Fermi Surface Physics

FROM

Gauged Supergravity

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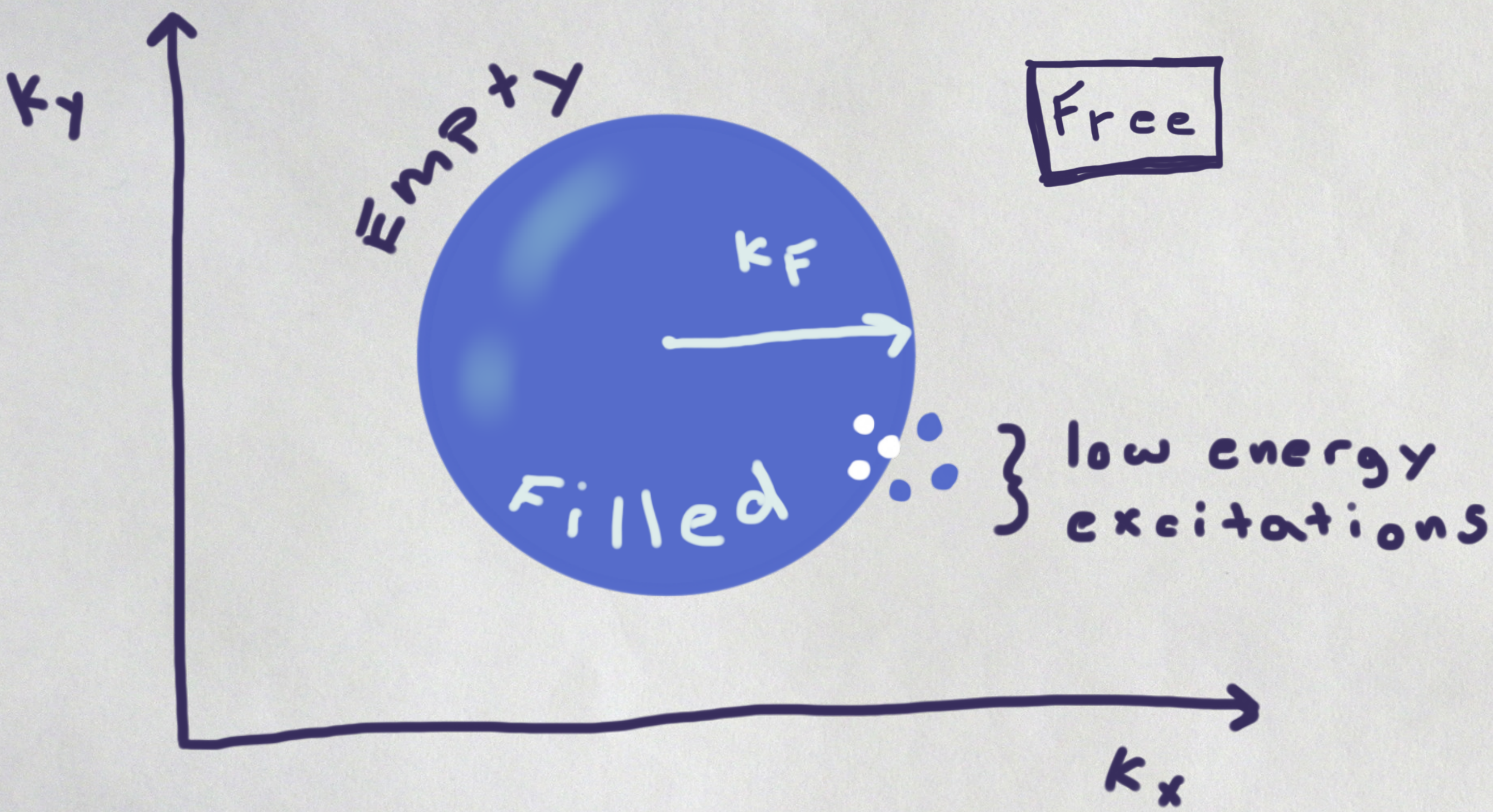
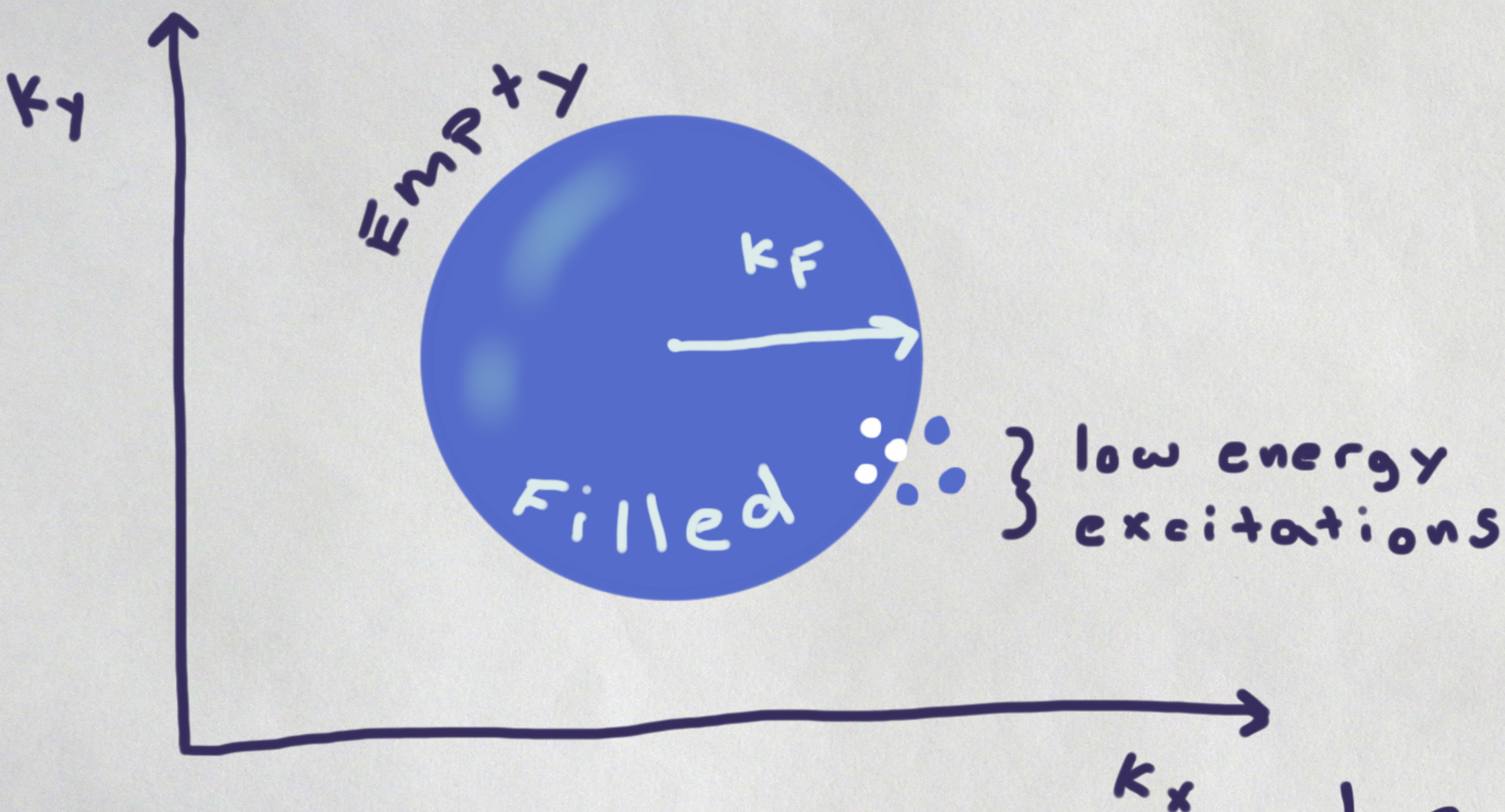
Basics of FS in QFT



