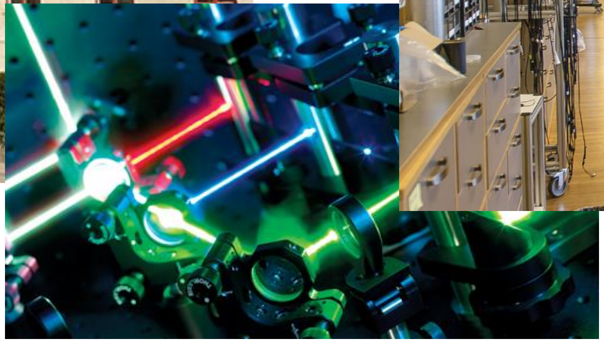
Meet the Danes

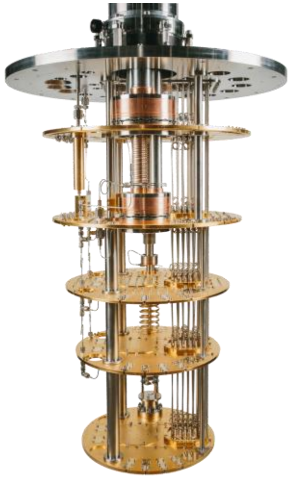
Robert Garbrecht Larsen

30 May 2024

Min baggrund

- **2018 – 2021: Bachelor i fysik ved KU (NBI) – projekt inden for kvanteoptik**
- **2021 – 2023: Kandidat i fysik ved KU (NBI) – projekt inden for kvante Hall effekt**
- **2022: CERN summer student – projekt om strålinghårde fibre**
- **2023 – 2026* Phd-studerende ved CERN(CERN doctoral programme)**





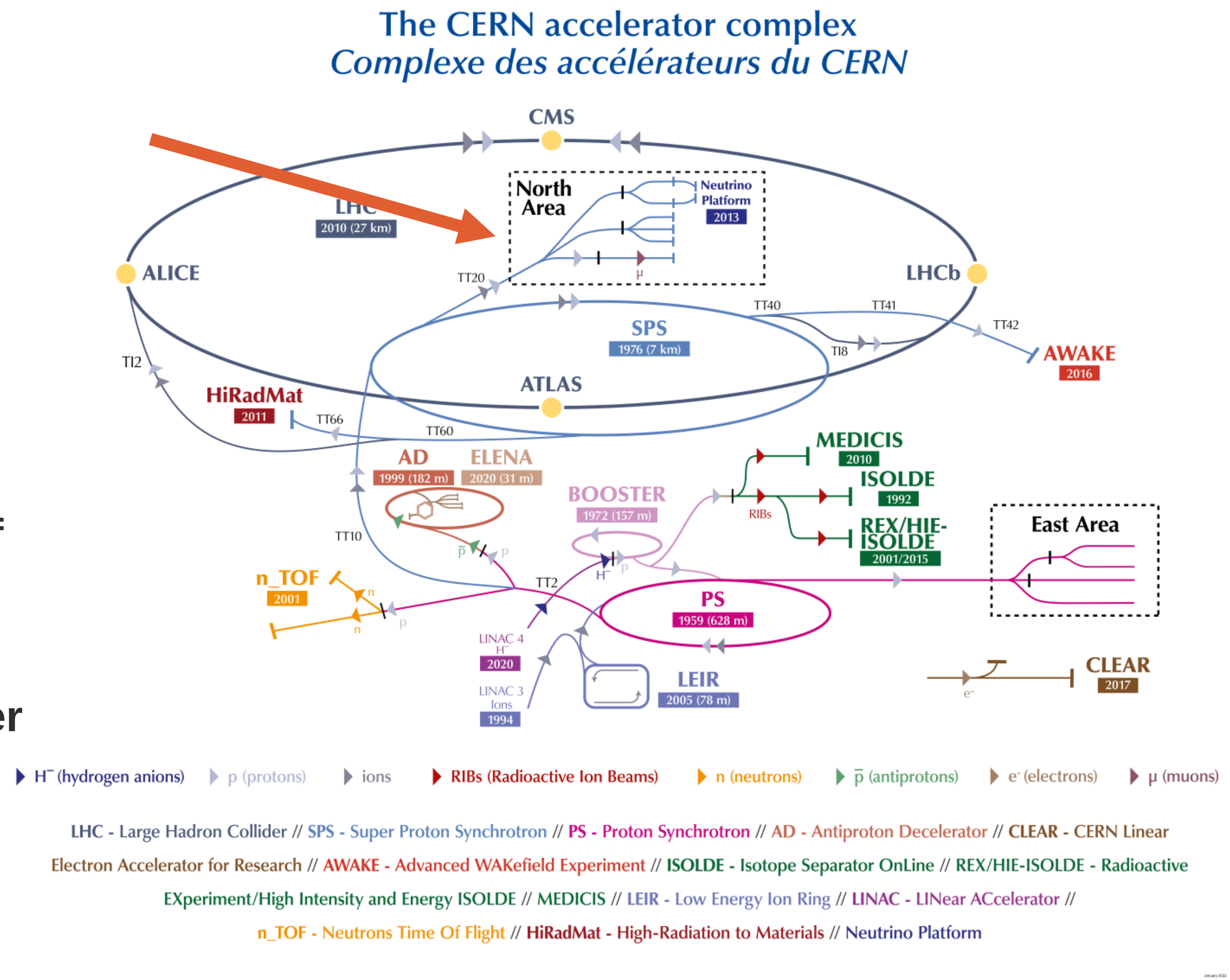
*planlagt

Mit projekt

Udvikling af ny instrumentering til brug i CERNs ”North Area”, særligt til linjer med høj strålingsdosis.

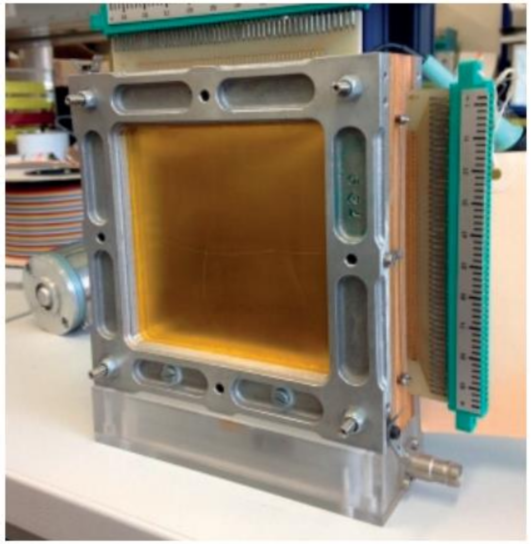
Skal måle profilen (størrelsen) af partikelstrålerne.

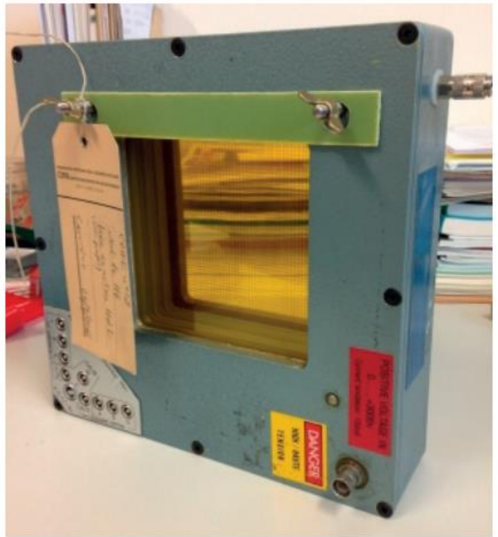
Har også anvendelsesmuligheder inden for FLASH terapi.



Beam Instrumentation in the North Experimental Area

- **There are different devices that measure the beam profile and intensity of secondary beams**
  - Scintillator paddles
  - Multi-Wire Proportional Chambers (MWPC) (1.1 bar 50% Argon 50% CO_2)
  - Delay Wire Chambers (DWC) - another type of wire chamber
  - Filament Scintillators (FISC)
- **Many of them are as old as the North Area**
- **Expertise is lost and they are difficult to maintain**
- **It’s time to upgrade! – Large North Area consolidation program on-going (2021 - 2035)**





North Area radiation-hard beam profile monitor R&D status update

Robert Garbrecht Larsen

24 May 2024

Contents

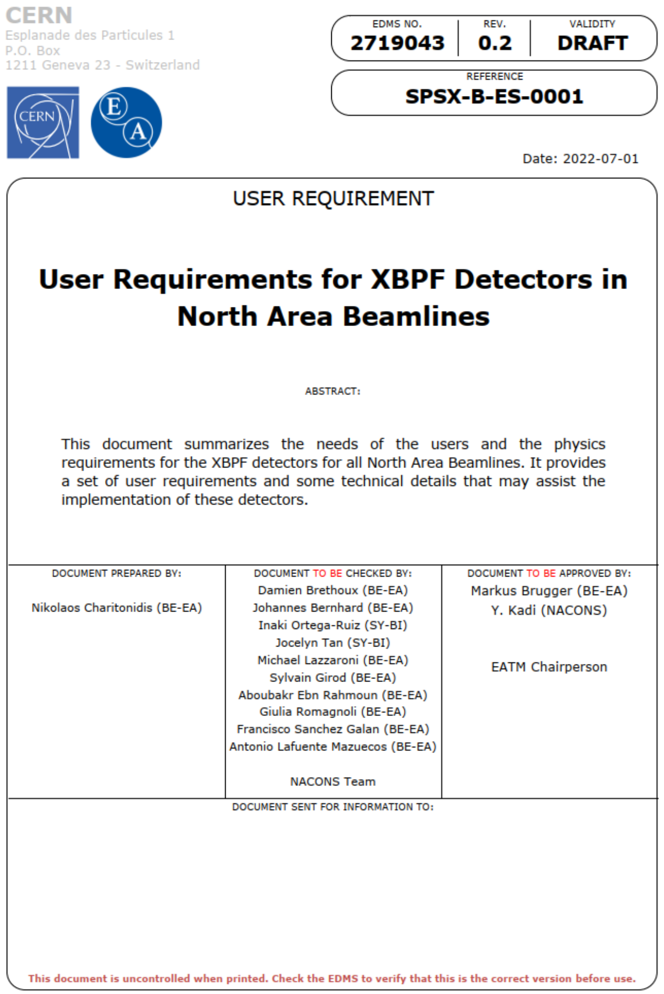
- **Motivation**

- **Previous work**
  - Liquid scintillator filled capillaries
  - Silica glass rods

- **Current work:**
  - Hollow core fibers
  - Straw detectors

New Radiation Hard Profile Monitor Requirements and Timeline

- For installation in M2 and K12 beamlines (20 monitors)
- Active area of **20 cm x 20 cm**
- A low as possible material budget **< 0.3% X0**
- A spatial resolution between 6 mm (current) and 1mm.
- Measure particle rates from **~10^5 Hz to ~10^{11} Hz** in the full energy range of 0.5 – 450 GeV/c
- Operational up to a minimum of 10 years of operation
- Operational in vacuum (10^{-3} mbar) and in air
- Possibility of in/out motorisation
- Installation of prototype during LS3 (2028)



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Date: 2022-07-01

USER REQUIREMENT

User Requirements for XBPF Detectors in North Area Beamlines

ABSTRACT:

This document summarizes the needs of the users and the physics requirements for the XBPF detectors for all North Area Beamlines. It provides a set of user requirements and some technical details that may assist the implementation of these detectors.

DOCUMENT PREPARED BY:	DOCUMENT TO BE CHECKED BY:	DOCUMENT TO BE APPROVED BY:
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DOCUMENT SENT FOR INFORMATION TO:

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Initial idea: radiation hard (or easily replaceable) fibers

- **Scintillation based:**
  - Organic scintillators
  - Inorganic scintillators
  - Liquid scintillators

- **Cherenkov based:**
  - Simple commercial fibres
  - Silica glass rods

Initial idea: radiation hard (or easily replaceable) fibers

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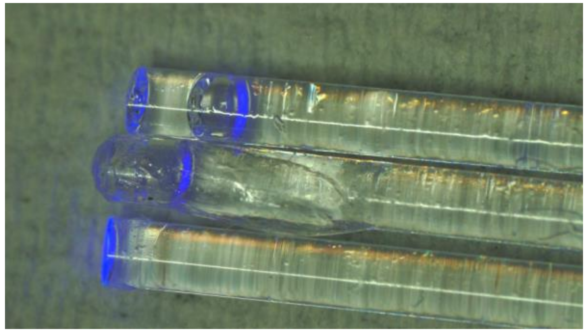
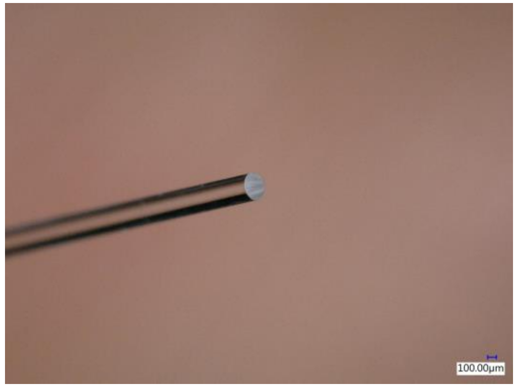
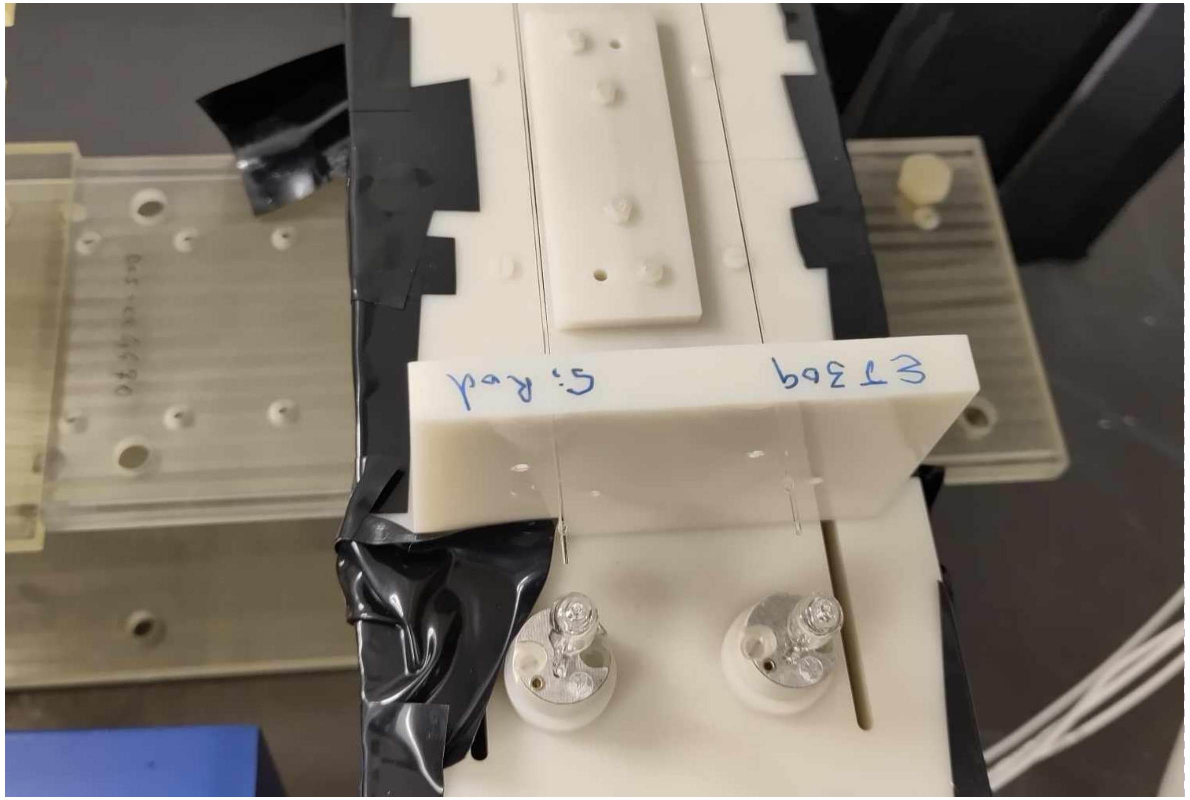




