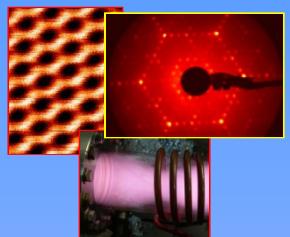


# H-graphite interactions: Experimental evidences of H atoms temperature influence

E. Aréou, C. Thomas, G. Cartry, J.M. Layet, T. Angot

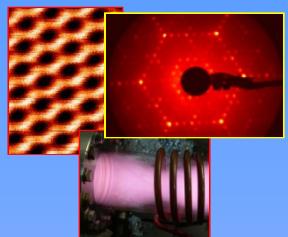
Laboratoire de Physique des Interactions Ioniques et Moléculaires  
UMR 6633 Université de Provence / CNRS



# Importance of H atoms energy in the adsorption / abstraction process

E. Aréou, C. Thomas, G. Cartry, J.M. Layet, T. Angot

Laboratoire de Physique des Interactions Ioniques et Moléculaires  
UMR 6633 Université de Provence / CNRS

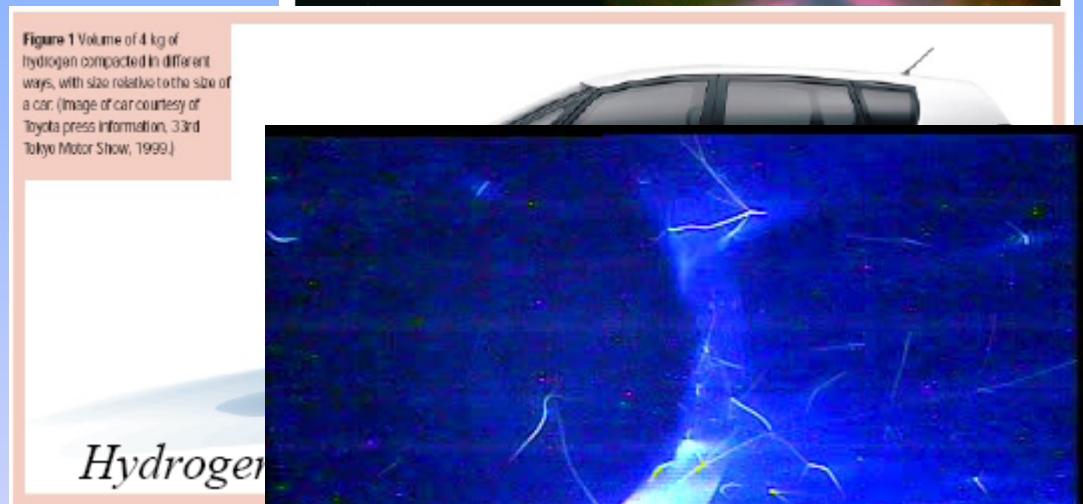


# Context

- Astrophysics:

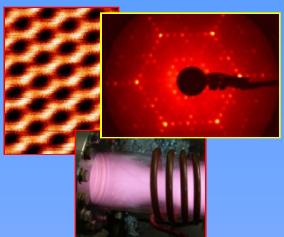


- H storage:



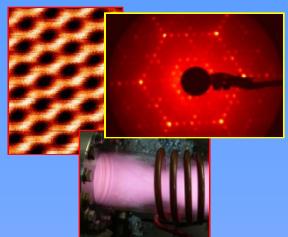
- Fusion applications:





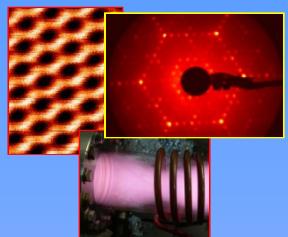
# Outline

- I. Experimental details
- II. H-graphite: adsorption barrier
- III. H-graphite: abstraction mechanism
- IV. Conclusions / Prospective

