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► **To cite this version:**

Ahlem Ghabi, F Manseur, P Escot Bocanegra, B Sarh, T Boushaki. Numerical and experimental study of laminar syngas flames. European combustion meeting ECM, Apr 2021, Virtual edition, Italy. hal-03403087

**HAL Id: hal-03403087**

**<https://hal.science/hal-03403087>**

Submitted on 26 Oct 2021

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# Numerical and experimental study of laminar syngas flames

A. Ghabi, F. Manseur, P. Escot Bocanegra, B. Sarh, T. Boushaki\*

ICARE CNRS, 1C Avenue de la Recherche Scientifique, 45071 Orléans, France  
GREMI, UMR7344, CNRS/ University of Orleans, Orleans, France

\*toufik.boushaki@cns-orleans.fr



## Context and objectives

- **Objective** : Characterization of syngas flames.
  - Experimentally: Stability, topology, pollutant emissions.
  - Numerically: Calculation of laminar burning velocity and adiabatic flame temperature of syngas flames.
- **Support** : Renew Value project of EranetMed II program.

## Numerical Method

```

import cantera as ct
import numpy as np
import matplotlib.pyplot as plt
import matplotlib as mpl

# Simulation parameters for flame0 case
p = 0.999325 # pressure [Pa]
width = 0.1 # m
loglevel = 1 # amount of diagnostic output

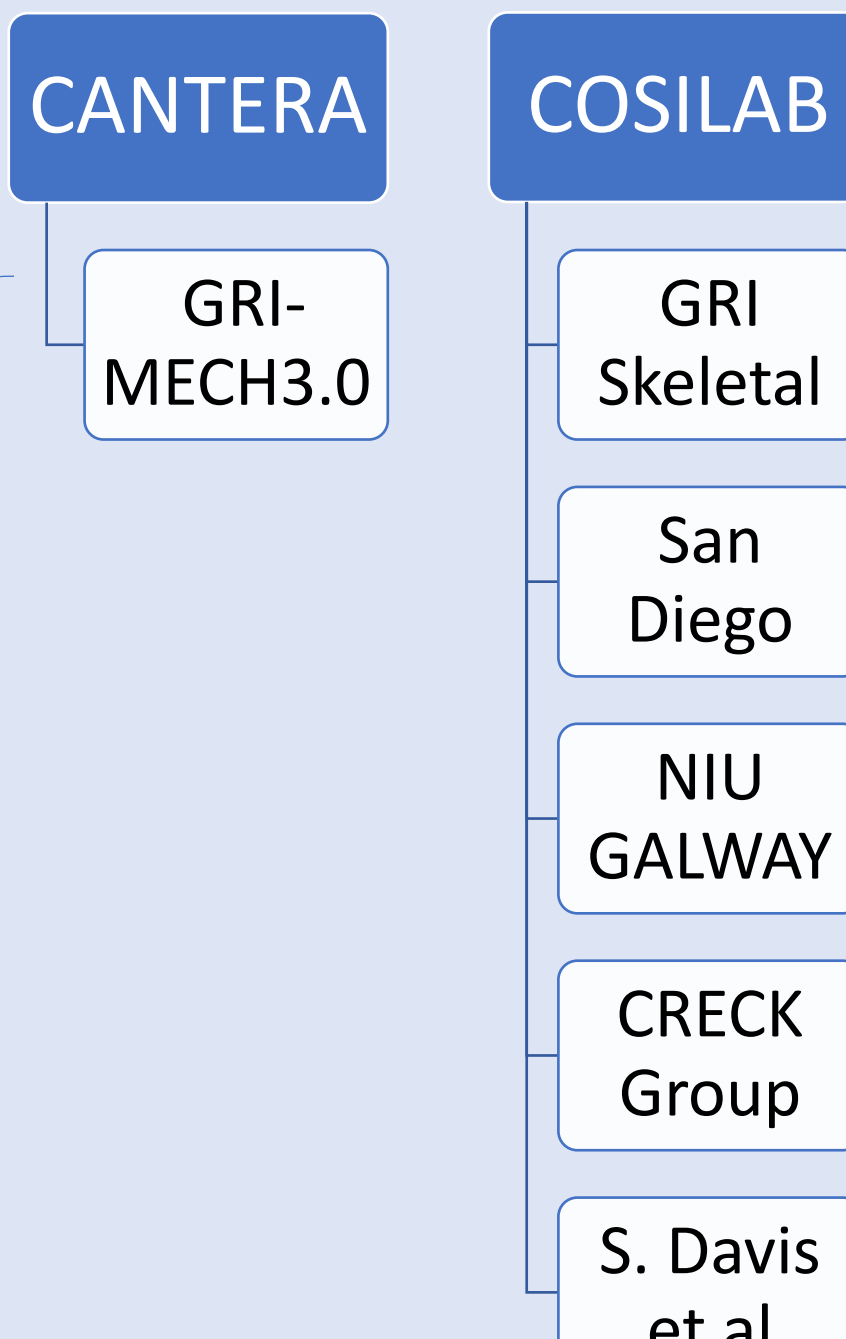
Tin = 298 # temperature of unburnt gas
phi_min = 0.4 # min equivalence ratio
phi_max = 4.5 # max equivalence ratio
phi_step = 0.2 # equivalence step of the equivalence range
tableaux = 0 # stable number
plt.figure(figsize=(8,5))

# for phi in np.arange(phi_min, phi_max, phi_step):
#     gas = ct.Solution('gri30.cti')
#     gas.TP = Tin, p
#     gas.set_equivalence_ratio(phi, 'CO:0.5, H2:0.5', 'O2:0.21, N2:0.79')
#     # Set up flame object
#     f = ct.FreeFlame(gas, width=width)
#     f.inlet.T = Tin
#     f.set_refine_criteria(ratio=3, slope=0.05, curve=0.12)
#     f.show_solution()
#     # Solve with the energy equation enabled
#     f.solve(loglevel=1, auto=True)
    
```

Calculation codes

(for laminar, 1D, premixed, and freely propagating flames)

