IAEA Collaborating Centre for Neutron Activation Based Methodologies of Research Reactors

Peter Bode

IAEA Collaborating Centres

Concept

- A Collaborating Centre is an institution which assists the Agency in implementing its regular budget programme through research and development and training in a relevant nuclear technology.
- The collaboration is implemented in accordance with a time-limited workplan (3 years maximum).
- The collaboration is at no cost to the Agency, but limited specialist supplies may be provided.

IAEA Collaborating Centres

- Designation as a Collaborating Centre is a public recognition of the work that the institution is doing for the Agency.

  It can be regarded as an acknowledgement of being an internationally recognized player in the specified field, and as an expression of thanks by the Agency.

- Designation does not confer any special status on the institute, nor does it infer any pre-eminence in its field compared with other institutions in the same country or elsewhere.

IAEA Collaborating Centres

20 Collaborating Centres worldwide (2011)

- South Korea: Terrestrial and marine environment
- Burkina Faso: Research and methods relevant to SIT against tsetse
- India: Nuclear techniques in nutrition
- Mexico: Development and Application of the Sterile Insect Technique (SIT) against fruit flies
- Poland: Radiation processing and industrial dosimetry
- Spain: Accelerator based analytical techniques for the study of long-lived radionuclides in marine samples
- Argentina: Human resource development for nuclear technologies and their applications
- Australia: Neutron scattering techniques
- Malaysia: Radiation processing of natural polymers
- Syria: Radioecology of naturally occurring radioactive materials (NORM)
- Japan: Radiobiology, charged particle therapy and molecular imaging
- Costa Rica: Learning and accelerated capacity building for food and environmental protection
- Hungary: Production and characterization of matrix reference materials
- Italy: Capacity building in synchrotron radiation applications
- Brazil: Animal genomics and bioinformatics
- Philippines: Studies on harmful algal blooms
- Korea: Research and education activities in nuclear medicine and molecular imaging
- China: Mutant germplasm enhancement and exploration in plants


Netherlands
North Sea
UNITED KINGDOM
FRANCE
BELGIUM
GERMANY
East Frisian Is.
West Frisian Is.
Texel
Waddenzee
Den Helder
Delfzijl
Leeuwarden
Groningen
Sneek
Assen
Heerenveen
Emmen
Hoogeveen
Enkhuizen
Alkmaar
Hoorn
Zwolle
Amsterdam
Flevoland
Veluwe
Almelo
Haarlem
Apeldoorn
Enschede
Leiden
The Hague
Delft
Utrecht
Arnhem
Rotterdam
Nijmegen
Dordrecht
Breda
Tilburg
Helmond
Middelburg
Eindhoven
Heerlen
Maastricht
0 25 Miles
0 25 Kilometers
53° N
51° N
3° E
5° E
7° E
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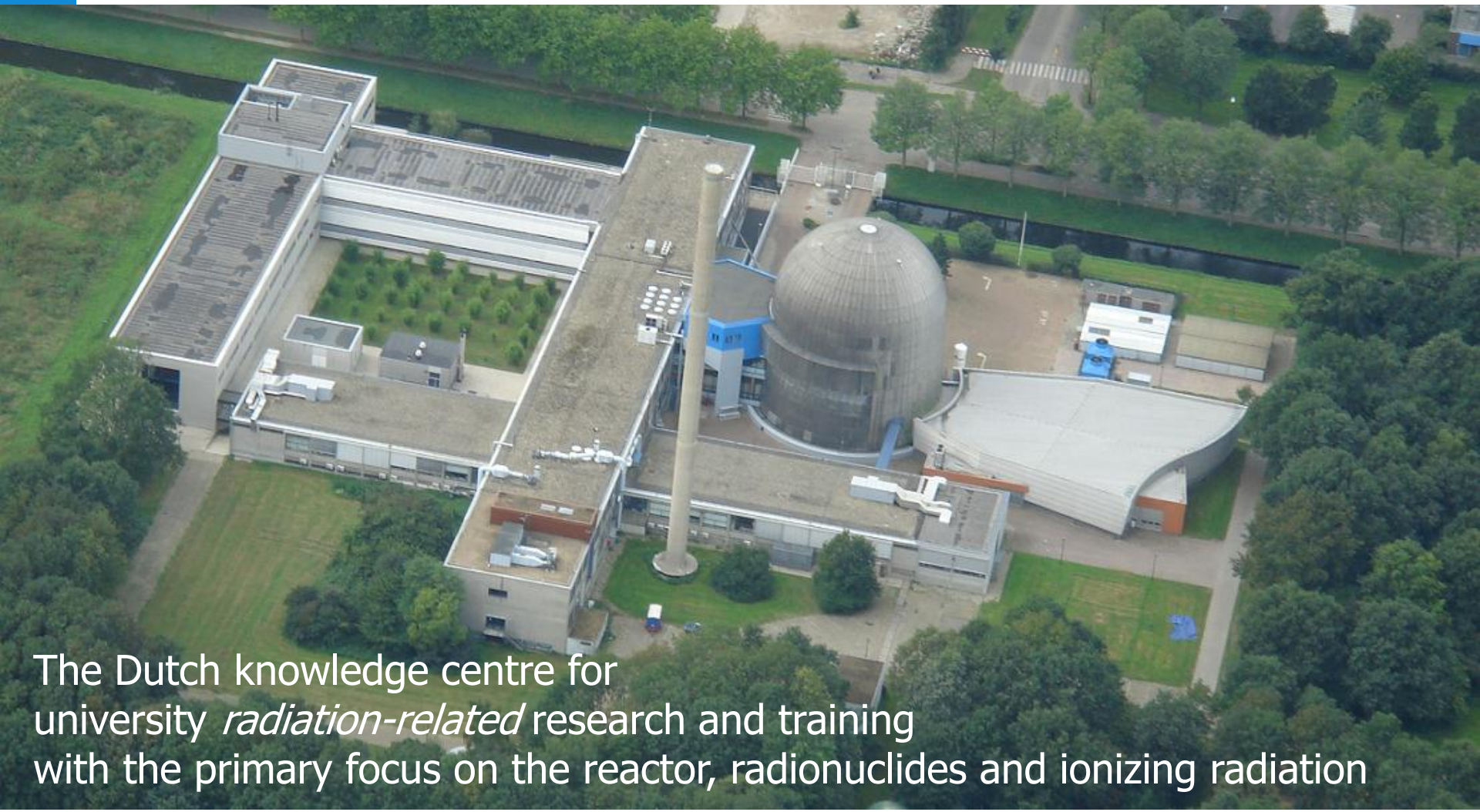
IAEA Collaborating Centre for Neutron Activation Based Methodologies of Research Reactors

