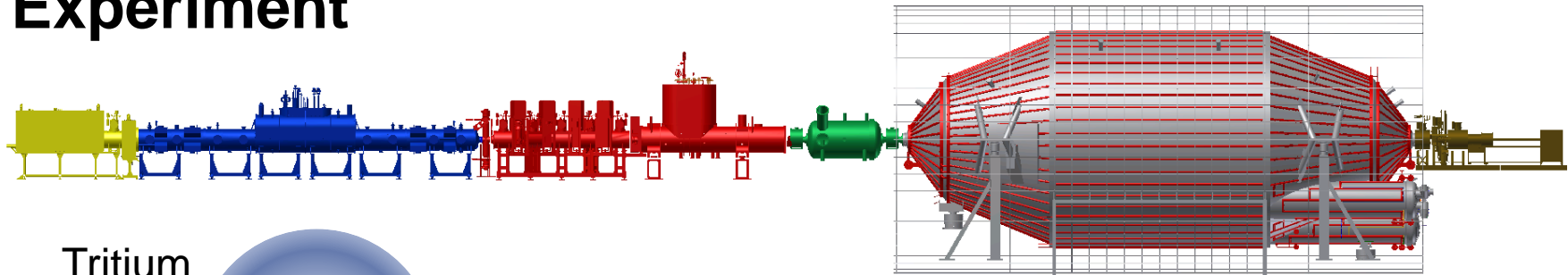
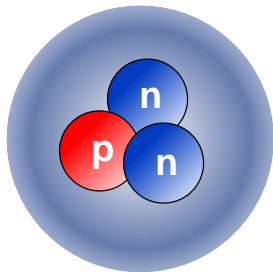




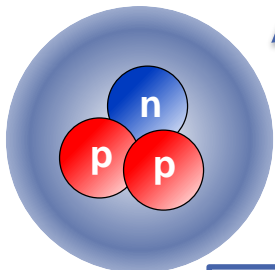
# The Karlsruhe TRitium Neutrino Experiment



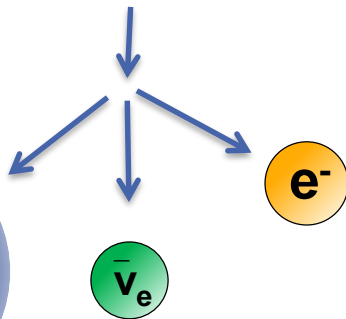
Tritium



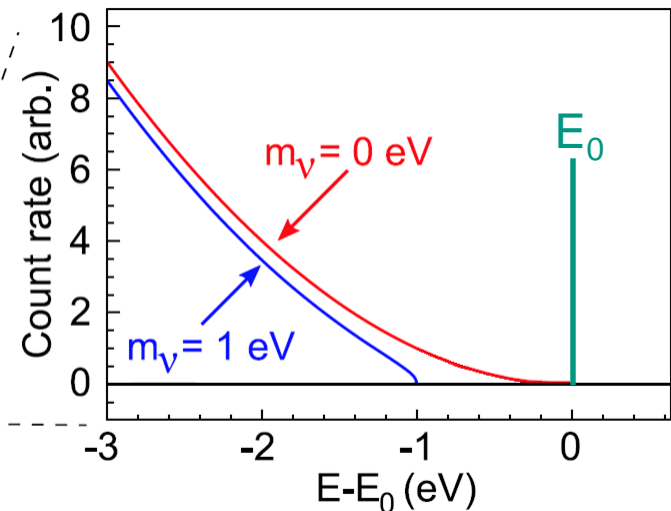
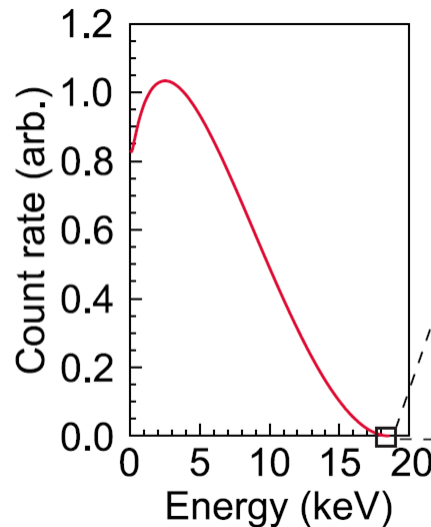
Helium-3



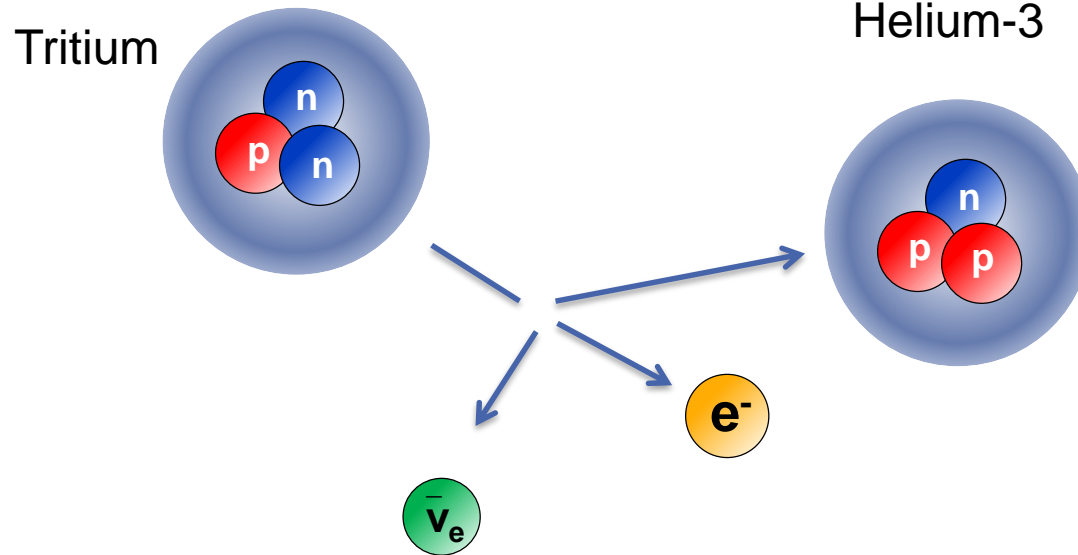
$E_0 = 18.6 \text{ keV}$



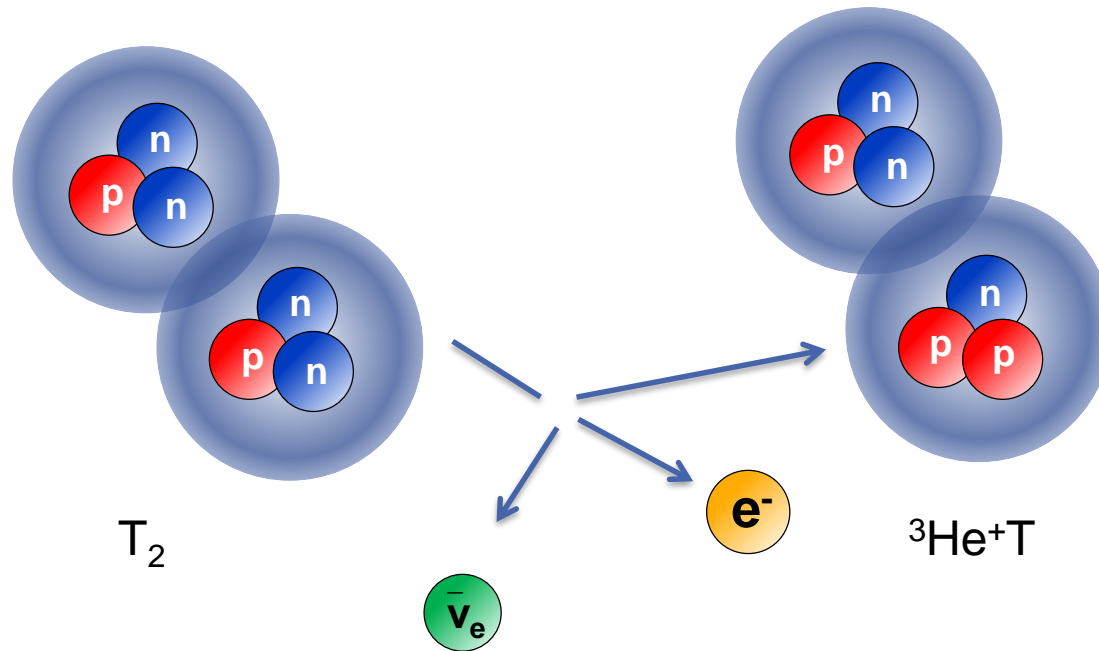
aim: measurement of the neutrino mass with  $0.2 \text{ eV}/c^2$  sensitivity (90% CL)



