Optical Cluster Beam Studies & Production of Laval Nozzles

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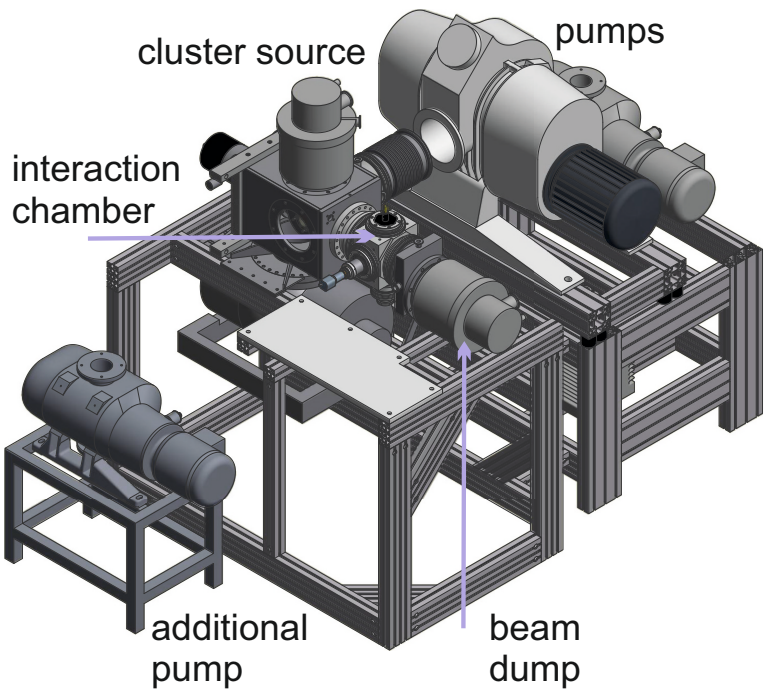
Optical Cluster Beam Studies

Cluster-jet Target MCT1S

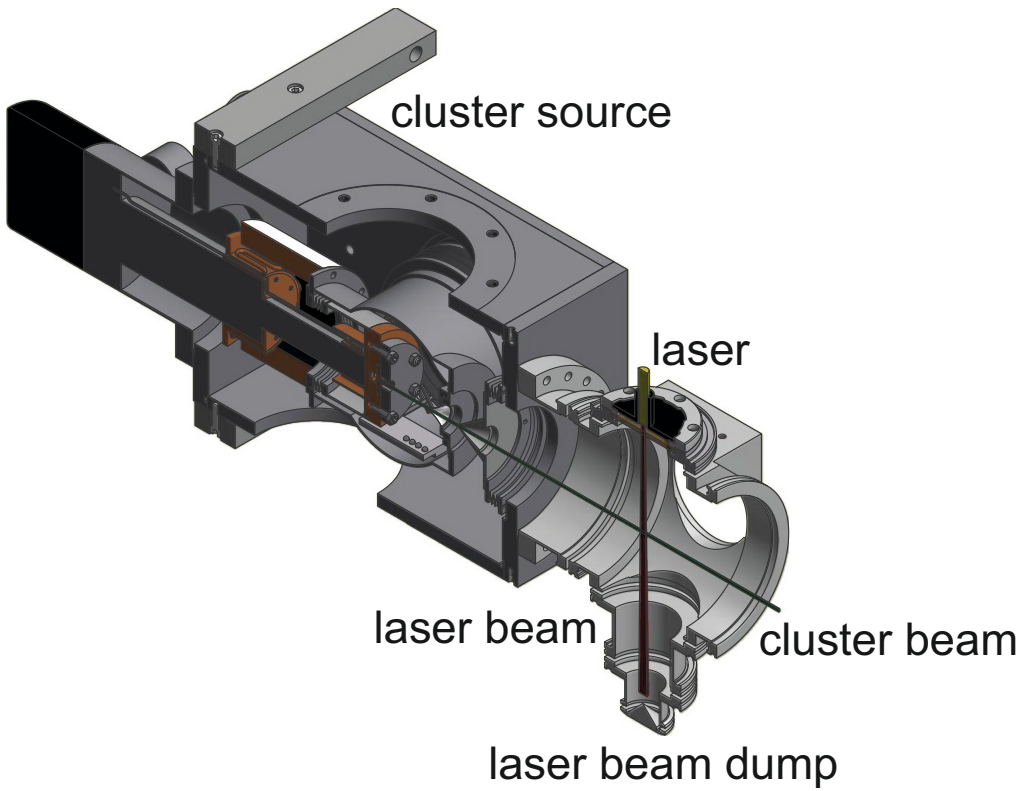
- A compact cluster-jet target was built up at Münster
  - Cluster source of the first target prototype for $\overline{\mathrm{P}}$ANDA
  - Cluster-jet target will be used for laser induced ion accelertion in cooperation with ILPP (M. Büscher)
  - Currently used for cluster beam studies (thickness, monitoring, position, stability...) $\mapsto$ $\overline{\mathrm{P}}$ANDA



Cluster beam analysis

Interaction chamber

- Analysis of the cluster beam (position, relative thickness, stability, ...)
- 33 cm distance from the nozzle
- No possibility for movable rods (MCT2)
- CCD camera in combination with a dot laser
- Valuable for $\overline{\mathrm{P}}$ANDA



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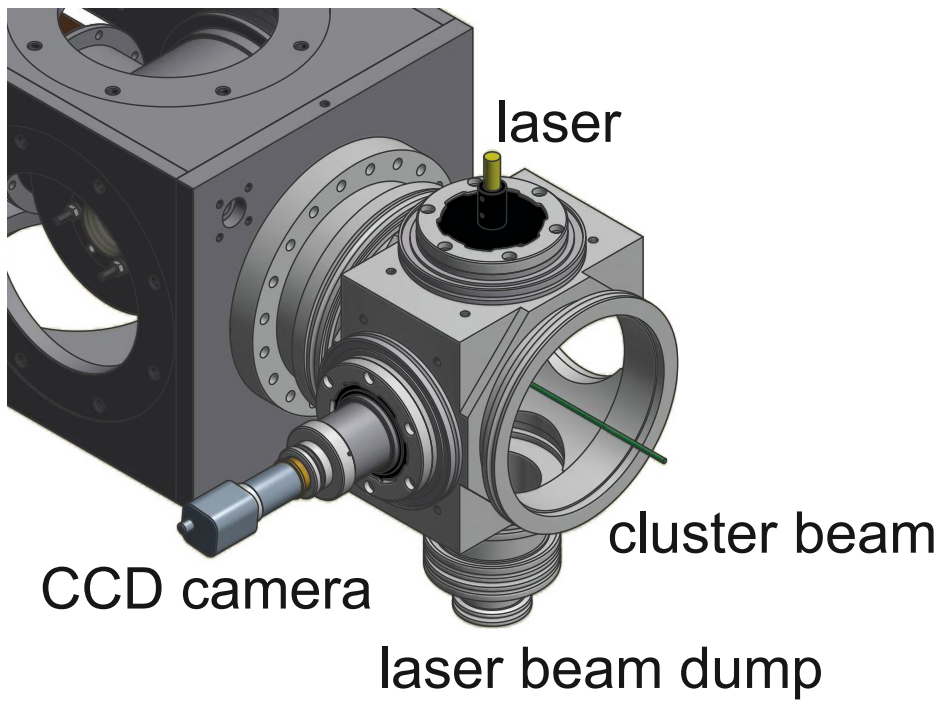
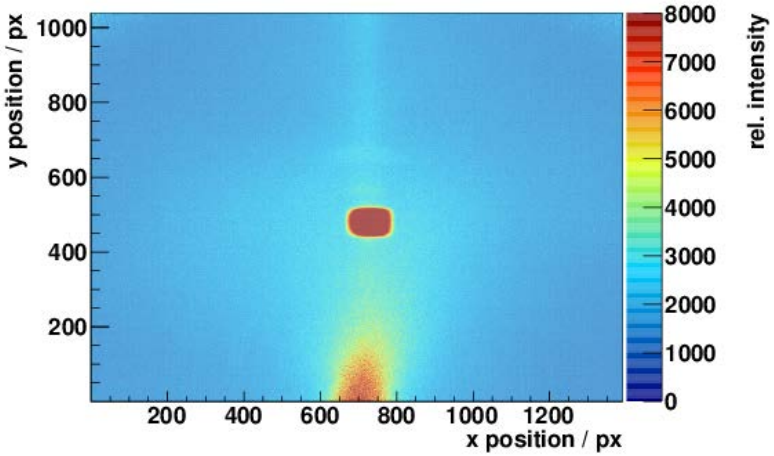


