Phenomenology of the Soft Wall

Searching for KK mode signals at the LHC

Based on J. de Blas, A. Delgado, B.O. and A. de la Puente. arXiv: 1205.xxxx

Bryan Ostdiek

University of Notre Dame

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General metric for warped 5D model.

$$ds^2 = e^{-2A(y)} \eta_{\mu\nu} dx^\mu dx^\nu - dy^2$$

RS models: $A(y) = ky$

- Two branes: $y_{UV} = 0$ and $y = y_{IR}$. All SM fields on IR brane.
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- Weaken the contributions to T when fermions also in the bulk, however, still large.
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- Weaken the contributions to T when fermions also in the bulk, however, still large.
- EWPD provide bounds on KK masses too large for reach of LHC.
- Gauging custodial symmetry protects the T parameter from large tree level contributions.
- Bounds on KK masses around a few TeV.

The Model

General metric for warped 5D model.

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- Hierarchy problem solved if $A(y_1) \sim 35$
- Higgs placed in the bulk.

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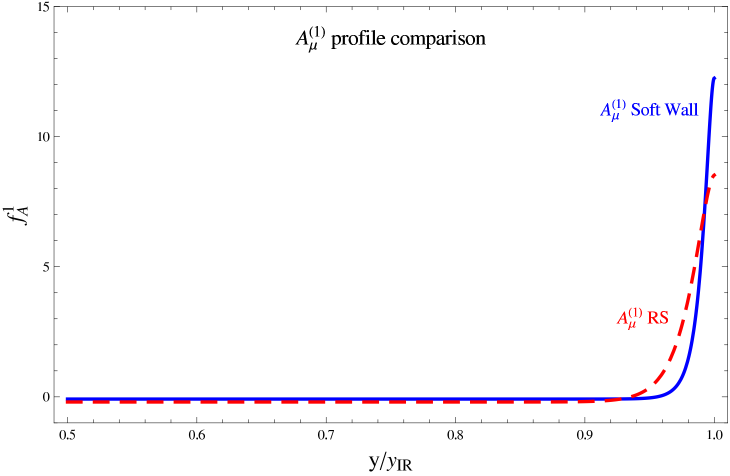
- Higgs placed in the bulk.
- Use of soft wall metric suppresses the coupling of EW KK modes to the Higgs which softens EWPO bounds without resorting to gauged custodial symmetry.

The Model

The soft wall metric pushes the KK gauge bosons towards the IR brane.



The Model

Literature gives a set of benchmark parameters which are within EWPO.

Bench Mark	k	y_1	y_s	ν	M_{gauge}^{KK}(TeV)
1	$5.13{\cdot}10^{17}$	$4.90{\cdot}10^{-17}$	$5.17{\cdot}10^{-17}$	0.55	2.4
2	$1.12{\cdot}10^{18}$	$2.48{\cdot}10^{-17}$	$2.62{\cdot}10^{-17}$	0.64	4.0
3	$1.79{\cdot}10^{18}$	$1.65{\cdot}10^{-17}$	$1.65{\cdot}10^{-17}$	0.73	5.2

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- Production cross section too small to search for signals other than in benchmark 1.

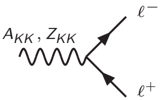
Production cross section at 14 TeV, $M^{KK} = 2.4$ TeV

$\sqrt{s} = 14$ TeV	A_{KK}	Z_{KK}	W_{KK}	G_{KK}
$\sigma(pp \to X)$	2.98 fb	3.66 fb	10.05 fb	133.15 fb

Production: leptonic final states

Cross Section times branching ratio:

Di-lepton $\sqrt{s} = 14$ TeV.



X	$\sigma(pp > X)$	$BR(X > \ell^+\ell^-)$	Total
Akk	2.98 fb	0.002	5.96 ab
Zkk	3.66 fb	$2.66\cdot 10^{-4}$	0.97 ab
Both	6.64 fb	-	6.94 ab

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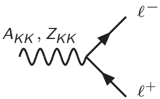

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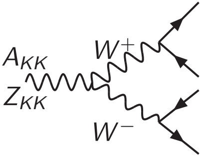

Di-boson fully leptonic $\sqrt{s} = 14$ TeV.

