Title: Lecture - AdS/CFT, PHYS 777

Speakers: David Kubiznak

Collection/Series: AdS/CFT (Elective), PHYS 777, March 31 - May 2, 2025

Subject: Quantum Fields and Strings, Quantum Gravity

Date: April 24, 2025 - 9:00 AM

URL: https://pirsa.org/25040033

WILSON LOOPS = NON-LOCAL GAUGE INVARIANT OPERATORS ≃ PARALLEL TRANSPORT OF QUARK ALONG CLOSED LOOP C.

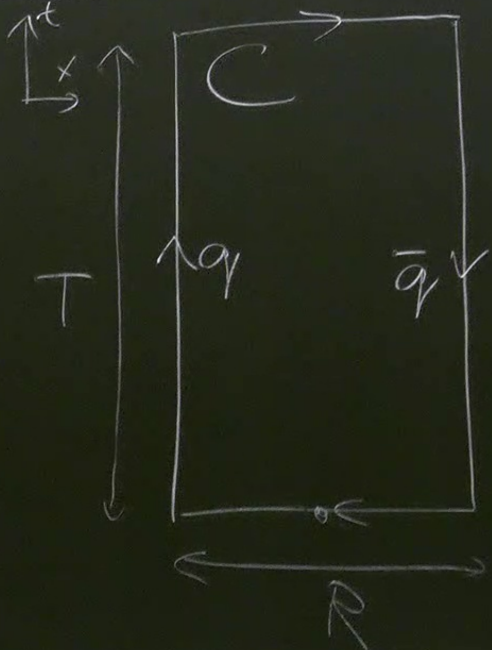
SP

$$\boxed{W(C) = \frac{1}{N_c} \mathrm{Tr}\left(P\exp\left(i\oint_C A_\mu dx^\mu\right)\right)}$$

$t \to iT$

$$A_\mu = (V, \vec{\cancel{0}}) \qquad dx^\mu = (dt, dx^i)$$

SPECIFICALLY CONSIDER C: "$q\bar{q}$ PAIR CREATION & ANNIHILATION"



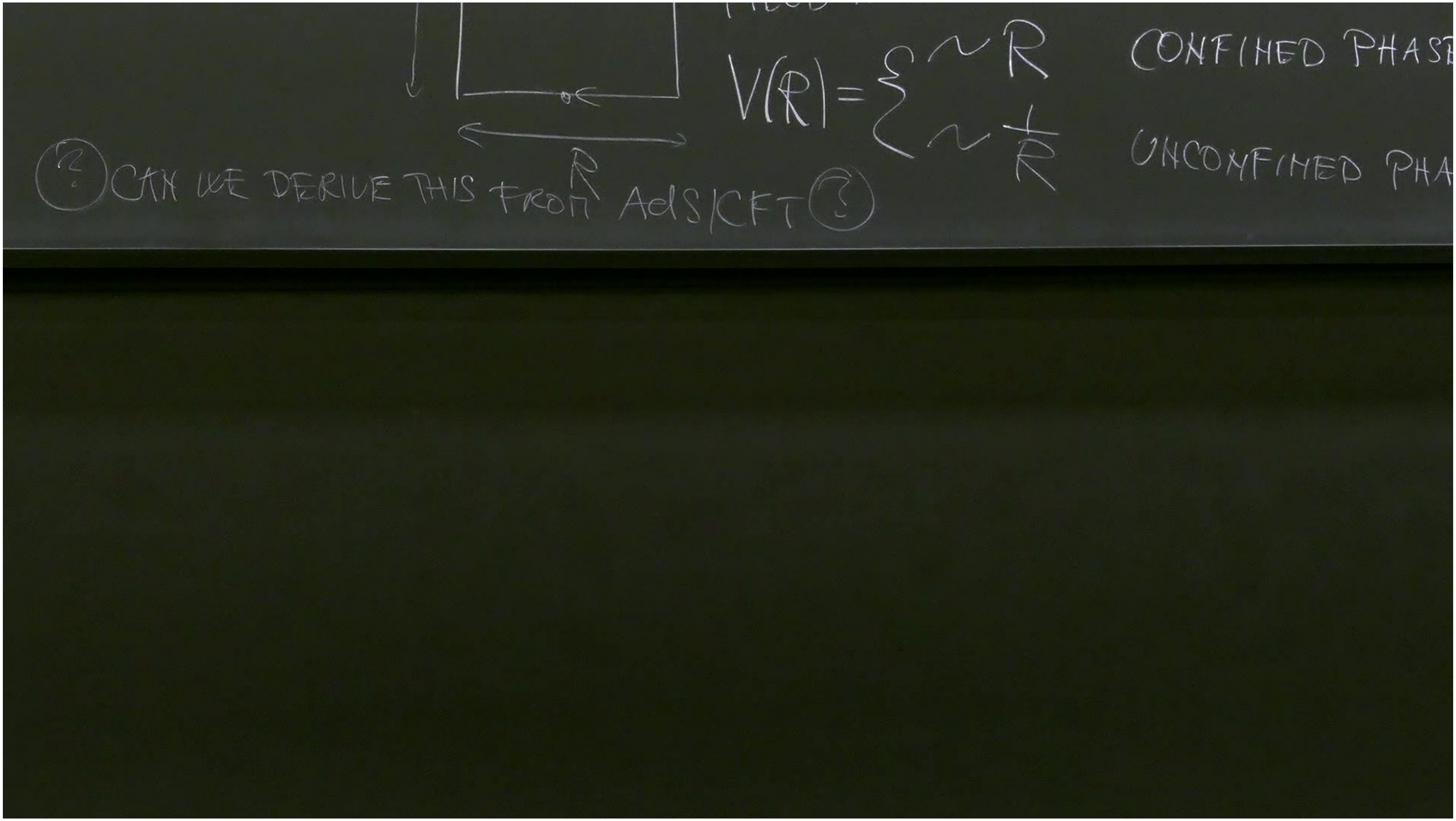
EUCL.

