Nuclear Effects on Parton Distributions

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Workshop on Physics of Nuclei with 12 GeV Electrons
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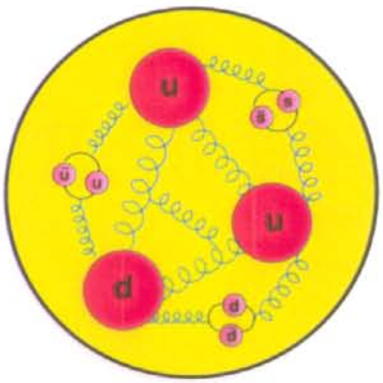
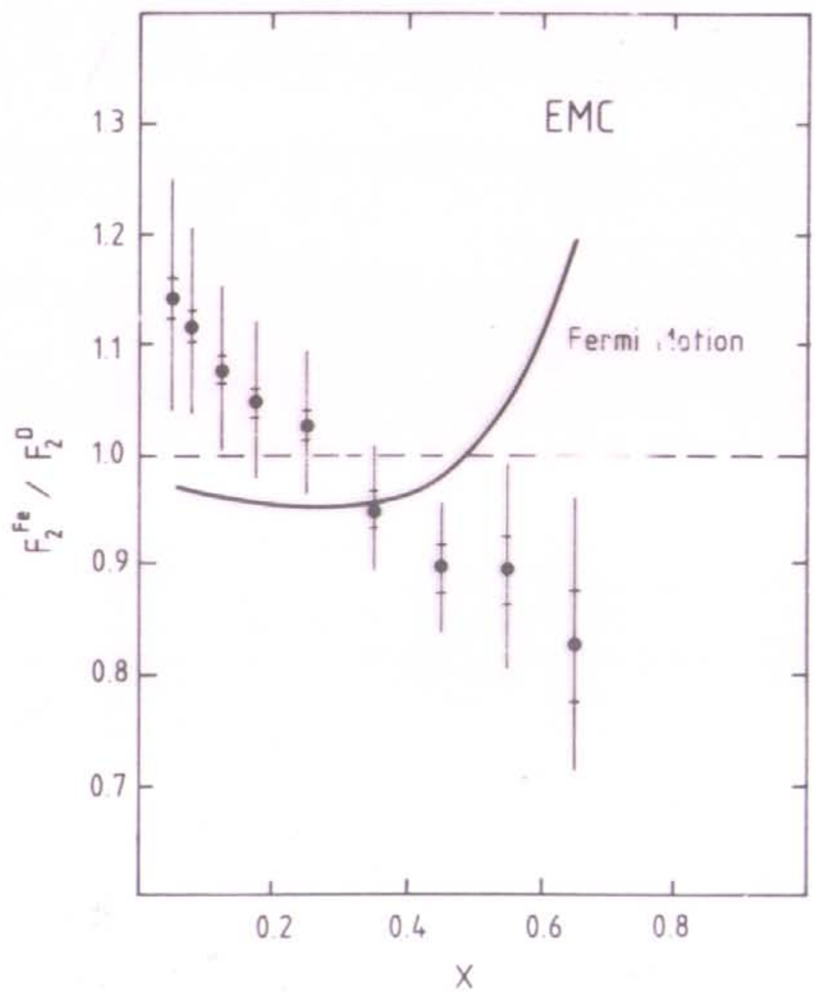


- Experimental information
- Resulting parametrisations
- Future measurements

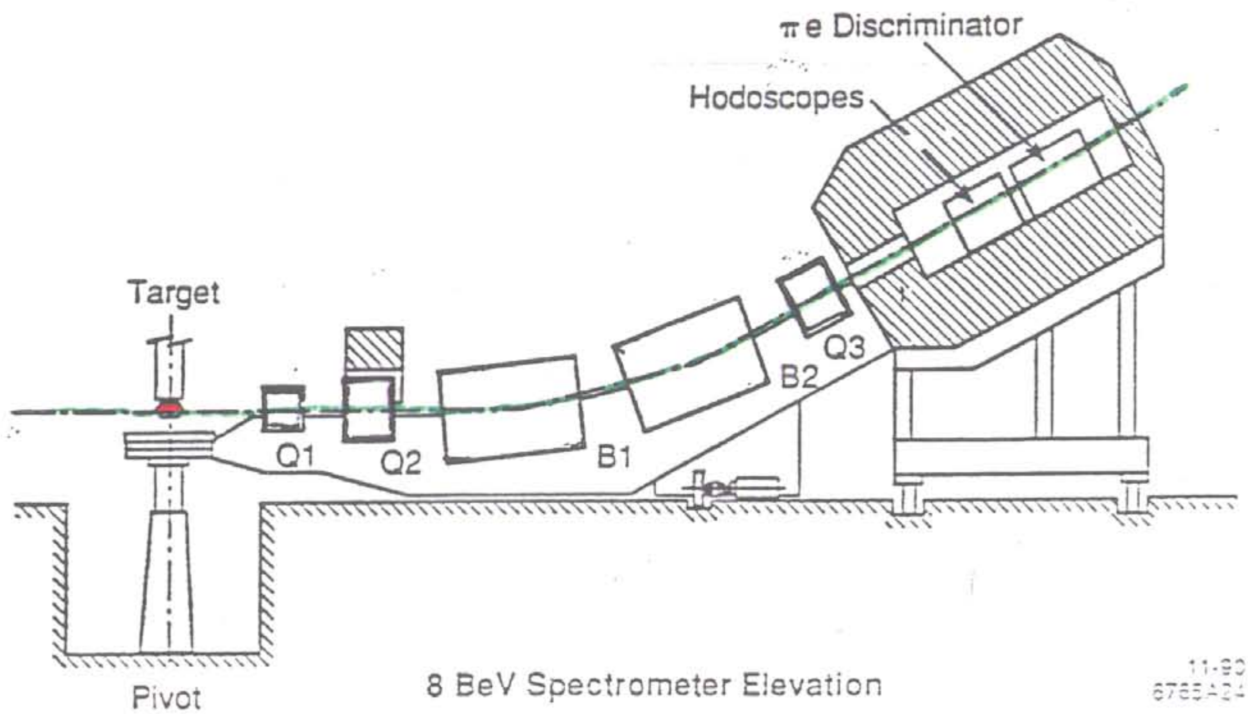
Nuclear Effects in Deep-Inelastic Scattering

- 1983: European Muon Collaboration (CERN)



$F_2(x)$ different in iron and deuterium !
$\longrightarrow$ modification of quark and/or gluon distributions in nuclear environment ?

