Beam diagnostics for medical application

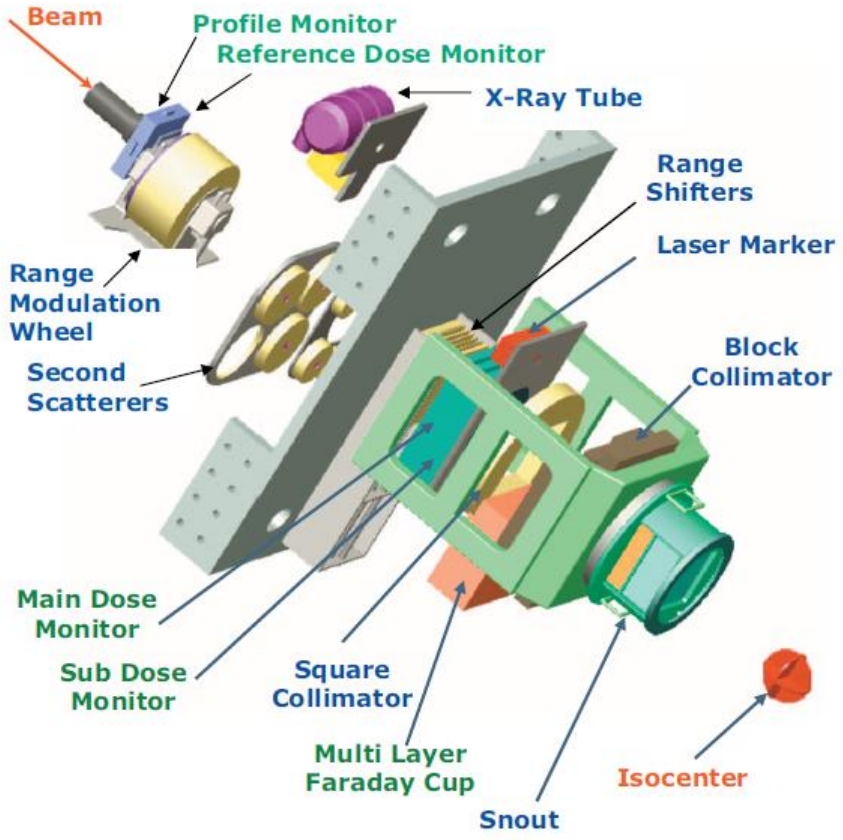
Hao Zhang

Diagnostics for proton beam overview

- Measure beam properties in an accelerator:
  - Current, position, profile, emittance, energy
- Treatment beam measurements:
  - Dose
  - Dose profile

Deliver the prescribed amount of dose to the target location!!

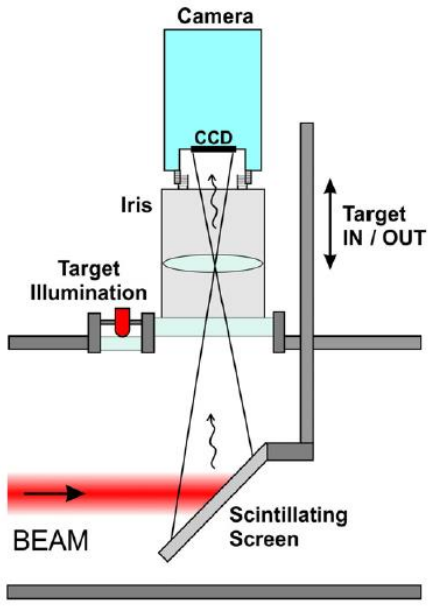
Beam monitors type and position in M.D. Anderson proton beam nozzle



