

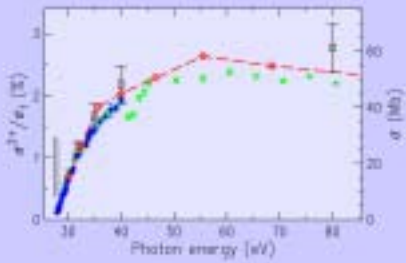


Single and Double Photoionization of Beryllium below 40 eV

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Double-to-total photoionization ratio

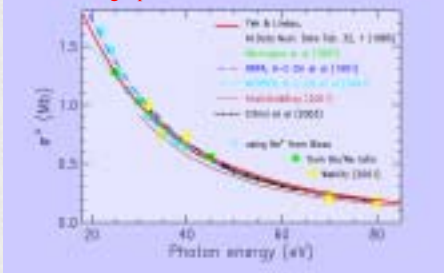


Double-to-total photoionization ratio (left scale) (blue circles) and previous measurements [1] (open squares) compared to the total cross section (right scale) of electron impact ionization of Be⁺ [2] (green triangles). The red diamonds connected by a dashed line are the calculated double-to-total photoionization ratios of Kheifets and Bray [3].

In a nutshell:

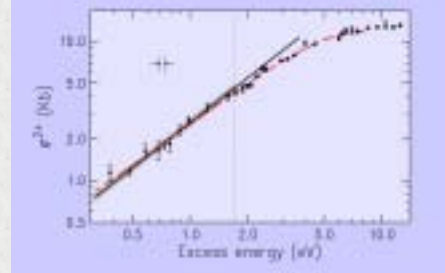
At the Synchrotron Radiation Center (SRC) we have measured the double-to-single photoionization ratio of beryllium (1s² 2s²) between 28 and 40eV and determined the relative single and double photoionization cross sections. In this energy region only *simultaneous* but not sequential emission of both 2s electrons can take place. We also compare our data with recent theoretical calculations and find good agreement with our data. The previously found scaling law for the double-to-single photoionization ratio is confirmed with high accuracy. Close to threshold the photon-energy dependence of the double-photoionization cross section can be described by the Wannier power law [12] up to 1.7 eV. However, we unexpectedly find oscillations in the cross section, which are in excellent agreement with a modulated threshold law based on the Coulomb-dipole theory [14,15].

Single photoionization cross section



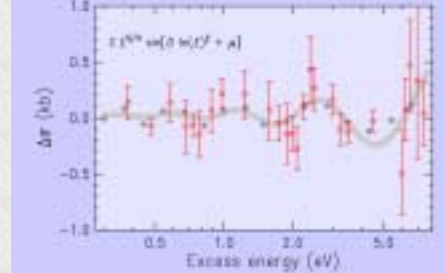
Relative single-photoionization cross section compared to theoretical calculations; green dotted line: R-matrix calculation [7]; blue dotted-dashed line: RRPA [8]; light-blue dashed line: MCRPRA [8]; black curve with dots: HRM-SOW [9]; thick solid line: Hartree-Fock-Slater calculation [10]; thin solid line: CCC calculation [3]; yellow diamonds: previous measurement [1]. Our data points (open and filled circles) were derived by different methods and scaled to the curve of Yeh&Lindau [10].

The Wannier law



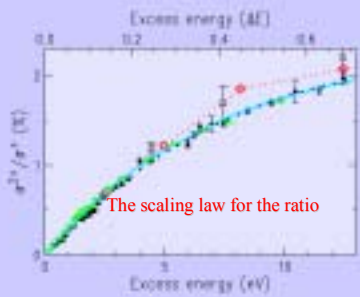
Double-photoionization cross section near threshold. The black solid line is a fit according to Wannier's power law [12] $\sigma = \sigma_0 (h\nu - E_0)^{\alpha}$; $\alpha=1.056$ fixed; gray line. The red dashed line is a fit curve according to the fourth-order Wannier theory [13]. The vertical dotted line indicates the approximate range of validity of the Wannier power law.

Oscillations in the double-ionization cross section



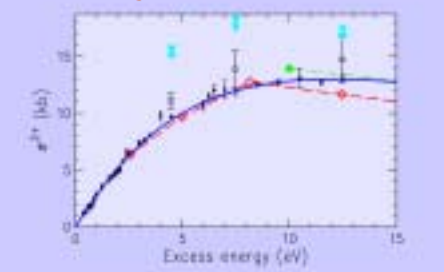
Cross section difference between our data and the fourth-order Wannier curve (points with error bars). The gray fit curve corresponds to the modulation term of the Coulomb-Dipole theory [14]: $\Delta\sigma = C E_{exc}^{5/4} \sin[D \ln(E_{exc}^2 + \mu)] + \sigma_0$. The dotted line is a similar fit but using an exponent of 1/4 instead of 5/4.

