Holographic duals of Argyres Douglas Theories

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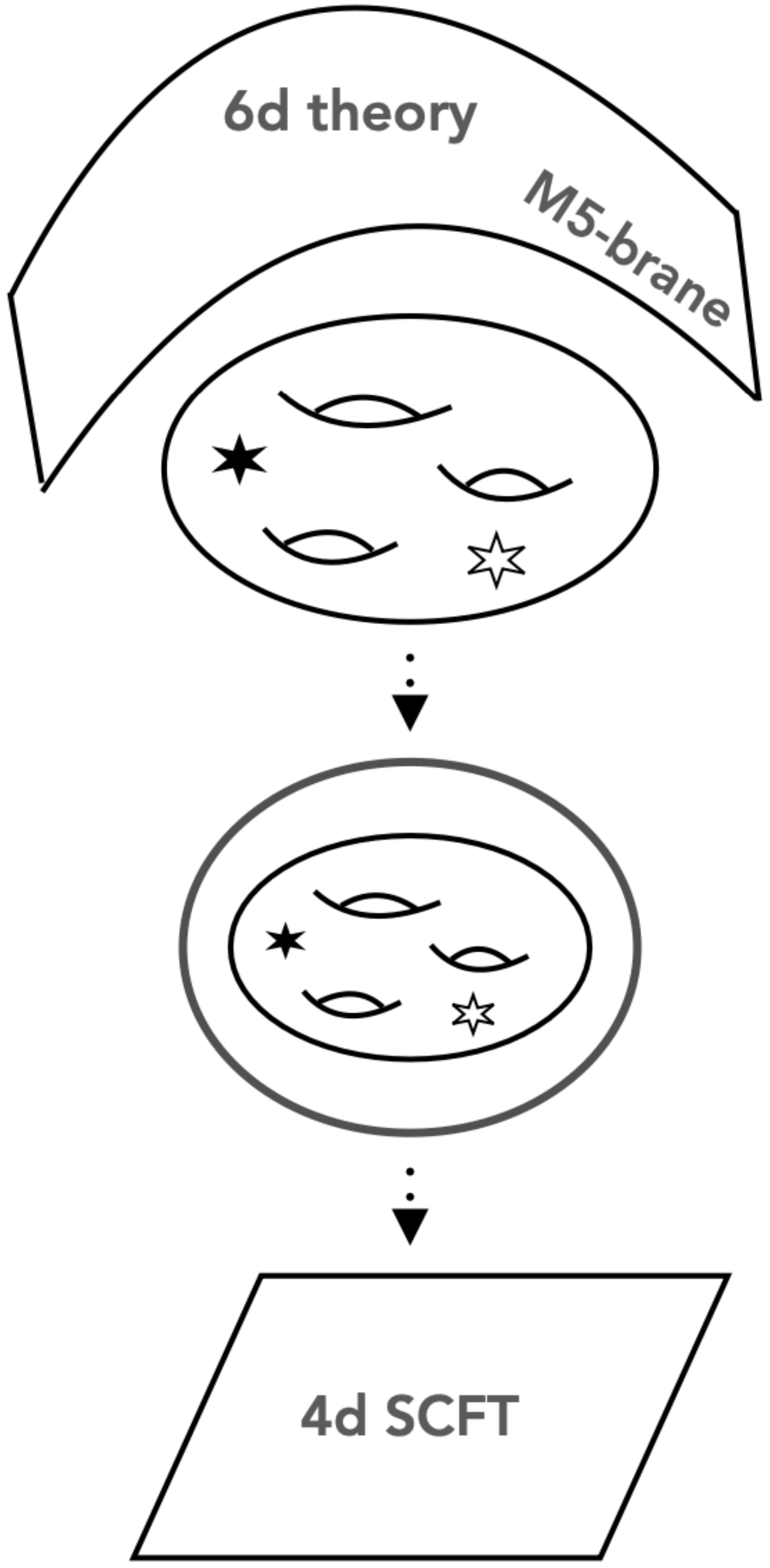
Motivation

- Recent interest in spindles and discs.
- Horizons of black objects which are not constant curvature.
- Admit singularities: conical singularities or worse.
- Despite this give sensible observables.
- Solutions should be the holographic duals of SCFTs compactified on these spaces.
- Can we identify these SCFTs?
- For M5-branes on a disc we can!

