



HAL
open science

Vibrational Excitation of CO₂ by Nanosecond Discharges at Atmospheric Pressure

Erwan Pannier, Valentin Baillard, Christophe O. Laux

► **To cite this version:**

Erwan Pannier, Valentin Baillard, Christophe O. Laux. Vibrational Excitation of CO₂ by Nanosecond Discharges at Atmospheric Pressure. 70th Gaseous Electronics Conference (GEC), Nov 2017, Pittsburgh, United States. hal-01866573

HAL Id: hal-01866573

<https://hal.science/hal-01866573>

Submitted on 19 Feb 2019

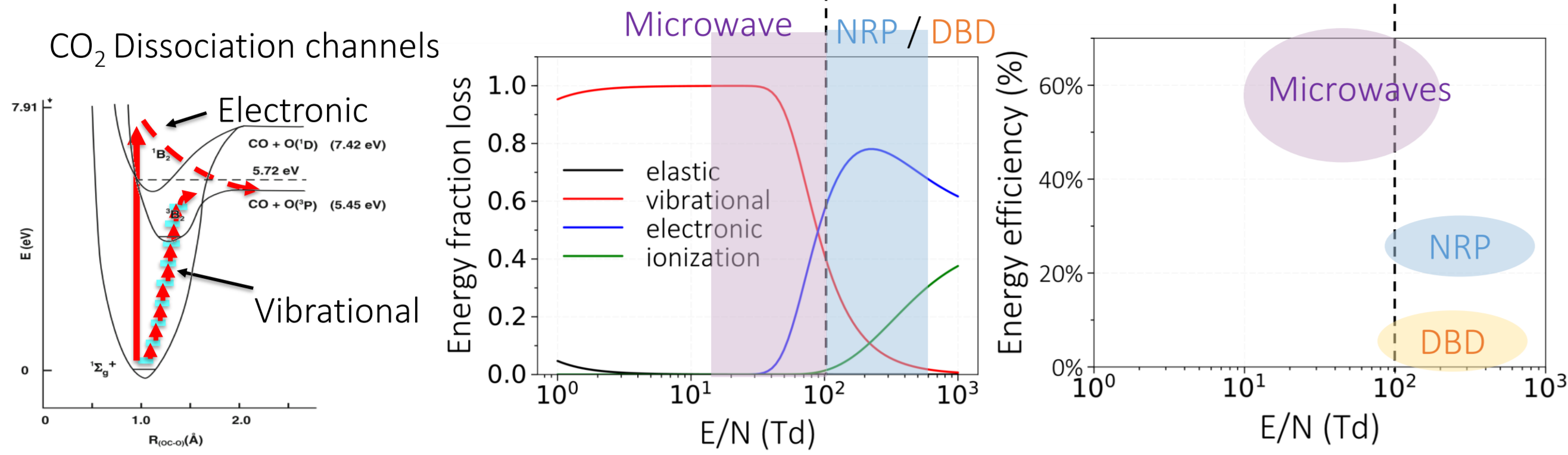
HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



