OpenFOAMを用いた噴霧モデルの検討

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Situation

■Diesel engines have been used for ships and big cars.

■Recently contributing global warming, Diesel engines for small cars are paid attention , especially in Europe.

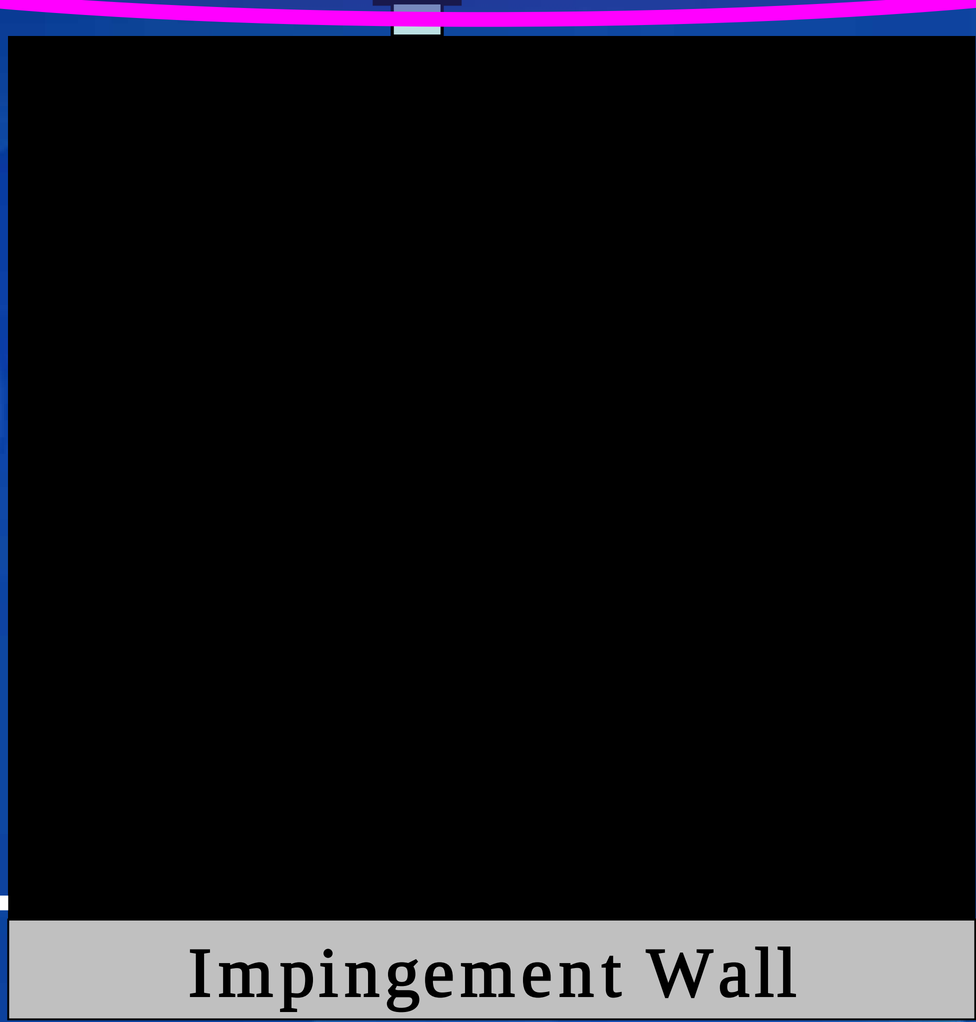
■Diesel engines are expected to be more clean and efficient.

Background

High pressure injection for clean exhaust gas

Phenomenon

- Rebounding
- Splashing
- Jet
- Adhesion



Influence

- Increasing ignition relay time
- Forming soot and unburned HC

**By numerical simulation ,
evaluating spray model and searching phenomenon**

Procedure

Evaluating breakup model

Evaluating wall model

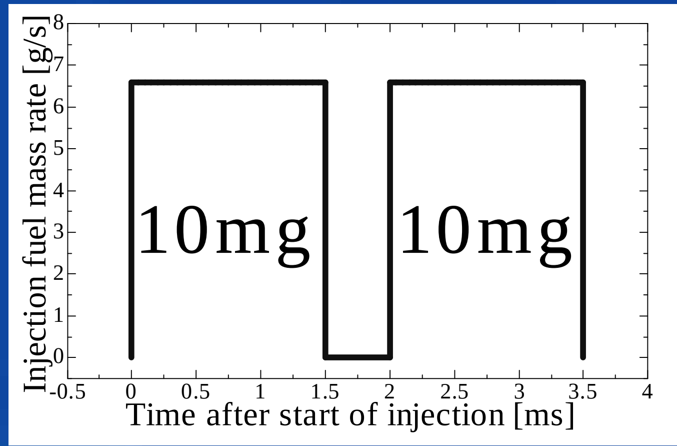
Calculation condition 1

Ambient pressure	2.6 MPa
Ambient temperature	573 K
Wall temperature	373 K
Fuel temperature	297 K
Injection pressure	135 MPa
Ambient density	16 kg/m^3
Nozzle diameter	0.15 mm
Injection fuel mass	20 mg
Injection duration	1.5 ms×2
Spray cone angle	15 °
Impingement distance	50 , 60 mm
Fuel	IDEA , Diesel

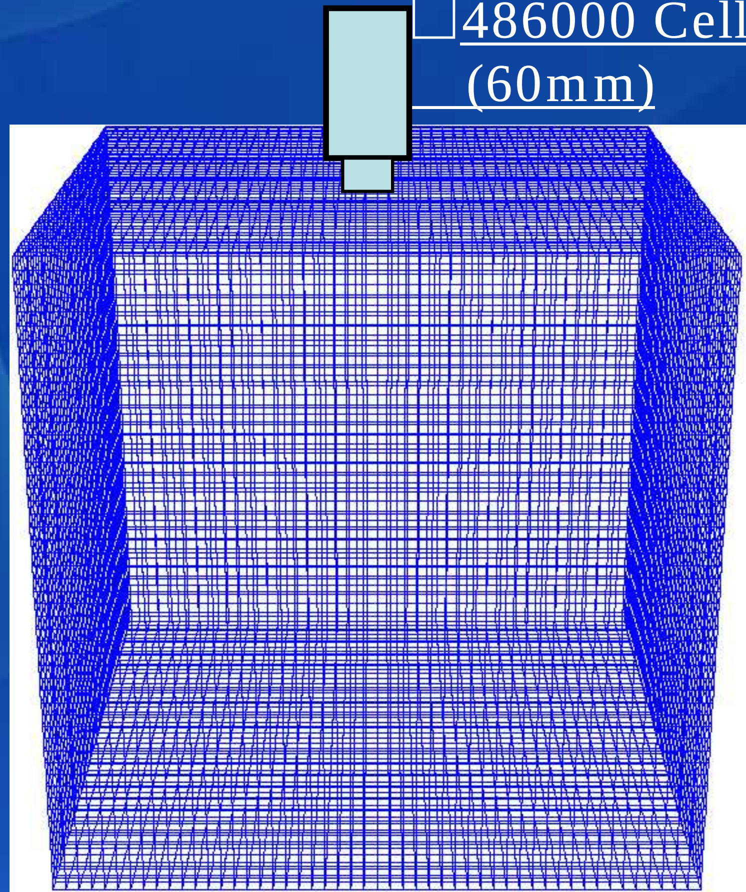
IDEA= n-decane70%+α-methyl-naphtalene30%

3D Calculation model

Breakup Model	ETAB
	ReitzKHRT
	ReitzDiwakar
Injector Model	HollowConeInjector
Evaporation Model	Standard Evaporation
HeatTransfer Model	RanzMarshall
Dispersion Model	Stochastic Dispersion
Drag Model	Standard Drag
Wall Model	Reflect
	BG
	WW
Droplet PDF	RosinRammler



□486000 Cells
(60mm)

