WWU MÜNSTER

Cluster size determination using shadowgraphy measurements

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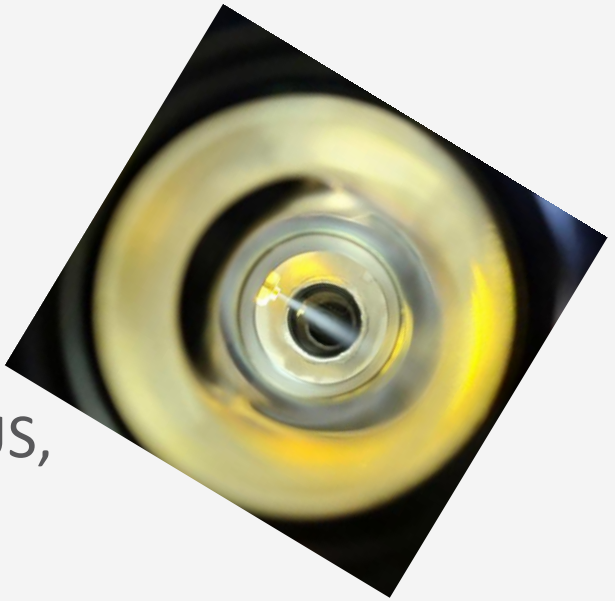
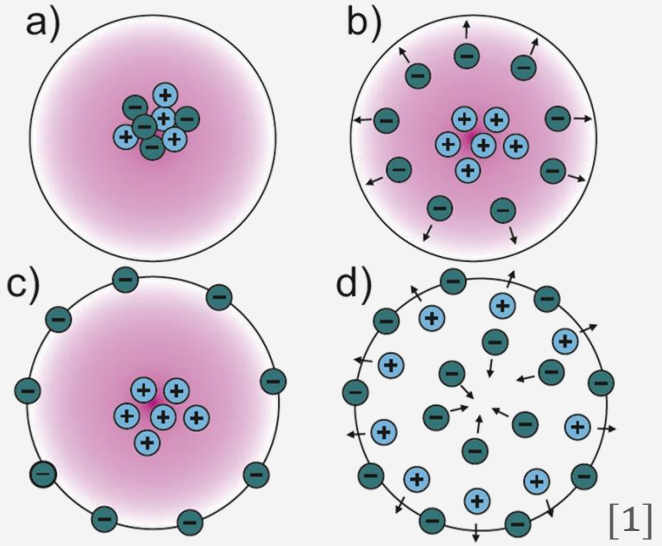
Motivation of Measurements



- Cluster-jet targets are important and central component of several experiments (e.g., for laser induced proton acceleration → ARCTURUS, or hadron physics → PANDA experiment)
- Investigation of target properties and cluster generation process
- Important properties of the targets are the sizes of clusters and the size distribution
  - Prediction of the beam's time structure
  - Understanding of the residual gas

Important Experiments with Cluster-Jet Targets

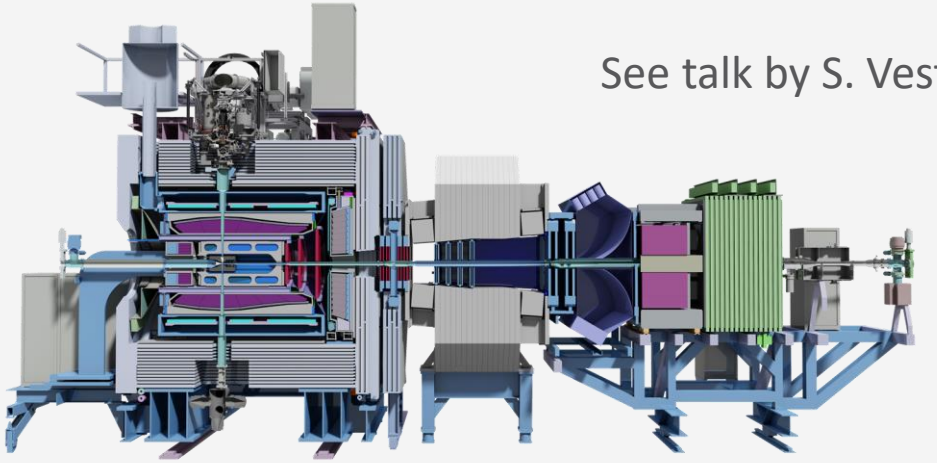
Laser induced proton acceleration



[1]

ARCTURUS TW laser at HHU Düsseldorf

Hadron physics



See talk by S. Vestrick

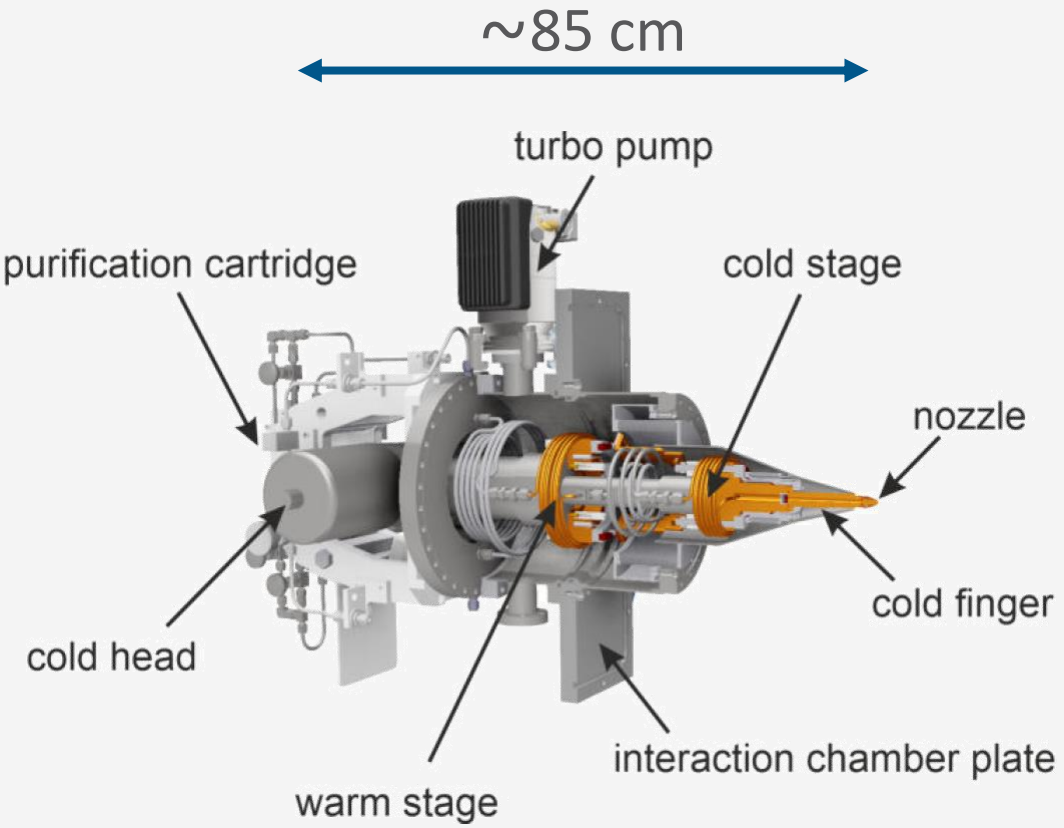
PANDA experiment at future HESR

And other experiments: See talk by P. Brand

[1] A.-M. Schroer. Doctoral thesis, HHU Düsseldorf, 2018

Set-up of Münster Cluster-Jet Targets

- Hydrogen is flowing through purification cartridge and cooled down by two-stage cold head
- Insulation vacuum chamber with turbo pump to ensure a thermal decoupling
- Cooled gas is pressed through laval nozzle with diameter of 37 µm
- Depending on target conditions, different cluster production processes occur



