Radion Mixing Effects in the Two-Doublet Model

(JL Hewett TGR)

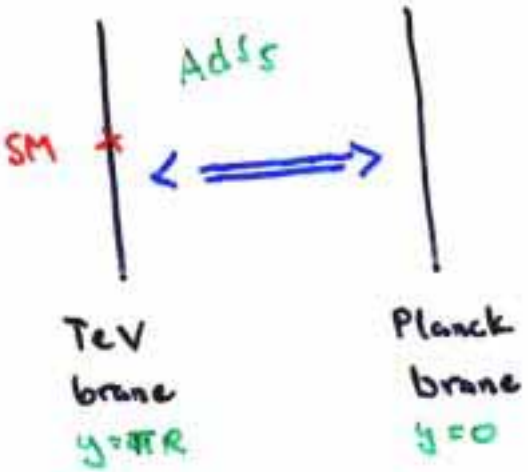
- Motivation
- Formalism
- Some Preliminary Results
- Summary / Conclusions

→ We consider only the radion of the original Randall-Sundrum model throughout ... all SM matter on TeV brane (no brane terms, no .....)

TG Rizzo 1/04

Recall

.. in RS



- The radion is a quantum excitation of the 2 brane separation

- RS in incomplete w/o a 'radion potential'

stabilization – eg, { Goldberger Wise } → { ~EWK scale }

→ generates m_{r_0}

Where ?

G_{AB} — 5-d graviton

KK →

$G_{\mu\nu}^{(n)} \rightleftharpoons G_{\mu 5}^{(n)} \rightleftharpoons G_{55}^{(n)} \Rightarrow \tilde{G}_{\mu\nu}^{(n)}$ (KK tower)

$G_{\mu\nu}^{(0)}$ (massless graviton)

$G_{\mu 5}^{(0)}$ (orbifolding)

$G_{55}^{(0)}$ (radion)

in 'unitary gauge' : only $G_{\mu\nu}^{(0,n)}$ + radion are present in RS

Motivation : SUSY !!

→ For various reasons, a SUSY version of RS

→ has been considered by several sets of authors:

. Altendorfer, Bagger + Nemeschansky : hep-th/0003117

. Gherghetta + Pomarol : hep-ph/0003129

⋮ ⋮ ⋮ ⋮

Since two Higgs doublets (at least) are required by SUSY ... it behooves us to examine this case

• Clearly this is more complicated than the single doublet model ...

→ What's new here ?

→ new signatures ?

→ modifications of SUSY-Higgs physics ...

— just beginning ...

→ Generalize Csaki, Graesser + Krib (PRD63 065002)

$$S_{mix} = \int_{TeV} d^4x \underbrace{\sqrt{g_{md}}}_{\text{Dim-4}} \underbrace{R(g_{md})}_{\text{Curvature}} \underbrace{\left[\xi_1 H_1^\dagger H_1 + \xi_2 H_2^\dagger H_2 + \xi_{12} H_1^\dagger H_2 + h.c. \right]}_{\text{Interaction}} \quad (\text{dim-4 interaction})$$

- $\xi_{1,2}$ + ξ_{12} are O(1) dimensionless parameters (assumed real here)

Expect (?) $\xi_1 = \xi_2$ but $\neq \xi_{12}$ in general

$$\mathcal{L}_5 = -6\Omega^2 \left[\Box \ln\Omega + (\nabla \ln\Omega)^2 \right] \left(\xi_1 H_1^\dagger H_1 \cdots \right)$$

$$\Omega = e^{-\gamma r_0/v} \uparrow \quad , \quad \gamma \equiv \frac{v}{\sqrt{6}\Lambda_\pi} \qquad \Lambda_\pi \gtrsim \text{few TeV}$$

unmixed radion field

→ Expand to quadratic order in fields...

$$\mathcal{L} = -\tfrac{1}{2} h_0 \Box h_0 - \tfrac{1}{2} m_{h_0}^2 h_0^2 - \tfrac{1}{2} H_0 \Box H_0 - \tfrac{1}{2} m_{H_0}^2 H_0^2 - \tfrac{1}{2} r_0 \Box r_0$$

$$- \tfrac{1}{2} m_{r_0}^2 r_0^2 - 3\sigma\gamma^2 r_0 \Box r_0 + 6\gamma \left(\tau_H H_0 \Box r_0 + \tau_h h_0 \Box r_0 \right)$$

h_0, H_0 = lightest (heaviest) neutral Higgs before radio mixing { note A, $H^\pm$ absent [CP] }

- σ, τ_h, τ_H are functions of $\left\{ \begin{matrix} \xi_{1,2}\,;\,\xi_{12} \\ s_\alpha, c_\alpha \end{matrix} \right.$ and t_β.

→ Rescale fields to remove kinetic mixing & Canonically normalise fields

$$\begin{cases} h_0 \to h' + 6\gamma\tau_h r'/Z \\ H_0 \to H' + 6\gamma\tau_H r'/Z \end{cases} \qquad r_0 \to r'/Z$$

$$Z = 1 + 6\gamma^2\left(\sigma - 6(\tau_h^2 + \tau_H^2)\right)$$

Then rotate $(h', H', r') \xrightarrow[\text{⟲}]{} (h, H, r)$ to diagonalize the mass^2 matrix ⇒ the physical basis, ie, mass eigenstates

Problems: tooo many parameters ... take h_0, H_0 from SUSY w/ $t_\beta = 10$, $m_A = 500\,\text{GeV}$ (e.g.)

$A_t = A_b = -\mu = 1\,\text{TeV}$, $\frac{m^2_{\tilde{t}_1} + m^2_{\tilde{t}_2}}{2} = (1\,\text{TeV})^2$

+ incorporate RC to masses etc { Carena, Haber, Logan & Mrenna PRD 65 }

Assume $\gamma \sim 0.05$, $|\xi_{12}/\xi_1| \sim O(1)$ ⇒ Sample results

$$\sigma \equiv \Sigma_1 c_\beta^2 + \Sigma_2 s_\beta^2 + 2\Sigma_{12} c_\beta c_\beta$$

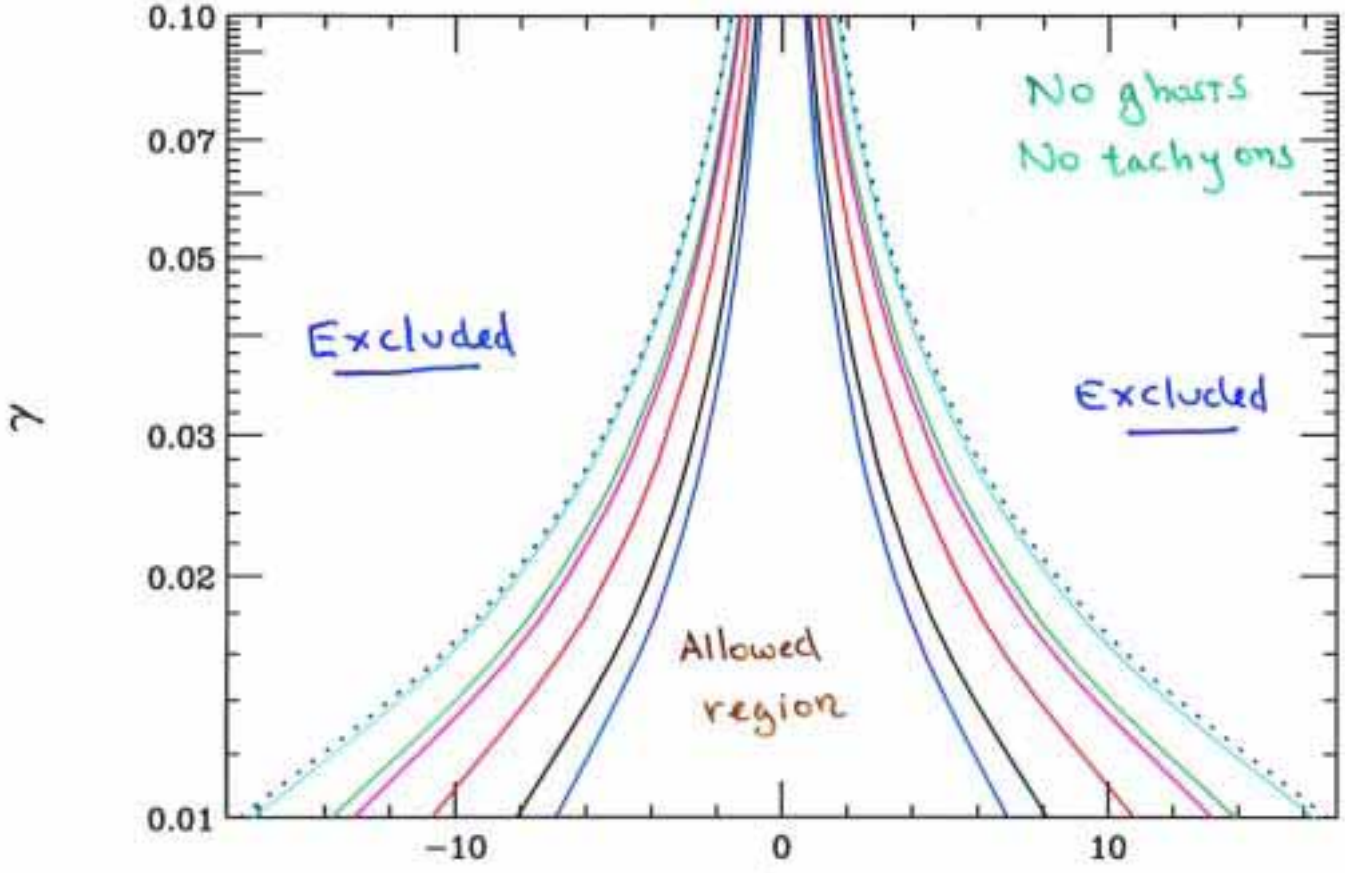
$$\tau_h \equiv -s_\alpha (\Sigma_1 c_\beta + \Sigma_{12} s_\beta) + c_\alpha (\Sigma_2 s_\beta + \Sigma_{12} c_\beta)$$

$$\tau_H \equiv c_\alpha (\Sigma_1 c_\beta + \Sigma_{12} s_\beta) + s_\alpha (\Sigma_2 s_\beta + \Sigma_{12} c_\beta)$$

