First proton beam measurements with gas jet in-vivo dosimeter for medical applications

Narender Kumar

Overview

Motivation and clinical benefits

Background and R&D

Measurements at UoB's Scanditronix MC40 cyclotron

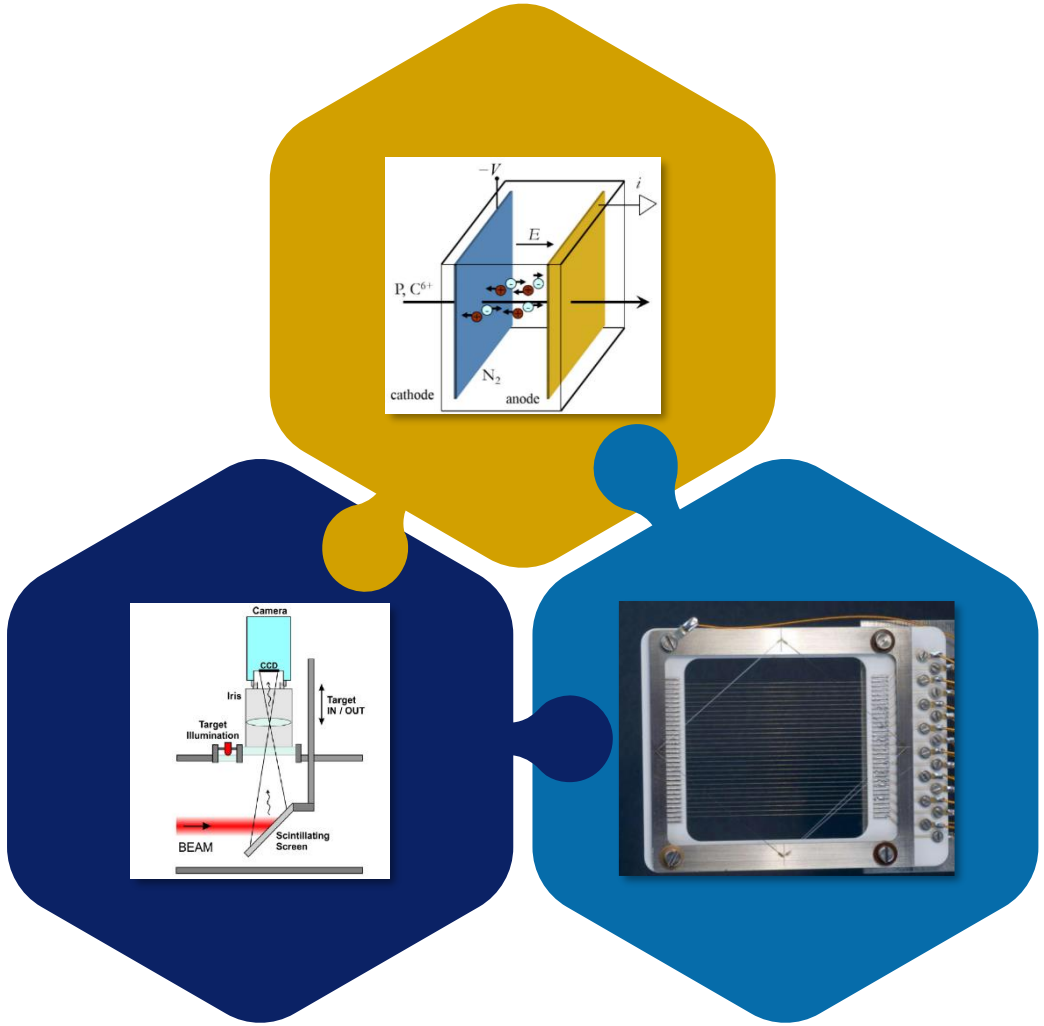
Hadron beam therapy

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

Existing diagnostics

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



