IAEA-CN301-074

IFAST Accelerators for Societal Applications

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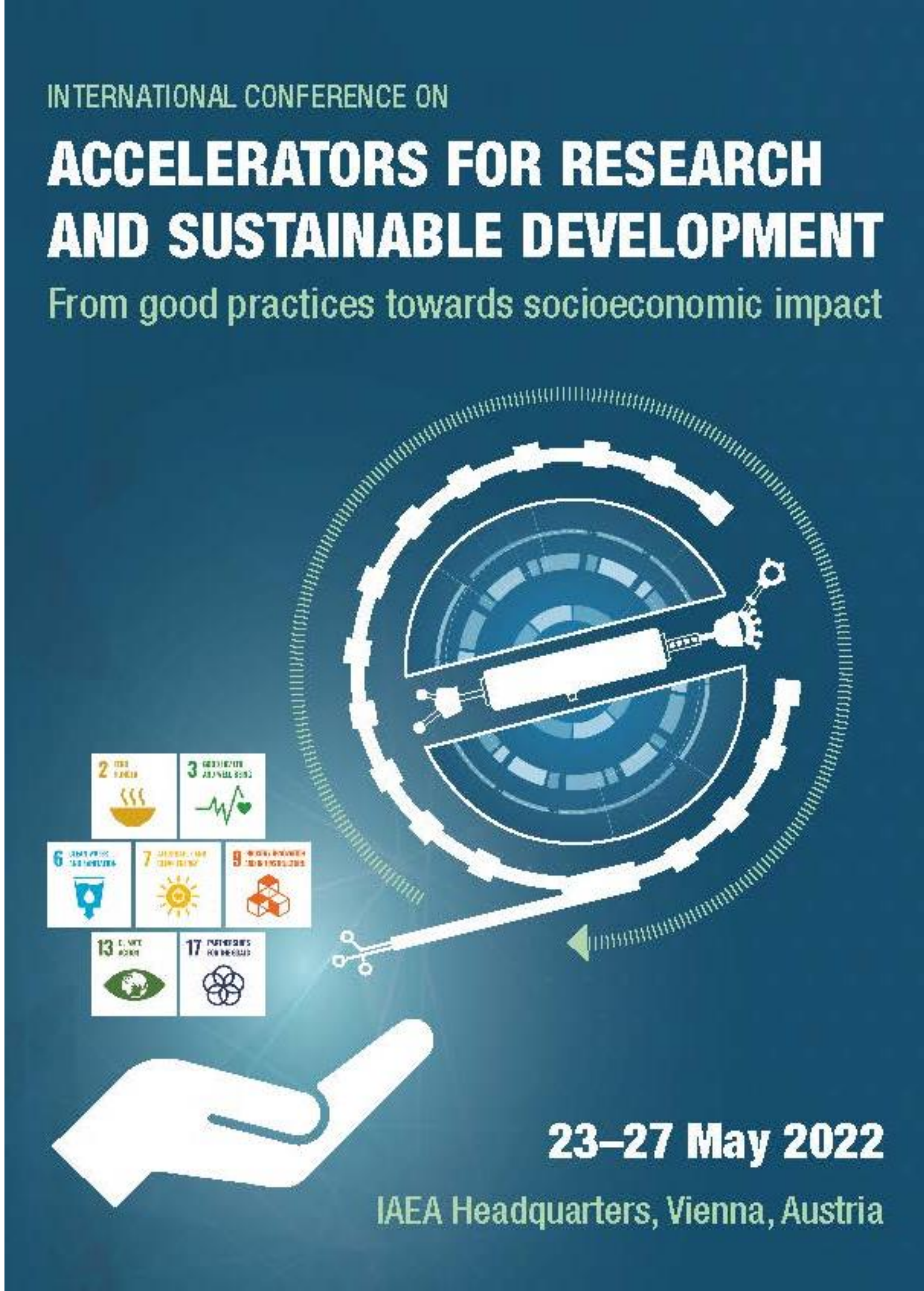

Objectives:

IFAST is the latest in a series of FP and H2020 EU projects undertaking accelerator R&D and coordinated by CERN.

