

Optical fibers for medical accelerators

Senior Scientist | Life Sciences

Cornelia Hoehr



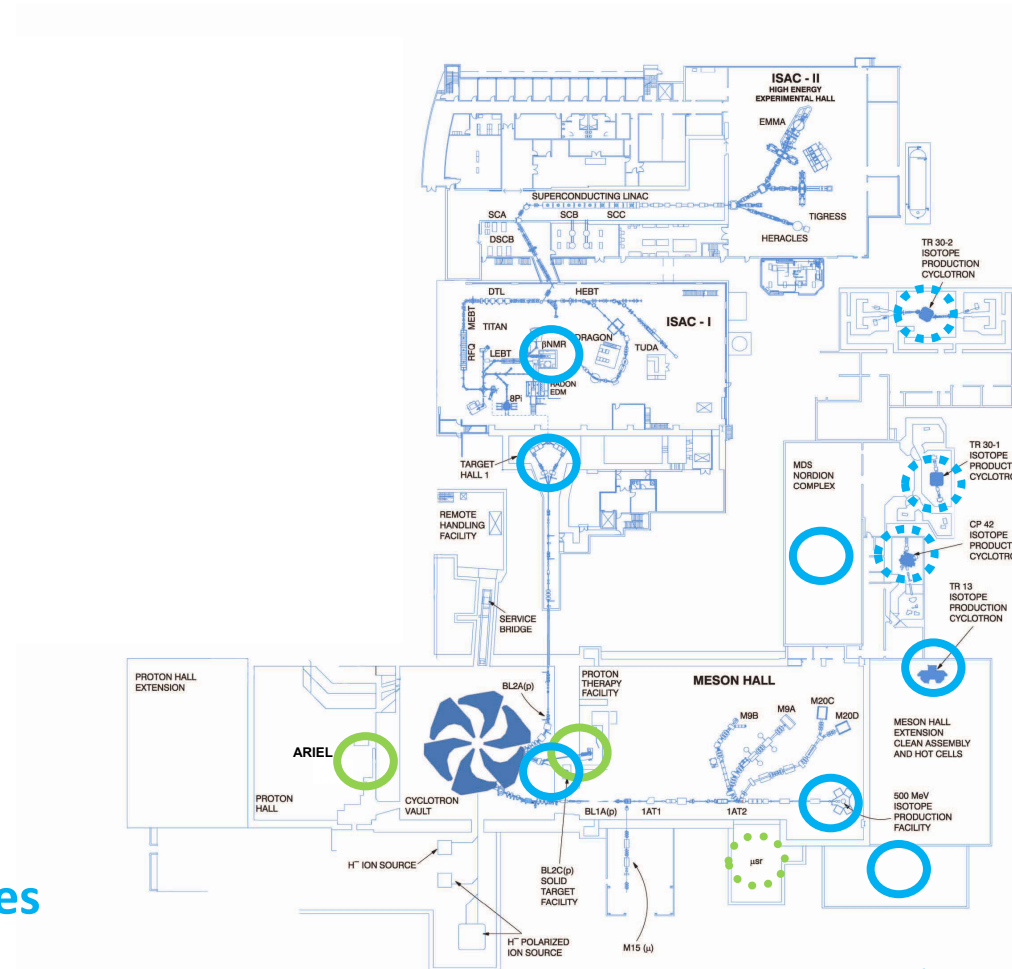
Introduction

TRIUMF - accelerator physics lab

Expertise in

- Accelerator technology
- Accelerator operation
- Detectors
- Targets for isotope production
- Interaction of particles

Applicable to medical isotopes
(and radiotherapy)



Norfolk, Virginia

AccelApp²⁴



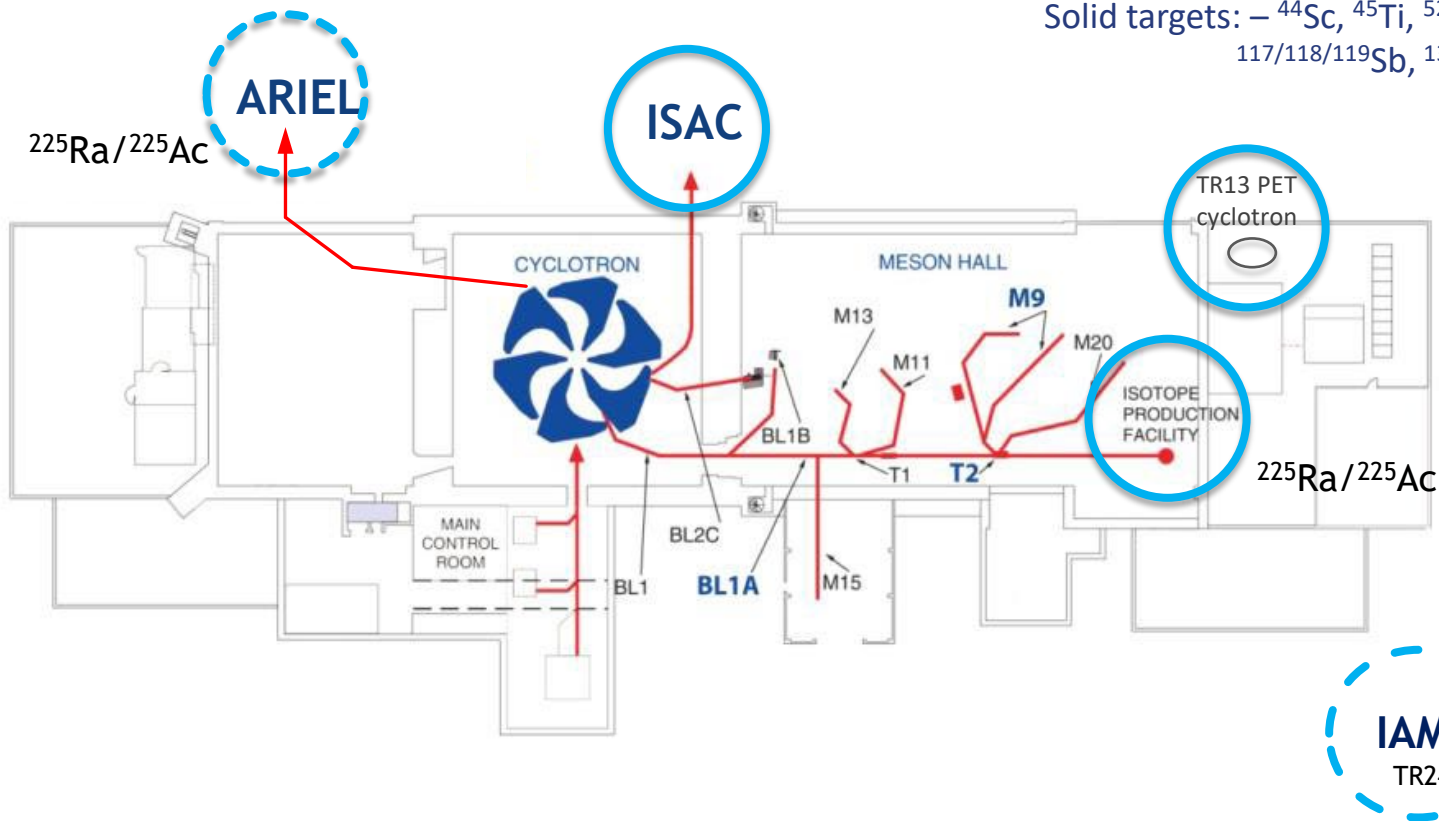
Medical isotopes @ TRIUMF

$^{211/209}\text{At}$, $^{225}\text{Ra}/^{225}\text{Ac}$, ^{224}Ra ,
 ^{165}Er , ^{155}Tb

Gas targets: ^{11}C , ^{18}F

Liquid targets: ^{13}N , ^{18}F , ^{68}Ga , ^{44}Sc , ^{58}Co , $^{61/64}\text{Cu}$, ^{86}Y ,
 ^{89}Zr , $^{94\text{m}}\text{Tc}$, ^{197}Hg

Solid targets: – ^{44}Sc , ^{45}Ti , ^{52}Mn , $^{61/64/67}\text{Cu}$, ^{68}Ga ,
 $^{117/118/119}\text{Sb}$, $^{132/135}\text{La}$, ^{192}Ir , ^{197}Hg , ^{203}Pb

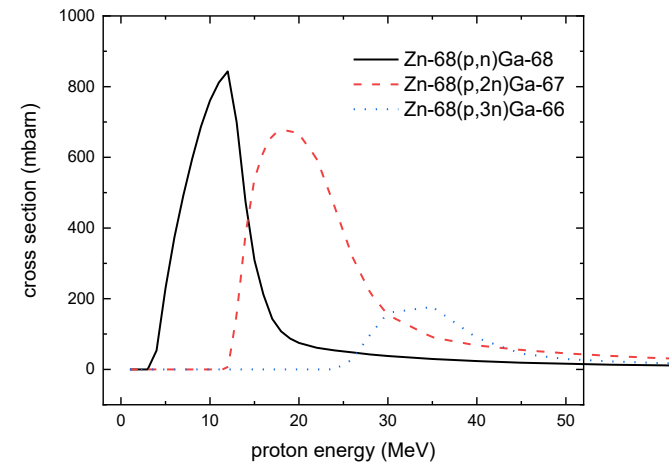
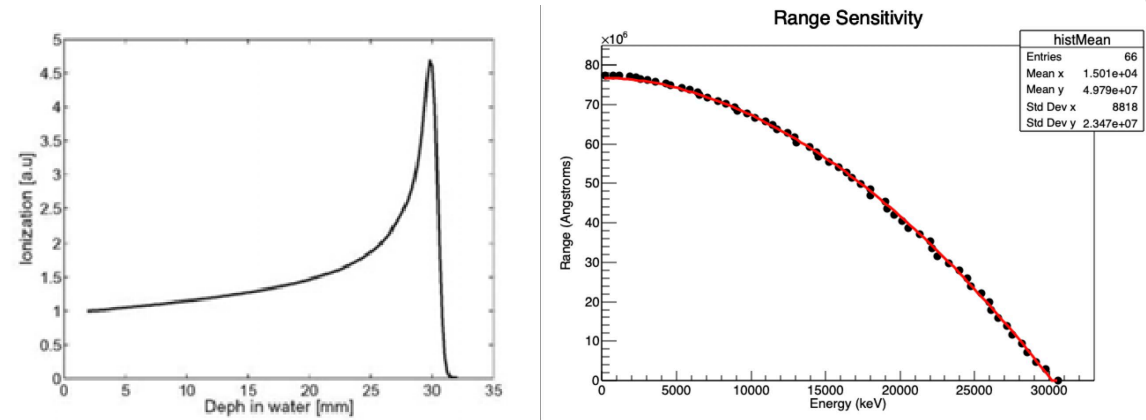