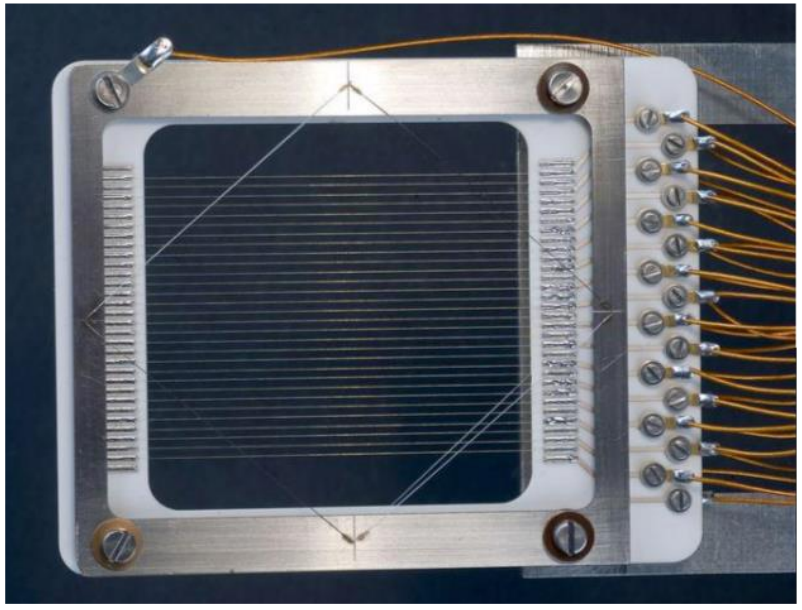
*A. Smith et. al. Med. Phys. 36, 2009

Interceptive diagnostics

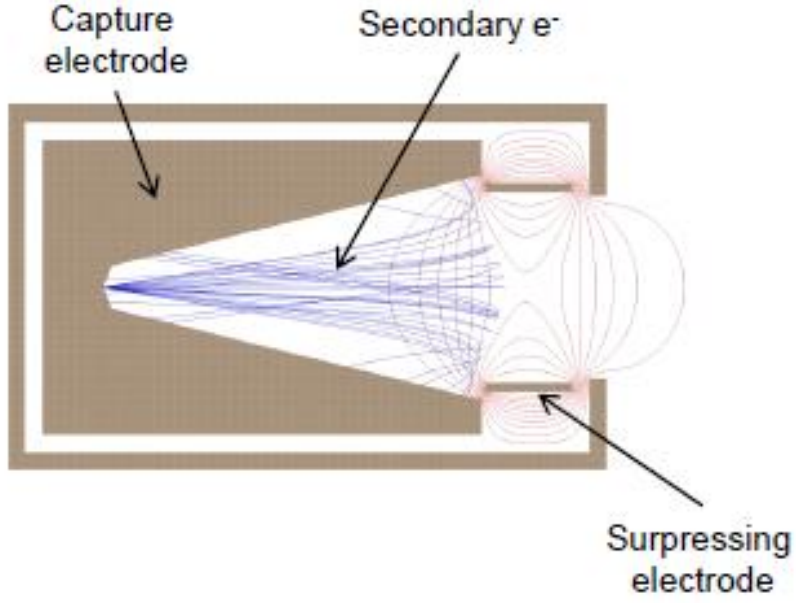
- Scintillating screen



- SEM Grid



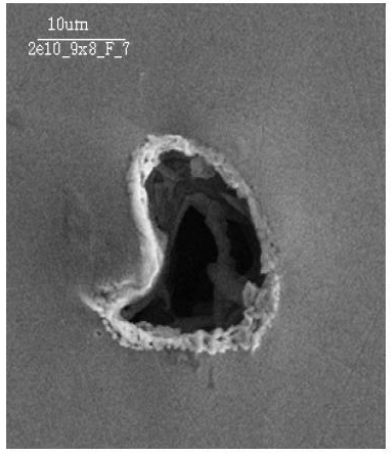
- Faraday cup

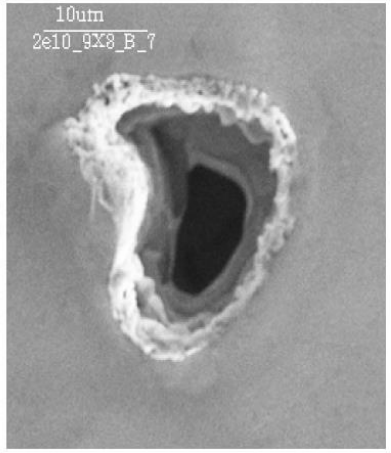


Credit: B. Walasek-Höhne, GSI and G. Kube, DESY

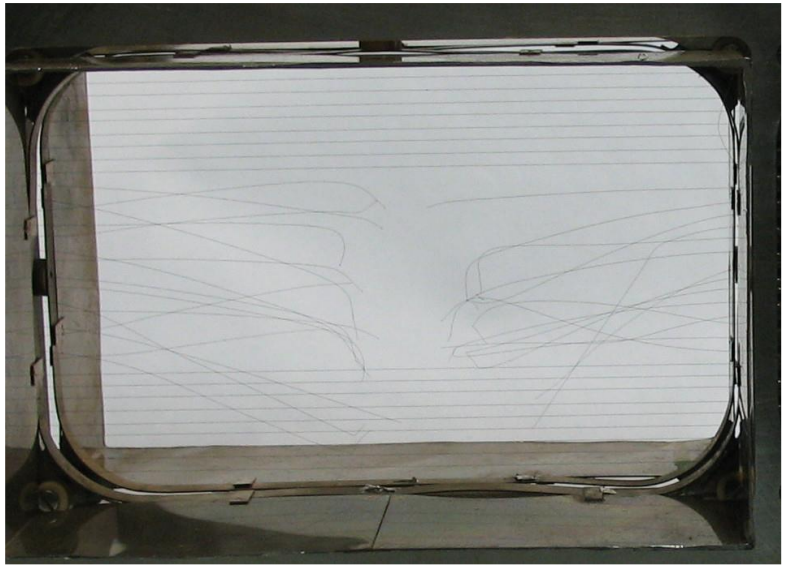
Beam profile of high intensity beams

- Energy deposition
  - Signals are often proportional to the deposited energy
  - Energy deposition can cause damage to the instrument





Damaged screen

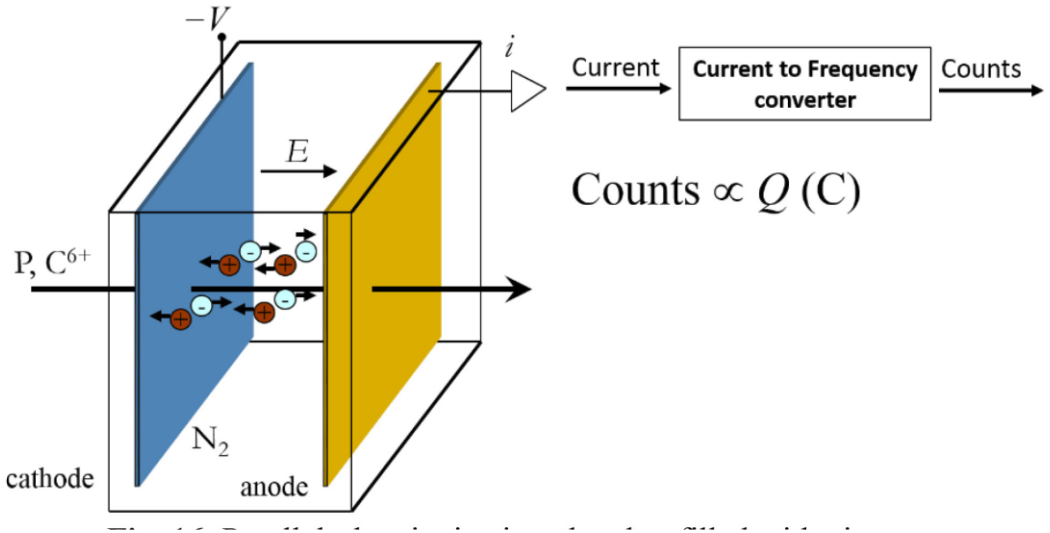


Damaged SEM Grid

- Ideally: Non-invasive.

