Experimental Signatures of the Randall-Sundrum model *

(On and Off the Wall!)

- Basics + on the wall SM
- Peeling the SM off the wall:
  - Gauge fields in bulk
  - Fermions + Gauge fields in bulk
  - Higgs ?
- Conclusions

* Davoudiasl, Hewett + R. (DHR)

PRL 84, 2080 (2000)
PLB B473, 43 (2000)
+ to appear

TeV1220
LBL
3/00

Basics w/ SM on the wall:

$$\mathcal{L} = -\frac{1}{\bar{M}_{Pl}} h^{(0)}_{\mu\nu} T^{\mu\nu} - \frac{1}{\Lambda_\pi} \sum_{n>0} h^{(n)}_{\mu\nu} T^{\mu\nu}$$

- $\Lambda_\pi \equiv \bar{M}_{Pl} e^{-kr_c\pi} \sim$ TeV
- $m_n = k x_n e^{-kr_c\pi}$: $J_1(x_n) = 0$

  $\approx O(100\text{'s})$ GeV $\Rightarrow$ <u>resonances</u> if enough $\sqrt{s}$ available

- "5D curvature" less than 5D Planck scale† <u>suggests</u> $c \equiv k/\bar{M}_{Pl} \lesssim 0.1$

- Below resonance production $\rightarrow$ Contact int's

$\Rightarrow$

- Higher energies: study <u>resonances</u>

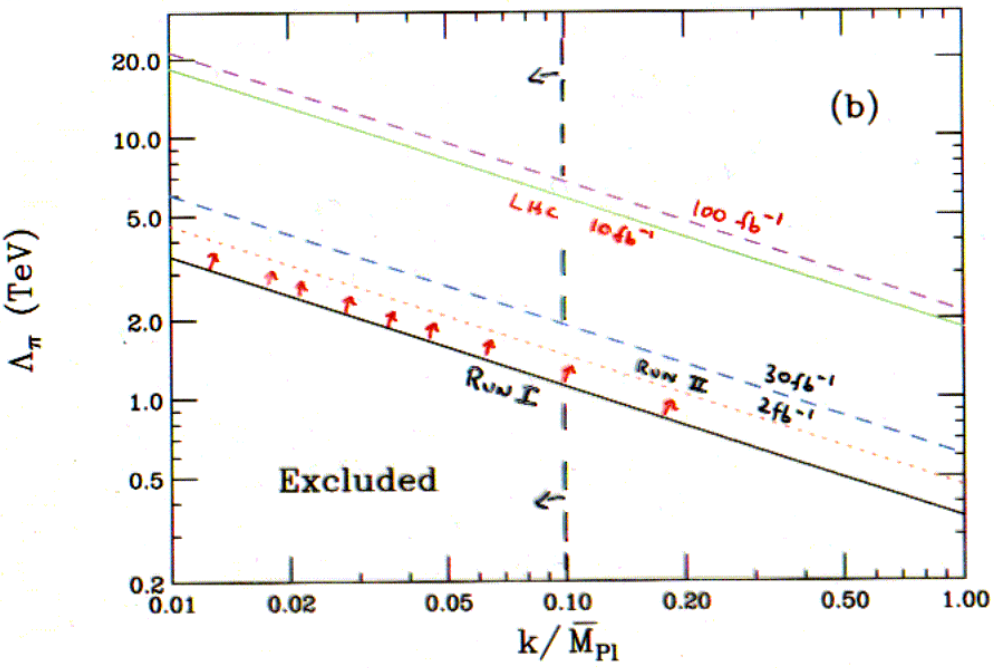
$\Rightarrow$

$\Rightarrow$ Two free parameters: (m_1, c) <u>or</u> (Λ_π, c)

