Eur. Phys. J. A **31**, 415–416 (2007)
DOI 10.1140/epja/i2006-10293-3

THE EUROPEAN PHYSICAL JOURNAL A

Special Article – QNP 2006

Extraction of G_M^n from inclusive electron scattering on D, ^{4}He

A.S. Rinat[1], M.F. Taragin[1], and M. Viviani[2,a]

[1] Weizmann Institute of Science, Department of Particle Physics, Rehovot 76100, Israel
[2] INFN, Sezione di Pisa and Physics Department, University of Pisa, I-56100, Italy

Received: 22 December 2006
Published online: 22 March 2007 – © Società Italiana di Fisica / Springer-Verlag 2007

Abstract. We use the relation between Structure Functions (SFs) of nuclei A and nucleons N in order to fomulate a criterion which isolates the QE part out of the total inclusive cross-section. From data points around the QEP we extract the reduced neutron magnetic form factor $\langle\alpha_n = G_M^n/\mu_n G_d\rangle$. The latter shows an unexpected decrease up to $Q^2 = 10\,\mathrm{GeV}^2$, the largest measured.

PACS. 14.20.Dh Protons and neutrons – 13.60.Hb Total and inclusive cross-sections (including deep-inelastic processes) – 25.30.Fj Inelastic electron scattering to continuum

1 Extraction of G_M^n

We report on the extraction of the neutron form factor (FF) $G_M^n(Q^2) = \mu_n G_d(Q^2)\alpha_n(Q^2)$ from reduced total cross-sections $K^A(E,\theta,\nu)$ of unpolarized electrons from a target A, defined as

$$K^A(E,\theta,\nu) = \frac{\mathrm{d}^2\sigma^A(E;\theta,\nu)}{\mathrm{d}\Omega\,\mathrm{d}\nu}\bigg/\sigma_M(E;\theta,\nu)$$
$$= \left[\frac{2xM}{Q^2}F_2^A(x,Q^2) + \frac{2}{M}F_1^A(x,Q^2)\mathrm{tg}^2(\theta/2)\right], \qquad (1)$$

E,θ,ν are beam energy, scattering angle and energy loss; M, Q^2 and $x = Q^2/2M\nu$ are the nucleon mass, squared 4-momentum and the Bjorken variable; σ_M is the Mott cross-section.

Nuclear SFs in (1) are related to those for p,n by [1]

$$F_k^A(x,Q^2) = \int_x^A \frac{\mathrm{d}z}{z^{2-k}} f^{PN,A}(z,Q^2)\left[F_k^N\left(\frac{x}{z},Q^2\right)\right],$$
$$F_k^N = [F_k^p + F_k^n]/2, \qquad (2)$$

where $f^{PN,A}$ is a calulable SF for a fictituous nucleus, composed of point-nucleons.

SFs of nucleons N may be decomposed in elastic and inelastic parts and eq. (2) defines the same for composite nuclei. The elastic N parts $NE^N = \sigma^{N;NE}$ are proportional to $\delta(1-x)$ and contain combinations of 4 FFs. $NI^p = \sigma^{NI;p}$ for a p has been measured, but there is no direct parallel information on the n. Indirect methods for F^n have to be devised [2], yielding in the end NI^N.

Given the above information on the averaged N, the nuclear counterparts $K^{A;NE,NI}$ follow from eq. (2). In view of the x-dependence of NE^N, $K^{A;NE}(x,Q^2)$ contains in addition to the FFs in $K^{N;NE}$ a factor $f^{PN,A}(x,Q^2)$. NI^A has to be computed from (1), using NI^N and $f^{PN,A}$.

For nearly the entire x-range $NI^A \gg NE^A$, but in the QE region both parts compete. An extraction of FFs in general, and of α_n in particular, requires an accurate isolation of $K^{A,NI}$ from $K^{A,data}$, eq. (1). The criterion is the approximate x-independence of the following LHS:

$$[K^{A,data}(x,Q^2) - K^{A,NI}(x,Q^2)]/f^{PN,A}(x,Q^2)$$
$$\Longleftrightarrow K^{A;NE}(x,Q^2)/f^{PN,A}(x,Q^2). \qquad (3)$$

When fullfilled, one identifies the LHS of eq. (3) with $K^{A;NE}$. α_n can then be extracted provided the remaining 3 FFs are known. For G_E^p we choose the parametrizations in ref. [3] and for G_E^n the Galster one, as up-dated in ref. [4]. We tested two conflicting versions for the proton E/M ratio G_E^p/G_M^p: I) from a polarization transfer measurements [5], II) from a Rosenbluth separation.

