DDT and Detonations, knowledge gaps

by
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Porsgrunn, Norway, 1985

Porsgrunn, Norway, 1997

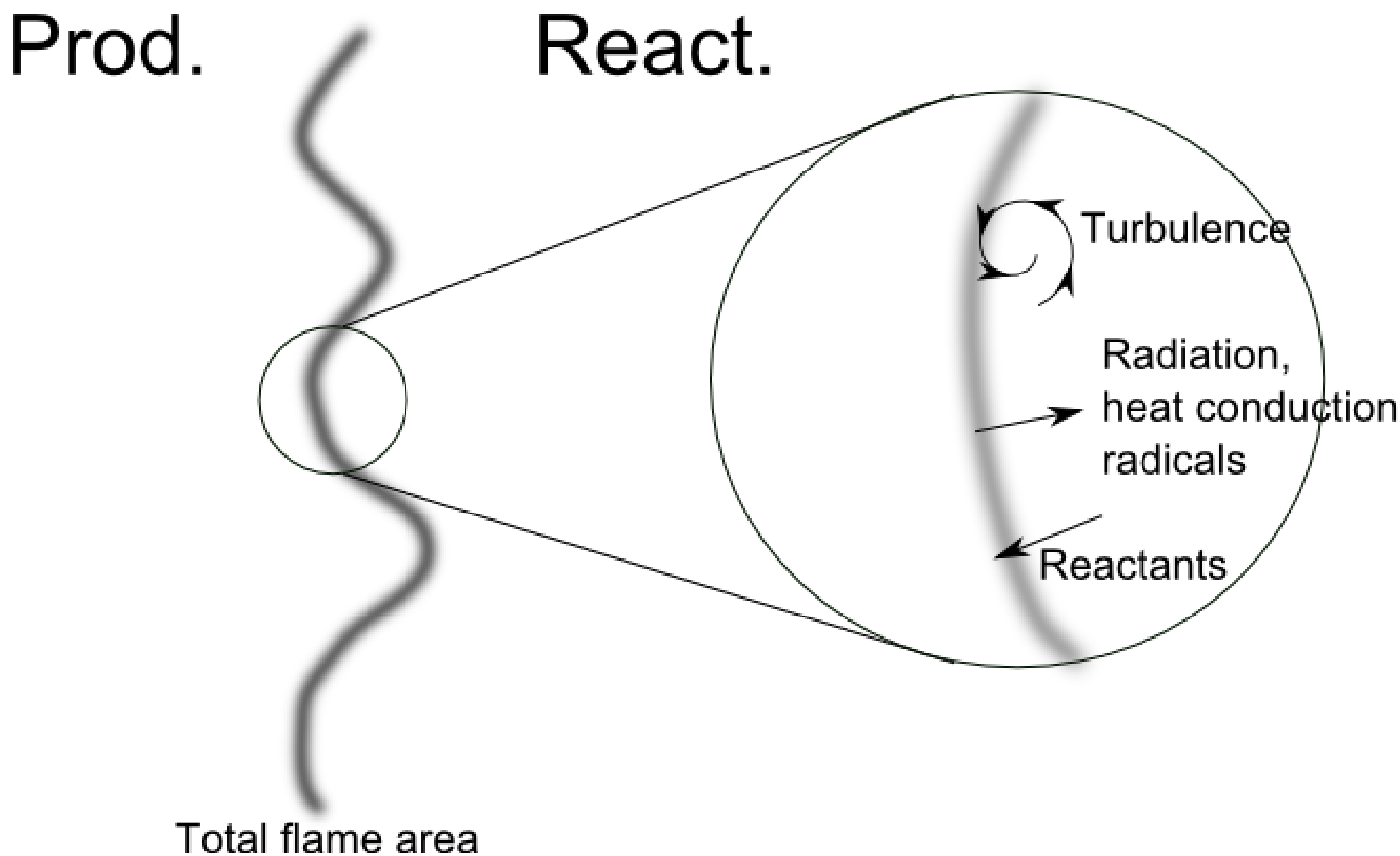
Outline

- DDT and detonations, simple explanation

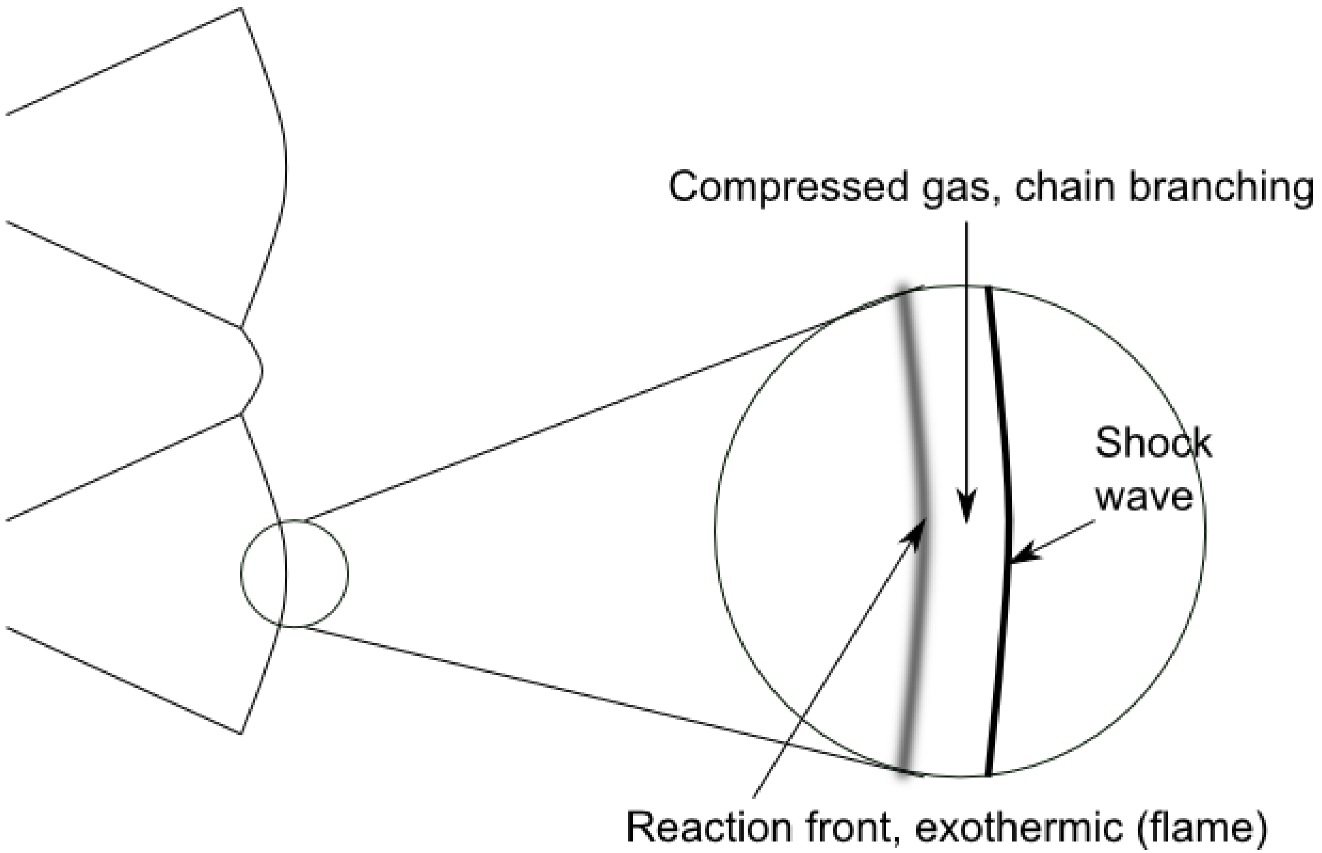
- Some of the work with H2 at Telemark UC

- Knowledge gaps

Deflagration



Detonation

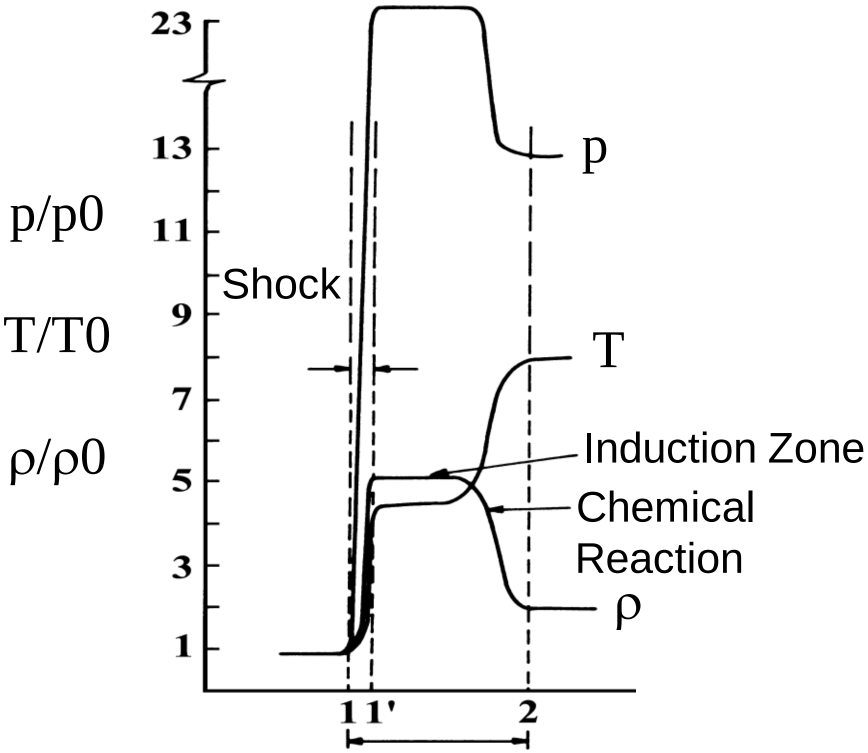


Compressed gas, chain branching
Shock
wave
Reaction front, exothermic (flame)

ZND

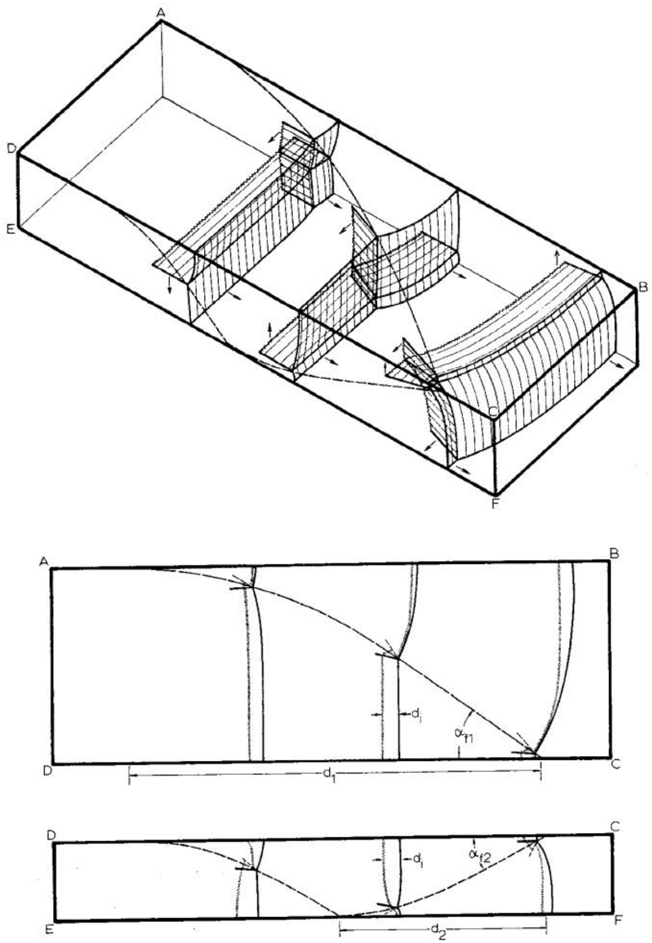
20% H_2-air

	1	**1'**	**2**
M	4.5	0.42	1.0
u	1525 m/s	1000	1800
p	1 atm	23	13
T	298K	1350	2425
ρ/ρ_0	1	5	1.8

