

# Little M-theory

Jesse Thaler (UC Berkeley)

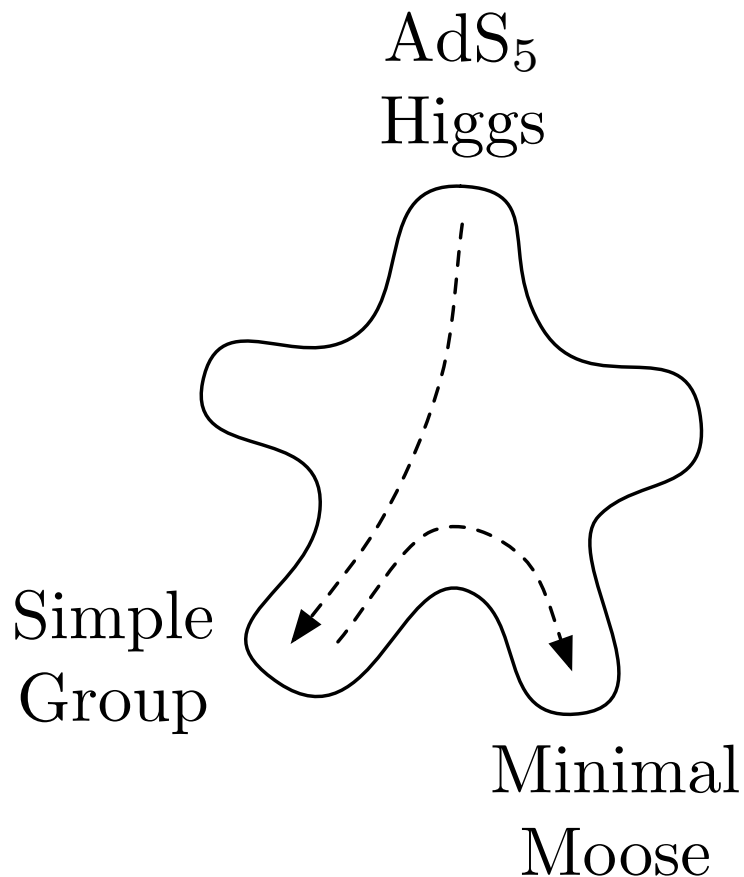
with Hsin-Chia Cheng and Lian-Tao Wang

JHEP 0609 (2006) 003

hep-ph/0607205

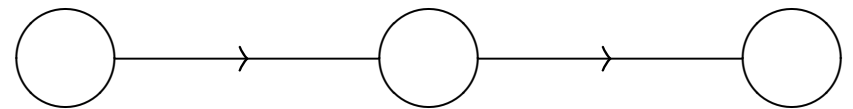
