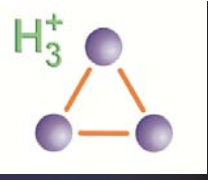
Charles University Prague
Faculty of Mathematics and Physics



Action spectroscopy of H_3^+ using overtone excitation Laser induced ion – molecule reactions

(IMR & Recombination of H_3^+)

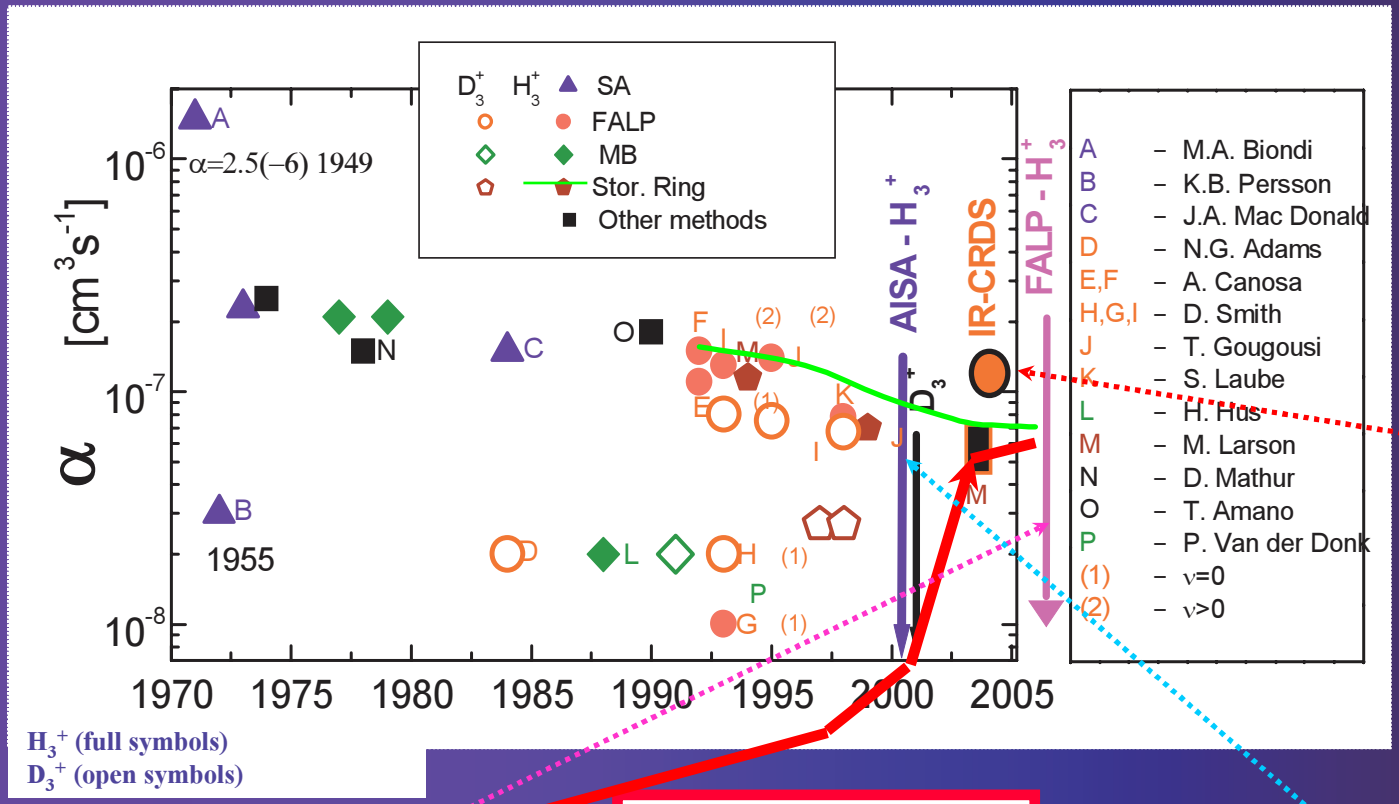
Juraj Glosík

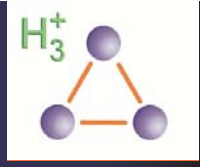
Charles University In Prague
Radek Plašil, Petr Hlavenka
Gregor Bánó, Ihor Korolov
Peter Macko, Oldřich Novotný
Jozef Varju, Tomáš Kotrík

MPIK Heidelberg (Freiburg)
Andreas Wolf, Hologer Kregel
Joachen Mikosch, Roland Wester
Daniel Zajfman, etc.

TU Chemnitz
Dieter Gerlich, Falk Windisch
Alfonz Luca

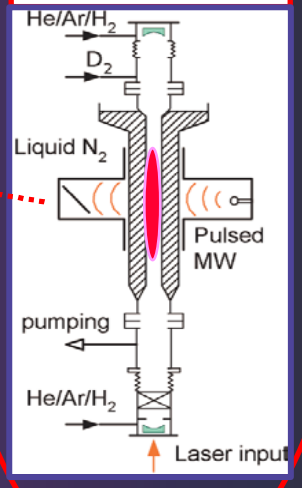
History of experiments –"time evolution" of $\alpha(H_3^+)$, $\alpha(D_3^+)$





