



HAL
open science

Numerical and experimental study of laminar syngas flames

Ahlem Ghabi, F Manseur, P Escot Bocanegra, B Sarh, T Boushaki

► **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-03403087v1>

Submitted on 26 Oct 2021

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.



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=0.1)
    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

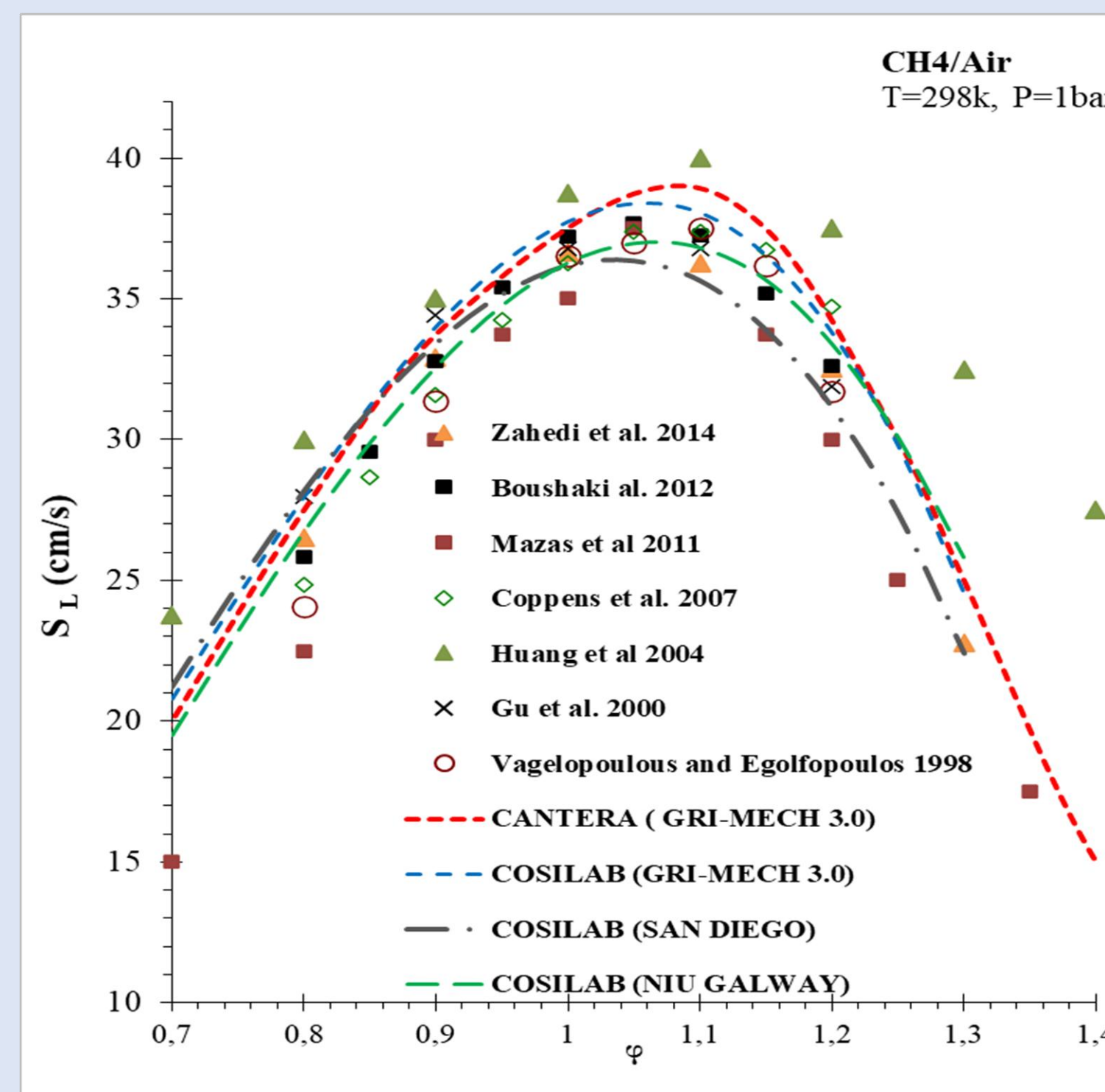
- CANTERA**
 - GRI-MECH3.0
- COSILAB**
 - GRI Skeletal
 - San Diego
 - NIU GALWAY
 - CRECK Group
 - S. Davis et al

