Fresnel Zonal Plates: Quantum Gas Jet Systems

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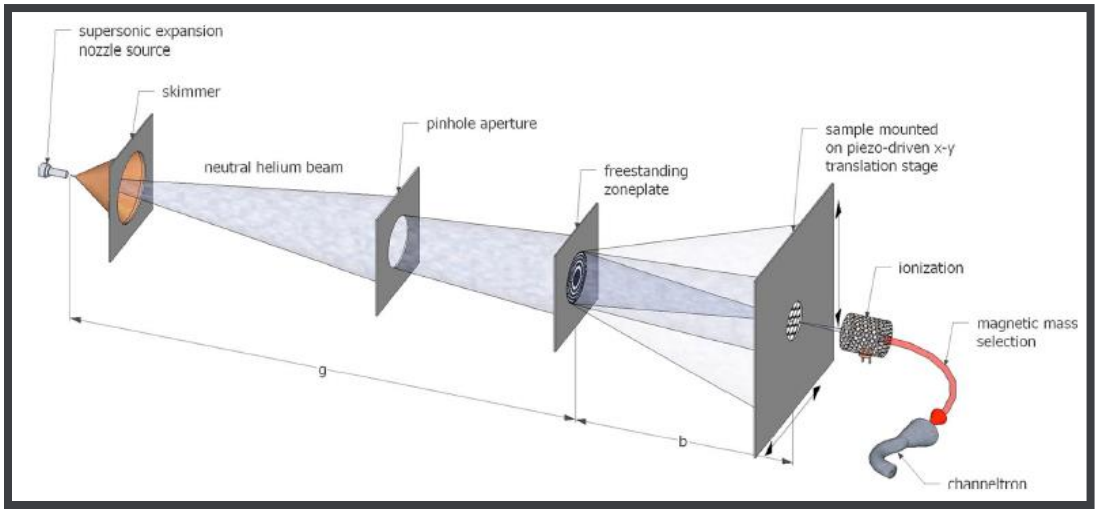
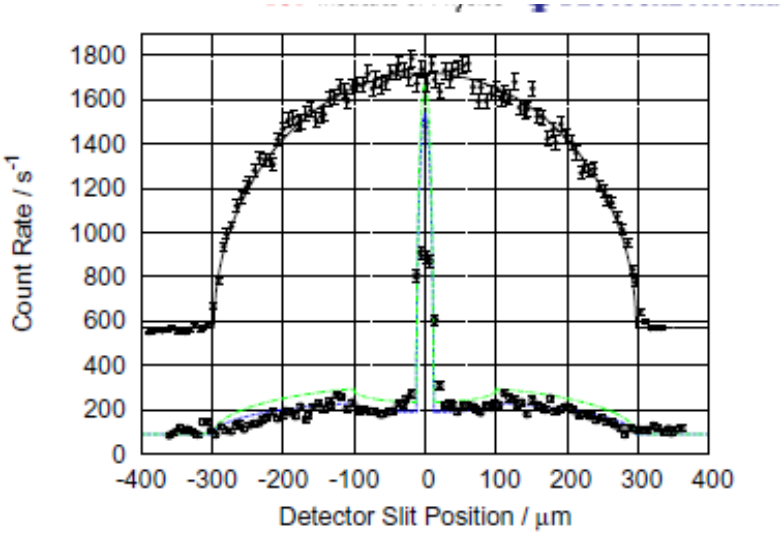
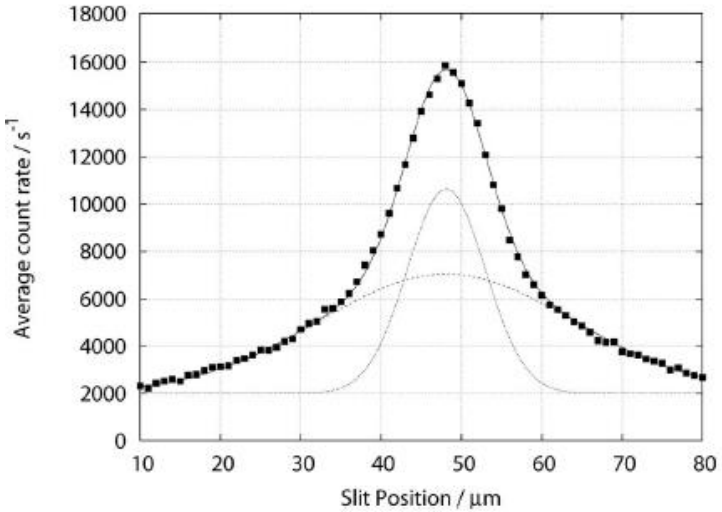
Literature on FZP based Quantum Gas Jet

- *Bergen University*
- *Supersonic D_2 beam focused down to 15.2±0.5 µm.*
- *Helium beam focused to diameter less than 1 µm*







*T. Reisinger et al. J. Vac. Sci. Technol. B 26(6), 2008, 2374-2379
**S. D. Eder et al. New J. Phys. 14 (2012), 073014

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FZP BASED QUANTUM GAS JET PROFILE MONITOR

- Key Features
  - Sub-mm gas jet
  - Analogous to wire scanner
  - FZP
  - Profiling of high intensity beams
- Work in Progress
  - Chamber and Holder Design for FZP
  - Experiments are planned to start in Early 2021
- UHVD Collaboration
  - TTX63 xyz manipulator (3months)

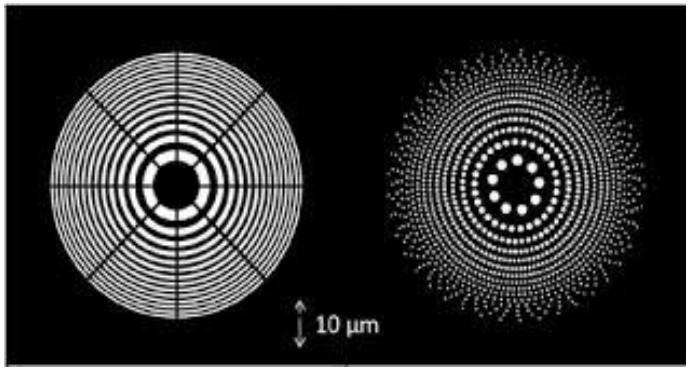
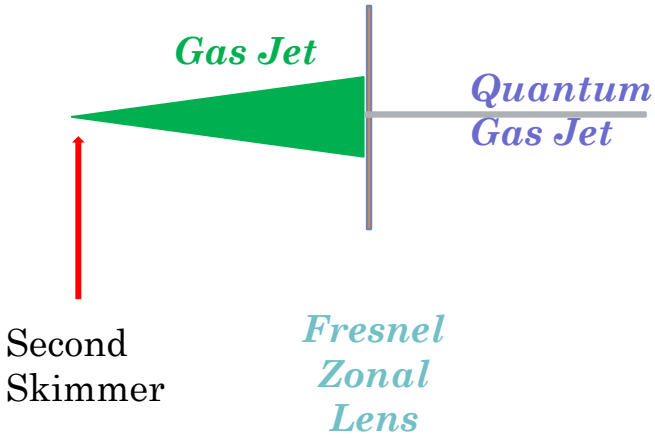


