

1. SUMMARY

Glueball decay rates calculable in the Witten-Sakai-Sugimoto model, a top-down holographic model of (nonsupersymmetric, nonconformal) QCD

- Prediction for decay pattern of a pseudovector $J^{PC} = 1^{+-}$ glueball, the lightest glueball with spin different from 2 or 0
- Glueball is dual to string-theoretic Kalb-Ramond field, couplings fixed by gauge invariance and D-Brane anomaly inflow
- Chern-Simons-like action determines dominant decay channels

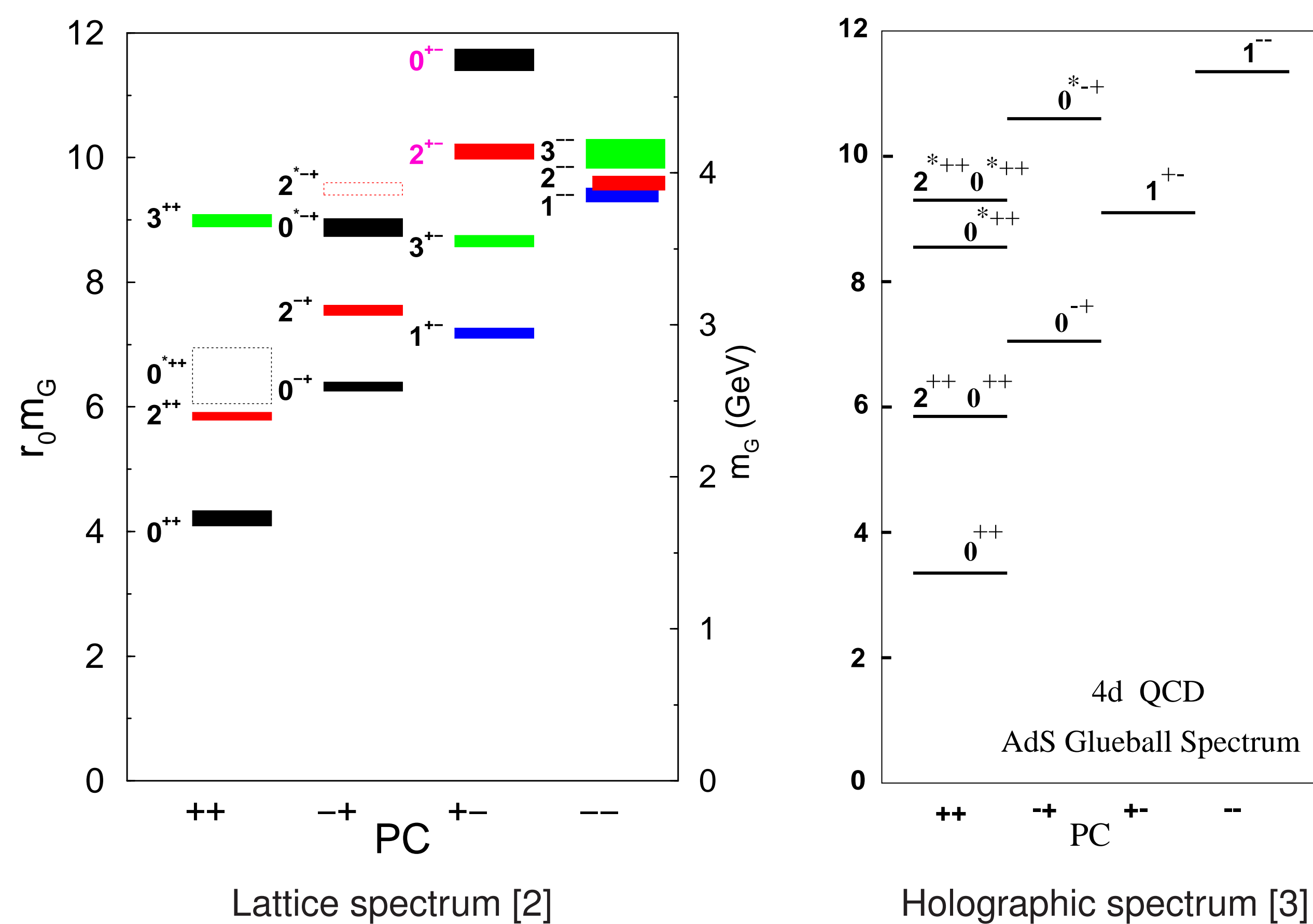
2. HOLOGRAPHIC GLOBE BALLS

Witten's IIA model [1]: holographic dual of five-dimensional large- N super-YM theory, supersymmetry broken by compactification $x^4 \simeq x^4 + 2\pi/M_{KK}$ → effective pure-gluon 4D Yang-Mills below Kaluza-Klein scale M_{KK} (gluinos get Masubara-like masses; adjoint scalars become massive through loop corrections)