“Little” : Composite Higgs Models

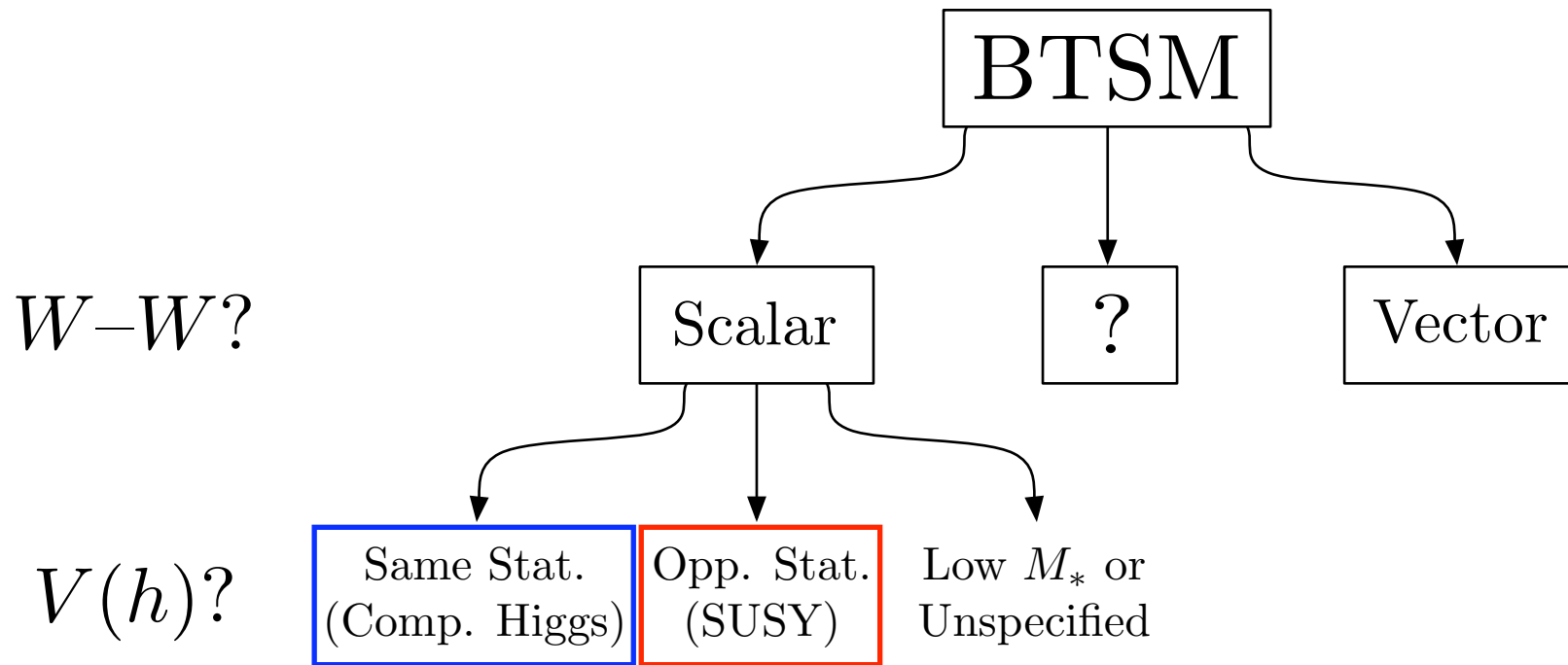
“M-theory” : Unified Framework

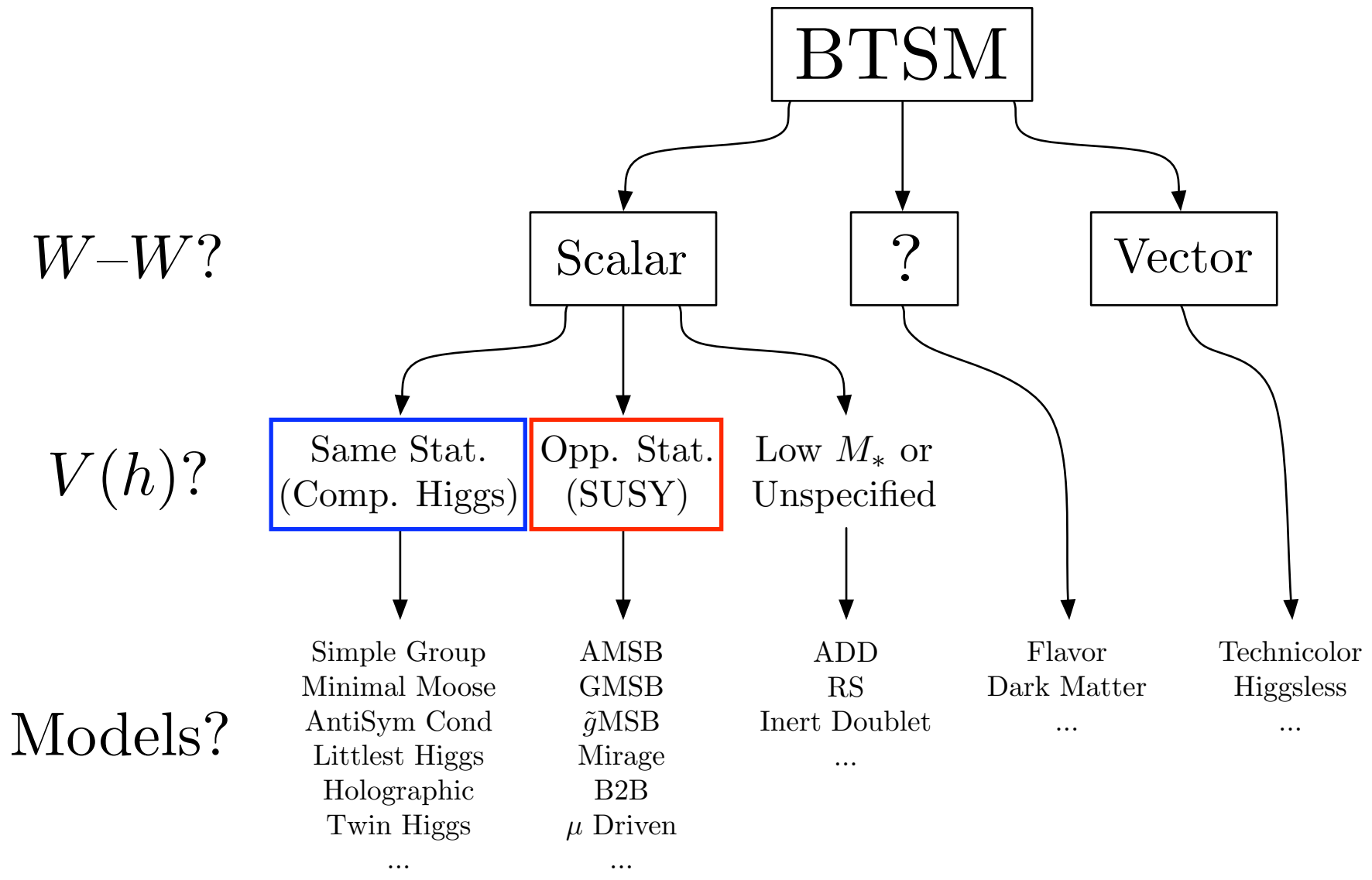


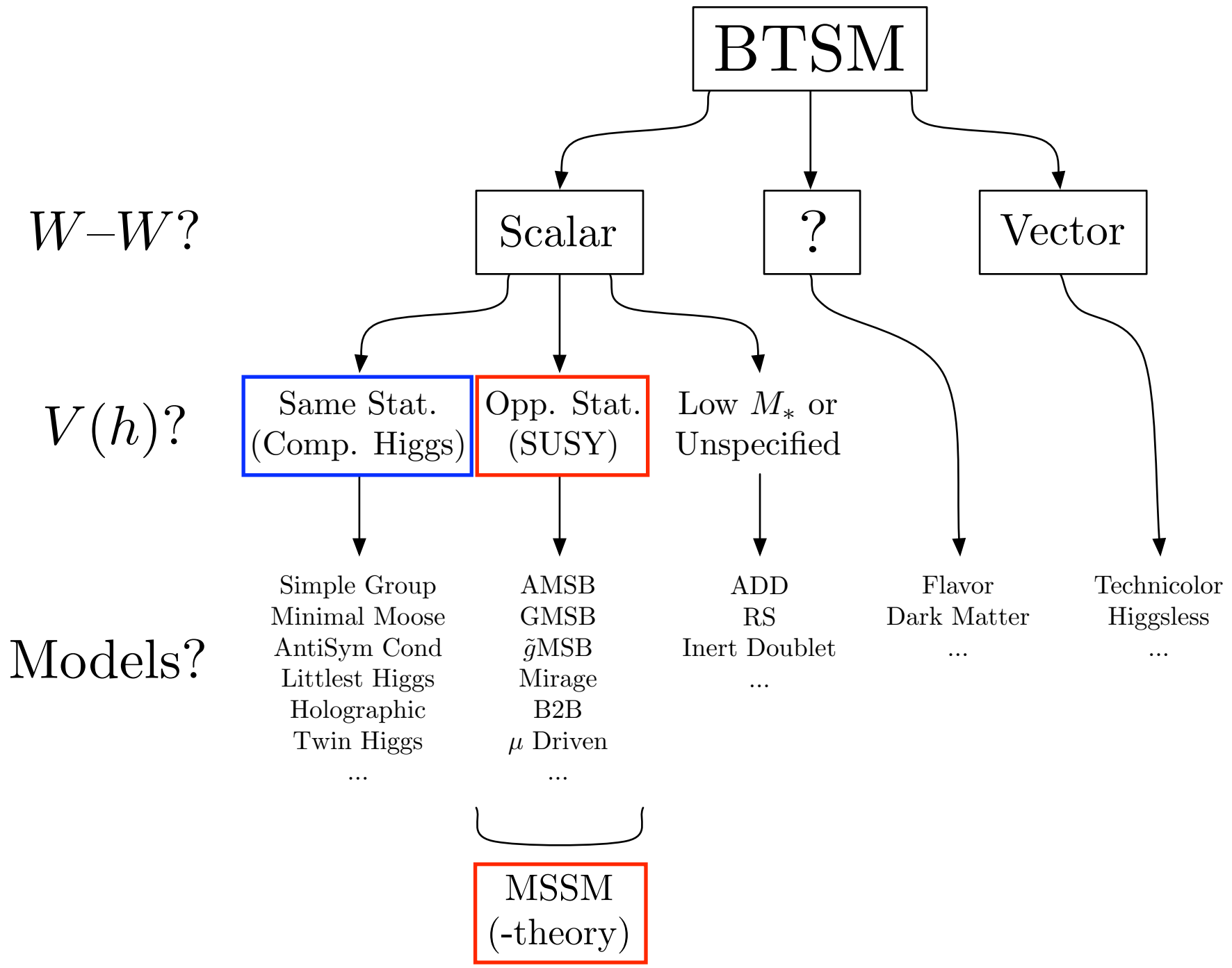
$\mathcal{L}_{\text{unified}}$ !

