

Hadronic Form Factors and meson photoproduction reactions

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References:

PRC 69, 035212 (2004); NPA 739, 69 (2004);

PRC 70, 045204 (2004); PLB 602, 212 (2004); nucl-th/0501005 (2005);



Motivations

- Quark models

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 - ⇒ $\gamma p \rightarrow K^+ \Lambda$

Motivations

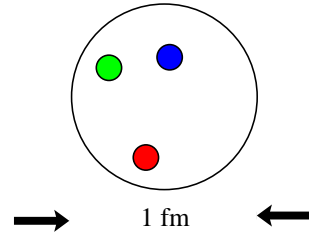
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 - ⇒ Missing resonances
 - ⇒ Coupled channels - meson clouds

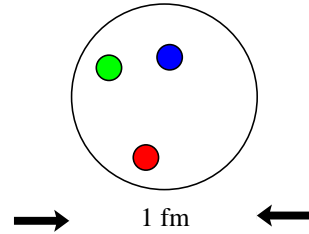
Relativistic Quark Models

In the few GeV region relativity is important:



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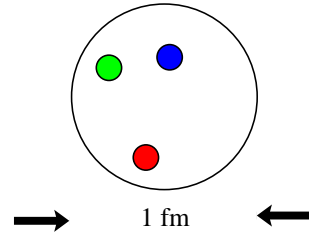
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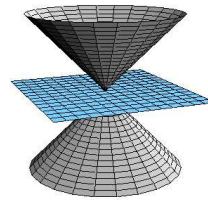
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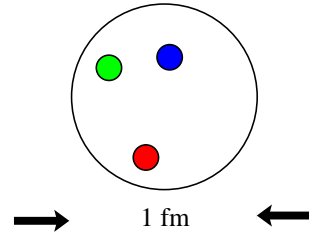
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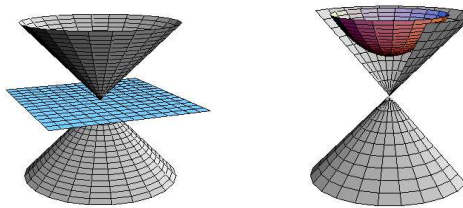
● Instant form

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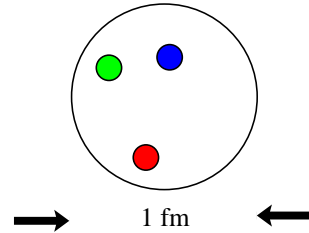
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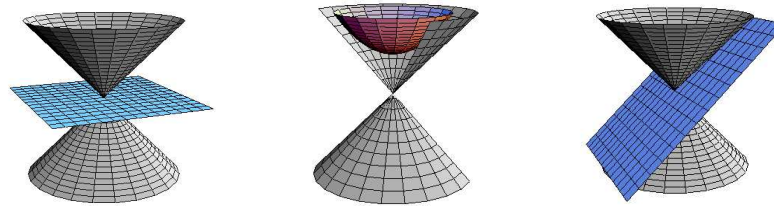
- Instant form
- Point form

Relativistic Quark Models

In the few GeV region relativity is important:



There are different ways of implementing relativity into a quark model formalism:



● Instant form

● Point form

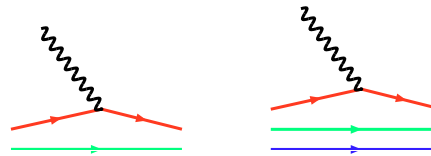
● Front form Plots form A. Krassnigg's PhD thesis

RQM (II)

Common assumptions to the three forms
Single quark current operator

● meson

● baryons

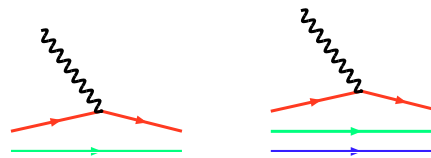


RQM (II)

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● Ground state wave functions with 2 or 3 parameters

$$\varphi_0^G(\vec{q}) = \frac{1}{(b\sqrt{\pi})^{3/2}} e^{-\vec{q}^2/2b^2}, \quad \varphi_0^R(\vec{q}) = \mathcal{N}(1 + \vec{q}^2/2b^2)^{-a},$$

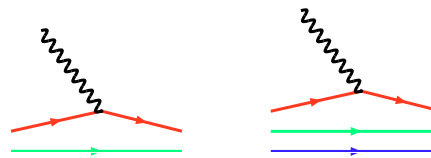
$$\varphi_0(P) = \mathcal{N} \left(1 + \frac{P^2}{4b^2} \right)^{-a}, \quad \text{with } P := \sqrt{2(\vec{\kappa}^2 + \vec{q}^2)}$$

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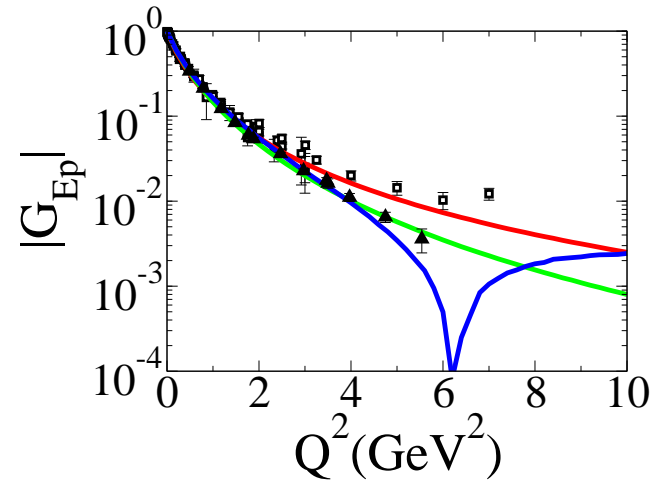
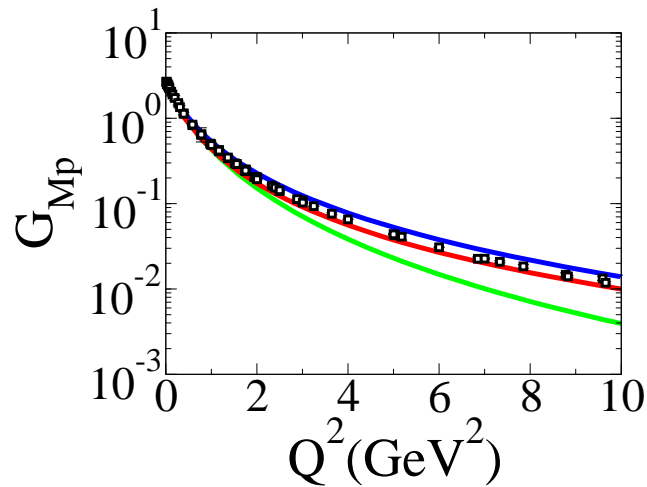
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$SU(6)_{FS}$ is used to build resonances