Used reaction mechanisms

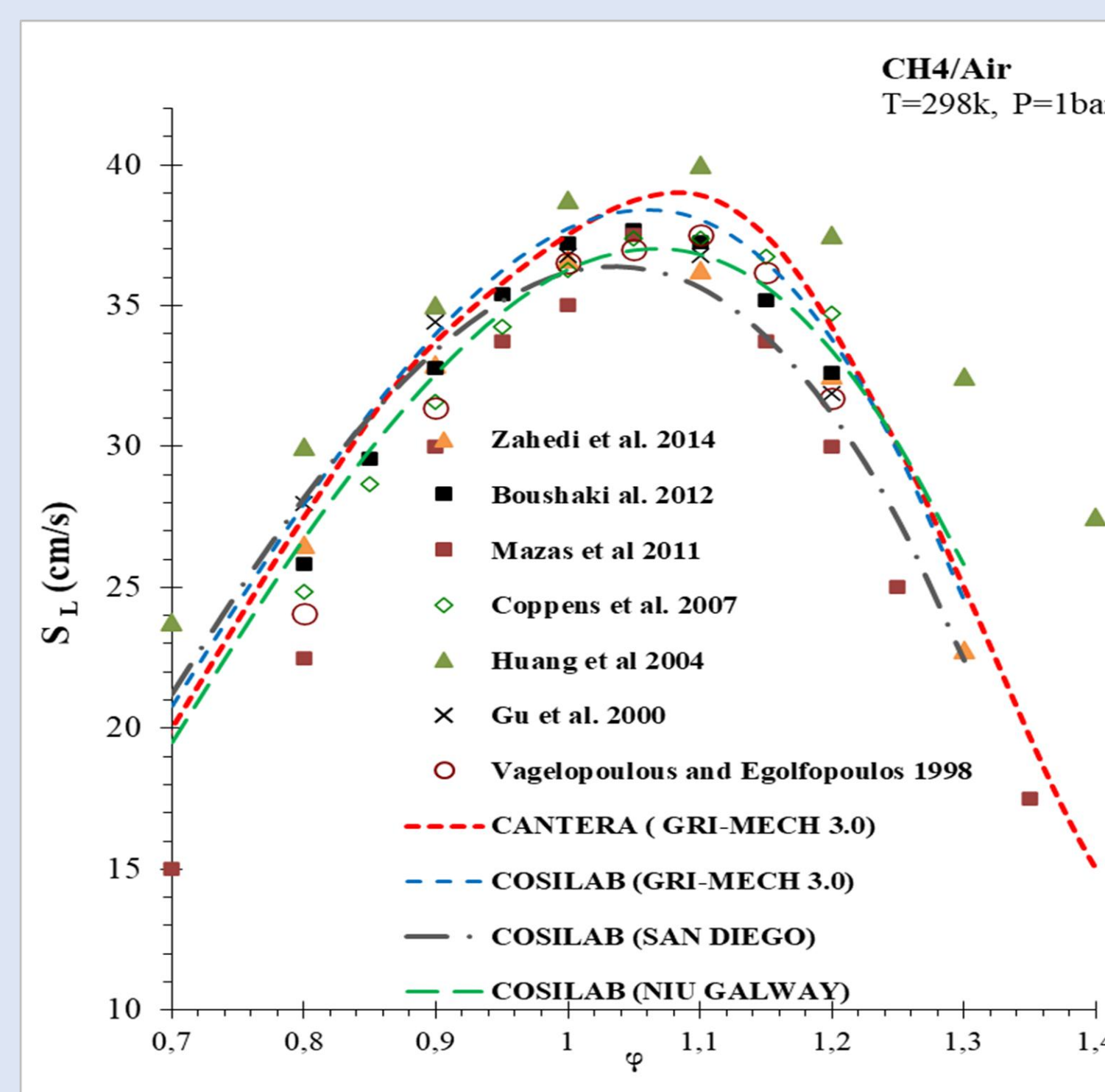


⇒ Laminar burning velocity ( $S_L$ ), Adiabatic flame temperature ( $T_{ad}$ ) of syngas flame.

