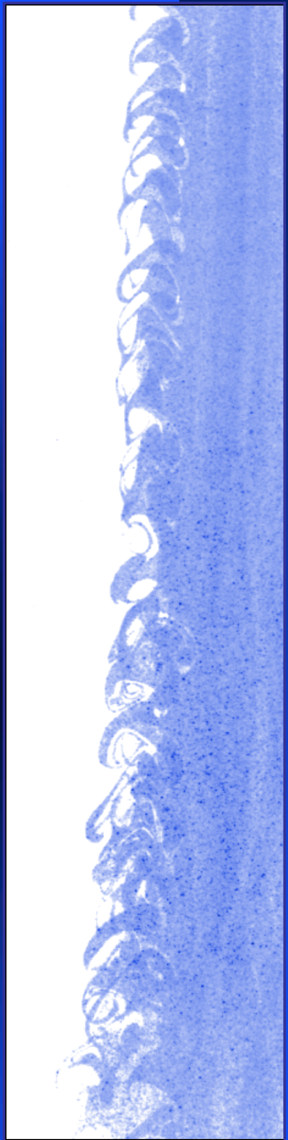

28th October 2002, Universität Magdeburg

Particle Flow Field in Electrostatic Precipitator

/ numerical simulation, turbulence modification study and experimental investigation via LDV /

J.M. Suda

Research co-operation with Otto-von-Guericke Universität Magdeburg

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MŰEGYETEM 1782

DEPARTMENT of FLUID MECHANICS
Budapest University of Technology and Economics

Objectives

R+D on dust separation process: „Investigation on dust particle motion in EHD flow field in *e*lectro*s*tatic *p*recipitator /ESP/" Ph.D. research project

N^r1) Numerical simulation

particle / gas flow field, dust concentration distribution, streamlines, turbulence characteristics, particle transport, etc.

N^r2) Experimental investigation

on turbulent flow field with Laser Doppler Velocimetry
(co-operation with Universität Magdeburg)

N^r3) Turbulence modification study

particle / gas interaction in two-phase flow, PIV, PTV(S), PDA, LDV
(diploma course at Von Karman Institute for Fluid Dynamics, 1999/2000)

Related publications:

Suda, J., Wunderlich, B., Lanzke, A., Kiss, I. and Pap, E. (2002) **On the Measurements of Particle Flow Field in an Electrostatic Precipitator with Laser Doppler Velocimetry.** *2nd Conf. on Mech. Eng.* GEPESZET'2002 Budapest HUNGARY 2002 May 30-31.

Suda, J. and Zimmer, L. (2002) **Single- and Two-Phase Flow Measurements in a Plane Free Shear Flow via PIV and PTV(S) Techniques.** *2nd Conf. on Mech. Eng.* GEPESZET'2002 Budapest HUNGARY 2002 May 30-31.

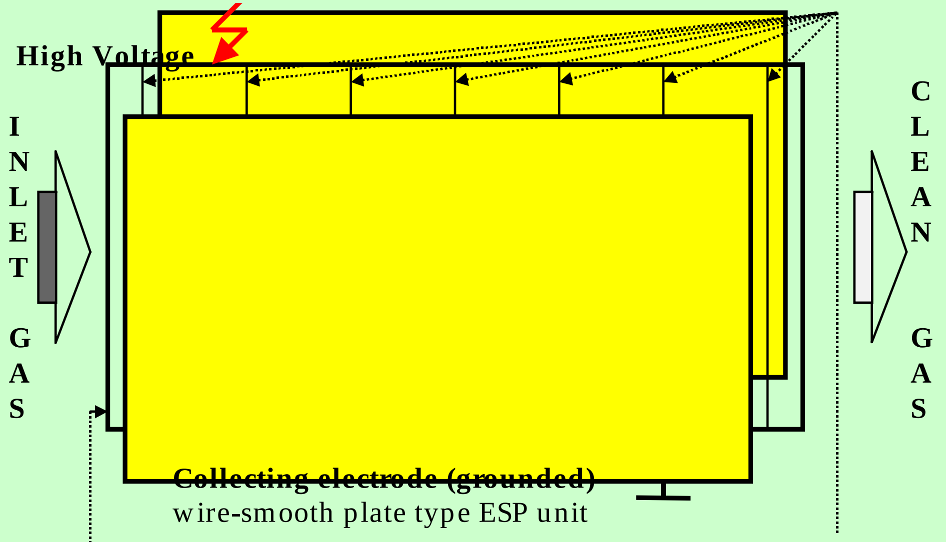
Suda, J., Kiss, I., Lajos, T. and Berta, I. (2001) **Study of Particle Dispersion and Turbulence Modification Phenomena in ESPs**. *8th Int. Conf. on Electrostatic Precipitation* ICESP VIII Birmingham /AL/ USA, 2001 May 14 - 17.

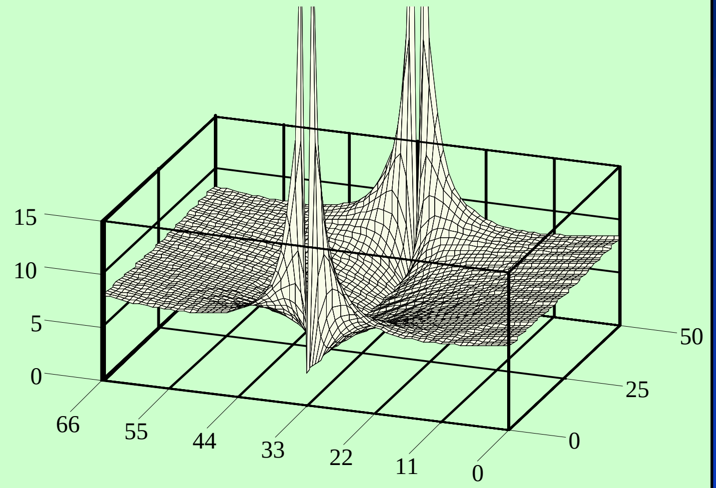
Suda, J., Zimmer, L. and Buchlin, J-M. (2001) **Experimental Investigation on Turbulence Modification by Droplets in Shear Layer Flow.** *4th Int. Conf. on Multiphase Flow* ICMF 2001 New Orleans /LA/ USA, 2001 May 27. - June 1.

Electrostatic Precipitation: gas/particle flow in electrostatically charged field

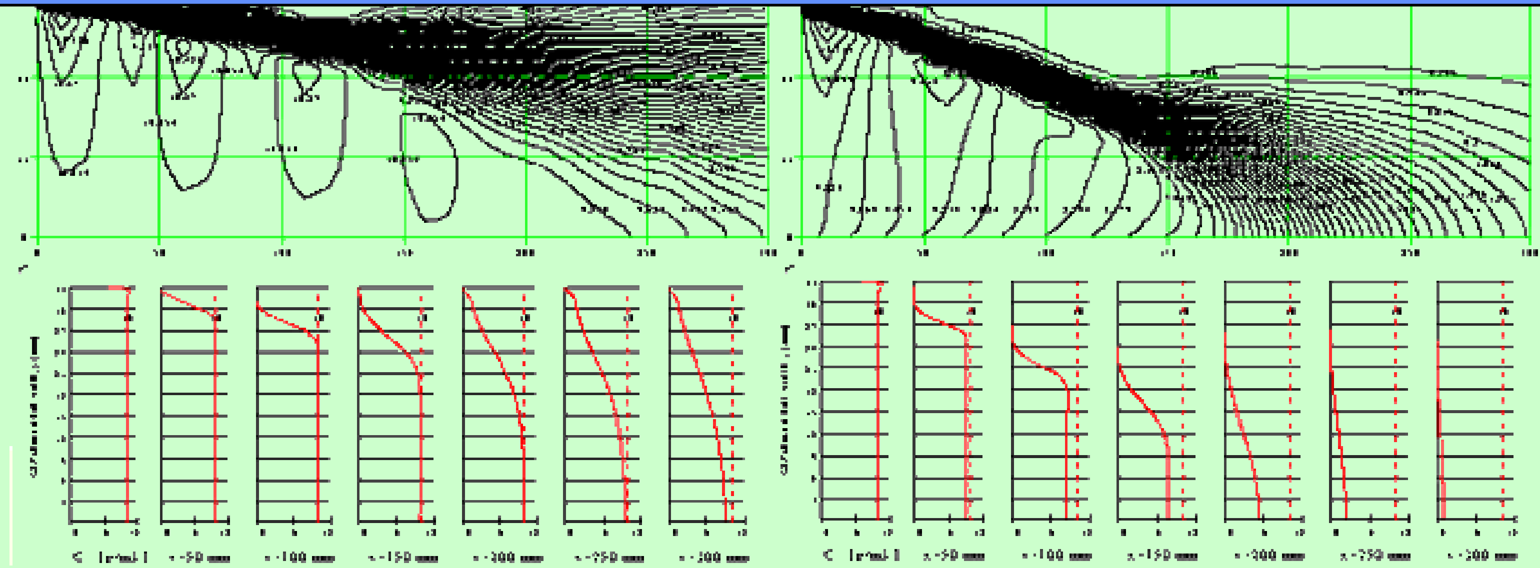
ESP channel: discharge wires between parallel collecting plates

Nr1)





Numerical simulation: particle concentration field - contours, profiles in one channel



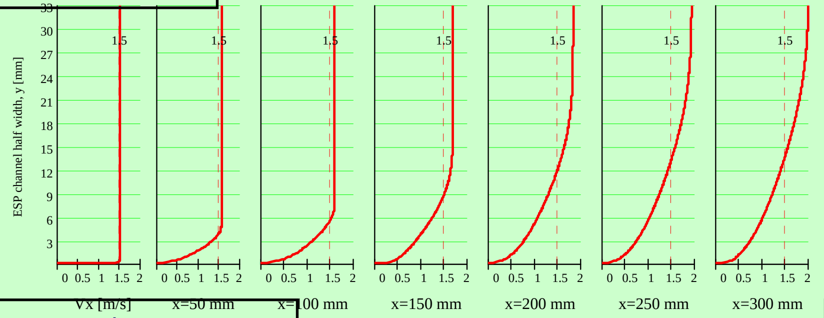
Electrostatic Precipitation: gas/particle flow in electrostatically charged field

ESP channel: discharge wires between parallel collecting plates

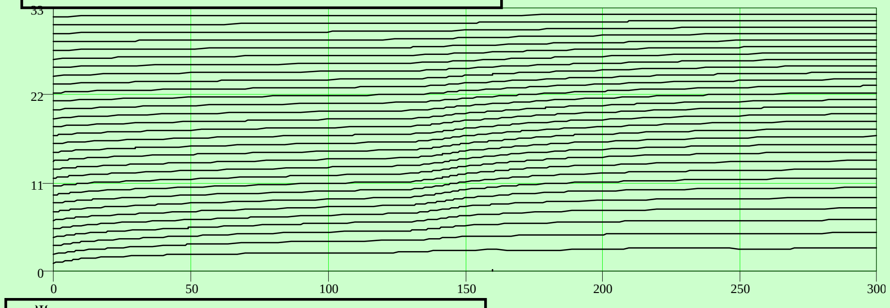
Nr1)

Numerical simulation: velocity and particle concentration field in one ESP channel