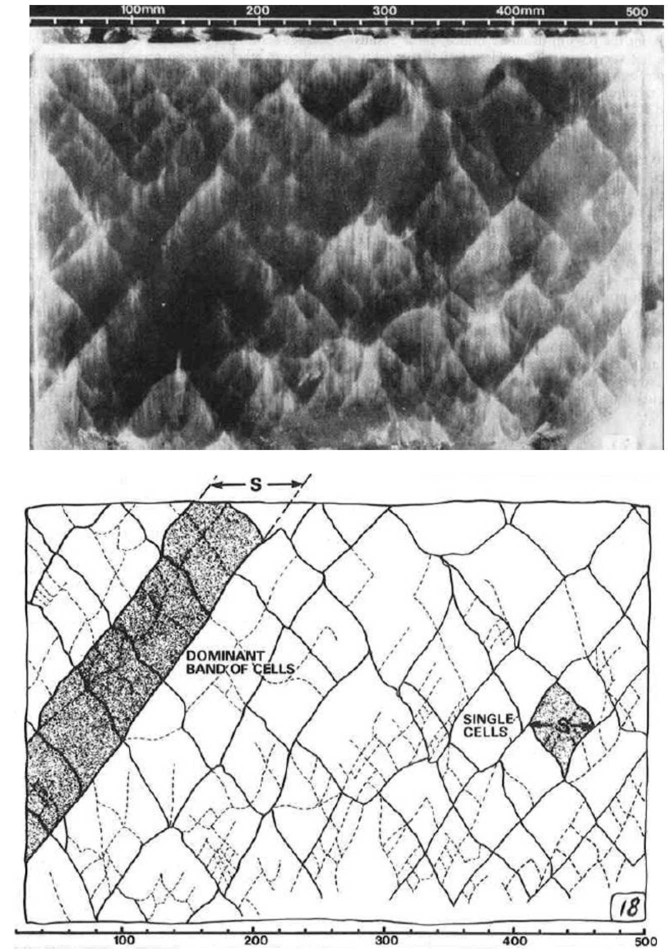


Glassman 1977

A Detonation Wave has 3-D Structure

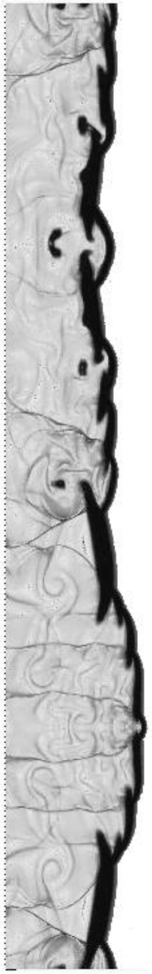


Steel and Oppenheim 1982

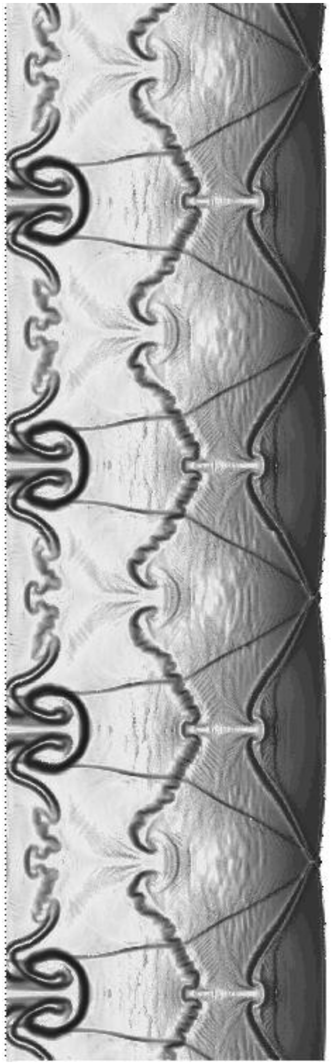


Moen et al. 1982

Unstuctured



Stuctured



Transition from deflagration to detonation

How does the reaction front propagation change transport method?

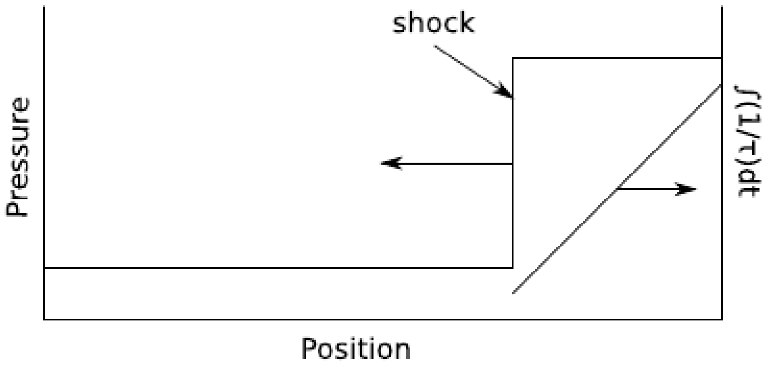
- From diffusion and turbulence to pressure wave (compression) controlled propagation

- Propagation of a detonation front is dominated by interaction of reactions and both normal and transverse shock waves (detonation cells).

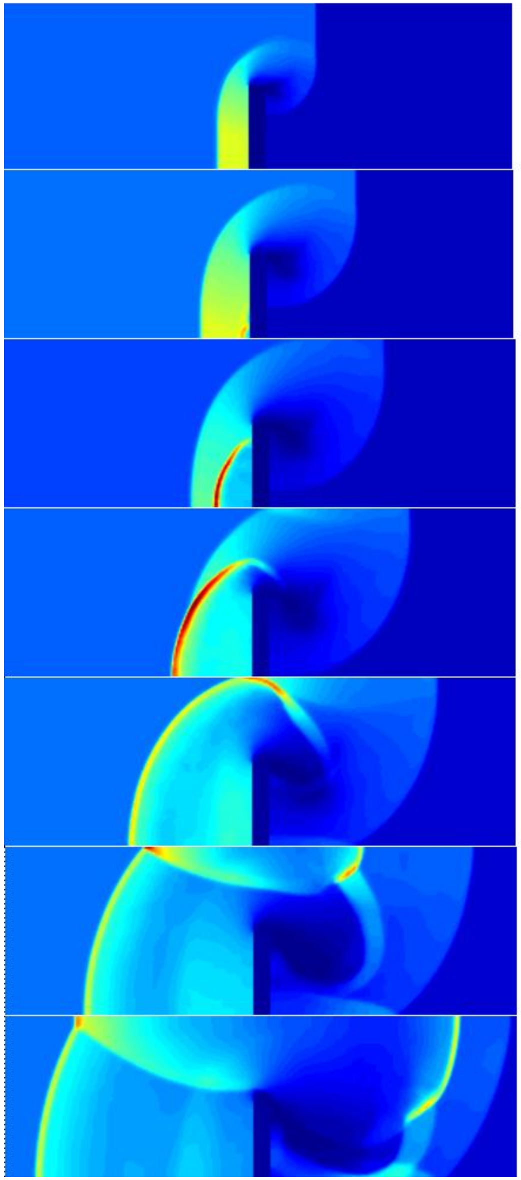
Zel’dovich mechanism

Induction time (τ): Several definitions
Here: time from compression of reactants to start of exothermal reaction (typical simulation assumption).

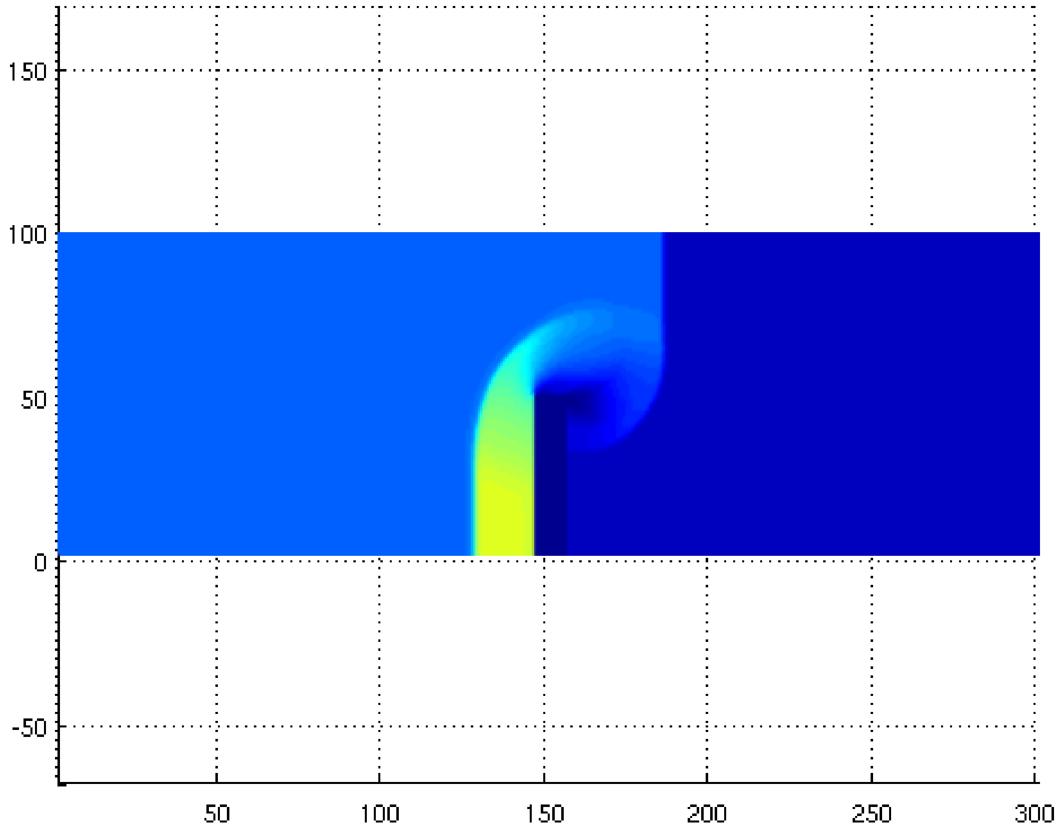
The induction time is the characteristic time of initiation and isothermal branching reactions.



