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Electron Screening in Nuclear Reactions

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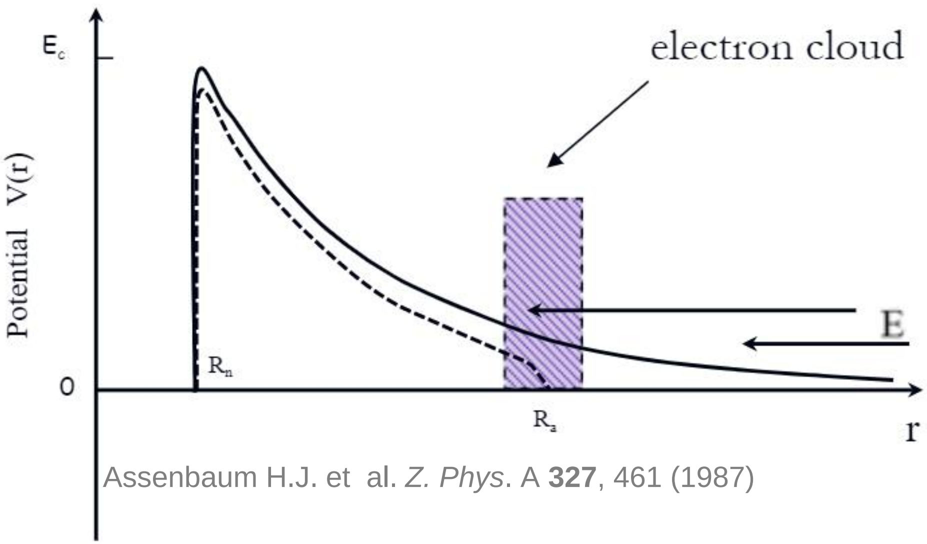
Research Topic

- The electron screening could have an important influence on nuclear astrophysics
- Interpretation of nuclear reactions at low energies
- Studying metal-hydrogen systems could help us to explain electron screening effects which are significant in understanding nuclear reactions involved in nucleosynthesis.
- Dependence of electron screening effect on the position of hydrogen in the crystal lattice

Electron Screening



Assenbaum H.J. et al. *Z. Phys.* A **327**, 461 (1987)

Target	Reaction U_e [keV] ^{7}Li+p	^{11}B+p	^{19}F+p
adiabatic	0.24	0.68	2.19
Graphite	10.3 ± 0.4	32 ± 4	115 ± 8
Pd	3.6 ± 0.7	8.0 ± 1.9	63 ± 6
TiH	3.9 ± 0.4	6.7 ± 1.8	62 ± 6
W	5.9 ± 0.9	-	75 ± 15
Graphite/ adiabatic	42.9 ± 1.7	47.1 ± 5.9	52.5 ± 3.6

A. Cvetinović et al., *Phys. Rev*. C **92,** 065801 (2015)

E_c - height of the Coulomb barrier,
R_n - nuclear radius,
R_a - atomic radius.