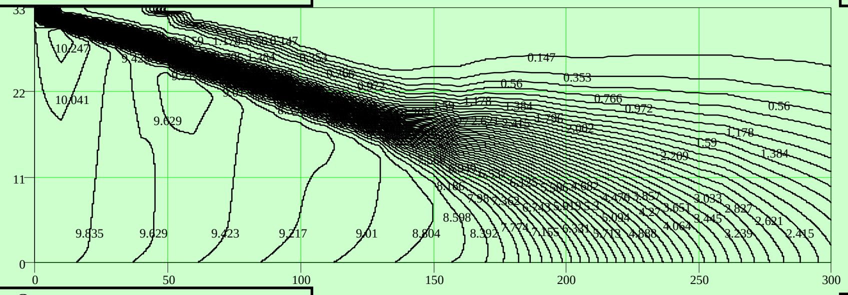
Velocity profiles



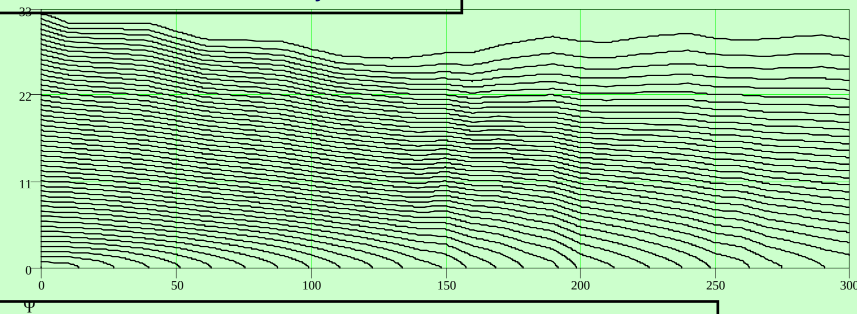
Particle streamlines, E = 0 kV/cm



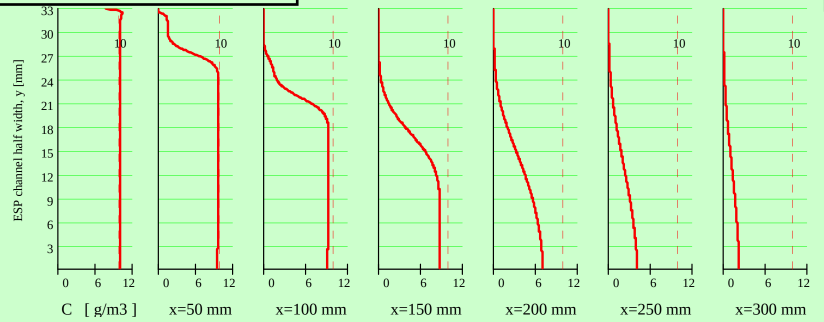
Concentration contours



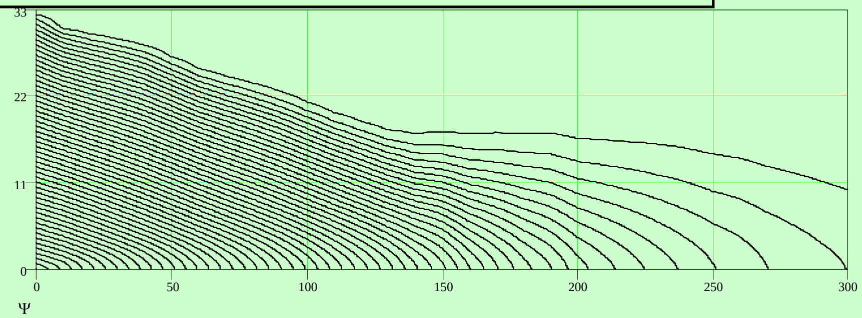
Particle streamlines, E = Eystat



Concentration profiles

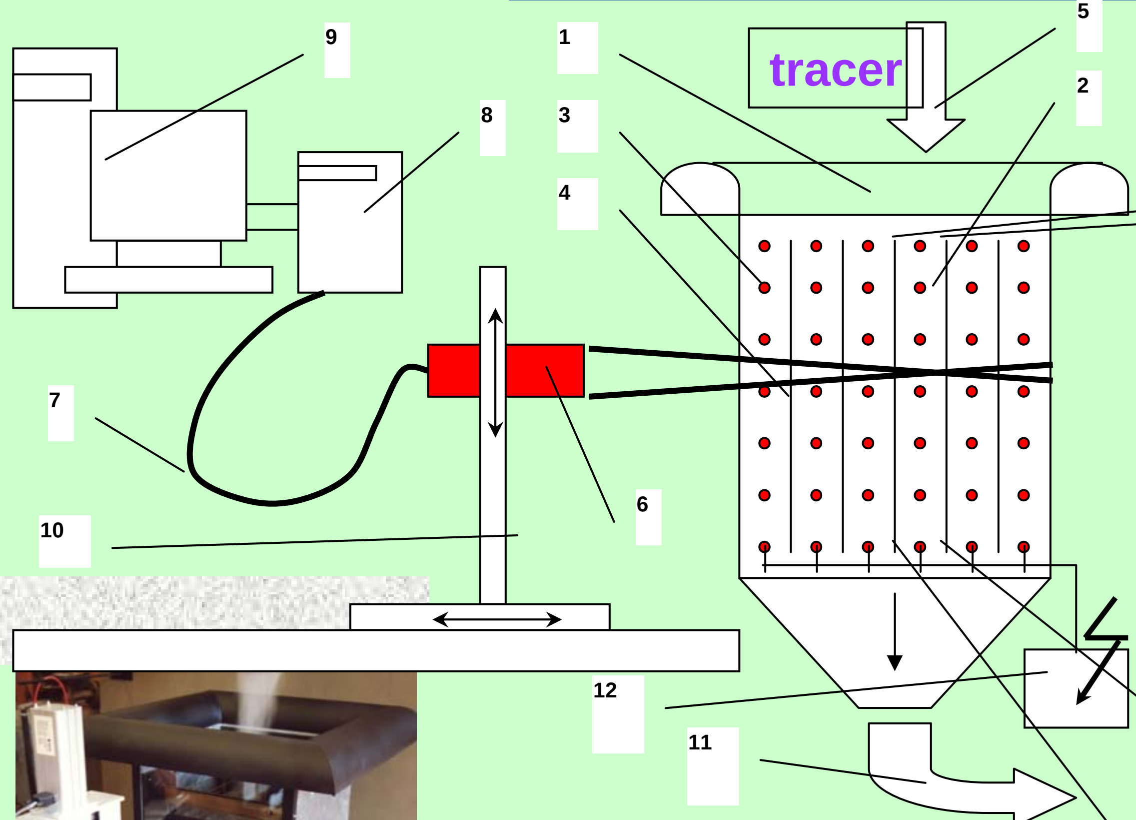


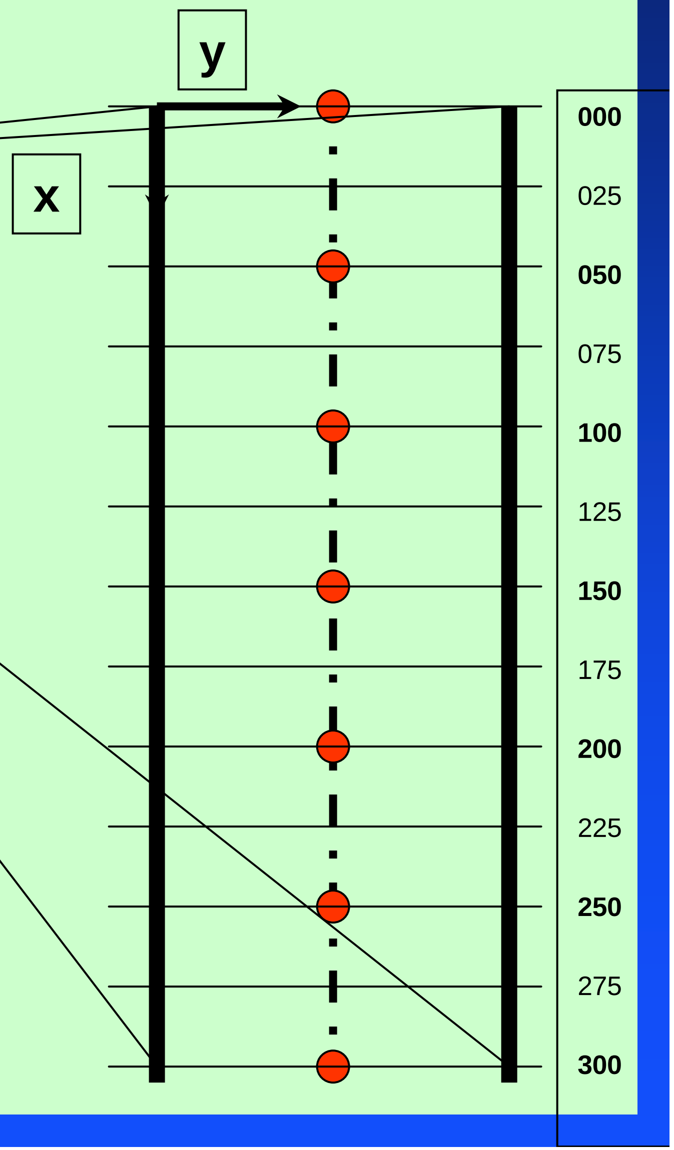
Particle streamlines, E = Eystat + E ion+dust space charge



Nr2)

Experimental Apparatus - model ESP

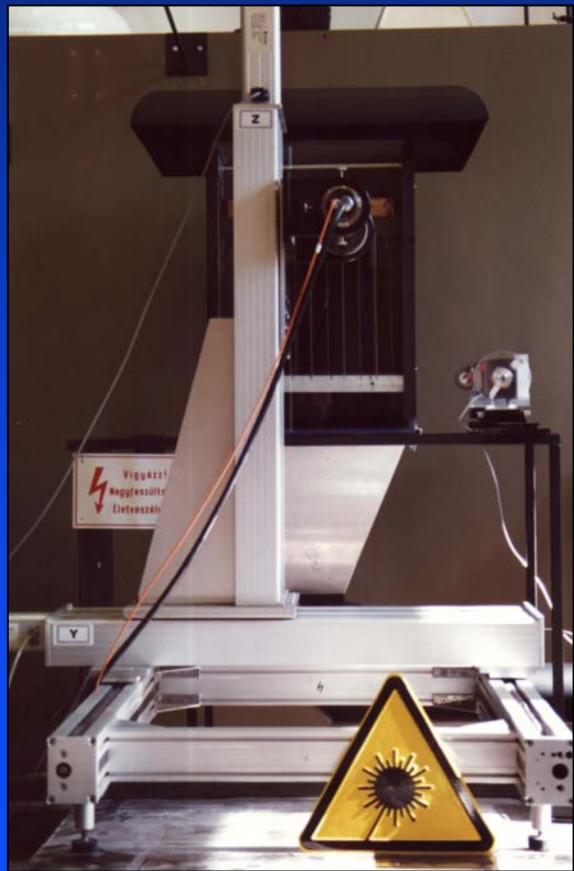




1 Model ESP
2 ESP channels
3 Corona electrodes
4 Collecting electrodes
5 Seeding
6 Polytec LDV 380
7 Optical cable
8 LDE 300 Controller and Flow Velocity Analyzer
9 Data processing PC
10 Positioning System of DANTEC
11 Tubing to the fan
12 High voltage power supply unit

