Asymmetry of Light Sea Quarks in Proton

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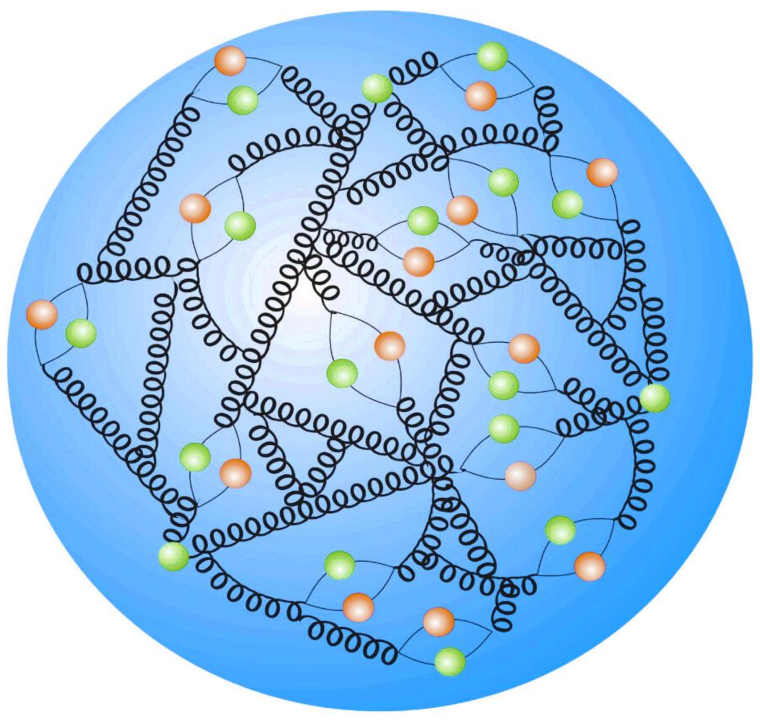
Abstract

The light sea quark distribution functions have been calculated explicitly for protons using the chiral constituent quark model, which has the connotation of chiral symmetry breaking and SU(3) symmetry breaking. Given the latest SeaQuest data, the results have been discussed thoroughly for the light antiquark asymmetries, and the Gottfried Integral has been calculated.

Motivation



Sea Quarks: If uud were only constituents then each quark should have carried 1/3 of proton's total momentum. Found to be less than 1/3. Rest of the momentum is carried by sea quarks.

$$I_G = \int_0^1 \frac{F_2^p(x) - F_2^n(x)}{x}\, dx = \frac{1}{3} + \frac{2}{3}\int_0^1 [\bar{u}(x) - \bar{d}(x)]\, dx$$

$$I_G = \frac{1}{3} \Rightarrow \bar{u}(x) = \bar{d}(x)$$
$$I_G \neq \frac{1}{3} \Rightarrow \bar{u}(x) \neq \bar{d}(x)$$

SLAC results: I_G = 0.200±0.040 ⇒ excess of $\bar{d}$.

Feynman: $q\,\bar{q}$ pairs are produced via gluon splitting. Production of $u\,\bar{u}$ quarks is suppressed compared to $d\,\bar{d}$ due to *Pauli Blocking*.

Problem: Contribution of Pauli Blocking is not large enough to explain the observed asymmetry.

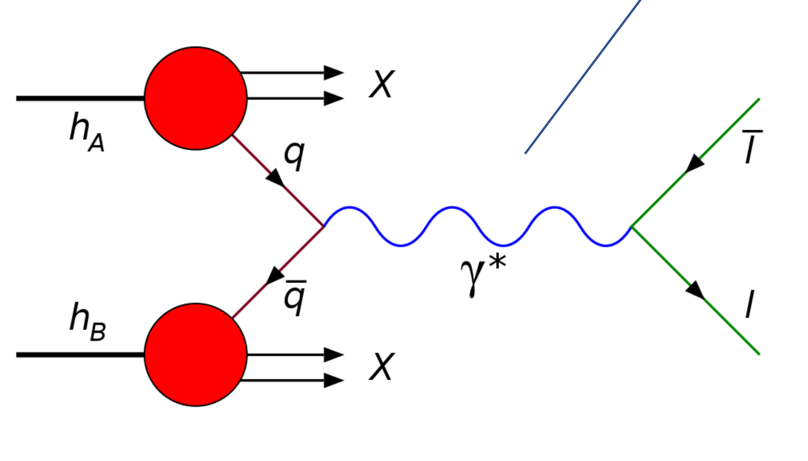
How to explain excess of down antiquarks in proton?

