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New targets for laminar flame speed determination and kinetic schemes assessment

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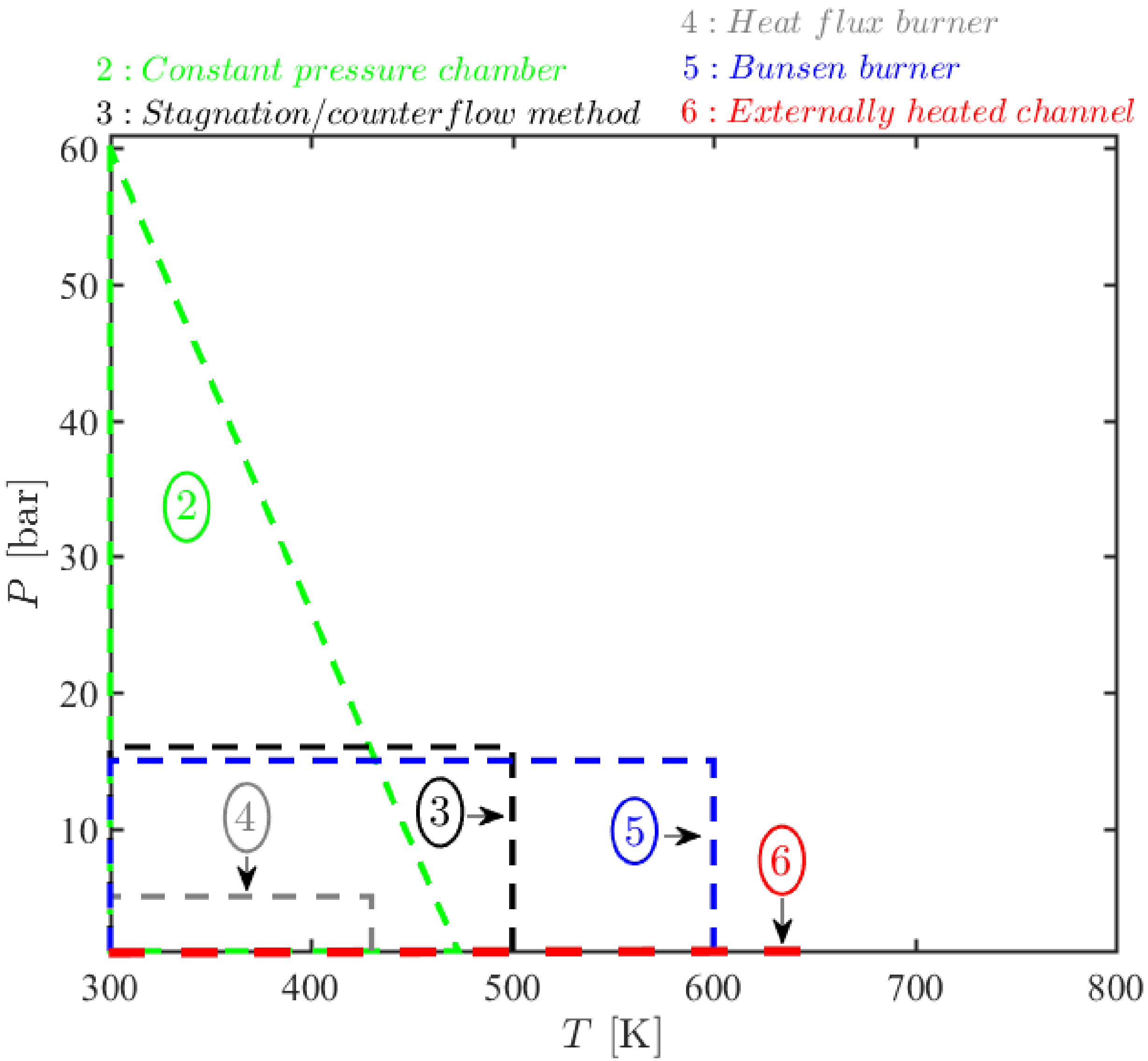
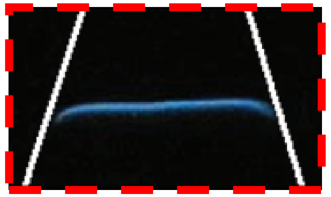
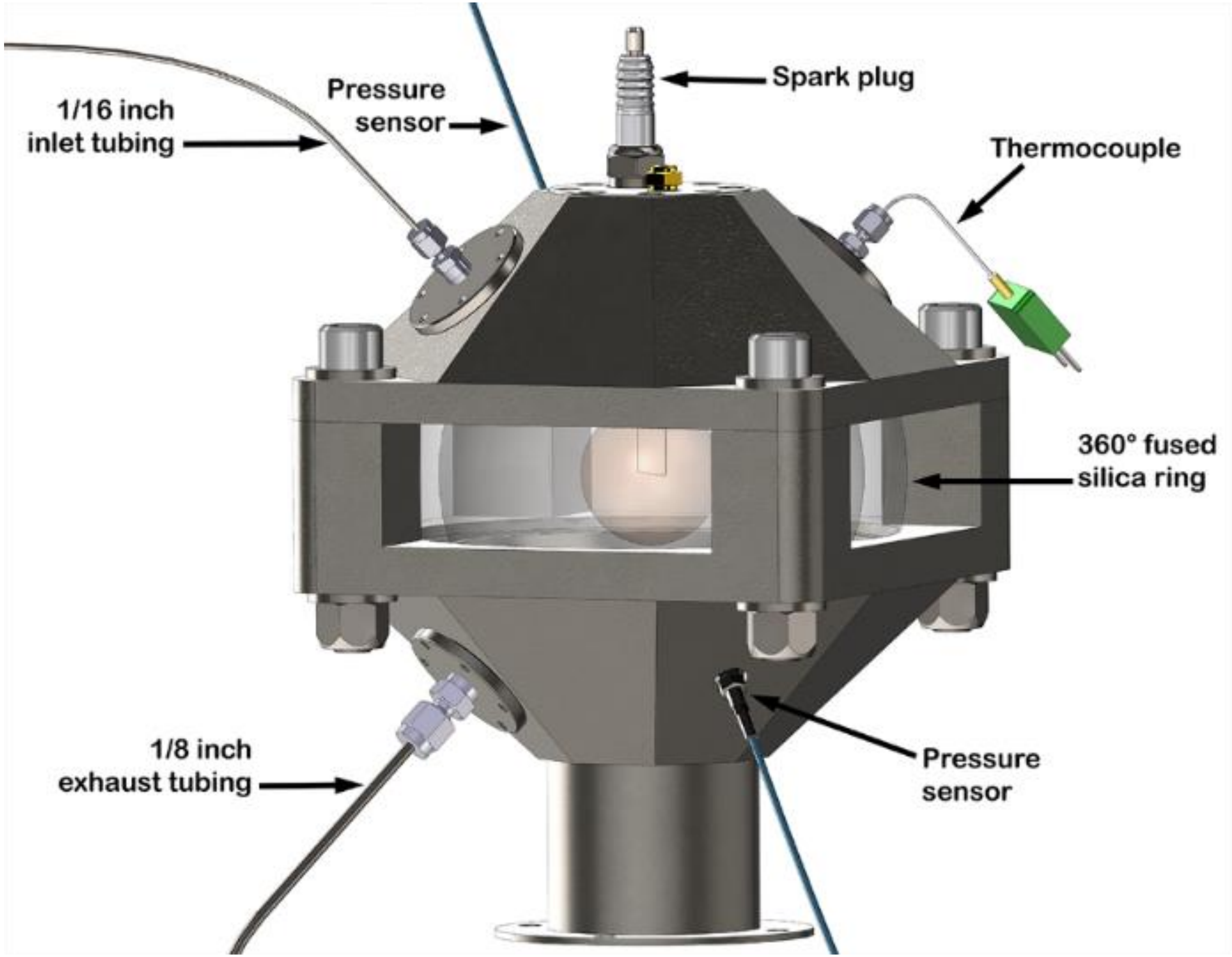
Introduction



