Low-energy structure of the nucleon from chiral effective field theory

Jose Manuel Alarcón

Cluster Excellence PRISMA of Institut für Kernphysik
Johannes Gutenberg-Universität, Mainz

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Proton structure corrections have the potential to explain this discrepancy!

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  - Covariant formulation *[Fuchs et al., PRD 68 (2003)]*: Relativistic form keeping its analytical properties. solves the problem with the counting via renormalization.

Scalar structure of the nucleon
(Sigma terms)

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(Polarizabilities)

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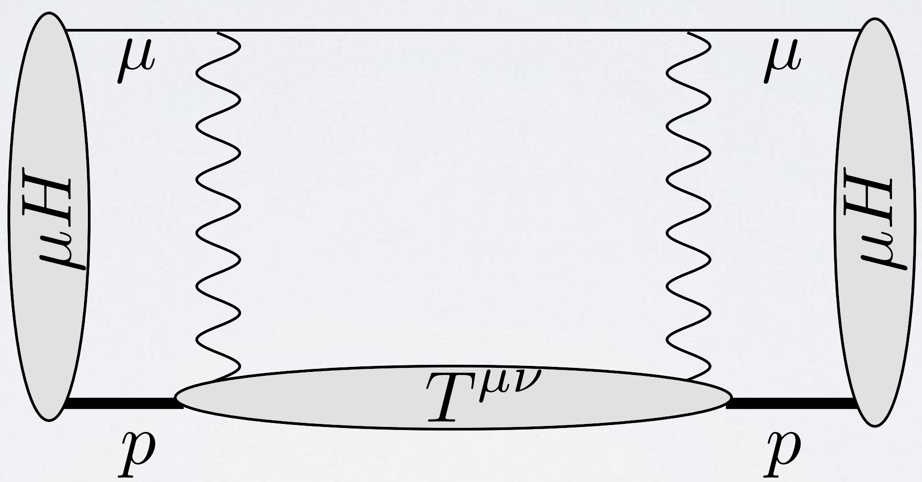

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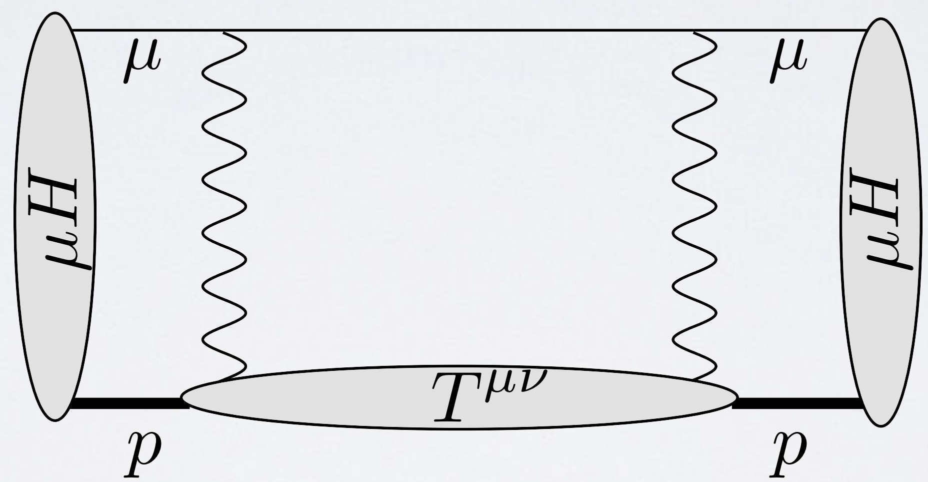

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$$\Delta E_{2S}^{(pol)} \approx \frac{\alpha_{em}}{\pi}\phi_{n=2}^2 \int_0^\infty \frac{dQ}{Q^2} w(\tau_\ell)\left[T_1^{(NB)}(0,Q^2) - T_2^{(NB)}(0,Q^2)\right]$$