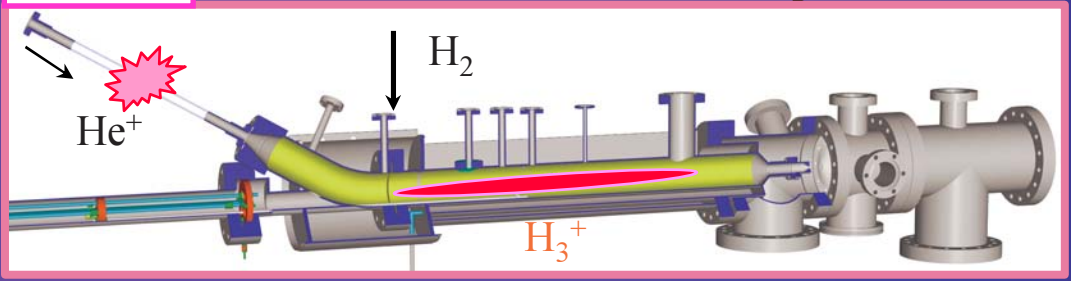
CRDS

Test Tube

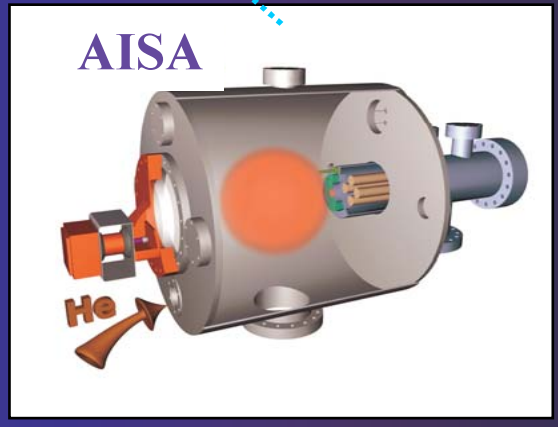


THEORY OF DR

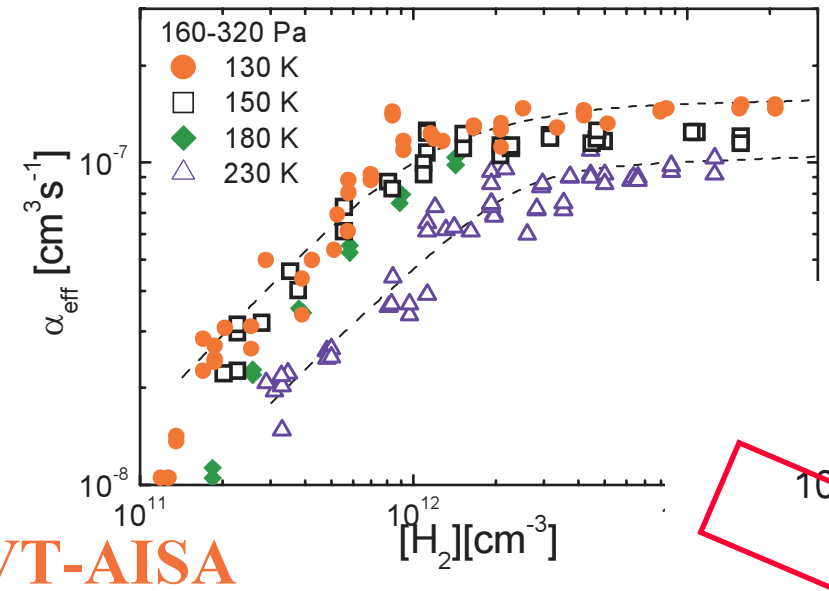
FALP



AISA

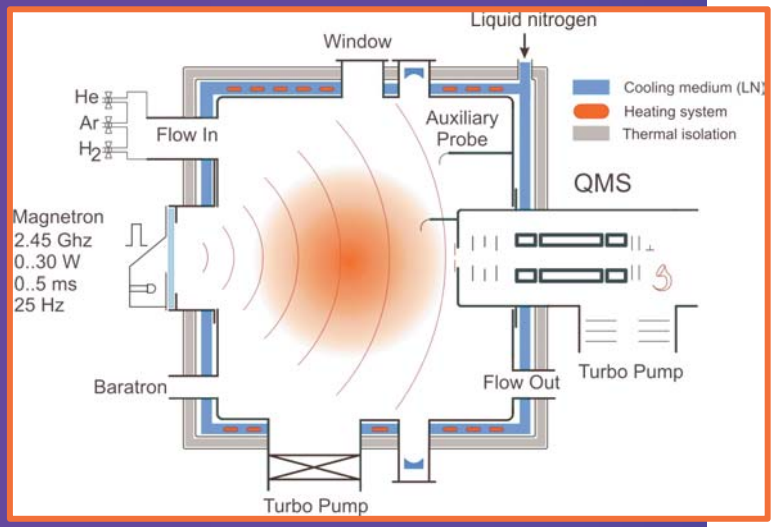


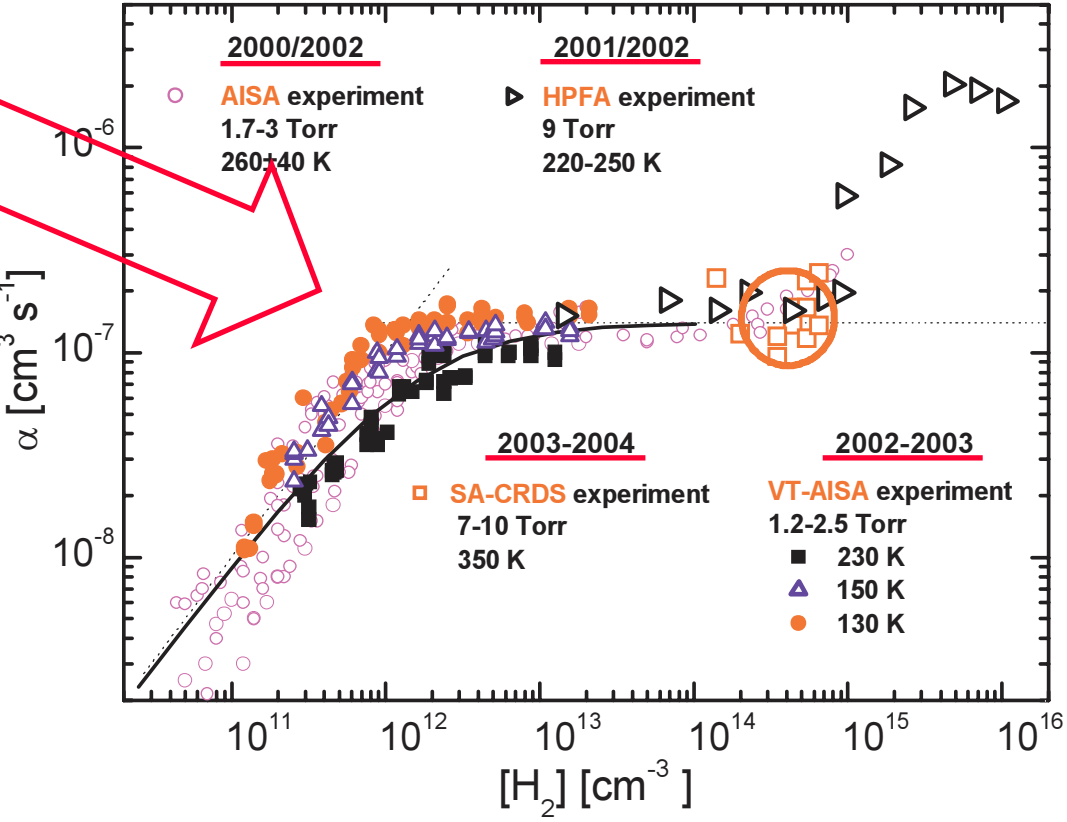
Temperature and pressure dependence (2004)



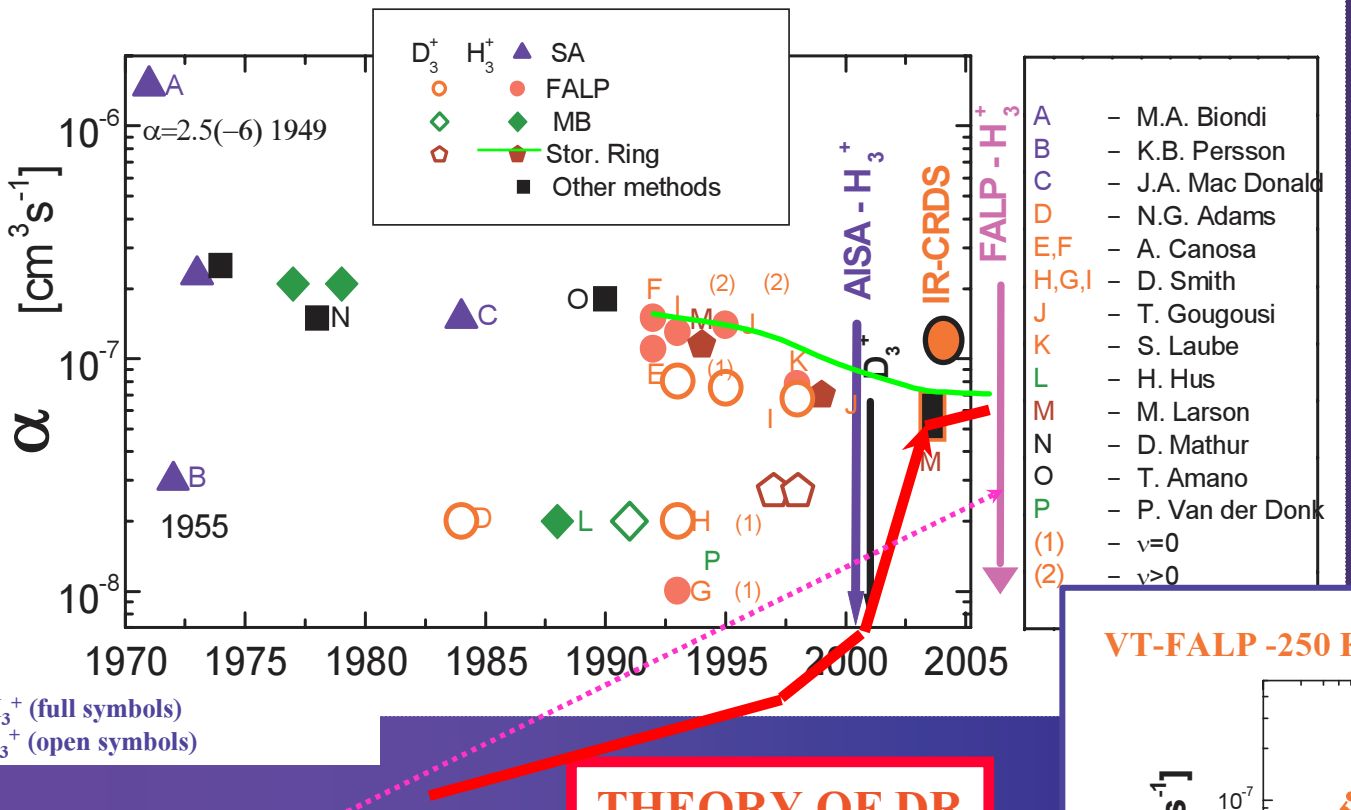
VT-AISA

$H_3^+ + e^-$



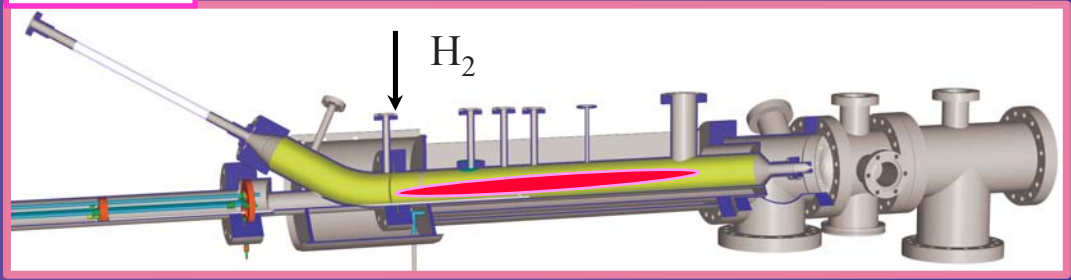


New experiments of $\alpha(H_3^+)$

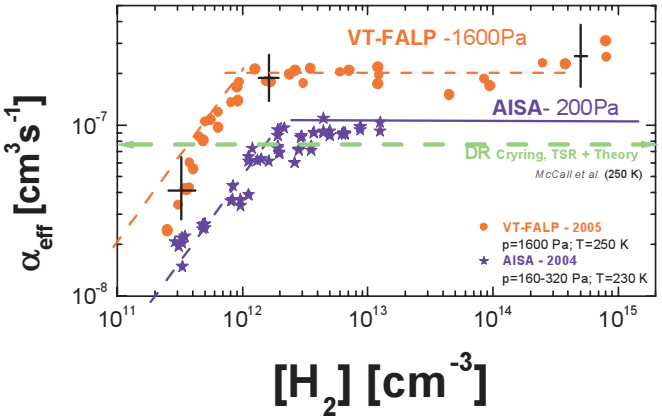


THEORY OF DR

FALP



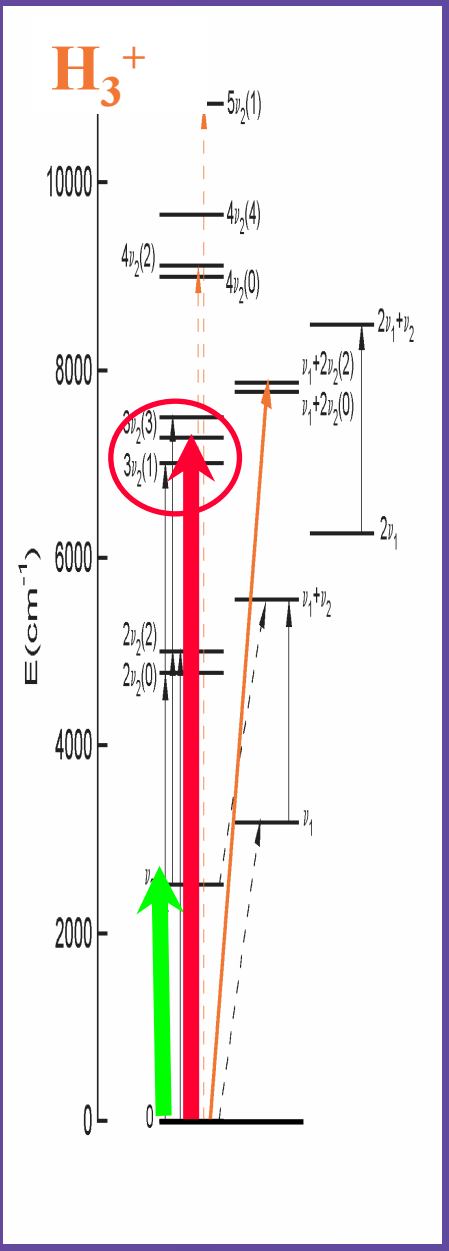
VT-FALP -250 K / AISA - 230 K



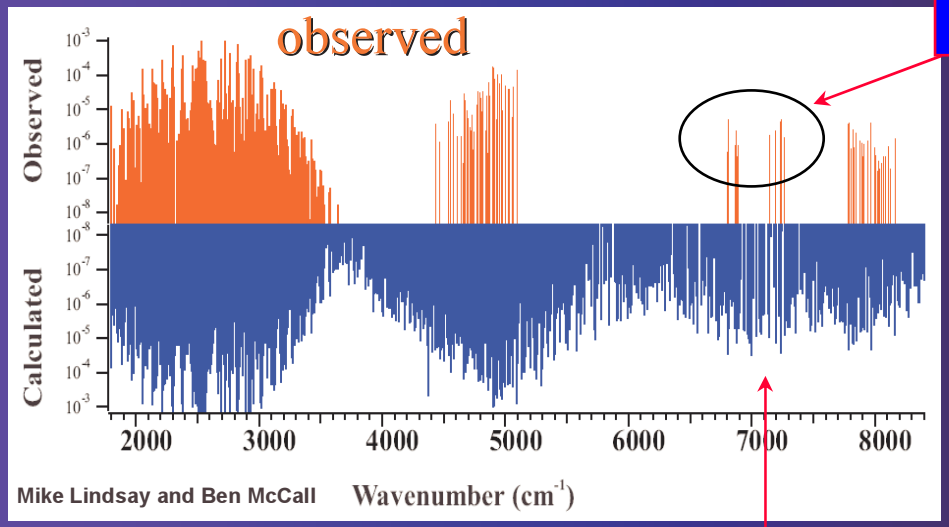
Life-time of H_3 Rydberg states?!
➔essential for recombination in plasma