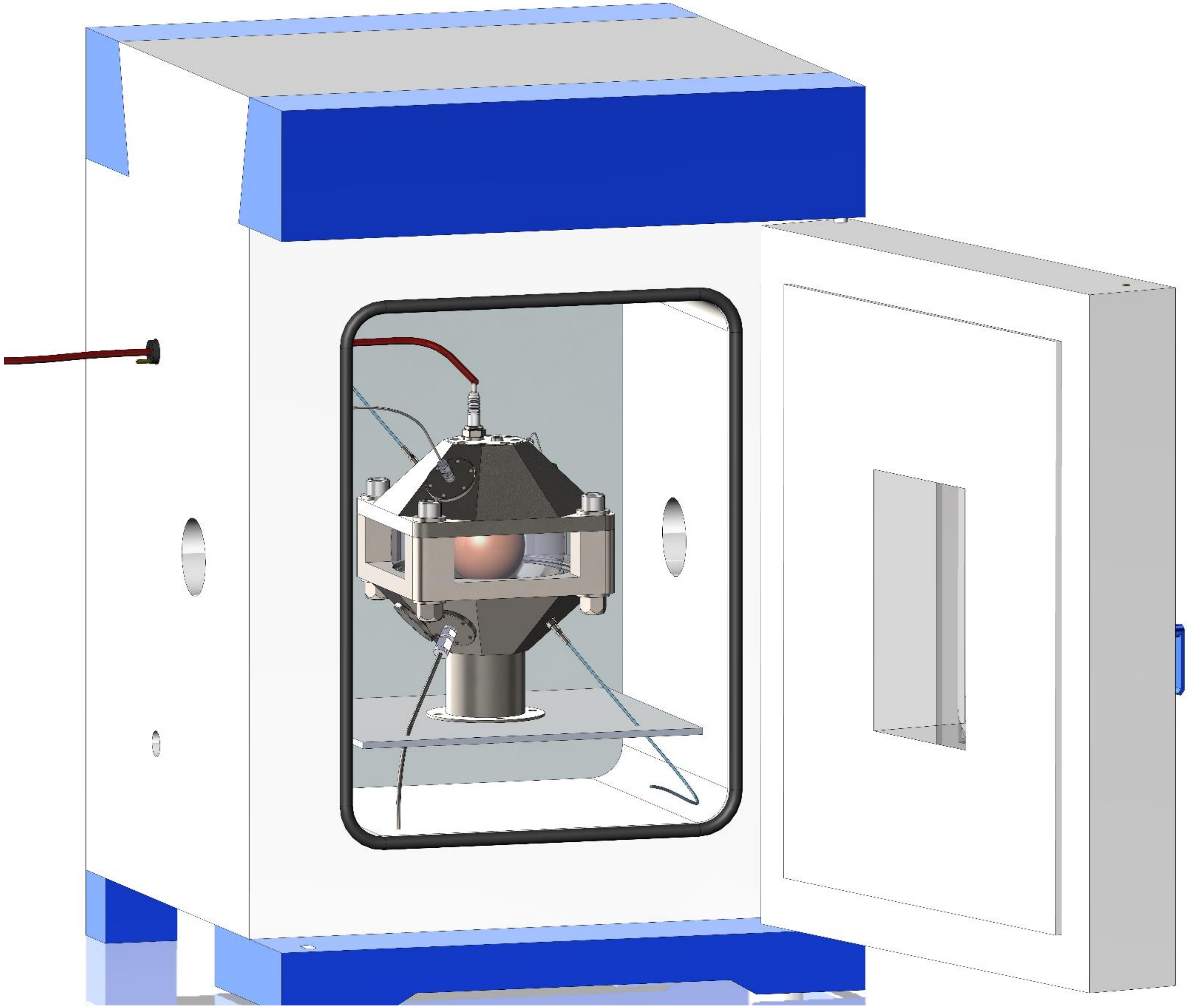


full OPTIcal access Perfectly spheRical combustIon chaMber (OPTIPRIM)

