united nations
educational, scientific
and cultural
organization

international atomic
energy agency

the
abdus salam
international centre for theoretical physics

ICTP 40th Anniversary

SMR.1555 - 20

Workshop on
Nuclear Reaction Data and Nuclear Reactors:
Physics, Design and Safety

16 February - 12 March 2004

Workshop Overview

Alan L. NICHOLS
International Atomic Energy Agency
Division of Physical & Chemical Sciences
Department of Nuclear Sciences & Applications
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AUSTRIA

International Atomic Energy Agency

Workshop on Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

16 February – 12 March 2004

ICTP Trieste

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Workshop Overview

Lecturers

Participants

ICTP

Trieste

Italy

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Alan Nichols

Section Head

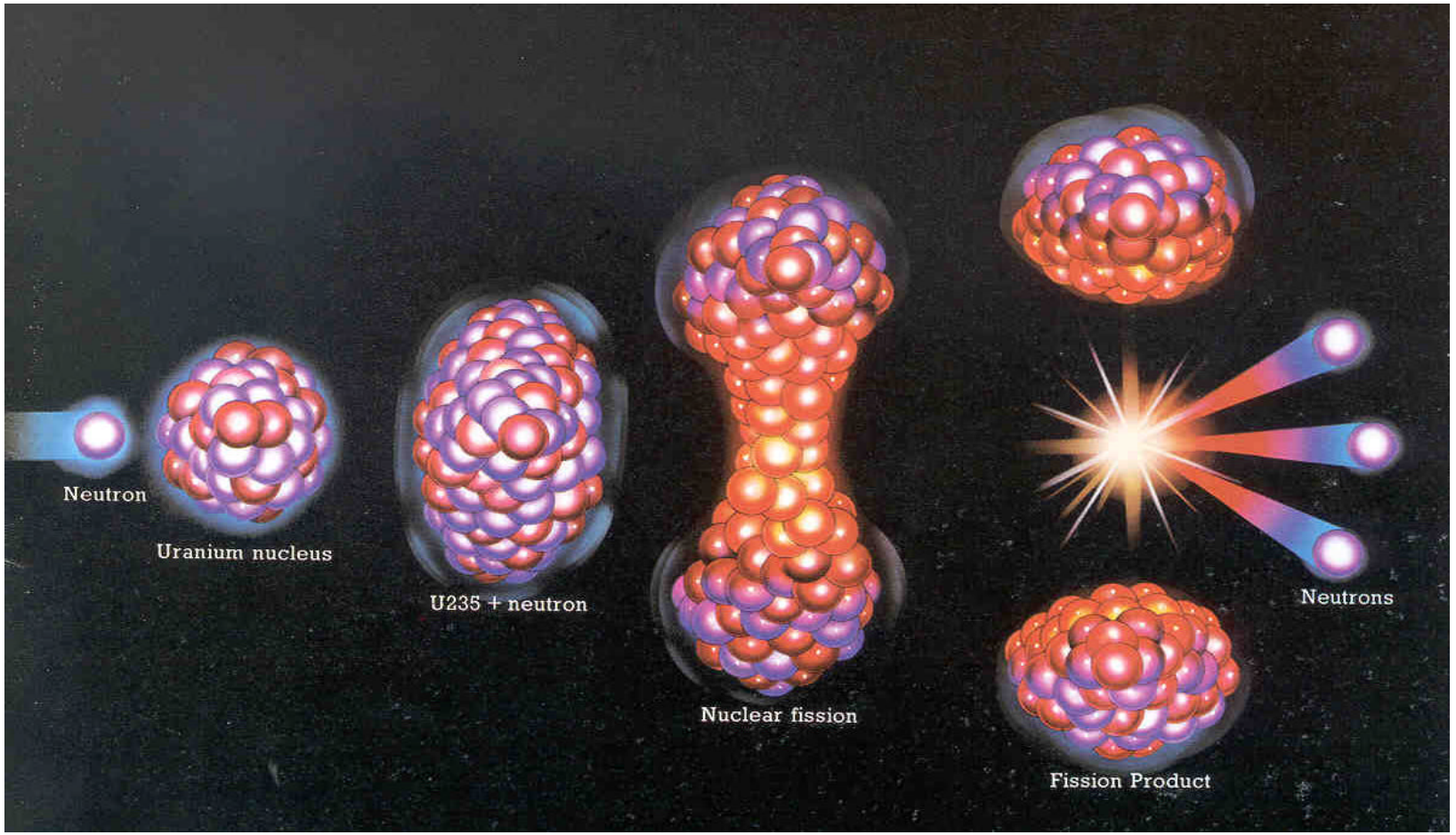
Nuclear Data Section

International Atomic Energy Agency (IAEA)

