Medical applications of particle physics

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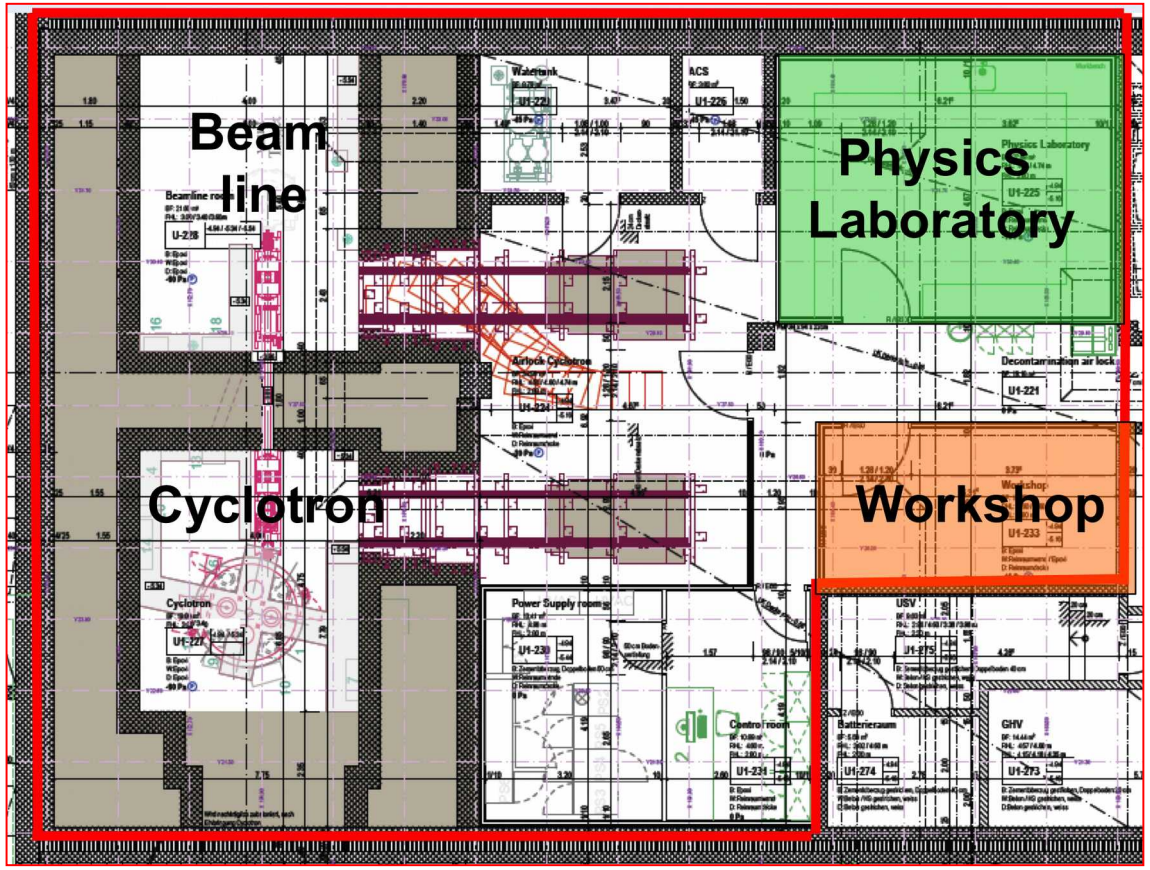
Laboratory for High Energy Physics (LHEP)
University of Bern

Outline

- Bern medical cyclotron as a facility for multidisciplinary science
- Theranostics and cross section measurements
- Developments on novel particle detectors
- Neutrons at the Bern cyclotron
- FLASH radiation therapy and a novel dosimeter (PROOF project)

The Bern medical cyclotron

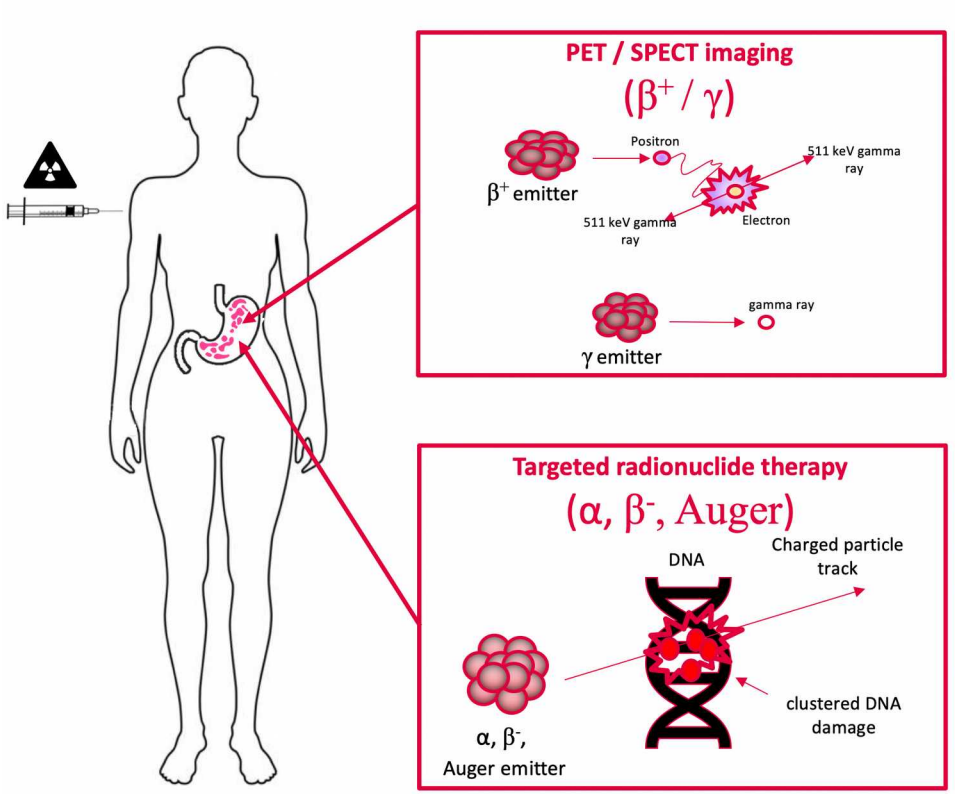


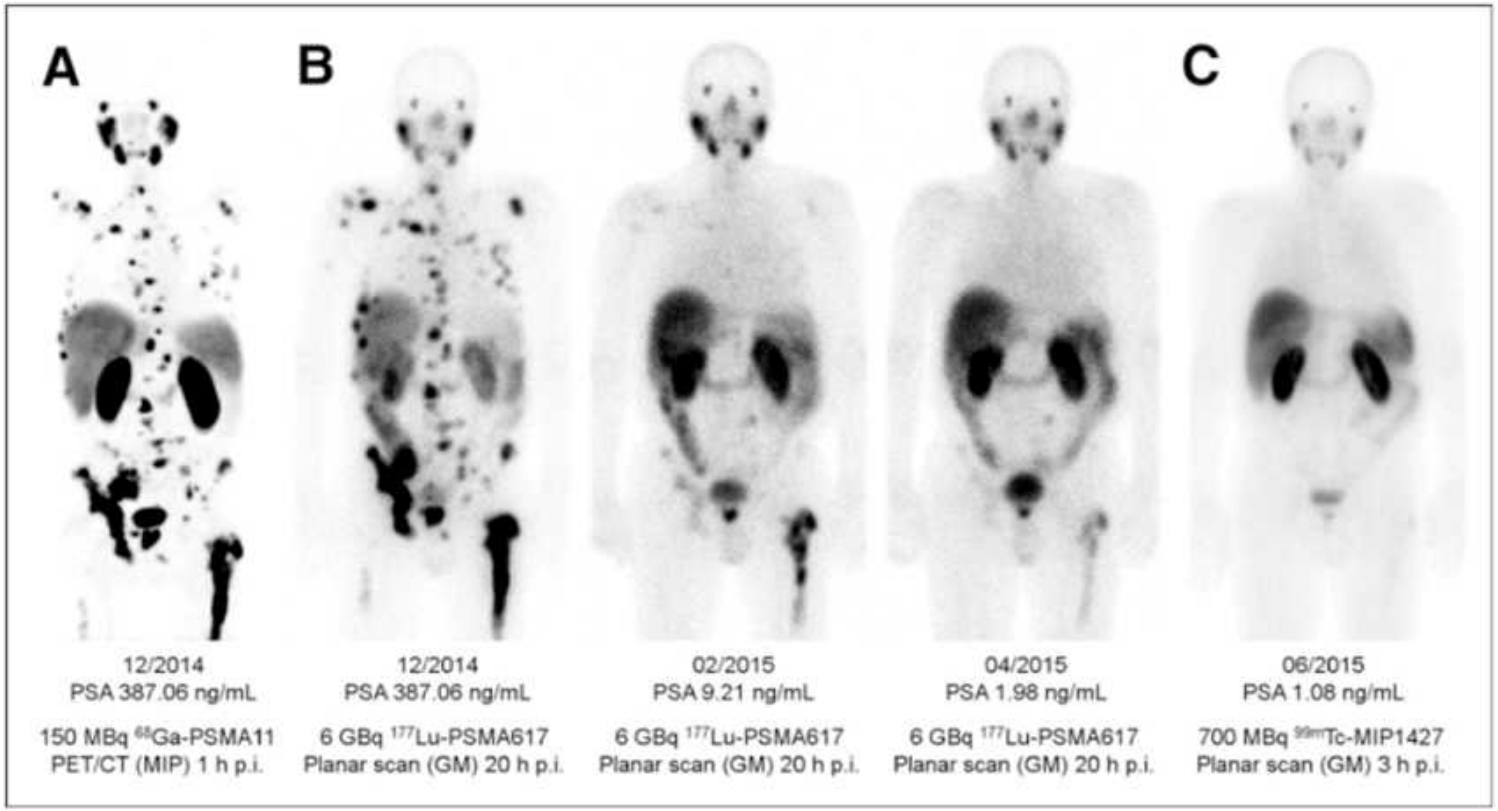
Cancer treatment with radiation: the theragnostic approach

- Surgery
- Chemotherapy
- Ionizing radiation

→ External Beam Radiation Therapy (EBRT)

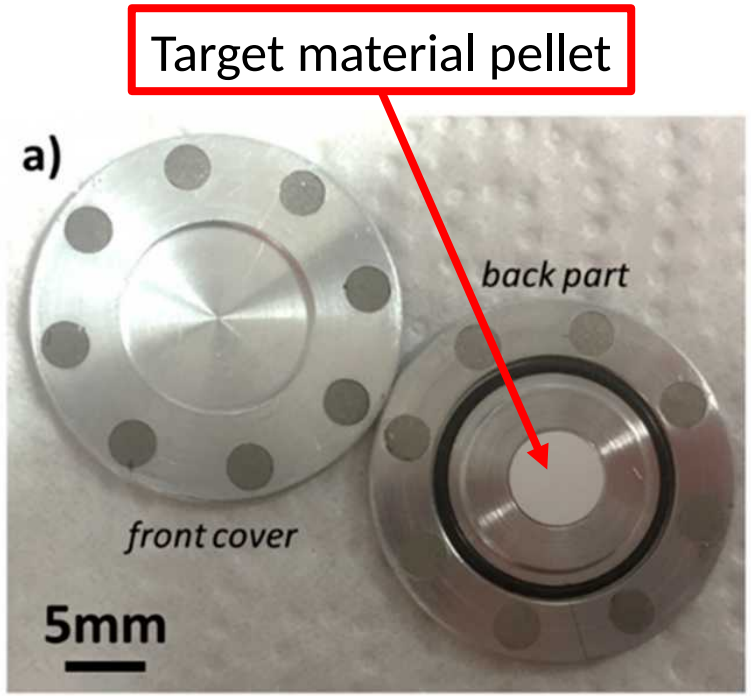
→ Targeted Radionuclide Therapy (TRT)



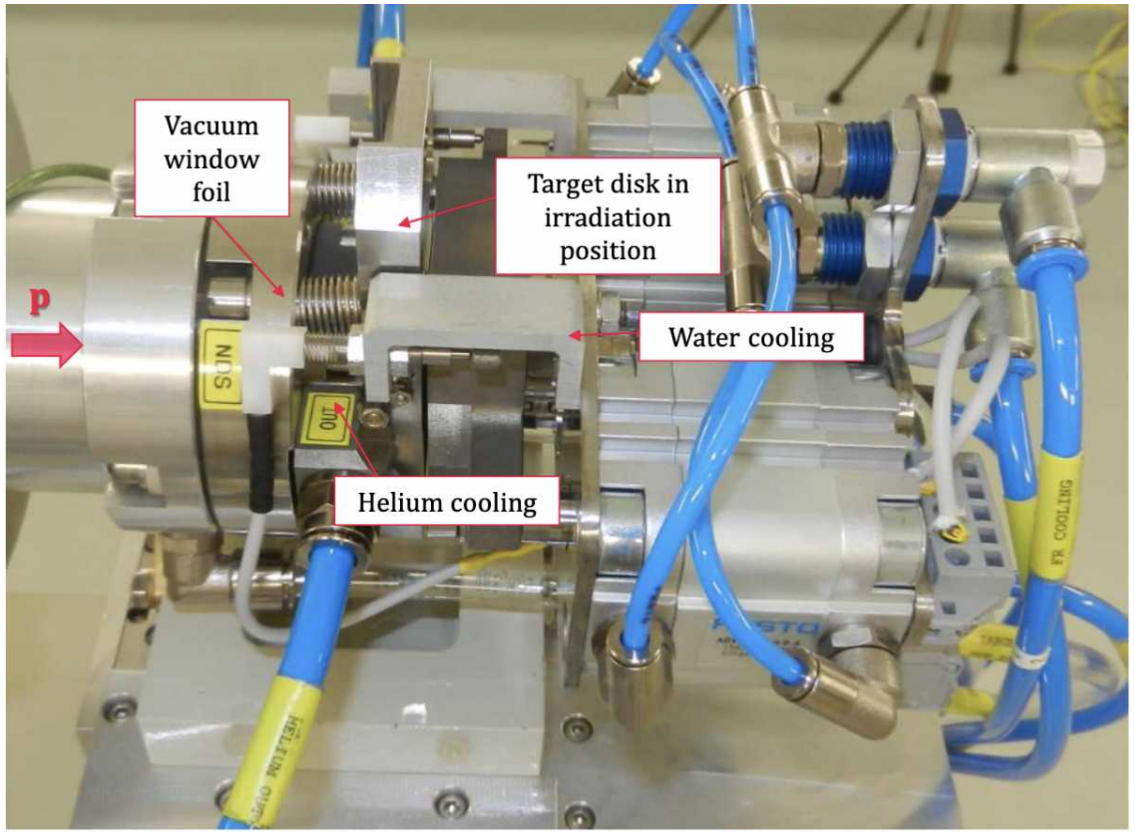


The target “coin” and the Solid Target Station (STS)

