



3<sup>rd</sup> MSE Colloquium  
04.07.2013, Garching

# Explosive Combustion of Stratified Hydrogen-Air Mixtures

Experimental Observations and Conclusions for Safety Applications

L. Böck, J. Haßlberger, T. Sattelmayer

Supported by:



Federal Ministry  
of Economics  
and Technology

on the basis of a decision  
by the German Bundestag

Funded by the German Federal Ministry  
of Economics and Technology (project number 1501425 and 1501338)



# Content

# H<sub>2</sub>

- (1) Relevance of Hydrogen Safety Research
- (2) Research Overview
- (3) Experimental Facility
- (4) Combustion Regimes in H<sub>2</sub>-Air Mixtures
- (5) Influence of Concentration Gradients
- (6) Conclusions for Safety Applications



## Motivation

### Potential future energy carrier

- „Power to Gas“
- Long-time energy storage
- Fuel cells

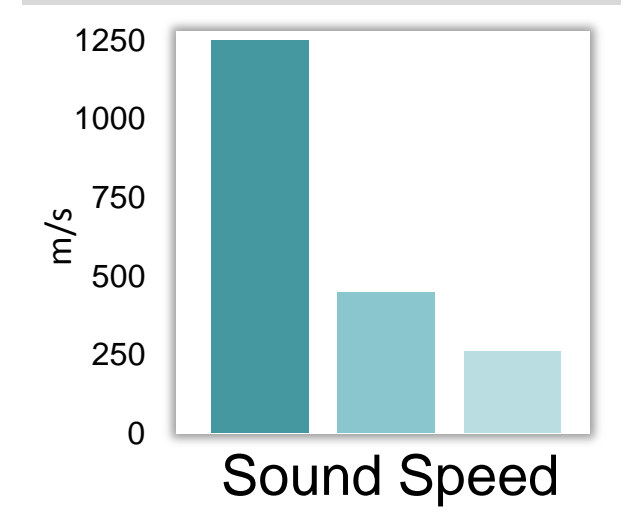
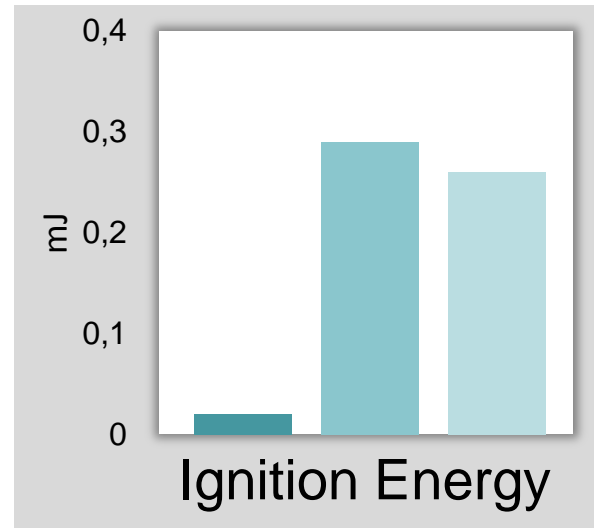
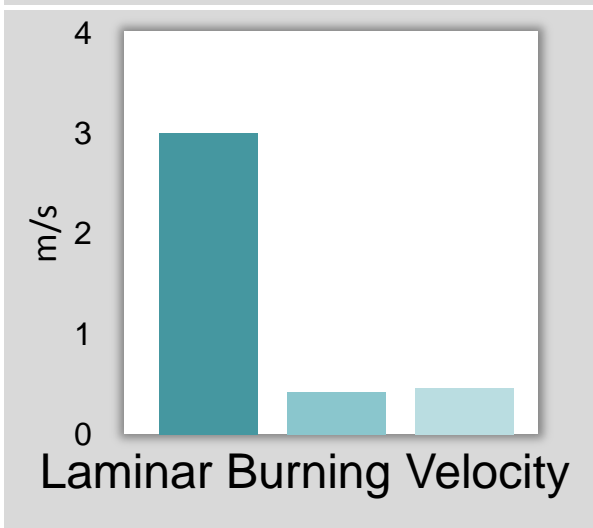
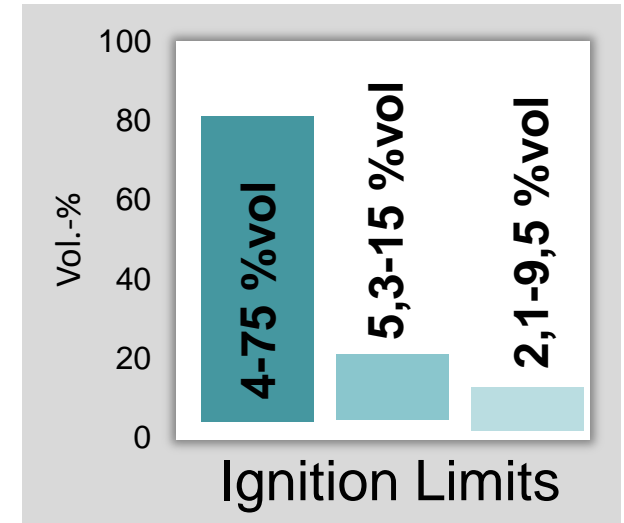
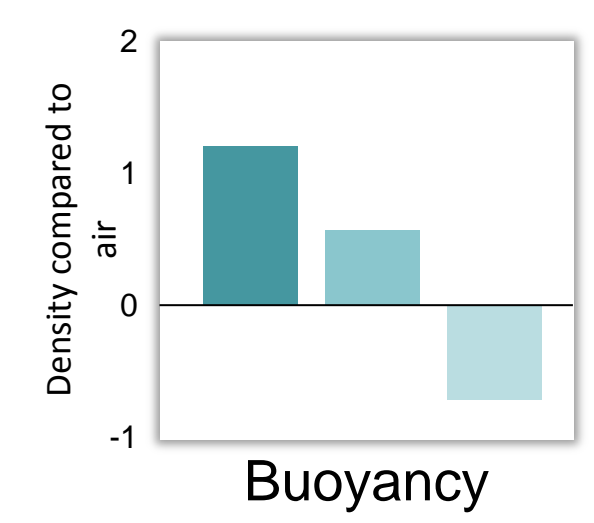
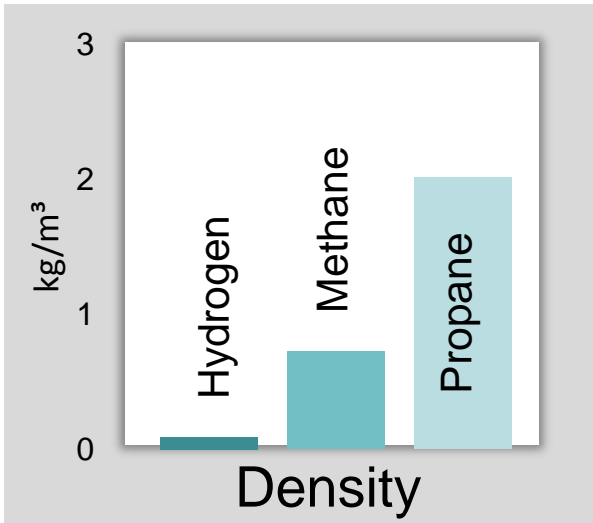