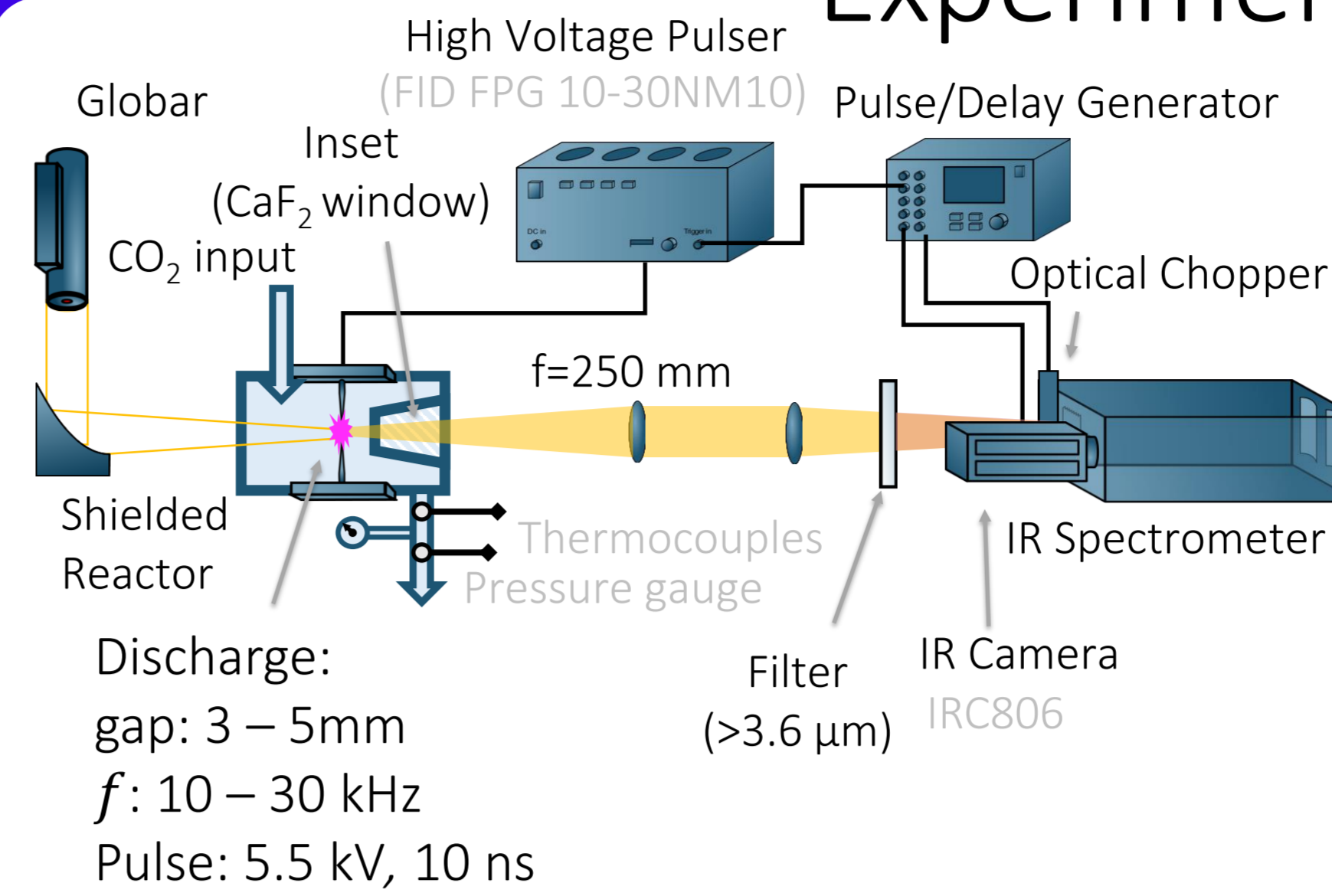
Motivation

CO₂ dissociation efficiency is maximized with high vibrational excitation (T_{vib}) and low heating (T_{trans}) [1]. Nanosecond Repetitive Pulses (NRP) are more efficient than DBD [2] at similar reduced field (E/N). Why?



Goal: **measure the vibrational contribution in NRP sparks CO₂ splitting**
How: OES meas. + Line by line (LBL) model + Line-of-sight (LOS) model

Experimental Setup



Measurements:

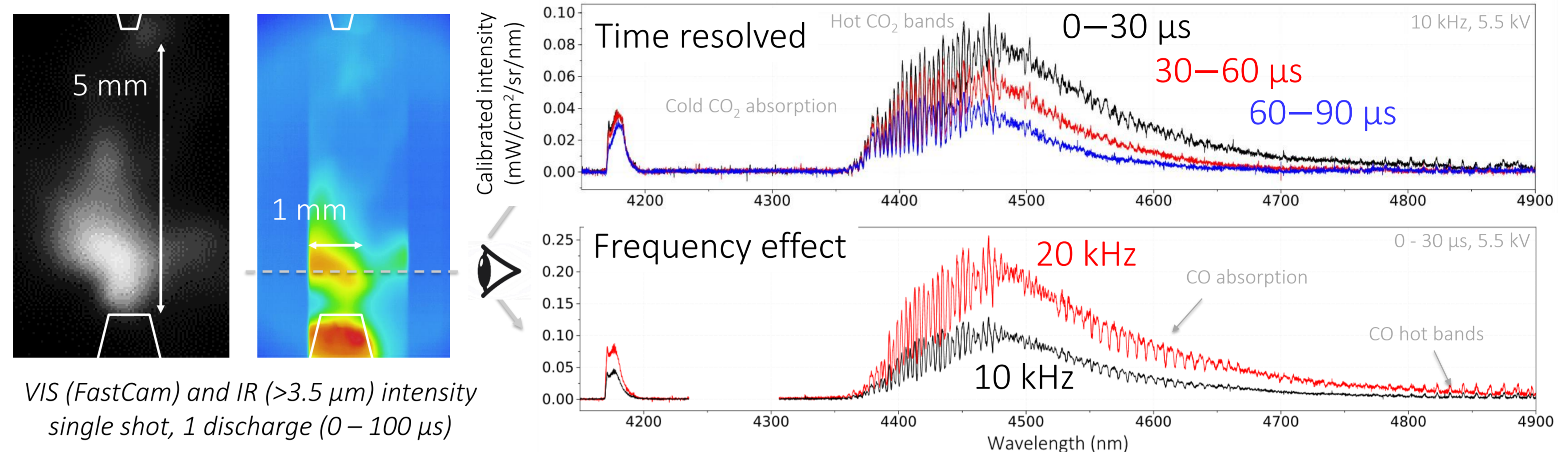
- CO₂: T_{vib} , T_{rot} , N
- mid-IR Absolute optical emission spectroscopy (OES), time-resolved (10 μ s), spatially resolved (500 μ m)
- CO: T_{vib} , T_{rot} , N
- Broadband IR Absorption production in post-discharge

