Fermi Surface Physics in ABJM Theory

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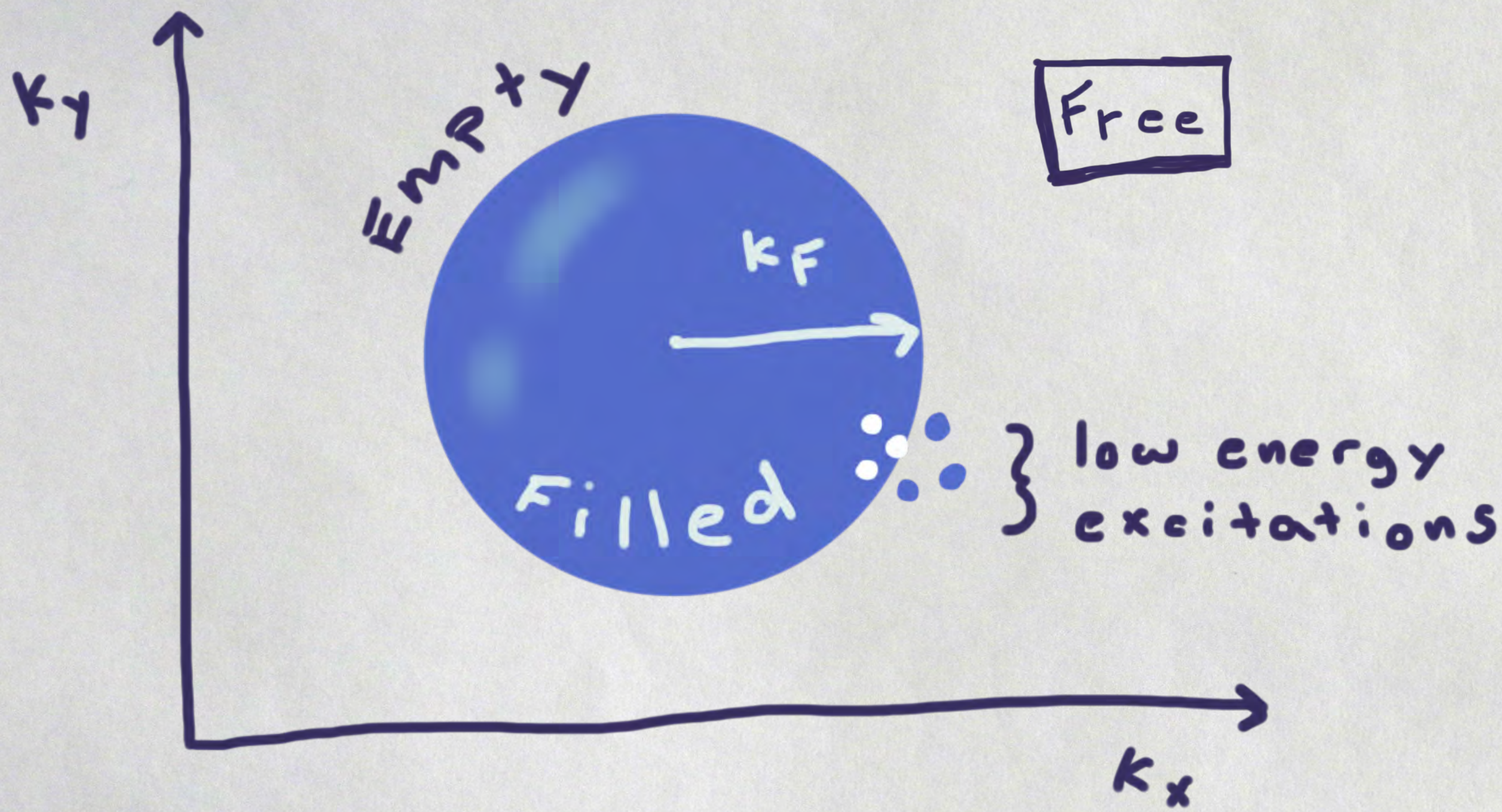
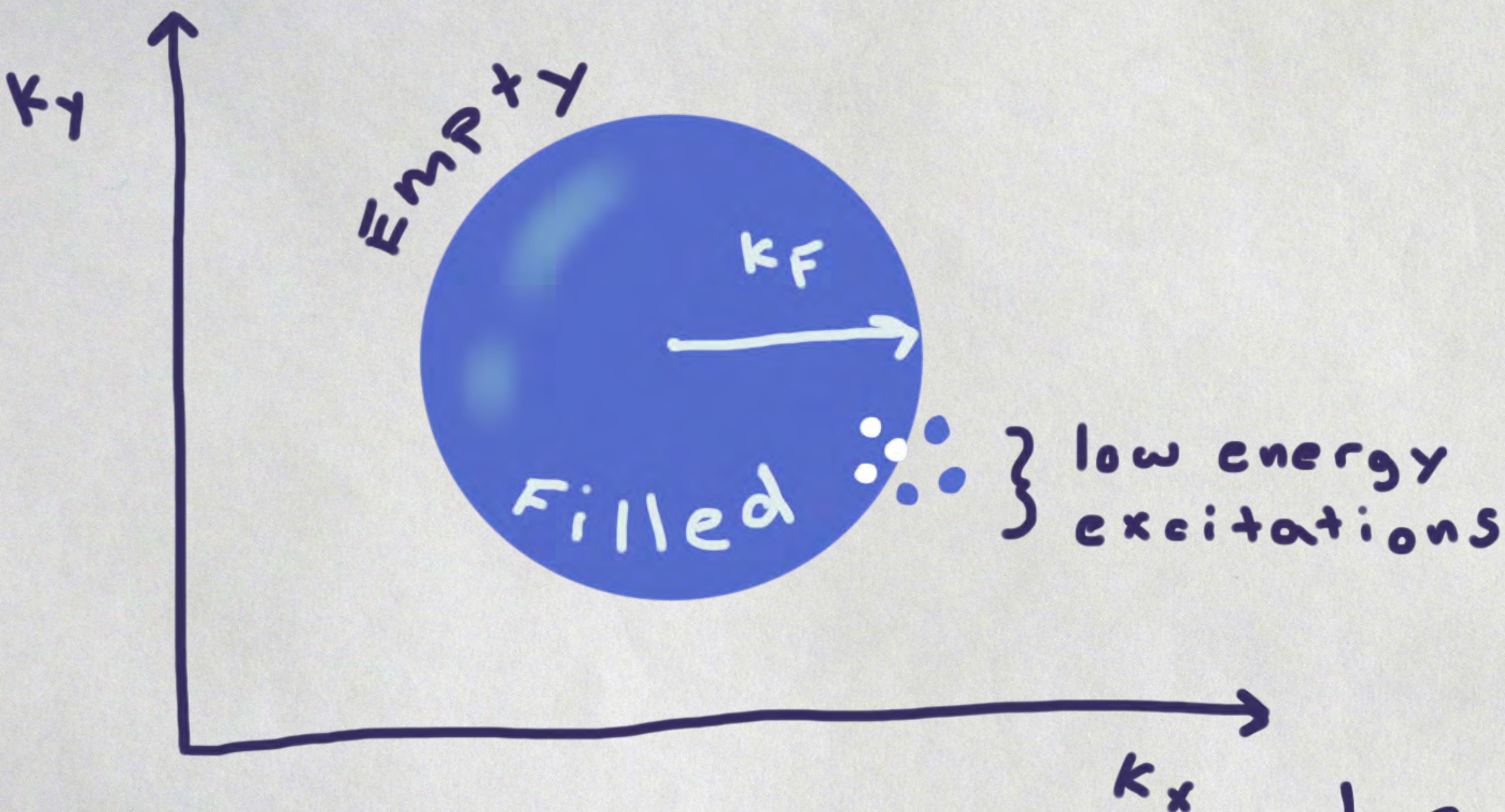
Basics of FS in QFT