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

Results and discussion

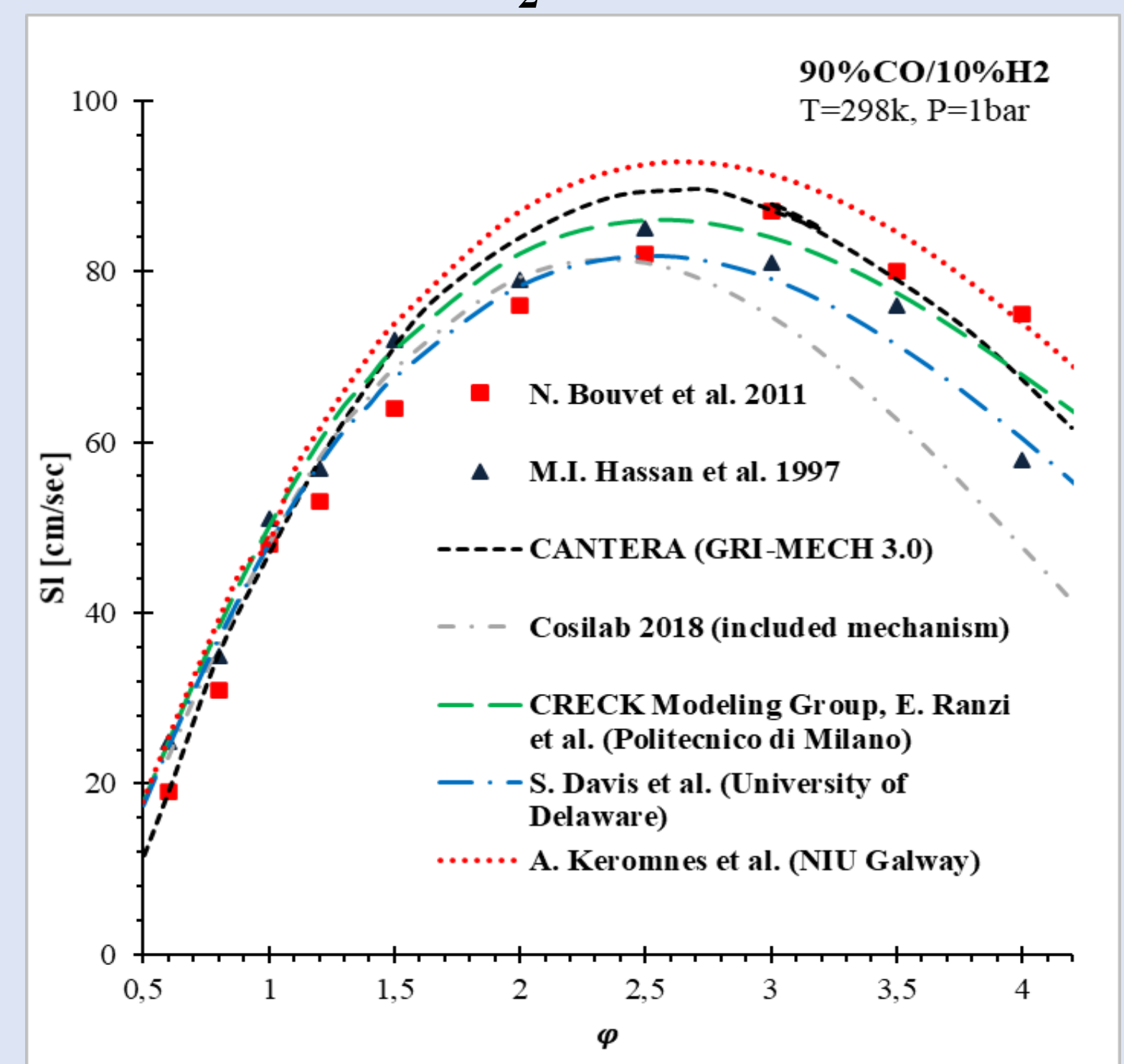
Case of CH₄/air flame

Laminar burning velocity (S_L) of CH₄-air with equivalence ratio at 1 bar and 298 K