$\boxed{\text{Free}}$

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

residue measures "e-ness"

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

excitation energy (above μ)

$k - k_F$

Fermi velocity

width

Basics of FS in QFT

Operationally

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

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

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

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

$\boxed{1}$ Can we study novel aspects of Fermi Surfaces in AdS/CFT?

[0907.2694]

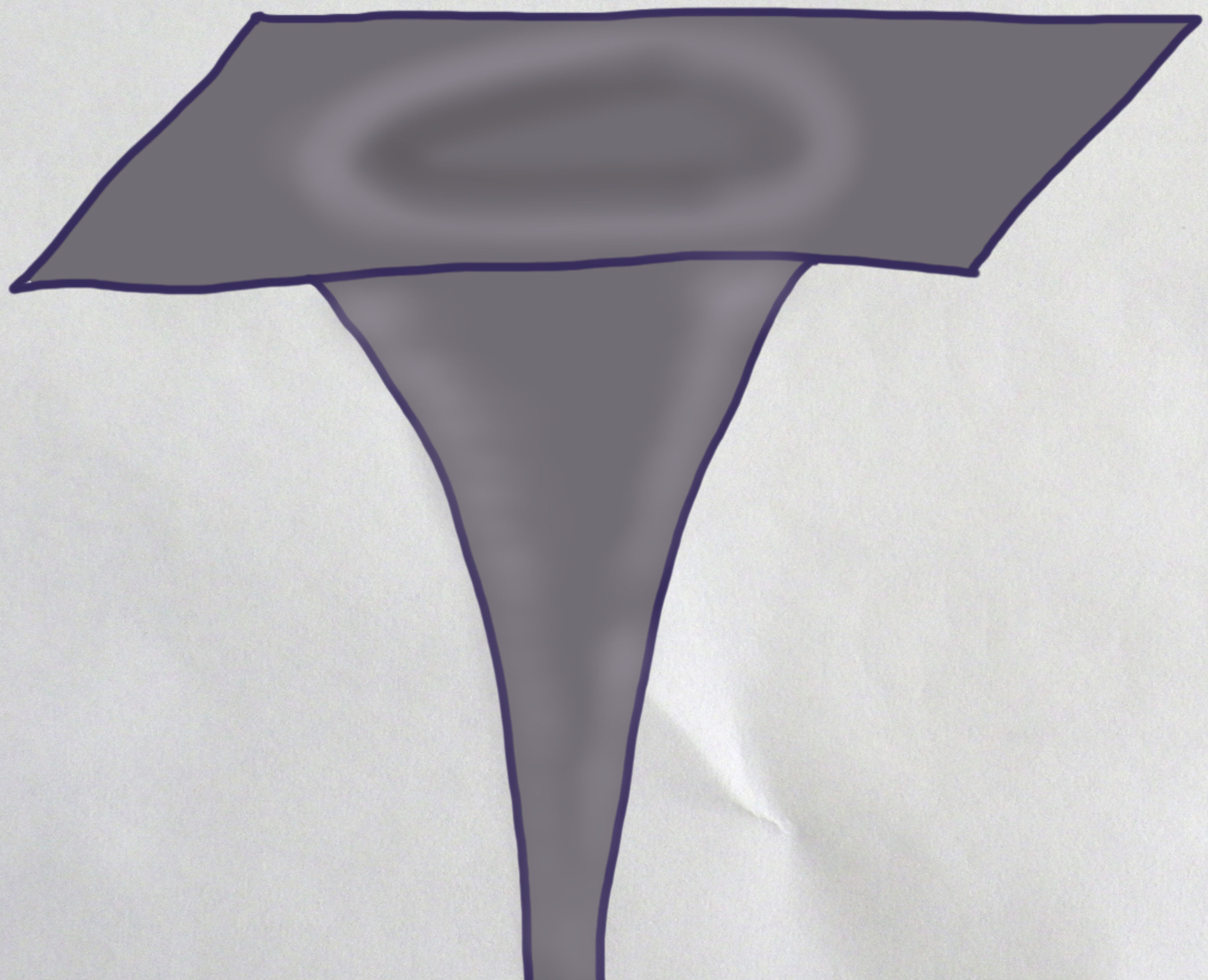
$\boxed{2}$ Can we do this in $\mathcal{N}=4$ or ABJM?

[1112.3036]

$\boxed{3}$ What happens??

