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COMSOL CONFERENCE 2015 GRENOBLE

Optimization of the Supersonic Gas Jets' Parameters for in-gas-jet Nuclear Spectroscopy Studies

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Plan:

1. The goal of the research;
2. Experimental technique;
3. Computer simulations in COMSOL Multiphysics software;
4. Results;
5. Conclusions and Outlook.

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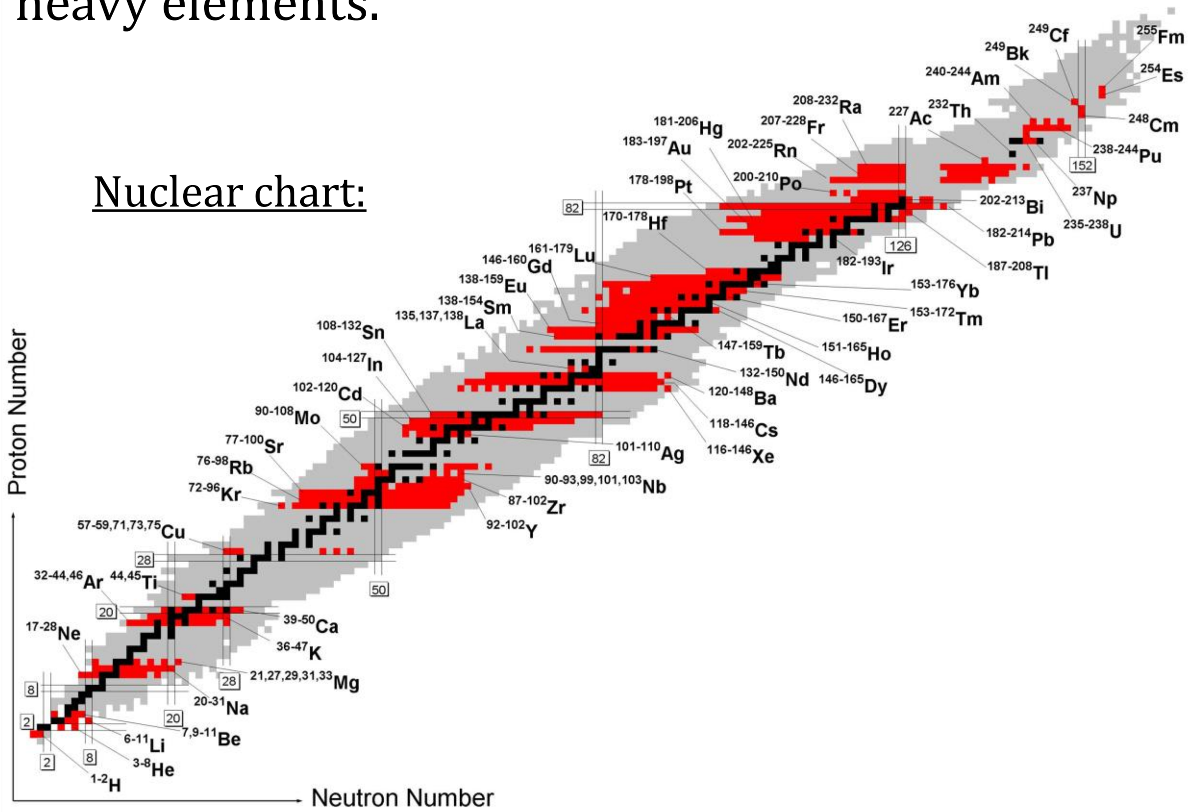
Heavy Elements Laser IOnization and Spectroscopy → HELIOS project (Institute for Nuclear and Radiation Physics, KU Leuven)

<u>The goal of the project:</u> to study nuclear and atomic properties of isotopes of the heavy elements.

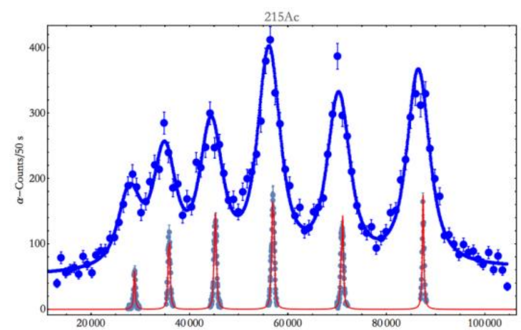
<u>Nuclear chart:</u>



Ways to enhance the spectral resolution and efficiency:

1. Low temperature $(\Delta\vartheta_{Doppler\_T} \sim \vartheta * \sqrt{T/A})$;
2. Low density $(\Delta\vartheta_{Collision} = \gamma^{293K} * (T/T_{293K})\text{\^{}}0.3 * \rho)$;
3. Uniform jet.

<u>→ µeV (hyperfine structure)!</u>



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In-gas-jet laser spectroscopy (experimental layout)