Case of 90%CO-10%H₂/air flame

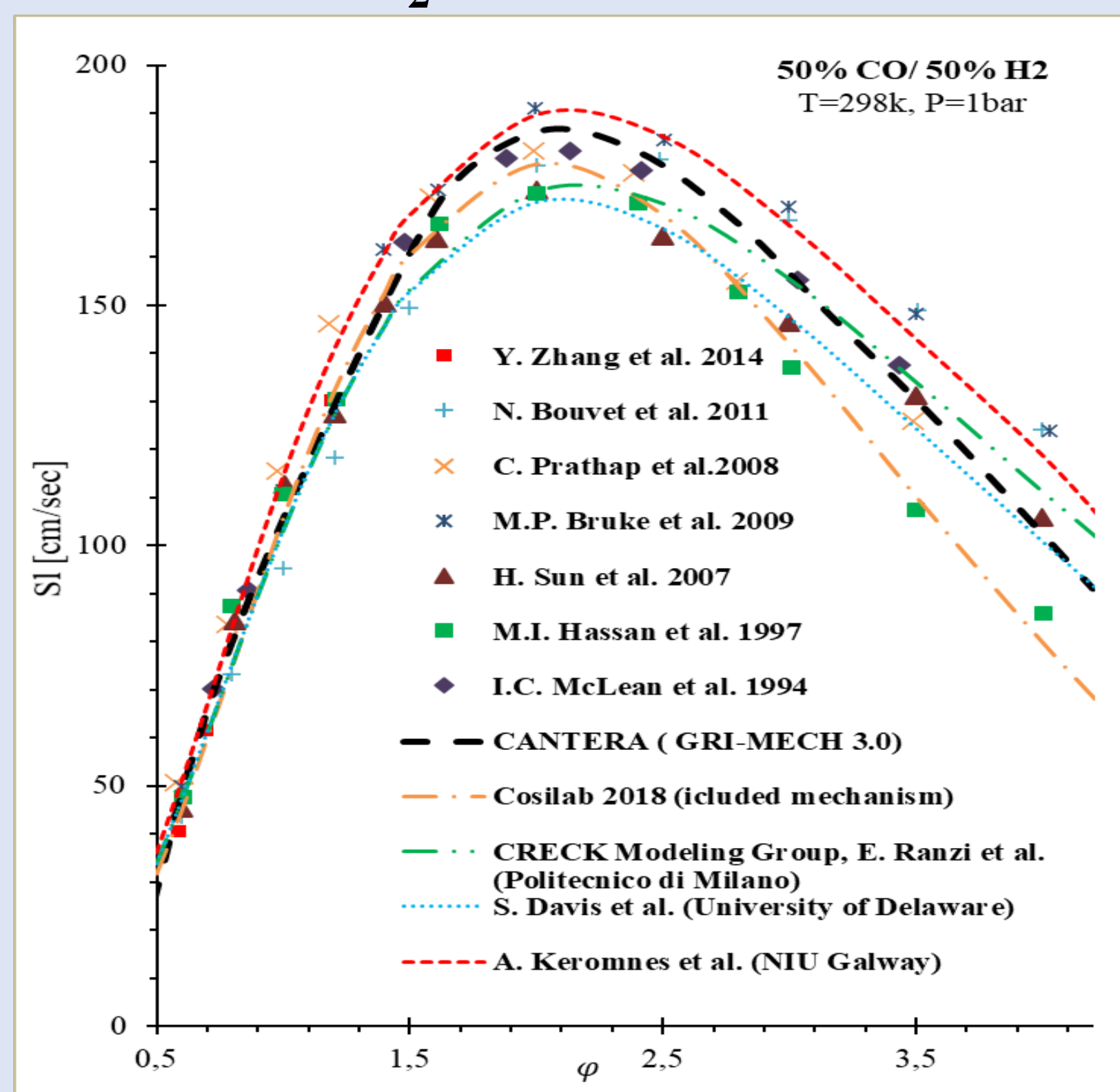
Laminar burning velocity (S_L) of 90%CO-10%H₂ at 1 bar and 298 K



