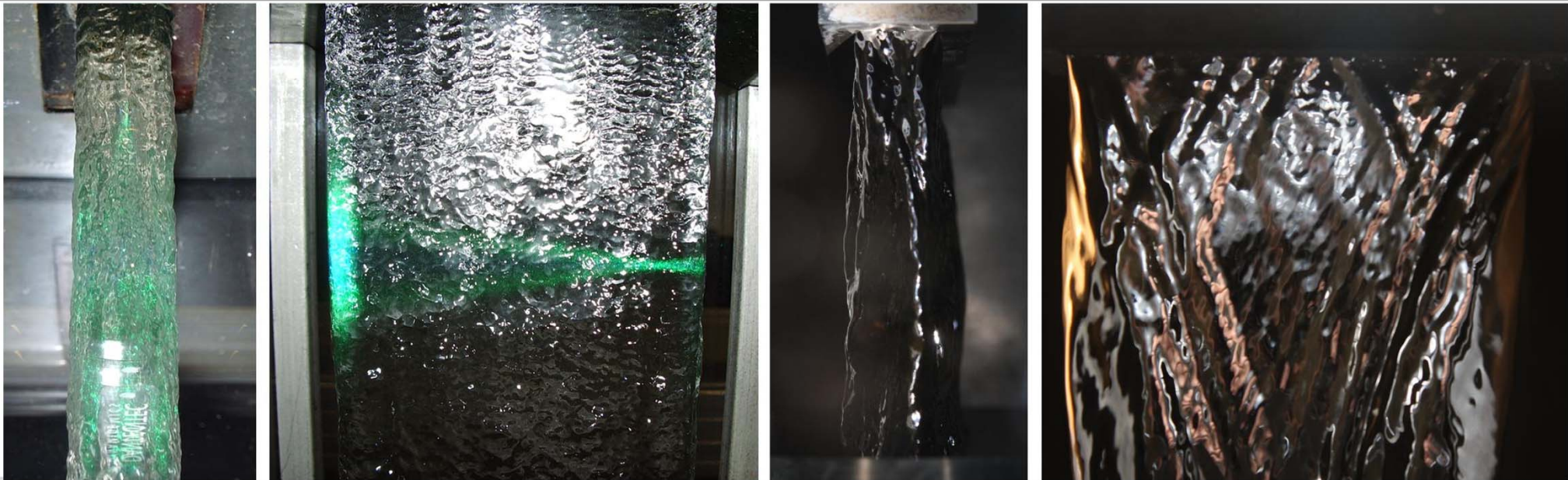


FAIR and IFMIF liquid metal free surface target experiments at KALLA

L. Stoppel, Th. Wetzel,

4th High Power Targetry Workshop, May 3, 2011

Institut für Kern- und Energietechnik



Content:

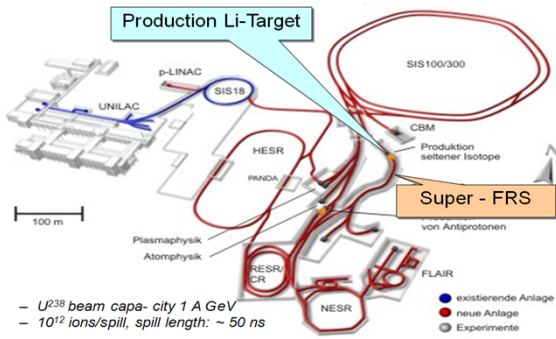
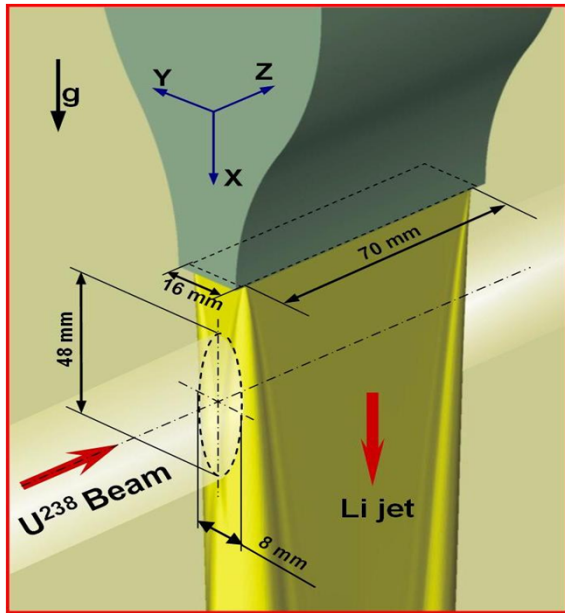
- **Overview of liquid metal targets and investigation strategy**
 - FAIR, IFMIF
 - Water experiment, validation of CFD, liquid-metal experiment
- **Water test facility - FIDES**
 - Objects, design, test section, experimental results
- **Liquid metal test facility - ALINA**
 - Objects, design, test section, experimental results
- **IFMIF test section**
 - Design, Taylor-Goertler instability, measuring technique
- **Summary and outlook**

Overview liquid metal targets

Nuclear physics research

Lithium target

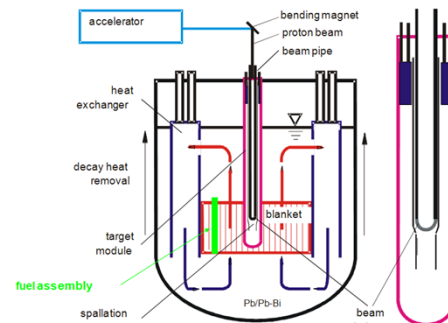
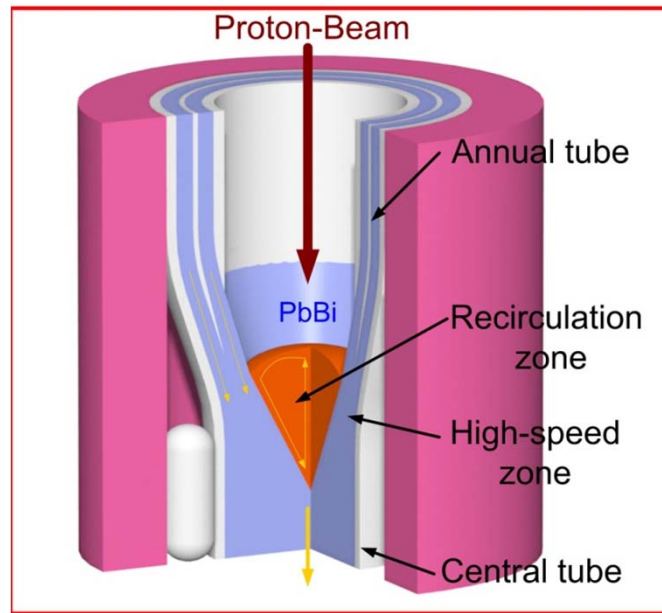
Facility for Antiproton and Ion Research (FAIR)



