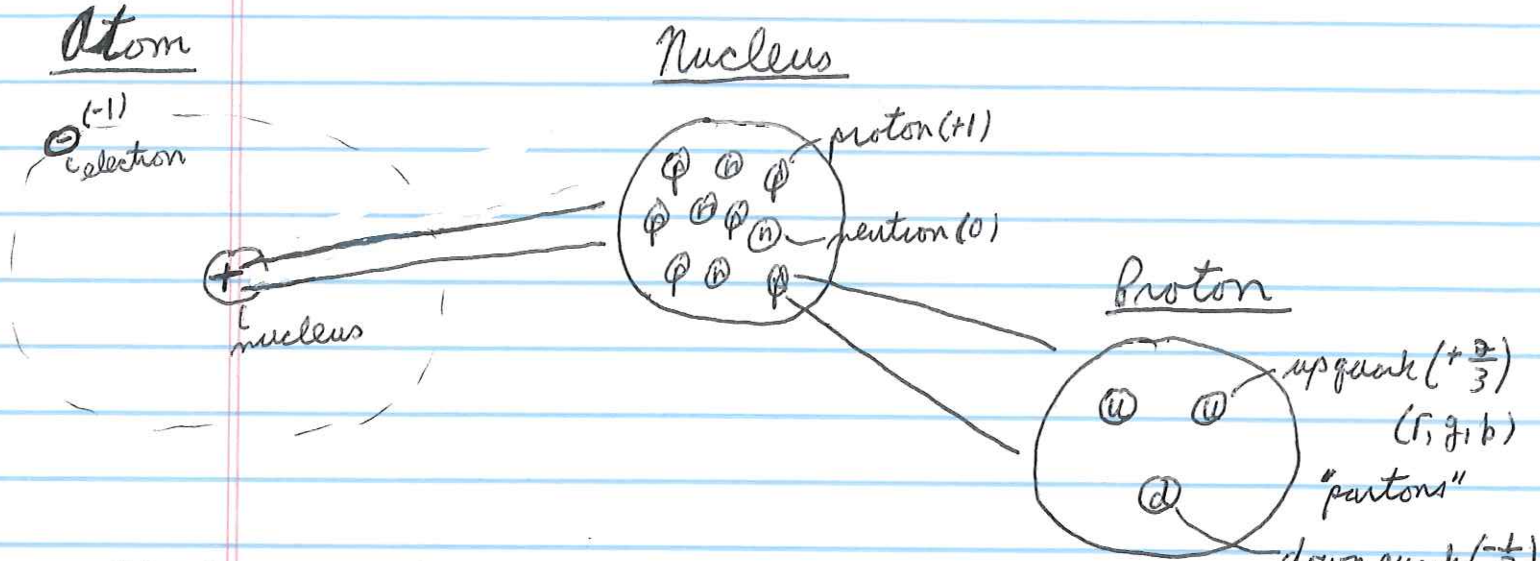
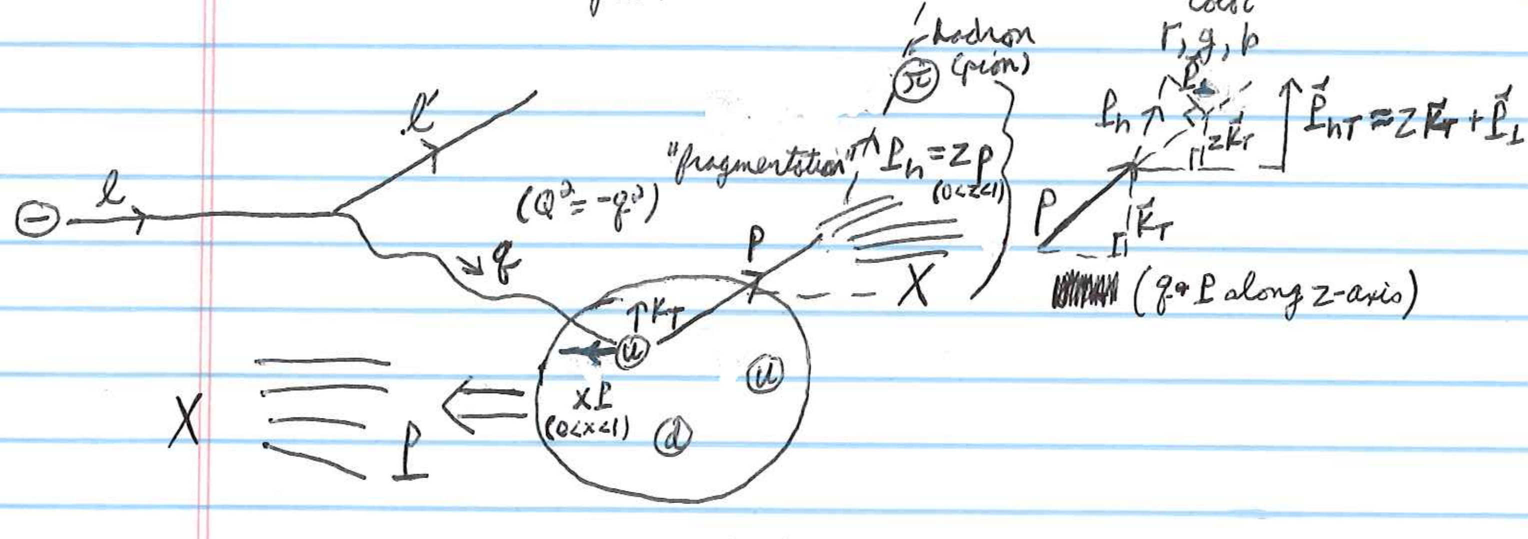
PHYS 296 Introduction to the Parton Model