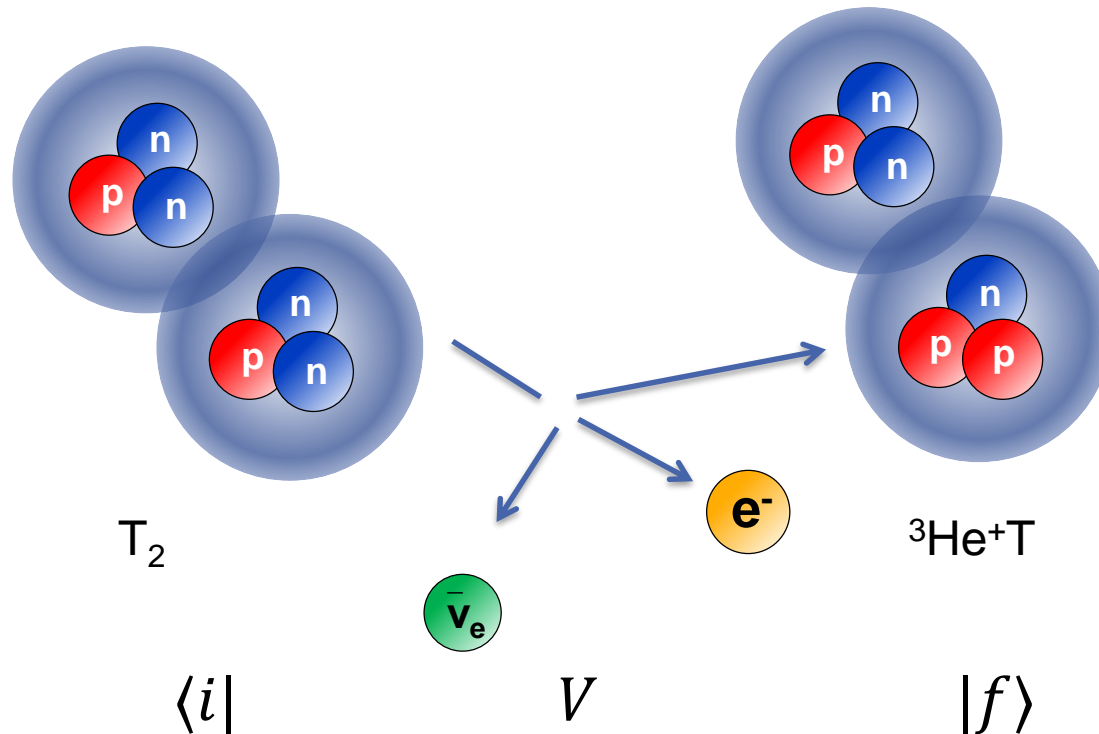
# Tritium beta-decay



# Molecular tritium beta-decay



# Molecular tritium beta-decay



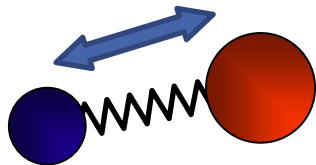
Fermi's golden rule:

$$W_{i \rightarrow f} = \frac{2\pi}{\hbar} |\langle i | V | f \rangle|^2 \rho(E_f)$$

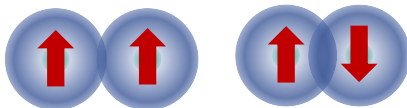
Beta spectrum depends on initial and final state distribution

# Initial state distribution

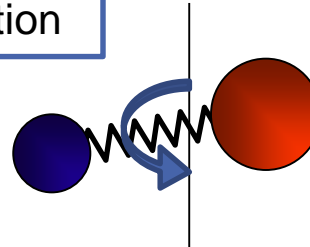
Vibration



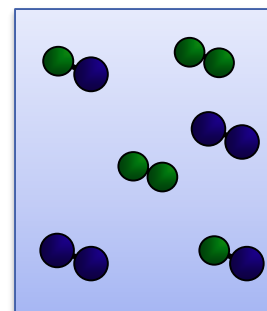
ortho/para  $T_2$ ,  $D_2$ ,  $H_2$



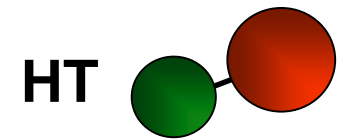
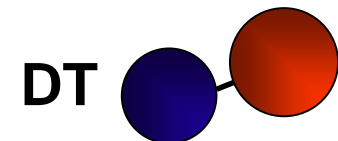
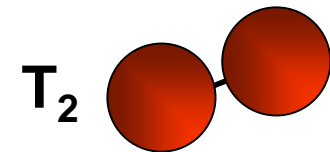
Rotation



Temperature  
+ pressure

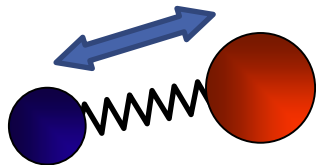


Concentration

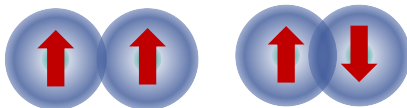


# Initial state distribution

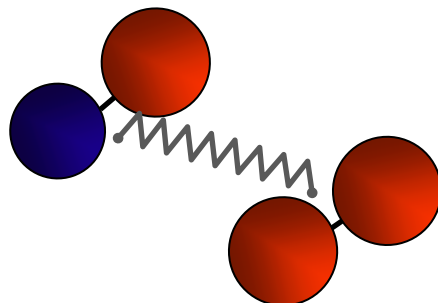
Vibration



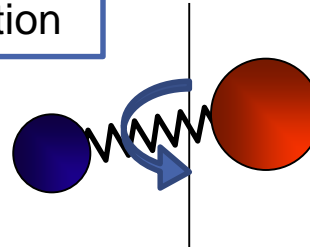
ortho/para  $T_2$ ,  $D_2$ ,  $H_2$



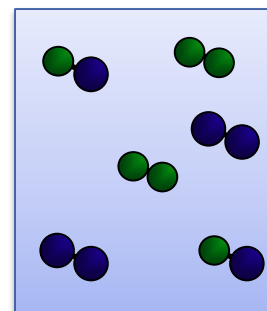
Van-der-Waals clusters



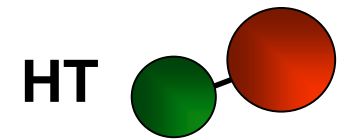
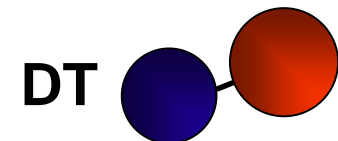
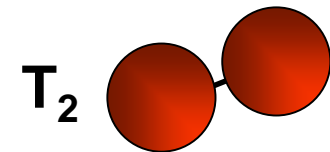
Rotation



