UNIVERSITÀ DI PAVIA

INFN PAVIA

Biomedical Physics: Research & Applications

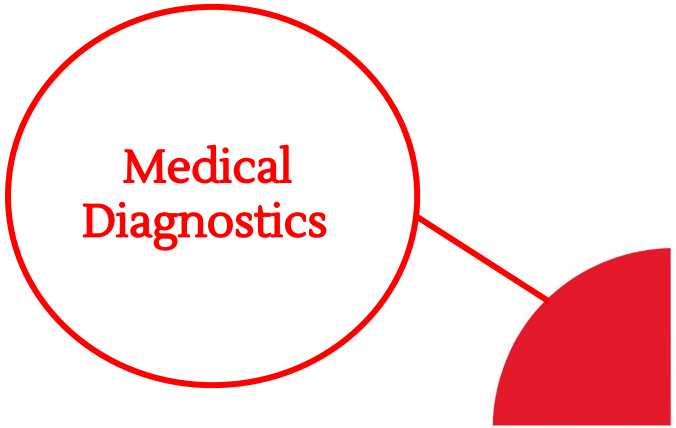
Congresso del Dipartimento di Fisica e della Sezione INFN di Pavia - February 2026

Biomedical Physics: Research & Applications

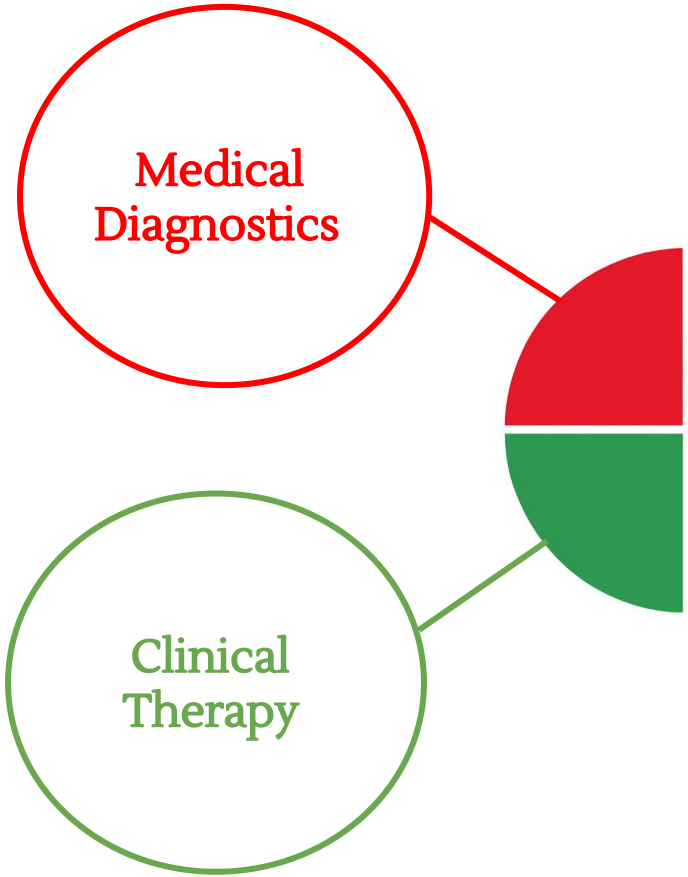
When physics drives decisions

- Measure
- Treat
- Protect

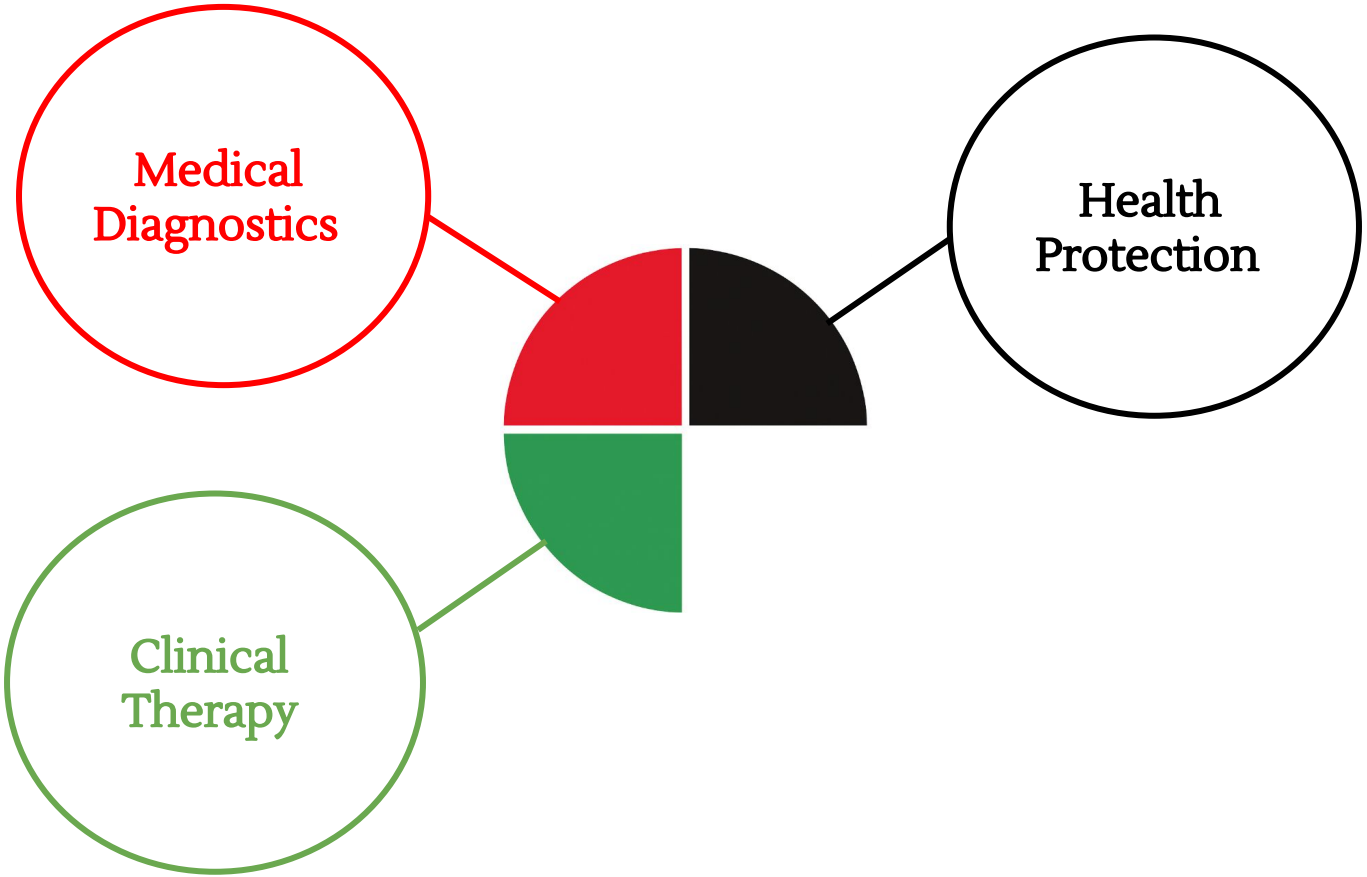
Biomedical Physics: Research & Applications



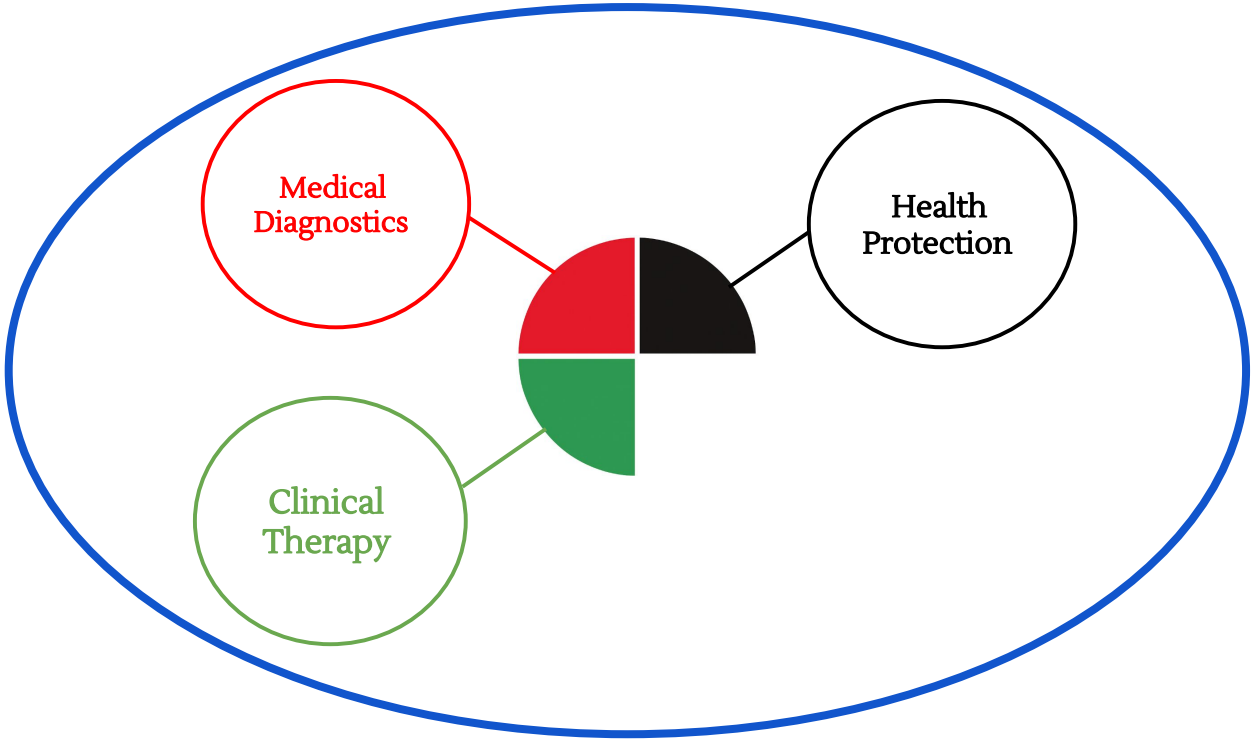
Biomedical Physics: Research & Applications



