Japan National Committee for IEA/CERT: Implemental Agreement on Energy Conservation and Emission Reduction in Combustion

32nd TLM-Nara

July 25(Sun)-29(Thu), 2010

http://narashikanko.jp/en/

Statement by Prime Minister Yukio Hatoyama at the United Nations Summit on Climate Change

New York, 22 September 2009

- Based on the discussion in the Intergovernmental Panel on Climate Change (IPCC), I believe that the developed countries need to take the lead in emissions reduction efforts. It is my view that Japan should positively commit itself to setting a long-term reduction target. For its mid-term goal, Japan will aim to reduce its emissions by 25% by 2020, if compared to the 1990 level, consistent with what the science calls for in order to halt global warming.

LDA/PIV Measurements of Gas Flow in a 4-stroke Motored Engine

1.4G
Investigate Combustion in Premixed Charge Spark/Compression Ignition Engines

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BACK GROUND

It is requested for I.C. engine to improve the thermal efficiency with satisfying the exhaust emission regulations.

To understand and control the gas flows in the cylinder is the key technology for improving the I.C. engine.
However, it is not easy to understand the turbulence characteristics of gas flows because they are intermittent, highly turbulent and 3-dimensional complex flows.

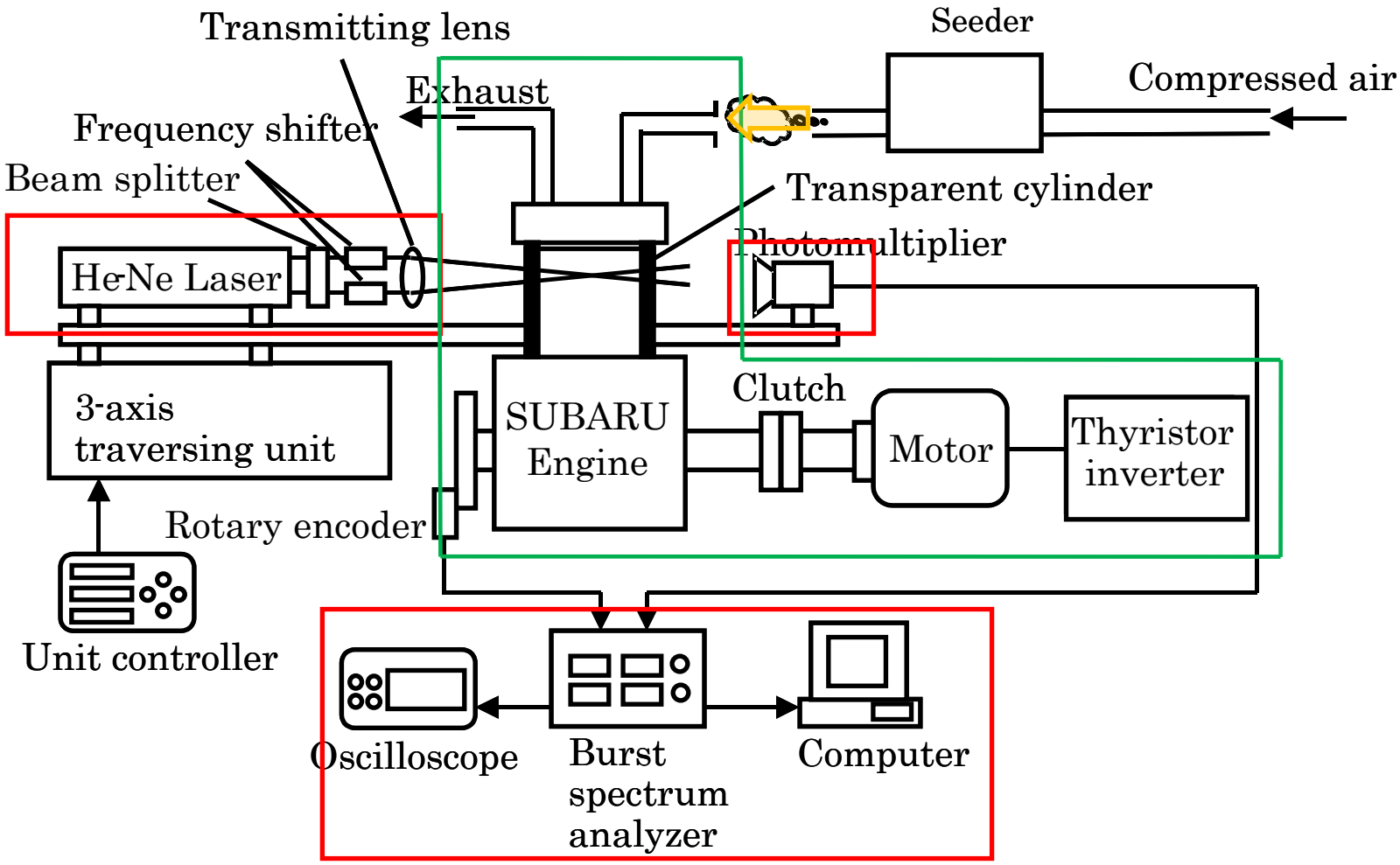
Recently, numerical simulations of gas flow and combustion are important and powerful tools to understand the gas flows in the cylinder.

But, it is important to verify the numerical simulation results by the reliable and detailed experimental data obtaining at the same engine.

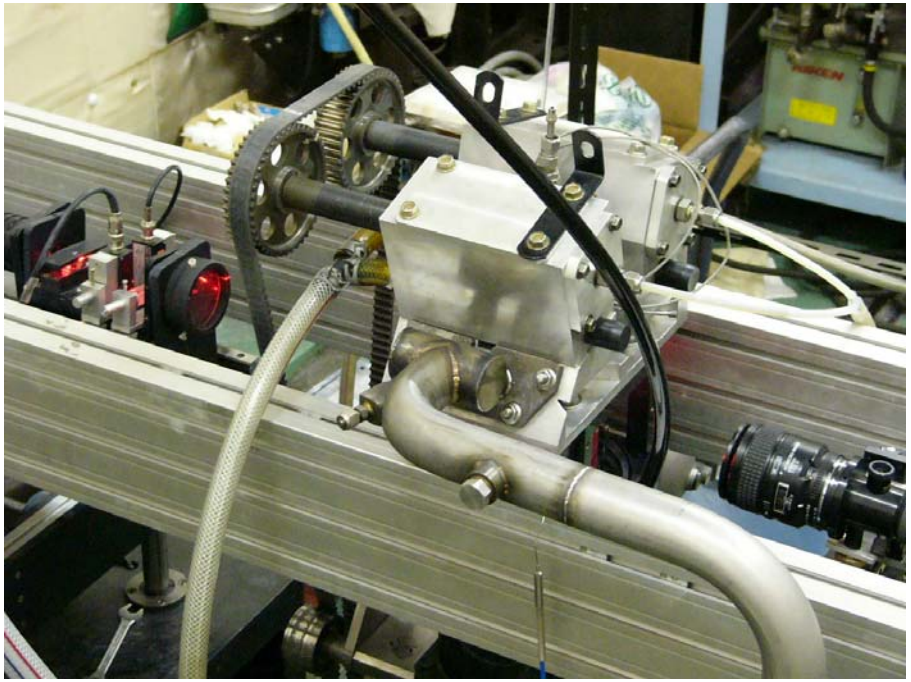
PURPOSE

- Many research groups in RC 238 of JSME are performing the numerical simulation of in-cylinder flow using the same engine specifications with different numerical simulation codes such as STAR-CD, VECTIS, Fluent and so on. It is like a competition.
- Our experiment group in JSME are preparing a reliable database on the turbulent characteristics of in-cylinder flows at the same engine by LDA and PIV for verifying the numerical results.
- Turbulent characteristics of gas flow in the I.C. engine are also analyzing experimentally under various operating conditions. Comparison between motoring and firing operations will be expected near future.

EXPERIMENTAL SETUP (LDA)



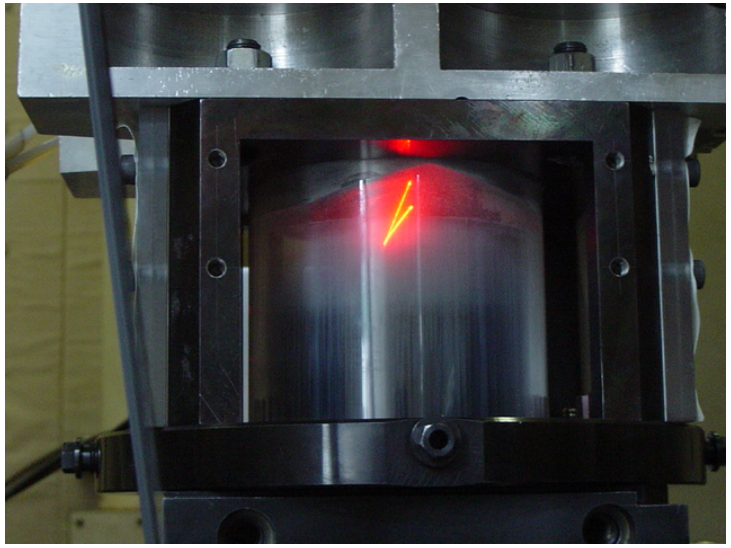
- Apparatus for this experiment divided into components of the optical system and the motored engine.
- Tracer particles are added in the intake airflow before the intake port.



Specifications of LDA

Wave length	632.8 nm
Beam separation	50 mm
Beam diameter	1.35 mm
Focal length	300 mm
Full beam cross angle	9.52 °
Calibration factor	3.81 m/s/MHz
Diameter of waist	179 μm
Measuring volume length	2.26 mm
Measuring volume width	179 μm
Shift frequency	10 MHz

A conventional 1-compornent LDA is used in this measurement.



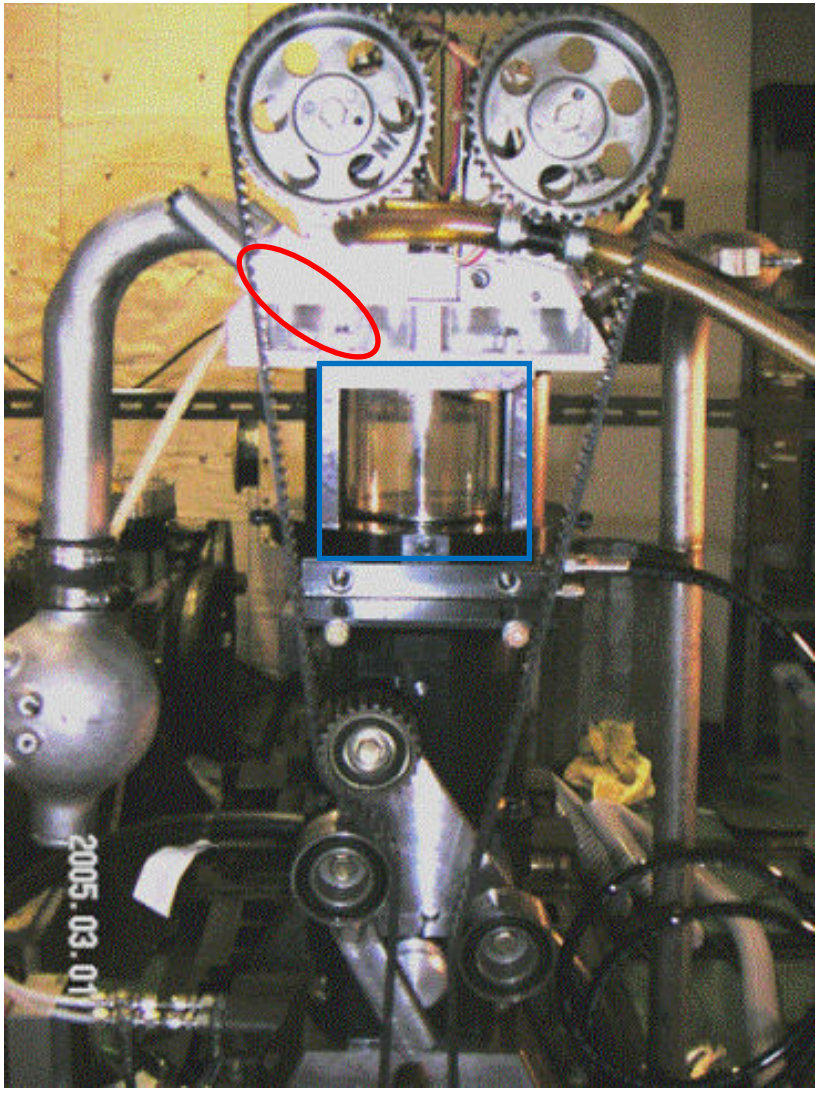
TiO_2 (KURONOS TITAN 2220)

Mean particle size	0.4 μm
Density	4.0 g/cm^3
Apparent relative density	900 kg/m^3

SiO_2 (Degussa AEROSIL R812)

Mean particle size	7 nm
Density	2.2 g/cm^3
Apparent relative density	50 kg/m^3

Titanium dioxide is used for the tracer particle.
For decrease in the effect of the humidity, silicone dioxide is added.