Field theory review

Theories of class S

- 6d $\mathcal{N} = (2,0)$ SCFT of type $\mathfrak{j}$ (simple, simply laced Lie Alg).
- Wrap on a Riemann surface Σ of genus g with n punctures, plus outer automorphism o twist lines.
- *Flows to a 4d $\mathcal{N} = 2$ SCFT.
- Theory labelled by $(\mathfrak{j}, \Sigma, n, o)$.
- Punctures correspond to defect M5-branes.
- Known examples: T_N theory, Argyres—Douglas theories, Carlos's talk +....



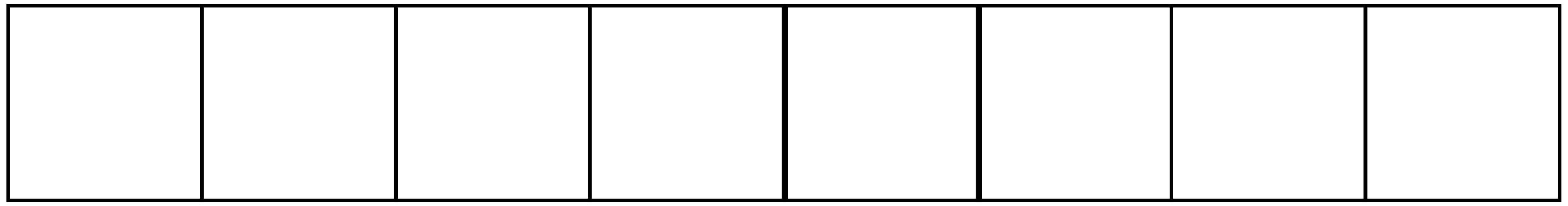
Argyres—Douglas Theories

- Argyres—Douglas theories are special $4d$ $\mathcal{N} = 2$ SCFTs.
- They have Coulomb branch operators of fractional dimension.
- Can be realised, for example, using geometric engineering in type IIB or in class S.
- In class S realised by compactification on a twice punctured sphere: 1 irregular (and 1 regular) puncture [Xie].
- Types of punctures classified by poles of a solution of the Hitchin system (Φ, A):

Regular: $\Phi(z) \sim \dfrac{T}{z}$: described by a Young diagram (in this talk)

