Superfast Quarks in the Nuclear Medium

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Kim Egiyan Memorial workshop SRC2006
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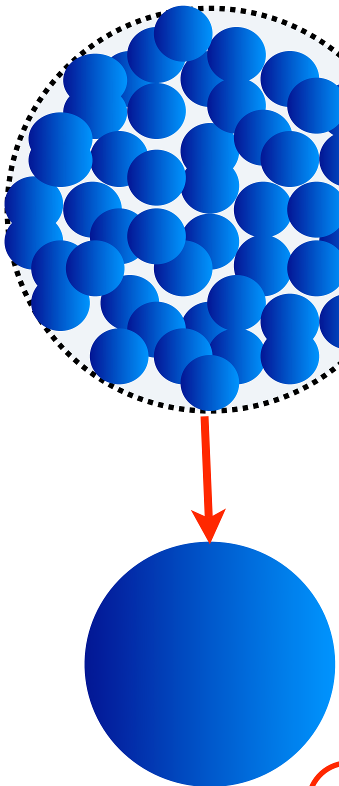
Nuclear Matter



$$\rho_0 = 0.17 fm^{-3}$$

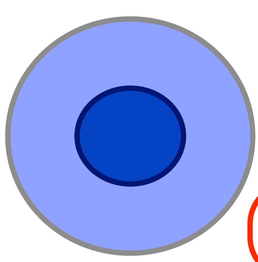
Electromagnetic Interaction

$$G_E = \frac{1}{(1+\frac{q^2}{R_0^2})^2} \qquad \rho(r) = \frac{R_0^3}{8\pi} e^{-R_0 r}$$

