On the axial-vector form factor of the nucleon and chiral symmetry

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- ✔ **Chiral symmetry for the πNΔ system**
- ✔ **Lattice results from two flavour ensembles**
- ✔ **Global fits and χPT convergence issues**
- ✔ **Summary and outlook**

Chiral extrapolation for QCD with up and down quarks

✔ consider $m_{u,d} \simeq 2 - 5$ MeV to be small in QCD

- approximate $\mathrm{SU}(2)_L \otimes \mathrm{SU}(2)_R$ chiral symmetry
- apply χPT in terms of the chiral Lagrangian

✔ how-to power count in the presence of heavy fields?

- controversial how to deal with the $\Delta(1232)$ baryon
- conventional expansion schemes appear very slow (if at all) convergent

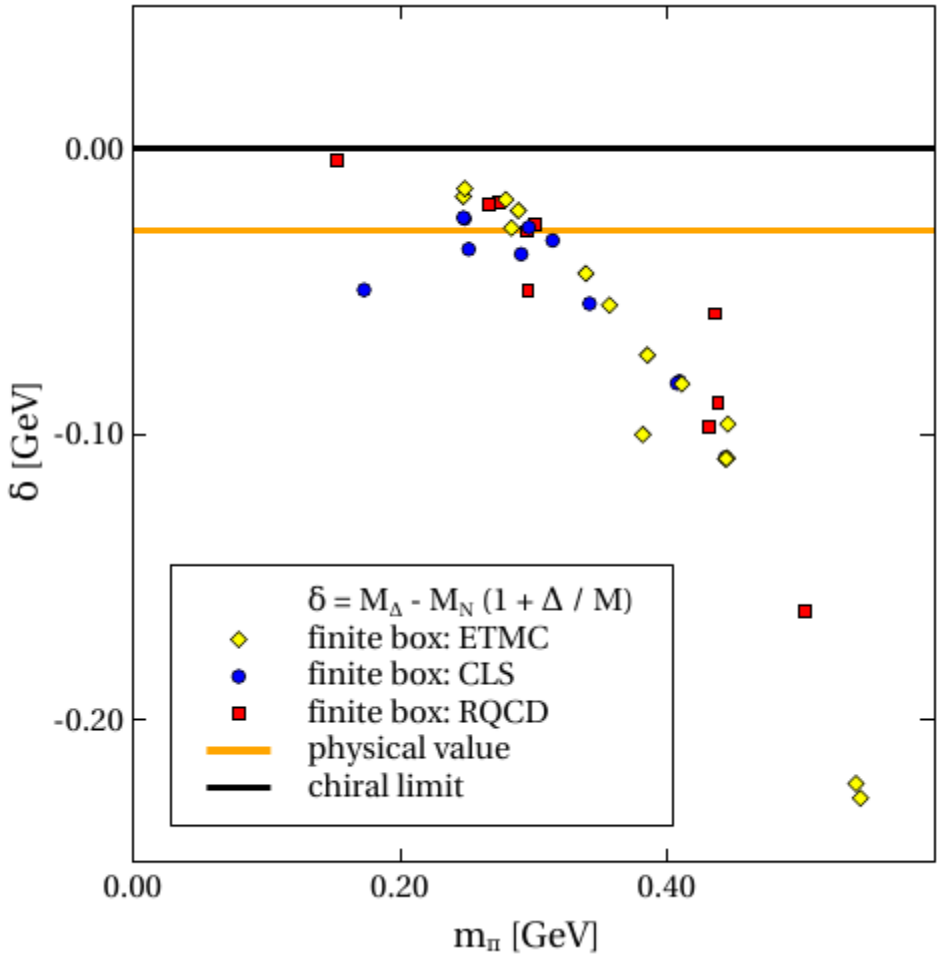
✔ novel expansion scheme in terms of on-shell masses

- pioneered for various hadrons on flavour SU(3) ensembles
- chiral expansion is not necessarily smooth - first order transitions are possible
- revisted for flavour SU(2) chiral expansions

U. Sauerwein, MFML, RGE Timmermans, arXiv:2105.06755
MFML, U. Sauerwein, RGE Timmermans, arXiv:2003.10158 main paper for this talk
X. Guo, Y. Heo, MFML, arXiv:1907.00714
MFML, Y. Heo, X. Guo, arXiv:1907.00237
MFML, Y. Heo, X. Guo, arXiv:1801.06417
A. Semke, MFML, arXiv:nucl-th/0606027

Expansion parameters

- $m_{u,d} \sim m_\pi^2 \sim Q^2$ $\qquad\qquad$ $M_N \sim Q^0$
- $\delta = M_\Delta - M_N\,(1 + \Delta/M) \sim Q^2$ $\qquad\qquad$ $\Delta/M \sim Q^0$
- with M and $M + \Delta$ from M_N and M_Δ in the chiral limit



