

Randall - Sundrum Warped Extra Dimensions at Linear Colliders



- Basics (thanks, Hooman!!)
- SM on the Brane { below or above threshold?
Contact int's or resonances?
- SM peeled off the Brane { The bulk gets crowded }
- Summary + comparison with ADD/LED scenario

Based on work

in



Devoudiasl, Hewett + R.

PRL 84, 2080 (2000)

PLB 473, 43 (2000)

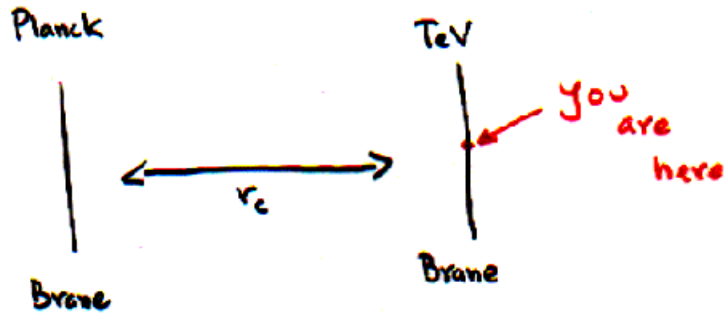
hep-ph/0006041 (PRD)

hep-ph/0006097 (PLB)

hep-ph/0010066

TCR1260
LCWS2000
10/2000

Basics:
(on the wall)



$$\bar{M}_{Pl}^2 = M_{SD}^3 / k$$

* $kr_c \approx 11-12$ to solve hierarchy problem

$$\Lambda_\pi = \bar{M}_{Pl} e^{-\pi kr_c}$$

$$m_n [C^{(n)}] = x_n k e^{-\pi kr_c} \quad w/ \quad J_1(x_n) = 0$$

$$\mathcal{L} = - \left\{ \frac{1}{\bar{M}_{Pl}} h_{\mu\nu}^{(0)} + \frac{1}{\Lambda_\pi} \sum_n h_{\mu\nu}^{(n)} \right\} T^{\mu\nu}$$

\Rightarrow fix m_i and $c \equiv k/\bar{M}_{Pl}$ ^{††} + all other parameters known

Off the Wall

• \square more parameter $v : \sim O(1)$

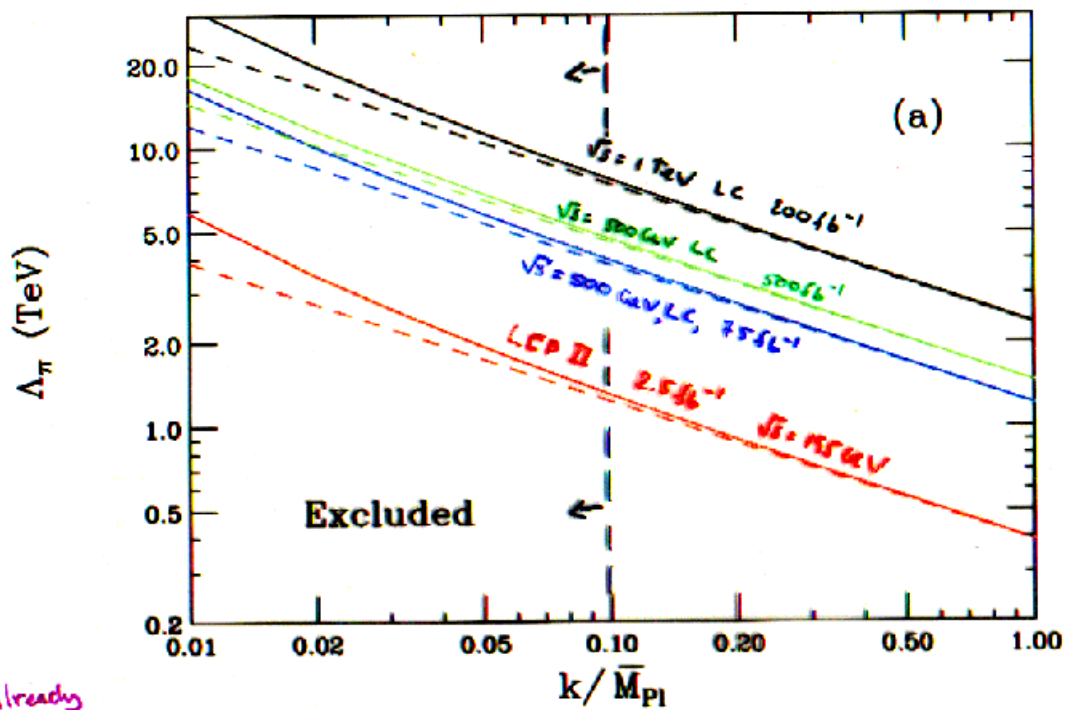
Common fermion mass parameter (~~F/NC~~)

\Rightarrow everything fixed - not bad!

†† c cannot be too small \rightarrow hierarchy again $2 \cdot 10^{-2}$ **BUT**

c cannot be too large Curvature constraint [?] $c \leq 1$?

