

Transverse Beam Profile Measurements with Gas Jet in-vivo Dose Profiler for Medical Accelerators

Dr Narender Kumar
Research Coordinator



Motivation and clinical benefits

Background and R&D

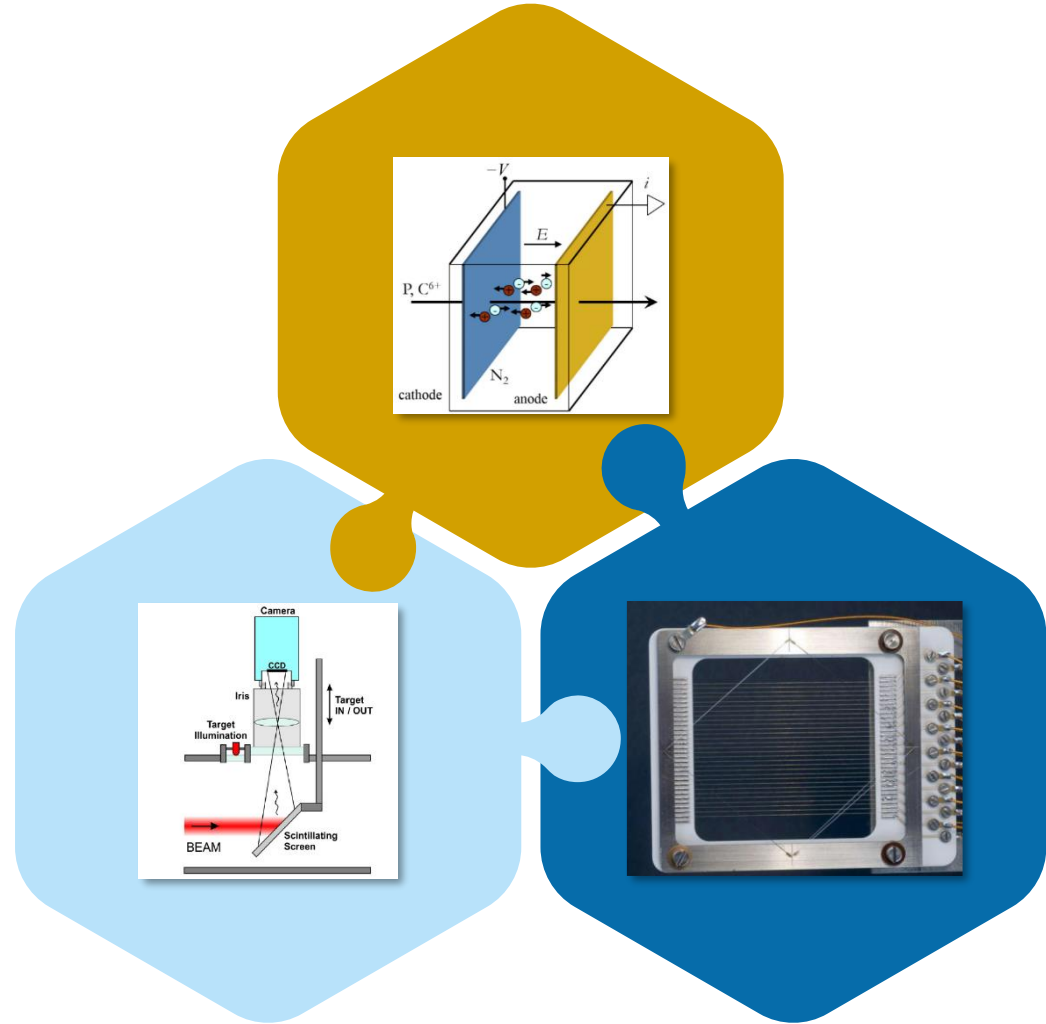
Proof-of-concept Measurements



CNAO Synchrotron, image courtesy CNAO.