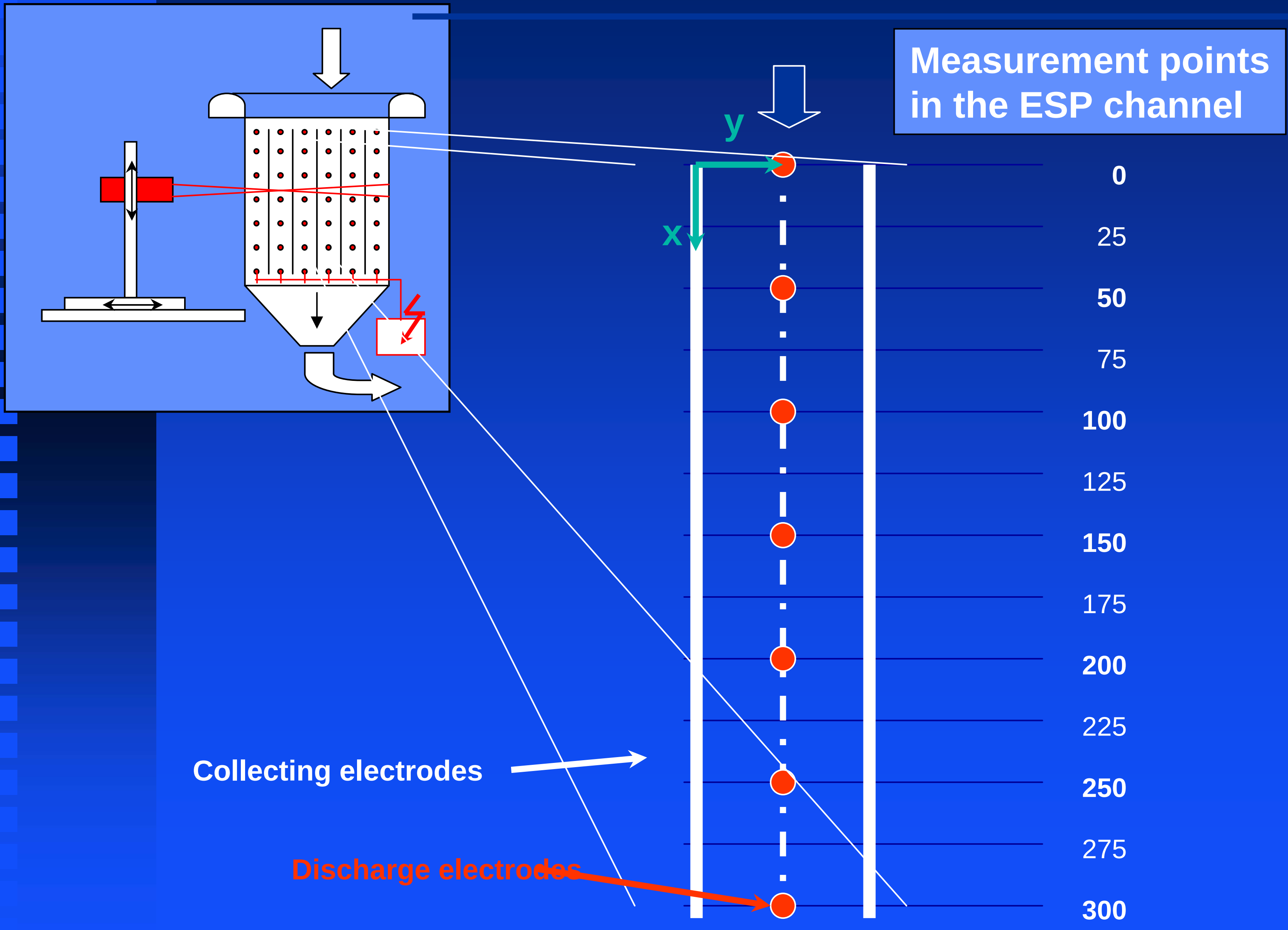
Nr2)

Experimental Apparatus



Nr2)

Experimental Apparatus



Nr2)

Laser Doppler Velocimeter

Polytec LDV 380

1D one velocity component

3D positioning system

λ = 810 nm (infrared beam)

D_L= 2.1 mm

D = 60 mm

F = 310 mm

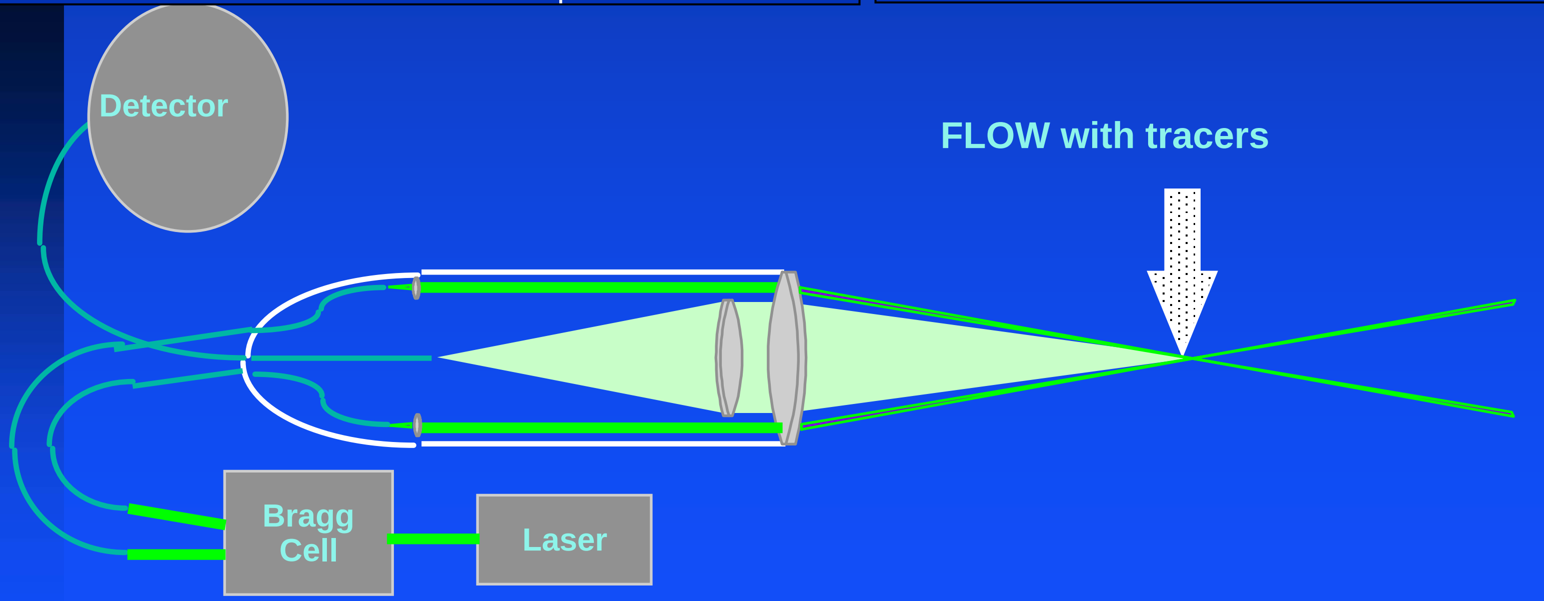
Seeding: particle mean dia: $d_{p\ 50}$=1,54 μm

Parameters to investigate:

Convective transport: u_{in} = 1, 1.5, 2 m/s, various inlet velocity - influence of convective transport

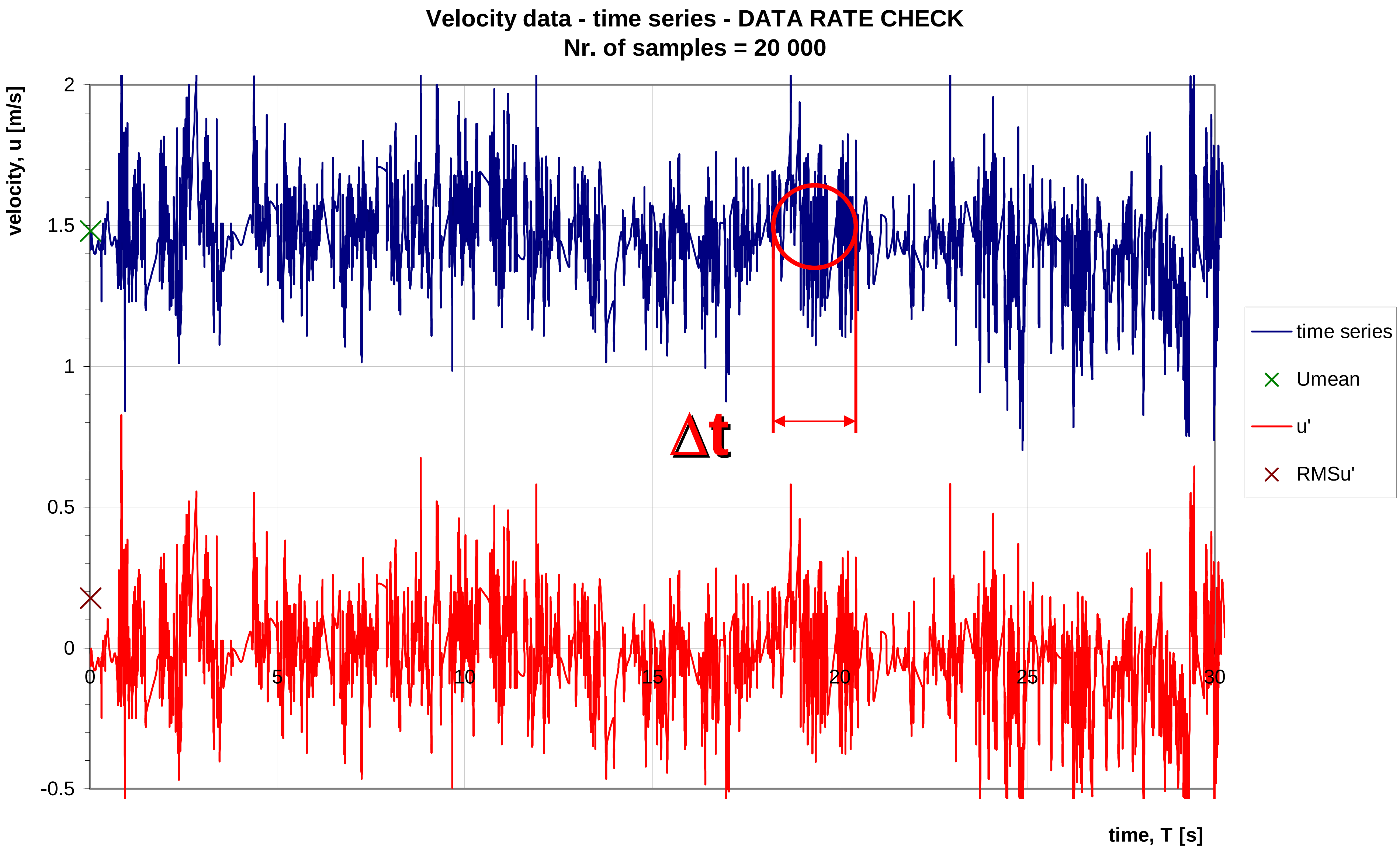
Diffusive transport: streamwise and transversal *rms and* **T.I.** turbulence intensity change

