Pentaquarks Θ^+ in hot asymmetric nuclear matter: $nK^+\pi^0$ and $pK^0\pi^0$ structure

Manisha Kumari and Arvind Kumar

Department of Physics
Dr. B. R. Ambedkar National Institute of Technology, Jalandhar

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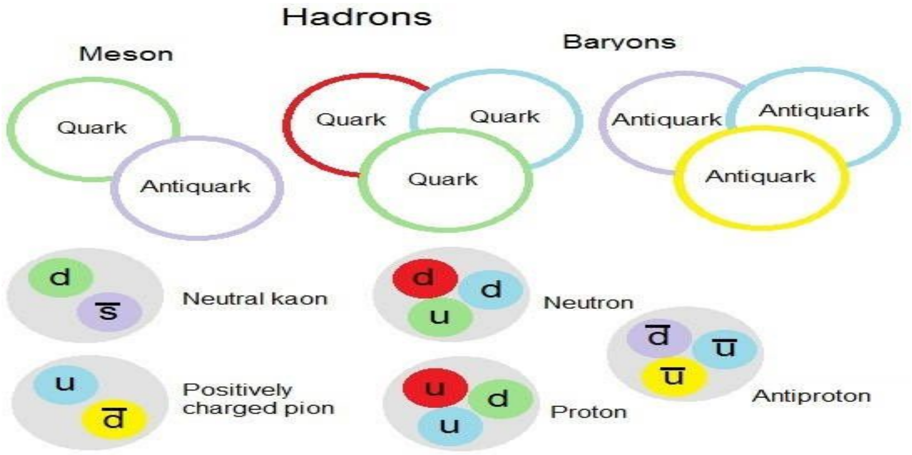
Overview

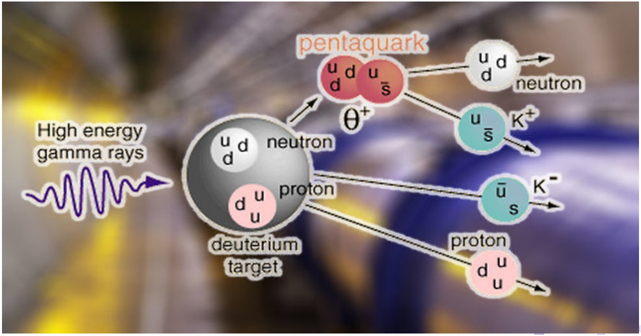
Introduction



Motivation

What are penta−quark ?

- Penta−quark is a subatomic particle consisting of 4-quarks and 1-antiquark bound together.
- The Θ^+ represents a new form of quark matter containing a minimum of five quarks.



Types of penta-quarks

"Non-exotic" penta-quarks:

- the antiquark has the same flavor as one of the other quarks
- difficult to distinguish from 3-quark baryons
- Example: $uuds\bar{s}$, same quantum numbers as uud
  Strangeness=0+0+0+-1+1=0

"Exotic" penta-quarks:

- the antiquark has the same flavor as one of the other quarks
- Unique identification using experimental conservation laws
- Example: $uudd\bar{s}$,
  Strangeness=0+0+0+0+1=+1

Methodology

Chiral SU(3) Model

Lagrangian density

$$\mathcal{L}_{\text{eff}} = \mathcal{L}_{Kin} + \sum_{M=S,V} \mathcal{L}_{NM} + \mathcal{L}_{vec} + \mathcal{L}_0 + \mathcal{L}_{SB} + \mathcal{L}_{KN} \tag{1}$$

- $\mathcal{L}_{Kin}$ is the kinetic term.
- $\mathcal{L}_{NM}$ nucleon meson interaction term.
- $\mathcal{L}_{vec}$ vector meson interaction term.
- $\mathcal{L}_0$ and $\mathcal{L}_{SB}$ are spontaneous and explicit symmetry breaking terms, respectively.
- $\mathcal{L}_{KN}$ is nucleon-kaon interaction term.

Nucleon- Kaon interaction in chiral SU(3) model

$$
\begin{aligned}
\mathcal{L}_{KN}^{chiral} = & -\frac{i}{4f_k^2}[(2\bar{p}\gamma^\mu p + \bar{n}\gamma^\mu n)(K^-(\partial_\mu K^+) - (\partial_\mu K^-)K^+) \\
& +(\bar{p}\gamma^\mu p + 2\bar{n}\gamma^\mu n)(\bar{K^0}(\partial_\mu K^0) - (\partial_\mu \bar{K^0})K^0)] \\
& +\frac{m_K^2}{2f_k^2}\left[(\sigma' + \sqrt{2}\zeta' + \delta')(K^+K^-) + (\sigma' + \sqrt{2}\zeta' - \delta')(K^0\bar{K^0})\right] \\
& -\frac{1}{f_k}[(\sigma' + \sqrt{2}\zeta' + \delta')(\partial_\mu K^+)(\partial^\mu K^-) + (\sigma' + \sqrt{2}\zeta' - \delta')(\partial^\mu K^0)(\partial^\mu \bar{K^0})] \\
& +\frac{d_1}{2f_k^2}[(\bar{p}p + \bar{n}n)((\partial_\mu K^+)(\partial^\mu K^-) + (\partial_\mu K^0)(\partial^\mu \bar{K^0}))] \\
& +\frac{d_2}{2f_k^2}[\bar{p}p(\partial_\mu K^+)(\partial^\mu K^-) + \bar{n}n(\partial_\mu K^0)(\partial^\mu \bar{K^0})] + (\partial_\mu \bar{K})(\partial^\mu K) - m_{K(\bar{K})}^2 \bar{K}K.
\end{aligned} \tag{2}
$$

Mass-Shift of penta-quarks

$$\delta m_{\Theta^+}(nK^+\pi^0) = \delta m_n + \delta m_{K^+}, \tag{3}$$

and

$$\delta m_{\Theta^+}(pK^0\pi^0) = \delta m_p + \delta m_{K^0}, \tag{4}$$

where,

$$\delta m_n = m_n^* - m_n,$$

$$\delta m_p = m_p^* - m_p,$$

$$\delta m_{K^+} = m_{K^+}^* - m_{K^+},$$

$$\delta m_{K^0} = m_{K^0}^* - m_{K^0}.$$

Result Analysis

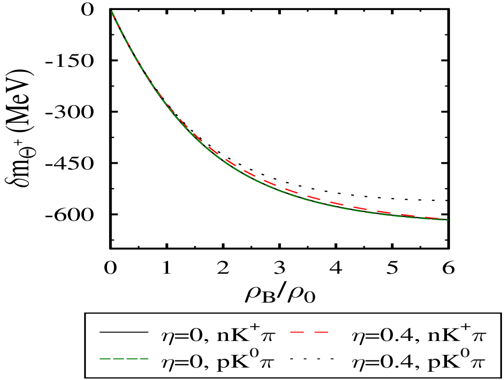


Figure: The mass-shift of penta-quarks having structure as $nK^+\pi^0$ and $pK^0\pi^0$ with baryonic density, ρ_B/ρ_0 for different value of η.

Result discussion and Conclusion

- for symmetric nuclear matter, the mass-shift of penta-quarks is same for both $nK^+\pi^0$ and $pK^0\pi^0$ structure with density
- no measurable change in mass-shift of penta-quark for asymmetric matter at lower density range
- for higher density , the negative mass-shift of $nK^+\pi^0$ is large as compared to $pK^0\pi^0$ at $\eta = 0.4$ due to large positive mass-shift of K^0


Thank you