Specifications of SUBARU test engine

Engine type	4-stroke, Single cylinder
Combustion chamber	Pentroof type
Bore × Stroke	96.9 mm×74 mm
Displacement	545.7 cc
Compression ratio	11.5
Intake valve opening	4 deg.
Intake valve closure	240 deg.
Exhaust valve opening	485 deg.
Exhaust valve closure	5 deg.

The cylinder of this engine is made by sapphire for optical measurement.

This engine has a tumble generation valve.
The in-cylinder flow structure is changed by the pattern of with and without the valve.

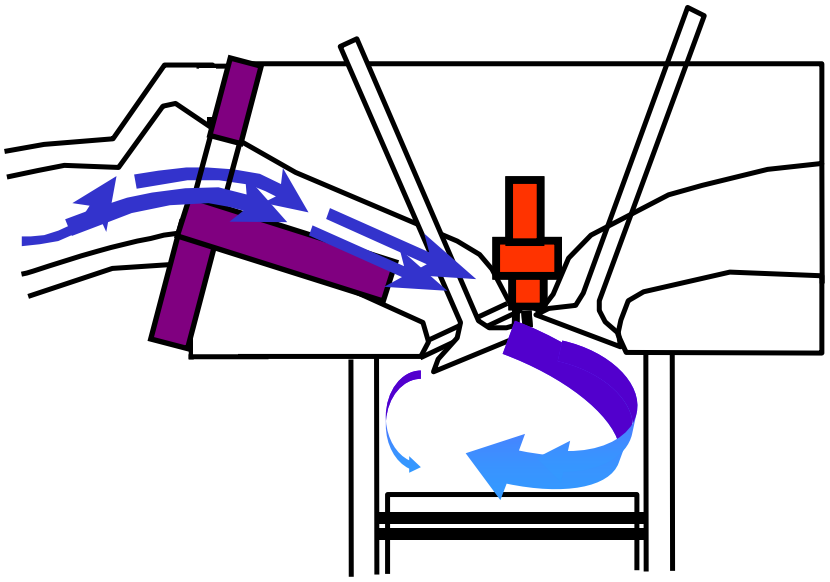
Operating condition

Motoring	600rpm
TGV	With TGV / Without TGV

□Tumble Generation Valve (TGV)

The motoring condition is sets with 600 rpm of engine speed in the measurement.

Prototype Tumble Generation Valve (TGV)



When the case of without TGV, half cylindrical structures of the TGV are removed.

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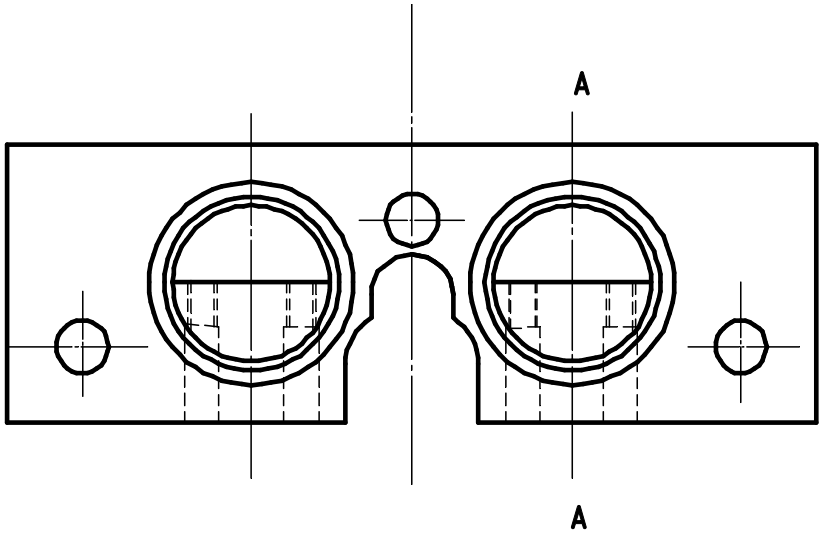
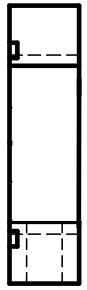
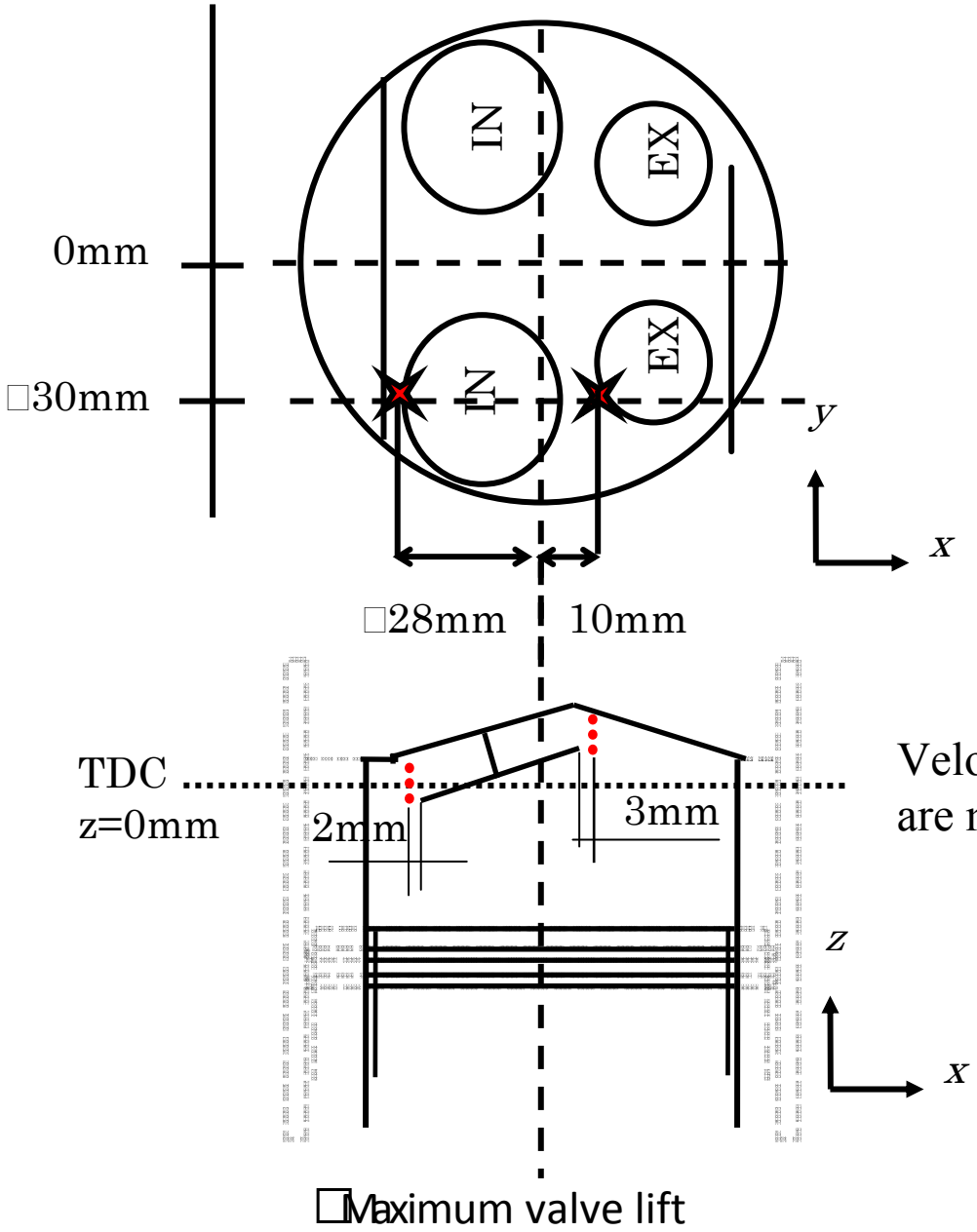
half of the intake port.





A－A

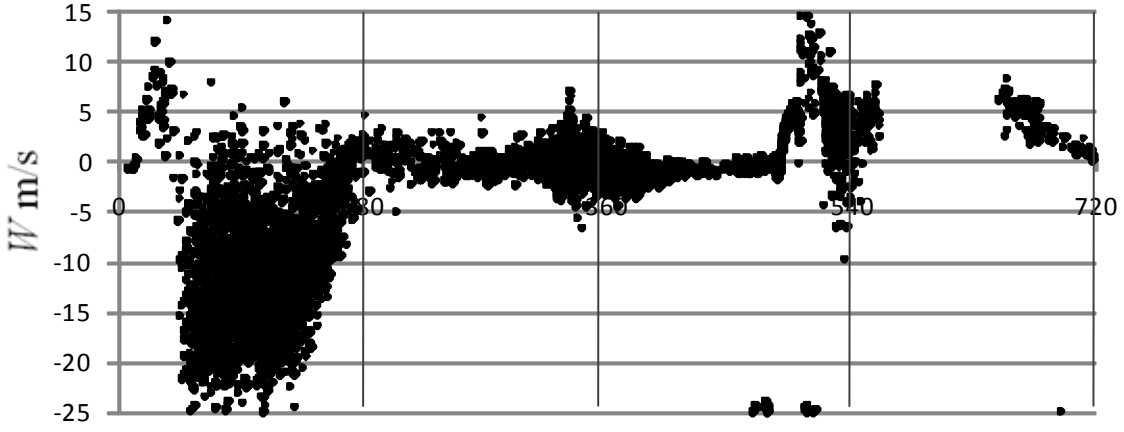
Result 1 Measurement of flow velocity through a intake valve.



Measure point

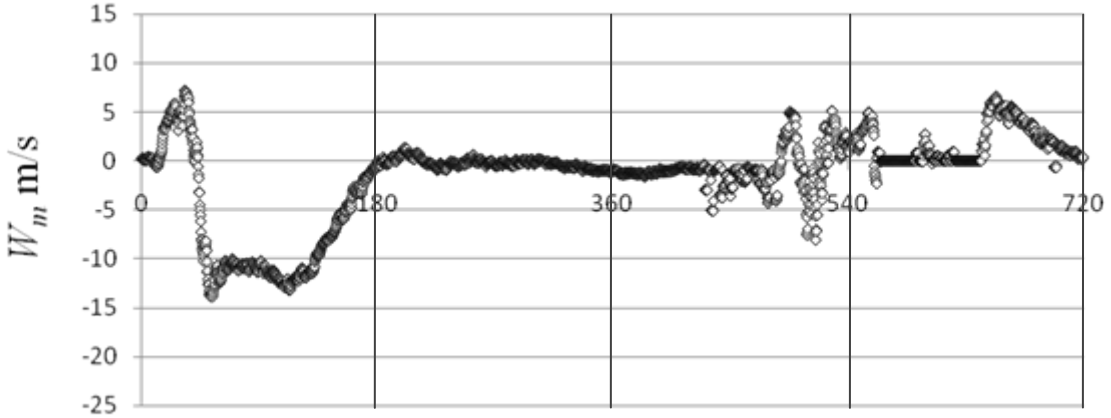
x,y =10,-30mm	z =9,7,4mm
x,y =-28,-30mm	z =2,0,-2mm

Velocities from the intake valve at some points are measured with and without TGV conditions.



