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Comparison of sea-quark contributions to electromagnetic and axial form factors

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OUTLINE

- Perturbative chiral quark model
- EM and axial form factors
- Sea-quark contributions
- Summary & Outlook

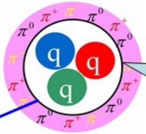
Perturbative chiral quark model (PCQM)

PRD**22** 2838(1980); NPA**426** 456(1984); PLB**229** 333(1989);PRC**64** 065203(2001); PRD**63** 054026(2001);

MIT bag model

Chiral symmetry: meson cloud

Cloudy bag model



including interaction of confined quarks with the pion fields on the bag surface

unphysical sharp bag boundary

Static quark potential

Effective Lagrangian of the PCQM

$$\mathcal{L}_{\rm inv}(x) = \underbrace{\bar\psi(x)[i\not\partial - \gamma^0 V(r)]\psi(x)}_{\mathcal{L}_q} + \underbrace{\frac{F^2}{4}{\rm Tr}[\partial_\mu U \partial^\mu U^\dagger]}_{\mathcal{L}_\Phi}$$
$$\underbrace{-\bar\psi(x){\rm S}(r)\left[\frac{U+U^\dagger}{2} + \gamma^5\frac{U-U^\dagger}{2}\right]\psi(x)}_{\mathcal{L}_{int}}$$

- Model potential

  $V(r)$: vector potential, $S(r)$: scalar potential.

- Model parameter

  $F = 88$ MeV.

- In SU(3) flavor symmetry

$$\mathrm{q-field}: \ \psi(x) = \begin{pmatrix} u(x) \\ d(x) \\ s(x) \end{pmatrix}, \quad \chi - \mathrm{field}: \ U = \exp\left[i\frac{\hat\Phi}{F}\right] \simeq 1 + i\frac{\hat\Phi}{F} + o\left(\frac{\hat\Phi}{F}\right),$$

$$\mathrm{meson\ field}: \ \hat\Phi = \sum_{i=1}^{8}\Phi_i\lambda_i = \begin{pmatrix} \pi^0 + \frac{1}{\sqrt3}\eta & \sqrt2\pi^+ & \sqrt2 K^+ \\ \sqrt2\pi^- & -\pi^0 + \frac{1}{\sqrt3}\eta & \sqrt2 K^0 \\ \sqrt2 K^- & \sqrt2\bar K^0 & -\frac{2}{\sqrt3}\eta \end{pmatrix}.$$

Chiral symmetry

$\mathcal{L}_{\rm inv}(x)$ is invariant under transformation

$$\psi_L \to U_L \psi_L$$

$$\psi_R \to U_R \psi_R$$

$$U \to U_R U U_L^\dagger$$

where

$$\psi_{L/R} = \frac{1}{2}(1 \mp \gamma^5)\psi$$

$$U_L = \exp\Big(-i\sum_{a=1}^{8}\Theta_a^L \frac{\lambda_a}{2}\Big)$$

$$U_R = \exp\Big(-i\sum_{a=1}^{8}\Theta_a^R \frac{\lambda_a}{2}\Big)$$

Previous works

PRC**64** 065203(2001); PRD**63** 054026(2001); PLB**520** 204(2001); PRC**65** 025202(2002); PRC**66** 055204(2002); PRC**68** 015205(2003); EPJA**20** 317(2004); JPG**30** 793(2004); JPG**35** 025005(2008).

- electromagnetic properties of baryons
- low-energy meson-baryon scattering
- strange nucleon form factors
- electromagnetic excitation of nucleon resonances
- axial form factor of the nucleon
- ......

Quark Wavefunction

- The radial parts $g(r)$ and $f(r)$ are expanded in Sturmian basis

$$g(r) = \sum_n A_n \frac{S_{n0}(r)}{r},$$
$$f(r) = \sum_n B_n S_{n0}(r),$$

where Sturmian functions

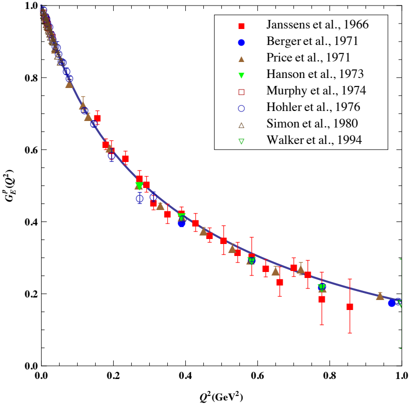
$$S_{nl} = \left[\frac{n!}{(n+2l+1)!}\right]^{1/2} (2br)^{l+1} e^{-br} L_n^{2l+1}(2br),$$

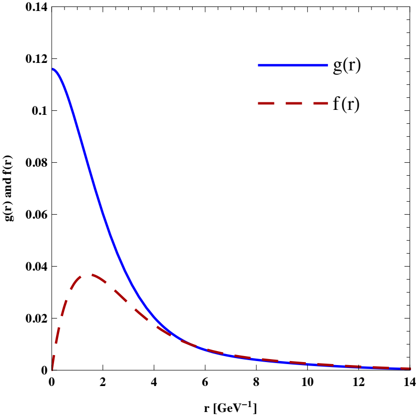
A_n, B_n, and b are free expansion parameters.