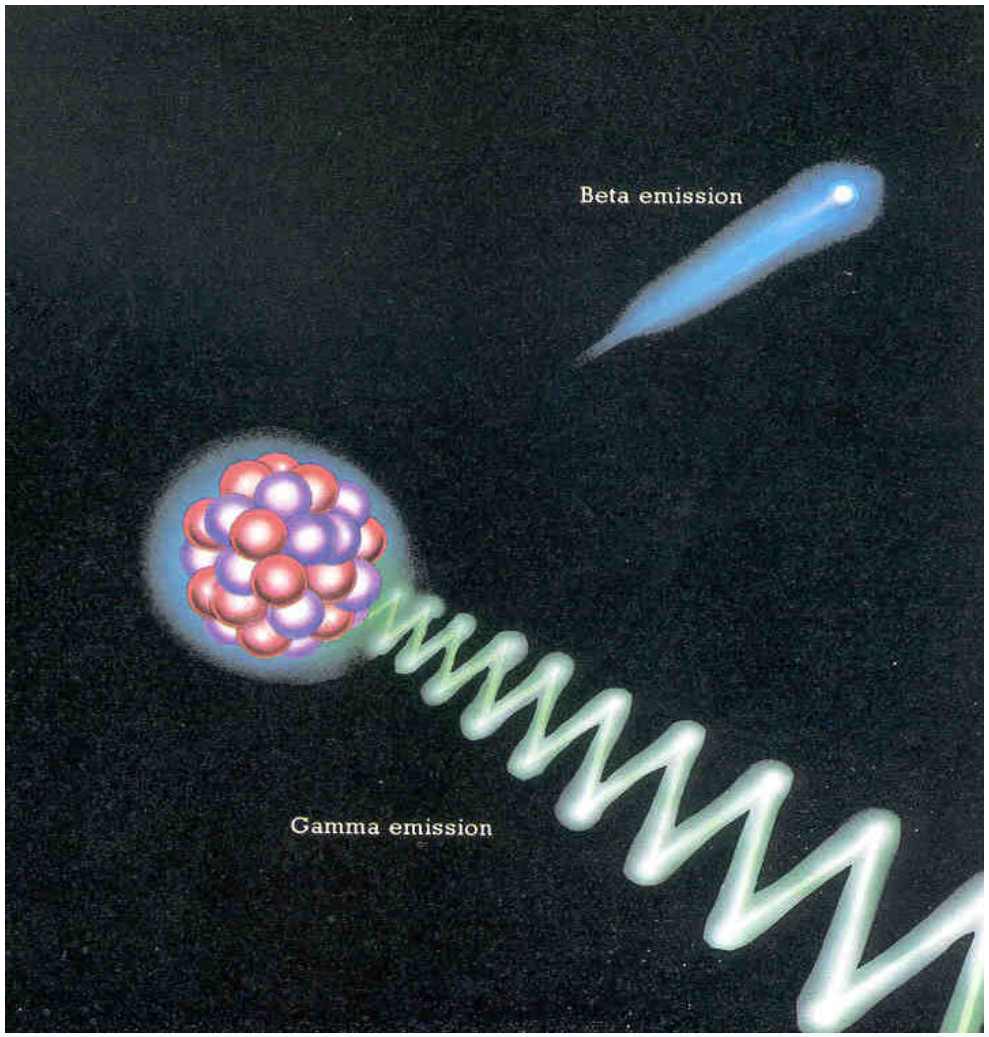
Vienna

Austria

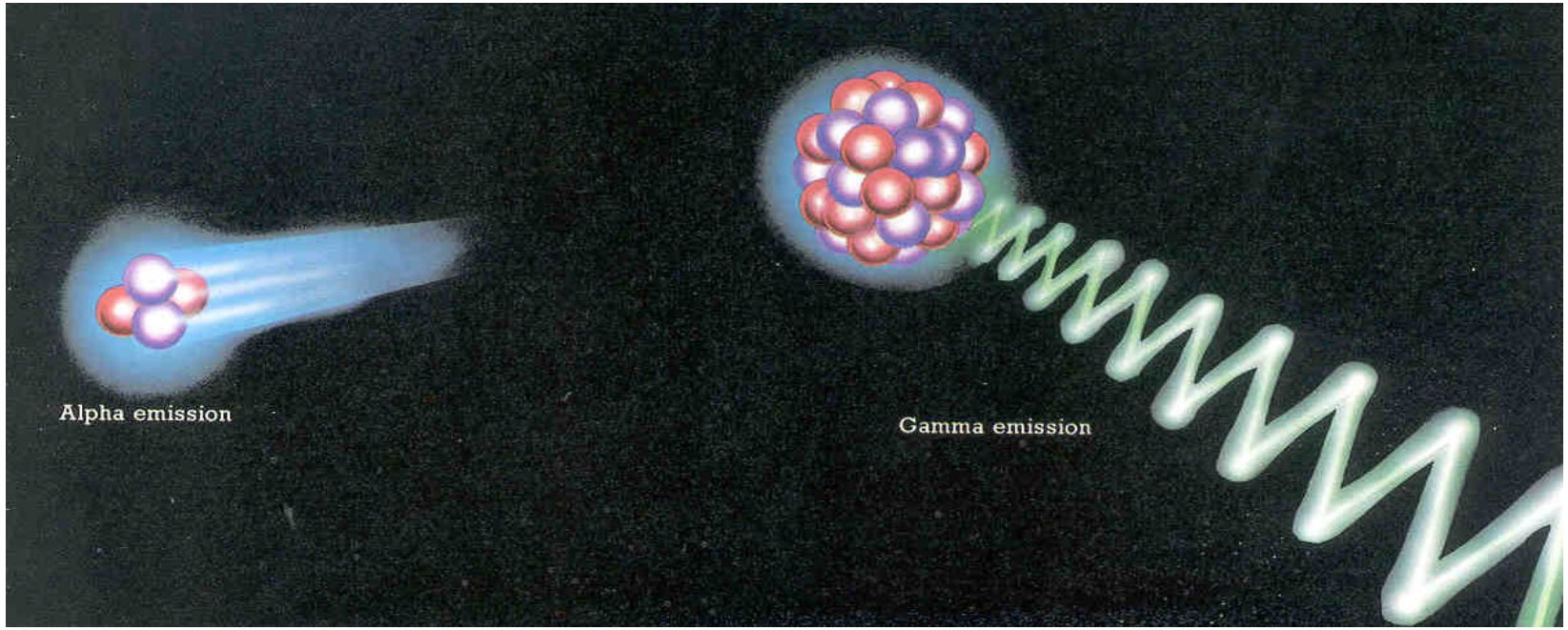
Neutron-induced Fission