† See, however, Kim, Kyae + Lee hep-ph/9912344

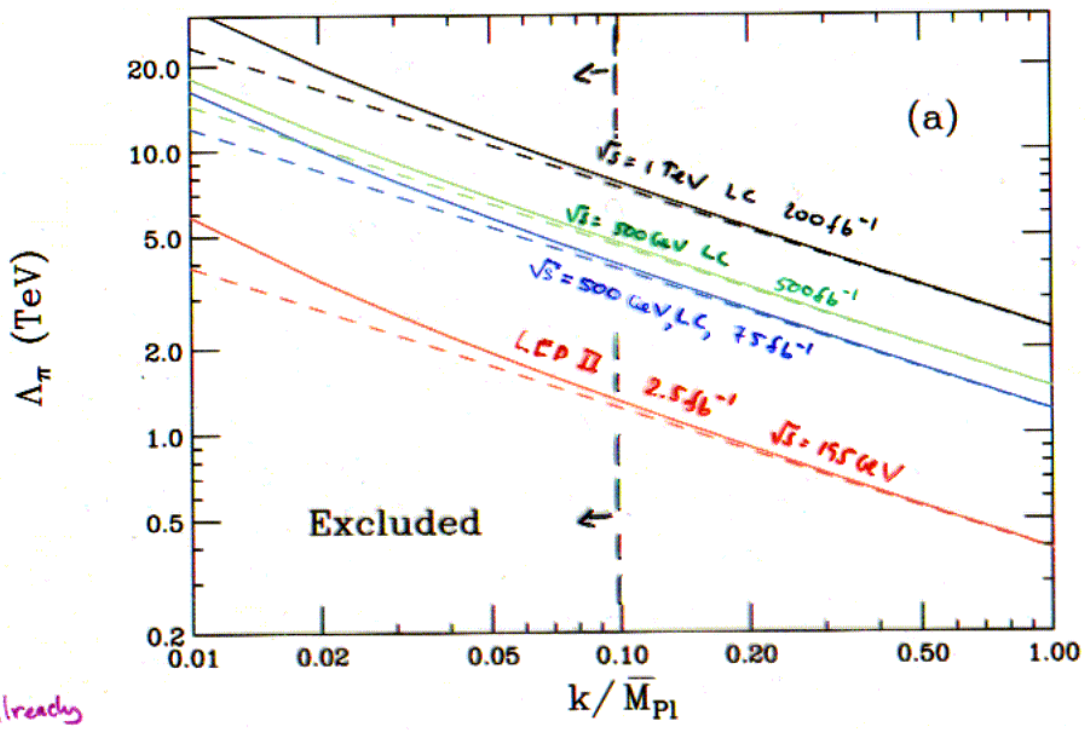
Contact Interactions

CI Constraints on Randall-Sundrum Model



At some point identifying Λ_π as not the weak scale
→ another hierarchy

CI Constraints on Randall-Sundrum Model

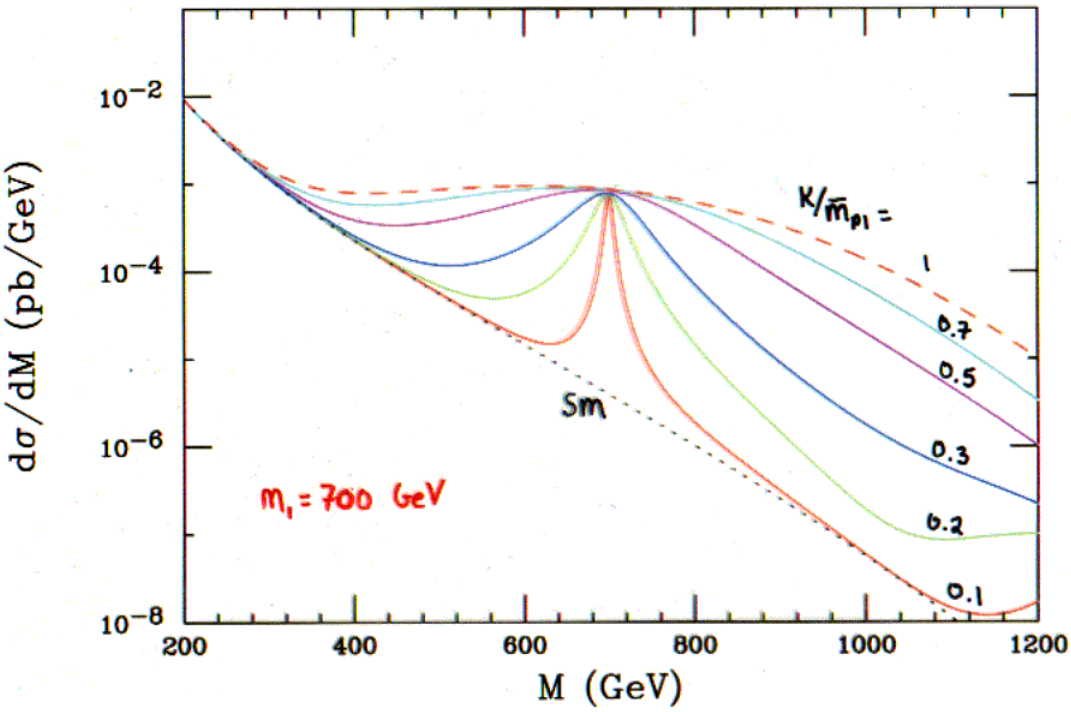


Already

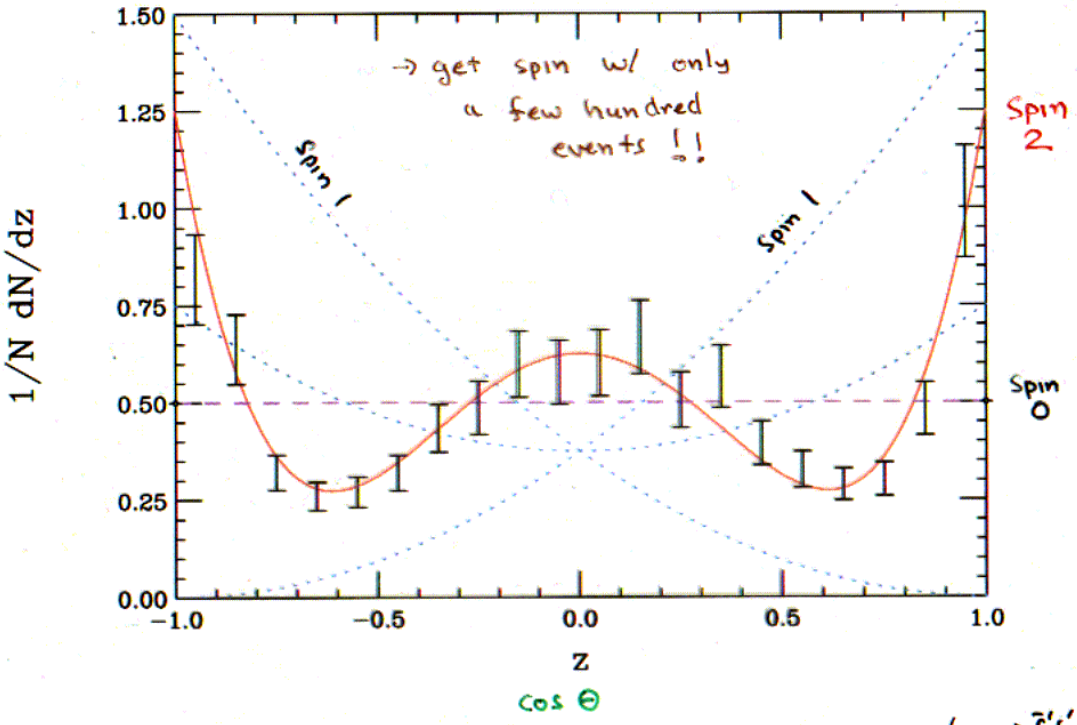
$k/\bar{M}_{Pl}$ much smaller than 10^{-2}

looks bad for hierarchy problem solution...

Drell-Yan Spectrum : Tevatron

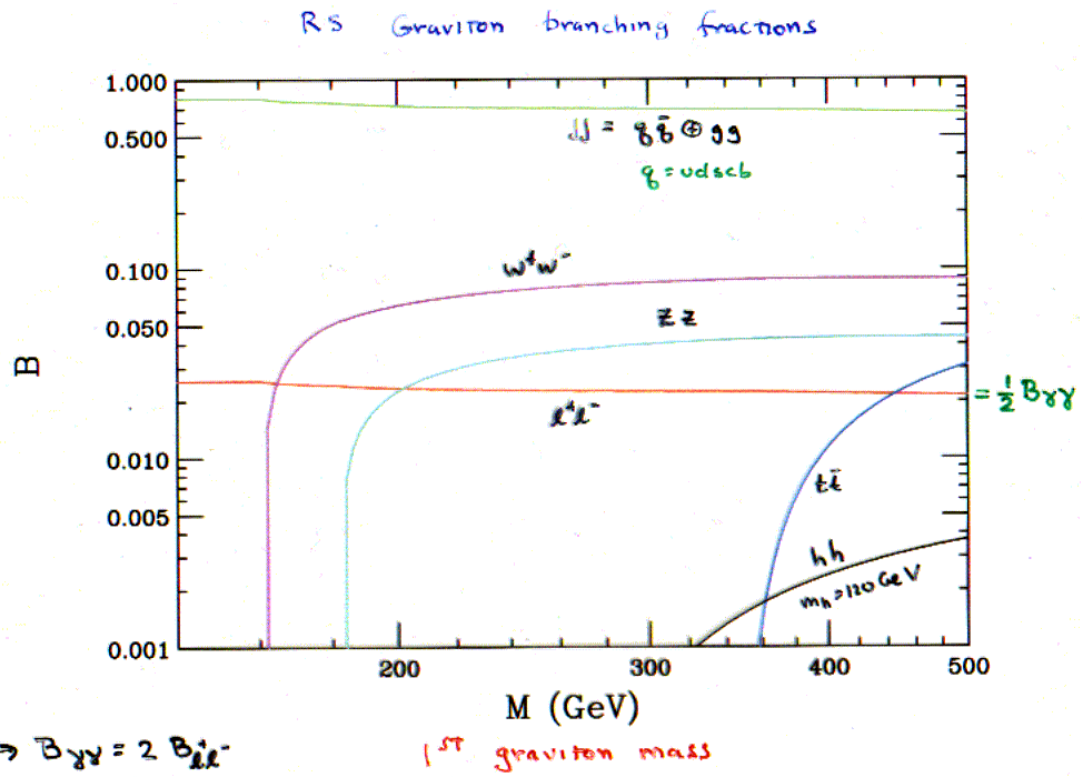


$f\bar{f} \to f'\bar{f}'$ on Graviton resonance



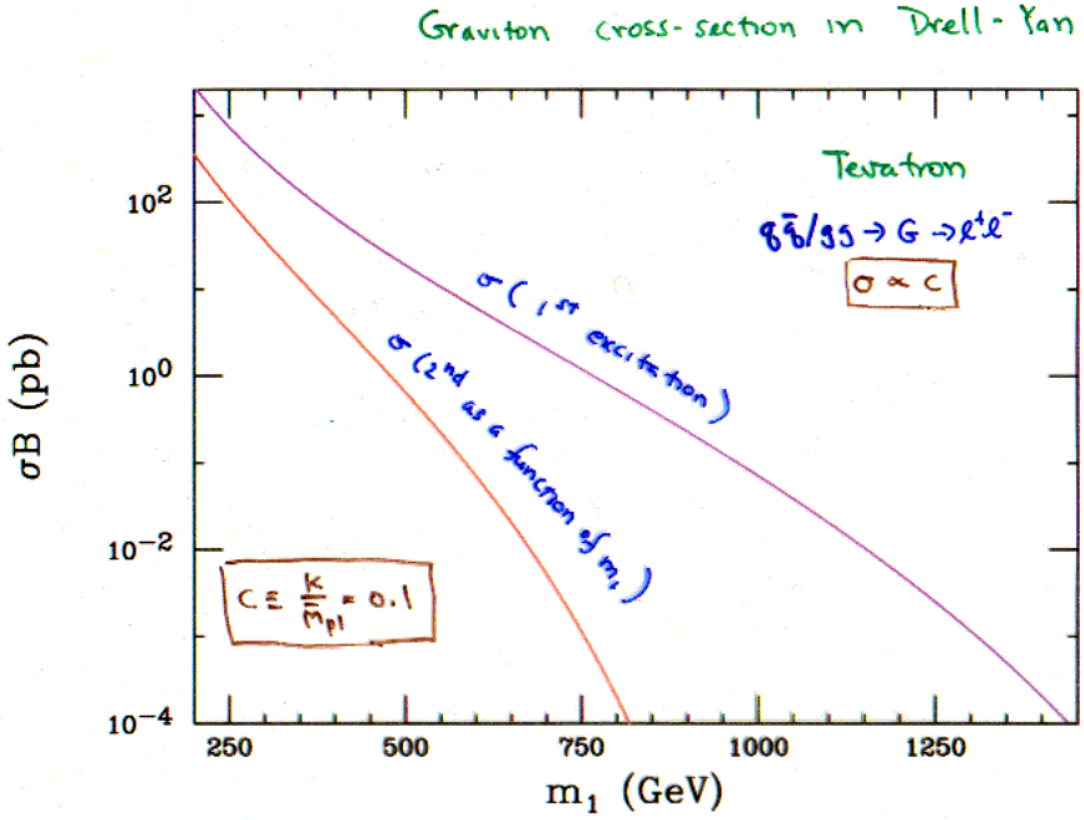
$(gg \to \bar{f}'f'$ (contamination?)

