CONFINEMENT and the ELECTROMAGNETIC PROPERTIES of the NUCLEON

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Motivation

- One Unified Microscopic Description of Mesons **and** Baryons
- Based on **Confined** Quark d.o.f.

Method Used

- Phenomenological **DSE** Approach
- Generalised Impulse Approximation (**GIA**)

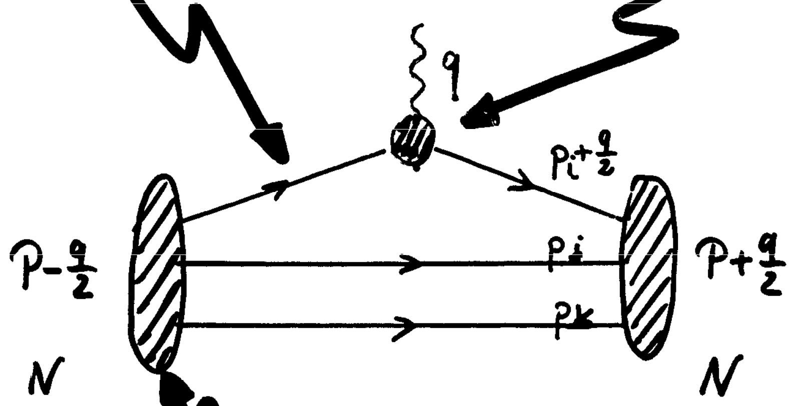
DSE

Quark Propagator $S(p)$

- No Mass Pole !
- $\xrightarrow[p^2 \to \infty]{} \frac{1}{i p \cdot \gamma + m}$
- Parameters fixed from **Meson Data**

Quark-Photon Vertex $\Gamma(p', p)$

- Ward-Takahashi Id. $\Rightarrow$ BC-Vertex
- totally determined by $S(p')$ & $S(p)$



GIA

Nucleon Fadde'ev Vertex $\Gamma_N(p_i \pm \frac{q}{2}, p_j, p_k)^{\{A\}}$

- **Model**
  - no quark production threshold
- (in principle): determined from Covariant Fadde'ev Eq.

ALGEBRAIC PROPAGATOR PARAMETRISATION

$$\bar\sigma_S^{m_f}(x) = \frac{1-e^{-b_1 x}}{b_1 x}\,\frac{1-e^{-b_3 x}}{b_3 x}\left(b_0 + b_2\frac{1-e^{-\Lambda x}}{\Lambda x}\right) + \frac{\bar m_f}{x+\bar m_f^2}\left(1-e^{-2\,(x+\bar m_f^2)}\right)$$

$$\bar\sigma_V^{m_f}(x) = \frac{2(x+\bar m_f^2) - 1 + e^{-2(x+\bar m_f^2)}}{2(x+\bar m_f^2)^2}$$

- u-quark: 5 Parameters: $b_0^u, b_1^u, b_2^u, b_3^u, m_u$ $(\Lambda = 10^{-4})$

  1. confinement effects
  2. gluon condensate effects
  3. quark condensate
  4. "dressed-quark" mass
  5. current-quark mass

  χ^2-fit to f_π
  $\pi\pi$-scattering lengths
  π form factor, radius
  $\pi\gamma\gamma$, $3\pi\gamma$-anomalies
  $\vdots$

- s-quark: 2 parameters allowed to differ: b_0^s, b_2^s

  1. different "dressed-quark" mass
  2. different current-quark mass

  χ^2-fit to f_K
  K formfactors & radii

- Simple Expedient for Numerical Calculations

- All parameters correlated via $D_{\mu\nu}(k)$

Modelling of Fadde'ev Vertex

$\Gamma_N(p_1,p_2,p_3)$ $A=\{(S,f)_1,(S,f)_2,(S,f)_3\}$ totally symmetric in $(S,f,p)_i \leftrightarrow (S,f,p)_j$

spin flavour

(COLOUR already taken care of)

