

# Effective technicolor

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work in progress

and

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# What?

- Rather than one more (5D, moose) model of EWSB
- **Effective theory** for EWSB with  $\rho_T$ 's &  $a_T$ 's (without Higgs)  
 $\implies$  MadGraph  $\implies$  Pythia  $\implies$  PGS (not in this talk, though)

# Why?

- (Very) many models of EWSB
  - Experimentalists to check all of them?
- **Interchangeable from LHC point of view** (low-energy spectrum)
  - **Build a generic EFT:** 5D Model  $\Leftrightarrow$  EFT  $\Leftrightarrow$  Experiment
  - Start by most striking case: no Higgs

# More why's

- In Higgsless (or Holo TC)
  - $S \simeq 0$  requires some tuning
  - Or large higher-order operator      Agashe, Csaki, Grojean, Reece '07
    - TC may not have such a nice 5D dual      (as QCD)
    - ⇒ Build EFT rather than model
- Take  $M_{a_T} \simeq M_{\rho_T}$  to get cancellations in  $S$  &  $\gtrsim 500$  GeV
  - 5D      Hirn, Sanz '06
  - 4D      Sundrum, Hsu '92, Appelquist, Sannino '93, Knecht, de Rafael '97
  - D-BESS      Casalbuoni, De Curtis, Redi '00
- Recent work in direction  $5D \implies$  EFT
  - Higgs and resonances      Contino, Kramer, Son, Sundrum '06
  - Higgs only      Giudice, Grojean, Pomarol, Rattazzi '07
  - ... Others?

# Three points

- Lesson from EFTs for QCD (20 years ago)
- What it means for EFTs of EWSB
- How we construct our EFT

# QCD: effective theories with resonances

- QCD  $< 1$  GeV: only (P)GBs  
 $\implies$  Chiral lagrangian  $\mathcal{L}_\chi$
- Beyond: include resonances
  - Idea: Green's functions **dominated by lowest res.** (LMD)
  - Effective lagrangian with all (symmetric) interactions
- **Paradox**
  - Deduce chiral lagrangian coeffs ( $L_i$ 's) **from res.?**
  - But most general interactions:  $\mathcal{L}_\chi + \mathcal{L}_{\text{GBs}+\text{res}}$
- Besides, vector res. could be introduced as  $A_\mu$  or  $B_{[\mu\nu]}$  (with constraints)
  - Only way to make them **agree: impose constraints from HE QCD**
    - **Fixes unambiguously the  $L_i$ 's in function of res. couplings**

# QCD: models with resonances

Example: VFF of  $\pi$

$$\langle \pi(p') | J_\mu^{\text{em}}(0) | \pi(p) \rangle = i(p + p') F(q^2)$$

$$F(q^2) = 1 + 2 L_9 \frac{q^2}{f^2} + \frac{q^4}{f^4} \sum \frac{f_V g_V}{M_V^2 - q^2}$$

- In QCD,  $F(q^2)$  soft HE,  $\implies$  **Sum Rules (SR)**

$$2 L_9 = \sum f_V g_V$$
$$f^2 = \sum f_V g_V M_V^2$$

- $L_9$  indeed attributable to res. exchange
- **SRs automatic** in models with (appropriate) **symmetries**
  - (Massive) **Yang-Mills** for the  $\rho$
  - Hidden local symmetry
    - Many  $\implies$  moose Son, Stephanov '03
    - $\infty \implies$  5D (Holographic QCD) Hirn, Sanz '05

# What about EWSB?

- If strong EWSB has the **same asymptotic softness**
  - Implement the **same HE constraints on its EFT**
    - This reduces # of indep. params
- In 5D or moose, can take Holographic QCD
  - Change the UV BCs to allow  $SU(2) \times U(1)$  there

## ≥ 2 ways of thinking

- More **holographic** way for **pen & paper**
  - GB kinetic term  $f^2 D_\mu U D^\mu U^\dagger \Rightarrow$  masses for the  $W$ 's
  - $\mathcal{L}_{SU(2) \times U(1)} + \mathcal{L}_{W_L + \text{resonances}} +$  kinetic mixing
    - Deduce **lots of SRs** in this way
- We want the **brutal method**  $\implies$  **computers**
  - It's just  $F_{MN}^2$  and we **plug in the wave-functions**

Hirn, Sanz '07

# Start with moose or 5D?

## Personal convenience:

- Both essentially implement the same constraints

We start from 5D because

- We prefer solving for  $\varphi(z)$  rather than diagonalizing matrices
- Generalization easy:
  - Add multiplets by considering more  $\varphi(z)$ 's, rather than adding links
  - Add a (gaugephobic) Higgs
- Most general on the market, that satisfies HE constraints (without Higgs)
  - Holo TC (Higgsless with bulk  $L R$  mixing)
- So, 5D with a truncation of the KK tower

# Didn't you just screw up your sum rules?

$$1/2 \sum_{n=1}^{N < +\infty} f_V g_V < L_9$$

- No such problem in mooses

Who cares?

- SR matters for HE, not LE pheno
  - For us, way of **reducing # of params**
  - OK if LMD anyway (few %) Hirn, Sanz '05
    - Can correct for this: separate first res. contrib to  $L_9$

# Reminder: What?

- Reduce 5D models to only  $SM - \text{Higgs} + \rho_T + a_T$ 
  - Do  $EFT$  with that

# Summary: How

- Besides  $symmetries$ , restrictions on resonance interactions?
  - Answered  $\simeq 20$  years ago in QCD
    - Impose  $HE$  constraints on model
    - Use model where  $automatic$
- We formulate lagrangian  $using 5D$ , but  $EFT$  will be general
  - Just embodies  $HE$  constraints

# Outlook

- Lots of work to be done
  - Hurry up before LHC starts!
- May want to include:
  - (gaugephobic) Higgs
  - a couple of resonance multiplets if they are light
- You may then relate your model to this EFT and check exclusion
  - Intermediate step:  
5D Model  $\Leftrightarrow$  EFT  $\Leftrightarrow$  Experiment