[1207.3352] [1312.7347] [NOW]

FS in AdS/CFT

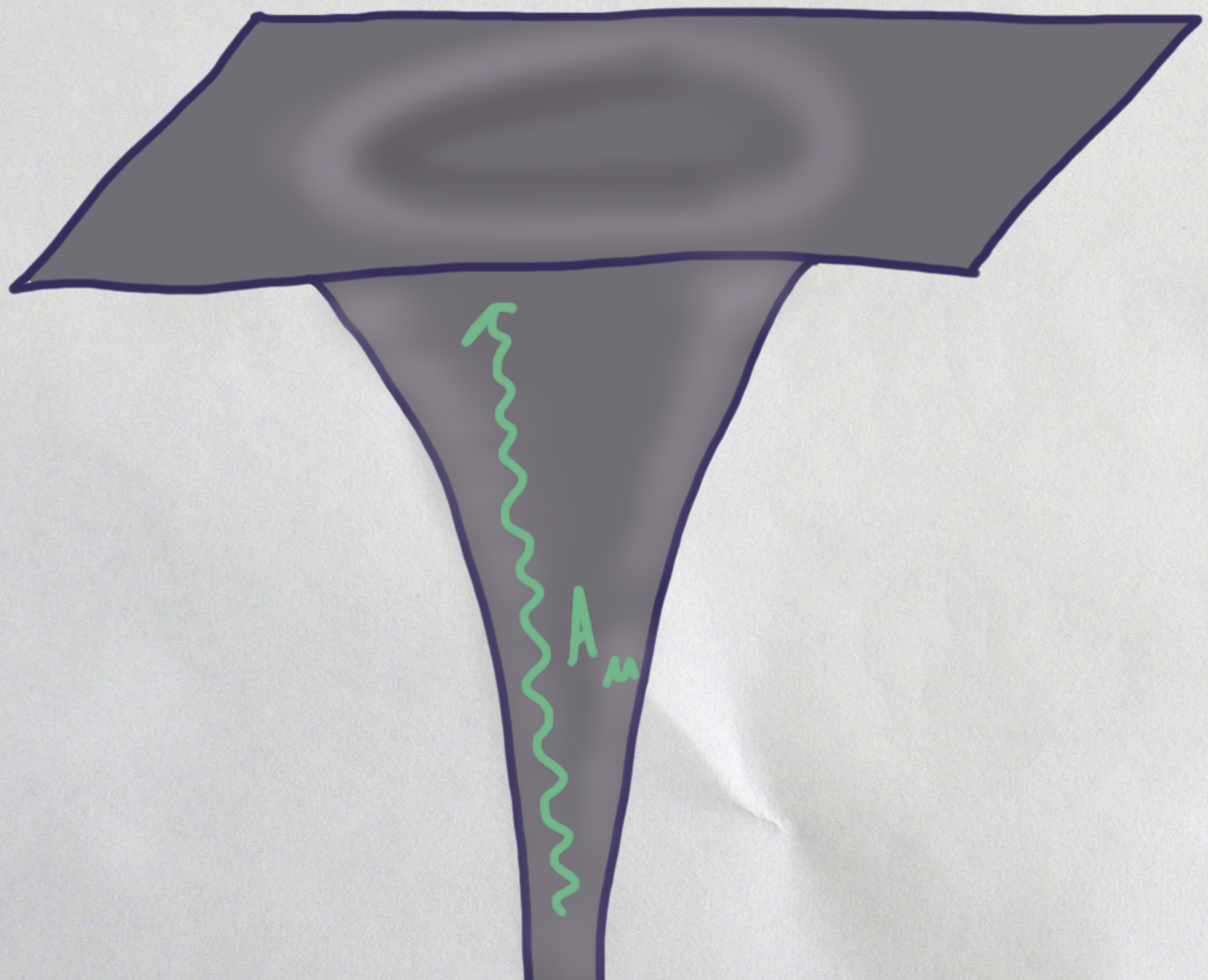


The minimal ingredients
(a probe fermion approach)

1 Extremal black brane

(Zero Temperature)

FS in AdS/CFT



The minimal ingredients
(a probe fermion approach)