SLAC : e-N

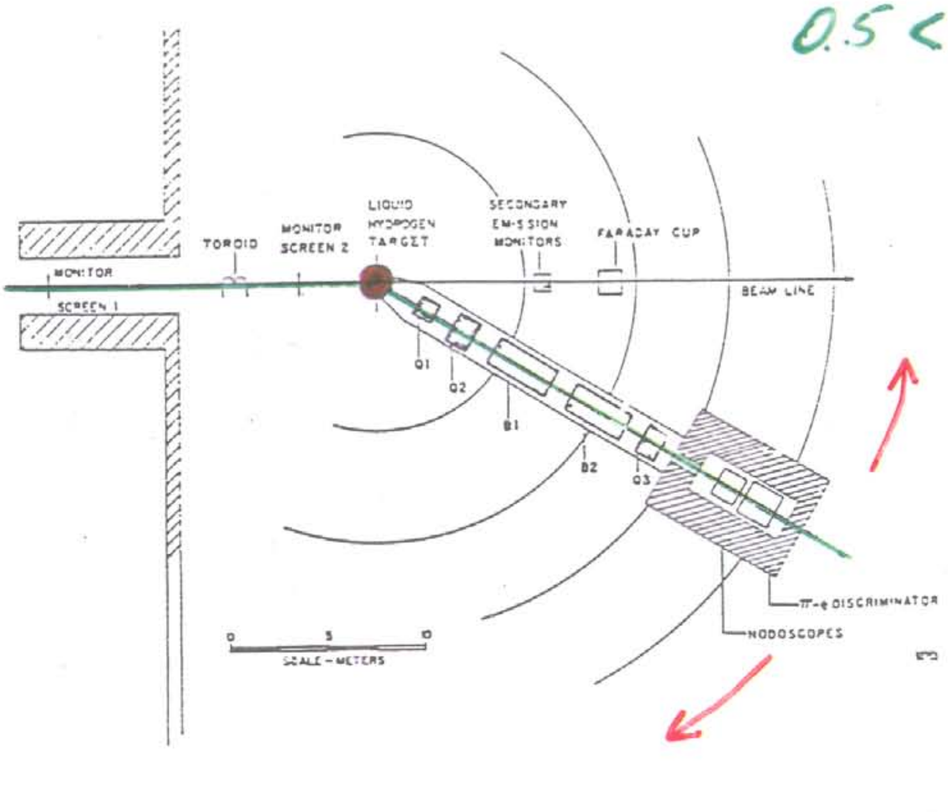


8 BeV Spectrometer Elevation

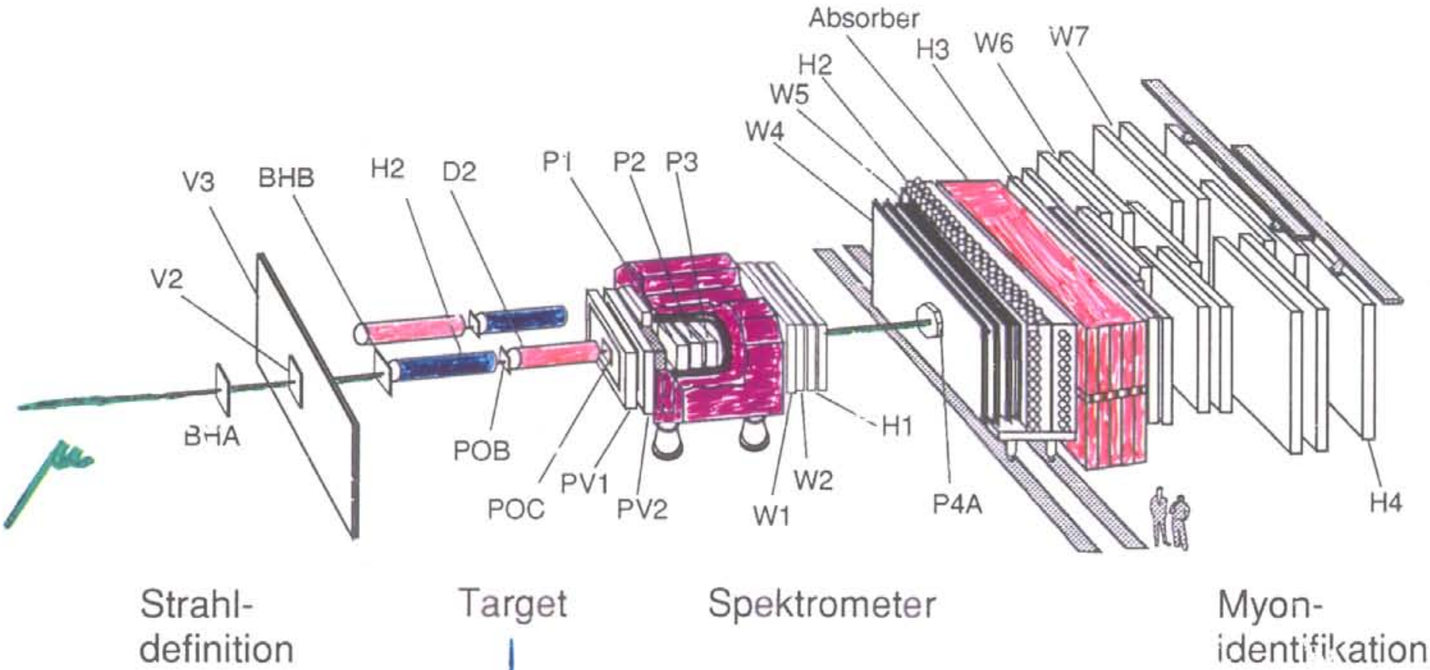
11-90
6765A24

$0.06 < x < 0.9$

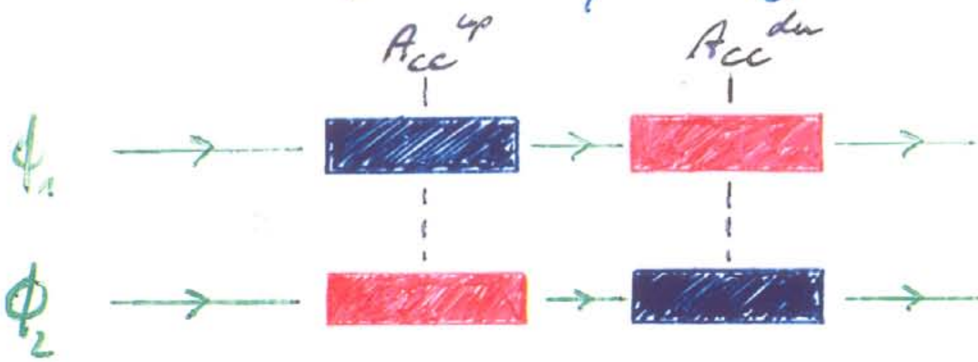
$0.5 < Q^2 < 20$



The NMC spectrometer



