Constraints on models with universal extra dimensions from dilepton searches at the LHC

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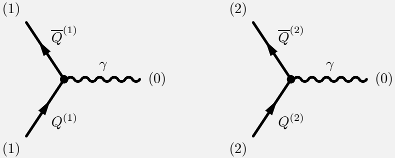
Basics

- UED models have additional flat, compact extra dimensions, where all particles enter the bulk [Appelquist, Cheng, Dobrescu, 2001]
- SM particles are the lowest (0) modes of the Kaluza-Klein (KK) towers
- MUED: minimal version (only 1 extra dimension with radius R, no boundary terms)
- "Free" parameters: Cut-off scale Λ and R^{-1}
- Compactification on a circle: $x_5 + 2\pi R \rightarrow x_5$
- Z_2 Orbifold projection $x_5 \rightarrow -x_5$ ($\rightarrow$ chiral fermions, KK-parity $\mathcal{P}_5$)

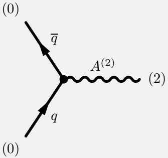
KK-number conserving:



Unsuppressed

$\leftrightarrow$

KK-number violating:

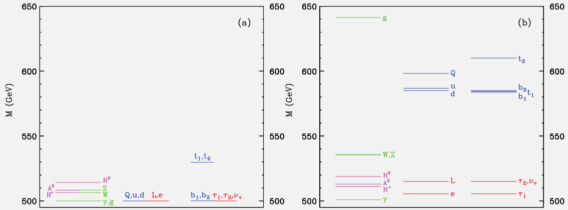


Loop-suppressed

Signals, Limits & Searches

Particle Spectrum

- KK-tower: "Copies" of the SM particles at mass $m_{KK}^2 = n^2/R^2 + m_{SM}^2$
- KK-parity induces a lightest, stable KK-particle (LKP) which can serve as a DM candidate!



[Cheng et al, 2002]

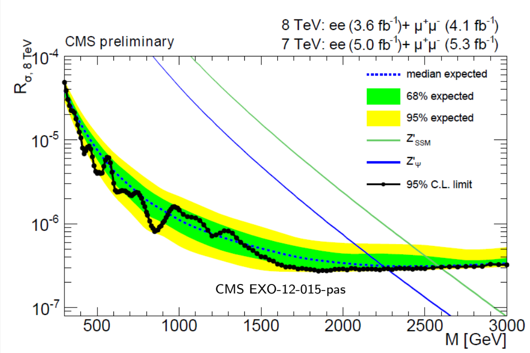
What are the limits?

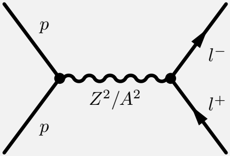
- Electroweak precision tests [Appelquist, 2003],[Baak et al, 20012], $R^{-1} \gtrsim$ 750 GeV
- FCNC $R^{-1} \gtrsim 650$ GeV [Buras et al 2003], [Buras etal, 2004, 2004], [Haisch et al, 2007]
- relic density of DM candidate $R^{-1} \lesssim 1.6$ TeV [Belanger et al, 2011]

Main Problem: Mass spectrum is compressed $\rightarrow \not{E}_T$ searches suffer in general from low detection efficiencies!

Resonant dilepton analysis

Search used here: Search for Resonances in the Dilepton Mass Distribution in pp Collisions at $\sqrt{s} = 8$ TeV ($20.6 fb^{-1}$, 2012) [CMS-PAS-EXO-12-061]



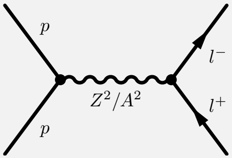


- ☺ KK-2 resonances gives a good discrimination against the MSSM
- ☺ Clear study
- ☹ EW process & Loop suppressed vertices!

Are there other contributions?

Where are the resonant lepton signals ???

→ direct resonant s-channel dilepton production is too low for interesting exclusion limits!



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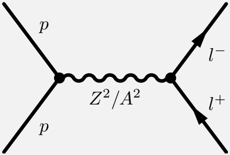
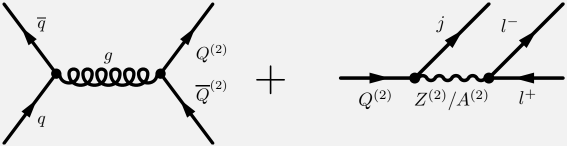


→ Can't we exploit the high production rates of the colored stuff?