Since FP7, there have been work packages studying societal applications

IFAST objectives:

- 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.

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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)

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

Sub-Task 2:

Novel forms of radiotherapy

(Angeles Faus-Golfe – CNRS)

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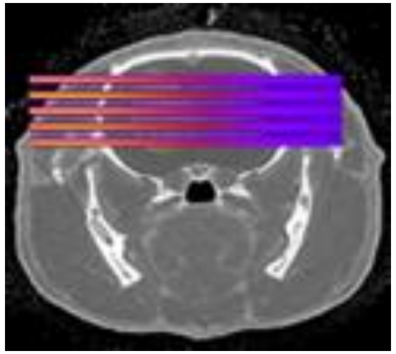
Sub-Task 2: OBJECTIVES

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



2. **Look at accelerator developments to deliver these and improve standard RT**

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

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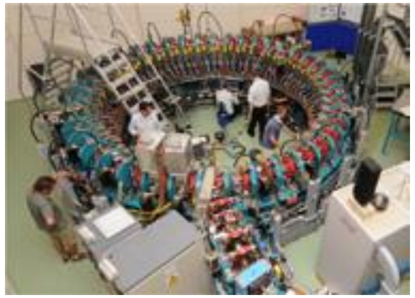
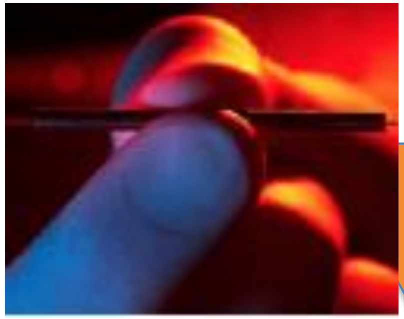
Sub-Task 2: ACCELERATOR TECHNOLOGY-HEALTH INDUSTRY

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).

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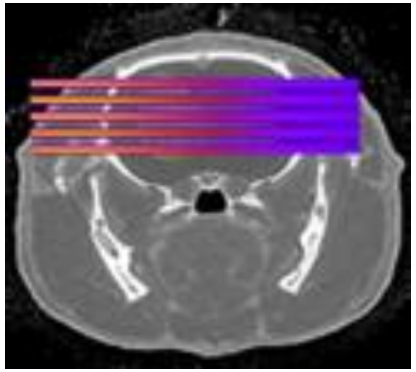
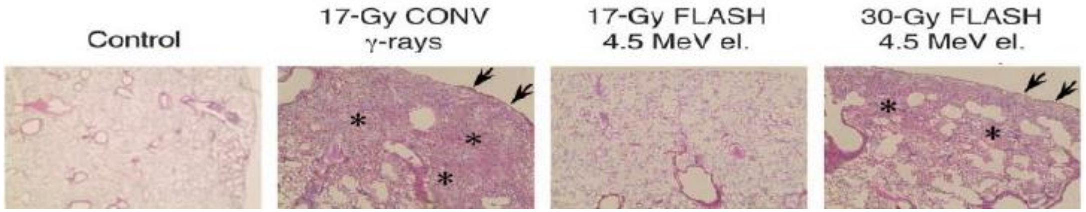
Sub-Task 2: CHALLENGES IN RADIOTHERAPY (RT)

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), BNCT**

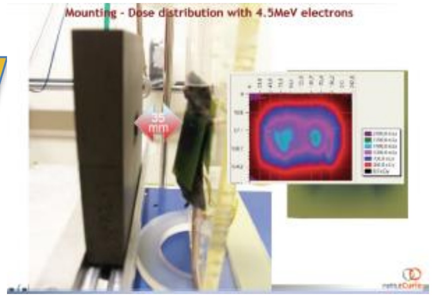


Mini-beams



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

FLASH RT



VHEE >100 MeV/m is now achievable in labs

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Sub-Task 3:

Environmental applications of electron beams

(Toms Torims – RTU, Andrzej Chmielewski - INCT)

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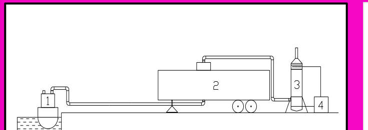
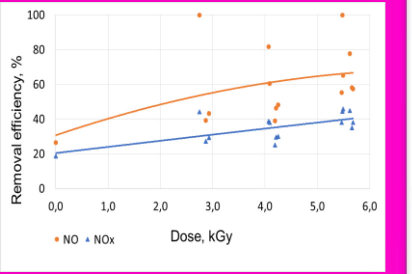
Sub-Task 3:

Accelerator based Technologies for Environment Pollution Control

Electron Beam Flue Gas Treatment



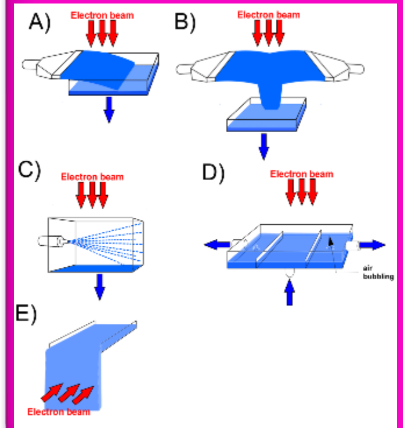
Scheme of hybrid electron beam flue gas treatment pilot plant
1 – flue gas source, 2 - mobile accelerator, 3 – scrubber, 4 – seawater tank



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



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.

Elimination of biological harmful organisms using doses < 5 kGy

Low x-ray emission to reduce thickness of shielding

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

Sub-Task 3:

Treatment of “new” pollutants…….microplastics, AMR, chemicals

PS PP PET PMMA LDPE PVC

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Sub-Task 3:

Treatment of “new” pollutants……microplastics, AMR, chemicals

Plastic	Sedimentation of non-irradiated material [% sinking material]	Sludge type	Sedimentation of irradiated material [% sinking material]	Sludge type	Sedimentation of irradiated material [% sinking material]
PS	5	After the AD	98-100 (all doses)	Before the AD	97.7 (200kGy)
PMMA	80		98-100 (all doses)		98 (200kGy)
PET	83		99-100 (56, 200kGy)		99 (200kGy)
PVC.P	63		98-100 (all doses)		100 (200kGy)
PVC.TC	65		98-100 (all doses)		97-100 (2, 200kGy)
PVC.B	77		97-99 (all doses)		98 (56kGy)

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Sub-Task 4:

Accelerator imaging

(Graeme Burt - ULANCS)

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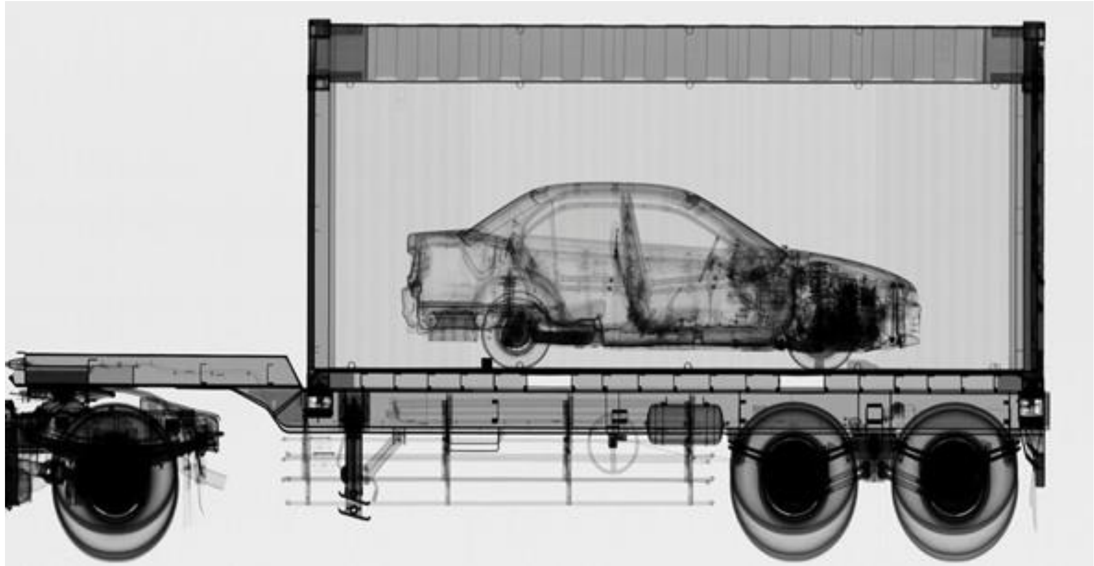
X-ray cargo scanning and non-destructive testing