Proton Form Factors

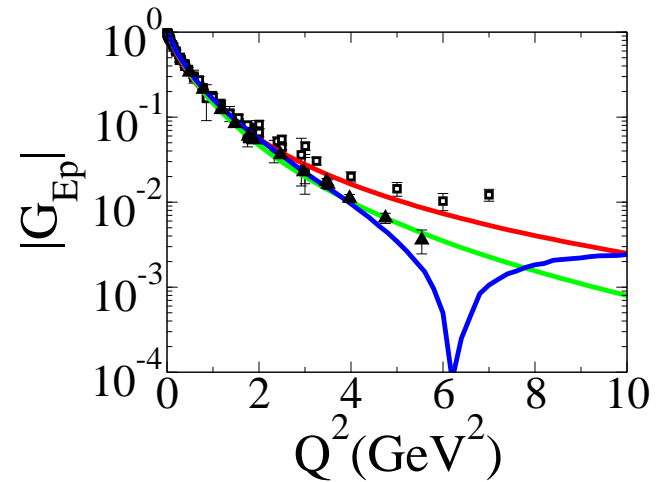
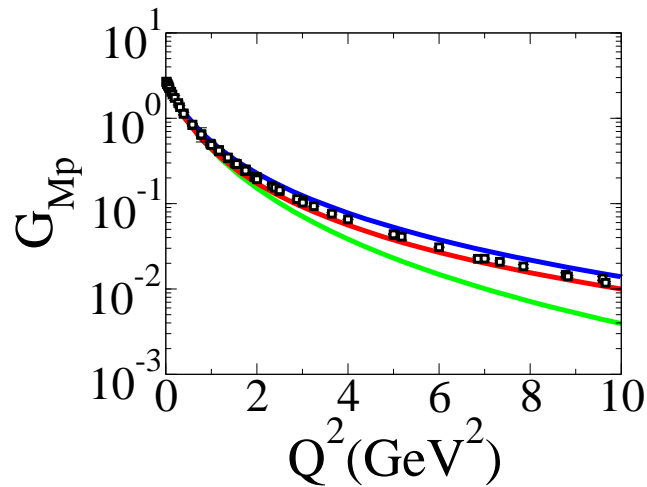
Instant
Point
Front



● Parameters fixed to G_{Mp}

Proton Form Factors

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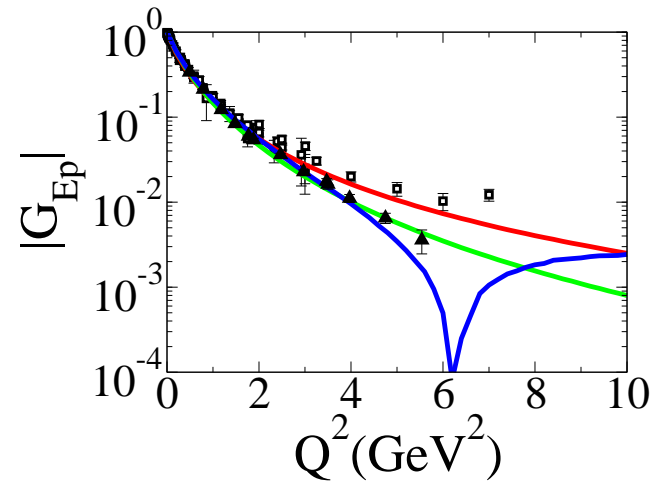
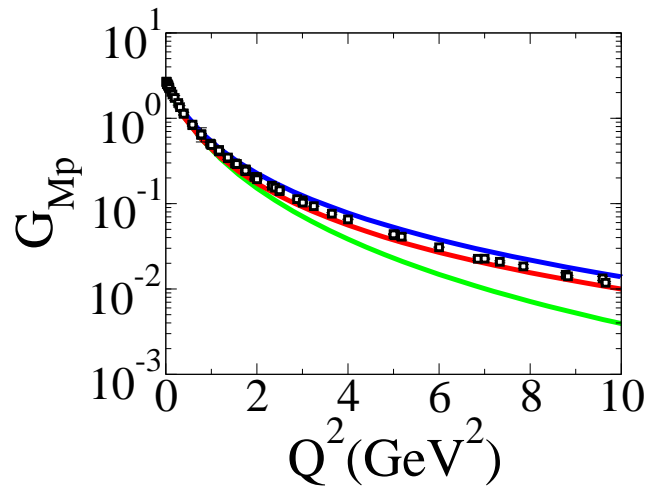
● All forms OK

∝ Chung & Coester, PRD 44, 229 (91)

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Proton Form Factors

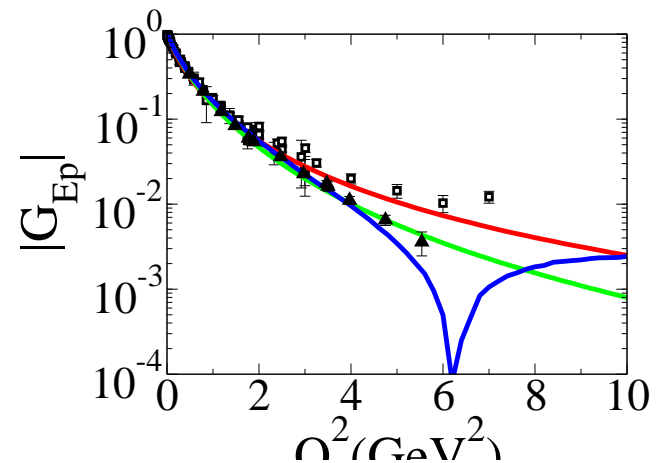
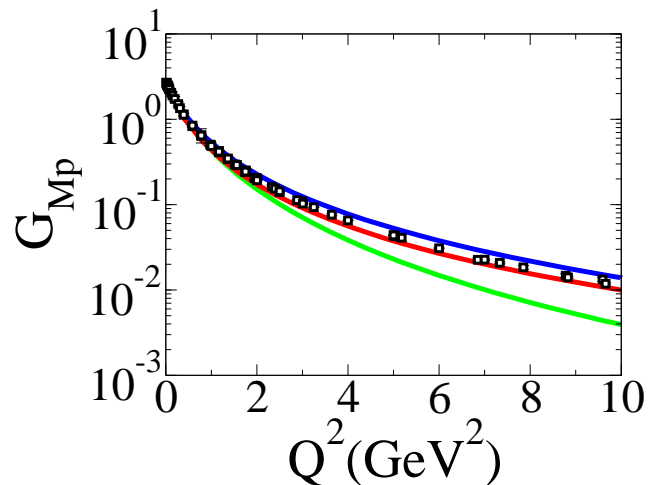
Instant
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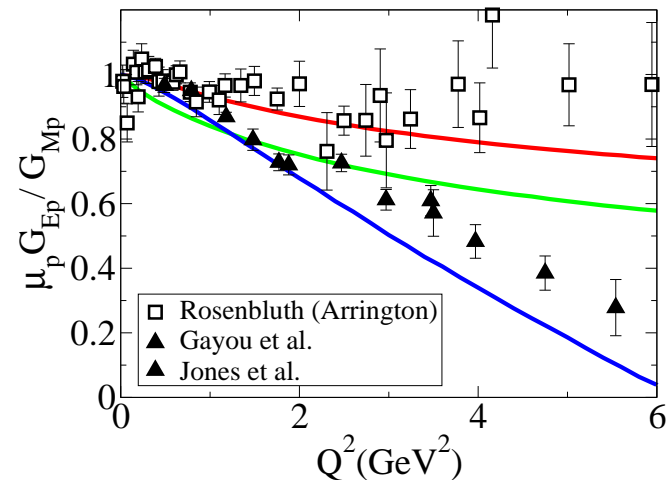
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Proton Form Factors

