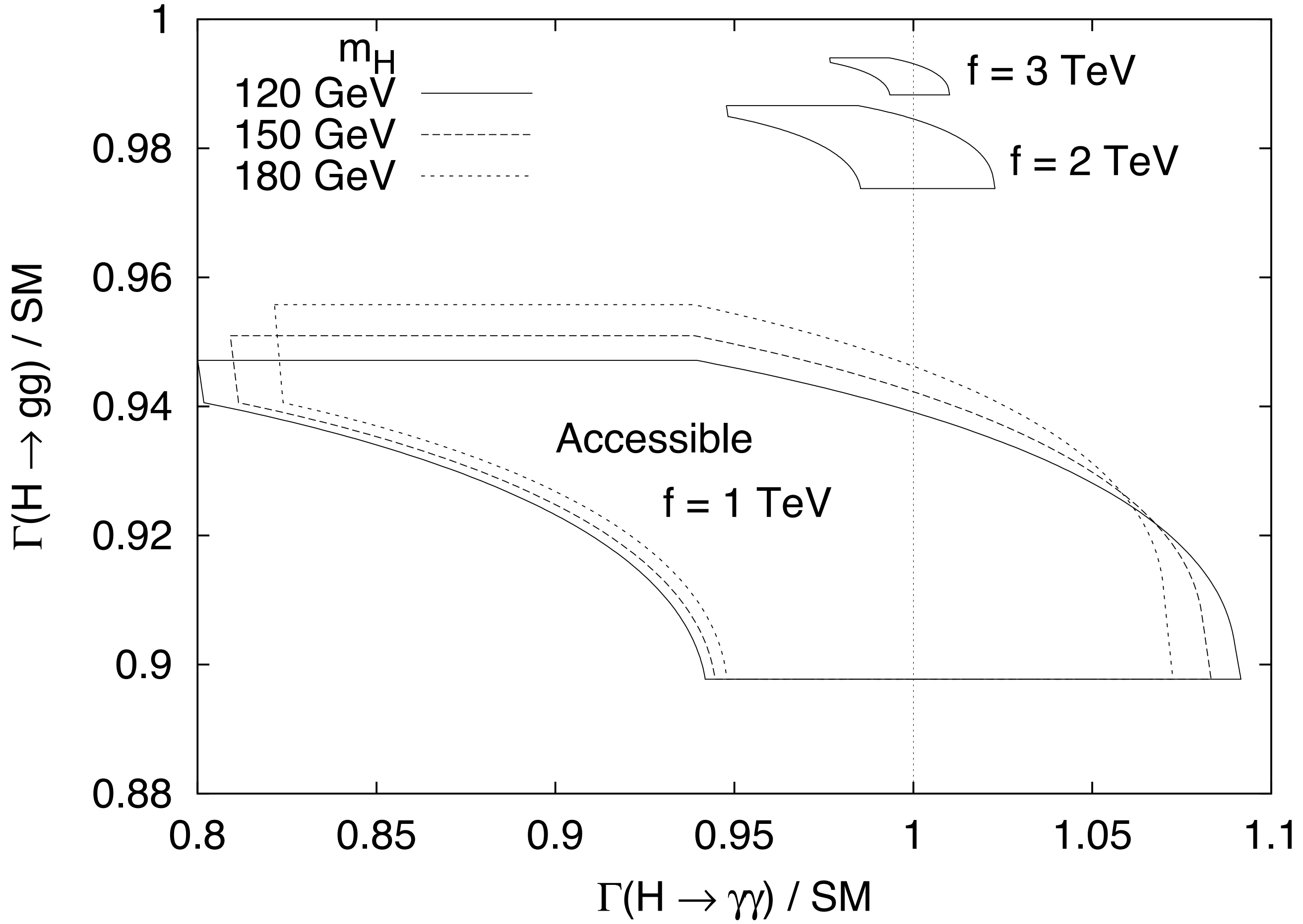
and giving a natural cutoff at

$$\Lambda = 4\pi f$$

- Models can be constrained with tripple gauge couplings at an LC

- Important question for an LC, can we tell if it is a "Little HIggs"

Possible values in minimal model of $h \to \gamma\gamma$ and $h \to gg$:



Requires very good determination of Higgs branching ratios

What do astrophysicists want high-energy physicists to measure?

