Applying Coulomb distortion correction on EMC world data

Patricia Solvignon

February 28, 2007

DRAFT

1 Introduction

In medium to heavy nuclei, the incident electron beam is subject to effects from the nucleus charge. Therefore the plane-wave approximation is not satisfying as distortions appear due to:

- the attractive electrostatic potential inducing an increase of the incident and scattered electron energies;
- the nucleus attractive potential focusing of the electron wave function in the nucleus vicinity.

In the case of highly relativistic electron propagating along the z-axis, the momentum inside the spherical charge distribution is:

$$\tilde{k} = k - V(z) \tag{1}$$

with the $V(r)$ being the electrostatic potential inside the charged sphere defined as followed:

$$V(r) = -\frac{3\alpha(Z-1)}{2R} + \frac{\alpha(Z-1)}{2R}\left(\frac{r}{R}\right) \tag{2}$$

and

$$R = 1.1A^{1/3} + 0.86A^{-1/3} \tag{3}$$

Because most the nucleons of heavy nuclei are located in the nucleus peripherical region, taking the electrostatic potential at the center of the nucleus will be an overestimate of the Coulomb effect. In the effective momentum approximation (EMA) [1], the effective potential used is $\bar{V} \approx (0.75...0.80)V(0)$. Fig. 1 shows the good agreement of the effective potential $\bar{V} = 0.75V(0)$ with the extracted effective potentials from positron and electron inclusive scattering experiments [2].

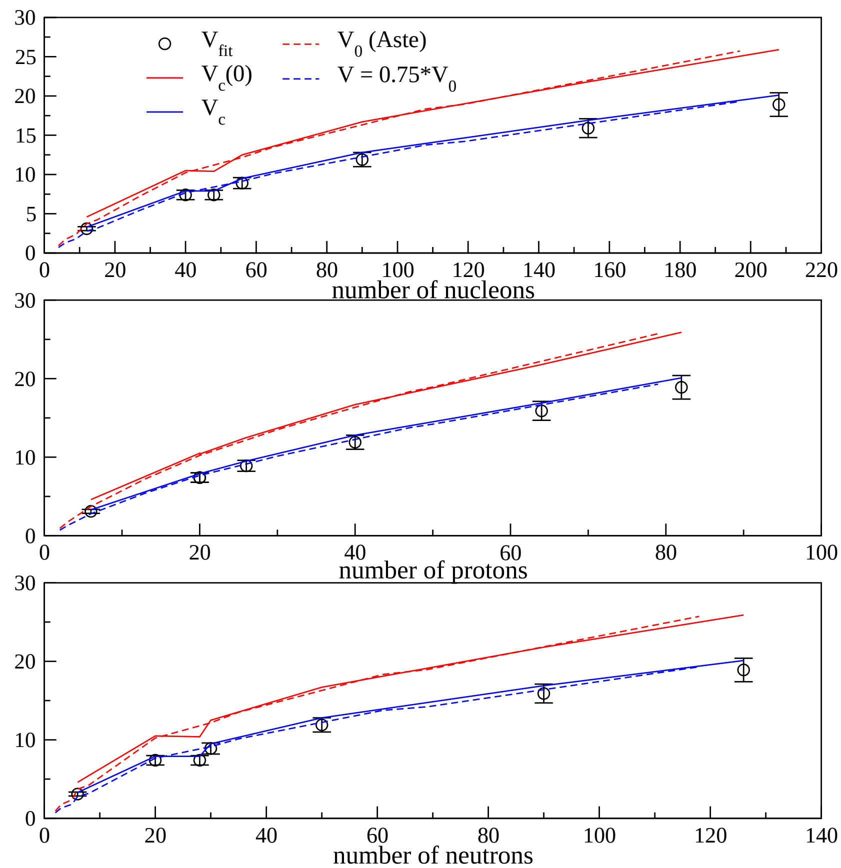

Figure 1: Determination of the effective potential factor. The data point are from [2].