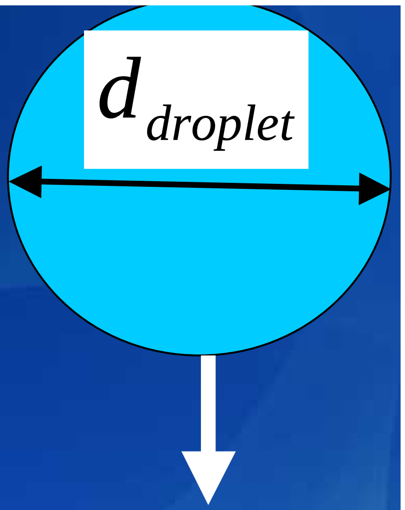


Weber number and Laplace number

Droplet viscosity $\mu_{droplet}$

Surface tension σ

Droplet density $\rho_{droplet}$



Droplet velocity $\vec{v}_{droplet}$

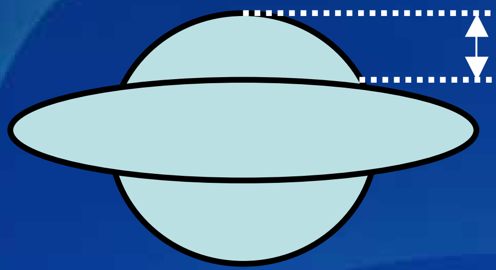
$\vec{V}_{gas}$ Gas phase velocity

ρ_{gas} Gas phase density

$$We = \frac{\rho_{gas} \left| \vec{V}_{gas} - \vec{v}_{droplet} \right|^2 d_{droplet}}{\sigma}$$

$$La = \frac{\sigma \rho_{droplet} d_{droplet}}{\mu_{droplet}^{\ 2}}$$

ETAB model



Deformation length y

Distortion parameter $x = \frac{2y}{r}$

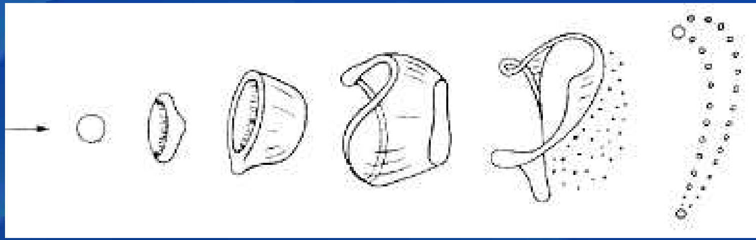
Oscillated and distorted droplet is described by damped-mass equation