The complementary target setup

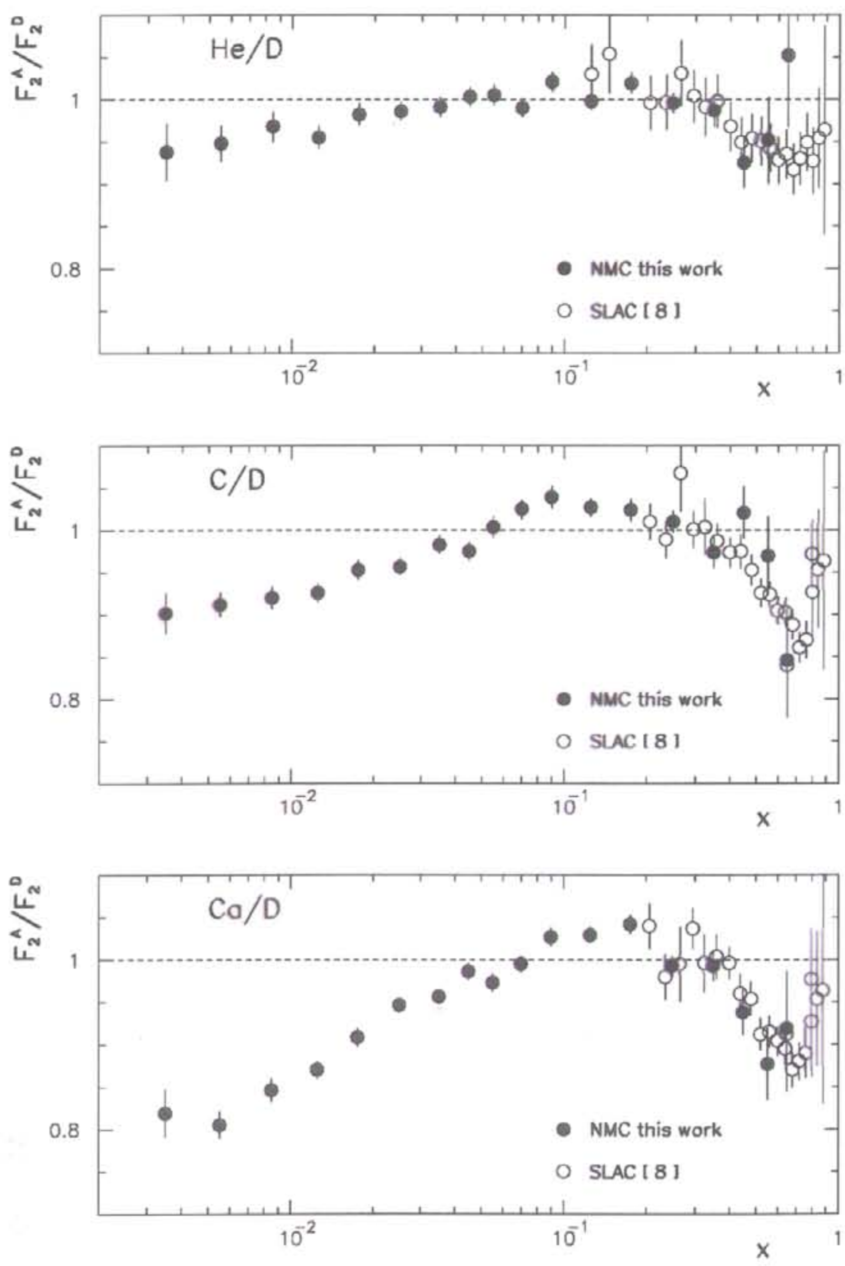


material A

material B

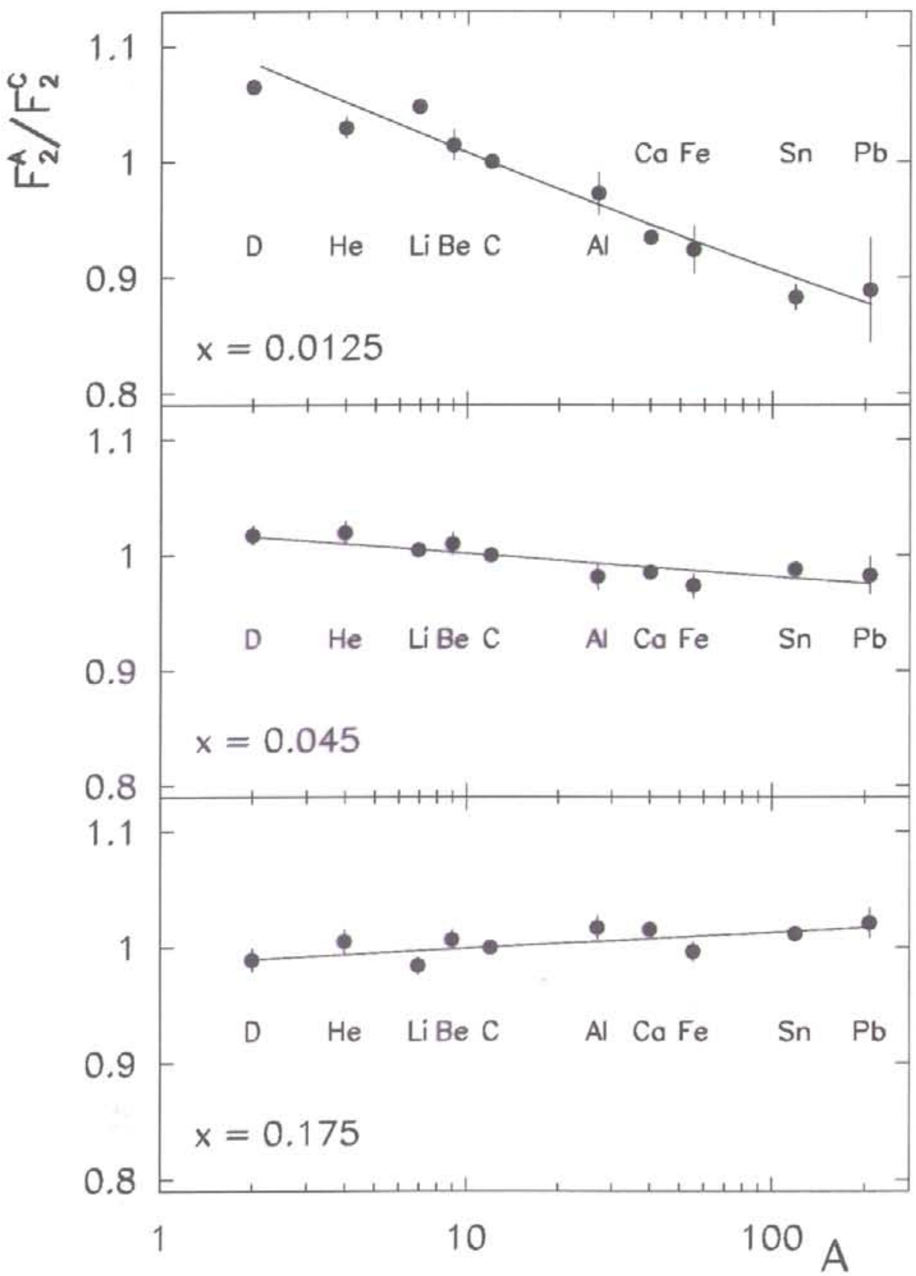
$$\frac{\sigma^A}{\sigma^B} \propto \sqrt{\frac{N^A_{up} \cdot N^A_{dn}}{N^B_{up} \cdot N^B_{dn}}}$$