Second overtone excitation–

plasma diagnostics,
ions characterization in RF trap
relaxation studies (by collisions)
ortho to para transitions



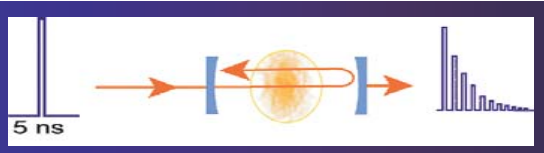
H3+

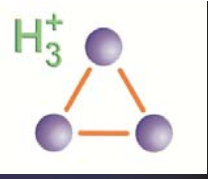


High sensitivity required

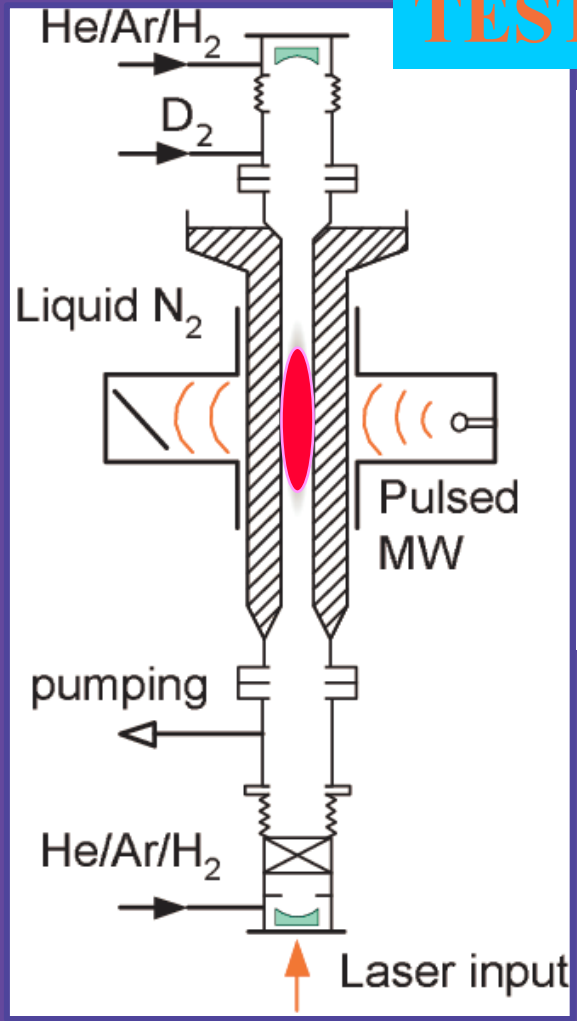
overtone band ν_2=3 ← 0 at 1.4 μm

IR absorption study cw CRDS





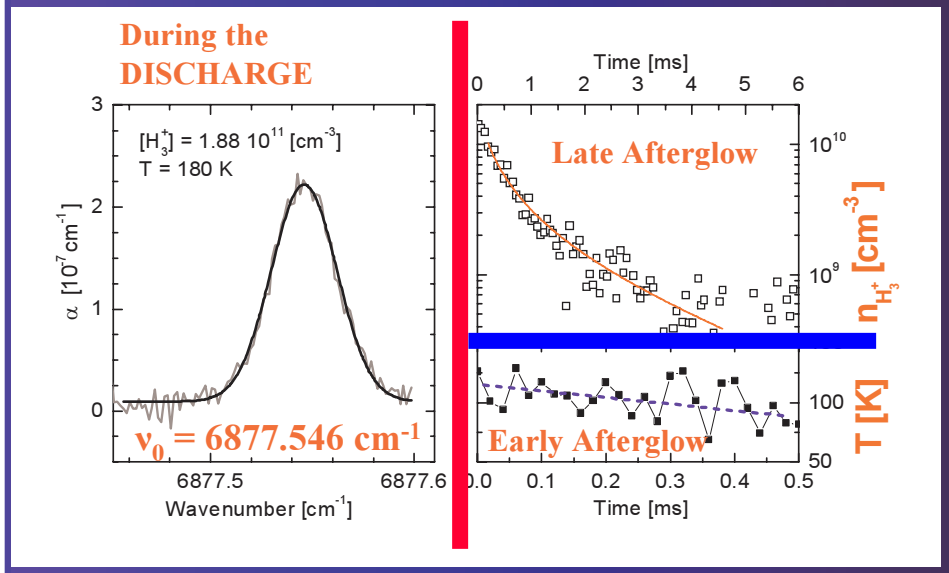
TEST TUBE



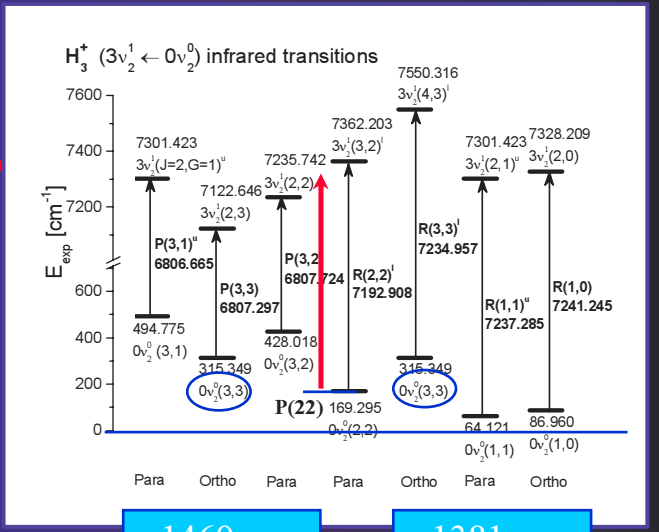
Laser – Single-mode tuneable **diode laser**, P ~ 3 mW

Mirrors – **R = 99.994%,**

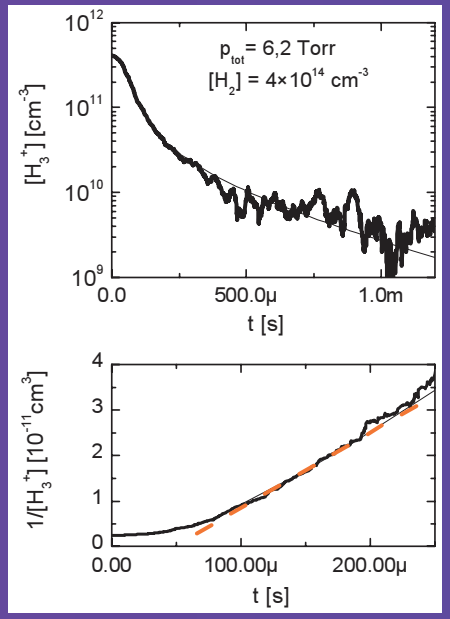
He/Ar/H_2 microwave **pulsed discharge**



DISCHARGE ON **OFF**



Recombination of $H_3^+(v=0)$ in $He/Ar/H_2$ SA

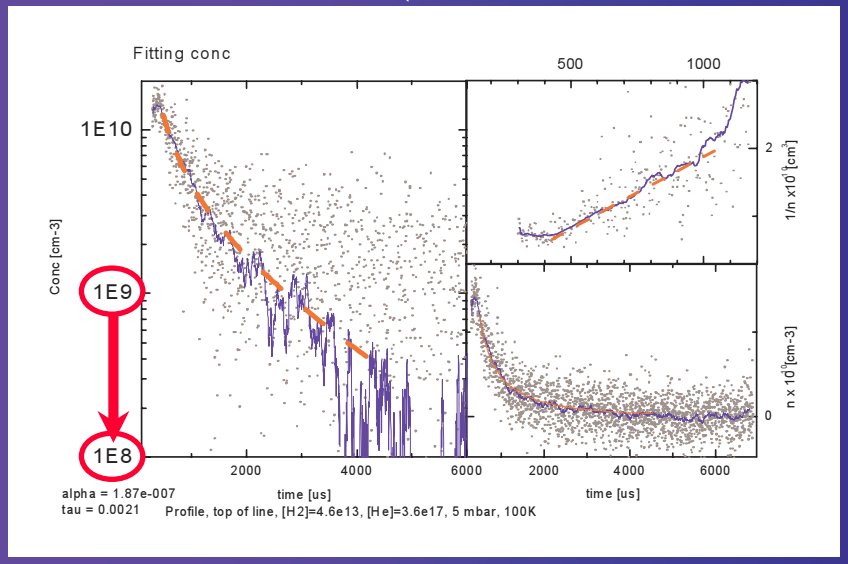


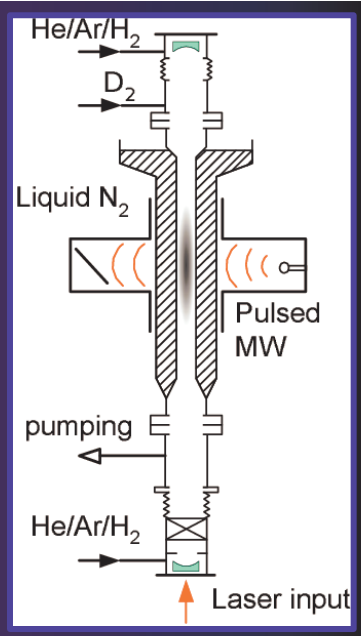
$$\frac{d[H_3^+]}{dt} = -\alpha[H_3^+]n_e = -\alpha[H_3^+]^2$$