$$m\ddot{x} + b\dot{x} + cx = F$$

Breakup occur

$$x(t) > 2$$

$$12 < We_g < 100$$

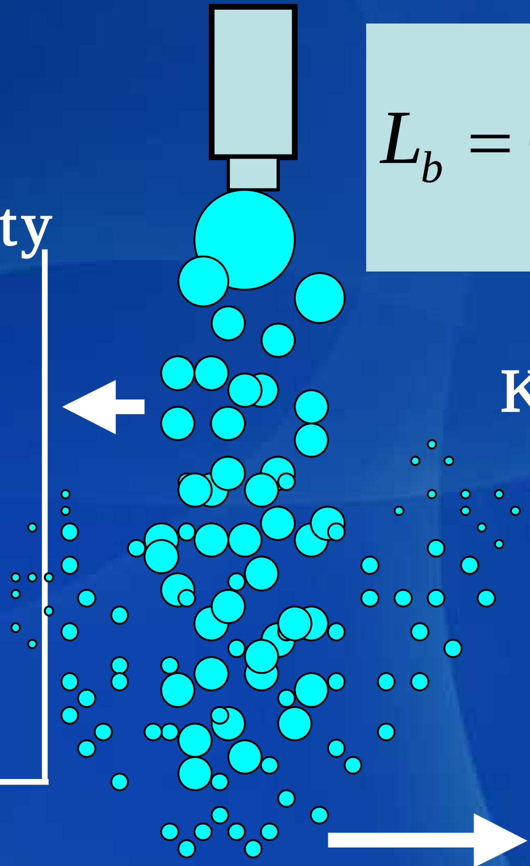


Bag breakup

$$100 \le We_g$$

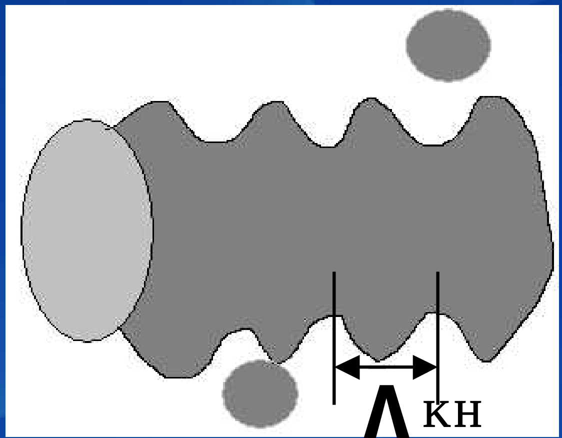
Stripping breakup

Reitz KHRT breakup model



$$L_b = C_b d_0 \sqrt{\frac{\rho_l}{\rho_g}}$$

Kelvin-Helmholtz instability

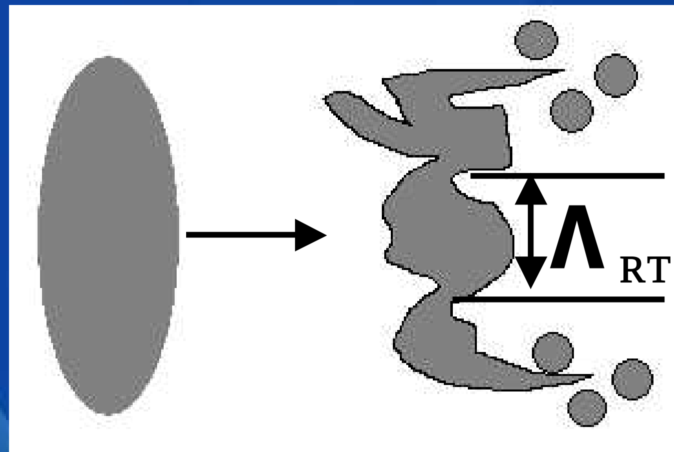


$$\tau_{KH} = \frac{3.726 B_1 r}{\Omega_{KH} \Lambda_{KH}}$$

Kelvin-Helmholtz instability

+

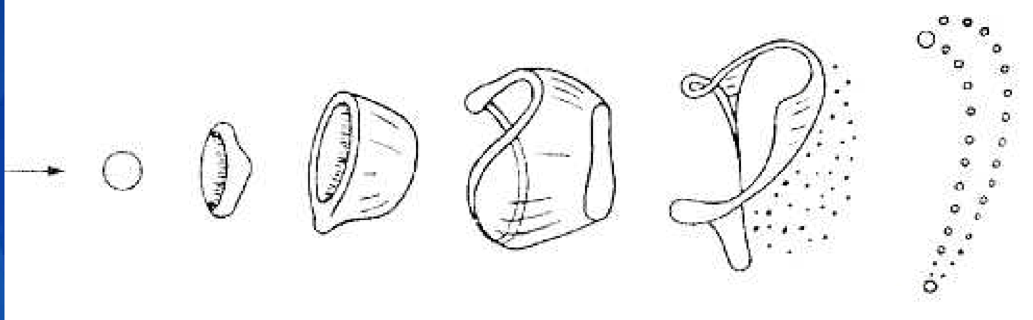
Rayleigh-Taylor instability



