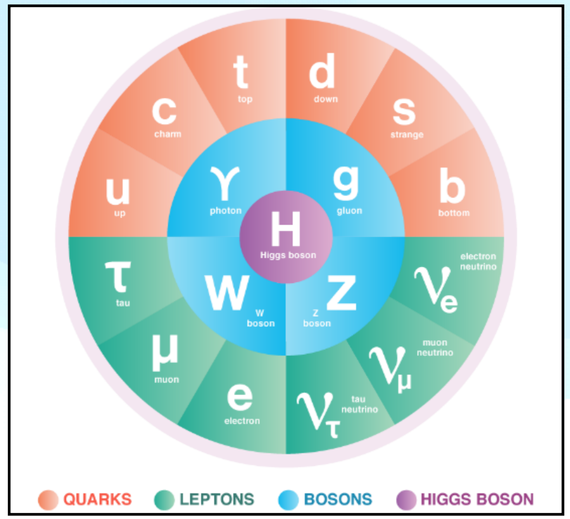
Flavour for $SO(11)/SO(10)$ Composite Higgs

Matt Starbuck (He/Him) - University of Sussex

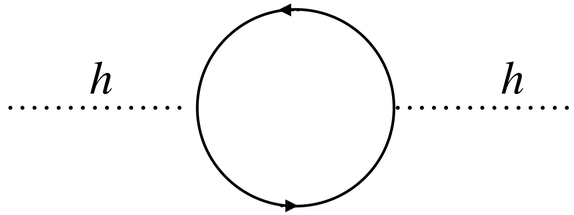
Based on work with: Wingfung Leung and Sebastian Jäger

The Standard Model Higgs

- The standard model Higgs has been **very successful** at describing nature so far.
- It is the **simplest** possible mechanism for electroweak symmetry breaking.
- Higgs mass is extremely **UV sensitive** (naturalness problem)
- Fermion masses have strange **hierarchical structure** with no established explanation