## Results and discussion

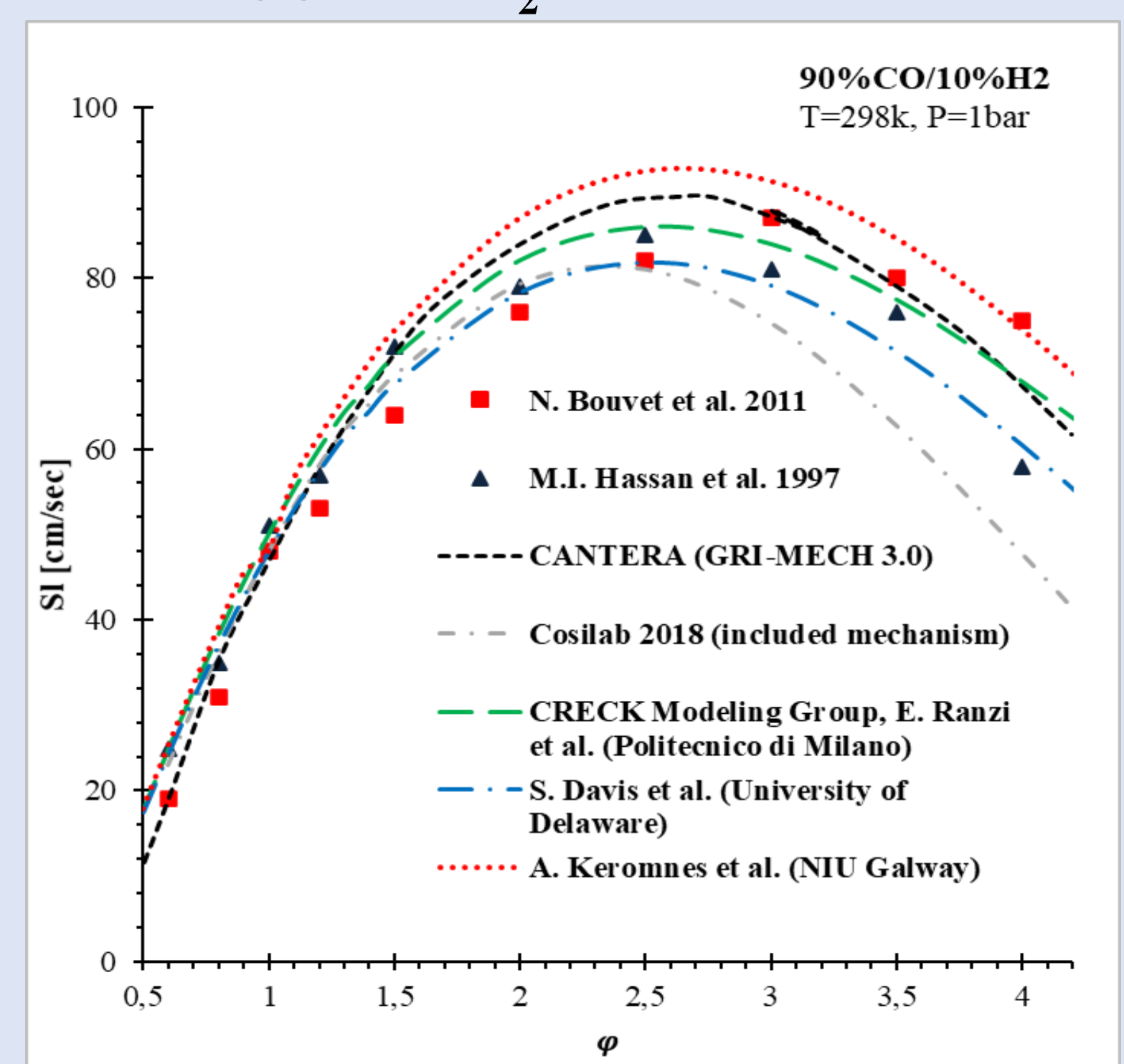
Case of CH<sub>4</sub>/air flame

Laminar burning velocity ( $S_L$ ) of CH<sub>4</sub>-air with equivalence ratio at 1 bar and 298 K



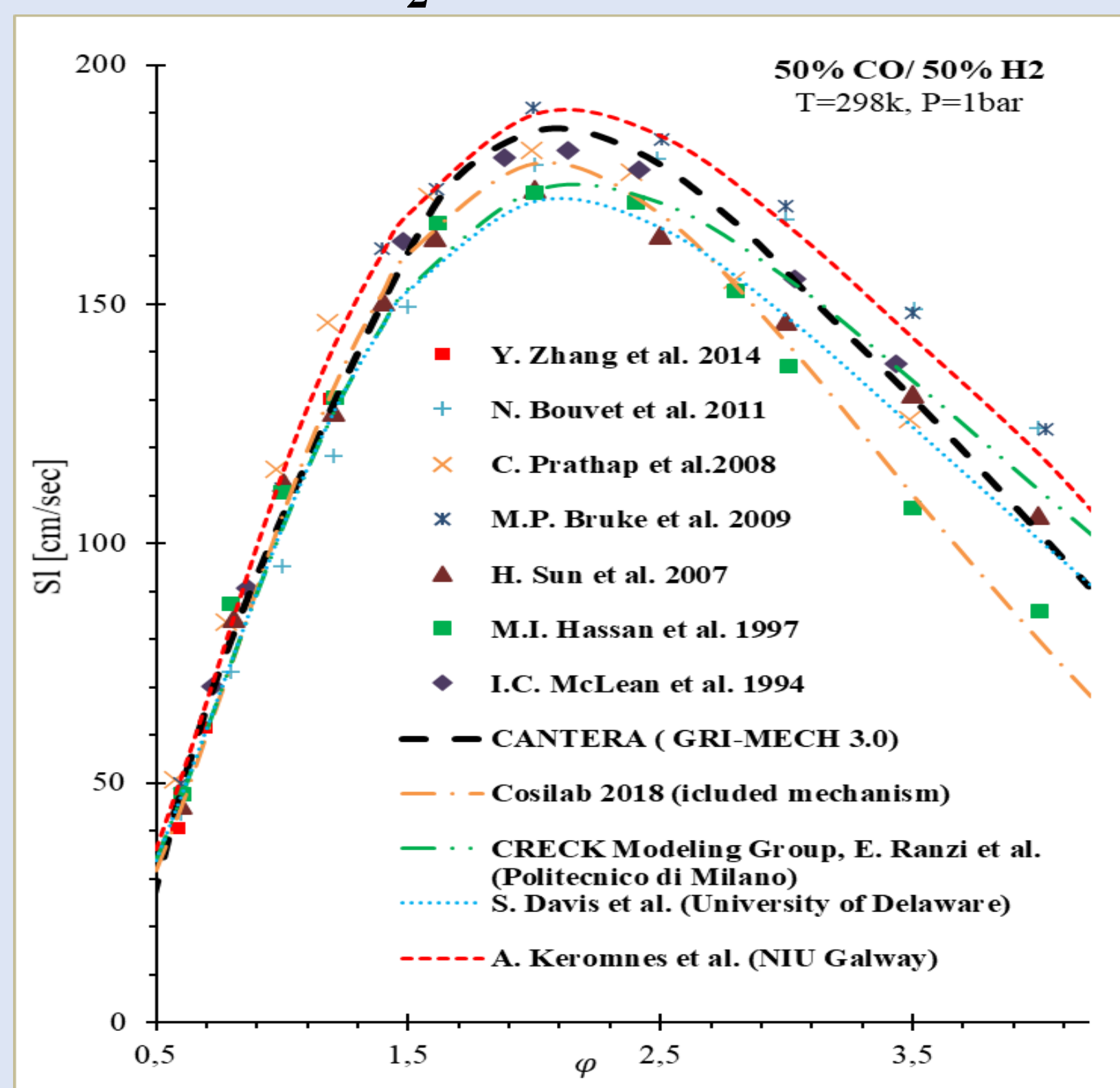
Case of 90%CO-10%H<sub>2</sub>/air flame