$$\tau_{RT} = \frac{1.0}{\Omega_{RT}}$$

Reitz Diwakar breakup model

$$6 < We_g < 0.5\sqrt{\mathrm{Re}_g}$$

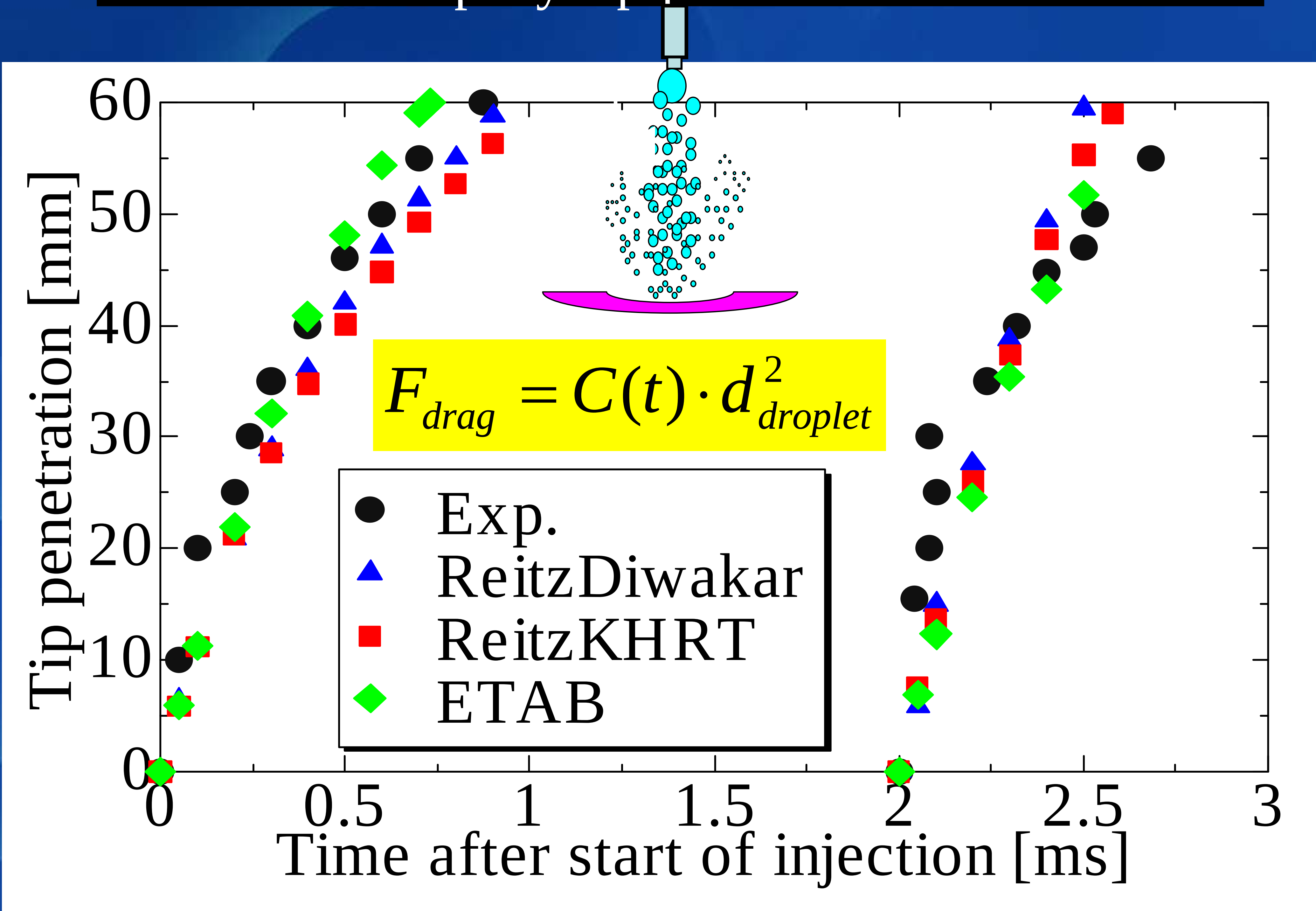


Bag breakup

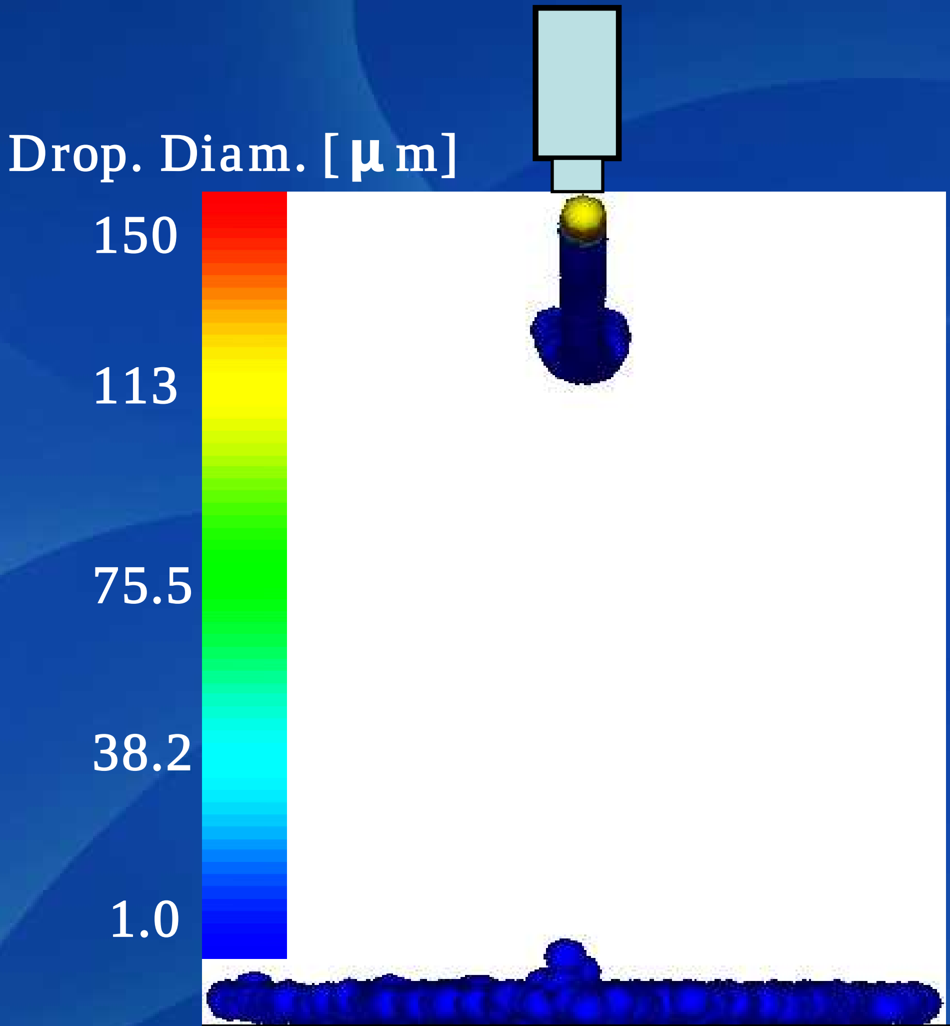
$$0.5\sqrt{\mathrm{Re}_g} \le We_g$$

Stripping breakup

Spray tip penetration



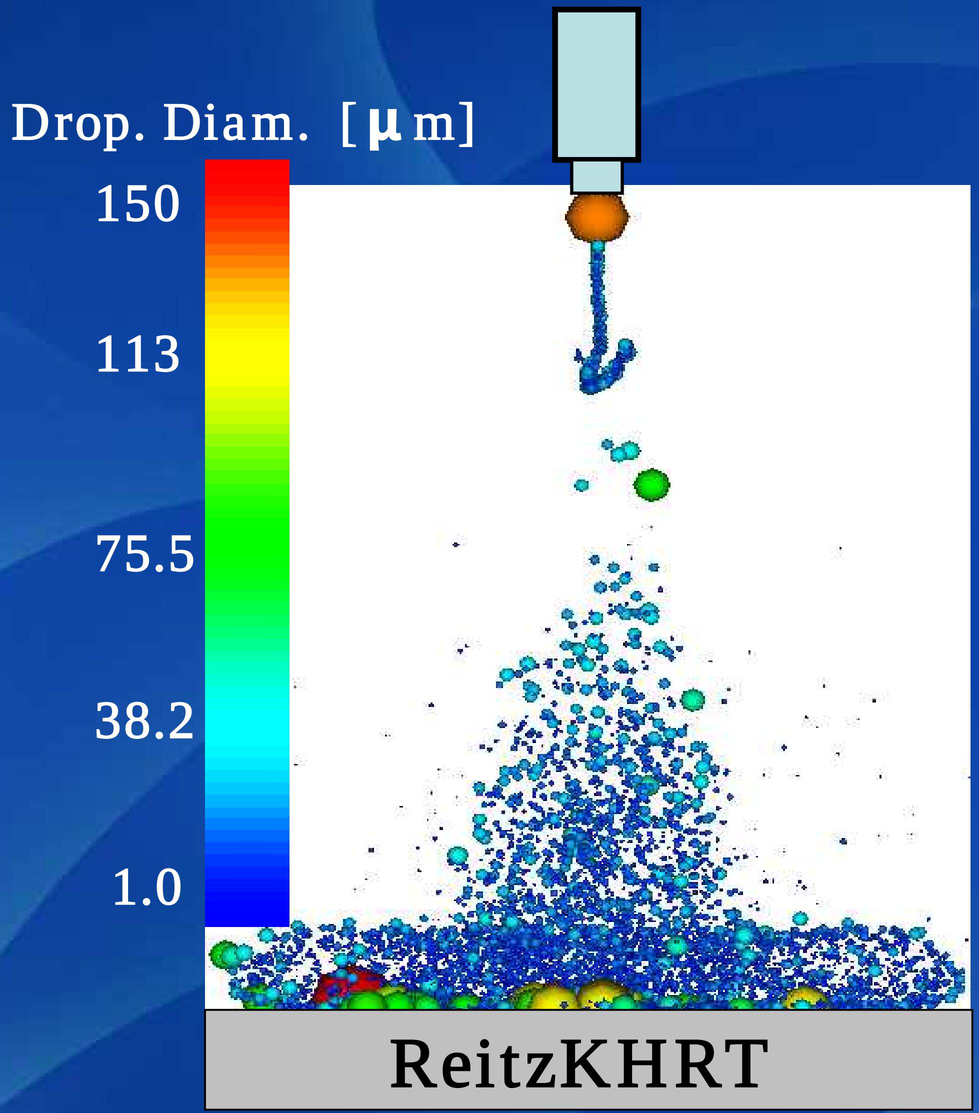
Spray shape at 2.1ms after start of injection



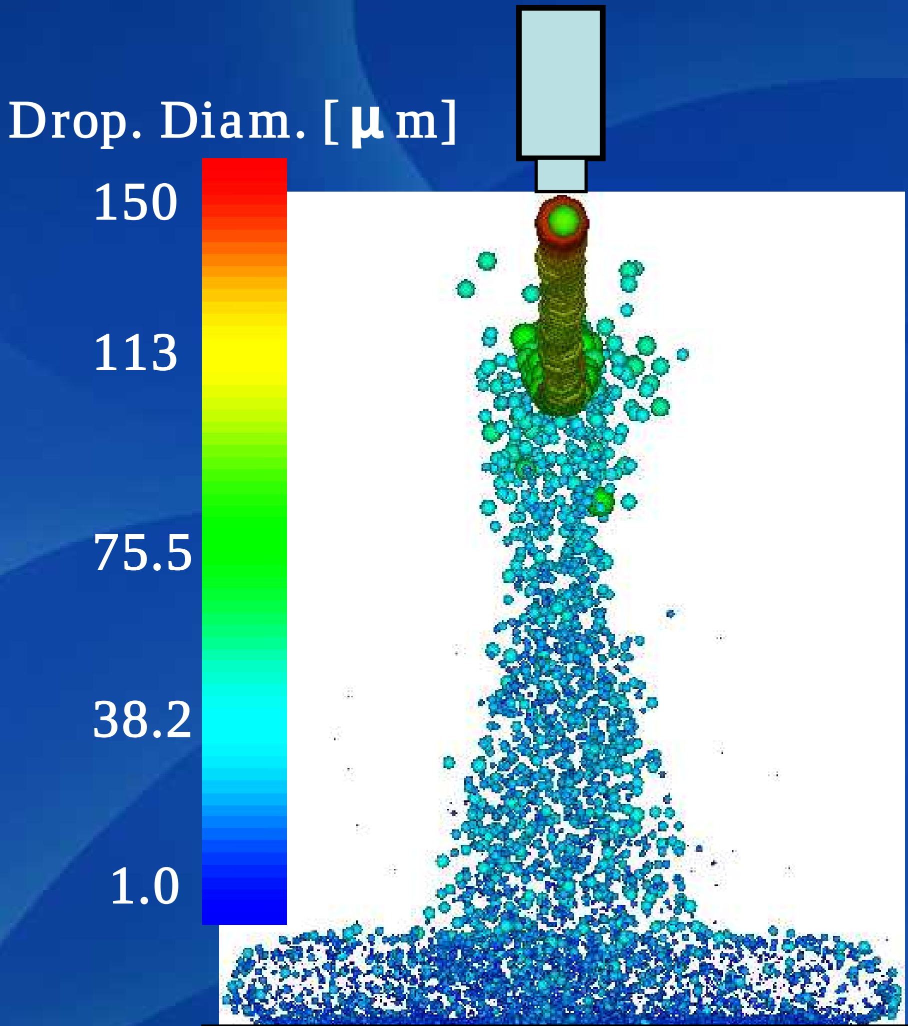
ETAB

Experiment

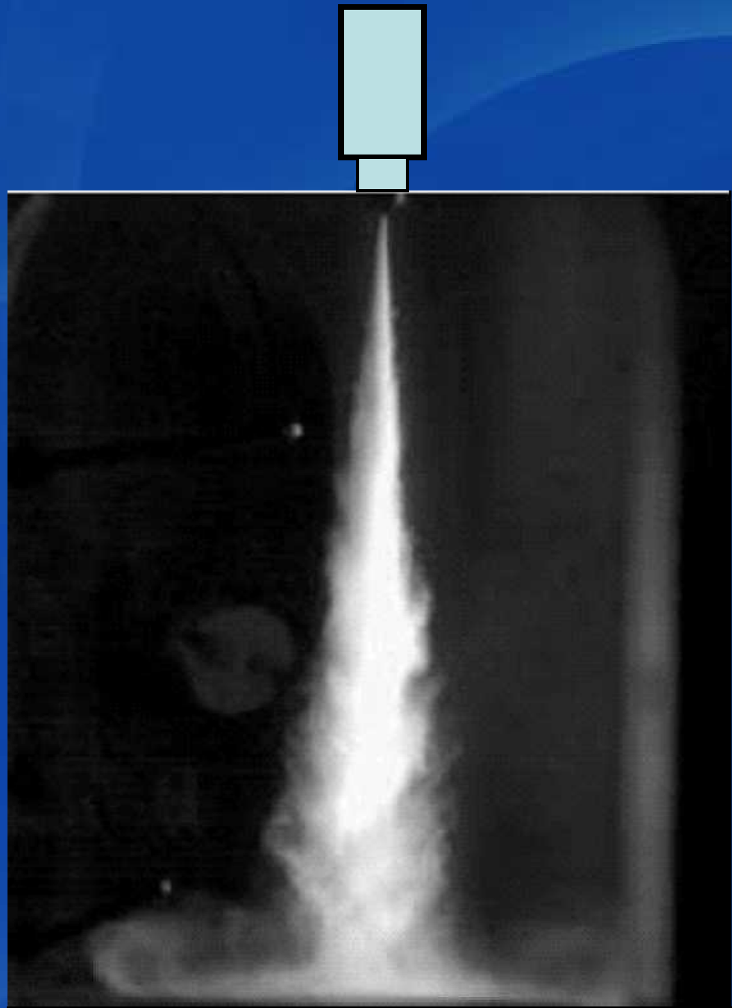
Spray shape at 2.1ms after start of injection