QUARK POTENTIAL

$$\boxed{\langle W(C) \rangle \propto e^{-TV(R)}}$$

FIELD THEORY WISDOM.

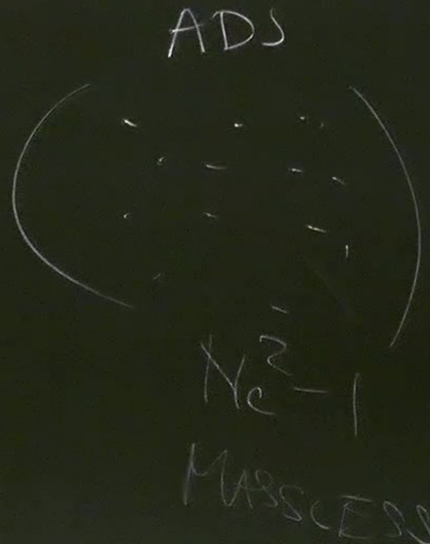
$$V(R) = \begin{cases} \sim R & \text{CONFINED PHASE} \\ \sim \frac{1}{R} & \text{UNCONFINED PHASE} \end{cases}$$

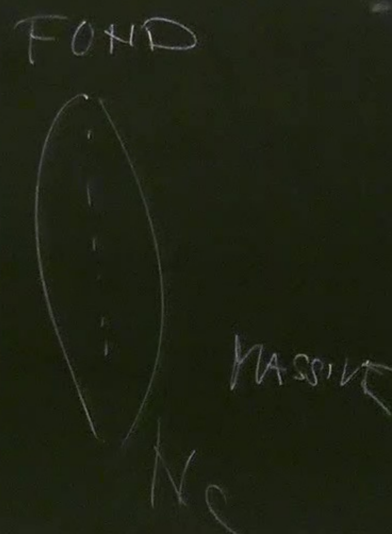

V(R) = ~R
CONFINED PHASE
~1/R
UNCONFINED PHA
R
CAN WE DERIVE THIS FROM AdS/CFT

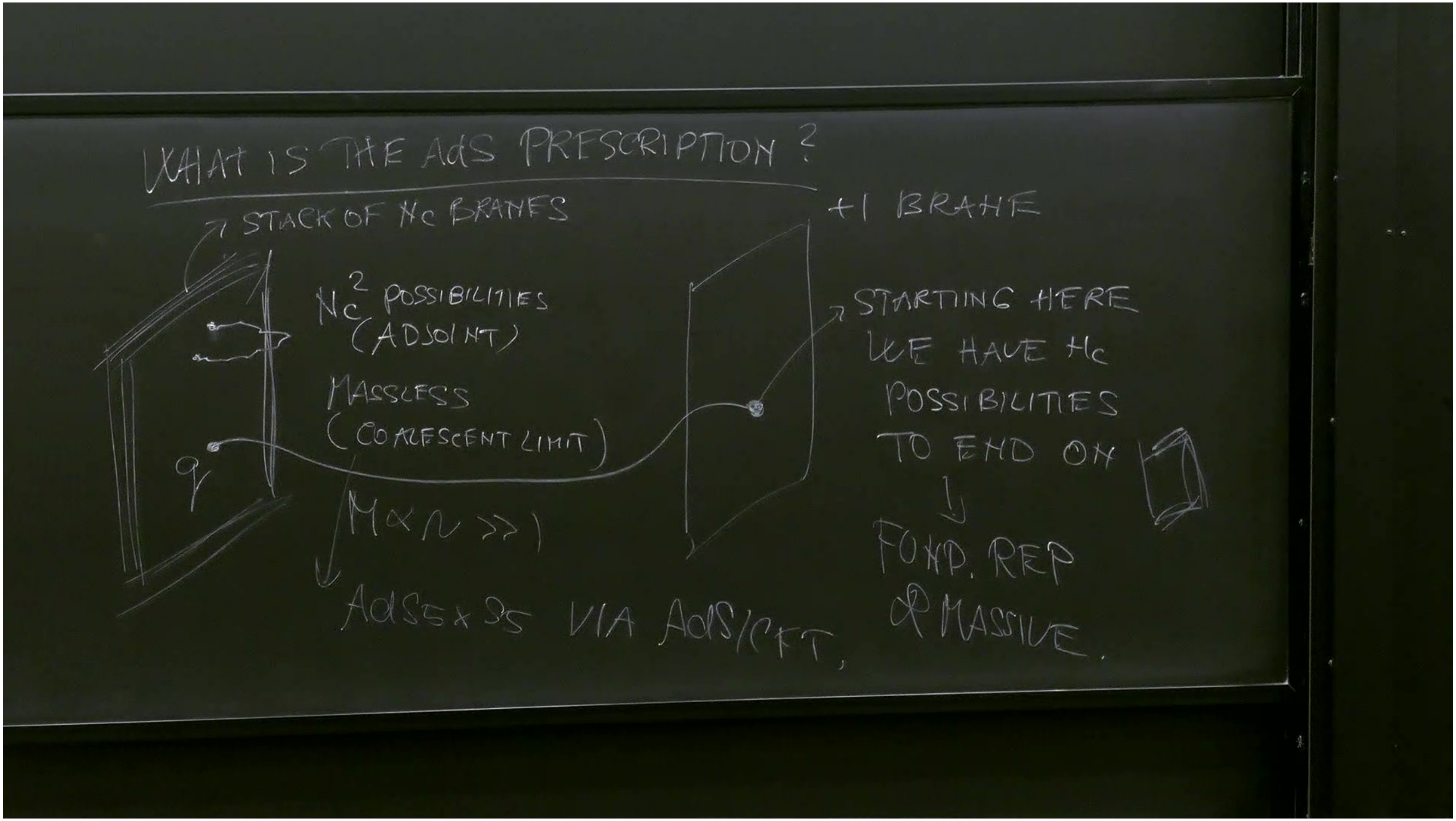
$A_\mu \ (V, \vec{\phi})$ $\quad dx^\mu = (dt, dx^i)$ $\quad$? CAN WE DERIVE

- HERE q IS MASSIVE & IN FUNDAMENTAL REP OF $SU(N_c)$

(C.F. MASSLESS & ADJOINT REP. OF $SU(N_c)$ ... SYM)






WHAT IS THE AdS PRESCRIPTION ?
STACK OF N_c BRANES
+1 BRANE
N_c^2 POSSIBILITIES
(ADJOINT)
MASSLESS
(COALESCENT LIMIT)
q
$M \propto r \gg 1$
$AdS_5 \times S_5$ VIA AdS/CFT,
STARTING HERE
WE HAVE N_c
POSSIBILITIES
TO END ON
FUND. REP
& MASSIVE.