Biomedical Physics: Research & Applications



Biomedical Physics: Research & Applications



AI-Enhanced Experimental & Computational Research

Biomedical Physics: Research & Applications

Medical diagnostics

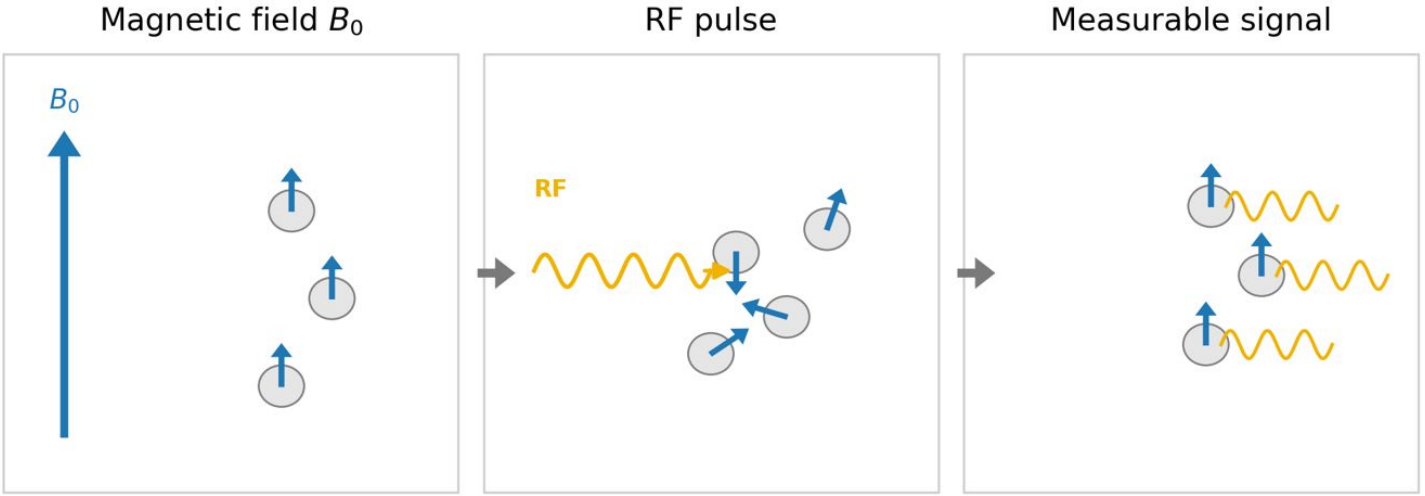
- Nuclear Magnetic Resonance & Magnetic Resonance Imaging
- Radiomics & AI

Medical diagnostics

NMR & MRI

Nuclear Magnetic Resonance (NMR)

Nuclei as local probes → study materials & tissues



Magnetic Resonance Imaging (MRI)

Spatially-resolved NMR image generation

MRI Benefit: non-ionizing, safe for clinical use

Medical diagnostics

NMR & MRI

Studies

Spin dynamics of magnetic nanoparticles by varying their shape/composition/coating

Nanoparticles
Enhance spin interactions → shorter T_1/T_2, improved MRI contrast

$$\frac{1}{T_1} = \frac{32\pi}{135000}\mu_{SP}^{\star 2}\gamma_I^2\left(\frac{N_a C}{r_d D}\right)\left\{7P\frac{L(x)}{x}J^F(\Omega(\omega_S,\omega_0),\tau_D,\tau_N) + \left[7Q\frac{L(x)}{x} + \right.\right.$$
$$\left.\left. + 3(P+Q)\left(1 - L^2(x) - 2\frac{L(x)}{x}\right)\right]J^F(\omega_I,\tau_D,\tau_N) + 3L^2(x)J^A(\sqrt{2\omega_I\tau_D})\right\}$$

No contrast

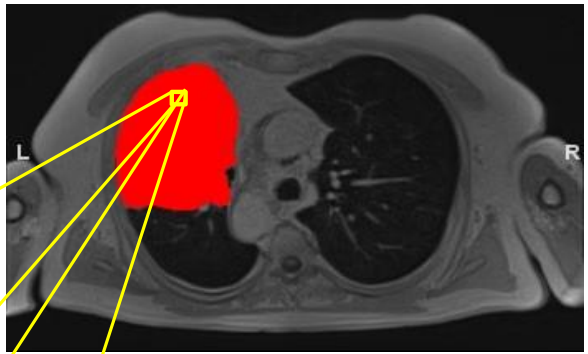
With contrast

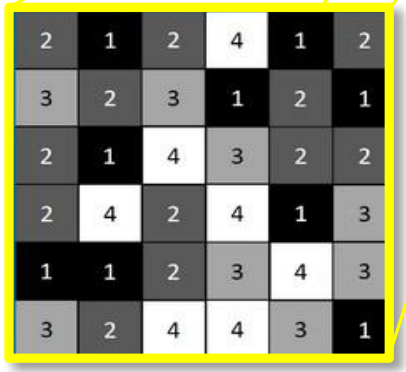
Advanced MRI technique (QSM) in neurodegenerative diseases

Medical diagnostics

Radiomics & AI

Radiomics is a quantitative method that allows the extraction of **mineable data** from medical imaging





To improve:

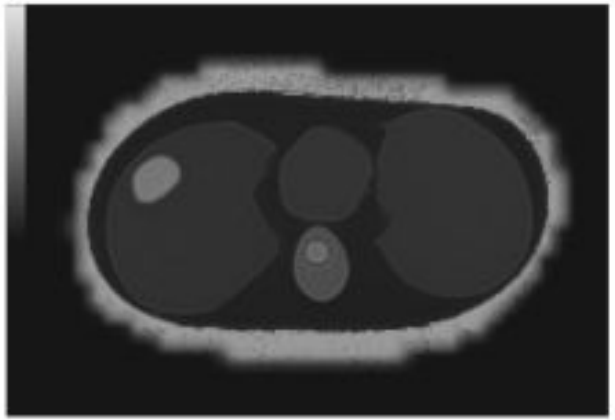
diagnosis
prognostication
clinical decision support

Medical diagnostics

Radiomics & AI

Studies

Lung Phantom Development for MRI acquisition optimization and Radiomics
Assessment of biomarkers expression in Lung Cancer based on MRI
Investigation of association patterns between Radiomic Features and Gene Expression
Development of a 3D CNN for Chronic Rhinosinusitis Diagnosis from CT Scans



Biomedical Physics: Research & Applications

Clinical Therapy

- Hadrontherapy
- Combining radiotherapy and chemotherapy
- Boron Neutron Capture Therapy
- Magnetic Hyperthermia
- Combining radiotherapy and immunotherapy
- NEutron Capture-enhanced Treatment of neurotoxic Amyloid aggRegates

Clinical Therapy

Hadrontherapy

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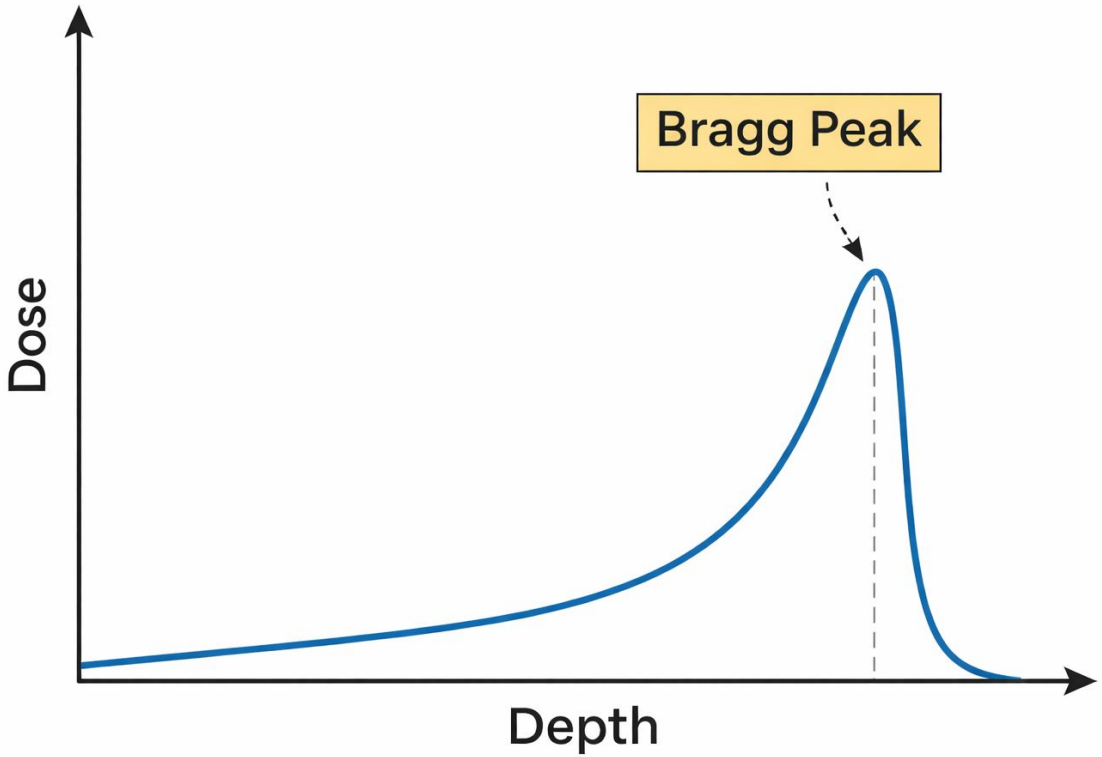
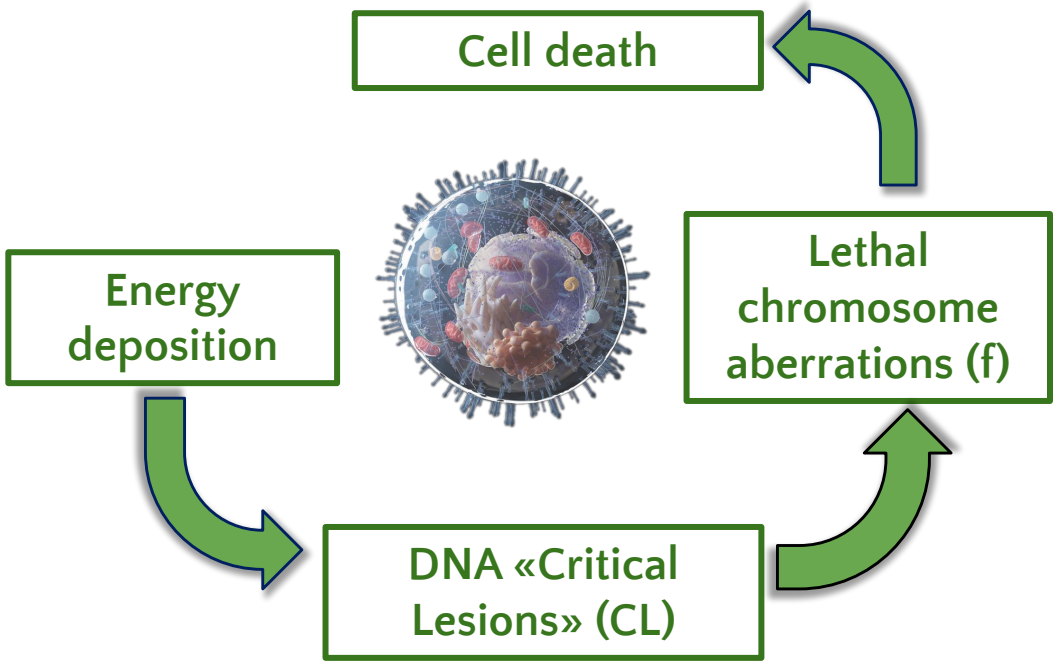


