New directions in Composite Higgs models

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works by
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Subject of the talk

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- Compositeness not breaking EW symmetry:

  Vectorlike

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- Linking the strong sector to an elementary Higgs: interpolation to Composite Higgs

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- Hierarchy problem main motivation for TeV-scale BSM
- SUSY: hopes for no-tuning faded away
- Strong dynamics: arguably tuning expected anyway
- Perhaps wrong perspective, but exploration not over yet

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number of techni-flavors	Yukawa	$N=3$ TCb	$N=3$ TCπ	$N=4$ TCb	$N=4$ TCπ	
$N_F = 2$		2	3	1	3	under TC-flavor SU(2)
model 1: $\mathcal{Q} = 2_{Y=0}$	0	charged	3	1	3	DM, under $\mathrm{SU}(2)_L$
$N_F = 3$		8	8	$\overline{6}$	8	under TC-flavor SU(3)
model 1: $\mathcal{Q} = 1_Y + 2_{Y'}$	1	1	no	1	no	DM, under $\mathrm{SU}(2)_L$
model 2: $\mathcal{Q} = 3_{Y=0}$	0	3	3	1	3	DM, under $\mathrm{SU}(2)_L$
$N_F = 4$		$\overline{20}$	15	$20'$	15	under TC-flavor SU(4)
model 1: $\mathcal{Q} = 4_{Y=0}$	0	charged	3	1	3	DM, under $\mathrm{SU}(2)_L$
$N_F = 5$		$\overline{40}$	24	$\overline{50}$	24	under TC-flavor SU(5)
model 1: $\mathcal{Q} = 2_Y + 3_{Y'}$	1	1	no	charged	no	DM, under $\mathrm{SU}(2)_L$
model 2: $\mathcal{Q} = 5_{Y=0}$	0	3	3	1	3	DM, under $\mathrm{SU}(2)_L$

Antipin, Redi, Strumia – 1410.1817

Further classifications

SU(N) techni-color. Techni-quarks	Yukawa couplings	Allowed N	Techni-pions	Techni-baryons	under
$N_{\rm TF}=3$			8	$8,\bar{6},\ldots$ for $N=3,4,\ldots$	$\mathrm{SU}(3)_{\rm TF}$
$\mathcal{Q}=V$	0	3	3	$VVV=3$	$\mathrm{SU}(2)_L$
$\mathcal{Q}=N\oplus L$	1	3, .., 14	unstable	$N^{N*}=1$	$\mathrm{SU}(2)_L$
$N_{\rm TF}=4$			15	$\overline{20},20',\ldots$	$\mathrm{SU}(4)_{\rm TF}$
$\mathcal{Q}=V\oplus N$	0	3	3×3	$VVV,VNN=3,\ VVN=1$	$\mathrm{SU}(2)_L$
$\mathcal{Q}=N\oplus L\oplus\tilde{E}$	2	3, 4, 5	unstable	$N^{N*}=1$	$\mathrm{SU}(2)_L$
$N_{\rm TF}=5$			24	$\overline{40},\overline{50}$	$\mathrm{SU}(5)_{\rm TF}$
$\mathcal{Q}=V\oplus L$	1	3	unstable	$VVV=3$	$\mathrm{SU}(2)_L$
$\mathcal{Q}=N\oplus L\oplus\tilde{L}$	2	3	unstable	$NL\tilde{L}=1$	$\mathrm{SU}(2)_L$
$=$	2	4	unstable	$NNL\tilde{L},L\tilde{L}L\tilde{L}=1$	$\mathrm{SU}(2)_L$
$N_{\rm TF}=6$			35	$70,\overline{105'}$	$\mathrm{SU}(6)_{\rm TF}$
$\mathcal{Q}=V\oplus L\oplus N$	2	3	unstable	$VVV,VNN=3,VVN=1$	$\mathrm{SU}(2)_L$
$\mathcal{Q}=V\oplus L\oplus\tilde{E}$	2	3	unstable	$VVV=3$	$\mathrm{SU}(2)_L$
$\mathcal{Q}=N\oplus L\oplus\tilde{L}\oplus\tilde{E}$	3	3	unstable	$NL\tilde{L},\tilde{L}\tilde{L}\tilde{E}=1$	$\mathrm{SU}(2)_L$
$=$	3	4	unstable	$NNL\tilde{L},L\tilde{L}L\tilde{L},N\tilde{E}\tilde{L}\tilde{L}=1$	$\mathrm{SU}(2)_L$
$N_{\rm TF}=7$			48	112	$\mathrm{SU}(7)_{\rm TF}$
$\mathcal{Q}=L\oplus\tilde{L}\oplus E\oplus\tilde{E}\oplus N$	4	3	unstable	$LLE,\tilde{L}\tilde{L}\tilde{E},L\tilde{L}N,E\tilde{E}N=1$	$\mathrm{SU}(2)_L$
$\mathcal{Q}=N\oplus L\oplus\tilde{E}\oplus V$	3	3	unstable	$VVV,VNN=3,\ VVN=1$	$\mathrm{SU}(2)_L$
$N_{\rm TF}=9$			80	240	$\mathrm{SU}(9)_{\rm TF}$
$\mathcal{Q}=Q\oplus\tilde{D}$	1	3	unstable	$QQ\tilde{D}=1$	$\mathrm{SU}(2)_L$
$N_{\rm TF}=12$			143	572	$\mathrm{SU}(12)_{\rm TF}$
$\mathcal{Q}=Q\oplus\tilde{D}\oplus\tilde{U}$	2	3	unstable	$QQ\tilde{D},\tilde{D}\tilde{D}\tilde{U}=1$	$\mathrm{SU}(2)_L$