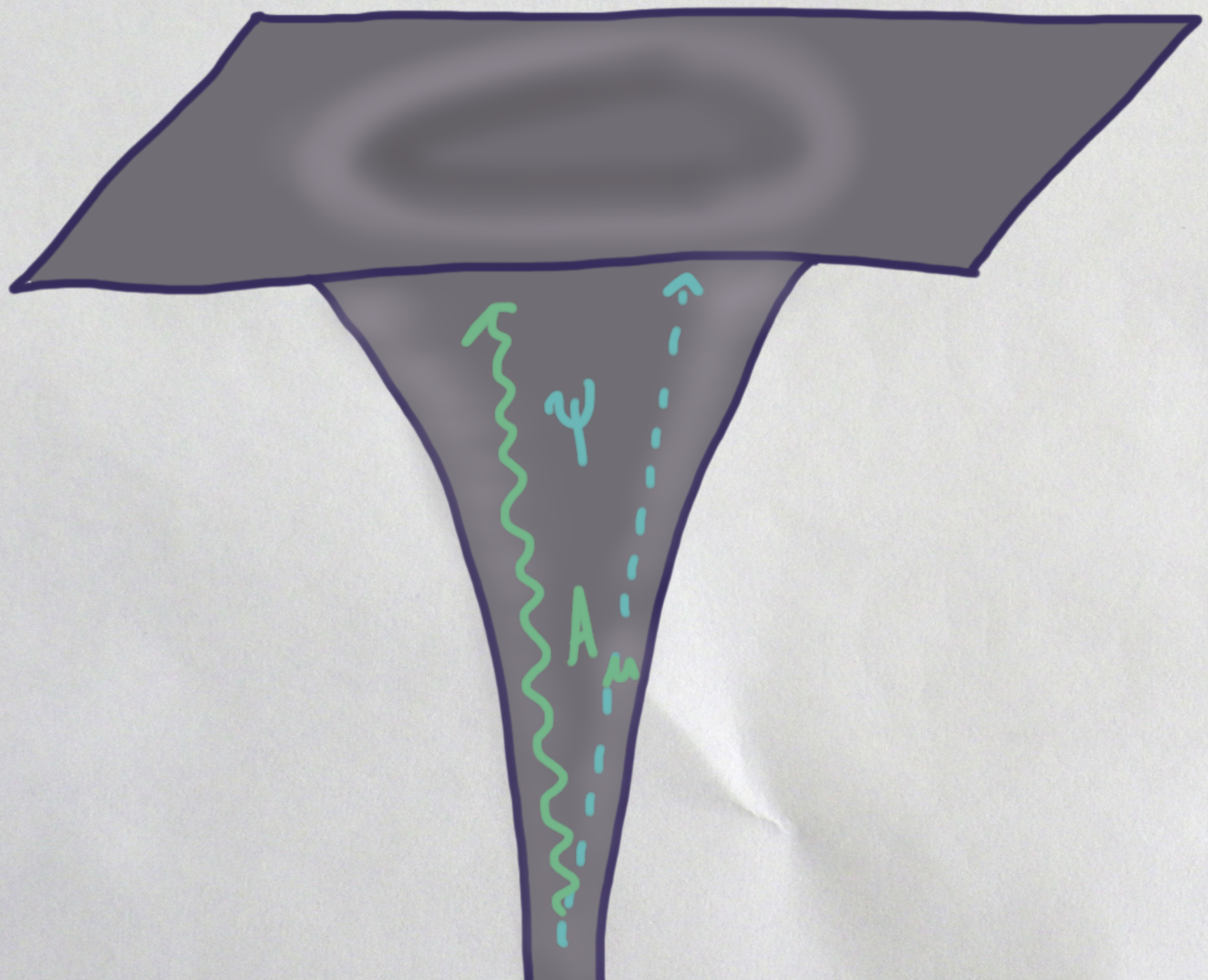
1 Extremal black brane

(Zero Temperature)

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

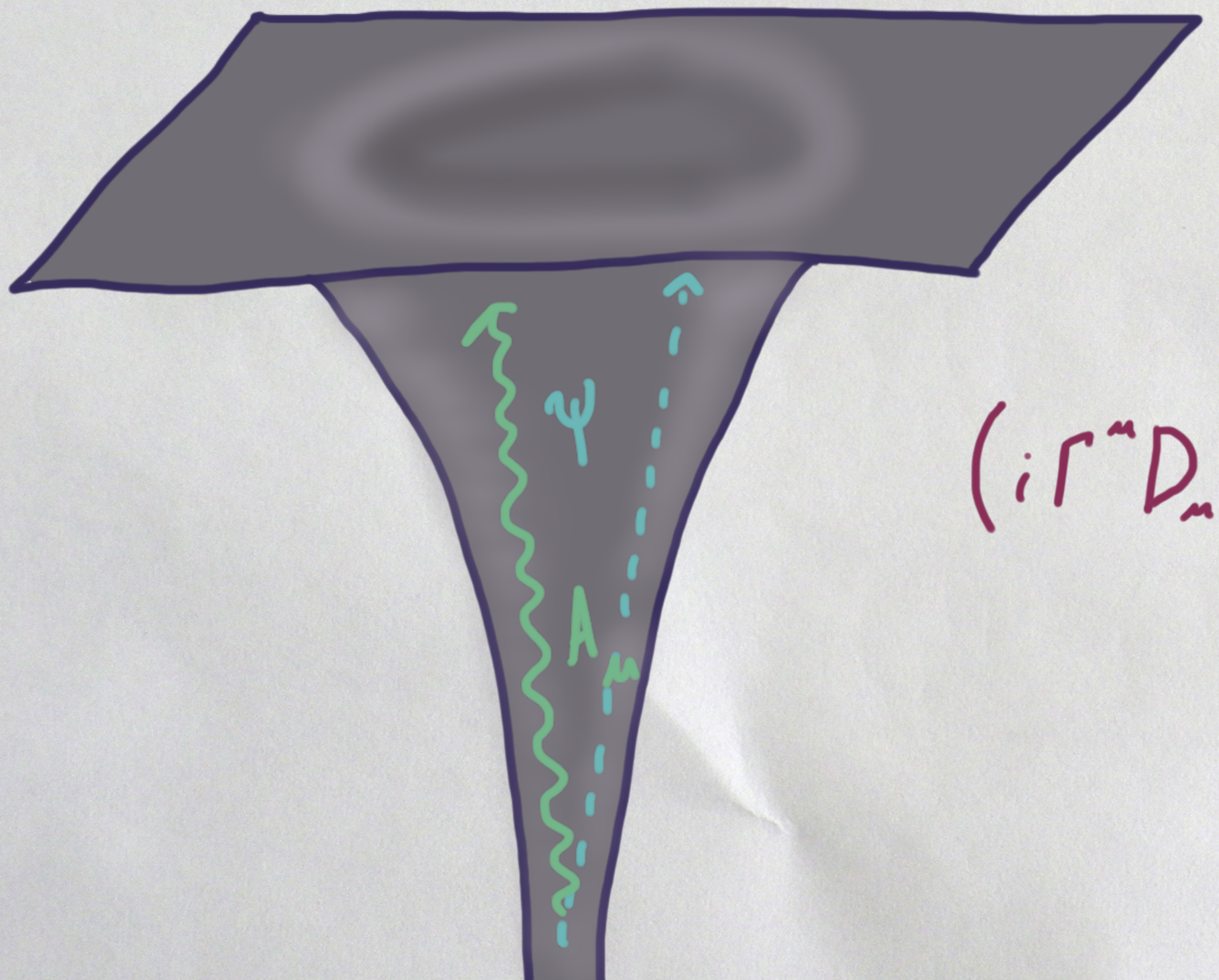
(Finite Density)

1 Bulk fermion

(Fermionic Operator)

FS in AdS/CFT

The minimal ingredients
(a probe fermion approach)