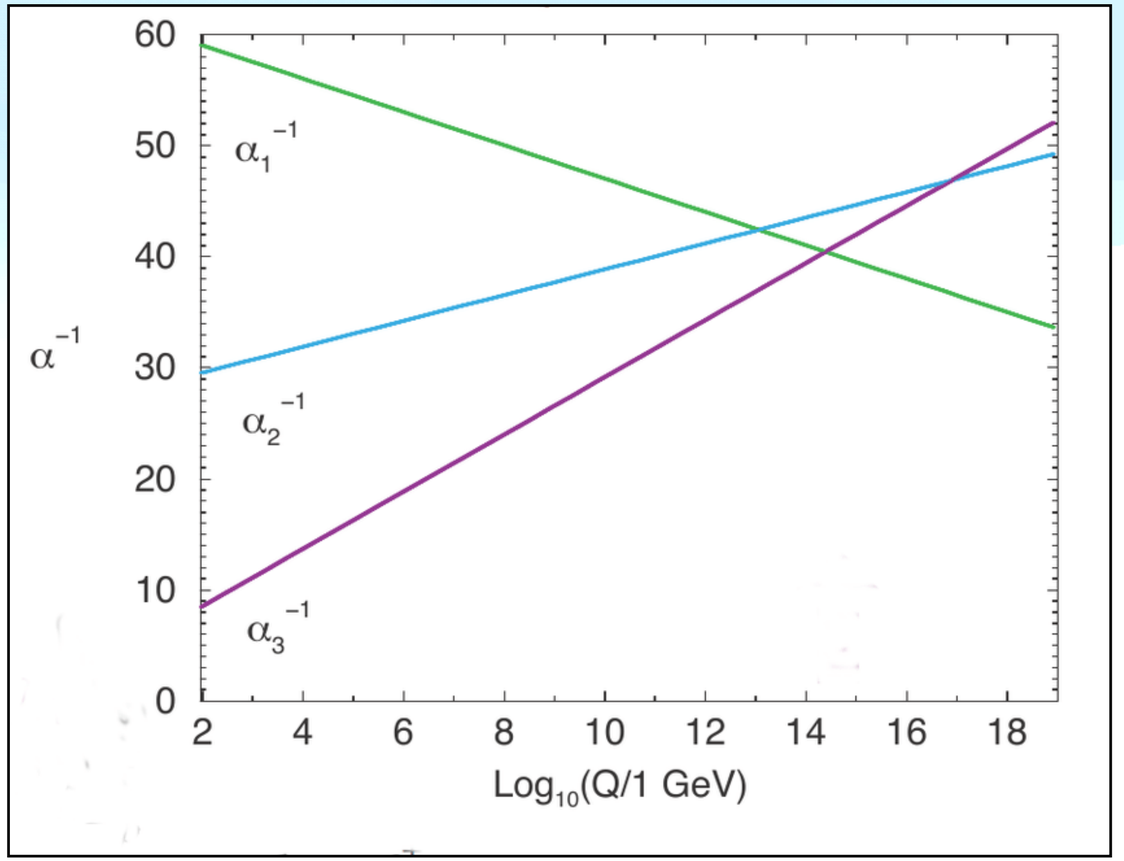


Fermilab/SLAC



Grand Unification

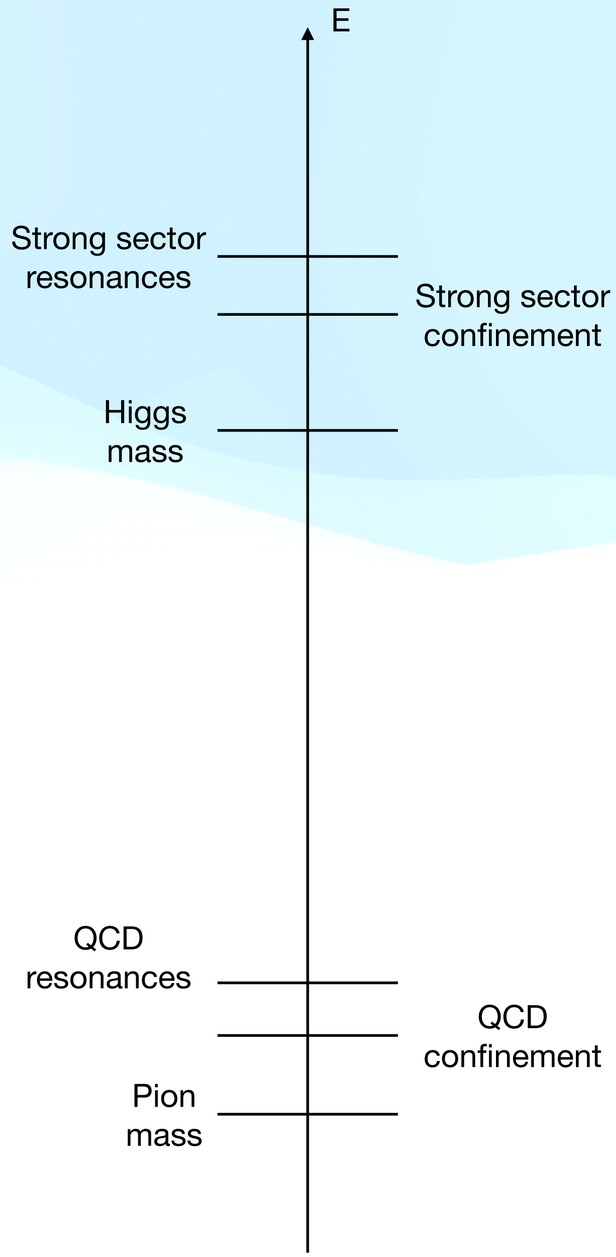
- Unification has been a theme in physics
- Gauge couplings must intersect at some energy scale
- The RG evolution of SM gauge couplings shows that they almost meet at Λ_{GUT}
- BSM physics might aid in helping their intersection



