GAS FLOW CALCULATIONS AND MEASUREMENTS FOR A GAS STOPPING CELL

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Along with several other nuclear physics laboratories around the world, the NSCL has undertaken the challenge of stopping a radioactive ion beam in order to make low-energy beams for experiments that require nearly thermal beam energies (precision mass measurements, laser spectroscopy, etc.). As part of the LEBIT (Low Energy Beam and Ion Trapping) Project at the NSCL, a gas stopping station is being constructed in the N4 vault. It will serve as a high-pressure, gas filled radioactive ion source for low energy beams.

The most critical component of the gas stopping station will be the Gas Stopping Cell. It is here that the NSCL s intermediate energy radioactive ion beam will be stopped in a high purity, high-pressure gas. In this cell, the ions will be thermalized and then extracted without re-ionization. Through the use of rf multipoles and other ion optical devices, the beam will be transported to one of several low-energy beam lines for nuclear physics research.

Intermediate energy beams of exotic nuclei will first encounter the gas cell s thick (several mm) silicon or beryllium window (Figure 1). Passing through this window, the ions will lost most of their energy and straggle into the high-pressure (~1 bar) helium gas, where they will slow to thermal energies. Using a combination of electric potentials and gas flow, the ions will be extracted from the gas cell through a supersonic nozzle and continue downstream.

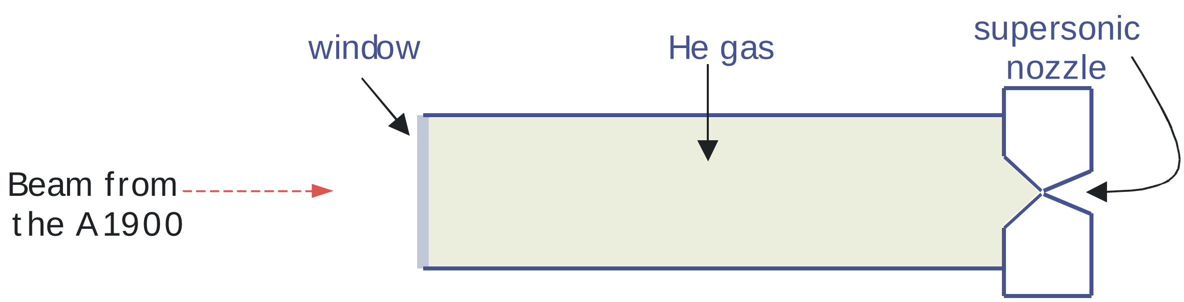

Figure 1: The Gas Stopping Cell

The task of stopping intermediate energy radioactive beams in a gas is complicated by the large degree of range straggling. This straggling problem was the subject of a study performed last year at the NSCL [1] and continues to impact on the design of the gas cell.

Although the design and function of this gas cell is still under study, the examination of gas flow from a high-pressure cell through a nozzle demanded attention first. That is, the feasibility of extracting ions using gas flow alone, or gas flow in combination with electric potentials was to be considered. This scrutiny arose from one of the project s goals: the ability to study nuclei with short half-lives (~10 ms). The focus of our feasibility study centered on gas flow calculations.

The calculation and simulation of the gas jets used the VarJet [2] code. This computer code is based on a solution of full time-dependent system of Navier-Stokes equations for multicomponent gas mixtures. A full set of input parameters for simulation includes: (1) geometry of the device under the study, (2) type of gas, or composition of the gas mixture, (3) stagnation gas pressure and temperature, (4) the background pressure in the vacuum chamber. There are no free parameters in the mathematical model. Therefore, results of simulation can be directly compared with experimental data without the use of any fitting.

The calculation afforded an excellent understanding of the characteristics of the gas jet leaving the gas cell s supersonic nozzle. It also demonstrated that ions could not be extracted from the cell within the desired amount of time without electric fields. However, as good as the calculations proved, full comprehension of the gas jet s characteristics could only be achieved by comparison to measurement. As such, an effort was started to measure the gas jet.