Basics of FS in QFT



Landau Says

- Turn on interactions adiabatically
- e's ↔ qp's (= fancy e^-)
- qp's govern transport, etc.

Basics of FS in QFT

Operationally

$$G_R^{\psi} = \frac{Z}{\omega - k_\perp v_F + i\Gamma(\omega^2)}$$

- Z: residue measures "e-ness"
- ω: excitation energy (above μ)
- $k_\perp$: $k - k_F$
- v_F: Fermi velocity
- $\Gamma(\omega^2)$: width

Basics of FS in QFT

Operationally

$$G_R^{\psi} = \frac{Z}{\omega - k_{\perp} v_F + i\,\Gamma(\omega^2)}$$

$$\boxed{\text{FS}: \; G^{-1}(\omega = 0, k = k_F) = 0}$$

Basics of FS in QFT

Operationally

$$G_R^{\psi} = \frac{Z}{\omega - k_\perp v_F + i\,\Gamma(\omega^2)}$$

for $\omega \neq 0$, $\omega \sim v_F k_\perp$ and $\Gamma/\omega \to 0$ @ FS $\Rightarrow$ LFL

Basics of FS in QFT

Operationally

$$G_R^{\psi} = \frac{Z}{\omega - k_\perp v_F + i\Gamma(\omega^2)}$$

(Describes **many** fermion liquids!!)

Basics of FS in QFT

... But not all!

strange metals, etc.

[There Exist NFL's]

$$G_R^{\psi} \sim \frac{Z}{k_\perp + c\, e^{i\gamma_F} \omega^{2\nu}}$$

$\nu < \frac{1}{2}$

Basics of FS in QFT

... But not all!

Strange metals, etc.

[There Exist NFL's]

$$G_R^{\psi} \sim \frac{Z}{k_\perp + c\, e^{i\gamma_F}\omega^{2\nu}}$$

Dispersion: $\omega_* \sim k_\perp^{\frac{1}{2\nu}}$

Residue: $Z \sim k_\perp^{\frac{1}{2\nu}-1} \to 0$ @ FS

Width: $\frac{\Gamma}{\omega_*} \sim \tan\frac{\gamma_F}{2\nu}$ = constant

Questions

1. Can we study novel aspects of Fermi Surfaces in AdS/CFT?

2. Can we do this in $\mathcal{N}=4$ or ABJM?

3. What happens??

Questions

1. Can we study novel aspects of Fermi Surfaces in AdS/CFT?

   [0907.2694]

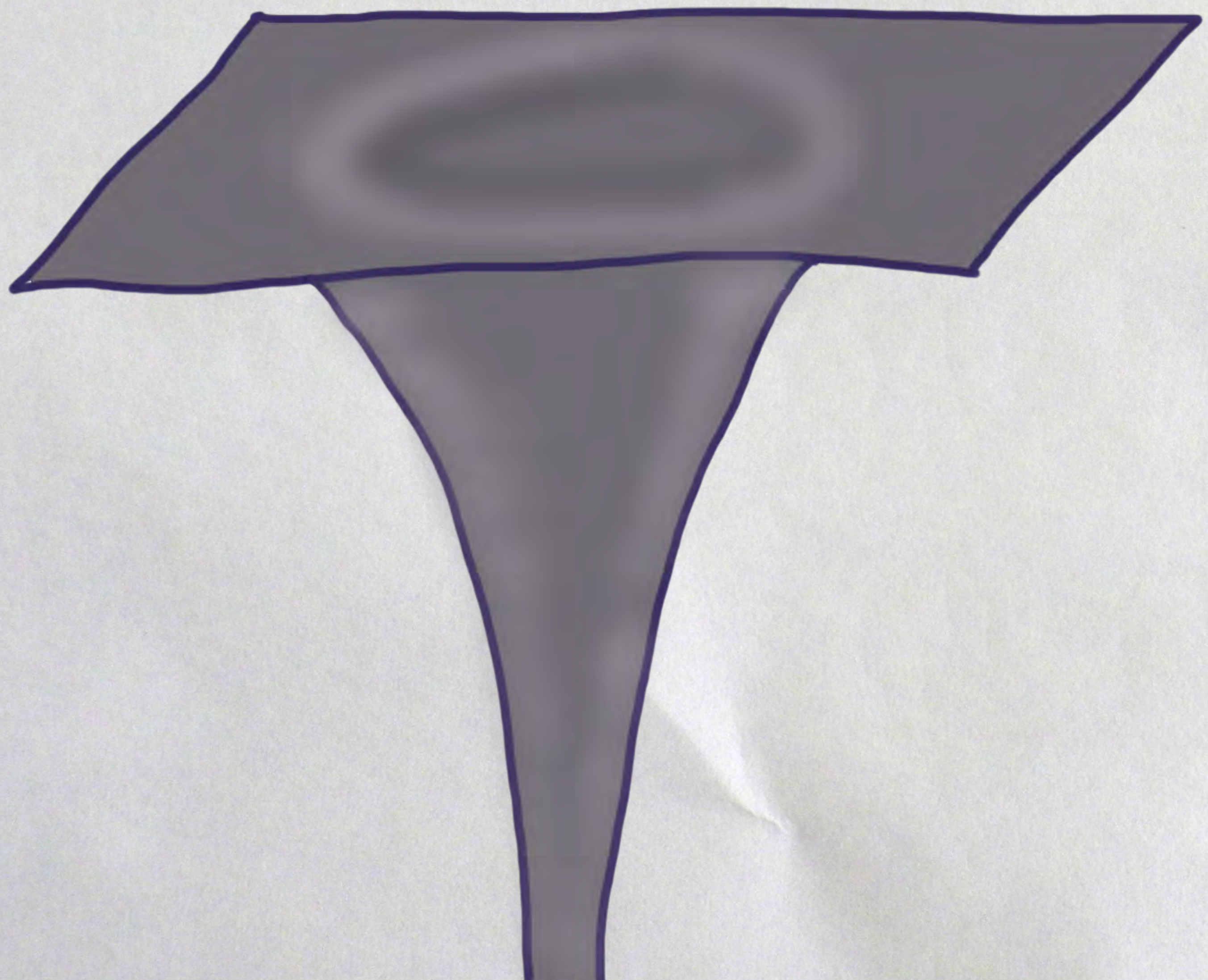
2. Can we do this in $\mathcal{N}=4$ or ABJM?

