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AIDA 2020

Silicon-based Microdosimetry System for Advanced Radiation Therapies (SMART)

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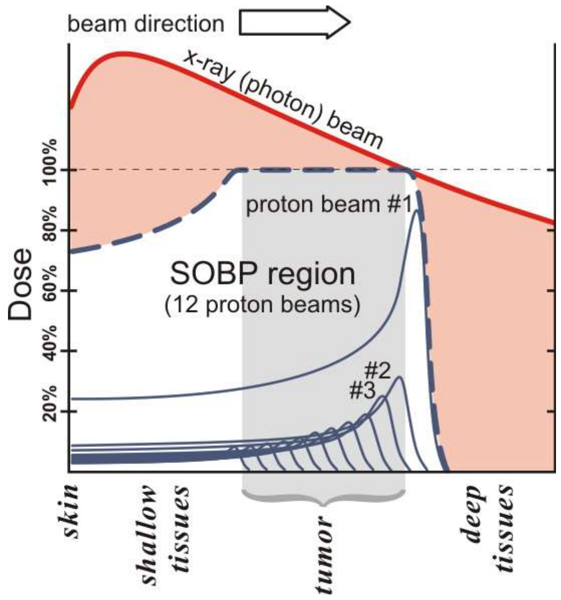
Barcelona, Spain

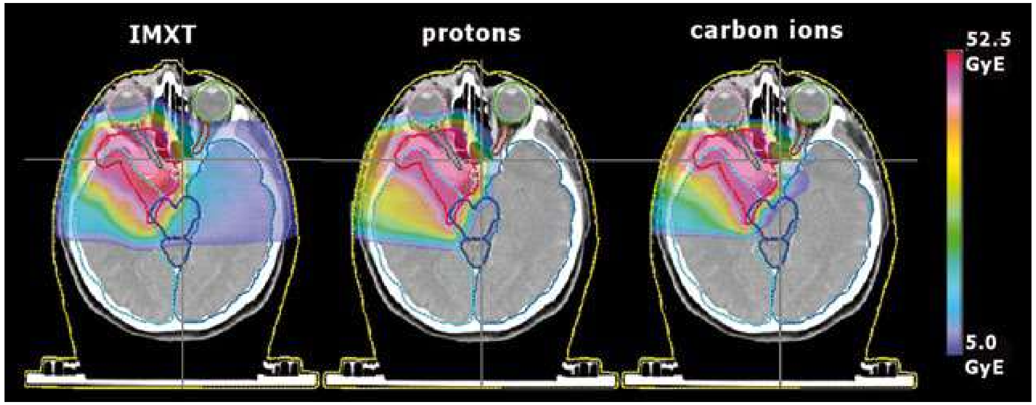
CNM

CSIC
CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

Motivation

- 1 out of 2 persons born today will be diagnosed with cancer in their lifetime *(SEER Cancer Statistics Review 1975-2013)*
- More than 50% of all cancer patiens will receive radiotherapy for curative or palliative aims
- **Hadrontherapy** is a fast-growing modality of radiation therapy





