

Little Technicolor

Jesse Thaler

hep-ph/0502175

Based on work with Itay Yavin, hep-ph/0501036.

References and genealogy during conclusions.

Little Technicolor

$SU(N)/H$ symmetry breaking



QCD with N flavors

Scaled-up QCD: $SU(N_c)$ confining gauge theory with N_f vector pairs of fermions.

QCD Dynamics

Ordinarily: $\psi = \mathbf{N}_c$ $\psi^c = \overline{\mathbf{N}_c}$

$$\langle \psi \psi^c \rangle : \quad SU(N_f)_L \times SU(N_f)_R \rightarrow SU(N_f)_V$$

Is $SU(N) \rightarrow H$ contained in QCD?

Original Technicolor: $SU(2)_{EW} \rightarrow \emptyset$

Little Technicolor:

Technicolor with Uneaten Goldstones (Little Higgs)

UV Completing Little Higgs

$$SU(N)/H \leftrightarrow \text{QCD with } N \text{ flavors}$$

$$SU(5)/SO(5) \leftrightarrow \text{QCD with } N_f = 5$$

$$(SU(3)/SU(2))^2 \leftrightarrow 2 \times \text{QCD with } N_f = 3$$

(or $1 \times \text{QCD with } N_f = 3$)

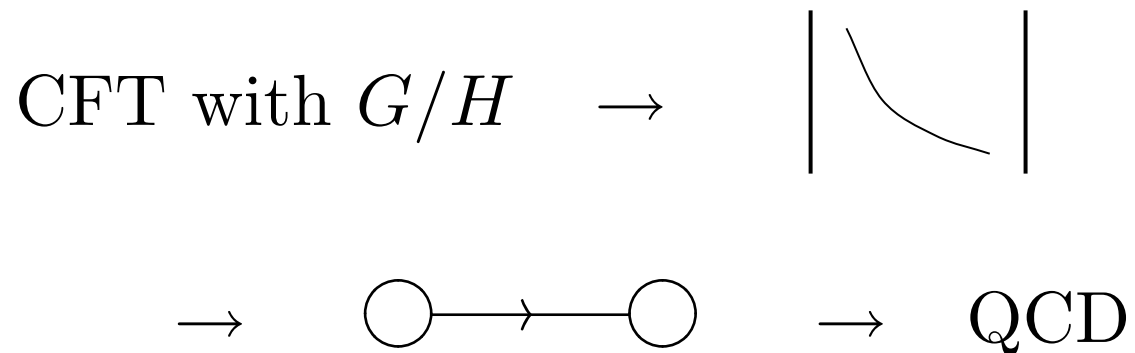
$$SU(6)/Sp(6) \leftrightarrow \text{QCD with } N_f = 6$$

Little Higgs theories from ordinary $L \times R \rightarrow V$ symmetry breaking!

Two Views of Little Technicolor

$$SU(N)/H \longleftrightarrow \text{QCD with } N \text{ flavors}$$

1. Deconstructing AdS/CFT



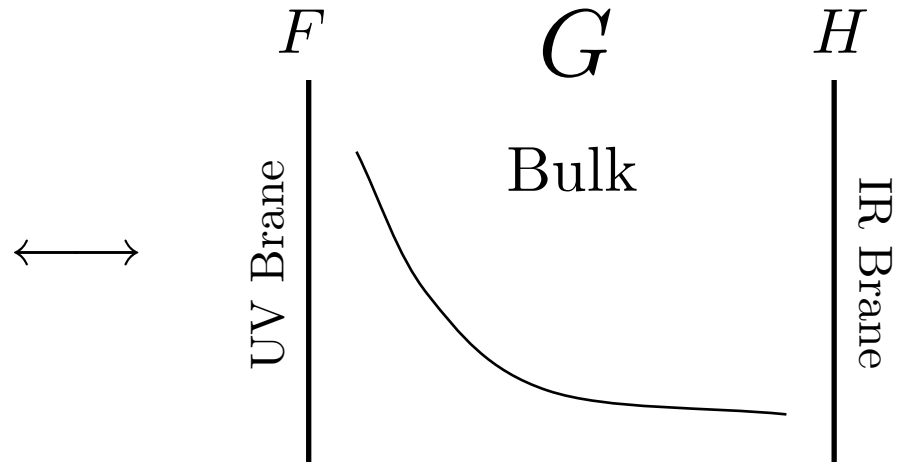
2. Pedagogical CCWZ (Hidden Local Symmetry)



