1st meeting

of the CLUSTER for BASIC STUDIES FOR TRANSMUTATION

1st BASTRA meeting

DECEMBER 5, 2001

CERN, GENEVA, SWITZERLAND

VOLUME III

First meeting of the Basic Studies for Transmutation
BASTRA Cluster
HINDAS / n_TOF-ND-ADS / MUSE / ISTC / OECD-NEA

Date: **Wednesday 5 December 2001**; *Place:* **CERN, Geneva, Switzerland**
BUILDING: **864 (Lab 2; Prevessin/F)**

Chairman: V. Bhatnagar; Co-chairman: P. Pavlopoulos

08:30	**Welcome, Introduction and Approval of the agenda**	**V. Bhatnagar**
08:50	**Presentation of the HINDAS Project (10'')**	**J.-P. Meulders**
	Experimental program from 20MeV to 200MeV (20")	**N. Olsson**
	Experimental program from 200 MeV to 2 GeV (20")	**K.H. Schmidt**
	Theoretical program (20")	**J. Cugnon**
10:05	*Coffee Break*	
10:25	**Presentation of the n_TOF-ND-ADS Project** (15")	**P. Pavlopoulos**
	The CERN Neutron TOF Beam (15")	**A. Zanini**
	Experimental Set-up & Preliminary Results (20")	**E. Gonzalez**
	Required Precision and Priority List of Elements (10")	**Y. Kadi**
	ND Evaluation & Modelling (15")	**H. Leeb**
11:40	**Presentation of the MUSE Project**	**R. Soule + W. Gudowski**
12:15	**Presentation from the Nuclear Data bank NEA/OCDE (Paris)** The Route from Experiment to Evaluation	**M. Kellett**
12:50	*Lunch*	
14:00	**Presentation of the n_TOF ND Evaluation Network**	**W. Furman**
14:15	**Presentation of the ISTC projects on Nuclear Data**	**15'' each**
	#B70: Transmutation of LLFP and MA in a Sub-critical Assembly Driven by a Neutron Generator	**S. Chigrinov**
	#1309: p- and n-induced X-sections of Pb and Neighbouring Nuclei in 20-200 MeV Region	**N. Olsson + S. Yavshits**
	#1372: Radiochemical and Activation Analysis of LL Nuclear Waste Transmutation in FR and Accelerators	**Y. Shubin**
	#1971 : n-Induced Fission X-section of Pu240, AM243 and W in the Range of 1-200 MeV	**A. Laptev**
	#2002 : Yields of Residual Products in Thin Pb and Bi Targets by 40-2600 MeV Protons	**V. Batyaev**
15:30	*Coffee Break*	
15:50	***Discussion on the needs of nuclear data studies for ADS and coverage by FP5 and other projects***	**Animated by P. Pavlopoulos**
17:30	***Actions to be taken***	
18:00	**Close of the meeting**	

List of participants BASTRA Kick-off meeting at CERN, December 5, 2001

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EXECUTIVE SUMMARY (Short Minutes)

<u>Extract from Ved Bhatnagar's Mission report (internal)</u>

The meeting proceeded with brief presentations of the three projects: HINDAS, n_TOF_ND_ADS and MUSE. In each case, the co-ordinators briefly outlined the objectives and scope of the work to be carried out in their projects followed by presentations made by work package leaders on the tasks that they are responsible for. Presentations were also made by 5 ISTC projects in this area including the one from Nuclear Data Centre at NEA. The aim of the discussion during and after the presentations was to highlight the issues that are of importance for nuclear data needs for an ADS and in particular the ones that are not being addressed in the presently running FP5 projects.

The main points of the discussion can be summarised as follows (Partially based on the slide that Noulis Pavlopoulos presented in the discussion)

- The Commission's initiative of clustering of related FP5 projects and facilitating exchange of information was highly appreciated. It was more so for the BASTRA cluster as not only the FP5 projects but also the ISTC related projects and OECD/NEA participation made the meeting more valuable.

- The nuclear (cross section) data bank at NEA/OECD is dealing with all kinds of cross section data, for all kinds of isotopes, in all energy ranges and for all kinds of applications. This has lead to a mammoth job which is becoming somewhat unwieldy and puts people off.