Electrostatic transport: U_0= 0- 18 kV applied high voltage



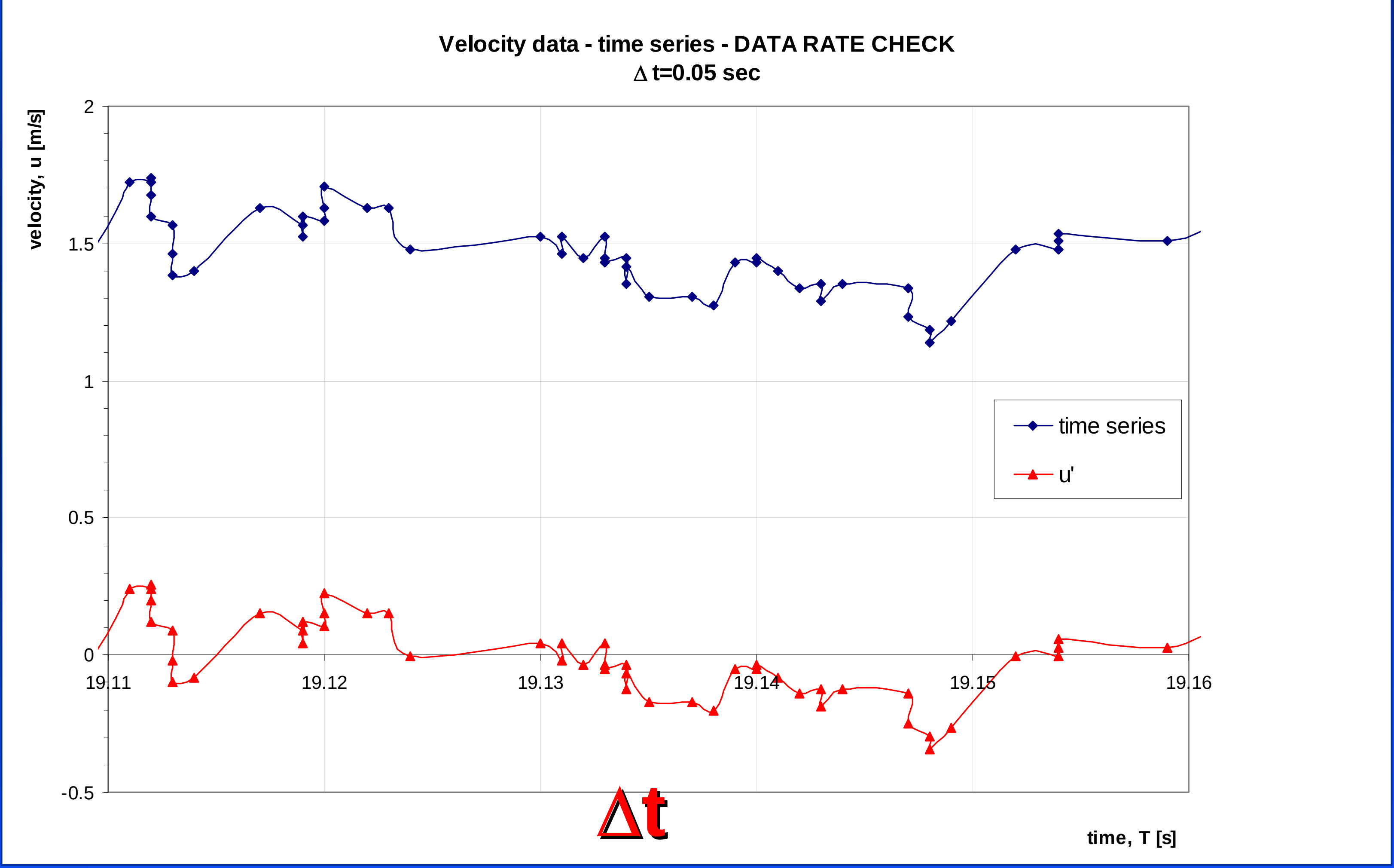
Nr2)

Results - data sample check



Nr2)

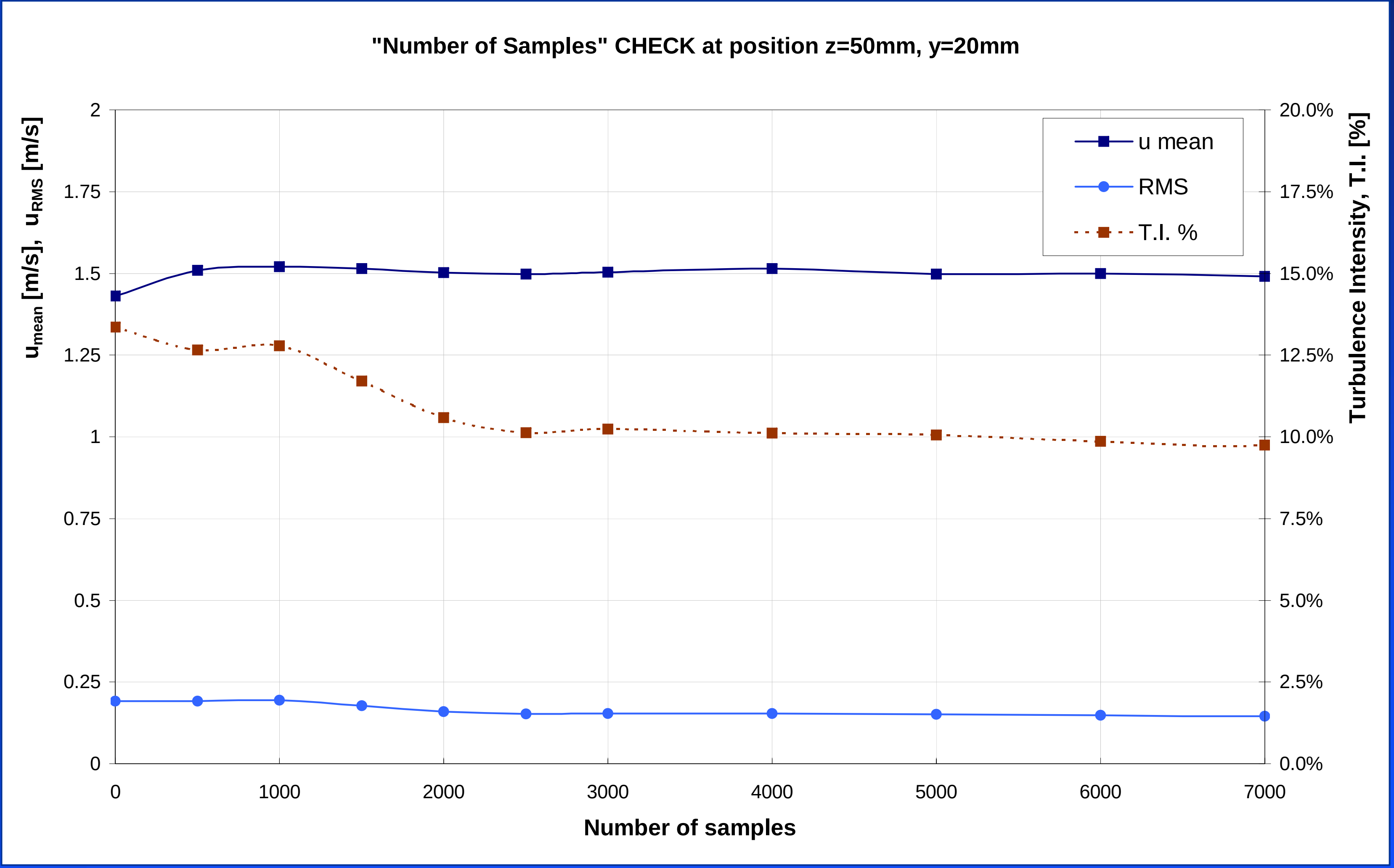
Results



Velocity data - time series - DATA RATE CHECK
Δ t=0.05 sec
velocity, u [m/s]
2
1.5
1
0.5
0
-0.5
19.11
19.12
19.13
19.14
19.15
19.16
time series
u'
Δt
time, T [s]

Nr2)

Results


"Number of Samples" CHECK at position z=50mm, y=20mm
u mean
RMS
T.I. %
umean [m/s], uRMS [m/s]
Turbulence Intensity, T.I. [%]
Number of samples
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
0.0%
2.5%
5.0%
7.5%
10.0%
12.5%
15.0%
17.5%
20.0%
0
1000
2000
3000
4000
5000
6000
7000

Nr2)

Experimental Results

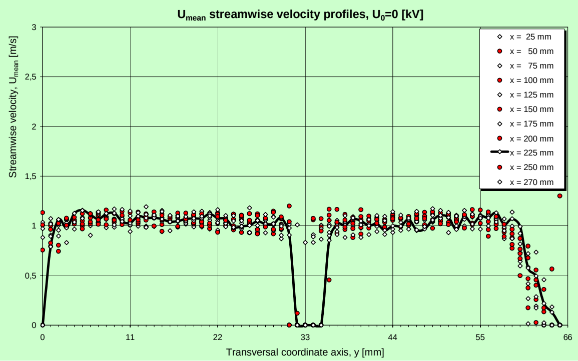
LDV measurements:

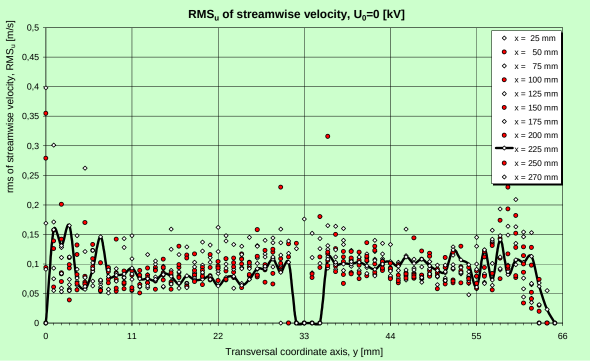
$U_0 = 0$ kV
(u_{inlet}=1 m/s)

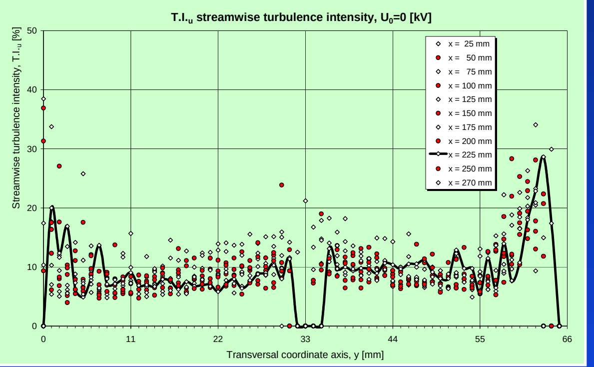
Velocity profiles

RMS profiles

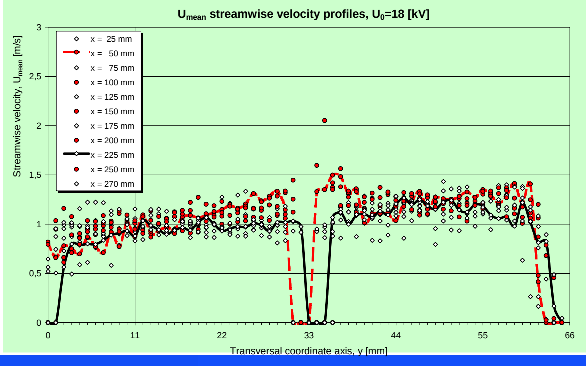
T.I. profiles

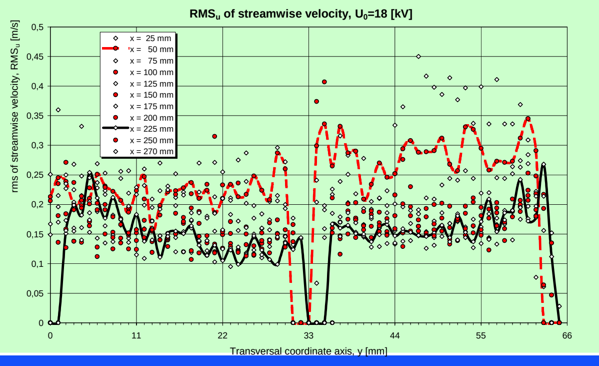


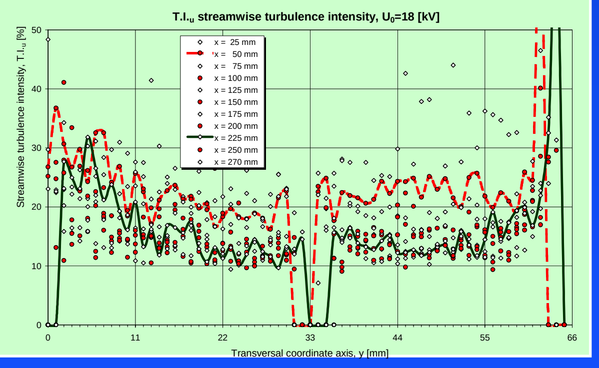




U_0=18 kV
(u_{inlet}=1 m/s)





