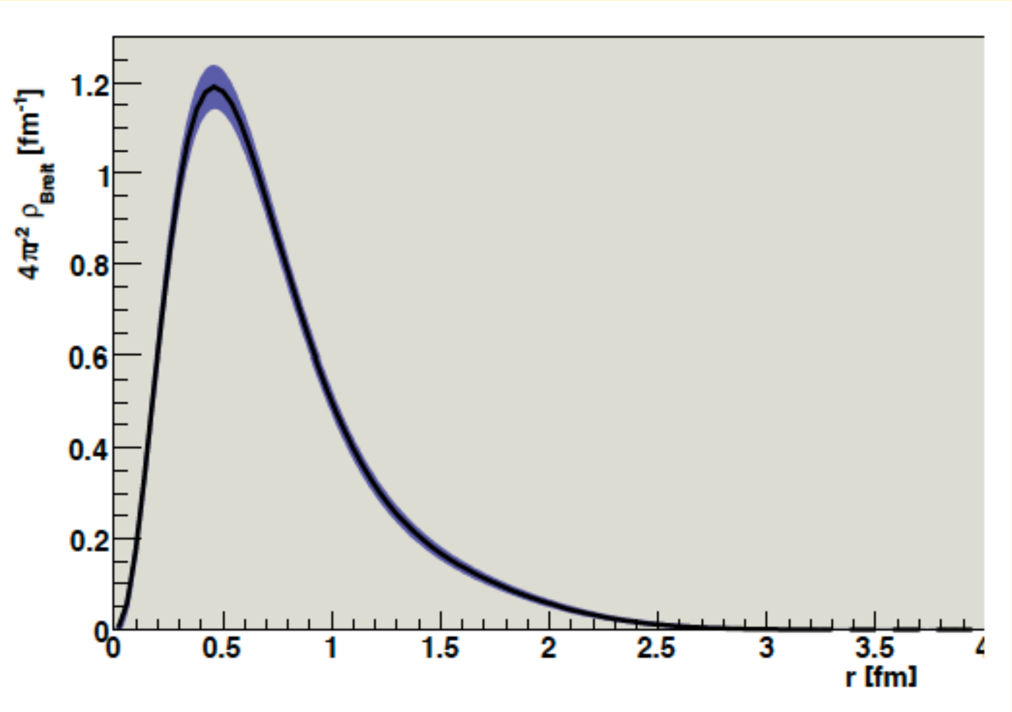
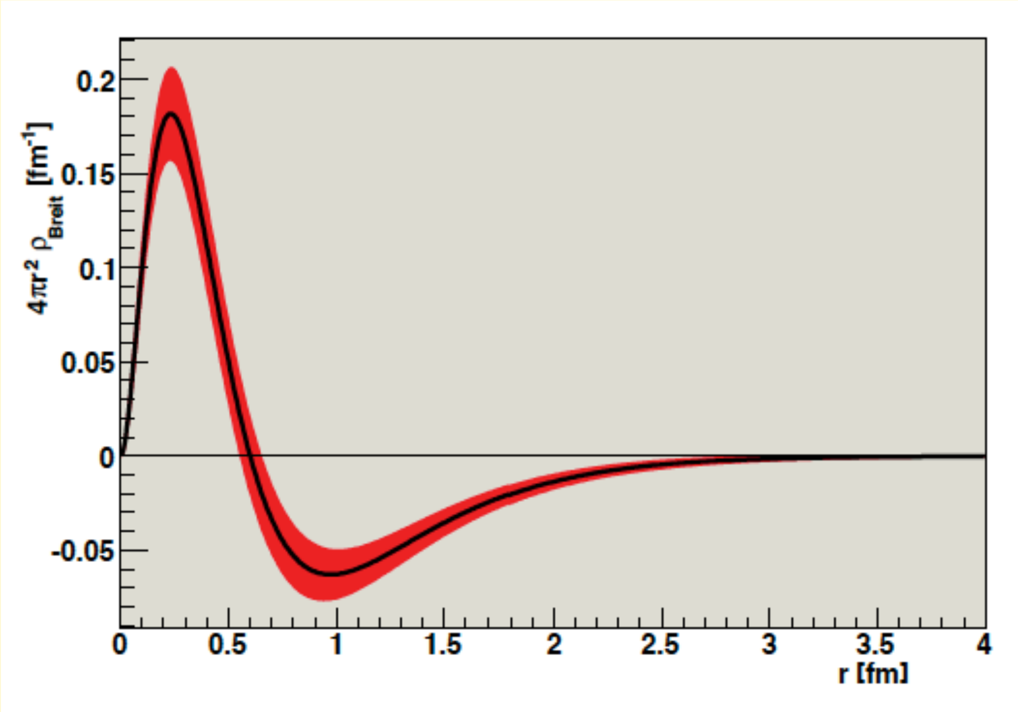
proton radial charge distribution from polarized electron scattering (JLAB)

Ref: The Frontiers of Nuclear Science – A Long Range Plan (2007), p.26



neutron radial charge distribution from polarized electron scattering (JLAB)

Ref: The Frontiers of Nuclear Science – A Long Range Plan (2007), p.26



Note that neutron charge density contains regions of both positive and negative charge, a clear hint for sub-structure.

neutron = (u d d)

up quark has q=+2/3,
down quark has q=-1/3.