HAVE THE FOLLOWING PRESCRIPTION

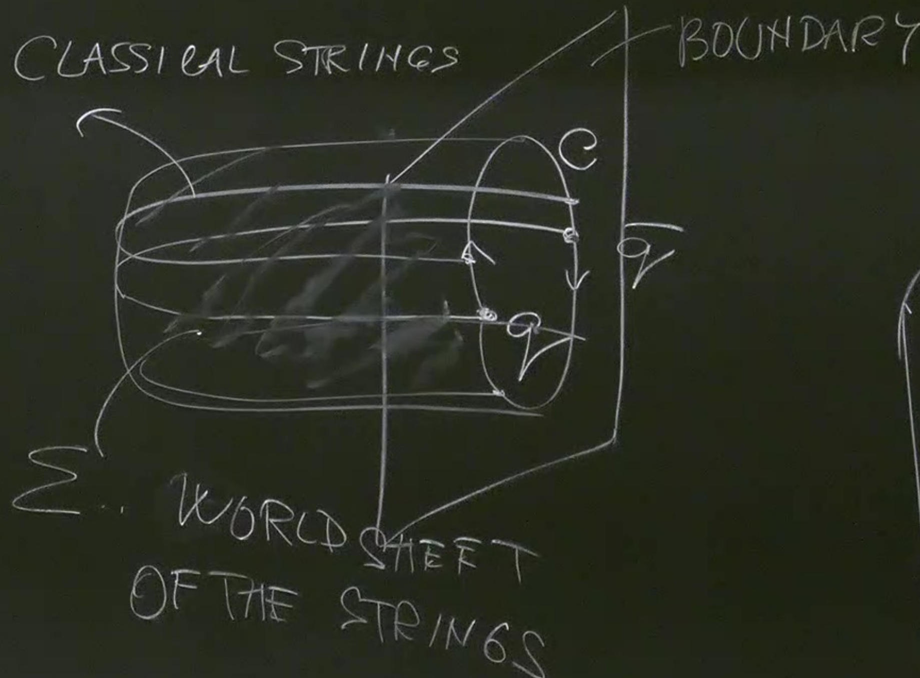
STRINGS GO

$\rightarrow$ SHAPE C

CO

AdS_5

BULK



$\langle W(C) \rangle \propto$

$\Rightarrow V(R) =$

... VIA AdS/CFT, ... MASSIVE.