May 11, 2009



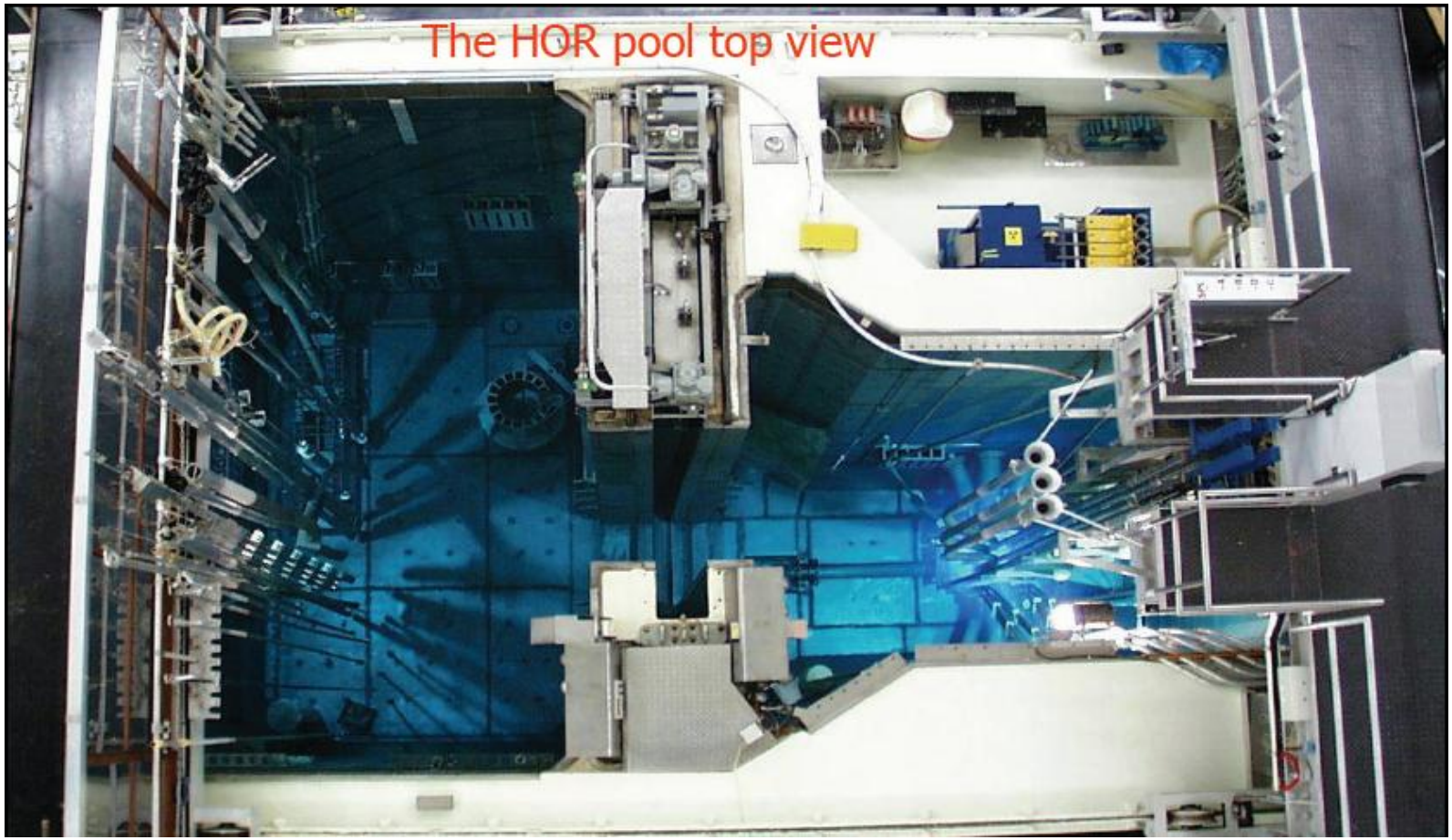
IAEA
International Atomic Energy Agency

IAEA COLLABORATING CENTRE FOR NEUTRON ACTIVATION BASED METHODOLOGIES OF RESEARCH REACTORS

TU Delft
Delft University of Technology

IAEA Collaborating Centre for Neutron Activation Based Methodologies of Research Reactors