Isotope production

Exercise in compromise:

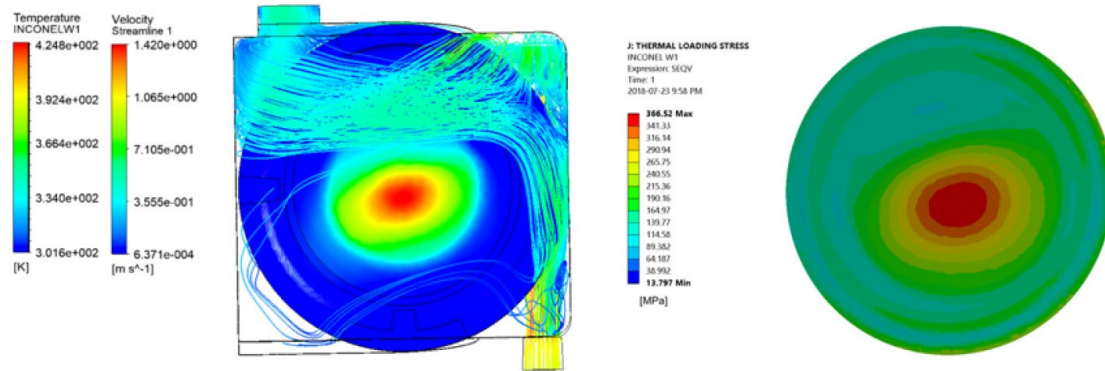
- Beam range (volume of irradiation)
- Cross section(s) (contaminants)
- Target material (gas, liquid, solid, enriched, recycling....)
- Target holder (corrosiveness, cooling, radiation hardness, activation....)





Irradiation modelling

- Temperature, mechanical stress
- Thermodynamics (convection currents, phase changes)
- Yields

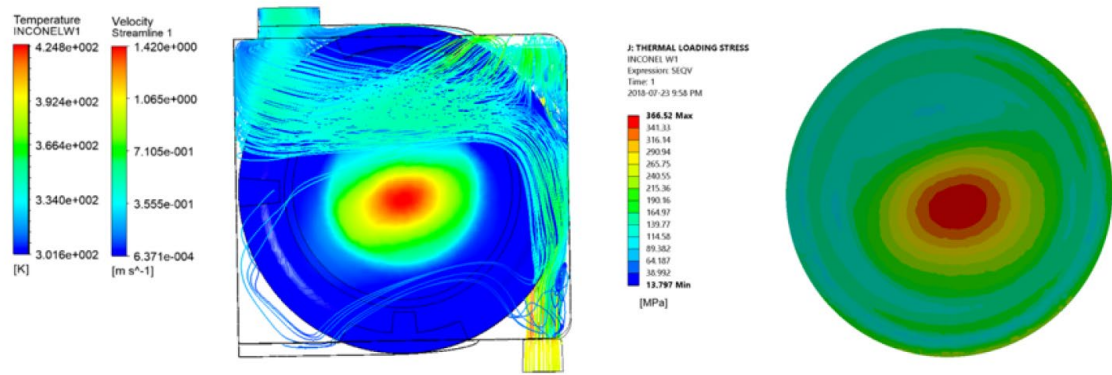
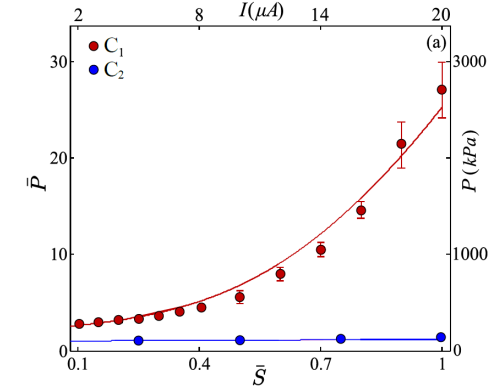
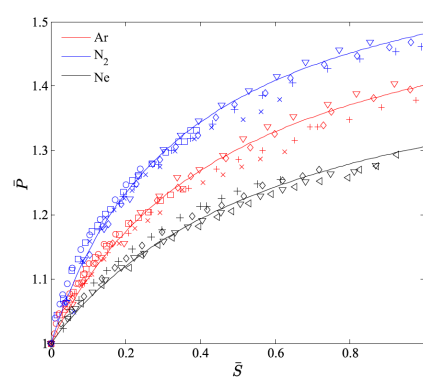


A. Robertson et al., Instruments 3 18 (2019)



Irradiation modelling

- Temperature, mechanical stress
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- Yields



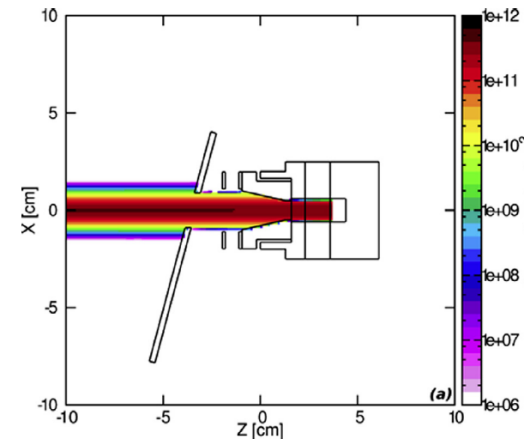
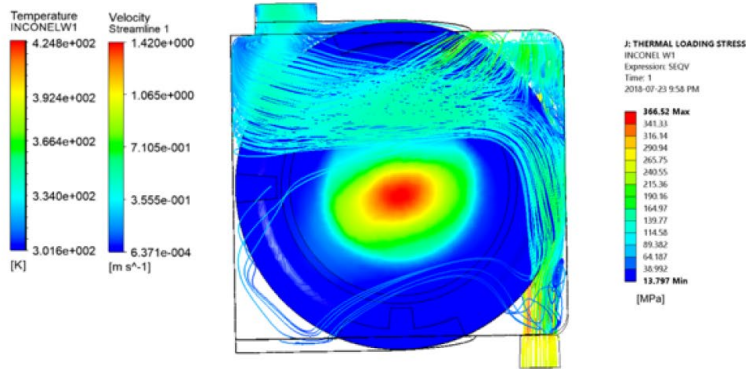
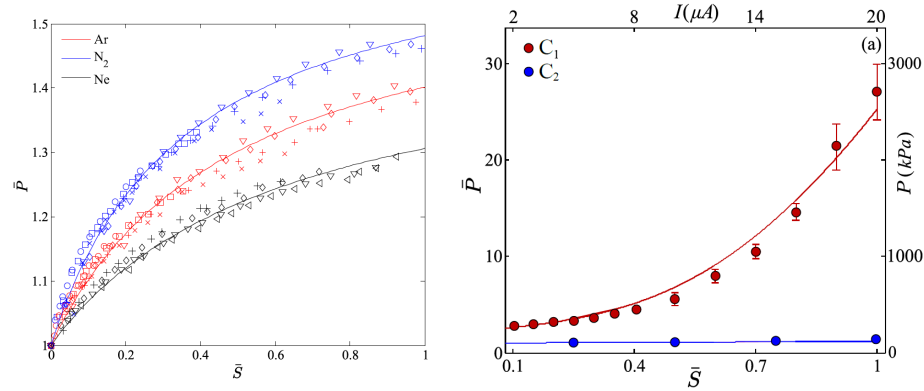
A. Robertson et al., Instruments 3 18 (2019)
P. Jahangiri, et al., Applied Radiation and Isotopes 107 252 (2016)
P. Jahangiri, et al., Applied Radiation and Isotopes, 120 22 (2017)





Irradiation modelling

- Temperature, mechanical stress
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- Yields

