APPLIED PHYSICS

Overview of the activities in applied physics to medicine

NQN: Neuroscienze e neuroimaging quantitativo

Referente Federico Giove

RAT: Radio e Adro Terapia radioterapia innovativa

Referente Michela Marafini

Giornata di presentazione delle attività del CREF al Consiglio Scientifico e Comitato Valutazione

2026

APPLIED PHYSICS To MEDICINE

IMAGINg

Neuroscienze e Neuroimaging quantitativo

CENTRO RICERCHE ENRICO FERMI · SAPIENZA UNIVERSITÀ DI ROMA · INFN · SANTA LUCIA NEUROSCIENZE E RIABILITAZIONE

Main activity: investigating the dynamics of brain function using quantitative experimental approaches based on magnetic resonance imaging (MRI), combined with computational models. The experimental activity focuses on studying the relationship between information processing at the cortical level, the energy consumption that supports it, and the micro-structural substrate that enables its transmission. Project activities also extend to functional dynamics induced by interaction with the environment and to spontaneous fluctuations.

External Funding

- PRIN 2022: PROGETTI DI RICERCA DI RILEVANTE INTERESSE NAZIONALE Prot. 202294JHK - RECENTRE - PI SAPIENZA
- COMMISSIONE EUROPEA NextGenerationEU e MUR PNRR M4 C2 - SINVASC - PI CREF

END 02/2026

Stefano Giagu	RECENTRE	Sapienza
Fabrizio Esposito	SINVASC	UniCampania

Personale del CREF o in enti convenzionati con fondi dedicati a NQN:

Federico Giove	Dirigente di Ricerca	**CREF**	90%
Matteo Mancini	Ricercatore	**CREF**	90%
Maria Guidi	Contratto di Ricerca	**CREF**	PNRR
Elena Russo	Post.Doc.	**CREF**	PNRR
Taljinder Singh	Post.Doc.	INFN	PNRR
Chiara Ercolano	Ph.D.	RomaTre Santa Lucia	PNRR
Luca Cairone	Ph.D.	Sapienza Santa Lucia	PNRR

Neuroscienze e Neuroimaging quantitativo

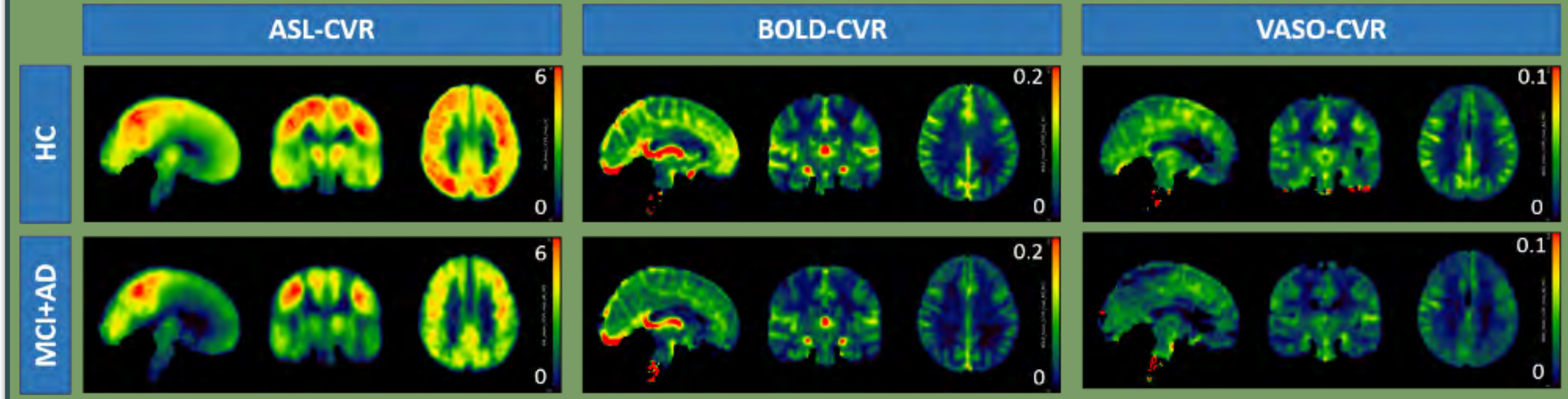


***Figure 1:** CVR maps obtained in healthy controls (HC), individuals with mild cognitive impairment (MCI), and patients with Alzheimer's disease (AD) using a gas challenge. The contrasts used include arterial spin labeling (ASL), blood oxygenation level dependent (BOLD), and vascular space occupancy (VASO). These maps represent a potential biomarker for neurological disorders associated with vascular impairment.*

METHODS: the research line pursues innovation in MRI technologies and the development of new multimodal analysis methodologies. The project has a strong interdisciplinary nature and aims, in the long term, to contribute to the development of advanced diagnostic tools for the characterisation, diagnosis, and treatment of neurological and psychiatric disorders.

MILESTONES:

1. **2026 Completion of the project on the characterisation of vascular and metabolic responses in aging.** Completion of cerebrovascular reactivity data processing and finalisation of the model for neuronal and vascular BOLD responses. Two publications.
2. **2026 Completion of the spinal cord imaging study.** Completion of data processing and interpretation. Standardisation of the spinal cord data processing pipeline for future studies. One publication.
3. **2027 Functional connectivity analysis on fMRI data acquired with different contrasts.** Development of fMRI methods for connectivity analysis using multi-contrast fMRI techniques is completed and formalised into pipelines available for application and related publication.

Responsabile Scientifico Federico Giove

RAT

The International Agency for Research on Cancer has estimated a 25% risk of cancer incidence in the European population. Cases are expected to increase. Prevention and early diagnosis remain essential tools, and nuclear imaging plays a crucial role in non-invasive diagnostics. At the same time, tumor treatments through photon and charged particle radiotherapy are continuously evolving. A strong synergy between technological research, applied physics, and clinical practice has led to a significant improvement in innovative treatment quality, thanks to increasingly efficient and effective irradiation/monitoring and planning techniques. Diagnostic imaging and tumor treatment using radiotherapy and innovative therapy are two main aspects of this research line.

External Funding

- **PRIN 2022: PROGETTI DI RICERCA DI RILEVANTE INTERESSE NAZIONALE Prot. 2022Z72Y3K - ReSPECT - PI CREF**
- **PRIN PNRR 2022: PROGETTI DI RICERCA DI RILEVANTE INTERESSE NAZIONALE Prot. P2022FZAC3 - MULTIPASS - PI INFN**

END 02/2026

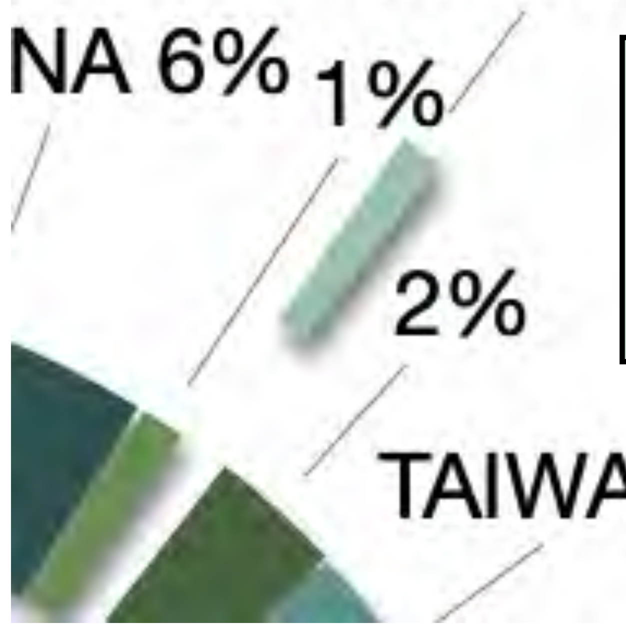
Roberto Passerone	ReSPECT	UNITN
Leonardo Mattiello	ReSPECT	SBAI
Marco Toppi	ReSPECT	SBAI
Ilaria Mattei	MULTIPASS	INFN Milano
Davide Pinci	MULTIPASS	INFN Roma

Personale del CREF o in enti convenzionati con fondi dedicati a RAT:

Michela Marafini	Ricercatore	**CREF**	80%
Marco Garbini	Primo Ricercatore	**CREF**	10%
March/April 2026	Ric. Tempo Determinato	**CREF**	90%
Arianna Vannucci	Assegno	**CREF**	
Luana Testa	PhD	**CREF/ Sapienza**	
Laura Rocchetta	PhD	**CREF/Tor Vergata**	
Adalberto Sciubba	Associato	-	
Vincenzo Patera	Associato	Sapienza	
Aurelio Patelli	Ricercatore	**CREF**	5%
Dario Mazzili	Ricercatore	**CREF**	5%

Innovative Radiotherapy

light ion therapy

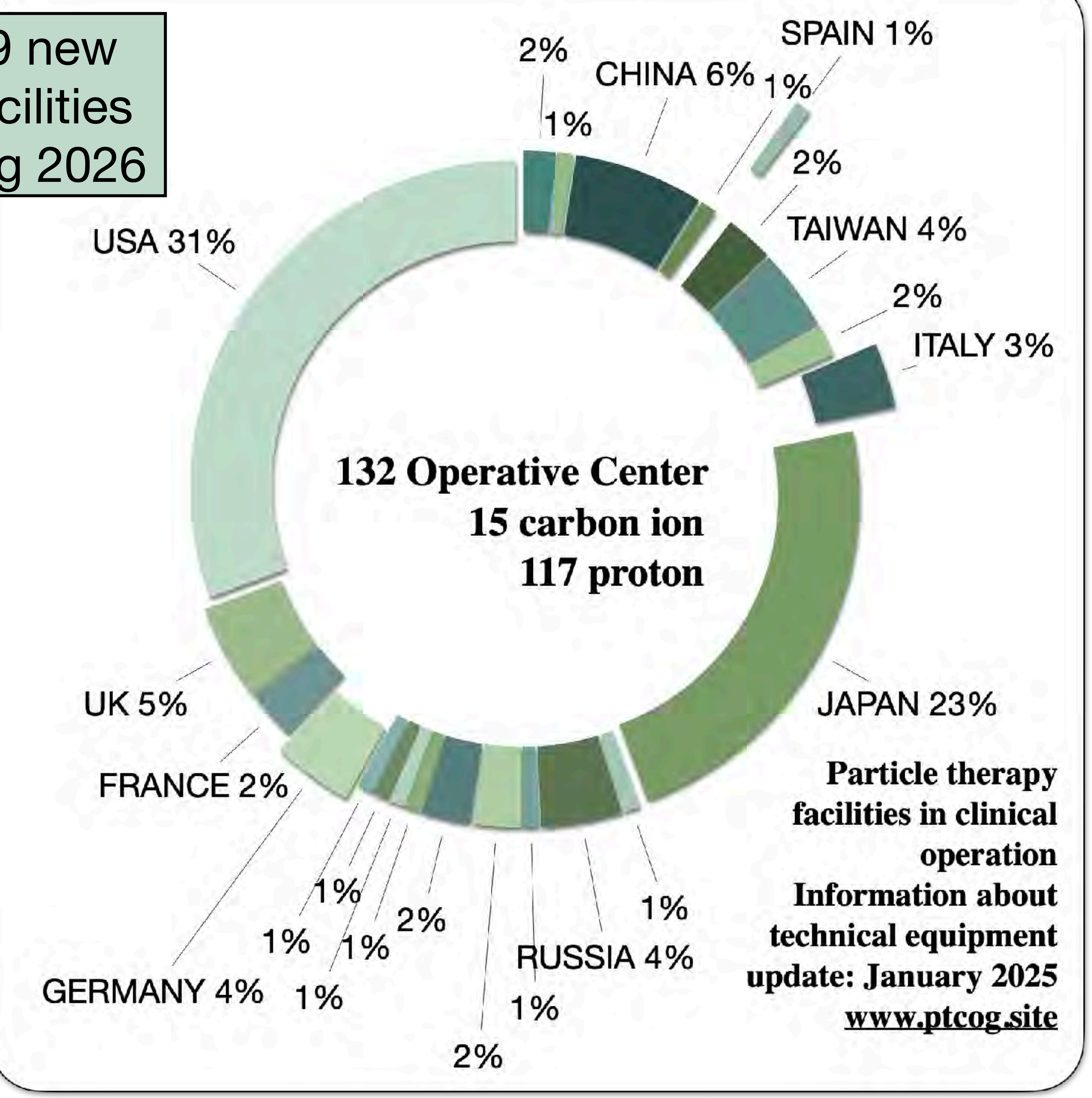


SPAIN: 9 new proton facilities in planning 2026

ITALY: 4 operating centres (proton and carbon ion beams) and 3 new proton beams expected in 2025-2027.

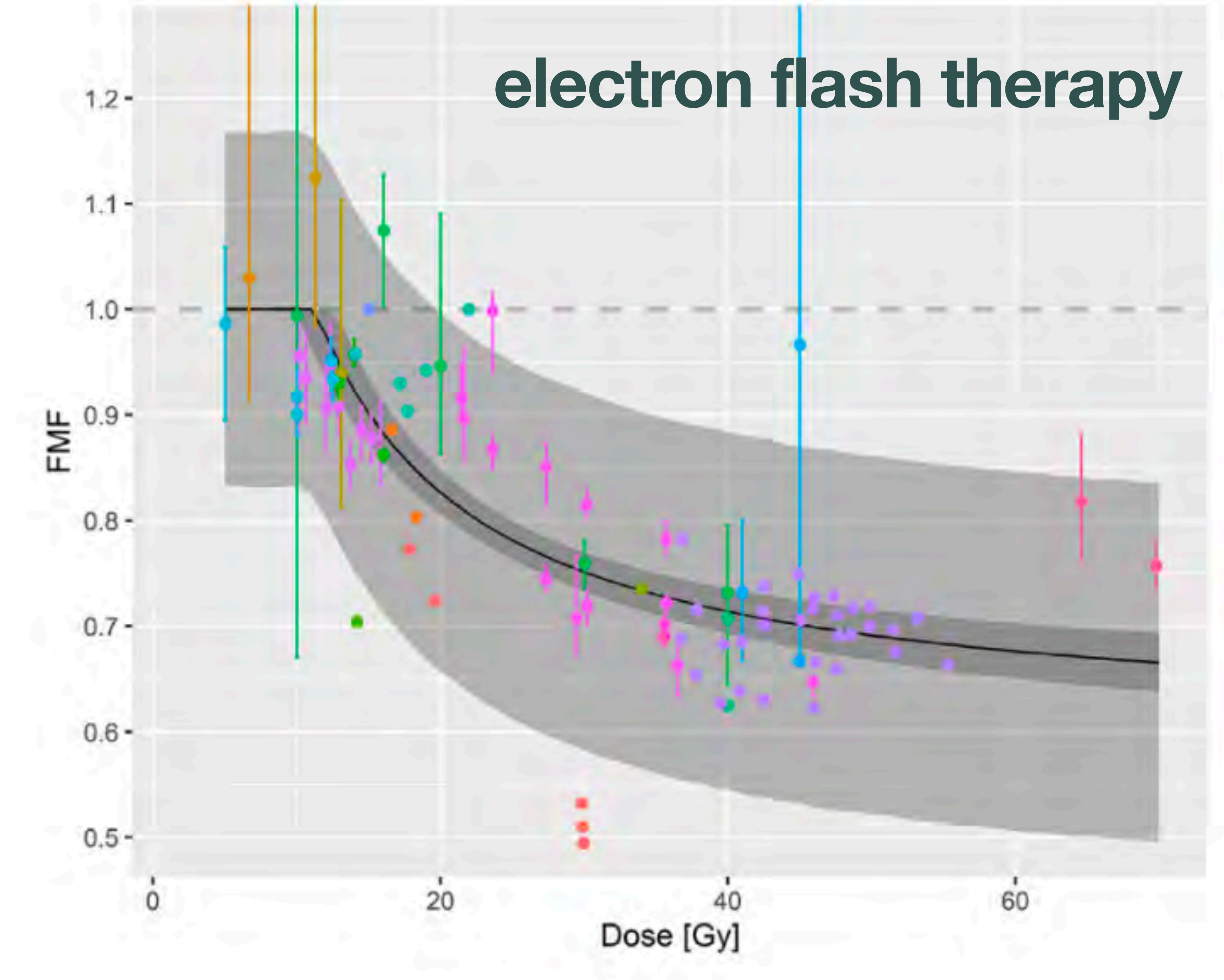
Helium ion beam in Commissioning

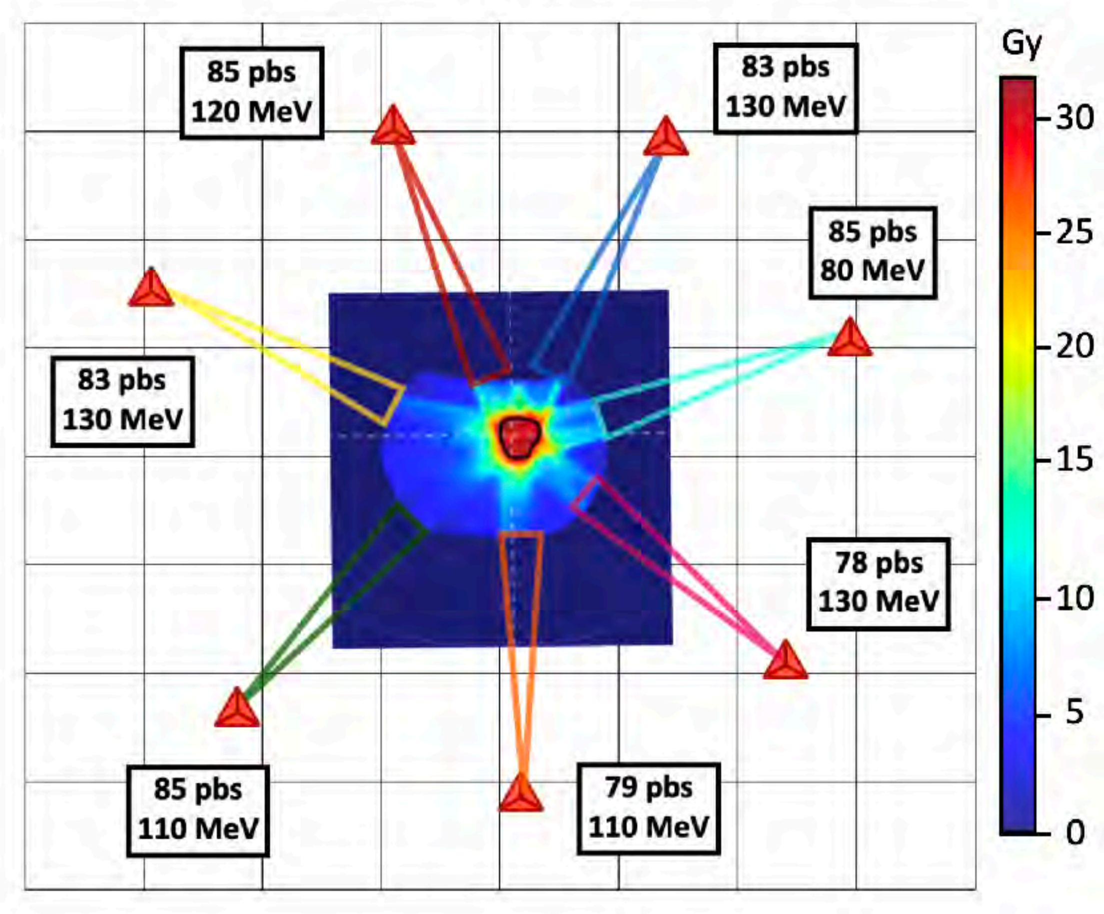
CNAO
Centro Nazionale di Adroterapia Oncologica



33 (3 C-ion) CPT gantry under construction, 34 (2 C-ion) CPT gantry planned 2028

electron flash therapy





Very High Electron Energy

SAFEST: electron beam and possible photon beam in Flash regime

10 MeV in 2026

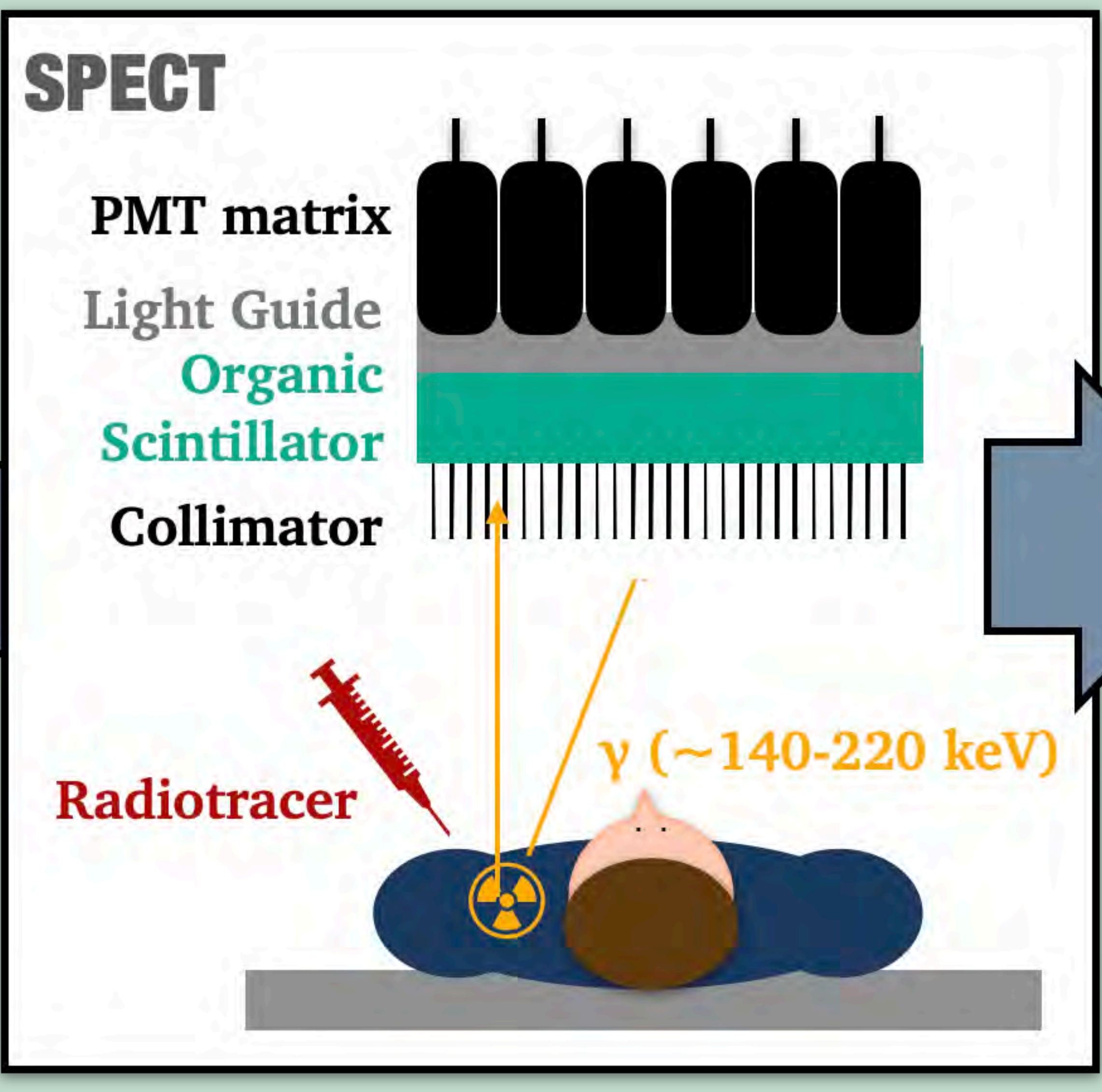
SBAI

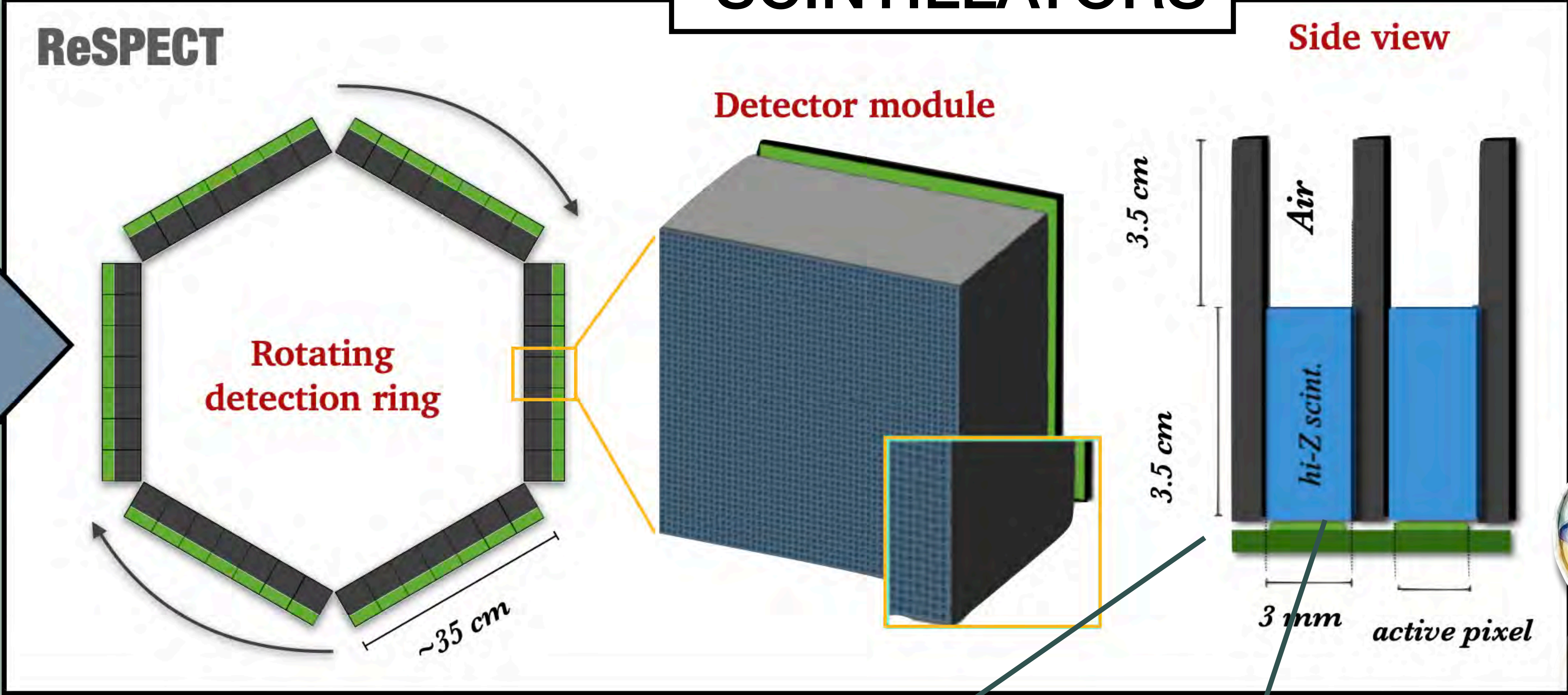
CENTRO RICERCHE ENRICO FERMI

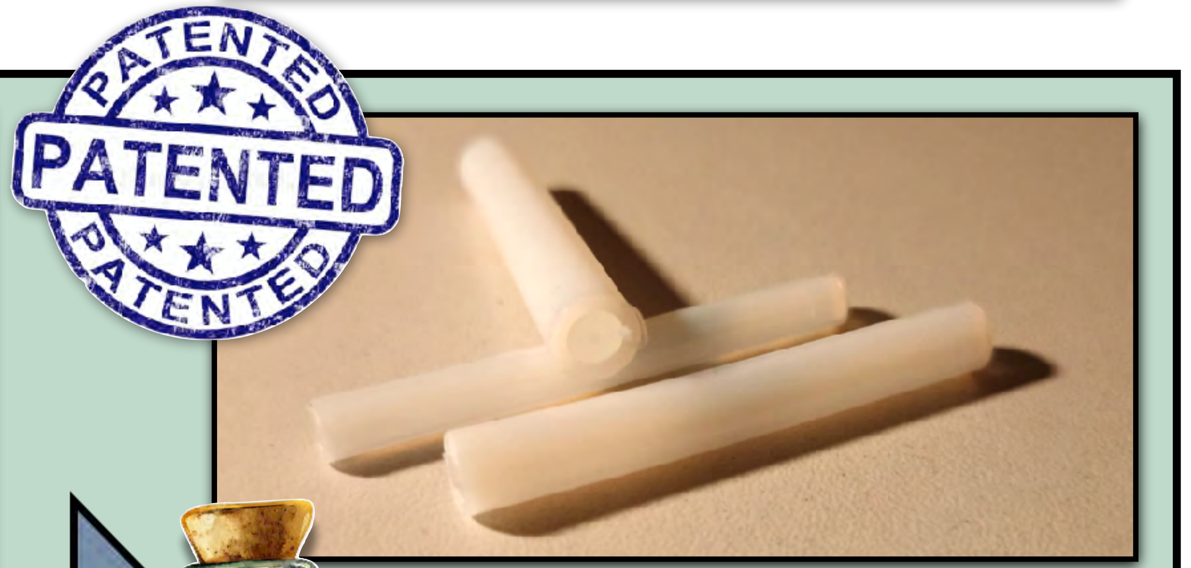
IMAGING

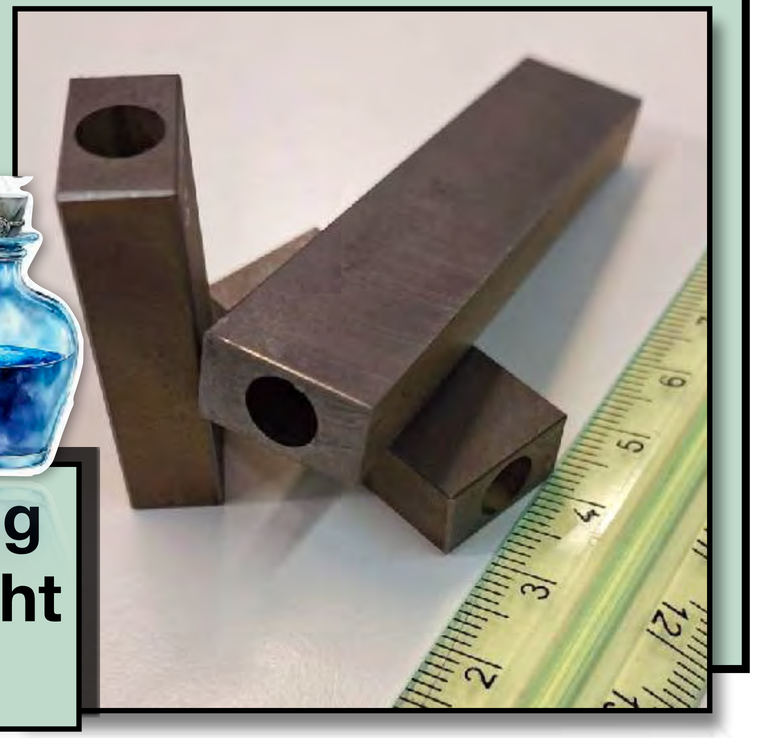
CENTRO RICERCHE ENRICO FERMI · SAPIENZA Università di Roma · UNIVERSITÀ DI TRENTO