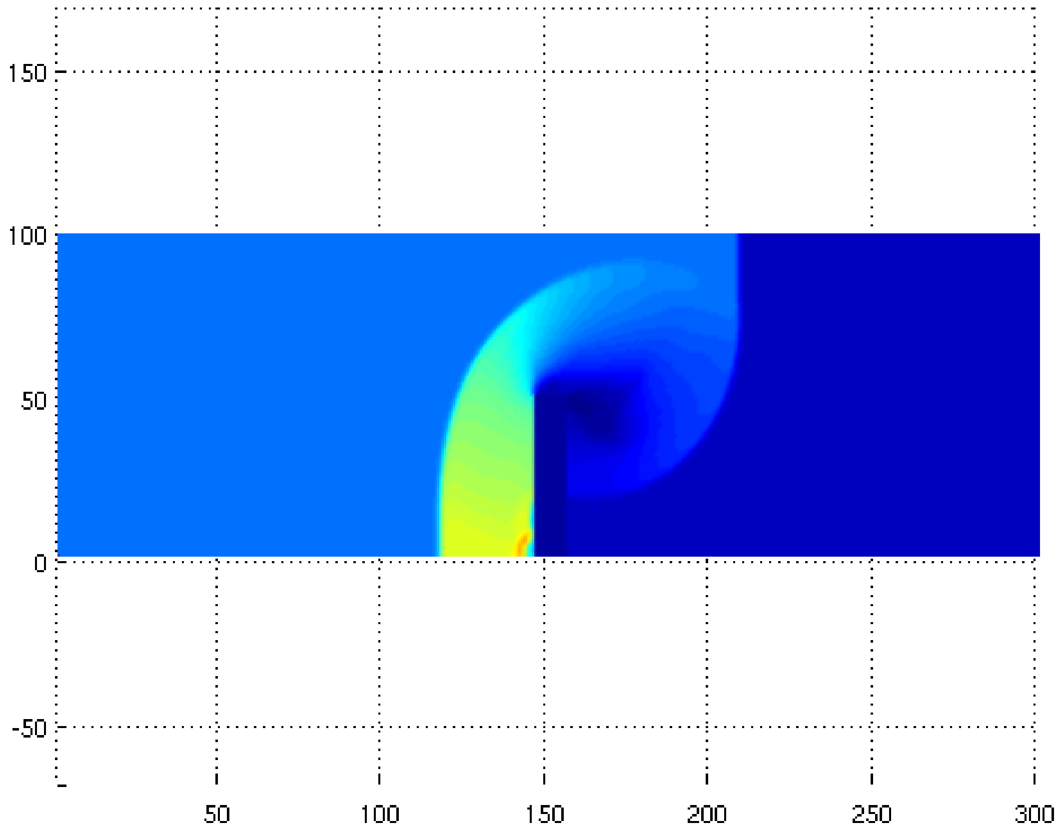
Direct initiation from shock reflection



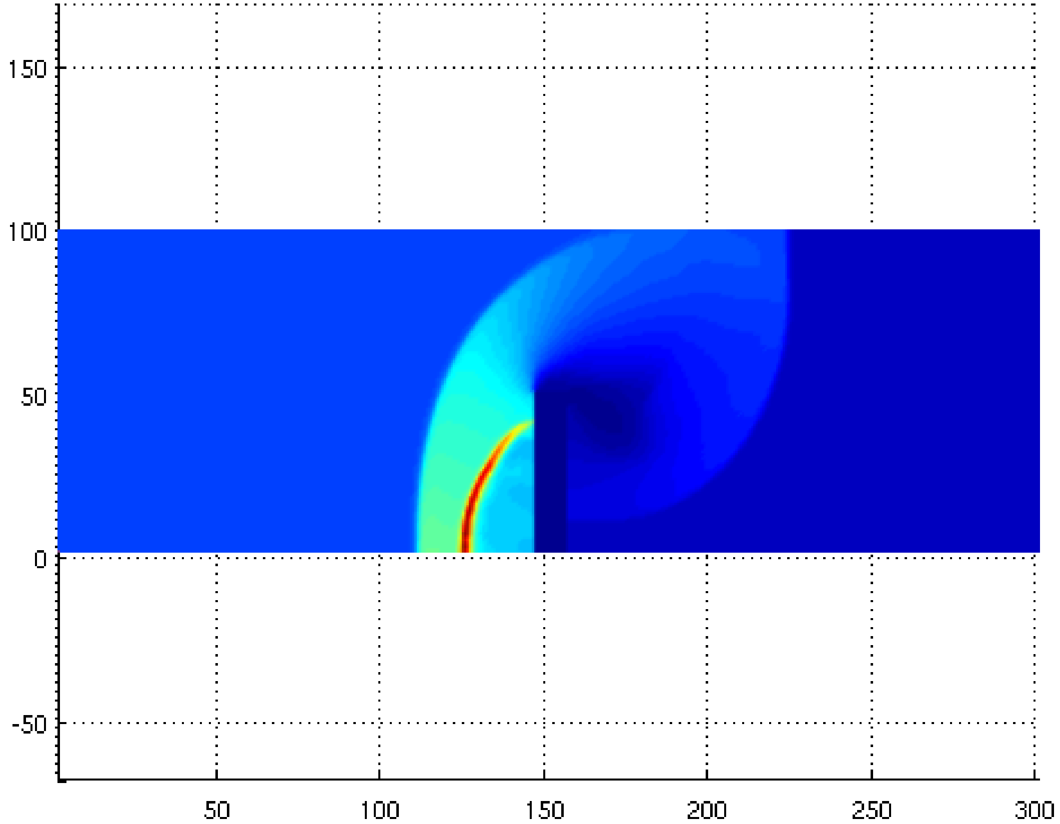
Direct initiation from shock reflection



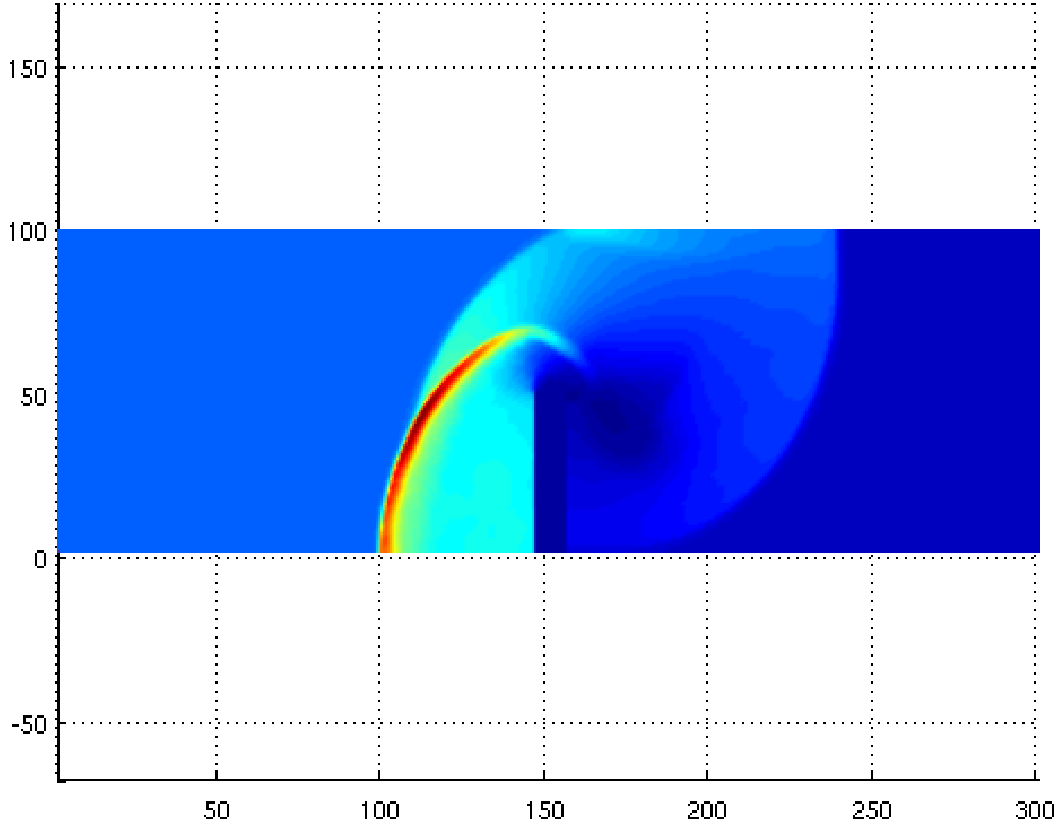
Direct initiation from shock reflection



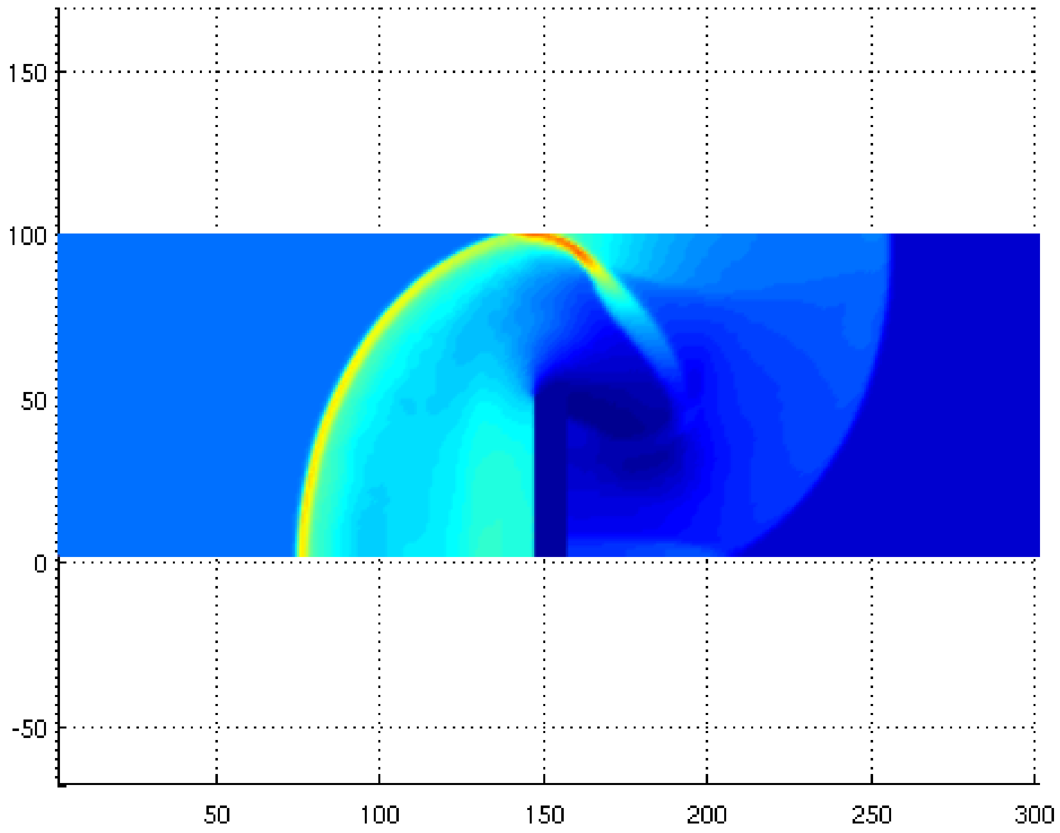
Direct initiation from shock reflection