Motivation

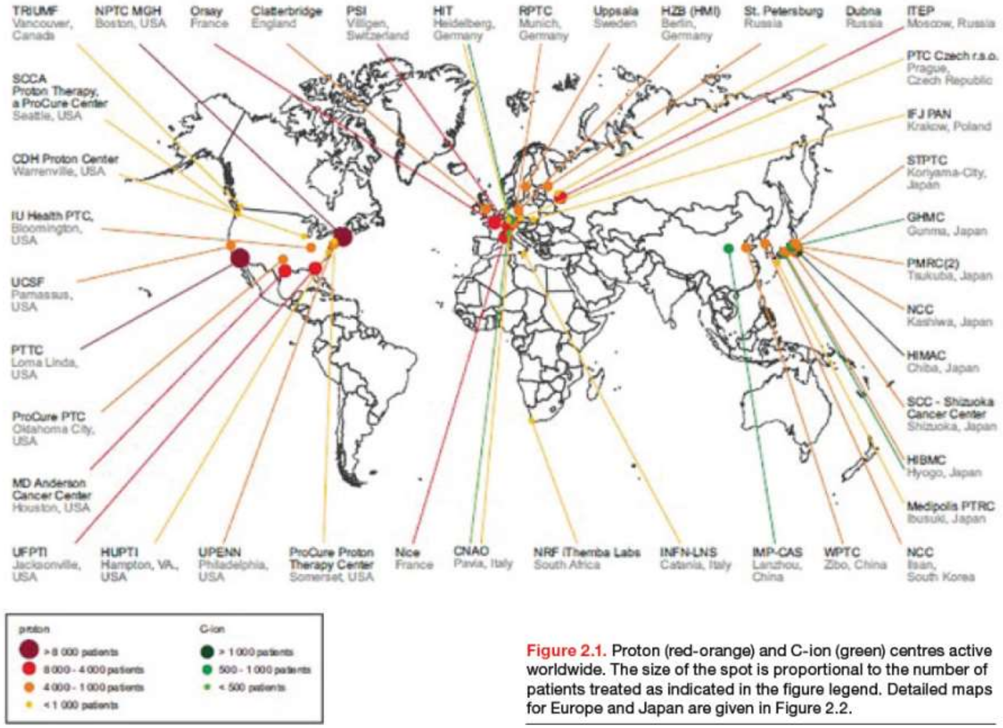
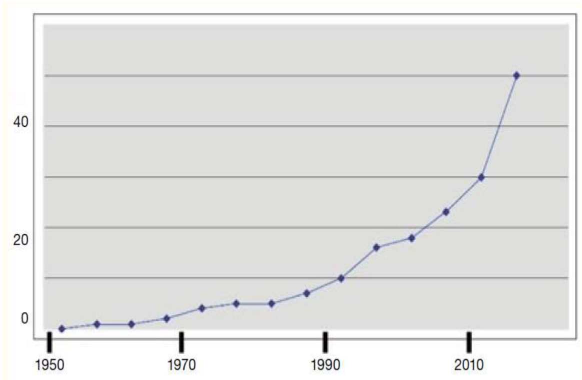


Figure 2.1. Proton (red-orange) and C-ion (green) centres active worldwide. The size of the spot is proportional to the number of patients treated as indicated in the figure legend. Detailed maps for Europe and Japan are given in Figure 2.2.