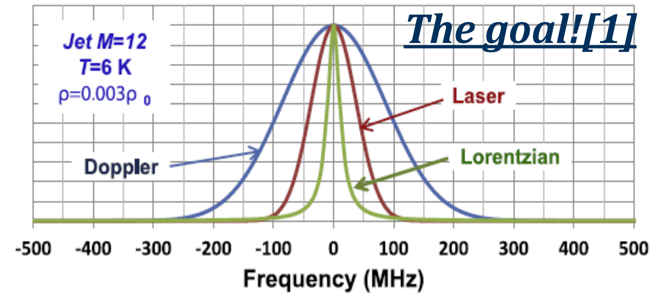
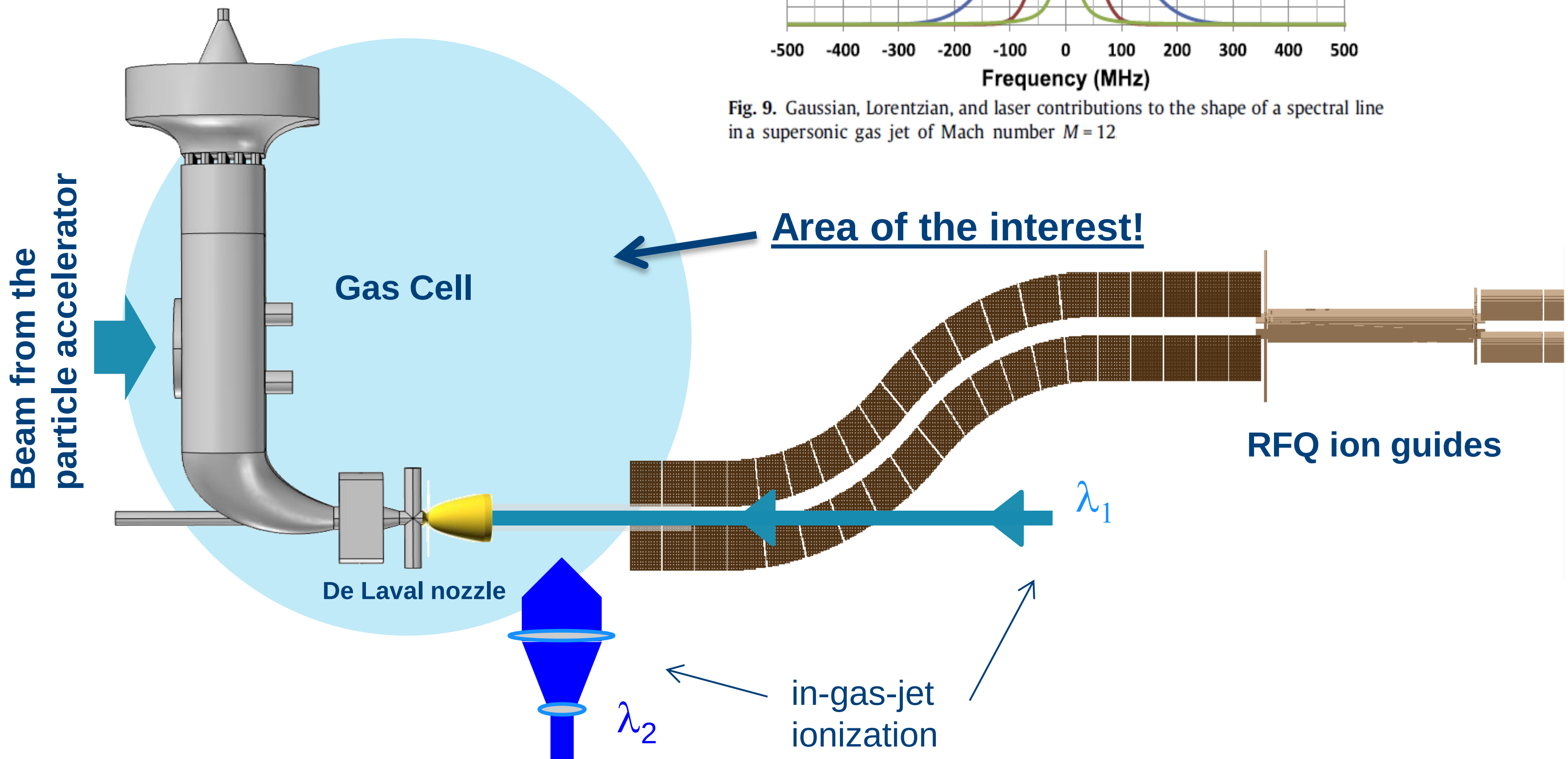
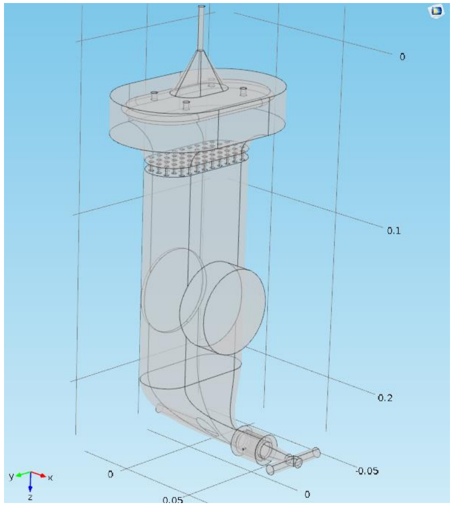


Fig. 9. Gaussian, Lorentzian, and laser contributions to the shape of a spectral line in a supersonic gas jet of Mach number $M = 12$



[1] Yu. Kudryavtsev et al, NIM B 297 (2013) 7 - 22

Optimization of the flow in the gas cell and in 'de Laval' nozzle



1. Computational Fluid Dynamics

Gas cell

2. Physics modules:

1) Laminar Flow

compressible flow;

turbulence model type – none;

boundary conditions – no slip.

2) Transport of Diluted Species

convection and diffusion.

3. Goals:

- provide non-turbulent flow inside the cell;
- decrease the convection and diffusion loses;
- decrease the evacuation time.

Nozzle

2. Physics module:

High Mach Number Flow

turbulence model type – none;

boundary conditions – no slip;

flow conditions for the outflow – supersonic.

3. Goals:

- uniform gas jet;
- low temperature;
- low density;
- to check the optimum conditions for the background pressure.