Phenomenological AdS/CFT

Duality (with IR brane): Same spectrum/ S -matrix

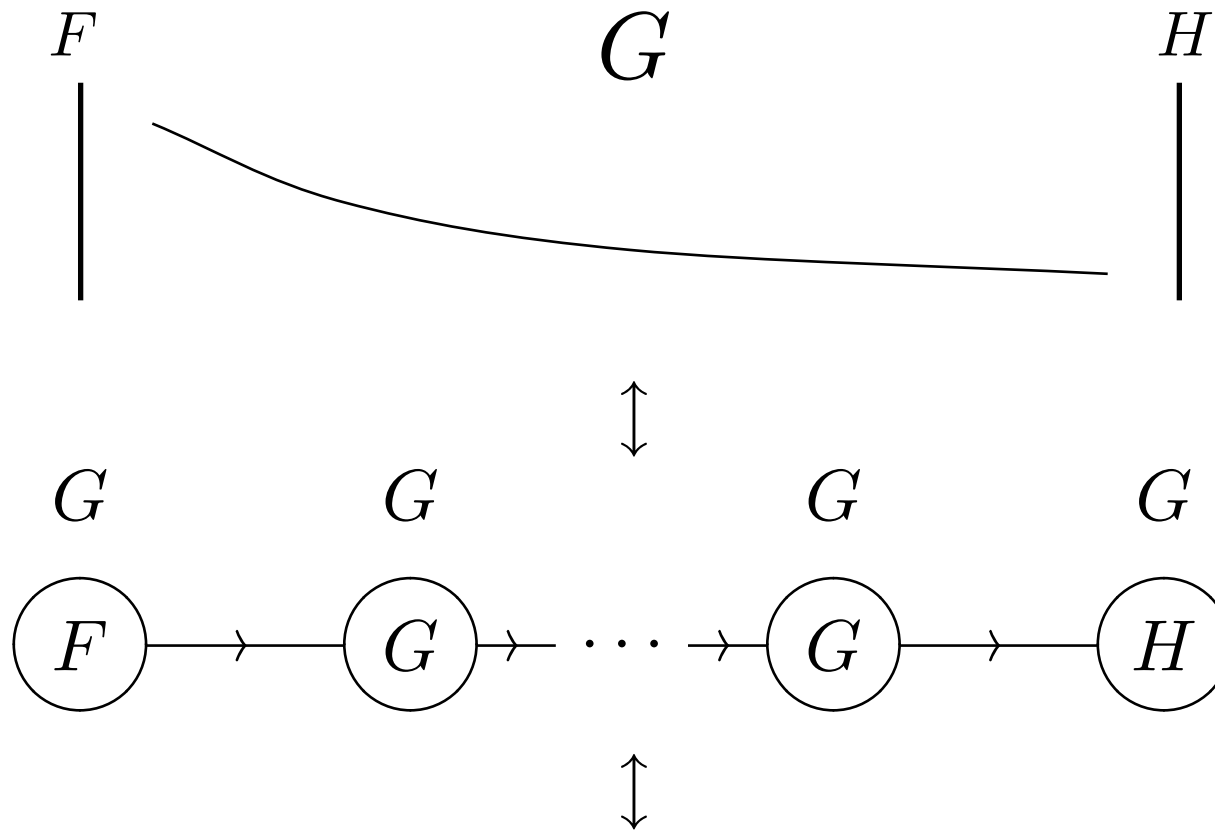
Large N CFT
 G global symmetry
 $F \subset G$ gauged
 $G \rightarrow H$ at Λ_{QCD}