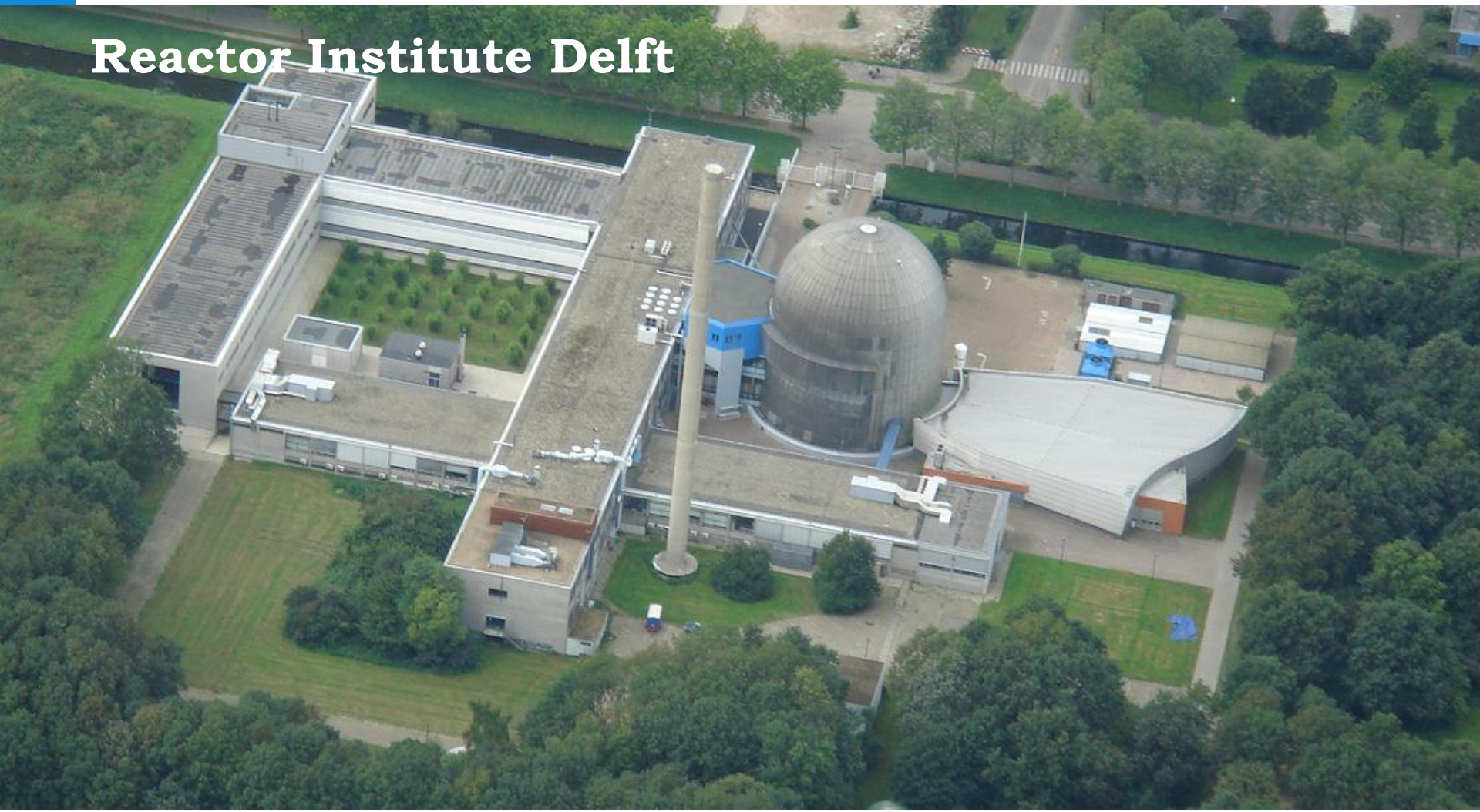
Challenge the future



Operational power level 2 MW
100 h/week continuous operation

Thermal neutron fluence rate in-core	4×10^{13} cm^{-2}s^{-1}
Thermal neutron fluence rate at core surface	1×10^{13} cm^{-2}s^{-1}
Integral fluence rate at neutron-guide exit	3×10^{7} cm^{-2}s^{-1}
Positron yield	2×10^{8} s^{-1}