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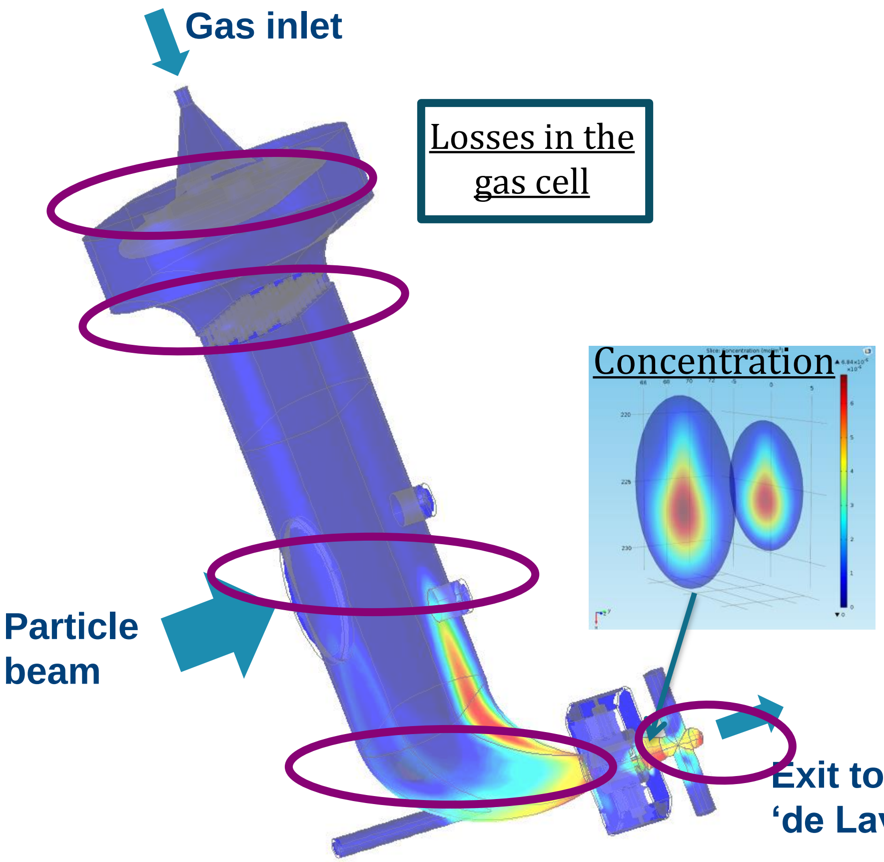
Optimization of the gas cell and of the de Laval nozzle

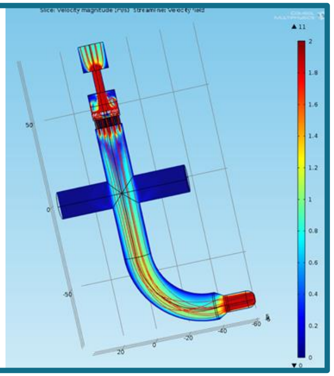
1. Gas cell



Important features in the optimization:

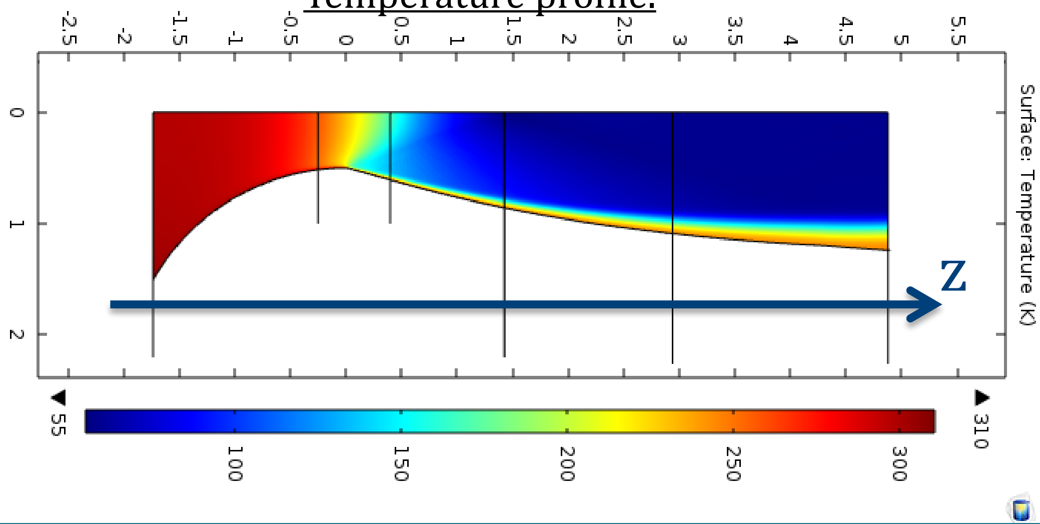
1) Decrease the velocity of the flow after the inlet;
2) Form the non-turbulent flow;
3) Avoid the losses of the nuclear reaction products on the walls of the cell;
4) Decrease the losses on the turning path;
5) Optimization of the diameter of the exit.