SCINTILLATORS





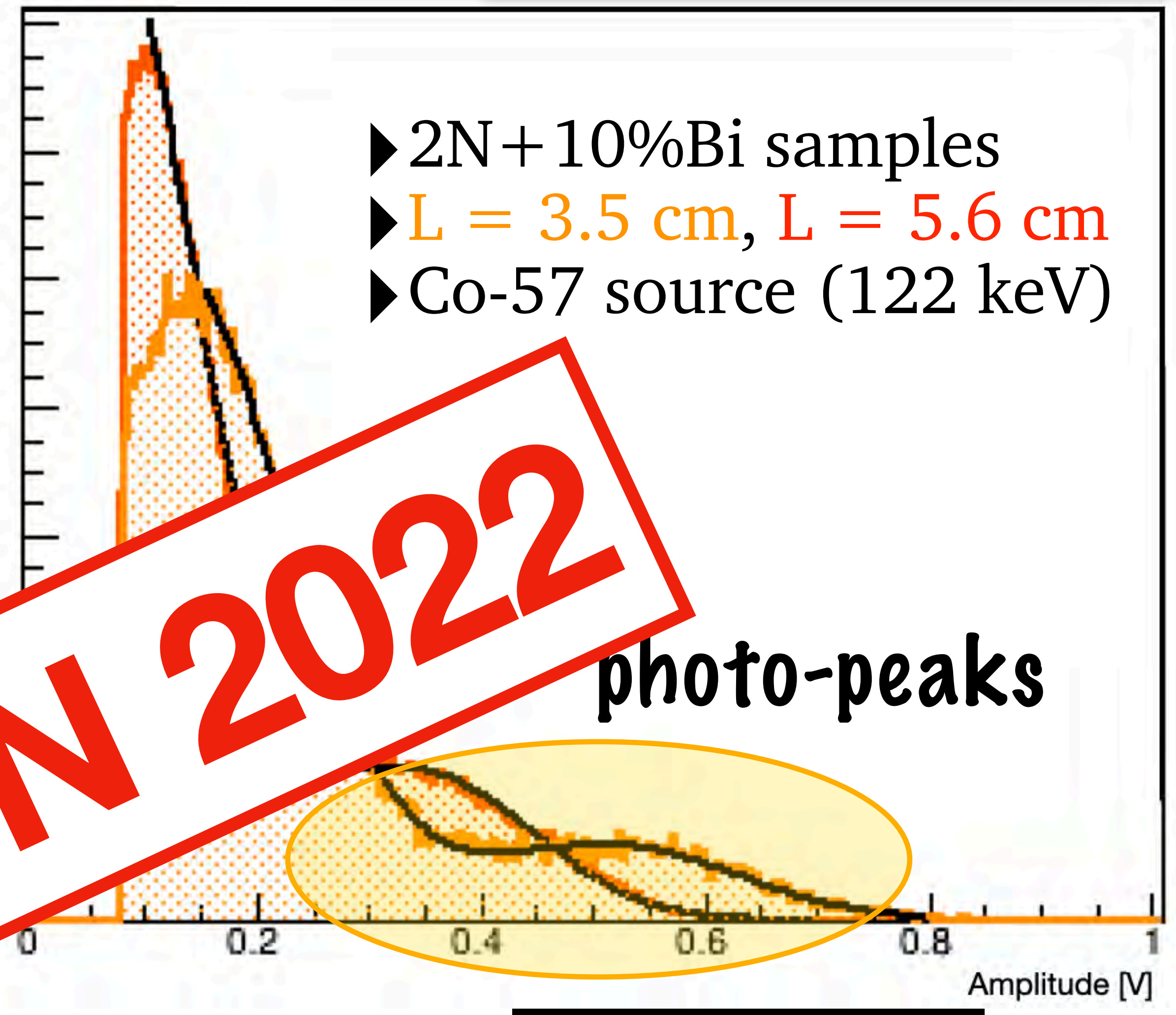




PTFE coating increases light collection.

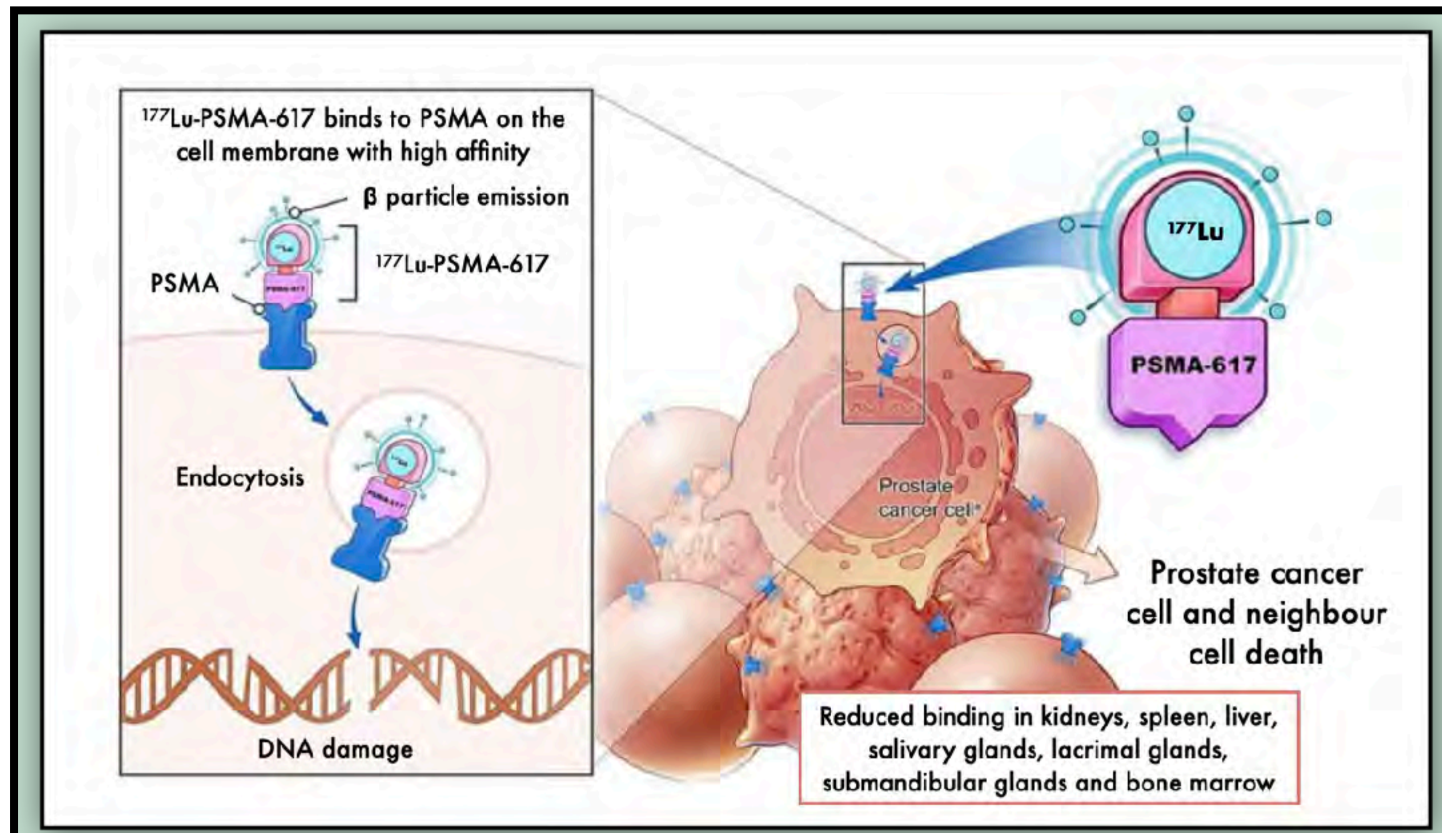
SPECT detection system	Sensitivity per module	Spatial resolution	Decay time	Rate capability	Total cost
	@140 keV	(FWHM) @10 cm	[ns]	cps/cm2	
Anger Camera (NaI) FoV: 53x39 cm²	170 cpm/μCi	7.4 mm	250	0.25k-3k	$$
reSPECT 6 rotating blocks, FoV: 35x35 cm²	184 cpm/μCi (cut 80 keV)	8.9 mm (pixel: 2 mm)	2-5	50M-200M	$

The pixelised readout is assumed in SiPMs or SPAD based arrays. Most of the efforts are devoted to design a FPGA system.



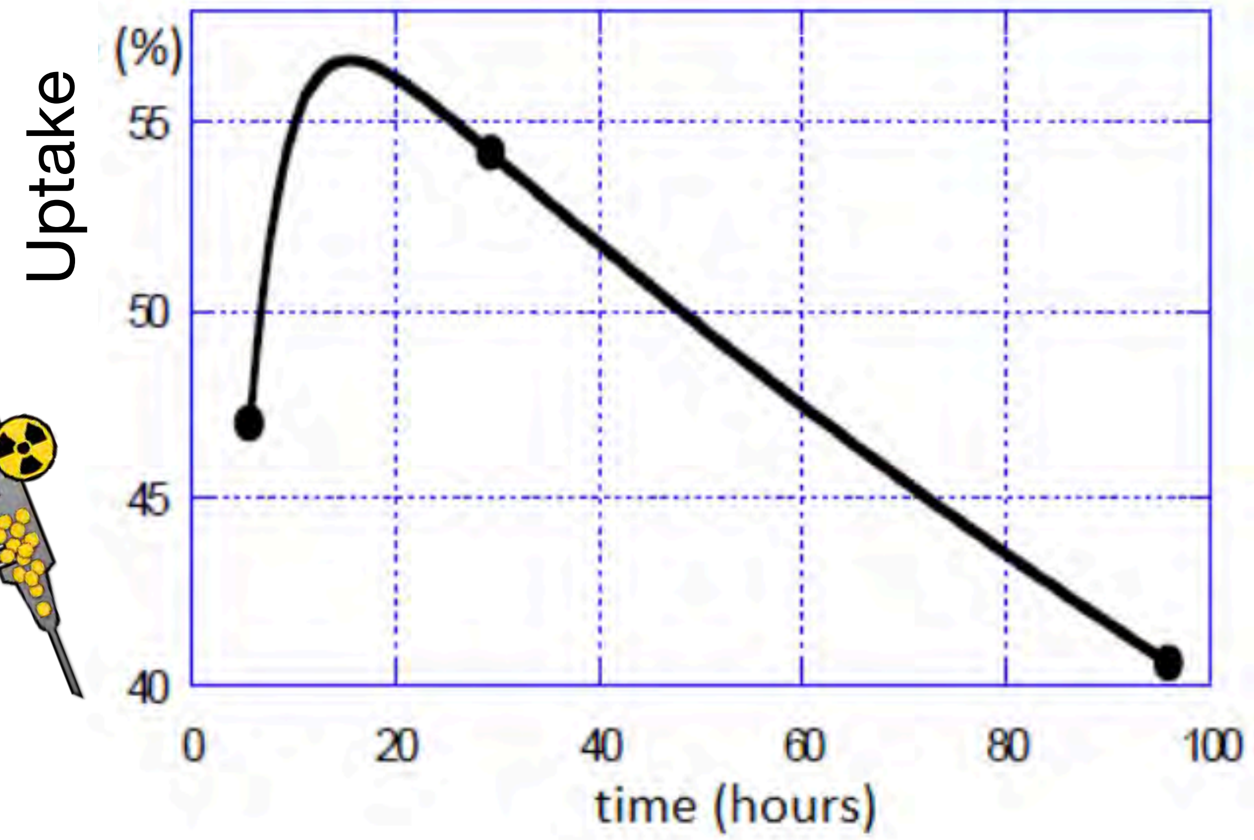
IMAGING and DOSIMETRY

CENTRO RICERCHE ENRICO FERMI — SAPIENZA Università di Roma — Azienda Ospedaliero-Universitaria Policlinico Umberto I

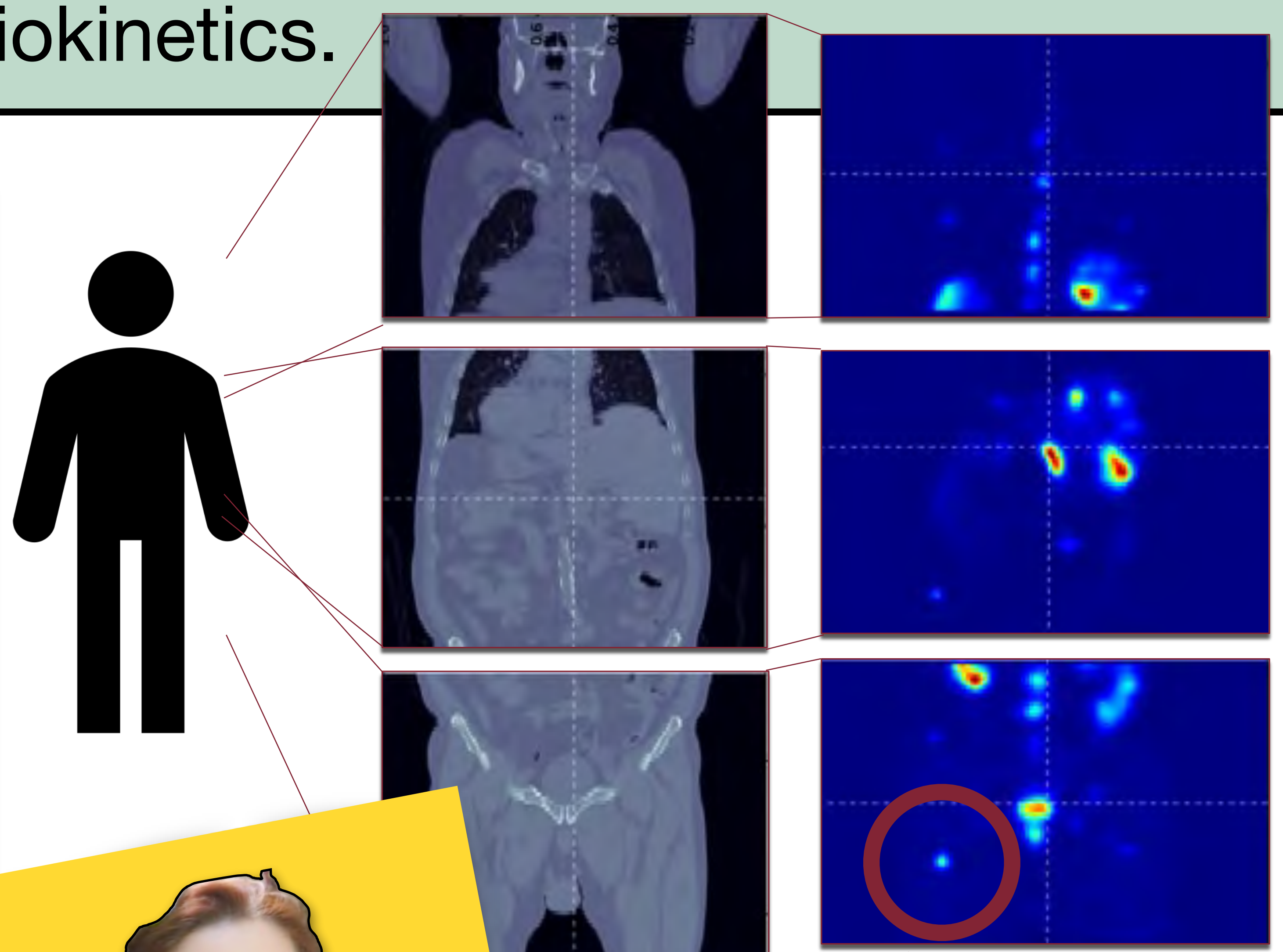


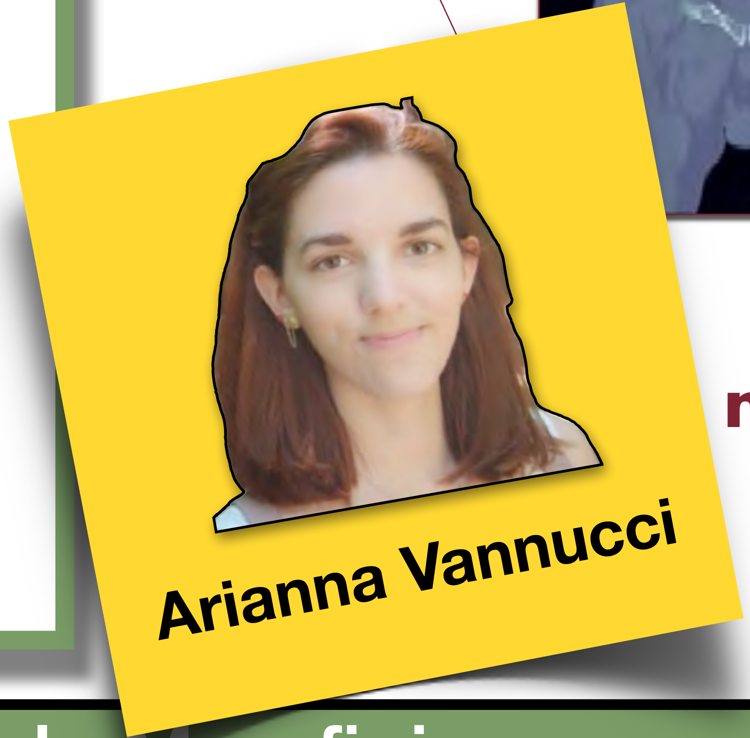
Theranostic is a medical treatement that combines therapy and diagnostics. This approach is particularly useful in **treating tumours with radio-pharmaceuticals**.

77Lu-PSMA-617 therapy for metastatic or treatment-resistant prostate cancer - the most effective treatment for metastatic Castration Resistant Prostate Cancer. Lu-177 not only **emits β^- electrons to damage cancer cells** but also **emits 208 keV gamma rays**, which can be detected with SPECT systems to **monitor** the radiopharmaceutical's biokinetics.



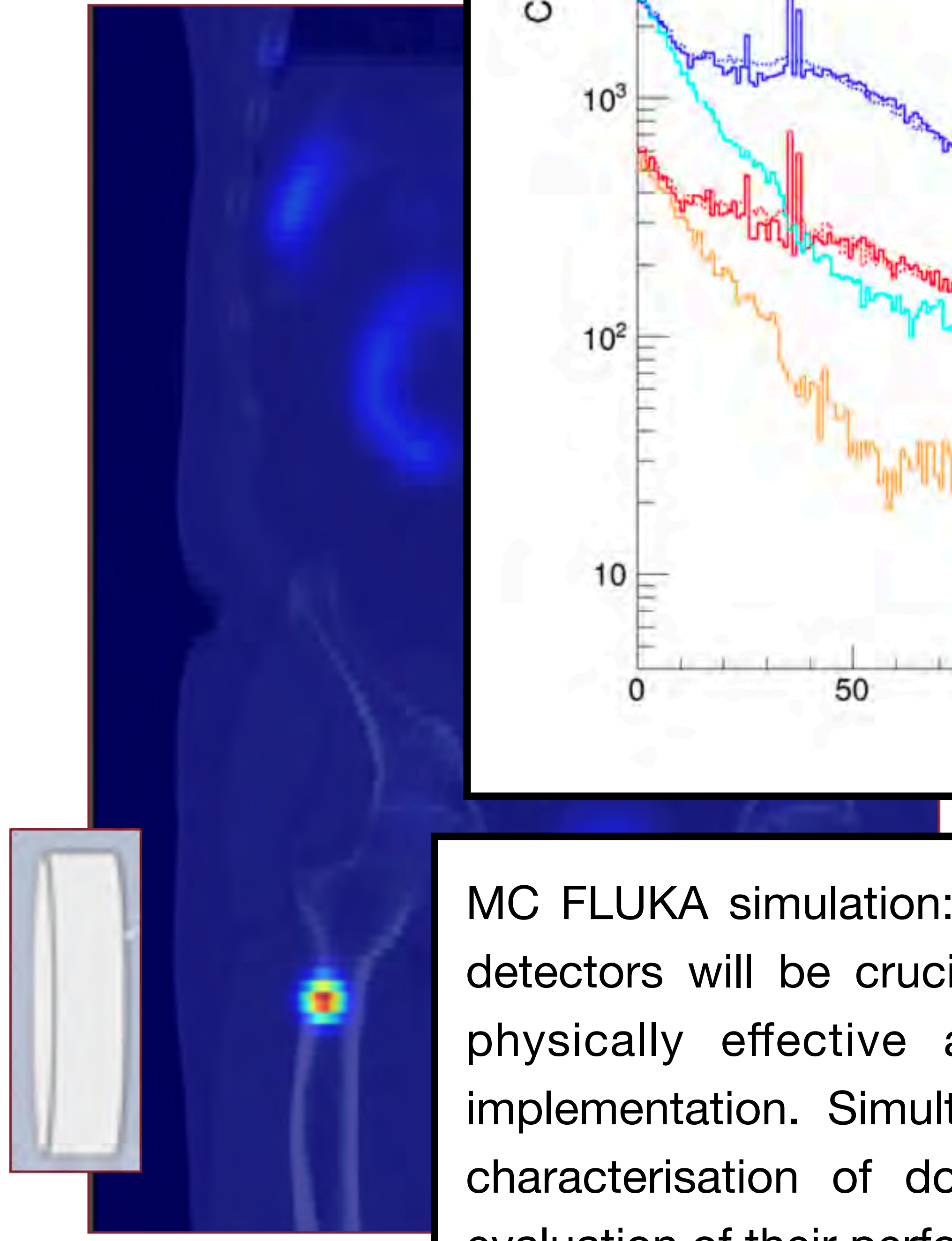
Portable γ-rays detector to retrieve the activity-vs-time curve for each patient after the administration of a reference (low) dose → determination of the radiopharmaceutical biokinetics.