$$U_e = \frac{Z_0 Z_1}{4\pi\varepsilon_0}\frac{e^2}{R_a}$$

Theoretical screening potential for d+d reaction

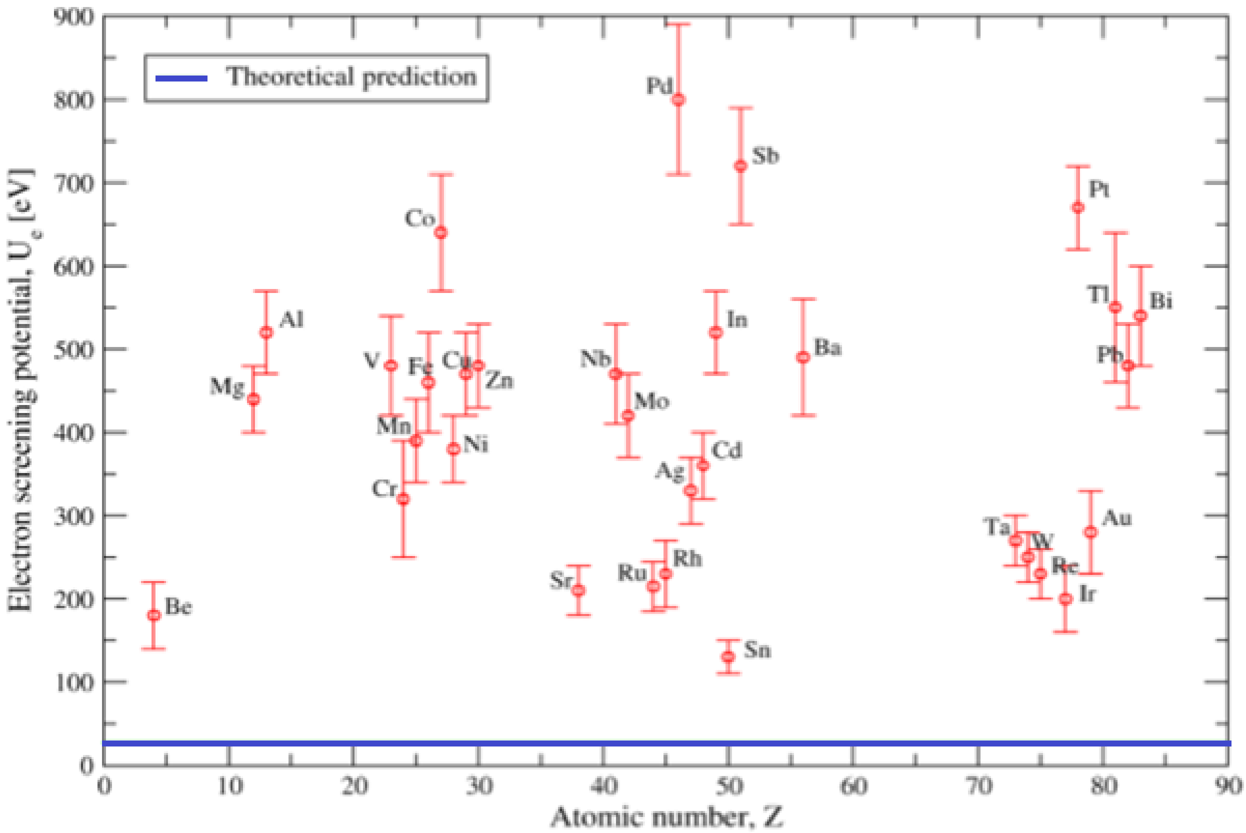
$$U_e = 27eV$$

- Enhancement factor

$$f(U_e) = \frac{e^{-2\pi\eta(E+U_e)}}{e^{-2\pi\eta(E)}}$$

Previous Results and Motivation

- The amplitude of electron screening potential dependent on target material
- Dependence of metallic environment around the nuclei on d+d reactions at low energies

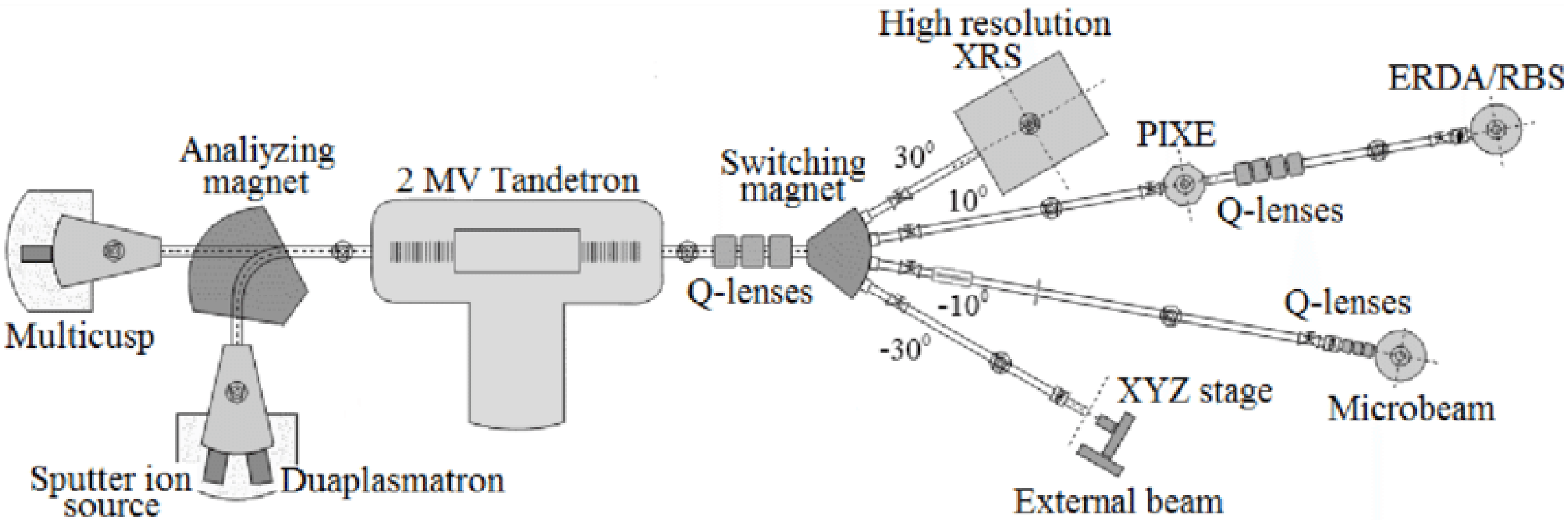


F. Raiola et al., *The Eur. Phys. J.* A **19**, 283 (2004)
Isabela Tišma, Electron screeninig and primodial nucleosynthesis, Presentation, Russbach (2018)