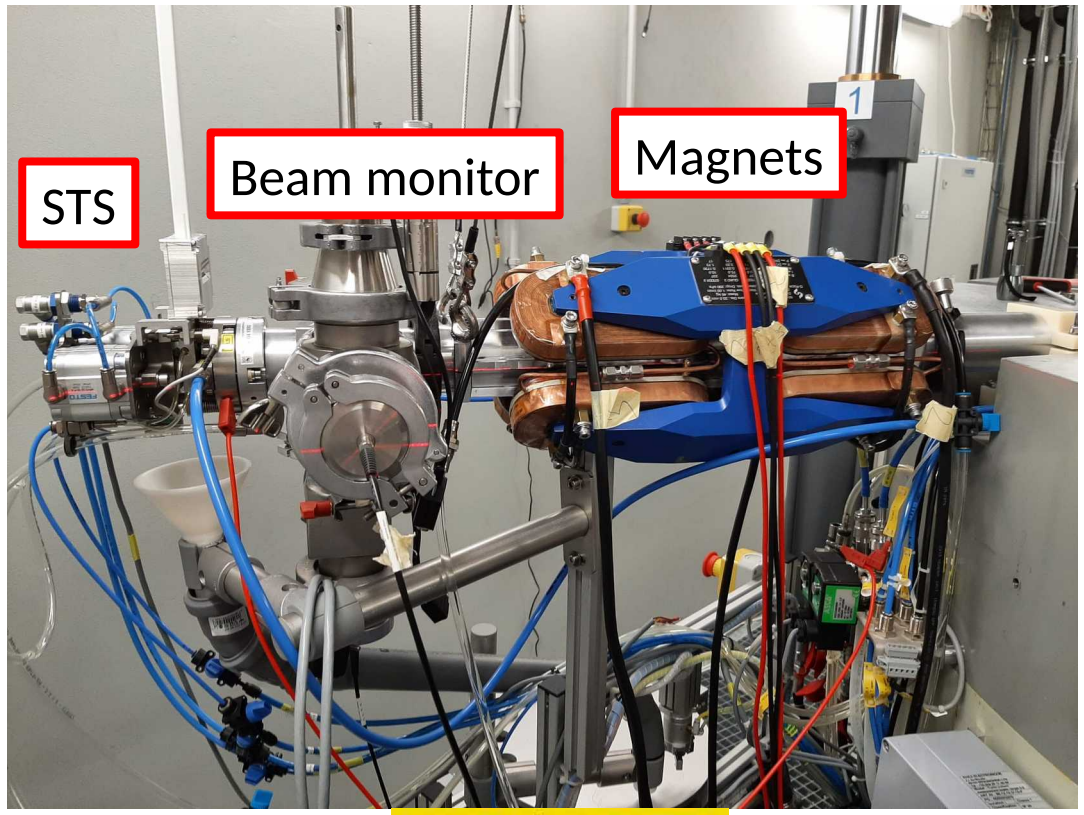
- Proton bombardment of solid targets
- 6 mm compressed powder pellets
- Coin produced by LHEP



- Compact Solid Target Station (STS)



Toward optimized radioisotope production: Automatic Focusing System (AFS)



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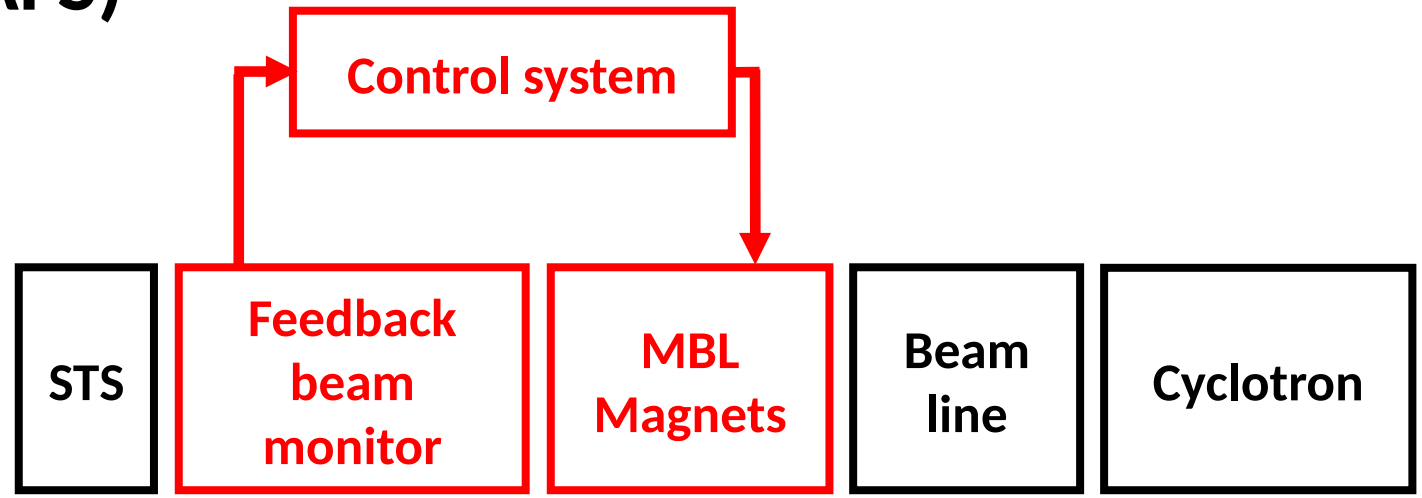
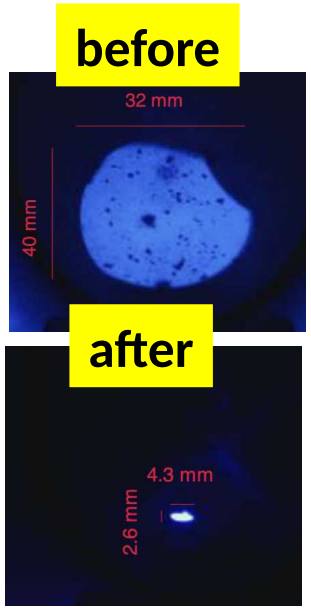
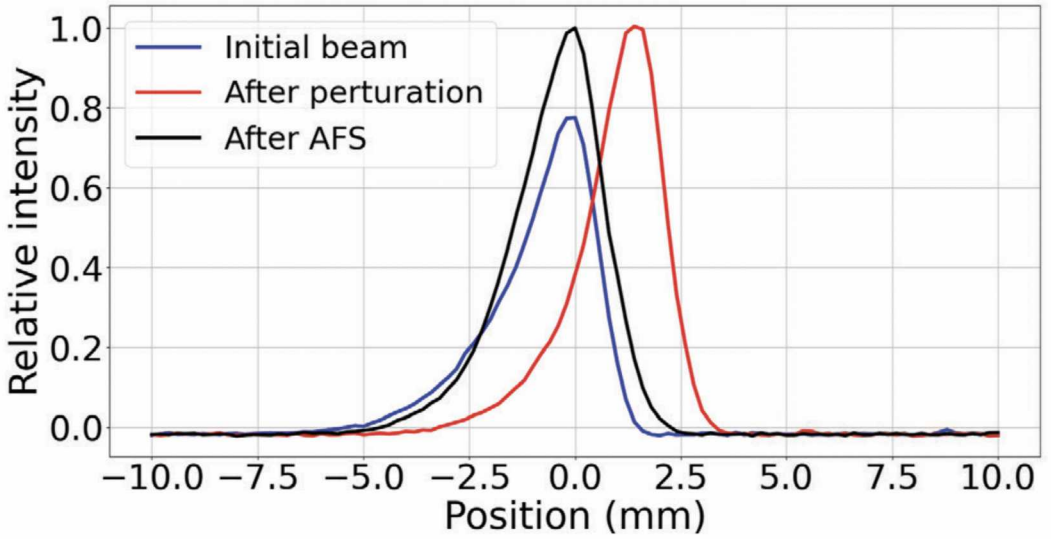
LHEP
UNIVERSITÄT BERN



