united nations educational, scientific and cultural organization

international atomic energy agency

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international centre for theoretical physics

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

"Charged Particle Data - Compilation and Standardization"

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Charged particle data-compilation and standardization

(important data, status of nuclear data, literature sources, methods of selection and standardization, available databases)

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- **Main fields of the nuclear medicine**
- **Types of nuclear data**
- **Data needs for medical and connected applications**
- **Main parameters of nuclear reaction data**
- **Status of the CP reaction data**
- **Flow of measurement, processing and application of nuclear data**
  - **Data measurement**
  - **Compilation**
  - **Model calculation**
  - **Evaluation**
  - **Application**
- **CP reaction data for isotope production**
- **CP reaction data for beam monitoring**
- **CP reaction data for therapy**
- **CP reaction data for medical research**

Main fields of the nuclear medicine

- Diagnostics with radioisotopes(SPECT, PET)
- Radiotherapy with:
  external particles(X,γ,p,n,HI)
  radioisotopes
- Research(nuclear analytic, biological studies)
- Development of medical equipment(wear meas.)
- Sterilisation of medical equipments(radiation processing)
- Dosimetry, radiation safety(space radiation effects, accelerator shielding)

Nuclear data
Classification

Nuclear structure data (level schemes)
mass excess, energy, spin, parity, transition prob., life time, etc.

Nuclear decay data(decay schemes)
Decay mode, half- life, energies, intensities of the transitions, etc.

Nuclear reaction data
Cross sections, energy spectra of emitted particle, etc

Induced by: γ, p, n, HI

Differential or integral data

Nuclear data needs for medical and connected applications

Field of application	Type of nuclear data		
	Decay	Reaction	Structure
Diagnostics			
SPECT	yes	yes	(th)
PET	yes	yes	(th)
Therapy			
endo	yes	yes	(th)
tele			
X	no	no	no
γ	yes	yes	(th)
e	yes	yes	(th)
p	yes	yes	(th)
n	yes	yes	(th)
HI	yes	yes	(th)
Others	yes	yes	(th)

Nuclear data
The nuclear data needs

Neutron therapy

- **Primary and secondary charged particle spectra for calculations of absorbed dose during the treatment**
- **Physics of neutron sources used for therapy**
- **Collimation and shielding**
- **Improvement the neutron transport calculation**
- **Kerma factors for the neutrons and partial and total cross sections for biological important elements (scattering cross sections,(n,x), (n,α) cross sections)**

Nuclear data
The nuclear data needs

Proton and heavy ion therapy

Mainly atomic data

- **Secondary charged particle spectra for calculations of absorbed dose during the treatment**
- **Collimation and shielding**
- **Kerma factors for the CP and partial and total cross sections for biological important elements**
- **Activation products in tissue**

Nuclear data
The nuclear data needs

Medical isotope production

- Reaction cross sections
- Production yields
- Shielding
- Dose calculation

Nuclear data
The nuclear data needs

Other applications(analitics, research)

- Reaction cross sections
- Production yields
- Shielding
- Dose calculation

Nuclear data
Main parameters of nuclear reaction data

- Total cross sections
- Partial cross sections
- Differential data
- Integral data
- Secondary particle spectra
- Isotopic data
- Elemental data
- Production yields
- Activation data, residual activities
- Direct , cumulative

Status of the CP reaction data

- Lack of data for many reactions
- Existing data are scattered and contraversary
- Inconsistencies
- Measured data are not allow to do proper evaluation
- Very few compilation
- Very evaluation
- Very few recommended data
- Very few standard data
- Comparison with the neutron induced reaction data
- Reason of the poor data base

Flow chart of measurement, processing and application of nuclear data

- **Data measurement**
- **Compilation**
- **Critical analysis**
- **Selection**
- **Model calculation**
- **Evaluation**
- **Application**

See Fig.

Sources of nuclear data

Experiment

Differential measurements are the primary source on which applications have to be based.

Integral data play important role in validating differential results and large number of different medical applications

Differential and integral have relative meanings

Experimental systematics

Systematics empirical formulas, graphs are important to predict unknown experimental data or to "validate" model calculations

Model calculations

Nuclear theory based model codes are important

for:

Prediction of unknown data

Inter and extrapolation

where:

large amount of data needed

experiment is difficult

Data evaluation

Before being used in applications, the experimental and theoretical data must pass through an evaluation stage:

Detailed compilation and critical review of experimental and theoretical data to make the necessary corrections and to select the best data.

Derivation of preferred values by appropriate combination of different processes(fitting, theory, systematics).
Recommended data are generated different way
In dependence of the available experimental data, on the capability of the model codes, on the requested accuracy of the application.

Main steps of the evaluation:

Evaluation of experimental data

- **Collection**
- **Data analysis**
- **Comparison**
- **Correction**
- **Analysis of existing model results and syst.**
- **New measurements**
- **Critical assessment and selection**

Experimental data processing

Data fit

- **Legendre polynomials**
- **Orthogonal polynomials**
- **Spline functions**
- **Rationale functions**
- **Fitted model results**
- **Eye guide**

Experiment based model calculations

Different models, different capabilities for different parameters for different energy ranges

Adjusted model input parameters to agree with experimental results

Main steps of the evaluation

Collection of experimental data

Scientist, specialist in the field!!!

Collection

- **Full use of all available data**
- **Importance of original publications**
- **Database bibliography**

Data analysis

- **Method of measurements**
- **Experimental technique**
- **Error calculation**
- **Nuclear data**
- **Laboratory**
- **Definitions**
- **Purpose**
- **Data evaluation**

Correction

- **Correction according to new standard data**

Comparison

- **The data are plotted to compare with other experimental results**

Analysis of existing model results and syst.