Reactor Institute Delft



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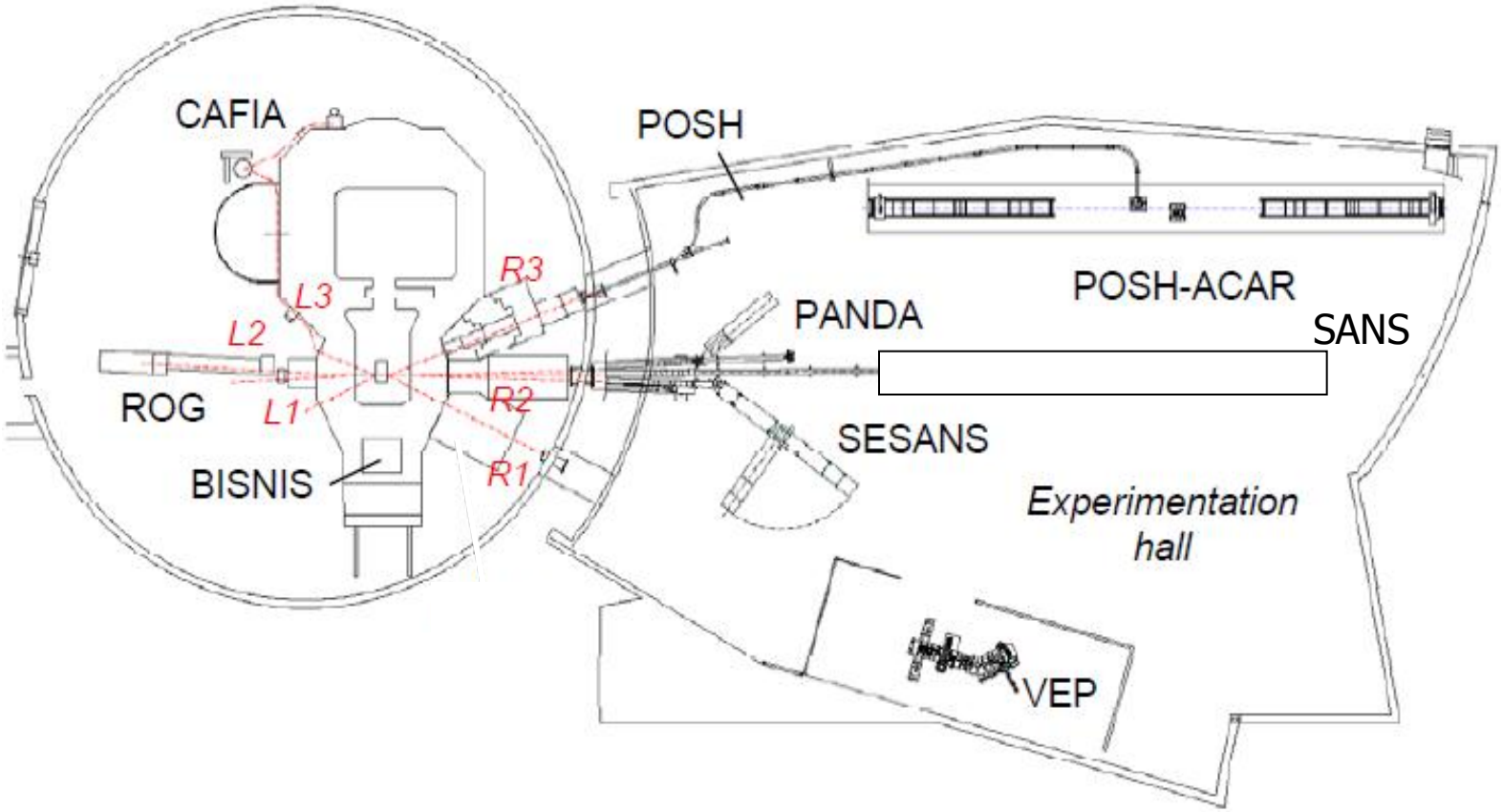
Hoger Onderwijs Reactor (HOR) facilities



IAEA Collaborating Centre: What

Neutron activation based methodologies

- Production of carrier-free radioisotopes of high specific activity via neutron activation.
- Neutron activation analysis with emphasis on automation, as well as analysis of large samples, and radiotracer techniques.
- Quality assurance and management in research and application of research reactor based techniques.

Assistance for the Agency's training programme

IAEA Collaborating Centre: How

- (Regional) training courses in Delft or in Member States
  - Radiotracer methodology
  - Neutron activation analysis
  - Metrology in nuclear analytical techniques
  - Quality assurance and management
- Hosting scientific visitors and providing research fellowship training
  - Radioisotope production
  - Automation in NAA
  - Logistics of large scale projects and sustainability of services
  - Quality assurance and management
- Transfer of technology
  - Large sample neutron activation analysis
  - New facilities in Member States
  - RID as benchmark
- Expert Services to Member States
- Participation of Member States in our research programs

IAEA Collaborating Centre

We offer training and assistance for Nuclear Analytical Techniques:

- Principle of Neutron Activation Analysis (NAA)
- Metrology of NAA
  (calibration, validation, uncertainty, primary method requirements)
- Quality Control/Quality Assurance in NAA
- Automation and facility design
- Principles of the radiotracer method
- Principles and applications of compartmental studies
- Principles of carrier-free production of radionuclides