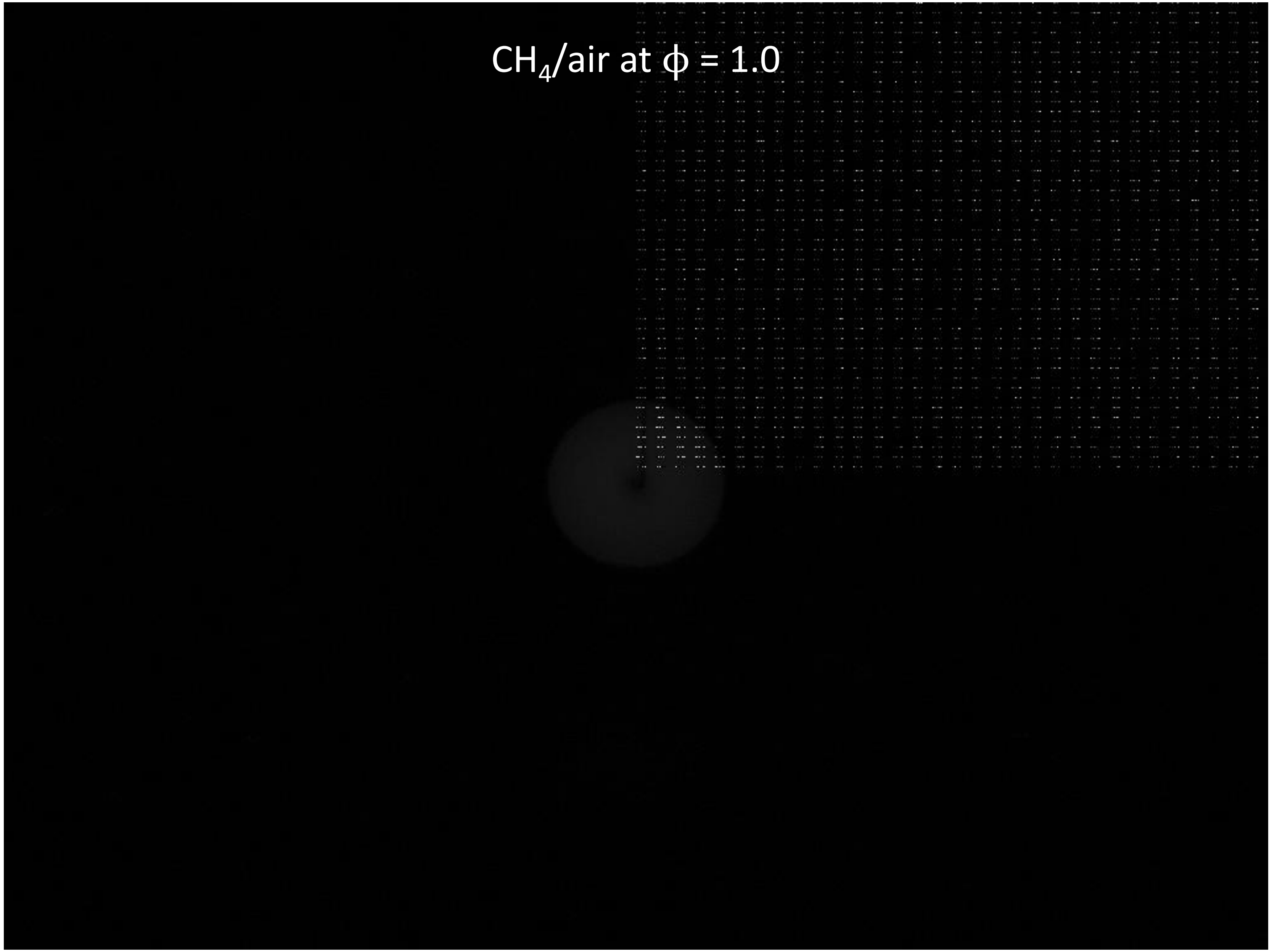


Experimental set-up

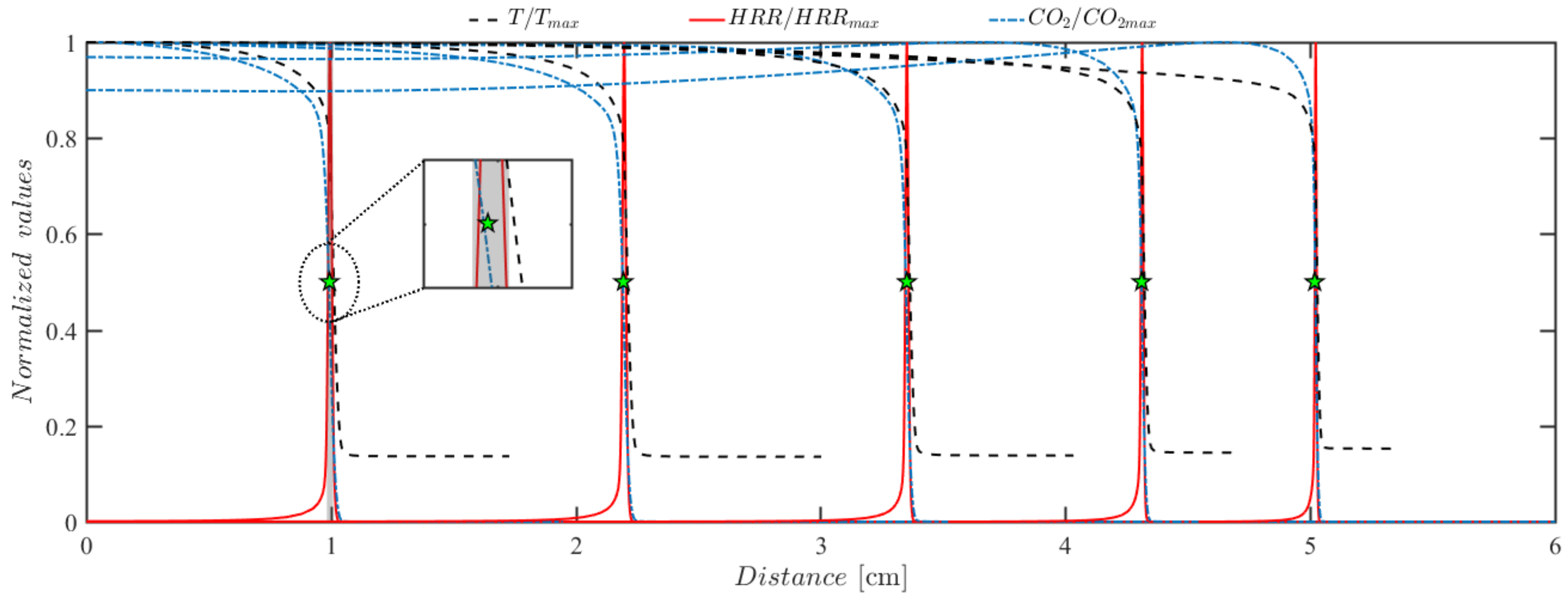
Fuel	T_0 (K)	P_0(bar)	ϕ (-)
CH_4	300	1	1
CH_4	300	1	1.3

