Potential Barrier Effects in Two-Photon Ionization and High-Order Harmonic Generation in the XUV Regime

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Outline

- **Potential Barrier Effects in Multiphoton Ionization**
  - *Background on Potential Barriers in Photoionization*
  - *Calculation of Two-Photon Generalized Cross Sections*
  - *Intermediate State Potential Barrier Effects*
  - *Final State Potential Barrier Effects*
- **Potential Barrier Effects in HHG**
  - *New Formulation for Harmonic Generation*
  - *Closed Form Analytic Formula for HHG Near the Cutoff*
  - *Potential Barrier Effects in HHG from Xe*
  - *Potential Barrier Effects in HHG from Transition Metal Ions*
- **Concluding Remarks**

Potential Barrier Effects in Multiphoton Ionization Processes

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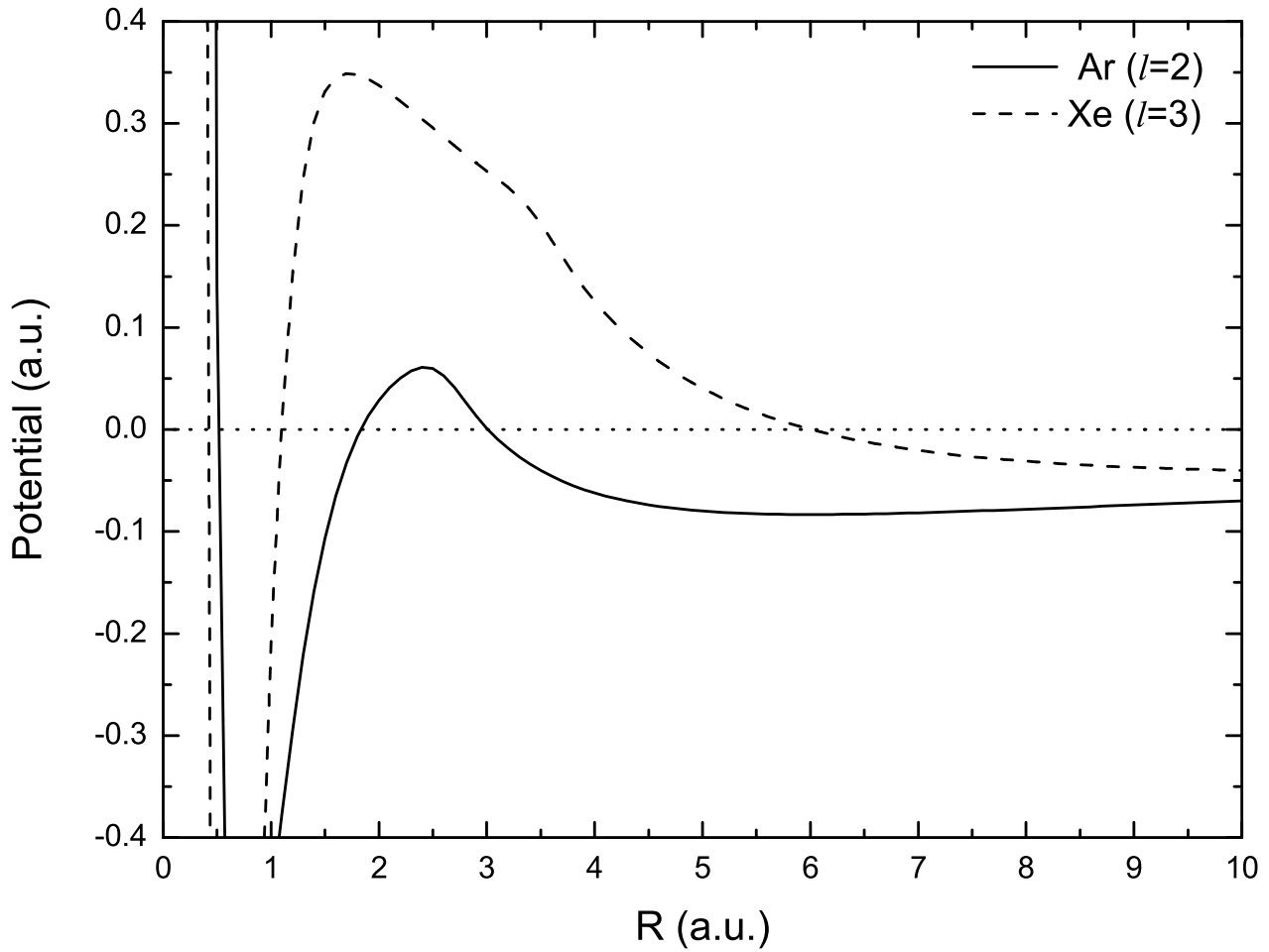
Reference: *Manuscript in preparation*

