This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under GA No 101004730.

12.1. A Strategy for Implementing Novel Societal Applications of Accelerators

CERN/the 4th of May 2022/I.FAST meeting

Andrea Sagatova/STU

iFAST

Objectives:

Task 12.1: A Strategy for Implementing Novel Societal Applications of Accelerators (M1-M48)

- Study some new and important societal applications of accelerators with the aim of developing roadmaps for their innovation:
  - *novel forms of radiotherapy for cancer treatment;*
  - *reduction of environmental pollution;*
  - *new imaging techniques;*
  - *improved methods for radioisotope production*.
- Develop a strategy to deliver these roadmaps.
- Study the barriers which discourage the use of accelerators in industry.

12.1 Sub-Tasks:

- Sub-task 1. Coordination and Communication
  - (Rob Edgecock – HUD, deputy coordinator: Andrea Sagatova – STU)
- Sub-task 2. Novel forms of radiotherapy
  - (Angeles Faus-Golfe – CNRS)
- Sub-task 3. Environmental applications of electron beams
  - (Toms Torims – RTU, Andrzej Chmielewski – INCT)
- Sub-task 4. Accelerator imaging
  - (Graeme Burt – ULANCS)
- Sub-task 5. Accelerator production of radioisotopes for imaging and therapy
  - (Diego Obradors, Conchi Oliver – CIEMAT)
- Sub-task 6. Barriers to accelerator adoption by industry
  - (Andrzej Chmielewski – INCT, Andrea Sagatova – STU)

12.1 Deliverable and Milestones:

	Title	Lead Beneficiary	Due Date	Means of Verification
D12.1	Strategy for Implementing Novel Societal Applications of Accelerators	43-HUD	M28	Report

MS57	Projects identification for development funding	43-HUD	M10	Abstract of proposals
MS58	Completion of strategy documents for each application area	43-HUD	M40	Report

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WP 12.1 Sub-Task 2:

Novel forms of radiotherapy

(Angeles Faus-Golfe – CNRS)

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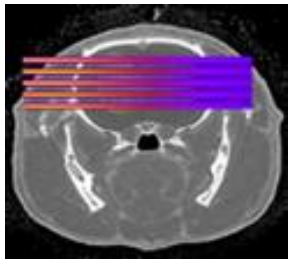
12.1 Sub-Task 2: OBJECTIVES

1. **Study the novel forms of radiotherapy for cancer treatment**
   - **FLASH and mini-beams**
   - **VHEE**

   with the aim of developing a roadmap for the innovation.

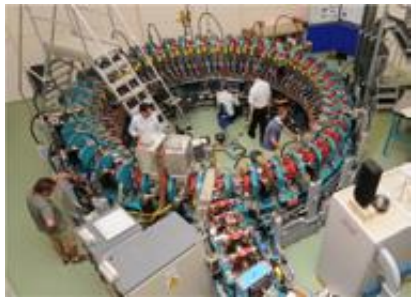


2. **Develop a strategy to deliver a roadmap (brainstorming writing meeting/workshop with identified experts, accelerator dedicated workshop…)**

3. **Study the barriers which discourage the use of these new techniques in industry in collaboration with medical doctors as users**

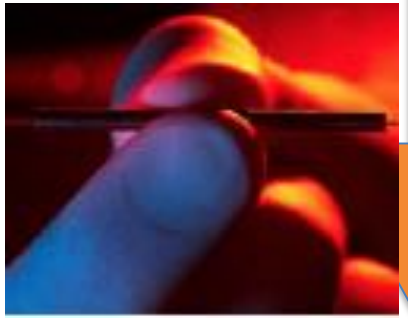
12.1 Sub-Task 2: ACCELERATOR TECHNOLOGY-HEALTH INDUSTRY

SCRF CEA



FFAG -EMMA

plasma cell - EuPRAXIA



terahertz accelerator module DESY

Current applications, especially in HEALTH INDUSTRY, tend to use rather OLD TECHNOLOGY but WELL-PROVEN and their performance, especially for newer applications, can be LIMITED by this. To expand and advance on the novel applications we have to use:

