New punctures for 6D CFT compactifications

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based on 2407.18049 and 2510.17972
with F. Apruzzi, B. Robinson, N. Mekareeya

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Introduction

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- Compactifying these 6d CFTs gives rise to new 4d models

sometimes a CFT_4.

- famous example: $\mathcal{N}=(2,0)$ on Σ_g. *Class S* theories

[Gaiotto '09]

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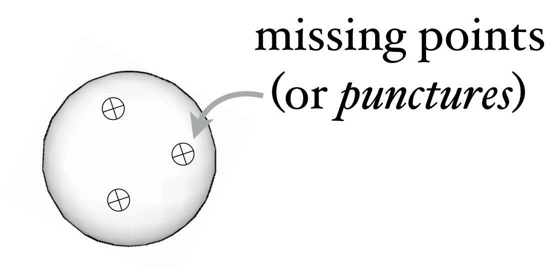

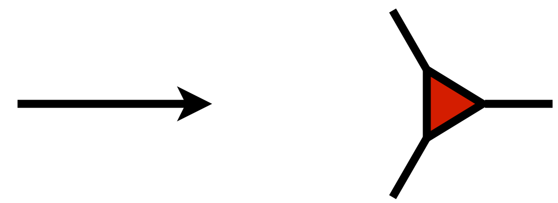

trinion CFT4:
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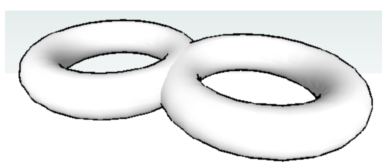

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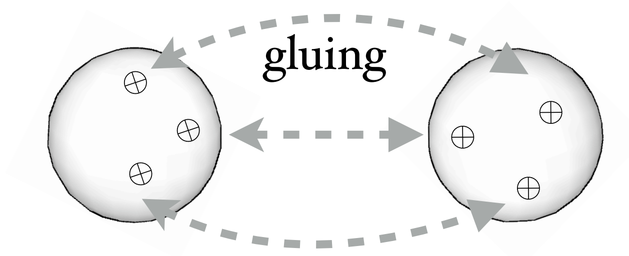

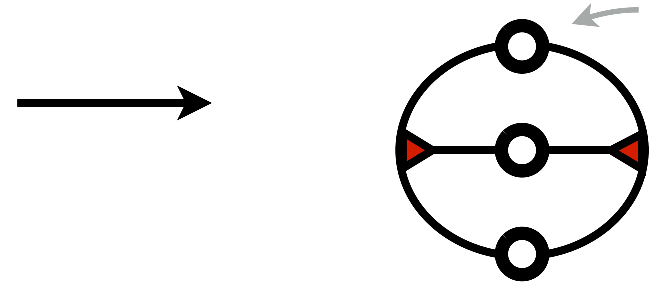

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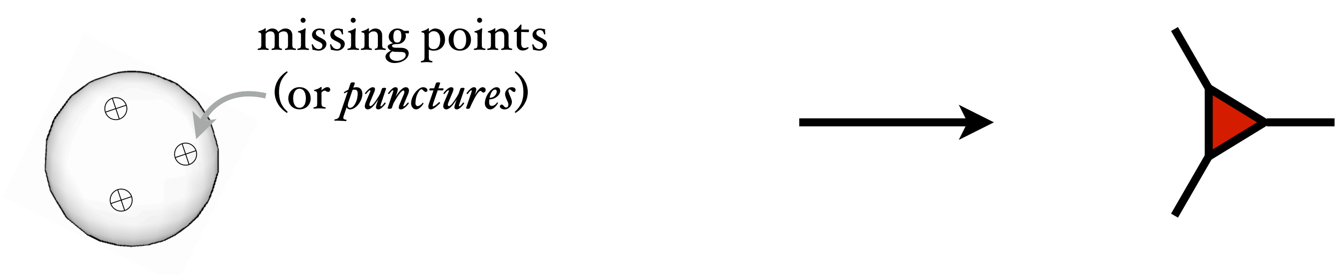

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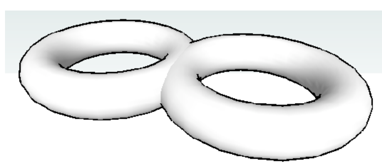
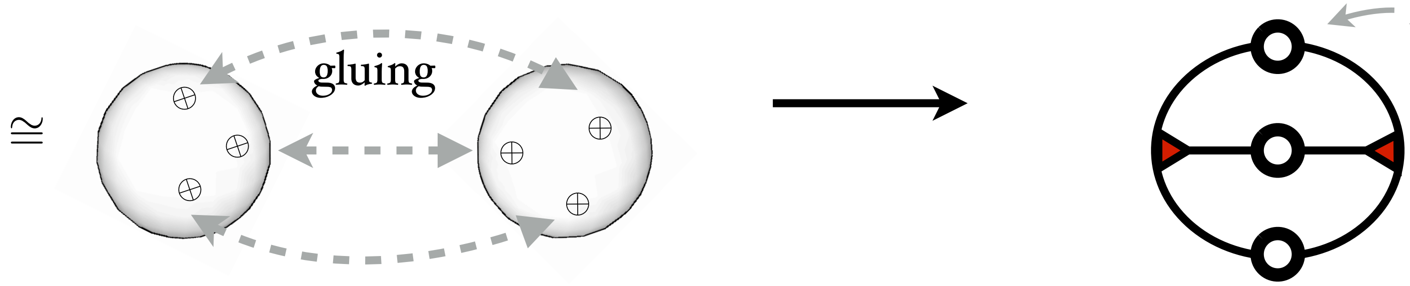
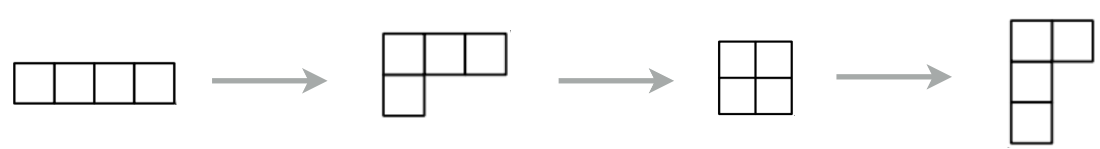




$\mathcal{N} = 2$ gauge theory

- Each puncture gives an $\mathrm{SU}(N)$ flavor symmetry; Higgsing $\leftrightarrow$ Young diagrams



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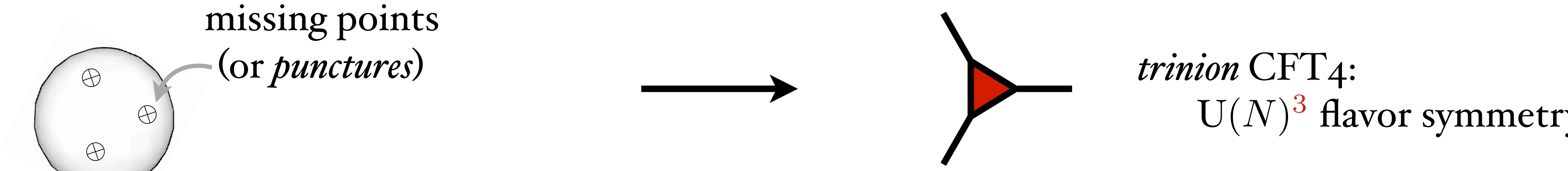

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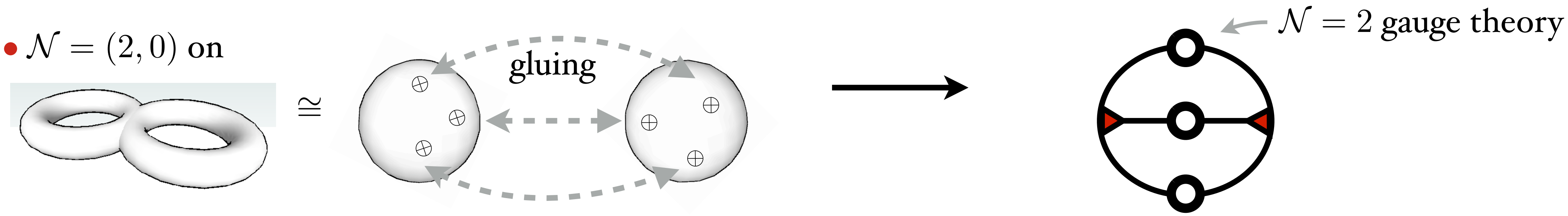

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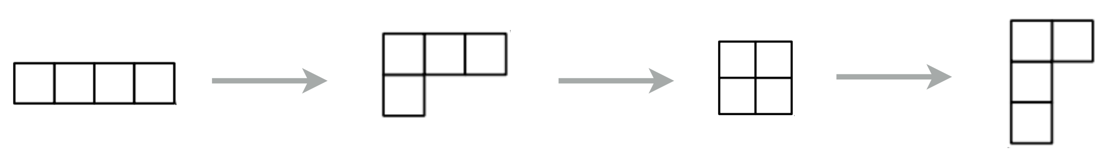

- A measure of the CFT degrees of freedom: a anomaly

$$\langle T^\mu{}_\mu \rangle \sim a \text{ Euler density} + c \text{ Weyl}^2$$

class S: $a = (2g-2)\frac{8N^3-3N-5}{48} + \sum a(\text{punctures})$

$\frac{8N^3-3N-5}{48} \wr a_{6d}$

$\sum a(\text{punctures})$ ← function of Young diagram

[Chacaltana, Distler '10, Chacaltana, Distler, Tachikawa '12...]