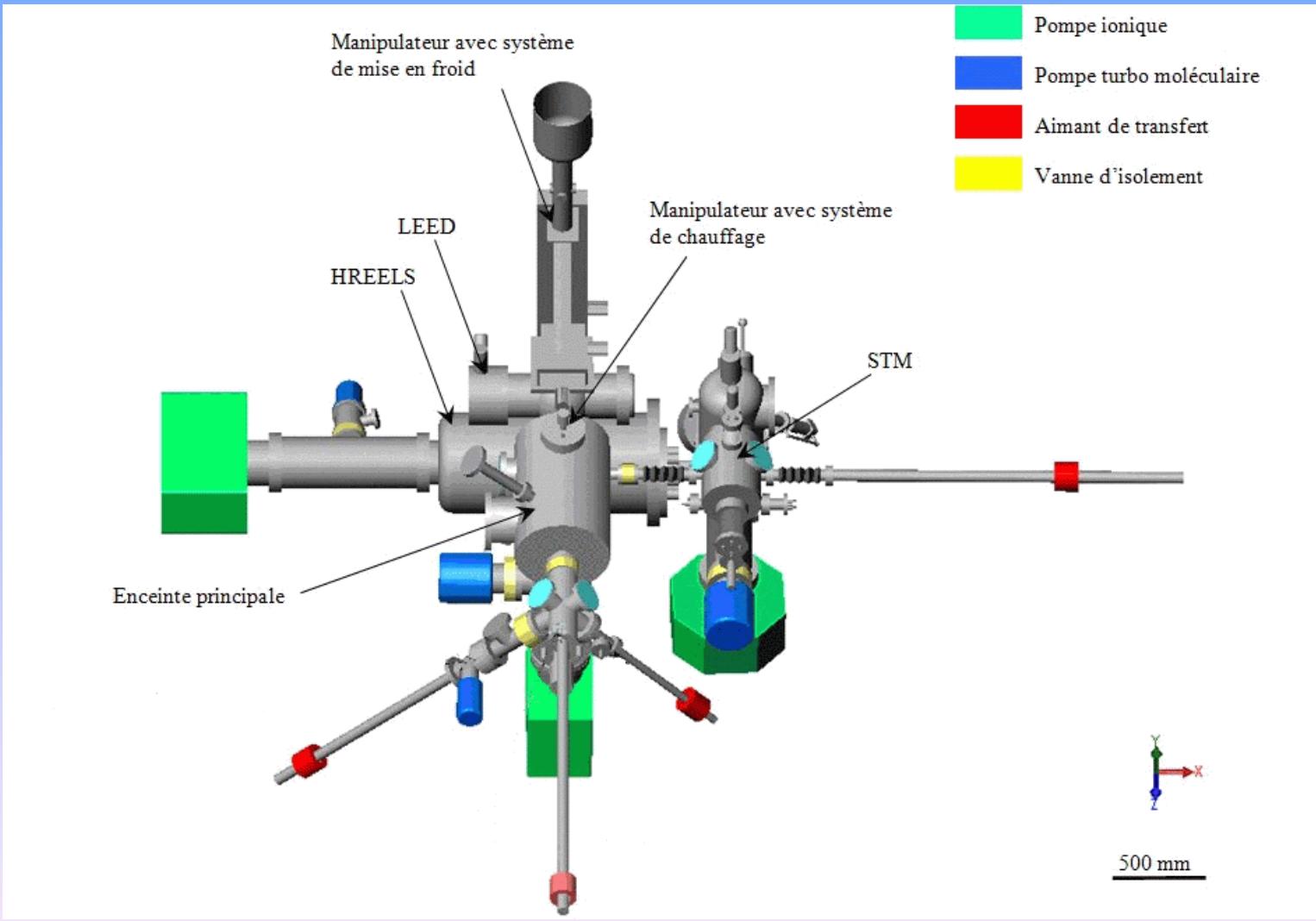


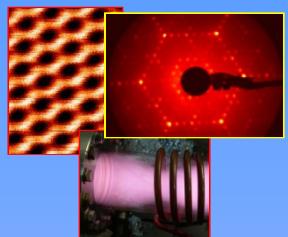
## Part I

# Experimental details

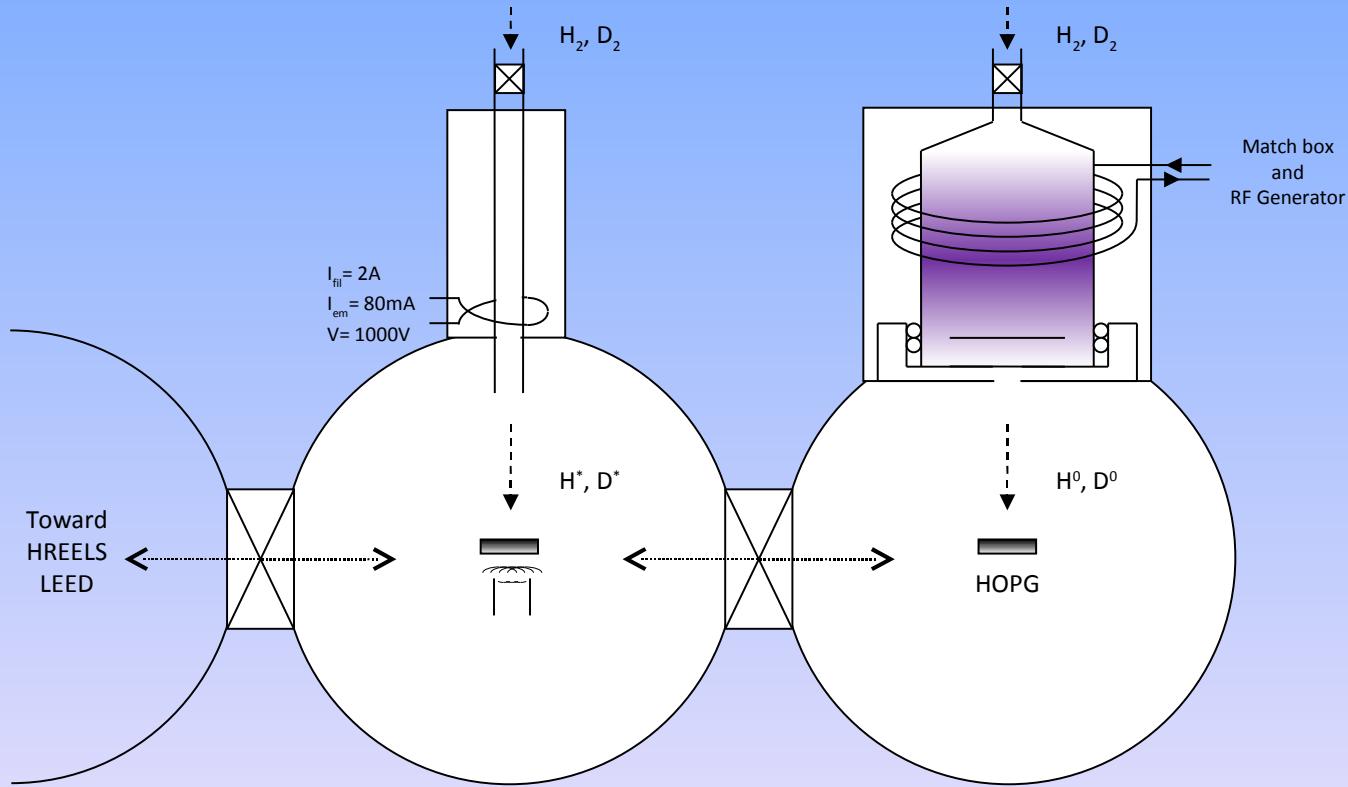


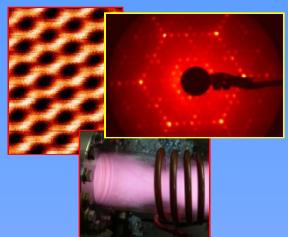
# Experimental overview (1)





# Experimental overview (2)





# Atomic H sources

## W- capillary (Omicron EFM-H)

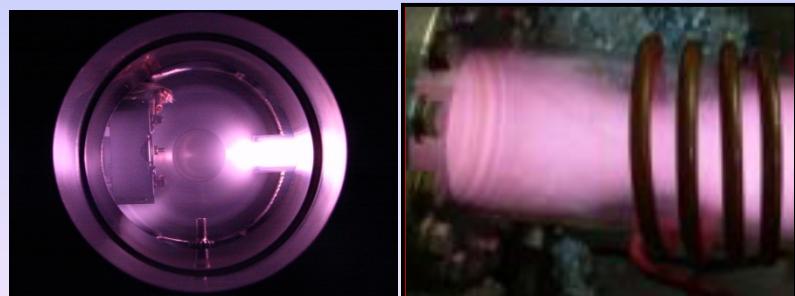
- Fine W capillary heated by  $e^-$  bombardment thermally dissociates  $H_2$
- Kinetic energy  $\approx 0.2$  eV
- Flux:  $10^{14}$ atoms.cm $^{-2}.$ s $^{-1}$