The above identification leads to α_n, which from eq. (3) could be x- and A-dependent, but both dependences are very weak. One thus selects a continuous x-range around $x \approx 1$ (the QEP), the region which is maximally sensitive to changes in α_n. An average $\langle\alpha_n\rangle$ can then be determined over the selected range for each set. By construction, $NE^A(\langle\alpha_n\rangle) + NI(\mathrm{comp})$ fits the data in that region on the average.

2 Results and discussion

In figs. 1, 2 we display two out of the 30 analyzed data sets, namely for the D with $E = 4.045\,\mathrm{GeV}$, $\theta = 55°$ [6], respectively $E = 18.476\,\mathrm{GeV}$, $\theta = 10°$ [7]. For the former only the part up to $\nu \approx 2.75\,\mathrm{GeV}$ is shown. Filled circles

[a] e-mail: michele.viviani@pi.infn.it

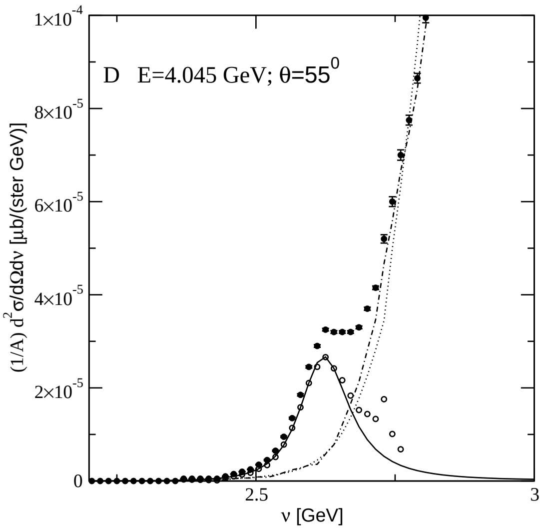

Fig. 1. For D: $E = 4.045\,\mathrm{GeV}$, $\theta = 55°$; $\bar{Q}^2 = 4.900\,\mathrm{GeV}^2$ [6]. NE curve for $\alpha_n = 0.958$.

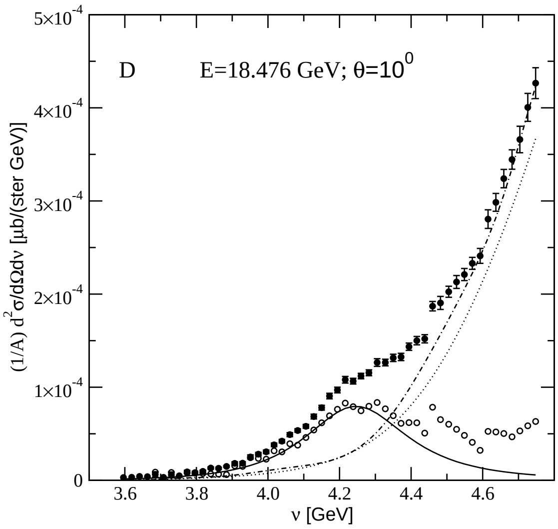

Fig. 2. For D: $E = 18.476\,\mathrm{GeV}$, $\theta = 10°$; $\bar{Q}^2 = 8.03\,\mathrm{GeV}^2$ [7]. NE curve for $\alpha_n = 0.879$.

are data with error bars, dotted lines represent NI^D(calc). Solid lines are $NE(\langle\alpha_n\rangle)$, while empty circles correspond to $NE^D(\mathrm{extr}) = \mathrm{data}^D - NI^D(\mathrm{calc})$.