$r_N \approx 0.86 fm$

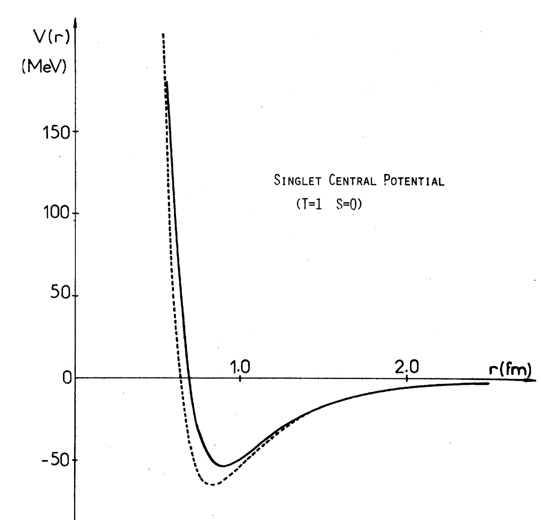
$R_0 \approx 4.27 fm^{-1}$

Strong Interaction



$R_c \approx 0.3 fm$

$$R_c \approx \frac{1}{R_0}$$



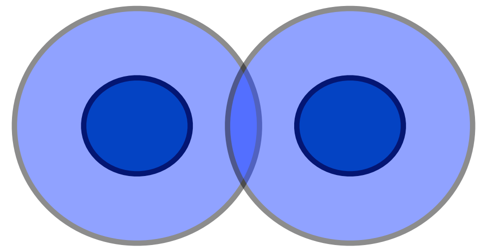
$$\frac{\rho(r=0)}{\rho_0} = 18.2$$

$$\frac{\rho(r=0.3fm)}{\rho_0} = 5.1$$

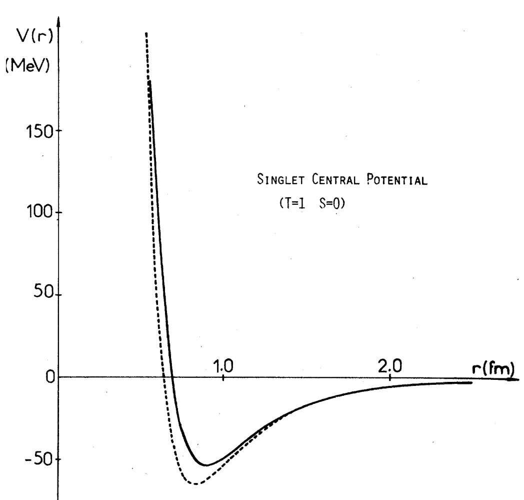
$$\frac{\rho(r=0.68fm)}{\rho_0} = 1$$

$$\rho(r) = \frac{R_0^3}{8\pi} e^{-R_0 r}$$

$$R_0 \approx 4.27 fm^{-1}$$



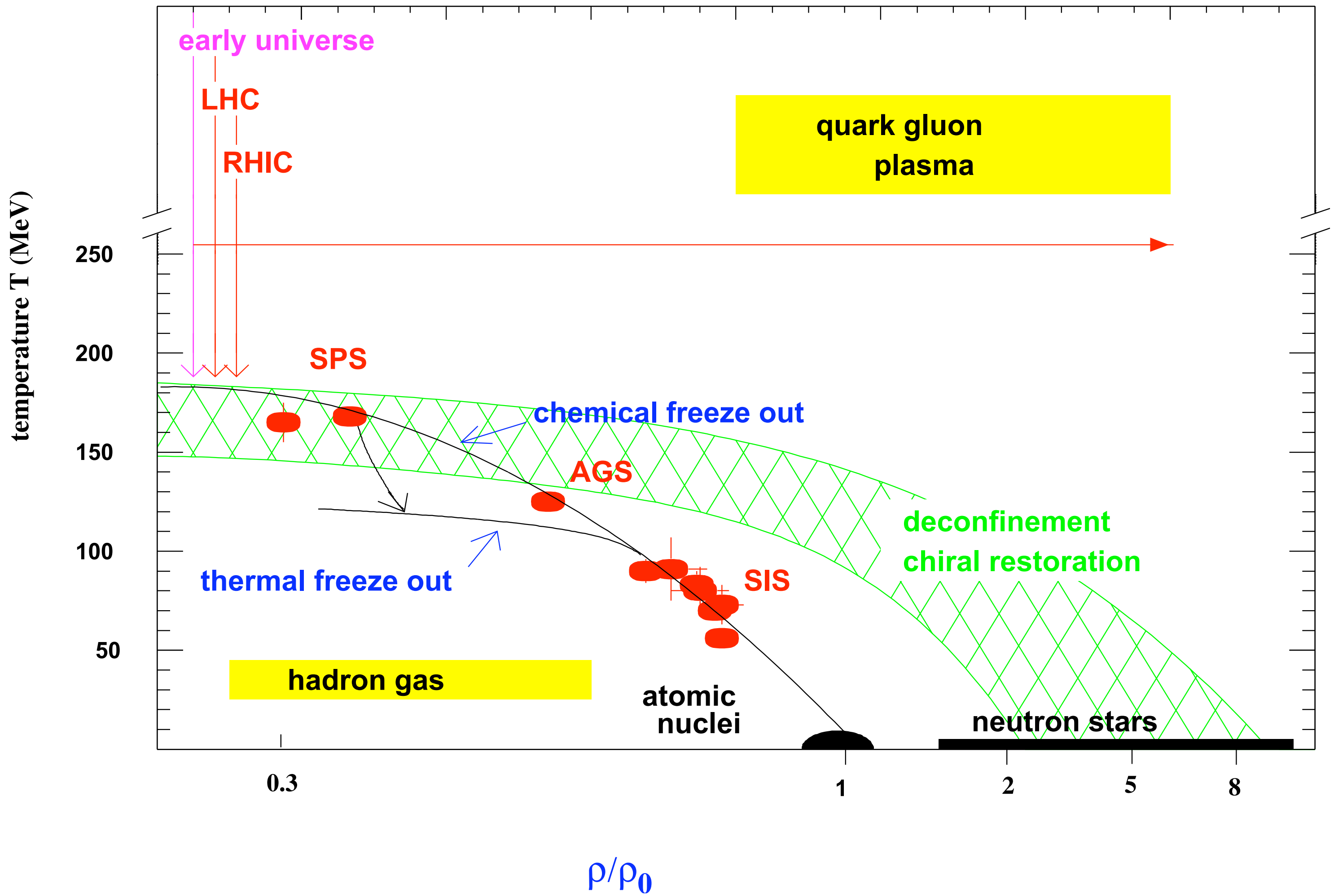
Quark Degrees of Freedom



$$r \leq \ \sim 0.3$$

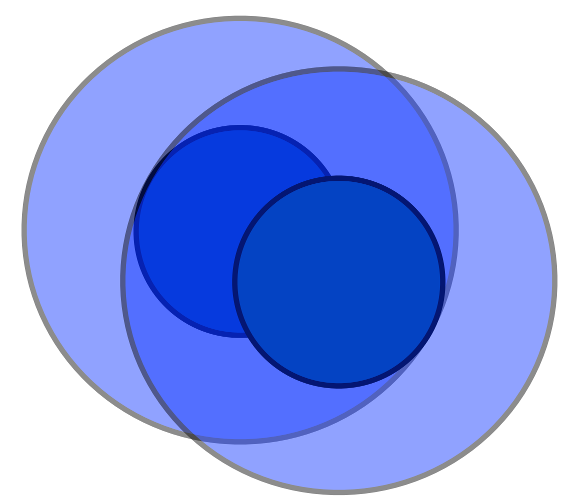
$$\rho \geq \ \sim 10\rho_0$$

Neutron Stars

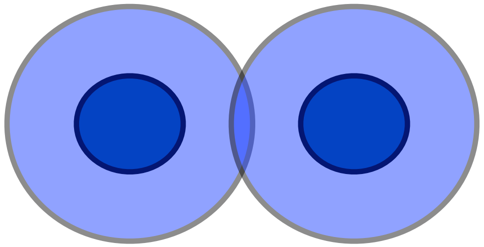


$$\frac{\rho(r=0)}{\rho_0} = 18.2$$