B. Walasek-Höhne, GSI and G. Kube, DESY
S. Giordanengo & M. Donetti, arXiv:1803.00893

JetDose - Novel diagnostics solution

1

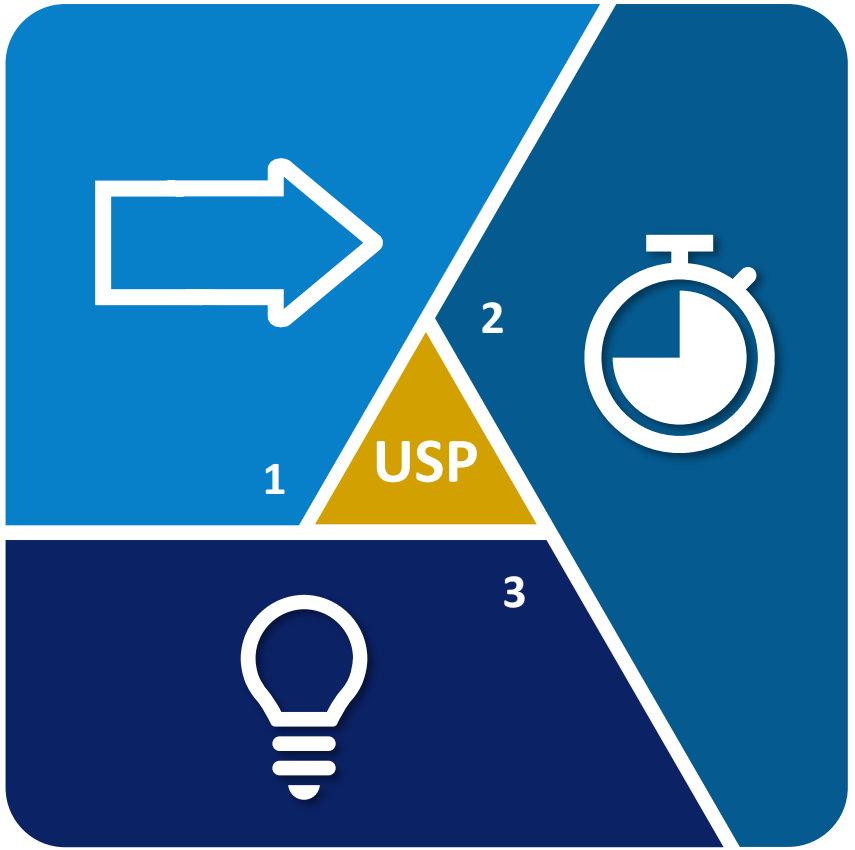
Minimally invasive

- ✓ 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

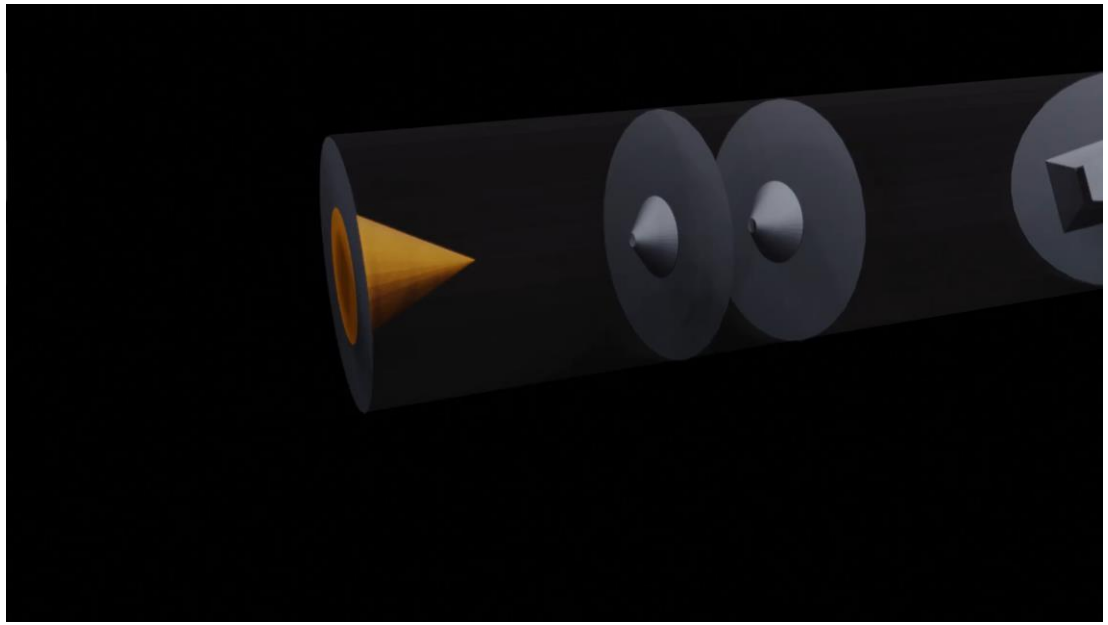
- ✓ No mechanical parts interact with the beam
- ✓ All key parameters monitored remotely
- ✓ Significantly reduced maintenance