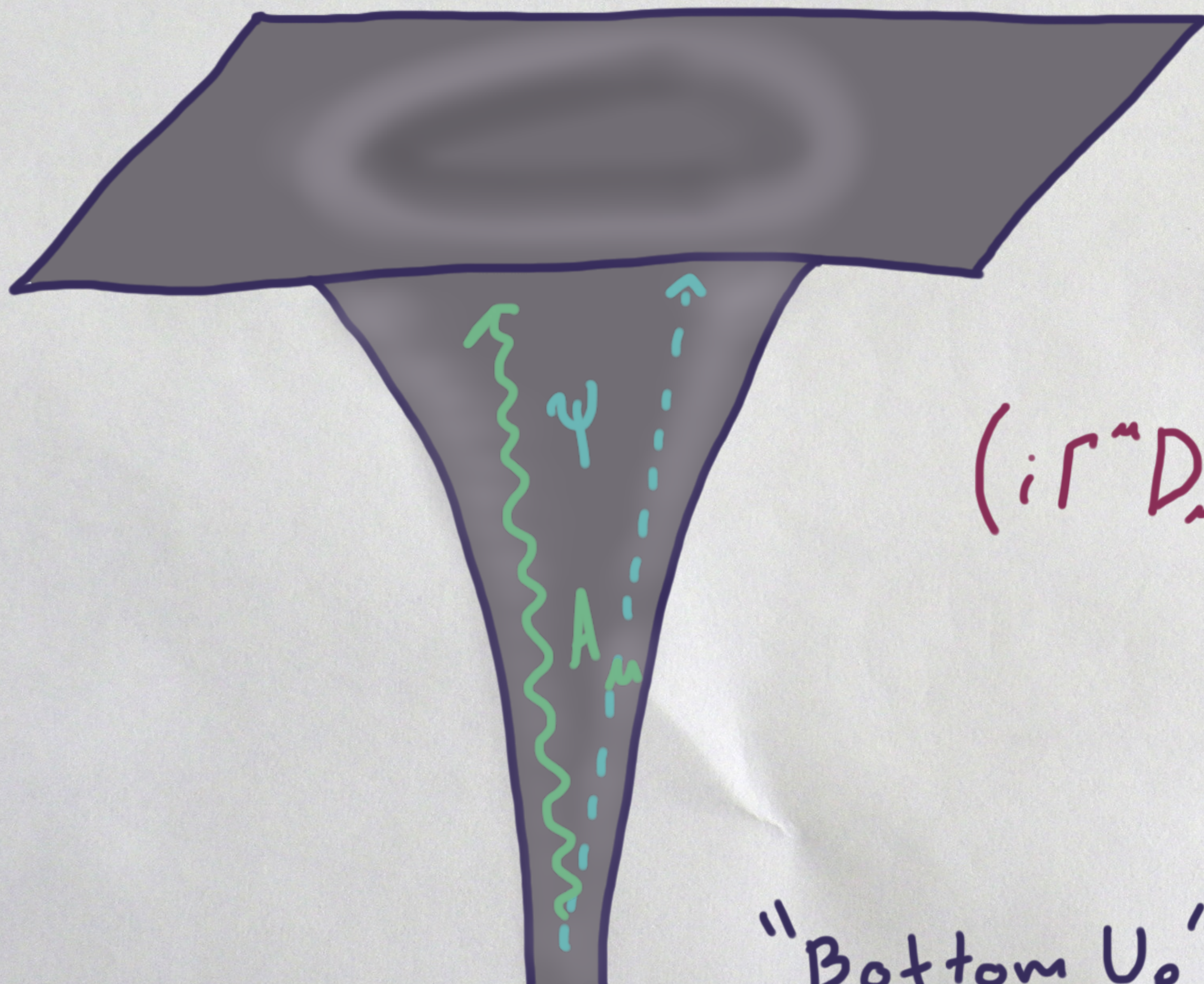


The fermionic sector is described by a Dirac equation, like

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

FS in AdS/CFT

The minimal ingredients (a probe fermion approach)



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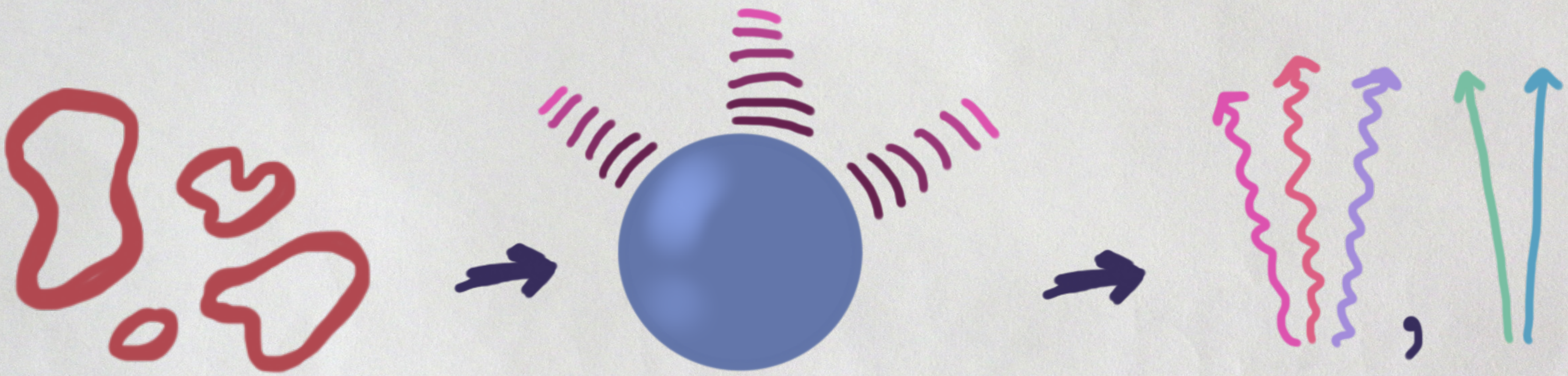
$$\left(i\Gamma^\mu D_\mu + q\Gamma^\mu A_\mu - m + \ldots\right)\psi = 0$$

?

"Bottom Up": Treat as parameters, explore

FS in AdS/CFT

There is a "top down" alternative...



