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COLLEGE ON MEDICAL PHYSICS
AND
WORKSHOP ON
NUCLEAR DATA FOR SCIENCE AND TECHNOLOGY:
MEDICAL APPLICATIONS
(20 SEPTEMBER - 15 OCTOBER 1999)

"Nuclear Data for Medical Applications"

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These are preliminary lecture notes, intended only for distribution to participants

Introduction to

Nuclear Data for Medical Applications

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Topics

- **General considerations**
- **Overview of data needs**
- **Development of data libraries**

Radioisotopes for Medical Applications

Use of Ra/Be-Source

1935 O. Chievitz, G. v. Hevesy
Phosphorous metabolism in rats (^{32}P)

1938 S. Hertz, A. Roberts, R.D. Evans
Physiology of thyroid (^{128}I)

Cyclotron Era

1937 J.G. Hamilton, R.S. Stone
Studies with ^{24}Na

1942 J.G. Hamilton, M.H. Soley
Therapeutic applications of radiophosphorous and radioiodine

1945 C.A. Tobias, J.H. Lawrence, F. Roughton
Inhalation of ^{11}Co

Reactor Era

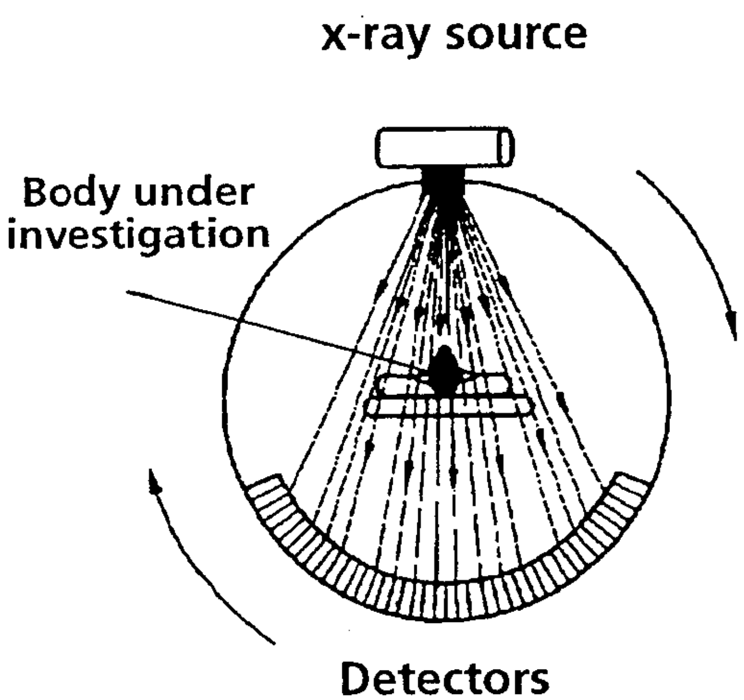
since 1946 Availability of many long-lived radioisotopes, e.g. ^{3}H, ^{14}C, ^{32}P, ^{60}Co, $^{125,131}I$ for
– In-vitro studies
– Biochemistry, Pharmacology, Therapy

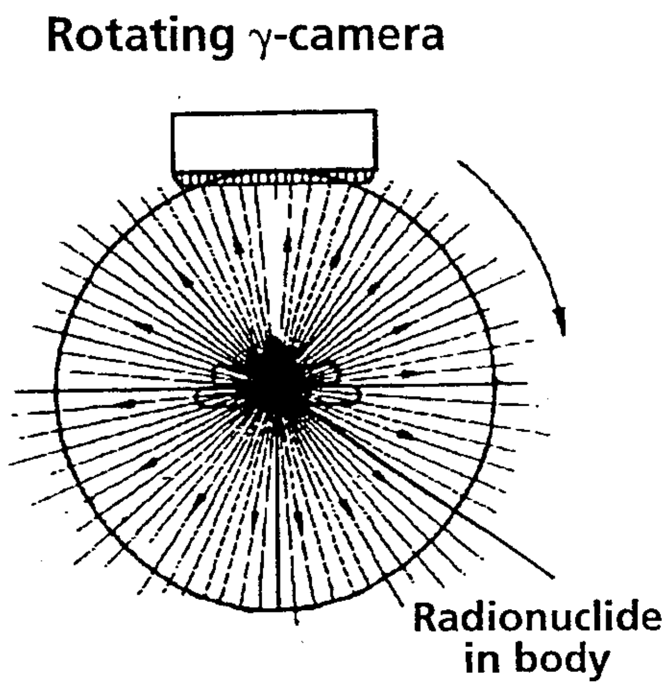
Renaissance of Cyclotron

since 1960 Production of large number of short-lived radioisotopes for in-vivo studies