HENCE,

$$\Gamma_N^A(p_1,p_2,p_3) = \sum_{\text{perm }\{i,j,k\}} \Phi^A(\{i,j\};k)$$

Spin-Flavour Structure

ANSATZ: $$\Phi^A(\{i,j\},k) = \sum_{J,F} \varphi^{P,C}_{(J,F)}(\{p_i,p_j\},p_k)\,\mathcal{M}^{P,C}_{(J,F),(s_k,f_k)}$$

$(\bar{3})_c$ or $(6)_c$ "**Diquark**" *Quantum Numbers* $J=s_i\oplus s_j$; $F=f_i\oplus f_j$

Parity P, Charge Conj. C

MODEL:

$$\Phi^A(\{i,j\},k) \equiv \Gamma^{qq}_{(J,F)}\left(\tfrac{1}{2}(p_i-p_j)\right) D^{qq}_{(J,F)}(p_i+p_j)\,\psi^{qq-q}_{(J,F),(s_k,f_k)}\left(\alpha p_k-(1-\alpha)(p_i+p_j)\right)$$

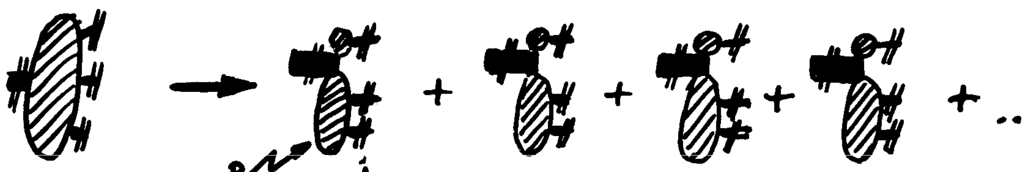
- Q-Q Correlation Amplitude: $$\Gamma^{qq}_{(J,F)}(k) = \frac{1}{1+k^2/\omega^2_{(J,F)}}$$

- Confining Q-Q Pseudoparticle Propagator:

  Spin-Projector $T_J(p)$, e.g. $T_1(p)=\delta_{\mu\nu}-\frac{p_\mu p_\nu}{p^2}$; $$D^{qq}_{(J,F)}(p) = \frac{1-e^{-(p^2+m^2_{(J,F)})}}{p^2+m^2_{(J,F)}}T_J$$

- QQ-Q Correlation Amplitude: $$\psi^{qq-q}_{(J,F)}(\ell) = \frac{1}{1+\ell^2/\Omega^2_{(J,F)}}$$