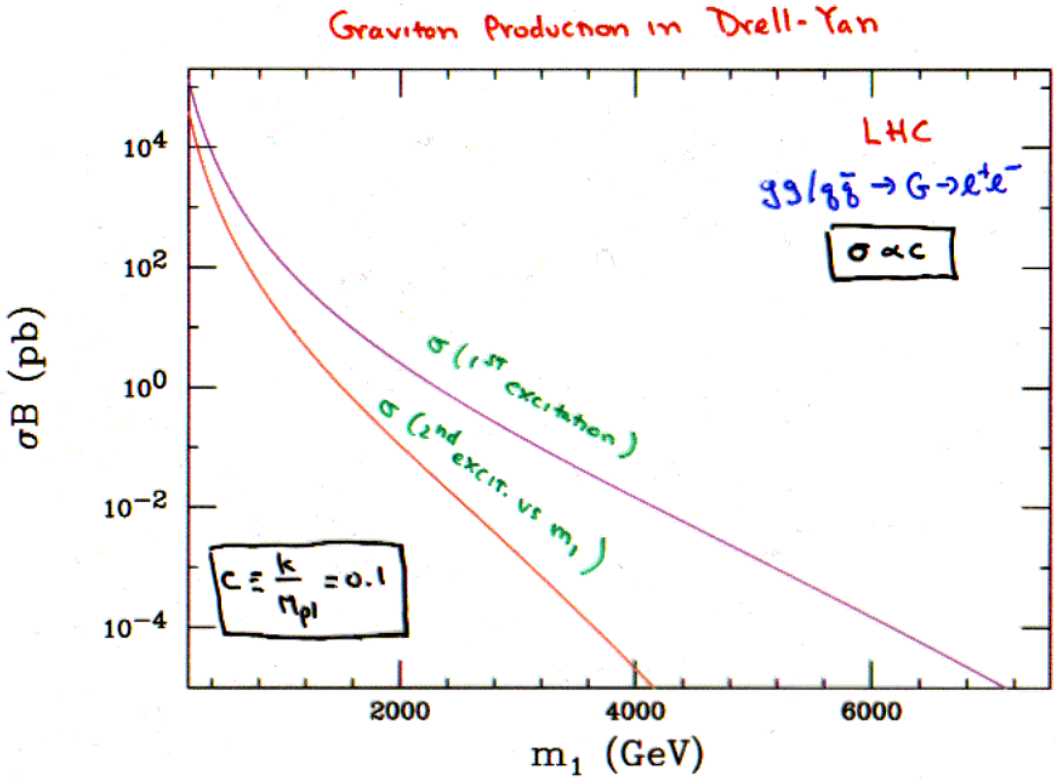
SM on wall



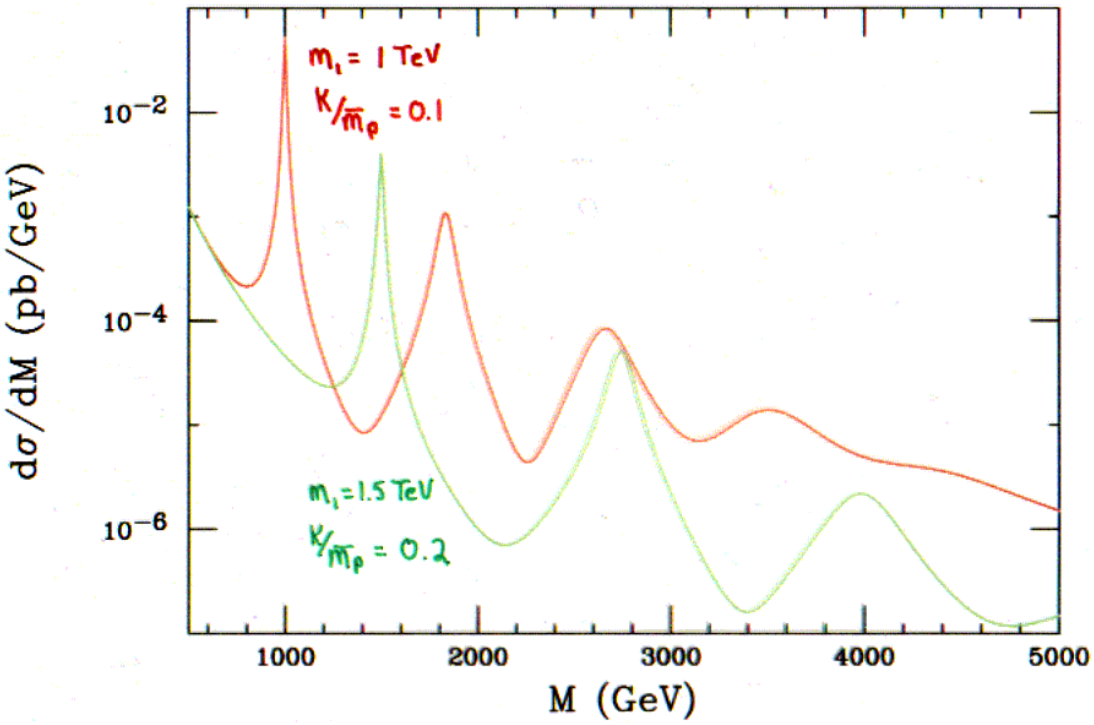
→ $B_{\gamma\gamma} = 2\, B_{\ell\ell}$

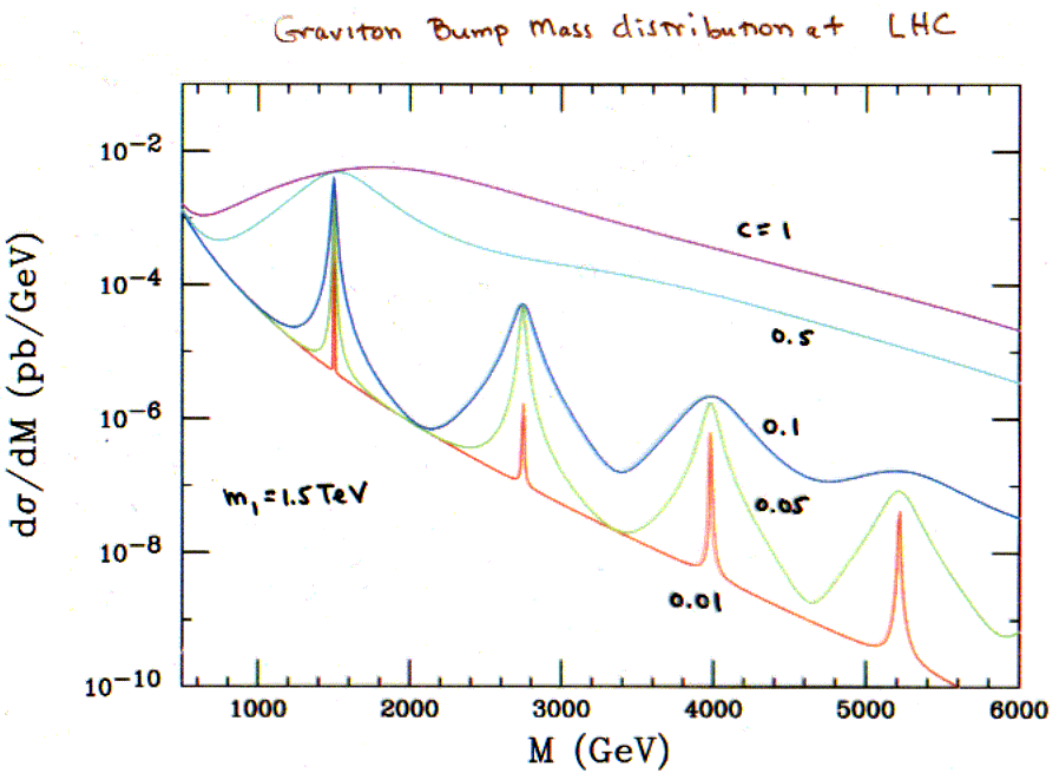
1st graviton mass


Graviton cross-section in Drell-Yan
Tevatron
$q\bar{q}/gg \to G \to \ell^+\ell^-$
$\sigma \propto c$
σ (1st excitation)
σ (2nd as a function of m_1)
$c \equiv \frac{k}{\bar{m}_{pl}} = 0.1$
σB (pb)
10^2
10^0
10^{-2}
10^{-4}
250
500
750
1000
1250
m_1 (GeV)


