Disentangling Nuclear and Nucleon Contributions

Vadim Lensky
(JGU Mainz)

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Some Thoughts and Observations

- Why disentangle?
- Nuclear elastic terms: sensitivity to form factors
- Single-nucleon inelastic terms: how to account for them?
- Other possible contributions?
- Comments?

Why Disentangle Nuclear from Nucleons

- Nuclear elastic contributions:
  - elastic FF data (parametrisations) have nucleon FFs inside
  - EFT calculations usually also account for nucleon FFs
- Nuclear inelastic contributions:
  - inelastic data (inclusive breakup) taken up to pion threshold and above also have the nucleon inelastic contributions
  - availability of quality data?
  - EFT calculations usually [read: known to me] do not account for inelastic channels beyond breakup [pion production etc.]

  ➔ Possibly need to account for the nucleon part of the inelastic contribution separately
- Nucleon subtraction contributions
  - need to be taken from theory (maybe can be obtained from nucleon data)

  ➔ Also need to be treated separately

Elastic Nuclear/Nucleon

- Sensitive to details of FFs/parametrisations
- EFTs are likely to do a better job at low Q
  - not only R_E but also higher derivatives need to be correct!

$$R_F^3 = \frac{48}{\pi} \int_0^\infty \frac{dQ}{Q^4} \left[G_C^2(Q^2) - 1 - 2G_C'(0)\, Q^2 \right]$$

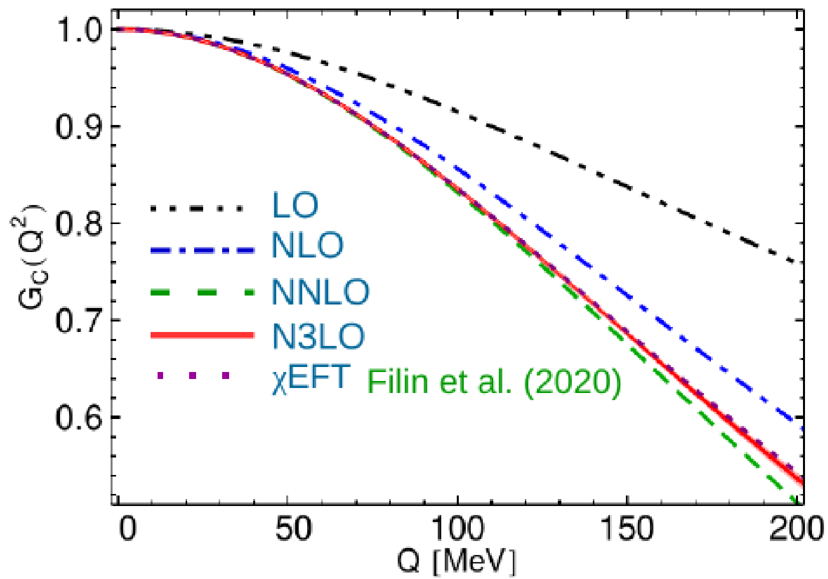
$$= \frac{3}{80\gamma^3} \{ Z\,[5 - 2Z(1 - 2\ln 2)] - 320/9\; r_0^2\gamma^2\,[Z(1 - 4\ln 2) - 2 + 2\ln 2] + 80(Z-1)^3\, l_1^{C0_S} \}$$

- Objects like R_F^3 and R_Z are not additive:

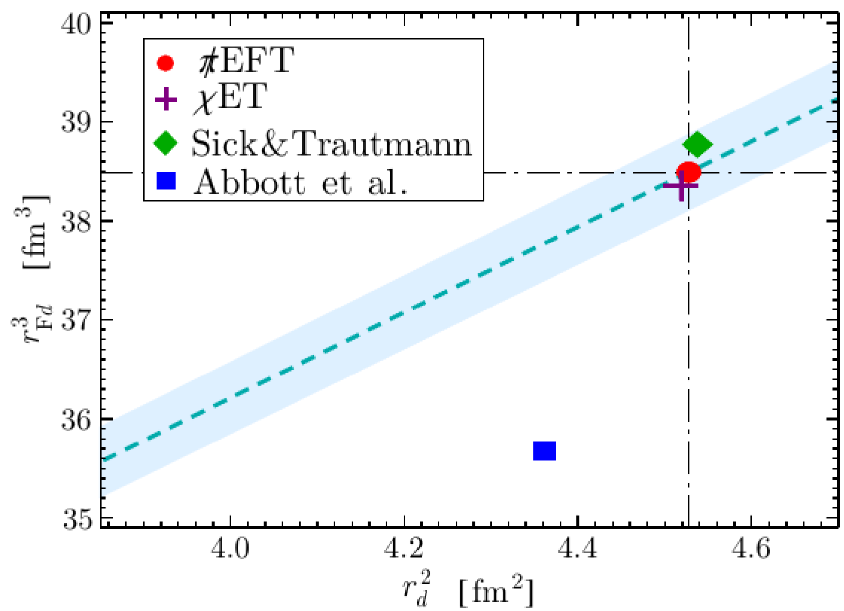
$$R_F^3 \neq R^3_{F,\,\text{pointlike}} + R^3_{F,\,\text{nucleons}}$$