Cluster beam analysis

Process of analysis



- Nozzle temperature: $22\,\mathrm{K}$
- Gas pressure: $16\,\mathrm{bar}$
- Exposure time: $15\,\mathrm{s}$

Cluster beam analysis

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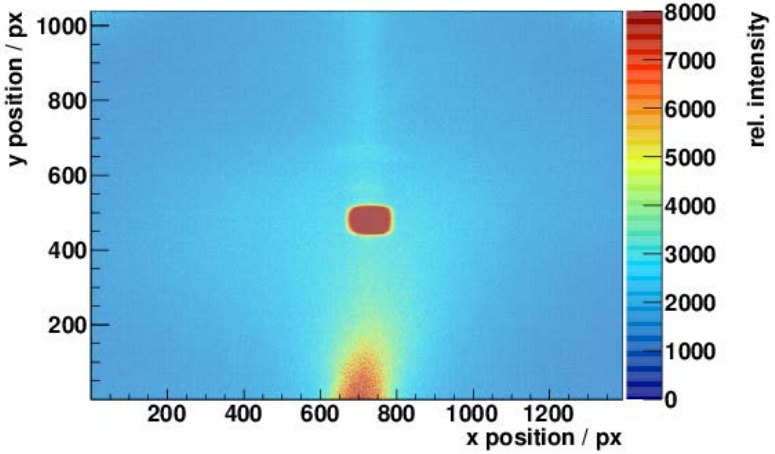

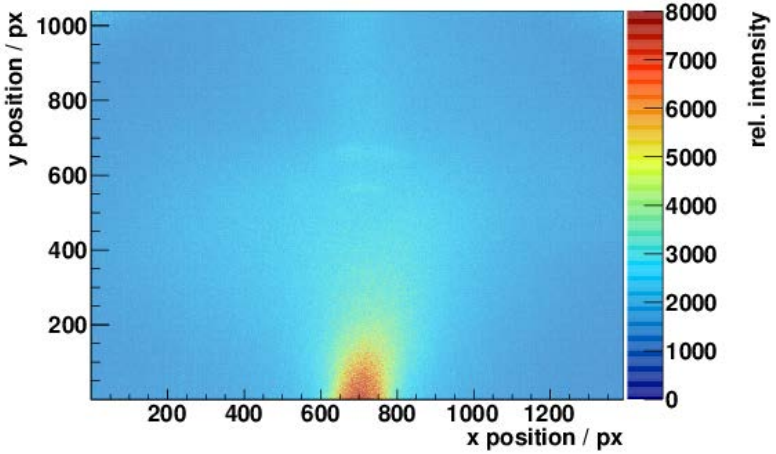

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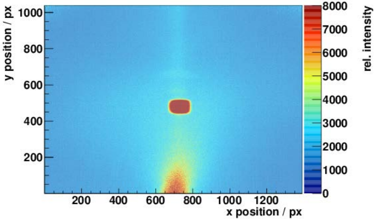
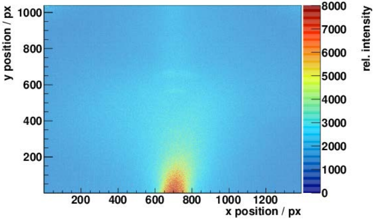
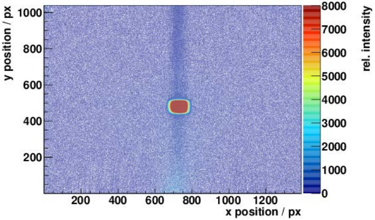