$$R_{BH} \leq 4km$$

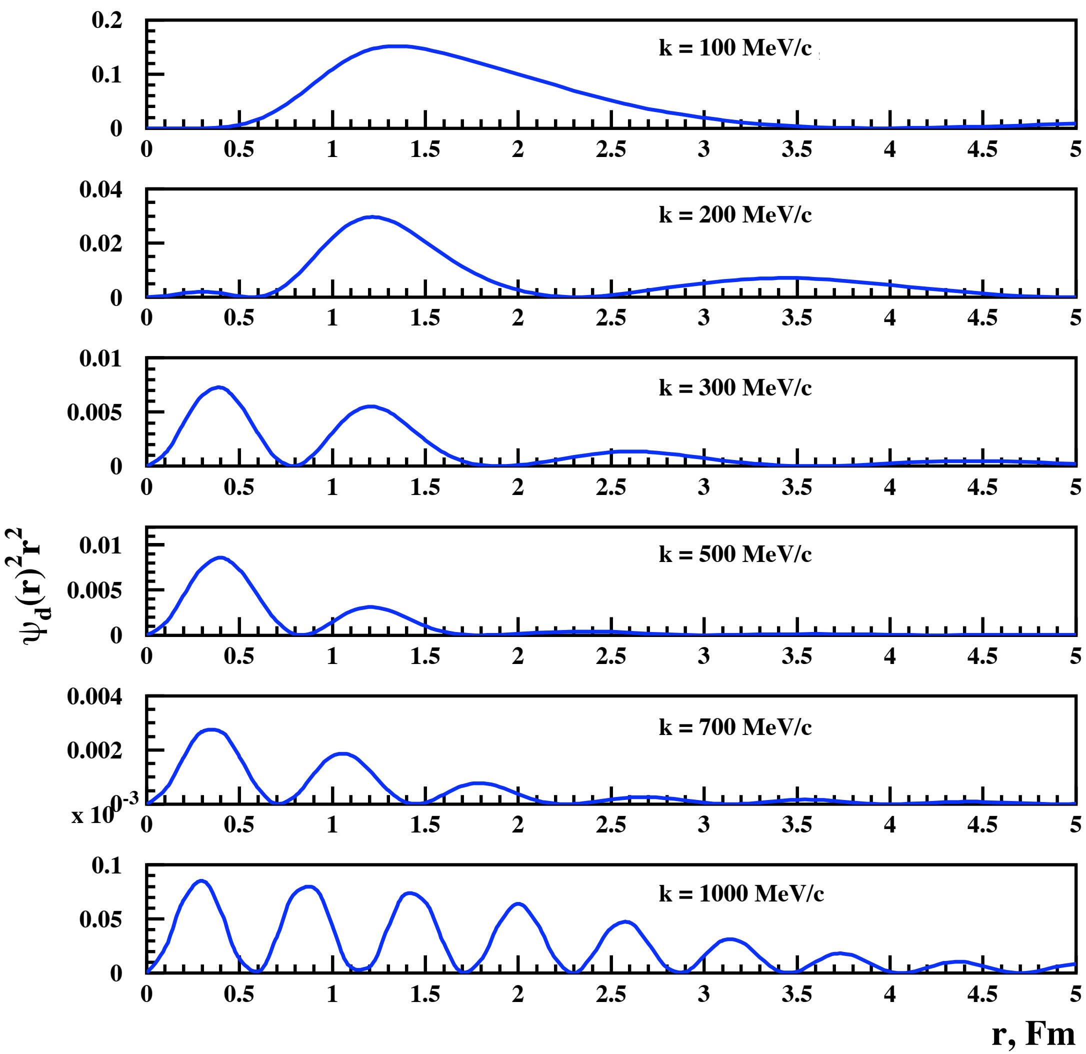


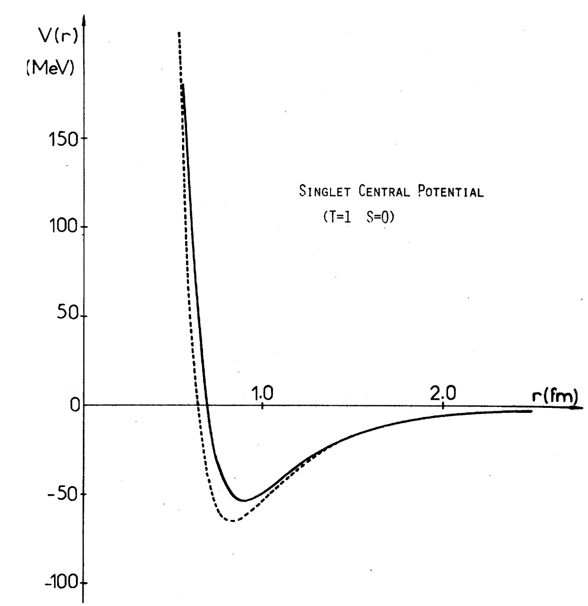
How to get nucleons close together



Probing at large relative momenta

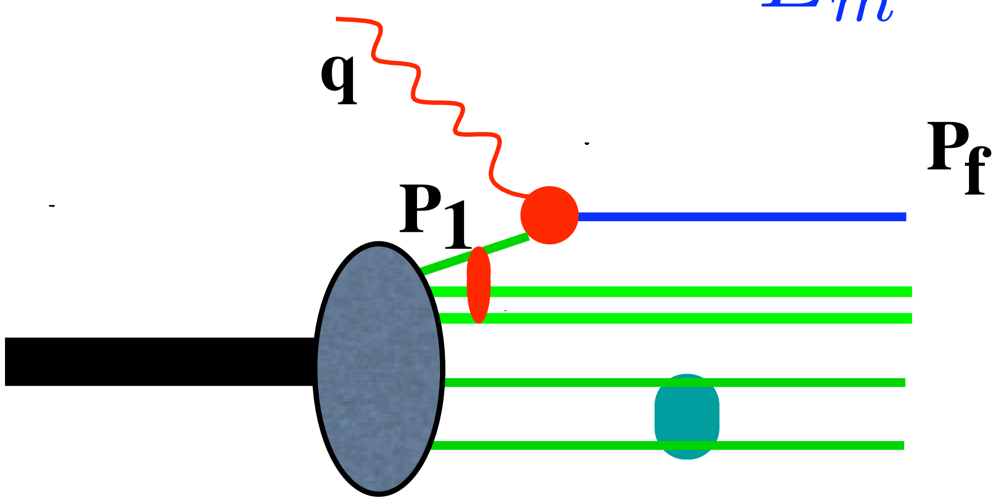
$$r \sim \frac{1}{k}$$



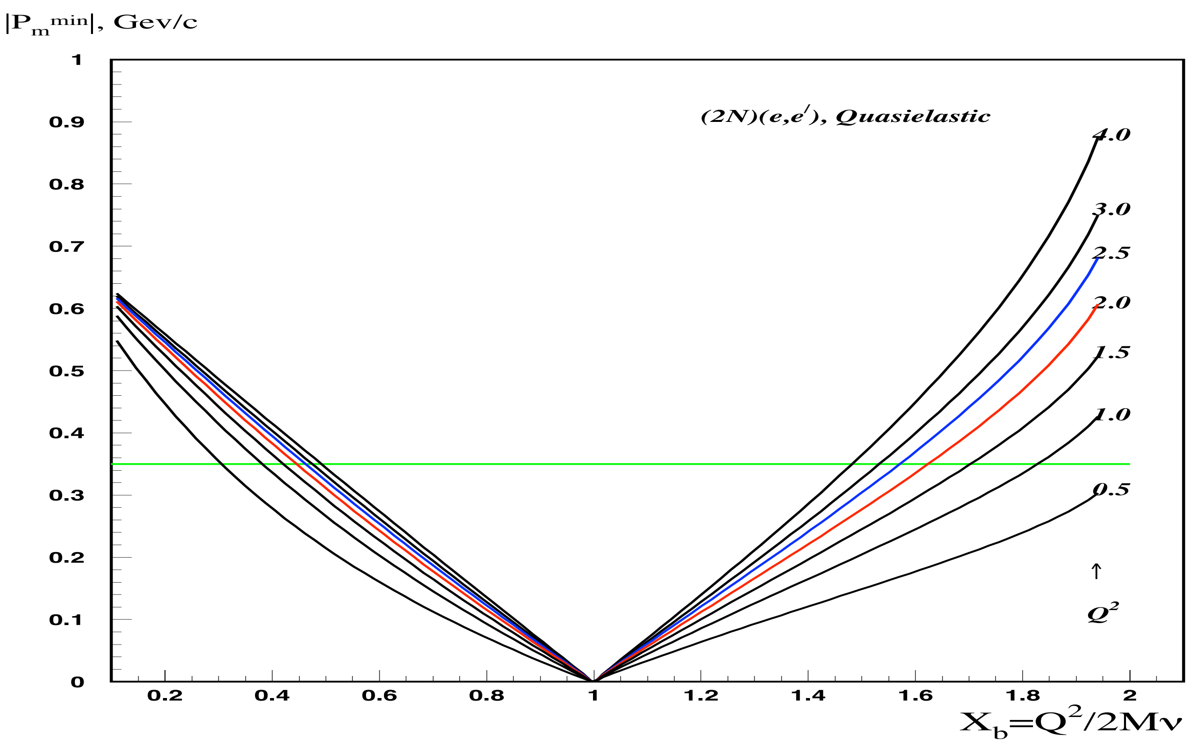


Quasi-Elastic Reaction

$$\vec{p}_1 = \vec{p}_f - \vec{q}$$
$$E_m = q_0 - T_f - T_{A-1}$$

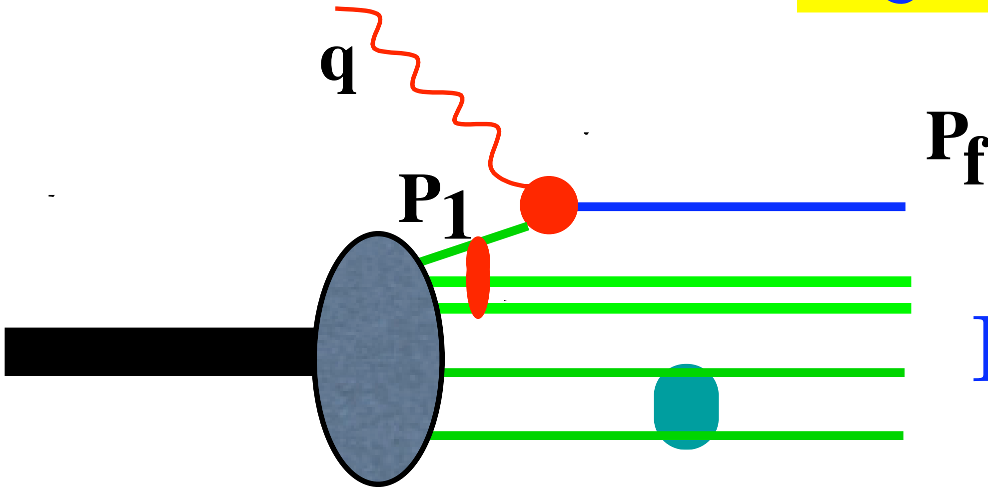


$$\alpha \geq x$$
$$\alpha \approx 1 + \frac{p_1^z}{m}$$
$$p_1^z \approx m(1-x)$$



Signatures

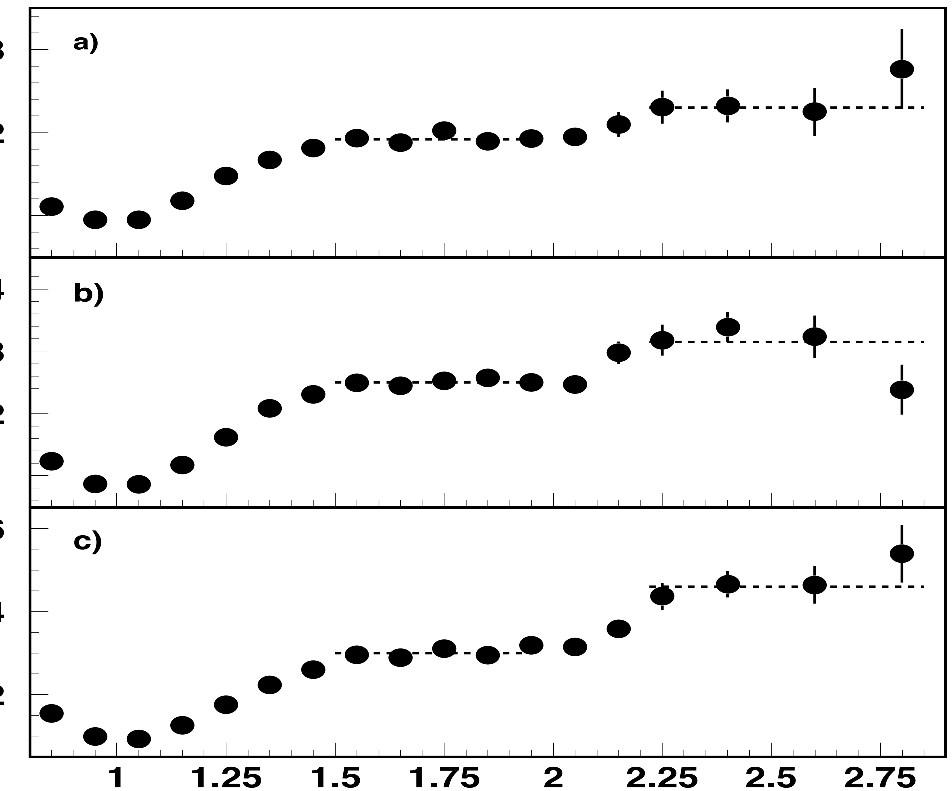
Frankfurt, Strikman, Phys.Rep 1988



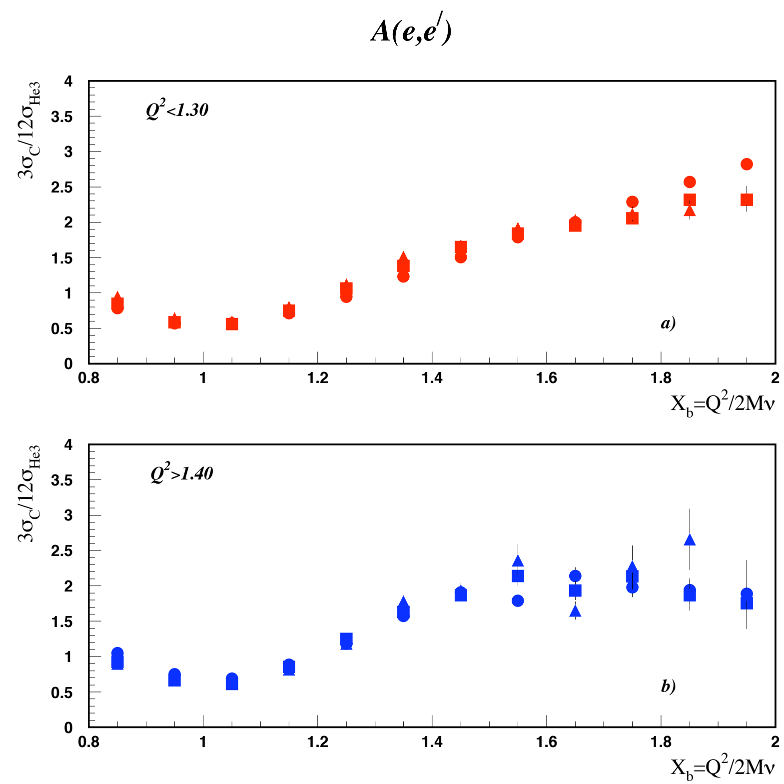
$$R = \frac{A_2\sigma[A_1(e,e')X]}{A_1\sigma[A_2(e,e')X]}$$