(cover over 2 lectures)



Electromagnetic force: (+) photon (+) ++ repulsive, +- attractive

Strong force: (u) gluon (d) QCD - quantum chromodynamics ("color" r, g, b)



What is the probability for this process to occur?

"Parton Model"

$$\sigma^{ep\to e'\pi X}(x, Q^2, z, \vec{P}_{hT}) \propto e_u^2 \, f_1^u(x, k_T; Q^2) \, D_1^{\pi/u}(z, P_\perp; Q^2)$$

$\sim \dfrac{d\sigma}{dx\, dQ^2\, dz\, d\vec{P}_{hT}}$ ↳ "cross section"

f_1^u: probability of finding a u quark w/ momentum fraction x + trans. momentum k_T

$D_1^{\pi/u}$: probability a u quark fragments into a pion that carries momentum frac. z and trans. mom. $P_\perp$

$$\sigma^{ep\to e'\pi X}(x,Q^2,z,\vec{P}_{hT}) \propto \sum_{a=u,d,s} e_a^2 \int d^2\vec{k}_T \int d^2\vec{P}_\perp \underbrace{\delta^{(2)}(z\vec{k}_T+\vec{P}_\perp-\vec{P}_{hT})}_{\text{momentum conservation}} f_1^a(x,k_T;Q^2)\, D_1^{\pi/a}(z,P_\perp;Q^2)$$

$$\int dx\, f(x) \underbrace{\delta(x-a)}_{\Rightarrow x=a} = f(a)$$

Dirac delta function

We want to determine what $f_1(x,k_T;Q^2)$ and $D_1(z,P_\perp;Q^2)$ are from experimental data → tells us about the internal structure of hadrons.

