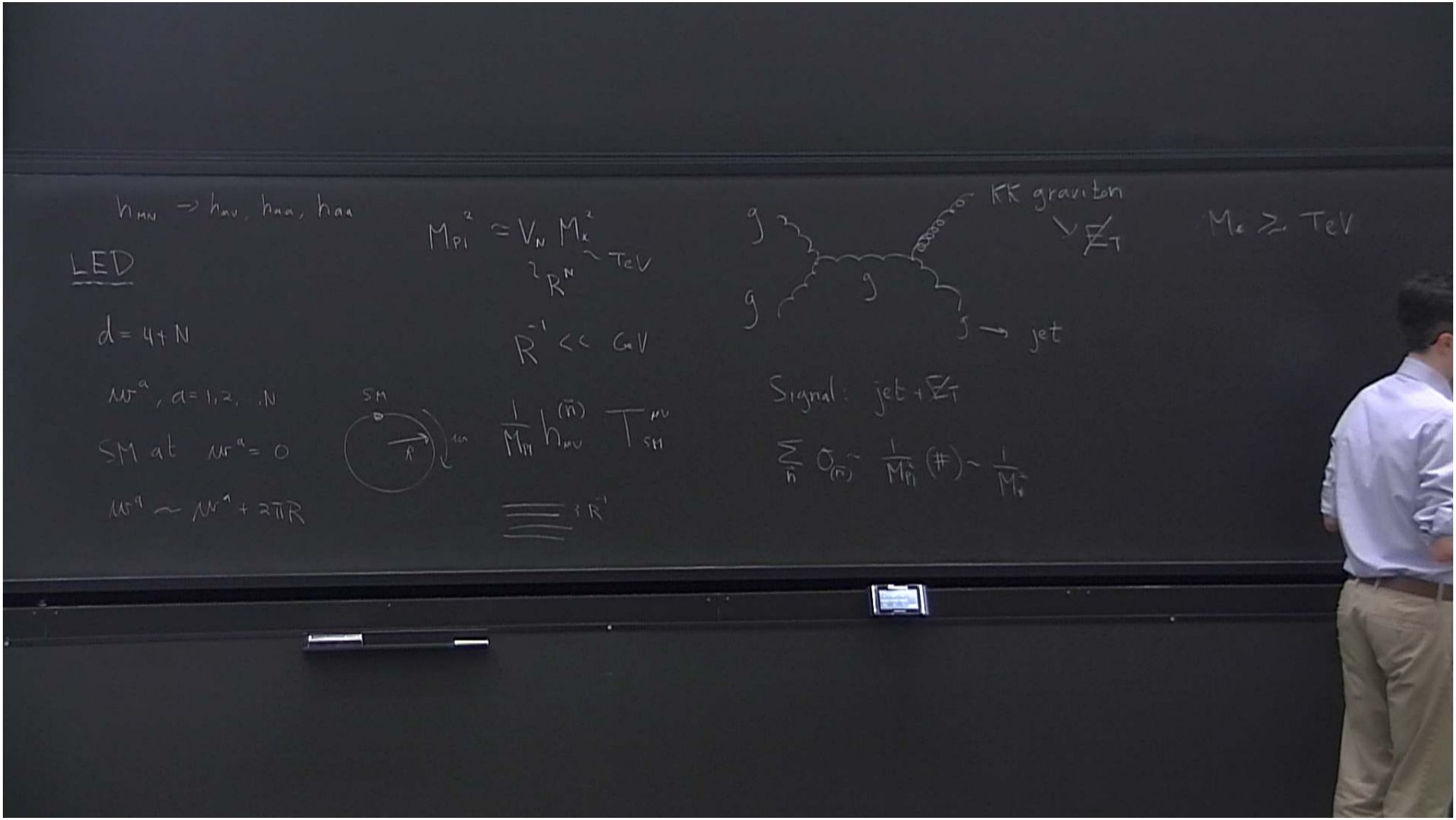
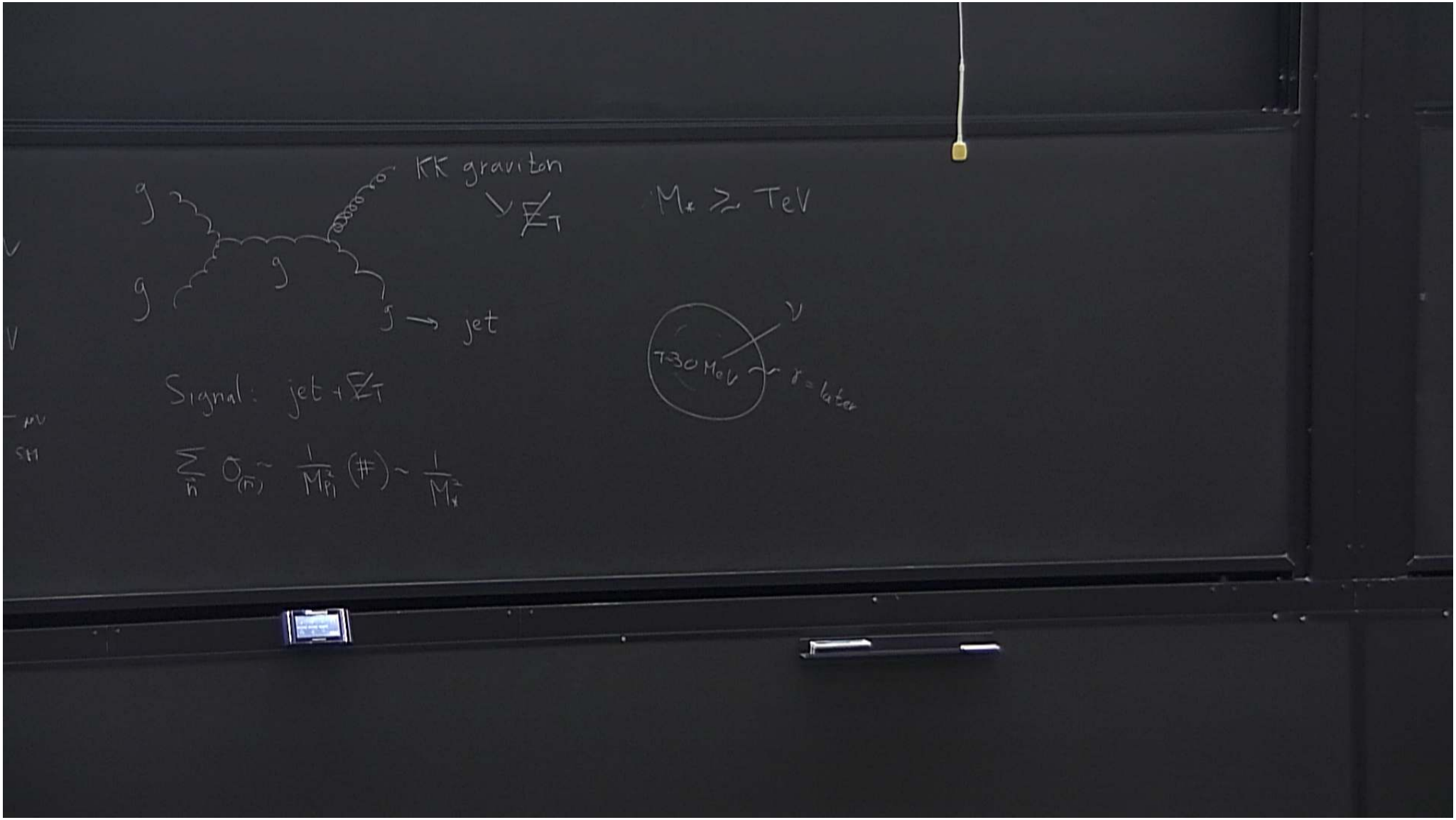
Title: PSI 2015/2016 More/Beyond Standard Model - Lecture 14