$c_\beta, s_\beta \equiv \cos\beta, \sin\beta$

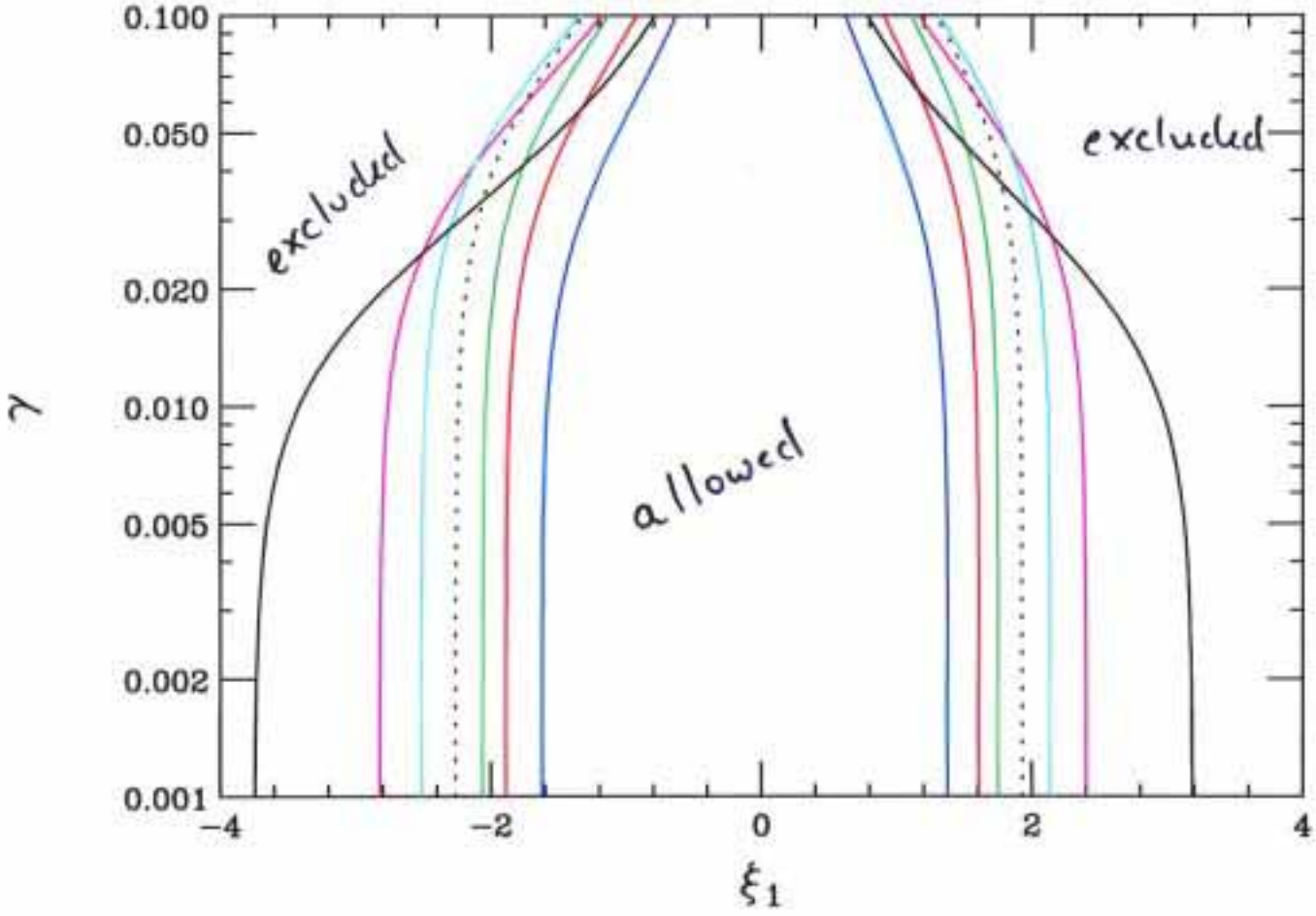
$c_\alpha, s_\alpha = \cos\alpha, \sin\alpha$ - the h^0, H^0 diagon. angle

Parameter space restrictions .....



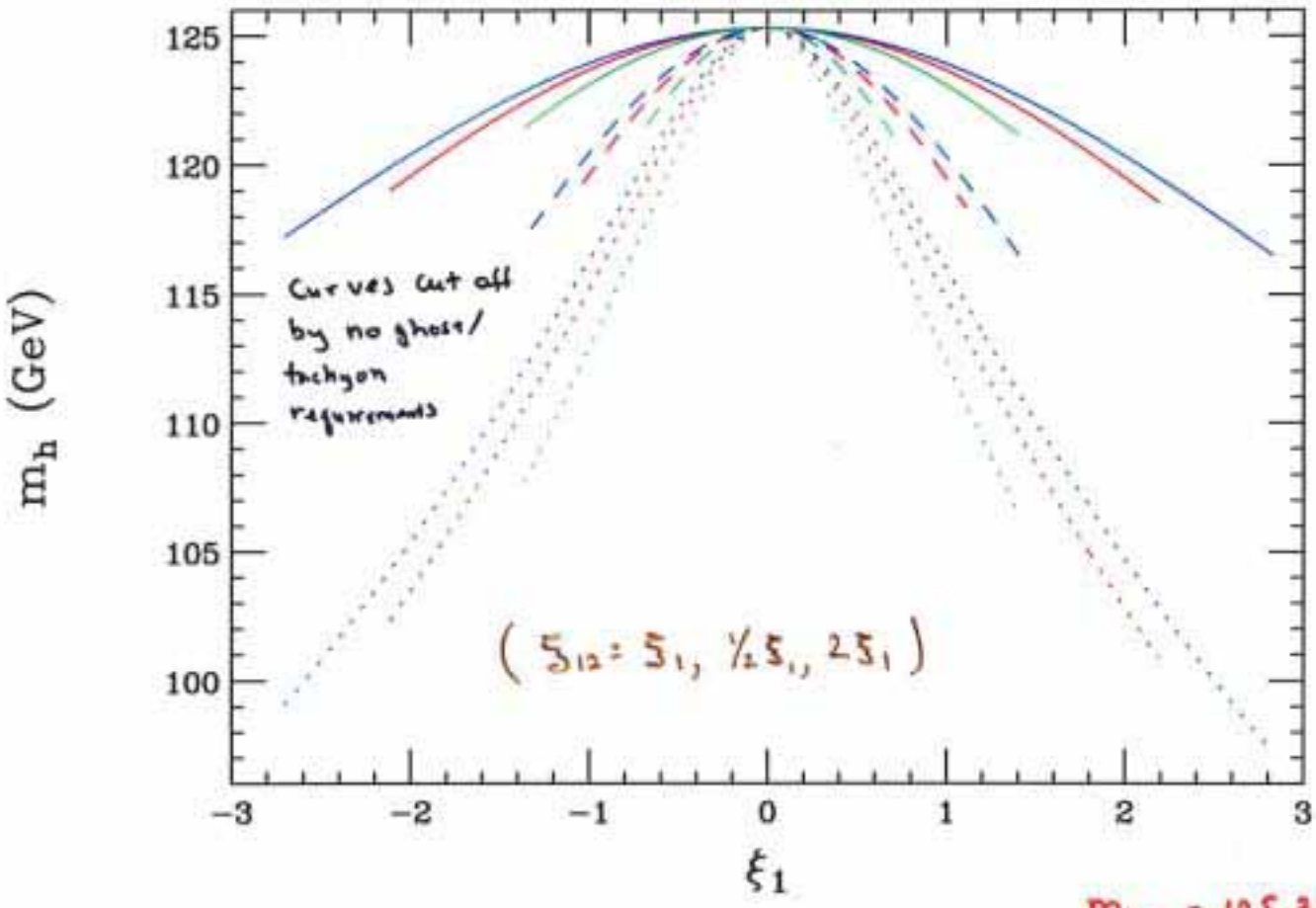
Red	$\xi_{12}=\xi_1$	magenta	$\xi_{12}=-\xi_1$
Green	$\frac{1}{2}\xi_1$	Cyan	$-\frac{1}{2}\xi_1$
Blue	$2\xi_1$	solid	$-2\xi_1$
		dot	0

Unitarity in WW→WW to Λ_{TeV}



Solid: $m_{r_0} = 300\,\text{GeV}$ $\gamma = 0.05$ | Dot $m_{r_0} = 150\,\text{GeV}$ $\gamma = 0.05$