x- and A-dependence of the EMC effect



$F_2^A \neq F_2^D$ for all values of x
effect increasing with atomic number A

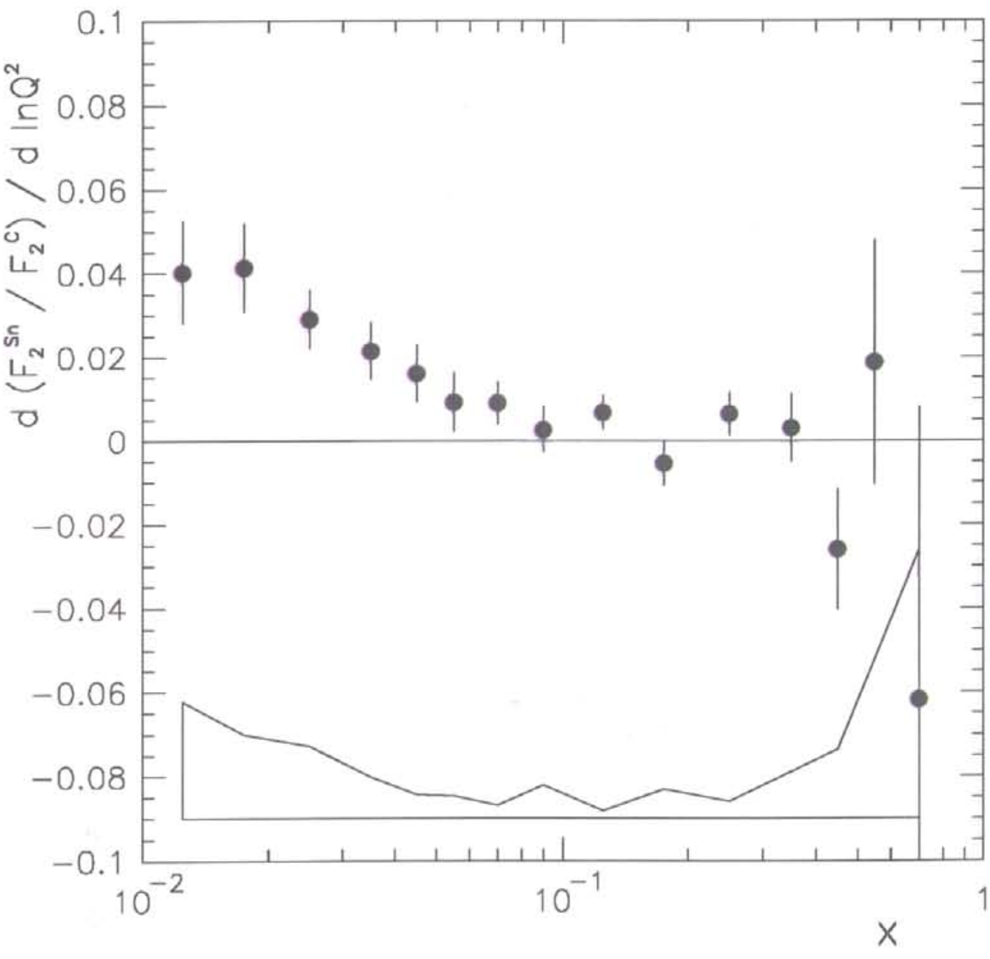
Parametrisations of the A-dependence



Simple power dependence A^α describes the data well

Q^2 dependence of the EMC effect

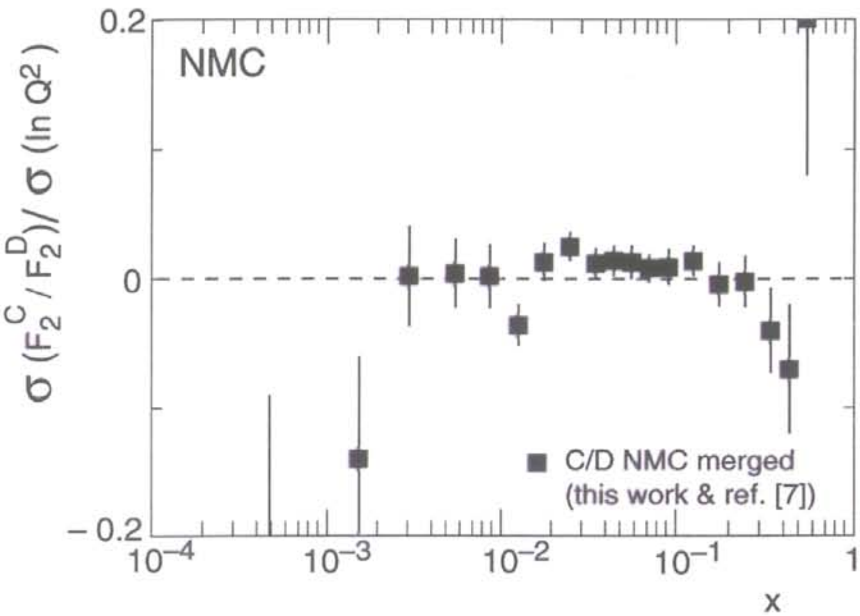
- Data on F_2^{Sn}/F_2^C collected at 4 different beam energies (NMC)



Small and positive Q^2 dependence at low values of x

Q^2 dependence of the EMC effect

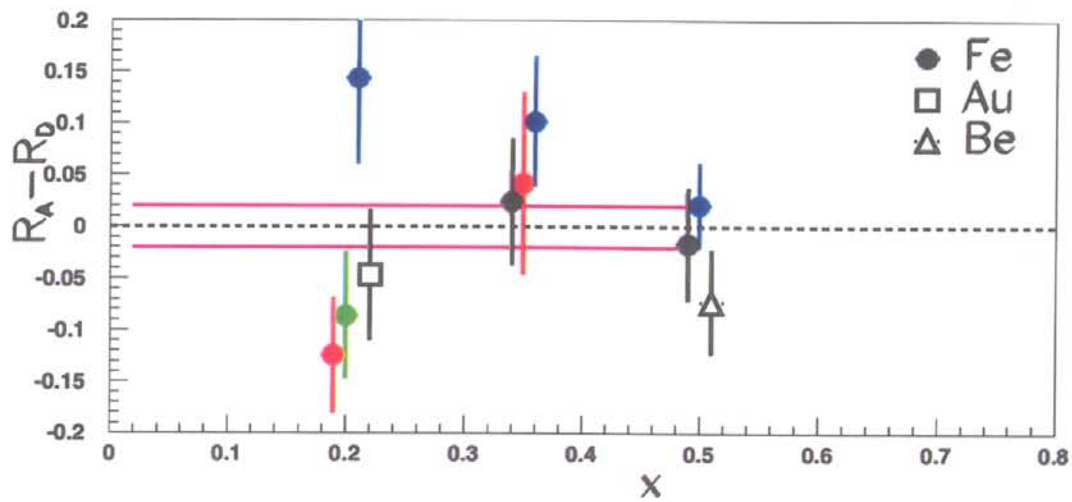
- Precision data on F_2^C/F_2^D (NMC)