Hao Zhang (haozhang@liverpool.ac.uk)

Ionisation chambers



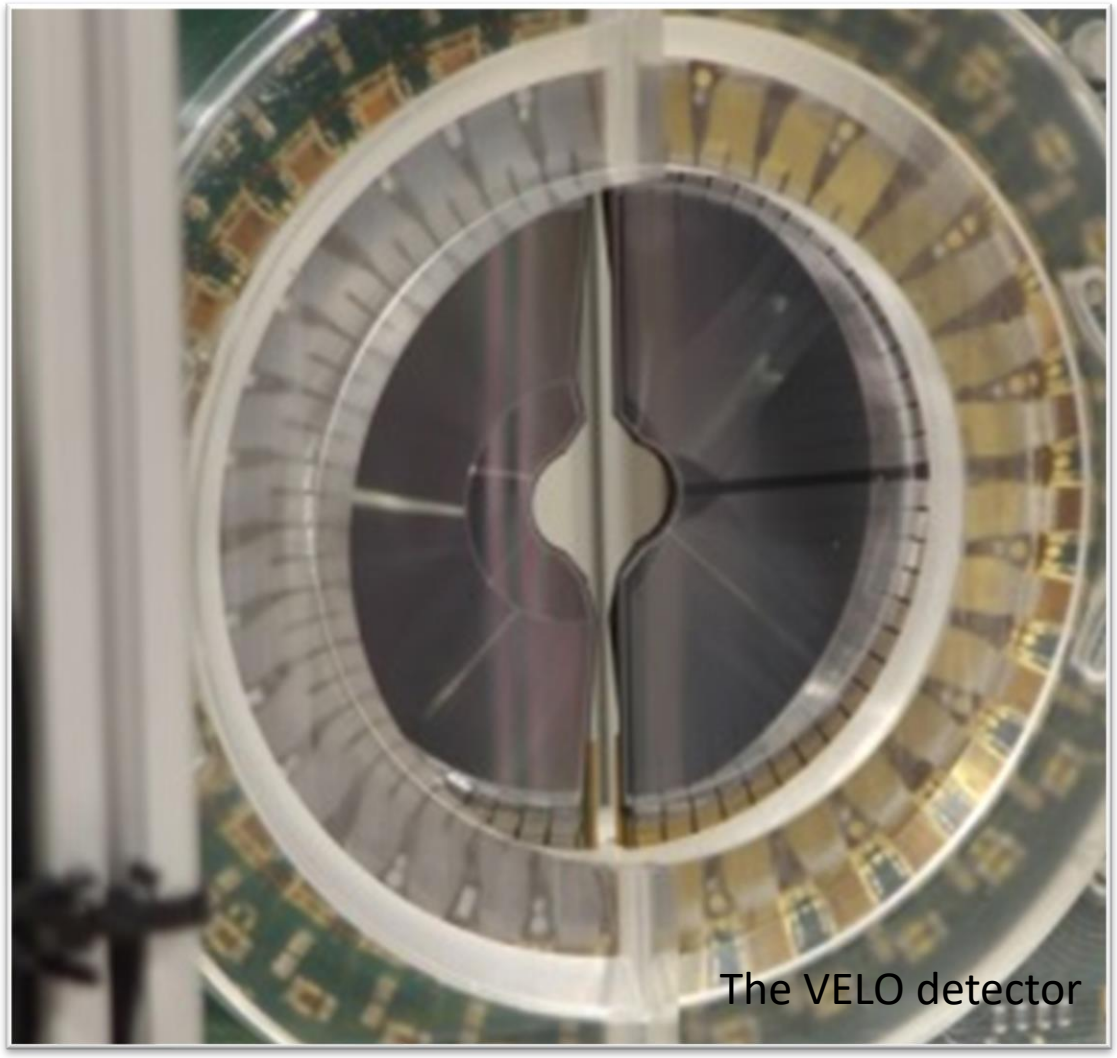
*S. Giordanengo & M. Donetti, arXiv:1803.00893

Still the Golden standard for online dose monitor!

- Advantages:
  - Robustness
  - Uniformity
  - Easiness of operation
  - Minimal perturbation
- IC array
  - Dose distribution
  - Spatial resolution is not great (5-8mm)
- Multi layers IC
  - Check the beam range, energy, and stability

Medical Diagnostics development in CI

VErtex LOcator (VELO)



The VELO detector

	VELO detector	
Silicon technology	$n^+ - in - n$	
Number of readout channels	2048	
Thickness of sensor	300 μm	
Number of regions	R: 4	Φ: 2

Provides r and ϕ-coordinates in the **polar coordinate** system.

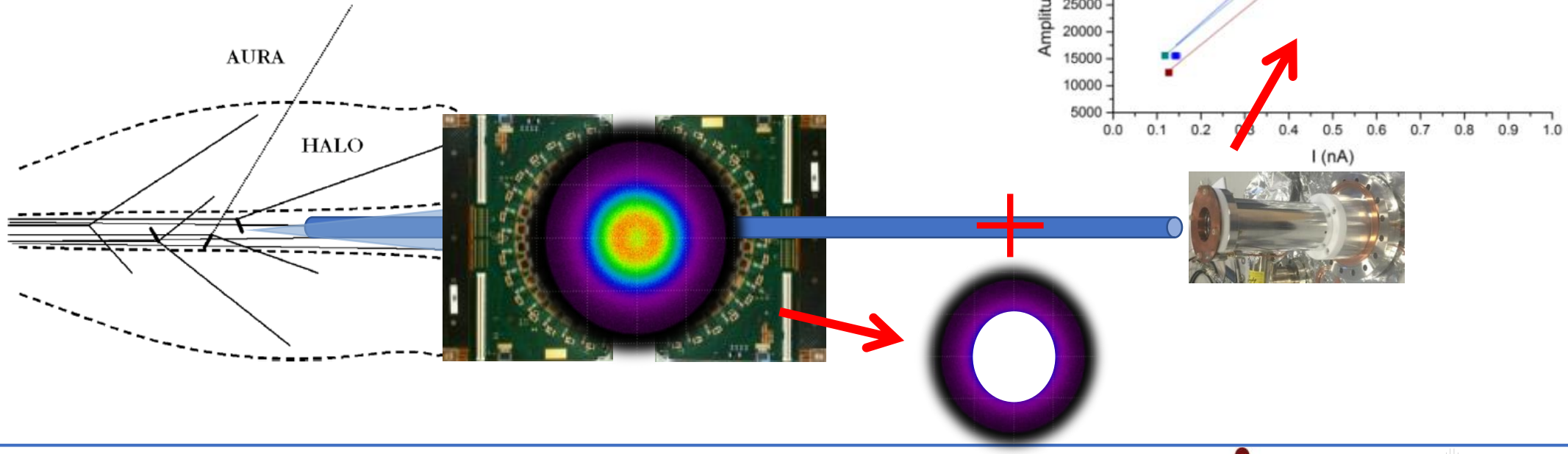
Approaching the core of the beam without interfering with it.