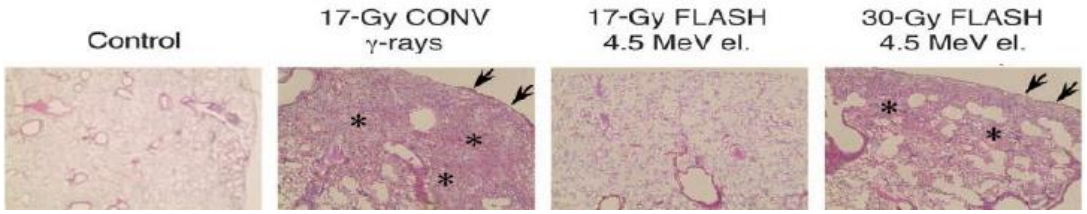
- **SUPERCONDUCTING (SC) magnets and RF cavities after 30 years of use in research start to be exploited in the commercial manufacture of accelerators.**
- **NEW COMPACT ACCELERATOR CONFIGURATIONS**
  - **Fixed Field Alternating Gradient Accelerator (FFAG).**
  - **Linear accelerator (linac).**
  - **Laser plasma acceleration (LPAs)** (100 GeV/m).
  - **Terahertz acceleration** (400 GHz with 1.5 cm long, 1mm wide).

3rd May Workshop: Elena Benedetto, Accelerators Health Applications

12.1 Sub-Task 2: CHALLENGES IN RADIOTHERAPY (RT)

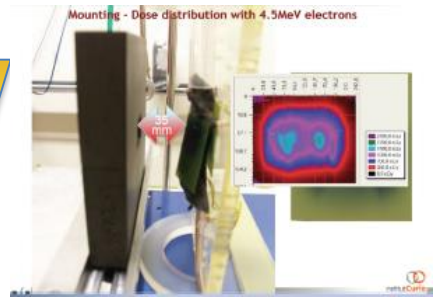
New radiotherapy approaches

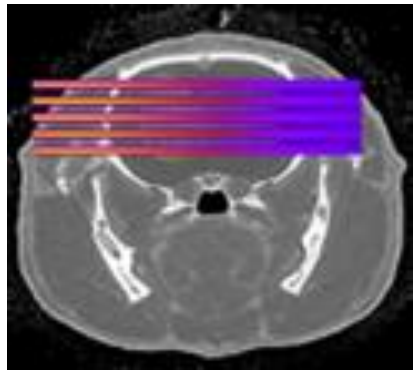
- ***RT treatment of some radio resistant tumours, pediatric cancers and tumours close to a delicate structure (i.e. spinal cord) is currently limited by induced toxicity to the healthy tissues surrounding tumours***
- **One of the main challenges is to find approaches to increase the normal tissue resistance**
- ***Possible strategies to spare normal tissue***
- **Different dose delivery methods: Grid Mini-beam or FLASH RT**
- **Different particle types: Very High-Energy Electrons (VHEE)**



FLASH spares lung at doses known to induce fibrosis in mice following conventional dose-rate irradiation (CONV).

FLASH RT





Mini-beams

VHEE >100 MeV/m is now achievable in labs

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WP 12.1 Sub-Task 3:

Environmental applications of electron beams

(Toms Torims – RTU, Andrzej Chmielewski - INCT)

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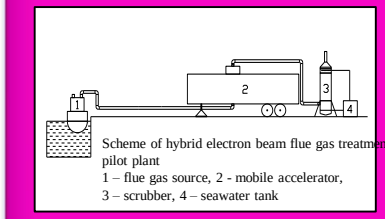
12.1 Sub-Task 3:

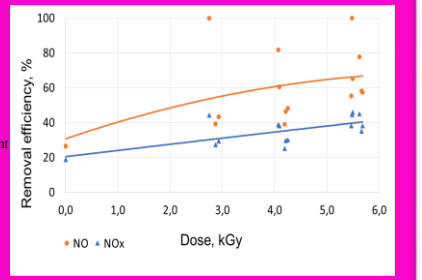
Accelerator based Technologies for Environment Pollution Control

3rd May Workshop:
Frank-Holm Roegner,
Accelerators
Environmental and
Industrial Applications

Electron Beam Flue Gas Treatment



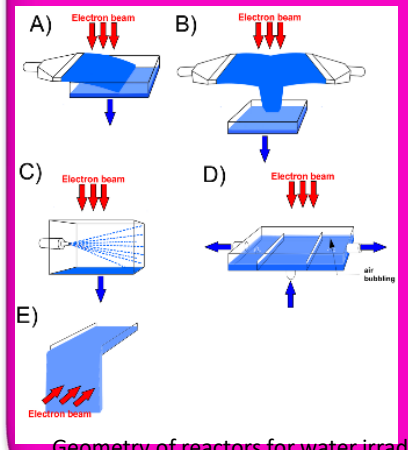
Scheme of hybrid electron beam flue gas treatment pilot plant
1 – flue gas source, 2 - mobile accelerator,
3 – scrubber, 4 – seawater tank



Reduce 40% NOx and 90% VOCs emission at 5.5 kGy dose

EBFGT installation at Riga Shipyard.
Mobile accelerator (R) & wet scrubber (L)

Safety of ships ballast water



Elimination of biological harmful organisms using doses
< 5 kGy

Low x-ray emission to reduce thickness of shielding

Geometry of reactors for water irradiation: (a) jet injection, (b) two opposite jets injection,
(c) sprayer, (d) up-flow system with air bub-bling, (e) natural flow.