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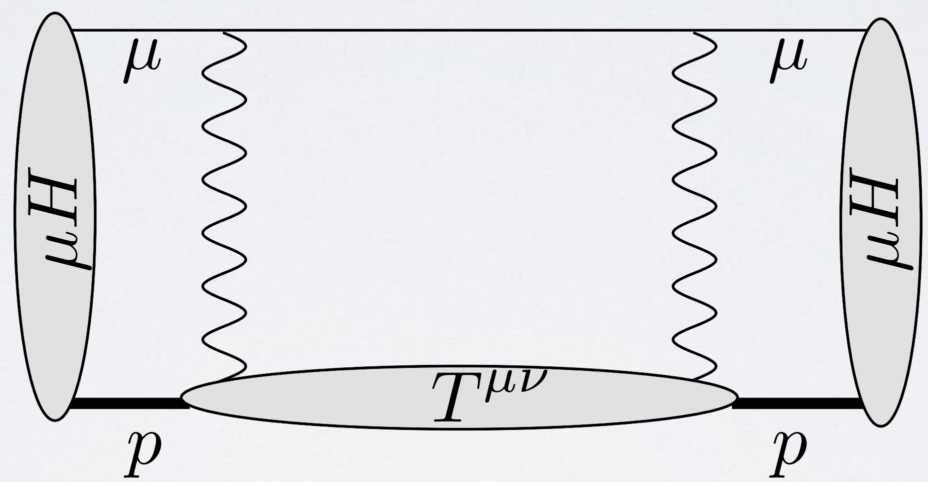

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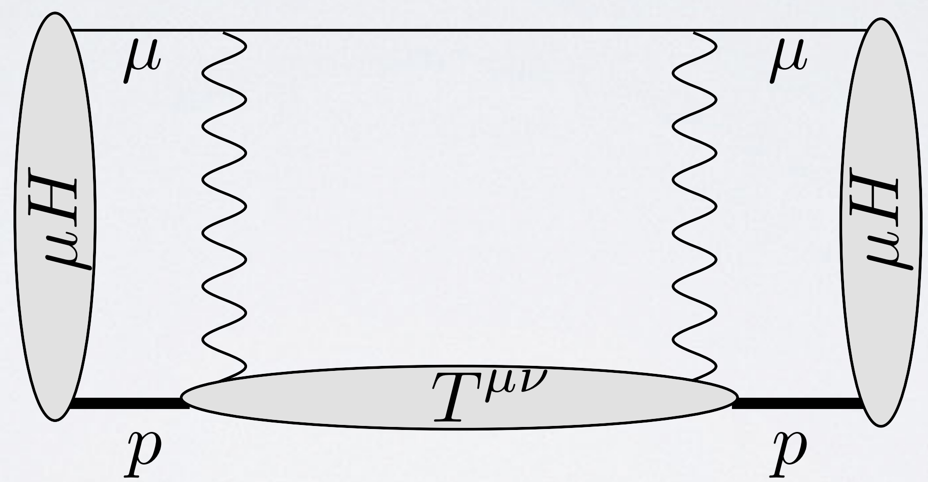

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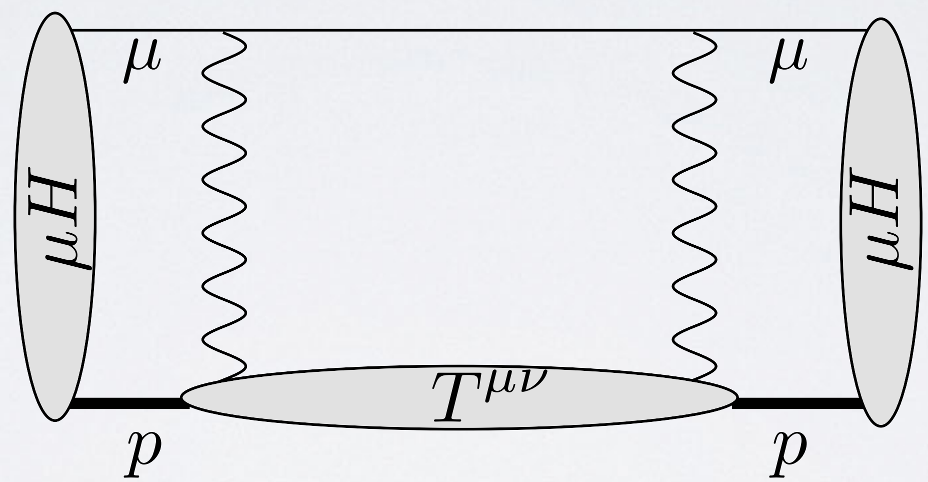