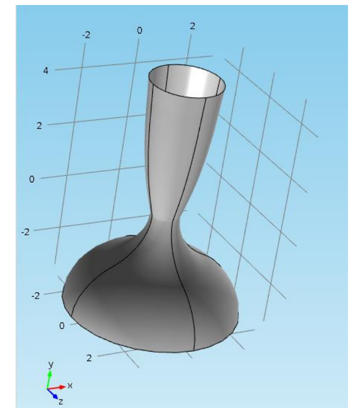
Gas cell for the first tests:

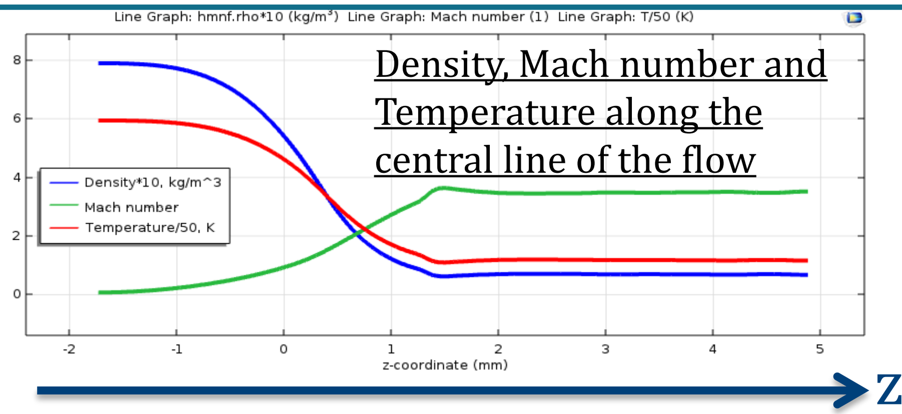


Optimization of the gas cell and of the de Laval nozzle
2. De Laval nozzle

Mach number = 3.5.
Temperature profile.







Density, Mach number and Temperature along the central line of the flow

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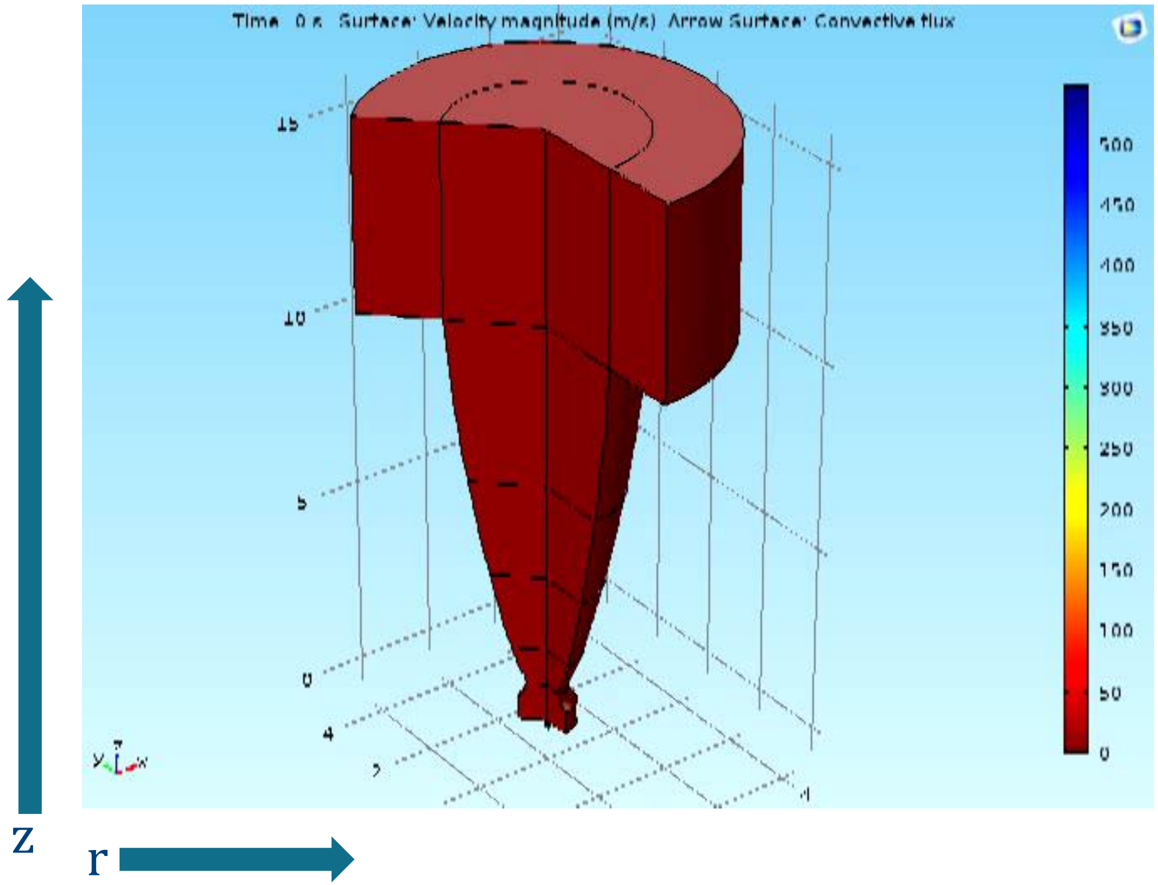
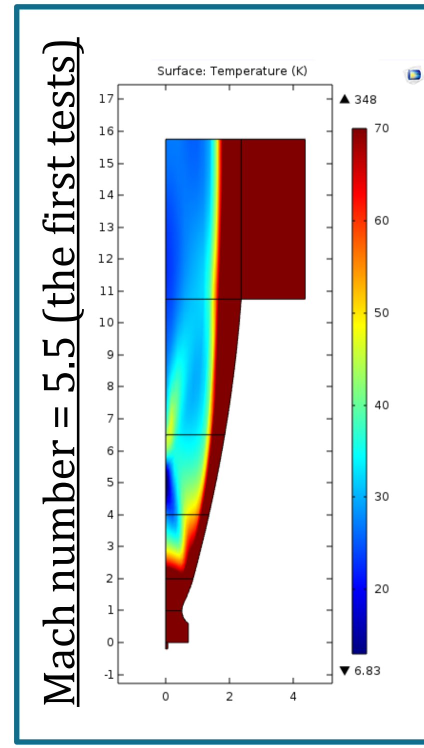
The flow of the argon after the de Laval nozzle





