Effect of Wall Impingement on Ambient Gas Entrainment, Fuel Evaporation and Mixture Formation of Diesel Spray

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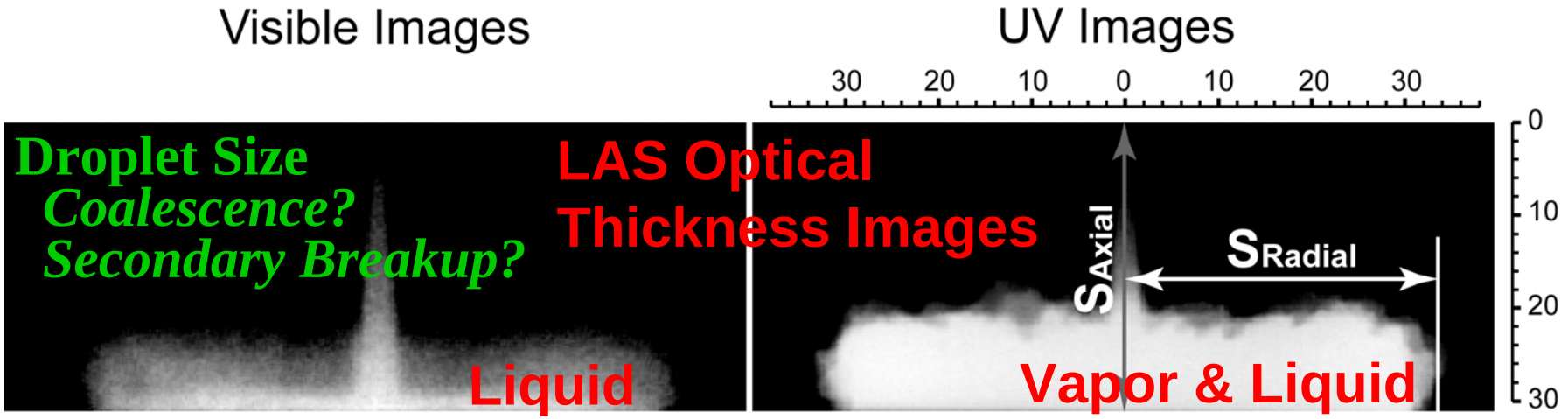
Diesel Spray Impinging on Flat Wall

Issues to Be Clarified



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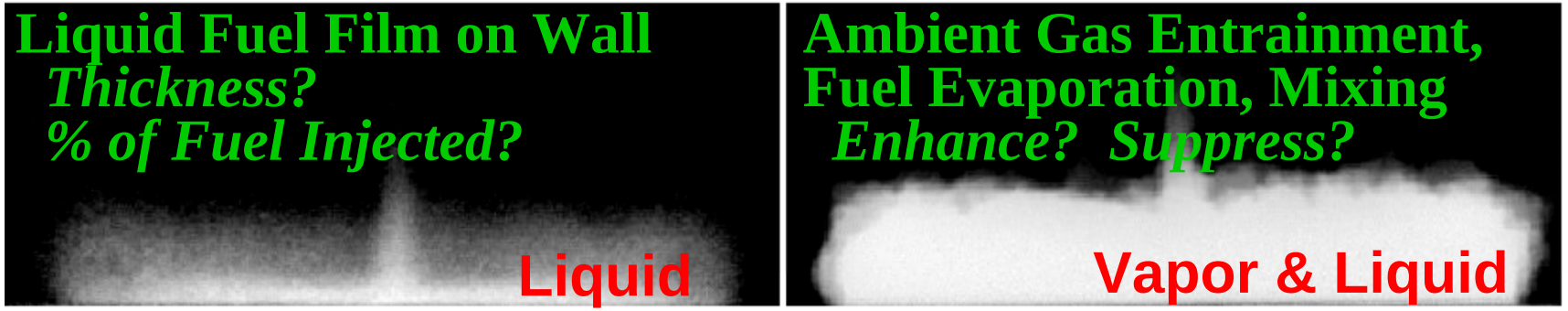


t_S=0msAEOI

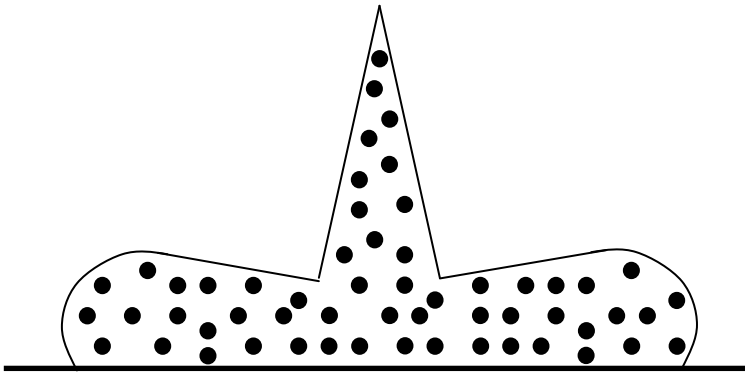
(a) d=0.16mm, P_{inj}=100MPa

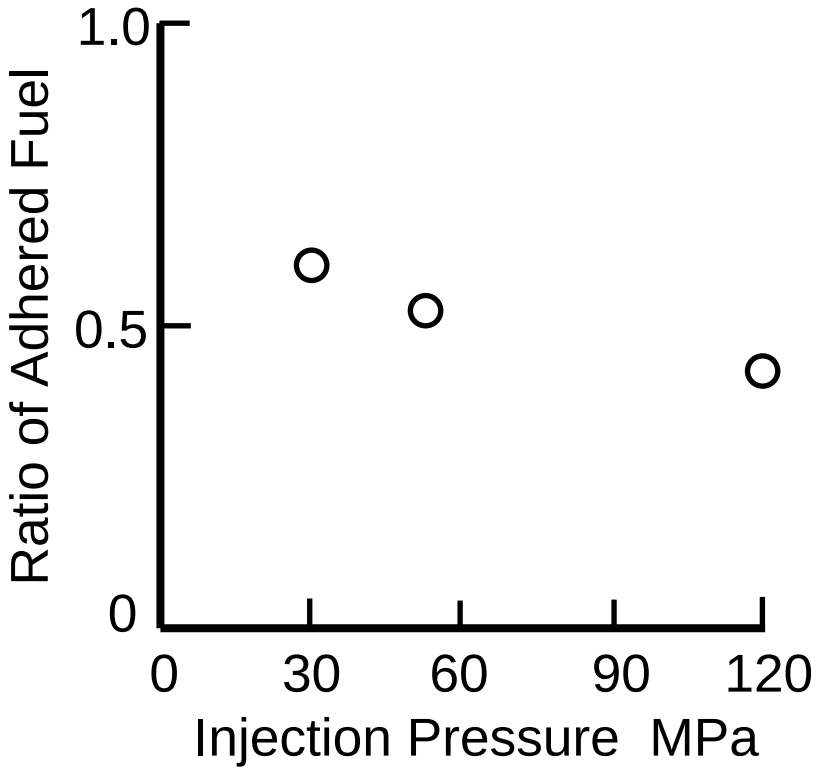
ρ_a=11kg/m^3 (Pa=2.6MPa, Ta=797K)

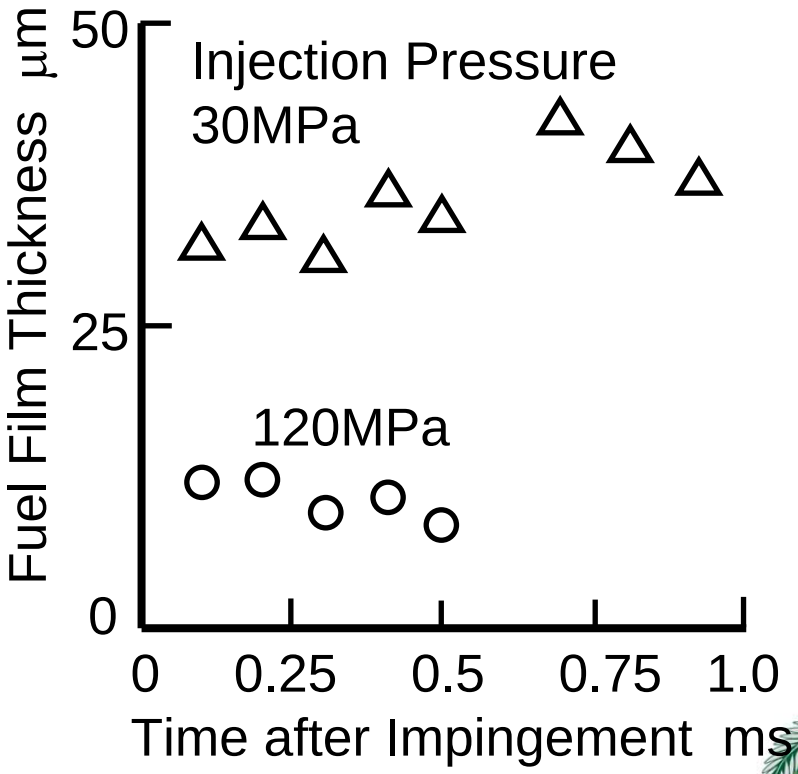
Previous Studies

Nozzle: 4x0.25mm
Injection Amount: 35mm^3/Inj.
Ambient Gas: N_2, 2.1MPa, Room Temp.