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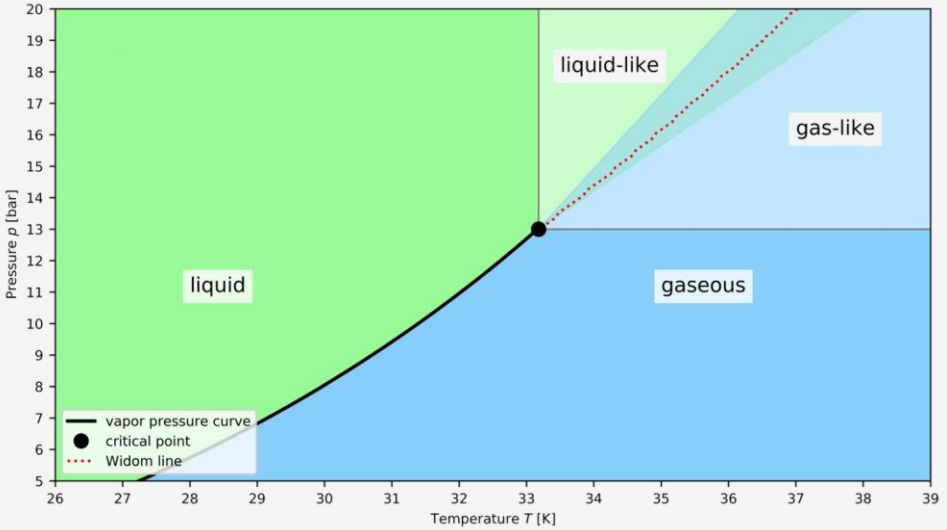
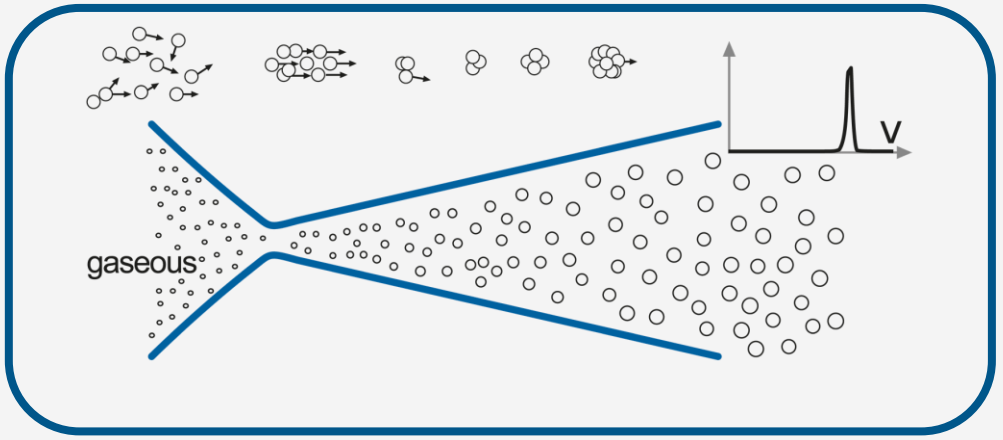
Cluster Production Process

Cluster size determination using shadowgraphy measurements

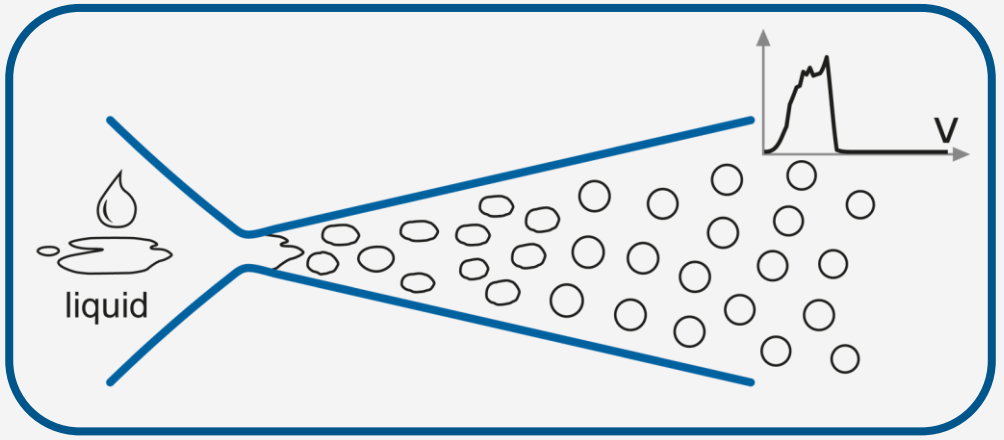


- Laval nozzle with convergent inlet and divergent outlet
- Hydrogen can be either gaseous or liquid in front of the nozzle → leads to different cluster formation processes

Gaseous



Liquid

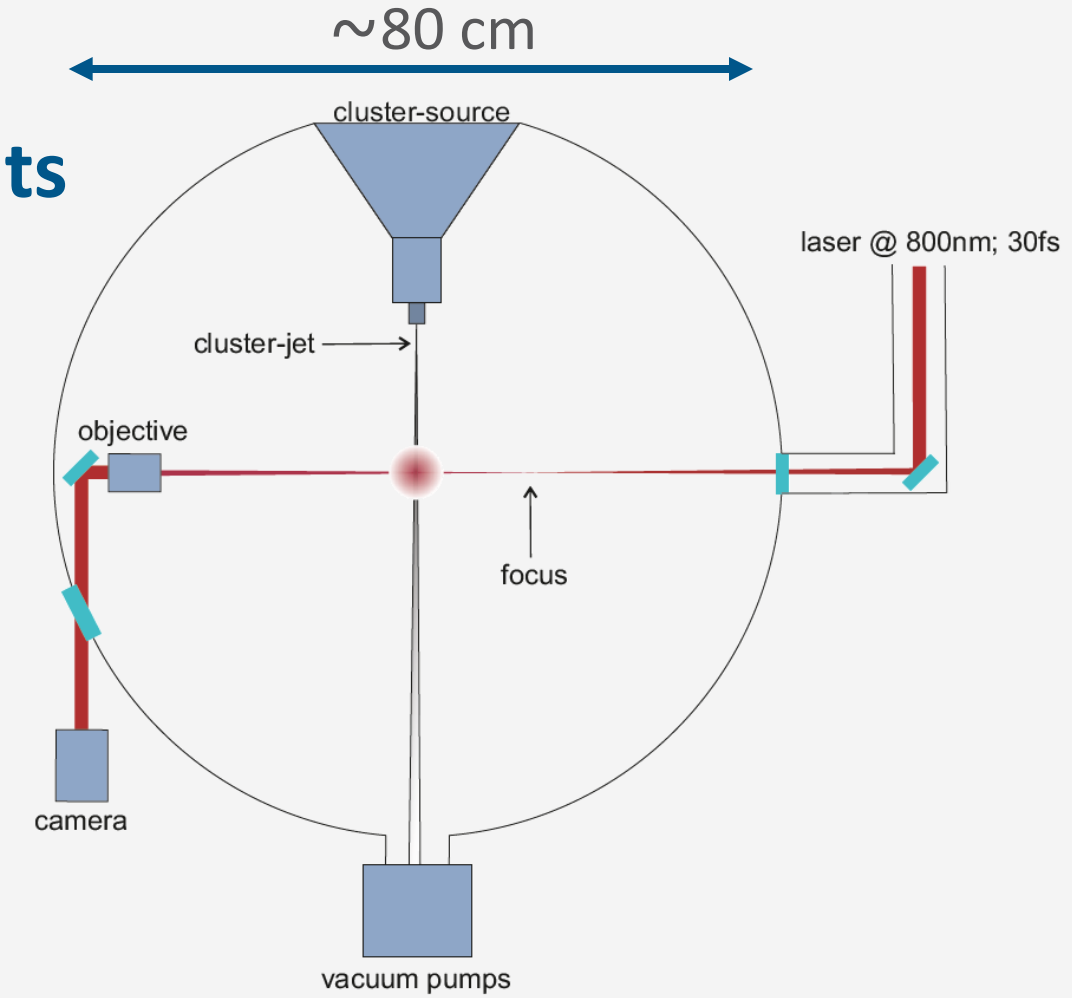


S. Vestrick et al., The Journal of Supercritical Fluids 188 (2022) 105686

Set-up for Shadowgraphy Measurements

- Top view of the experimental set-up
- Cluster-Jet Target, developed and built up in Münster
- Target setting determines:
  - Target beam thickness
  - Cluster size distribution