CI Constraints on Randall-Sundrum Model



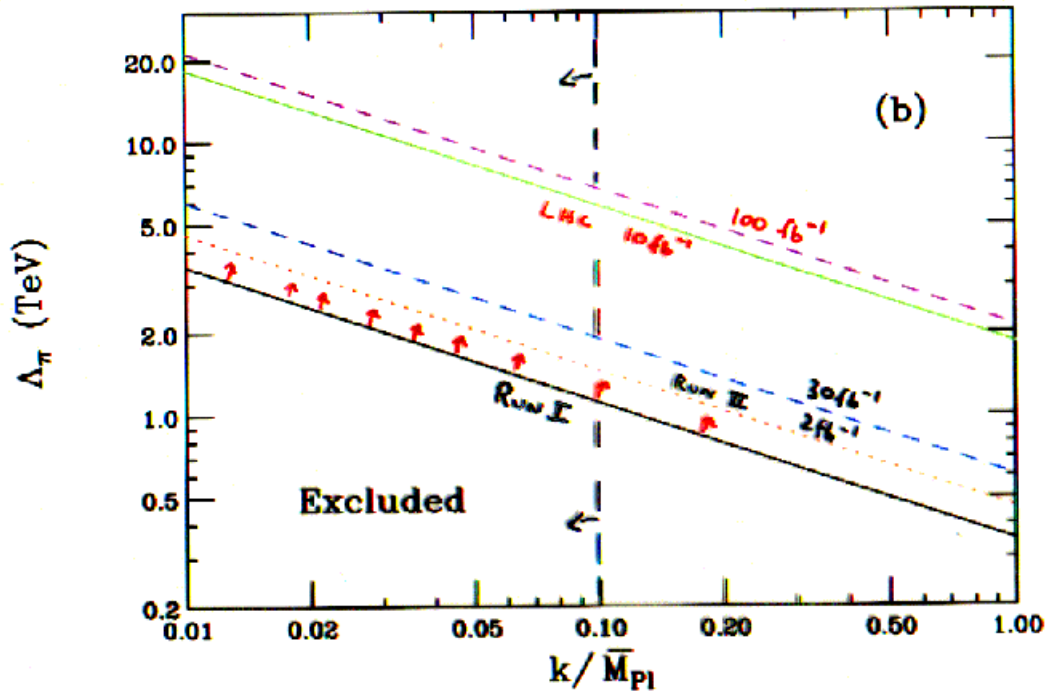
Already

k/\bar{M}_{Pl} much smaller than 10^{-2}

looks bad for hierarchy problem solution...