Laminar burning velocity ( $S_L$ ) of 90%CO-10%H<sub>2</sub> at 1 bar and 298 K



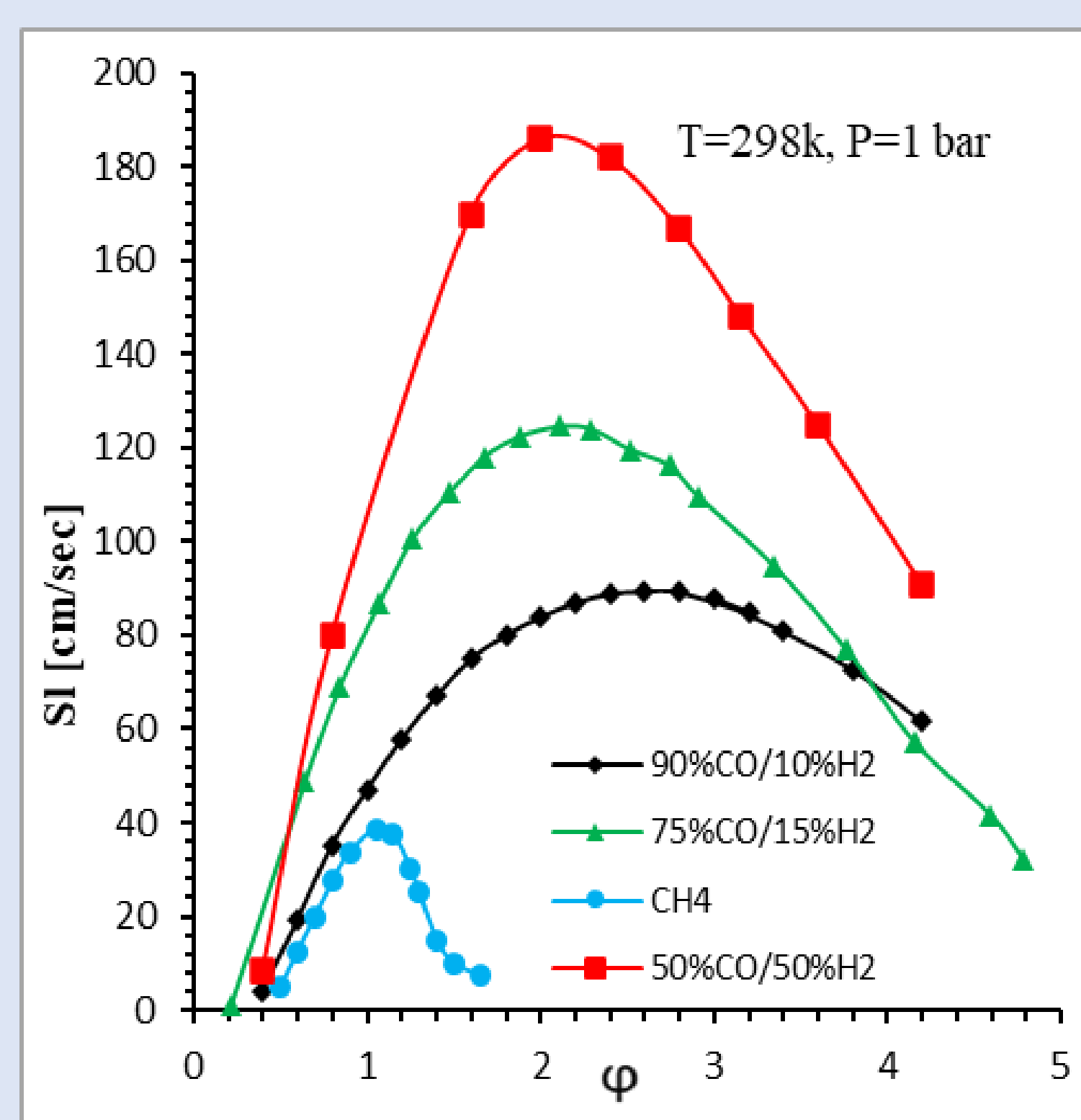
✓ The agreement between the present results and data from the literature is good.

Case of 50%CO-50%H<sub>2</sub>/air flame  
Laminar burning velocity ( $S_L$ ) of 50%CO-50%H<sub>2</sub> at 1 bar and 298 K