Illustration of Fresnel Zone Plate used for the generation of focused quantum gas jet



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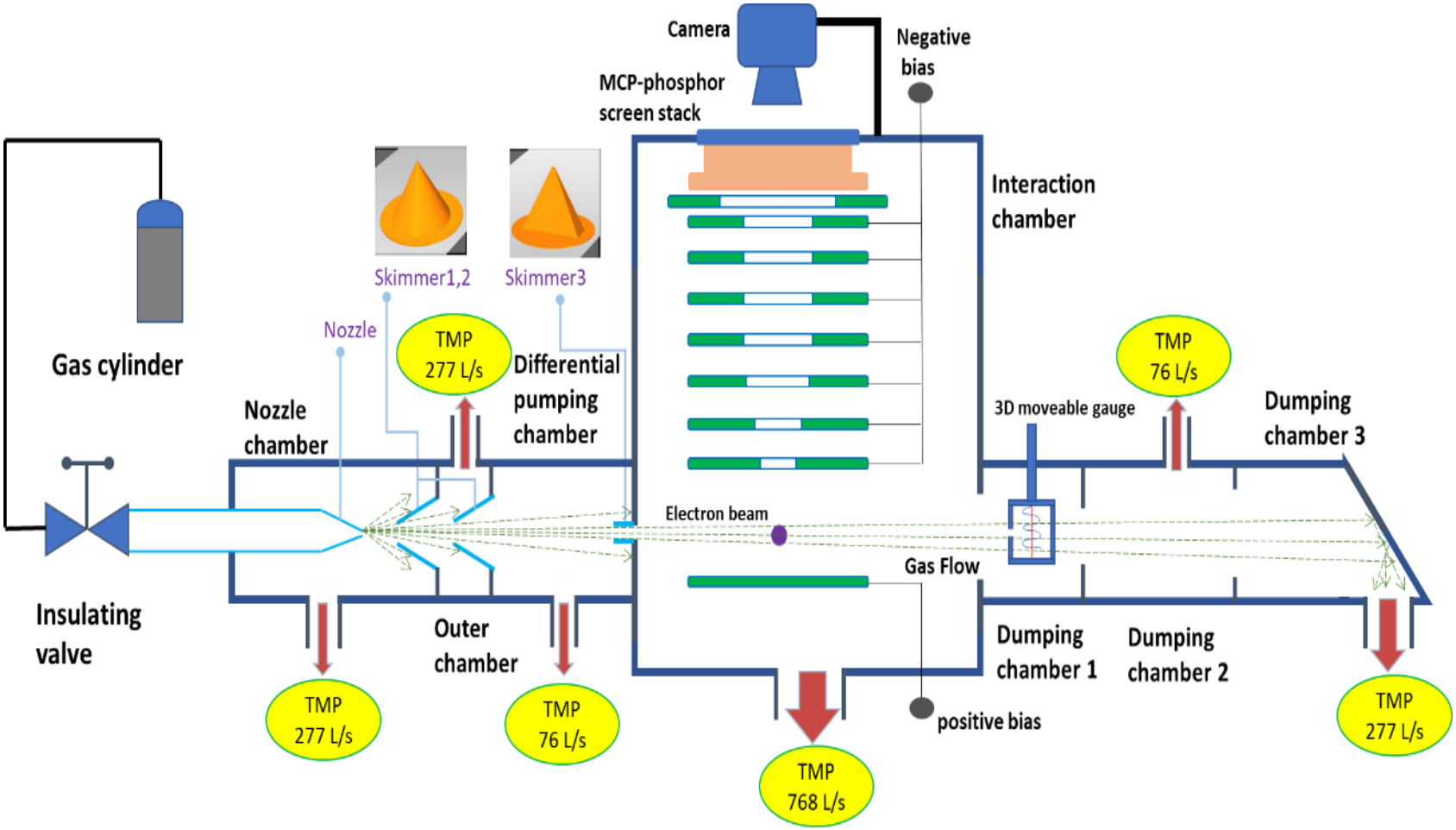
Gas jet beam profile monitor based on IPM



Schematic of a prototype gas curtain based beam profile monitor using beam induced ionization.

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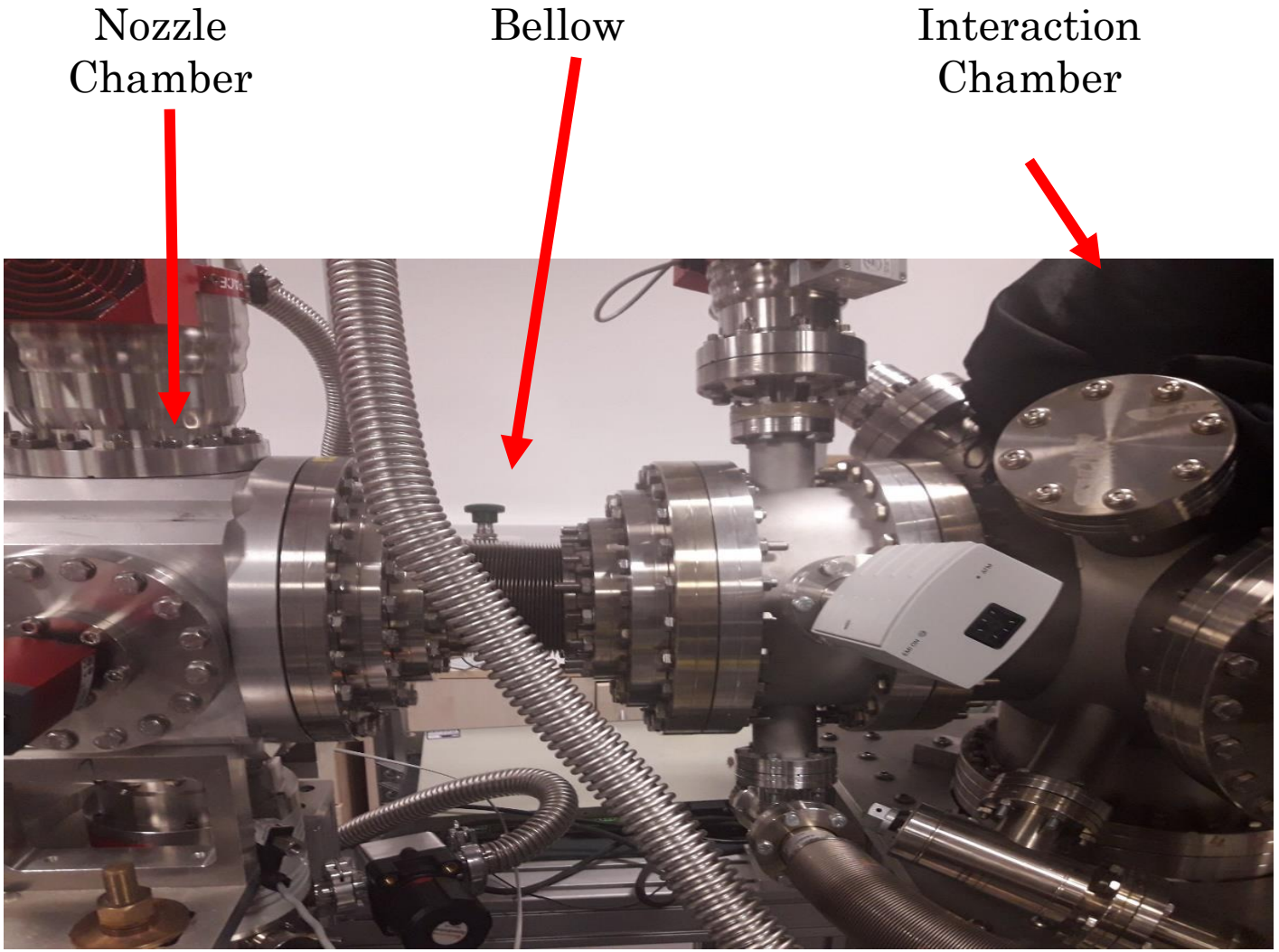
Current IPM System at CI and Location for Mounting FZP