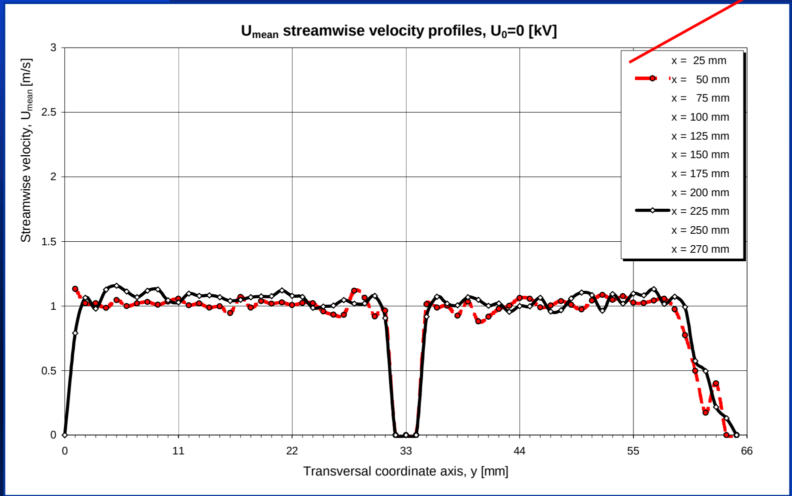


Nr2)

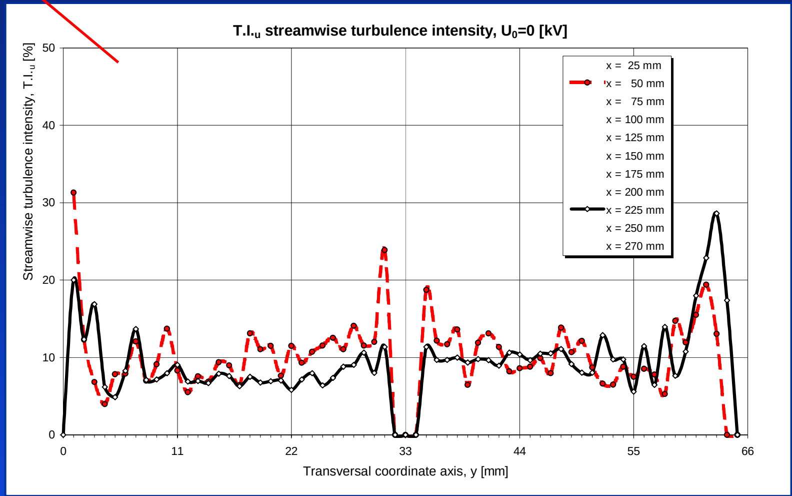
Results

U_0=0 kV

Velocity profiles

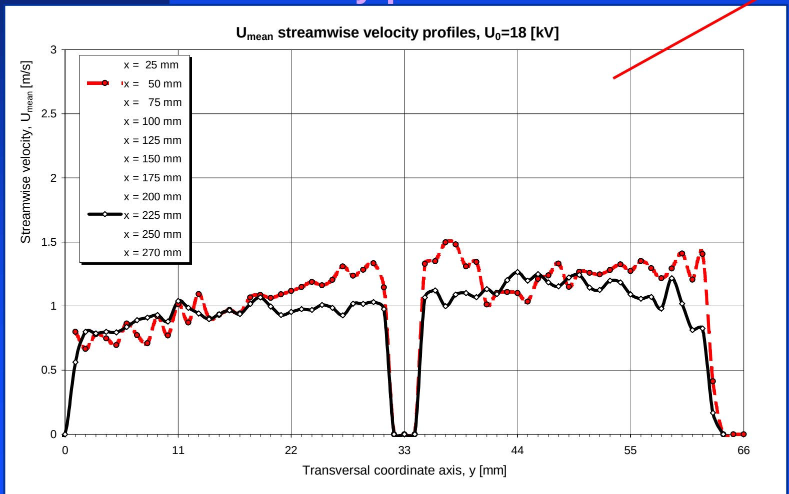


T.I. profiles

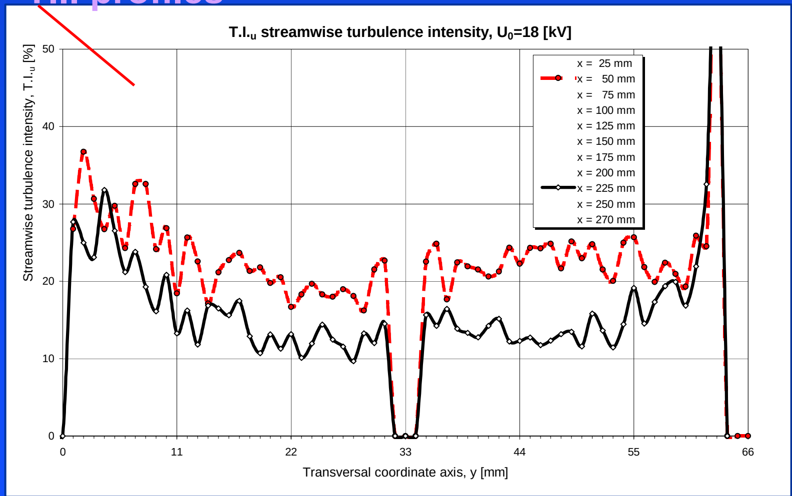


U_0= 18 kV

Velocity profiles



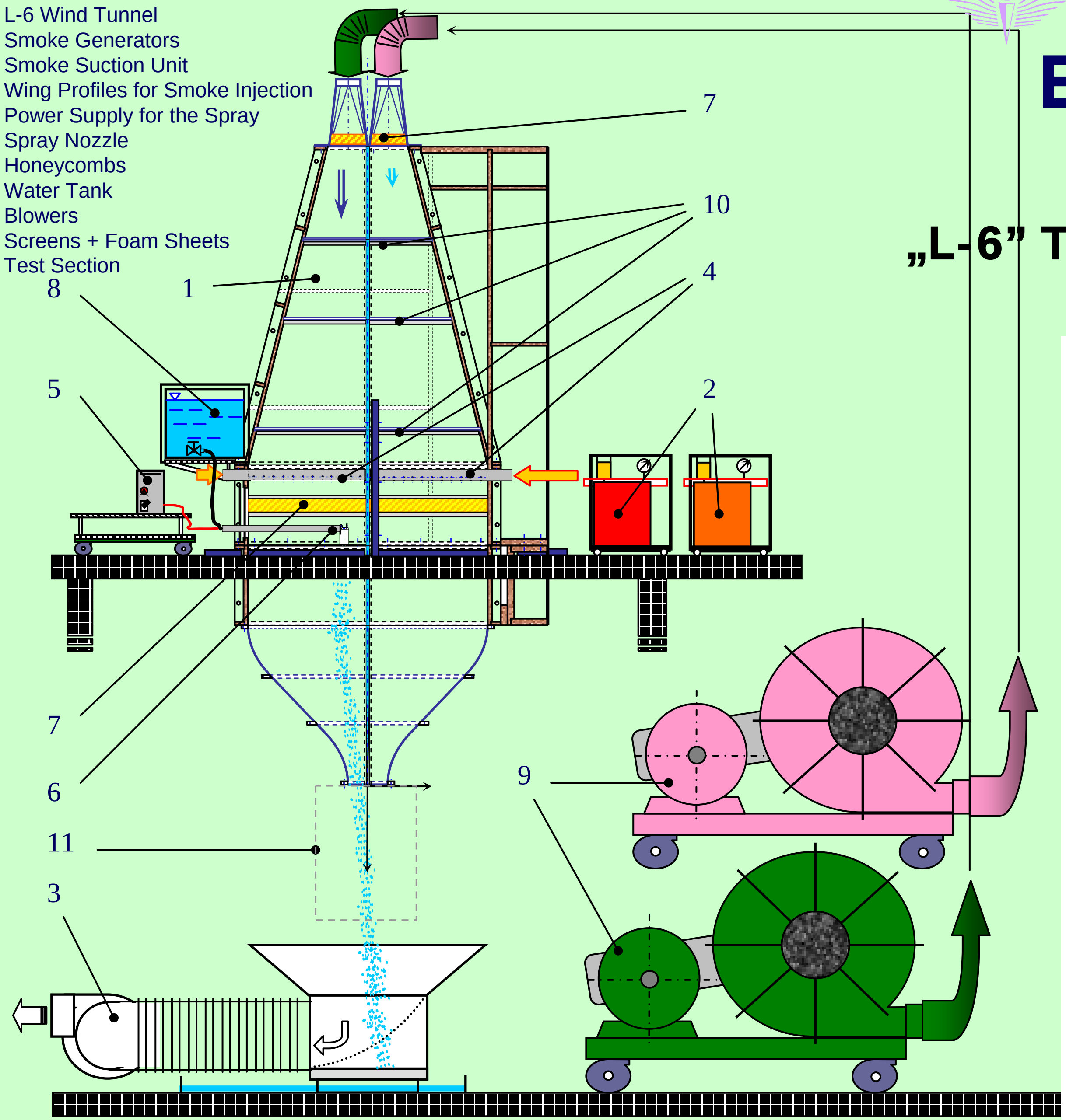
T.I. profiles

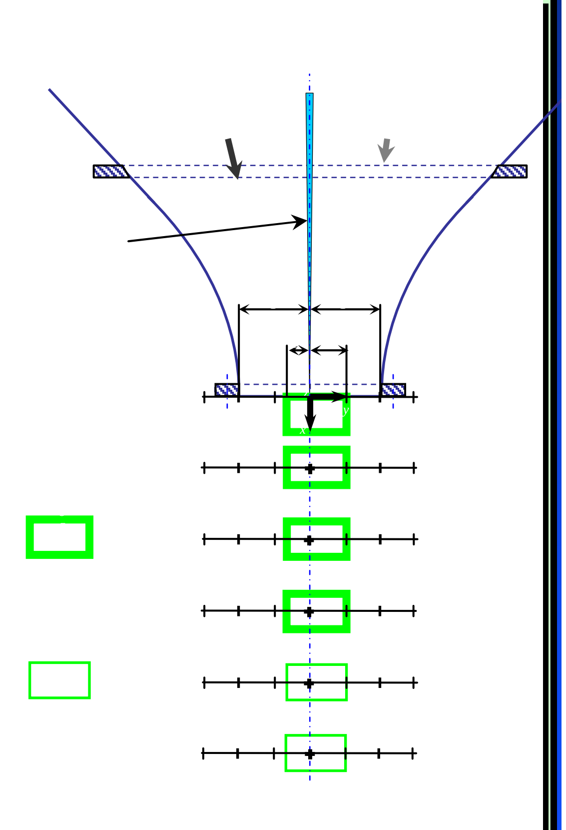


Experimental Apparatus

„L-6" Twin-Jet Shear Layer Wind Tunnel

1 L-6 Wind Tunnel
2 Smoke Generators
3 Smoke Suction Unit
4 Wing Profiles for Smoke Injection
5 Power Supply for the Spray
6 Spray Nozzle
7 Honeycombs
8 Water Tank
9 Blowers
10 Screens + Foam Sheets
11 Test Section