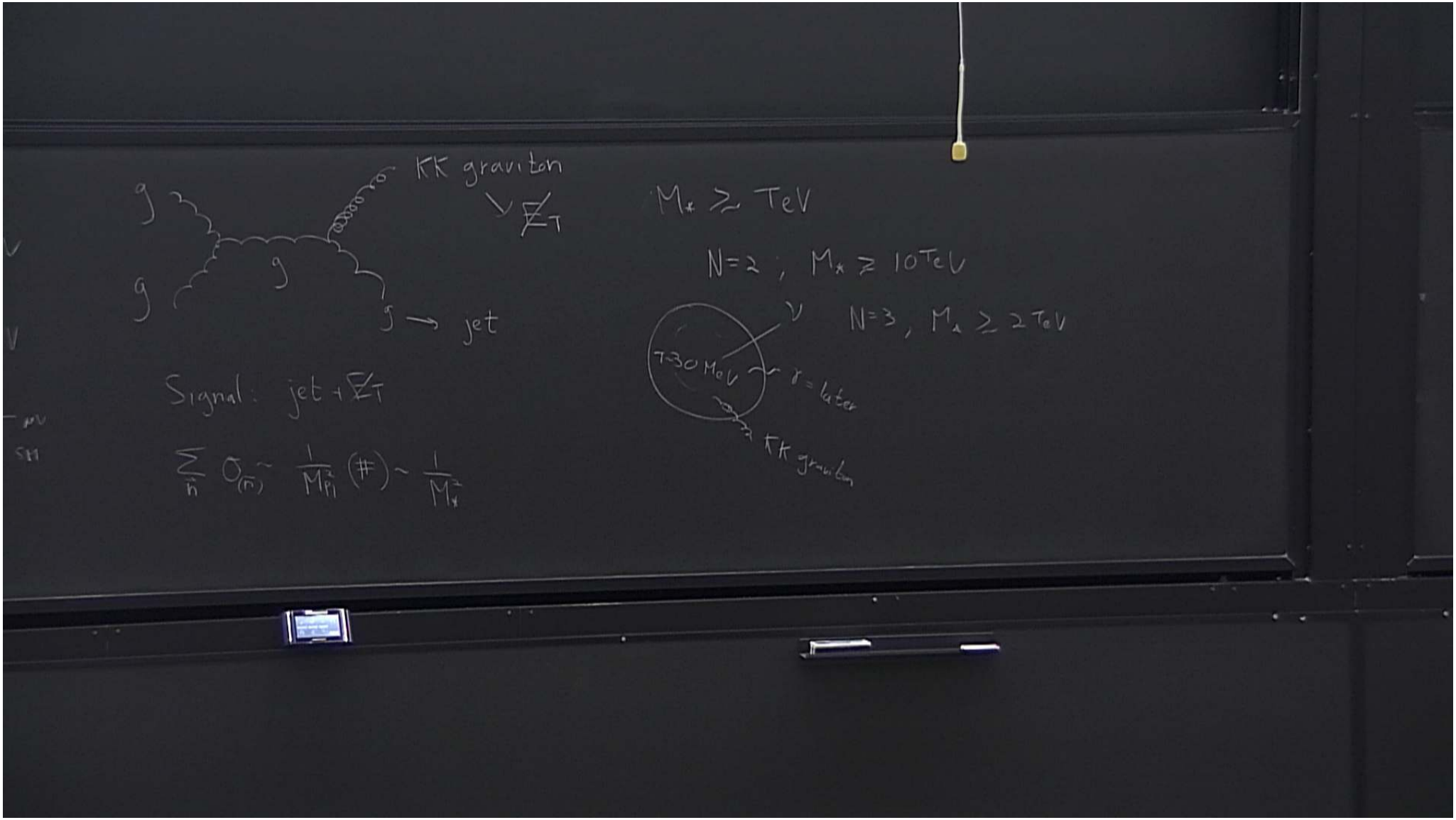
Date: Mar 10, 2016 09:00 AM

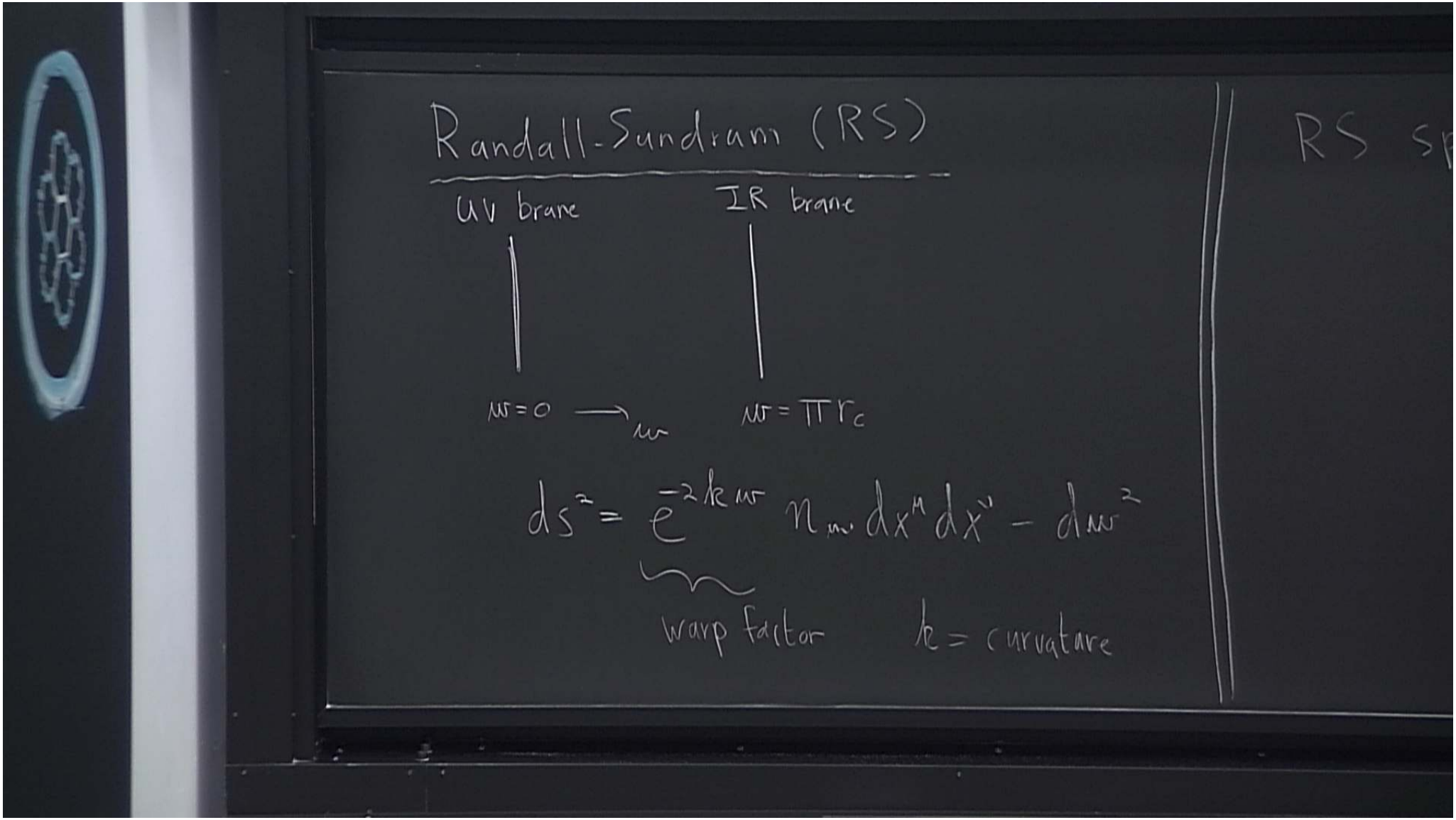