Allanach (2016)

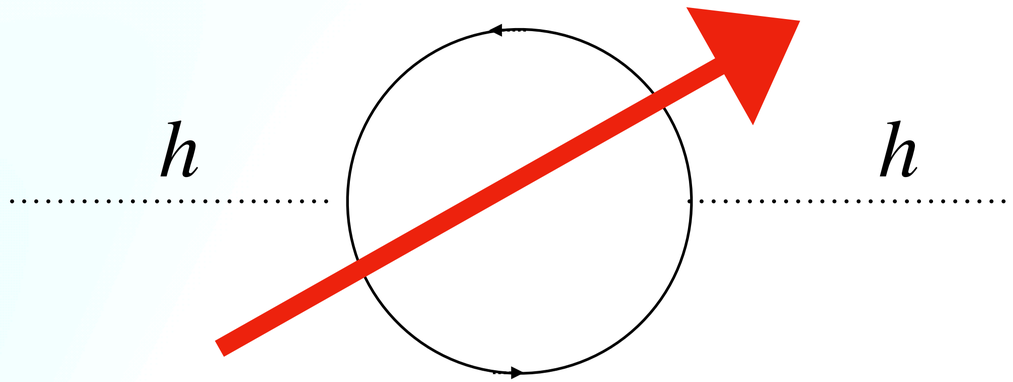
Composite Higgs

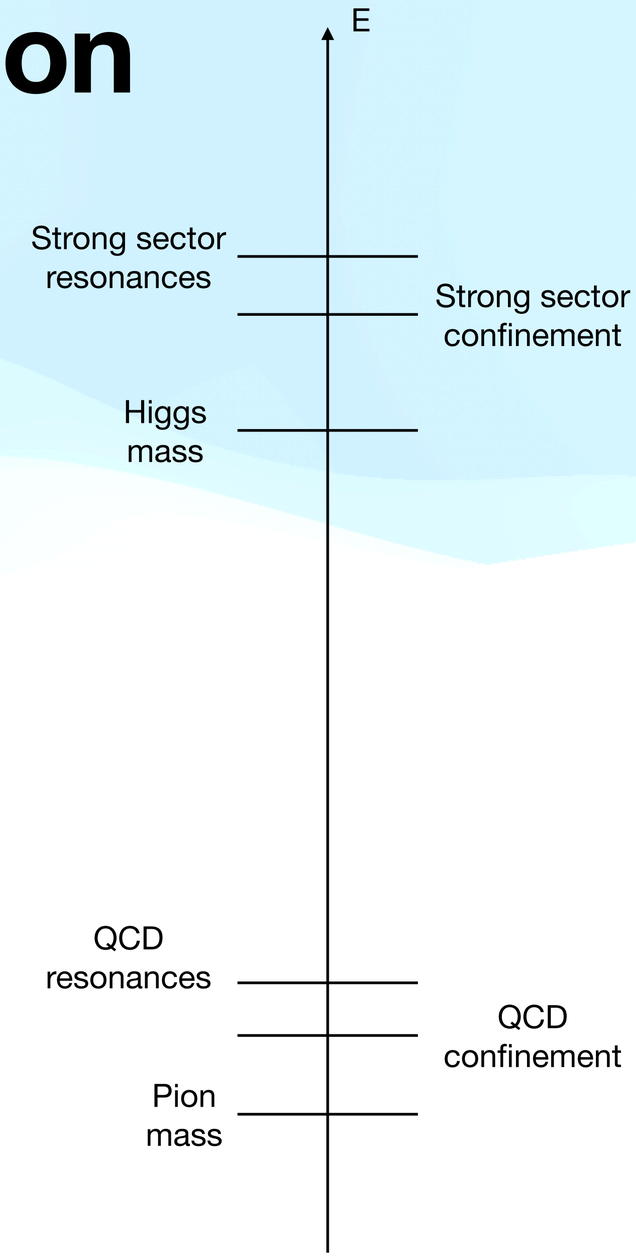
- Higgs might be a **composite** particle
- Higgs cannot be a bound state of QCD as it is too heavy
- Need a **new strong interaction** to produce the Higgs



