DEA cross section in H_2 and D_2
at the 4 eV resonance

Juraj Fedor

J. Heyrovský Institute of Physical Chemistry
Czech Academy of Sciences

Prague

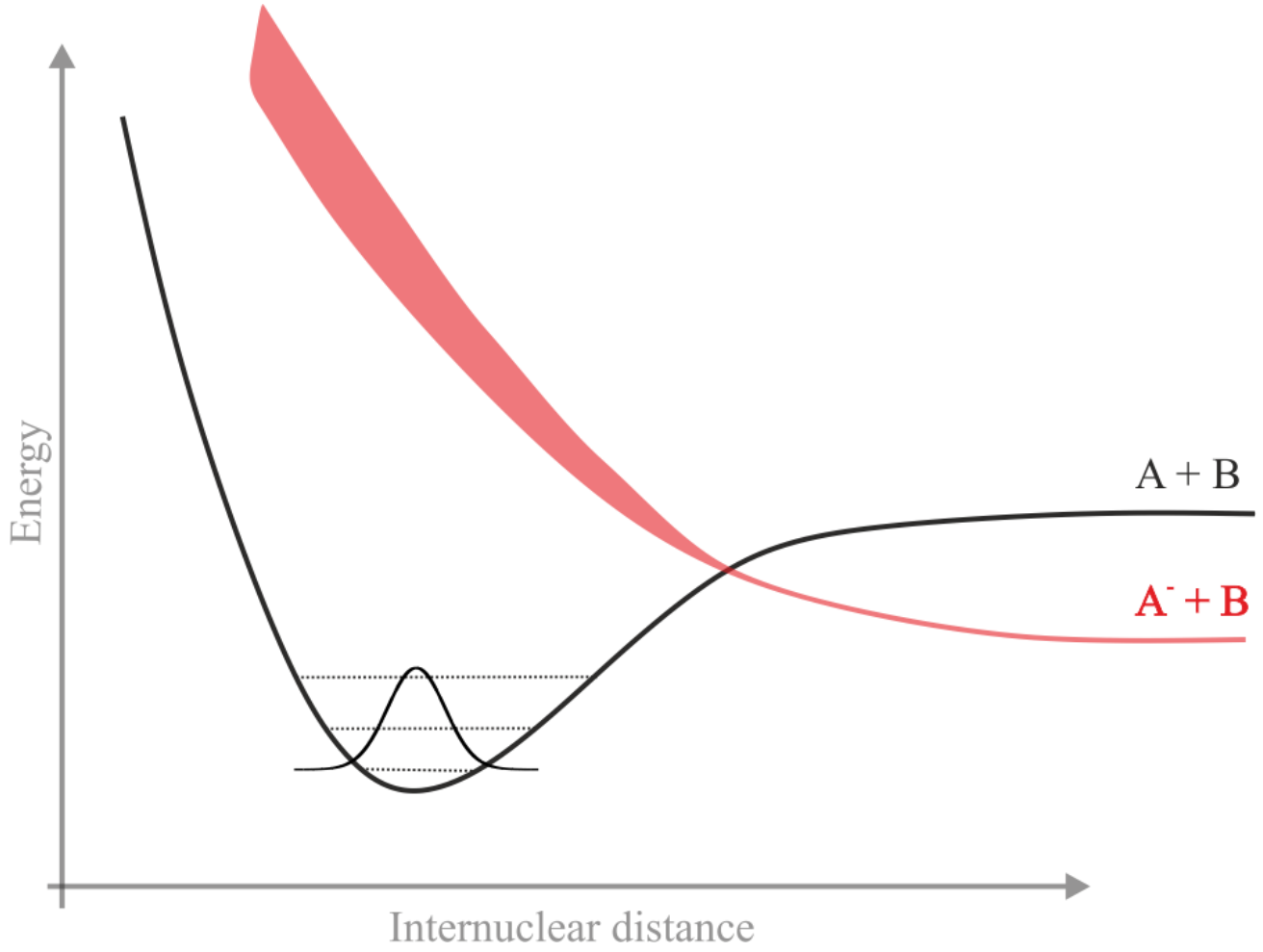
Dissociative electron attachment

$$H_2 + e \rightarrow (H_2^-)^* \rightarrow H^- + H$$

$$D_2 + e \rightarrow (D_2^-)^* \rightarrow D^- + D$$

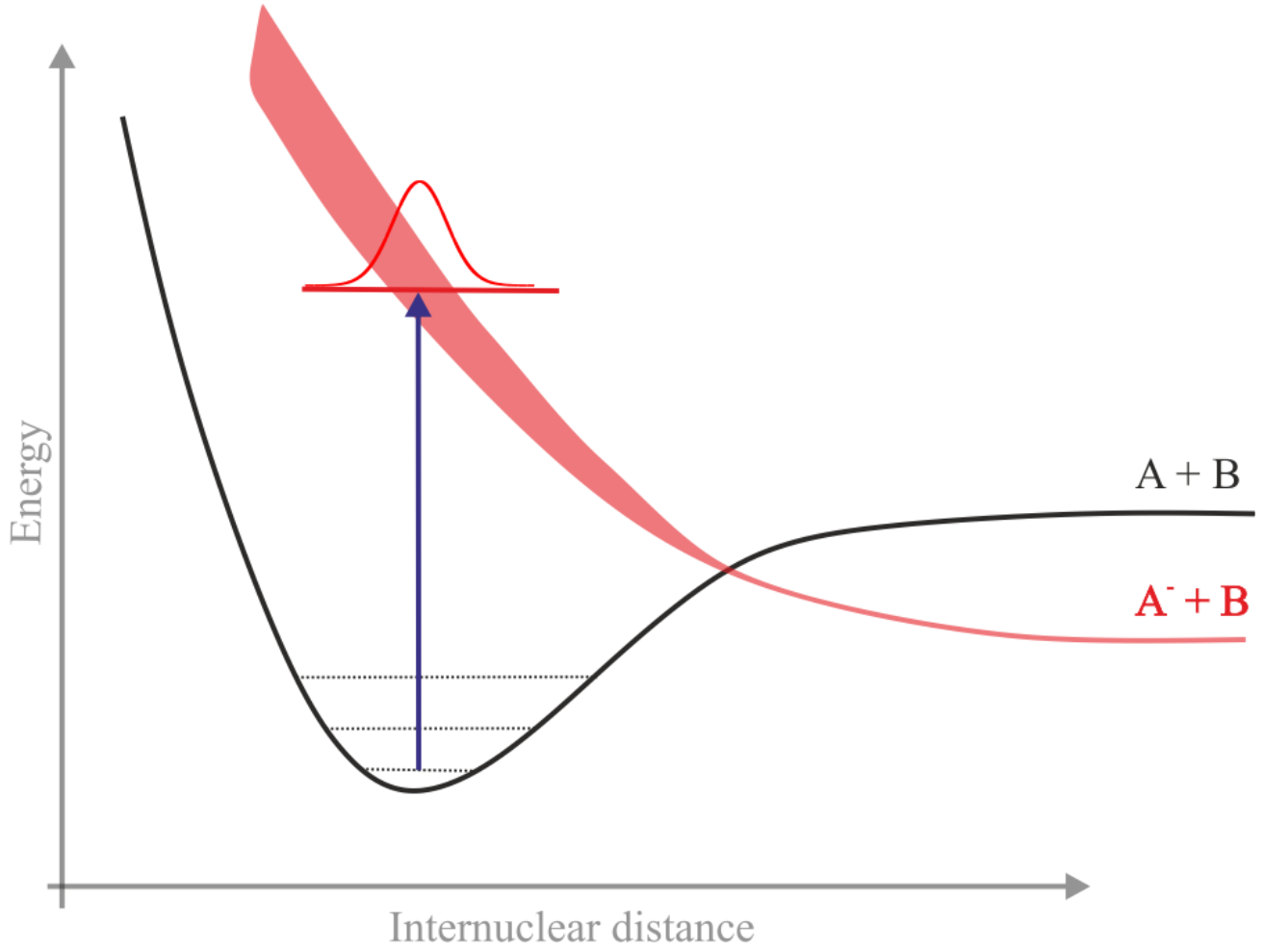
Resonant electron collisions