Transmission Tomography

Emission Tomography



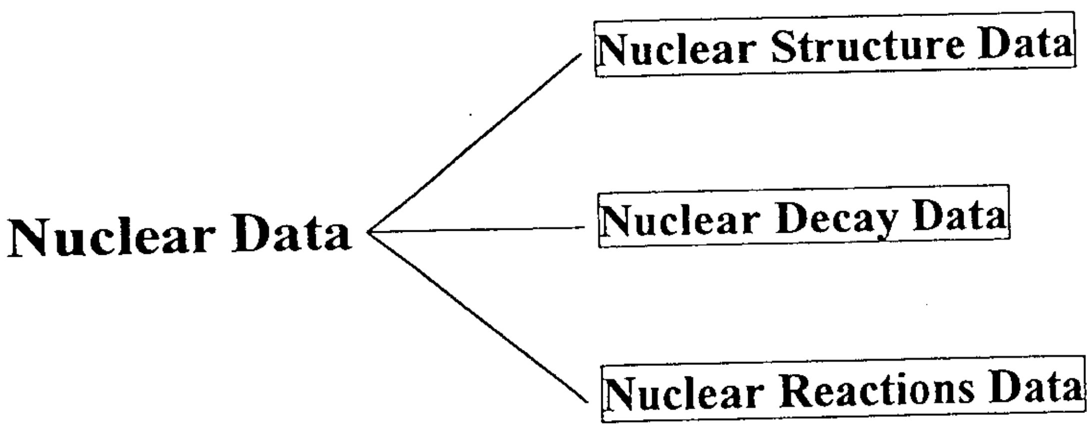


Medical Application of Radioisotopes

Factors Contributing to Recent Progress

- High intensity accelerators dedicated to radioisotope production
- New efficient nuclear routes
- Fast methods of labelling biomolecules with radioisotopes
- Progress in fast separation and purification methods (GC, HPLC etc.)
- Advances in radiopharmacology (tracer evaluation)
- Development of high-resolution emission tomographs (SPET and PET)

- **Term „Nuclear Data" very broad; encompasses interactions of nuclei as well as their properties**



Nuclear structure and decay data play an important role in the choice of a radioisotope for medical application and the reaction data in its production in a pure form

Medical Applications

- **Diagnosis**

via imaging techniques, mainly emission tomography

- choice of a radioisotope (decay data)
- production of the radioisotope in a pure form (reaction data)
- preparation of a suitable radiopharmaceutical (fast radiochemistry)

Radiation dose should be as low as possible

- **Therapy**

via external radiation

- reaction data and radiation transport calculations

via internal uptake

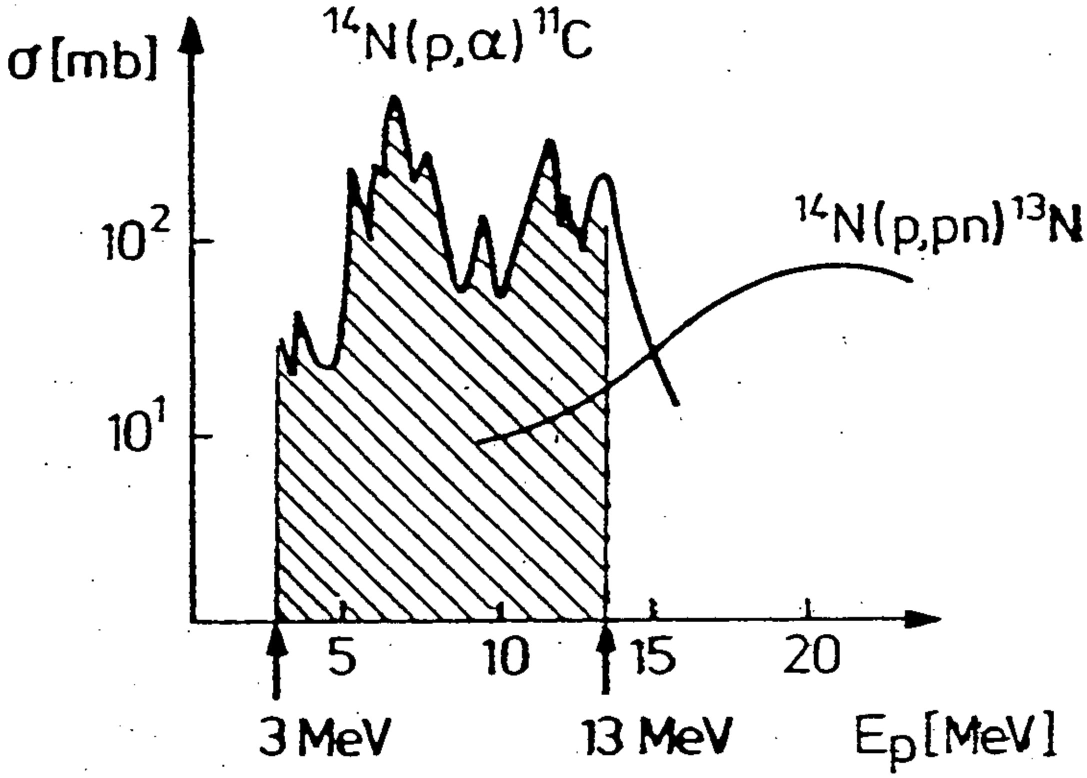
- nuclear decay data and pharmacokinetics