10D IIB SUGRA

S^5 compactification

5D SO(6) gauged SUGRA

OR

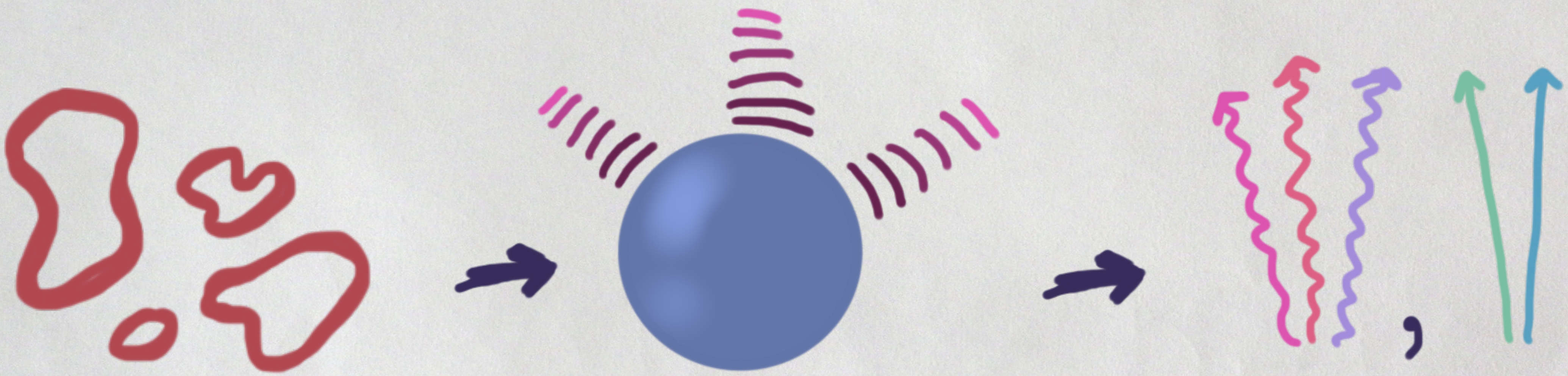
11D SUGRA

S^7 compactification

4D SO(8) gauged SUGRA

FS in AdS/CFT

There is a "top down" alternative...



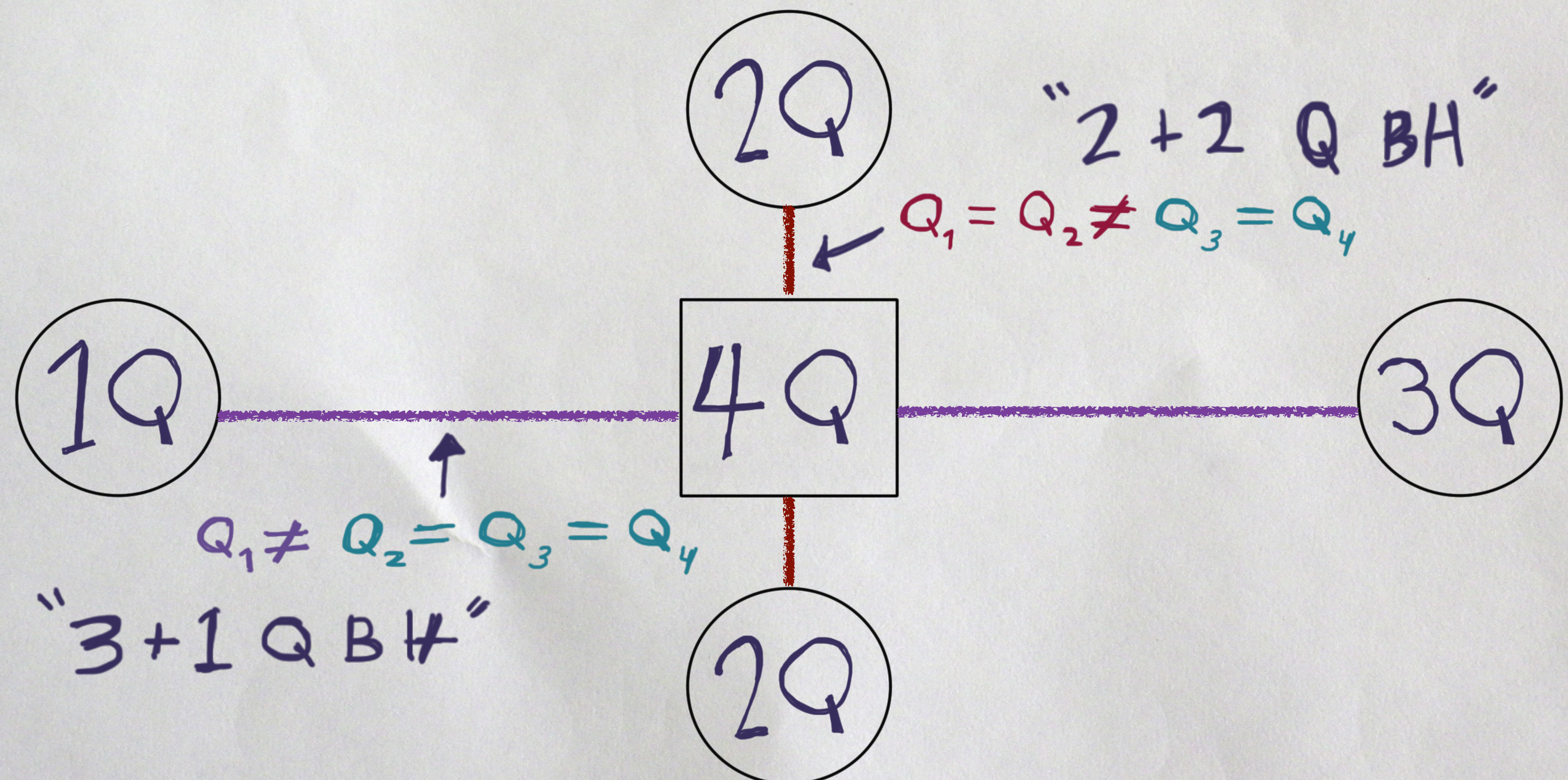
10D IIB SUGRA → S^5 compactification → 5D SO(6) gauged SUGRA

(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 sol^{n}s have Q_1, Q_2, Q_3, Q_4