Root mean square (rms) - radii for proton and neutron

The mean square radius can be obtained from the measured density distribution

$$\langle r^2 \rangle = \int r^2 \rho(r) d^3r = \int 4\pi r^4 \rho(r) dr$$

The root mean square (rms) radius is defined as

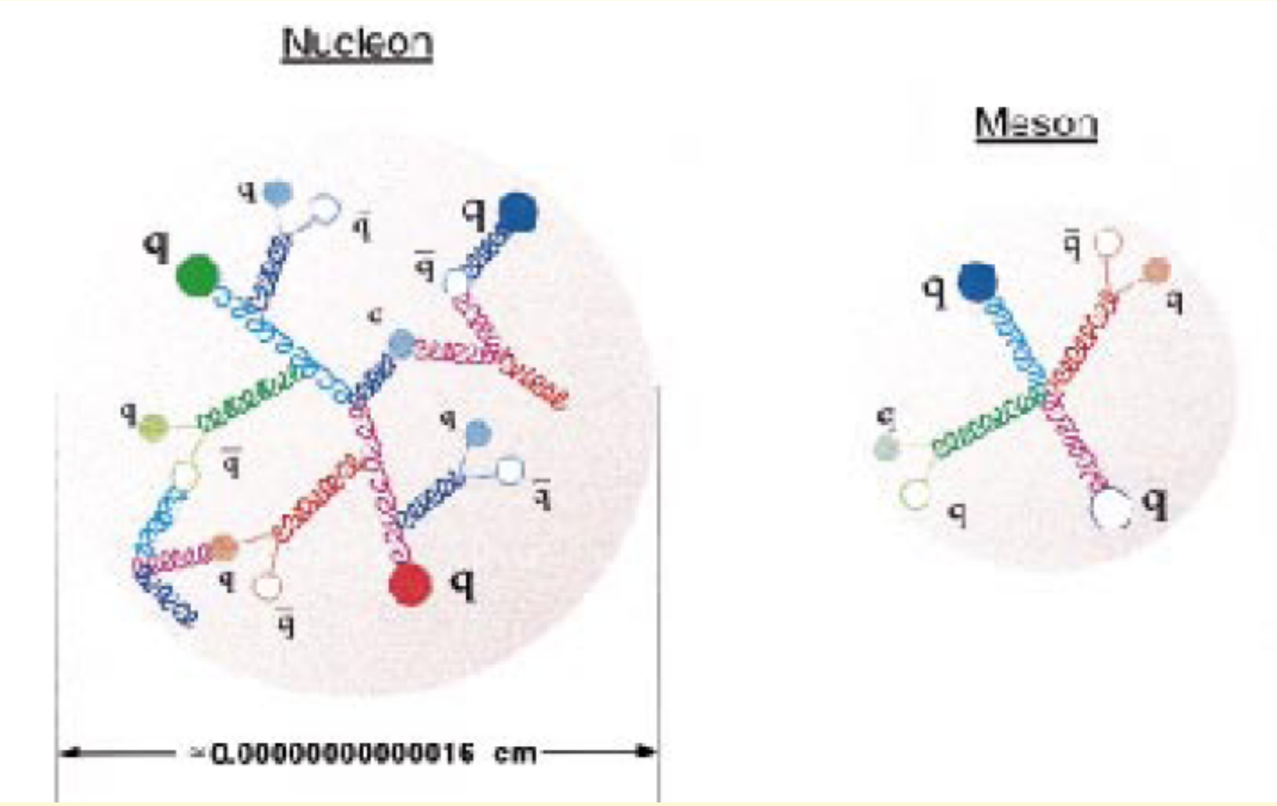
$$R_{rms} = \sqrt{\langle r^2 \rangle}$$