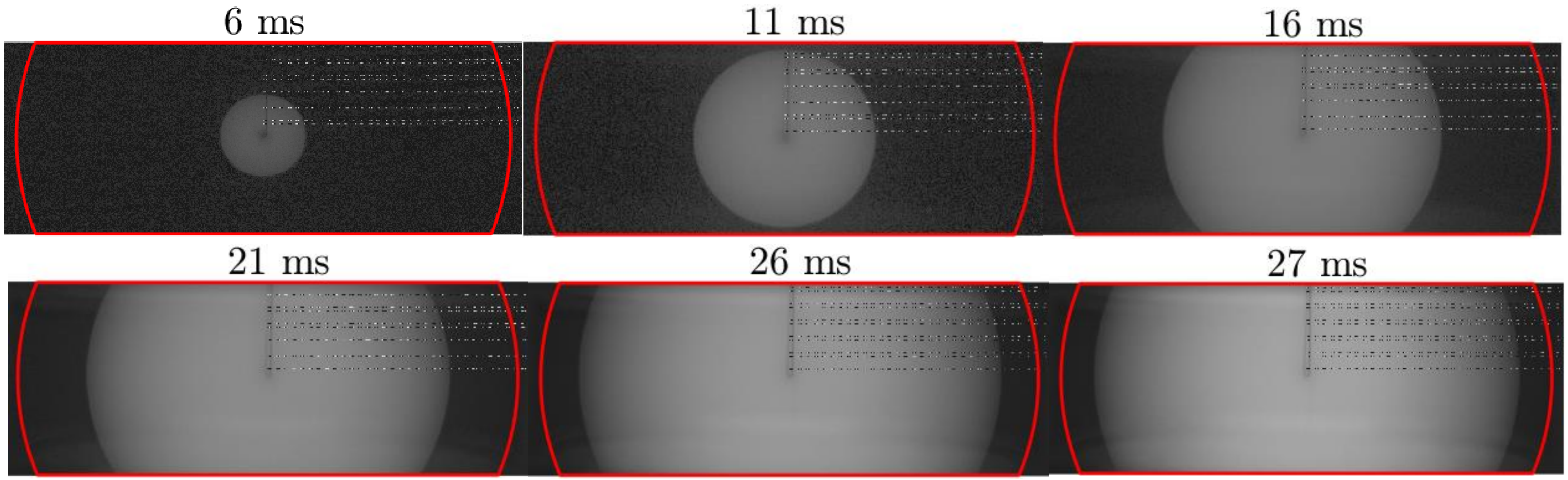


Flame propagation



Flame visualisation





1. INTRODUCTION

2. SET-UP

2,1 Flame visualisation

2,2 Rf and P trace

3. Validation & limits

3,1 Heat losses

3,2 Stretch

4. RESULTS

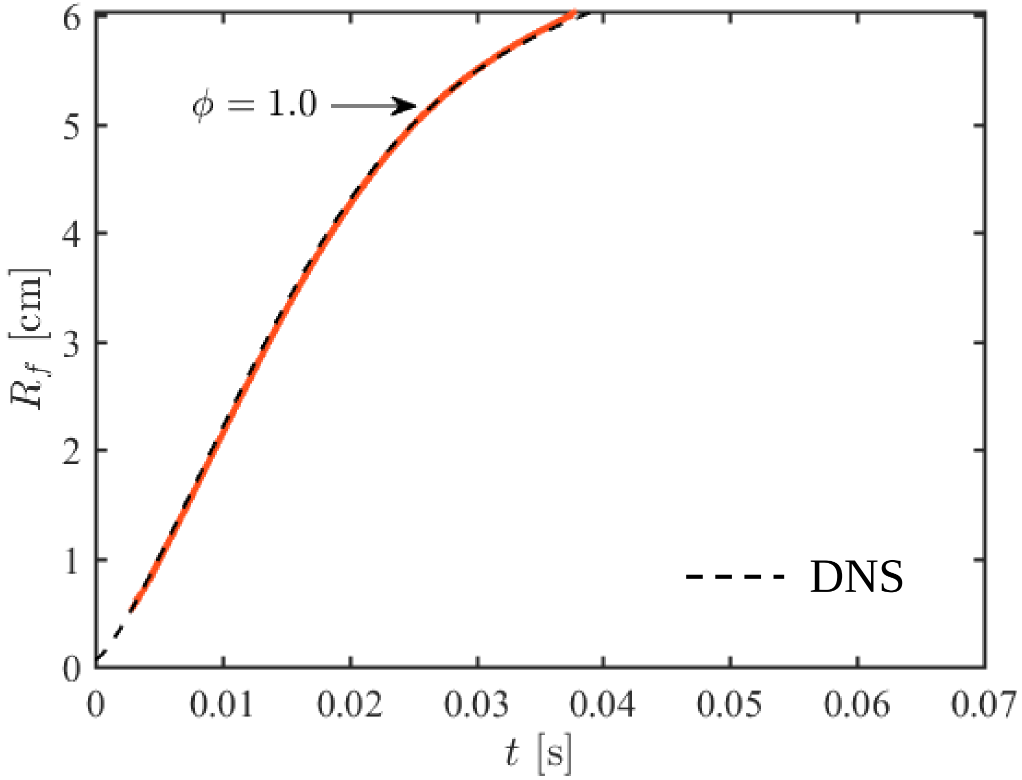
4,1 Flame speed

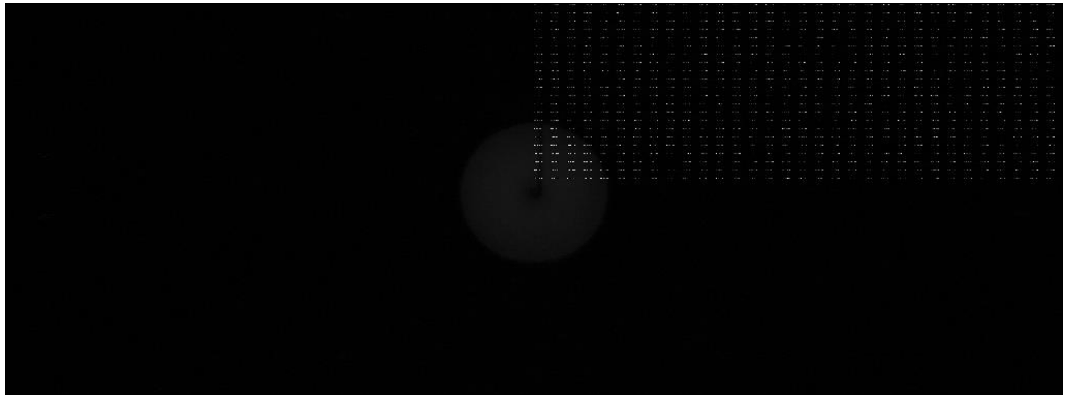
4,2 New target

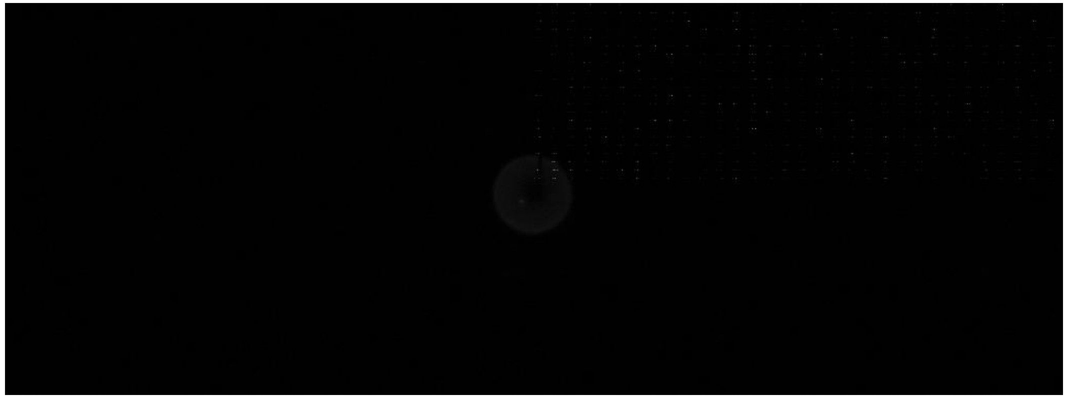
4,3 New method

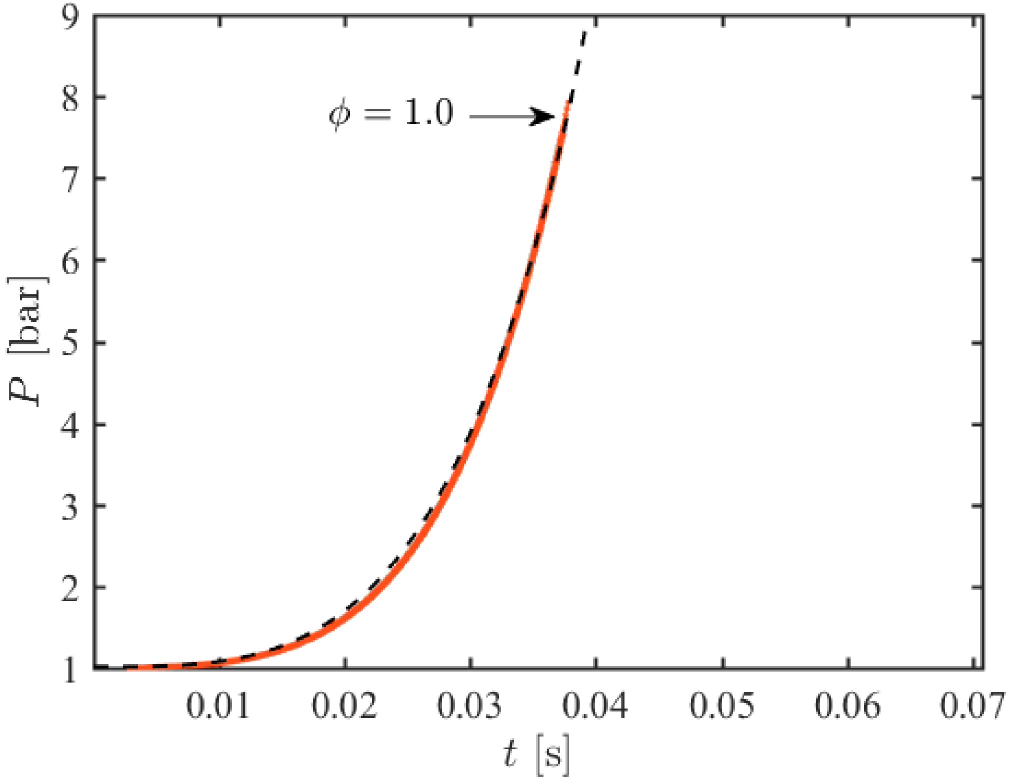