$A_\mu(+, +)$	' γ '	Massless gauge bosons	g
$A_\mu(+, -)$	' W '	Gauge bosons, mass from SSB	$m_W = gf$
$A_\mu(-, +)$	' ρ '	Spin-1 resonances of CFT	$m_\rho = \frac{4\pi}{\sqrt{N}} f$
$A_\mu(-, -)$			
$= A_5(+, +)$	' π '	Uneaten goldstone bosons	f

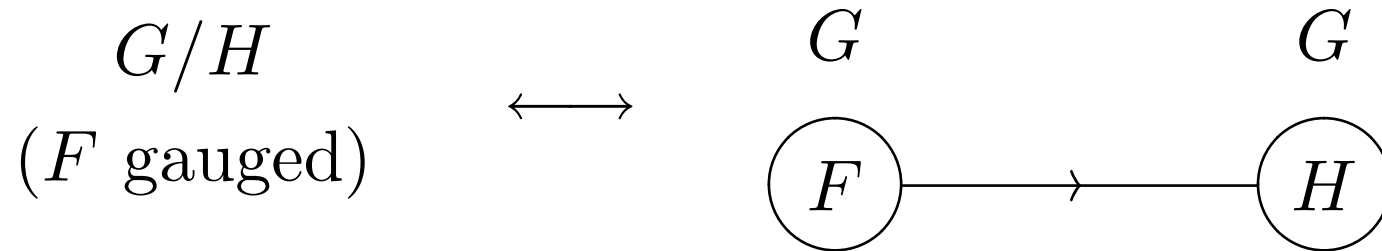
Deconstructing AdS/CFT

Same low energy degrees of freedom:



G/H symmetry breaking ($F \subset G$ gauged)

Key Realization



H is just the “gauge symmetry” for the spin-1 ρ .

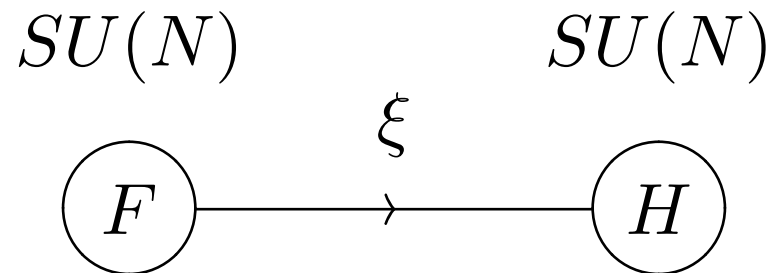
If we only care about low energy degrees of freedom, there is no way to distinguish:

‘ ρ ’ meson vs. ‘ W ’ boson

Towards a UV Completion

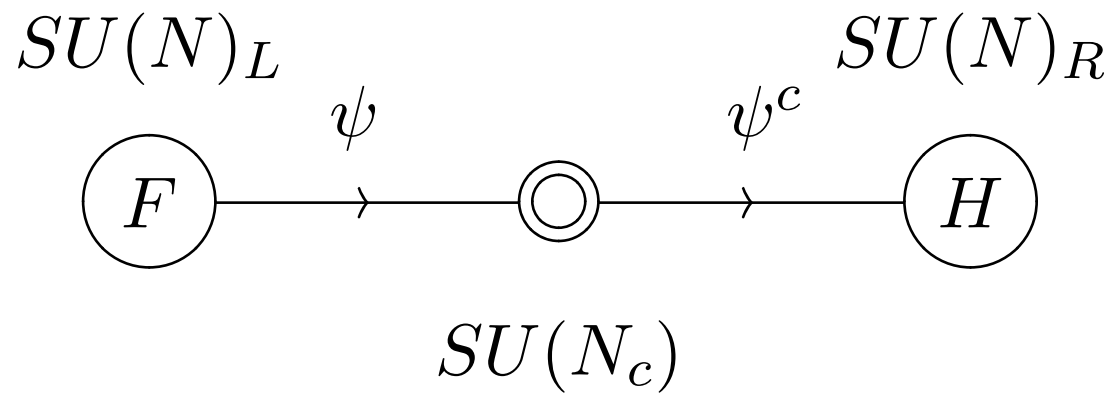
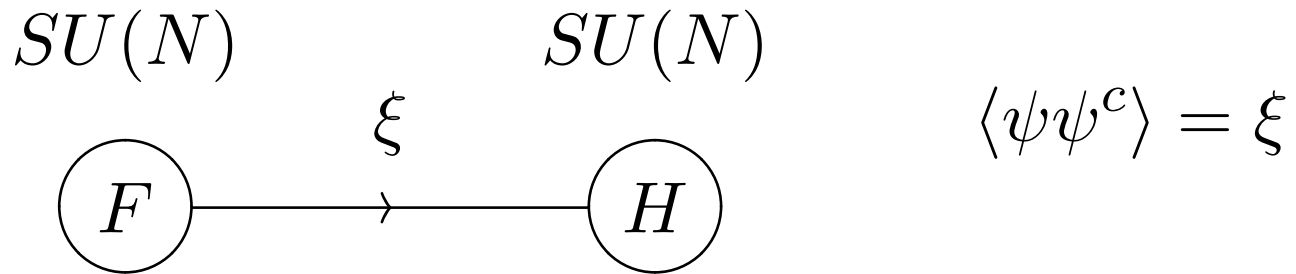
If $G = SU(N)$...