$$AB + e \rightarrow (AB^{-})^{*} \rightarrow \ ...$$



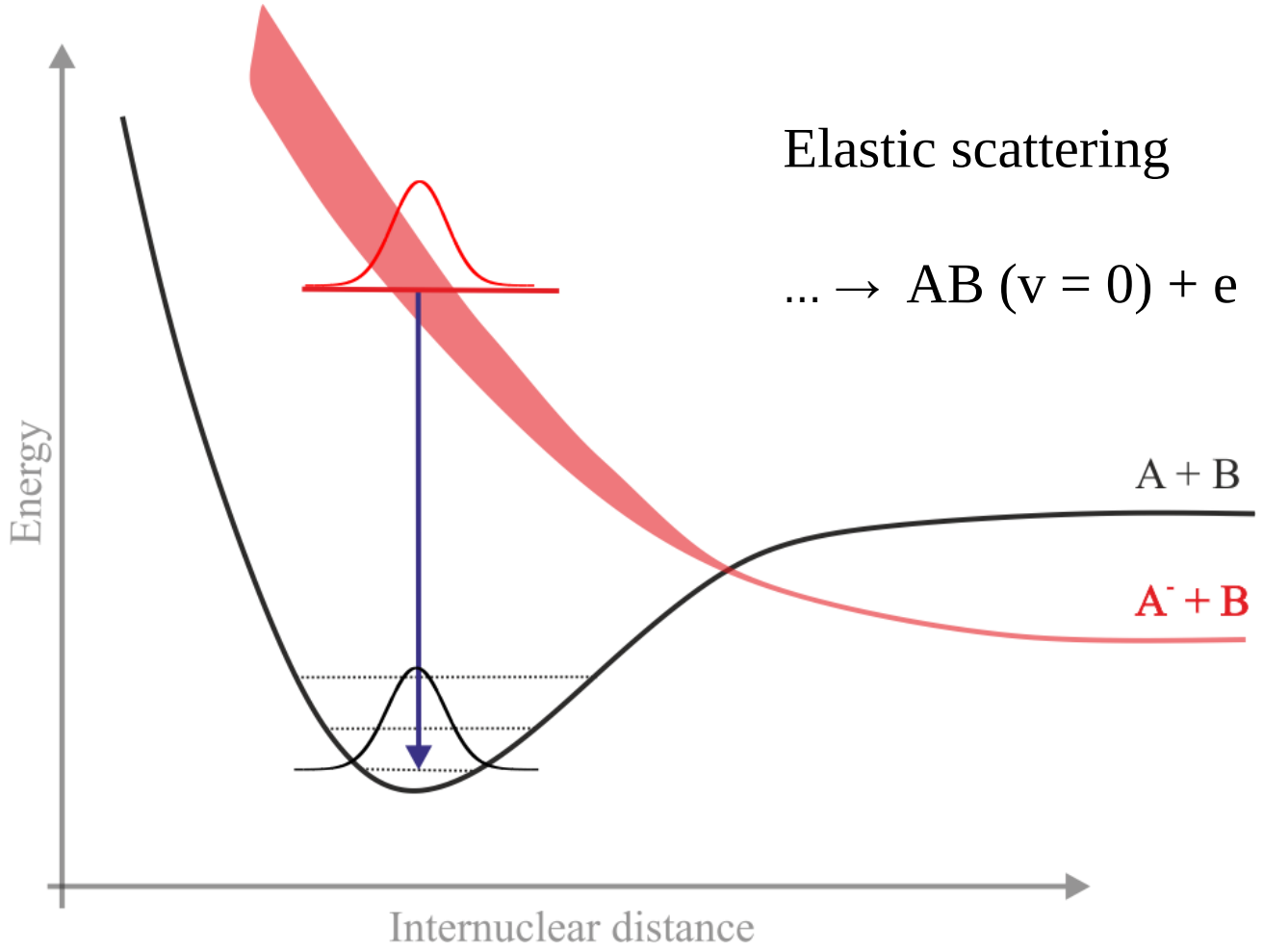
Resonant electron collisions

$AB + e \rightarrow (AB^{-})^{*} \rightarrow ...$



Resonant electron collisions

$AB + e \rightarrow (AB^{-})^{*} \rightarrow ...$

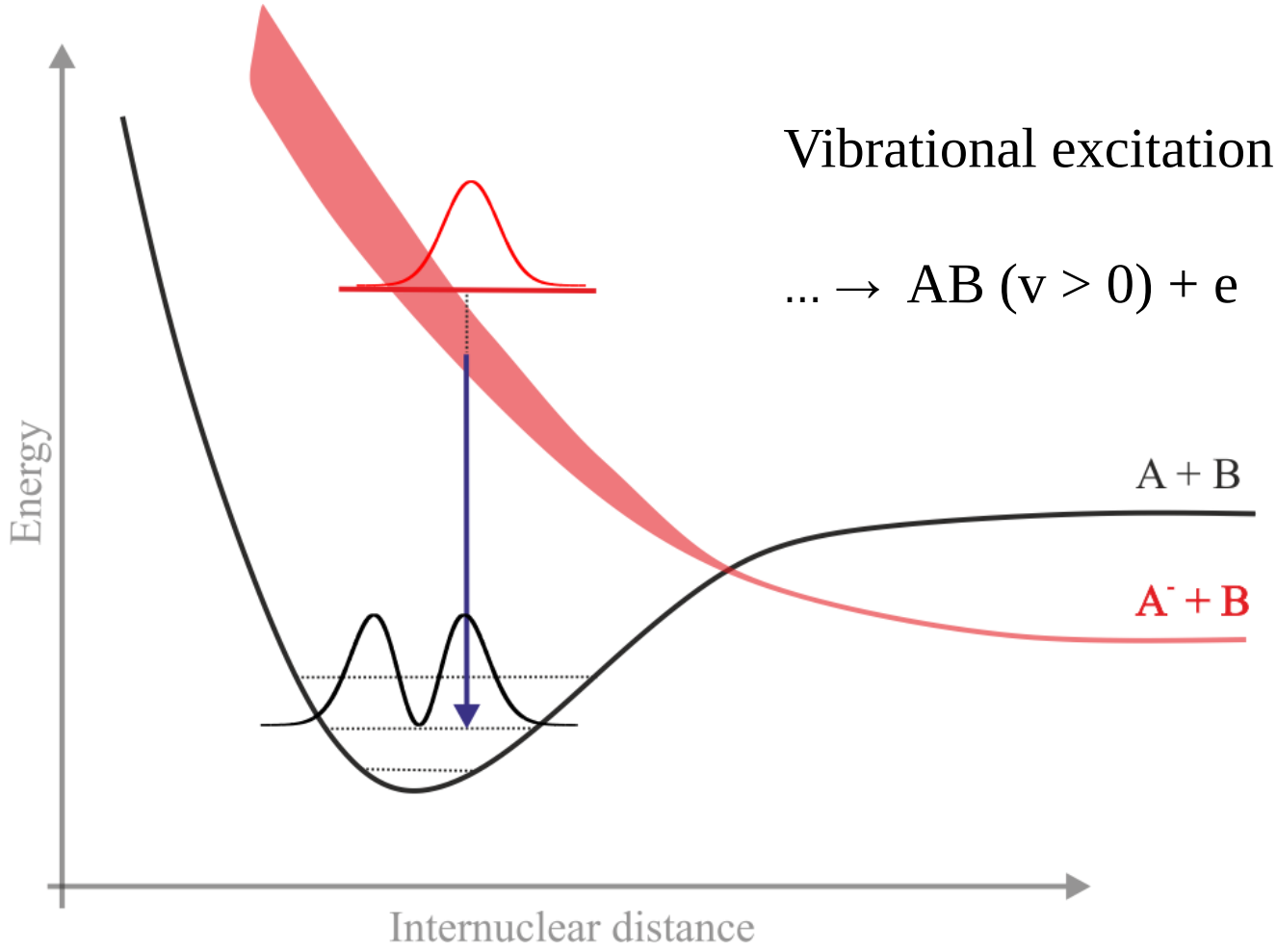


Elastic scattering

... → AB (v = 0) + e

Resonant electron collisions

$AB + e \rightarrow (AB^{-})^{*} \rightarrow \ldots$

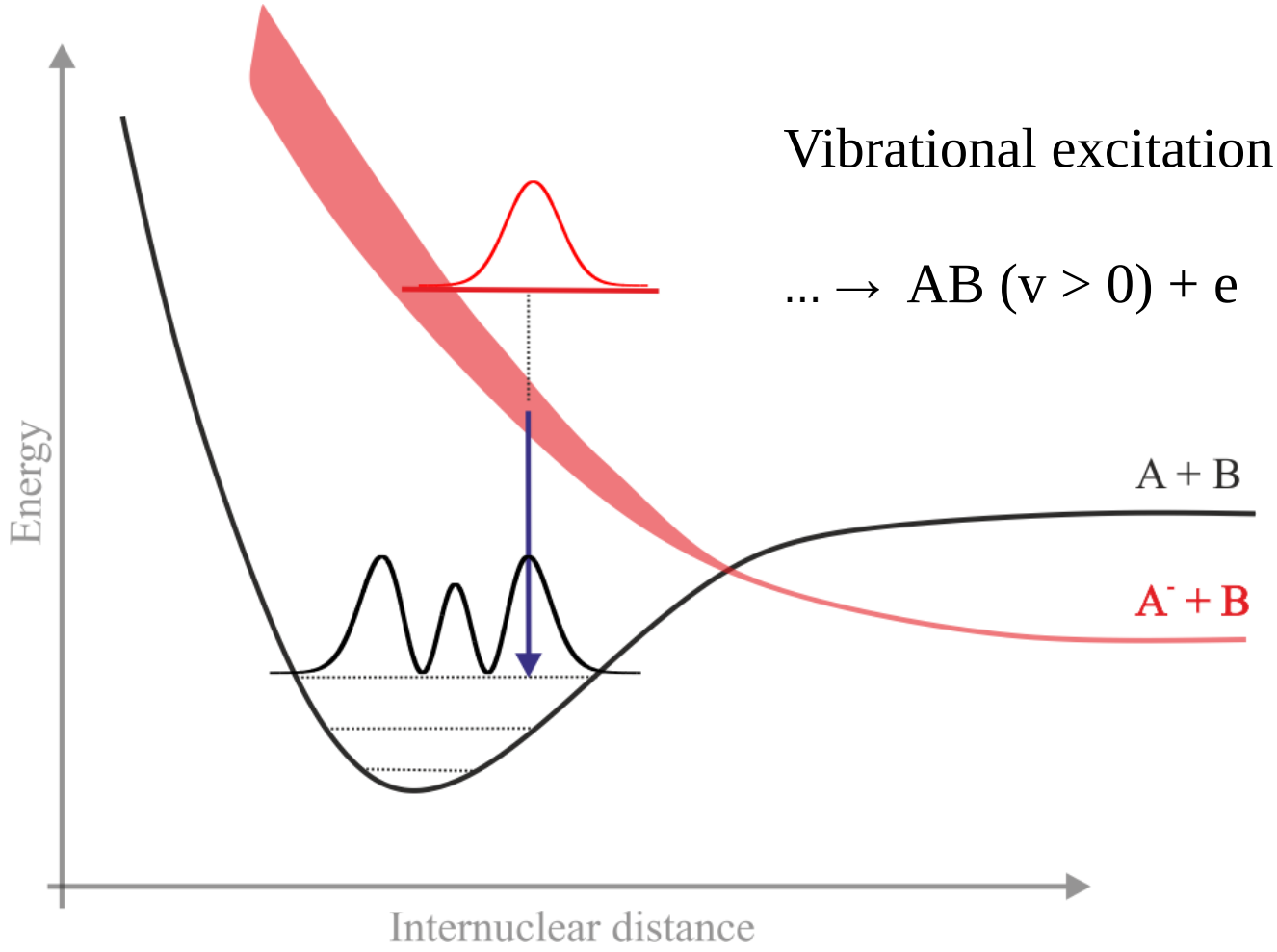