Sewage sludge hygienization

- Completely elimination of biological harmful organisms at the dose
  < 4 kGy
- a good fertilizer after hygienization process

An installation for flow irradiation of sewage sludges under ILU-6 accelerator

12.1 Sub-Task 3:

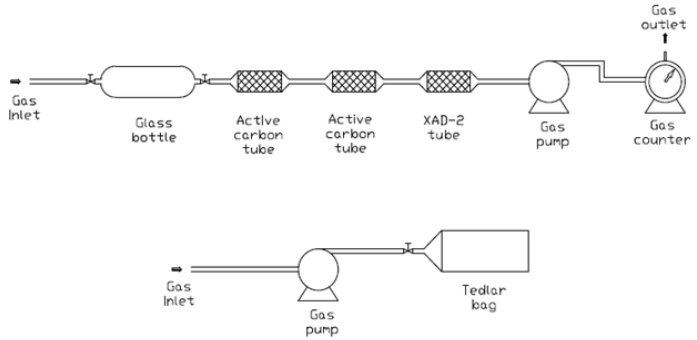
WORK DONE:

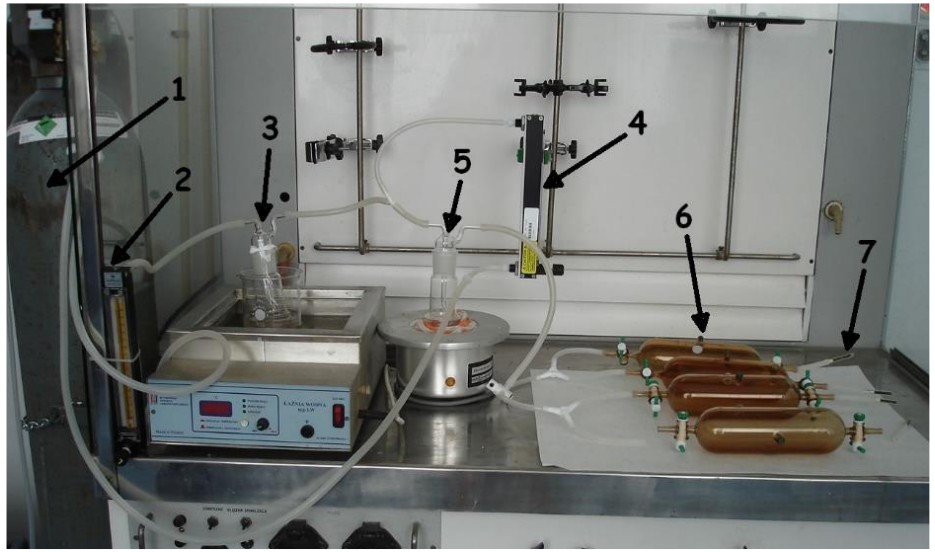
- The removal efficiency of VOC (Volatile Organic Compounds)at different conditions were simulated.

LABORATORY RESEARCH ON VOCs FOCUSED ON:

- 1. Influence of process conditions: dose, temperature, humidity on the removal efficiency,
- 2. Distribution of products of decomposed VOCs,
- 3. Process mechanism clarification.

