Simulation study of a supersonic gas jet curtain for beam profile monitoring

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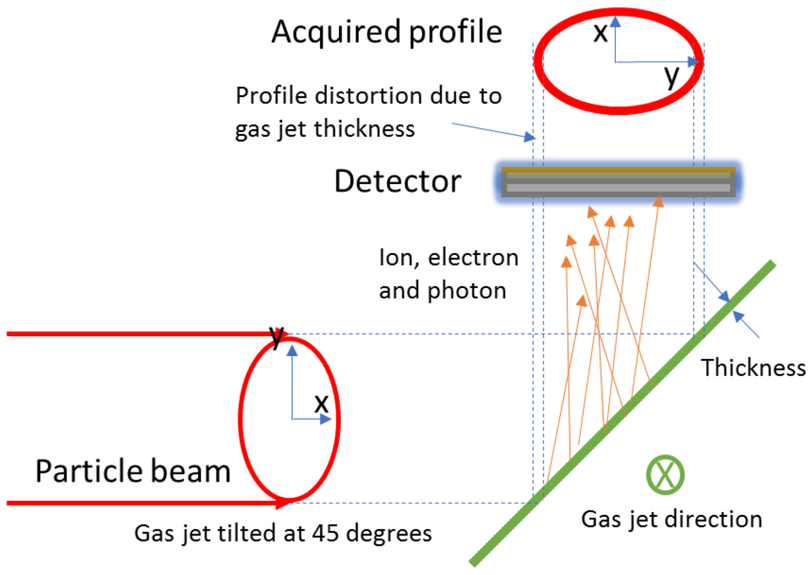
Abstract

A Gas jet beam profile monitor was developed in Cockcroft Institute for non-invasive 2D beam profile measurement. It is designed for high energy and high intensity beam like LHC and HEL. Recently, we also find applications such as helium atom microscope and non-invasive in-vivo beam dosimetry in hadron beam cancer therapy. One of the key challenges for these applications is to understand in detail the gas jet generation process and its dynamics, a hybrid simulation method was developed to study the gas jet curtain formation and was verified with experiments.