   [1112.3036]

3. What happens??

   [1207.3352] [1312.7347] [NOW]

FS in AdS/CFT

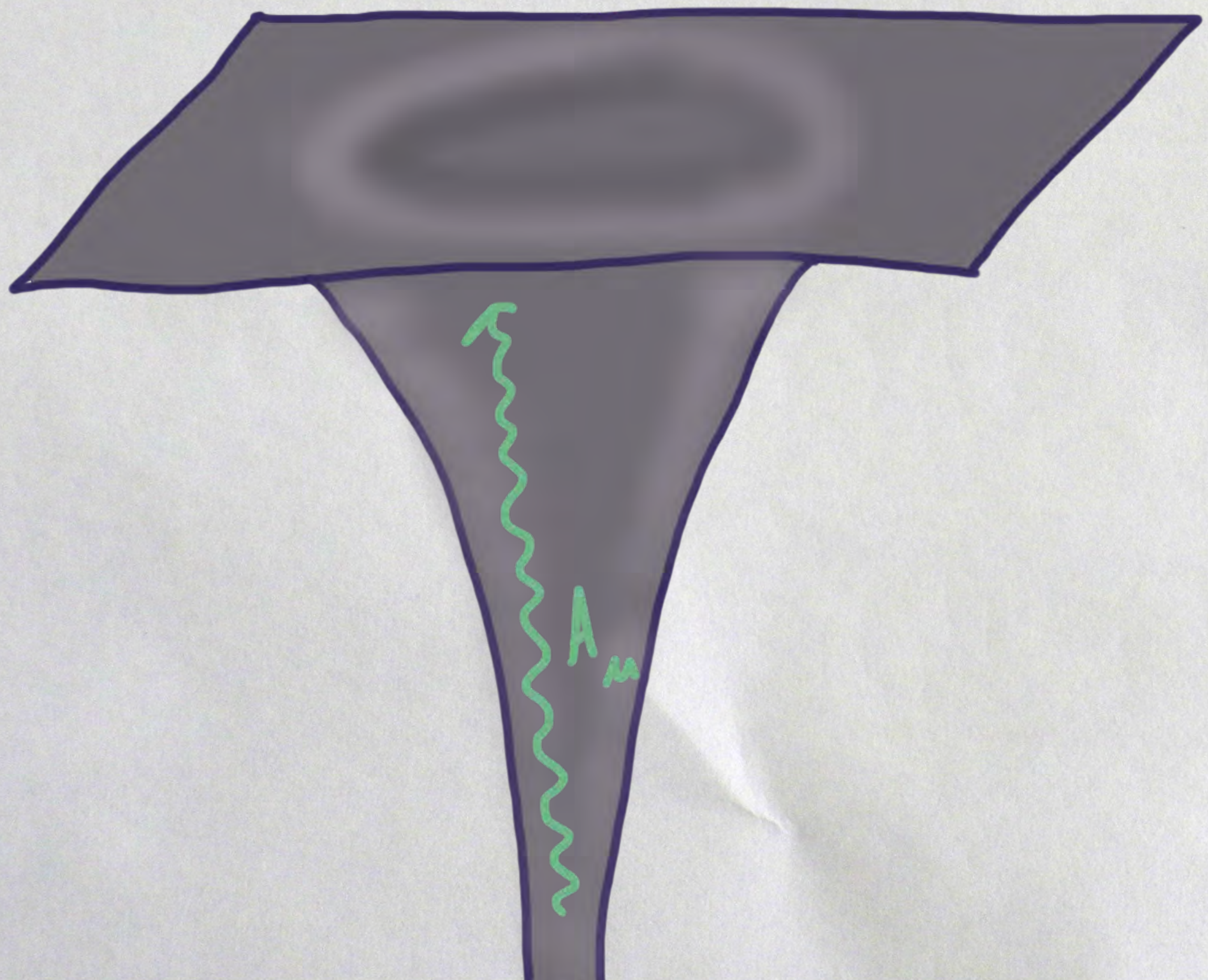


The minimal ingredients
(a probe fermion approach)

1 Extremal black brane

(Zero Temperature)

FS in AdS/CFT



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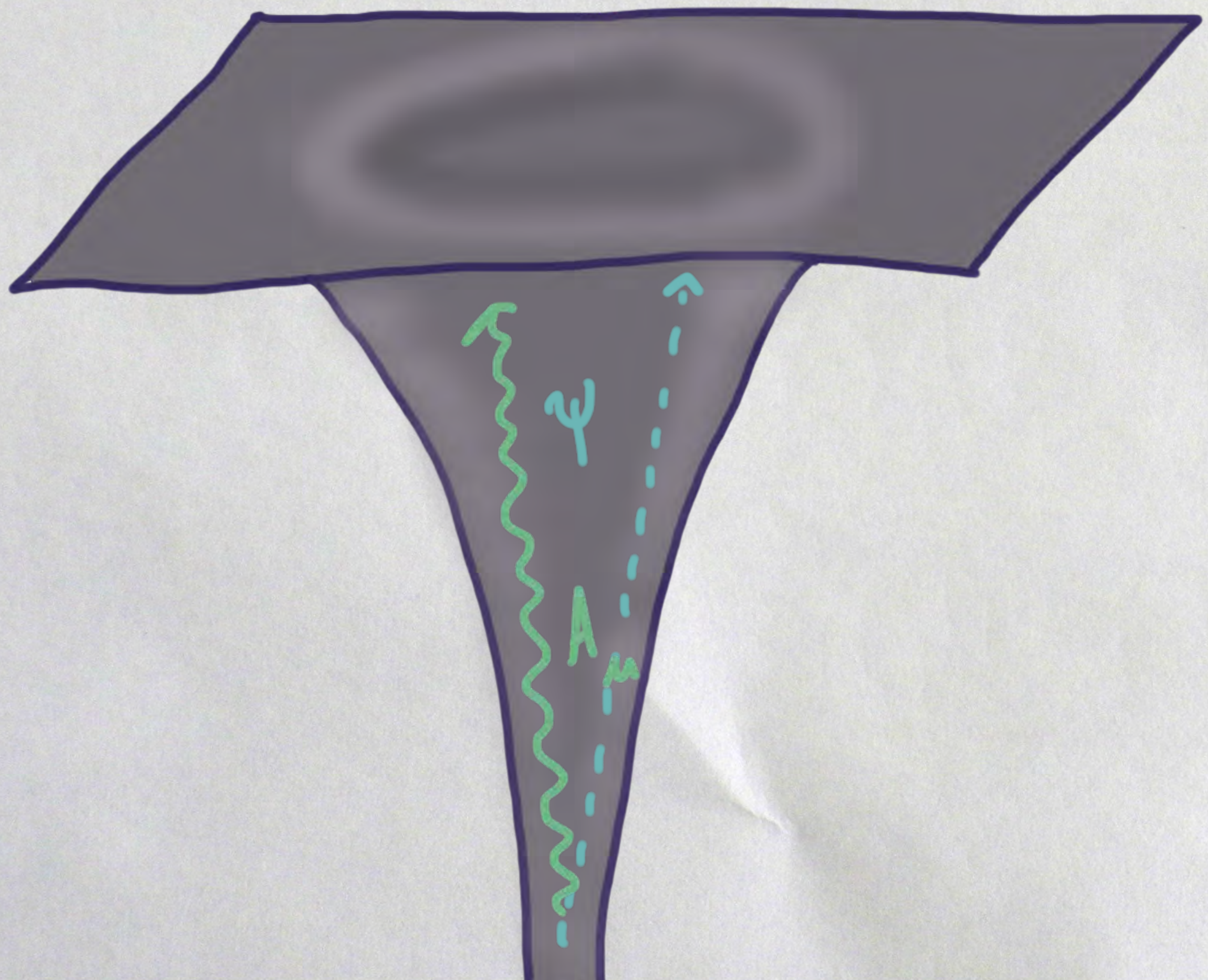
1-2 U(1) Gauge fields
(Finite Density)

