PARITY DOUBLING STRUCTURE OF NUCLEON AT NON-ZERO DENSITY IN THE HOLOGRAPHIC MEAN FIELD THEORY

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Motivation: QCD Phase Diagram

- Perturbative QCD, Lattice QCD methods are improper to study density matter
- What happens at high density place like compact stars?
### Spin\(1/2\) baryon mass spectrum @ \(z_m = 1/0.33(m_\rho = 780\text{MeV})\)

<table>
<thead>
<tr>
<th>Mass Spectrum (GeV)</th>
<th>Parity Even</th>
<th>Parity Odd</th>
</tr>
</thead>
<tbody>
<tr>
<td>(p(n))</td>
<td>0.939</td>
<td>1.440</td>
</tr>
<tr>
<td>(N(1440))</td>
<td>1.440</td>
<td></td>
</tr>
<tr>
<td>(N(1535))</td>
<td>1.535</td>
<td></td>
</tr>
<tr>
<td>... (N(2100))</td>
<td>2.100</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
- **Auto Fixed**: \(m_\rho\)
- **Matching with Experiment**: Parity coincides with Experiment

**References:**
Holographic mean field theory

5D field decompose

\[
\begin{align*}
X(x, z) &= X(z) + x(x, z) \\
V_M(x, z) &= V_M(z) + v_M(x, z) \\
A_M(x, z) &= A_M(z) + a_M(x, z) \\
N_1(x, z) &= N_1(z) + n_1(x, z) \\
N_2(x, z) &= N_2(z) + n_2(x, z)
\end{align*}
\]

Mean field only distribution (depends) on the \( z \) coordinate, the other coordinates are flat (average) value. The mean field take the role of source.

ND - $\sigma$ relation @ $z_m = 1/0.33 (m_\rho = 780 \text{MeV})$

Using:

$$\sigma \approx 2 \frac{X(z)}{z^3} \mid _{z \to 0}$$

<table>
<thead>
<tr>
<th>UV</th>
<th>IR</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_1$</td>
<td>0</td>
</tr>
<tr>
<td>$N_2$</td>
<td>0</td>
</tr>
</tbody>
</table>

Physical meaning:

$c_2$: Number Density
$c_1$: Chiral breaking

$\frac{\sigma}{\sigma_0}$ denote normalized $\sigma$ by its value at zero density.


They only consider $c_1=0$, in a same order with our results.
ND - $M^*$ relation @ $z_m = 1/0.33$ (EKSS)

Walecka type model:

$$\mu = \sum_{n=1}^{\infty} \frac{g_{\omega(n)NN}^2}{m_{\omega(n)}^2} \rho_b + \sqrt{k_E^2 + M^*^2}$$

<table>
<thead>
<tr>
<th>(n)</th>
<th>$m_{\omega(n)}$ [GeV]</th>
<th>$g_{\omega(n)NN}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.78</td>
<td>15.6</td>
</tr>
<tr>
<td>2</td>
<td>1.79</td>
<td>9.3</td>
</tr>
<tr>
<td>3</td>
<td>2.82</td>
<td>4.3</td>
</tr>
</tbody>
</table>

The decreasing of $M^*$ at high density consistent with experiment result.
Summary

- We study the property of baryon at zero and finite density base on Holographic QCD models.

- At zero density, we discuss a dynamical way to generate the nucleon mass and found a kind of chiral invariant mass.
  - We discuss the relation between $c_1$ and chiral invariant mass.

- At finite density, by adopting the holographic mean field theory, we discuss the quark condensate $\sigma$, chemical potential $\mu$ and effective mass $M^*$ with their dependence of number density.
  - We find that quark condensate $\sigma$ will decrease at high density, which means chiral symmetry partially restored at high density.
  - We find that effective mass $M^*$ will decrease at high density, which consistent with experiment result.
Thank you for your attention!