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

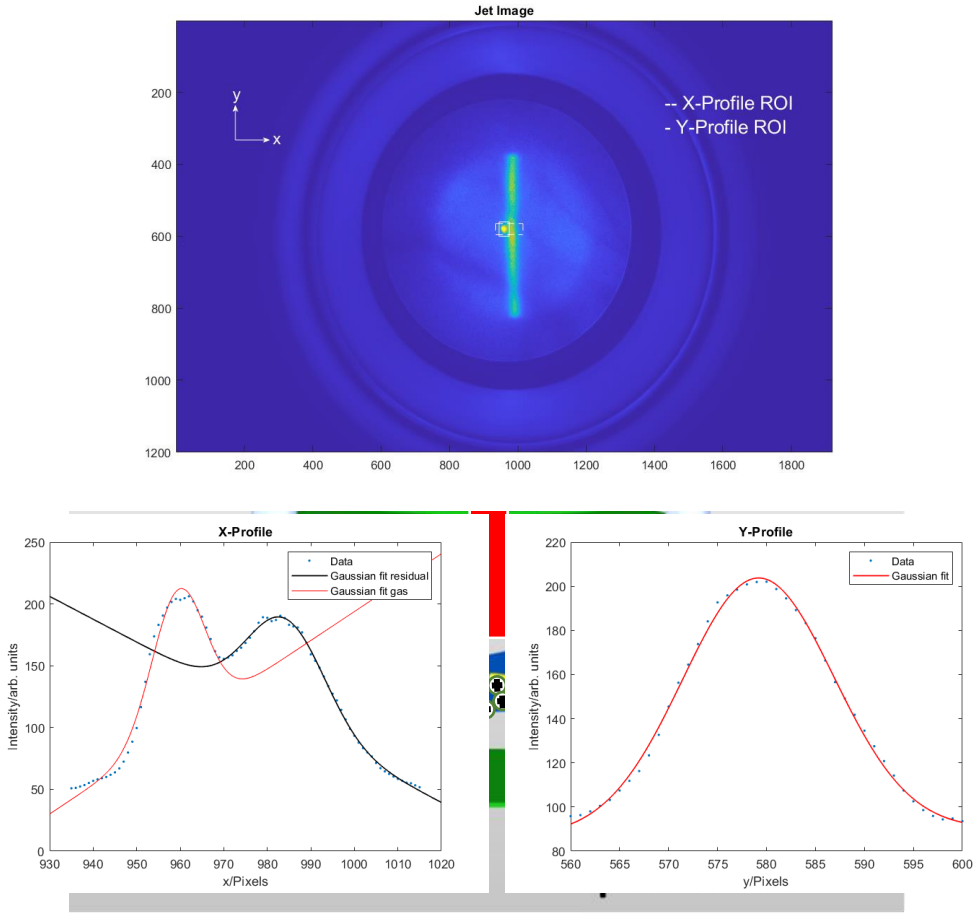
S. Jolly, C.P. Welsch, et al., *"Technical challenges for FLASH proton therapy"*, Phys Med 2020 – **Galileo Galilei Award, best paper in 2020**

