Discriminating Universal Extra Dimension from other new physics scenarios at the ILC.

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Based on:

Biplob Bhattacherjee and Anirban Kundu Physics Letters B 627, 127 (2005)

and

BB, Anirban Kundu, Santosh Kumar Rai, Sreerup Raychaudhuri, Physical Review D(2008)

Extra dimensions

- First motivated by Kaluza (1921) and Klein (1926) .
- Today motivation comes from string theory, which need a number of compactified EDs.
- Different models: Number of EDs, compactification manifold, and which particles can go into the bulk.
- In Universal Extra Dimension (UED) type models,all standard model particles are placed in the bulk.
- No need for branes.

Minimal UED model

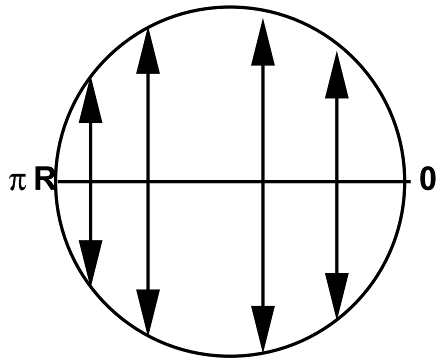
- Minimal UED : We consider a five-dimensional model (x^μ, y) (Appelquist, Cheng and Dobrescu, PRD 64, 035002, 2001)

  Radius of compactification

  ($R^{-1} \sim$ 300GeV and $\leq$ 900 GeV)

  Orbifolding: Necessary to get chiral fermions of the SM

  $y \equiv -y$ ($\mathcal{Z}_2$ symmetry)



  $y = 0, \pi R$ are *fixed points* under $\mathcal{Z}_2$

Dimensional reduction

- In 4D for each low mass(zero mode) SM particle we get an associated KK tower:equispaced ($\backsim$1/R)