Laboratory installation for experiments on EB VOC treatment

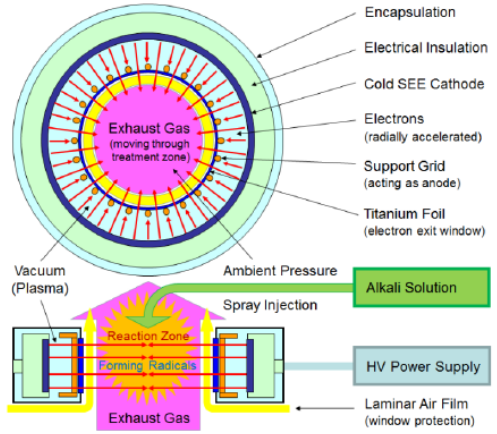


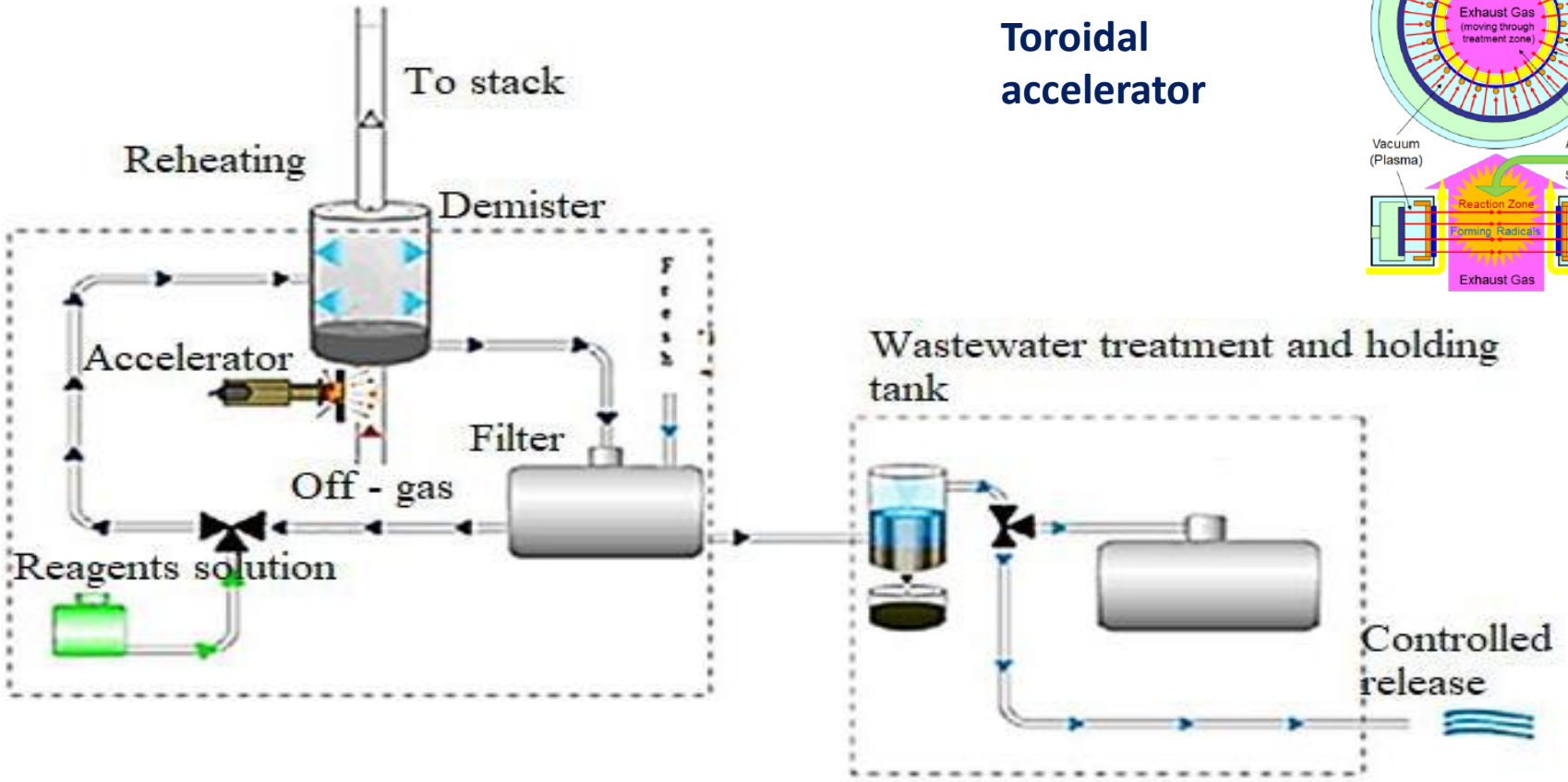


12.1 Sub-Task 3:

Conceptual scheme of the installation using EB technology for SOx and NOx removal as applied onboard, water closed or hybrid system - EU Project proposal „HERTIS”

FEP Dresden Toroidal accelerator





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WP 12.1 Sub-Task 4:

Accelerator imaging

(Graeme Burt - ULANCS)