Composite Higgs Motivation

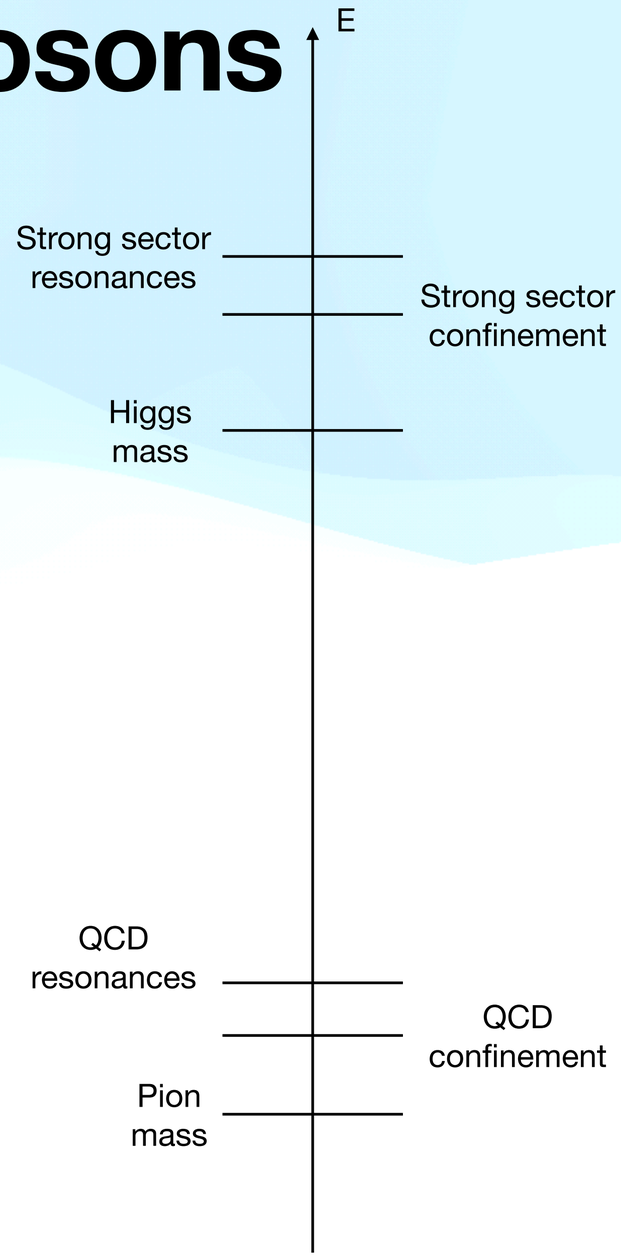
- A composite Higgs can solve **naturalness problem** with Higgs mass
- Radiative corrections to Higgs mass peak at strong sector confinement scale $m_\star \sim TeV$