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

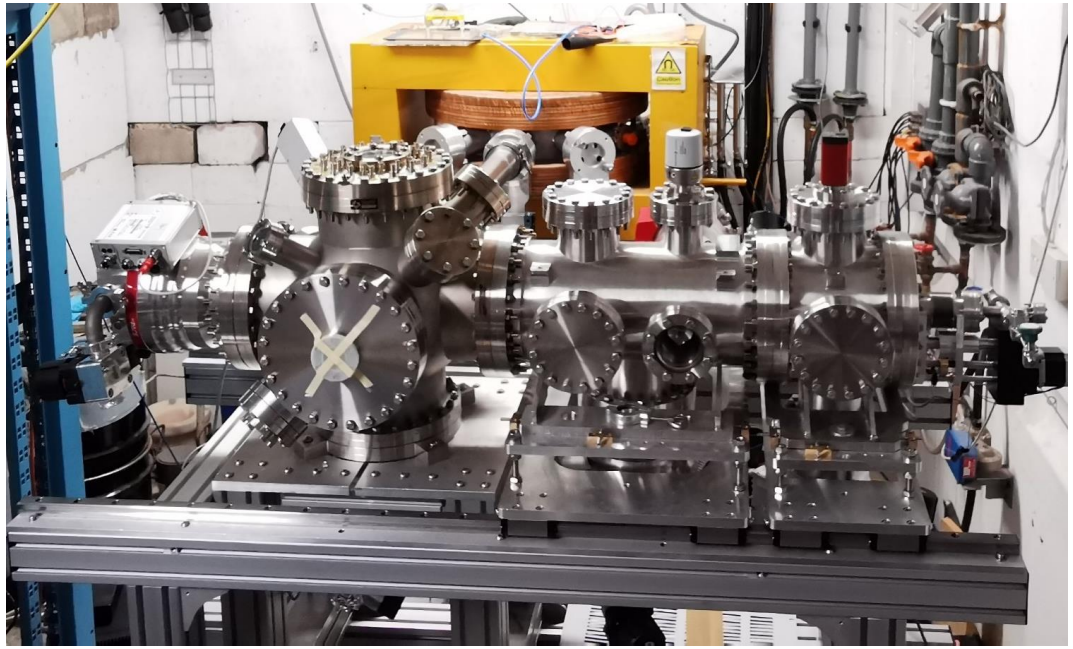
Building up on previous developments

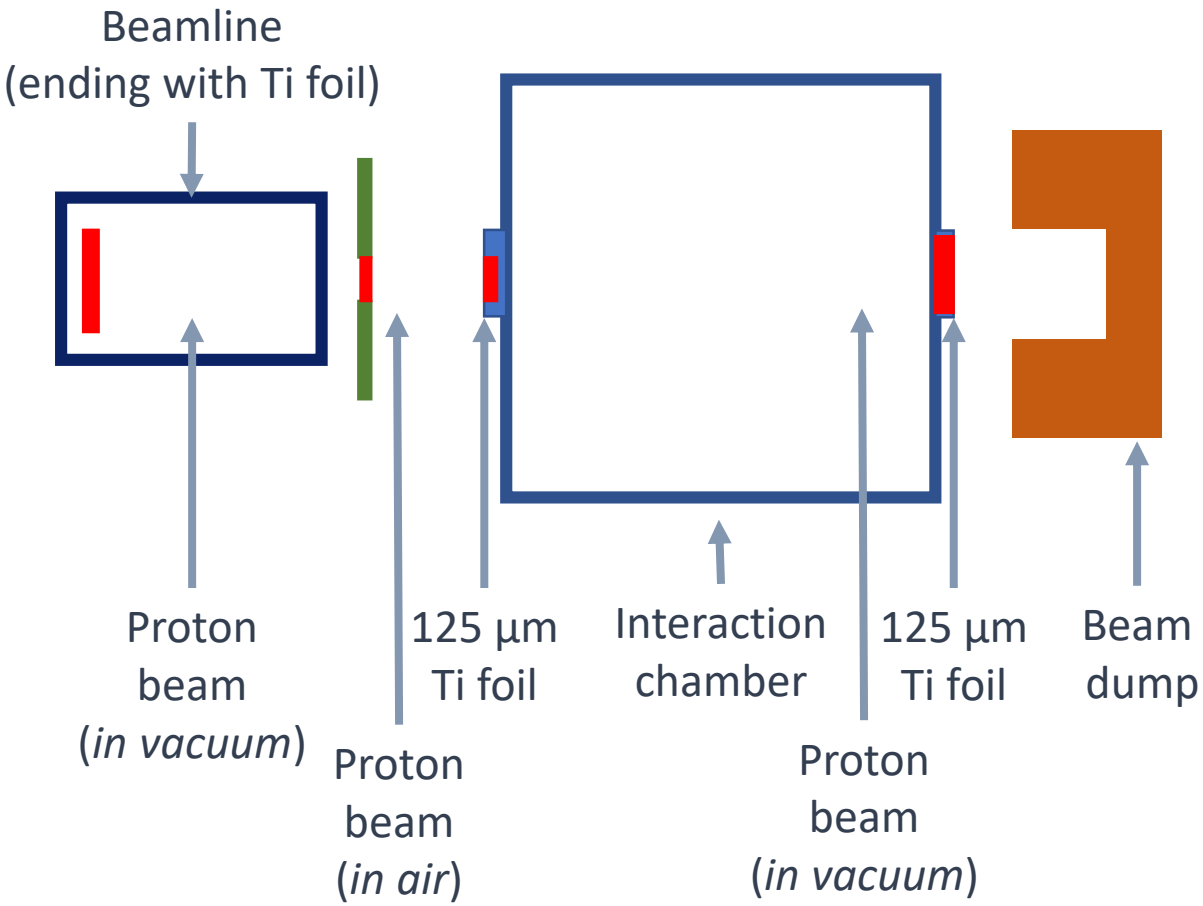


Gas jet shaping



Measurements with protons at UoB's Scanditronix MC40 cyclotron