Ira Wasserman

Short answer: Astrophysicists want to know why

$$\frac{\text{Baryon Density}}{\text{Dark Matter Density}} \sim 0.1$$

$$\frac{\text{Dark Matter Density}}{\text{Dark Energy Density}} \sim 0.3$$

This combination allowed structure to form – why do we live in universe where this is true:

$$\delta_H \left(\frac{\rho_{\text{eq}}}{\rho_V}\right)^{1/3} \sim \frac{\delta_H(\eta m)^{4/3}}{\rho_V^{1/3}} \sim 1$$

δ_H – fluctuations from inflation, ρ_V vacuum density, $\eta \sim (M_P m \langle \sigma v \rangle_{\text{ann}})^{-1}$

Another important message to particle physics

$\Rightarrow$ Dark matter may be clumpy
$\Rightarrow$ Direct detection of dark matter may fail

Can accelerators based experiments tell astrophysicists how clumpy the dark matter is?

Can we predict signals for annihilation of dark matter, e.g. neutrinos, photons?

Stau physics and neutralino dark matter – Bhaskar Dutta (as told by M. Peskin)

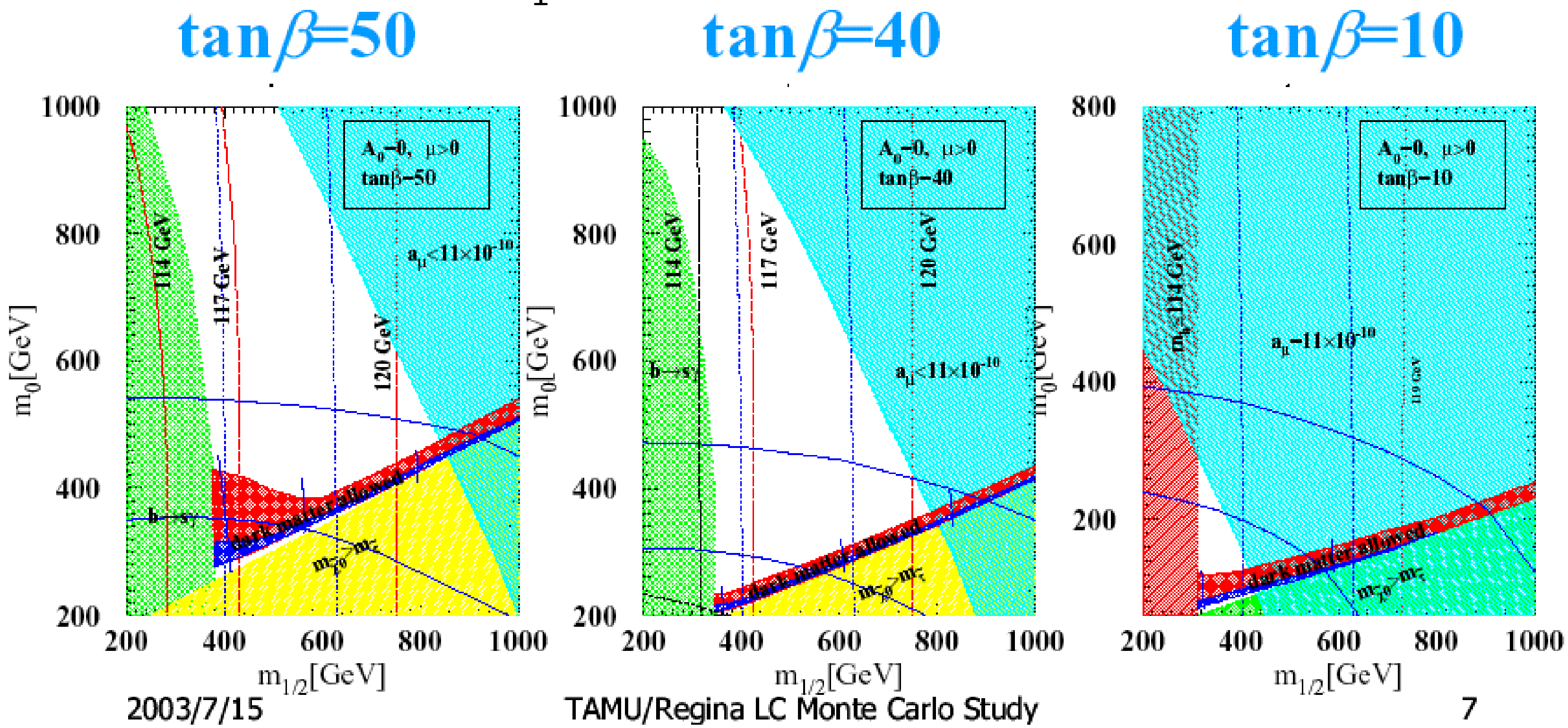
- Standard mSUGRA produces too much dark matter