Clinical Therapy

Hadrontherapy

The BIANCA model (UniPV)

BIANCA can predict cell death and chromosomal damage, induced by ionizing radiation, across multiple ion species (p, He and heavier ions), energies and cell lines



Clinical Therapy

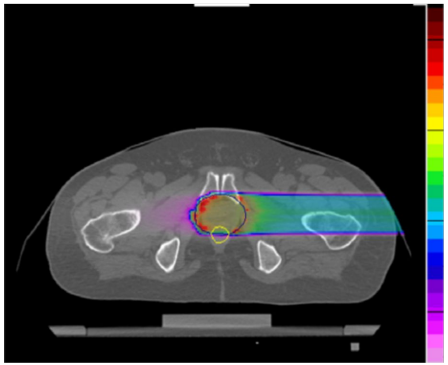
Hadrontherapy

Studies

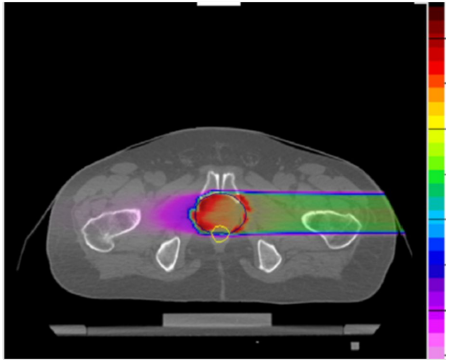
Application of the BIANCA biophysical model to carbon-ion patient cases
Healthy Tissue Damage Following Cancer Ion Therapy
Biological effectiveness of He-3 and He-4 ion beams for cancer hadrontherapy
Prediction of normal tissue complication probability following ion irradiations

Prostate

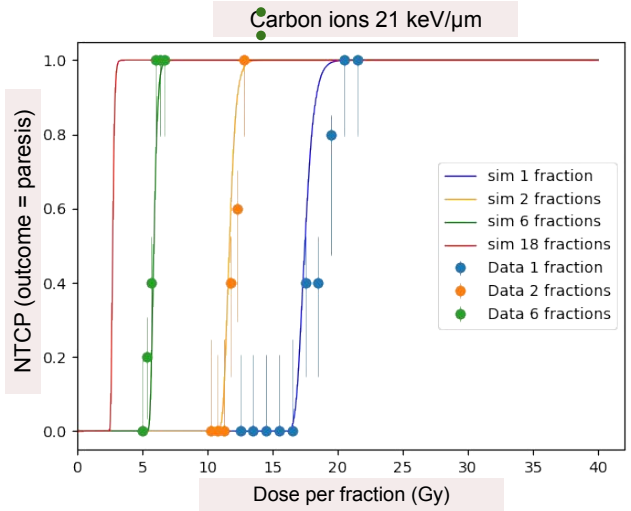
Bianca cell death



Bianca chromosome damage

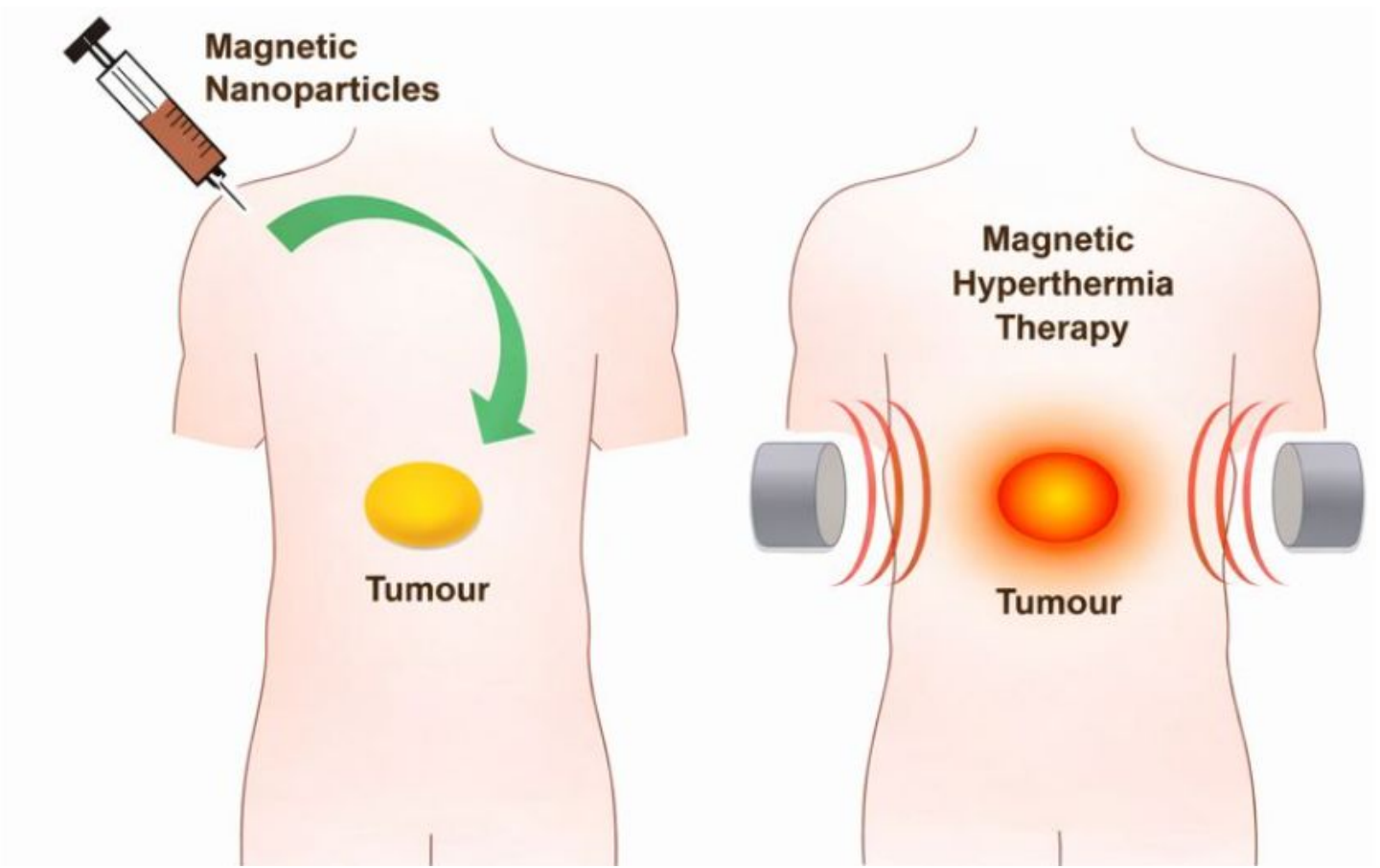


NTCP



Clinical Therapy

Magnetic hyperthermia

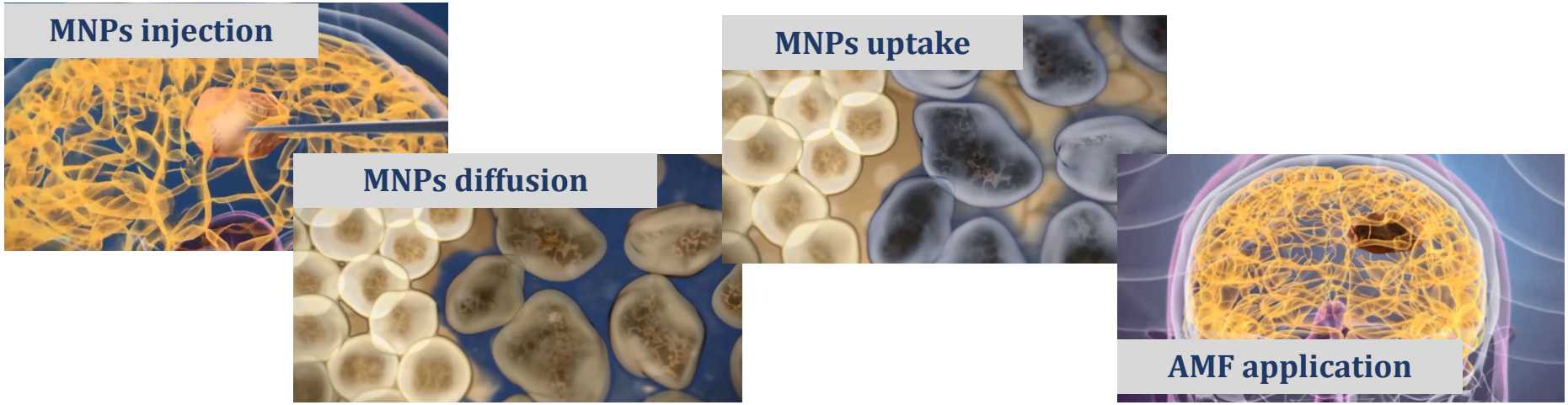


Clinical Therapy

Magnetic hyperthermia

Studies

MATHER3D (INFN): Magnetic hyperthermia and hadrontherapy applied to pancreatic cancer
Hyperthermal properties of magnetic nanoparticles, varying their shape/composition/coating