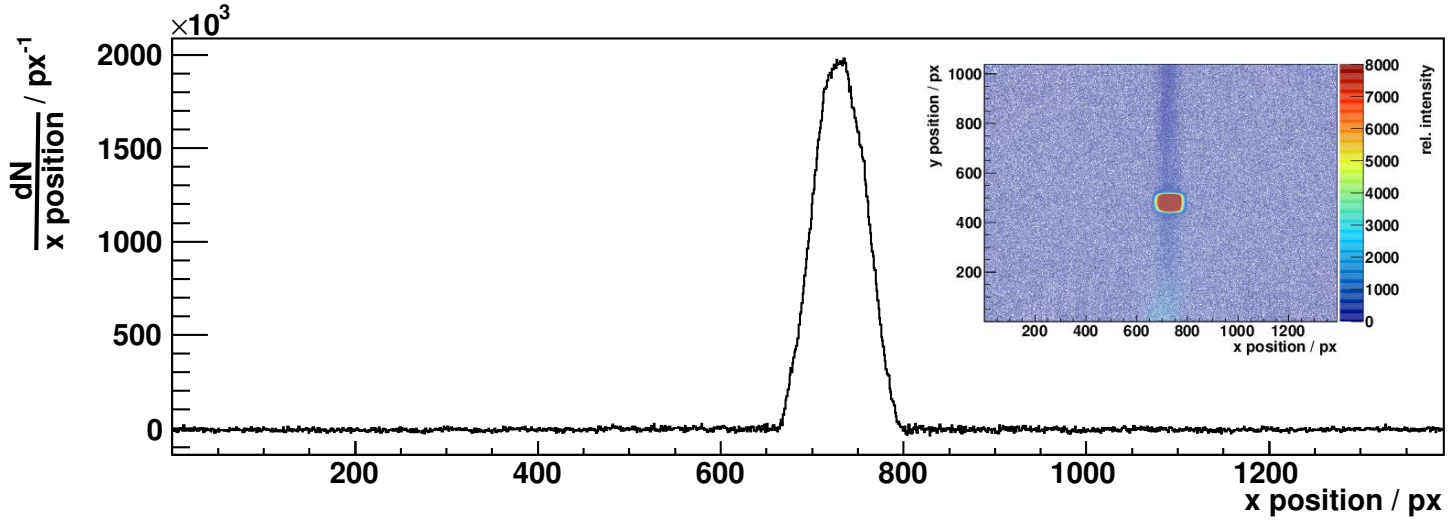


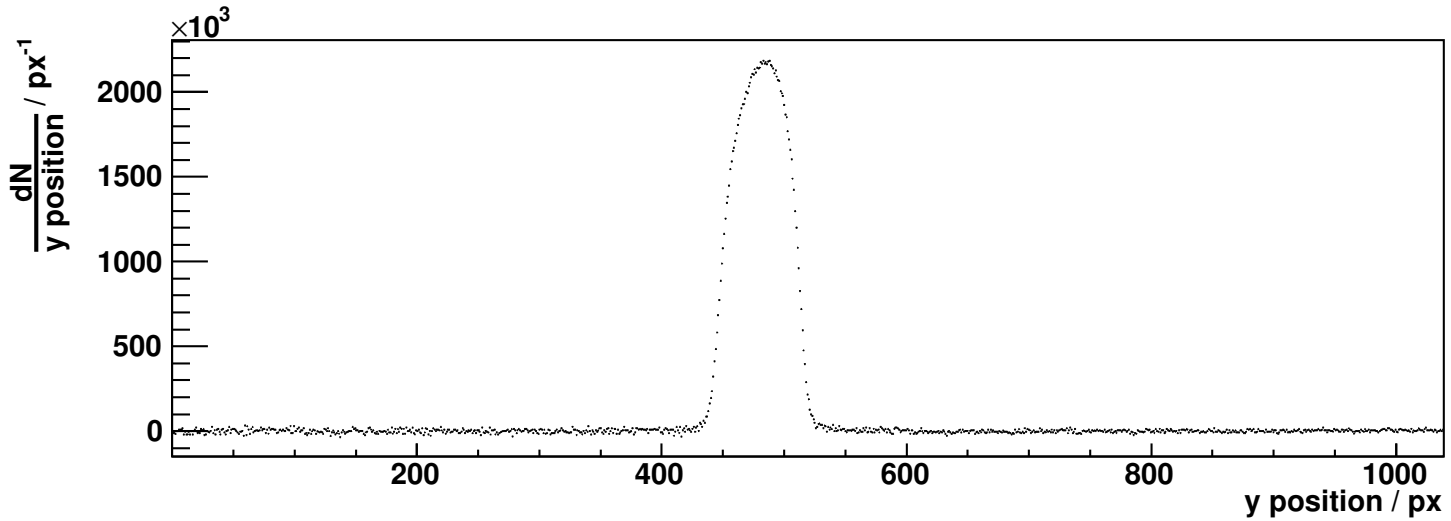


- Nozzle temperature: 22 K
- Gas pressure: 16 bar
- Exposure time: 15 s

Cluster beam analysis

Projections





Cluster beam analysis

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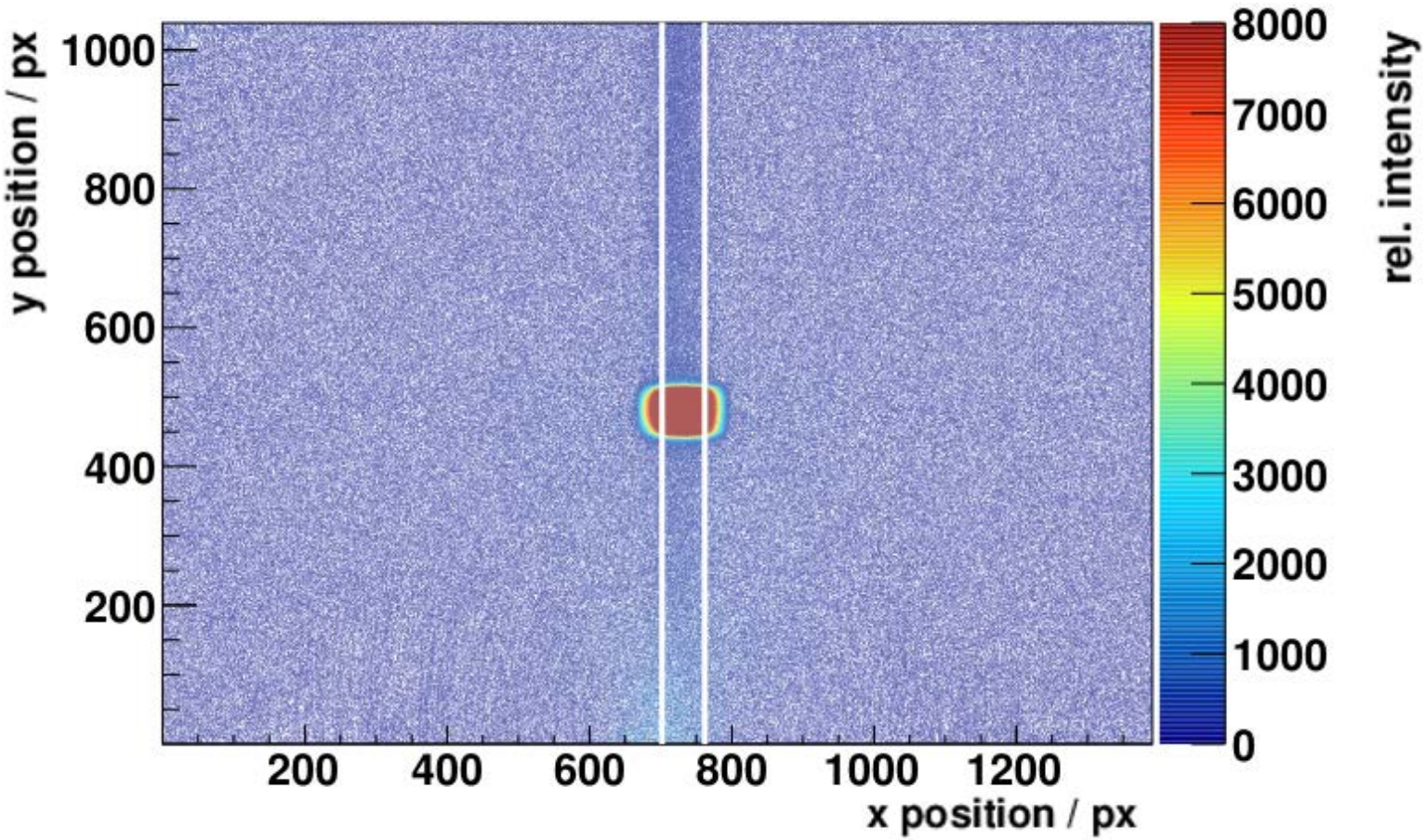


