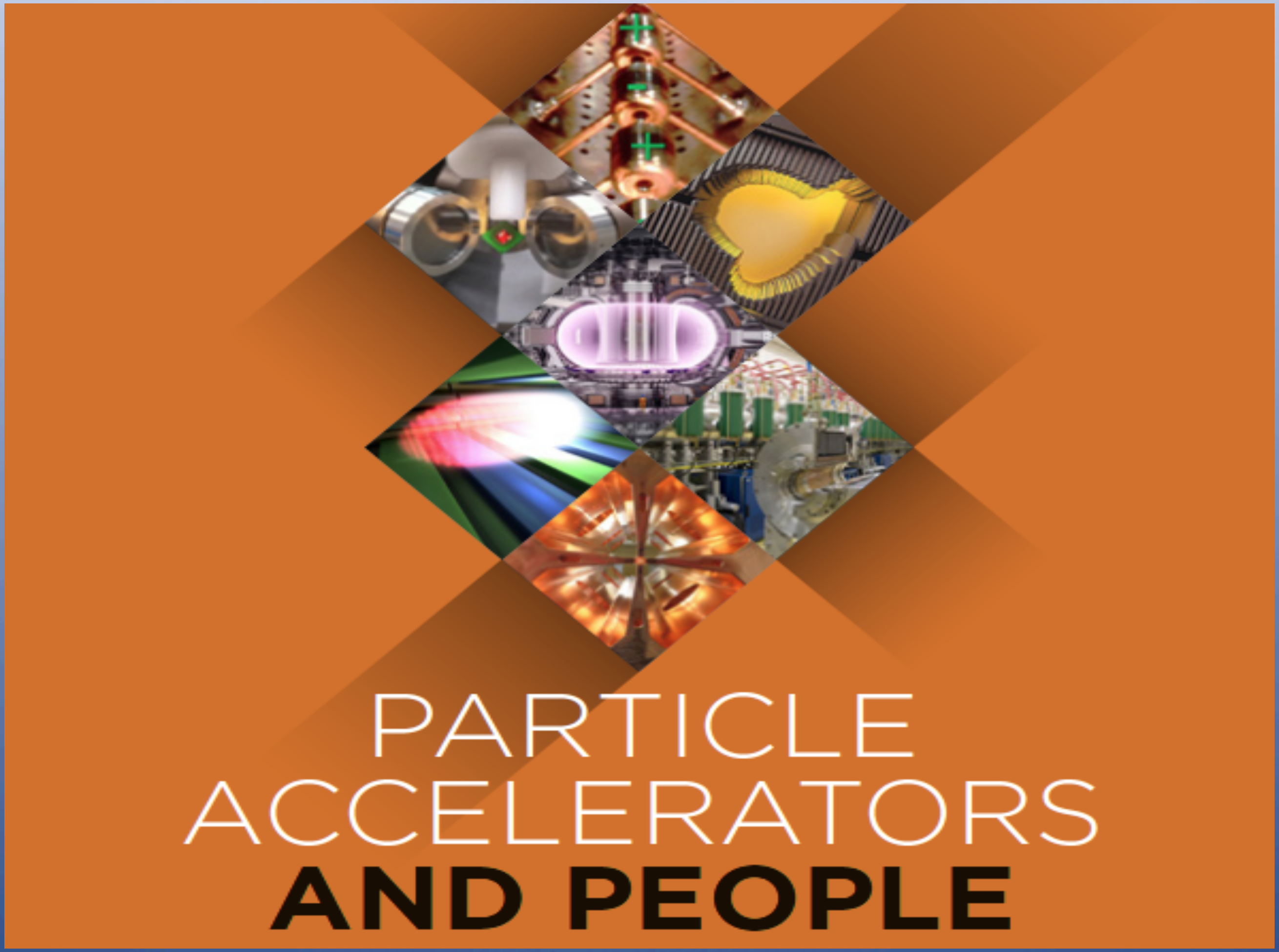
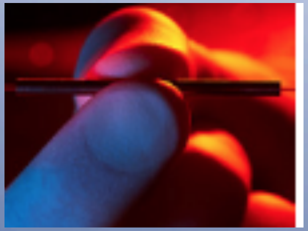
INNOVATION: the potential of nuclear and radiation technology to deliver social benefits in the future



INNOVATION: the potential of nuclear and radiation technology to deliver social benefits in the future

A Key for innovative use of radiation

PARTICLE ACCELERATORS



During the past century ACCELERATORS and their technology have played an essential role in delivering great SCIENTIFIC advances that have led to improved standards of livings and wellbeing.