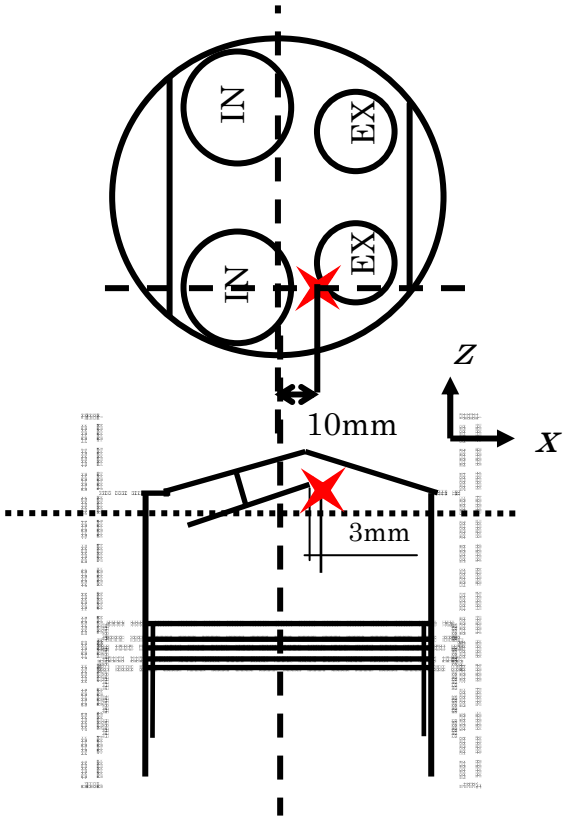
Crank angle degree

Ensemble instantaneous velocity through a valve

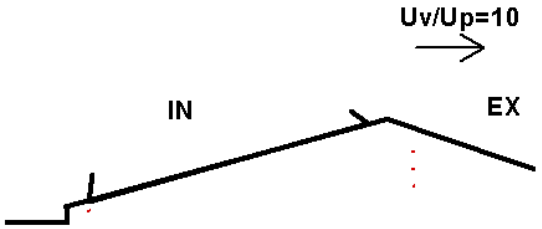


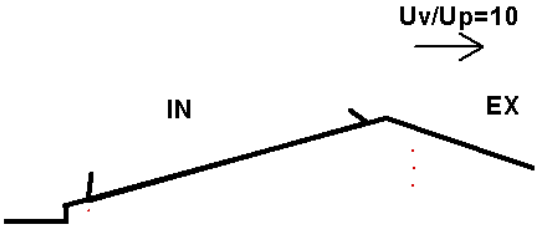
Crank angle degree

Ensemble averaged mean velocity through a valve □θ0.25deg.

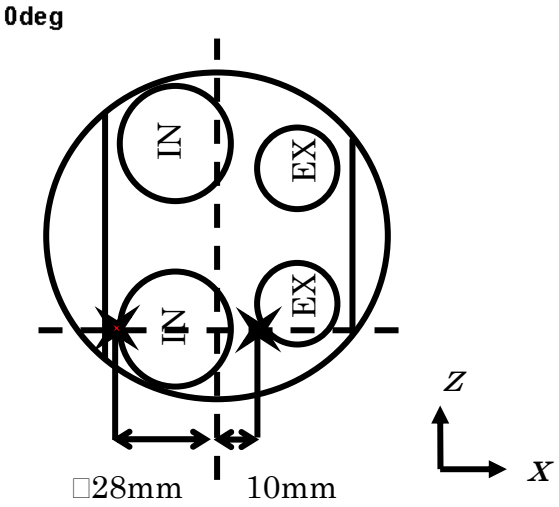


Examples of ensemble axial velocity through a valve
at x=10 mm y=□30 mm z=4 mm with TGV.





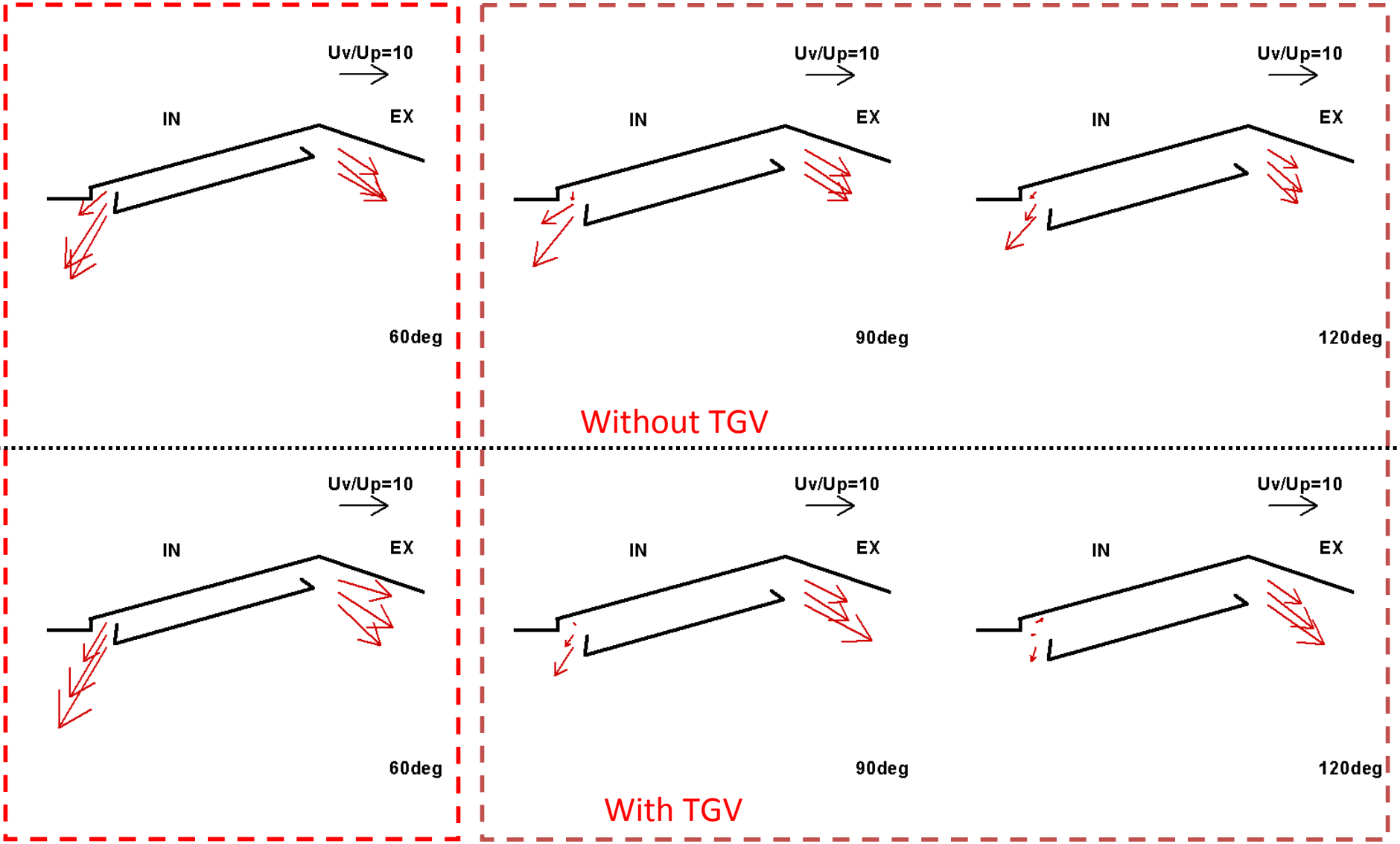
Without TGV



With TGV

0deg

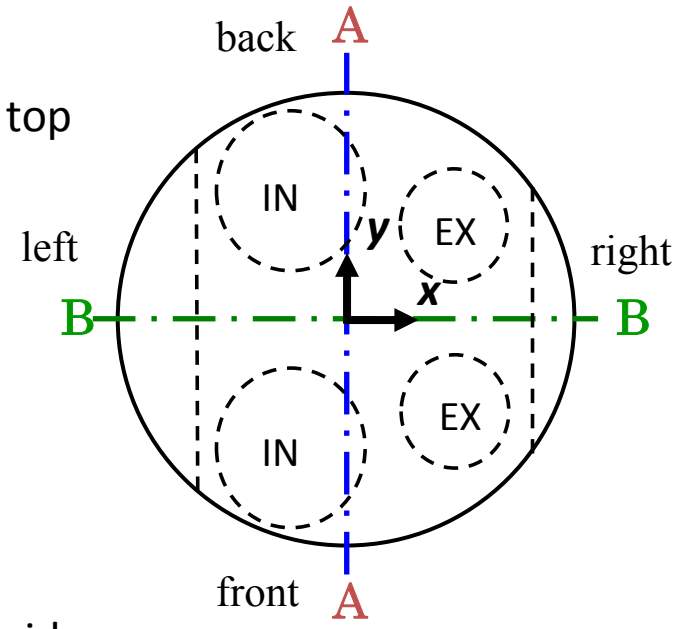
Animations of the flow velocity through a valve

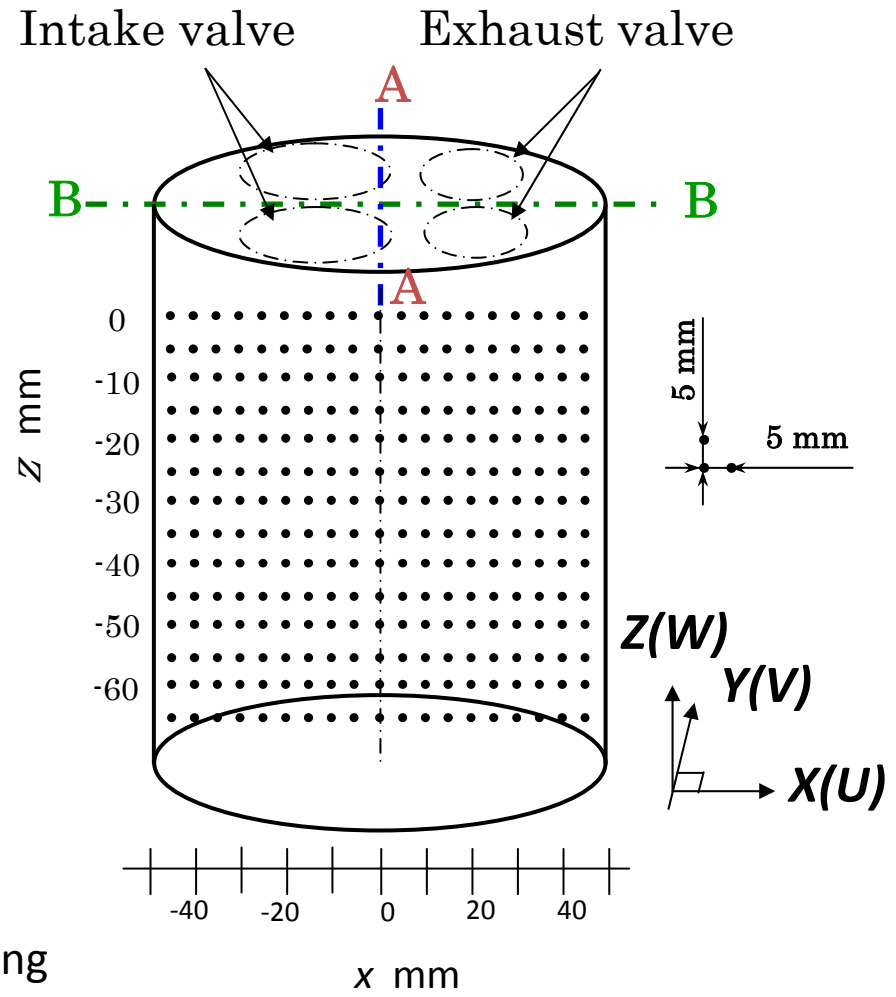


At 90 degree of the crank angle, the velocity at the right hand side with TGV becomes larger than that of without TGV case. The difference in the left hand side is more remarkable than that of the right hand side.
At the 120 degree of the crank angle, the velocity tendencies are almost same with that of the 90 degree of crank angle.