- Clear healthcare benefits for certain cancer types;
- Significant investment through NHS and private facilities in the UK;
- Optimization of Medical Accelerators (OMA) network identified key R&D challenges:
 - Significant time goes into Q&A
 - New technology solutions needed for novel treatment modalities such as FLASH
 - Desirable machine operation modes not currently possible due to lack of non-invasive (online) diagnostics

- + High resolution
- + Reliability
- + Validity
- Interceptive
- Ongoing calibration
- Beam perturbation
- Limited live feedback



1

Minimally invasive

- ✓ No beam perturbation
- ✓ Online monitoring
- ✓ Superior error detection

3

Novel treatments and improved operation

- ✓ Enabling technology for FLASH and Mini-Beam treatments
- ✓ Active machine regulation based on live feedback becomes feasible



2

Significantly reduced calibration time

- ✓ No mechanical parts interact with the beam
- ✓ All key parameters monitored remotely
- ✓ Significantly reduced maintenance

N. Kumar, C.P. Welsch, et. al, Physica Medica 73, p 173-178 (2020).

S. Jolly, C.P. Welsch, et al., "Technical challenges for FLASH proton therapy", Phys Med 2020 – Galileo Galilei Award, best paper in 2020

"Non-Invasive Gas Jet In-Vivo Dosimetry for Particle Beam Therapy", contributed talk at IPAC21



2D Transverse Beam Profile

Reaction Rate =

Ionization cross section
X Density of the gas curtain
X Thickness of the gas curtain
X No. of incident ions