Today, accelerators in various configurations are producing beams of subatomic particles and charged atoms that help to manage our HEALTH and the ENVIRONMENT. They also provide a significant tool for MANUFACTURING INDUSTRY, for sustaining GREENER, SAFER ENERGY, and for securing our BORDERS and ensuring NATIONAL SECURITY. They offer ADVANCE INVESTIGATION METHODS considered essential in many fields of BASIC AND APPLIED SCIENCE

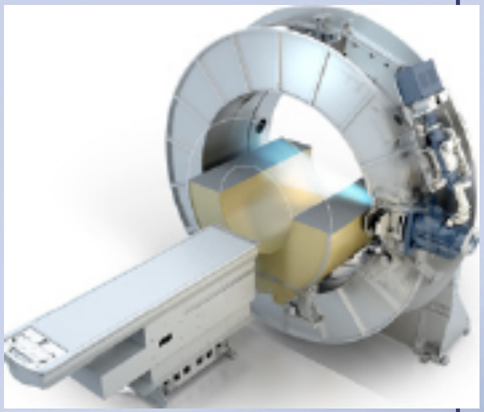
INNOVATIVE TECHNICAL DEVELOPMENTS ARE IN PROGRESS OR ON THE HORIZON, IN EUROPE AND ELSEWHERE, AND WILL EXTEND THE PRACTICAL USES OF ACCELERATORS EVEN FURTHER FOR THE SOCIAL AND ECONOMIC BEBEFIT OF ALL

NOVEL TECHNOLOGIES AND NEW APPLICATIONS :

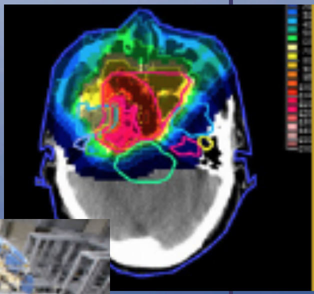
- **HEALTH** accelerators produce particles, radiation and radioactive isotopes for use in cancer treatment, imaging and medical research
- **INDUSTRY** accelerators generate particle beams used to analyse and fabricate modern materials such as those used in electronics and engineering
- **ENERGY** accelerators can be employed to destroy radioactive nuclear waste and to research into new, safer forms of nuclear energy
- **SECURITY** accelerators generate radiation and particles used for screening operations in border security, counterterrorism and nuclear security
- **ANALYSIS WITH PHOTONS** accelerators can be configured to emit extremely bright light (photons) used to probe the atomic or molecular structure and behavior of materials that are important in the life sciences and in industry
- **ANALYSIS WITH NEUTRONS** accelerators can generate subatomic particles called neutrons, which are also employed to study matter in a complementary way to photons.

HEALTH: RADIOTHERAPY
What are the CHALLENGES?

- ***X ray Radiation Therapy***
  - **Image guided RT**
  - **Integration of measuring devices for dose reconstruction**
  - **More precise and efficient 4D simulation**
  - **New delivery system techniques**
  - **Reduction of cost and size**

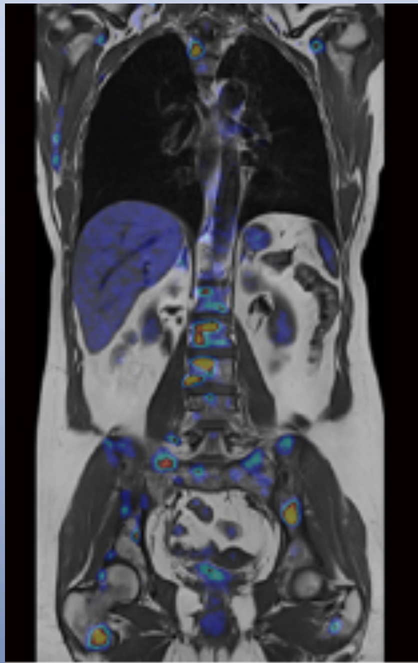


- ***Particle therapy***
  - **Improved accelerator design: FFAG, synchrotron, linacs, dielectric, laser based**
  - **Superconducting techniques**
  - **Combined imaging and treatment**
  - **Other particles: High-Energy electrons, BNCT, Helium…**



- ***Generic***
  - **More research/industry collaboration**

HEALTH: RADIONUCLIDES
What are the CHALLENGES?