Nozzle to FZP distance ~420 mm and image location to FZP distance is ~217 mm

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FRESNEL ZONE PLATE at CI

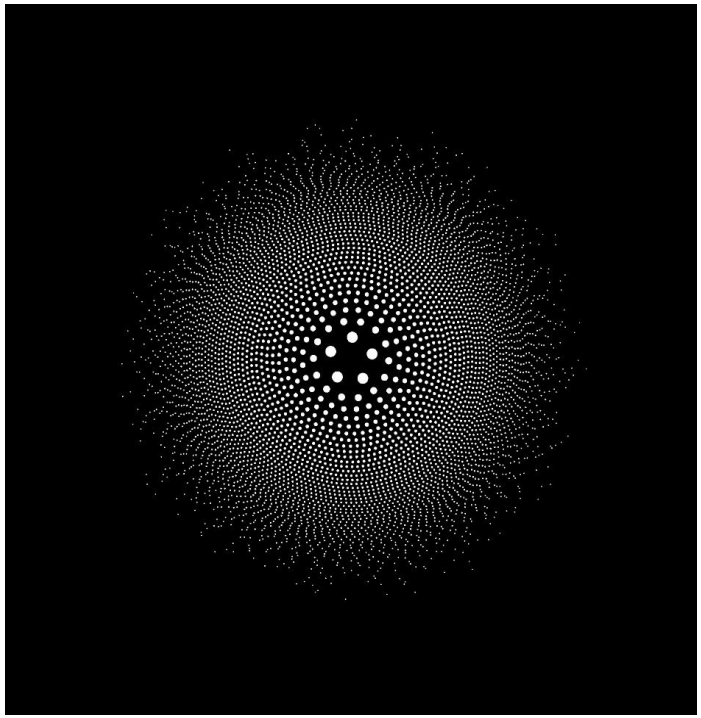
No of zones, N = 55
Radius, r = 30 μm

Focal length, $f = \frac{r^2}{N\lambda}$

λ is the de-Broglie's wavelength

$\lambda = \frac{h}{mv}$

where h is Planck's constant, mass of atom and v velocity of the atom



Design of Fresnel Zone Plate on Si wafer of 150 mm diameter
Size of Image is 100 μm X 100 μm

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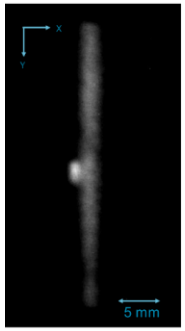
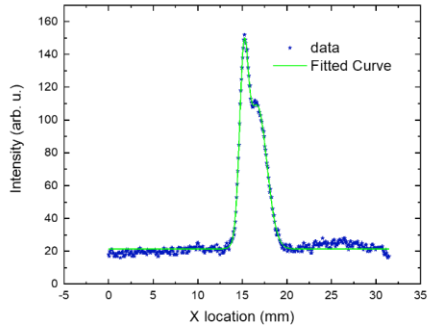
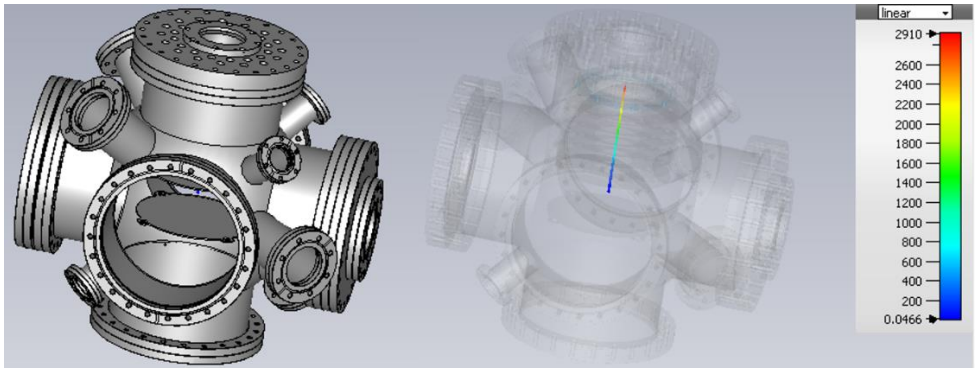
Since, for Helium, we are not having exact value for the velocity of He atom in our system. We have done literature survey and estimation of He gas jet velocity by image analysis and comparing with CST simulations.

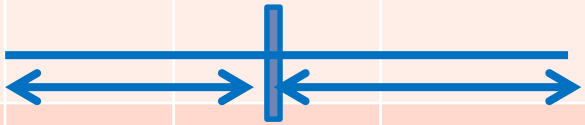






From Literature:
Average velocity is 1129±3 m/s which corresponds to wavelength: 0.0882±0.0003 nm for source pressure 81 bar (Gottingen Zone Plate), Skimmer dia. 2.5±0.1 µm
From Experiment at CI and CST simulation: 5 bar He gas, estimated velocity is ~ 1200m/s
By using these 2 cases,
For Literature , focal length of our FZL is 184.88-186.16 mm
From Experiment and CST simulation, focal length of FZL is 196.96 mm

	Velocity of He Jet (m/s)	Focal Length (mm)	Current distance b/w nozzle and FZP location (mm)	Image location from FZP (mm)	New Locations for nozzle w.r.t FZP (mm)	Image location w.r.t FZP (mm)
Rough Estimate based on CST simulations and Image analysis	1200	196.96	420	370.89	400	***388.02***
Case 1 (Literature)	1129± 3	184.88-186.16	420	330.25-334.36	450	313.80-317.51
Case 2 (Literature)	1129± 3	184.88-186.16			490	296.90-300.22
Gap in (image + object distance) Case 1 w.r.t estimate				~40-36		~24-20
Gap in (image + object distance) Case 2 w.r.t estimate						~±1-2