➲Precise measurement of the **beam halo**

VELO Detector as online dose monitor

The halo of the proton beam is generated from scattering components.

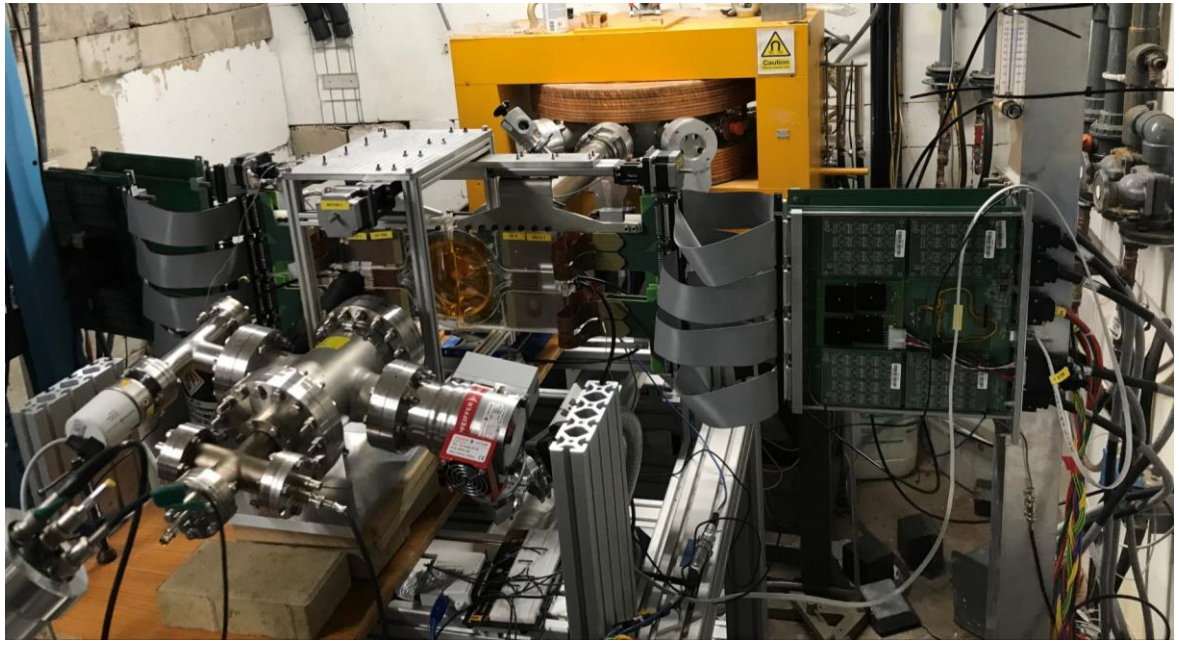
- Halo measurement for **beam monitoring**
  - Correlation to dose delivery and beam profile