Alternative techniques:
 - CO₂ Raman scattering: difficult to analyze ✗
 - FTIR: excellent time, spectral resolution [3] ✓ but no spatial resolution ✗

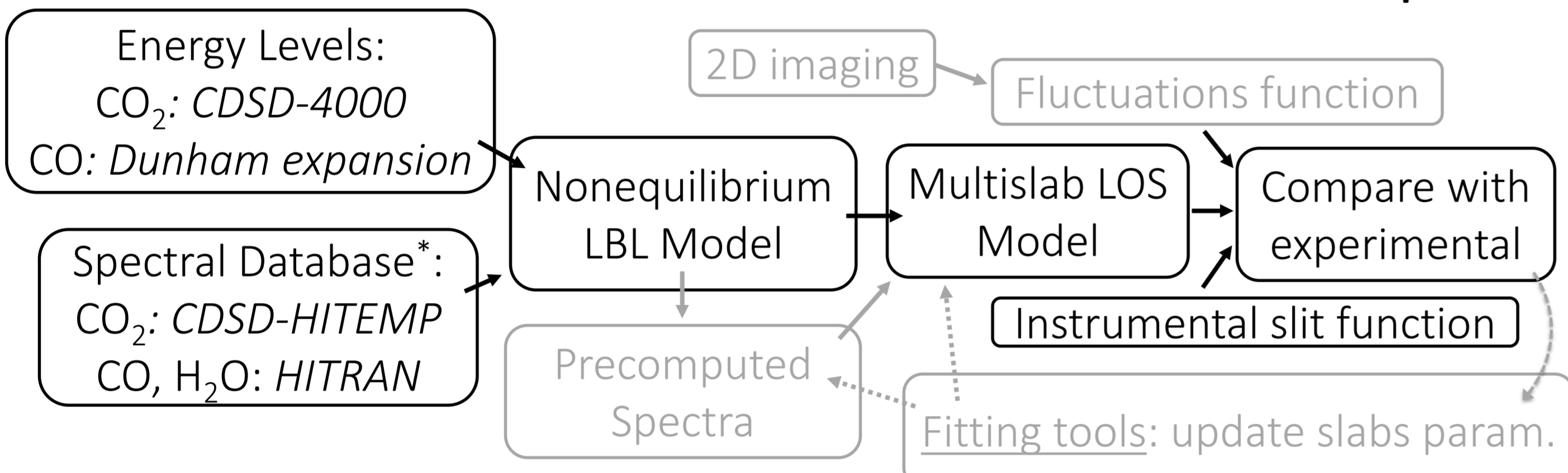
Challenges

- Electromagnetic interferences \rightarrow shielded reactor design ✓
- Room air absorption \rightarrow optical train purged for absolute calibration ✓
- Spatial fluctuations (hydrodynamics) \rightarrow spatially resolved spectra ✓
- Signal-to-dark ratio \sim 1/400 \rightarrow phase locked capture of dark drift ✓
- Camera mistrigs \rightarrow post-processing detection algorithm ✓
- 2D: Large data generation (\sim 8 hrs, 200 Gb / full spectrum)
- Atmospheric pressure: broad, overlapping lines