Irregular: $\Phi(z) \sim \dfrac{T}{z^{2+r}}, \quad r = \dfrac{k}{N} > -1$

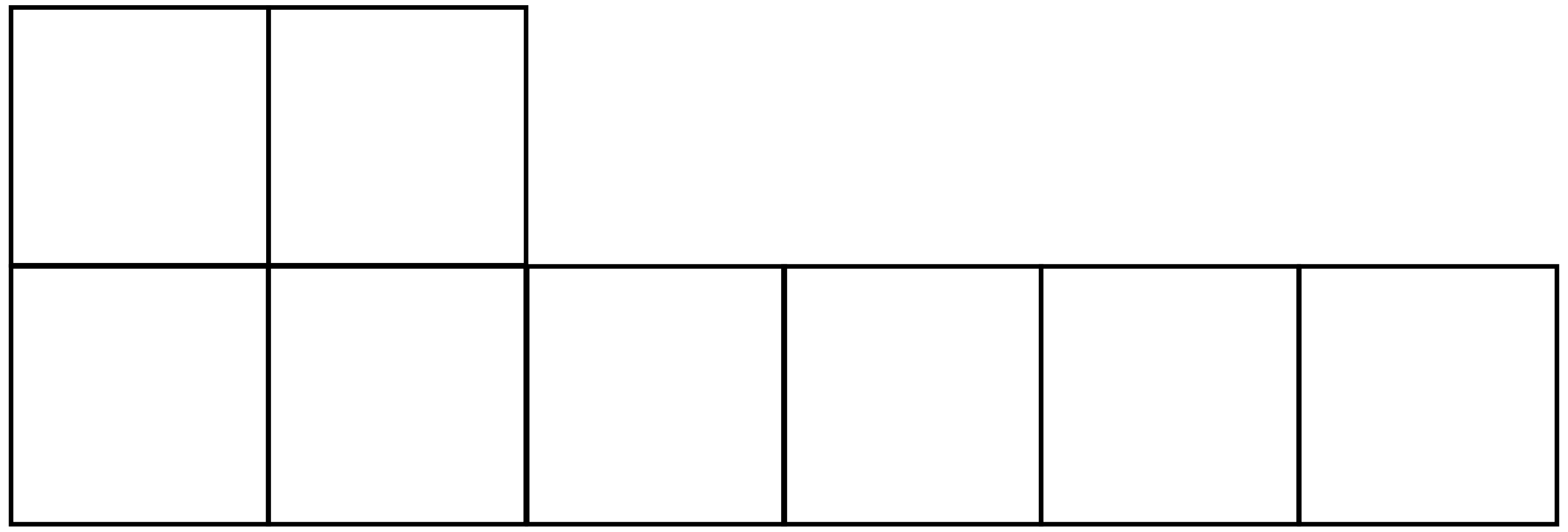
$D_p(ABCD)$ theories



$[1^8]$

- The $D_p(ABCD)$ theories arise from compactifcation on punctured sphere with a maximal puncture.
- ABCD label the algebra $\mathfrak{j}$ and the outer-automorphism twist.
- Theory has a flavour symmetry, one of: $\mathrm{SU}(N), \mathrm{SO}(2N+1), \mathrm{USP}(2N), \mathrm{SO}(2N)$.
- Can Higgs the flavour symmetry: breaks the flavour symmetry to smaller subgroups.
- Rules on how this can be broken for BCD.

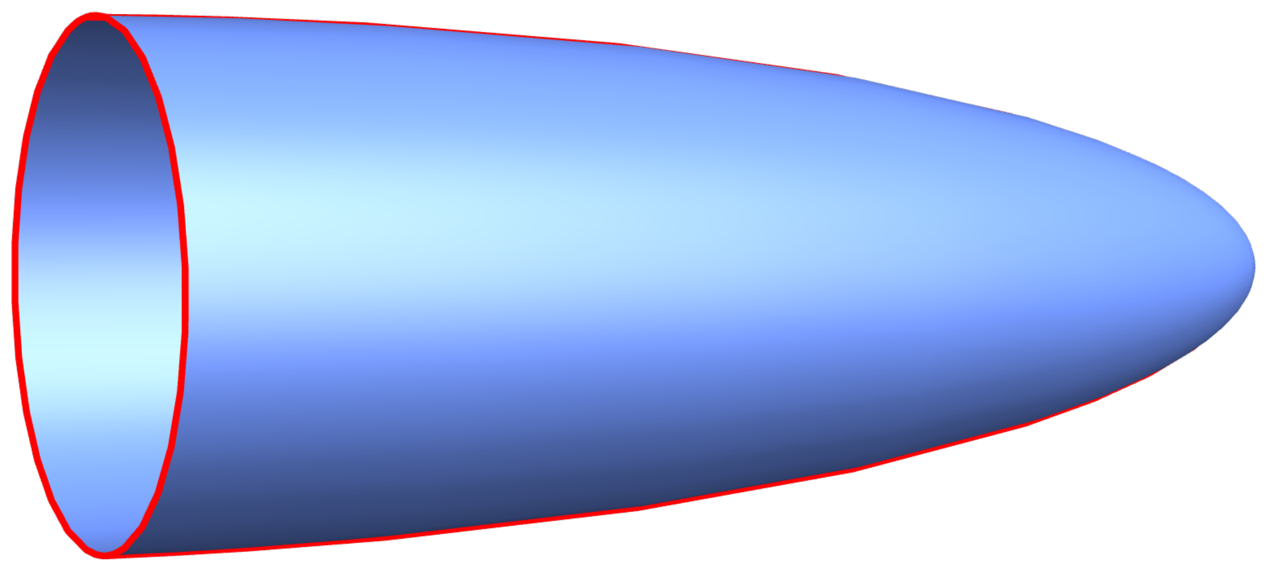
$$\mathrm{SU}(8) \longrightarrow \mathrm{SU}(4) \times \mathrm{SU}(2)$$