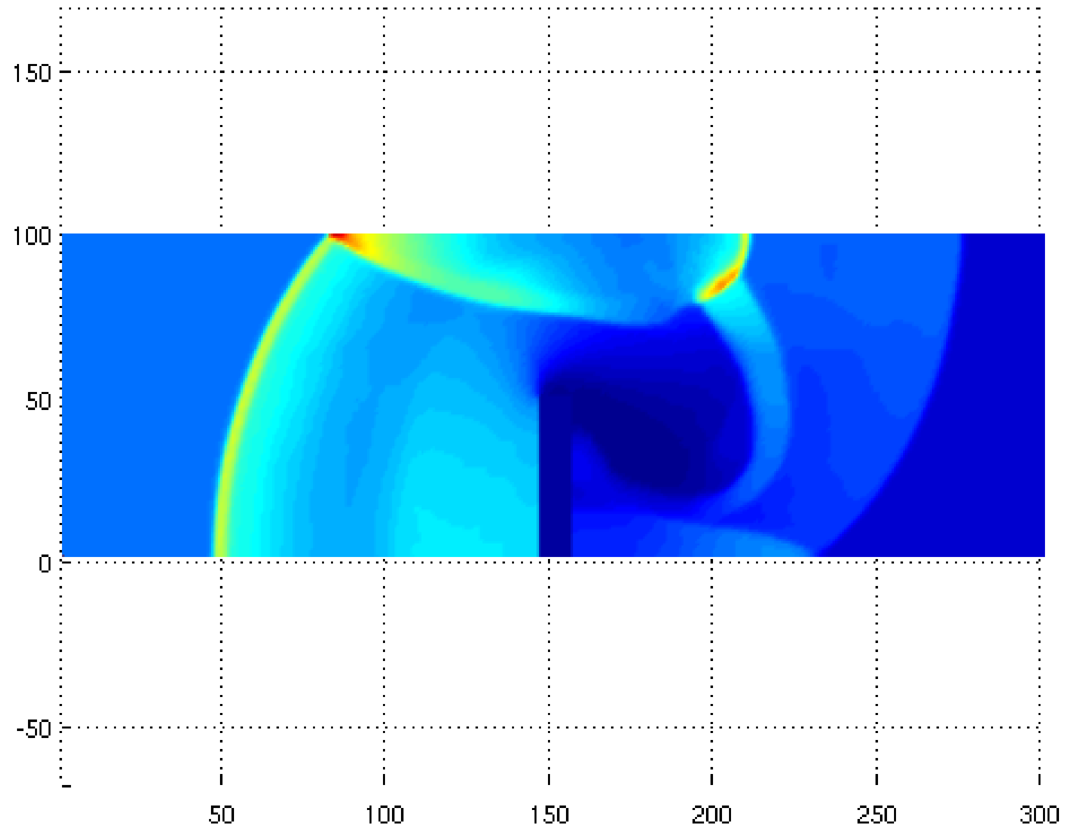
Direct initiation from shock reflection



Direct initiation from shock reflection

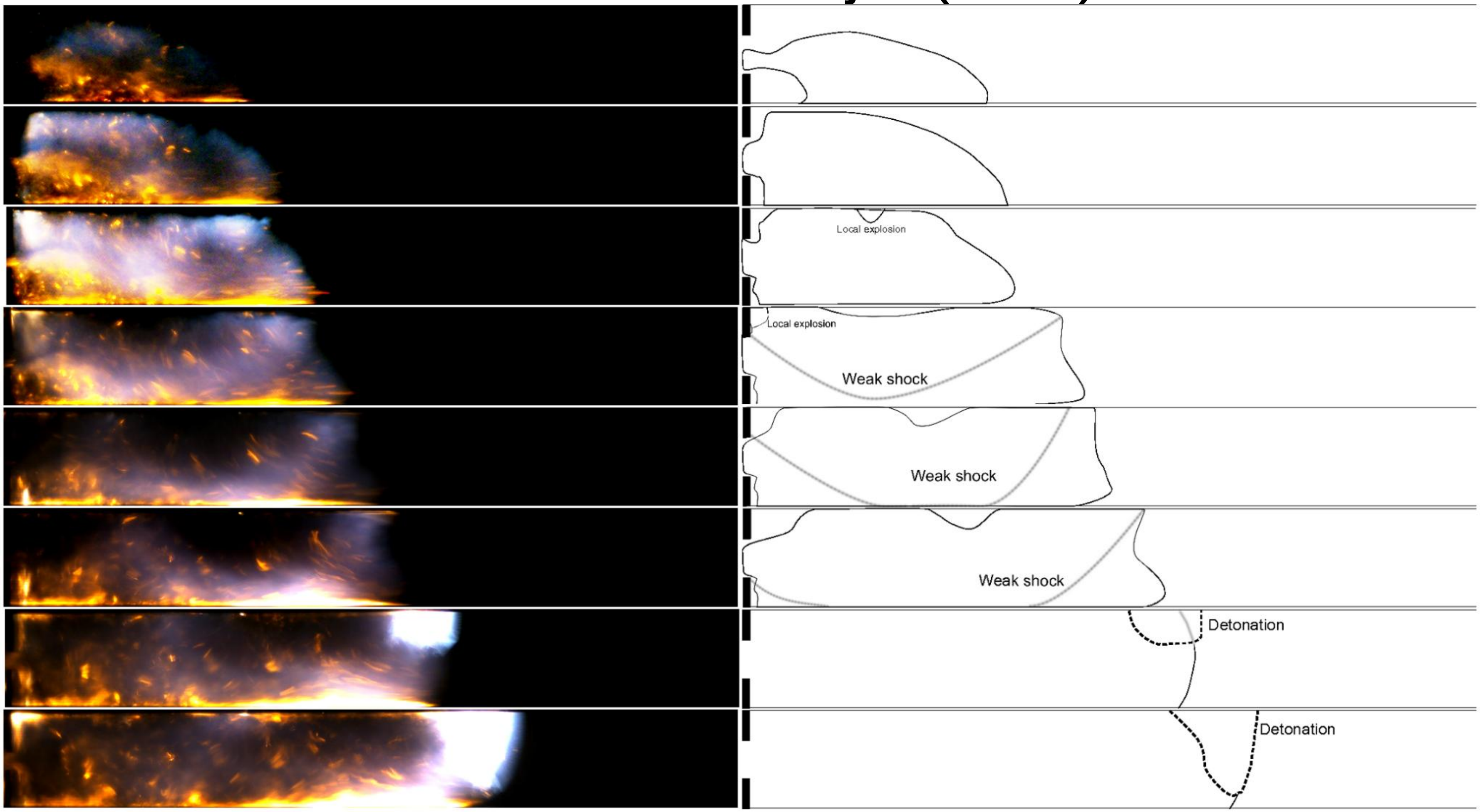


Direct initiation from shock reflection

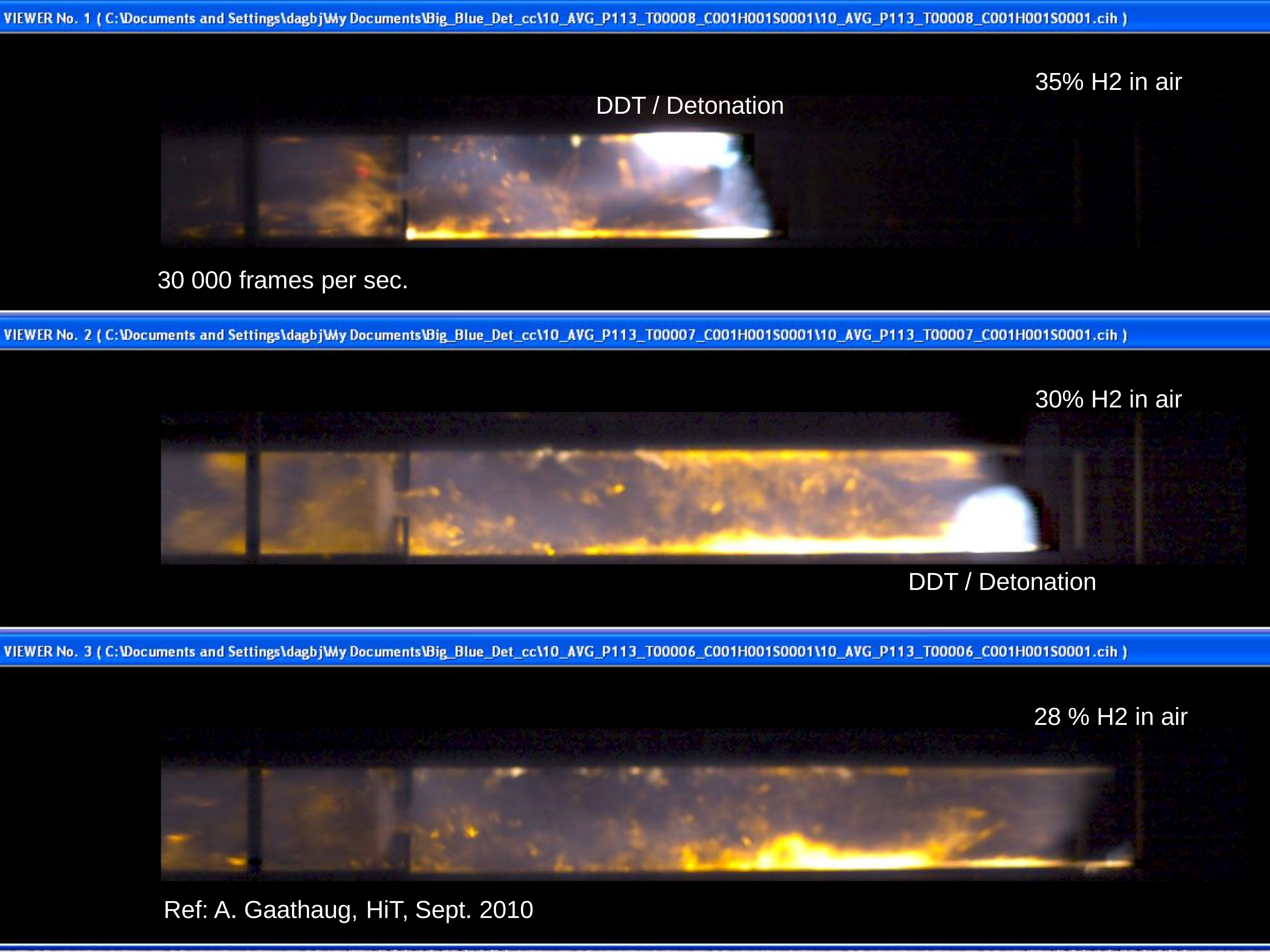


Initiation from flame acceleration (DDT)

DDT in confined jet (TUC)