5. CONCLUSIONS

Flame radius & pressure evolutions



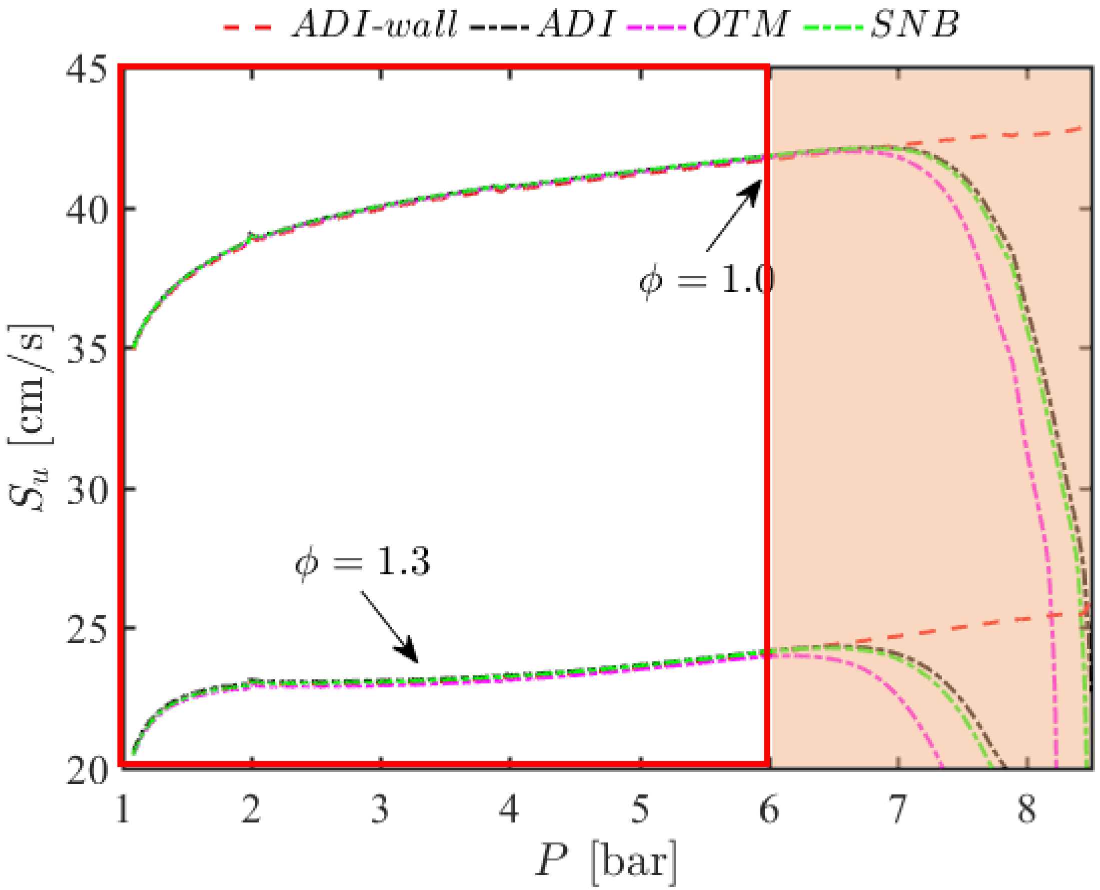






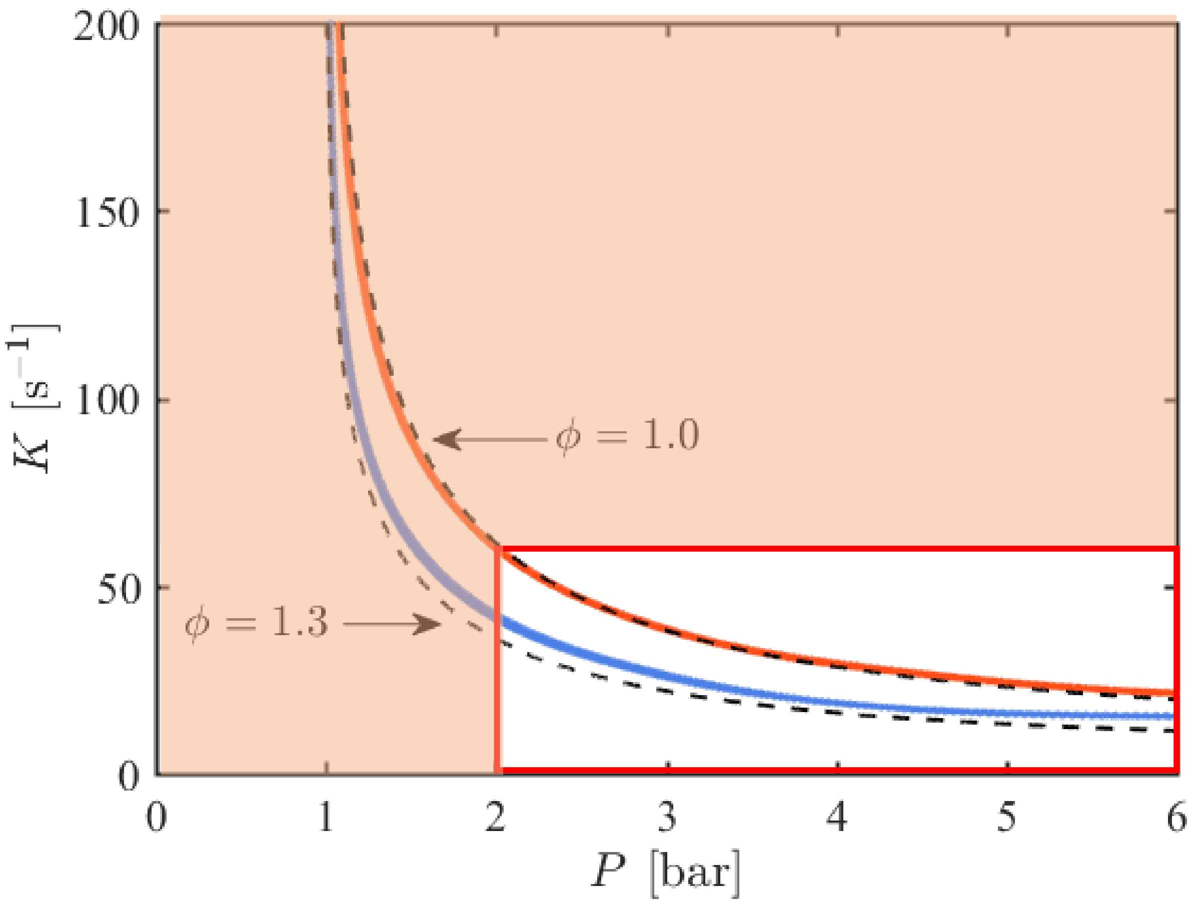
Radiation and heat losses to the walls

ADI-wall	adiabatic walls
ADI	adiabatic model with no radiative loss
OTM	optically thin model considering emission but no absorption
SNB	statistical narrow band model with both radiation emission and absorption



Stretch effect