Spray shape at 2.1ms after start of injection



ReitzDiwakar



Experiment

breakup model

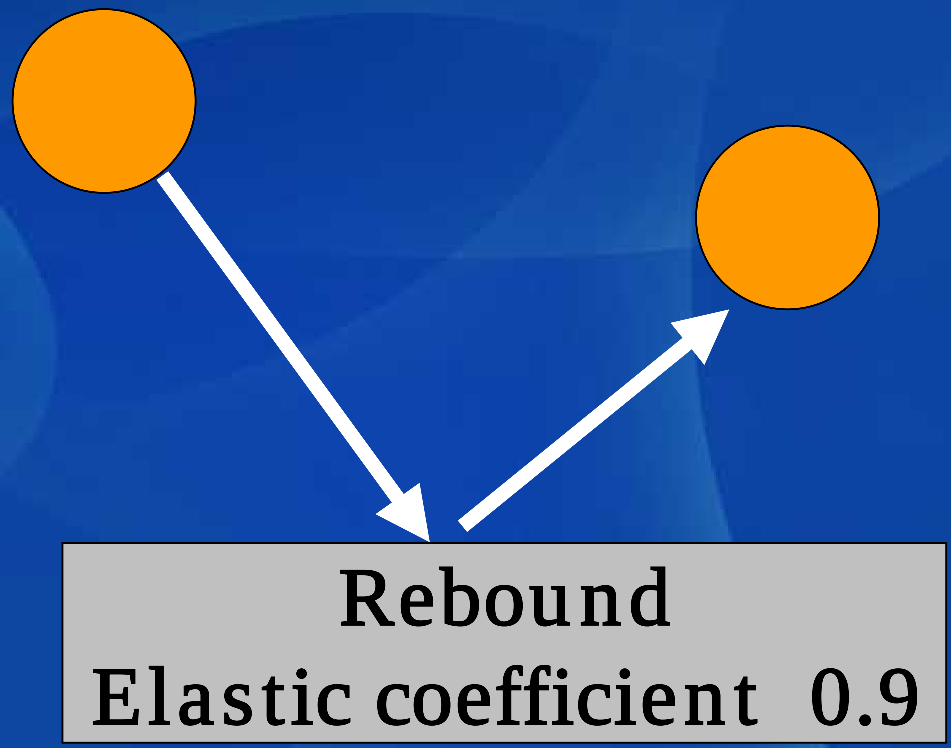
In this calculation condition

☆ReitzDiwakar ,ReitzKHRT and ETAB breakup models were good agreement with experimental result about tip penetration.

☆ReitzDiwakar and ReitzKHRT breakup models were good agreement with experimental result about spray shape.

☆ETAB breakup model was bad agreement with experimental result about spray shape.

Reflect model

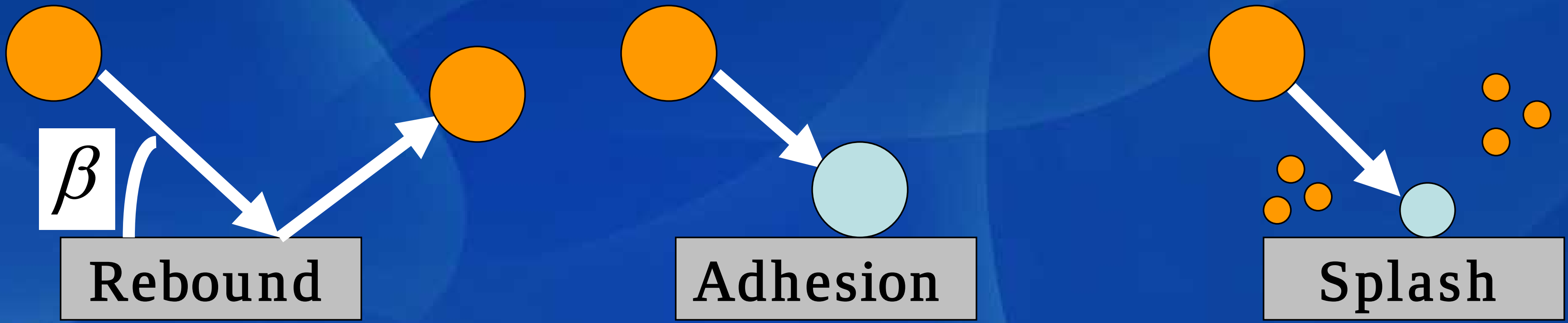


BG model

$$We_{liquid} < 5$$

$$5 \le We_{liquid} < A \cdot La^{-0.18}$$

$$A \cdot La^{-0.18} \le We_{liquid}$$



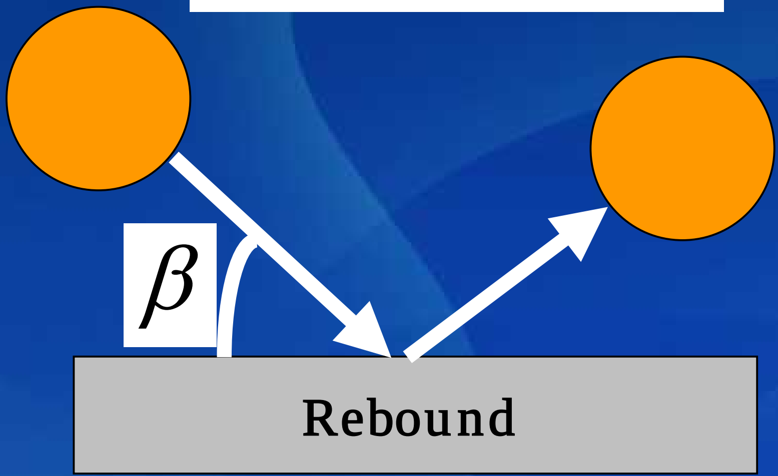
Elasticity coefficient

$$0.18 \le 0.993 - 1.76\beta + 1.56\beta^2 - 0.49\beta^3 \le 0.993$$

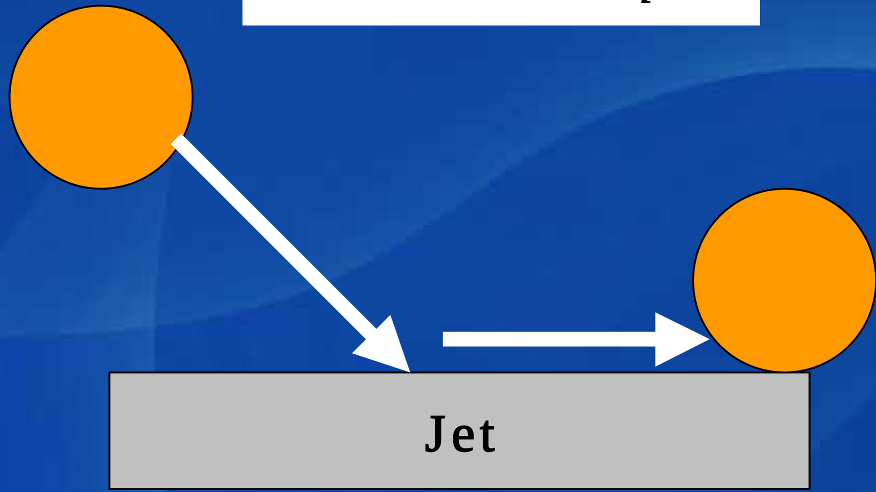
β	Elasticity coefficient
30 °	0.37
60 °	0.298
90 °	0.179