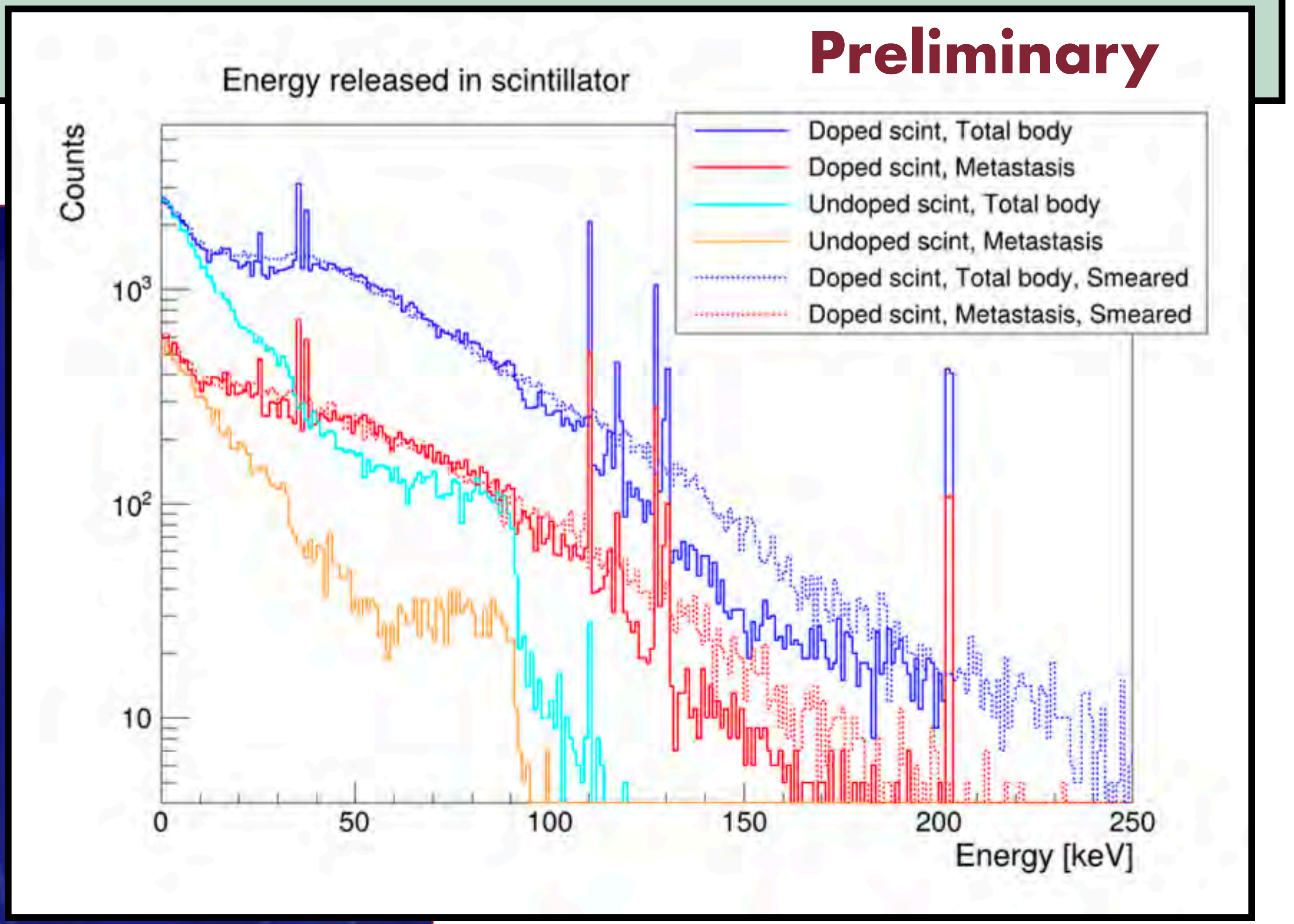




bone metastasis

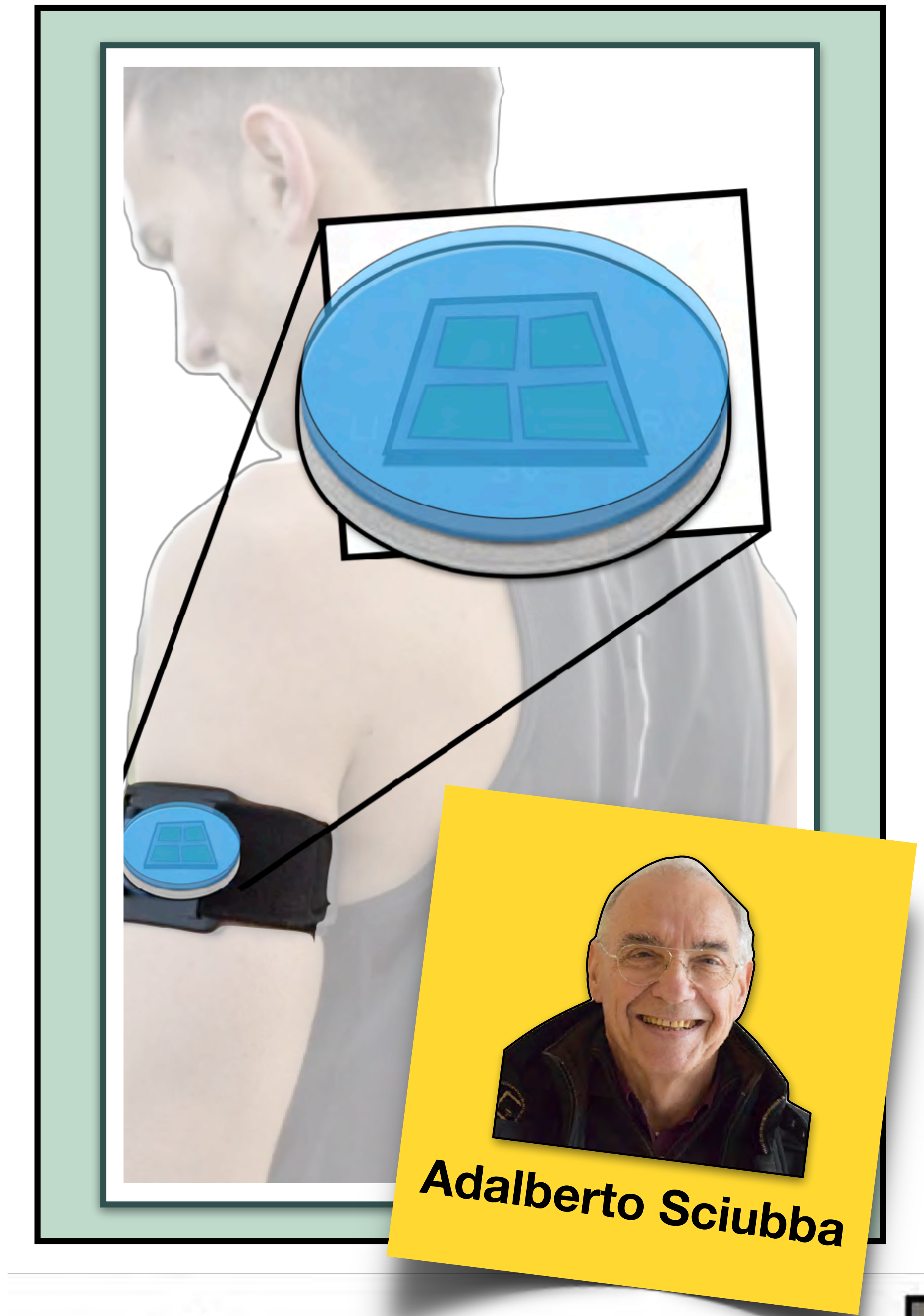
detector (dosimeter)



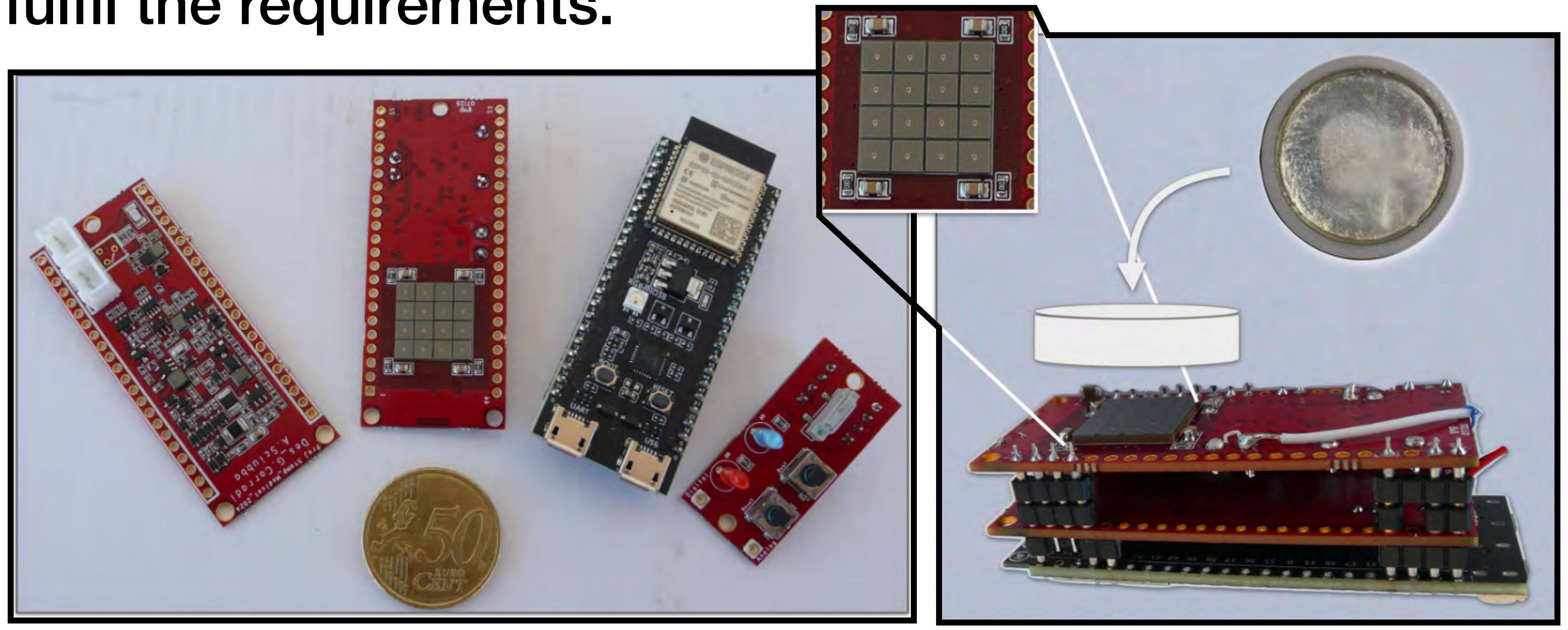


MC FLUKA simulation: Optimising the number and placement of detectors will be crucial to identify configurations that are both physically effective and feasible for practical and clinical implementation. Simultaneously, future work will include further characterisation of doped detector samples and experimental evaluation of their performance.

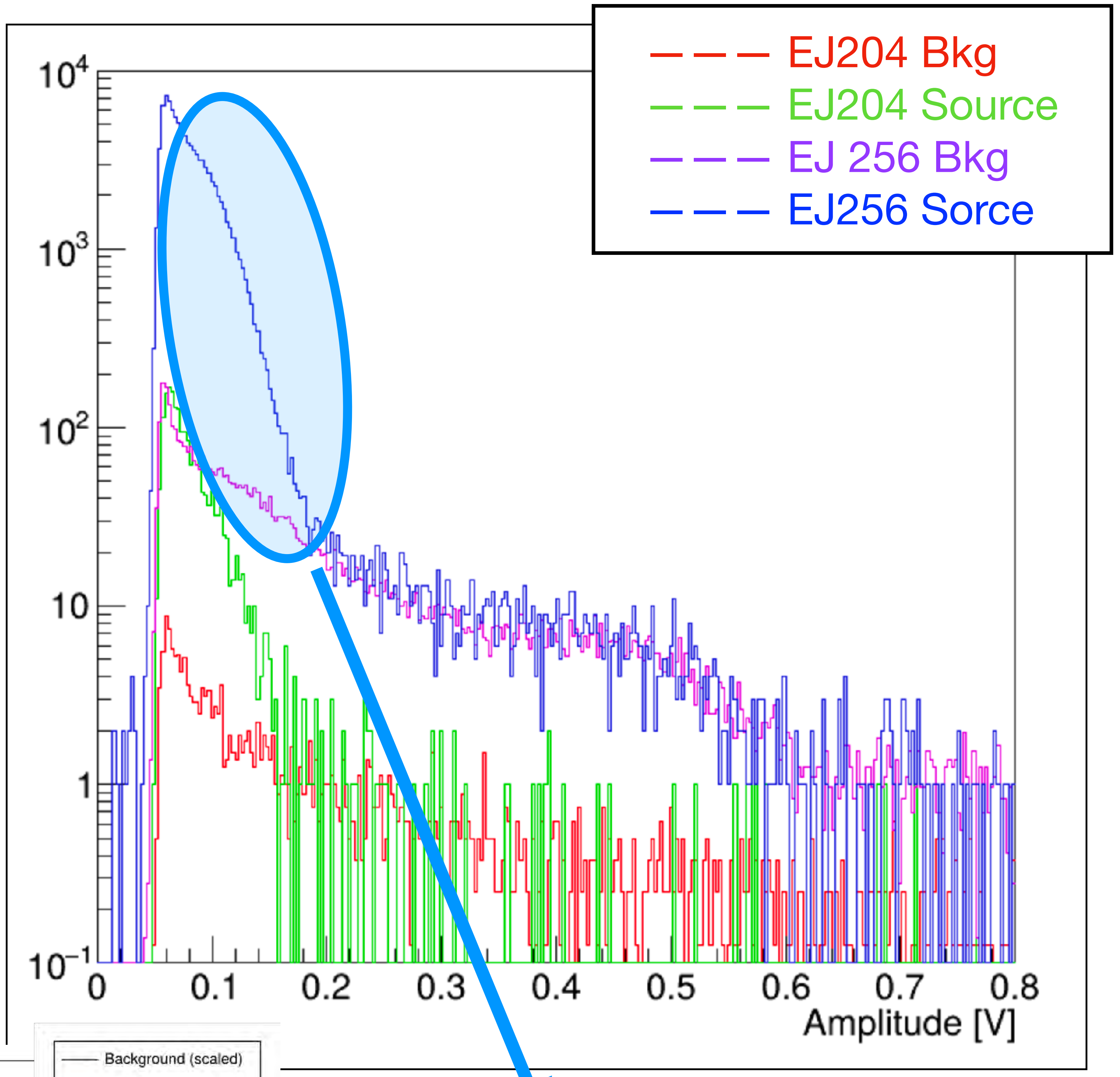
IMAGING and DOSIMETRY



The readout and DAQ system has to be compact and wireless. We are developing a dedicated prototipe to fulfil the requirements.

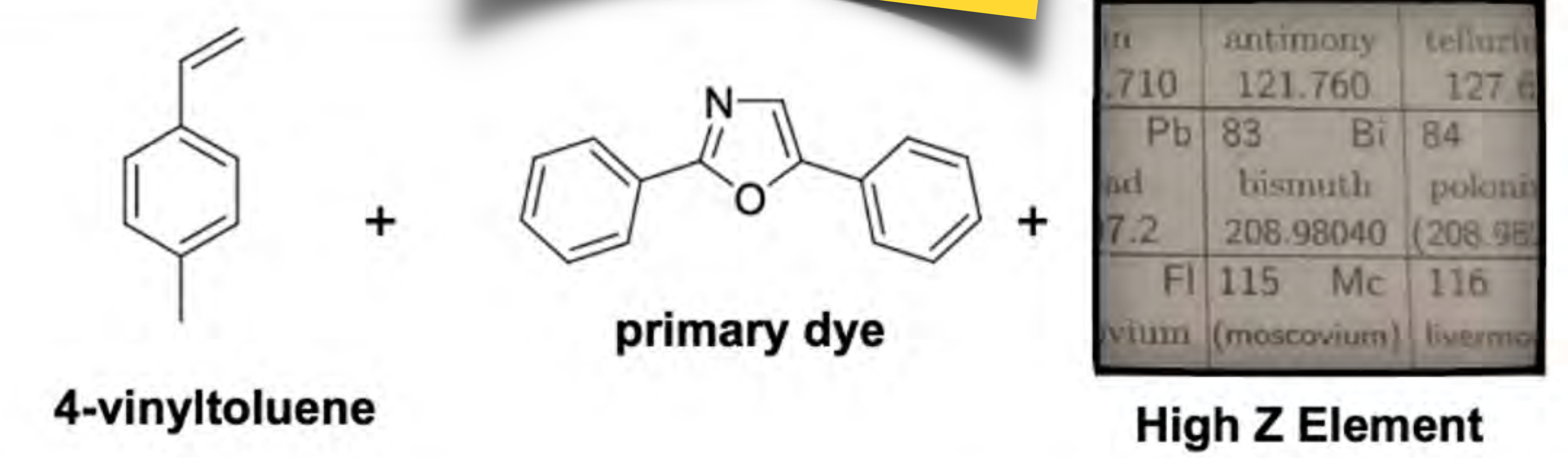


Developing organic scintillators doped with high-Z elements to exploit advantages of fast scintillation signals together with the improved photoelectric absorption probability allowing Compton scattering discrimination in the patient.

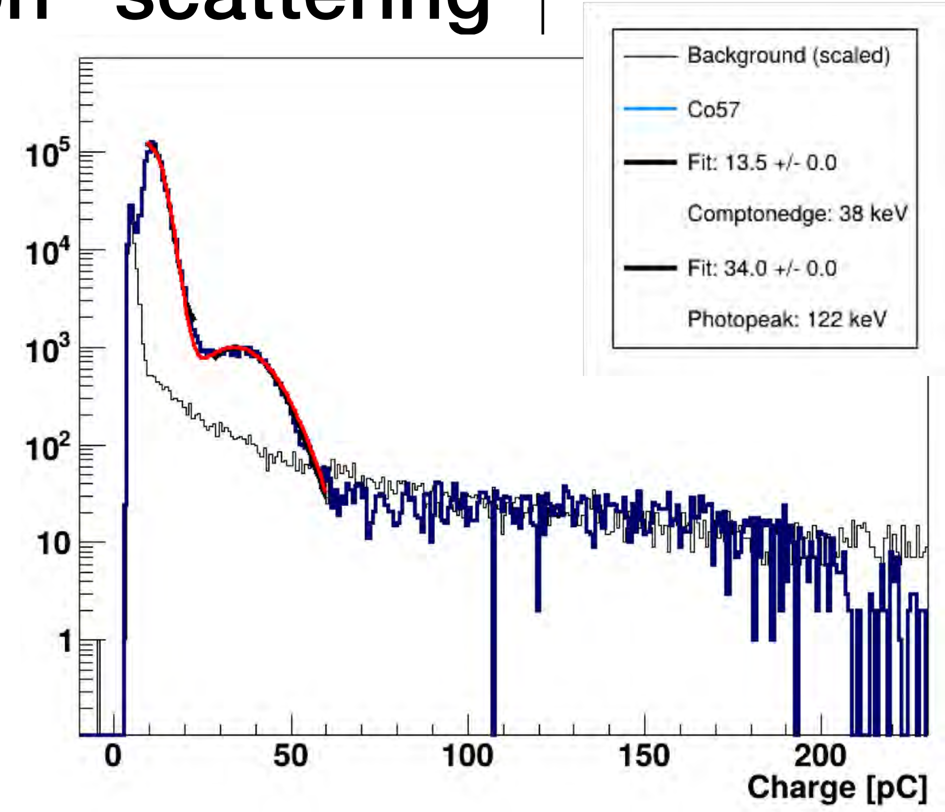


^{57}Co source - gamma at 136 keV

Test with commercial scintillators, EJ204 as a reference and EJ256 doped at 5% of Pb.
Measurements with homemade samples are ongoing.



The custom electronic system that has been developed is giving very good results (low noise, dynamic range).
A 2.0 system will be delivered in one year (problem fixing and optimisation of the crucial parameters) for next level steps.



SECONDARY PARTICLES IN INNOVATIVE RADIOTHERAPY

FOOT (INFN) experiment: measurement of fragmentation cross-sections relevant for particle therapy and radio protection in space.

Physics	Application field	Beam	Target	Upper Energy (MeV/nucleon)	Kinematic approach	Interaction process
Target fragmentation	PT	^{12}C	C, C_2H_4	200	inverse	p+C
Target fragmentation	PT	^{16}O	C, C_2H_4	200	inverse	p+O
Beam fragmentation	PT	^{4}He	C, C_2H_4	250	direct	α+C, α+H,
Beam fragmentation	PT	^{12}C	C, C_2H_4	400	direct	C+C, C+H,
Beam fragmentation	PT	^{16}O	C, C_2H_4	500	direct	O+C, O+H,
Beam fragmentation	Space	^{4}He	C, C_2H_4	800	direct	α+C, α+H,
Beam fragmentation	Space	^{12}C	C, C_2H_4	800	direct	C+C, C+H,
Beam fragmentation	Space	^{16}O	C, C_2H_4	800	direct	O+C, O+H,

(*) Cross section on H target will be got by stoichiometric subtraction between cross section on polyethylene (C2H4) and C target

Radiobiological desiderata in PT:

- ✓ $d\sigma/dE$ for target fragm. in PT ~ 10%
- ✓ $d^2\sigma/d\Omega dE$ for projectile fragm. in PT ~ 5%
- ✓ ΔZ ~ 2-3% ; ΔA ~ 5%

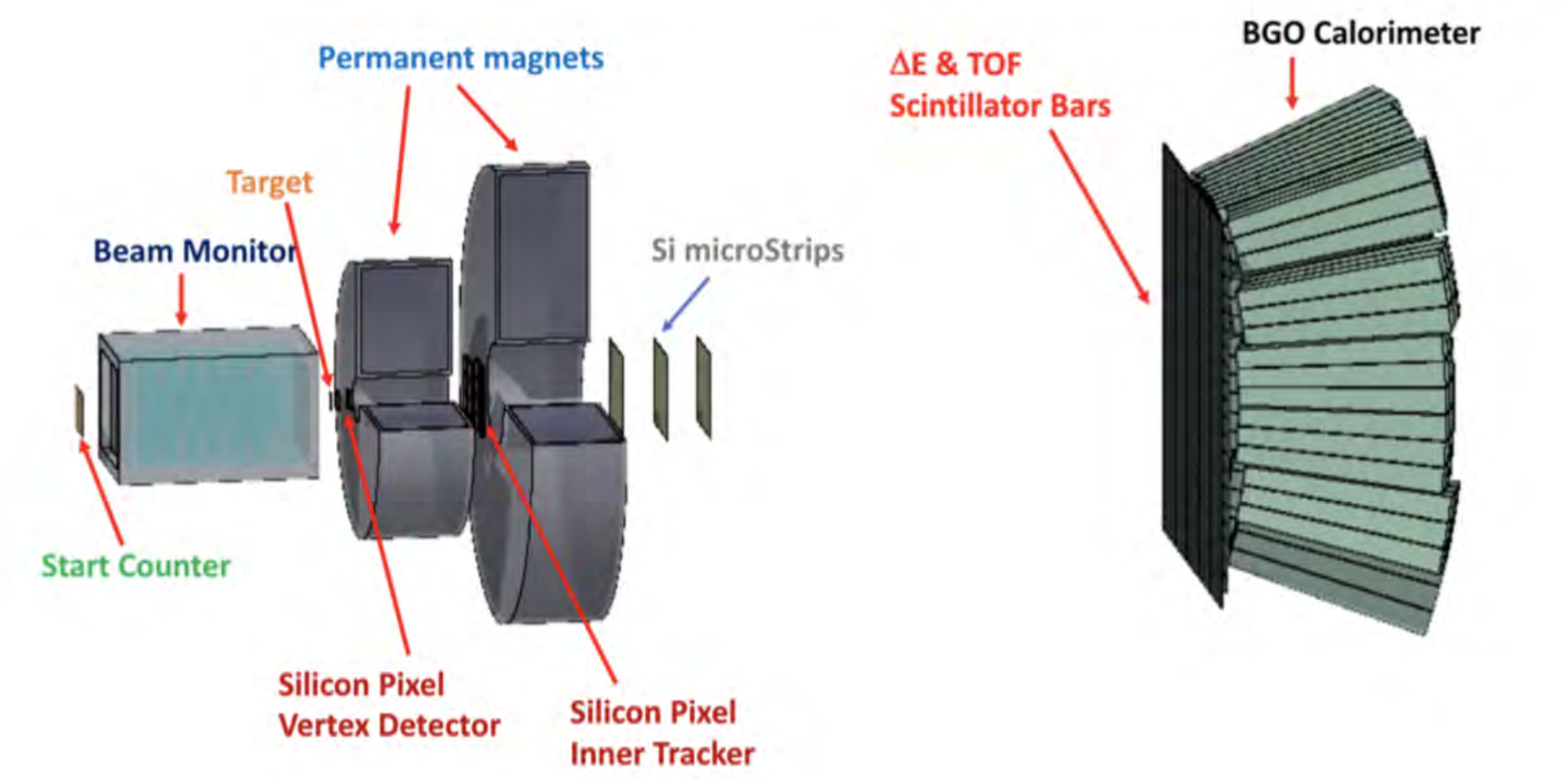
Required FOOT performances:

- ✓ $\sigma(p)/p < 5\%$
- ✓ $\sigma(E_{kin})/E_{kin} < 3\%$
- ✓ $\sigma(\Delta E)/\Delta E < 5\%$
- ✓ $\sigma(TOF) < 100$ ps

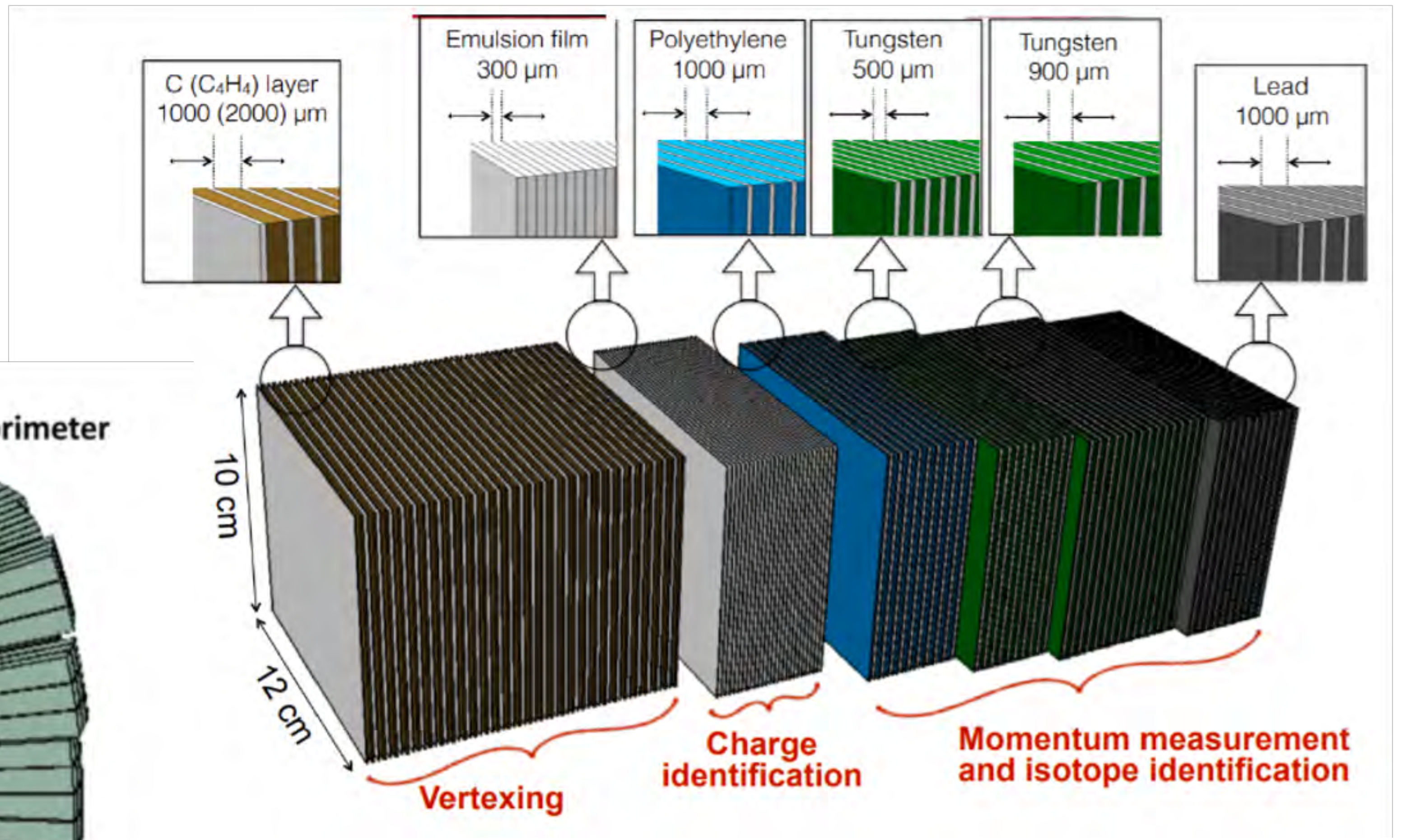
Laura Rocchetti

new CREF PhD 2025

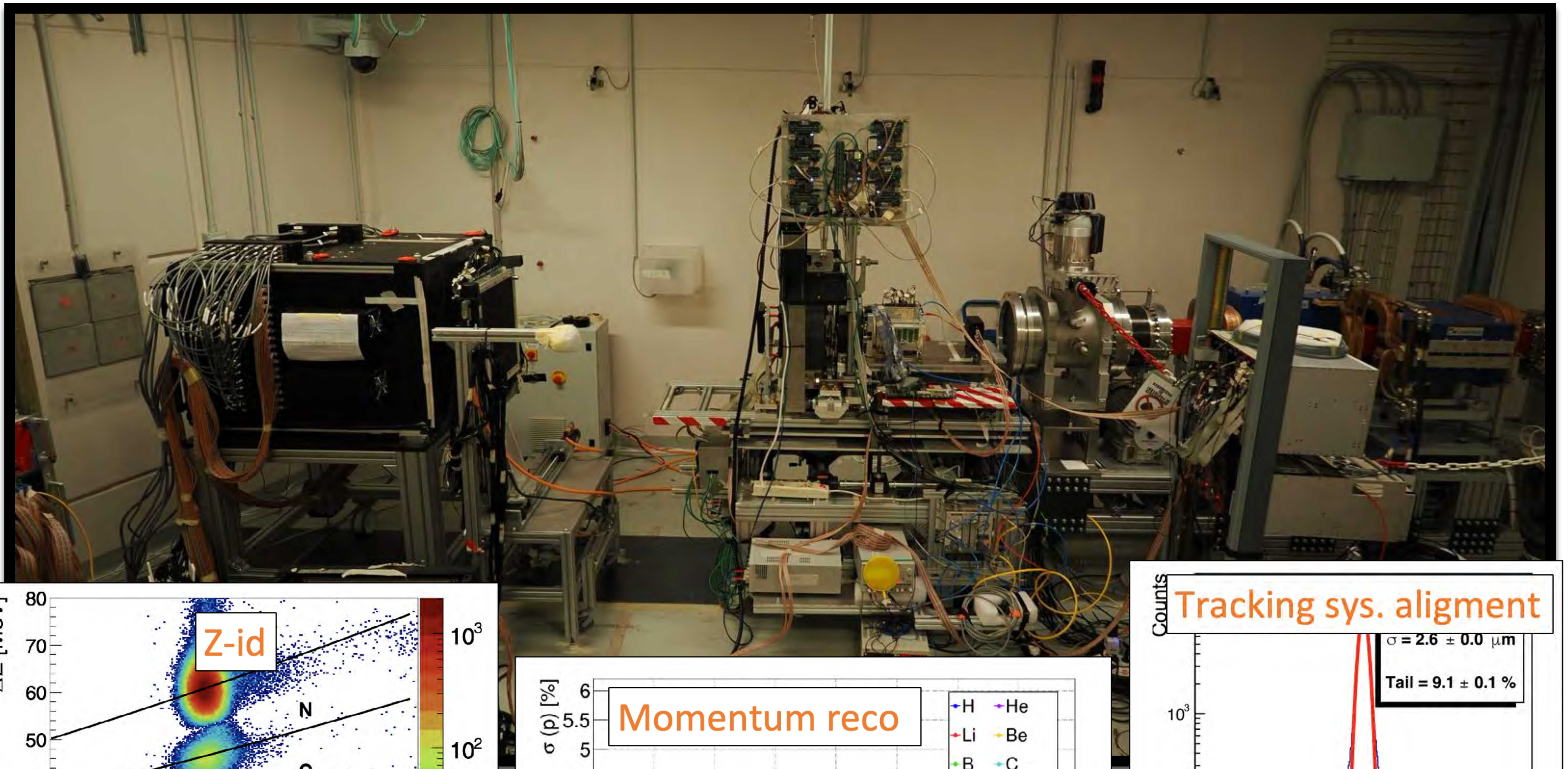
Spectrometer setup (Z>=2)