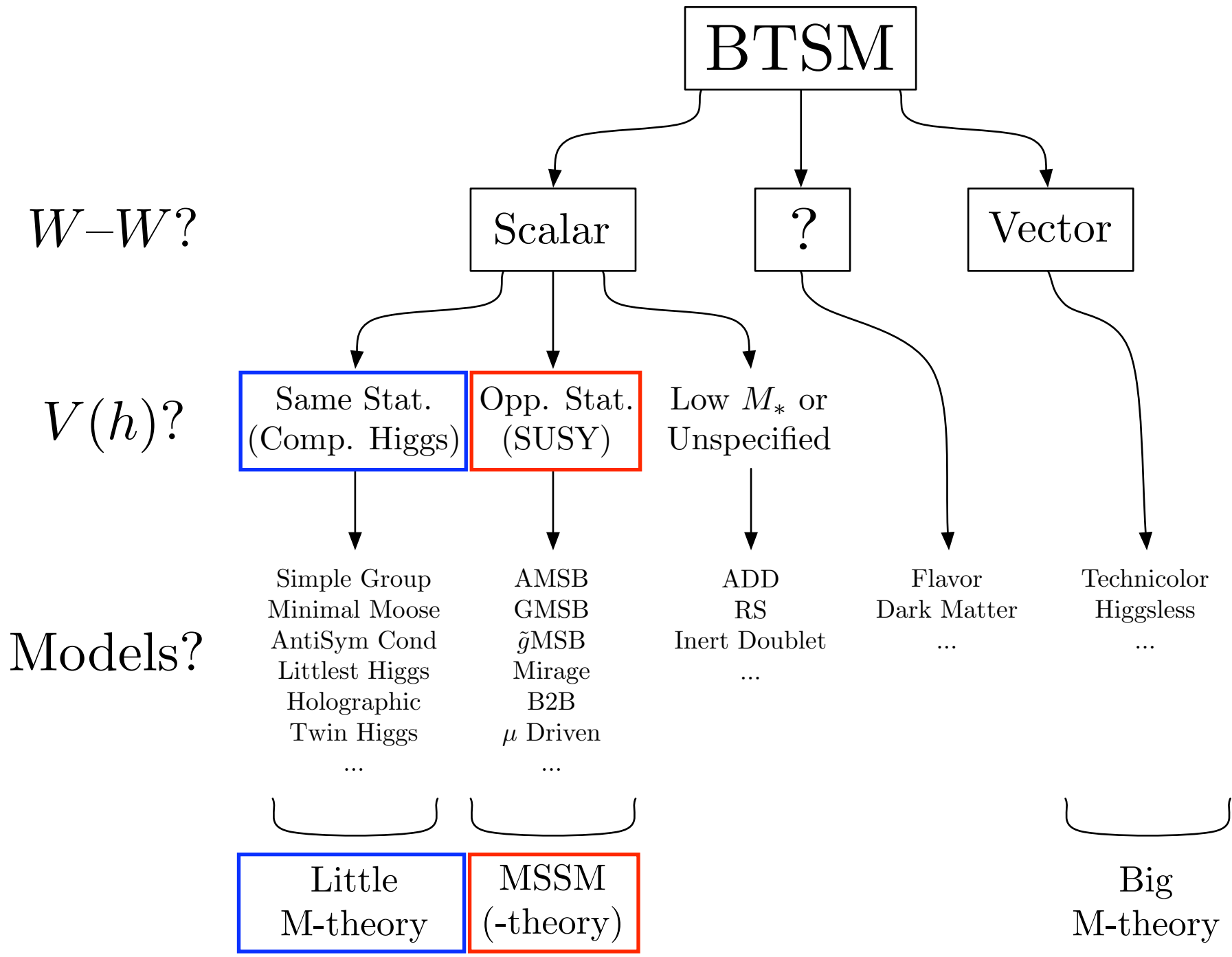
One “weakly coupled”  
mother (moose) theory.











# SUSY

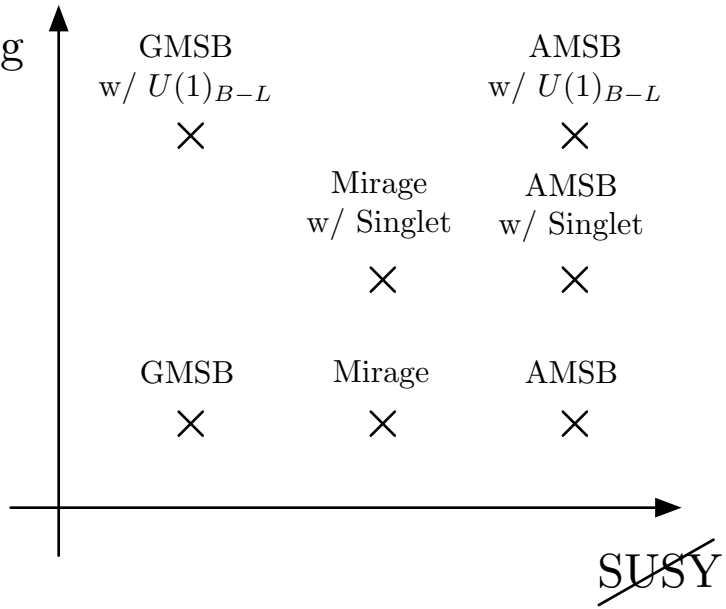
GMSB w/ $U(1)_{B-L}$		AMSB w/ $U(1)_{B-L}$
×		×
	Mirage w/ Singlet	AMSB w/ Singlet
	×	×
GMSB	Mirage	AMSB
×	×	×

# Composite Higgs

$\ell H$		$\ell H$ in $AdS_5$
×		×
	MM w/ $SU(2)_C$	$AdS_5$ w/ $SU(2)_C$
	×	×
SG	MM	$AdS_5$ CH
×	×	×