Hydrogen release  
in worst-case  
scenarios in nuclear  
power plants

Safety concerns  
and lack of acceptance

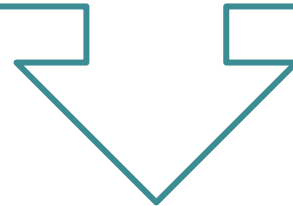
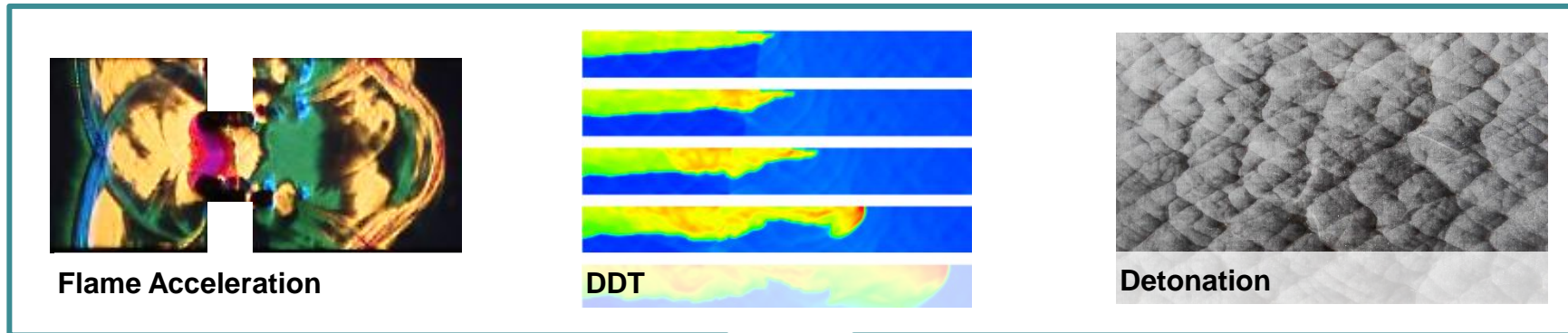
Safety problem  
(e.g. Fukushima)

