FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

Resonant particle production in branonium

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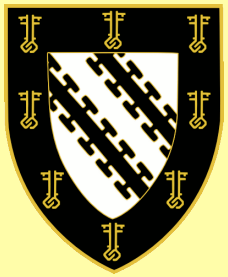

arXiv:0711.0658 [hep-th]
Phys. Rev. D77:126004, 2008

UniverseNet School, University of Oxford
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GENERAL PROPERTIES

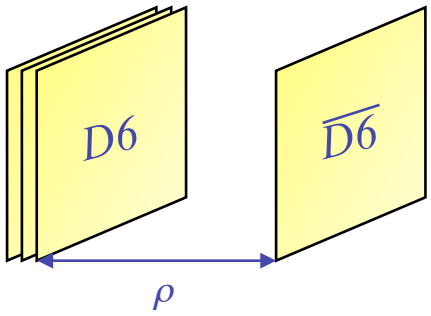
- Brane models have several applications in Cosmology and BSM physics

- ***D*-branes**:
  - ½ BPS *(p+1)*-dimensional solutions in supergravity;
  - Confine endpoints of open strings in string theory;

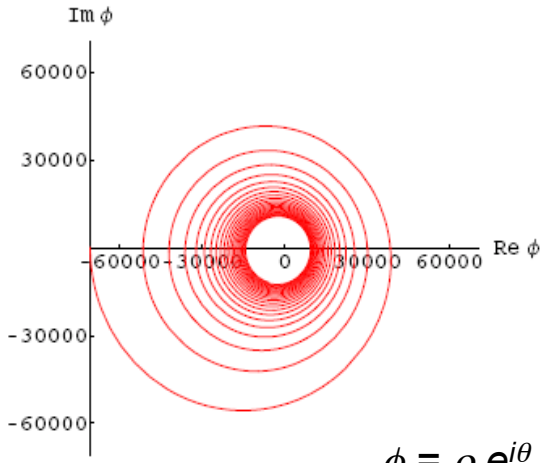
- **Massive point charges** (transverse space) and **extended objects** (longitudinal space)

- ***Branonium*** *(Burgess et al.,2003)*:
  probe *p*-antibrane orbiting a stack of *N* parallel *p*-branes in transverse space

- **Interactions:**
  - Graviton-dilaton (*Born-Infeld action*)
  - RR form (*Wess-Zumino action*)



$$\ddot{\rho} + 3H\dot{\rho} - \frac{l^2}{\rho^3} + \frac{1}{2}\frac{\sigma}{\rho^2} = 0$$



$\phi = \rho\, e^{i\theta}$

RESONANT PARTICLE PRODUCTION

- **Scalar particles in probe brane's world-volume**:

$$S_\eta = -T_6 \int d^7\xi \; e^{-\Phi} \sqrt{-\hat{\gamma}} \left(-\frac{1}{2}\hat{\gamma}^{\mu\nu}\partial_\mu\eta\partial_\nu\eta - \frac{1}{2}m^2\eta^2 \right)$$

- **Fourier modes** ($m = 0$):

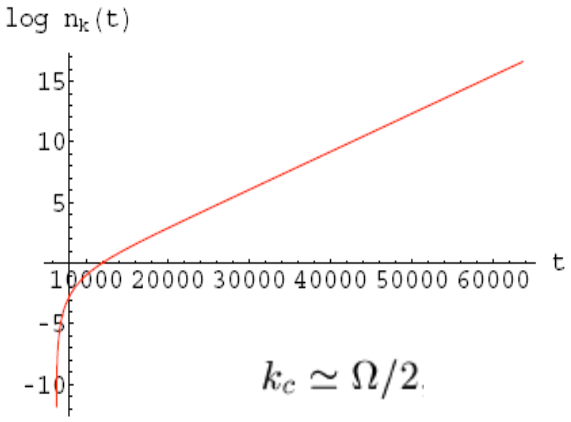
$$\ddot{X}_k + \omega_k^2 X_k = 0$$

$$\omega_k^2 \;=\; \frac{k^2}{a^2}(1-hv^2) - \frac{1}{4}(3H-F)^2 - \frac{1}{2}(3\dot{H}-\dot{F}) = \; k_{phys}^2 + \Delta^2$$

- **NON-EXPANDING UNIVERSE**:
(elliptical orbits of small eccentricity, $hv^2 << 1$)

$$X_k'' + \left(A_k - 2q\cos(2z)\right)X_k = 0 \quad \longrightarrow \quad \textbf{Mathieu Equation}$$

$$A_k \equiv \frac{4k^2}{\Omega^2}\,, \qquad q \equiv -2\frac{\delta^2}{\Omega^2} \qquad \delta^2 \equiv \frac{1}{4}\sqrt{\frac{T_6 V_3}{2}}\frac{Q_6}{R}e\Omega^2$$