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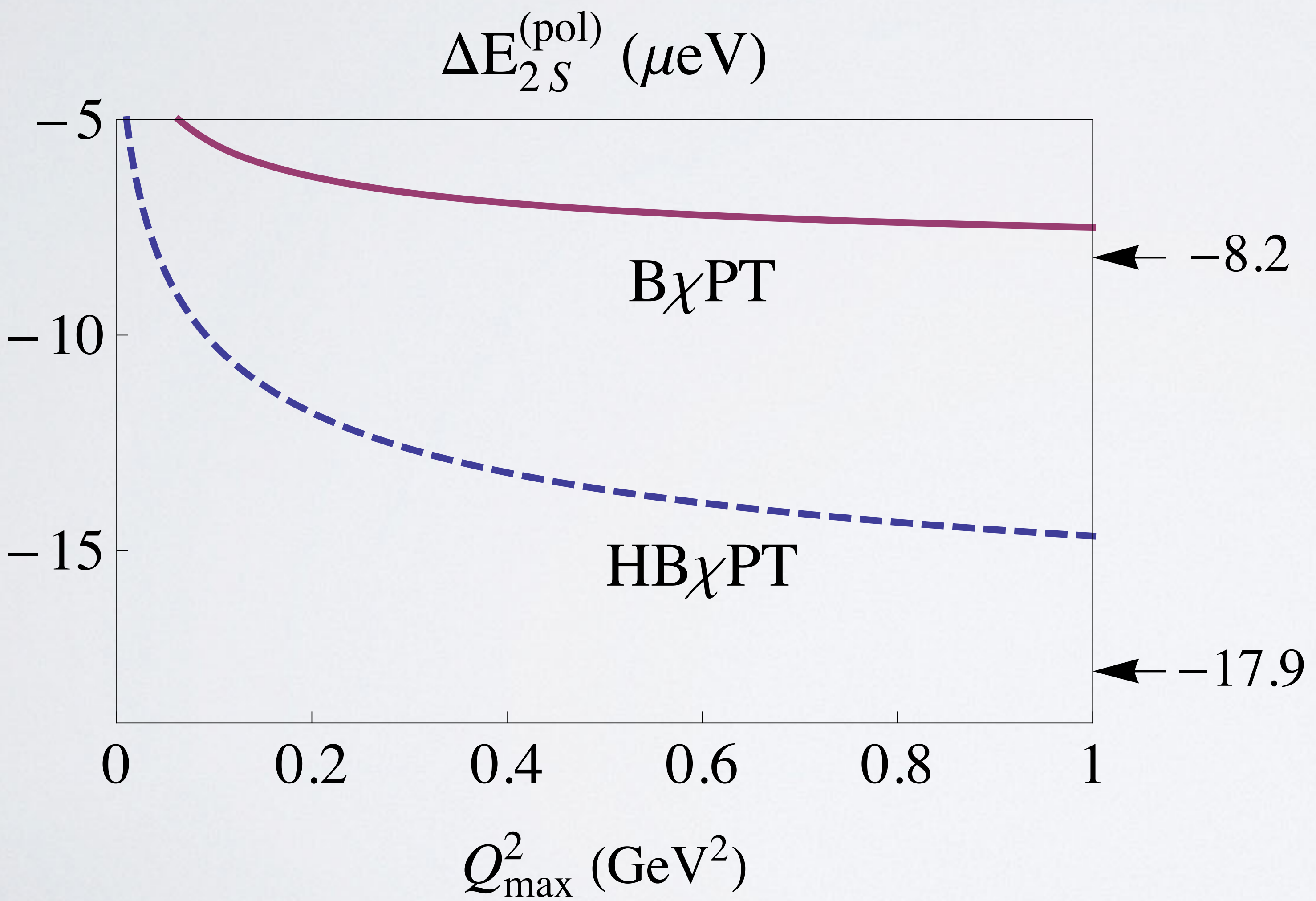

[Alarcón, Lensky, Pascalutsa, EPJ C 74 (2014).]

