

Neutrino-Nucleus Reactions at Medium and Low Energies

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1. Neutrino and weak interaction

- elementary particles :
hadrons, leptons, gauge particles
- leptons

particle

$$\begin{pmatrix} e^- \\ e \end{pmatrix}$$

$$\begin{pmatrix} \mu^- \\ \mu \end{pmatrix}$$

$$\begin{pmatrix} \tau^- \end{pmatrix}$$

anti-
particle

$$\begin{pmatrix} e^+ \\ - \\ e \end{pmatrix}$$

$$\begin{pmatrix} \mu^+ \\ - \\ \mu \end{pmatrix}$$

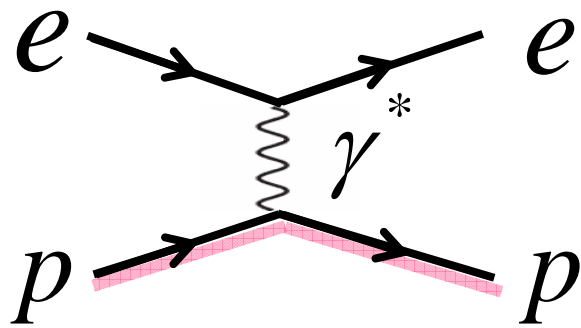
$$\begin{pmatrix} \tau^+ \\ - \end{pmatrix}$$

Neutrino and charged lepton make a pair.