Objective

By fitting the parameters of Chiral Constituent Quark Model to the SeaQuest and NuSea experimental data we extract $\bar{u}(x)$ and $\bar{d}(x)$ distribution functions. Take the difference $\bar{d}(x) - \bar{u}(x)$ and compare the results with experiments measuring $\bar{d} - \bar{u}$. With the help of these distribution functions calculate the Gottfried Integral. No evolution effects have been included in the analysis.

SeaQuest: Q^2=22-40 $(GeV/c)^2$
NuSea: Q^2=54 $(GeV/c)^2$

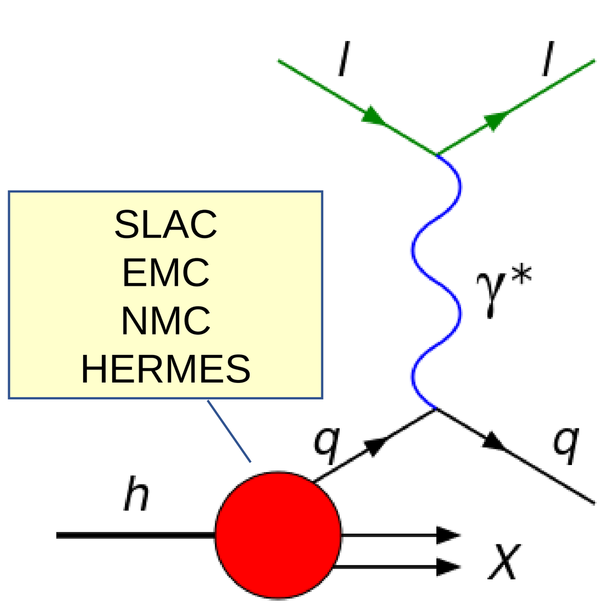
Drell-Yan



$$\frac{\sigma^{pd}}{2\sigma^{pp}} \approx \frac{1}{2}\left(1 + \frac{\bar{d}(x)}{\bar{u}(x)}\right)$$

DIS

SLAC
EMC
NMC
HERMES

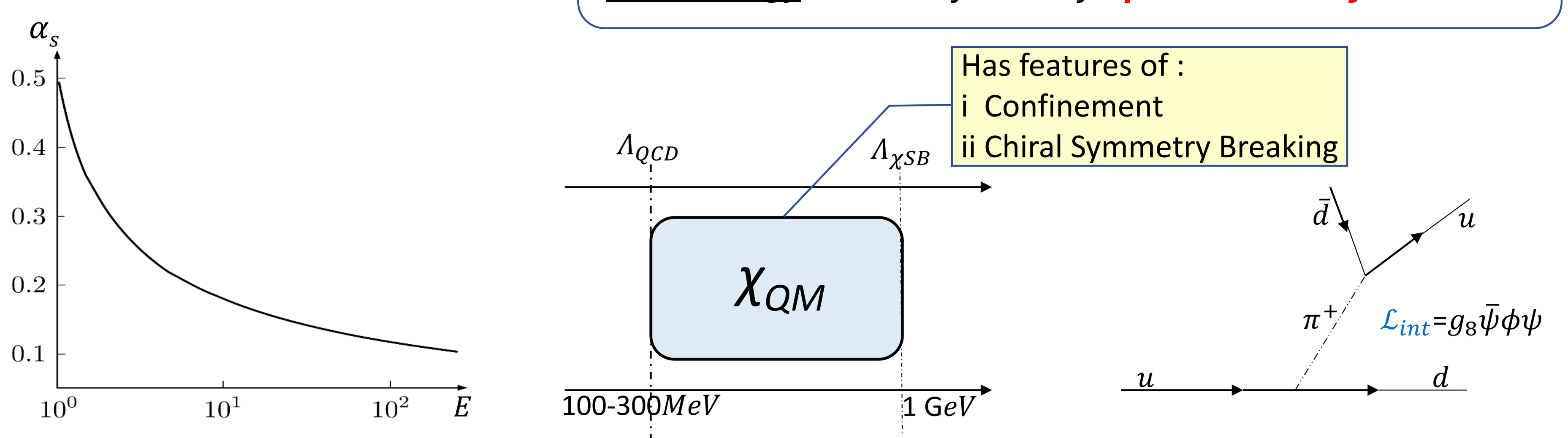


Methodology

$$\mathcal{L}_{QCD} = -\frac{1}{4}G^a_{uv}G_a^{uv} + i\bar{\psi}_R \not{D}\psi_R + i\bar{\psi}_L \not{D}\psi_L - \bar{\psi}_L M\psi_R - \bar{\psi}_R M\psi_L$$