Data

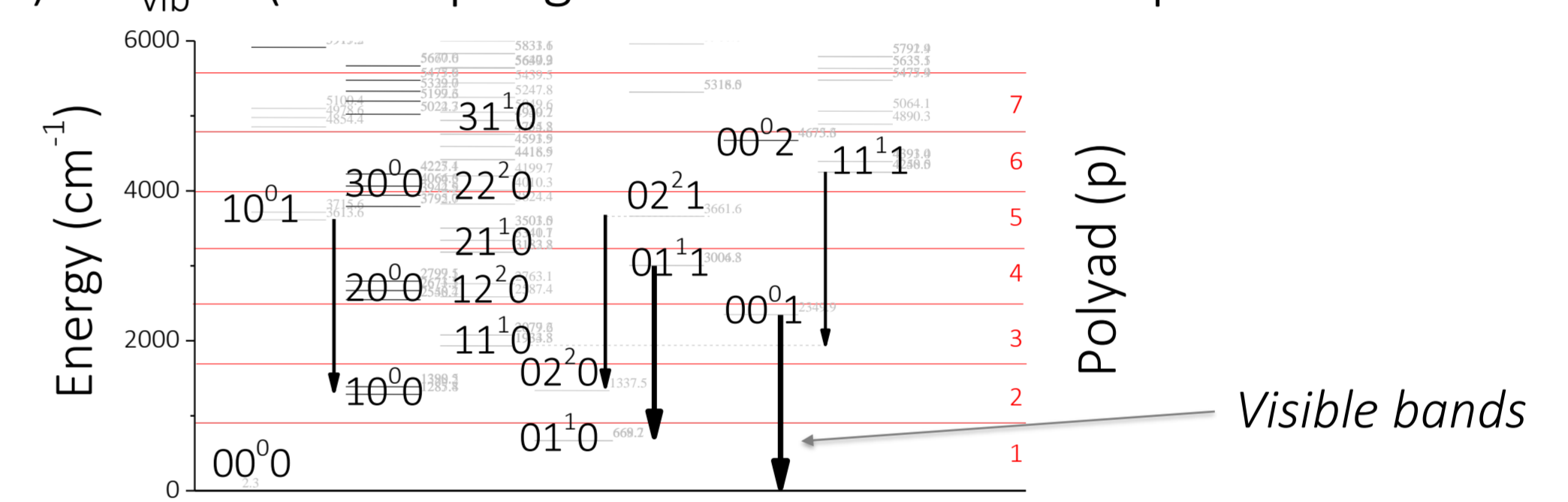


Nonequilibrium LBL Model



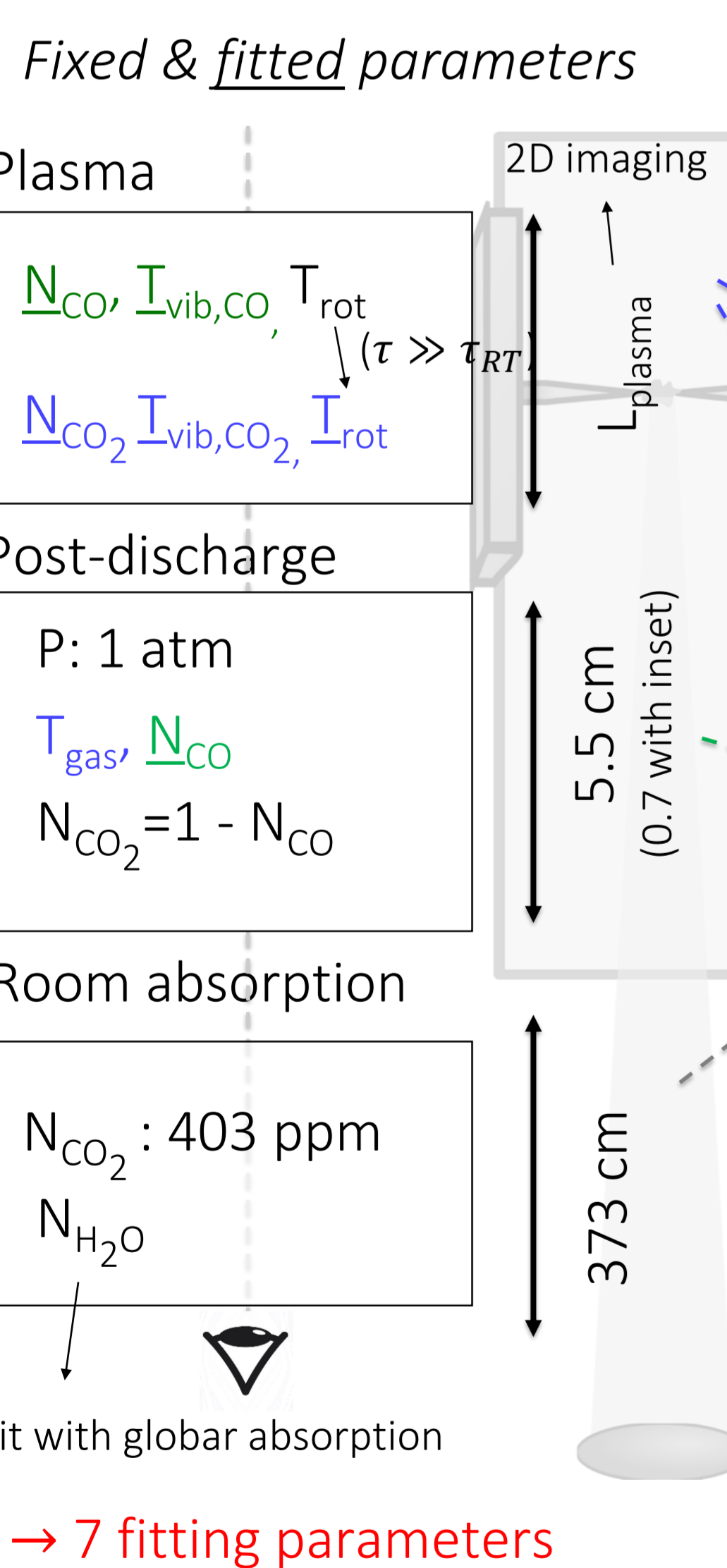
CO₂ vib / rot coupling: $E = E_{vib} + E_{rot} + E_{coupling}$. In CDS polyad nomenclature (p,J,c,N) we chose $E_{vib} = E(p,0,c,N)$, $E_{rot} = E(p,J,c,N) - E_{vib}$ (\rightarrow coupling included in rotational partition function)

CO₂ low lying level (HITRAN notation vs polyads)