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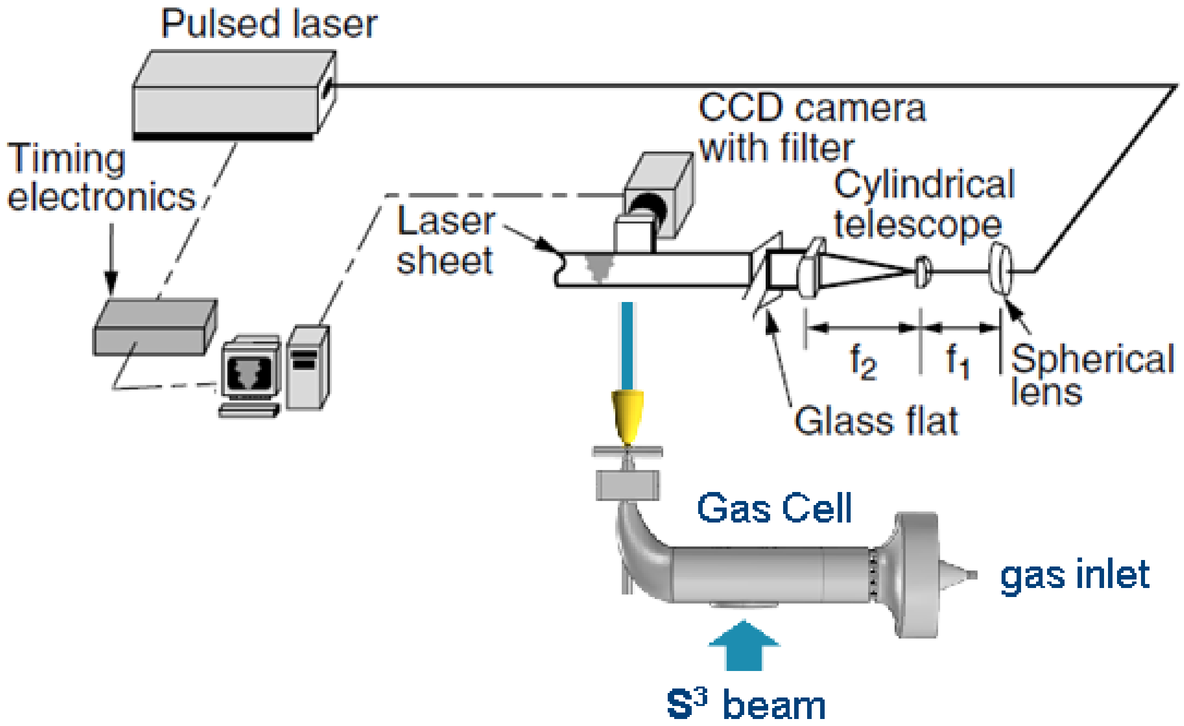
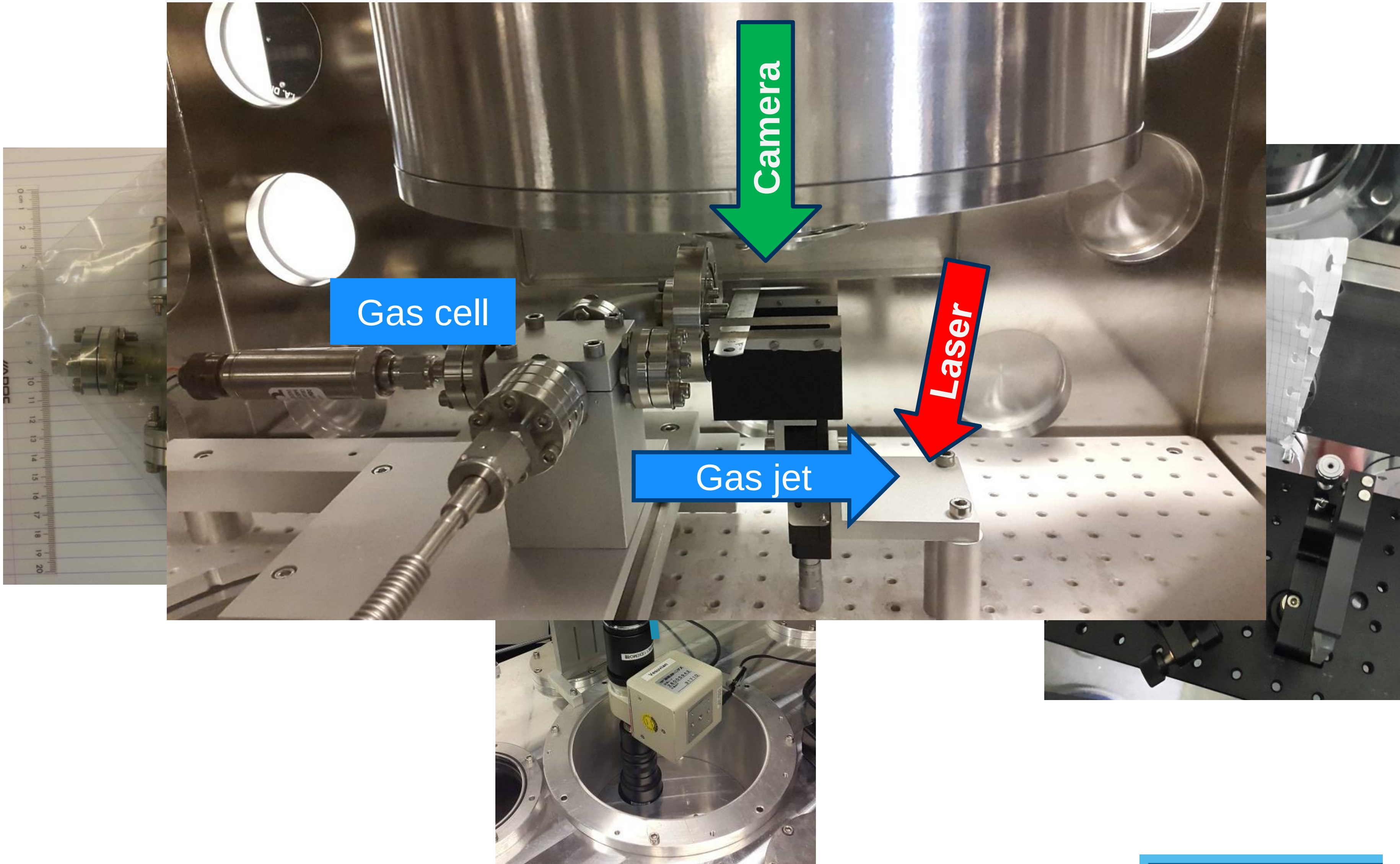
Planar Laser Induced Fluorescence - technique (PLIF)