Transmutation

PbBi-Target

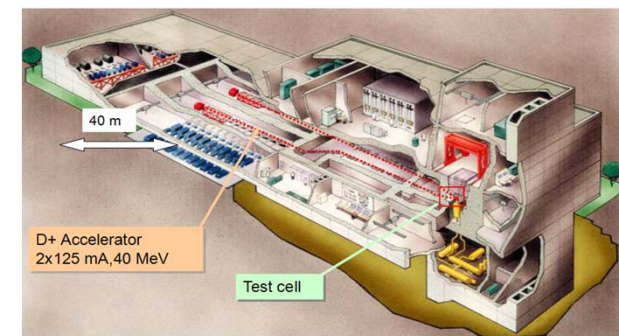
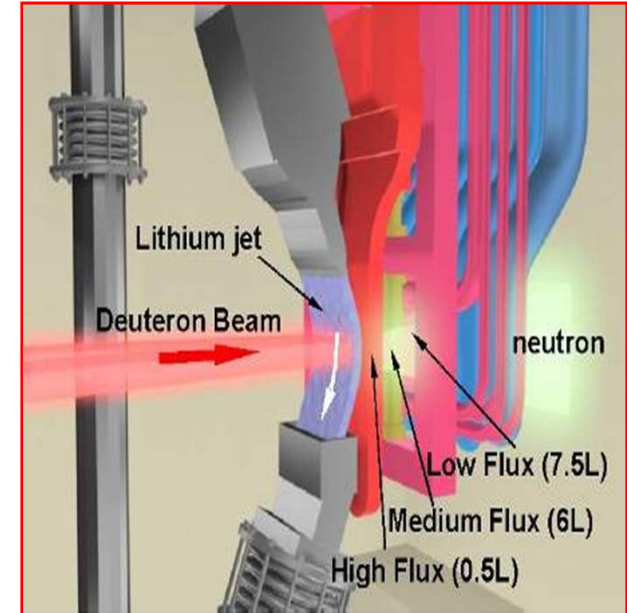
Accelerator Driven System (ADS)



