Strangeness in the Meson Cloud Model

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Overview

- History
- Quark – Anti-quark Asymmetry
- SU(3) Flavour Breaking
- Conclusion
AIS PhD topic (85)

• Related to Ericson + Thomas (83) paper on EMC effect
• Extended Thomas (83) work on Cloudy Bag to strange sector
• Included contributions from both meson and baryon components
Contribution to parton dist is convolution:

\[
x\bar{s}(x) = \int_x^1 dy f(y) \left( \frac{x}{y} \right) s_K \left( \frac{x}{y} \right)
\]

\[
xs(x) = \int_x^1 dy f(y) \left( \frac{x}{y} \right) s_H \left( \frac{x}{y} \right)
\]

Fig. 1. Non-perturbative contributions to the strange sea of the nucleon. (a) The incoming photon is absorbed by a virtual kaon. (b) The incoming photon is absorbed by a virtual hyperon.
Antistrange dist is harder than strange

Fig. 2. The non-perturbative contribution to $x\bar{s}(x)$ for two bag radii compared with the experimental determination of $x\bar{s}(x)$ (dot-dash line).
1987

Wasn't perfect -
- Used invariant formulation with off-shell target
- Approximations for hadron structure functions
- No $Q^2$ dependence
- Net strangeness!

\[
\int_0^1 dx \left[ s(x) - \bar{s}(x) \right] < 0
\]
Quark – Antiquark Asymmetry

NuTeV anomaly

- Measured Paschos-Wolfsenstein ratio
  \[ R^- = \frac{\sigma_{NC}^\nu - \sigma_{NC}^{\bar{\nu}}}{\sigma_{CC}^\nu - \sigma_{CC}^{\bar{\nu}}} = \frac{1}{2} - \sin^2 \theta_W \]
- Extracted weak mixing angle 2% smaller than world av.
- P-W ratio gets corrections from symmetry breaking pdfs
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\[ R^- = \frac{\sigma^{\nu}_{NC} - \sigma^{\bar{\nu}}_{NC}}{\sigma^{\nu}_{CC} - \sigma^{\bar{\nu}}_{CC}} = \frac{1}{2} - \sin^2 \theta_W + 1.3 \left[ \frac{1}{2} \left( \langle \delta u \rangle - \langle \delta d \rangle \right) - \langle x(s - \bar{s}) \rangle \right] \]

• Only require [ ] = -0.0038 to get NuTeV value = world av.

• Charge Symm. Breaking v. small (PRC 62 015203 (2000))

• Strange quark – antiquark asymmetry possible explanation
• CTEQ analysis allows small asymmetry

\[ s_-(x, Q_0) = s_+(x, Q_0) \frac{2}{\pi} \tan^{-1} \left[ c x^a (1 - \frac{x}{b}) e^{dx + ex^2} \right] \]

\[ -0.001 < \langle x \rangle_{s_-} < 0.005 \]
Quark – Antiquark Asymmetry

Revisit original MCM calculation of \( s(x) - \bar{s}(x) \)

- MCM in TO pert. th. Uses on-shell structure functions
- Fluctuation functions for meson and baryon conserve momentum
  - ie. \( f_{\Lambda K/p}(y) = f_{K\Lambda/p}(1 - y) \)
- Hadron structure functions from expt (K) or bag (\( \Lambda \), \( \Sigma \))
- Soft form factors (\( \Lambda_c \approx 1 \text{ GeV} \))
- NLO \( Q^2 \) dependence to \( Q^2 = 16 \text{ GeV}^2 \)
Baryon fluctuation function harder, but $K$ pdf is harder than $\Lambda$ $\Sigma$

⇒ small difference in convolution
Quark – Antiquark Asymmetry

$x(s(x) - \bar{s}(x))$

- is small $\langle x(s - \bar{s}) \rangle \sim O(10^{-4})$
- some dependence on form factor
- adding $K^*$ states changes sign
- Probably not responsible for NuTeV result
Quark – Antiquark Asymmetry

In polarized case asymmetry is slightly larger (includes K* states)

Overall strange polarization is small in MCM
Can MCM help in determining strange + antistrange dist?

- Hermes (2008) data not in agreement with NuTeV
- Parameters have large uncertainties eg CTEQ6.5
SU(3) Flavour Breaking

SU(3) asymmetry $\bar{u}(x) + \bar{d}(x) - s(x) - \bar{s}(x)$

picks up leading contributions in MCM from

$|N\pi\rangle - |\Lambda K\rangle, \quad |\Delta \pi\rangle - |\Sigma K\rangle, \ldots$

- Compares well with
  Hermes data
SU(3) Flavour Breaking

Can estimate $s(x) + \bar{s}(x)$ by subtracting light sea

NLO analysis of NuTeV data PRL99(2007)192001
SU(3) Flavour Breaking

And strange suppression

\[ r(x) = \frac{s(x) + \bar{s}(x)}{\bar{u}(x) + \bar{d}(x)} \]
Conclusions

• Strange quarks still have surprises for us
• MCM is good laboratory for non-pert symmetry breaking among quark dists
• Recent paper (Strikman + Weiss PRD80 114029 (2009)) confirms picture at large impact parameter, but requires other symmetry breaking also – Fermi blocking, phase space …
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Happy Birthday Tony!