Graviton Production in Drell-Yan
LHC
$gg/q\bar{q} \to G \to \ell^+\ell^-$
$\sigma \propto c$
σ (1st excitation)
σ (2nd excit. vs m_1)
$c = \frac{k}{m_{pl}} = 0.1$
10^4
10^2
10^0
10^{-2}
10^{-4}
σB (pb)
2000
4000
6000
m_1 (GeV)

KK Spectrum at LHC



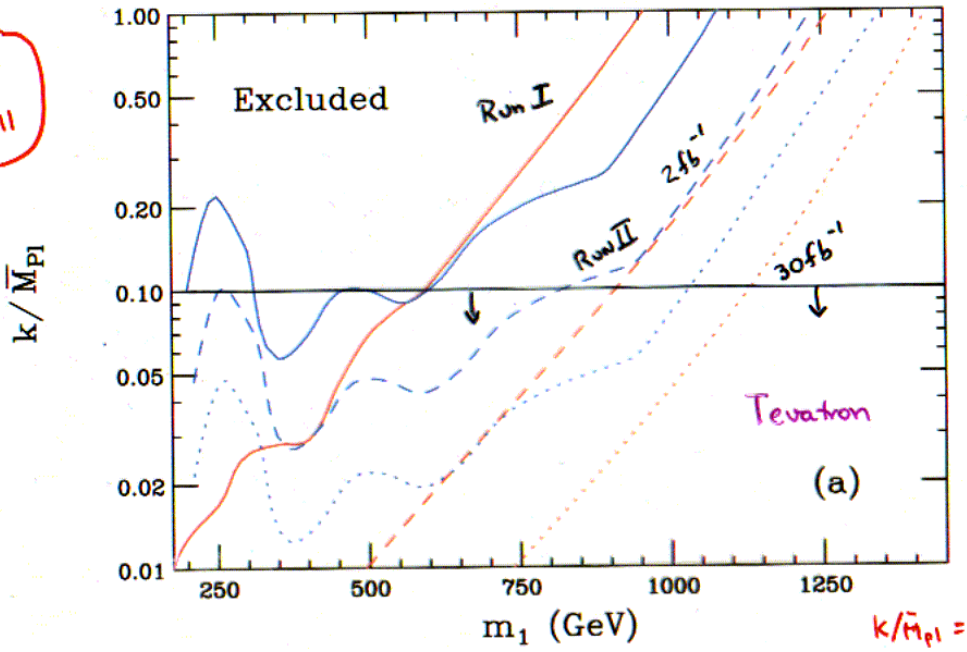

Graviton Bump Mass distribution at LHC
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
dσ/dM (pb/GeV)
c = 1
0.5
0.1
0.05
0.01
m_1 = 1.5 TeV
1000
2000
3000
4000
5000
6000
M (GeV)