Beam Charge and Energy Profiles

Beam Charge

Calibration with any other measurement technique i.e. FC

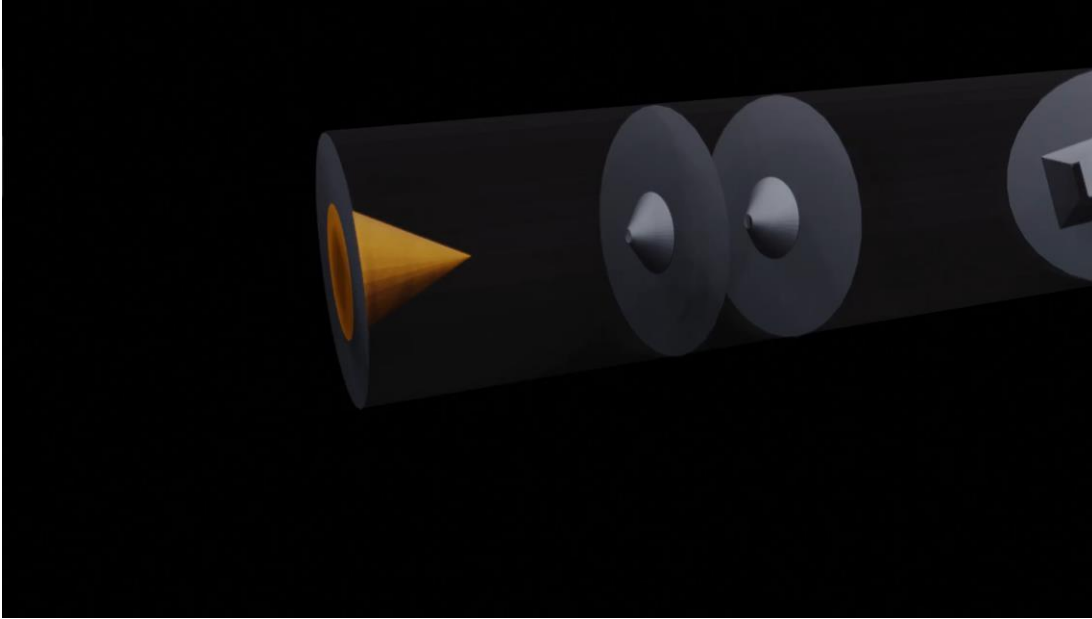
Beam Energy

Data base for ionization cross section

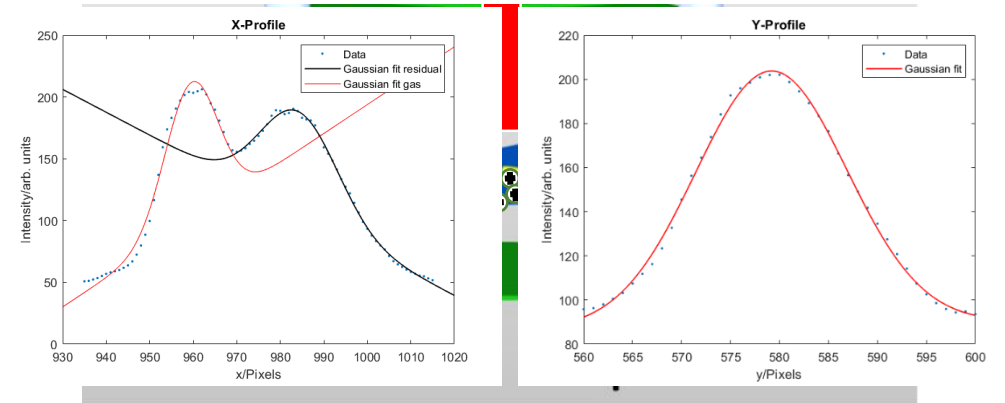
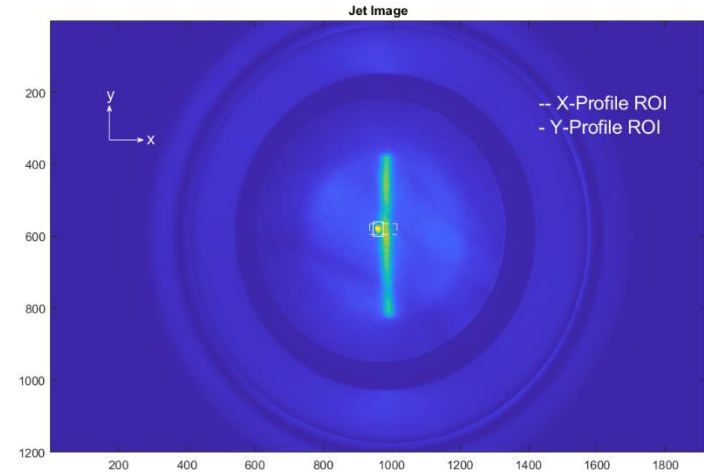