  Mass of n-th level state is

  $$m_n^2 = m_0^2 + \frac{n^2}{R^2}$$

  n is the KK number

  Since m_0« $\frac{1}{R}$ so $m_n \simeq \frac{n}{R}$

- Mass degenerate spectrum
- Conservation of KK number:conservation of p_5

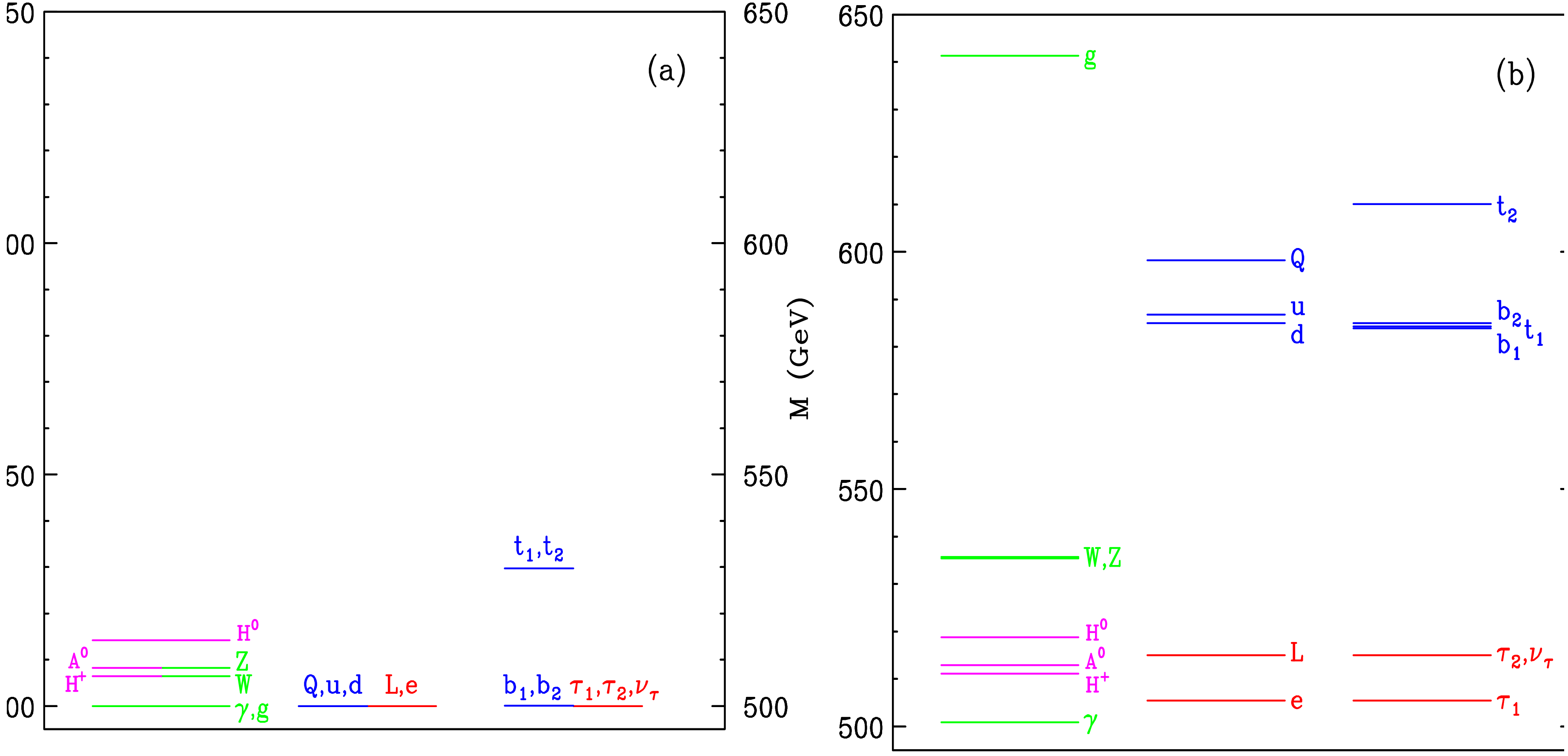
Radiative Corrections

- Tree level relation gets modified when radiative corrections are taken into account.
- Two types:

  a.Bulk Corrections : (breaking of Lorentz invariance)

  b.Orbifold Corrections :(breaking of translational invariance in 5th dim.)
- Boundary corrections break KK number down to KK Parity $(-1)^n$, which is conserved.
- Weinberg angle is $\sim$ 0 except for n=0
- $n = 1$ particles must be pair produced(Conservation of KK Parity) They cascade down to to γ_1 (LKP:D.M Candidate)

UED Spectrum(One loop corrected)



Taken from Cheng, Matchev, Schmaltz, PRD 66, 036005, 2002

SUSY Vs UED

- Collider signature of UED: Multijet + multilepton + Missing energy
- The signal can mimic SUSY at collider
- Difference
- Spins are different.
- (Spin measurement is difficult at the LHC)
- n=2,3 .... excited states
- Pair production of n=2 states are difficult at the LHC