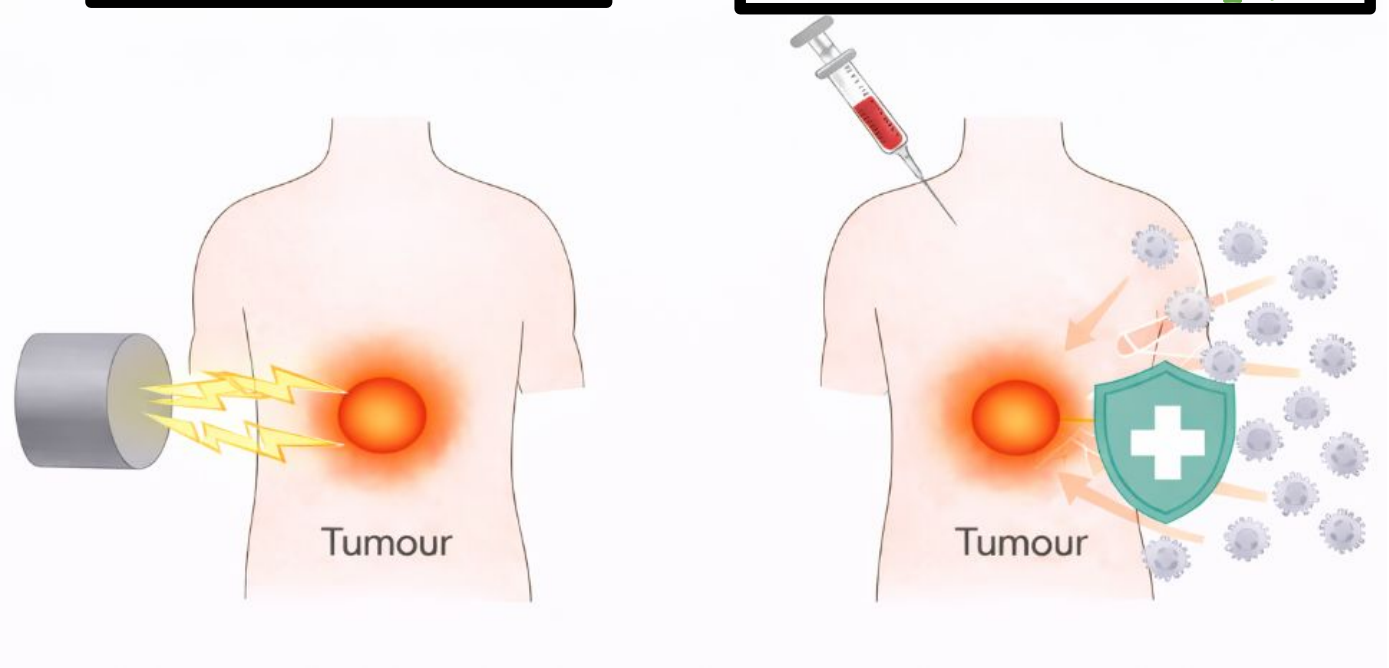


Clinical Therapy

Combining radiotherapy and immunotherapy

Radiotherapy

Immunotherapy

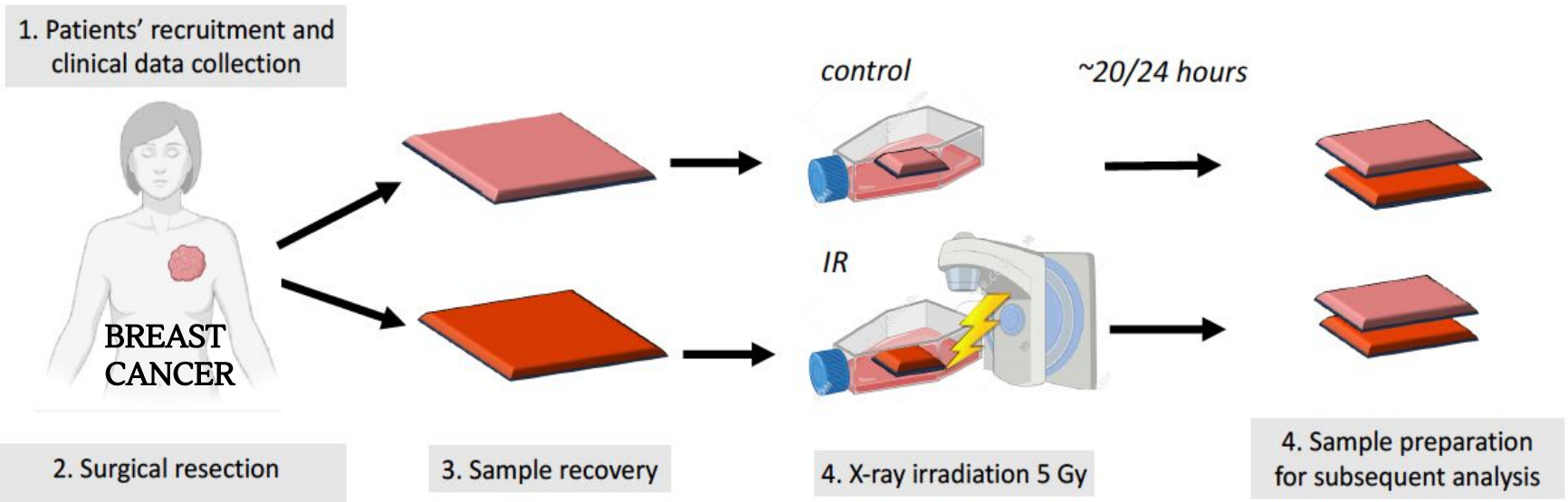


How do we optimize RT and what is its impact on the patients' immune system?

Clinical Therapy

Combining radiotherapy and immunotherapy

Studies



EU co-funded - IMAGEOMICS/PIANOFORTE (EURATOM), collaboration with IRCCS S. Matteo

Clinical Therapy

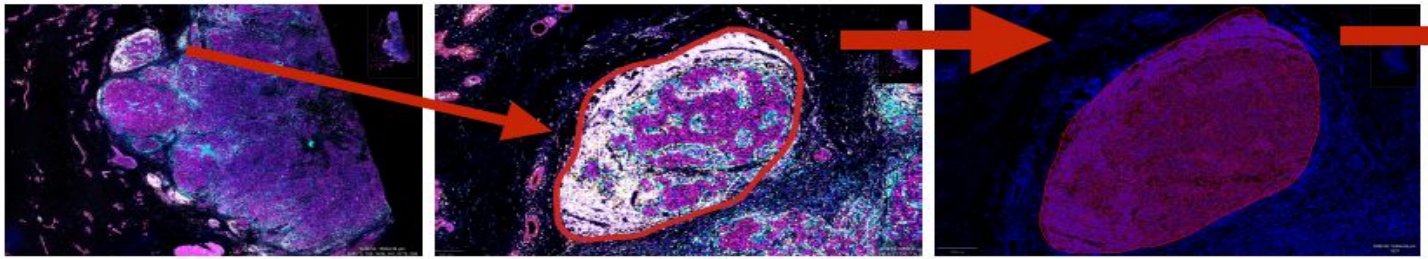
Combining radiotherapy and immunotherapy

Data acquisition

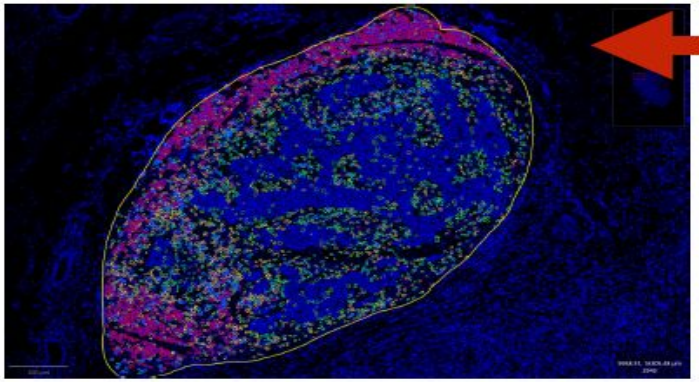
ROI selection

Cell segmentation

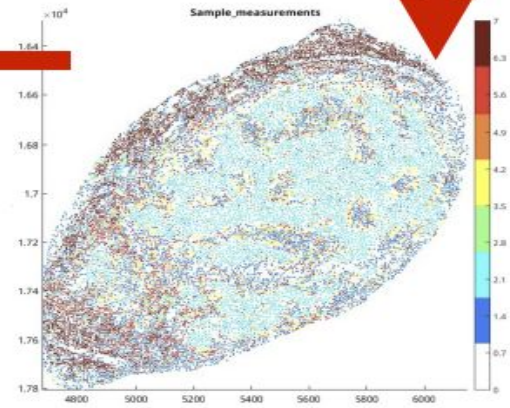
Dimensionality reduction and clustering for marker expression



Spatial -omics data (proteomics, transcriptomics)