Direct Bump Searches

Drell-Yan = red

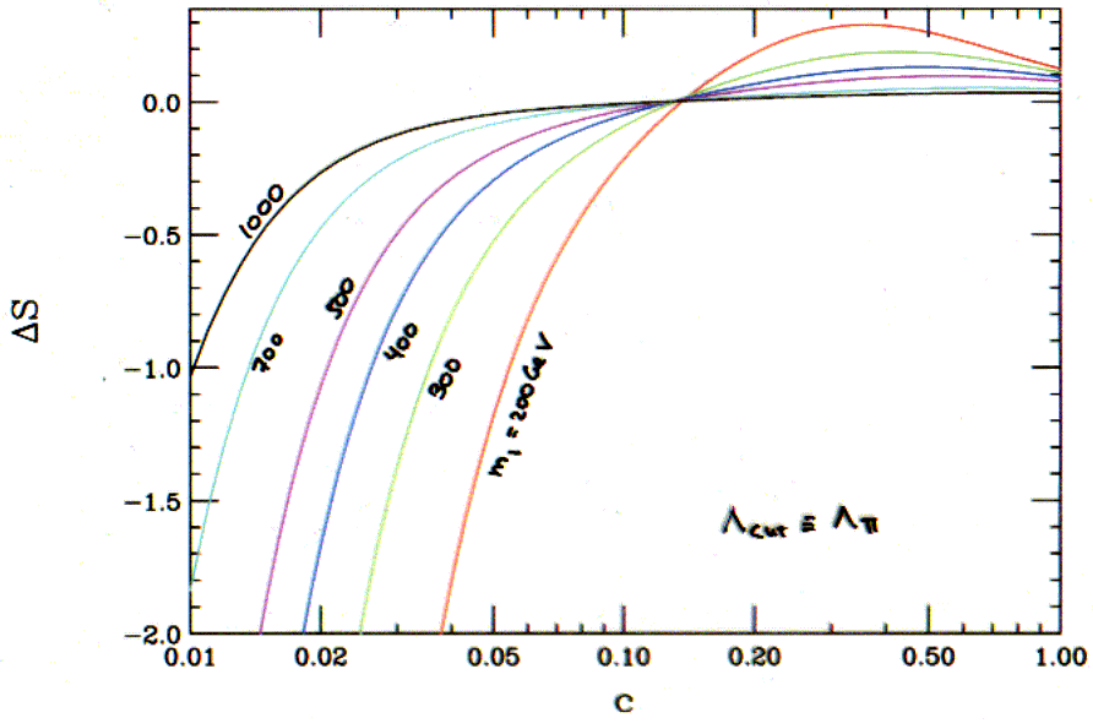
Dijet bumps = blue

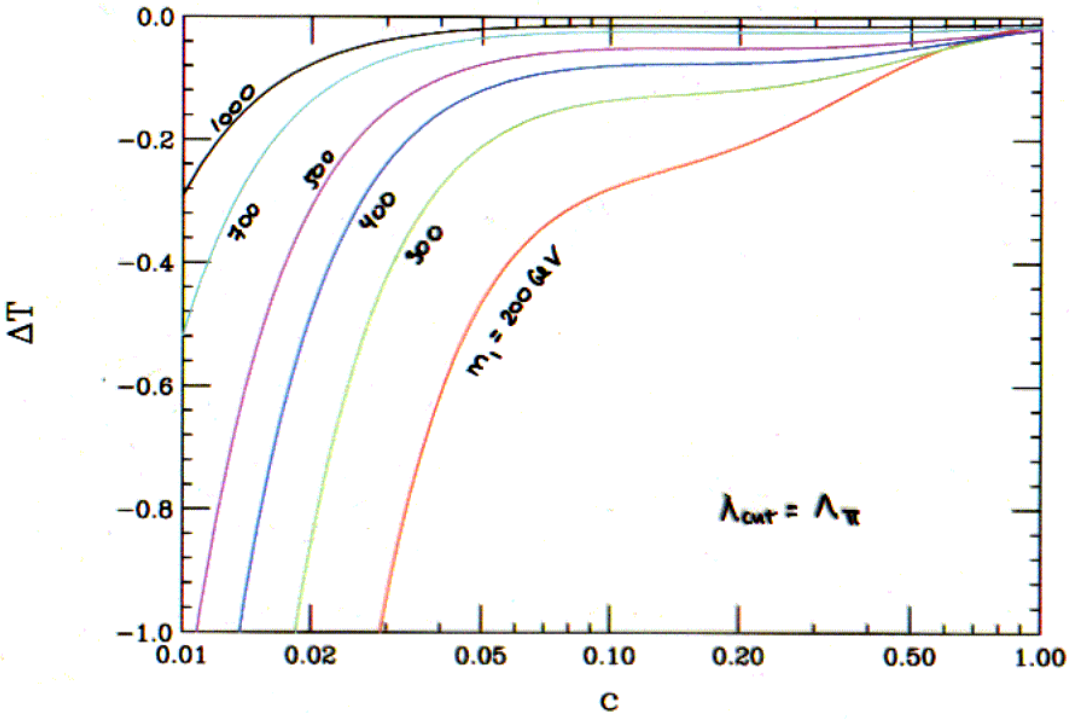
SM on wall

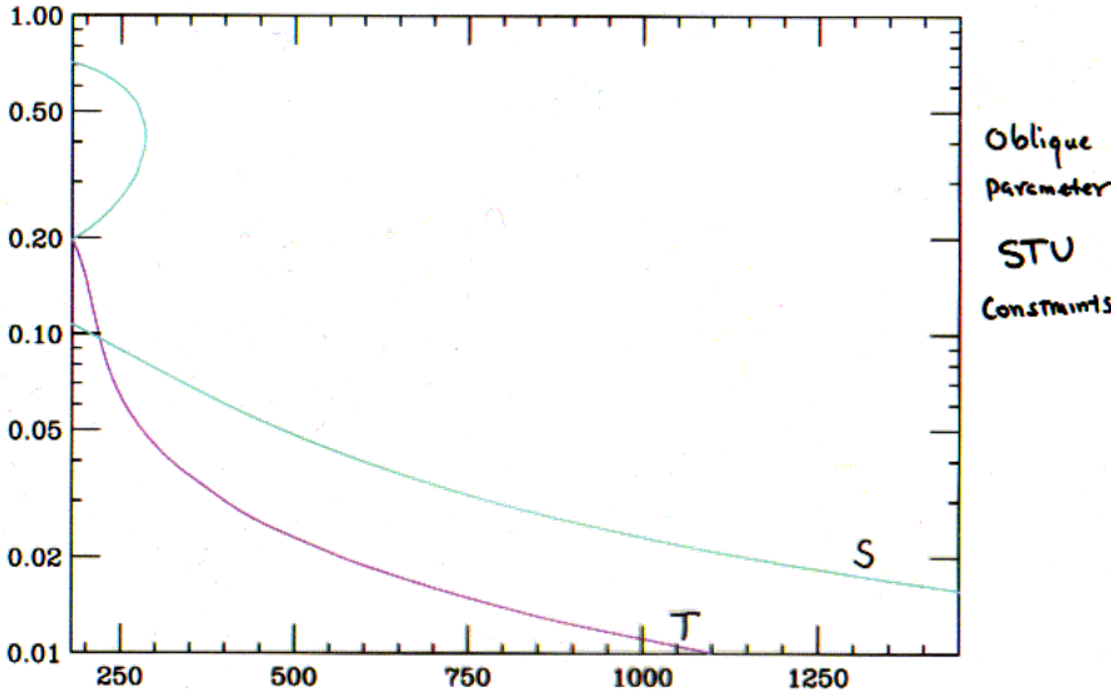


$k/\bar{M}_{Pl} = 0.1$

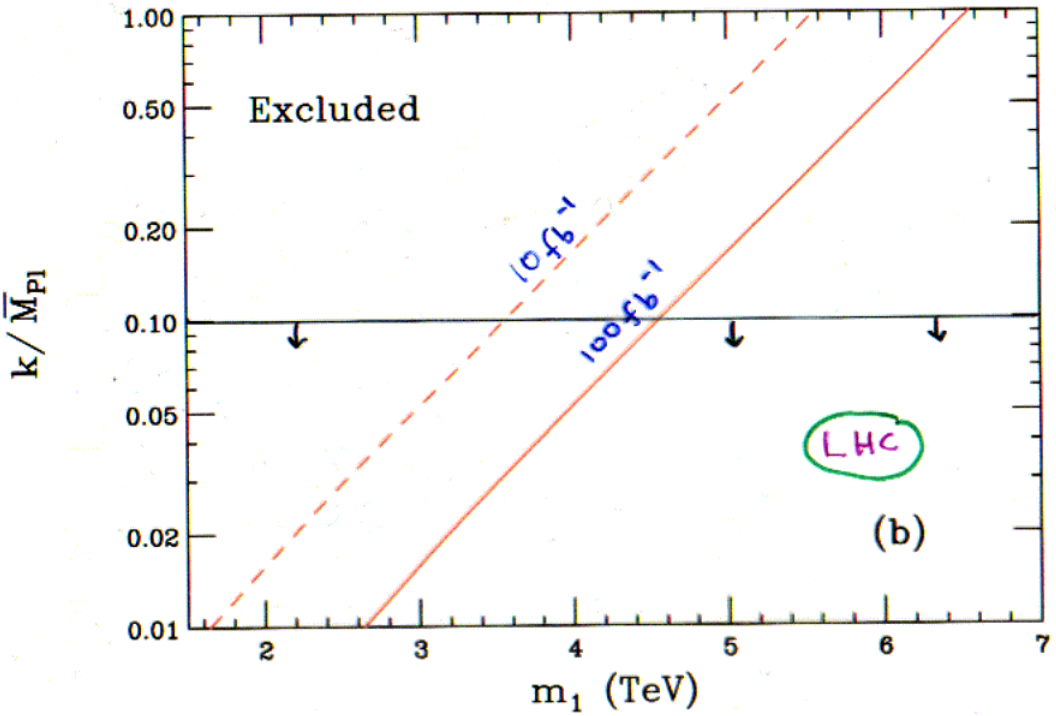
Randall-Sundrum model parameter constraints → $m_1 \gtrsim 600$ GeV


ΔS
0.0
−0.5
−1.0
−1.5
−2.0
0.01
0.02
0.05
0.10
0.20
0.50
1.00
c
1000
700
500
400
300
m_t = 200 GeV
Λ_cut = Λ_TC

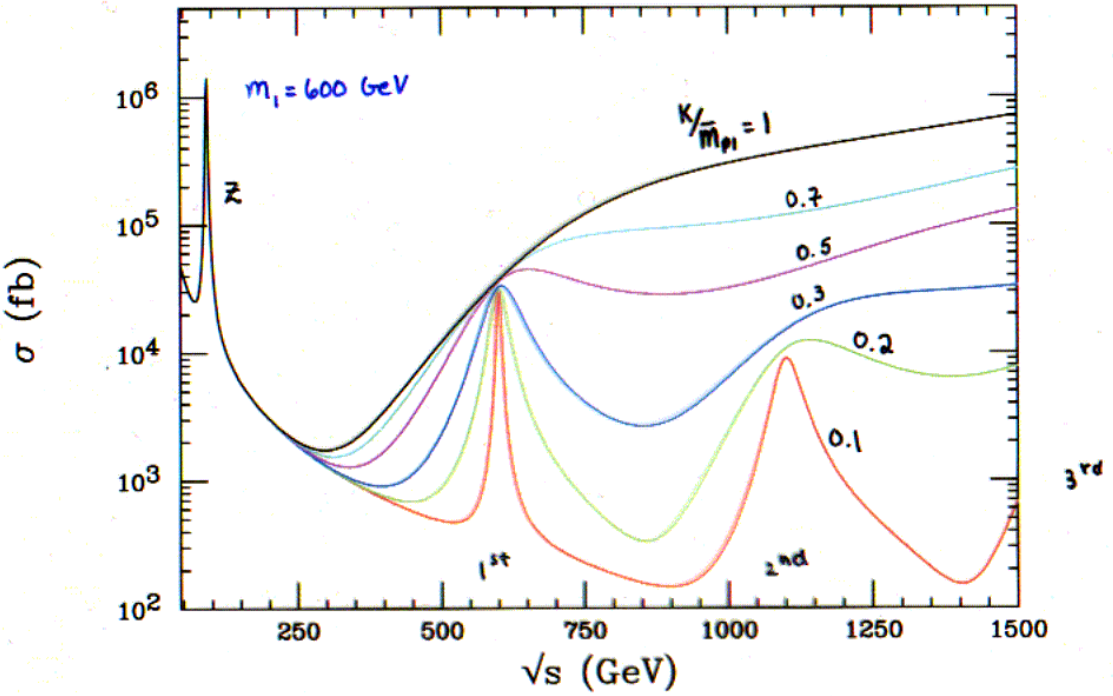

0.0
−0.2
−0.4
−0.6
−0.8
−1.0
ΔT
0.01
0.02
0.05
0.10
0.20
0.50
1.00
c
1000
700
500
400
300
m1 = 200 GeV
Λcut = Λπ


1.00
0.50
0.20
0.10
0.05
0.02
0.01
250
500
750
1000
1250
S
T
Oblique
parameter
STU
Constraints

