Connection between spacelike (SL) and timelike (TL) form factors

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Various regions

- scattering region (SL): $e^- B \to e^- B'$

$$q^2 = q_0^2 - \vec{q}^2 < 0 \qquad (Q^2 := -q^2 > 0)$$

- Dalitz decay region (low-energy TL): $B' \to B\, \ell^+\ell^-$

$$0 < 4m_\ell^2 < q^2 < (M_{B'} - M_B)^2$$

- unphysical region:

$$(M_{B'} - M_B)^2 < q^2 < (M_{B'} + M_B)^2$$

- pair-production region (high-energy TL): $e^+e^- \to B'\bar{B},\ \bar{B}'B$

$$q^2 > (M_{B'} + M_B)^2$$

What where?

- Which physics is probed in which region?
- What do we learn?
- Which theory approaches/models work
  in which region best, not at all, ...?
- How to justify microscopically/from first principles the often successful concept of vector-meson dominance (VMD)?
  (Is there are proper definition of VMD?)

Dispersion relation for form factors (schematic)

$$\int d^4x\, e^{iqx} \langle B' | j^\mu(x) | B \rangle =: \bar{u}_{B'} \gamma^\mu F^{\text{Dirac}}_{BB'}(q^2) u_B + \ldots$$

$$F_{BB'}(q^2) \sim \int\limits_{\text{threshold}}^{\infty} ds\, \frac{\text{Im} F_{BB'}(s)}{q^2 - s + i\epsilon} \sim \sum_X \int\limits_{\text{thr.}}^{\infty} ds\, \frac{T_{\bar{B}B' \to X}(s)\, F_X^*(s)}{q^2 - s + i\epsilon}$$

- relates spacelike to timelike information and form factor to other form factor(s) and scattering amplitudes
- note: integration range includes "unphysical" region

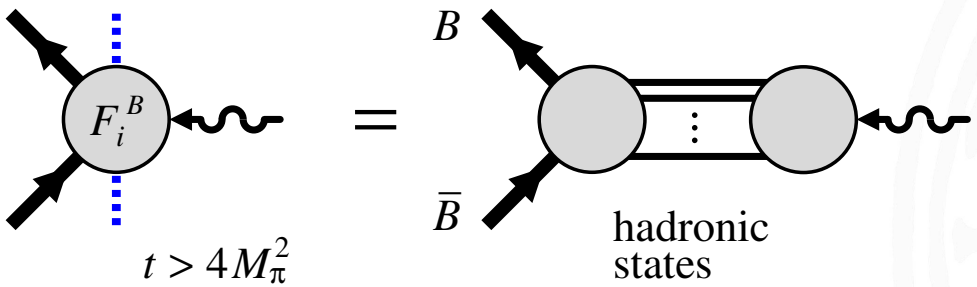


figure from J.M. Alarcón et al., arXiv:1703.04534 [hep-ph]

Quark counting rules

for large Q^2: $F(Q^2) \sim 1/Q^{2\beta}$

in simplest case: $\beta = (\#\text{quarks}) - 1$

S.J. Brodsky, G.R. Farrar, Phys. Rev. D11, 1309 (1975)

- how large is "large" in practice?
- agreement of spacelike (SL) and timelike (TL) form factor for asymptotically large momenta
  - true?
  - where does it set in?
  - onset different for SL vs. TL?