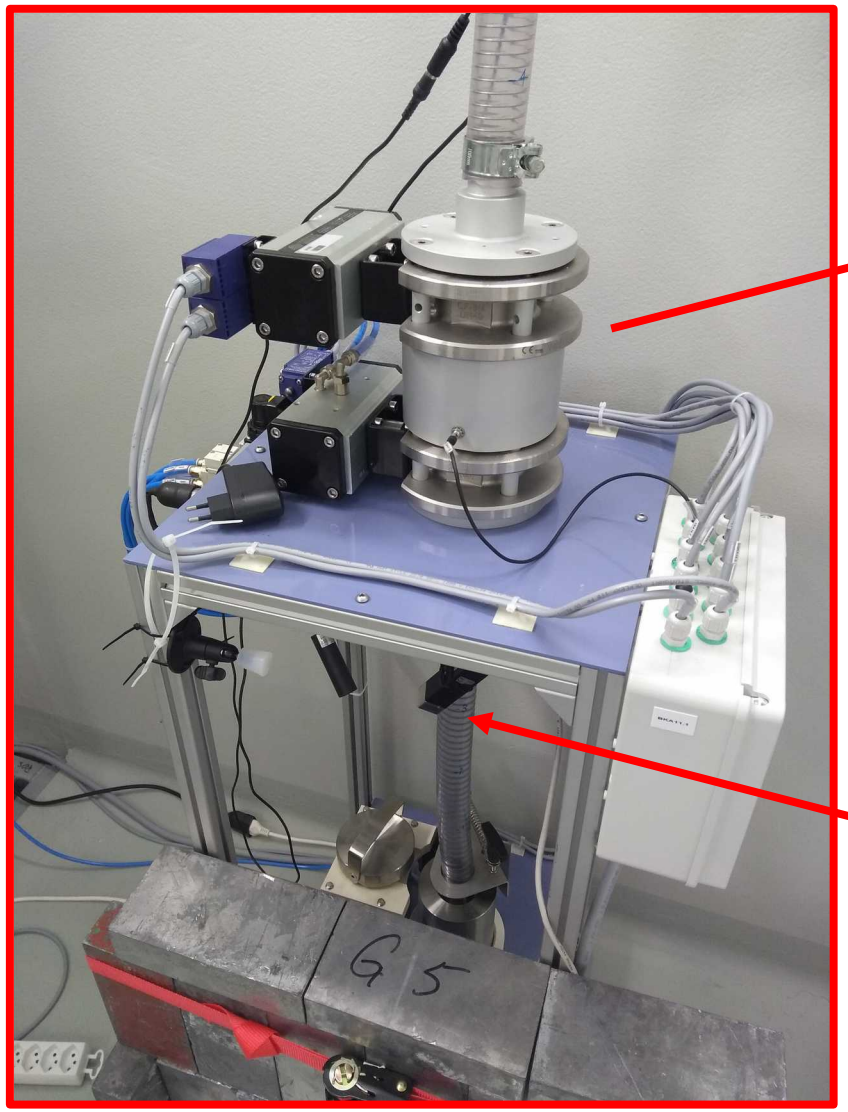


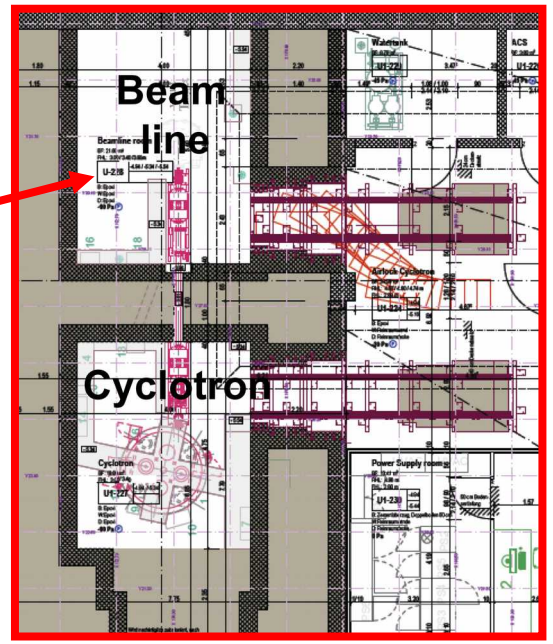


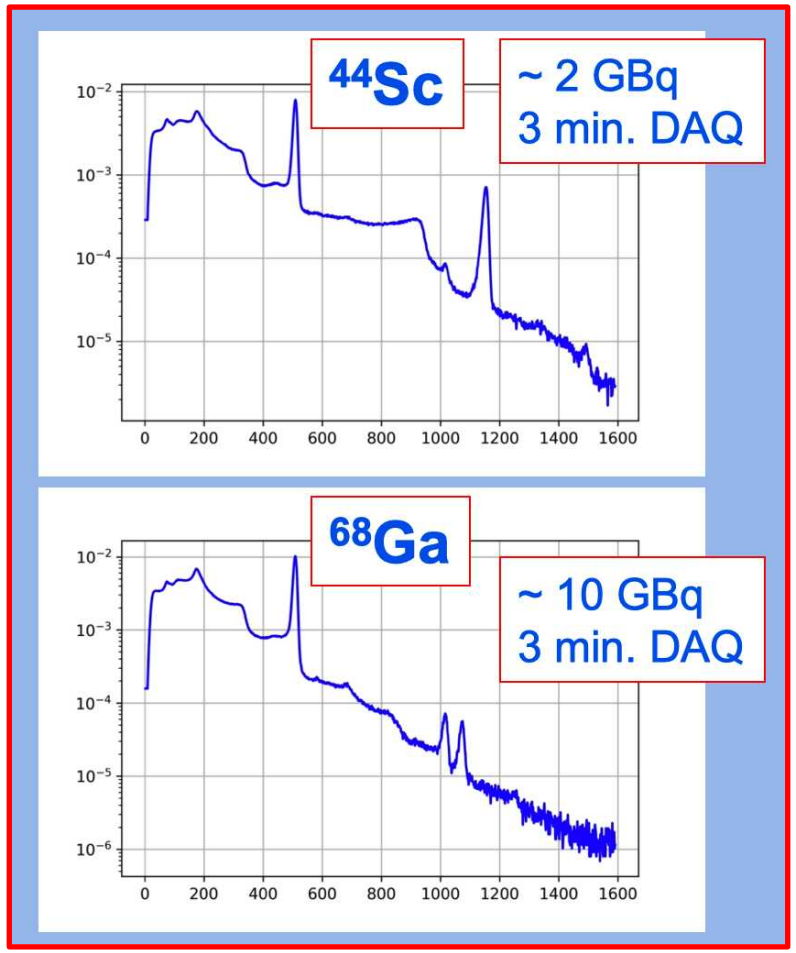
P. Haffner et al., Appl. Sci. 11.6 (2021): 2452
P. Casolaro et al., IBIC2021

The hyperloop by LHEP

The receiving station and the CZT detector



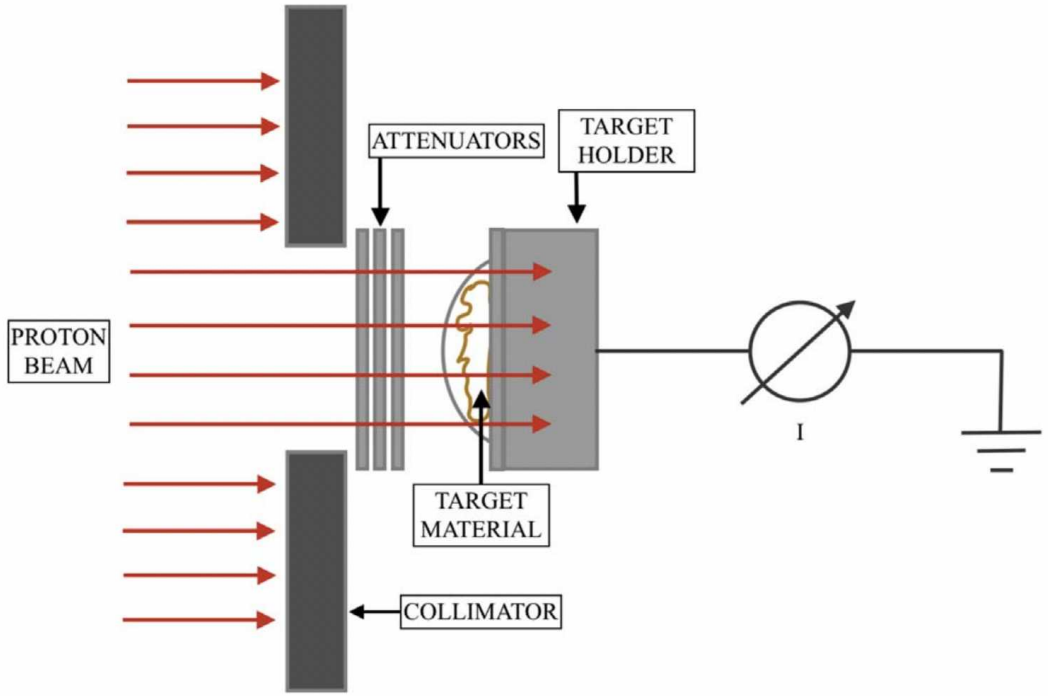




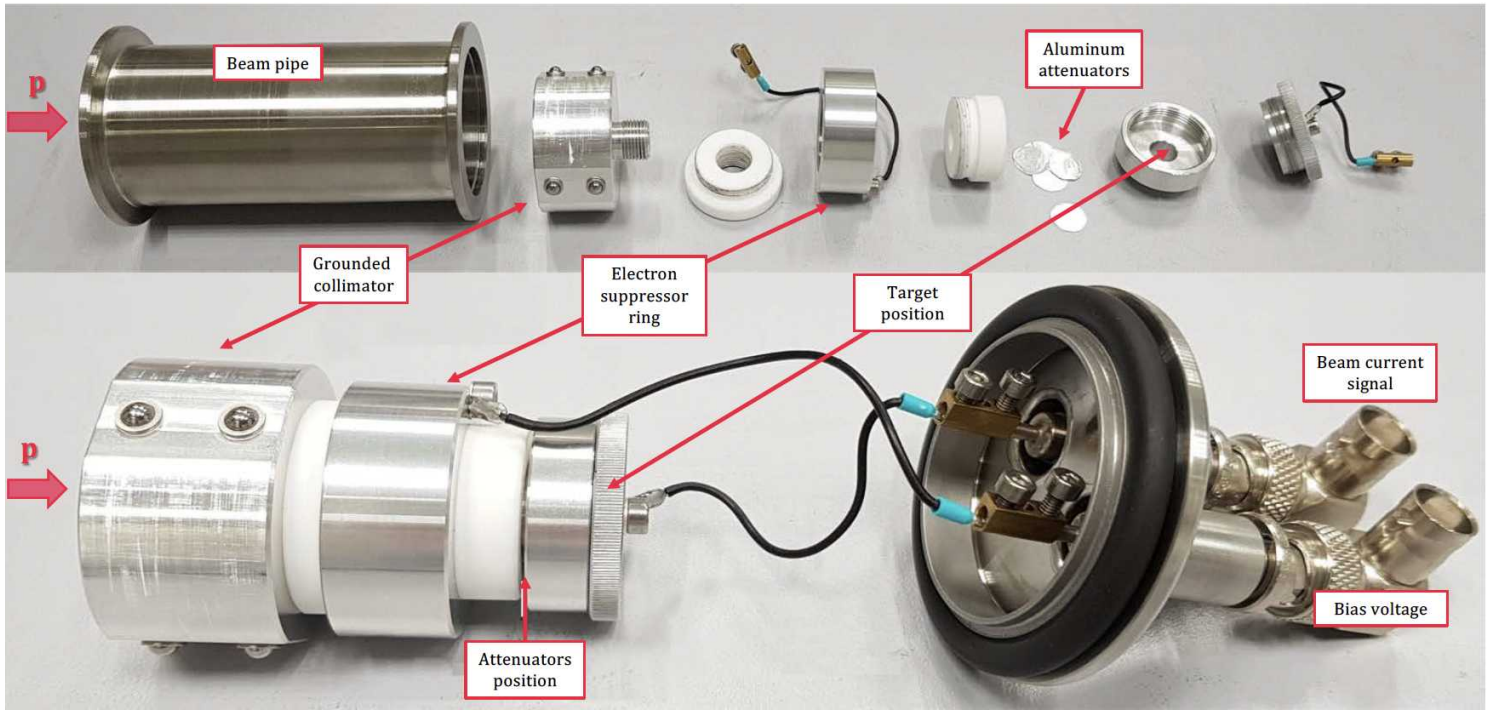
- ~ 1 cm^3 CdZnTe (CZT)
- Gamma spectroscopy

G. Dellepiane, *Il nuovo cimento C* 44.4-5 (2021): 1-4
N. Voeten, Master thesis, LHEP-MAPP (2022)

Experimental methodology for cross section measurements



New method for cross section measurements



Target station constructed by LHEP

T.S. Carzaniga, Appl Radiat Isot, 2017

Scientific achievements: cross section and yield measurements of selected radioisotopes

Isotope	Reaction	Target	Mass [mg]	Charge [μAh]	Y [GBq/μAh]
^{44}Sc	(p,n)	$^{enr-44}$CaO pellet	30	27	0.6
^{47}Sc	(p,α)	$^{enr-50}TiO_2$ pellet	35	3.9 E-3	0.001
^{61}Cu	(p,α)	$^{enr-64}$Zn pellet	40	2.7 E-4	0.14
^{64}Cu	(p,n)	$^{enr-64}$Ni deposition	63	160	0.13
	(p,α)	$^{enr-67}$ZnO pellet	59	2.7 E-4	0.02
^{67}Cu	(p,α)	$^{enr-70}$ZnO pellet	34	1.7 E-3	0.001
^{68}Ga	(p,n)	$^{enr-68}$Zn pellet	40	0.24	4.5
^{155}Tb	(p,n)	$^{enr-155}Gd_2O_3$ pellet	40	1.1 E-3	0.004
	(p,2n)	$^{enr-156}Gd_2O_3$ pellet	40	1.1 E-3	0.01
^{165}Er	(p,n)	^{nat}Ho metal disk	160	1.7	0.07
^{165}Tm	(p,2n)	$^{enr-166}Er_2O_3$ pellet	59	1.1	0.02
^{167}Tm	(p,n)	$^{enr-167}Er_2O_3$ pellet	41	0.01	0.003

G. Dellepiane et al, Appl Rad Isot 189 (2022): 110428 (scandium)
G. Dellepiane et al, Appl Rad Isot 191 (2023): 110518 (copper)
S. Braccini et al., Appl Rad Isot 186 (2022): 110252 (gallium)
G. Dellepiane et al, Appl Rad Isot 184 (2022): 110175 (terbium)

^{44}Sc ready for clinical applications

molecules

Molecules 2020, 25(20), 4706

MDPI

Article

Developments toward the Implementation of ^{44}Sc Production at a Medical Cyclotron

Nicholas P. van der Meulen [1,2,*], Roger Hasler [2], Zeynep Talip [2], Pascal V. Grundler [2], Chiara Favaretto [2], Christoph A. Umbricht [2], Cristina Müller [2], Gaia Dellepiane [3], Tommaso S. Carzaniga [3] and Saverio Braccini [3]

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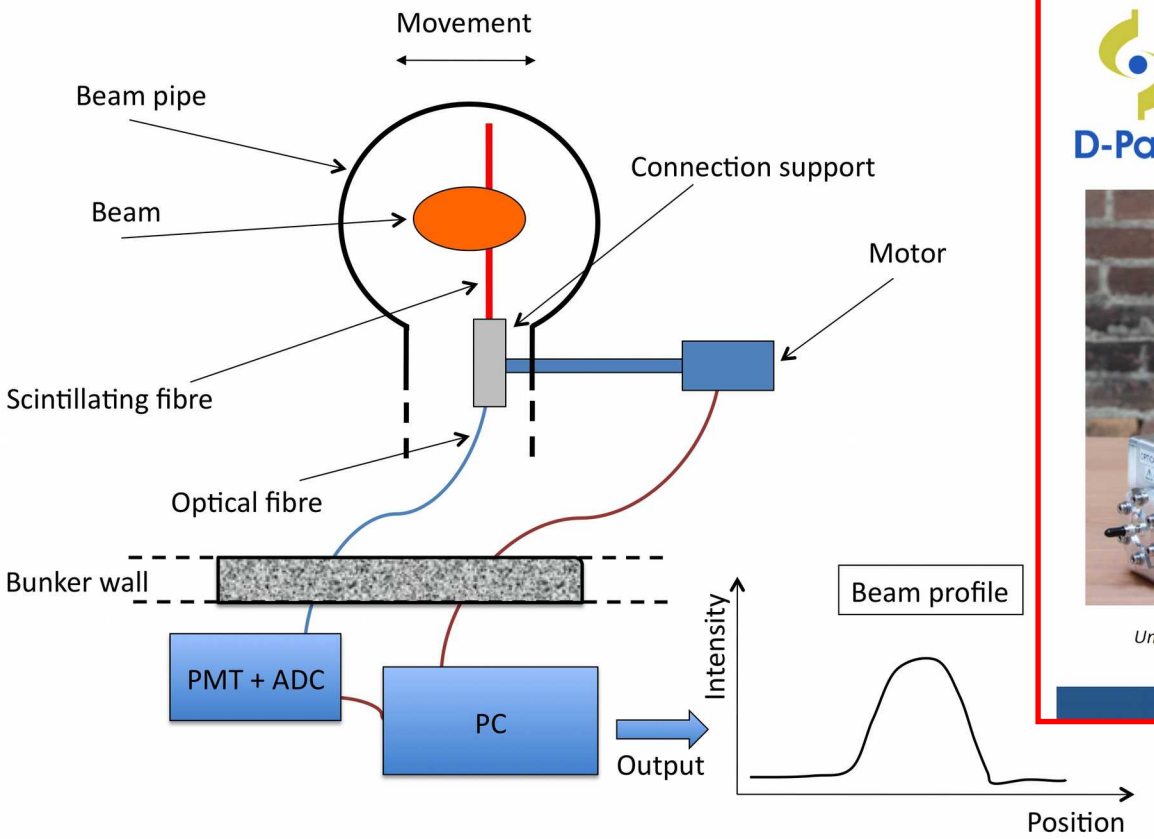
3 Albert Einstein Center for Fundamental Physics, Laboratory of High Energy Physics, University 3012 Bern, Switzerland; gaia.dellepiane@lhep.unibe.ch (G.D.); tommaso.carzaniga@lhep.unibe. saverio.braccini@lhep.unibe.ch (S.B.)

