IAEA-CN301

Conference Summary and Highlights: Focus on Applications and the IAEA support

IAEA, Vienna

May 27, 2022

Dr. Natesan Ramamoorthy

Independent Consultant, India

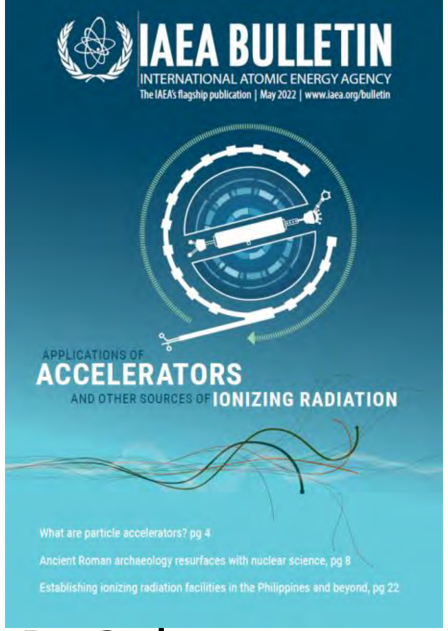
(*Ad-hoc*) Rapporteur

(nramasta@gmail.com)

Introductory Remarks and Disclaimer

- Very vast, intense **'dose'** of information, experience, new knowledge, technologies, projects, …. all shared at the Conference this week!
- Presentations ranged from being extremely academic, covering technical nuances, etc. to sharing national & institutional experience to emerging advanced (some exotic too) technologies; from established & emerging applications to exploratory efforts!
- Session Chairs' inputs and Book of Abstracts form the basis of the highlights to be presented!
- *Focus on applications of the accelerators, IAEA roles & support*
- Coverage cannot be exhaustive and apologies for inescapable and inadvertent omissions.

Spectrum of Accelerator Applications



- Opening address by the DG, IAEA
- Remarks of DDGs of NA, NE, TC
- 2 key-note plenary talks →

- <u>Environmental Monitoring and Climate Change Related Studies</u> - Dr. D. Cohen, ANSTO, Australia
- MV accelerators techniques: Particle Induced X-ray Emission (PIXE), Particle Induced Gamma Ray Emission (PIGE), Rutherford Backscattering (RBS), Elastic Recoil Detection and Accelerator Mass Spectrometry (AMS), most commonly used - very small samples, short time → pollution studies
- <u>Electron Accelerator-Based Systems for Air, Water and Soil Pollution Control</u> - Dr. A. Chmielewski, INCT, Poland
- development of new high power electron accelerators, which can be used for on-line processing of huge flow streams of liquid or gaseous pollutants (incl. on ships)

Accelerator Applications: **Support to UN-SDGs**

- Accelerator-based ionizing radiation facilities (IRF) and associated technologies are applied in medicine and health care, water security, food and agriculture, research, energy production, industrial and consumer products, forensic investigations, in the preservation of cultural heritage.
- They are contributing to the attainment of related UN Sustainable Development Goals (SDGs) -
- Sharing existing accelerator-based facilities and establishing more around the world will lead to better, cost-effective access to derive such benefits.
- IAEA project to establish a state-of-the-art ion beam facility (IBF) in Seibersdorf → will enable applied research and provision of analytical services, as well as help educate and train scientists on the diverse applications of ion beams, incl. production of secondary particles as neutrons.

Accelerator Applications: **Environment**

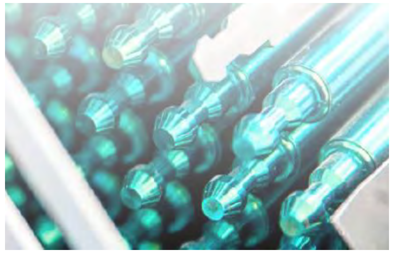
- Contribution of accelerator-based research projects in environmental samples characterization, as well as in the investigation of isotope ratio studies for chronology and environmental remediation has proven to be powerful cost-effective techniques.
- AMS systems have more and more smaller footprints (m^2, energy consumption, human resources,…), hence, world-wide distribution of facilities mainly for ^{14}C applications has much increased in the last years → affordable AMS measurements for interdisciplinary research.
- PIXE and other IBA techniques seem to be the most-efficient analytical methods to characterize chemical composition of particles from air pollution, especially for toxic elements.
- More sophisticated X-Ray absorption methods such as performed at the IAEA beam line at the Italian synchrotron facility add further capability.