1.1 Formalism of Coulomb corrections

In the plane-wave Born approximation, the total cross section σ_{tot} is the product of the Mott cross section σ_{Mott} and the nuclei spectral function S_{tot} written as follows:

$$\sigma_{tot}^{PWBA} = \sigma_{Mott}\ S_{tot}^{PWBA}(|\vec{q}|, \omega, \theta) \tag{4}$$

with $\sigma_{Mott} = 4\alpha^2 \cos^2(\theta/2) E_p^2/Q^4$

The nucleus charge induces the transformation $Q^2 \longrightarrow Q^2_{eff}$ where E becomes $E + \bar{V}$ and E_p becomes $E_p + \bar{V}$:

$$Q^2_{eff} = 4(E + \bar{V})(E_p + \bar{V}) \sin^2(\frac{\theta}{2}) \tag{5}$$

There are two equivalent methods to perform the Coulomb corrections (which is true for EMA and DWBA exact calculation):

1. The Mott cross section stays unchanged. Only the spectral function is subjected to the transformation:

$$S_{tot}^{PWBA}(|\vec{q}|, \omega, \theta) \longrightarrow S_{tot}^{PWBA}(|\vec{q}_{eff}|, \omega, \theta) \tag{6}$$

   No additional focusing factor are needed. Therefore the total cross section corrected for Coulomb distortion can be written as:

$$\sigma_{tot}^{CC} = \sigma_{Mott} \cdot S_{tot}^{PWBA}(|\vec{q}_{eff}|, \omega, \theta) \tag{7}$$

2. The Mott cross section undergoes the transformation $\sigma_{Mott} \longrightarrow \sigma_{Mott}^{eff}$ with reppla:

$$\sigma_{Mott}^{eff} = 4\alpha^2 \cos^2(\theta/2)(E_p + \bar{V})^2/Q^4_{eff} \tag{8}$$

   with Q^2_{eff} already defined in Eq. 5. The spectral function is subjected to the same transformation as defined in Eq. 6. However, the incoming focusing factor F^i_{foc} needs to be applied too:

$$F^i_{foc} = \frac{E + \bar{V}}{E} \tag{9}$$

   Now the expression of the corrected total cross section becomes:

$$\sigma_{tot}^{CC} = (F^i_{foc})^2 \cdot \sigma_{Mott}^{eff} \cdot S_{tot}^{PWBA}(|\vec{q}_{eff}|, \omega, \theta) \tag{10}$$

   which is equivalent to Eq. 7

1.2 EMC world data

In the deep inelastic scattering region, the total cross section can be expressed as a function of the two unpolarized structure function F_1 and F_2:

$$\sigma_{tot} = \sigma_{Mott}[\frac{2}{M}\tan^2\frac{\theta}{2}F_1(x,Q^2)] + \frac{1}{\nu}F_2(x,Q^2) \tag{11}$$

Using method#1 of the previous section, the Coulomb correction will affect the total cross section as follows:

$$\sigma_{tot}^{cc} = \sigma_{Mott}[\frac{2}{M}\tan^2\frac{\theta}{2}F_1(x_{eff},Q^2_{eff}) + \frac{1}{\nu}F_2(x_{eff},Q^2_{eff})] \tag{12}$$

with Q^2_{eff} defined as in Eq. 5 and the Bjorken variable being now $x_{eff} = Q^2_{eff}/2M\nu$.