Flow velocity through a valve at 60,90,120deg.

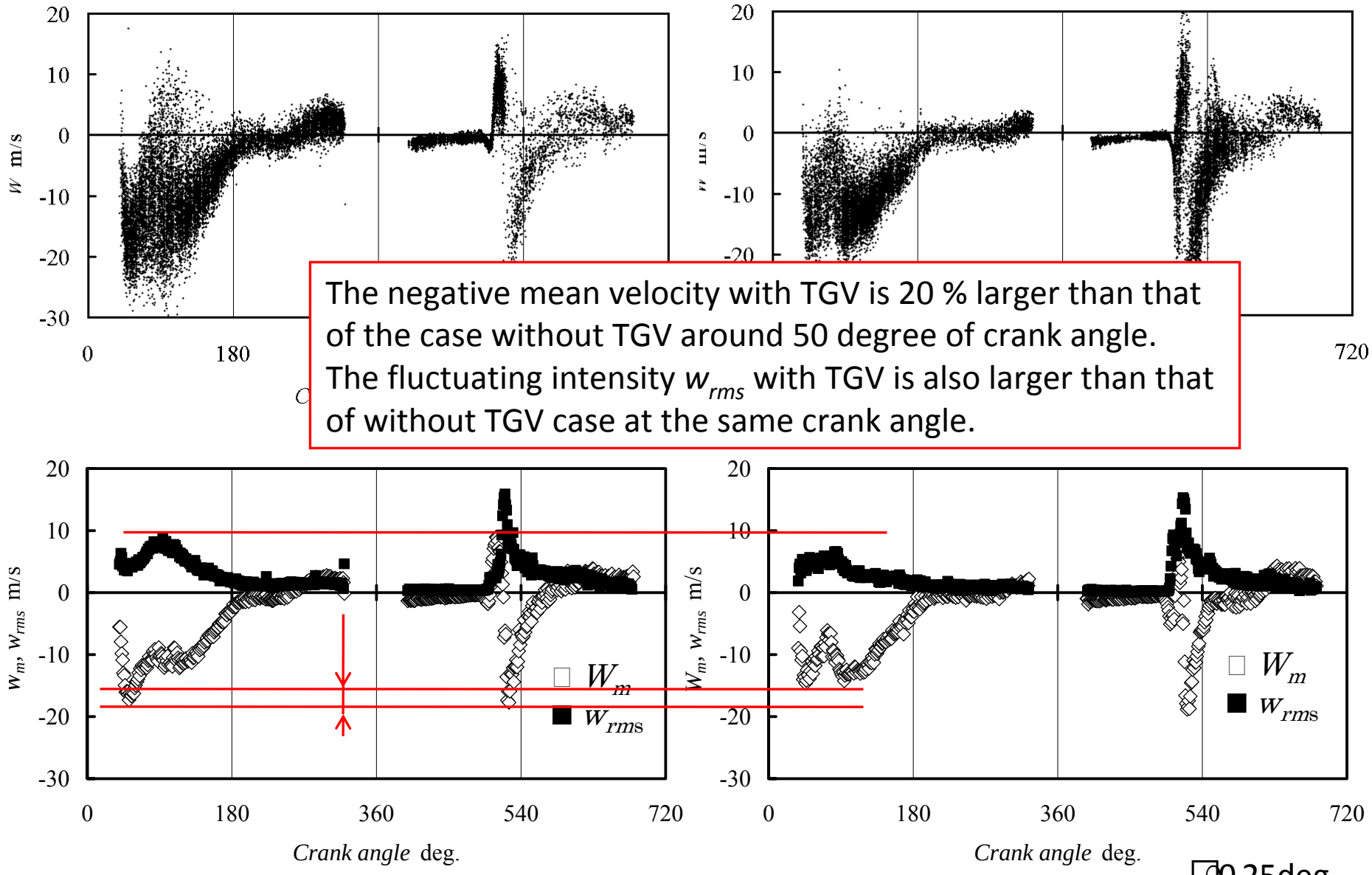
Result 2 Measurement of in-cylinder flow velocity .





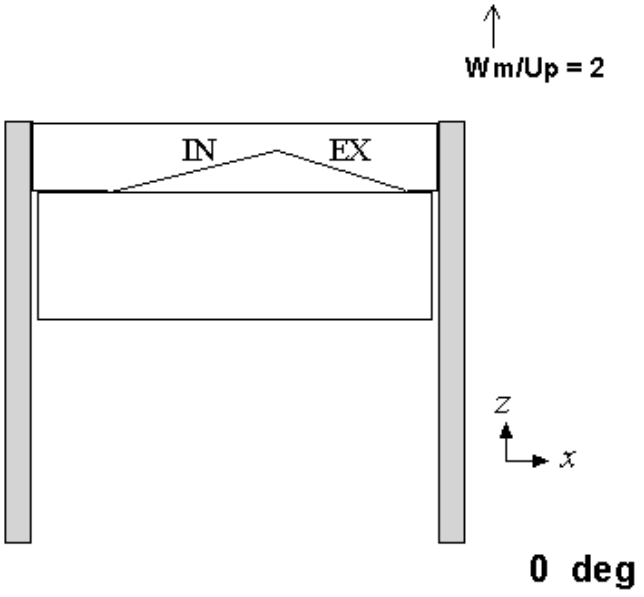
50,000 samples are obtained at all of the measurement points.

The velocity of cylinder and swirl directions on the A-A and B-B planes are measured.
The instantaneous velocity components of *U*, *V* and *W* are directed to *x*, *y* and *z*.

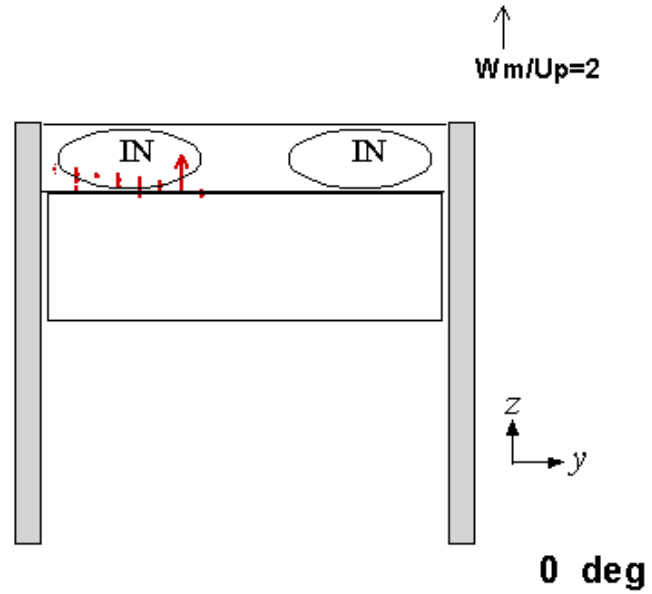


Ensemble averaged mean velocity and fluctuating intensity

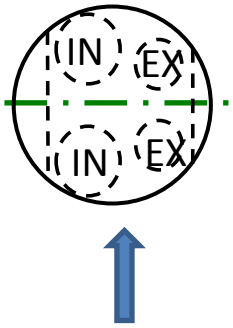
Examples of axial velocity data (x,y,z = 0,0,-10mm)