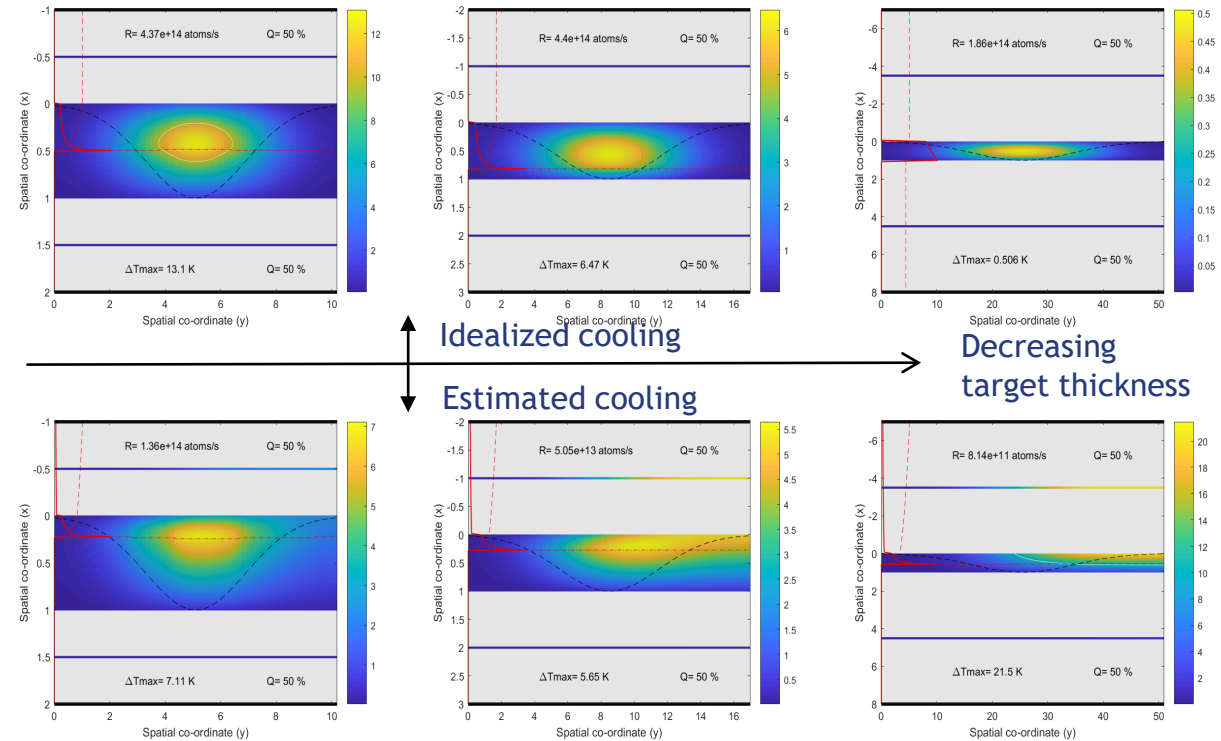


A. Robertson et al., Instruments 3 18 (2019)
 P. Jahangiri, et al., Applied Radiation and Isotopes 107 252 (2016)
 P. Jahangiri, et al., Applied Radiation and Isotopes, 120 22 (2017)
 A. Infantino et al., NIM B 366 117 (2016)



Irradiation modelling

- **One model:** temperature, mechanical stress, thermodynamics (convection currents, phase changes), yields
- Local observables needed for validation





Monitors

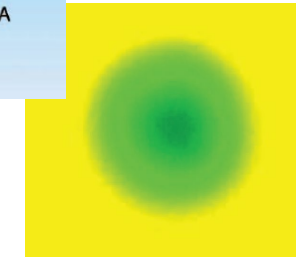
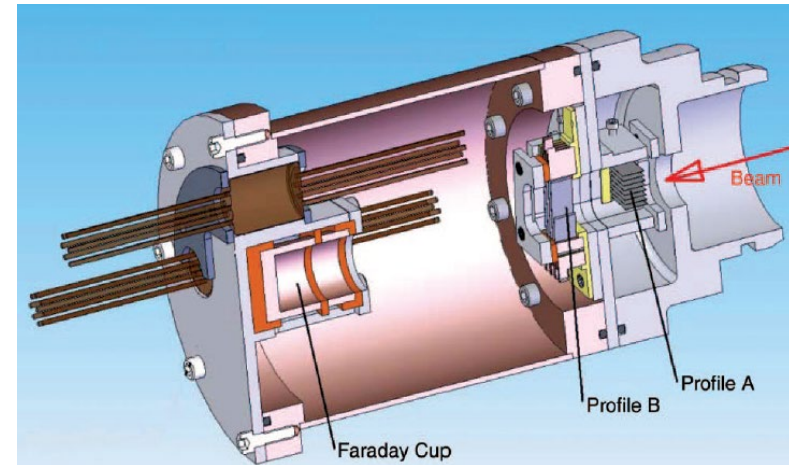
- Small (spatial resolution, limited space)
- Radiation hard
- Temperature
- Pressure
- Real time
- Dose (photons, protons, neutrons)
- Ionizing radiation (beam alignment)
- Independent of environment
(electromagnetic field, temperature, light)





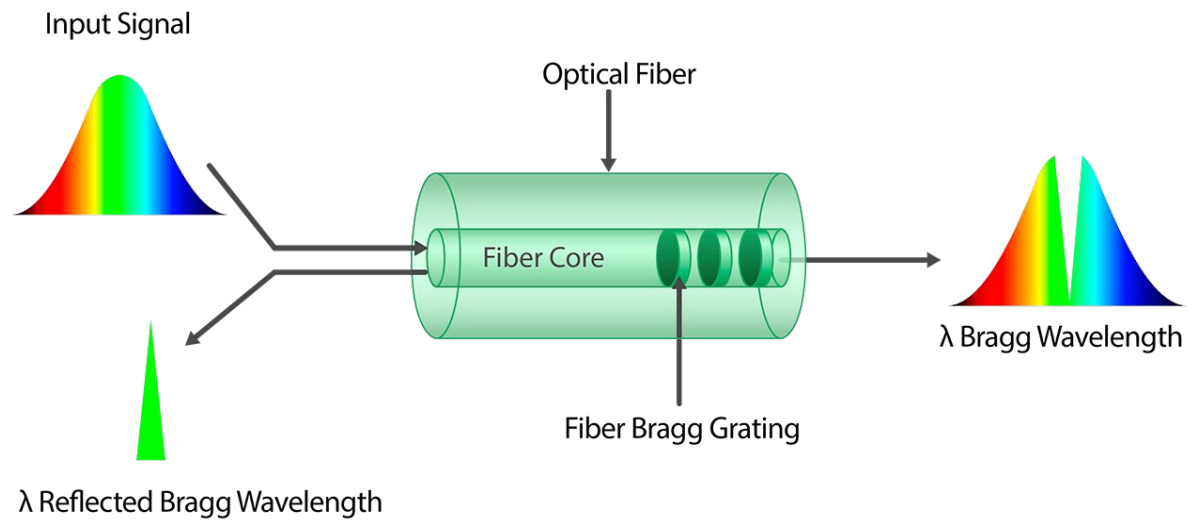
Monitors

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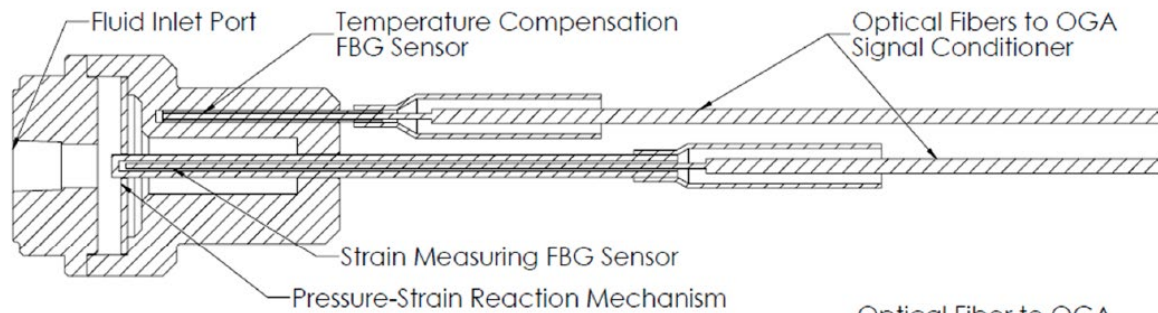


- Pressure transducers (global)
- Thermocouple (global)
- Beam monitors
- Radiochromic films
- Optical fibers?

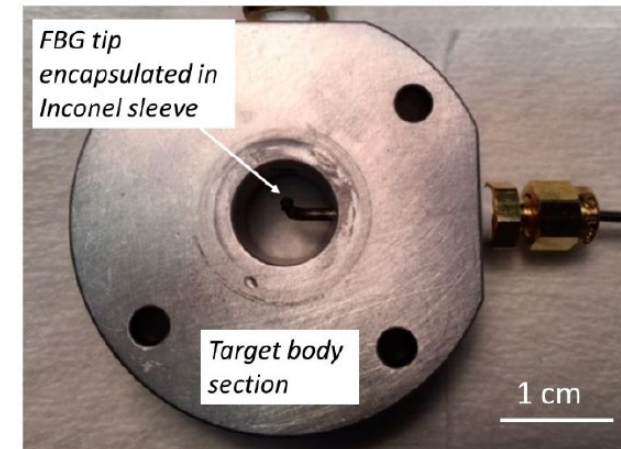
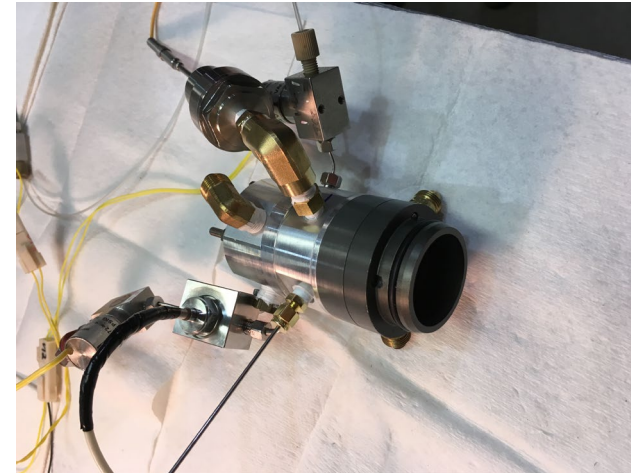
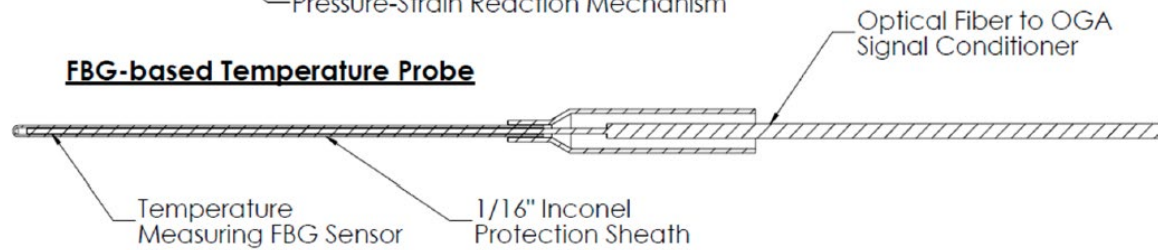
- Localized temperature/pressure unknown in gas/liquid targets – often only global measured
- Silica fibers with grating are radiation ‘hard’
- Can measure temperature to 0.1 °C, up to 1000 °C

