Nonlocal potential obtained from a quark model in hypernuclei

☑ Construct a QCM potential (energy-independent nonlocal potential)
☑ Construct an on-shell equivalent local potential
☑ To investigate the effect of nonlocality, compare the two potentials by looking into their G-matrices.
☑ $^4\Sigma$He.
   ◊ Use of the nonlocal potential is essential in strong Pauli-blocking channels.
   ◊ Local approximation is good in weak Pauli-blocking channels

YN cross section given by QCM
Def of QCM two baryon potential

Schrödinger eq for 6 quarks: \( H_q = K_q + V_q \)

can be reduces into the RGM equation,

\[
\int dR' \left( H_{RGM}(R, R') - E N(R, R') \right) \chi(R') = 0 ,
\]

which can be rewritten in Shrödinger-like eq:

\[
\left( \overline{H} - E \right) \overline{\chi} = 0
\]

with \( \overline{H} = N^{-1/2} H N^{-1/2} \) \( \overline{\chi} = N^{1/2} \chi \).

QCM potential can be defined by:

\[
V_{QCM} = \overline{H} - K_0 , \quad \text{which is Energy-independent and nonlocal potential.}
\]
Features of QCM baryon potential

- $V_{qcm} = V_{local} + V_{nonlocal}$

Channel where quark Pauli-blocking is **Weak**.  

Channel where quark Pauli-blocking is **Strong**.
Nonlocality can be seen as off-shell effects

how to identify the effect of nonlocality

Quark model → Nonlocal Baryon potential

Equivalent local potential (unique)

Inverse scattering problem

On-shell variables: $\delta, (\text{BE, res})$

Off-shell variables: $\psi \ G$

Off-shell variables: $\psi \ 'G'$

Size of the difference corresponds to the effect of nonlocality
Examples of On-shell Equivalent Local Potentials

- phase shifts

-Equivalent local potentials
  - quark Pauli-blocking is large
  -> Local potential is large

![Graph showing phase shifts and local potentials](image-url)
G-matrices -- Weak Pauli-blocking channel

- G-matrix by the original QCM potential
  \[ \Sigma N^{41} s_0 \]

- G-matrix by the equivalent local potential
  \[ \Sigma N^{41} s_0 \]

The nonlocal potential can be simulated by the equivalent local potential in this channel.
G-matrices -- Strong Pauli-blocking channel

- G-matrix by the original QCM potential
  \[ \Sigma N^{21}s_0 \]

- G-matrix by the equivalent local potential
  \[ \Sigma N^{21}s_0 \]

The nonlocal potential cannot be simulated by the equivalent local potential in this channel.
Keep nonlocality in the Kinetic term

When the kinetic term is kept nonlocal

- Potential has a form:
  \[ V_{\text{knloc}} = V_K + V_{\text{local}} \]

G-matrices are well-simulated by considering nonlocality in the kinetic term, even for the channels where the quark Pauli-blocking is large.
• Applied to $^4\Sigma$He

QCM 1.24MeV
Equiv local 1.36MeV
Kin-nonlocal 1.26MeV

Nonlocal effect is rather small because the wave function is

$$\frac{4}{9}^4S_0 + \frac{1}{2}^2^3S_1 + \frac{1}{18}^2^1S_0$$

how about $^4^3S_1$?

because the channel is repulsive

how about $\Xi N$?
Comment on the $\Sigma$-mixture

- Quark Pauli-blocking allows for $(TS) = (1/2 \ 0)(0s)^6$ configuration
  
  $\sqrt{9/10} |\Lambda N> + \sqrt{1/10} |\Sigma N>$

  only

  $-\sqrt{1/10} |\Lambda N> + \sqrt{9/10} |\Sigma N>$

  but not

There is always $\Sigma$ in $\Lambda$-hypernuclei. and $\Lambda$ in $\Sigma$-hypernuclei.
This effect is essentially nonlocal.
Construct a QCM potential \(\text{(energy-independent nonlocal potential)}\)

Construct an on-shell equivalent local potential

To investigate the effect of nonlocality, compare the two potentials by looking into their G-matrices.

\( ^4\Sigma \text{He.} \)

- Use of the nonlocal potential is essential in strong Pauli-blocking channels. G-matrices of the two potentials are very different from each other in the channels where the quark Pauli-blocking effect is large. → Keep the nonlocality in the Kinetic term
- Local approximation is good in weak Pauli-blocking channels. The QCM potential can be simulated by the local potential where the quark Pauli-blocking effect is small.