Instant
Point
Front

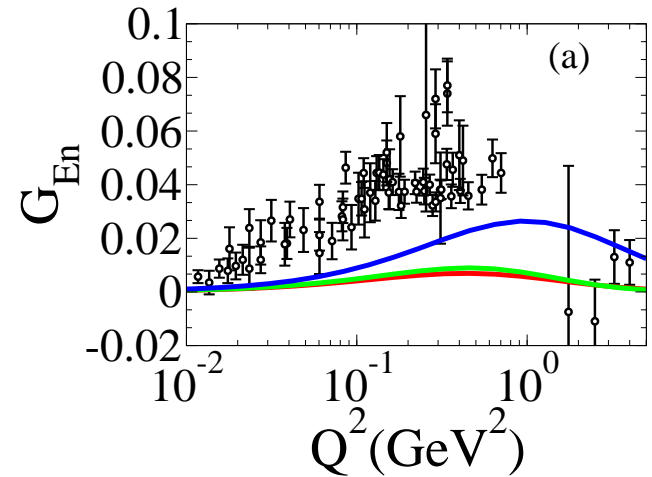
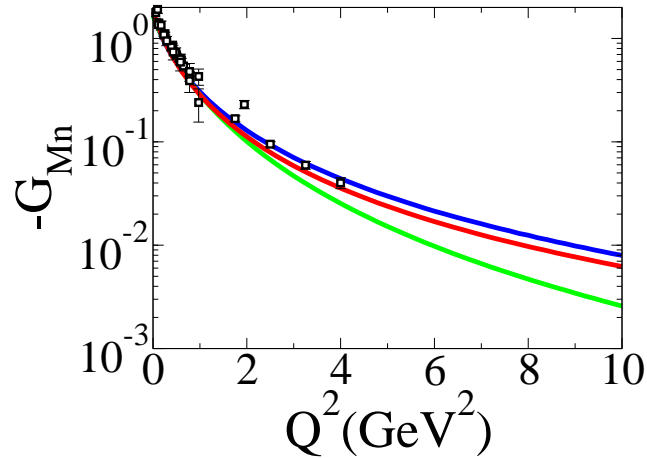


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- Front form has a node



Neutron Form Factors

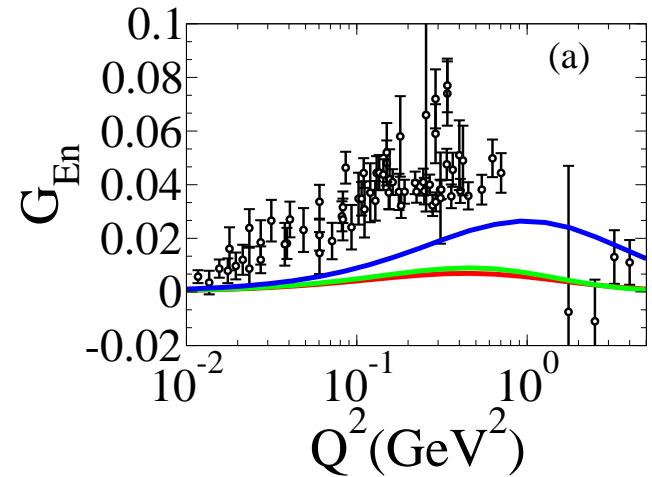
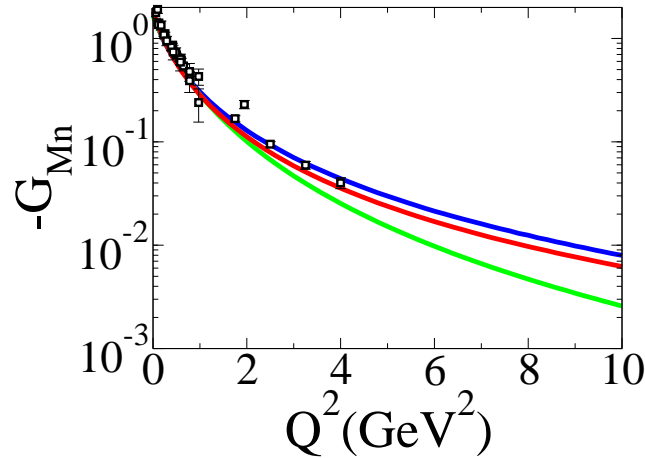
Instant
Point
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● G_{Mn} comes out nicely

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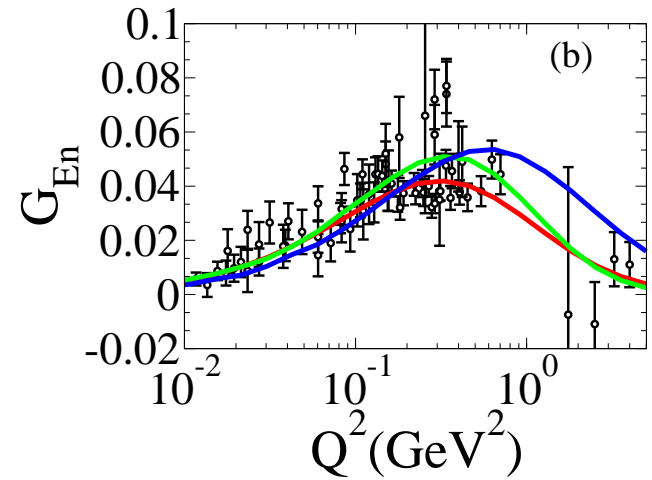
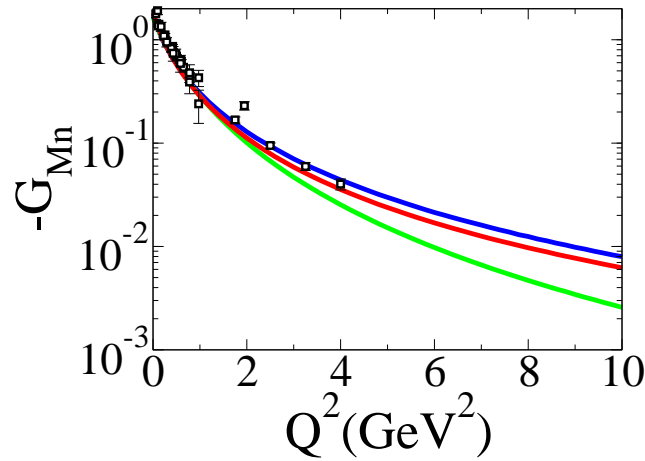
Instant
Point
Front



- G_{Mn} comes out nicely
- G_{En} , Point and Instant: off

Neutron Form Factors

Instant
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D-state effects $N \rightarrow \Delta$ (I)

$N \rightarrow \Delta$ electromagnetic transition



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General expression:

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G_i related to standard:

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see Burkert and Elouadrhiri,

PRL 75, 3614 (1995)