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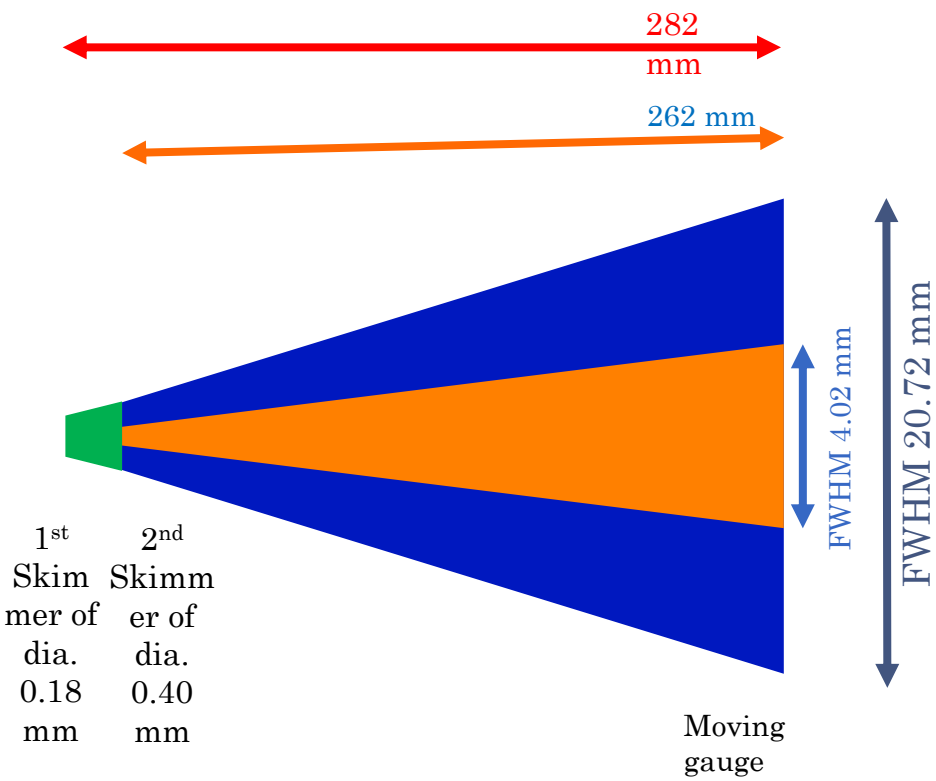
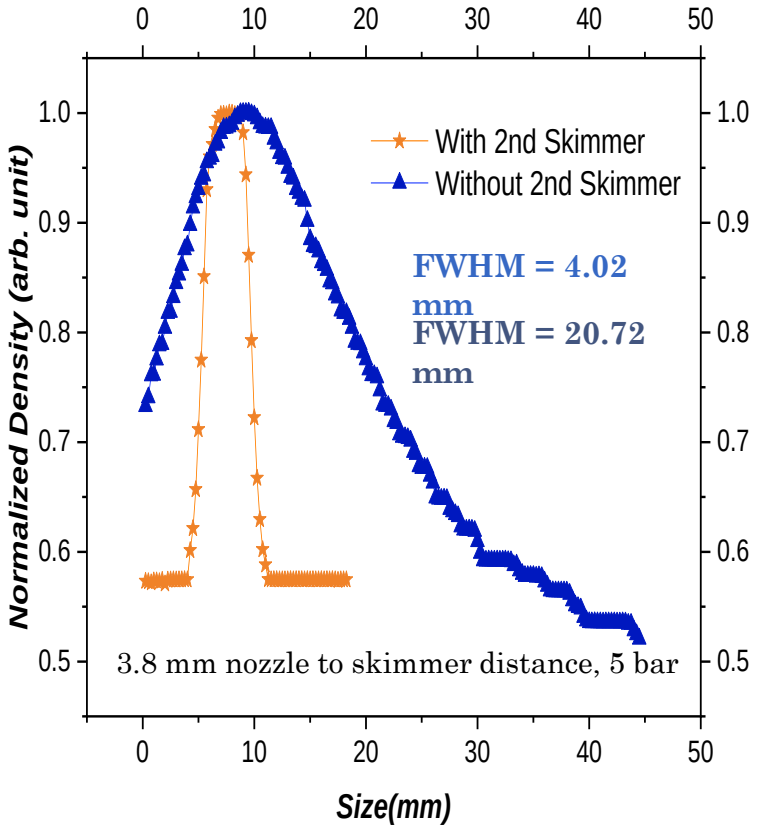
Experimental Data for gas-jet size

Current Location of Interaction point = 583 mm from 2nd Skimmer (0.4 mm diameter)
New Location of Interaction point= 389.53 mm from 2nd skimmer (0.4 mm diameter)

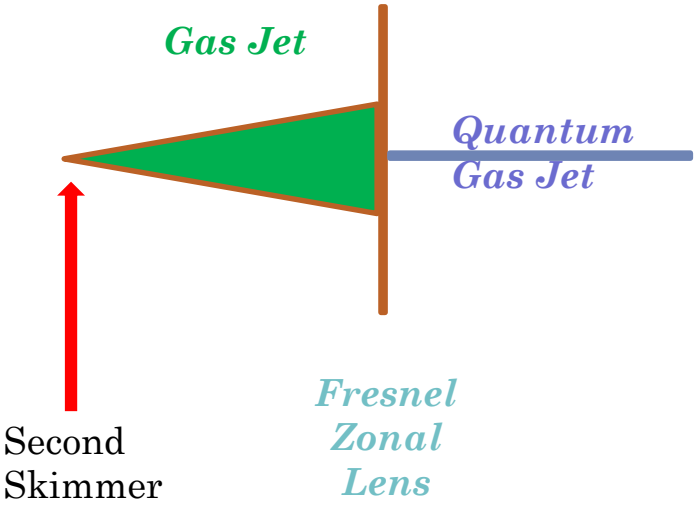




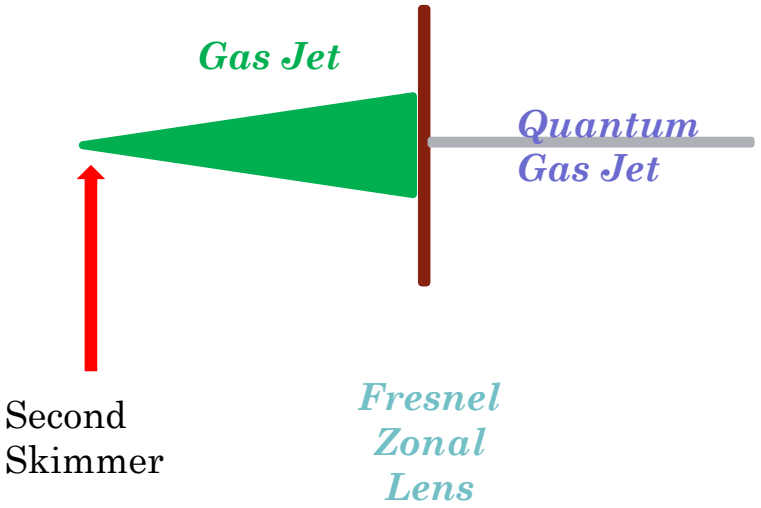
Data from Oct-Nov 2019

Pin Hole Gauge Data located at 262 mm from 2nd Skimmer (0.4 mm Diameter)