$SU(N)/H$ ($F \subset SU(N)$ gauged)



...then there is a simple UV completion of the link field!

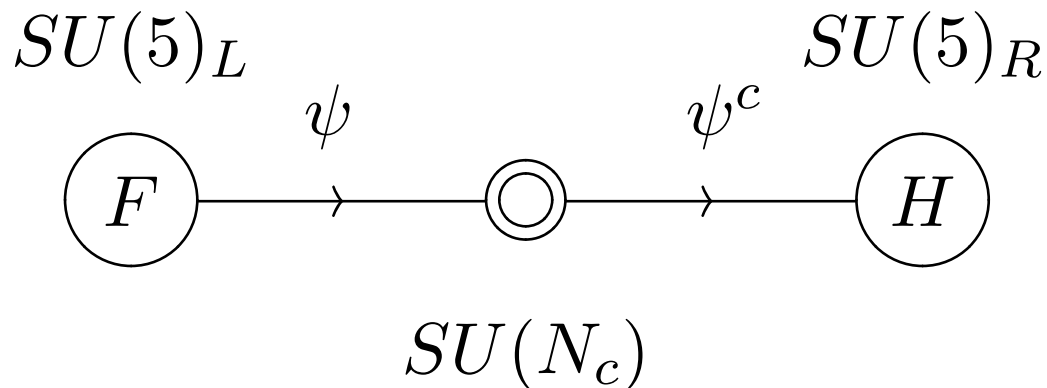
Little Technicolor



$SU(N)/H \longleftrightarrow$ QCD with N flavors

Littlest Higgs in QCD

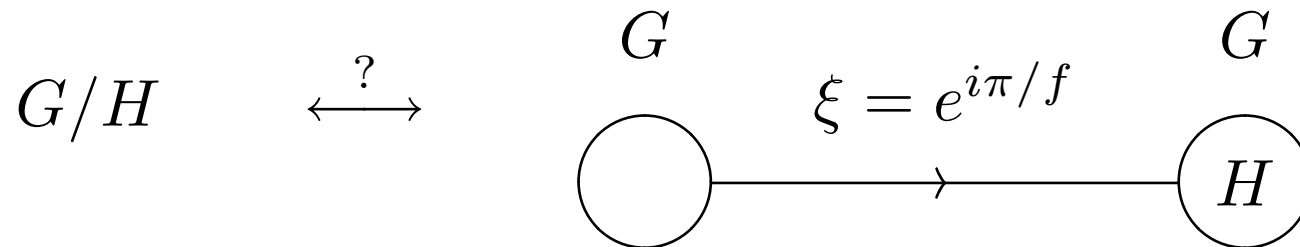
Based on $SU(5)/SO(5)$. Can arise from strong $SO(N_c)$ dynamics with 5 Weyl fermions, or...



$$F = SU(2)_1 \times SU(2)_2 \times U(1)_Y \quad H = SO(5)$$

...QCD with five flavors! (Plus anomalies, standard model fermions, etc...)