Gaussian function e^{-x^2}

"Gaussian ansatz"

$$f_1^a(x,k_T;Q^2) = \underbrace{f_1^a(x;Q^2)}_{\text{known from other experiments}} \frac{1}{\pi\langle k_T^2\rangle} e^{-k_T^2/\langle k_T^2\rangle}$$

$\langle k_T^2\rangle$: average trans. momentum of the quark in the proton
↳ free parameter to fit to exp. data

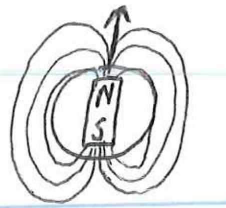
$$D_1^{\pi/a}(z,P_\perp;Q^2) = \underbrace{D_1^{\pi/a}(z;Q^2)}_{\text{known from other experiments}} \frac{1}{\pi\langle P_\perp^2\rangle} e^{-P_\perp^2/\langle P_\perp^2\rangle}$$

$\langle P_\perp^2\rangle$: avg. TM of the pion relative to the frag. quark
↳ free parameter to fit to exp. data

We are extracting information about the "intrinsic" motion of partons inside of hadrons.

$$\sigma^{ep\to e'\pi X}(x,Q^2,z,\vec{P}_{hT}) \propto \sum_a e_a^2\, f_1^a(x;Q^2)\, D_1^{\pi/a}(z;Q^2)\, e^{-P_{hT}^2/\langle P_{hT}^2\rangle}$$

where $\boxed{\langle P_{hT}^2\rangle = z^2\langle k_T^2\rangle + \langle P_\perp^2\rangle}$



- Spin of atoms in our body is basis for how a MRI works
- Like a tiny bar magnet is inside

(CLAS)
Data from JLab is for A_{LL} → sensitive to the "spin" of quarks

↳ electron is spin-$\frac{1}{2}$ → can be "spin up" or "spin down"

quarks are also spin-$\frac{1}{2}$

⇒ We need a function that also gives us the probability of finding a quark with a specific <u>spin</u> along with x, k_T

"longitudinal spin" or "helicity"

$\xrightarrow{\quad P \quad}$
$S \rightarrow e \leftarrow$

$$\underbrace{g^a_{1L}}_{\text{"longitudinal spin" or "helicity"}}(x, k_T; Q^2) = \underbrace{g^a_1(x;Q^2)}_{\text{known}} \frac{1}{\pi \underbrace{\langle k_T^2\rangle_L}_{\text{free parameter}}} e^{-k_T^2/\langle k_T^2\rangle_L}$$

$\vec{e}\vec{p} \rightarrow e'\pi X$

$$\sigma_L(x, Q^2, z, P_{hT}) \propto \sum_a e_a^2\, g_1^a(x;Q^2)\, D_1^{\pi/a}(z;Q^2)\, e^{-P_{hT}^2/\langle P_{hT}^2\rangle_L}$$

where $\boxed{\langle P_{hT}^2\rangle_L = z^2\langle k_T^2\rangle_L + \langle P_\perp^2\rangle}$

$$A_{LL} = \frac{\sum_a e_a^2\, g_1^a(x;Q^2)\, D_1^{\pi/a}(z;Q^2)\, e^{-P_{hT}^2/\langle P_{hT}^2\rangle_L}}{\sum_a e_a^2\, f_1^a(x;Q^2)\, D_1^{\pi/a}(z;Q^2)\, e^{-P_{hT}^2/\langle P_{hT}^2\rangle}}$$

CLAS gives A_{LL} as a function of P_{hT} and integrates over the other variables, where their bins are: $0.12 < x < 0.48$; $0.4 < z < 0.7$; $0.9 < Q^2 < 5.4\ \text{GeV}^2$

$$\boxed{A_{LL}^{CLAS} = \frac{\sum_a e_a^2 \int_{0.12}^{0.48} dx \int_{0.4}^{0.7} dz \int_{0.9}^{5.4} dQ^2\, g_1^a(x;Q^2)\, D_1^{\pi/a}(z;Q^2)\, e^{-P_{hT}^2/\langle P_{hT}^2\rangle_L}}{\sum_a e_a^2 \int_{0.12}^{0.48} dx \int_{0.4}^{0.7} dz \int_{0.9}^{5.4} dQ^2\, f_1^a(x;Q^2)\, D_1^{\pi/a}(z;Q^2)\, e^{-P_{hT}^2/\langle P_{hT}^2\rangle}}}$$