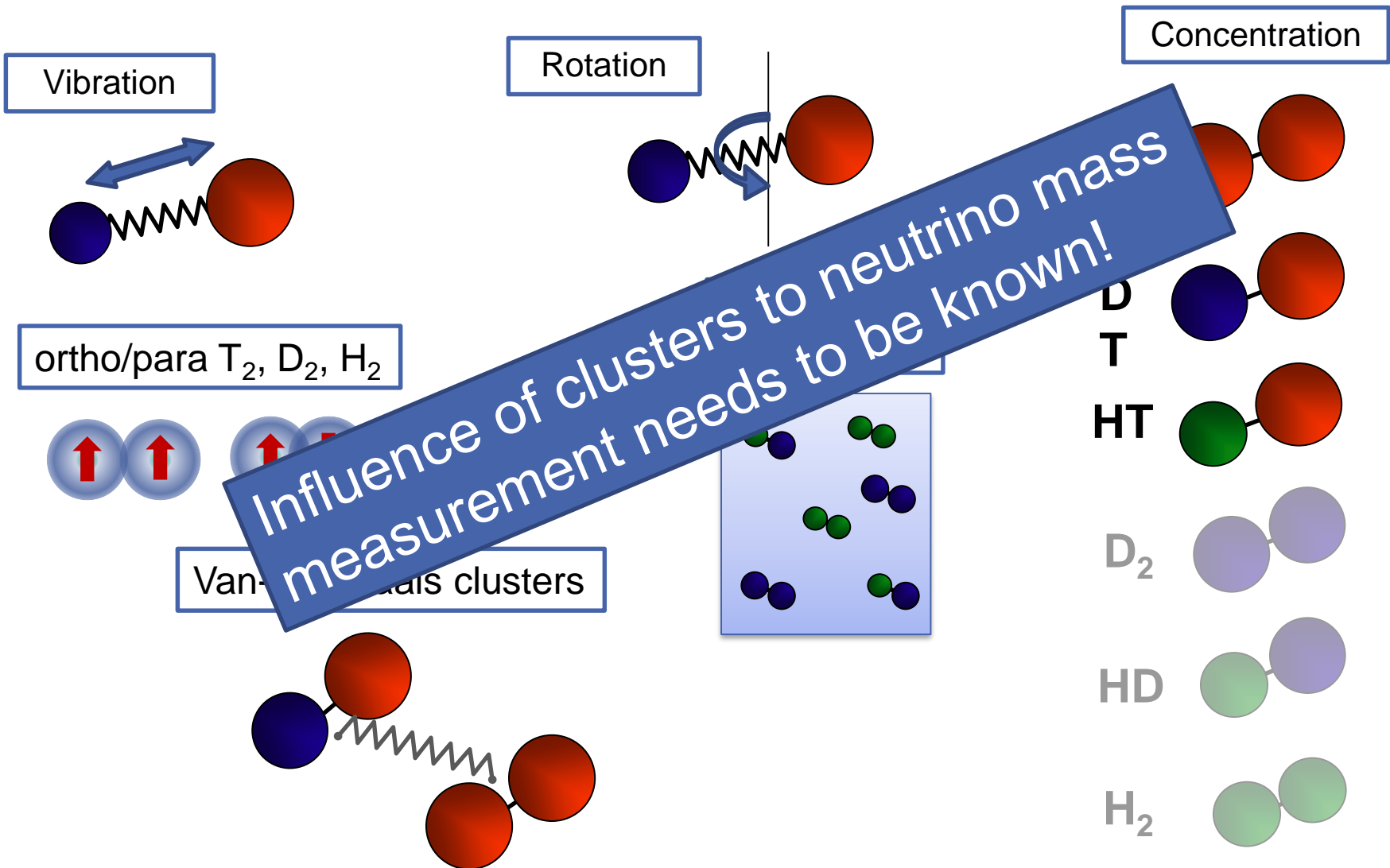
Temperature  
+ pressure



Concentration

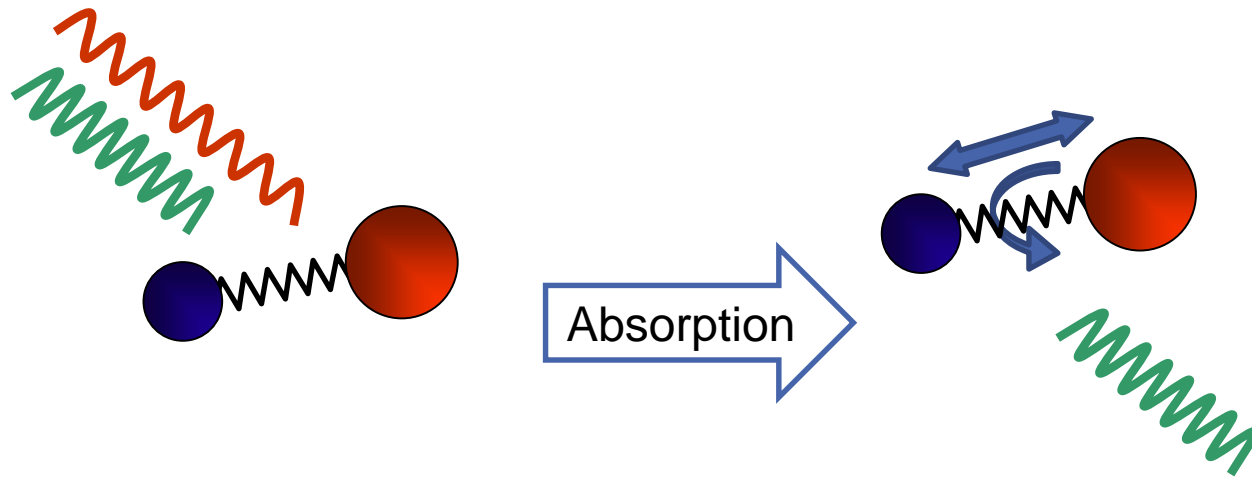


# Initial state distribution

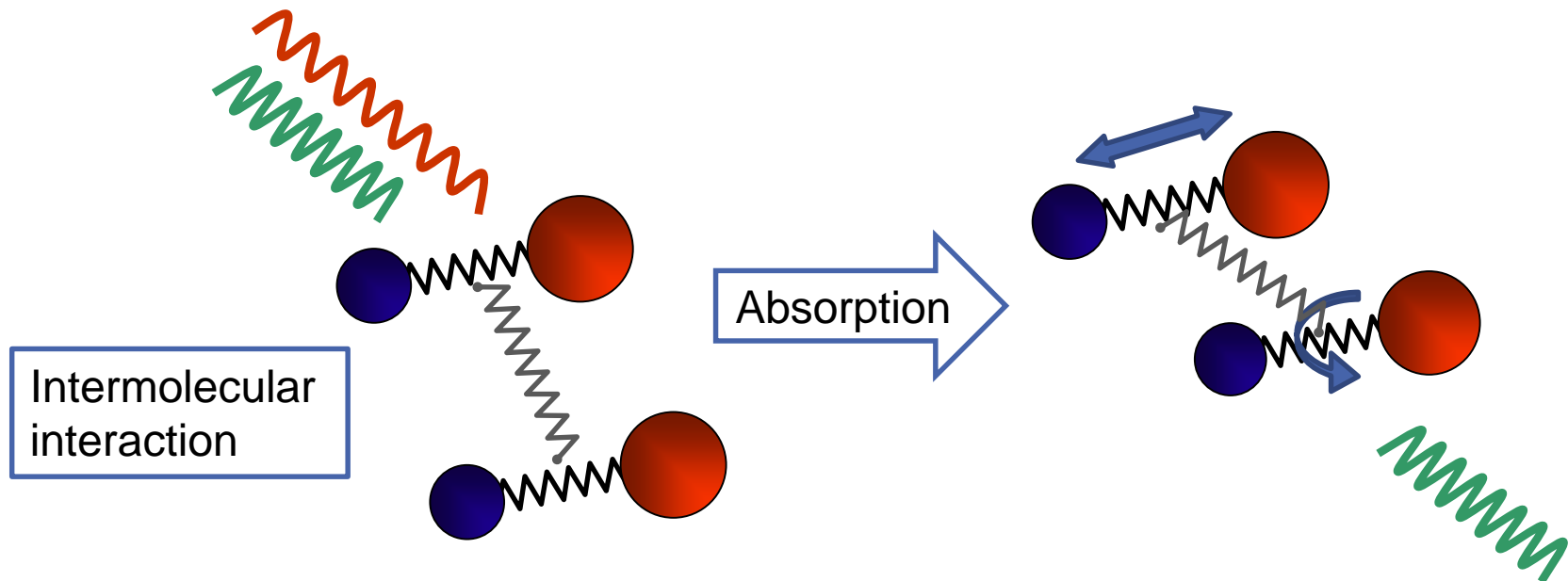




# Experimental method: IR absorption spectroscopy



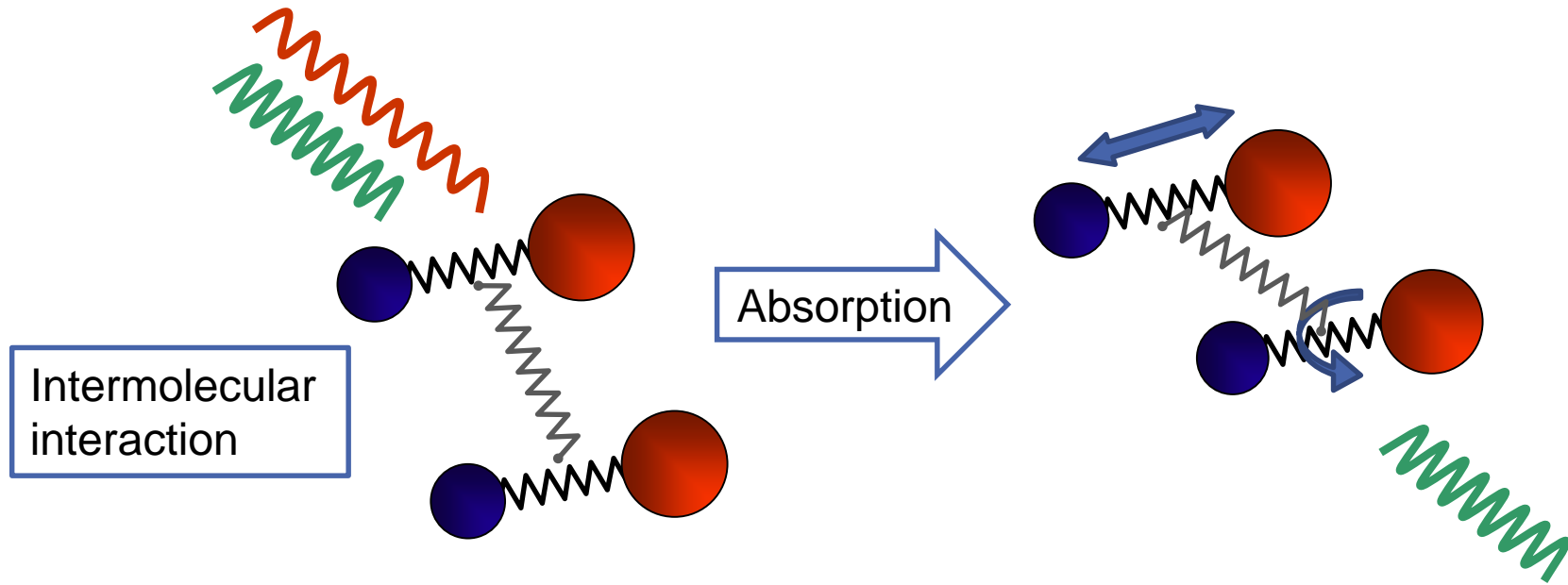
# Experimental method: IR absorption spectroscopy



Sensitive to:

- Intermolecular interaction  
→ Van-der-Waals complex
- Composition
- Vibration / rotation
- Ortho/para ratio
- Temperature