# Specific Properties of Hydrogen

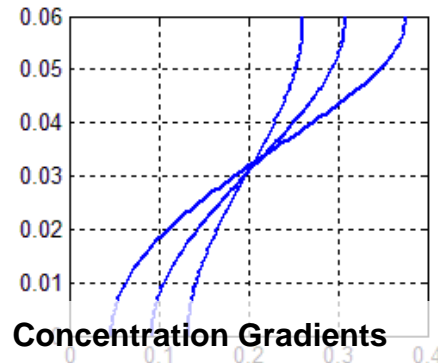




# Research overview - Chair of Thermodynamics, TUM



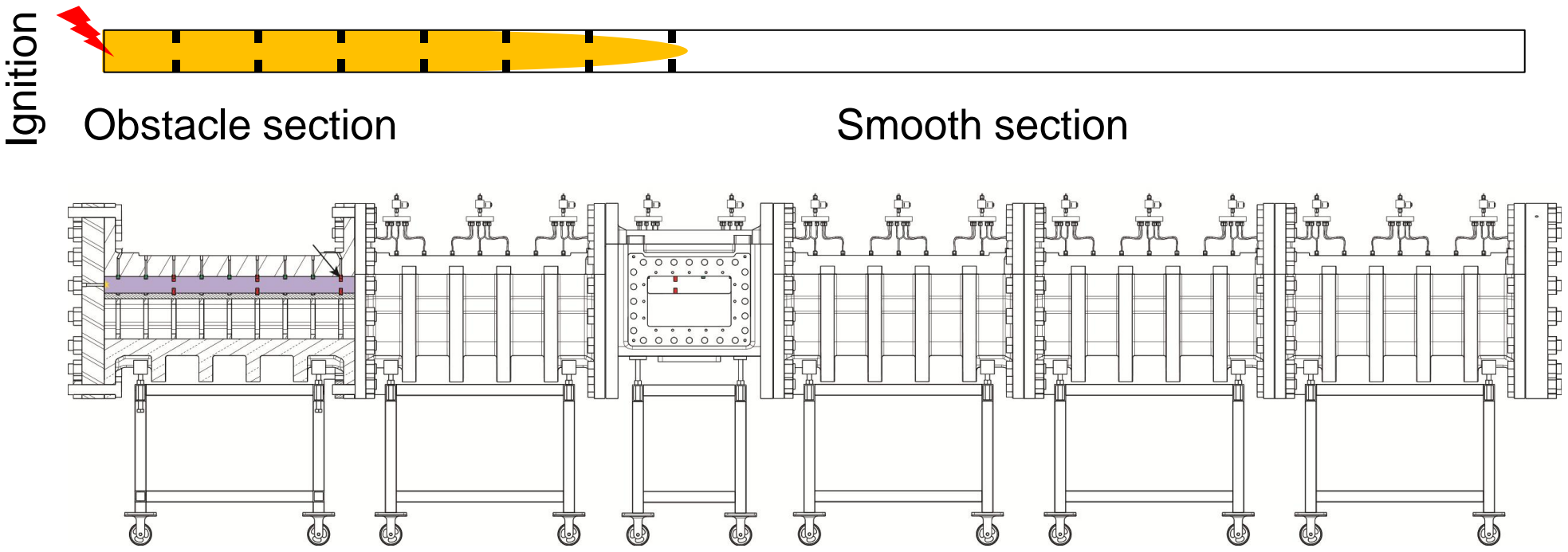
Experiments



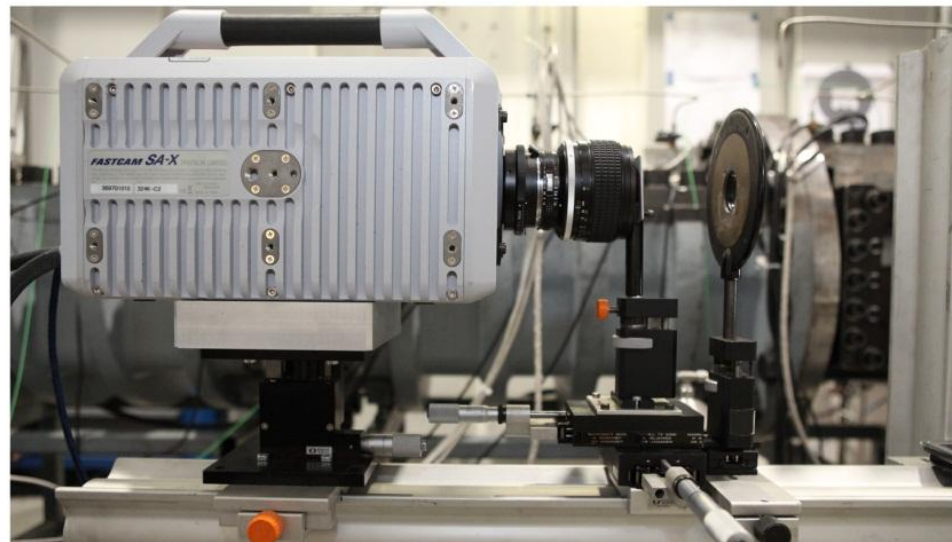