... 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

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

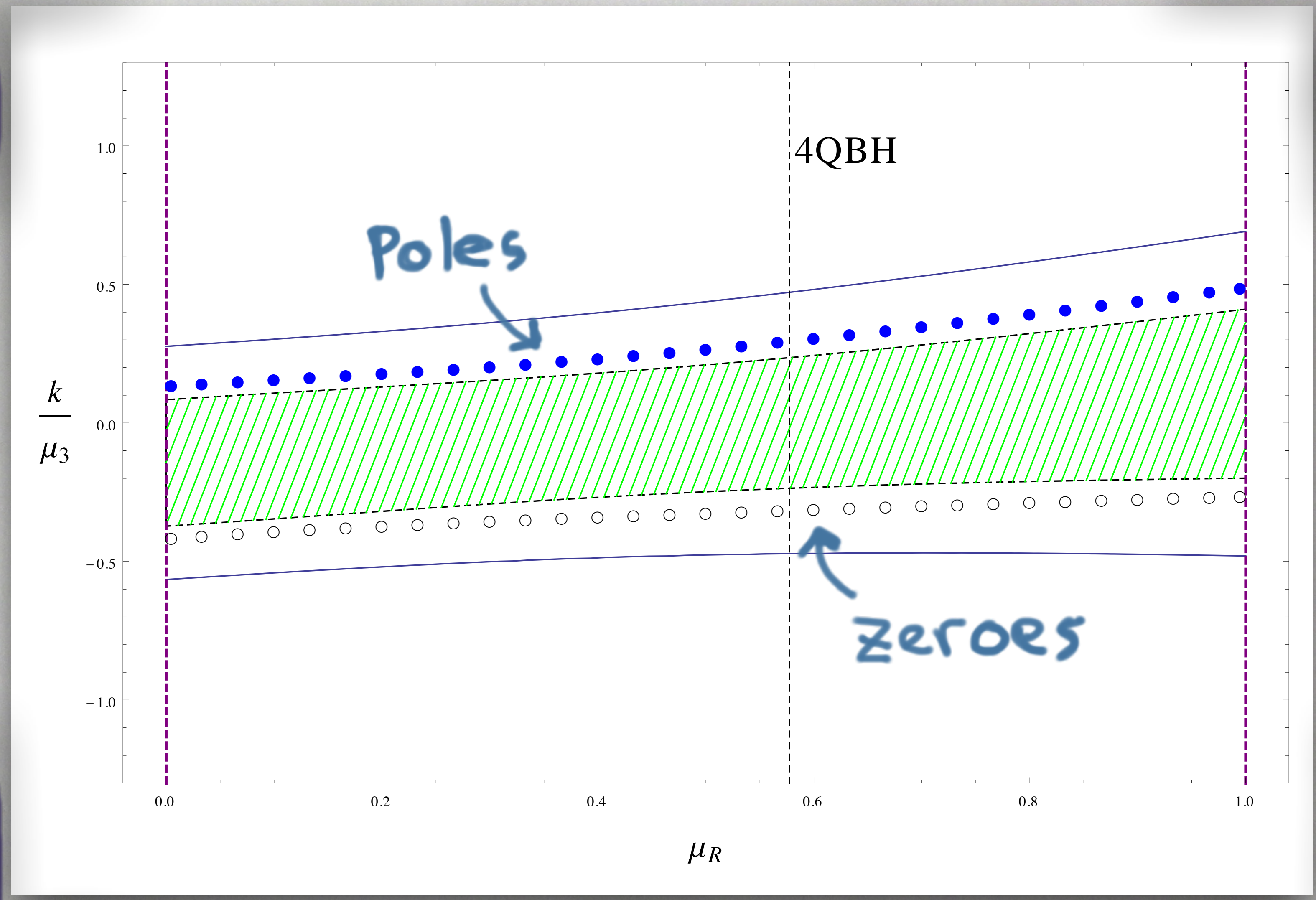
$\boxed{2}$ Compute $G_R \Leftrightarrow \frac{B_\psi}{A_\psi}$ spinor fall-offs near boundary

$\boxed{3}$ Hunt for poles @ $\omega = 0$

FS in AdS/CFT

$\boxed{3+1\ Q}$

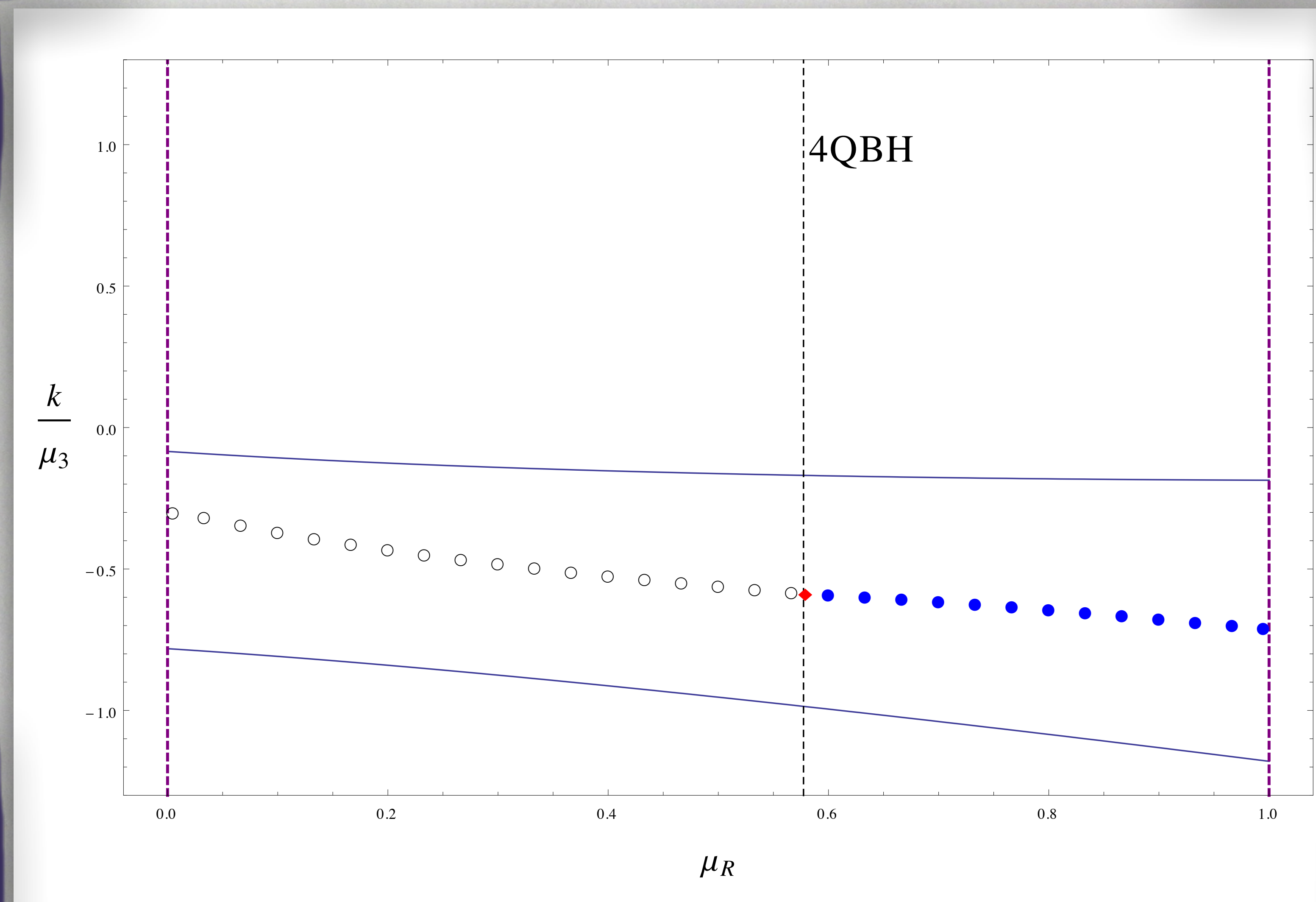
- There are FS singularities
- There is an "oscillatory region"
- Excitations about FS are not LFL