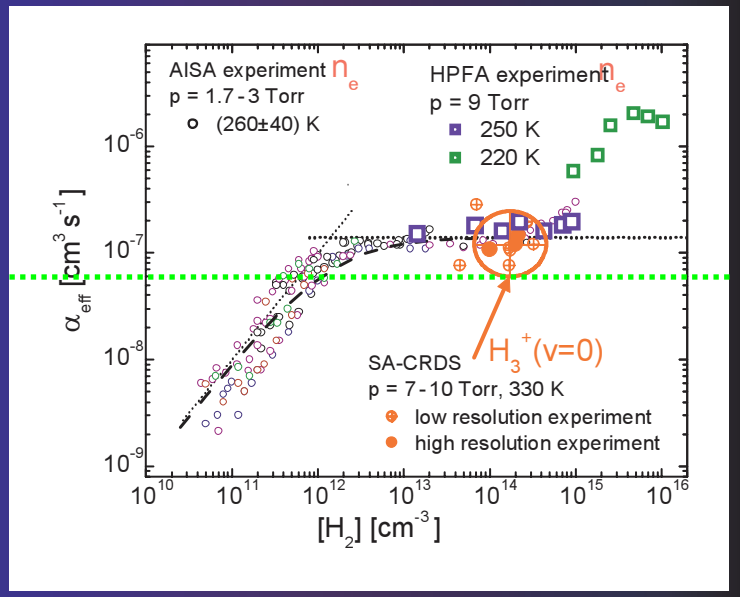
100µs

$$\frac{1}{[H_3^+]} = \frac{1}{[H_3^+]_0} + \alpha t$$

1000µs



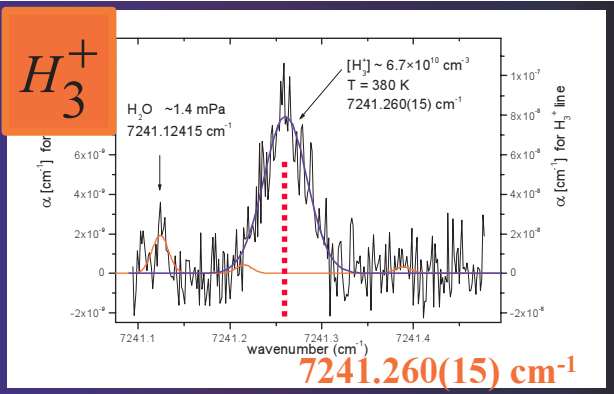




Absorption studies

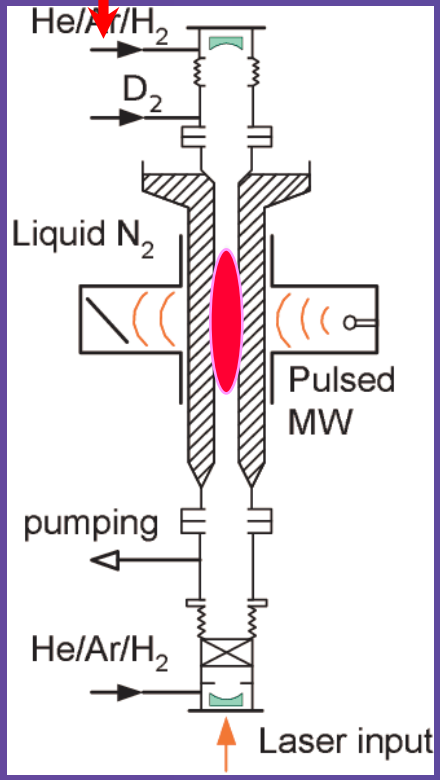
D_3^+ ???