n = 2 Gauge Boson

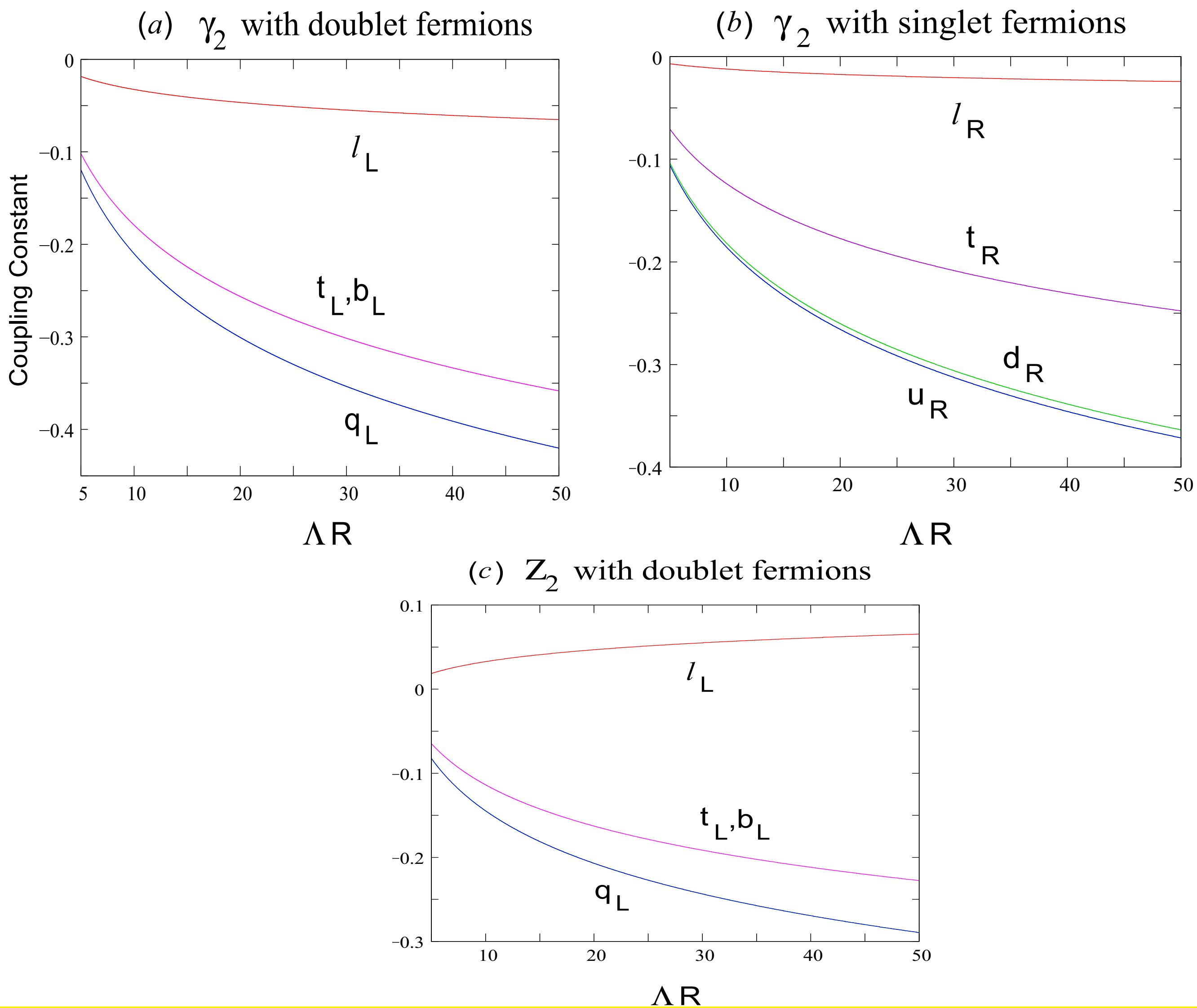
Bhattacherjee and Kundu, PLB 627, 137 (2005)

- $n = 2$ gauge bosons can be produced alone as s-channel resonances
- Need same energy to produce two $n = 1$ states or one $n = 2$ state
- The production goes through the coupling

$$(-ig\gamma^{\mu}T_a P_+)\,\frac{\sqrt{2}}{2}\left(\frac{\bar{\delta}(m_{V_2}^2)}{m_2^2} - 2\frac{\bar{\delta}(m_{f_2})}{m_2}\right)$$

where $m_2 = 2/R$, T_a is the group generator

Couplings


(a) γ_2 with doublet fermions
(b) γ_2 with singlet fermions
(c) Z_2 with doublet fermions
Coupling Constant
ΛR
l_L
t_L, b_L
q_L
l_R
t_R
d_R
u_R
0
−0.1
−0.2
−0.3
−0.4
0.1
5
10
20
30
40
50