$\psi \to \gamma^5\psi$ (Chiral transformation)

High energy: $\mathcal{L}_{QCD}$ has $SU(3)_L \times SU(3)_R$ ***chiral symmetry.***
Low energy: Chiral symmetry ***spontaneously broken.***

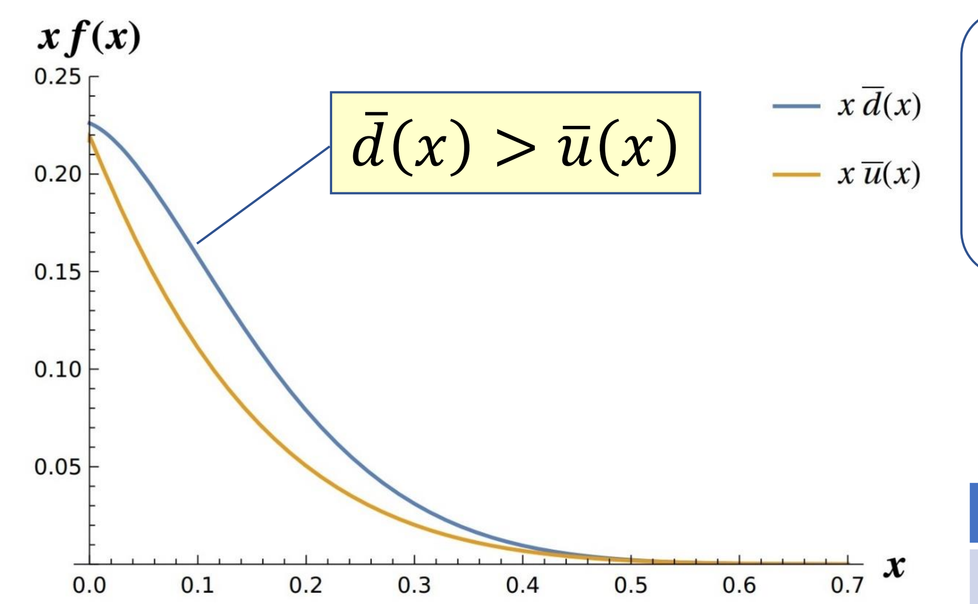


Non-perturbative QCD models required. In χ_{QM}, valence quark transitions create *Goldstone Bosons*. $\mathbb{P}_{\text{transition}} \propto 1/M_{GB}$. Asymmetry is measured using probability parameters.

$$\bar{u} = \varepsilon\left(\frac{7}{4} + \frac{\kappa^2}{12} + \frac{\xi}{3} + \frac{\xi^2}{3} + \frac{\kappa}{6} + \frac{\kappa\xi}{3}\right)$$
$$\bar{d} = \varepsilon\left(\frac{11}{4} + \frac{\kappa^2}{12} - \frac{\xi}{3} + \frac{\xi^2}{3} - \frac{\kappa}{6} + \frac{\kappa\xi}{3}\right)$$

$u(d) \to \pi^{+(-)} + d(u)$	$\mathbb{P} = \varepsilon$
$u(d) \to K^{+(0)} + s$	$\mathbb{P} = \varepsilon\lambda^2$
$u(d,s) \to \eta + u(d,s)$	$\mathbb{P} = \varepsilon\kappa^2$
$u(d,s) \to \eta' + u(d,s)$	$\mathbb{P} = \varepsilon\xi^2$