- ***Novel diagnostic or therapeutic radionuclides***
- ***Test of alternatives routes of established medical radionuclides***
- ***Generic***
  - **Ensuring an adequate supply of medical isotopes in Europe**
  - **Perception of the clinical use of radioactive isotopes**

HEALTH: RADIOTHERAPY
What are the needed R&D?

- *Multidisciplinary approach, including the biological info and immunological protocols -> personalized medicine*
- *Multiparticle facility design, superconducting magnet technology, high-gradient ions*
- *Systematic RBE experiments including in-vivo animal studies and clinical studies for new therapies*
- *Ion secondary-particle imaging and dose-delivery instrumentation*
- *Reduction of initial investment and functional costs*
- *Cooperation between academics, industry, international research centres, public and private hospitals and universities*

HEALTH: RADIONUCLIDES
What are the needed R&D?

- *Alternative mechanisms for ^{99}Mo and ^{99m}Tc in Europe*
- *Compact sources for PET radionuclide production directly in hospitals*
- *Novel radionuclides for therapy and imaging*
- *Ion secondary-particle imaging and dose-delivery instrumentation*
- *Compact, high-current and multiparticle accelerators for radionuclide production for therapy and imaging*

INDUSTRY: e^- beams

What are the CHALLENGES?

- ***Very low energy e^-*** *(<330 keV)*

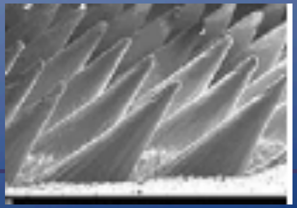
Non-Thermal

  - **New high-voltage generator and new insulation materials/technologies for compact modules**
  - **Well adapted e^- sources for 3D shaped applications**
  - **New concepts for exit windows for applications below 80 keV**
  - **Enlarged sealed with longer lifetime**
  - **New surfaces with lower X-ray reflections to reduce shielding**
  - **Minituarised systems for 3D printers**

Thermal

  - **Self-diagnostic tools for smart, automation, realistic simulation of e^- emission, e^- beam guiding and e^- substrate interaction for e^- beam welding, re-melting and evaporation**
  - **e^- beam structuring tools for scales 1-10 um**
  - **New powder concepts, better surface quality, large possible part-size and in-line quality controls for additive manufacturing by e^- beam melting**

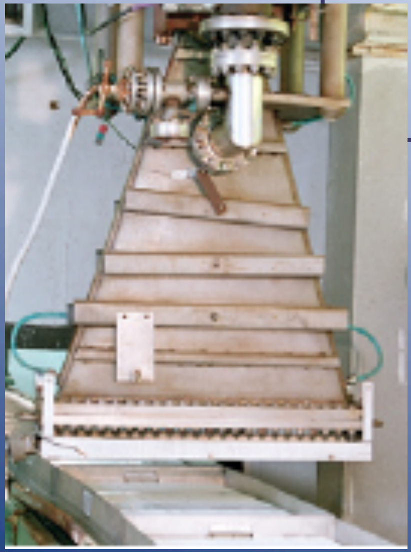
- ***Generic***
  - **Laws and regulations**



INDUSTRY: e^- beams

What are the CHALLENGES?

- ***Low energy e^-*** *(330 keV – 70 MeV)*
  - **Application in nanotechnology**
  - **Widening the use in decontamination**
- ***Generic***
  - **Low cost, compact accelerators**
  - **Dual e^- beams X-rays systems**
  - **More efficient and reliable machines**



INDUSTRY: e- beams

What are the needed R&D?