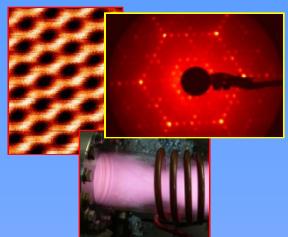


## Plasma source (designed by team)

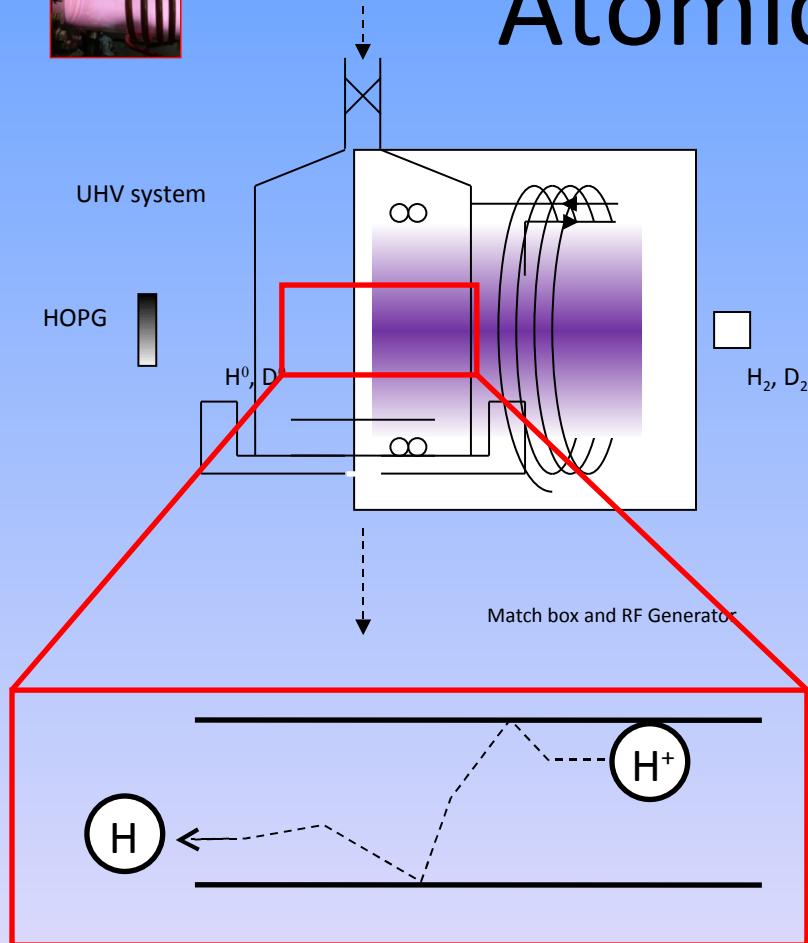
- Charged particles created in RF plasma recombine on pyrex tube
- Kinetic energy  $\approx 0.026$  eV
- Flux:  $10^{18}$ atoms.cm $^{-2}.$ s $^{-1}$
- Versatile source:

Atomic source or plasma source





# Atomic H sources

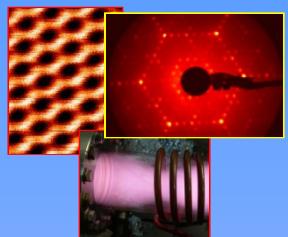


$H^+$  neutralize on pyrex tube

## Plasma source (designed by team)

- Charged particles created in RF plasma recombine on pyrex tube
- Kinetic energy  $\approx 0.026$  eV
- Flux:  $10^{18}$  atoms.cm $^{-2} \cdot s^{-1}$
- Versatile source:  
Atomic source or plasma source





# Atomic H sources

## W- capillary (Omicron EFM-H)

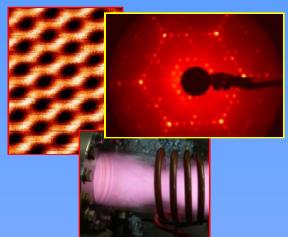
- Fine W capillary heated by  $e^-$  bombardment thermally dissociates H,
- Kinetic energy  $\approx 0.2$  eV
- Flux:  $10^{14}$ atoms.cm $^{-2}$ .s $^{-1}$

“HOT” Atoms

## Plasma source (designed by team)

- Charged particles created in RF plasma recombine on pyrex tube
- Kinetic energy  $\approx 0.026$  eV
- Flux:  $10^{18}$ atoms.cm $^{-2}$ .s $^{-1}$
- Versatile source:  
Atomic source or plasma source

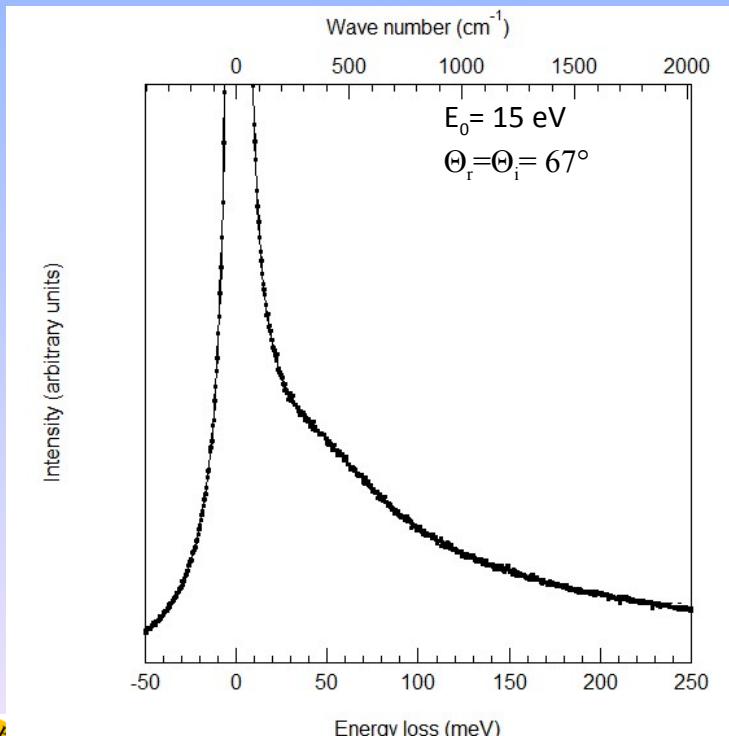
“COLD” Atoms



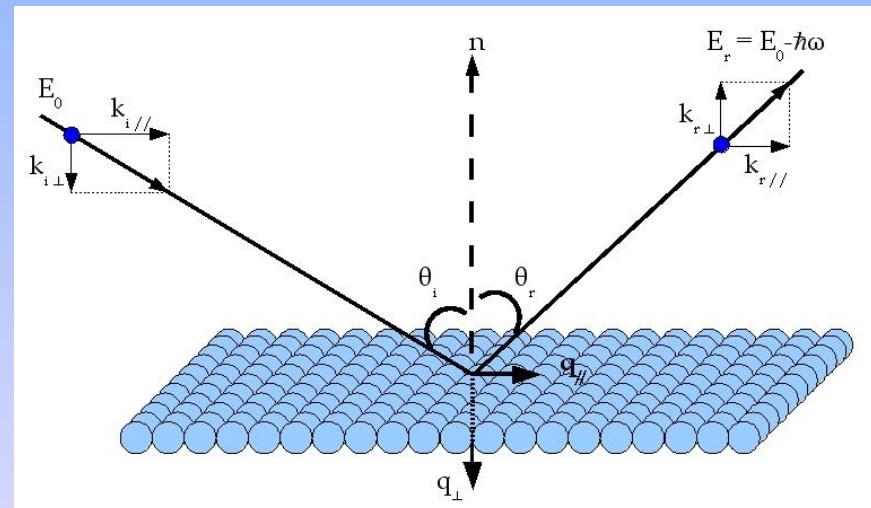
# Surface analysis

- High Resolution Electron Energy Loss Spectroscopy

Low energy primary  $e^-$  are scattered by the surface and analyzed according to their energy.