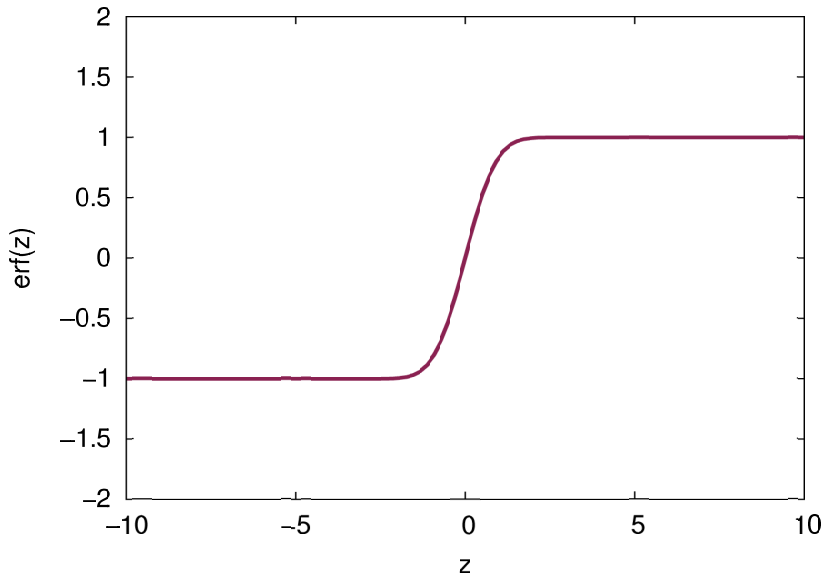
- $p(x) = I_0 \cdot p_e(x - x_0) + I_U$

  with $p_e(x) =$

$$\int_{-\infty}^{\infty} dy \int_{x-\frac{d}{2}}^{x+\frac{d}{2}} \frac{1}{2}\left(1 - erf\,\frac{r-R}{s}\right) dx$$

I_0: Height of the peak, intensity
x_0: Position of the maximum
I_U: Background
R: Half peak width, radius
s: Smearing factor
$r = \sqrt{x^2 + y^2}$

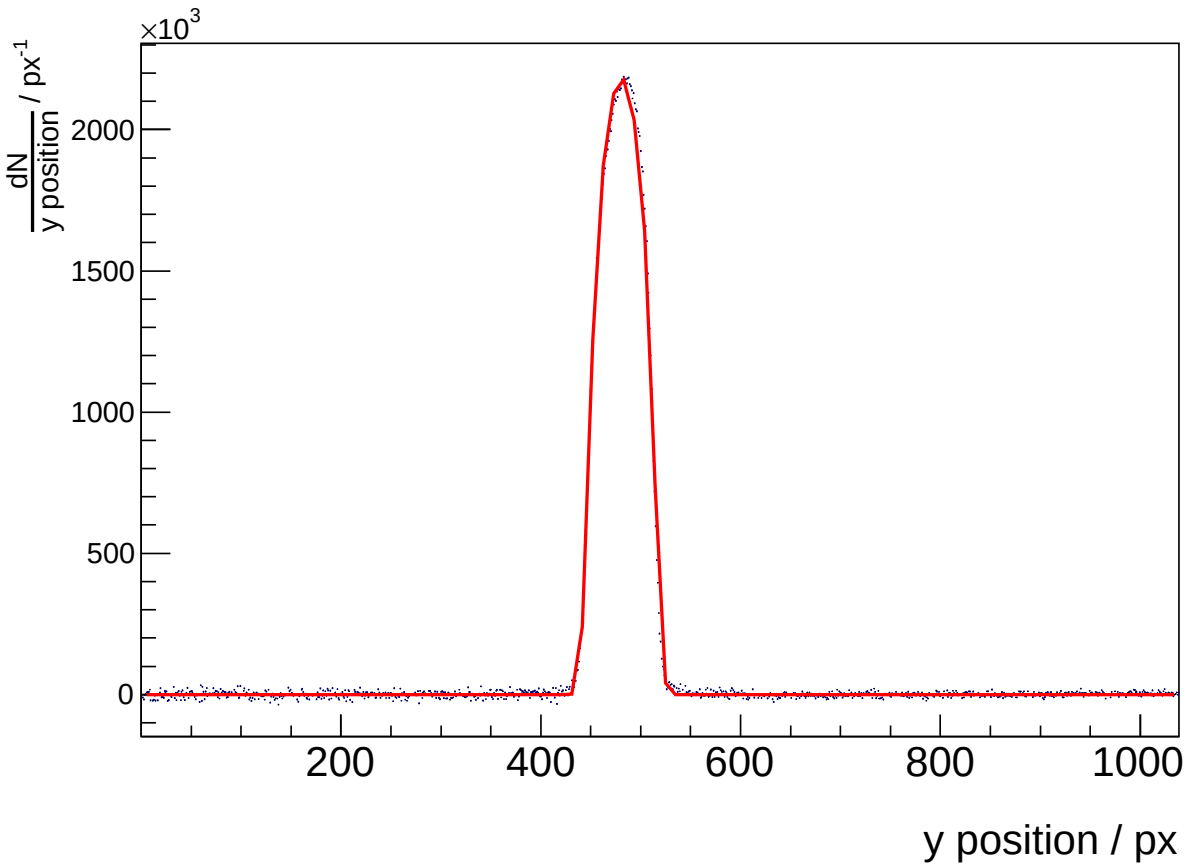
$$erf(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-\tau^2} d\tau$$



Cluster beam analysis

Error Fit

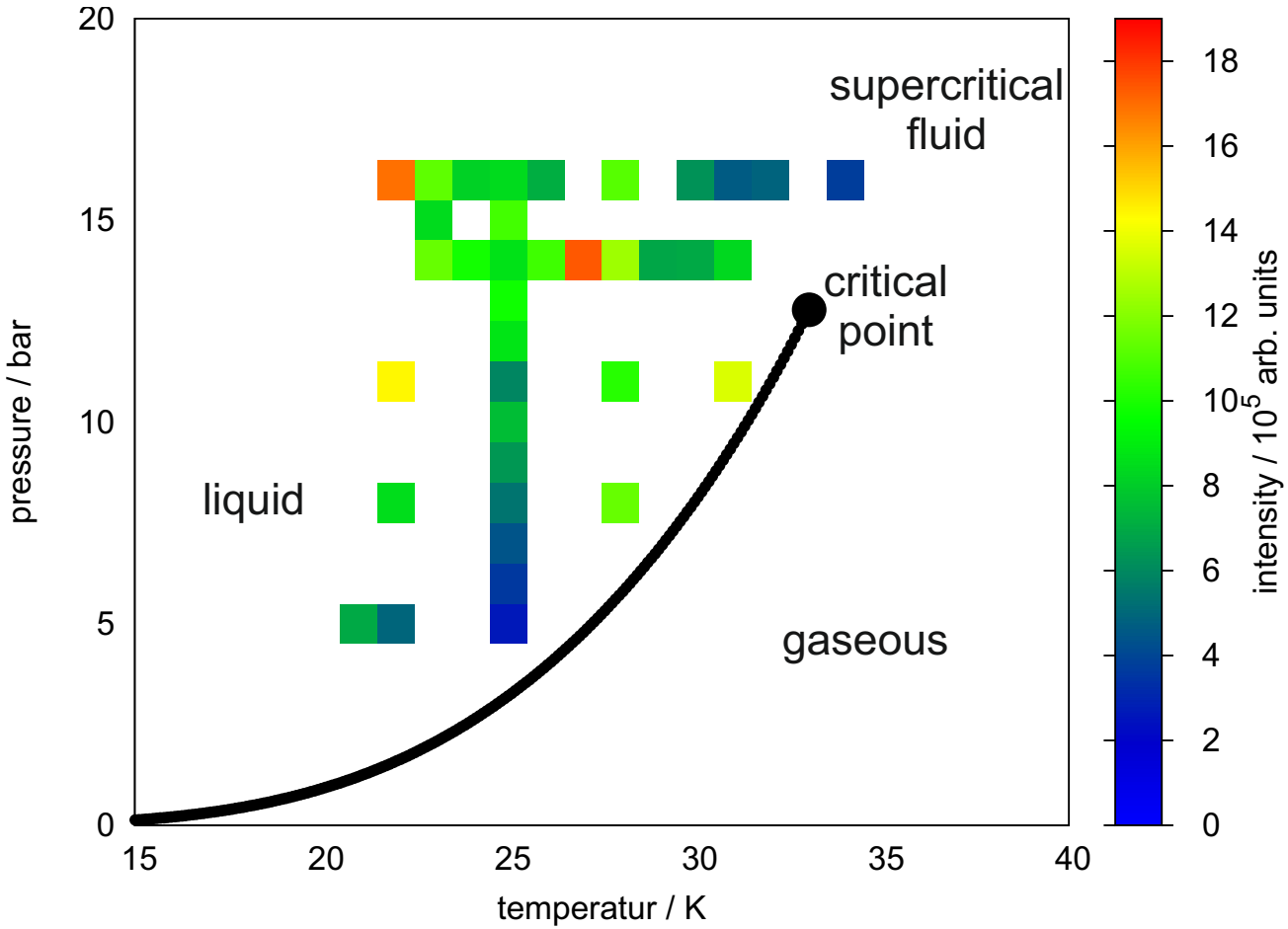
$$p(x) = I_0 \cdot p_e(x - x_0) + I_U \text{ with } p_e(x) = \int_{-\infty}^{\infty} dy \int_{x-\frac{d}{2}}^{x+\frac{d}{2}} \frac{1}{2}\left(1 - erf\,\frac{r-R}{s}\right) dx$$