Vibrational excitation

$\ldots \rightarrow AB\ (v > 0) + e$

Resonant electron collisions

$AB + e \rightarrow (AB^{-})^{*} \rightarrow \ldots$

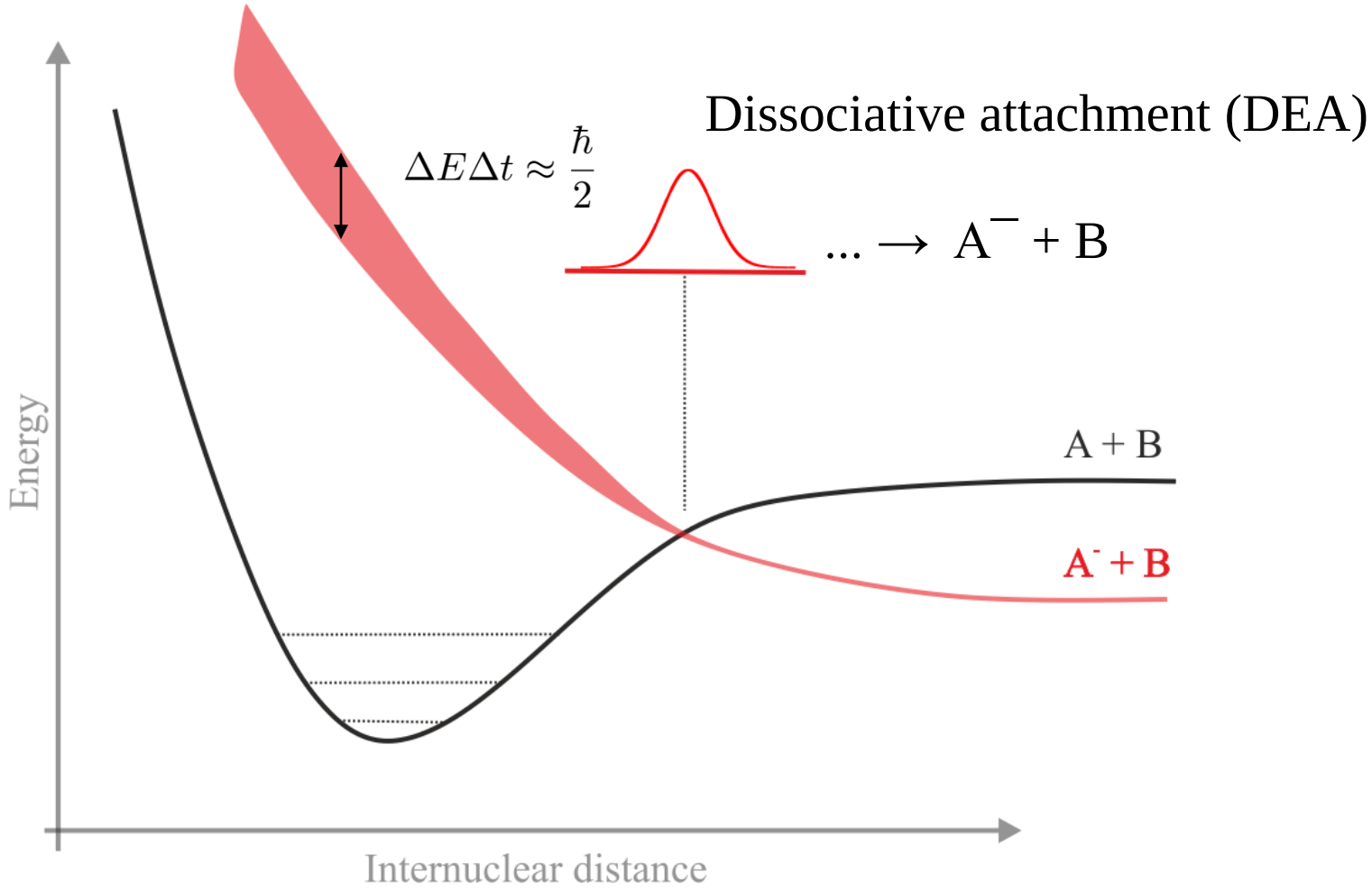


Vibrational excitation

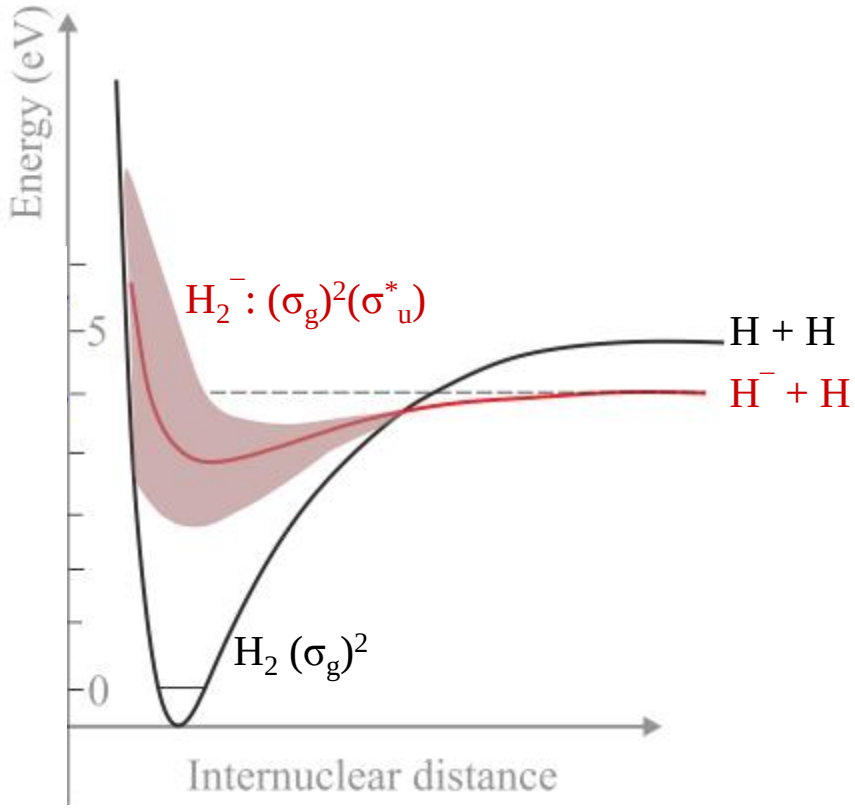
$\ldots \rightarrow AB\ (v > 0) + e$

Resonant electron collisions

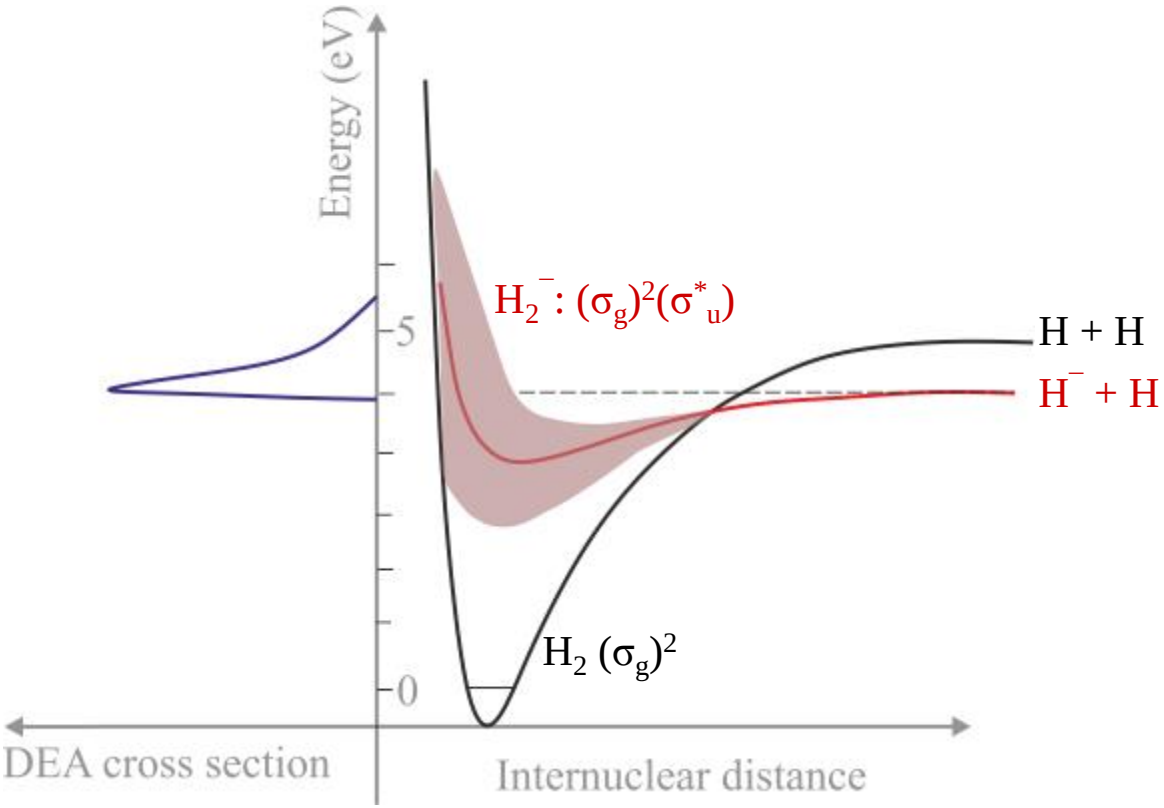
$AB + e \rightarrow (AB^{-})^{*} \rightarrow ...$