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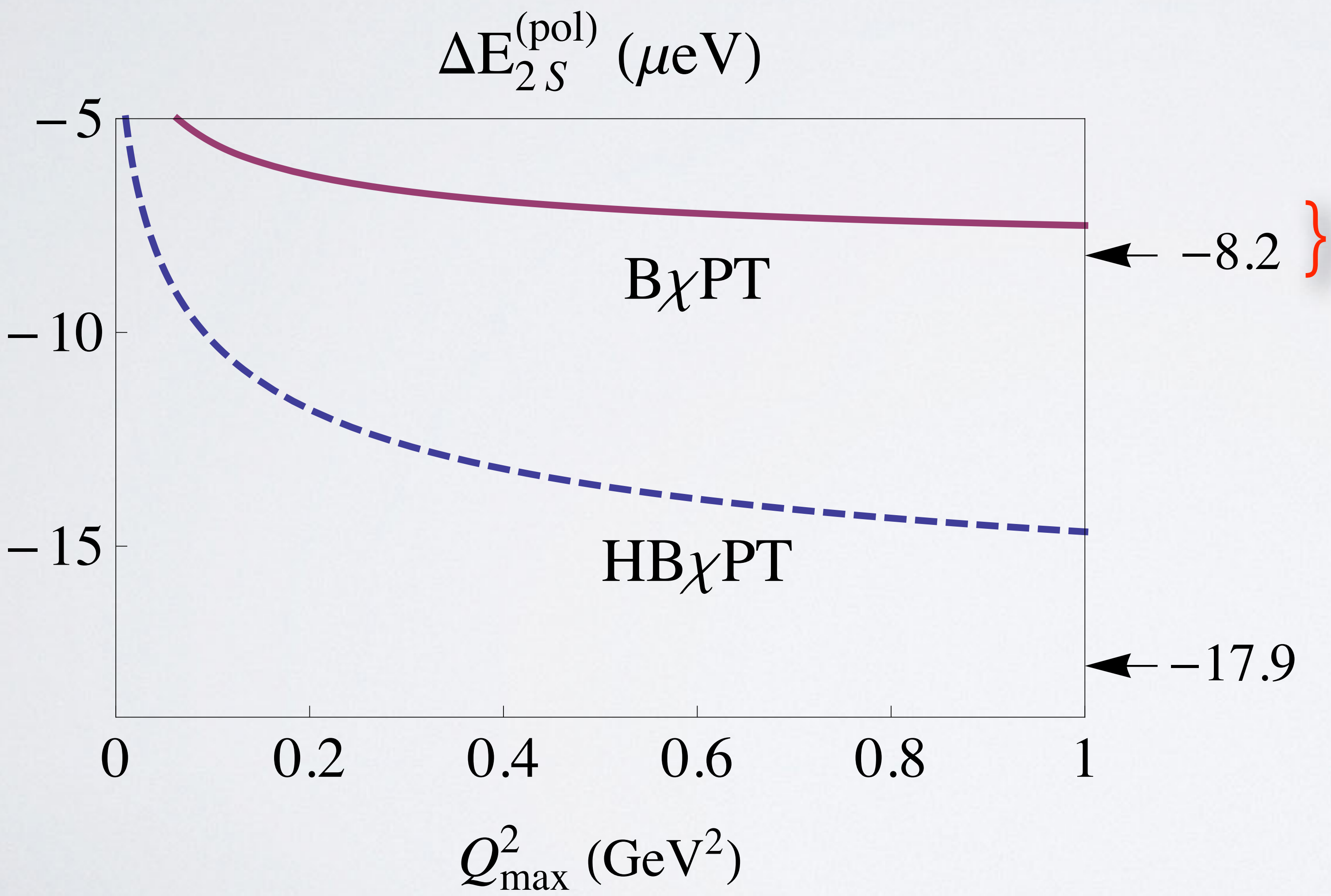