For comparison to calculations, jet measurements were performed to determine the dynamic pressure of the gas jet after it expanded through a nozzle and into an expansion chamber. Vital to these measurements was the assembly of a Pitot tube which was designed and manufactured at the NSCL. A Pitot tube (Figure 2) is formed from narrow concentric tubes. The innermost tube samples the dynamic pressure created by the jet and transmits the sampled gas through a flexible hose to a manometer that indicates the resulting pressure.

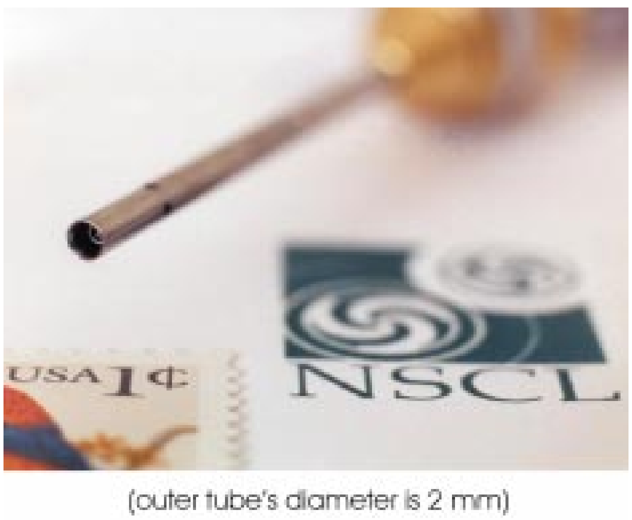

Figure 2: Close-up of the Pitot Tube

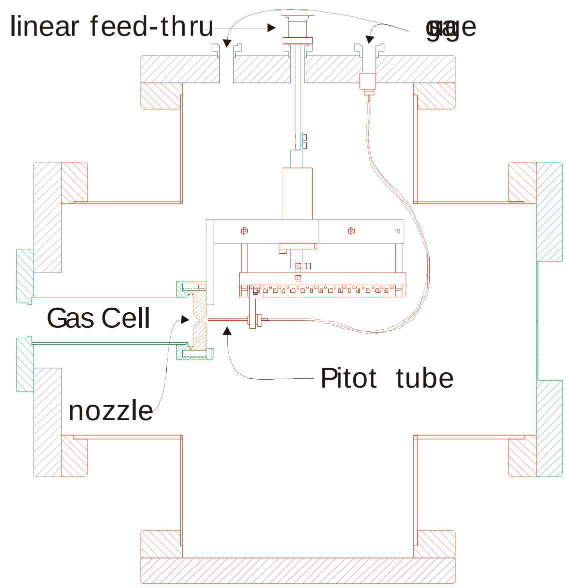

Figure 3: Jet measurement set-up

For the gas jet measurements, helium was maintained at 1 bar pressure in the gas cell, while the background pressure (the pressure in the expansion chamber where the measurements were made) was typically between 0.05 and 0.1 mbar. For comparison, two separate nozzles were machined at the NSCL into ConFlat flanges one having a simple, straight orifice and the other having a supersonic or horn shape cross section. The Pitot tube was moved vertically through the resulting jet in steps as small as 0.5 mm by means of a linear feed-through (Figure 3). Horizontal increments of 1 cm were achieved by positioning the Pitot tube along a perforated bar. Baratron capacitance manometers were used to measure both the Pitot tube (dynamic) pressure and the background pressure in the expansion chamber.

Shown next is a comparison of calculation and measurement for the two different nozzles.

