The electromagnetic N-Δ transition form factor and its impact on dilepton spectra

Janus Weil

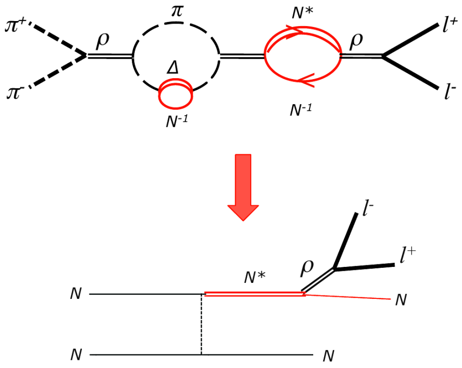
Frankfurt Institute for Advanced Studies

in collab. with G. Ramalho, M.T.Peña, H. van Hees, U. Mosel

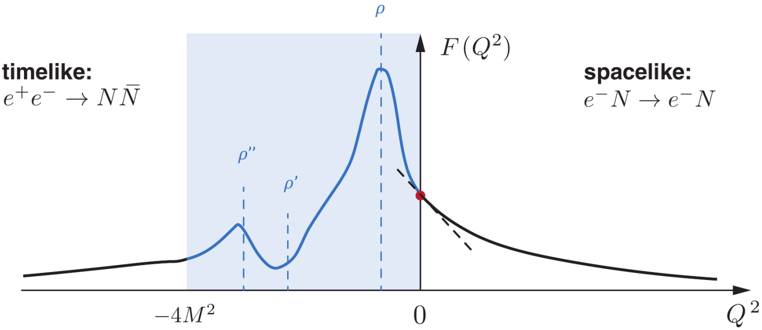
DPG Spring Meeting, Darmstadt
March 14, 2016

Intro

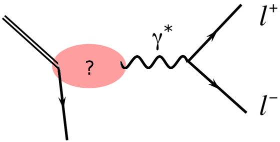
- HADES: "the quest for **baryonic em. formfactors**" (in the time-like region)
- usually people think more about in-medium **spectral functions**, but in fact FF and SF are closely related



ELECTROMAGNETIC FORM FACTORS

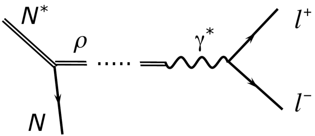


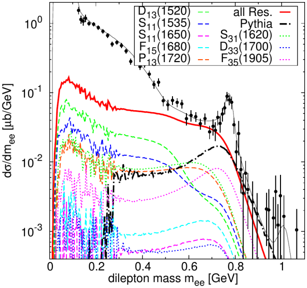
- em. form factors occur in different physical processes
- vector-meson region only accessible via dilepton decays



BARYONIC FORM FACTORS & VMD

- experimental problem: there are many N^* and Δ^* states, their contributions are hard to disentangle
- theoretical problem: FF hard to compute from first principles
- most reasonable ansatz: vector-meson dominance (VMD), "all hadrons couple to the em. sector primarily via vector mesons"
- we apply the VMD hypothesis in a transport framework via 2-step treatment: $N^* \to \rho N \to e^+ e^- N$
- the two-step procedure provides a full kinematic model of the form factor





Δ em. transition FF

- what about the $\Delta(1232)$?
- Δ em. transition FF measured in spacelike region (electron scattering) and at the real-photon point
- so far: experimentally unknown in the time-like region
- Δ Dalitz decay width (Krivoruchenko et al.):

$$\frac{\mathrm{d}\Gamma}{\mathrm{d}q} = \frac{2\alpha}{3\pi q}\frac{\alpha}{16}\frac{(W+m_N)^2}{W^3 m_N^2}\sqrt{(W+m_N)^2-q^2}\left[(W-m_N)^2-q^2\right]^{3/2}|F(q^2,W)|^2$$

- $q^2 = m_{ee}^2$ (dilepton mass), $W = \Delta$ mass
- in principle there are three FFs (G_E, G_M, G_C), but G_M dominates strongly for the Δ

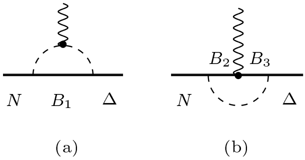
- we will try different approches for the form factor:
  - 'QED' (constant FF, fixed at photon point)
  - two-component model (Ramalho et al)
  - “2-step VMD“ (as for N^*)

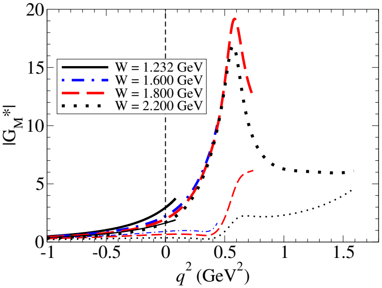
Ramalho/Peña model

- "covariant spectator quark model"
- phenomenological model:
  bare quark core + meson cloud