Global fit to lattice data from ETMC, CLS and RQCD

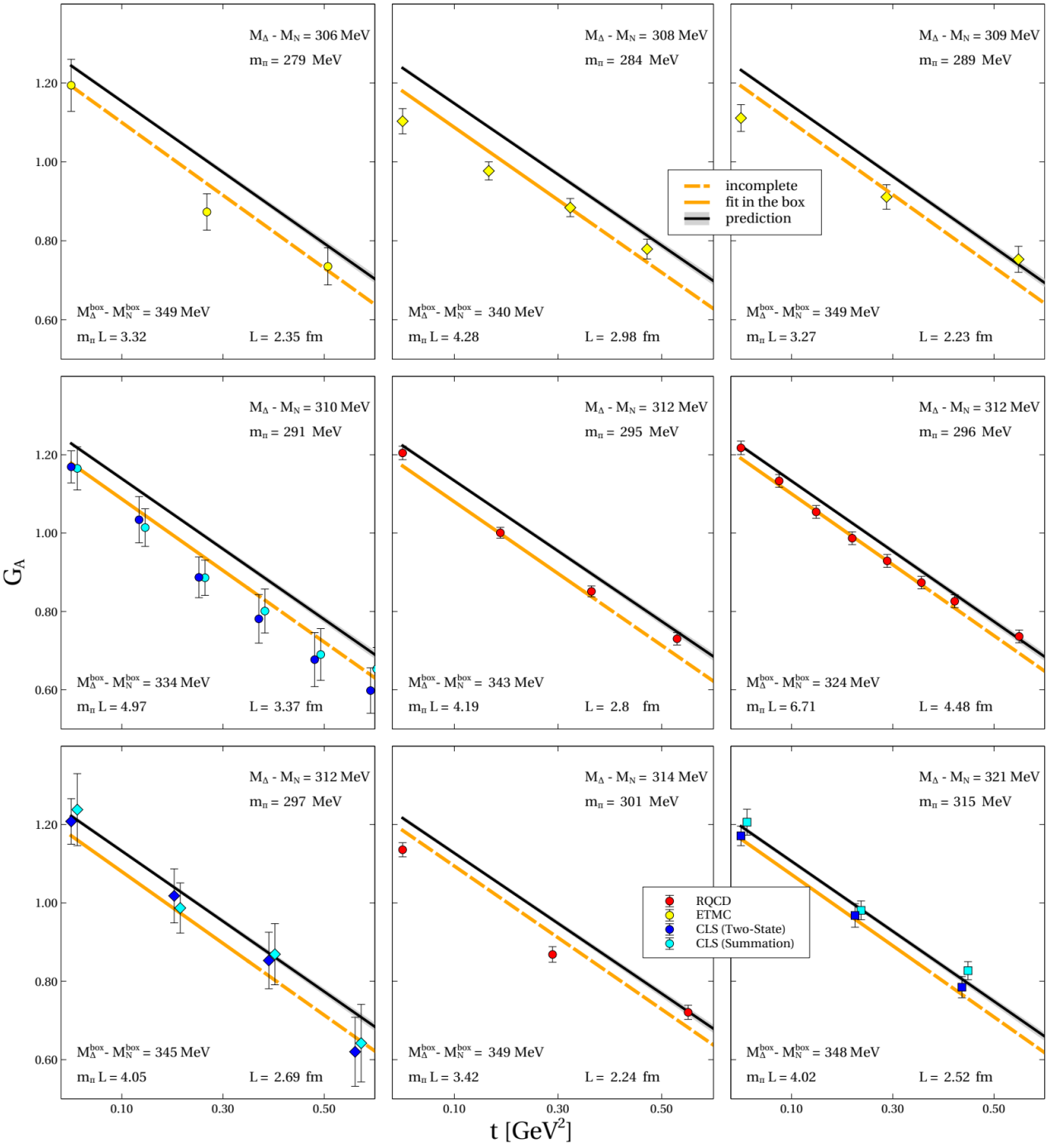
- consider masses (M_N, M_Δ)

  axial-vector form factor

- 99 data points

  $\chi^2/N_{df} \simeq 1.40$

- compare finite-box (orange) with infinite-box (black)
- the value of M_Δ matters!