URL: http://pirsa.org/16030043

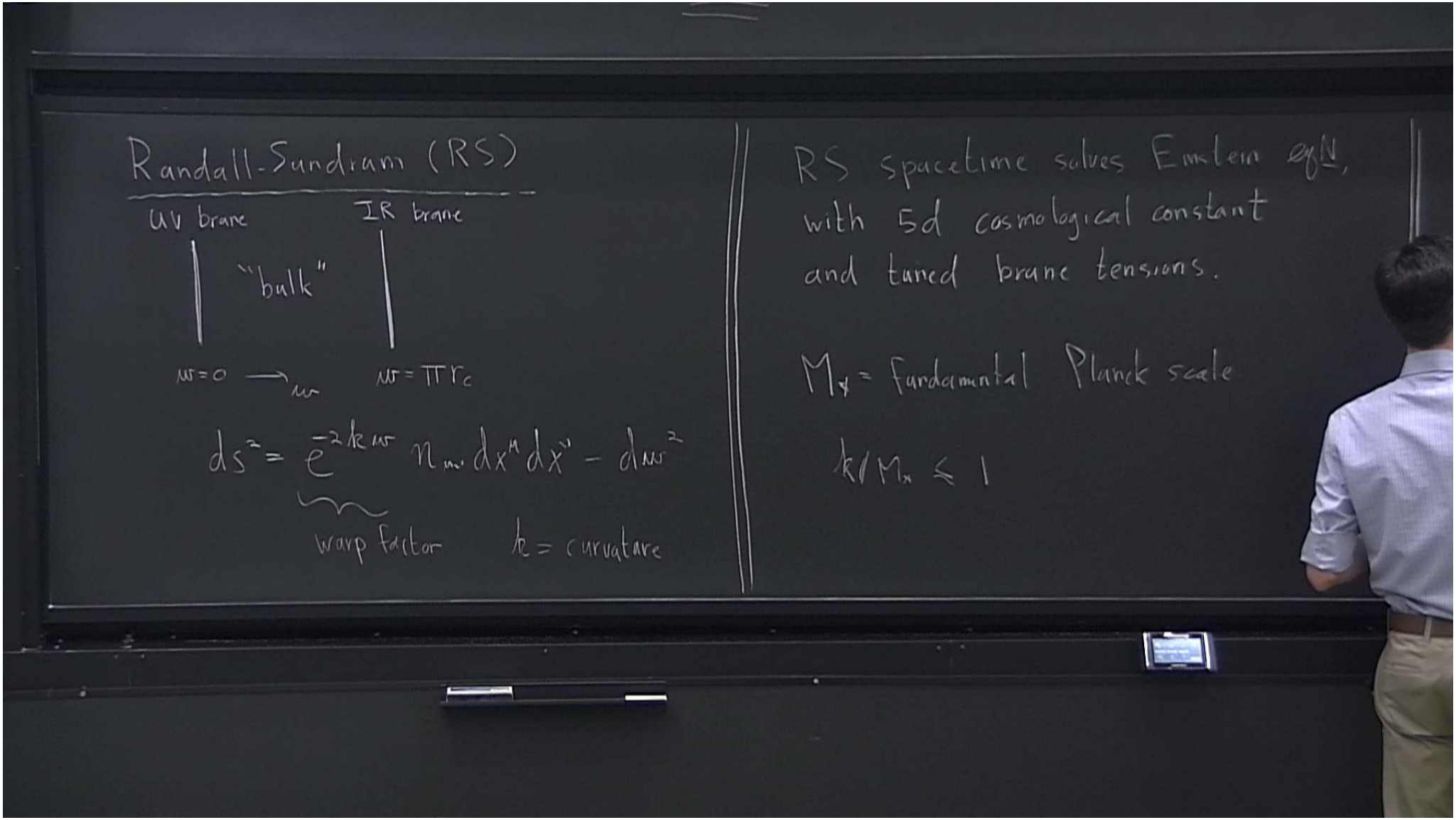
Abstract:

