Revealing Randall-Sundrum Hidden Valleys

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w/ Don Bunk (S.U.)

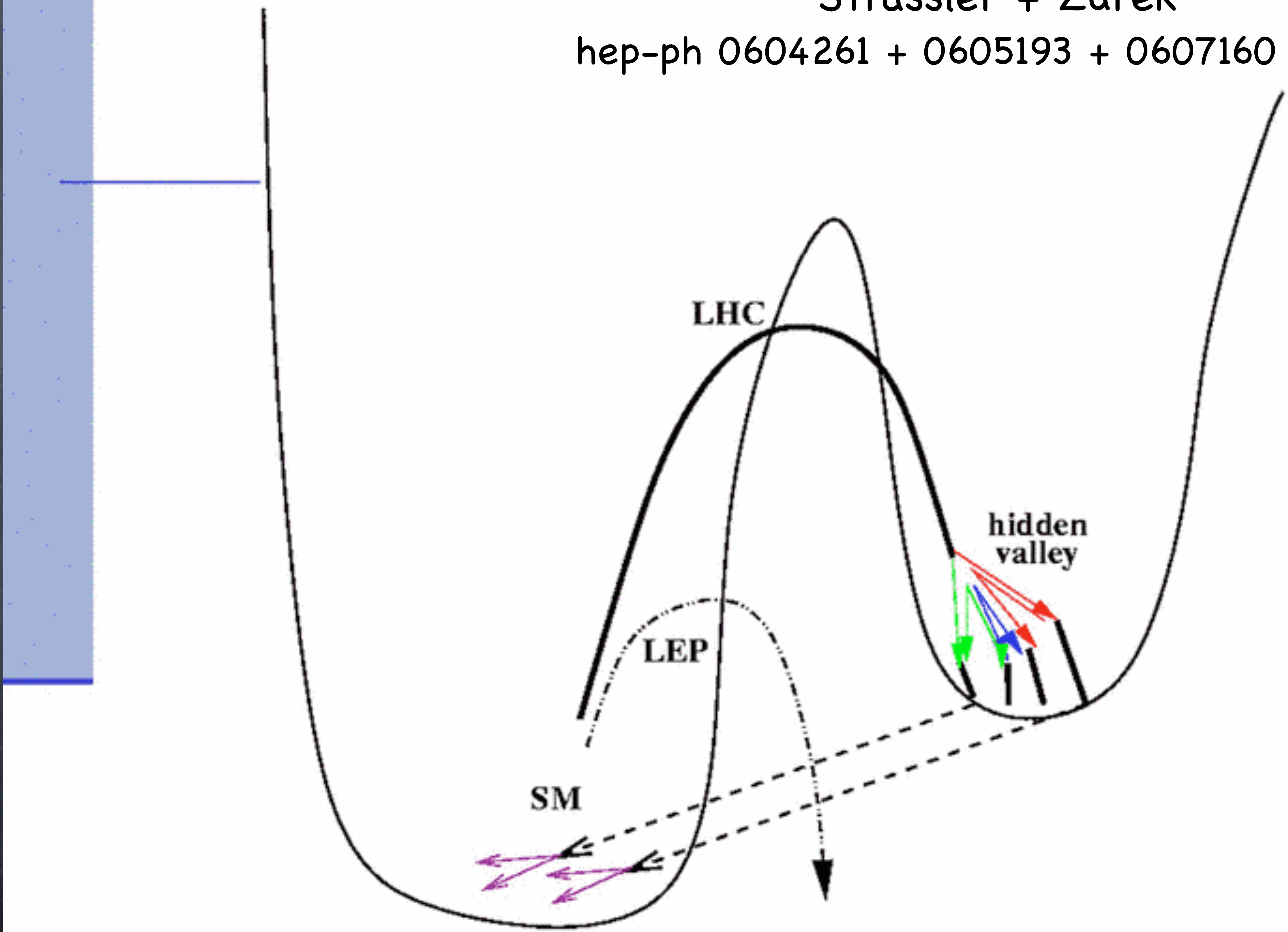
arXiv:1002.3160 [hep-ph]

arXiv:0901.2933 [hep-ph] (for related work)