- This talk: Can this story be generalized to $\mathcal{N}=(1,0)$ theories?

- (Partial) evidence of a similar story exists in some cases [Gaiotto, Razamat '15; Razamat, Zafrir '18; Kim, Razamat, Vafa, Zafrir '18...]

- Here we will use holography to get some (also partial) information on a large class of theories.

Plan

- Holographic 6d theories
  - 4d compactification without punctures
    - Punctures as defects

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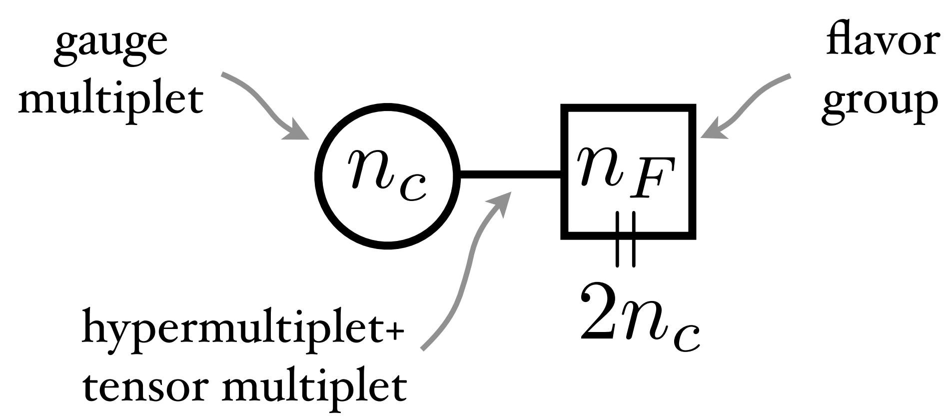

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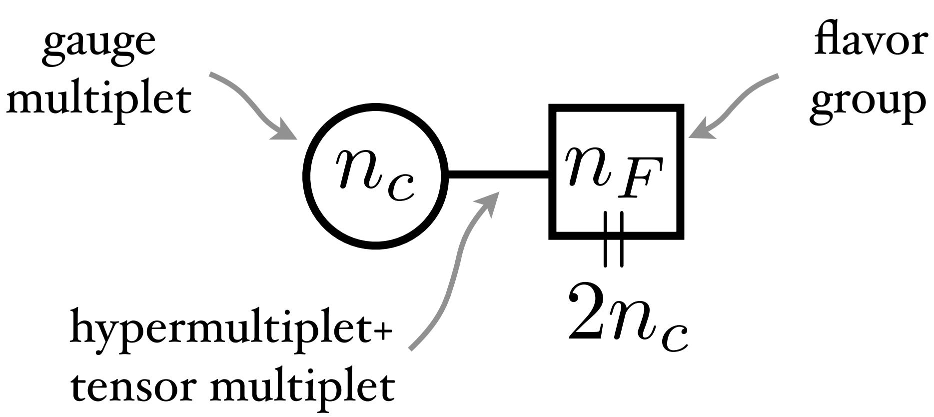

(Pseudo-)bosonic action:
[must be supplemented by $h = *h$]

[Samtleben, Sezgin, Wimmer '11,'12]
[Bandos, Samtleben, Sorokin '13]

$$\mathcal{L} = \phi\,\mathrm{Tr}(F^2 - \vec{D}^2) + (\partial\phi)^2 + h^2 + b \wedge \mathrm{Tr}(F \wedge F) + |Dq|^2 + (q^\dagger \vec{\sigma} q) \cdot \vec{D}$$

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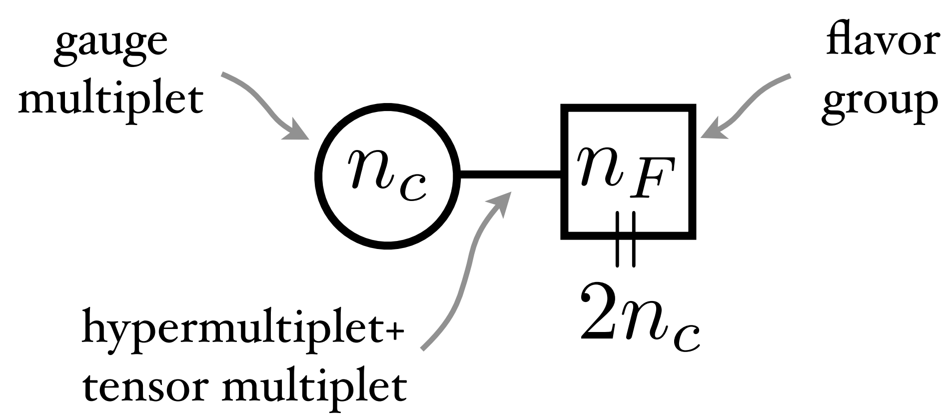

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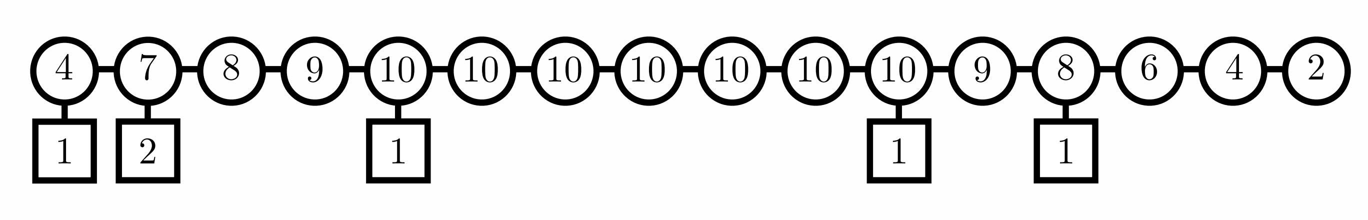
gauge coupling
||
scalar in tensor mult.

$\phi = 0$: strong coupling. CFT?

- Example:

  At each node, $n_F = 2n_c$



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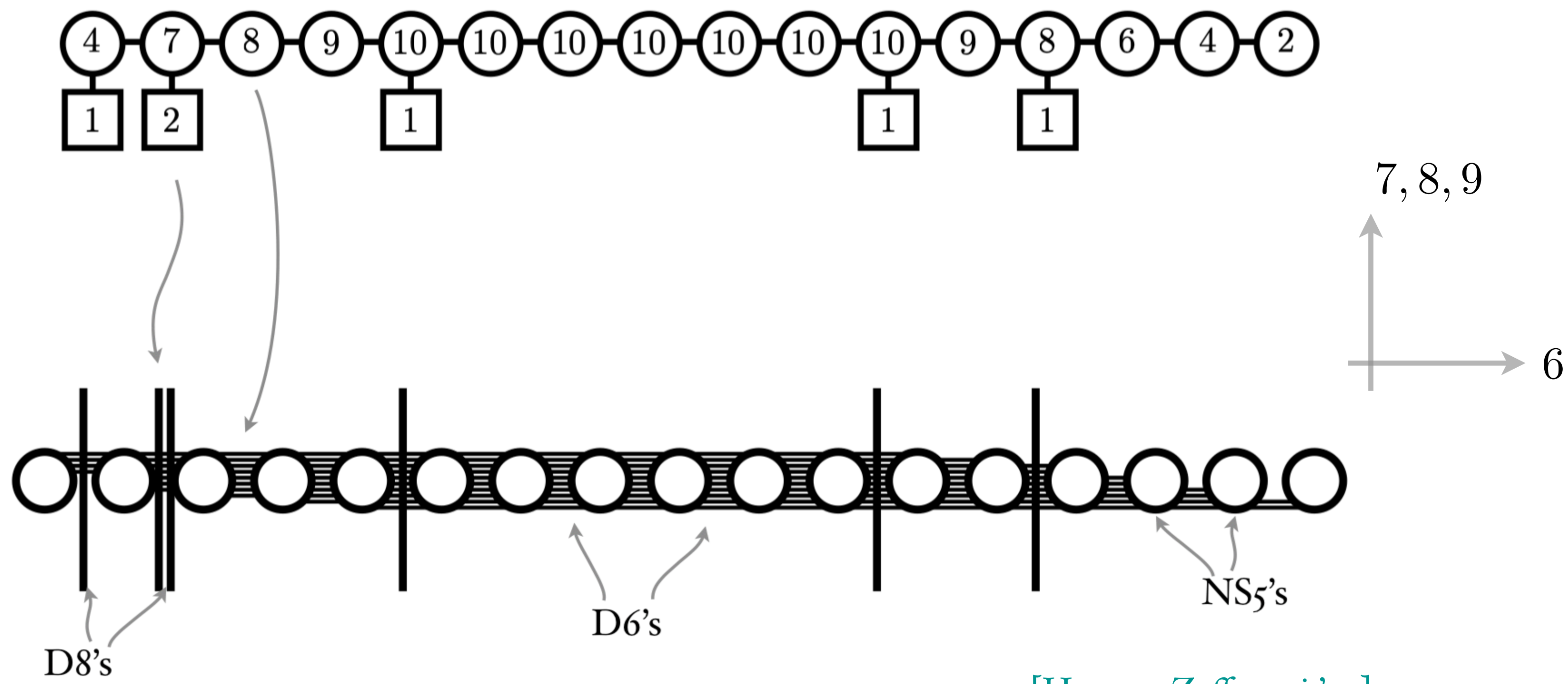

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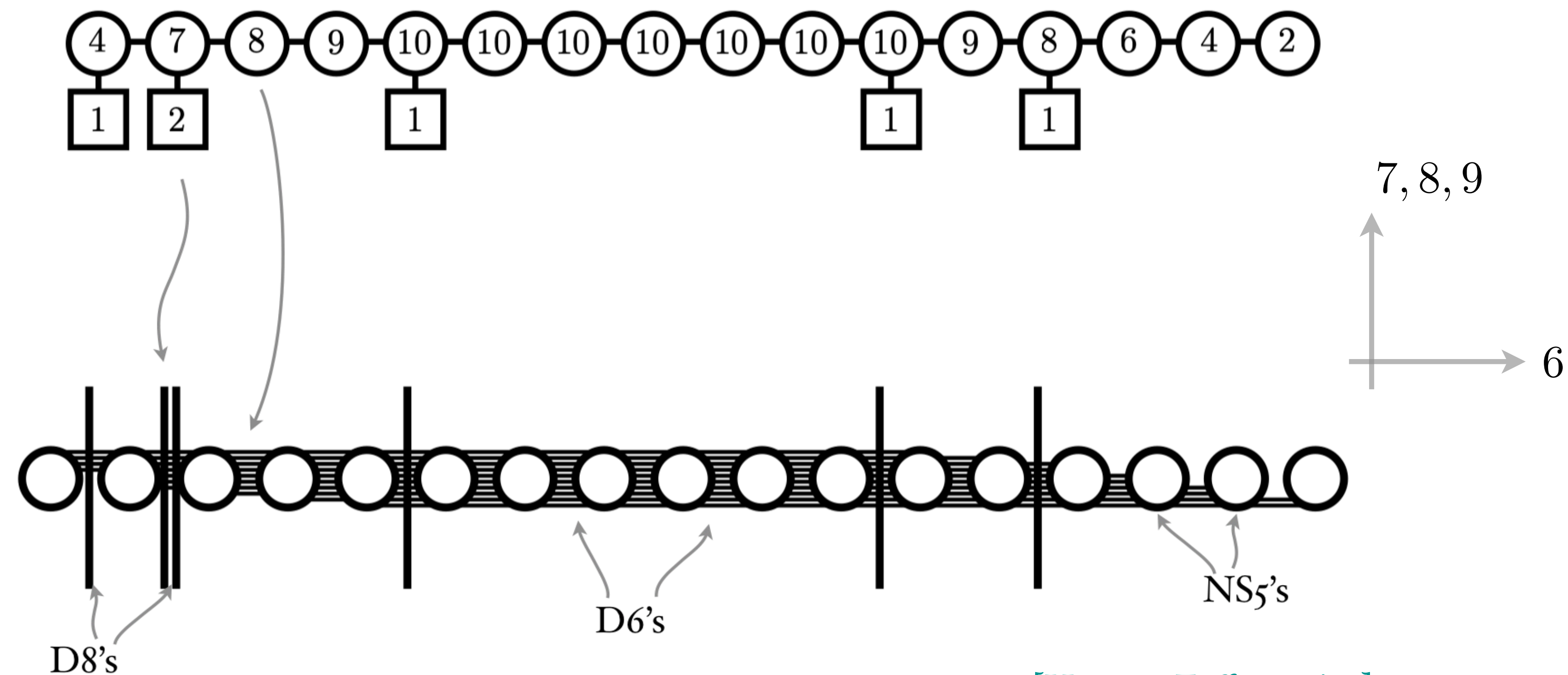

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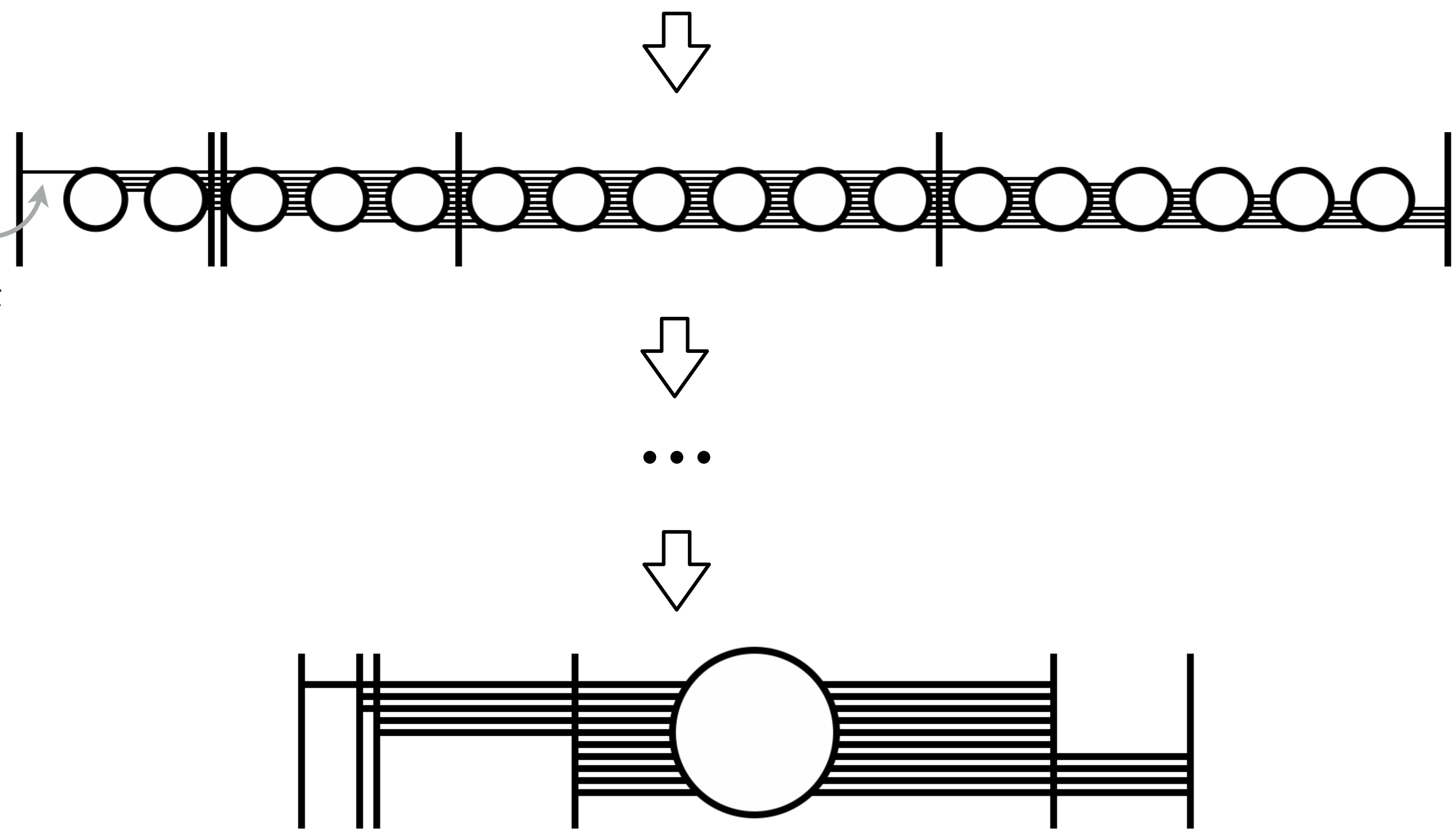
- we can rearrange the branes:

  Hanany-Witten brane-creation effect



Until the NS5 are all coincident: CFT

- AdS7 solutions are classified.
  None in IIB sugra,
  ∞ in massive IIA.

