Joint ICTP-IAEA Workshop on

DEVELOPMENT OF RADIATION RESISTANT MATERIALS

hosted by the ICTP
Trieste, Italy, 20-24 April 2009

Andrej ZEMAN

IAEA/NAPC/Physics Section

IAEA
International Atomic Energy Agency

Outline

IAEA introduction

Physics Section

Workshop activities

Coordinated Research

International Atomic Energy Agency (IAEA)

Atoms for Peace (1953)
addressed by D.Eisenhower, to the 470th Plenary Meeting of the UN GA

- **Founded 1957**
- HQ in Vienna, Austria
- **146 Member States**
- 6 Divisions
- 2300 Staff
- About 300 MEuro Budget
- www.iaea.org

IAEA

The Nobel Peace Prize 2005

"for their efforts to prevent nuclear energy from being used for military purposes and to ensure that nuclear energy for peaceful purposes is used in the safest possible way"

International Atomic Energy Agency (IAEA)

1/2 of the prize

Vienna, Austria

Founded in 1957

Mohamed ElBaradei

1/2 of the prize

Egypt

Director General of IAEA

b. 1942

IAEA

Pillars of the IAEA

- Promoting Science & Technology

  the world's focal point to mobilize peaceful applications of nuclear science and technology for critical needs in developing countries

- Promoting Safeguards & Verification:

  the world's nuclear inspectorate

- Promoting Safety and Security

  helps countries to upgrade nuclear safety and security

IAEA's 50 Years of Atoms for Peace (2007)

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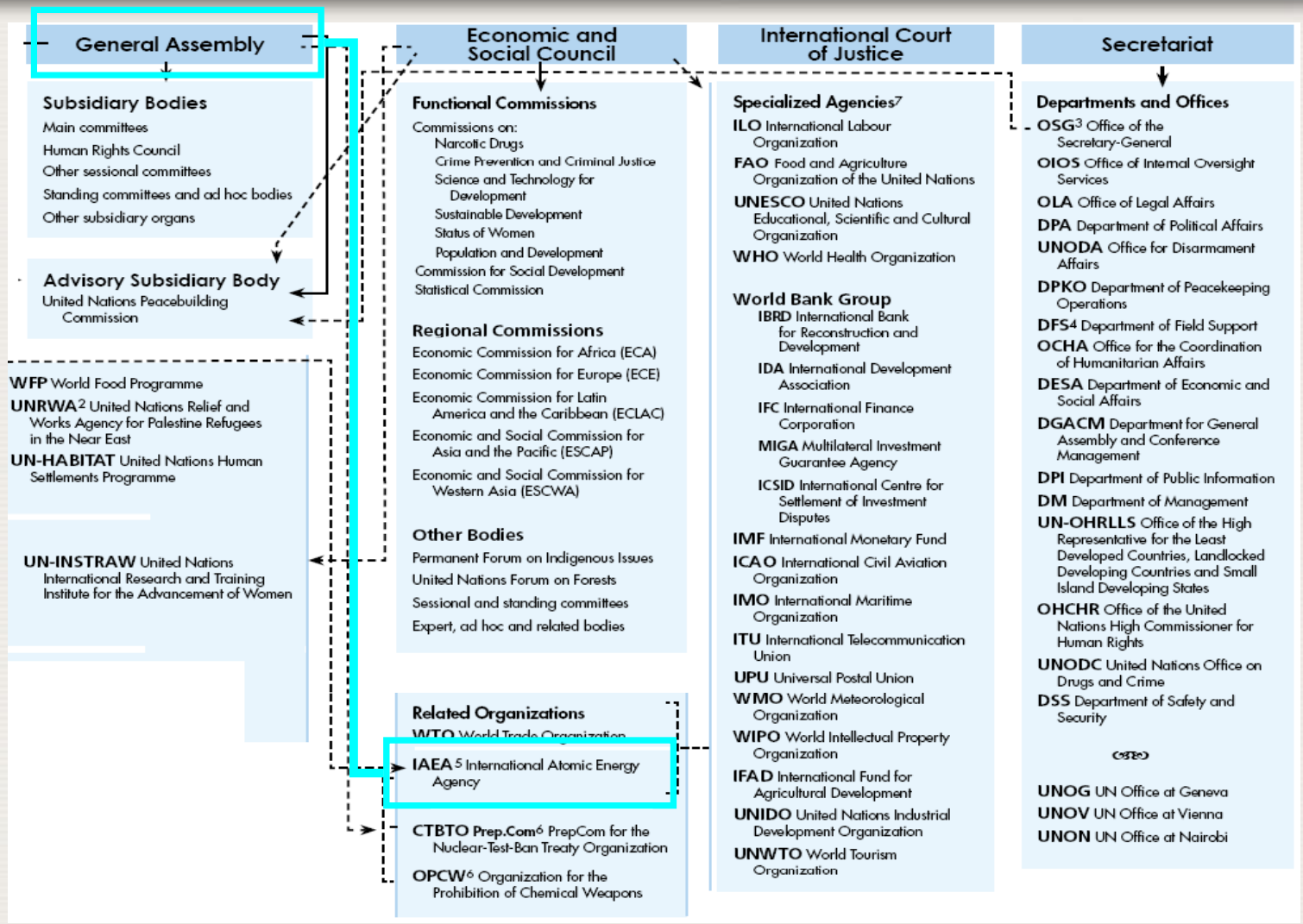
IAEA in UN system