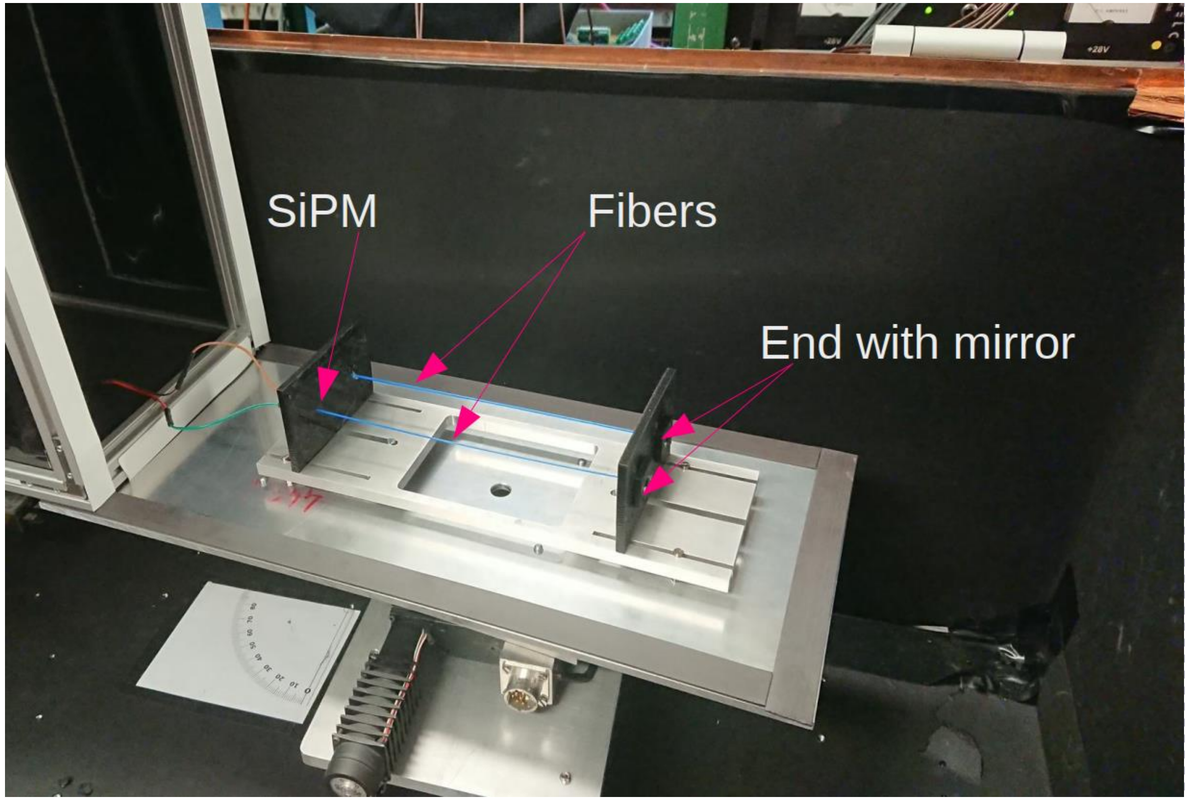
Pros	Cons
Could reuse XBPF motorization solution easily.	Will need radiation hard photosensors or transport fibers.
Easy to meet resolution requirements.	Difficult to satisfy entire dynamic range.
	Fragile
	Time consuming to produce
	Liquid scintillator (EJ-309) is toxic

Single fiber tests

IRRAD

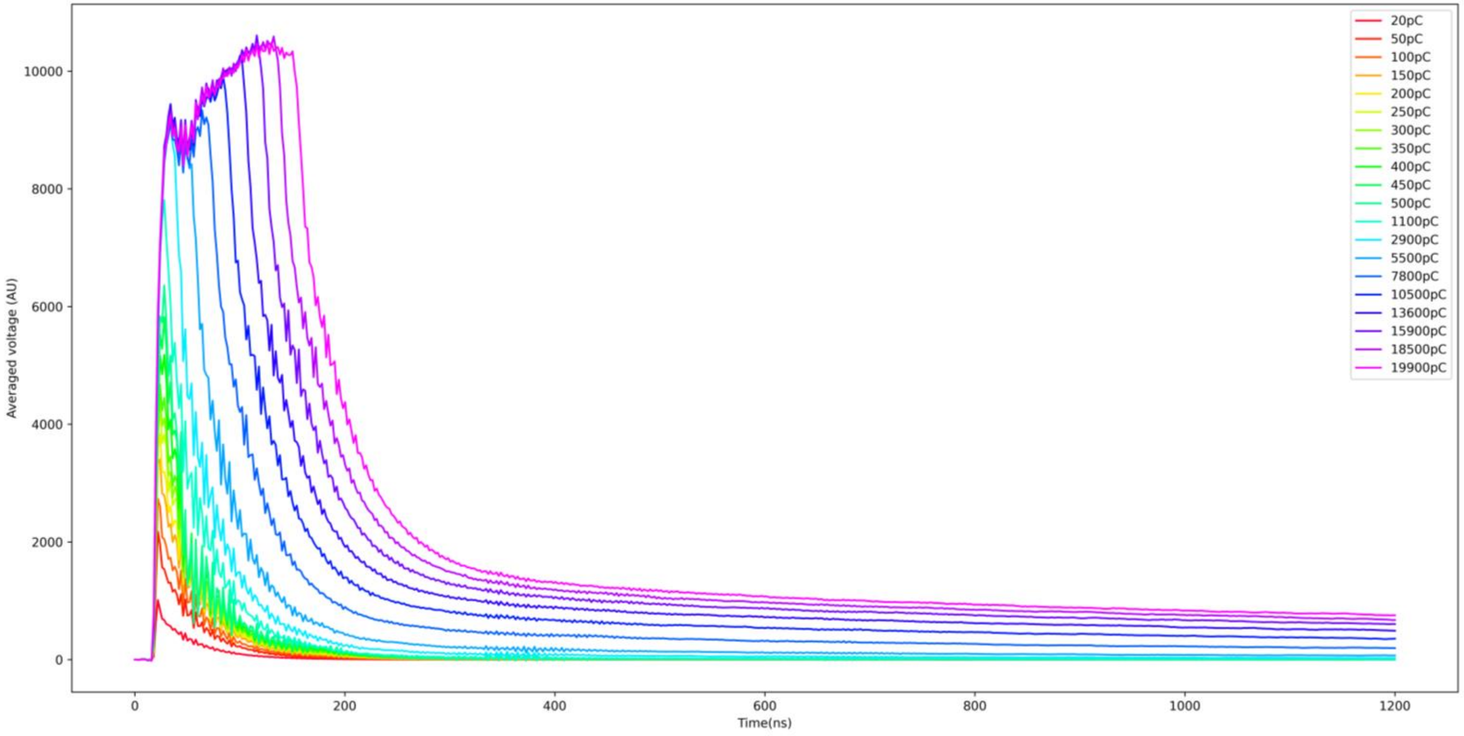


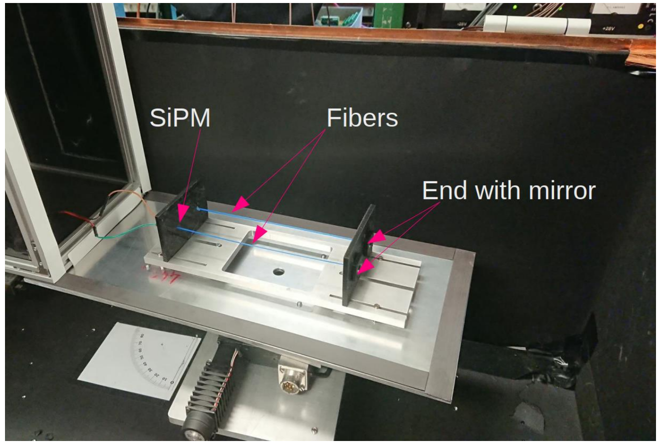
CLEAR

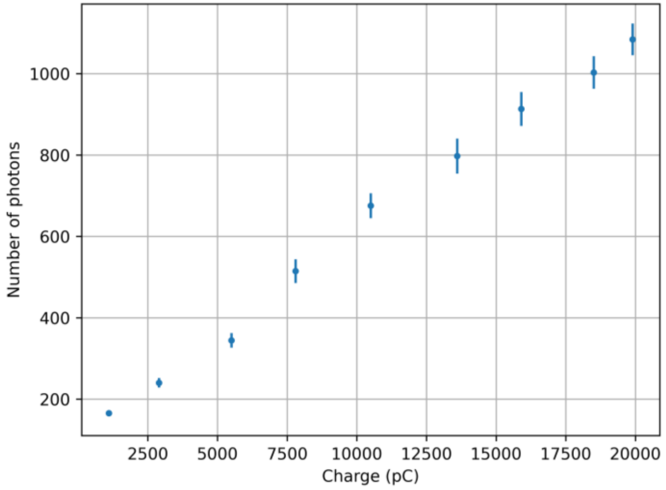


CLEAR

- **Multiple experiments since summer 2022.**
- **Positive results for intense beams with silica rods.**
- **Positive results with liquid scintillator filled capillaries.**

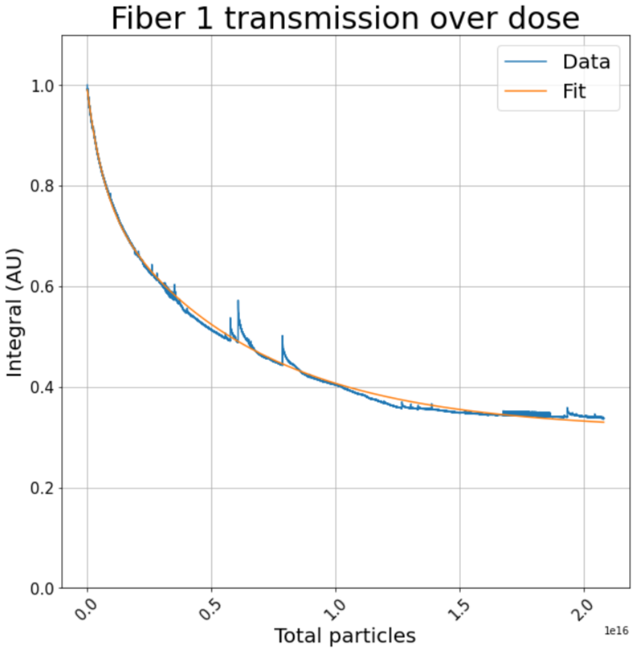


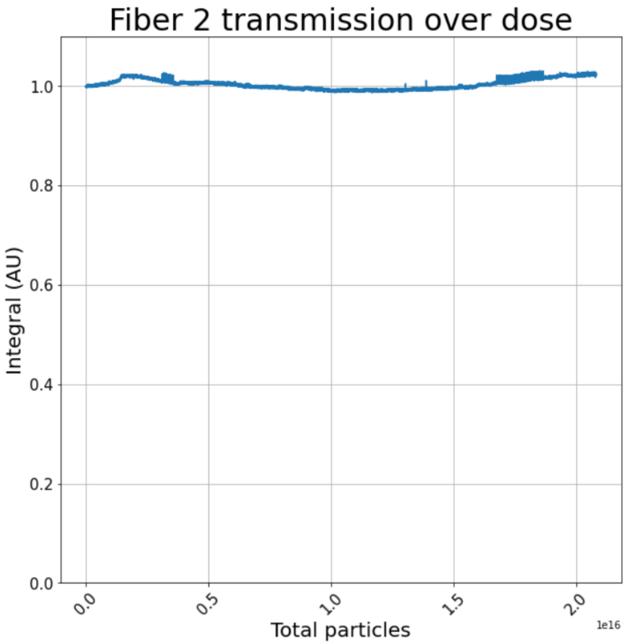


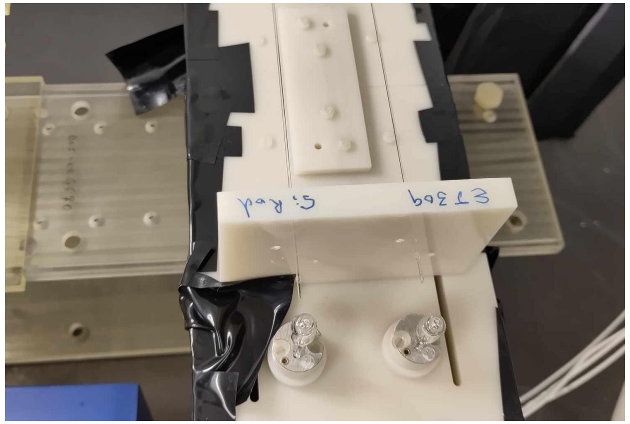


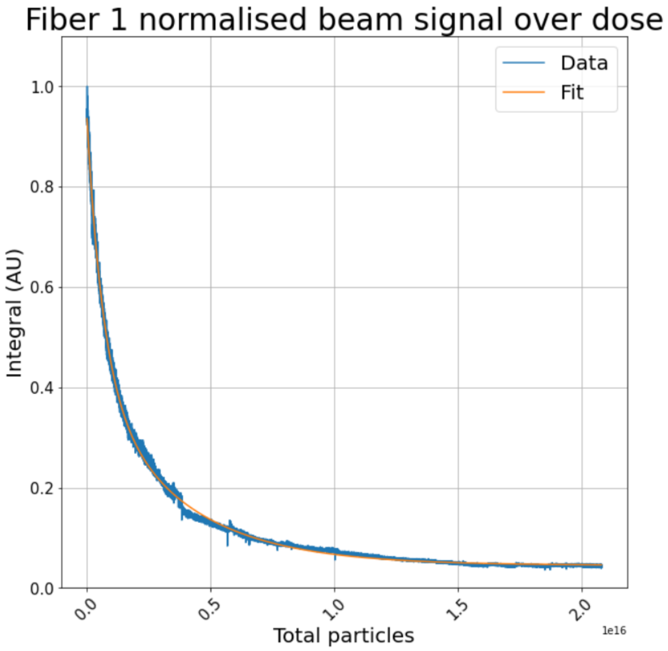
IRRAD

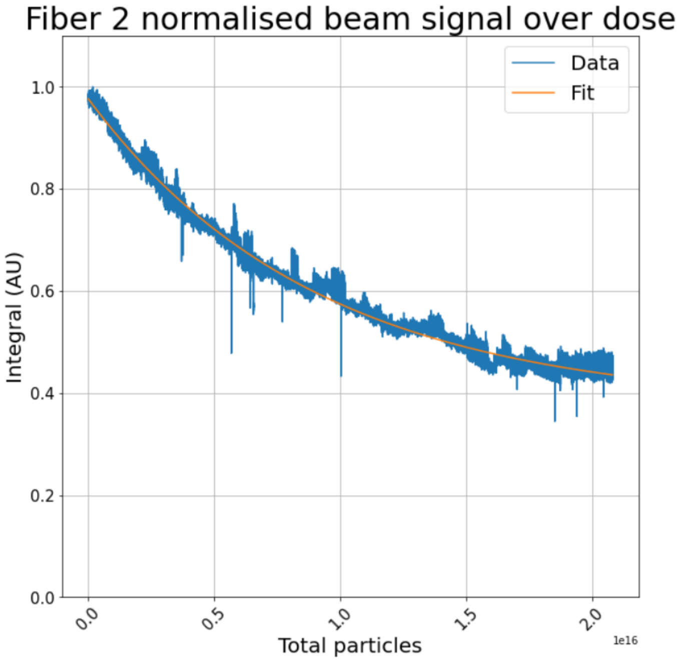
- Experiment conducted in summer 2023.
- Fiber 1 was a silica glass rod, and fiber 2 was a liquid scintillator filled capillary.
- Especially glass rod shows dramatic drop in signal as the dose received increases.