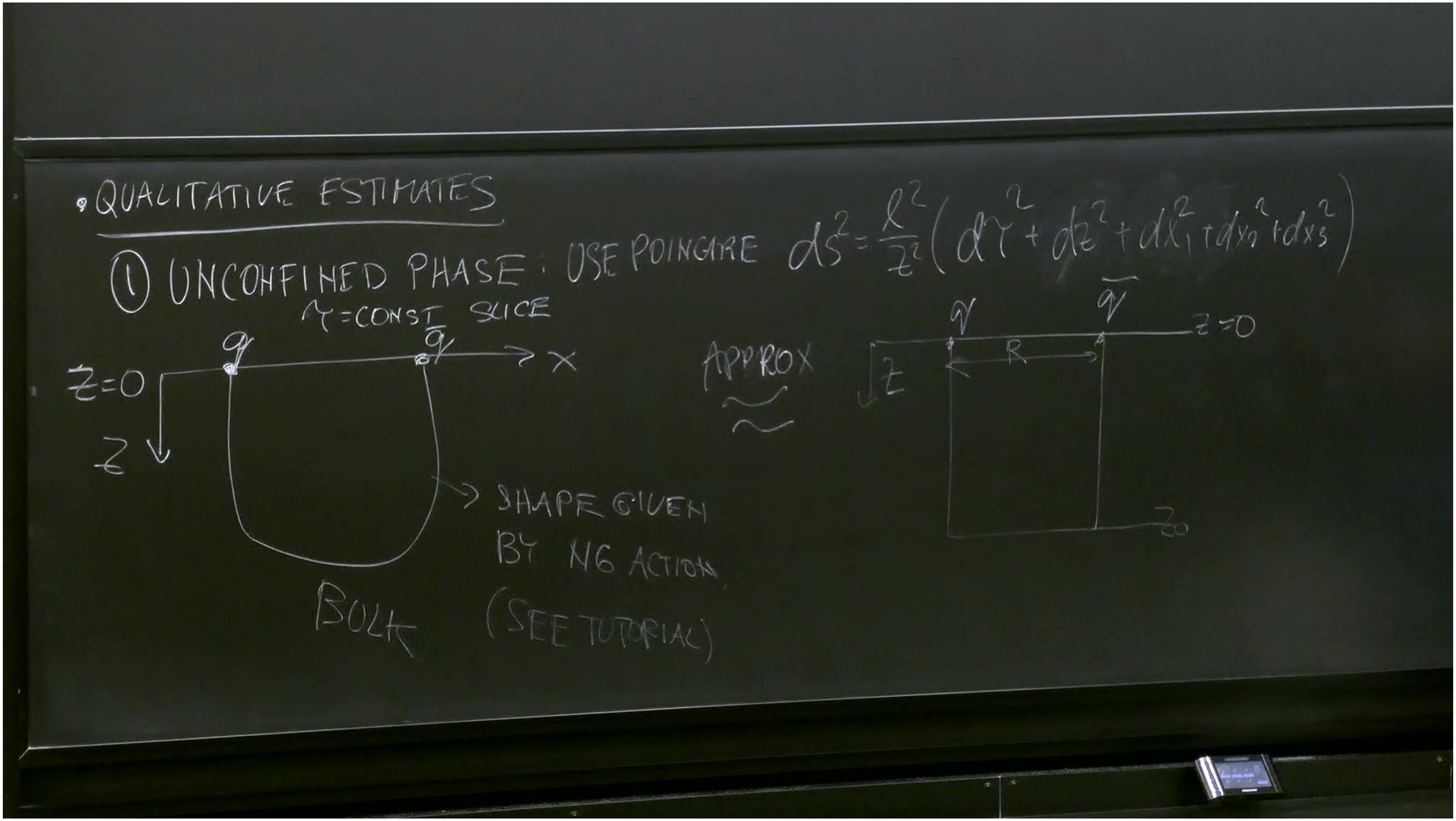
... OVERNED BY CLASSICAL NG ACTION

... OF Σ EXTREMIZING NG SUBJECT TO BOUNDARY

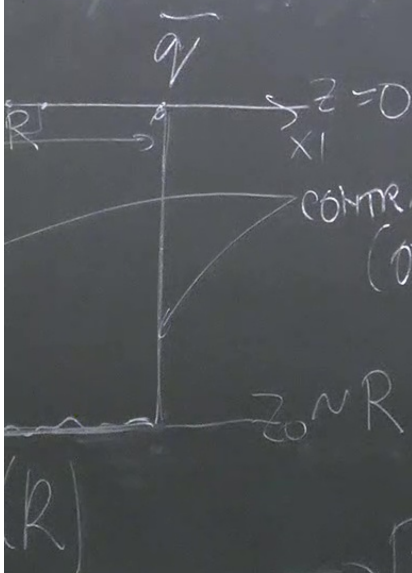
... ONDITION : $\partial\Sigma = \Sigma / \partial AdS = C$

$$\ldots \propto e^{-S_{NG,EXTR}} \,, \qquad S_{NG} = \frac{1}{2\pi\alpha'} \int_{\Sigma : \partial\Sigma = C} d^2\sigma \sqrt{\det \gamma_{AB}}$$

$$\ldots = \frac{S_{NG}}{T} \ldots \text{QUARK POTENTIAL}$$


• QUALITATIVE ESTIMATES
① UNCONFINED PHASE: USE POINCARE $ds^2 = \frac{\ell^2}{z^2}\left(d\tau^2 + dz^2 + dx_1^2 + dx_2^2 + dx_3^2\right)$
τ = CONST SLICE
q
$\bar{q}$
x
$z=0$
z
SHAPE GIVEN BY NG ACTION
BULK
(SEE TUTORIAL)
APPROX
R
z_0