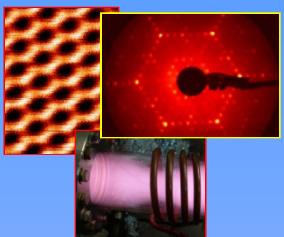


Oshima et al., *Solid State. Com.* (1998)



Electron-hole pair excitation, plasmon

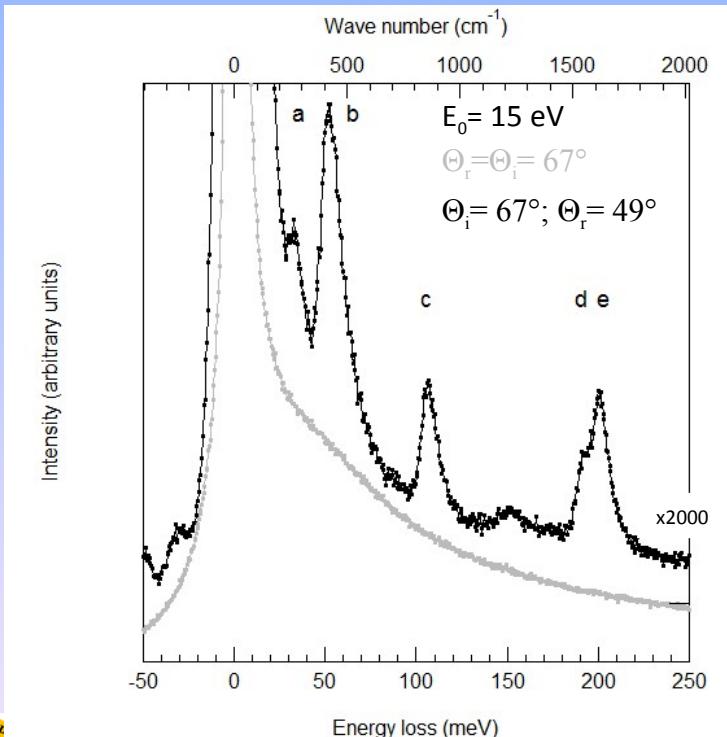
→ intense background losses



# Surface analysis

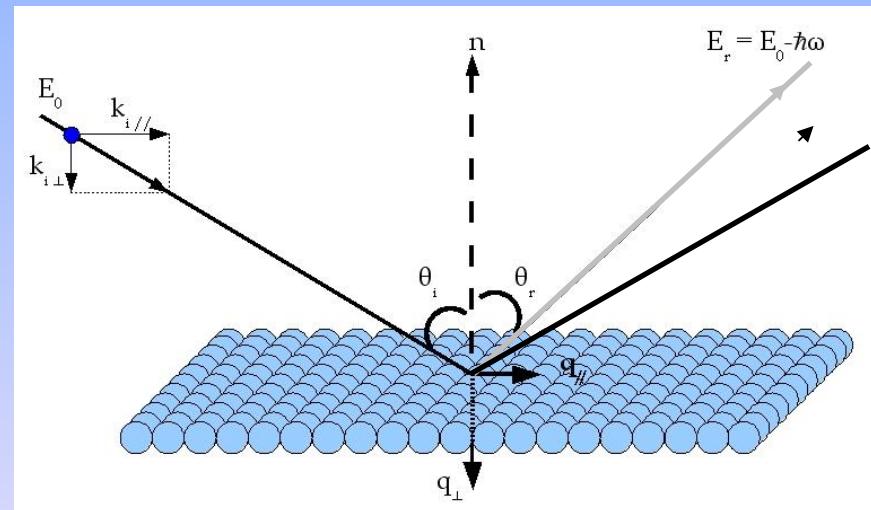
- High Resolution Electron Energy Loss Spectroscopy

Low energy primary  $e^-$  are scattered by the surface and analyzed according to their energy.

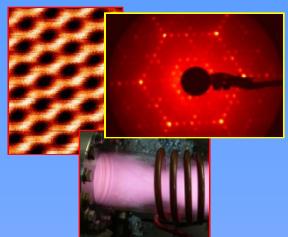


Oshima et al., Solid State. Com. (1998)

GDR Arches - 05/05/09

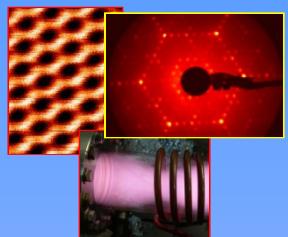


Out-of-specular geometry to access  
phonons and C-H (C-D) bonds vibrations.