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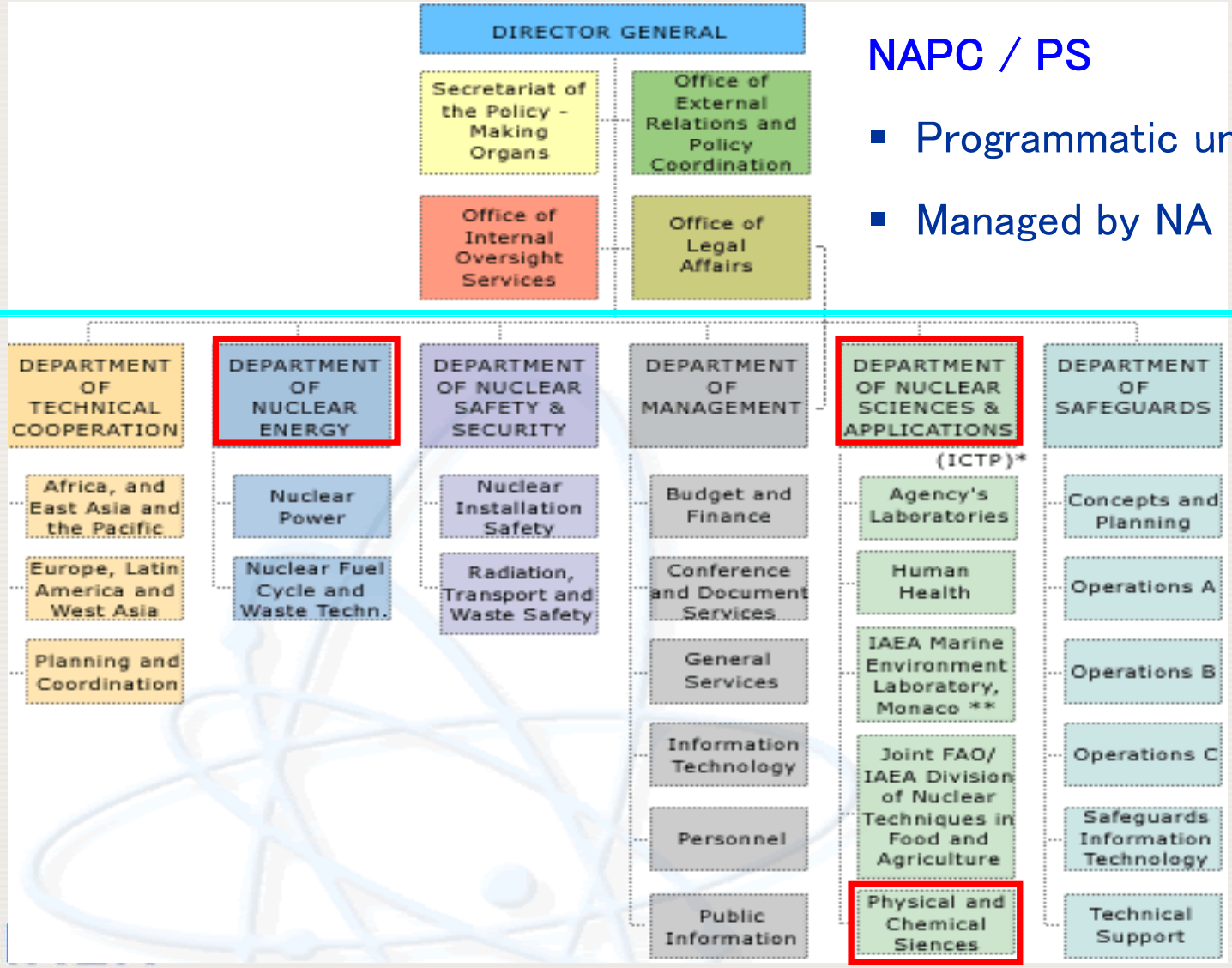
IAEA organizational chart