- This problem can be solved with coannihilation

$$\begin{aligned} \tilde{\chi}\tilde{\chi} &\rightarrow XX \quad \text{(P-wave, suppressed)} \\ \tilde{\tau}\tilde{\tau} &\rightarrow YY \\ \tilde{\tau}\tilde{\chi} &\rightarrow XY \end{aligned}$$

If $\Delta m = \tilde{\tau} - m_{\tilde{\chi}}$ is small production will be suppressed

Allowed range (blue) is severely limited by WMAP and other constraints. $(0.094 < \Omega_{\chi_1^0} h^2 < 0.129)$



- Detection of of $\tilde{\tau}$ and $\tilde{\chi}_1^0$ difficult in low Δm situation favored by WMAP

- Complete program of study of backgrounds underway

- Polarization is important in reducing four-fermion backgrounds

- Two photon background is under control if we instrument down to 2° (34mrad)

- Need to guess at how likely Δm ¡ 5 GeV is

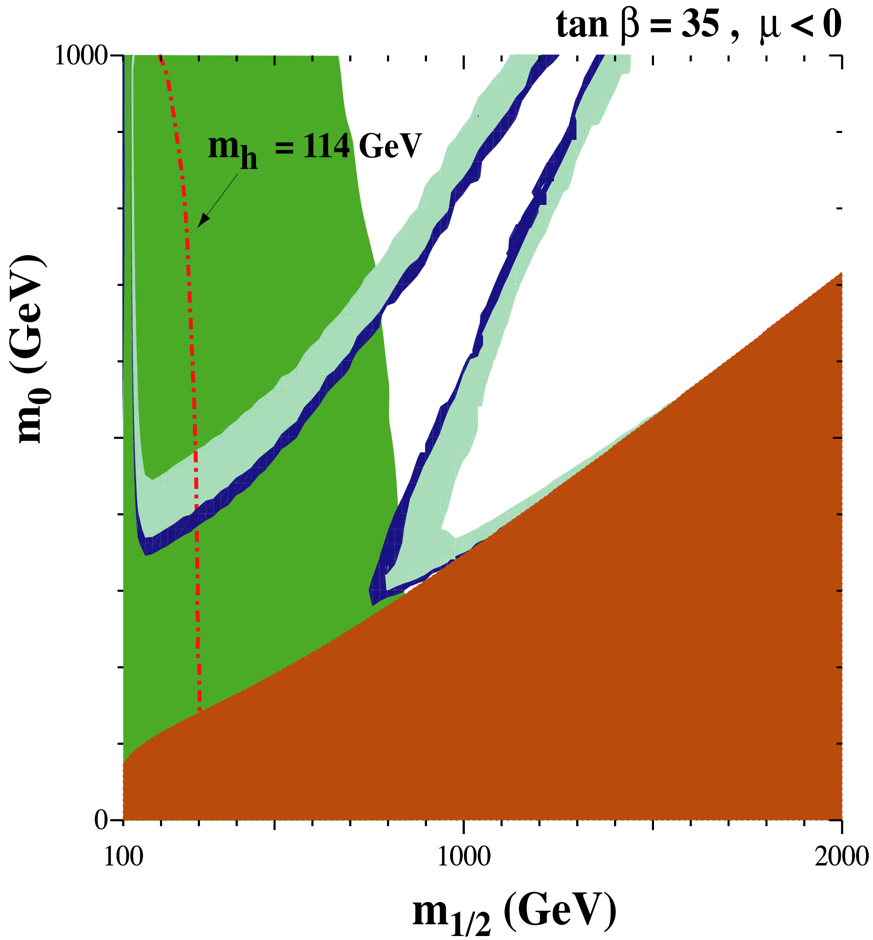
Supersymmetric dark matter and particle searches at accelerators
–Vassilis Spanos
Use constraints from