- It was suggested that the BASTRA cluster focus on the specific needs of nuclear cross section data for Accelerator Driven Systems for P&T. This implies reiterating (some information is already available from NEA) and listing the (Z,A) of the isotopes, nuclear reaction mechanisms and the energy range for which this data is required.

- There is a need to review and take stock of the situation of the data that already exist, the data that is being acquired and planned during the present FP5 and other projects on nuclear data. This would culminate in defining properly the future needs and efforts required in this direction. A sub group is proposed to be set up to work it out and for reporting (see below).

- It was suggested that the input data should have to be filtered by a quality control system (or criteria) before it is accepted for dissemination via the Nuclear Data for ADS (NUDADS) databank (name coined by myself!) possibly managed by NEA/OECD. The quality control parameters should be defined and may include $\Delta E/E$, precision, completeness parameters etc.

- There should be more complete horizontal activities relating to interactions between authors of different theoretical models including transport codes so that they can sort out the reasons for discrepancies among different evaluations that are accepted in the dedicated ADS database. In this context, source codes should be made available to other with due care of IPRs.

- There should be collaborative efforts so that specialists in certain areas or those implementing specialised techniques may also perform tests or measurements on samples coming from other institutions.

- Efforts should be made via financing of the fellowships such as Marie Curie or others so that young scientists are attracted to the field of nuclear data evaluation as veteran scientists become unavailable through natural wastage.

- It is proposed to establish several subgroups (2 or 3 persons each) which will report back to the cluster chairman on certain specific topics such as: (a) ADS designers' requirements for the nuclear data, (b) Sensitivity studies on nuclear cross section data, (c) Overlap of work being done at FP5 and ISTC projects in nuclear data, (d) Theoretical models etc.

The next meeting of the cluster is informally proposed (to be confirmed) to take place in Uppsala, Sweden on 13/14 September 2002 together with the progress meeting of HINDAS project.

The route from experiments to evaluation

M. Kellett and A. Nouri
OECD Nuclear Energy Agency

Outline

- Data dissemination via the NRDC and EXFOR
- What should an Evaluation contain?
- Experimental needs and choices
- U-235 as an example of an evaluation
- The ENDF-6 format
- Nuclear models and processing codes

Nuclear Reaction Data Centres

- Main Four Data Centres are:

  NEA Data Bank, Paris

  NNDC Brookhaven National Lab, USA

  NDS International Atomic Energy Agency, Vienna

  CJD Obninsk, Russia

- Also includes:

  JNDC and JAERI, Japan

  CNDC, China and KAERI, Korea

  and a number of other specialised centres in Russia

Areas of common interest

- **CINDA**
- **EXFOR**
- Evaluated libraries,

  JEFF, ENDF/B, JENDL,

  BROND, CENDL, etc.
- Database design and software
- Web retrieval interfaces and visualisation
- User services

EXFOR

- Co-ordination of compilation

  coverage of world-wide publications;

  neutron induced data "complete",

  charged particle being added retrospectively
- Discussion on coding rules/formats

  in order to maintain clarity for the user
- Checking of entry preparation prior to distribution, via NDS Vienna ftp site