NAPC / PS

- Programmatic under NE
- Managed by NA

IAEA's Laboratories Seibersdorf and Vienna

Environmental Protection

- Conduct research into animal health
- Develop new plants for harsh environments
- Conduct research in Sterile Insect Technique
- Strengthen MS capacity to measure radioactivity in the environment
- QA/QC of radiation dosages in medicine and industrial applications
- Provision of analytical services, and development of nuclear methods & instrumentation

IAEA's Laboratories in Monaco

- **Research for the protection of the marine environment** from radioactive and non-radioactive pollution.
- **Applications of nuclear & isotopic techniques for tracking oceanic processes**, understanding marine ecosystems and assessing pollution impacts.
- **Expertise, training & Reference Materials** essential for Member States' commitment to the sustainable **development and monitoring of their marine environments**.
- **Strategic partnerships with international organisations** and other UN ocean agencies (IOC/UNESCO, UNEP, UNDP, IMO) to deliver the UN-WSSD programs on sustainable development of the ocean.

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Education & training activities

The Abdus Salam
International Centre for Theoretical Physics

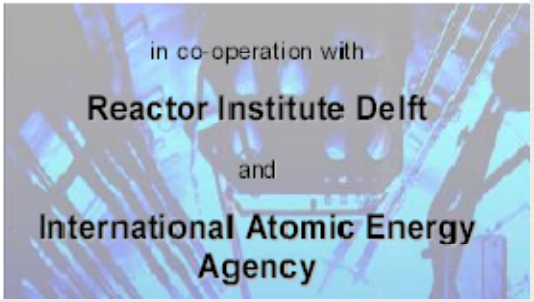
TU Delft
Delft University of Technology

IAEA
International Atomic Energy Agency

Neutron probing for compositional and structural characterization of materials and biological samples

11 – 15 May 2009

(TU Delft - Reactor Institute Delft, The Netherlands)



- **Support of international and regional education and training courses**
- **Cooperation with ICTP and other collaborating centres (ANSTO, RID, Elletra, etc.)**

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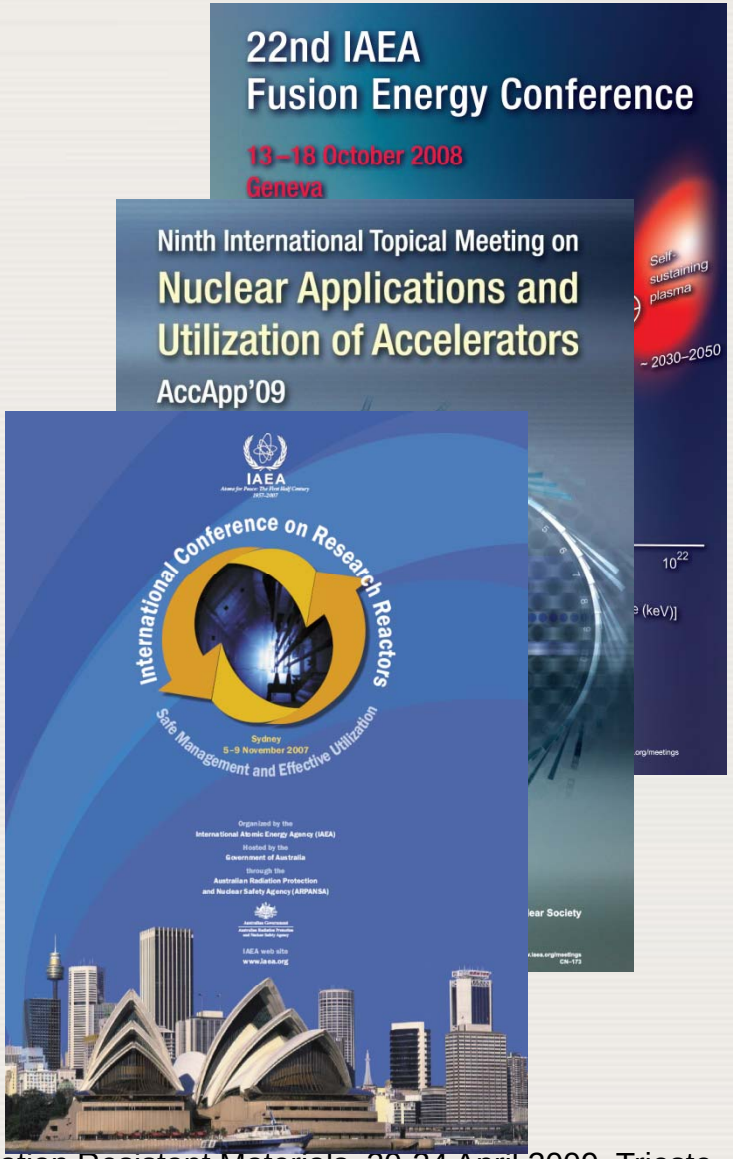
Profile of the Physics Section