- ***Very low energy e⁻*** *(<330 keV)*
  - ***High-voltage power supplies for more compact and robust systems, easy to handle, cheap and simple***
  - ***Up-dating of laws, especially in food***

- ***Low energy e⁻*** *(330 keV – 70 MeV)*
  - ***Powers of tens of kW, with lower cost and size, higher efficiency and simpler operation***
  - ***Superconducting technologies for high-power, higher efficiency, low cost and size***

- ***Basic education and training for e- beam applications***
- ***Move e⁻ beam from laboratory to industry***
- ***Mobile accelerators, higher efficiency, simple operation***
- ***Better connection between R&D and industry and users and suppliers***

INDUSTRY: Ions beams
What are the CHALLENGES?

- *Ion Beam Analysis (IBA)*
    - Aerosol composition
    - Multilayer analysis in heritage objects
    - Intra analysis of metal objects

- *Ion implantation*
    - Charge integration to improve dosimetry and uniformity
    - Micro beams, high brightness
    - Flexibility, low cost and small footprint

INDUSTRY: Ions beams
What are the needed R&D?

- *New areas of exploitation and application*
- *Basic education and training for ion beam applications*
- *Move ion beam from laboratory to industry*
- *Complementarity of the analysis with other environmental techniques (chemical, optical..)*
- *Non-destructive, high sensitivity, depth resolved, mobile accelerators and low cost.*
- *Combine irradiation with detection to avoid non-visible, reversible and irreversible changes.*
- *Better outreach about these applications*
- *Better connection between R&D and industry and users and suppliers*

ENERGY

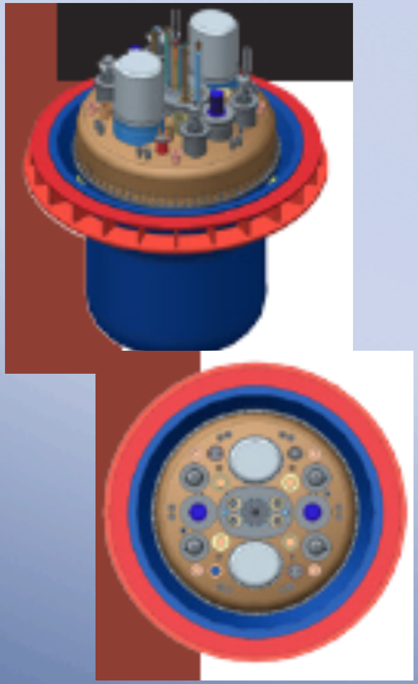
What are the CHALLENGES?

- ***Nuclear Fission***
  - **Detailed reactor-core studies**
  - **Powerful and reliable accelerators (ADSs)**
  - **Design and safety analysis of non typical reactor materials**

- ***Nuclear Fusion***
  - **Material qualification for fusion reactors**
  - **Handling of high-power and high-intensity beams**

ENERGY

What are the needed R&D?



- *Development of high-Intensity, high reliability proton and deuteron beams injectors*
- *Superconducting in high-power and high-reliability context*
- *High-current beams dynamics and beam halos*
- *Innovative beam instrumentation*
- *Modelling of the reliability of particle accelerators*
- *Safety studies of high-energy, high current proton accelerators and their coupling to spallation target*

SECURITY

What are the CHALLENGES?

- ***Border Security***
  - **More advance X-ray systems**
  - **Simpler-to-use, universal screening systems**
  - **More precise radiation dosage**
  - **Better detection of nuclear material (use of protons)**
- ***Nuclear Security***
  - **Support to maintaining international treaties, safeguards and nuclear arms control**
  - **Support to stockpile and stewardship**

- ***Generic***
  - ***Clearer EU policy on screening and irradiation regulation***
  - ***Optimising the radiation dose***
  - ***Ensuring public safety***
  - ***Safeguarding electronics goods***
  - ***Improve public understanding and perceptions***

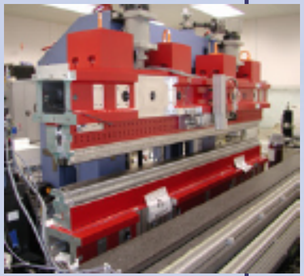
SECURITY

What are the needed R&D?

