Flame characteristics

of

Hydrogen-enriched Methane/Air Flames at High Pressure

IEA Meeting, August 2006

Motivation

General

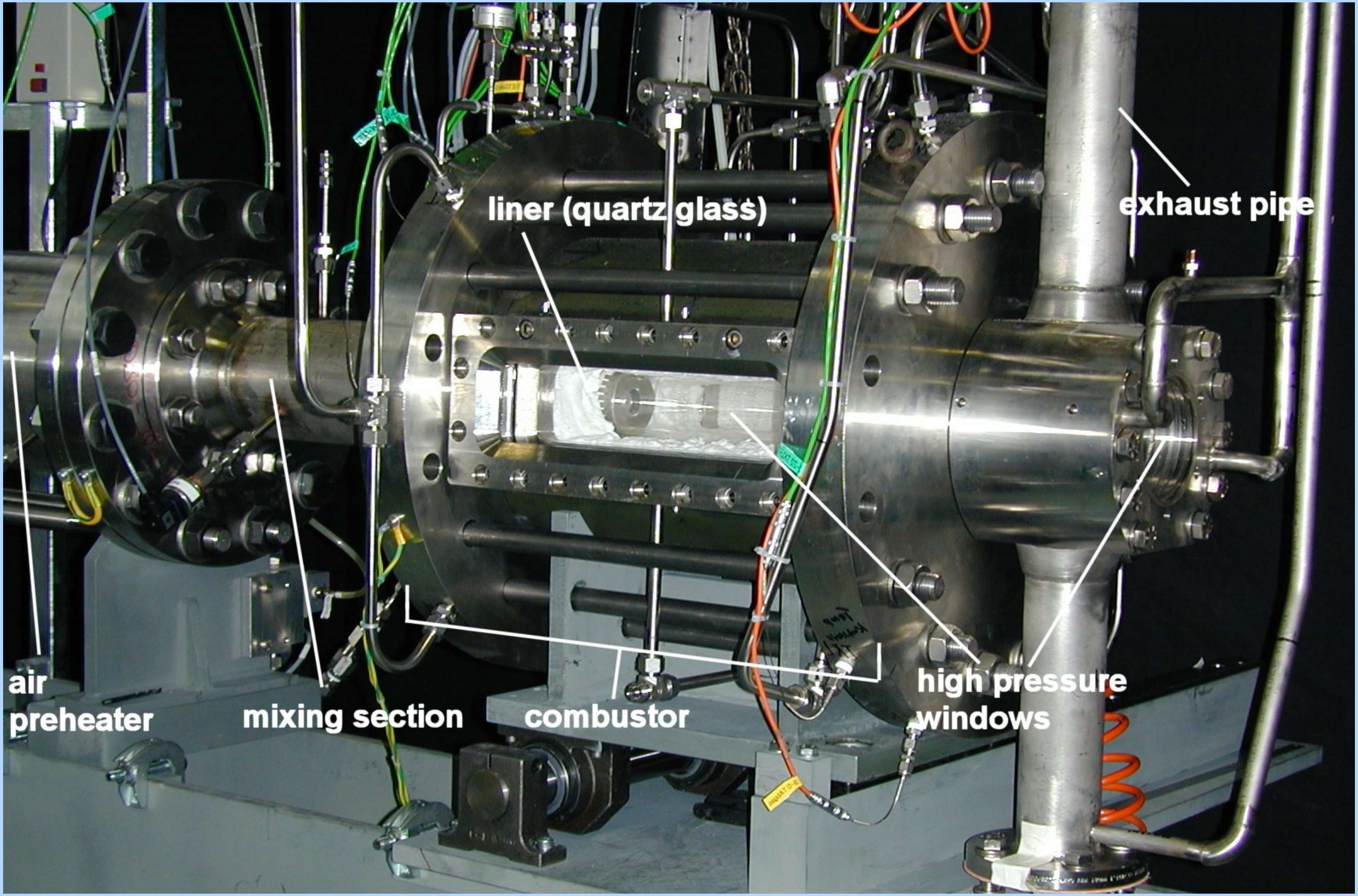
- **Further improvement of lean premixed combustion technology for gas turbines**
  - Improved flame stability (e.g. less thermo-acoustic pulsations)
  - lower NO_x emissions
- **Generation of experimental database for validation of numerical combustion models**