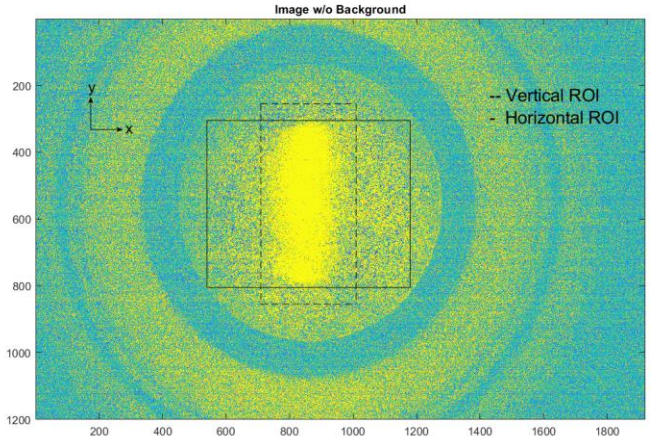


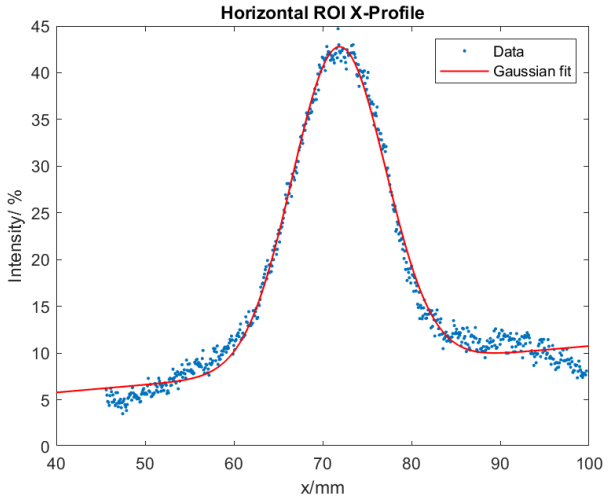


Beam Parameters

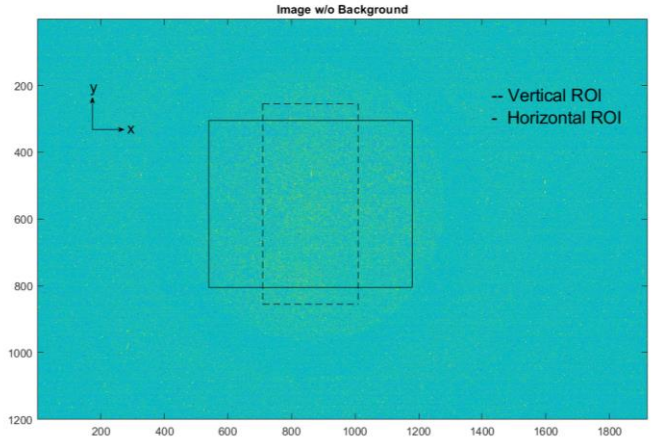
Beam Species:	***Protons***
Beam Energy:	***28 MeV***
Beam Current:	***150-750 nA (on FC1)***
Beam Collimator Area:	***4-100 mm²***