FS in AdS/CFT



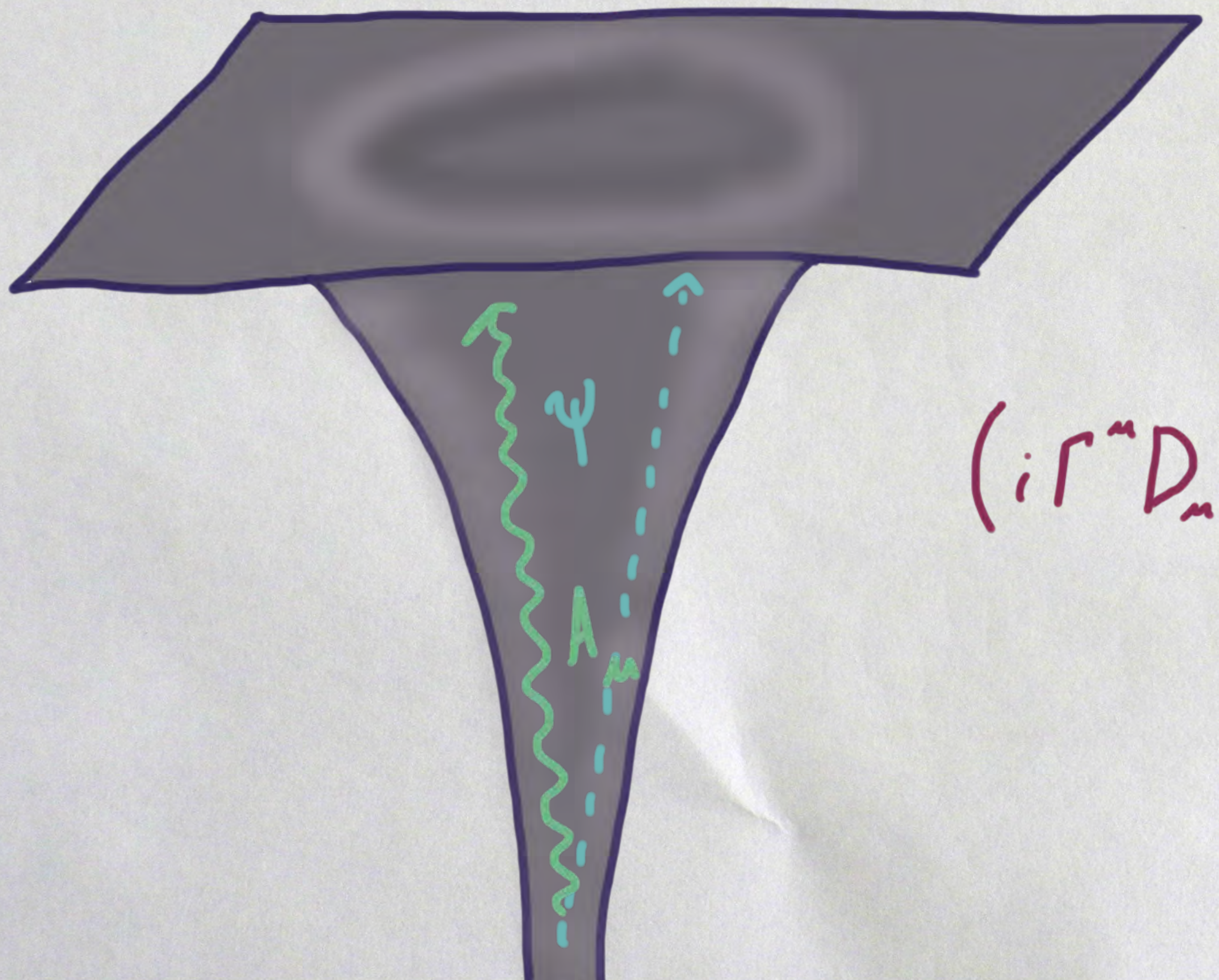
The minimal ingredients
(a probe fermion approach)

1 Extremal black brane
(Zero Temperature)

1-2 U(1) Gauge fields
(Finite Density)