IAEA Collaborating Centre

We offer training and assistance for QC/QA/QM:

- Principles and pragmatics of
  quality control, quality assurance and quality management
- Interpretation and implementation of the
  requirements of the ISO/IEC 17025:2005
- Training in Internal Auditing in nuclear science related laboratories

IAEA Collaborating Centre

We are available to help you via Expert Services, and national and regional training courses on

- Neutron activation analysis
- Gamma-ray spectrometry
- QC/QA/QM + ISO/IEC 17025 implementation
- Gap analysis of quality management systems
- Automation in NAA, handling of large-scale projects
- Commercial services
- Metrology in nuclear analytical, and chemical measurements
- Radiotracer methodology and applications

IAEA Collaborating Centre

Support to IAEA 1999-2011

135 man-weeks in expert missions and consultant/technical meetings

17 contributions to IAEA scientific publications

35 scientific visitors and fellows hosted for total 156 man-weeks

8 workshops and training courses hosted

2 research agreements

IAEA Collaborating Centre

Activities 2009-2011

- ICTP- IAEA-RID Advanced Workshop on "Neutron probing for compositional and structural characterization of materials and biological samples"
- IAEA Regional Training Course on "Physical Protection of Nuclear Materials and Facilities"
- Second Research Coordinating Meeting of the IAEA CRP-1499 "Application of Large Sample Neutron Activation Analysis Techniques for Inhomogeneous Bulk Archaeological Samples and Large Objects"
- 5 Weeks Scientific Visitors (5 persons)
- 16 Weeks Fellowship Training (3 persons)
- 3 Expert missions
- Participation in IAEA Technical- and Consultants' meetings
- Serving as help desk for k_0-IAEA software

IAEA Collaborating Centre

Activities for 2012

- IAEA 1st RCM on new CRP "Routine Automation in NAA"
- IAEA Feedback meeting on evaluation of laboratory intercomparison results of European NAA laboratories
- Hosting scientific visitors (2 visits already planned)
- Providing fellowship training
- Availability for Expert missions, and for participation in IAEA Technical and Consultants' meetings
- Continuing the help desk for k_0-IAEA software
- At sufficient interest: Summer school (2 weeks) on NAA

IAEA Collaborating Centre: Related research activities

Innovative Ways of Carrier-Free Radioisotope Production

- Use of Szilard-Chalmers chemistry
  - 1 patent registered (^{99}Mo)
  - 2 patents submitted
  - 1 patent in preparation
- Dedicated Irradiation Facilities
- New Radioisotope Generators

IAEA Collaborating Centre: Related research activities

Radiotracer Methodology

- Radiolabeling
  Lipid-based nanomaterials with tumor-specific peptides
- Kinetic and stability constants
  Free Ion Selective Radiotracer Extraction
- Absorption of tracers to surfaces
  Thin Gap method and neutron reflectometry
- Non-invasive chemical speciation
  Perturbed Angular Correlation Spectrometry
- Toxicity of metal mixtures
  Cell cultures
- Behavior, distribution and site effects of (nano)elements
- Human and Animal Metabolism Studies
  Compartmental analysis

IAEA Collaborating Centre: Status

Neutron Activation Analysis

- Leading developments in detectors, software, automation, methodologies and applications
- In-house developed software, based on k_{Zn} method since 1970
- 3 well type detectors, 3 coaxial detectors (all with sample changers)
- 2 fast rabbit systems (1 with sample changer)
- Typical throughput 2,500 samples/year (capacity ~ 10,000)
- Management system accredited since February 1993 (ISO/IEC17025:2005)
- Large sample NAA facility (max. 50 kg)
- 2 George Hevesy Medal Award winners (2003 and 2011)