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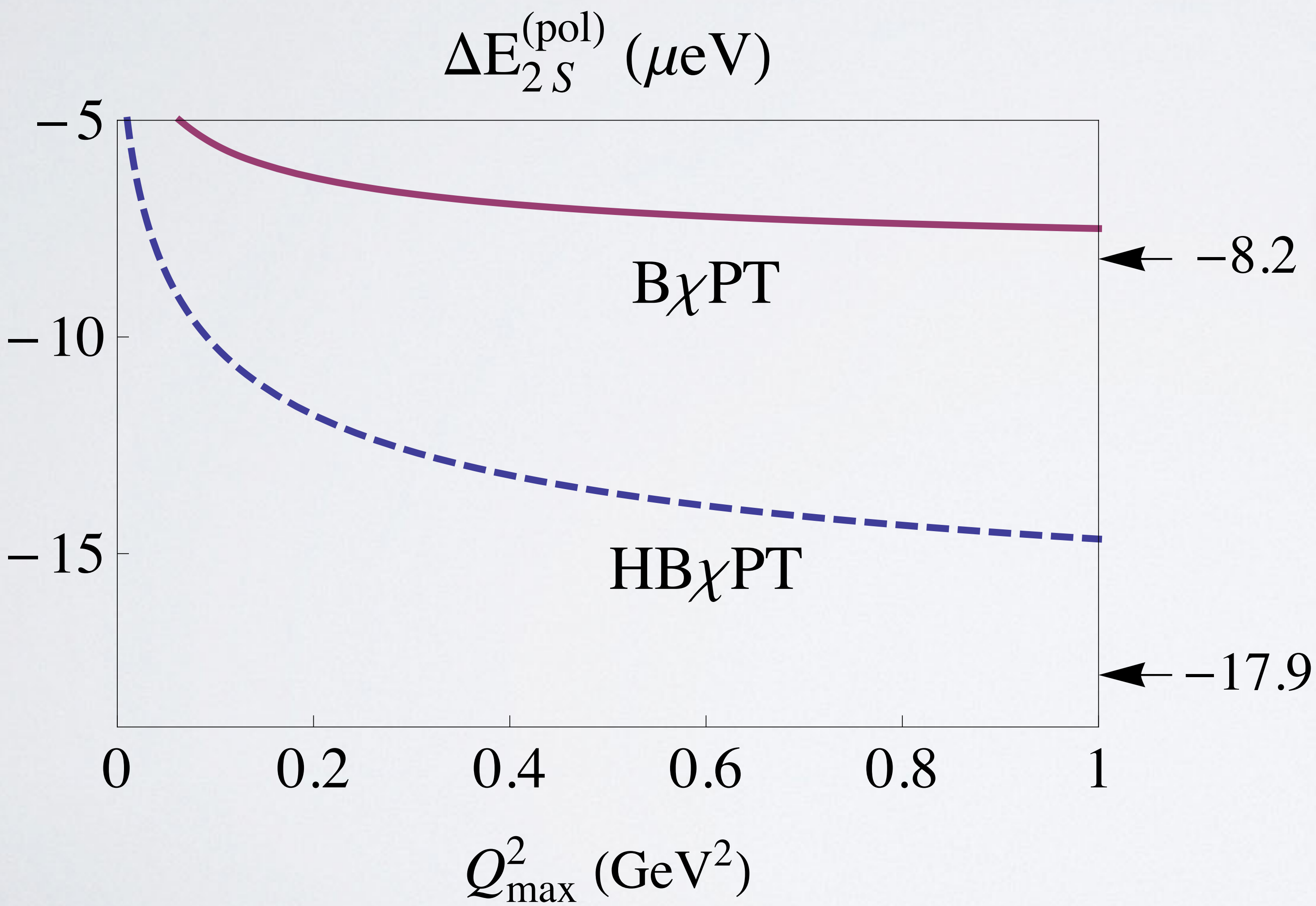

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- The relativistic structure is important to agree with phenomenological determinations of $\Delta E_{2S}^{(\mathrm{pol})}$.