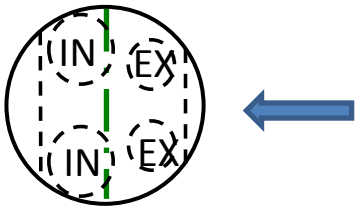


B-B



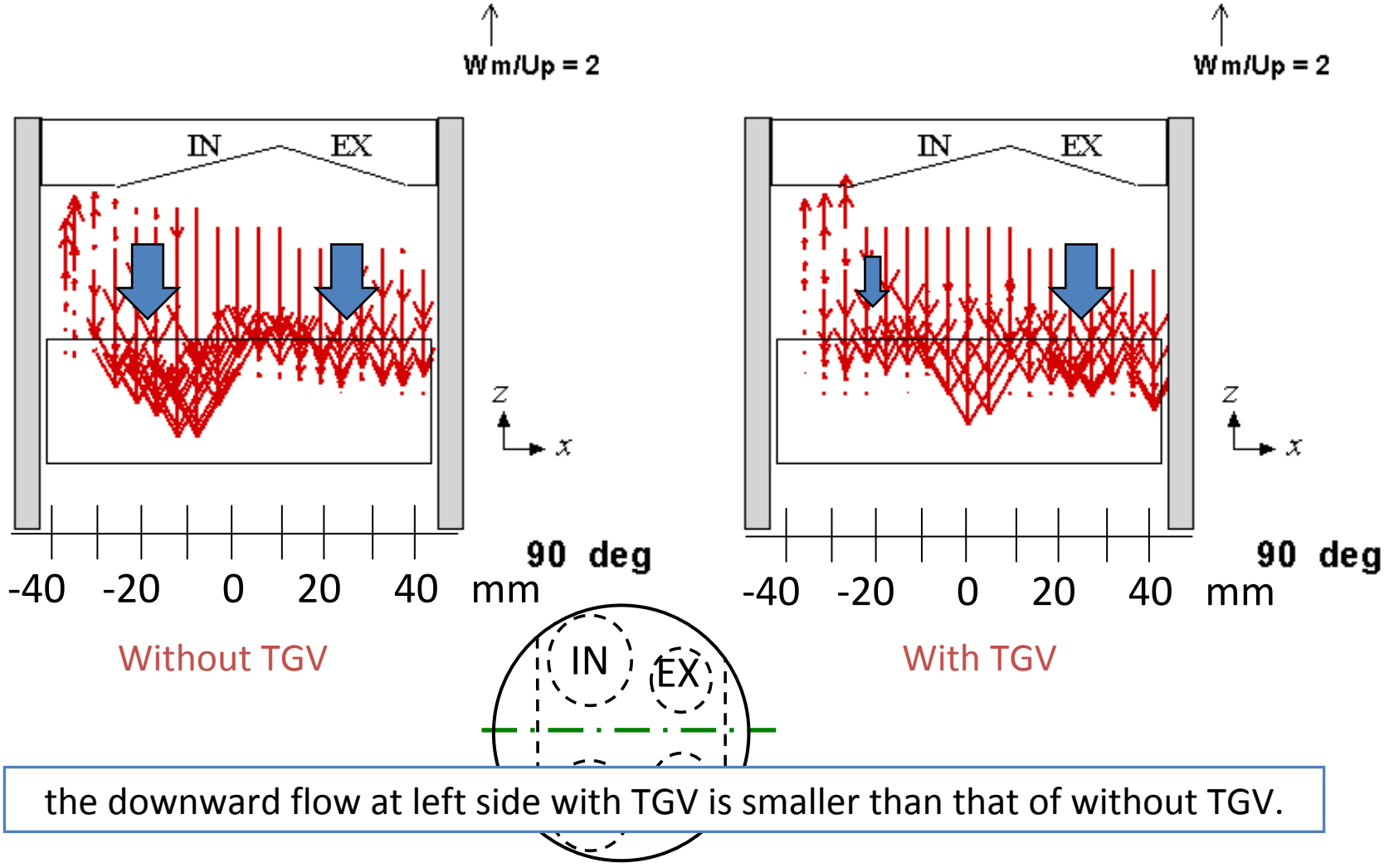
A-A





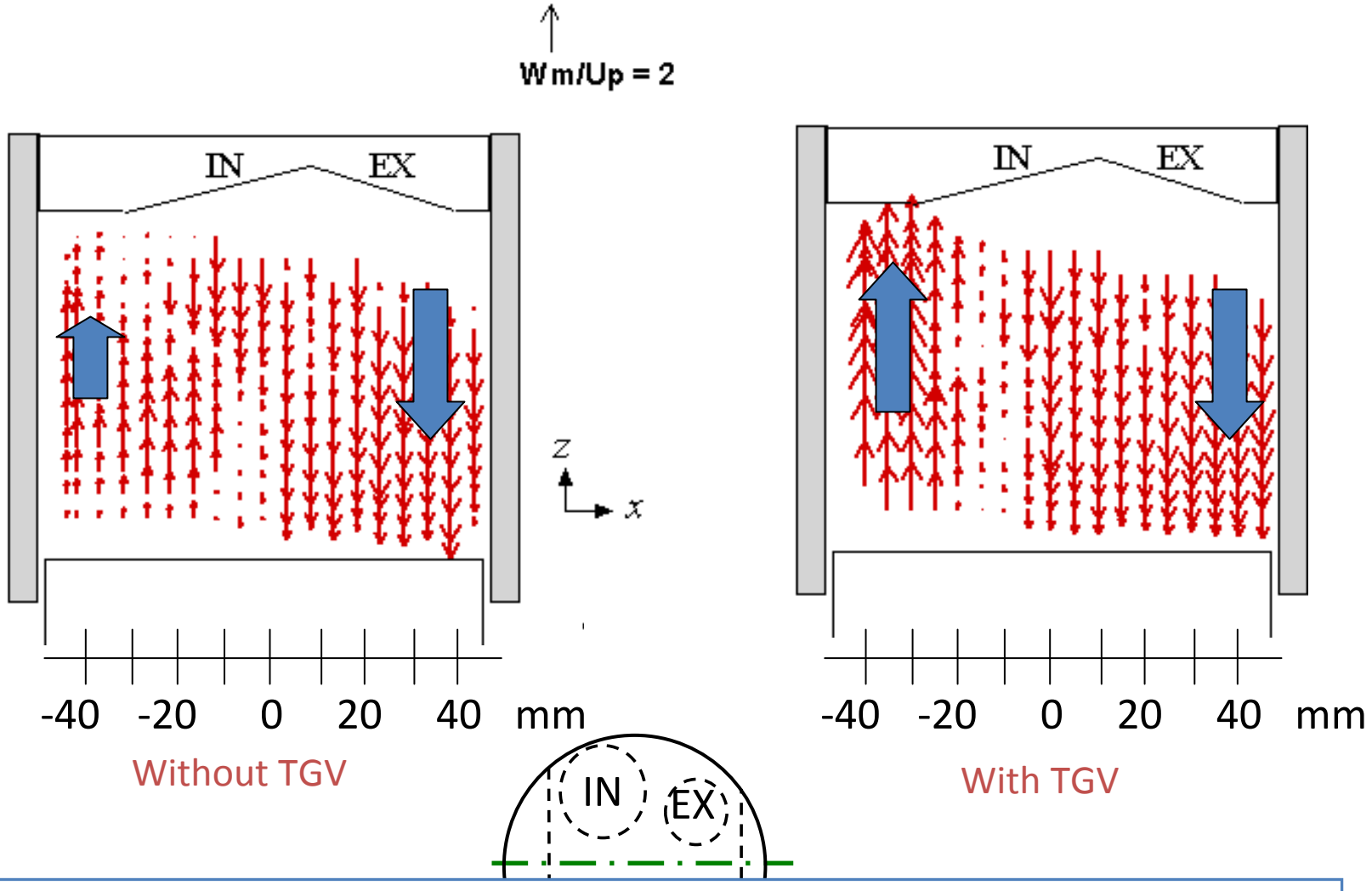
The velocities are normalized by the mean piston velocity

Animation of the ensemble averaged velocity distributions of Wm at vertical section of B□Band A□Awith TGV



the downward flow at left side with TGV is smaller than that of without TGV.

Ensemble averaged velocity distributions of W_m in the vertical section at 90deg.



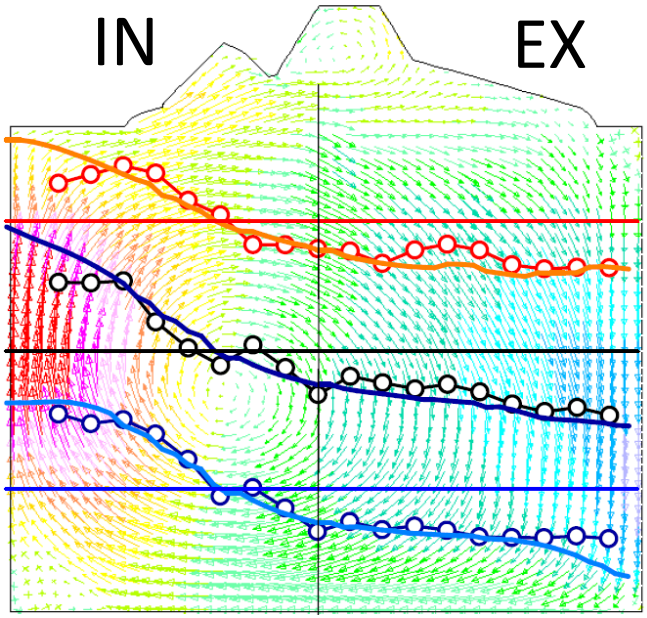
The results indicate the strong tumble motion with TGV condition.
The upward flow at left side is not disturbed by the flow from the intake valve.

Ensemble averaged velocity distributions of W_m in the vertical section at 180deg.

Example of comparison between CFD result and experiment

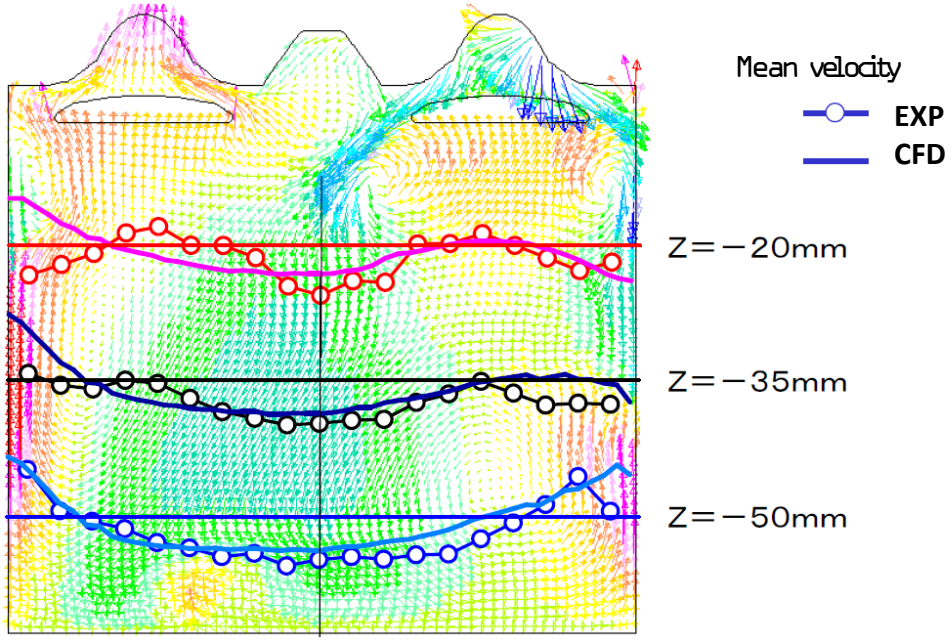
- Vector maps of in-cylinder flow are performed by using the simulation code of STAR-CD.
- Lines show the mean axial velocity distributions by the simulation and marked lines show the mean velocity distributions by the experiment.

This figure was made by Dr. Makoto KANEKO



B-B Plane

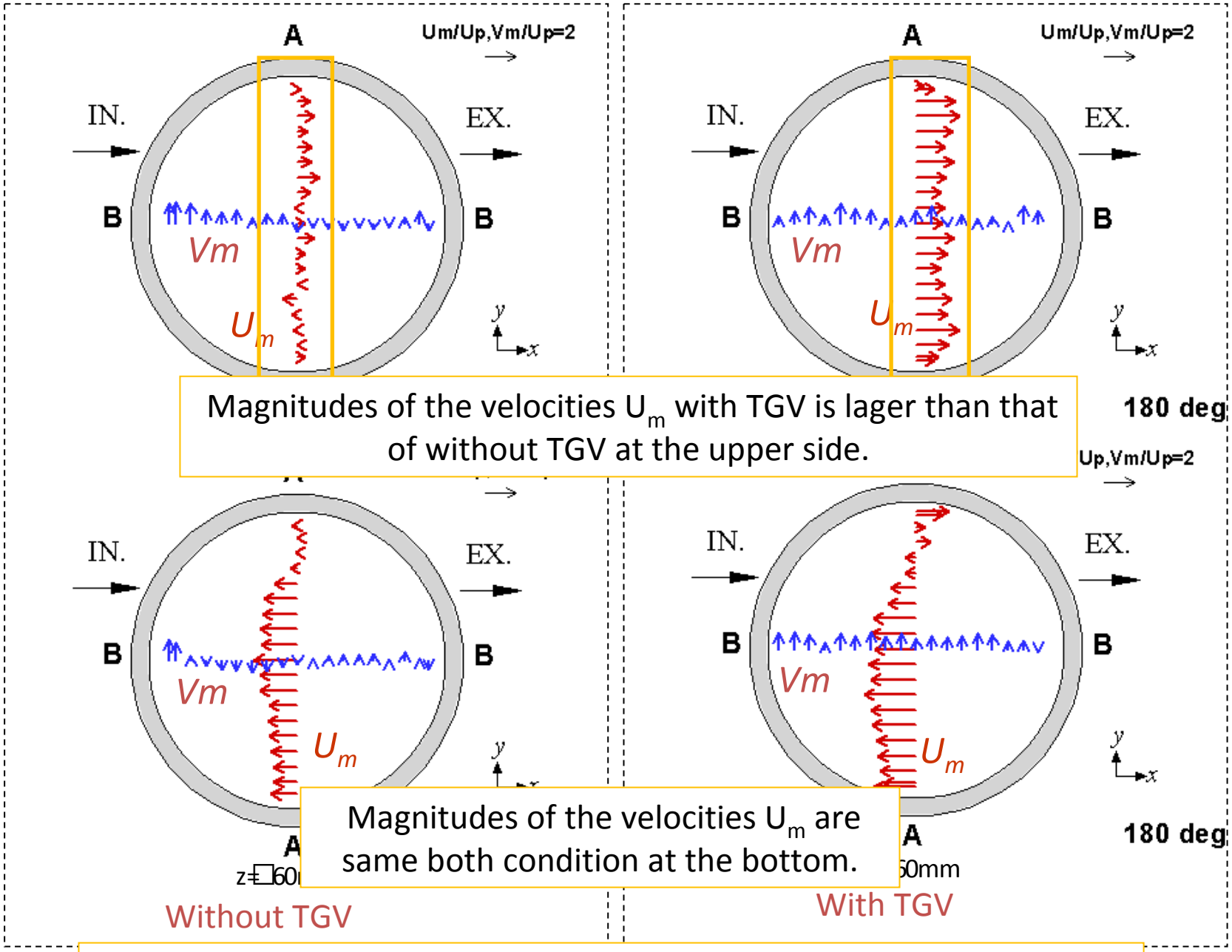
Simulation results are in excellent agreement with experimental results in points of mean velocity distributions and center of the tumble rotation.



A-A Plane

The mainstream on this plane of the simulation result is coincident with that of the experiment.

Axial velocity distributions of A-A and B-B section at 180degree with TGV.



Magnitudes of the velocities U_m with TGV is lager than that of without TGV at the upper side.

Magnitudes of the velocities U_m are same both condition at the bottom.

The effect of the TGV at upper side of the cylinder become large compared with lower side of the cylinder.