X	$\sigma(pp > X)$	BR($X > W^+W^-$)	BR($W > \ell\ \nu_\ell$)	Total
Akk	2.98 fb	0.136	0.2132	18.4 ab
Zkk	3.66 fb	0.0236	0.2132	3.93 ab
Both	6.64 fb	-	-	22.33 ab

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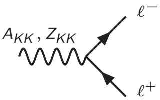

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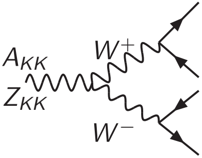

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Di-boson semi leptonic $\sqrt{s} = 14$ TeV.

X	$\sigma(pp \to X)$	BR($X \to W^+W^-$)	BR($W \to \ell\ \nu_\ell$)	BR($W \to jj$)	$\times 2$	Total
Akk	2.98 fb	0.136	0.2132	.676	$\times 2$	117 ab
Zkk	3.66 fb	0.0236	0.2132	.676	$\times 2$	24.9 ab
Both	6.64 fb	-	-	-	-	142 ab

Widths

Small signals in lepton channels dominated by small branching ratios.

$m_{A_{KK}} = 2.442$ TeV			$m_{Z_{KK}} = 2.465$ TeV		
Decay	Width (GeV)	BR	Decay	Width (GeV)	BR
$t\bar{t}$	27.767	0.695	$b\bar{b}$	56.387	0.570
$b\bar{b}$	6.245	0.156	$t\bar{t}$	37.696	0.381
W^+W^-	5.453	0.136	W^+W^-	2.338	0.024
$q\bar{q}$	0.387	0.010	ZH	1.797	0.018
$\ell^+\ell^-$	0.111	0.003	$q\bar{q}$	0.626	0.006
-	-	-	$\nu\bar{\nu}$	0.074	0.001
-	-	-	$\ell^+\ell^-$	0.036	$3.63 \cdot 10^{-4}$
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Decay	Width (GeV)	BR	Decay	Width (GeV)	BR
$t\bar{t}$	113.790	0.520	$t\bar{b}$	120.060	0.907
$b\bar{b}$	102.370	0.468	W^+Z	5.764	0.044
$u\bar{u}$	0.645	0.003	W^+H	5.669	0.043
$d\bar{d}$	0.645	0.003	$q\bar{q}$	0.700	0.006
$s\bar{s}$	0.644	0.003	$\ell^+\nu_\ell$	0.038	$2.87\cdot10^{-4}$
$c\bar{c}$	0.622	0.003	-	-	-
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$\sqrt{s}$	$\sigma(pp \to W_{KK})$	BR($W_{KK} \to tb$)	BR($t \to Wb$)	BR($W \to \ell\nu_\ell$)	Total
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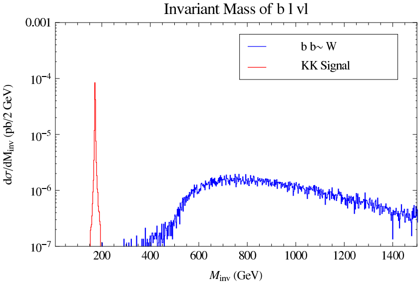

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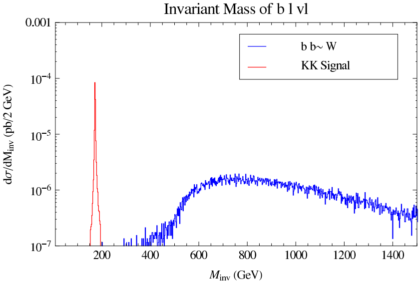

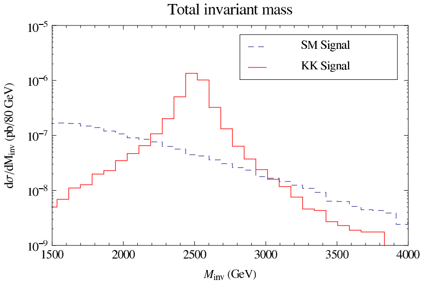

After cuts: Signal cross section = 0.323 fb
Background cross section = 0.175 fb.

