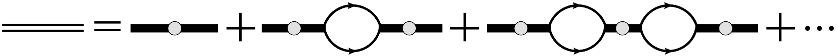
Consistent Regularization in Two and Three-Body Sector

Jared Vanasse

Ohio University

January 14, 2016

LO dressed dibaryon propagators given by infinite sum of diagrams



(LO)

(NLO)

Single bubble contribution in cutoff regularization given by

$$
\begin{aligned}
iI_0 =& i\frac{y^2 M_N}{4\pi}\left[-\sqrt{\frac{1}{4}\vec{\mathbf{p}}^2 - M_N p_0 - i\epsilon} + \frac{2\Lambda}{\pi}\right] \\
&+ i\frac{y^2 M_N}{2\pi^2}\sqrt{\frac{1}{4}\vec{\mathbf{p}}^2 - M_N p_0 - i\epsilon}\,\arctan\left(\frac{\sqrt{\frac{1}{4}\vec{\mathbf{p}}^2 - M_N p_0 - i\epsilon}}{\Lambda}\right)
\end{aligned}
$$

Resumming bubble contribution gives LO dibyaron propagator

$$iD(p_0,\vec{\mathbf{p}}) = i\frac{4\pi}{M_N y^2}\frac{1}{\frac{4\pi\Delta}{M_N y^2} - \sqrt{\frac{1}{4}\vec{\mathbf{p}}^2 - i\epsilon} + \frac{2\Lambda}{\pi} + \frac{2}{\pi}\sqrt{\frac{1}{4}\vec{\mathbf{p}}^2 - M_N p_0 - i\epsilon}\,\arctan\left(\frac{\sqrt{\frac{1}{4}\vec{\mathbf{p}}^2 - M_N p_0 - i\epsilon}}{\Lambda}\right)}$$

Imposing pole condition gives

$$\frac{4\pi\Delta}{M_N y^2} = \gamma_t - \frac{2\Lambda}{\pi} - \frac{2}{\pi}\gamma_t\arctan\left(\frac{\gamma_t}{\Lambda}\right)$$

Substituting expression back in gives

$$iD(p_0,\vec{\mathbf{p}}) = i\frac{4\pi}{M_N y^2}\frac{1}{\gamma_t - \sqrt{\frac{1}{4}\vec{\mathbf{p}}^2 - i\epsilon} - \frac{2}{\pi}\gamma_t\arctan\left(\frac{\gamma_t}{\Lambda}\right) + \frac{2}{\pi}\sqrt{\frac{1}{4}\vec{\mathbf{p}}^2 - M_N p_0 - i\epsilon}\,\arctan\left(\frac{\sqrt{\frac{1}{4}\vec{\mathbf{p}}^2 - M_N p_0 - i\epsilon}}{\Lambda}\right)}$$

Residue about pole gives LO wavefunction renormalization

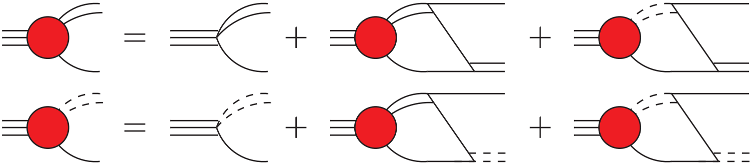
$$Z_{\mathrm{LO}}^{\Lambda} = \frac{8\pi\gamma_t}{M_N^2 y^2}\left(1 - \frac{2}{\pi}\arctan\left(\frac{\gamma_t}{\Lambda}\right) - \frac{2\gamma_t}{\pi\Lambda}\frac{1}{1+\left(\frac{\gamma_t}{\Lambda}\right)^2}\right)^{-1}$$

Doublet S-wave and Bound state

The three-body Lagrangian is

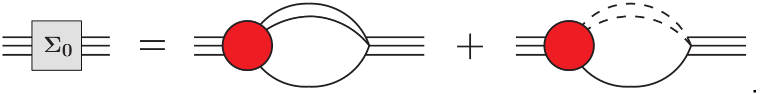
$$\mathcal{L}_3 = \hat{\psi}^\dagger\left(i\partial_0 + \frac{\vec{\nabla}^2}{6M_N} + \frac{\gamma_t^2}{M_N} + \Omega\right)\hat{\psi} + \omega_t\hat{\psi}^\dagger\sigma_i\hat{N}\hat{t}_i + \omega_s\hat{\psi}^\dagger\tau_a\hat{N}\hat{s}_a + \mathrm{H.c.},$$

where ψ is an auxiliary triton field. The LO triton vertex function $\mathbf{G}_0(E,p)$ is given by following coupled integral equations (Hagen, Hammer, and Platter (2013))



Inhomogeneous term is set to **1** to factor three-body forces out of vertex functions.

Defining



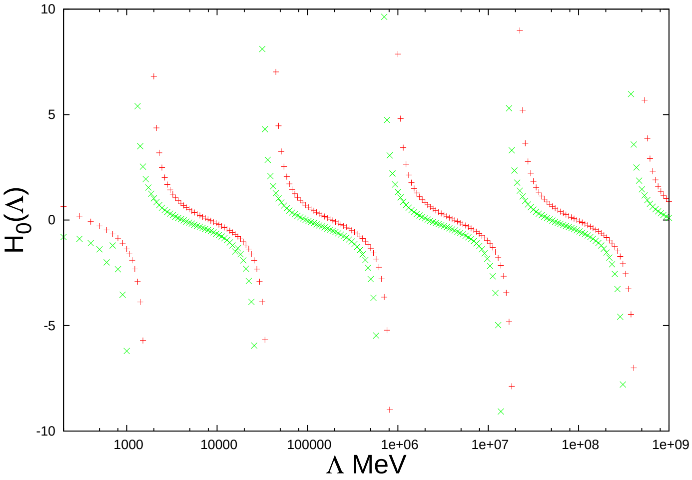
The dressed triton propagator is given by the sum of diagrams

which yields

$$\begin{aligned} i\Delta_3(E) =& \frac{i}{\Omega} - \frac{i}{\Omega} H_{\rm LO}\Sigma_0(E)\frac{i}{\Omega} + \cdots \\ =& \frac{i}{\Omega}\frac{1}{1 - H_{\rm LO}\Sigma_0(E)}, \end{aligned}$$

where

$$H_{\rm LO} = -\frac{8\omega_t^2}{\pi\Omega} = -\frac{8\omega_s^2}{\pi\Omega} = \frac{8\omega_t\omega_s}{\pi\Omega}.$$


10
5
0
-5
-10
1000
10000
100000
1e+06
1e+07
1e+08
1e+09
$H_0(\Lambda)$
Λ MeV

LO Three-body Force

LO three-body force is given by (Bedaque, Hammer, and Kolck (1999))

$$H_{0,0}(\Lambda) = c\frac{\sin\left(s_0 \ln\left(\frac{\Lambda}{\Lambda^*}\right) + \arctan s_0\right)}{\sin\left(s_0 \ln\left(\frac{\Lambda}{\Lambda^*}\right) - \arctan s_0\right)}$$

$c \simeq 0.877 \pm 0.003$

(Braaten, Kang, and Platter (2011))