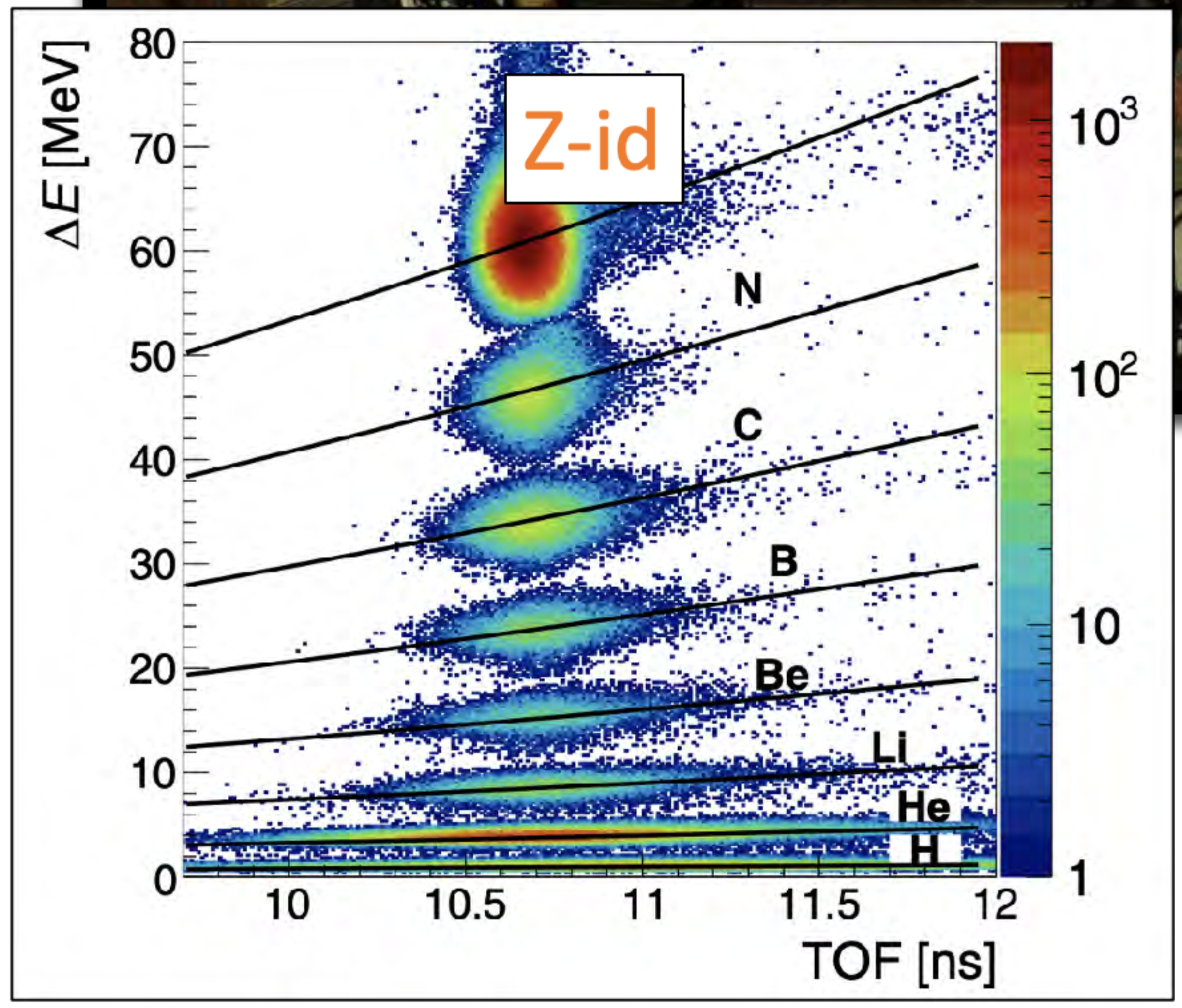


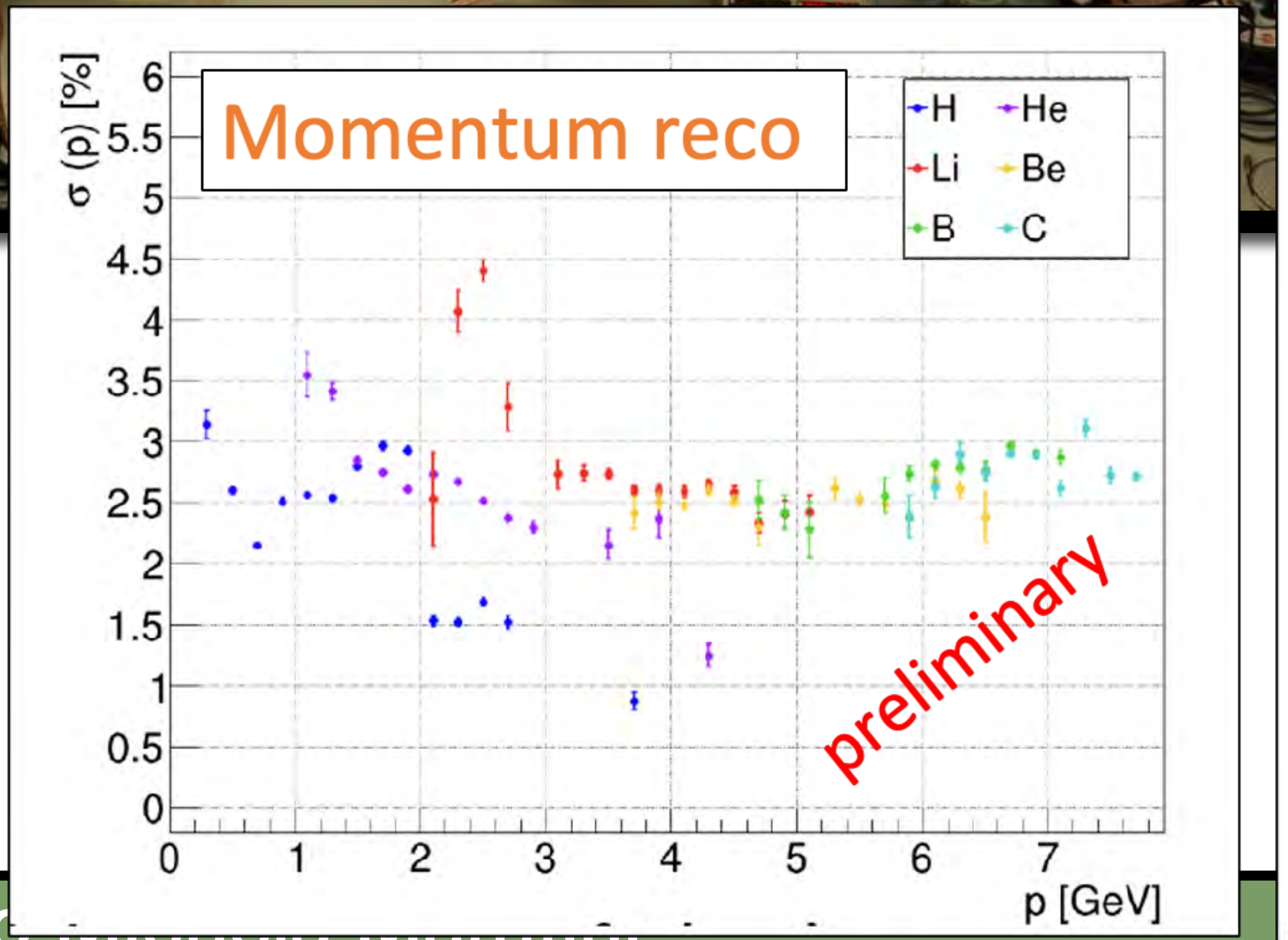
Emulsion setup (Z<=3)