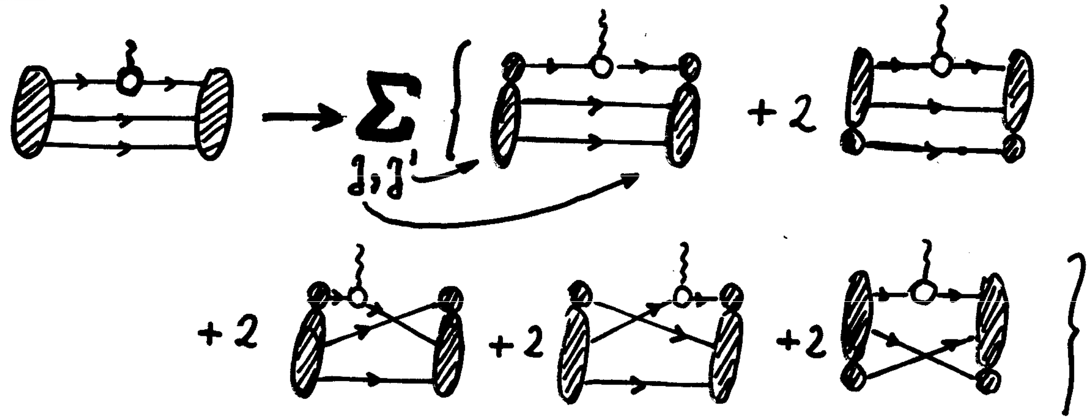
ILLUSTRATION



$$J^P_T = \quad 0^+_0(S) \quad 0^-_0(P) \quad 1^-_0(V) \quad 1^+_1(A)$$

HENCE,

$$\Gamma_\mu^{NN\gamma} =$$



$$\sum_{j,j'}$$

NOTATION

e.g.: "SA" component in

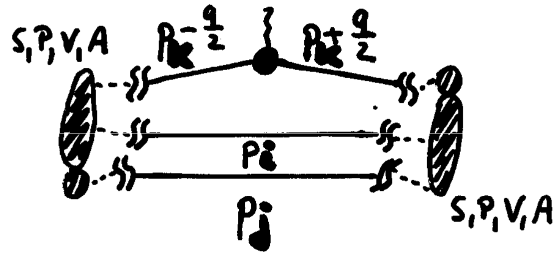
FORM FACTORS

$$\left. {}_N\!\left\langle P-\tfrac{q}{2}\right| \Gamma_\mu^{NN\gamma}\left(P-\tfrac{q}{2}, P+\tfrac{q}{2}\right)\left|P+\tfrac{q}{2}\right\rangle_N \right|_{(P\pm\frac{q}{2})=-M_N^2}$$

$$= \frac{2M_N}{4M_N^2+q^2}\left\{ P_\mu\, \mathbf{G_E}(q^2) + \varepsilon_{\mu\nu\alpha\beta}\gamma_5\gamma_\nu \frac{P_\alpha q_\beta}{2M_N}\, \mathbf{G_M}(q^2) \right\}$$

Momentum Partitioning

MODEL A

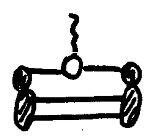


$$p_i = k + \frac{l}{2} + \frac{\alpha}{2}\mathbf{P}$$
$$p_j = -k + \frac{l}{2} + \frac{\alpha}{2}\mathbf{P}$$
$$p_k = -l + (1-\alpha)\mathbf{P}$$

k, l: **spacelike** loop momenta

same α as in ψ^{qq-q}

RESULTS

- Diagram  <u>dominates</u>, mainly SS & AA
- Momentum Partitioning α very <u>large</u> ($\sim 0.8 \sim 0.9$)
- Only <u>small</u> dependence on ω^{qq}, m_{qq}, Ω^{qq-q}

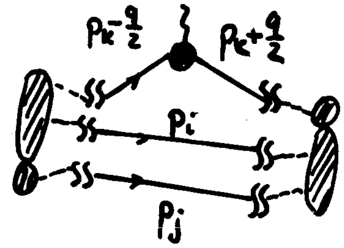
  (all [S,P,V,A] set equal)

? Model for Fadde'ev Vertex, GIA, ...

? Model for Quark Propagator

MODEL B

$$\sum_{\mathrm{perm}\{i,j,k\}}$$

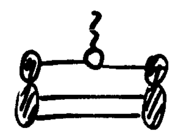


$$p_1 = \quad k + \frac{\ell}{2} + \beta_1 \mathbf{P}$$

$$p_2 = -k + \frac{\ell}{2} + \beta_2 \mathbf{P}$$

$$p_3 = \qquad -\ell + (1 - \beta_1 - \beta_2)\mathbf{P}$$

different to α in ψ^{qq-q}, $\alpha = \alpha(\beta_1, \beta$

PRELIMINARY RESULTS (only )

- SS & AA dominate G_E
- VV & AA dominate G_M
- no mixing SV, VS.
- almost **no dependence** on α
- larger m_{qq} decreases contribution

$\Rightarrow$ **promising**

Summary

- Exploratory Study of Nucleon Form Factors in **phenomenological** DSE approach.
- Modelling of Fadde'ev Amplitude
  → **no** quark production thresholds
- proper anti-symmetrisation of Fadde'ev amplitude **essential**
- Product ansatz for Fadde'ev amplitude:
  - **s**calar & **a**xialvector quasi-diquark dominate $\mathbf{G_E}$
  - **v**ector & **a**xialvector (& scalar) quasi-diq. dominate $\mathbf{G_M}$