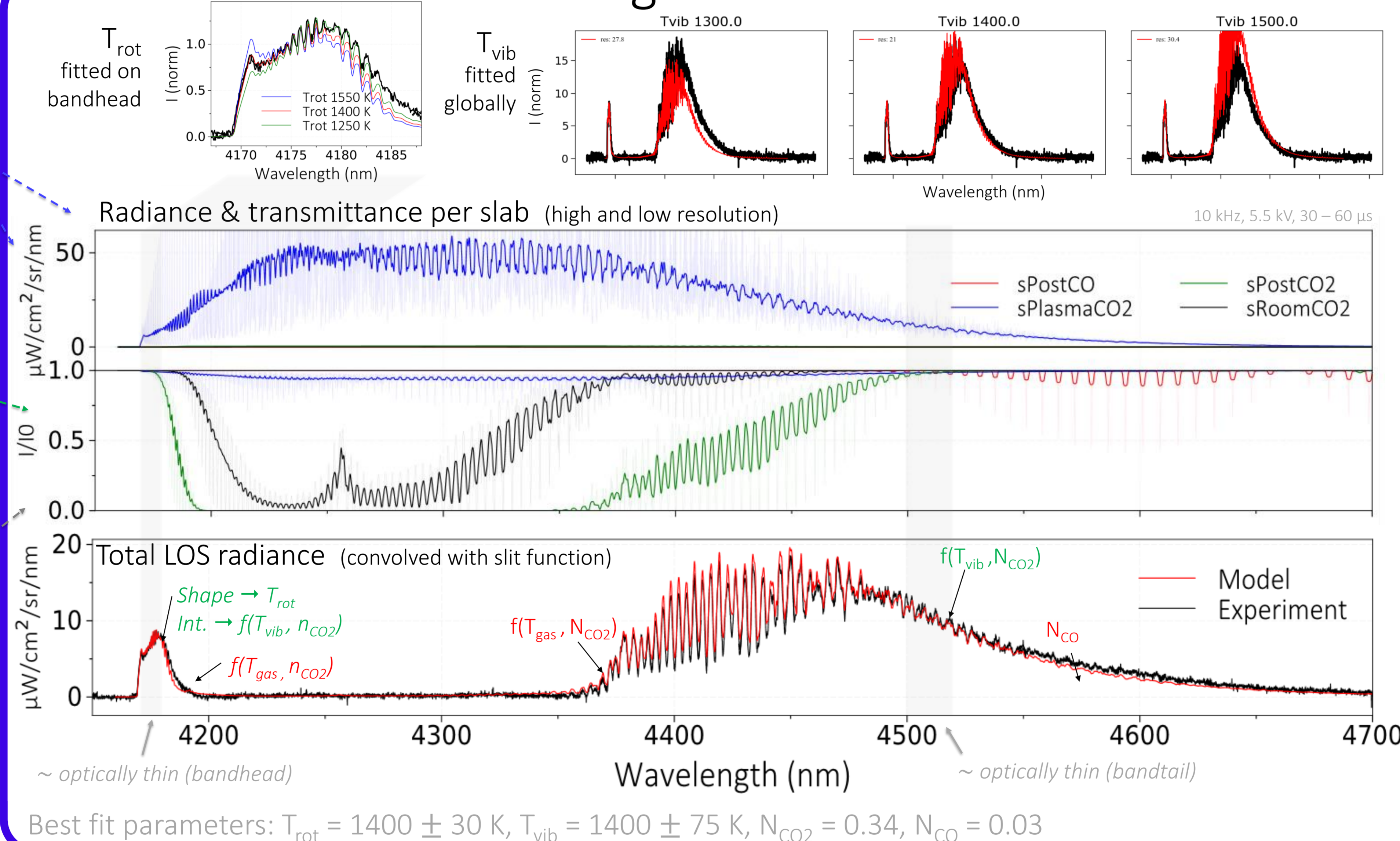


Distribution: overpopulation factors allow arbitrary non equilibrium distributions of vibrational levels; rotational \sim Boltzman