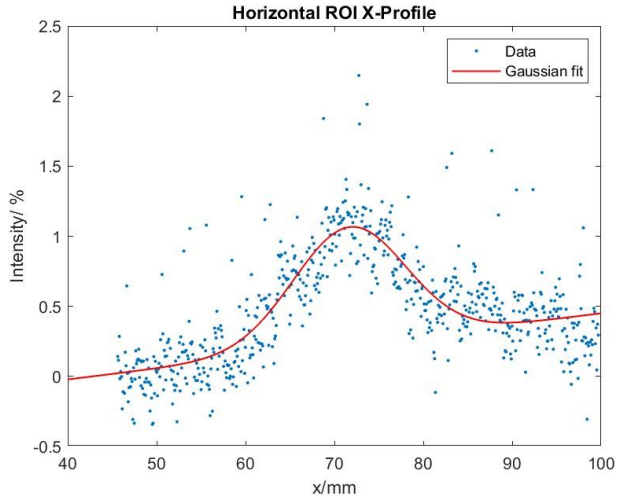
Measurements with protons at UoB's Scanditronix MC40 cyclotron





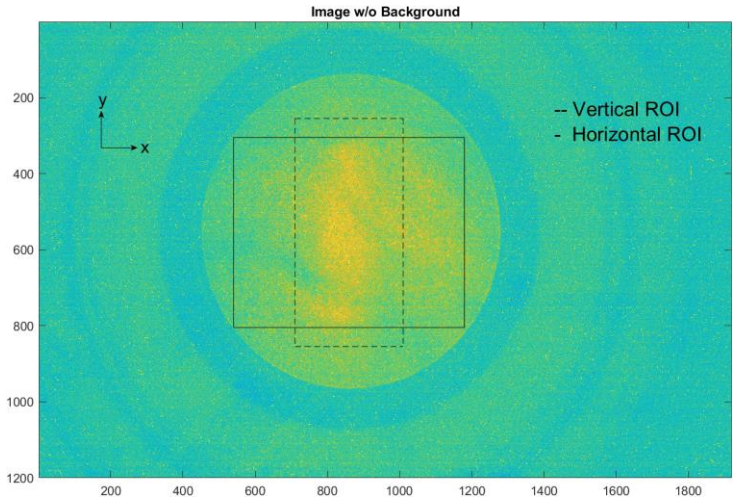
Beam collimator Area= 100 mm^2
Integration time = 1second
Gas Pressure in Interaction chamber = 1.2 $\times 10^{-5}$ mbar
σ = 5.4mm
Beam current at FC1= 150nA

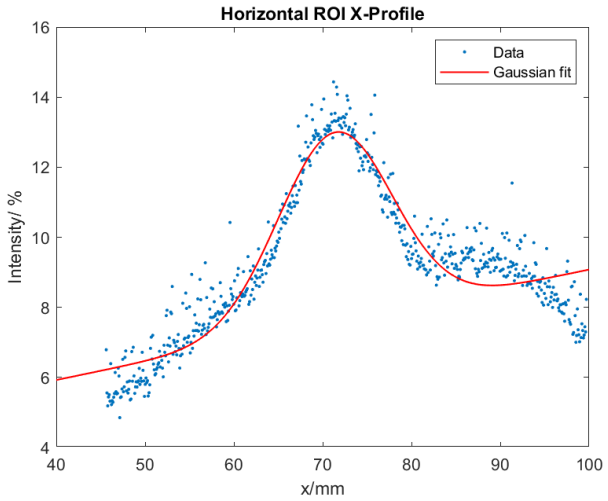




Beam collimator Area= 4 mm^2
Integration time = 20seconds
Gas Pressure in Interaction chamber = 1.2 $\times 10^{-5}$ mbar
σ = 6.4mm
Beam current at FC1= 150nA