H_3^+

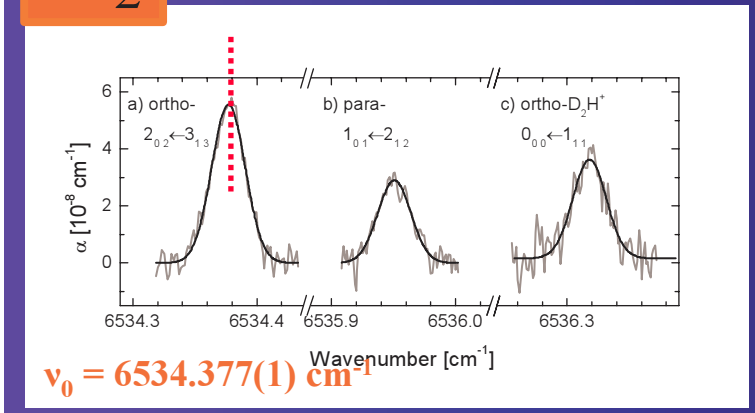


7241.260(15) cm^{-1}

He/Ar/H_2/D_2

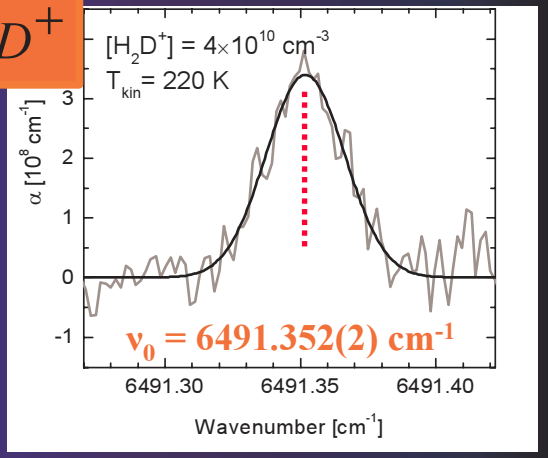


HD_2^+



ν_0 = 6534.377(1) cm^{-1}

H_2D^+

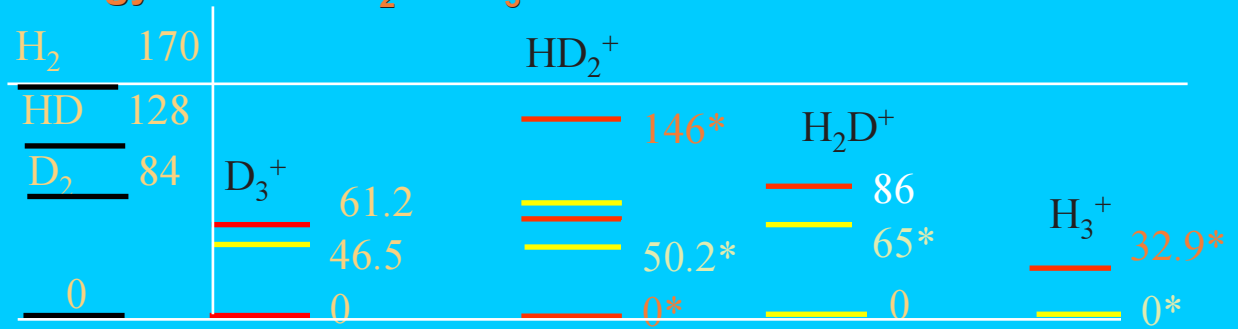


ν_0 = 6491.352(2) cm^{-1}

para

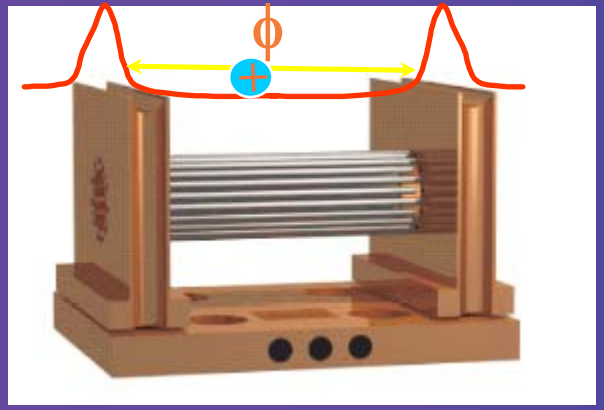
ortho

Energy levels of H_2..... D_3^+ in K - rotational excitation

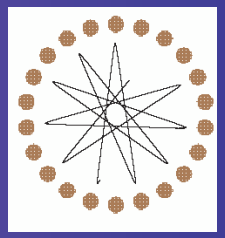


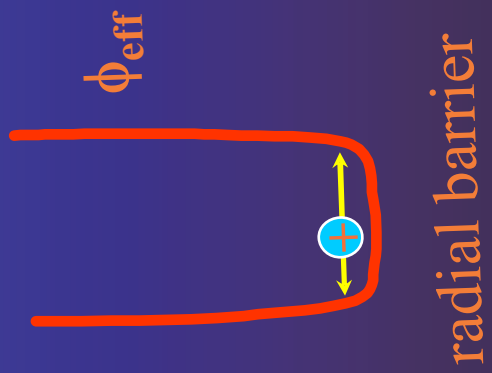
Ions in low temperature 22-pole RF trap

axial barriers

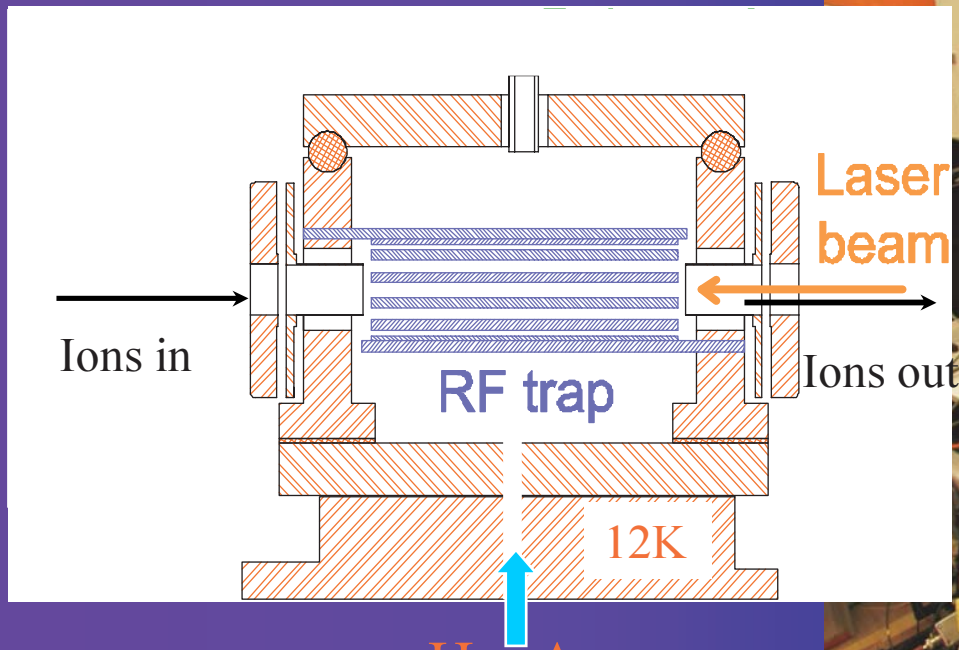


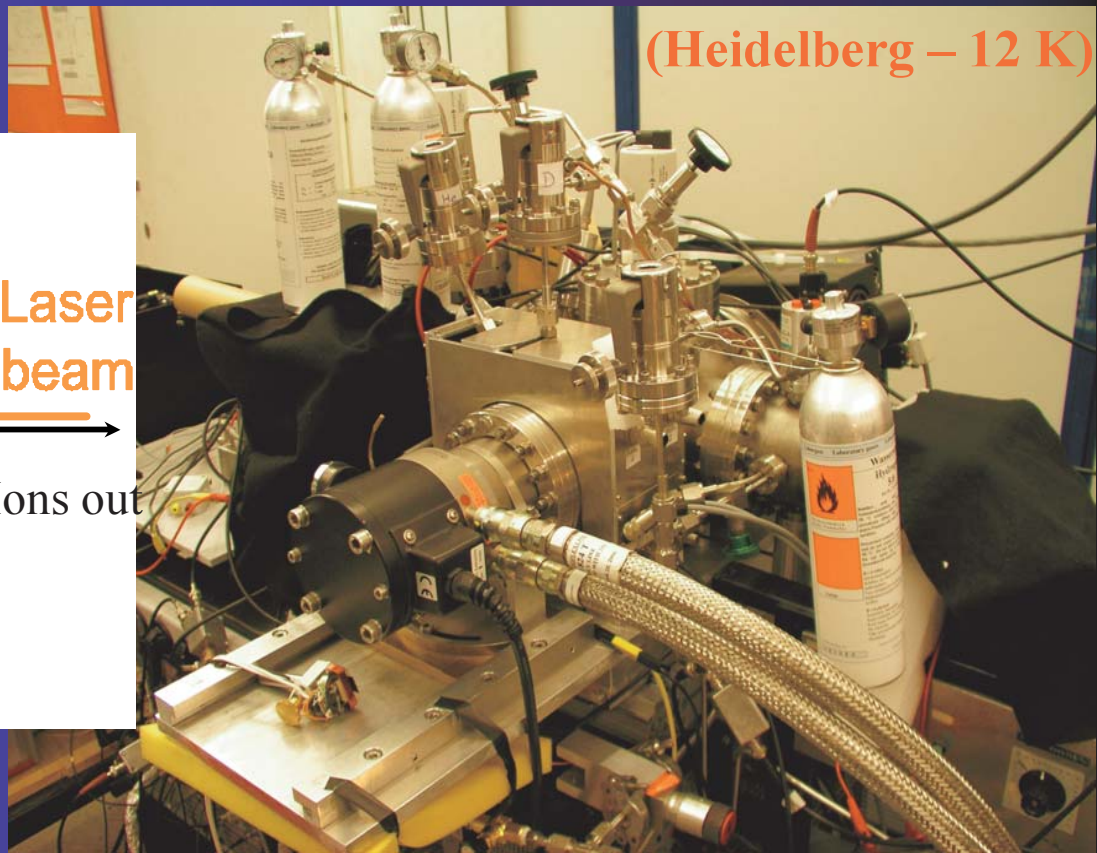
22-pole trap





Collisional cooling



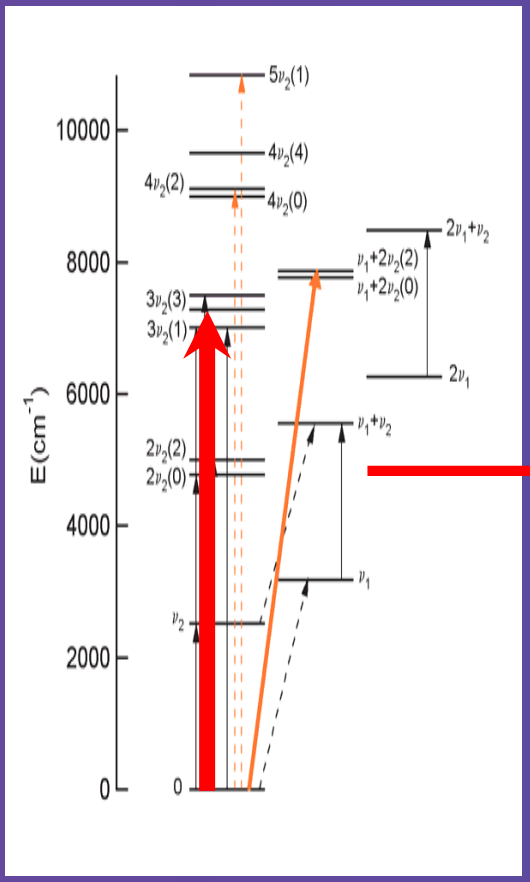


Laser enhanced IMR – Laser Induced Reactions LIR

$$H_3^+(0) + Ar \Rightarrow no \quad reaction$$

$$H_3^+ + h\nu \Rightarrow H_3^+(3\nu_2)$$

$$H_3^+(3\nu_2) + Ar \Rightarrow ArH^+, Ar^+$$



Ar → ArH^+

Every absorption of photon produces ArH^+

ZERO BECKGROUND EXPERIMENT

Small problems ….

- Radiative deexcitation of just excited ions…
- Internal excitation of injected ions
- Presence of H_2 from source
- Ar high condensation temperature
- HD, D_2 or H_2 can react dependent on ortho/para …

Timing

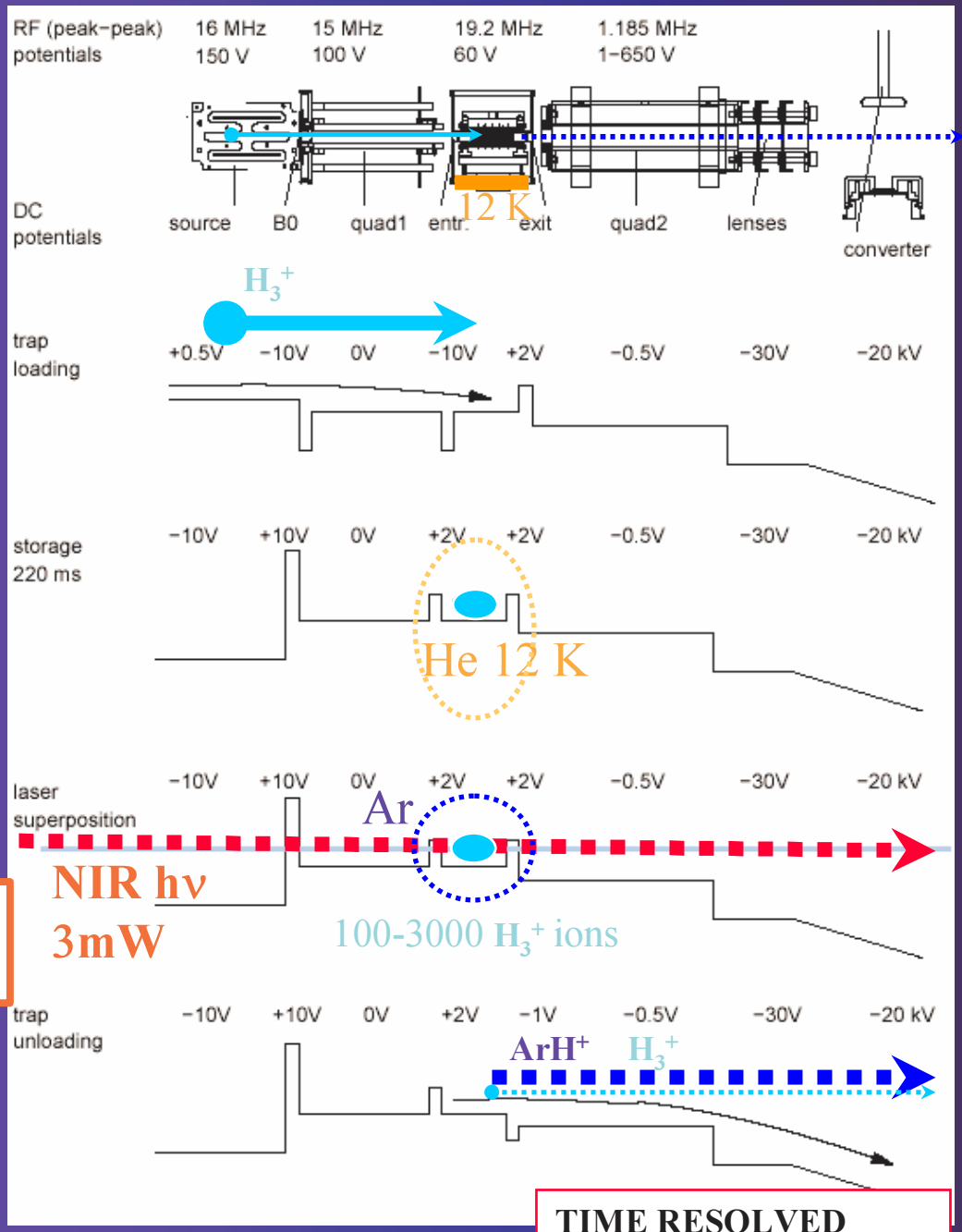
Ion injection

Ion cooling in collisions with He 12 K

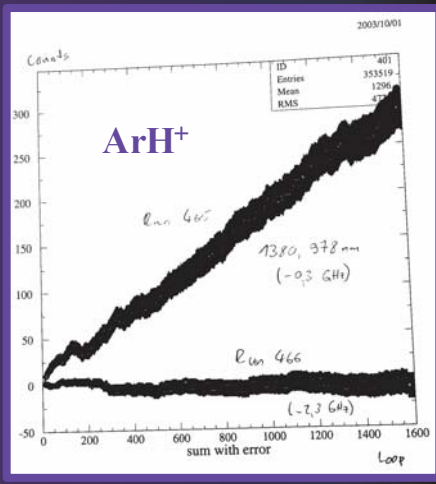
LIR studies

$$H_3^+ + h\nu \Rightarrow H_3^+(3\nu_2)$$
$$H_3^+(3\nu_2) + Ar \Rightarrow ArH^+, Ar^+$$