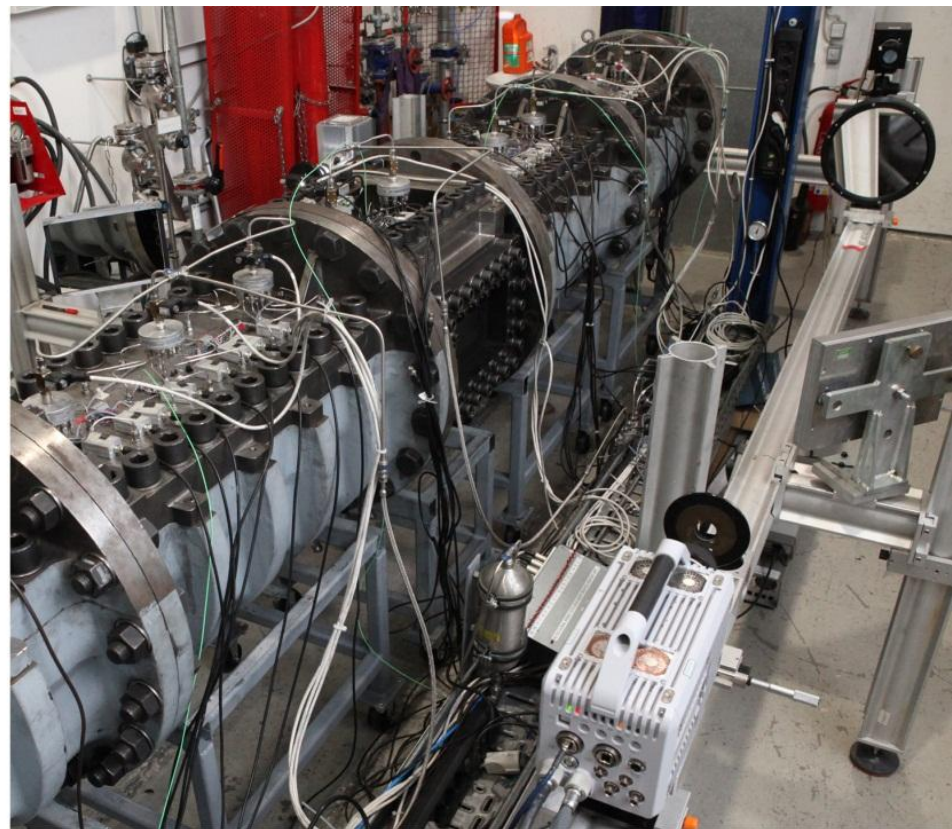
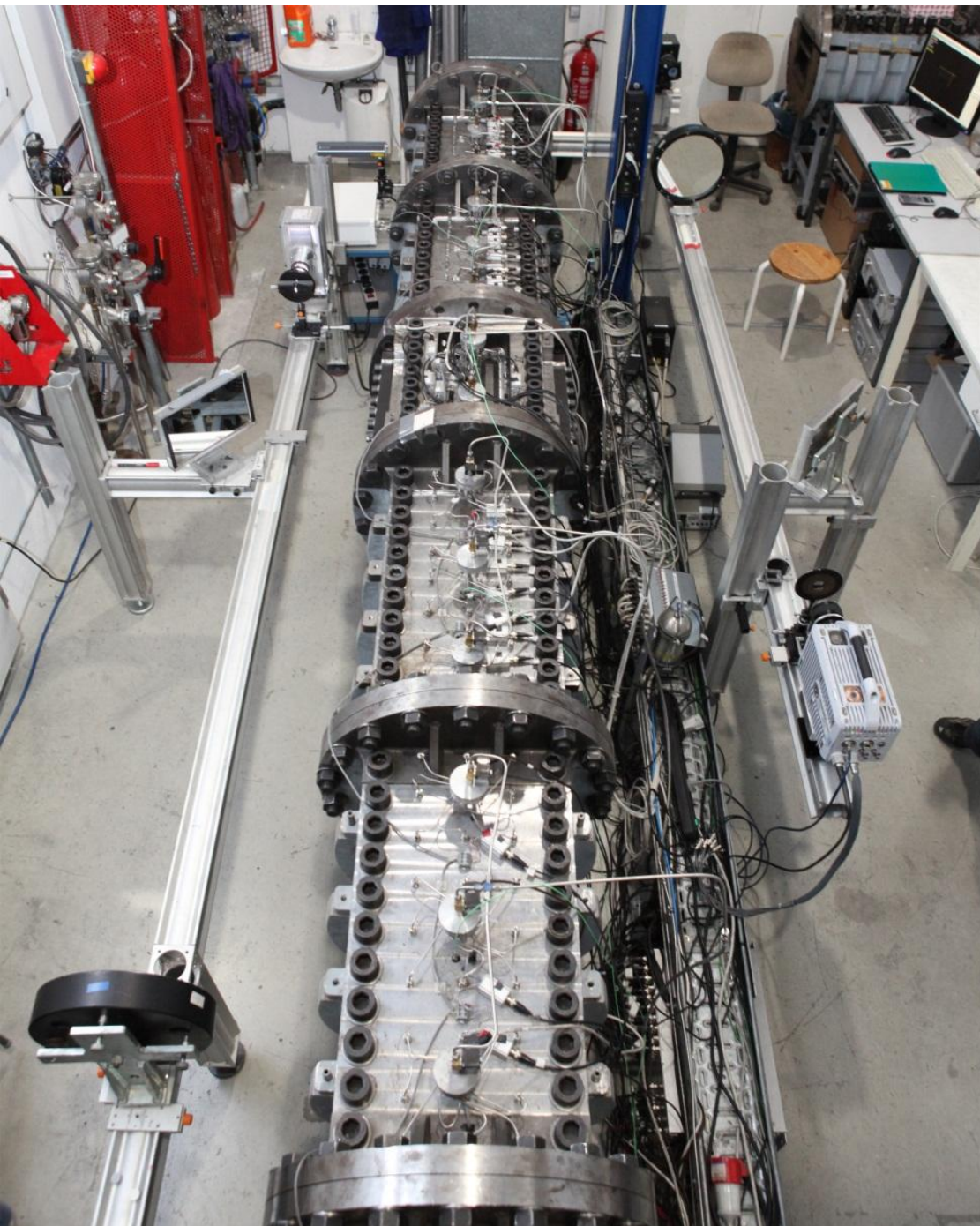
CFD-Simulation

# Experimental Facility

- ▶ Closed rectangular channel (5.4m x 0.3m x 0.06m)
- ▶ Obstacle section
- ▶ Initial atmospheric pressure and temperature