Drell-Yan Constraints on Randall-Sundrum Model

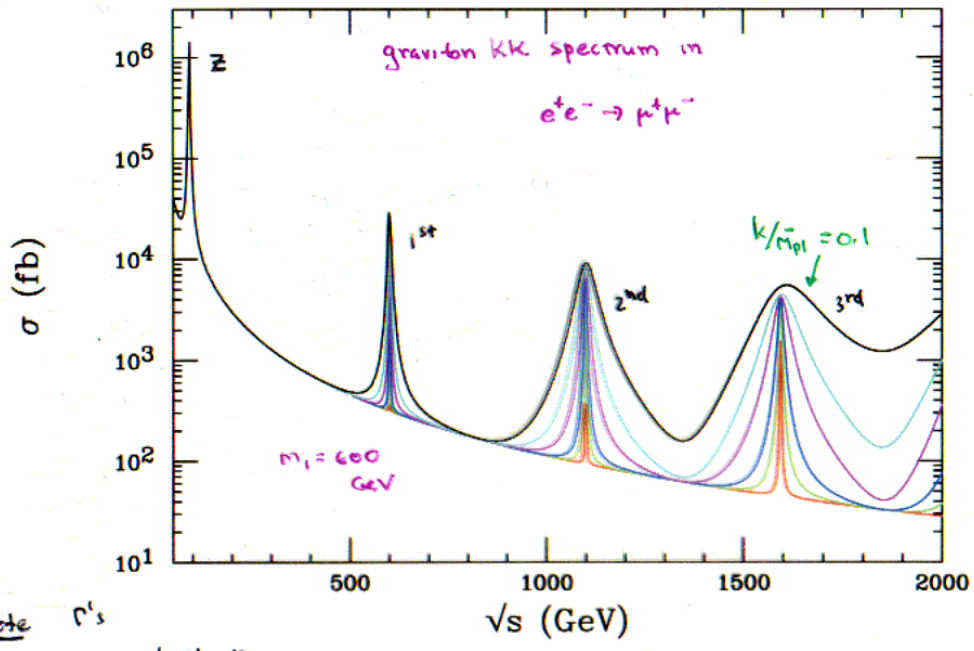


KK spectrum in $e^+e^- \to \mu^+\mu^-$



Warped Extra Dimensions

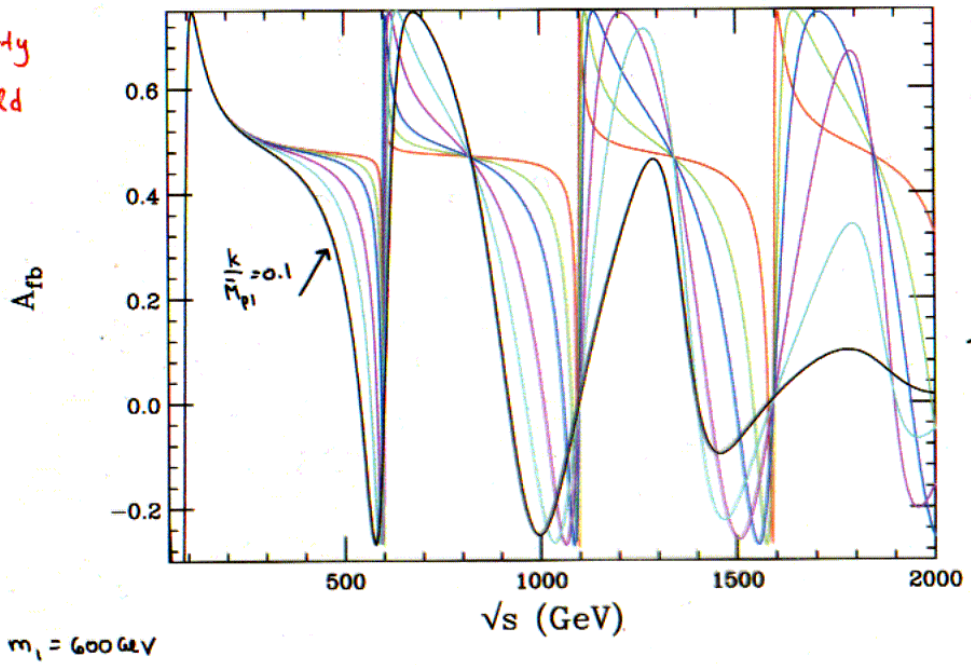
Davoudiasl, JLH, Rizzo
Phys Rev Lett 84, 2080 '00



⇒ Note Γ's increase with both n and $k/\bar{M}_{Pl}$

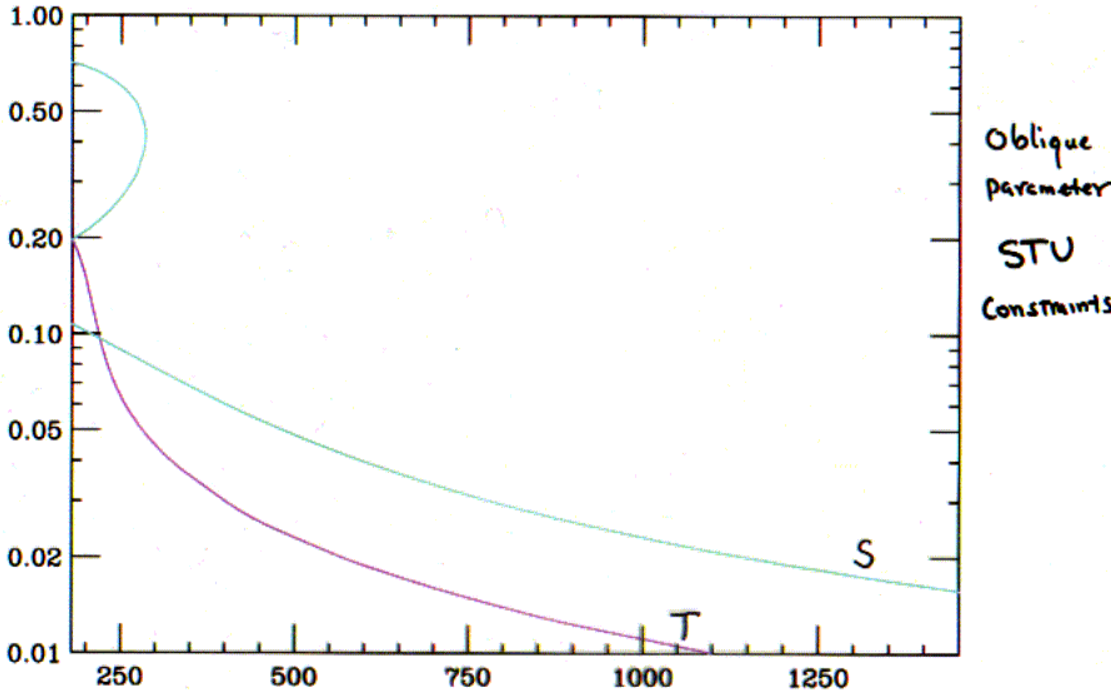
A_{FB} in $e^+e^- \to \mu^+\mu^-$ via RS gravitons