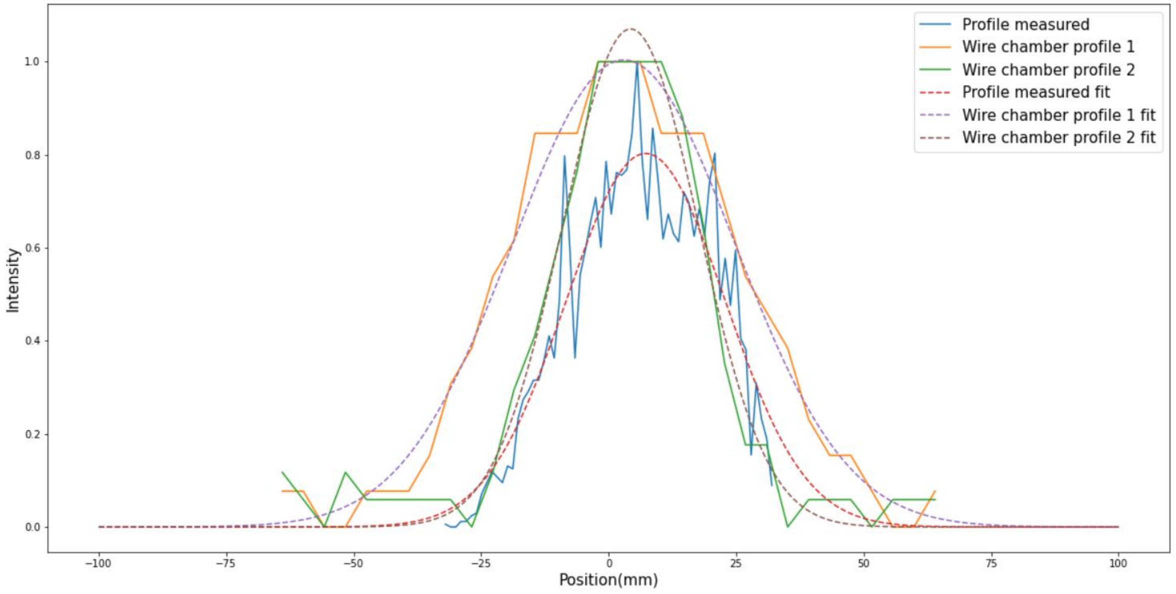


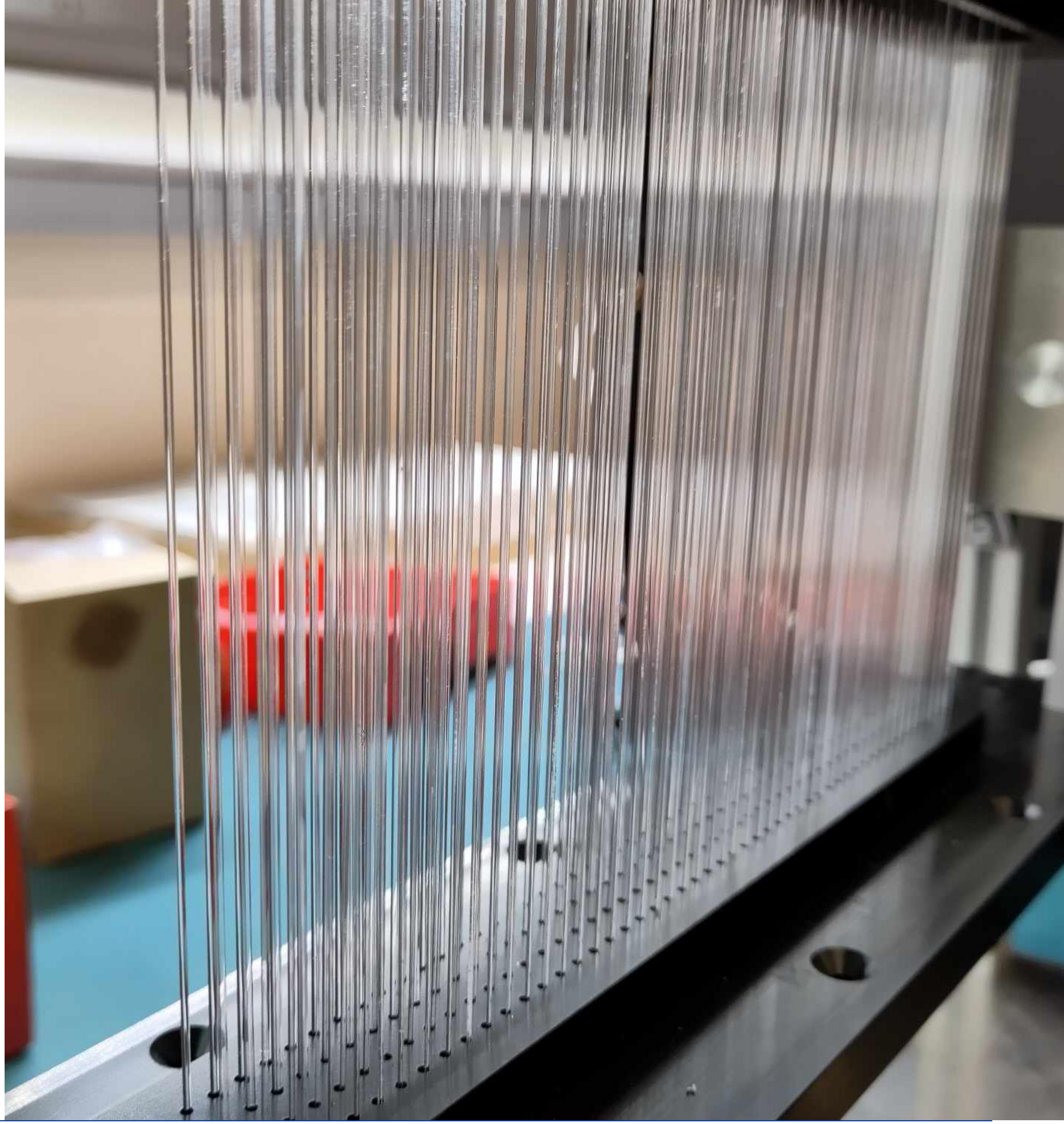




XBPF-style prototype

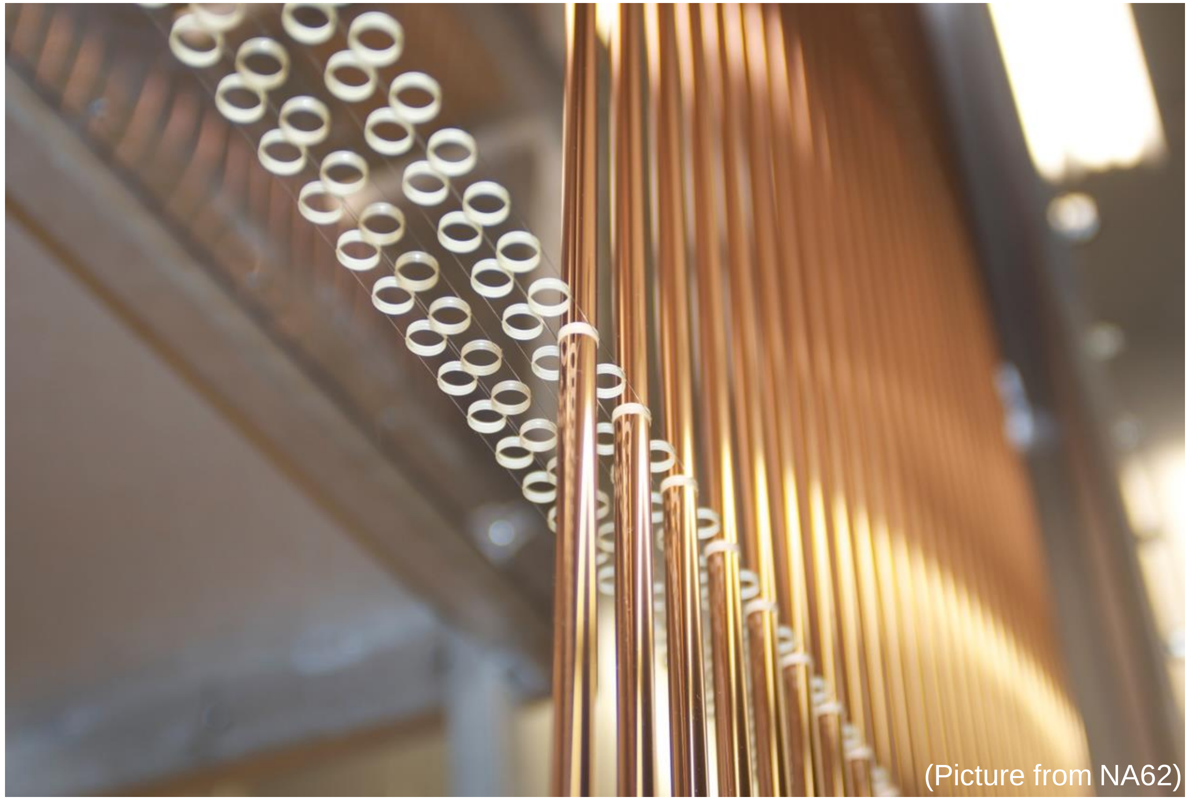
- First campaign in August/September 2023 in M2 beamline.
- Second installation closer to targets in June 2024.
- Combination of Silica fibres, capillaries with liquid scintillator, and plastic scintillating fibres.





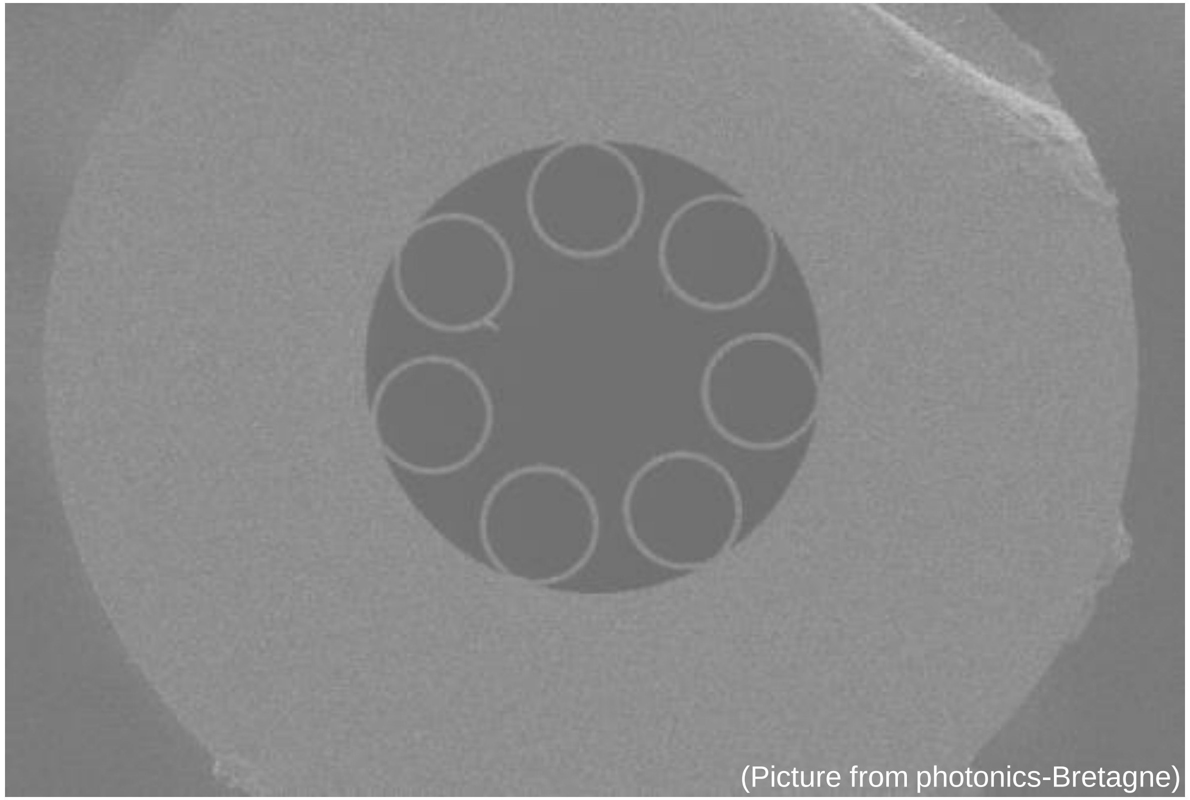
Two main current directions of research

Straw detectors



(Picture from NA62)

Gas filled Hollow Core Fibers (HCF)



(Picture from photonics-Bretagne)