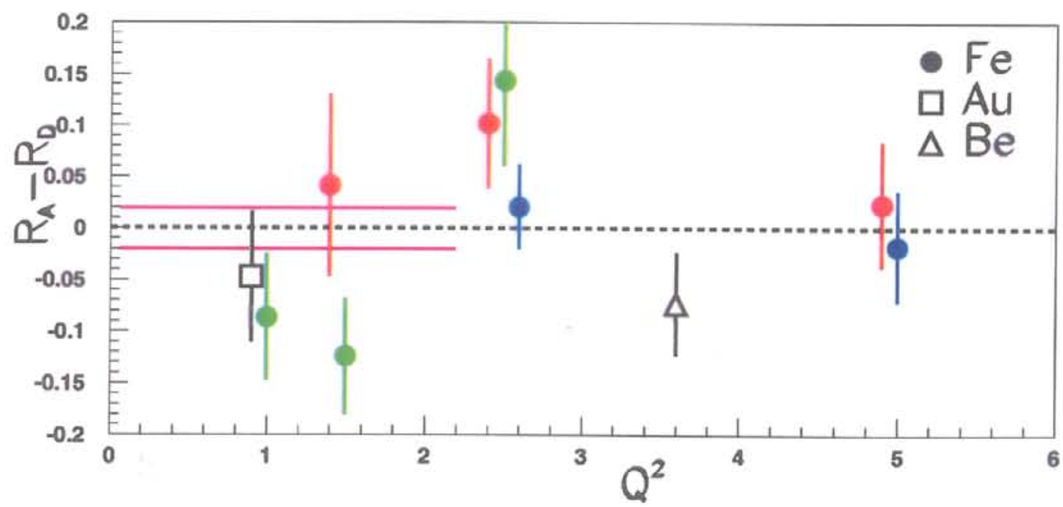


No significant Q^2 dependence observed

Nuclear effects in $R(x, Q^2)$

- SLAC data

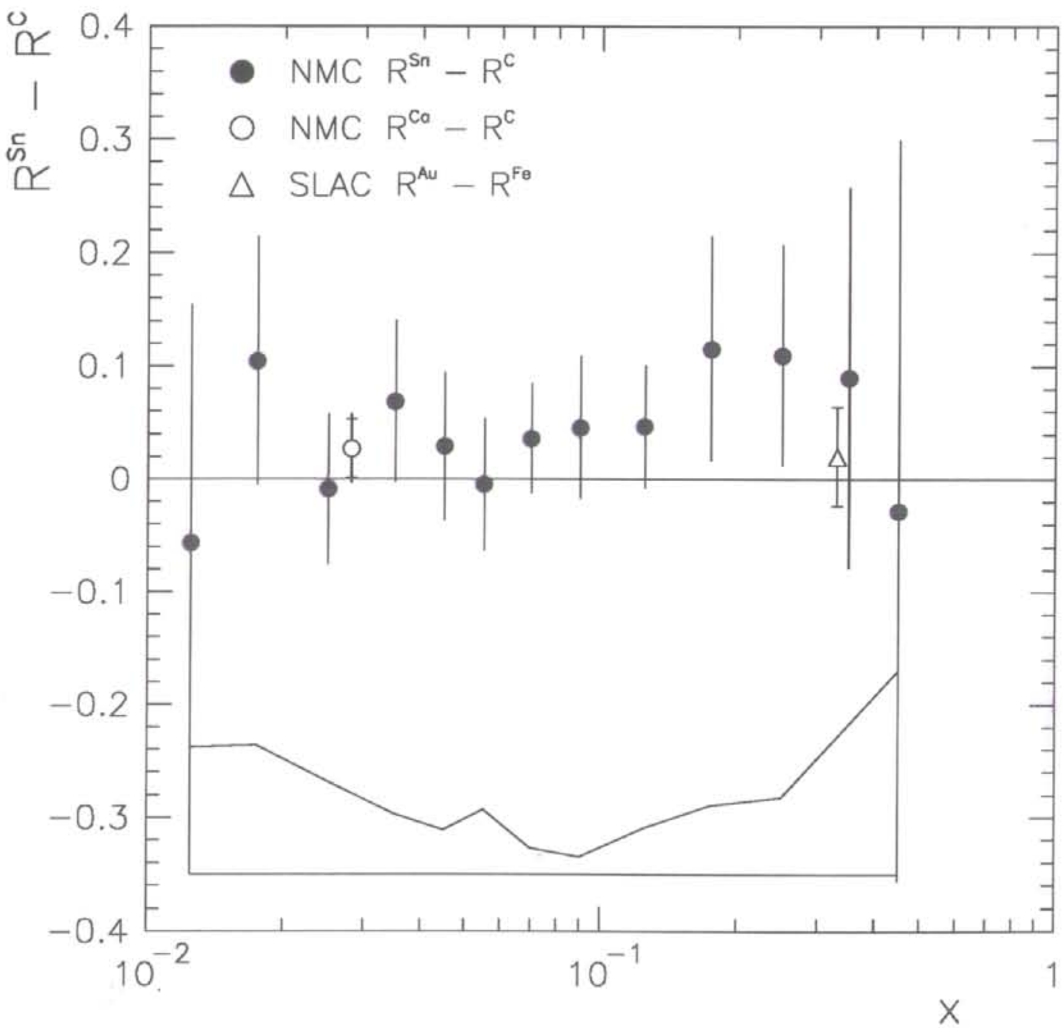




$R_A - R_D$ consistent with zero for $x > 0.2$ and $Q^2 > 1$ GeV^2

Nuclear effects in $R(x, Q^2)$

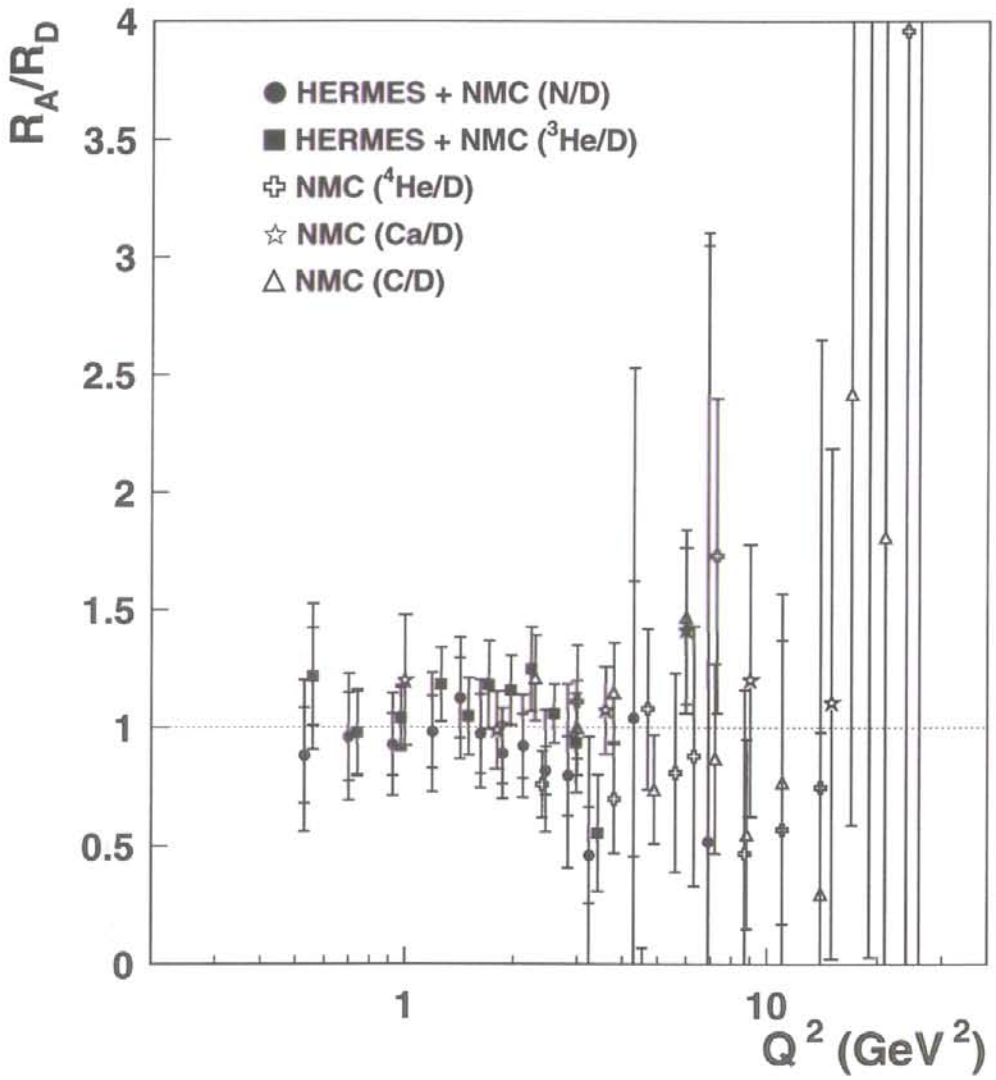
- NMC data



$R_A - R_D$ consistent with zero for $x > 0.02$ and $Q^2 > 3$ GeV^2

Nuclear Effects in $R = \sigma_L/\sigma_T$

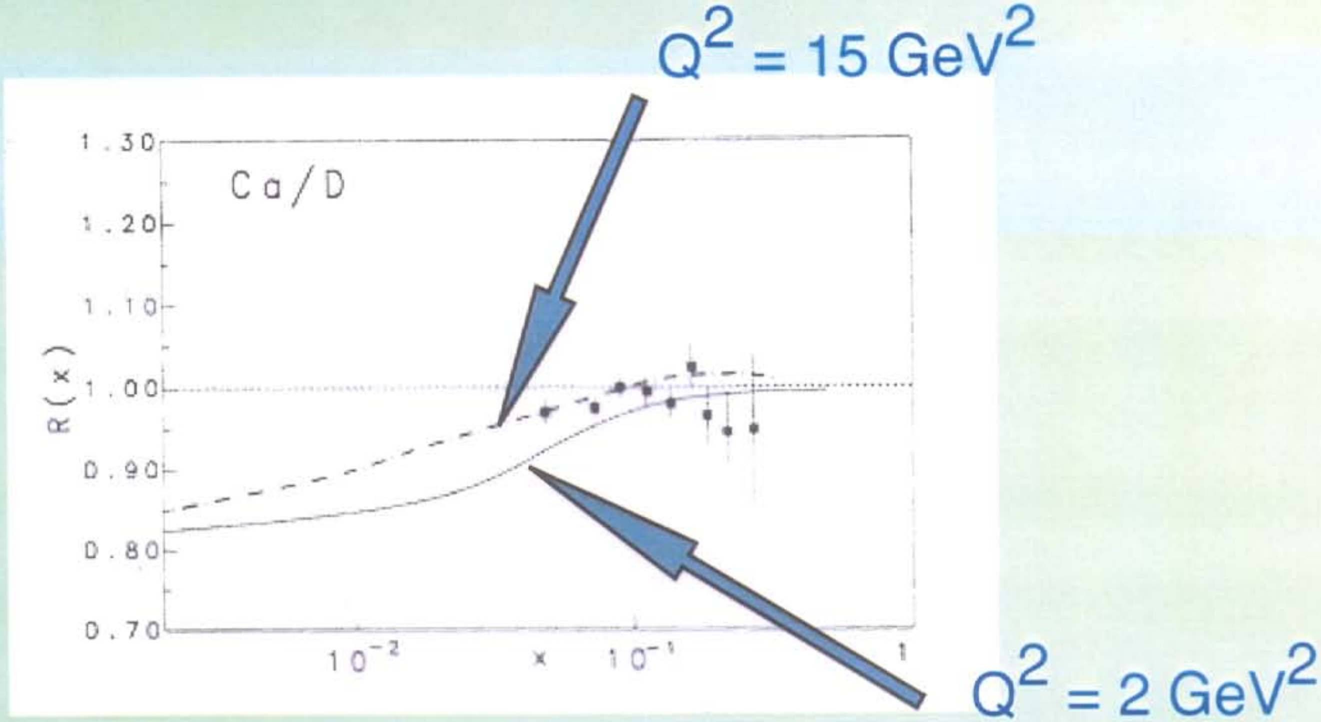
- Use NMC measurement of F_2^A/F_2^D
- Fit R_A/R_D only



