It’s a Graviton! or maybe not...

Ricky Fok, Caroline Guimaraes, Randy Lewis, Veronica Sanz

York University

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Finding KK gravitons in colliders

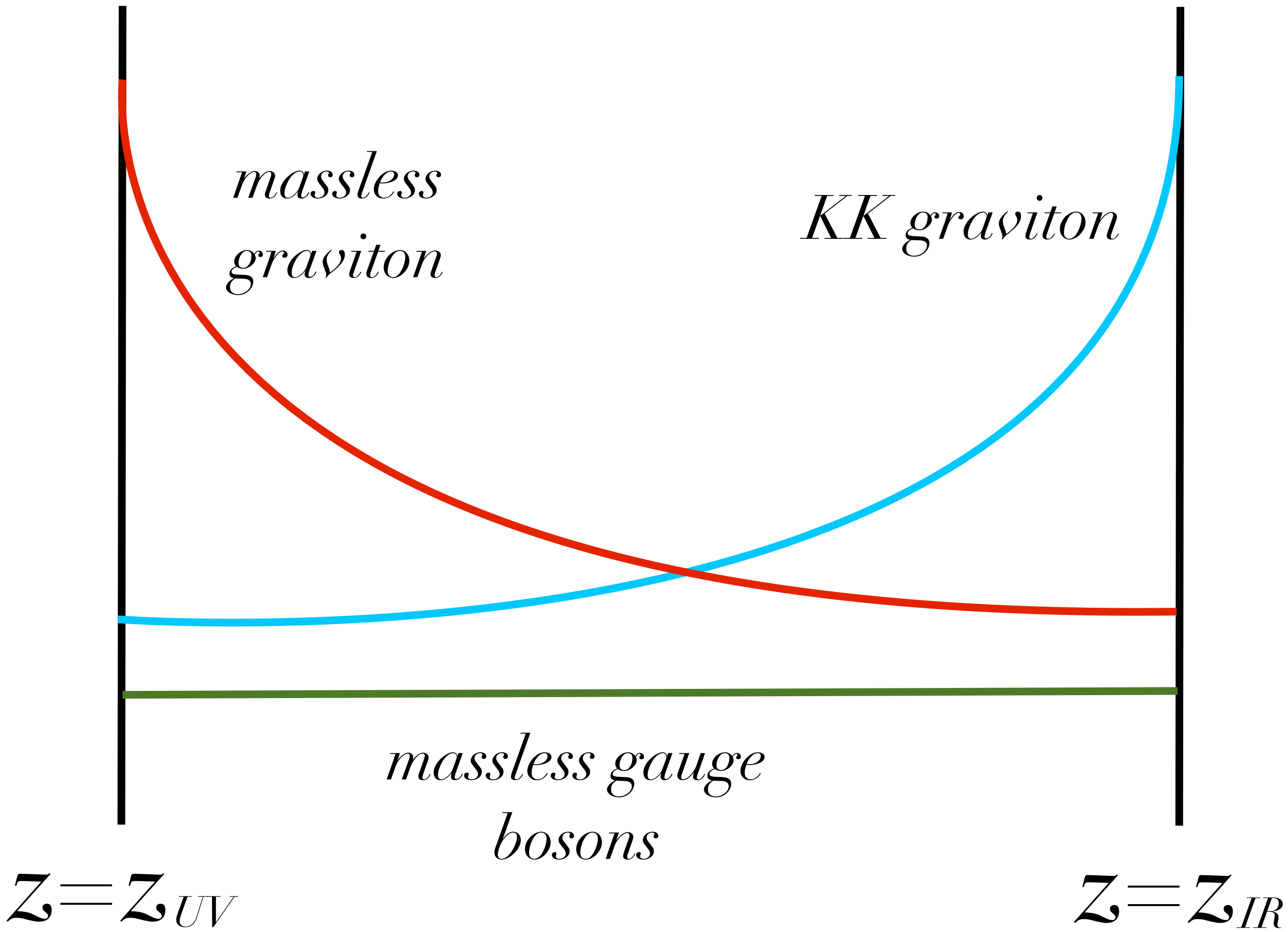
- Spin-2 resonances exist in other new physics. E.g. Technicolor
- Could have the same mass range ~ O(TeV)
- Need to find a true smoking gun signal for KK gravitons in colliders.