# SUSY

Model  
Building

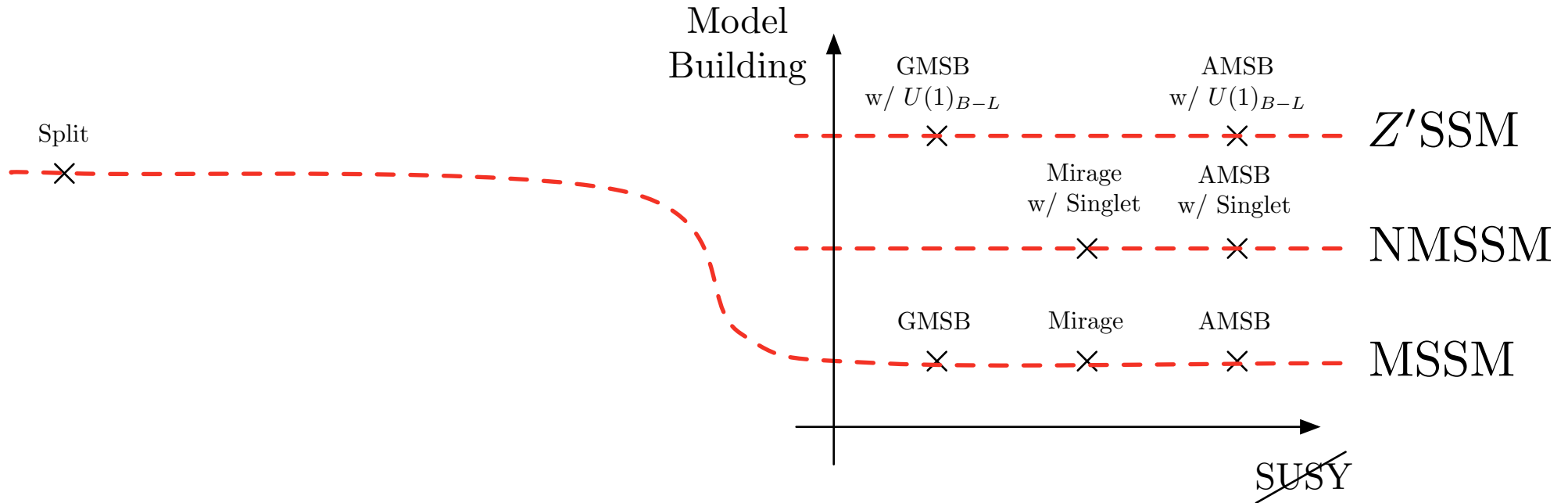


# Composite Higgs

$\ell H$		$\ell H$ in $AdS_5$
×		×
	MM w/ $SU(2)_C$	$AdS_5$ w/ $SU(2)_C$
	×	×
SG	MM	$AdS_5$ CH
×	×	×



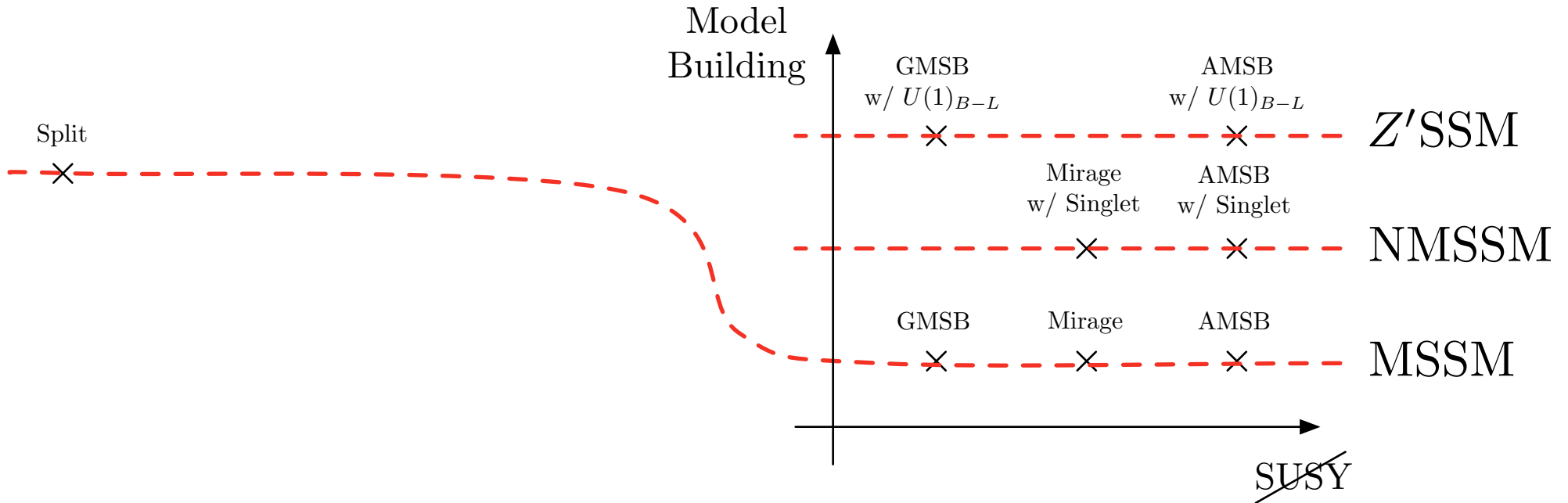
# SUSY



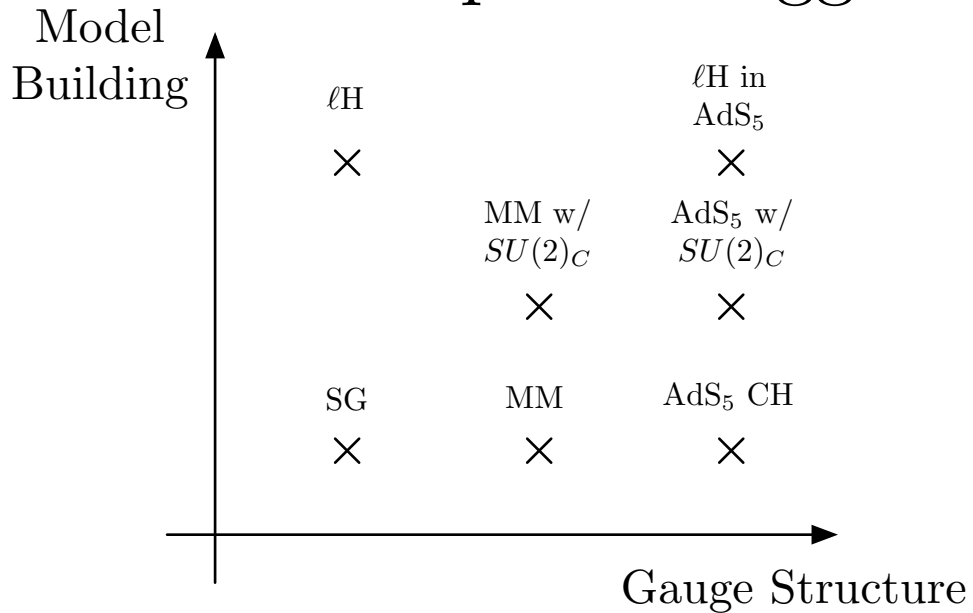
# Composite Higgs

$\ell H$		$\ell H$ in $AdS_5$
$\times$		$\times$
	MM w/ $SU(2)_C$	$AdS_5$ w/ $SU(2)_C$
	$\times$	$\times$
SG	MM	$AdS_5$ CH
$\times$	$\times$	$\times$

