Large mass hierarchies from BSM strongly-coupled dynamics

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from arXiv:1605.04258, with Andreas Athenodorou, Georg Bergner, Daniel Elander, C.-J. David Lin, Biagio Lucini, and Maurizio Piai

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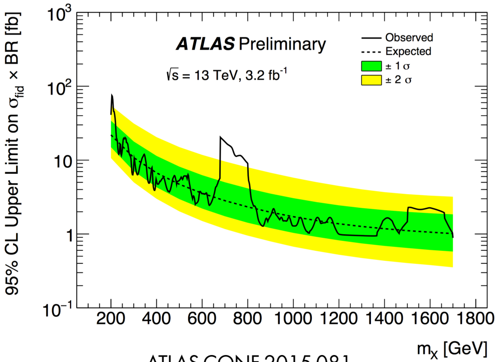
Introduction



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- Tentative hints of a 750GeV state not predicted by SM—$6 \times m_{\mathrm{H}}$
- A hierarchy of states emerges
- Can we see a similar hierarchy emerge from strong dynamics?

Outline

- Introduction
  - Quantifying the hierarchy
  - Mass deformation and infrared behaviour
- Gauge–gravity predictions
- Lattice results
  - $\mathrm{SU}(2), N_\mathsf{f} = 2$
  - $\mathrm{SU}(2), N_\mathsf{f} = 1$
- Conclusions

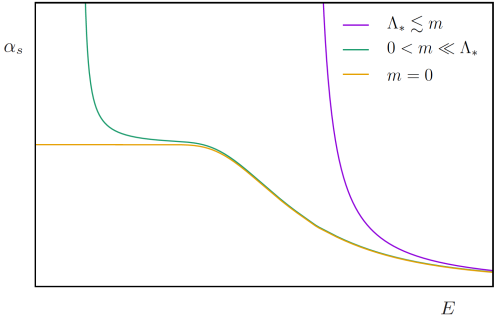
Quantifying the hierarchy

- We need a mass ratio that:
  - …is near 1 for QCD (as we don't see a hierarchy of states)
  - …can be defined in a variety of theories
- All QFTs have $T_{\mu\nu}$
- …and thus have trace and traceless parts of $T_{\mu\nu}$
- These correspond with scalar (M_0) and tensor (M_T) states
- So consider the ratio

$$R \equiv \frac{M_\mathsf{T}}{M_0}$$

  - Small ($R \approx \sqrt{2}$) for $\mathrm{SU}(2)$ Yang–Mills

Mass deformation and infrared behaviour 1



A conformal theory with deforming mass m and scale Λ_* has three regimes:

- $\Lambda_* \lesssim m$: Indistinguishable from a confining theory
- $m = 0$: only scale is Λ_*
- $0 < m \ll \Lambda_*$: Signals of confinement appear at small E

Mass deformation and infrared behaviour 2

- If $0 \leq m \ll \Lambda_*$, then spectral masses scale as

$$M \propto m^{\frac{1}{\Delta}}$$

- Lattice introduces IR cutoff, giving a scaling variable $x = Lm^{\frac{1}{\Delta}}$
- Take lowest-lying state to be linear in m, then $LM_0 \propto x$

$$\Rightarrow LM_i = f_i(LM_0)$$

- So looking at ratios:

$$\frac{M_i}{M_j} = \frac{f_i(LM_0)}{f_j(LM_0)}$$

as a function of LM_0

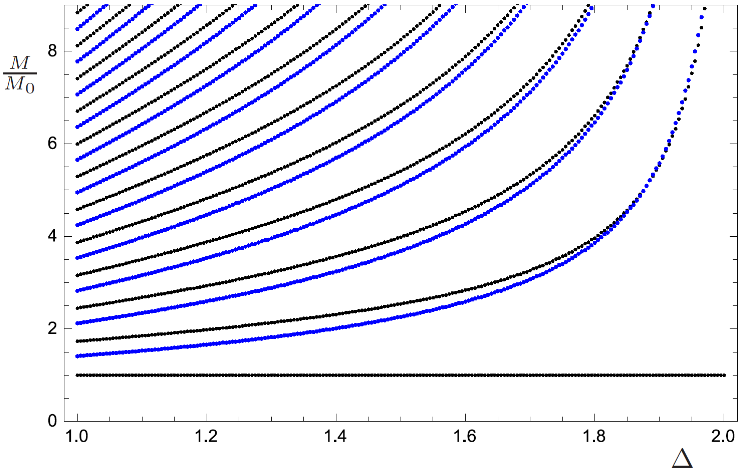
Mass deformation and infrared behaviour 3

We expect ~ 4 regimes for R:

- m large: "quenched"
  - R consistent with Yang–Mills ($R = 1.44(4)$ for $\mathrm{SU}(2)$)
- m small:
  - L small
    - "femto-universe"
    - $R \approx 1$
  - L large
    - Smaller IR cutoff
    - Small E region explored
  - L intermediate
    - Region of interest
    - Can be extrapolated to chiral limit

Gauge–gravity predictions

Considering a toy model, constructed to have scaling dimension Δ



At $\Delta = 1$, $R = \sqrt{2}$

Lattice results

- Wilson plaquette action, Wilson fermion action
- $\mathrm{SU}(2), N_\mathsf{f} = 2$
  - Inside conformal window (e.g. 1104.4301)
  - $\beta = 2.25, \Delta = 1.371(20)$
  - Gauge–gravity prediction: $R \approx 1.95(4)$
- $\mathrm{SU}(2), N_\mathsf{f} = 1$
  - Near lower end of conformal window (e.g. 1412.5994)
  - $\beta = 2.05, \Delta = 1.925(25)$
  - Gauge–gravity prediction: $R \approx 6.53^{+1.50}_{-0.91}$

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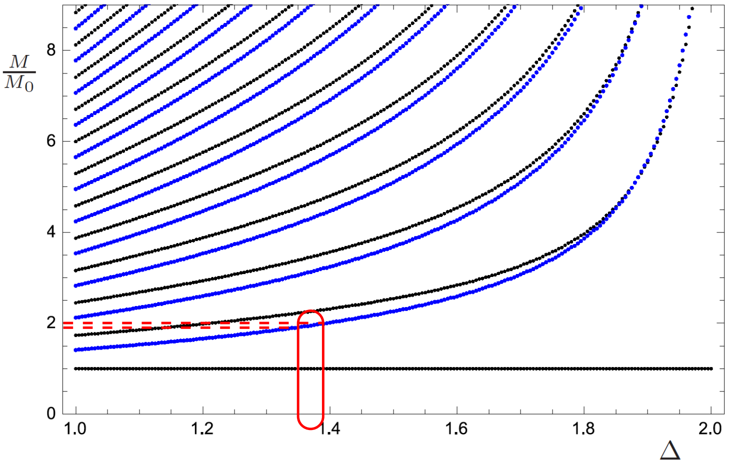

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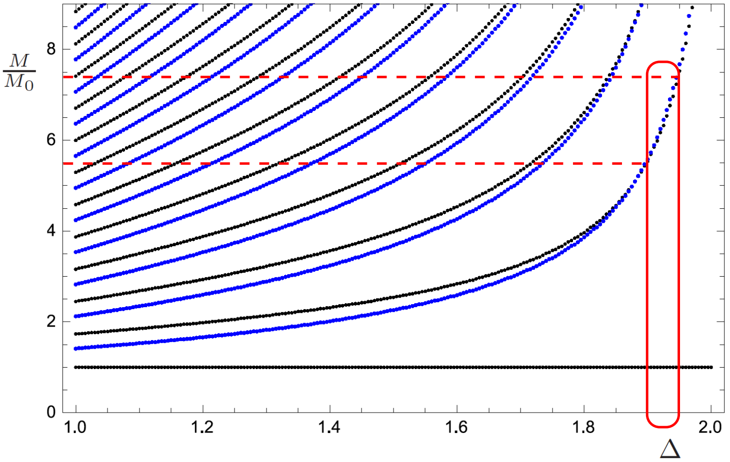