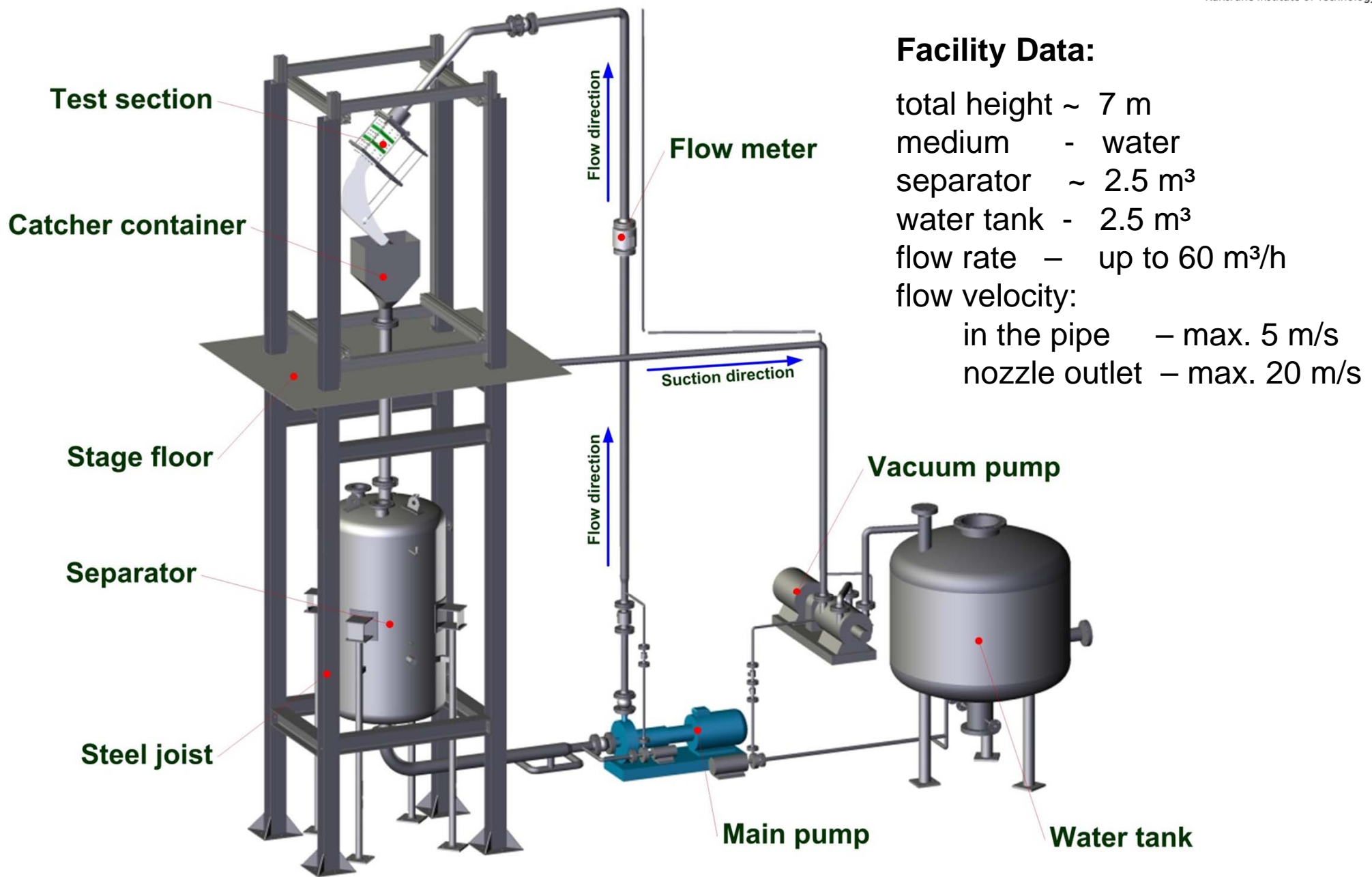
Fusion technology

Lithium target

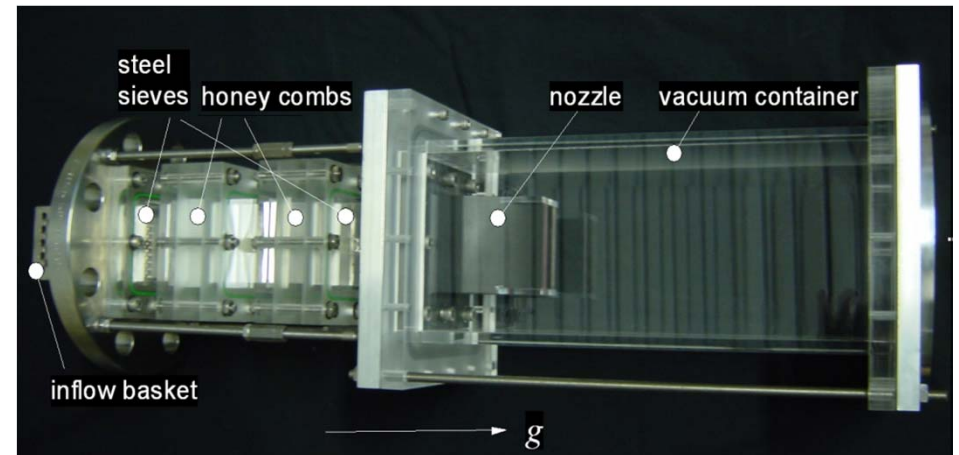
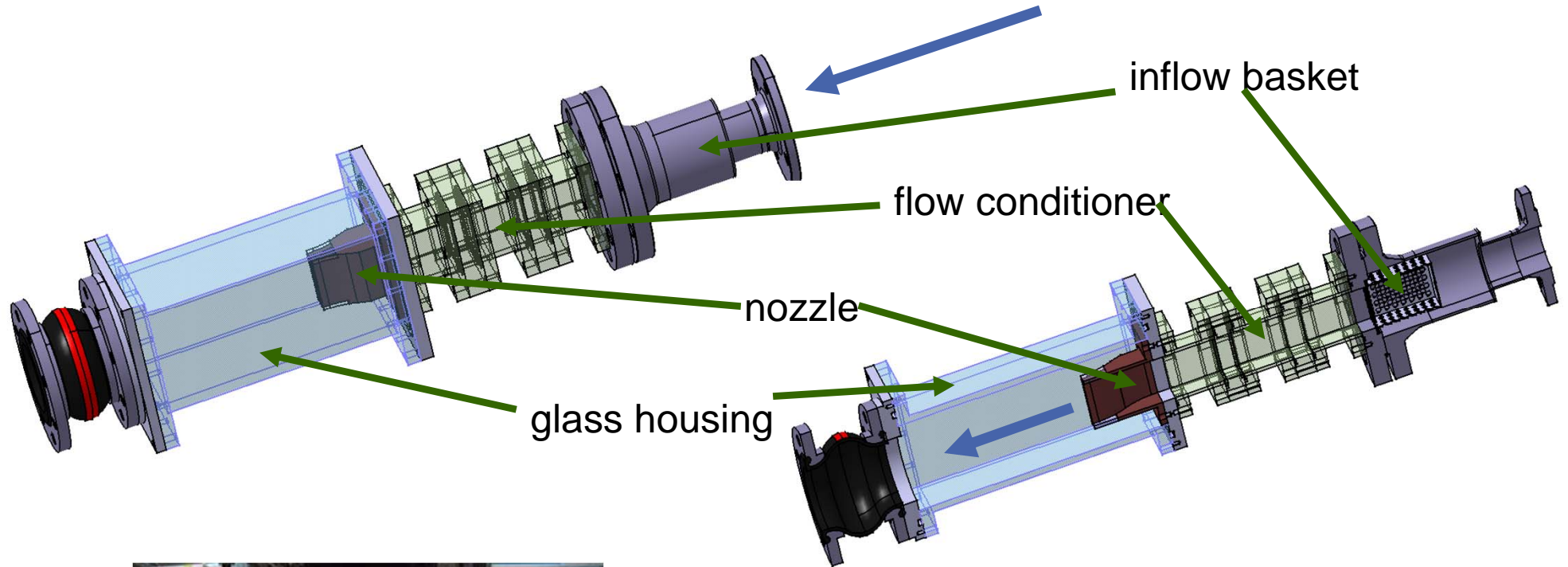
International Fusion Material Irradiation Facility (IFMIF)



FIDES – water facility design



Water test section design (FAIR)

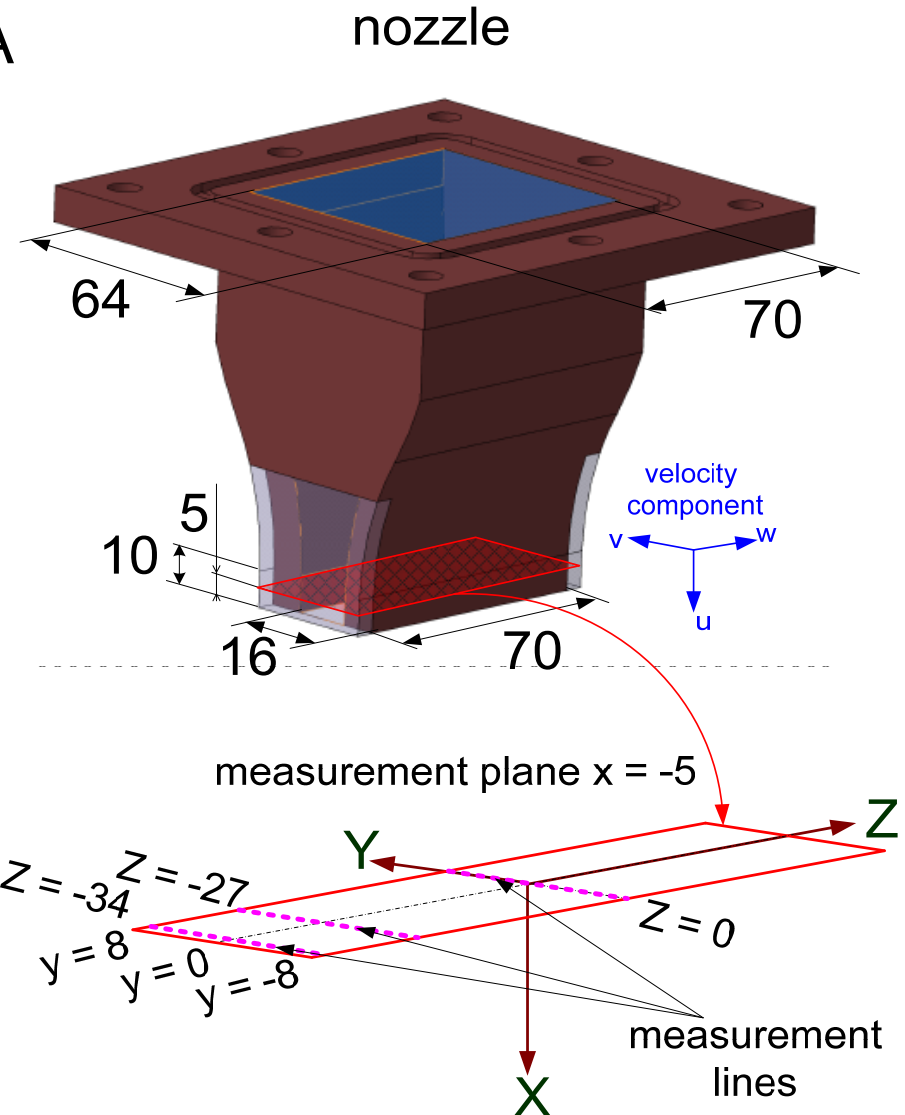
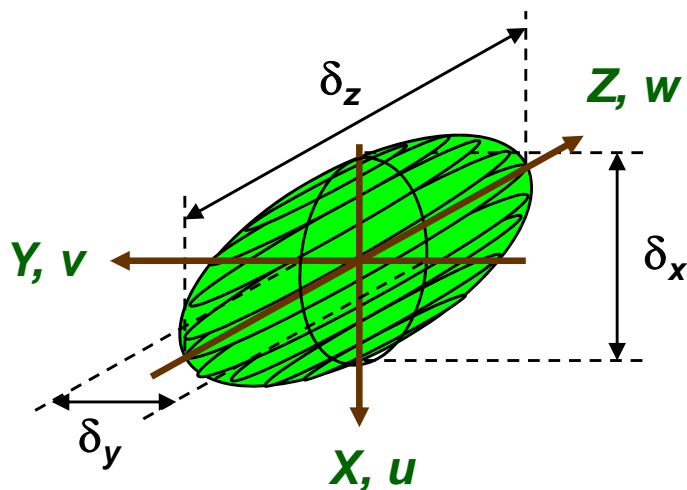


Water-jet investigation (nozzle flow)

- Quantitative analysis by means of LDA
- Acquisition of viscous boundary layer (minimized measurement volume)