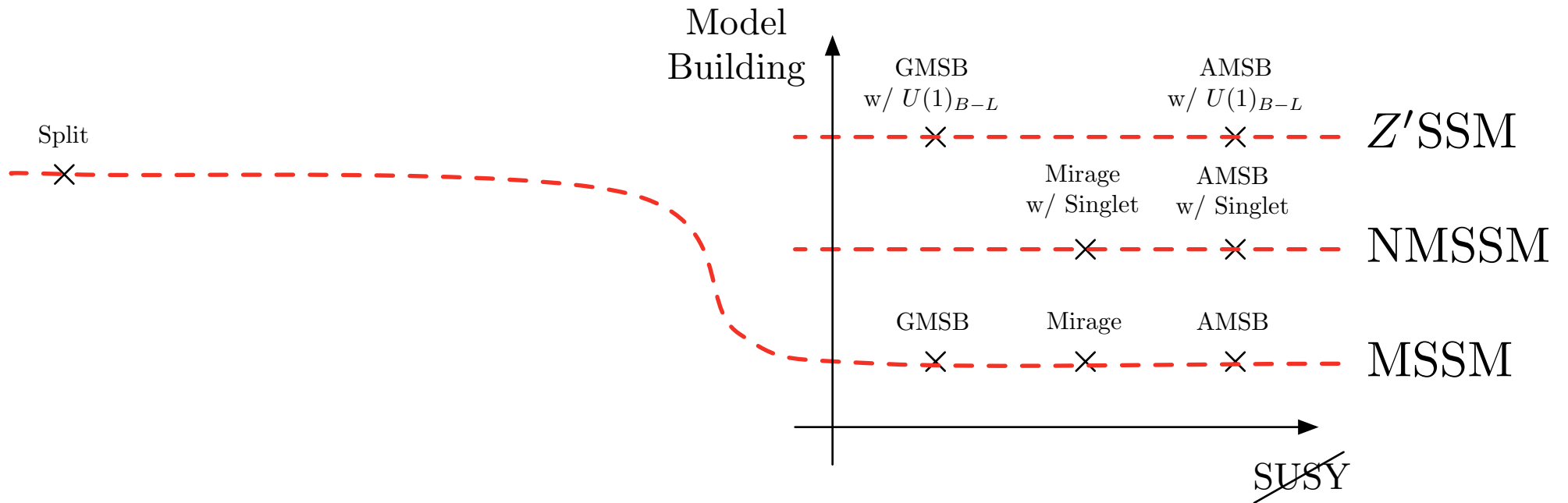
# SUSY



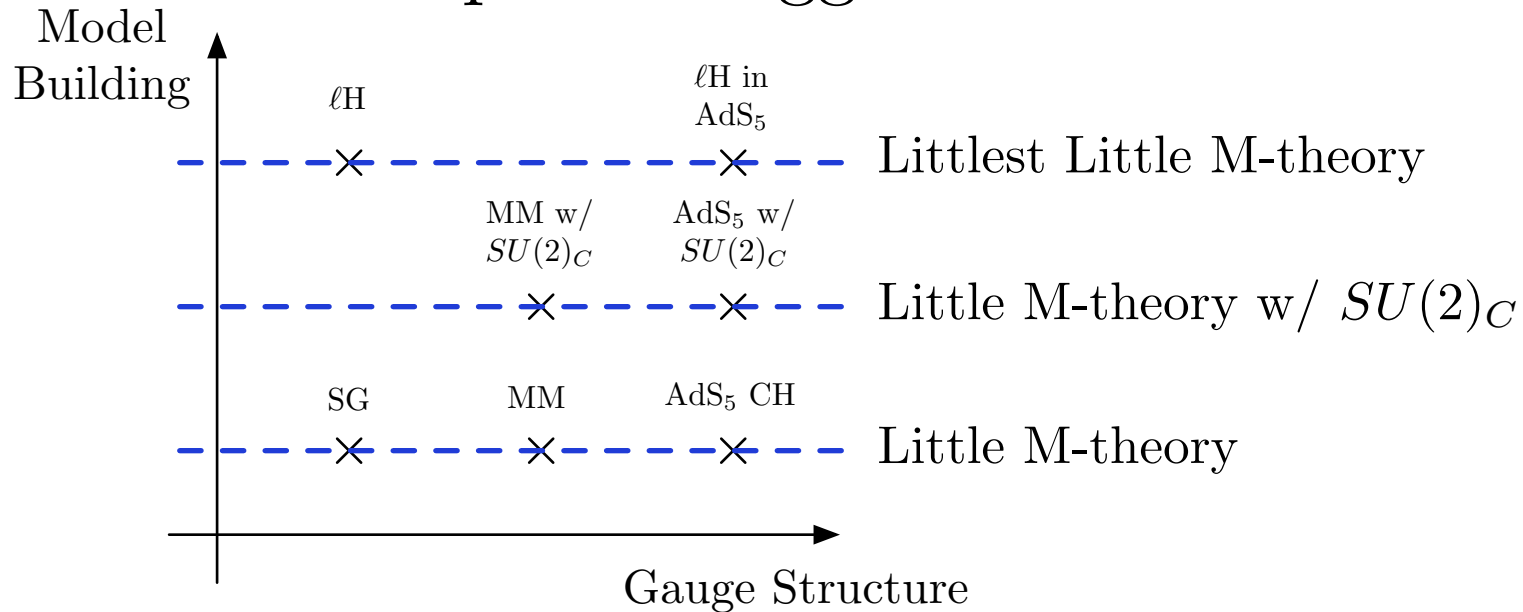
# Composite Higgs



# SUSY



# Composite Higgs



# Why This is Interesting...

Model A }  $\mathcal{L}_{\text{unified}} \Rightarrow$  One MC  
Model B } Tool!

Model A } Model A  $\cos \theta + B \sin \theta \Rightarrow$  New  
Model B } Benchmarks!

**SUSY** & **Composite Higgs** on the Same Footing!

**MSSM** & **Little M-theory**:

Flexible Frameworks for Studying  
Broad Classes of Terascale Models

# How is this Possible?

Minimal Moose : Moose w/ Gauged  $SU(2)^2$

(Arkani-Hamed, Cohen, Gregoire, Katz, Nelson, Wacker)

Simple Group : Sigma Model w/ Gauged  $SU(3)$

(Schmaltz, Kaplan)

Original Holographic Higgs :  $AdS_5$  w/ Gauged  $SU(2)$

(Contino, Nomura, Pomarol)

Unify Different Frameworks/Symmetries?