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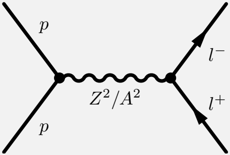

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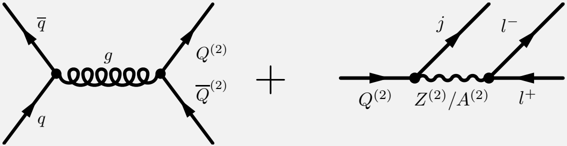

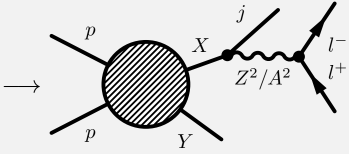

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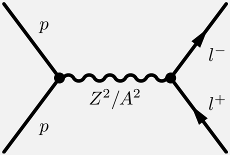

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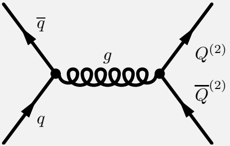

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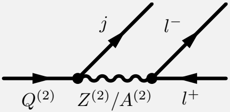

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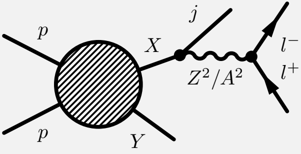
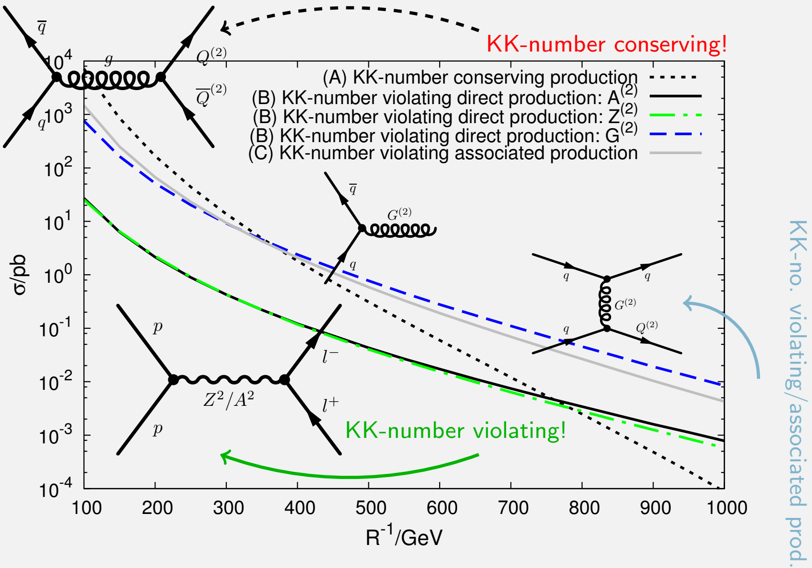
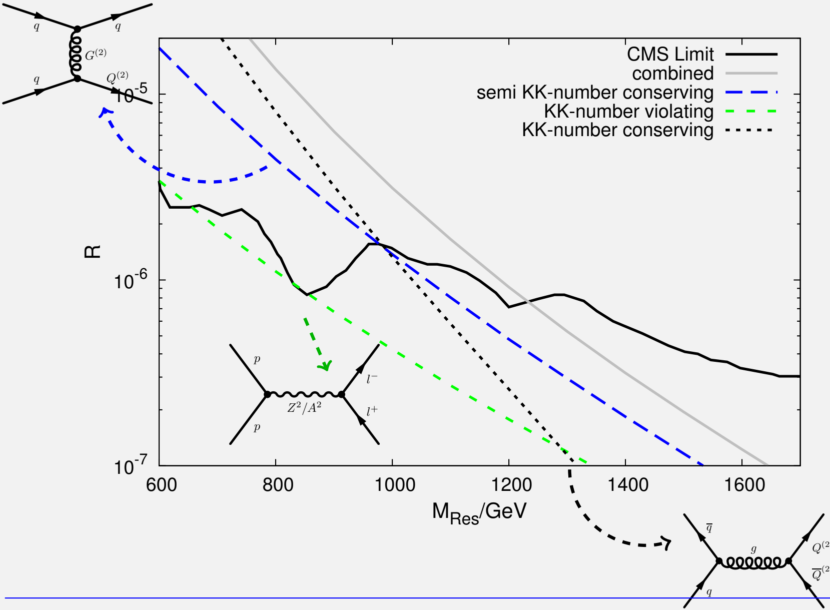


Cuts? Acceptances? ✓

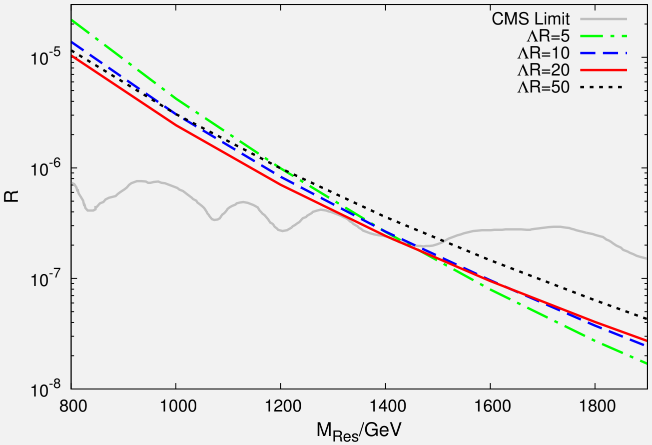
Production Crosssection



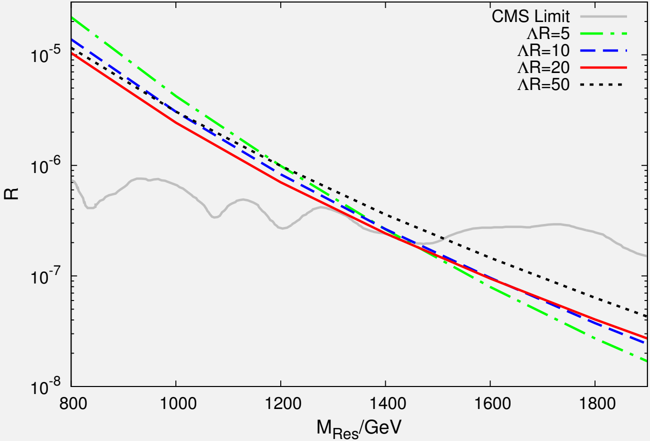
Some contributions...