Dash: " $\gamma = 0.1$



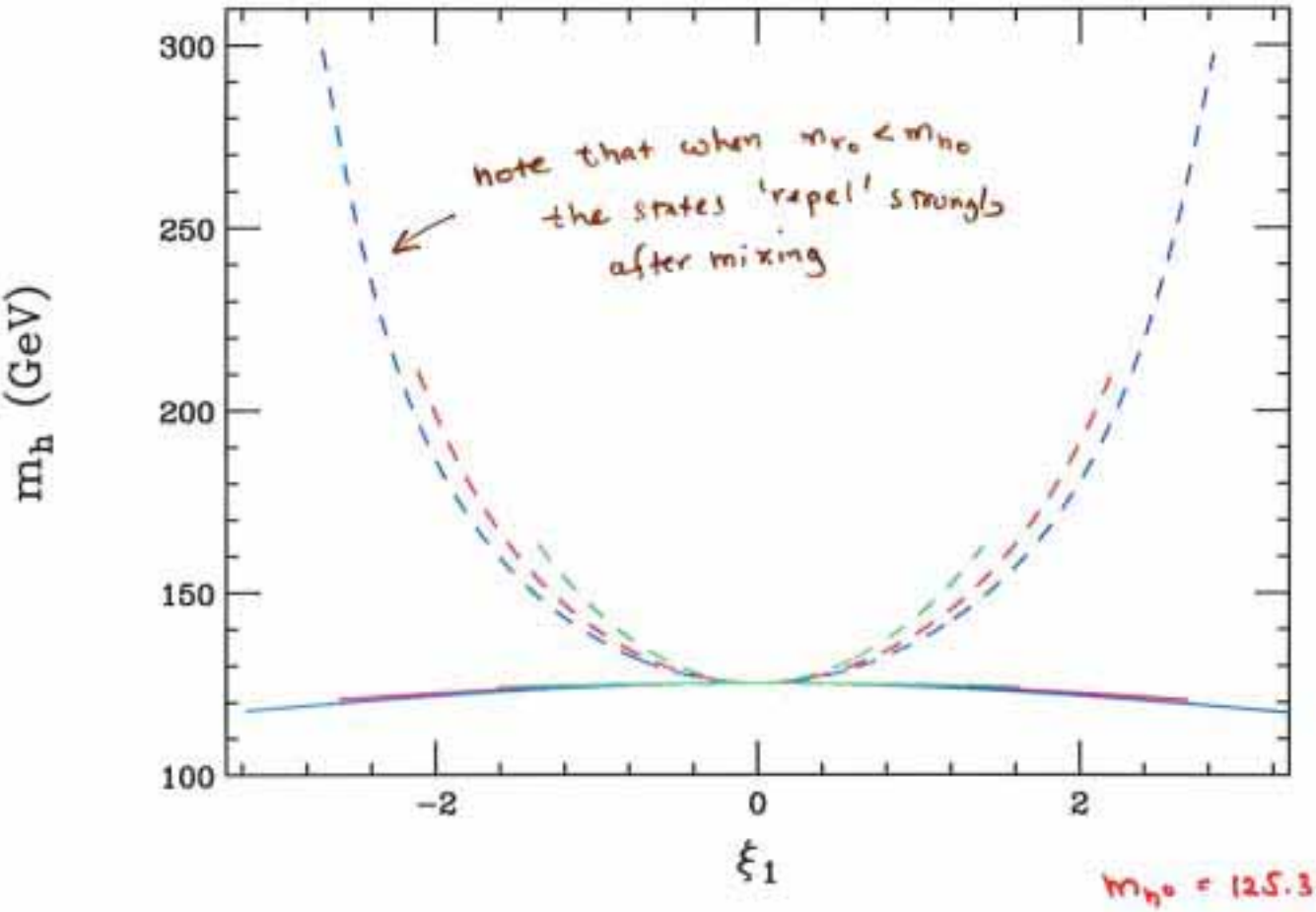
$m_{h_0} = 125.34\,\text{GeV}$

$\tan\beta = 10$

$m_A = 500\,\text{GeV}$

Solid : $m_{r_0} = 300$ $\gamma = 0.05$ $\xi_{12} = -\xi_1, -\frac{1}{2}\xi_1, -2\xi_1$

Dash : $m_{r_0} = 80$ $\gamma = 0.05$ $\xi_{12} = \xi_1, \frac{1}{2}\xi_1, 2\xi_1$