High speed frames with sketches of their phenomena. BR=0.84, H2 conc. 30%, 30000 fps Gaathaug et al. (2011).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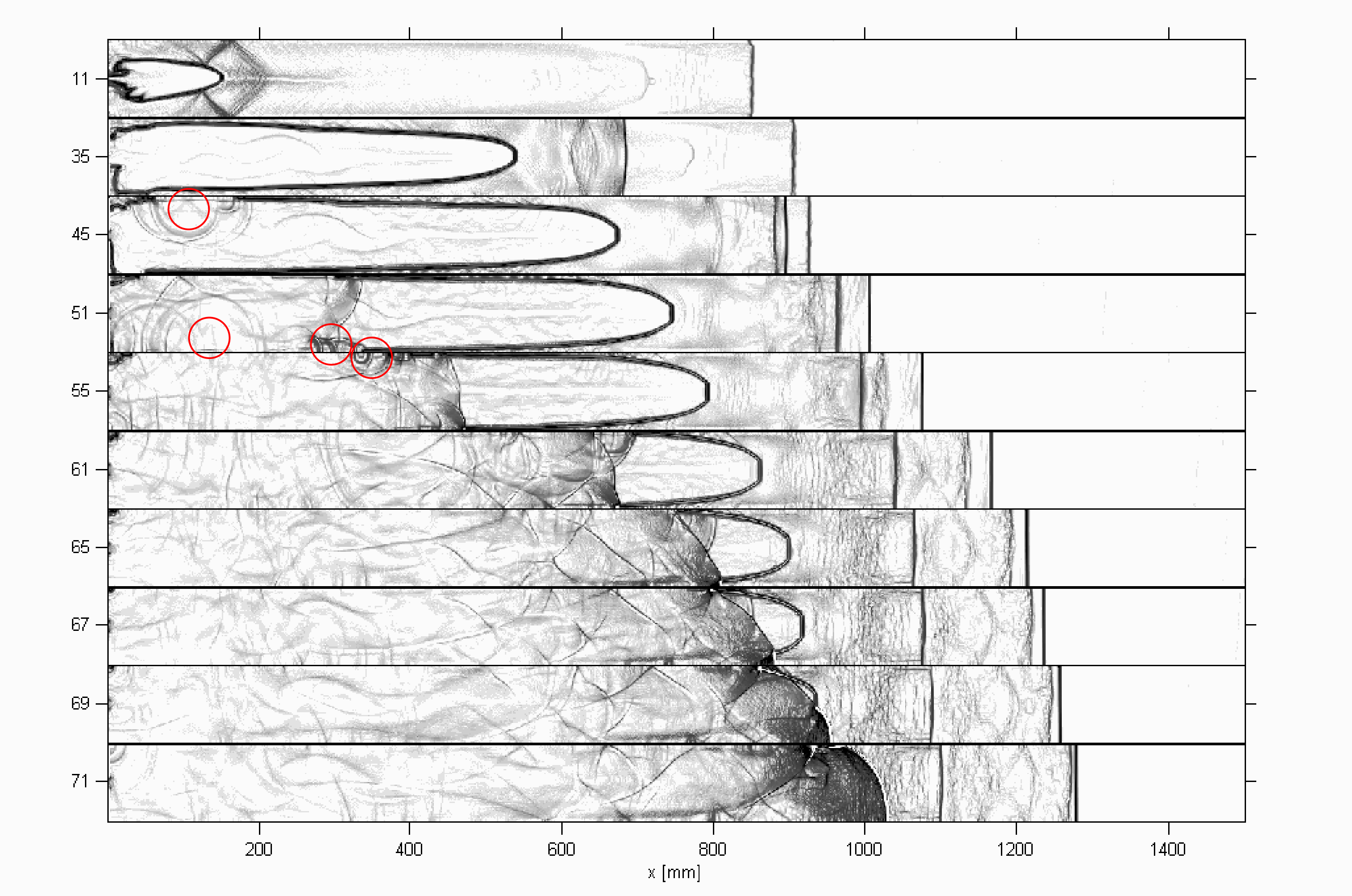
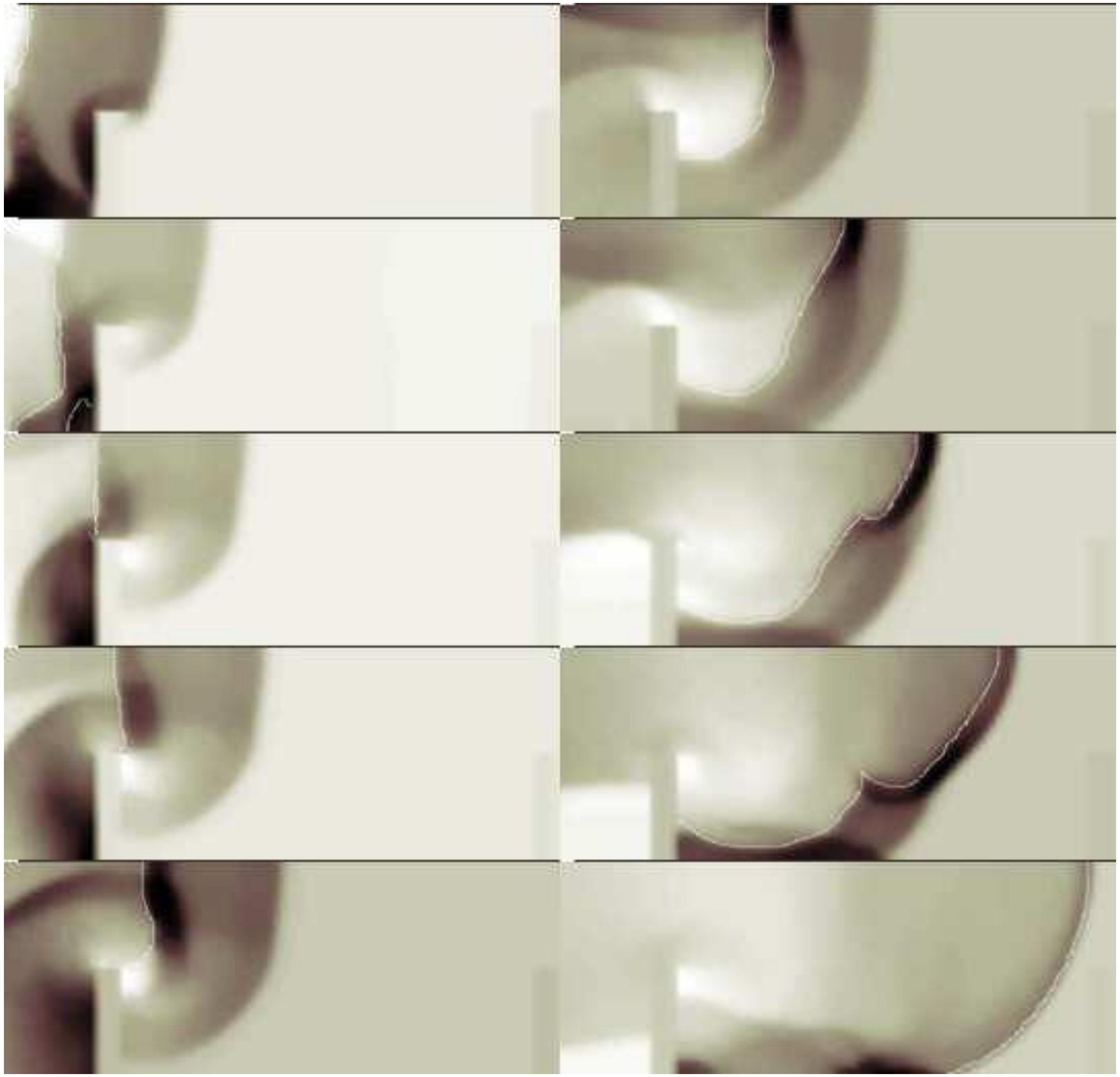
35% H2 in air
DDT / Detonation
30 000 frames per sec.
VIEWER No. 2 (C:\Documents and Settings\dagbj\My Documents\Big_Blue_Det_cc\10_AVG_P113_T00007_C001H001S0001\10_AVG_P113_T00007_C001H001S0001.cih)
30% H2 in air
DDT / Detonation
VIEWER No. 3 (C:\Documents and Settings\dagbj\My Documents\Big_Blue_Det_cc\10_AVG_P113_T00006_C001H001S0001\10_AVG_P113_T00006_C001H001S0001.cih)
28 % H2 in air
Ref: A. Gaathaug, HiT, Sept. 2010

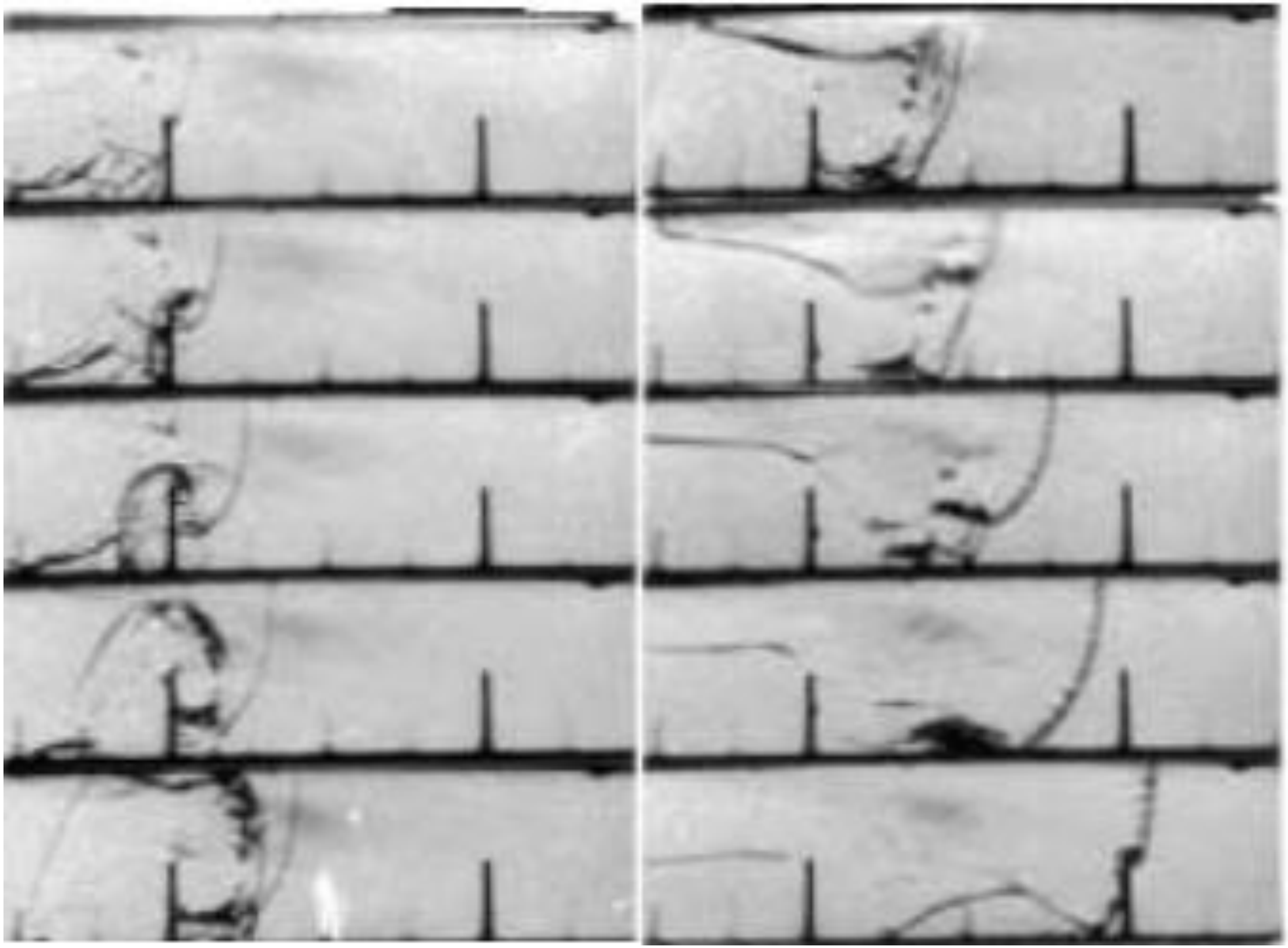
Numerical results



- **Numerical schlieren pictures from the simulation case with BR=0.84 and 35% H2 in air.**
- **Frames are not equidistant in time. Induction model: del Alamo.**

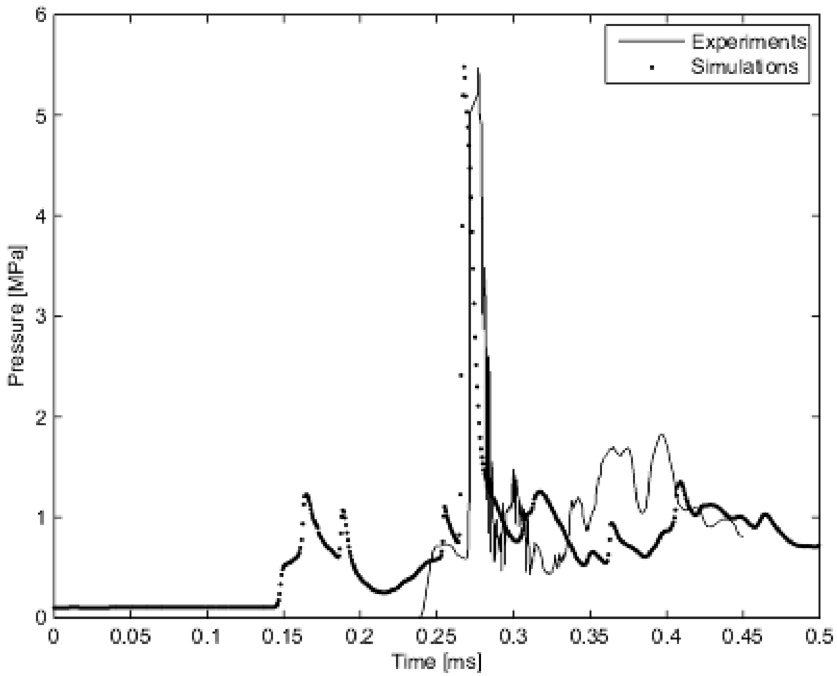
DDT repeated obstacles (TUC)