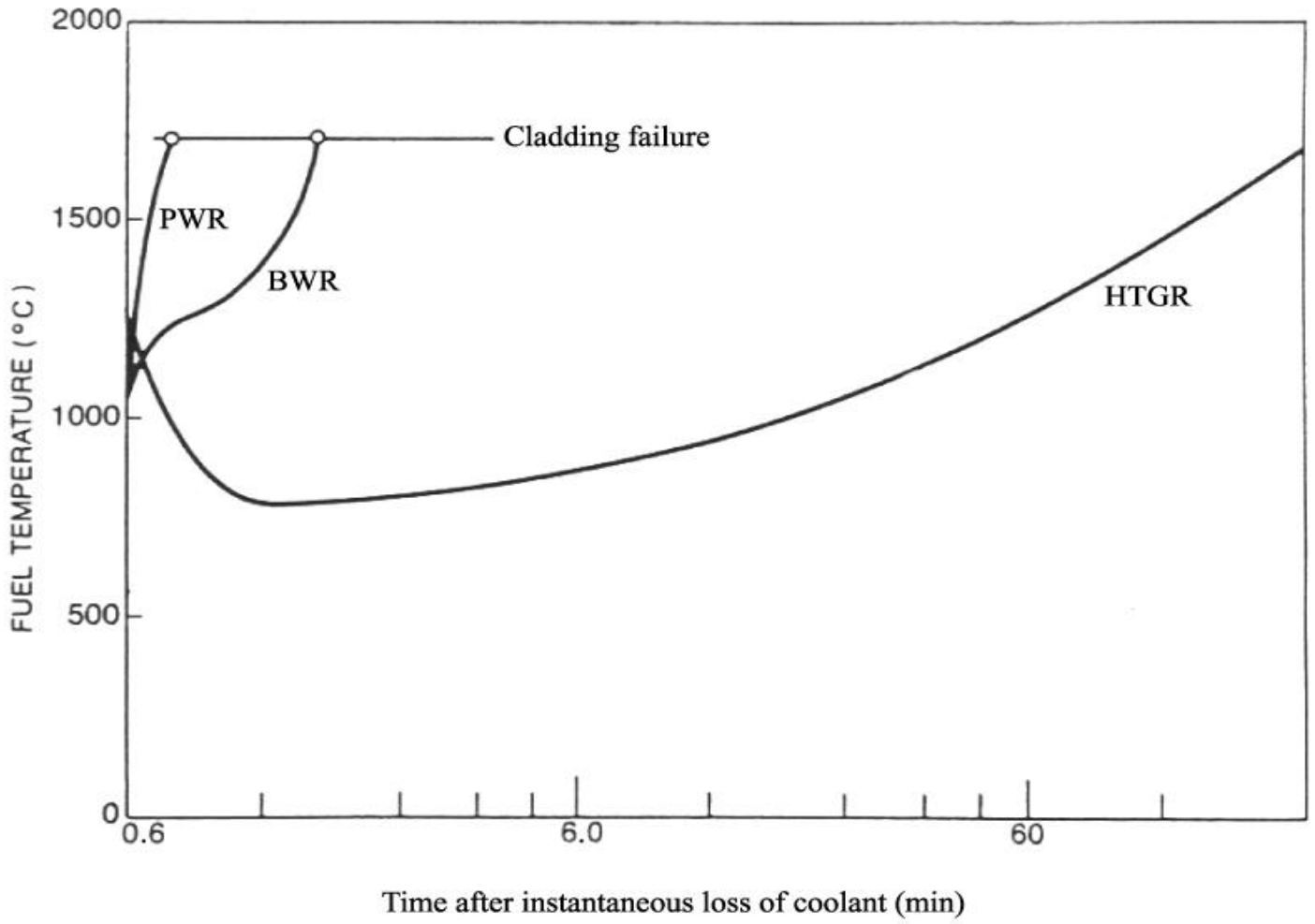


Beta and Gamma Decay



Alpha and Gamma Decay





Temperature in the core of a pressurised-water reactor (PWR), a boiling-water reactor (BWR) and a high-temperature gas-cooled reactor (HTGR) after loss-of-coolant.