The scaling law for the ratio



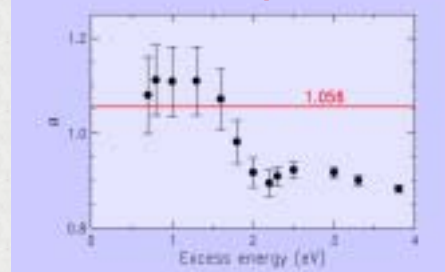
Double-to-single photoionization ratio as a function of excess energy (black circles: this work, open squares: [1]). The red diamonds (connected by a dotted line) are calculated values from Kheifets and Bray [3]. The solid line is the scaled ratio of He [4] in excess-energy units ΔE , with ΔE being the energy difference between the double- and single-ionization thresholds. The green crosses are the scaled ratios of Li [5] also in units of ΔE . The blue dotted line (partly overlapping with the solid line) is a fit to our data using a universal shape function [6].

Double-photoionization cross section



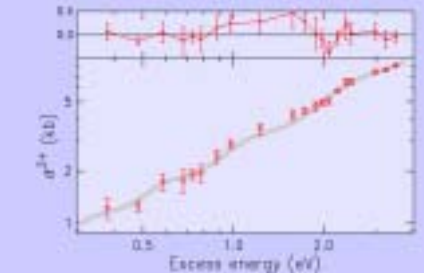
Relative double-photoionization cross section (filled circles). Previous measurement [1] (open squares); CCC calculations [3] (red open diamonds); TDCC calculations [11] (filled diamond); HRM-SOW calculations [9] in L, V, and A gauges (triangles). The blue solid line is a fit to our data using a universal shape function [6].

The Wannier exponent



The Wannier exponent [12] α as a function of the upper limit of the fit range using fixed parameters except for α . The horizontal line indicates the theoretical value for α .

The Coulomb-Dipole theory



The double-photoionization cross section (points with error bars) and a fit curve according to the Coulomb-Dipole theory $\sigma = E_{exc} (1 + C E_{exc}^{-1/4} \sin[D \ln(E_{exc}^2 + \mu)])$. The upper panel shows the deviation of the data points from the fit curve. For more information on the Coulomb-Dipole theory, see Ref. [15]. Please see also poster D1.071.

References

- [1] R. Wehlitz and S. B. Whitfield, J. Phys. B **34**, L719 (2001).
- [2] R. A. Falk and G. H. Dunn, Phys. Rev. A **27**, 754 (1983).
- [3] A. F. Kheifets and I. Bray, Phys. Rev. A **65**, 012710 (2001).
- [4] J. A. R. Samson, W. C. Stolte, Z.-X. He, J. N. Cutler, and Y. Lu, Phys. Rev. A **57**, 1906 (1998).
- [5] R. Wehlitz, J. B. Bluett, and S. B. Whitfield, Phys. Rev. A **66**, 012701 (2002).
- [6] T. Pattard, J. Phys. B **35**, L207 (2002).
- [7] K. Berrington, L. Quigley, and H. L. Zhang, J. Phys. B **30**, 5409 (1997).
- [8] H.-C. Chi, K.-N. Huang, and K. T. Cheng, Phys. Rev. A **43**, 2542 (1991).
- [9] F. Citrini, L. Malegat, P. Selles, and A. K. Kazansky, Pjus. Rev. A **67**, 042709 (2003).
- [10] J. J. Yeh and I. Lindau, Atom Data Nucl. Data Tab. **32**, 1 (1985).
- [11] J. Colgan and M. S. Pindzola, Phys. Rev. A **65**, 022709 (2002).
- [12] G. H. Wannier, Phys. Rev. **90**, 817 (1953).
- [13] J. M. Feagin, J. Phys. B **28**, 1495 (1995).
- [14] A. Temkin, priv. comm. and poster D1.071.
- [15] A. Temkin and Y. Hahn, Phys. Rev. A **9**, 708 (1974); A. Temkin, Phys. Rev. Lett. **49**, 365 (1982).

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The universal shape function for double photoionization [6] which is based on a previously proposed shape function for ionization by both projectiles, was introduced by T. Pattard.

$$\frac{\sigma^{(2)}}{\sigma^{(1)}}(E) = \frac{2\sigma_0}{\Gamma(1/2)} \frac{\Gamma(1/2)}{\Gamma(1/2)} \frac{1}{(1 + (E/E_0)^2)^{1/2}}$$

$$\sigma(E) = \sigma_0 E^{\alpha} \left(\frac{E/E_0}{1 + (E/E_0)^2} \right)^{1/2 + \beta}$$

$\alpha = 1.056$ (for double photoionization)
 σ_0 : asymptotic high-energy ratio
 E_0 : Li-III ionization

$\beta = C/T_0$
 T_0 and C : position and height of the cross section maximum,
 $(C, T_0) = \sigma(E_0)$