Accelerator Applications: **Cultural Heritage**

characterisation; provenanace; forensics for authenticity; preservation

- Ion beam Analysis (IBA) and Accelerator Mass Spectrometry (AMS) techniques have expanded the field of applications allowing to contribute to the preservation of cultural heritage objects as well as the detection of art forgeries
- PIXE techniques played major role in determining original compositions of different alloys as well as individual elements – e.g. revealing the past of Apoxyomenos statue (Roman copy of Greek original?)
- AMS (^{14}C) to distinguish original pieces from later restorations for a better knowledge of their production as well as for their presentation in an exhibition - e.g. ancient music instrument of Egypt

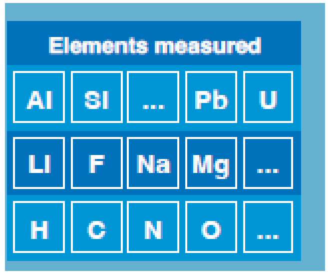
Accelerator Applications: **Material Sciences**



from characterisation, modification, … to advanced materials (nano-materials, semi-conductors), … to aiding advanced fission and fusion research

for nuclear energy programme: material selection; ageing management; waste management;

- Testing materials with accelerator-based heavy ion beams is faster than using irradiations at research reactors; samples remain non-radioactive and damaged areas can be carefully sectioned for post-irradiation examination
- Accelerator-assisted creation of gaseous products such as hydrogen and helium allows testing resilience to radiation in unmoderated neutron systems such as fast fission and fusion reactors



Accelerator Applications: **Nuclear Data**

For advanced nuclear energy systems; radiation damage studies; analytical applications; radioisotope production; ….

- Versatile tools to probe and experiment the nuclear, atomic physics and materials sciences landscapes
- Worthy complement to the declining fleet of research reactors and emergence of accelerator-based neutron sources, including Compact Accelerator Based Neutron Sources (CANS).
- Need for & interest in modern stopping power estimates → IAEA will release a new Stopping Power database in July 2022.
- Growing popularity of IBA facilities → emerging need for further improved nuclear data in the IBANDL database.

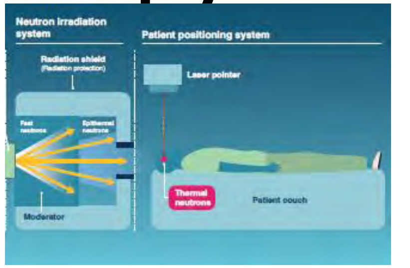
Accelerator Applications: **Food & Agriculture**

for food safety, security, quality, facilitated trading-exports, ….

- Phytosanitary treatment applications mostly drive the adoption accelerator technologies
- Reducing food spoilage by extending the shelf- life of foods and reducing the potential for pathogens in and on foods will become major drivers for the adoption of these technologies.
- Significant diversity in the types of microbial pathogens and spoilage organisms that need to be addressed by this technology → greater understanding needed!

traditional culture-based methods have been used as the cornerstone of identifying the response of microbial cells to ionizing radiation; however, even though cells when exposed to lethal doses are unable to replicate and multiply, these microbial cells are exhibiting very defined metabolic processes several days post-irradiation treatment

Accelerator Applications: **Medicine - Cancer Therapy**



- Expanding need for wider use of established radiotherapy (RT) systems - teletherapy and brachytherapy
- Advances in proton and carbon ion therapy - many new centres, initiatives
- Accelerator produced neutrons for cancer therapy, e.g. BNCT - world-wide facilities pursuing R&D - recent advances for treating recurrent cancers - e.g. success stories from Japan

RT is an essential component of effective cancer care → very high impact → enabling LINAC technology - that encompasses the machine, the AI/ML assistance in machine capability and enhancing medical expertise - can thro' a global trusted network fill the current shortfall of >5,000 LINACs worldwide (International Cancer Expert Corps, ICEC, global NGO efforts)

→ IAEA role - along with all stakeholders, incl industry - will be invaluable.