Cluster size determination using shadowgraphy measurements

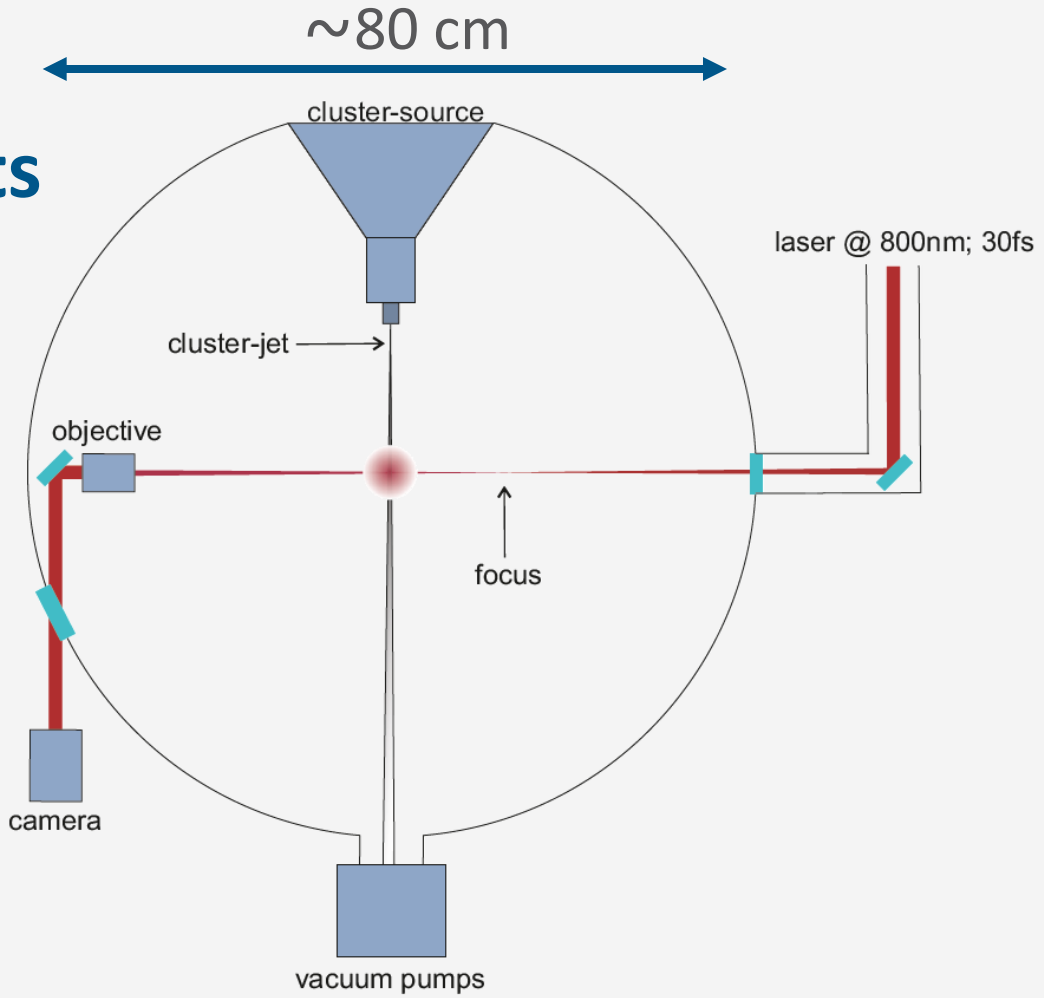


Created by Christian Mannweiler

Set-up for Shadowgraphy Measurements

- ARCTURUS TW laser system of HHU Düsseldorf
- Ultrashort-pulse laser (30 fs) is used as background lightening
- Pictures of clusters are taken with a camera in combination with a microscope objective
- With longer exposure time clusters at about (200 - 1000) m/s would no longer be recognizable as dots

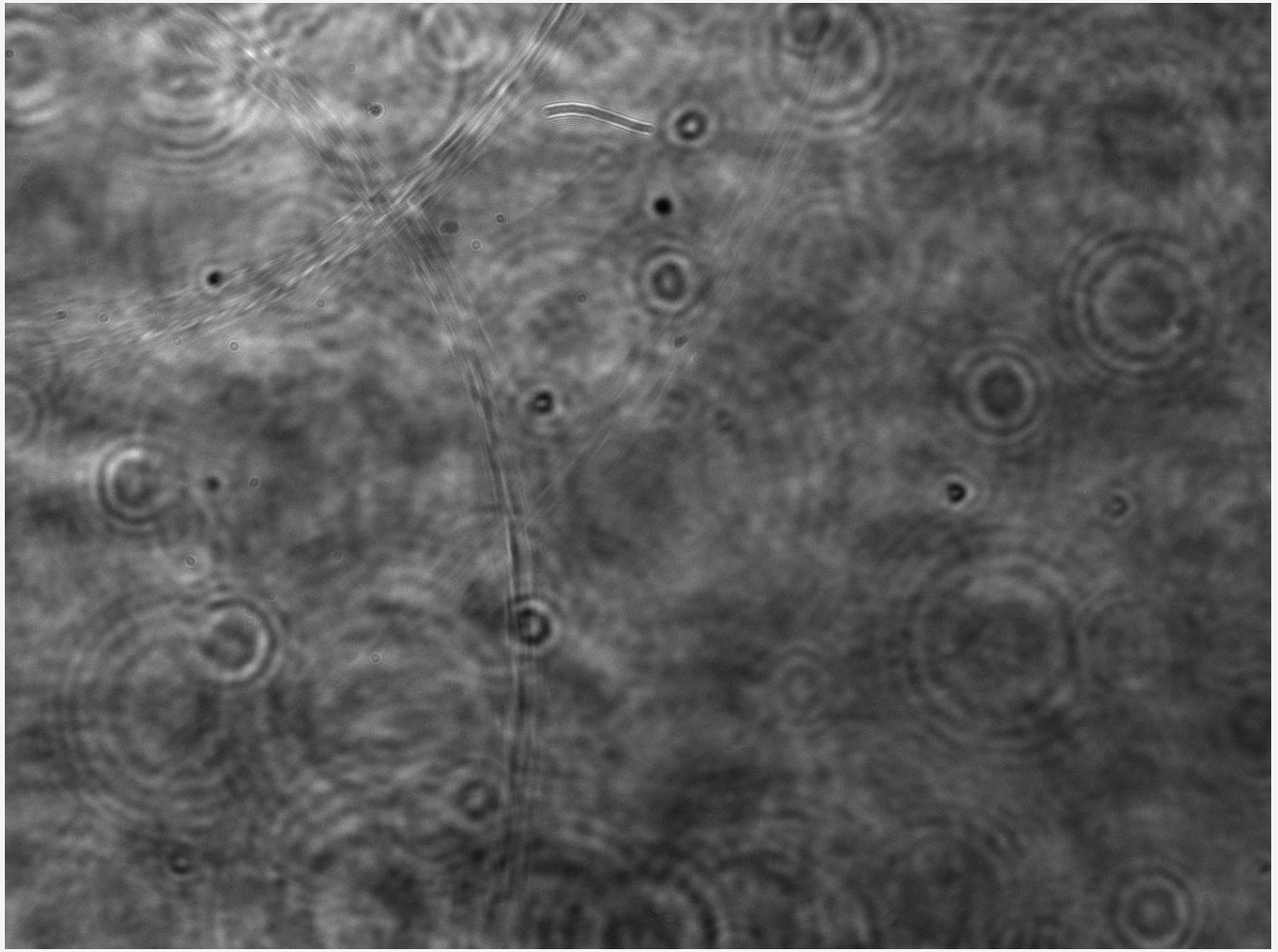
Cluster size determination using shadowgraphy measurements



Created by Christian Mannweiler

Shadowgraphy Image

- Shadowgraphy image (background subtracted) with …
  - some sharp clusters
  - a lot of interference rings
  - dust on camera and optics (some of this is eliminated by background subtraction)