- Quark WF will be determined by fitting theoretical results of p charge form factor to the experimental data.

Quark wavefunctions

X. Y. Liu *et al*, J. Phys. G: Nucl. Part. Phys. **41** (2014) 055008.

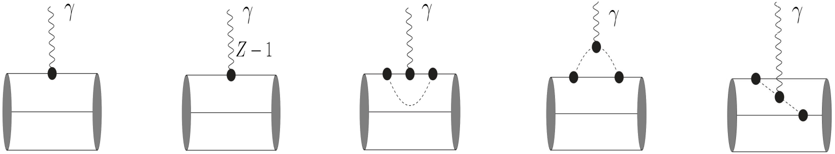




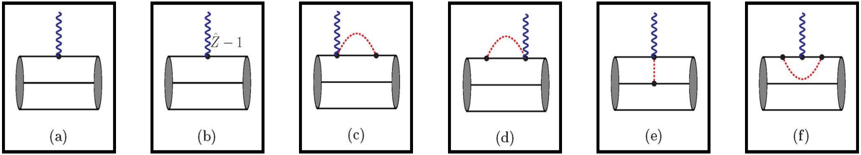
- 5-term (n=5), by fitting with experimental data of $G_E^p(Q^2)$

Feymann Diagrams

- Diagrams contributing to EM form factor

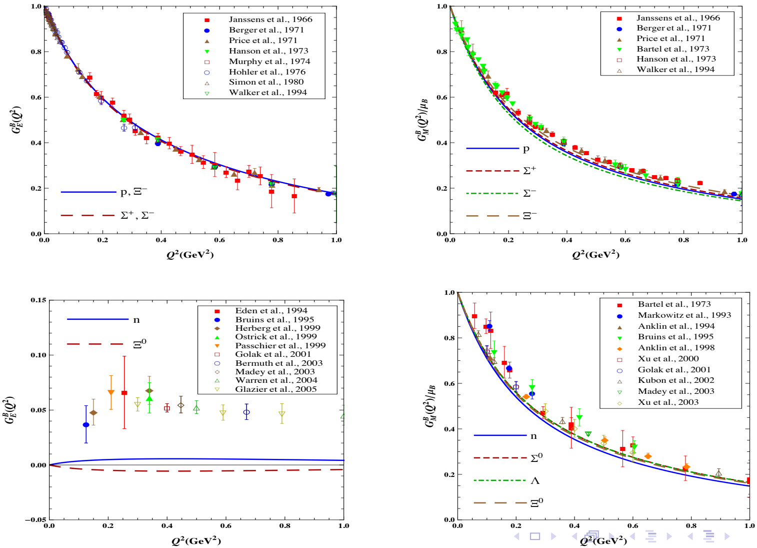


- Diagrams contributing to axial form factor



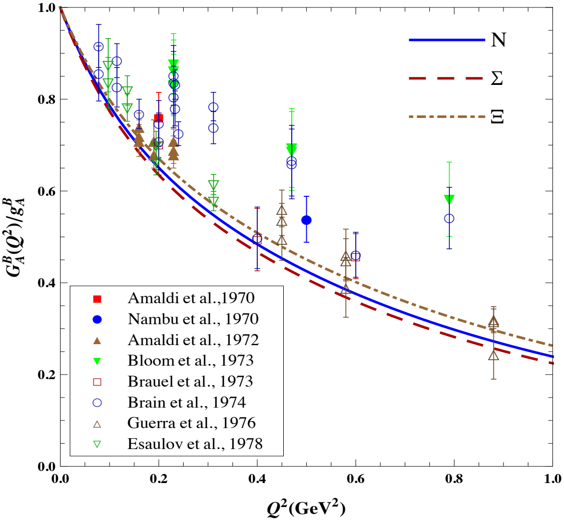
Electromagnetic form factors

X. Y. Liu *et al*, J. Phys. G: Nucl. Part. Phys. **41** (2014) 055008.

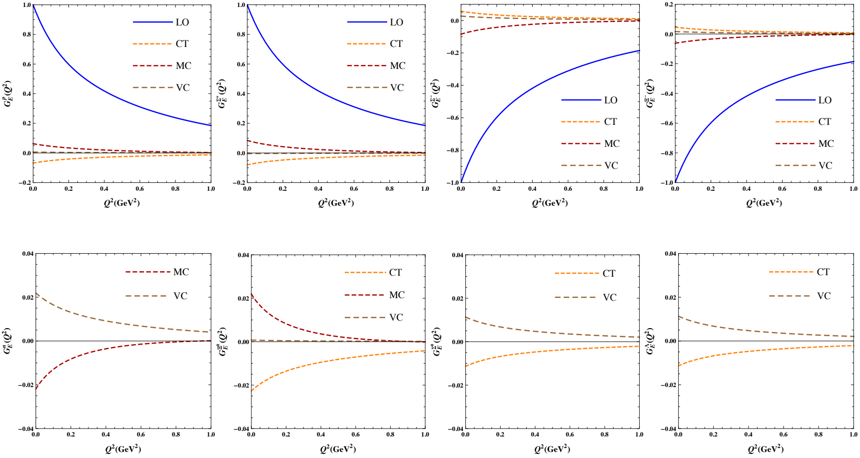


Axial form factors

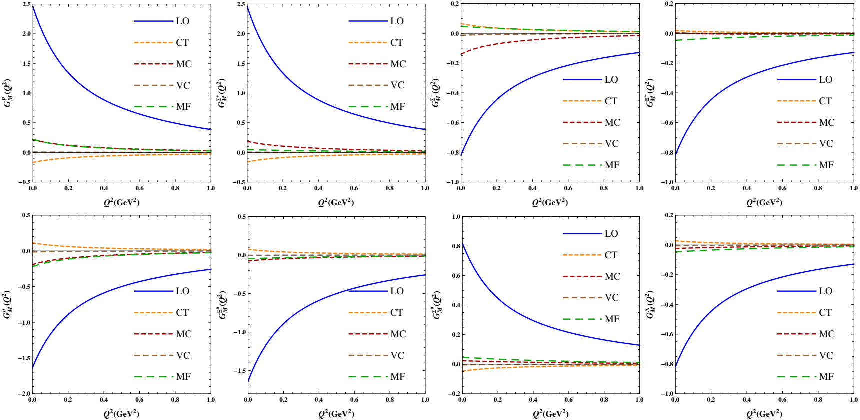
X. Y. Liu *et al*, Phys. Rev. D **91** (2015) 034022.



The individual contributions of charge form factors



The individual contributions of magnetic form factors



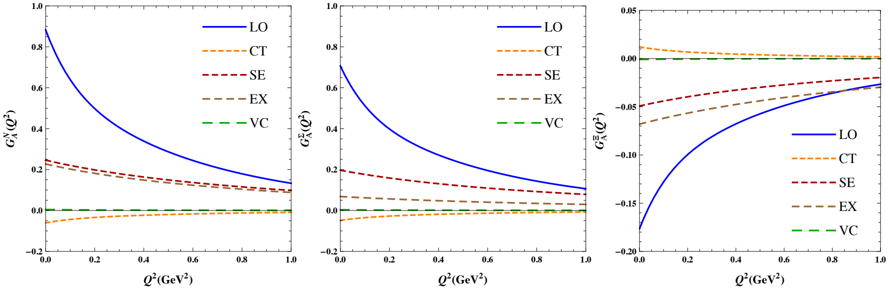
- Meson cloud contributing to EM form factors is less than 10%.
- The LO diagram results in a dipole-like form factor.
- The meson cloud leads to a flat contribution to EM form factor.

π, K and η mesons contribute to the μ_B

	Meson loops		
	π	K	η
μ_p	0.281	0.002	−0.006
μ_n	−0.339	0.018	0.004
μ_{Σ^+}	0.032	0.055	−0.008
μ_{Σ^0}	−0.039	−0.062	−0.004
μ_{Σ^-}	−0.109	0.068	0
μ_Λ	0	−0.052	0.004