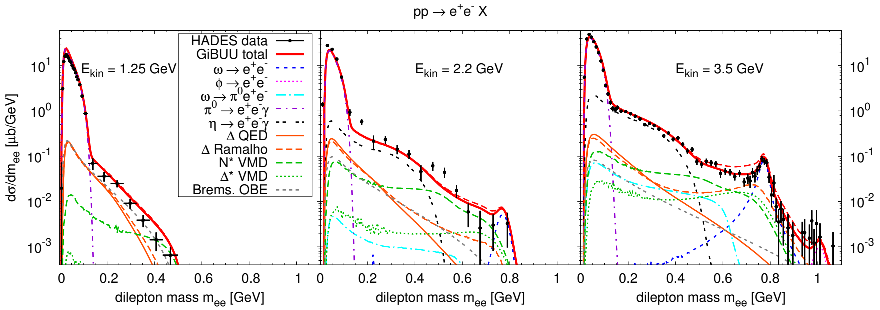
$$G(q^2, W) = G^b(q^2, W) + G^\pi(q^2)$$

- bare quark contribution calibrated with lattice QCD data
- pion-cloud contribution relies on measured pion form factor
- W dependence in pion cloud neglected
- Ramalho et al.,
  Phys. Rev. D 93 (2016) no.3, 033004





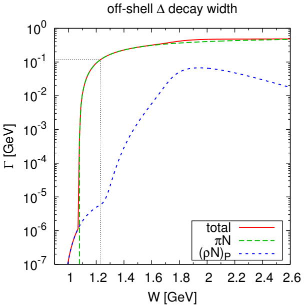
GiBUU results with Ramalho FF

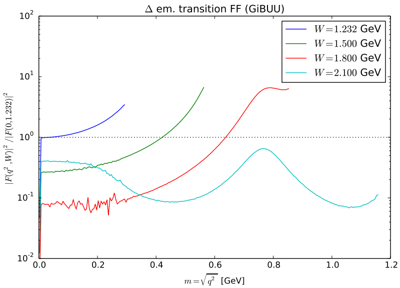


- at low energies FF has only minor influence
- at higher energies it enhances the yield by more than an order of magnitude
- slightly conflicting with HADES data when added to other channels (N^*, Δ^*)

2-step VMD: ρ-Δ coupling

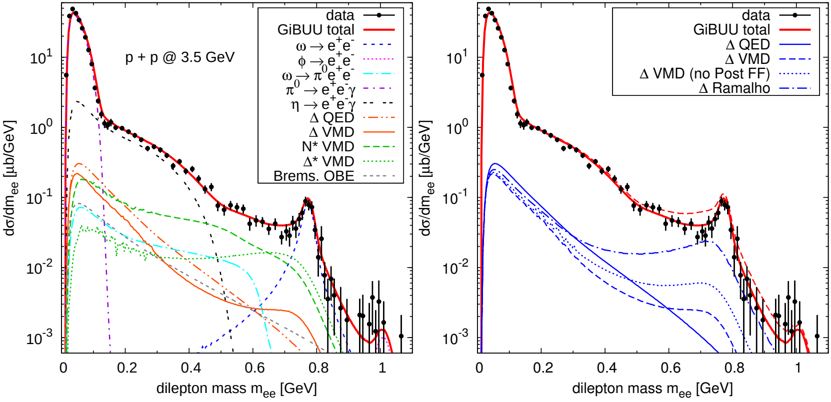
- $\Delta \to \rho N$ coupling can not be directly inferred from PWA of $\pi N \to 2\pi N$ data
- Δ is too light to decay into ρN (on the mass shell)
- but: off-shell Δ can decay into off-shell ρ
- this coupling can be important for dilepton spectra
- we introduce a p-wave decay with an (on-shell) BR of $5 \cdot 10^{-5}$
- $\to$ consistent 2-step VMD approach for all baryons





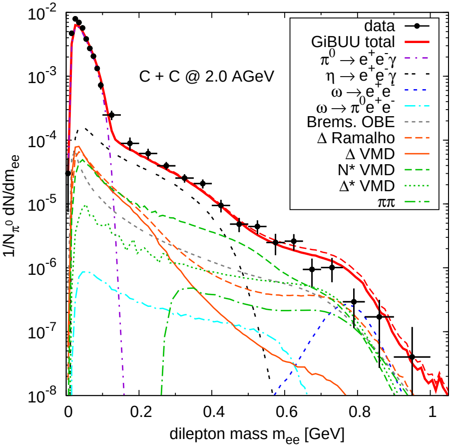
GiBUU results with 2-step VMD

- VMD vs Ramalho model
- result: very similar dependence on q^2 (i.e. dilepton mass)
- but: different W dependence (apparently important!)



other systems: C+C at 2 AGeV

- similar picture in nucleus-nucleus collisions
- Ramalho model tends to overshoot the data slightly (probably due to neglected W dep.)



CONCLUSIONS

- em. transition form factors are quantities that can actually be **generated** by microscopic transport simulations (instead of being taken as input from outside)

- two-step VMD treatment ($R \to \rho N \to e^+e^-N$) is a useful approach for all baryons (including Δ)
- generates form factors with 'reasonable' q^2 and W dependence
- we need tighter exp. constraints

- how does it perform for mesons, e.g. ω Dalitz?
  $\Rightarrow$ HK 10.3 (J. Staudenmaier)