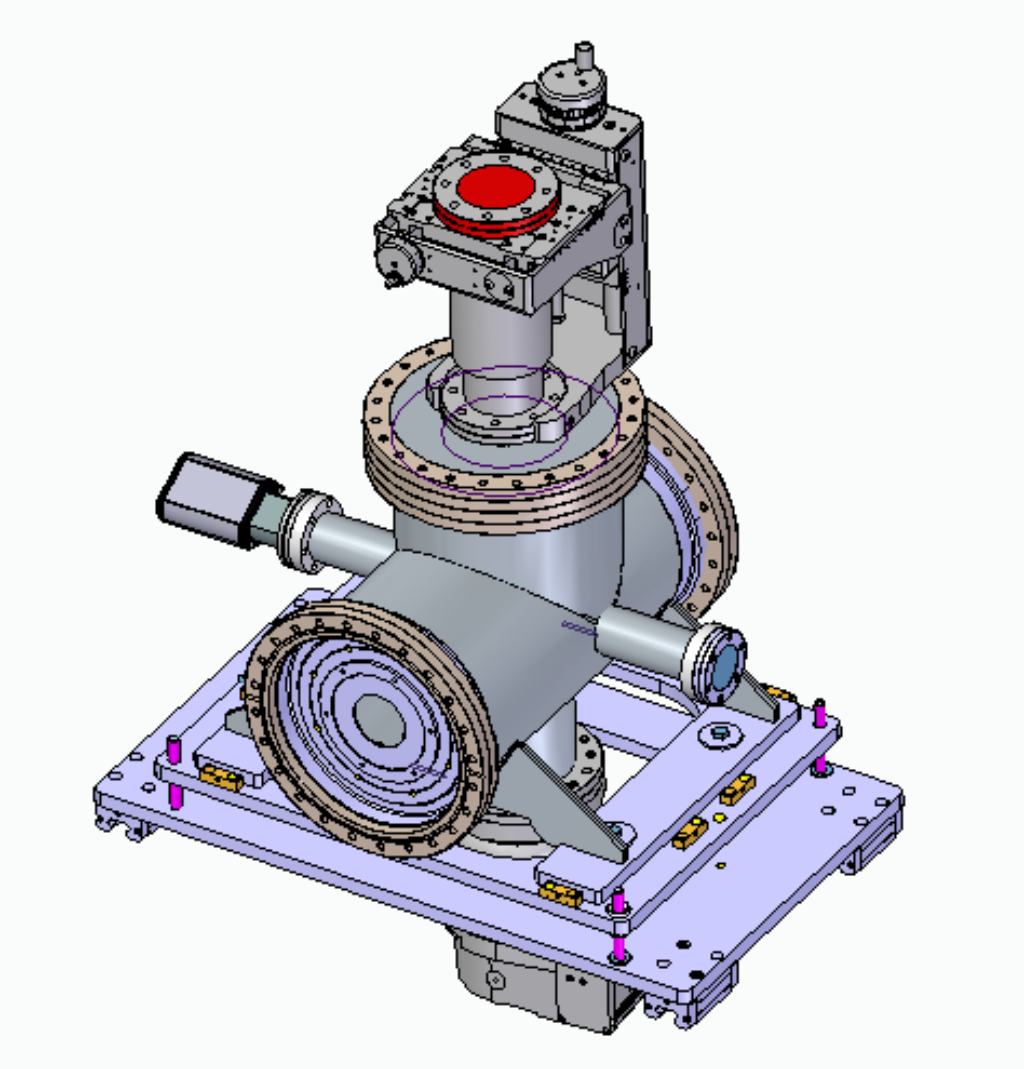
Previous Design work's Scheme

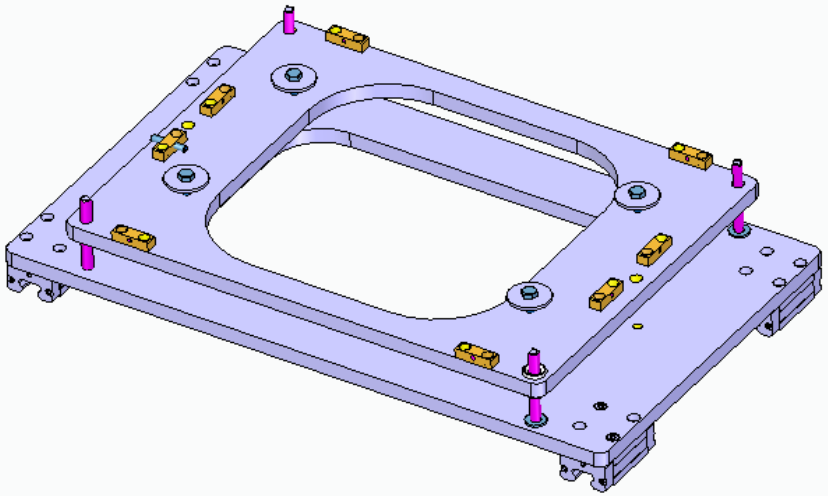


Current Design work's Scheme

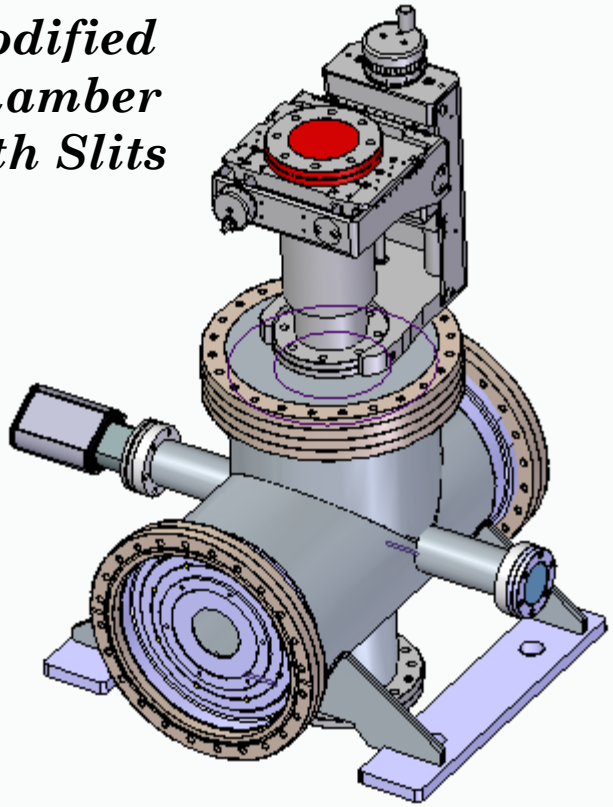


Modified Drawing of FZL Chamber with Stand

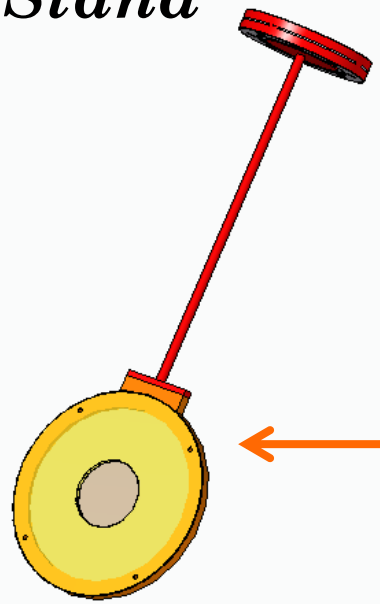




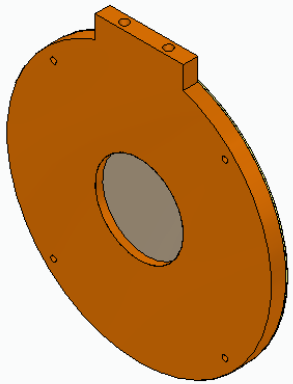
Modified Chamber with Slits