Hidden Valley Models

Strassler + Zurek

hep-ph 0604261 + 0605193 + 0607160



Simple Picture

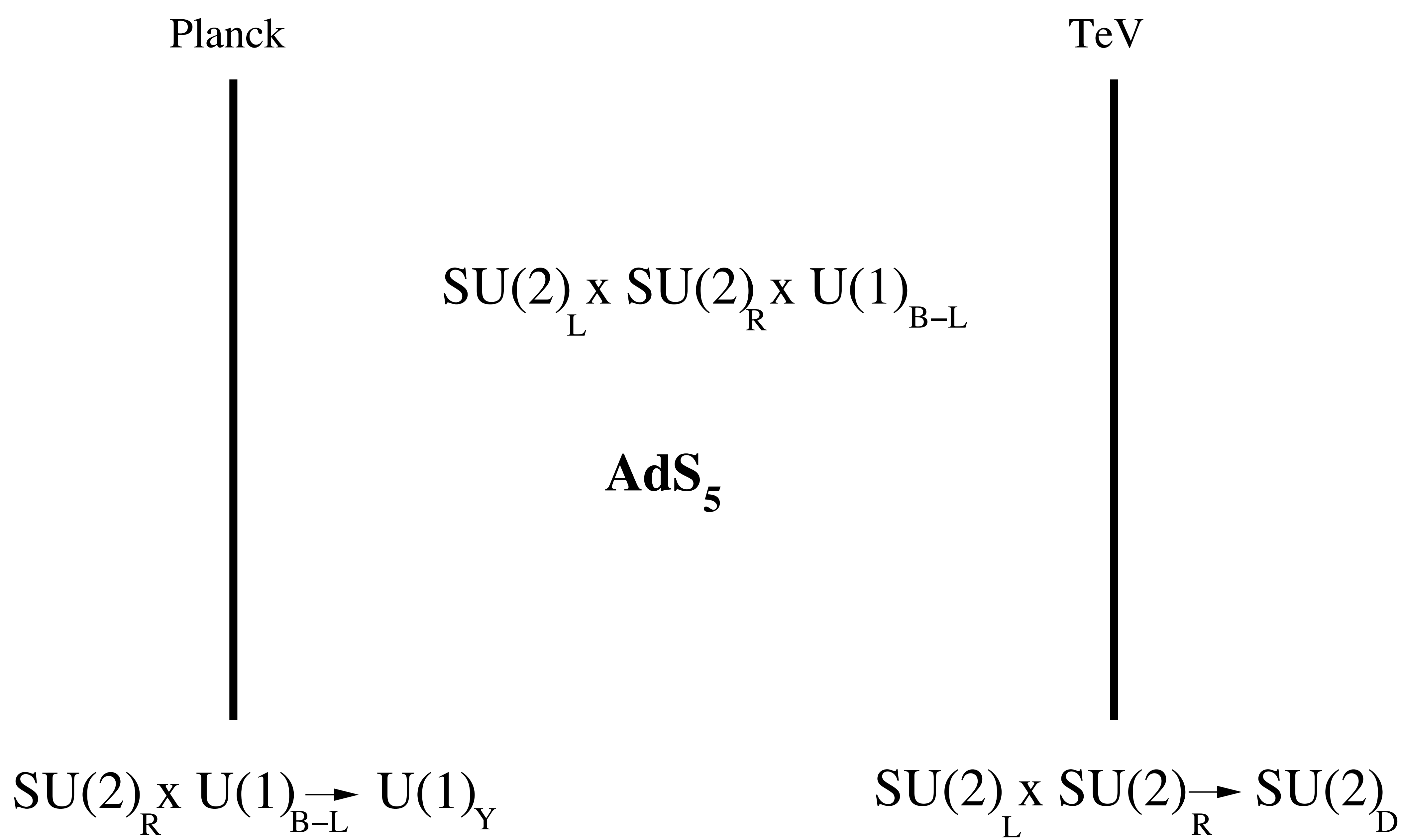
Hidden Valley Models

- Hidden sectors which are on the verge of discovery through some TeV scale bridge
  - Poorly constrained
    (no LEP - TeVatron bounds)
- Many potential unique signatures
  - displaced vertices - long "tunneling" rate
  - non-standard Higgs decays:
    http://arxiv.org/abs/hep-ph/0605193
    - e.g. dramatic multi-leptons, etc.