The Physics Section supports the IAEA Member States regarding utilization of:

- Accelerators
- Research reactors
- Cross-cutting material research
- Controlled fusion
- (Nuclear instrumentation)



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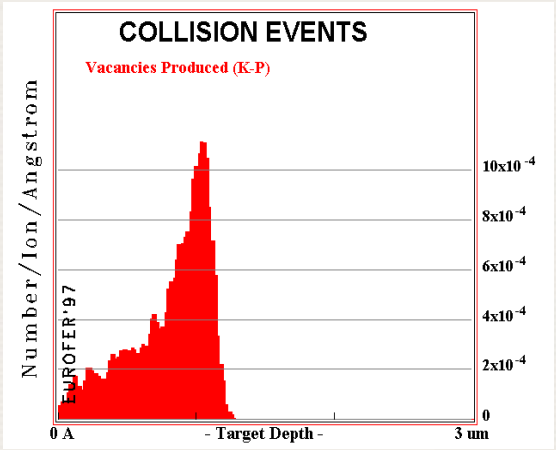
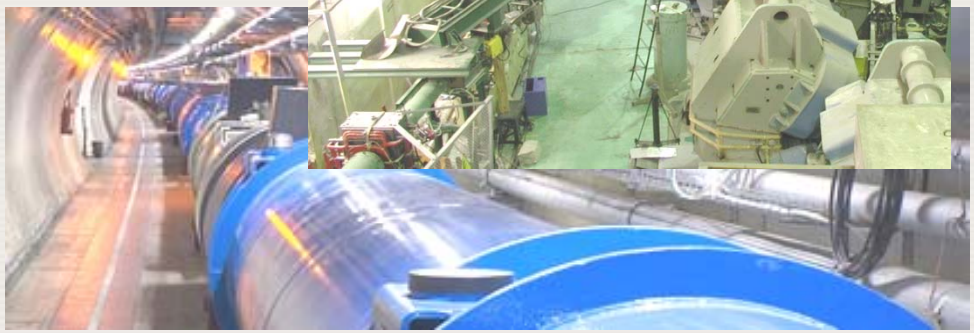
Application of accelerators:

- Accelerators and its application in research and industry.
- Particle and X-ray sources
- Various probing methods
- Development of advanced materials and simulation of various processes in energy systems (fission, fusion)





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Applications of RRs:

- Irradiation programmes (radio-isotopes, R&D structural materials…)
- Training activities (high-skilled staff, under-graduated students)

- Basic & applied science (neutron physics & neutron based techniques)
- Non-nuclear applications (biology, medicine, semiconductors/electronics…).