Movable Stand



Modified FZL Holder



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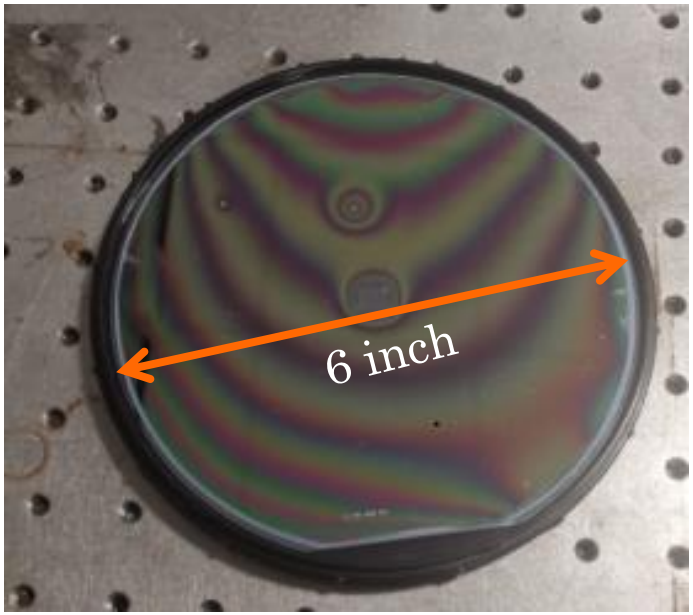
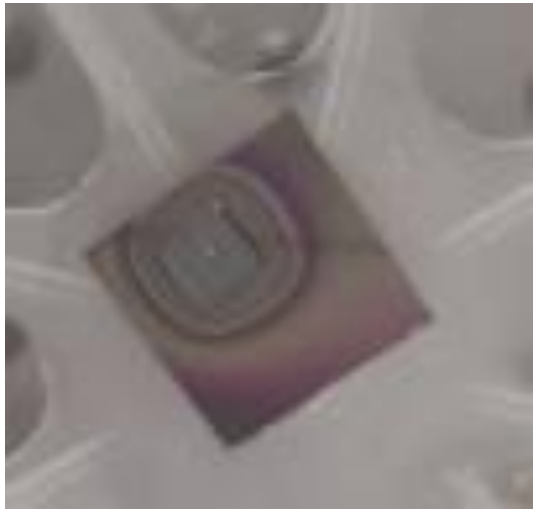


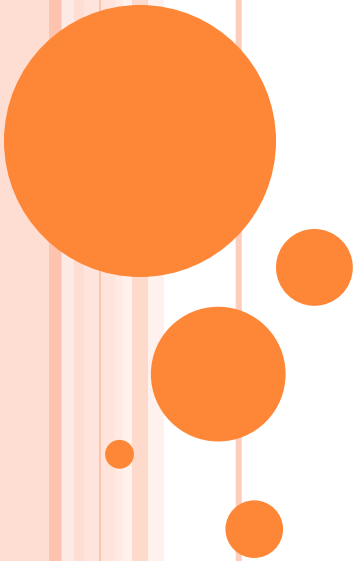
Fresnel Zone Plate on Si wafer of ~150 mm diameter



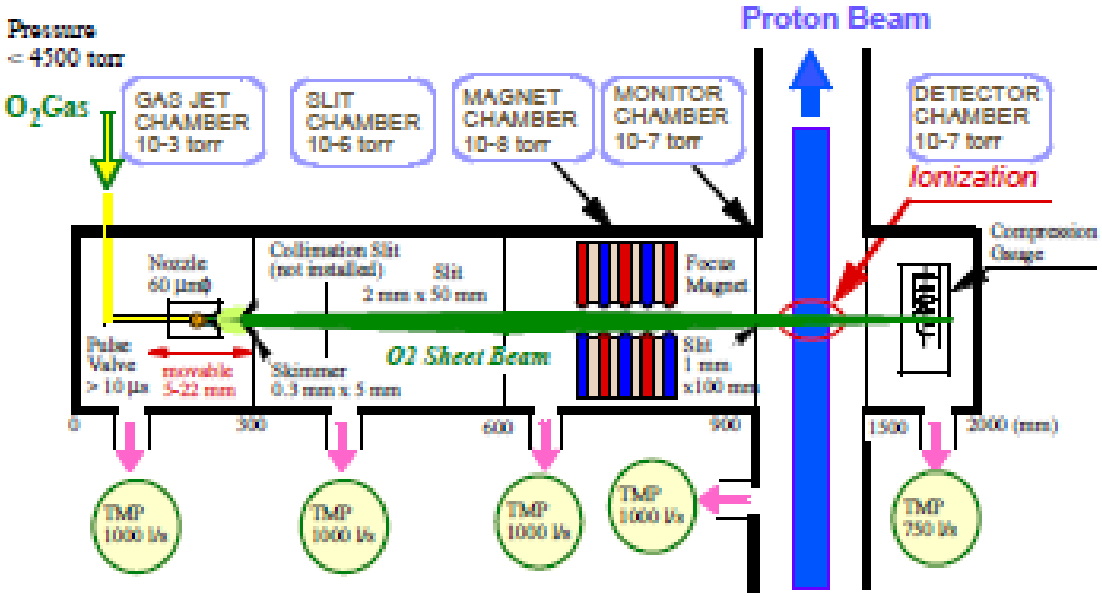
Fresnel Zone Plate of size ~23 mm X ~22-23 mm