$$\ldots + dz^2 + dx_1^2 + dx_2^2 + dx_3^2)$$



• INDUCED METRIC

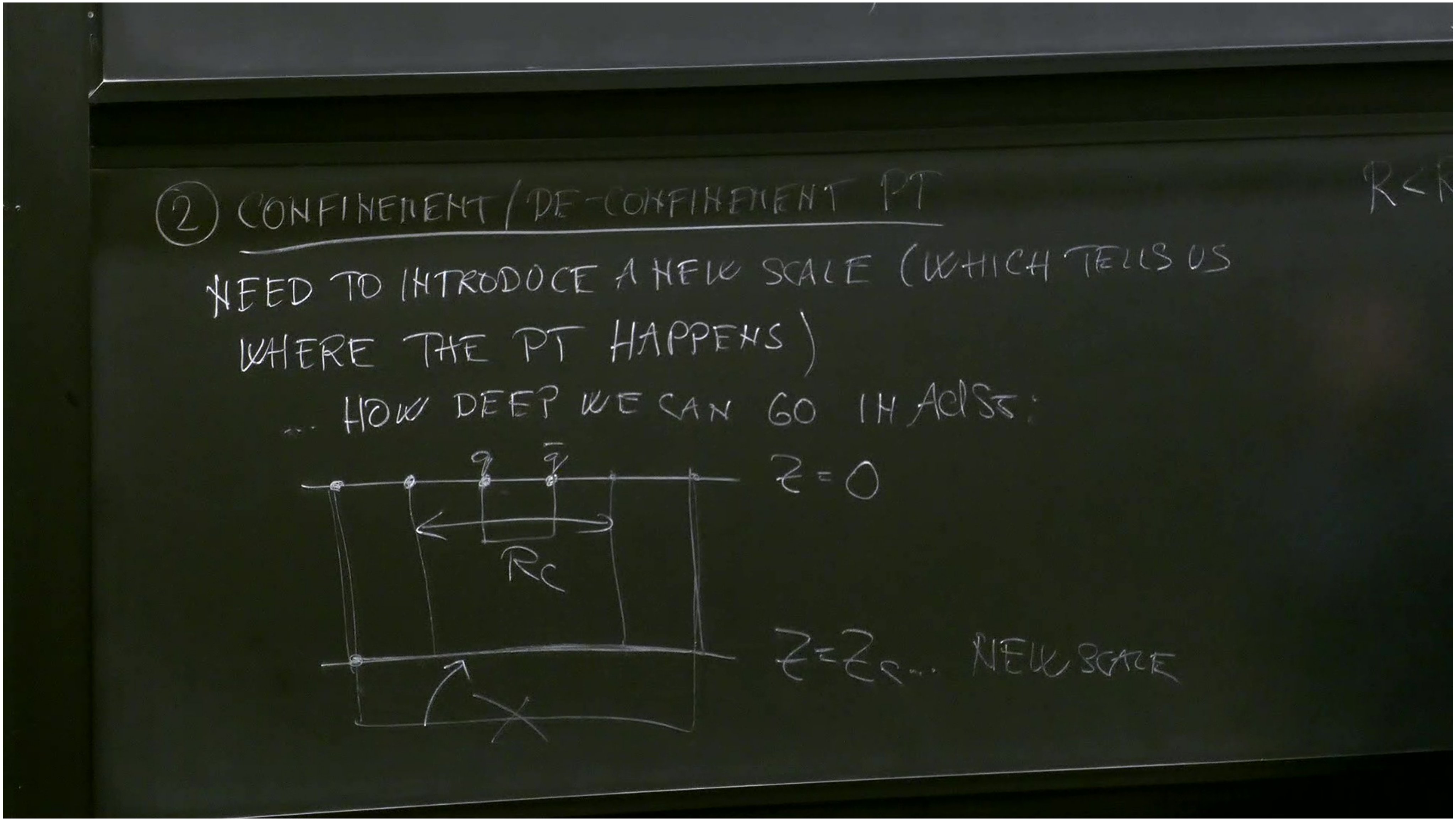
$$dg^2 = \frac{\ell^2}{z^2}\left(d\tau^2 + dx_1^2\right)$$

$$\sqrt{\det g} = \frac{\ell^2}{z^2} = \frac{\ell^2}{z_0^2}$$

$$S_{NG} \propto \frac{1}{\ell_s^2}\frac{\ell^2}{z_0^2}\underbrace{\int d\tau\, dx}_{TR} = \underbrace{\frac{\ell^2}{\ell_s^2}}_{\sqrt{\lambda}}\frac{TR}{R^2} \sim \frac{\sqrt{\lambda}\,T}{R}$$