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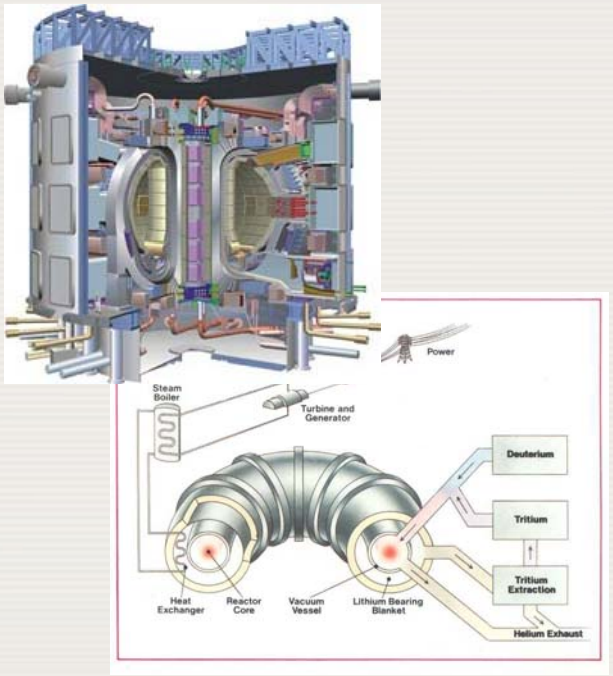
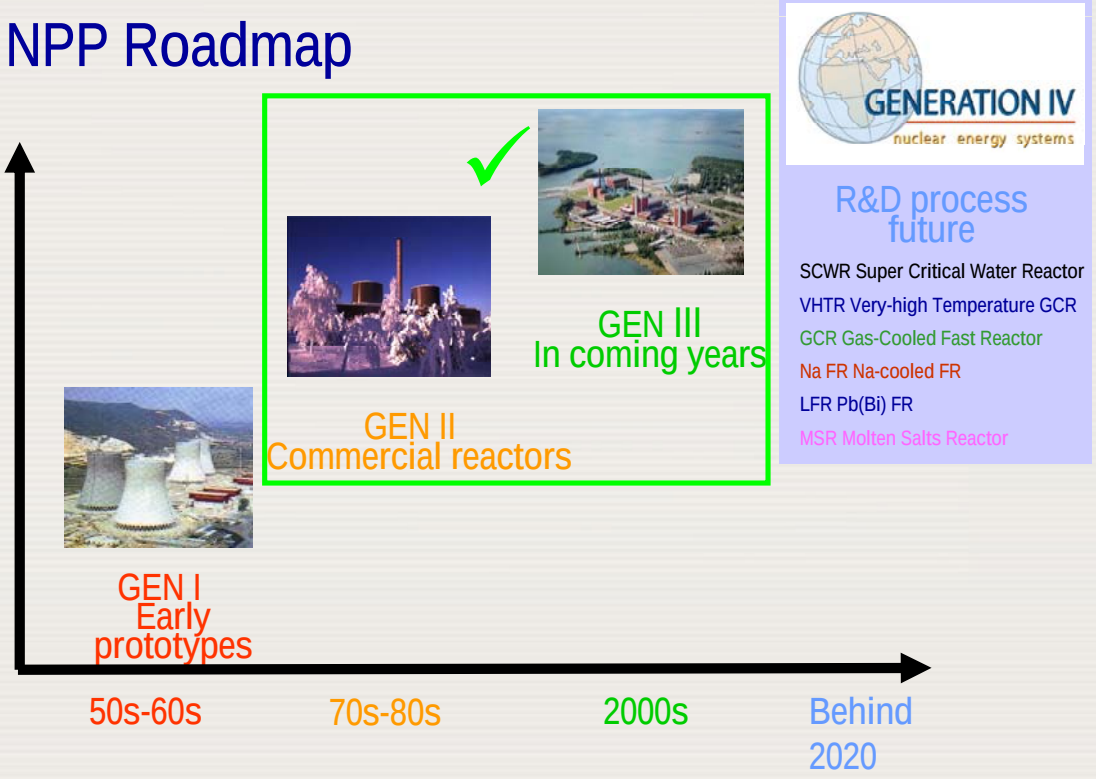
Materials science

- Studies of present NPP structural materials
- Investigation of degradation mechanisms
- Contribution to R&D programmes of new materials





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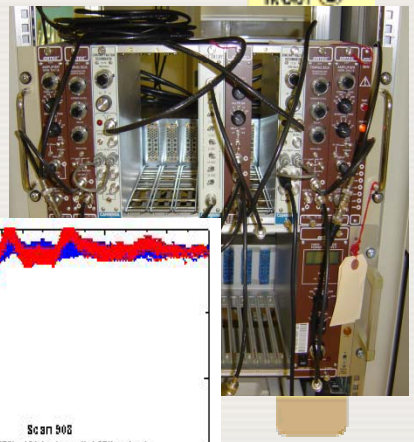
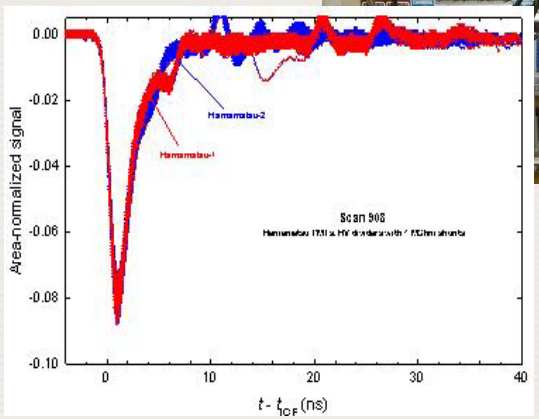
Nuclear instrumentation

