# Lecture12

Monday, November 13, 2017 3:05 PM

## Quarks within Proton and Neutron

$$F_2(x) = \sum e_i^2 x f_i(x)$$

$$F_1(x) = \frac{1}{2} \sum e_i^2 f_i(x)$$

$$2x F_1(x) = F_2(x)$$

$$\frac{d\sigma}{dE\,d\Omega} = \sigma_{Mott}\left(\frac{F_2(x)}{q_0} + 2\tan^2\frac{\theta}{2}\,\frac{F_1(x)}{M}\right)$$

$\Rightarrow$ Introducing $y = \frac{p_N \cdot q}{p_N \cdot k} = \frac{q_0}{E_e}$

Show that

$$\frac{d\sigma}{dQ^2\,dx} = \frac{2\pi\alpha^2 y^2}{Q^4}\left[2F_1(x) + \frac{1}{2xy^2}\left((2-y)^2 - y^2\left(1 - \frac{4x^2m^2}{Q^2}\right)\right)F_2(x)\right]$$

## Quarks within the Proton and Neutron

about

$F_1(x)$ $F_2(x)$ information

Quark distribution

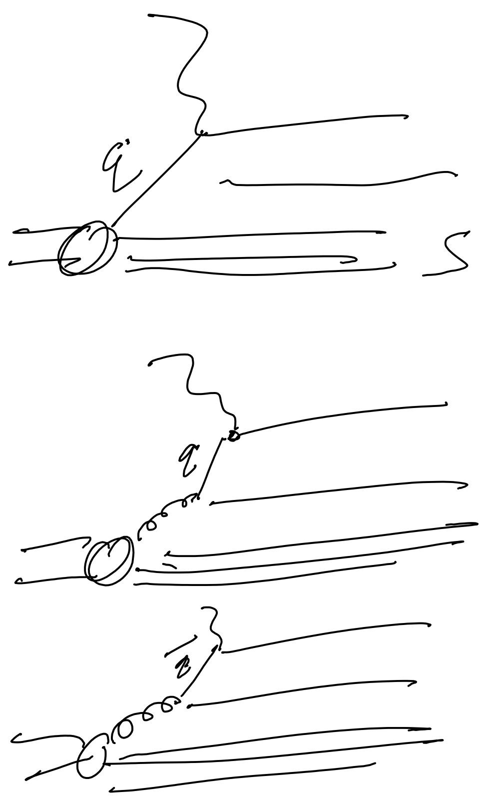
$$\frac{1}{x}F_2^{ep}(x) = \left(\frac{2}{3}\right)^2\left[u^p(x)+\bar{u}^p(x)\right]+\left(\frac{1}{3}\right)^2\left[d^p(x)+\bar{d}^p(x)\right]$$

$$+\left(\frac{1}{3}\right)^2\left[s^p(x)+\bar{s}^p(x)\right]$$

$q$ — quarks
$\bar{q}$ — antiquarks

**Quarks**

| | M | Q | S |
|---|---|---|---|
| u | 2.4 MeV | $\frac{2}{3}$ | $\frac{1}{2}$ |
| d | 4.8 MeV | $-\frac{1}{3}$ | $\frac{1}{2}$ |
| s | 95 MeV | $-\frac{1}{3}$ | $\frac{1}{2}$ |
| c | 1.275 GeV | $\frac{2}{3}$ | $\frac{1}{2}$ |
| b | 4.18 GeV | $-\frac{1}{3}$ | $\frac{1}{2}$ |
| t | 172.44 | $\frac{2}{3}$ | $\frac{1}{2}$ |




Valence

S

$q = \bar{q}$

Sea quarks

$$\frac{1}{x} F_2^{eN} = \left(\frac{2}{3}\right)^2 \left[u^n + \bar{u}^n\right] + \left(\frac{1}{3}\right)^2 \left[d^n + \bar{d}^n\right] +$$

$$+ \left(\frac{1}{3}\right)^2 \left[s^n + \bar{s}^n\right]$$

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Number of u quarks in proton