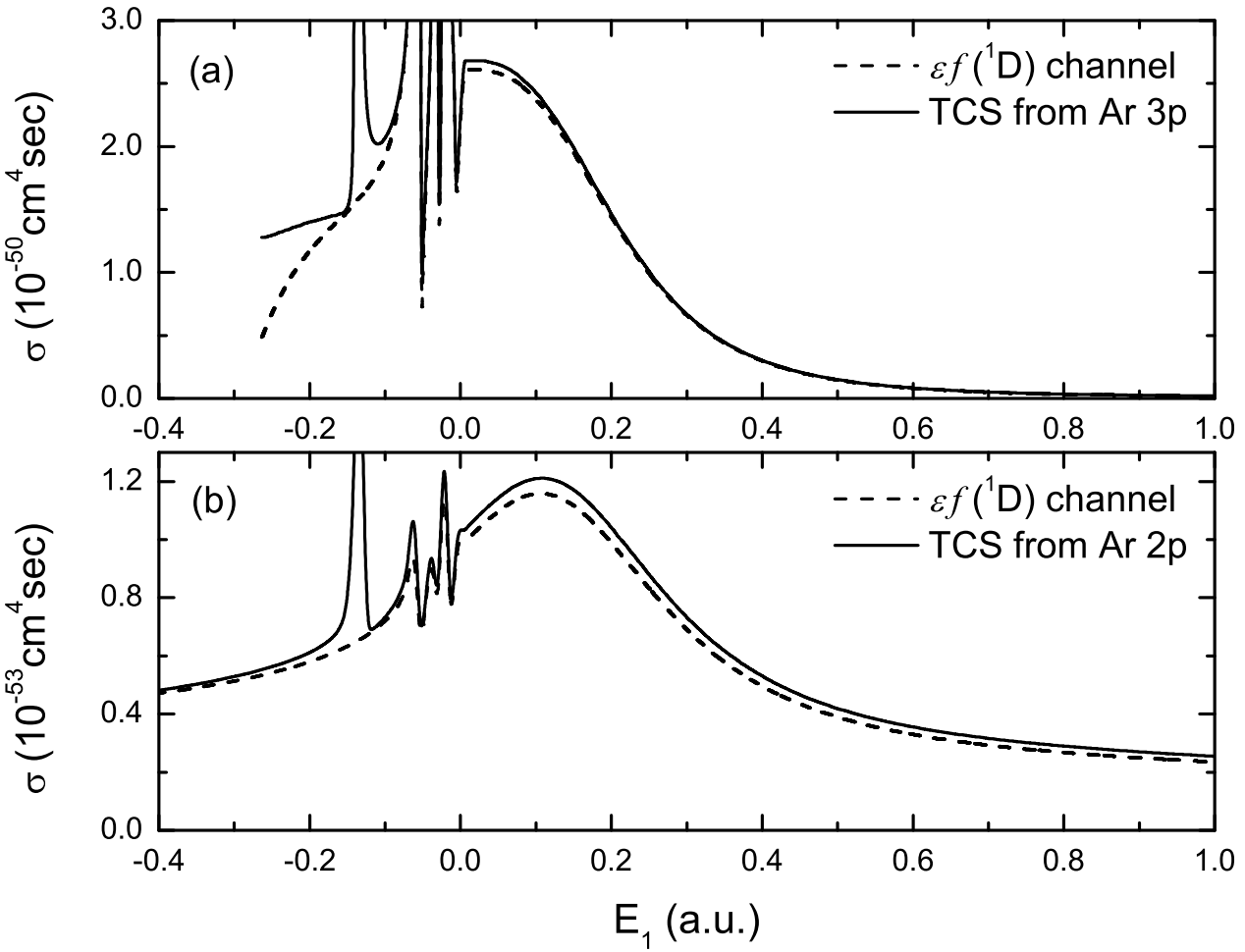
Potential Barrier Effects

- Effective potential for Ar (l=2) and Xe (l=3)



