Laval Nozzle Production for Internal Targets*

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A powerful type of target for internal fixed target experiments at storage rings is given by the cluster-jet target which allows for typical target thicknesses of 10^{12} to $10^{15}\,\mathrm{atoms/cm^2}$. Furthermore, this type of target provides a stream of particles which is homogeneous and constant in space and time. At the University of Münster several cluster-jet targets were already designed and constructed, e.g., for COSY-11, ANKE, and $\overline{\text{P}}$ANDA, where the latter one is currently under construction. The target density can be easily adjusted by changing the temperature or pressure of the gaseous target material (e.g., hydrogen, deuterium) before the so-called Laval nozzle, the heart of a cluster source. The specific convergent-divergent shape of the Laval nozzle generates a supersonic flow of the target material. Supported by the adiabatic cooling the, e.g., hydrogen, molecules condensate to clusters (see Figure 1). The mean velocity and the velocity distribution of the extracted and shaped cluster-jet beams are strongly dependent on the operational parameters. In recent measurements mean velocities of 200 to 1000 m/s were observed when a $28\,\mu\mathrm{m}$ Laval nozzle was operated with hydrogen at 17 bar and a temperature between 20 and 50 K [1, 2]. This velocities could be described by numerical calculations [3]. Essential

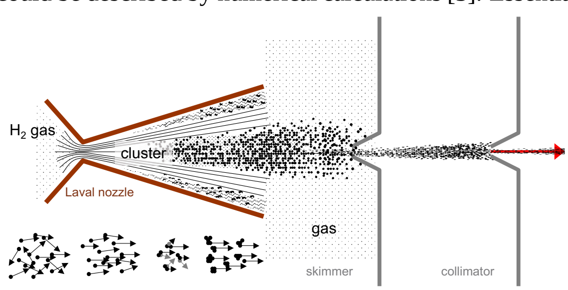

Figure 1: Cluster production process with a Laval nozzle. Skimmer and collimator are responsible for extracting and beam shaping [4].

for the performance of a cluster-jet target are the properties of the Laval nozzle which itself can be divided into an inlet and an outlet zone (see Figure 1). The short inlet zone converges to the narrowest point of the nozzle and merges into the divergent, long outlet zone. The production of a small inner diameter (e.g., $30\,\mu\mathrm{m}$) in combination with the long trumpet part with an opening angle of, e.g., 7 °, represents a major technical challenge. In the past these fine Laval nozzles were produced at CERN but the manufacture was discontinued [5]. To ensure the production of these fine Laval nozzles for future internal targets and for further target optimisation studies an improved production process

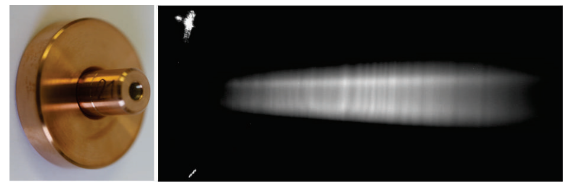

Figure 2: Left: Finished Laval nozzle of the first successfully produced set, Right: First cluster-jet beam of a new Laval nozzle (beam direction from left to right) installed at the $\overline{\text{P}}$ANDA cluster-jet target prototype.

based on the initial CERN production was recently developed at the University of Münster. Due to several optimised production steps a minimal failure rate of the particularly fine Laval nozzles is ensured.
A first set of Laval nozzles was successfully produced and initial measurements with these new nozzles (see Figure 2 left) are running at the $\overline{\text{P}}$ANDA cluster-jet target prototype. Figure 2 (right) presents the first cluster-jet beam of a new nozzle with the characteristic high intense core beam structures [6]. The part of the cluster beam directly after the Laval nozzle (left, not visible) is illuminated with a laser diode. The possibility to produce new micrometer nozzles opens the way for future investigations on the cluster production process with the modification of, e.g., length and aperture angle of the trumpet, with the objective to further optimise cluster-jet targets for storage rings.

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