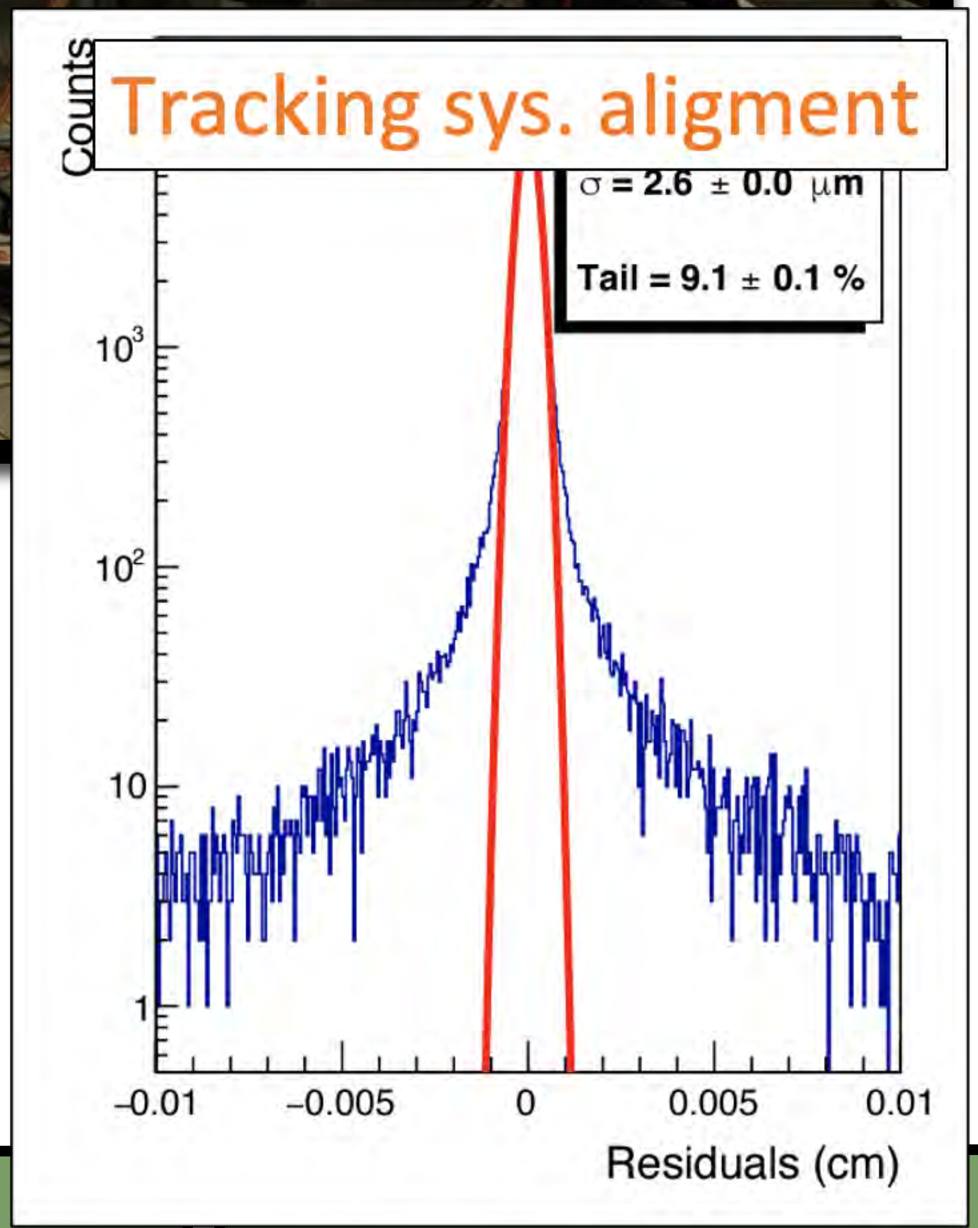


SECONDARY PARTICLES IN INNOVATIVE RADIOTHERAPY



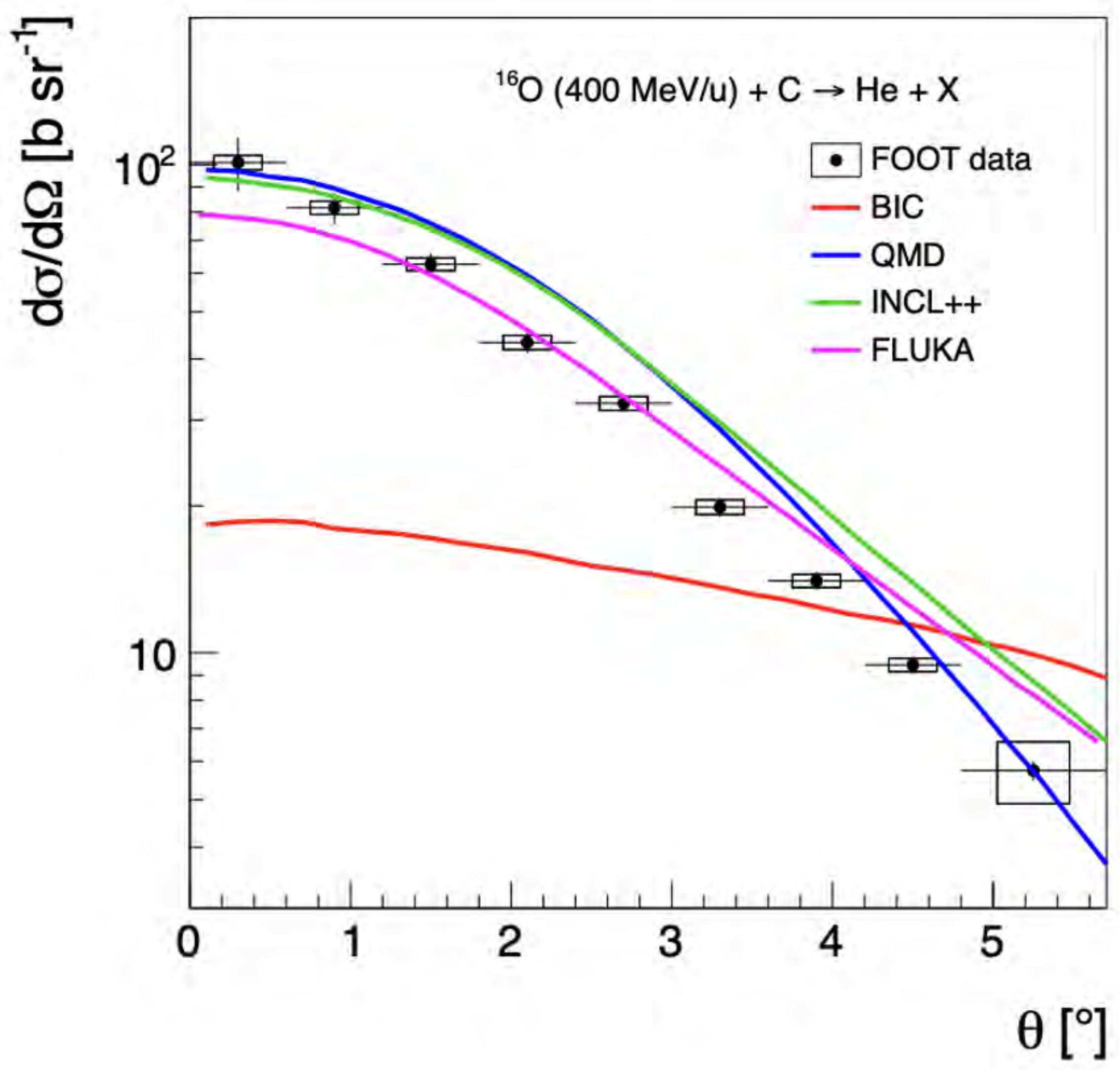


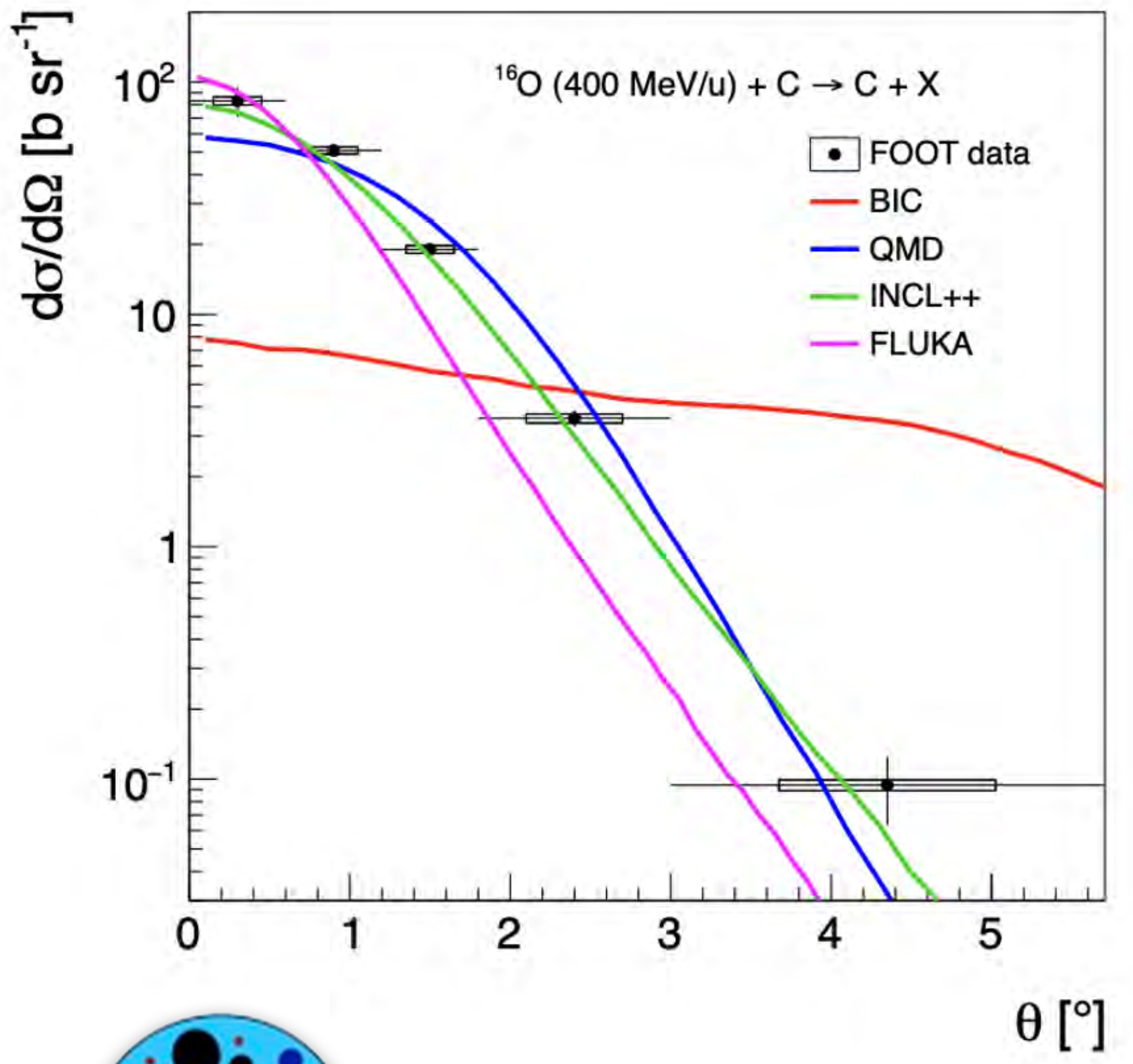




Ridolfi R. et al, Physics Review C, 2025,
DOI: https://doi.org/10.1103/nmw9-ldrm

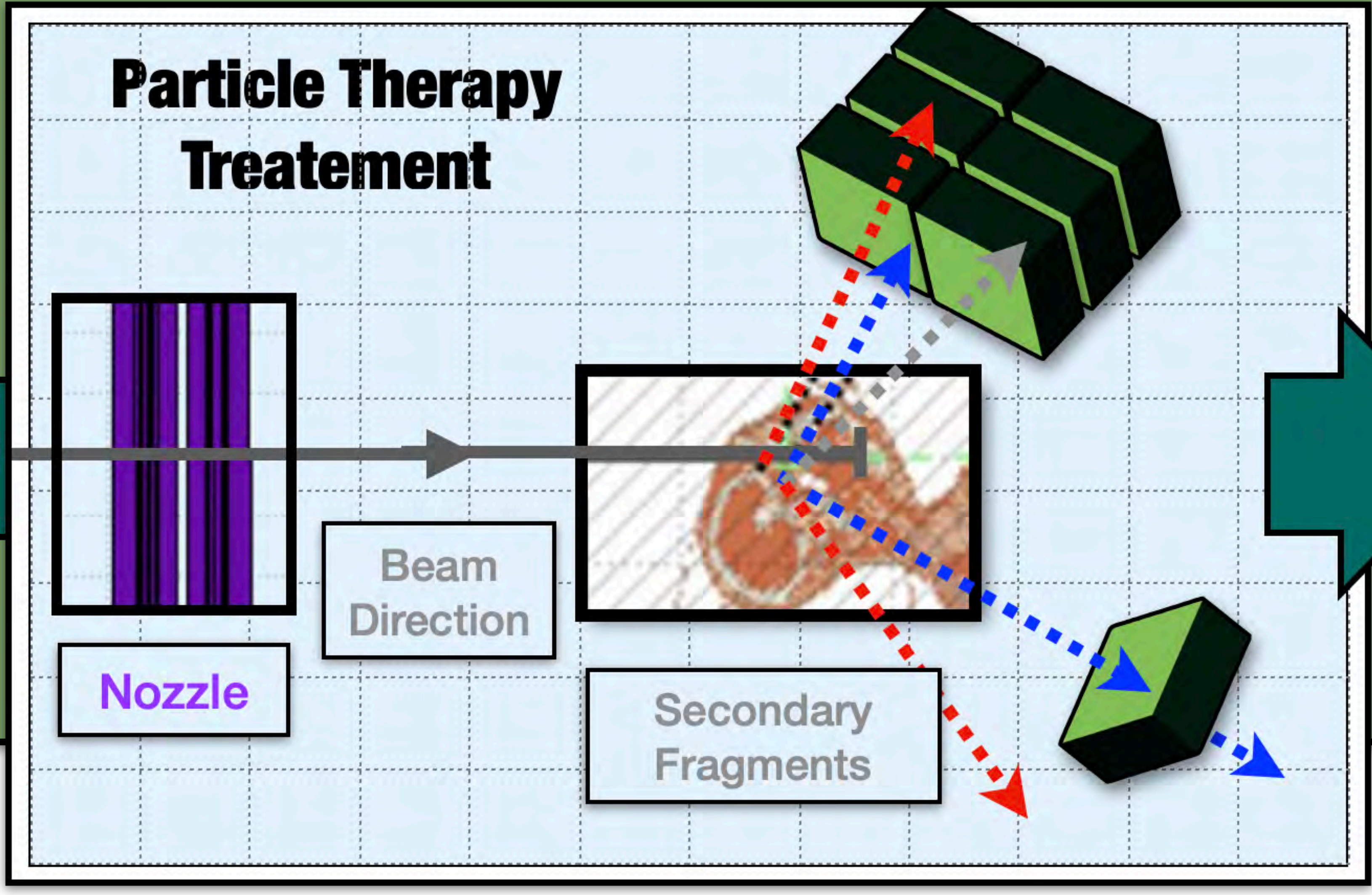
Data collected @ GSI 2021

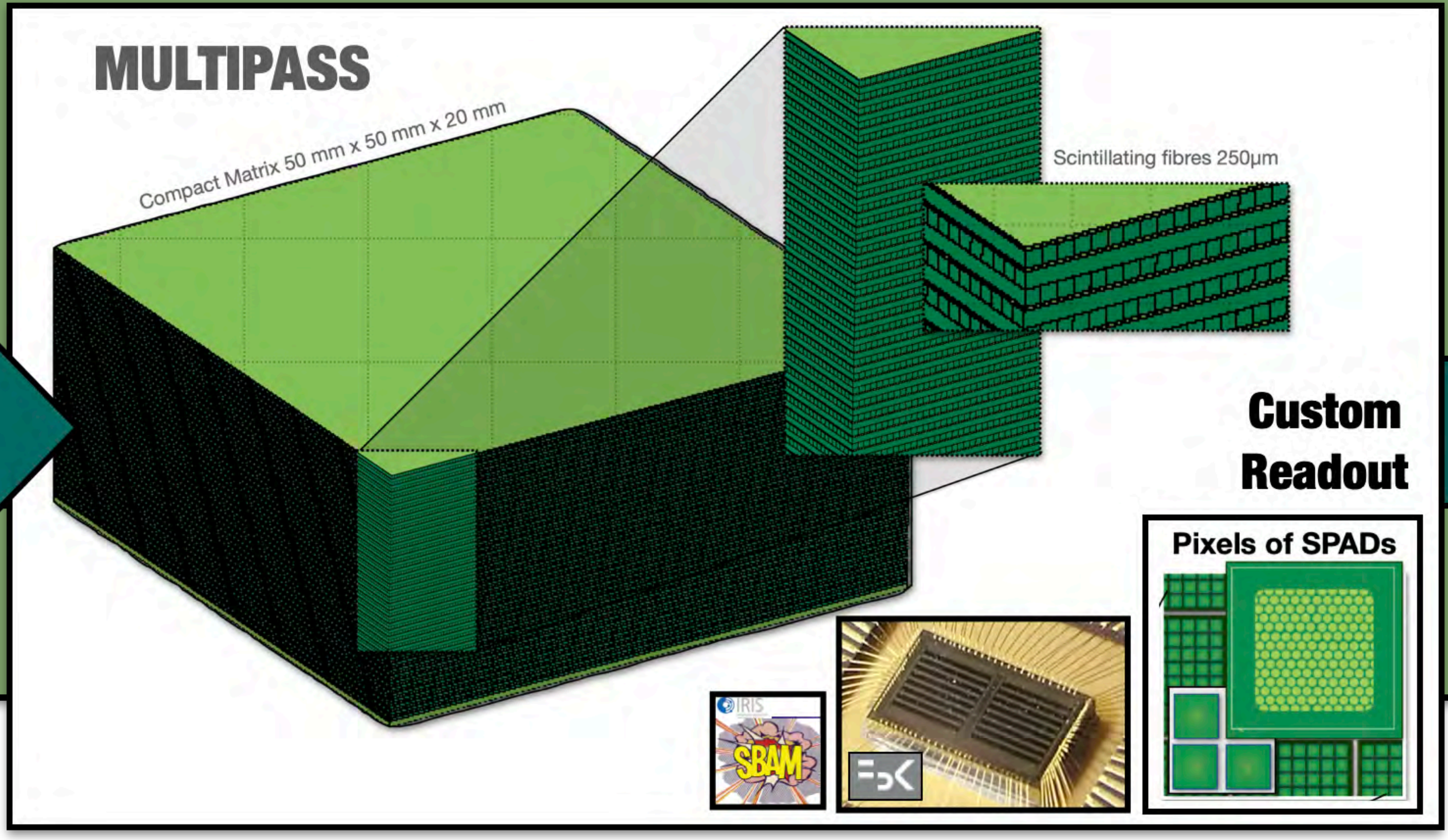




MONITORING TREATEMENTS

PRIN PNRR 2022



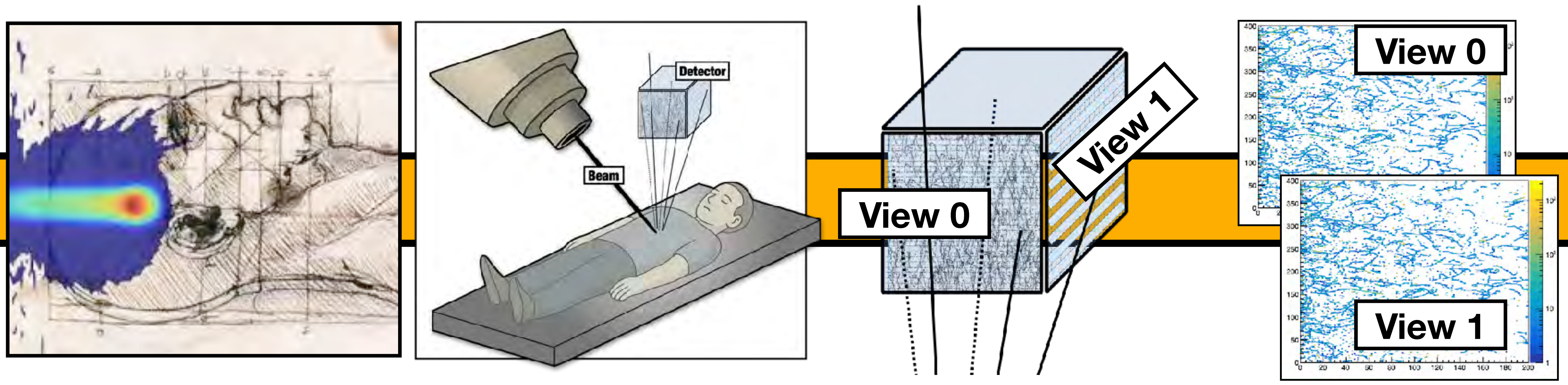


ON LINE MONITORING IS STILL AN OPEN AND CHALLENGING TASK IN PARTICLE THERAPY

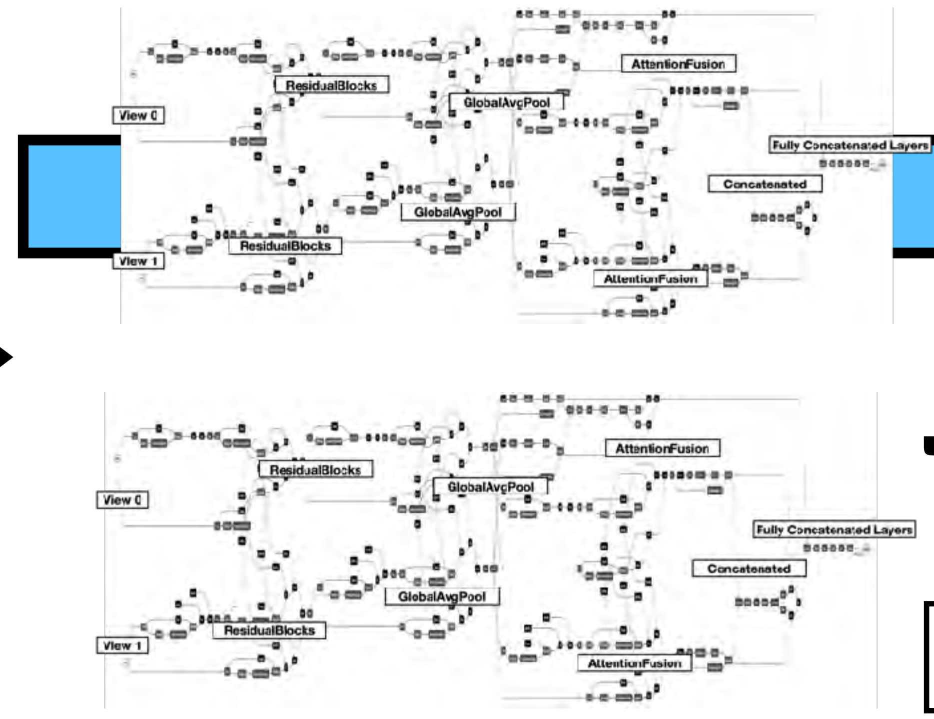
Luana Testa

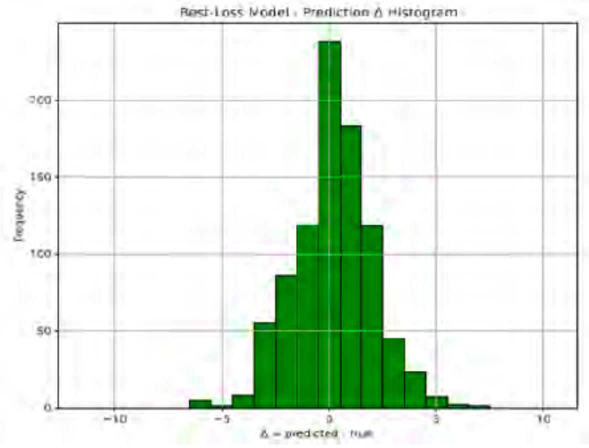
new CREF PhD 2025

MC simulation of a specific case: Simulated Response



AI-Elaboration



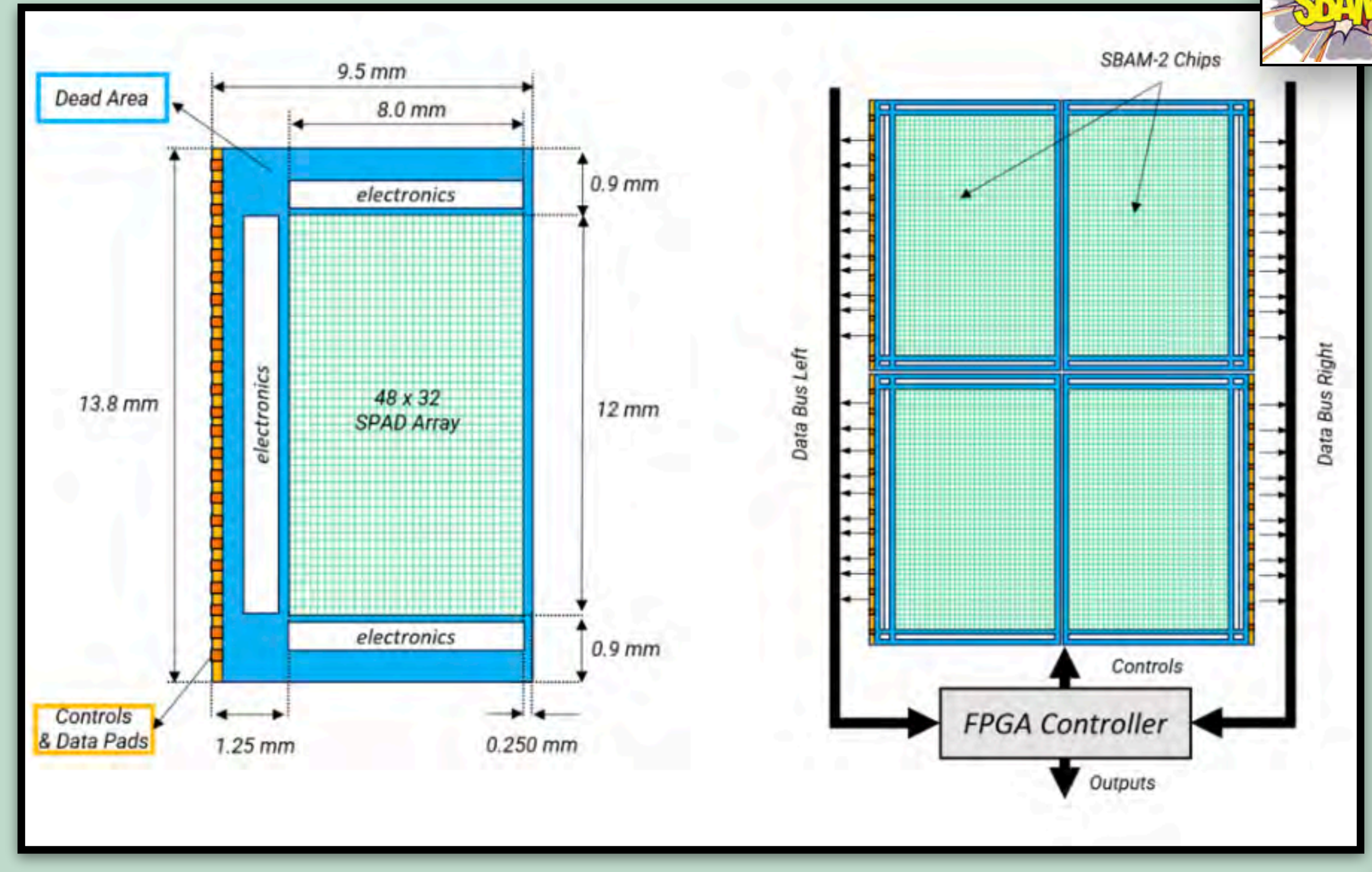


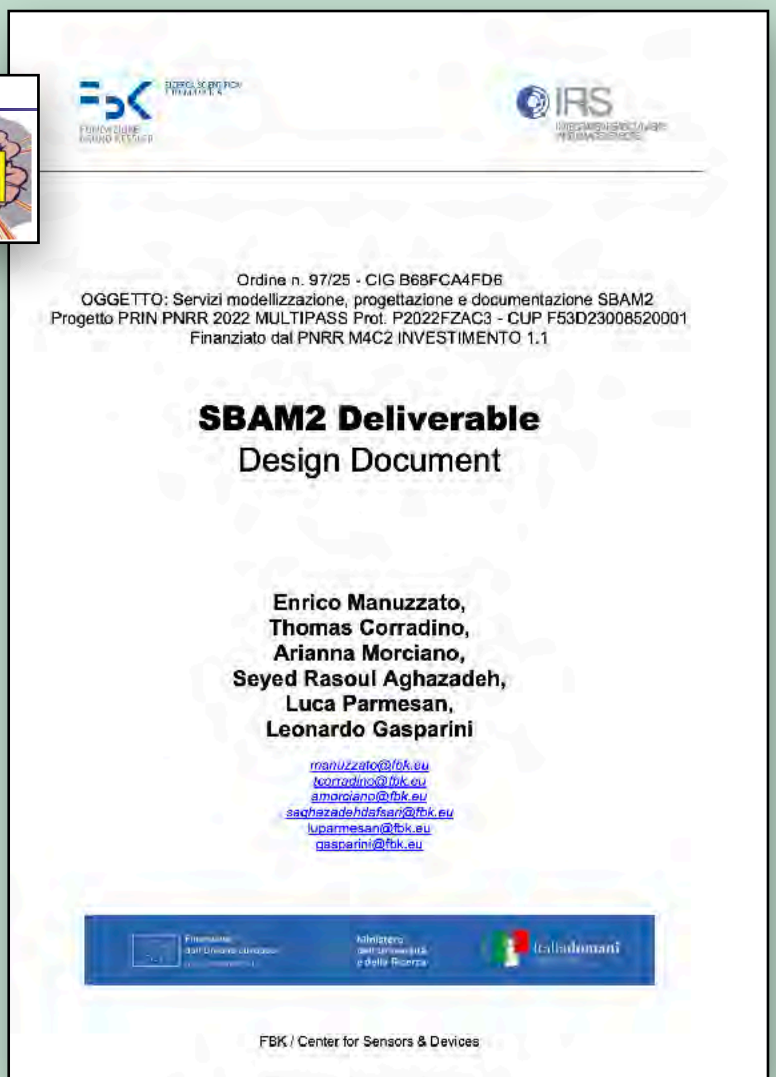
AI-Feedback

Finanziato dall'Unione europea NextGenerationEU · Ministero dell'Università e della Ricerca · Italiadomani Piano Nazionale di Ripresa e Resilienza

MONDO => MULTIPASS => NEXT

- Design of the new chip - SBAM 2





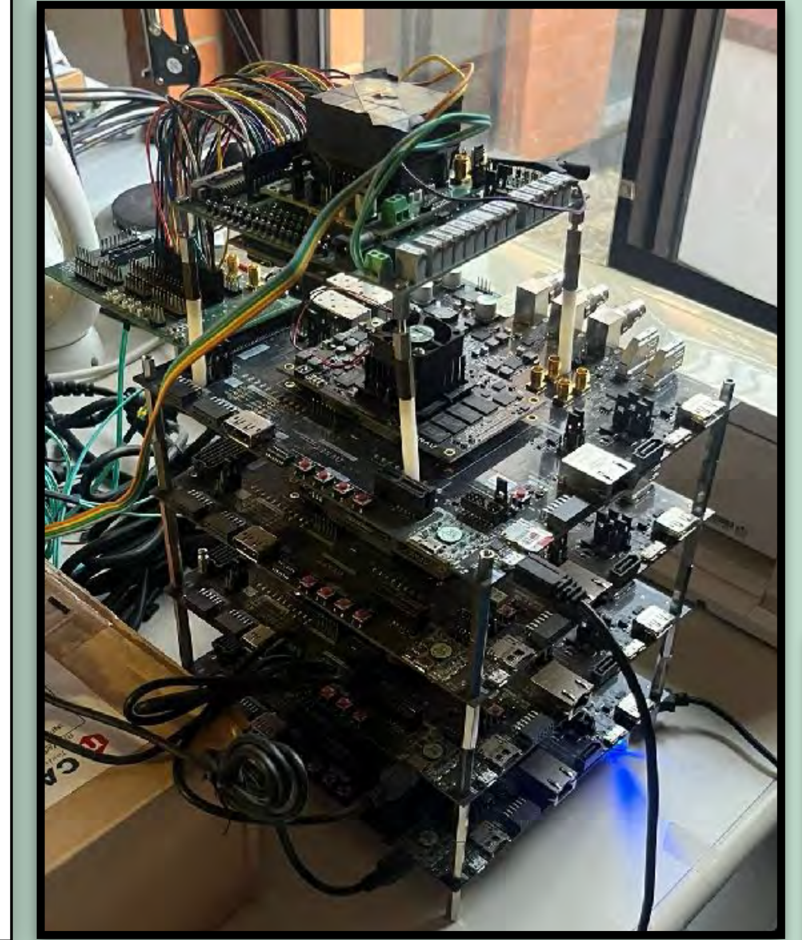
Ordine n. 97/25 - CIG B68FCA4FD6
OGGETTO: Servizi modellizzazione, progettazione e documentazione SBAM2
Progetto PRIN PNRR 2022 MULTIPASS Prot. P2022FZAC3 - CUP F53D23008520001
Finanziato dal PNRR M4C2 INVESTIMENTO 1.1

SBAM2 Deliverable
Design Document

Enrico Manuzzato,
Thomas Corradino,
Arianna Morciano,
Seyed Rasoul Aghazadeh,
Luca Parmesan,
Leonardo Gasparini

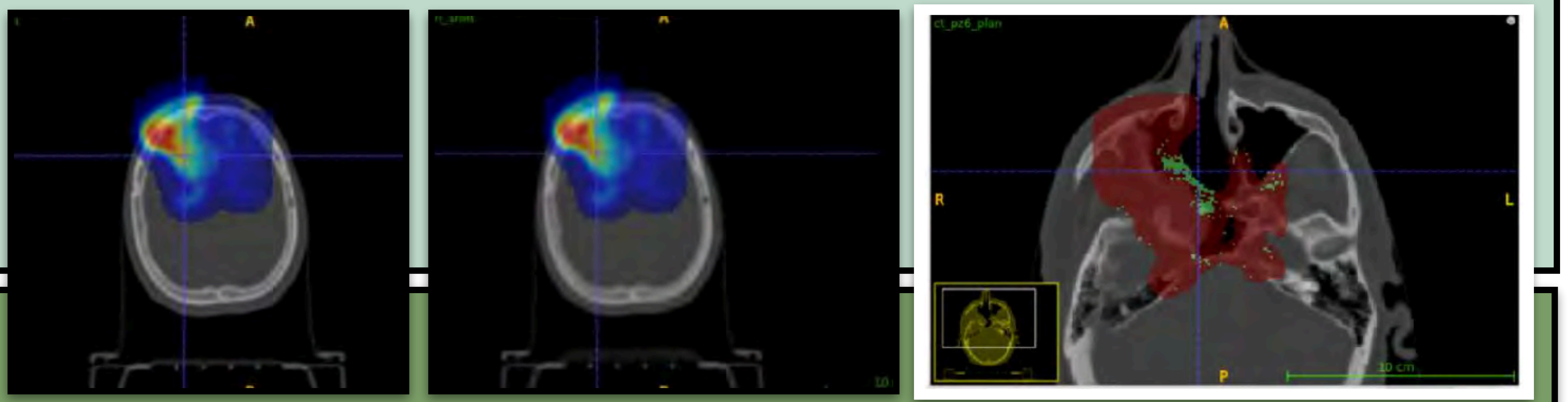
FBK / Center for Sensors & Devices

- Architecture FPGA sys.

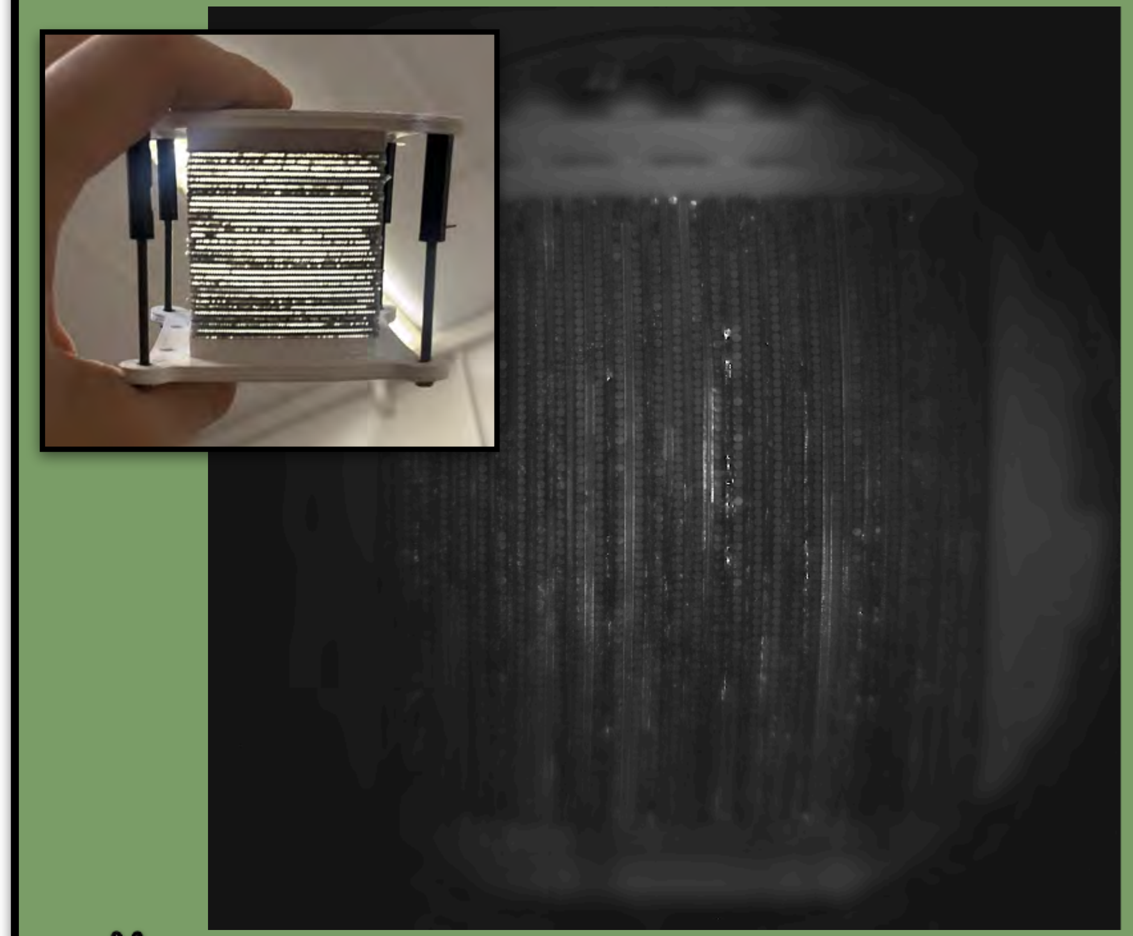


- Montecarlo Simulation (FLUKA)

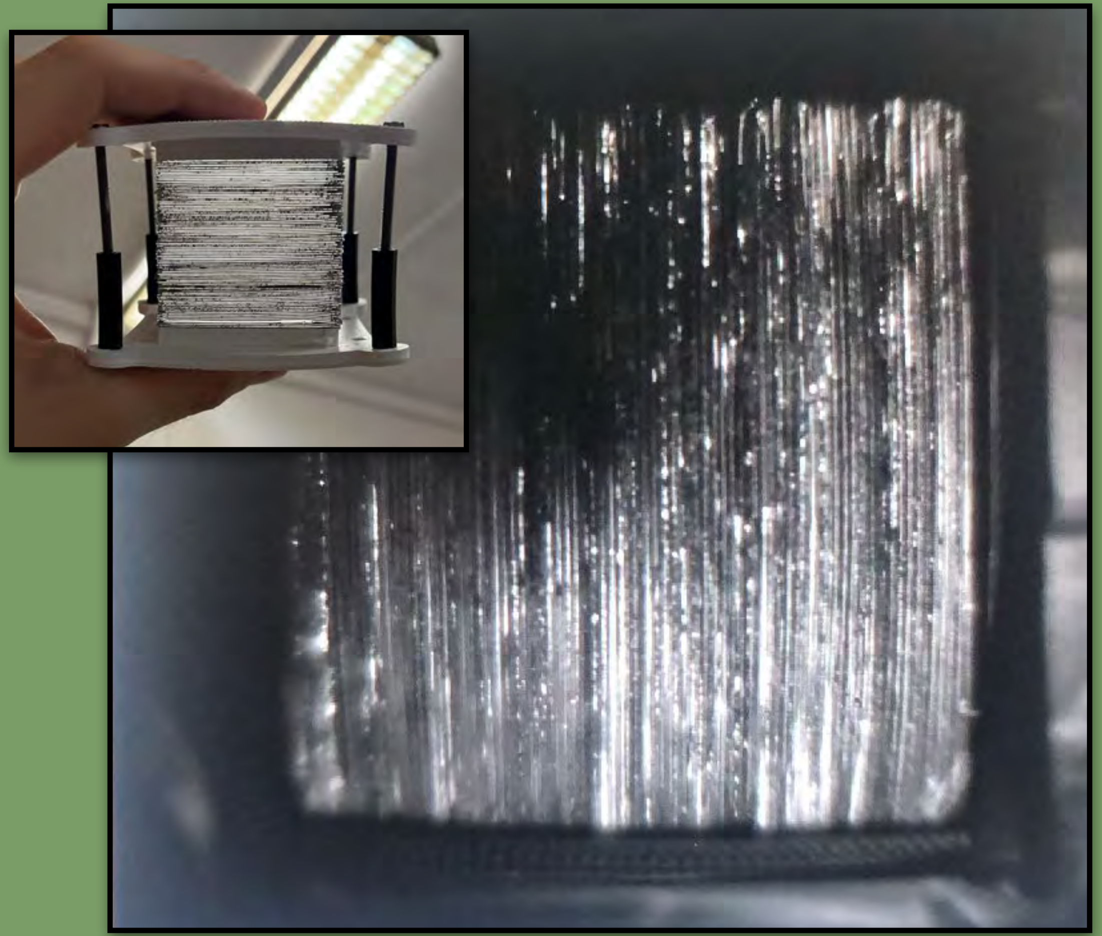
MC study: investigate the potential of the detector as a 3D inter-fractional monitor of anatomical changes in a real case scenario. 3D spatial emission maps of reconstructed secondary protons by the detector have been obtained by simulating the 12C ion therapy treatment plan of the selected patient on its planning CT. Gamma-index map visualized in pass-rate mode superimposed to the CT1: green voxels are the discrepant ones between the compared 3D emission maps obtained from CT1 and CT2. Non-discrepant voxels between maps are shown in red.