NUCLEAR DATA FOR DECAY HEAT CALCULATIONS
- THERMAL AND FAST NEUTRON FISSION

$$H_a(t) = \sum_{i=1}^{M} l_i^T \, N_i(t) \, E_a^i$$

$$H_b(t) = \sum_{i=1}^{M} l_i^T \, N_i(t) \, E_b^i$$

$$H_g(t) = \sum_{i=1}^{M} l_i^T \, N_i(t) \, E_g^i$$

NUCLEAR DATA FOR DECAY HEAT CALCULATIONS

$s_{a,k}^{F}$ - effective group-averaged fission cross section of actinide *a* in the k^{th} neutron group,

$s_{i,j}^{A}$ - total neutron absorption cross section of fission product *i*,

$s_{i,j}^{(n,g)}$ - (n, γ) cross section of fission product *i*,

$s_{i,j}^{(n,2n)}$ - (n, 2n) cross section of fission product *i*,

$Y_{a,k}^{i}$ - independent yields for fission product *i*,

l_i - decay constant(s) of fission product *i*,

k_a, k_{b^-}, k_{b^+} - branching fractions for α, β^- and β^+ decay to nuclide Z, A,

E_a^i, E_b^i, E_g^i - mean alpha, beta and gamma energy releases per disintegration of nuclide *i*.

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Aims of Workshop:

Training of scientists and engineers (YOU):

- Nuclear reaction theory
- Production of nuclear data
- Use of nuclear data

Emphasis – nuclear physics, design and safety

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Aims of Workshop:

Generate greater awareness:

- Available nuclear data libraries
- On-line retrieval of data
- Existence and use of up to date computer codes
- New trends in advanced nuclear systems

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Issues:

- Improve safety → need wide spectrum of knowledgeable scientific and technical personnel
- Improve plant efficiency → need wide spectrum of knowledgeable scientific and technical personnel

knowledge: nuclear reactions, particle transport, use of nuclear data libraries, engineering and safety principles

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

2.4 weeks: Nuclear models, data evaluation and processing

B V Carlson	Centro Técnico Aeroespacial, Brazil
M Herman	Brookhaven National Laboratory, USA
R Capote	IAEA Nuclear Data Section, Austria
N Larson	Oak Ridge National Laboratory, USA
M Sin	University of Bucharest, Romania
A Trkov	IAEA Nuclear Data Section, Austria
O Schwerer	IAEA Nuclear Data Section, Austria
L Hutton	Serco Assurance, UK
M Verpelli	IAEA Nuclear Data Section, Austria
P K McLaughlin	ex-IAEA, Austria

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

1.6 weeks: Reactors – design, safety and applications

J Kupitz	IAEA Nuclear Power Technology Development Section, Austria
B Misra	IAEA Nuclear Power Technology Development Section, Austria
A Stanculescu	IAEA Nuclear Power Technology Development Section, Austria
A Badulescu	IAEA Nuclear Power Technology Development Section, Austria
N Tikhonov	Moscow Engineering and Physics Institute (MEPhI), Russian Federation
I Kodeli	OECD/Nuclear Energy Agency, France
V S Kagramanian	IAEA Planning and Economic Studies Section, Austria
R Spiegelberg	IAEA Nuclear Power Engineering Section, Austria
M Cumo	University of Rome, Italy
A Gandini	University of Rome and ENEA, Italy
N Burgio	ENEA, Italy
R Jacqmin	CEN Cadarache, France
G B Bruna	Framatome, France
P Ravetto	Politecnico di Torino, Italy

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Co-Directors

Week	Co-Director	Affiliation
1	Alan Nichols	IAEA
2	Andrej Trkov	IAEA
3	Jürgen Kupitz	IAEA
4	Augusto Gandini	University of Rome and ENEA

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Local organizer

Brian Stewart - ICTP

Administrative support

Doreen Sauleek - ICTP

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Bret Carlson:

Overview of reaction theory

- Description of nuclear reactions

  $\rightarrow$ cross sections
- Optical model calculations
- Strong channel coupling – ECIS code
- Distorted-wave Born approximation (DWBA)

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Mike Herman:

EMPIRE

Nuclear reaction code

- Statistical model
- Level densities

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Roberto Capote:

EMPIRE

Nuclear reaction code

- Coupled channels
- Pre-equilibrium

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Nancy Larson:

Resonance theory

- Neutron cross sections
  - Experimental data
  - Differential data – transmission, capture, absorption, fission etc
- SAMMY
  - Reich-Moore resonance representation
  - Scattering theory
  - Integral data

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

END OF FIRST WEEK

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Mike Herman:

RIPL (Reference Input Parameter Library)

Comprehensive databases for modeling calculations:

- Nuclear masses
- Optical model parameters
- Ground state deformation
- Discrete levels
- Decay schemes
- Fission barriers
- γ-ray strength functions
- Moments of inertia

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Mihaela Sin:

EMPIRE

Nuclear reaction code

- Fission channel

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Mike Herman/Mihaela Sin/Roberto Capote:

Yet more EMPIRE

+

Trouble shooting

(or what do you do when EMPIRE strikes back ?)

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Andrej Trkov/Otto Schwerer:

Nuclear data

Data services

- IAEA Nuclear Data Section
- Data retrieval
- Customer services

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Andrej Trkov (replacing Bob MacFarlane):

Nuclear data formats

- ENDF-B format (Evaluated Nuclear Data Files)
- NJOY – nuclear data processing system

  Converts evaluated data in ENDF-B format to useful forms for application(s):

  gas production, heating and radiation damage etc

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

YOUR PRESENTATIONS:

25 February 2004

14:00 to 17:30 hours

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

END OF SECOND WEEK

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Andrej Trkov:

More to NJOY

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Les Hutton:

WIMS

Reactor analysis

- Reactor lattice code for reactor physics calculations
- Predict reactor operational characteristics

  fuel depletion, reactivity feedback, fuel temperature, burn-up behaviour
- Continuous development – bringing up to date

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Reactor design, safety and applications:

- Desalination
- Fast reactor
- Accelerator-driven systems
- INPRO → innovative nuclear power reactors and fuel cycles
- Nuclear power plant simulators
- Research reactors
- NEA Data Bank → modeling tools for nuclear technology

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

END OF THIRD WEEK

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Vladimir Kagramanian:

Different energy sources

- Comparative assessment(s)
- Potential role(s)
- Sustainable energy mix

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Rejane Spiegelberg:

Operational performance of nuclear reactors

Nuclear Power Information System (PRIS)

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

YOUR PRESENTATIONS:

ADVANCED REACTORS

8 March 2004

14:00 to 17:30 hours

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

FACTS

- 440 commercial nuclear reactors operate in 31 countries (> 360,000 MWe)
- 16% of global needs
- Over 11,000 accumulated reactor-years experience of civil nuclear power
- 56 countries operate 280 research reactors ® neutron beams for research, and production of medical and industrial isotopes

BUT

- Fewer nuclear power plants being built than during 1970s/80s
- Only 3 new commercial reactors commissioned between 1997 and 2001
- Electrical output has increased over these same 5 years ® equivalent to output from 40 large nuclear plants

HOW ??

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

BETTER performance from EXISTING reactor units:

more efficient and safer operation

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

But problem of perception

Public stance - safety issues of concern when considering expansion of nuclear energy

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Next generation of reactors:

- More economic
- Safer
- Anti-proliferation
- Anti-diversion
- Reduced radiological risk
- Public acceptability

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

M Cumo:

Principles of nuclear safety

- Power reactor design and safety
- Present safety regulations
- Industrial requirements and standards

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Augusto Gandini:

Nuclear reactor analysis

- Power reactor operation
- Sensitivity theory
- Safe operational procedures based on continuous on-line monitoring

Innovative reactors

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Nunzio Burgio:

Monte-Carlo analysis techniques: theory and exercises

- Understand/use Monte-Carlo method
- Utilization in reactor calculations

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

Robert Jacqmin:

Analysis and correlation of experimental data

- Learn to exploit information contained in measurement campaigns
- Experimental reactors
- Research facilities

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

G Bruna:

Reactivity and power

- Control of PWRs

Recycling plutonium

Reactor design

- Monte-Carlo calculations

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

P Ravetto:

Reactor dynamics

Reactor kinetics and dynamic analysis

Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety

THE END