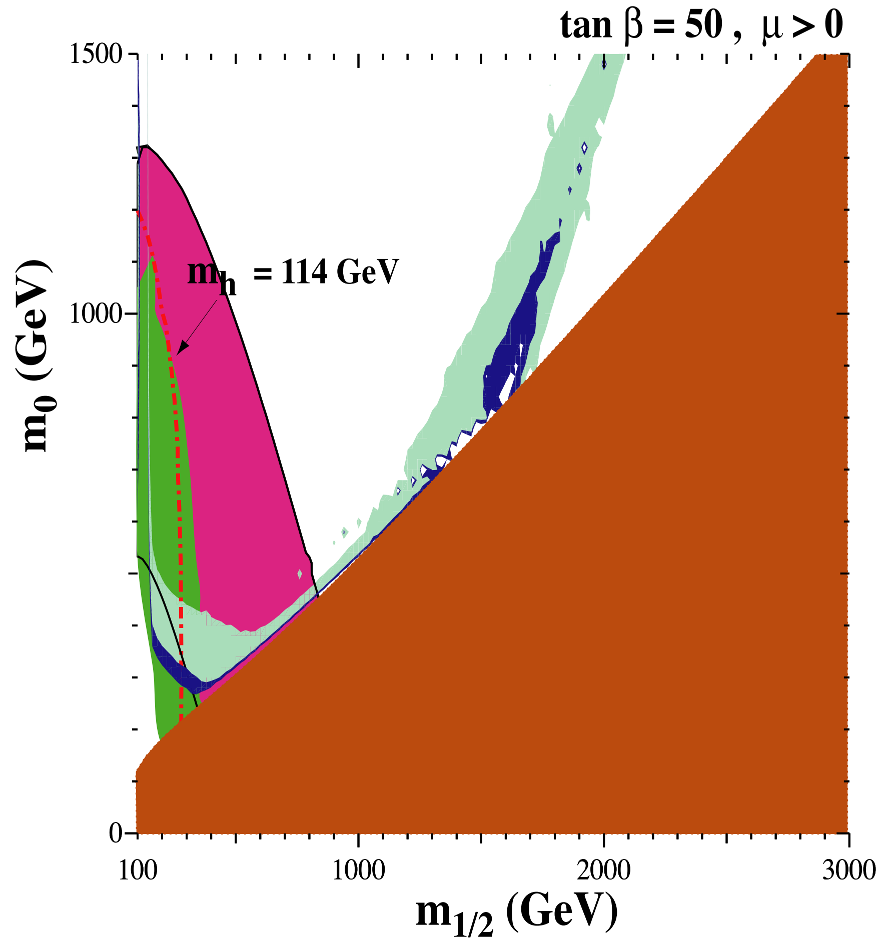
- WMAP $\Omega_{DM} h_0^2 = 0.1126^{+0.0161}_{-0.0181}$
- $g-2$ clouded by uncertainty in running of α_{QED}

Consider various data points in the CMSSM:

1. 'Focus point Region' $m_0 > 1$ TeV
2. Coannihilation region $M_{1/2} > 1$ TeV
3. Large $\tan\beta$ $M_{1/2}, m_0 > 1$ TeV