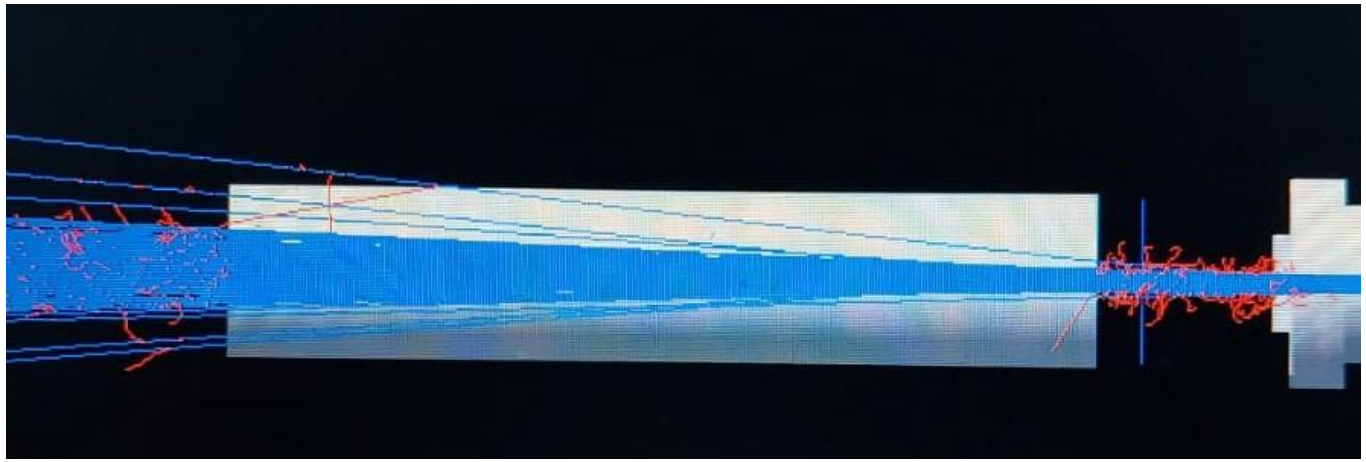
Measurements with protons at UoB's Scanditronix MC40 cyclotron

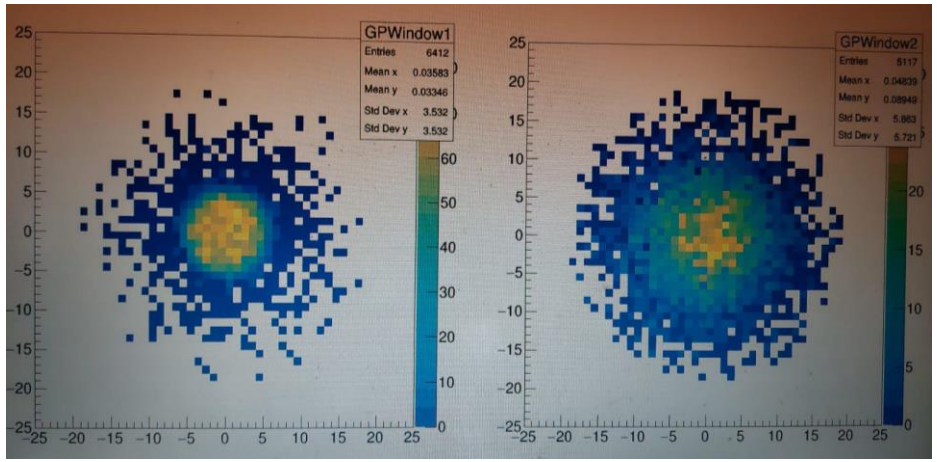




Beam collimator Area= 4 mm^2
Integration time = 20seconds
Gas Pressure in IC= 1.2 $\times 10^{-5}$ mbar
σ = 6.6mm
Beam current at FC1= 750nA