$$\text{For } 1 < x < 2 \;\; R \approx \frac{a_2(A_1)}{a_2(A_2)}$$

$$\text{For } 2 < x < 3 \;\; R \approx \frac{a_3(A_1)}{a_3(A_2)}$$



x_B Egiyan, et al PRL 2006

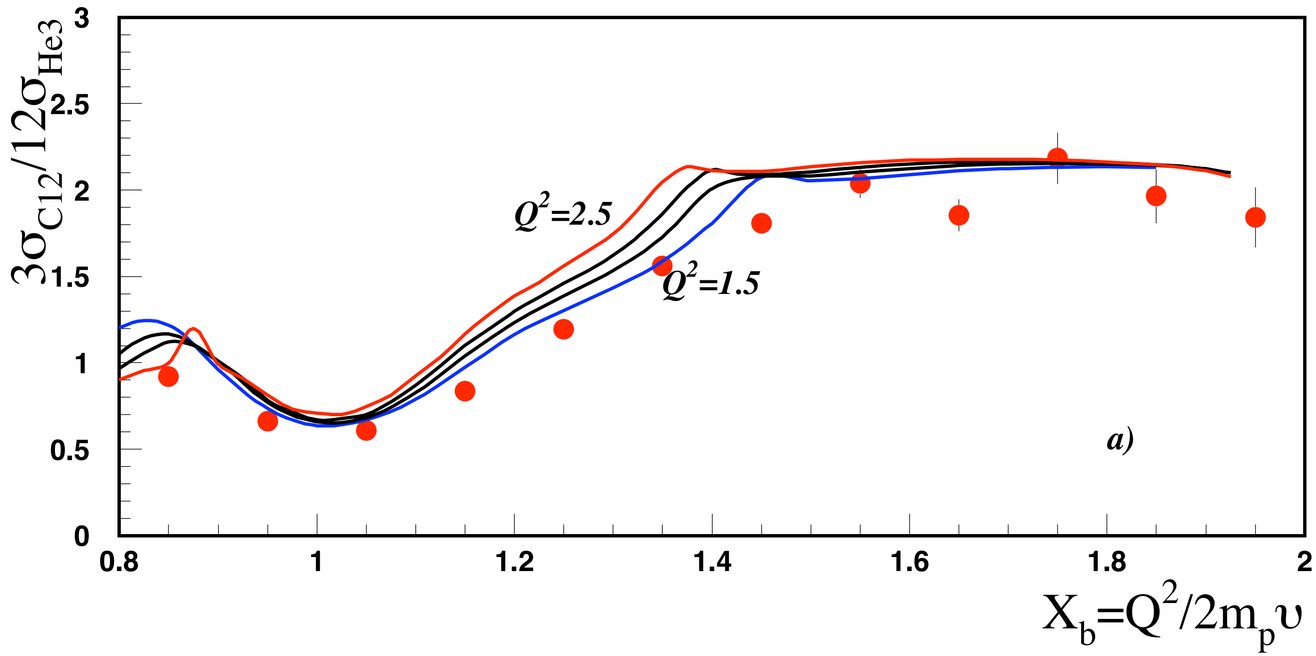


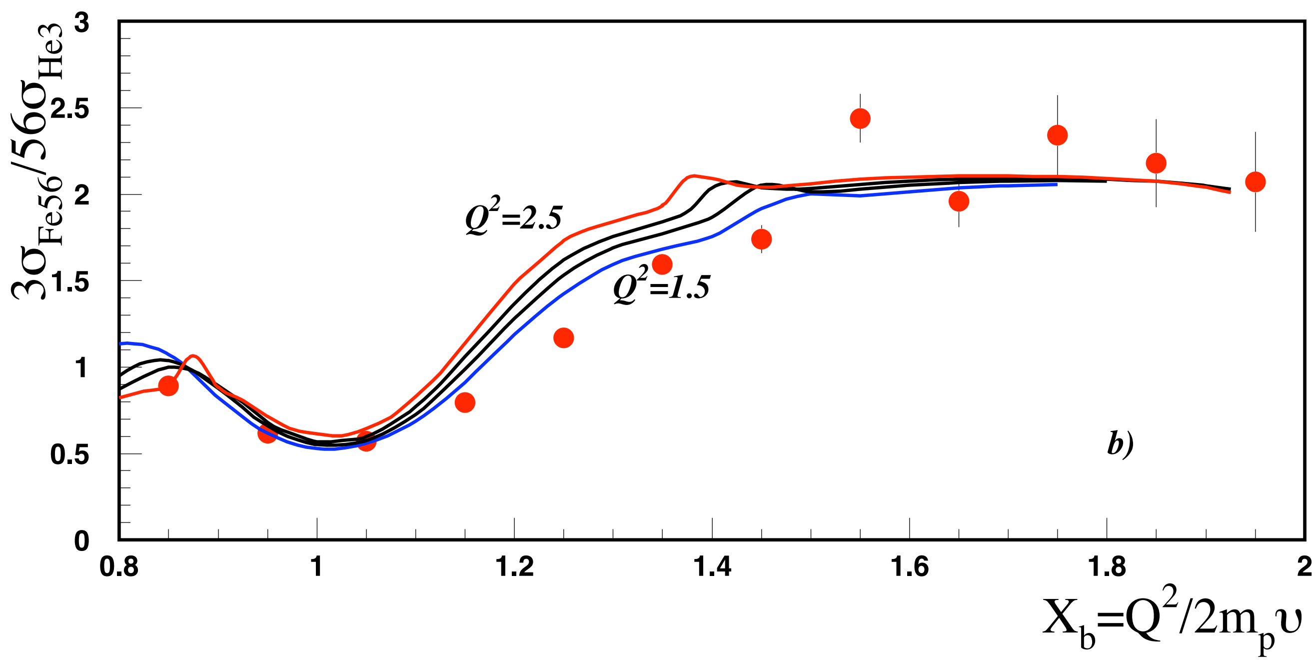
Egiyan, et al PRC 2004

$A(e,e')$

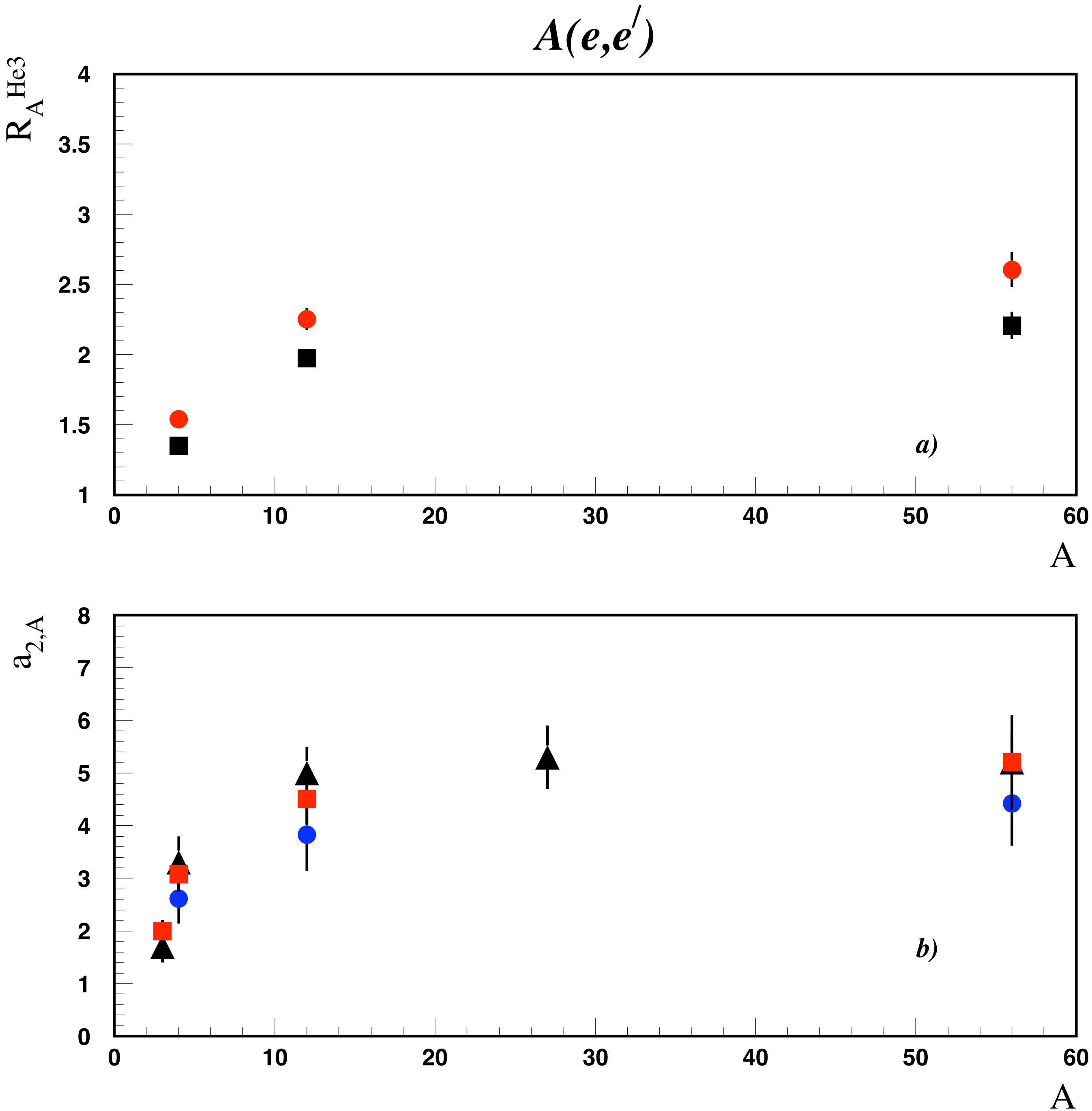
Calculations

Day, Frankfurt, MS, Strikman, PRC 1993





Data Egiyan, et al PRC 2004

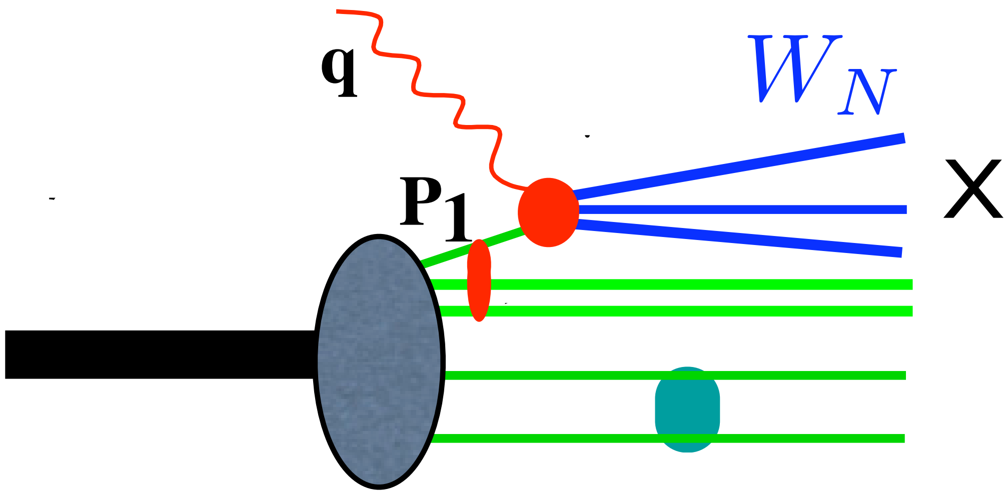


A(e,e/)
R_A^{He3}
4
3.5
3
2.5
2
1.5
1
a)
0
10
20
30
40
50
60
A
$a_{2,A}$
8
7
6
5
4
3
2
1
0
b)
0
10
20
30
40
50
60
A