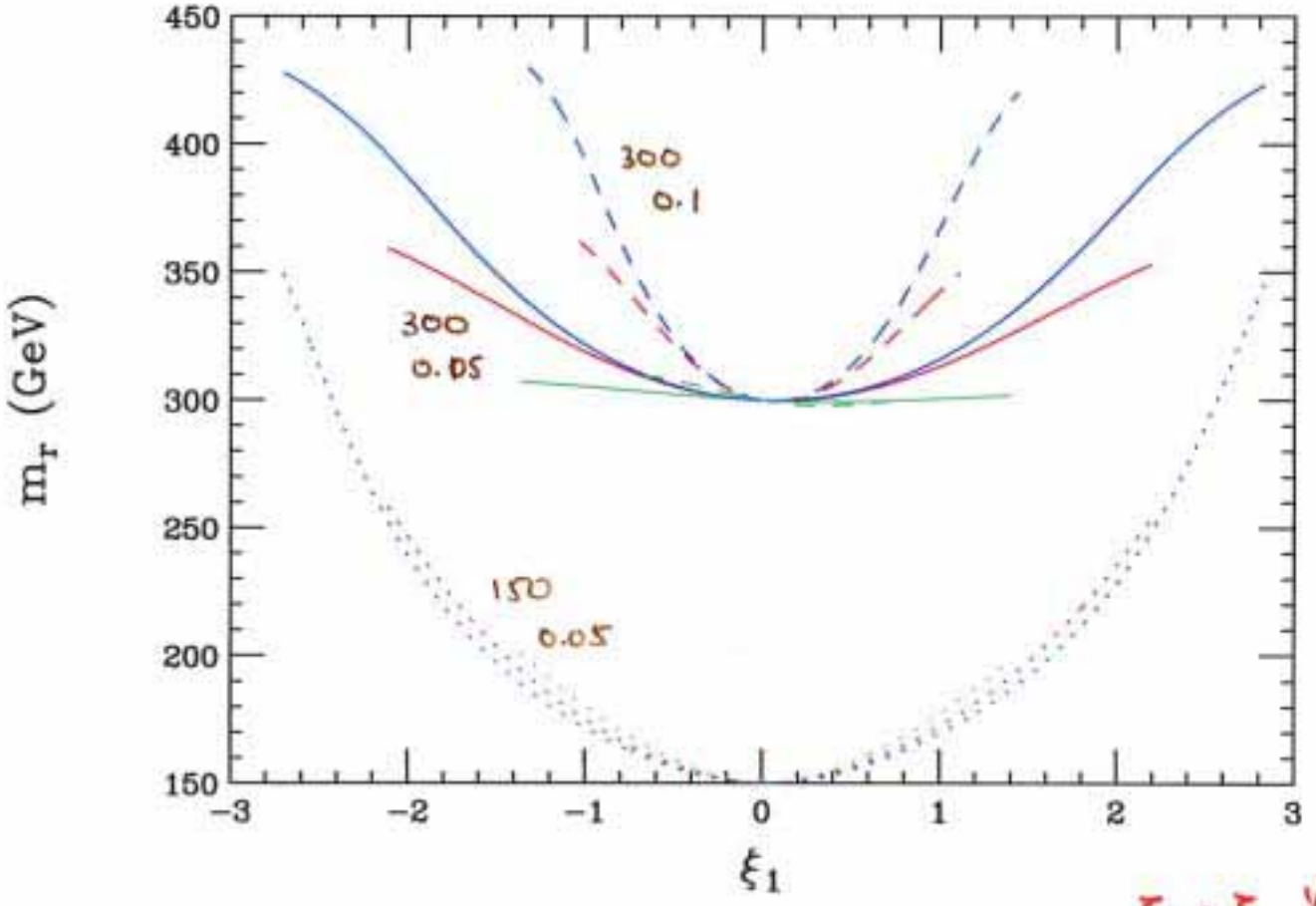


$m_{h^0} = 125.346\,\text{GeV}$

$m_A = 500\,\text{GeV}$

$\tan\beta = 10$

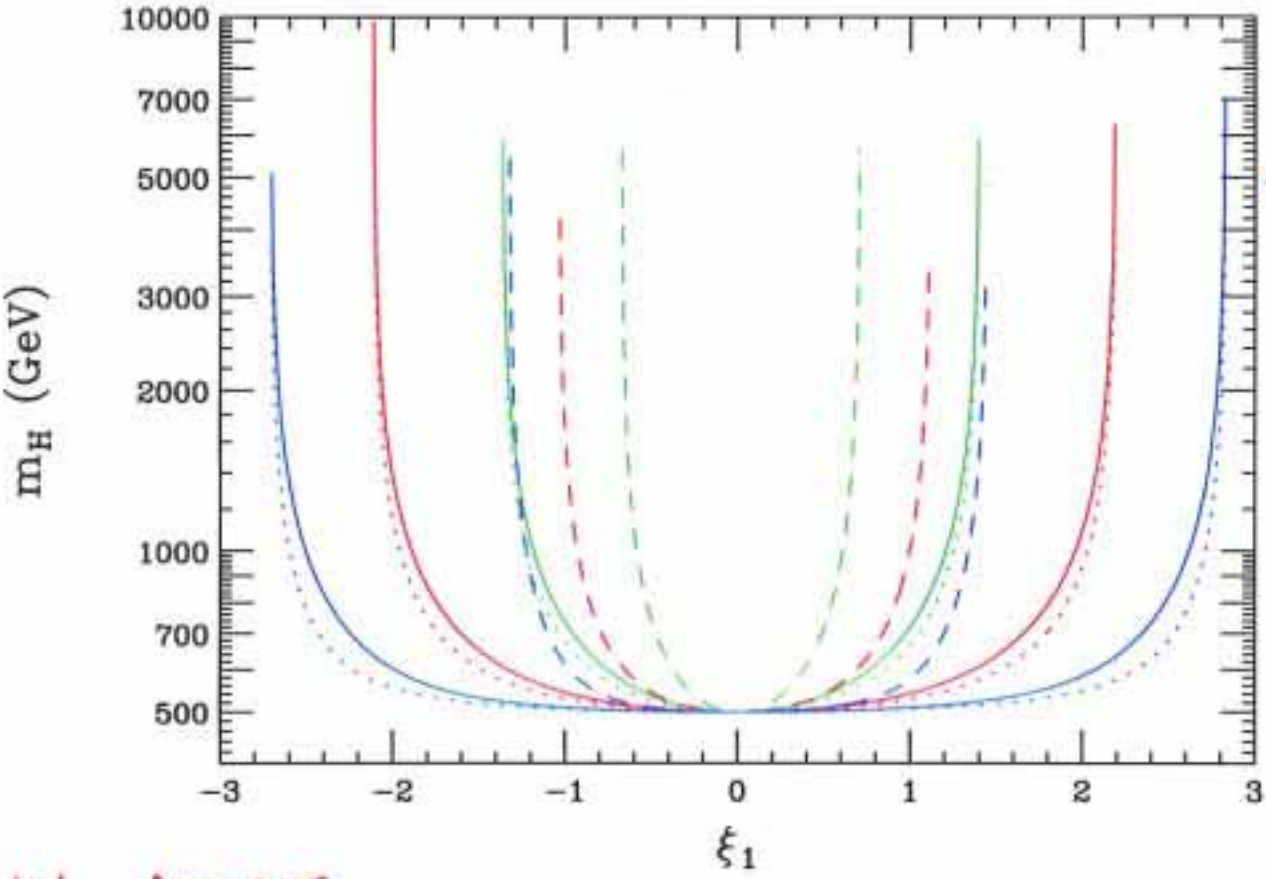
Radion Mass



$\xi_{12} = \xi_1, \frac{1}{3}\xi_1, 2\xi_1$

'Heavy' Higgs mass

Strongly pushed upwards



← STeV!