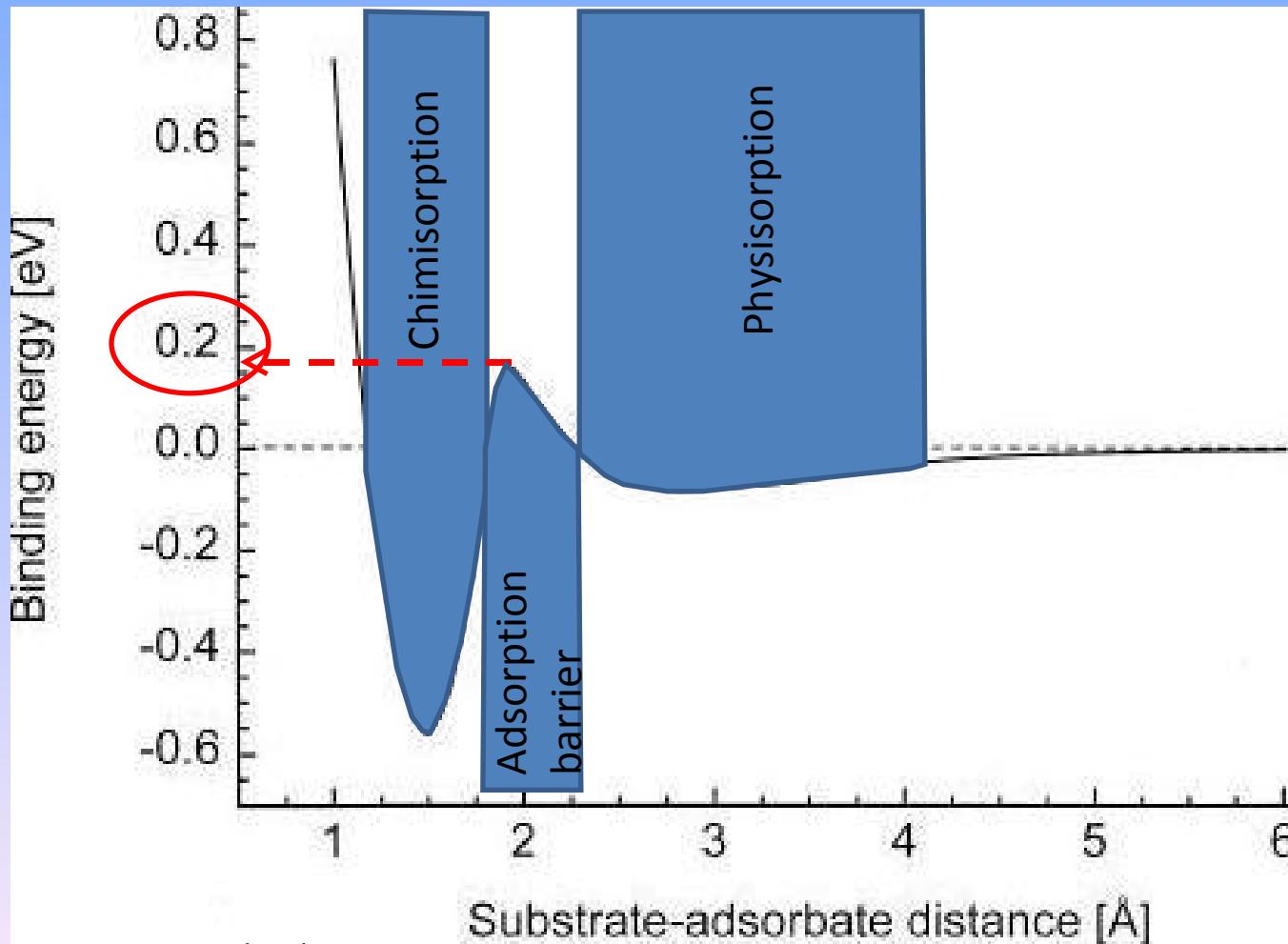


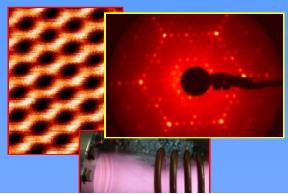
## Part II

# Cold H-graphite interaction: Adsorption barrier

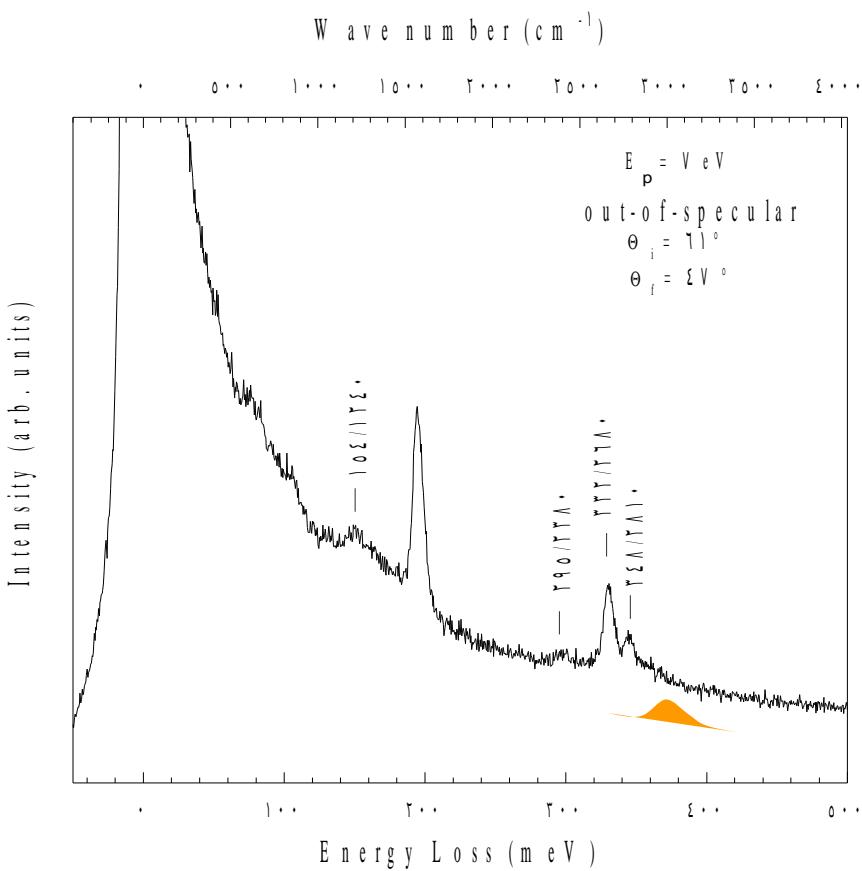


# Adsorption model: monomer

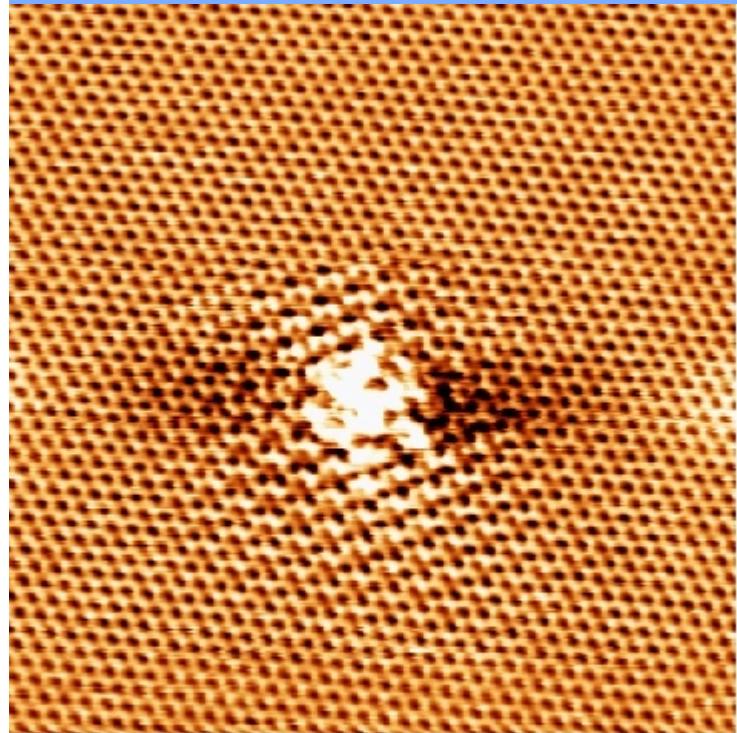




# Case of « hot » H



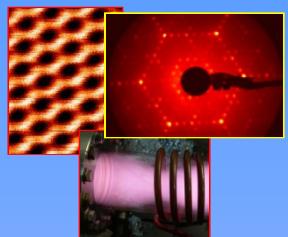
A. Allouche et al., *JCP* (2005)