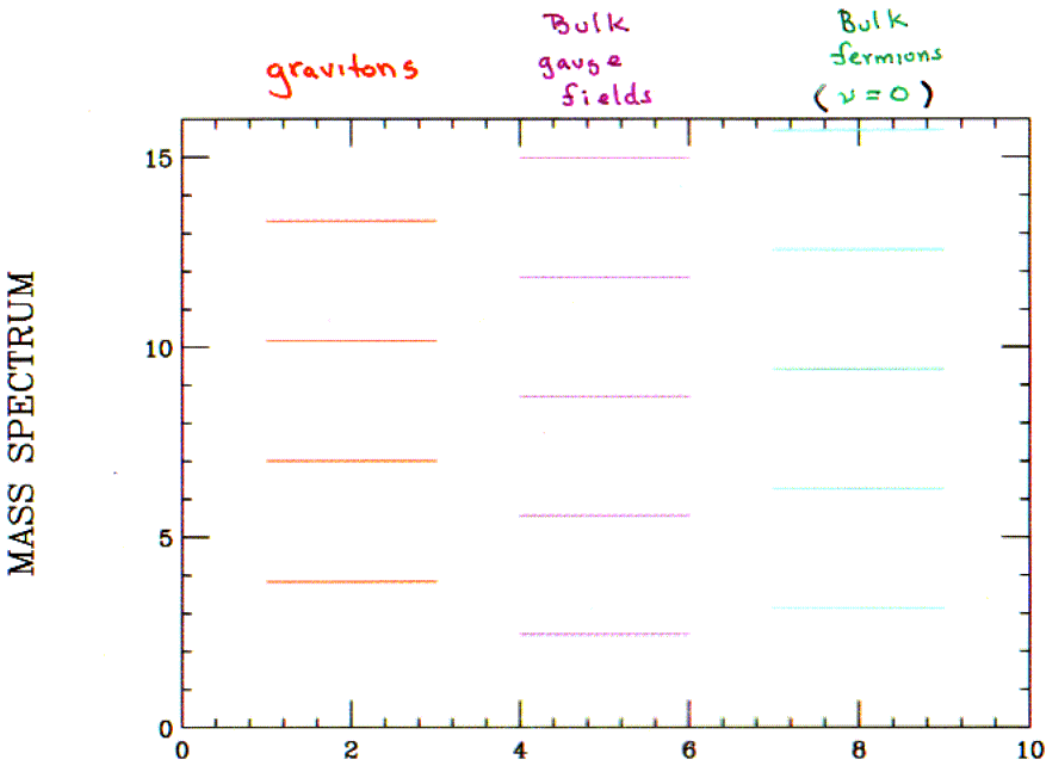
Pretty Wild



Note Damping !!

$m_1 = 600$ GeV


1.00
0.50
0.20
0.10
0.05
0.02
0.01
250
500
750
1000
1250
S
T
Oblique
parameter
STU
Constraints



Once **ONE** mass is fixed, all others are fixed within model

(for fermions we need ν as well)

⇒ Introduces an additional parameter :

The fermion 'Bulk' mass $m_{bulk} = \nu k$

$\nu \simeq O(1)$ parameter

gauge in
forbids bu
gauge boson
masses *
ditto for g

Find :

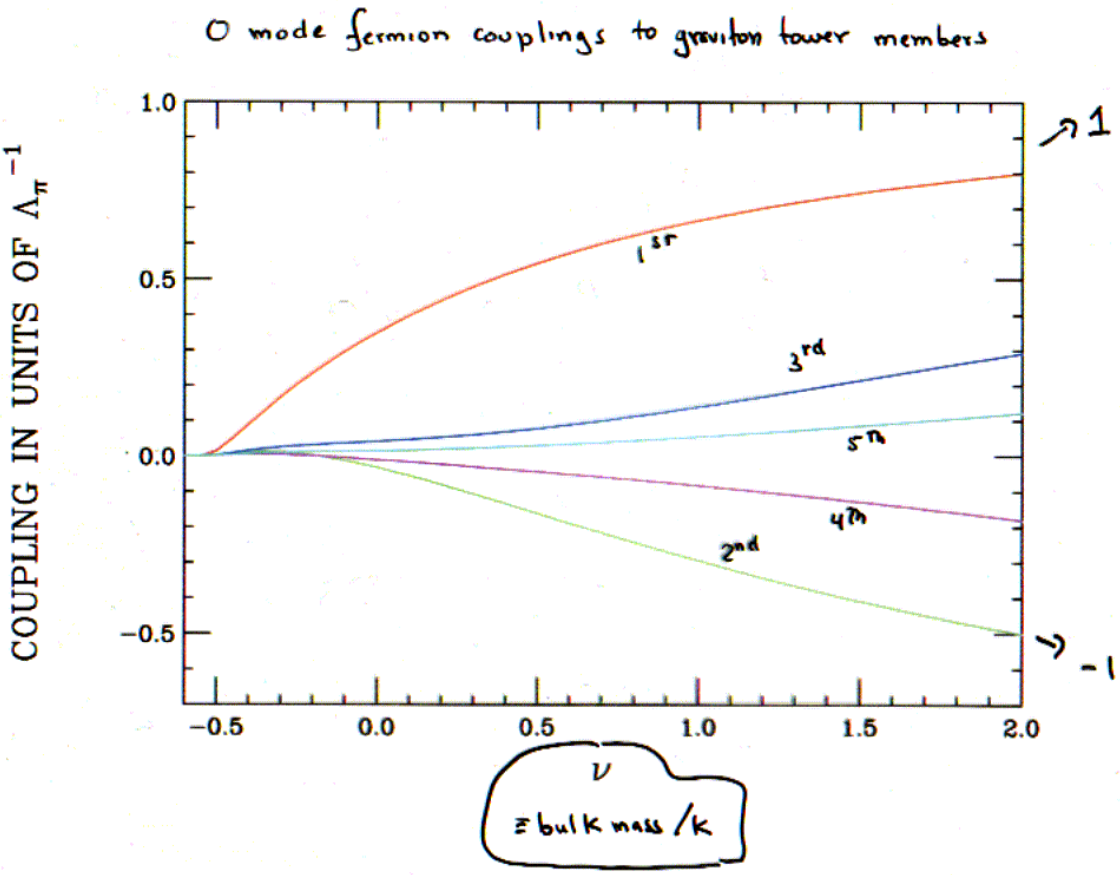
Zero modes couple more weakly than do wall states, e.g.,

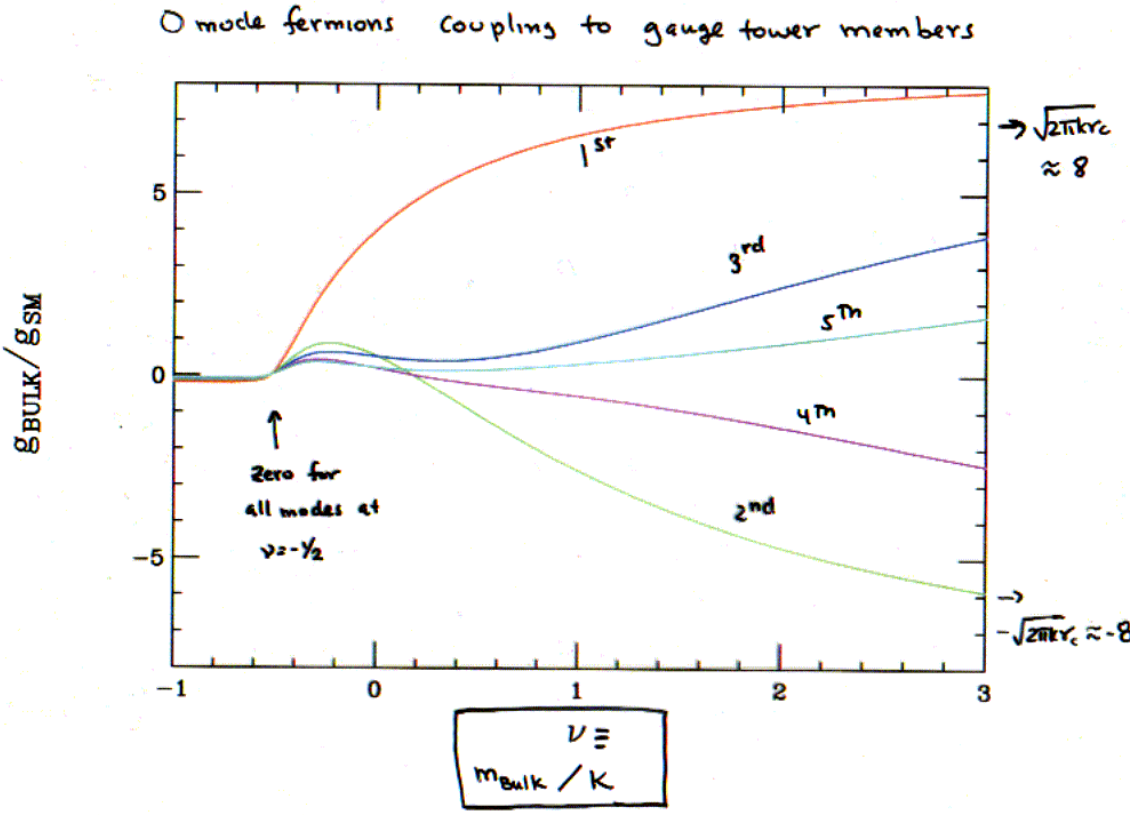
- For $\nu \lesssim -1/2$, sm fermions decouple from graviton tower. (gauge^2 graviton coupling very weak too)
- For $\nu \lesssim -1/2$, sm fermions couple weakly to gauge boson tower $g^{(n)}/g_{sm} \lesssim 0.2$!!