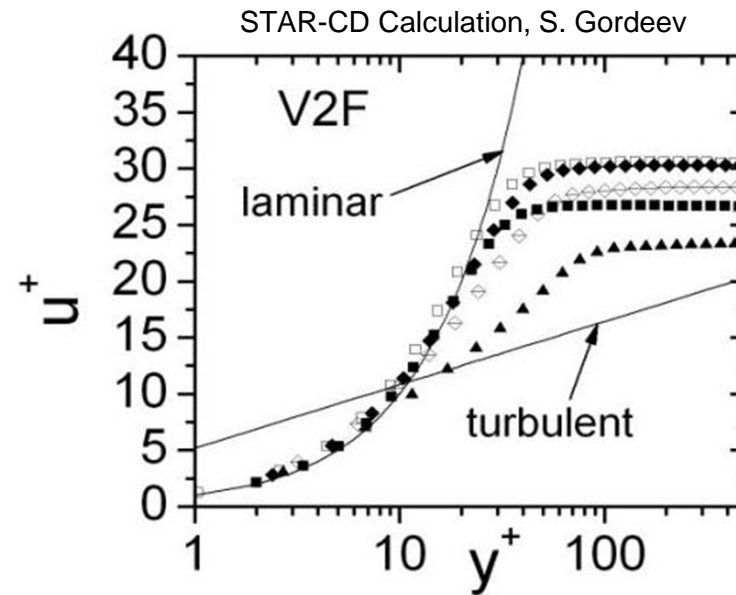
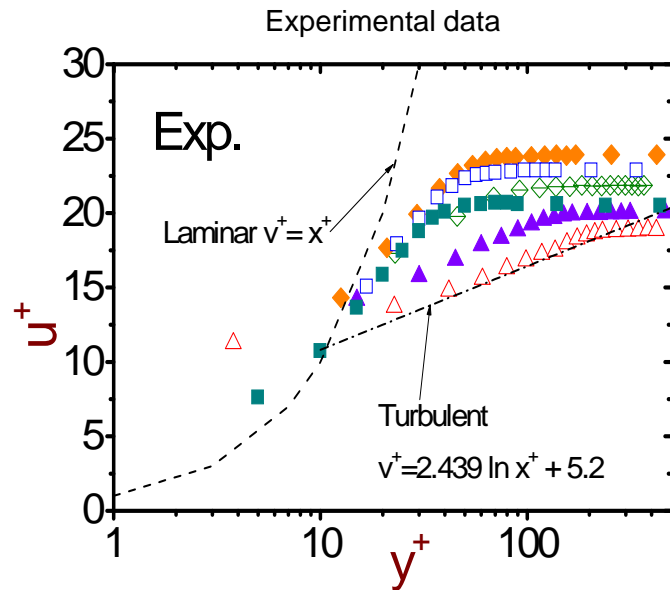
Probe volume

λ, nm	$\delta_x, \mu\text{m}$	$\delta_y, \mu\text{m}$	$\delta_z, \mu\text{m}$
488	56	56	353
514.5	59	59	372



Water-jet investigation (nozzle flow)

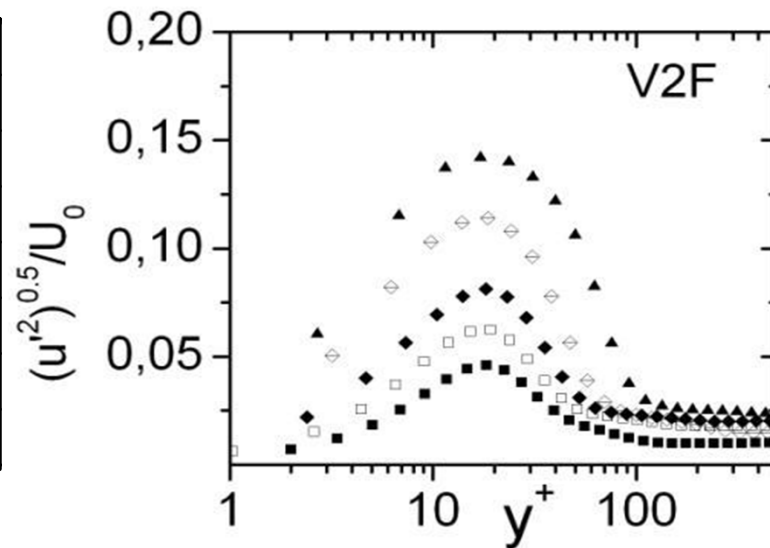
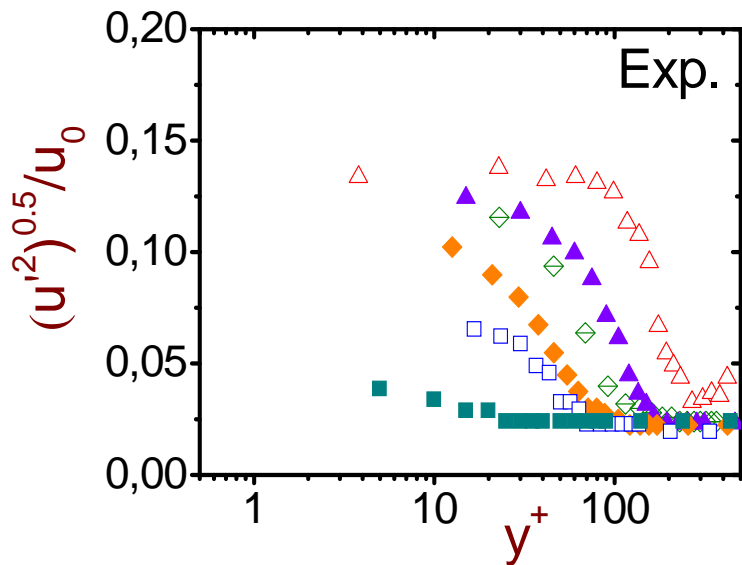
Boundary layer **velocity** and **turbulence intensity** distribution



$$y^+ = yU_\tau/\nu$$

$$U_\tau = (\tau_w/\rho)^{0,5}$$

τ_w – wall shear stress



- 2m/s
- 3m/s
- ◆ 4m/s
- ◇ 5m/s
- ▲ 6m/s
- △ 7m/s

Water-jet investigation (free surface)