Future experiments - Studying electron screening effects in different deuterated materials

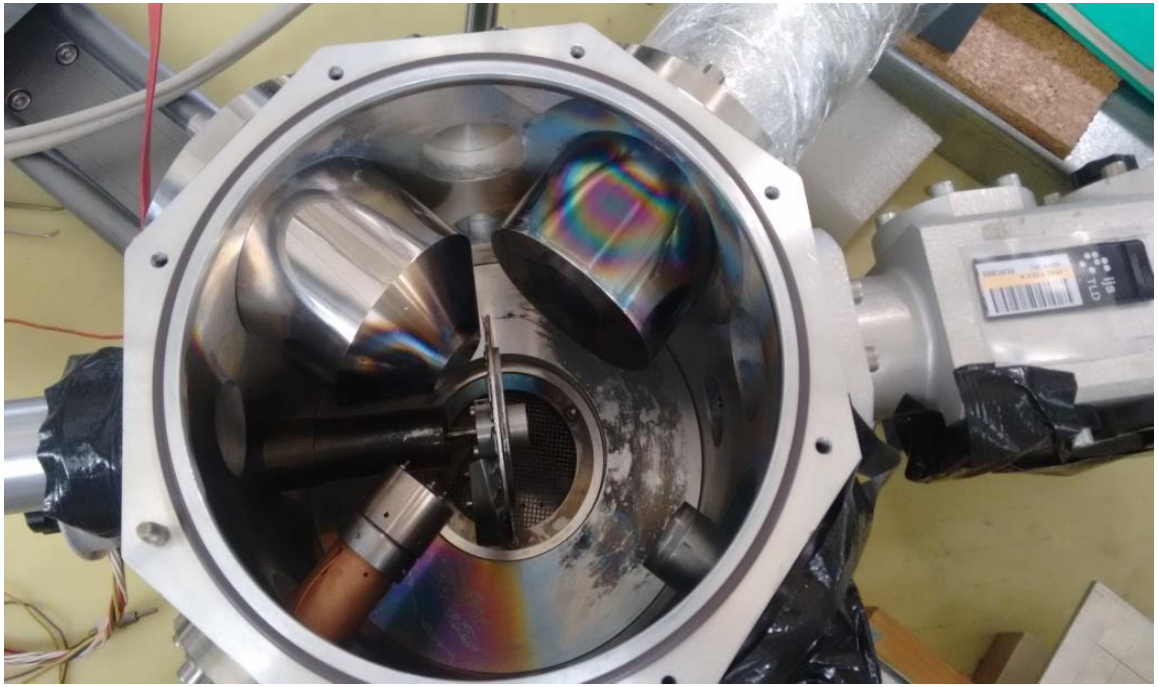
Tandetron accelerator at Jožef Stefan Institute

Bombarding deuterons implanted into various materials with different beams



Schematic view of the accelerating system at IJS

Target Chamber



- Low-pressure environment
- Turning ring with places for targets
- Inputs for detectors (Germanium and Silicon) and beamline

$^{1}H(^{19}F,p)^{20}F$
$^{1}H(^{7}Li,\alpha)\,^{4}He$
$^{1}H(^{11}B,\alpha)\,^{4}He$
$^{1}H(^{19}F,\alpha\gamma)^{16}O$
$^{1}H(^{7}Li,\alpha)\,^{4}He$

Spectroscopic Methods

- **Nuclear reaction analysis**

(for studying hydrogen content and depth profiles)

- **Elastic recoil detection analysis**

(quantitative analysis of hydrogen in solids)

- **Thermal desorption spectroscopy**

(for observing desorbed molecules from a surface when the surface temperature is increased)

- **Nuclear magnetic resonance spectroscopy**

(for studying electron density at the place of the proton or deuteron)

- **X-ray diffraction spectroscopy**

(to get information about the crystal structure, chemical composition and physical properties of materials)

Conclusion

- Despite many theoretical and experimental studies, a theory that can explain electron screening effect has not yet been found

- The size of electron screening differs in different materials

- What causes these differences?

- Better understanding of the materials interesting for this research is possible using spectroscopic methods

Acknowledgements: Matej Lipoglavšek, Aleksandra Cvetinović, Isabela Tišma

Thank you for your attention!