Situation in H_2 (4 eV resonance)



Situation in H_2 (4 eV resonance)



$m = 0$
→ high autodetachment rate
→ low DEA cross section

→ strong isotope effect

Reference number

$$\frac{\sigma(H^-/H_2)}{\sigma(D^-/D_2)} = 200$$

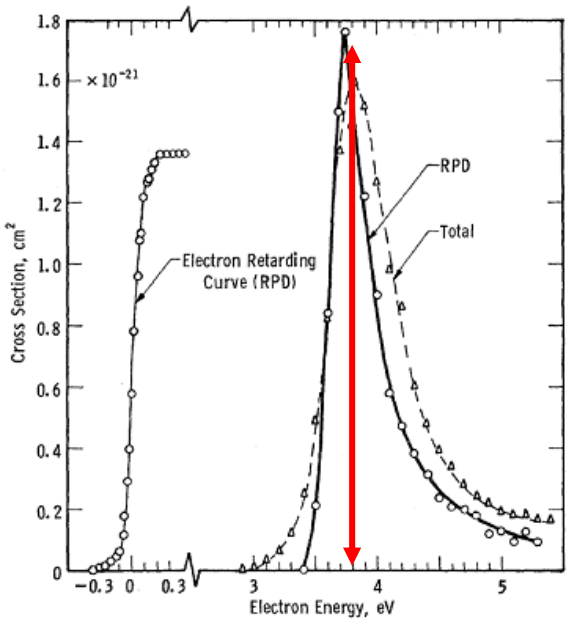
Situation in H_2 (4 eV resonance)

PHYSICAL REVIEW VOLUME 158, NUMBER 1 5 JUNE 1967

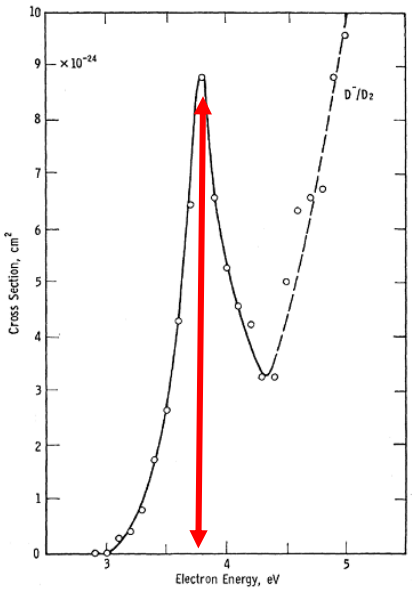
Isotope Effect in the Dissociative Attachment in H_2 at Low Energy*

G. J. SCHULZ† AND R. K. ASUNDI‡
Westinghouse Research Laboratories, Pittsburgh, Pennsylvania
(Received 6 September 1966)

H^-/H_2



D^-/D_2



?

'Reference' number

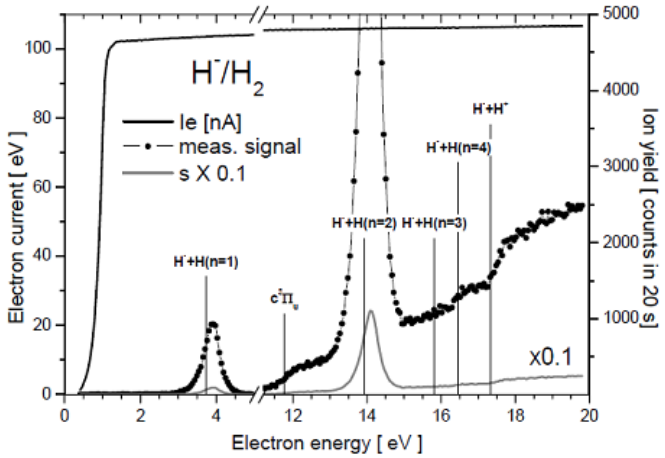
$$\frac{\sigma(H^-/H_2)}{\sigma(D^-/D_2)} = 200$$

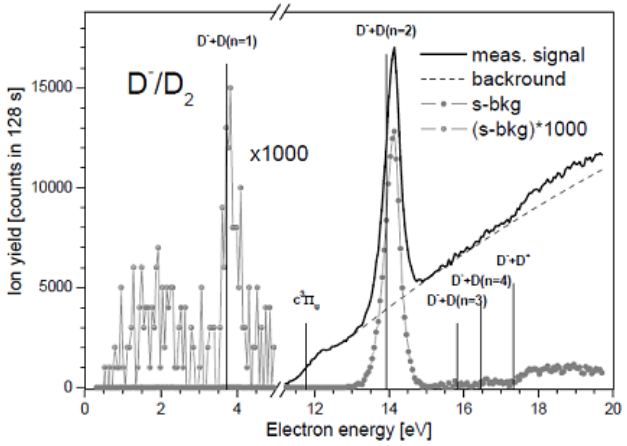
Situation in H_2 (4 eV resonance)

24th Summer School and International Symposium on the Physics of Ionized Gases IOP Publishing
Journal of Physics: Conference Series 133 (2008) 012029 doi:10.1088/1742-6596/133/1/012029

Processes with neutral hydrogen and deuterium molecules relevant to edge plasma in tokamaks

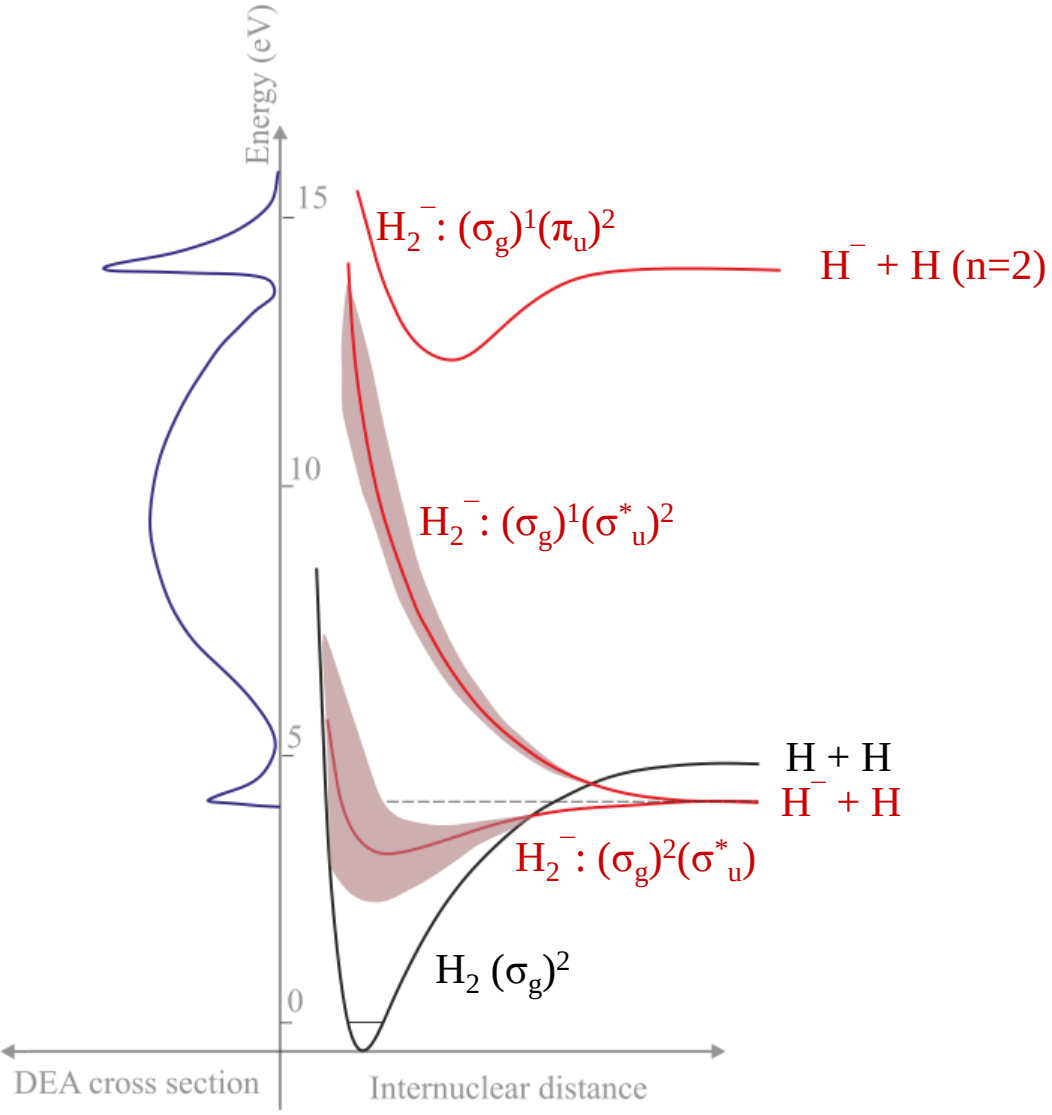
Iztok Čadež, Sabina Markelj, Zdravko Rupnik and Primož Pelicon
Jožef Stefan Institute, Jamova cesta 39, 1000 Ljubljana, Slovenia