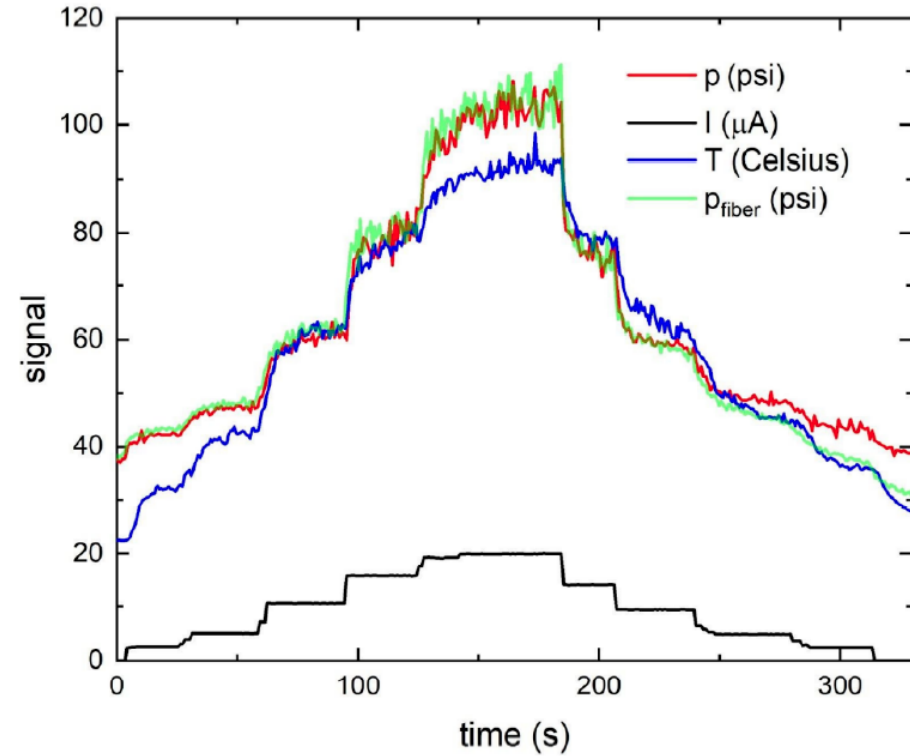
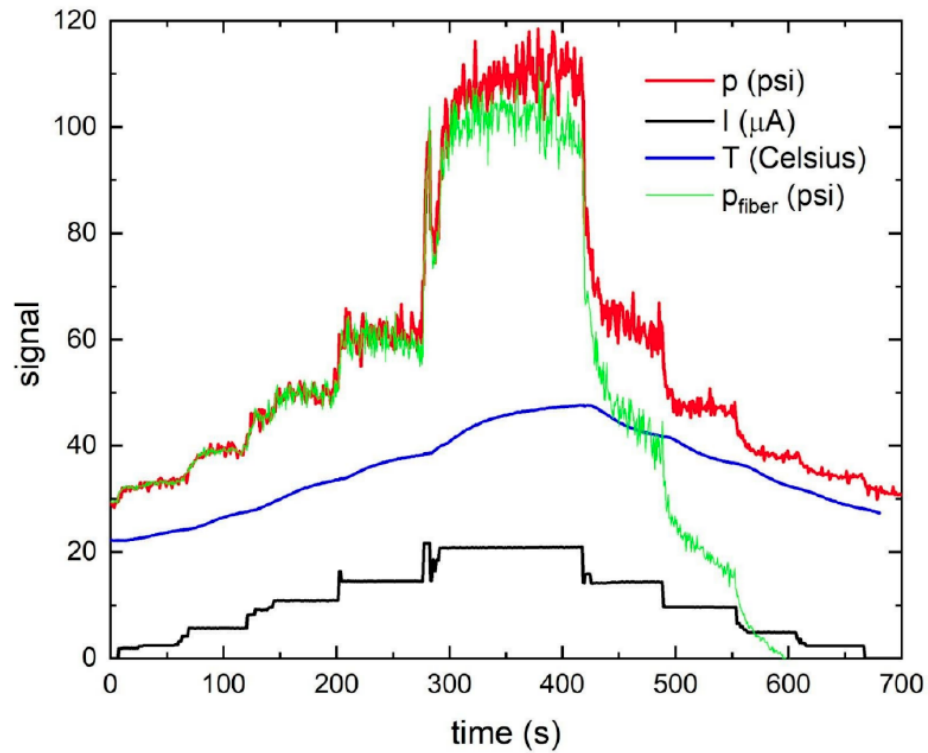
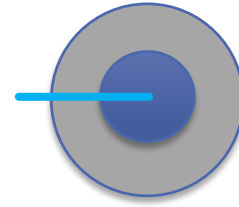
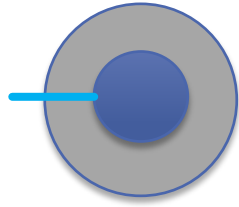


FBG-based Pressure Transducer



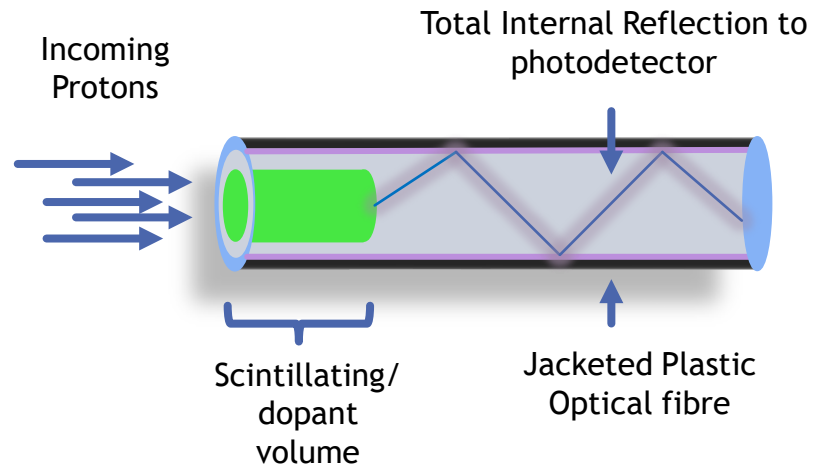
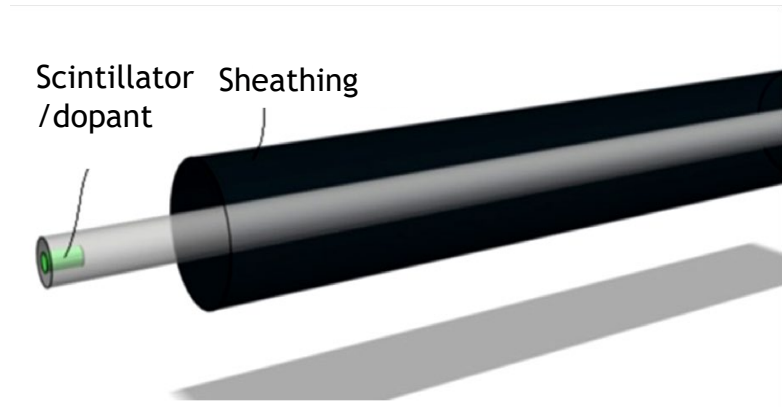
FBG-based Temperature Probe







Optical Fibers – Ionizing radiation



Organic fibers (PMMA)

- $Gd_2O_2S:Tb$
- $Gd_2O_2S:Eu$
- YVO_4
- $Y_2O_2S:Eu$
- $Y_2O_3:Eu$
- EJ_{260}
- Kuraray

Inorganic fibers (silica)