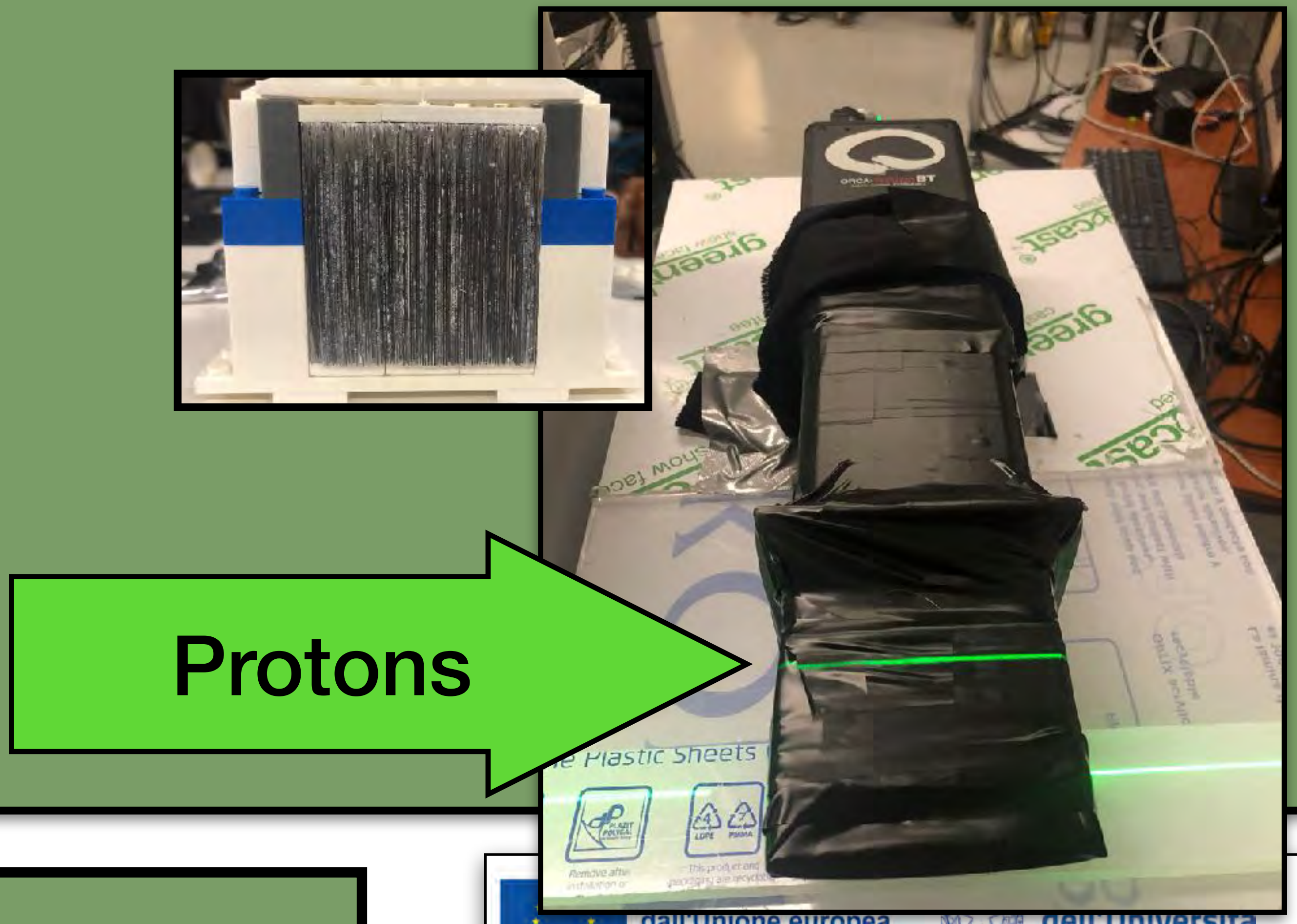
- Single cladding, rounded 700µm

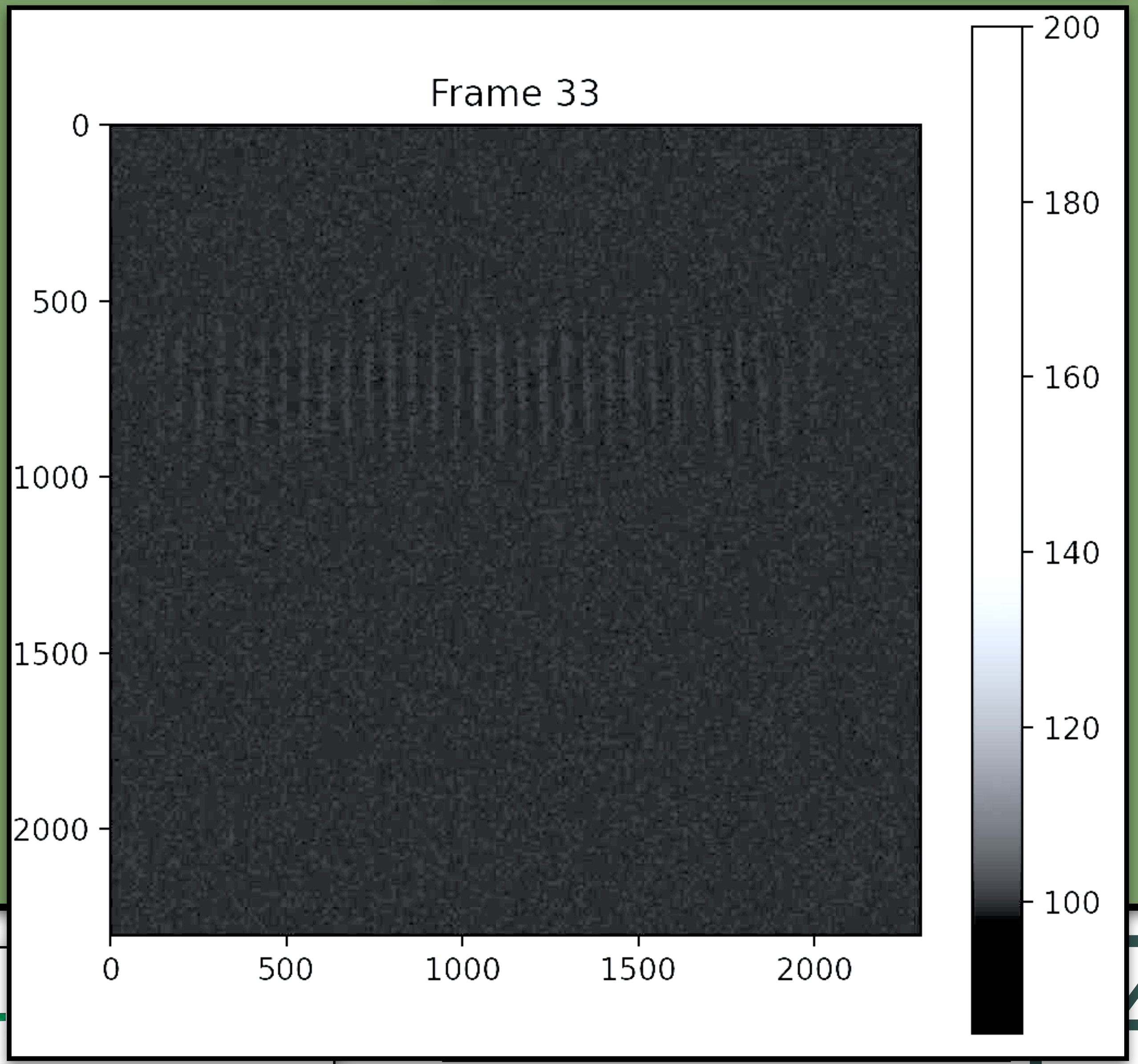


- Double cladding, squared 250µm



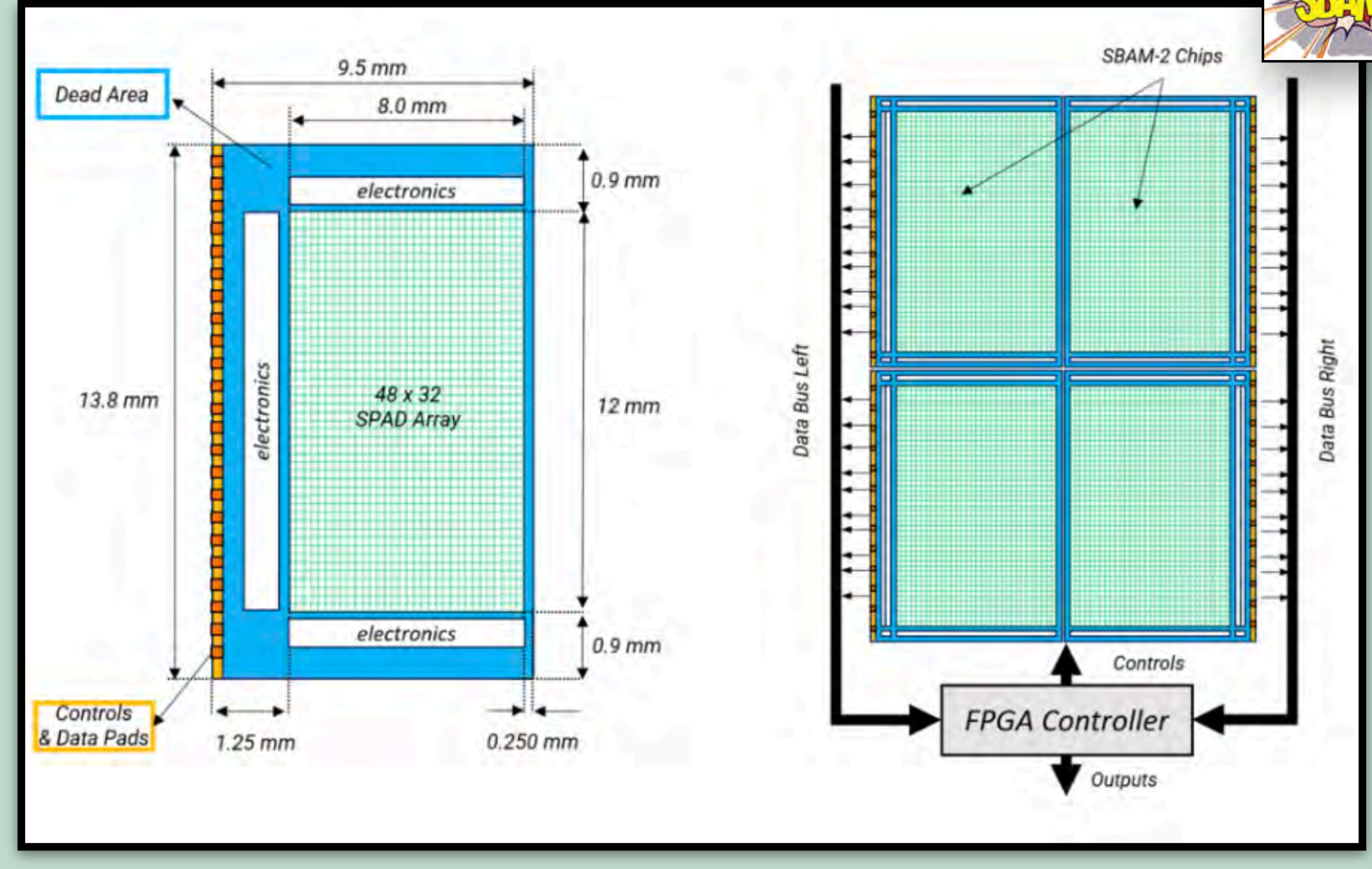
Test on Proton Beam (2 days ago) at CNAO with tracker prototypes:

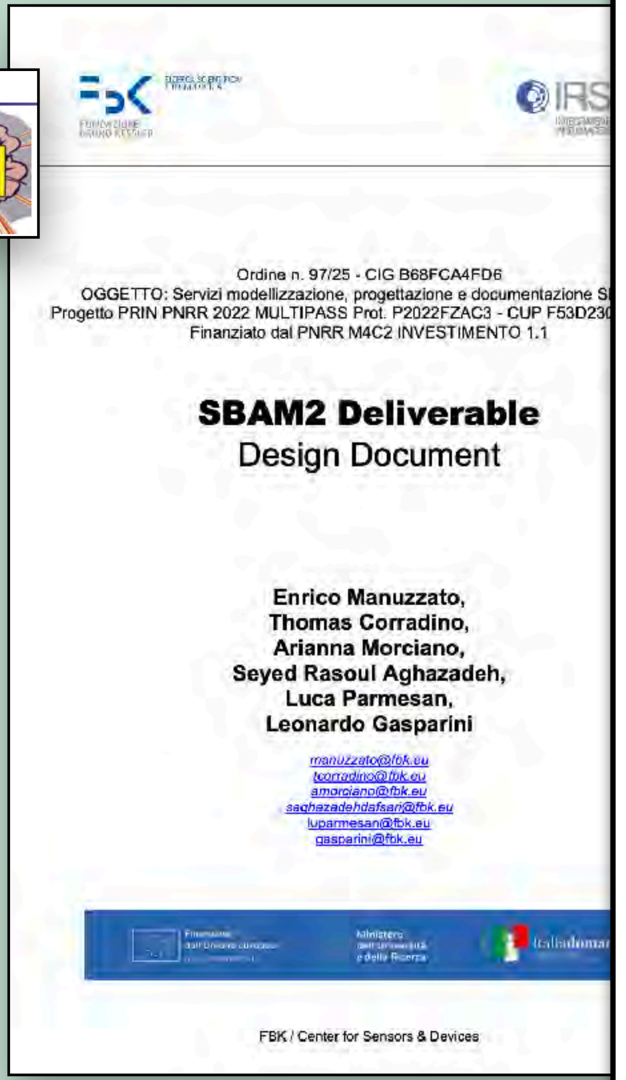




MONDO => MULTIPASS => NE

- Design of the new chip - SBAM 2





Ordine n. 97/25 - CIG B68FCA4FD6
OGGETTO: Servizi modellizzazione, progettazione e documentazione S
Progetto PRIN PNRR 2022 MULTIPASS Prot. P2022FZAC3 - CUP F53D230
Finanziato dal PNRR M4C2 INVESTIMENTO 1.1

SBAM2 Deliverable
Design Document

Enrico Manuzzato, Thomas Corradino, Arianna Morciano, Seyed Rasoul Aghazadeh, Luca Parmesan, Leonardo Gasparini

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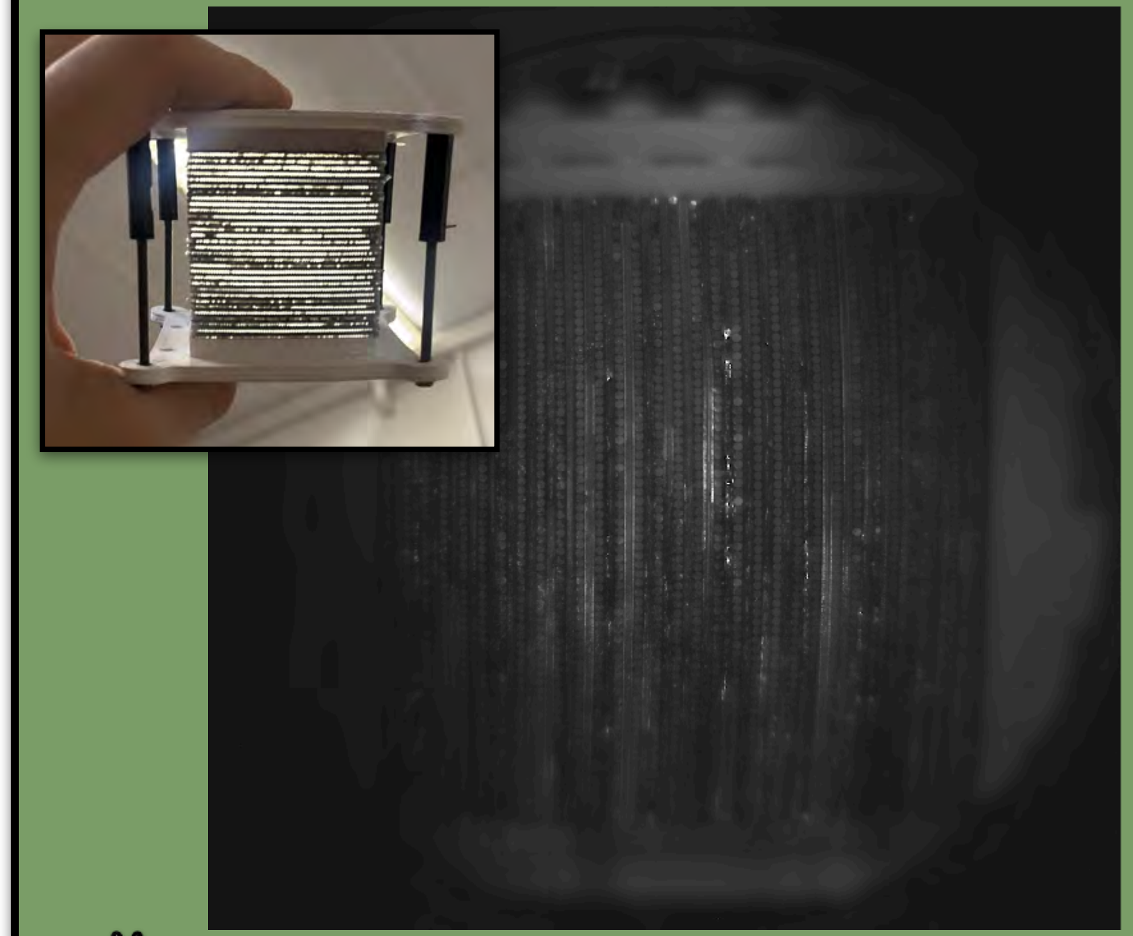
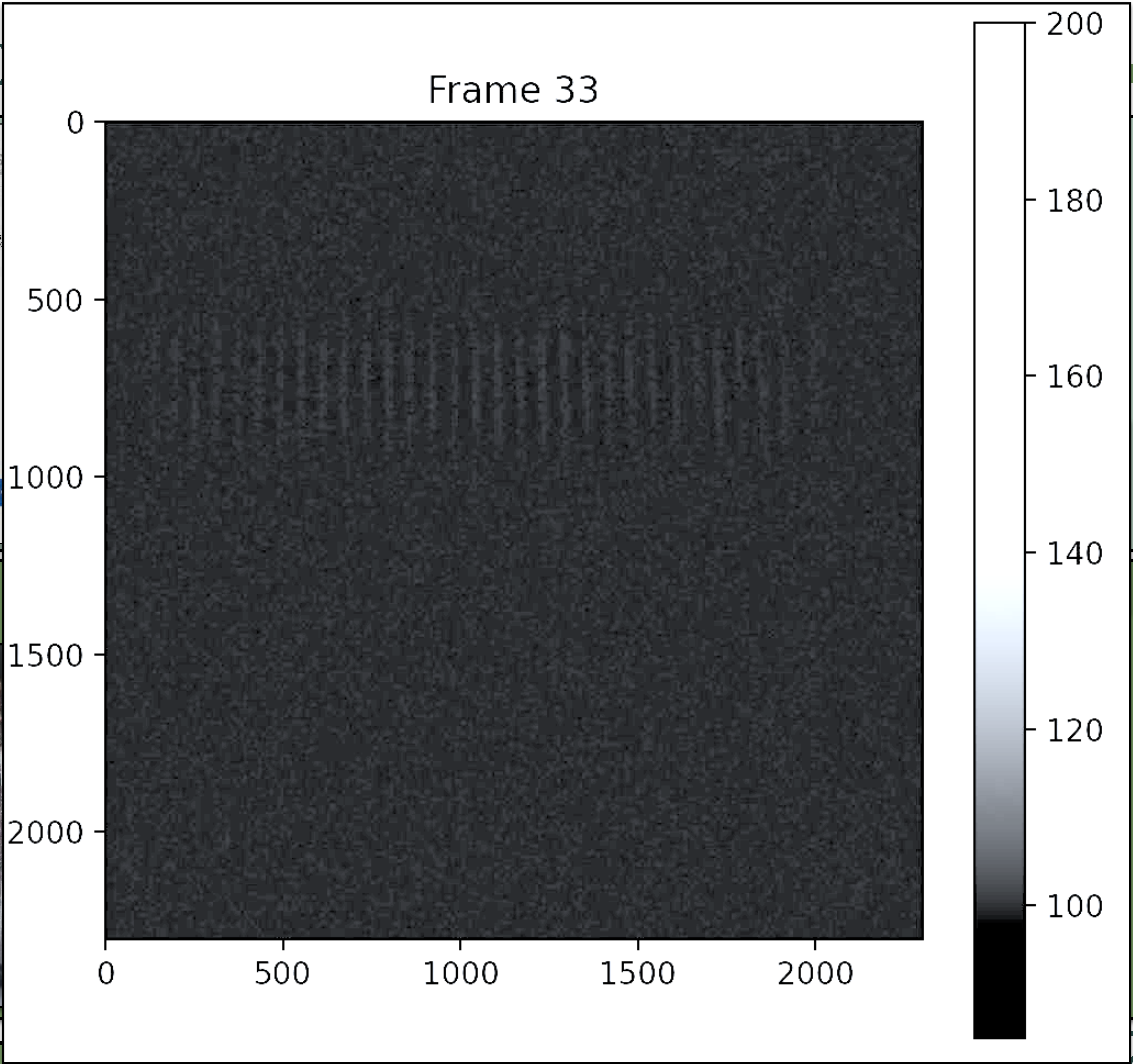
luparmesan@fbk.eu
gasparini@fbk.eu

FBK / Center for Sensors & Devices

- Single cladding, rounded 700µm



- Double cladding, squared 250µm



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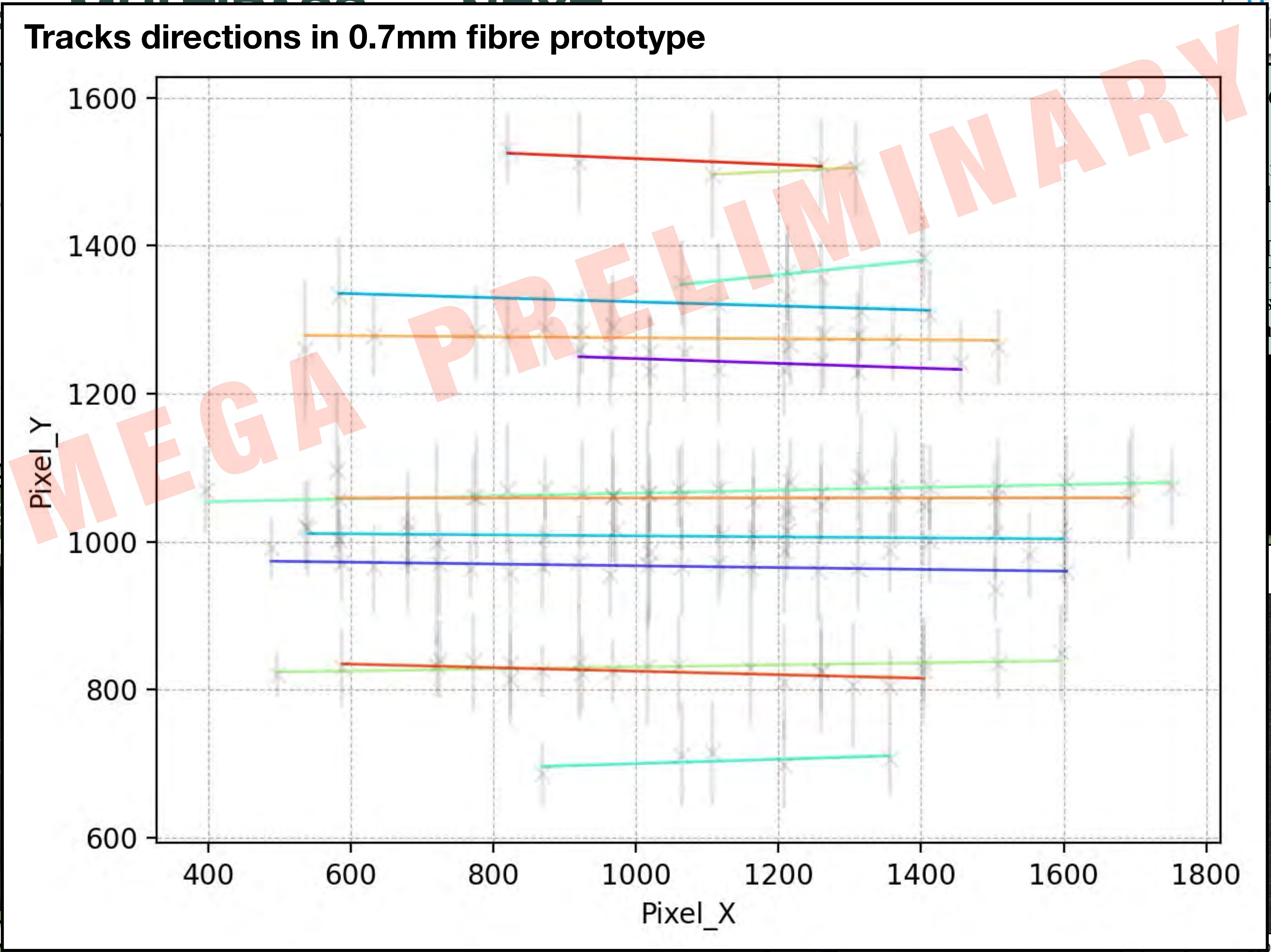
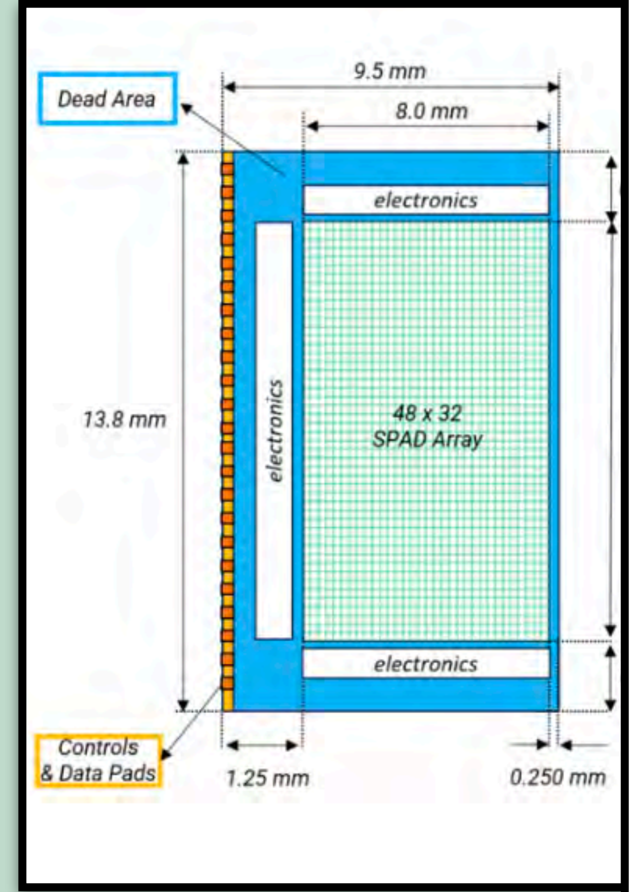
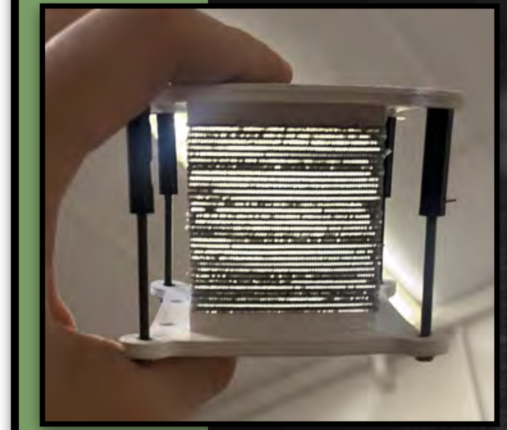
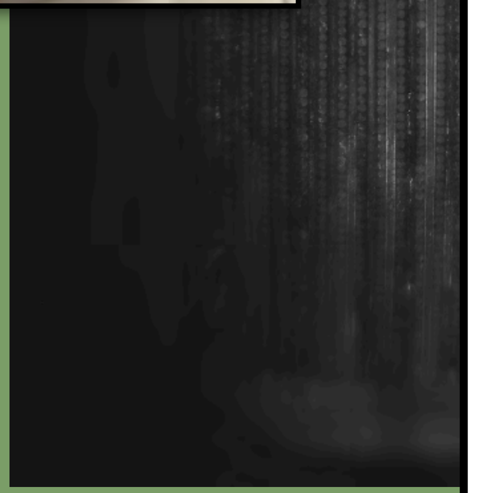