Outline

- KK gravitons and its couplings to SM fields
- Interactions of the impostors
- Collider observable

Fields in extra dimension

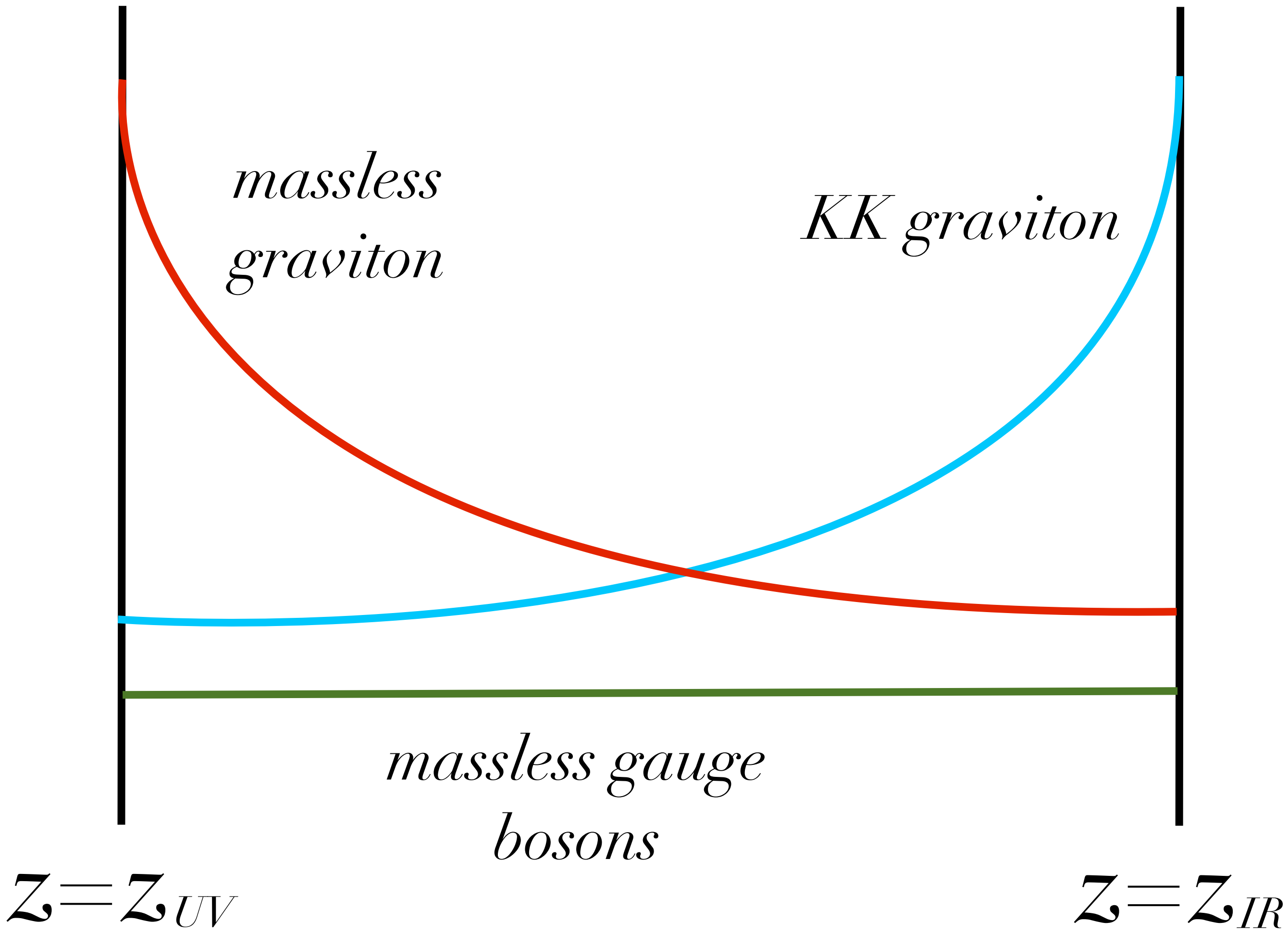
$$ds^2 = w^2(z)\left(\eta_{\mu\nu}dx^\mu dx^\nu - dz^2\right)$$



Fermions can be localized anywhere.