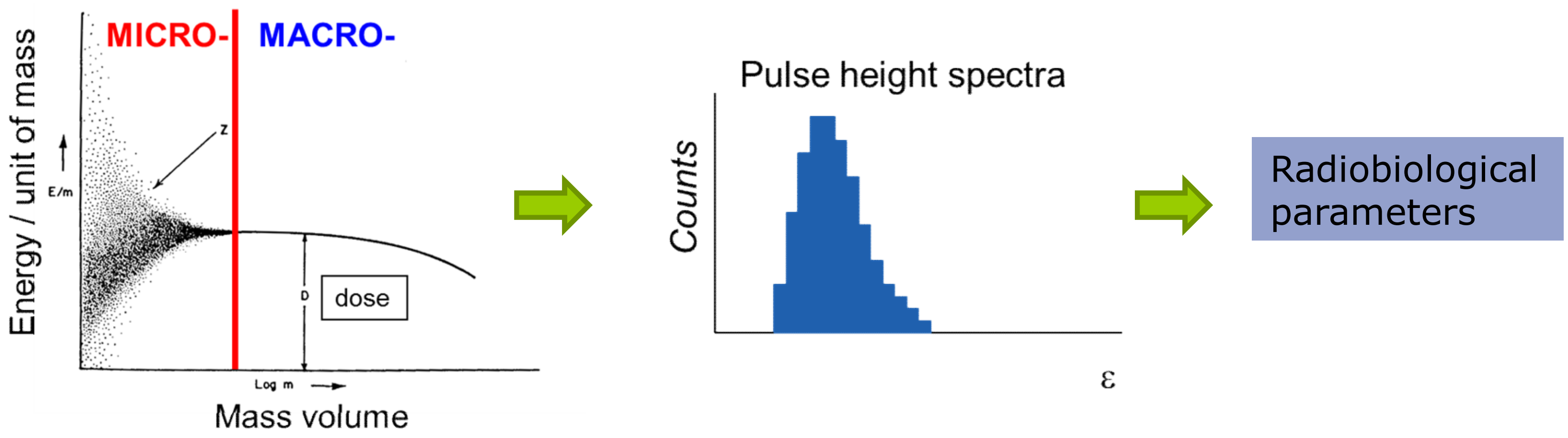
Proton therapy centers 1950-2015

(Nuclear Physics European Collaboration Committee, NuPECC Report "Nuclear Physics for Medicine“, 2014)

There are 61 hadrontherapy centers in the world with 32 others under construction (19 and 10 in Europe, respectively).

Microdosimetry

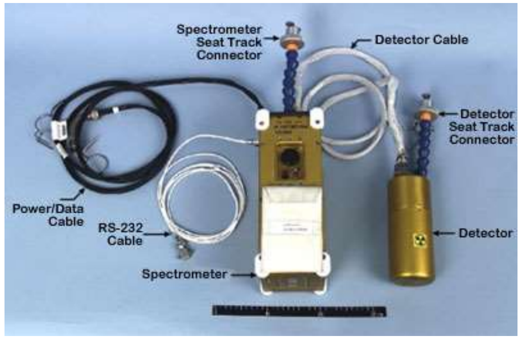
- **Study of energy deposition in microscopic volumes (e.g.: cells)**
- Microdosimetry ≠ dosimetry in small volumes
- Dosimetry: averages (absorbed dose, J/kg)
- However, the energy deposition by hadrons is <u>stochastic</u> → statistical fluctuations
- **Microdosimetry** studies the complete process of energy deposition at the microscopic scale. The results are expressed in terms of probability distributions.
- The biological effect of radiation not only depends on absorbed dose, but on its distribution



The need

- Treatment planning systems are used to determine the dose distribution obtained for a certain beam arrangement to be applied to a tumor volume.
- **No adequate bio-dosimeters are currently available** for the routine verification of biological dose in hadrontherapy

- Current methods:
  - Software: Monte-Carlo simulations of particle transport in a patient
  - Gas detectors (TEPC): large (mm^2), wall effects, need gas supply, limited spatial resolution



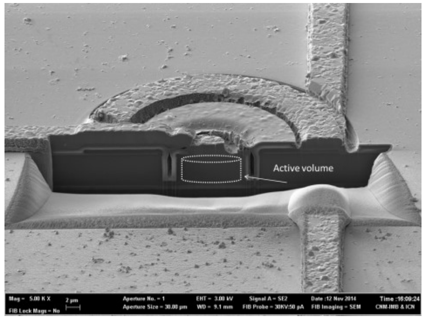
- A dosimeter for hadrontherapy should have:
  - Well defined active volume, micrometric dimensions
  - Real-time operation and fast response to avoid pile-up
  - Spatial resolution (measurement of 2D profiles)

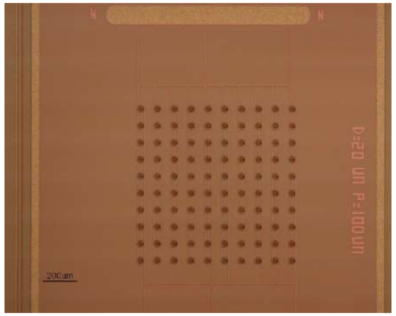
→ **Silicon micro-sensors** are ideal candidates!