analysis of tumor microenvironment

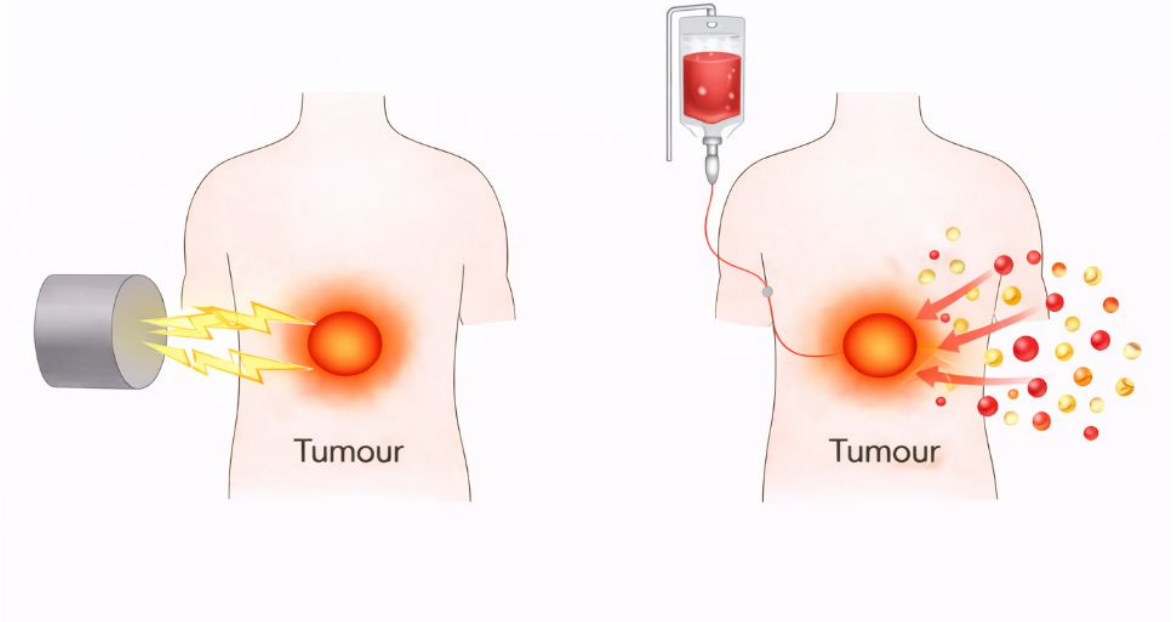


spatial coordinates integrated with cluster annotation

Clinical Therapy

Combining radiotherapy and chemotherapy

Radiotherapy + **Chemotherapy**



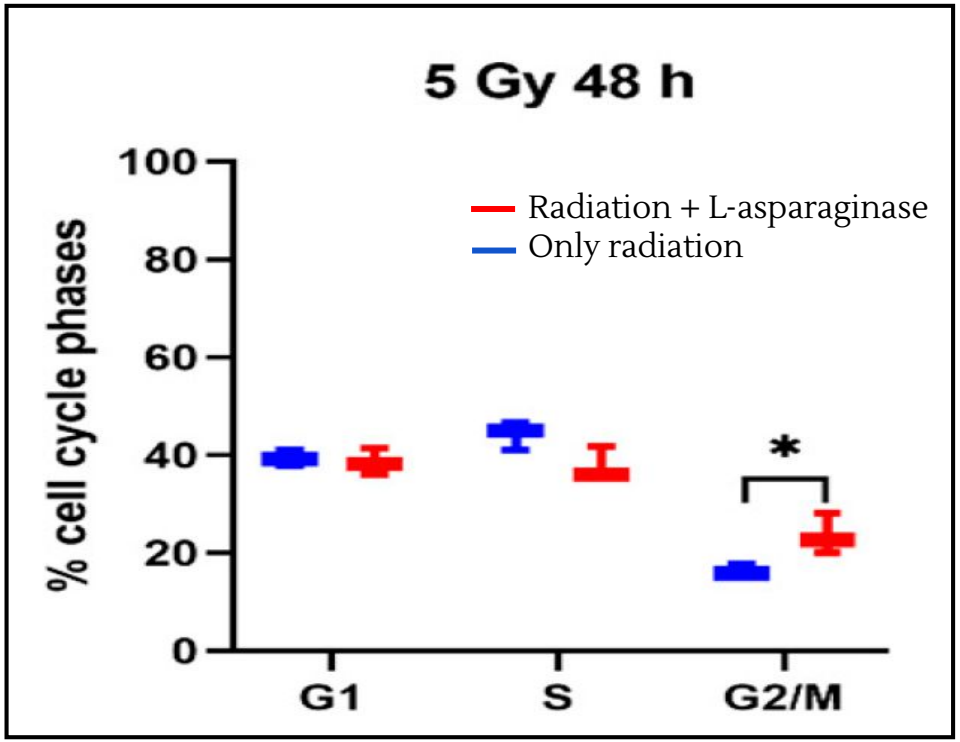
What are the mechanisms of action of drugs targeting cancer cell metabolism, and is the combined action of such drugs and radiation synergistic?

Clinical Therapy

Combining radiotherapy and chemotherapy

Studies

Cell lines, tested for their response to L-Asparaginase, a drug that deprives cancer cells of essential amino acids (asparagine and glutamine), **in use for leukemia, being investigated for solid tumours**



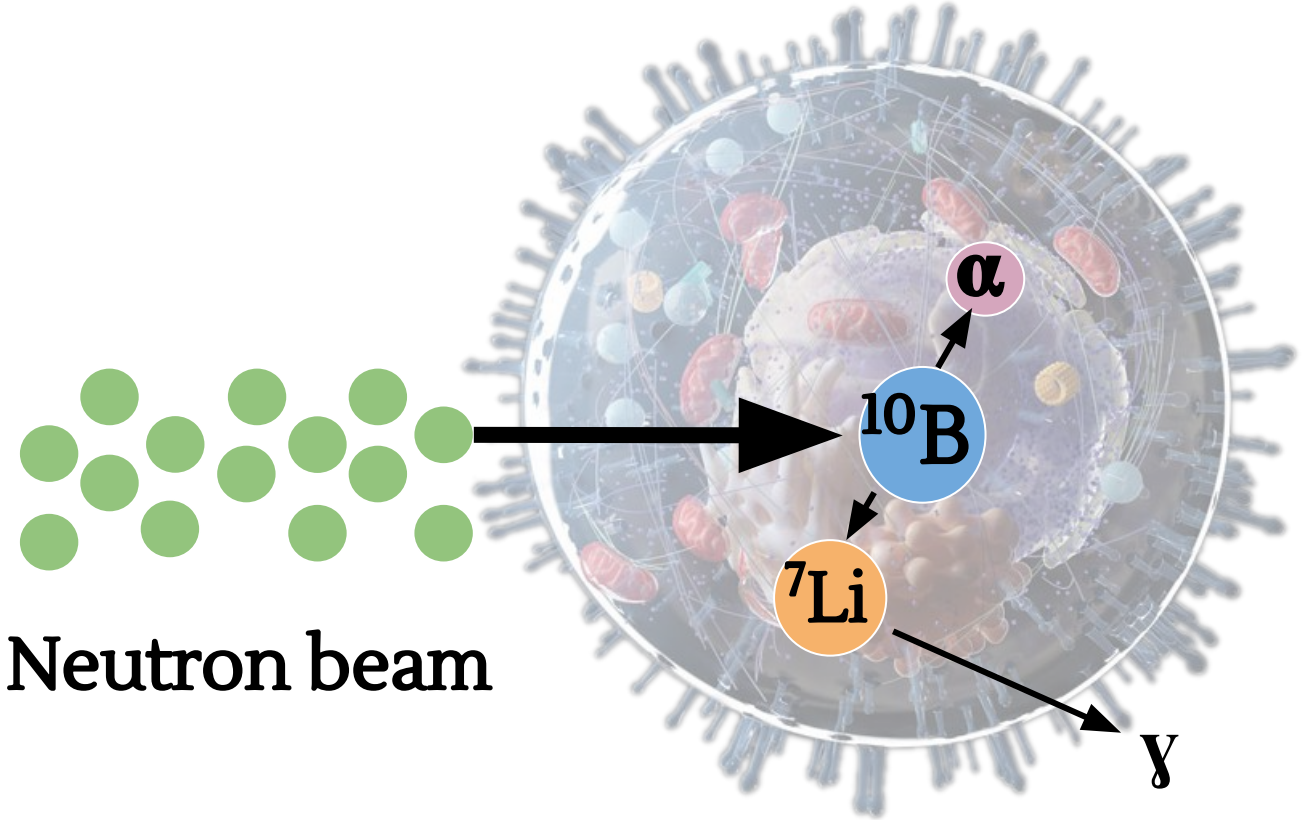
Modelli matematici per studiare sinergismo

L'effetto molecolare del trattamento attraverso l'analisi dell'espressione genica a singola cellula

In collaboration with the Unit of Immunology and General Pathology, Molecular Medicine Dept., UniPv