For a perfect theory and data $NE^D(\langle\alpha_n\rangle) + NI(\mathrm{comp})$ should fit the data over the entire (x,ν)-range, but on the inelastic side of the QEP, about starting where $NI^D \approx NE^D$, the above-determined NE^D(extr) is not smooth and $< 15\%$ larger than $NE(\langle\alpha_n\rangle)$. It reaches a peak in cross-sections around the first maximum, which (if noticible) reflects inclusive N-Δ excitation on a bound nucleon, beyond which the discrepancy rapidly vanishes. Part of the observation may be due to noise in the data, but the near universality of the relative size and shape of the discrepancy makes one believe that the input F^p is at fault. That SF has been represented by the inclusive excitation of 5 resonances, and a slight increase of the N-Δ strength will only locally affect the small tail of F^p, and thus of

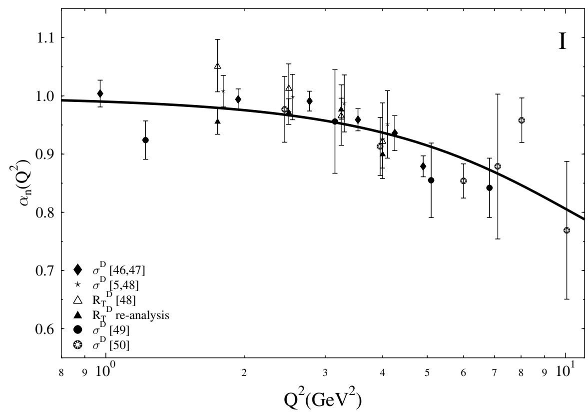

Fig. 3. $\alpha_n(\bar{Q}^2)$, extracted from D data.

F^A on the elastic tail side. It is not possible to change a single parameter out of the 20 odd parameters of the used representation without spoiling the fit [8]. In the figures we mark the local effect of an empirical, dot-dashed lines NI^D(emp), which causes NE^D(extr) and $NE^D(\langle\alpha_n\rangle)$ to coincide over the entire $x(\nu)$ interval of the data set. Incidentally, beyond the above-mentioned peak region, the unmodfified $F^{p,A}$ produce good, and frequently excellent agreement with the data.

Since different data sets occasionally overlap in Q^2, a consistency test requires the same $\alpha_n(Q^2)$ for those Q^2. That requirement appears well obeyed.

A mayor result of the analysis is the behavior of $\alpha_n(\bar{Q}^2)$, as a function of $\bar{Q}^2$, the representative value at the QEP. We display only the results for option I from D data (fig. 3), which show an unexpected, continuously decreasing α_n down to the largest measured $Q^2 \approx 10\,\mathrm{GeV}^2$. For option II the decrease is even steeper. Preliminary CLAS data appear to be flatter [9]. The only available scarce and older He data draw on low-Q^2 data. For those, the underlying theory is less reliable than for higher values. For overlapping Q^2 one finds approximately the same α.

A much more extended account can be found in refs. [10].

References

1. R.L. Jaffe, *Proceedings of Los Alamos Summer School (1983)* (Wiley, New York, 1984) p. 360; S.A. Gurvitz, A.S. Rinat, Phys. Rev. C **65**, 024310 (2002); A.S. Rinat, M.F. Taragin, Phys. Rev. C **73**, 045201 (2006).
2. A.S. Rinat, M.F. Taragin, Phys. Lett. B **551**, 284 (2003).
3. H. Budd, A. Bodek, J. Arrington, `arXiv:hep-ex/0308005`.
4. A.F. Krutov, V.E. Troitsky, Eur. Phys. J. A **16**, 285 (2003).
5. M. Jones *et al.*, Phys. Rev. Lett. **84**, 1398 (2000); O. Gayou *et al.*, Phys. Rev. Lett. **88**, 092301 (2002).
6. I. Niculescu *et al.*, Phys. Rev. Lett. **85**, 1182 (2000).
7. S. Rock, *et al.*, Phys. Rev. Lett. **49**, 1139 (1982); Phys. Rev. D **46**, 24 (1992).
8. Y. Liang *et al.*, `arXiv:hep-ph/0403058`.
9. W. Brooks, private communication; Nucl. Phys. A **750**, 261 (2005).
10. A.S. Rinat, M.F. Taragin, M. Viviani, Phys. Rev. C **70**, 014003 (2004); Nucl. Phys. A **784**, 25 (2007) .