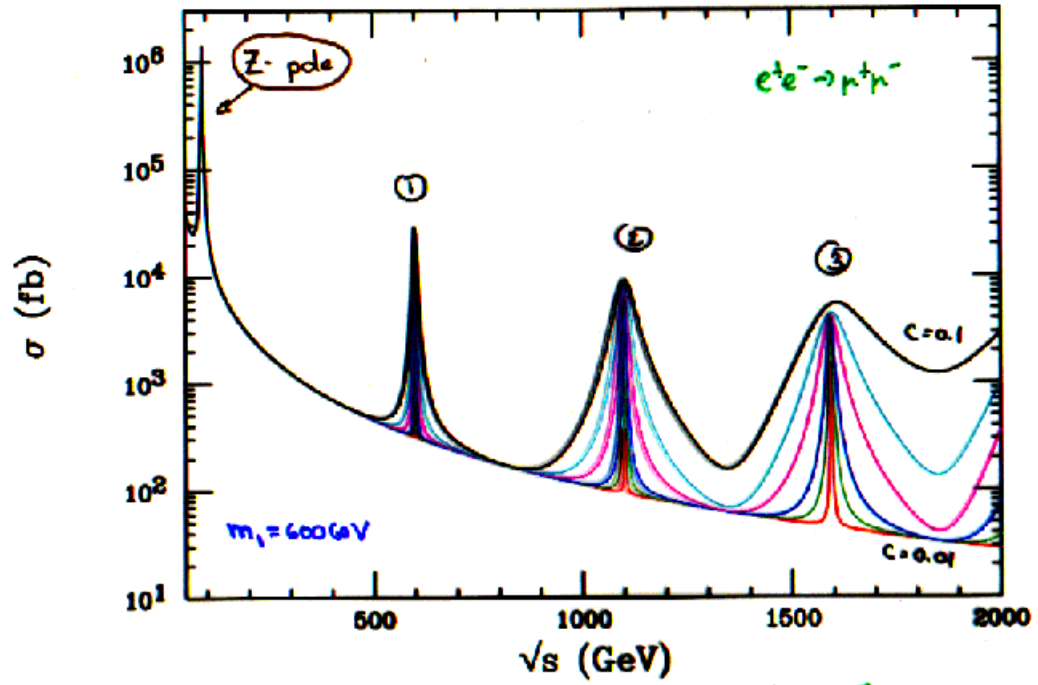
Contact Interactions

CI Constraints on Randall-Sundrum Model



At some point identifying Δ_{π} as not the weak scale
→ another hierarchy

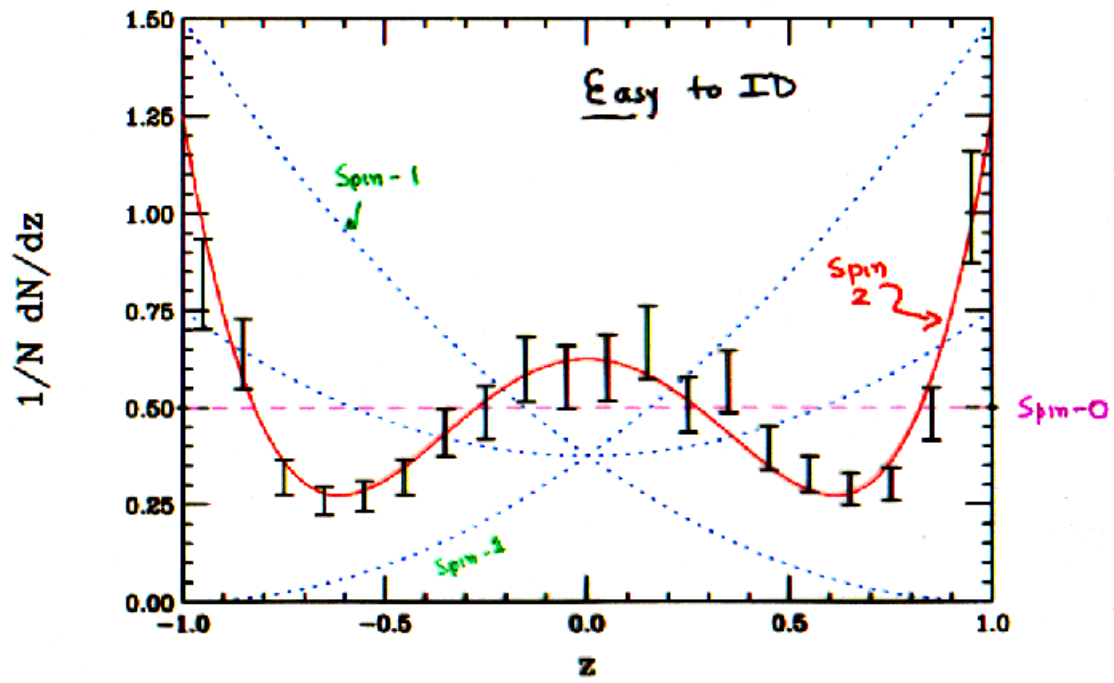
Graviton resonances at LC



Not Equally Spaced

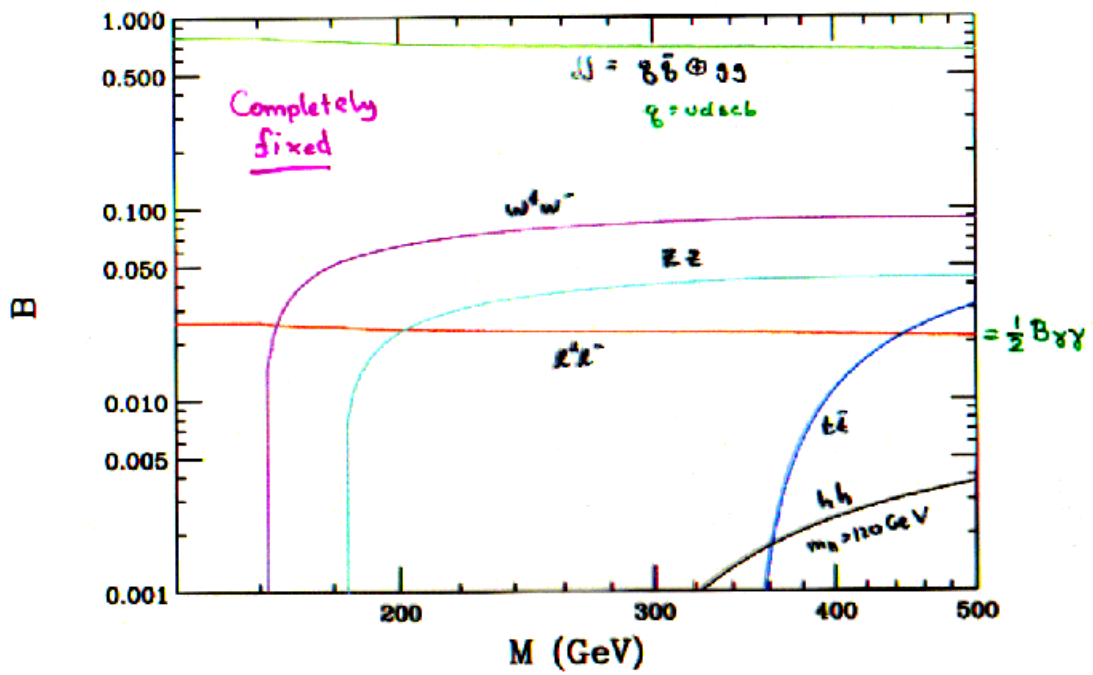
Γ increases with both c and m_n

$f\bar{f} \rightarrow f's'$ on a graviton resonance