Impingement Angle: 90deg.
Impingement Distance: 25mm







Kawamura, 4th Atomization Seminar (2010.7.9, Tokyo, Japan)

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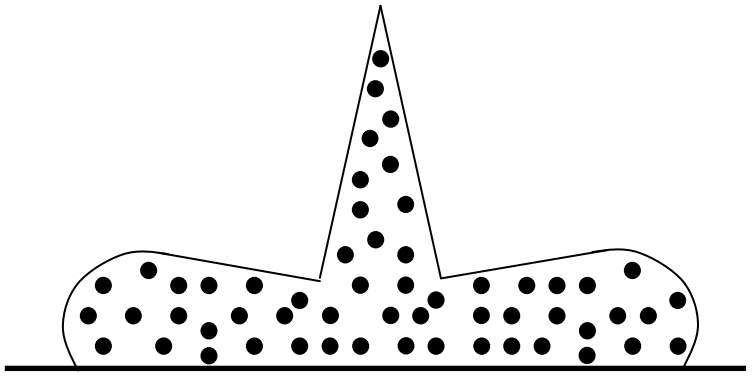

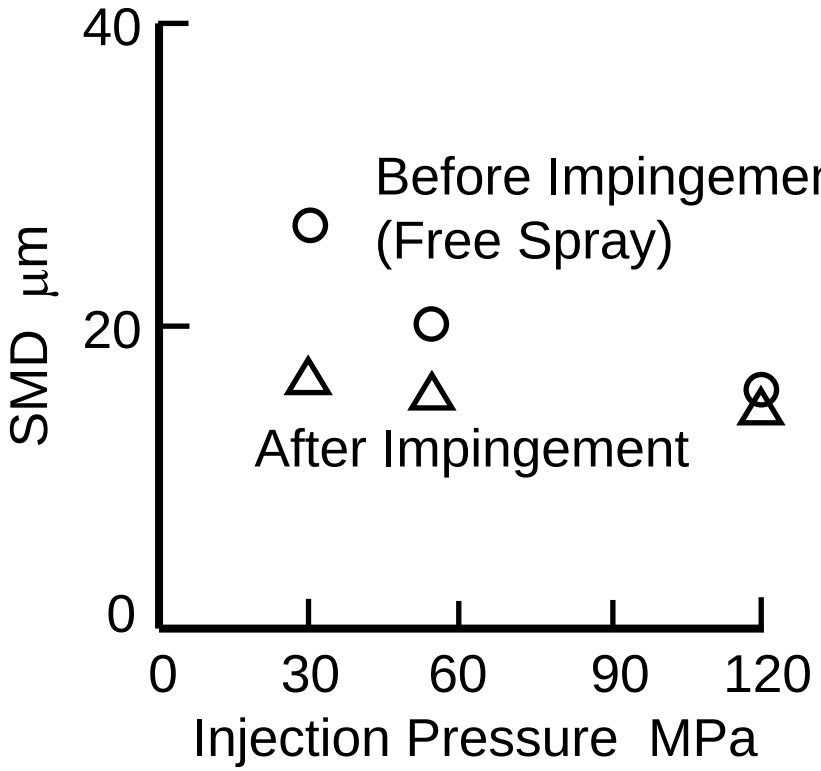

Kawamura, 4th Atomization Seminar (2010.7.9, Tokyo, Japan)

Two Test Cases

Diesel Spray (Relatively Small Amount Injected)

- ✓ Injection Pressure 90, 120MPa
- ✓ Nozzle Hole/Injection Amount 0.135mm/3.40mg (6 Holes, 20mg)
- ✓ Ambient Gas Nitrogen, 3.9MPa/760K/17.7kg/m^3
- ✓ Impingement Distance/Angle 30mm/90deg.
- ✓ Fuel DMN (Tb=266deg.C)

Diesel Spray (Relatively Large Amount Injected)

- ✓ Injection Pressure 100□300MPa
- ✓ Nozzle Hole/Injection Amount 0.16mm/15.47mg (4.5Holes, 70mg)
- ✓ 0.08mm/3.87mg (18Holes, 70mg)
- ✓ Ambient Gas Nitrogen, 2.6MPa/797K/11kg/m^3
  4.04MPa/885K/15kg/m^3
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Case 1

Diesel Spray (Relatively Small Amount Injected)

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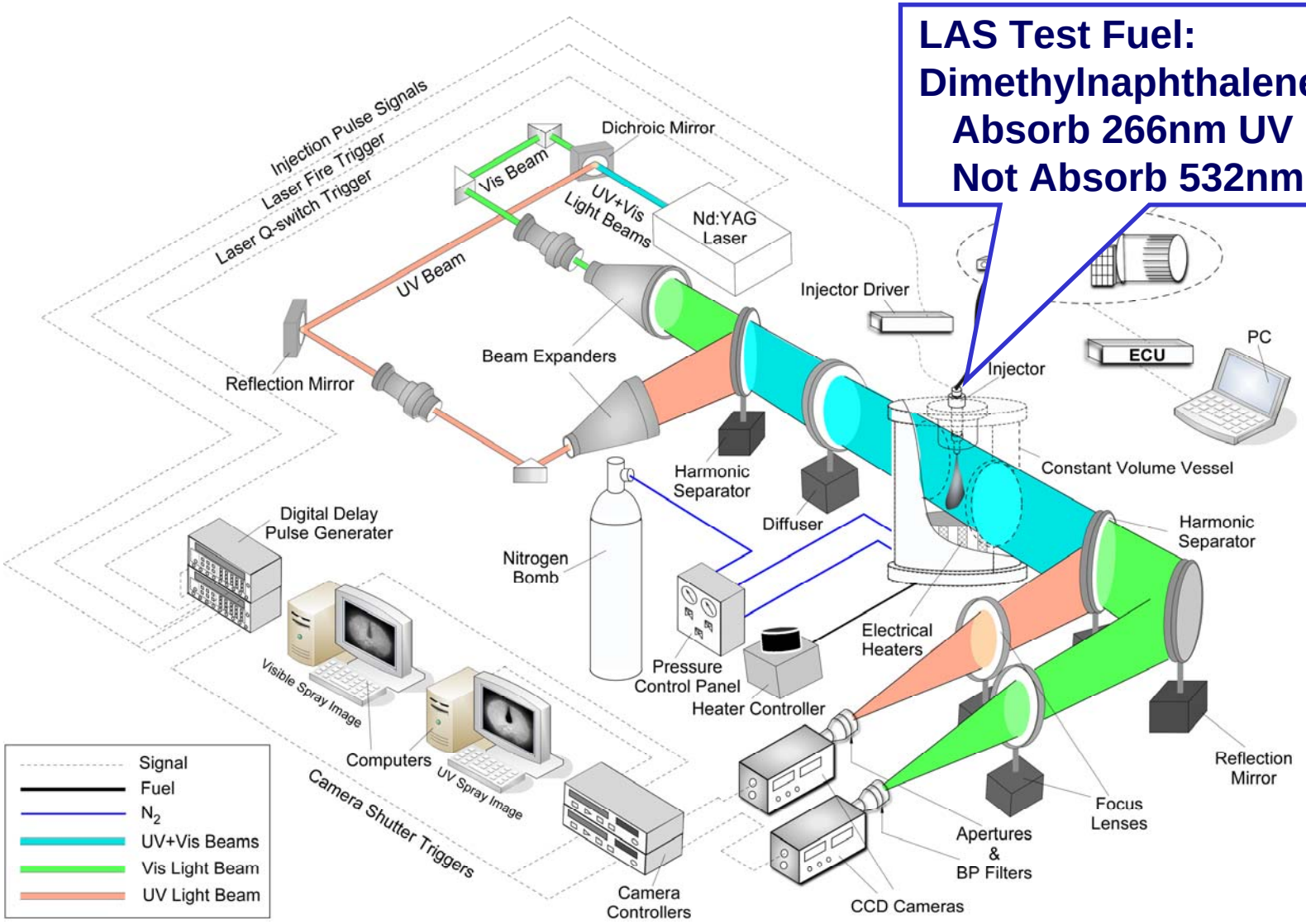
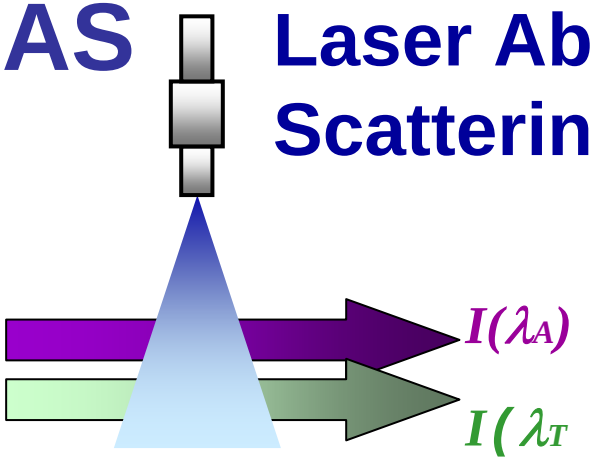
LAS Optical System, Spray Test Rig

LAS Test Fuel:
Dimethylnaphthalene (DMN)
- **Absorb 266nm UV**
- **Not Absorb 532nm VIS**