	$a_{2N}(A)$
^{3}He	0.080±0.000± 0.004
^{4}He	0.154±0.002± 0.033
^{12}C	0.193±0.002± 0.041
^{56}Fe	0.227±0.002± 0.047

$a_{3N}(A)$
0.0018±0.0000±0.0006
0.0042±0.0002±0.0014
0.0055±0.0003±0.0017
0.0079±0.0003±0.0025

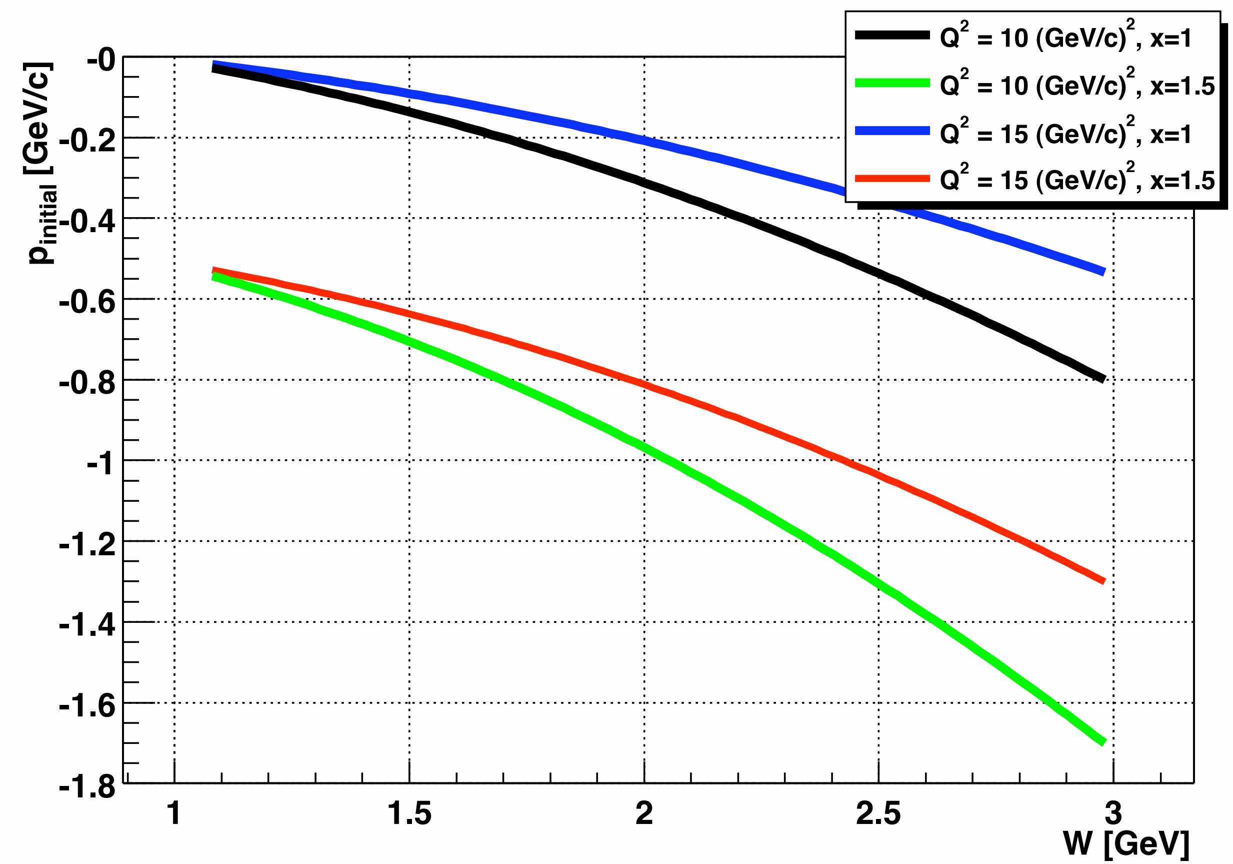
Deep Inelastic Scattering at x>1



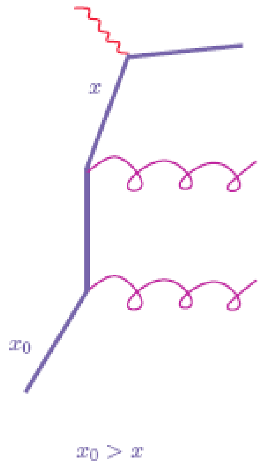
Two processes driving nucleons close together

First: Kinematics

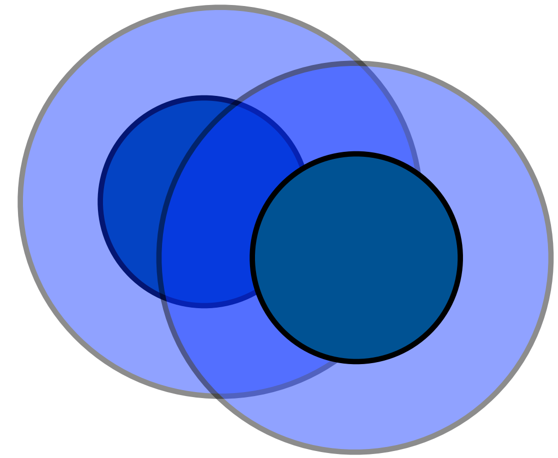
$$p_1^z = m(1 - x - x\left[\frac{W_N^2 - m^2}{Q^2}\right])$$