[Apruzzi, Fazzi, Rosa, AT '13]

Natural match:

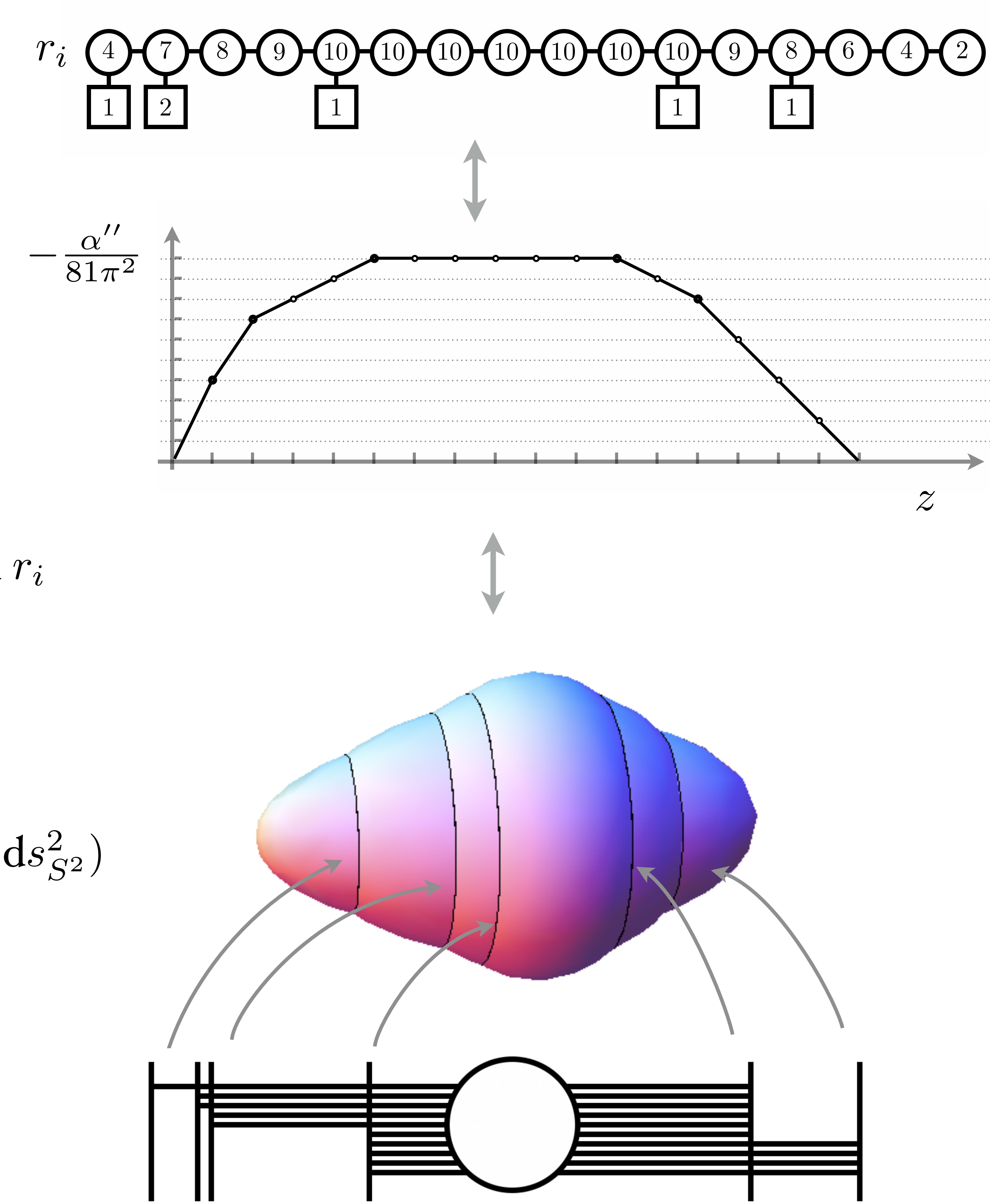
[Gaiotto, AT '14; Cremonesi, AT '16]

$\alpha''(z=i) \propto i$-th gauge rank r_i

$$\frac{1}{\pi\sqrt{2}}ds^2 = 8\sqrt{-\frac{\alpha}{\alpha''}}ds^2_{\mathrm{AdS}_7} + \sqrt{-\frac{\alpha''}{\alpha}}\left(dz^2 + \frac{\alpha^2}{\alpha'^2 - 2\alpha\alpha''}ds^2_{S^2}\right)$$

- Various checks; e.g. a_{6d}

[Cremonesi, AT '16, Apruzzi, Fazzi '17...]



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- Holographic dual? Expectation:

interpolating gravity solution

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$$\mathrm{AdS}_7 \times M_3 \longrightarrow \mathrm{AdS}_5 \times \Sigma_g \times \tilde{M}_3$$

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- indeed such solutions can be found:

$$ds^2_{M_3} = \pi\sqrt{2}\sqrt{-\frac{\alpha''}{\alpha}}\left(dz^2 + \frac{\alpha^2}{\alpha'^2 - 2\alpha\alpha''}ds^2_{S^2}\right)$$

[Apruzzi, Fazzi, Passias, AT '15]

$$ds^2_{\tilde{M}_3} = \sqrt{\frac{3}{2}}\pi\sqrt{-\frac{\alpha''}{\alpha}}\left(dz^2 + \frac{\alpha^2}{\alpha'^2 - \frac{3}{2}\alpha\alpha''}Ds^2_{S^2}\right)$$

$$Ds^2_{S^2} = d\theta^2 + \sin^2\theta(d\phi + A)^2$$

- There are similar compactifications to other dimensions: [Rota, AT '15; Passias, Rota, AT '15]

$$\mathrm{AdS}_4 \times \underline{H_3}/\Gamma \times \tilde{M}_3 \qquad\qquad \mathrm{AdS}_3 \times \underline{H_4}/\Gamma \times \tilde{M}_3$$

compact hyperbolic spaces

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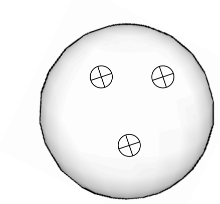

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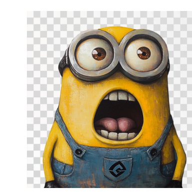
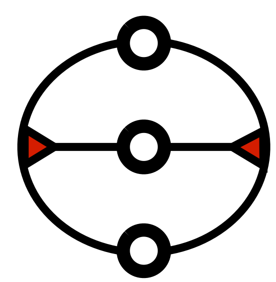


and glue them together, as in Class S.



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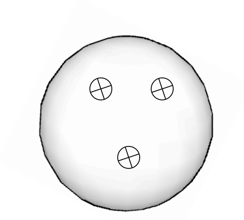

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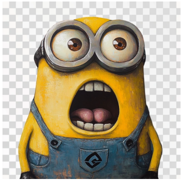

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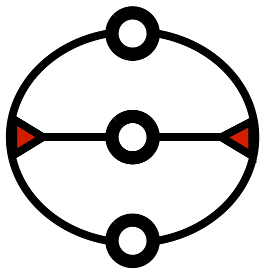

- Idea: think of these punctures as defects.