- Design of the



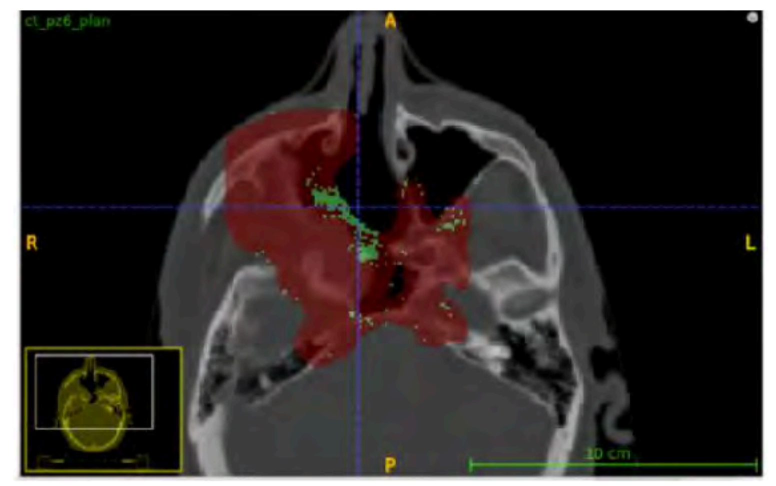
- Single cladding
rounded 700μm

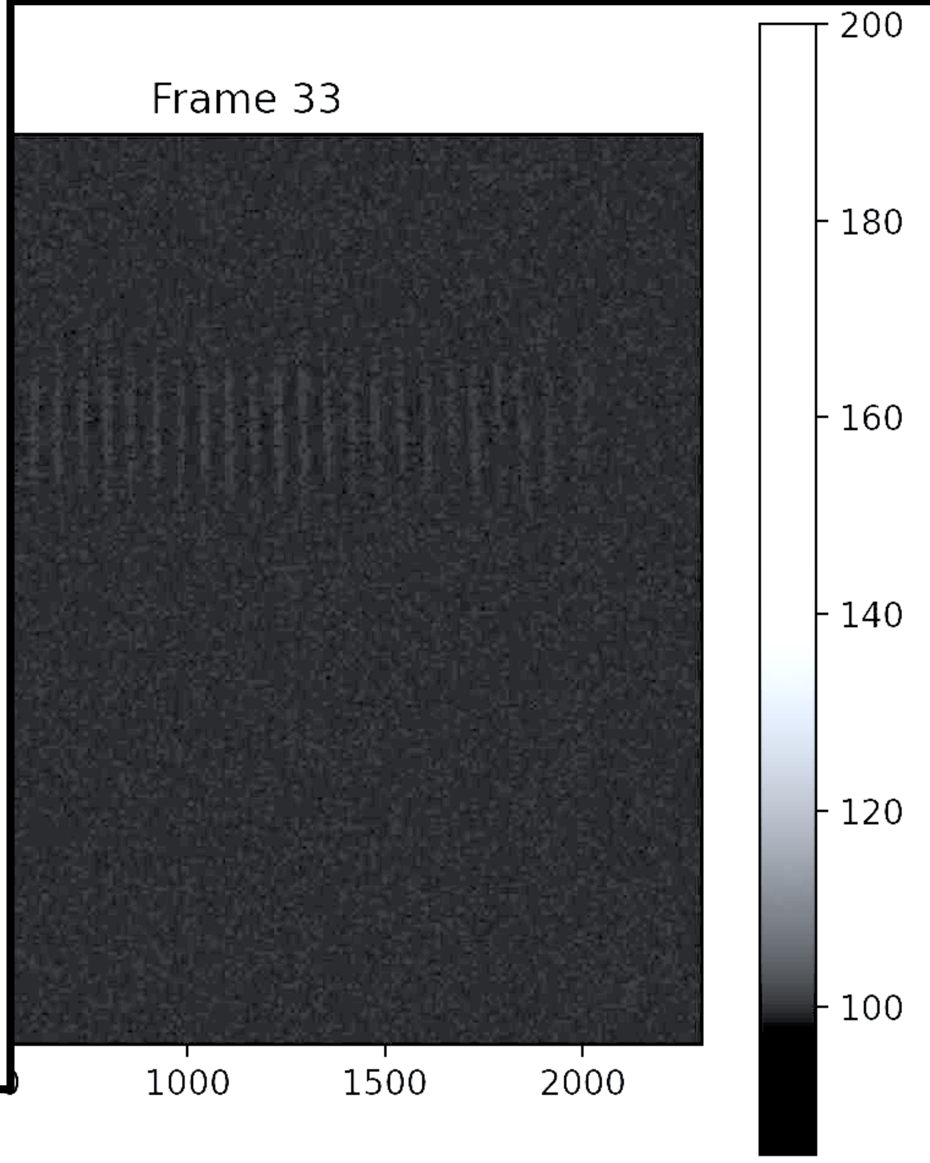




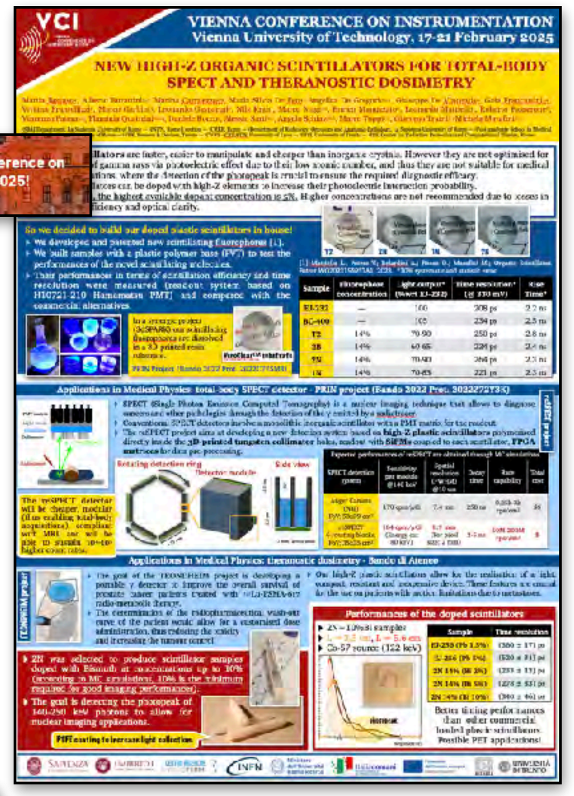
carlo Simulation (FLUKA)

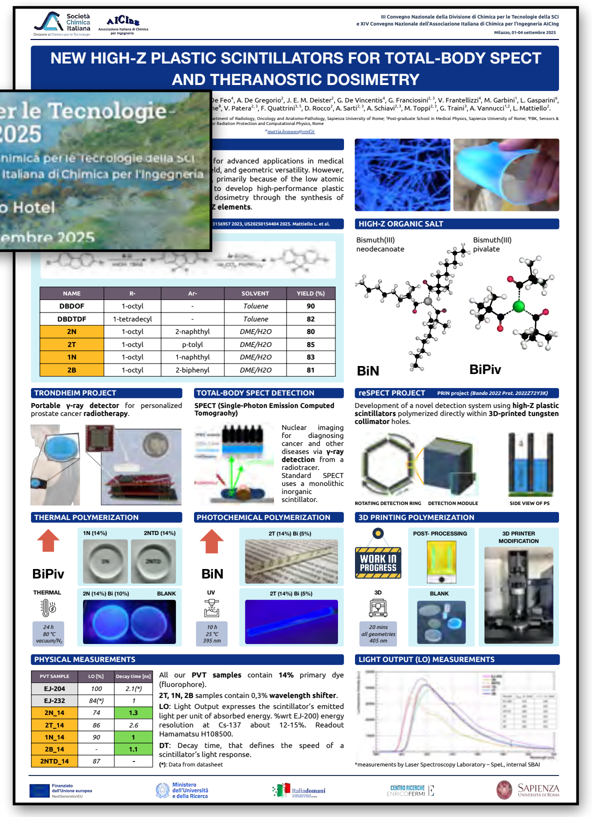
of the detector as a 3D inter-
nges in a real case scenario. 3D
l secondary protons by the detector
12C ion therapy treatment plan of
T. Gamma-index map visualized in
T1: green voxels are the discrepant
sion maps obtained from CT1 and
naps are shown in red.





APPLIED PHYSICS PUBLICATIONS





Publication in International, National Journals and Editorials in 2025

1. Y. Dong et al., *Cross section measurements of large angle fragments production in the interaction of carbon ion beams with thin targets* (accepted 2025, on proof 2026)European Physical Journal A DOI:10.1140/epja/s10050-025-01693-4

2. A. De Gregorio et al., *In silico evaluation of the potential of very high energy electrons delivered in both conventional and FLASH regimes for the SBRT treatment of pancreatic cancer: A report of three case studies* (2025) Physica Medica 17, 105076, DOI: https://doi.org/10.1016/j.ejmp.2025.105076 *Open Access*

3. R. Ridolfi., *Angular differential and elemental fragmentation cross sections of a 400 MeV/nucleon 16O beam on a graphite target with the FOOT experiment* (2025) Physical Review C 112, 1 DOI: 10.1103/nmw9-ldrm *Open Access*

4. A.Trigilio et al., *Characterization of a permanent magnetic dipolar system for the FOOT experiment* (2025) Technical Report JINST 20 DOI: 10.1088/1748-0221/20/09/T09010 *Open Access*

5. N. Bartosik, et al., *Development and performance assessment of the BGO calorimeter module for the FOOT experiment* (2025) JINST 20 P03021 DOI:10.1088/1748-0221/20/03/P03021 *Open Access*

6. Y.Dong et al., *The FLUKA Monte Carlo simulation of the magnetic spectrometer of the FOOT experiment* (2025) COMPUTER PHYSICS COMMUNICATIONS 307, 109398 DOI: 10.1016/j.cpc.2024.109398

7. G.Franciosini et al., I*OeRT conventional and FLASH treatment planning system implementation exploiting fast GPU Monte Carlo: The case of breast cancer* (2024) Physica Medica 121, 103346 DOI: 10.1016/j.ejmp.2024.103346 *Open Access*

Fascicolo speciale de Il Nuovo Cimento - Colloquia and Communications in Physics

A theranostic approach for personalized optimization of ^{177}Lu-PSMA-617 treatment in mCRPC

A. Vannucci([1])([2])(*), M. Bonuso([1]), A. Burattini([2]), M. Carruezzo([3])([4])([5]), M.S. De Feo([6]), G. De Vincentis([6]), G. Franciosini([3])([5]), V. Frantellizzi([6]), L. Frassi([7]), M. Garbini([1]), M. Magi([3])([5]), M. Marafini([1])([5]), L. Mattiello([3]), V. Patera([3])([5]), F. Quattrini([7])([5]), A. Sarti([3])([5]), A. Schiavi([3])([5]), L. Testa([7])([1]), M. Toppi([3])([5]) and G. Traini([5])

([1]) "Enrico Fermi" Historical Museum of Physics and Research Centre (CREF), Rome, Italy
([2]) Post-graduate School in Medical Physics, Sapienza University of Rome, Rome, Italy
([3]) Department of Basic and Applied Sciences for Engineering, Sapienza University of Rome, Rome, Italy
([4]) Italian National Institute of Health, Rome, Italy
([5]) National Institute for Nuclear Physics (INFN), Roma I Section, Rome, Italy
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Migliori Comunicazioni Congresso Nazionale SIF 2025, Sezione 5

INNOVATIVE APPLICATIONS OF HIGH-Z DOPED PLASTIC SCINTILLATORS IN RADIOMETABOLIC DOSIMETRY: THE ReSPECT AND TRONDHEIM PROJECTS

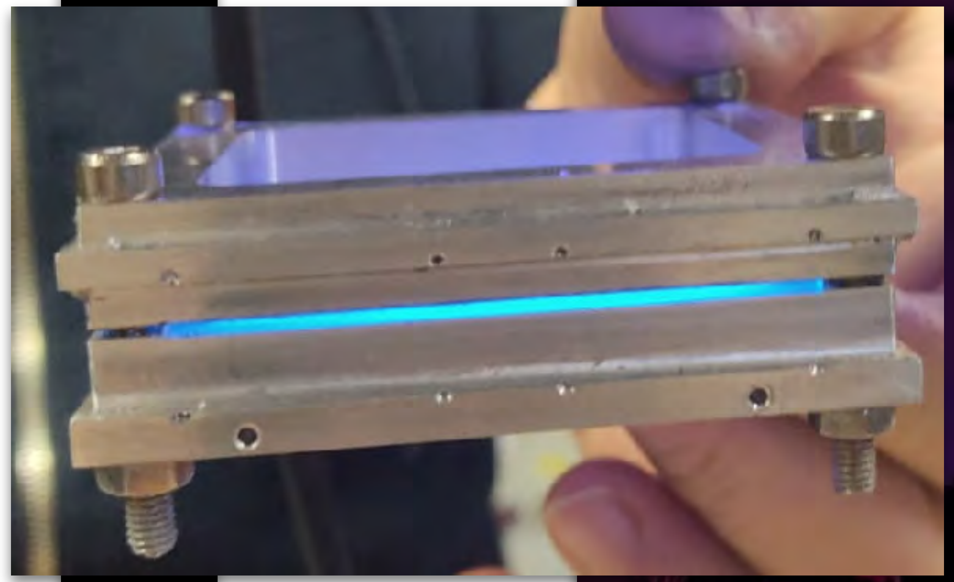
Società Italiana di Fisica
Scuola Internazionale di Fisica "E. Fermi"
Frontiers in Medical Physics, Varenna, 2025

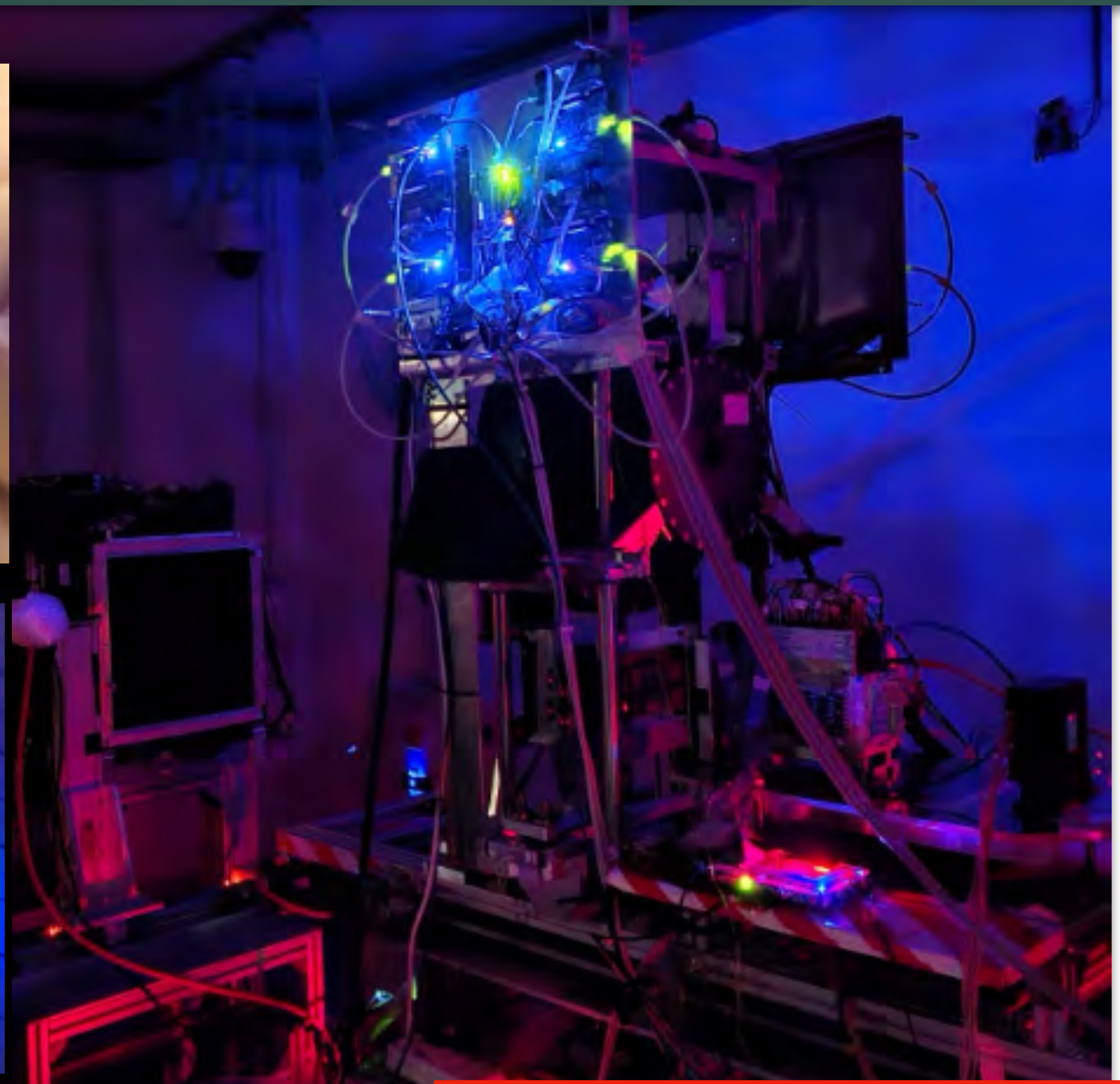
Master Thesis in 2025/2026: Flavia Allegra, Johannes Elias Maria Deister, Luana Testa, Laura Frassi, Mattia Stefanini, Giorgio Splendiani.

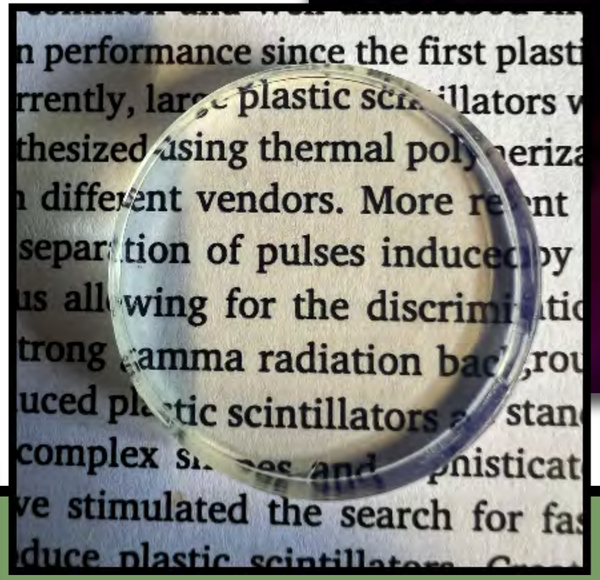
IMAGINg

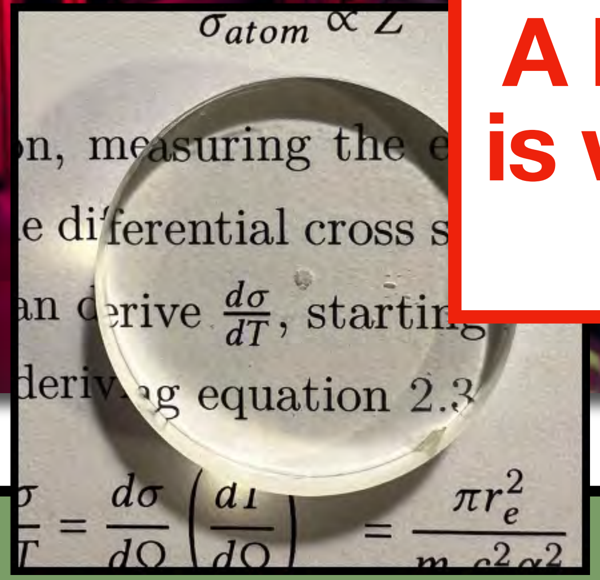
RAT

- IMAGING/DOSIMETRY
- TREATMENTS TOOLS
- SECONDARY NUCLEAR FRAGMENTATION
- NEUTRONS IN INNOVATIVE RADIOTHERAPY









A lot of hardware work is waiting for a space in new CREF lab!

Milestones

1. **2026 Dosimeter prototype.**

   In the context of wearable diagnostic imaging, characterisation of the first dosimeter prototype using ~100 keV radiation sources.

2. **2026 First measurements with a fibre tracker.**

   In the context of evaluating the potential of a fibre tracker read out by a camera: beam measurements, fragmentation product tracks, and neural network–based dose reconstruction.

3. **2026 Fragmentation measurements with FOOT.**

   Preliminary results on isotopic fragmentation cross sections for C+C interactions at 200 MeV/u.

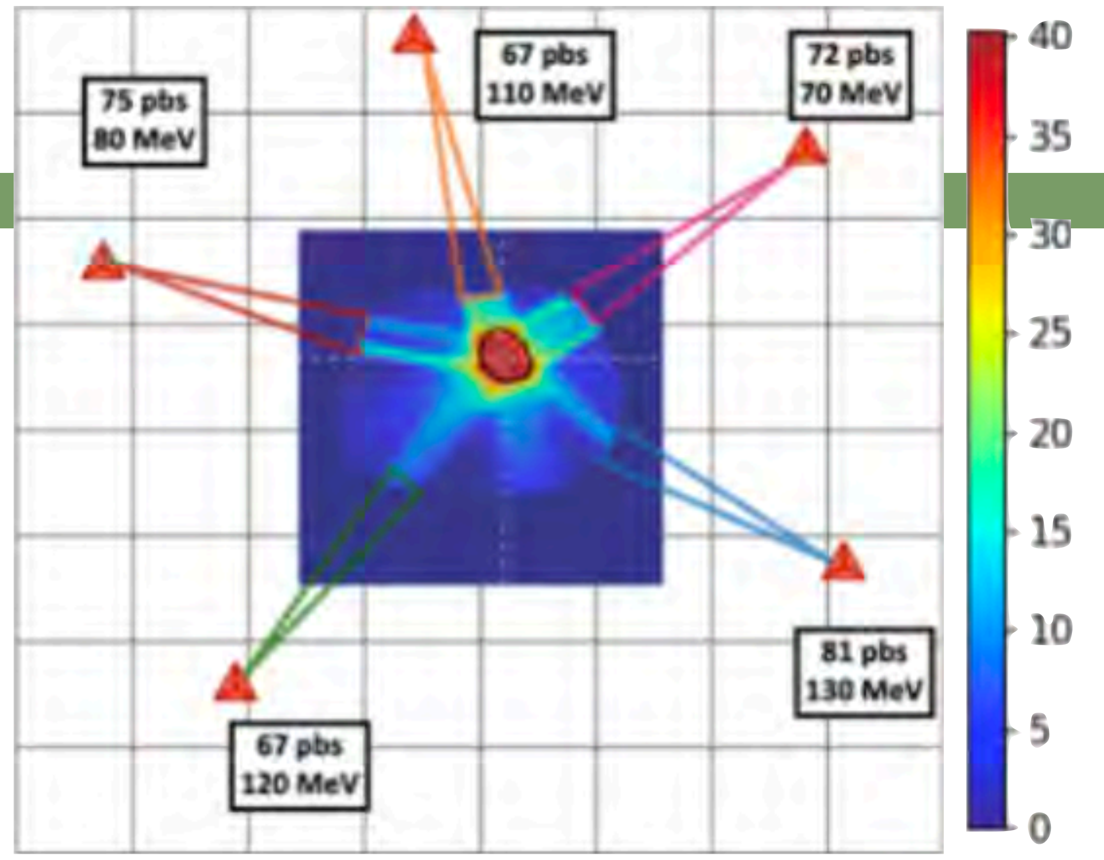
4. **2027 Fibre tracker optimisation.**

   Study of the expected performance of a scintillating fibre tracker, definition of the required readout system, and detector dimensions.

Be like a neutron..keep going

IMAGINg

TREATEMNTS in UHDR



CENTRO RICERCHE ENRICO FERMI — SAPIENZA Università di Roma — INFN

The value of the parameters *FMF* and *Dose thr.* are correlated to the dose at the PTV: in particular conditions the dose absorbed by the 100% of the PTV on the z-axis increases of 95%.

VHEE and UHDR

	VMAT	VHEE	VHEE-FLASH
PTV	99%	98.32%	98.32%
Duodenum	35.88 Gy	35.11 Gy	31.06 Gy
Stomach	31.04 Gy	33.28 Gy	29.97 Gy

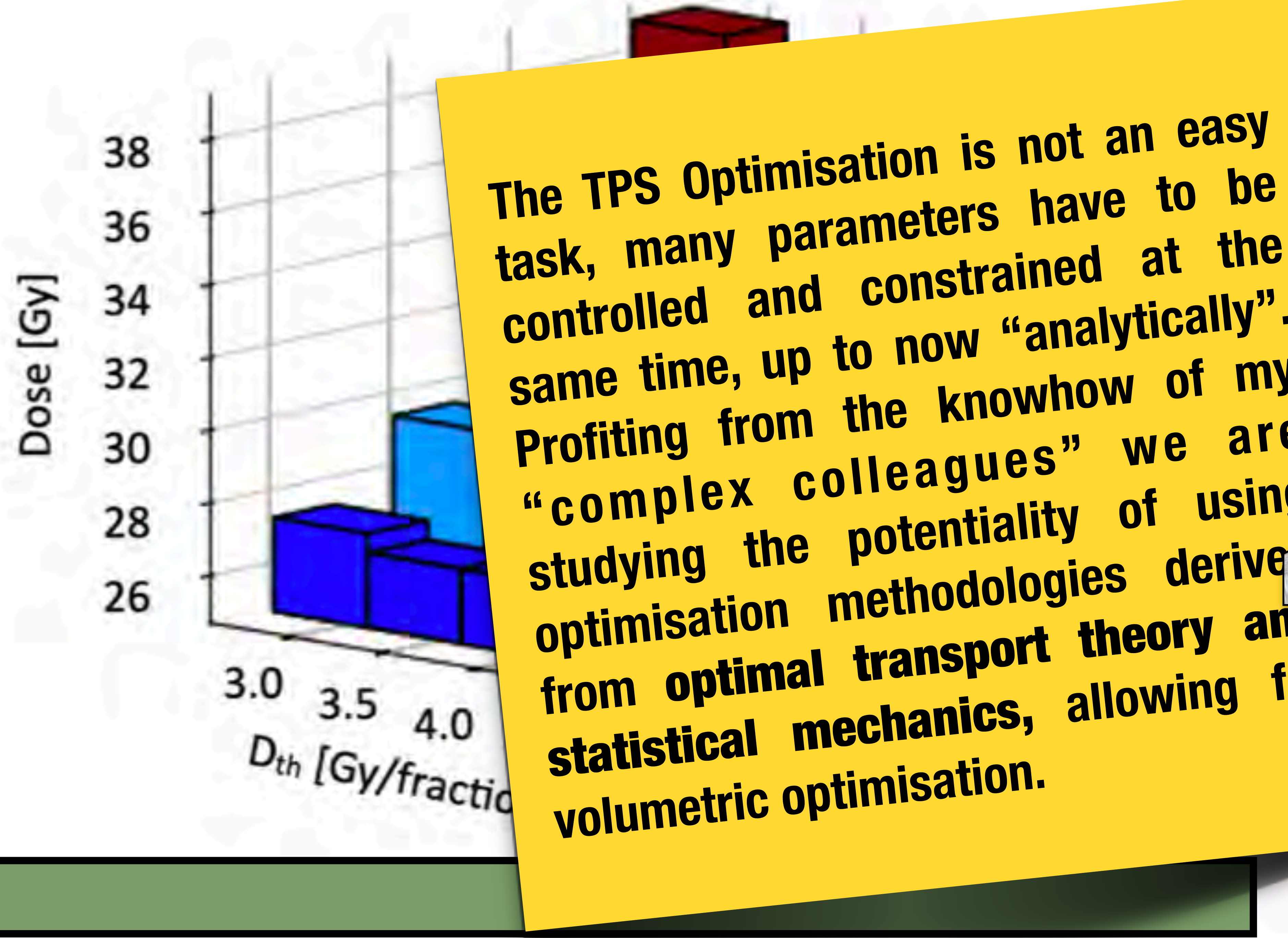
- Study the performances achievable in UHDR condition is done assuming plausible conditions to trigger the FLASH effect, extracting the already measured spearing parameters. The results obtained so far suggest that it is **possible to escalate the PTV dose without increasing OAR damage.**

$$D_{FMF} = FMF \cdot D$$

$$FMF = \begin{cases} 1 & \text{if } D \leq D_T \\ (1 - FMF^{min})\frac{D_T}{D} + FMF^{min} & \text{if } D > D_T \end{cases}$$