1 Bulk fermion
(Fermionic Operator)

FS in AdS/CFT



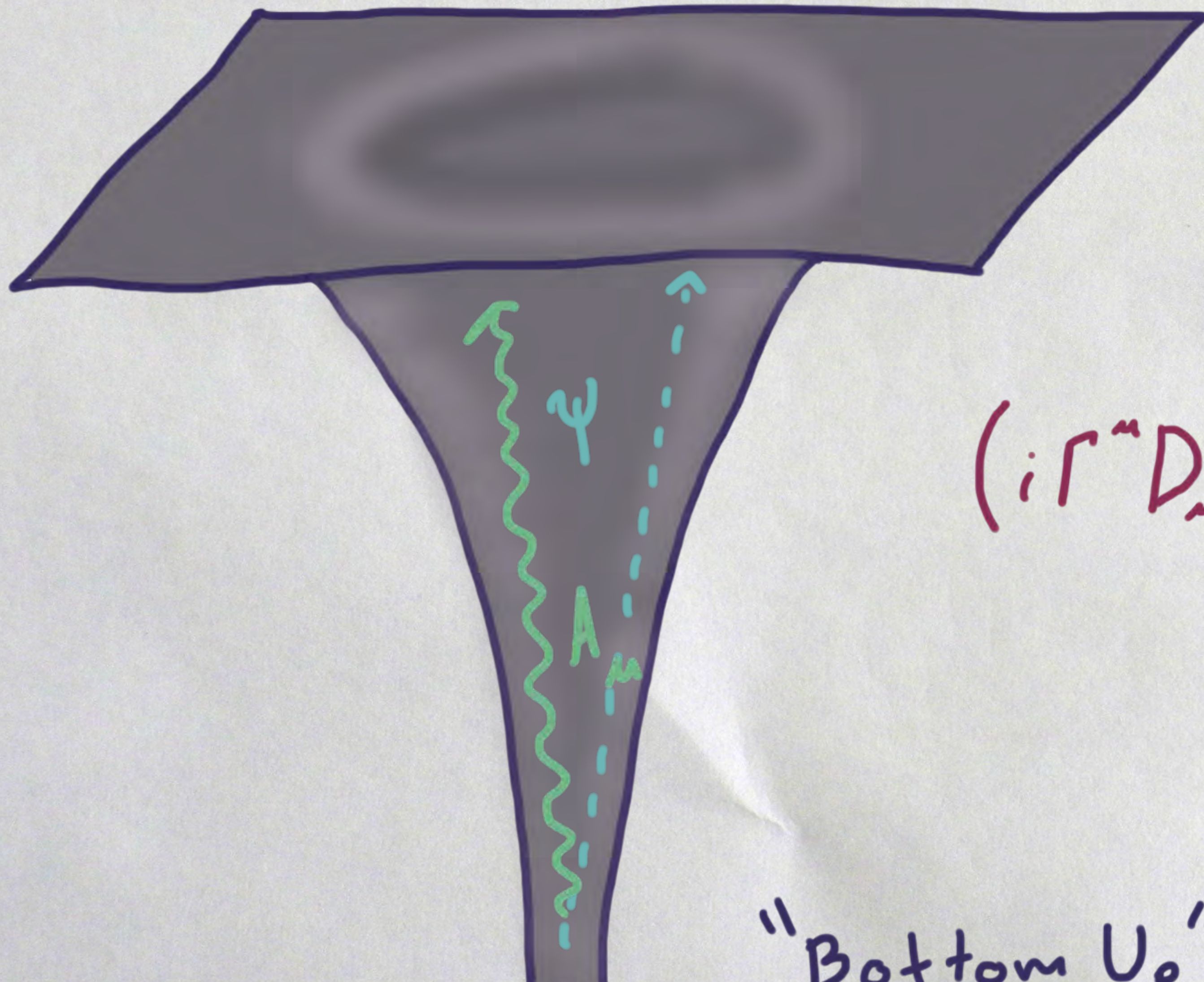
The minimal ingredients
(a probe fermion approach)

The fermionic sector is described by a Dirac equation, like

$$\left(i\Gamma^\mu D_\mu + q\Gamma^\mu A_\mu - m + \ldots\right)\psi = 0$$

FS in AdS/CFT

The minimal ingredients
(a probe fermion approach)



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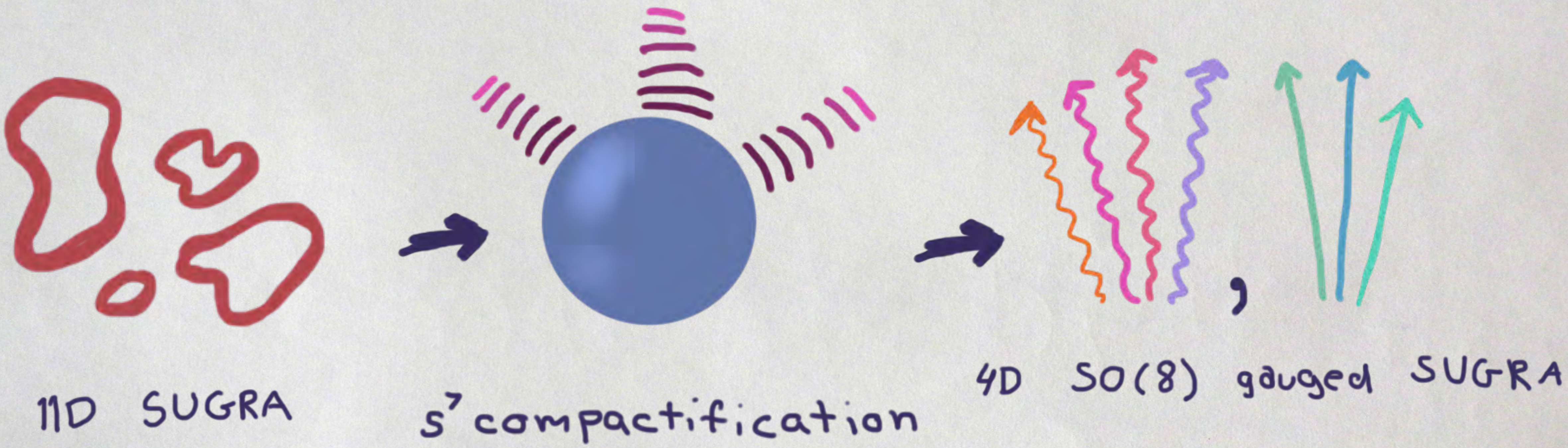
$$\left(i\Gamma^\mu D_\mu + q\Gamma^\mu A_\mu - m + \ldots\right)\psi = 0$$

?

"**Bottom** Up": Treat as parameters, explore

FS in AdS/CFT

There is a "top down" alternative...