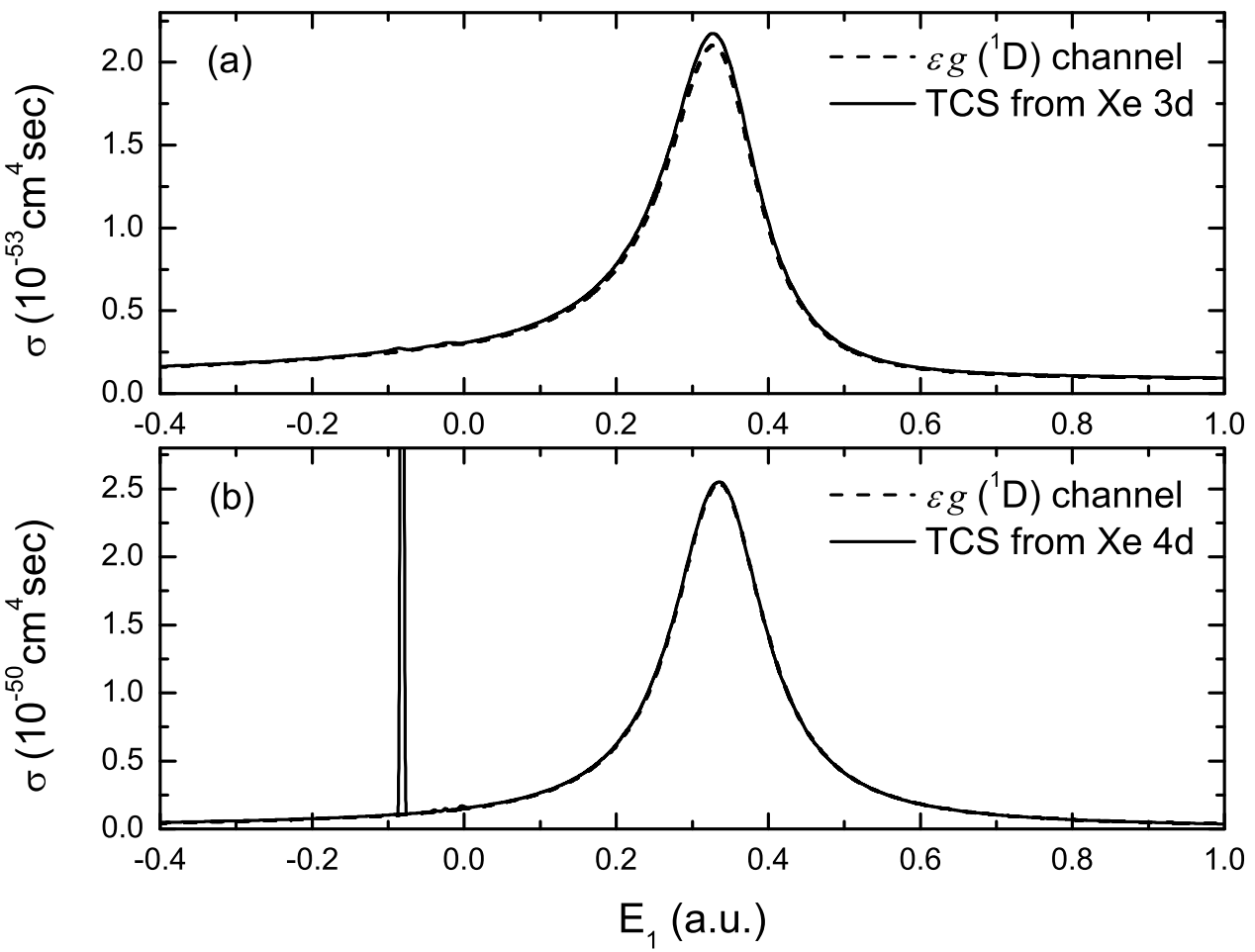
Potential Barrier Effects

- Generalized cross sections for two-photon ionization of the Ar 2p- and 3p-subshells



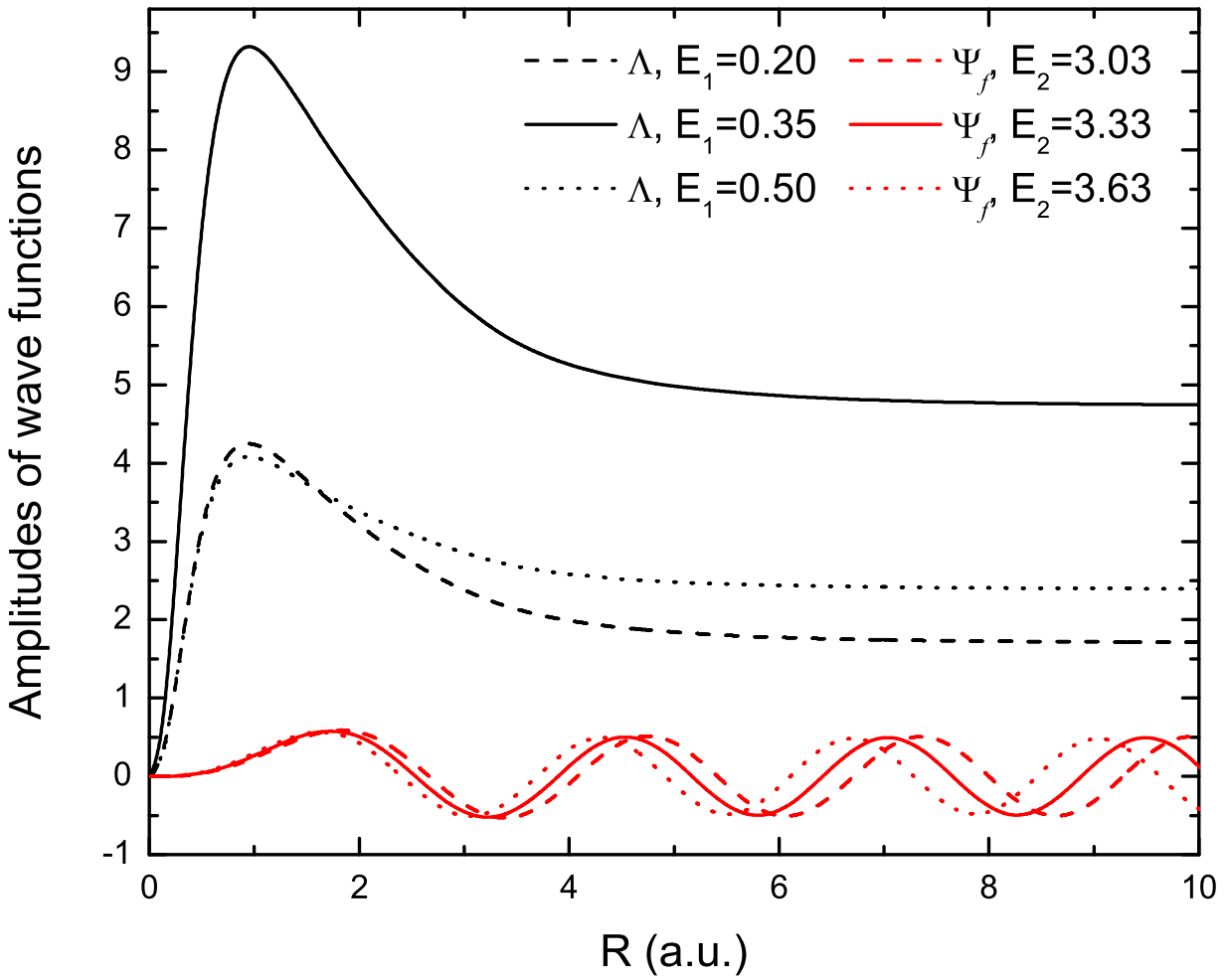
Potential Barrier Effects

- Generalized cross sections for two-photon ionization of the Xe 3d- and 4d-subshells