KK Graviton couplings

$$\mathscr{L}_{int} = -\frac{c_i}{M_{eff}} G^{\mu\nu} T^i_{\mu\nu}$$



IR localized: $c \sim 1$

Flat profile: $c \simeq \frac{1}{\int_{z_{UV}}^{z_{IR}} w(z) dz}$

UV localized: $c \sim \left(\frac{TeV}{M_{Pl}}\right)^a$

KK graviton coupling negligible for UV localized fields

KK graviton impostor couplings

Imposing Lorentz and gauge invariance, up to dim 5

$\hat{O}^{decay}_{\mu\nu}$	CP
$i\bar{\psi}\gamma_\mu\partial_\nu\psi$	$+$
$i\bar{\psi}\gamma^5\gamma_\mu\partial_\nu\psi$	$-$
$F_\mu^{\ \rho}F_{\rho\nu}$	$+$
$\epsilon_{\alpha\beta\mu\delta}F_\nu^{\ \delta}F^{\alpha\beta}$	$-$
$\partial_\mu H\,\partial_\nu H$	$+$

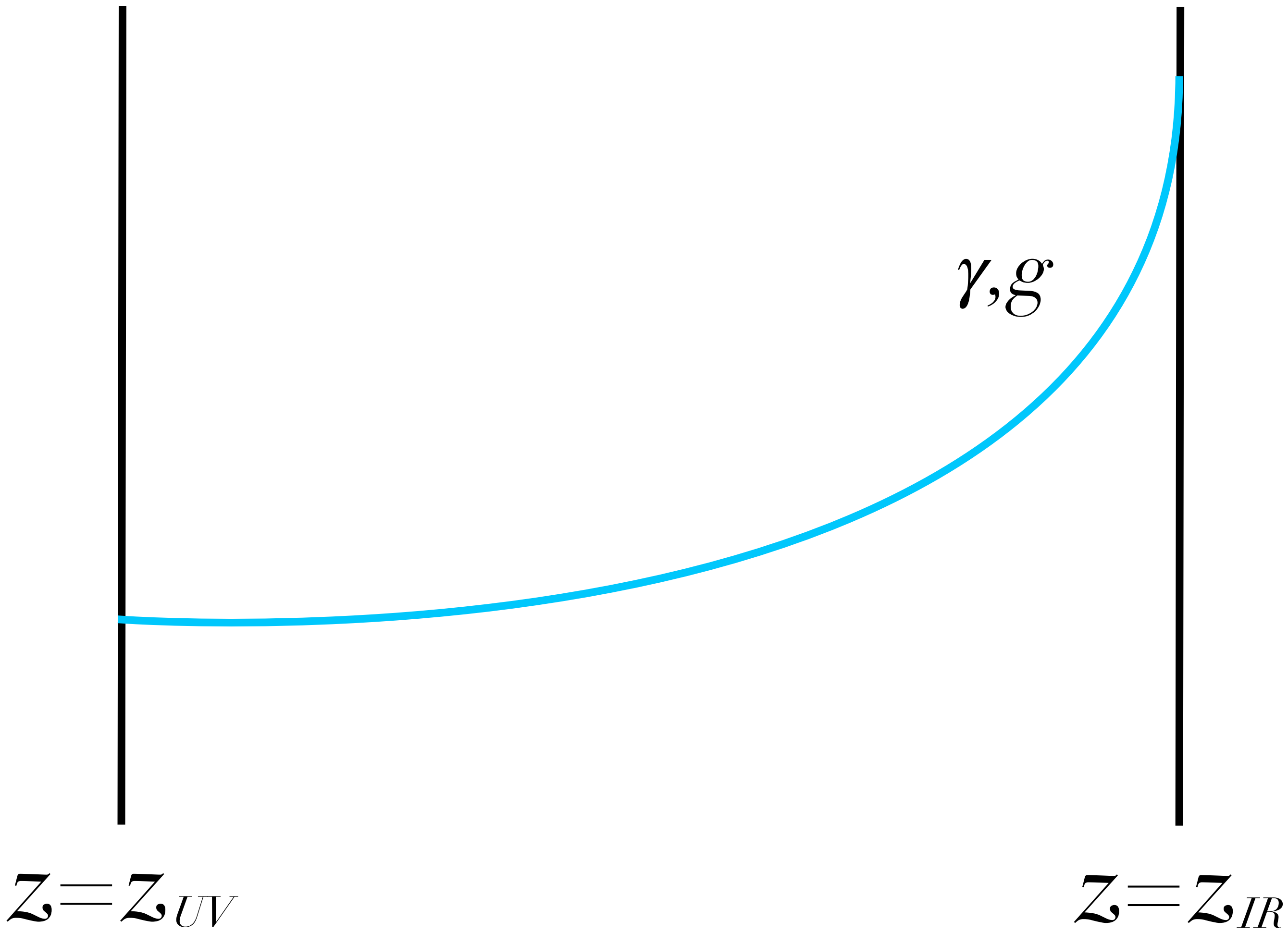
$$T^f_{\mu\nu} \supset \frac{i}{2}\,\bar{\psi}\gamma_\mu\partial_\nu\psi + (\mu \leftrightarrow \nu),$$
$$T^A_{\mu\nu} \supset -F_\mu^{\ \rho}F_{\rho\nu},$$
$$T^H_{\mu\nu} \supset \partial_\mu H\partial_\nu H + (\mu \leftrightarrow \nu)\ .$$