Cluster beam analysis

Result of the measurement: **intensity**

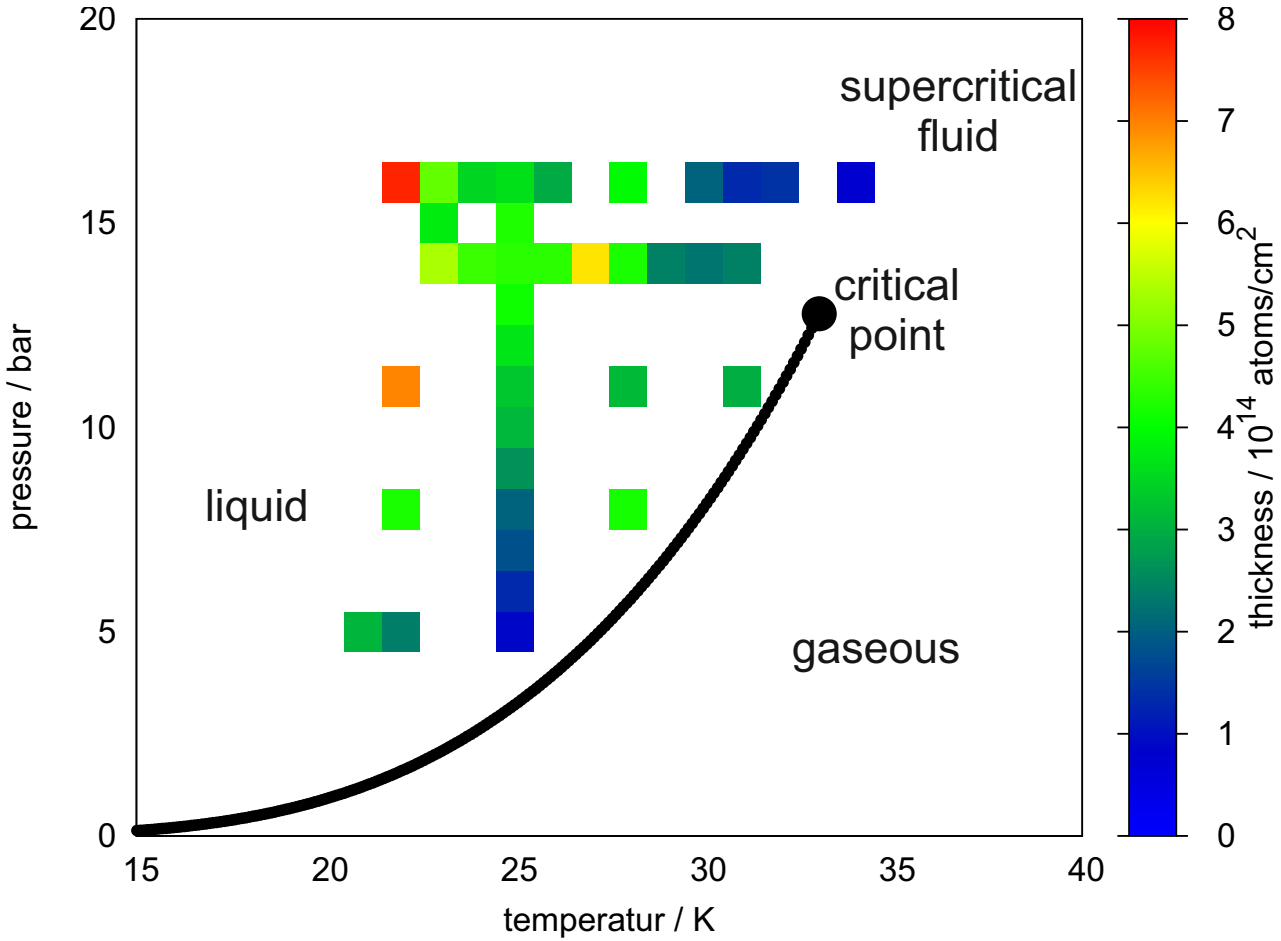
Exposure time: 15 s



Cluster beam analysis

Result of the measurement: **thickness**

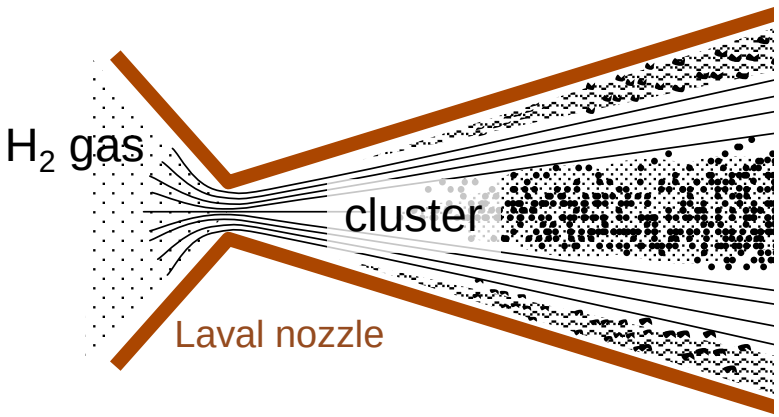
$\rho_T \propto$ pressure increase



Production of new Laval nozzles

Motivation

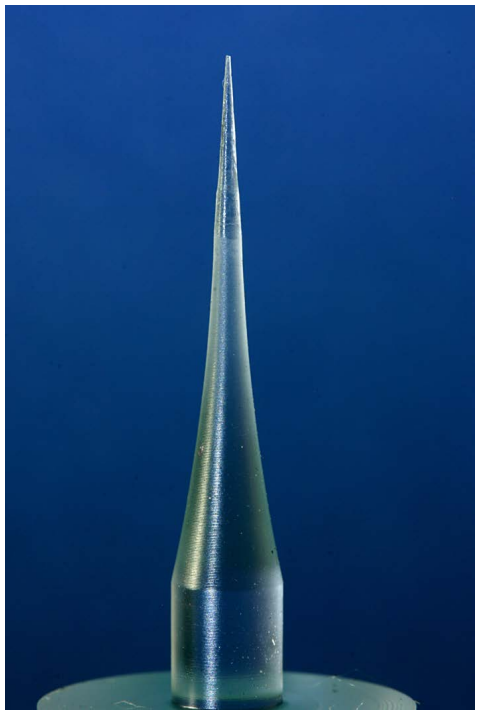
- Laval nozzle is the heart of a cluster source
- Specific convergent-divergent shape