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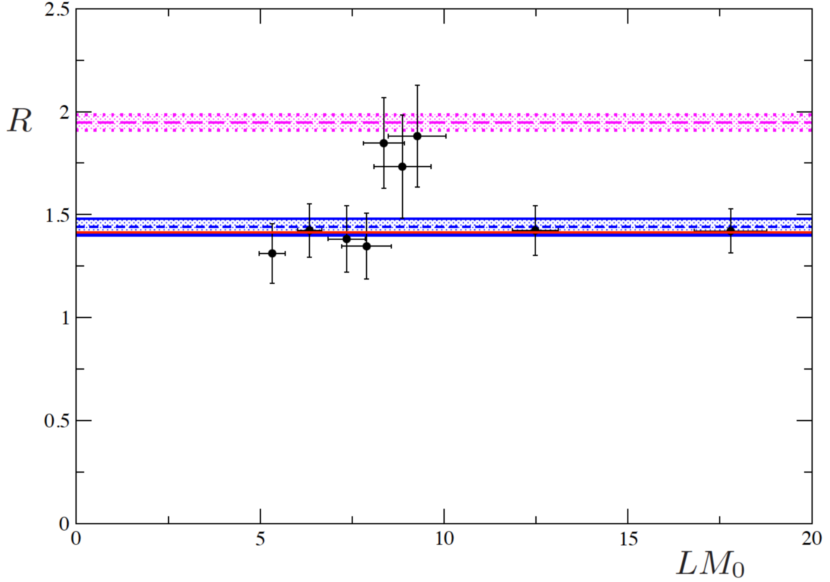

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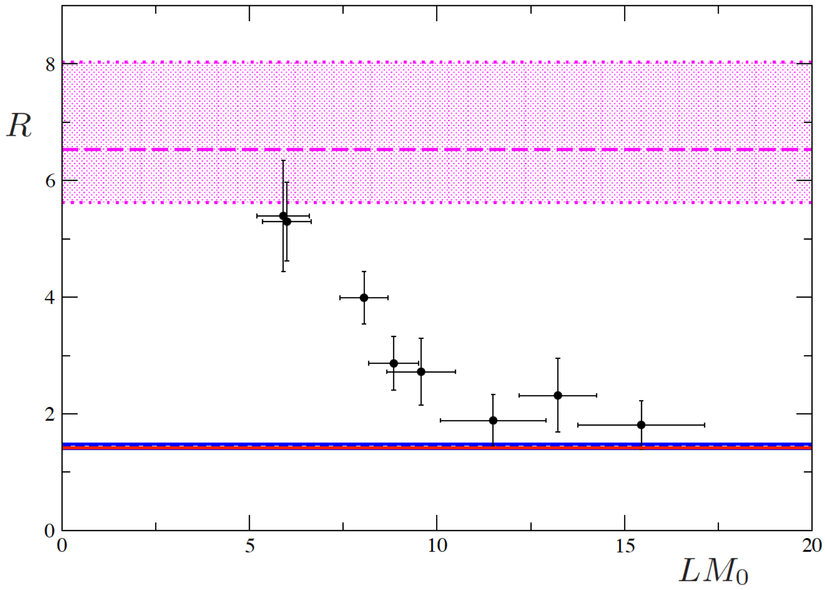

Conclusions

- $R \equiv \frac{M_\mathsf{T}}{M_0}$ shows agreement between lattice and string-inspired models $\Rightarrow$ universality?
- R is significantly enhanced (above Yang–Mills or QCD) for theories with large Δ
- Significant for strongly-interacting BSM dynamics

Next steps

- A detailed study of R as a function of LM_0 for a single mass
- Study R in a more diverse range of lattice models
  - many-flavour $\mathrm{SU}(3)$
  - $\mathrm{SU}(3)$ sextet, ...