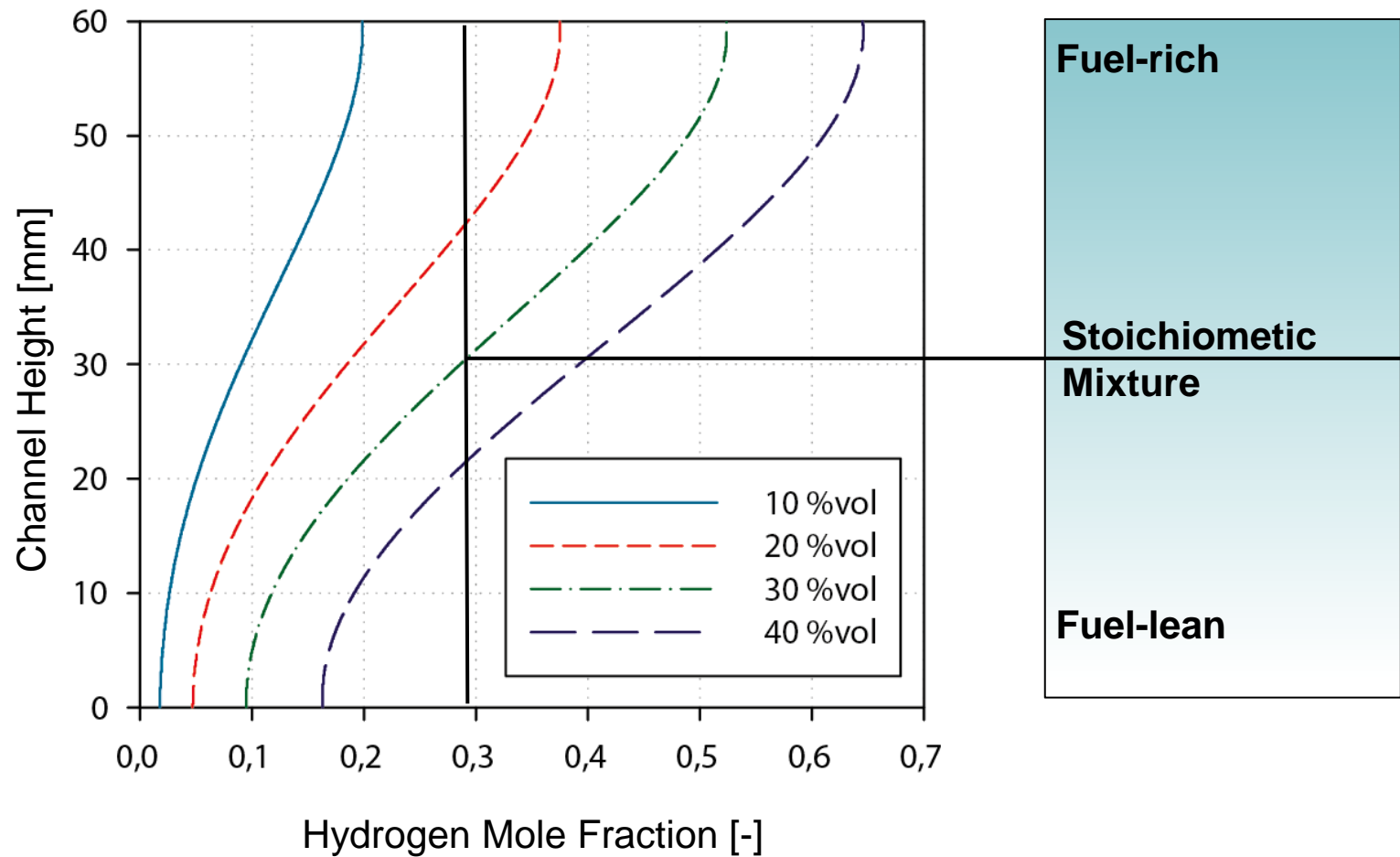






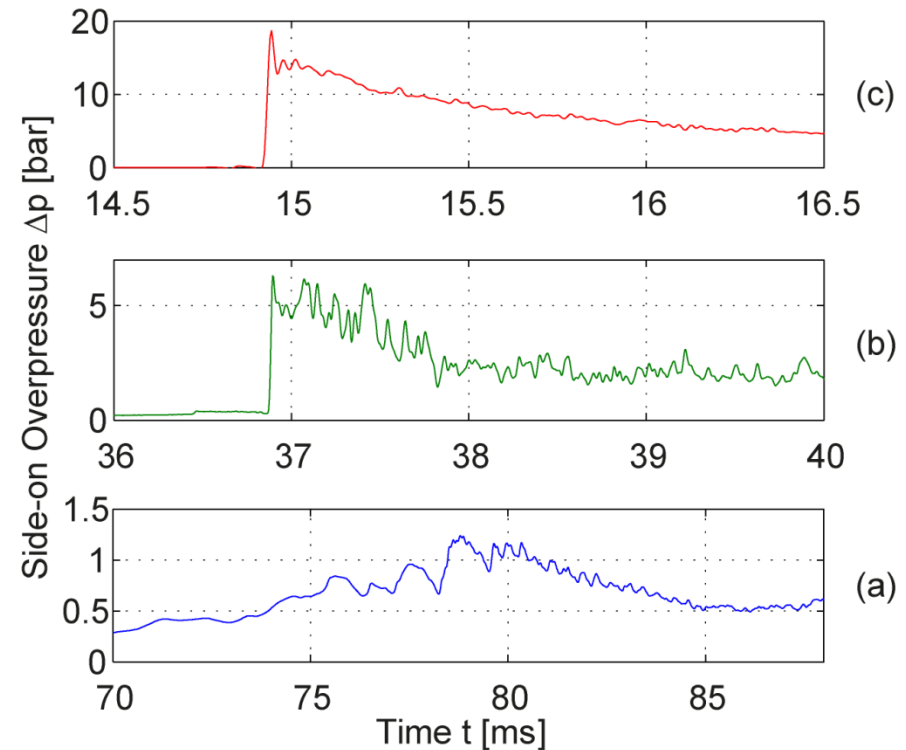