Z_2/γ_2 Physics

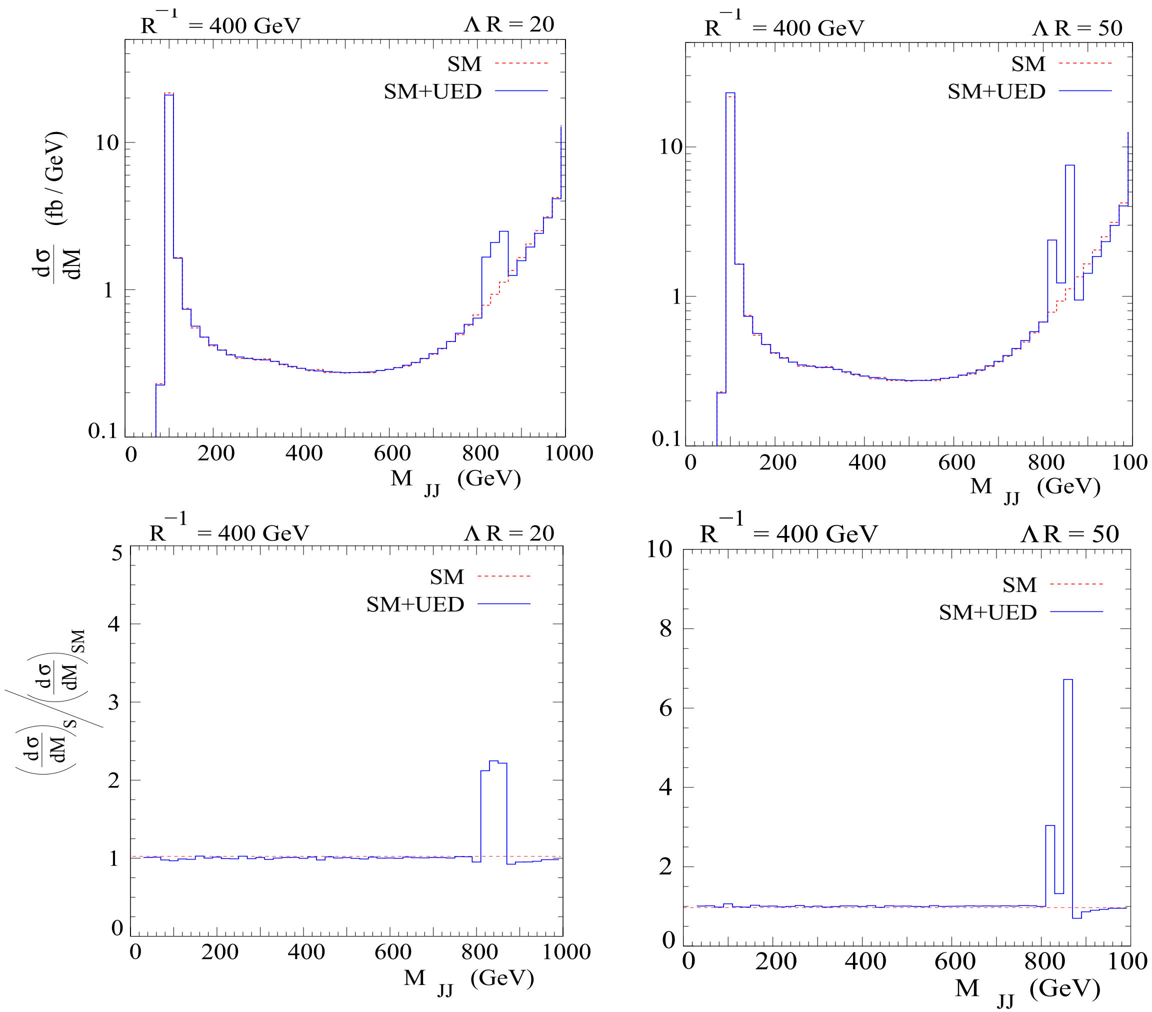
- Z_2 can decay to leptonic KK-conserving channels (kinematics) or KK-violating channels, but it is almost W_3, so couples only to doublets
- γ_2 can decay only through KK-number violating channels (two SM particles, no missing energy.)
- KK conserving and violating decays are equally important: either kinematic or phase-space suppression

Gauge Boson Decay (contd.)