- Background geometry:

$$ds^2 = \frac{r^2}{L^2} (f(r)dx_4^2 + \eta_{\mu\nu}dx^\mu dx^\nu + dx_{11}^2) + \frac{L^2}{r^2} \frac{dr^2}{f(r)} + \frac{L^2}{4} d\Omega_4^2$$

- Glueballs: dual to gravitational fluctuations of this background
- Spectrum: solutions of the linearized Einstein equations for various polarizations (irreducible representations of $SO(4)$)
- Good qualitative agreement with lattice QCD



3. KALB-RAMOND GLOBE BALL

- $J^{PC} = 1^{+-}$ glueball with polarization ε_ρ is dual to $B_{\mu\nu}$ field fluctuation

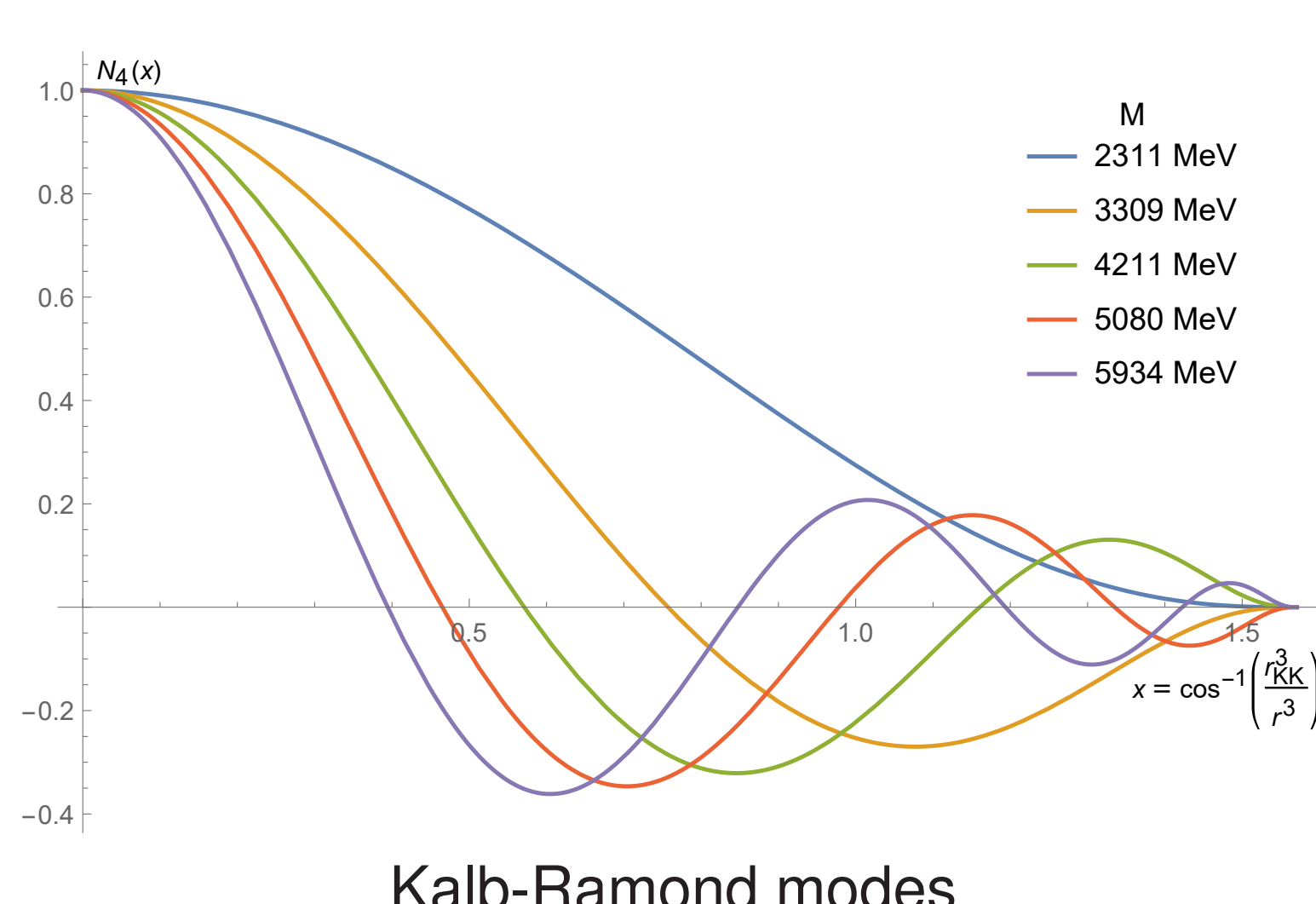
$$\delta B_{\mu\nu} = r^3 N_4(r) \tilde{B}_{\mu\nu} = \frac{r^3}{M} N_4(r) \eta^{\lambda\rho} \eta^{\kappa\sigma} \varepsilon_{\mu\nu\lambda\kappa} \varepsilon_\rho \partial_\sigma \tilde{V}^{(\varepsilon)}(x^\alpha)$$