WW model

$$We_{liquid} < 80$$



$$80 \le We_{liquid}$$

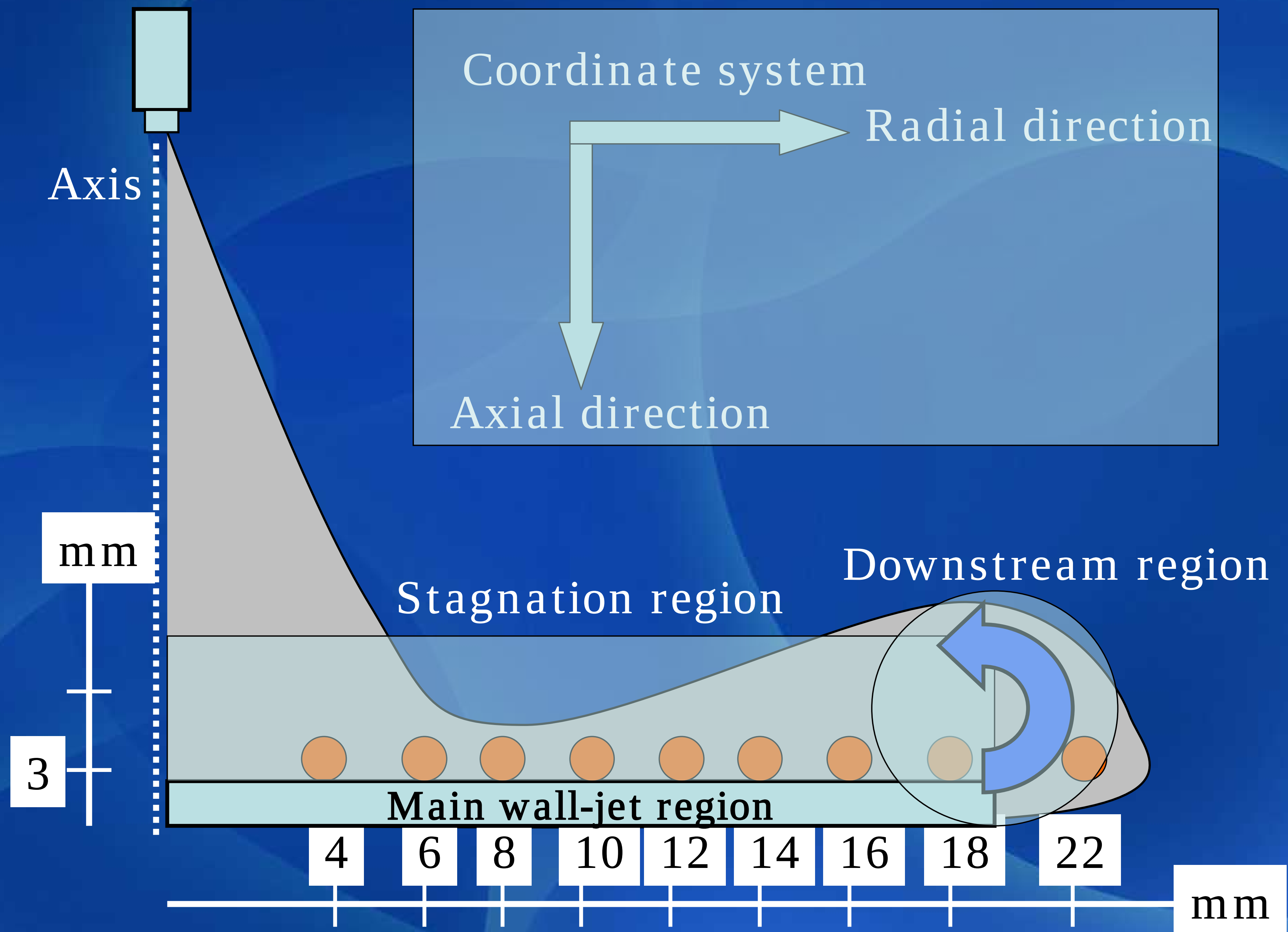


Elasticity Coefficient

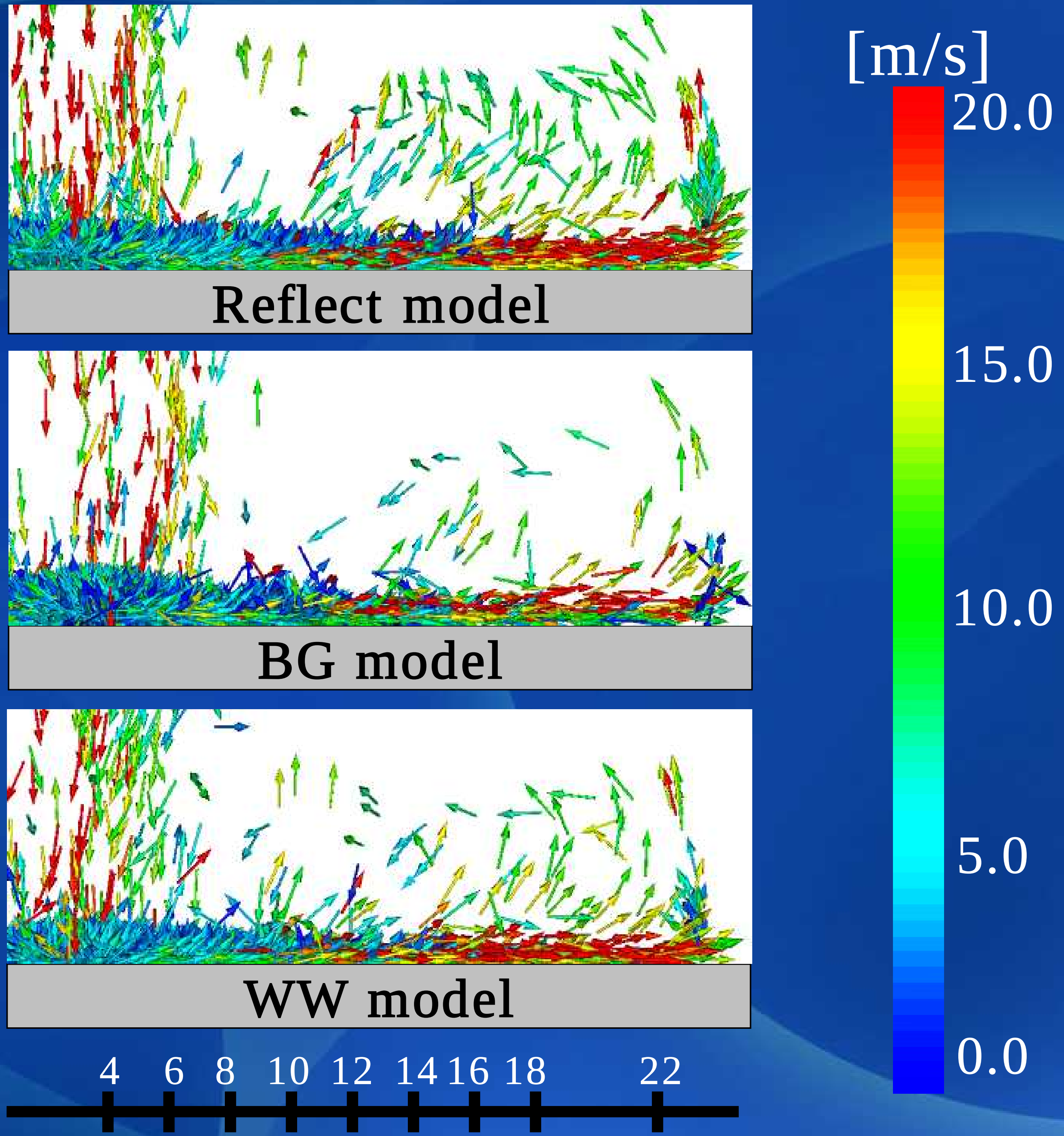
$$0.95 \le \sqrt{1 - 0.05 \sin^2 \beta} \le 1$$