- *To decrease the inspection time and increase the throughput*
  - *Development od 3D imaging*
  - *Automated image recognition*
  - *Accelerators that supports enhanced techniques as nuclear resonance fluorescence to discriminate illegal cargo from legitimate goods*
- *Development of single-energy X-ray sources to improve the operation in nuclear resonance fluorescence and active nuclear detection*
- *Novel compact, high performance as the use of terahertz technique from laboratory to security environment*

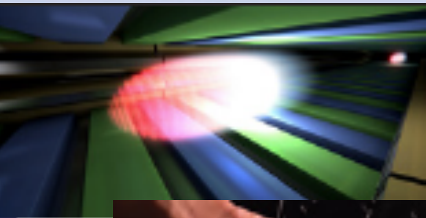
PHOTON SOURCES

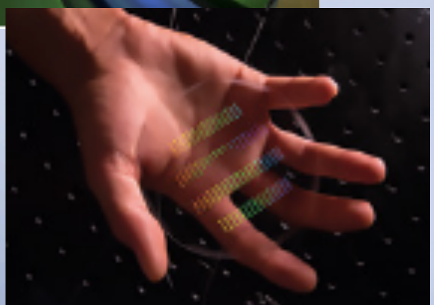
What are the CHALLENGES?



- ***Synchrotron-Based Light Sources***
  - **Controlling the beam position (reduced emittance beams)**
  - **Extending to harder X-rays (superconducting technology)**
- ***Self-Amplified Spontaneous Emission FELs***
  - **Extending to faster processes (timing systems)**
  - **Tunable source by seeding techniques**

- ***Energy Recovery Linacs***
  - ***Generation and conservation low-emittance beams***
  - ***Improve photocathodes material***
  - ***RF technologies for high-power generation and control of resonant modes***
- ***Generic***
  - ***Adequate capacity for research***
  - ***Improving reliability***
  - ***Improving data acquisition and processing***





PHOTON SOURCES
What are the needed R&D?

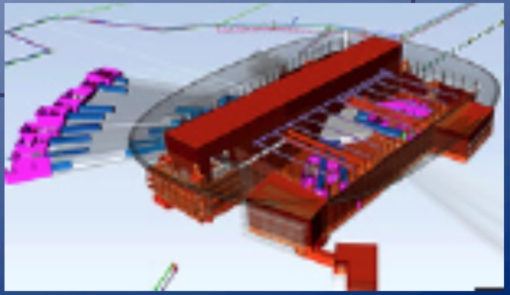
- *High-brightness, high repetition e- guns (longer duty cycle FELs)*
- *Development of superconducting cavities with high-order-mode damping for ERLs for high-current operation*
- *Improve modelling and simulation for low-emittance e- beam transport from source to undulators*
- *Undulators operating in-vacuum and superconducting undulators with shorter period lengths*
- *New RF power sources*

NEUTRON SOURCES

What are the CHALLENGES?

- *Higher Beam powers and control of losses*
- *More efficient control of the accelerated beam with target*
- *Improved RF power sources, cheaper and more efficient*
- *Efficient injection and extraction of particles*
- *Development of high-intensity cyclotrons*
- *Higher-energy Compact Neutron Sources at lower cost and easy to operate*

- *Generic*
  - *Further technical challenges (target, moderator chopper, neutron guides..)*
  - *Retaining of skills (closure of research reactors)*
  - *Impact on environment*



NEUTRON SOURCES
What are the needed R&D?

- ***Energy efficient RF sources***
- ***High-power RF Quadrupoles***
- ***New low-loss injection schemes and long-pulse extraction scheme for synchrotrons***
- ***High-quality superconducting RF cavities***
- ***Cheaper, more efficient and more reliable superconducting and normal accelerating structures and accelerator systems***

SUMMARY of KEY RECOMMENDATIONS

- ***Compact accelerators***
- ***Improved designs and cost-effectiveness***
- ***Improved academia-industry interactions***
- ***Improved student training and knowledge transfer***
- ***Improved public understanding of accelerators and their science***
- ***Further development of combined irradiation and imaging***