Ion extraction

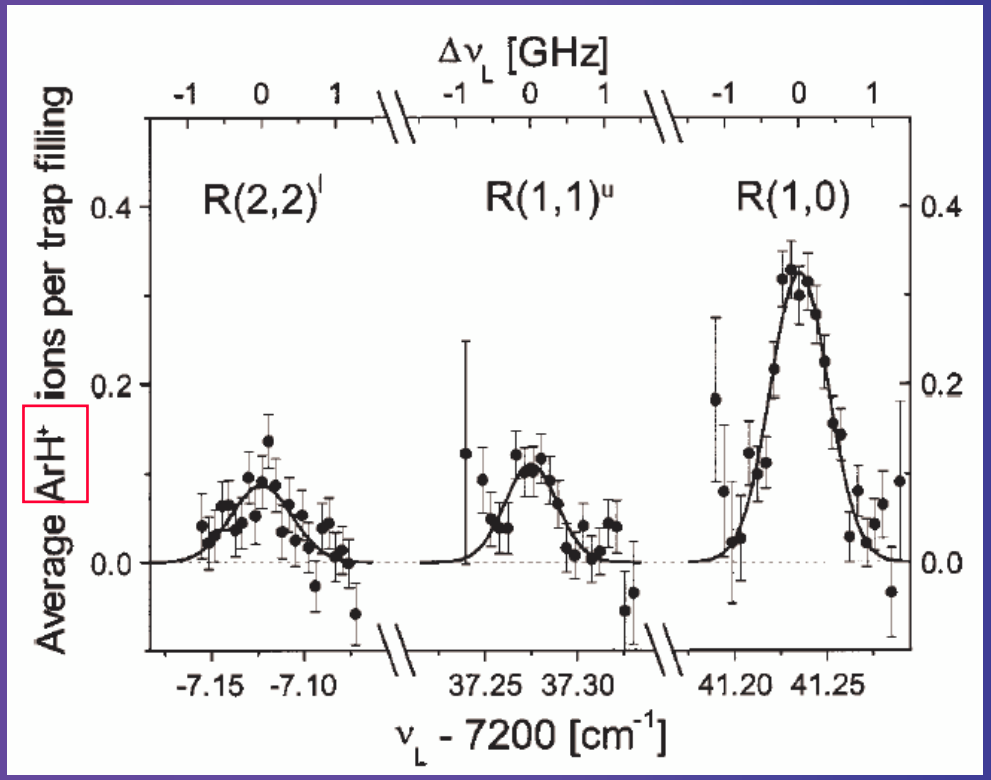


Synchronous detection and Σ over many loops

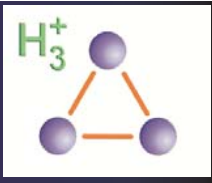


TIME RESOLVED ArH^+ extraction

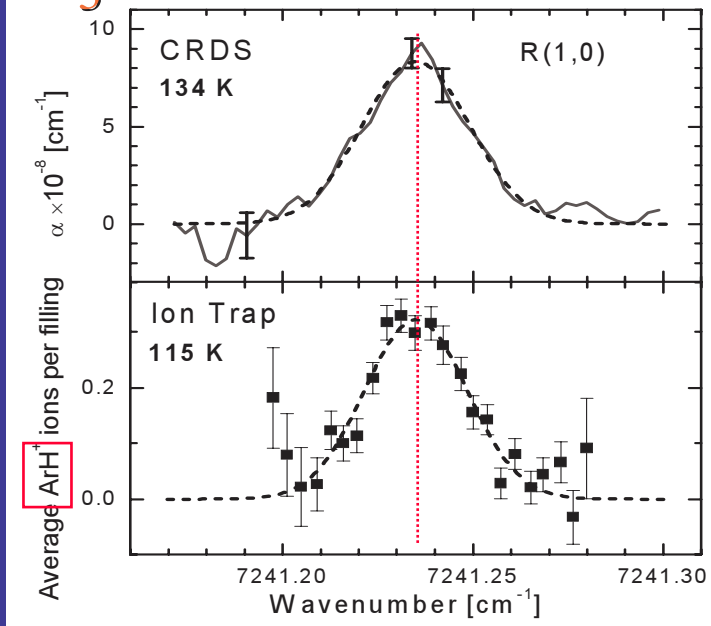
H_3^+ Spectrum at 50 K



State population
Transition frequencies
T_{KIN} , T_{rot},



H_3^+



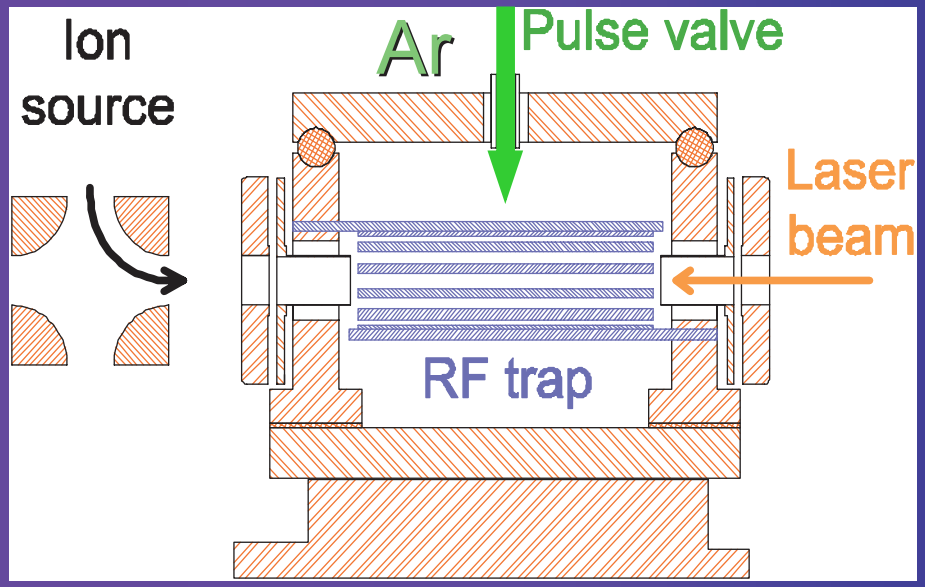
Transition	ν_{calc} $(cm^{-1})^a$	ν_{exp} $(cm^{-1})^b$	ν_{exp} $(cm^{-1})^c$
$R(1,0)$	7241.025	7241.244(70)	7241.235(17)
$R(1,1)^u$	7237.058	7237.285(70)	7237.277(17)
$R(2,2)^l$	7193.311	7192.908(70)	7192.875(17)

Source of cold H_3^+ for TSR

B. F. Ventrudo, 1994

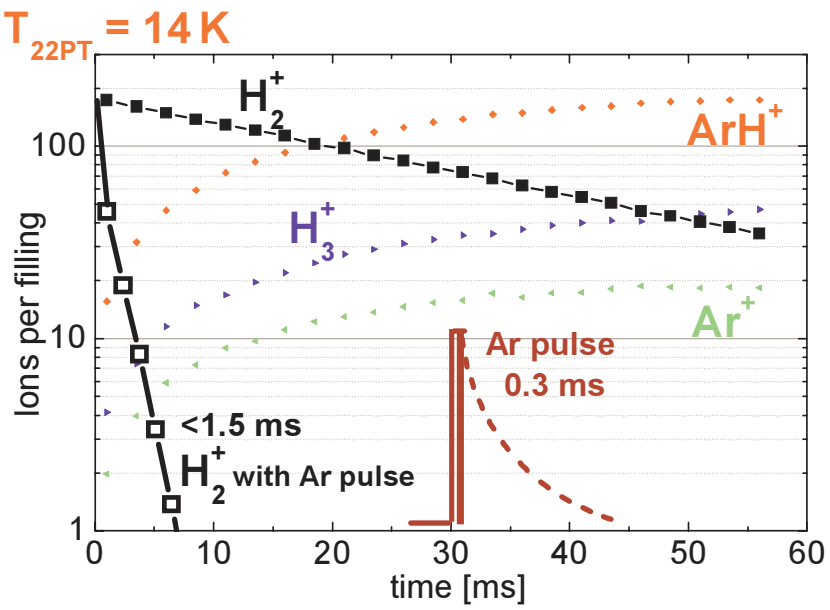
The next step 14 K LIR

$$H_3^+ + h\nu \Rightarrow H_3^{+*} + Ar \Rightarrow ArH^+, Ar^+$$



Separated ion source

Pulsed Beam of Ar



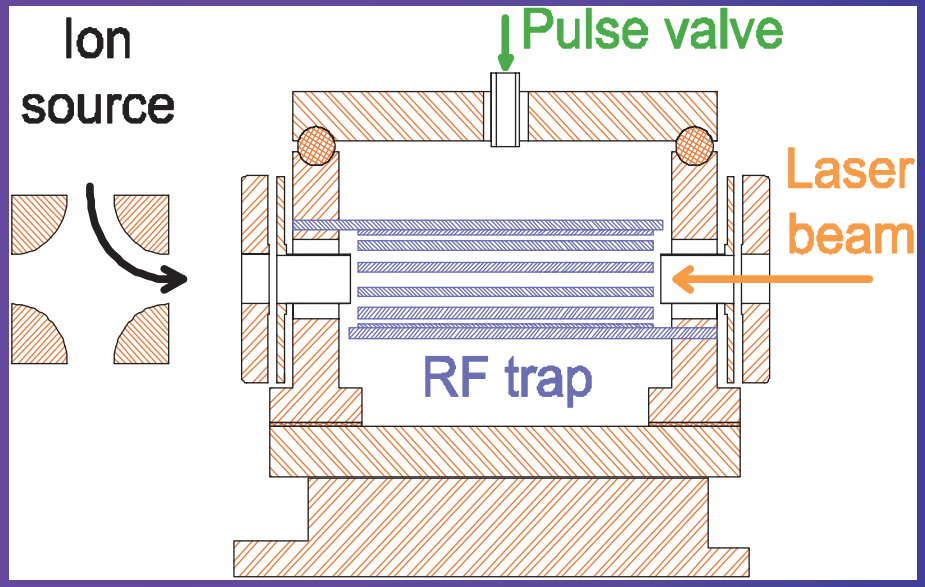
Test of
Pulsed Beam of Ar

$$H_2^+ + Ar \rightarrow ArH^+, Ar^+ + \ldots.$$

$$H_2^+ + H_2 \rightarrow H_3^+ + H$$

during the pulse $\tau_{Ar} \sim 10\,\mu s$

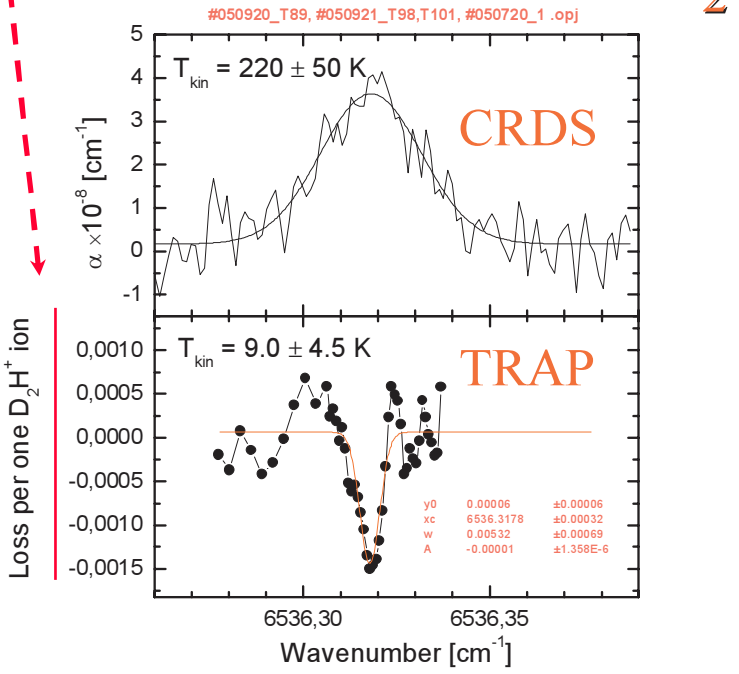
LIR HD_2^+ at 10K with Pulsed Beam of Ar