$$\Rightarrow \boxed{V(R) \sim \frac{\sqrt{\lambda}}{R}}$$ ← STRONG COUPLING

UNCONFINED PHASE


② CONFINEMENT / DE-CONFINEMENT PT
NEED TO INTRODUCE A NEW SCALE (WHICH TELLS US
WHERE THE PT HAPPENS)
... HOW DEEP WE CAN GO IN AdS5:
q $\bar{q}$
$z = 0$
R_c
$z = z_c$ ... NEW SCALE
R<

- $R < R_c$ ... SITUATION AS BEFORE ... UNCONFINED PHASE $V \sim \frac{1}{R}$
- $R > R_c$ DEEPEST WE CAN GO IS $z = z_c$.

$$\sqrt{\det \gamma} = \frac{\ell^2}{z_c^2}$$

$$S_{NG} \propto \frac{1}{\ell_s^2} \frac{\ell^2}{z_c^2} \int d\tau \, dx_1 \sim \frac{\ell^2}{\ell_s^2} \frac{RT}{z_c^2} \sim \sqrt{\lambda} \frac{RT}{z_c^2}$$

$$\boxed{V \sim \sqrt{\lambda} R}$$ ... CONFINED PHASE !

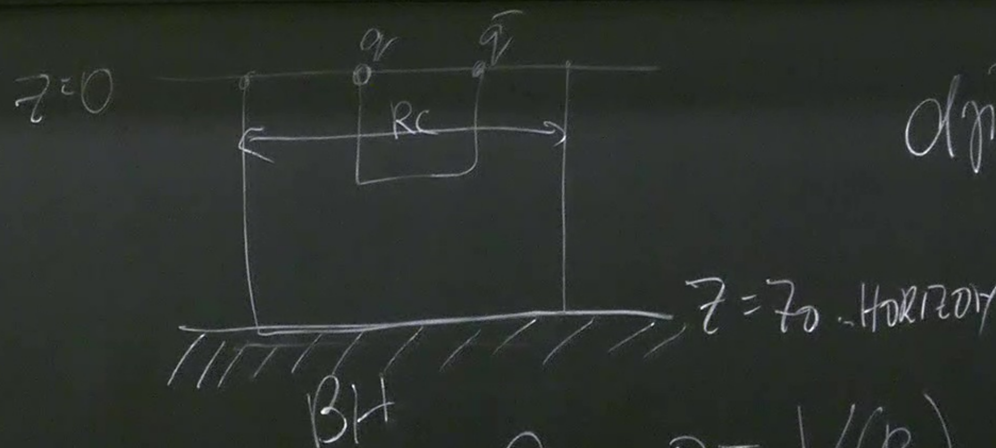
③ FINITE TEMP: PLASMA PHASE:

BH IN THE BULK GIVES CFT A FINITE TEMPERATURE $T = T_H$

$$ds^2_{AdS_5\,BH} = \frac{\ell^2}{z^2}\left(f\,d\tau^2 + \frac{dz^2}{f} + dx_1^2 + dx_2^2 + dx_3^2\right)$$