Experiments in CCC and Birmingham

Clatterbridge Cancer Centre

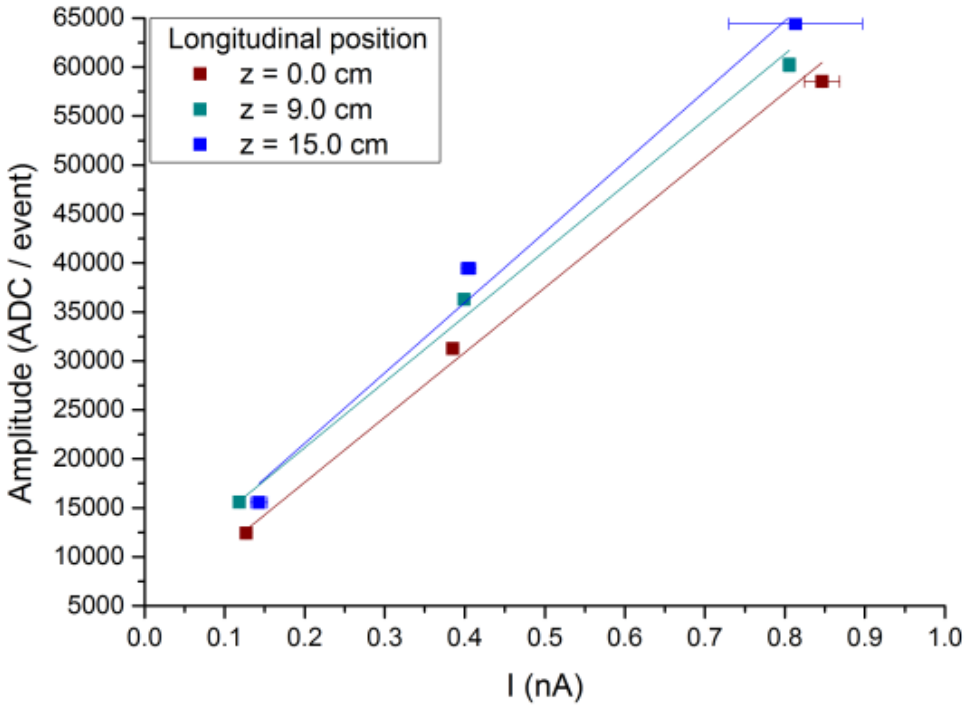
60-MeV clinical proton beam



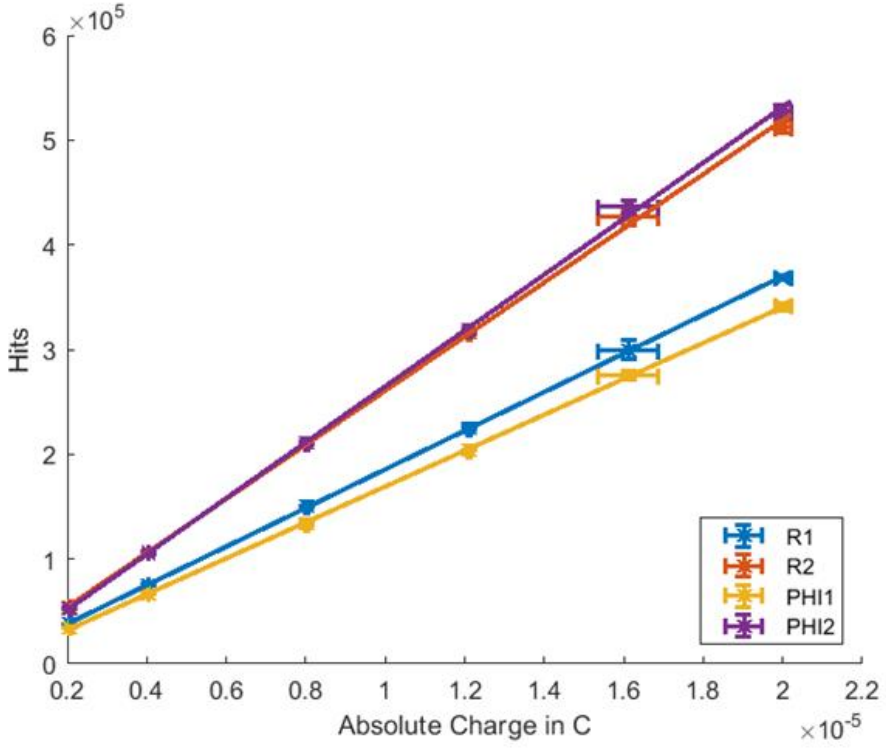
Birmingham proton beamline

MC40, 35 MeV cyclotron

Results: Linear correlation with charge



Measurement at CCC

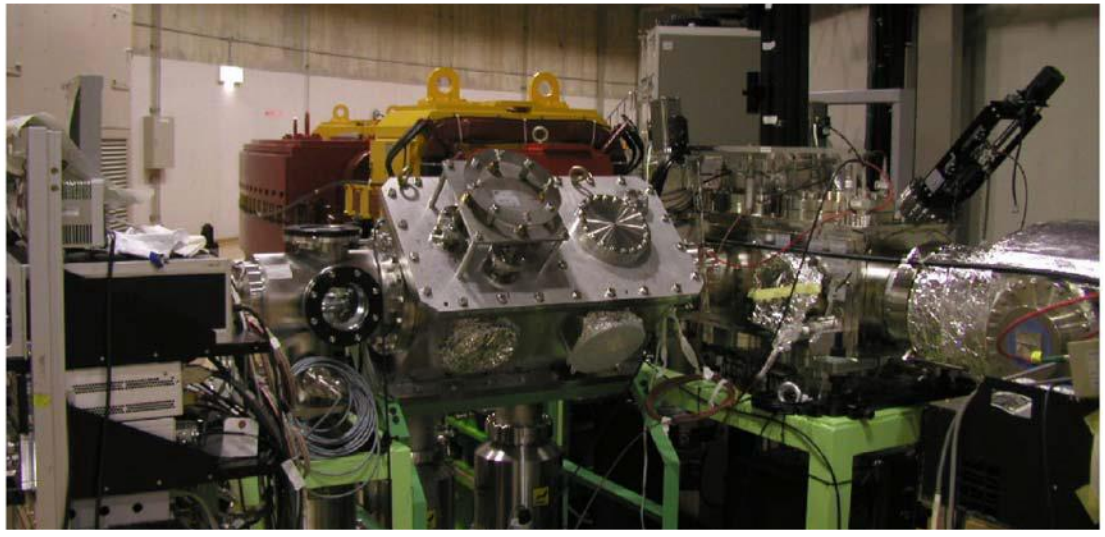


Measurement at Birmingham proton beam line

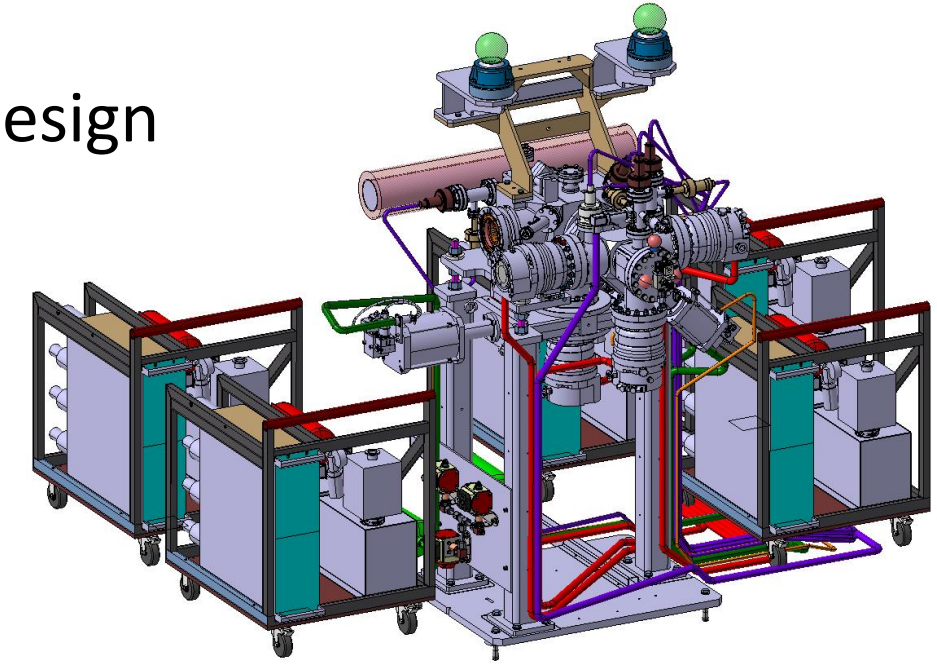
Current R&D

Gas jet monitor

- Non-invasive or minimum invasive method
- Not only counting Ions or electrons generated but measuring the 2d distribution
- Research efforts are focusing on compact design