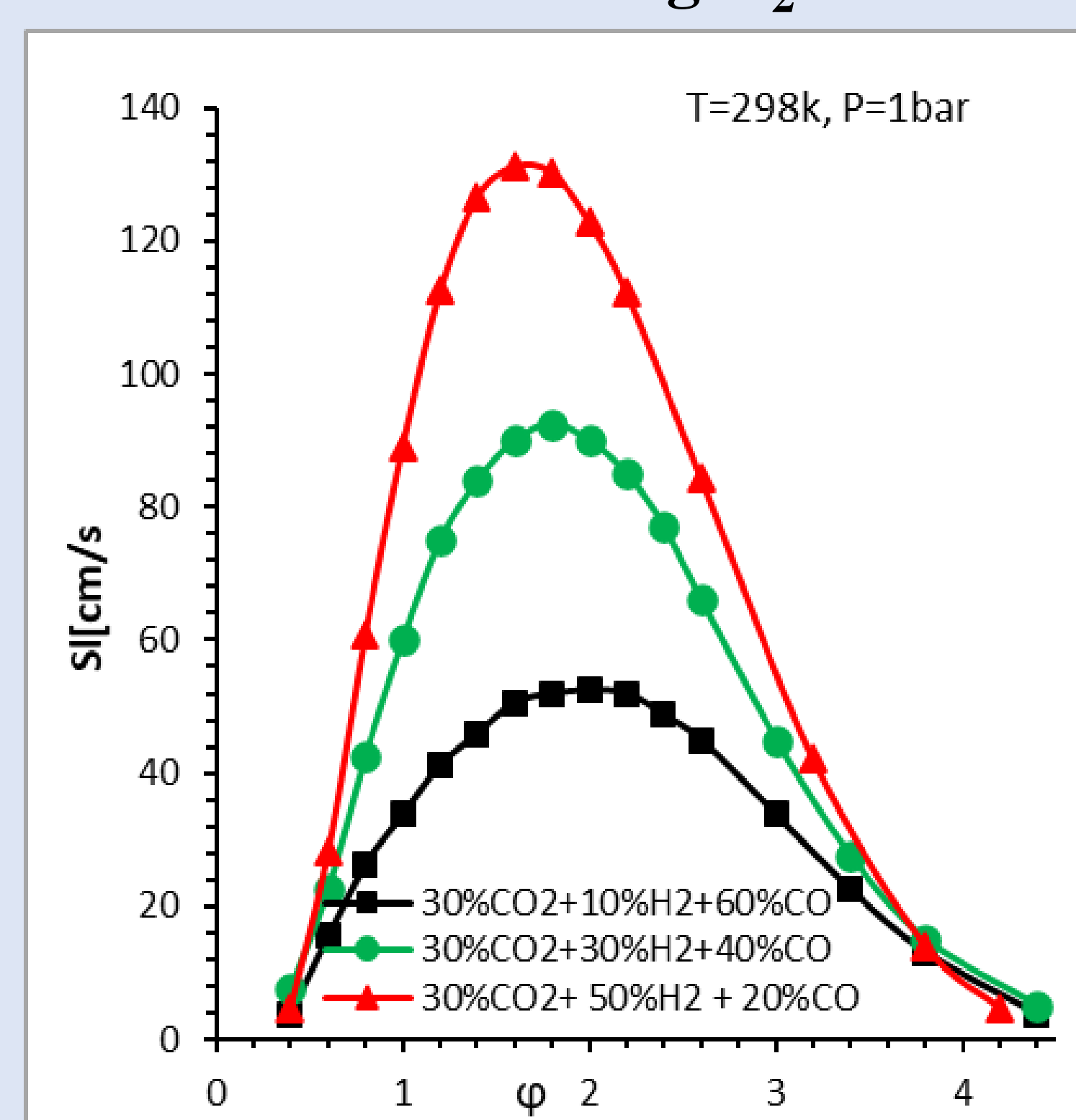
✓ Numerical results show a good similarity with data from the literature mostly for the lean side ( $\phi < 1$ ).

$S_L = f(\phi)$  at 1 bar and 298K

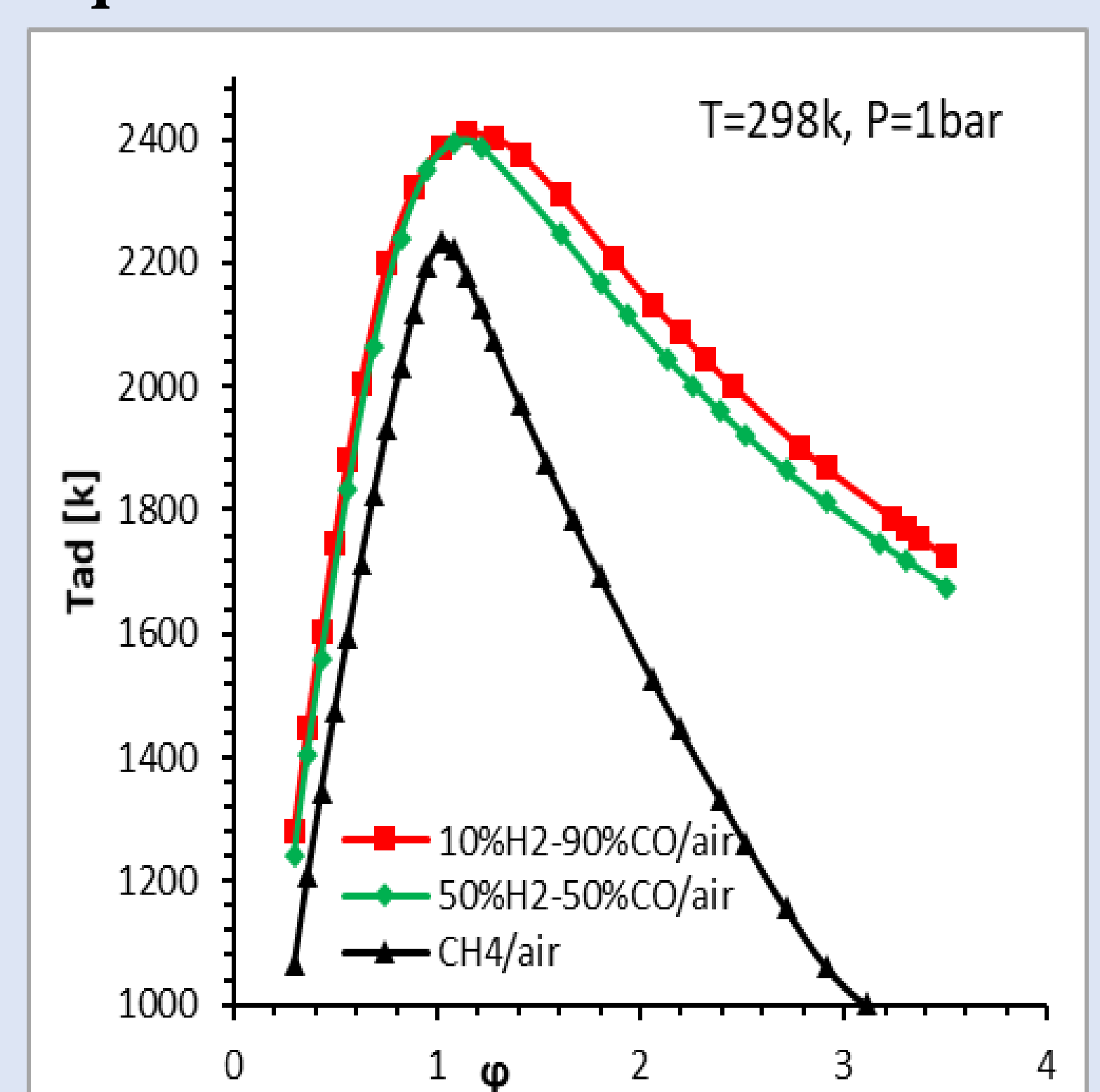


- ✓  $S_L \nearrow$  with H<sub>2</sub> ⇒ high reactivity and flammability of H<sub>2</sub>.
- ✓  $S_L \searrow$  with CO<sub>2</sub> addition ⇒ CO<sub>2</sub> acts as a diluent.
- ✓ The addition of H<sub>2</sub> ⇒  $T_{ad} \nearrow$  : For  $\phi = 1$ , adding 40% of H<sub>2</sub>, increases  $T_{ad}$  from 2222 to 2349 K.