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

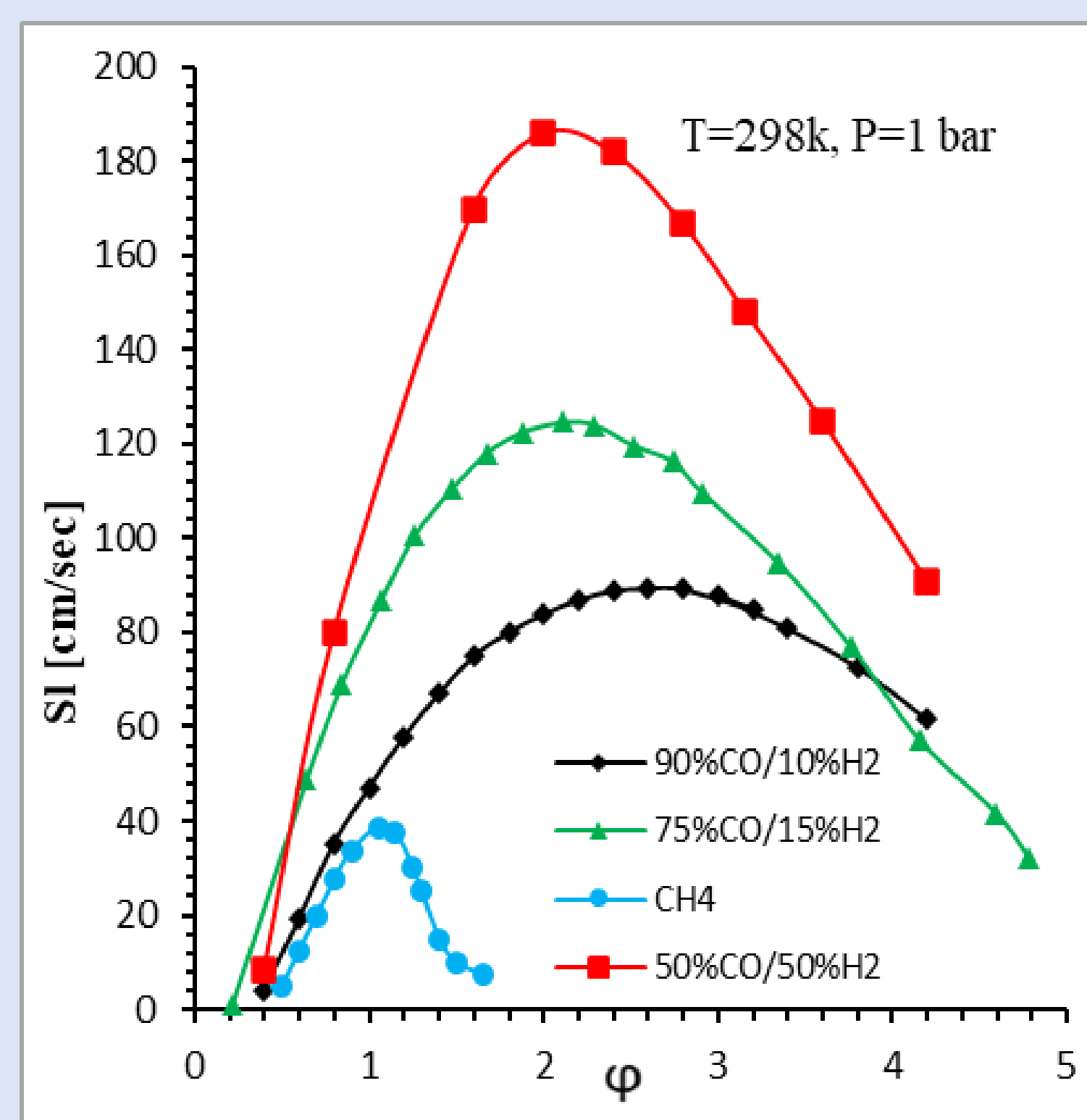
Case of 50%CO-50%H₂/air flame

Laminar burning velocity (S_L) of 50%CO-50%H₂ at 1 bar and 298 K

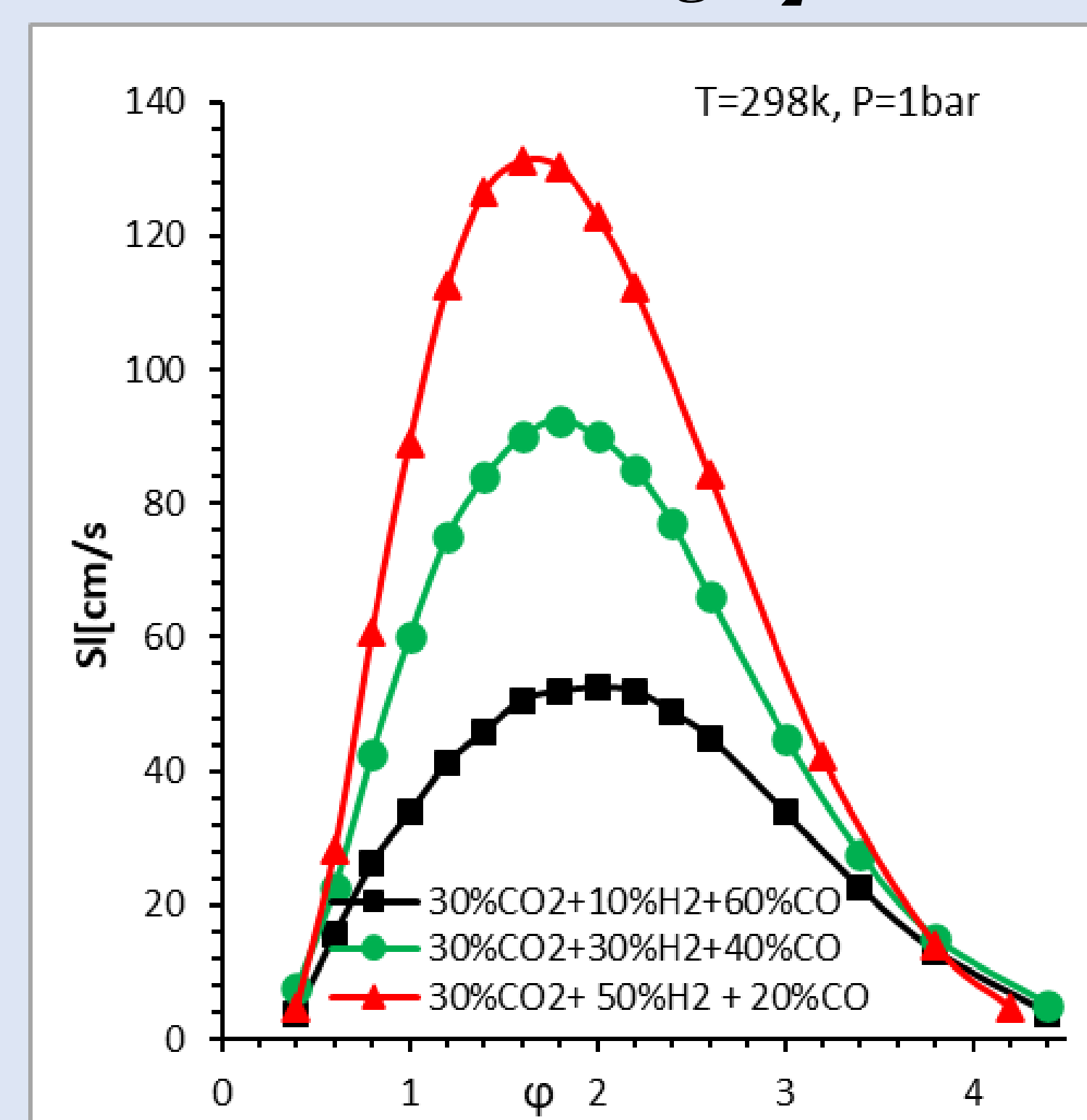


✓ Numerical results show a good similarity with data from the literature mostly for the lean side ($\phi < 1$).