β	Elasticity coefficient
30 °	0.99
60 °	0.98
90 °	0.97

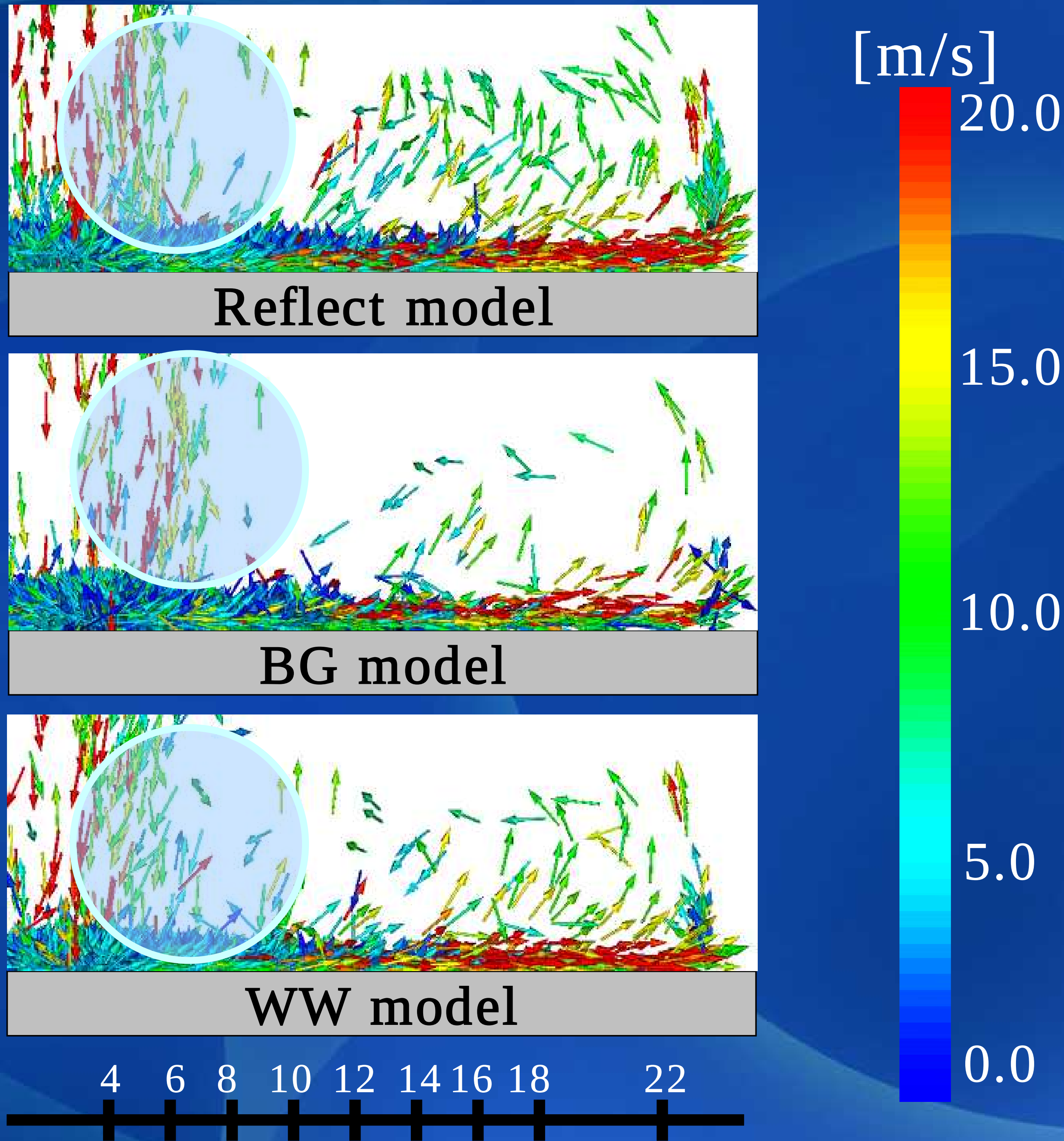
Observation points of sauter mean diameter , velocity