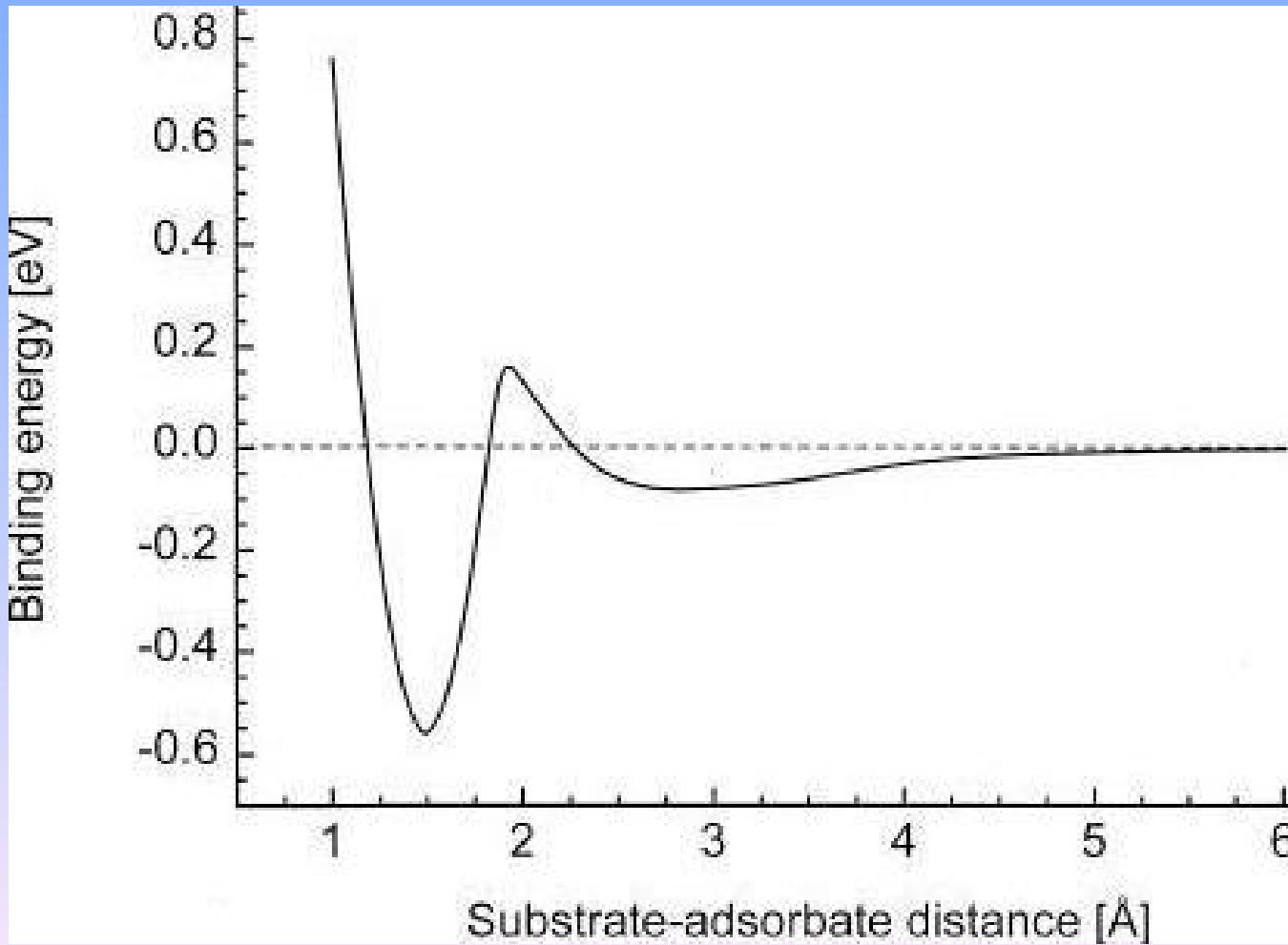
10.3 nm x 10.3 nm,  
 $V_{\text{bias}} = +30 \text{ mV}$ ,  $I_t = 0.25 \text{ nA}$ .

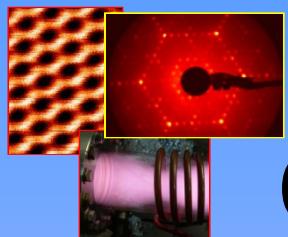
« Hot » H adsorb on HOPG surface.

What happens with « cold » H?

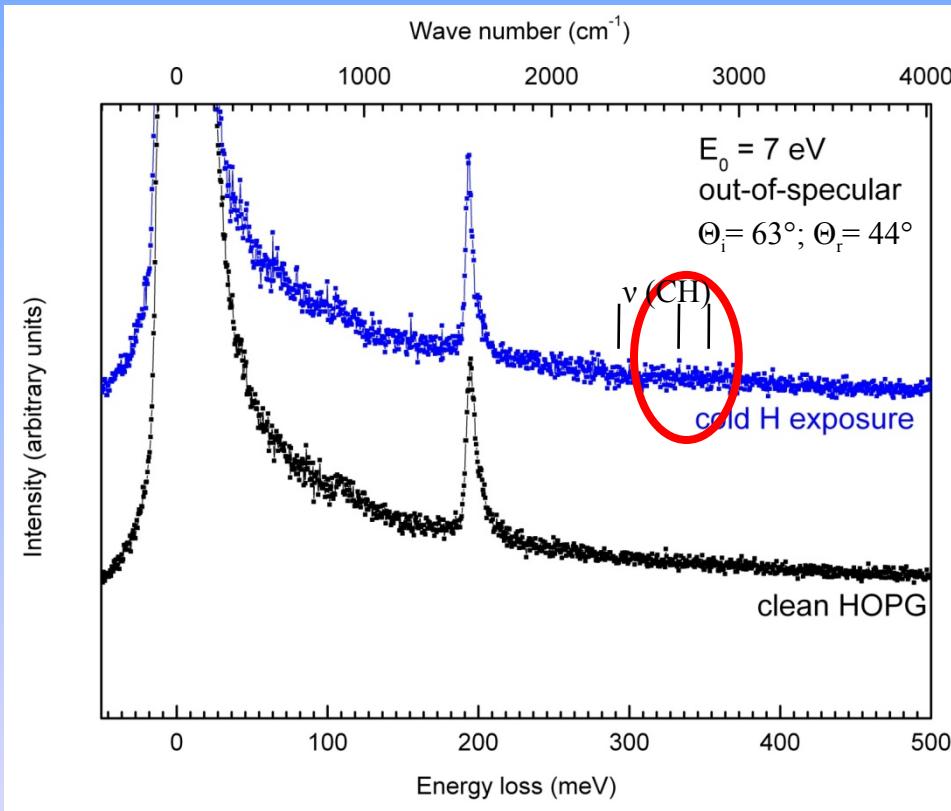


# Case of « cold » H (theory)





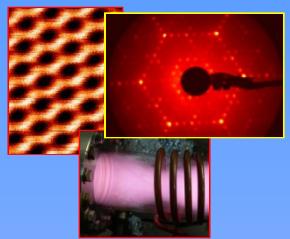
# Case of « cold » H (experiment)



No CH bond

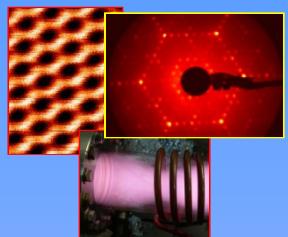
« Cold » H do NOT adsorb + « Hot » H do adsorb