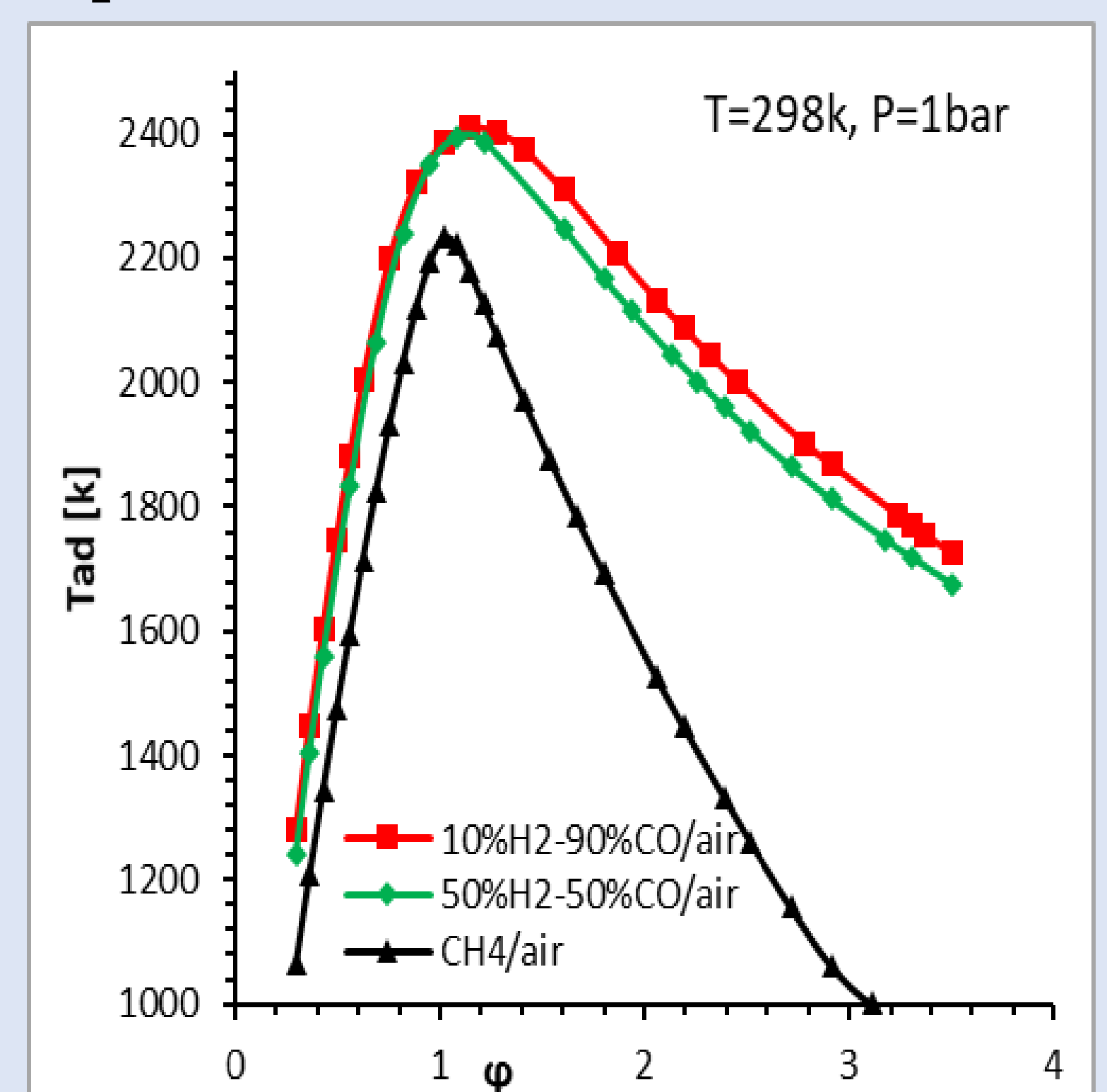
$S_L = f(\phi)$ at 1 bar and 298K



$S_L = f(\phi)$, for CO/H₂/CO₂ mixture with increasing H₂ rate

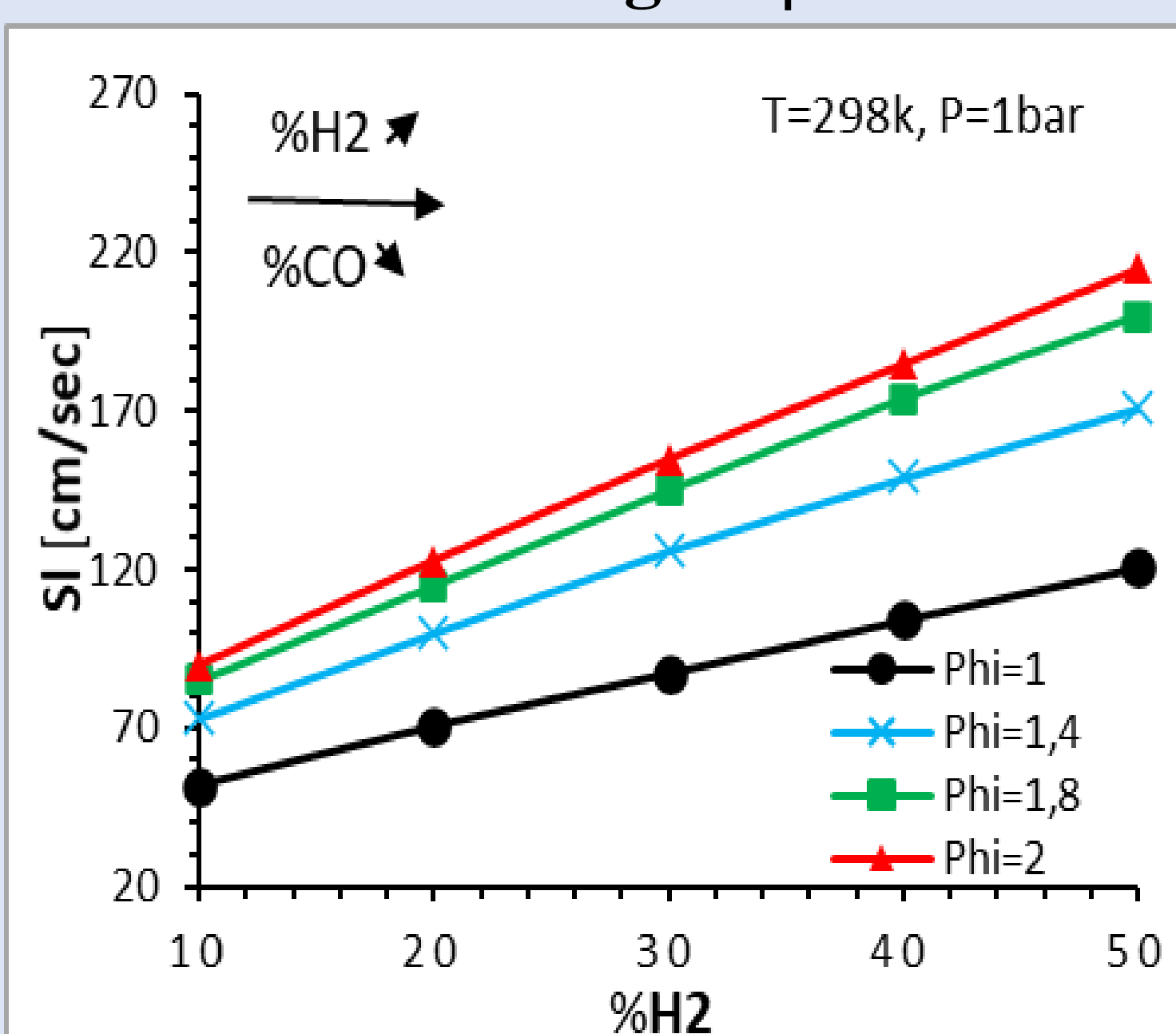


Adiabatic flame temperature with equivalence ratio at 1 bar and 298K