FS in AdS/CFT

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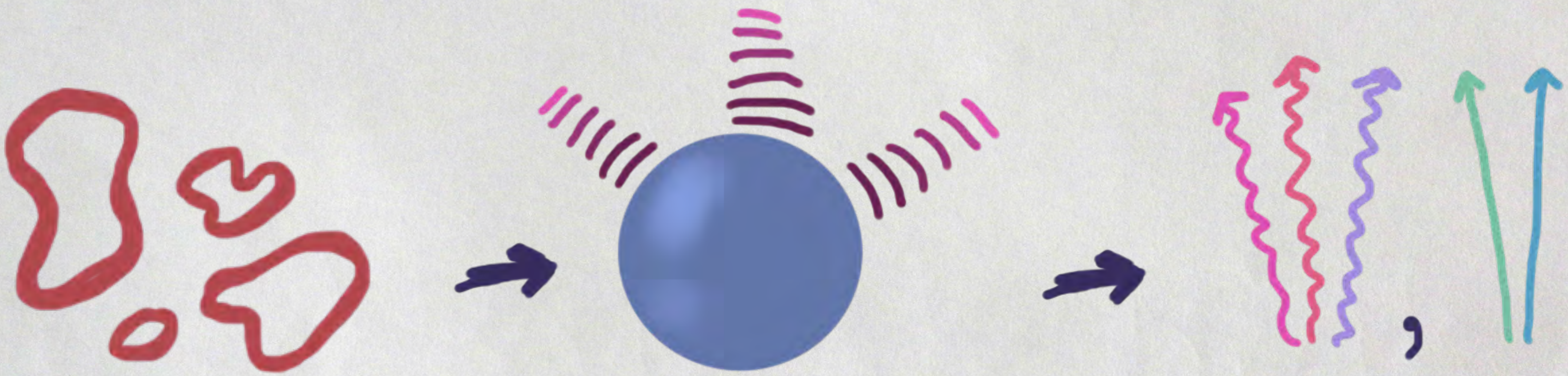


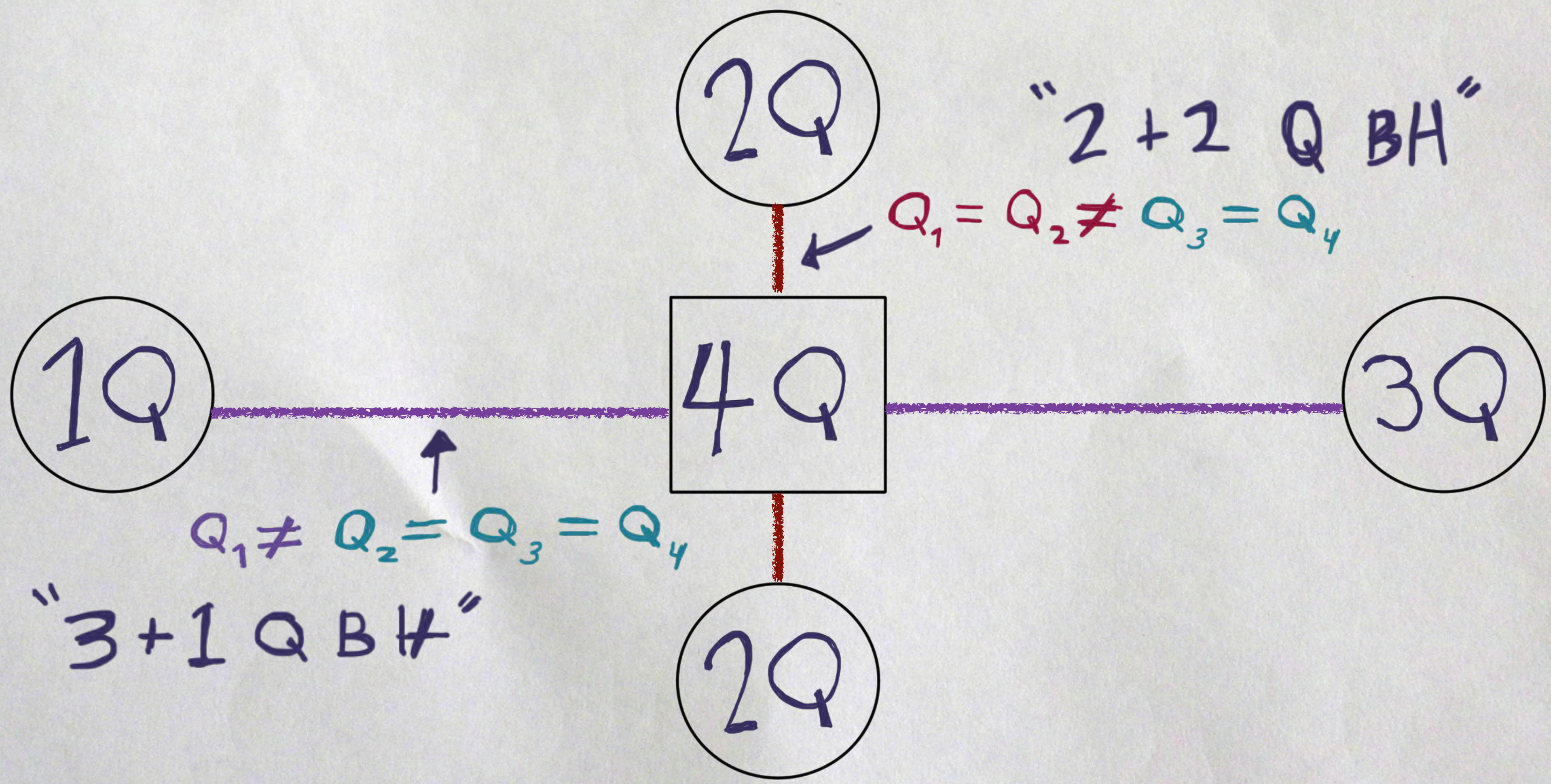
11D SUGRA → S^7 compactification → 4D SO(8) gauged SUGRA

(These are STU-type truncations with $U(1)^n \leftrightarrow n\ Q_i$ and some φ_i)

FS in AdS/CFT

Parameter Space

These 4D SUGRA solⁿs have Q_1, Q_2, Q_3, Q_4



FS in AdS/CFT

...There are fermions too!

- spin $3/2$ gravitini [1106.4694] [1106.6030]

- Various spin $1/2$ modes unmixed with gravitini

$$\psi \longleftrightarrow \mathrm{tr}\,\lambda X \quad \text{with} \quad \Delta = 3/2$$