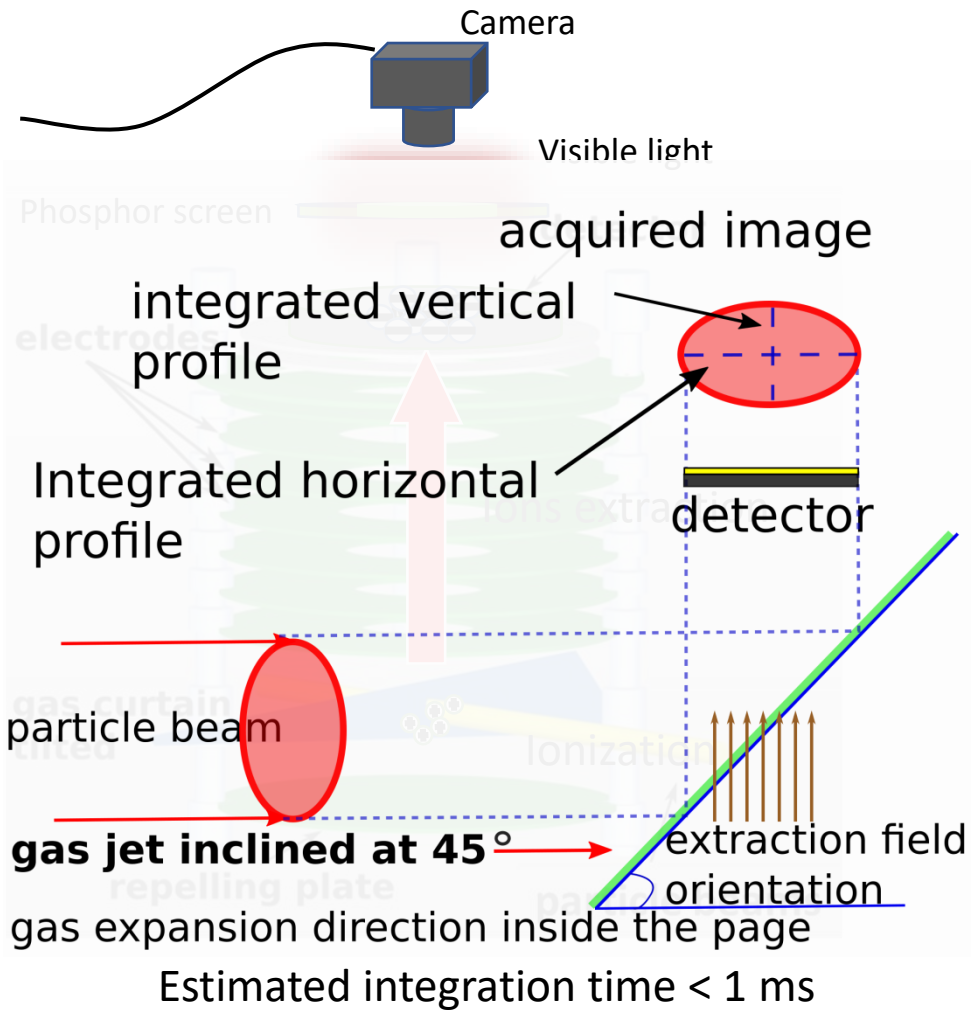


Gas jet monitor installed in the HIMAC synchrotron



Gas jet monitor designed and installed for LHC proton beam

Gas jet monitor

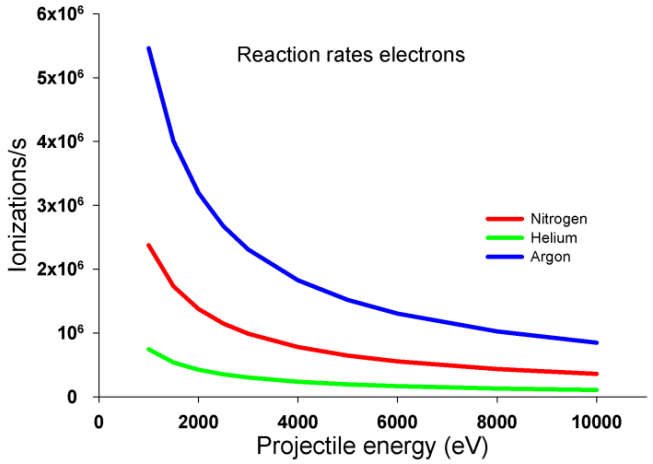


Estimated integration time < 1 ms

- Estimated jet property

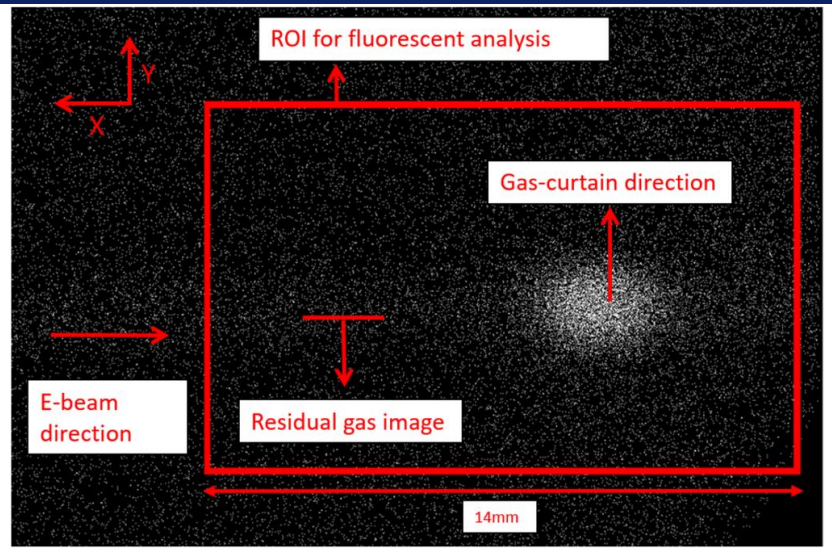
Parameter	Value
Density	1e-6 mbar or $2.5*10^{16}$ particle/m^3
Background pressure	<1e-8 mbar
Thickness	0.5 mm
Vertical size	5 mm

- Reaction rate

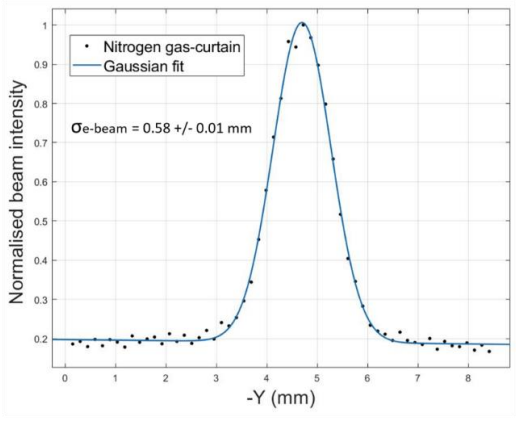


Hao Zhang (haozhang@liverpool.ac.uk)