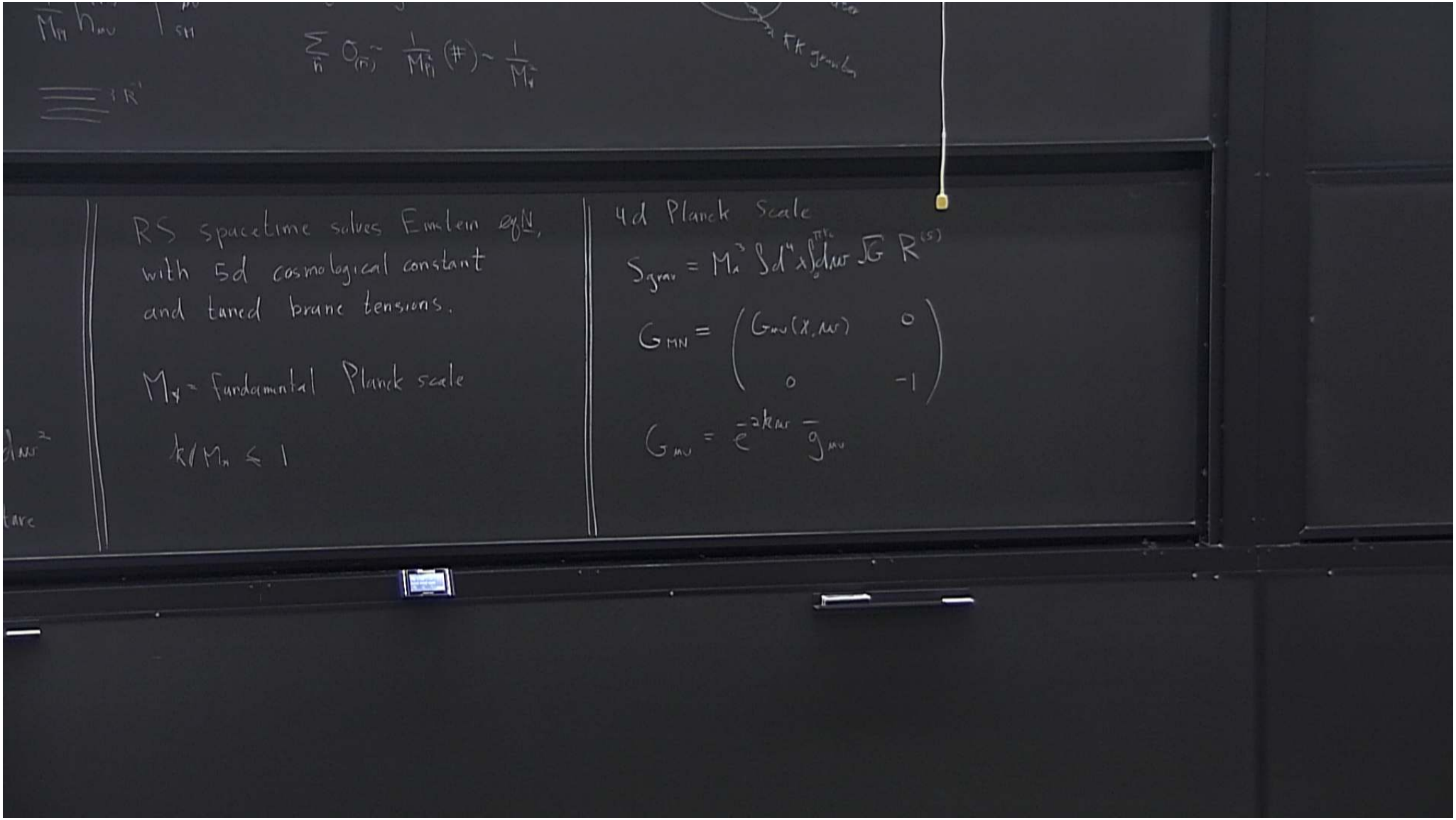

$h_{MN} \to h_{\mu\nu}, h_{\mu a}, h_{ab}$
LED
$d = 4 + N$
$M_{Pl}^2 \simeq V_N M_*^{2+N}$
$\sim$ TeV
$R^{-1} \ll$ GeV
x^a, $a = 1, 2, .N$
SM at $x^a = 0$
$x^a \sim x^a + 2\pi R$
SM
R
$\frac{1}{M_{Pl}} h_{\mu\nu}^{(\vec{n})} T_{SM}^{\mu\nu}$
$\equiv R^{-1}$
g
g
g
g
KK graviton
$\not{E}_T$
jet
Signal: jet + $\not{E}_T$
$\sum_{\vec{n}} O_{(\vec{n})} \sim \frac{1}{M_{Pl}^2} (\#) \sim \frac{1}{M_*^2}$
$M_* \gtrsim$ TeV


g
g
g
g
KK graviton
$\not{E}_T$
$M_* \gtrsim$ TeV
jet
Signal: jet + $\not{E}_T$
$\sum_n \sigma_{(n)} \sim \frac{1}{M_{Pl}^2}(\#) \sim \frac{1}{M_*^2}$
T=30 MeV
γ = later


g
g
g
KK graviton
$\not{E}_T$
g → jet
Signal: jet + $\not{E}_T$
$\sum_n \sigma_{(n)} \sim \frac{1}{M_{Pl}^2}(\#) \sim \frac{1}{M_*^2}$
$M_* \gtrsim$ TeV
N=2, $M_* \gtrsim$ 10 TeV
N=3, $M_* \gtrsim$ 2 TeV
T=30 MeV
ν
γ = later
KK graviton


Randall-Sundrum (RS)
UV brane
IR brane
$r = 0$
$r = \pi r_c$
$ds^2 = e^{-2kr} \eta_{\mu\nu} dx^\mu dx^\nu - dr^2$
warp factor
k = curvature
RS


Randall-Sundrum (RS)
UV brane
IR brane
"bulk"
$w = 0$
$w = \pi r_c$
$ds^2 = e^{-2k|w|} \eta_{\mu\nu} dx^\mu dx^\nu - dw^2$
warp factor
k = curvature
RS spacetime solves Einstein eqn.
with 5d cosmological constant
and tuned brane tensions.
M_* = fundamental Planck scale
$k/M_* \lesssim 1$


RS spacetime solves Einstein eqn,
with 5d cosmological constant
and tuned brane tensions.
M_5 = fundamental Planck scale
$k/M_5 \lesssim 1$
4d Planck Scale
$S_{grav} = M_5^3 \int d^4x \int dy \sqrt{G}\, R^{(5)}$
$G_{MN} = \begin{pmatrix} G_{\mu\nu}(x,y) & 0 \\ 0 & -1 \end{pmatrix}$
$G_{\mu\nu} = e^{-2ky} g_{\mu\nu}$

RS spacetime solves Einstein eq^{n}, with 5d cosmological constant and tuned brane tensions.

M_* = fundamental Planck scale

$k/M_* \lesssim 1$

4d Planck Scale

$$S_{grav} = M_*^3 \int d^4x \int_0^{\pi r_c} dy \sqrt{G}\, R^{(5)} = \frac{M_*^3}{2k}\left(1 - e^{-2\pi k r_c}\right) \int d^4x \sqrt{\bar{g}}\, \bar{R}^{(4)}$$

$$G_{MN} = \begin{pmatrix} G_{\mu\nu}(x, y) & 0 \\ 0 & -1 \end{pmatrix}$$

$$G_{\mu\nu} = e^{-2k|y|}\, \bar{g}_{\mu\nu}(x)$$

$$\sqrt{G}\, R^{(5)} = \sqrt{-\bar{g}}\, \bar{R}^{(4)} e^{-2k|y|}$$

RS spacetime solves Einstein eq^N, with 5d cosmological constant and tuned brane tensions.