Pedagogical CCWZ



$$\mathcal{L} = -\frac{1}{2g_H^2} \text{tr} H_{\mu\nu}^2 + f^2 \text{tr} |D_\mu \xi|^2 \quad D_\mu \xi = \partial_\mu \xi - i\xi H_\mu$$

Go to unitary gauge and integrate out H_μ :

$$\mathcal{L} = f^2 \text{tr} (p^\mu p_\mu^\dagger) \quad p_\mu = \xi^\dagger \partial_\mu \xi|_{G/H}$$

CCWZ Lagrangian for G/H nonlinear sigma model!

What Happened?

We want an $SU(N)/H$'s worth of Goldstone bosons.

Chiral symmetry breaking in QCD yields an $SU(N)$'s worth of Goldstones

An H 's worth of the Goldstones are eaten by H_μ , leaving an $SU(N)/H$'s worth of Goldstones.

Symmetries guarantee that Lagrangian below mass of H_μ must look like $SU(N)/H$ CCWZ Lagrangian.

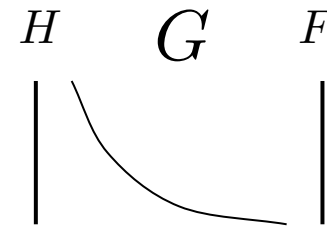
Analogy with Standard Model

Linear Sigma (1979 Nobel)

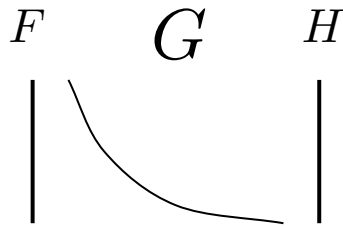
$$\langle \Phi \rangle: G/H$$

$$(F \subset G \text{ gauged})$$

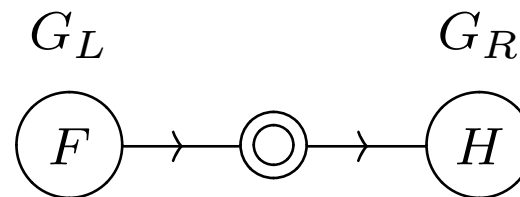
Holographic Abbott-Farhi



Holographic Technicolor



Original Technicolor



$$F = SU(2)_{EW} \quad G = SU(2)_{EW} \quad H = \emptyset$$

Pre-LEP: all possibilities equally plausible.