Defects

- contribution to Weyl anomaly:

$$\langle T^{\mu}{}_{\mu} \rangle \sim a \text{ Euler density} + \text{Weyl}$$

$$+\delta(D)(a_D \text{Euler}_D + \text{ second fund. form} + \text{Weyl})$$

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- in a holographic CFT:

on-shell action of B $\Rightarrow$ a_D

power-divergent terms removed by counterterms;

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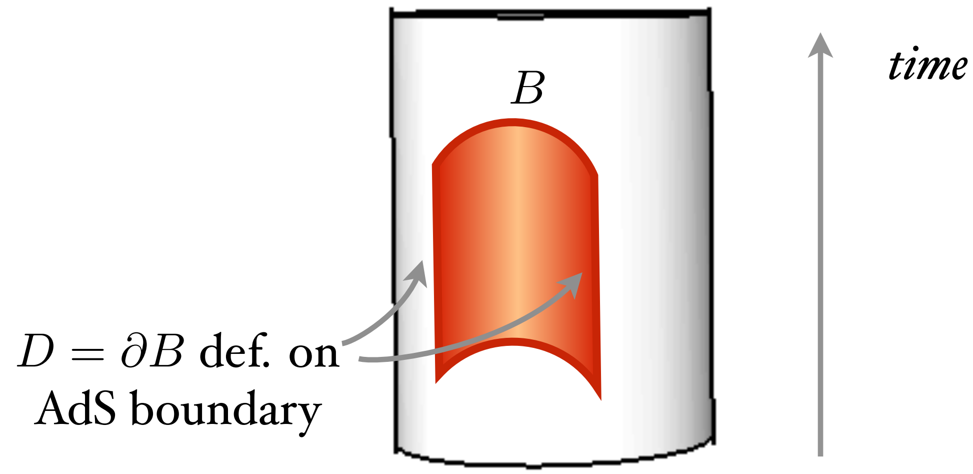

[Graham, Witten '99...]

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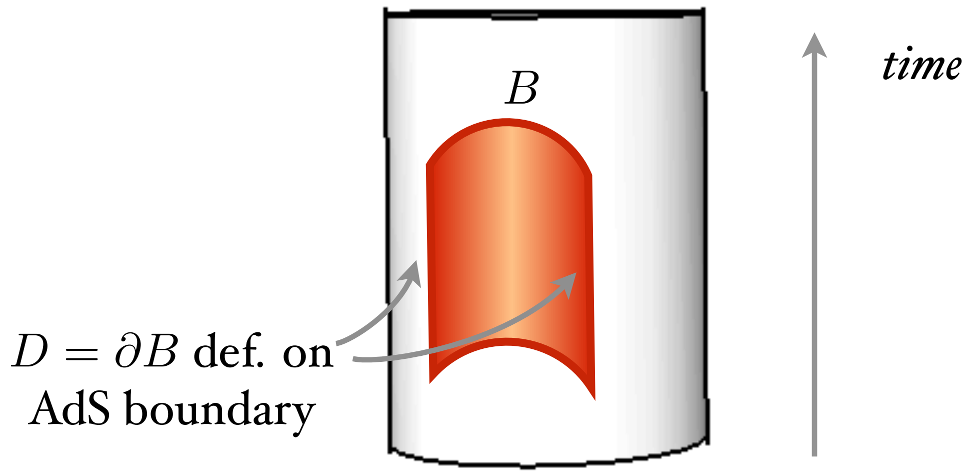

[Graham, Witten '99...]

- We studied defects with codimension 4 and 2 [Apruzzi, Mekareeya, Robinson, AT '24, '25]

- Today let's focus on codimension 2 defects

  [Apruzzi, Mekareeya, Robinson, AT '25]

cod. 2 defect

two possibilities:

	0	1	2	3	4	5	6	7	8	9
NS5	×	×	×	×	×	×	–	–	–	–
D6	×	×	×	×	×	×	×	–	–	–
D8	×	×	×	×	×	×	–	×	×	×
def. D4	×	–	–	×	×	×	–	–	–	×
def. D6	×	–	–	×	×	×	×	×	×	–

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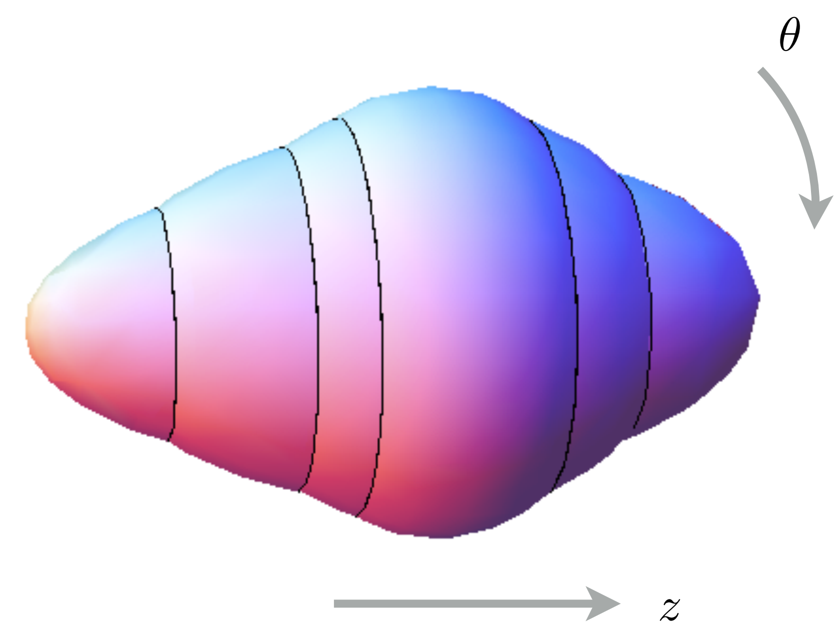

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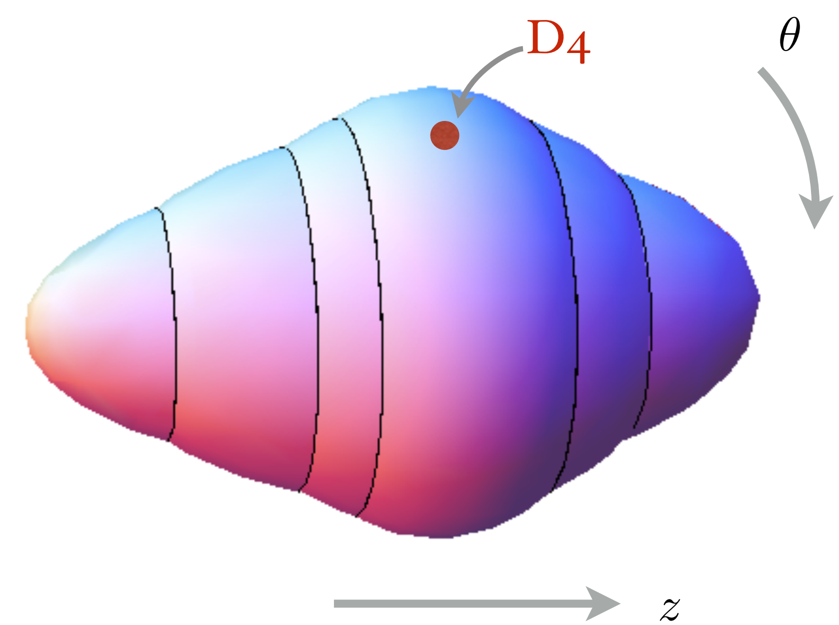
evaluating on-shell action:

$$a_D = \frac{4}{81\pi^2}\alpha_{\max}$$



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D6/D4: $\mathrm{AdS}_5 \times M_2 \subset \mathrm{AdS}_7 \times M_3$

universal shape: $\alpha(z) = \frac{\mathrm{const.}}{\cos\theta}$

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$$a_D = \frac{4}{81\pi^2}\alpha_{\max}$$

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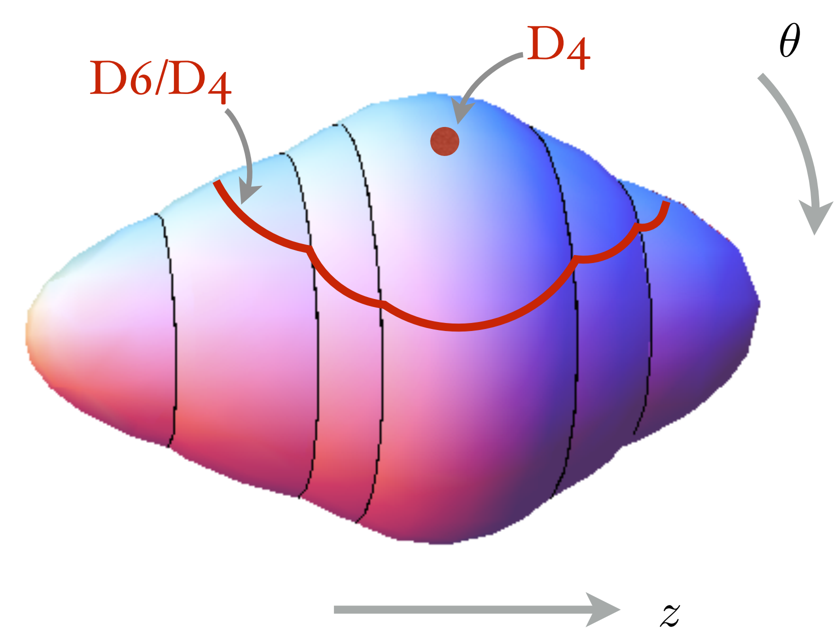