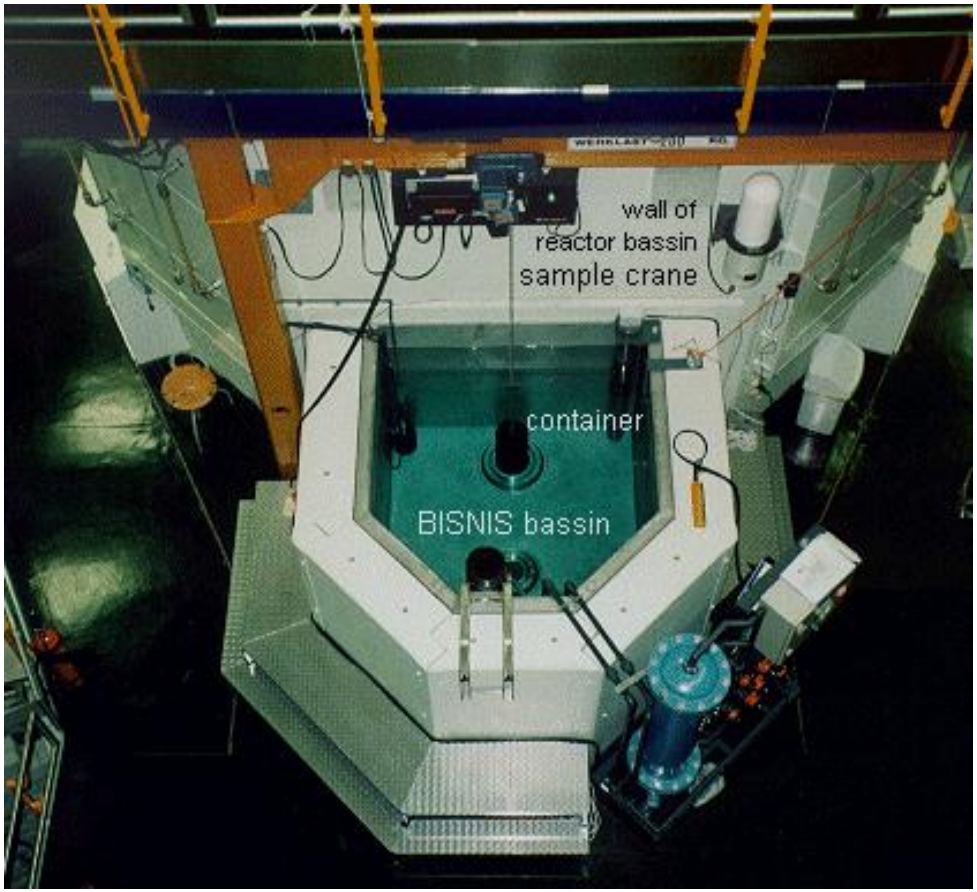
- From 2012 onwards: No scientific research anymore, only commercial applications

IAEA Collaborating Centre

Neutron Activation Analysis

IAEA Collaborating Centre

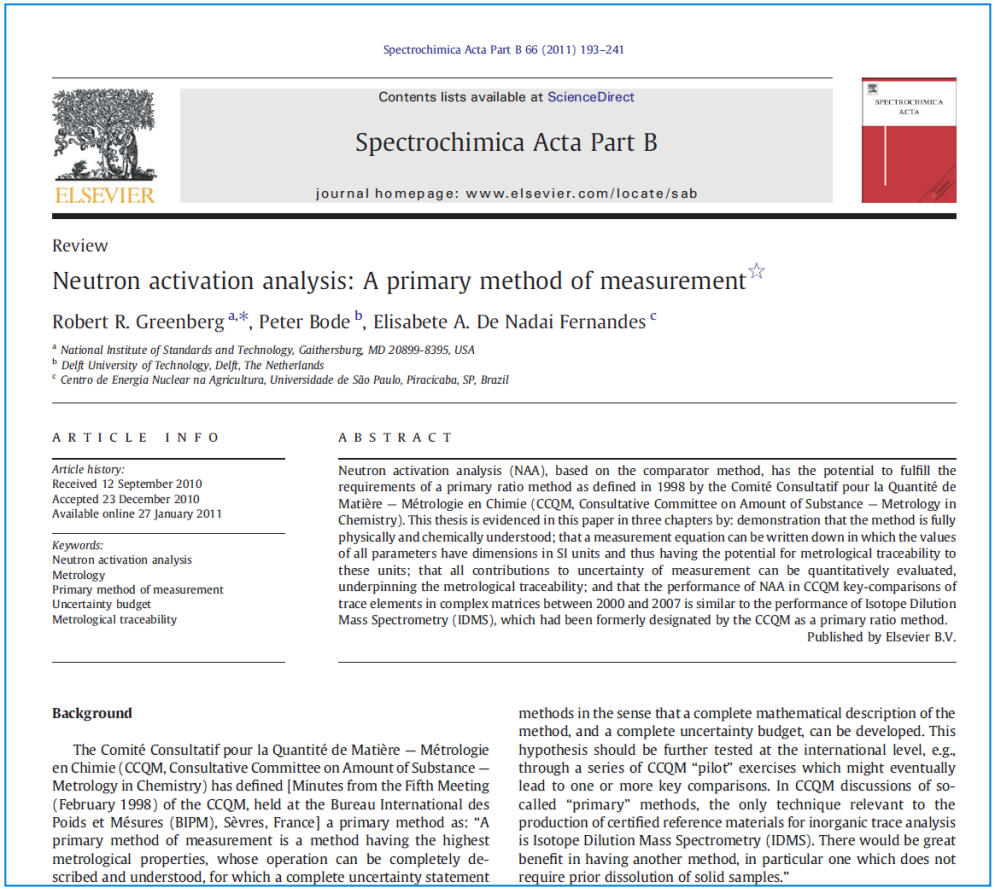
Neutron Activation Analysis



Large sample NAA facility

IAEA Collaborating Centre

Neutron Activation Analysis: a Primary Method of Measurement



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Review

Neutron activation analysis: A primary method of measurement ☆

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Metrological traceability

ABSTRACT

Neutron activation analysis (NAA), based on the comparator method, has the potential to fulfill the requirements of a primary ratio method as defined in 1998 by the Comité Consultatif pour la Quantité de Matière — Métrologie en Chimie (CCQM, Consultative Committee on Amount of Substance — Metrology in Chemistry). This thesis is evidenced in this paper in three chapters by: demonstration that the method is fully physically and chemically understood; that a measurement equation can be written down in which the values of all parameters have dimensions in SI units and thus having the potential for metrological traceability to these units; that all contributions to uncertainty of measurement can be quantitatively evaluated, underpinning the metrological traceability; and that the performance of NAA in CCQM key-comparisons of trace elements in complex matrices between 2000 and 2007 is similar to the performance of Isotope Dilution Mass Spectrometry (IDMS), which had been formerly designated by the CCQM as a primary ratio method.