- Holographic mode satisfies differential equation

$$\frac{d}{dr} r(r^6 - r_{KK}^6) \frac{d}{dr} N_4(r) - (L^4 M^2 r^3 - 27r^5 + \frac{9r_{KK}^6}{r}) N_4(r) = 0$$

- Modes are normalizable for discrete mass spectrum with mass gap

- First mode has the mass $M \approx 2311$ MeV and is the lightest glueball with spin different from 2 or 0



- Canonical normalization of $\tilde{V}^{(\varepsilon)}$ for

$$N_4(r_{KK})^{-1} = 0.00983838 L^3 \lambda^{\frac{1}{2}} N_c M_{KK}$$

4. HOLOGRAPHIC MESONS

Sakai-Sugimoto model [4]: Massless quarks introduced by embedding N_f probe $D8 - \bar{D}8$ -brane pairs in the background above

- Geometric realization of chiral symmetry and its breaking

$$SU(N_f)_L \times SU(N_f)_R \rightarrow SU(N_f)_V$$

- Mesons as gauge fields on flavor branes: massless pions and massive tower of vector- and axial-vector mesons

- Low energy meson action from Dirac-Born-Infeld and Chern-Simons action for D8-branes:

$$S_{DBI} = -T_{D8} \text{STr} \int d^9 x e^{-\Phi} \sqrt{-\det(g_{MN} + B_{MN} + 2\pi\alpha' F_{MN})}$$

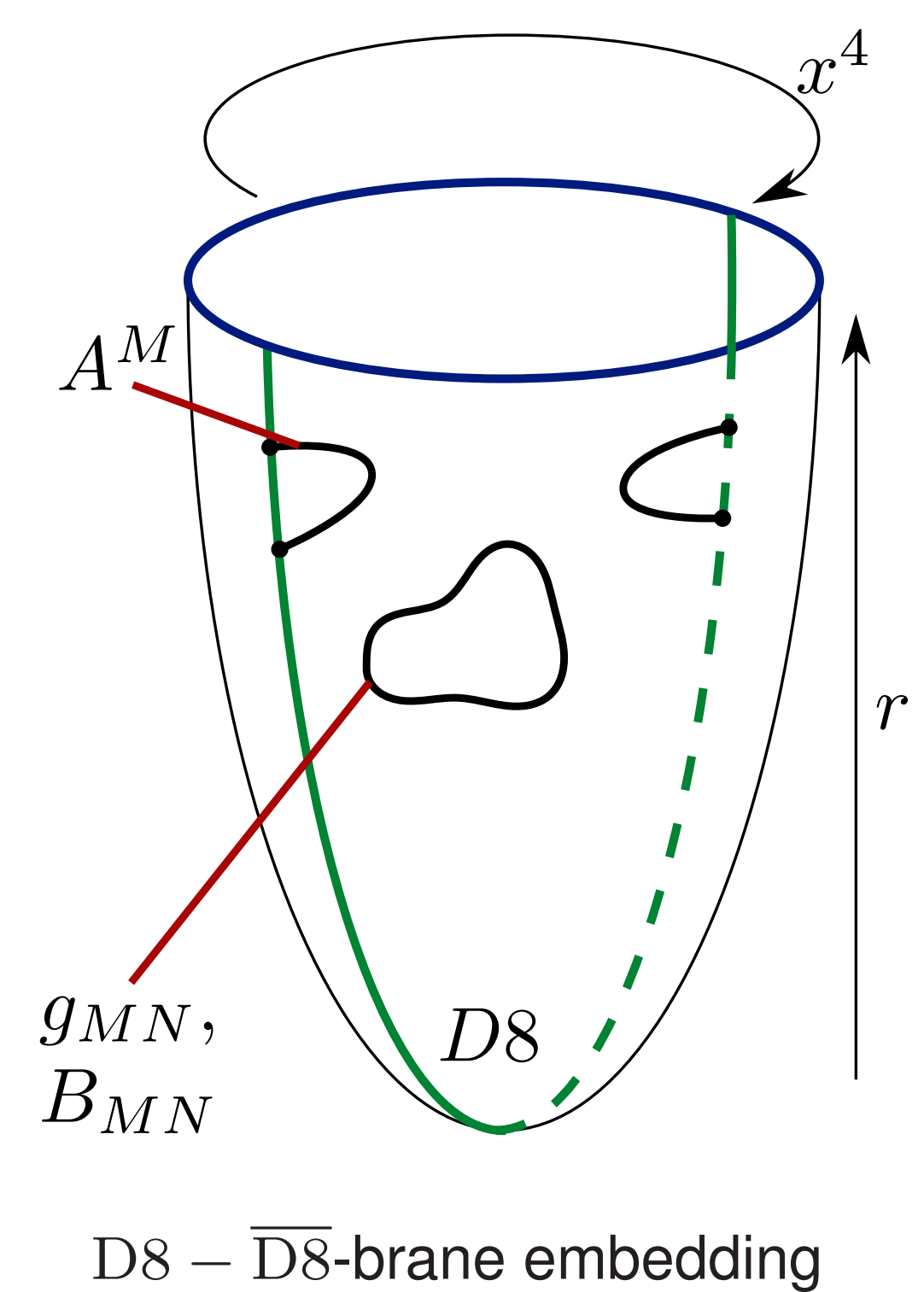
$$S_{CS} = T_{D8} \text{Tr} \int \left[\exp(2\pi\alpha' F_2 + B_2) \wedge \sum_q C_q \right]$$