Summary

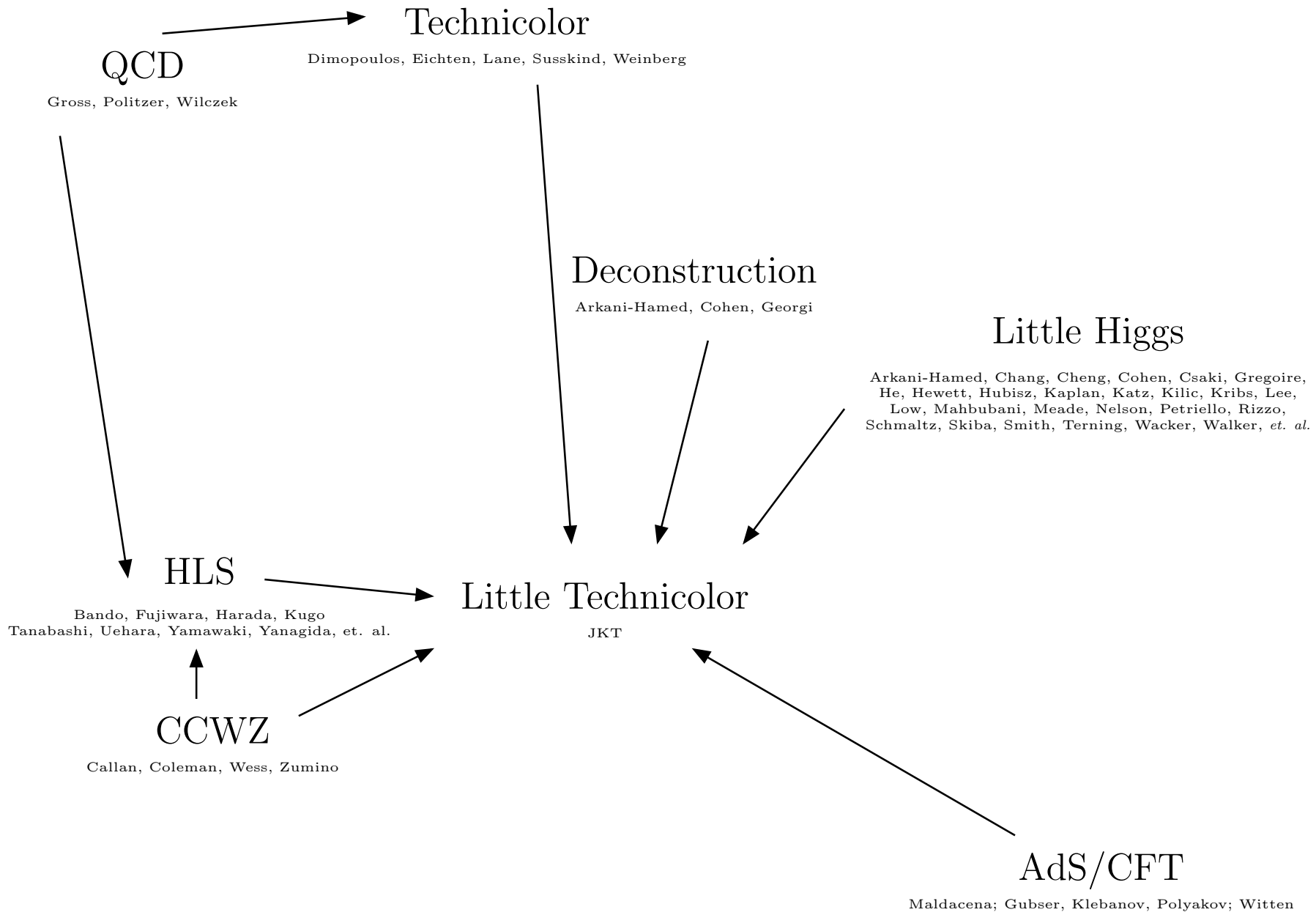
$$SU(N)/H \longleftrightarrow \text{QCD with } N \text{ flavors}$$