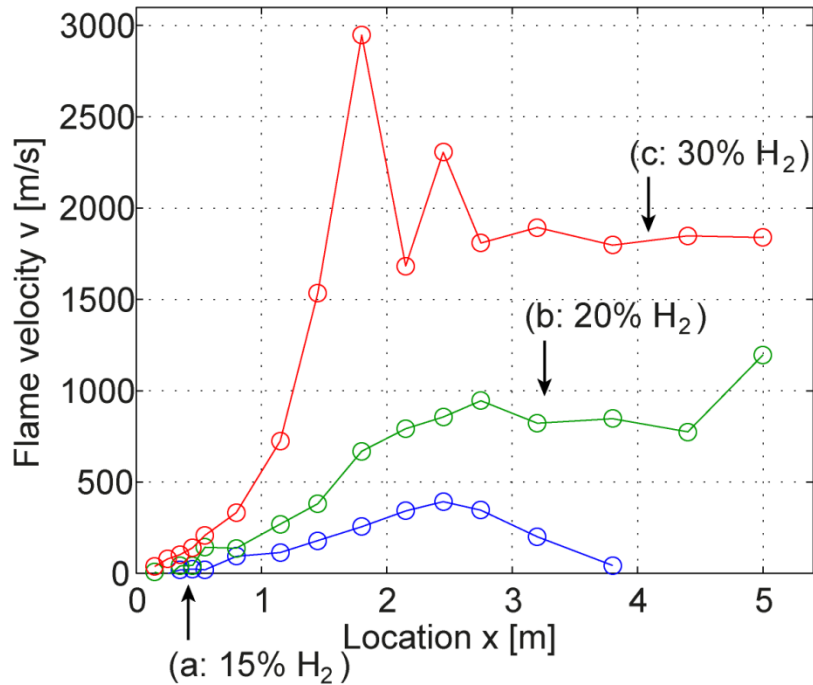
# Test Facility – Concentration Gradients