RESONANT PARTICLE PRODUCTION

- **MASSIVE PARTICLES:**

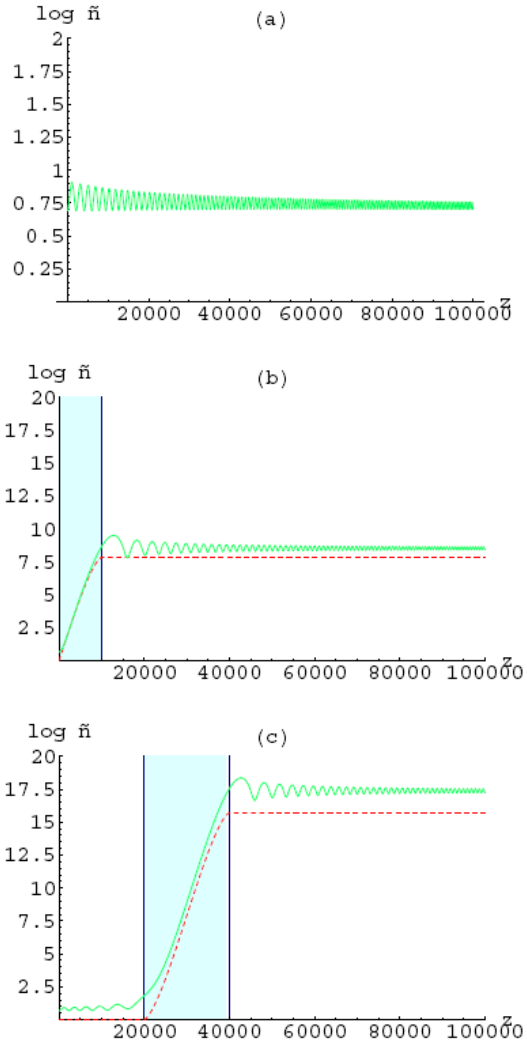
  Resonance occurs for maximum mass of

$$m_{max} = \sqrt{\frac{Q_6}{2R_{phys}}}\frac{l_s}{R_{phys}}M_s$$

- **EXPANDING UNIVERSE (*late times*):**

  - Resonance band moves towards higher momenta

  - High momentum modes production suppressed



CREATION OF ANGULAR MOMENTUM

- **COMPACT TRANSVERSE 3-TORUS**

  - Hypercubic lattice of "brane images":

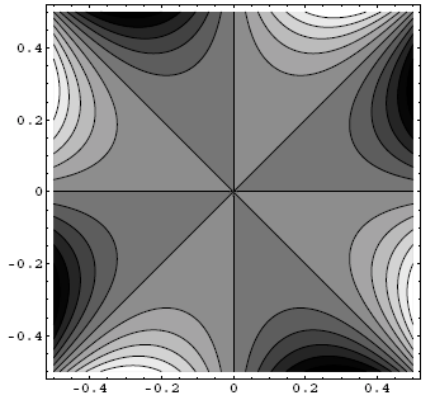
$$h(\mathbf{y}) = 1 + \sum_i \frac{Q_p}{|\mathbf{y} - \mathbf{y_i}|^{\bar{d}}}$$

  - Modifies probe brane potential:

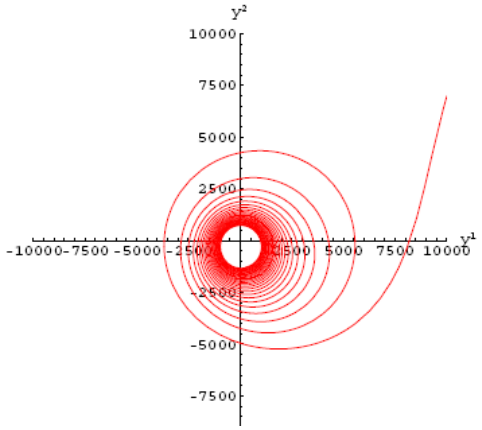
$$V(\phi) = -\frac{\sigma}{|\phi|} - \sigma_J |\phi|^2 - \sigma_A(\phi_R^4 + \phi_I^4 - 6\phi_R^2\phi_I^2)$$

"jellium" term ***"asymmetry" term***

Generation of angular momentum
(*similar to Affleck-Dine mechanism*)



Probe brane feels torque



No initial angular momentum!

STABILIZATION AND COSMOLOGY

- **PROBE ANTIBRANE:** annihilation with central stack at late times (tachyonic mode)
- **PROBE BRANE:** possible stabilization from SUSY breaking
  - RR-potential (and dilaton) acquire mass, giving Yukawa potential (Dvali, 1999):

$$V(r) = T_6 V_3 Q_6 \left(\lambda \frac{e^{-m_{RR} r}}{r} - \frac{1}{r} \right)$$

  - Local minimum at $r_0 \sim m_{RR}^{-1}$ for $\lambda > 1$