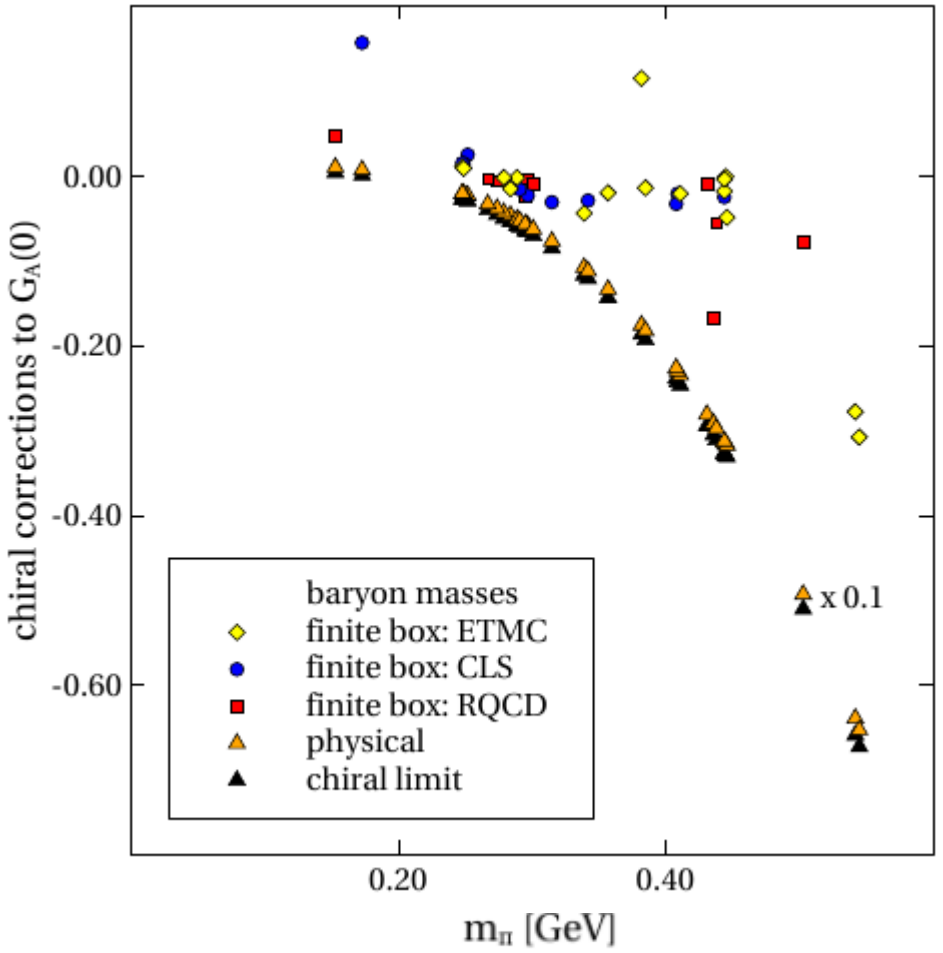
Chiral corrections for the axial form factor

- $\delta = M_\Delta - M_N\,(1 + \Delta/M) \sim Q^2$

  with M and $M + \Delta$ from M_N and M_Δ in the chiral limit

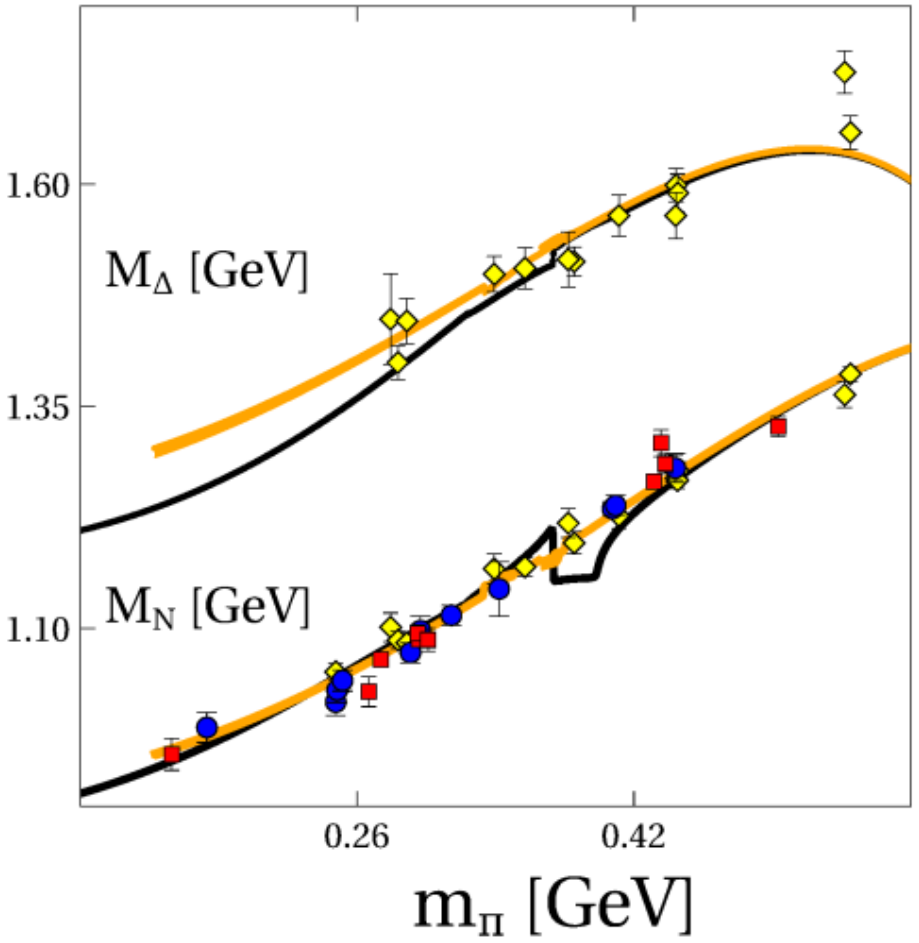
- consider different assumptions for M_N and M_Δ (one-loop level)