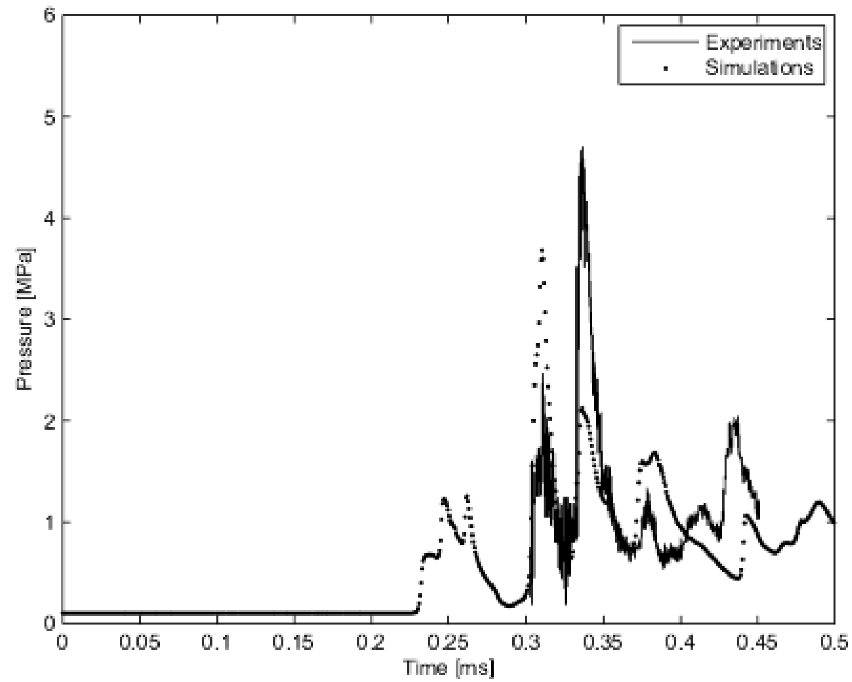


A. Teodorczyk, J. H. S. Lee, R. Knystautas, *Propagation Mechanism of Quasi-Detonations*, Proceedings of the Combustion Institute 22, 1988, 1723–1731.

Simulated and experimental pressure records



875 mm from ignition



955 mm from ignition

Experiments by Teodorczyk (2007).

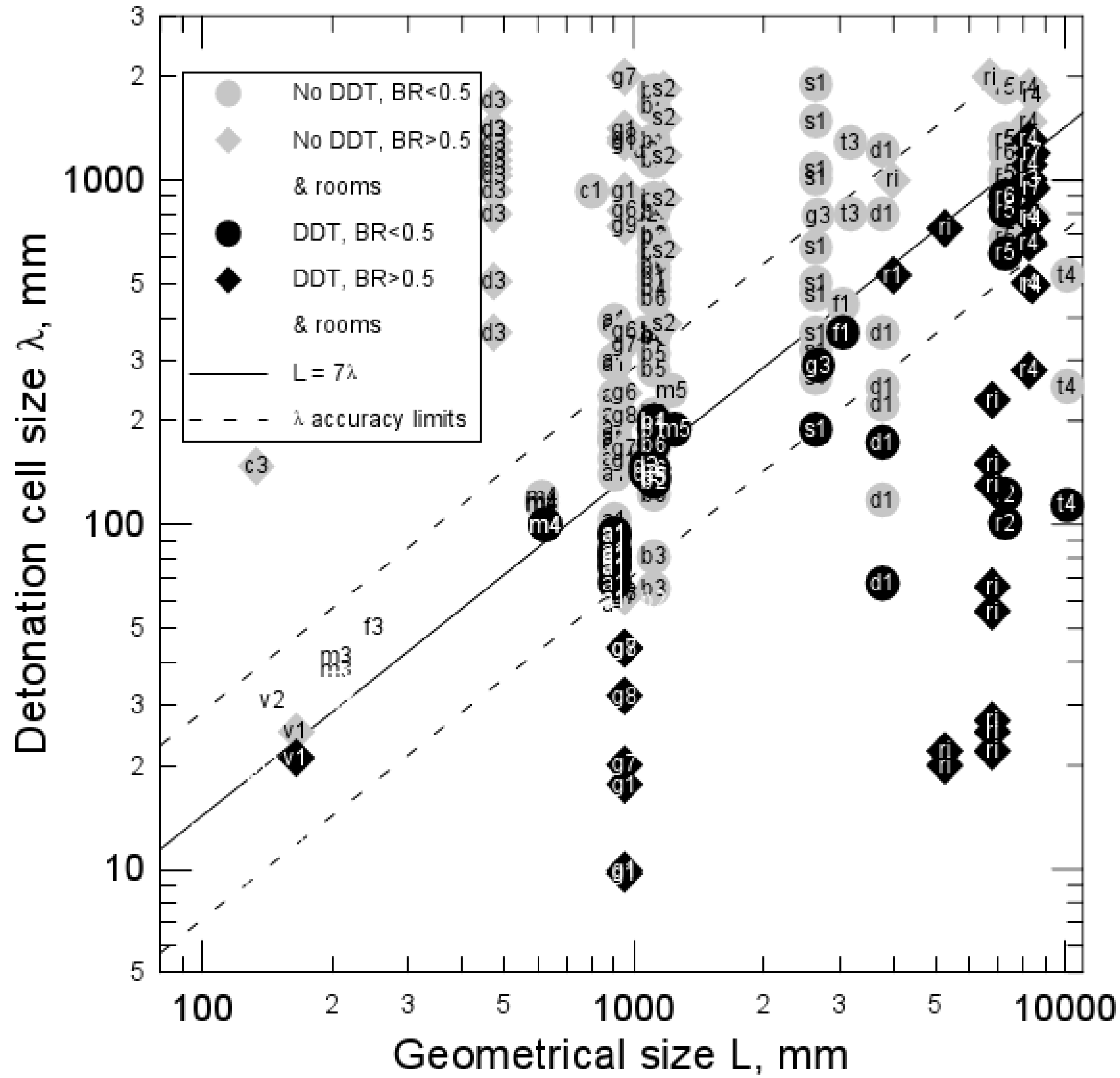
What we know and can do

- We have a qualitative understanding of the phenomena

- We can simulate DDT at lab scale (NRL, TUC)

- There are many correlations that describe possibility for DDT

Correlations

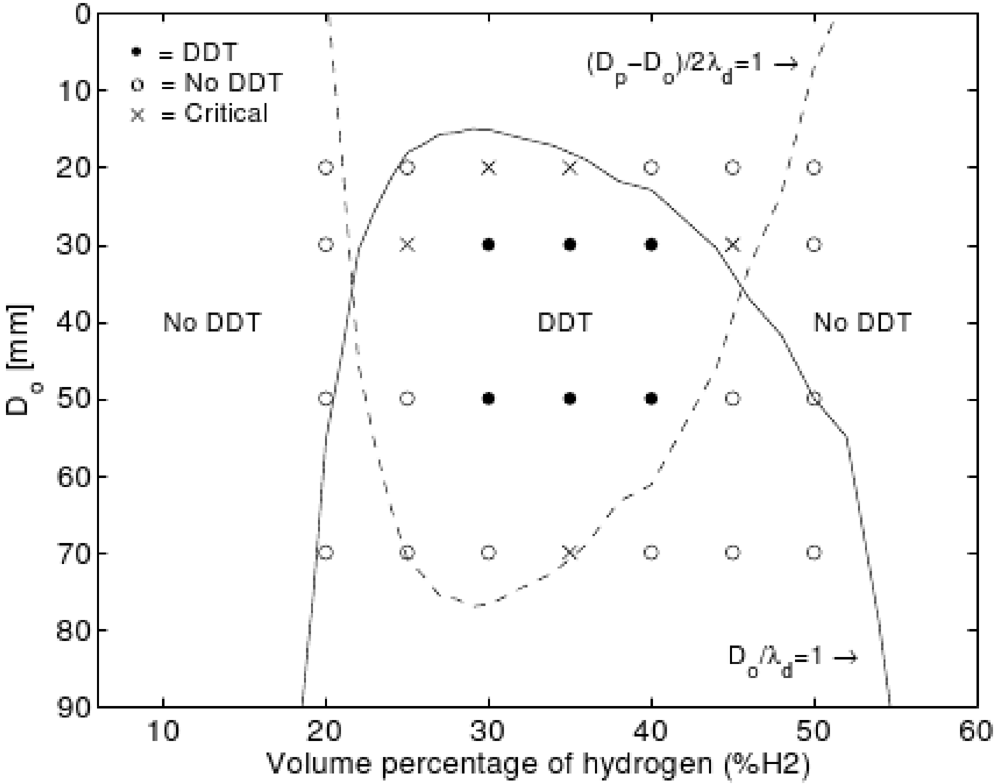


Dorofeev, Kotchourko and others

KIT ToolBox (?)

Høgskolen i Telemark

Correlations



Confined jet, Knudsen (TUC), 2006

What’s next

-We don’t have a complete quantitative understanding of DDT.

-We can’t simulate DDT in full scale. DDT happens at length scales smaller than the practical mesh size.

Simulation of DDT at «practical» scales

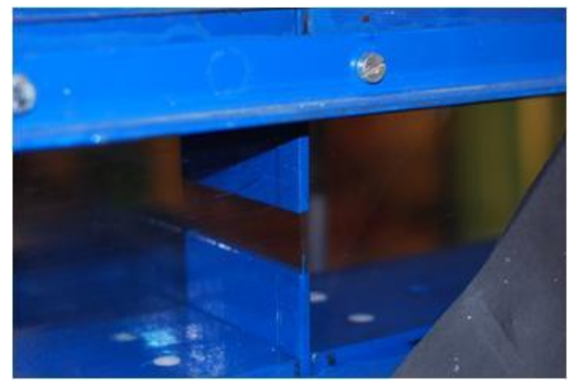
- If we want to be able to simulate DDT for engineering purposes we need to develop models for sub-mesh scale initiation of detonations.
    - Maybe an approach as done with turbulence (transport of length scale and time scale)

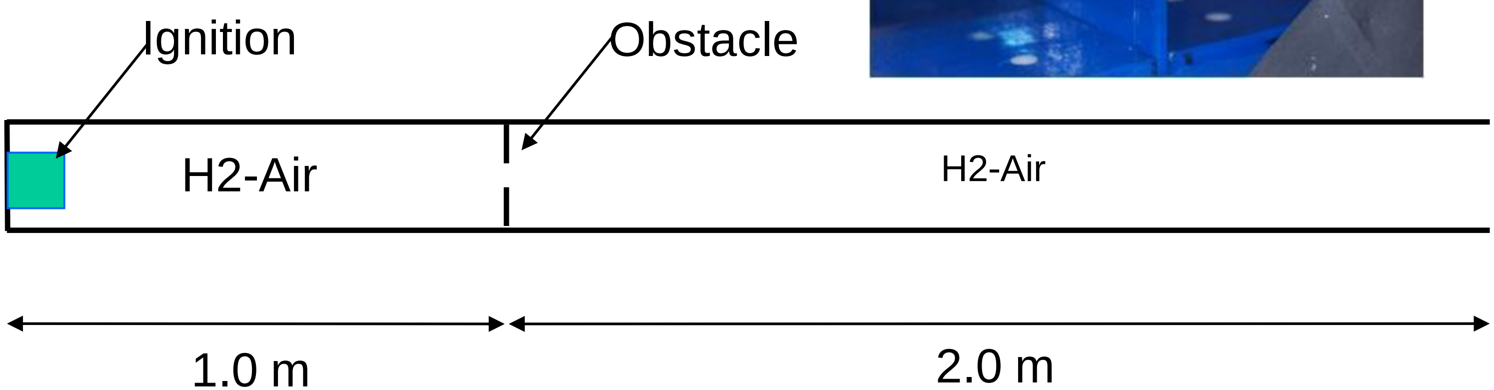
-We need full scale experiments
    - Complex geometries
    - Inhomogeneous clouds

- Is it possible?