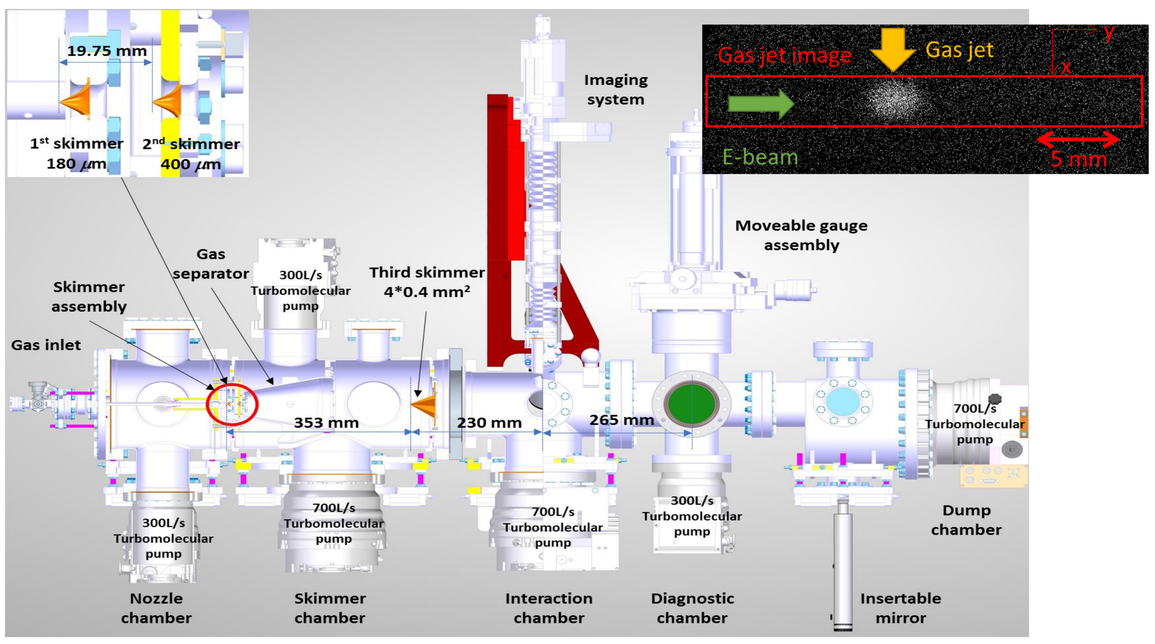
Detecting principle

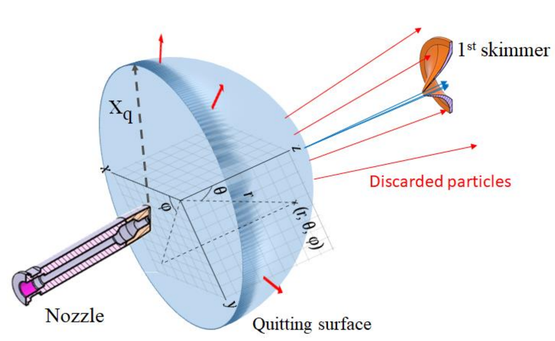
Advantages:

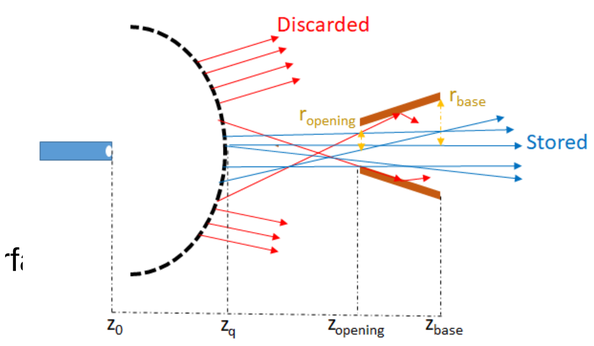
1. Minimum-invasive measurement with two dimensional capability.
2. Vacuum friendly, non-consumable.
3. Versatile to beam species and energy
4. Shorter integration time than traditional IPM and BIF.



Gas jet set up, simulation and measurement

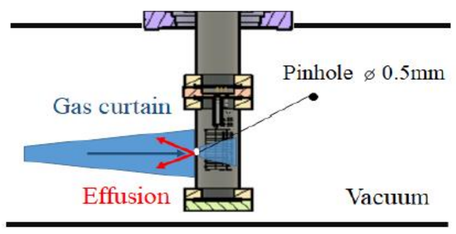






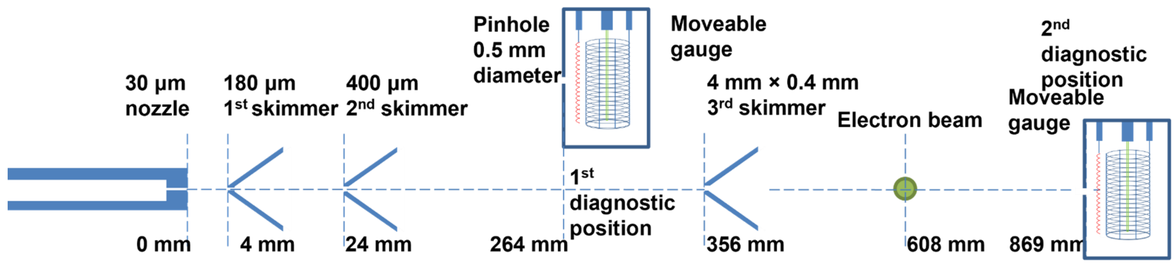
$$\rho = \frac{P_0}{k_B T_0}\left(1 + \frac{\gamma - 1}{2} M^2\right)^{-\frac{1}{\gamma - 1}}$$