In collaboration with PSI

IBA Award 2020

The UniBEaM detector

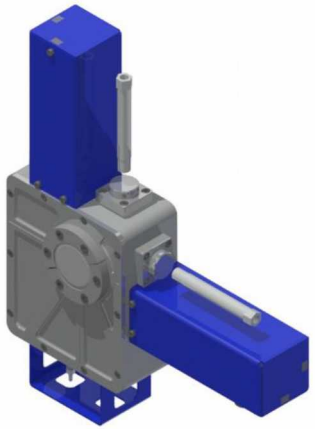


D-Pace

UniBEaM25

Ion Beam Profiler using Optical Fiber Sensor
Single and Dual Axis Systems

UniBEaM25-S – Single Axis Probe



UniBEaM25-D – Dual Axis Probe

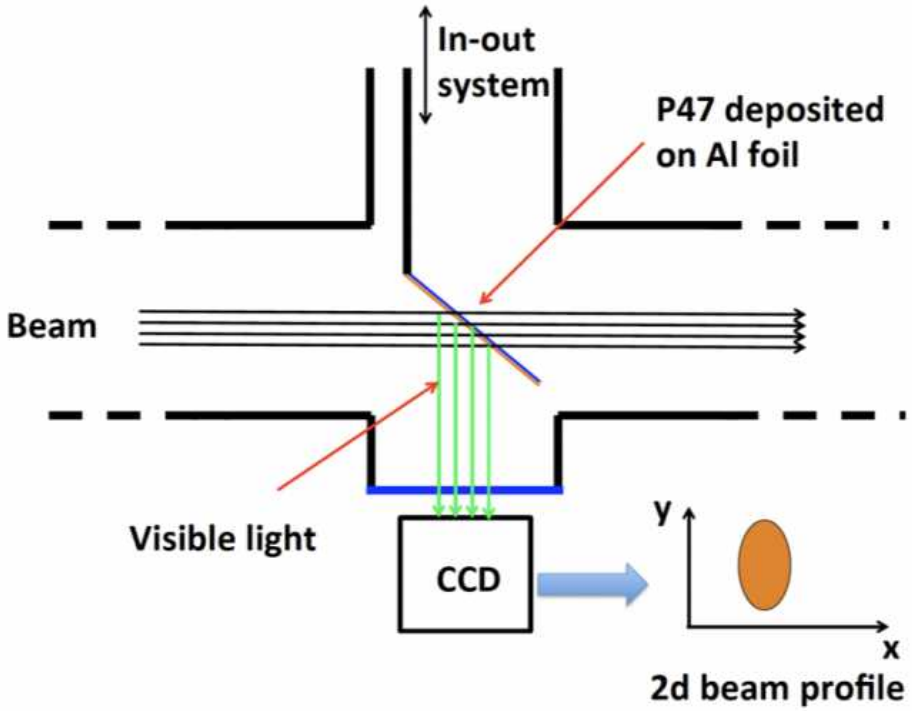
UniBEaM was conceived by the **AEC-LHEP** of the **University of Bern**[1] and commercialized by **D-Pace.**

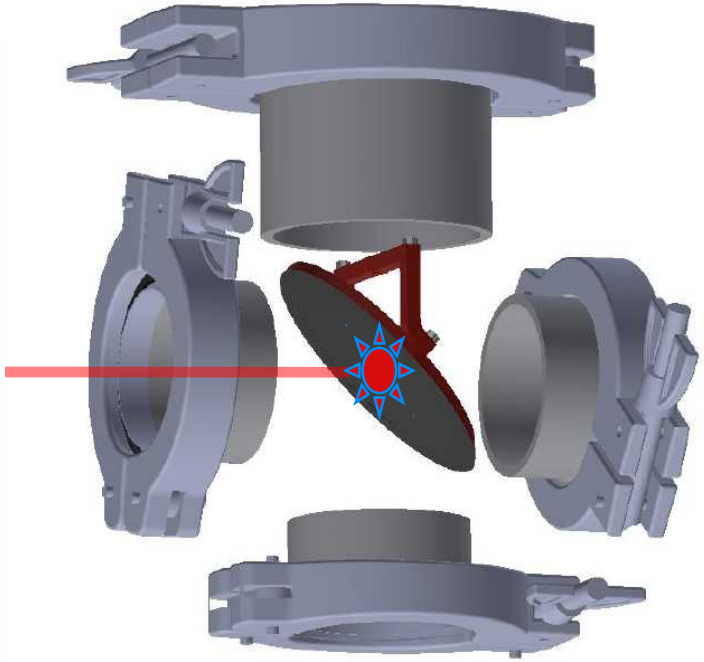
- 2D beam profiler based on (doped) optical fibres
- On-line, minimal interference with the beam
- Developed by LHEP and commercialized by D-Pace (Canada)

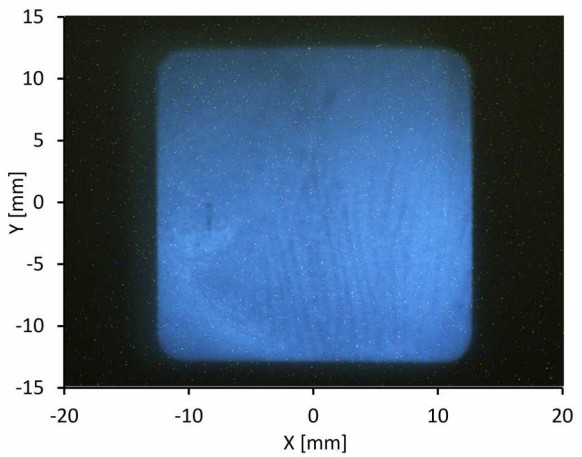
S. Braccini et al., 2012 JINST 7 T02001

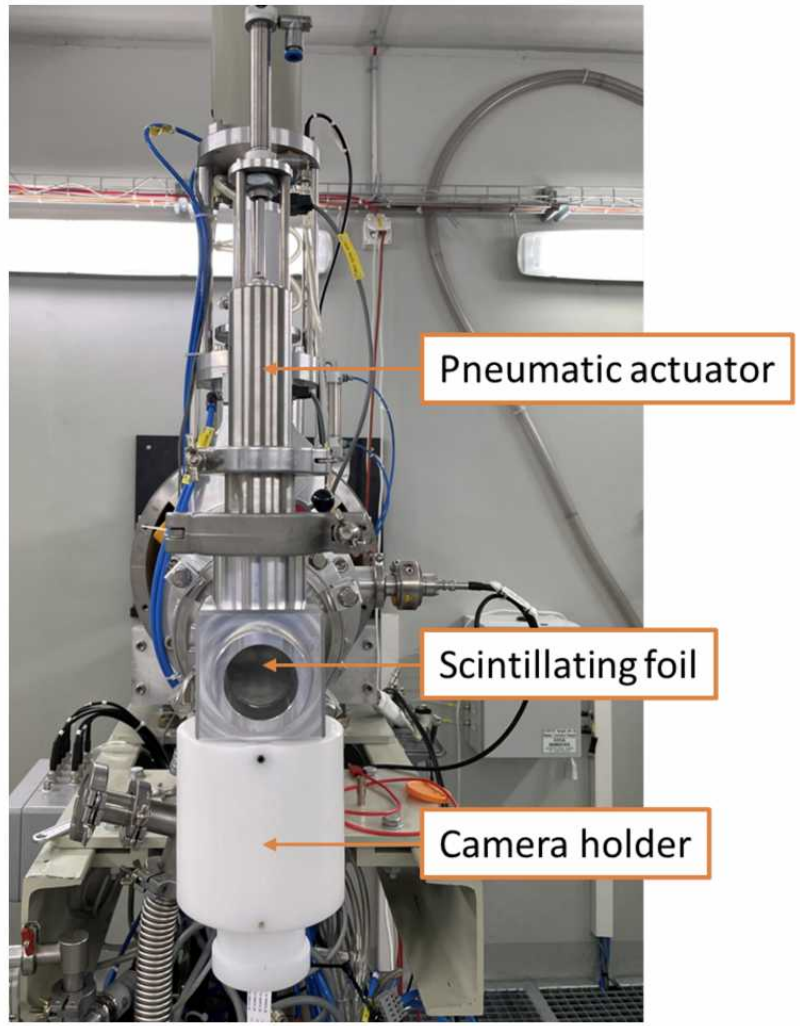
Online beam monitoring with the UniBEaM

The π^2 detector









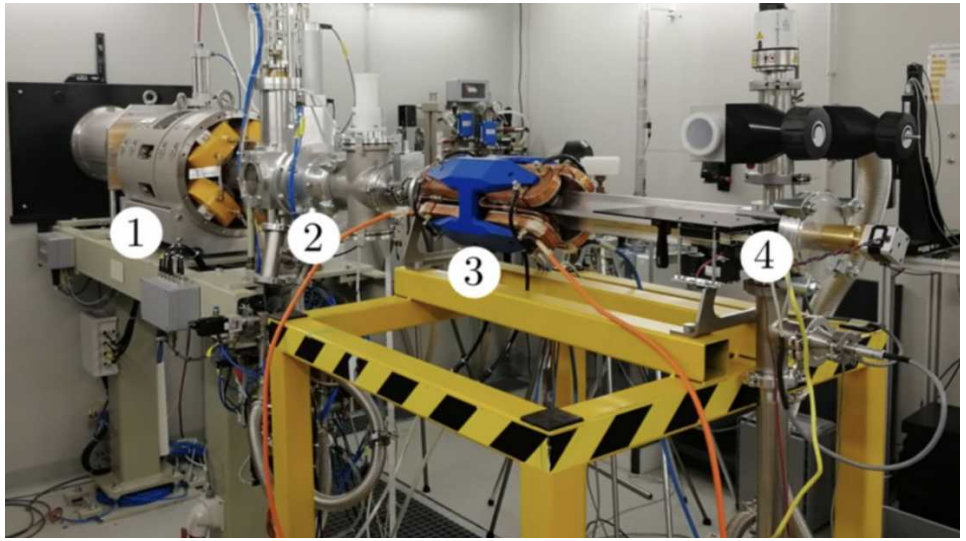
- P47 phosphor screen
- CMOS readout
- Stable response up to $3 \cdot 10^{15}$ p/cm^2

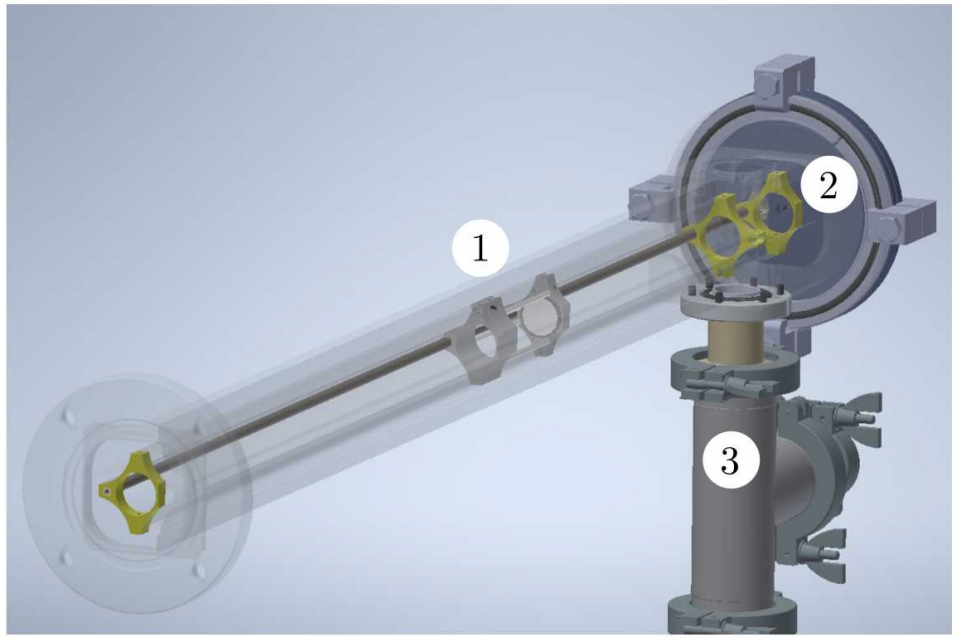
S. Braccini et al., 2023 Appl. Sci. 13(6), 3657