For both proton and neutron one finds rms radii of about 0.8 fm

Standard model of elementary particle physics

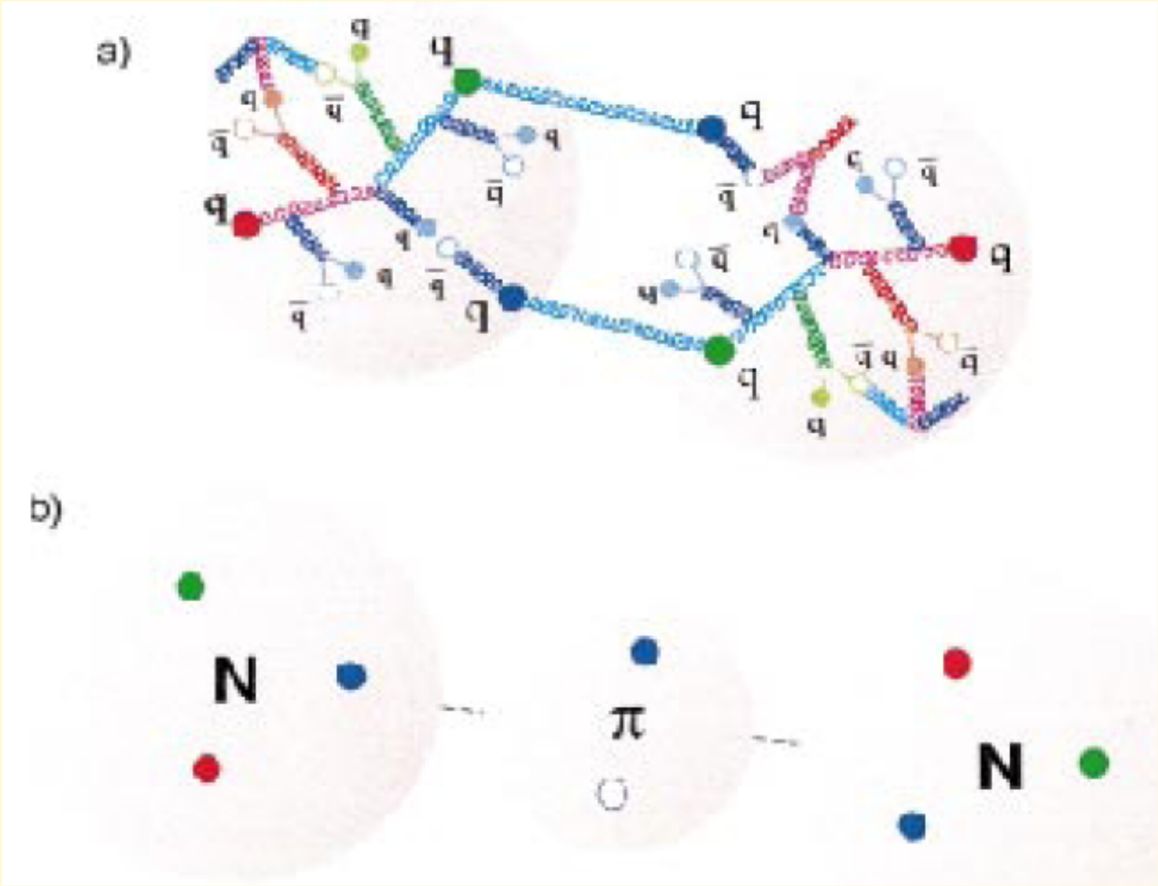
Quark sub-structure of nucleon and meson