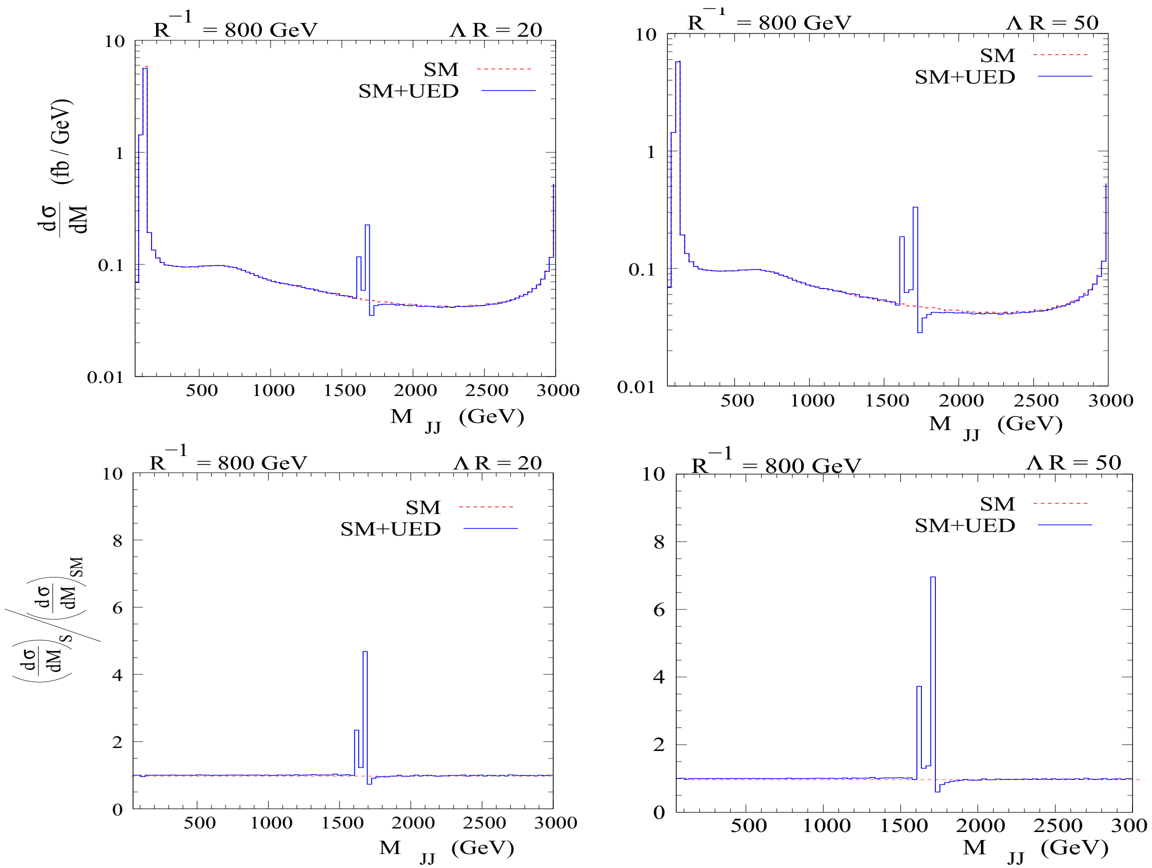
- Z_2 and γ_2 can be produced as s-channel resonances at the LHC/ILC
- Positions of these two peaks should give Λ and R and should completely determine the fermionic UED spectrum
- Study shows that LHC will find resonance in dilepton channel (Datta, Kong, Matchev, PRD72:096006,2005)
- Z_2 and γ_2 peaks may not be resolvable
- What is the status of Linear Collider?

Bump hunting at the ILC

Bhattacherjee,Rai,Raychaudhuri,Kundu PRD (2008)