- Recall that very [very!] roughly

$$G_C(Q^2) = G_{C,\,\text{pointlike}}(Q^2)\,\bar{G}_{C,\,\text{nucleon}}(Q^2)$$

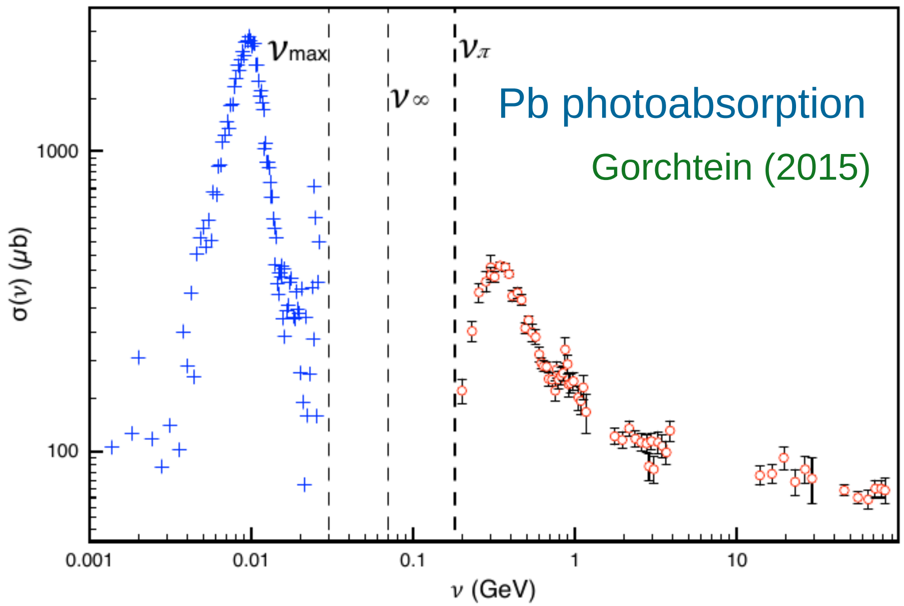


VL, Hiller Blin, Pascalutsa (2021)

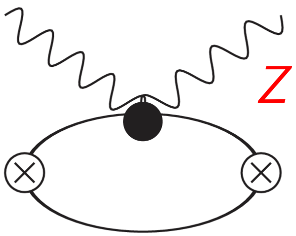


VL, Hagelstein, Pascalutsa (2022)

Inelastic Nuclear/Nucleon



- No subtraction needed for low ν part
- Nuclear theory will also produce well-behaving response functions
- Inelastic nucleon part from data:
  - just integrate over high ν
- Data not available:
  - use nucleon data/EFT and rescale by $|\phi_n(0)|^2$
  - „sticking in“ the nucleon amplitude
  - works well for d (and probably ^{4}He)
  - not so obviously for ^{3}He: $2\alpha_p + \alpha_n$, but $0\gamma_p + \gamma_n$