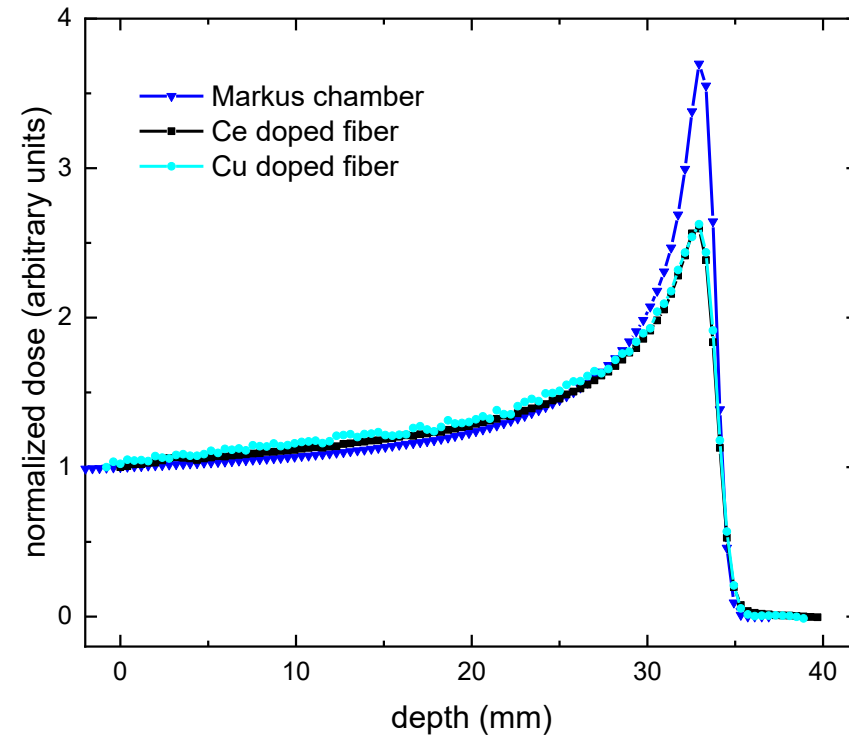
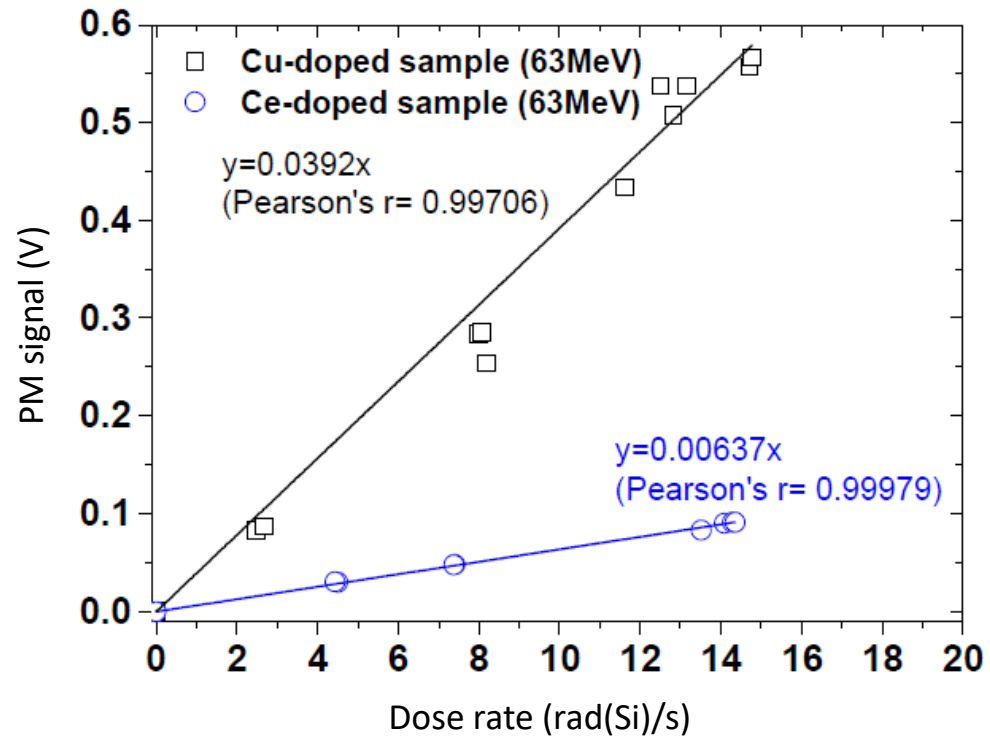
- Ce-doped
- Cu-doped
- Gd-doped
- N-doped
- Ge-doped
- B-doped