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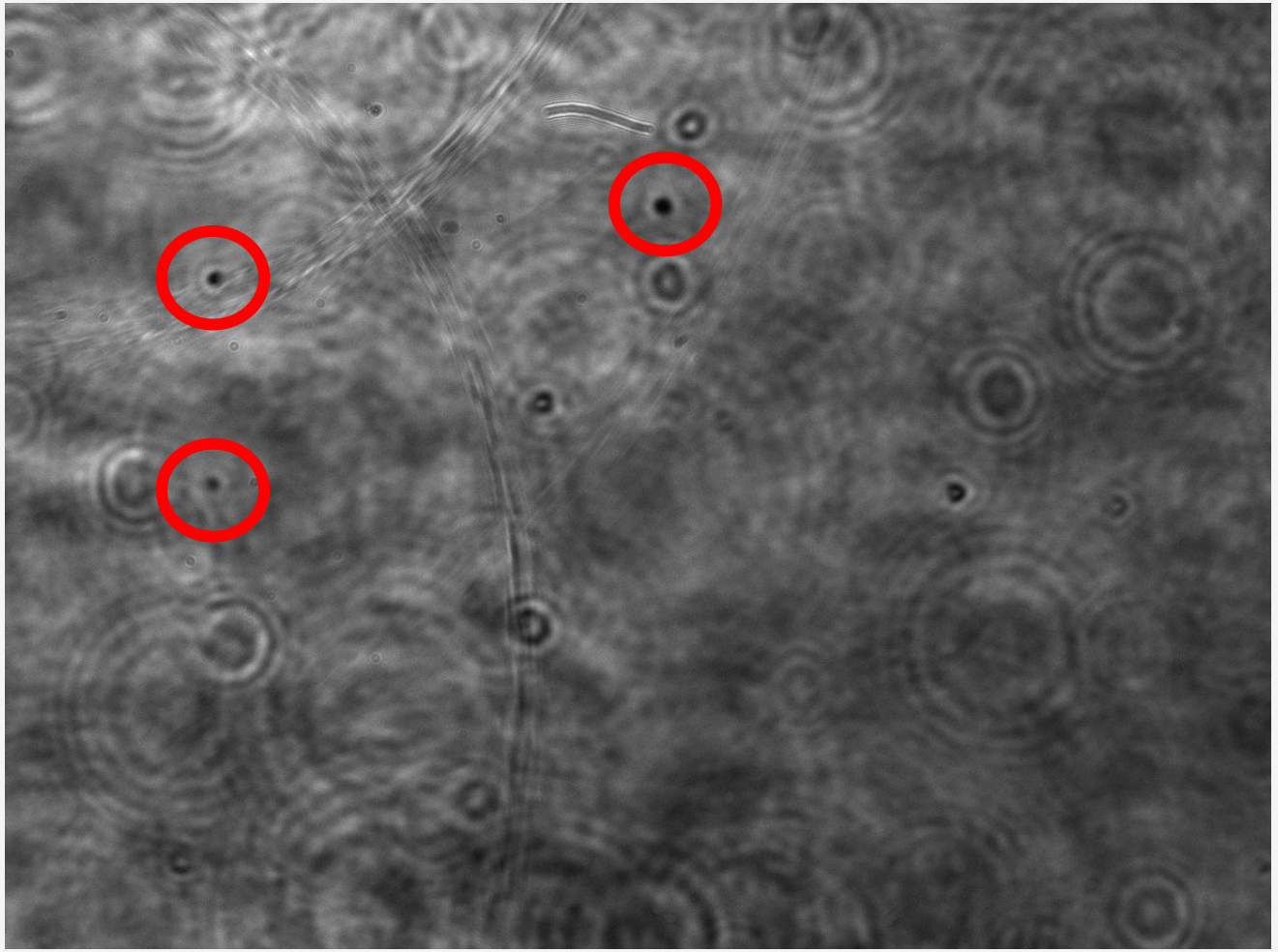

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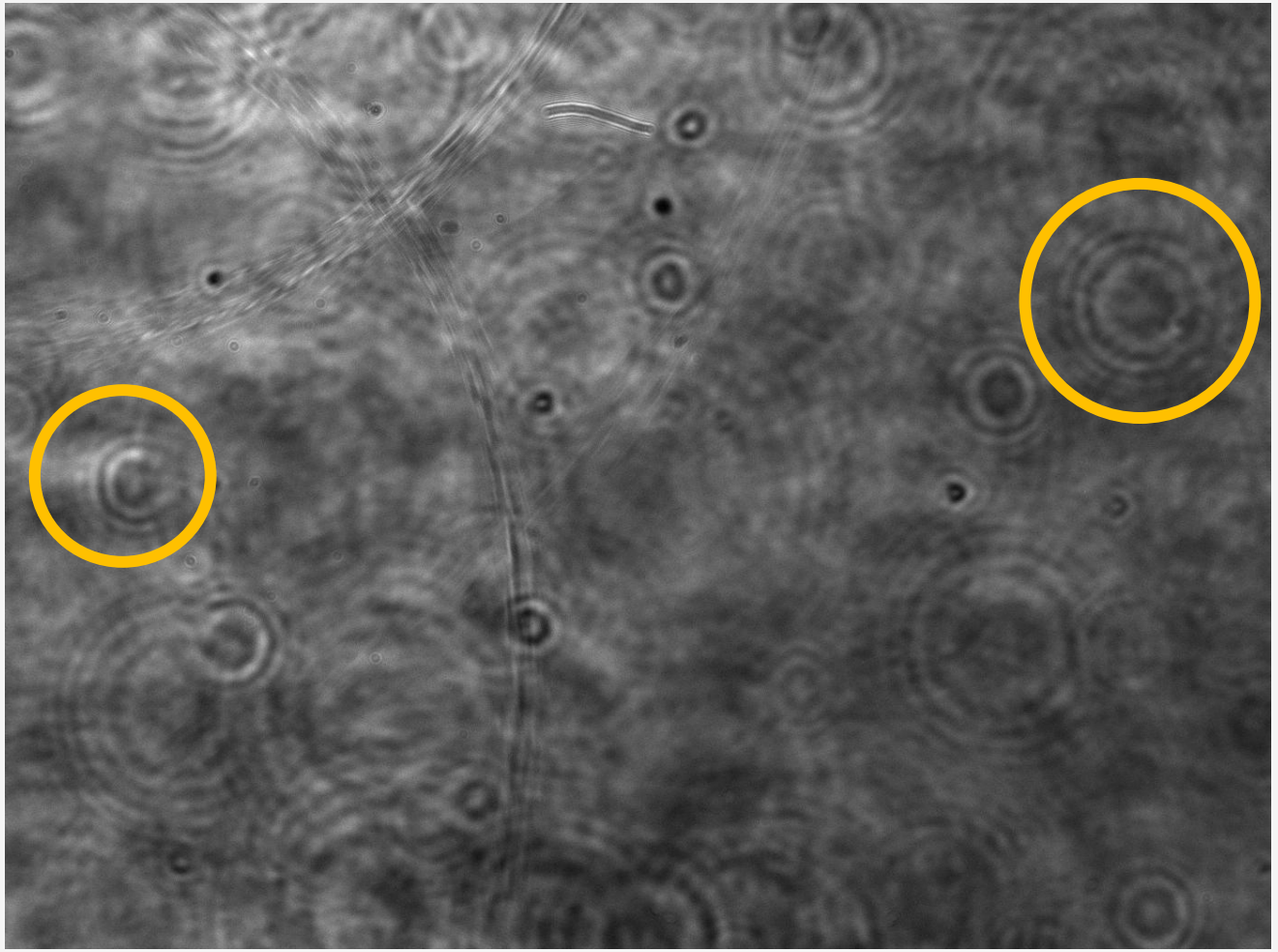