M_* = fundamental Planck scale

$k/M_* \lesssim 1$

4d Planck Scale

$$S_{grav} = M_*^3 \int d^4x \int_0^{\pi r_c} d\varphi \sqrt{G}\, R^{(5)} =$$

$$\underbrace{\frac{M_*^3}{2k}\left(1 - e^{-2\pi k r_c}\right)}_{\frac{M_{Pl}^2}{2}} \underbrace{\int d^4x \sqrt{\bar{g}}\, \bar{R}^{(4)}}_{\text{4d-EH}}$$

$$G_{MN} = \begin{pmatrix} G_{\mu\nu}(x,\varphi) & 0 \\ 0 & -1 \end{pmatrix}$$

$$G_{\mu\nu} = e^{-2k|\varphi|}\, \bar{g}_{\mu\nu}(x)$$

$$\sqrt{G}\, R^{(5)} = \sqrt{-\bar{g}}\, \bar{R}^{(4)} e^{-2k|\varphi|}$$

$$M_{Pl}^2 = \frac{M_*^3}{k}\left(1 - e^{-2\pi k r_c}\right) \approx 2.4 \times 10^{18}\ \text{GeV}$$

(exp. negl. globally)

$w = 0 \longrightarrow w \qquad w = \pi r_c$

$$ds^2 = \underbrace{e^{-2kw}}_{\text{warp factor}} \eta_{\mu\nu} dx^\mu dx^\nu - dw^2$$

k = curvature

M_* = fundamental Planck scale

$k/M_* \lesssim 1$

$$G_{MN} = \begin{pmatrix} \ldots & \\ 0 & -1 \end{pmatrix}$$

$$G_{\mu\nu} = e^{-2kw}\, \bar{g}_{\mu\nu}(x)$$

$$\sqrt{G}\, R^{(5)} = \sqrt{-\bar{g}}\, \bar{R}^{(4)} e^{-2kw}$$

$M_{Pl}^2 =$

Warping and the Higgs

H = Higgs field, on IR brane

$$G = \det(G_{MN}) = \left(e^{-2kw}\right)^4 \cdot 1 \,, \quad G^{\mu\nu} = e^{+2kw} \eta^{\mu\nu} dx_\mu dx_\nu - dw^2$$

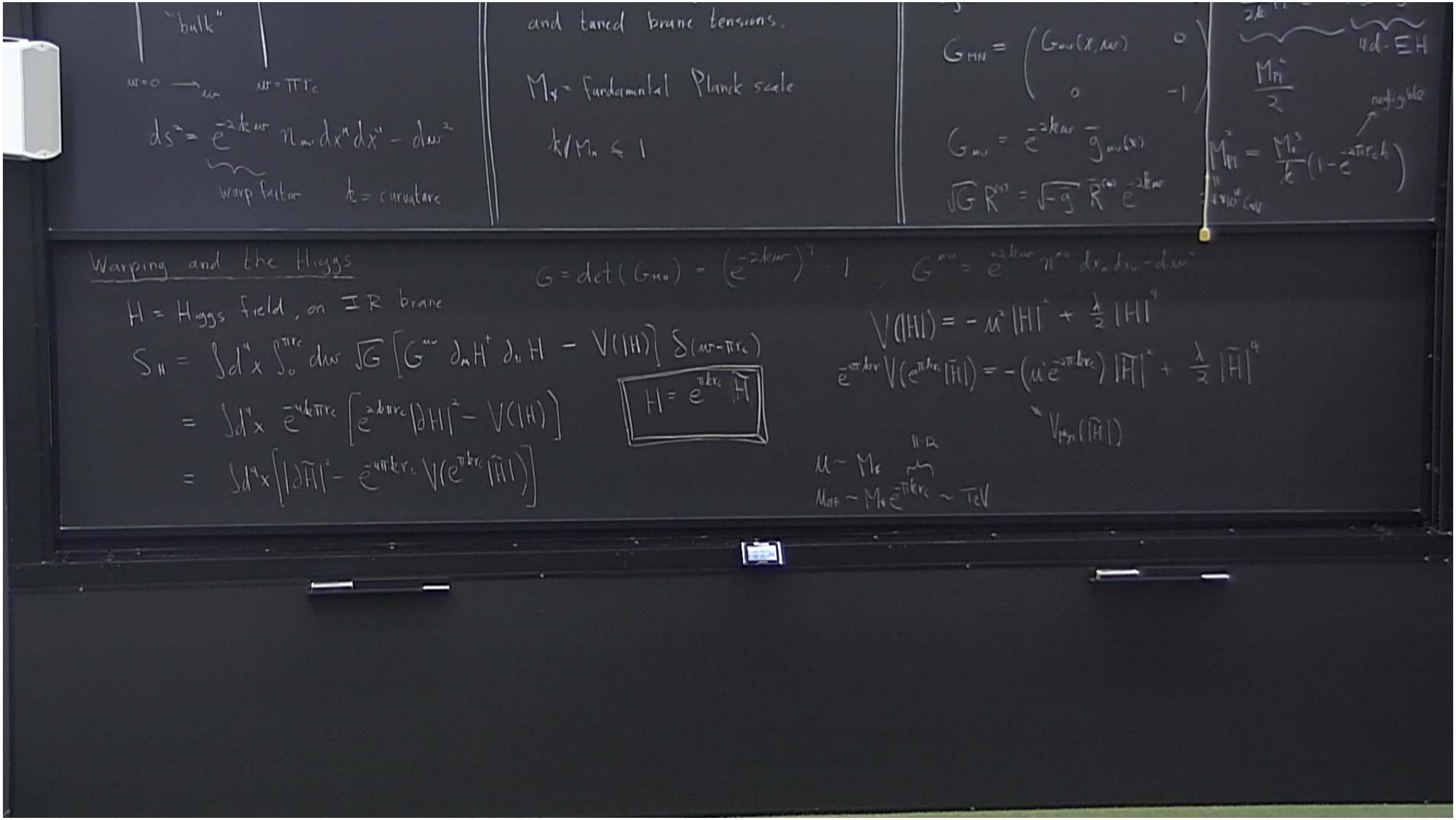
$$V(|H|) = -\mu^2 |H|^2 + \frac{\lambda}{2} |H|^4$$