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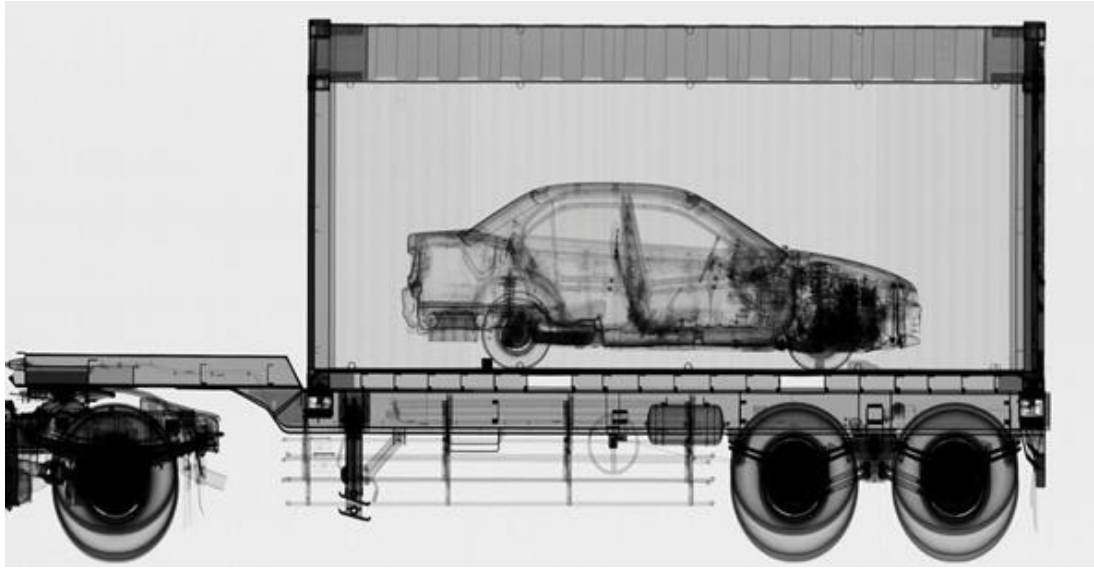
X-ray cargo scanning and non-destructive testing

State of the art

- Based on bremsstrahlung sources of X-rays and emerging neutron sources.
- 2D transmission images mostly with newer backscatter developing

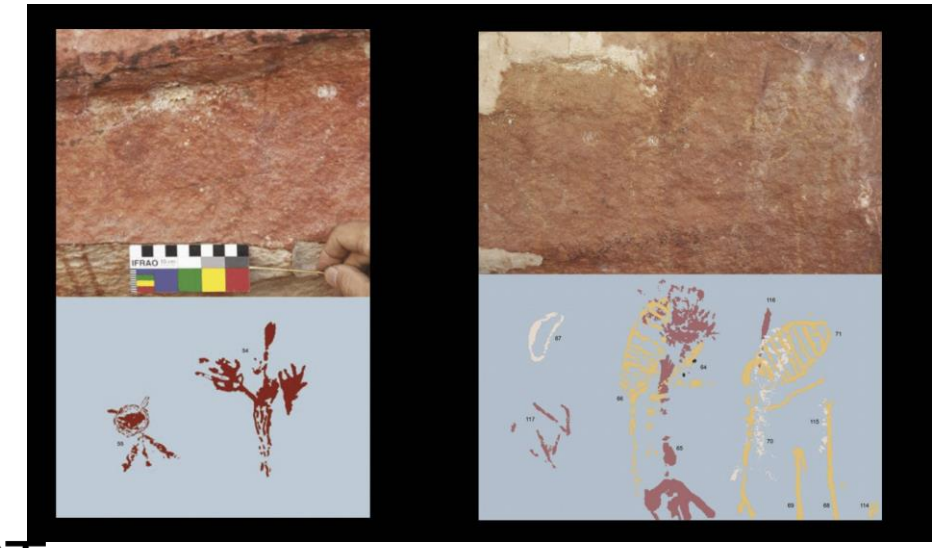
What are the advances that will shape that market in the next few years?

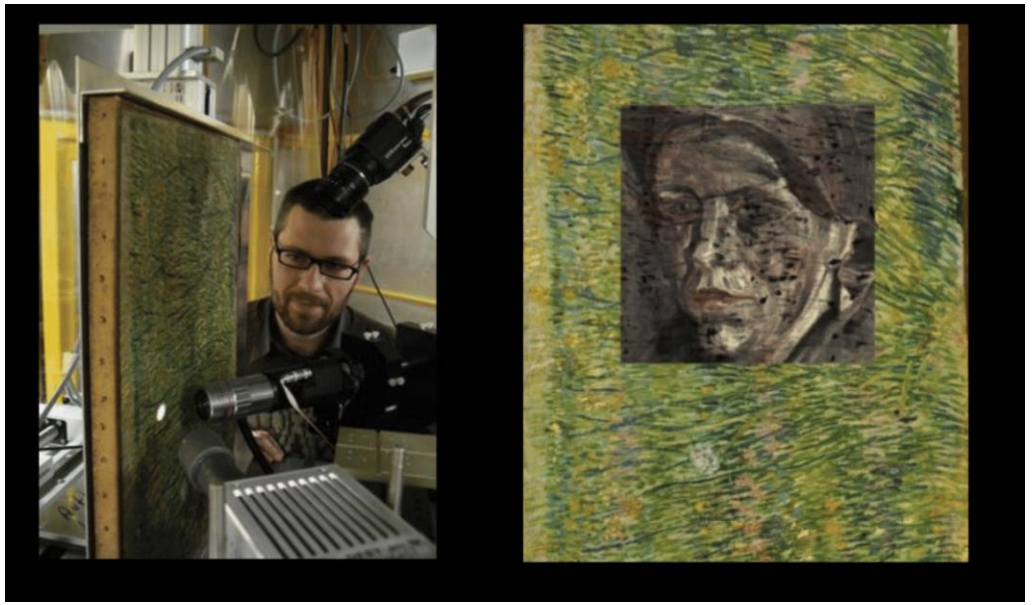
- Is there any disruptive technologies?
- Are their challenges without solutions?
- Are their better ways of addressing the special nuclear material and nuclear resonance florescence applications?
- Will compact muon sources shrink enough to find an application.