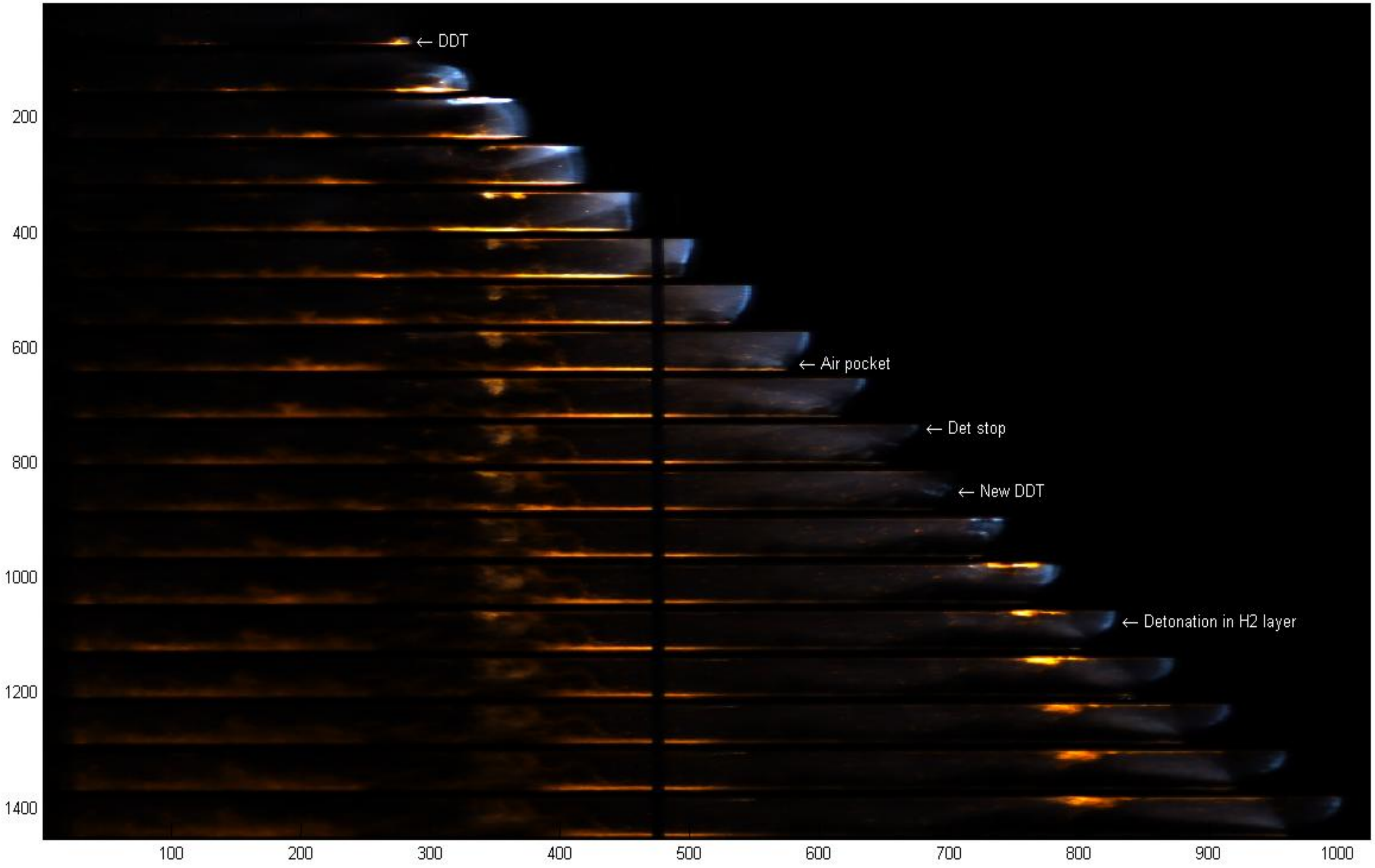
Experimental Set-up

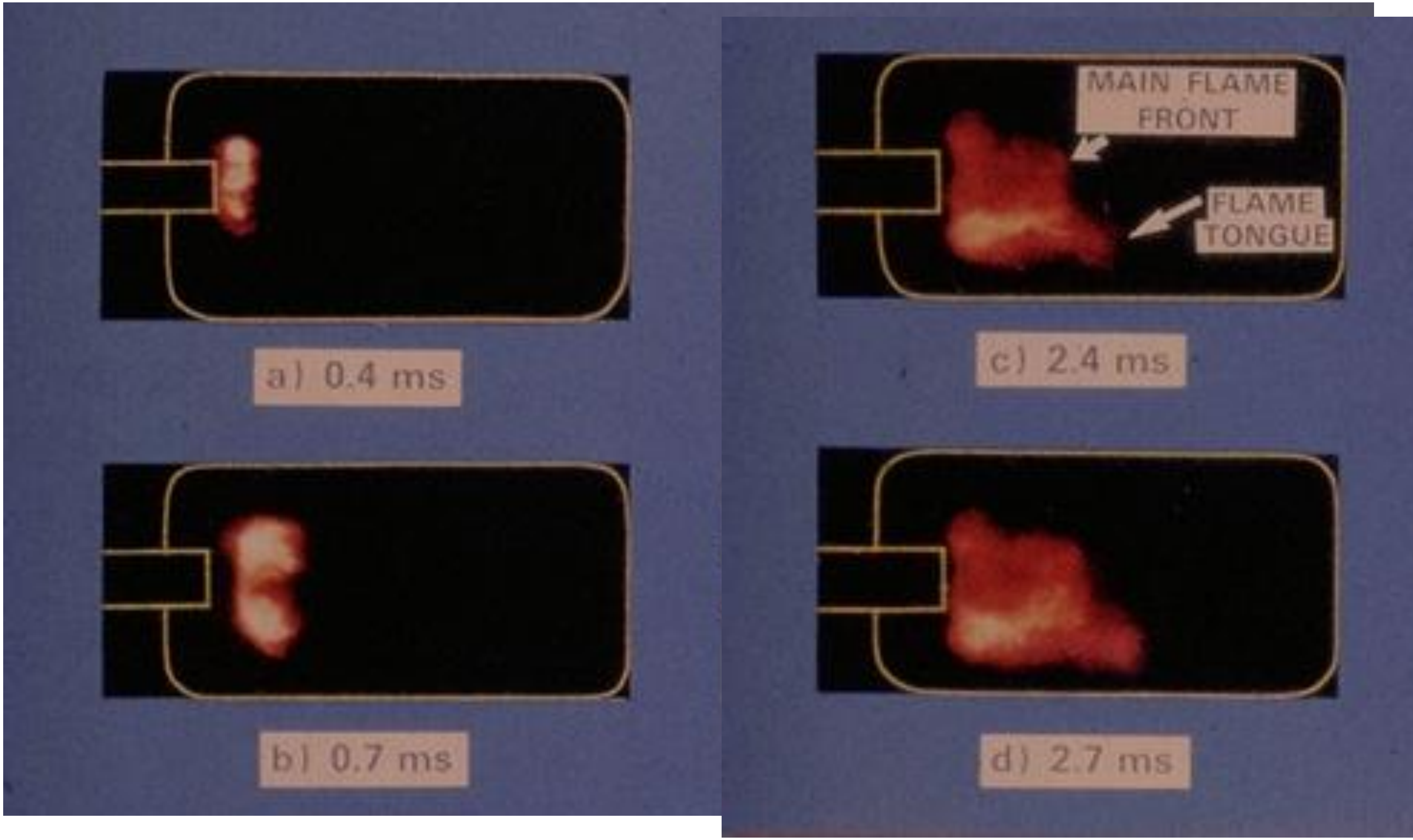
- 3.0 m long channel, 0.1 x 0.1 m2 cross section, with one obstacle and open in one end
- Single spark (point ignition)
- Blockage ratio, BR = 0.75
- 15%, 20%, 25%, 28%, 30%(stoich.) and 35% hydrogen in air