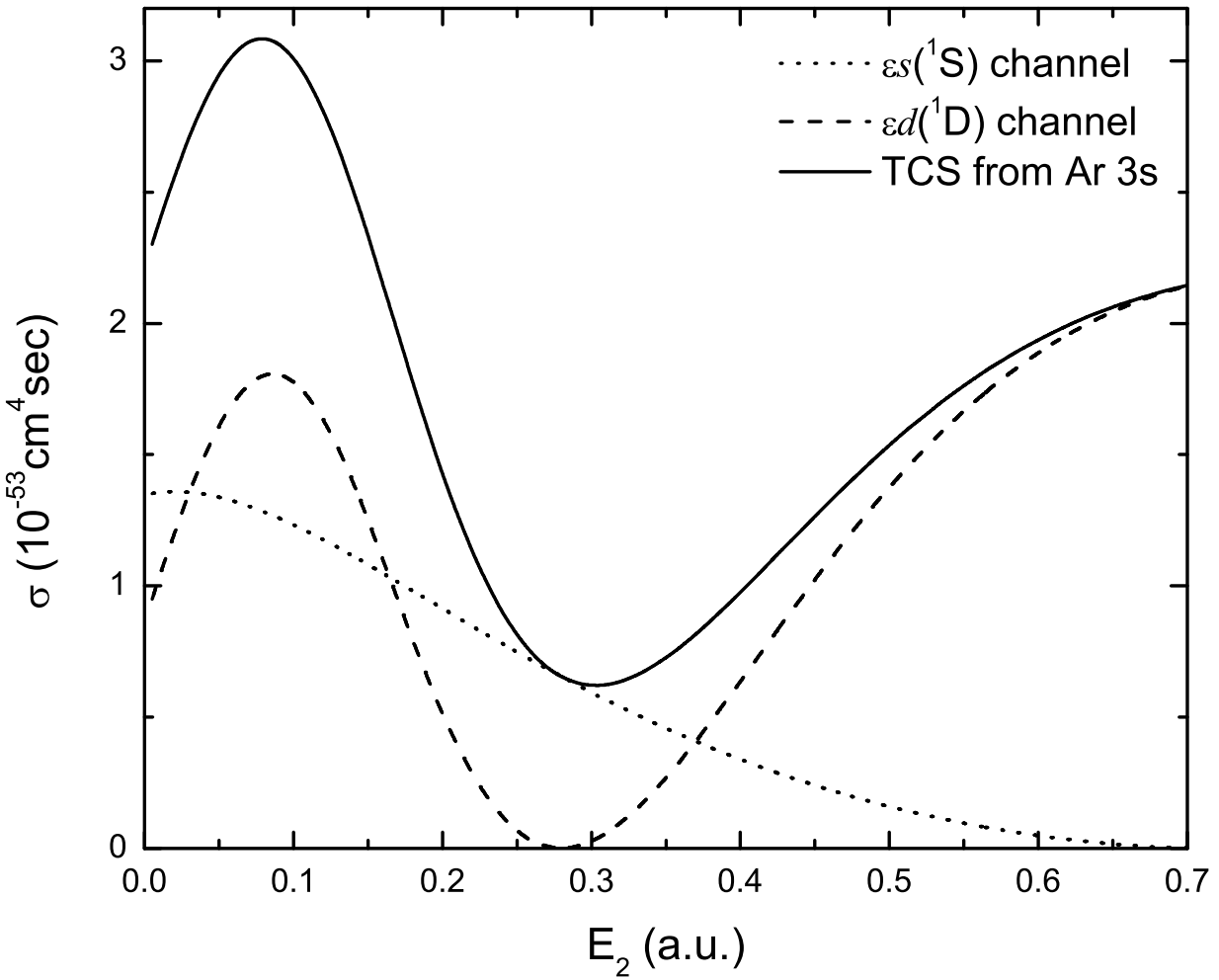
Potential Barrier Effects

- Amplitudes of the intermediate state Λ and the final state Ψ for 2-photon ionization of Xe 4d