Ion beam analysis for cultural heritage

- New compact RFQ-based ion sources have been developed and are being developed for applications
- Can these devices be mobile?
- What applications are their that this technology can target?
  - Rock art?
  - Paintings and statues
- Can the technology be improved?





Medical imaging

- Proton radiography
  - Full body imaging needs 350 MeV, can this be addressed without a separate machine?
  - What other accelerator medical imaging applications should we consider? MeV photon CT?
- Plasma based X-ray imaging
  - Plasma technology offers compact coherent X-ray sources which higher resolution than current X-ray scanners?
  - What is needed to break this technology through to the market
- Prompt Gamma
  - Range verification technology in radiotherapy

IFAST WP activities

Activities to date

- Has a WP workshop in January with each session dedicated to one of the thematic areas, and a lead for each theme took responsibility for the programme
- Call for mini-projects launched

Next steps

- Workshops focused on each of the 4 key areas to answer the questions
- Development of mini-projects within the thematic areas
- Production of a report

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WP 12.1 Sub-Task 5:

Accelerator production of radioisotopes for imaging and therapy

(Diego Obradors, Conchi Oliver – CIEMAT)

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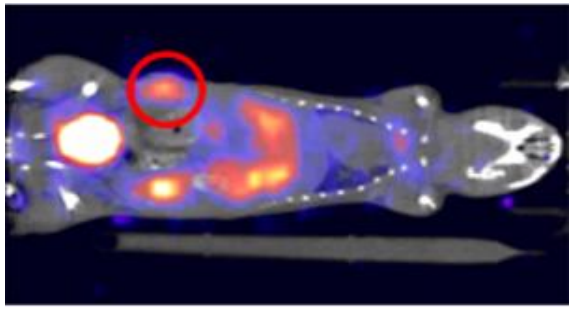
12.1 Sub-Task 5:Radioisotopes for imaging and therapy

- The availability of new radioisotopes and radiopharmaceuticals may generate unprecedented solutions to clinical problems by providing better diagnosis and more efficient therapies.

Personalized medicine through diagnostic and therapeutic



Diagnostic:
Diagnostic procedures for identifying the presence and extent of malignancy.

Therapeutic:
Treat numerous cancers and other diseases. The radioactive agent delivers radiation specifically targeted cancer cells, with a minimal effect oh healthy cells.

Both (Theranostic):
Integration of diagnosis and therapeutics. Molecular imaging and diagnosis can be followed by personal treatment utilizing the same targeting molecules.

New trends

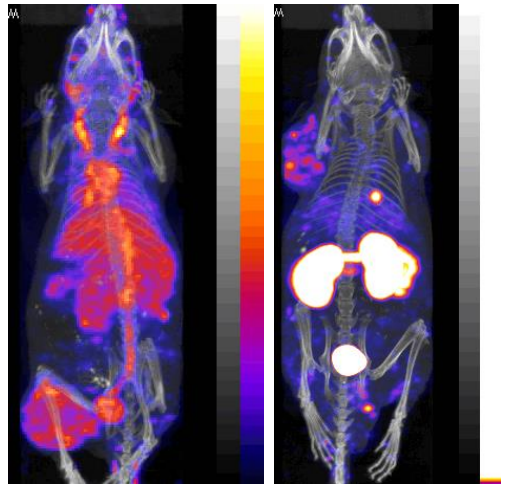
- SPECT and PET
- $^{43,44}Sc$, ^{64}Cu, ^{68}Ga, ^{82}Rb, ^{99m}Tc, ^{132}Ce

- Alpha, Beta, Auger electrons
- ^{90}SY, ^{117m}Sn, $^{188,191,193,195m}Pt$, ^{211}At, ^{212m}Pb, $^{212,213}Bi$, ^{223}Ra, ^{225}Ac