Bump hunting at the CLIC



- Observation of a high-mass resonance, or a pair of such resonances=UED ?
- No

Other models

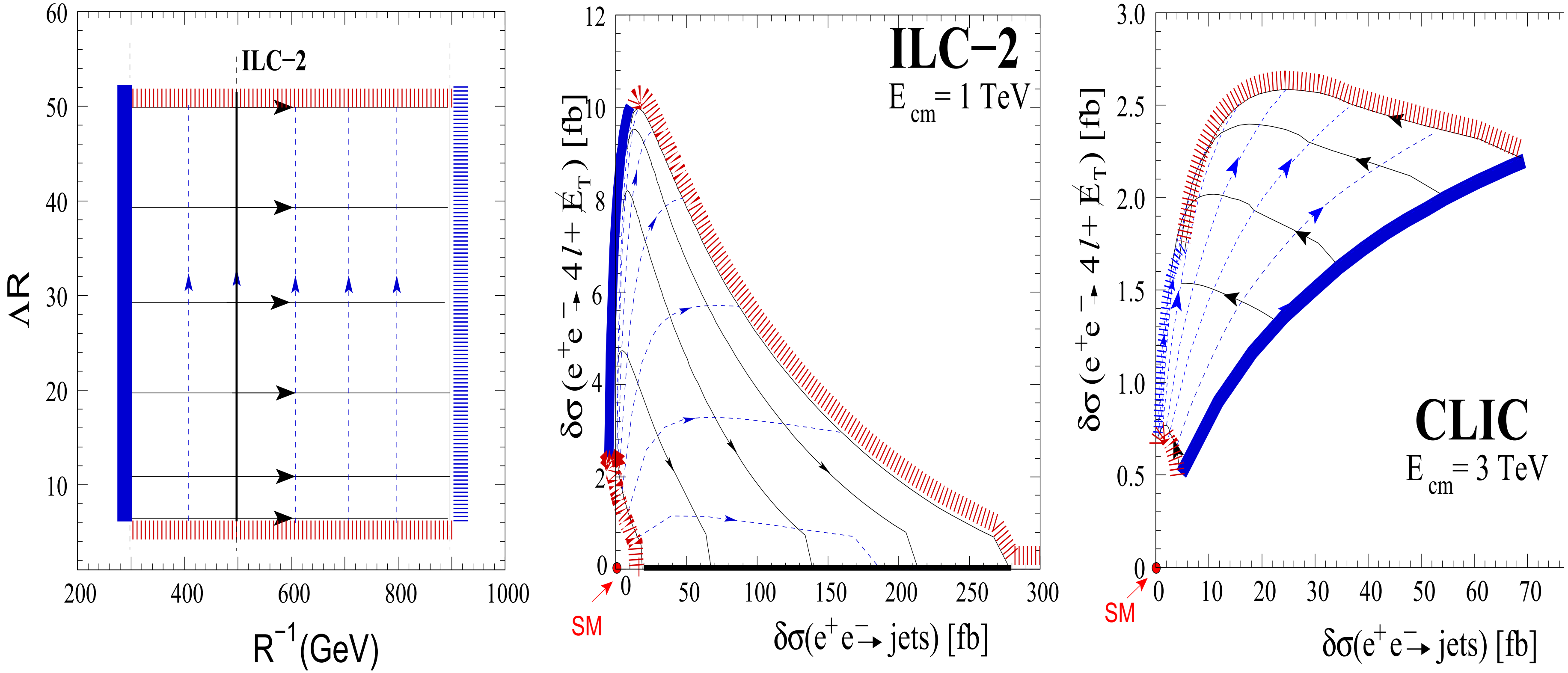
Possible source of a single bump:

- A resonant Z' boson, predicted in models with extra $U(1)$ symmetries.
- A heavy sneutrino $\widetilde{\nu}_\mu$ or $\widetilde{\nu}_\tau$ in a SUSY model with R-parity-violating couplings.
- A massive graviton G_1, predicted in the Randall-Sundrum model.

Other models

- Another Gold plated signal of UED: $4\ell + \not{E}_T$
- Possible source of $4\ell + \not{E}_T$:
- A pair of heavy Z' bosons, with an ordinary Z boson radiated from any of the fermion legs
- a pair of heavy $W'^{\pm}$ bosons, with an ordinary Z boson radiated from any of the fermion legs
- A pair of heavy neutralinos $\widetilde{\chi}_i^0 \widetilde{\chi}_j^0$ $(i, j > 1)$, each of which decays as $\widetilde{\chi}_i^0 \to \ell \widetilde{\ell} \to \ell(\ell \widetilde{\chi}_1^0)$ (irreducible)

Correlation plot:UED



Summary

- There is no ‘smoking gun’ signal of UED.
- the simple two-dimensional signature space with at most, a spin measurement added, would be more-or-less sufficient to identify an underlying UED model
- Moreover, we have chosen two final states, viz., dijets and 4ℓ plus missing p_T, for which data will certainly be collected and stored at any high energy e^+e^- machine.

Thank You