- Electron beam and Neutrino beam

Electromagnetic interaction

$$e + p \rightarrow e + p$$

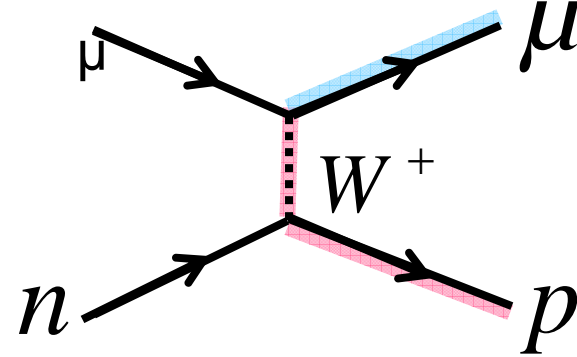


a virtual photon

Weak interaction

charged current

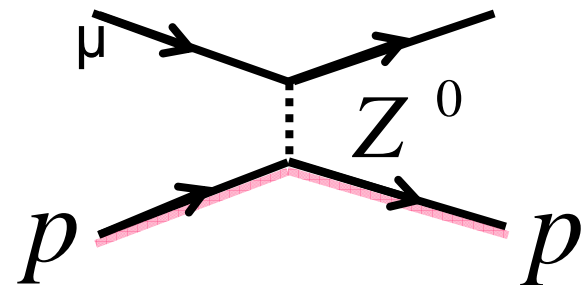
$$\mu + n \rightarrow \mu + p$$



W^\pm boson

neutral current

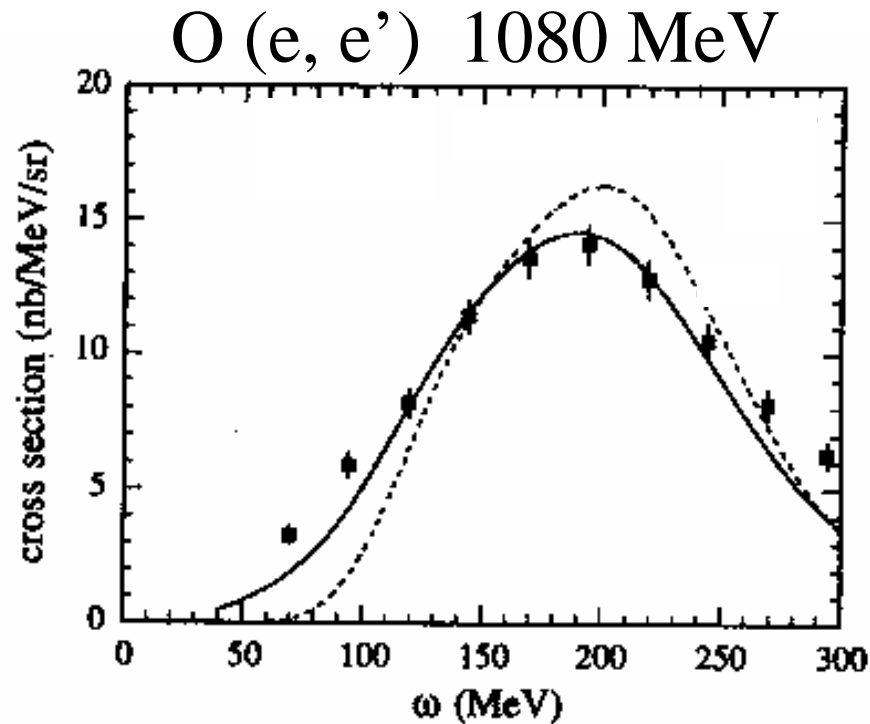
$$\mu + p \rightarrow \mu + p$$



Z^0 boson

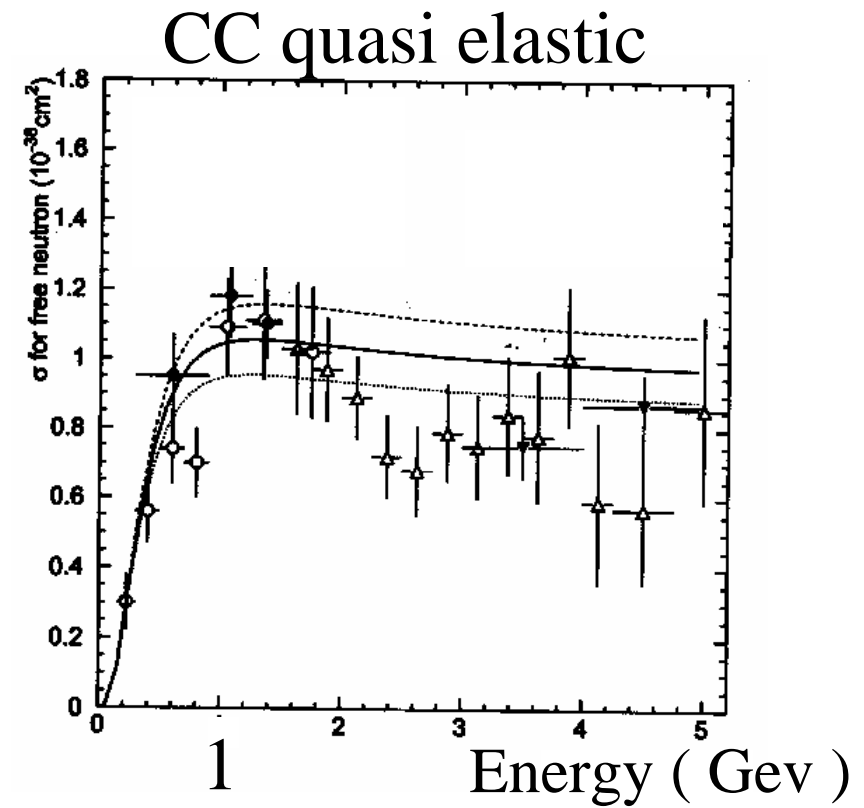
2. Cross section for ν -A and e-A reactions

e-A reaction



$$\sigma_e \approx 10^{-5} \text{ barn}$$

ν -A reaction



$$\sigma_\nu \approx 10^{-14} \text{ barn}$$

ν -A cross section is much smaller than e-A cross section.

3. EMC effect

$e(\mu)$ -A reaction is different from $e(\mu)$ -N reaction.

D: deuteron

1 proton, 1 neutron
(They are approximately
free nucleons.)

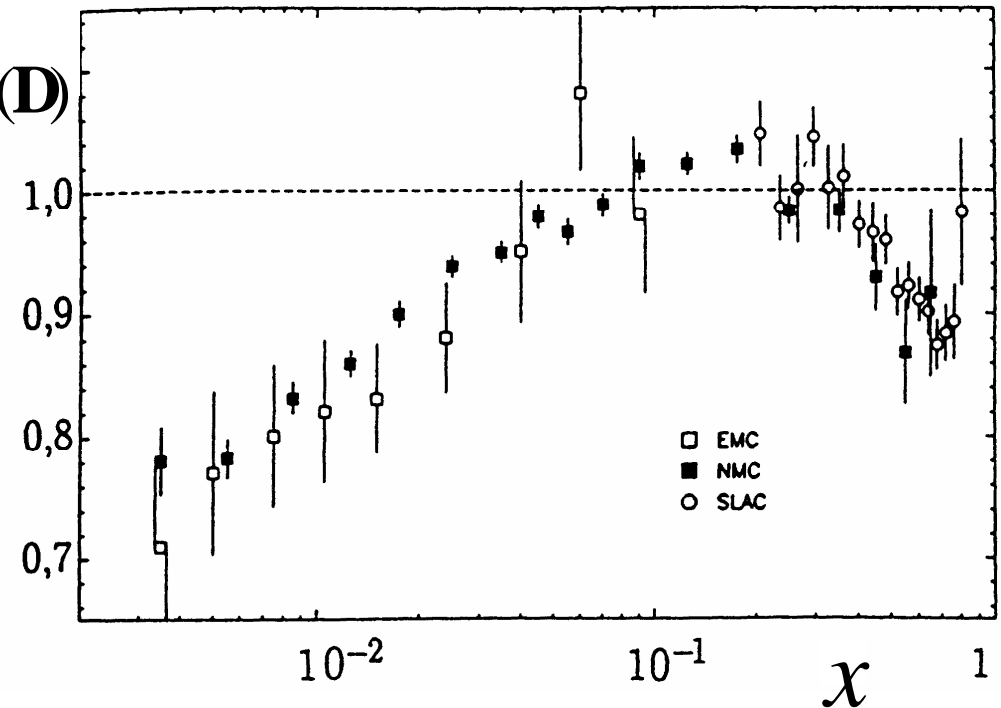
$$\frac{\sigma(\text{Ca})}{20} / \sigma(\text{D})$$