- Support of nuclear instrumentation in developing countries
- Promotion new instrumentation methods (e.g. digitalization)
- Development of QA/QC procedures and protocols
- Training activities (high-skilled staff, under-graduated students)





Outline

IAEA introduction

Physics Section

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CRP activities

ICTP-IAEA Workshop

Main purpose:

- Provide state-of-the-art information about modern nuclear, accelerator and research reactor based techniques used for simulation and studies of radiation damage in reactor core structural materials
- Overview of advanced physical models and computational codes developed for prediction of high-dose radiation effects.

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ICTP-IAEA Workshop

Theme of this Workshop is in accordance with the rationale of IAEA's programme:

- 1.1.4 (INPRO), 1.1.5 (Technology development for advanced reactor lines), 1.2.2 (Nuclear power reactor fuel engineering), 1.2.4 (Nuclear fuels and fuel cycles for advanced and innovative reactors), 1.4.2.1 (Enhancement of utilization and applications of Research Reactors), 1.4.3.1 (Improvement of knowledge and data for the design and engineering of advanced materials of economic importance), 1.4.4 (Nuclear fusion) Nuclear Science Programme (1.4) towards supporting materials research for advanced reactors

ICTP-IAEA Workshop

This event provides unique opportunity to get consistent information on basic physical processes of radiation damage as well as overview of structural materials for fission and fusion reactors including related R&D activities.

- 24 lectures by 7 experts
- Poster sessions for participants
- Selected attendees can give short oral presentation
- Participants will get official CERTIFICATE however full presence during the workshop is required

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IAEA introduction

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Coordinated Research


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D24013
Isolation and Characterization of Genes Involved in Mutagenesis of Crop Plants
2009-02-04
D62008
Development of Generic Irradiation Doses for Quarantine Treatments
2008-12-11
D52036
Development of Radiometric and Allied Analytical Methods to Strengthen National Residue Control Programs for Antibiotic and Anthelmintic Veterinary Drug Residues. (activity 5)
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T13013
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Coordinated Research Project 1

Accelerator Simulation and Theoretical Modeling of Radiation Effects (Jointly NA-NE)

- Better understanding of radiation effects and mechanisms of material damage and basic physics of accelerator irradiation under specific conditions.
- Contribution to developmental of theoretical models for radiation degradation mechanism
- Improvement of knowledge and data for the present and new generation of structural materials
- Fostering the advanced or innovative technologies by promotion of information exchange, collaboration and networking.
- Launched 1/2009, 13 MS (BEL, CHN, EC, ESP, FR, IND, POL, RUS, SVK, UKR, USA)

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Coordinated Research Project 2

Large sample neutron activation analysis (LSNAA)

- Development of new technique for analysis of inhomogeneous samples (archaeology, geology, waste and sediments, etc).
- Harmonisation of new technique for bulk sample analysis
- Establishment of QA/QC procedures for sample irradiation and data treatment for both, research reactor and accelerator based neutron sources
- Launched 1/2009, 15 MS (BRA, CHN, EGY, GHN, GRE, IND, JAP, MAL, NET, PER, ROM, SYR, THA, USA

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Coordinated Research Project 3

Application of Nuclear Methods in Microstructural Characterisation and Performance Testing Of Materials for Hydrogen Fuel Cell and Storage Technologies

- Contribution to the **R&D programs related to the hydrogen fuel cell and storage material** properties.
- **Improved methodology for testing of hydrogen fuel cell and storage material** properties.
- **Enhancement of knowledgebase and strengthening of networking** and transfer of knowledge between scientists from developed and developing countries.
- To be launched 11/2009, 15 MS expected

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Nuclear techniques (1/2):

Important nuclear methods for studies of materials related to Fuel cells and hydrogen cycle technologies:

Nuclear technique	Fuel cells	Hydrogen storage
Neutron diffraction (ND)	Crystal structure determination, molten carbonates, including $LiCoO_2$, solid oxides (Ni-Zr,Y).	Crystal structure determination.
Small-angle neutron scattering (SANS)	Gas diffusion electrodes, Structure of ionomer membrane and suspensions (ex-situ), Ni electrode microporosity, metallic cluster distribution in PEFC.	Size and shape of nanoparticles and nanopores (e.g. nanostructured Mg hydrides).
Inelastic neutron scattering (INS)	Gas diffusion electrodes and catalyst characterisation	Phonons states, hydrogen dynamics
Quasi-elastic neutron scattering (QENS).	Gas diffusion electrodes, Dynamic of water/protons within ionomer.	Hydrogen diffusion and librations.
Neutron reflectivity measurements.	Hydrogen profile in thin films, Swelling properties of thin ionomer films.	Hydrogen profile in thin films
Neutron radiography methods and tomography.	2D and 3D water and gas distribution in fuel cells and stacks	Hydrogen distribution

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Nuclear techniques (2/2):

Important nuclear methods for studies of materials related to Fuel cells and hydrogen cycle technologies:

Total scattering experiments	Local structure determination	Local structure determination
Positron annihilation spectroscopy	Defects of structures and vacancies in HT fuel cell materials	Defects of structures and vacancies
Muon spin rotation (μSR).	Hydrogen dynamics	Hydrogen dynamics
Prompt Gamma Activation Analysis (PGAA)	Determination of trace elements	Determination of trace elements
X-Ray diffraction (XRD)	Crystal structure determination	Crystal structure determination
Synchrotron radiography and tomography.	Local transport and distribution in gas diffusion electrodes	Dynamics of hydrogenation
Nuclear magnetic spin resonance (NMR)	Water profile in fuel cells and structural analysis	Hydrogen mobility and diffusion, structural analysis
Mössbauer spectroscopy (MS)	Local structure	Local structure
Ion beam analysis	2D and 3D hydrogen profile	Hydrogen stoichiometry

Examples (neutron imaging)

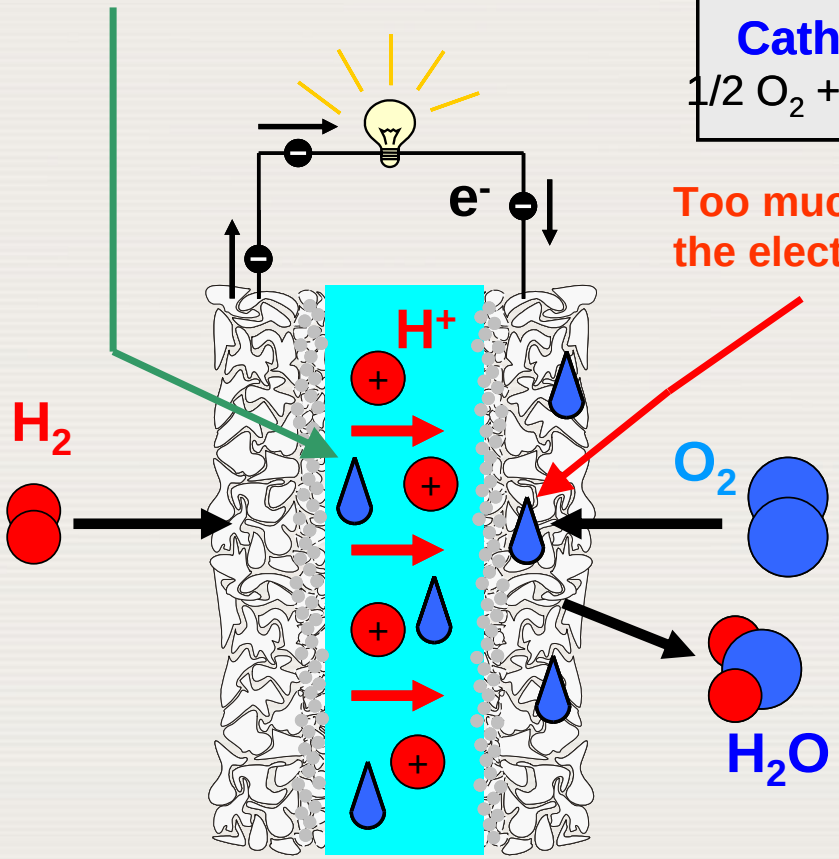
The membrane needs moisture for electric charge transfer