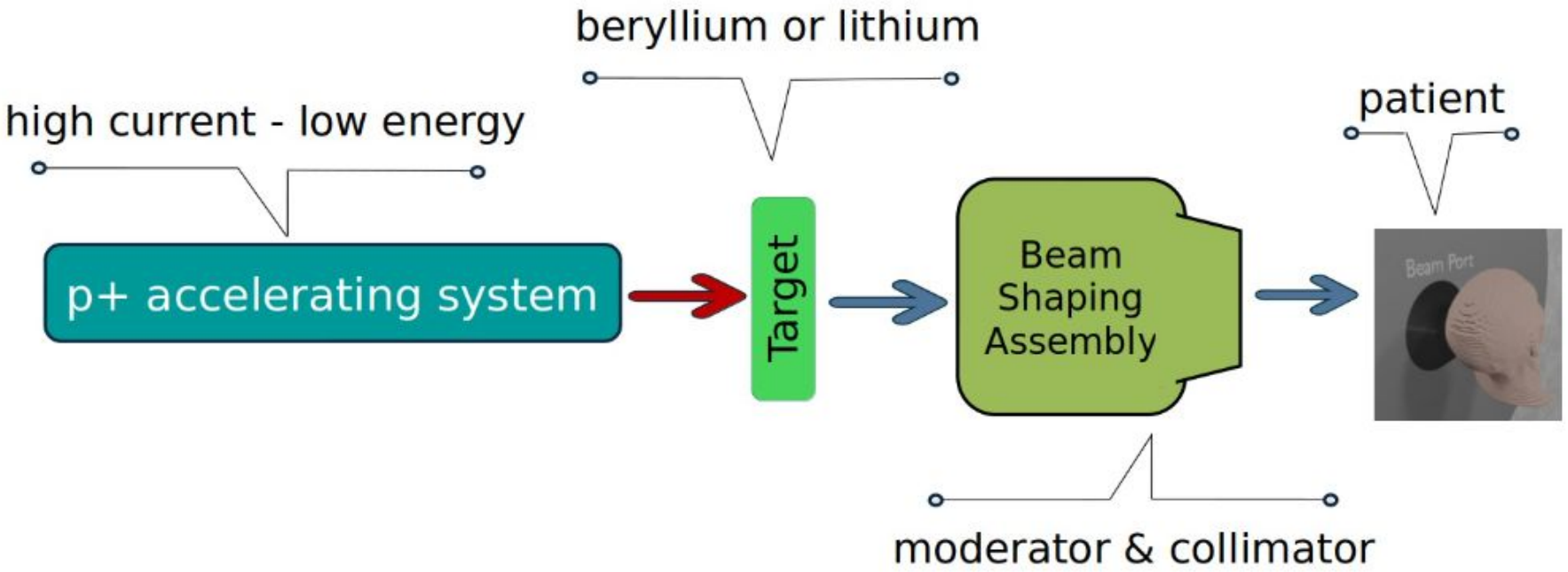
Clinical Therapy

BNCT



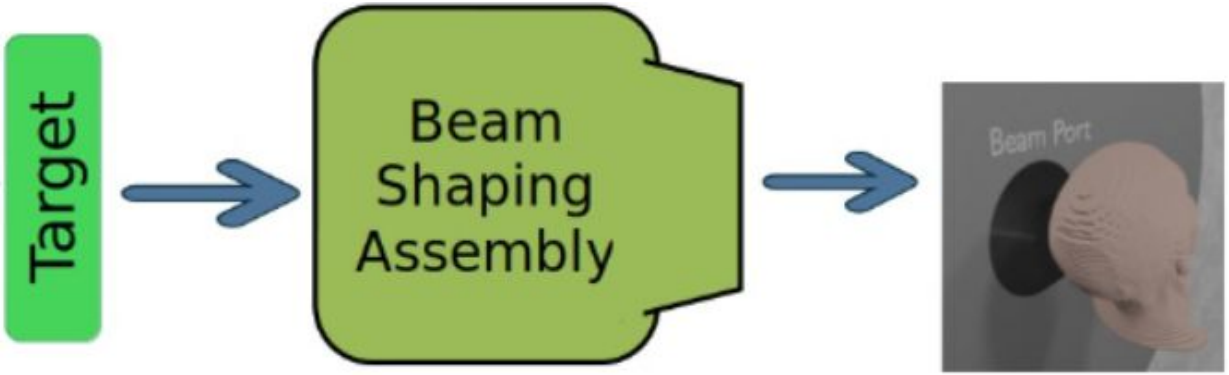
Clinical Therapy

BNCT



Clinical Therapy

BNCT



Cross section studies for n production

New materials for neutron moderation

Dosimetry
Treatment planning
AI techniques
Radiobiology
Boron measurements

Clinical Therapy

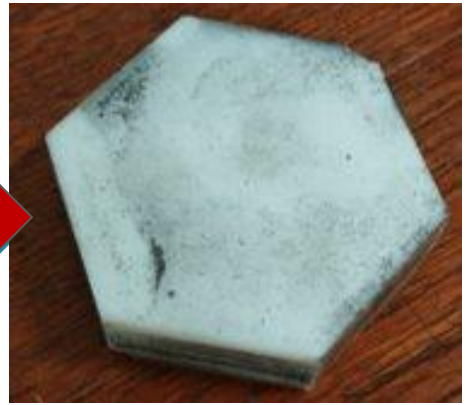
BNCT

R4I grant INFN “Sinter”

OFFICINA INFN PAVIA

SINTER

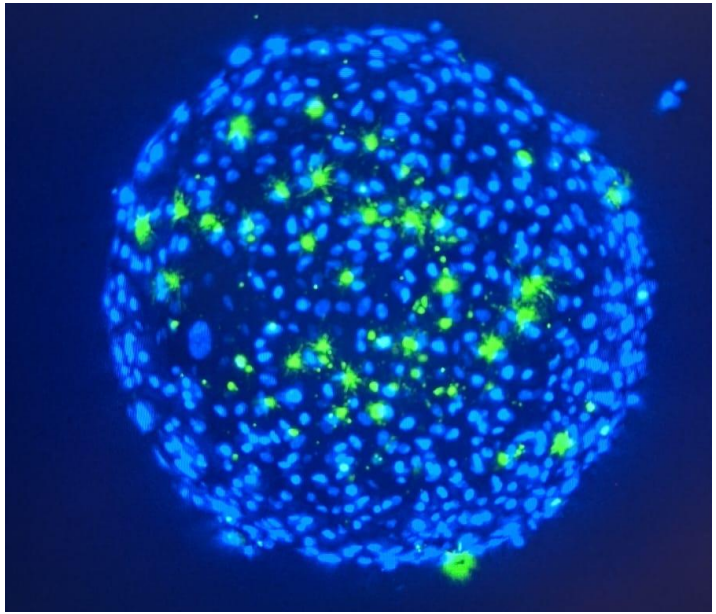
Pressure + Heat



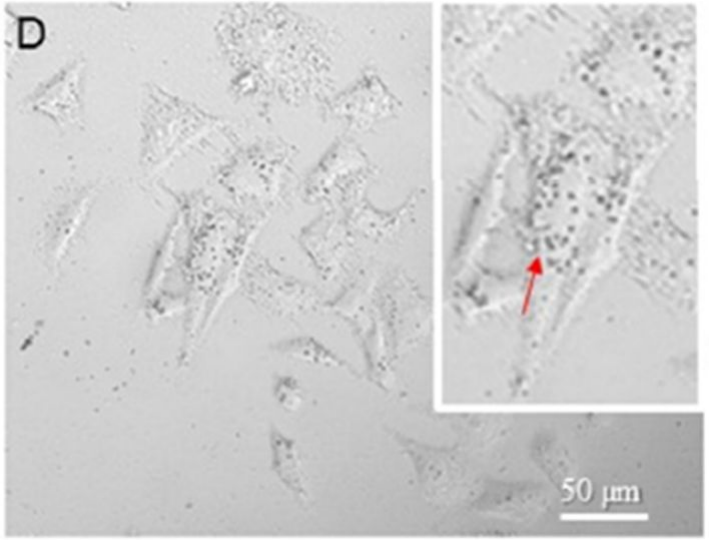
Building design
Radiation protection
BSA Radiobiology
Treatment Planning

Production of radiobiological data for BNCT

GIOCONDA



3D models

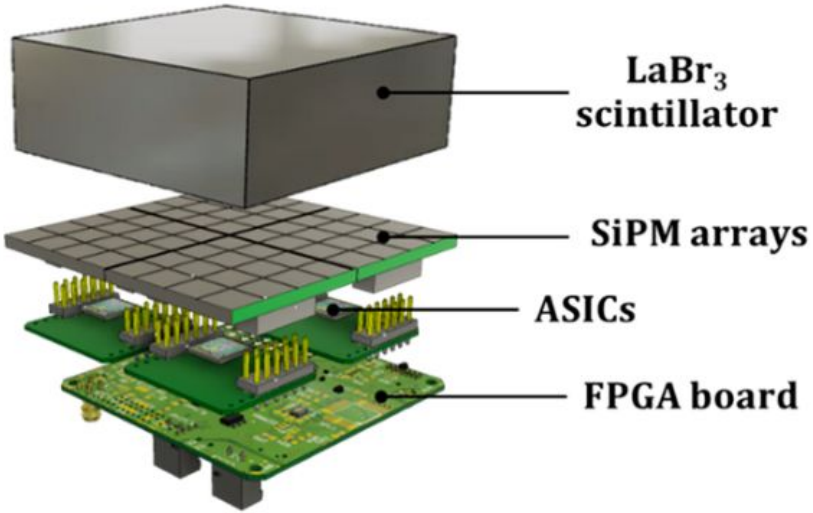


new B carriers and methods for biodistribution measurements

Clinical Therapy

BNCT

Development of a SPECT detector prototype for dose measurements in BNCT & SPect for Online boron dose verification in bnCt



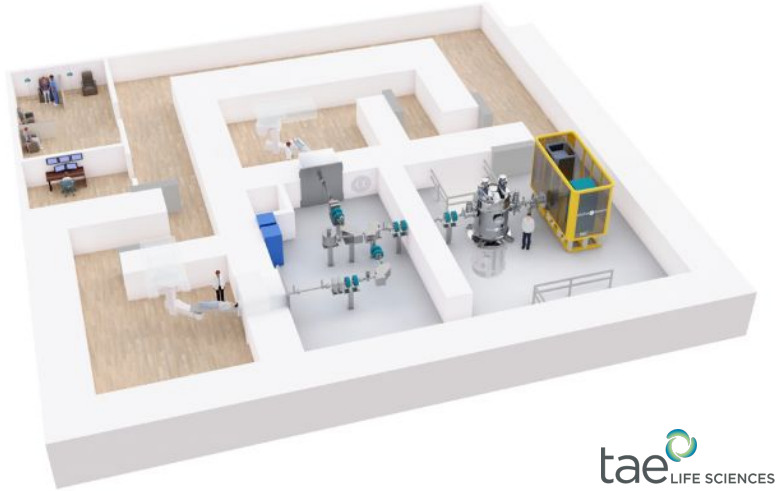
PRIN 2022 PNRR + INFN CSN5 SPOC project

Clinical Therapy

BNCT at CNAO

Centro Nazionale di Adroterapia Oncologica

On-going installation of TAE Life Science AB-BNCT(start ~ 2022)
Framework agreement CNAO/INFN/PoliMI/UNIPV



tae LIFE SCIENCES

Thanks to Collabora & Innova call (Nov.2024): project "PROGRESS-BNCT", @ CNAO

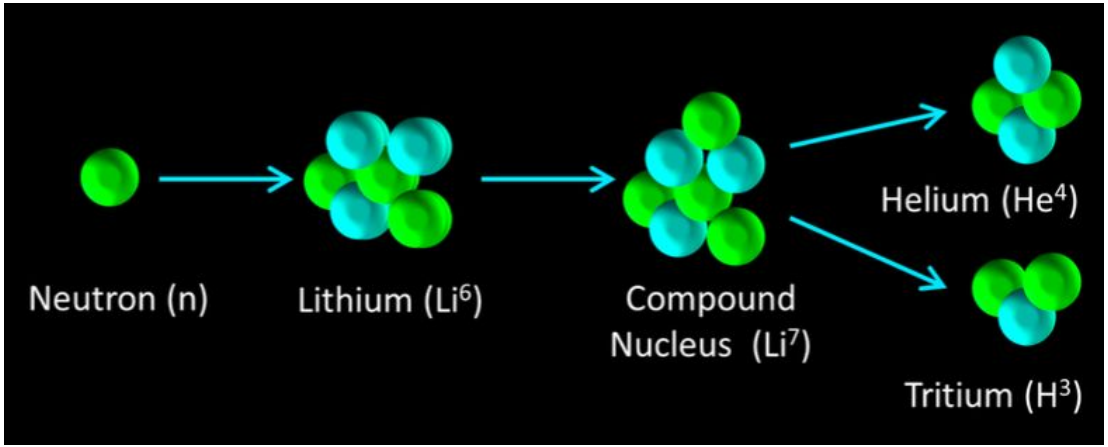
PROGRESS
BNCT@CNAO
PROGettazione, Ricerca E Sviluppo Sperimentale per la terapia BNCT