EXFOR Data Format

- **ASCII** format for ease of transfer between systems
- Flexible coding of reactions
- Basic and computational format
- Use of first bibliographic **SUBENTRY** followed by data containing **SUBENTRIES**

```
ENTRY            10267     860620                                  10267000     1
SUBENT        10267001     860620                                  10267001     1
BIB                 11         56                                  10267001     2
INSTITUTE  (1USAORL)                                               10267001     3
REFERENCE  (J,NSE,59,79,7602)                                      10267001     4
           (J,ANS,15,481,7206)                                     10267001     5
           (W,GWIN,7611) FINAL CROSS SECTION DATA.                 10267001     6
           (W,GWIN,7504) REVISIONS AND ADDITIONAL DATA.            10267001     7
AUTHOR     (R.GWIN,E.G.SILVER,R.W.INGLE,H.WEAVER)                  10267001     8
TITLE      MEASUREMENT OF THE NEUTRON CAPTURE AND FISSION CROSS    10267001     9
           SECTIONS OF 239-PU AND 235-U, 0.02 EV TO 200 KEV, THE   10267001    10
           NEUTRON CAPTURE CROSS SECTIONS OF 197-AU, 10 TO 50 KEV,10267001    11
           AND NEUTRON FISSION CROSS SECTIONS OF 233-U, 5 TO       10267001    12
           200 KEV.                                                10267001    13
FACILITY   (LINAC) OAK RIDGE ELECTRON LINEAR ACCELERATOR           10267001    14
INC-SOURCE (PHOTO) PHOTONEUTRONS. ENERGY DEPENDENCE OF NEUTRON     10267001    15
            FLUX MEASURED USING B-10 (N,ALPHA) REACTION AND ITS    10267001    16
            ENERGY DEPENDENCE AS GIVEN IN ENDF/B-III MAT=1155      10267001    17
            EVALUATION.                                            10267001    18
METHOD      DIRECT DETECTION                                       10267001    19
           (COINC)  COINCIDENCE COUNTING                           10267001    20
DETECTOR   (SCIN) LIQUID SCINTILLATION DETECTOR                    10267001    21
           (FISCH) FISSION CHAMBER                                 10267001    22
ERR-ANALYS  THE UNCERTAINTIES SHOWN ON THE DATA ARE STANDARD       10267001    23
            DEVIATIONS AND REPRESENT THE PRECISION OF THE          10267001    24
            EXPERIMENTS AND THEIR ANALYSIS AND DO NOT              10267001    25
            INCLUDE SYSTEMATIC ERRORS. THE PRECISION WAS           10267001    26
            ...
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...
           THE NEUTRON FLUX. THIS IS 4.0PER-CENT ABOVE 80.KEV.TO 10267001   35
           THESE MUST BE ADDED ERRORS IN THE NEUTRON CROSS-      10267001   36
           SECTIONS USED FOR NORMALIZATION AND THE ENERGY        10267001   37
           DEPENDENCE OF THE B-10(N,ALPHA) CROSS-SECTION. FOR THE10267001   38
           VALUE OF ALPHA(CAPTURE-FISSION RATIO) A FRACTIONAL    10267001   39
           UNCERTAINTY EQUAL TO(0.02*(1.0+ALPHA)/ALPHA) SHOULD BE10267001   40
           COMBINED WITH THE PRECISION ERRORS IN THE DATA TABLES.10267001   41
           ERRORS IN THE CAPTURE CROSS-SECTION SHOULD BE OBTAINED10267001   42
           FROM THE COMBINED ERRORS IN THE FISSION CROSS-SECTION 10267001   43
           AND ALPHA. THE ERROR IN THE RATIO OF NEUTRON CROSS-   10267001   44
           SECTIONS INCLUDED AN UNCERTAINTY OF 0.5PER-CENT FOR   10267001   45
           THE NORMALIZATION OF EACH ISOTOPE, 1.0PER-CENT FOR    10267001   46
           THE U-235 FISSION CROSS-SECTION AT THERMAL ENERGY AND 10267001   47
           0.5PER-CENT FOR THE PU-239 FISSION CROSS-SECTION AT   10267001   48
           THERMAL ENERGY. A 1.0PER-CENT ERROR IS ASSUMED IN THE 10267001   49
           U-233 FISSION CROSS-SECTION NORMALIZATION.            10267001   50
STATUS    (APRVD) APPROVED BY R.GWIN 79/2/13.                    10267001   51
HISTORY   (721209C)                                              10267001   52
          (750422A) BIB CHANGES                                  10267001   53
          (760520A) DATA UPDATED AND ADDED                       10267001   54
          (770201U) CORRECTED VOLUME NO. IN MAIN REFERENCE.      10267001   55
          (781205A) CONVERTED TO REACTION FORMALISM.             10267001   56
                    BIB CORRECTIONS.                             10267001   57
          (860620A) BIB UPDATE.                                  10267001   58
ENDBIB              56                                           10267001   59
NOCOMMON             0          0                                10267001   60
ENDSUBENT           59                                           102670019999
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SUBENT        10267006     781205                                 10267006    1
BIB                  3          3                                 10267006    2
REACTION   (92-U-235(N,F),,SIG,,AV)                               10267006    3
STATUS     (DEP,10267024)                                         10267006    4
HISTORY    (781205A) DATA FROM 20-100 KEV DELETED, SEE 10267030.  10267006    5
ENDBIB               3                                            10267006    6
NOCOMMON                                                          10267006    7
DATA                 4         20                                 10267006    8
EN-MIN     EN-MAX     DATA       DATA-ERR                         10267006    9
KEV        KEV        B          B                                10267006   10
0.1        0.2        20.47      0.17                             10267006   11
0.2        0.3        19.74      0.07                             10267006   12
0.3        0.4        12.75      0.04                             10267006   13
0.4        0.5        13.12      0.09                             10267006   14
0.5        0.6        14.66      0.09                             10267006   15
0.6        0.7        11.11      0.09                             10267006   16
...
2.0        3.0        5.14                                        10267006   21
3.0        4.0        4.58                                        10267006   22
4.0        5.0        4.08       0.06                             10267006   23
5.0        6.0        3.72       0.05                             10267006   24
6.0        7.0        3.14       0.02                             10267006   25
7.0        8.0        3.05       0.03                             10267006   26
8.0        9.0        2.88       0.01                             10267006   27
9.0        10.0       3.01       0.01                             10267006   28
10.0       20.0       2.46       0.03                             10267006   29
100.0      200.0      1.49       0.02                             10267006   30
ENDDATA             22                                            10267006   31
ENDSUBENT           30                                            102670069999
```