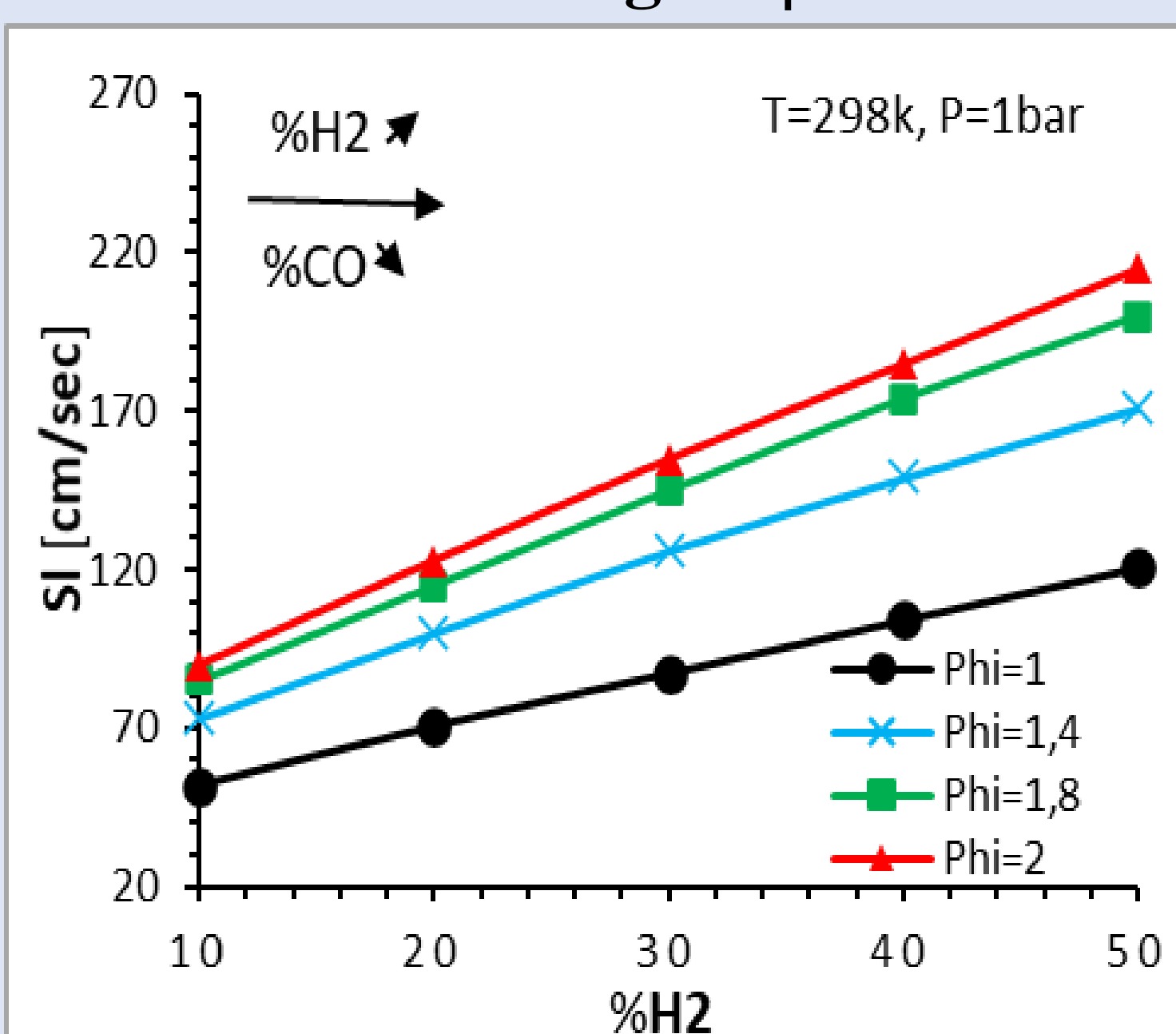
$S_L = f(\phi)$ , for CO/H<sub>2</sub>/CO<sub>2</sub> mixture with increasing H<sub>2</sub> rate