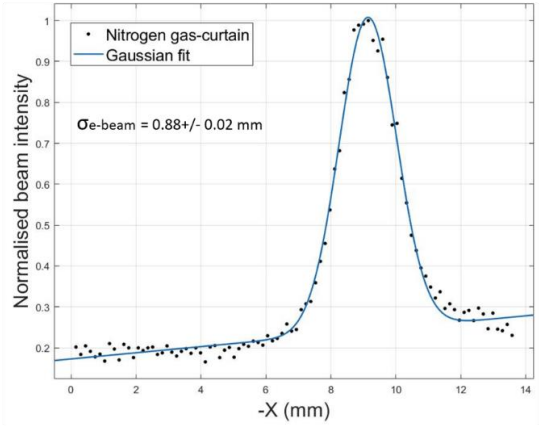
Typical 2D transverse profile



(a)



(b)



(c)

Online Dose 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

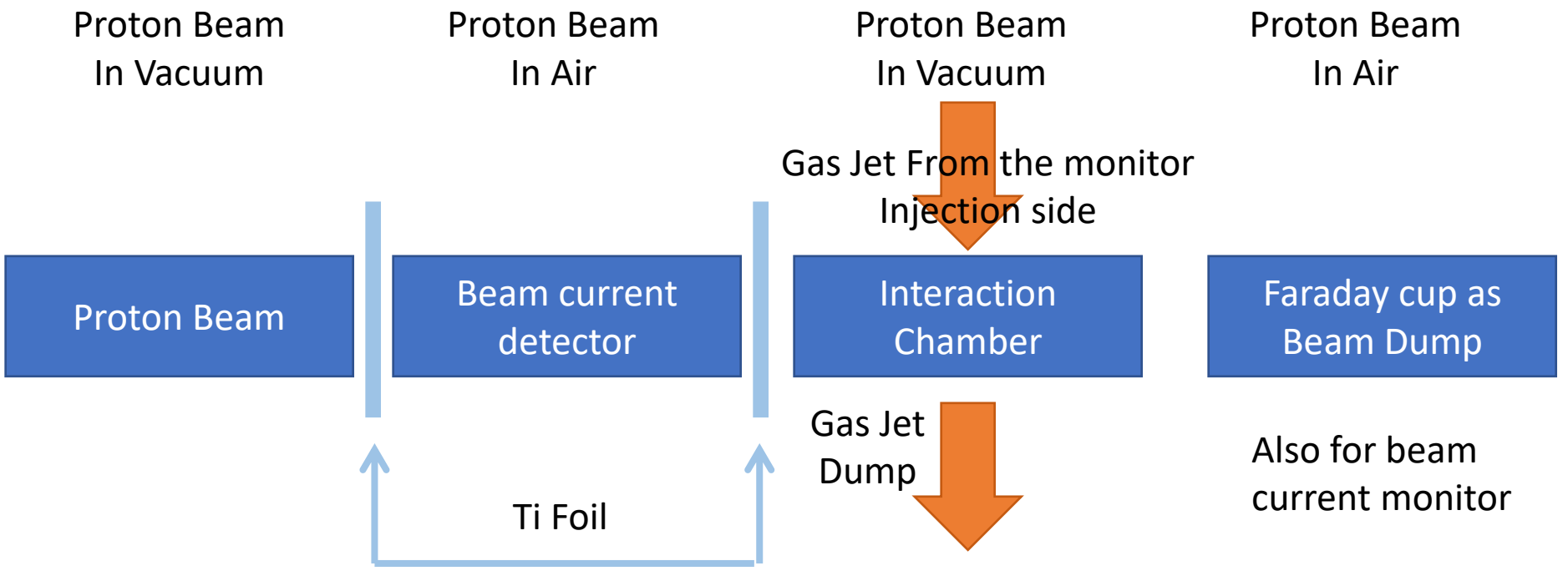
1. ***Gas Jet Injection system***
2. ***Interaction Chamber***
3. ***Imaging system***
4. ***Gas dump section***

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

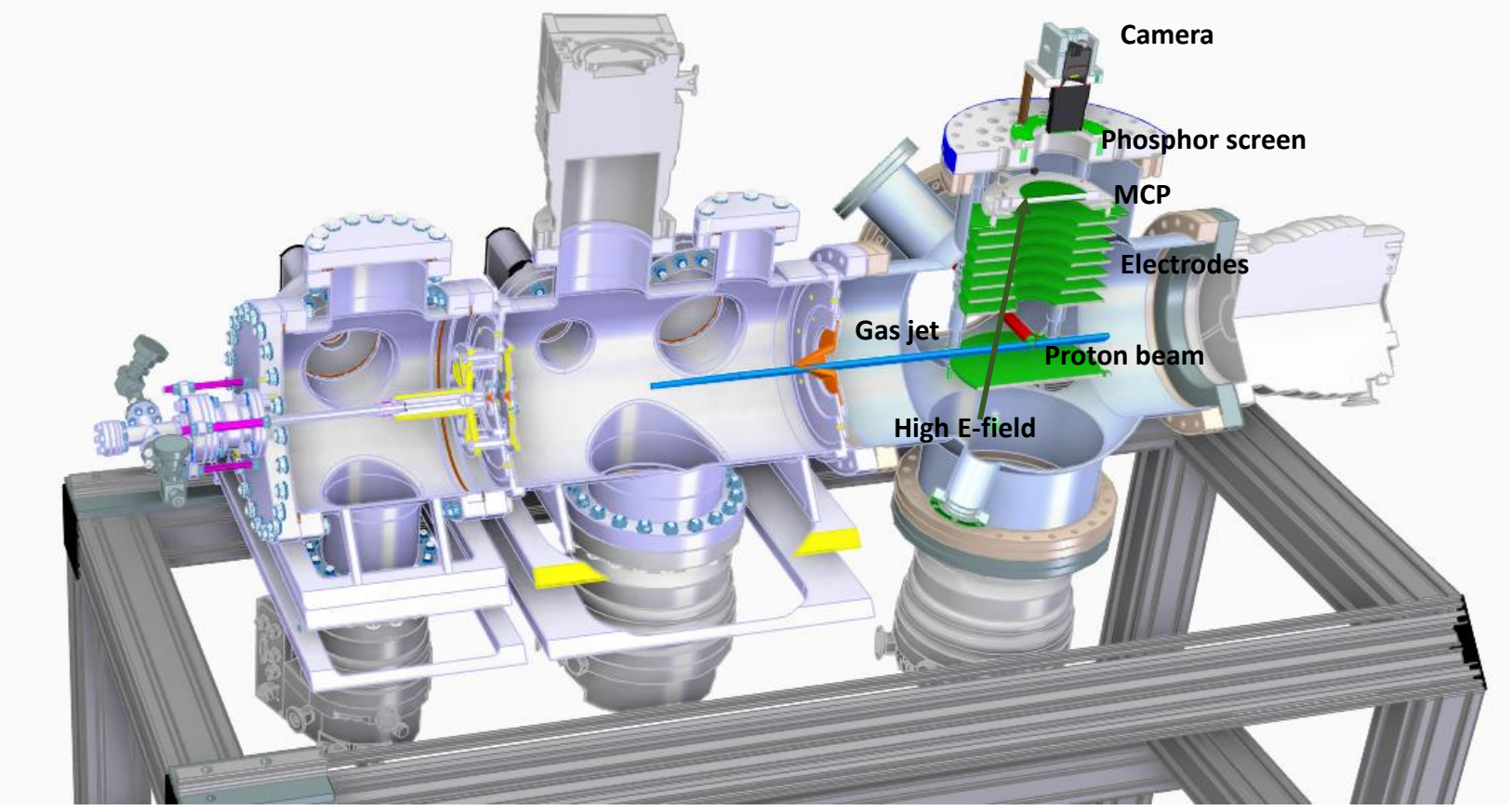
The system will be installed in one of the beam lines of Cyclotron facility at UoB with various beam energies, shapes and currents.