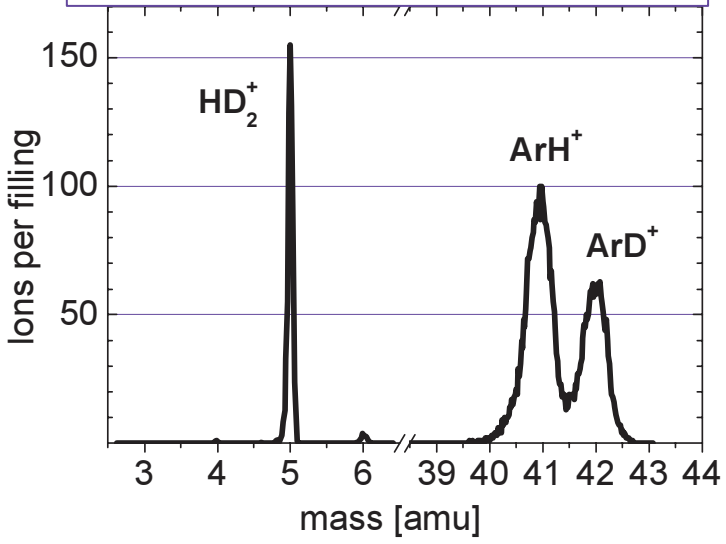
$$HD_2^+ + h\nu \Rightarrow HD_2^{+*}$$

$$HD_2^{+*} + Ar \Rightarrow ArH^+, ArD^+$$

HD_2^+

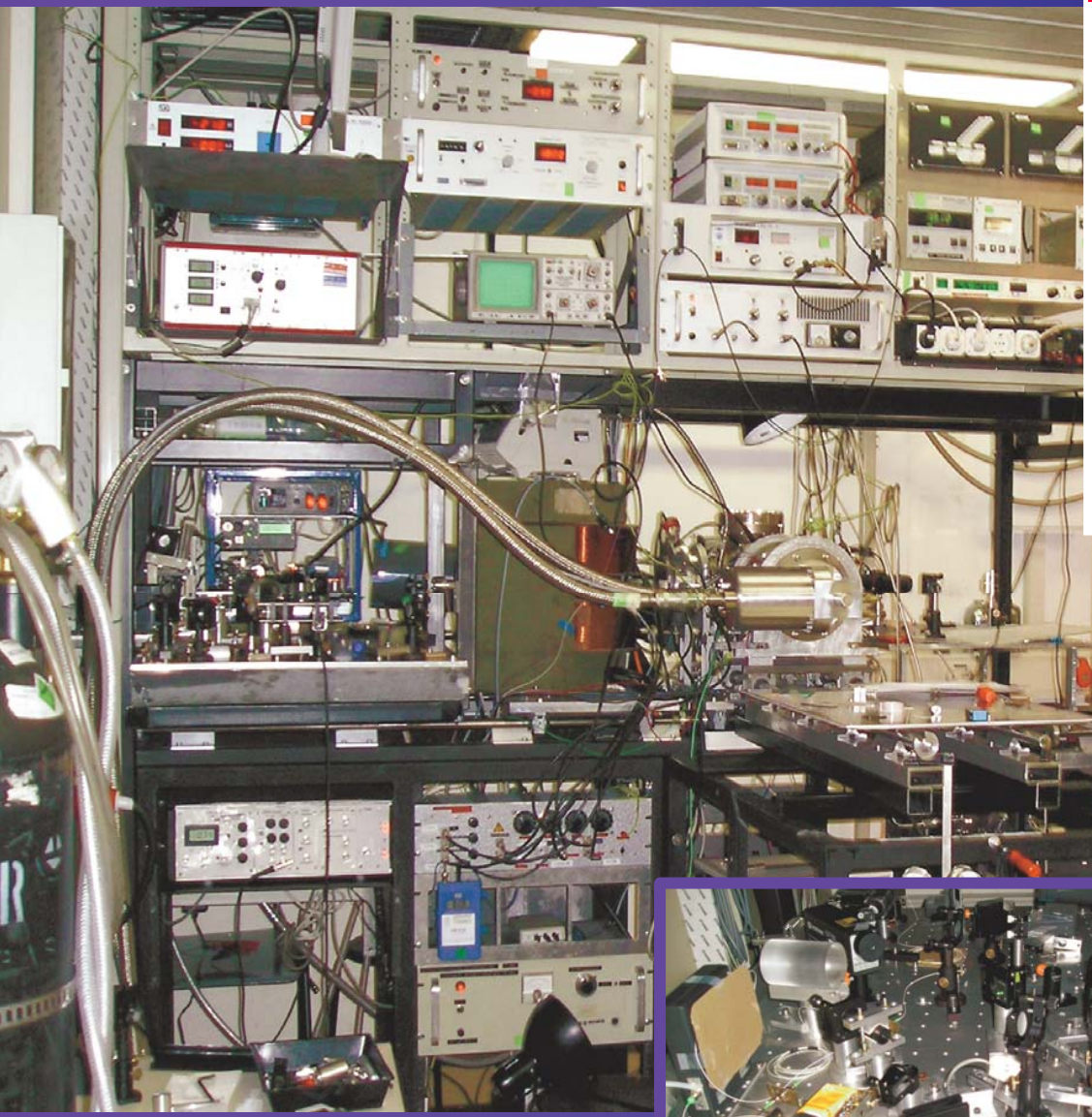


$$HD_2^{+\#} + Ar \Rightarrow ArH^+, ArD^+$$

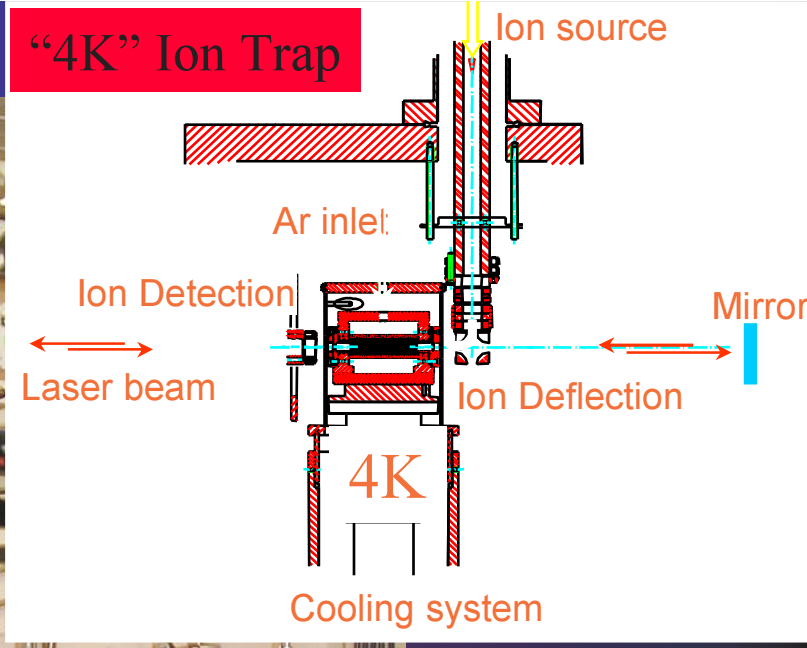


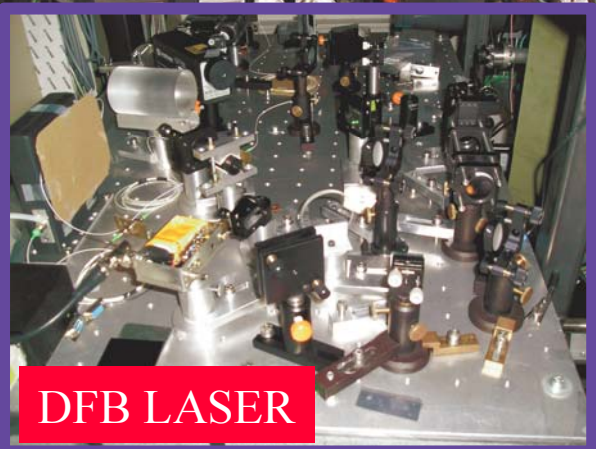
9 K ground state ortho HD_2^+

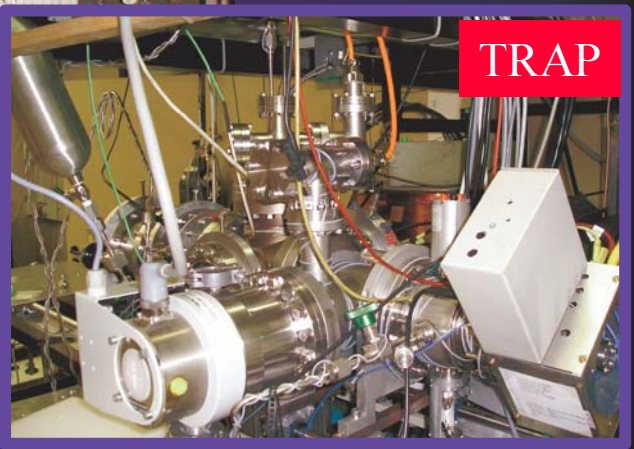
For theoreticians (In operation-Chemnitz)