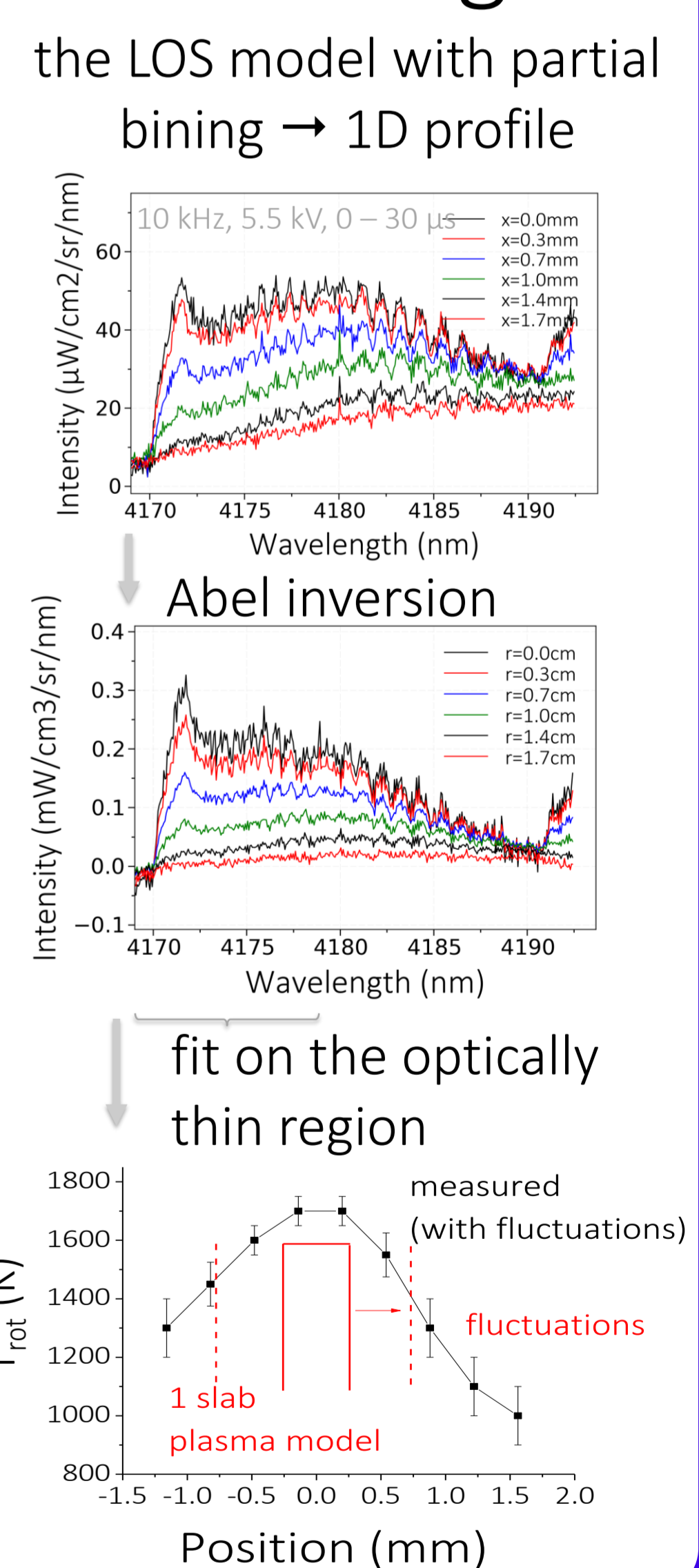
LOS Model



Fitting method

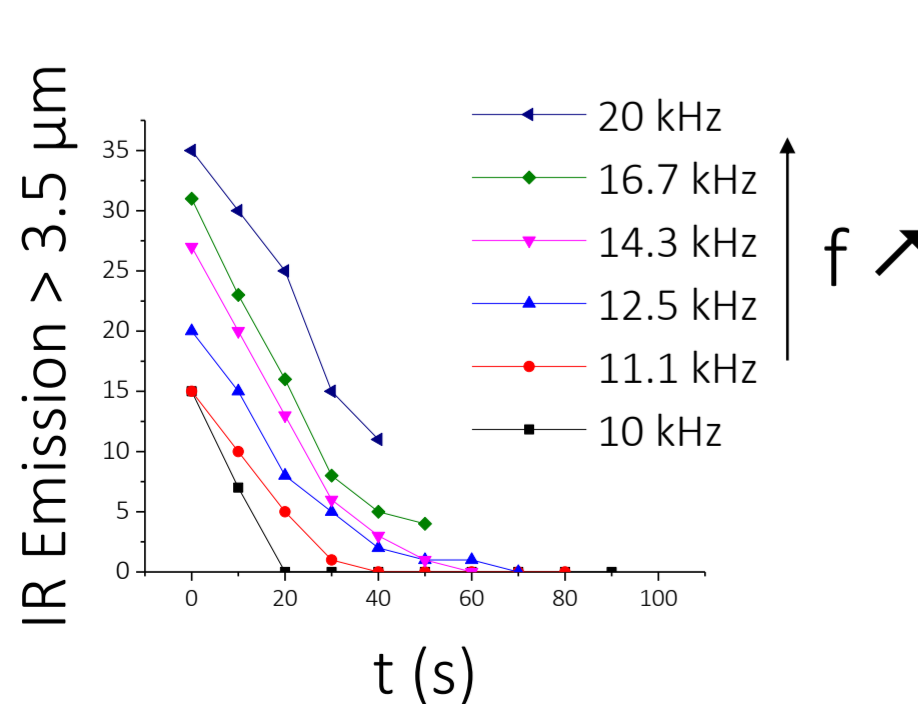


Refining

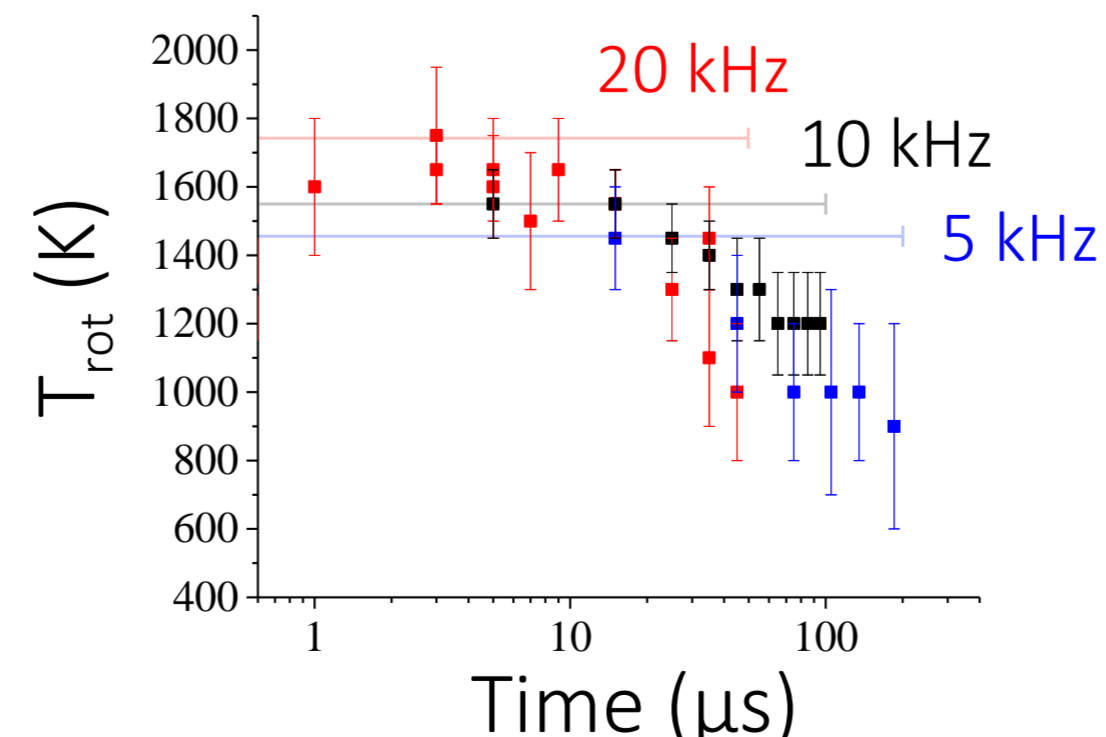


Results & Conclusions

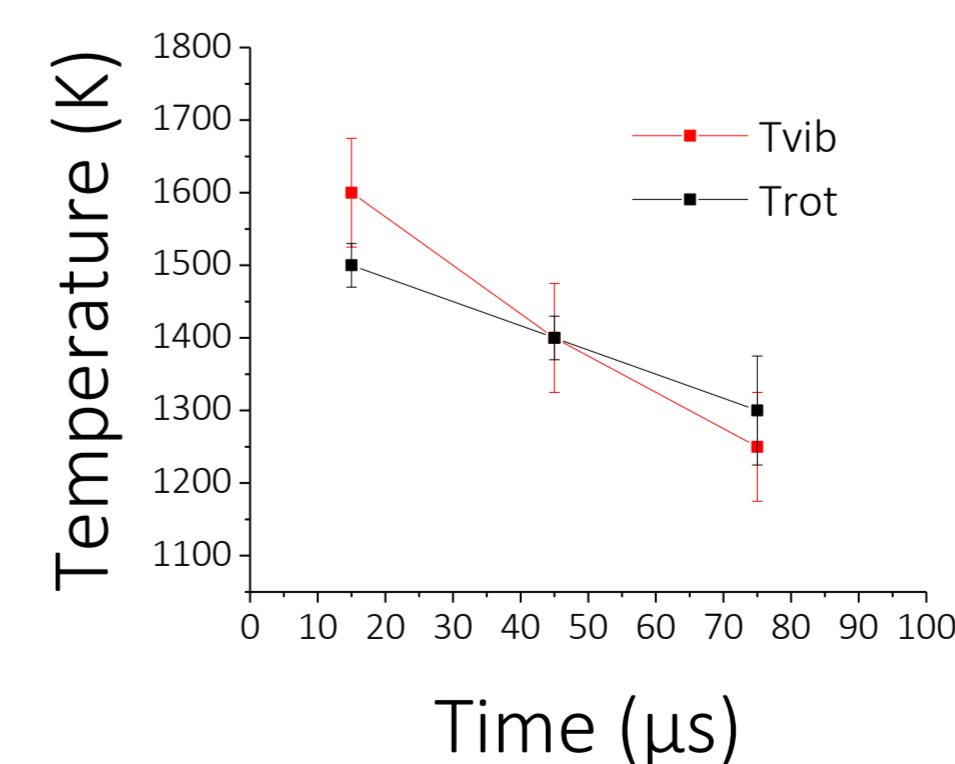
Total IR emission ($>$ 3.5 μ m)



T_{rot} measured by bandhead fitting (2, 10, 30 μ s period)



T_{vib} measured by global fitting (30 μ s period, 10 kHz)



Fitting results:

- 10 kHz: $T_{vib} - T_{rot}$ equilibrium achieved within the first 30 μ s after the discharge. Correct modelling can be obtained with a simplified 3-slabs model
- 20 kHz: evidence of non-equilibrium in the first 30 μ s with a departure from a 1- T_{vib} Boltzmann vibrational distribution model

Next step: compare measured vibrational populations with predictions of a 0D-kinetic model