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● **NRQM Predictions**

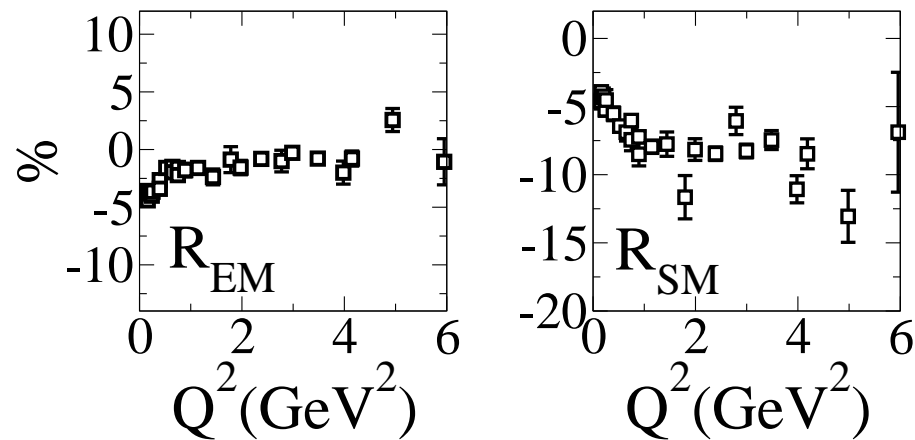
● $R_{SM} \rightarrow 0$

● $R_{EM} \rightarrow 0$



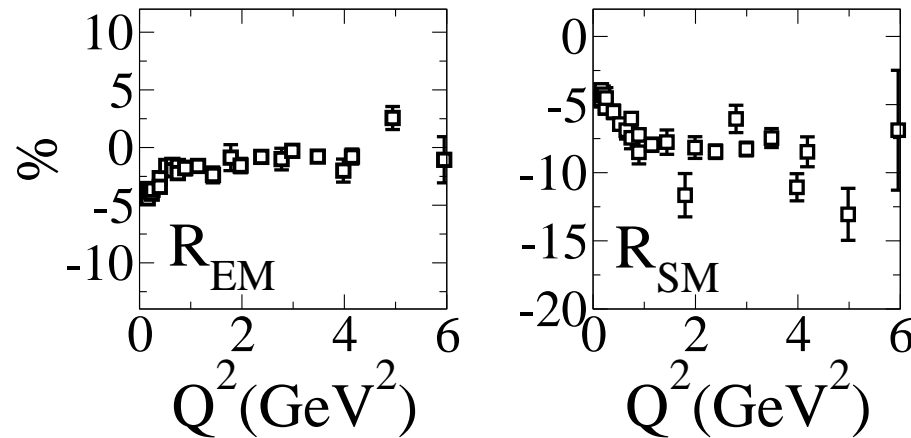
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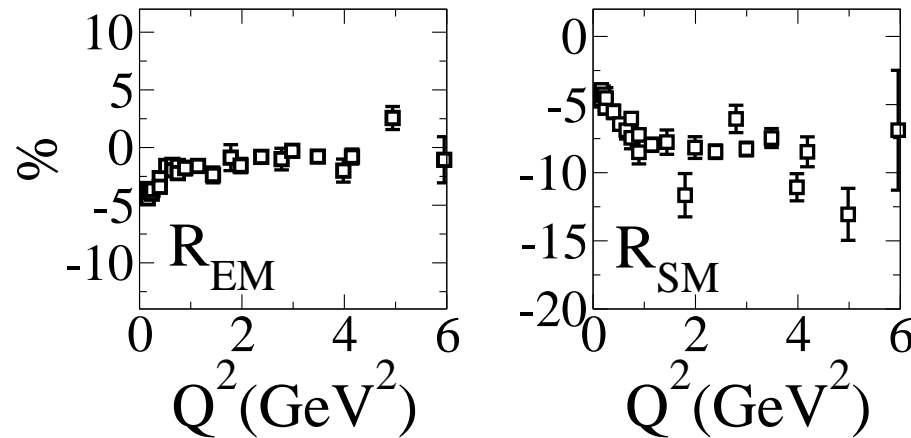


Inclusion of Boosts could
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see Bienkowska et al., PRL 59 624
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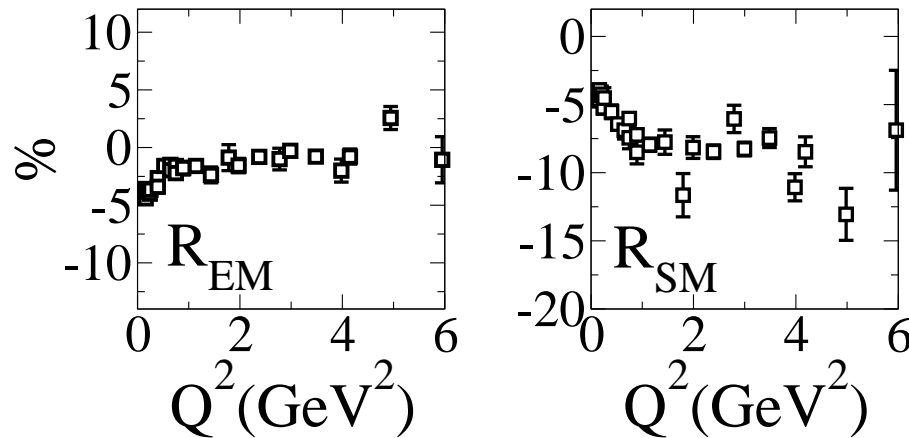


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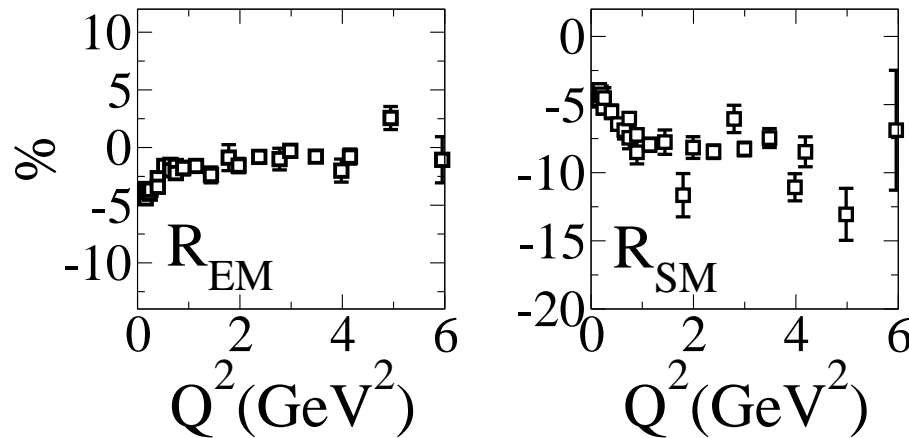