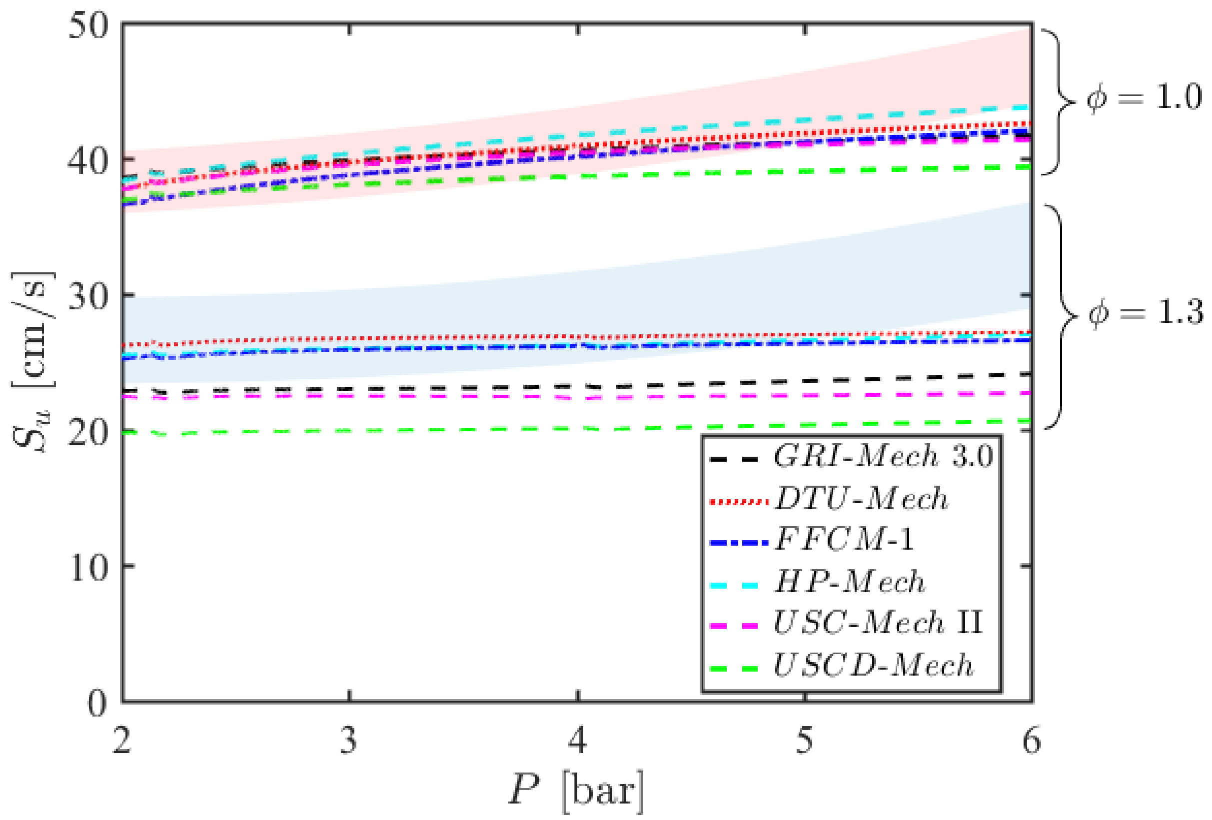
Fuel	T_0 (K)	P_0 (bar)	ϕ (-)	S_u^0 (m/s)	L_u (mm)
CH_4	300	1	1	0.36	-0.13
CH_4	300	1	1.3	0.22	0.3



Flame speed evaluation

$$S_u = \frac{dR_f}{dt} - \frac{\left(R_c^3 - R_f^3\right)}{3\gamma_u R_f^2 P}\frac{dP}{dt}$$

Mechanism	Species	Reactions
GRI Mech 3.0 [1]	53	325
FFCM-1 [2]	38	291
USC Mech II [3]	111	784
UCSD Mech [4]	58	270
DTU Mech [5]	68	631
HP Mech [6]	92	625