# Experimental method: IR absorption spectroscopy



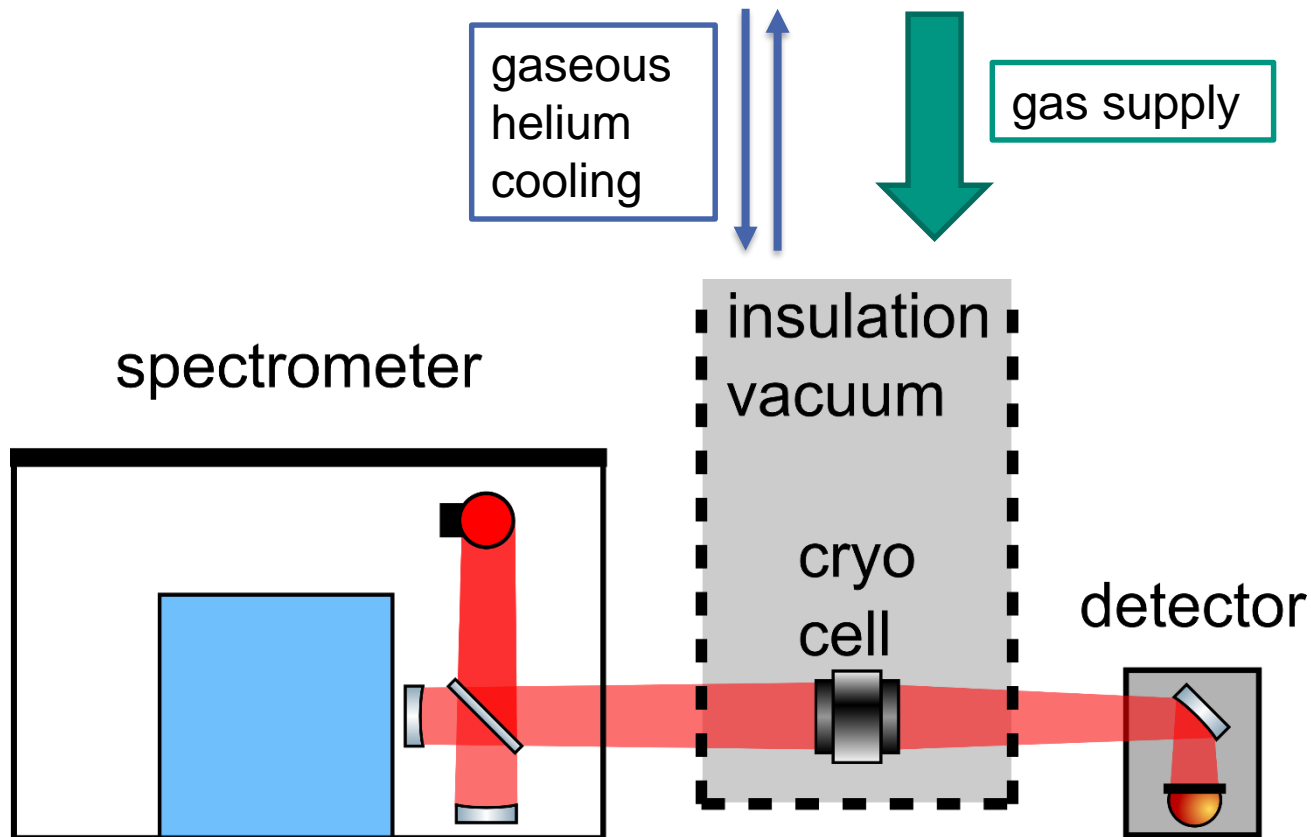
Sensitive to:

- Intermolecular interaction  
→ Van-der-Waals complex
- Composition
- Vibration / rotation
- Ortho/para ratio
- Temperature

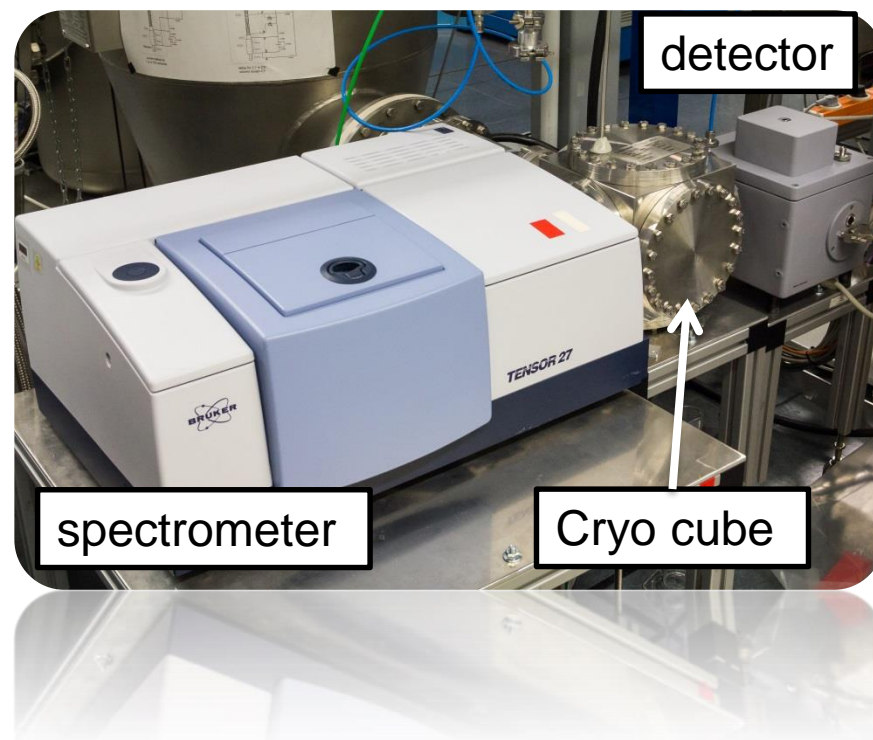
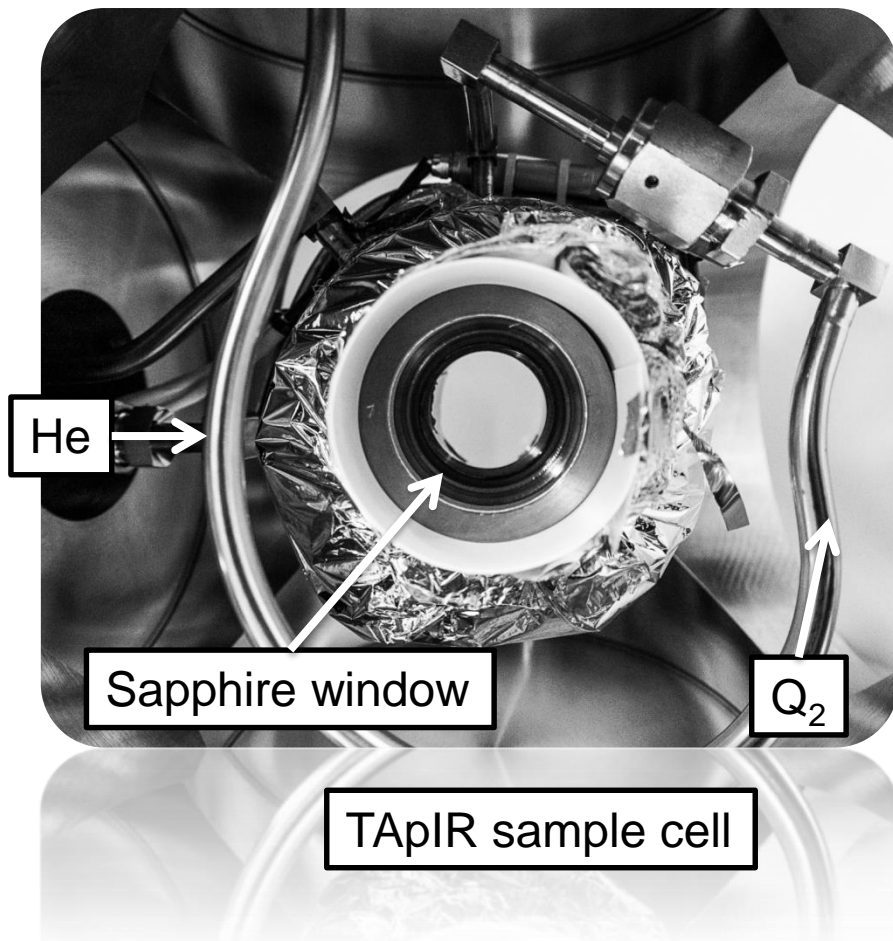
Ideal method: IR spectra only possible with intermolecular interaction

# TApIR Setup

- Temperature: 18 K to 35 K
- Only H<sub>2</sub> HD D<sub>2</sub> mixtures



# Experimental Setup



# Focus of this talk

- Can we see clusters at all?
  - Liquid Phase:
    - High cluster density
    - High signal expected
- Can we see cluster in the gaseous phase?
- Does the cluster concentration depend on the temperature and pressure?