Test Section

VON KÁRMÁN INSTITUTE FOR FLUID DYNAMICS

Measurement Techniques

PARTICLE IMAGING VELOCIMETRY

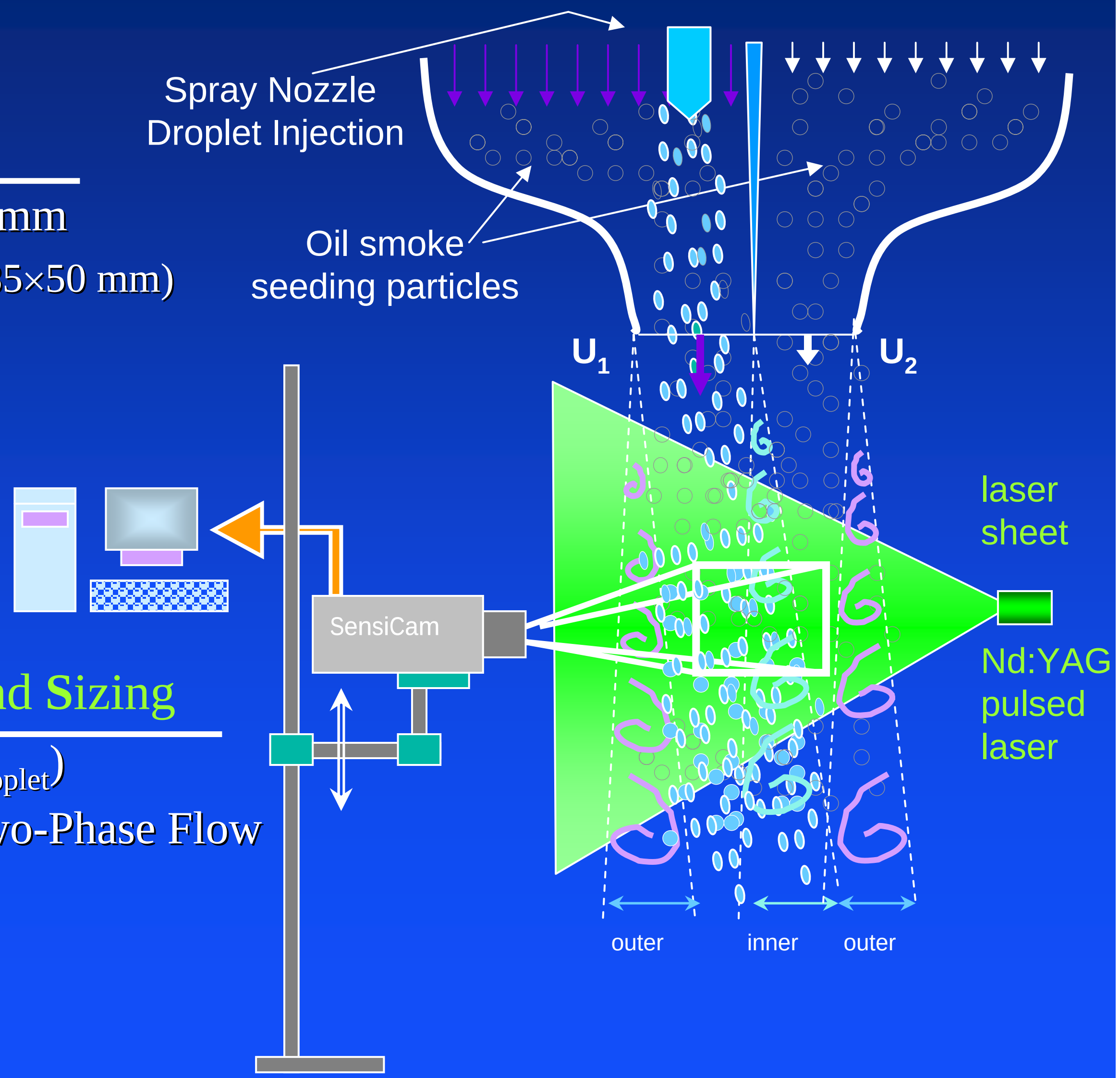
PIV /for single-phase flow/

- new PCO camera + NIKKOR 35mm
  - Image size: 1280×768 pixel (≈ 85×50 mm)
- Nd:YAG pulsed laser /6W/
- Positioning system
- SensiCam acquisition software

PTV(S) /for two-phase flow/

Particle Tracking Velocimetry and Sizing

- Size Discriminating ($d_{seeding} \ll d_{droplet}$)
- Gas Phase Flow Field Data in Two-Phase Flow

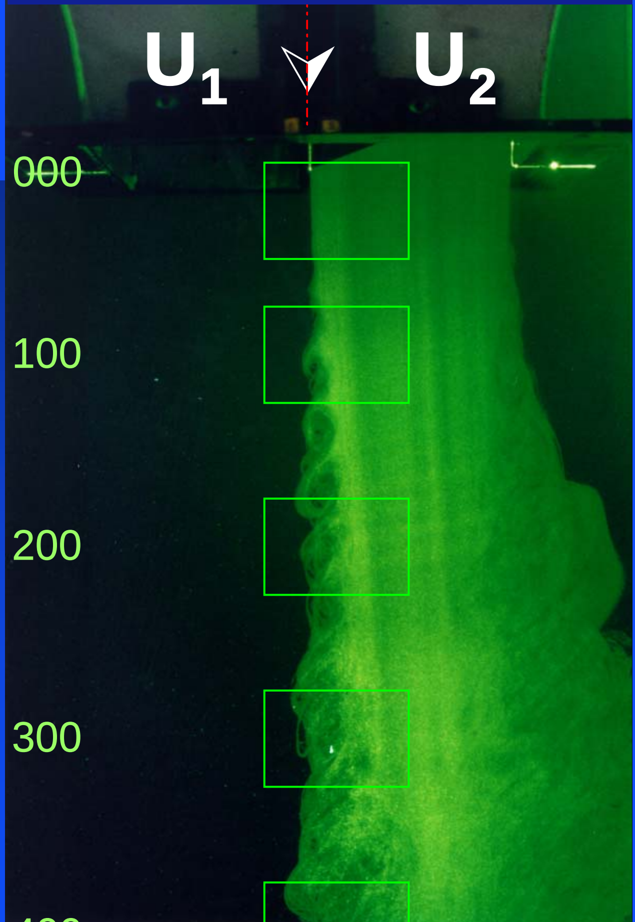


Post-processing:

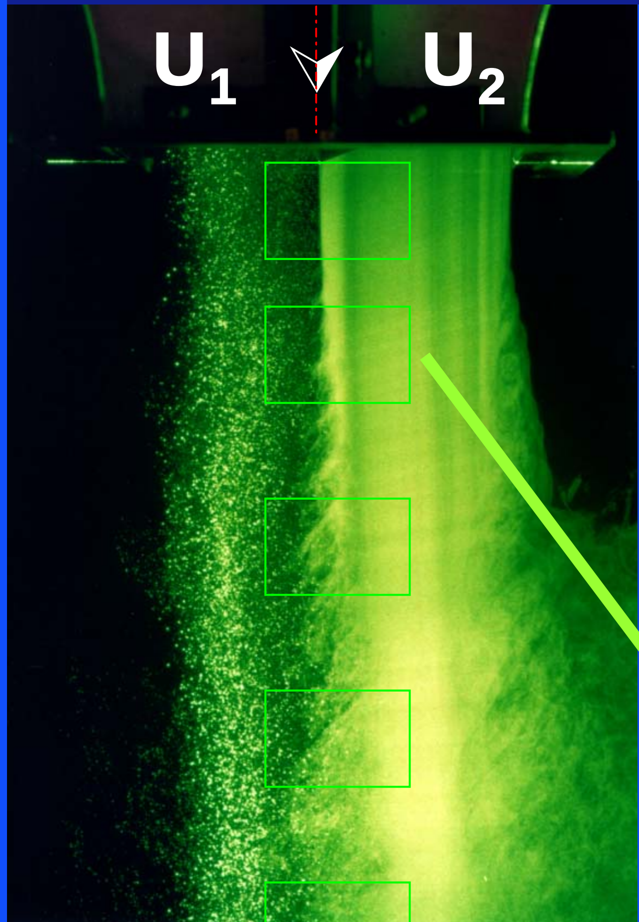
- Matlab, TecPlot, Excel

Nr3)

Single-phase flow



Two-phase flow



000
100
200
300
400
500

Flow Visualization

U_1 = 2 m/s
U_2 = 1 m/s

Digital Image Recording for Particle Imaging Velocimetry

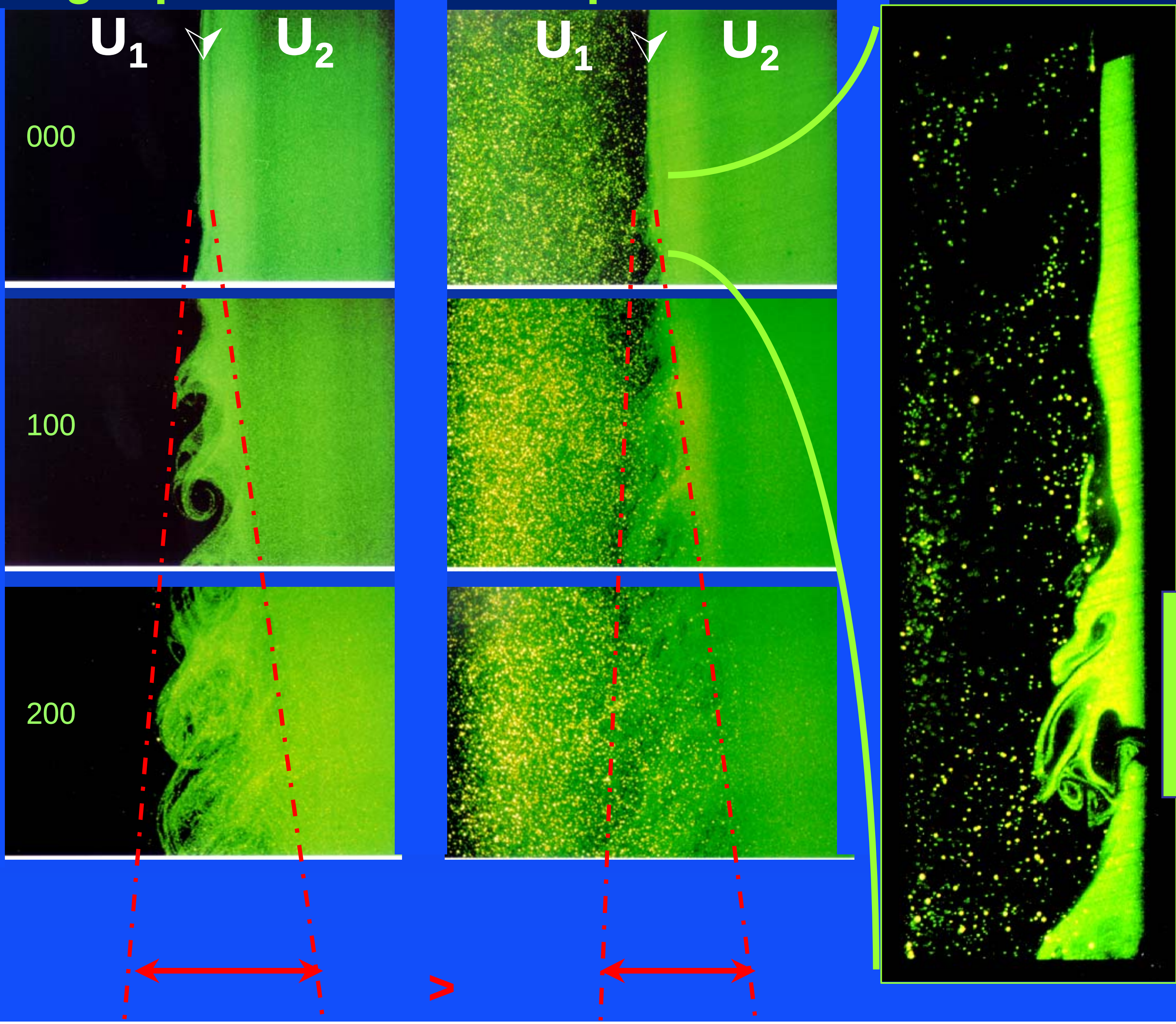
PIV | **PTV(S)**

well defined mixing layer developement

Nr3)