Optical Fibers – Ionizing radiation

Light output or light attenuation
proportional to absorbed dose



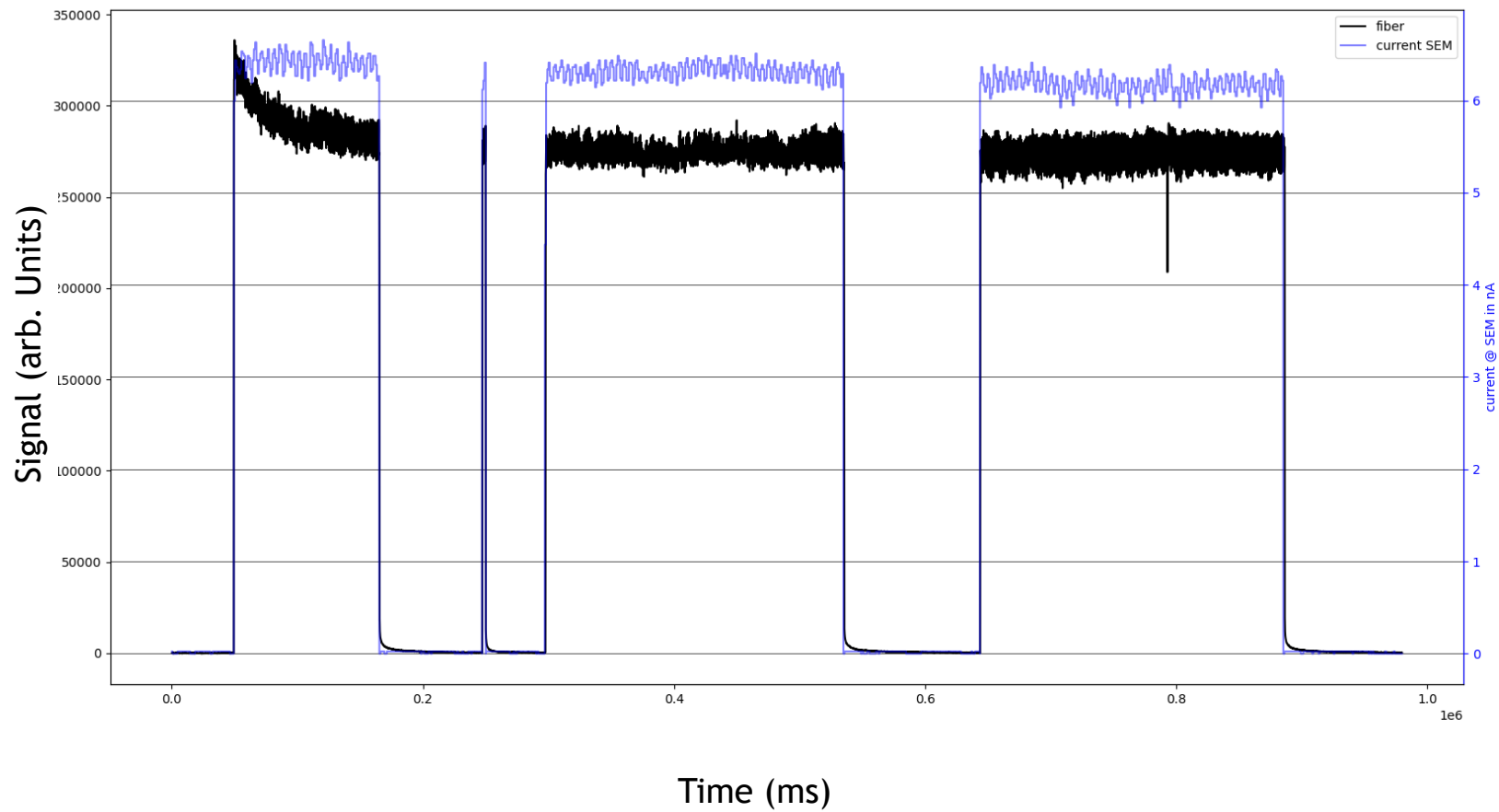
Norfolk, Virginia

AccelApp²⁴



Optical Fibers – Ionizing radiation

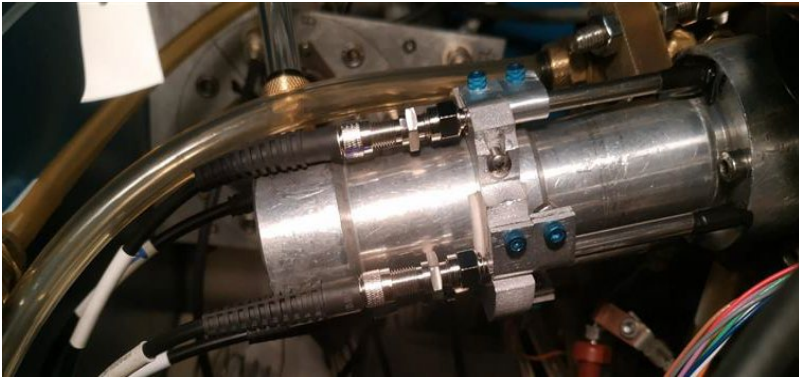
Radiation hardness



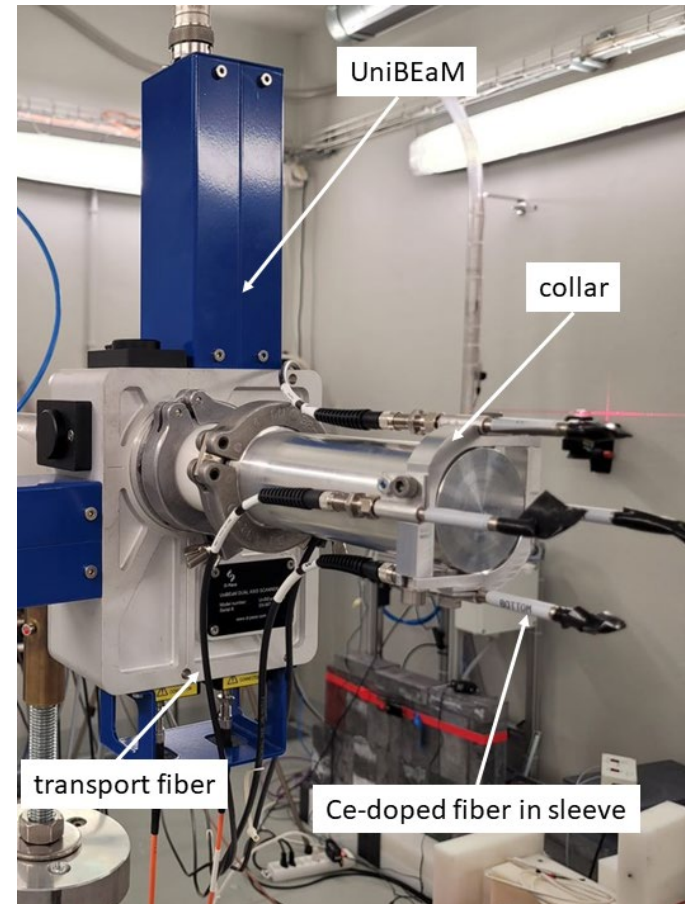


Beam monitoring

TR13 cyclotron, TRIUMF



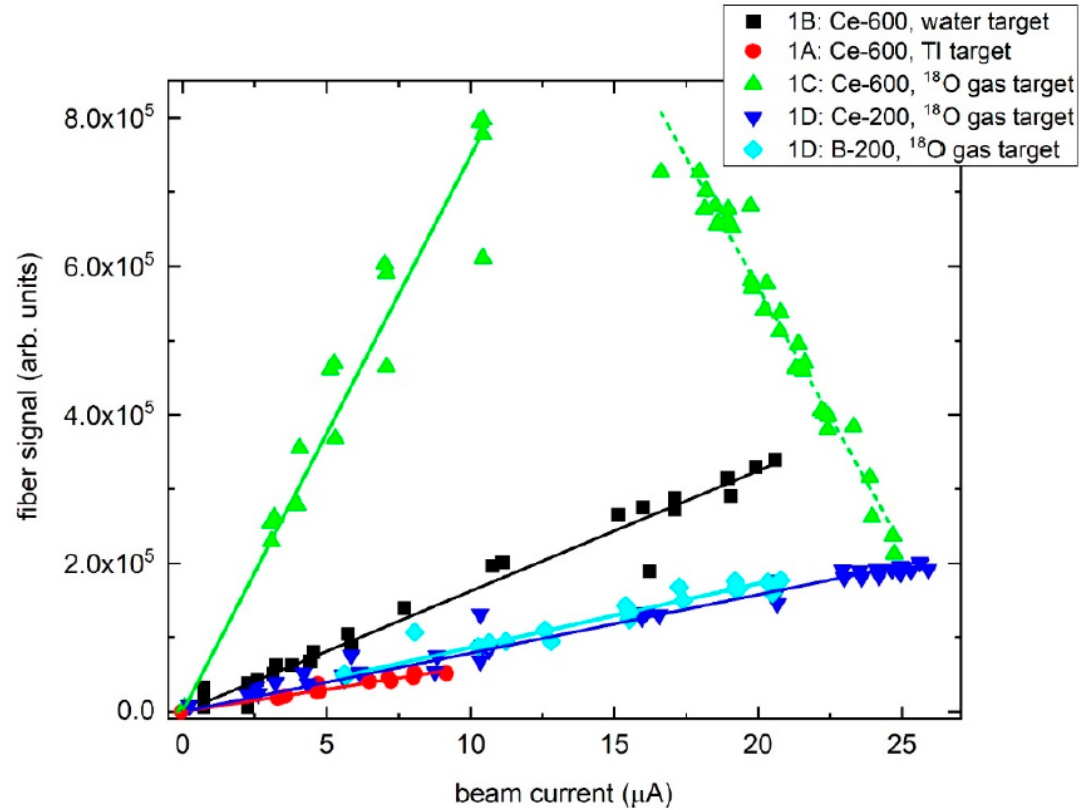
18 MeV IBA cyclotron, U Bern



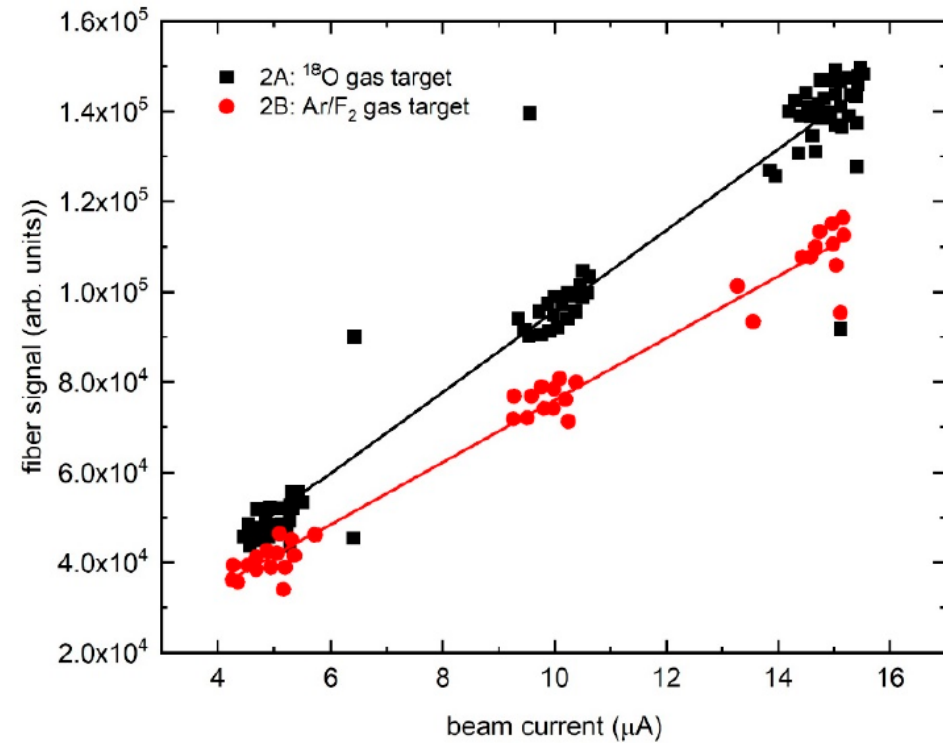


Beam monitoring

Beam current



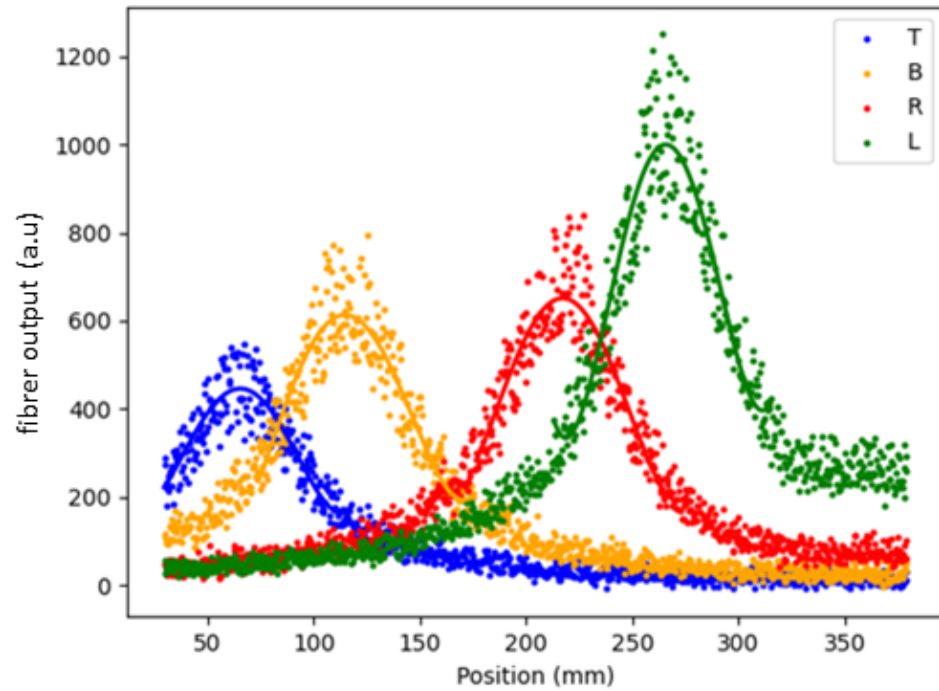
