Progress in the characterization of the gas jet target at IFUNAM

F Favela, E Chávez, O de Lucio, E Andrade and M E Ortíz
Instituto de Física, Universidad Nacional Autónoma de México Apartado postal 20-364, 01000, México, D.F., México
E-mail: ffavela@gmail.com

Abstract.
The windowless gas target (supersonic jet) at IFUNAM has been characterized using the Elastic Backscattering Spectrometry (EBS) technique with proton beams. Jets of Air, Nitrogen and Argon at different pressures were studied. Areal densities above $10^{18}$ atoms/cm$^2$ have been achieved.

1. Introduction
An ideal target for experiments in nuclear physics would be one that has a large number of the target nucleus of interest and no others (dense), in a well-defined region of space (thin) and finally that it does not change its properties with beam exposure over time.

A supersonic gas jet closely resembles such an ideal target. Systems like this have been used in the past [1, 2, 3] and a more contemporary example has been developed in the University of Notre Dame [4].

The 5.5 MV Van de Graaff accelerator laboratory at IFUNAM (Instituto de Física Universidad Nacional Autónoma de México) underwent in 2012-3 a significant upgrade in the experimental area. The addition of a switching magnet allowed the number of beam lines to increase from 1 to 7. One of these has been designated to host the supersonic gas jet target. The scientific program behind its design and construction is mainly related with nuclear physics and astrophysics research. Although Atomic physics and Material Sciences studies are also possible.

2. Experimental methods
Figure 1 shows a picture of the setup for the jet characterization experiments. Inside the scattering chamber a special stainless steel table was made to support charged particle detectors. The table is held from the central catcher and it has holes in order to preserve the pumping speed of the system. On this table, two Silicon charged particle detectors are placed, left and right, 15 cm away from the gas target at an angle of 150 degrees relative to the beam direction.

Three millimeter in aperture diameter and one centimeter long, collimators where placed in front of the detectors in order to shield the detector from the scattering of the beam as it goes through the scattering chamber before and after the jet (the surrounding region is not perfect vacuum). The solid angle for each detector, with their collimator, is $\Omega \approx 4 \times 10^{-4}sr$ and the pressure in the surrounding region of the jet was $\approx 10^{-1}$ Torr.
Figure 1. EBS setup. During an experiment the beam should go from left to right.

3. Results
For the first test, we chose the easiest target; air. The nozzle’s valve was simply opened to let in air from the laboratory (a huge leak under control). A 2.8 MeV proton beam ($\approx 1 \mu A$) was used to produce EBS data to characterize our target.

Figure 2 shows two of the spectra taken. Both show the two expected peaks from proton scattering on the principal components of air: N and O. The spectrum on the left however has a significant count yield at lower and higher energies. The spectrum on the right hand side was taken in the same conditions using the collimator described above and shows a significant reduction of this background.

EBS data was analyzed using the SINMRA software [5]. This program takes advantage of a rather large cross section data base (IBANDL [6]) to simulate EBS spectra for a given experimental setup (beam, detector and target configuration). It is through this analysis that we can extract both target composition and density. Table 1 shows the elemental abundance of the main components of air extracted from our data in comparison with typical reported values [7].

Using the same experimental protocol, we proceed to characterize gas jet targets of pure gases: Ar and N. This time, SIMNRA analysis is not needed to extract the elemental composition, but to yield the target density, a parameter of utmost importance for our target.

Figure 3 shows the evolution of the areal density with the input pressure of the gas bottles. There is a nearly proportional dependence similar in both gases. However, the main result is the absolute value of the areal density obtained which is in excess of $10^{18}$ particles/cm$^2$. 
Table 1. Comparison of the SIMNRA simulation and the reported percentages in Air.

| Peak    | SIMNRA    | reported |
|---------|-----------|----------|
| Nitrogen| 78.0%     | 78.09%   |
| Oxygen  | 21.3%     | 20.95%   |
| Argon   | 0.97%     | 0.93%    |

Figure 3. Areal density evolution with pressure in nitrogen and argon.

4. Conclusions
In this work we showed the performance of the supersonic gas jet target recently built at IFUNAM.

Targets of Air, Nitrogen and Argon were studied and characterized using EBS data with proton beams and data reduction with the SIMNRA code.

The main result is that we showed that we can reach jet densities in excess of $10^{18}$ particles/cm$^2$.

The more intense ion source planed in the near future for the 5.5MV accelerator will enhance the capability of the supersonic gas jet target beam line to its full potential and take on astrophysical experiments.

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