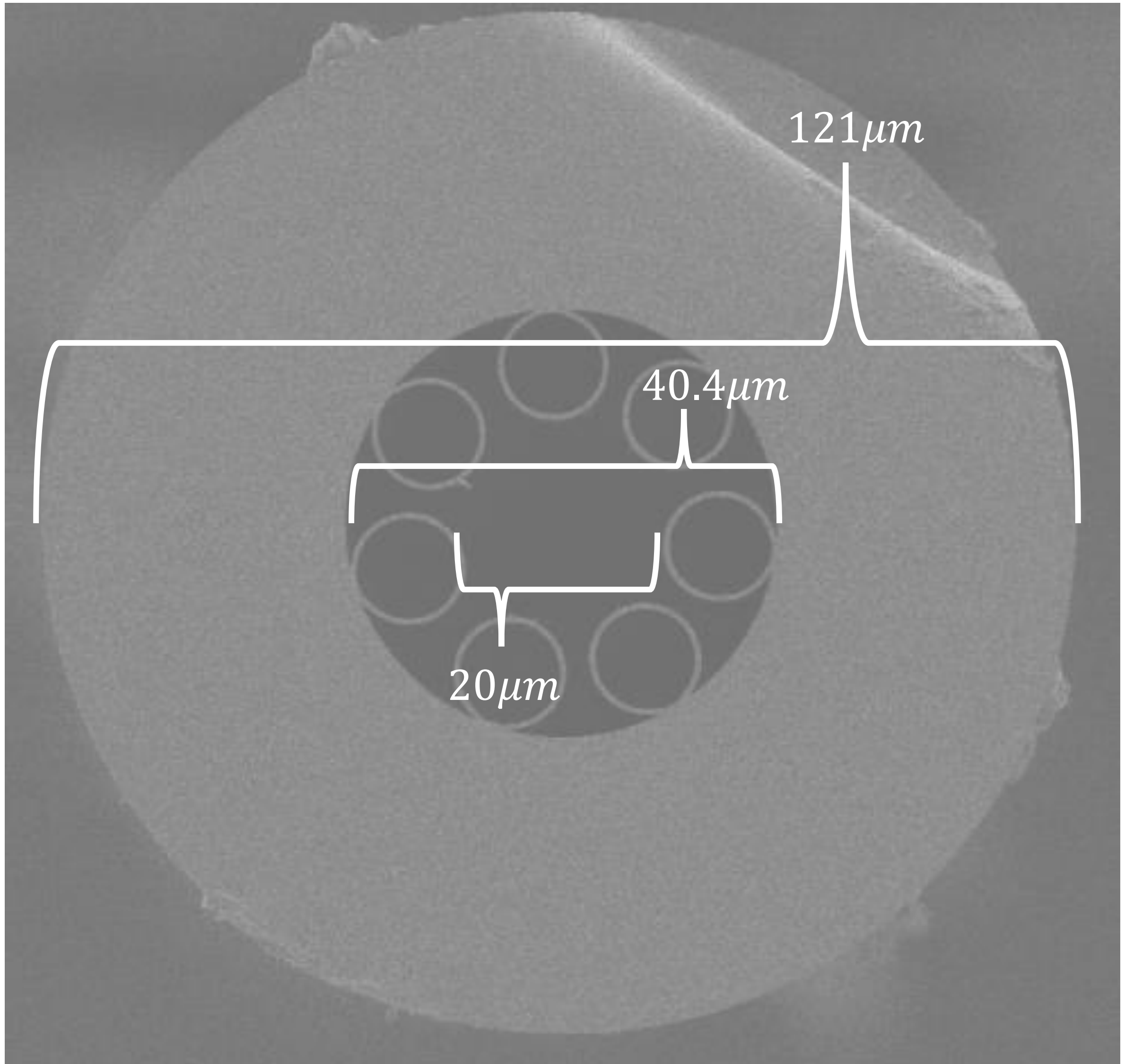
HCF

- **Light is guided in air, so not susceptible to color center formation.**

- **Can be filled with liquid or gas.**

- **Very small hollow core compared to glass capillaries.**

- **Difficult to model light-trapping in GEANT4.**

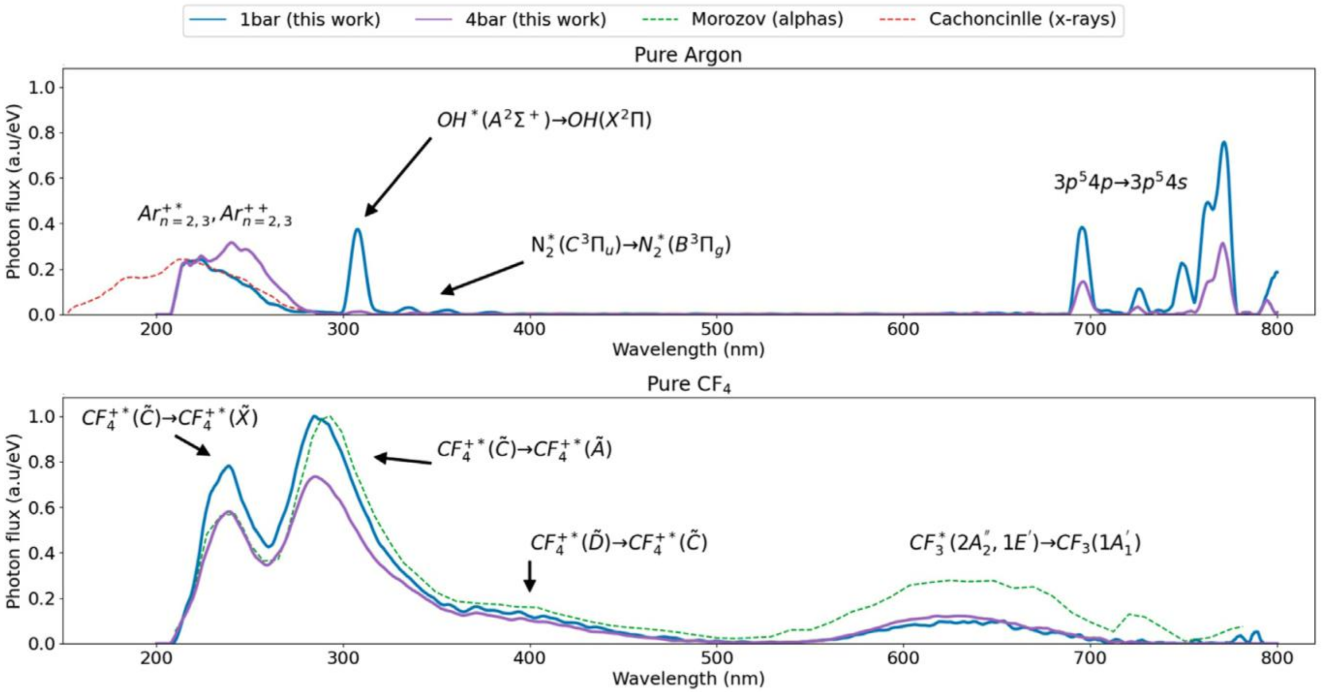


(Picture from photonics-Bretagne)

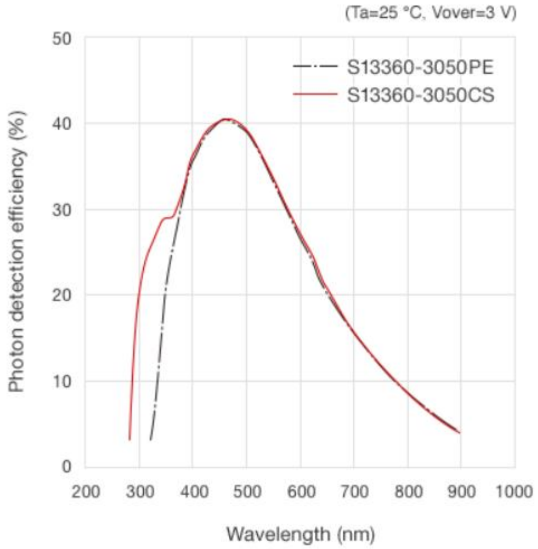
Gas choice

- **CF4 scintillates in region where SiPM photodetectors have reasonable efficiency.**

- **For Argon a wavelength shifter, such as N2, is needed. (Main peak is at 127nm)**



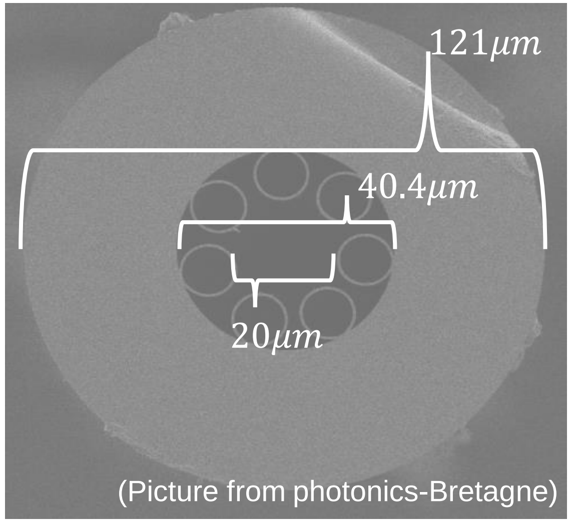
(Amedo et. al. 2023, Frontiers in Detector Science and Technology)

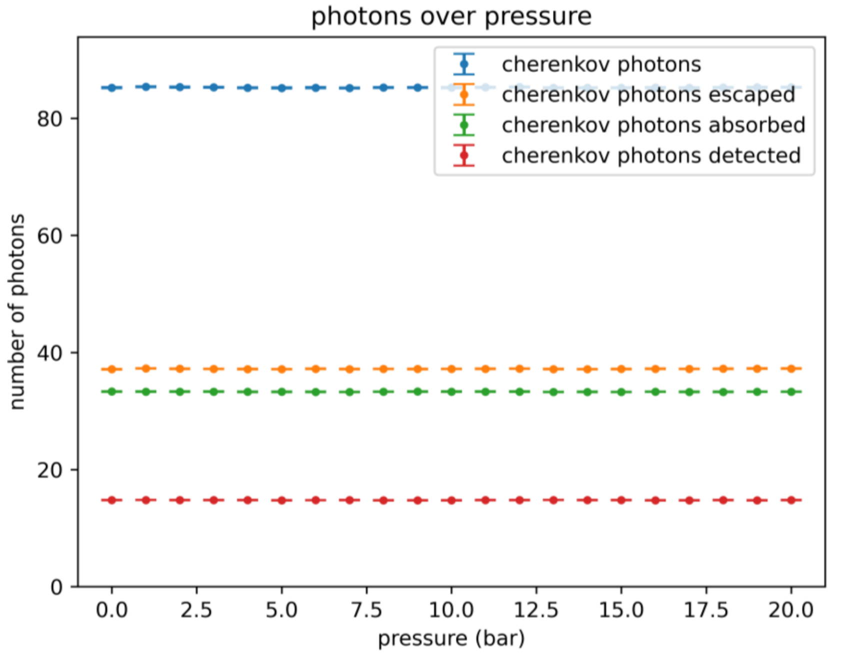


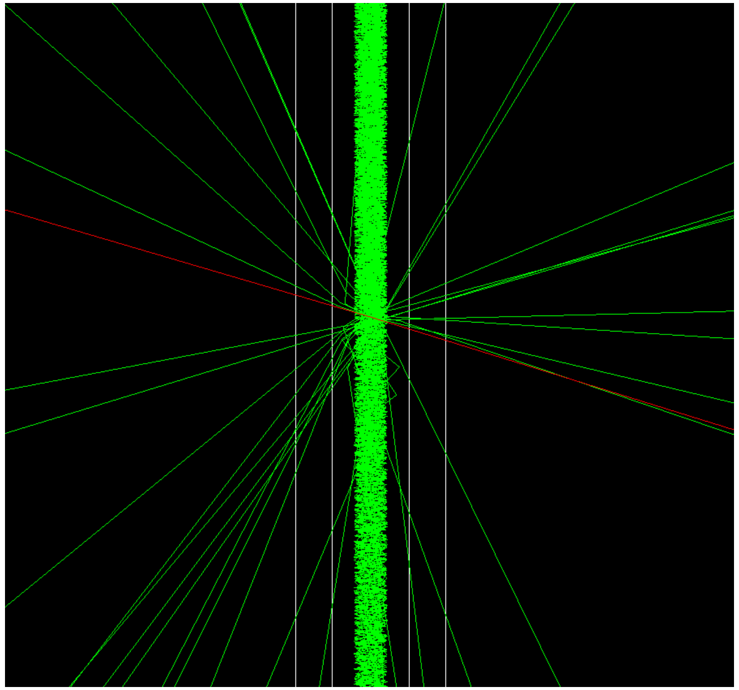
(From Hamamatsu-photonics)

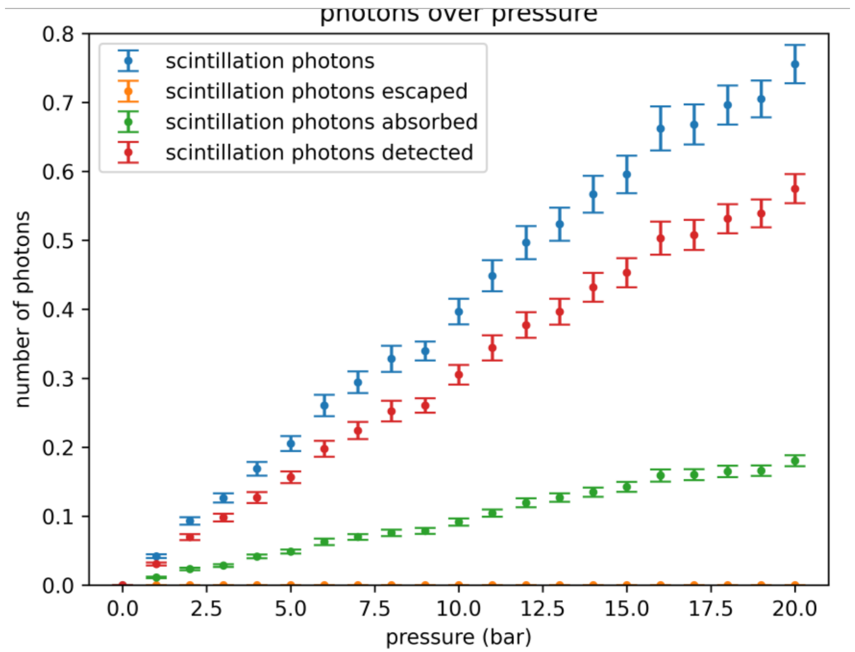
GEANT4 simulation

- **200 Mev electrons.**
- **Plots show number of photons per primary.**
- **Trapping modelled with a reflective surface.**