Target material



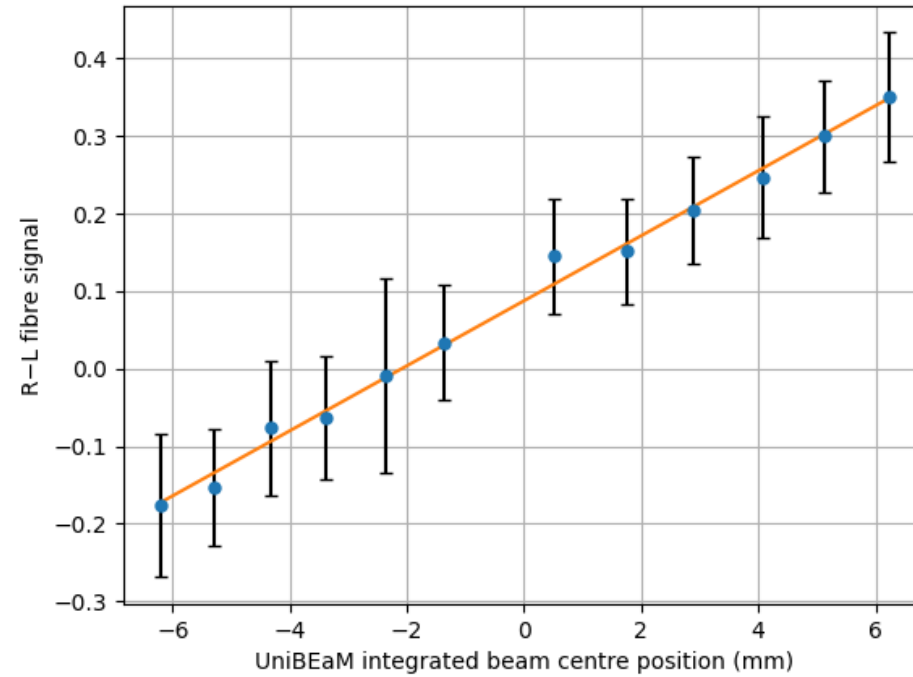


Beam monitoring

Channel calibration



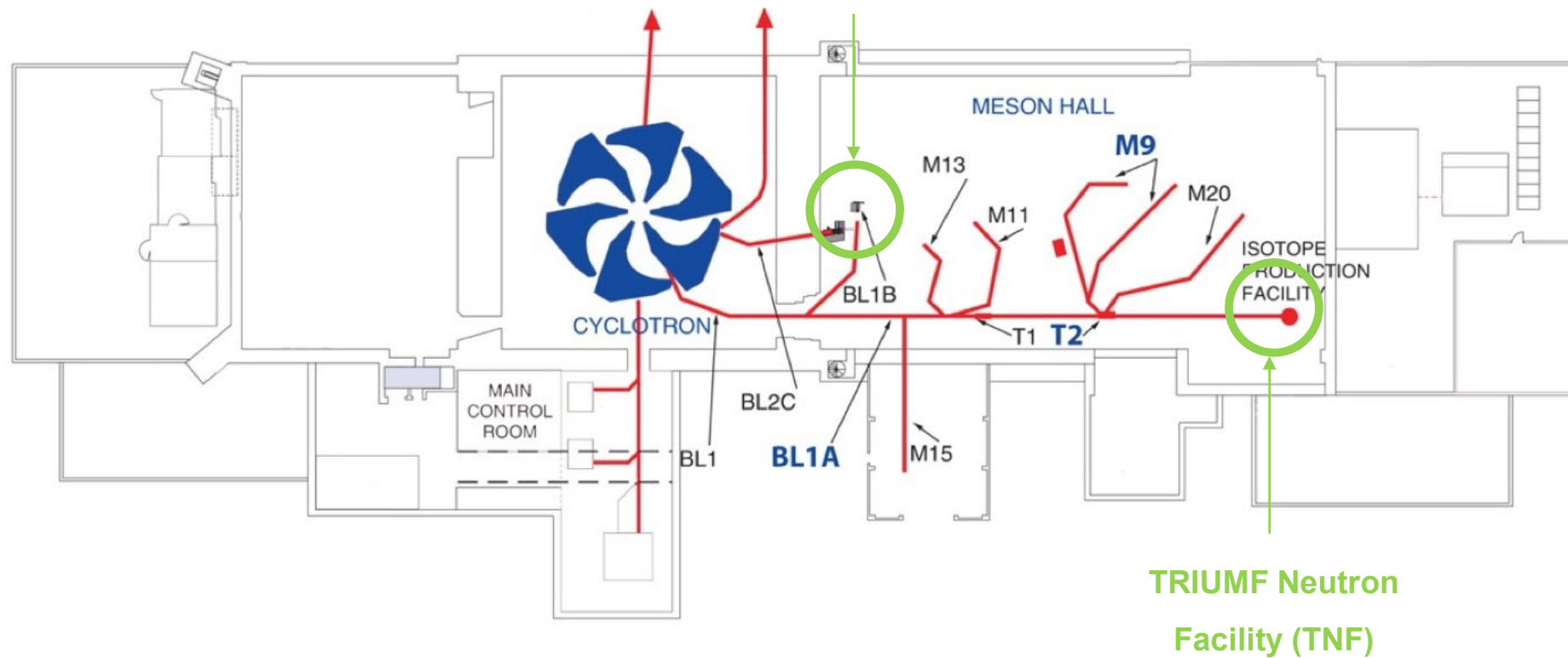
Beam alignment





Particle Discrimination

Proton Therapy Research Center (PTRC)



TRIUMF Neutron Facility (TNF)

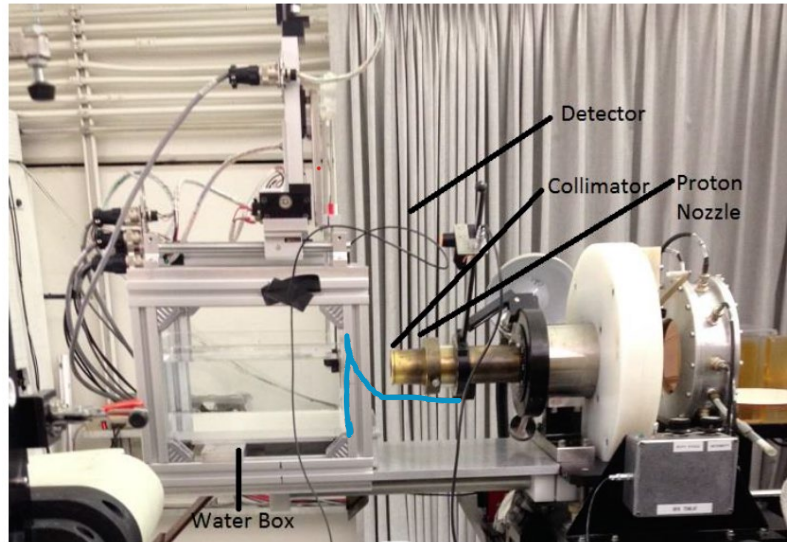


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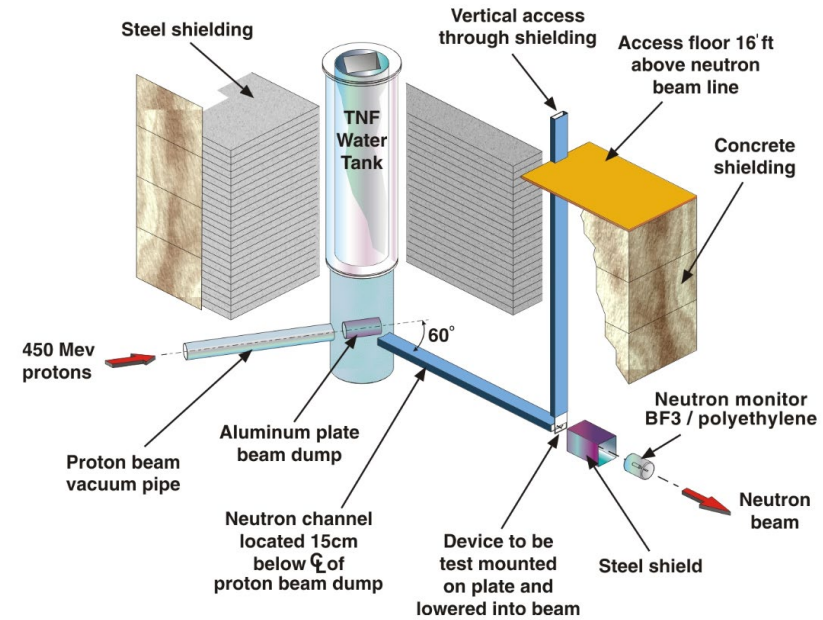
AccelApp'24



Particle Discrimination



PTRC - protons (with photons & neutrons)



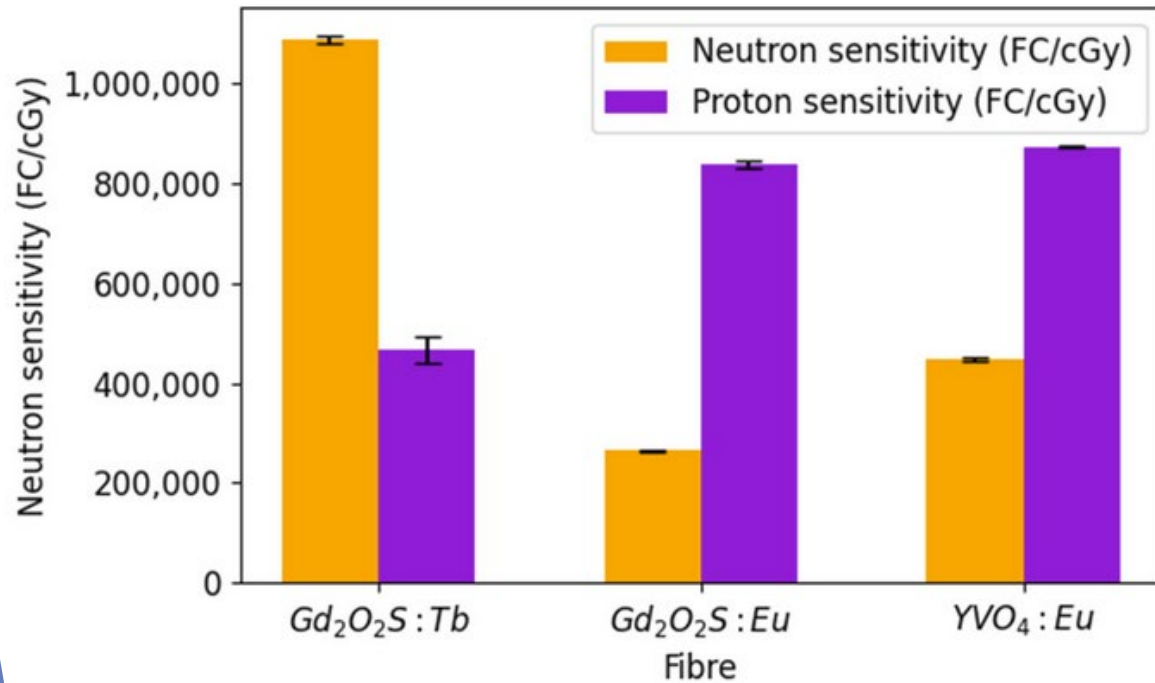
TNF - neutrons (with photons)