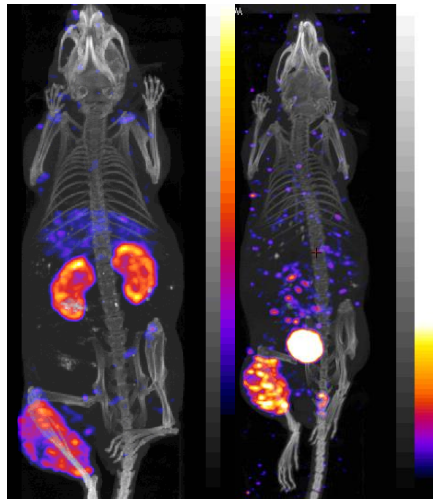
- Real time monitoring of treatment
- ^{47}Sc, ^{67}Cu, ^{117}Lu, $^{186,188,189}Re$

12.1 Sub-Task 5: Marker needs

- Development of innovative routes of production of therapeutic and diagnostic radionuclides.
- Development of optimized irradiation targets, that are interchangeable to allow use within the whole supply network.
- Urgent need for achieving convergence on radiation dosimetry and safety aspects.
- Ensuring an adequate supply of radioisotopes with reduction of costs along the whole supply chain.
- The demand for alpha-emitting radionuclides significantly exceed their supply.



Umass Chan medical School Pictures



Umass Chan medical School Pictures

12.1 Sub-Task 5: Performed activities

- Continuous market research/analysis to get a view of an important points related to the emerging radioisotopes, trends, and identify synergies with respect to the demand of these radionuclides and accelerator technology that will require innovations to reduce cost and increase the capability of production methods in a efficient manner.
- Attendance at the following seminars and meetings:

  - *State of art of Positron Emission Tomography (PET) technology and current challenges*. Maurizion Conti, (director, PETPhysics and Reconstruction, Siemens Healtineers). 06-09-2021.

  - 2021 Isotope User meeting managed by U.S. Department of Energy Isotope Program focused in four sessions of the the following emerging alpha and beta emitters:

    - Actinium-225
    - Astatine-221
    - Lead-212
    - Copper-67.

- Internal talk*: "Identification of requirements for future isotopes and plans"*. Mini millestones IFAST WP12

12.1 Sub-Task 5: Next steps

- Continuous research/analysis of particle accelerators technology, programmes and projects related to emerging radionuclides into medical diagnostics and treatment.
- Regular monitoring and continuous analyses of the radiopharmaceutical market and needs, identifying new developments and trends.
  - 8th International Symposium on Medical Radioisotopes, May 6, 2022, Belgium
  - 35th Annual Congress of the European Association of Nuclear Medicine. October 15-19, 2022, Barcelona, Spain.
- Set up a network of RI producers based on accelerators, beyond the companies (difficult to get information) in order to define new challenges or common dificulties:
  - CERN- MEDICIS.
  - MYHRRA.
  - ARRONAX.
  - PRISMAP.
  - Laser production.
  - Spallation Sources
  - Neutron Sources.



- Webinar / Workshop / (funding dependency) : ***Radiopharmaceutical market and future trends***. To provide scientists and professionals working in the fields of production of radioisotopes and radiopharmaceuticals an international forum for discussing the most recent developments in the field. Several topics could be covered including development, production, and uses of diagnostic, therapeutic and theragnostic radioisotopes as well as issues related to their production.

- *Need to generate a database of contacts for network of RI.*
- International cooperation is encouraged and collaborations are welcome.

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WP 12.1 Sub-Task 6:

Barriers to accelerator adoption by industry

(Andrzej Chmielewski – INCT
Andrea Sagatova – STU)

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Barriers to accelerator adoption by industry

Done:

Study on technological, financial and knowledge barriers:

Barriers identified:

- The technologies that are in principle feasible and proven from research accelerators on laboratory scale must be available at reasonable cost before they can be used in machines for industrial and societal applications.
- Absence of in-house specialized and auxiliary facilities and equipment for accelerator service and maintenance.
- Absence of in-house accelerator experts and staff for accelerator operation, service and maintenance.

Solution:

- Offering machines which are reliable, reproducible, simply operable.
- Development of the remote customer-support technologies.
- Introduction of dedicated educational schemes and study programs bringing together accelerator experts, IT engineers and users.