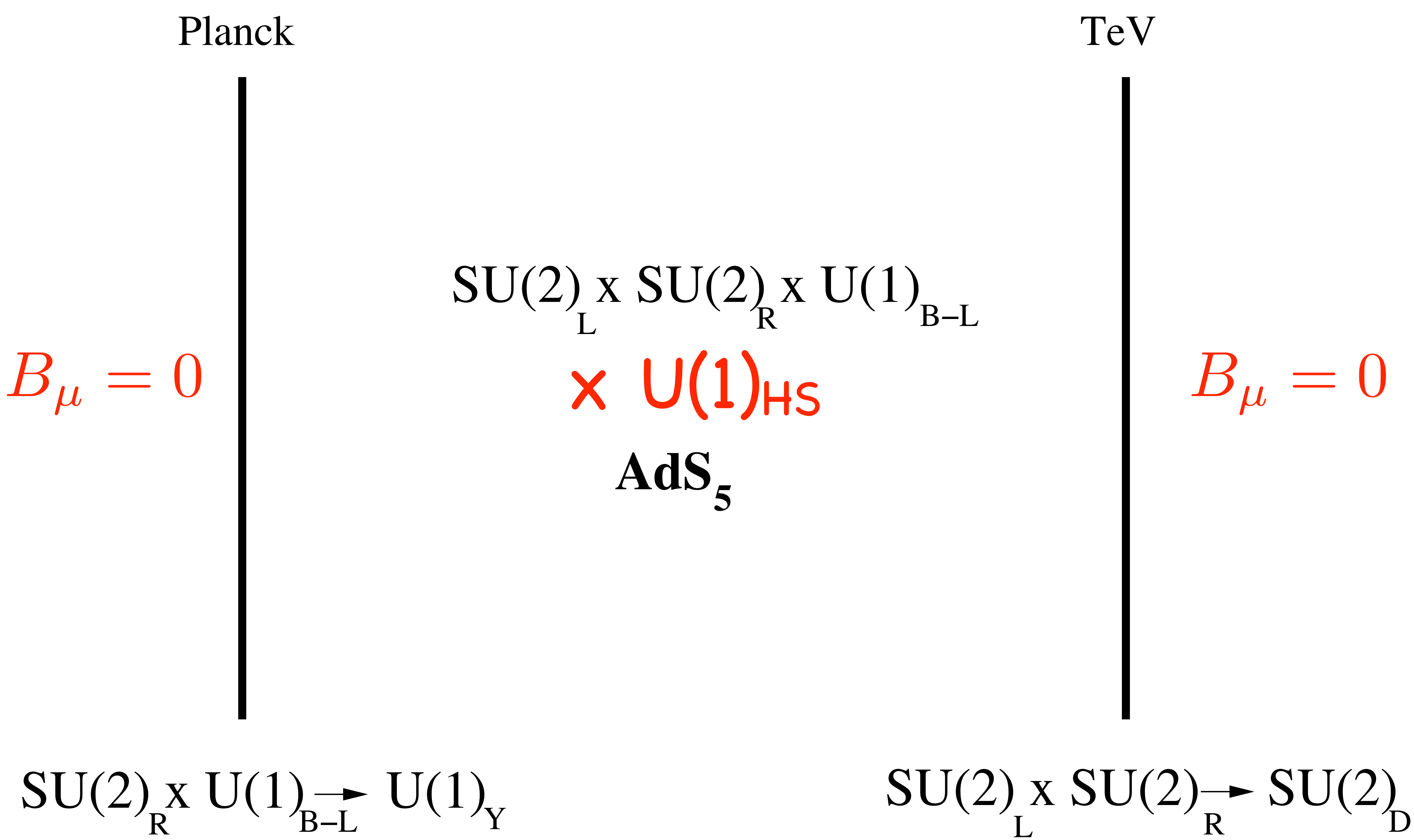
RS "Higgs" Models

- Many models of electroweak symmetry breaking in RS geometry
  - Higgsless models (review: hep-ph/0510275)
  - 5D Composite Higgs (ph/0412089 ph/0306259)
  - RS flavor arXiv:0904.2137 [hep-ph]
- Geometric warping explains the hierarchy between the Planck and electroweak scales
- AdS/CFT relates such models to 4D strongly coupled theories (but 5D model is calculable)