VON KÁRMÁN INSTITUTE FOR FLUID DYNAMICS

Single-phase flow   Two-phase flow

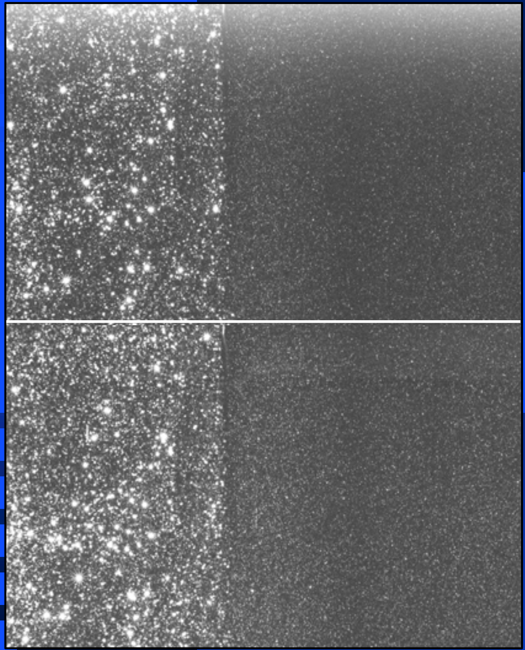


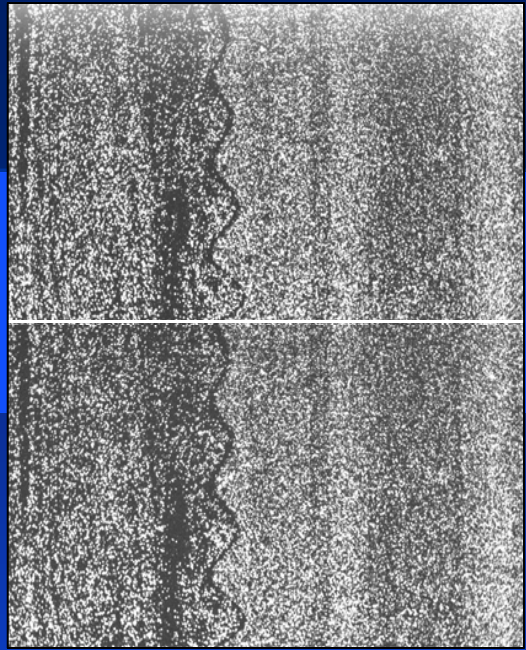
Flow Visualization

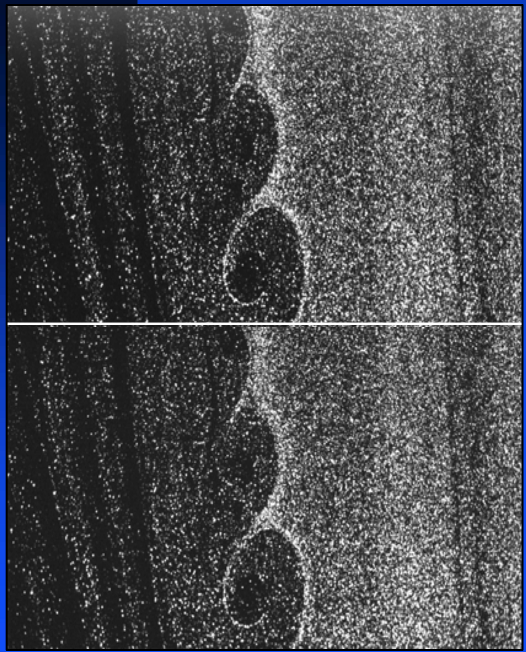
$U_1 = 2$ m/s
$U_2 = 1$ m/s

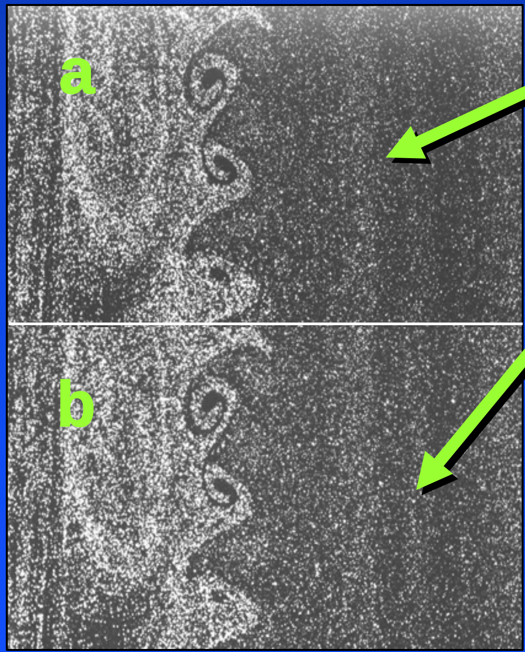
shear layer flow structure
/droplets in the mixing layer/

Experimental Results





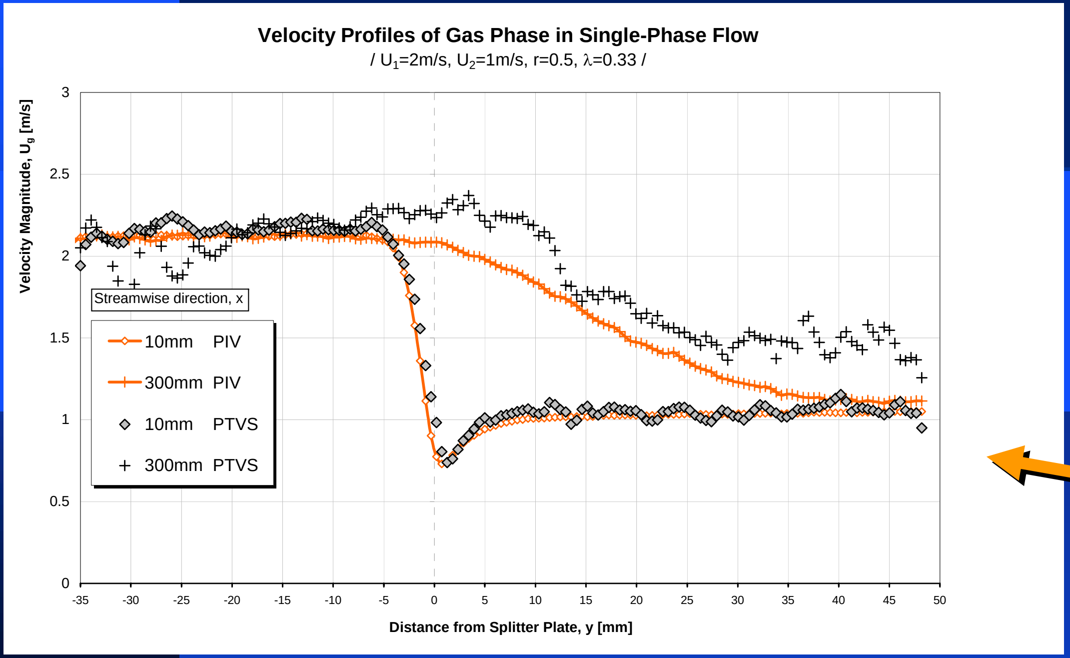




Digitally recorded successive images

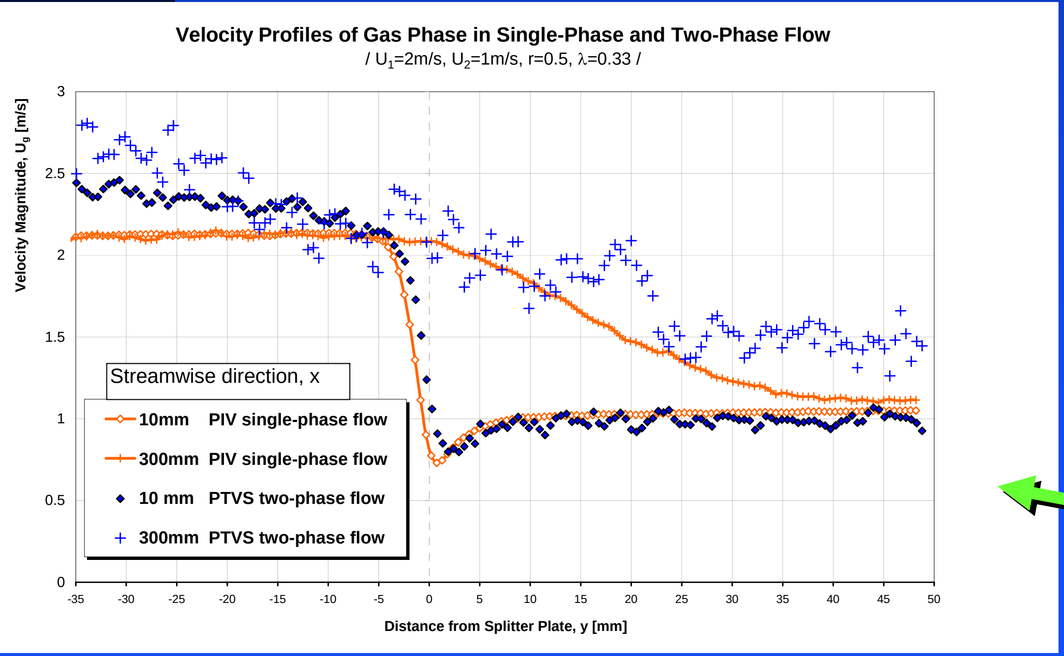
$\Delta t_{a\text{-}b}$

Experimental Results



single-phase flow PIV

/ comparison of PIV-PTV(S) /

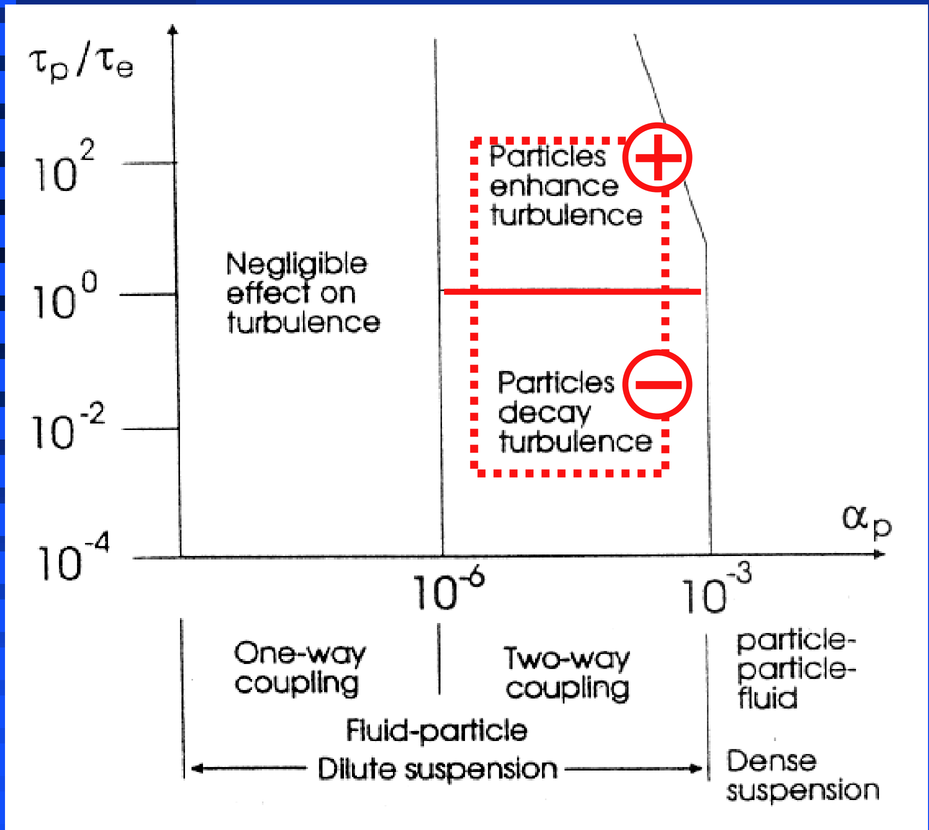


two-phase flow PTV(S)

Two-phase flow characteristics

Introduction

[ELGHOBASHI, 1994]



[GORE and CROWE, 1989]