# Little M-theory is Possible Because...

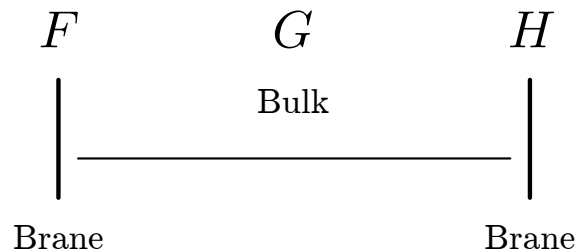
Theoretical Fact : All (known) **non-SUSY BTSM** theories are describable by **mooses** at low energies!

Experimental Fact : The **LHC has finite reach** and we should probably take the **LEP paradox** seriously.

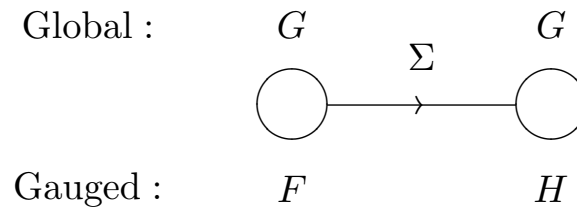
# Theoretical Fact

All (known) non-SUSY BTSM theories are either:

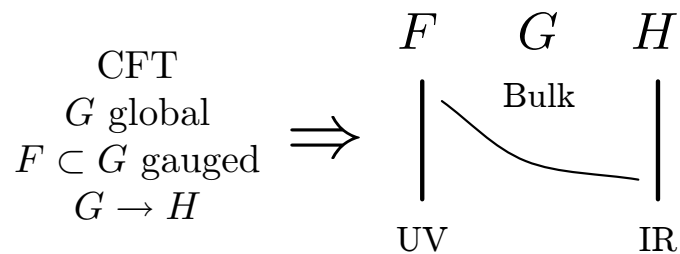
Based on Extra Dimensions



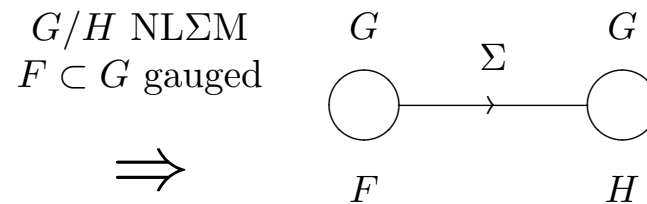
Based on Moose Diagrams



Approx. Extra Dimension  
(AdS/CFT)



Approx. Moose Diagram  
(HLS, aka Little Technicolor)

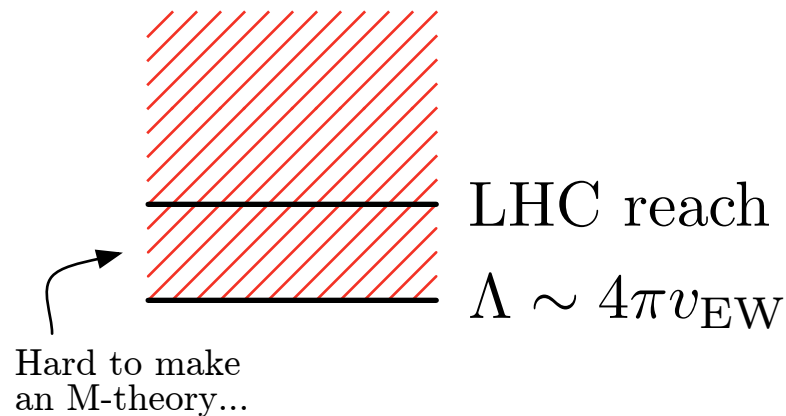


**Deconstruction: All of these are Approx. Mooses!**

# Experimental Fact

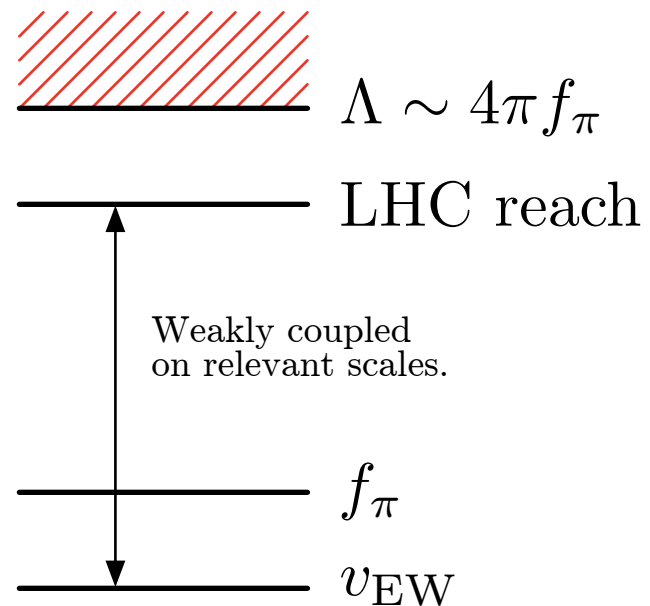
LEP : Evidence for Little Hierarchy

LHC : 14 TeV Center-of-Mass



$v_{EW}$

Technicolor-like



Composite Higgs-like



# Let's Make an M-theory

Composite Higgs  $\left\{ \begin{array}{l} W-W? \text{ Scalar Higgs} \\ V(h)? \text{ Same Statistics Partners} \\ \text{Little Hierarchy? } v_{EW} \ll f_\pi \end{array} \right.$

1. Construct **Non-Linear Sigma Model**
2. Map  $NL\Sigma M$  to  $AdS_5$  Using **AdS/CFT**
3. **Deconstruct**  $AdS_5$  (This is the **M-theory!**)
4. Explore Various **Limits**
5. Add Bells and Whistles

# Step 1 : Construct NL $\Sigma$ M

Turn off  $U(1)_Y$

Consider NL $\Sigma$ M  $SU(3)/SU(2)$

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$SU(3)/SU(2) \Rightarrow 8 - 3 = 5$  Goldstones

$$\Phi = e^{i\Pi/f} \begin{pmatrix} 0 \\ 0 \\ f \end{pmatrix} \quad \Pi \sim \begin{pmatrix} \eta & 0 & h_1 \\ 0 & \eta & h_2 \\ h_1^\dagger & h_2^\dagger & -2\eta \end{pmatrix}$$

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Gauge  $SU(2)_L \subset SU(3)$