Example:
Higgsless Models



Higgsless Models + $U(1)_{HS}$

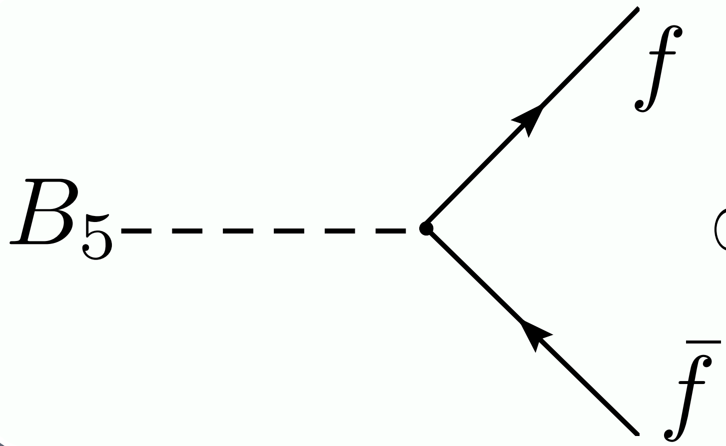


massless B_5 and massive (TeV) B_μ KK-modes

B_5 is a Goldstone boson (associated shift symmetry)

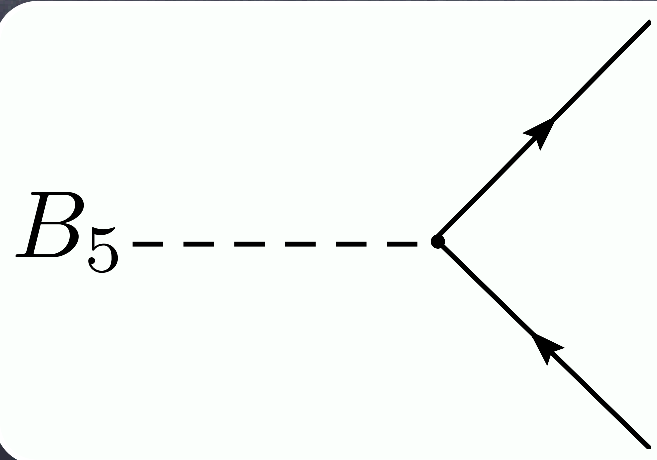
Hiding the Hidden Sector

- I. Take a very small gauge coupling



$$\propto \frac{1}{f_{\rm eff}} = \frac{\sqrt{2} g_{5\rm D} R'}{\sqrt{R}}$$