Plans for future:

- Study on legislative and security barriers;
- In-depth studies of application-specific barriers;

12.1 Sub-Task 6:

Elaboration of feasibility study of EB irradiation plant for a private developer

INSTITUTE OF NUCLEAR CHEMISTRY AND TECHNOLOGY

ELABORATION

AUTHOR: ZBIGNIEW ZIMEK	
TITLE: Upgraded pre-feasibility study of setting up an electron beam facility	
Project / agreement / (*title and number*): **Logstor order nr 4501015736**	
Completed on	**October, 2021**
Division: Centre for Radiation Research and Technology, INCT	

ELABORTED BY	CHECKED	APPROVED
Dr. Zbigniew Zimek Head of Center for Radiation Research and Technology, INCT	Prof. H.Lewandowska-Siwkiewcz Head of Polimer Lab Center for Radiation Research and Technology, INCT	Prof. A.G.Chmielewski Director of the Instytute of Nuclear Chemistry and Technology
Date and signature: 15102021	Date and signature: 26102021	Date and signature: Dyrektor Instytutu Chemii i Techniki Jądrowej prof. dr hab. inż. Andrzej G. Chmielewski

Attachment No 1.

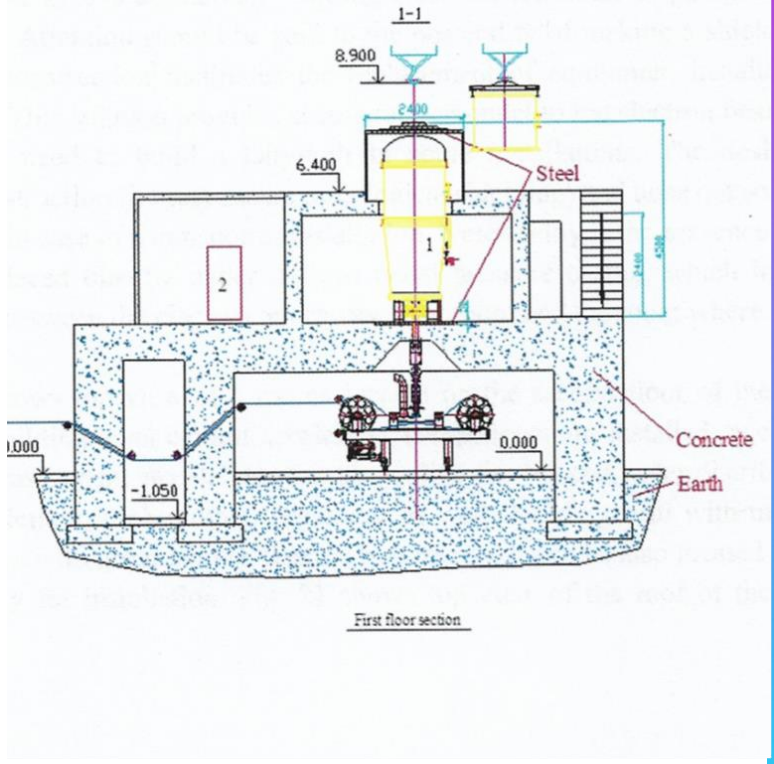
Radiation technologies, requirements, potential market, adaptation to primary process conditions

Zbigniew Zimek
INCT

Content

Warsaw, October 2021

Institute of Nuclear Chemistry and Technology, Dorodna 16 Str., Warsaw



First floor section

Horizon Europe
THE NEXT EU RESEARCH & INNOVATION PROGRAMME (2021 – 2027)
European Commission

Project proposal prepared by I.FAST Team and Accepted

- **Call: HORIZON-EURATOM-2021-NRT-01** (Nuclear Research and Training)
- **Topic: HORIZON-EURATOM-2021-NRT-01-11: Cross-sectoral synergies and new applications of nuclear technologies**
- **Type of Action: EURATOM-IA**
- **Proposal number: 101061694**
- **Proposal acronym: RADOV**
- **Proposal title: RADiation harvesting of bioactive peptides from egg prOteins and their integration in adVanced functional products**
- **48 months since Sept 2022, budged ≈2 M€**
    - **Project** explores completely new routes for the production of bioactive peptides from egg proteins based on radiation-induced fragmentation. New products containing bioactive proteins/peptides will be designed and developed with the use of electron beam irradiation to manufacture them. In particular, two target products will be developed as demonstrators of egg-derived AMPs by radiation-induced fragmentation: peptide-laden antimicrobial/antioxidant hydrogel wound dressings and peptide-grafted active food packaging film.

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12.1 CONCLUSIONS:

All subtasks of WP 12.1 have made a good progress.

Future plans:

Six abstracts (3 talks, 3 posters) were accepted for the IAEA: International Conference on Accelerators for Research and Sustainable Development: From Good Practices Towards Socioeconomic Impact (Vienna, 23.-27. May 2022)

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WP 12.1

Thank you for your attention !

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