Objectives of Present Study

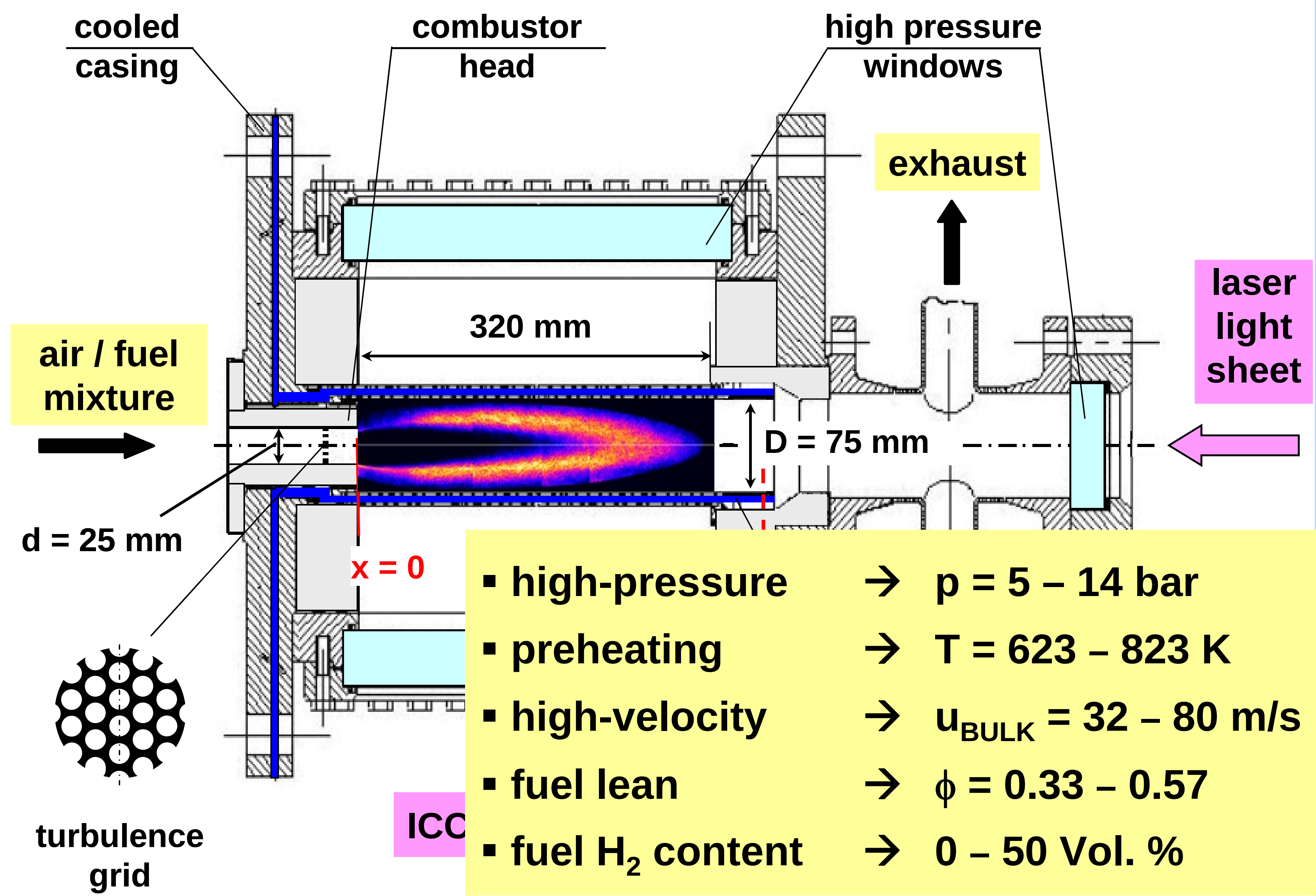
Investigation of influences of H_2 enrichment on:

- **Lean Blowout Limits (LBO)**
- **NO_X emissions**
- **Flame positions**

High-pressure Test Rig



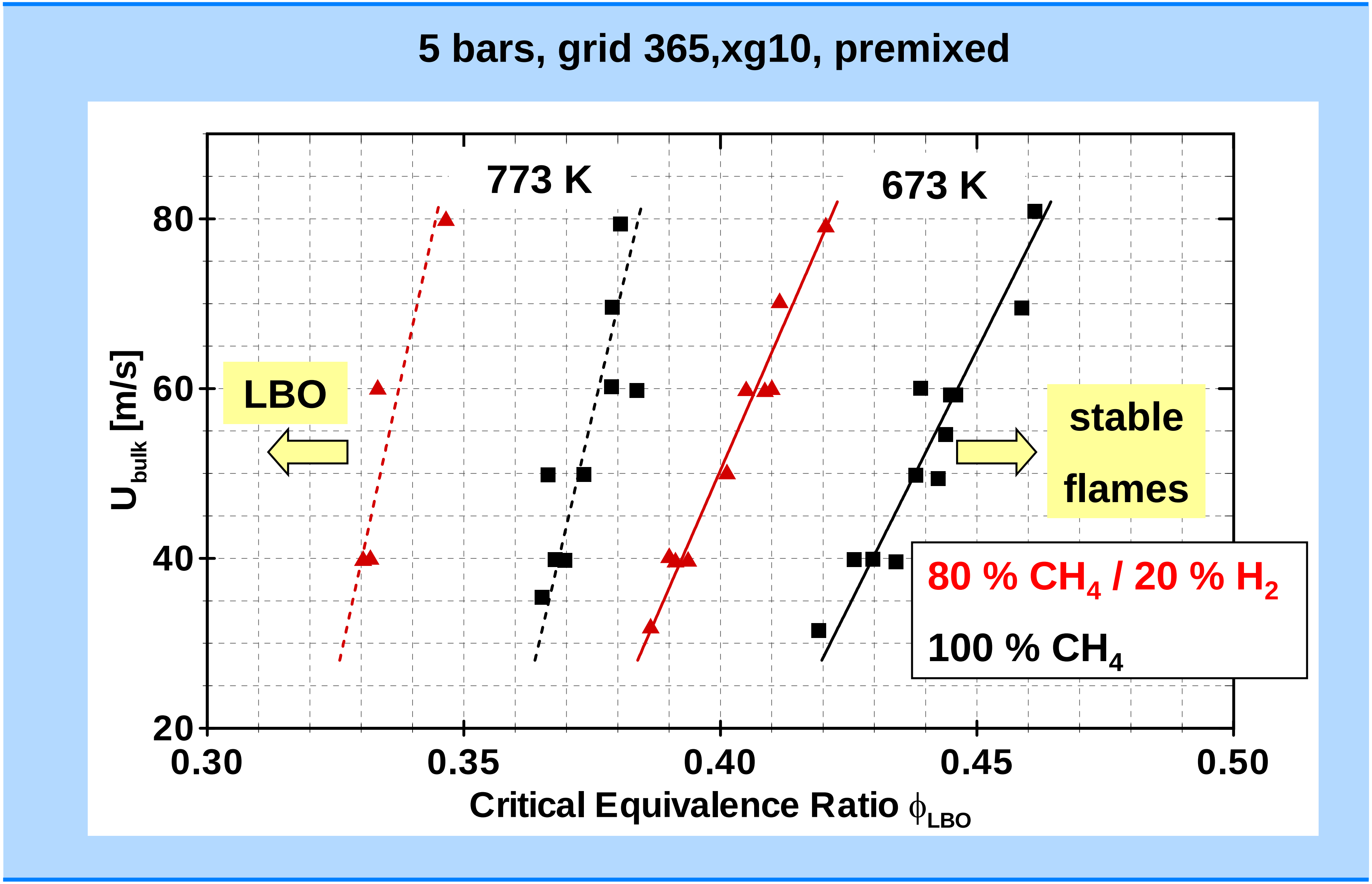
Experimental Set-up



- high-pressure → p = 5 – 14 bar
- preheating → T = 623 – 823 K
- high-velocity → u_{BULK} = 32 – 80 m/s
- fuel lean → ϕ = 0.33 – 0.57
- fuel H_2 content → 0 – 50 Vol. %