- II. SM has no direct interactions with hidden sector

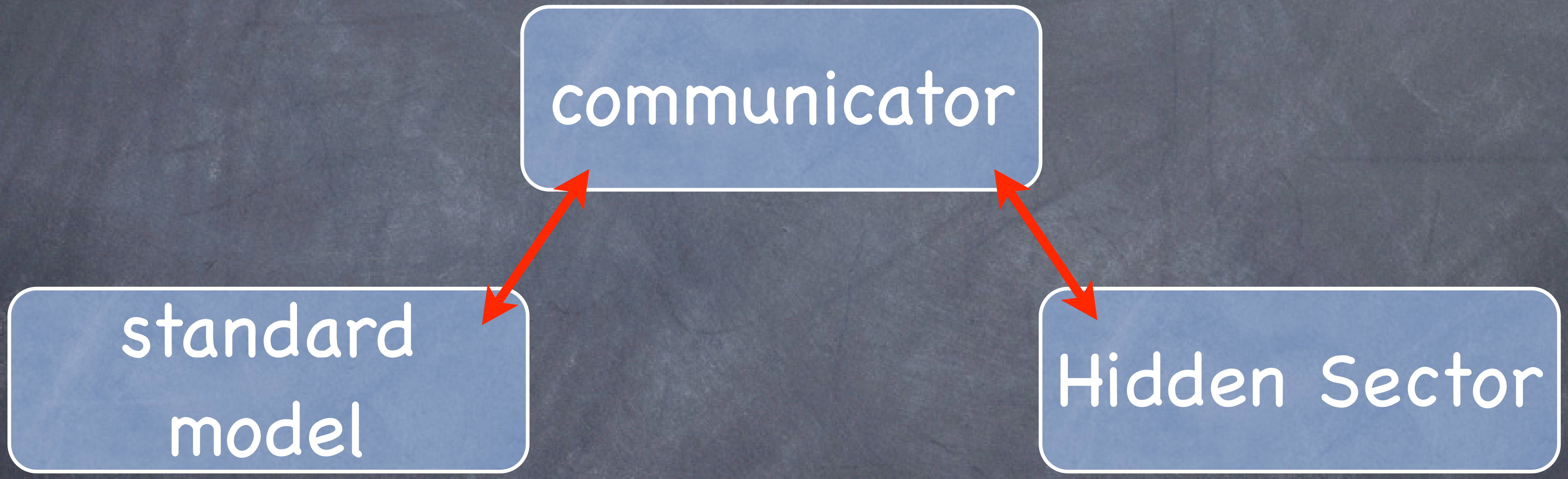


$$= 0$$

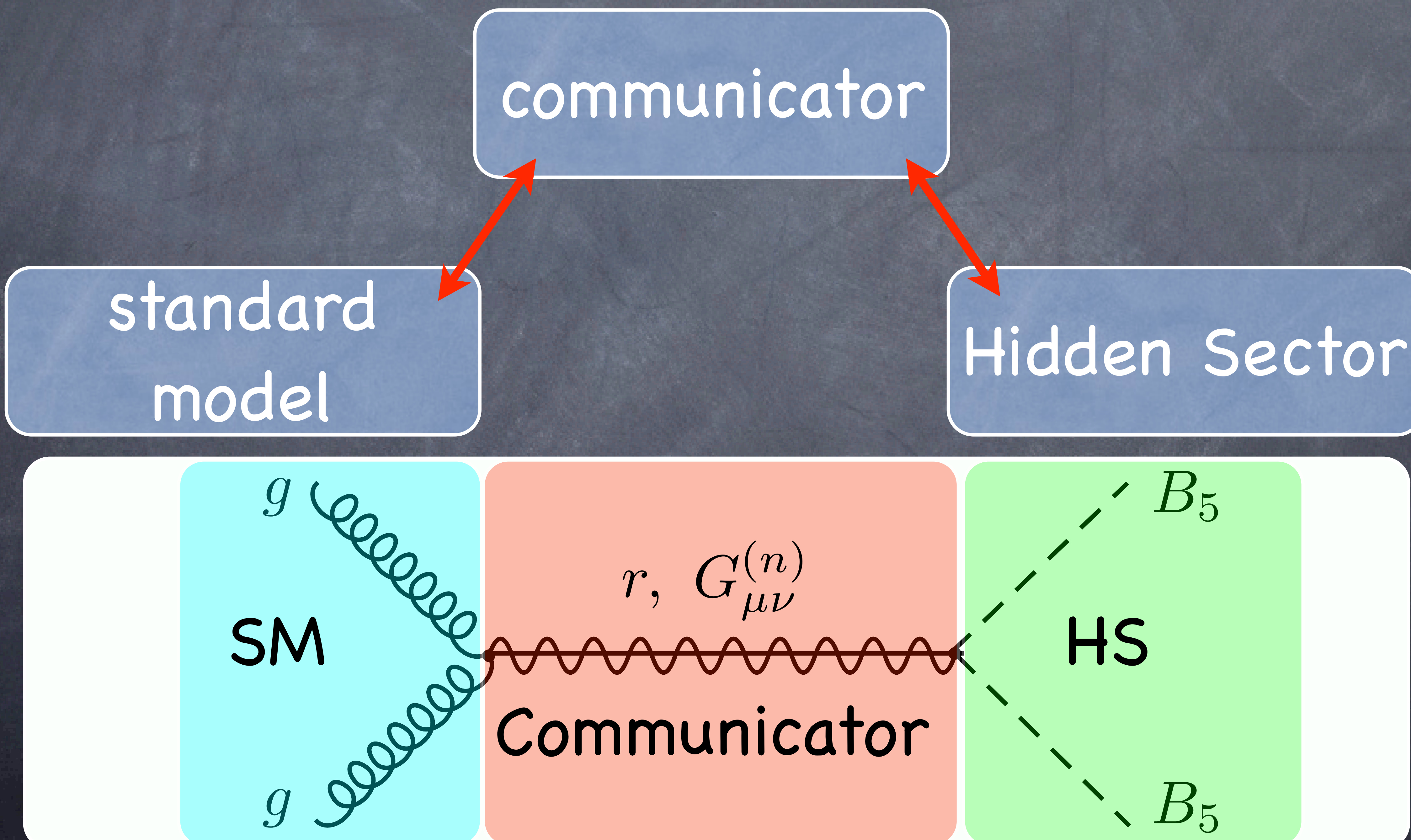
RS Gravity as a Bridge

- Usual gravity couples proportional to $1/M_{Pl}$
- In RS, warping causes radion and KK-gravitons to couple proportional to 1/TeV