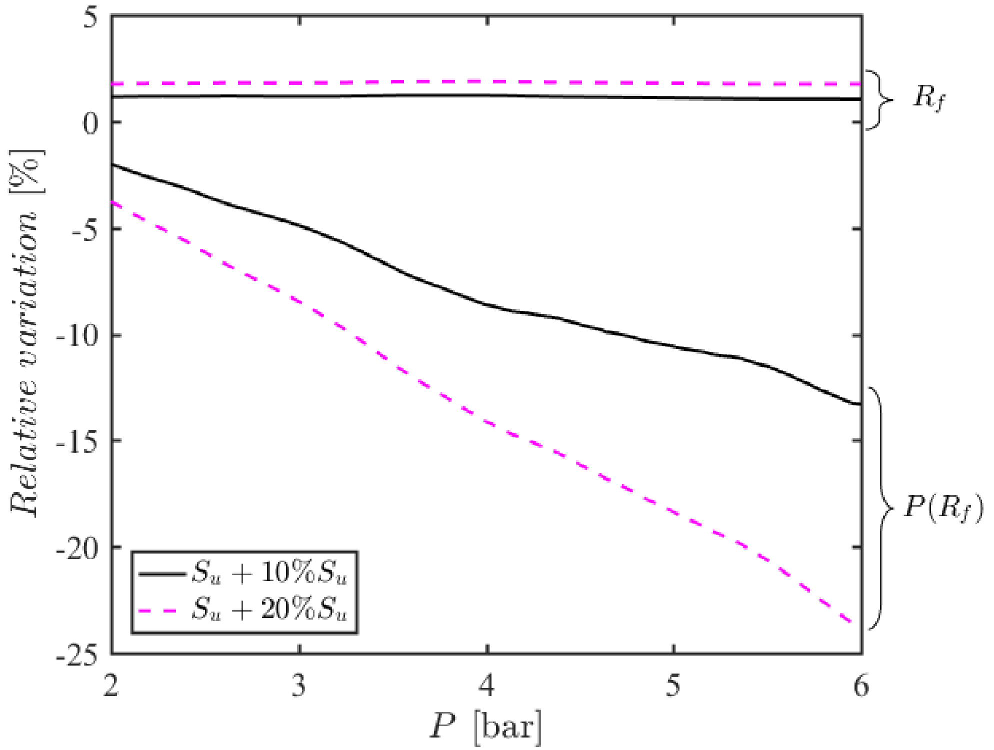


[1] G. P. Smith, et al. , http://www.me.berkeley.edu/gri_mech/
[2] G. P. Smith, et al. , http://nanoenergy.stanford.edu/ffcm, (2016)
[3] H. Wang, et al. , http://ignis.usc.edu/USC_Mech_II.htm, (2007)
[4] Chemical-Kinetic Mechanisms for Combustion Applications, San Diego Mechanism web page, Mechanical and Aerospace Engineering (Combustion Research), University of California at San Diego (http://combustion.ucsd.edu)
[5] H. Hashemi, et al. , High-pressure oxidation of methane, *Combustion and Flame*, 172:349-64 (2016)
[6] http://engine.princeton.edu/mechanism/HP-Mech.html,

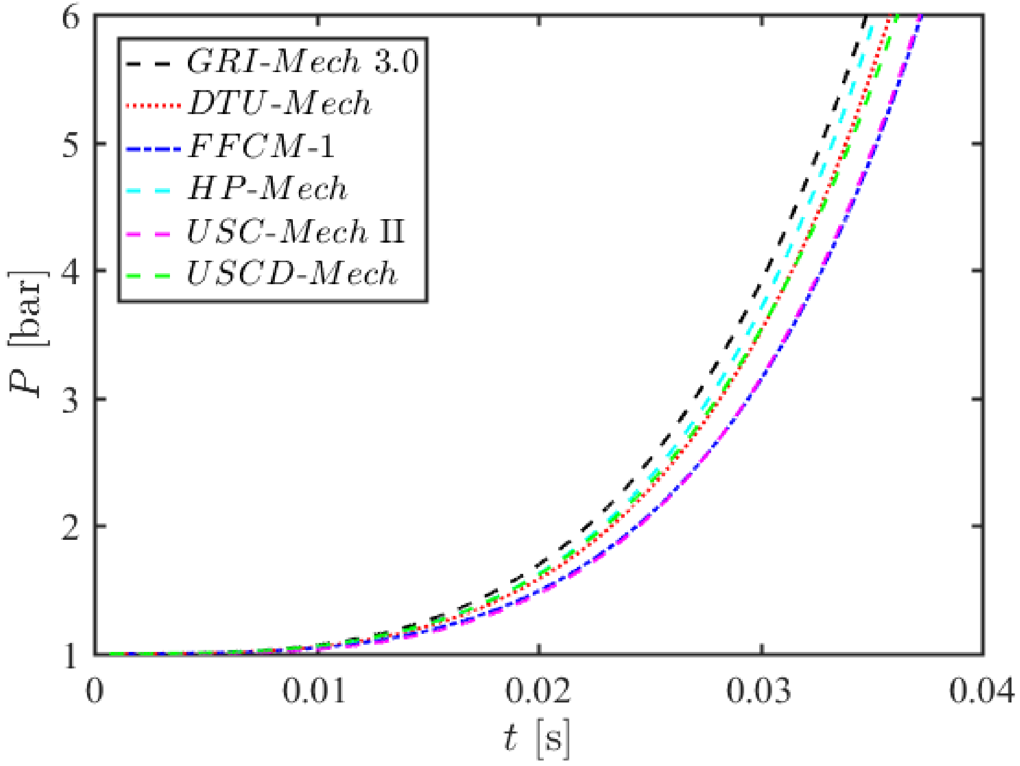
Alternative method

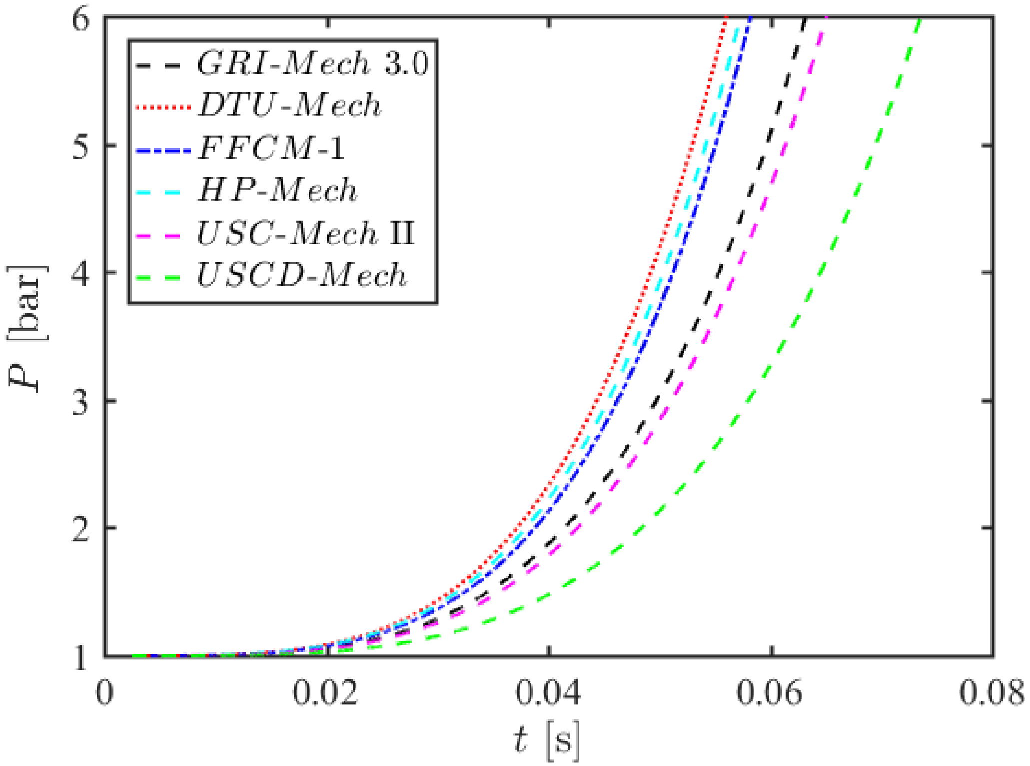
$$S_u = \frac{dR_f}{dt} - \frac{\left(R_c^3 - R_f^3\right)}{3\gamma_u R_f^2 P}\frac{dP}{dt} \longrightarrow S_{u,n} = \frac{R_{f,n+1} - R_{f,n}}{t_{n+1} - t_n} - \frac{R_c^3 - R_{f,n}^3}{3\,\gamma_{u,n}\,P_n\,R_{f,n}^2}\,\frac{P_{n+1} - P_n}{t_{n+1} - t_n}$$