- ***Waiting for a report from former colleague to gather more details on smaller FZP which can be used in existing skimmer chambers of version2 setup at CI***

Applications in Medical Accelerators

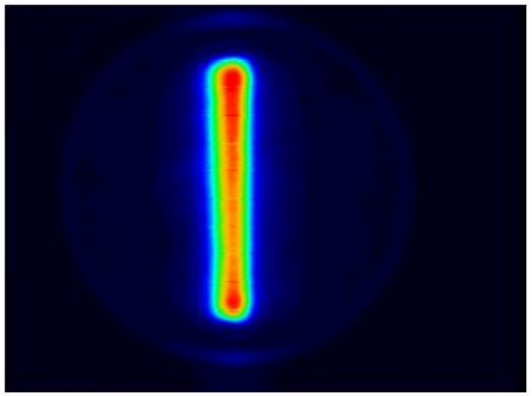


Literature on Online Profile Monitoring for Medical Accelerators



Schematic Gas jet monitor installed in the HIMAC synchrotron

Gas jet monitor installed in the HIMAC synchrotron



Profile of 8 MeV Proton beam with mean current 10 nA

*Y. Hashimoto et at. EPAC2020, 1729-1731,Vienna, Austria

Online Dose and Profile Monitoring for Medical Accelerators

Aims

1. *Online monitoring the beam current and shape of the dose implanted to treat tumor/cancer.*

2. *Proof of concept (PoC) measurements with 28-36 MeV Proton beam at Cyclotron facility at University of Birmingham (UoB), UK.*

3. ***To build compact design of the dose monitor for easing the installation in the medical accelerators.***

4. ***Using Machine Learning techniques for better control of dose delivery system.***

Key Components

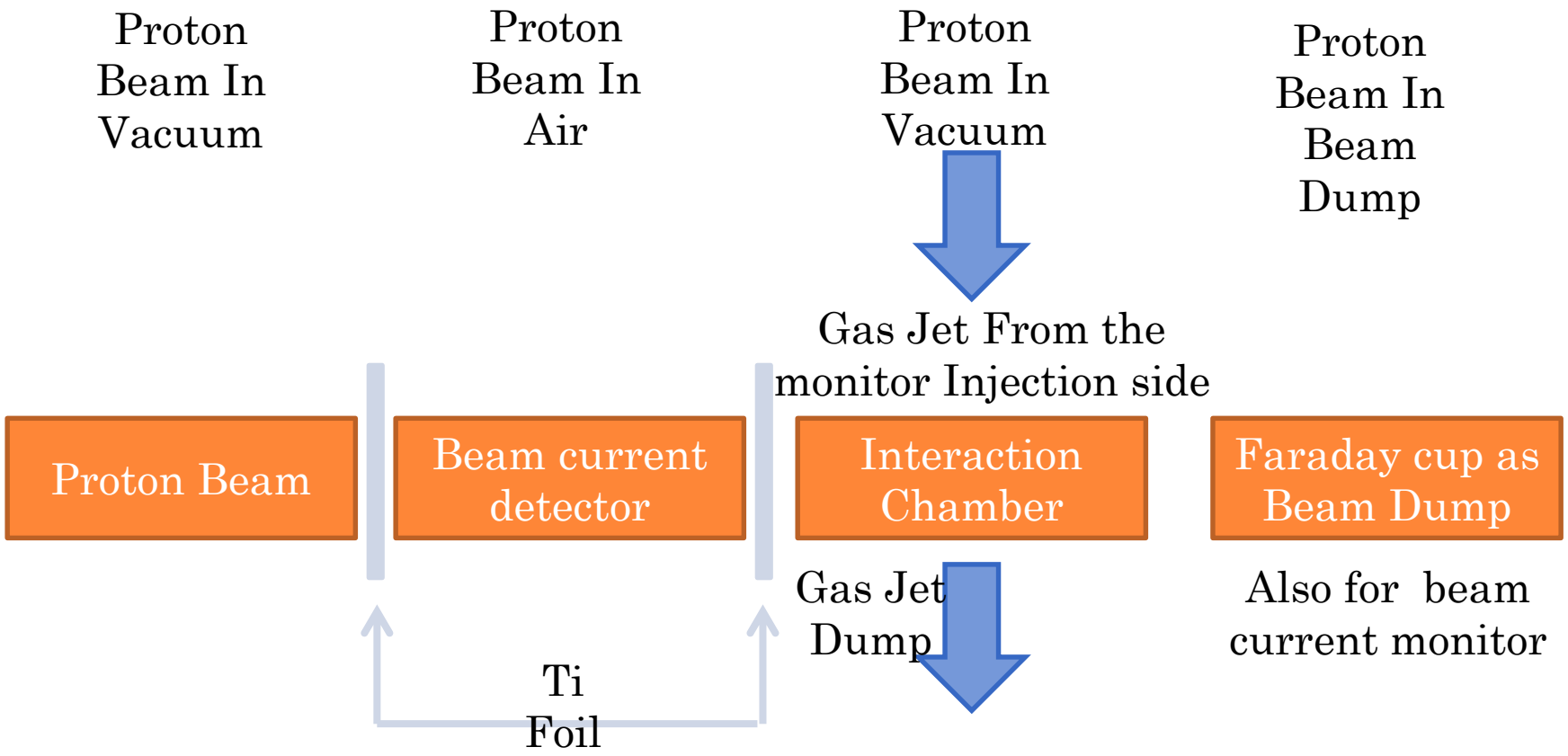
1. ***Gas Jet Injection system***
2. ***Interaction Chamber***
3. ***Imaging system***
4. ***Gas dump section***