For light and medium heavy nuclei R_A/R_D consistent with unity within $\sim 20\%$ for all x and Q^2 $(0.5 < Q^2 < 20\ \text{GeV}^2)$

- No enhancement/ Suppression of antiquarks at $0.15 \geq x$
  (Drell -Yan process - FNAL)

$\bar{q}_A/\bar{q}_N$



A-dependence of antiquark distribution, data are from FNAL nuclear Drell-Yan experiment, curves - pQCD analysis of Frankfurt, Liuti, MS 90

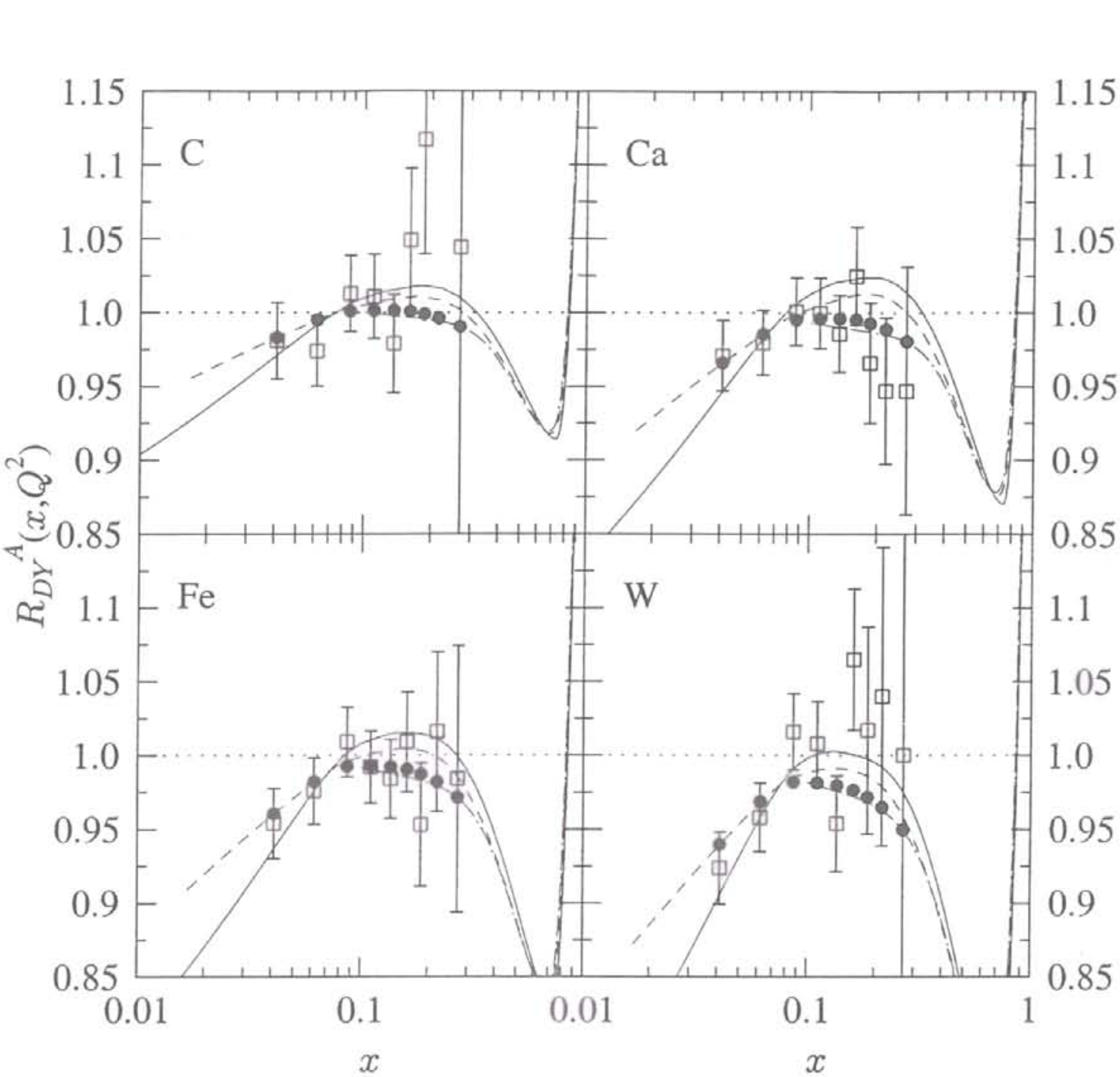


Figure 8: The ratios of differential Drell-Yan cross sections in pA and pD as functions of $x = x_2$ for $^{12}_{6}C/D$, $^{40}_{20}Ca/D$, $^{56}_{26}Fe/D$ and $^{184}_{74}W/D$. Our calculation for $R^A_{DY}(x, Q^2)$ of Eq. (20) is shown at fixed values of the invariant mass $Q^2 = 2.25$ GeV^2 (solid line), 24.2 GeV^2 (dashed), and 139 GeV^2 (dotted-dashed). The data shown by the boxes is from E772 [14]. In the graph the statistical errors and the quoted 2 % systematic errors are added in quadrature. The filled circles show our calculation at the $\langle Q^2 \rangle$ of the data [27].