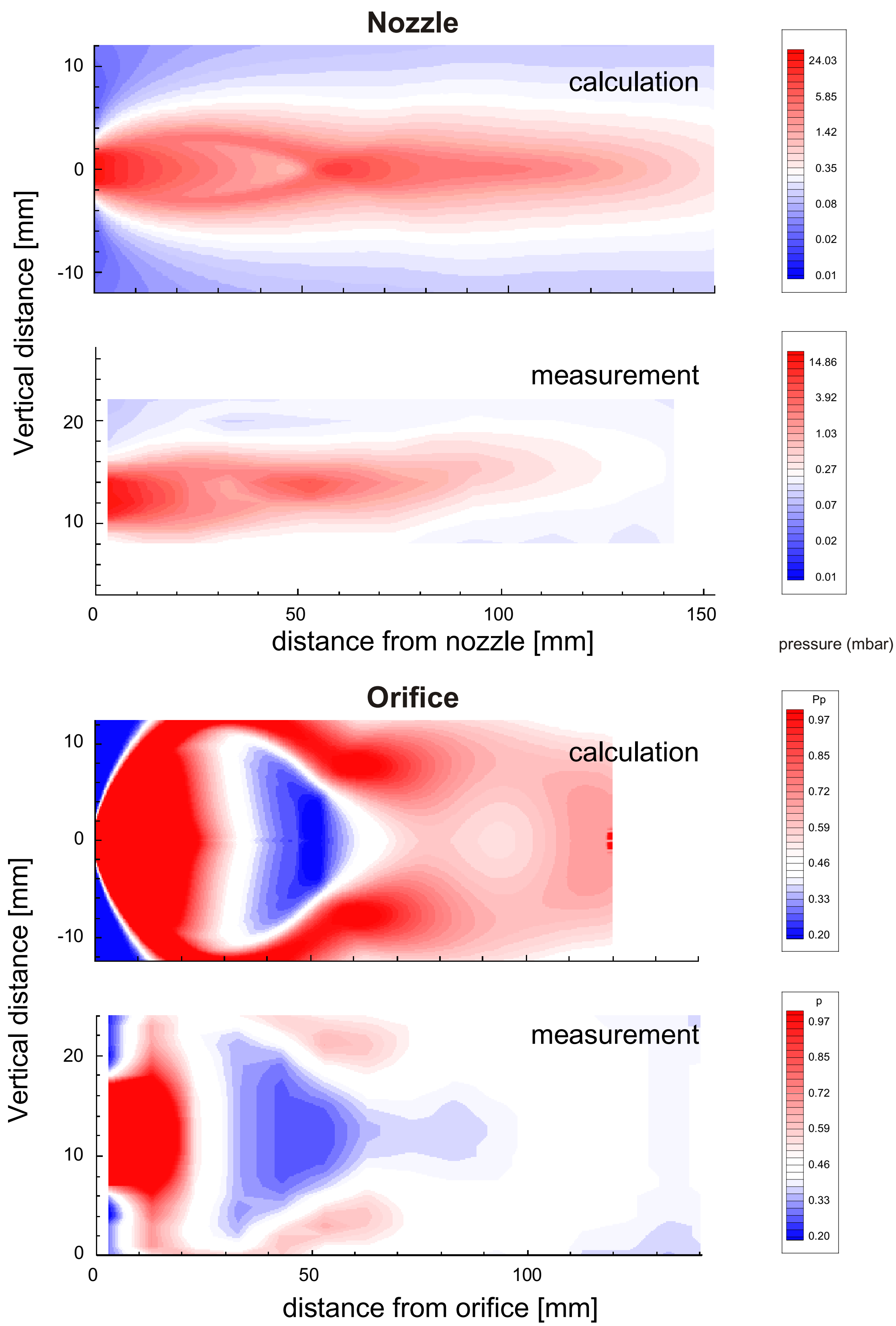

Figure 4: Calculations and measurement of the gas jets from two nozzle types

The calculations and measurements give a more certain picture of the gas cell s ability to extract the ions which will come to rest in the helium gas. Similar analyses using different features in the gas cell, nozzle and expansion chamber are ongoing and are valuable for the design of electrostatics and ion guides which will also become part of the gas stopping system.

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