Antipin, Redi, Strumia, Vigiani – 1503.08749

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- Yukawas with SM Higgs allowed in some cases

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transforms as H and condenses into K

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$$\langle H \rangle = v_{EW} \sin\beta \qquad \langle K \rangle = v_{EW} \cos\beta$$

- Changes alignment direction of condensate

Source of EWSB

$$\begin{pmatrix} \mu_K^2 & \mu_{mix}^2 \\ \mu_{mix}^2 & \mu_H^2 \end{pmatrix}$$

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- Large H scale & EWSB from mixing: composite

Getting the Higgs mass

- Mass of Higgs (in SU(4)/Sp(4)) $\frac{m_h^2}{v_{EW}^2} \propto \frac{m_q}{f} \cos^4\beta + \lambda \sin^4\beta$

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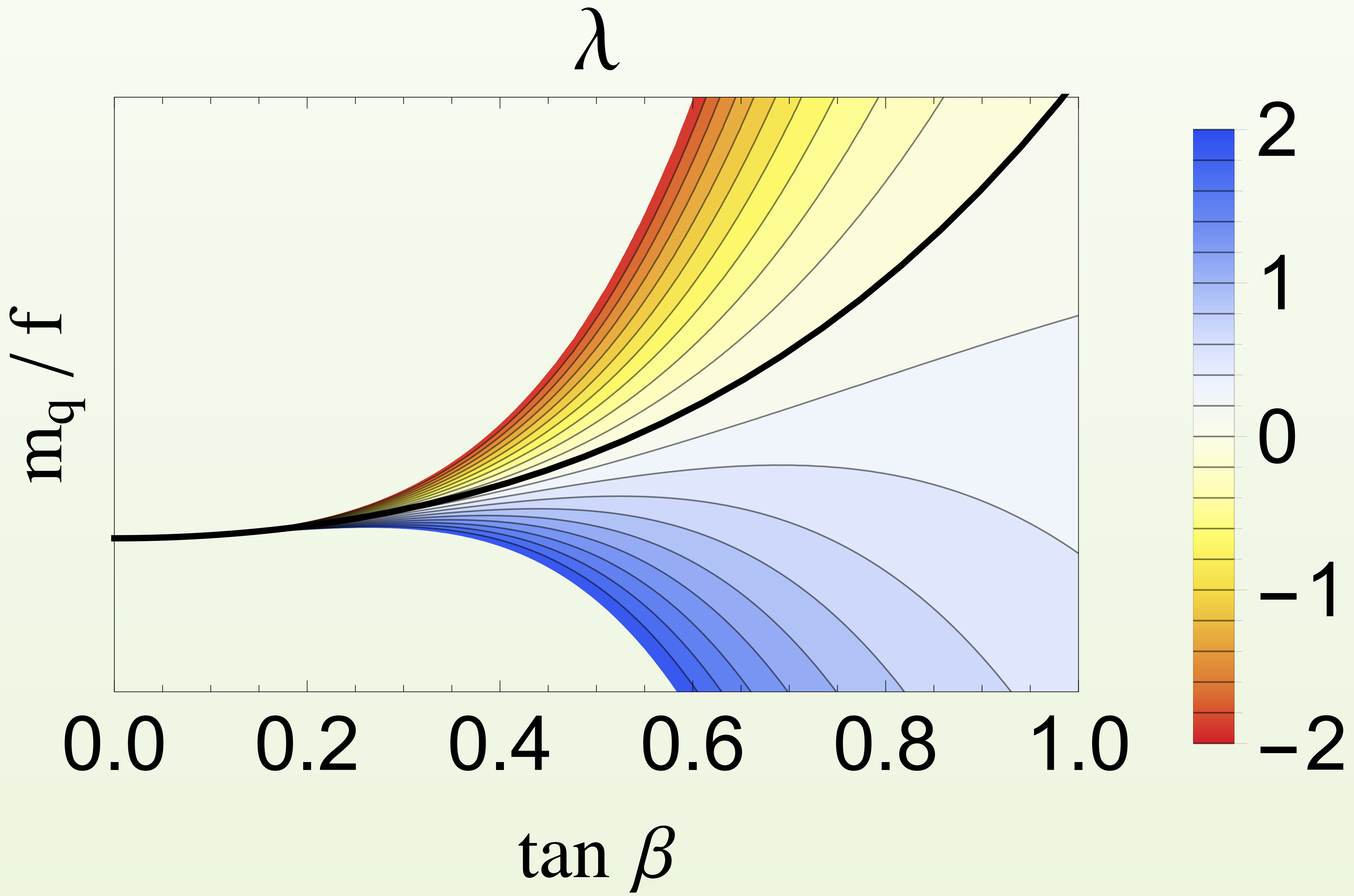