Principle of LAS

Laser Absorption Scattering



Incident Light Intensity

Transmitted Light Intensity Attenuated by Spray

Absorption Wavelength λ_A

$$\log\left(\frac{I_0}{I}\right)_{\lambda_A} = \int_0^L \varepsilon(\lambda_A)\cdot C_v dx + \int_0^L K_{ext}(\lambda_A)dx$$

Total Optical Thickness at λ_A	Vapor Optical Thickness	Drop Optical Thickness =Drop Scattering +~~Drop Absorption~~

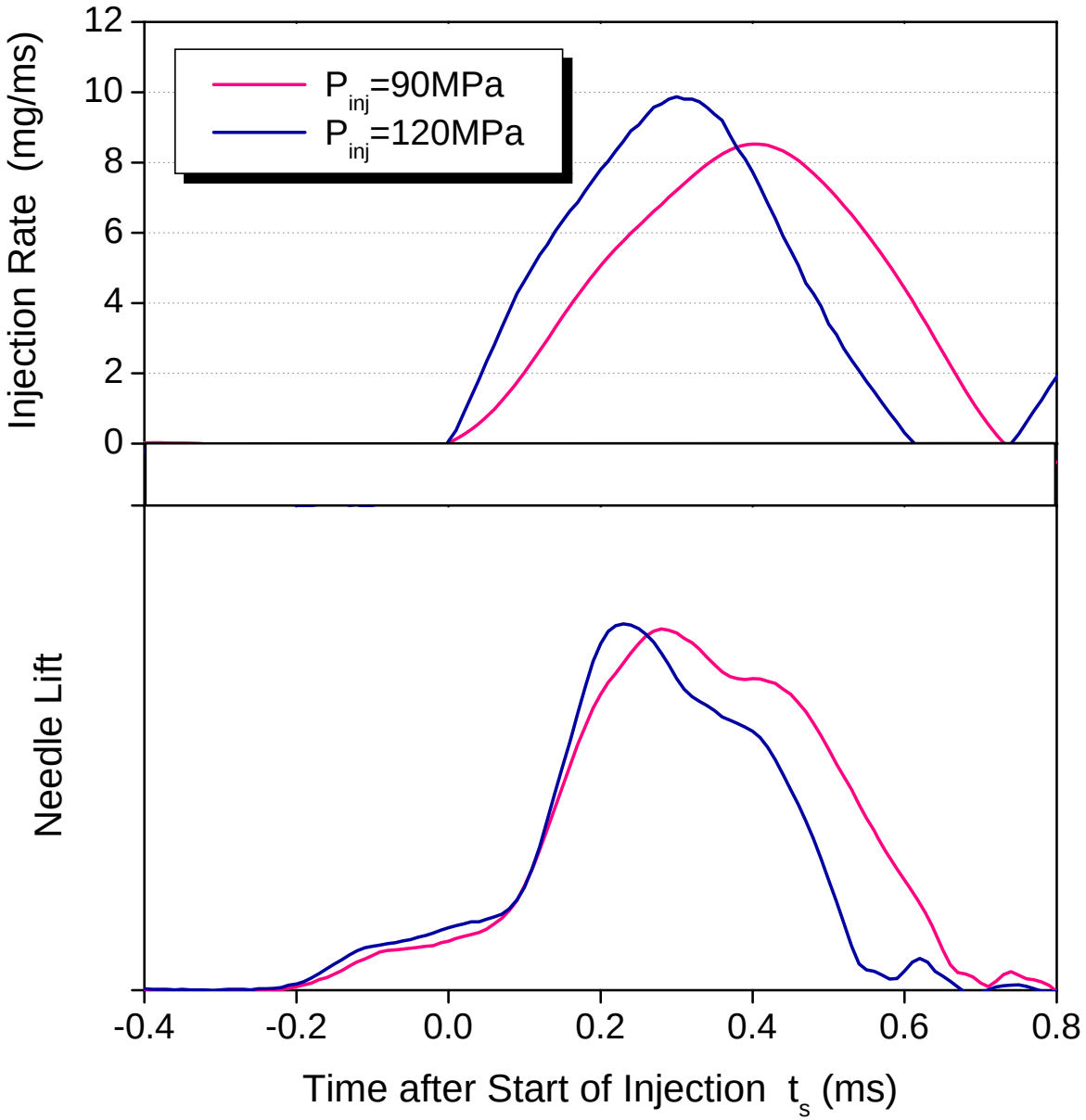
Transparent Wavelength λ_T

$$\log\left(\frac{I_0}{I}\right)_{\lambda_T} = \int_0^L K_{sca}(\lambda_A)dx$$

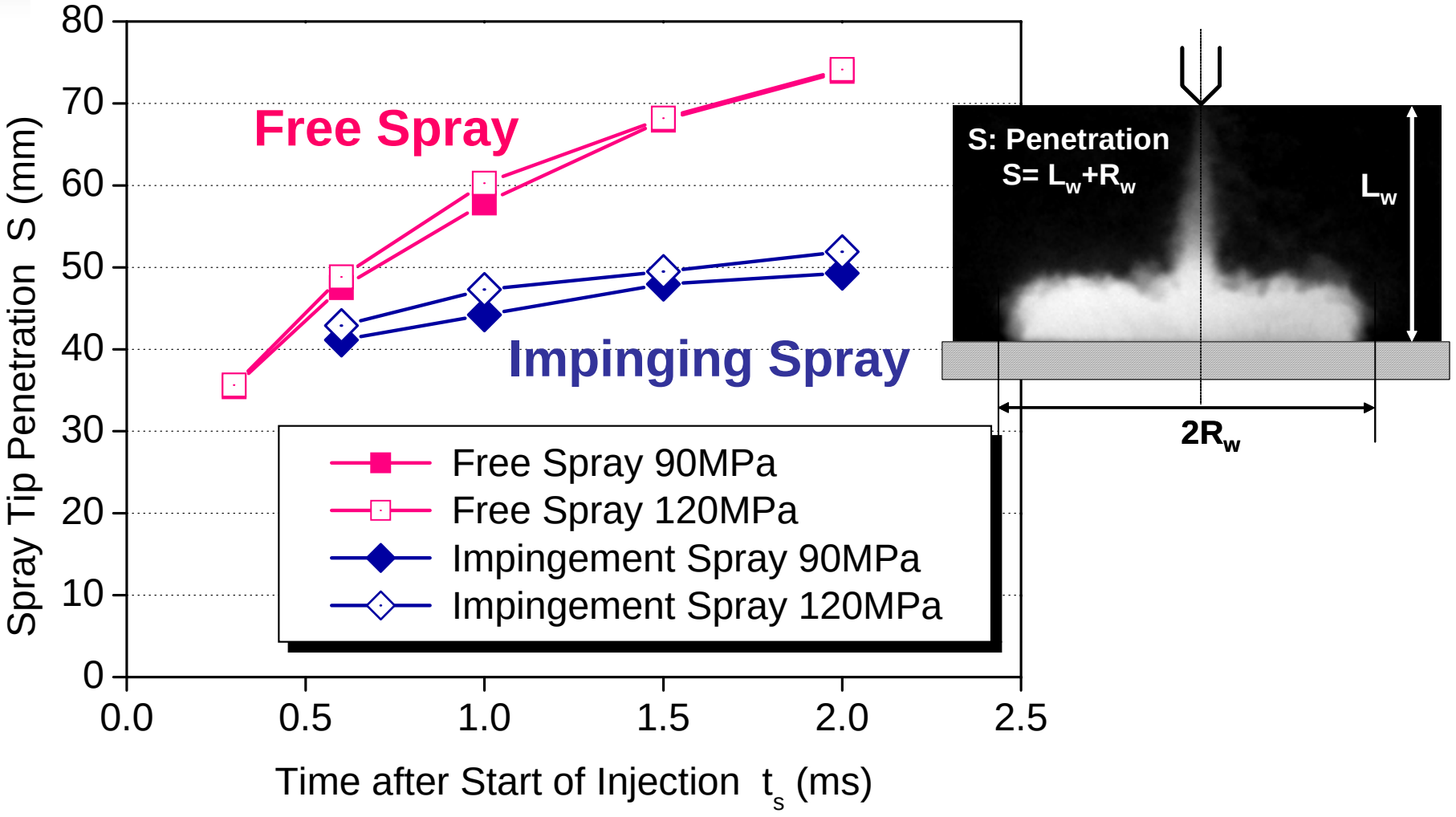
Drop Scattering Optical Thickness

$$K_{ext}(\lambda_A) = -\frac{\pi}{4} C_n \int_0^\infty Q_{ext}(\lambda_A) N(D) D^2 dD$$