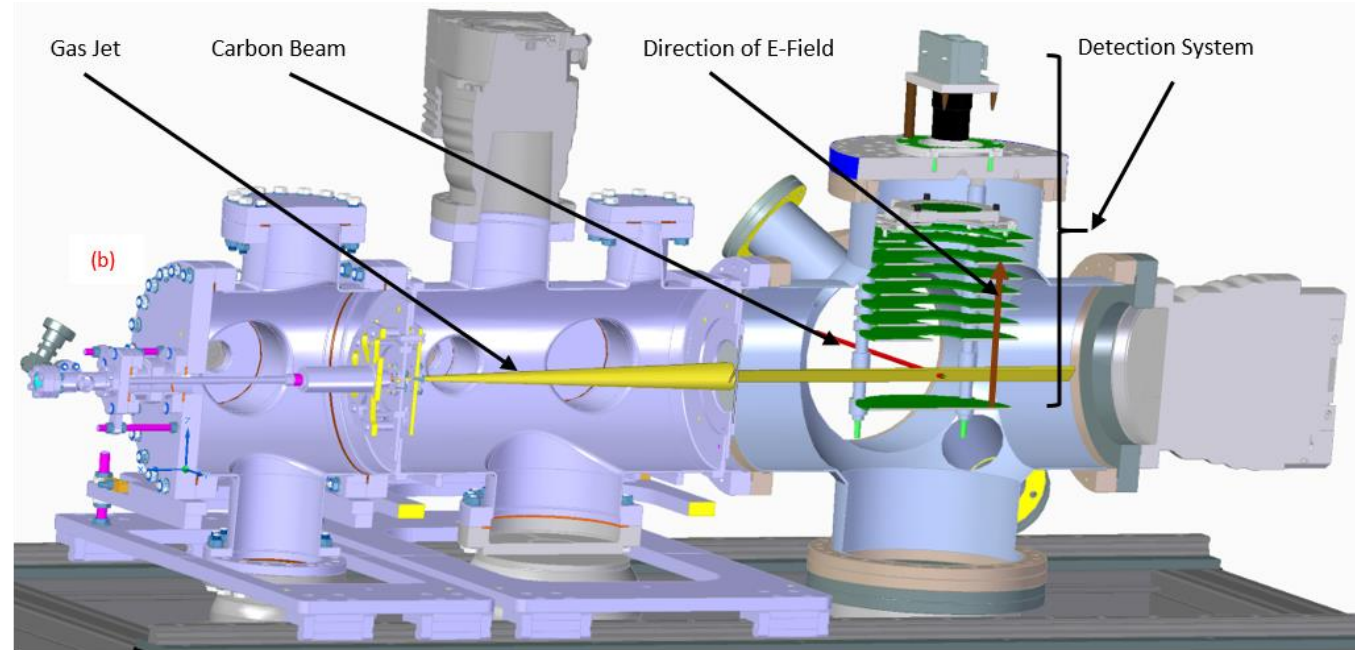
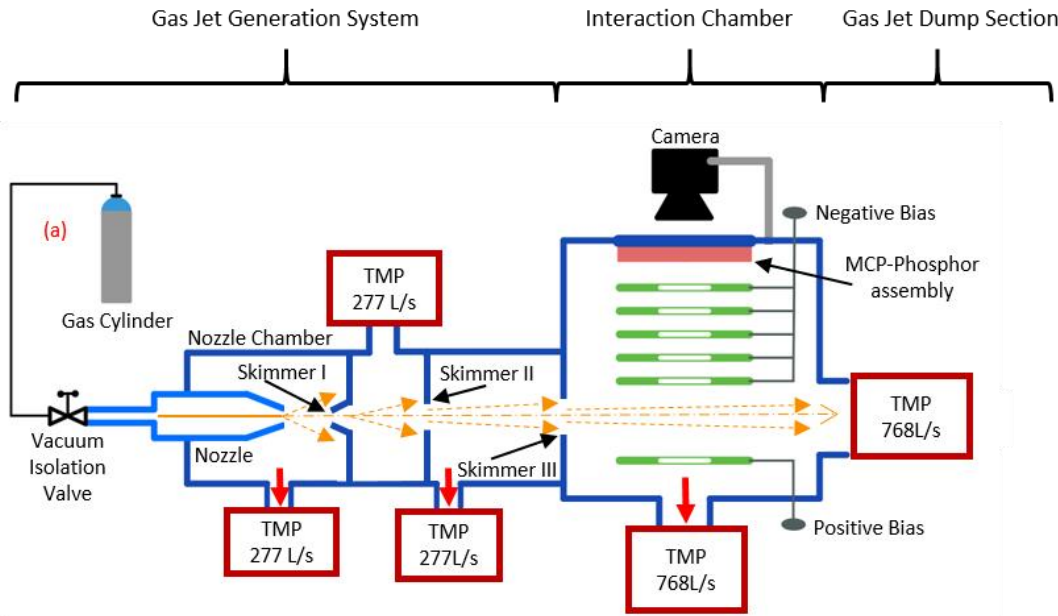
In-Vivo Dosimetry