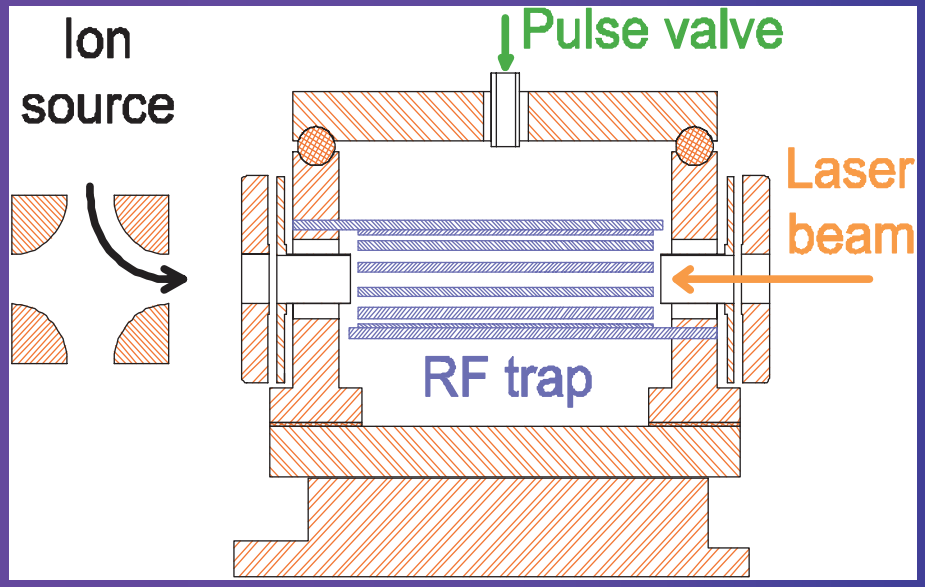
10-3000 ions
T ~ 4-50K

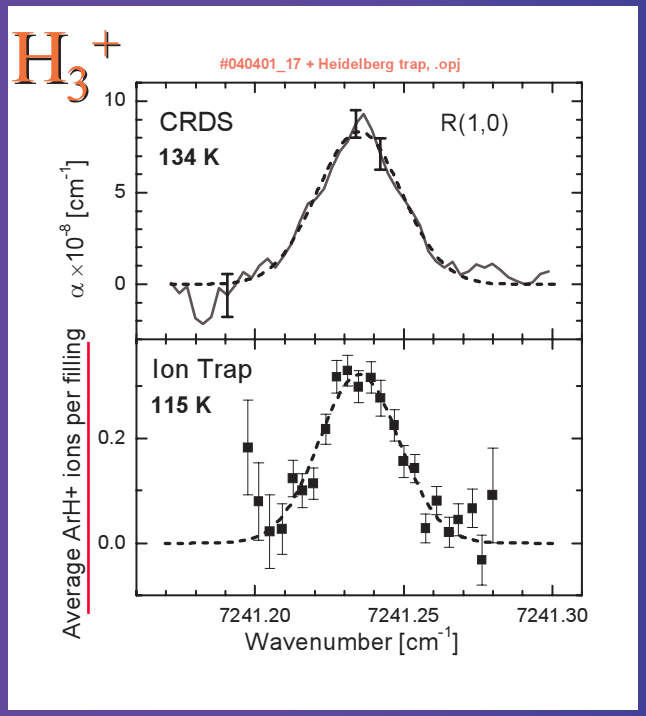


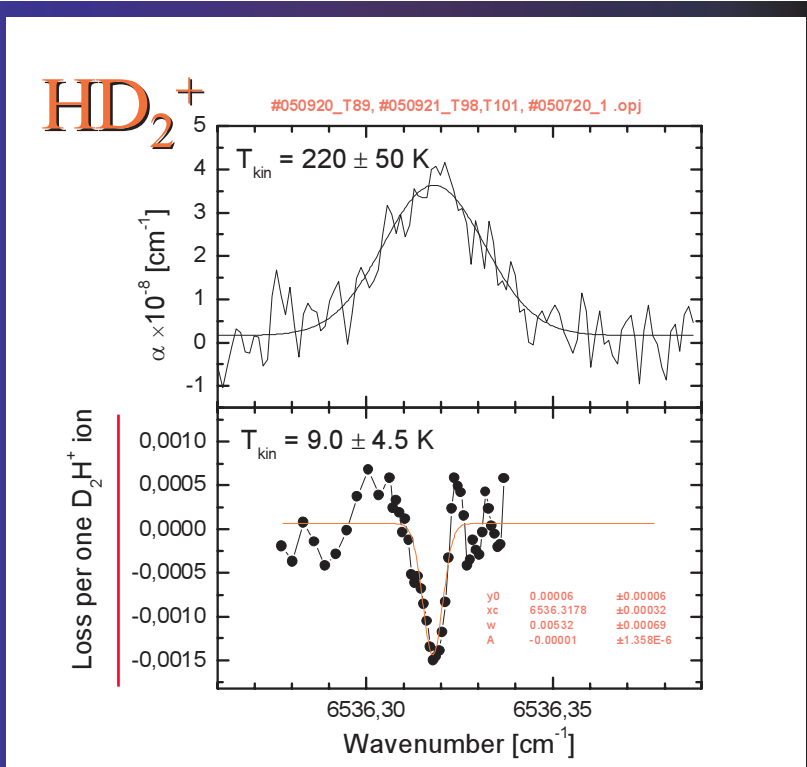


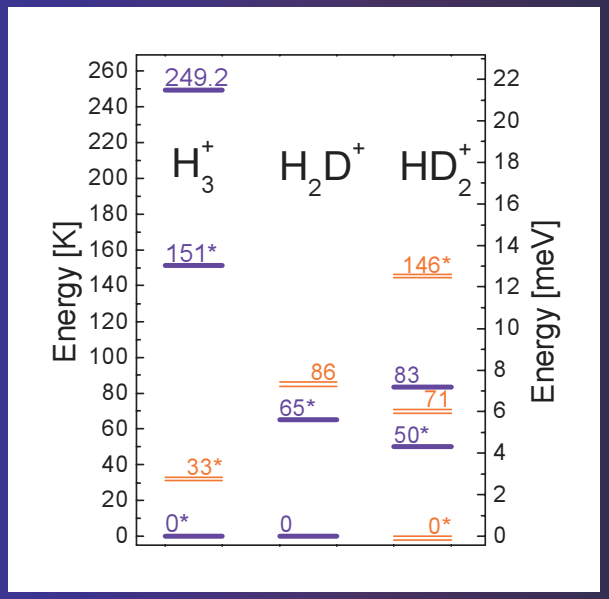


NIR LIR with Ar as the monitor





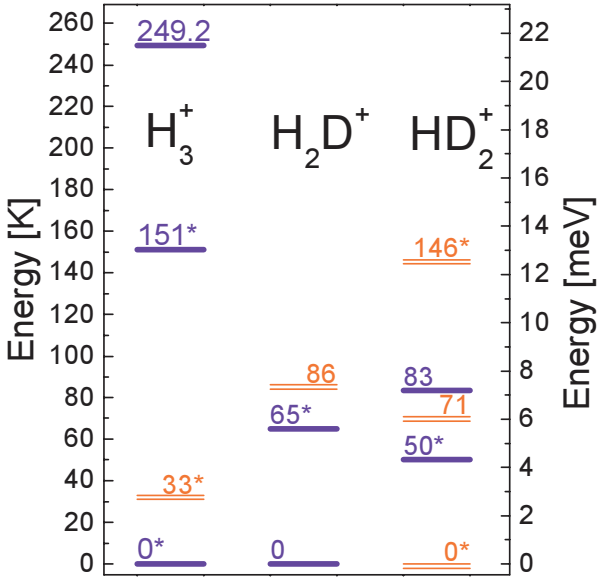


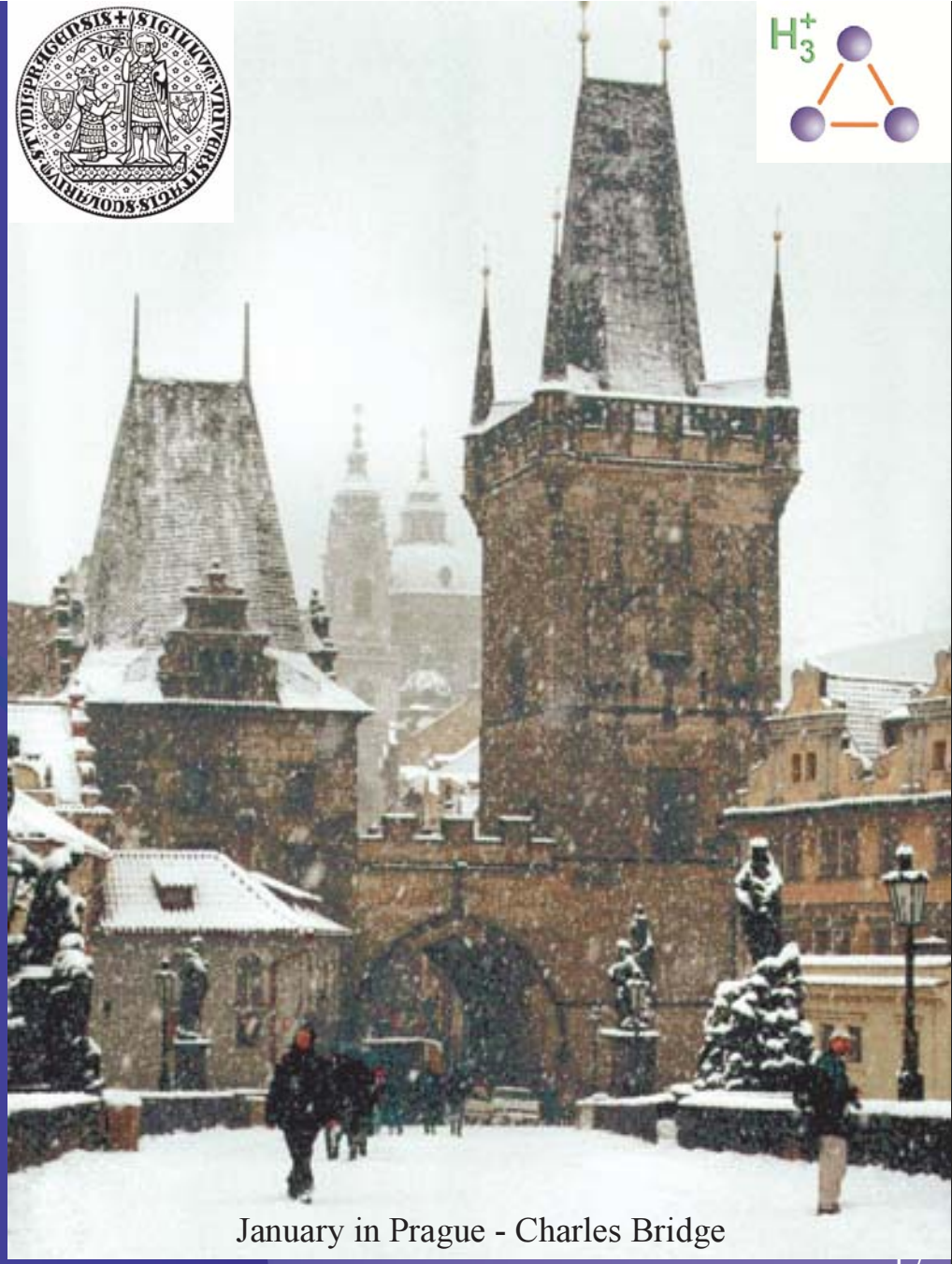


Charles University Prague
Faculty of Mathematics and Physics

It is pleasure to be here

Quo vadis H_3^+





January in Prague - Charles Bridge

Juraj.Glosik@mff.cuni.cz

Charles University Prague