Ref: National Research Council Report, 1999

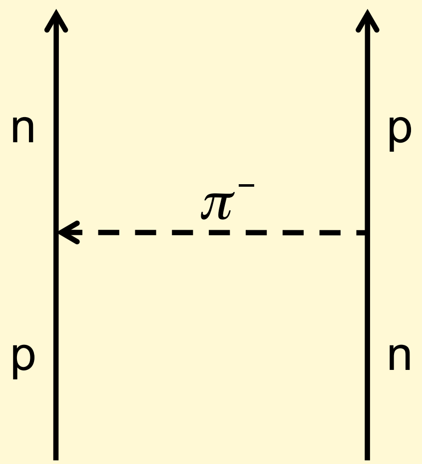


Nucleon-nucleon interaction in quark picture / baryon-meson picture

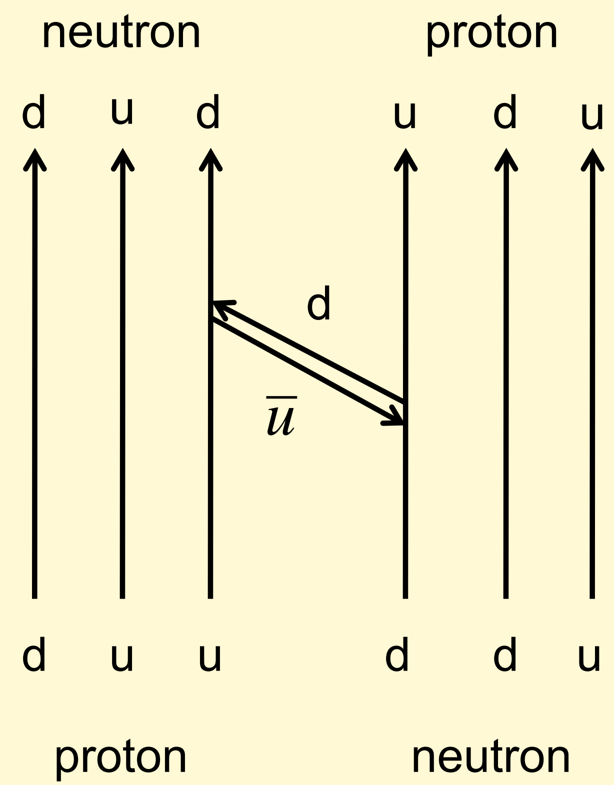
Ref: National Research Council Report, 1999



Nucleon-nucleon interaction in baryon-meson picture and in quark picture



Feynman diagram of
one-pion exchange
(pointlike p, n, π).
Baryon-meson quantum
Field theory



Feynman diagram in
quark picture

Nucleon-nucleon interaction in potential picture

At low energies, the two nucleons "see" each other as structure-less point particles (large de Broglie – wavelength, see section 1.4). The N-N interaction can be adequately described by an interaction potential which depends on the positions, momenta, spins, and isospins of the two nucleons:

$$V_{NN} = V_{NN}\left(\vec{r}_1, \vec{p}_1, s_{z1}, t_{z1}; \vec{r}_2, \vec{p}_2, s_{z2}, t_{z2}\right)$$

The N-N interaction potential can de derived from quantum field theory of baryons interacting via virtual meson exchange; the potential is obtained from the T-matrix in the static limit.

Ref: Bjorken & Drell, Relativistic quantum mechanics

From quarks to nuclei

Ref: RIA Physics White Paper 2000

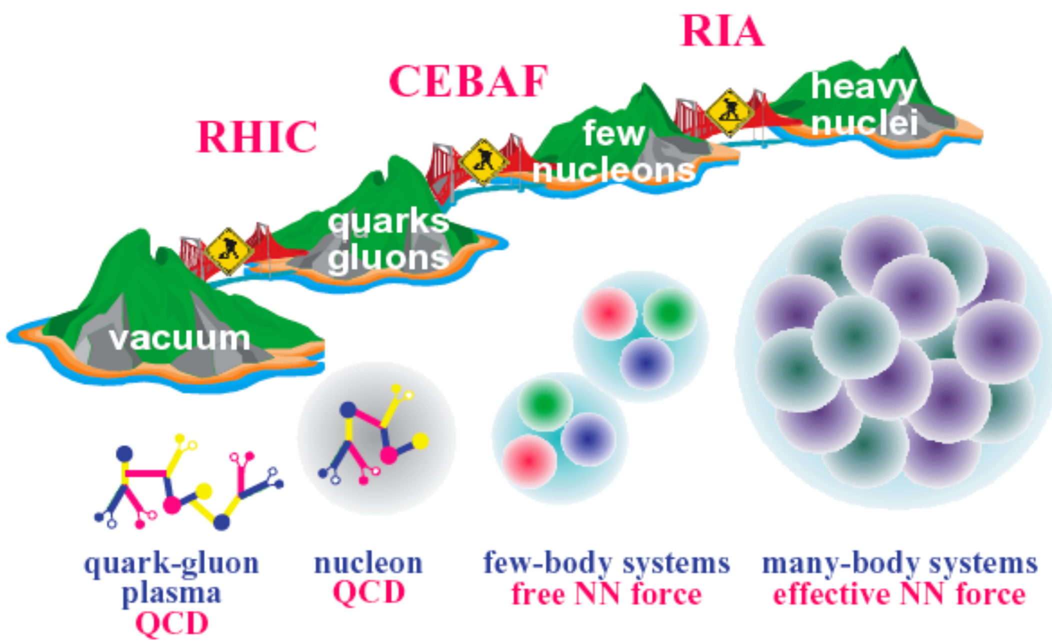


Figure 1: From QCD vacuum to heavy nuclei: the intellectual connection between the hadronic many-body problem (quark-gluon description of a nucleon) and the nucleonic many-body problem (nucleus as a system of Z protons and N neutrons). The bridges illustrate major physics challenges: the mechanism of quark confinement, the understanding of the bare nucleon-nucleon interaction in terms of the quark-gluon dynamics, and the understanding of the effective interactions in heavy nuclei in terms of the bare force.