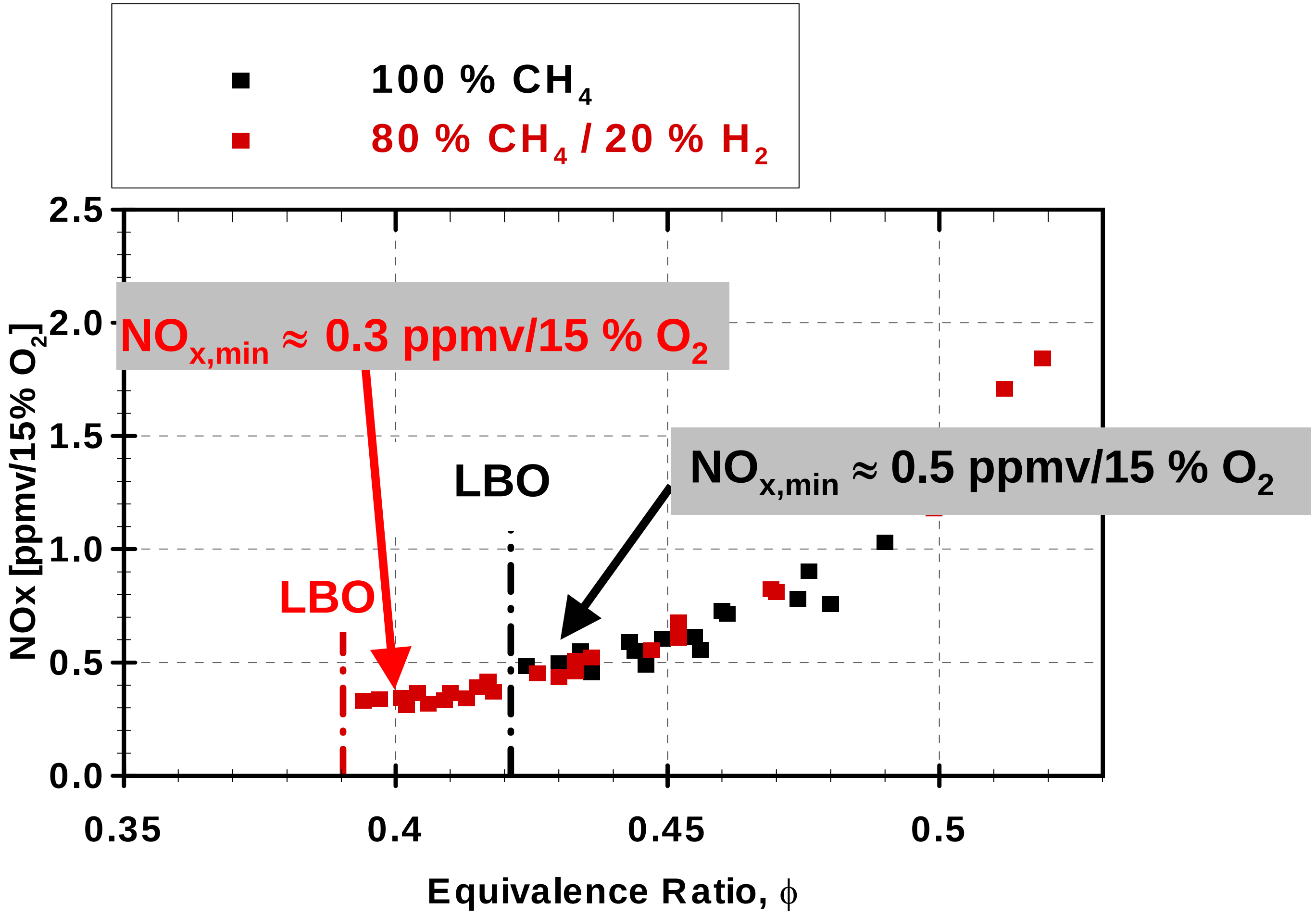
H_2 premixed

Lean Blowout Limits (Stability Map)



NO_x, CO Emissions (Influence of H_2)