Regione Lombardia

Clinical Therapy

LiNCT

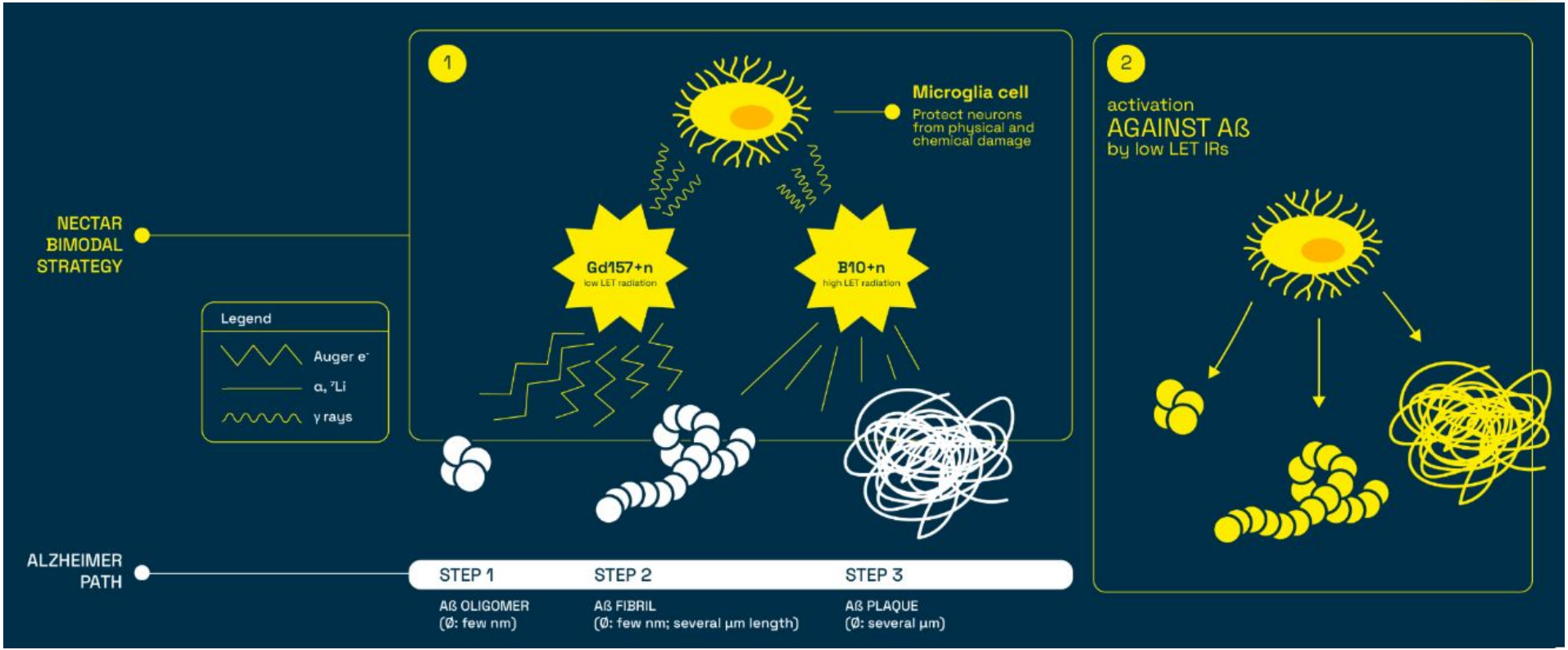
In vitro and ex-vivo safety and efficacy of Li-NCT



Since 01/01/2026, till end 2029, the activity is supported by Horizon Europe Staff Exchange project TUMORGPLAT, GA #101236487: *making patient-derived TUMor ORGanoids a reliable cancer therapy testing PLATform*

Clinical Therapy

NEutron Capture-enhanced Treatment of neurotoxic Amyloid aggRegates (NECTAR)



Biomedical Physics: Research & Applications

Health protection

- Radiation risks
- Space radiation studies
- Dosimetry
- Radiation biology

Health protection

Radiation risks: astronauts

3 mSv (365 days)

350 mSv (365 days)

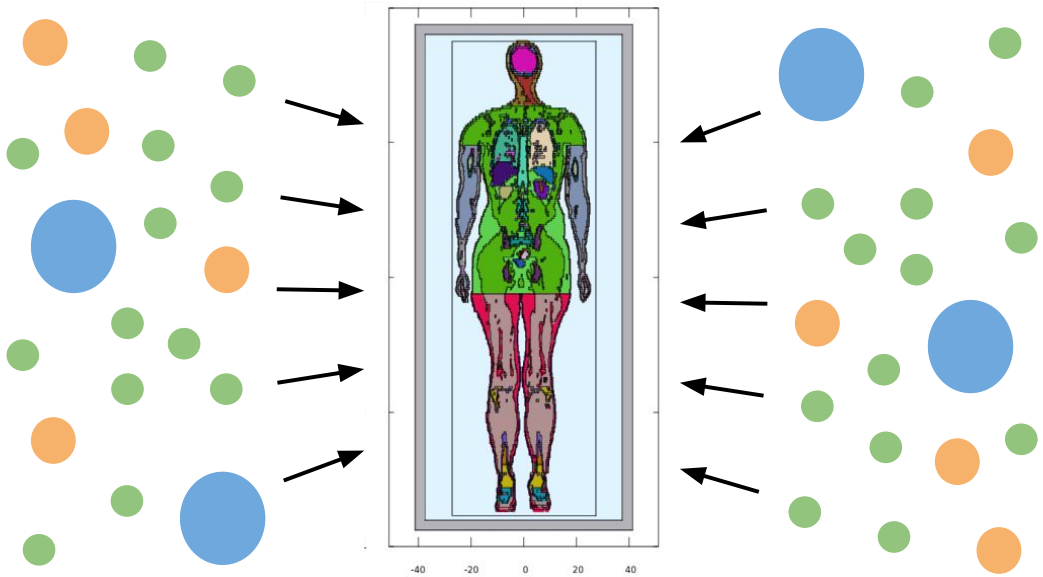
900 mSv (650 days)

Health protection

Radiation risks: astronauts

Studies

Radiobiological damage of space radiation: **extension of BIANCA model up to Fe ions**
ARES (INFN) : Astronauts' risks by space Radiation in future Exploration missions
COSMIC (ASI Project) : Effects of space radiation on microcirculation in a 3D organ-on-chip model



Health protection

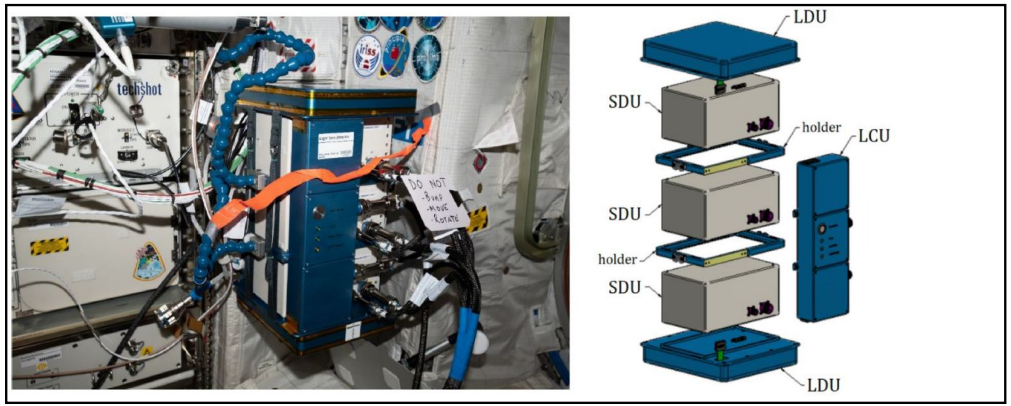
Radiation risks: astronauts and nuclear workers

Studies

Healthy cell lines or ex-vivo tissues exposed to space radiation qualities

Monte carlo modeling (radiation detector, radiation field and its impact at the cell level)

Funds by ASI, exp. at CNAO, detector on board the ISS



The EU-funded projects TRANSAT and TITANS studied the biological effects of tritiated cement or steel particles that can be accidentally released in the environment and inhaled by workers in the dismantling of a nuclear fission facilities.