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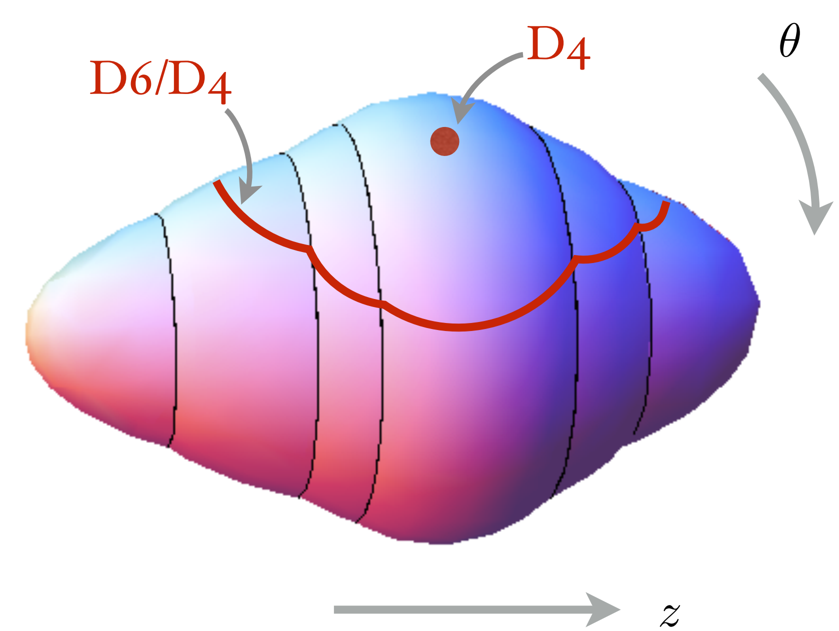
- Similar results for $AdS_5 \times \Sigma_g$. Universal relation:

$$a_D^{AdS_5} = \frac{27}{64} a_D^{AdS_7}$$

Can be explained by comparing symmetry generators;

similar to $27/32$ in [Tachikawa, Wecht '09]



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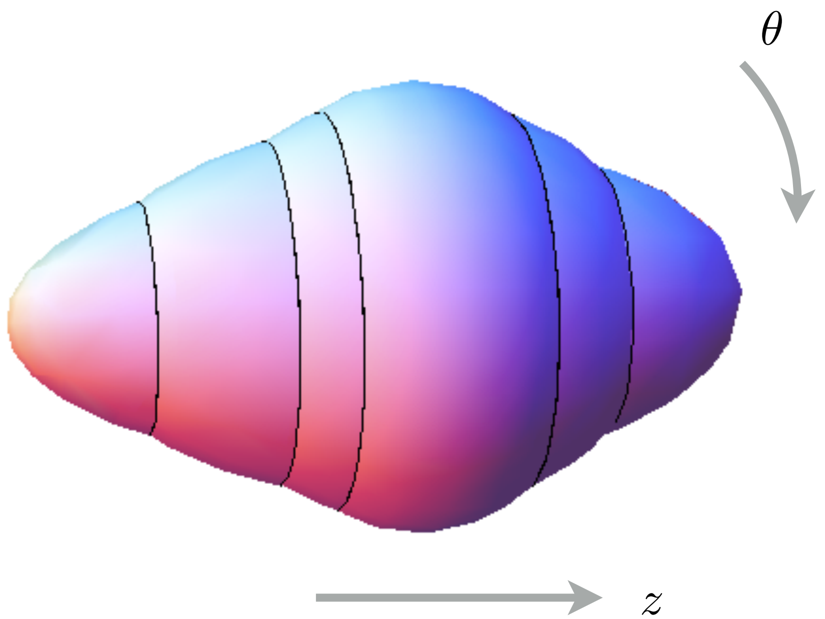

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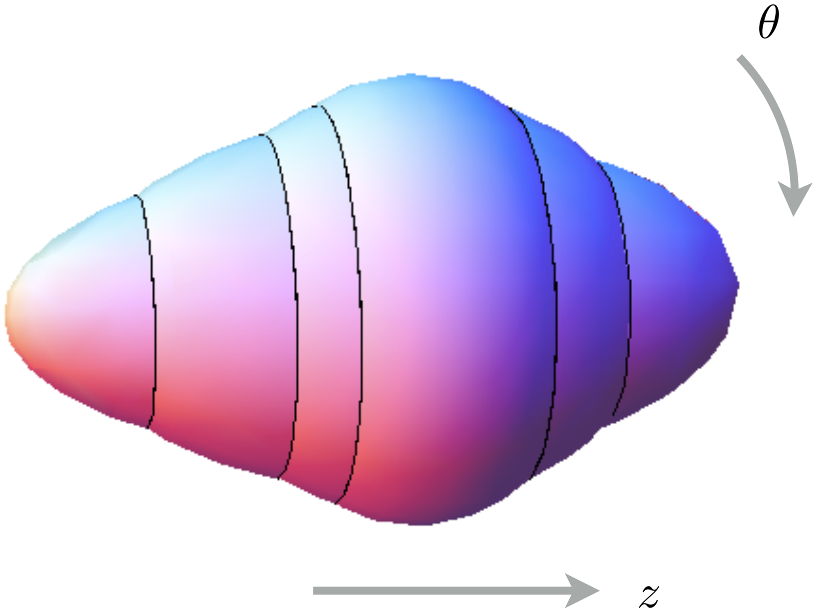
$\int_{\Sigma_g}$ ⇨ $a_{4\mathrm{d}} = (2g-2)a_{6\mathrm{d}} + \sum_i a_{D_i}$ as in class S.



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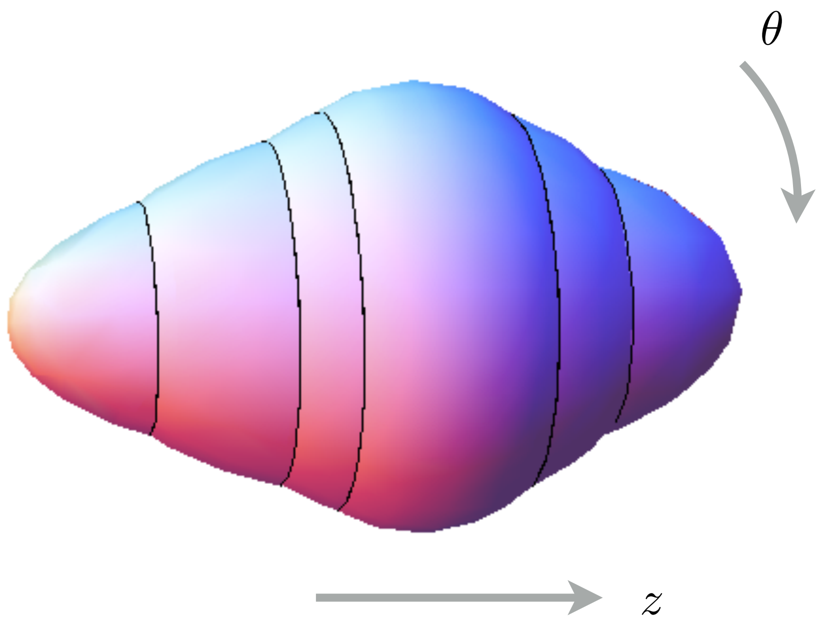