$[1^4, 2^2]$

Gravity

Discs in SUGRA



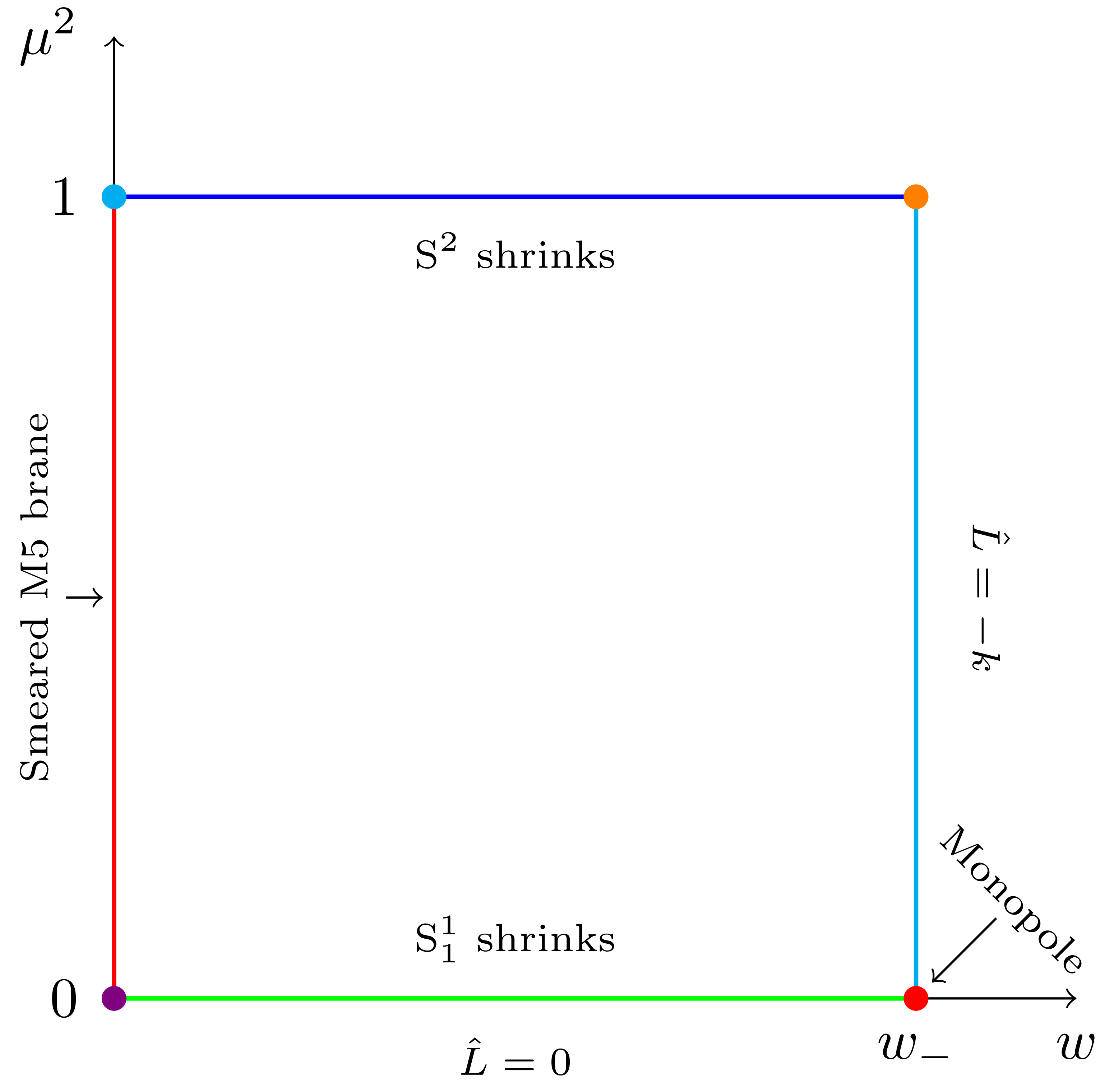
- Take a spindle and cut it in two, ⇒ topological disc.
- There is one end-point which is a $\mathbb{R}^2/\mathbb{Z}_k$ orbifold.
- The other end-point is topologically a cylinder with a boundary.
- Euler character given by

$$\chi = \frac{1}{k} = 2 - \left(1 - \frac{1}{k}\right) - 1$$

- First disc in [Bah, Bonetti, Minasian, Nardoni], many more by: [CC, Macpherson, Passias], [Suh], [CC, Stemerdink, Van de Heisteeg], [Karndumri, Nuchino], [Bah, Bonetti, Nardoni, Waddleton]

BBMN

- Solution is $\mathrm{AdS}_5 \times S^2 \times T^2 \rtimes (L_1 \times L_2)$.
- $\mathbb{R}^2/\mathbb{Z}_k$ point becomes $\mathbb{R}^4/\mathbb{Z}_k$, an $\mathcal{N} = 2$ puncture.
- Disc boundary becomes a smeared M5-brane.
- Solution has (bad) singularities but they are physical.