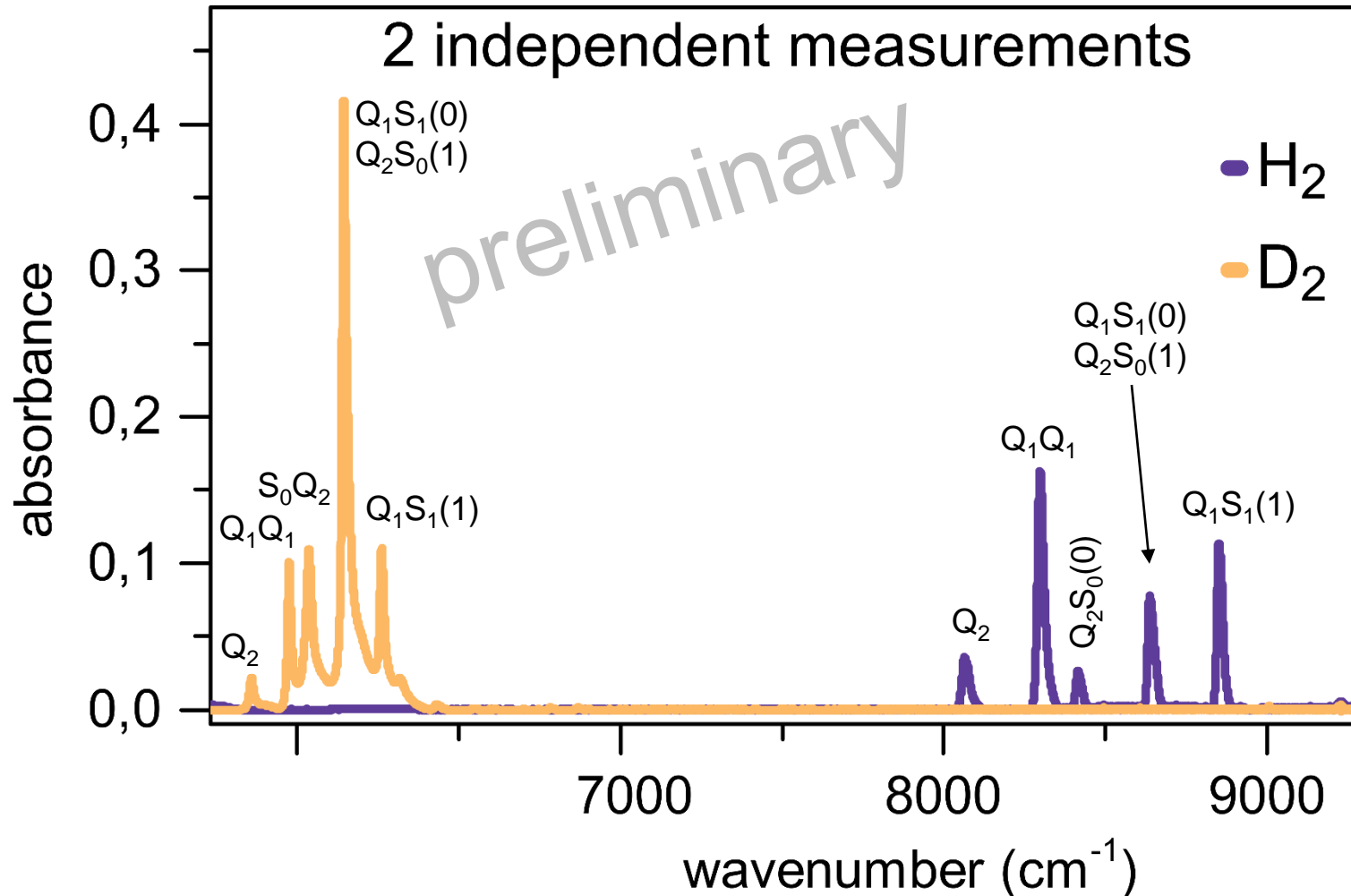
# Focus of this talk

- Can we see clusters at all?
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# Liquid phase, ~20 K