$$\frac{\sigma(H^-/H_2)}{\sigma(D^-/D_2)} = 325$$

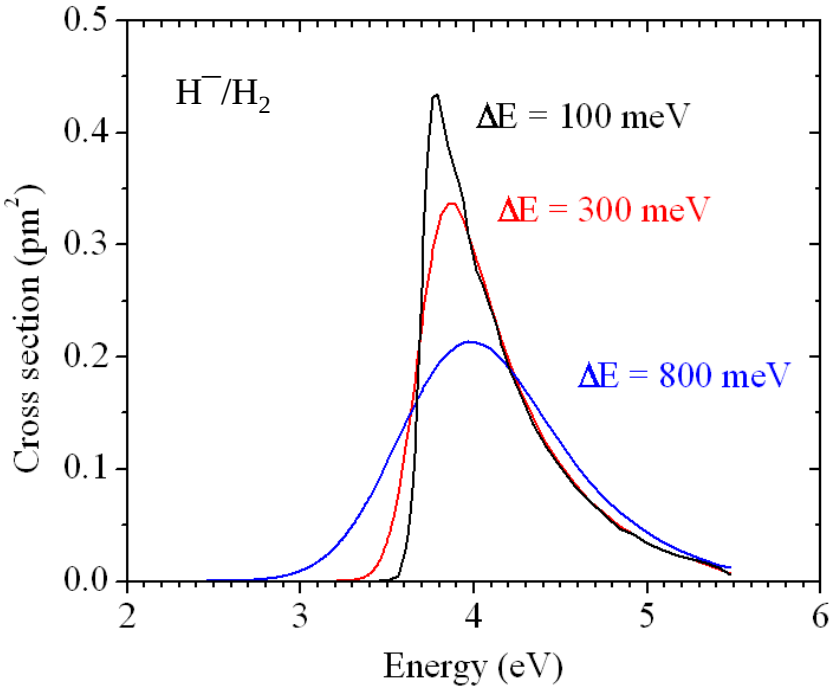
Situation in H_2 (higher-lying resonances)



Experimental DEA cross sections:

- Schulz, Asundi 1965, 1967
- Rapp, Briglia 1965
- Krishnakumar et al. 2011

Effect of electron-beam resolution



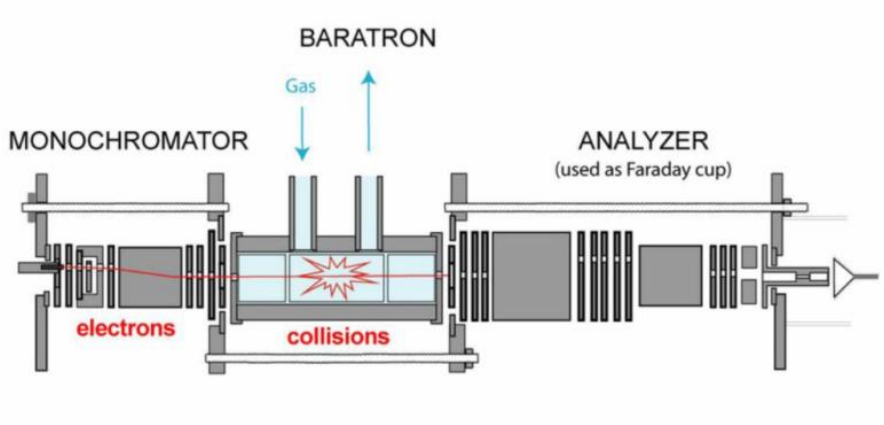
Invariant: energy-integrated cross section $\sigma_I = \int \sigma(E) dE$

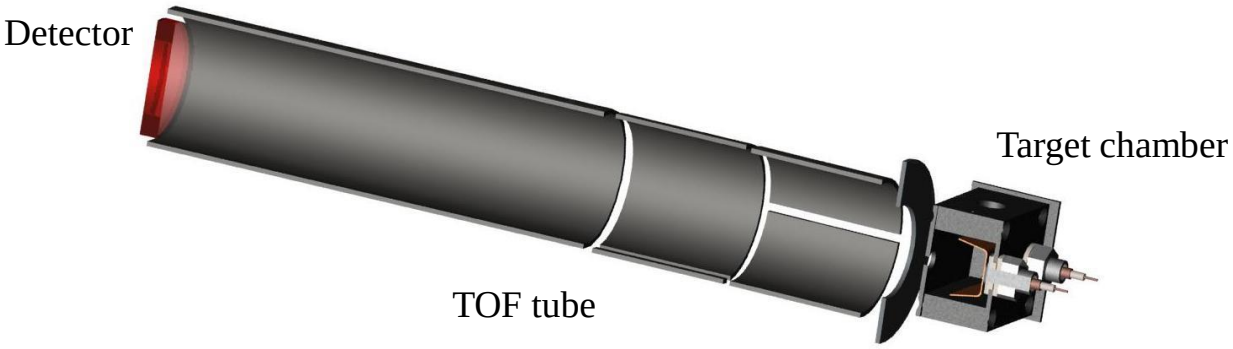
$[\sigma_I]$ = pm^2 eV

1 pm^2 = 10^{-20} cm^2

Experiment (Fribourg $\xrightarrow{2015}$ Prague)

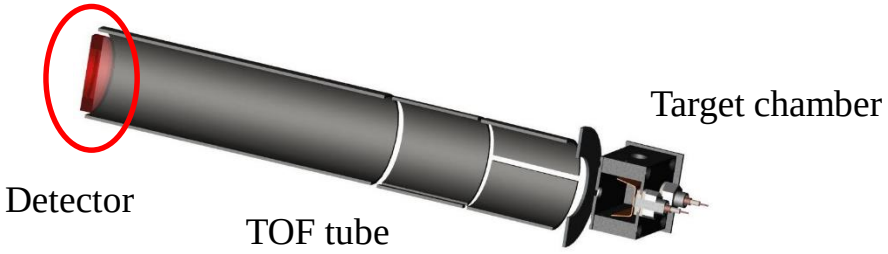
Quantitative negative-ion TOF spectrometer





Experiment

Quantitative negative-ion TOF spectrometer



Recent upgrade:

RoentDek time- and position-sensitive detector

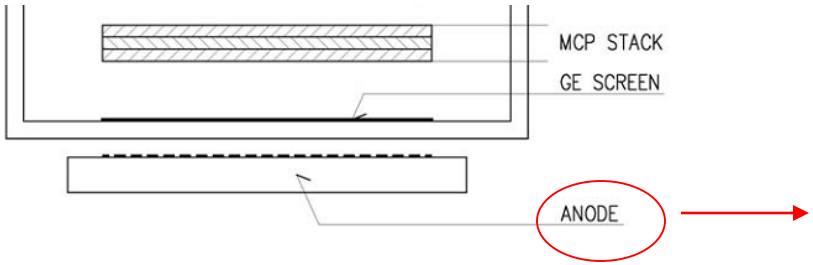
MCP

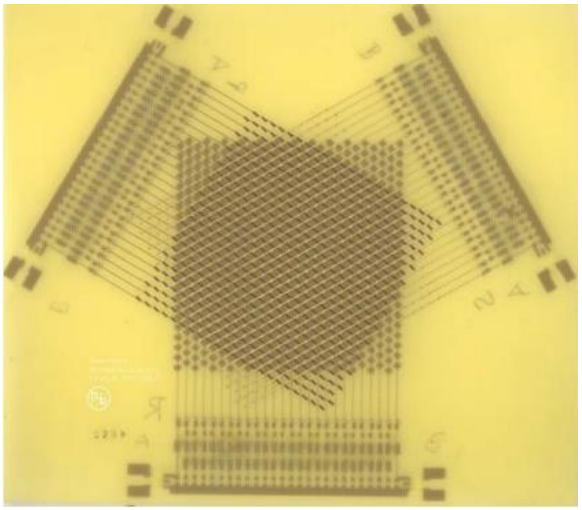
↓

Resistive Ge screen

↓

External charge-pickup delay-line anode



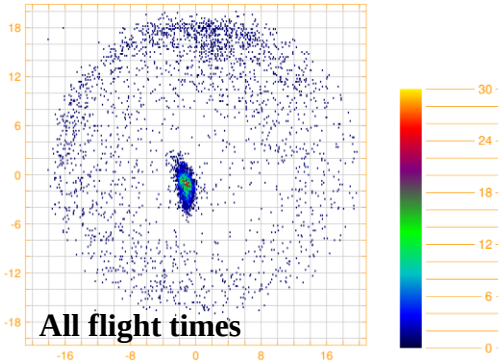


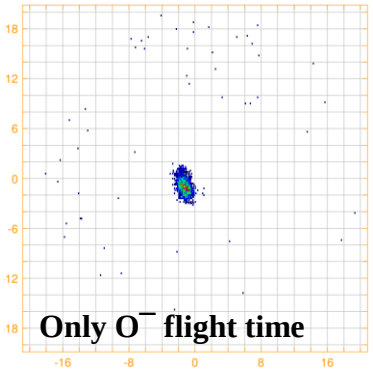
Experiment

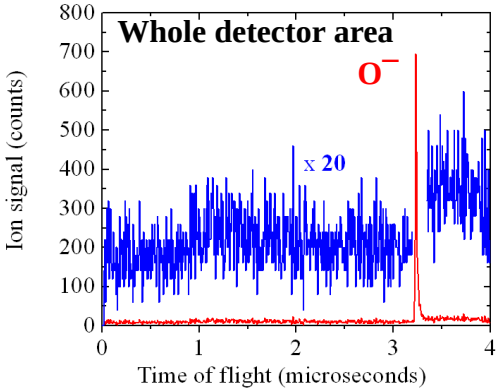
Position information

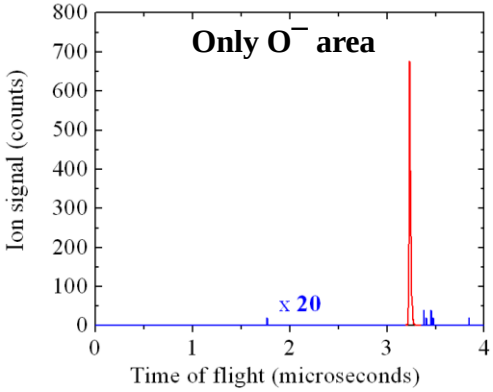
Timing information

O^-/CO_2, E_e = 4.4 eV (σ_I = 13.3 eV pm^2)