Injection Rate and Needle Lift Curves

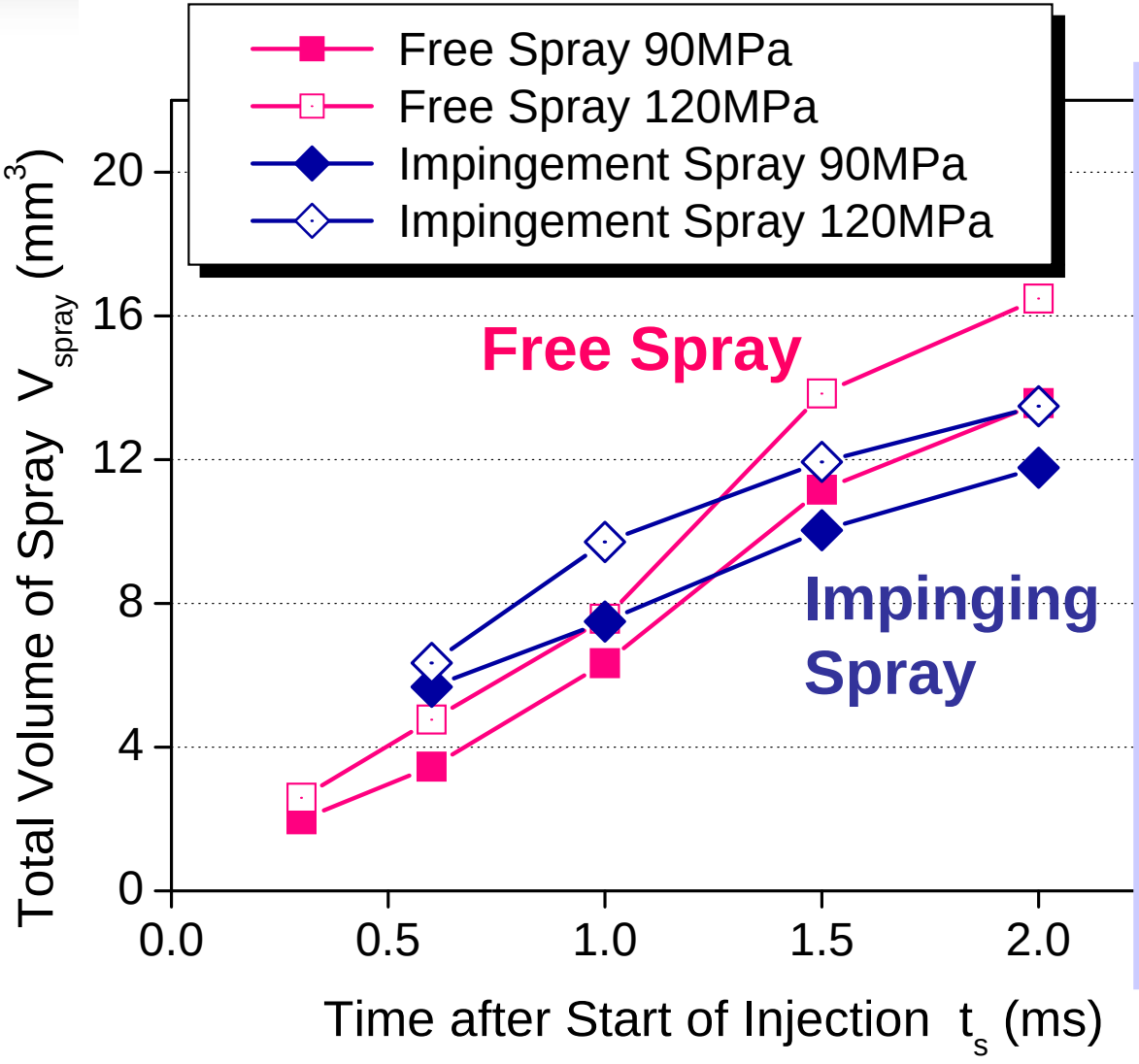


Spray Tip Penetration



Wall impingement decreases the spray tip penetration.

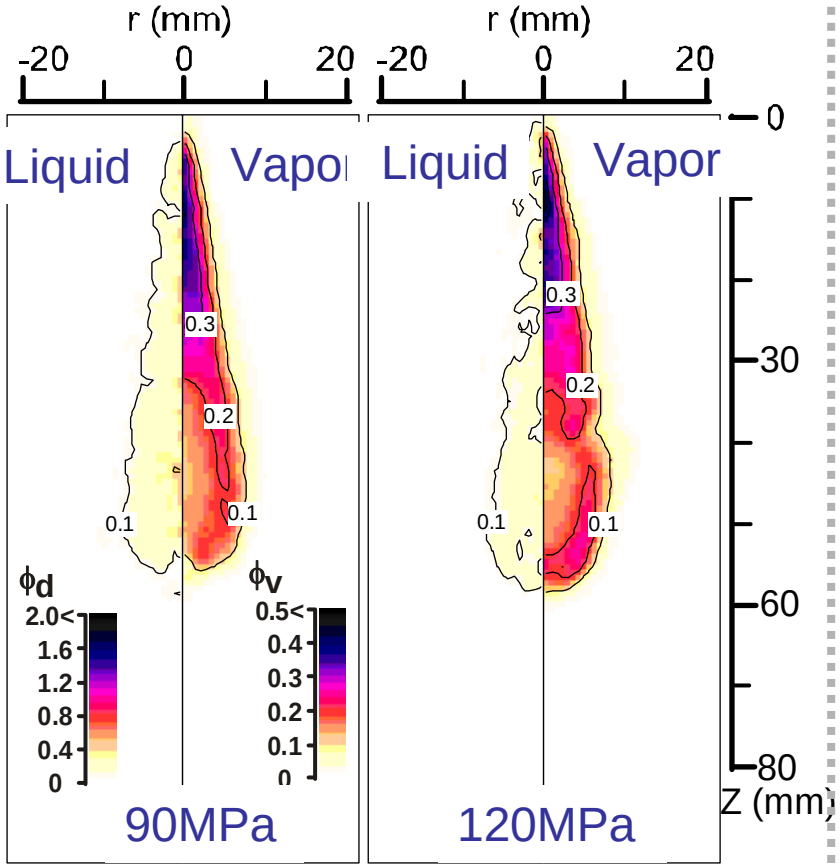
Spray Volume



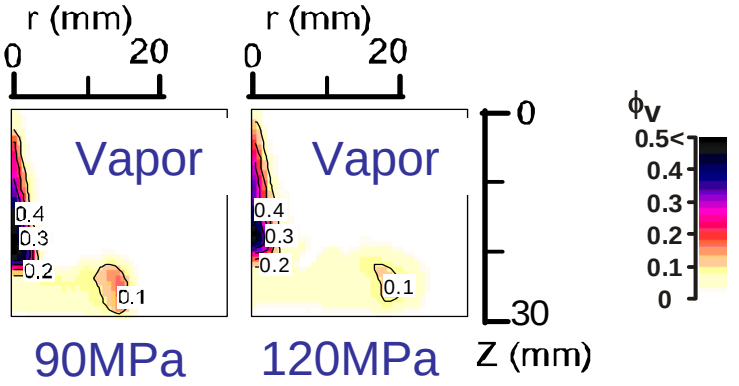
The temporal variation of the free spray volume is the “S” shape.
The wall impingement increases the spray volume just after the impingement, and then decreases it.
The injection pressure effect is more dominant than that for the spray tip penetration.

Equivalence Ratio Distributions (1.0ms ASOI)