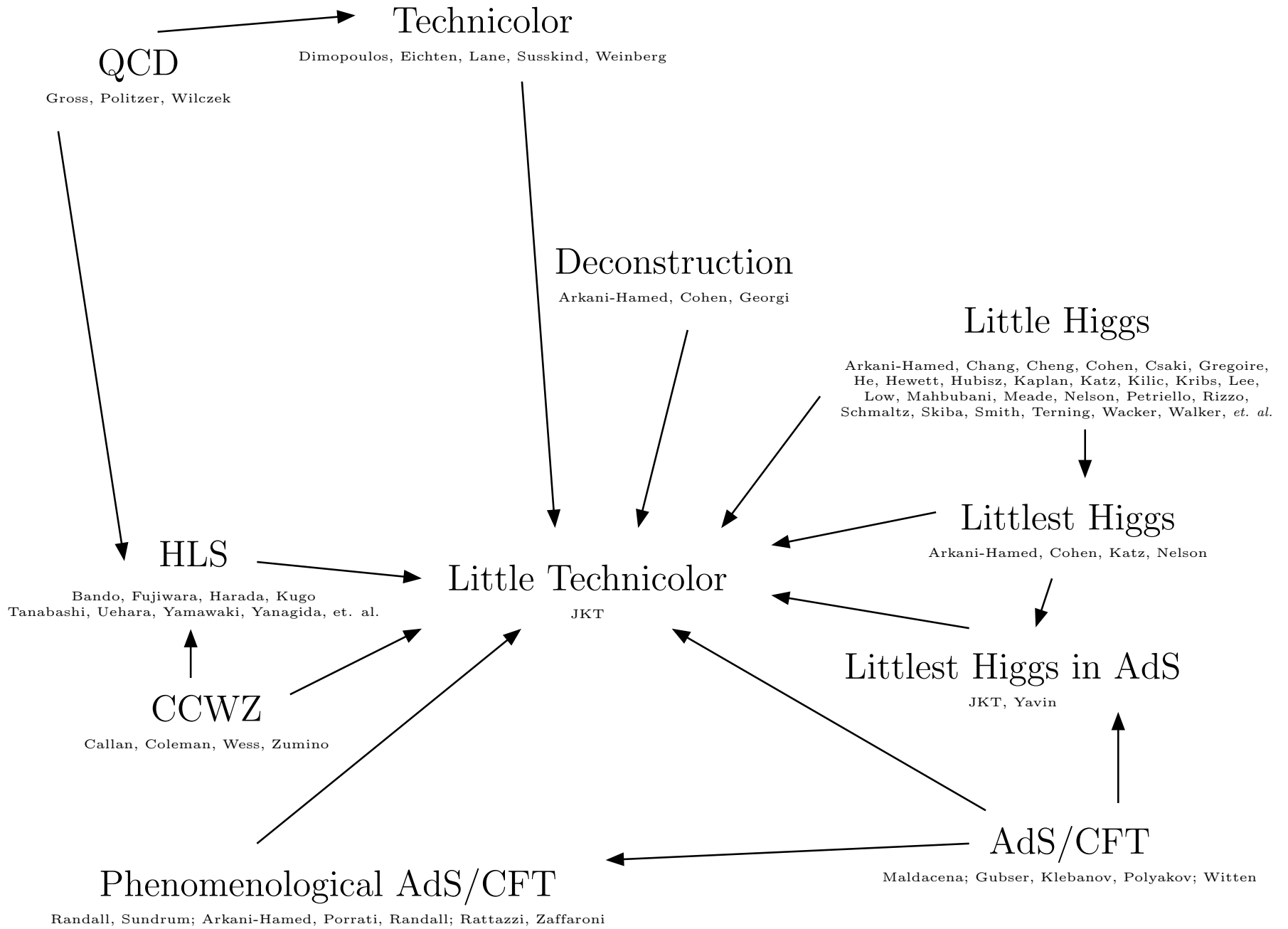
Allows novel UV completions of Little Higgs theories.