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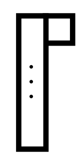
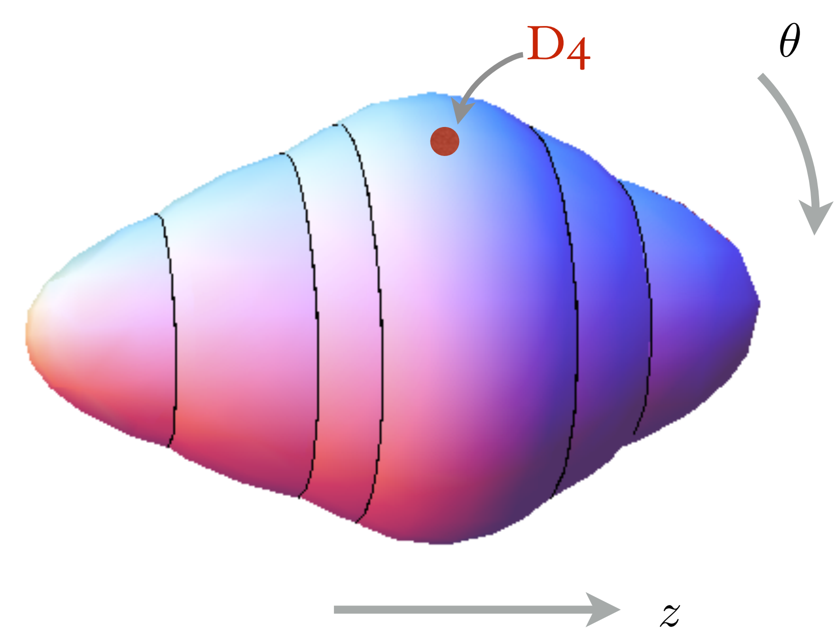
- simple puncture $[N-1,1]$  $a_D = \frac{27}{32}\frac{N^2}{4}$ ✓

[Tachikawa, Wecht '09]



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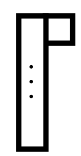
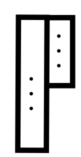
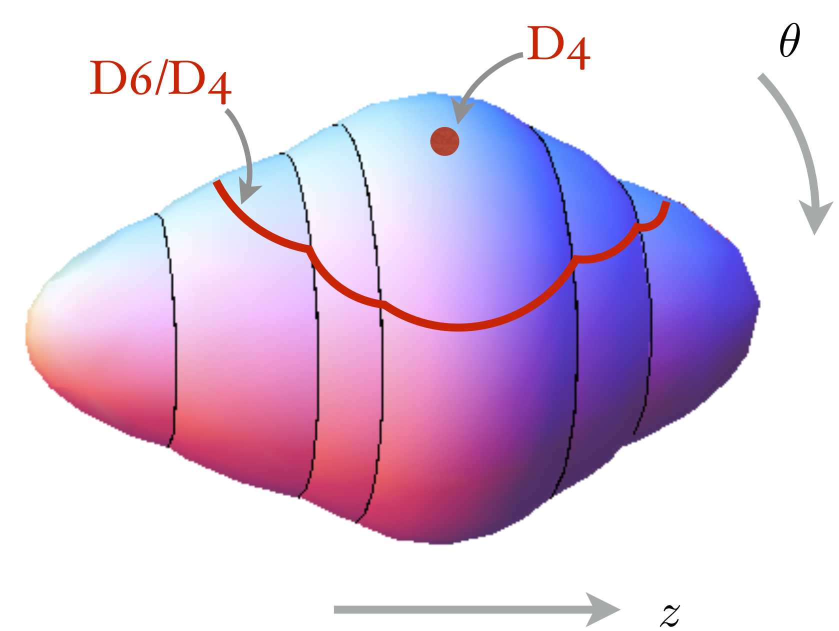
- simple puncture $[N-1,1]$  $a_D = \frac{27}{32}\frac{N^2}{4}$ ✓ [Tachikawa, Wecht '09]
- more general: $[N-w,w]$  $a_D = \frac{27}{32} w\left(\frac{N^2}{4} - \frac{w^2}{3}\right)$ ✓



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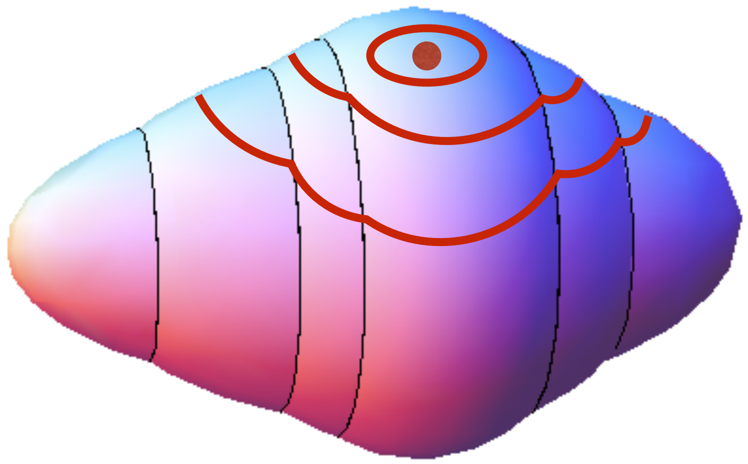

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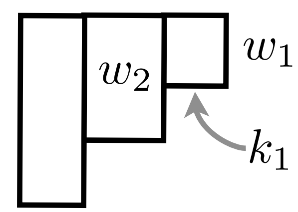


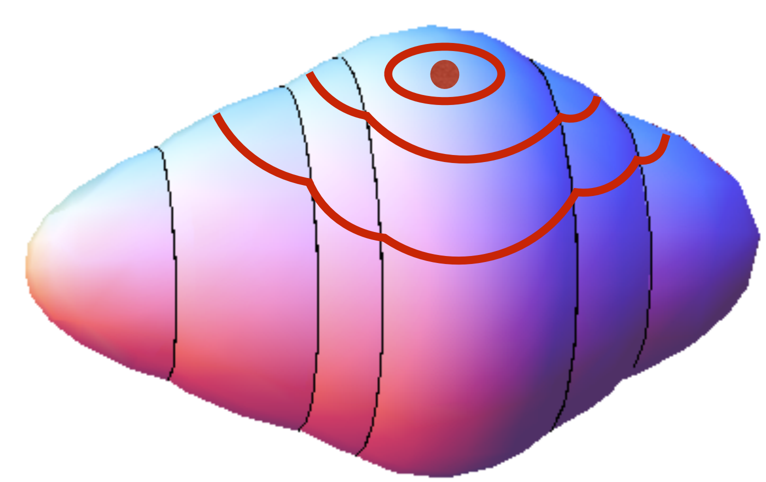
w_a = column heights = M5 charges

k_a = jumps = $\mathbb{Z}_{k_a}$

$$a_D = \frac{1}{48}N(8N^2-3) - \frac{1}{4}\sum_{a=1}^{p}\left(N k_a\left(w_a^2 - \frac{1}{4}\right) - \frac{w_a^3 k_a^2}{3} + \sum_{b=a+1}^{p} k_a k_b\left(\frac{w_a^3}{3} - w_a^2 w_b - \frac{w_a - w_b}{4}\right)\right)$$

for more complicated punctures, nonlinear interactions

$\Rightarrow$ probe approximation fails.



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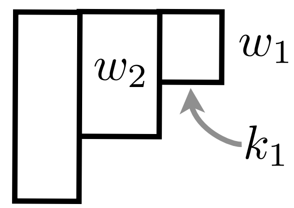

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for more complicated punctures, nonlinear interactions

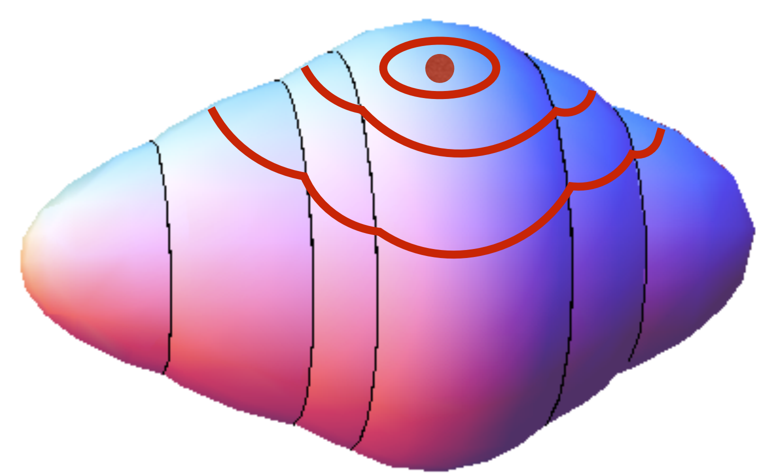
⇨ probe approximation fails.