State of the art

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



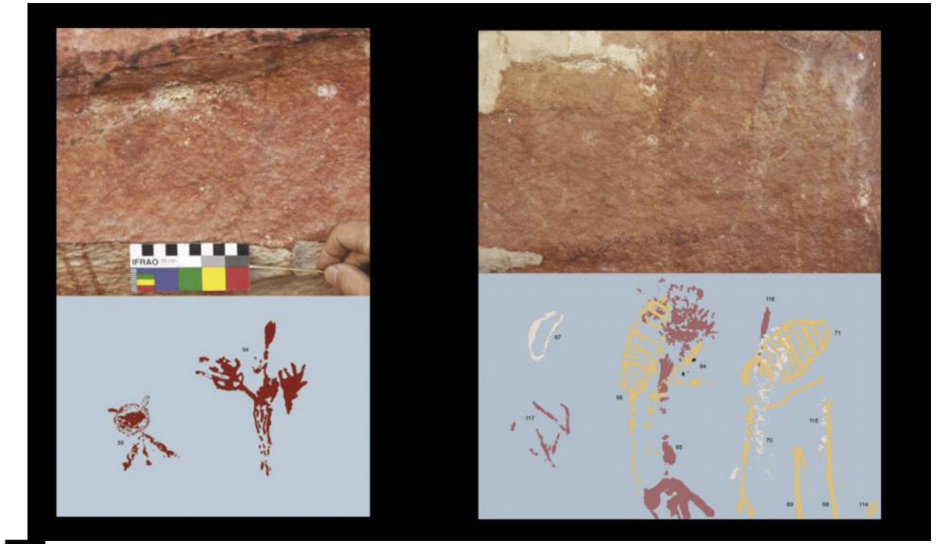
What are the advances that will shape that market in the next few years?

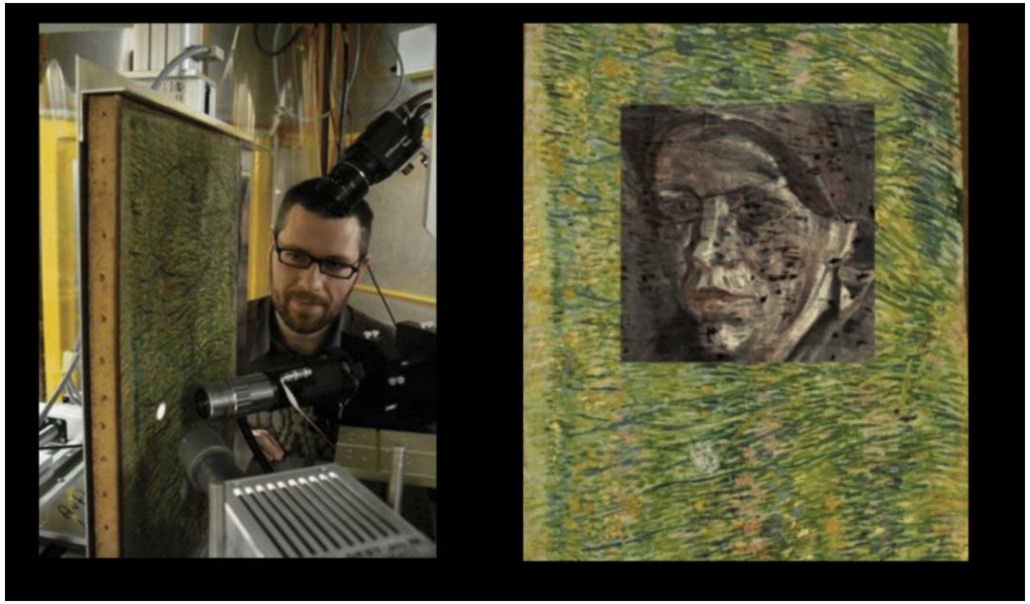
- Is there any disruptive technologies?
- Are there challenges without solutions?
- Are there better ways of addressing the special nuclear material and nuclear resonance florescence applications?
- Will compact muon sources shrink enough to find an application.