**Example: 30 %vol H<sub>2</sub>**



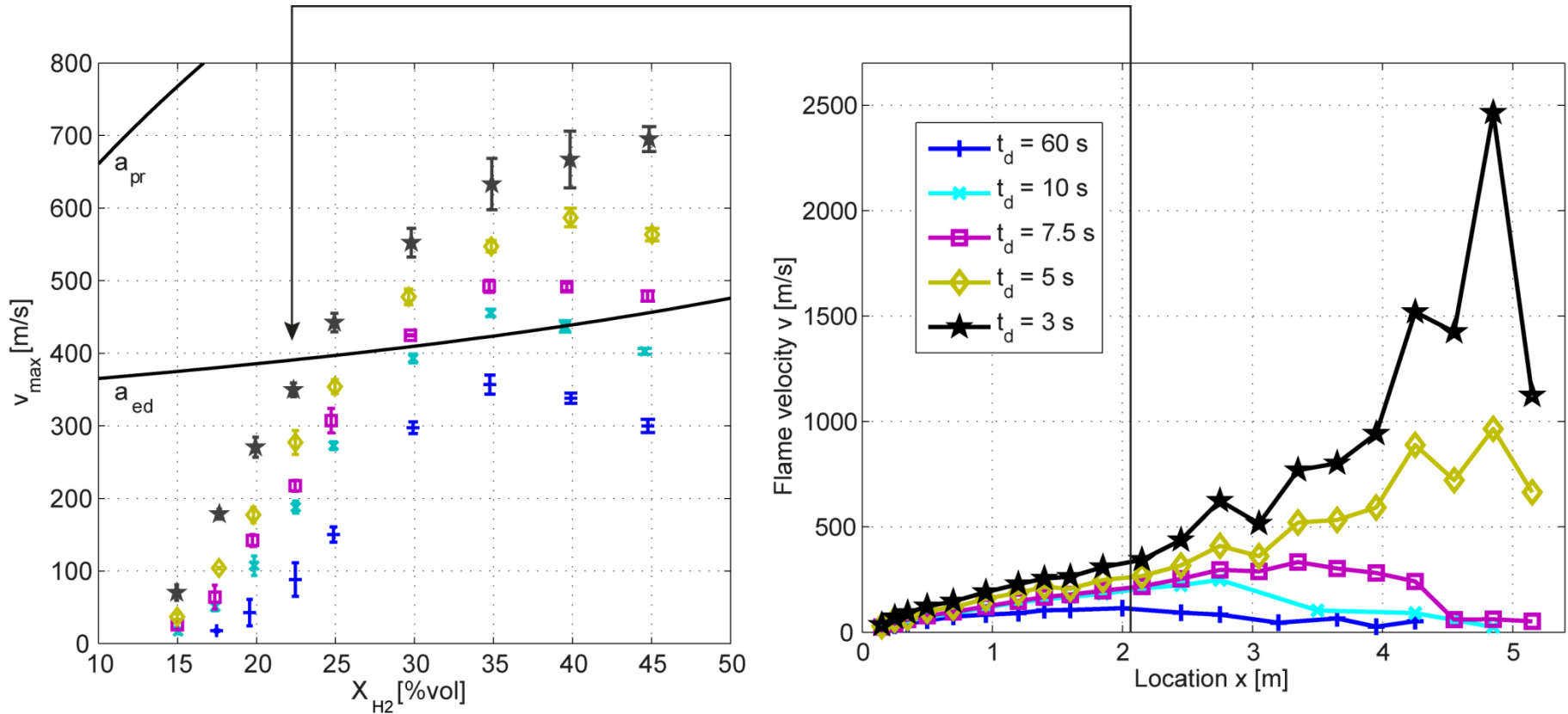


# Combustion Regimes – Homogeneous Mixtures



▶ (a) Slow Flame	Subsonic Velocity	Moderate Overpressures
▶ (b) Fast Flame	Sonic Velocity	Challenging Overpressures
▶ (c) Detonation	Supersonic Velocity	Destructive Overpressures

# Inhomogeneous Mixtures – Smooth Channel



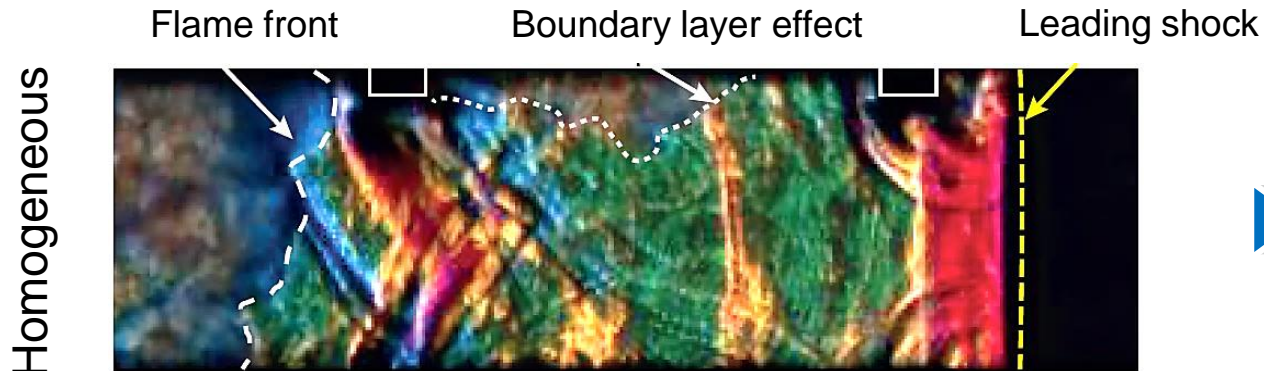
▶ Slow flame regime in homogeneous mixture

▶ Fast flame regime at intermediate concentration gradients

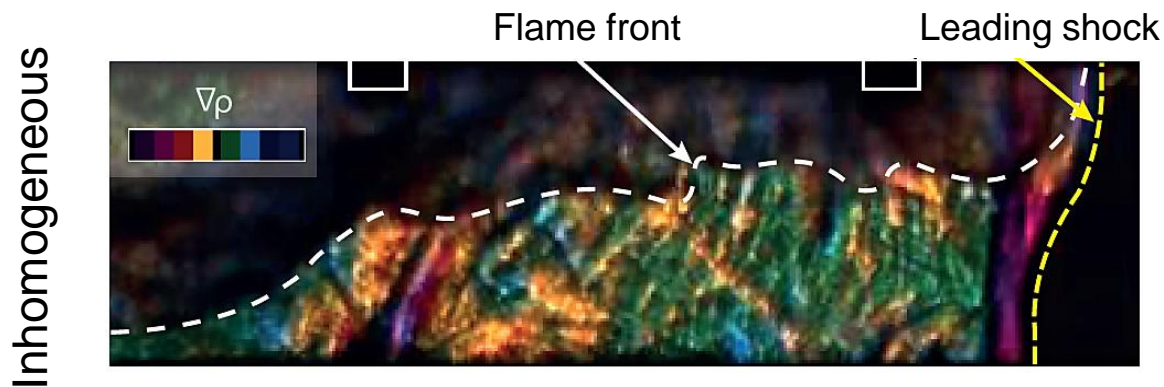
▶ Detonation at steepest concentration gradient close to the end plate