u = 2m/s

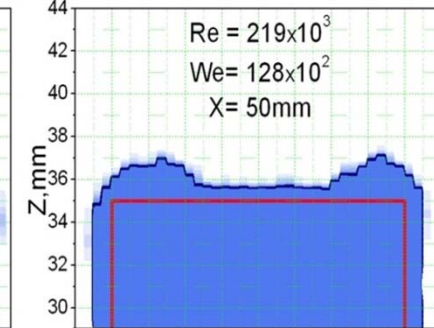
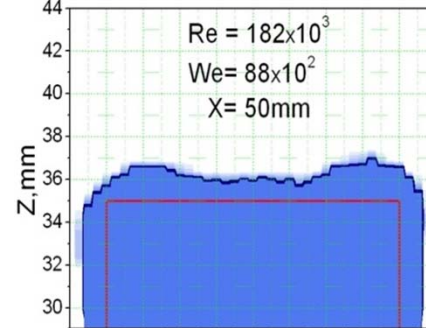
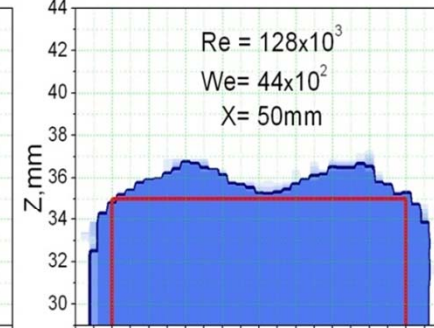
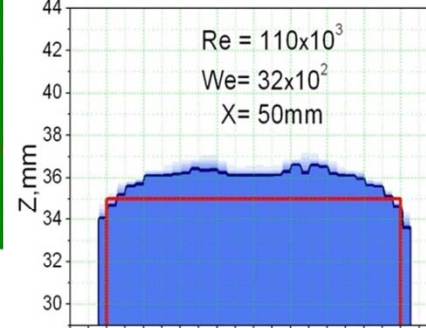
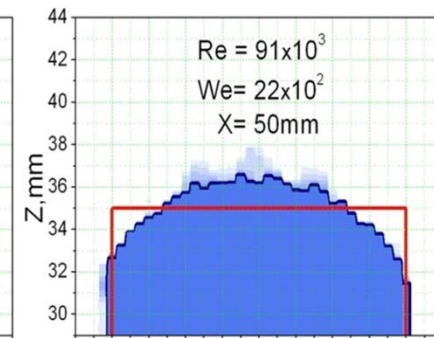
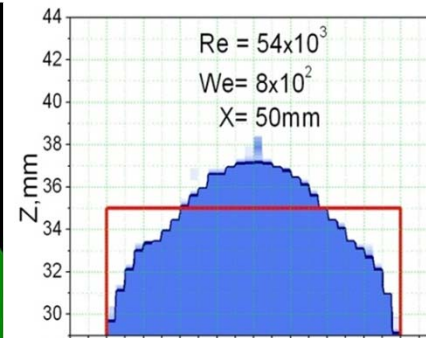
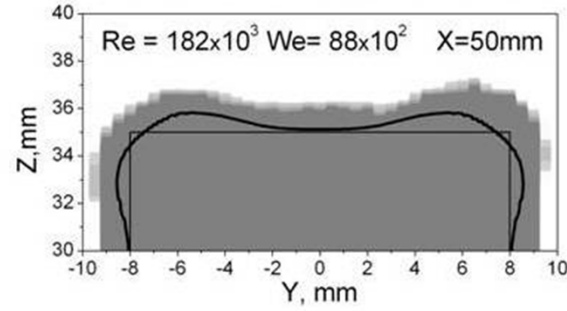
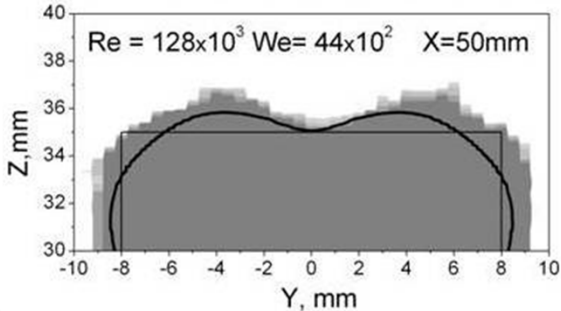
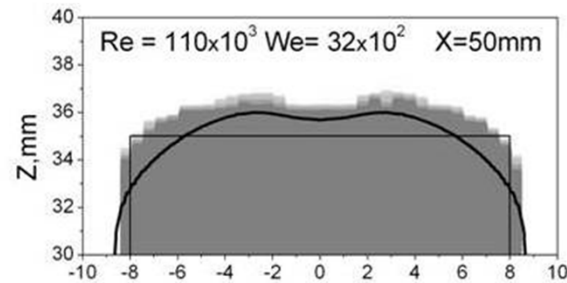
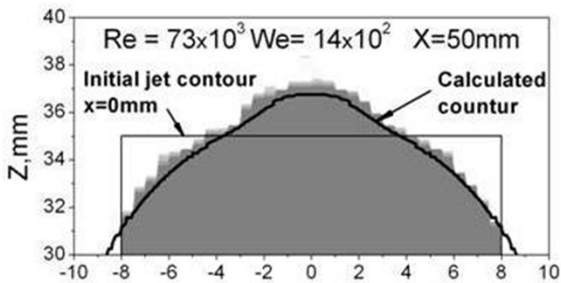
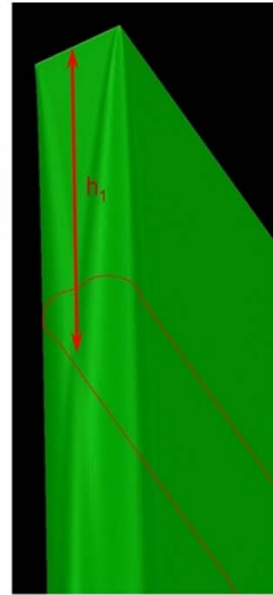
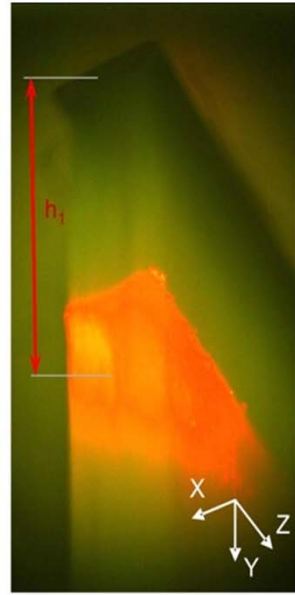
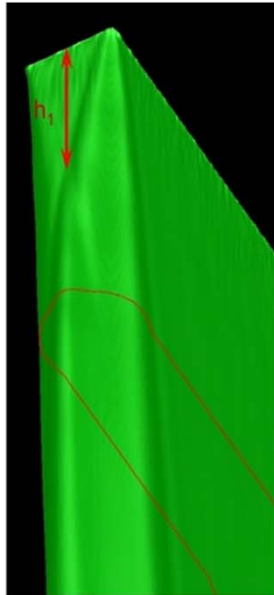
u = 4m/s

Experiment

SST-model

Experiment

SST-model



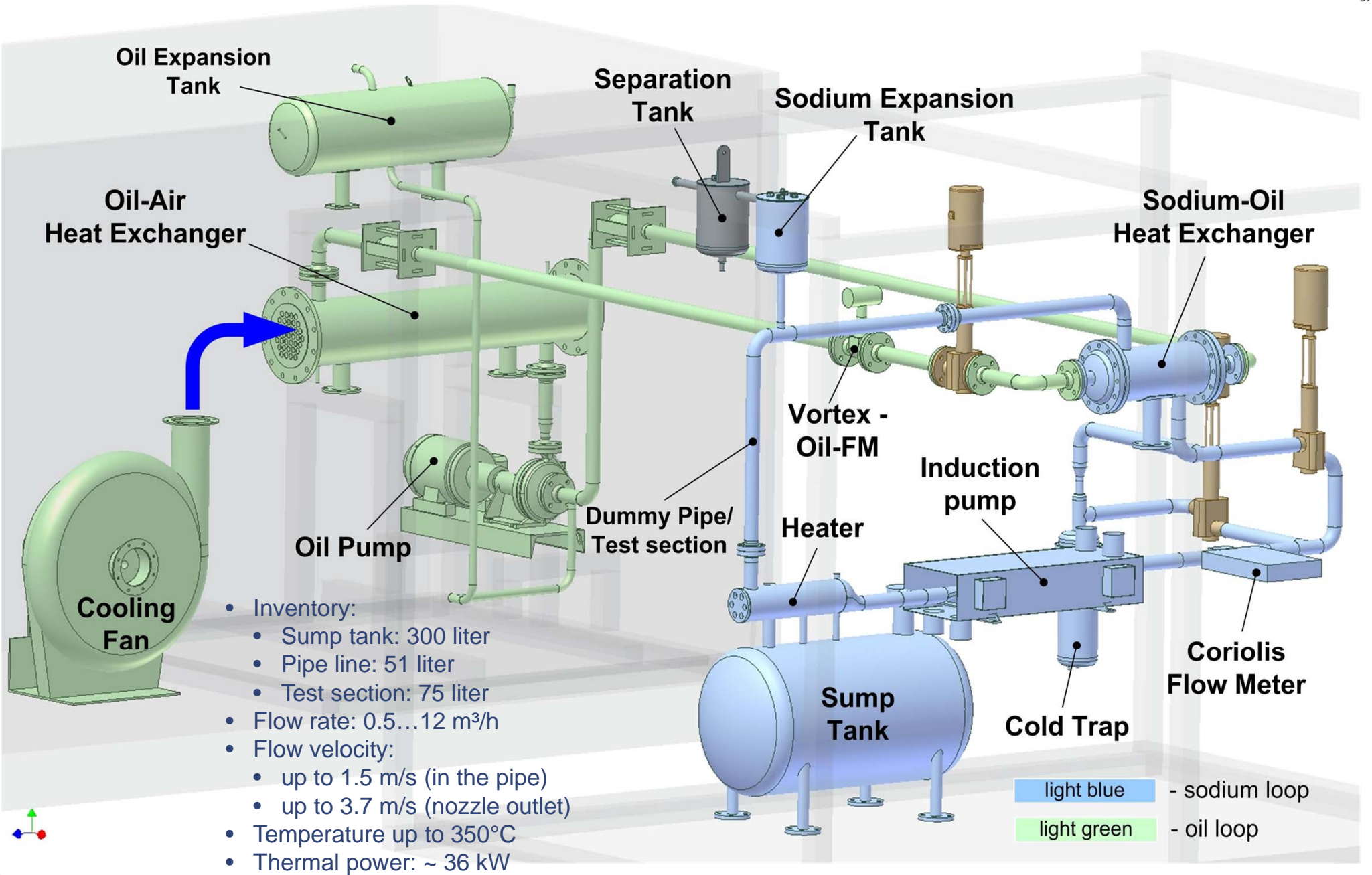
— Nozzle exit contour — Free surfaces profiles