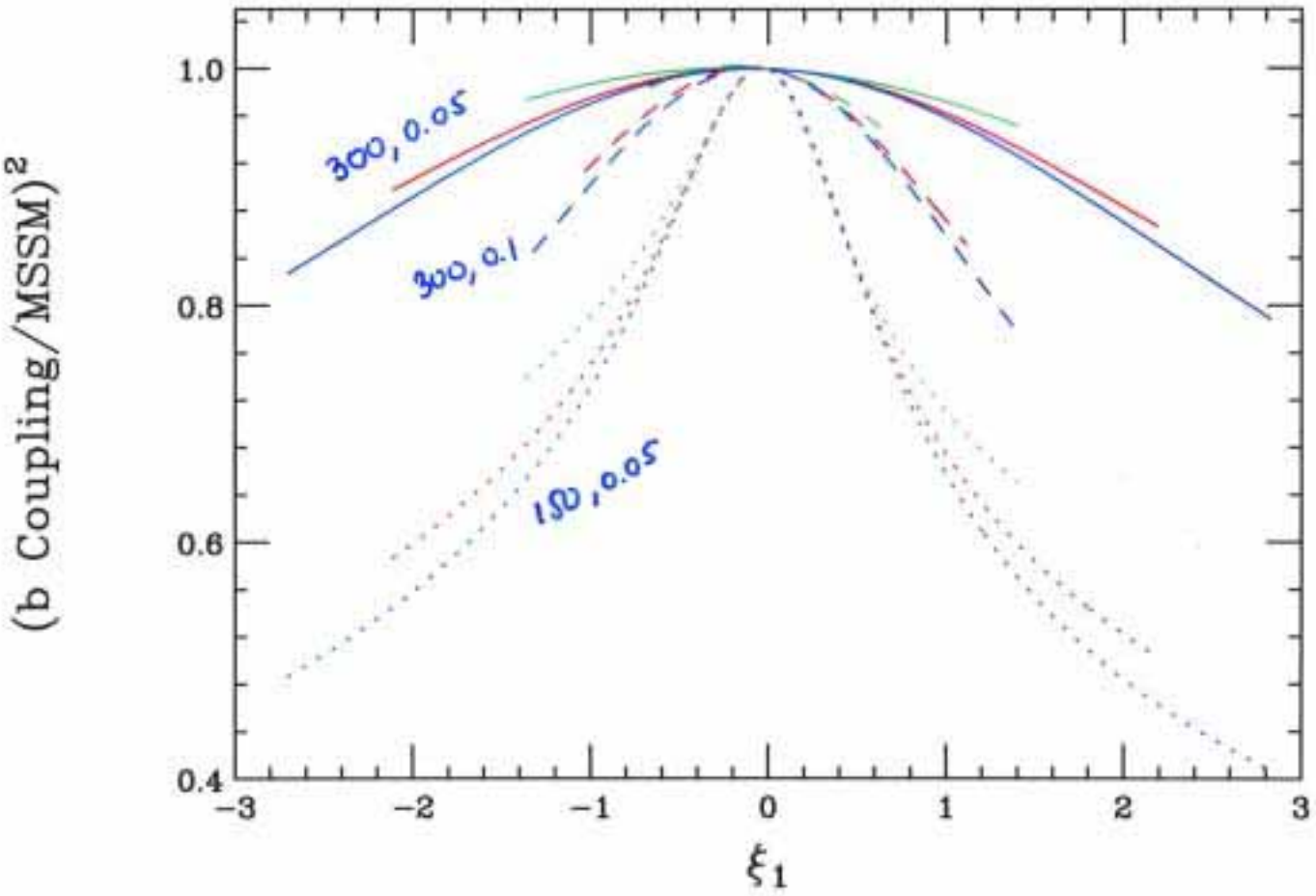
Sol: d 300, 0.05

Dash 300, 0.1

Dot 150, 0.05

$\xi_{12} = \xi_1, \xi_1/2, 2\xi_1$

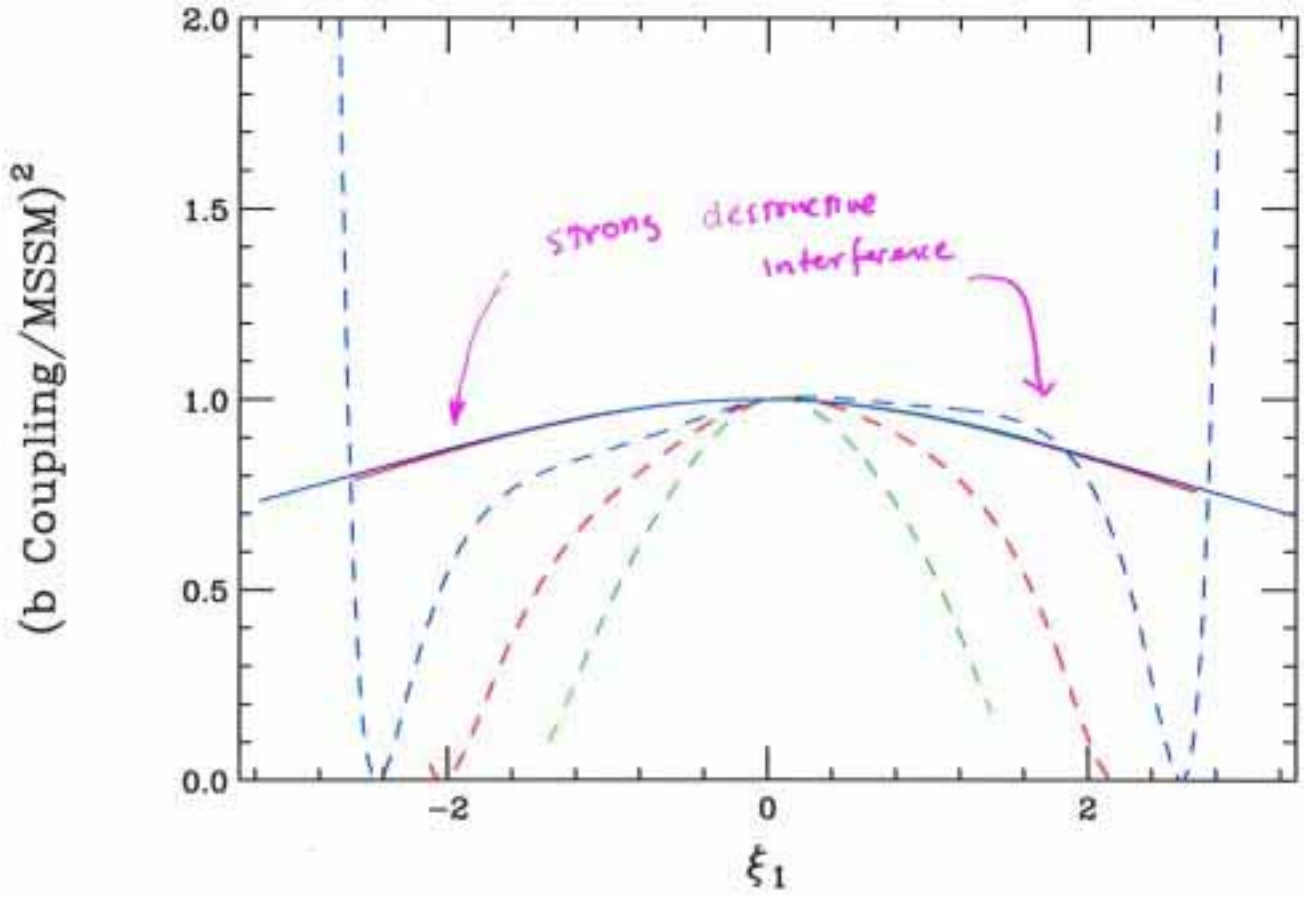
$h\,b\bar{b}$ coupling



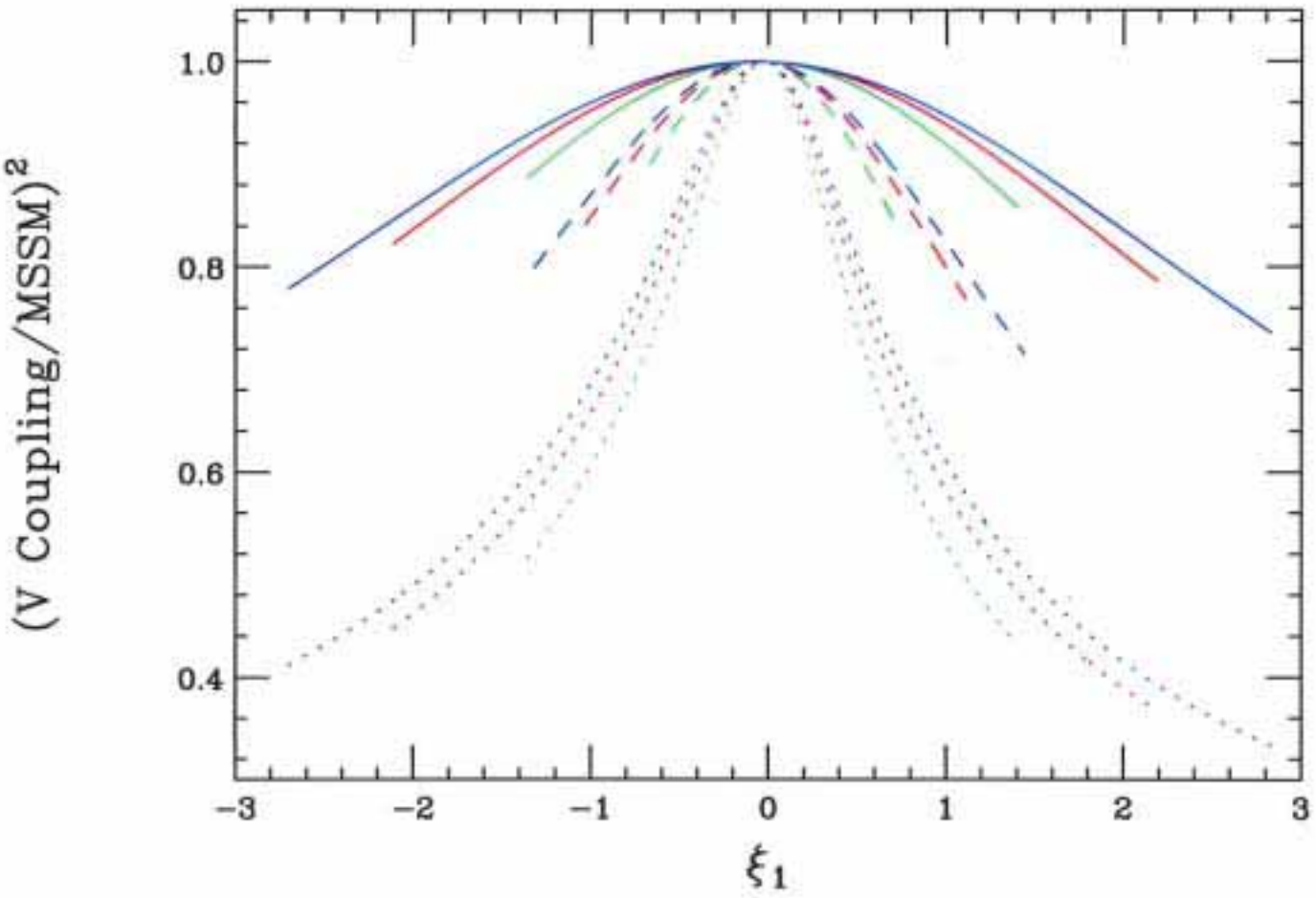
$5_{12} = 5_1,\ \tfrac{1}{2}\mathbf{1}_1,\ 23_1$

$h^0 b\bar{b}$ coupling

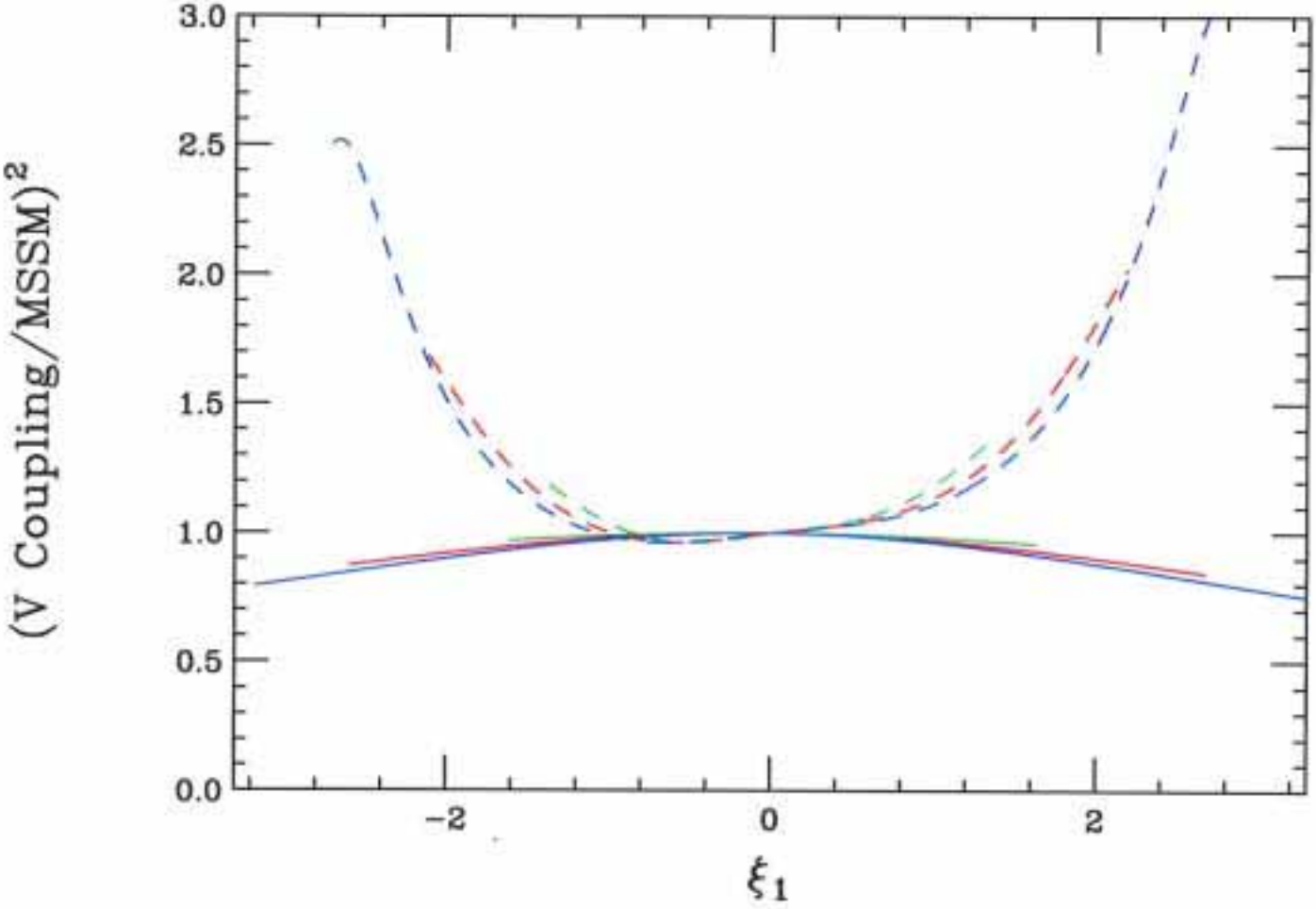
{ Solid $m_{r_0} = 300$, $\gamma = 0.05$ (ξ_{12} neg ξ_1)
Dash $m_{r_0} = 80$, $\gamma = 0.05$