FS in AdS/CFT

Plan of Attack

1. Numerically solve Dirac EQ$^{\underline{n}}$

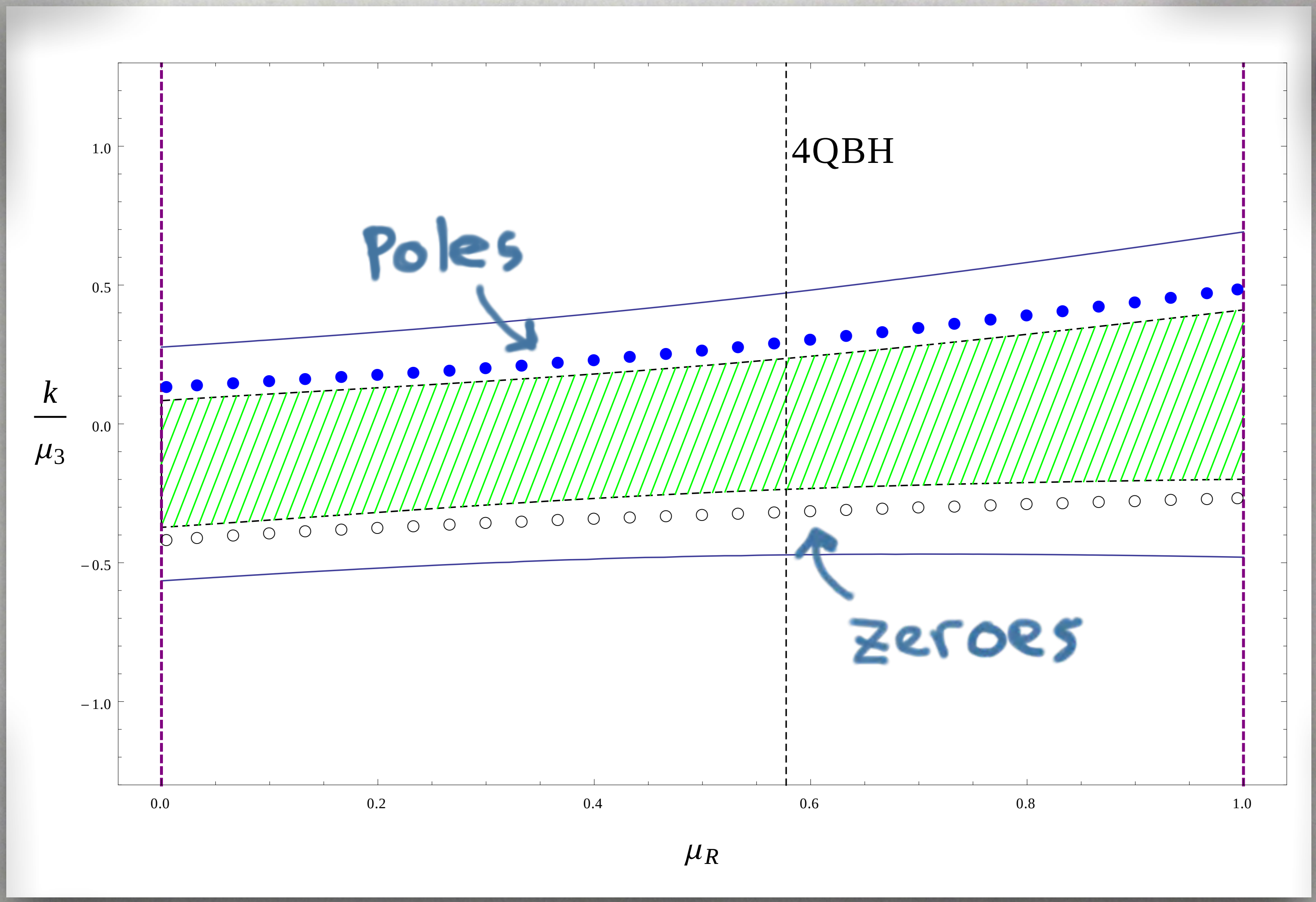
2. Compute $G_R \Leftrightarrow \frac{B_\psi}{A_\psi}$ } spinor fall-offs near boundary

3. Hunt for poles @ $\omega = 0$

FS in AdS/CFT

3+1 Q

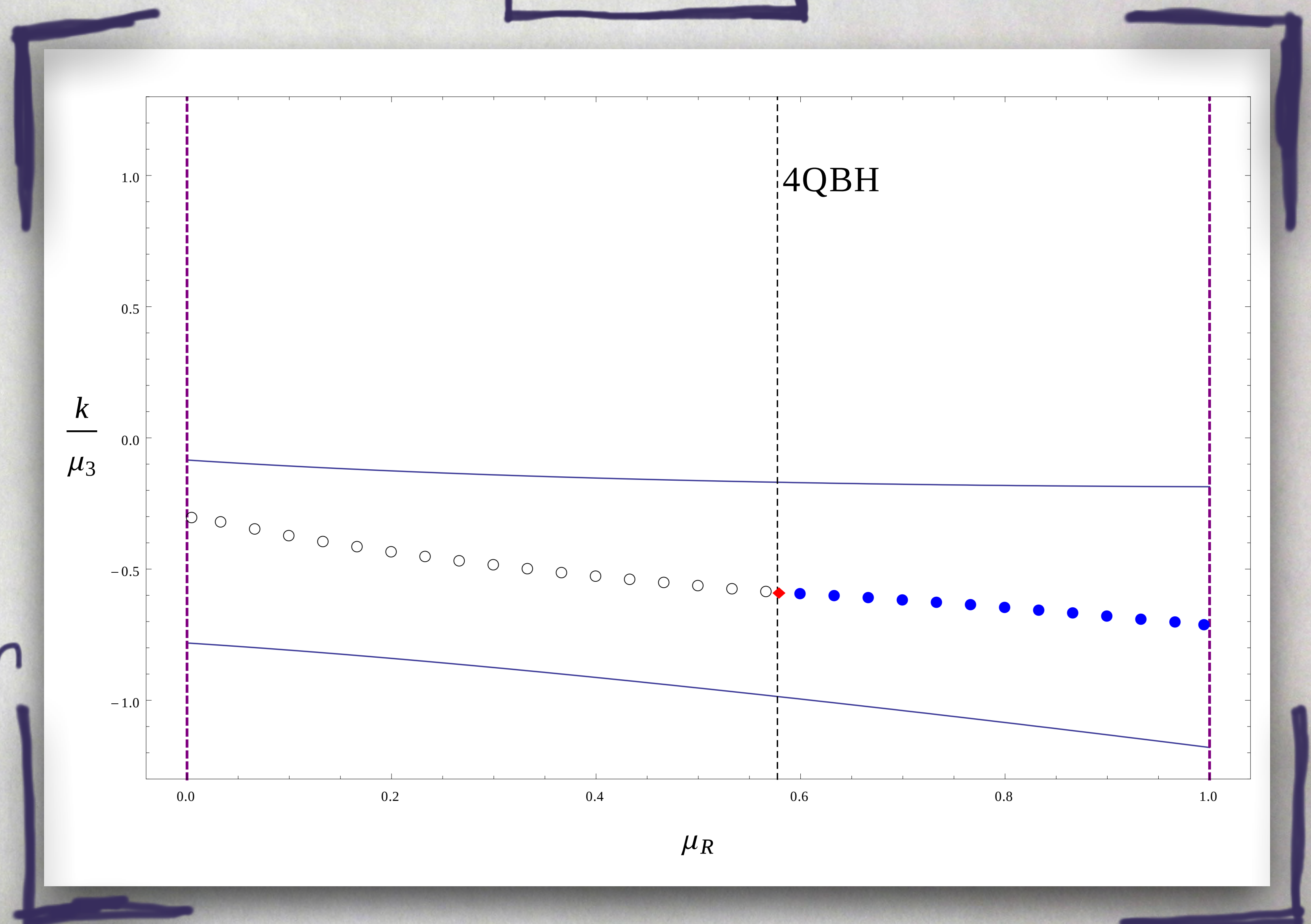
- There are FS singularities
- There is an "oscillatory region"
- Excitations about FS are not LFL