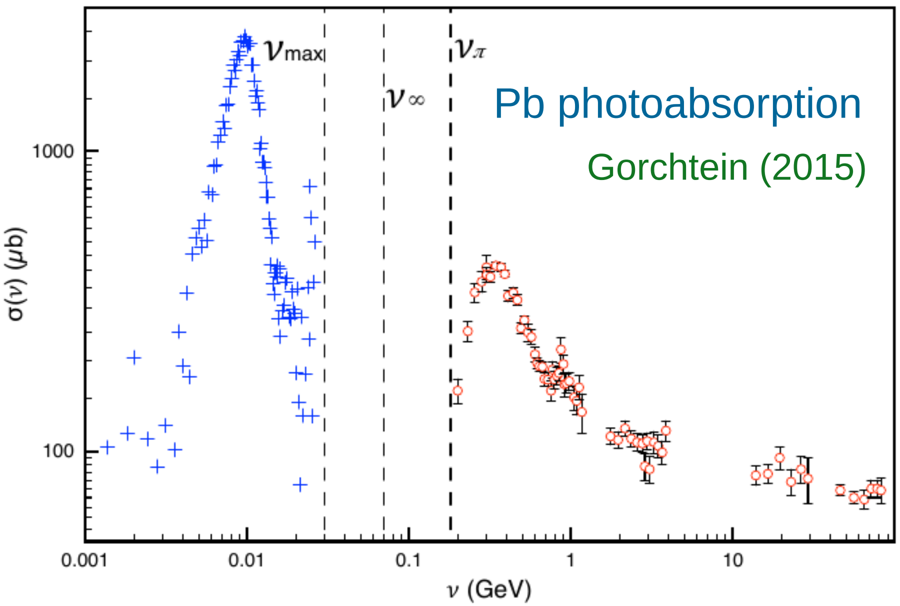


$Z\delta_p + N\delta_n$

RCS, Margaryan et al. (2018)

- Similarly take into account the nucleon subtraction function
- Is it always a good approximation (at least for light nuclei)?
- Can this treatment be improved? Should it be improved?

Inelastic Nuclear/Nucleon



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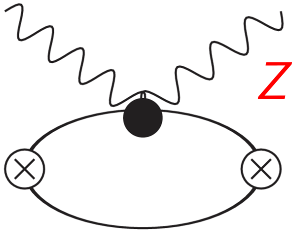


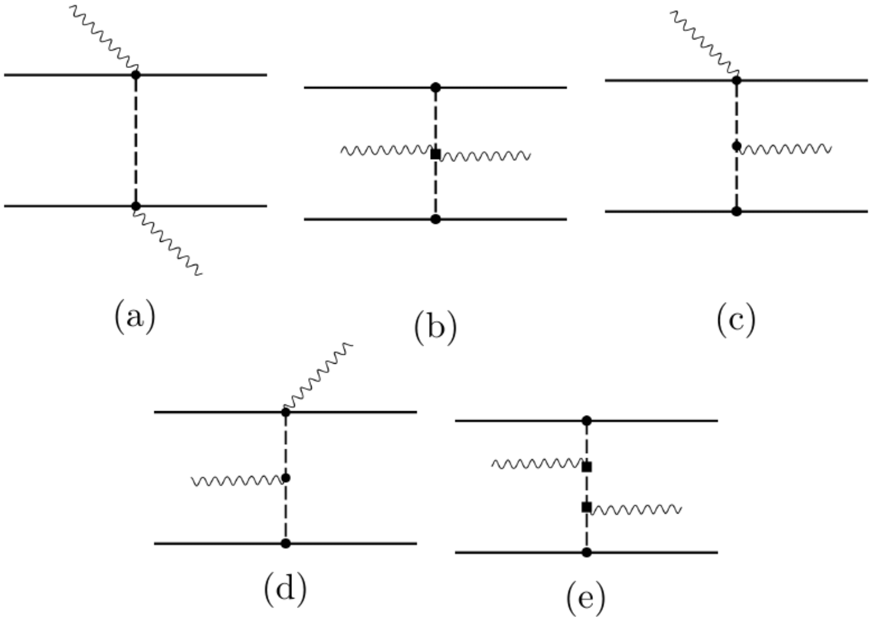
- Nucleon inelastic (as well as its uncertainty) is not so small:

Ji et al. (2018)

	δ^A_{Zem}	δ^A_{pol}	δ^N_{Zem}	δ^N_{pol}	δ_{TPE}
μ^2H	−0.423(04)	−1.245(13)	−0.030(02)	−0.020(10)	−1.718(17)
μ^3H	−0.227(06)	−0.480(11)	−0.033(02)	−0.031(17)	−0.771(22)
μ^3He$^+$	−10.49(23)	−4.23(18)	−0.52(03)	−0.25(13)	−15.49(33)
μ^4He$^+$	−6.14(31)	−2.35(13)	−0.54(03)	−0.34(20)	−9.37(44)

Other Possible (TPE) Contributions?

- Pion rescattering?
  - investigated in HBχEFT
  - found negligibly small at current level of precision



Moore, PhD Thesis (2020), McGovern, Moore (unpublished)

- What other contributions can potentially be missing?

Comments? Ideas? Critique?