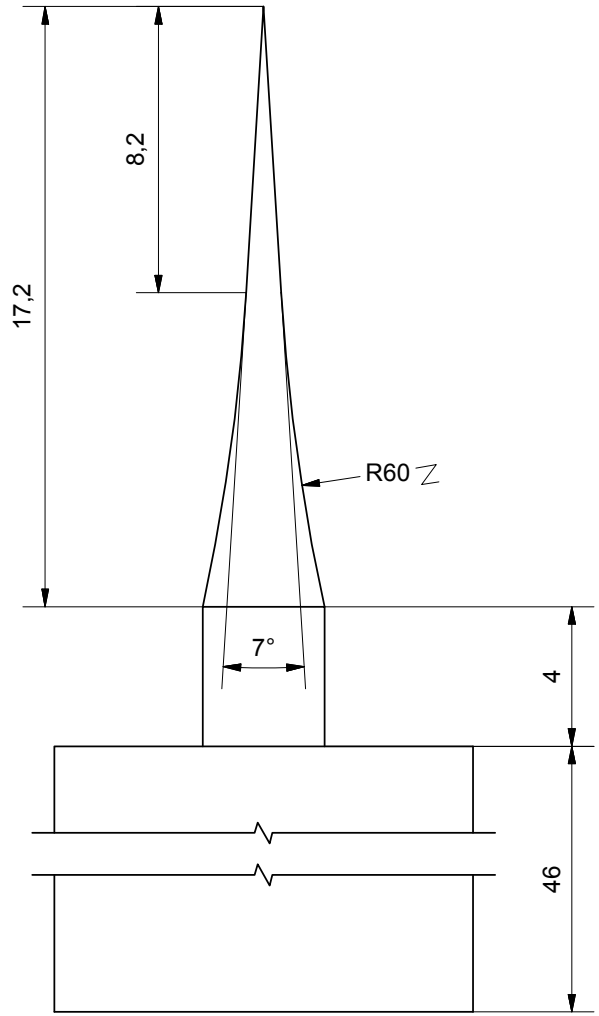


- Production of a small inner diameter (< 30 µm) $\rightarrow$ a major technical challenge
- In the past these fine Laval nozzles were produced at CERN
- To ensure the production an improved production process based on the CERN production was recently developed at the University of Münster

Production process of the new Laval nozzles

Negative of the trumpet

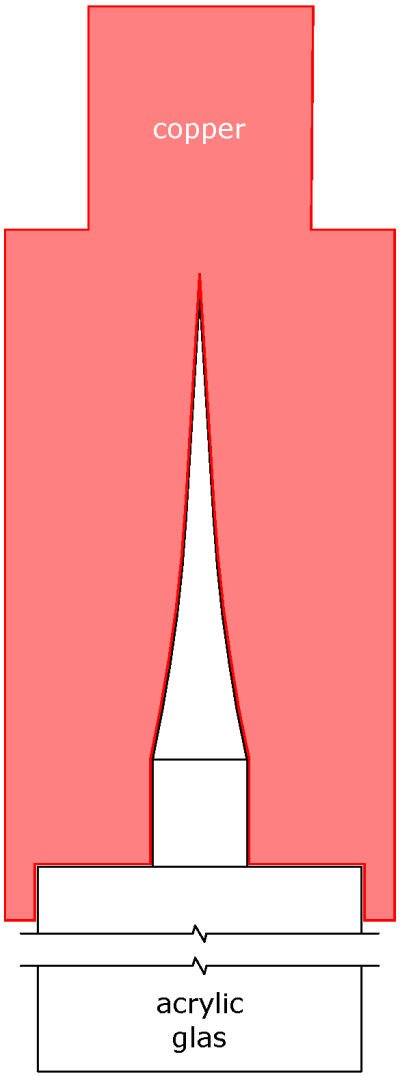




- Turned acrylic glass
- 30 to 60 µm at the narrowest point

Production process of the new Laval nozzles

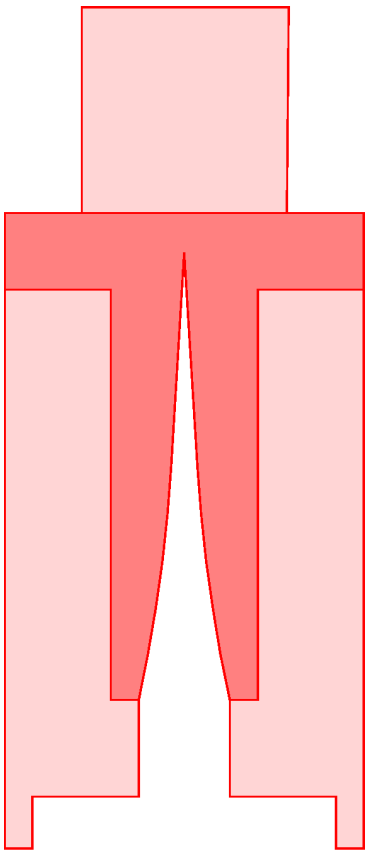
Body of the Laval nozzle

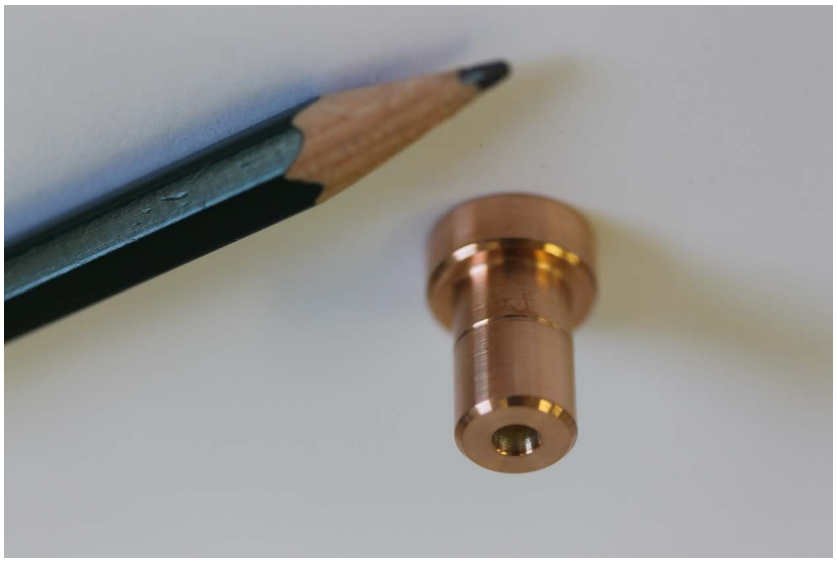


- Galvanic deposition of copper
- Chloroform to remove remainder of the acrylic glass
- Accurate and clean extraction of the trumpet negative