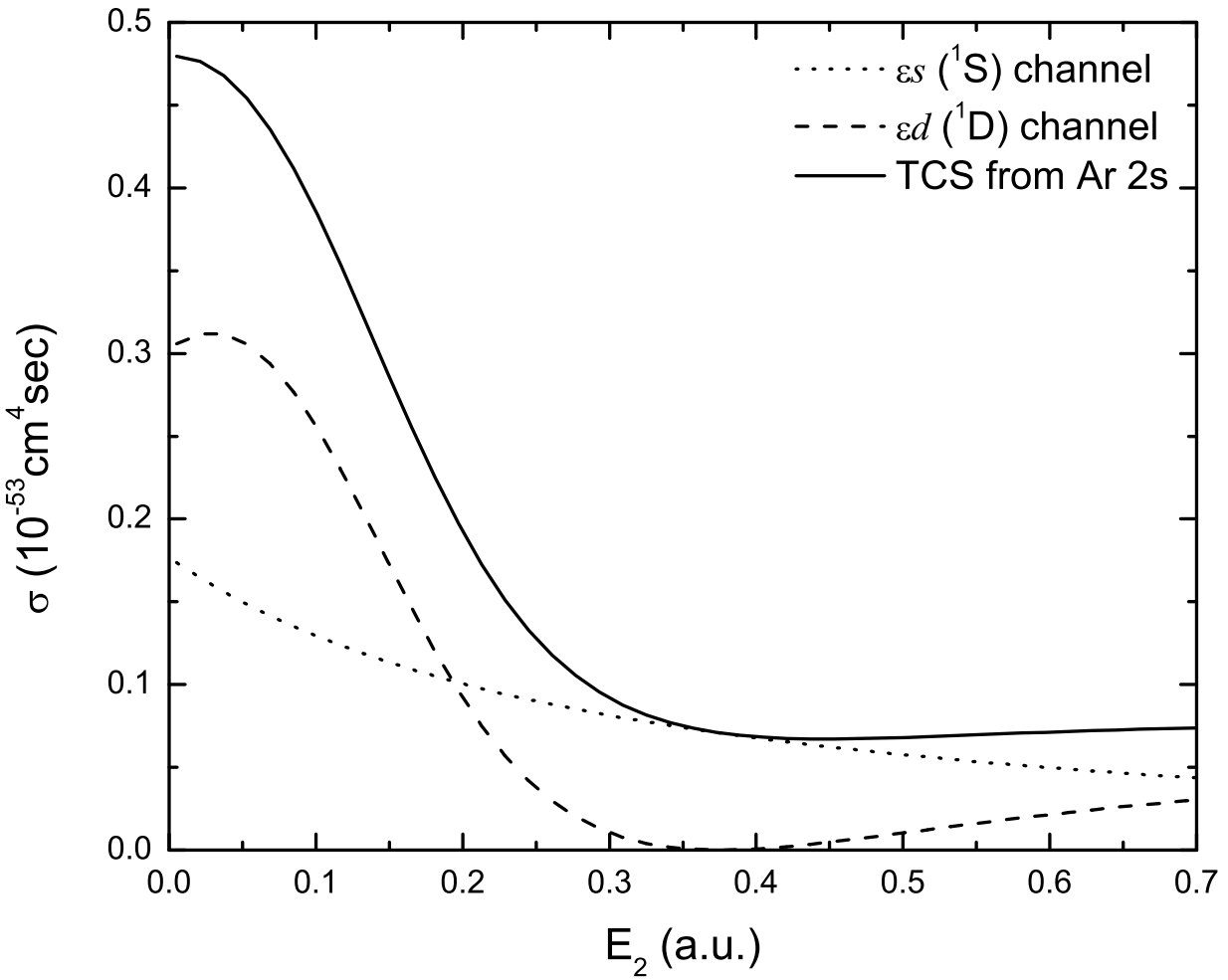
Potential Barrier Effects

- Generalized cross section for two-photon ionization of the Ar 3s-subshell



Potential Barrier Effects

- Generalized cross section for two-photon ionization of the Ar 2s-subshell



Potential Barrier Effects in High Harmonic Generation

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References: M.V. Frolov *et al.*, *Phys. Rev. A* **82**, XXXXXX (2010), in press.

M.V. Frolov *et al.*, *Phys. Rev. Lett.* **102**, 243901 (2009).

Key HHG References

References

[1] M.V. Frolov, A.V. Flegel, N.L. Manakov, and A.F. Starace, *Phys. Rev. A* **75**, 063407 (2007) **[General Formulation]**

[2] M.V. Frolov, A.V. Flegel, N.L. Manakov, and A.F. Starace, *Phys. Rev. A* **75**, 063408 (2007) **[Application to TDER model]**

[3] M.V. Frolov, N.L. Manakov, T.S. Sarantseva and A.F. Starace, J. Phys. B **42**, 035601 (2009) **[Analytic HHG Formula for TDER model]**

[4] M.V. Frolov, N. L. Manakov, T.S. Sarantseva, M.Yu. Emelin, M.Yu. Ryabikin and A.F. Starace, Phys. Rev. Lett. **102**, 243901 (2009) **[Analytic HHG Formula for neutral atoms; potential barrier effects seen in Xe]**