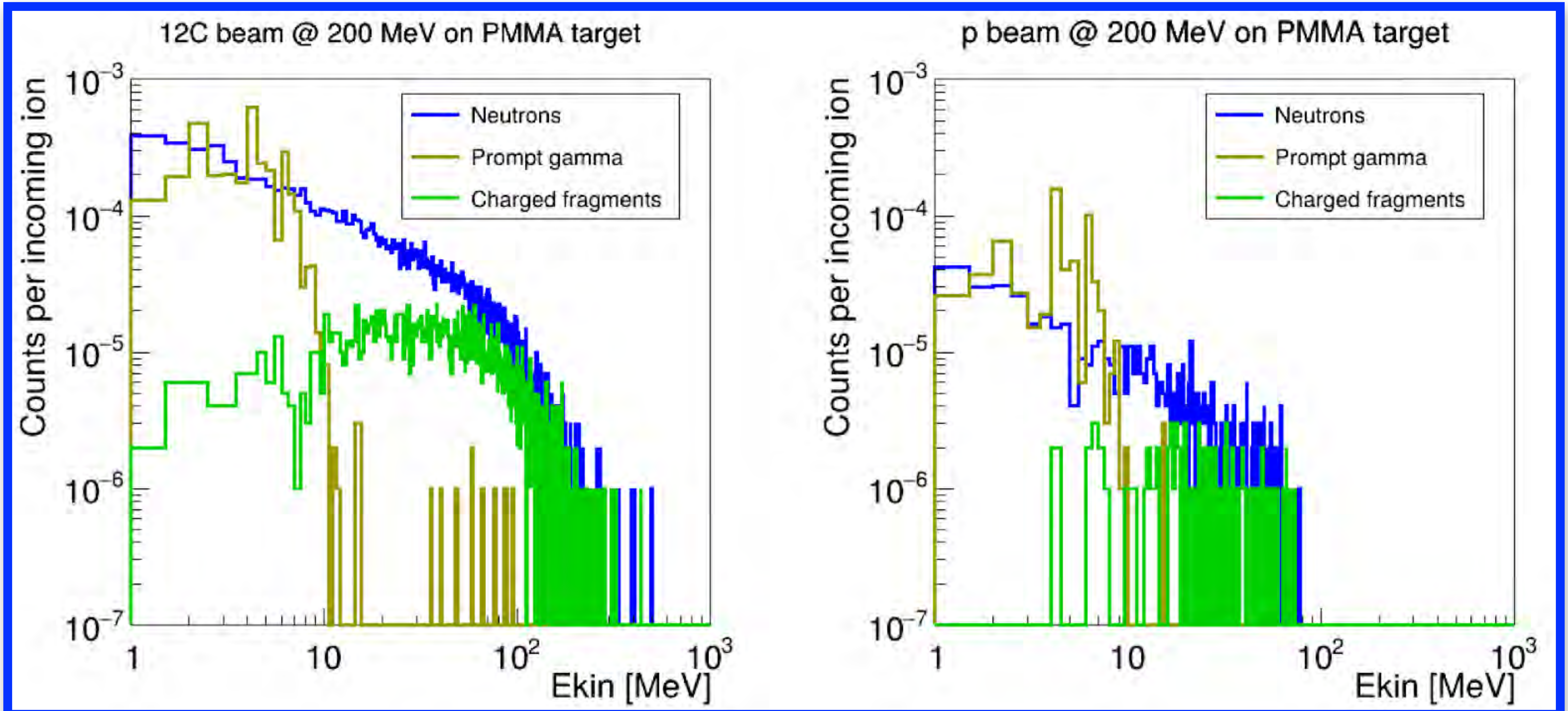
PT3

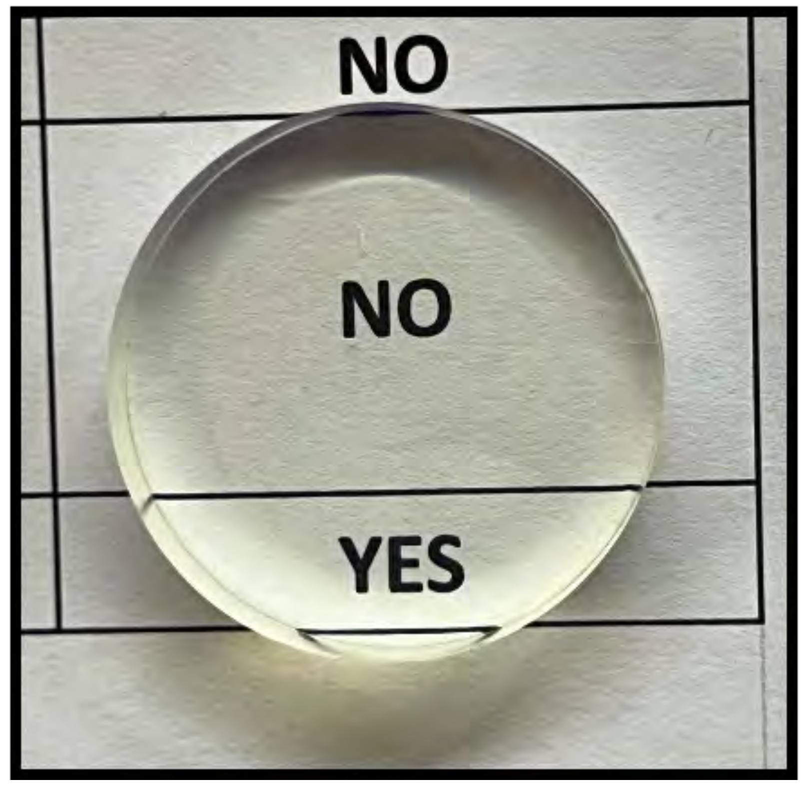
- **Pancreatic tumour**: five fields were used, with a prescription to the **PTV of 30 Gy** in **5 fractions**.
- Crucial to minimise radiation-induced **toxicity** to the nearby **duodenum**.



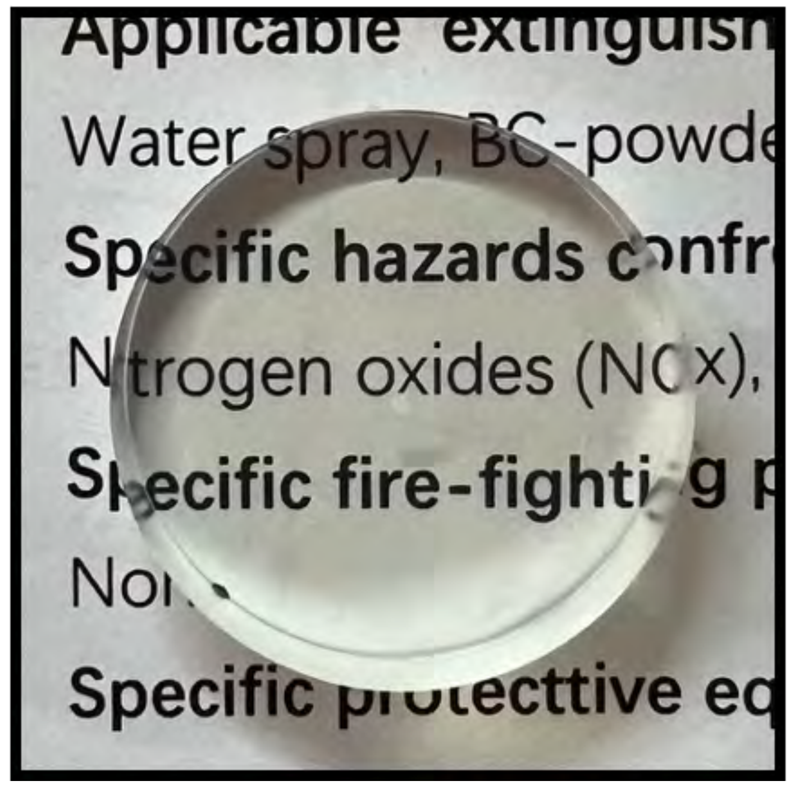
The TPS Optimisation is not an easy task, many parameters have to be controlled and constrained at the same time, up to now "analytically". Profiting from the knowhow of my "complex colleagues" we are studying the potentiality of using optimisation methodologies derived from optimal transport theory and statistical mechanics, allowing for volumetric optimisation.

NEUTRONI

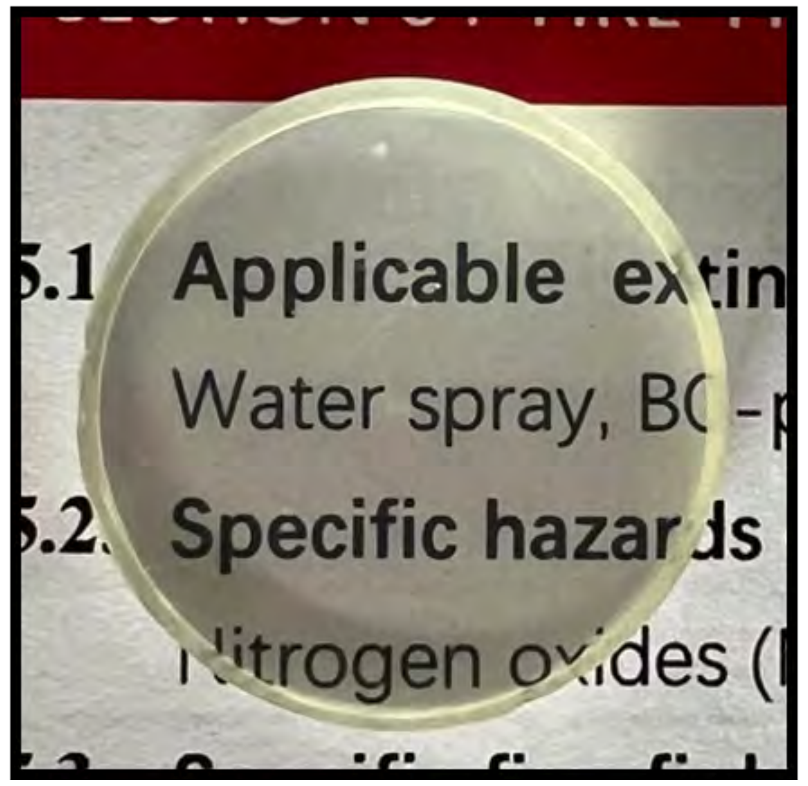

12C beam @ 200 MeV on PMMA target
Counts per incoming ion
Neutrons
Prompt gamma
Charged fragments
Ekin [MeV]
p beam @ 200 MeV on PMMA target
Counts per incoming ion
Neutrons
Prompt gamma
Charged fragments
Ekin [MeV]



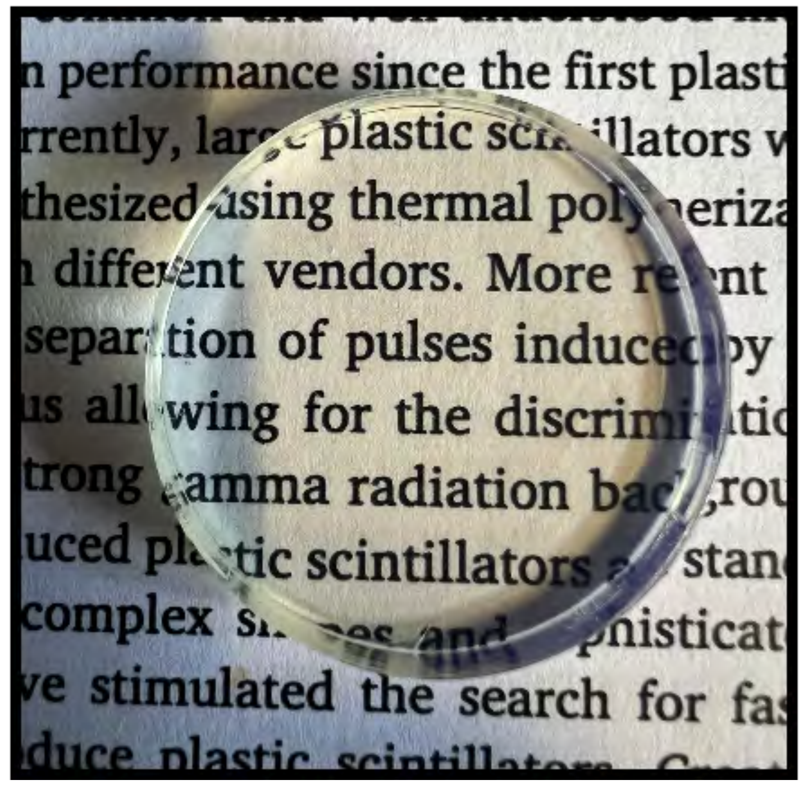
14% 2T_0,3.MDAC



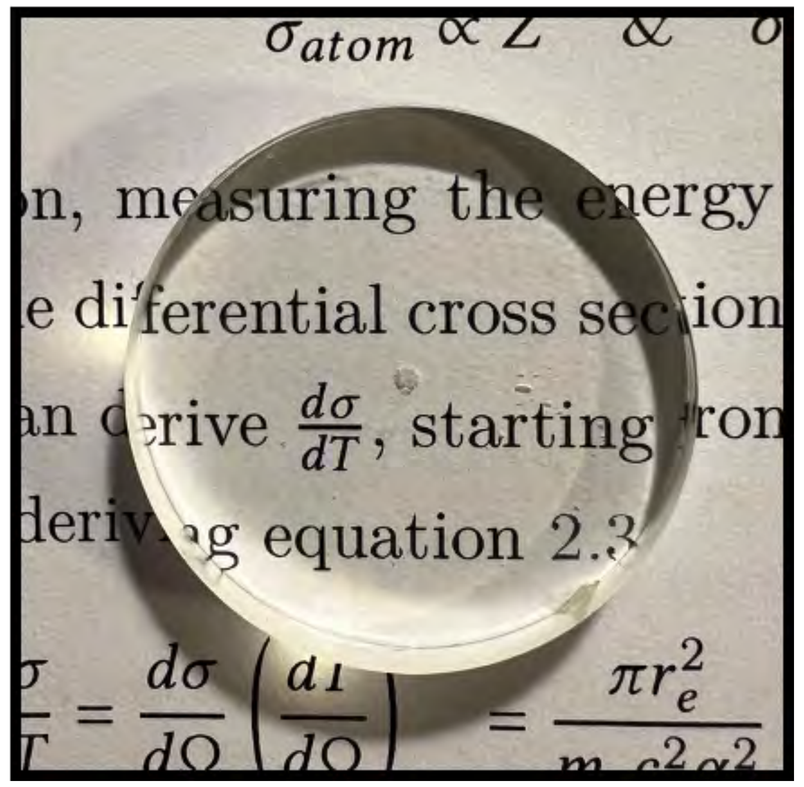
14% 2N



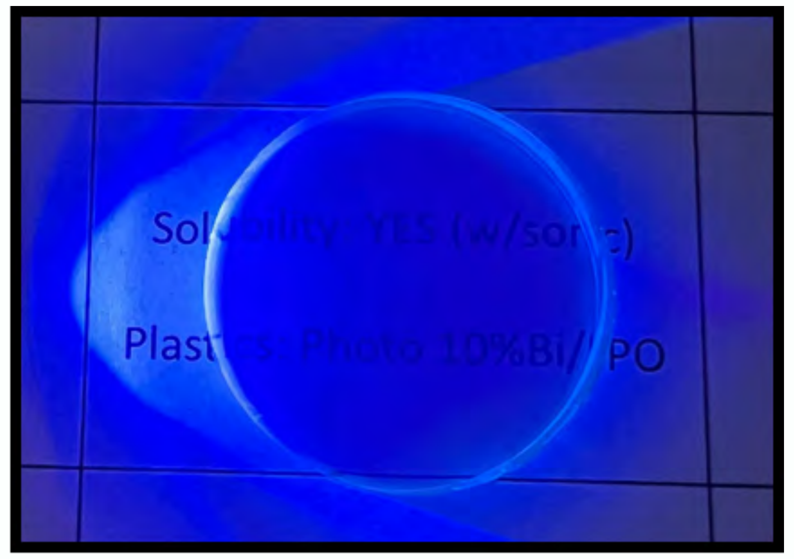
14% 2NTD



14% 1N_0,3.MDAC

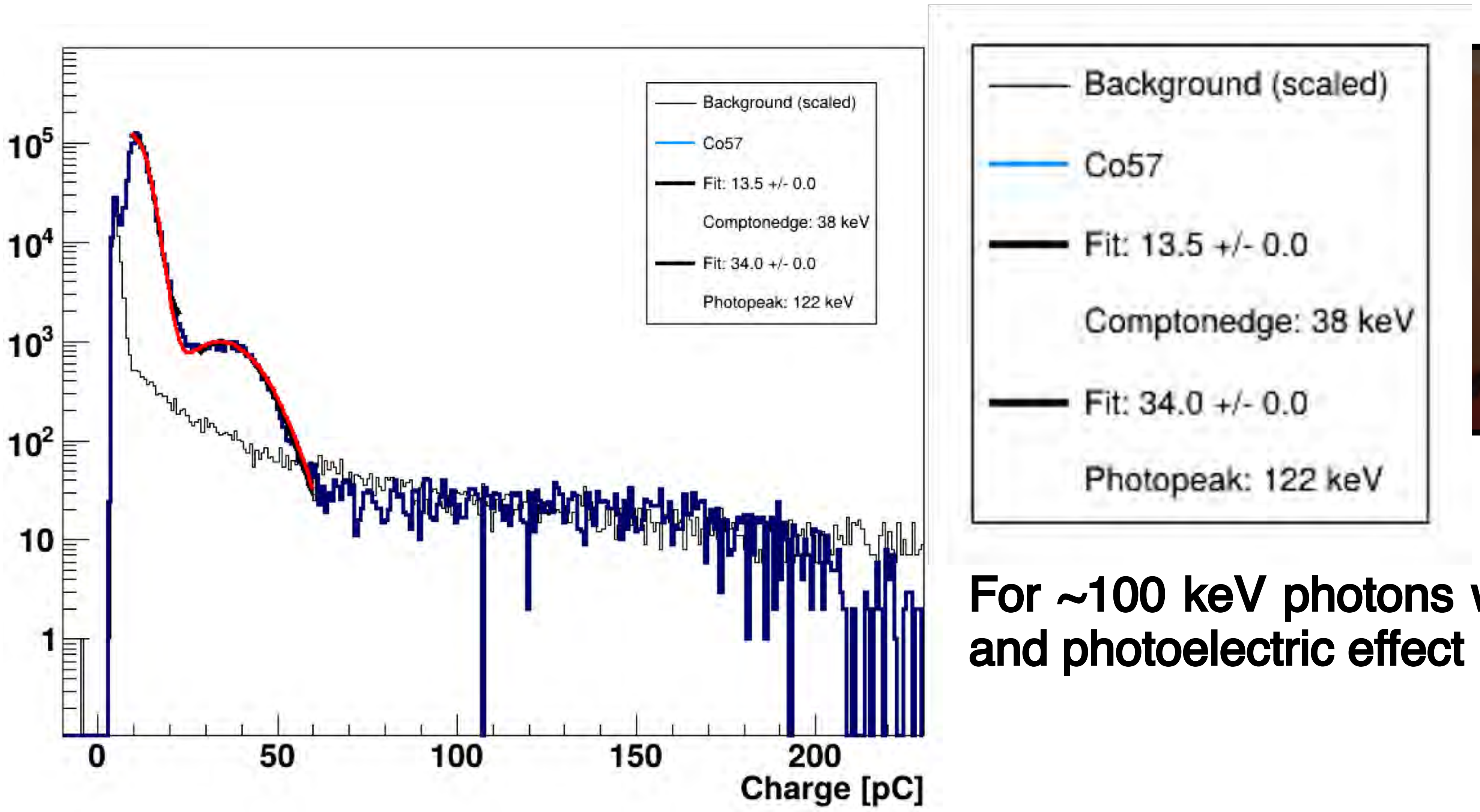


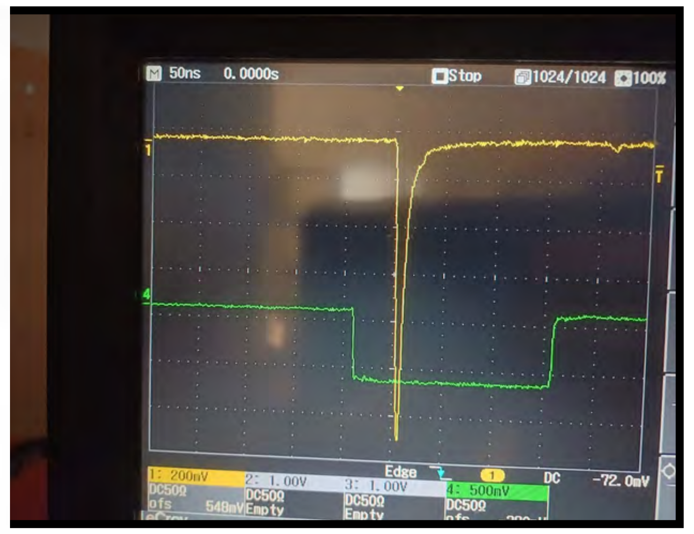
14% 2B_0,3.MDAC



This shape has been chosen to be light and "portable". The final idea is to add Hi-Z element, if possible, in those samples. Before characterising the "doped" element we need to fully characterise the "pure" ones. The light output is important is absolute but we keep in mind that the aim is to ensure the possibility of add Hi-Z elements.

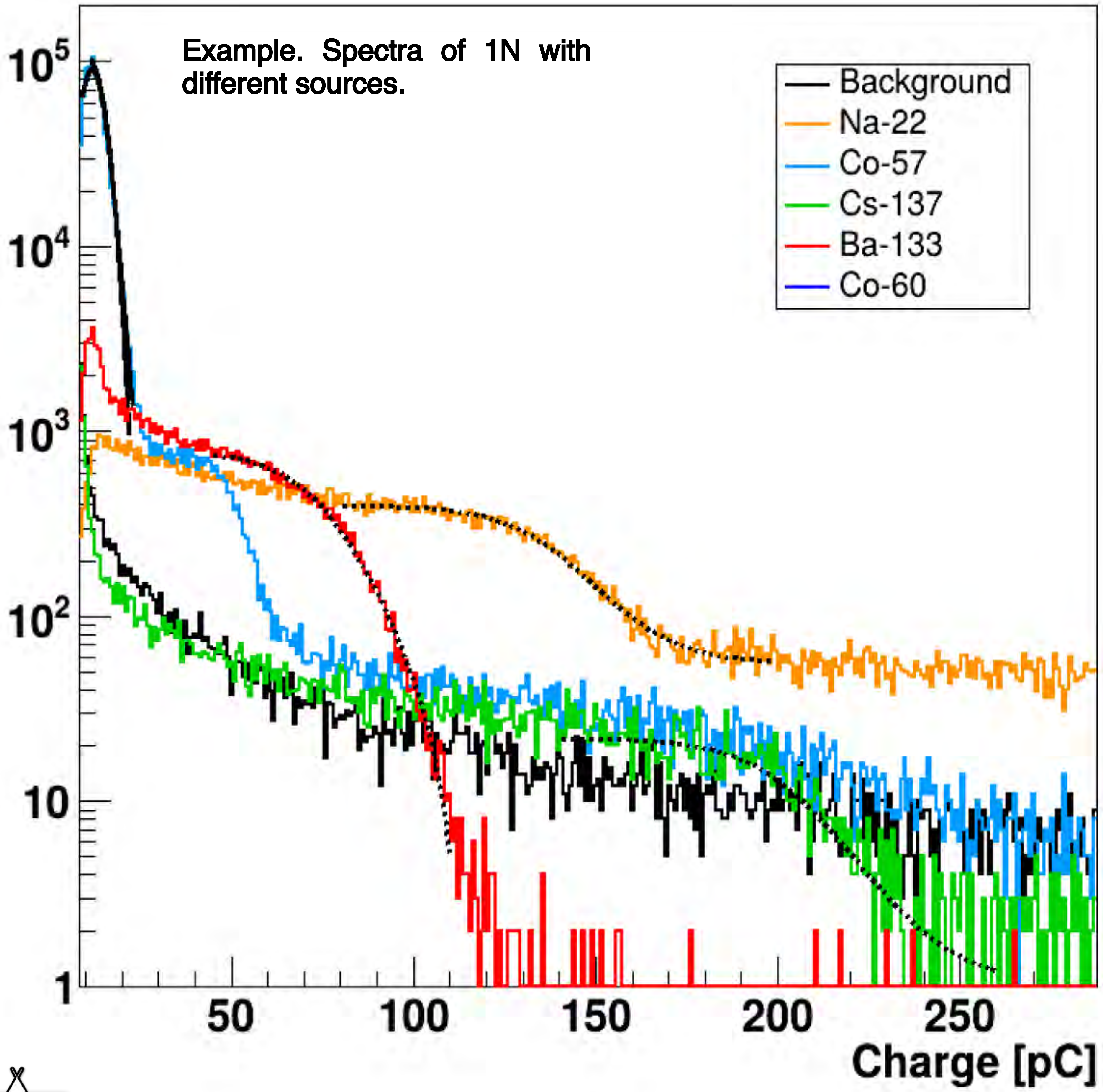
The samples have been tested with different sources and the Compton edge has been used to perform a calibration study.

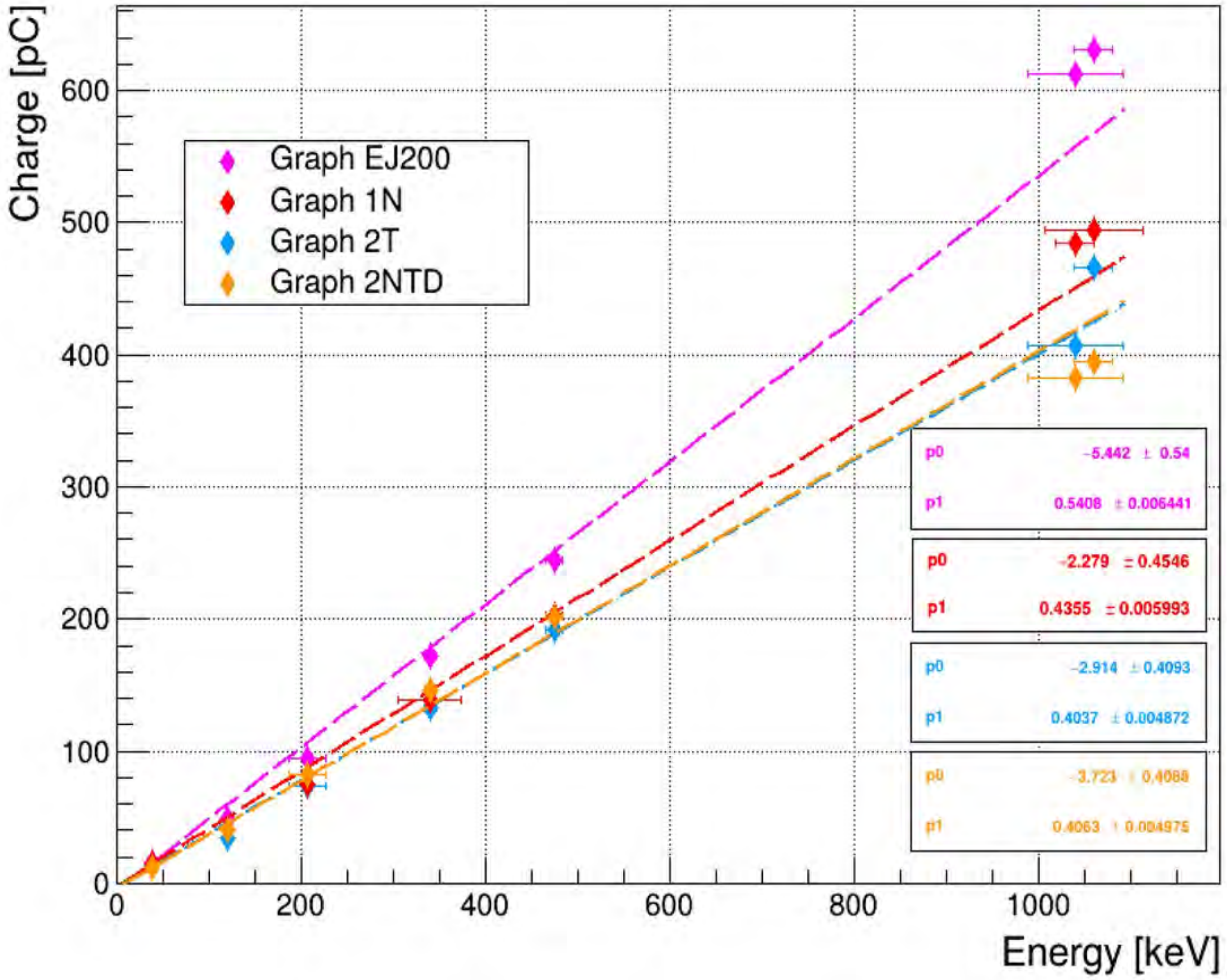




Signals are fast, all in 20 ns

For ~100 keV photons we have both Compton and photoelectric effect in "pure samples.





MEASUREMENTS WITH GAMMA SOURCES