CFD-Calculation, S. Gordeev

The mission of the liquid metal ALINA-Facility

- Experimental research on hydrodynamic phenomena of the free surface liquid metal flow (FAIR, IFMIF)
- Thermal-hydraulic investigation of the systems with liquid metal flow
- Design optimization and testing of new technological solution for liquid metal facilities
- Developing and testing of new measuring techniques

3D-View of the experimental facility ALINA

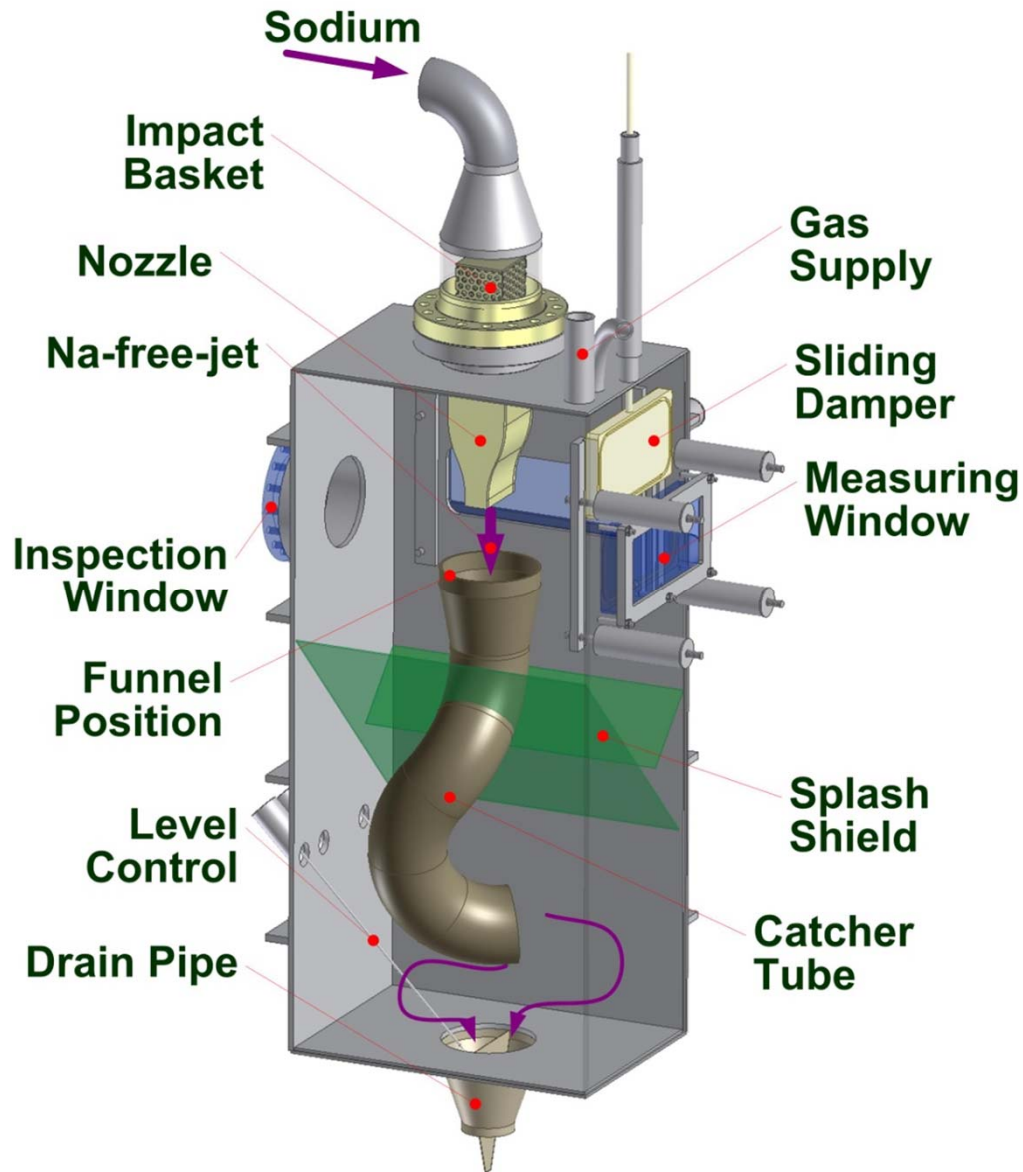


- Inventory:
 - Sump tank: 300 liter
 - Pipe line: 51 liter
 - Test section: 75 liter
- Flow rate: 0.5...12 m³/h
- Flow velocity:
 - up to 1.5 m/s (in the pipe)
 - up to 3.7 m/s (nozzle outlet)
- Temperature up to 350°C
- Thermal power: ~ 36 kW

