

Bell Inequality in the Holographic EPR Pair and the String Worldsheet in AdS

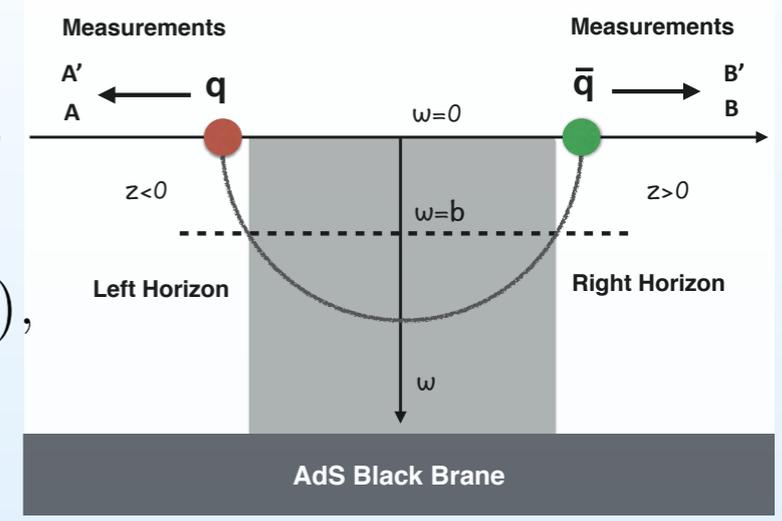


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CHSH formula $\langle C \rangle = \langle AB \rangle + \langle AB' \rangle + \langle A'B \rangle - \langle A'B' \rangle,$

For Quantum System $|\langle C \rangle| \leq 2\sqrt{2}$ $|\psi_s\rangle = \frac{1}{\sqrt{2}}(|\uparrow\rangle \otimes |\downarrow\rangle - |\downarrow\rangle \otimes |\uparrow\rangle),$

For Classical System $|\langle C \rangle| \leq 2,$
 $A = \vec{n}_A \cdot \vec{\sigma}, A' = \vec{n}_{A'} \cdot \vec{\sigma},$
 $B = \vec{n}_B \cdot \vec{\sigma}, B' = \vec{n}_{B'} \cdot \vec{\sigma}.$



$$\langle C_{\mathcal{F}} \rangle = \langle A_{\mathcal{F}} B_{\mathcal{F}} \rangle + \langle A_{\mathcal{F}} B'_{\mathcal{F}} \rangle + \langle A'_{\mathcal{F}} B_{\mathcal{F}} \rangle - \langle A'_{\mathcal{F}} B'_{\mathcal{F}} \rangle$$

$$= \cos \theta_{AB} + \cos \theta_{AB'} + \cos \theta_{A'B} - \cos \theta_{A'B'}$$

$$\theta_{AB} = \theta_{AB'} = \theta_{A'B} = \pi/4, \quad \theta_{A'B'} = 3\pi/4$$

Holographic EPR Pair $\langle C_{\mathcal{F}} \rangle = 2\sqrt{2}.$

$$A_{\mathcal{F}} = (\cos \theta_A \mathcal{F}_A^x + \sin \theta_A \mathcal{F}_A^y) / \langle \mathcal{F}_A^x \mathcal{F}_A^x \rangle^{1/2},$$

$$B_{\mathcal{F}} = (\cos \theta_B \mathcal{F}_B^x + \sin \theta_B \mathcal{F}_B^y) / \langle \mathcal{F}_B^x \mathcal{F}_B^x \rangle^{1/2},$$

$$iG_{AB}^{ij}(\tau, x) = \langle \mathcal{F}_A^i(\tau, x) \mathcal{F}_B^j(0) \rangle$$

Nambu-Goto action

$$S_{\text{NG}} \simeq -\frac{1}{2\pi\alpha'} \int dr dt \left[1 - \frac{1}{2f(r)} (\dot{\mathbf{x}})^2 + \frac{r^4 f(r)}{2} (\mathbf{x}')^2 \right],$$



$$S_{\text{ren}}^{(2)} = \frac{1}{2g_s^2} \int_0^{\beta} d\tilde{\tau} \left[(\ddot{\tilde{\epsilon}})^2 - \left(\frac{2\pi}{\beta} \right)^2 (\dot{\tilde{\epsilon}})^2 \right]$$

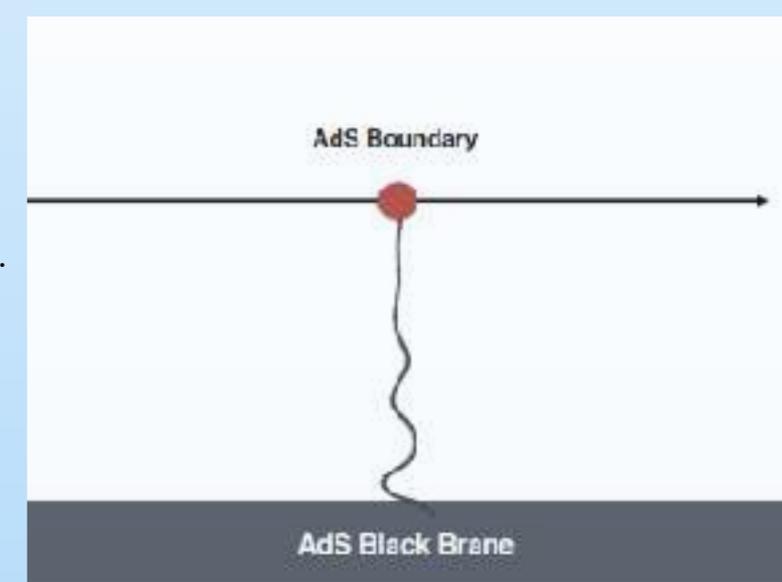
String fluctuations in the Bulk

Schwarzian action

$$S_{\text{Sch}} = \frac{1}{2g_s^2} \int_0^{\beta} d\tau \left[\left(\frac{\dot{\mathbf{g}}}{\mathbf{g}} \right)^2 - \left(\frac{2\pi}{\beta} \right)^2 (\dot{\mathbf{g}})^2 \right].$$



SYK model on the Boundary?



1] Bell inequality in the holographic EPR pair [Chen, Sun, Zhang, on Phys.Lett. B791 (2019) 73-7]
 2] The String Worldsheet as the Holographic Dual of SYK State [Cai, Ruan, Yang, Zhang: 1709.06297]