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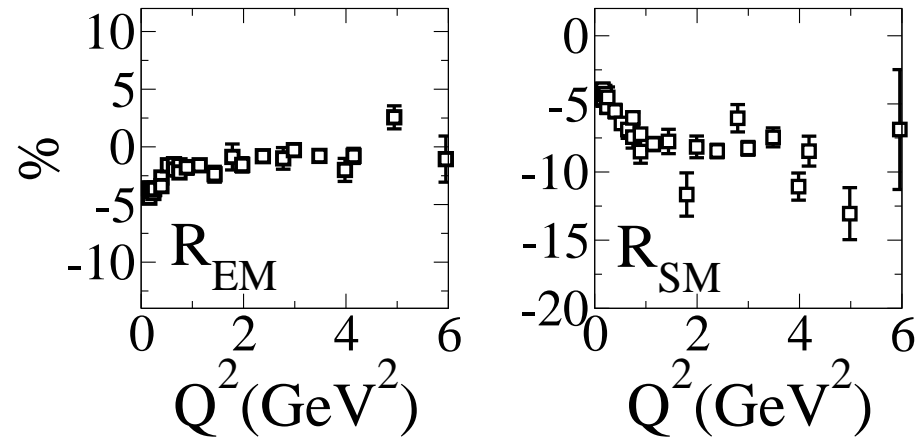
We study the effect of including a D-state component in the rest frame wave functions:

$$\phi_N = a_N \phi_S + b_N \phi_D \quad \phi_D^{j_3} = \frac{1}{\sqrt{2}} \sum_{ms} (2 \frac{3}{2} ms | \frac{1}{2} j_3) \left\{ \kappa^2 Y_{2m}(\hat{\kappa}) \chi_F^{MS} + q^2 Y_{2m}(\hat{q}) \chi_F^{MA} \right\} \varphi_2(P) \chi_S^{S; s}$$



D-state effects $N \rightarrow \Delta$ (III)

Instant and
Point form

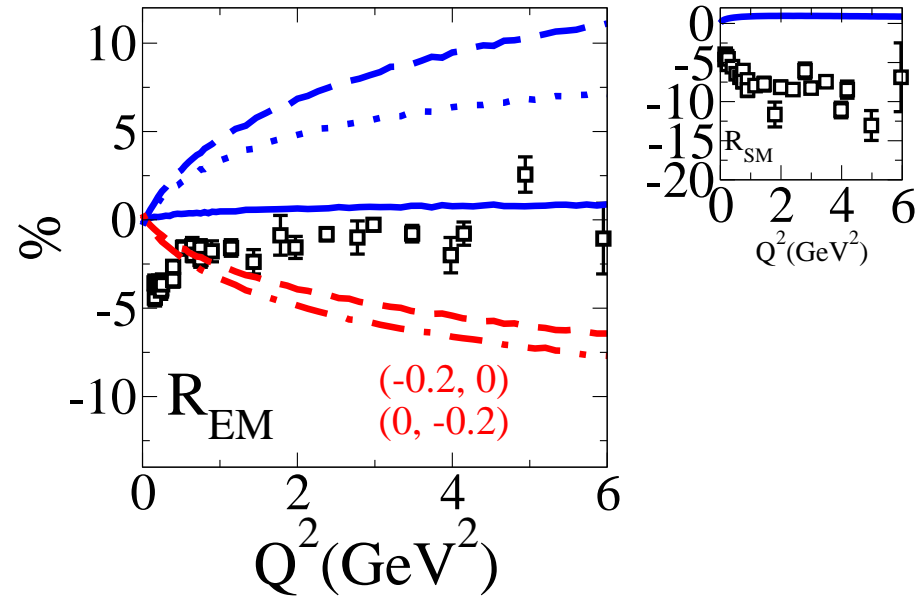


D-state effects $N \rightarrow \Delta$ (III)

Instant and
Point form

● A small D-state component
in Δ or N w.f. improves

but does not provide the
low Q^2 structure



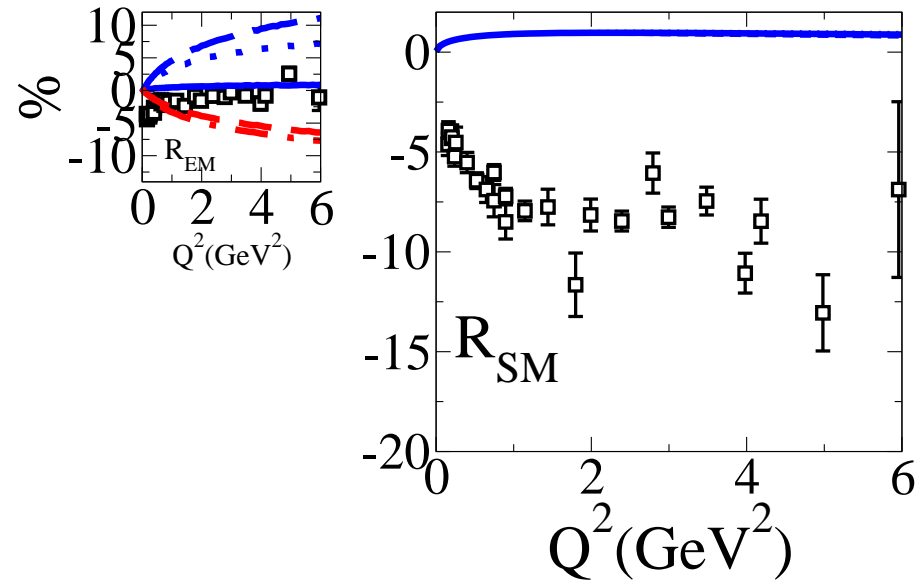
D-state effects $N \rightarrow \Delta$ (III)

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- R_{SM} insensitive



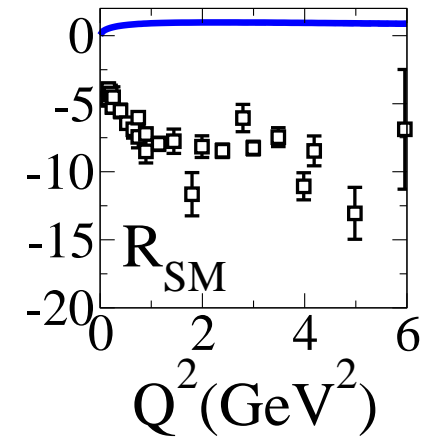
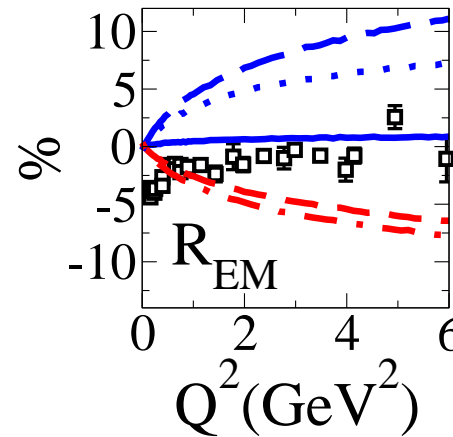
D-state effects $N \rightarrow \Delta$ (III)

Instant and Point form

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- R_{SM} insensitive
- Instant and Point qualitatively similar



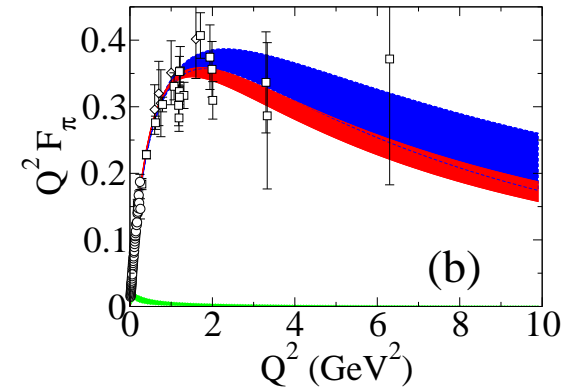
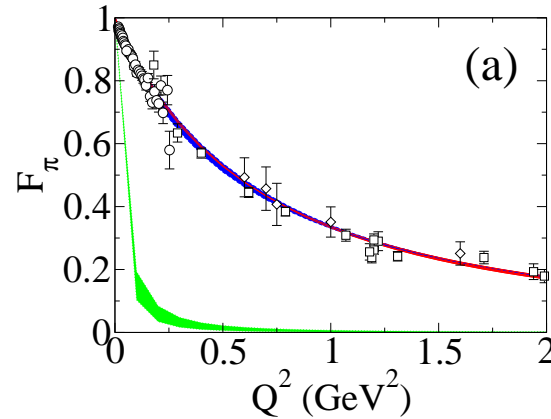
Meson Form Factors