We are going to assume CP is conserved. Then the imposters have the same set of dim 5 operators as the KK graviton!

Distinguishing KK gravitons and impostors

- Both have the same set of dim 5 operators
- KK graviton couples to all massless gauge bosons universally, and impostors generally do not.
- E.g. composite spin-2 resonance from color singlet charged technifermions.
- For KK gravitons, $\frac{BR(G \to gg)}{BR(G \to \gamma\gamma)} = 8$

What if photons and gluons are localized?

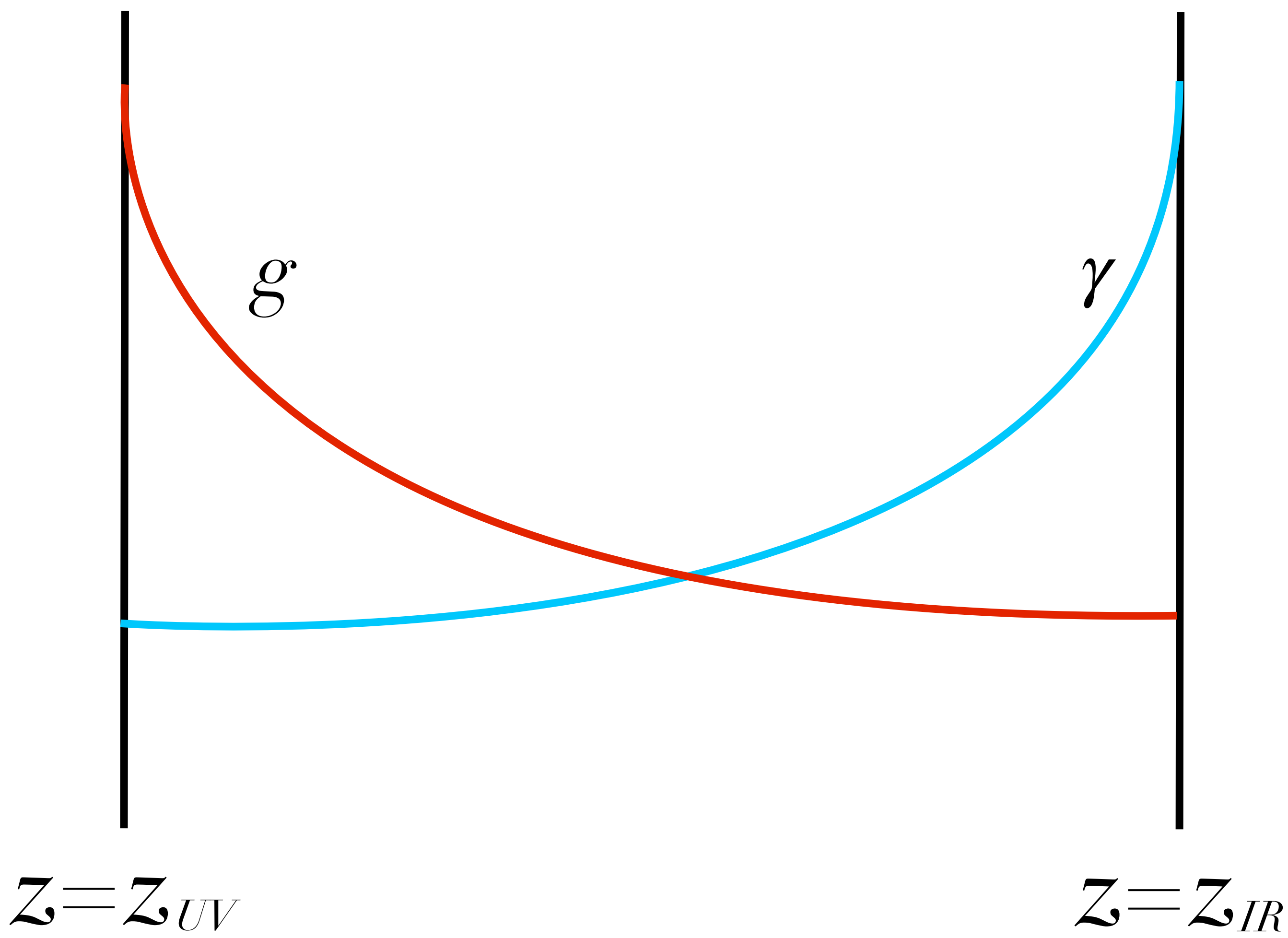


γ and g on IR brane

Same profile

$$\frac{BR(G \to gg)}{BR(G \to \gamma\gamma)} = 8$$ holds

What if photons and gluons are localized?



γ and g on different branes

Ruled out, because

quarks interacts with both

$$\frac{BR(G \to gg)}{BR(G \to \gamma\gamma)} = 8$$ holds for a large class of models!

KK Gravitons in colliders

KK gravitons couple to $-F_{\mu}^{\ \rho} F_{\rho\nu}$

$$G \to \gamma\gamma \qquad G \to gg \qquad G \to ggg \qquad G \to gggg$$

Only want diphoton or digluon events

Assume that G has already be discovered by other channels (dilepton, say)

Choose a window around the G invariant mass

Reject digluon events with invariant masses outside this window

KK Gravitons in colliders

- If top quarks are localized on the IR brane, the coupling between graviton and top can be large.
- Gravitons can decay into ttbar.
- Need to distinguish gluon and top jets.
- Jet substructure analysis could do this on an event by event basis