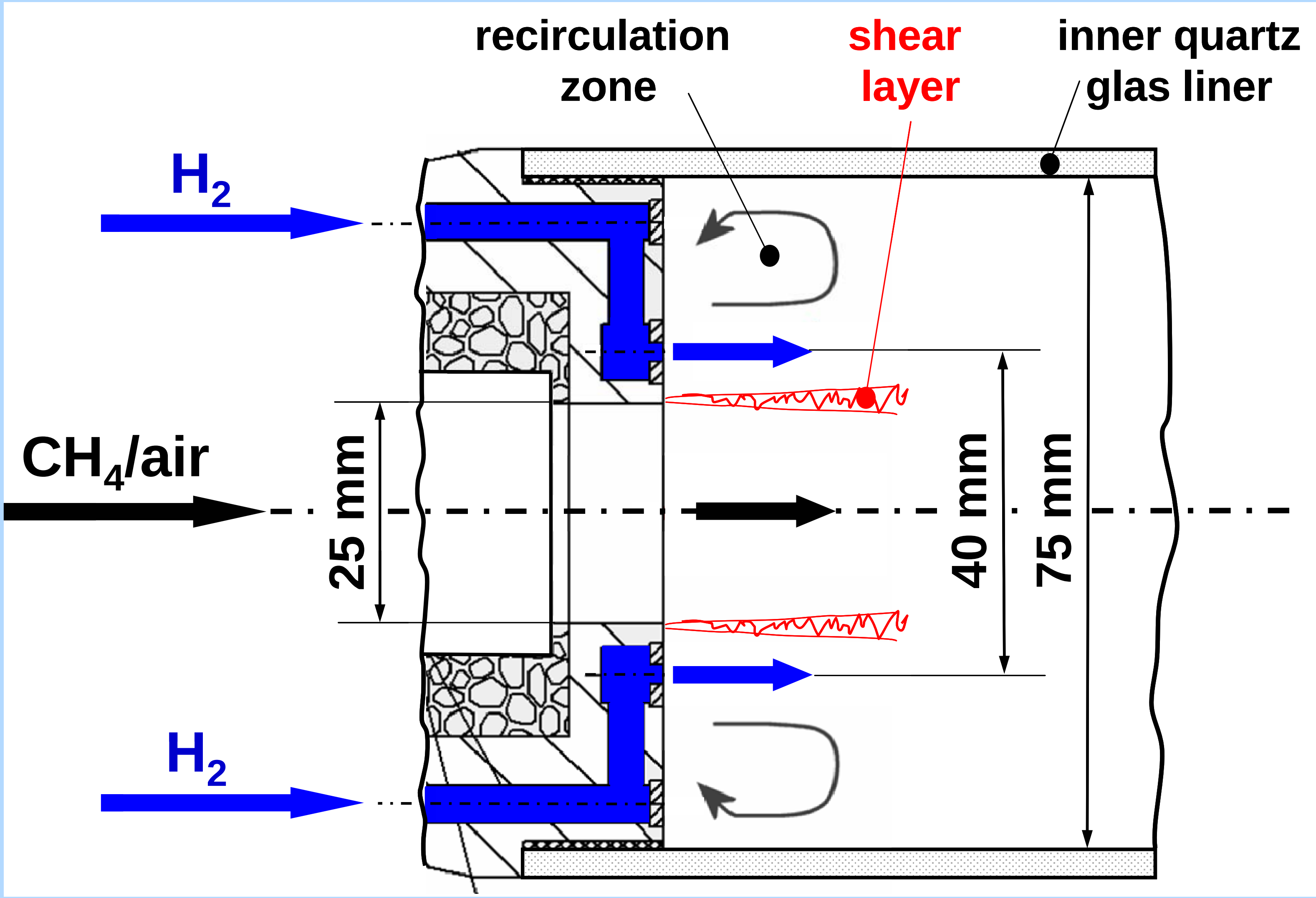
5 bars, 40 m/s, grid 365,xg10, premixed



20 Vol. % H_2 enrichment significantly decreases NO_x (≈ 35 %)