Free Spray

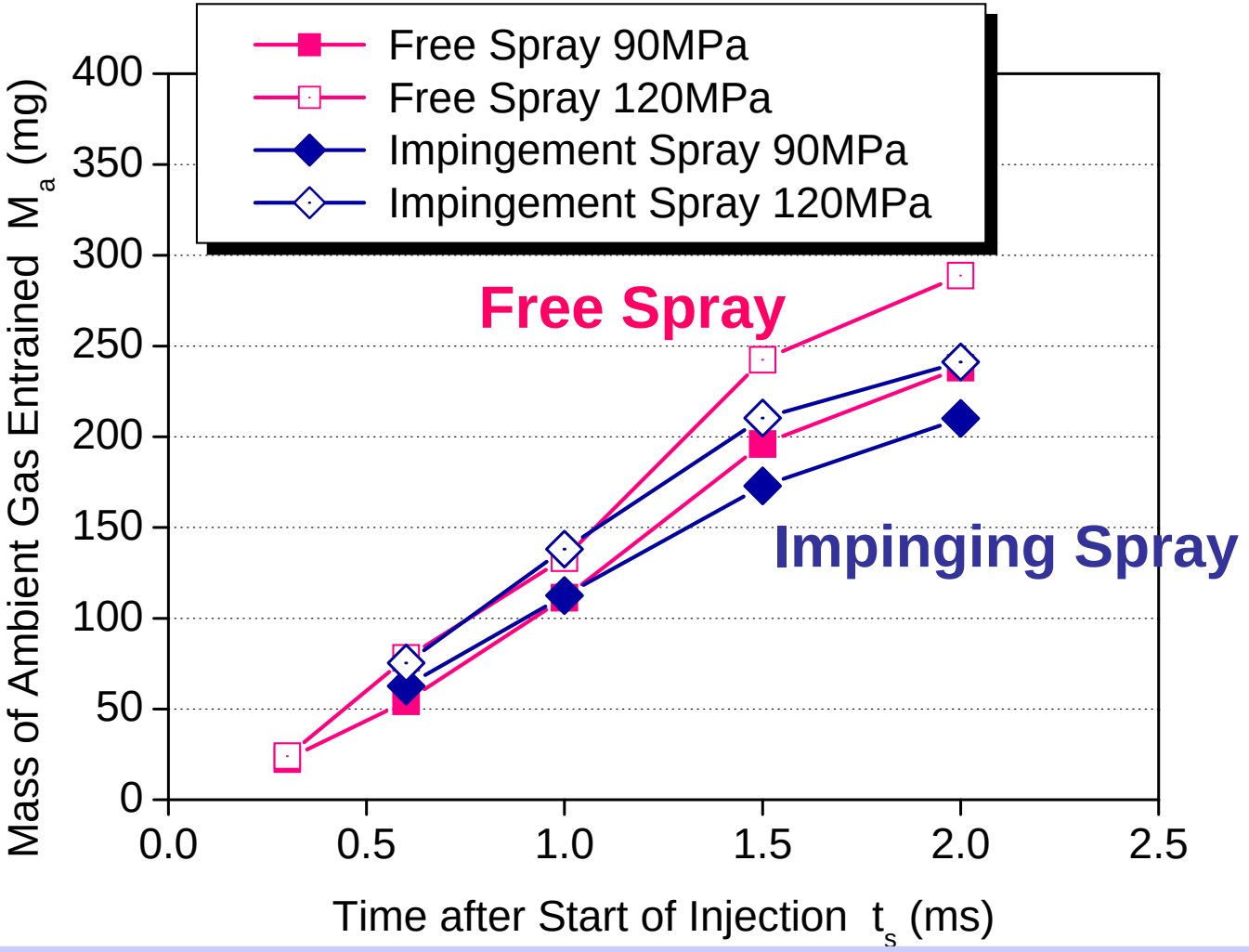


Impinging Spray



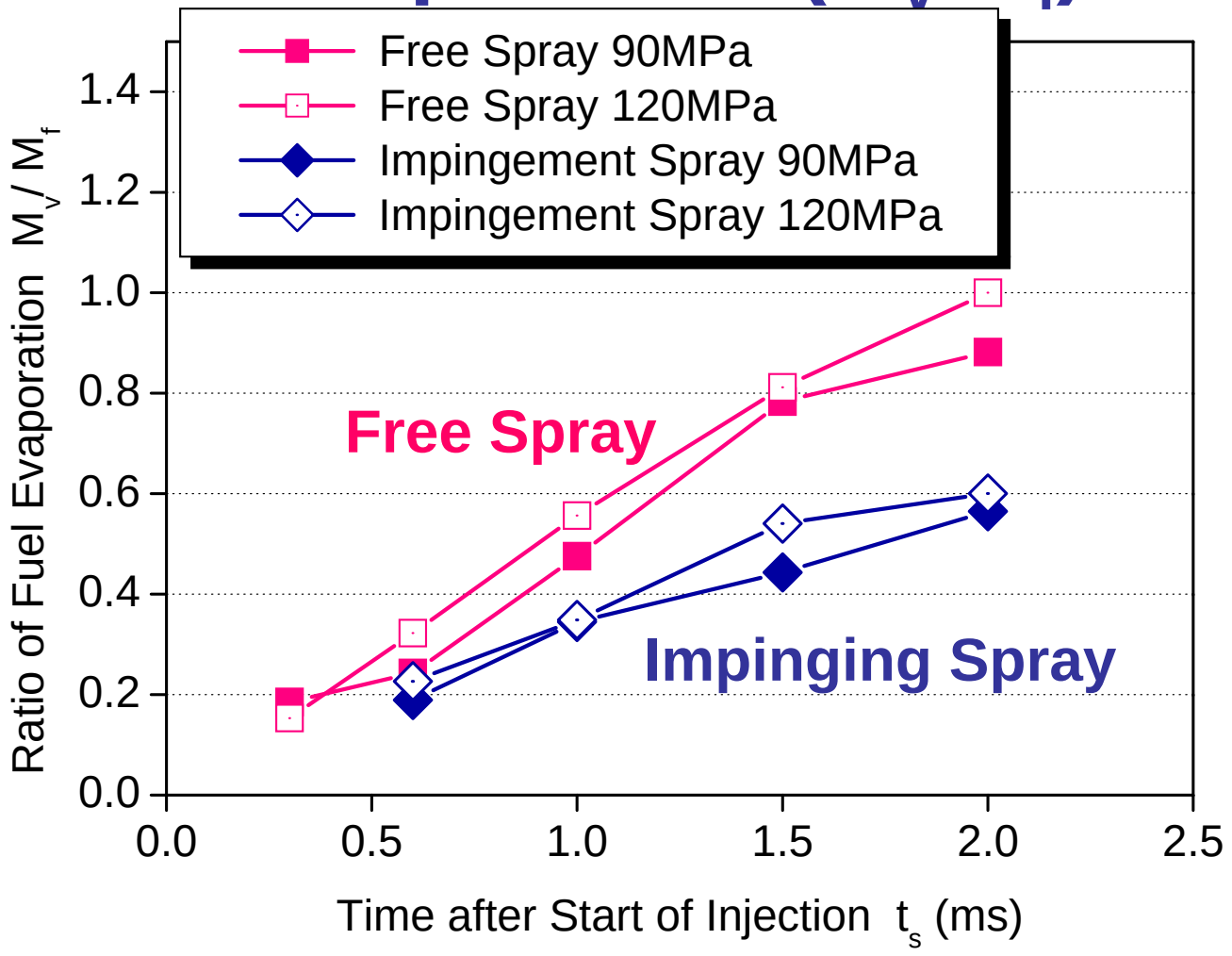
The vapor equivalence ratio in the spray after the impingement is lower than that before the impingement.

Ambient Gas Entrainment



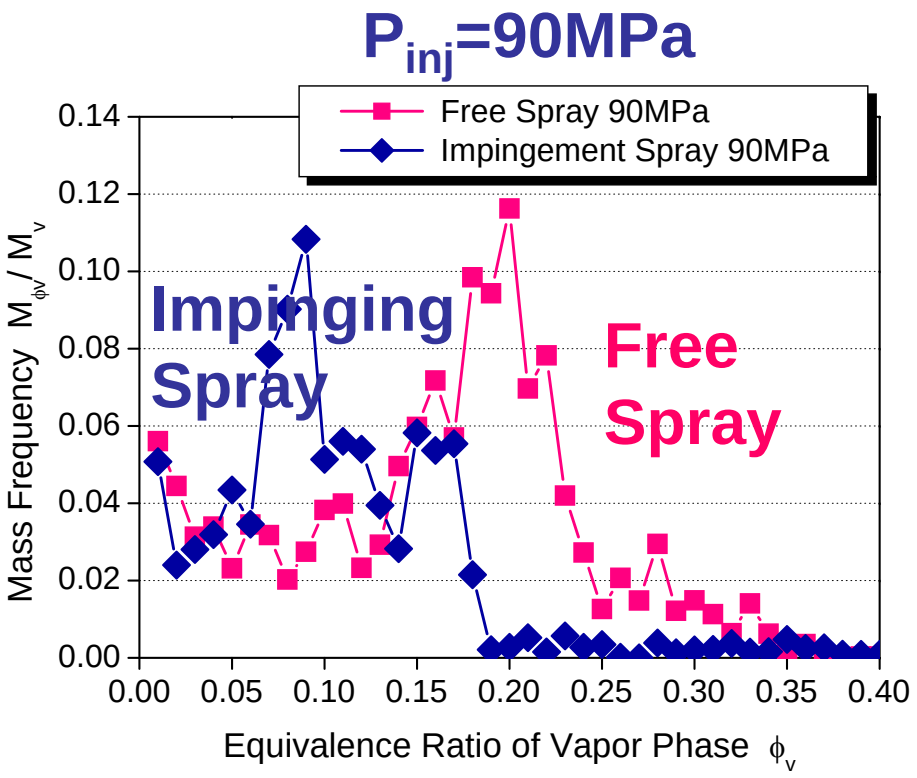
The wall impingement suppresses the ambient gas entrainment.
Higher injection pressure enhances the ambient gas entrainment.

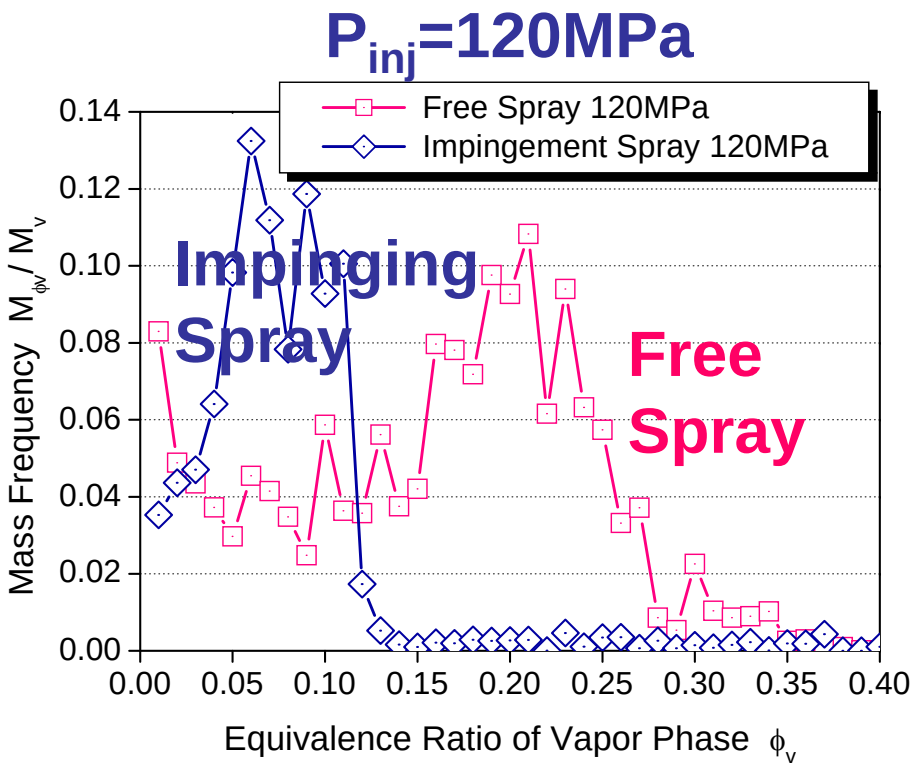
Ratio of Evaporation (M_v/M_f)



The wall impingement suppresses the fuel evaporation. The decrease in the fuel evaporation is more dominant comparing with the ambient gas entrainment. Supposedly due to the fuel film formation on the wall.