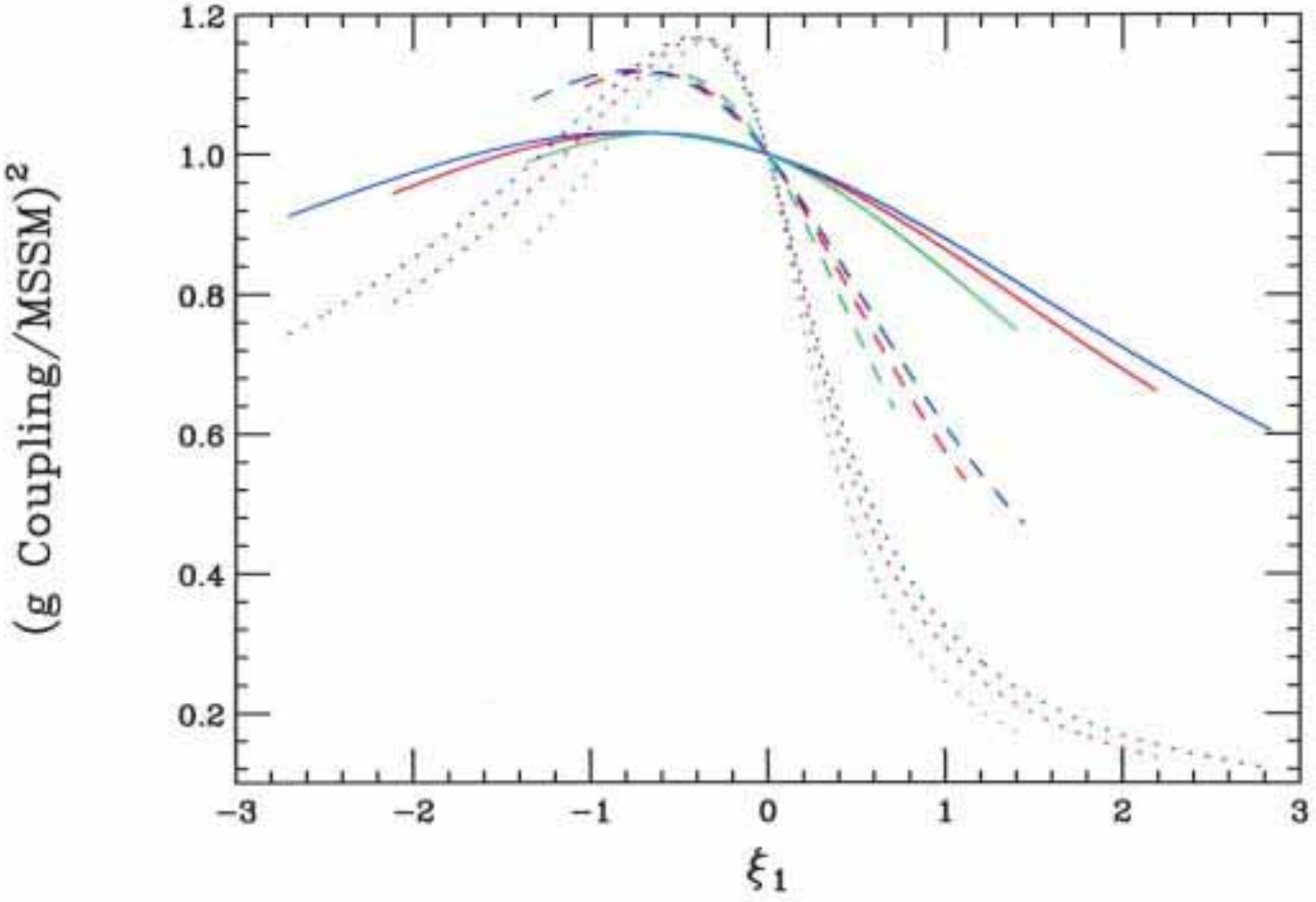
hVV coupling



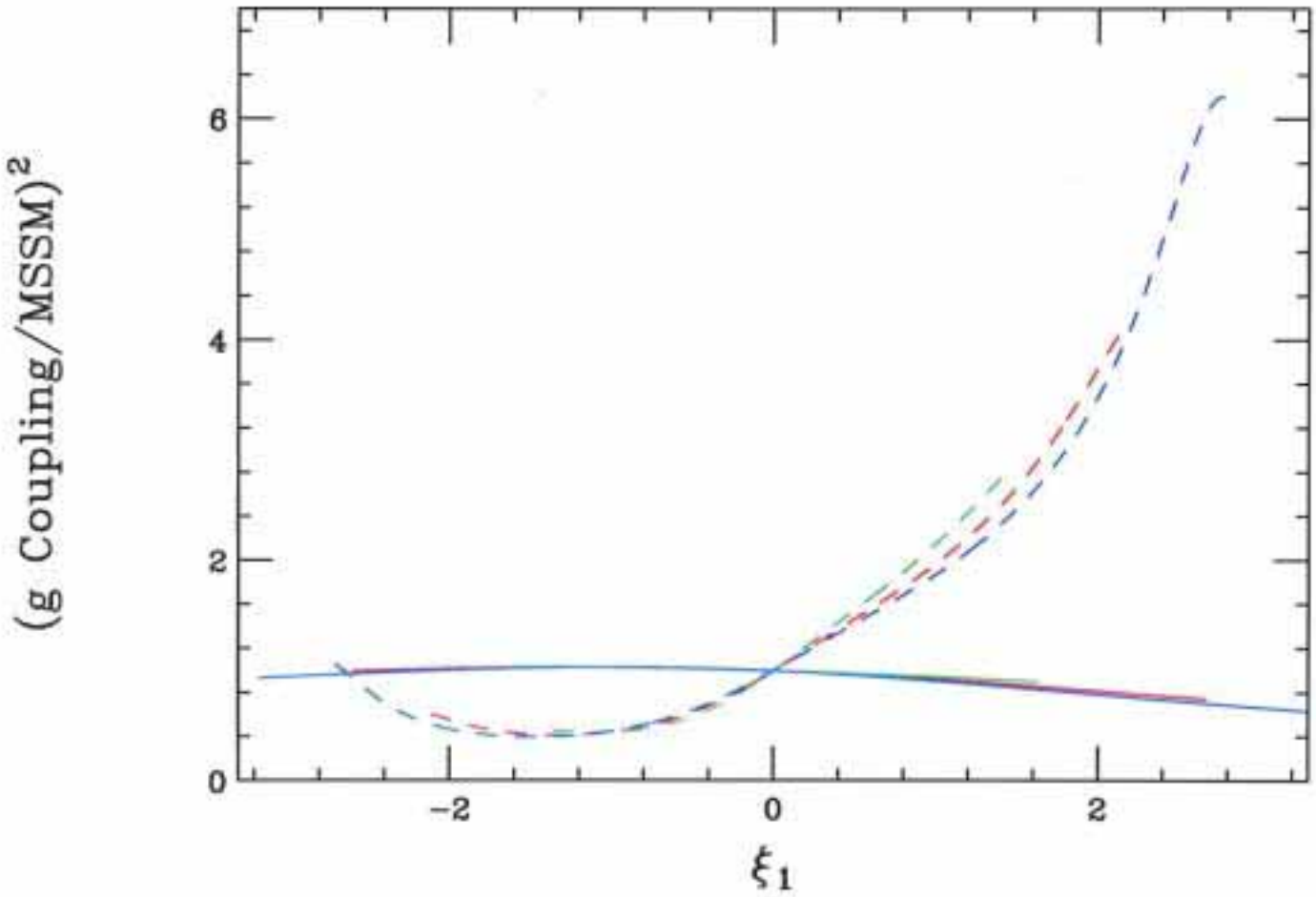
hVV coupling



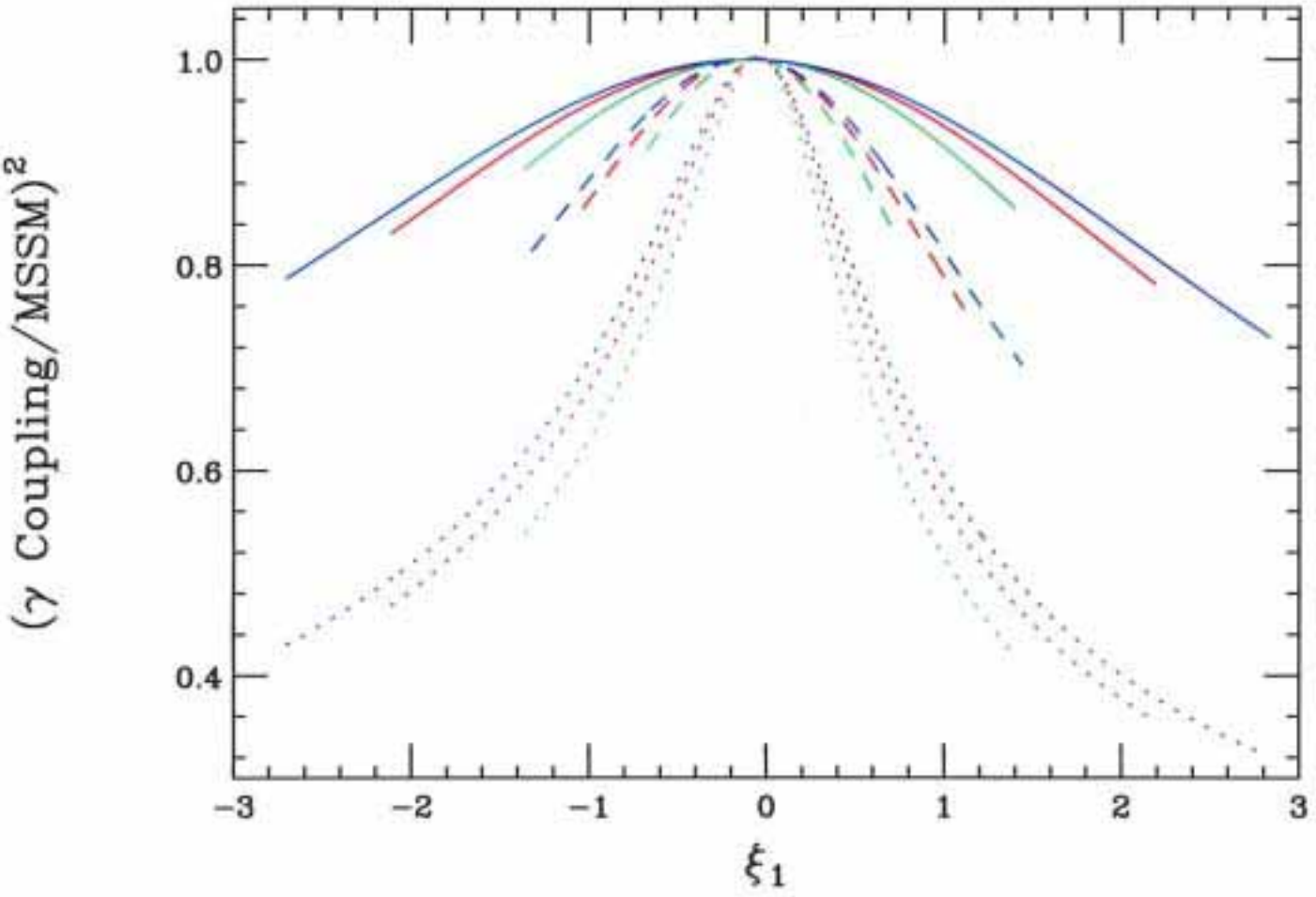
hgg coupling



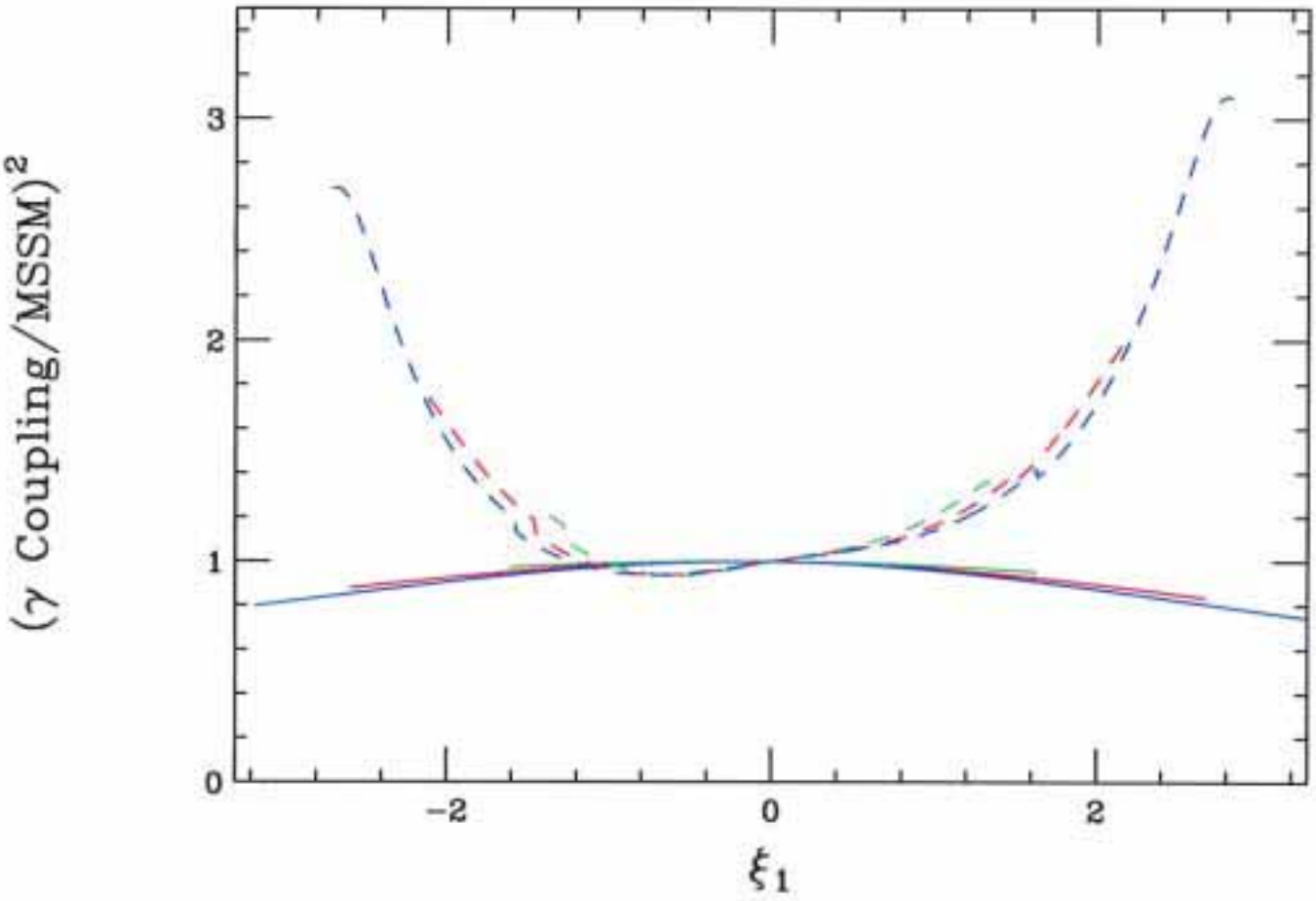
h gg coupling



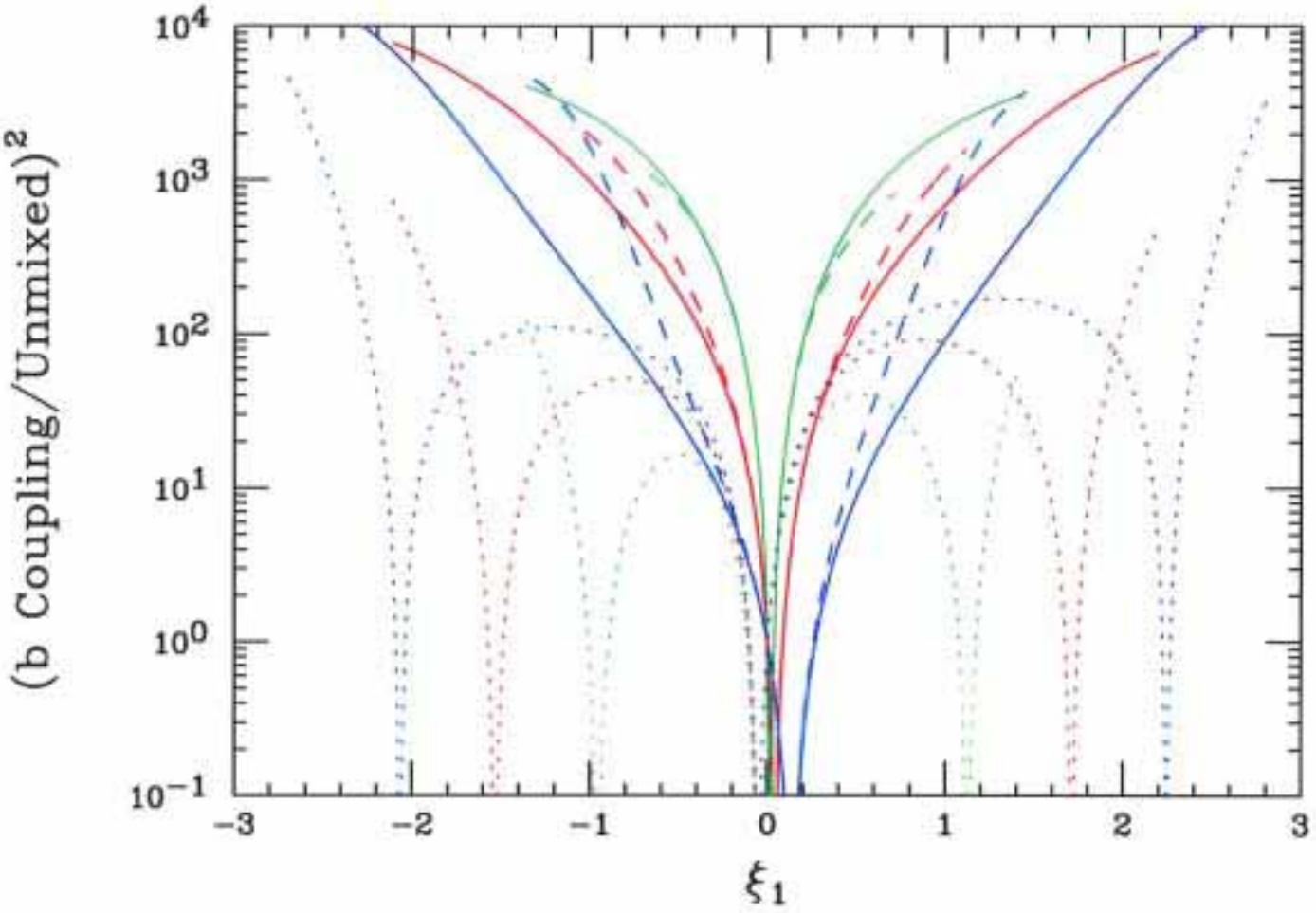