⇒ Serious reduction in collider sensitivity to RS phenomena For This parameter space region !!

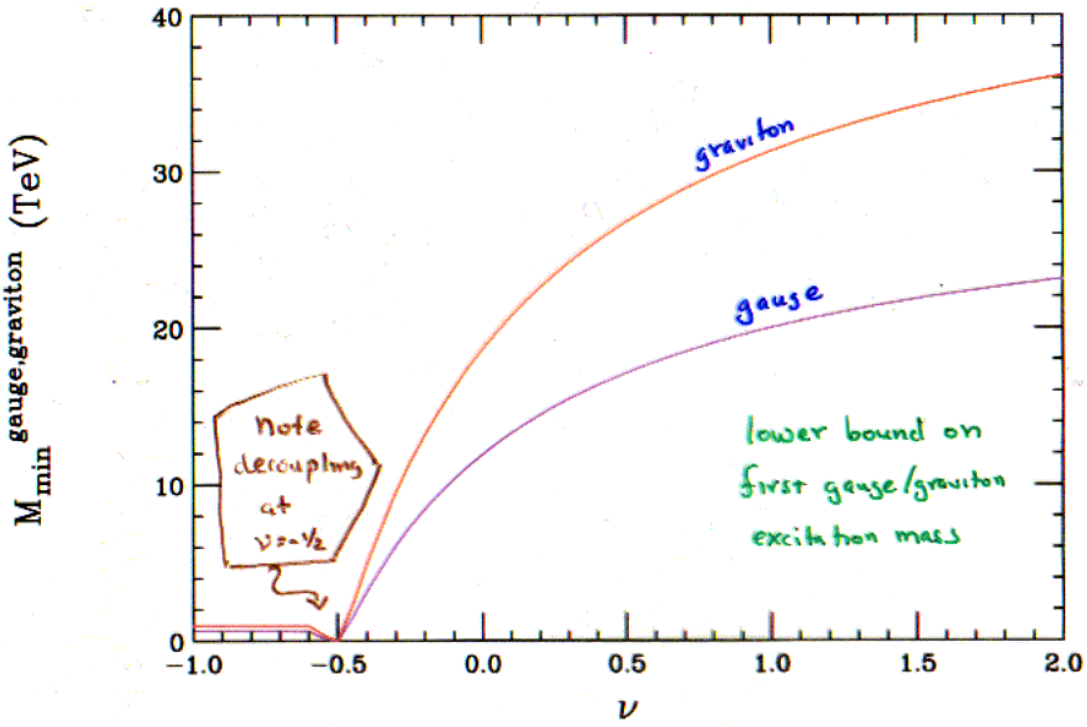
e.g., $m_1^{gauge} \gtrsim 25$ TeV $\Longrightarrow$ 0.6 TeV !!

Work in Progress ....


0 mode fermion couplings to graviton tower members
COUPLING IN UNITS OF Λ_π^{-1}
1.0
0.5
0.0
−0.5
−0.5
0.0
0.5
1.0
1.5
2.0
1st
3rd
5th
4th
2nd
→ 1
→ −1
ν
≡ bulk mass / k

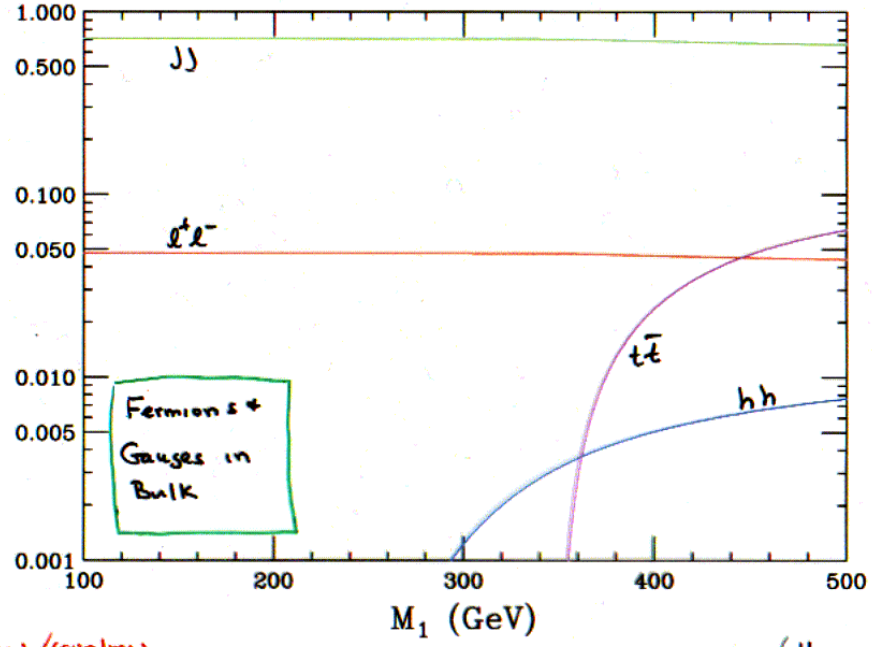

0 mode fermions coupling to gauge tower members
g_{BULK}/g_{SM}
5
0
−5
−1
0
1
2
3
1st
3rd
5th
4th
2nd
zero for all modes at ν=-½
→ √(2πkr_c) ≈ 8
→ −√(2πkr_c) ≈ -8
ν ≡ m_Bulk / k

Precision EWK data Constraints



Graviton Branching Fractions

$\nu > -1/2$

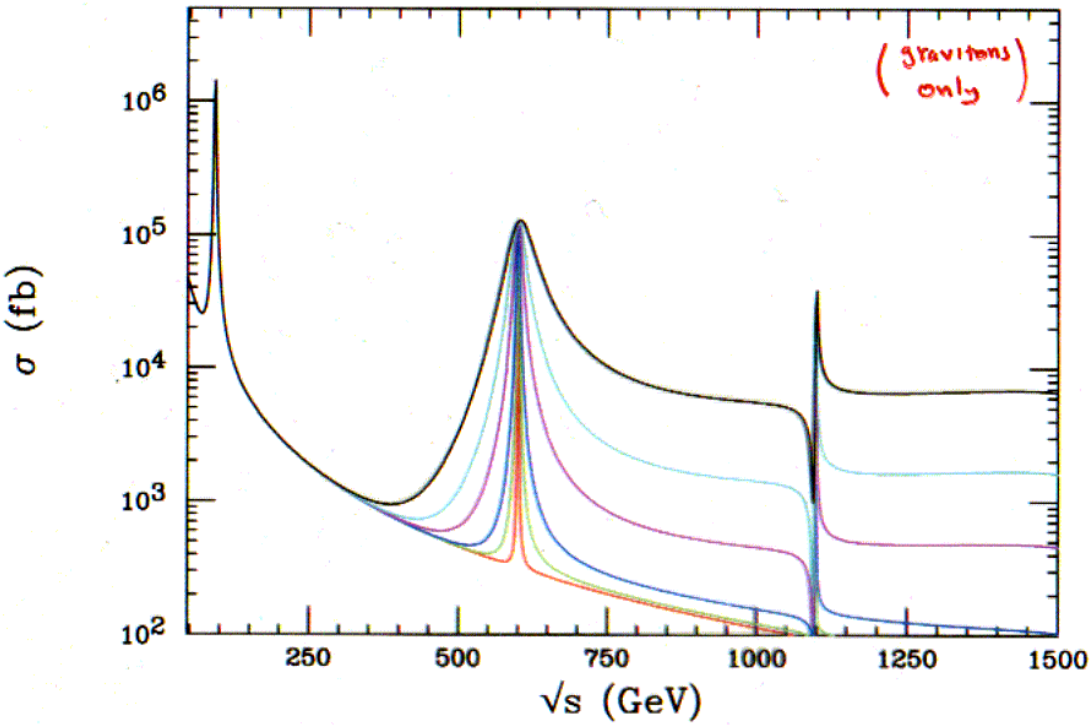


Note:

≈ No decays/couplings to gauge bosons

(Higgs on wall)

$\nu = 0$ Bulk fermions



Conclusions

- RS with SM on the wall is a well understood scenario, with only (2) free parameters, predicting graviton resonances at colliders

- The phenomenology is much enriched when gauge fields + fermions also are in the bulk

Much work remains to understand the RS model in this case .. the phenomenological details will be quite sensitive to the parameter ν

→ Back to work!