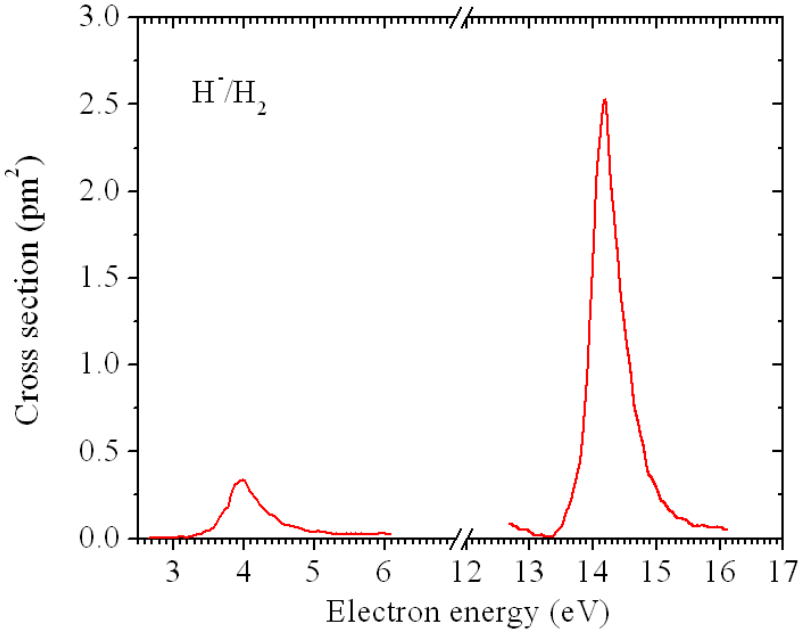


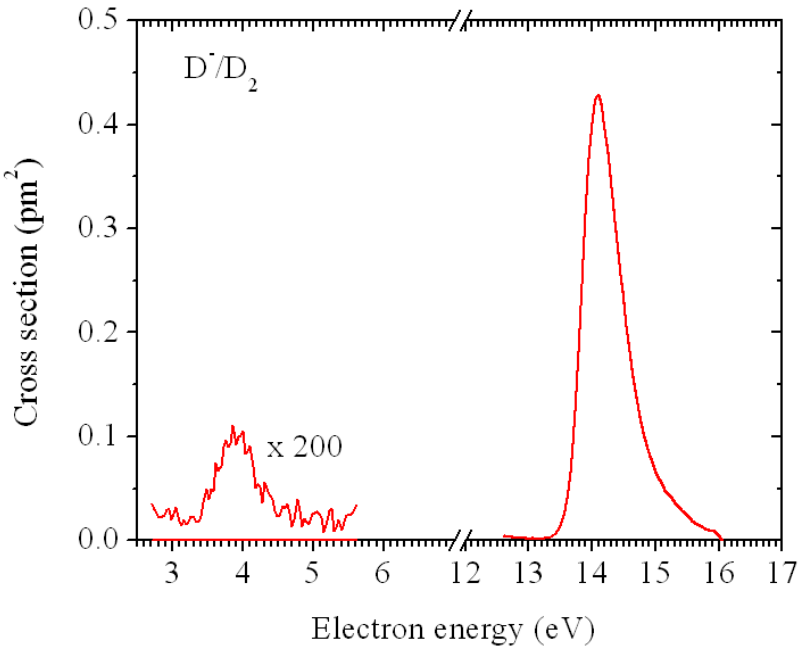






Results

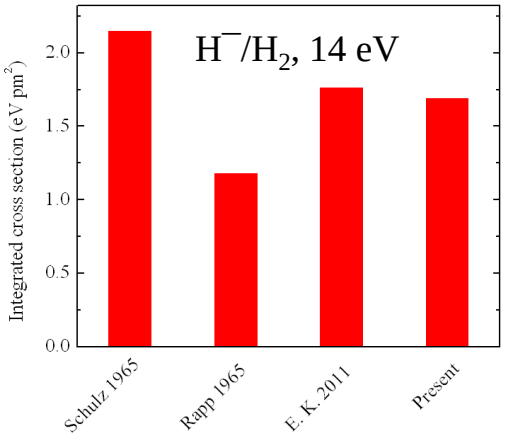


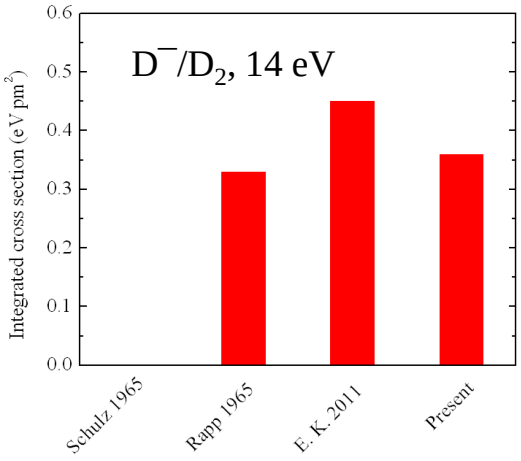


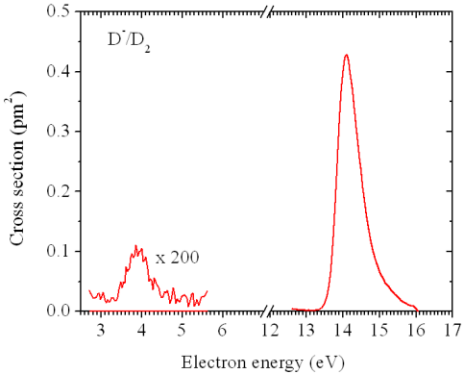
$$\frac{\sigma_I(H^-/H_2)}{\sigma_I(D^-/D_2)} = 780$$