(μeV)	Pachucki [1]	Martynenko [2]	Nevado & Pineda [3]	Carlson & Vanderhaeghen [4]	Birse & McGovern [5]	Gorchtein Llanes-Estrada & Szczepaniak [6]	Alarcón, Lensky & Pascalutsa [7]	Peset & Pineda [8]
$\Delta E_{2S}^{(\mathrm{pol})}$	-12(2)	-11.5	-18.5	-7.4(2.4)	-8.5(1.1)	-15.3(5.6)	$-8.2^{+1.2}_{-2.5}$	-26.5

Chiral EFT calculations (light blue: Nevado & Pineda, Alarcón, Lensky & Pascalutsa, Peset & Pineda)

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[1] K. Pachucki, Phys. Rev. A 60 (1999).
[2] A. P. Martynenko, Phys. Atom. Nucl. 69 (2006).
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(MeV)	Old value	Updated
$\sigma_{\pi N}$	45(8)	59(7)
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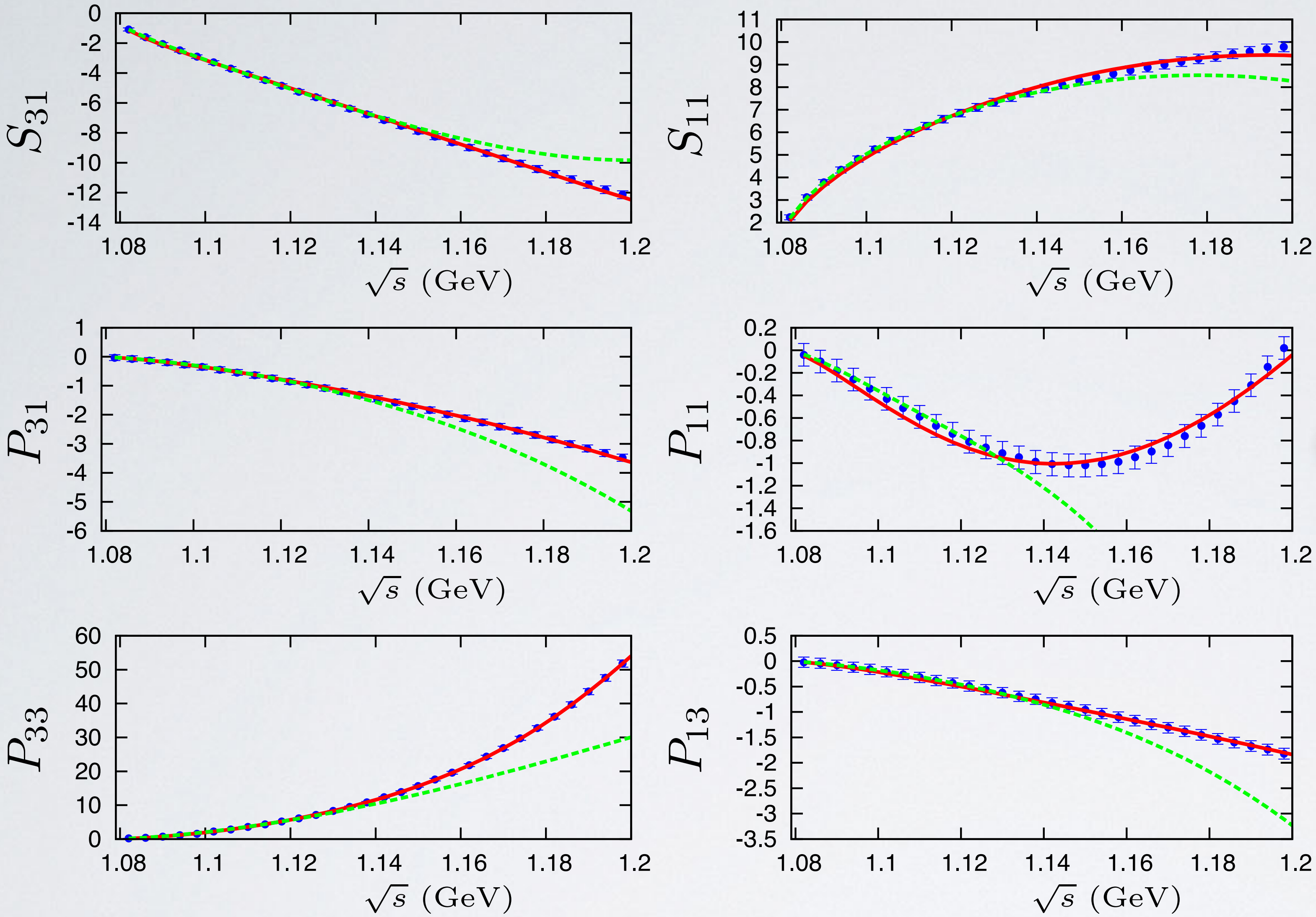
FIN

Spares

Scalar structure of the nucleon

[Alarcón, Martin Camalich and Oller, Ann. of Phys. 336 (2013)]



Δ-less ChPT

Δ-ChPT

Excellent description of the phase-shifts!