$$\begin{cases} R_{f,n+1} = R_{f,n} + S_{u,n}.(t_{n+1} - t_n) + \dfrac{R_c^3 - R_{f,n}^3}{3\,\gamma_{u,n}\,P_n\,R_{f,n}^2}.(P_{n+1} - P_n) \\ P_{n+1} = P_n + \left(\left(R_{f,n+1} - R_{f,n}\right) - S_{u,n}.(t_{n+1} - t_n)\right).\dfrac{3\,\gamma_{u,n}\,P_n\,R_{f,n}^2}{R_c^3 - R_{f,n}^3} \end{cases}$$



Pressure evolutions



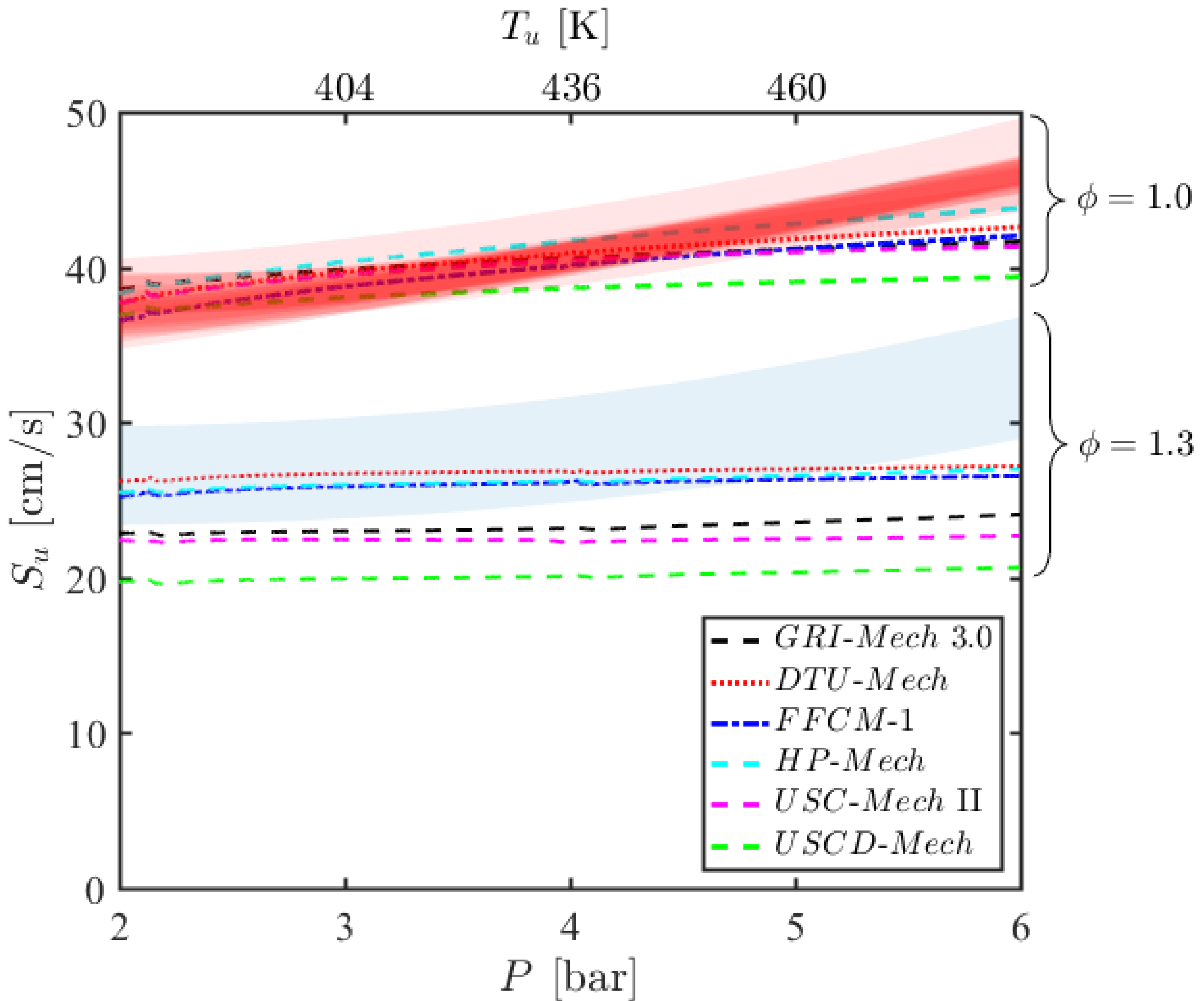


$$\begin{cases} P_{n+1} = P_n + \left(\left(R_{f,n+1} - R_{f,n}\right) - S_{u,n}.\left(t_{n+1} - t_n\right)\right).\dfrac{3\,\gamma_{u,n}\,P_n\,R_{f,n}^2}{R_c^3 - R_{f,n}^3} \\ T_{n+1} = T_n\left(\dfrac{P_n}{P_{n+1}}\right)^{(1-\gamma_{u,n})/\gamma_{u,n}} \end{cases}$$

+ 1D steady simulation

Flame speed as a function of pressure

$$P_{n+1} = P_n + \left(\left(R_{f,n+1} - R_{f,n}\right) - S_{u,n}.\left(t_{n+1} - t_n\right)\right).\frac{3\,\gamma_{u,n}\,P_n\,R_{f,n}^2}{R_c^3 - R_{f,n}^3} \quad + \quad S_u = f(P,T)$$



Conclusions

- full OPTIcal access Perfectly spheRical combustIon chaMber
- **Simultaneous** recording of the **pressure** inside the chamber and, fully innovative, of the flame **radius** until the walls
- Accurate flame speed as a function of pressure/temperature evolution
- **Pressure** is the correct target to assess the accuracy of a kinetic mechanism
- A relative error lower than ±5 % over almost the entire pressure range was obtained

- The unmatched accuracy allows to **optimize** kinetic schemes