μ_{Ξ^0}	−0.008	−0.055	0.012
μ_{Ξ^-}	−0.027	−0.058	0.010

- π-meson dominates nucleon magnetic moments.
- K-meson contributions to hyperons are in the same oder.
- η-meson contributions are negligible.

The individual contributions of axial form factors



- Meson cloud contributing to axial form factor is about 30%
- The LO diagram results in a dipole-like form factor
- The meson cloud leads to a flat contribution to axial form factor

π, K and η mesons contribute to the g_A^B

	Meson loops		
	π	K	η
g_A^N	0.375	0.045	−0.002
g_A^Σ	0.118	0.104	−0.002
g_A^Ξ	−0.030	−0.077	−0.001

- π-meson dominates nucleon axial charges.
- K-meson contributions to hyperons axial charges are in the same order as the π ones.
- η-meson contributions are negligible.

Summary

- Sea-quark contributions to EM form factors are about 10%.
- Sea-quark contributions to axial form factors are about 30%.
- π meson dominates the contribution of nucleon form factor, K meson has a considerable contribution to the form factors of hyperons while η meson contribution is suppressed.

Outlook

- The flat meson contributions may indicates the sea-quark distribute mainly in a very small region.
  The form factor distribution in r-space could be obtained by inverse Fourier transform as

$$\rho(r) = \frac{1}{(2\pi)^3} \int F(q^2) e^{iqr} d^3q.$$

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