Production process of the new Laval nozzles

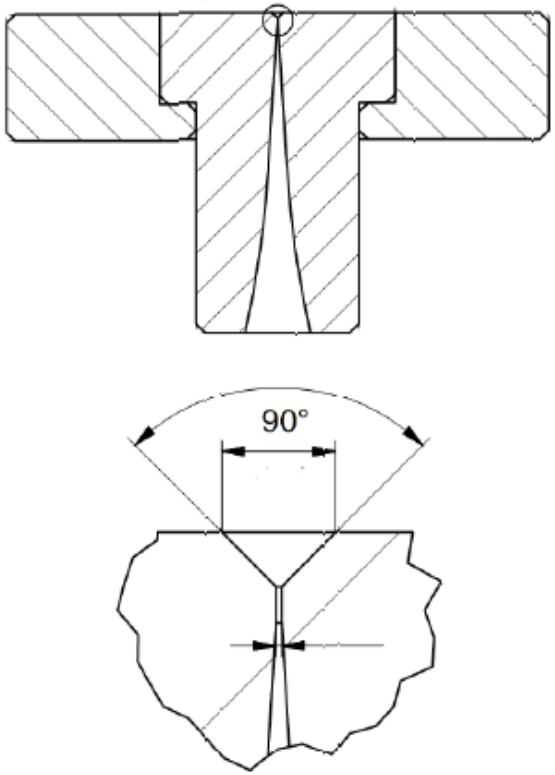
The final shape of the nozzle





- The final shape is turned out of the nozzle body

Production process of the new Laval nozzles



- Cone bore by fine mechanical workshop of institute
- Connection lasered by company
- Production of ring to fix the nozzle at the target cold head

The finished Laval nozzles

An example of the first set

- Finished Laval nozzle of the first successfully produced set of 11 nozzles
- Inner diameter between 42 µm and 105 µm
- Initial measurements with these new nozzles at the $\overline{\text{P}}$ANDA cluster-jet target prototype (27 K, 5 bar)

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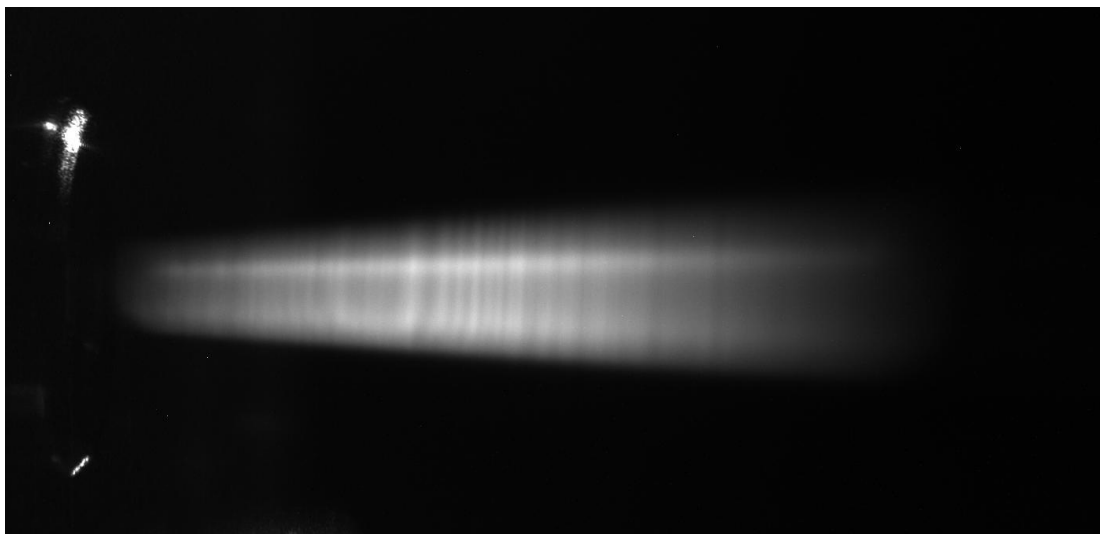
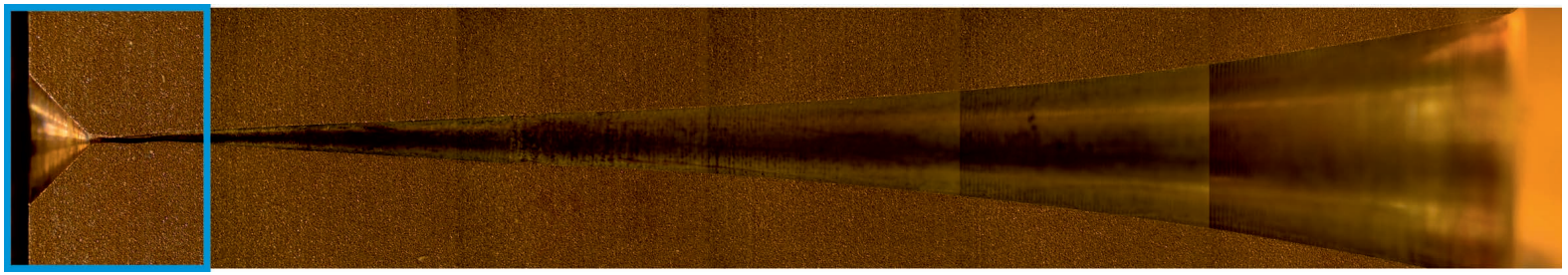
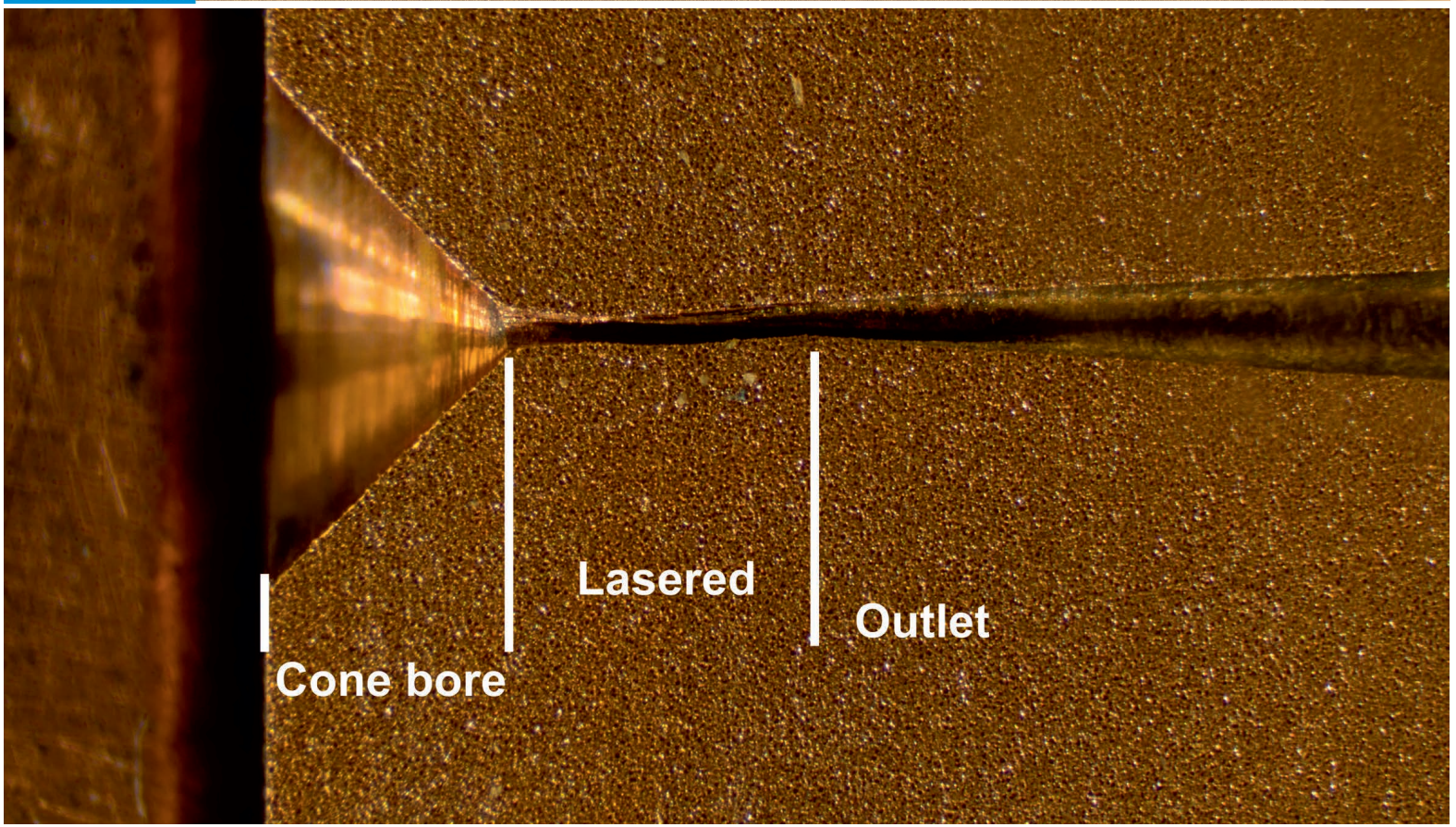