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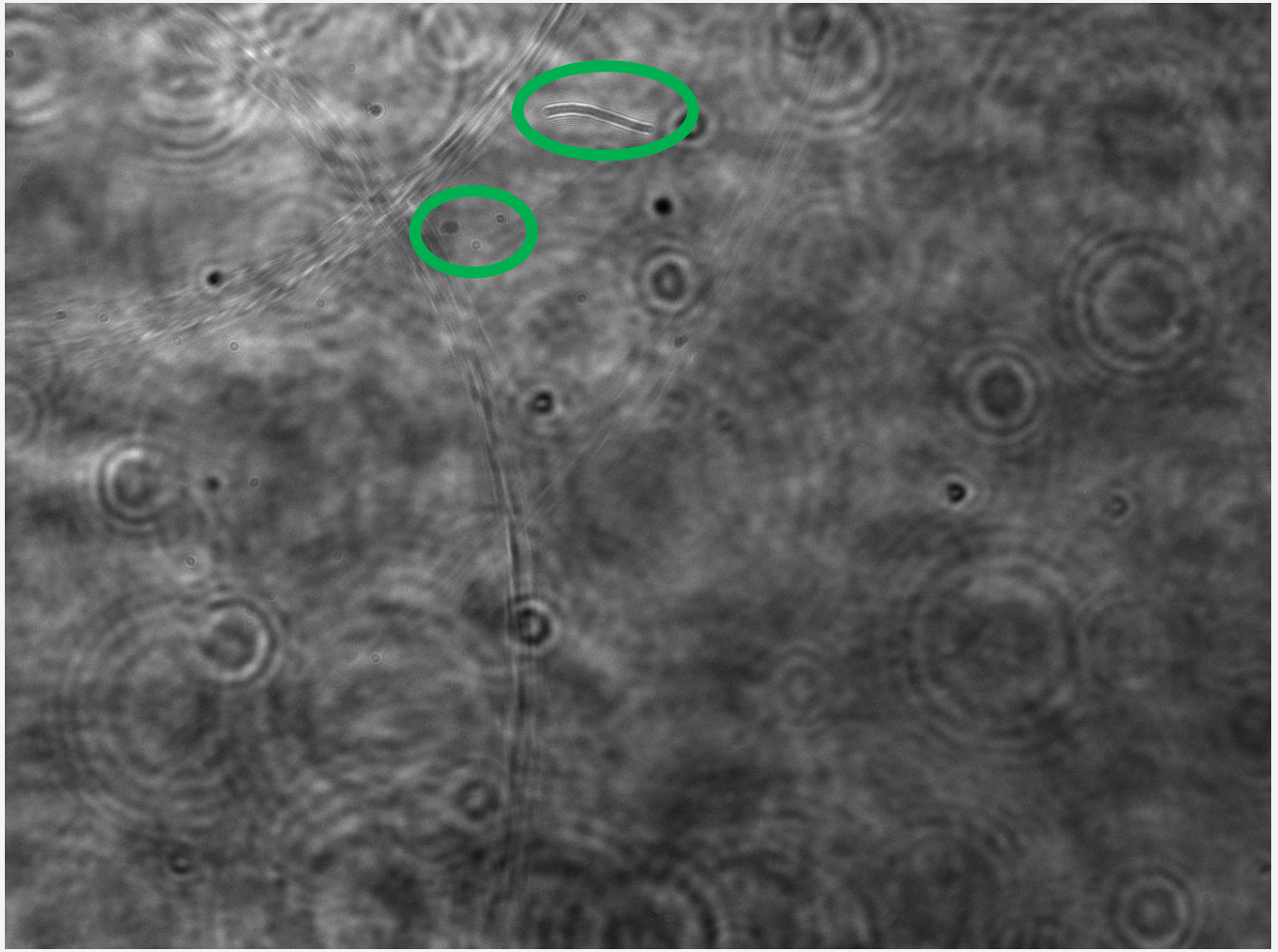
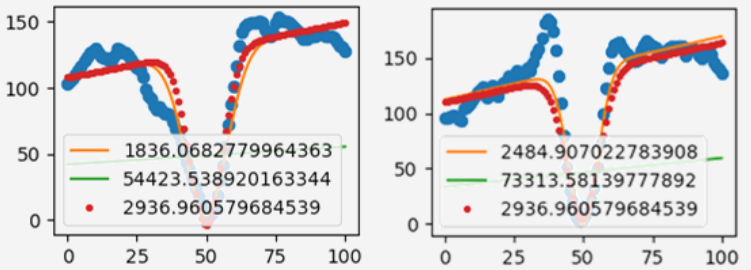


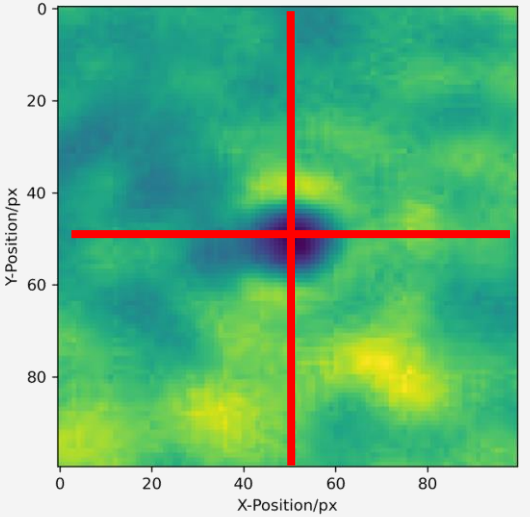
Cluster Selection Criteria

- For every target setting and position in the cluster beam 1000 pictures were taken → impossible to analyze all by hand
- An automated procedure is required to find potential cluster candidates and to decide with cluster selection criteria whether they are clusters or not
- The image processing program *ImageJ* [2] is used to identify potential cluster candidates

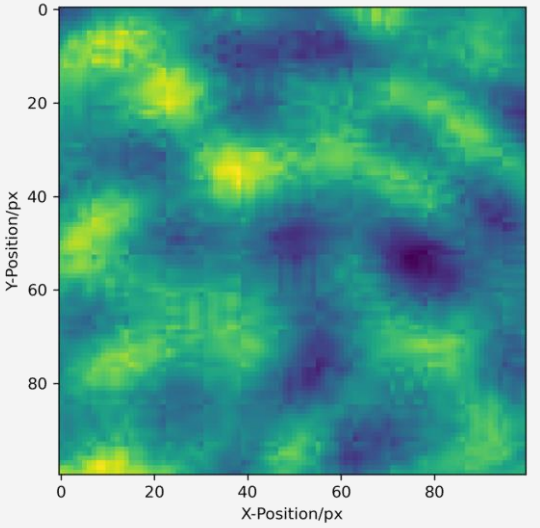
[2] ImageJ: https://imagej.nih.gov/ij/

Cluster Selection Criteria





- Widths of both profiles must be similar in size
- Amplitude of peak must have significant height
- Background must not be too uneven
- Sorted out when light spot (Poisson spot) appears in center → too far away from focal plane



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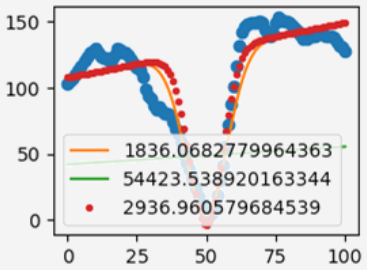