In order to obtain information about *density, temperature and velocity distributions* for the gas jet and for the isotopes in the gas jet we can use PLIF-technique.

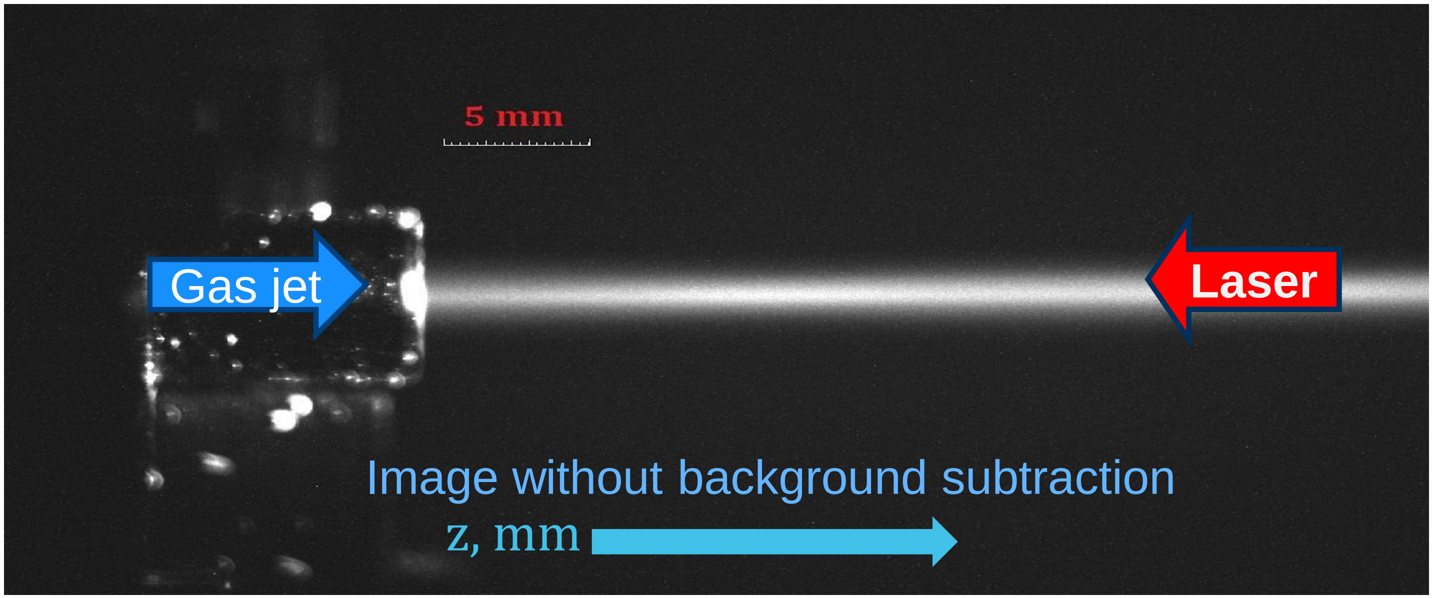


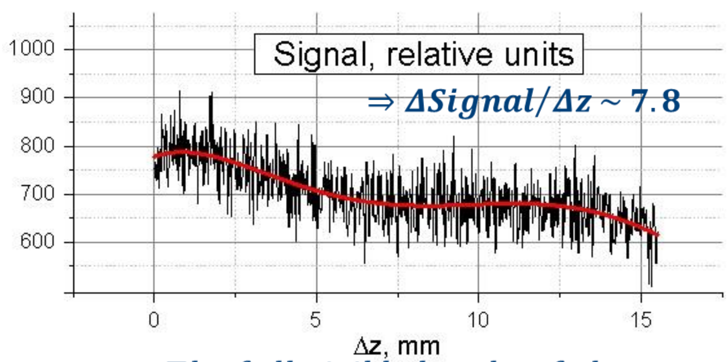

Camera
Gas cell
Laser
Gas jet

Acetone PLIF (longitudinal direction)