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Background

The Comité Consultatif pour la Quantité de Matière — Métrologie en Chimie (CCQM, Consultative Committee on Amount of Substance — Metrology in Chemistry) has defined [Minutes from the Fifth Meeting (February 1998) of the CCQM, held at the Bureau International des Poids et Mésures (BIPM), Sèvres, France] a primary method as: "A primary method of measurement is a method having the highest metrological properties, whose operation can be completely described and understood, for which a complete uncertainty statement methods in the sense that a complete mathematical description of the method, and a complete uncertainty budget, can be developed. This hypothesis should be further tested at the international level, e.g., through a series of CCQM "pilot" exercises which might eventually lead to one or more key comparisons. In CCQM discussions of so-called "primary" methods, the only technique relevant to the production of certified reference materials for inorganic trace analysis is Isotope Dilution Mass Spectrometry (IDMS). There would be great benefit in having another method, in particular one which does not require prior dissolution of solid samples."

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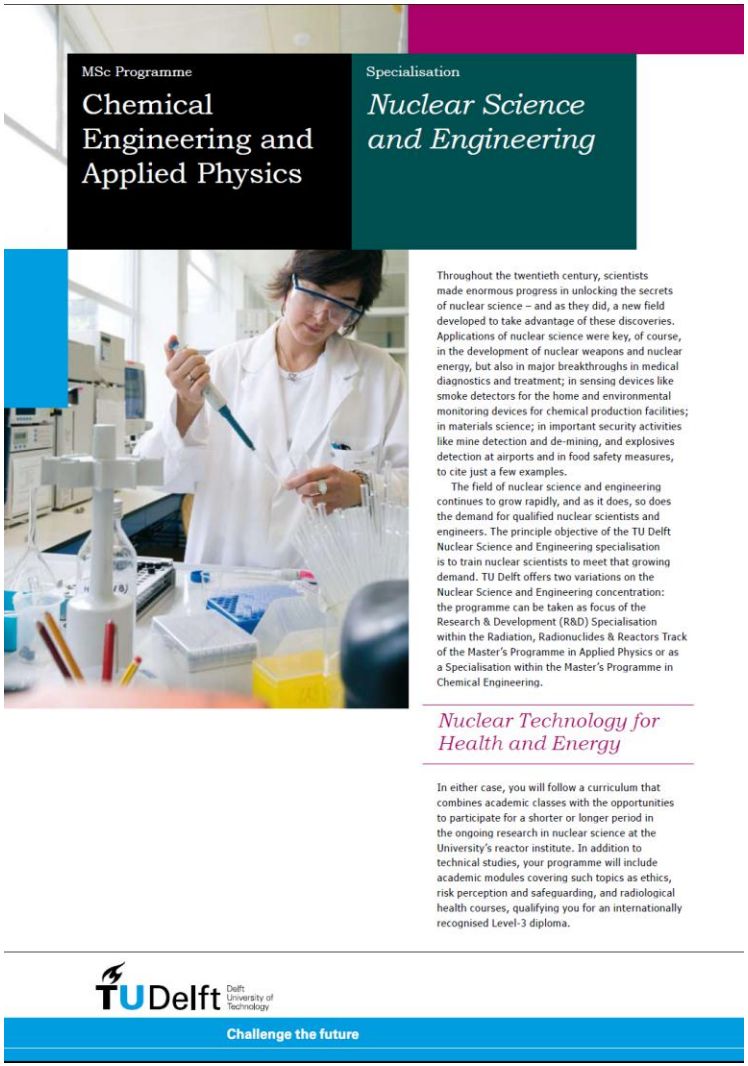
Chapter 1 – Neutron Activation Analysis: Principles and Analytical Characteristics
Peter Bode

Chapter 2 - Evaluation of Uncertainties for NAA Measurements Using the Comparator Method of Standardization
Robert R. Greenberg, Richard M. Lindstrom, Elizabeth A. Mackey, and Rolf Zeisler

Chapter 3 - Performance of NAA Laboratories in CCQM Key Comparisons and Pilot Studies
Elisabete A. De Nadai Fernandes and Márcio Arruda Bacchi

Other opportunities for capacity building in Delft



M.Sc. Specialization
Nuclear Science and Engineering

Both for
Chemical Engineering
Applied Physics

Focus on Energy or Health, e.g.

- Nuclear reactors
- Chemistry of the nuclear fuel cycle
- Radiation and isotopes for health
- Medical imaging
- .....

