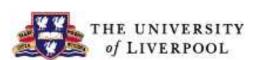
Parity mixing in the TM spectrum

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Hadronic Spectrum - mixing

Let me illustrate this: in a simple mass mixing model of π_0 and σ In the continuum we have two states π and σ which do not mix. To order a, the L_5 term (odd in parity) will induce a mixing. This will shift the masses of the two states as well as inducing off-diagonal correlators.

This can be encapsulated by using a mass mixing matrix. The mass mixing matrix of bare (or continuum) states (π, σ) is

$$\begin{pmatrix}
m_1 & \epsilon \\
\epsilon & m_2
\end{pmatrix}$$

where ϵ is given by $<\pi|L_5|\sigma>$ (up to some normalisation factor). The mass shift is $-\epsilon^2/(m_2-m_1)$ for the pion (π_0 rel π_+ where π_+ mixing is negligible)

Hadronic Spectrum - mixing II

The mixed (lattice) states are approx $p\equiv\pi+\eta\sigma$ and $s\equiv\sigma-\eta\pi$ with $\eta=\epsilon/(m_2-m_1)$, $\Delta=m_2-m_1$

The two state lattice fit with states p and s has amplitudes:

(2)
$$c_5 = <0|P|p> = <0|P|\pi>$$
 $c_1 = <0|S|p> = \eta <0|S|\sigma>$ $d_5 = <0|P|s> = -\eta <0|P|\pi>$ $d_1 = <0|S|s> = <0|S|\sigma>$

So one can get η from $\eta^2 = -(c_1/c_5)*(d_5/d_1)$

Here S and P refer to "physical basis" for clarity - (lattice results have "lattice basis" with operators S, P interchanged, Here I assume that we are at maximal twist - so that S and P are exchanged completely.) The lattice correlators are vacuum subtracted ($\langle AB \rangle - \langle A \rangle \langle B \rangle$) but include fermionic disconnected loops as required.

(You can also use fuzzed operators to check this - namely $\eta^2=-(c_2/c_6)(d_6/d_2)$ getting a consistent result)

Also there is a cross-check that (in this two state mixing approach)

$$c1 * c5 = -d1 * d5$$

Hadronic Spectrum - mixing III

From the fit (eg. μ =0.004 β =3.9), one can estmate η^2 with bootstrap method getting 0.029(19)

Then with $\Delta=m(s)-m(p)=0.131(25)$, one has expected mass shift of π_0 (downwards) rel π_+ due to L_5 induced mixing of $ma=\eta^2\Delta=0.0038(25)$ compared to observed shift of $\pi_+-\pi_0$ =0.027.

($\mu=0.003,\,\beta=4.05\,\,\eta^2=0.046(17)$ so rel mass shift not smaller - but big errors)

Therefore L_6 must be important compared to $L_5.L_5$ (or my simple 2 state fit and 2 state model is over-naive).

Mixing heavy-light mesons

 $J^P=0^-$ and 0^+ static-light mesons $\mu=0.004,\,\beta=3.9,$ levels Ea 0.171 apart

Fit agrees with model and gives mixing parameter $\eta^2=0.082$. Then $\Delta=0.171$ so expected mass shift $\eta^2\Delta=0.014$, so 8% effect. More tricky here since "physical states" need Z's to evaluate them since mixing from lattice states is at 45°. Qualitatively situation is as above.

To be checked at $\beta = 4.05$.

Mixing parity

Similar effects occur all over (in TMQCD)

$$\rho \ a_1$$
 $D(0^-) \ D(0^+)$
 $n(\frac{1}{2}^+) \ n(\frac{1}{2}^-)$

Essential to measure full correlator (including "parity-violating" part) to get at mixing and estimate possible effect on spectrum. Also important to control effects of ground state contamination in study of excited (opposite parity) state.