Combine all these information to provide 2D dose information



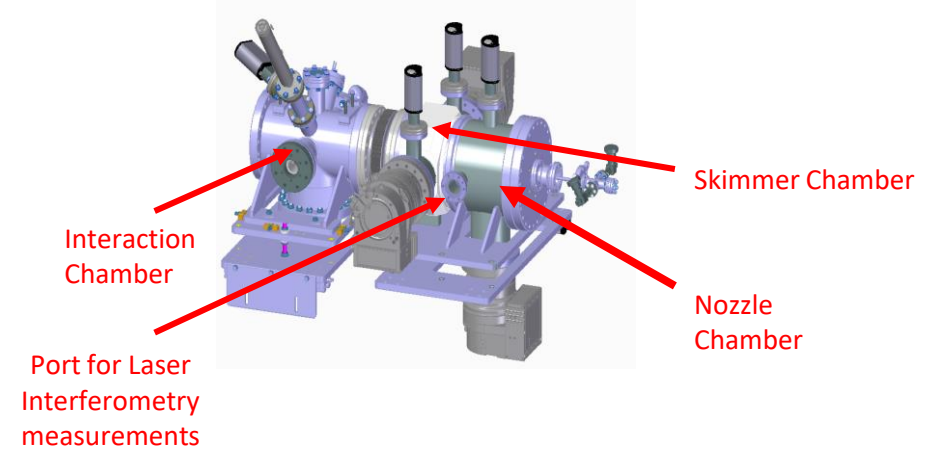
Gas jet shaping



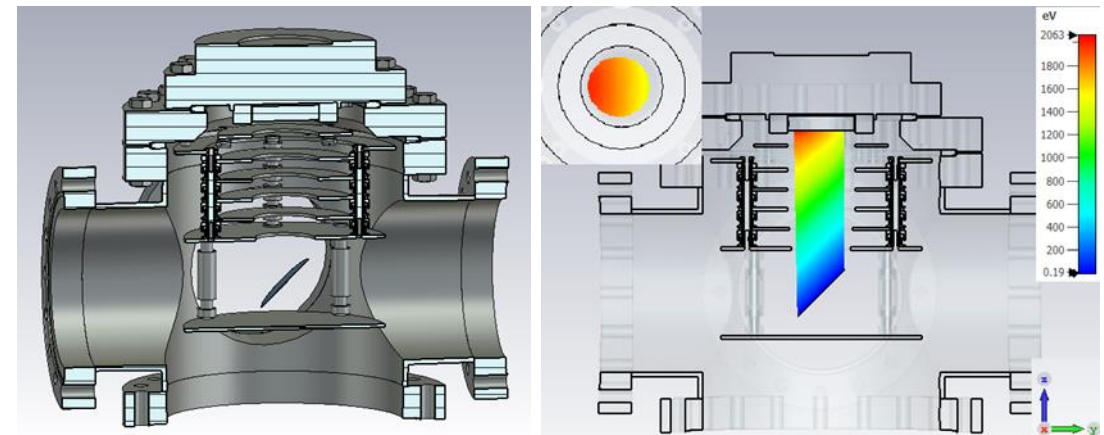


Status		Pressure (mbar)			
Gas Jet	Beam	Nozzle Chamber	Skimmer Chamber (b/w 1 st - 2 nd)	Skimmer Chamber (b/w 2 nd - 3 rd)	Interaction Chamber
Off	Off	3.98×10^{-08}	7.10×10^{-09}	3.00×10^{-09}	1.73×10^{-08}
On	Off	4.84×10^{-03}	5.60×10^{-06}	4.60×10^{-07}	2.13×10^{-08}
On	On	4.93×10^{-03}	5.60×10^{-06}	4.60×10^{-07}	2.16×10^{-08}

- More compact and flexible design for easier system integration.
- Optimization of gas jet density at interaction point to meet vacuum requirements.
- More experiments to identify gases with higher ionization cross-sections
- Upgrade to extraction system for enhanced detection limit.



More flexible design for nozzle skimmer assembly and tuning
Compact system: total length $\approx 1\text{m}$



- Proof-of-concept measurements were successfully completed.
- Supersonic gas jet ionization profile monitor has successfully demonstrated capability for 2D transverse beam profile measurements with beams close to the requirements for ion beam cancer therapy.
- Additional measurements were recently completed at the University of Birmingham with wider proton beams at lower intensities.
- The design will now be updated to improve the detection limit.

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