PDF of Vapor Equivalence Ratio (1.0ms ASOI)





The wall impingement shifts the PDF peak to the leaner side.
Supposedly evaporation delay due to the fuel film formation on the wall.

Summary, Case 1

- ✓The wall impingement increases the spray volume just after the impingement, and decreases it when spray develops more along the wall.
- ✓The wall impingement suppresses the ambient gas entrainment and the fuel evaporation. The decrease in the fuel evaporation is more dominant comparing with the ambient gas entrainment. It is supposedly due to the fuel film formation on the wall.
- ✓The wall impingement shifts the PDF peak of the vapor equivalence ratio in the whole spray to the leaner side.

Case 2

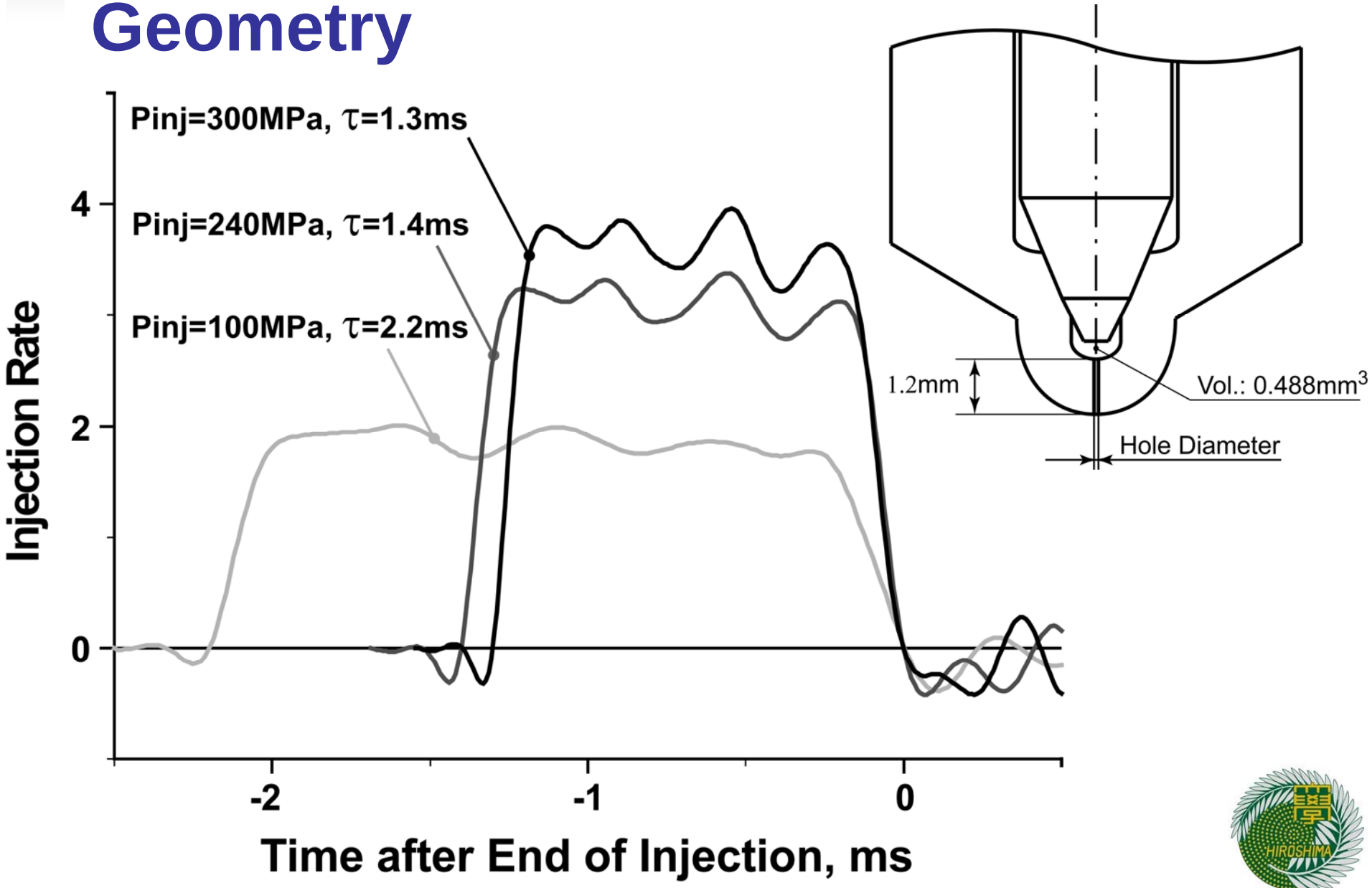
Diesel Spray (Relatively Large Amount Injected)

- ✓ Injection Pressure 100□300MPa
- ✓ Nozzle Hole/Injection Amount 0.16mm/15.47mg (4.5Holes, 70mg)
  0.08mm/3.87mg (18Holes, 70mg)
- ✓ Ambient Gas Nitrogen, 2.6MPa/797K/11kg/m^3
  Nitrogen, 4.04MPa/885K/15kg/m^3
- ✓ Impingement Distance/Angle 30mm/90deg.
- ✓ Fuel DMN (Tb=266deg.C)

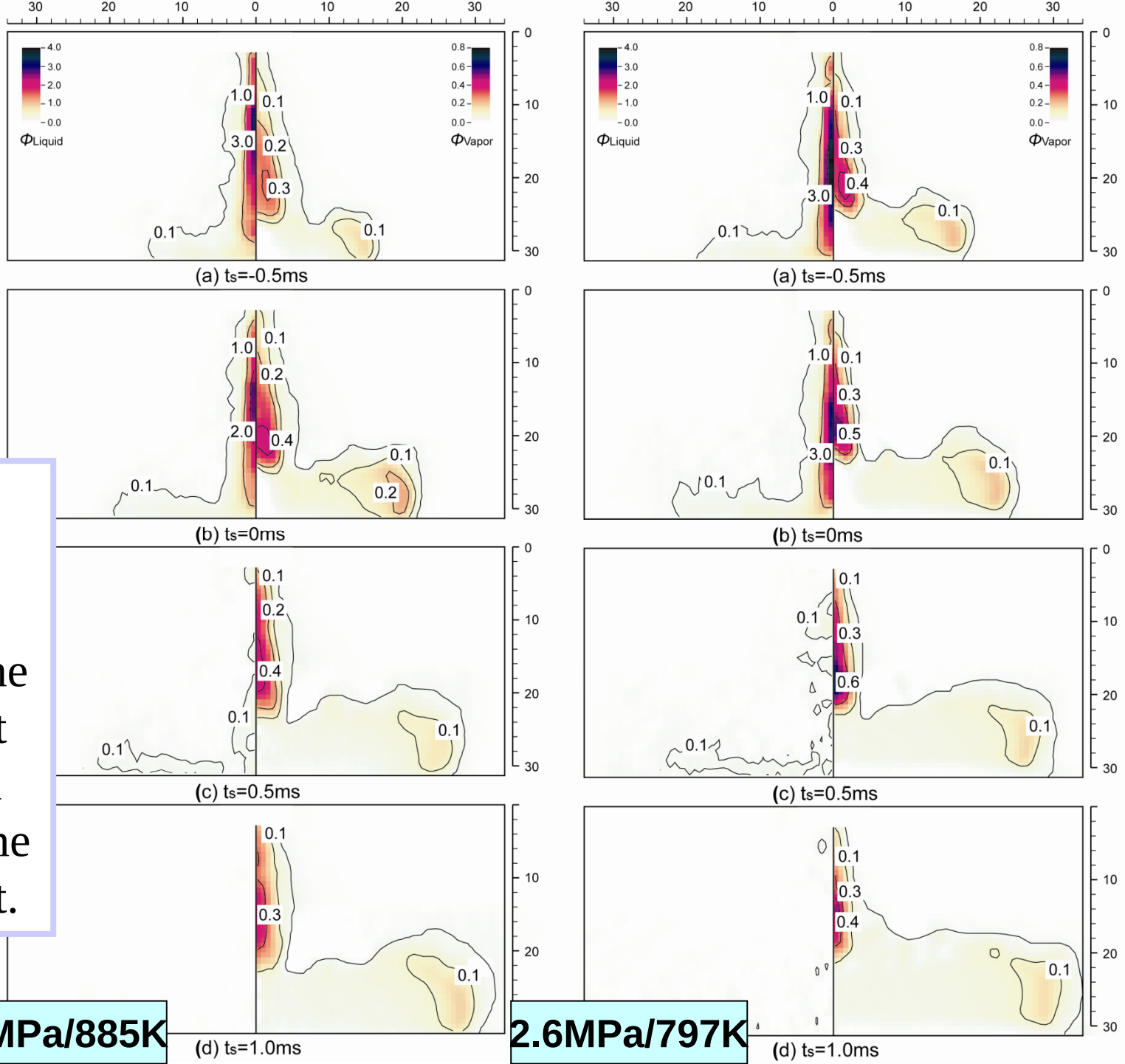
Experimental Conditions

Ambient Gas Density (kg/m^3) Pressure (MPa) / Temperature (K)	11 2.6 / 797		15 4.0 / 885	
Corresponding Crank Angle (deg. ATDC)	-20		-10	
Nozzle Hole Diameter (mm)	0.16	0.08	0.16	0.08
Injection Quantity (mg)	15.47	3.87	15.47	3.87
Injection Pressure (MPa)	100	100 300	100	100 300
Injection Duration (ms)	2.2	2.2 1.3	2.2	2.2 1.3
Laser Timing (ms AEOI)	-0.5 0	-0.5, 0 0.5, 1	-0.5 0	-0.5, 0 0.5, 1