Accelerator Applications: **Radioisotopes** Production for **Nuclear Medicine** Practices

- High-energy Linacs for spallation reaction for specific RI of importance - e.g. ^{82}Sr, ^{68}Ge, ^{225}Ac

- e.g. BLIP at BNL-USA when operating at maximum proton energy of 200 MeV can have simultaneous production of several medically relevant isotopes; e.g. Ac-225, Cu-67, Se-72/As-72, Sr-82/Rb-82, Ti-44/Sc-44

- Cyclotron-based products for PET - growing use of ^{18}F, ^{68}Ga, ^{89}Zr, ^{64}Cu,

- Success stories of socio-economic impact from MC centres - both in Govt. sector (e.g. Brazil) and private sector (e.g. Kerala, India)

- Complementary or alternates to reactor-based products: $^{99}Mo/^{99m}Tc$
- Progress in technology development for Isotope separation on line (ISOL) - advances at CERN, PSI, INFN, … production of exotic radionuclides intended for medical purposes

Regulatory aspects of Accelerator Facilities

- Accelerators are widely used worldwide in many areas and technologies evolve very fast. This situation represents a challenge to the regulatory bodies, who have to deal with new technologies, for which no specific requirements may exist in the national legal and regulatory framework.
- Regulatory bodies have to quickly adjust and find solutions to authorize and inspect the facilities and activities; challenges: review and assessment of complex safety cases, including shielding and ventilation systems; need to optimize authorization and inspection process, by establishing a new categorization (revision) for the different accelerators.
- Regulatory bodies face challenges to adjust their National Regulatory framework for this widely and very evolving technology in terms of requirements, training and regulatory processes.

IAEA support through multiple means

- Facilitated access to accelerator facilities

- for countries without high-end accelerators thro' Collaborating Centres, CRPs, other arrangements

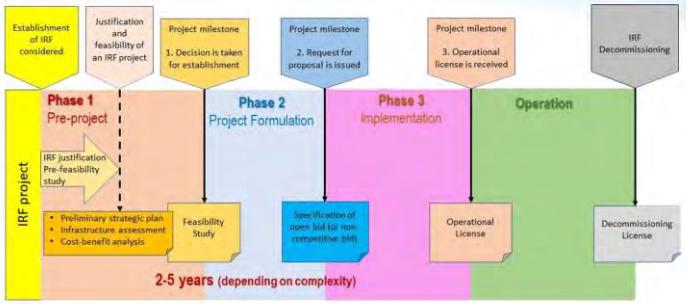
- proven at Side event 2 on IAEA-CC; also by bilateral agreements of IAEA with Elettra Synchrotron facility in Trieste and Ruder Boskovic Institute in Zagreb

- IAEA Collaborating Centres Scheme - success stories - Side event 2
- IAEA accelerator knowledge portal (AKP) and databases

Delegates may review and update accelerator data bases available thro' IAEA Accelerator Knowledge Portal (AKP) - unique source of information - lists hundreds of accelerators, associated irradiation facilities and instrumentation → provides practical information, incl. contact details on accelerators worldwide, their use for potential users and other stakeholders.

- IAEA Documents and publications
- Coordinated Research Projects (CRPs) and Technical Cooperation (TC) projects
- Support to Human Resource Development (HRD), capacity building, ….
- Proficiency testing, reference materials, QA&QC methodology and procedures
- Facilitated strengthening of safety, security, regulatory aspects of accelerator facilities and applications

IAEA's recent **IRF Guidance Document**



- Projects to establish a new accelerator-based ionizing radiation facility need to be planned, managed and conducted in such a way to guarantee successful progress of their implementation and full utilization after the facility begins operation and provision of services.
- A systematic phased approach developed by the IAEA was released to Member States (MS) during the Conference
- MS can use it for the development of IRF projects and for the assessment of the required 'hard' and 'soft' infrastructure.
- **Specific Considerations and Guidance for the Establishment of Ionizing Radiation Facilities, IAEA Radiation Technology Series No. 7 (2022)**

Emerging **Conclusions & Recommendations**

Continuing and growing relevance of accelerators, associated technologies and their applications → more so in the light of UN-SDGs, Climate Change impact → Role of the IAEA to support Member States is vital! →

- Continue to provide strong support for fostering accelerator based systems and technologies for the diverse and relevant applications
- Hold periodic events, including Conference like the current one, to enable and enhance collaborations and networking
- Identify gaps for facilitating adoption of accelerator technologies and applications having high impact - e.g. cancer management - need for rugged system of Linac for large-scale deployment in the world
- Expand and strengthen facilities at the IAEA Physics Lab. (Seibersdorf) to provide direct and enhanced support to MS, e.g. by establishment of accelerator-based Ion Beam Facility (IBF) and e-beam irradiator

Thank you

shukran; xie xie; merci; cpacibo; gracias

Acknowledgements

-Danas Ridikas, Celina Horak and other members of the Conference Scientific Secretariat for the confidence shown and assigning me a sudden duty!

-Chair persons of the Sessions