Meson Form Factors

For the π :

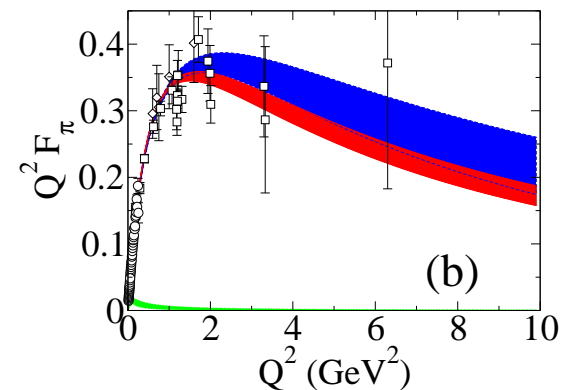
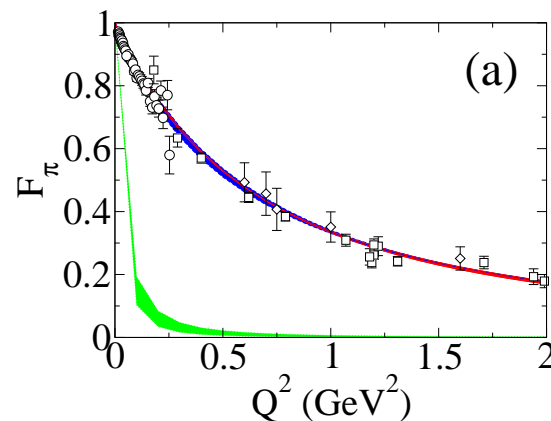
Instant Form
Front Form
Point Form



Meson Form Factors

For the π :

Instant Form
Front Form
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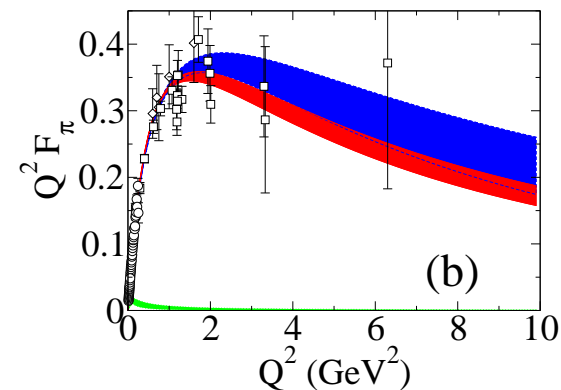
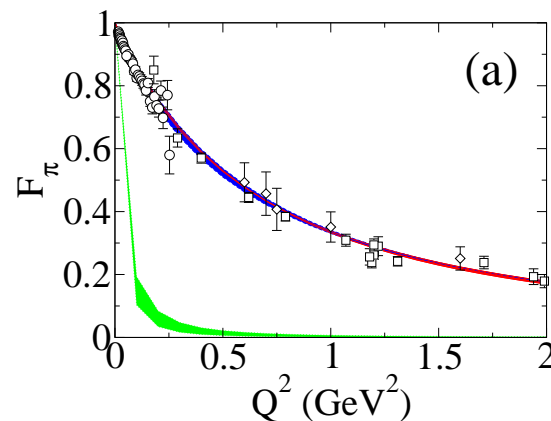
- Instant and Front:
nice agreement



Meson Form Factors

For the π :

Instant Form
Front Form
Point Form



- Instant and Front:
nice agreement
- Point form: off

\neq Allen & Klink PRC 58, 3670 (98)

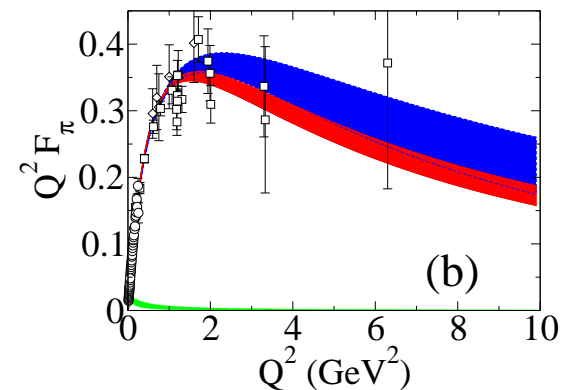
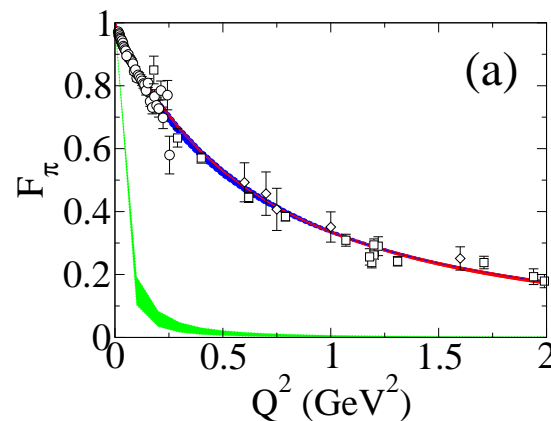
\propto Amghar et al. PLB 574, 201 (03)



Meson Form Factors

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≠ Allen & Klink PRC 58, 3670 (98)

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● Independent of the shape

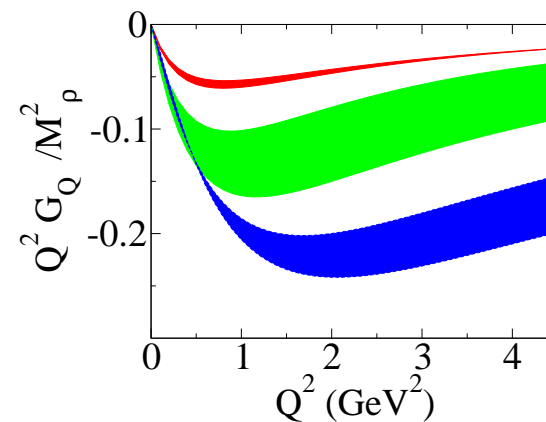
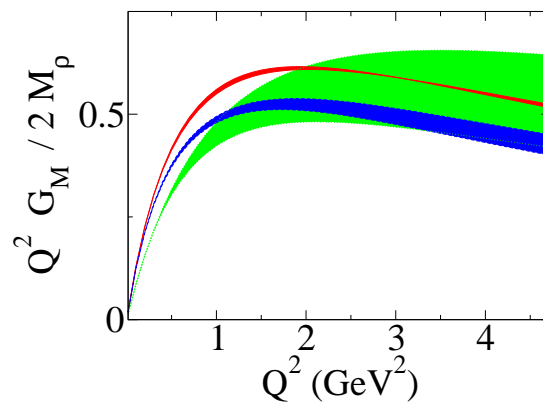
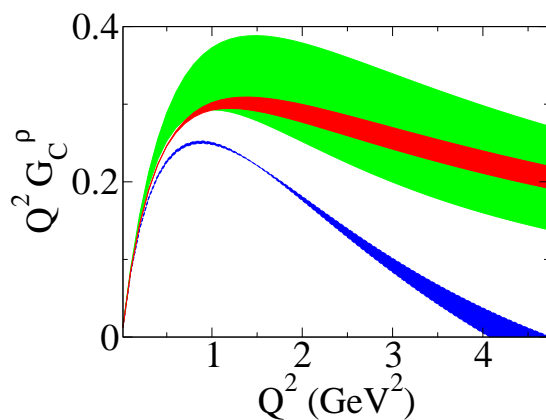
● ... (bands)