Injection Rate Curves, Nozzle Hole Geometry



Inj: 0.08mm/ 300MPa



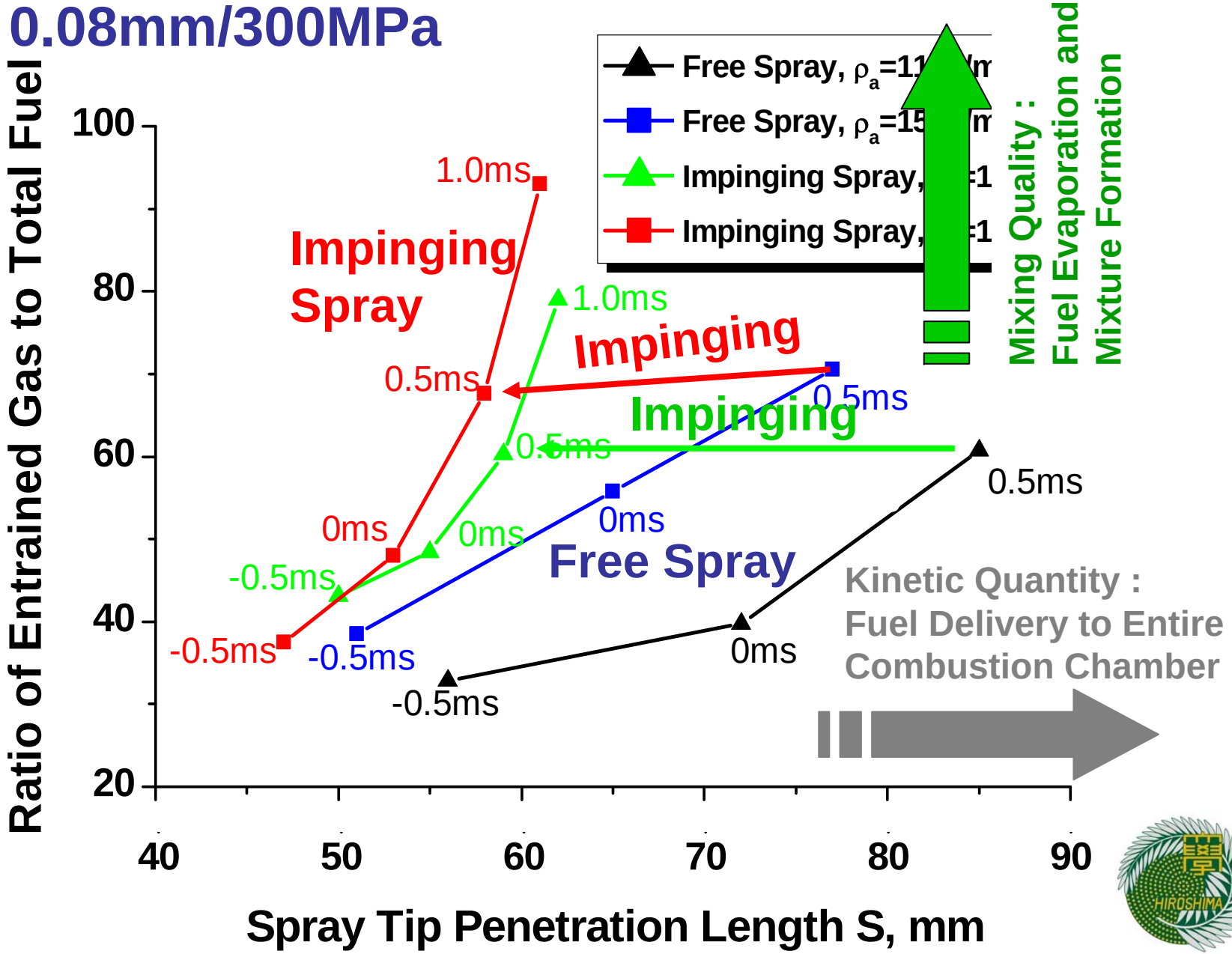
The vapor equivalence ratio in the spray after the impingement is lower than that before the impingement.

4.0MPa/885K

2.6MPa/797K

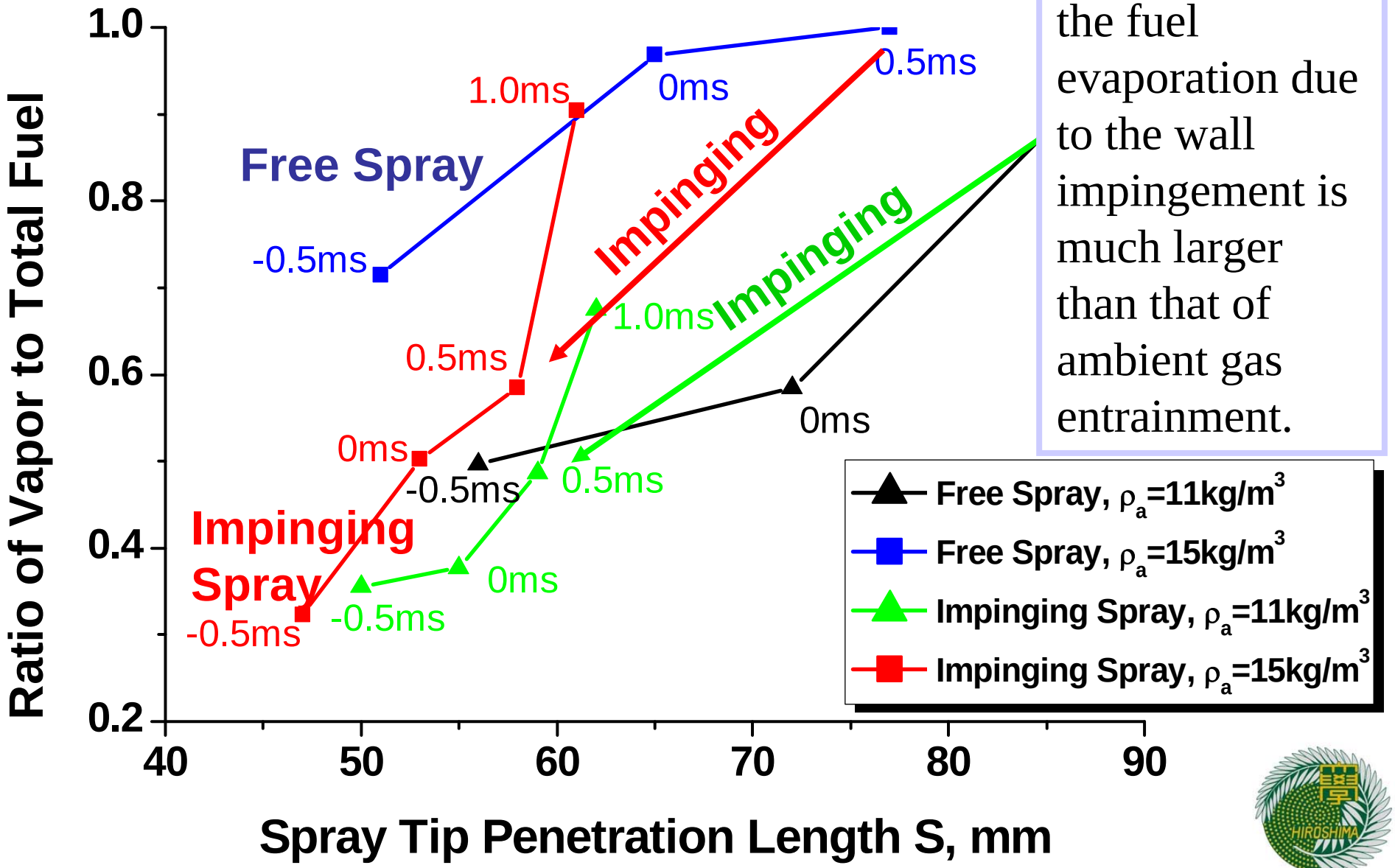
E-P Map (Entrainment-Penetration)