Radiation dose should be compatible with the therapy requirement

Importance of Nuclear Reaction Cross Section Data

- **Determination of optimum energy range of a production process**
- **Calculation of expected thick target yield of the radio-isotope to be produced**
- **Estimation of yields of radionuclidic impurities for a given thickness and enrichment of the target material**

Example: Production of ^{11}C via the $^{14}N(p,\alpha)$-Process



Optimum energy range:	$E_p = 13 \rightarrow 3$ MeV
^{11}C-yield:	103 mCi/μAh
^{13}N-impurity:	ca. 5 %

Significance of Decay Data

- **Data needed for radiation dose calculations**

  $\bar{D} = 2.13\,\bar{c} \sum_i n_i \bar{E}_i \Phi_i$

  where

  $\bar{c}$ = **cumulative concentration of activity** $(Bq.\frac{T_{eff}}{\ln 2} / kg)$

  n_i = **No. of emitted particles or photons per decay**

  $\bar{E}_i$ = **Average energy of the emitted radiation**

  Φ_i = **Part of the radiation absorbed in the organ**

  T_{eff} = **Effective half-life of the radioisotope in the organ**

- **Short-lived single photon and β^+ emitters preferred for diagnostic investigations**
- **Corpuscular radiation required in endotherapeutic studies**

Nuclear Data Measurements

Motivations

Production data

- Search for alternative routes of production
  - Constraint of available charged particle and energy
  - Demand for higher purity
- Development work on potentially important radioisotopes

Decay data

- **Removal of discrepancies and uncertainties, e.g.**
  - **β^+ branching in ^{120g}I**
  - **intensities of 135 and 167 keV γ-rays of ^{201}Tl**

Radiation Therapy

- Biological changes under the impact of radiation
- Of significance is linear energy transfer (LET) to tissue

Types of Therapy

- Photon therapy: use of linear accelerators
  (low-LET radiation)
- Fast neutron therapy: accelerators with $E_p > 50$ MeV
  (high-LET radiation)
- Proton beam therapy: accelerators with $E_p = 70 - 250$ MeV
  (treatment of deep-lying, rather resistant tumours)
- Heavy-ion beam therapy
  (rather specialized; limited application)
- Boron neutron capture therapy (BNCT):
  use of low energy neutrons
  (pharmacological problem: comparable to endotherapy)

Nuclear data required to

- calculate the absorbed dose at a point in the tissue
- optimize the design of the treatment delivery system

Data Needs (up to 250 MeV)

- Total and non-elastic cross sections
- Production yields and average energies of n, p, d, α, γ
- Double differential cross sections at various incident energies
- Excitation functions for the formation of radioactive products

Radioisotopes for Therapy

- Uptake of a radiopharmaceutical in tumour via physiological processes

An exact knowledge of energy and intensity of ionising radiation is crucial.