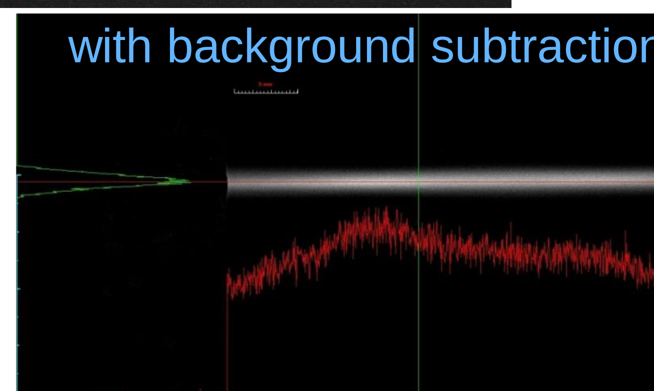
*image were taken with the camera Hamamatsu Photonics, C11440-42U

P0 = 1350mbar; P_jet_5.5 = 3.3mbar. P1 = 4mbar. **P1>P_jet!**



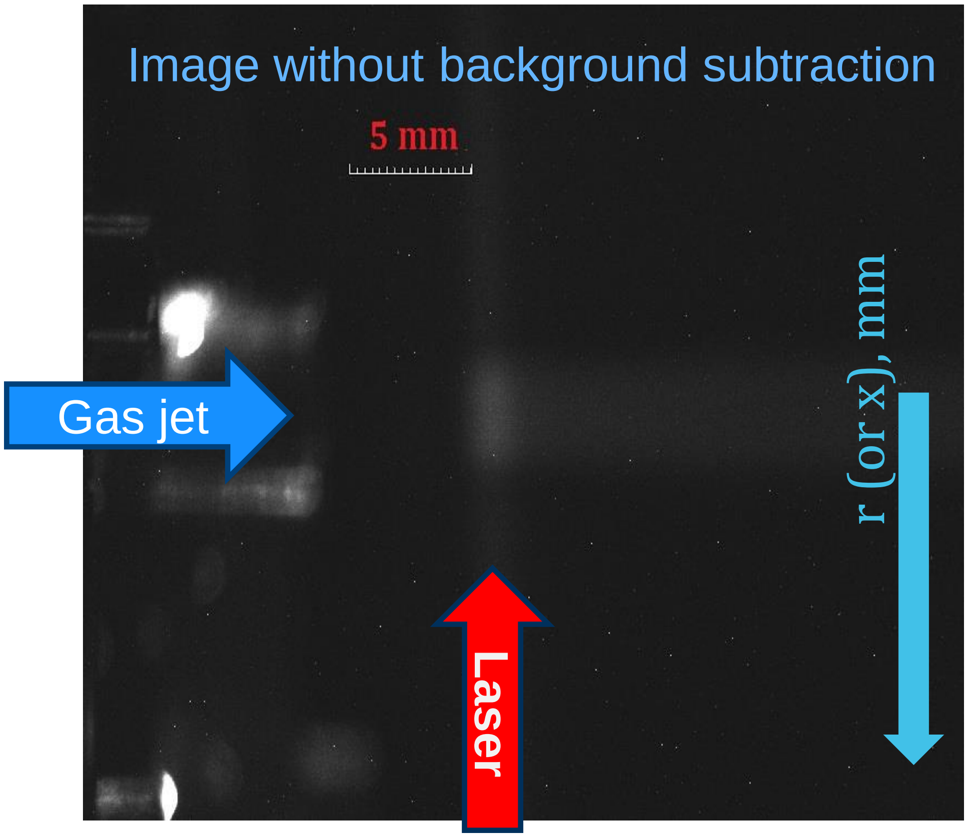


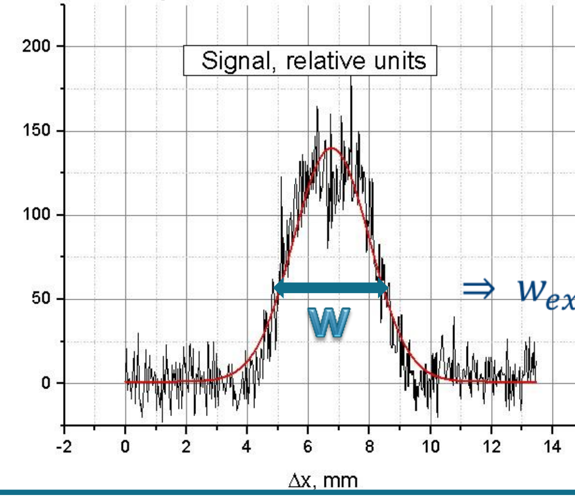
The full visible lenght of the gas jet during the test ~ 15 cm



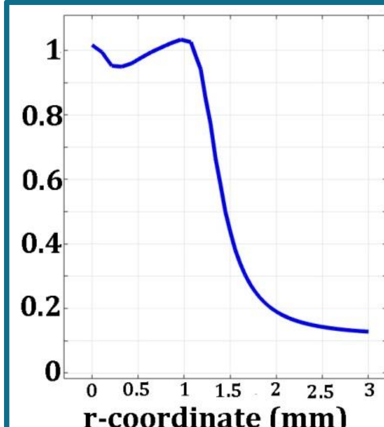
Acetone PLIF (transversal direction)

*image were taken with the camera Hamamatsu Photonics, C11440-42U
P0 = 1350mbar; P_jet_5.5 = 3.3mbar. P1 = 4mbar. **P1>P_jet!**