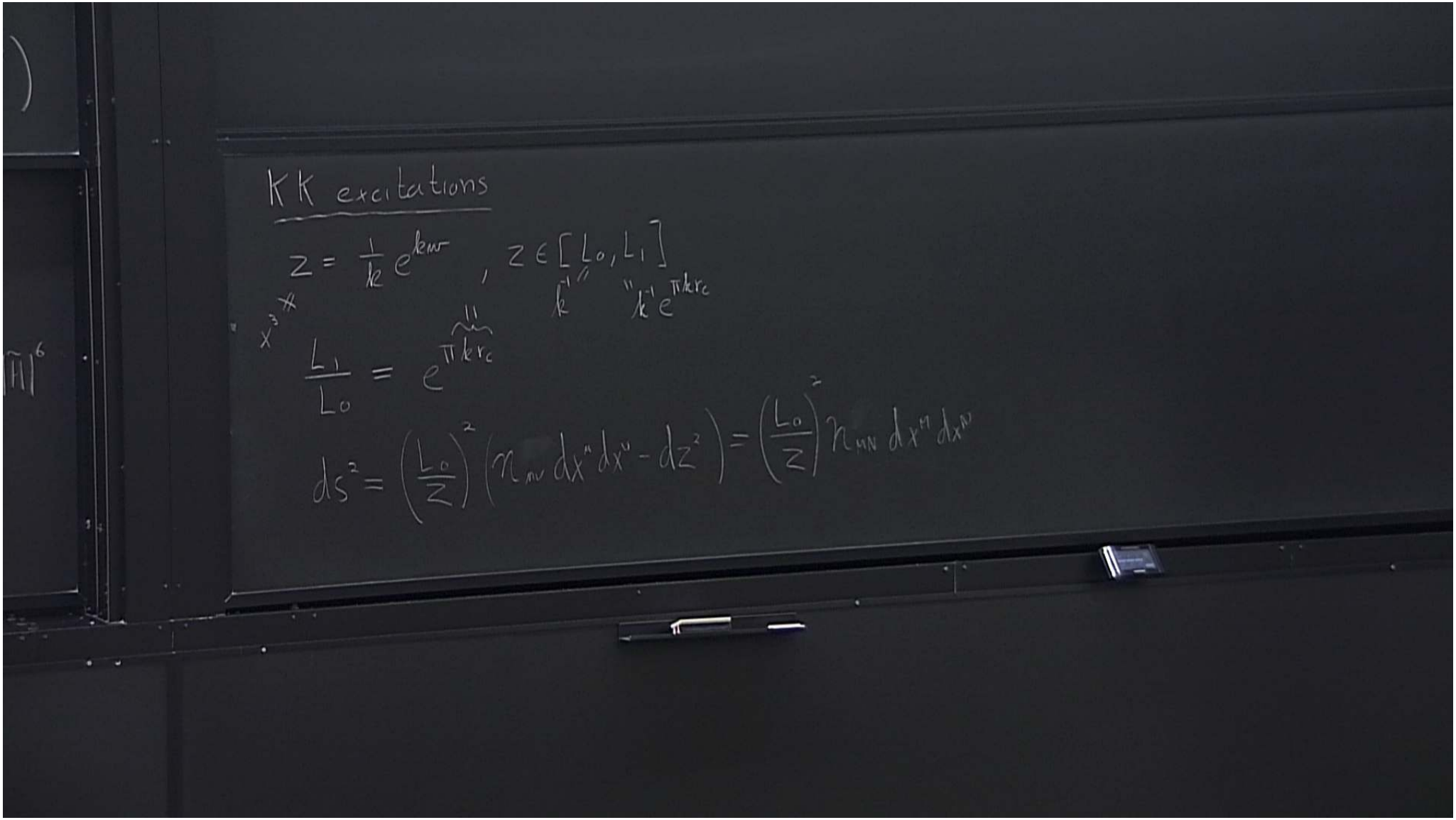
$$S_H = \int d^4x \int_0^{\pi r_c} dw \sqrt{G} \left[G^{\mu\nu} \partial_\mu H^\dagger \partial_\nu H - V(|H|) \right] \delta(w - \pi r_c)$$

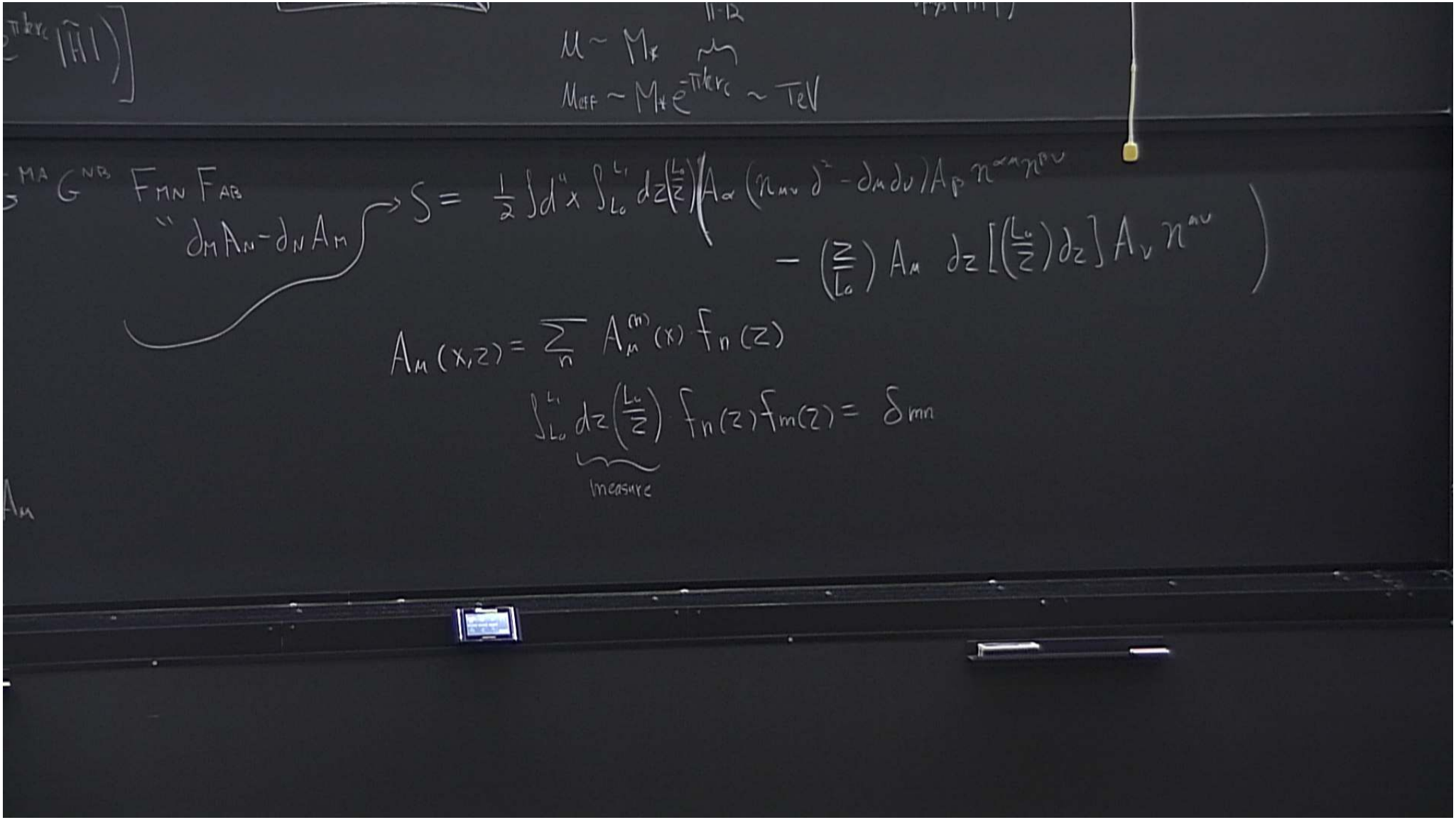
$$= \int d^4x\, e^{-4k\pi r_c} \left[e^{2k\pi r_c} |\partial H|^2 - V(|H|) \right]$$