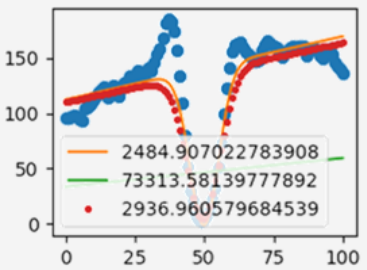

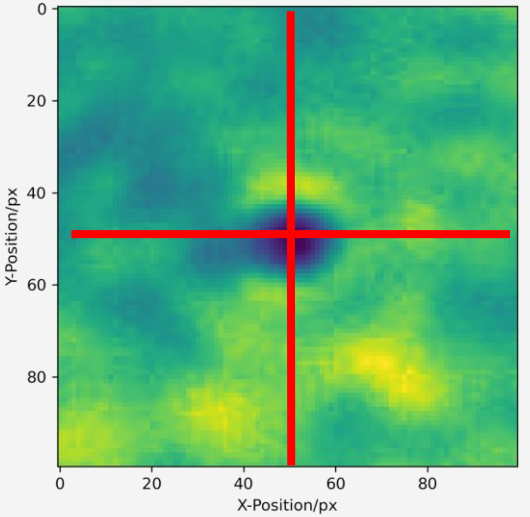

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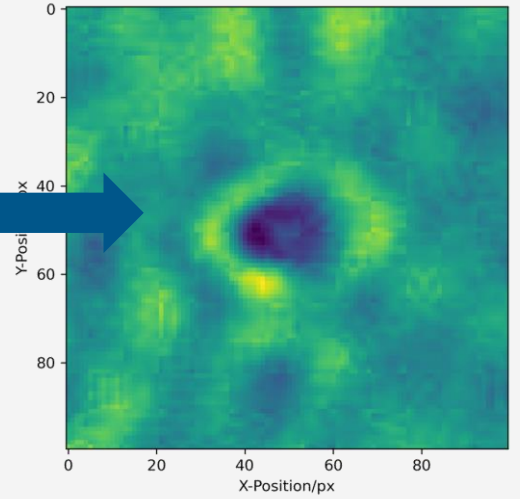
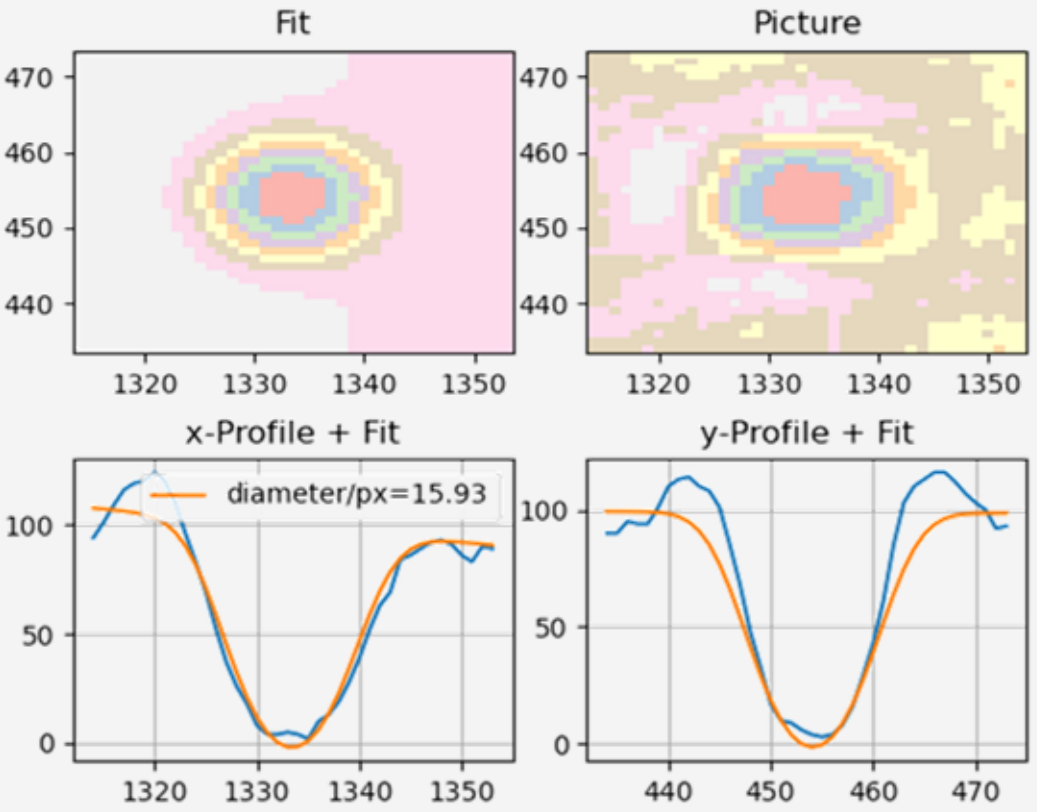
Light spot



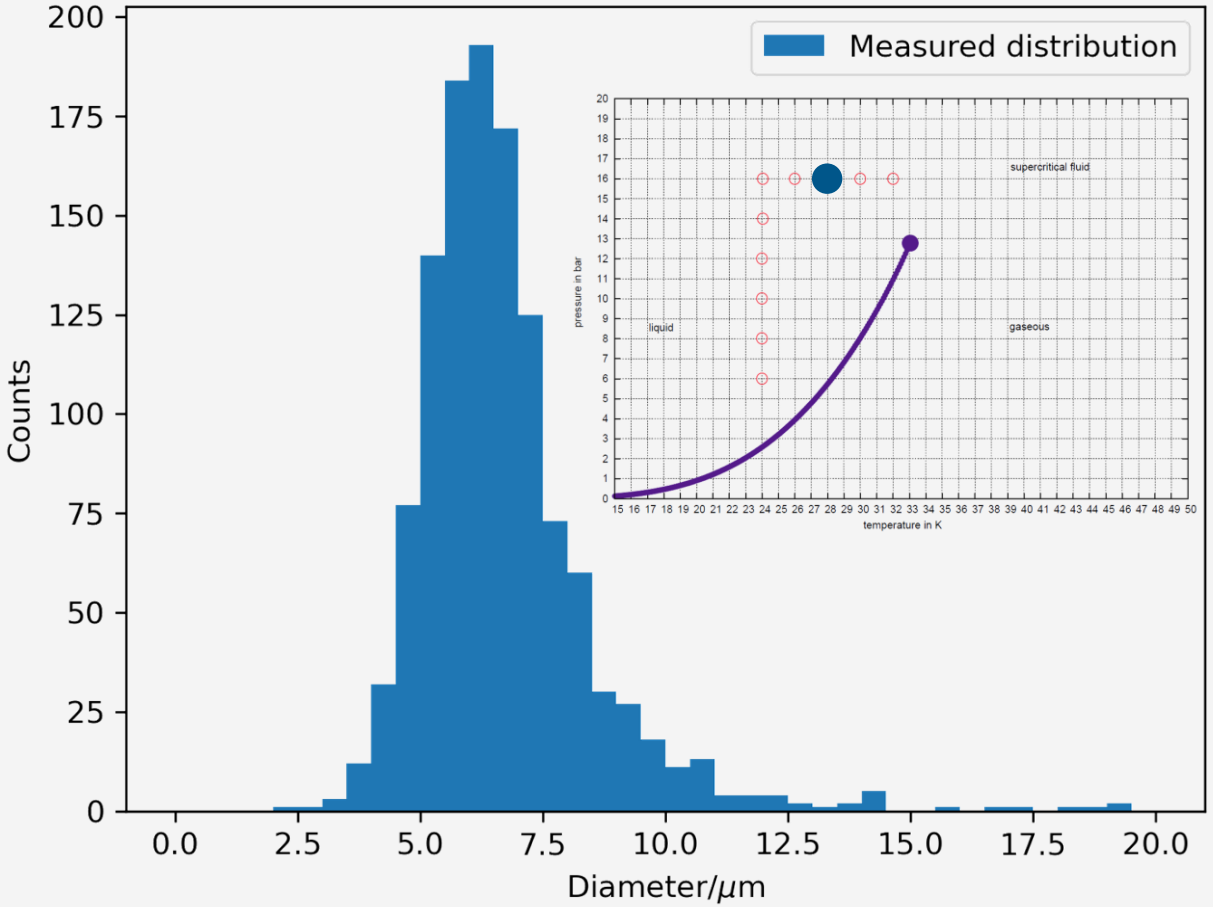
Calculation of Cluster Diameter

- After identifying real clusters, a 2-dimensional fit is applied which includes the diameter as fit parameter
- By means of a calibration measurement (wire measurement) the camera pixel information is converted into a size information in µm