(Generic)

FS in AdS/CFT

3+1 Q

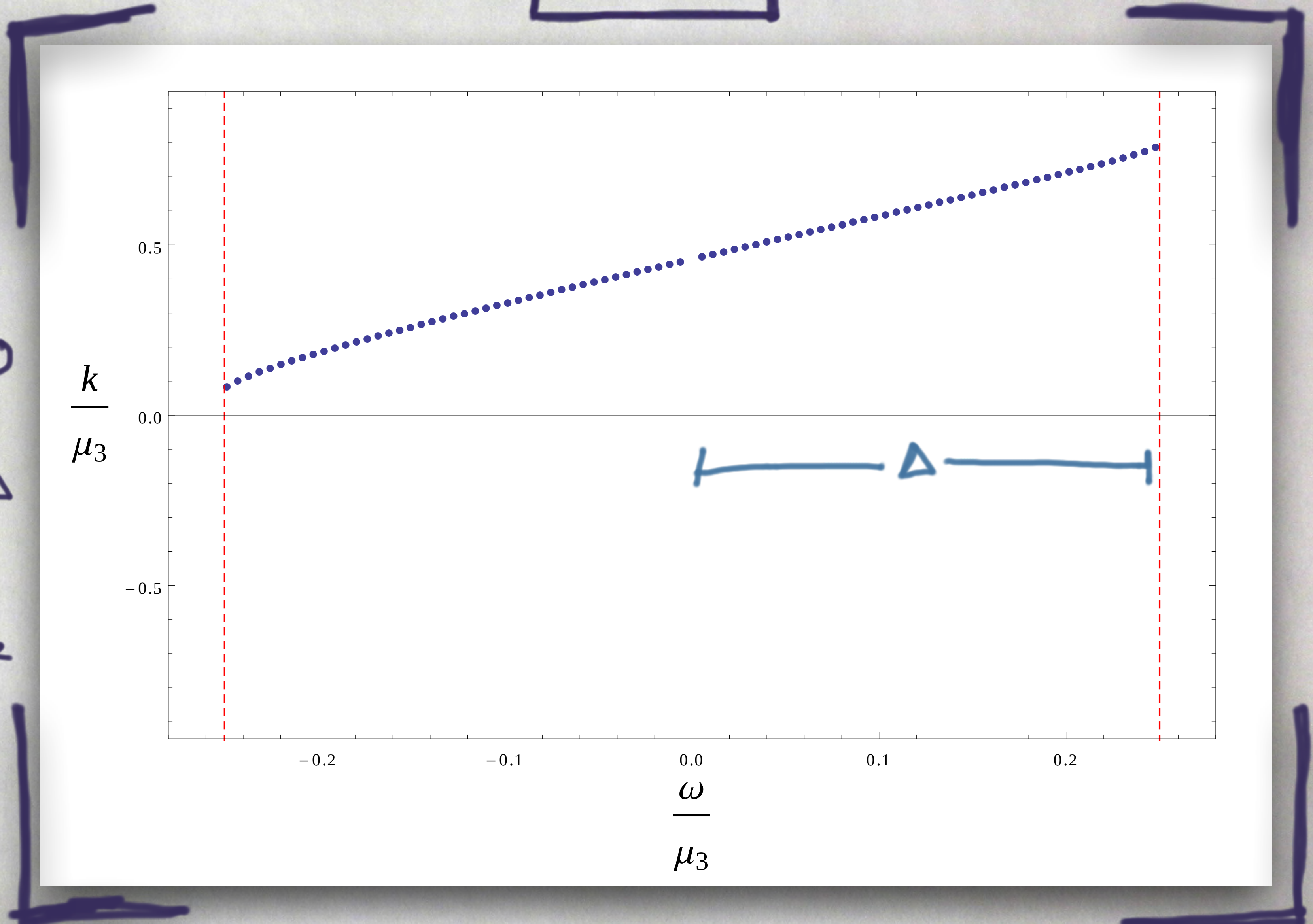


- In ABJM theory, states with a FS can transition into states without

FS in AdS/CFT

3Q

- This state has $s \to 0$ as $T \to 0$
- stable modes for $-\Delta < \omega < \Delta$
- Singular IR geometry can be resolved by lift to $AdS_3 \times \mathbb{R}^2$



Questions

- What can we say about the zeroes ↔ poles transitions we observe?
- What can we learn from the states in the corners of this parameter space?
- Many open issues persist--is there sufficient data to close some?

Thank You!

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NSRF
2007-2013
programme for development
EUROPEAN SOCIAL FUND

Co-financed by Greece and the European Union

This research has been co-financed by the European Union (European Social Fund, ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning"
of the National Strategic Reference Framework (NSRF), under the grants schemes "Funding
of proposals that have received a positive evaluation in the 3rd and 4th Call of ERC Grant Schemes" and the EU program ``Thales'' ESF/NSRF 2007-2013.

Singularity Resolution

The "gap" comes from the singular nature of the bulk geometry...

Ex

$$G_{MN} \Rightarrow G_{\mu\nu},\ G_{\mu 6},\ G_{66}$$

G_{MN} ← $AdS_3 \times R^3$; $G_{\mu\nu}$ ← 2Q BB; $G_{\mu 6}$ ← A_μ; G_{66} ← φ

$$S = -\int d^6x \sqrt{-\hat{g}}\, \hat{g}^{MN} \partial_M \eta\, \partial_N \eta$$

reduce

$$-\int d^5x \sqrt{-g} \left(g^{\mu\nu} D_\mu \eta D_\nu \eta + e^{\frac{4\varphi}{\sqrt{6}}} q_1^2 \eta^2 \right)$$

$$m_\eta(\varphi) = \pm q_1 e^{2\varphi/\sqrt{6}}$$

but

$$m_{SUGRA}(\varphi) = 2 m_2 e^{2\varphi/\sqrt{6}}$$

so

$$\boxed{2 m_2 = \pm q_1}$$

Singularity Resolution

The "gap" comes from the singular nature of the bulk geometry...

Ex

$$G_{MN} \Rightarrow G_{\mu\nu} \,,\, G_{\mu 6} \,,\, G_{66}$$

G_{MN} ↖ $AdS_3 \times R^3$; $G_{\mu\nu}$ ↑ 2Q BB ; $G_{\mu 6}$ ↗ A_μ ; G_{66} ↑ φ

Also:

$$k_M = (q, \omega, \vec{0})$$

so

$$k_M k^M = \frac{1}{2r^2}\left(\Delta^2 - \omega^2\right)$$

Which is to say Δ is the minimum energy needed for a mode to be time-like