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  ➡ In preparation with Agugliaro, Antipin, De Curtis, Redi

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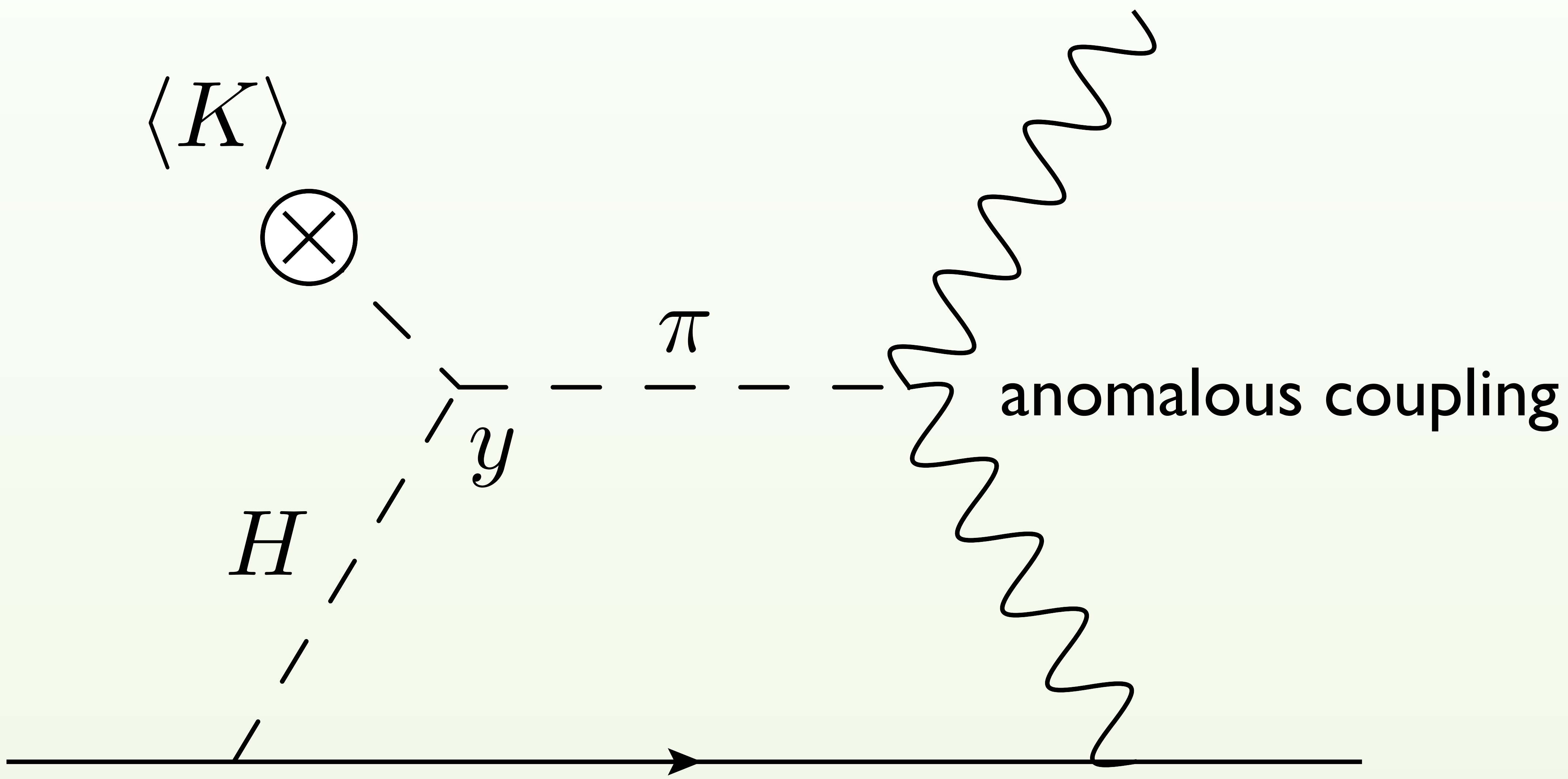