= d quarks in neutron

$$u^p = d^n \equiv u(x)$$

$$d^p = u^n \equiv d(x)$$

$$s^p = s^n \equiv s$$

– quantum number of proton and

– quarks that define QN of Proton/Neutron

Valence quarks

$$u_s(x) = \bar{u}_s(x) = d_s(x) = \bar{d}_s(x) = s_s(x) = \bar{s}_s(x)$$

$$\equiv S(x)$$

$$u(x) = u_v(x) + u_s(x)$$

$$d(x) = d_v(x) + d_s(x)$$

Sum Rules

$$\int_0^1 [u(x) - \bar{u}(x)]\,dx = 2$$

$$\int_0^1 [d(x) - \bar{d}(x)]\,dx = 1$$

$$\int_0^1 [s(x) - \bar{s}(x)]\,dx = 0$$

$$\Rightarrow \boxed{\begin{aligned} \frac{1}{x}F_2^{eP} &= \frac{1}{9}[4u_v + d_v] + \frac{4}{3}S \\ \frac{1}{x}F_2^{eN} &= \frac{1}{9}[u_v + 4d_v] + \frac{4}{3}S \end{aligned}}$$

$x$

$x$

$$\frac{F_2^{eN}}{F_2^{eP}} = \frac{u_v + 4d_v + 12S}{4u_v + d_v + 12S}$$

max $\quad u_v = 0 \quad S = 0 \qquad \frac{F_2^{eN}}{F_2^{eP}} = 4$

min $\quad d_v = 0, \quad S = 0 \qquad \frac{F_2^{eN}}{F_2^{eP}} = \frac{1}{4}$

$$\frac{1}{4} \leq \frac{F_2^{en}}{F_2^{ep}} \leq 4$$

$\Rightarrow$ It is empirical known that at fixed $Q^2$, $q_0 \to \infty$ ($x \to 0$) $\sigma_T = \text{const}$

We have
$$\sigma_T = \frac{4\pi^2\alpha}{MK} = \frac{4\pi^2\alpha}{M\nu}\frac{1}{2}\sum e_i f_i(x)$$

$$= \frac{4\pi^2\alpha \, Q^2}{2M\nu \, Q^2}\sum e_i f_i(x) = \frac{4\pi^2\alpha}{Q^2}\sum e_i x f_i(x) \xrightarrow[x\to 0]{} \text{const}$$

$$f_i(x) \xrightarrow[x\to 0]{} \frac{1}{x}$$

$\Rightarrow$ One expects

$$\left.\frac{F_2^{en}(x)}{F_2^{ep}(x)}\right|_{x\to 0} \longrightarrow 1$$

$$\frac{F_2^{en}(x)}{F_2^{ep}(x)} \xrightarrow[x\to 1]{} \frac{u_v + 4d_v}{4u_v + d_v} \longrightarrow ?$$

$\Rightarrow$ From (+)

$$\frac{1}{x}\left[F_2^{ep}(x) - F_2^{en}(x)\right] = \frac{1}{3}\left[u_v(x) - d_v(x)\right]$$

where r f?
peaks?

## Momentum Sum Rules

$$\int_0^1 x\,dx\left[u+\bar{u}+d+\bar{d}+s+\bar{s}\right] = 1-\varepsilon_g$$

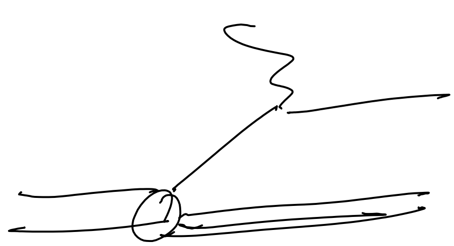
$$\varepsilon_g = \frac{P_g}{P}$$

$$\int dx\, F_2^{ep}(x) = \frac{4}{9}\varepsilon_u + \frac{1}{9}\varepsilon_d = 0.18\times 2$$

$$\int dx\, F_2^{en}(x) = \frac{1}{9}\varepsilon_u + \frac{4}{9}\varepsilon_d = 0.12$$

$$\varepsilon_g = 1-\varepsilon_u-\varepsilon_d = 0.46$$

## Partonic Evolution



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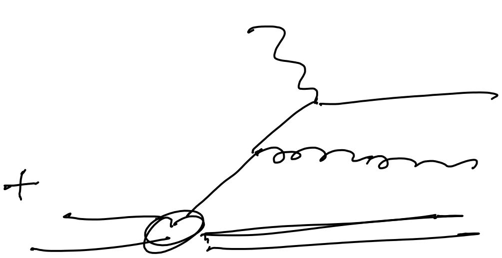

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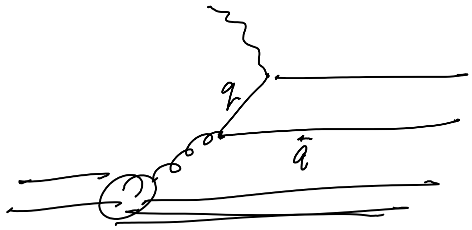

$q$
$\bar{q}$