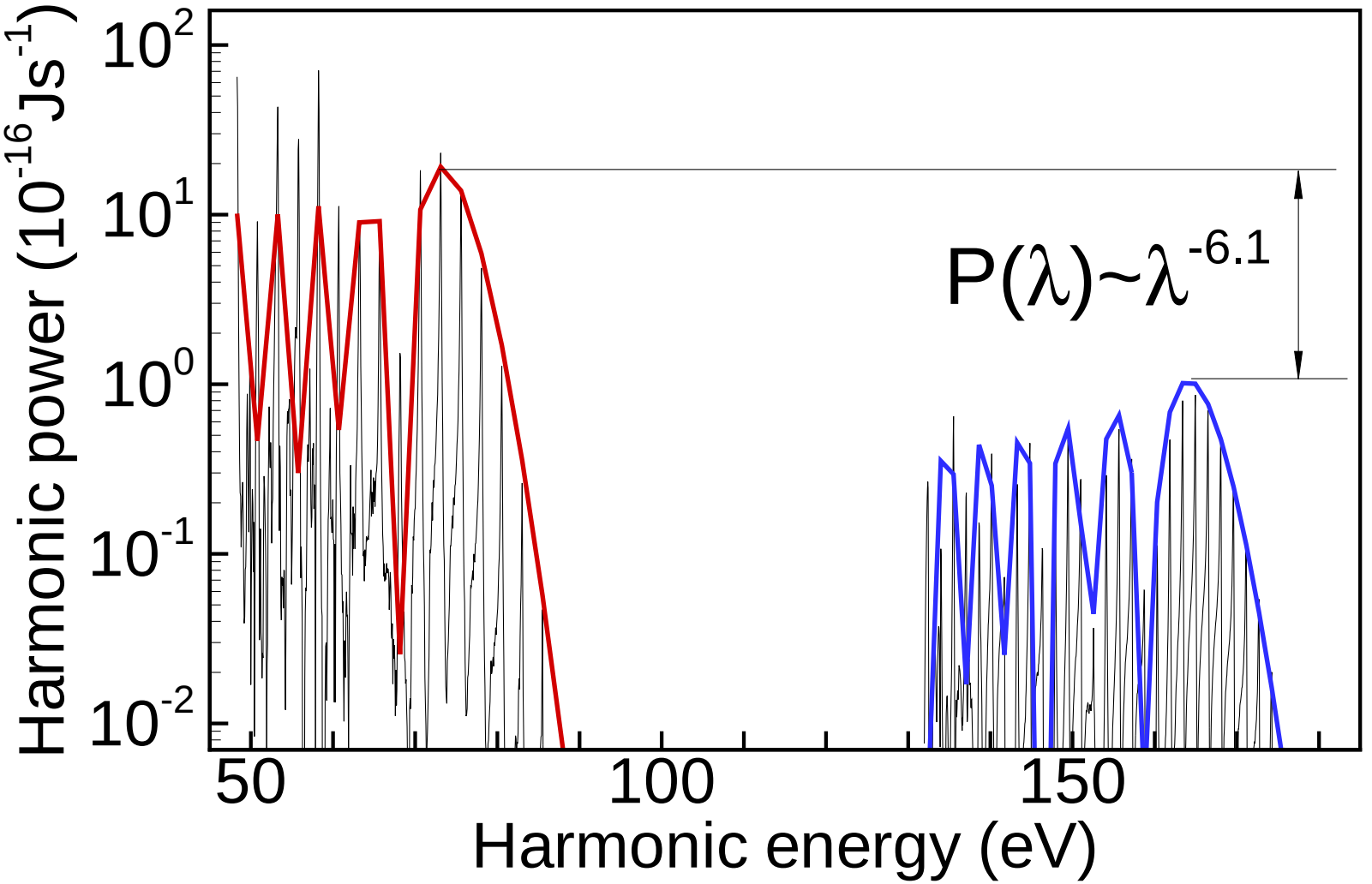
[5] M.V. Frolov, N.L. Manakov and A.F. Starace, Phys. Rev. A **82** (in press) (2010)

[Resonant HHG for transition metal ions Cr+ and Mn+]

Comparison of HHG for H-Atom

$\lambda = 1.0\ \mu$m (left) and $\lambda = 1.6\ \mu$m (right), $I = 2 \times 10^{14}$W/cm^2.

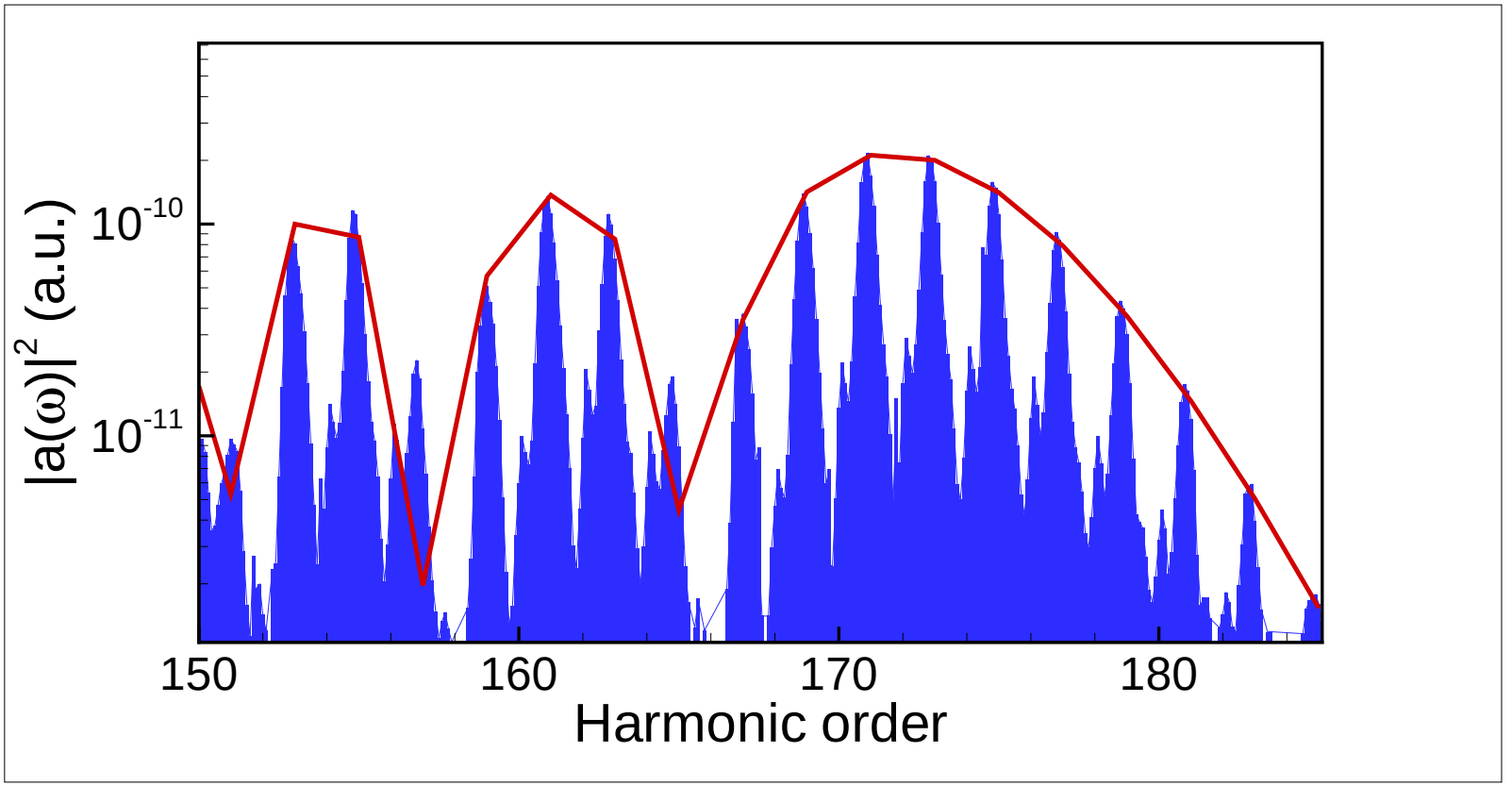
Thick Lines: Analytic Formula Results; *Thin Lines:* TDSE Results.