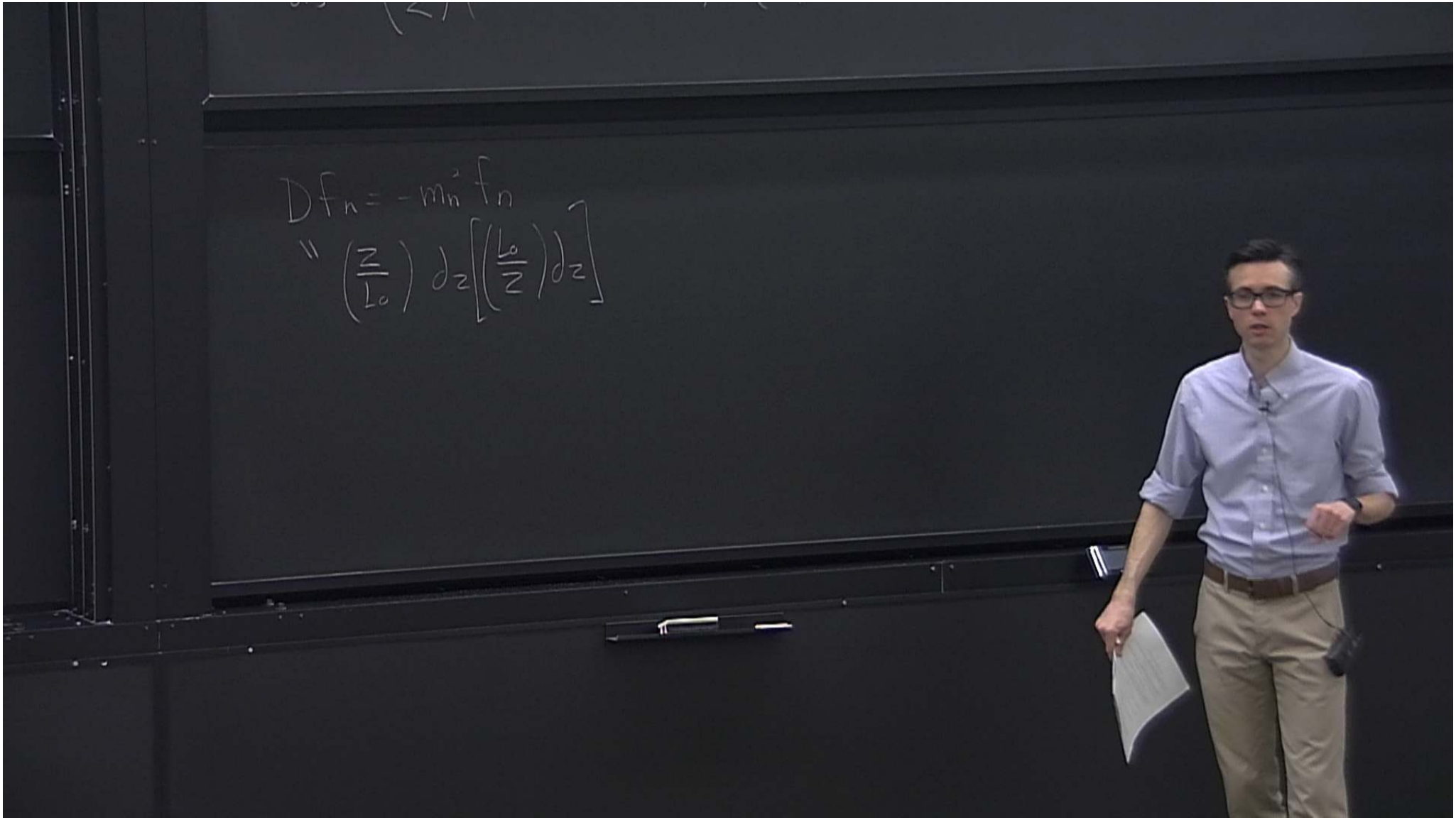
$$\boxed{H = e^{\pi k r_c} \tilde{H}}$$

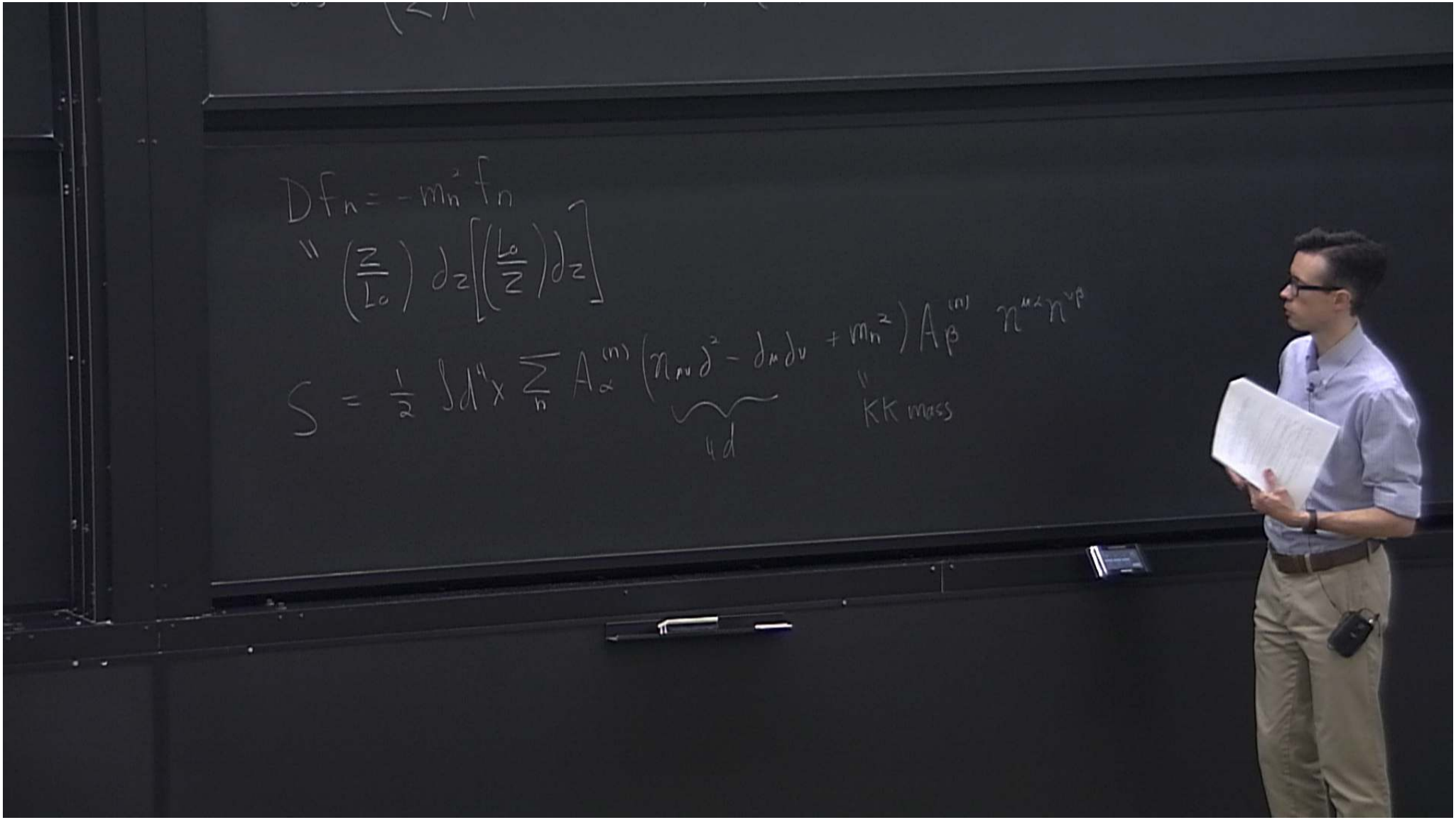
$$= \int d^4x \left[|\partial \tilde{H}|^2 - e^{-4\pi k r_c} V\left(e^{\pi k r_c} |\tilde{H}|\right) \right]$$


"bulk"
$y=0$
$y=\pi r_c$
$ds^2 = e^{-2k|y|}\eta_{\mu\nu}dx^\mu dx^\nu - dy^2$
warp factor
k = curvature
and tuned brane tensions.
M_5 = fundamental Planck scale
$k/M_5 \lesssim 1$
$G_{MN} = \begin{pmatrix} G_{\mu\nu}(x,y) & 0 \\ 0 & -1 \end{pmatrix}$
$G_{\mu\nu} = e^{-2k|y|}\bar{g}_{\mu\nu}(x)$
$\sqrt{G}R^{(5)} = \sqrt{-\bar{g}}\bar{R}^{(4)}e^{-2k|y|}$
$\frac{M_{Pl}^2}{2}$
$M_{Pl}^2 = \frac{M_5^3}{k}(1-e^{-2\pi r_c k})$
negligible
Warping and the Higgs
H = Higgs field, on IR brane
$G = \det(G_{MN}) = (e^{-2k|y|})^4 = 1$, $G^{MN} = e^{+2k|y|}\eta^{\mu\nu}dx_\mu dx_\nu - dy^2$
$S_H = \int d^4x \int_0^{\pi r_c} dy \sqrt{G}\left[G^{\mu\nu}\partial_\mu H^\dagger \partial_\nu H - V(|H|)\right]\delta(y-\pi r_c)$
$= \int d^4x\, e^{-4k\pi r_c}\left[e^{2k\pi r_c}|\partial H|^2 - V(|H|)\right]$
$= \int d^4x\left[|\partial\tilde{H}|^2 - e^{-4k\pi r_c}V(e^{\pi k r_c}|\tilde{H}|)\right]$
$H = e^{\pi k r_c}\tilde{H}$
$V(|H|) = -\mu^2|H|^2 + \frac{\lambda}{2}|H|^4$
$e^{-4\pi k r_c}V(e^{\pi k r_c}|\tilde{H}|) = -(\mu^2 e^{-2\pi k r_c})|\tilde{H}|^2 + \frac{\lambda}{2}|\tilde{H}|^4$