Interdisciplinary Nuclear Data Activities

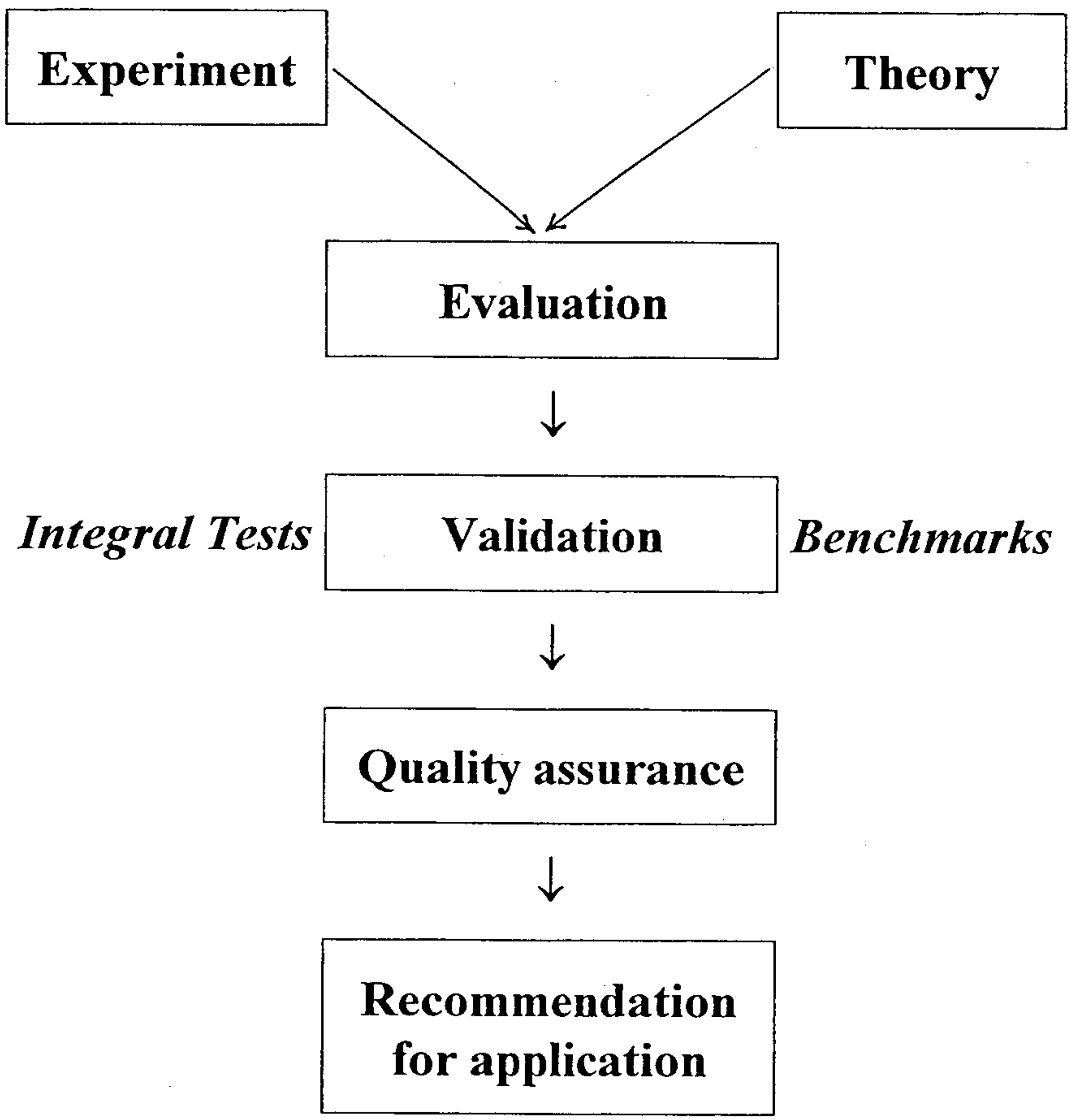
- **Experimental measurements**
  - On-line and off-line methods
  - Interdisciplinary techniques
  - Detailed description of experiment, uncertainties and their correlations

- **Compilations and evaluations**
  - Collection of data in a uniform format
  - Evaluations

    (Critical consideration of experimental parameters, standardization of data, development of systematics, use of nuclear models, construction of data files)

- **Nuclear theory**
  - Improvement of known models and parameters
  - Development of new models of high predictive values

Nuclear Data Development for Applications



Nuclear Data Centres

- NNDC, Brookhaven, USA
- OECD-NEA Data Bank, Paris, France
- IAEA Nuclear Data Section, Vienna, Austria
- Nuclear Data Centre, Obninsk, Russia

Other Smaller Groups

- Chinese Nuclear Data Centre, Beijing, PR China
- Japanese Nuclear Data Centre, Tokai Mura, Japan

International Co-ordinating Bodies

IAEA (INDC)

- Energy related applications
- Non-energy related applications

Functions

- CINDA
- WRENDA
- Training
- Coordinated Research Projects
- Limited Data Files

NEA (NSC)

- Energy related applications
- Spin-off effects of nuclear energy
- Nuclear sciences

Functions

- JEF
- Data Bank
- Conferences
- Monographs