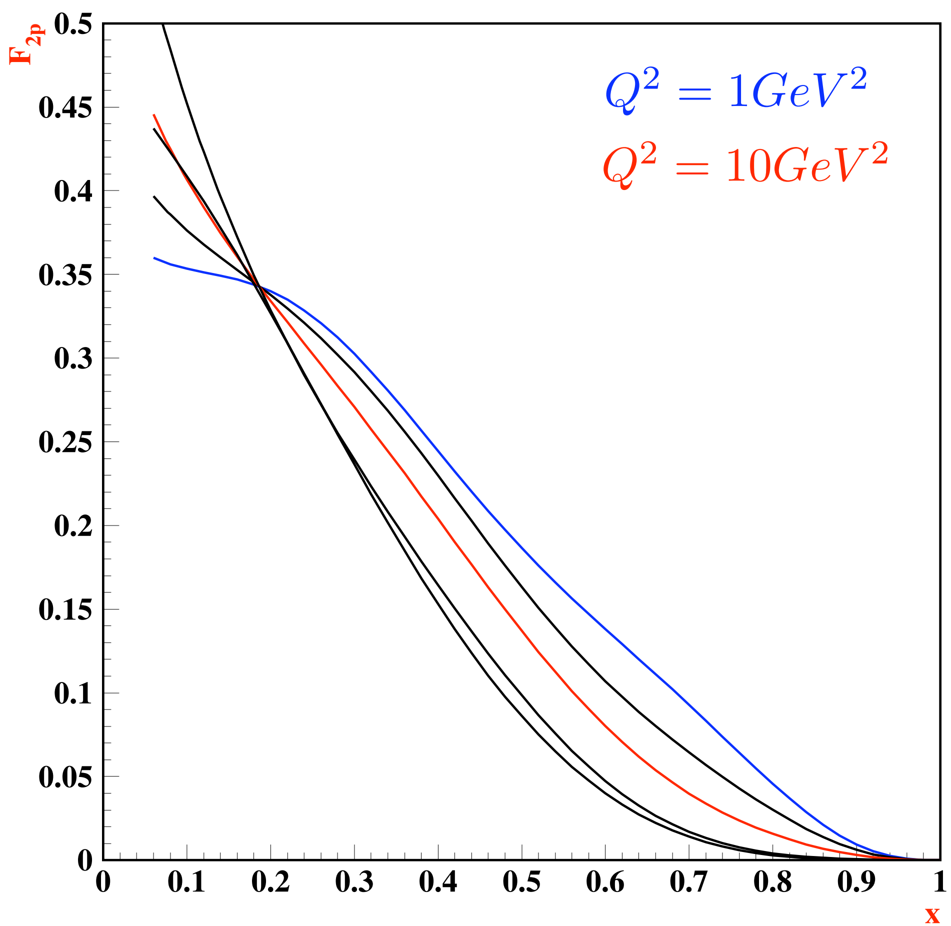


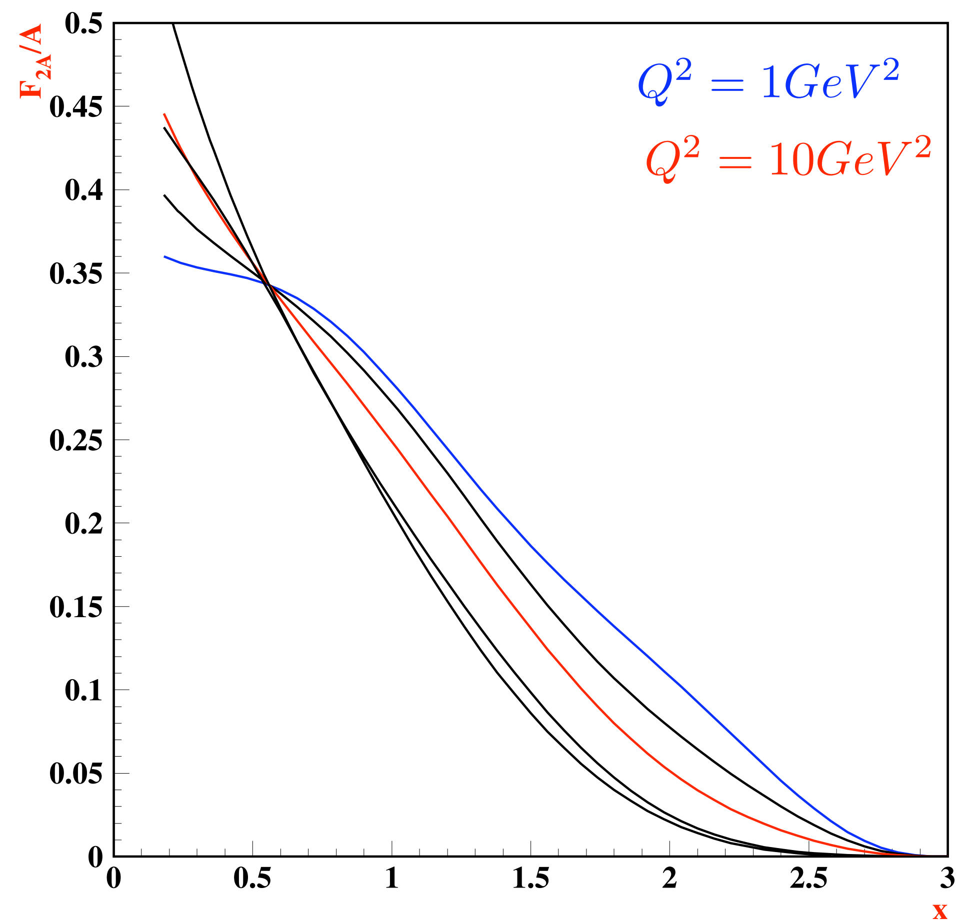
Second: Dynamics



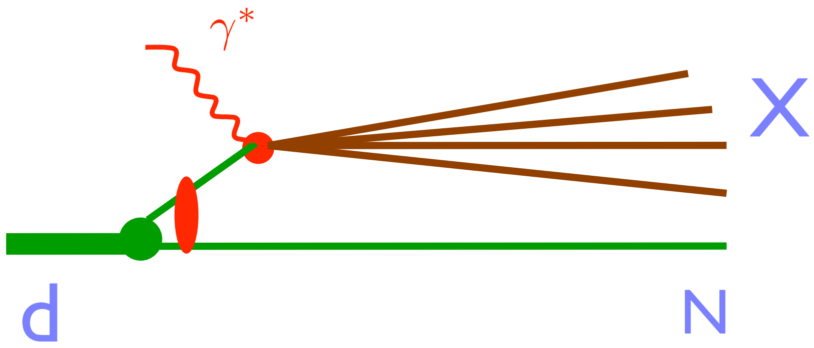
Consider: Deuteron





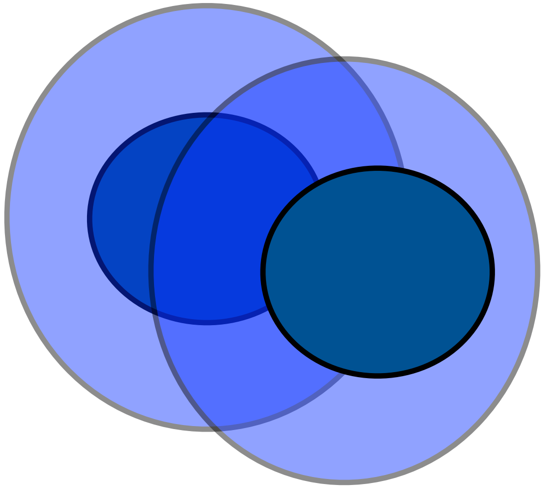


Convolution Model

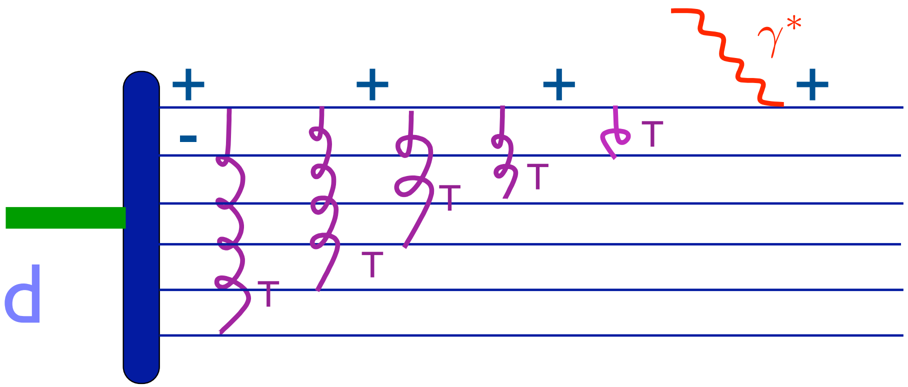


$$F_{2d} = \int_x^2 \rho_d^N(\alpha, p_t) F_{2N}\left(\frac{x}{\alpha}, Q^2\right) \frac{d^2\alpha}{\alpha} d^2 p_t$$

$$F_{2N} \rightarrow F_{2N}^{mod}$$

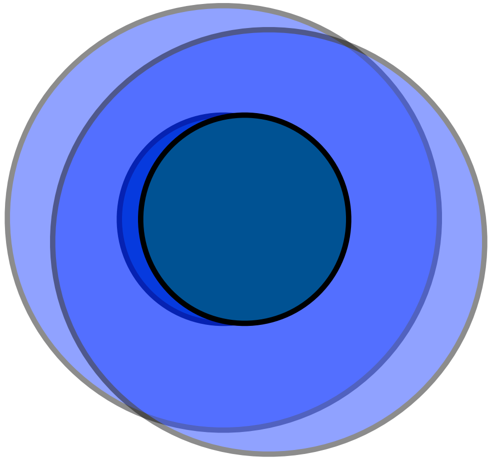


Quark-Cluster - 6q - Model



$$F_2 \sim (1-x)^{2N-3+2|\Delta\lambda|}$$

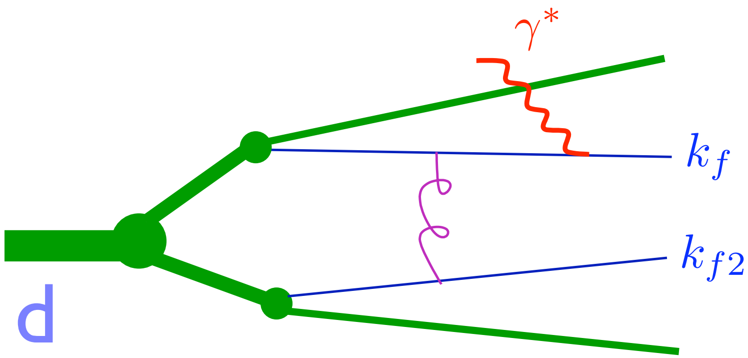
Gunion, Nason, Blankenbecler, PRD 1984

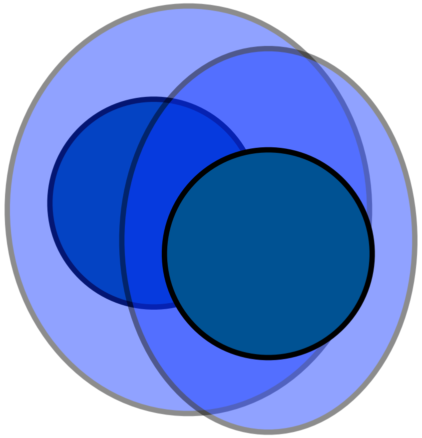


$$F_{2D} = F_{2,(6q)} \sim (1-\frac{x}{2})^{10}$$

Carlson, Lassila, Sukhatme, PLB 1988,1991

Hard Gluon-Exchange Model



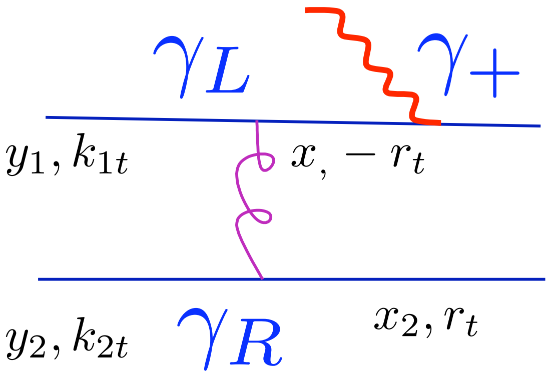


$$\mathcal{M}^\mu = \int \frac{\Psi_d(\alpha, p_t)}{(1-\alpha)} \frac{d\alpha}{\alpha} \frac{d^2 p_t}{2(2\pi)^3} \times$$

$$\bar{u}(k_f)[e_q \gamma^\mu] u_{\zeta'}(k_f - q) \frac{1}{(k_f - q)^2 - m_q^2} \bar{u}_{\zeta'}(k_f - q)[g T^a \gamma^{\nu_1}] u_\zeta(k_1) \frac{\psi_N(y_1, k_{1t})}{y_1}$$

$$\bar{u}_{\eta'}(k_{f2})[g T^b \gamma^{\nu_2}] u_\eta(k_2) \frac{\psi_N(y_2, k_{2t})}{y_2} \frac{d^{\nu_1,\nu_2} \delta_{ab}}{(k_2 - k_{f2})^2}$$

$$F_{2d} = W^{++} \cdot \nu \left(\frac{m_N}{p_{d+}} \right)^2 \qquad W^{++} = \frac{1}{4\pi m_d} \int |\mathcal{M}^+|^2 dQ$$



$$\gamma_{R,L} = \gamma_x \pm \gamma_y$$

$$\gamma_{\pm} = \gamma_0 \pm \gamma_z$$

Reference Frame

$$q_+ = 0$$

$$q = (0, \frac{2\nu m_d}{p_{d+}}, \sqrt{Q^2})$$

$$p_d = (p_{d+}, \frac{m_d^2}{p_{d+}}, 0)$$

$$kernel = \sqrt{x x_2}(1-\alpha)\alpha(1 - \frac{x}{y_1 + y_2})\frac{8p_{d+}}{((1-\alpha)y_1 + \alpha y_2)r_t^2}$$