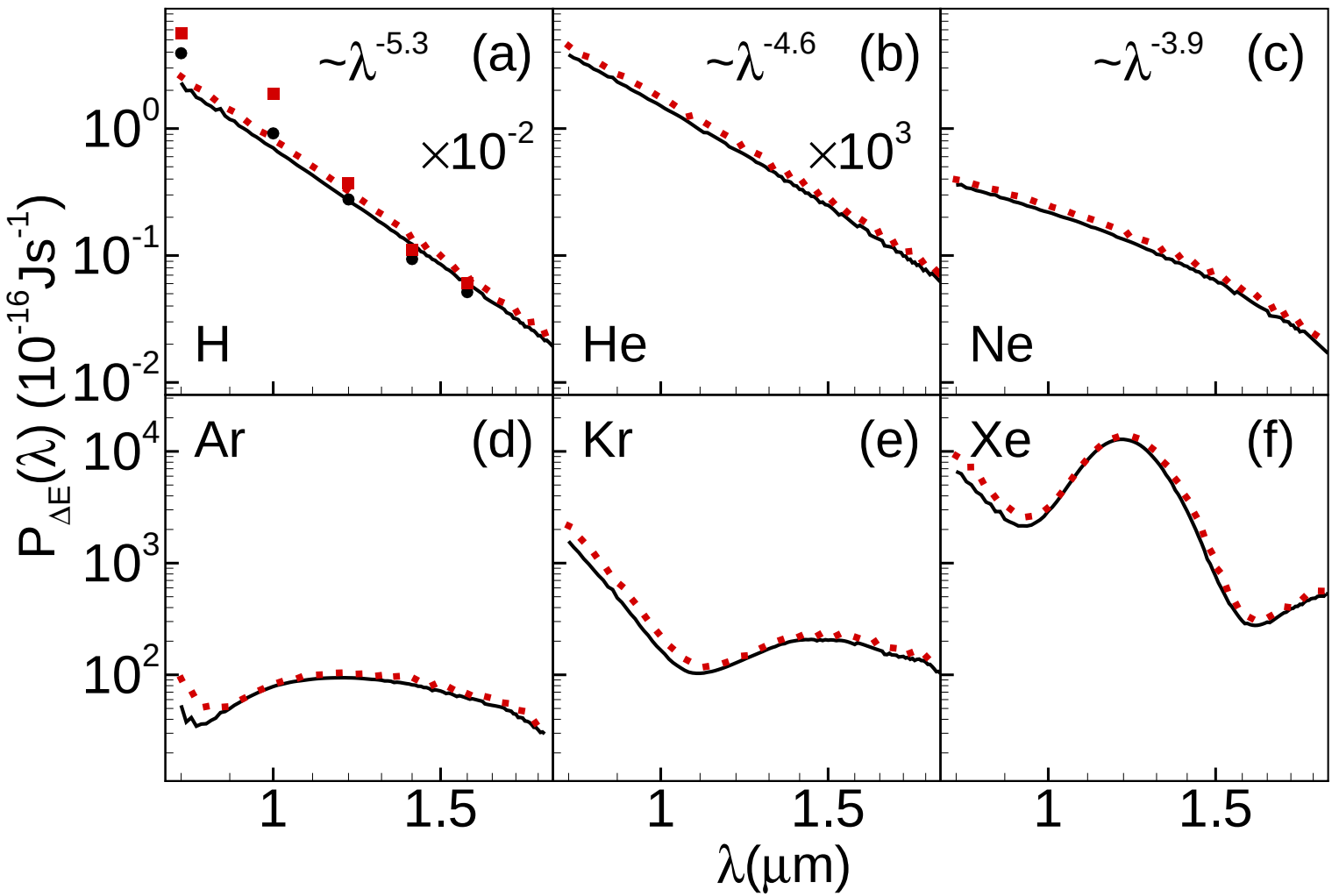
Comparison of HHG for H-Atom

Thin Lines: J.A. Pérez-Hernández *et al.*, *Opt Exp* **17**, 9891 (2009) TDSE results for $\lambda = 1.6\ \mu$m, $I = 1.6 \times 10^{14}$W/cm^2

Thick Lines: Present Analytic Formula Results



Harmonic power, $P_{\Delta E}(\lambda)$, vs. λ for H and rare gases with $I = 2 \times 10^{14}$ W/cm^2 and $\Delta E = 20$ eV (solid lines) and 30 eV (dotted lines)



Cr Plasma HHG Spectra

PHYSICAL REVIEW A **75**, 063806 (2007)