Ca

20 protons, 20 neutrons
(They are bound)

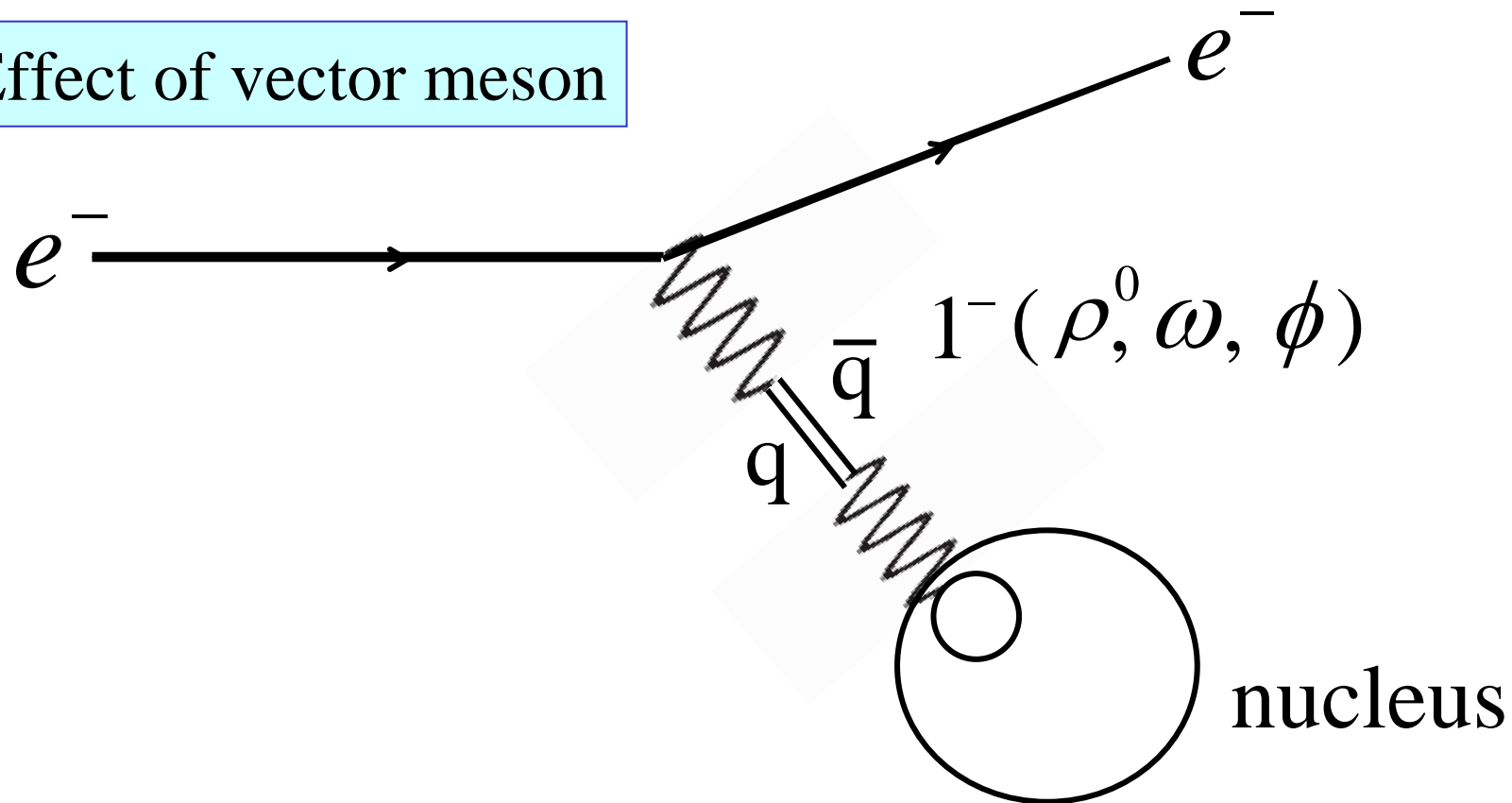
x : Bjorken scaling variable

momentum fraction carried
by a quark



$$\frac{\sigma(\text{Ca})}{20} \neq \sigma(\text{D})$$

Effect of vector meson



A part of EMC effect may be due to hadronic component of the virtual photon, not due to the structure of the target nucleus.

Is e^-A reaction different from e^-N reaction ?

4. My study

There are large amounts of data available on e-A reactions.



If e-A data and γ -A data are combined, we can understand γ -A reactions better.



my study

Overall study of γ -A and e-A reactions

- collect experimental data of e-A and γ -A reactions
- build a model for these reactions

5. Summary

- The structure of nucleus can be studied with electron scattering and neutrino scattering.
- In electromagnetic interaction a virtual photon is exchanged. In weak interaction W^\pm or Z^0 is exchanged.
- -A cross section is much smaller than e-A cross section.
- e-A reaction is different from e-N reaction (EMC effect).
A part of EMC effect may be due to hadronic component of the virtual photon.
- If e-A data and -A data are combined, we can understand -A reactions better.
- I collect experimental data of -A reactions and build a model for these reactions.