# Inhomogeneous Mixtures – Smooth Channel

## Color Schlieren Imaging



▶ Straight flame front



▶ Inclined flame front

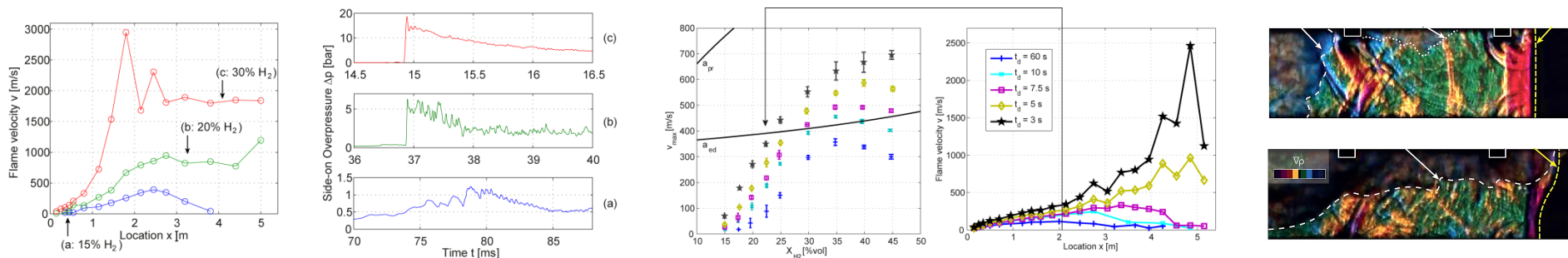
▶ Enlarged flame surface area

▶ Higher fuel consumption rate

# Conclusions for Safety Applications

# H<sub>2</sub>

- Fast combustion regimes lead to destructive overpressures
- Potential for flame acceleration is given for a large variety of hydrogen-air mixtures
- Concentration gradients can lead to much stronger flame acceleration, especially in a smooth channel
- Homogeneous mixtures cannot be considered as the worst case scenario in most configurations







3<sup>rd</sup> MSE Colloquium  
04.07.2013, Garching

# Explosive Combustion of Stratified Hydrogen-Air Mixtures

Experimental Observations and Conclusions for Safety Applications

L. Böck, J. Haßlberger, T. Sattelmayer

Supported by:



Federal Ministry  
of Economics  
and Technology

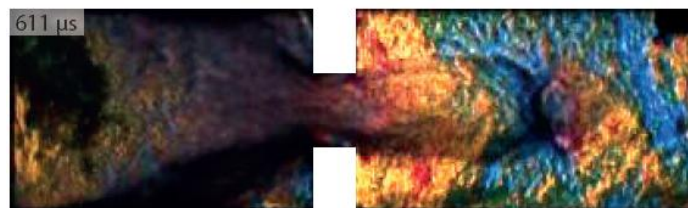
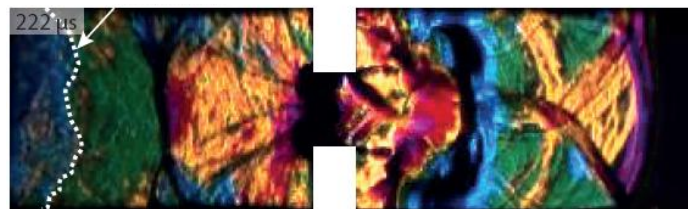
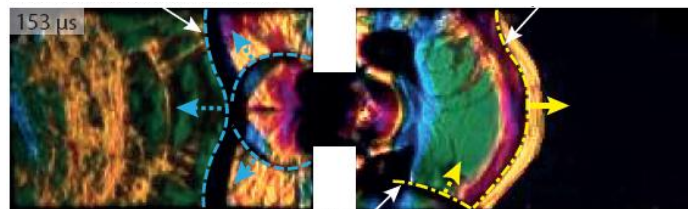
on the basis of a decision  
by the German Bundestag

Funded by the German Federal Ministry  
of Economics and Technology (project number 1501425 and 1501338)

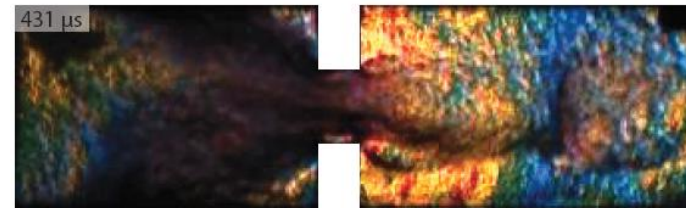
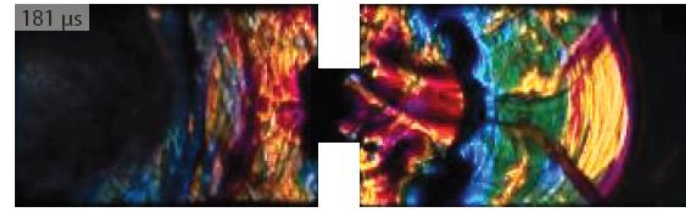
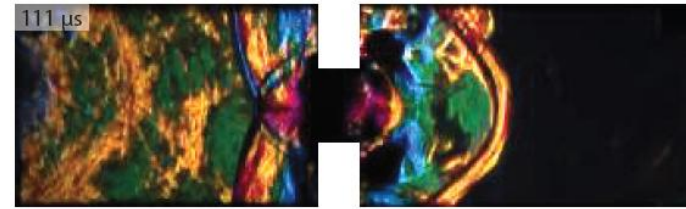
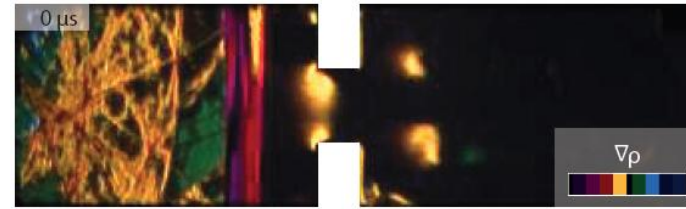


# Inhomogeneous Mixtures – Obstructed Channel

## Color Schlieren Imaging



Homogeneous Mixture



Inhomogeneous Mixture