1.2.1 Q^2-dependence at fixed x

Following the analysis steps of [3]:

1.2.2 A and ρ-dependence at fixed x

References

[1] A. Aste *et al.*, Eur. Phys. J. A **26**, 167 (2005)

[2] P. Guèye *et al.*, Phys. Rev. C **60**, 04308 (1999)

[3] J. Gomez *et al.*, Phys. Rev. D **49**, 4348 (1994)

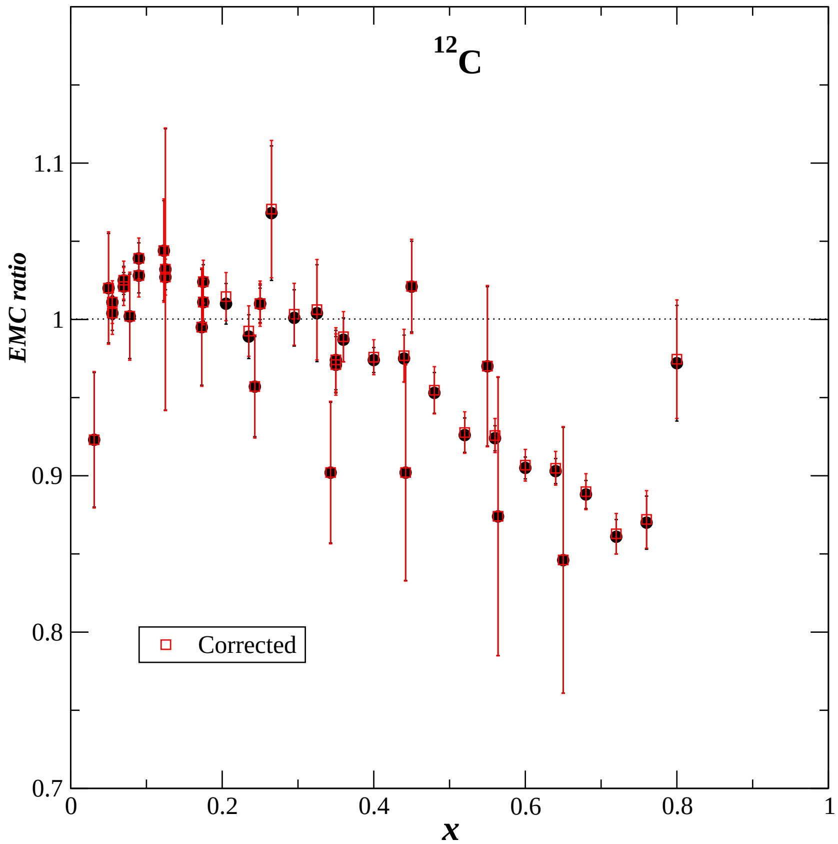

Figure 2: Coulomb effects on ^{12}C EMC data

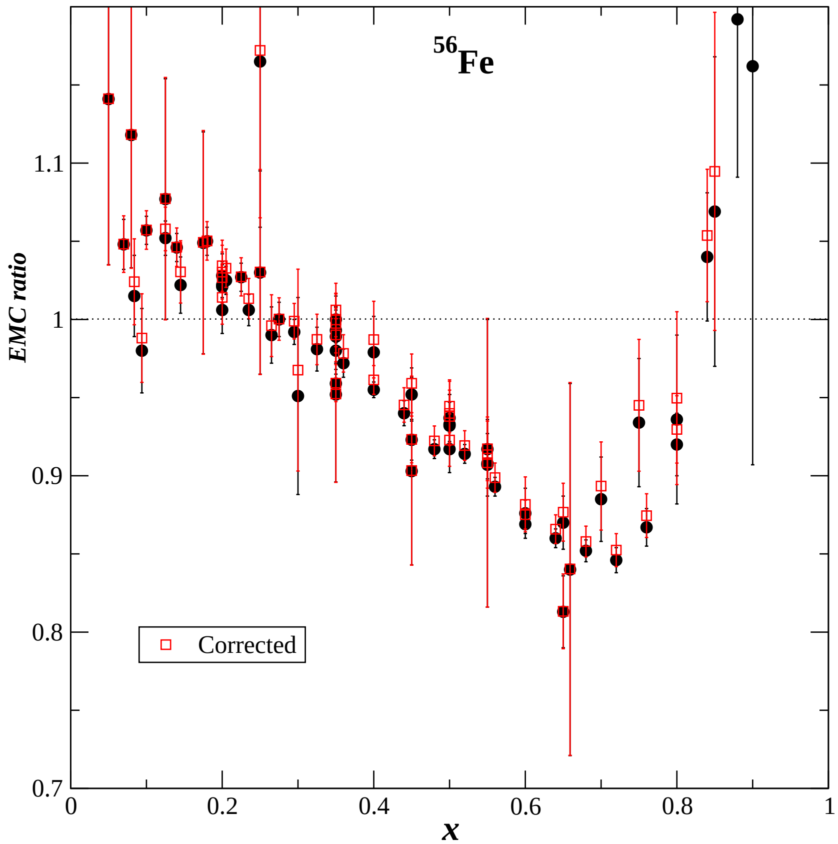

Figure 3: Coulomb effects on ^{56}Fe EMC data

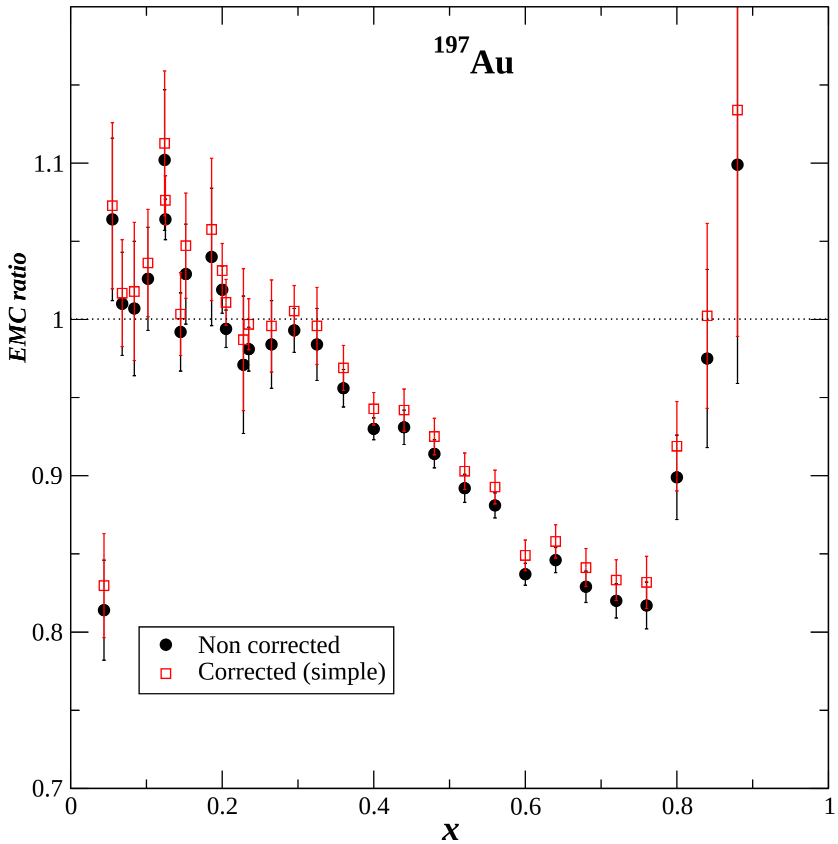

Figure 4: Coulomb effects on ^{197}Au EMC data