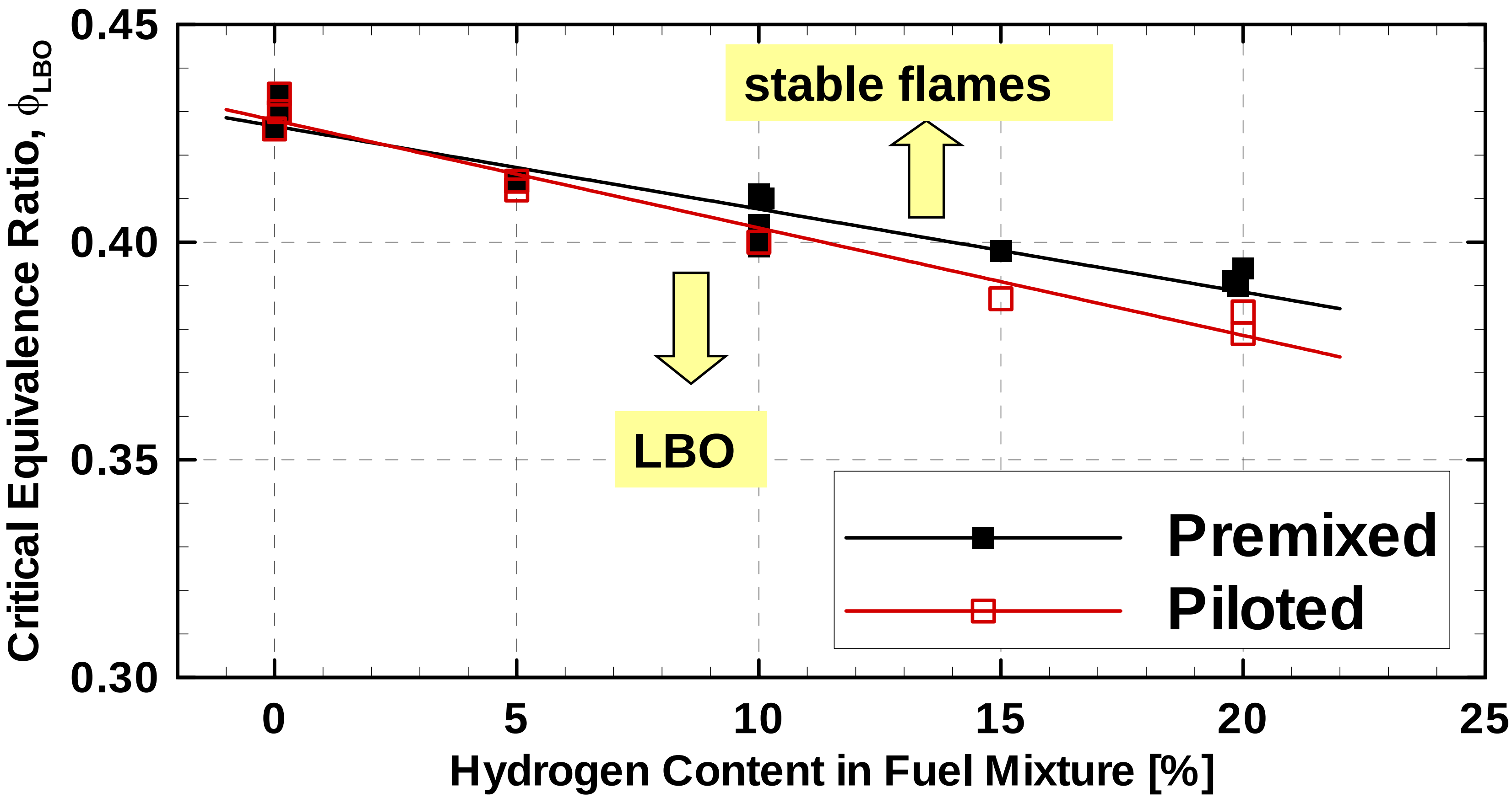
H_2 piloting

H_2 Piloting (Set-up, Detail)



Lean Blowout Limits (Premixed versus Piloted)