Anode :

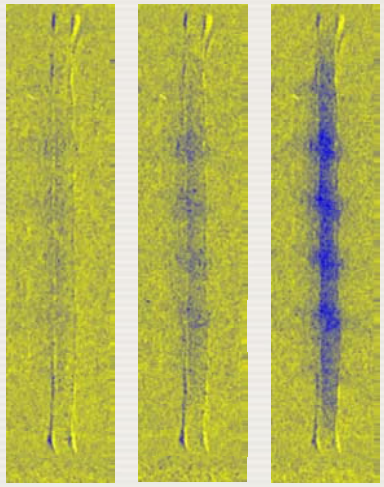
$H_2 \longrightarrow 2\ H^+ + 2\ e^-$

Cathode :

$1/2\ O_2 + 2\ H^+ + 2\ e^- \longrightarrow H_2O$



Too much water can disturb the electro-chemical process



Water distribution in the membrane under different operational conditions

Source: P. Boillat, Electrochemistry, PSI

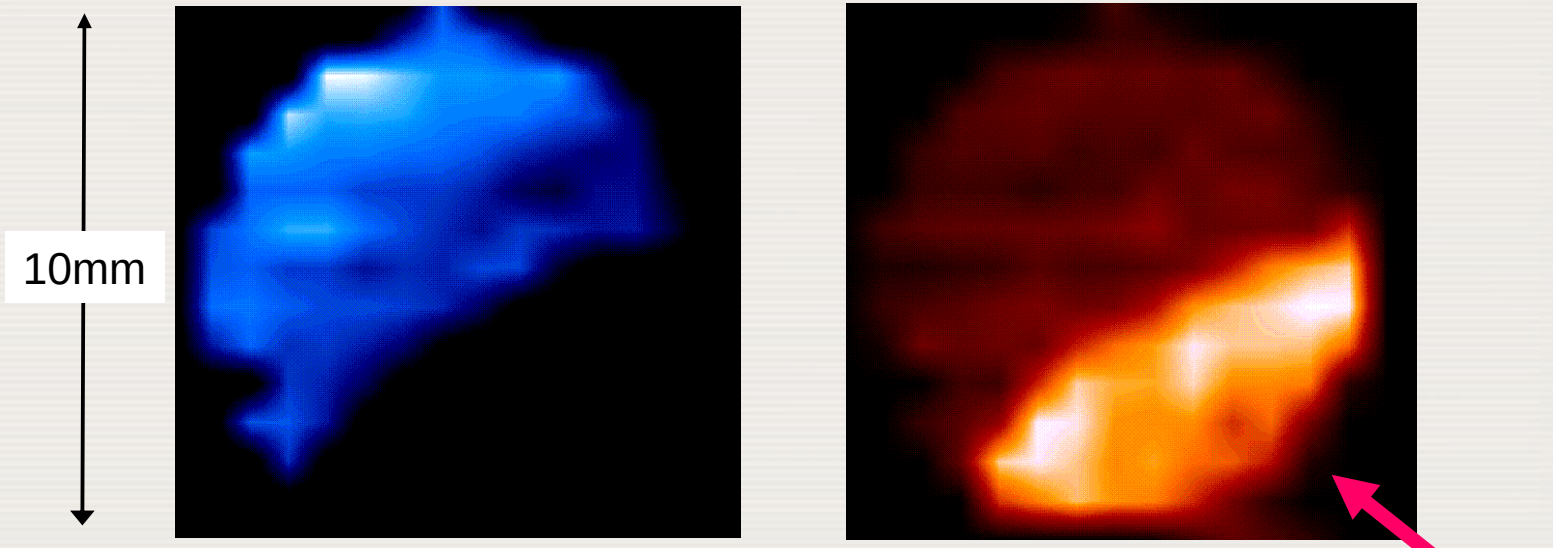
Examples (synchrotron techniques)

Hydrogenation of $LaNi_5H_X$ - the added complexity of an inhomogeneous sample

Mapping the position of the (101) powder line against the position of the beam relative to the sample cell – we can see the distribution of partially hydrogenated material. Note: H_2 enters at bottom right

(101) Line at Q = 1.990 $Å^{-1}$

(101) Line at Q = 2.125 $Å^{-1}$



α phase image

β phase image

Source: E. Gray, U. Qld and D. Cookson, ASRP

Thank your for your attention!