Meson Form Factors

..and for the ρ meson

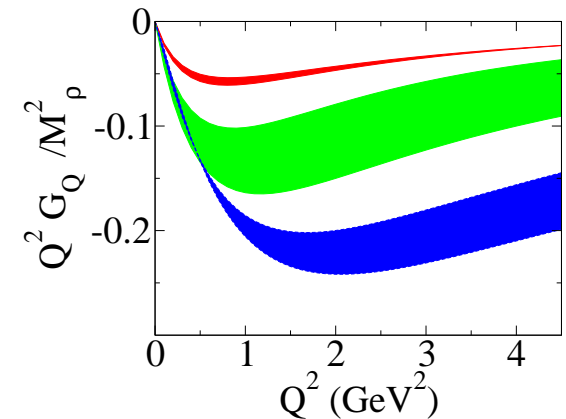
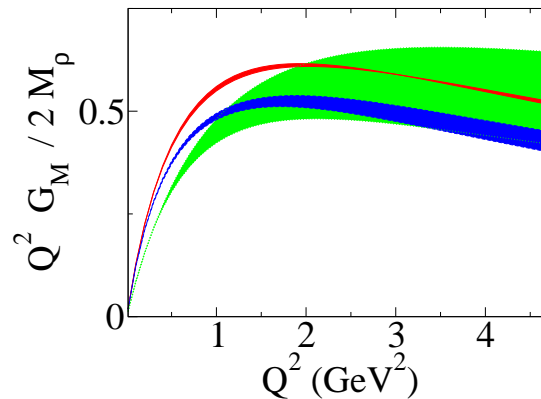
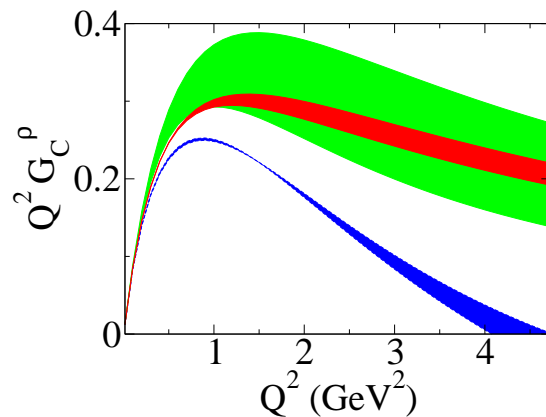
Instant Form
Front Form
Point Form



Meson Form Factors

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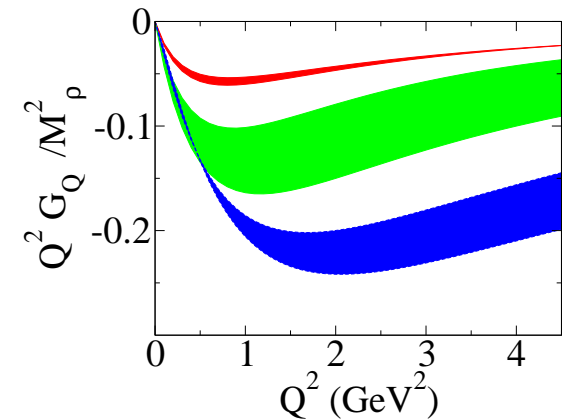
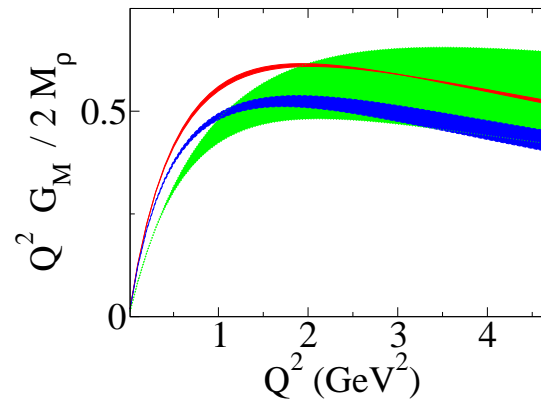
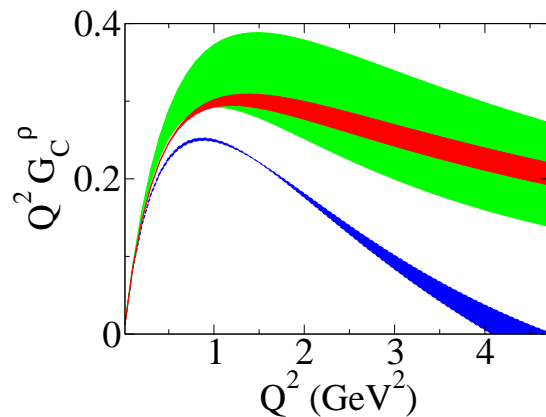
● Point and instant forms: similar results



Meson Form Factors

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Instant Form
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- Point and instant forms: similar results
- Notice the zero in the charge form factor in front form

Kaon photoproduction

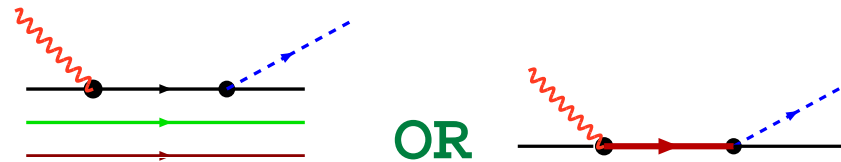
Meson photoproduction touches the heart of the problem



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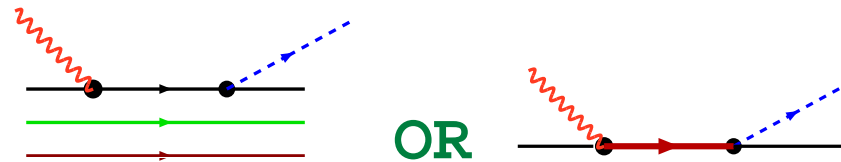
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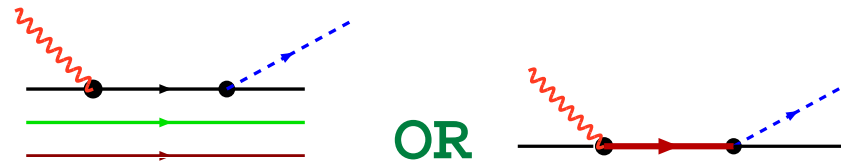


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Kaon photoproduction

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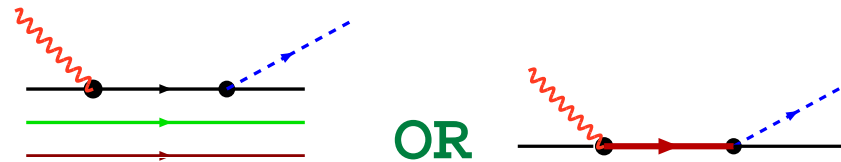


- How does the transition occur?
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Kaon photoproduction

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- Which degrees of freedom are relevant?