h88 coupling



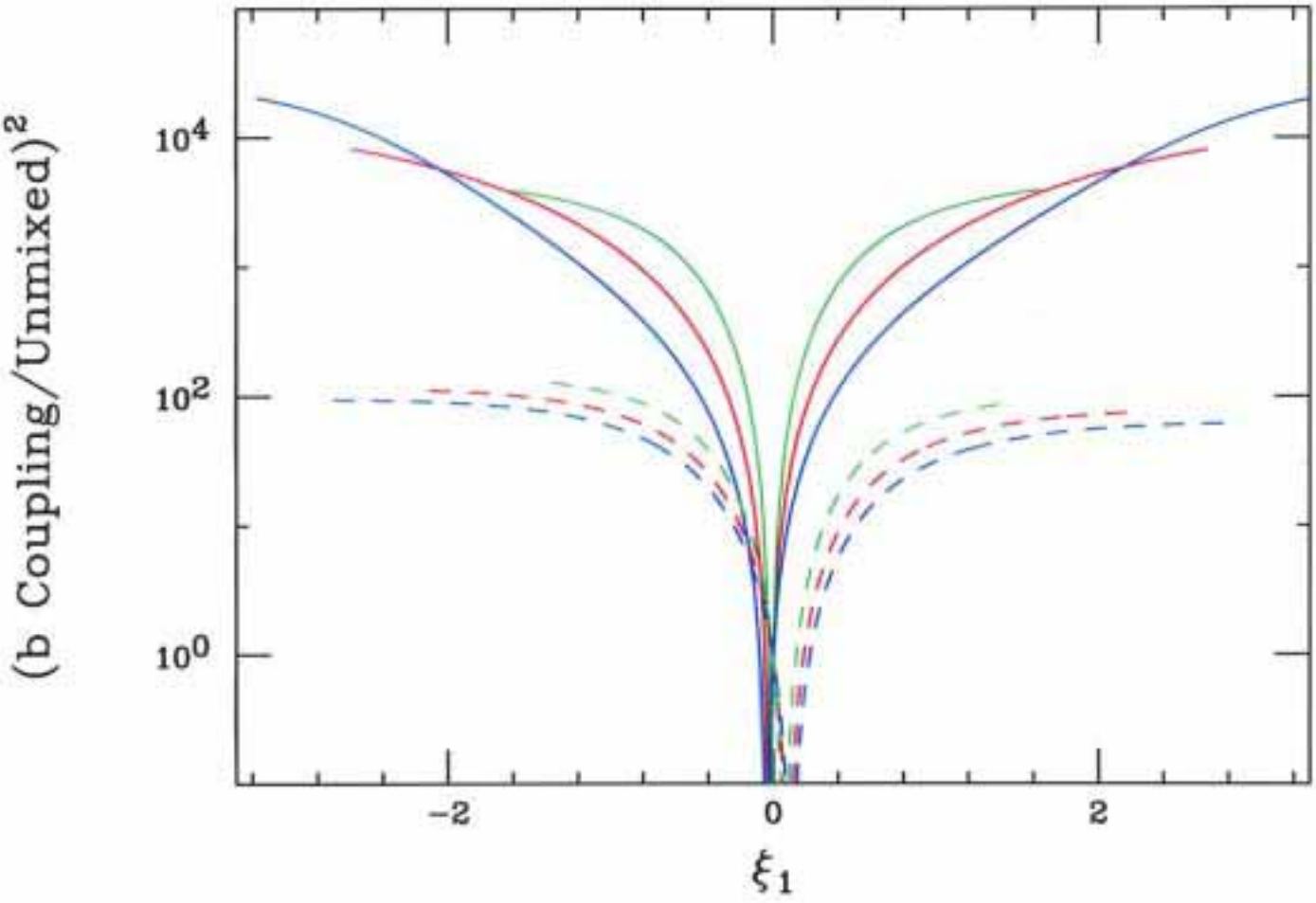
h γγ coupling



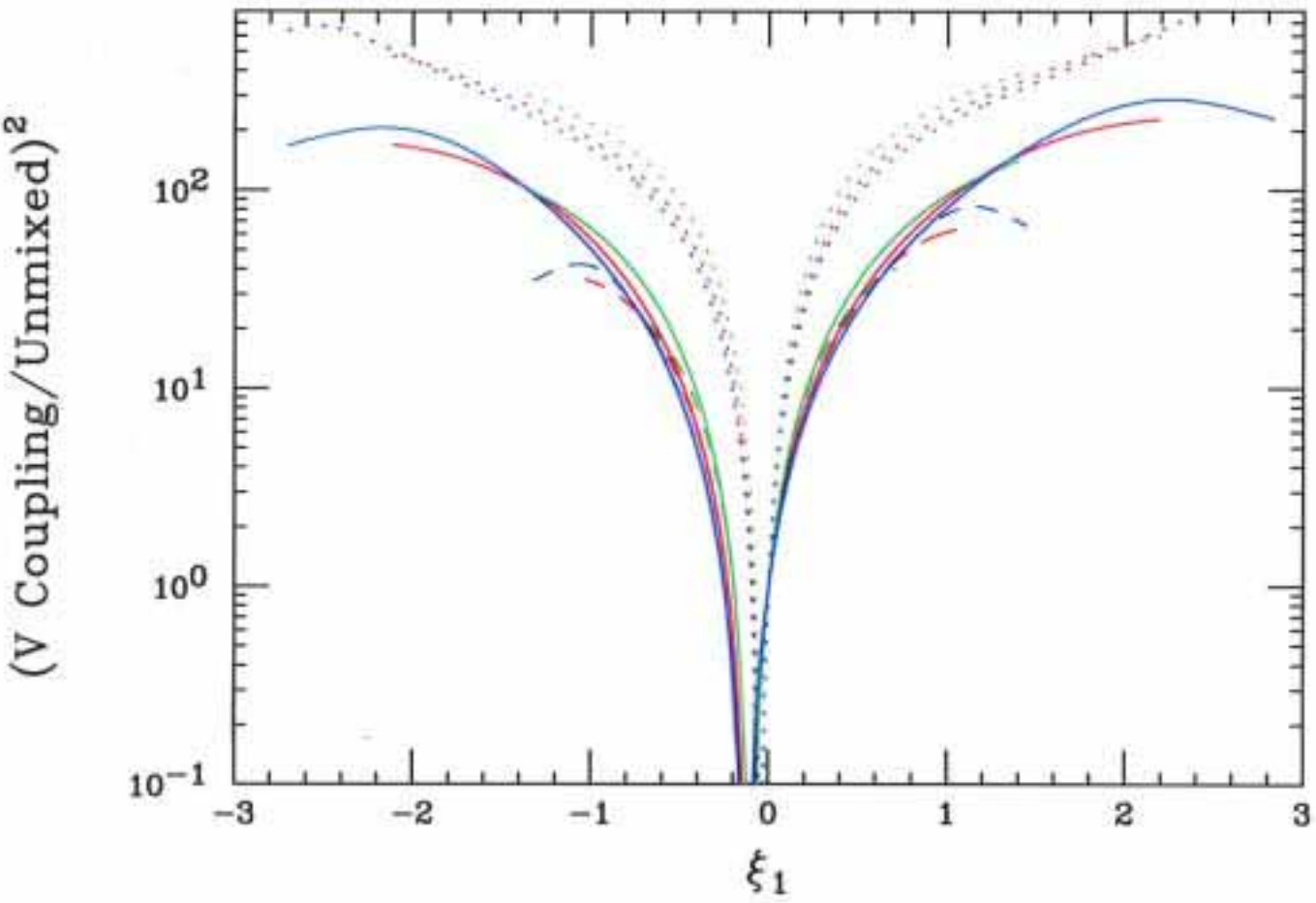
Radion couplings $r b\bar{b}$



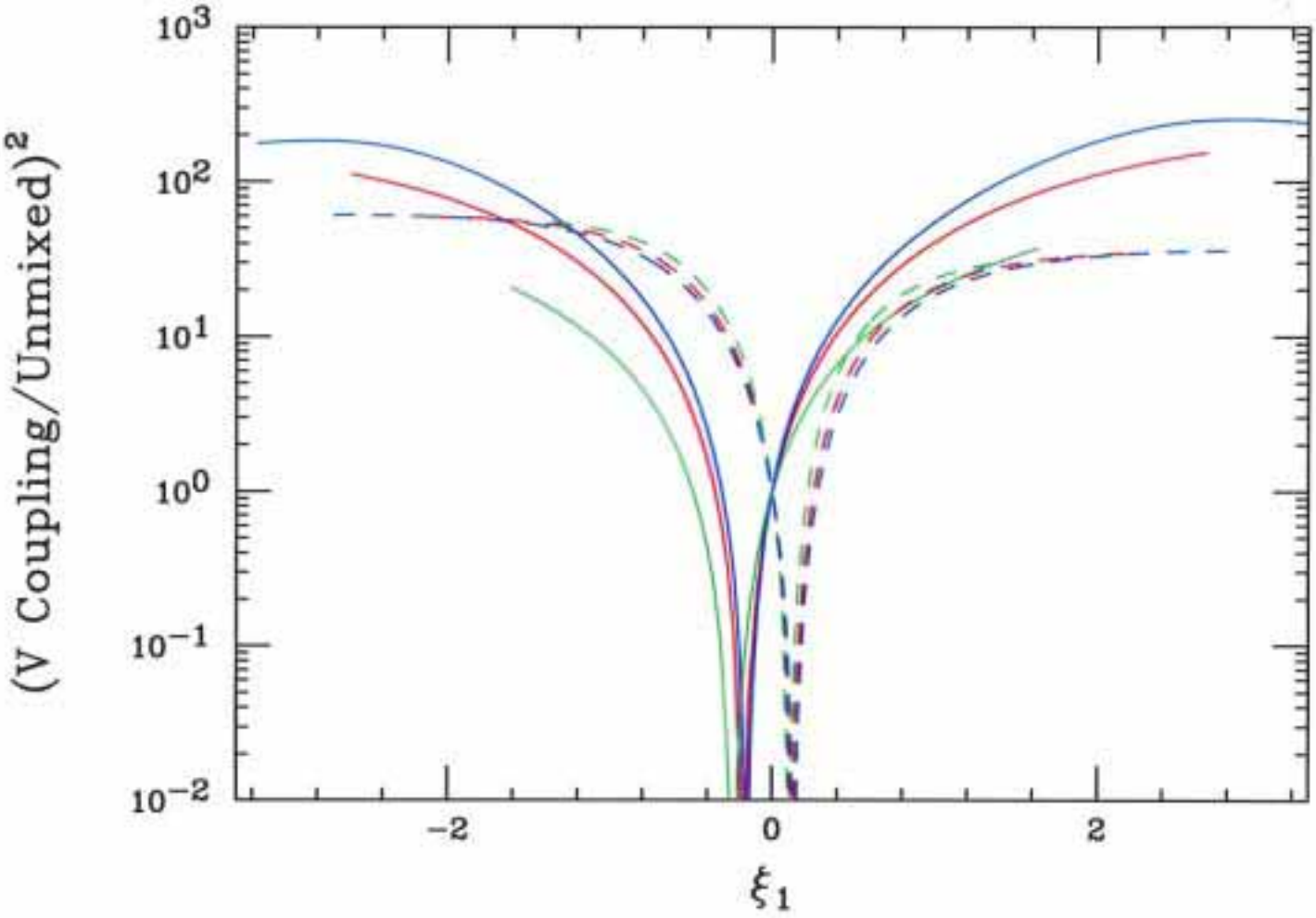
$\gamma\, b\bar{b}$



rVV coupling



rVV coupling



Summary + Conclusions

- Motivated by SUSY RS, we need to explore radion - TD mixing
- Unfortunately the parameter space is LARGE + we've only begun looking
- As expected, variations in masses & couplings are greater than in the one-doublet case
- Plenty of work remains...