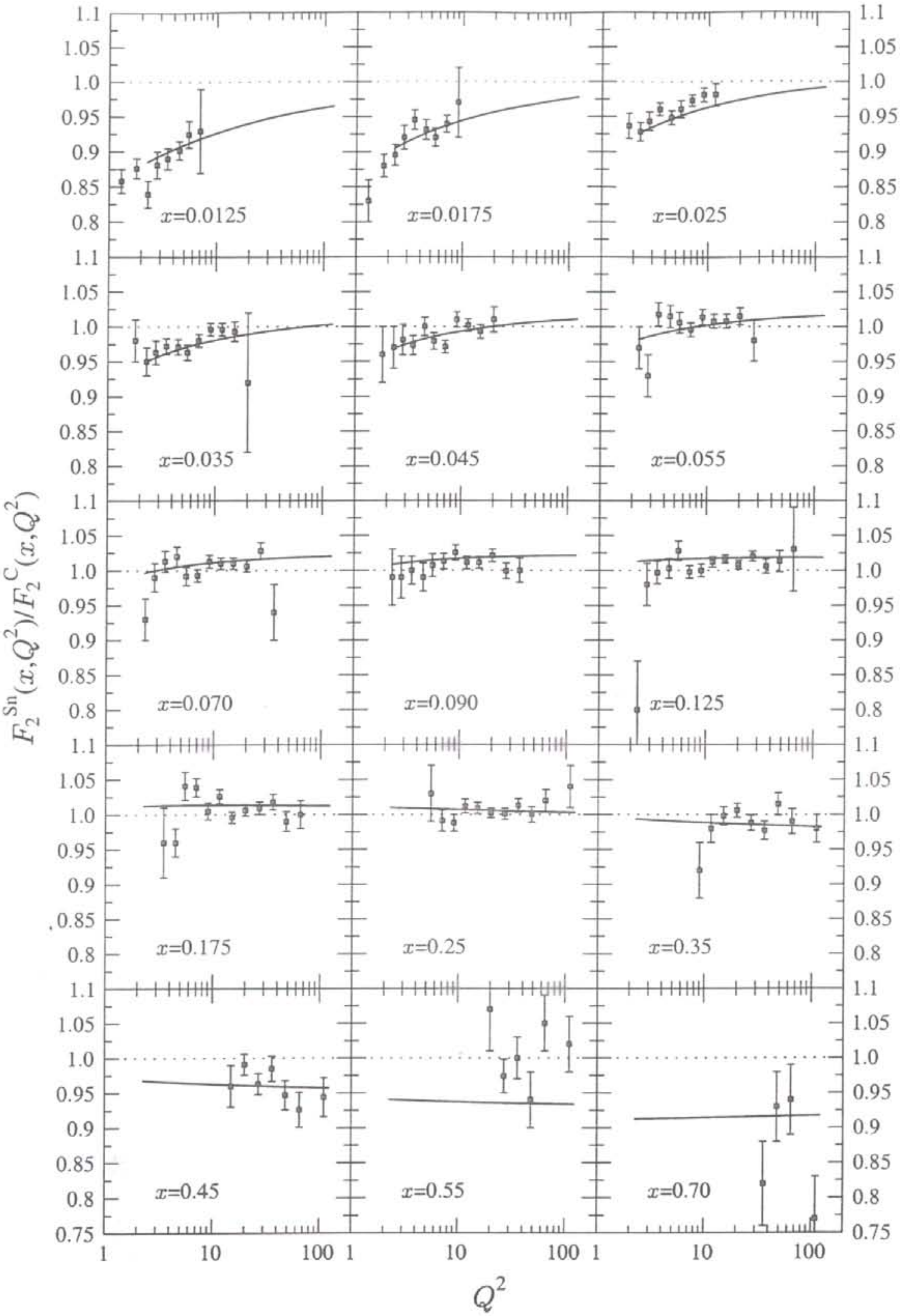


Figure 10: The calculated scale evolution of $F_2^{\rm Sn}(x,Q^2)/F_2^{\rm C}(x,Q^2)$ compared with the NMC data [3] at different fixed values of x. The data are plotted with statistical errors only.

Escola et al

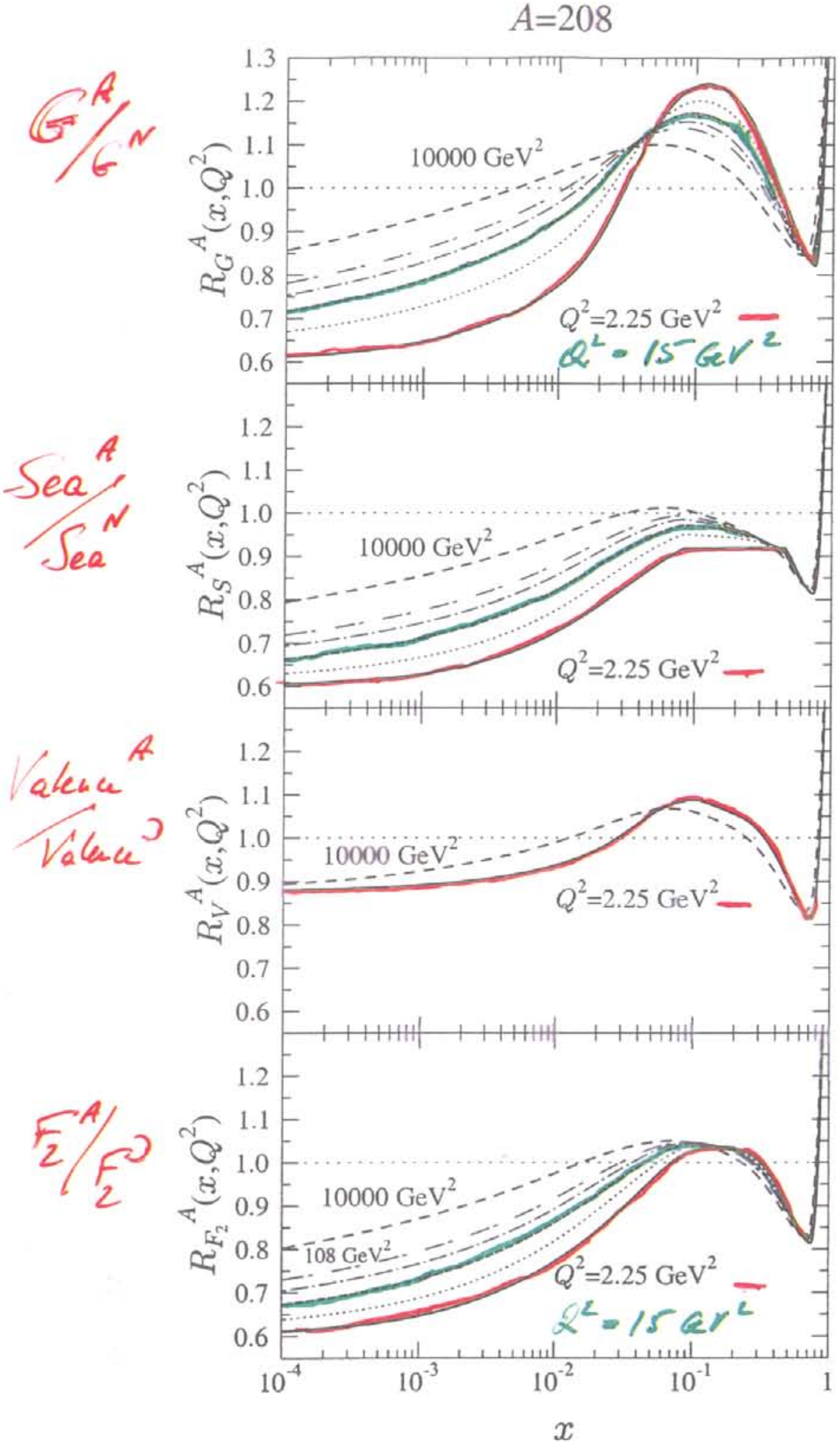


Figure 3: Scale evolution of the ratios $R_G^A(x,Q^2)$, $R_S^A(x,Q^2)$, $R_V^A(x,Q^2)$ and $R_{F_2}^A(x,Q^2)$ for an isoscalar nucleus A=208. The ratios are shown as functions of x at fixed values of $Q^2 = 2.25$ GeV^2 (solid lines), 5.39 GeV^2 (dotted), 14.7 GeV^2 (dashed), 39.9 GeV^2 (dotted-dashed), 108 GeV^2 (double-dashed), equidistant in $\log Q^2$, and 10000 GeV^2 (dashed). For R_V^A only the first and last ones are shown.