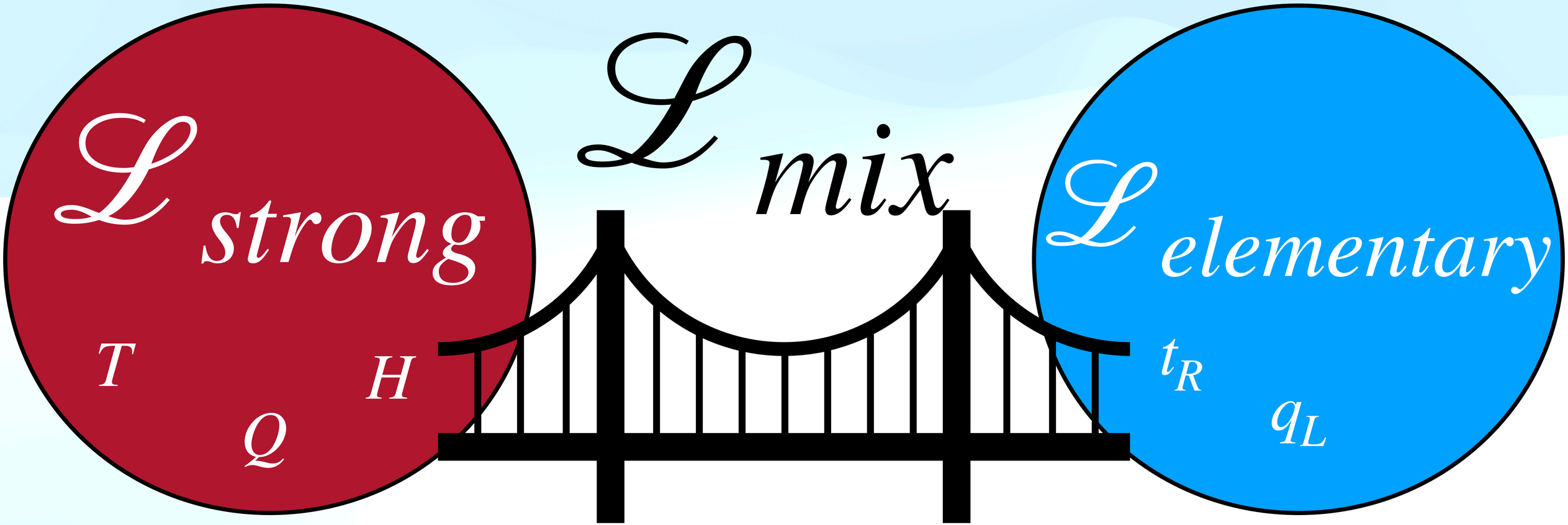


Pseudo Nambu-Goldstone Bosons

- Higgs should be a **pseudo Goldstone Boson** (pNGB) like Pion
- pNGBs arise from spontaneous breaking of an approximate global symmetry
- Potential generated by **explicit breaking** of Goldstone Symmetry

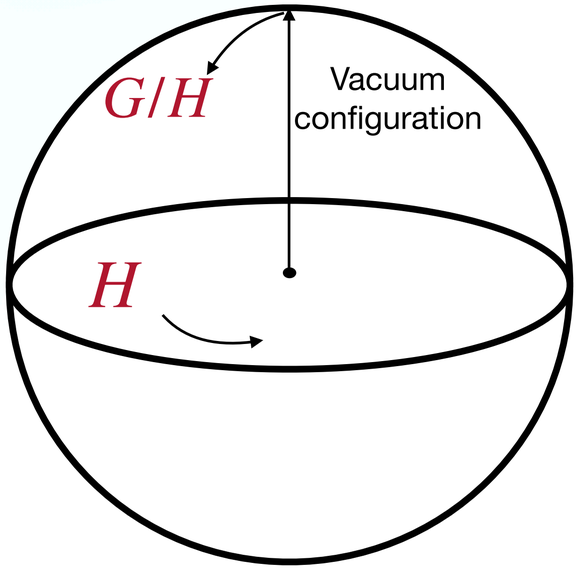


Typical Composite Higgs Models



The Strong Sector

- The sector is invariant under an **exact** global symmetry G
- The vacuum of the theory is invariant under only a subgroup H
- This produces **exactly massless** goldstone bosons for each broken generator



The Strong Sector

- Minimal viable model has $G = SO(5)$ and $H = SO(4) \simeq SU(2)_L \times SU(2)_R$

  Agashe et al (2004)
- Grand unified model contains this
- Produces composite fermionic partner resonances for each SM fermion