Systematic investigation of resonance-induced single-harmonic enhancement in the extreme-ultraviolet range

R. A. Ganeev,[1,2,*] L. B. Elouga Bom,[1] J.-C. Kieffer,[1] and T. Ozaki[1]

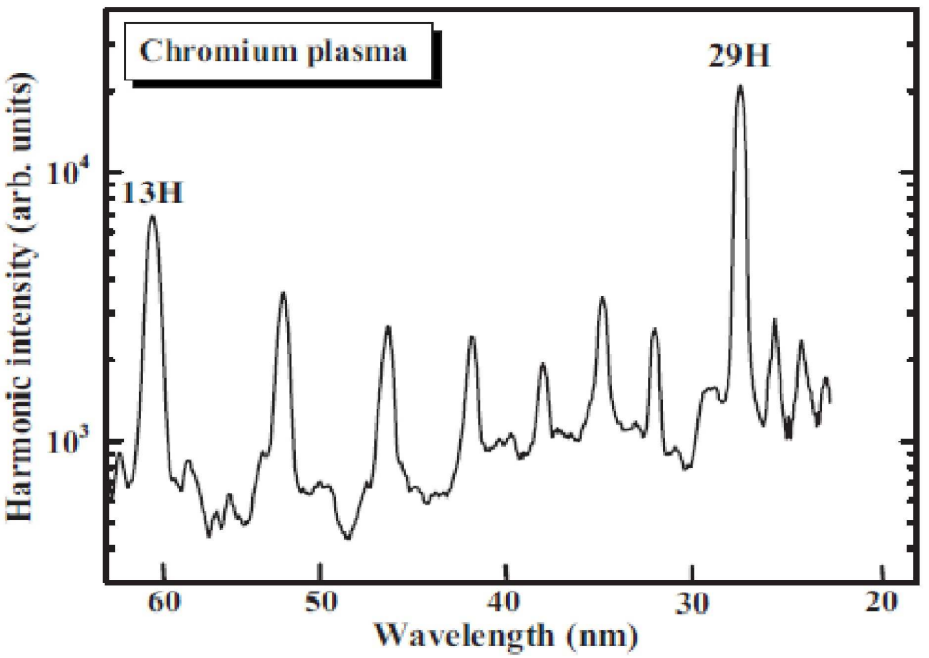


FIG. 4. Harmonic spectra from Cr plasma in the case of 800 nm, 35 fs chirp-free main pulses.

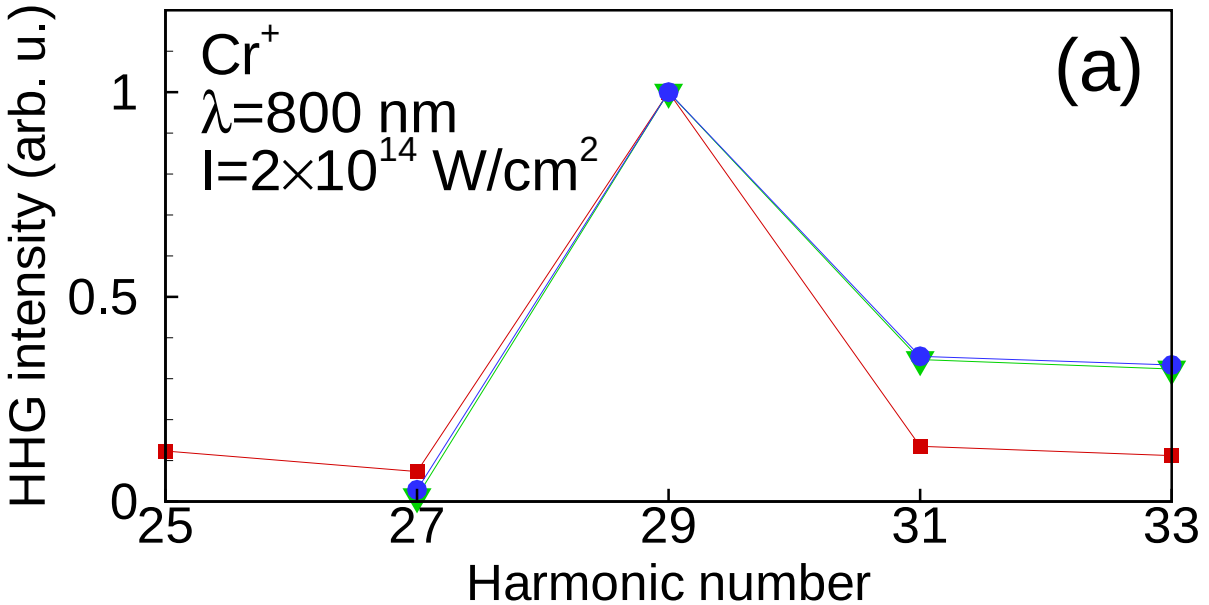


Figure 1: HHG spectra of Cr^+ for $\lambda = 800$nm. Squares (red): Ganeev *et al.* results [Phys. Rev. A **75**, 063806 (2007)]. Circles (blue): present results for $\beta = 0$. Triangles (green): present results for Cr^+ with the asymmetry parameter $\beta \neq 0$.

Physics of recombination:

(i): $Cr^{++}3p^6 3d^4(^5D) + \epsilon\ell \rightarrow Cr^+ 3p^5(^2P)3d^6(^5D)(^6P)$

(ii): $Cr^+ 3p^5(^2P)3d^6(^5D)(^6P) \rightarrow Cr^+ 3p^6 3d^5(^6S) + \gamma$.