SM on wall

RS Graviton branching fractions

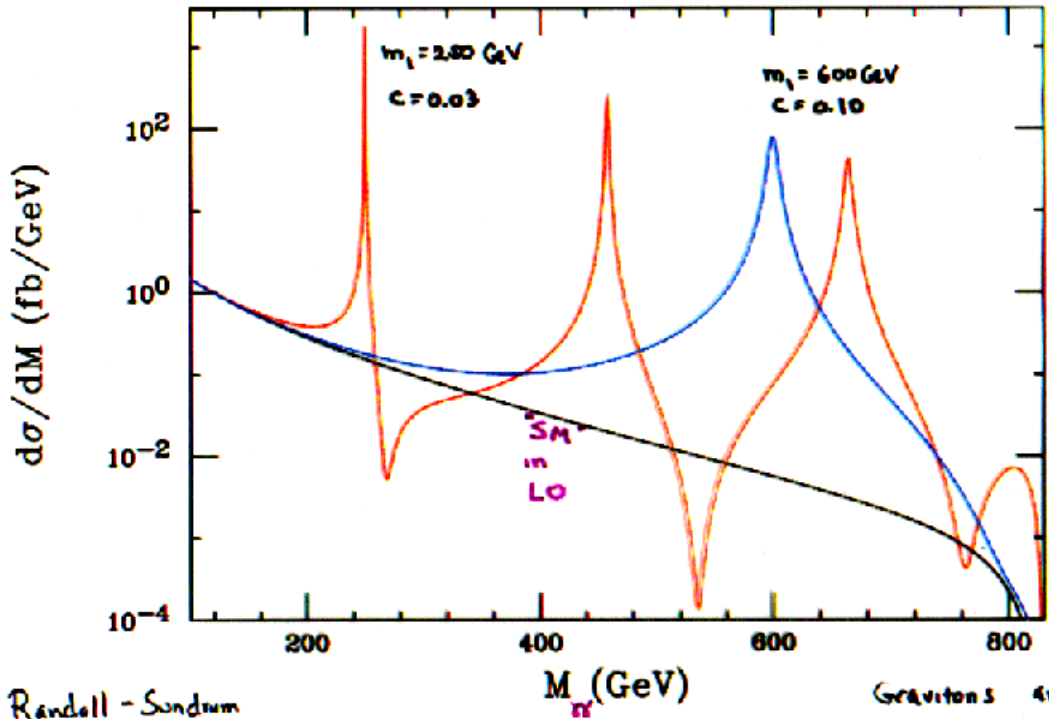


$\rightarrow B_{\gamma\gamma} = 2 B_{\nu^i\nu^j}$

1st graviton mass

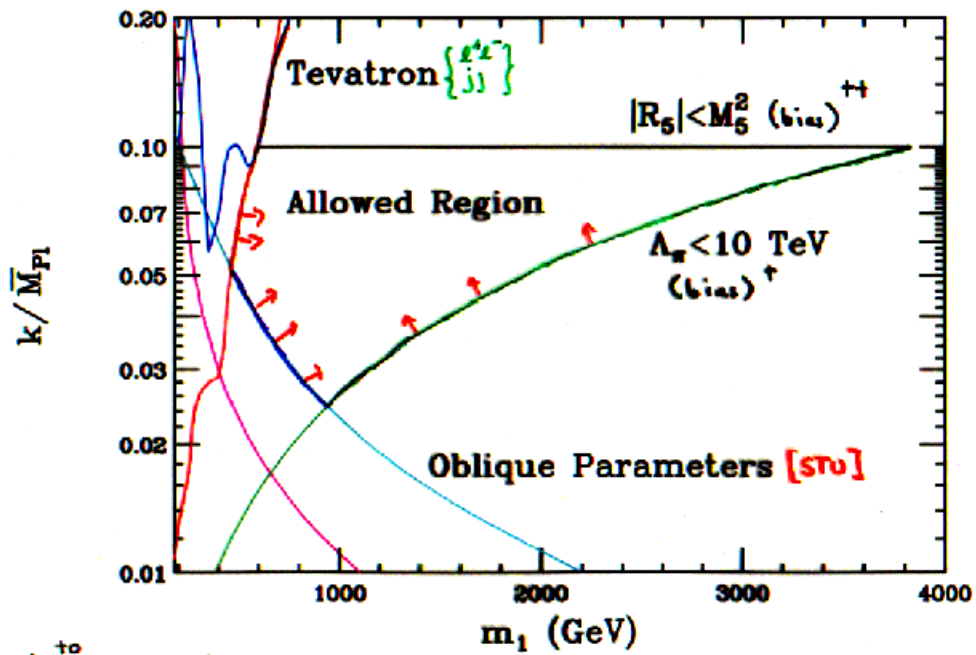
$\sqrt{s} = 1 \text{ TeV}$

$\gamma\gamma \rightarrow b\bar{b}$



Randall-Sundrum
model

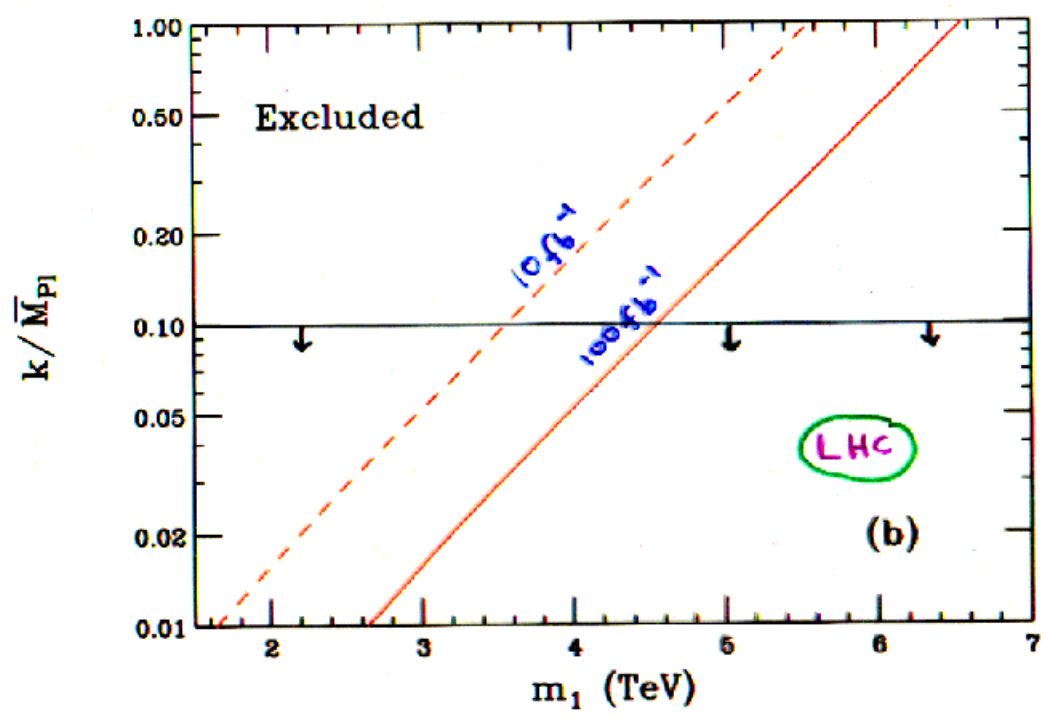
Gravitons are
everywhere!