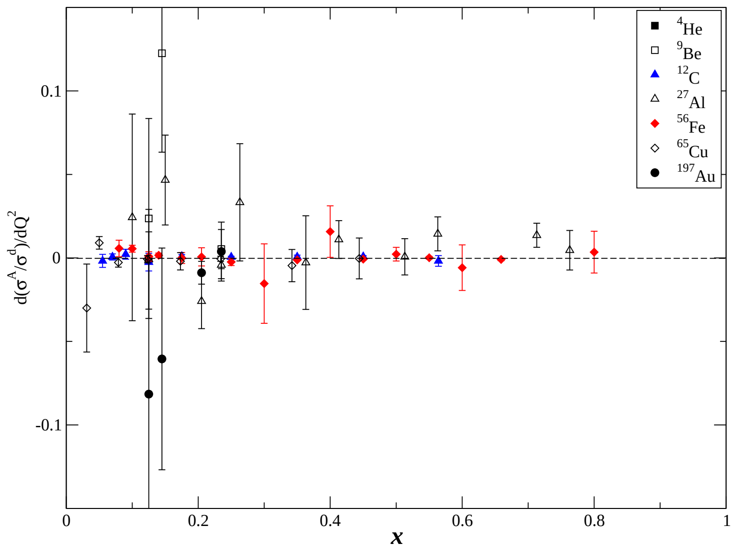

Figure 5: Q^2-dependence study on world data before applying Coulomb correction.

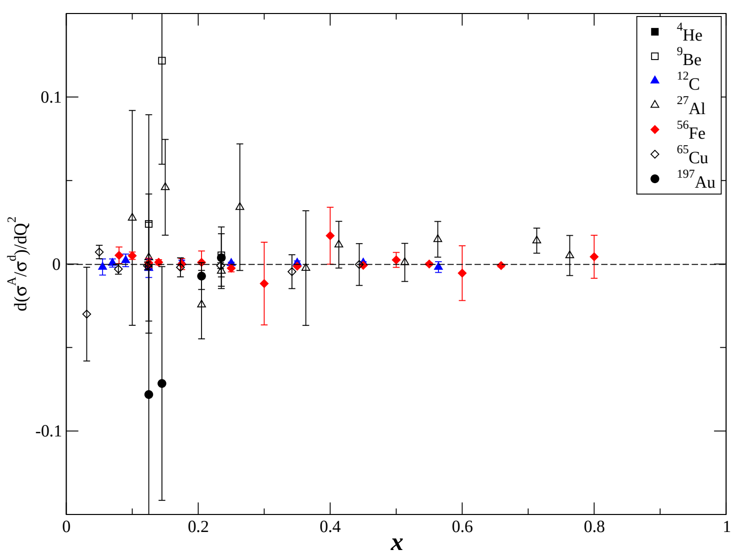

Figure 6: Q^2-dependence study on world data after applying Coulomb correction.