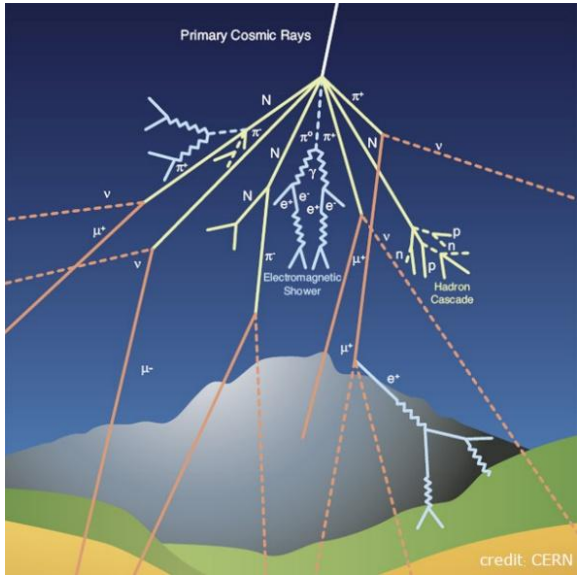
Health Protection

Clinical Therapy

Radiation Biophysics and Radiobiology Lab @UniPv

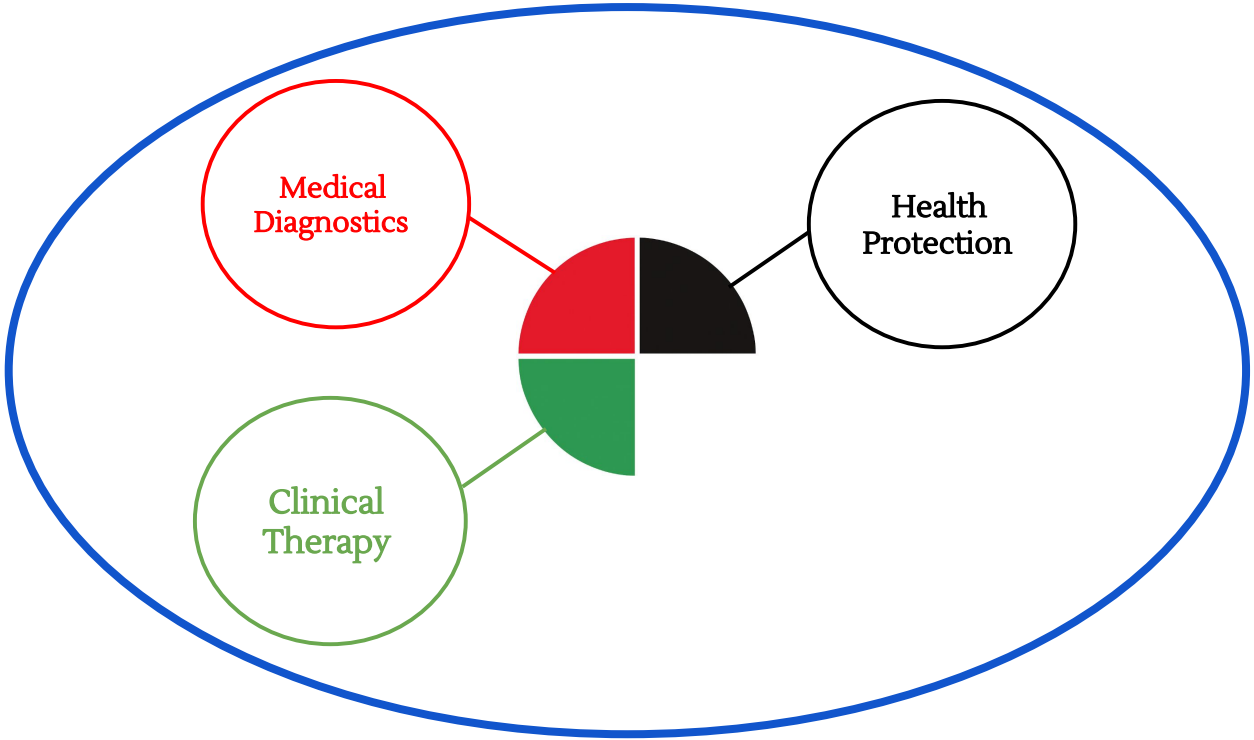
Studies

Fundamentals: molecular mechanisms of radiation action



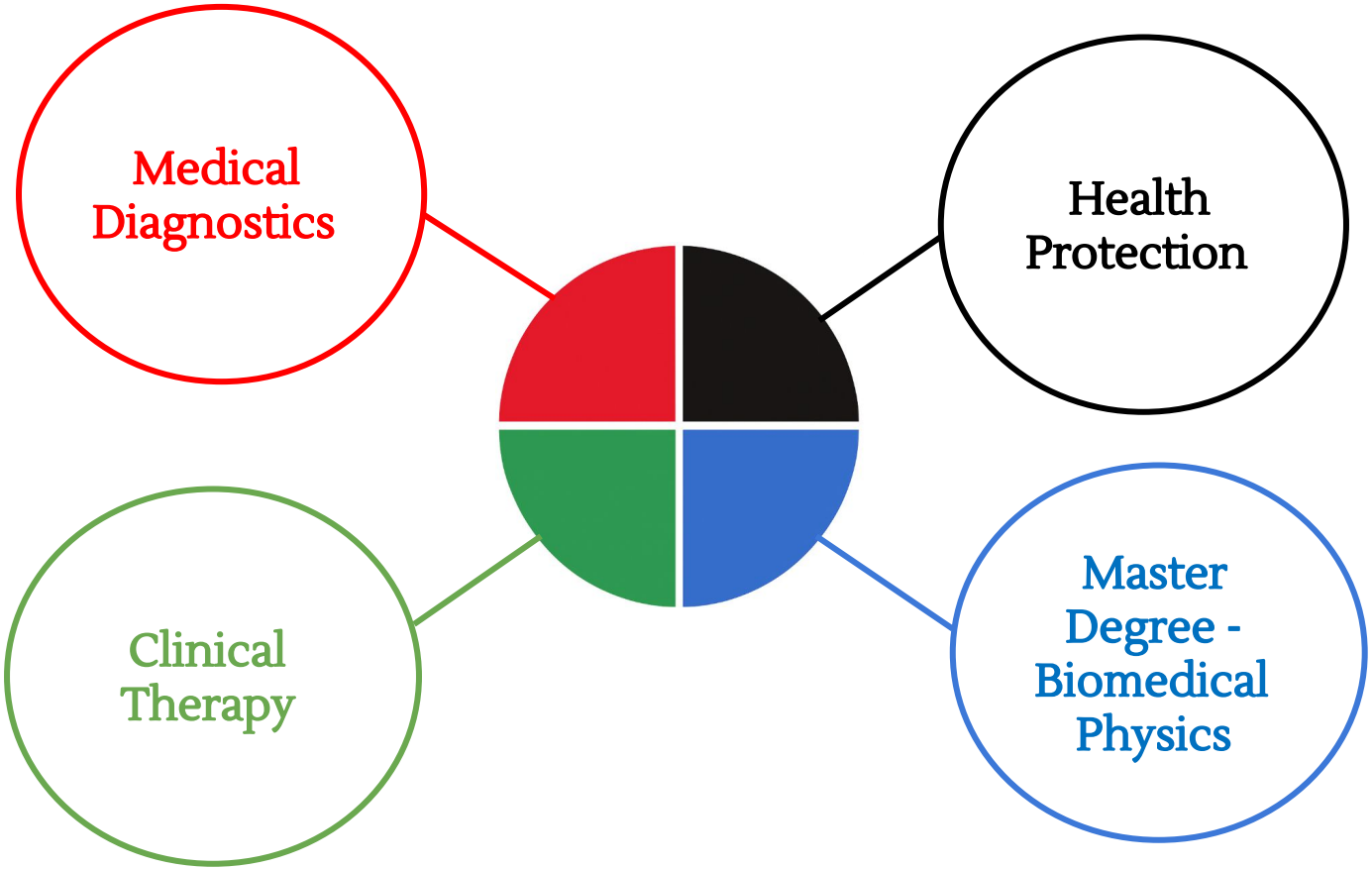
ECLIPSE project, funded by INFN GR5

Biomedical Physics: Research & Applications

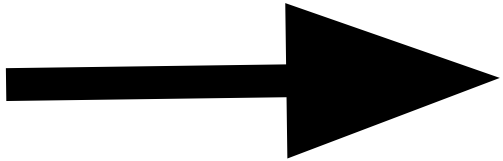


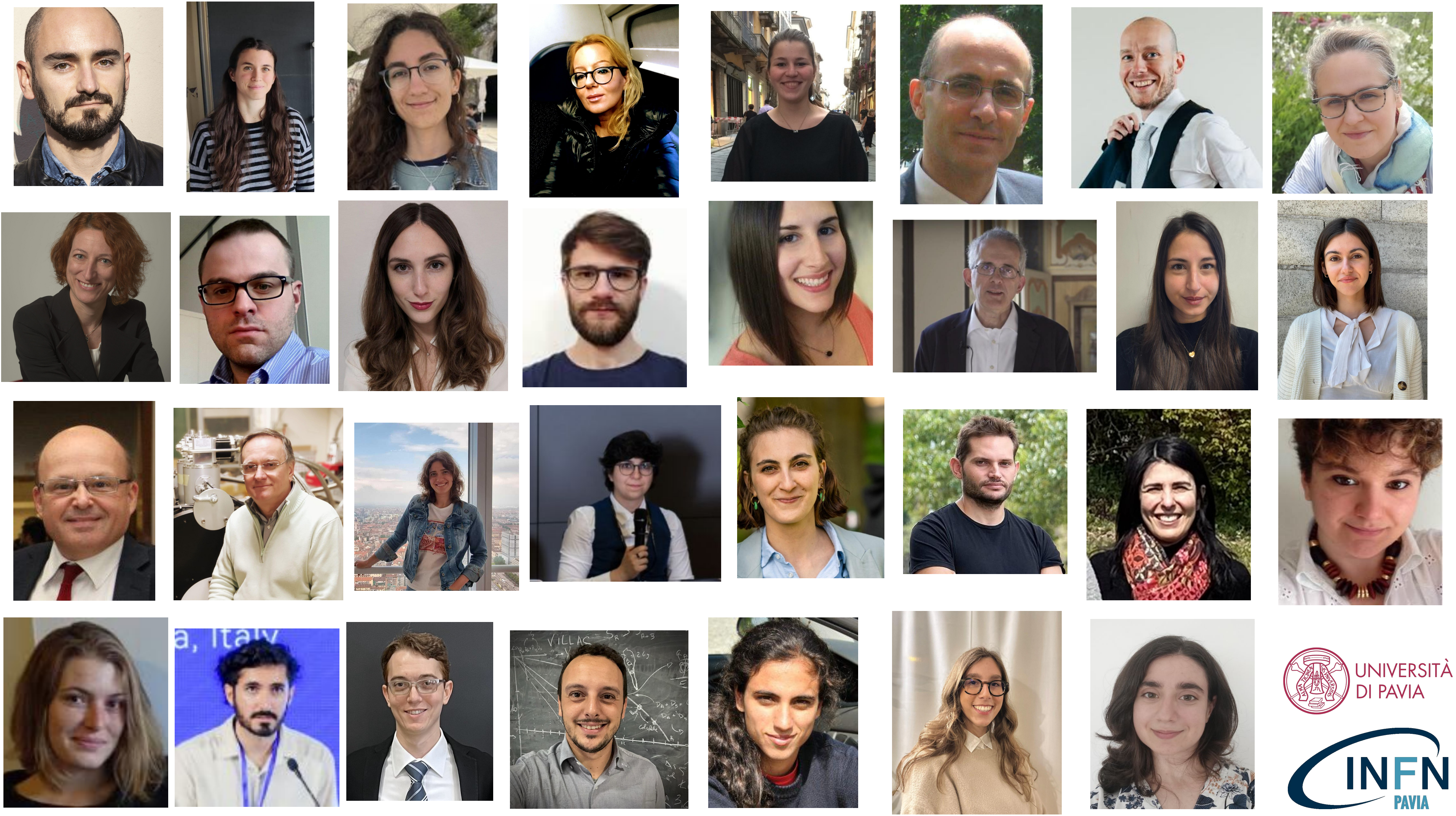
AI-Enhanced Experimental & Computational Research

Biomedical Physics: Research & Applications



Biomedical Physics: Research & Applications





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