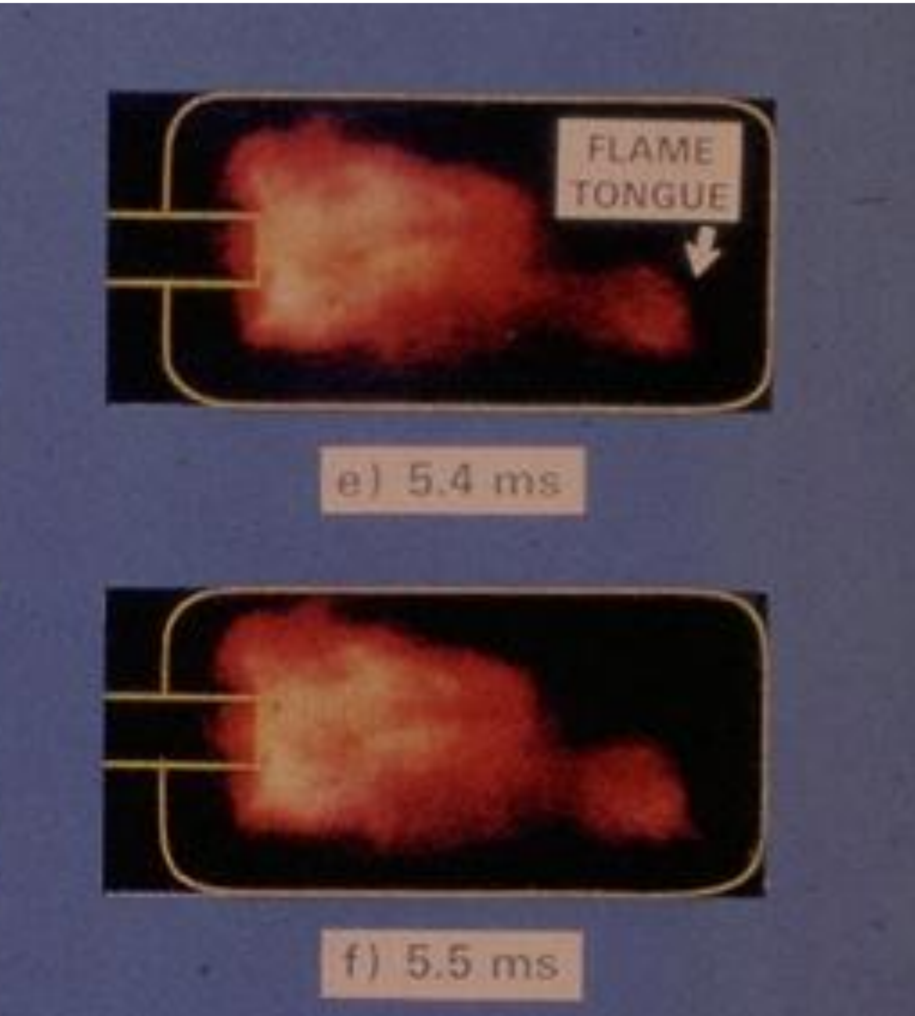


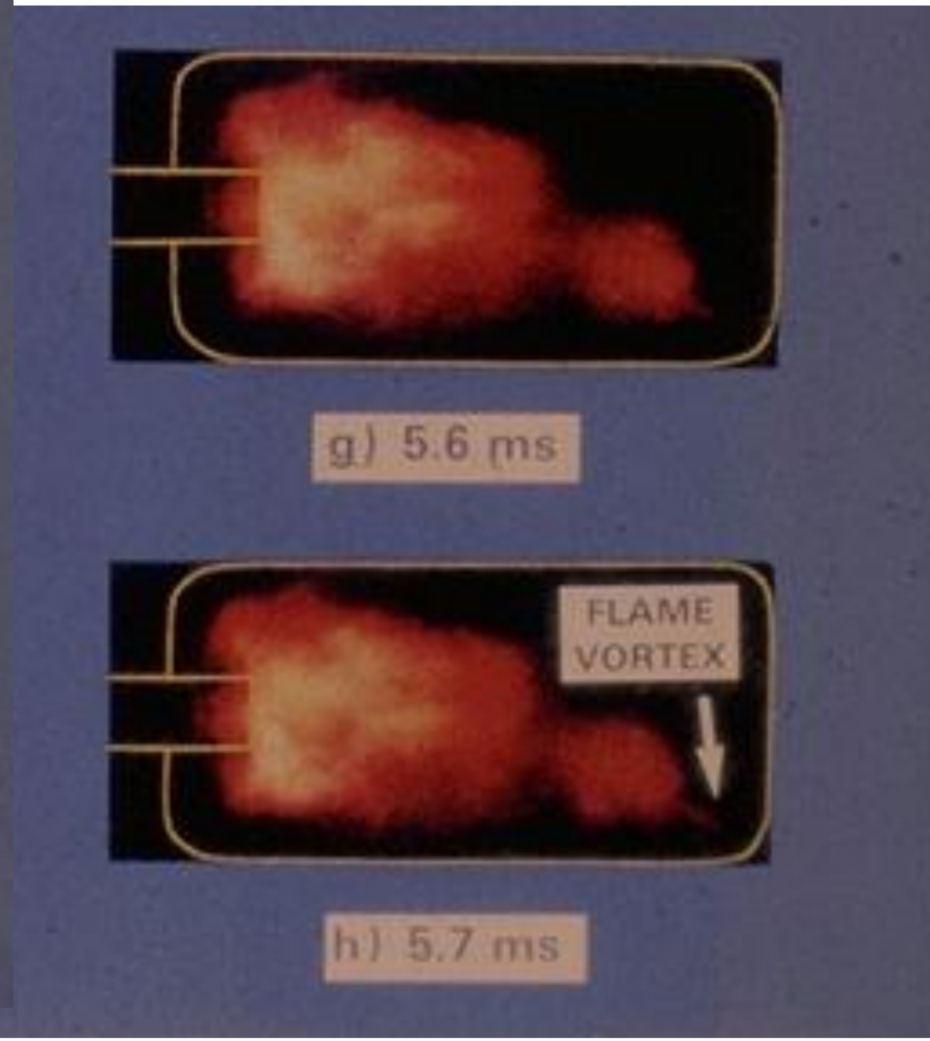


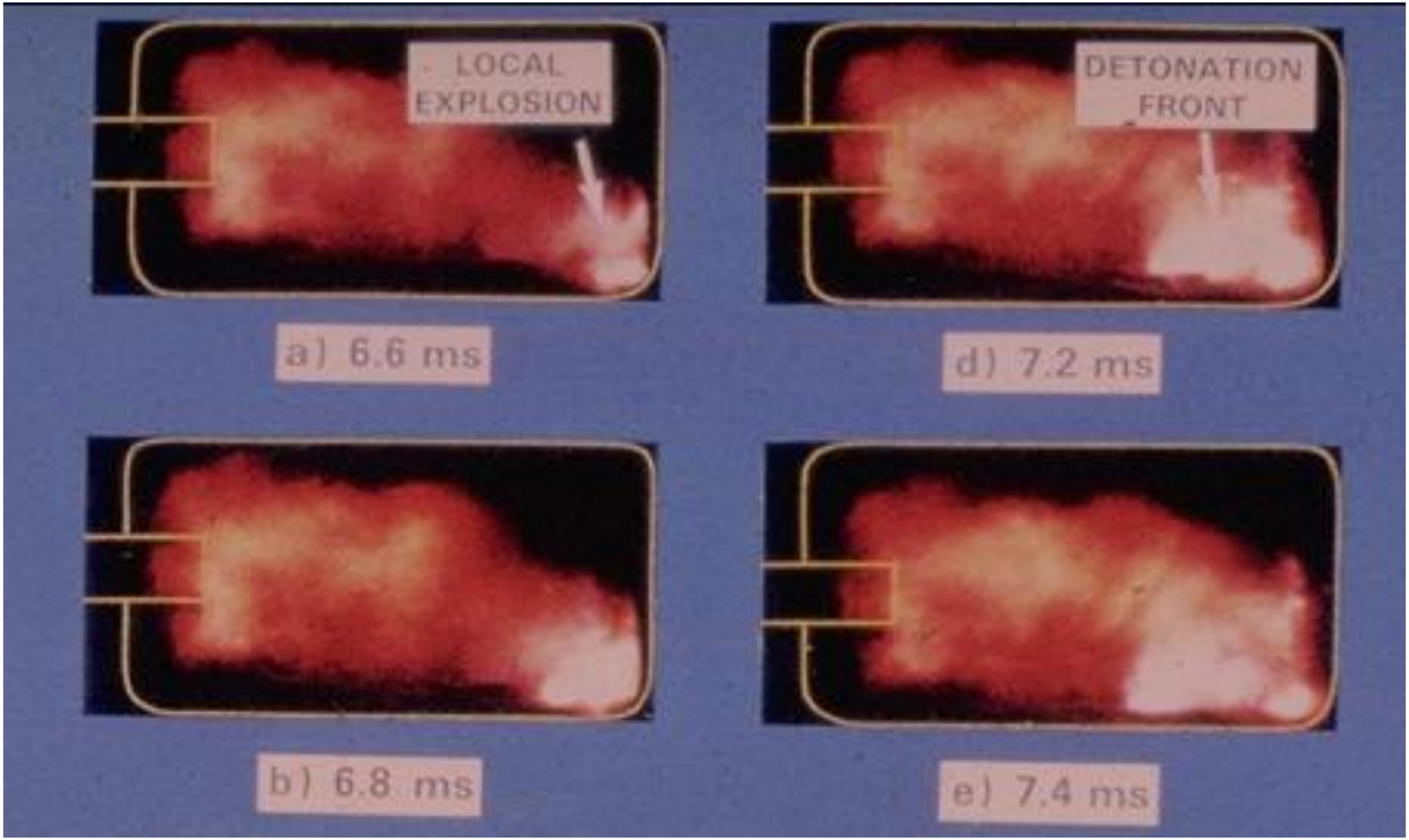
DDT in inhomogeneous mixture, H2-air (TUC)

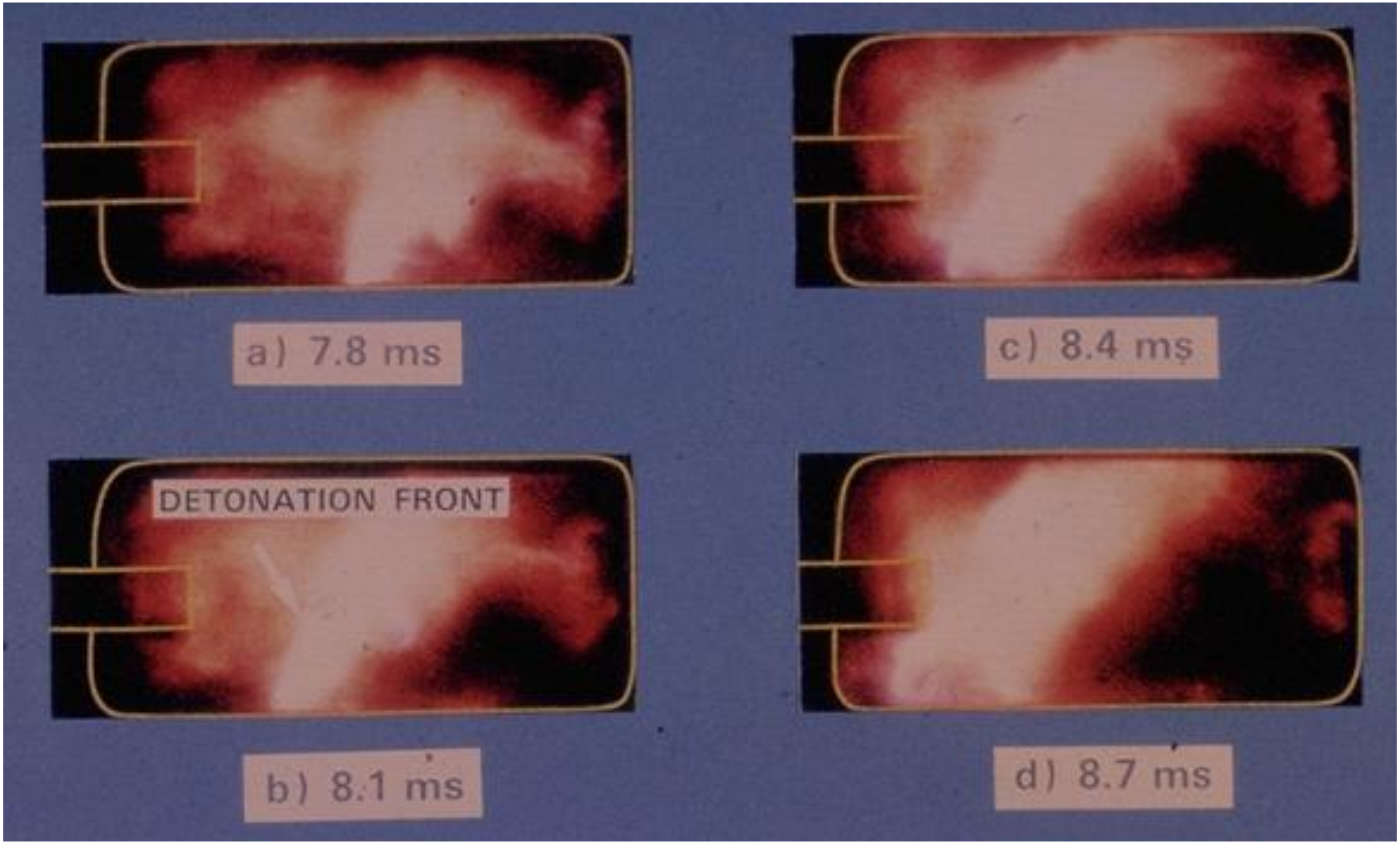



a) 0.4 ms
b) 0.7 ms
MAIN FLAME FRONT
FLAME TONGUE
c) 2.4 ms
d) 2.7 ms


FLAME
TONGUE
e) 5.4 ms
f) 5.5 ms


g) 5.6 ms
FLAME
VORTEX
h) 5.7 ms


LOCAL EXPLOSION
a) 6.6 ms
DETONATION FRONT
d) 7.2 ms
b) 6.8 ms
e) 7.4 ms



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