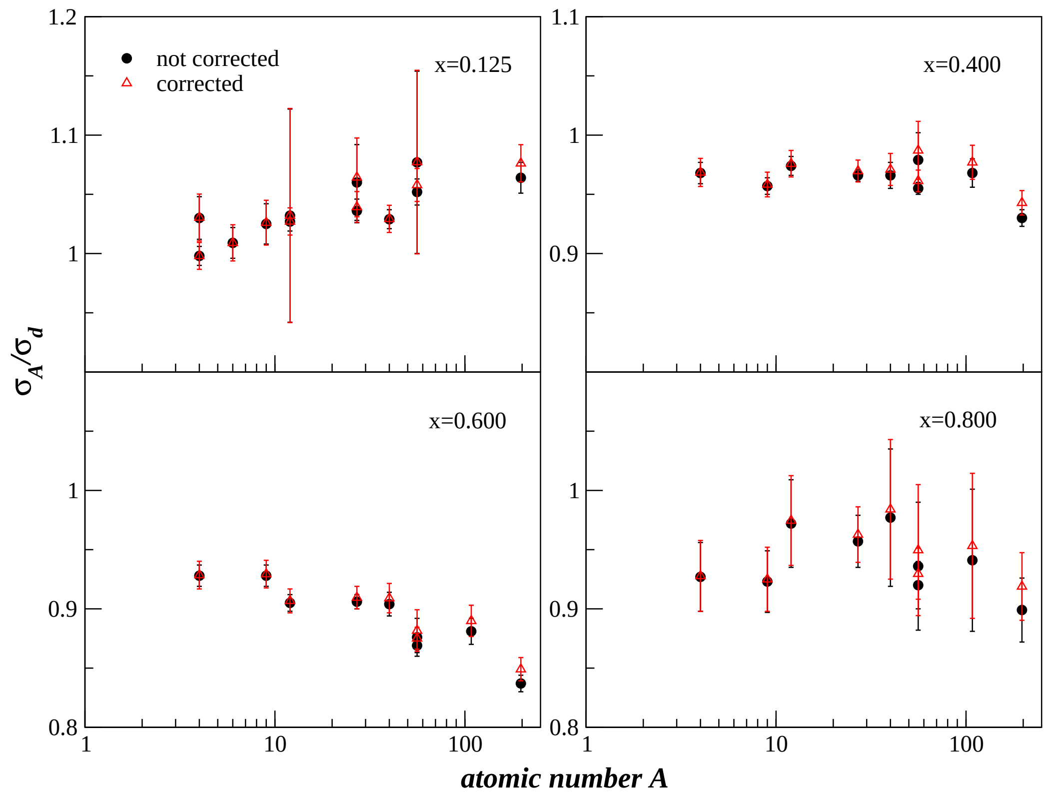

Figure 7: A-dependence study on world data before and after applying Coulomb correction.

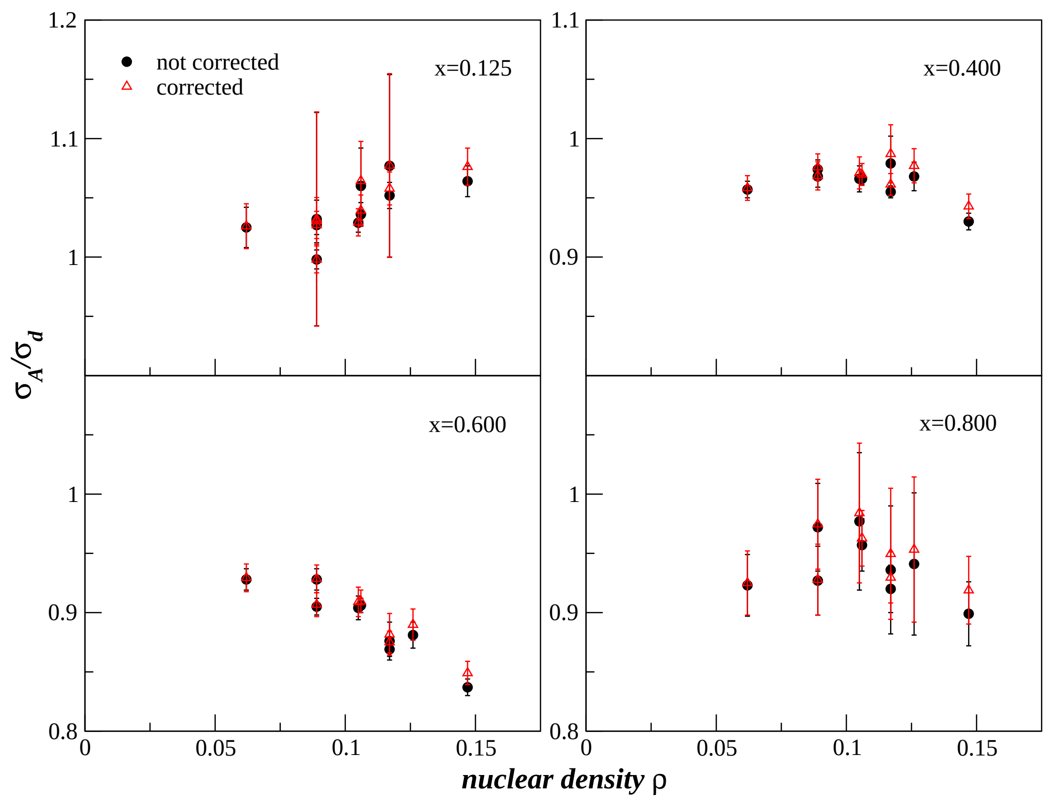

Figure 8: ρ-dependence study on world data before and after applying Coulomb correction.