(Generic)

FS in AdS/CFT

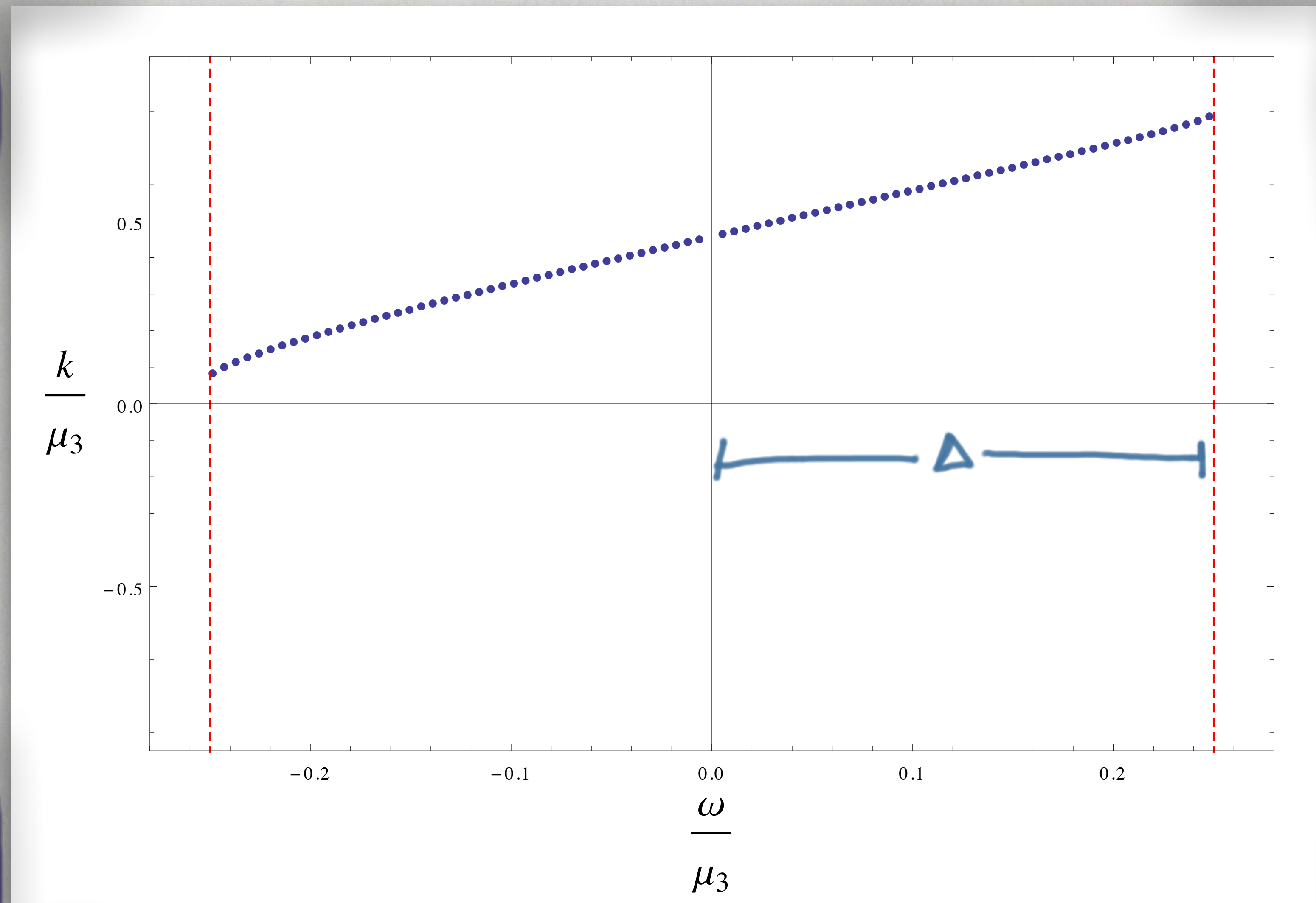
3+1 Q



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

FS in AdS/CFT

$\boxed{3Q}$



- 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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Singularity Resolution

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

Ex

$$\underset{AdS_3 \times R^3}{G_{MN}} \Rightarrow \underset{2Q\,BB}{G_{\mu\nu}}\,,\ \underset{A_\mu}{G_{\mu 6}}\,,\ \underset{\varphi}{G_{66}}$$

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

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

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

so

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

Singularity Resolution

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

Ex

$$\underset{\overset{\nearrow}{AdS_3 \times R^3}}{G_{MN}} \Rightarrow \underset{\overset{\uparrow}{2Q\,BB}}{G_{\mu\nu}} \,,\ \underset{\overset{\nearrow}{A_\mu}}{G_{\mu 6}} \,,\ \underset{\overset{\uparrow}{\varphi}}{G_{66}}$$

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