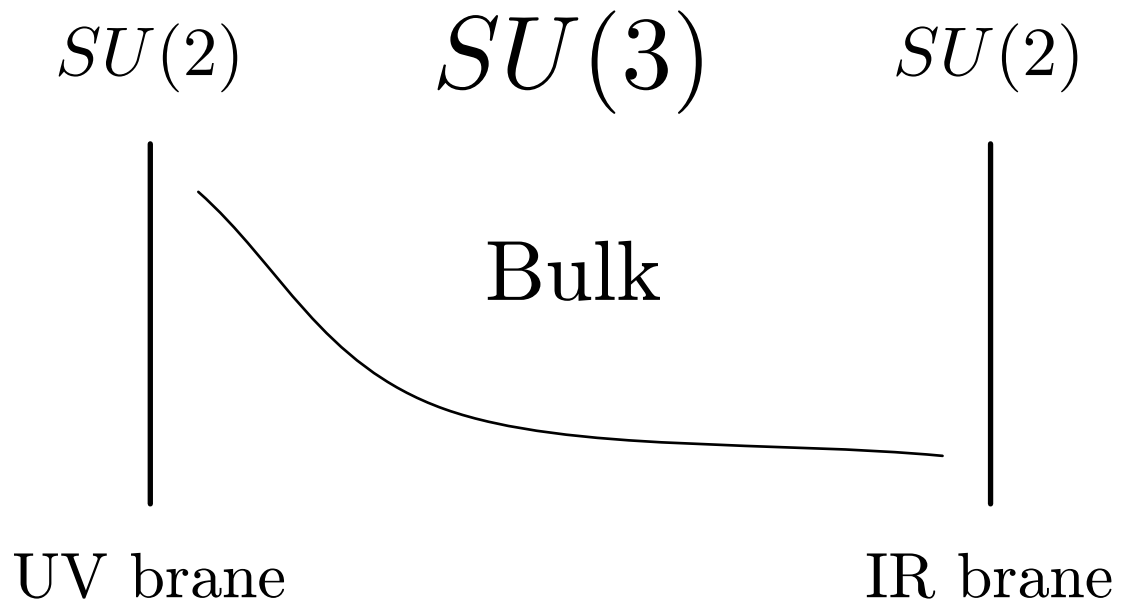
$h$  : doublet of  $SU(2)_L$       $\eta$  : singlet of  $SU(2)_L$

(Dimopoulos, Georgi, Kaplan; Georgi, Kaplan)

# Step 2 : Use AdS/CFT

$$\text{CFT} \left\{ \begin{array}{l} SU(3) \text{ global symmetry} \\ SU(3) \rightarrow SU(2) \text{ spontaneous symmetry breaking} \\ SU(2)_L \subset SU(3) \text{ gauged} \end{array} \right.$$

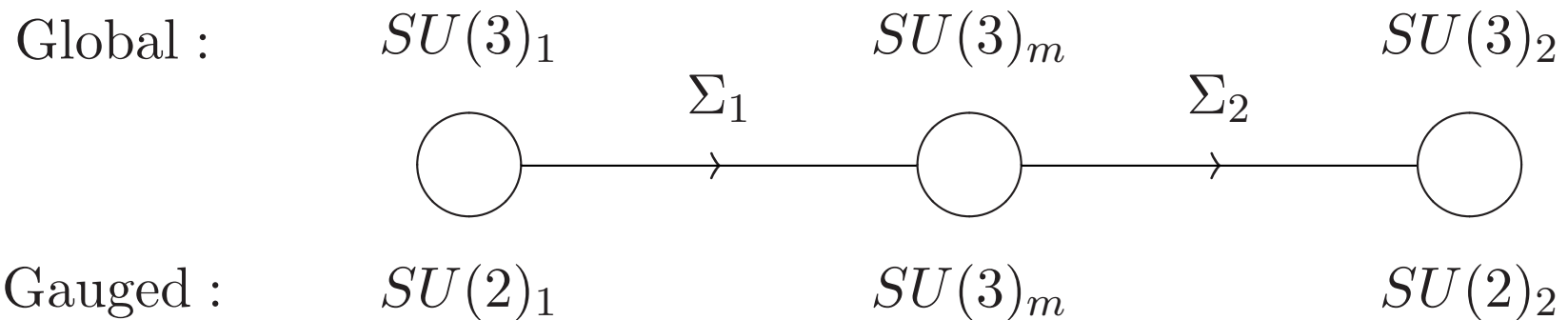
This is (essentially)  
the Original  
Holographic Higgs!



(Arkani-Hamed, Porrati, Randall; Rattazzi, Zaffaroni; Contino, Nomura, Pomarol)

# Step 3 : Deconstruct

Slice of  $AdS_5$   $\left\{ \begin{array}{l} SU(3) \text{ Bulk Symmetry} \\ \text{Reduce to } SU(2) \text{ on UV Brane} \\ \text{Reduce to } SU(2) \text{ on IR Brane} \end{array} \right.$