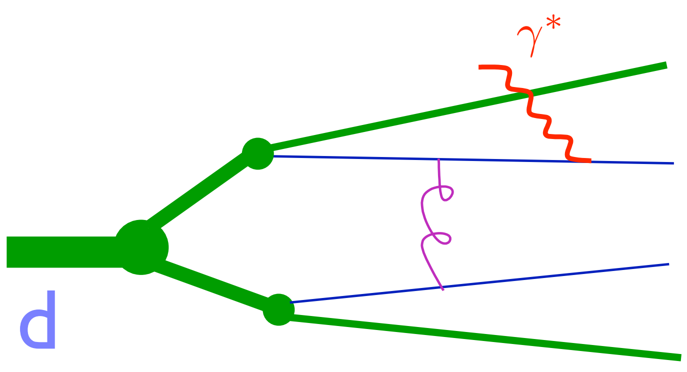
$$F_{2D} \approx N\left[\int \psi_d(\alpha, p_t)\cdot \frac{d\alpha}{\alpha}\frac{d^2 p_t}{2(2\pi)^3}\right]^2 \times$$

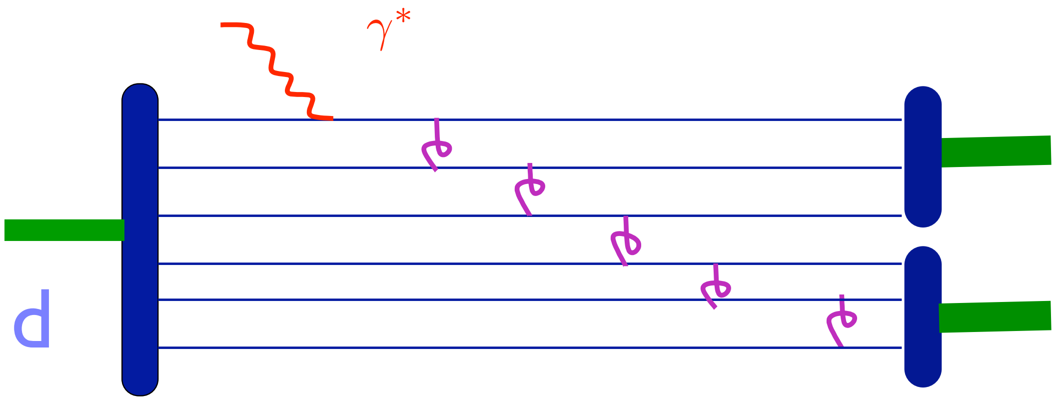
$$\times \int_0^1\int_0^1 \left(1 - \frac{x}{y_1+y_2}\right)^2 \theta(y_1 + y_2 - x) f_1(y_1) f_2(y_2)\, dy_2\, dy_1$$

