New extended interpolating fields built from three-dimensional fermions

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Physical Features
- 3D propagators on initial and final time-slices grant better overlap with the states of interest thus leading to a better signal.
- Short distance behaviour greatly improved by the use of extended operators compared to standard local operators.
- Extended operators are well behaved under renormalization.
- 3D fermions mass $m$ tuned for a better overlap with physical states. Known how to keep $m$ fixed while the lattice spacing $a$ is varied.

Baryonic Operators
Operators are representations of $G(3) \in \text{Spin}(1,2)$ where $a,b$ is the spin $SU(2)$ representation while $s$ and $x$ are the total spin and its projection. The operators are written in the Weyl spinor formalism [3]:

\[ \Psi_{a,b}(x) = \sum_{s,x} \Omega_{s,x,a,b}(x) \]

Extended Operators
Non-local operators are built from quenched three dimensional fermions fields coupled via pseudo-scalar bilinears with ordinary four dimensional fermions in the four dimensional bulk. The quark propagator takes the form:

\[ S(x,t) = \sum_{\Psi} \langle \Psi(x,0)|\mathcal{S}(t)|\Psi(x,0)\rangle \]

In this image there is a schematic representation of the baryonic two point function for the extended operators. On the time-slices $x_3 = 0$ and $x_3 = t$ there are the two 3D baryonic operators $\Psi_{a,b}$. These are coupled via pseudo-scalar bilinear operators to the bulk and therefore can propagate between the time-slices.

Comparison with other Methods
Data has been obtained from 2+1 $SU(3)$ degenerate CLS configurations [2] on a $96 \times 32 \times 32$ lattice with open boundary conditions. We compare with point sources:

\[ \Psi_{a,b}(x,y) = \delta_{a,b} \delta(t - y) \]

and Jacobi smearing:

\[ \Psi_{a,b}(x,y) = \sum_{i=0}^{N} \lambda_{i} \delta_{a,b} (y - x) \]

In (a) is shown the effective mass of the Omega and the Nucleon obtained with the GEVP method, the extracted effective masses for the extended operators in lattice units are:

\[ m_{\Omega} = 0.52 \pm 0.02 \]
\[ m_{N} = 0.49 \pm 0.03 \]

In figure (b) a comparison between the effective mass extracted from the diagonal part of the correlator made by the single operators:

\[ C_{ij}(t) = \langle \Psi_{a,b}(x,y)|\mathcal{S}(t)|\Psi_{a,b}(x,y)\rangle \]

of the nucleon and the GEVP is made. The GEVP uses additional information by building a matrix correlation $M_{ij}$ function from the $N$ different interpolating operators on two different time-slices [1]. We have utilized the operators $\mathcal{G}_{p}$ and diagonalized $M_{ij}$ for all methods separately:

\[ M_{ij} = \sum_{a,b} \langle \Psi_{a,b}(x,y)|\mathcal{S}(t)|\Psi_{a,b}(x,y)\rangle \Omega_{a,b} \]

Even with a small basis of operators, $N = 3$ for the nucleon and $N = 2$ for the omega, the GEVP has a better excited states suppression. Notice that the first two nucleon operators $i = 0$ and $i = 1$ in (b) have the same coupling with the nucleon state.

References