H

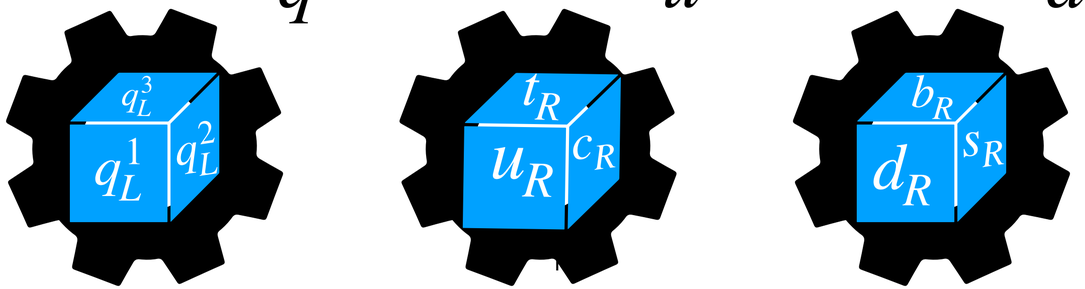
T Q

B

The Elementary Sector

- Contains all the Standard model particles except for the Higgs
- Invariant under the standard model gauge group G_{SM}, but not the strong sector G
- 3 copies of each fermion representation under G_{SM} (3 generations)

$$U(3)_q \times U(3)_u \times U(3)_d$$

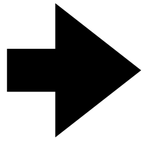


The Mixing Sector

$$\mathscr{L}_{mix} \sim \lambda_q \bar{q}_L Q + \lambda_t \bar{t}_R T$$

- Elementary fermions and composite resonances linearly mix
- Physical mass states are a mixture of elementary and composite
- Goldstone symmetry is explicitly broken and a Higgs potential generated
- $U(3)^3$ flavour symmetry explicitly broken generating flavour structure

$$q_L \to \begin{pmatrix} 0 \\ \vdots \\ q_L \end{pmatrix} \quad t_R \to \begin{pmatrix} 0 \\ \vdots \\ t_R \end{pmatrix}$$



The $SO(11)/SO(10)$ Model

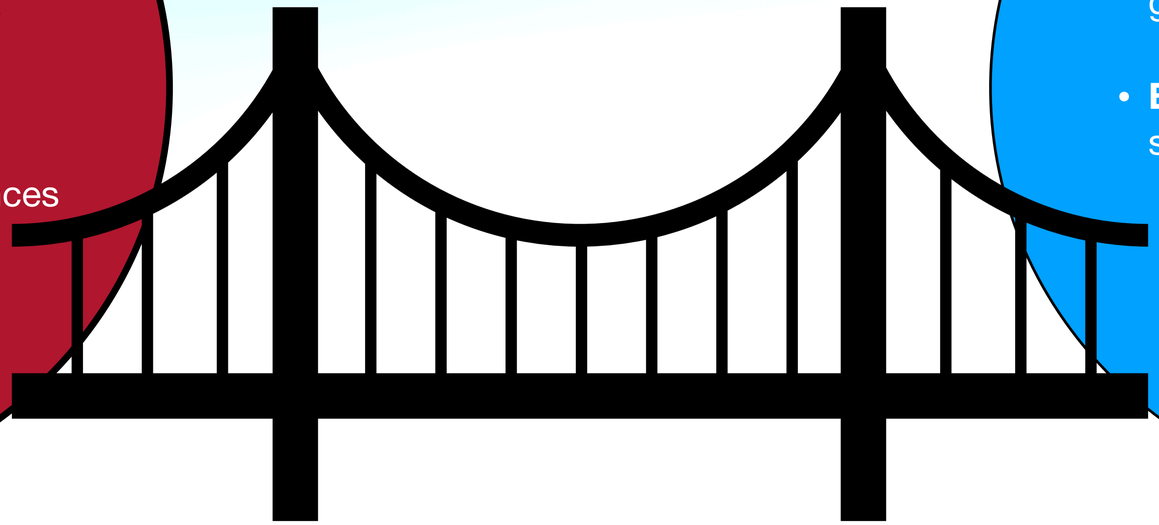
Jäger, Kvedaraite, G. Lee, S.J. Lee. To be published (2024)