12.1 Sub-Task 4:

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

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Sub-Task 5:

Accelerator production of radioisotopes for imaging and therapy

(Diego Obradors, Conchi Oliver – CIEMAT)

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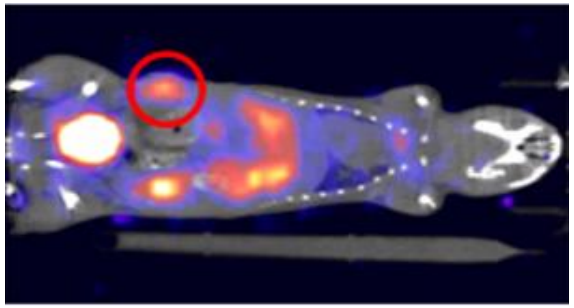
Sub-Task 5: Radioisotopes for imaging and therapy

- 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**

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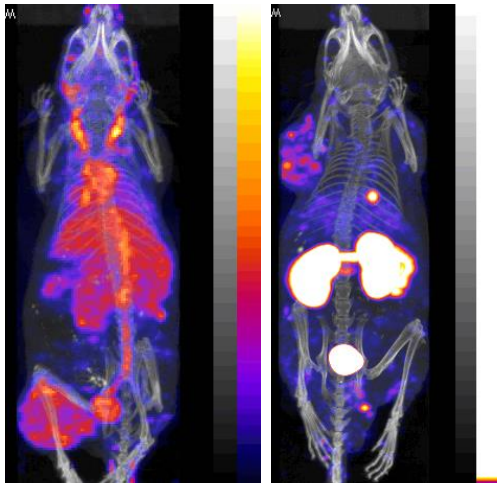
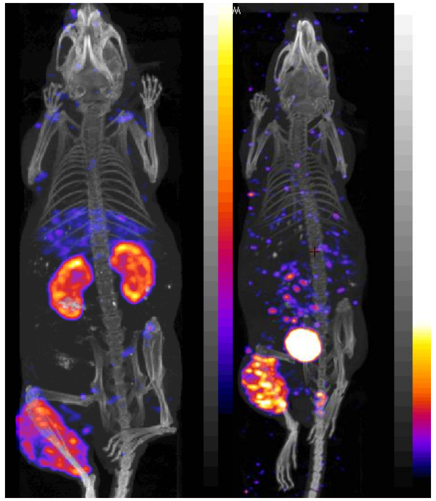
Sub-Task 5: Marker needs

- 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

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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 of 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.

Possible solutions:

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

CONCLUSIONS:

- IFAST Societal applications WP is studying applications in the medical, environmental and imaging sectors
- Building on work from previous projects
- Funding is limited
- Main aim is to identify projects and collaborators
- Seek funding from other sources
- If you would like more information or to join us, please contact:

  t.r.edgecock@hud.ac.uk