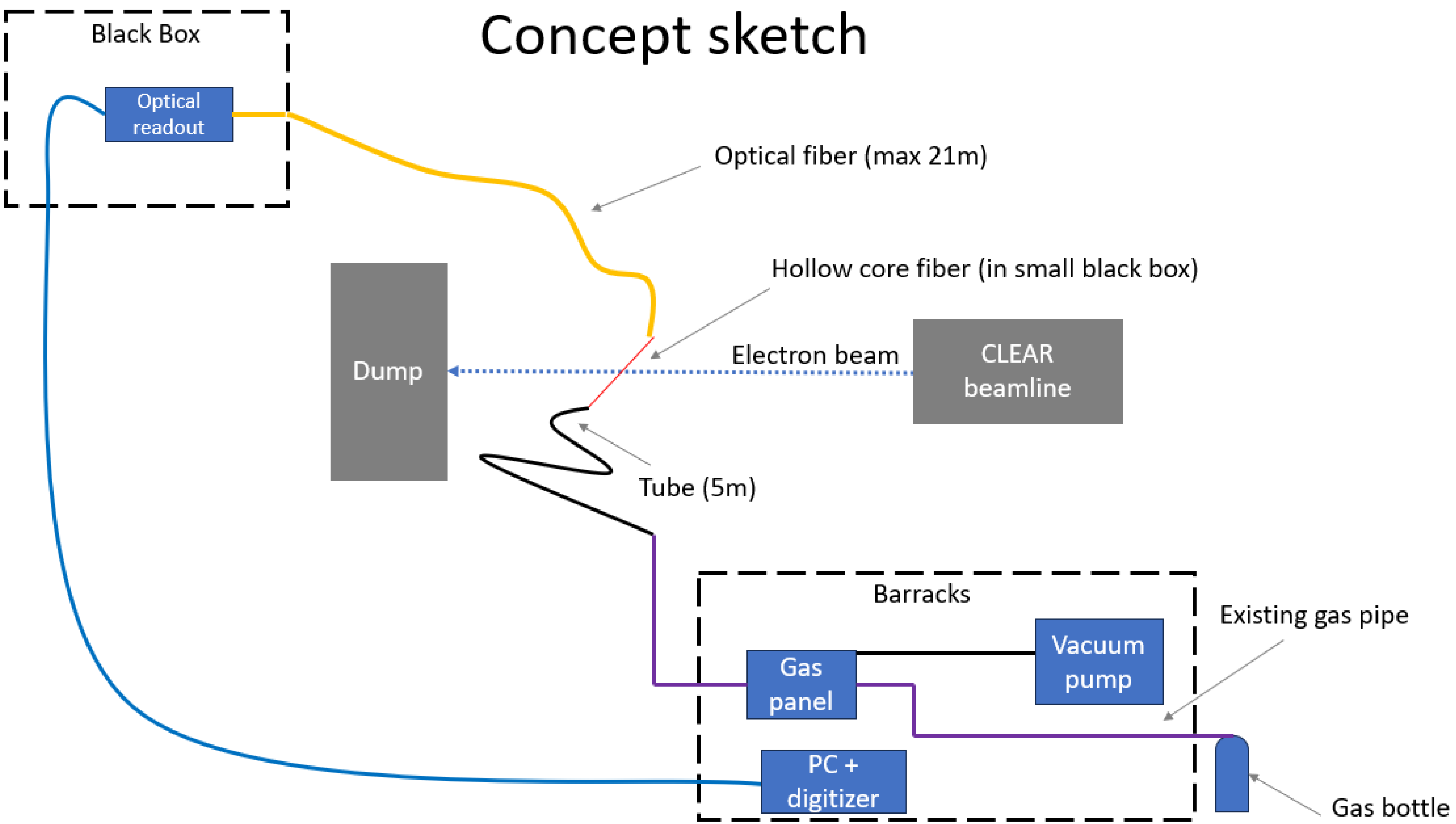




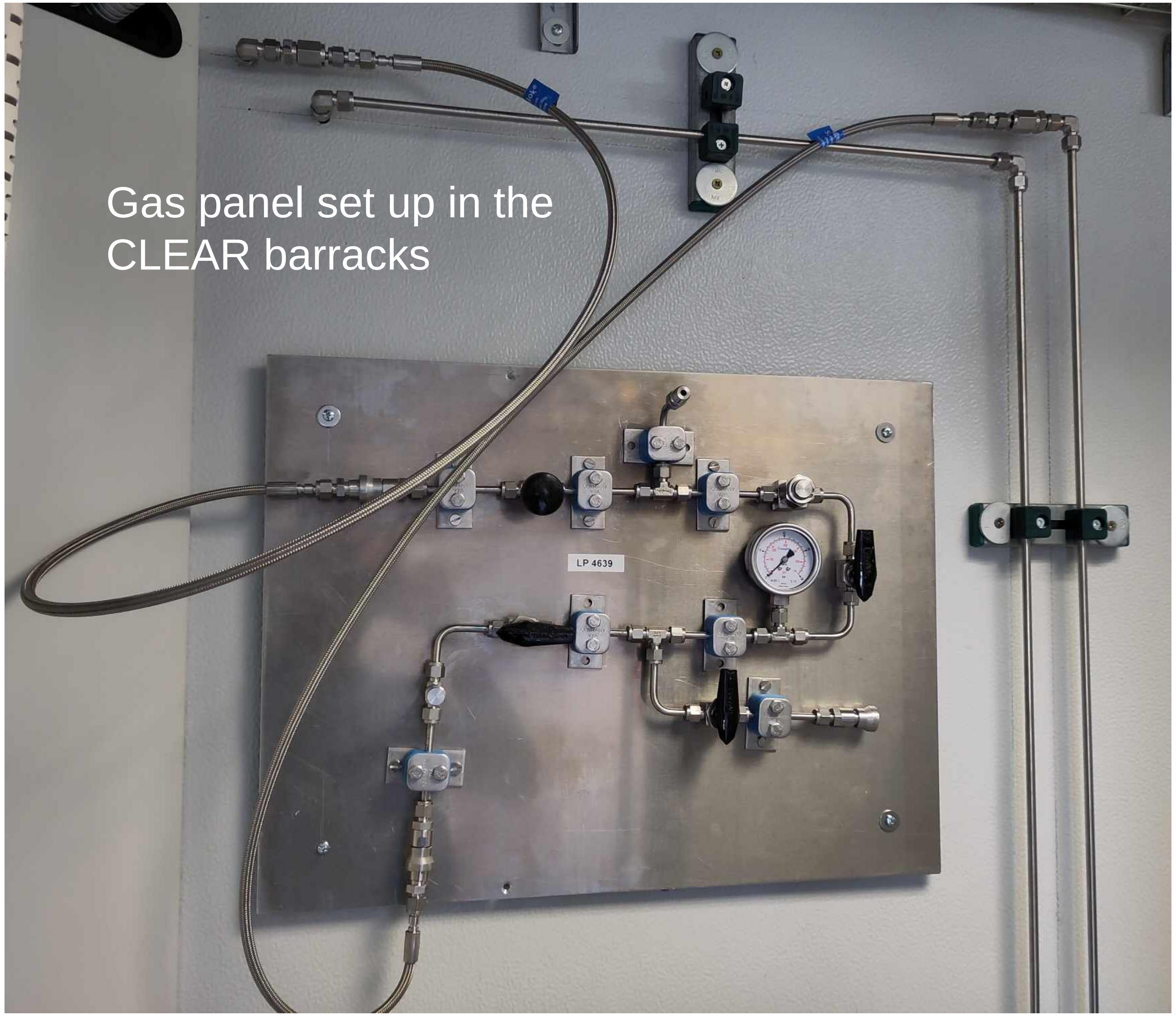




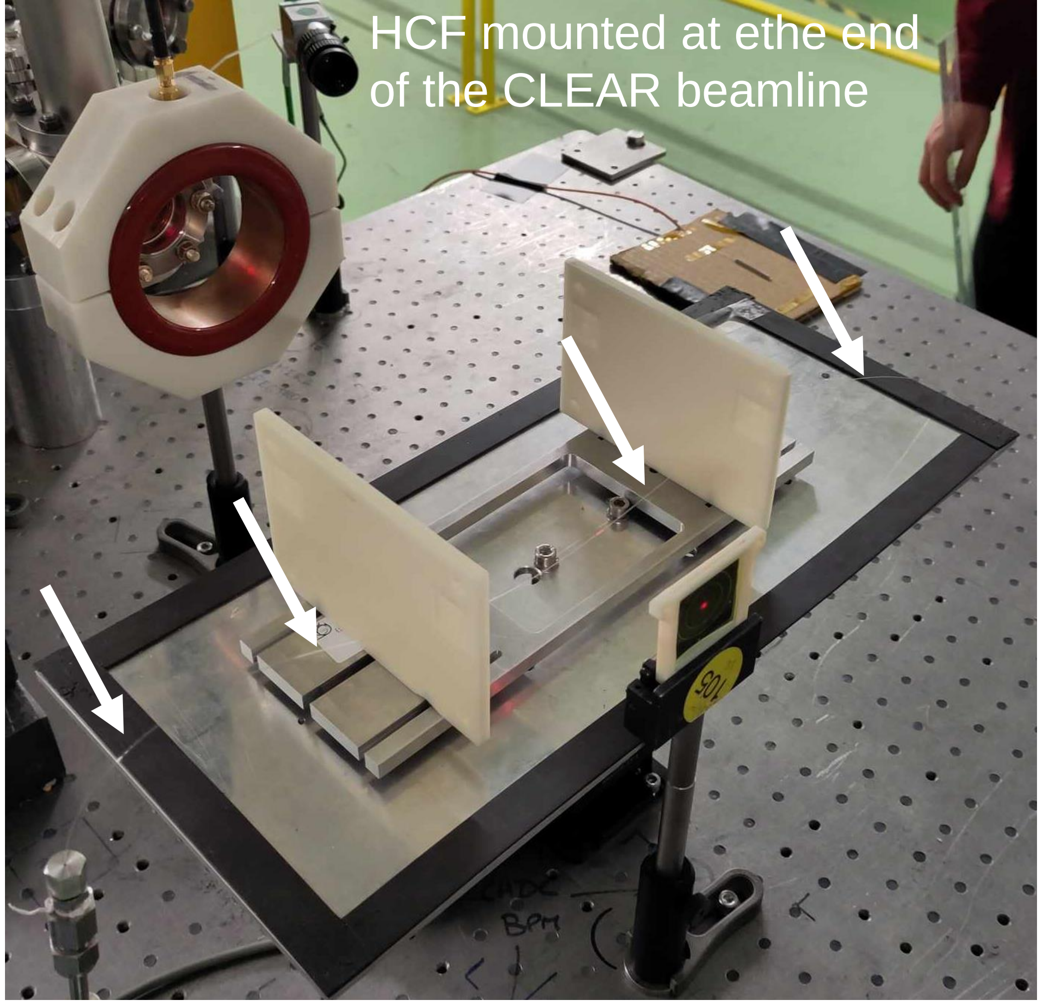
HCF Experiment in CLEAR



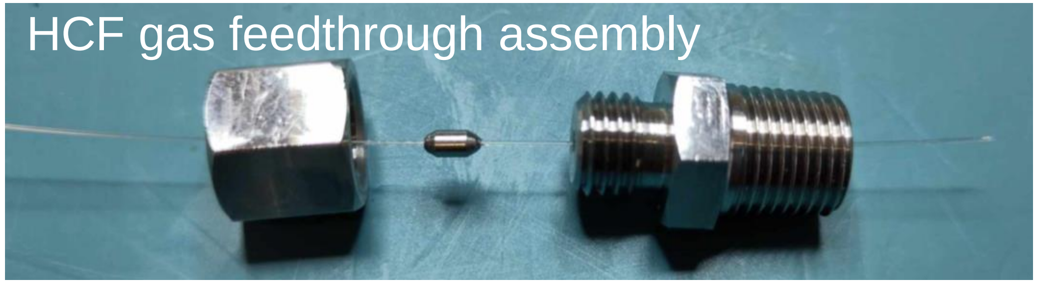
HCF Experiment in CLEAR



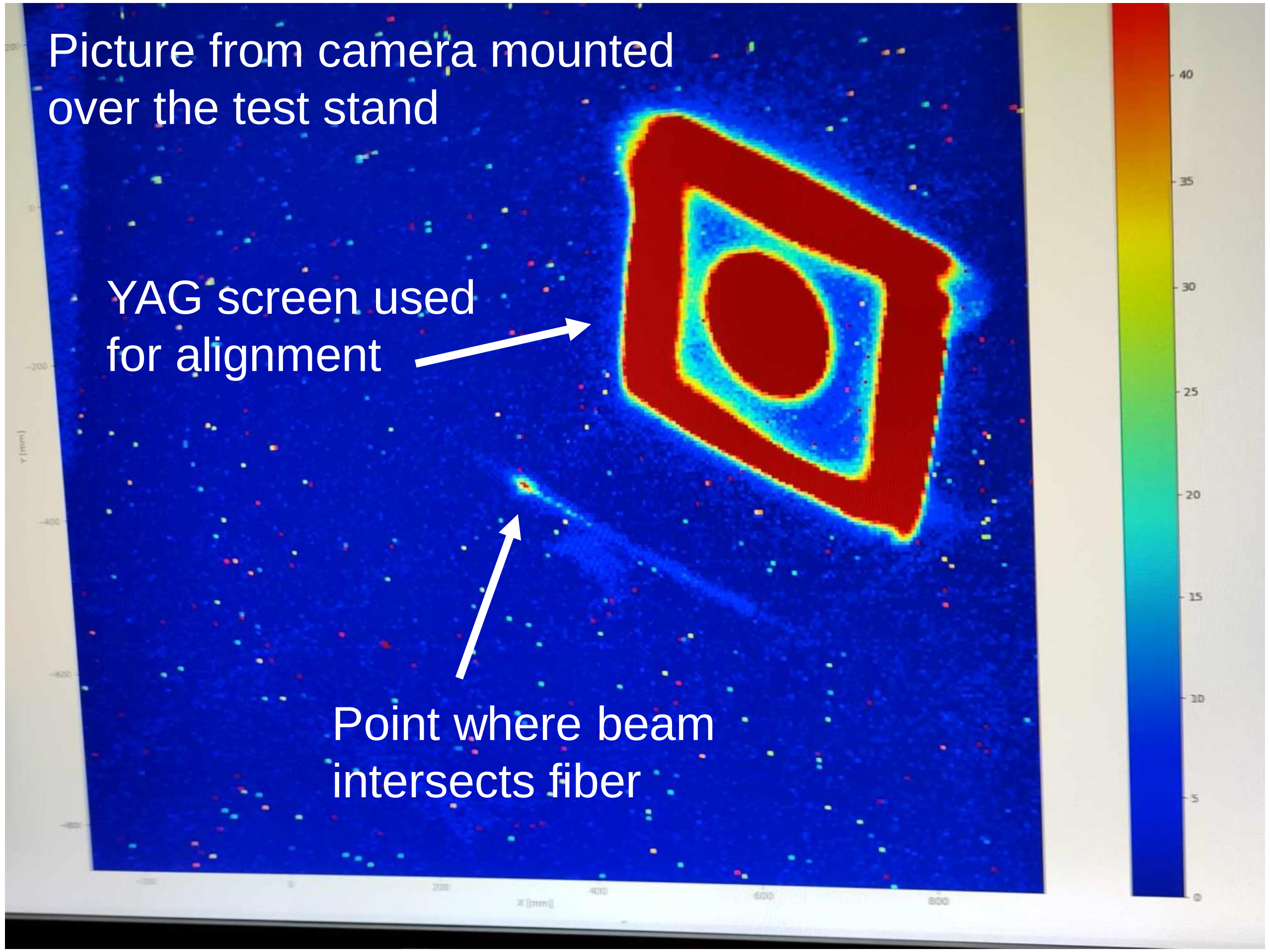
Gas panel set up in the CLEAR barracks

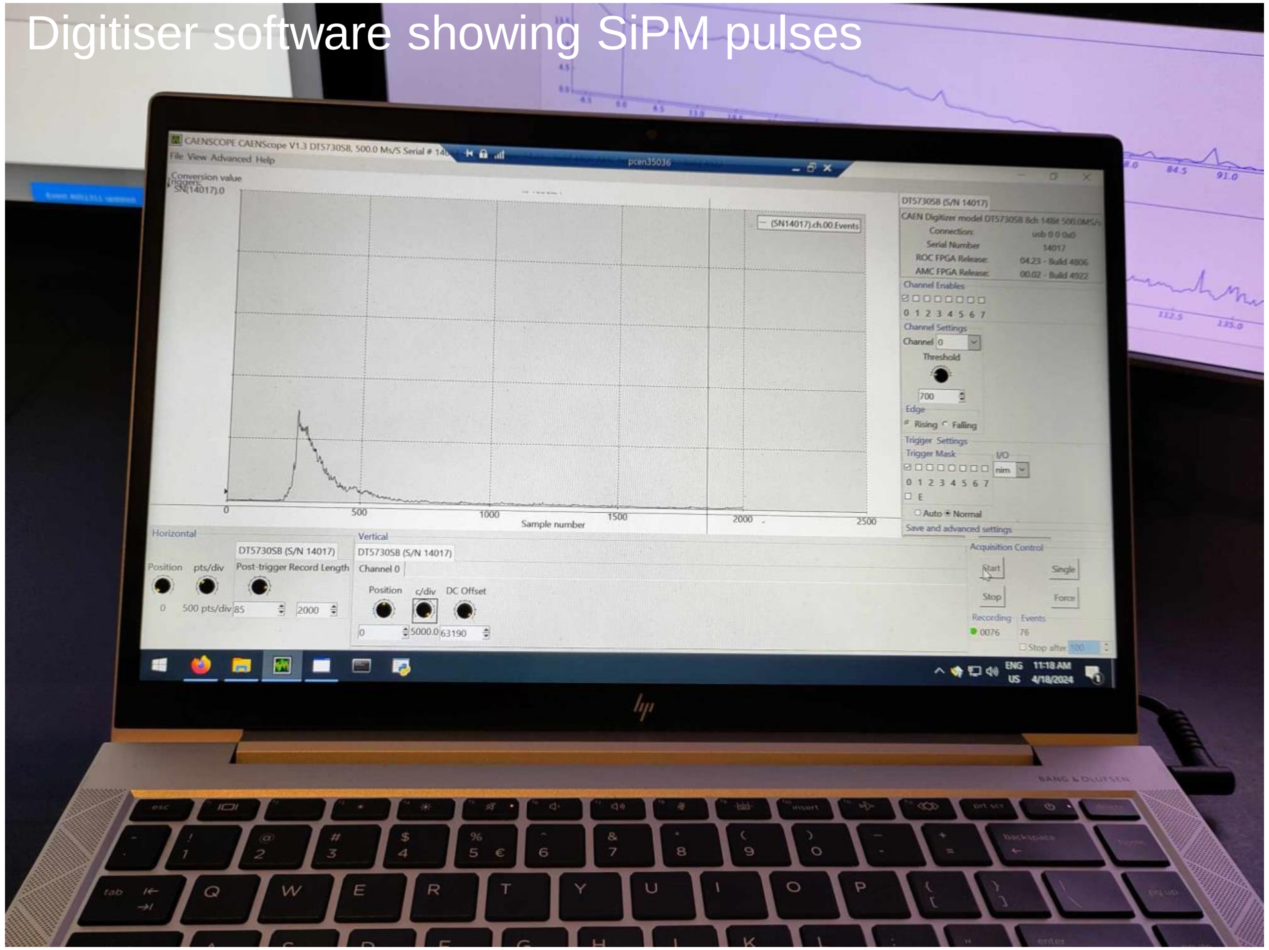


HCF mounted at ethe end of the CLEAR beamline


HCF gas feedthrough assembly

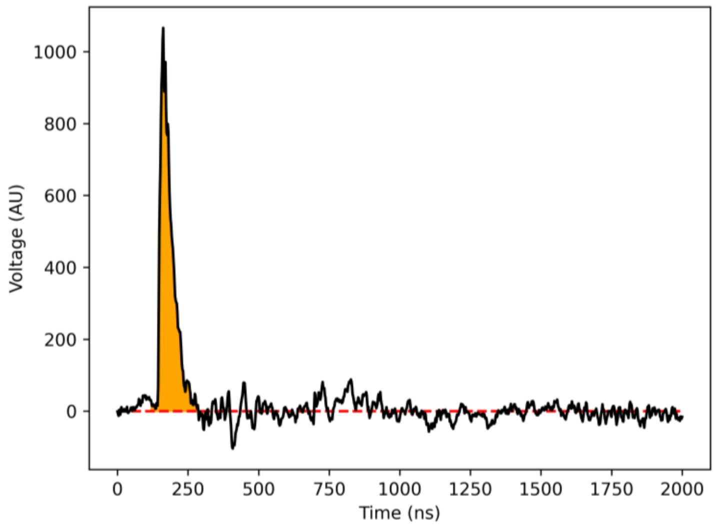
HCF Experiment in CLEAR

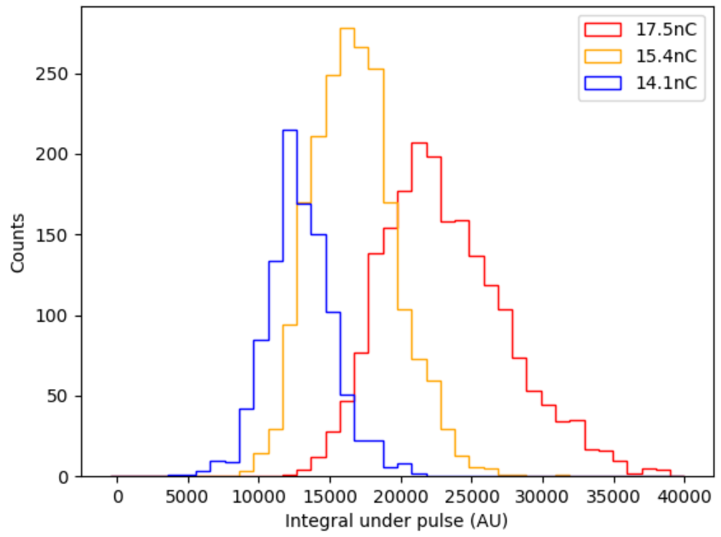