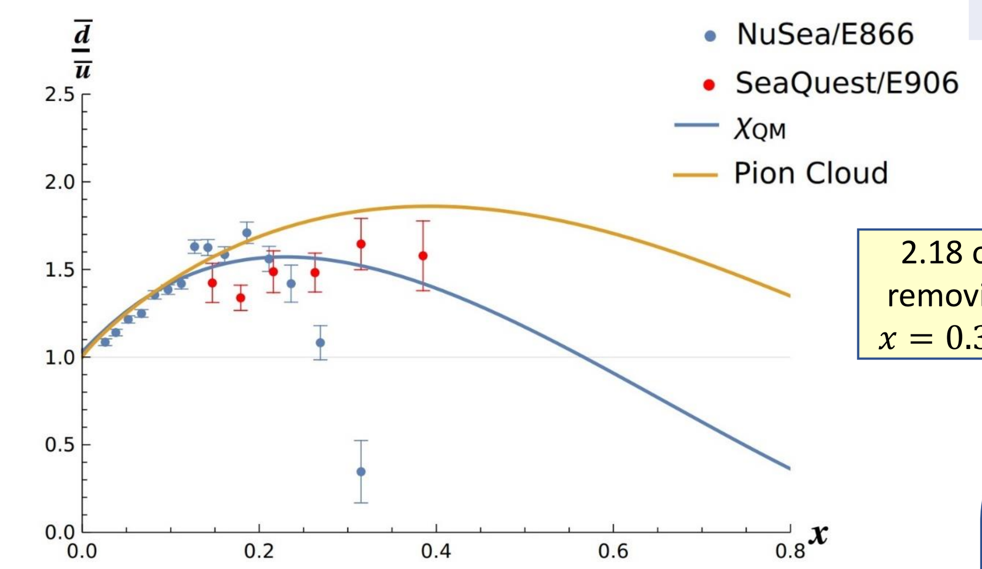
Results and conclusion



$\varepsilon = 0.114,\ \kappa = 0.45,\ \xi = -0.75$
$\bar{u} - \bar{d} = -0.118$
$\bar{u}/\bar{d} = 0.652$

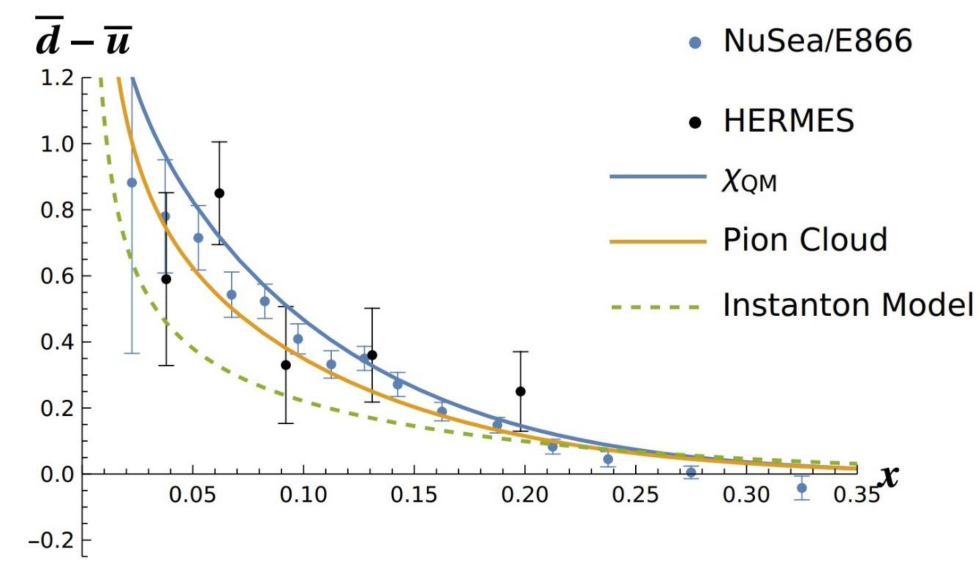
$$\bar{q}(x) = (Nx)^A(1-x)^B(1+Cx)$$

	χ_{QM}	N	A	B	C
$\bar{d}(x)$	0.3391	1.5	-1.00	9.0	8.000
$\bar{u}(x)$	0.2211	1.0	-0.99	7.5	1.0875



$\bar{d}/\bar{u}$ Experiment	χ^2/N_{Pts}
SeaQuest	1.70
NuSea	2.63

2.18 on removing $x = 0.315$



$\bar{d}(x)/\bar{u}(x)$ curve shows that ratio lies between 1 and 1.57 in range $0 < x < 0.57$ with peak at $x = 0.23$.

$\bar{d}(x) - \bar{u}(x)$ approaches zero with increasing x. It does not become negative within experimental range.

Experiment	Gottfried Integral (I_G)
EMC	0.235±0.099
NMC	0.235±0.026
HERMES	0.226±0.020
NuSea	0.254±0.005
Present work	$I_G(0,1)$=0.219 $I_G(x_{min}, x_{max})$=0.263

References

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