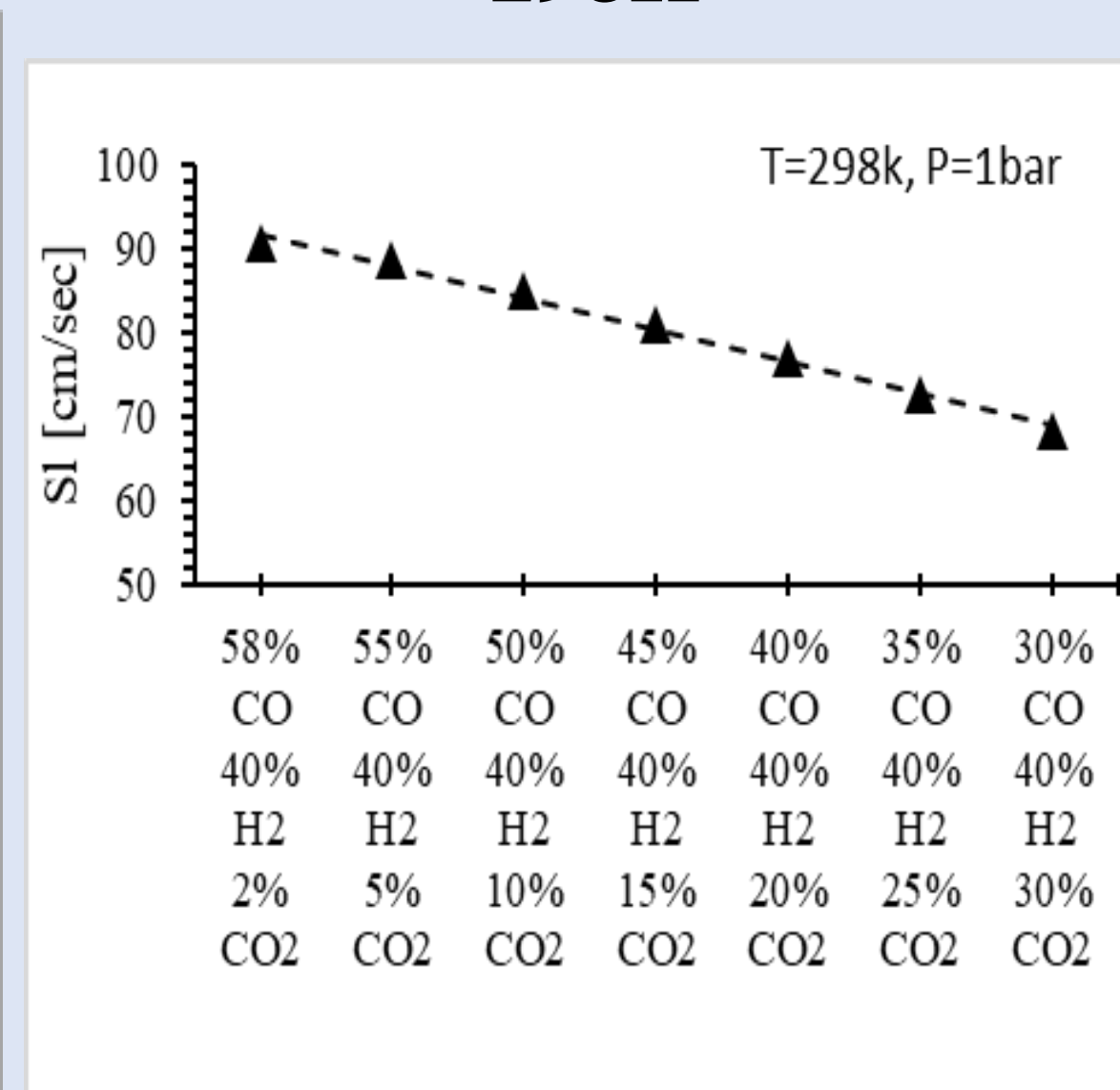
- ✓ $S_L \nearrow$ with H₂ ⇒ high reactivity and flammability of H₂.
- ✓ $S_L \searrow$ with CO₂ addition ⇒ CO₂ acts as a diluent.
- ✓ The addition of H₂ ⇒ $T_{ad} \nearrow$: For $\phi = 1$, adding 40% of H₂, increases T_{ad} from 2222 to 2349 K.

