Simulation and prototype design of window-less gas-jet target

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Target in nuclear physics experiment plays a crucial role in measuring the reaction cross-section, especially in nuclear astrophysics where the cross-sections are very low (∼nanobarn or picobarn) with large backgounds [1]. The nuclear astrophysics experiments rely on inverse kinematics technique to counter high background and low cross-section events [2]. However, it is difficult to make light targets such as H and He for the inverse kinematic reactions. Sometimes it is possible to produce a solid compound containing light nuclei, or build gas cells with thin windows. They may also require backing materials for mechanical stability, which contribute additional backgrounds. Therefore, these strategies may not always be appropriate because of the low density and the presence of other materials in the compound or the windows. In addition, the accurate measurement of reaction cross-section require the targets to be well confined, high density, thickness to maximize the count rates but minimize the energy loss and straggling of reaction product, etc. Therefore, making an window-less gas-jet target is only the optimal solution.

There are mainly two components in windowless gas-jet target : nozzle and skimmer [1]. The nozzle mainly disperse the gas perpendicular to the gas-jet axis, while skimmer captures the gas and helps keep the gas stream contained. The nozzle plays a large part in order to confine and shape the gas-jet. A high capacity roots pump must be used to extract the gas through skimmer as well as to maintain a low vacuum as much as possible in the target chamber. The target region lies between nozzle and skimmer. The skimmer can extract ∼90% of the incoming gas. The remaining gas is generally pumped by a series of differential pumping systems. Therefore, in addition to the skimmer roots pump, the target chamber is also connected to high vacuum pumps to keep the pressure as low as possible. In this work, a simulation has been performed using the COMSOL multiphysics software [3] in order to optimize the design parameter of the nozzle and skimmer which basically shapes the gas-jet, and a prototype windowless gas-jet target chamber has been designed.

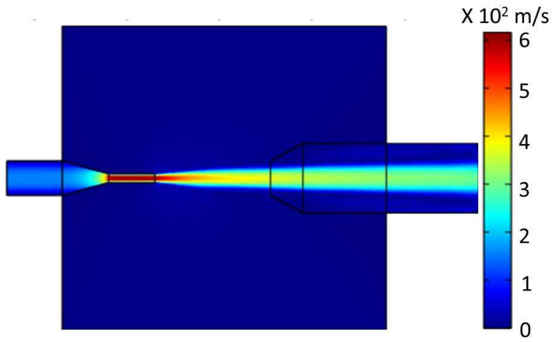

FIG. 1: *Simulation of gas-jet flow of an window-less gas-jet target. The gas-jet is along the Z-direction. Diameter of inlet of nozzle and exit of skimmer are 1 and 4 mm, respectively. The distance between nozzle and skimmer is ∼ 15 mm; Lentgh of the nozzle throat is 5 mm.*

The gas-flow of a windowless gas-jet target obtained by simulation is shown in Fig. 1. The simulation has been performed using the COMSOL multiphysics software [3] in order to fix the shape and size of the nozzle to calculate the spreading of gas, number density in the target region, etc. In the simulation, a two

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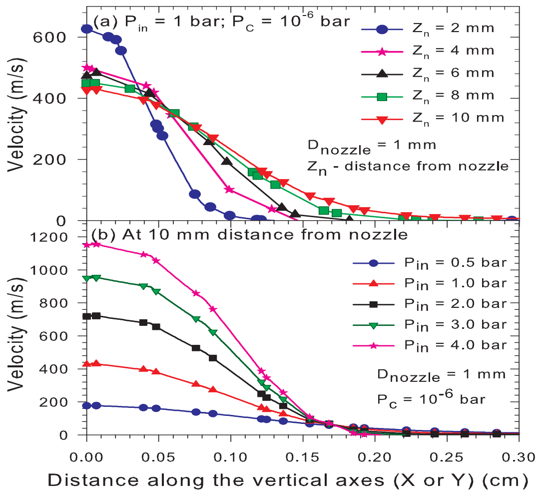

FIG. 2: *Velocity of gas-jet (a) at different distance from nozzle entry with P_{in} = 1 bar and P_c = 10^{-6} bar; (b) at 10 mm distace for different inlet pressure (P_{in}=1-5 bar).*

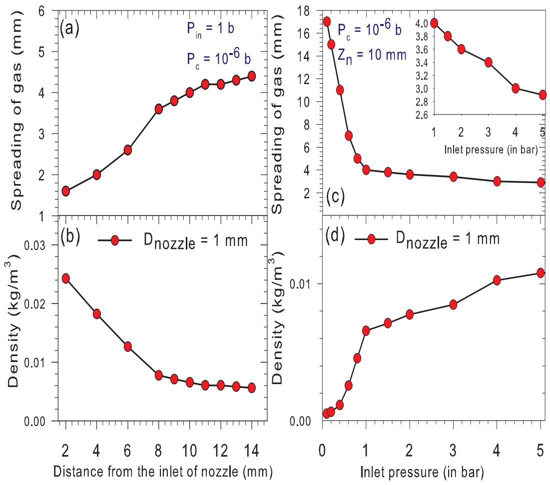

FIG. 3: *Spreading and density of gas (a,b) at different distances from the inlet of nozzle with P_{in} = 1 bar and P_c = 10^{-6} bar and (c,d) at 10 mm distance from the inlet of nozzle for different inlet pressure.*

dimensional axisymmetric geometry has been taken. A proper mesh selection of geometry is important in order to get the results as accurate as possible, and finer mesh has been used in the present work. Helium gas was injected along the Z-direction at different high pressure (1-5 bar) through the nozzle (Diameter = 1 mm) and collected by gas receiving system skimmer (Diameter = 4 mm). The gas will spread along the vertical direction (X and Y) due to expansion while entering from high pressure (P_{in} = 1 bar) to low pressure target chamber ($P_c = 10^{-6}$ bar). The velocity distribution of the gas along the vertical axes inside the chamber have been extracted at a different distance from the inlet of nozzle for different inlet pressure (as shown in Fig. 2) keeping the chamber pressure ($P_c = 10^{-6}$ bar) fixed. The spreading of gas has been calculated (shown in Fig. 3) from the velocity distribution and found to be 4 mm at 10 mm distance from inlet of nozzle (dia $\sim$ 1 mm) with P_{in} = 1 bar and $P_c = 10^{-6}$ bar. The spreading of gas has been used to calculate the the density of gas-jet target at different distance and shown in Fig. 3. The number density of the target has been calculated considering 1 mm beam diameter and found to be $\sim 10^{17}$ atoms/cm^2 at 10 mm distance from the inlet of nozzle. It should be mentioned that the different parameter of the COMSOL simulation such as inlet pressure, chamber pressure, size and shape of the nozzle and skimmer, throat length of the nozzle, etc are all played to optimize the thickness of the gas-jet target in beam interaction region and finally a prototype design of the window-less gas-jet target chamber has been designed for testing purpose. The details of its prototype design will be presented in the conference.

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