- Only two parameters as input:

$m_\rho = 776$ MeV and $f_\pi = 92.4$ MeV or large- N lattice string tension fix

$$M_{KK} \approx 949 \text{ MeV}, \quad \lambda \equiv g^2 N \approx 16.63 \dots 12.55$$

- Background fluctuation introduce **glueball-meson interactions**



5. RESULTS FOR GLOBE BALL DECAY RATES

- Decay rate and pattern of dilatonic scalar glueball matches experimental data on $f_0(1710)$ meson [5]
- Tensor glueball rather broad $\Gamma/M_T \sim 0.4 - 0.6$ when extrapolated to $M_T \sim 2.4$ GeV from lattice QCD [6]
- Pseudoscalar glueball (C_1 RR-field) very narrow [7]

New results for pseudovector glueball [8]:

- Chern-Simons action contains dominant vertices for decay of **pseudovector glueball** into 2 and 3 **pseudoscalar/vector** mesons

$$\mathcal{L}_{4,\text{int}}^{CS} \supset \frac{1}{2} b_1 (\Pi^a \partial_\mu V_\nu^a + V_\mu^a \partial_\nu \Pi^a) \epsilon^{\mu\nu\rho\sigma} \tilde{B}_{\rho\sigma} - \frac{i}{2} b_2 \text{Tr}(T^a [T^b, T^c]) \eta^{\mu\rho} \eta^{\nu\sigma} \Pi^a V_\mu^b V_\nu^c \epsilon^{\mu\nu\rho\sigma} \tilde{B}_{\rho\sigma},$$

where $b_1 = 56.03 N_c^{-1} \lambda^{-\frac{1}{2}}$ and $b_2 = 2571.72 N_c^{-\frac{3}{2}} \lambda^{-1}$

yield very broad decay width $\Gamma/M \sim 1$:

decay channel	Γ/M	decay channel	Γ/M
$\pi\rho$	0.3624...0.4803	$\eta'\phi$	0.0020...0.0079
KK^*	0.1945...0.2578	$\pi\rho\rho$	0.2595...0.4556
$\eta\omega$	0.0530...0.0941	$\pi K^* K^*$	0.0213...0.0375
$\eta\phi$	0.0086...0.0076	$KK^*\rho$	0.0032...0.0056
$\eta'\omega$	0.0168...0.0203	$KK^*\omega$	0.0011...0.0019
		total	0.9225...1.3685

Table 1: Numerical results

- Decays from Dirac-Born-Infeld action are subleading $\Gamma \propto N_c^{-3} \lambda^{-4}$

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