1. PoC measurements will be carried out using existing gas jet profile monitor installed at Cockcroft Institute (CI), UK

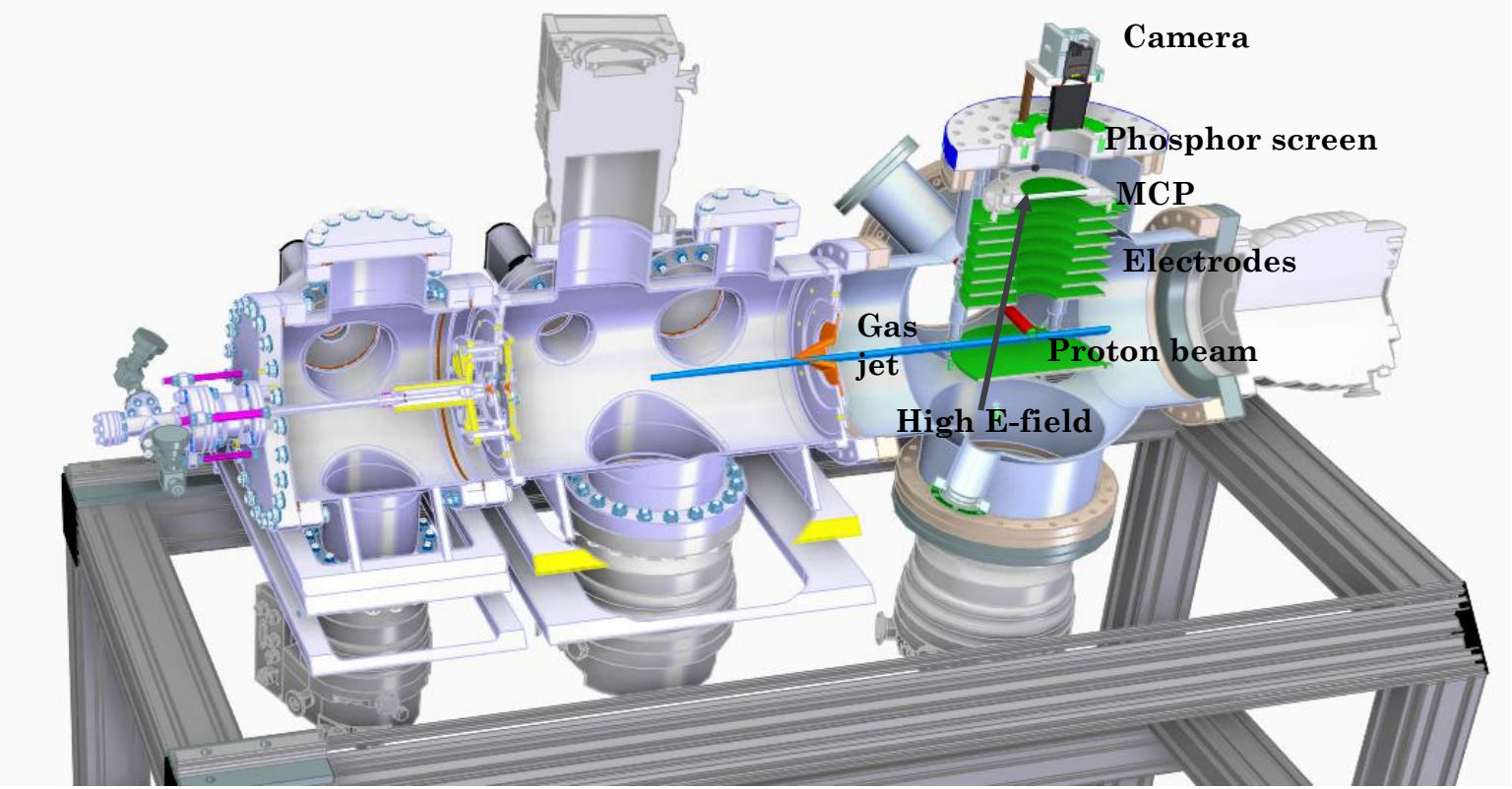
2. The system will be installed in one of the beam lines of Cyclotron facility at UoB with various beam energies, shapes and currents.

3. Studies will be performed to co-relate the beam intensity with the images obtained from the measurements.

Scheme for PoC measurements at UoB



Proposed Birmingham Proton Beam Experimental Setup



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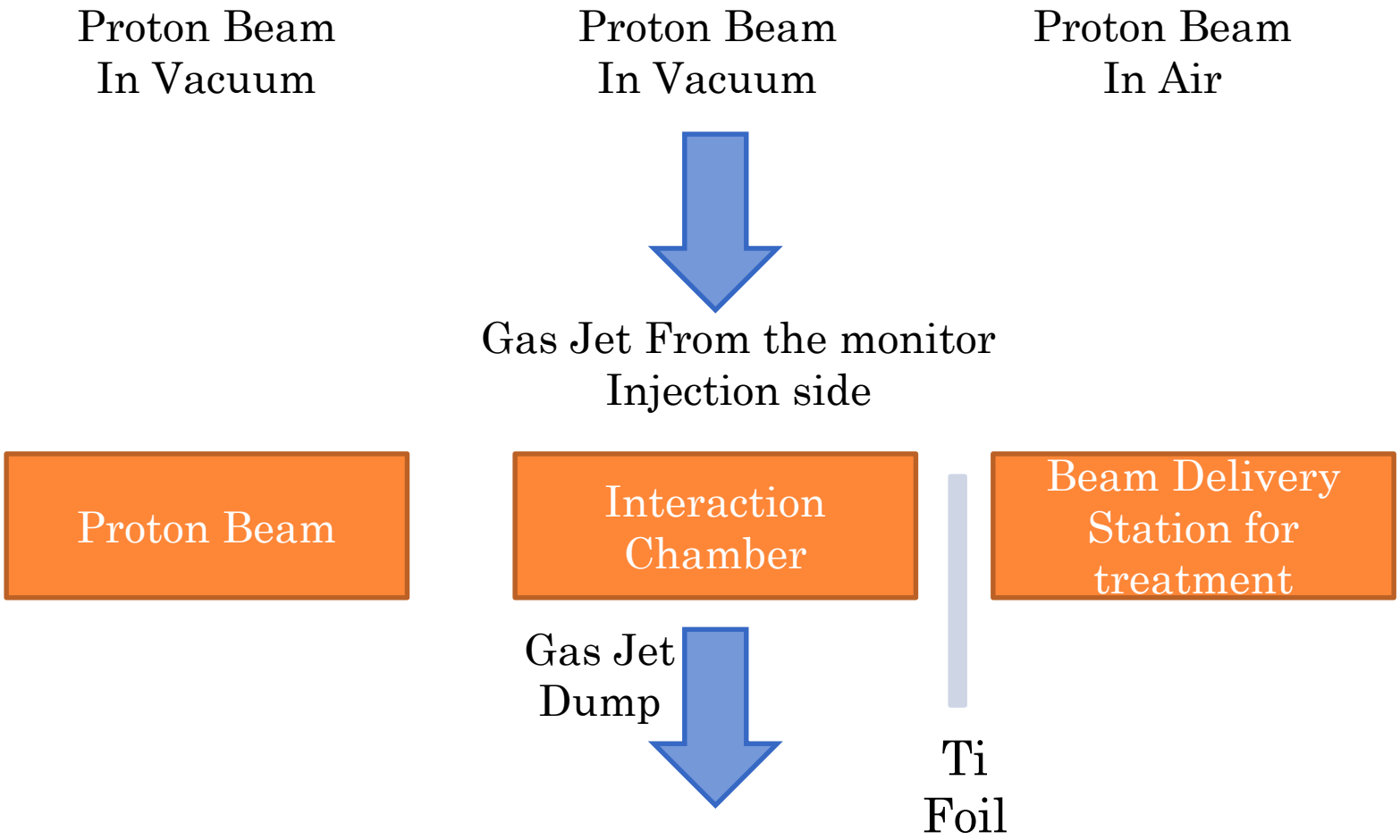
Scheme for actual monitoring system at a treatment centre



❖ ***Future design of the gas jet monitor would be much more compact with least components***

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Thank you for listening!

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