$\mathscr{L}_{strong}$

- $SO(11) \to SO(10)$ spontaneously broken at scale $f > v$
- Produces NGB composite Higgs
- $G_{SM} \subset SO(10)$
- Produces other Partner Resonances

T H Q

$$\mathscr{L}_{mix} \sim \lambda_q \bar{q}_L Q + \lambda_t \bar{t}_R T$$



$\mathscr{L}_{elementary}$

- Chiral fermions and gauge fields
- $U(3)$ flavour symmetry between generations of fermions
- **Explicitly** breaks the $SO(11)$ strong sector symmetry

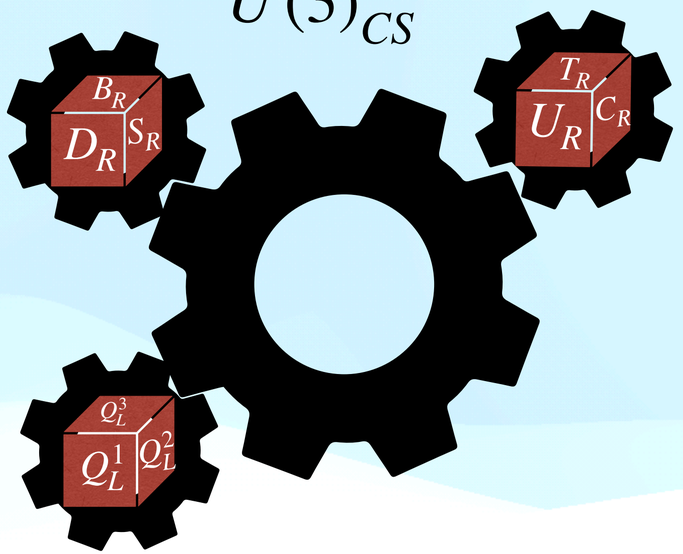
t_R q_L

Our Research

- The $SO(11)/SO(10)$ model needs extending to contain all SM fermions
- Will have to introduce **flavour structure** to composite sector likely $U(3)$ or $U(2)$ **flavour symmetry** Redi and Weiler (2014) Barbieri et al (2012)
- **Field redefinition** found between models where the Higgs is pNGB and where the Higgs is a generic resonance
- Main **phenomenological constraints** to satisfy must be found

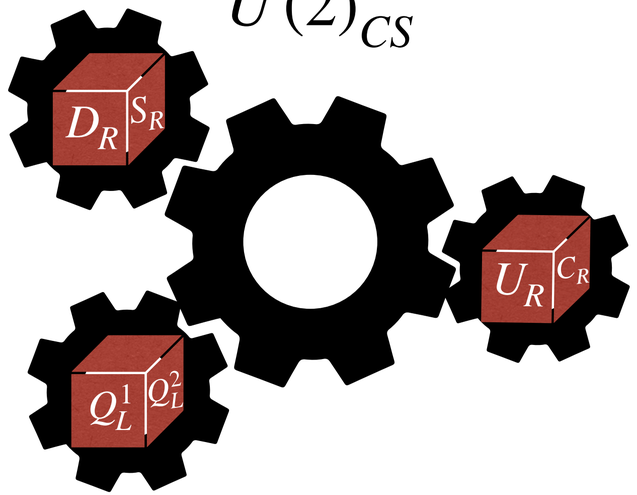
Composite

$U(3)_{CS}$



Composite

$U(2)_{CS}$



Thanks for listening!!