- How does the transition occur?
- Role of FSI?
- New accurate experimental DATA:

[JLAB] J.W.C. McNabb *et al.*, PRC 69 (2004) 042201.

[SAPHIR] K.H. Glander *et al.*, EPJA 19 (2004) 251.



Kaon photoproduction (II)

Coupled channel formalism

the photoproduction process is described by:

$$a_{\ell\pm}^{\gamma N \rightarrow KY}(q_{KY}, k) =$$
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Direct mechanism form Quark
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Coupled channel formalism

Direct mechanism form Quark Model $\pi N \rightarrow KY$: **Chiang et al**

the photoproduction process is described by:

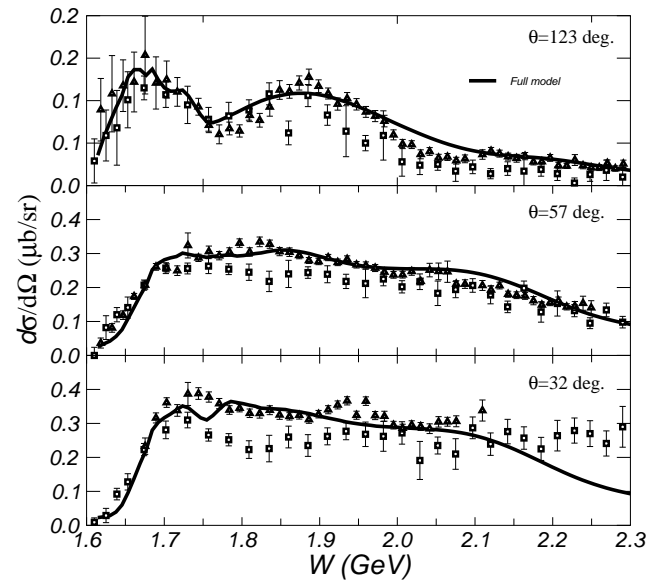
$$\begin{aligned} a_{\ell\pm}^{\gamma N \rightarrow KY}(q_{KY}, k) &= b_{\ell\pm}^{\gamma N \rightarrow KY}(q_{KY}, k) \\ &+ \sum_{\alpha=KY} \int dp_{\alpha} p_{\alpha}^2 t_{\ell\pm}^{\alpha \rightarrow KY}(q_{KY}, k) G_{0\alpha}(p_{\alpha}) b_{\ell\pm}^{\gamma N \rightarrow \alpha}(p_{\alpha}, k) \\ &+ \sum_{\alpha=\pi N} \int dp_{\alpha} p_{\alpha}^2 t_{\ell\pm}^{\alpha \rightarrow KY}(q_{KY}, k) G_{0\alpha}(p_{\alpha}) b_{\ell\pm}^{\gamma N \rightarrow \alpha}(p_{\alpha}, k) \end{aligned}$$

where KY , πN refers to the different channels.



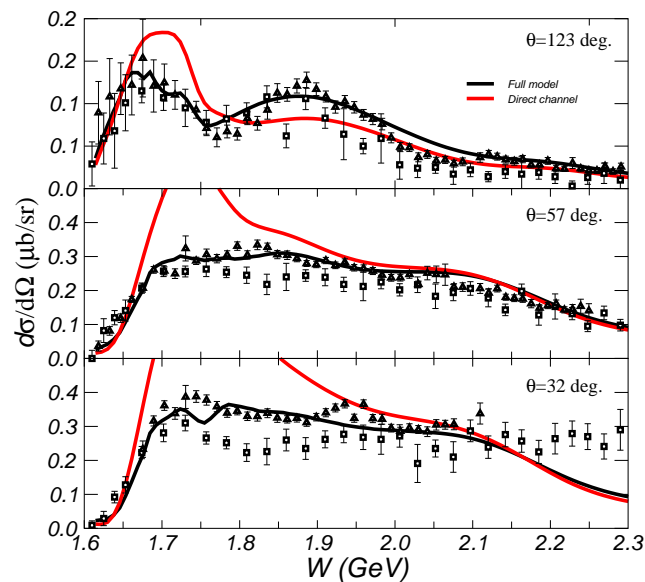
Kaon photoproduction (III)

- Quark Model fixed in full model



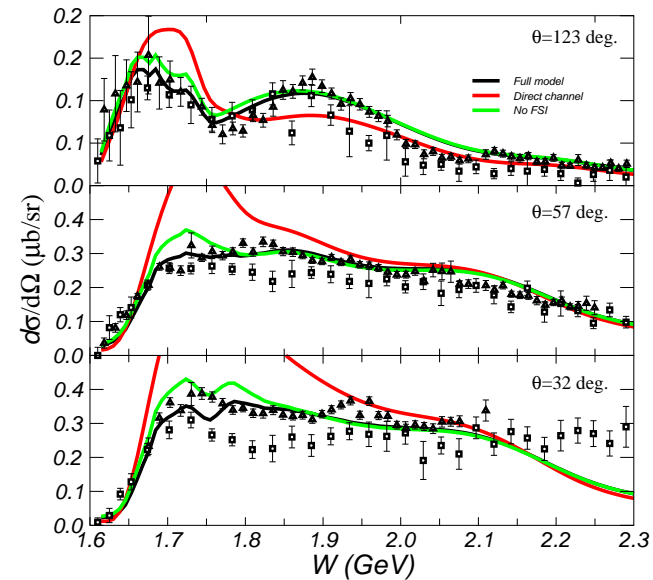
Kaon photoproduction (III)

- Quark Model fixed in full model
- Now, we switch off coupled channel



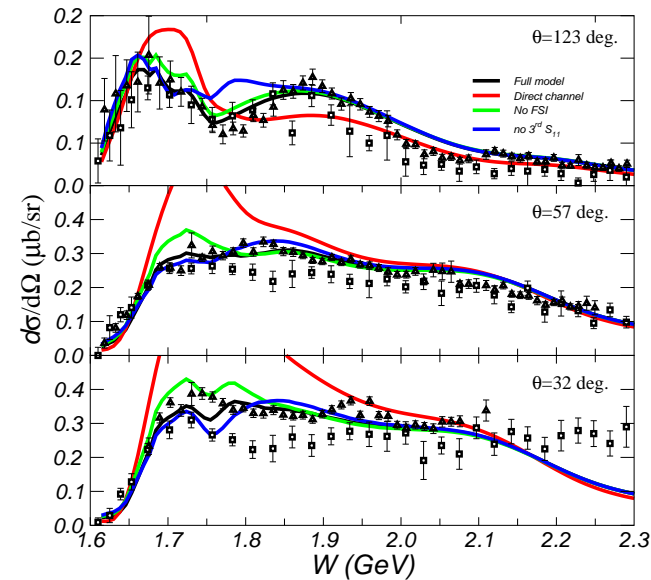
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Kaon photoproduction (III)

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Summary, perspectives...

Several relevant issues have been addressed:

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