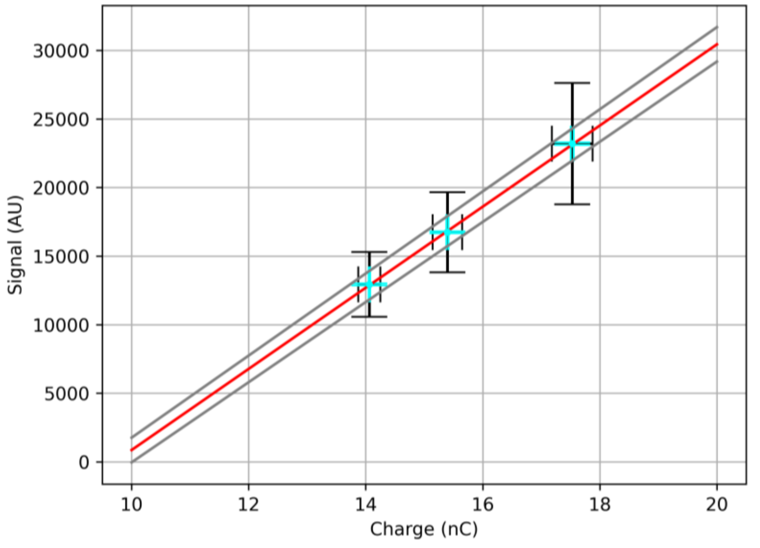


HCF Experiment in CLEAR

Regular analysis pipeline



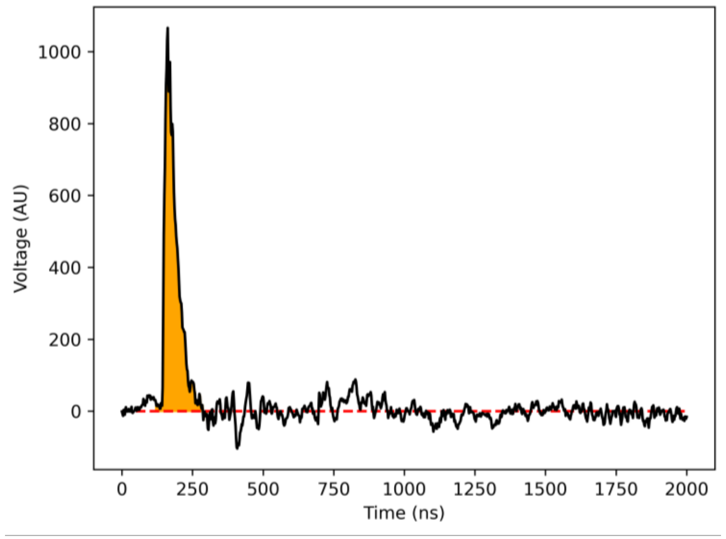


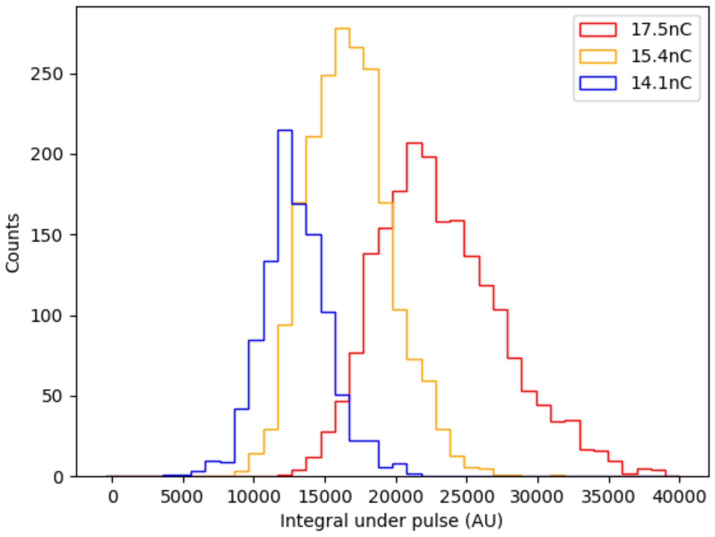


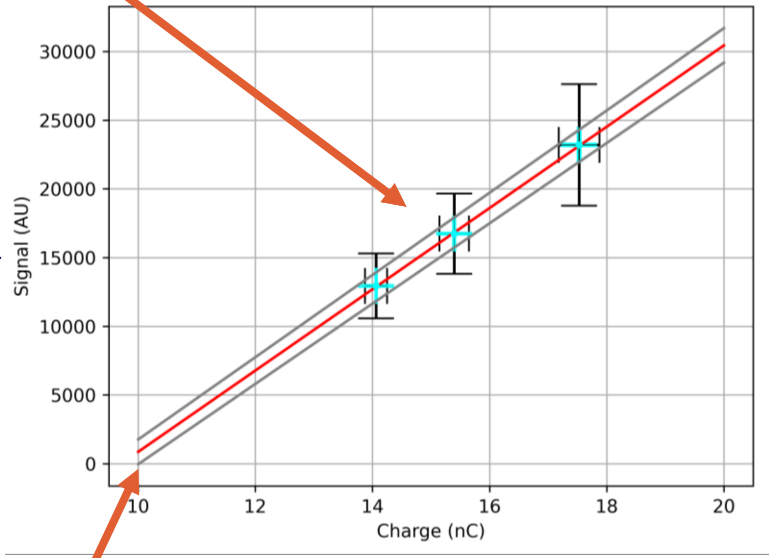
HCF Experiment in CLEAR

Regular analysis pipeline

Looks nice and linear



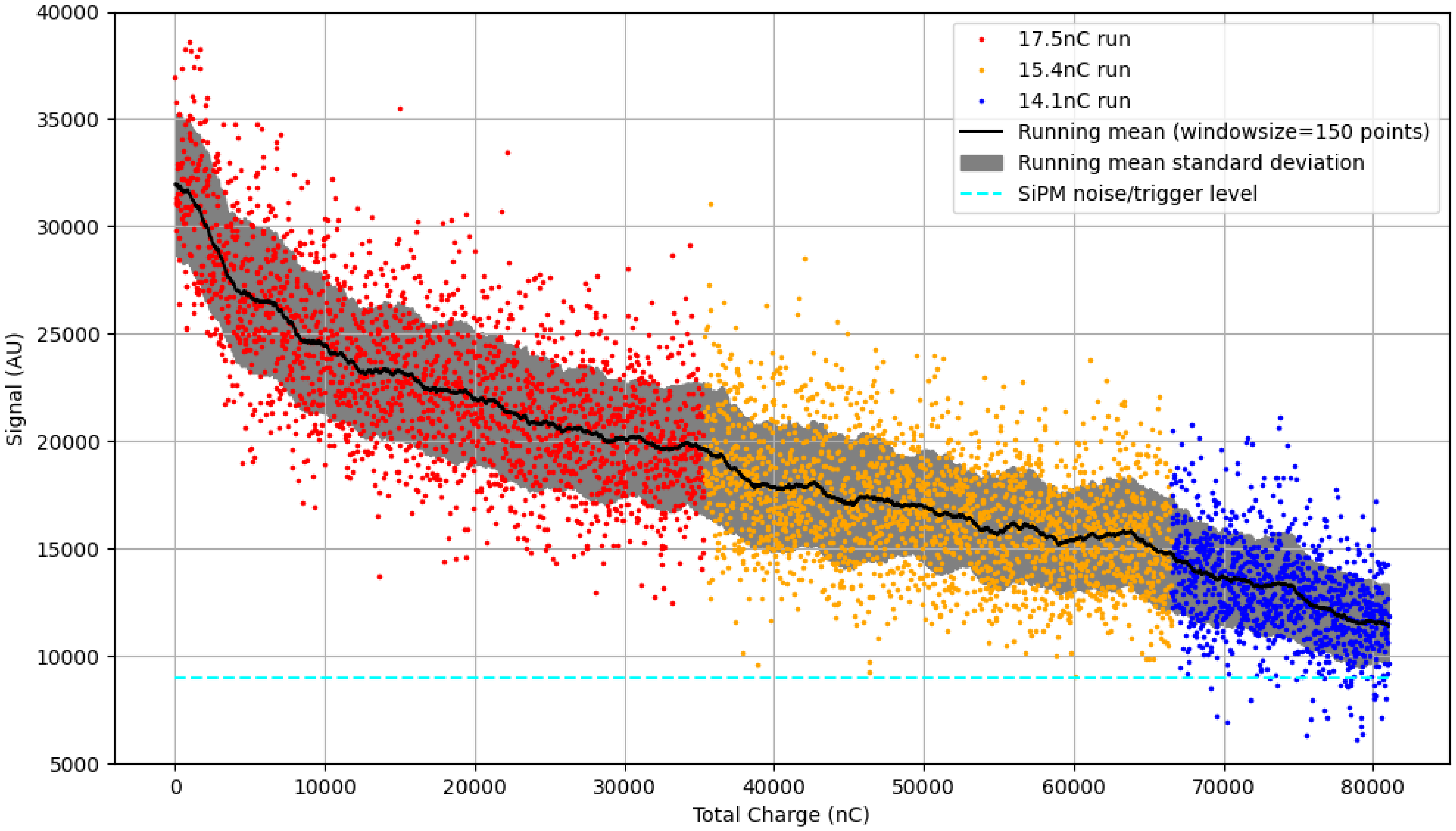




But something is clearly wrong, since zero signal does not correspond to zero charge!

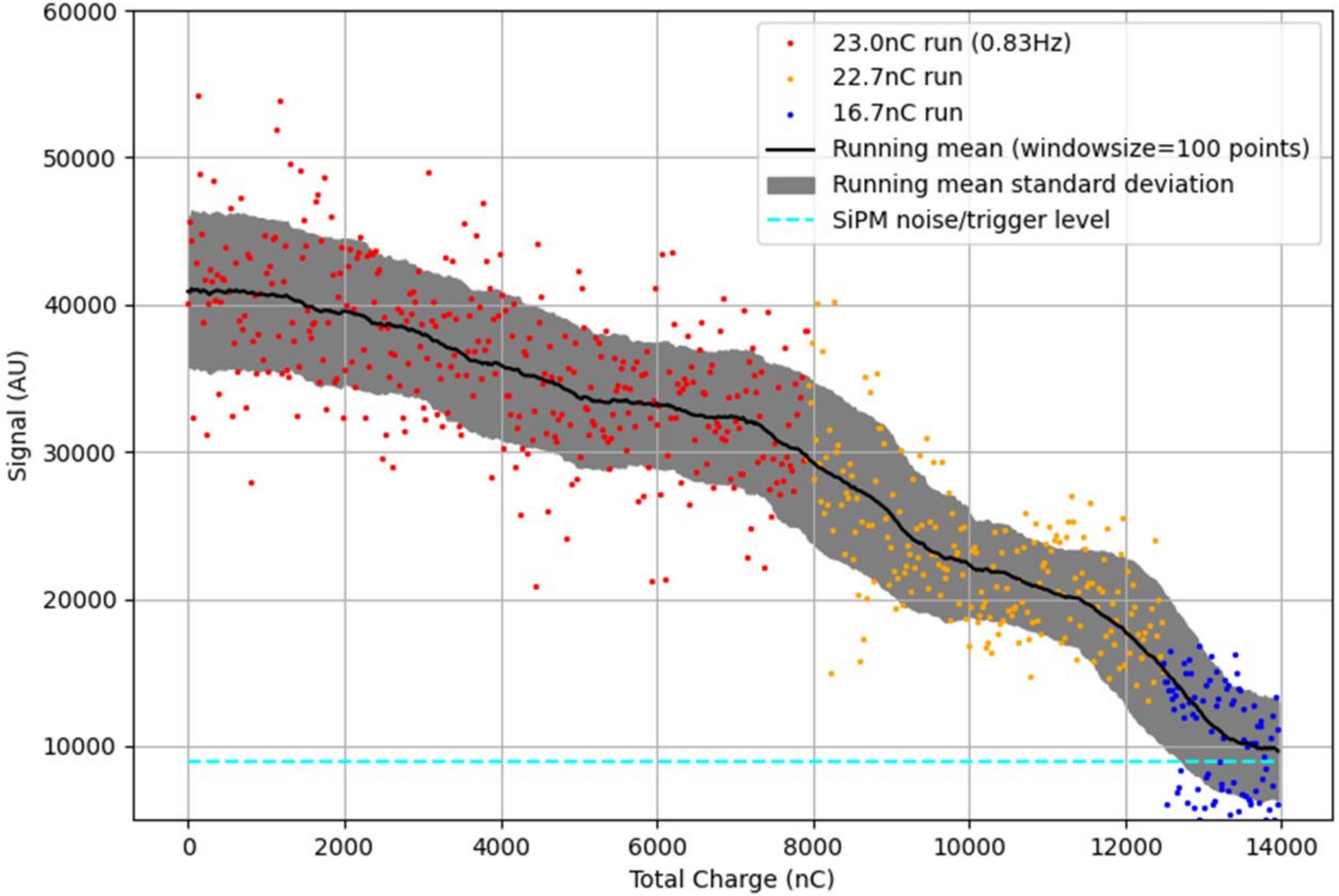
HCF Experiment in CLEAR

HCF1 (6 bar CF4)