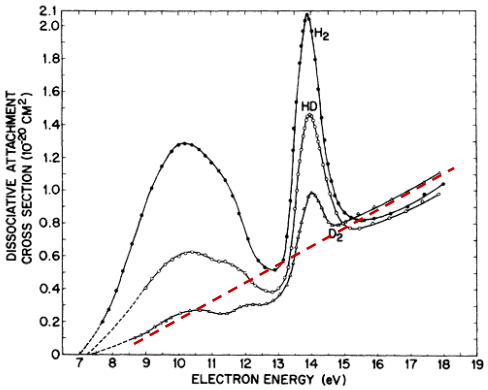
1 pm^2 = 10^{-20} cm^2

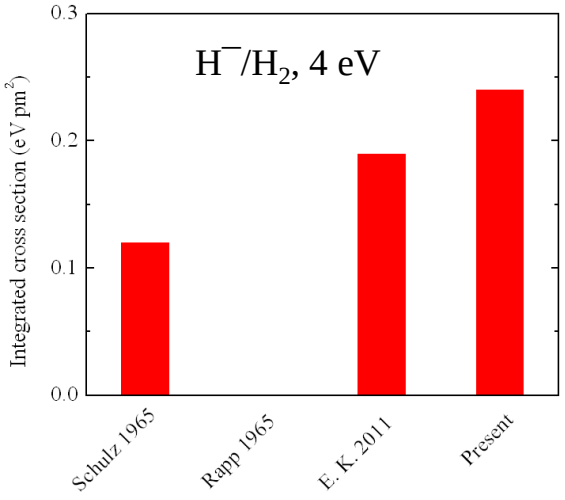
Comparison with existing exp. data

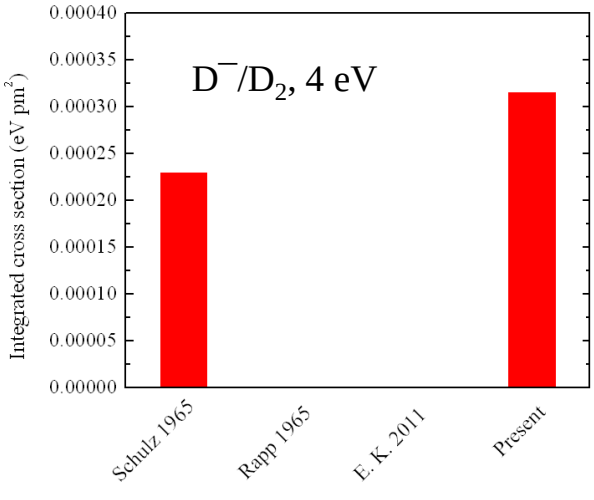


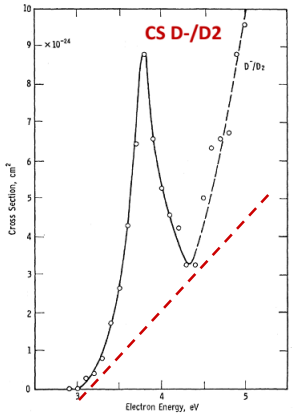




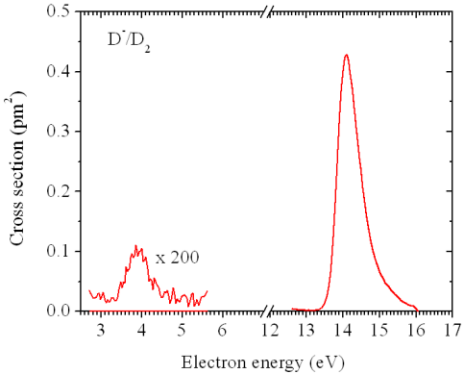






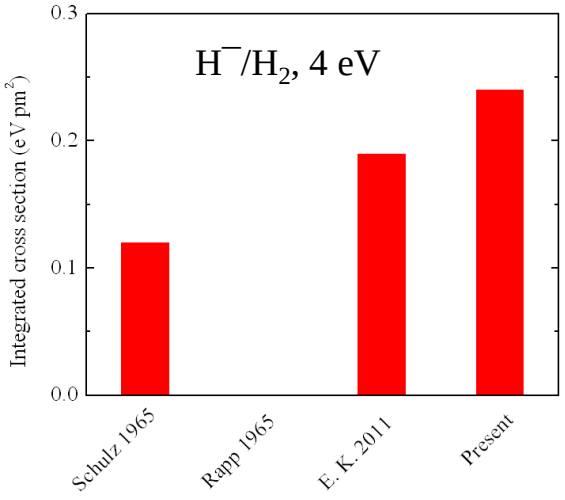


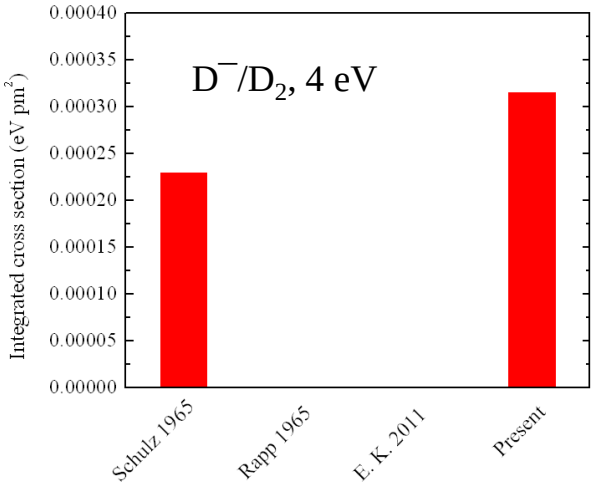
Comparison with existing exp. data

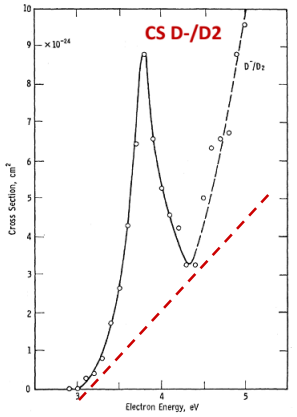


Schulz 1967: $\dfrac{\sigma_I(H^-/H_2)}{\sigma_I(D^-/D_2)} = 510$

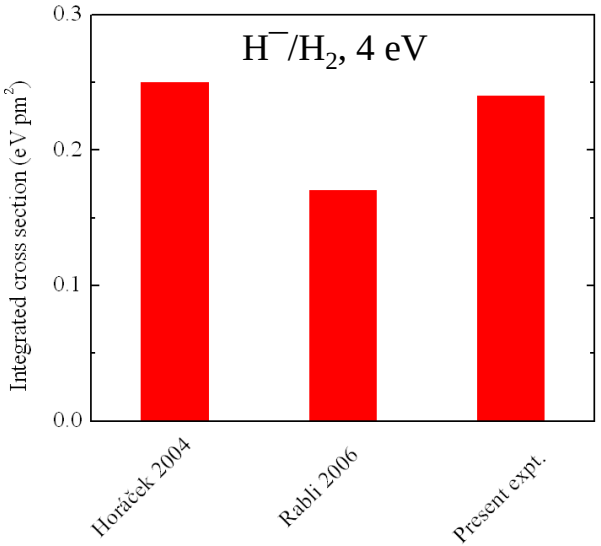
Present: $\dfrac{\sigma_I(H^-/H_2)}{\sigma_I(D^-/D_2)} = 780$







Comparison with theory (4 eV resonance)



PHYSICAL REVIEW A **70**, 052712 (2004)

Dissociative electron attachment and vibrational excitation of H_2 by low-energy electrons: Calculations based on an improved nonlocal resonance model

J. Horáček,* M. Čížek, K. Houfek, and P. Kolorenč
Institute of Theoretical Physics, Charles University, Prague, Czech Republic

W. Domcke
Department of Chemistry, Technical University of Munich, D-85747 Garching, Germany
(Received 21 May 2004; published 23 November 2004)

Horáček 2004: $\dfrac{\sigma_I(H^-/H_2)}{\sigma_I(D^-/D_2)} = 385$ Present: $\dfrac{\sigma_I(H^-/H_2)}{\sigma_I(D^-/D_2)} = 780$

Associative detachment: $H^- + H \rightarrow H_2 + e^-$

www.sciencemag.org **SCIENCE** VOL 329 2 JULY 2010

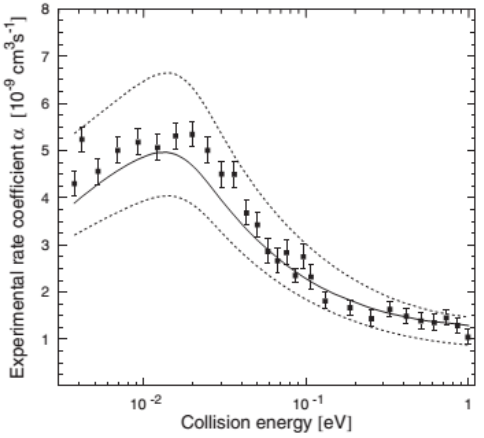
Experimental Results for H_2 Formation from H^- and H and Implications for First Star Formation

H. Kreckel,[1]*† H. Bruhns,[1]‡ M. Čížek,[2] S. C. O. Glover,[3] K. A. Miller,[1] X. Urbain,[4] D. W. Savin[1]

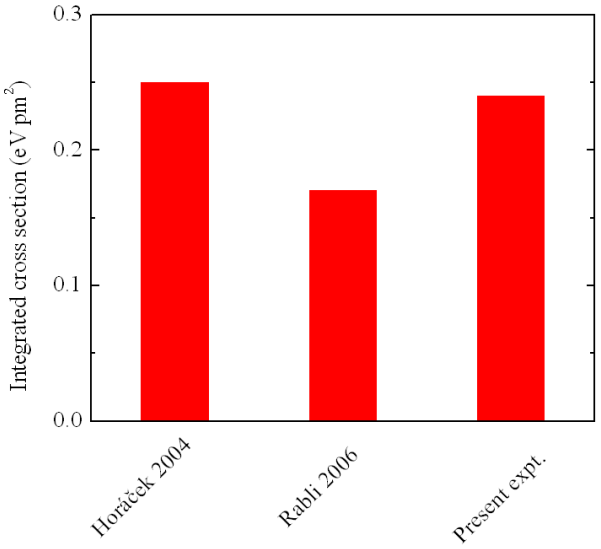
PHYSICAL REVIEW A **86**, 032714 (2012)

Isotope effect for associative detachment: $H(D)^- + H(D) \rightarrow H_2(D_2) + e^-$

K. A. Miller,[1] H. Bruhns,[1,*] M. Čížek,[2] J. Eliášek,[2] R. Cabrera-Trujillo,[3] H. Kreckel,[1,†]
A. P. O'Connor,[1] X. Urbain,[4] and D. W. Savin[1]



Comparison with theory (4 eV resonance)



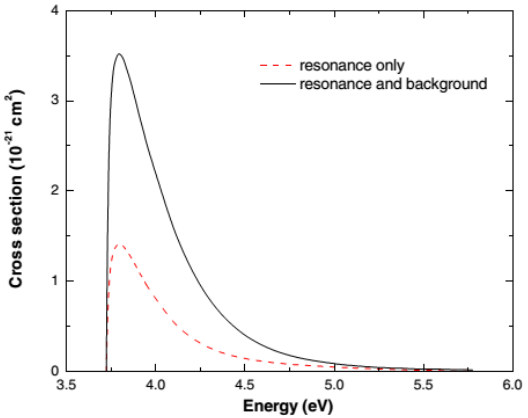
PRL **97,** 013201 (2006) PHYSICAL REVIEW LETTERS week ending 7 JULY 2006

Importance of Nonresonant Scattering in Low-Energy Dissociative Electron Attachment to Molecular Hydrogen

Djamal Rabli and Michael A. Morrison*

Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma, Norman, Oklahoma 73019-2061, USA

(Received 23 March 2006; published 7 July 2006)



Conclusion

Updated experimental cross sections for

$$H_2 + e \rightarrow (H_2^-)^* \rightarrow H^- + H$$

$$D_2 + e \rightarrow (D_2^-)^* \rightarrow D^- + D$$

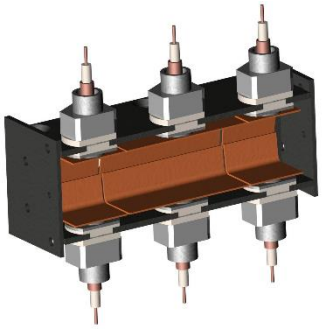
Experimental uncertainty

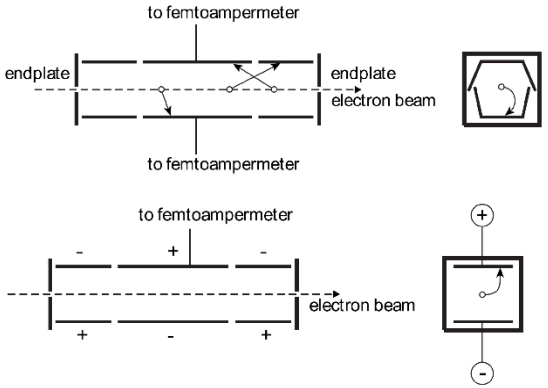
± ?