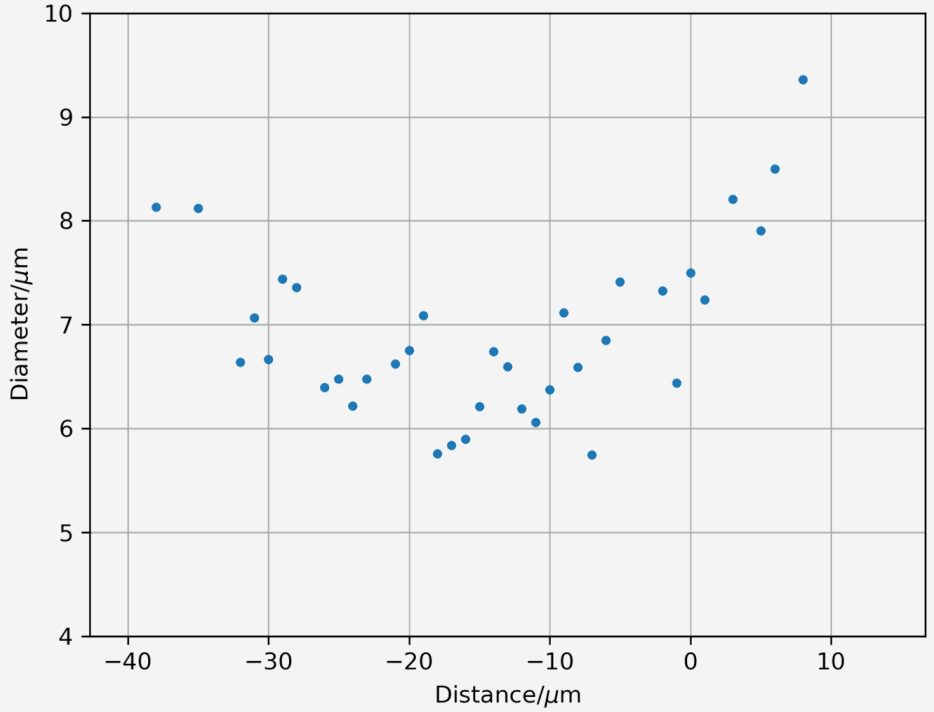


Cluster Size Distribution

- Cluster size distribution (1000 pictures) for one target setting
- Steeper edge on left side and longer tail on right side → ‘real’ distribution on right side, but resolution limit on left side

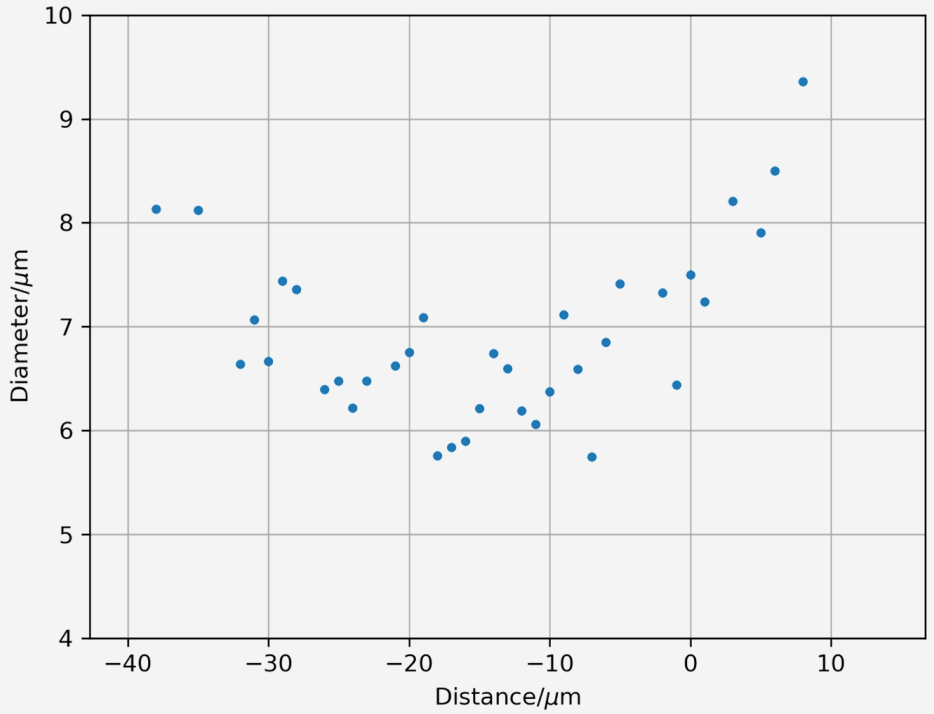


Do we really see the True Distribution?



- To measure depth of every picture, calibration measurements using µm-sized toner particles were performed
- Toner inks were moved at location of target through laser in micrometer steps
- First intention: Look at one specific toner particle and find out in which range it can be found and analyzed

Do we really see the True Distribution?



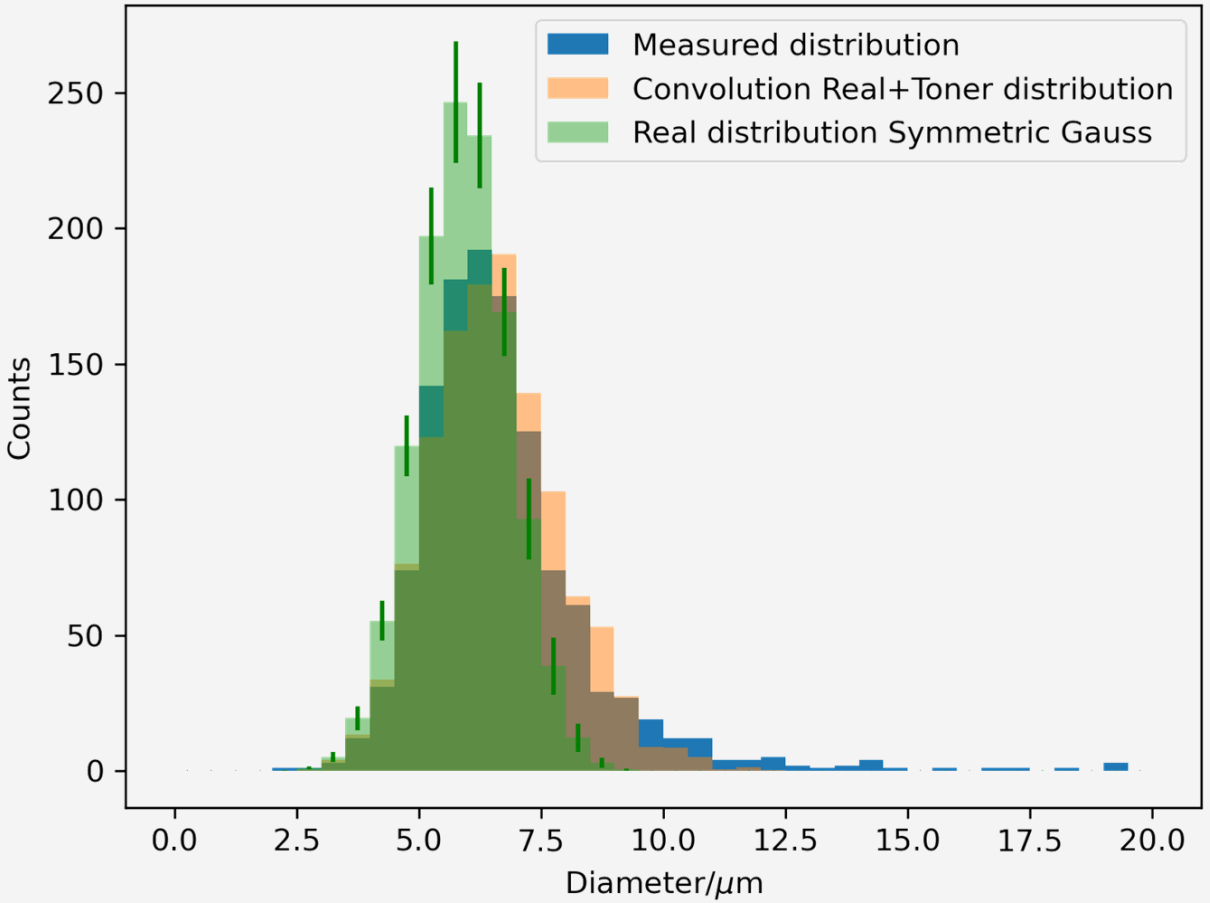
- The observation made is that the ‘toner clusters’ look larger the further they are away from the focal plane
- The found distribution is not the true distribution
- Bringing together information from the measured distribution and the toner clusters (deconvolution)