  - radion (relative motion of the two branes) particle with mass ~ 114-1000 GeV
    - very well studied (lightest new particle?)
  - KK-gravitons ~ 1000-3000 GeV
- **COUPLINGS ARE INDEPENDENT OF g_{5D}**

Simple Picture

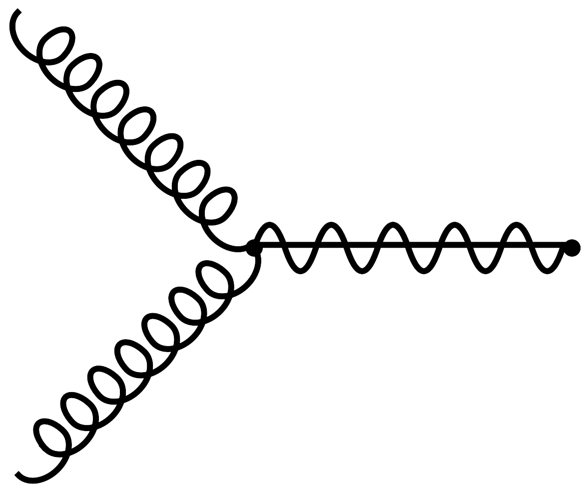


Simple Picture

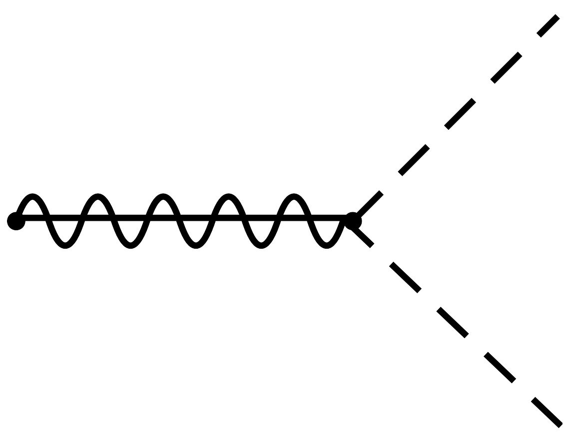


Radion Couplings

arXiv:0705.3844 [hep-ph] (Csaki JH and Lee)