- A more precise computation might be possible along the lines of M-theory

[Bah, Bonetti, Minasian, Nardoni '19]

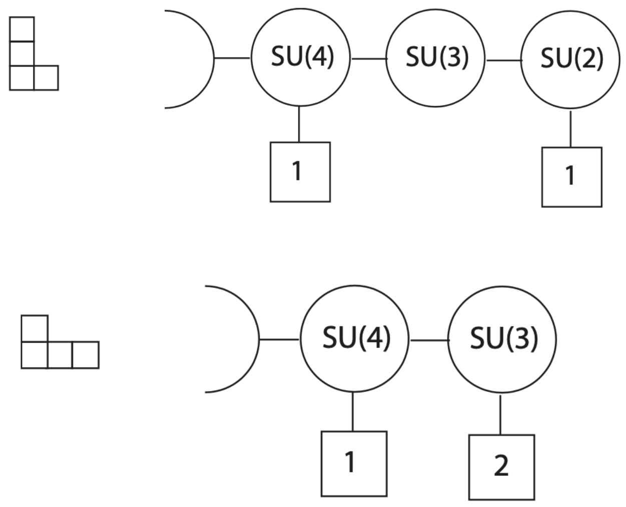
- Backreacted punctures?
  one solution exists

[Bah, Passias, AT '17]



- In class S, punctures also give rise to *quiver tails*

[Gaiotto '09]



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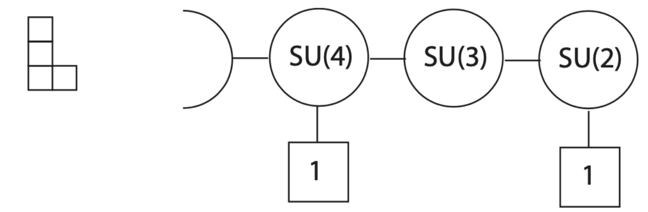
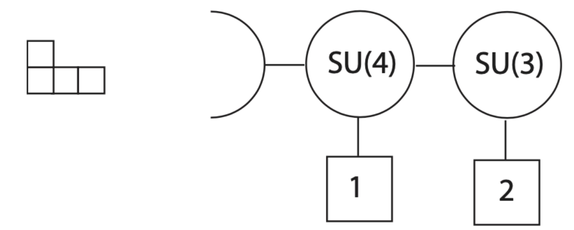
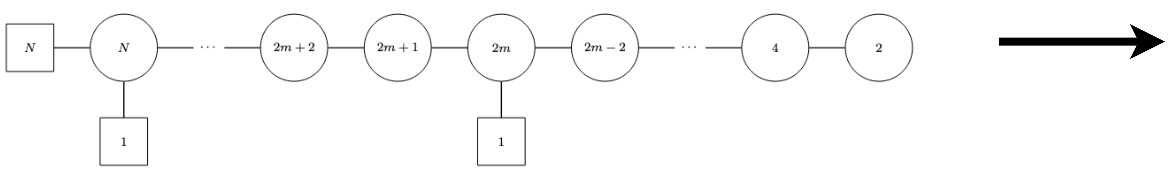


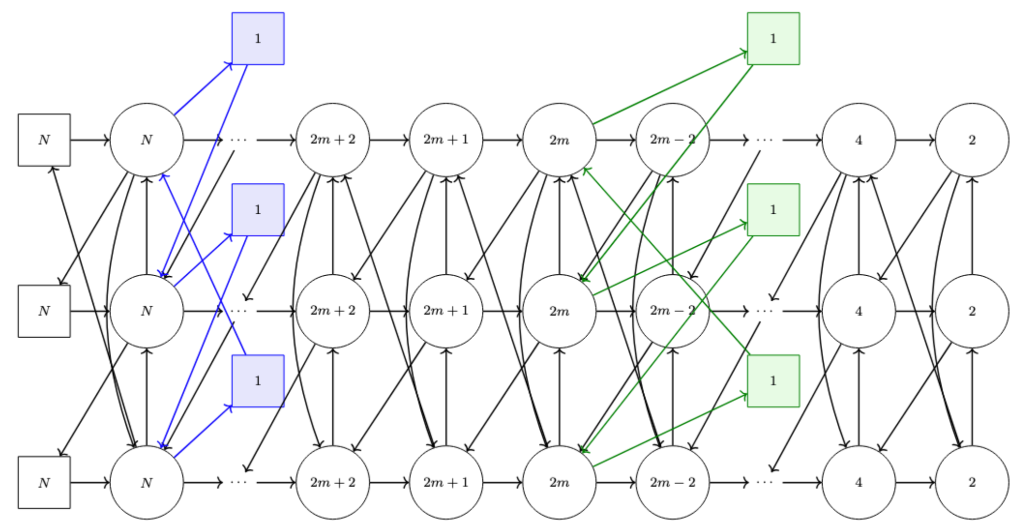


- Relatively unexplored already in class S_k

[Gaiotto, Razamat '15; Heckman, Jefferson, Rudelius, Vafa '16]

simplest possibility: orbifold each gauge group





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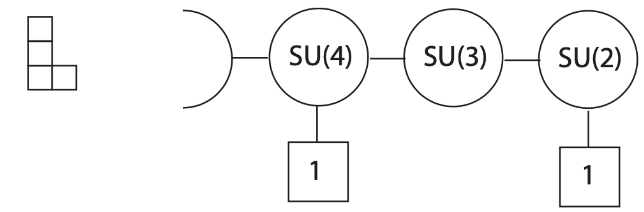

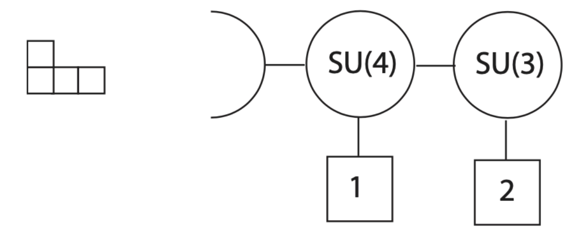

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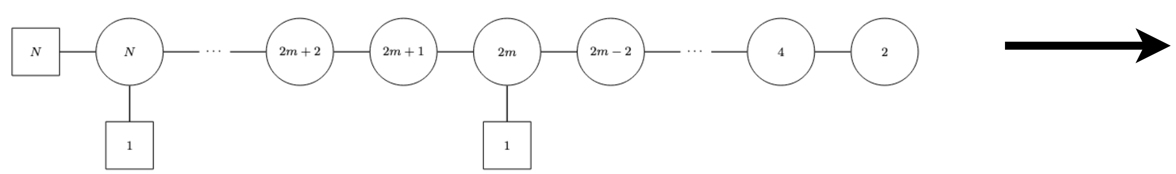

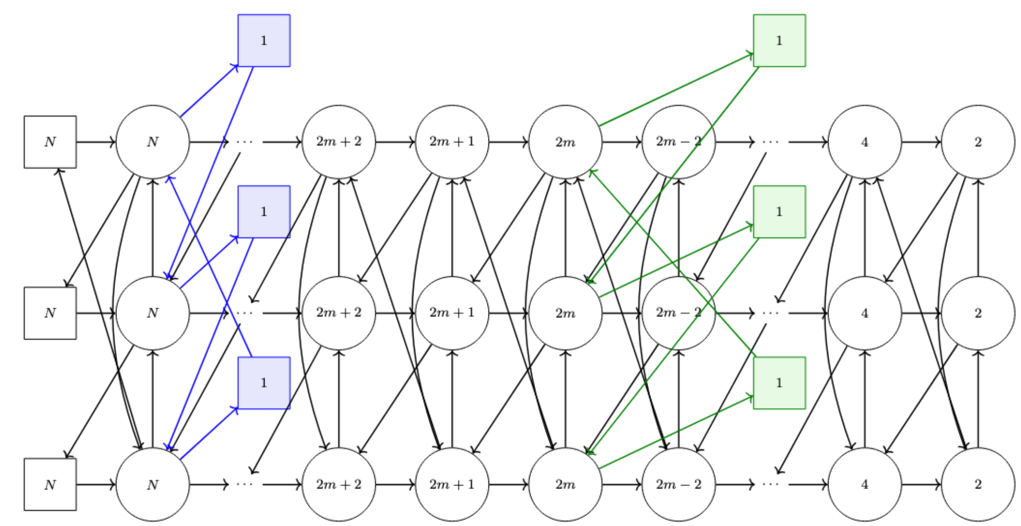

- Possible general idea: Hitchin equation with two Higgs fields

[one for D6/D8, one for puncture]

[Heckman, Jefferson, Rudelius, Vafa '16]

Conclusions

- Analogues of class S expected for every $\mathcal{N} = (1,0)$ 6d SCFT
  - Key ingredient: punctures
- Some progress in holographic theories, viewing punctures as defects:
  - Expected punctures, anomaly contribution
  - A small step towards establishing a massive class S.
- Similar techniques applicable to compactifications from $d \neq 6$