Adiabatic flame temperature with equivalence ratio at 1 bar and 298K

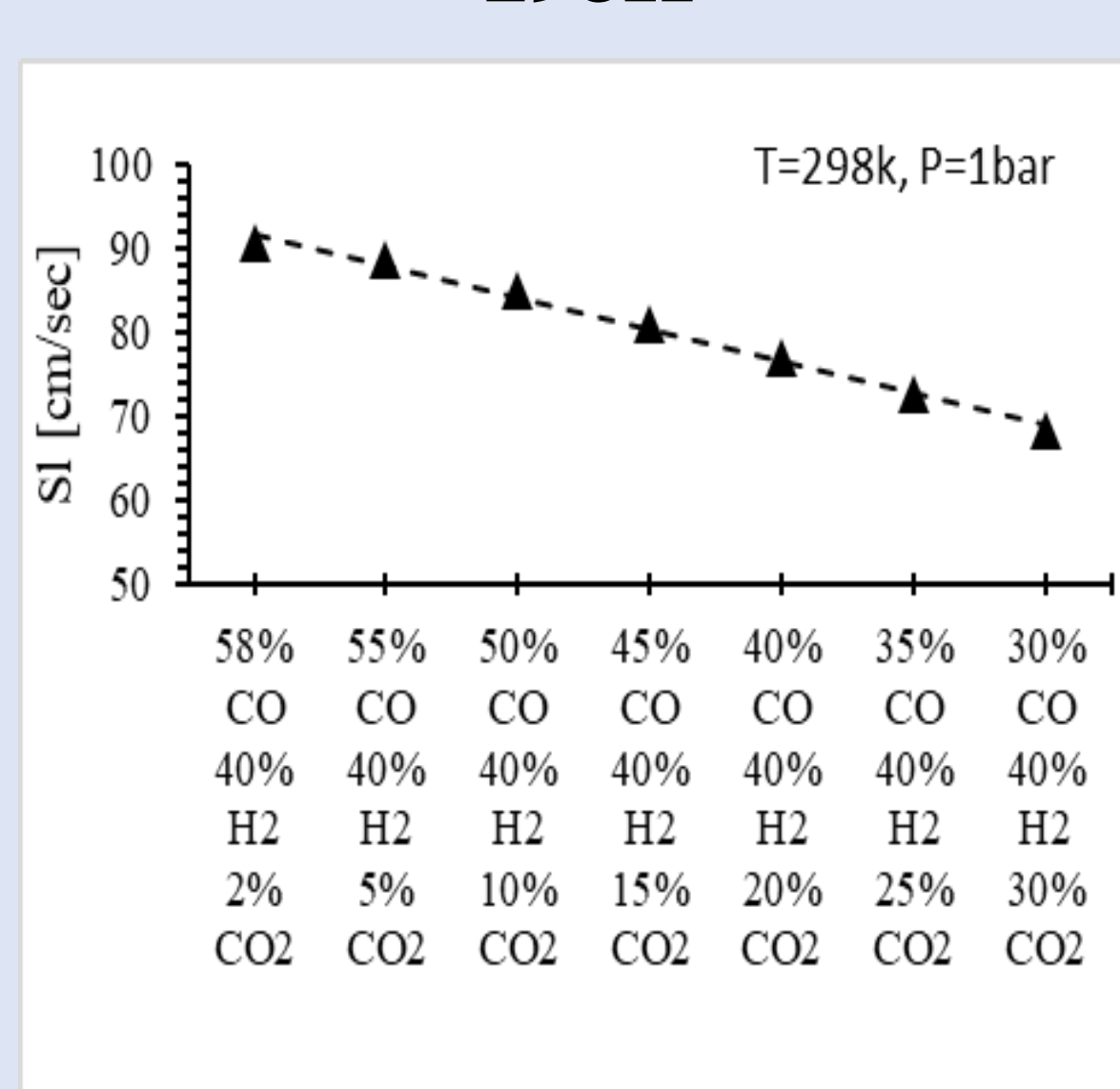


$S_L$  with H<sub>2</sub> fraction with increasing of  $\phi$



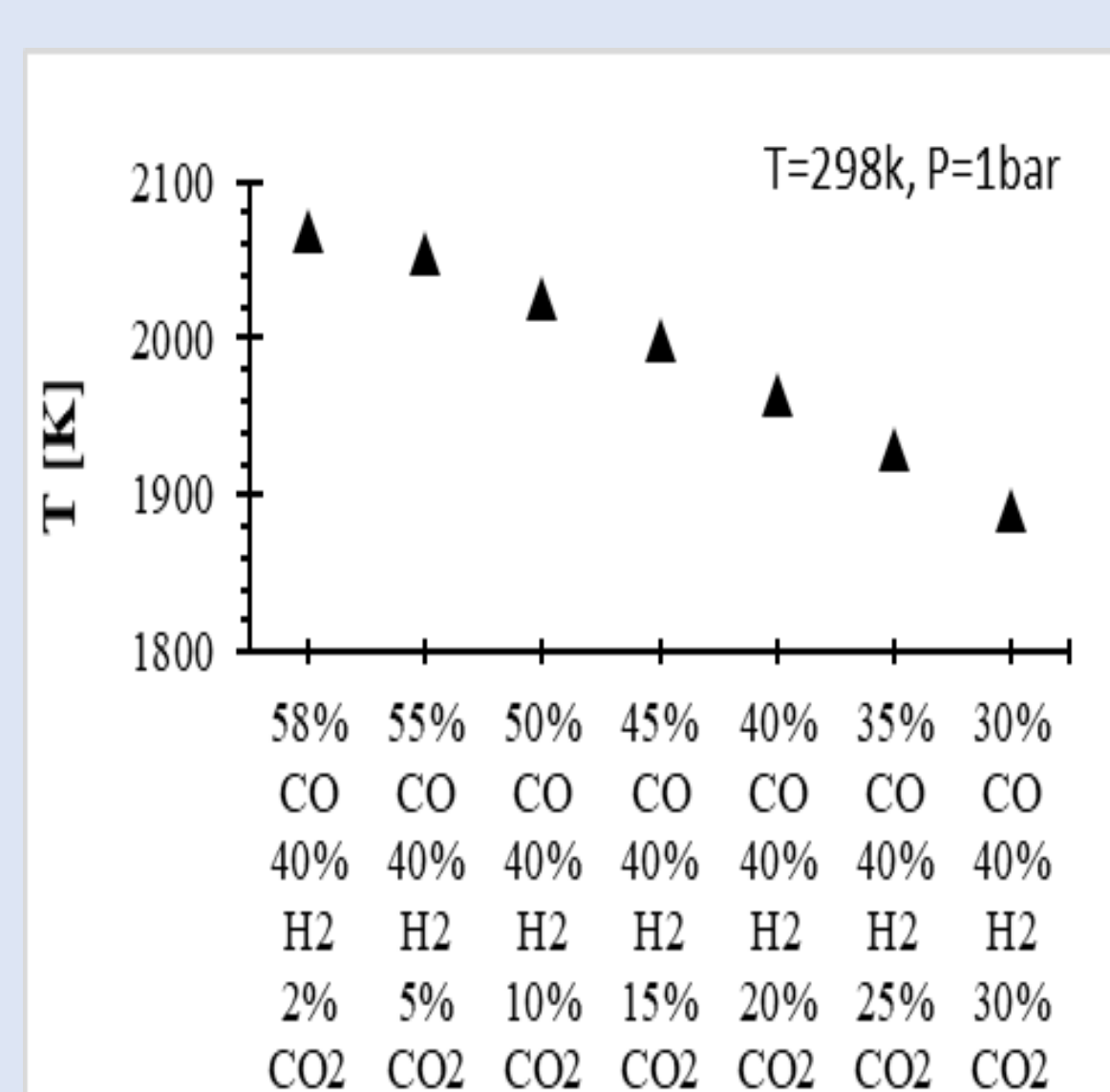
- ✓  $S_L \searrow$  and  $T_{ad} \nearrow$  with H<sub>2</sub> addition.
- ✓  $S_L \nearrow$  with H<sub>2</sub> at all equiv. ratios.