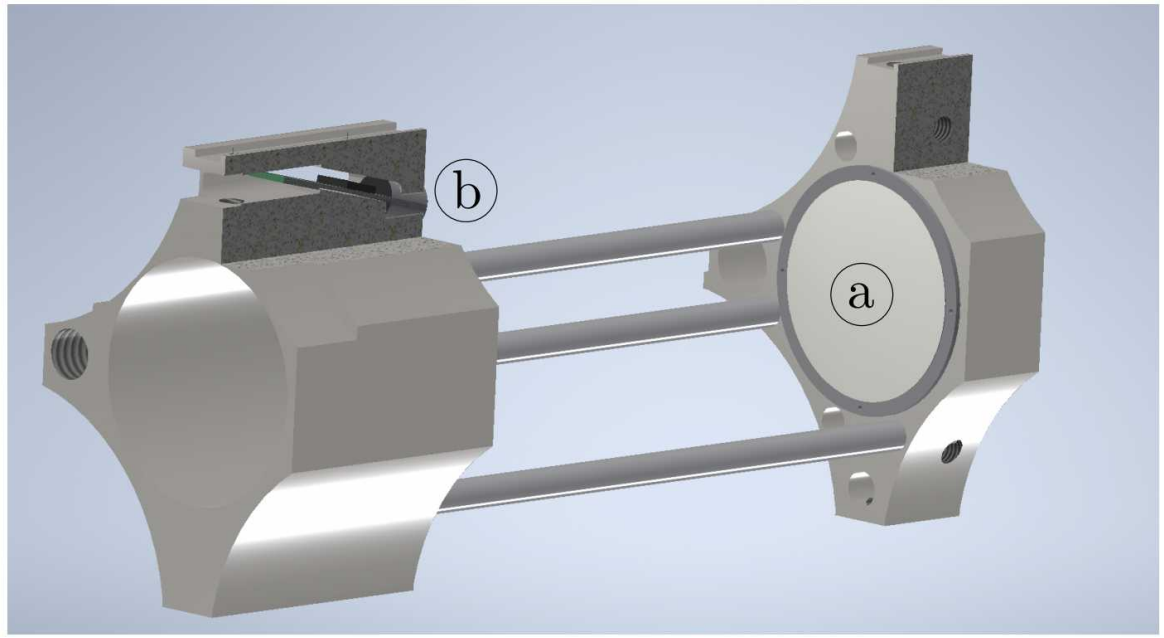
The π^3 detector

- Problem: monitor the beam envelop within the MBL
- Solution: The π^3 detector
- Further applications: Unique 3D beam monitor usable at any ion beam facility

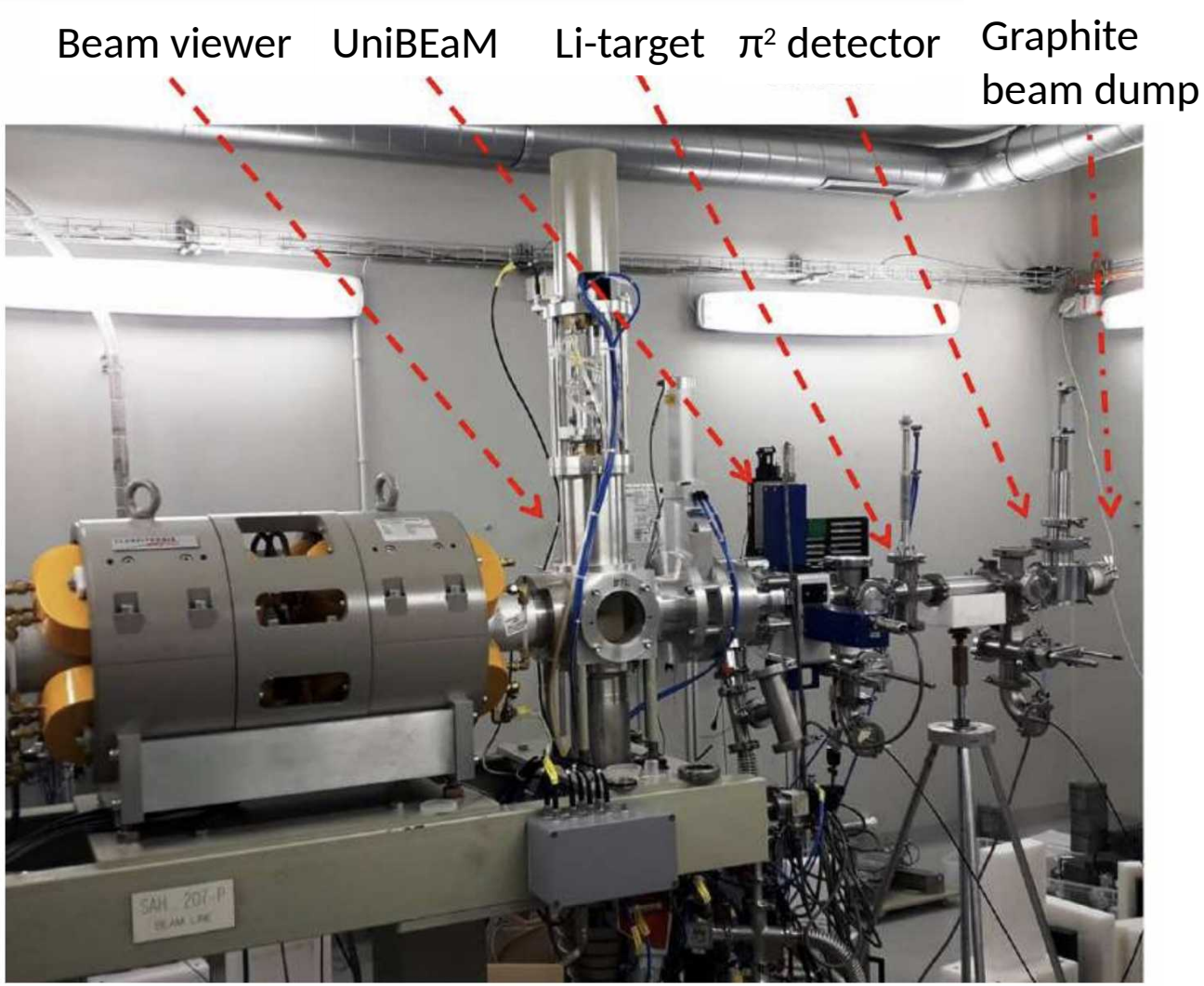
C Belver-Aguilar, 2020 Appl. Sci. 10.22, 2817



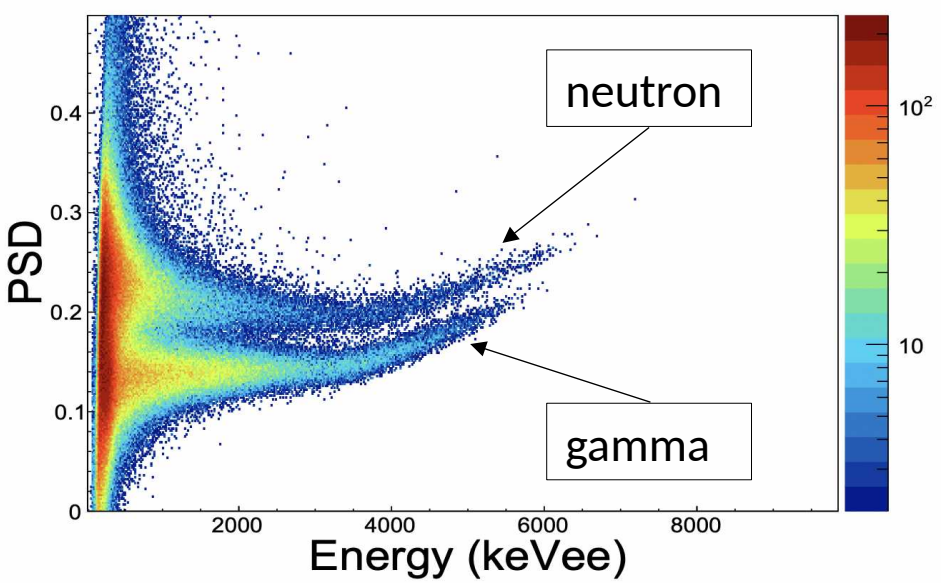




Neutron production at the Bern cyclotron

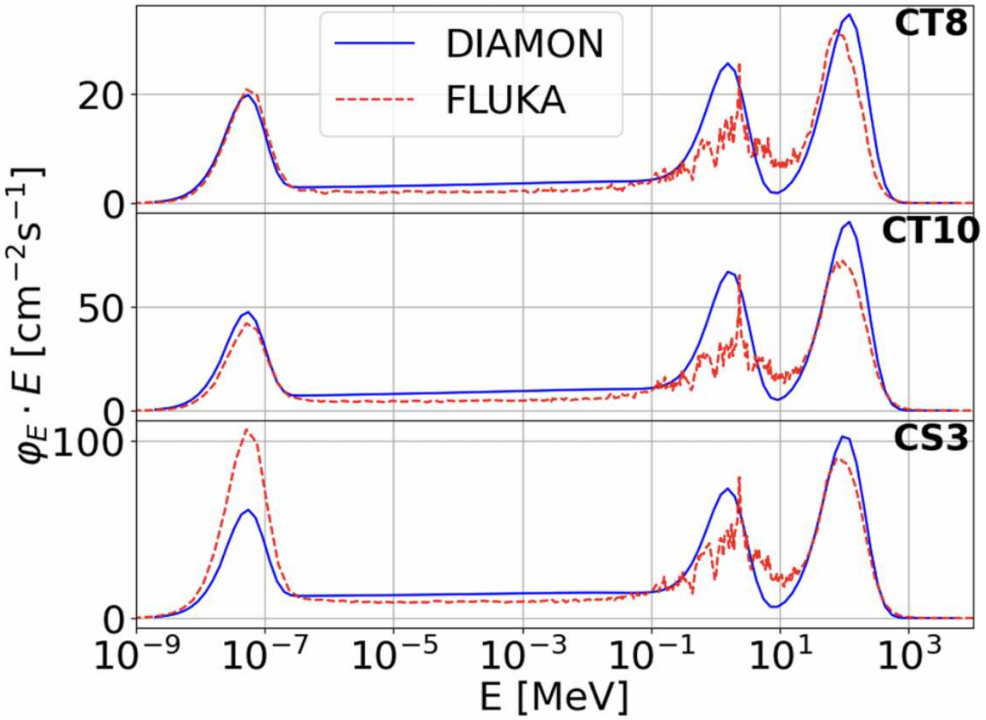


- DIAMON detector (next slide)
- Organic scintillators
- Pulse Shape Discrimination (PSD)



S. Braccini et al., IEEE RADECS, 2019
Casolaro, PhD Thesis, JINST, 2019

A novel approach to characterize neutron fields



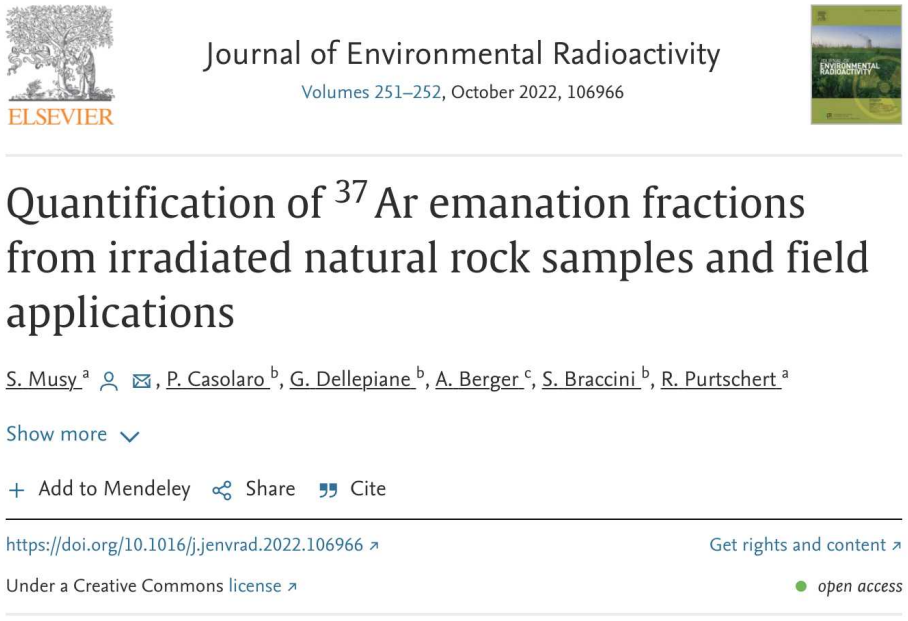
Characterization of neutron fields induced by :

- 120 GeV/c hadrons
- 18 MeV protons

S. Braccini et al., SciRep, 2022
P. Casolaro, IEEE NSS, 2021

Neutrons for science

- New routes for medical radioisotopes, ex. $^{64}Zn(n,p)^{64}Cu$
- Neutron damage on electronic and materials
- Study of fundamental properties of the neutron (ex. nEDM)
- Radionuclides of interest for environmental studies



ELSEVIER

Journal of Environmental Radioactivity

Volumes 251–252, October 2022, 106966

Quantification of ^{37}Ar emanation fractions from irradiated natural rock samples and field applications