$$f = 1 - \left(\frac{z}{z_0}\right)^4$$ ← BLACKENING FACTOR

$$f\big|_{HOR} = 0$$



$$ds^2 = \frac{\ell^2}{z^2}\left(f\,d\tau + dx_1^2\right)$$

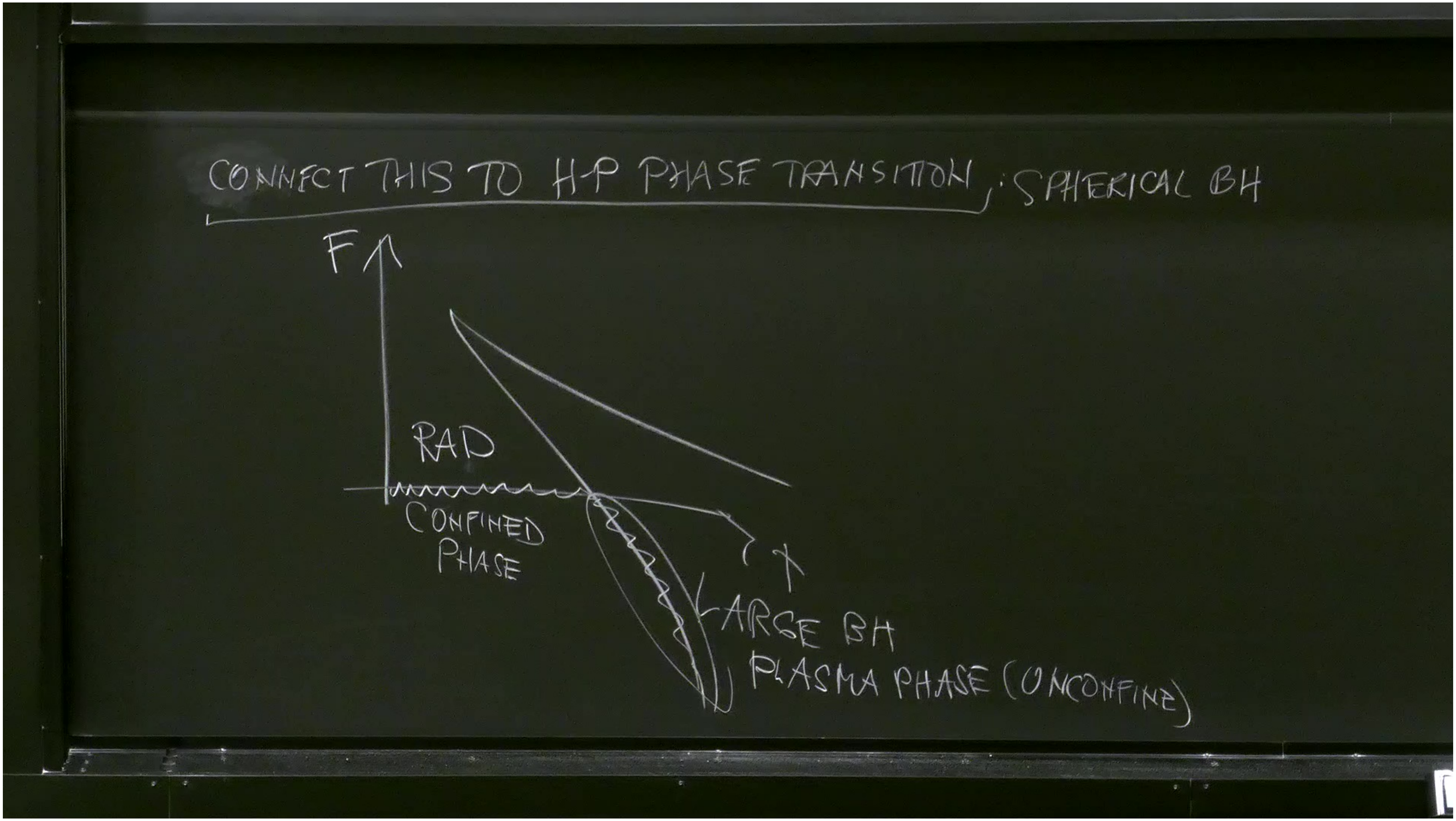
$$\sqrt{\det g} = \frac{\ell^2}{z^2}\sqrt{f} = 0$$

ON HORIZON

$$\Rightarrow S_{NG} = 0 = V(R)$$

DEBYE SCREENING ... STANDARD IN PLASMA

$= 0$


CONNECT THIS TO H-P PHASE TRANSITION, : SPHERICAL BH
F
RAD
CONFINED PHASE
T
LARGE BH
PLASMA PHASE (UNCONFINE)

(3) FINITE TEMP: PLASMA PHASE.

BH IN THE BULK GIVES CFT A FINITE TEMPERATURE $T = T_H$

$$ds^2_{AdS_5\,BH} = \frac{\ell^2}{z^2}\left(-f\,d\tau^2 + \frac{dz^2}{f} + dx_1^2 + dx_2^2 + dx_3^2\right)$$

$$f = 1 - \left(\frac{z}{z_0}\right)^4$$

BLACKENING FACTOR

$$f\big|_{HOR} = 0$$