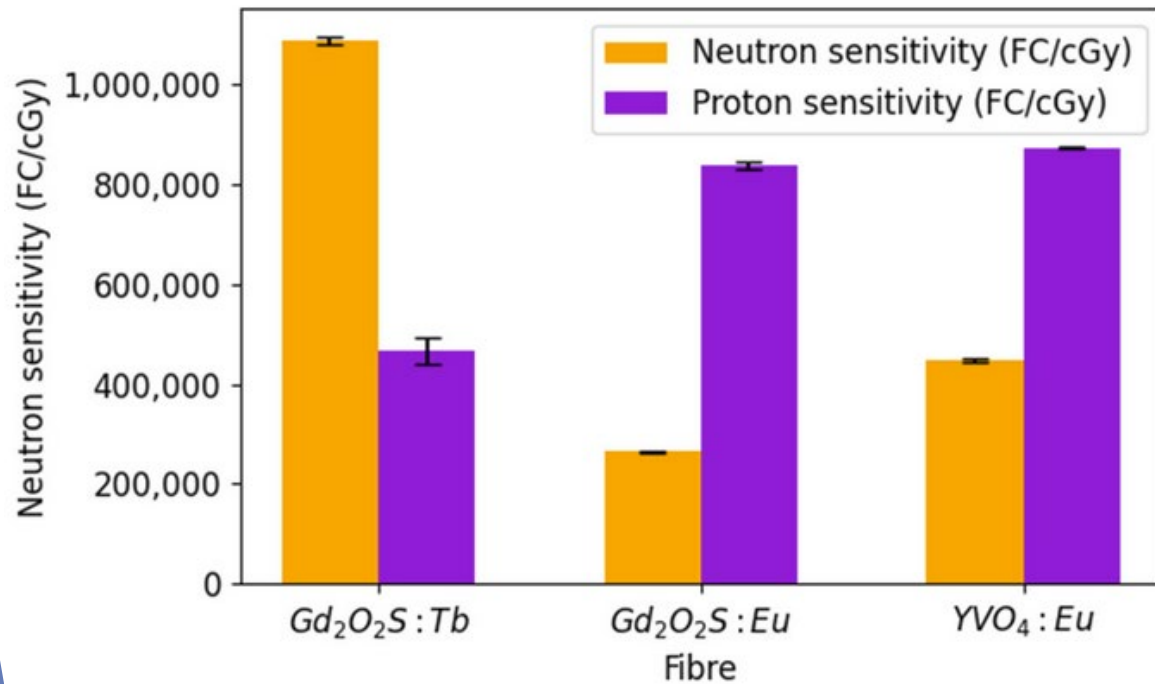
Particle Discrimination

Total signal discrimination

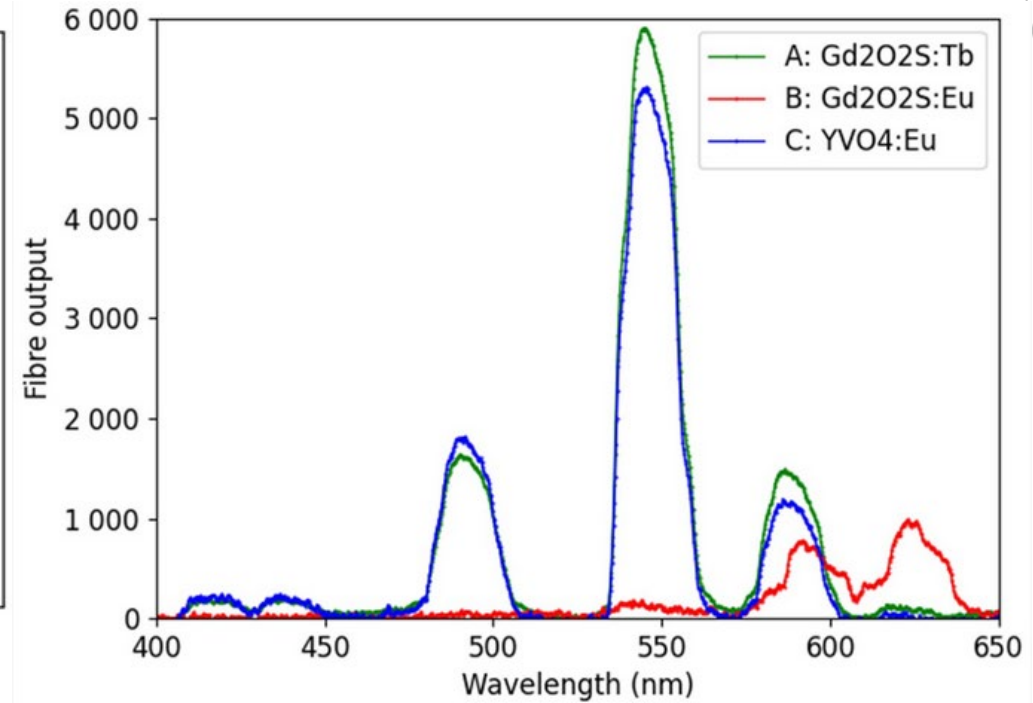




Total signal discrimination



Spectrometric discrimination



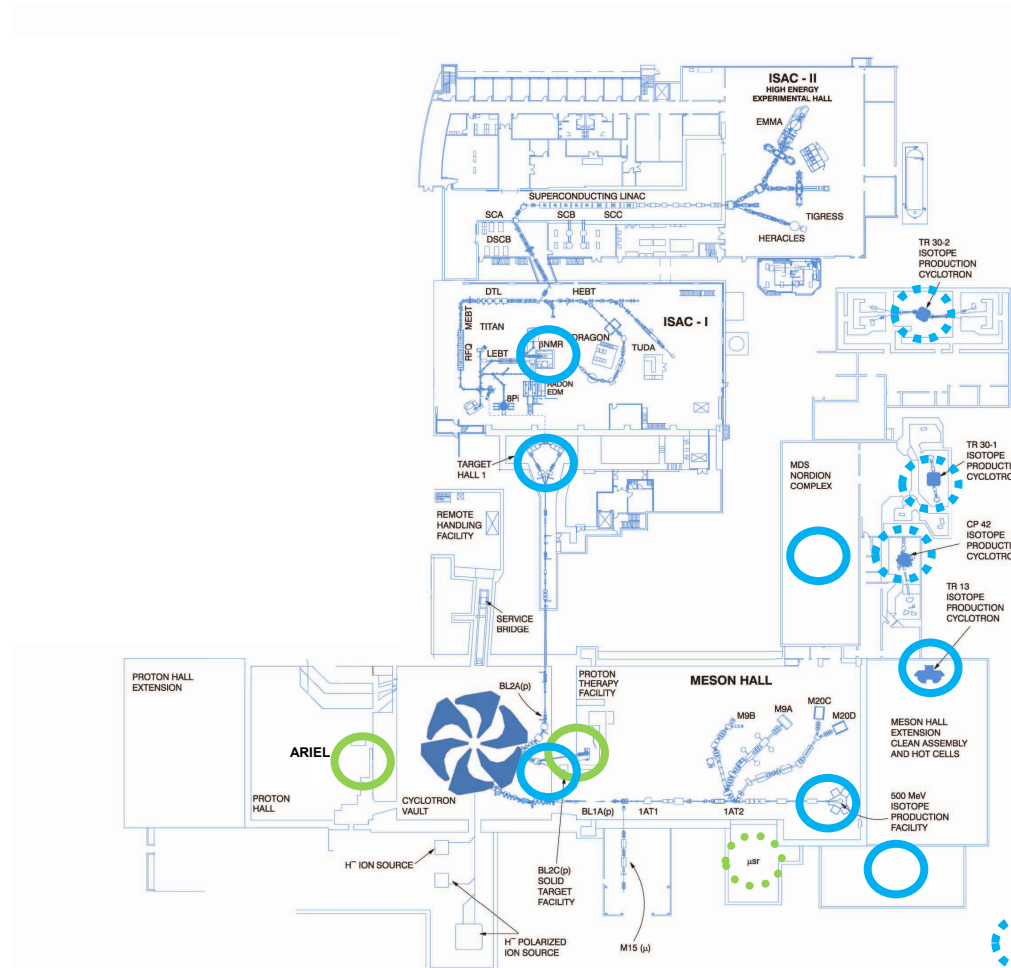


Summary

Fibers potentially monitor for isotope production targets to measure:

- ✓ Local temperature
- ✓ Local pressure
- ✓ Beam current
- ✓ Target material
- ✓ Beam alignment
- ✓ Particle discrimination

Goal: Establish combined target-irradiation model



Norfolk, Virginia

AccelApp²⁴

- TRIUMF: Matthew Hannah, Samuel Usherovich, Jana Niedermeier, Crystal Penner, Janina Hohnholz, Grace Dehnel, Stefan Zeisler, Camille Belanger-Champagne, Mike Trinczek
- Michael Bakaic (FIBOS, Toronto, ON) – fiber gratings
- Morgan Dehnel (D-Pace, Nelson, BC) – fibre monitor
- Saverio Braccini (University of Bern) – fibre monitor
- Cheryl Duzenli (BC Cancer, Vancouver) - dosimetry
- Sinead O’Keeffe (Limerick, Ireland) – organic fibers
- Sylvain Girard (St.Etienne, France) – inorganic fibers

Thank you!
Merci!