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

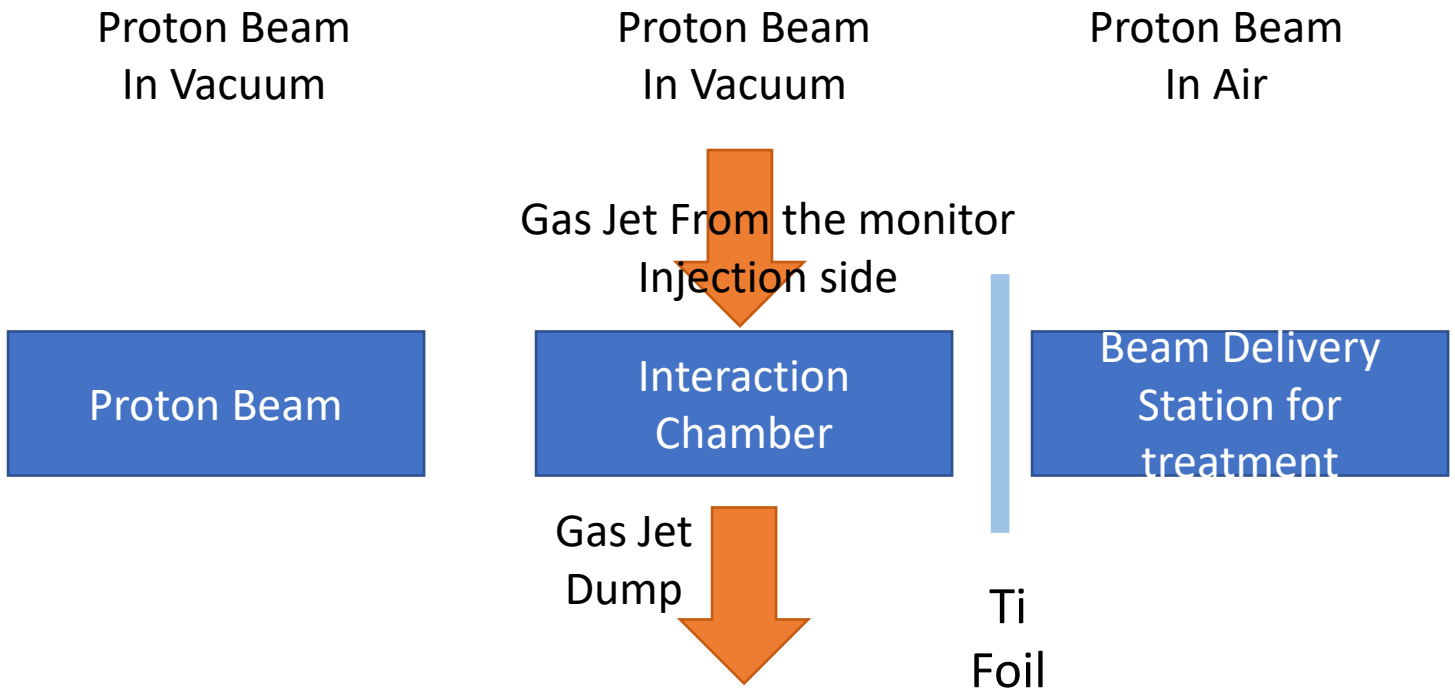
Scheme for PoC measurements at UoB



Proposed Birmingham proton beam experiment



Alternative scheme at a treatment centre



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

OMA network

- Optimization of Medical Accelerators
- Funding for 15 Fellows, start Feb 2016
- One of the largest Marie Curie networks in this call with a budget of around 4 M€
- Gives industry an important role in training the next generation of scientists !
- Allows for organizing (large) number of events.
- Recognized importance of R&D at interface between physics and life sciences at European level !

Beneficiaries, Partner Organizations and more

Research focus and events

- OMA pushed developments across its three R&D work packages beyond state of the art
  - Improved diagnostics
  - Enhanced simulation codes
  - Enhanced facility design
- OMA has organized a large number of events for its Fellows and the wider community
  - Schools on Medical Accelerators
  - Topical workshops across the scientific WPs
  - Conference, Symposium and many outreach events
- All of this information is available via the project website www.oma-project.eu

Summary

- Beam diagnostics for Medical proton beam or heavy ion beam is a fast developing area.
- Many current accelerator diagnostics could be used in this field.
- Online diagnostics with minimum-invasive method will be required.
- Communication between accelerator physicist, medical physicist and industrial partners will strengthen the development.

Thank you for listening!

UNIVERSITY OF LIVERPOOL

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Hao Zhang (haozhang@liverpool.ac.uk)