$$rG_{\mu\nu}G^{\mu\nu}\frac{R'}{4\sqrt{6}\log R'/R}$$



$$r\partial_\mu B_5 \partial^\mu B_5 \frac{R'}{\sqrt{6}}$$

Both SM and Hidden sector couple with TeV scale strength to RS gravity

There are many couplings relevant for phenomenology

$rB^{(0)\mu}\partial_\mu B_5$	$1.09\frac{M_1}{\kappa\Lambda_r}$	$\hat{h}^{\mu\nu}_{(1)}B^{(1)}_\mu\partial_\nu B_5$	$-0.134\frac{M_1}{\kappa\Lambda_1}$	$\hat{h}^{\mu\nu}_{(2)}B^{(1)}_\mu\partial_\nu B_5$	$.099\frac{M_1}{\kappa}\Lambda_2$
$rB^{(1)}_\mu B^{(1)\mu}$	$\frac{4}{3}\frac{M_1^2}{2\kappa\Lambda_r}$	$\hat{h}^{\mu\nu}_{(1)}B^{(1)}_\mu B^{(1)}_\nu$	$-.137\frac{M_1^2}{2\kappa\Lambda_1}$	$\hat{h}^{\mu\nu}_{(2)}B^{(1)}_\mu B^{(1)}_\nu$	$.050\frac{M_1^2}{2\kappa\Lambda_2}$
$rB^{(1)}_{\mu\rho}B^{(1)\mu\rho}$	$\frac{1}{3}\frac{1}{2\kappa\Lambda_r}$	$\hat{h}^{\mu\nu}_{(1)}B^{(1)}_{\mu\rho}B^{(1)\rho}_\nu$	$.137\frac{1}{2\kappa\Lambda_1}$	$\hat{h}^{\mu\nu}_{(2)}B^{(1)}_{\mu\rho}B^{(1)\rho}_\nu$	$.053\frac{1}{2\kappa\Lambda_2}$
$r(\partial_\mu B_5)^2$	$2\frac{1}{2\kappa\Lambda_r}$	$\hat{h}^{\mu\nu}_{(1)}\partial_\mu B_5\partial_\nu B_5$	$-.219\frac{1}{2\kappa\Lambda_1}$	$\hat{h}^{\mu\nu}_{(2)}\partial_\mu B_5\partial_\nu B_5$	$.049\frac{1}{2\kappa\Lambda_2}$

Couplings of RS gravity to SM fields:

A. L. Fitzpatrick, J. Kaplan, L. Randall and L. T. Wang, JHEP **0709**, 013 (2007) [arXiv:hep-ph/0701150]. K. Agashe, H. Davoudiasl, G. Perez and A. Soni, Phys. Rev. D **76**, 036006 (2007) [arXiv:hep-ph/0701186].

(our results conform to this previous work in relevant limits)

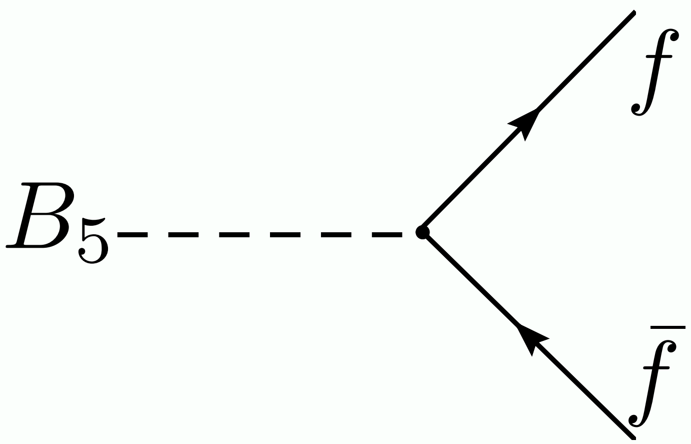
Accessible Hidden Sector Phenomenology

- At colliders - without hidden sector, radion production and decays are very similar to a SM Higgs
  - new decay mode of the radion:

$$\boxed{gg \to r \to B_5 B_5}$$

  - dominates width for light (< 160 GeV) radions
  - 20% of width for higher mass radions

Weak Coupling: Displaced vertices!



$$\Gamma = \frac{q^2}{4\pi}\left(\frac{m_f}{f_{\mathrm{eff}}}\right)^2 m_{B_5}$$

for small gauge coupling ($1/f_{\mathrm{eff}}$), B_5 can have collider-scale time of flight:

$$\Delta x = 58\mathrm{cm}\left(\frac{f_{\mathrm{eff}}}{10^6\mathrm{GeV}}\right)^2\left(\frac{10\mathrm{GeV}}{m_{B_5}}\right)\sqrt{\left(\frac{E}{m_{B_5}}\right)^2 - 1}$$

What might such a hidden sector be doing?

- The light scalar field most prominently discussed in the literature is the axion
- See Talk by Don Bunk in this session

Conclusions

- RS models are natural candidates for Hidden Valley theories
  - RS gravity automatically and unavoidably bridges between SM and hidden RS gauge sectors
- Such hidden sectors can dramatically change the phenomenology of RS gravity (non-standard radion decays which may lead to very non-standard Higgs decays)
- Such a hidden sector may be responsible for resolving issues with the SM (strong CP - Don Bunk)
  - such models predict new processes relevant for collider pheno of RS gravity (displaced vertices - LHCb)