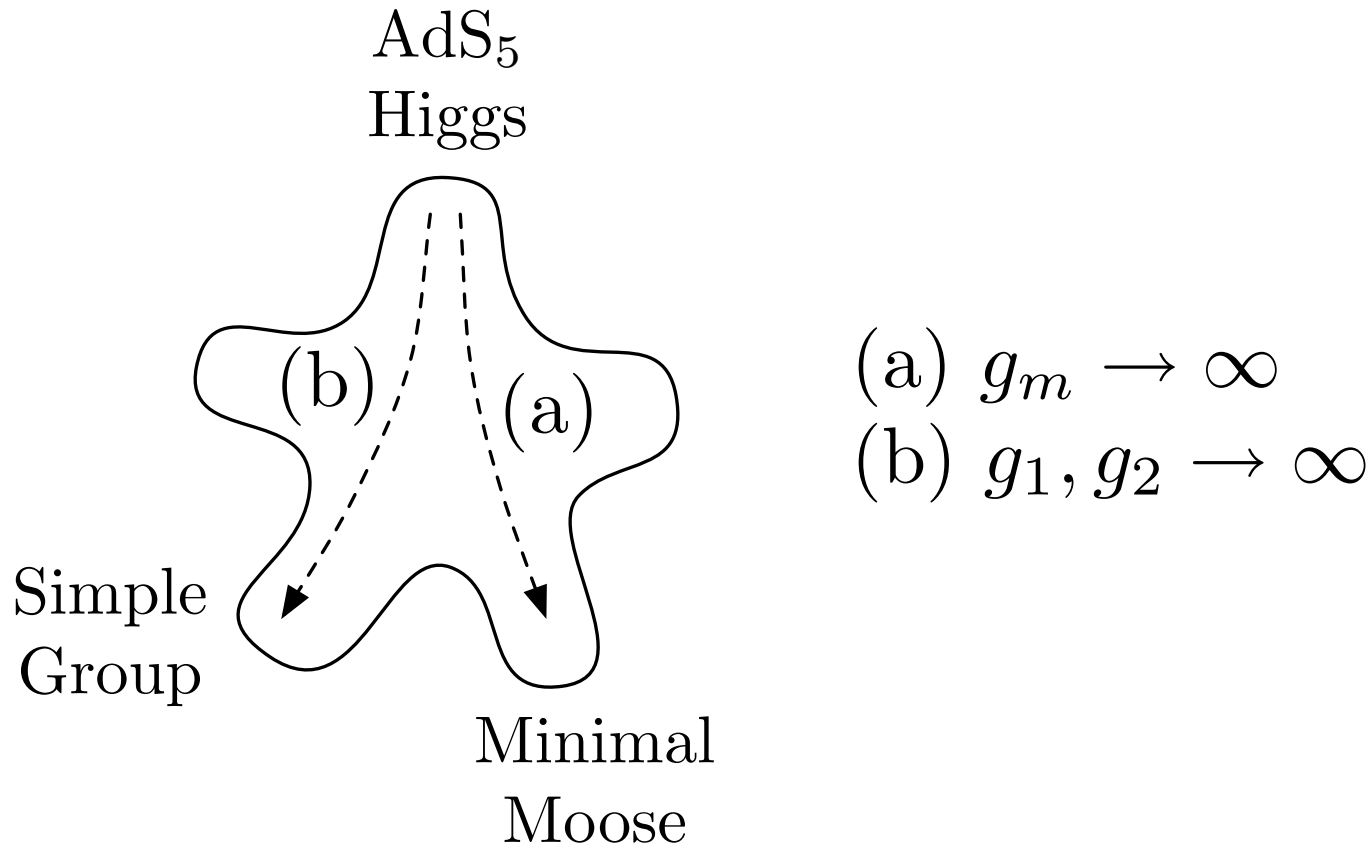


This is Little M-theory!

Spin-0 and Spin-1 Sector :  $f_1, f_2, g_1, g_m, g_2$

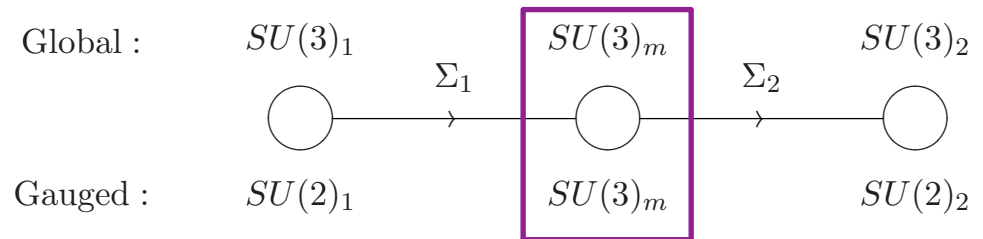
(Arkani-Hamed, Cohen, Georgi)

# Step 4 : Explore Limits



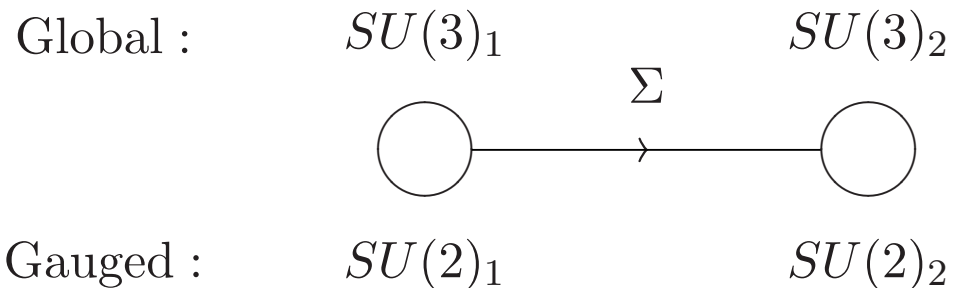
# Minimal Moose Limit

Little M-theory :



$$g_m \rightarrow \infty$$

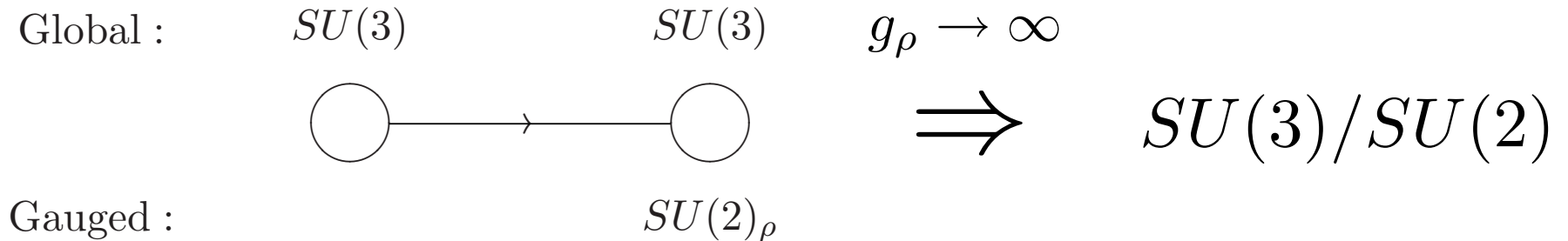
Integrate Out Middle Site



This is (essentially)  
the Minimal Moose!

# Simple Group Limit

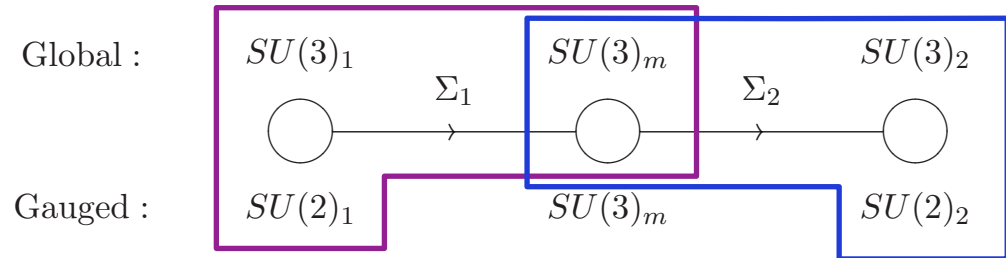
Recall Technique of Hidden Local Symmetry  
(aka Little Technicolor):



(Bando, Kugo, Uehara, Yamawaki, Yanagida; JKT)

# Simple Group Limit

Little M-theory :



$$g_1, g_2 \rightarrow \infty$$

Integrate Out Outside Sites

$$\left( \frac{SU(3)}{SU(2)} \right)^2$$

$SU(3)_V$  gauged

This is (essentially)  
the Simple Group!



# Step 5 : Bells and Whistles

- Hypercharge
- Fermions
- Custodial SU(2)
- Minimal Flavor Violation
- Minimal Isospin Violation
- T-parity
- See [hep-ph/0607205](https://arxiv.org/abs/hep-ph/0607205) for details...
- Complete model based on Sp(4)/SO(4)
- Anomaly Free
- Lots of Dials
- Rich LHC Phenomenology

# Little M-theory

SUSY : Composite Higgs :: MSSM : Little M-theory

- Simplifies and Broadens Composite Higgs Model Space
- Flexible Framework for Exploring Composite Higgs Theories at the LHC
- Midpoint Between Top-Down Model Building and Bottom-Up LHC Discoveries?