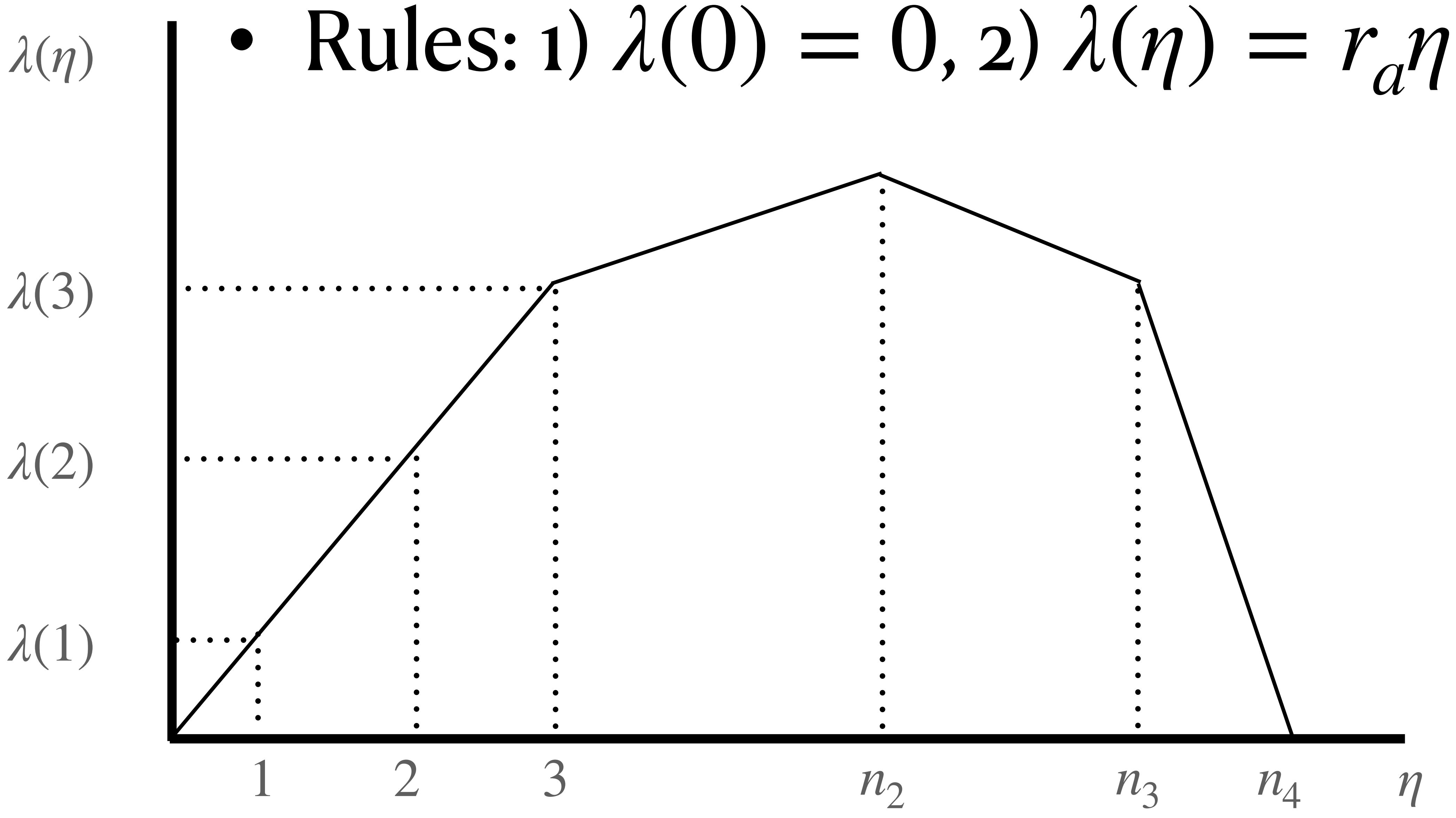
- BBMN conjecture dual to $D_p(A)$ theory with rectangular regular puncture.
- Can this be extended to arbitrary regular puncture, what about BCD?