Hirai, Kumano + Nagai

all DIS and DY data
including error estimate

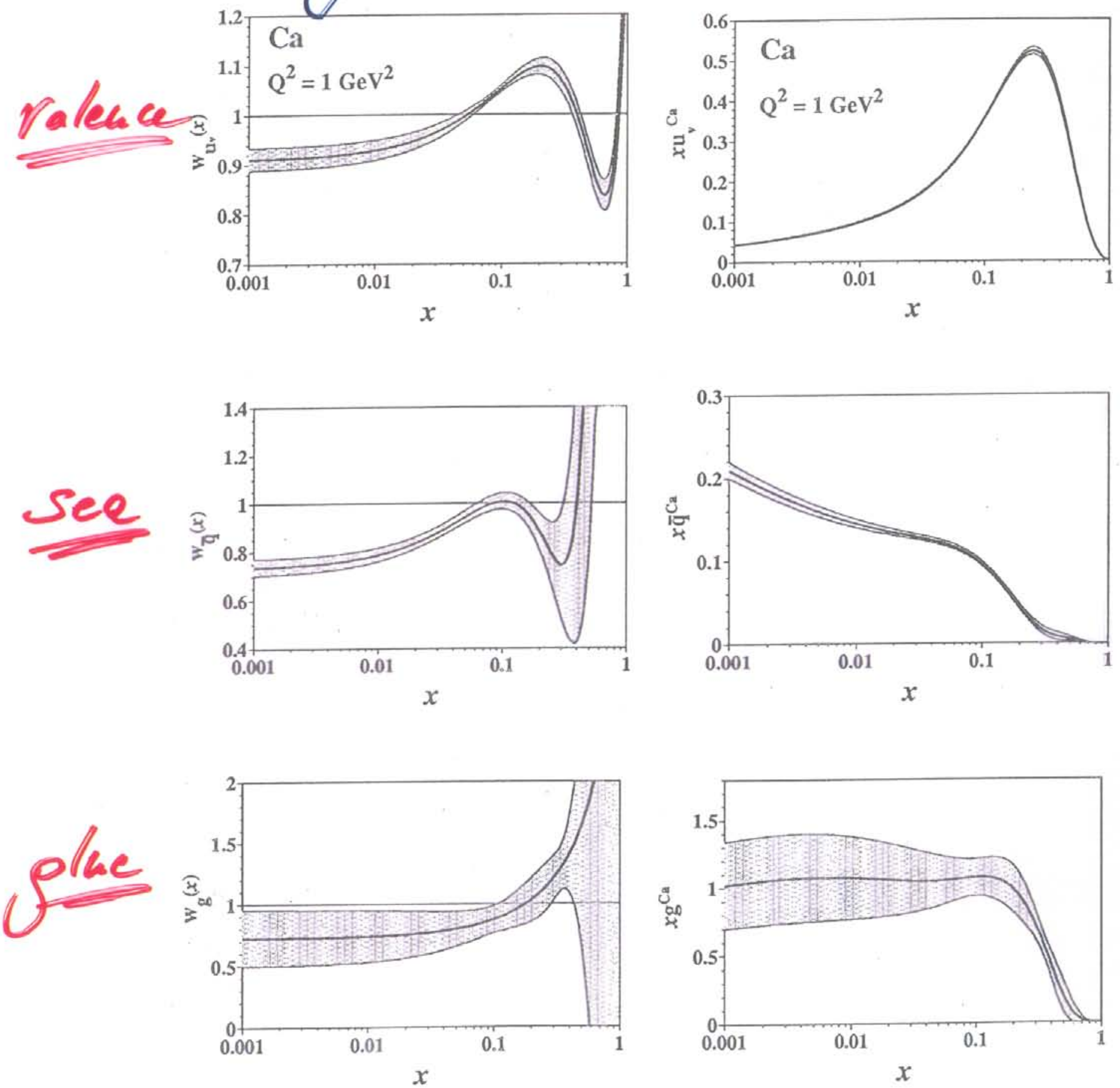


FIG. 9: (Color online) The weight functions and the nuclear parton distribution functions are shown for the calcium nucleus at Q_0^2. The uncertainties are shown by the bands.

Future Measurements

- Semi-inclusive pion production
  $\longrightarrow$ nuclear modification of valence distributions
  $\longrightarrow$ difference between u and d quarks ?
  problem: nuclear effects in hadronisation !!!

- Tagged structure functions (on ^{2}H or ^{3}He targets)
  $\longrightarrow$ free nucleon structure function

- Scaling violation of F_2^A/F_2^D at large Q^2
- A dependence of σ_L
- A dependence of open and hidden charm production

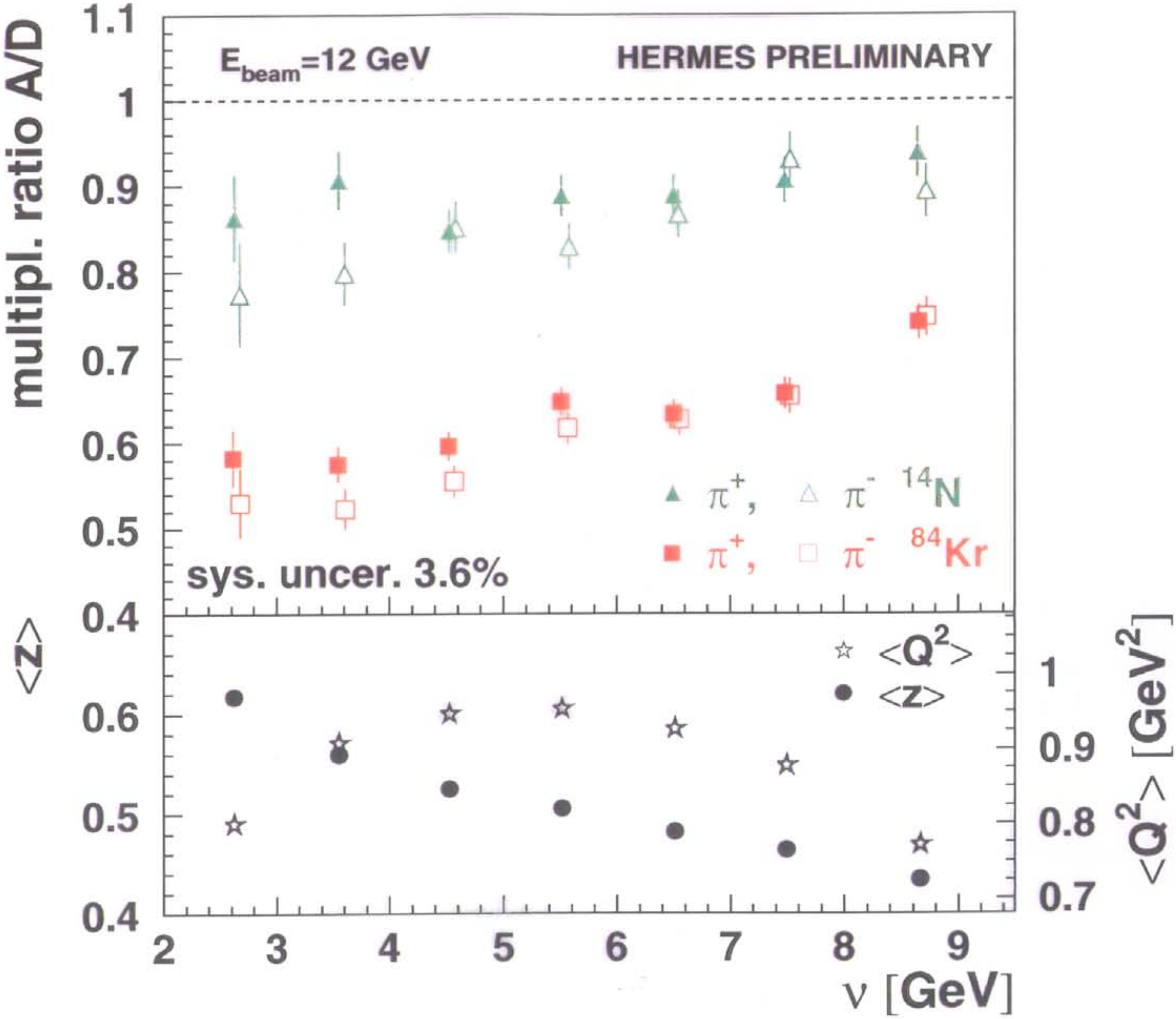
} gluon distribution in nuclei

The ways to measure valence quarks and antiquarks

Valence quarks: measure difference of the inclusive spectra of positive and negative pions:

$$\frac{\dfrac{d\sigma(e + A \rightarrow e + \pi^+ + X)}{dz\,dx\,dQ} - \dfrac{d\sigma(e + A \rightarrow e + \pi^- + X)}{dz\,dx\,dQ}}{\dfrac{d\sigma(e + N \rightarrow e + \pi^+ + X)}{dz\,dx\,dQ} - \dfrac{d\sigma(e + N \rightarrow e + \pi^- + X)}{dz\,dx\,dQ}} = \frac{V_A(x,Q)}{V_N(x,Q)}$$

$$= V_A(x,Q)/V_N(x,Q)$$



multipl. ratio A/D
E_beam=12 GeV
HERMES PRELIMINARY
π⁺, π⁻ ¹⁴N
π⁺, π⁻ ⁸⁴Kr
sys. uncer. 3.6%
<z>
<Q²>
<Q²> [GeV²]
ν [GeV]
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
2
3
4
5
6
7
8
9