First experimental evidence of the existence of an adsorption barrier

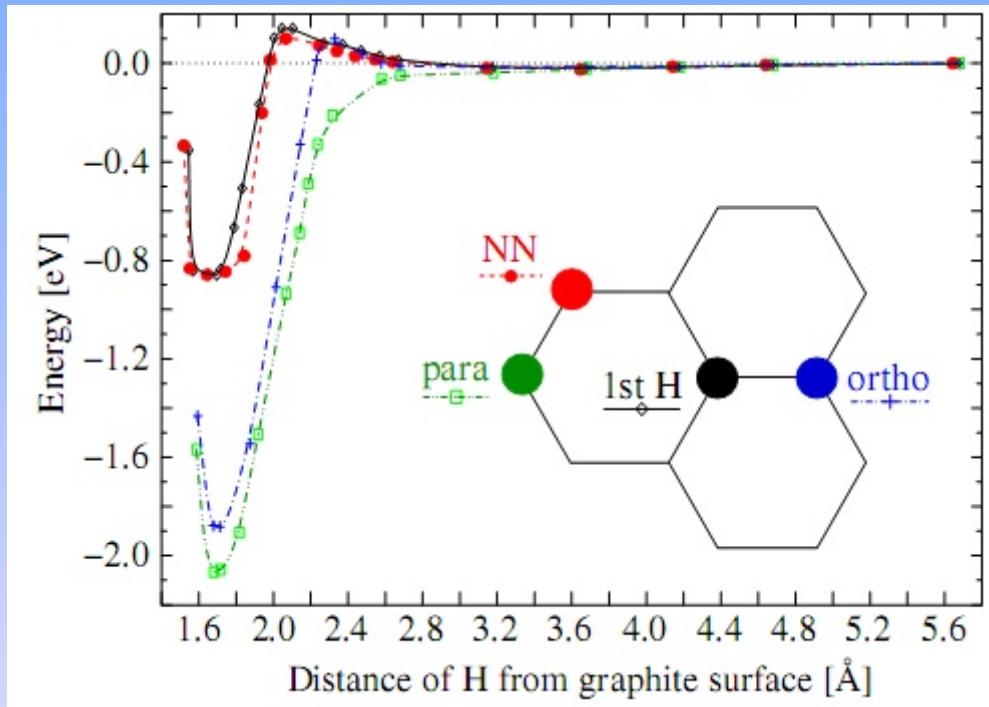


## Part III

# Cold H-graphite interaction: Abstraction mechanism



# Adsorption model: dimers

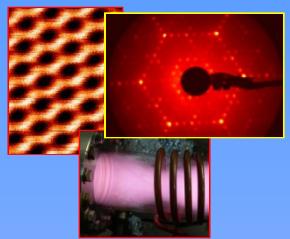


Adsorption of H on hydrogenated HOPG.

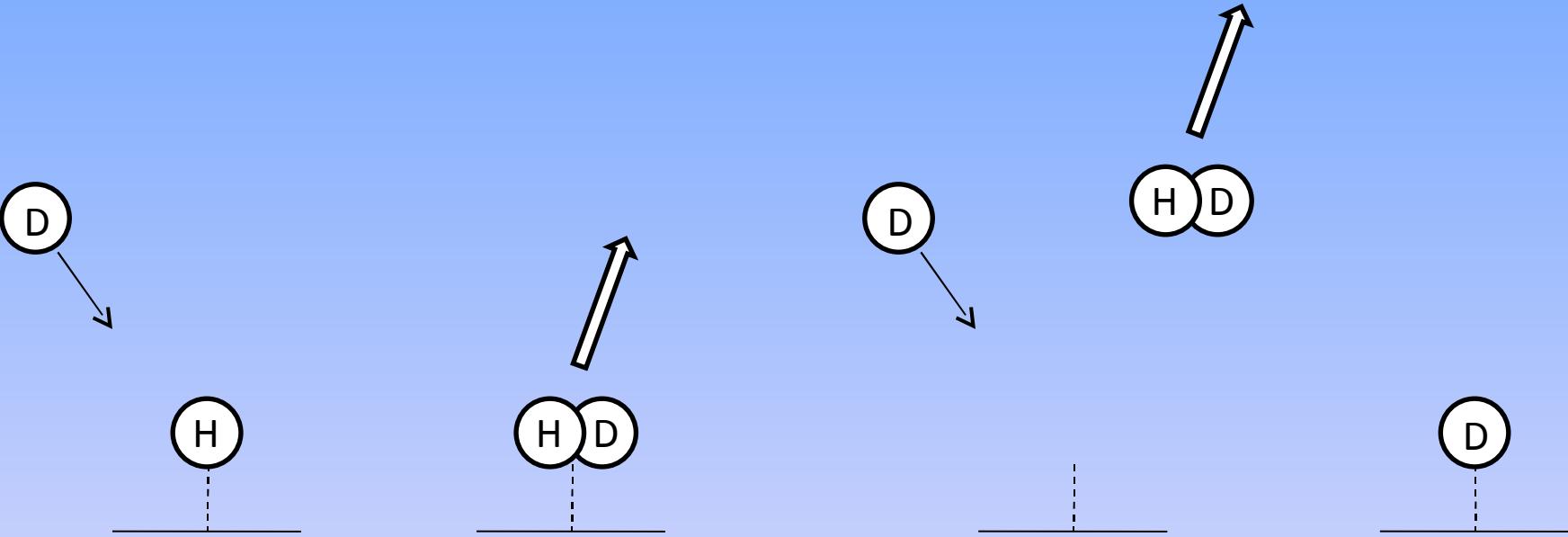
Barrier reducing and even vanishing for the second H atom into para-dimer.

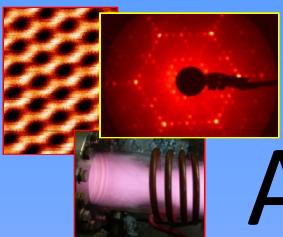
Y. Ferro et al., *CPL* (2003)  
 L. Hornekaer et al., *PRL* (2006)  
 N. Rougeau et al., *CPL* (2006)

Will « cold » atoms adsorb on hydrogenated (or deuteriated) surface?