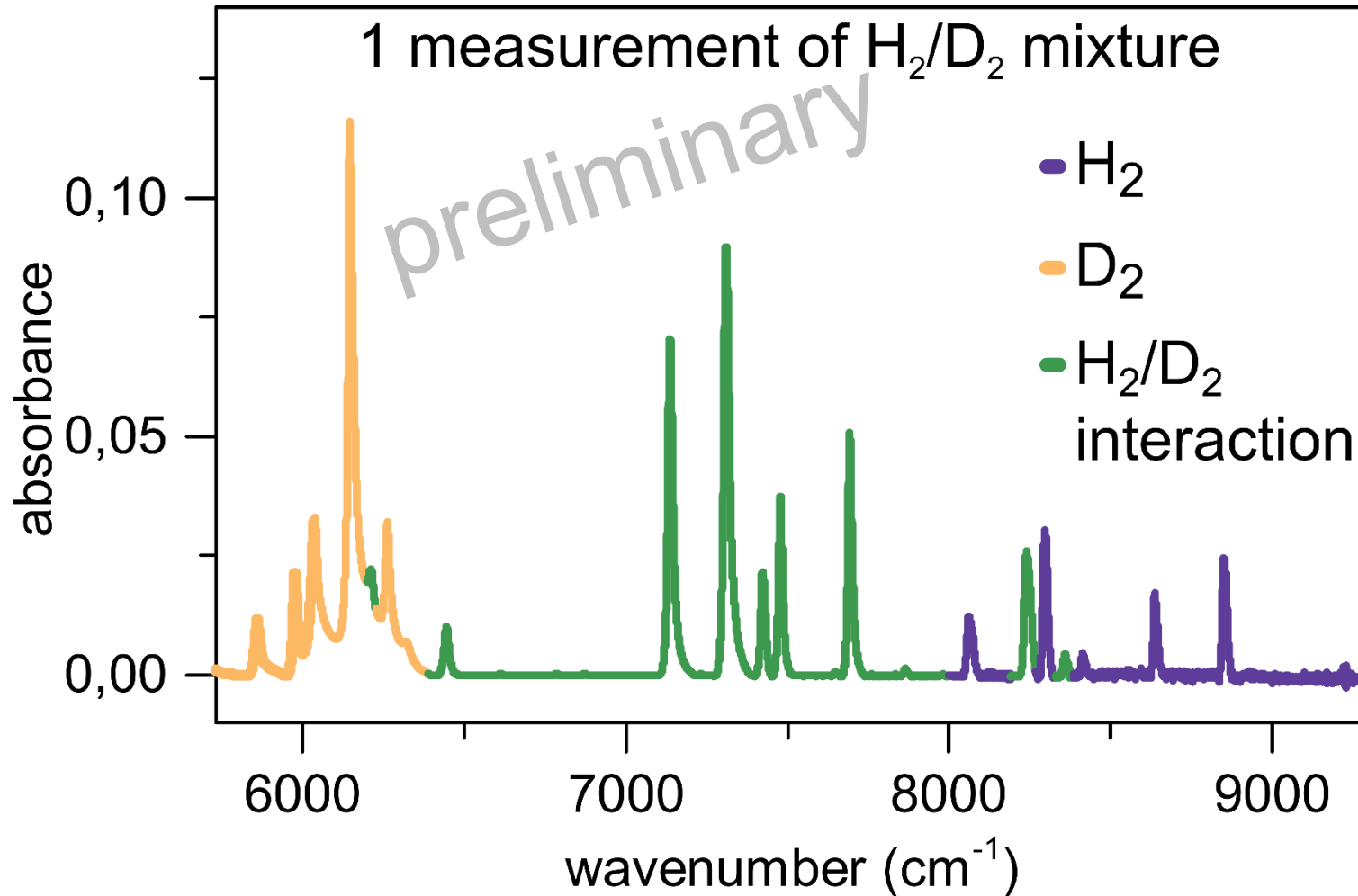
2<sup>nd</sup> vibrational band





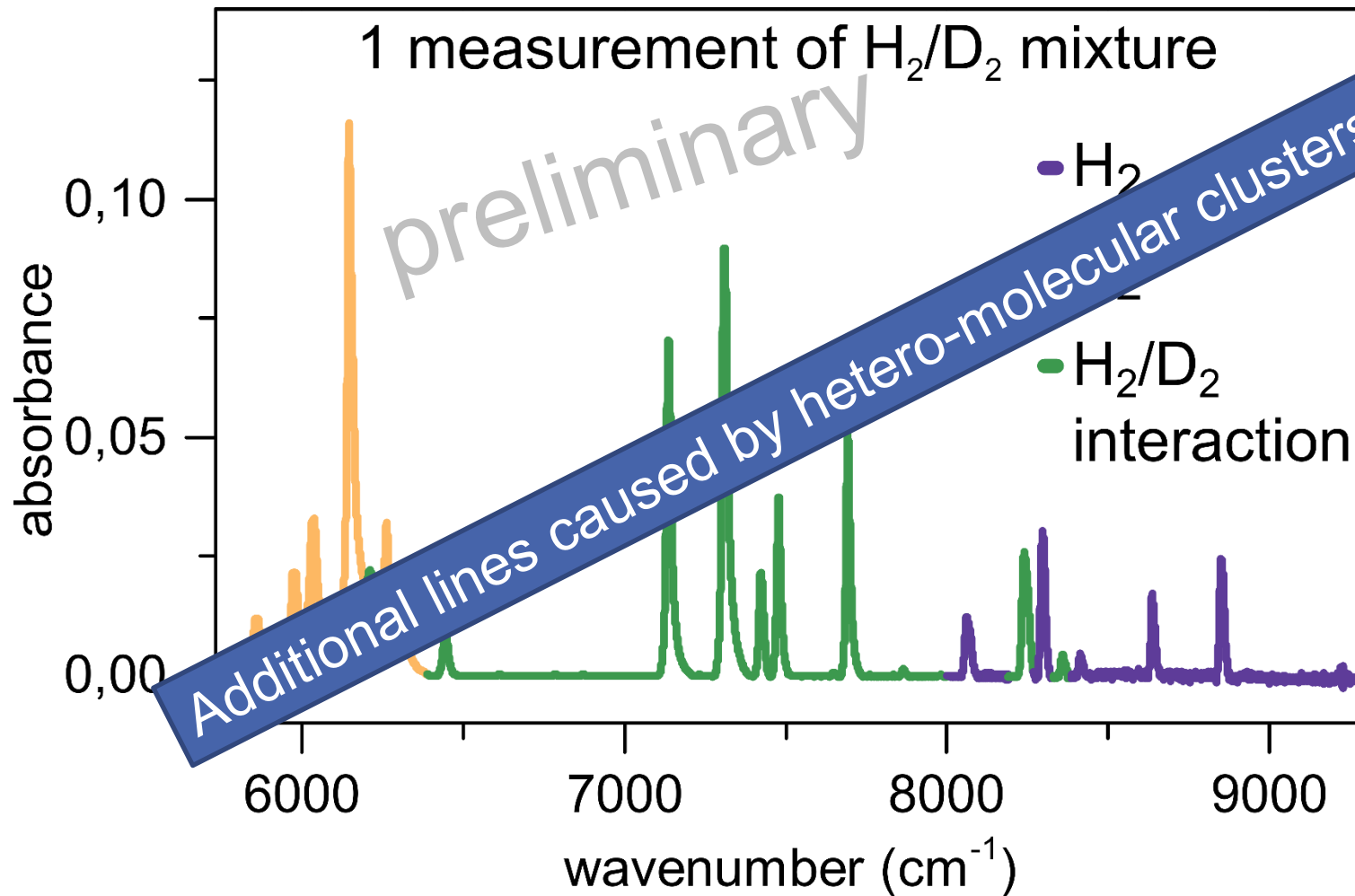
# Liquid phase, ~20 K

2<sup>nd</sup> vibrational band



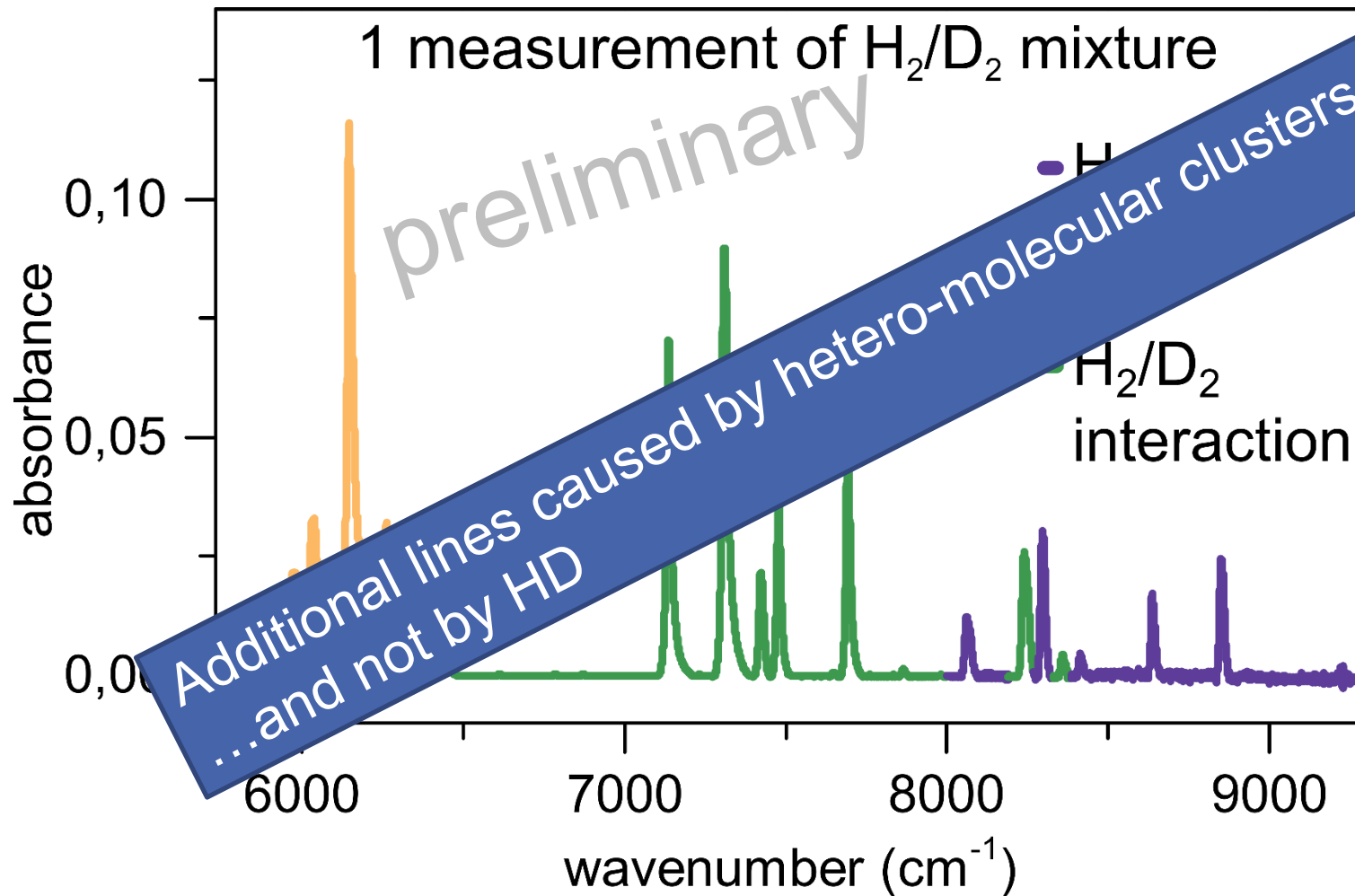
# Liquid phase, ~20 K

2<sup>nd</sup> vibrational band



# Liquid phase, ~20 K

2<sup>nd</sup> vibrational band



# Focus of this talk

- Can we see clusters at all?
  - Liquid Phase:
    - High cluster density
    - High signal expected
  
- Can we see cluster in the gaseous phase?
  
- Does the cluster concentration depend on the temperature and pressure?



# Focus of this talk

## ■ Can we see clusters at all?

### ■ Liquid Phase:

- High cluster density
- High signal expected



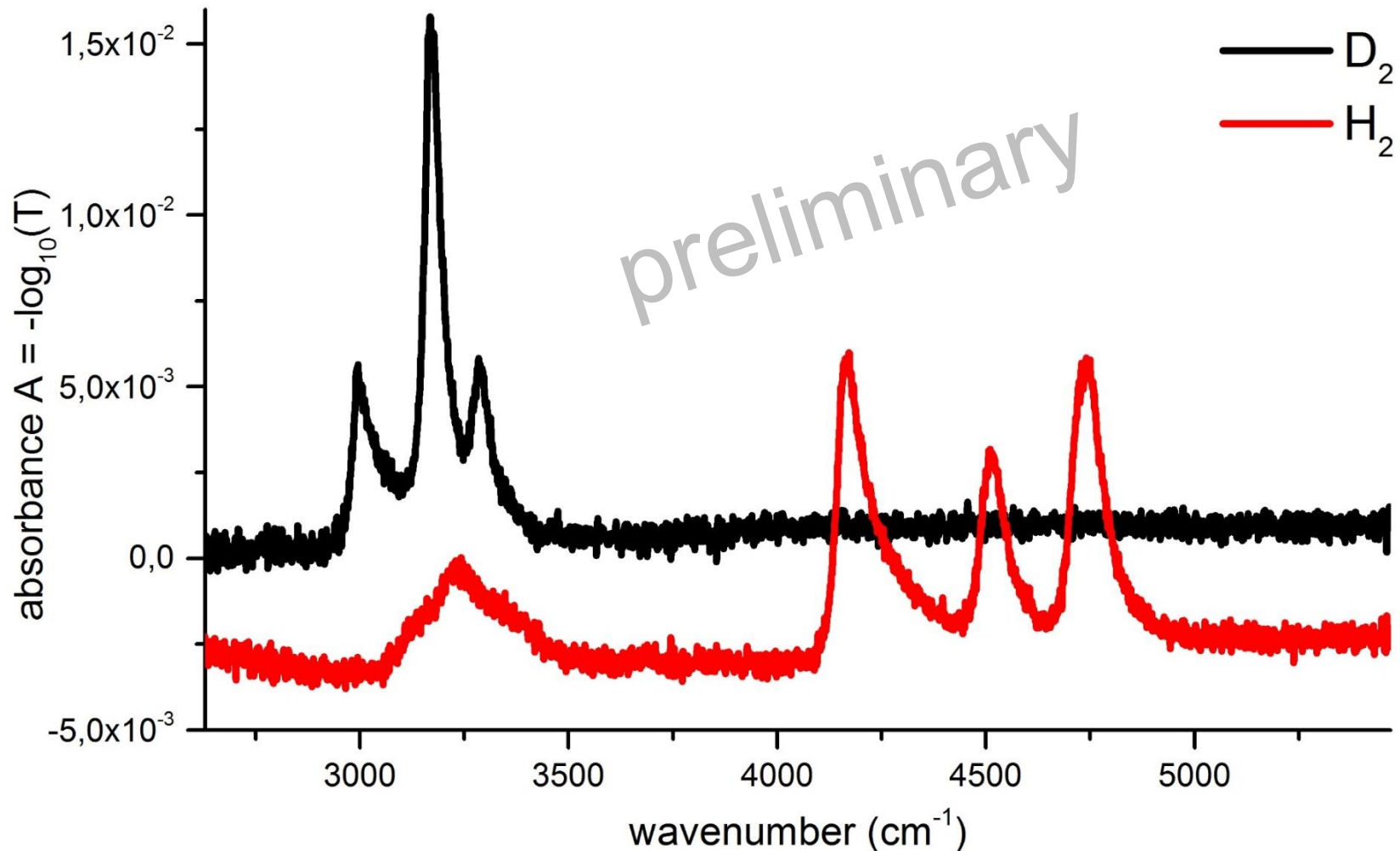
## ■ Can we see cluster in the gaseous phase?