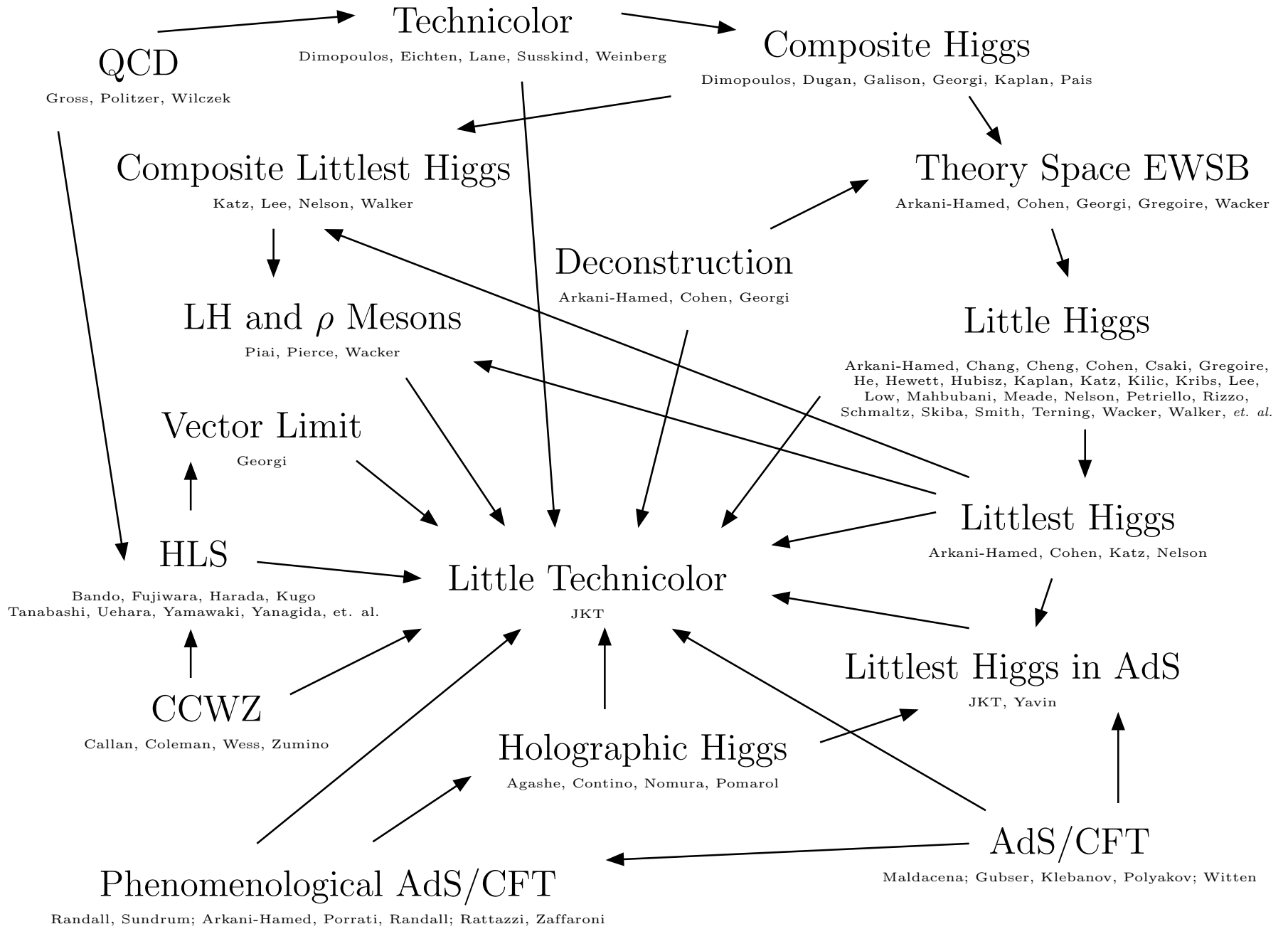
Inspires flexibility in model building:

$$\begin{array}{ccccc} G/H & & G/F & & G \times G/G \\ (F \text{ gauged}) & \longleftrightarrow & (H \text{ gauged}) & \longleftrightarrow & (F \times H \text{ gauged}) \end{array}$$

“M-theory” for BTSM Physics?



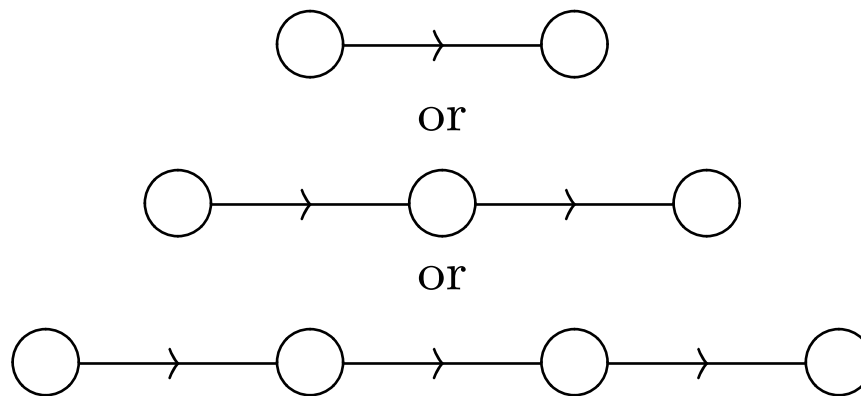




“M-theory” for BTSM Physics?

Every* non-SUSY BTSM proposal is a moose!

Technicolor
Top See-Saw
UED
Higgsless
Little Higgs
Composite Higgs
Holographic Higgs
Twin Higgs



Great for collider phenomenology!

Continuous Simple Group \leftrightarrow Minimal Moose
Deformation: \leftrightarrow Original Holographic Higgs