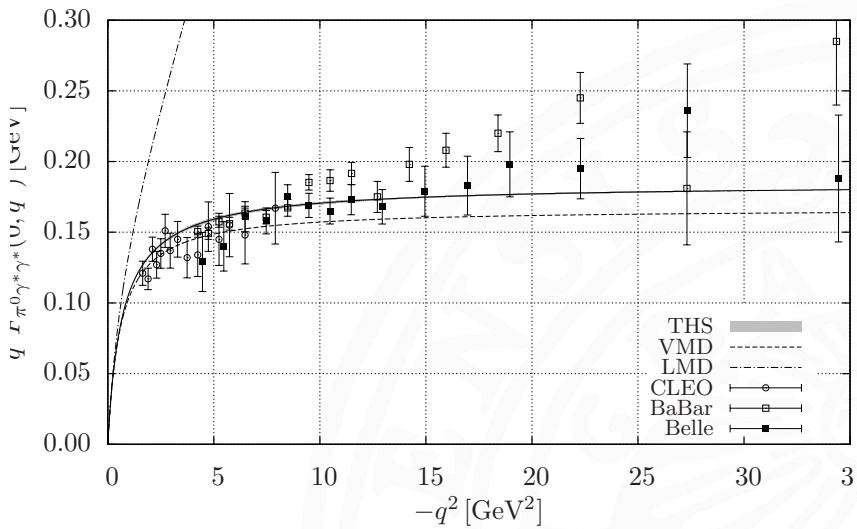


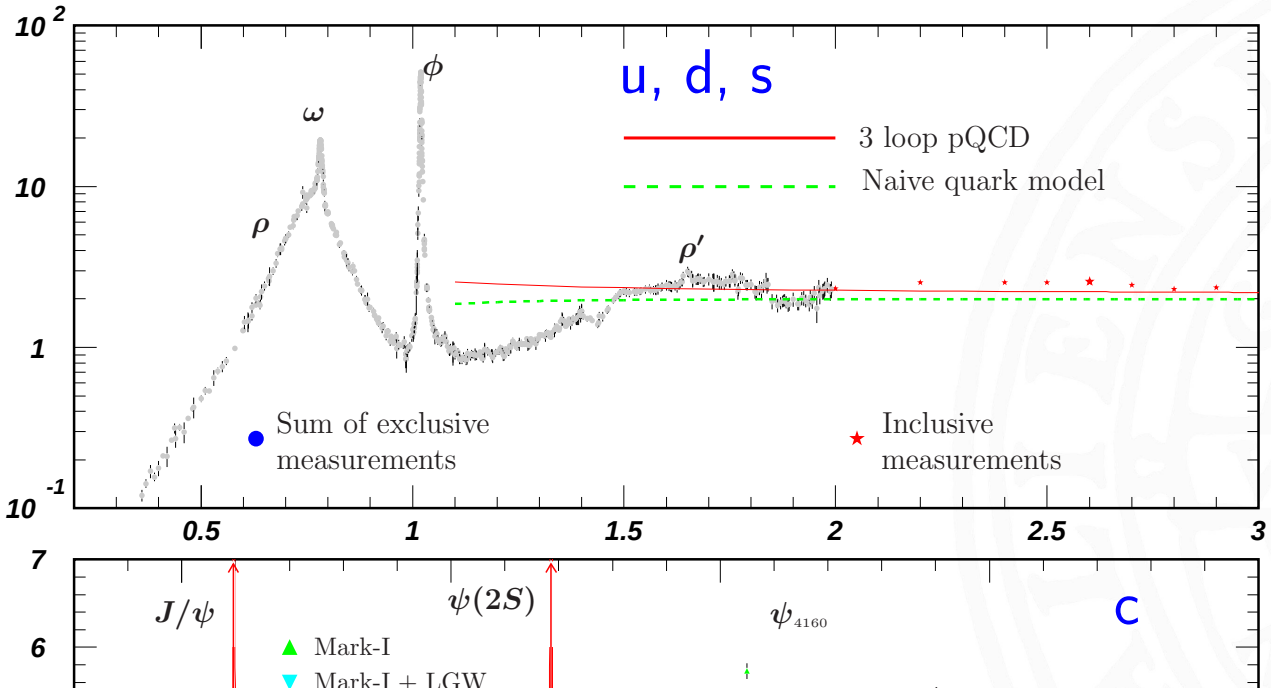
figure from T. Husek/SL, EPJ C 75, 586 (2015)

Duality

- connection between quarks and hadrons?

↪ one "sees" quarks after sufficient averaging

R in Light-Flavor, Charm, and Beauty Threshold Regions



inside and outside of duality region

personal speculations:

- in high-energy timelike (TL) region:

↪ spectral information of many channels might average to quark "information"

- in high-energy spacelike (SL) region:

↪ spectral information is smeared out/averaged → quark "information"

- in low-energy region (TL and SL):

↪ details of close-by spectral information matter

↪ pion (cloud) physics

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