$\Rightarrow w_{exp} \sim 3\ mm$



Normalized density at 5mm distance from the exit of the de Laval nozzle*

$\Rightarrow w_{comp.simulations} \sim 2.9\ mm$

*Simulations in COMSOL Multiphysics

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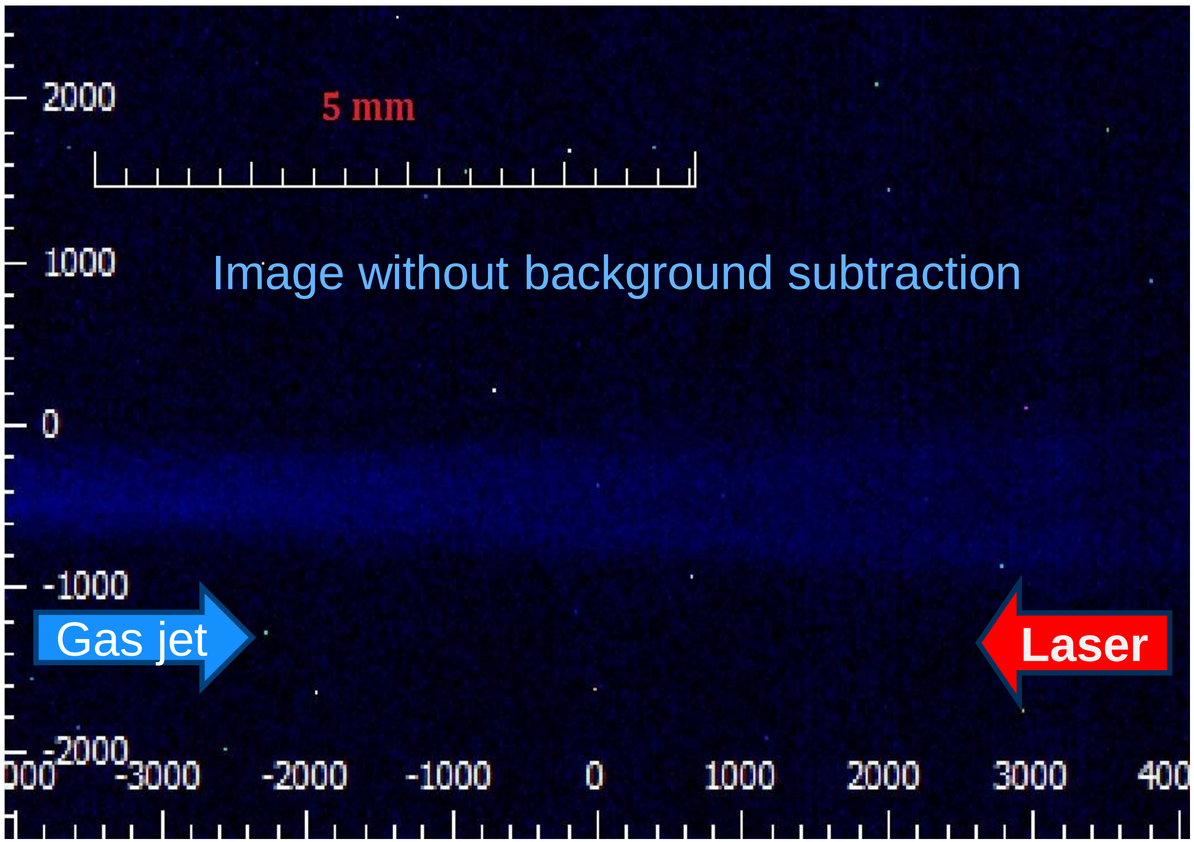
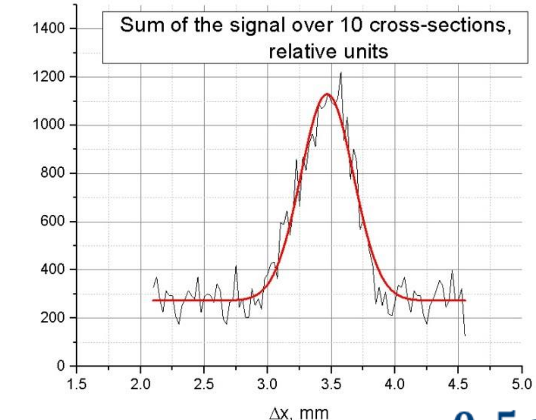
Acetone PLIF (longitudinal direction)

*image was taken with Thorlabs camera

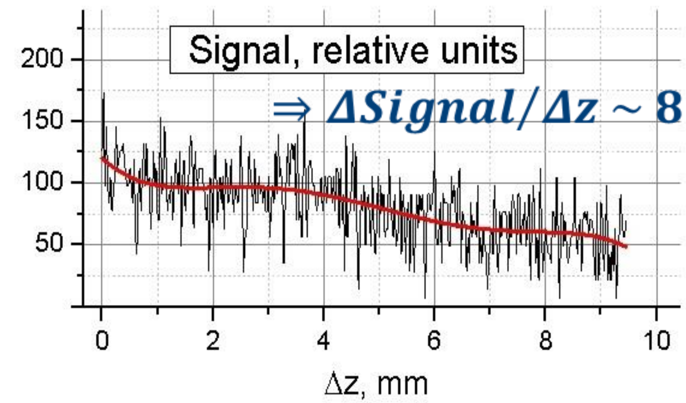
P0 = 1600 mbar; P_jet_5.5 = 3.9 mbar; P1 = 0.36 mbar. **P1<P_jet!**





$w_{exp\_5mm\_from\_the\_nozzle} \sim 0.5\ mm$

jet is divergent!



$\Rightarrow \Delta Signal/\Delta z \sim 8$

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Conclusions

- Simulations in Computational Fluid Dynamics module of the COMSOL Multiphysics software were applied for the optimization of the parameters of the gas cell and of the 'de Laval' nozzle;

- The first experimental tests were performed and the preliminary analysis shows a good agreement between the experimental data and the output from the computer simulations.

Thanks for your attention!