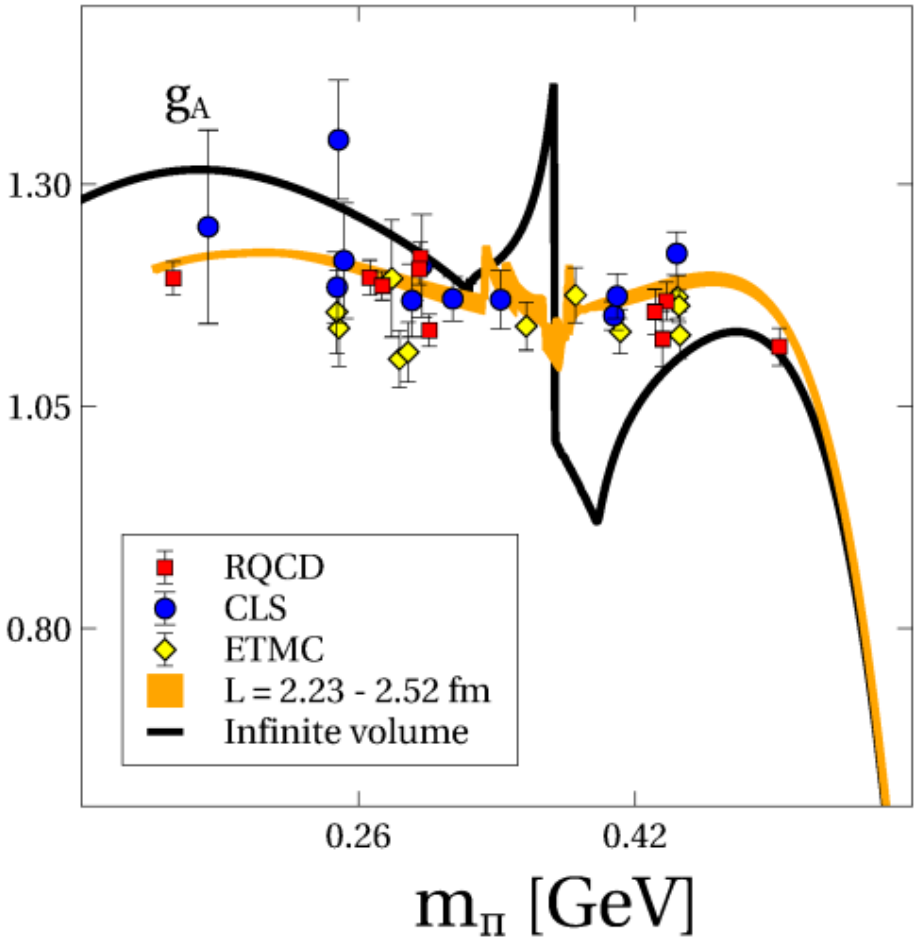
- convergence only with on-shell M_N and M_Δ



QCD lattice results on two flavour ensembles

- predict phase-transition at unphysical quark masses (infinite volume case)
- smooth behavior in finite box
- lattice results do not exclude such a behavior so far





Summary and Outlook

✔ Chiral extrapolation of hadron masses and form factors

- chiral expansion with up and down quarks is well convergent
  iff expansion parameters are used in terms of on-shell hadron massses
- quantitative reproduction of two-flavour lattice data sets (ETMC, RQCD, CLS)
- predict low-energy constants of the chiral Lagrangian

✔ Precision extrapolation results for baryons ?

- should use ensembles at physical strange quark mass
  we predicted the isobar strangeness sigma terms to be large
  form factor have a significant dependence on the isobar mass
- need more precision data on the isobar

✔ Parameteric phase transitions in QCD ?

- are not ruled out by current lattice data
- ensembles at large boxes and large pion masses would be needed
- in flavour SU(3) ensembles at smaller strange quark mass
- such a phase transition could be a candidate for strange dark matter