S. Musy [a], P. Casolaro [b], G. Dellepiane [b], A. Berger [c], S. Braccini [b], R. Purtschert [a]

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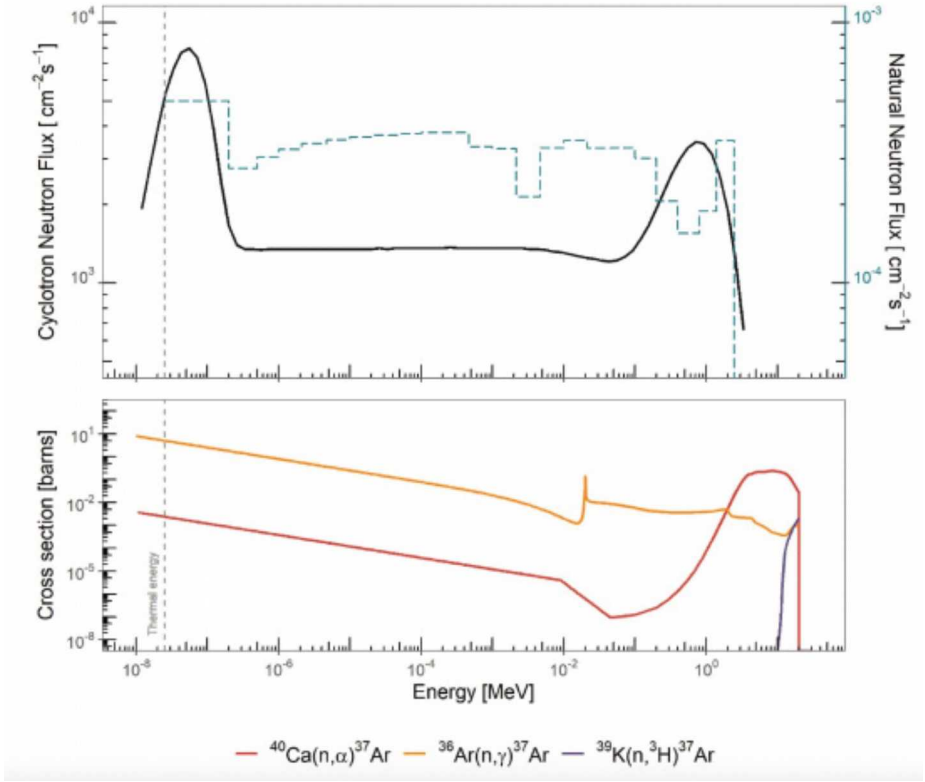
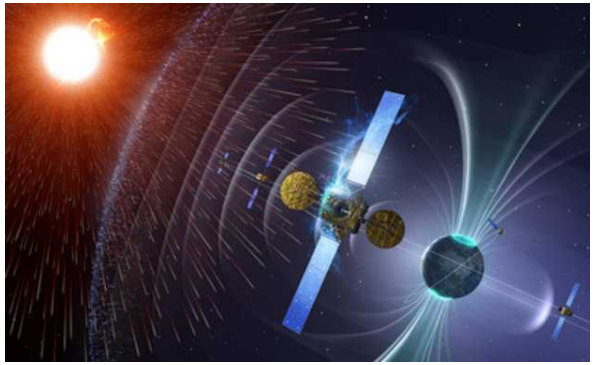
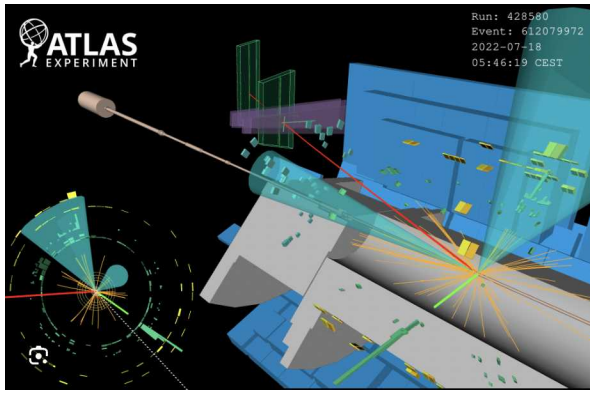


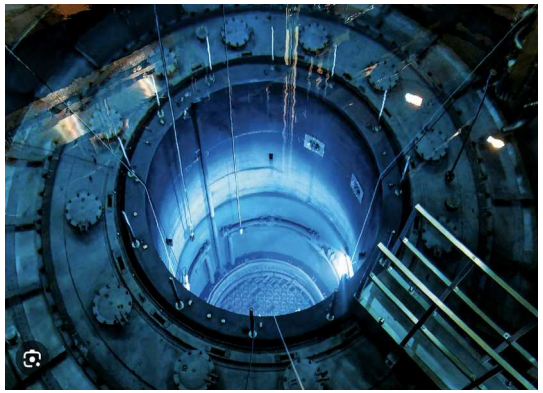
Radiation hardness

UNIVERSITÄT BERN

Applications in space, HEP, reactors…







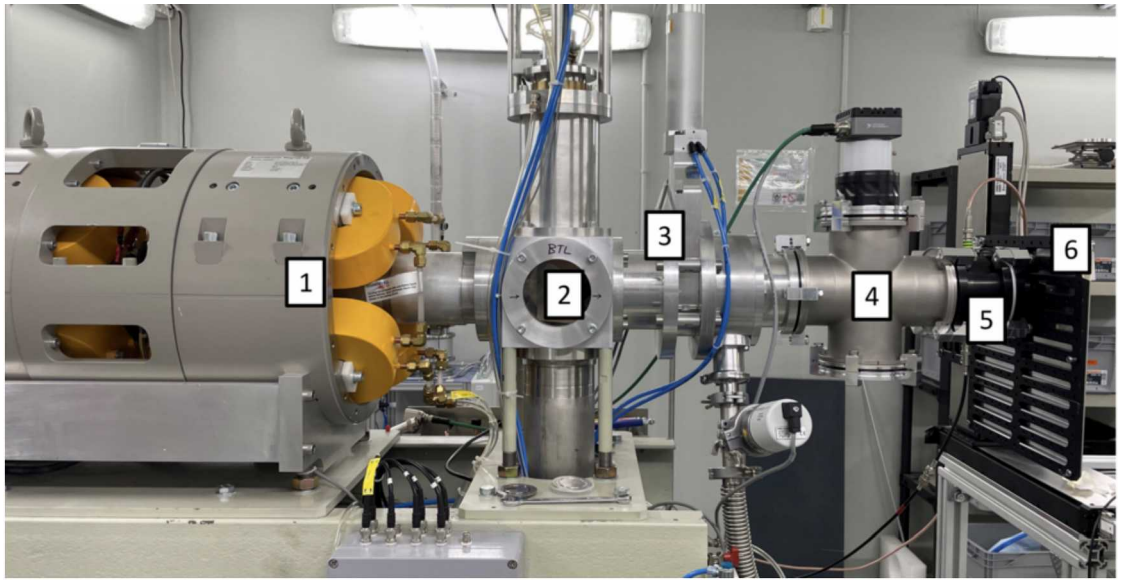
Jinst

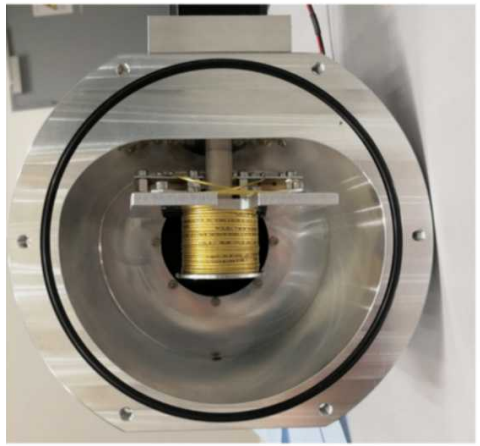
A facility for radiation hardness studies based on a medical cyclotron

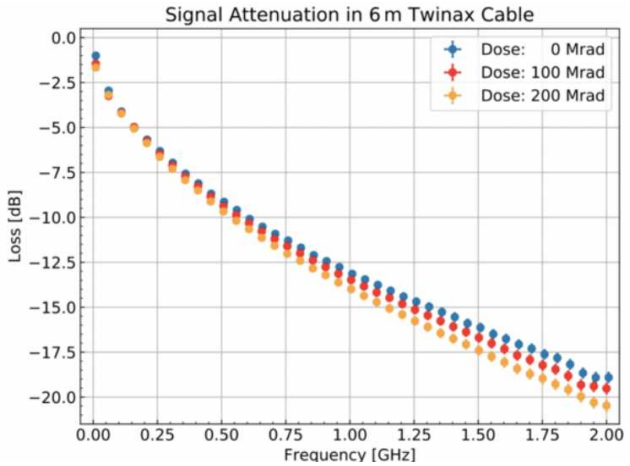
J. Anders, S. Braccini, T.S. Carzaniga,[1] P. Casolaro, M. Chatterjee, G. Dellepiane, L. Franconi, L. Halser, A. Ilg,[2] I. Mateu,* F. Meloni,[3] C. Merlassino,[4] A. Miucci,[5] R. Müller, M. Rimoldi[3] and M. Weber

Albert Einstein Center for Fundamental Physics (AEC), Laboratory for High Energy Physics (LHEP), Sidlerstrasse 5, CH-3012 Bern, Switzerland

Radiation damage studies @ Bern cyclotron

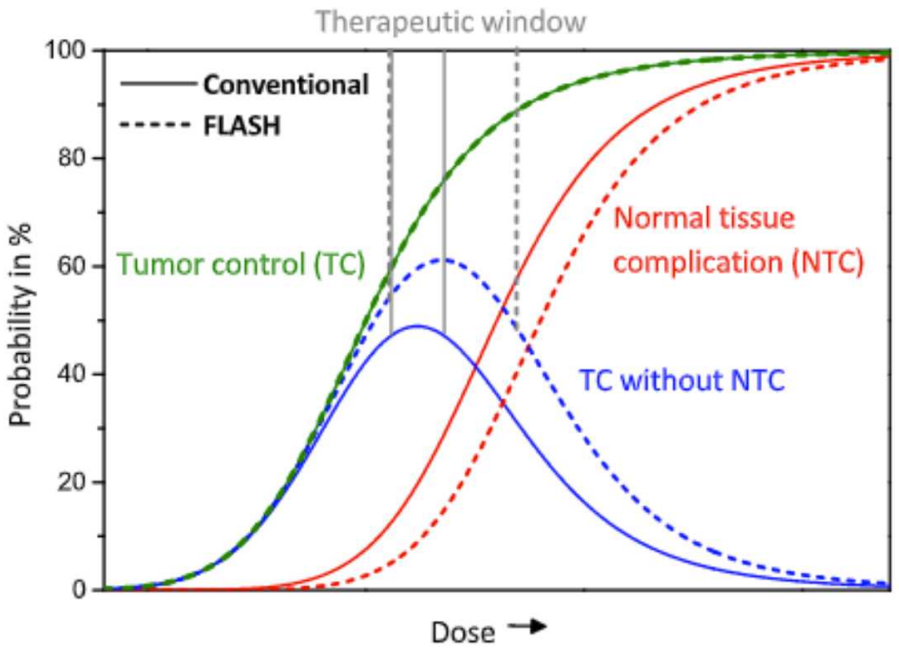






Future: FLASH Radiation Therapy

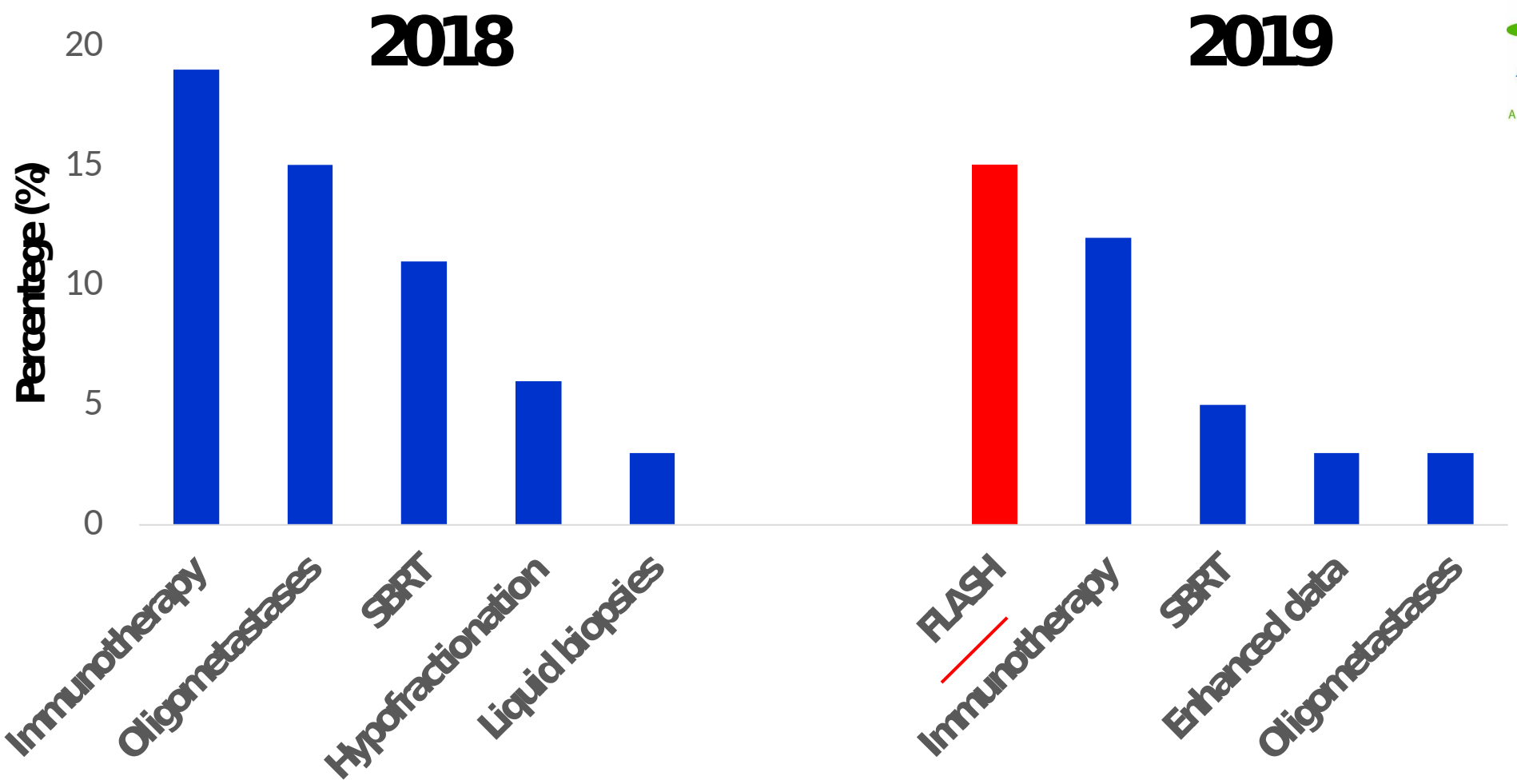
CONVENTIONAL RADIOTHERAPY	FLASH THERAPY
~ 0.1 Gy/s	> 40 Gy/s
~ Minutes	< 500 ms