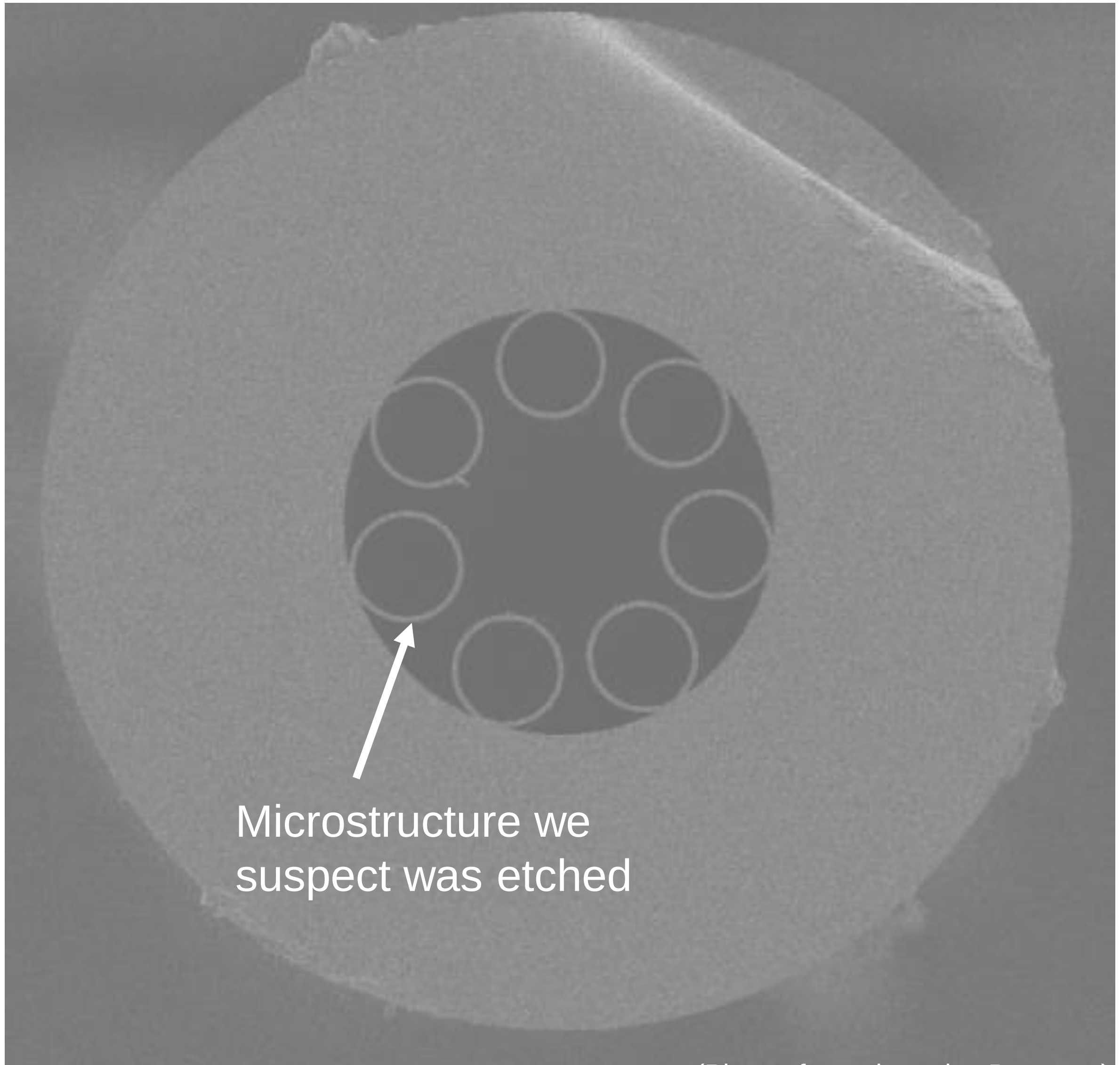
HCF Experiment in CLEAR

HCF2 (20 bar CF4)



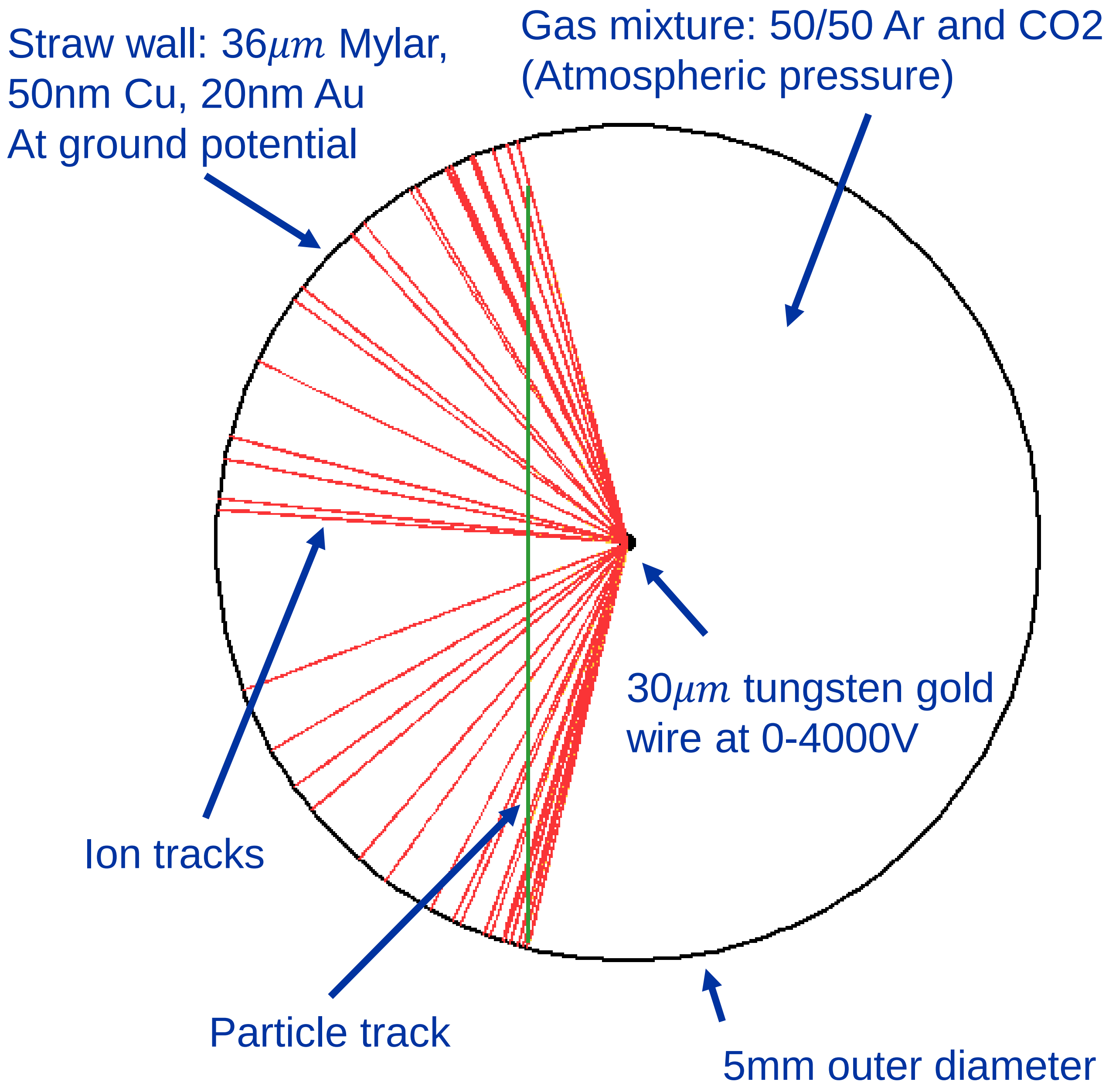
HCF Experiment in CLEAR

- We saw no signal when HCF was filled with atmospheric air or vacuum.
- Transmission through fiber rapidly dropped when exposed to beam.
- We observed a faster drop when fiber was pressurized with a higher gas pressure.
- We suspect Fluor radicals chemically etched the silica structure.
- Fiber has been shipped back to Southampton for imaging.
- Follow up experiment with Argon and Nitrogen mix planned for September



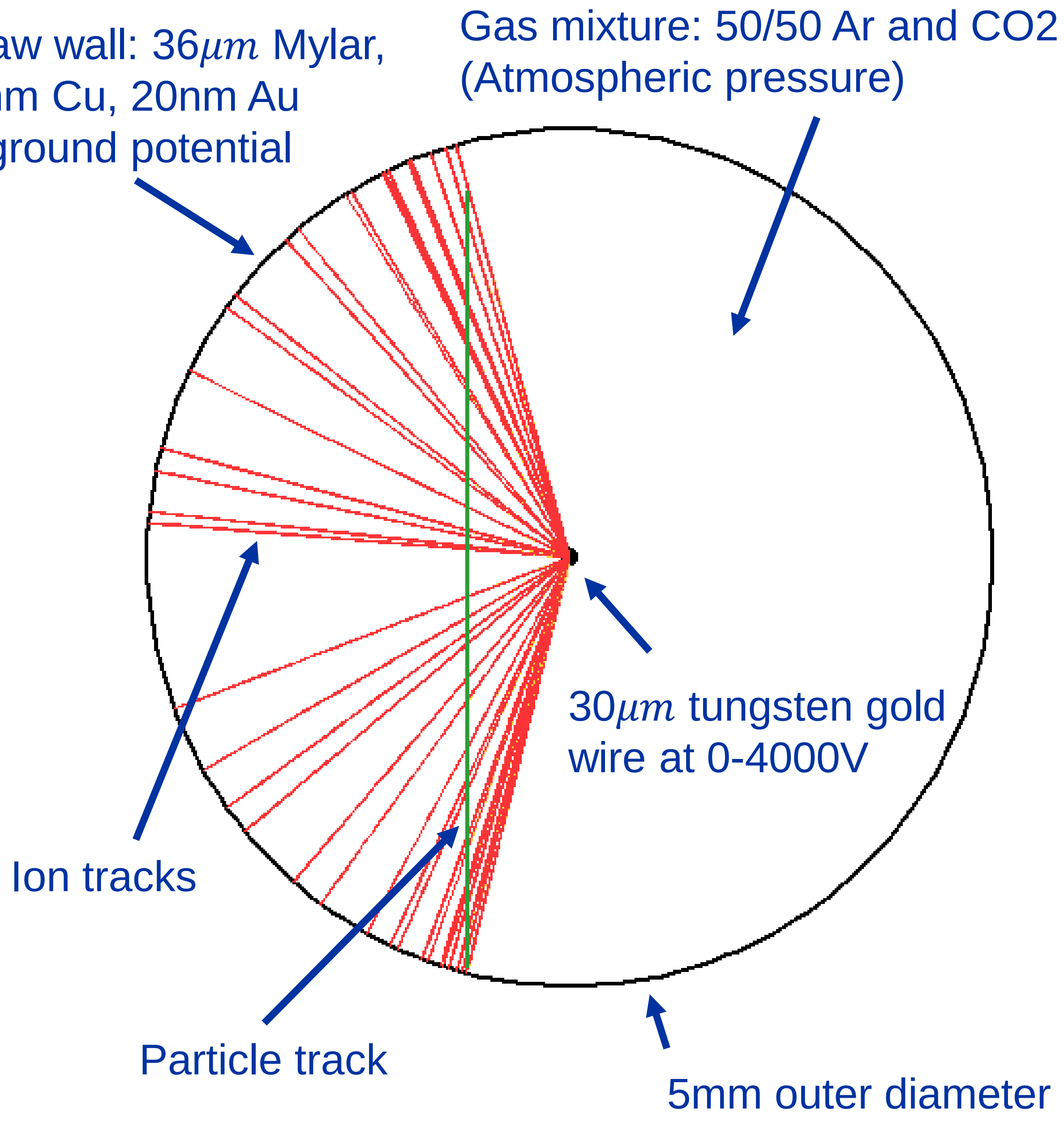
(Picture from photonics-Bretagne)

Straw based monitor

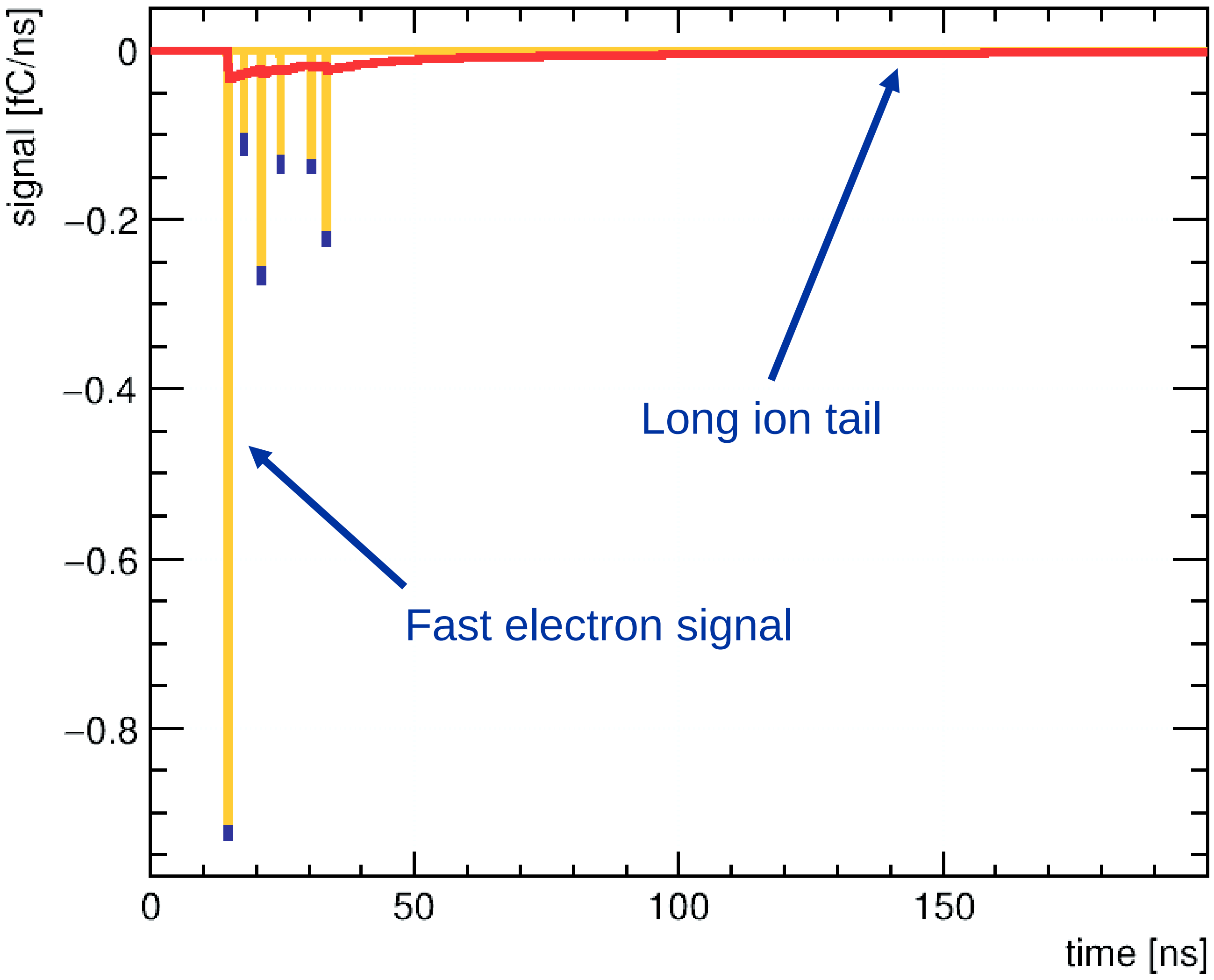


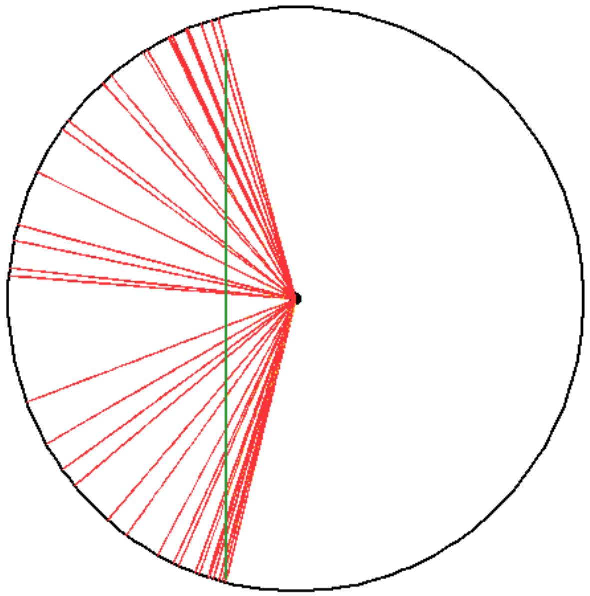
Straw based monitor

Pros	Cons
Electronics can be situated far from the beam.	Lower resolution than fibers when timing information is not used.
Large dynamic range by using control over HV.	More difficult to fit into XBPF motorization solution.
Can reuse wire chamber infrastructure (readout, gas distribution, high voltage).	
Potential for conversion to single particle tracking by changing electronics.	
Extremely low material budget.	