Inj: 0.08mm/300MPa



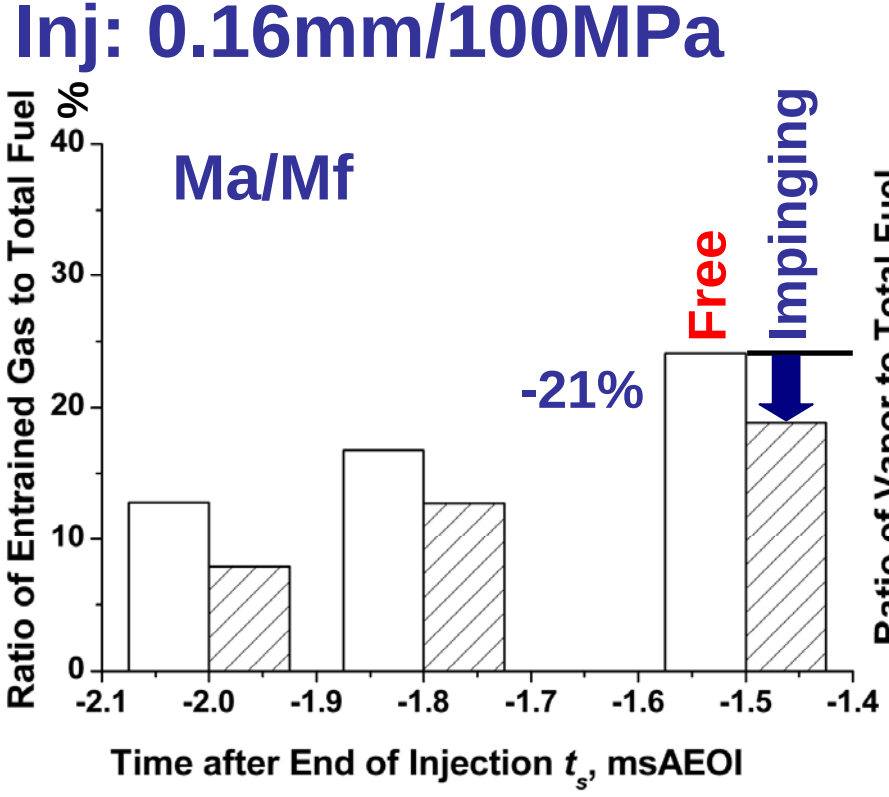
E-P Map (Evaporation-Penetration)

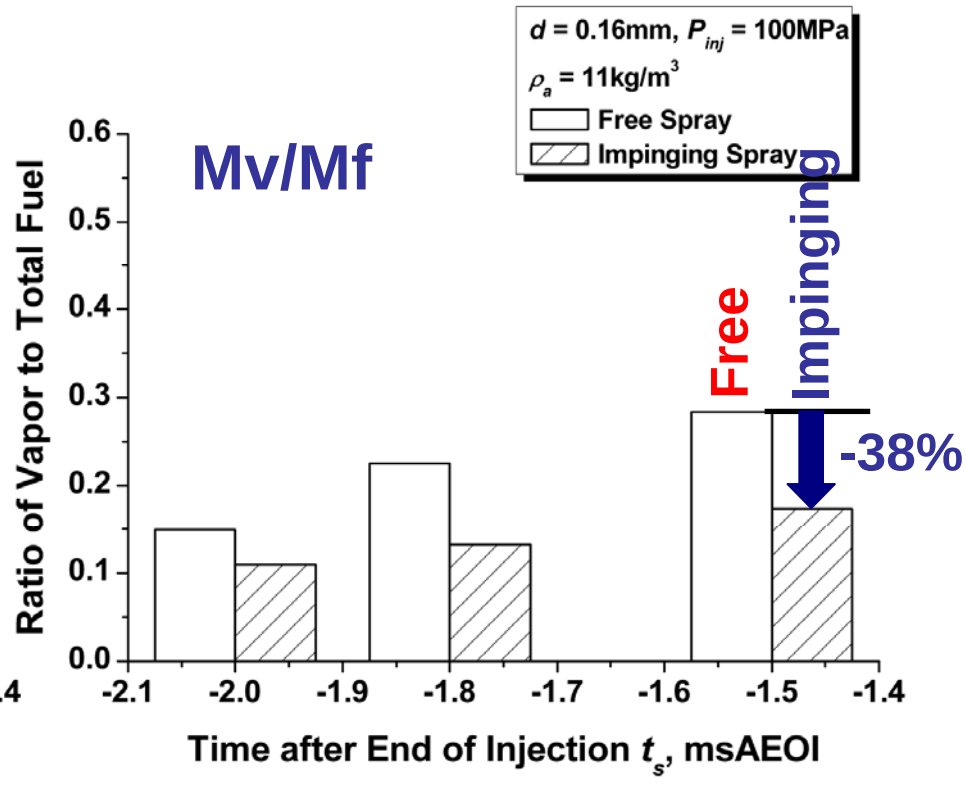
Inj: 0.08mm/300MPa



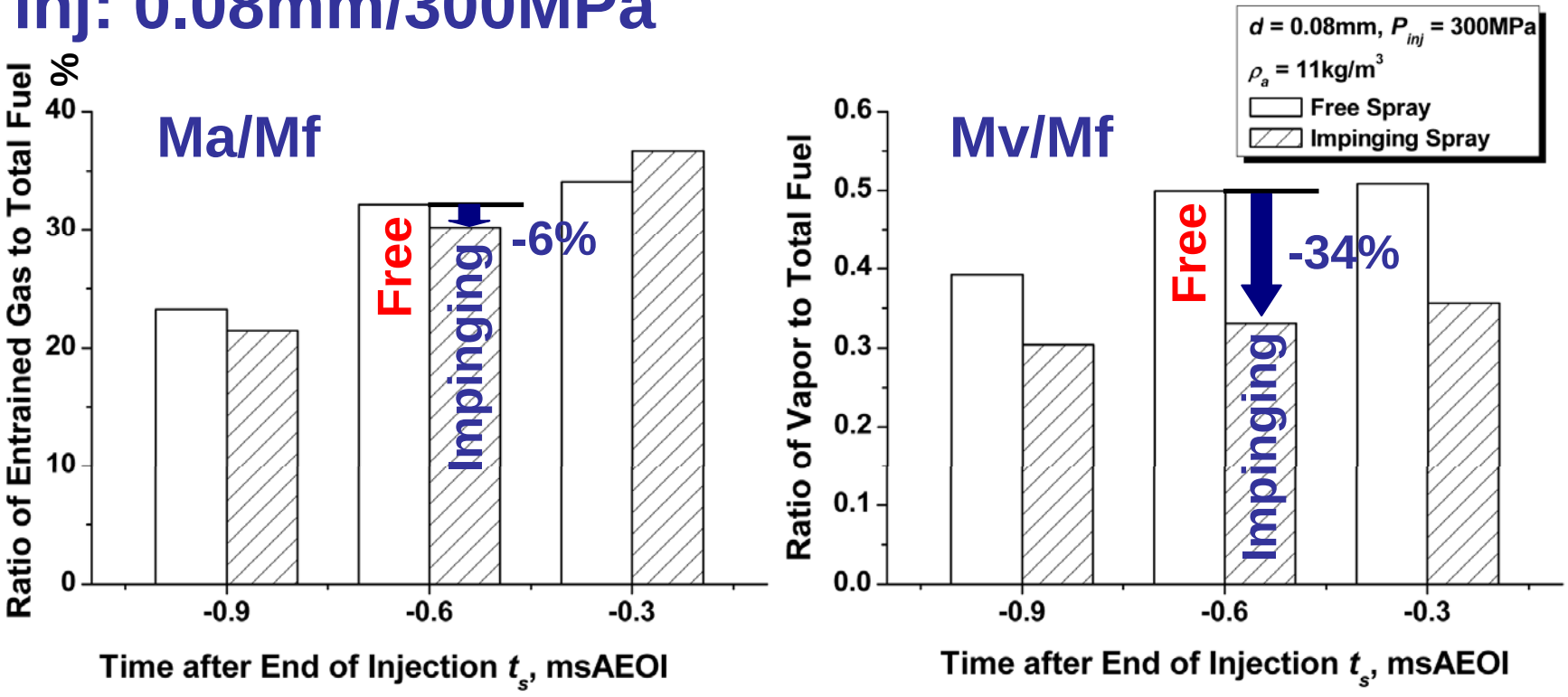
Suppression of the fuel evaporation due to the wall impingement is much larger than that of ambient gas entrainment.

Ambient Gas Entrainment Ma□
Fuel Evaporation Mv
Inj: 0.16mm/100MPa





Ambient Gas Entrainment Ma
Fuel Evaporation Mv
inj: 0.08mm/300MPa



Suppression of the fuel evaporation due to the wall impingement is much larger than that of ambient gas entrainment.

The wall impingement effect is smaller for 0.08mm/300MPa than that for 0.16mm/100MPa.

Summary, Case 2

- ✓The wall impingement effects similar to the case 1 were found.
- ✓The wall impingement effect is smaller for 0.08mm/300MPa than that for 0.16mm/100MPa.

Future Work

Remaining Issues

- Droplet size and fuel film thickness, especially for evaporating sprays.
- Spray impinging on the wall with a three dimensional shape, such as an engine piston cavity.
- Correlation of the wall impingement effects with combustion characteristics.