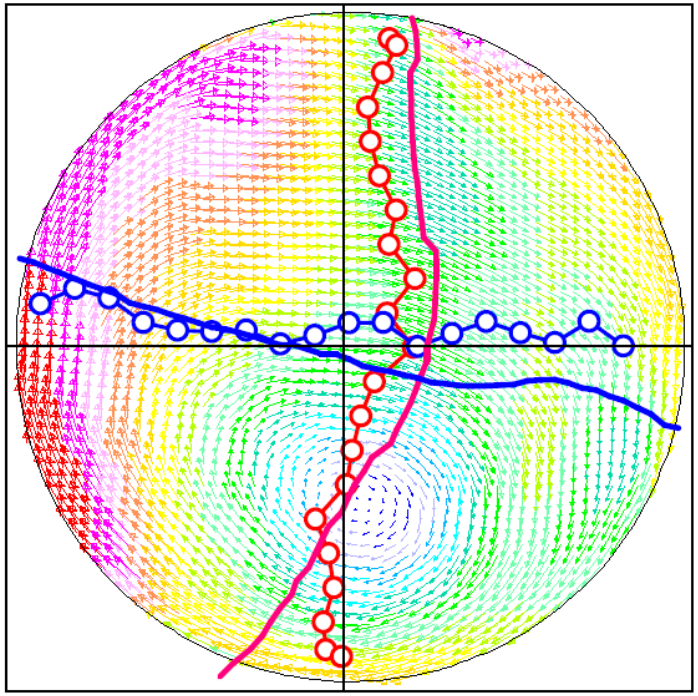
Ensembl

0deg.

Example of comparison between CFD result and experiment

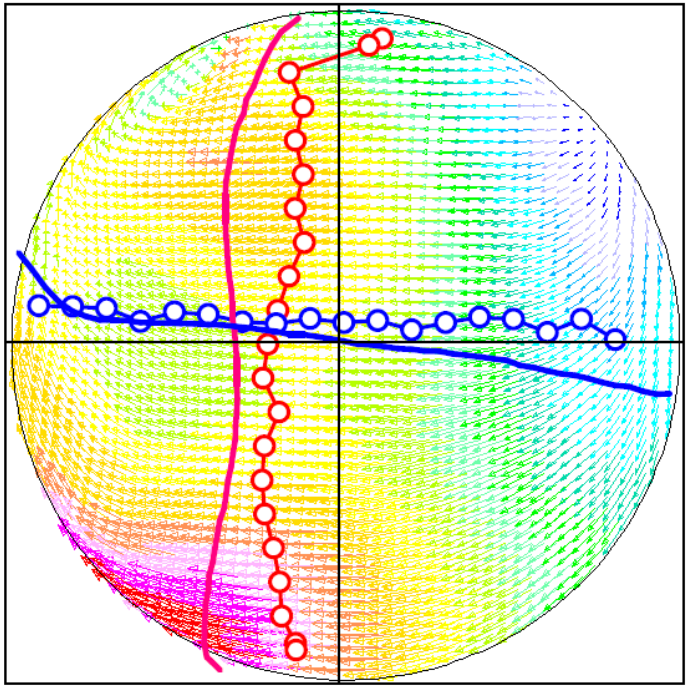
- Vector maps of in-cylinder flow are performed by using the simulation code of STAR-CD.
- Lines show the mean swirl direction velocity distributions by the simulation and marked lines show the mean velocity distributions by the experiment.

This figure was made by Dr. Makoto KANEKO



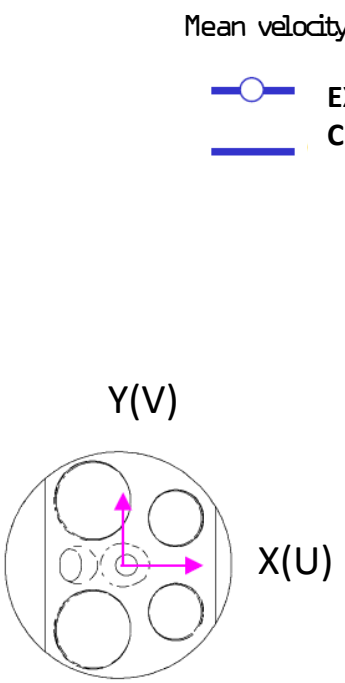
Z=-20 mm

Velocity distributions of simulation are roughly coincident with the result of the experiment.



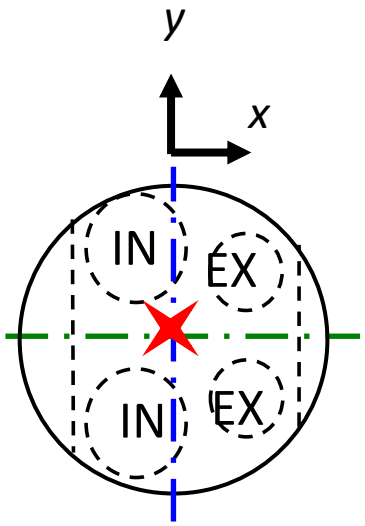
Z=-50 mm

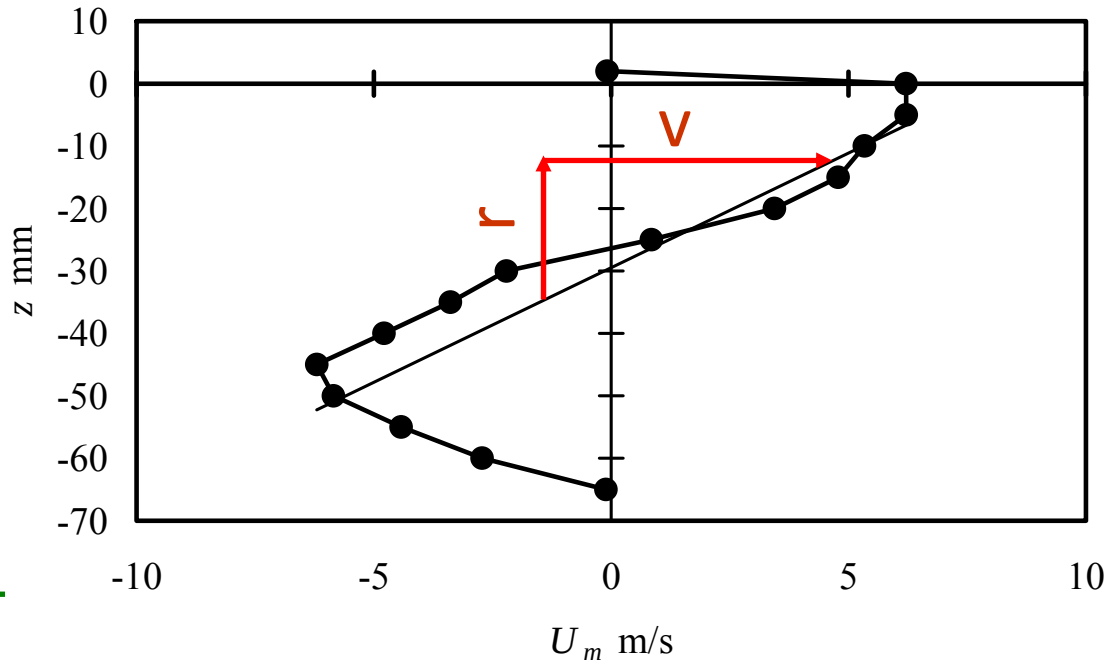
Velocity magnitudes at X direction of the simulation is lager those of the experiment. The tendency of the velocity distributions are same with both conditions.



Swirl direction velocity distributions of transversal section at 240degree with TGV.

Result 3 Tumble ratio





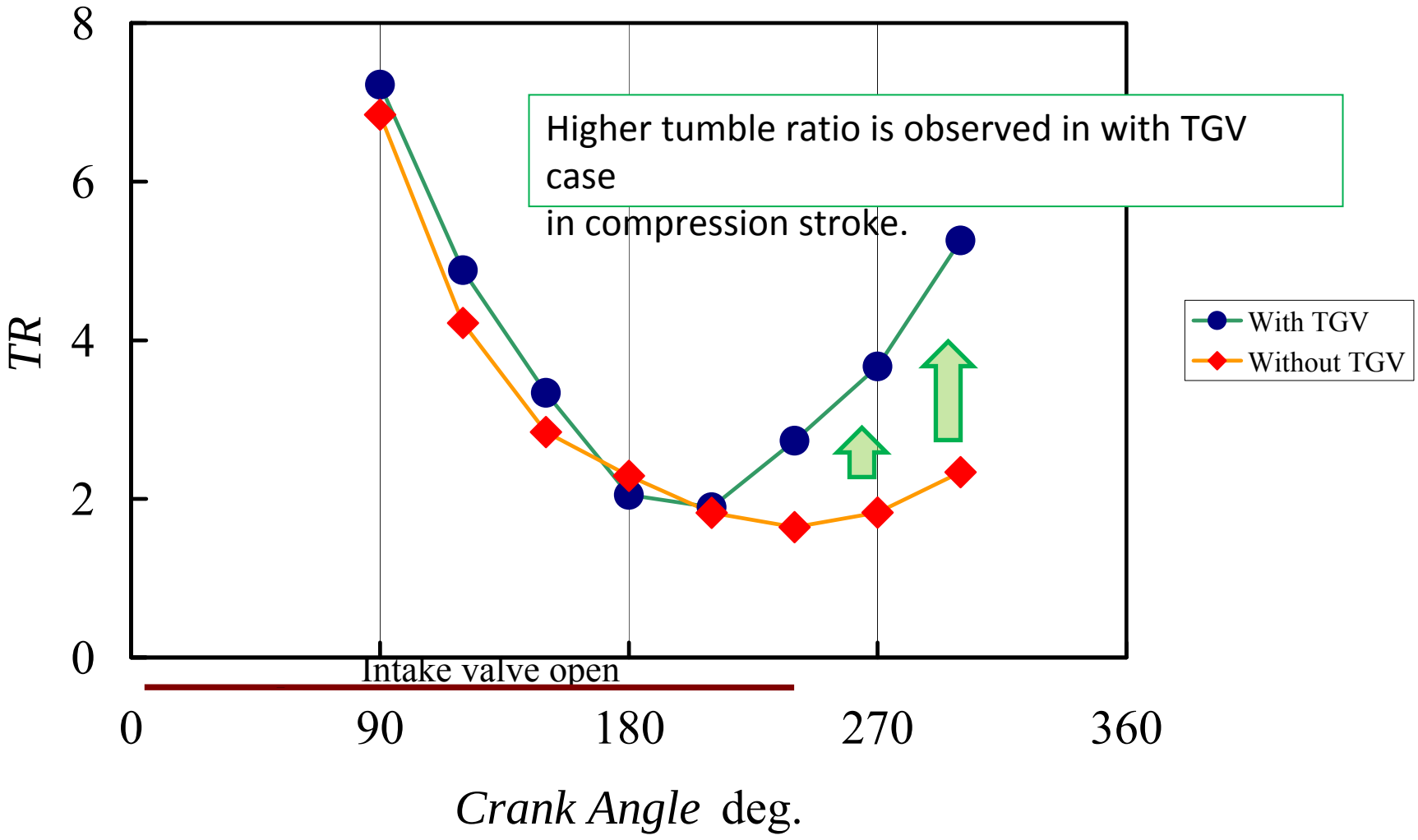
$$\text{Tumble ratio} = \frac{V}{r}$$

- Linear approximation by least squared method is obtained from velocity distribution in vertical section of the cylinder.