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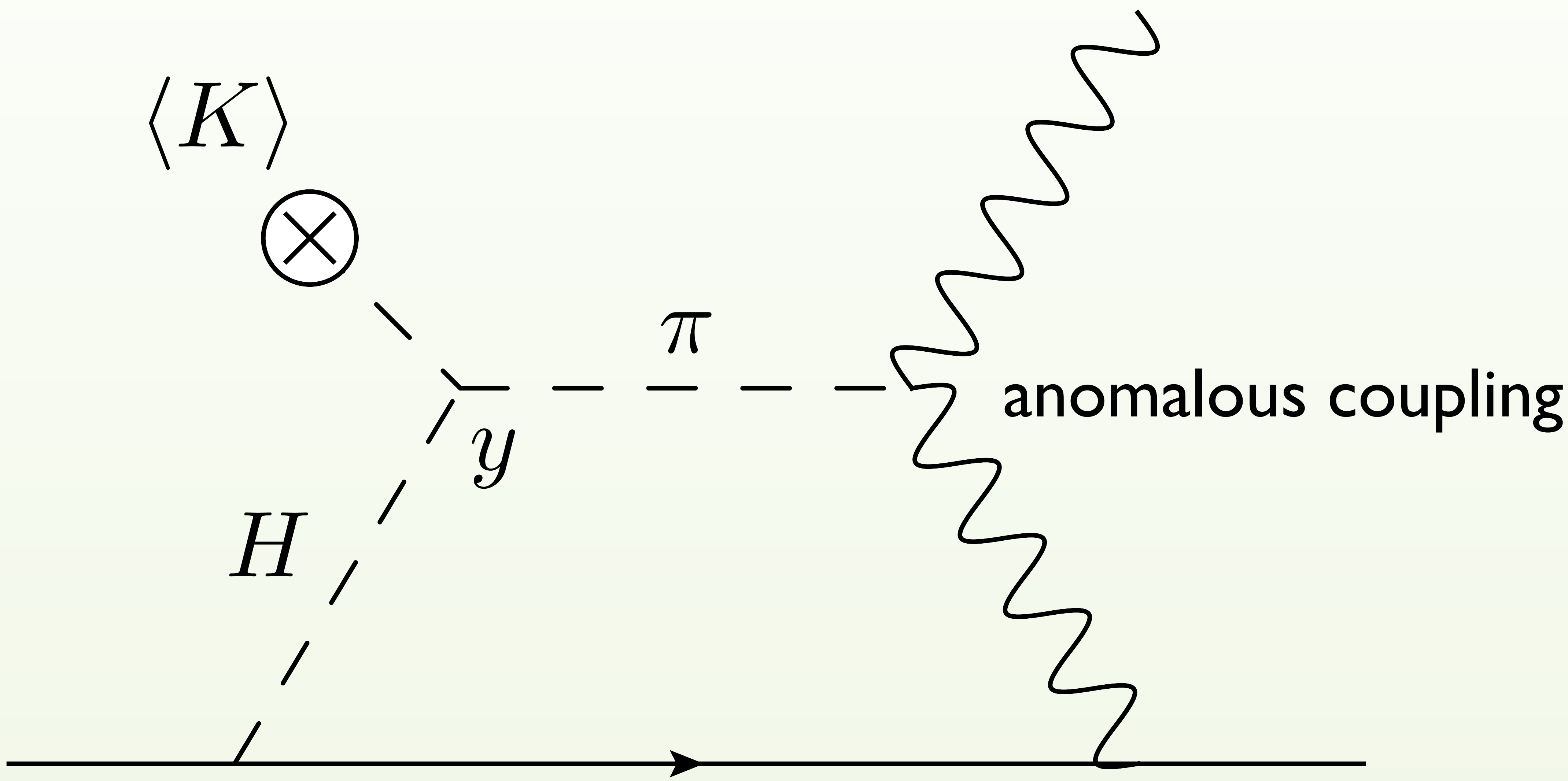

- Generally expected, however in minimal SU(4)/Sp(4) ~ SO(6)/SO(5) not present

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Grazie!