From quitting surface: Molecular flow => Mote Carlo simulation Particle tracing

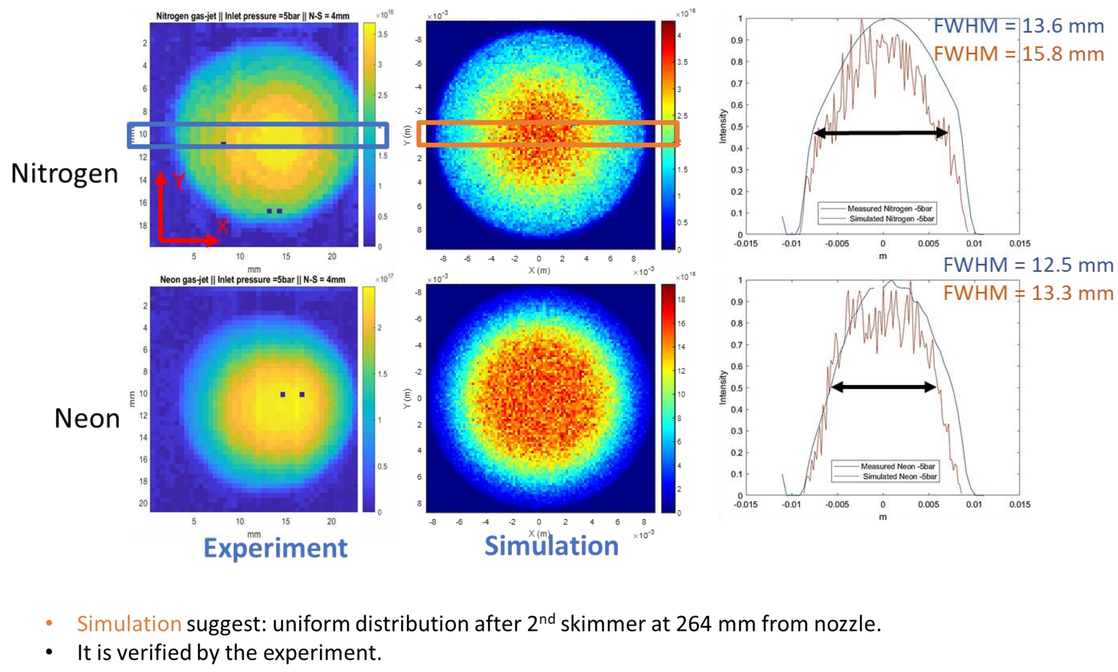


Gas jet density measurement using movable gauge at diagnostic chamber:

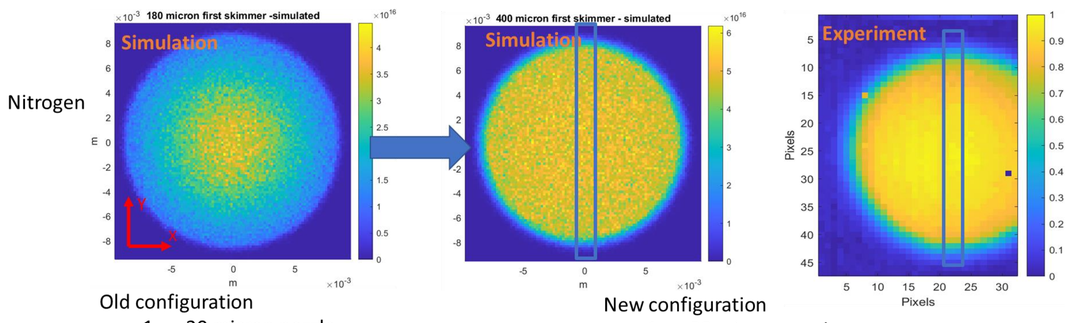
Results



- ***Gas jet density distribution*** verified with old configuration at 264 mm from nozzle:
  - **Nozzle : 30micron; Skimmer I : 180 micron; Skimmer II: 2mm**



- Simulation suggest: uniform distribution after 2nd skimmer at 264 mm from nozzle.
- It is verified by the experiment.

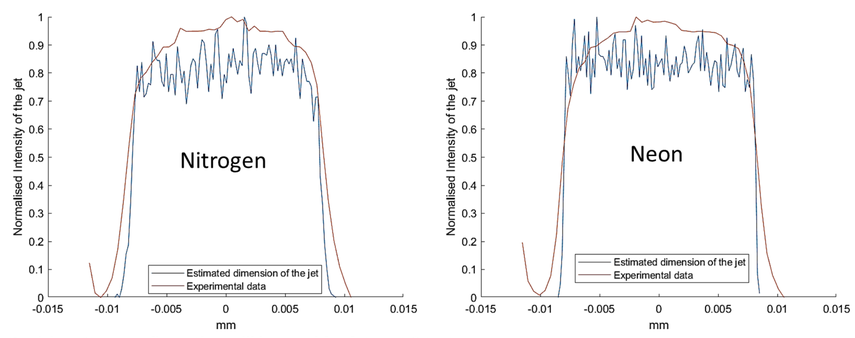


Old configuration

1. 30 micron nozzle
2. **180 micron** first skimmer
3. 2mm second skimmer

New configuration

1. 30 micron nozzle
2. **400 micron** first skimmer
3. 2mm second skimmer



Decision: New configuration will be used for future V3 test.

Outlook

In this contribution, we discussed a hybrid simulation method for gas jet generation. For the future, with collaboration with Liv.inno and STFC computational fluid group, we want to replace the analytic quitting surface model with CFD simulation to check the application limit of current hybrid code and then using these simulation to help future design of such monitors.

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