† solve ^{to} hierarchy problem

†† no higher order curvature: ^{unless} Gauss-Bonnet (K₁₀₀, K₄₀₀ + Long) $R^2 - 4R_{AB}R^{AB} + R_{ABCD}R^{ABCD}$

Drell-Yan Constraints on Randall-Sundrum Model



- SM off the wall : gauges only ? NO!

$$g^{(n)} / g^{(10)} = \sqrt{2\pi k r_c} \approx 8 !! \quad \text{Strong coupling!}$$

[SM]

Tower exchanges alter precision EWK data !!

∴ must be heavy [V analysis, ^{Rizzo + Wells}]

$$\Rightarrow m_1^{\text{gauge}} \gtrsim 25 \text{ TeV} \rightarrow M_1^{\text{grav}} \gtrsim 40 \text{ TeV}$$

$$\Rightarrow \Lambda_{\pi} \gtrsim 100 \text{ TeV} \quad \text{too far from weak scale}$$

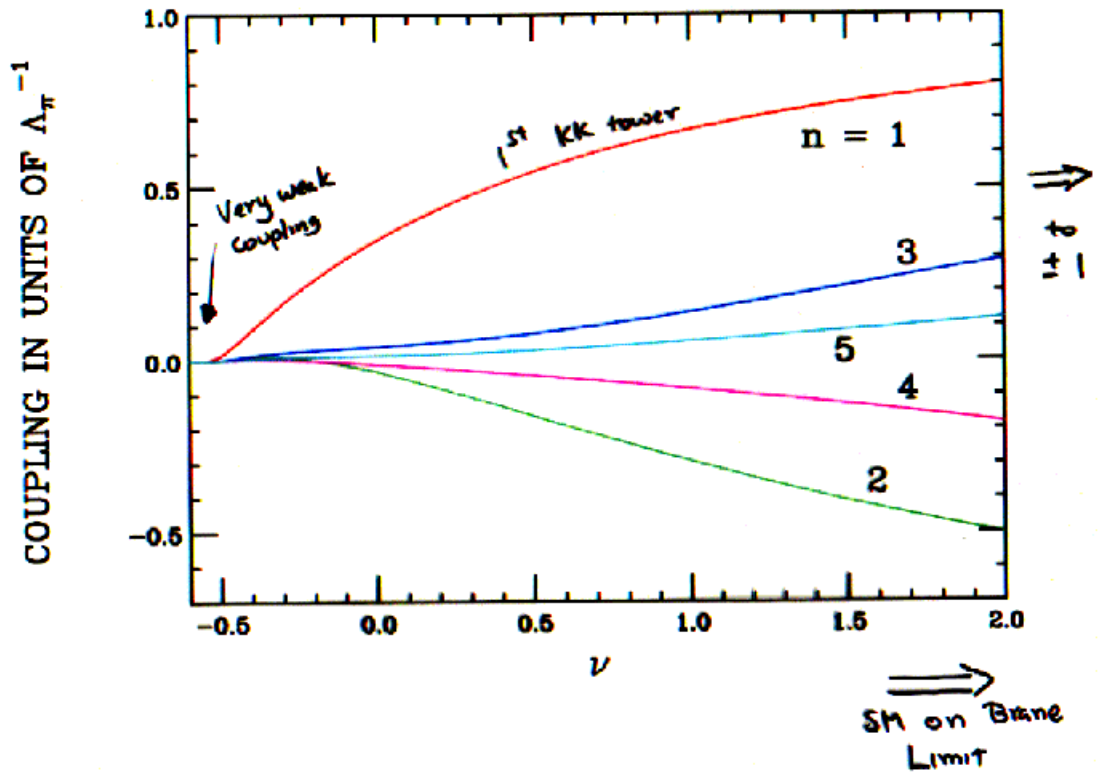
- Fermions ⊕ Gauges in Bulk : weaker bound for some range of v WHY?

⇒ { Graviton + Gauge couplings of fermions now depend on v ...

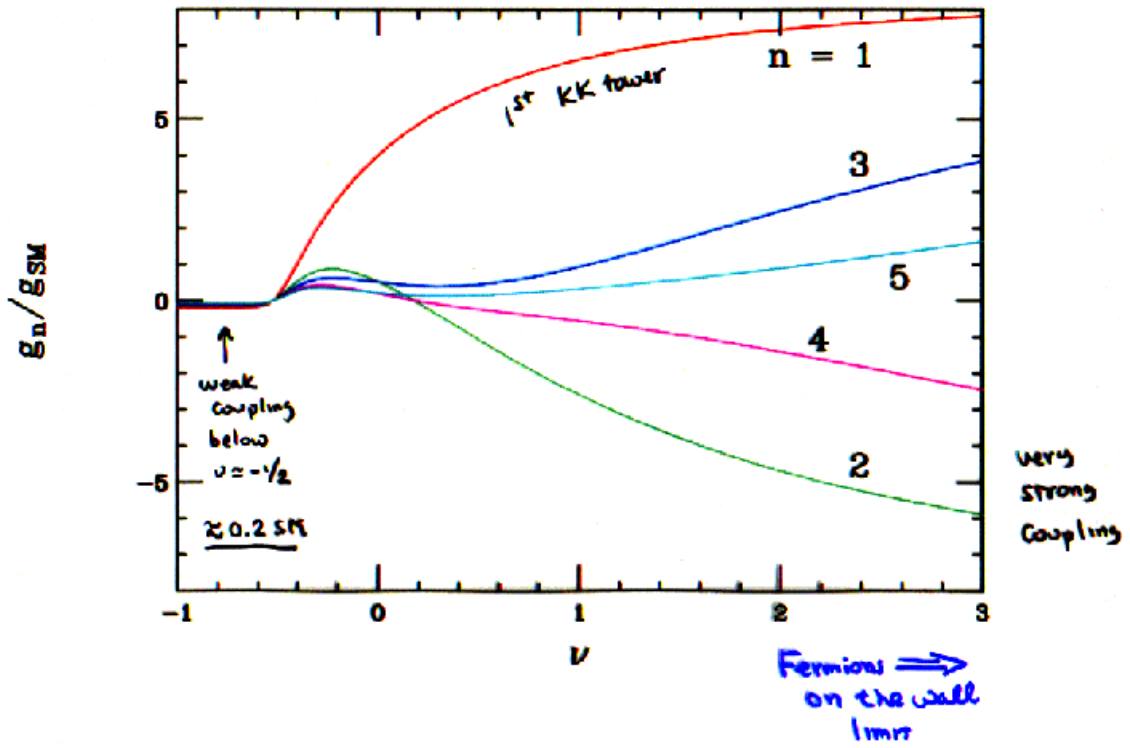
- For 'large' v we recover "fermions on the wall" limit, ...