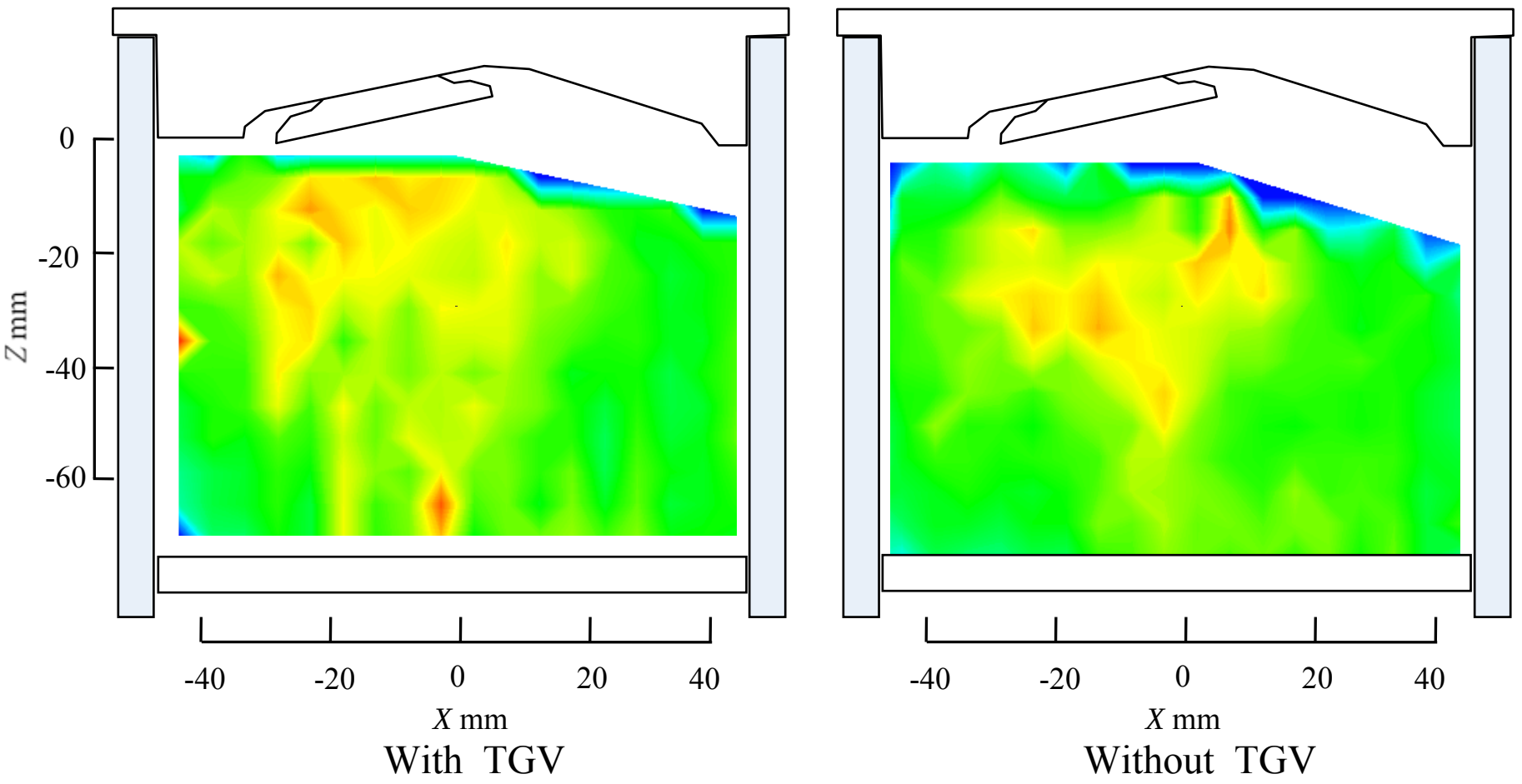
- It assumes that the angular velocity is inverse number of the gradient of that.

- This shows the simple tumble ratio in this presentation.

Tumble ratio

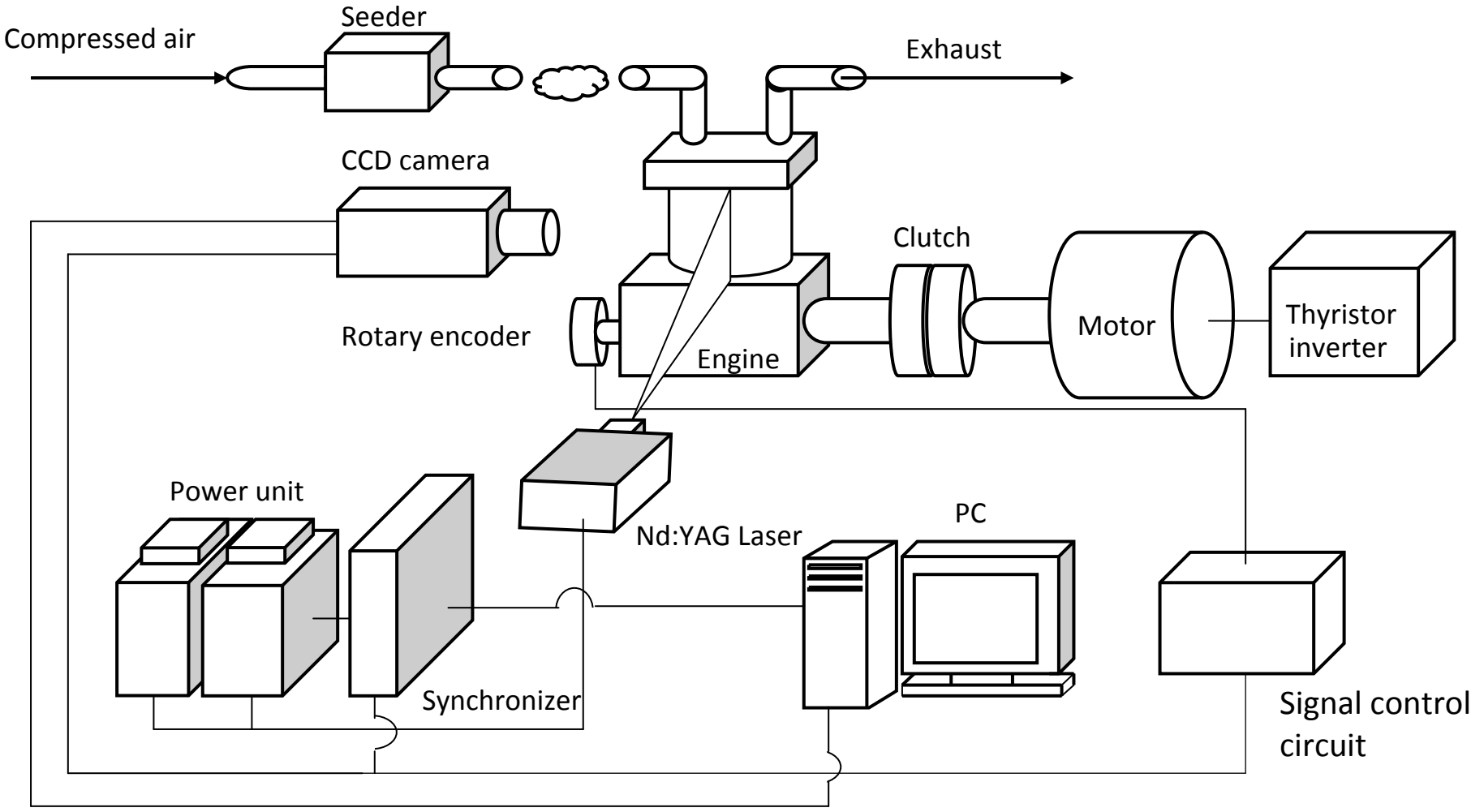


Result 4 Fluctuating intensity



Fluctuating intensity distributions of W_{rms} on vertical section at 180deg.

EXPERIMENTAL SETUP (PIV)



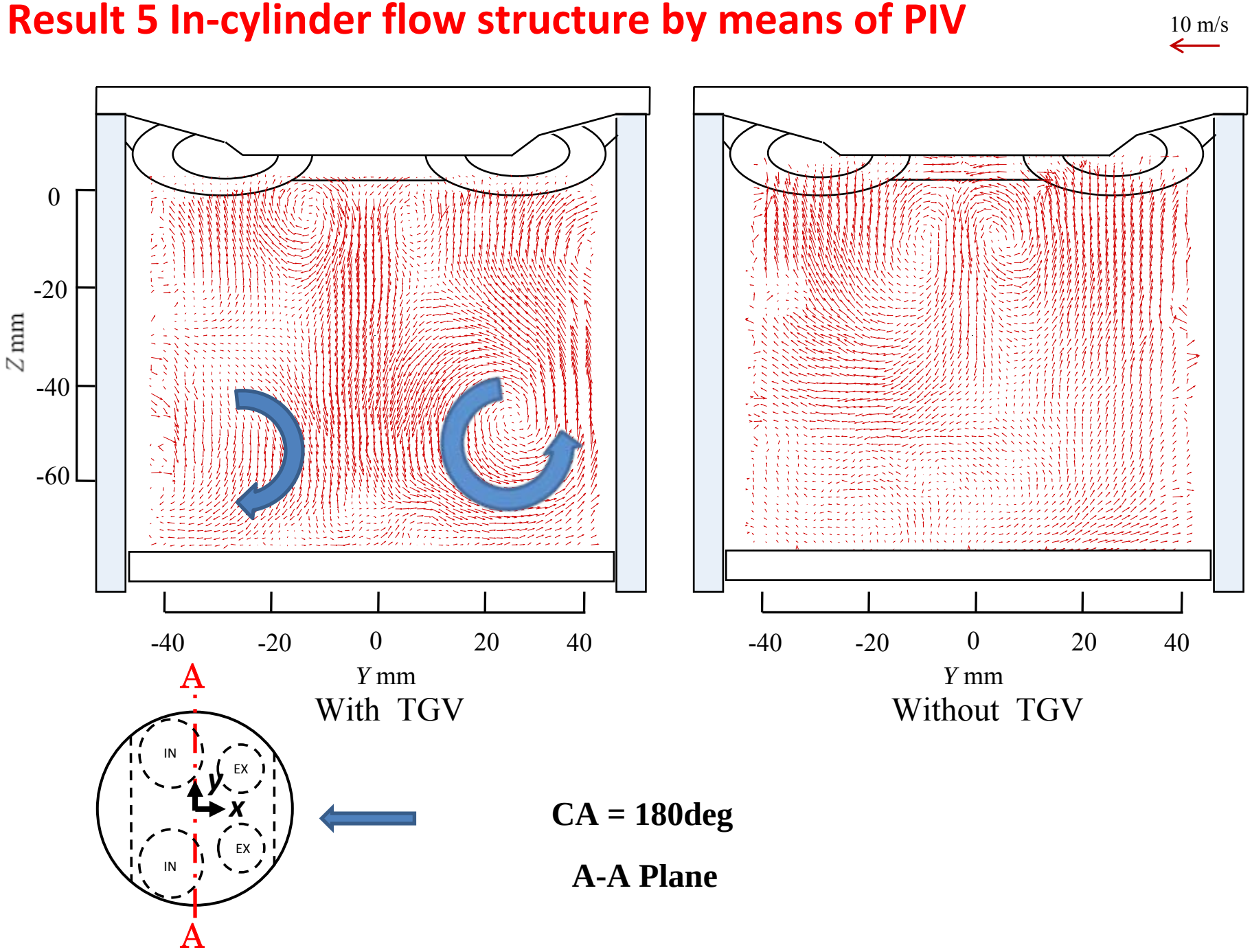
Specifications of PIV

Laser source	Double pulses Nd:YAG
Wave length	532.8nm
Laser Thickness	1.0mm
CCD Camera definition	1000×1016pix
Interrogation area	32×32pix
Actual Interrogation area	3.0×3.0mm
Pulse interval	10μs□20μs
Over lap	50%

TiO_2(KURONOS TITAN 2220)