## ■ Does the cluster concentration depend on the temperature and pressure?



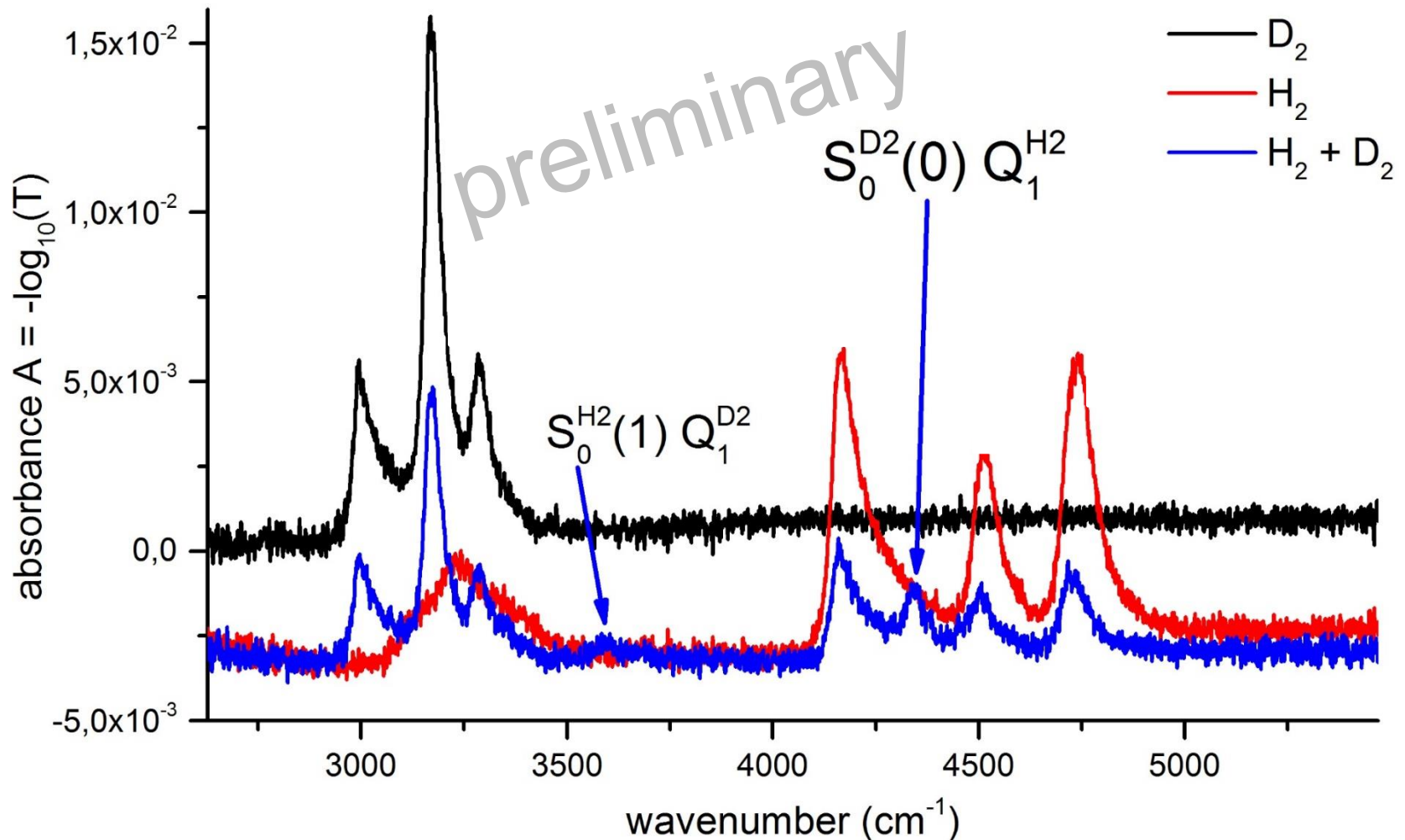
# H<sub>2</sub>-D<sub>2</sub>-Dimers in the gaseous phase at ~30K, 2 bar pressure

1st vibrational band



# H<sub>2</sub>-D<sub>2</sub>-Dimers in the gaseous phase at ~30K, 2 bar pressure

1st vibrational band



# Focus of this talk

## ■ Can we see clusters at all?

### ■ Liquid Phase:

- High cluster density
- High signal expected



## ■ Can we see cluster in the gaseous phase?



## ■ Does the cluster concentration depend on the temperature and pressure?





# Focus of this talk

## ■ Can we see clusters at all?

### ■ Liquid Phase:

- High cluster density
- High signal expected



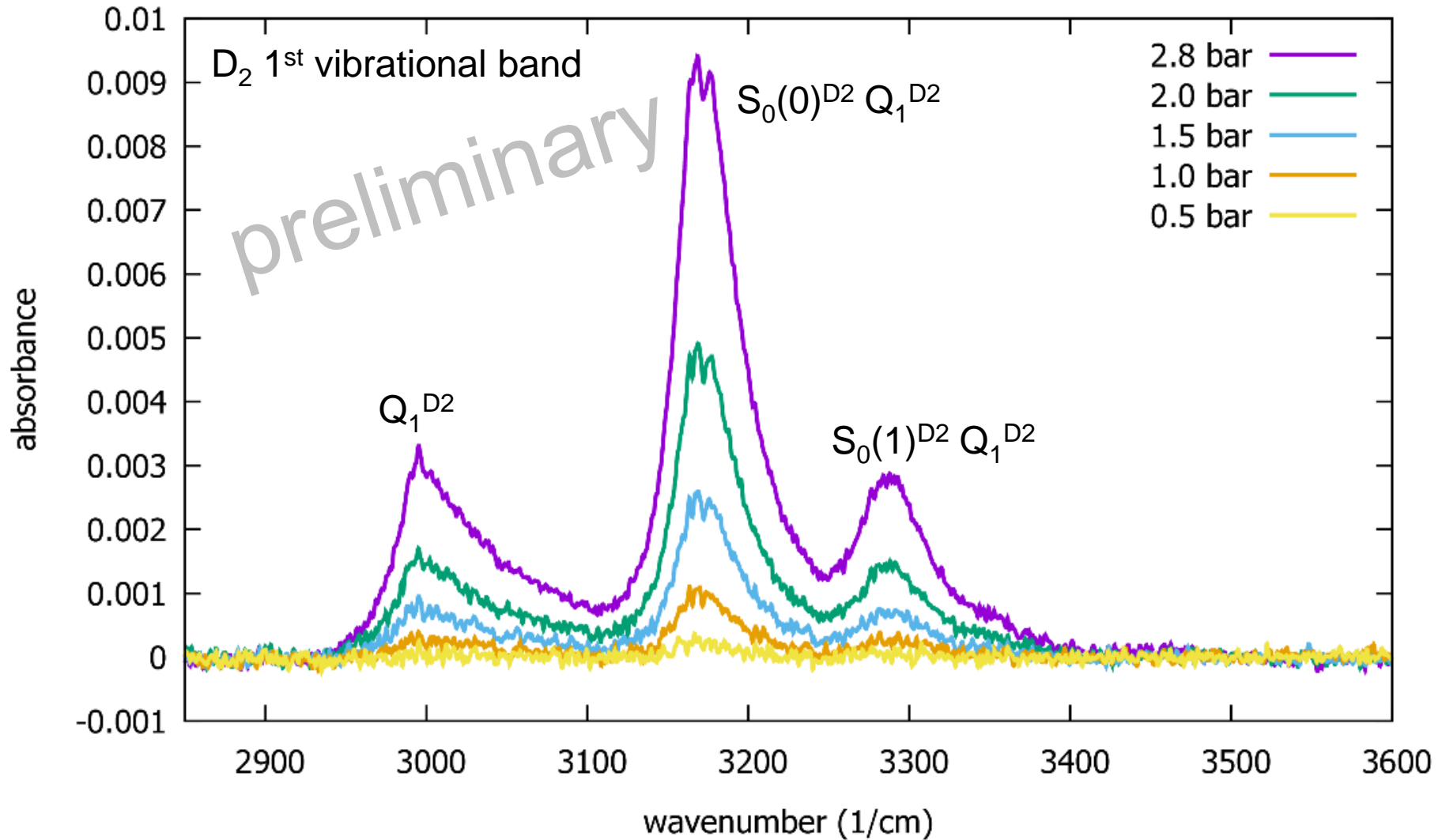
## ■ Can we see cluster in the gaseous phase?



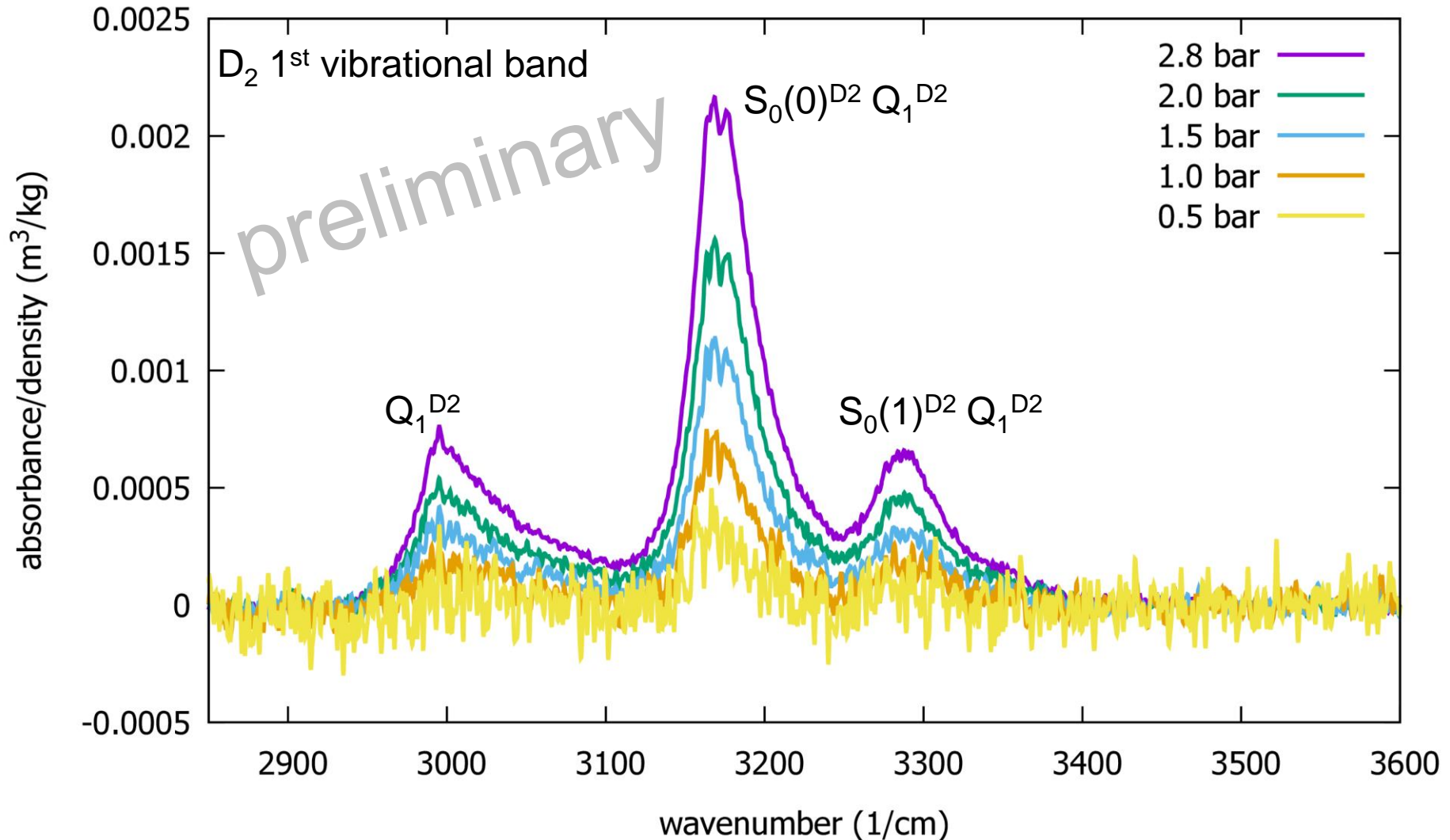
## ■ Does the cluster concentration depend on the temperature and pressure?