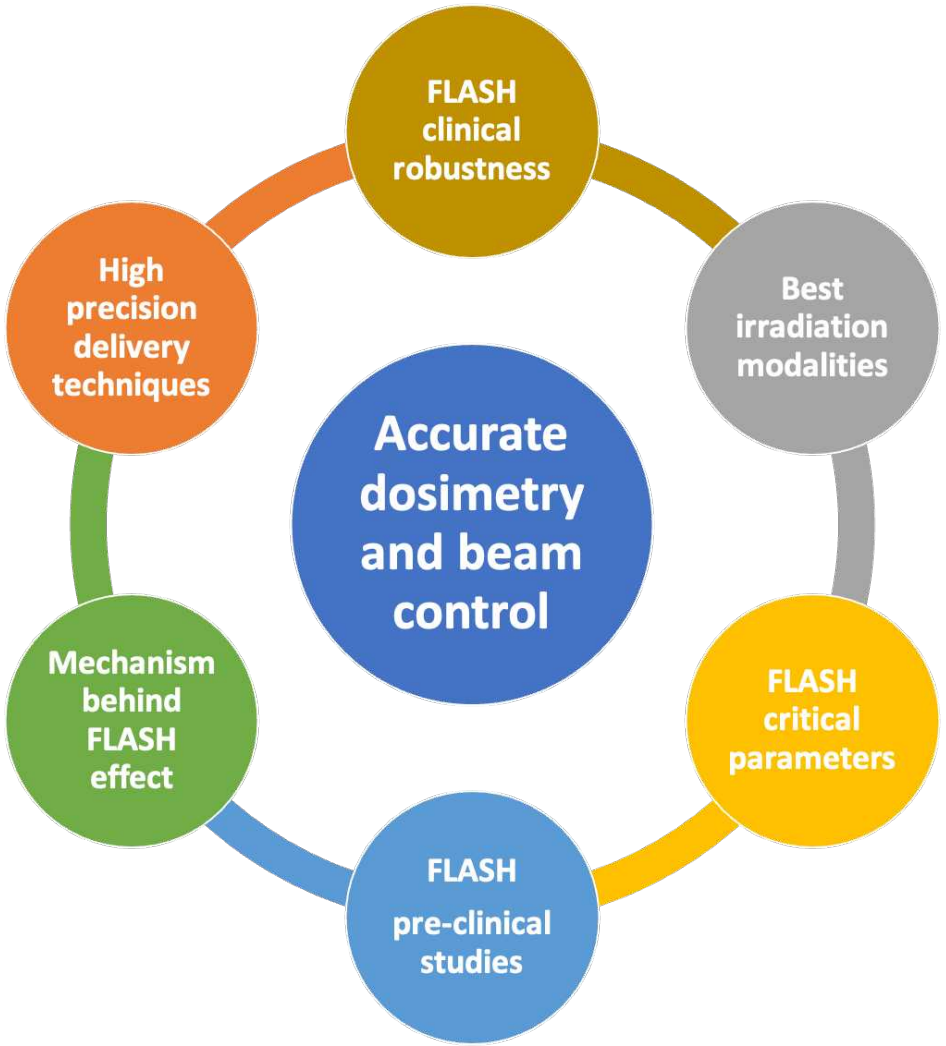
First FLASH treatment in the world in Lausanne (2019)

1 day | 3 weeks | 5 months

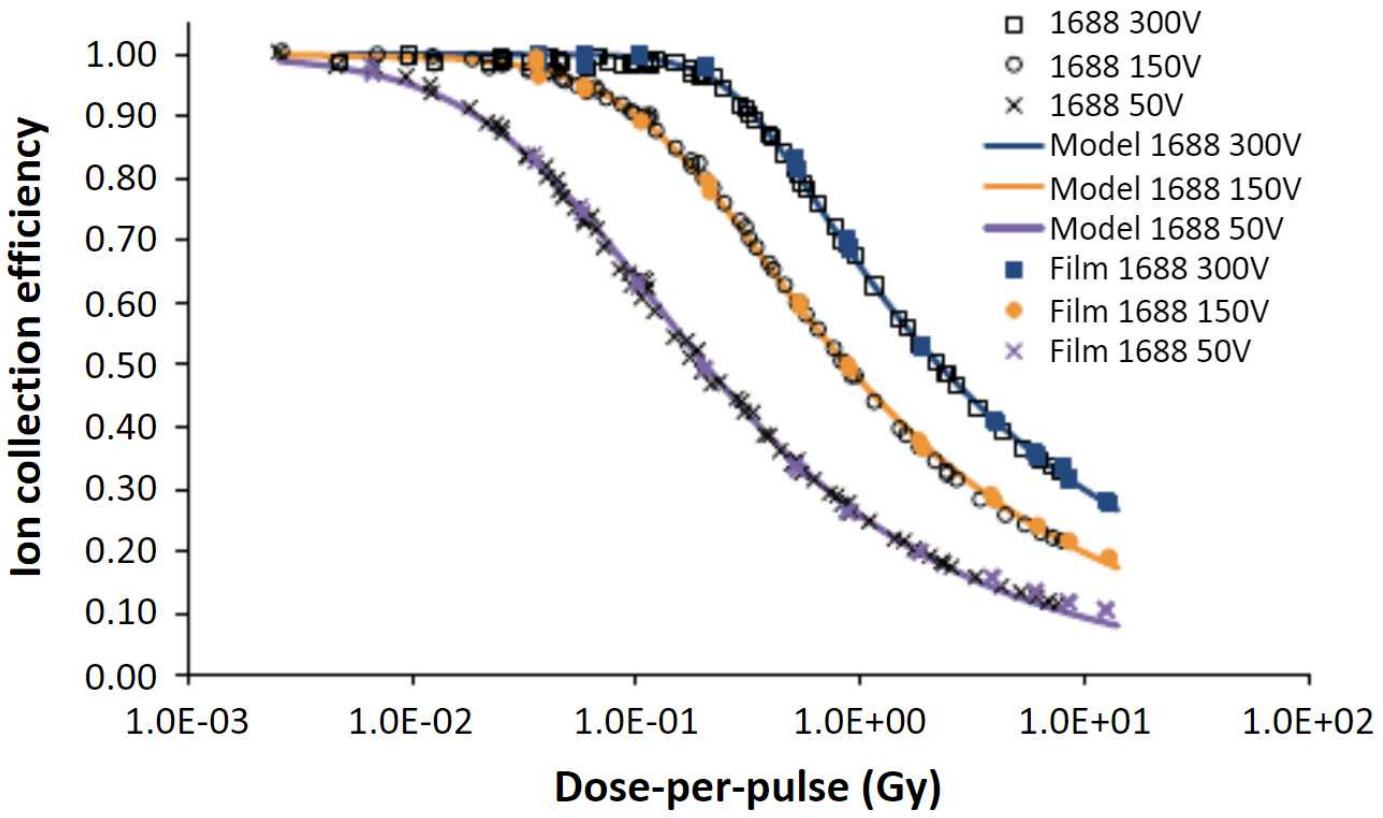
ASTRO survey – What is the One Big Discovery that needs to be translated into the clinic right now?



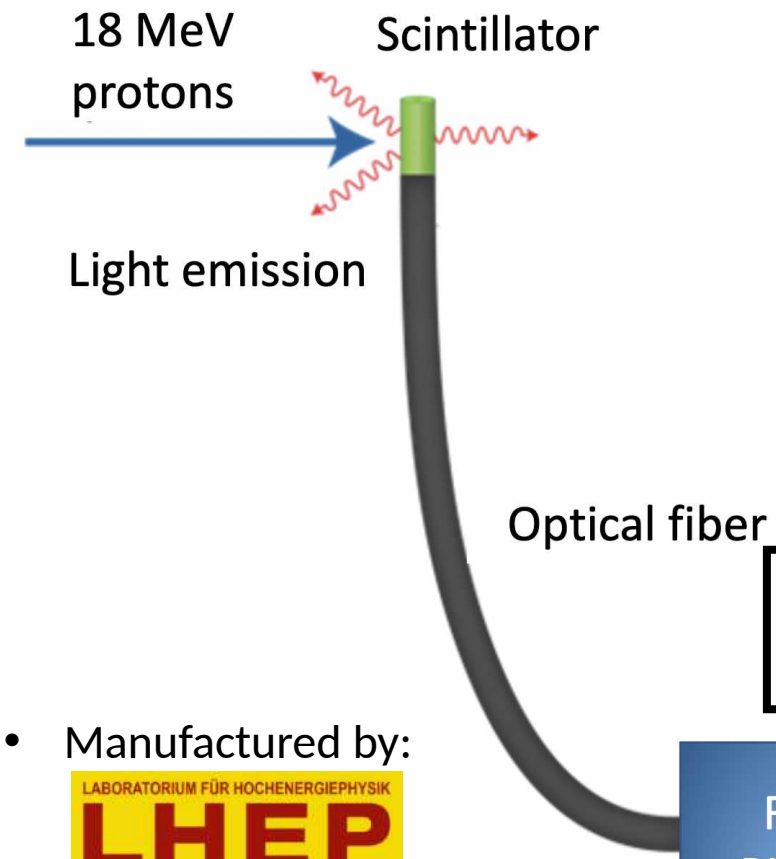
Towards the FLASH clinical translation



- Ion chambers: gold standard for CONV-RT but … saturate at FLASH dose rates



PROOF (PRecision dOsimetry in FLASH radiotherapy with Optical Fibers)



Bern Center for Precision Medicine (BCPM)

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< Current Projects: Young Investigators

PROOF (PRecision dOsimetry in FLASH radiotherapy with Optical Fibers)

Principal Investigator:
Dr. Pierluigi Casolaro, Albert Einstein Center for Fundamental Physics (AEC), Laboratory for High Energy Physics (LHEP), University of Bern. For more information, please visit the website.

External funds --> **SASRO Research Grant 2022**

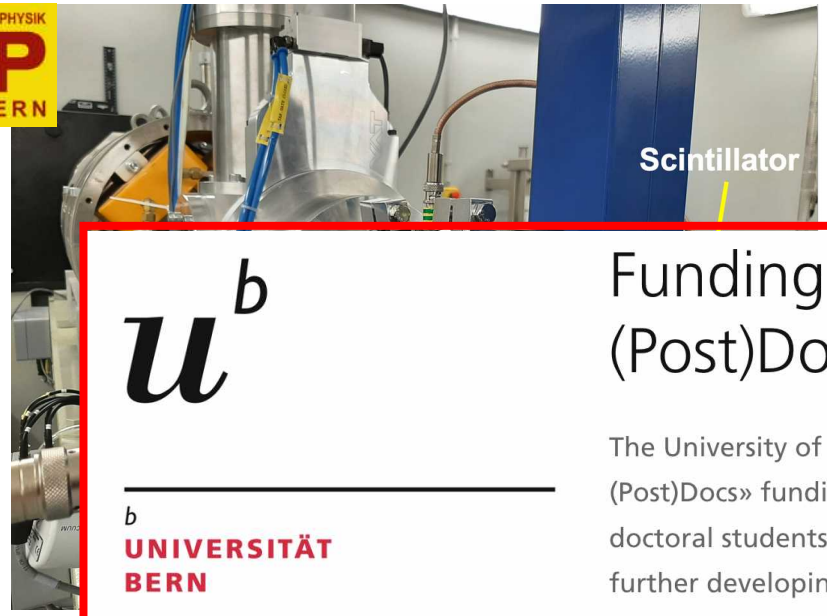
SASRO
Scientific Association of Swiss Radiation Oncology