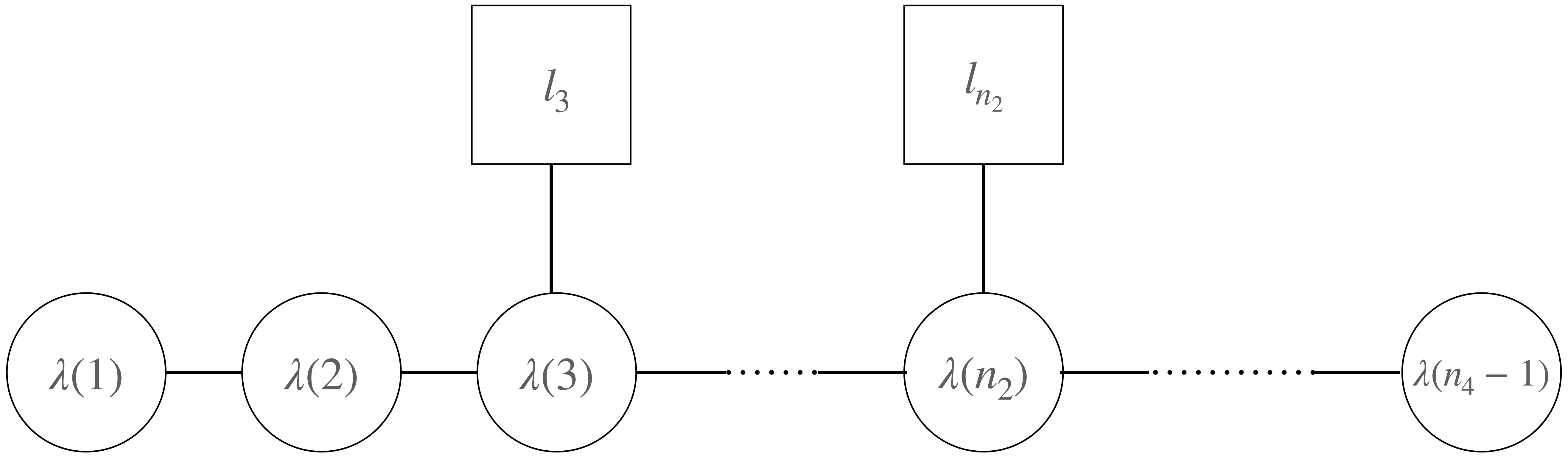
4d N=2 holographic duals

- $\mathcal{N}=2$ AdS$_5$ solutions of M-theory described by an electrostatic problem.

$$\mathrm{d}s^2 = \left(\frac{\dot{V}\tilde{\Delta}}{2V''}\right)^{1/3}\left[4\mathrm{d}s^2(\mathrm{AdS}_5) + \frac{2\dot{V}V''}{\tilde{\Delta}}\mathrm{d}s^2(S^2) + \frac{2V''}{\dot{V}}\left(\mathrm{d}\eta^2 + \mathrm{d}\rho^2 + \frac{2\dot{V}}{2\dot{V}-\ddot{V}}\rho^2\mathrm{d}\phi^2\right) + \frac{2(2\dot{V}-\ddot{V})}{\dot{V}\tilde{\Delta}}\left(\mathrm{d}\chi + \frac{2\dot{V}\dot{V}'}{2\dot{V}-\ddot{V}}\mathrm{d}\phi\right)^2\right]$$

- Depends only on a potential satisfying $\ddot{V} + \rho^2 V'' = 0$.
- Determined by a line charge $\lambda(\eta)$ and some boundary conditions.
- Gaiotto—Maldacena tell us how a line charge gives rise to a quiver.
- Rules: 1) $\lambda(0)=0$, 2) $\lambda(\eta) = r_a\eta + m_a$, $r_a, m_a \in \mathbb{Z}$, 3) $r_{a-1} - r_a = l_a > 0$, 4) $n_a \in \mathbb{Z}$





Electrostatics

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- Can now study the BBMN solution in this frame-work.
- Something odd. GM tell us there is a quiver but AD theory non-Lagrangian.
- Disc solution has $r_a \in \mathbb{Q}$. This is allowed by regularity: no quiver description.

(Related to whether the Torus action is regular or quasi regular: cycle M5's wrap.)

- Through the rewriting obtain a building block potential V.
- Laplace equation linear: take linear combinations.
- Use this to generate arbitrary regular puncture.