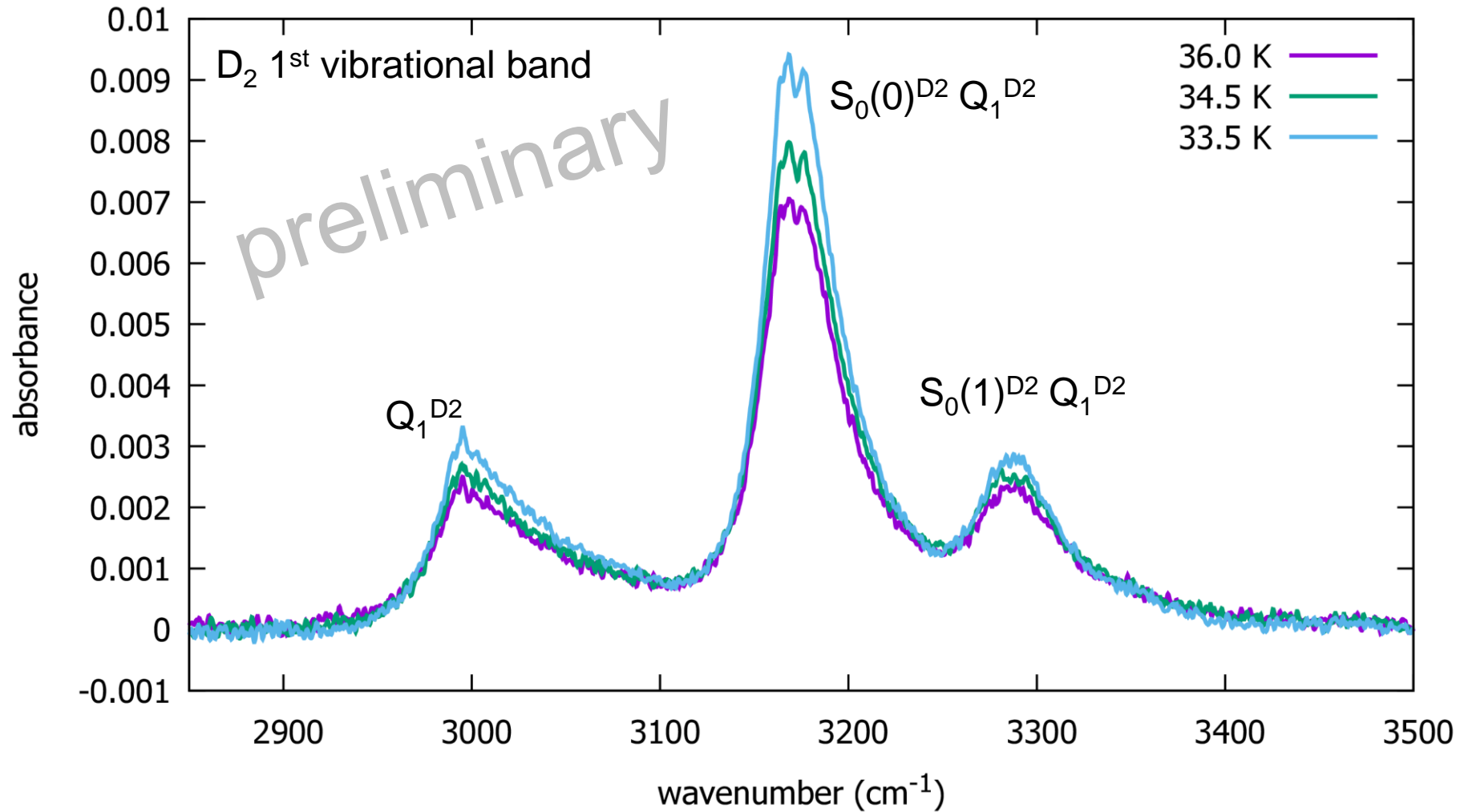
# D<sub>2</sub> gas phase, 27K



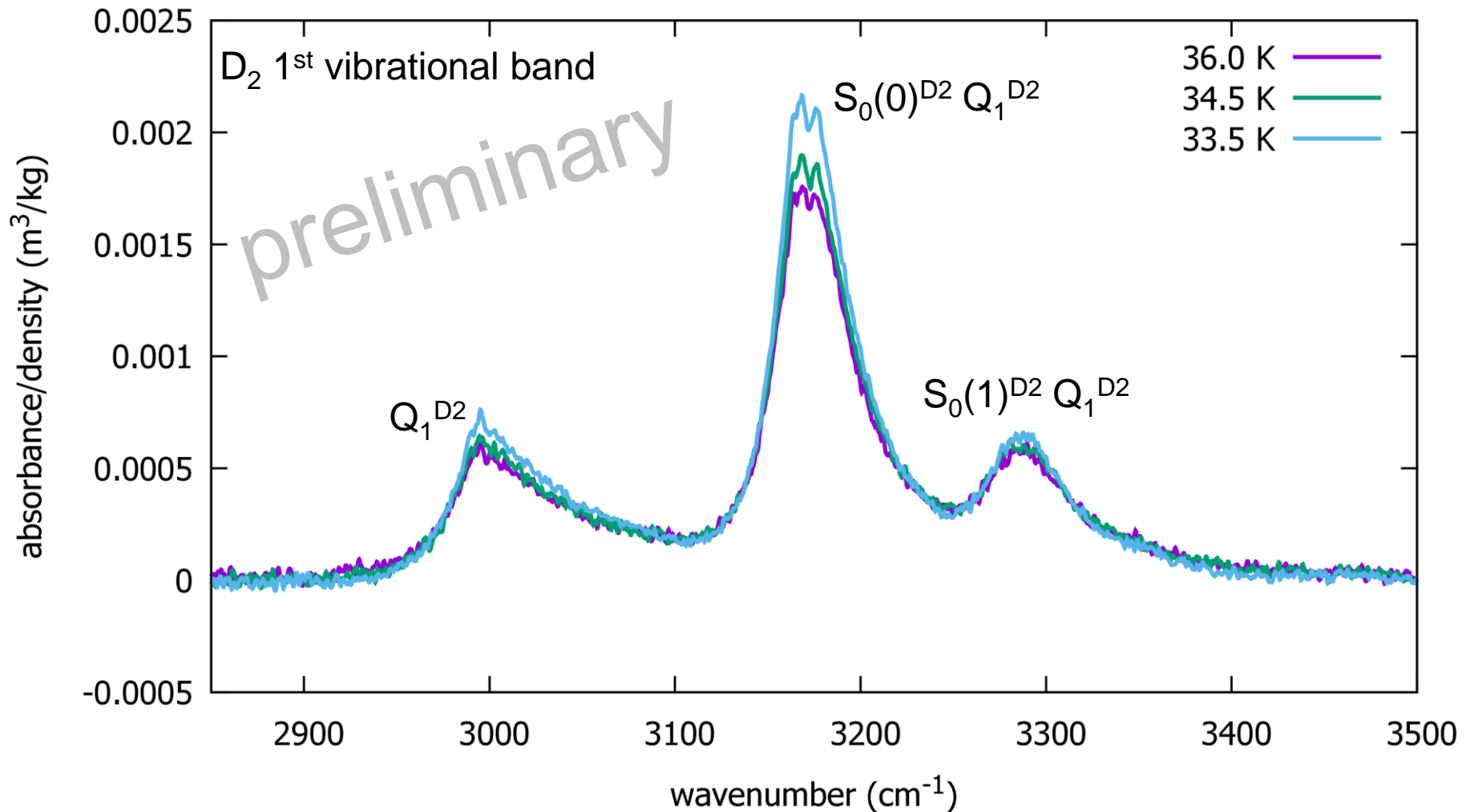
# D<sub>2</sub> gas phase, 27K, density corrected



# D<sub>2</sub> gas phase, 2.8 bar



# D<sub>2</sub> gas phase, 2.8 bar, density corrected



# Focus of this talk

## ■ Can we see clusters at all?

### ■ Liquid Phase:

- High cluster density
- High signal expected



## ■ Can we see cluster in the gaseous phase?



## ■ Does the cluster concentration depend on the temperature and pressure?



# Outlook

- Detailed temperature and pressure dependency analysis
  
- Impact on KATRIN
  - Systematic study of temperature and pressure influence on clusters, WGTS between ~27 and 33 K
  - Cluster concentration?
    - systematic influence on neutrino mass can be simulated
  
- Gas phase with tritium
  - New T<sub>2</sub>ApIR experiment
    - commissioning 2017





**THANK YOU FOR YOUR ATTENTION!**