summary TFFs

- basics

- data

- models for pi+N to N+dilepton and
  NN to NN+dilepton

- quark-based models for FFs, TFFs

- vector-meson dominance and extensions

(T)FF = (transition) form factor

basics

- kinematics: spacelike (SL) region of transition form factors (=electroproduction) continues via photon point to dilepton production region (=Dalitz decays)
  - – similar physics; structures in Dalitz decays (vector mesons) translate to slopes in SL region
  - – timelike FF of baryon-antibaryon production less relevant
- spectral function not a measurable object, phase shift is
- resonance FF defined for peak mass; need some range around peak to identify resonance over background

data

- elastic nucleon scattering; electric and magnetic FF for proton and neutron, JLAB data from polarized measurements (vs. Rosenbluth)

- electroproduction of baryon resonance on nucleon; similar high-energy behavior, quark counting

- timelike Delta TFFs (dominated by magnetic one) from HADES (pp run)

- future: timelike TFFs for other resonances from HADES pion beam

- angular distributions measurable

models for pi+N and NN to dileptons

- Friman, Lutz, Soyeur (pi N):
    - dynamical generation of resonances
    - coupled channels pi N, gamma N, V N
    - based on corresponding data
    - strong destructive interference in mass range 15XX
- Kämpfer et al. (NN and pi N)
    - baryon resonances (+ one-boson exchange)
    - cutoff form factors, issue of gauge invariance
    - based on decay and elastic NN data

models for pi+N and NN to dileptons

- Zetenyi/Wolf (pi N):
  - similar to Kämpfer et al.
- Teis model, updated (=input for GiBUU)
  - similar ...
  - from elementary analysis (Bonn/Gatchina etc.): resonances in 1520-1750 range shine less into isovector channel (2pi) than what's in PDG, Manley -> possible impact on rho/dileptons
- maybe in future contributions from other models
  - Sato-Lee, Gießen, Jülich
- (future) task:
  - establish formulae for angular distributions

quark-based approaches

- quark model Pena/Ramalho (FFs and TFFs)
  - quark core calculated
  - fit to lattice (with heavy pions)
  - get meson cloud from hadronic models
  - problem with using Iachello meson cloud part in timelike region
    - Iachello paper is on nucleon FF, extension to Delta TFF in a PhD thesis
    - contains Frazer-Fulco (=Gounaris-Sakurai?) with right two-pion threshold, but "wrong" rho mass
    - suggestion: fit to spacelike region with correct rho mass

quark-based approaches

- lattice QCD
  - to come (David, Friday)
- Dyson-Schwinger
  - to come (Gernot, Saturday)
  - why is it so good (when comparing to lattice)?

VMD and extensions

- meson TFFs
  - strict VMD works for eta to photon TFF
  - does not work for omega to pion TFF
    - or does it? other sources in NA60 analysis?
    - hard to get last points of NA60 (and of LEPTON-G)
  - Rapp/Gale: omega to pion TFF, includes hadron cutoff form factor on rho
  - Terschlüsen/SL: omega to pion TFF, assigns different importance to various interaction terms (inspired by effective field theory (EFT))

VMD and extensions

- meson TFFs
  - dispersive treatment (DT)
    - get as much as possible phaseshift data in
    - looks sometimes like VMD, sometimes not
- baryon TFFs
  - future: extend DT and EFT inspired formalisms from mesons to baryons
- extended VMD
  - pin down couplings at photon point and at vector-meson point