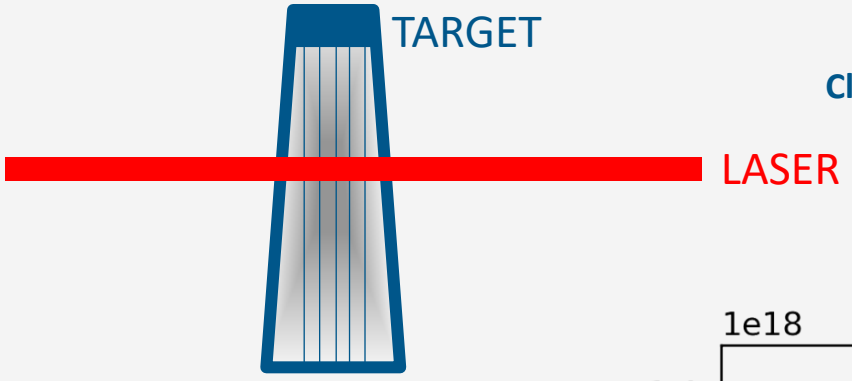
True Cluster Size Distribution

Result with assumption that true distribution is symmetric Gaussian

→ More quantities can be determined (volume density, gas flow) and compared with measured values and theoretical calculations

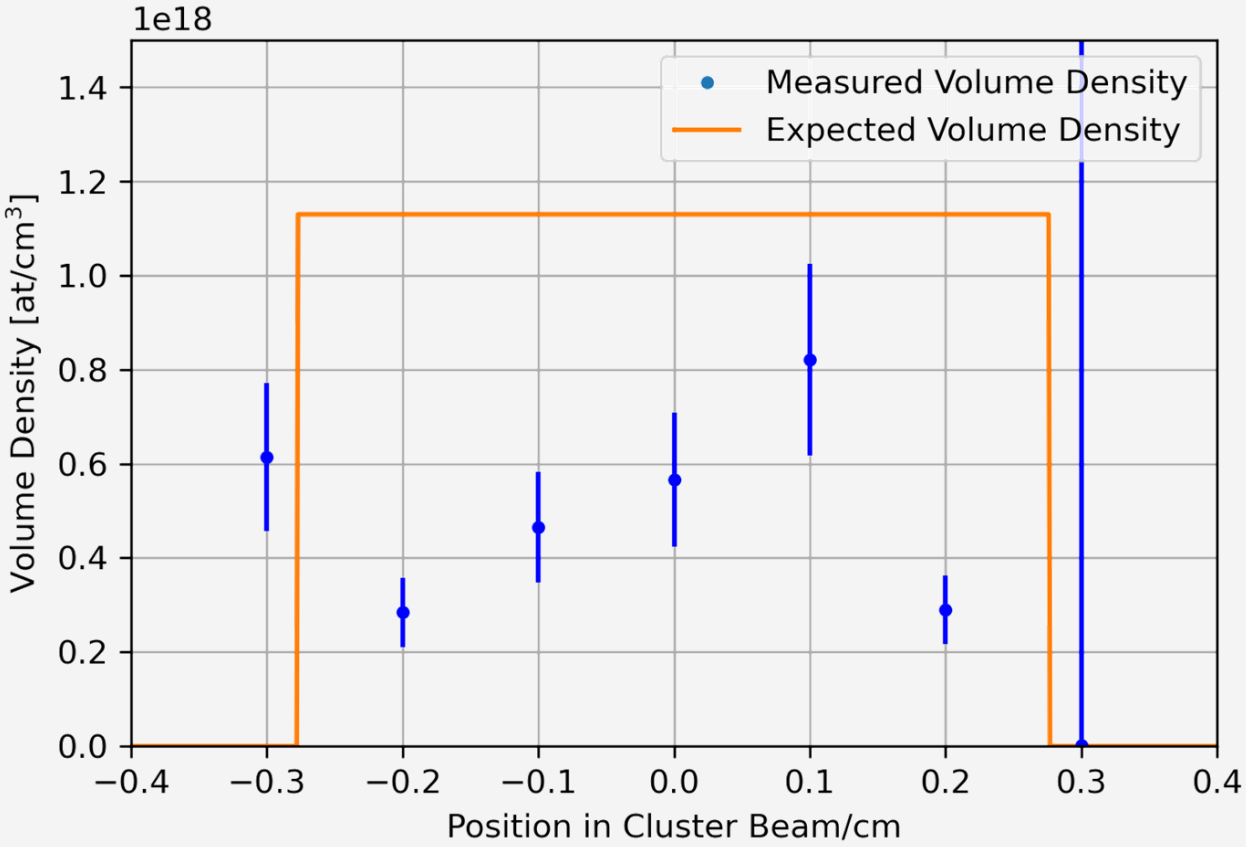
Symmetric Gaussian





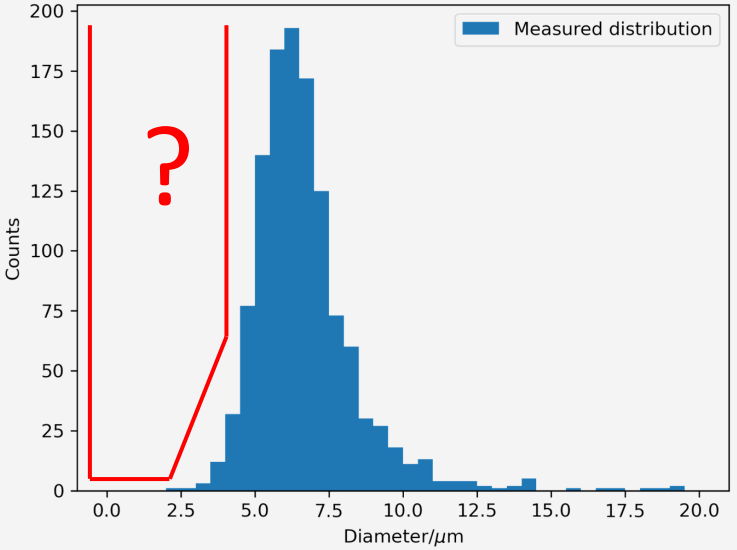
Volume Density

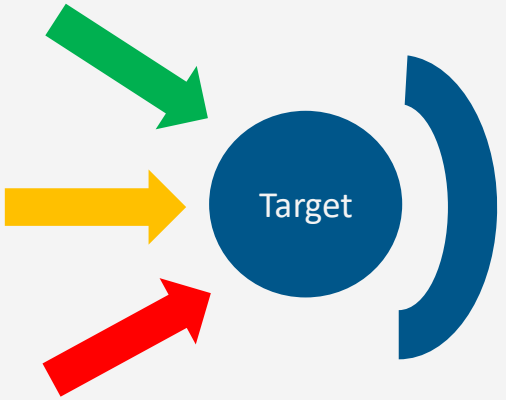
- For different positions in the cluster beam, a volume density (blue) can be calculated from size distributions
- Expected volume density (orange) is higher than calculated → Also smaller clusters have an influence on volume density
- Structure in cluster beam → Core beams



Outlook

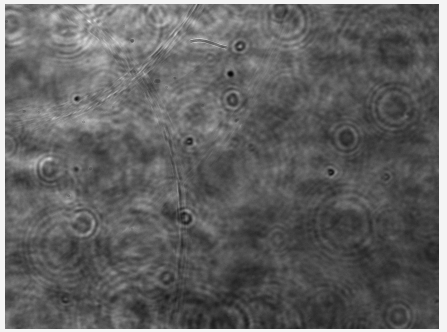
- It is very likely that there are also smaller clusters, but they cannot be found with pure shadowgraphy method (at the mentioned conditions)
- Methods to find the distribution of smaller clusters will be tested in the future (3-WEM measurements)

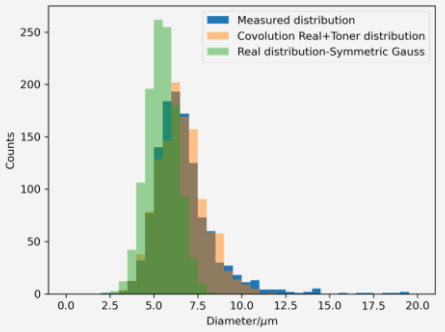




Summary

- Shadowgraphy measurements were performed at the ARCTURUS laser in Düsseldorf to estimate the cluster size distribution of a Münster Cluster-Jet target
- A routine was developed to find, select and analyze the clusters, which can be seen as dark spots on the shadowgraphy images
- Preliminary cluster size distribution was calculated, and the information of the toner measurements is used to find out the ‚real' distribution





Thanks a lot for your attention!