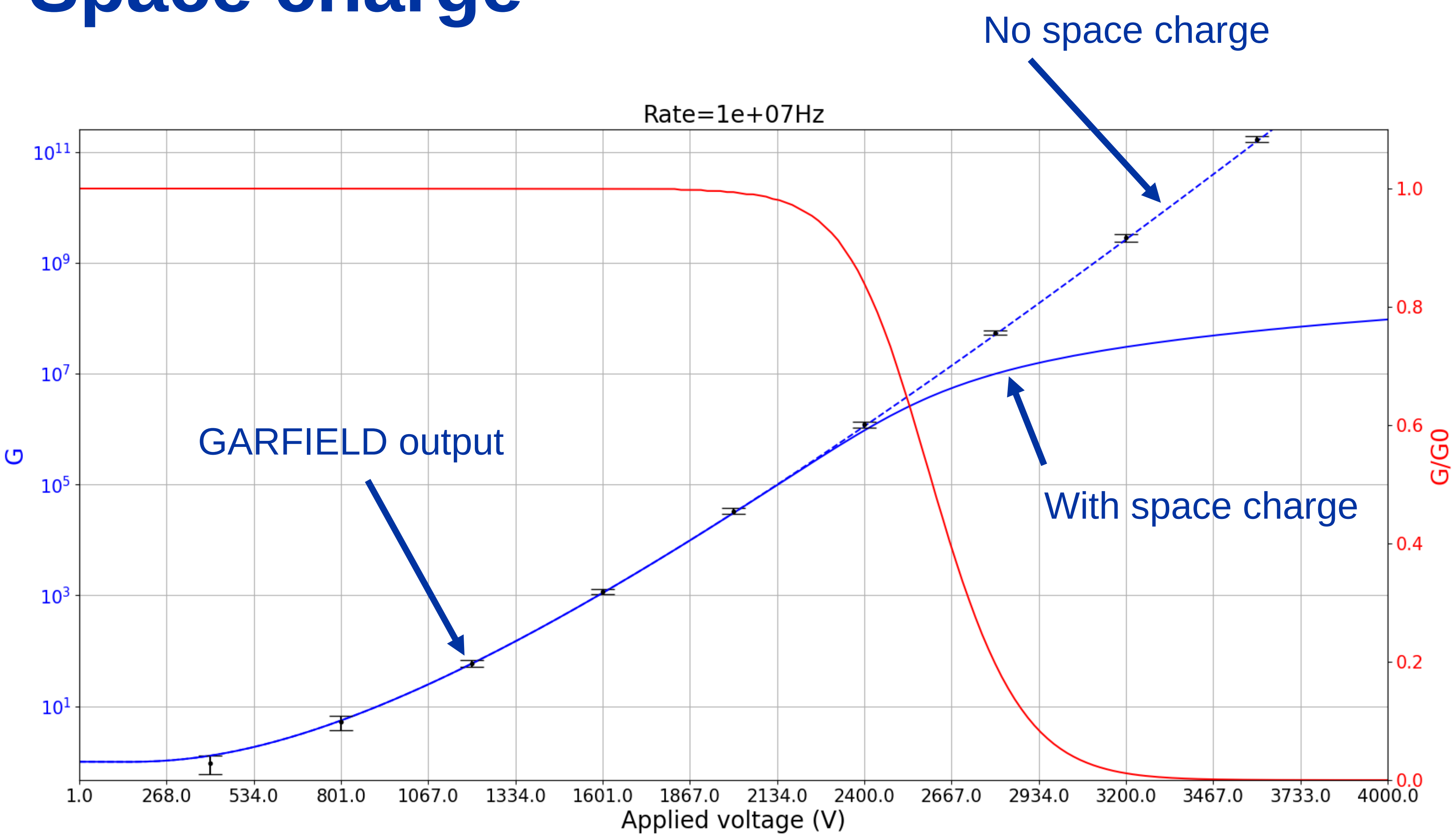


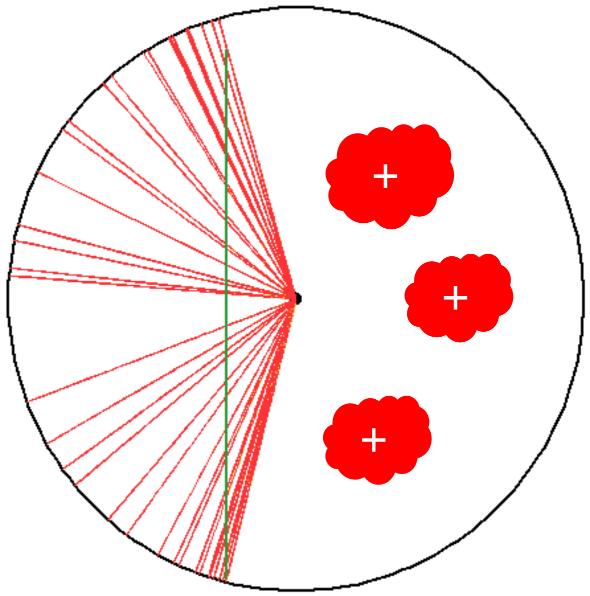
GARFIELD simulations



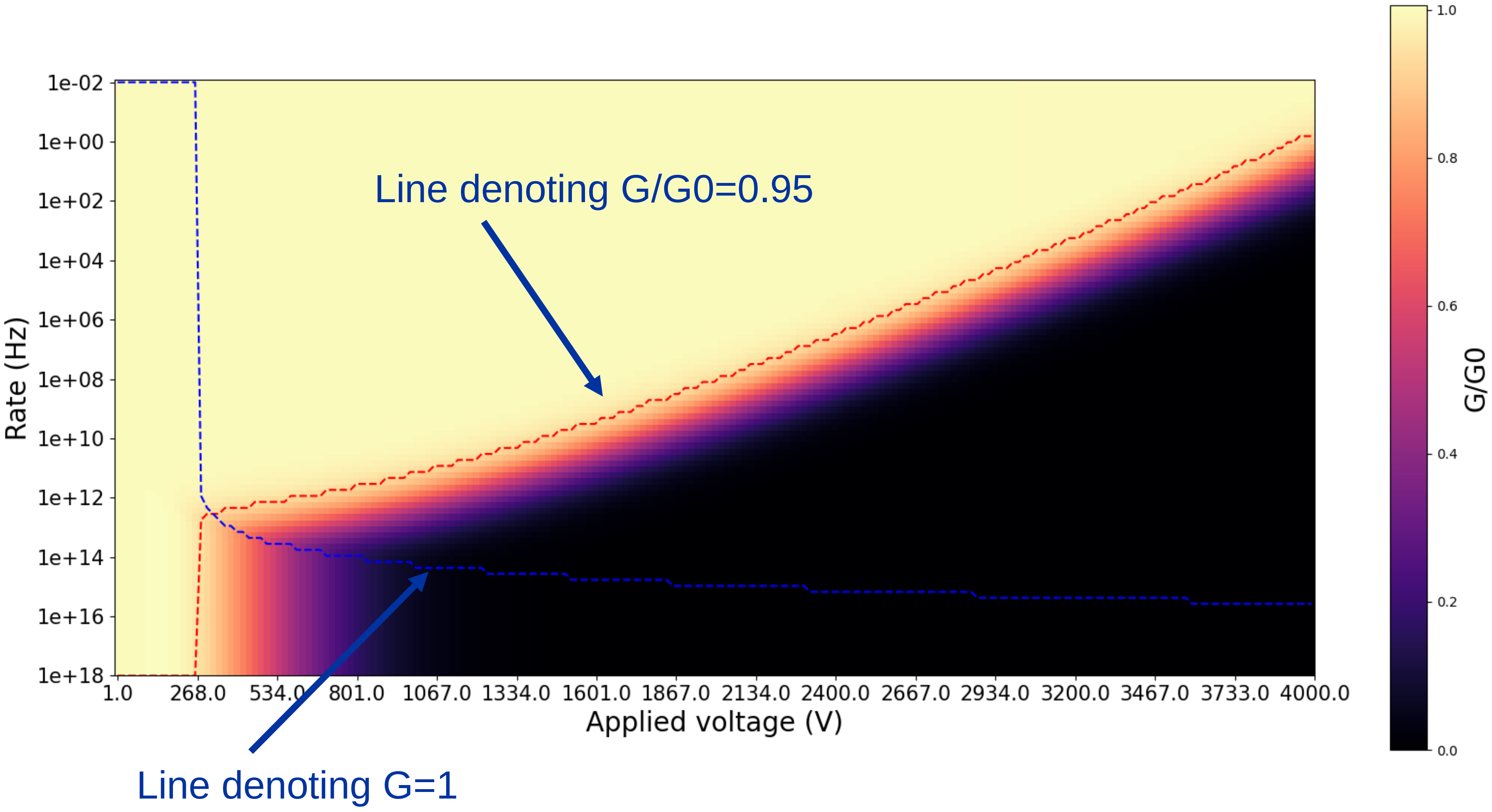


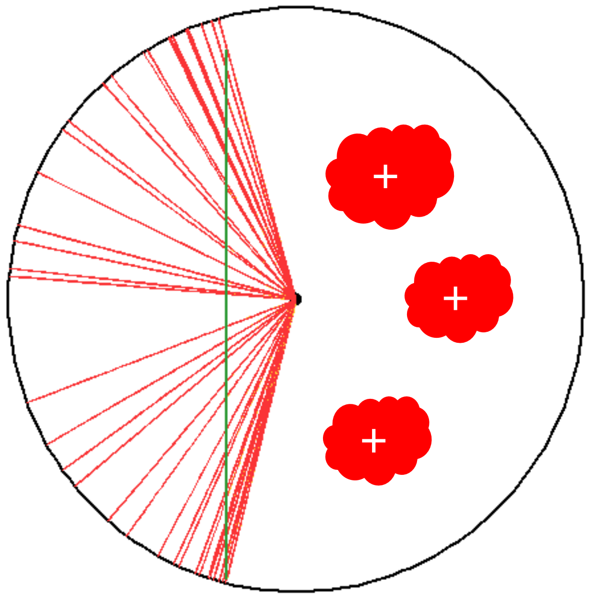
Space charge



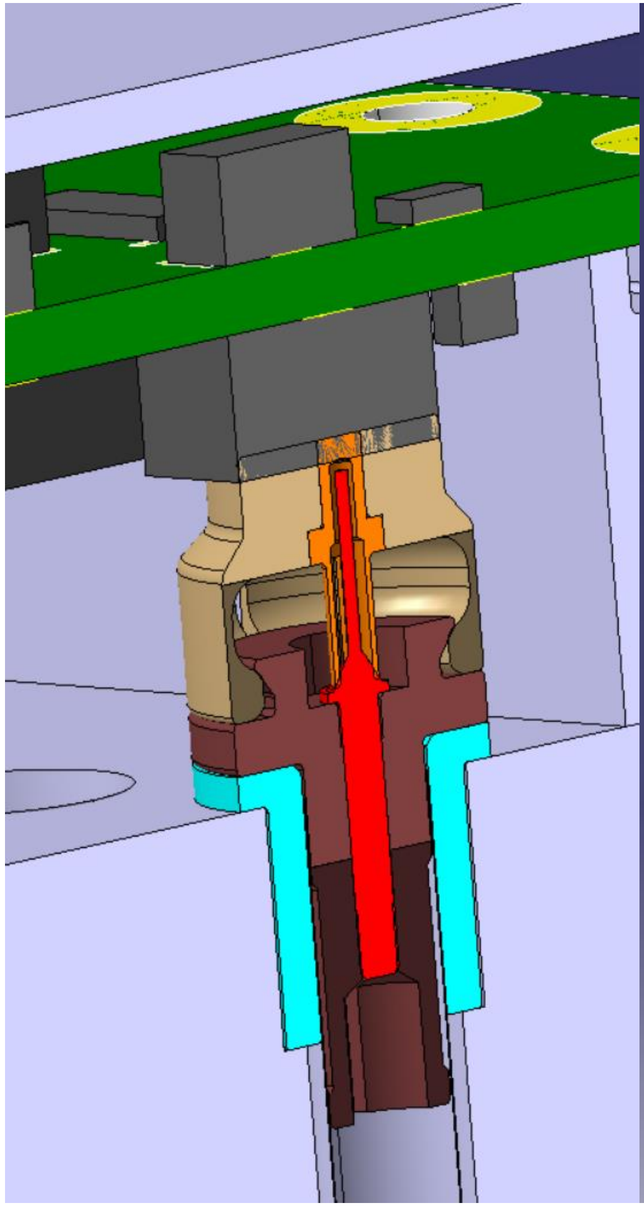


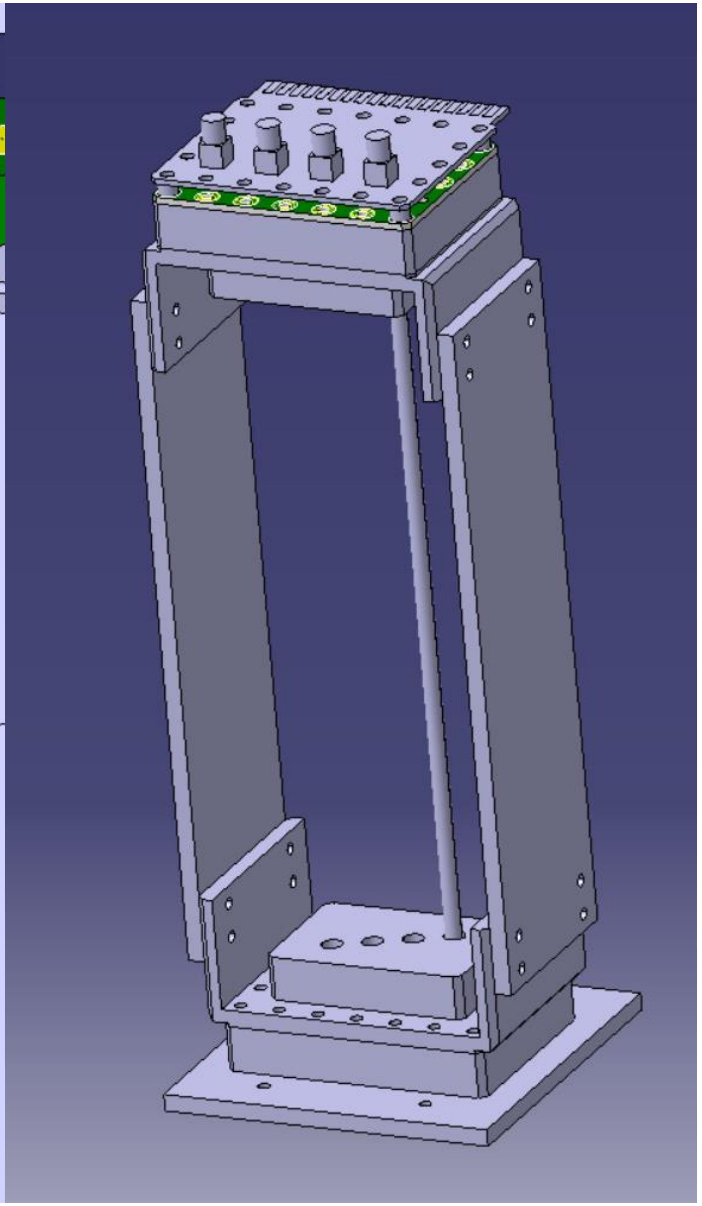
Space charge





Straw based monitor





- **We are assembling a 4-straw demonstrator for testing first with a radioactive source in the lab, and then in IRRAD.**

- **If this proves successful, we will assemble a full-sized prototype (20cm x 20cm).**

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