	KA85 Δ-ChPT	WI08 Δ-ChPT	EM06 Δ-ChPT	KA85	WI08
$\bar{d}^+_{00}(M_\pi^{-1})$	-1.48(15)	-1.20(13)	-0.97(2)	-1,46	-1,3
$\bar{d}^+_{01}(M_\pi^{-3})$	1.21(10)	1.20(9)	1.08(2)	1,14	1,19

Good convergence in the subthreshold region!

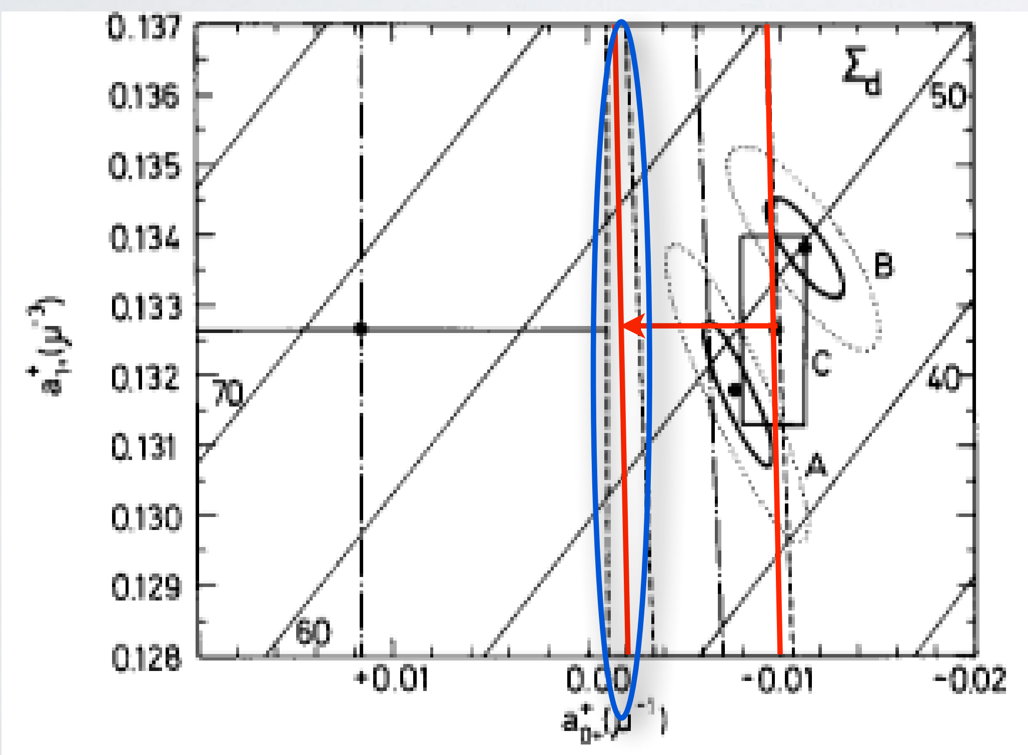
Scalar structure of the nucleon

- This result must be checked with independent extractions.
- a_{0+}^{+} is strongly correlated to the value of $\sigma_{\pi N}$

	KA85 Δ-ChPT	WI08 Δ-ChPT	EM06 Δ-ChPT	π-atoms *[1]* $(\pi^+ p, \pi^- p)$
a_{0+}^{+} $(10^{-3} M_\pi^{-1})$	-11(10)	-1.2(3.3)	2.3(2.0)	-1.0(9)

[1] Baru, Hanhart, Hoferichter, Kubis, Nogga & Phillips, NPA 872 (2011)

π-atoms agrees with large $\sigma_{\pi N}$!



[Gasser, Leutwyler & Sainio, PLB 253 (1991)]

Updating a_{0+}^{+}, the resulting $\sigma_{\pi N}$ is also larger!

Updated experimental information points to a large $\sigma_{\pi N}$!