Allowed region is becoming fractal



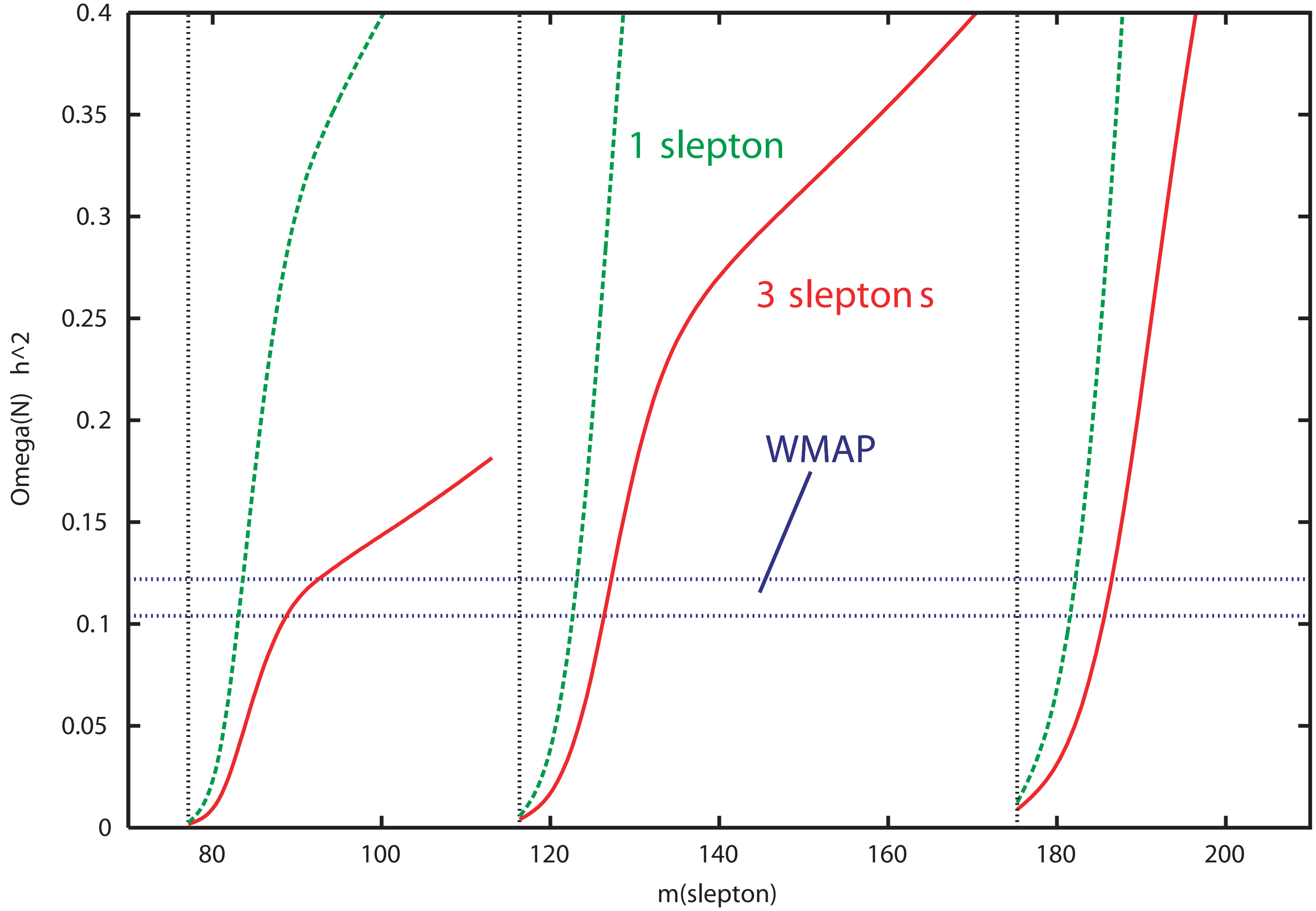


Blue: WMAP Allowed Brown: Theory forbidden Green: g-2 allowed

Purple: g-2 forbidden

Dark Matter and Precision Supersymmetry -Michael Peskin, Ee Hou Yong

Gaugino region for neutralino (MSUGRA)



WMAP makes a very precise prediction for $m_{slepton}$

At current WMAP precision Ωh^2 sensitive to

- 1 GeV in slepton mass
- 0.5 GeV in stau mass
- 100mrad in neutralino/chargino mixing angles...

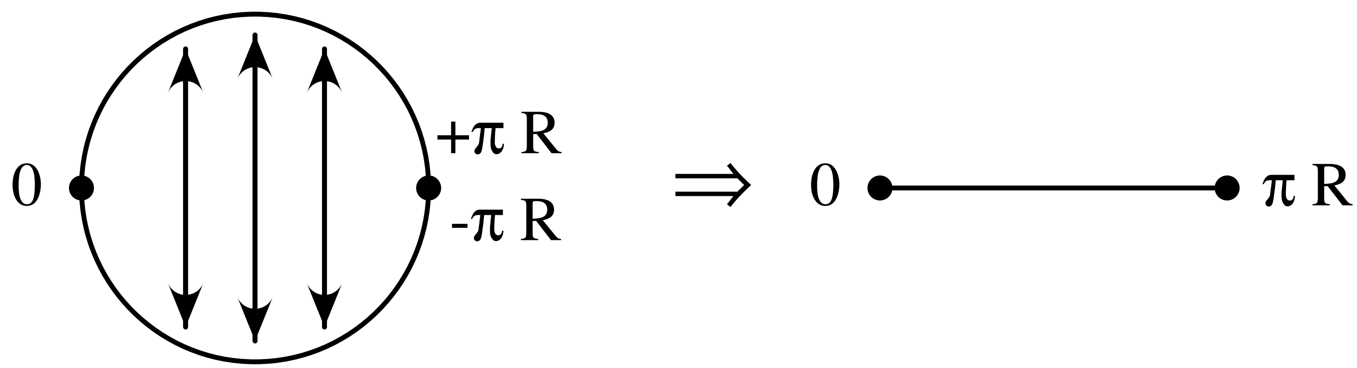
More studies to come ...

Dark matter candidates from extra dimensions –Tim Tait

• In Universal Extra Dimensions (UED) all particles live in extra dimensions

• Can have a stable lightest stable neutral KK state (LKP)

• Requires "Orbifold" geometry to avoid parity violation, etc.



• Explore parameter space for B^1_μ to be LKP

Relic Density