{ Grossman + Neubert
Gherghetta + Pomarol
⋮

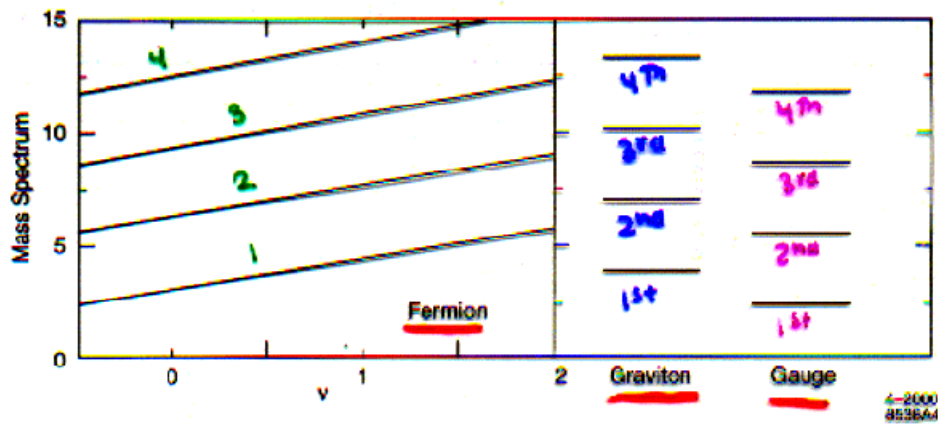
Graviton Coupling to fermions



Gauge TOWER to fermion coupling strength



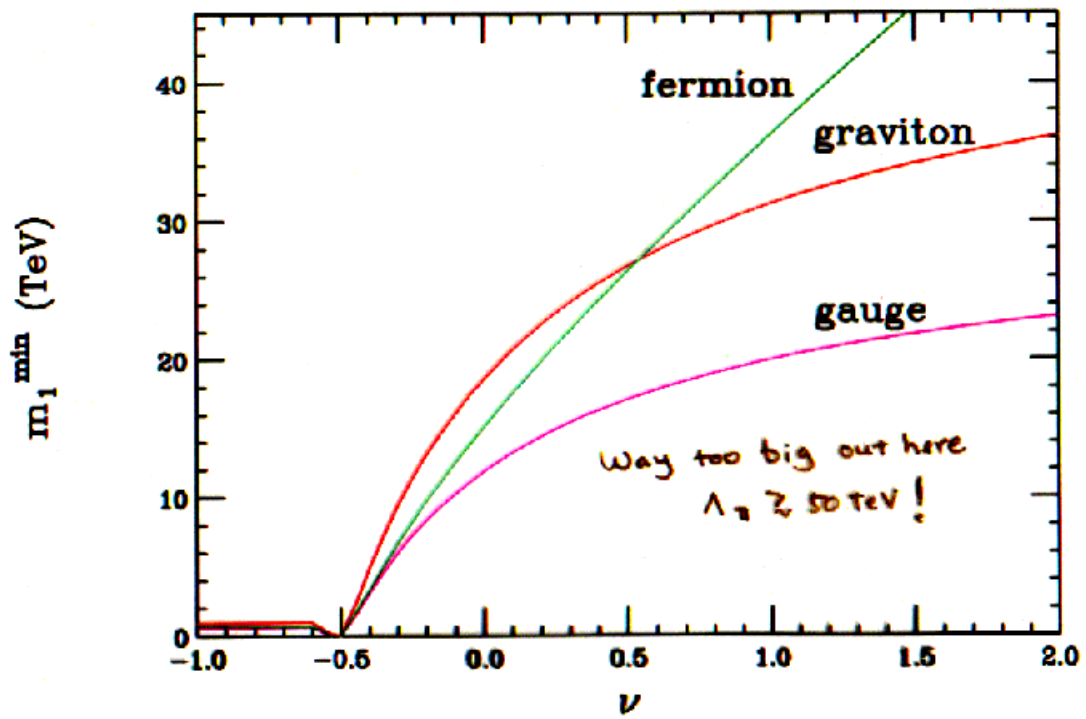
KK Fermion Masses, relative to gravitons +
gauges are ν dependent....