$S_L$  with CO<sub>2</sub> at 1bar and 298K

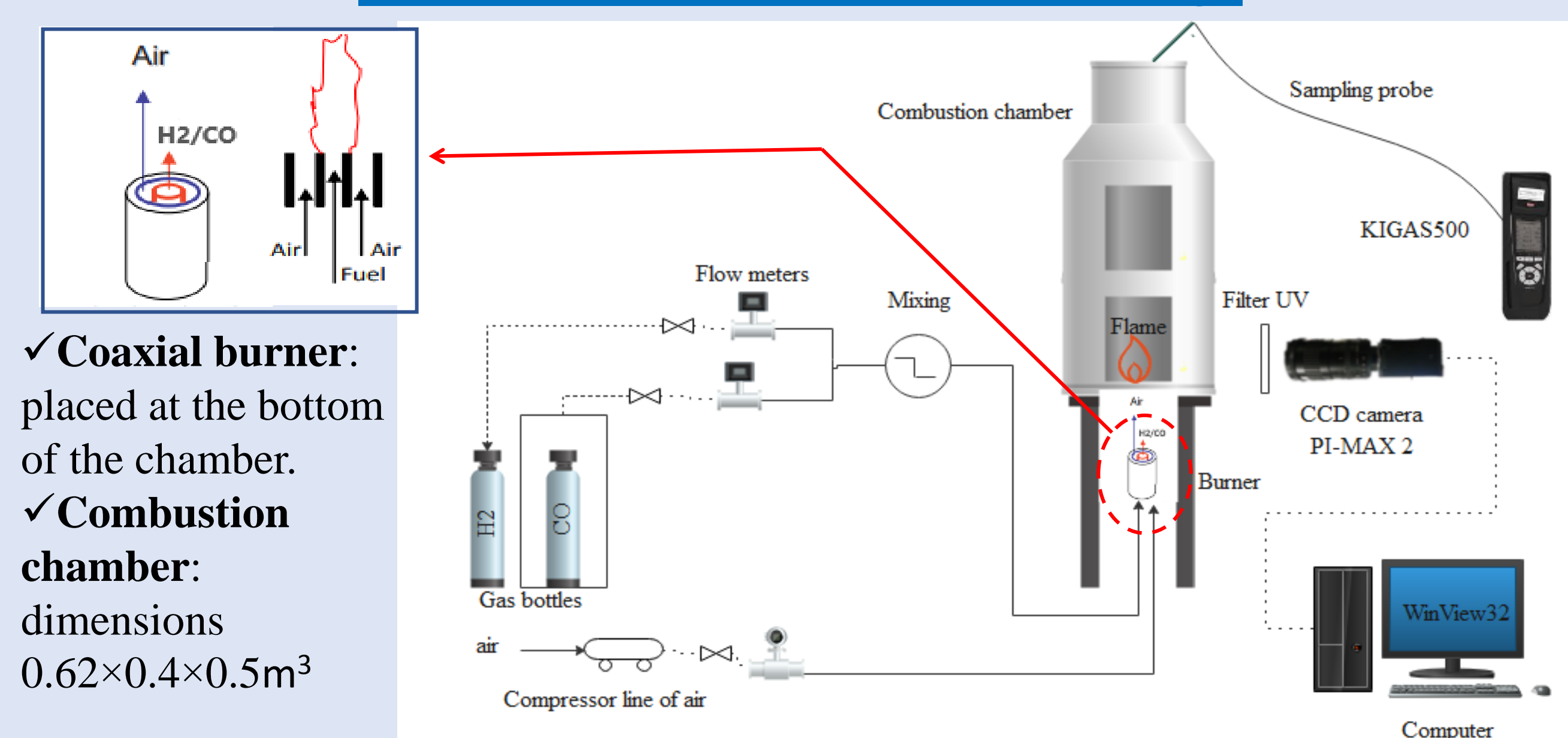


- ✓  $S_L \searrow$  with CO<sub>2</sub> addition (CO<sub>2</sub> acts as a diluent).
- ✓  $T \searrow$  with CO<sub>2</sub> (adding 50% of CO<sub>2</sub> decreases T from 1973K to 1780K) ⇒ CO<sub>2</sub> increases the thermal capacity of the mixture.

$T_{ad}$  with CO<sub>2</sub> at 1bar and 298K



## Experimental study



- ✓ Coaxial burner: placed at the bottom of the chamber.
- ✓ Combustion chamber: dimensions 0.62×0.4×0.5m<sup>3</sup>
- ✓ Study the characteristics of CO/H<sub>2</sub>-Air flames: flame stability (by chemiluminescence of OH\* /CH\*), pollutant emissions (by multi-gas analyzer).
- ✓ Combustion experiments were not done because of the sanitary crisis of COVID.
- ✓ Some studies from the literature about syngas combustion:
  - Azimov et al: H<sub>2</sub>  $\searrow$  ⇒ CO and HC emissions  $\searrow$  but NO<sub>x</sub>  $\nearrow$ .
  - Noble et al: H<sub>2</sub> dominates the characteristics of the mixture blow off.