$V_{new}(|\tilde{H}|)$
$\mu \sim M_5$
$M_{eff} \sim M_5 e^{-\pi k r_c} \sim$ TeV


KK excitations
$z = \frac{1}{k} e^{k x^3}$, $z \in [L_0, L_1]$
k^{-1} $k^{-1} e^{\pi k r_c}$
$\frac{L_1}{L_0} = e^{\pi k r_c}$
$ds^2 = \left(\frac{L_0}{z}\right)^2 (\eta_{\mu\nu} dx^\mu dx^\nu - dz^2) = \left(\frac{L_0}{z}\right)^2 \eta_{\mu\nu} dx^\mu dx^\nu$


$M \sim M_*$
$M_{eff} \sim M_* e^{-\pi k r_c} \sim TeV$
$F_{MN} F_{AB}$
$\partial_M A_N - \partial_N A_M$
$S = \frac{1}{2} \int d^4x \int_{L_0}^{L_1} dz \left(\frac{L_0}{z}\right) \left(A_\alpha (\eta_{\mu\nu} \partial^2 - \partial_\mu \partial_\nu) A_\beta \eta^{\alpha\mu} \eta^{\beta\nu} - \left(\frac{z}{L_0}\right) A_M \partial_z \left[\left(\frac{L_0}{z}\right) \partial_z\right] A_\nu \eta^{\mu\nu} \right)$
$A_M(x,z) = \sum_n A_M^{(n)}(x) f_n(z)$
$\int_{L_0}^{L_1} dz \left(\frac{L_0}{z}\right) f_n(z) f_m(z) = \delta_{mn}$
measure
A_M


$Df_n = -m_n^2 f_n$
$= \left(\frac{z}{L_0}\right) \partial_z \left[\left(\frac{L_0}{z}\right) \partial_z\right]$


$Df_n = -m_n^2 f_n$
$= \left(\frac{z}{L_0}\right) \partial_z \left[\left(\frac{L_0}{z}\right) \partial_z\right]$
$S = \frac{1}{2} \int d^4x \sum_n A_\alpha^{(n)} \left(\eta_{\alpha\nu} \partial^2 - \partial_\mu \partial_\nu + m_n^2\right) A_\beta^{(n)} \eta^{\mu\alpha} \eta^{\nu\beta}$
4d
KK mass