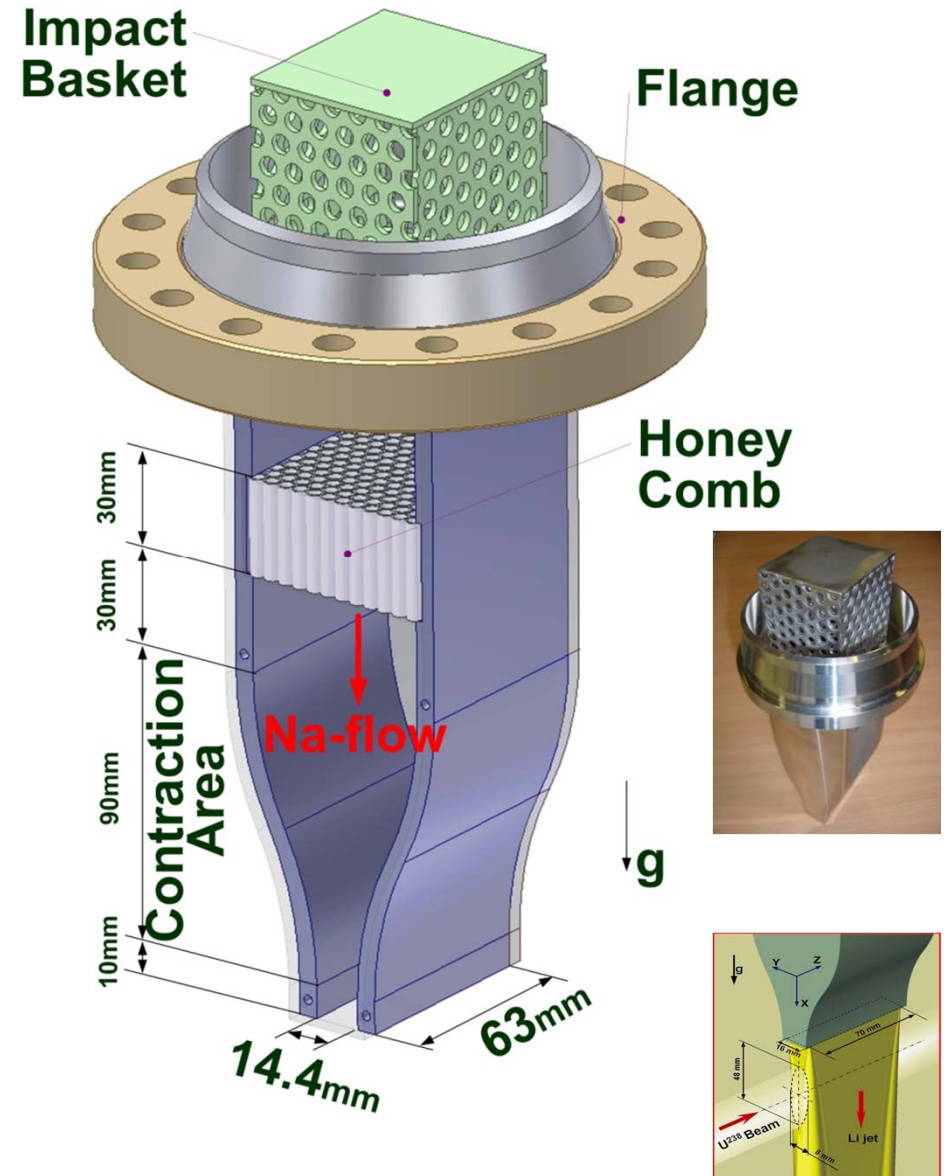
light blue - sodium loop
 light green - oil loop

ALINA test section design (FAIR)

Test section assembly



Nozzle



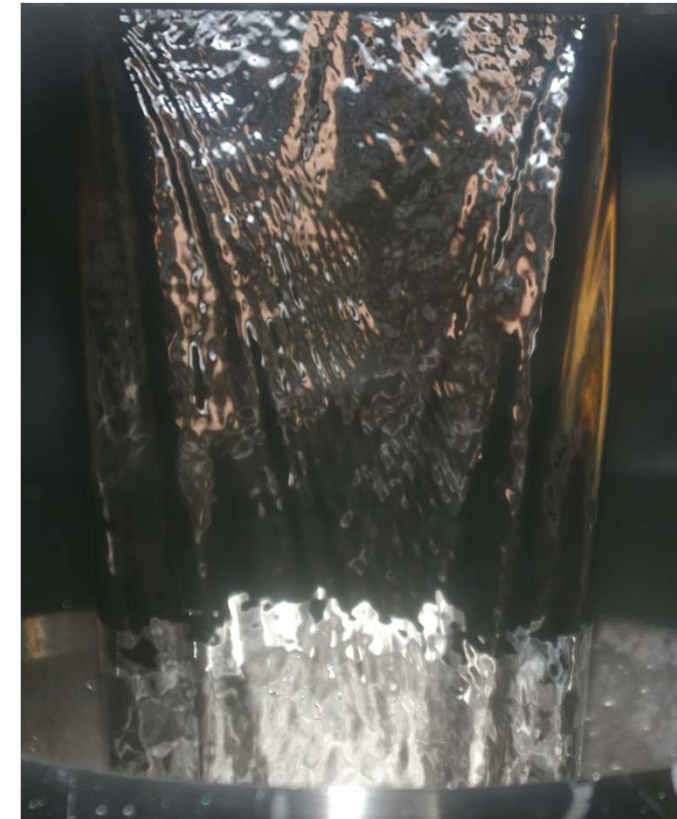
- Example: liquid metal jet mean velocity $U = 2.5 \text{ m/s}$ at $T=200^\circ\text{C}$