S_L with H₂ fraction with increasing of ϕ



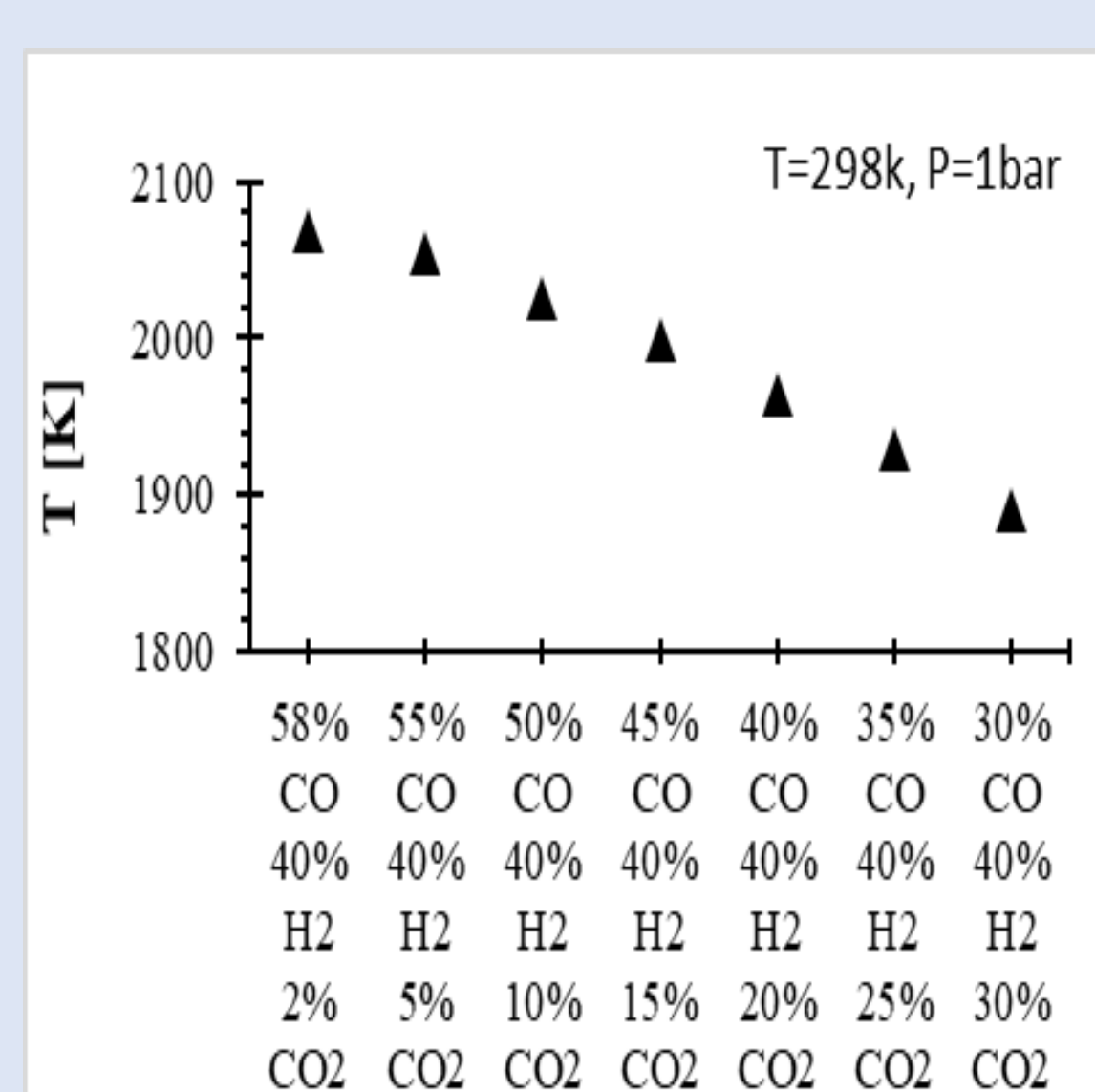
- ✓ $S_L \searrow$ and $T_{ad} \nearrow$ with H₂ addition.
- ✓ $S_L \nearrow$ with H₂ at all equiv. ratios.