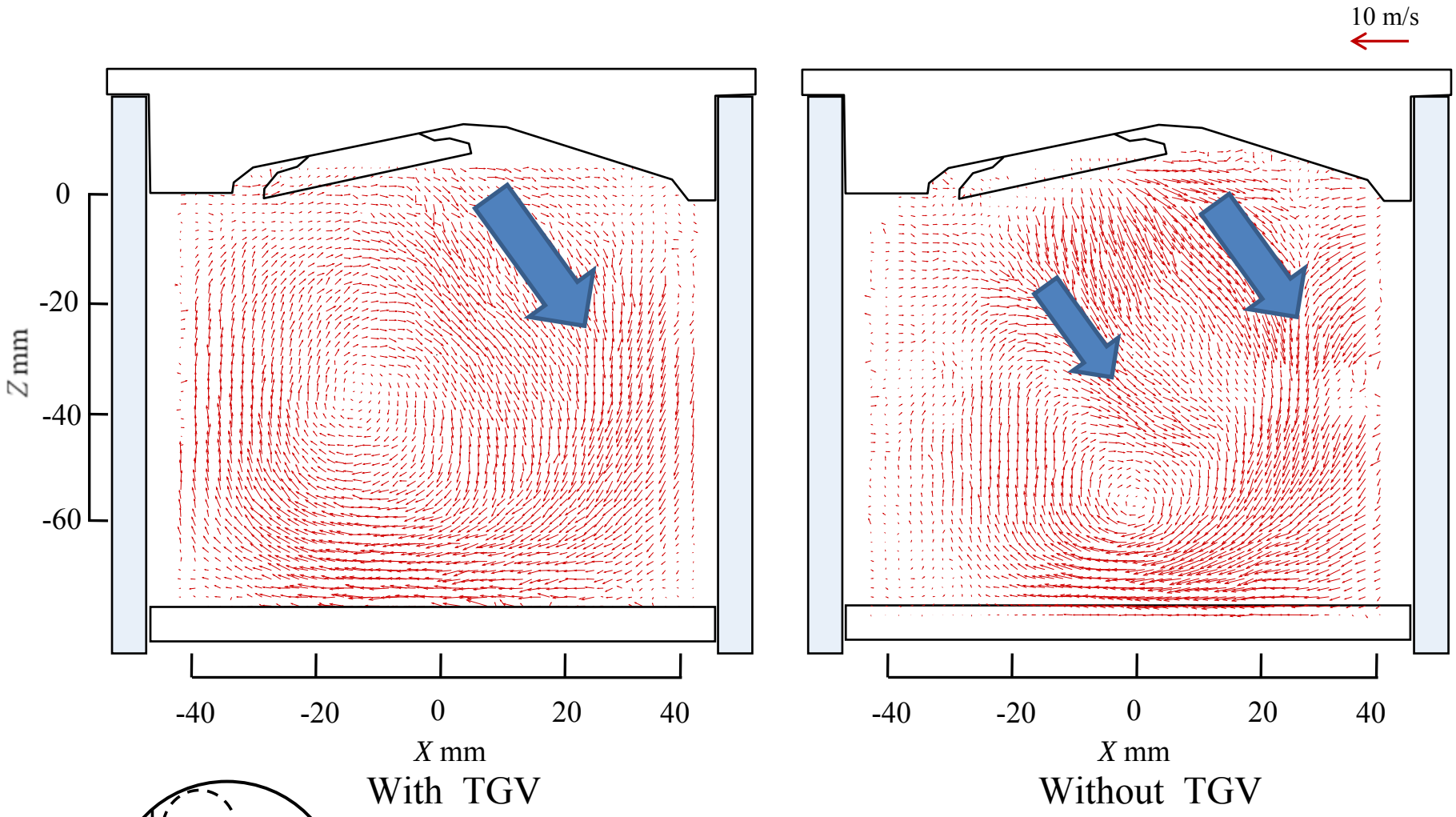
Mean particle size	0.4 μm
Density	4.0 g/cm^3
Apparent relative density	900 kg/m^3

Result 5 In-cylinder flow structure by means of PIV



CA = 180deg

A-A Plane

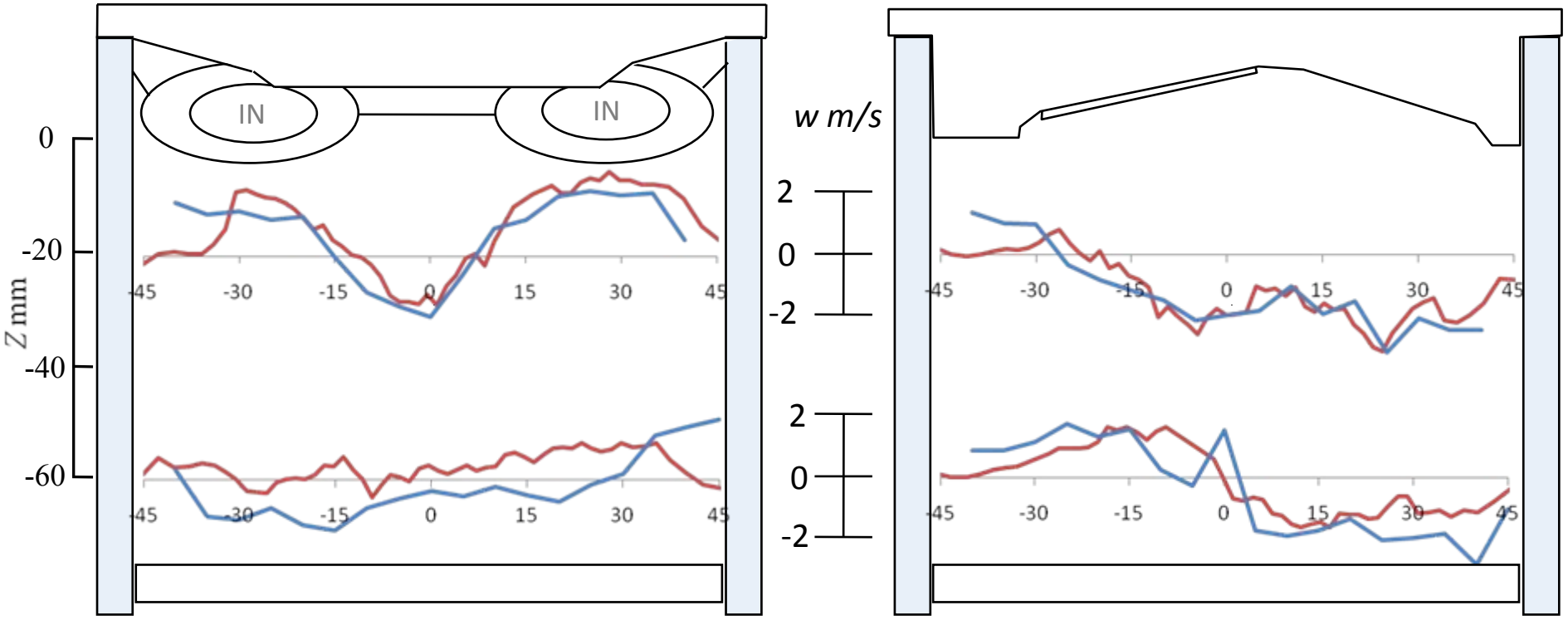


CA = 180deg

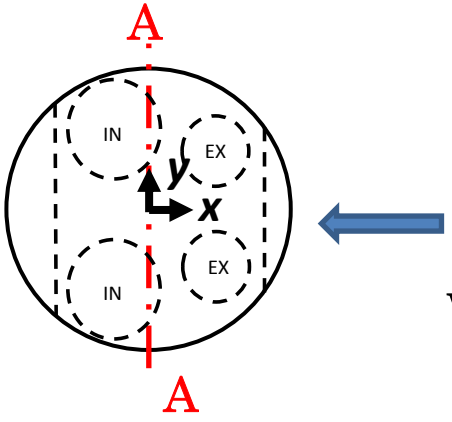
B-B Plane

Result 6 Comparisons between LDA and PIV

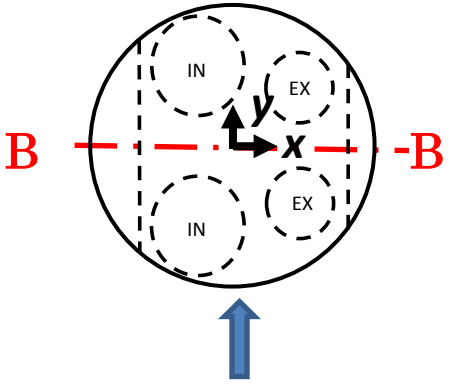
PIV LDA



A-A Plane

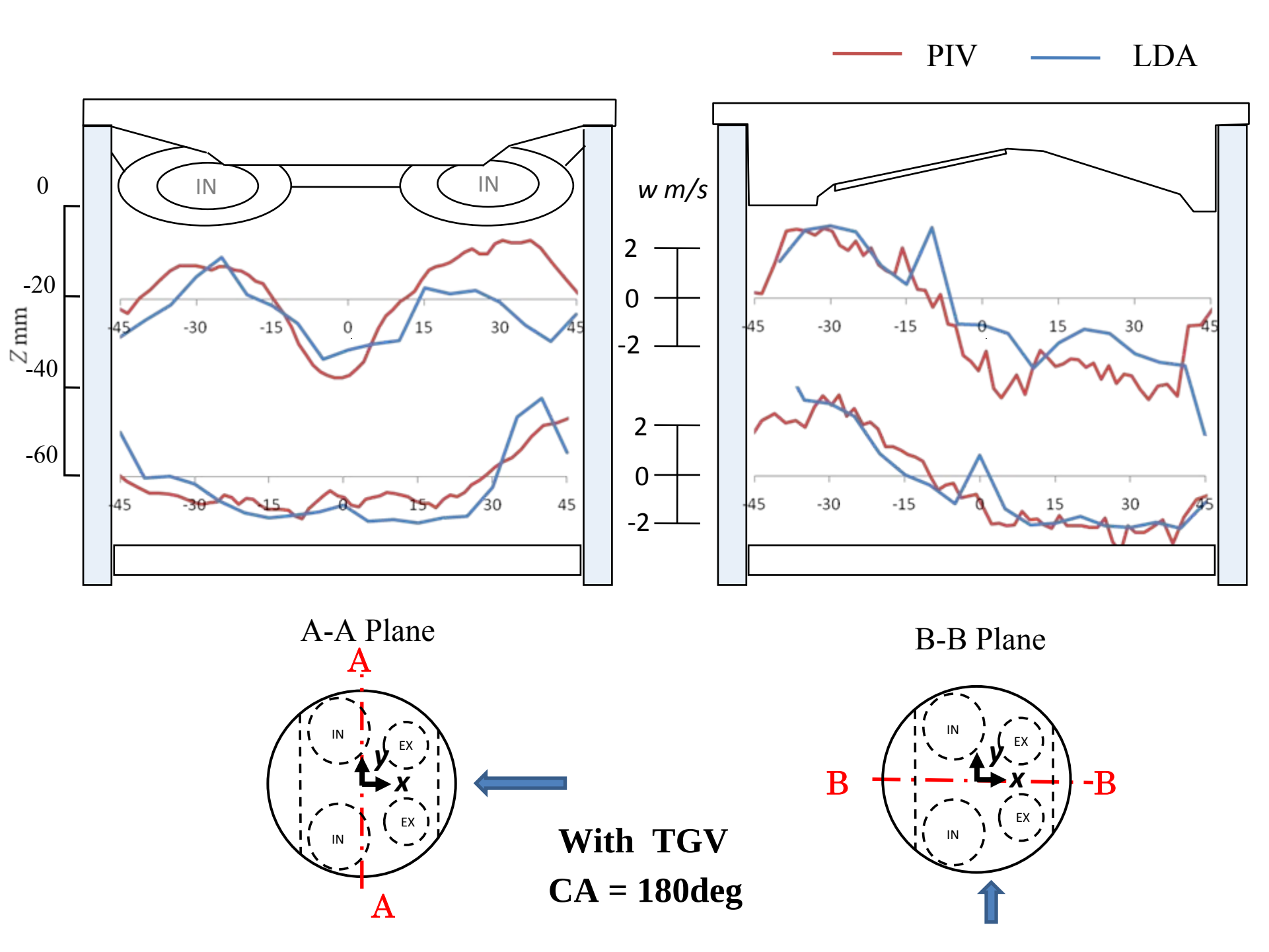


B-B Plane



Without TGV

CA = 180deg


PIV
LDA
IN
IN
0
-20
-40
-60
Z mm
w m/s
2
0
-2
2
0
-2
-45
-30
-15
0
15
30
45
A-A Plane
A
IN
EX
IN
EX
y
x
A
With TGV
CA = 180deg
B-B Plane
B
-B
IN
EX
IN
EX
y
x

CONCLUSION

- Velocity distributions in two-directions are obtained with each crank angle. They can be used for verification of numerical simulations.

- The effect of TGV is clarified by the experimental data. The effect of the TGV is remarkable in the upper side of the cylinder.

- From the PIV measurement, the effect of the TGV is observed at the compression stroke compared with the result without TGV.

- Velocity distributions by means of LDA and PIV nearly correspond throughout the cylinder.

Thank you for your attention.