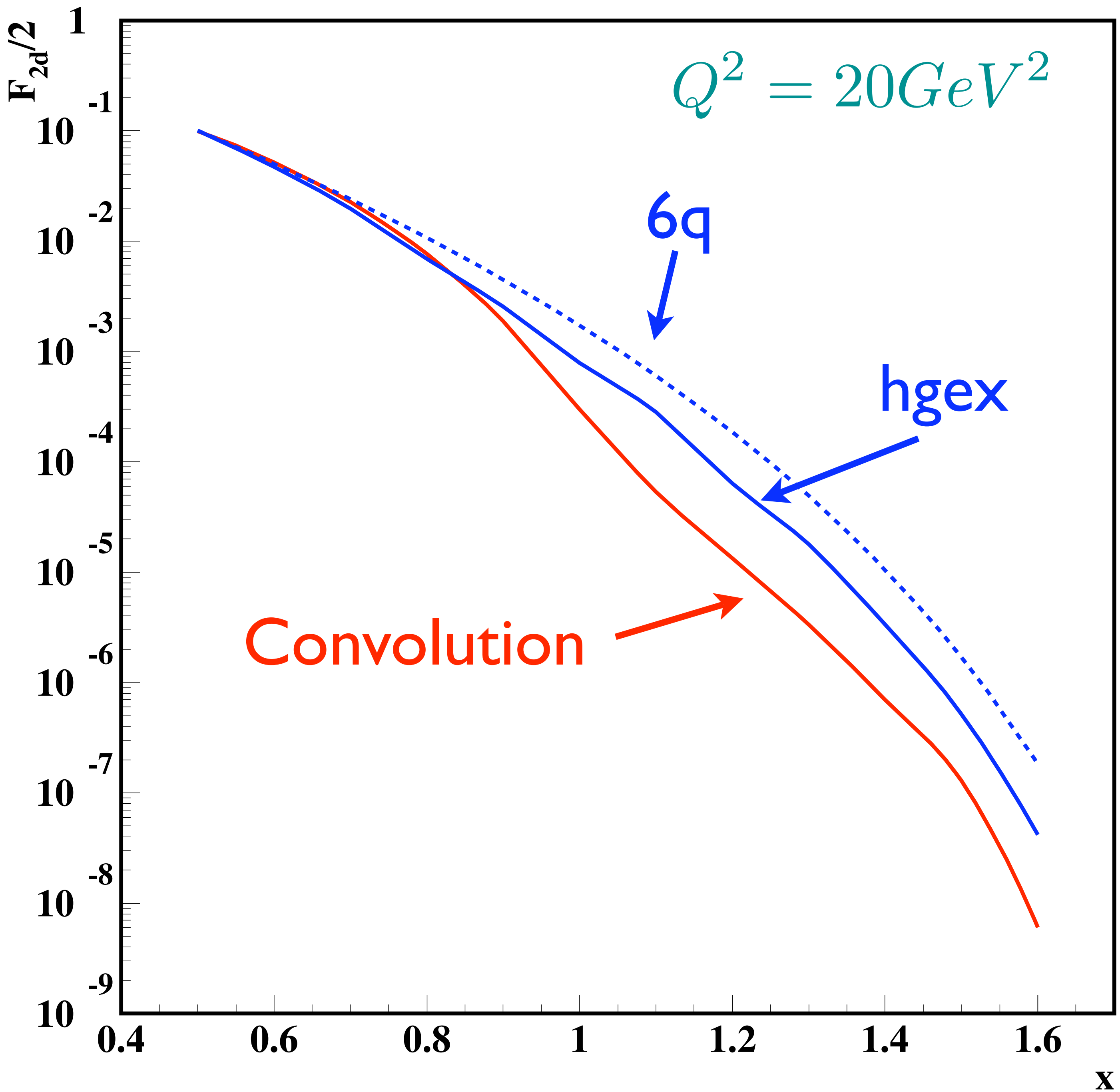
-This softening of x distribution

-This may be unique to DIS

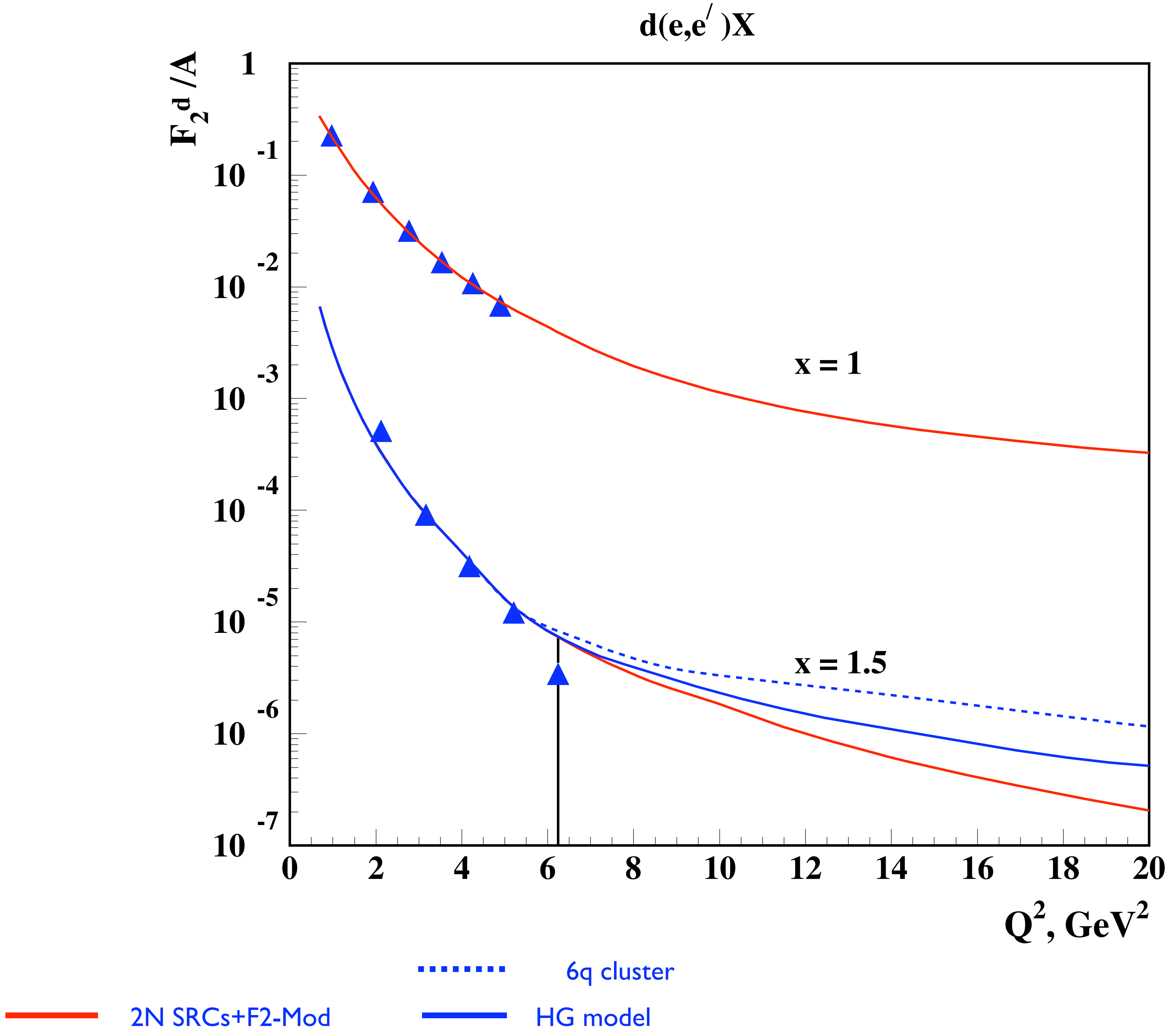
-May not happen to QE scattering





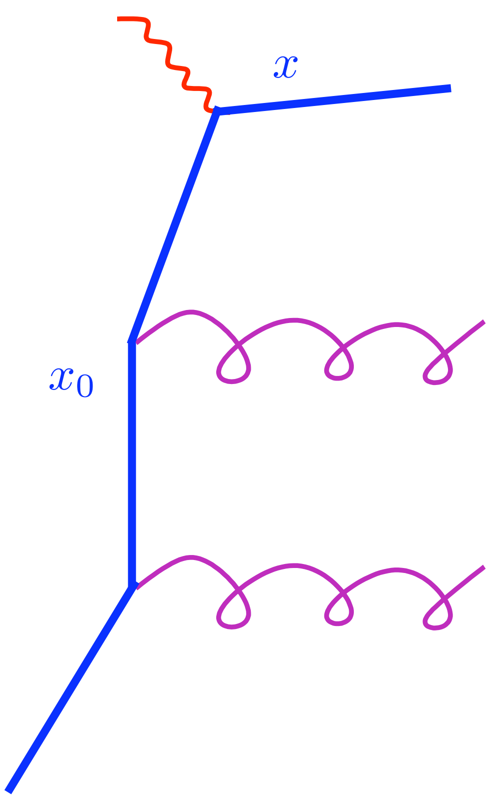


$F_{2d}/2$
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
0.4
0.6
0.8
1
1.2
1.4
1.6
x
$Q^2 = 20GeV^2$
6q
hgex
Convolution

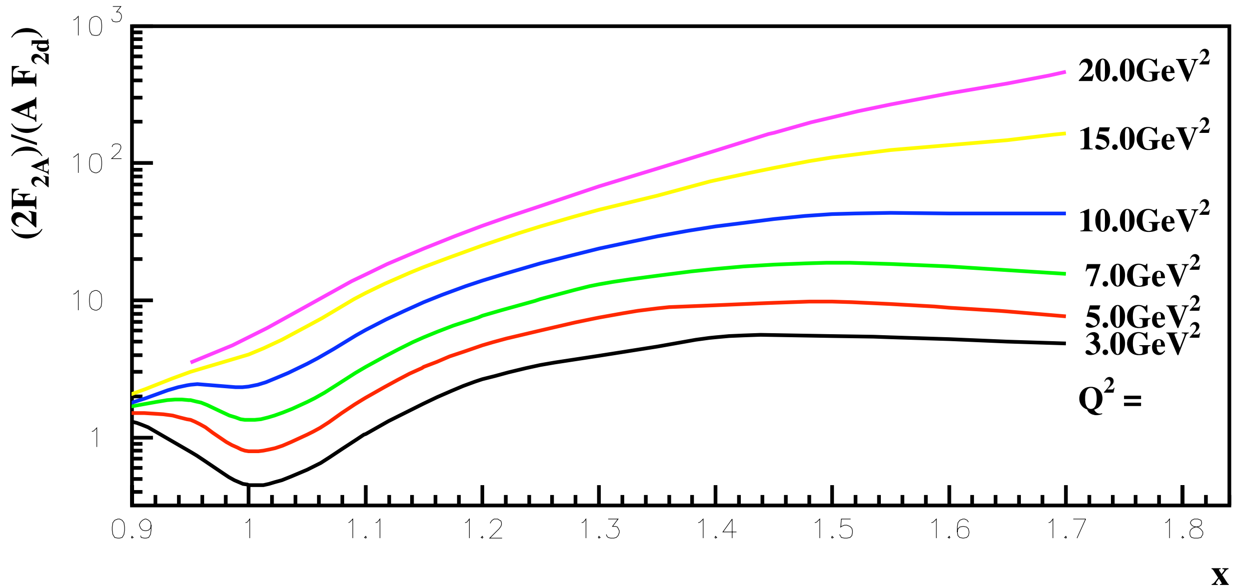


d(e,e/)X
F2d /A
1
10-1
10-2
10-3
10-4
10-5
10-6
10-7
0
2
4
6
8
10
12
14
16
18
20
Q2, GeV2
x = 1
x = 1.5
6q cluster
2N SRCs+F2-Mod
HG model

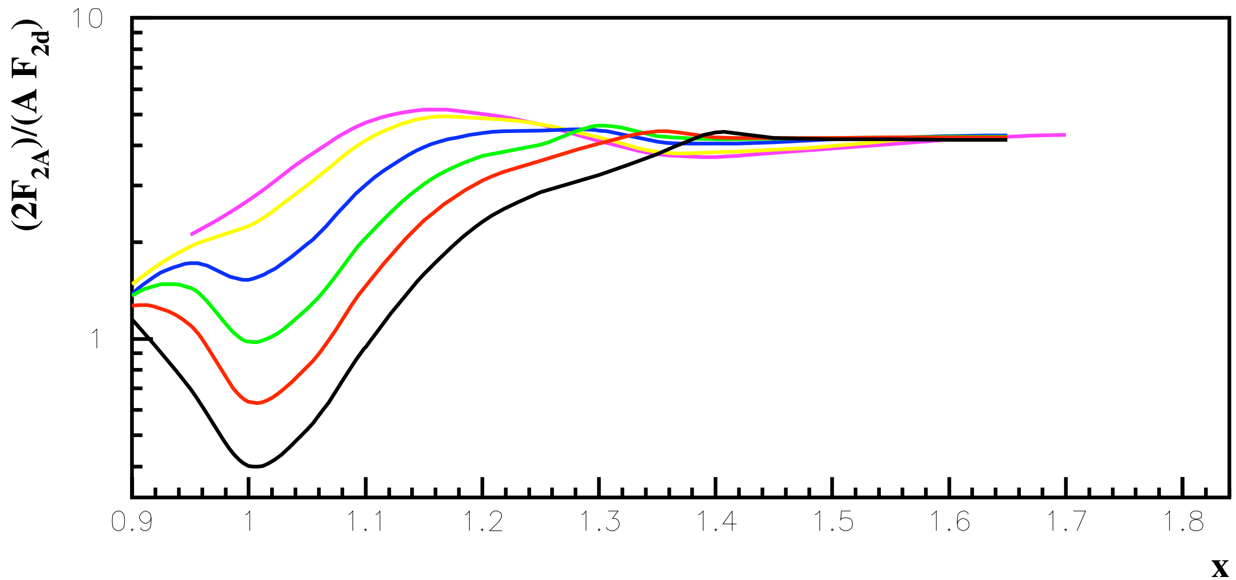
A/d Ratios with Parton Evalution



$x_0 > x$



2N+3N models



2N models only

Summary

- QE scatterings show a sizable 2N and finite 3N SRCs in Nuclei

- DIS reactions at x>1 may allow to probe the content of the nuclear core

- They allow to study the hadron-quark transition at short space time separation in nuclei

- Our study shows that within fast quark picture nuclear core is more accessible than within standard hadronic picture