Mesons in $N\bar{N}$ channel in composite superconformal string model

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Motivation

- Aim: description of hadron interaction (mesons and baryons) - amplitudes and spectrum.
- Description of mesons and baryons at low and intermediate energies (0,1 - 7 GeV).
    - QCD in this energy region has coupling constant $g \gg 1$.
    - We have to find approach which contains small parameter.
- String theories in tree approximation gives linear Regge trajectories.
- Unitary (string loop) corrections lead to nonlinear Regge trajectories.
- Consistent construction can lead to necessary smallness of these corrections.

Classical string models

- The absence of ghosts (negative norm states) in physical state spectrum for $\alpha_0 = 1$ in the case of open strings.
- Open string sector contains massless vector particle (gluon).
- Closed string sector contains massless tensor particle (graviton).
- Relation for scale parameters of open and close string:

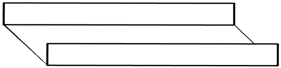
$$\alpha'_{open} = 2\alpha'_{closed}$$

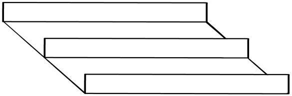
- Classical string models describe interaction on Planck scale

$$\alpha' \sim \frac{1}{m_{Pl}^2}$$

Composite superconformal string model

- Superconformal symmetry on two-dimensional surface.
- The absence of ghosts (negative norm states) in physical state spectrum for leading meson trajectory intercept $\alpha_0 = 1/2$.
- Possibility to make independent scale parameters α'_{open} and α'_{closed} due to new topology:





- meson momentum:

$$p = \sqrt{\alpha'_H}(k_1 - k_2), \quad \alpha'_H \sim 1 GeV^{-2}$$

- baryon momentum:

$$p = \sqrt{\alpha'_H}(k_1 + k_2) + \sqrt{\alpha'_{Pl}} k_f, \quad \alpha'_{Pl} \sim 10^{-38} GeV^{-2}$$

Formulation of string models

- Functional integration:

$$A_N = \int \prod dz_i \int DX(z) \int Dg(z) e^{S(z)} V_1(z_1) \dots V_N(z_N),$$

where z-coordinate on two-dimensional surface, $X(z)$-fields on two-dimensional surface, $g(z)$-metric on two-dimensional surface.

- For tree approximation it is convenient to use amplitude in VV-formalizm:

$$A_N = \int \prod dz_i \langle 0 | V_1(z_1) \dots V_N(z_N) | 0 \rangle,$$

where

$$V_i(z_i) = z_i^{-L_0} V(1) z_i^{L_0}$$

Vertex operator

- Ground state emission vertex operator

$$\hat{V}(z_i) = z_i^{-L_0} \left\{ G, \hat{W} \right\} z_i^{L_0}, \quad \hat{W} \sim: e^{ikX} :$$

where G is the super Virasoro algebra generators for Neveu-Schwarz case.

- super Virasoro algebra for fields with conformal spin 0, $\frac{1}{2}$, 1:

$$\begin{aligned}[L_n, L_m] &= (n-m)L_{n+m} + \delta_{n,-m} c_1 n(n^2-1), \\ \{G_r, G_s\} &= 2L_{r+s} + c_2 \left(r^2 - \frac{1}{4}\right) \delta_{r,-s}, \\ [L_n, G_r] &= \left(\frac{n}{2} - r\right) G_{n+r}.\end{aligned}$$

- Additional symmetry

$$[\hat{V}, Y_i k_i] = 0$$

Two-dimensional fields

- Basic surface fields:
  ∂X_μ, I^a, and anticomutating superpartners H_μ, θ^a;
  Lorentz index $\mu = 0...3$, $a = 1...6$. The 6-th field has hadron scale, 1-5-th fields gives neglectible contribution into tree approximation.
- i-th edging surface fields:
  $Y_\mu^{(i)}$ and anticommutating superpartner $f_\mu^{(i)}$;
  anticommutating $\phi_{(1)}^{(i)}$, $\phi_{(2)}^{(i)}$, $\phi_{(3)}^{(i)}$ - nonlinear realization of supersymmetry on two-dimensional surface.
- Ridge surface fields:
  $Y_\mu^{(f)}$ and anticomumtating superpartner $f_\mu^{(f)}$.