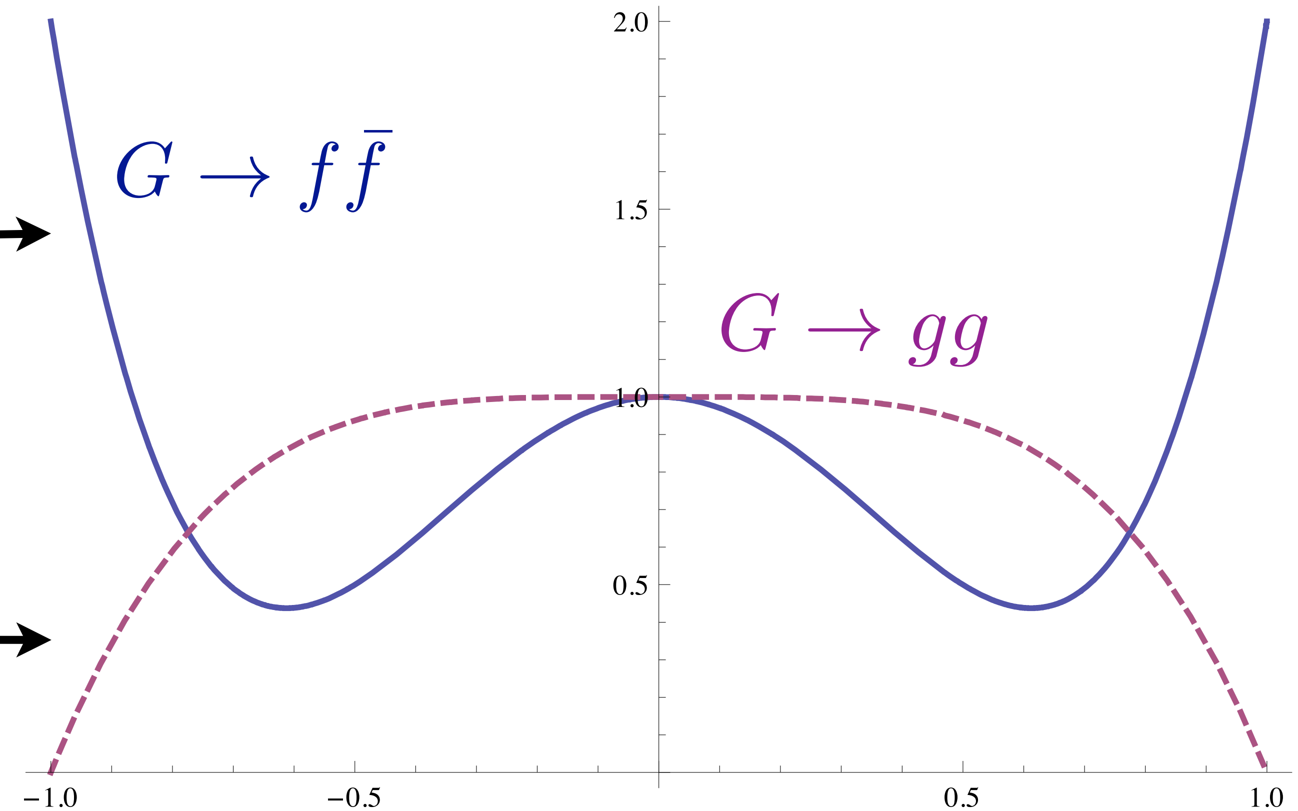
Or look at angular distributions

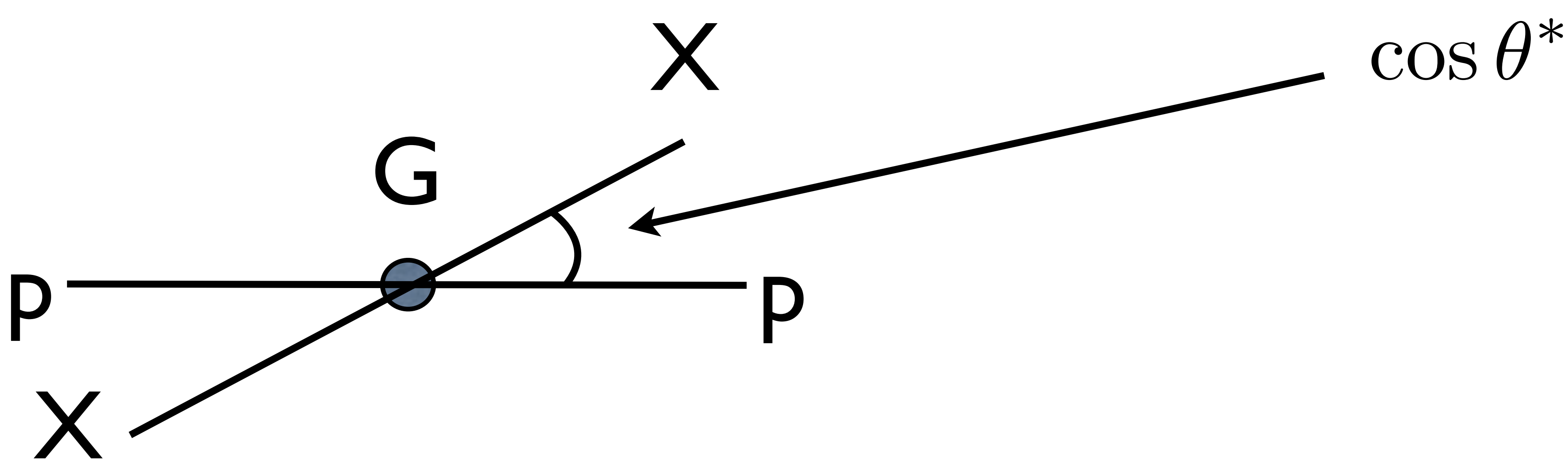
$$\frac{d\sigma}{d\cos\theta^*}(q\bar{q} \to G \to f\bar{f})$$

$$1 + \cos^2\theta^* \left(1 - 4\sin^2\theta^*\right)$$

$$\frac{d\sigma}{d\cos\theta^*}(q\bar{q} \to G \to gg)$$

$$1 - \cos^4\theta^*$$





Conclusion and outlook

- We proposed a true smoking gun signature for KK gravitons, $\frac{BR(G\rightarrow gg)}{BR(G\rightarrow\gamma\gamma)}=8$
- In the scenario where the graviton to top coupling is significant, a more detailed study is required to distinguish top and gluon jets.