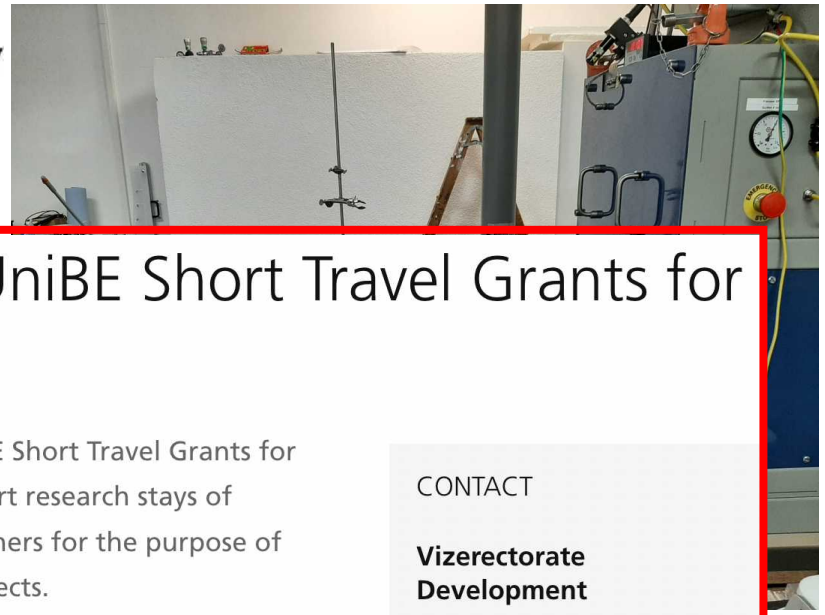
- Manufactured by:

LABORATORIUM FÜR HOCHENERGIEPHYSIK LHEP UNIVERSITÄT BERN

FAST PMT / PHOTODIODE → ELECTROMETER / PHOTON COUNTER → LAPTOP FOR DATA ANALYSIS

Tests at accelerators with different beams and results



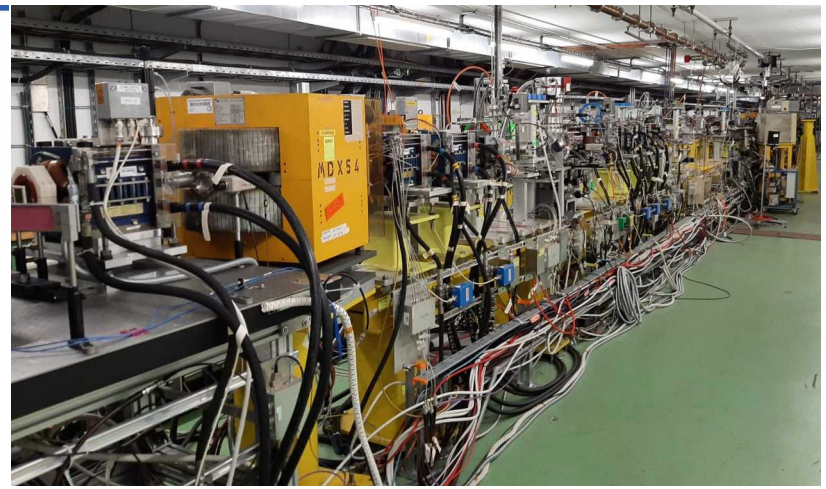


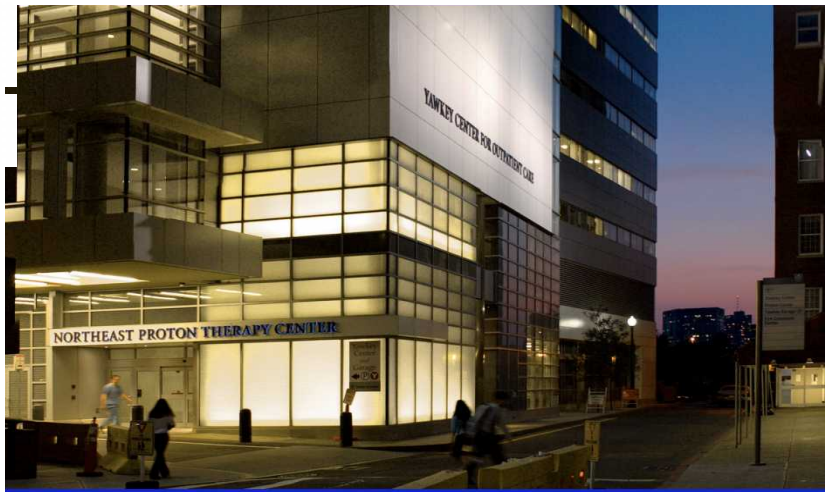
Funding Program «UniBE Short Travel Grants for (Post)Docs»

The University of Bern, by way of its «UniBE Short Travel Grants for (Post)Docs» funding program, supports short research stays of doctoral students and postdoctoral researchers for the purpose of further developing their own research projects.

CONTACT

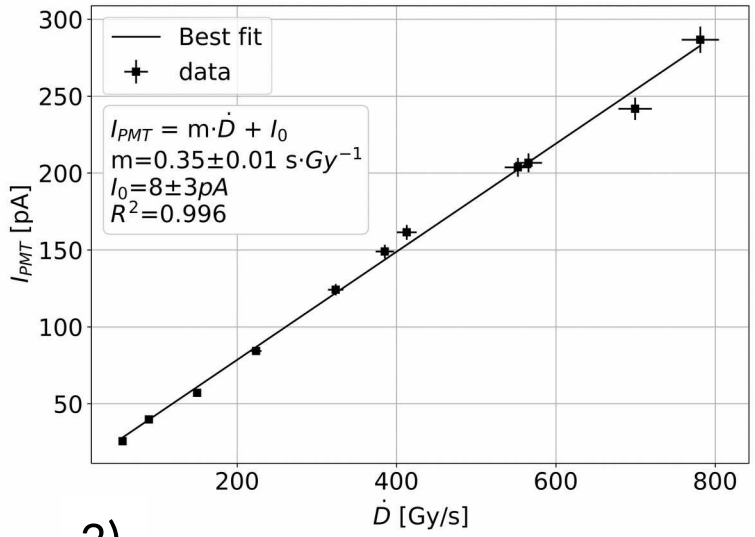
Vizerectorate Development





Experimental results

1)



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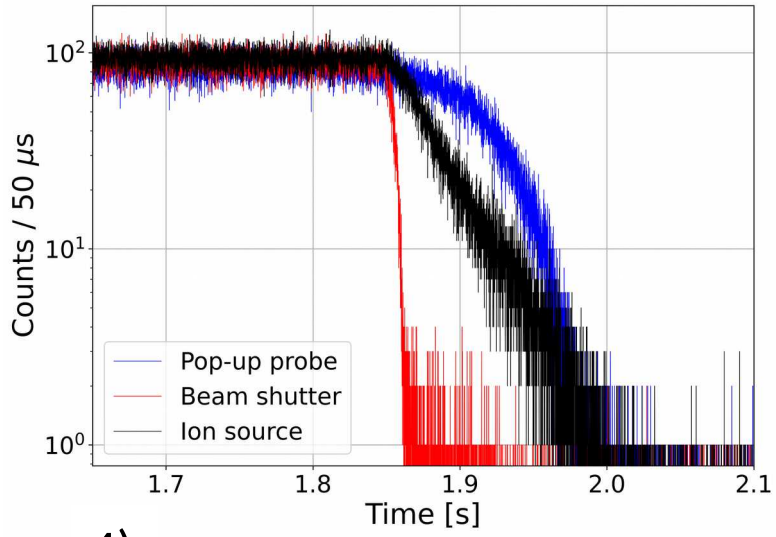
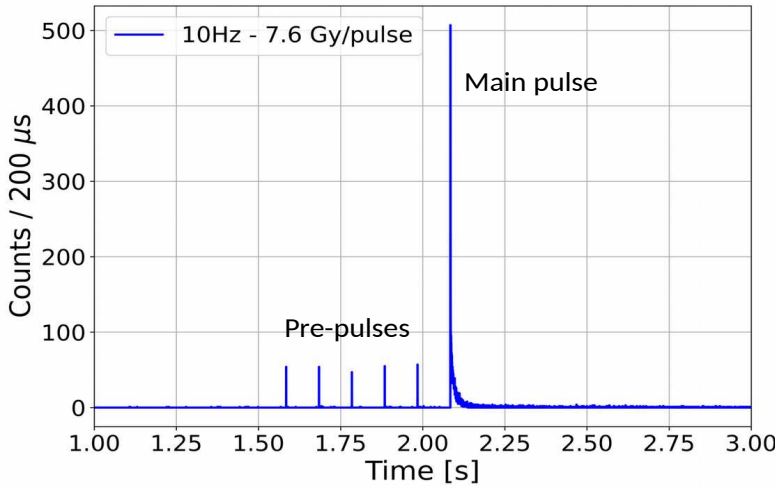


1) Linear in FLASH regime
2) High time resolution
3) Sensitivity (pre-pulses detection)
4) Bragg curve
5) Beam profile

3)



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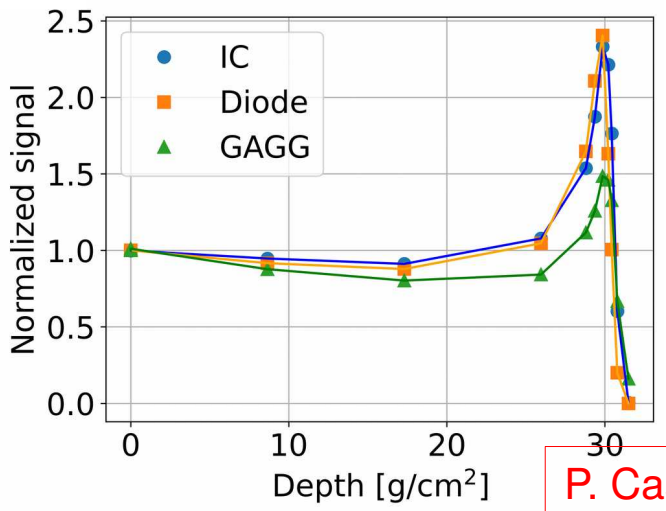
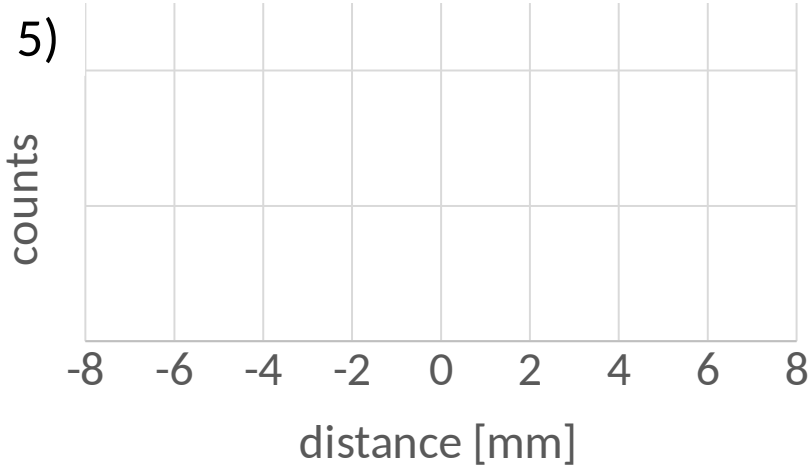
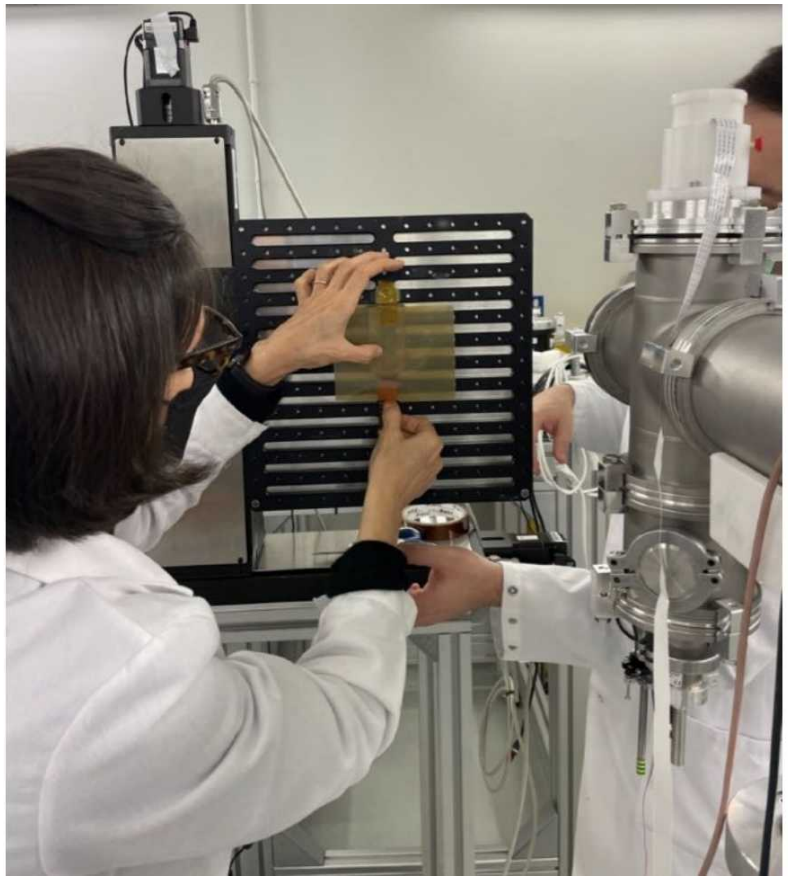


5)



P. Casolaro et al., 11th Int. Beam Instrum. Conf. (2022)
D. Wermelinger, Bachelor theis, University of Bern (2023)

Cell irradiations for radiobiology experiments



- Recent collaboration with Institute of Anatomy (Prof. Djonov's group)
- Setting-up of beamline for CONV, FLASH & novel modalities (e.g. minibeams)
- Erasmus master student (M.V. Rossi from Uninsubria, Como)

Thank you very much for your attention