- **For orientation(threshold, magnitude, shape)**

New measurements

- **Dedicated, in case of necessity**

Main steps of the evaluation

Critical analysis and selection

Necessary corrections, if the data important and the correction is reasonable

Single and simultaneous evaluation and selection process

Equal weight selection or deselecting of minority data sets

Normalisation of systematically shifted data to fill the gaps

Typical problems

Main steps of the evaluation

Experimental data processing

Data fit

Legendre polynomials

Orthogonal polynomials

Spline functions

Rationale functions

Fitted model results

Eye guide

Problems

Realistic uncertainties

Covariences

Scattered points

Not existing resonances

Existing resonance

Energy scale problems

Main steps of the evaluation

Nuclear reaction theory and model calculations

Application field:

Many CPND to evaluate
Very difficult to measure
Unpredictable time delay
Expensive, manpower

Apriory model calculations

To show the tendencies
To filter the contraversary data
To make more realistic estimations
To make quick estimations

Very limited accracy,"approximatelly"

Models with appropriate parameters based on experimental data

The present power:

- For extrapolation and interpolation of experimental data
- To predict unknown nuclear data like cross section, angular and energy distribution, double differential cross sections
- To check inconsistencies between measurements

Fields of CPND evaluations

- **Calculations and evaluations for protons and HI for radiotherapy**
- **Evaluation for medical radioisotope production**
- **Evaluation for CP beam monitoring**
- **Evaluation of intermediate nuclear data for waste transmutation**
- **Evaluation of nuclear reactions for wear measurement(TLA)**
- **Evaluation of CP nuclear reactions for fusion**

Few remarks

Success of theory depend on, what to predict
Total cross section
Residual cross section

Preevaluation, exp., final evaluation

Overlapping of different evaluations
Co-ordination of compilation and evaluation

To keep the data base in good shape, continuos evaluation

Format of evaluated data file
Electronic, not hardcopy

Different weight of different application (isotope production, therapy)

Weight of different evaluations
Broad application

Methods of compilation of data base for CRP on " CRP data for medical isotope production"

- The program
- Participating institutes
- List of reactions
- Compilation : sources and methods
- New measurements
- Critical selection
- Fitting of experimental data
- Model calculations
- Recommended data
- Data

Cf. examples

CPD comp. and standardization(F. Tárkányi, Trieste, 1999)

List of participating laboratories

No	Institution	Investigator	Profile
1	Free University Brussels, Belgium	A. Hermanne	compilation, selection, experiment
2	CNDC Beijing, China	Zhuang Youxiang	theory, calculation, fitting
3	INC Forschungszentrum Julich, Germany	S. M. Qaim	compilation, selection, experiment
4	INR HAS Debrecen, Hungary	F. Tárkányi	compilation, selection, experiment, fitting
5	NAC Faure, South Africa	M. Nortier, (H. Mills)	compilation, selection, experiment
6	IPPE Obninsk, Russia	Yu. Shubin	theory, calculation, fitting
7	LLNL Livermore, USA	M. Mustafa, (M. Blann)	theory, calculation, fitting

Status	Nuclear reaction	Responsible for compilation	Available data	New measurement	Selected data
Production reactions for diagnostic radioisotopes					
Diagnostic gamma emitters					
	$^{67}Zn(p,n)^{67}Ga$	Atomki	11	Hermanne et al. (1999)	8
	$^{68}Zn(p,2n)^{67}Ga$	Atomki	10	Hermanne et al. (1999)	8
	$^{82}Kr(p,2n)^{81}Rb$	Faure	3		3
	$^{nat}Kr(p,x)^{81}Rb$	Faure	7		3
	$^{111}Cd(p,n)^{111}In$	Atomki	10		10
	$^{112}Cd(p,2n)^{111}In$	Atomki	4		4
	$^{123}Te(p,n)^{123}I$	Atomki	7		7
	$^{124}Te(p,2n)^{123}I$	Atomki	5		3
	$^{124}Te(p,n)^{124}I$	Atomki	8		2
	$^{127}I(p,5n)^{123}Xe$	Faure	9		7
	$^{127}I(p,3n)^{125}Xe$	Faure	10		8
	$^{124}Xe(p,2n)^{123}Cs$	Julich	2		2
	$^{124}Xe(p,pn)^{123}Xe$	Julich	2		2
	$^{203}Tl(p,3n)^{201}Pb$	VUB	8		4
	$^{203}Tl(p,4n)^{200}Pb$	VUB	6		4
	$^{203}Tl(p,2n)^{202}Pb$	VUB	4		4
Diagnostic positron emitters					
	$^{14}N(p,\alpha)^{11}C$	Julich	10		9
	$^{16}O(p,\alpha)^{13}N$	Julich	11		10
	$^{15}N(p,n)^{15}O$	Julich	5		5
	$^{14}N(d,n)^{15}O$	Julich	9	Szucs et al. (1997)	5
	$^{18}O(p,n)^{18}F$	Julich	7		1
	$^{20}Ne(d,\alpha)^{18}F$	Julich	3	Fenyvesi et al. (1997)	3
	$^{69}Ga(p,2n)^{68}Ge$	VUB	3		2
	$^{nat}Ga(p,x)^{68}Ge$	VUB	3		2
	$^{85}Rb(p,4n)^{82}Sr$	Faure	3		2
	$^{nat}Rb(p,x)^{82}Sr$	Faure	3		1

CPD comp. and standardization(F. Tárkányi, Trieste, 1999)

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