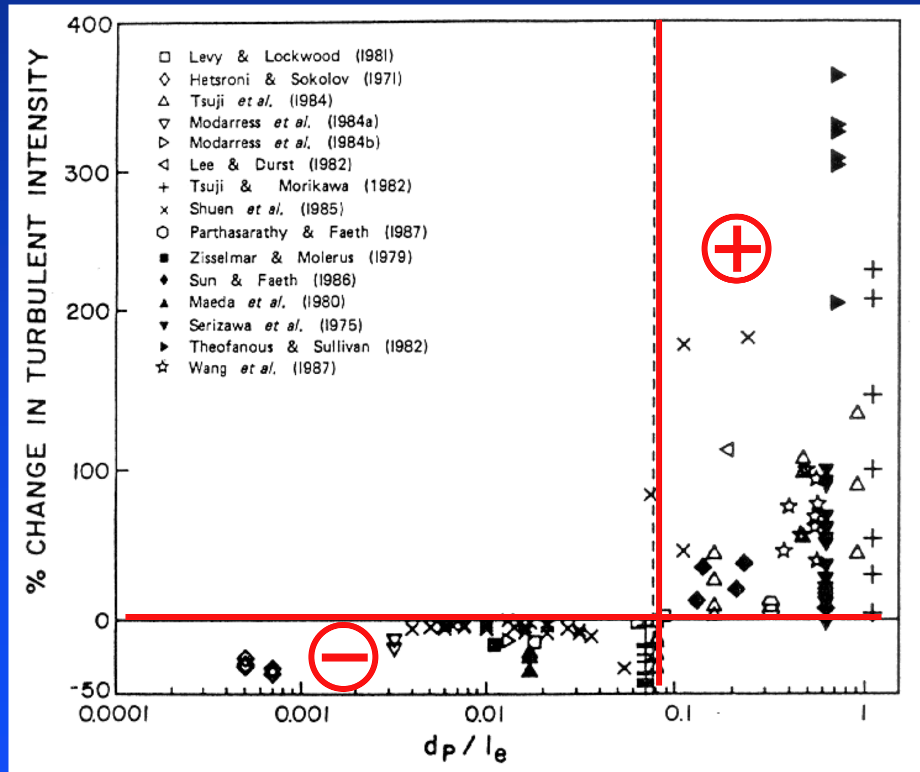


Figure 2. Change in turbulent intensity as function of length scale ratio.

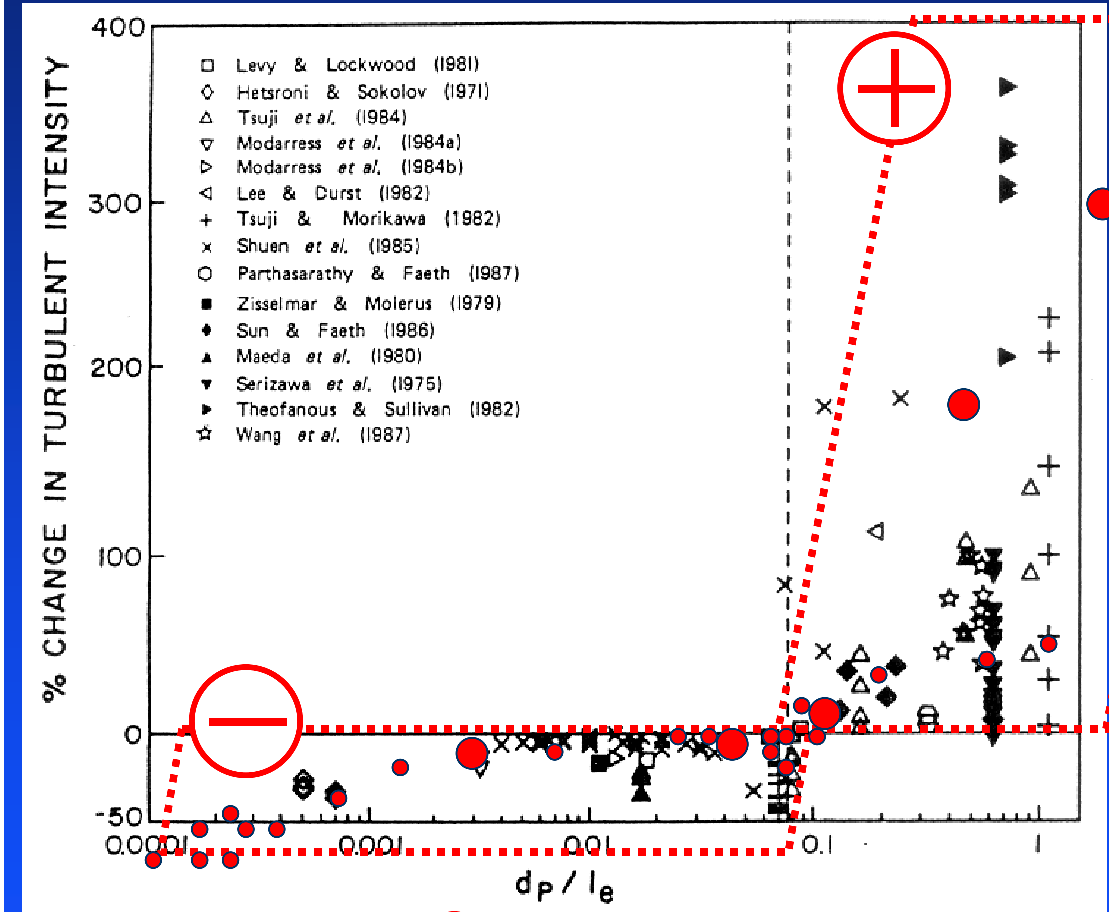
$\alpha_p = 10^{-4} \div 10^{-5}$ $St_p = 10^{-3} \div 10^2$

$\Delta(T.I.) = f\,(d_p/l_e)$

Nr3) VON KÁRMÁN INSTITUTE FOR FLUID DYNAMICS

Turbulence Modulation Map

- **exp. results: Suda 2000.**



- Effect of **characteristic length scale ratio** on modulating turbulent intensity:

$$\Delta(\text{T.I.}) = f\,(d_p/l_e)$$

d_p - particle diameter

l_e - fluid length scale (integral length scale or characteristic length of the most energetic eddy)

$$\Delta\left(T.I._{\text{carrier phase}}\right) = \frac{T.I._{\text{two-phase}} - T.I._{\text{single-phase}}}{T.I._{\text{single-phase}}}$$

T.I. of the fluid based on PIV and PTVS velocity meas.

Mixing Layer: ⊖ **negative** rel. change (- 90%)

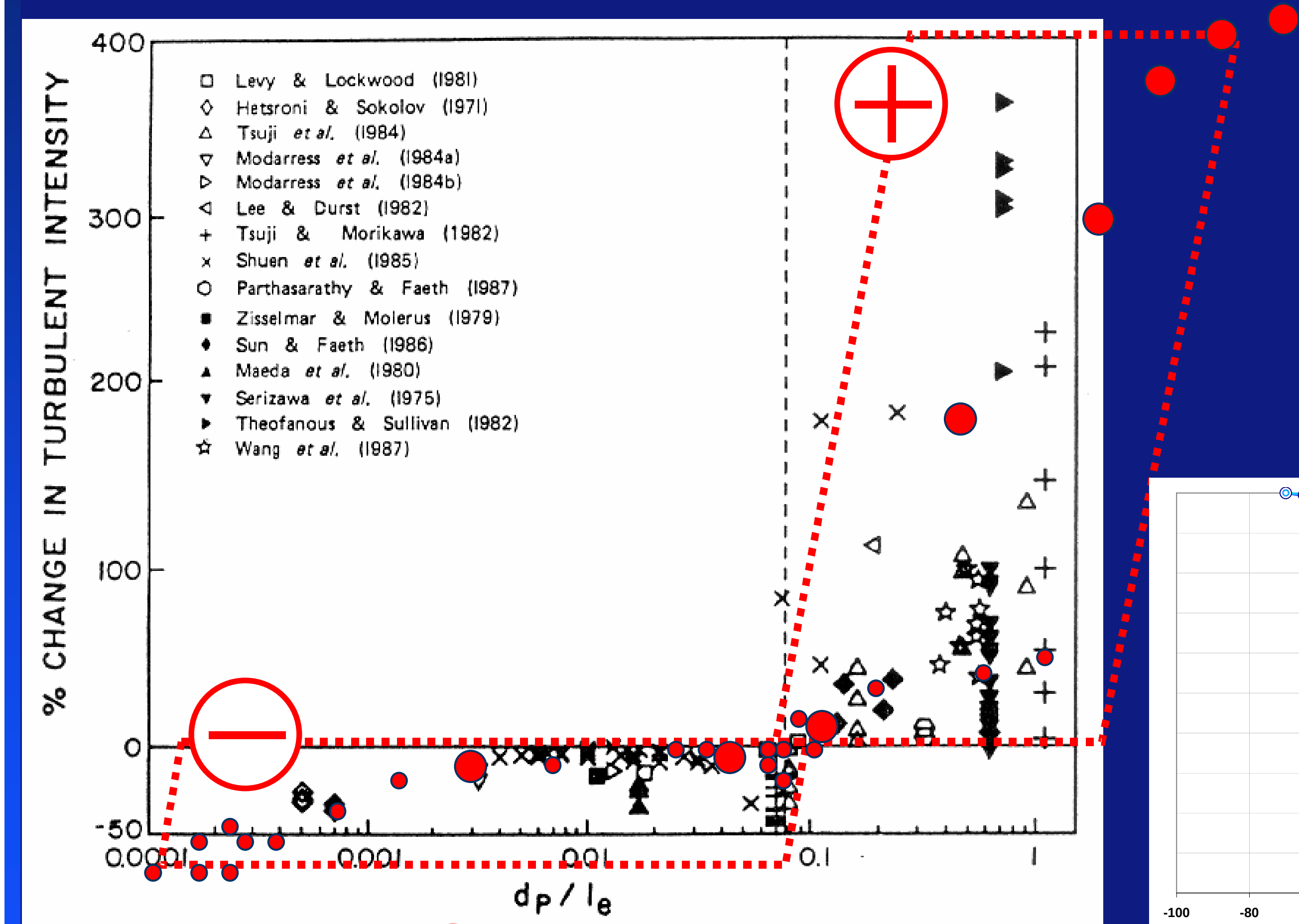
Main Flow: ⊕ **positive** rel. change (+1500%)

graph from [Gore and Crowe, 1989] *in Int. J. Multiphase Flow* Vol.**15**. No.2, pp.279-285.

Nr3)

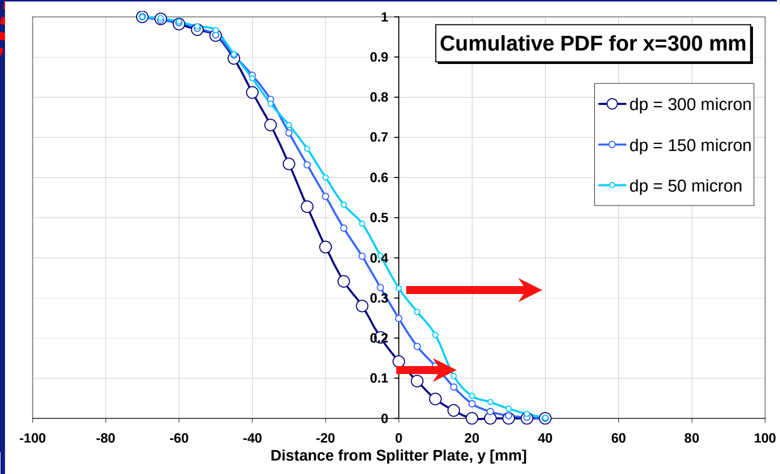
CHANGE in Turbulence Intensity CONCLUSIONS

● exp: [Suda, 2000]



33% of d_p= 50μm

14% of d_p=300μm



Mixing Layer: ⊖ **negative** rel change (- 90%)

Main Flow: ⊕ **positive** rel change (+1500%)