CFD-Calculation, S. Gordeev

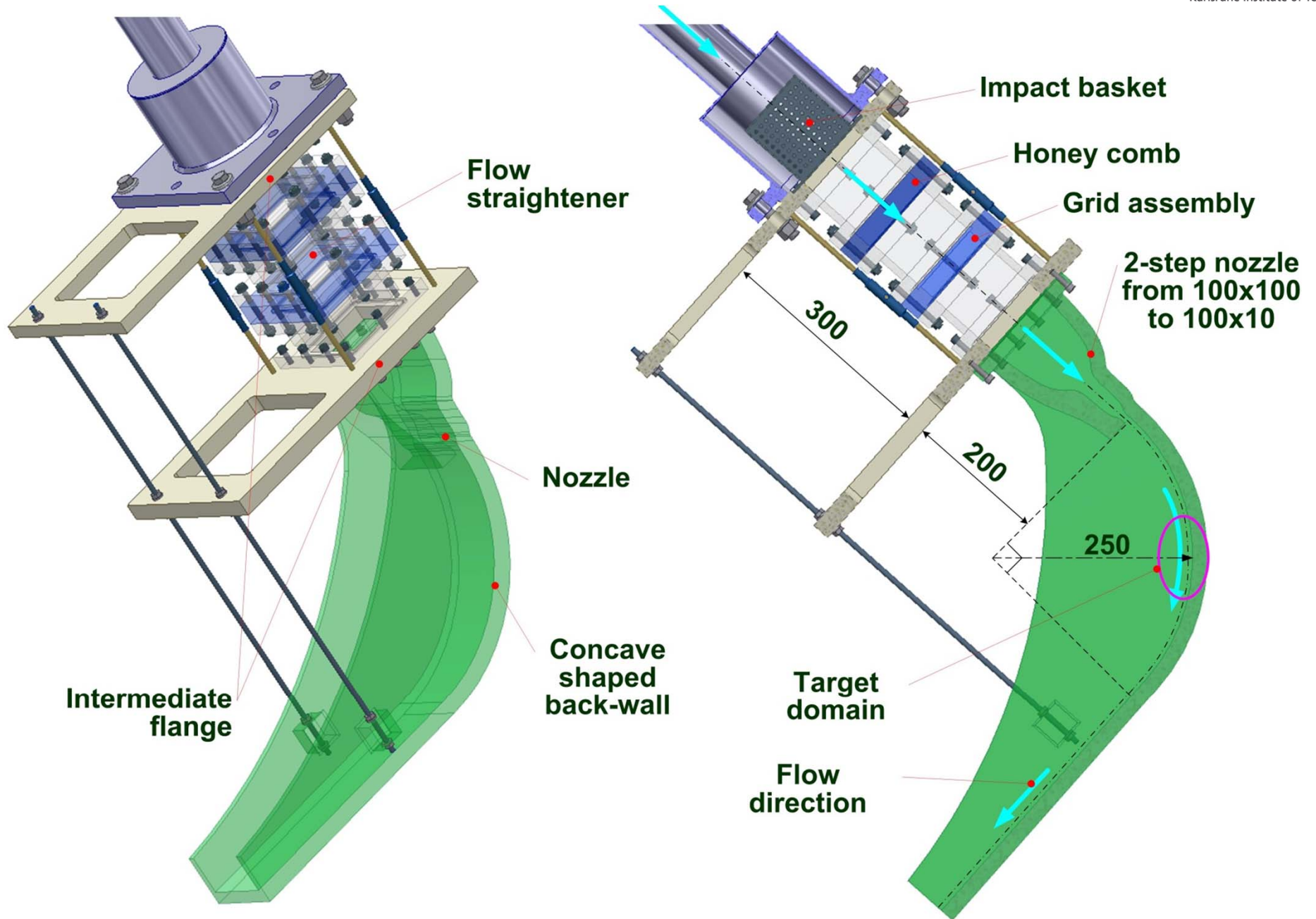


exposure 1/30 sec



exposure 1/200 sec

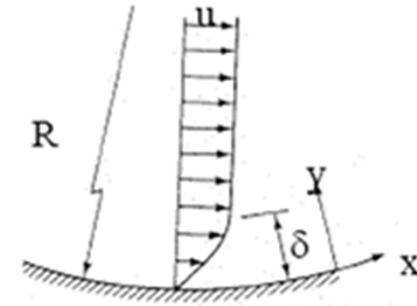
IFMIF water test section design



Taylor-Goertler instability

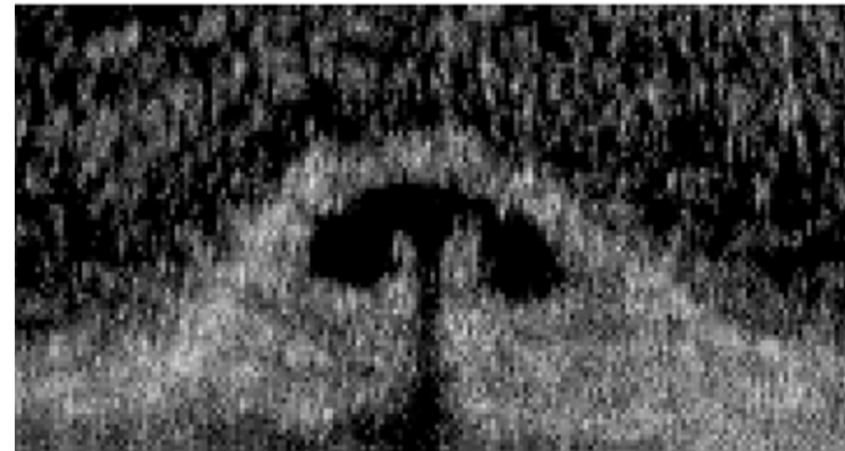
Investigation subjects:

- Velocity distribution in the jet flow
- Formation and development of Goertler vortices
- Influence on the free surface

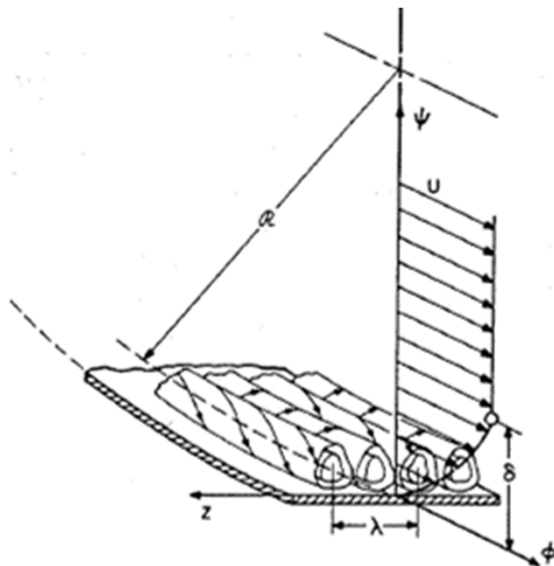


$$Go = \frac{U_\infty \cdot \theta}{\vartheta} \cdot \sqrt{\frac{\theta}{R}} = R_\theta \cdot \sqrt{\frac{\theta}{R}} \quad Go_{cr} \approx 7$$

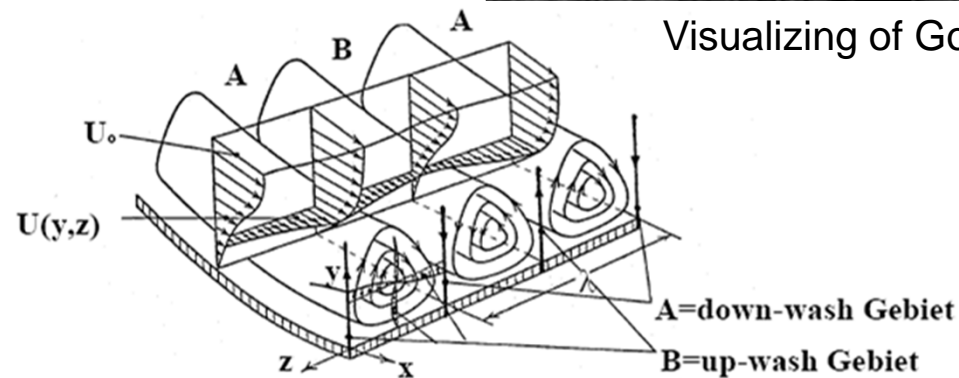
Goertler number as a critical stability parameter



Visualizing of Goertler vortices



Goertler vortices, Saric



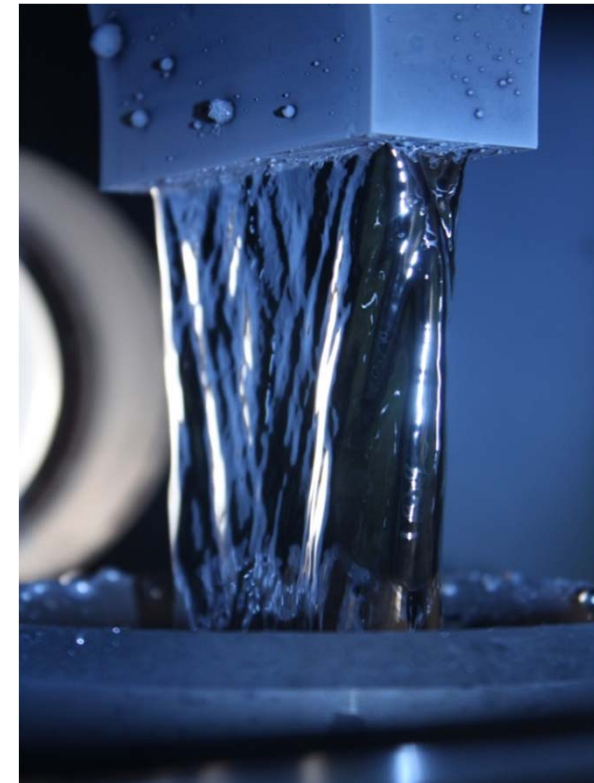
Goertler vortices, Wortmann

Summary

- Experimental background for investigation of liquid metal free surface flows has been created:
 - Water test facility FIDES has been constructed
 - Liquid-metal facility ALINA was built and successfully tested
 - Facilities have been equipped by modern measuring technics.
- FIDES-facility was improved and rebuilt to IFMIF-conditions

Outlook

- Experimental investigation of:
 - Instabilities in the flow - Goertler vortices
 - Stability of the free surface
 - Flow conditioning
- Application of High Speed PIV system (up to 1000Hz)





*Thank you for your
Attention!*