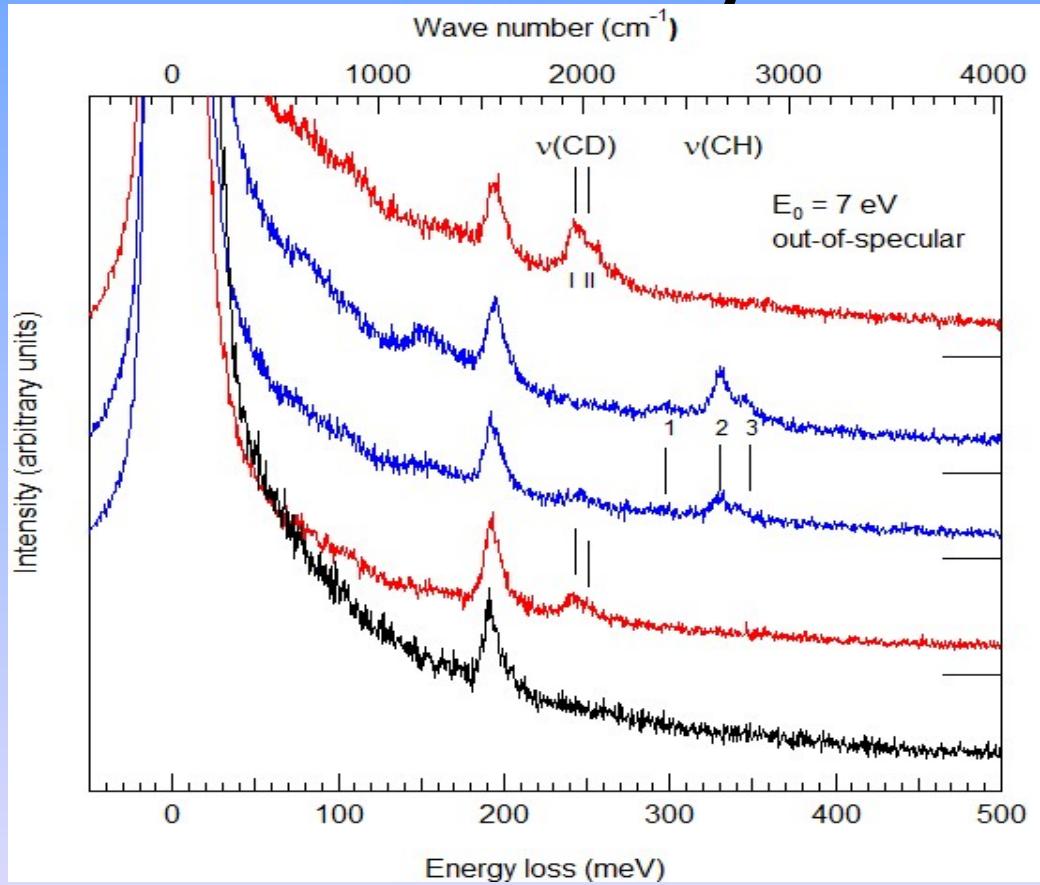


# Eley-Rideal mechanism





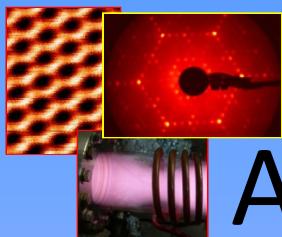
# Abstraction of D by « hot » H



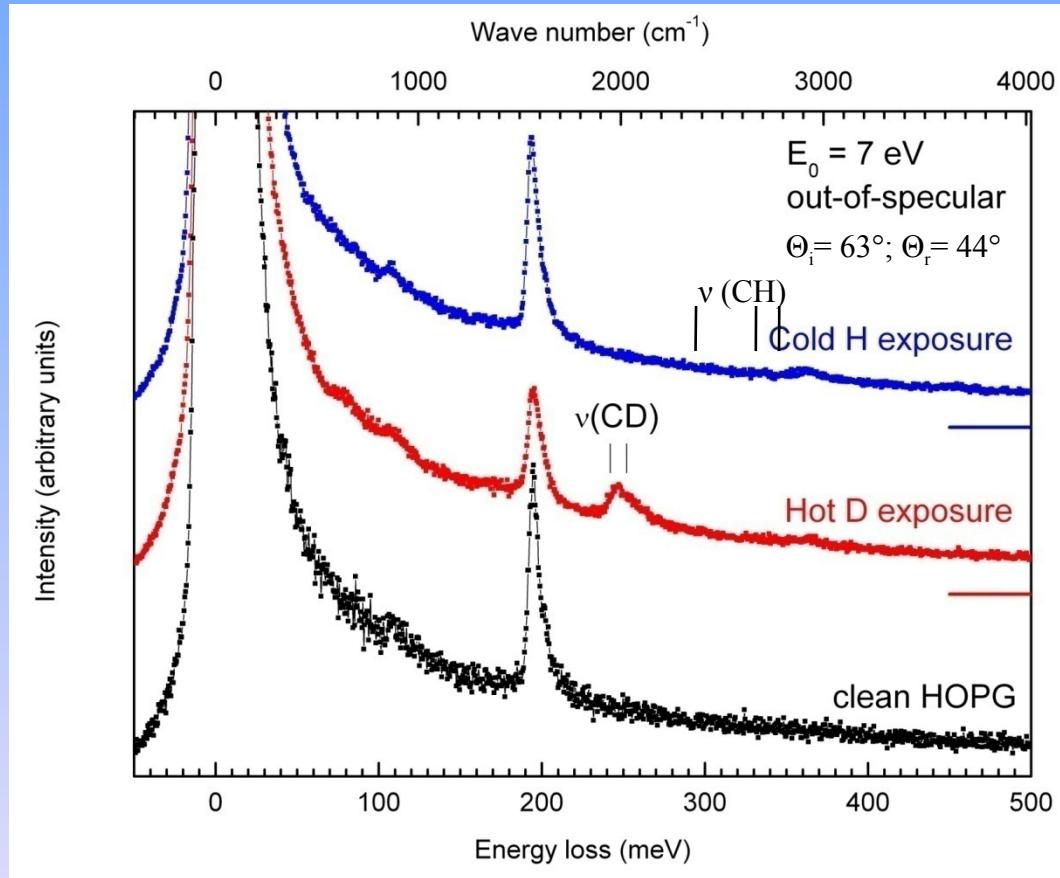
C. Thomas et al., *Surf. Science* (2008)

D (or H) abstracted by H (or D) following by D (or H) adsorption.

What happens with « cold » H?



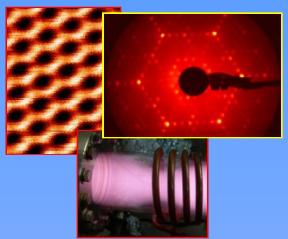
# Abstraction of D by « cold » H



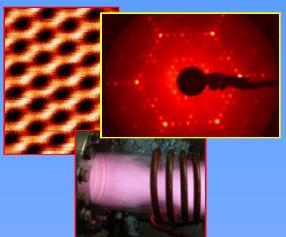
No CD bond  
No CH bond  
Phonon recovery

Adsorbed D completely removed of the surface but incoming “cold” H do NOT stick.

Recombination more efficient than sticking?



# Conclusions and prospectives



## Conclusions:

- Newly designed versatile source
- No adsorption of cold H
- Abstraction of adsorbed D by cold H

## Prospective:

- Plasma source flux reduction
- TDS experiments: Kinetic abstraction with cold atoms
- Atomic H temperature variation