2 years, 120 ECTS

Other opportunities for capacity building in Delft

European Master course "Nuclear Security"

1 year, 60 ECTS
Starting 2012/2013

Coordinated by Delft University of Technology,
in partnership with
- United Kingdom
- Germany
- Norway
- Greece
- Austria

and aligned with the IAEA

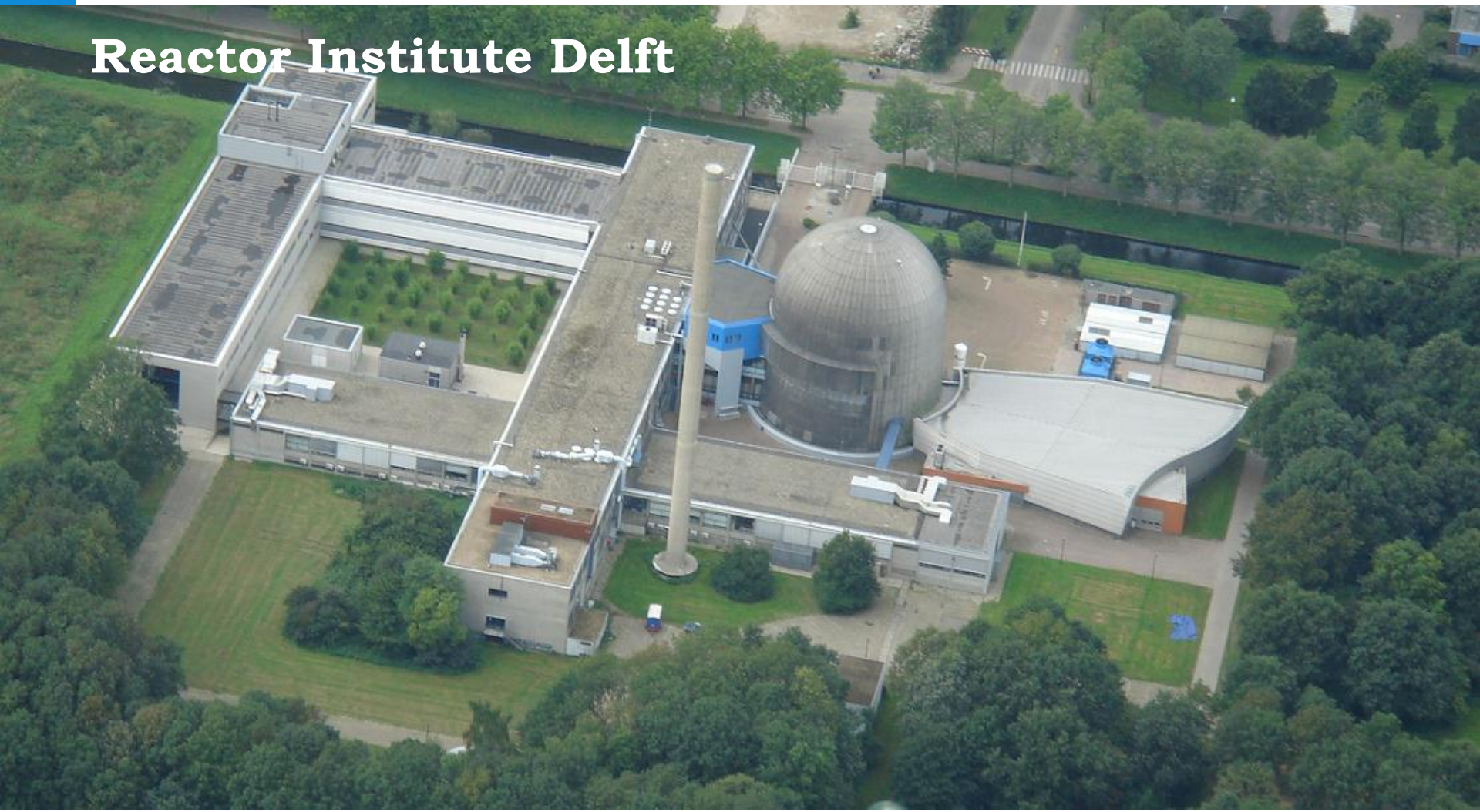
Optimistic developments in Delft

1. 2009: Start Nuclear Science and Engineering MSc specialization
2. 2009: New (young) full professors at all sections:
   - Radiation Detection and Measurement techniques
   - Neutron Beam physics
   - Radiochemistry
   - Defects in materials (positron research)
   - Reactor physics
3. 2009: IAEA Collaborating Center
4. 2010: Grant for innovative neutron diffractometer
5. 2011: Proposal submitted for multi-purpose neutron polarization instrument
6. 2012: Proposal to be submitted for neutron imaging facility
7. 2012: Approval for upgrade reactor and (beam) facilities: OYSTER
8. 2012: Start building Proton Cancer Therapy Clinic (operational 2016)
9. 2012/2013: Start MSc education Nuclear Security
10. 2013: 50 years' operation of reactor

Outcome of Upgrade

- Neutron fluence rate: factor 40 ↑
- Positron intensity: factor 5 ↑
- Neutron/gamma ratio: factor 400 ↑
- Neutron instruments gain: factor 150 ↑
- Positron instruments gain: factor 60 ↑

Reactor Institute Delft



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End (of this presentation)