Spin-parity structrure

- Eigenvectors λ_i of zero components I_0^a of fields $I^a(z) = I_0^a + \sum_{n\neq 0} I_n^a z^n$ carries quark quantum numbers - spin and isospin.
- Nucleon spin structure $J^P = \frac{1}{2}^+$:

$$(\tilde{\lambda}_i \lambda_j)\lambda_f, \quad (\tilde{\lambda}_i \gamma_5 \lambda_j)\lambda_f \gamma_5$$

- Nucleon isospin structure $T = \frac{1}{2}$:

$$(\tilde{\lambda}_i \lambda_j)\lambda_f, \quad (\tilde{\lambda}_i \tau^a \lambda_j)\lambda_f \tau^a$$

- π-meson structure:

$$(\bar{\lambda}_i \tau^{(i)} \gamma_5 \lambda_j)$$

- η-meson structure:

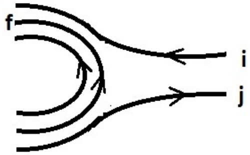
$$(\bar{\lambda}_i \gamma_5 \lambda_j)$$

Nucleon vertex operator

- To make possible transition $N\bar{N} \to \pi$ it is necessary to have two types of nucleon vertex operator $V_N = V^{NS} + V^{BH}$:
  $\hat{V}^{NS}_{i,i+1}(z_j) = z_j^{-L_0} \left\{ G_r, \hat{W}_{i,i+1} \right\} z_j^{L_0}$ with odd number of anticommutating field components
  $\hat{V}^{BH}_{i,i+1}(z_j) = z_j^{-L_0} \left\{ G_r, \hat{F}\hat{W}_{i,i+1} \right\} z_j^{L_0}$ with even number of anticommutating field components
- $\left[\left\{ G_r \hat{F} \right\} \hat{W} \right] = 0$
- Conformal spin of vertex operator should be equal to 1.
- Requirement of π-meson to be a state with minimal mass.
- Two-dimensional fields of conformal spin 1 should commutate with each other: ∂X, I^a.
- We choose: $(\tilde{\lambda}_i \lambda_j)\lambda_f$ for $\hat{V}^{BH}$,
  $(\tilde{\lambda}_i \gamma_5 \tau^a \lambda_j)\lambda_f \gamma_5 \tau^a$ for $\hat{V}^{NS}$.

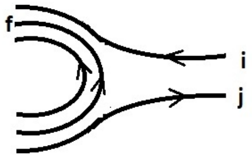
π-meson

- Different isospin structure of V_{BH} and V_{NS} leads to different eigenvalues of zero component of field I^6 for $T = 1$ and $T = 0$: $I_0^{isovec} \neq I_0^{isoscal}$.
- These values are found from equations for conformal spin equal to 1 of vertex operators:
  V_{NS}: $-\frac{m_N^2}{2} + \xi^2 + \frac{I_0^{(isovec)2}}{2} = \frac{1}{2}$
  V_{BH}: $-\frac{m_N^2}{2} + \xi^2 + \frac{I_0^{(isoscal)2}}{2} = 0$
- π-meson has spin-parity $J^P = 0^-$, isospin $T = 1$.
- Such quantum numbers can appear in $\bar{V}_{BH} V_{NS}$ channel.



η-meson

- η-meson has spin-parity $J^P = 0^-$, isospin $T = 0$.
- Such quantum numbers can appear in $\bar{V}_{BH} V_{BH}$ channel.
- The mass conditions $L_0 = 1$ for η-meson and π-meson give us relatoin for their masses:
  $m_\pi^2 + \frac{1}{2} m_\rho^2 = m_\eta^2$.
- We choose $m_N^2 = \frac{3}{2} m_\rho^2$, take into account $m_\pi^2 = 0$ and then get $m_\eta = 544$ MeV.
- For ground states of the first and the second daugter Regge trajectories we predict: 1140 MeV for $\eta(1295)$, 1520 MeV for $\eta(1405)$.



Summary

- We formulate vertex operator for nucleon.
- We get π and η mesons in $N\bar{N}$ channel.
- Using parameter $m_N^2 = \frac{3}{2}m_\rho^2$ we predict masses of η mesons.

Thank you for attention.