S_L with CO₂ at 1bar and 298K

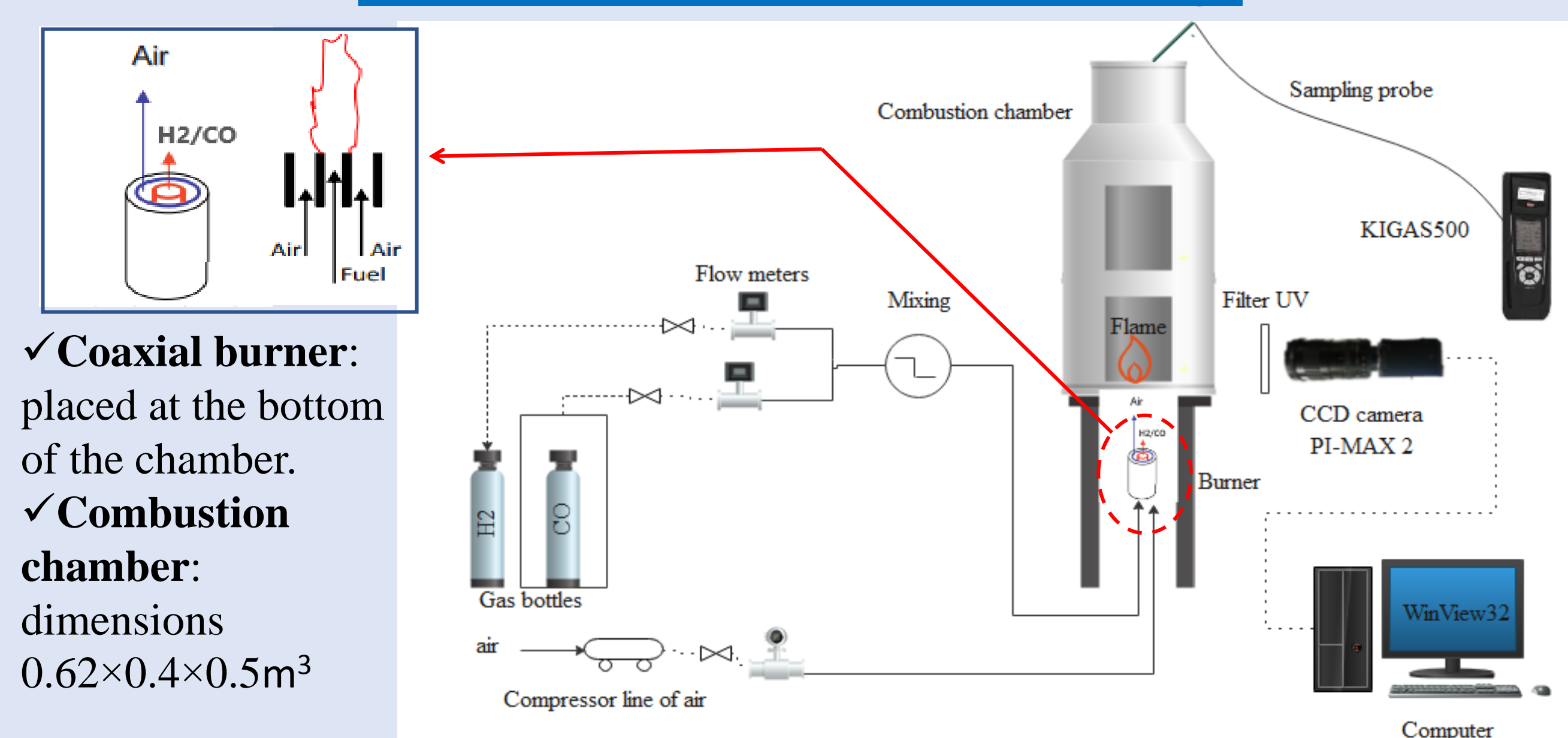


- ✓ $S_L \searrow$ with CO₂ addition (CO₂ acts as a diluent).
- ✓ $T \searrow$ with CO₂ (adding 50% of CO₂ decreases T from 1973K to 1780K) ⇒ CO₂ increases the thermal capacity of the mixture.

T_{ad} with CO₂ at 1bar and 298K



Experimental study



- ✓ **Coaxial burner**: placed at the bottom of the chamber.
- ✓ **Combustion chamber**: dimensions 0.62×0.4×0.5m³
- ✓ Study the characteristics of CO/H₂-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: H₂ \searrow ⇒ CO and HC emissions \searrow but NO_x \nearrow .
 - Noble et al: H₂ dominates the characteristics of the mixture blow off.