14 TeV	Basic			$2000 \leq M_{inv} \leq 3000$		
50 fb $^{-1}$	Events	S/B	$S/\sqrt{B}$	Events	S/B	$S/\sqrt{B}$
W_{KK}	16	2	5.65	12	12	12
SM	8			0		

$t\bar{t}$ production

$\sqrt{s} = 8$ TeV			
X	$\sigma(pp \to X)$(fb)	BR($X \to t\bar{t}$)	Total (fb)
A_{KK}	0.227	0.695	0.158
Z_{KK}	0.244	0.381	0.093
G_{KK}	9.32	0.520	4.85
All	9.79	-	5.10
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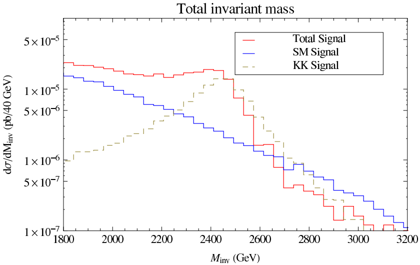

Cut: $p_{T,t} \geq 800$ GeV

- S_8: 4.61 fb B_8: 8.06 fb.
- S_{14}: 58.6 fb B_{14}: 120.5 fb.

8 TeV	Basic			$2200 \leq M_{inv,t\bar{t}} \leq 2600$		
10 fb $^{-1}$	Events	S/B	$S/\sqrt{B}$	Events	S/B	$S/\sqrt{B}$
G_{KK}	46	0.575	5.14	29	3.22	9.67
SM	80			9		
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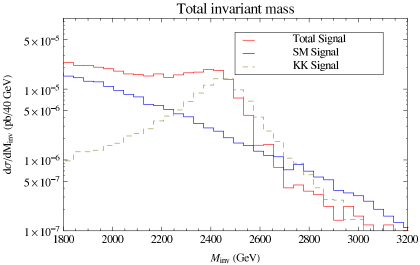

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- Cross section for leptonic final states too small for detection
- Gluon KK mode detectable with 10 fb^{-1} integrated luminosity at $\sqrt{s} = 8$ TeV.
- W KK mode detectable with 50 fb^{-1} integrated luminosity at $\sqrt{s} = 14$ TeV.
- Have signal of both charged and neutral new gauge bosons with the same mass.
- Peaks should be spread due to large decay widths.
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- Peaks should be spread due to large decay widths.
- $t\bar{t}$ production takes less luminosity, should see it first.
- Possible to discover KK modes by the end of the year!

Backup Slides

Fermion localization

Equation of motion

$$\begin{aligned} \partial_y f_L^n(y) - M_\psi(y) f_L^n(y) &= e^{A(y)} m_n f_R^n(y) \\ \partial_y f_R^n(y) + M_\psi(y) f_R^n(y) &= e^{A(y)} m_n f_L^n(y) \end{aligned}$$

0 mode profile

$$f_{L,R}^{(0)} = \frac{e^{\pm c_\psi A(y)}}{\left[\int_0^{y_1} e^{A(y')\left(1\pm 2c_\psi\right)} dy'\right]^{1/2}}$$

With $M_\psi(y) = c_\psi A'(y)$

Fermion localization

Fermion c-values used.

$c_{(u,d)_L} = 0.71$	$c_{(c,s)_L} = 0.63$	$c_{(t,b)_L} = 0.31$
$c_{u_R} = 0.74$	$c_{c_R} = 0.57$	$c_{t_R} = 0.42$
$c_{d_R} = 0.68$	$c_{s_R} = 0.67$	$c_{b_R} = 0.66$
$c_{(\ell,\nu_\ell)_L} = c_{\ell_R} = 0.52$		

J. A. Cabrer, G. von Gersdorff and M. Quiros, JHEP **1201**, 033 (2012) [arXiv:1110.3324 [hep-ph]].