Improvements

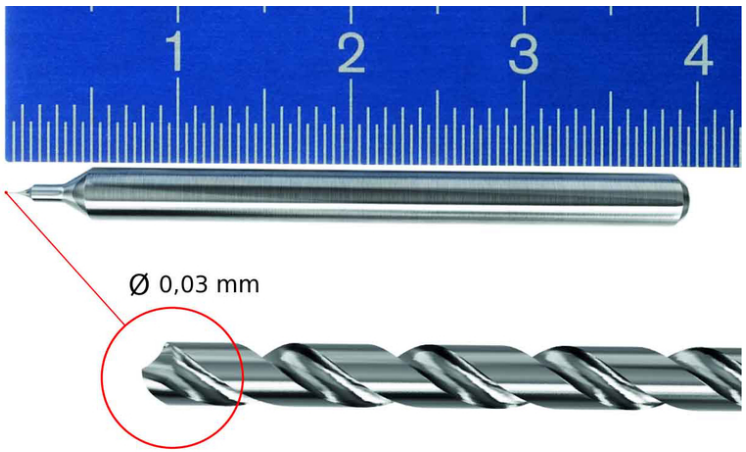
- Nozzle cut through by wire erosion

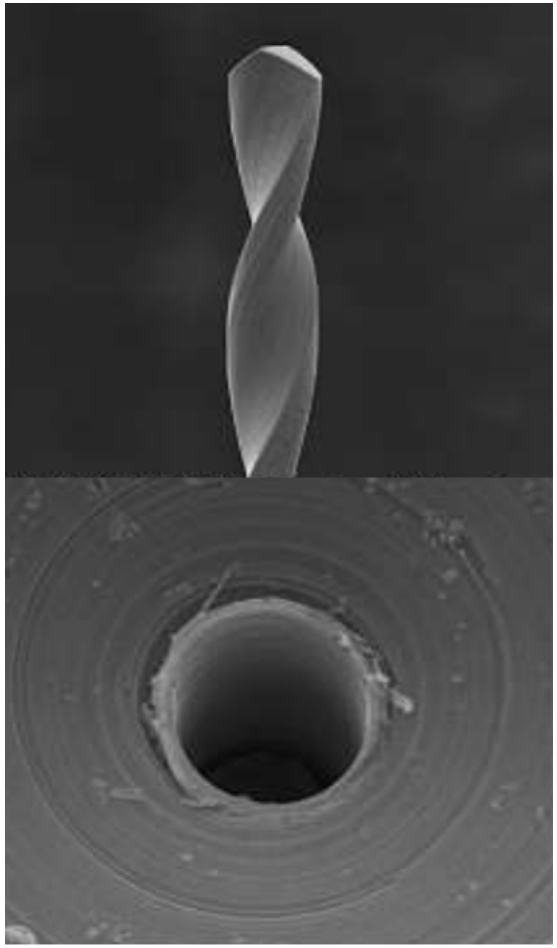




Improvements

- Drilling of the small inner diameter
  - Above: drill (800-times magnified)
  - Below: bore in aluminum (1500-times magnified)

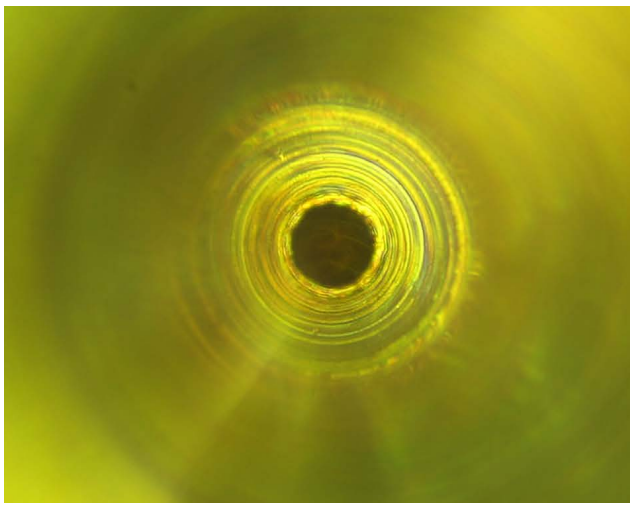




[Rabensteiner Präzisionswerkzeuge]

Improvements

- Drill by company „KERN“
  $\rightarrow$ 3 nozzles with inner diameter of about 30 µm
  $\lightning$ Drill does not reach the opening cone



- Possible reasons: By the galvanic deposition the tip of the negative
  - became skew
  - got blunted

Summary & Outlook

Cluster beam studies

- Development of optical method for cluster beam studies
- Possibility to do precise online cluster beam analysis about position, intensity, thickness, size, ... without any affecting of the beam during the operation of the experiment

Production of Laval nozzles

- An improved production process was developed at the WWU Münster
- Initial measurements with new nozzles at the $\overline{\text{P}}$ANDA cluster-jet target prototype were performed
- Future investigations on the cluster production process to optimise the required target thickness
- More produced Laval nozzles and additional measurements at the $\overline{\text{P}}$ANDA cluster-jet target prototype will follow