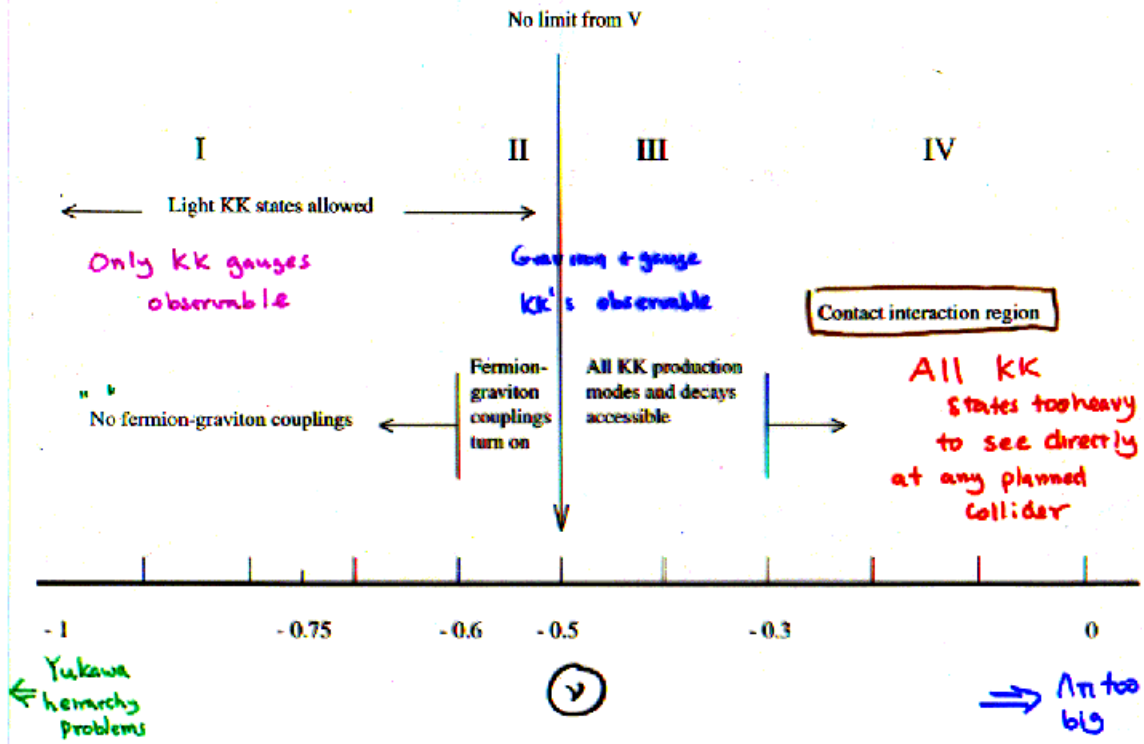
$$m_n^f \approx A_n |\nu + 1/2| + B_n$$

For a fixed ν , specifying any one mass
gives all others !!