Results from Dilepton Bounds



- Low ΛR: KK-no. conserving interactions are dominant (second KK modes are lighter)
- High ΛR: KK-no. violating interactions are enhanced ($\propto Log(\Lambda R)$)



95% C.L. lower bounds on R^{-1} for different cutoff parameters ΛR:

ΛR	5	10	20	50
R^{-1}/[GeV]	720	730	715	755

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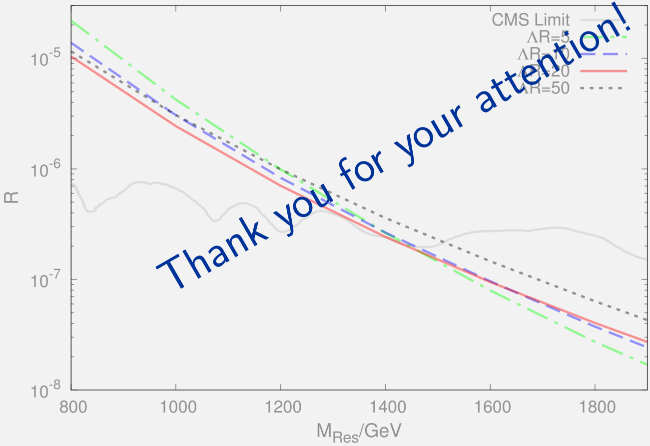

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Appendix

Some important Details of the model part I: The mass spectrum

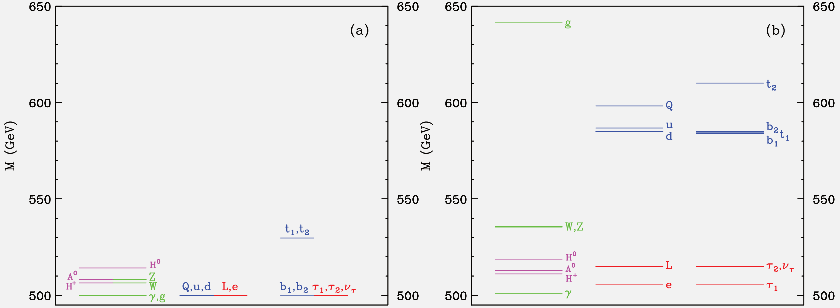
Degenerate mass spectrum: $m_n^2 = \frac{n^2}{R^2} + m_{SM}^2$

Mass spectrum

$$m^2_{\mathcal{G}(n)} = \left(\frac{n}{R}\right)^2 + a_{\mathcal{G}} \frac{\zeta(3)}{16\pi^4} \frac{1}{R^2} + \frac{b_{\mathcal{G}}}{16\pi^2} \ln\left(\frac{\Lambda^2}{\mu^2}\right) \frac{n^2}{R^2}$$

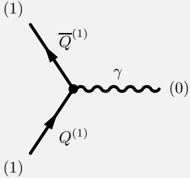
$$m_{\psi(n)} = \left(\frac{n}{R}\right) + \frac{b_\psi}{16\pi^2} \ln\left(\frac{\Lambda^2}{\mu^2}\right) \frac{n}{R}$$

5D mass (tree level); bulk corrections; boundary corrections [Cheng et al, 2002]



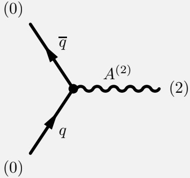
Some important Details of the model part II: The couplings

□ Every vertex conserves KK parity: $(\pm n_1 \pm n_2 \pm n_3) =$ even;
e.g. (1+1+0); tree-level.
Not important here.



□ KK number violating vertices $(\pm n_1 \pm n_2 \pm n_3) =$ even;
e.g. $(2 \pm 0 \pm 0)$;
loop suppressed

$$\mathcal{L} \supset -ig_{\mathcal{G}} \left[\frac{b_{\mathcal{G},2} - 2b_{\psi,2}}{\sqrt{2}\,16\pi^2} \ln\left(\frac{\Lambda^2}{\mu^2}\right) \right] \overline{\psi}^{(0)} \gamma^{\mu} T^a P_+ \psi^{(0)} \mathcal{G}_{\mu}^{a(2)}$$



□ KK number preserving vertices: $(\pm n_1 \pm n_2 \pm n_3) = 0$;
e.g. $(2 \pm 1 \pm 1)$, $(2 \pm 2 \pm 0)$
tree level, but two KK-2 modes involved!