Standard procedure: error budget ± 25 % **essure, current, calibration compound)**

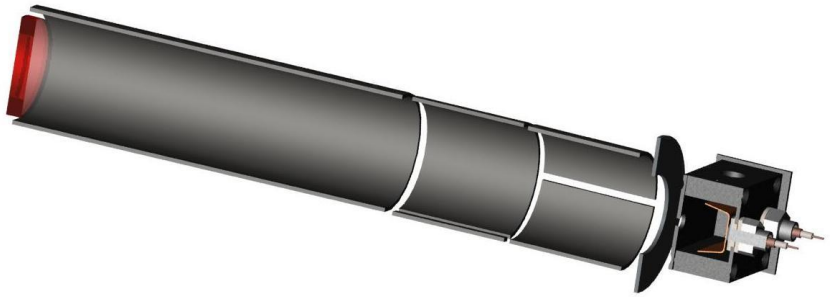
Additionally: measure the same cross section in different ways

Total ion collection





TOF anion analysis

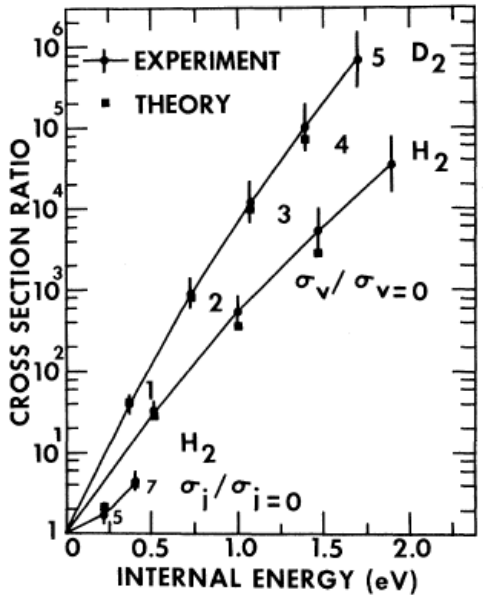


Significance: small cross section?

VOLUME 41, NUMBER 26 PHYSICAL REVIEW LETTERS 25 DECEMBER 1978

Effect of Vibrational and Rotational Exictation on Dissociative Attachment in Hydrogen

M. Allan and S. F. Wong
Department of Engineering and Applied Science, Mason Laboratory, Yale University, New Haven, Connecticut 06520
(Received 21 September 1978)

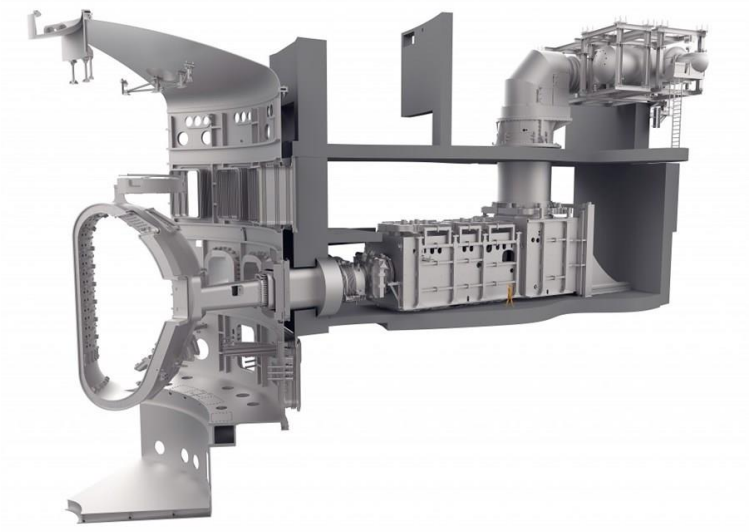


Dramatic increase at elevated temperature!

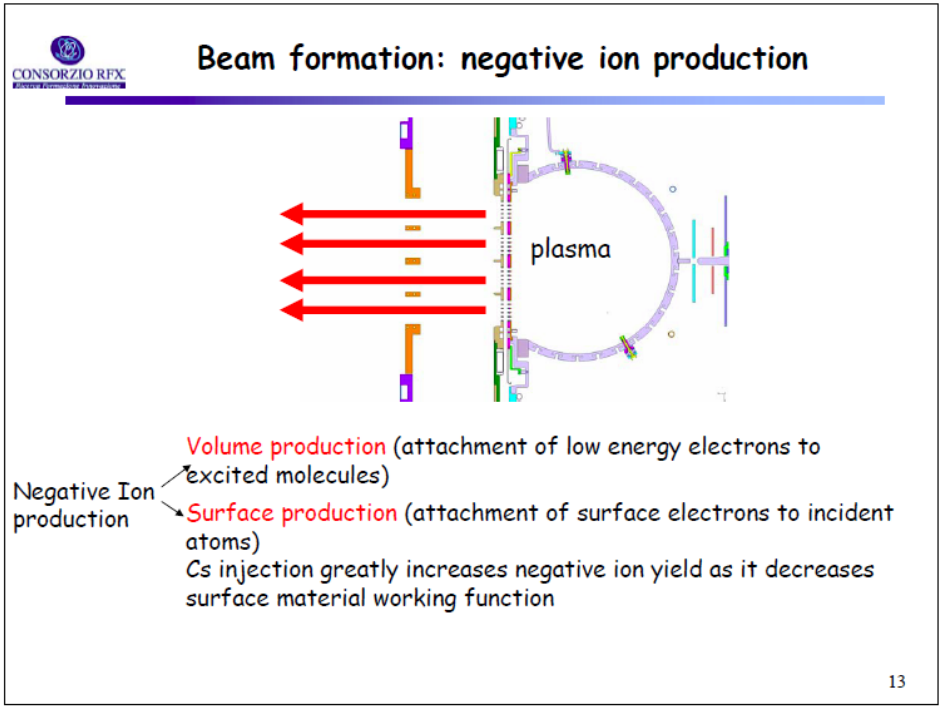
Significance: neutral-beam injection heating for ITER

Ion source → **Acceleration (MeV)** → **Neutralization** → **Injection**

H^- / D^-



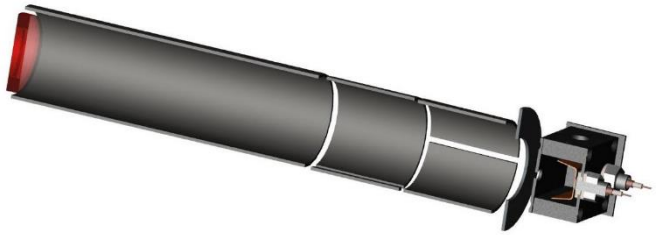
www.iter.org



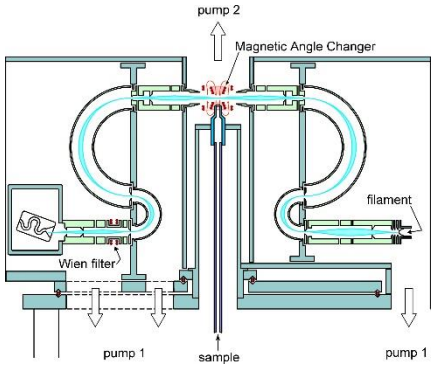
Outlook

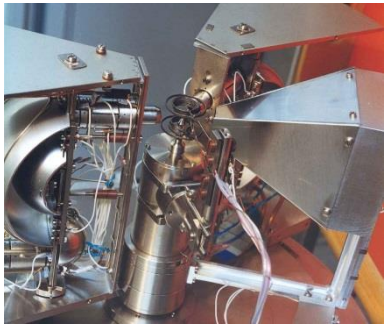
Prague electron collision laboratory fully operative

DEA cross sections



Scattering cross sections





Collaborations welcome!

2 Postdoc positions available (spring/summer 2017)

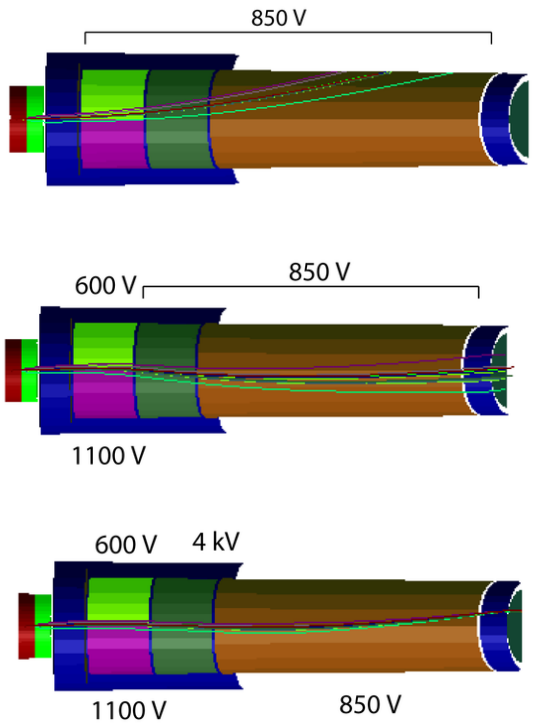
Acknowledgements

R. Janečková

J. Kočišek

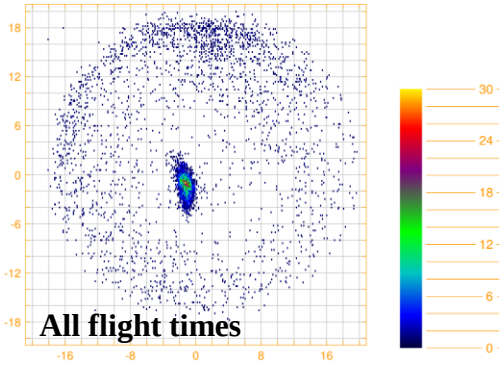
Experiment

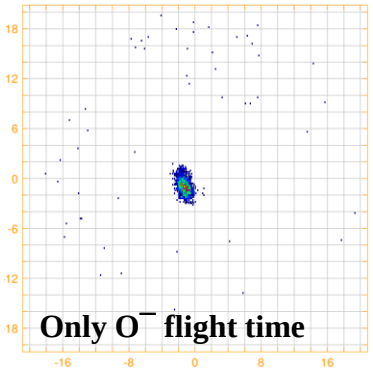
CPO3D simulations (2008)



Time-and-position sensitive detector (2014)

O^-/CO_2, E_e = 4.4 eV (σ_I = 13.3 eV pm^2)





Signal-background separation