Precision Measurements Bound on Masses

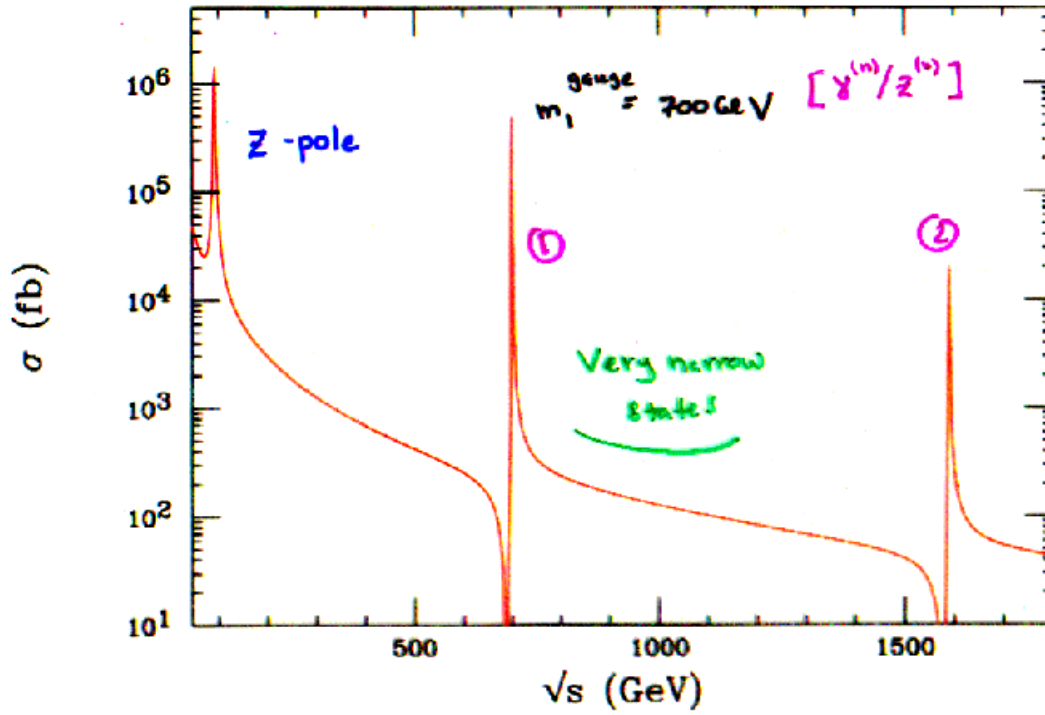


NLC probes all regions



$e^+e^- \rightarrow \mu^+\mu^-$

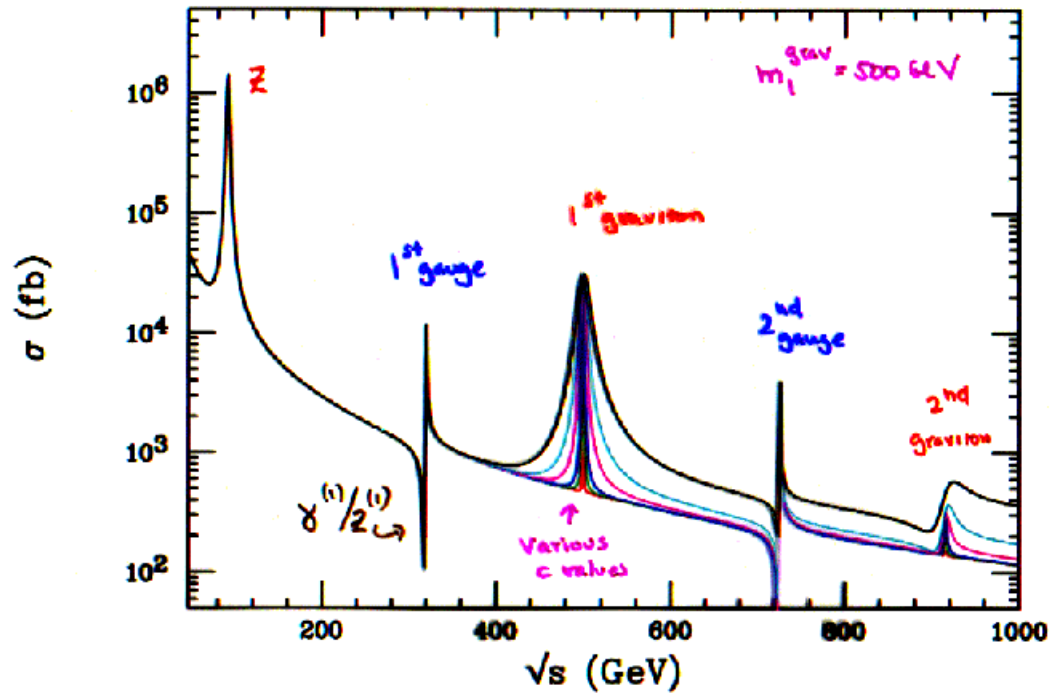
Region I



No graviton resonances BUT there are very narrow gauge KK's

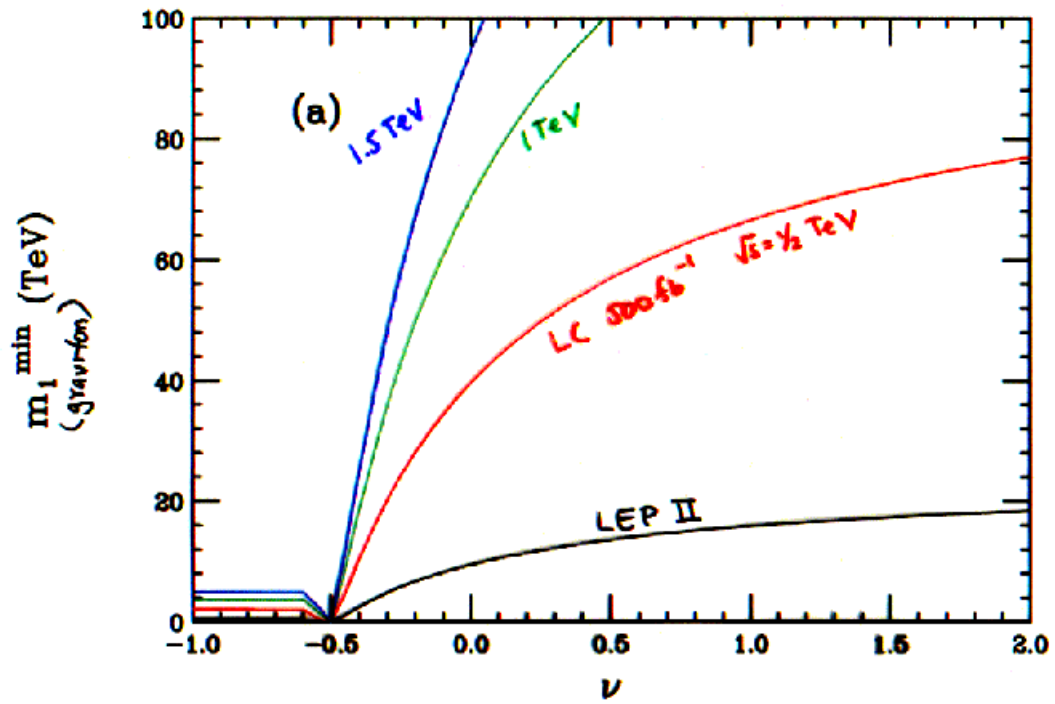
$e^+e^- \rightarrow \mu^+\mu^- e LE$

$\nu \approx -0.45$



Regions II + III

LC Contact Int. reach { gauge + graviton }



Region IV

Comparisons

ADD/LED

Deviations from
Newton's Law
at $\sim 100 \mu\text{m}$?

Yes, if $n=2$
otherwise not

Astrophysical
Constraints?

Strong if $n=2$
otherwise not
[Supernovae]

Missing E
signals at
colliders?

Yes

New dim-8
operators from
virtual gravitons
?

Yes

Graviton
Resonances?

No

SM in
Bulk?

No, unless
 $n > 2$ and some
dims are TeV
scale

RS/WED

No

model Dependent
[Cosmic Rays]

No

Yes, if
below threshold

Yes

Yes

Conclusions :

- LC's can probe important aspects of RS model whether or not SM is on the wall
- Production of BOTH graviton + gauge KK resonances would be extremely interesting...