Droplet velocity vector

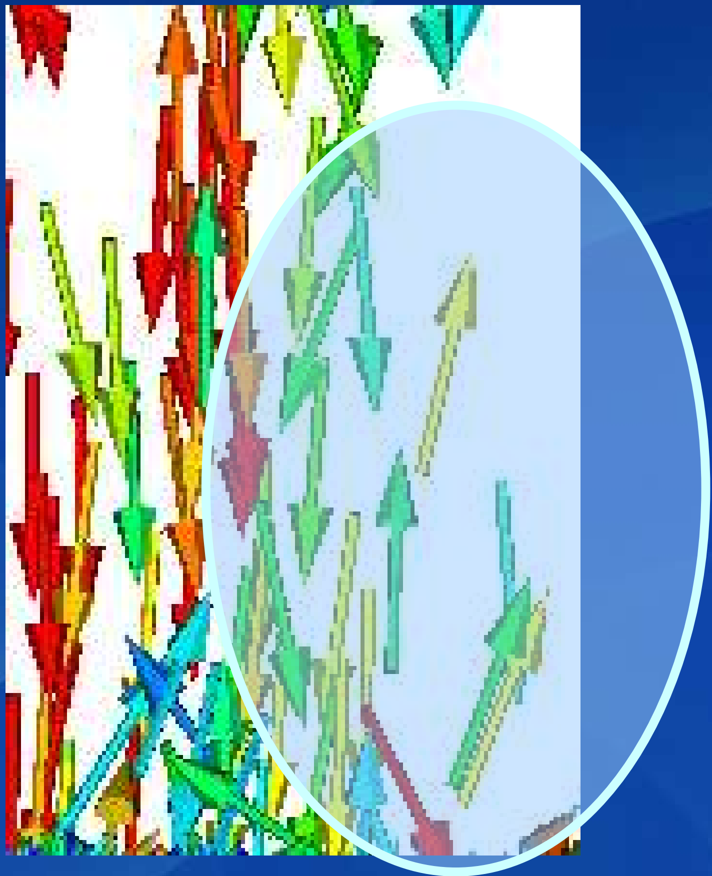


Droplet velocity vector



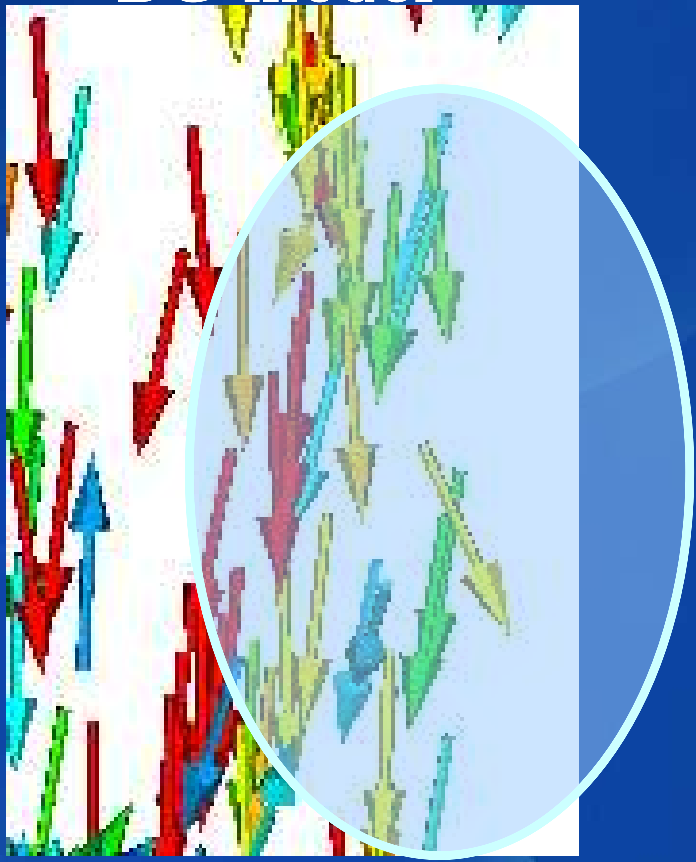
Local droplet velocity vector

Reflect model



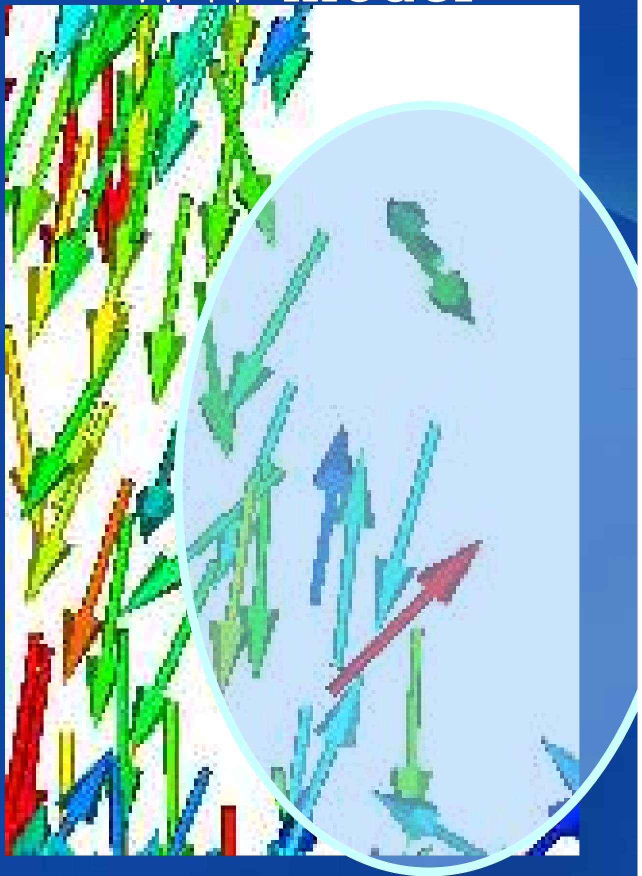
e=0.9

BG model



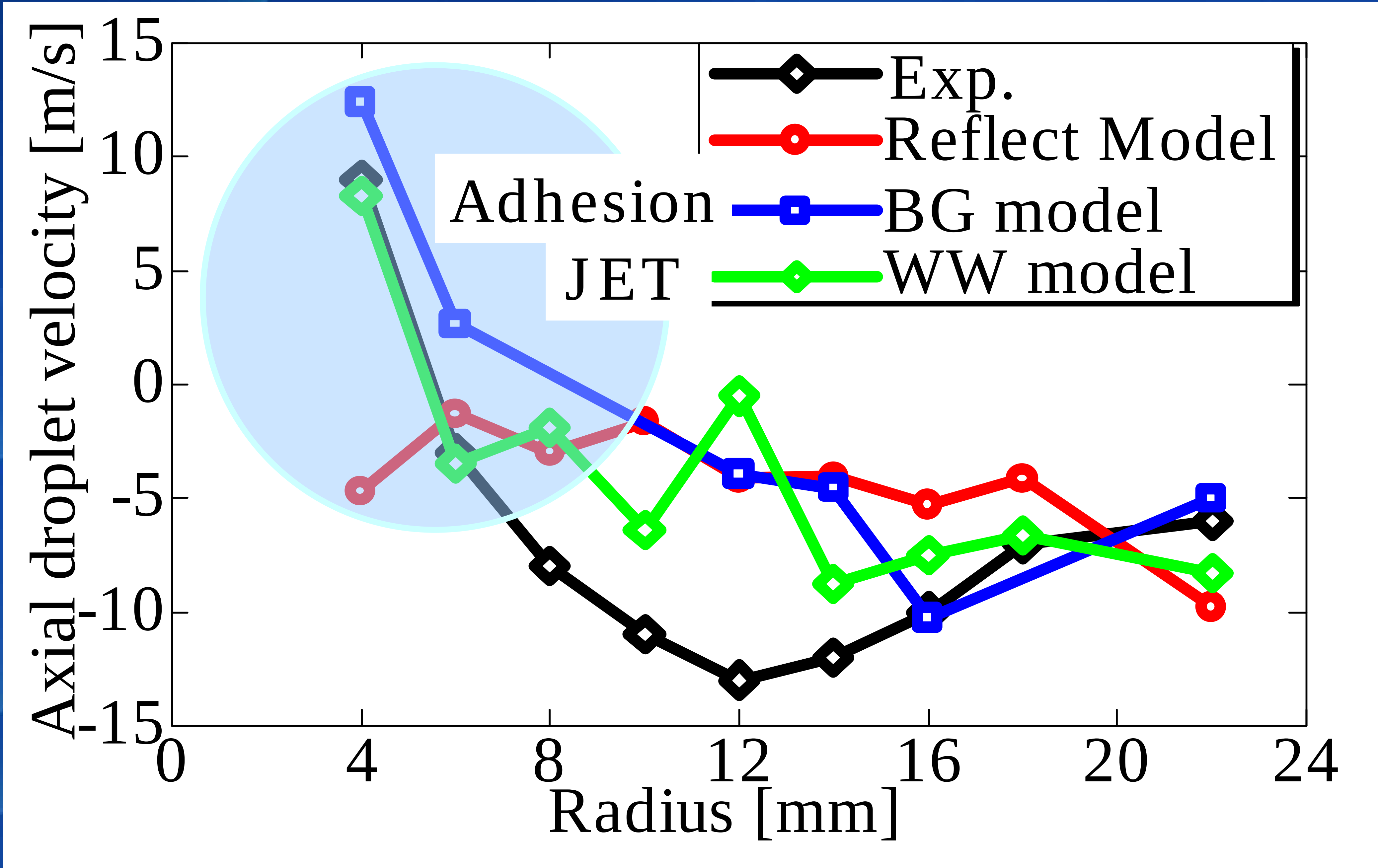
β	e
30 °	0.37
60 °	0.298
90 °	0.179

WW model

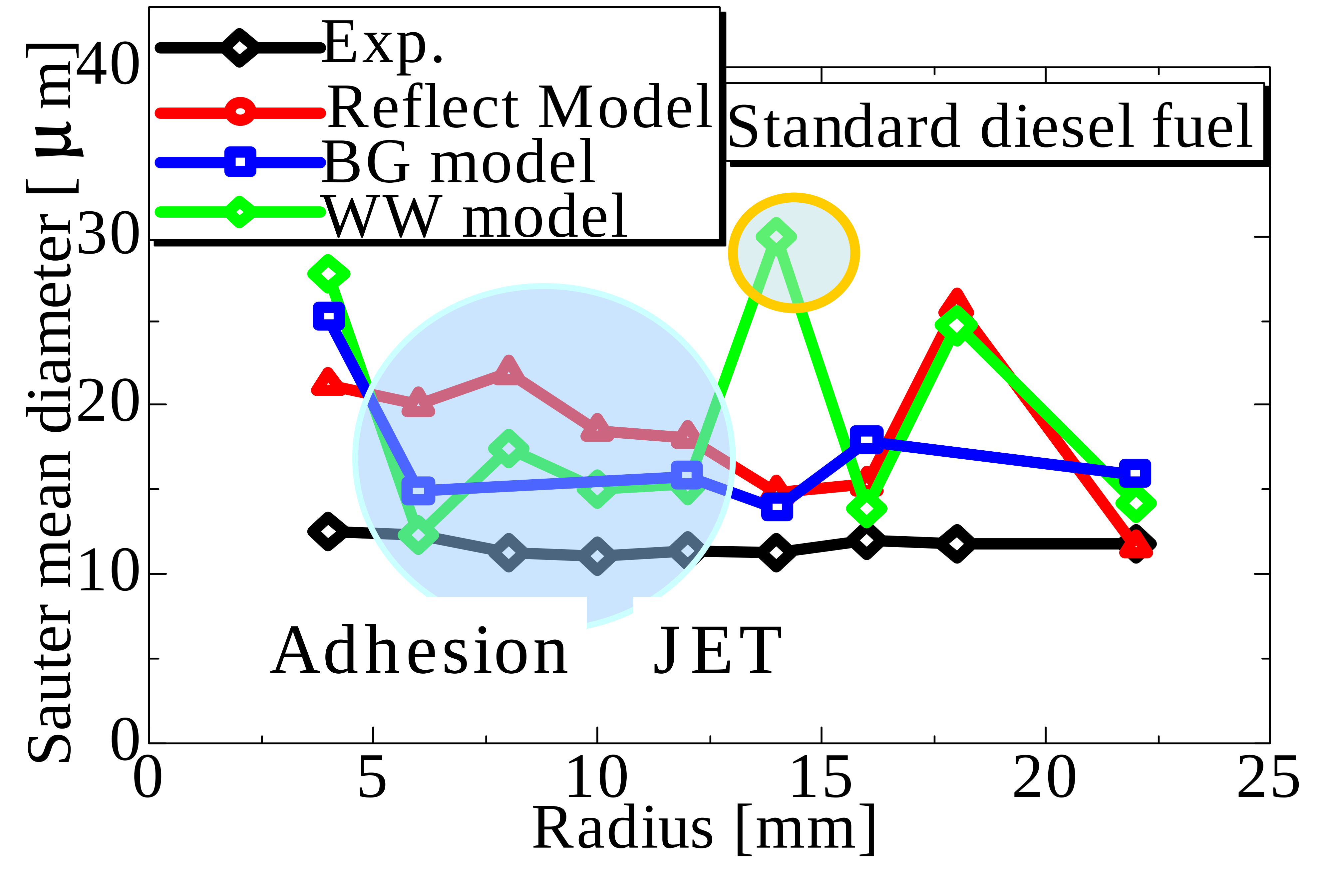


β	e
30 °	0.99
60 °	0.98
90 °	0.97

Axial droplet velocity at 2.1ms after start of injection



Sauter mean diameter at 2.1ms after start of injection



wall model

In this calculation condition

☆BG and WW models were better agreement with experimental results than Reflect model about local Sauter mean diameter and droplet mean velocity.

END