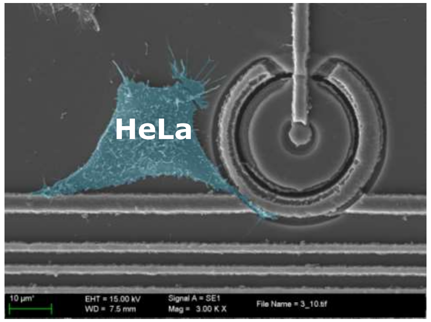
The expertise

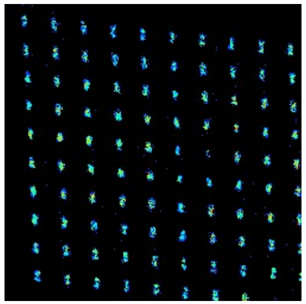
- ✓ IMB-CNM-CSIC has **more than 15 years' experience** of producing advanced silicon detectors for nuclear and high energy physics experiments
- ✓ IMB-CNM-CSIC has developed a silicon microsensor technology that can provide **cell-like silicon sensitive volumes to allow for unprecedented spatial and dose resolution**.
- ✓ **Proof-of-concept devices have already been used** to characterize with high accuracy the radiation quality parameters of carbon and proton beams

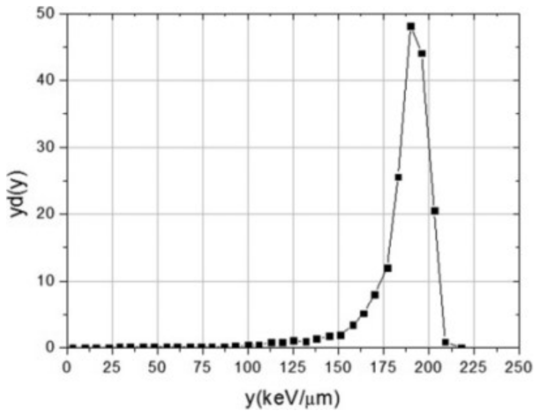
[1] JINST10, P01008 (2015).
[2] Phys. Med. Biol. 61, 4036–4047 (2016).
[3] Appl. Phys. Lett. 107, 023505 (2015).











The idea

- Our objective of the SMART project is the realization of a new microdosimetry tool optimized for clinical application for **verification of hadron treatment plans.**

- The system consists of **CSIC's novel silicon microsensors** together with **a multi-channel readout electronics** and will be capable to provide detailed microdosimetric distributions in space and time.

Potential impact

- The successful development this system has the potential to improve the cancer treatment planning in the growing modality of radiation therapy with hadrons. **Millions of cancer patients worlwide could be benefited**.

- The system could also **address the radiation protection requirements in avionics and space radiation environments**, helping to understand and thus minimize the cancer risk for aircrew personnel and astronauts.