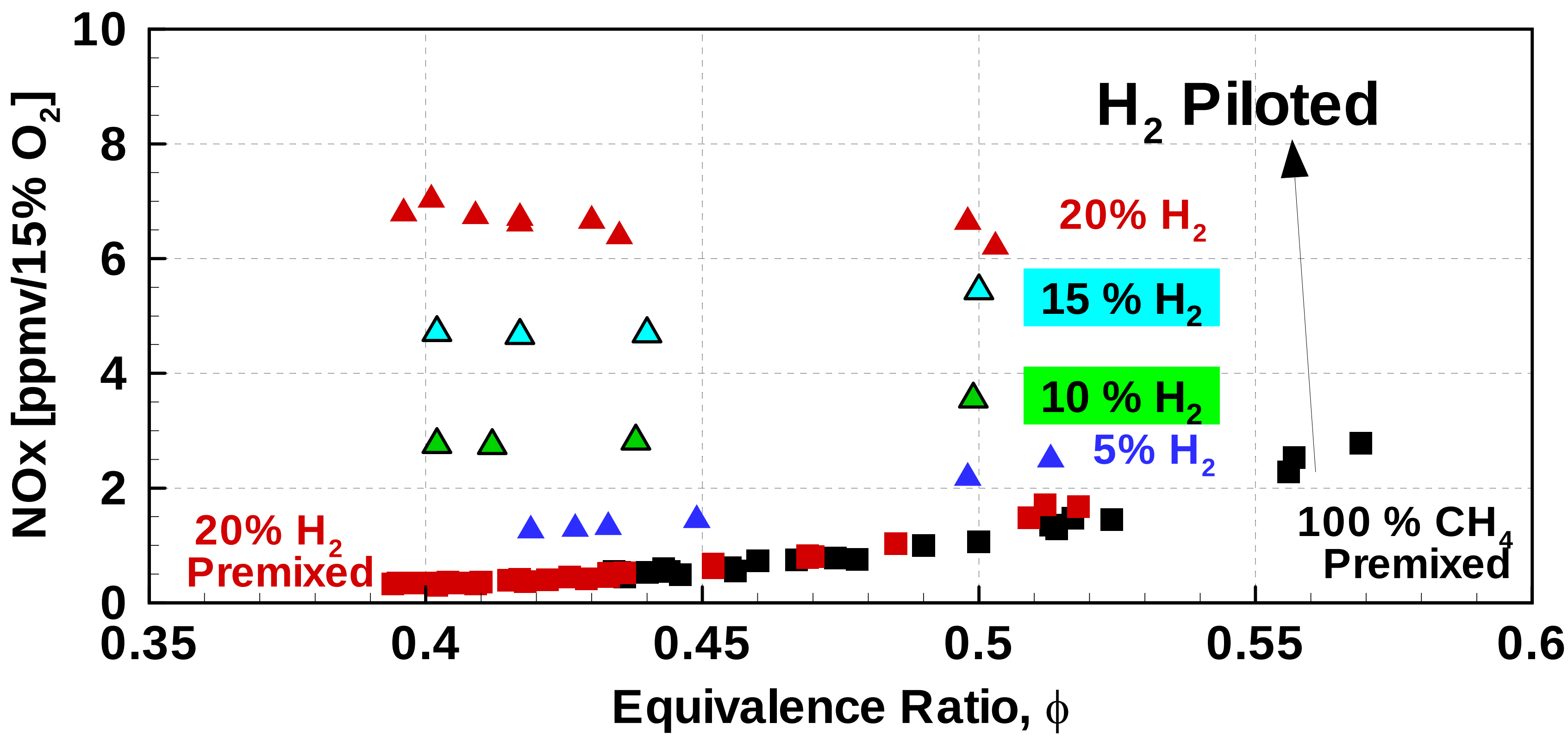
673 K, 5 bars, 40 m/s, grid 365,xg10



H_2 doping of recirculation zone is ineffective to significantly extend LBO limits

NO_x Emissions (Premixed versus Piloted)

673 K, 5 bars, 40 m/s, grid 365,xg10



H_2 doping of recirculation zone strongly increases NO_x (≈ factor 10) due to high-temperature zones.

Summary / Conclusions

LBO, NO_x of H_2-enriched CH_4/air flames were studied at gas turbines relevant conditions

1. H_2 enrichment (Premixed)

- **20 Vol. % H_2:**
  - extends the LBO limits by ≈ 10 %
  - decreases NO_x by ≈ 35 %
  - decreases the flame position by ≈ 20-25 %
- chemical effect of H_2 on NO_x at less lean conditions
- minimum NO_x does not depend on preheating temperature

2. H_2 Piloting (doping the recirculation zone)

- is ineffective to significantly extend LBO
- strongly increases NO_x (≈ factor 10) due to high-temperature zones

Outlook

Flame characterisation for a broad fuel spectrum at GT conditions

- **H_2- enriched CH_4/air flames (continuation of present work)**

  determine flame front positions, flame brush thicknesses, turbulent flame speeds S_T (OH-PLIF)

  motivation: demonstrate LBO, NO_x improvements and characterise H_2-enriched flames at GT conditions

- **Methane/propane mixtures**

  Investigate effects of higher hydrocarbons on NO_x and S_T

  motivation: demonstrate save, low-emission combustion of “off-spec” natural gas qualities

- **Syngas (H_2/CO/inerts) combustion**

  study LBO limits, NOx emissions, flame characteristics

  motivation: demonstrate save, low-emission combustion of fuels from biomass (CO_2-neutral)