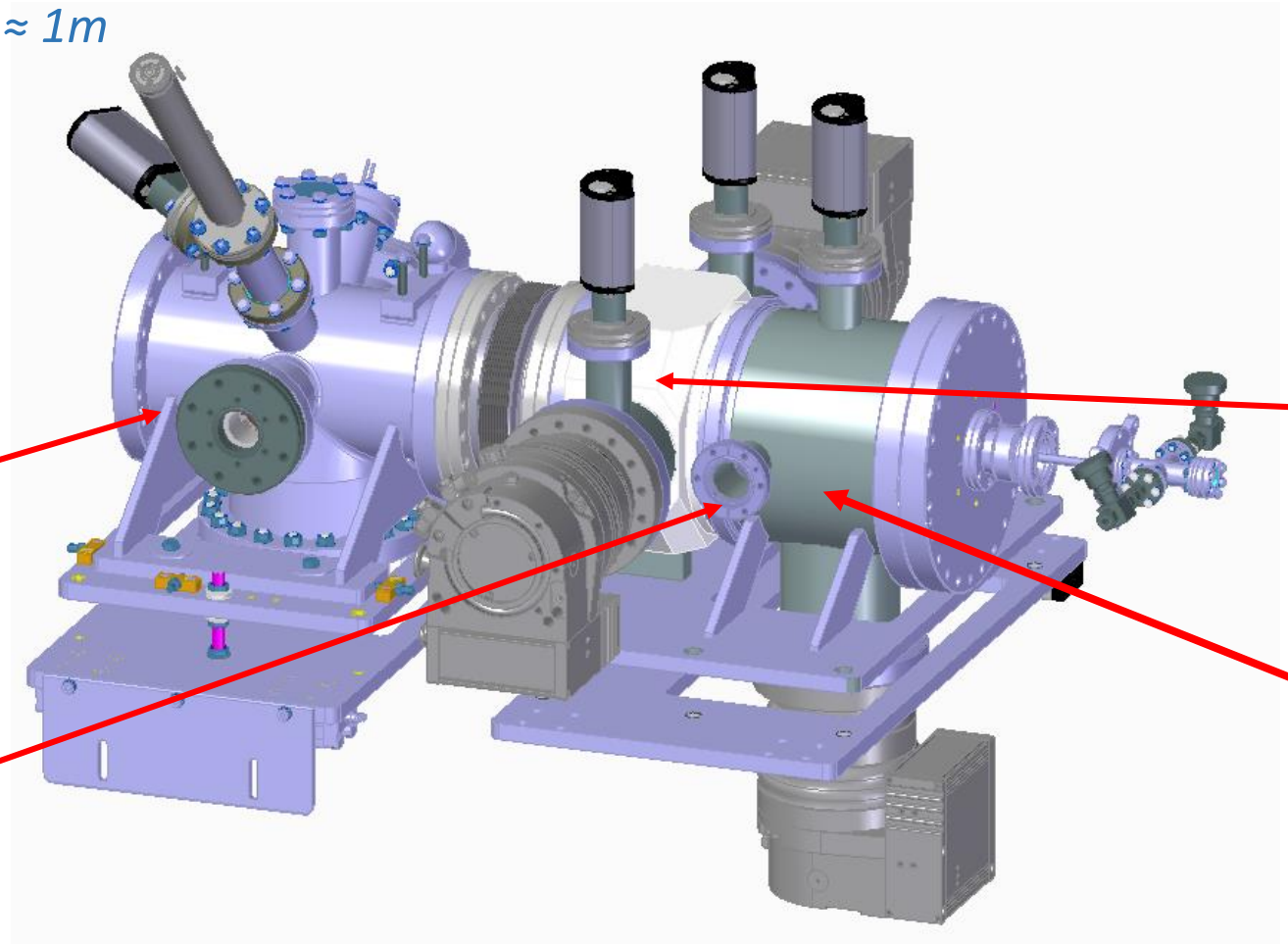
GEANT4 simulations





Updated design

More flexible design for nozzle skimmer assembly and tuning
Compact system: total length ≈ 1m



Summary

- First measurements were done with a proton beam. Good agreement was found with results from simulation.
- It was shown that 1 s integration time is sufficient for having a density equivalent to 10^{-5} mbar gas pressure.
- System integration is subject to optimization; considering direct coupling to existing system.
- R&D into increasing gas jet density at the interaction point is ongoing.

Thank you for your attention

Special thanks to

I. Maltusch, O. Stringer, J. Wolfenden, H. Zhang, T. Price, C.P. Welsch