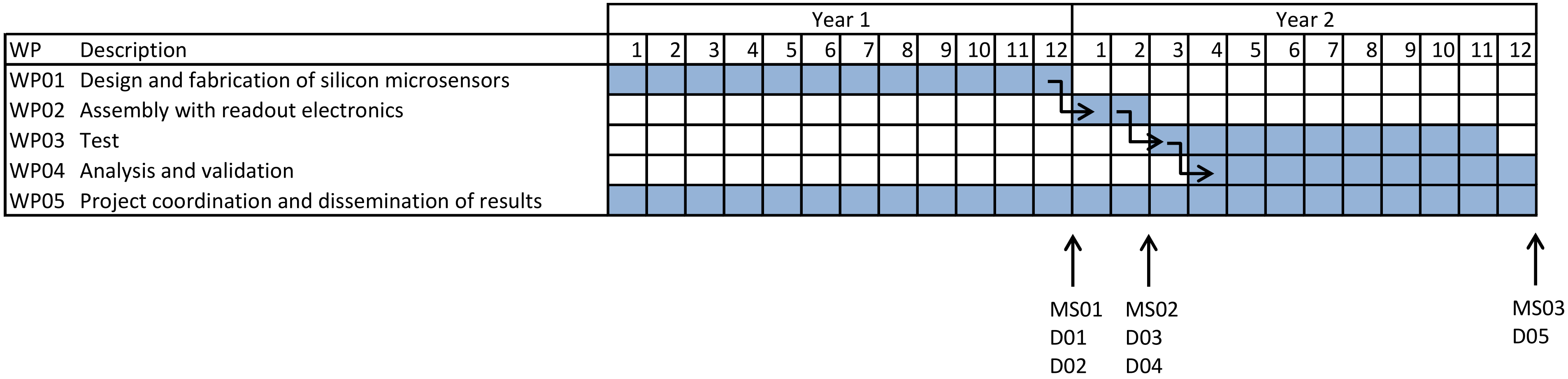
Personnel

- **Dr Celeste Fleta**: Project Coordinator, sensor design, organization of test campaigns
- **Dr Giulio Pellegrini**: assembly of sensors with the pixelated readout electronics, dissemination leader
- **Dr David Quirion**: sensor fabrication at IMB-CNM's clean room
- **Student**: test and data analysis, will also participate in all other aspects of the project
- **Technical teams** of IMB-CNM's Clean Room and Electronics Laboratory

Other collaborators

- IMB-CNM has a long-time collaboration with groups specialized in new particle therapies
- NARA (New Approaches in Radiotherapy) at IMNC-CNRS and the Roberts Proton Therapy Center at the University of Pennsylvania are providing advise on best device design for clinical application

Timeline



Deliverables *(H=Hardware, R=Report)*
D01 (H): Silicon microsensors for microdosimetry measurements in particle beams.
D02 (R): Results of the fabrication and electrical characterization of the microsensors.
D03 (H): Complete silicon-based microdosimetry system composed of microsensors and multi-channel electronics.
D04 (R): Results of the laboratory tests of the microdosimetry system.
D05 (R): Final report including results of beam tests and analysis.

Milestones
MS01. Silicon microsensors for particle beam measurements fabricated and electrically tested.
MS02. Complete detector system composed of pixellated sensor and multi-channel readout electronics assembled and tested in laboratory.
MS03. Detector system validated in relevant radiation environment.

Budget

- Funding received from AIDA2020: **45,600€**

Concept	Cost (EUR)
Photolitography masks (8 levels)	5,000
Silicon-on-insulator wafers	4,000
Detector fabrication and assembly to electronics	7,000
Multi-channel readout electronics	10,000
Other test hardware (water equivalent material, cables, adaptors, boxes,...)	2,000
Beam time and travel not covered by AIDA Transnational Access	5,500
Dissemination activities	2,980
Indirect costs (25% rate)	9,120
Total	45,600

- Other (personnel costs, assumed by CSIC) **47,684€**

- Total budget **93,284 €**

Transfer to industry

- **Exploitable foreground**: Sensors in a first step, full system at project end

- Two options are considered for **industry transfer**:
  - License the product to industry
    - One option is Alibava Systems (a spin-off of IMB-CNM-CSIC + Liverpool Uni + IFIC Valencia) that already commercializes other CSIC's products under license.
    - Leaders in the medical equipment industry are being actively searched through CSIC and Collaborator's contacts in the medical field.
    - In parallel: searching for other distribution channels envisaging an extension of licensing agreements to other markets (space, aviation, nuclear security…)
  - Create dedicated spin-off Company

Conclusions

- **This proposal falls fully within the scope of AIDA-2020** as it brings innovative technologies developed for HEP to medical hadrontherapy, a field with **major economic, social, human and scientific interest**.

- IMB-CNM-CSIC, with its long experience in silicon radiation detector technology, is uniquely situated to **take a leadership role** in the field.

- The project takes advantage of the unique opportunity for access to high-quality infrastructures provided by the AIDA-2020 network and will help to **put Europe in the vanguard of hadrontherapy research.**

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