$D_p(A)$ with Higgsed Flavour symmetry

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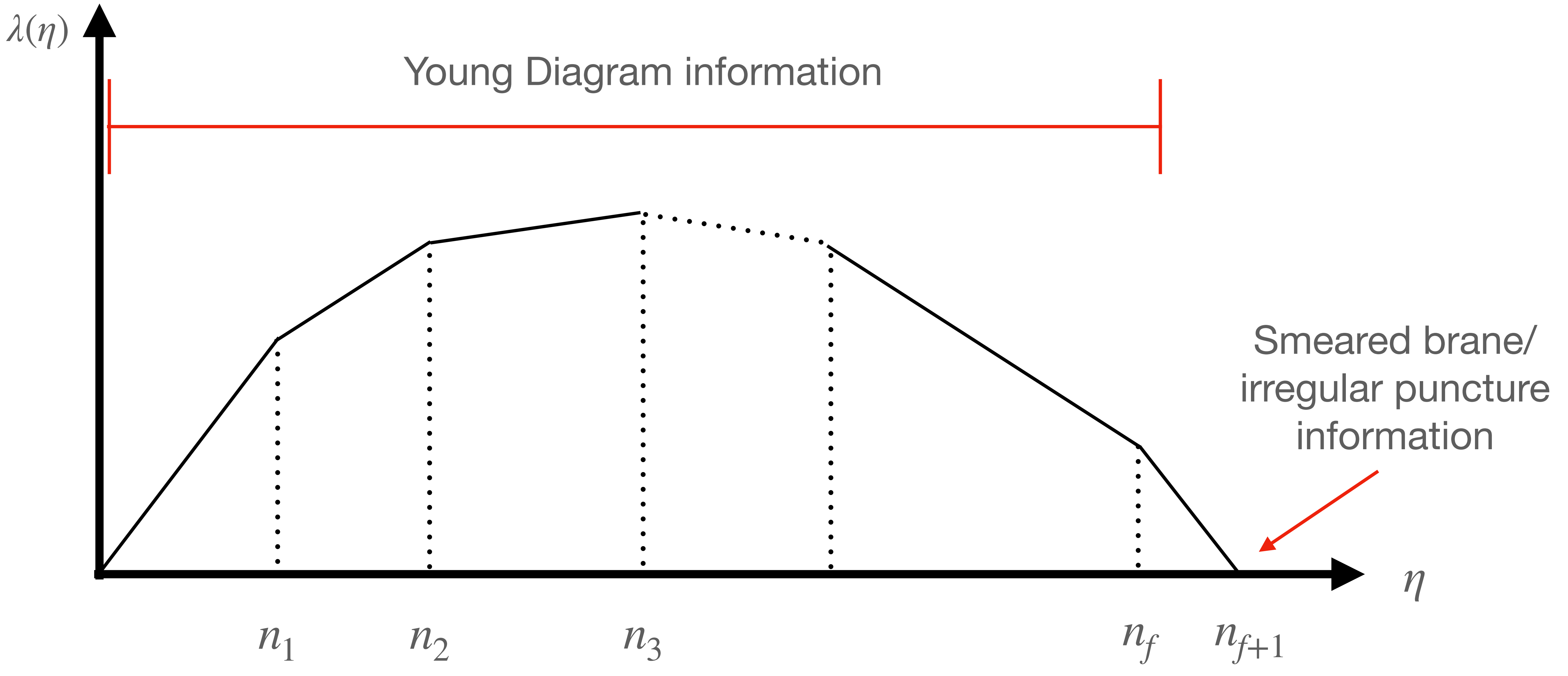
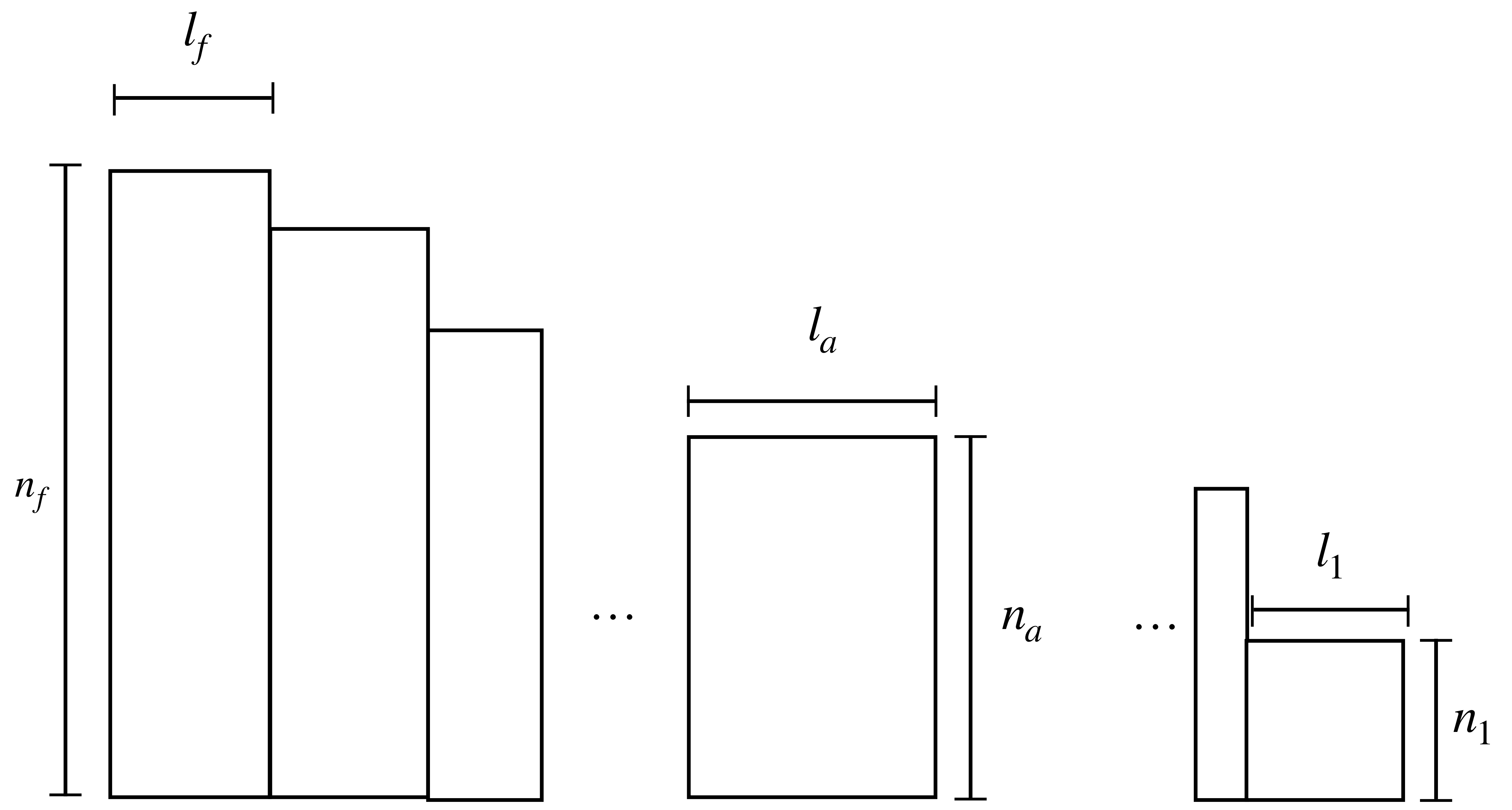
- Location of kinks $\longrightarrow$ height of Young diagram box.
- Change in slope $\longrightarrow$ width of Young diagram box~ flavour symmetry.
- Location of 0-intercept $\longrightarrow$ Irregular puncture data.
- (Flavour) central charges agree for large N.





$D_p(BCD)$ with Higgsed flavour symmetry

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- Can also consider *BCD* partitions.
- Need to introduce orientifold 5-planes: SU → USp/SO. [Nishinaka]
- 4-types of $O5$'s. Differentiated by torsion cycles in geometry.
- Additional constraints on line charge from presence of $O5's$. Leads to the BCD partitions.
- Compute anomalies and find agreement to leading order.

Conclusion and future directions

- Studied holographic duals of Argyres—Douglas theories of class S.
- Explicit duals for (Higgsed) $D_p(ABCD)$ theories.
- Requires modifying conditions of GM: extensions to other types of solutions?
- Can we do something similar for M5-branes on spindles? 4d $\mathcal{N} = 1$ SCFT.
- Disc solutions are more wide-spread. What about $4d\ \mathcal{N} = 4$ SYM, ABJM on a similarly punctured sphere?
- Prefer M5's. What about compactifying these AD theories further on 2d surfaces?
- Higher form symmetries from SUGRA.

Thank you