EXFOR Reaction coding

- Reaction - 92-U-235(N,F), (N,XN), (P,XN)...
- Cross section data - SIG
- Differential data - DA, DE, DA/DE
- Fission product yield - FY
- Others - NU, ETA, EN, WID etc...

EXFOR Compilation- How it works

- Readers/compilers in the NRDC “find” articles, by scanning journals/publications
- Bibliographic information is added and tabulated data if shown, otherwise
- Data extraction from figures:
  - Recent publications: author contacted for tabulated data
  - Older publications are digitically scanned

Data Storage and Retrieval

- NEA uses Oracle relational database for:
  CINDA, EXFOR and EVALUATED data
  allows use of Perl scripts with SQL for retrieval/loading
- NEA uses Perl/CGI for online access:
  gives direct communication between WWW and Oracle,
  EXFOR online plotting using JavaScript in place,
  JEF-PC re-design will allow ~full visualisation capabilities,
  beta test version of JANIS available now

Conclusions - EXFOR

- EXFOR/CINDA give access to world-wide experimental data
- CINDA allows quick access to find references
- EXFOR gives complete information on the experiment and its results
- EXFOR gives information essential to the evaluation/validation process of nuclear data files, but updates can sometimes be delayed

What should an evaluation contain?

- An evaluation should contain all nuclear data needed to perform transport calculations (fixed source or eigen value), depletion calculation… for the entire energy range
  - cross-sections
  - energy distributions
  - angular distribution
  - activation x-s
  - γ production
  - Decay data, Fiss.yields

What goes into an evaluation?

- Experimental data are a necessary input (direct input or from benchmarks) but not sufficient
- Model codes are extensively used:
  - to parameterize the data (resonance range)
  - to predict data (above URR)

The need for different experiments

- Different flight paths
- Different sample thicknesses (case of resonance structure)
- Transmission/Capture/Fission/multiplicity energy-angle correlations
- Possibly at low temperature (Doppler)

Choice of experimental data

- The evaluator has fragmented measurements performed under different experimental conditions:
  - experimental results are not always consistent (normalisation problems)
  - experimental data do not cover the whole energy range and do not contain information on all processes

U-235 experimental datasets

- The following slides show the datasets available for the recent U-235 fission cross section evaluation work
- Datasets do not generally cover the complete range in energy
- In some cases there are more than one dataset for the same or overlapping energy ranges
- The evaluation process takes these datasets as a starting point to produce one reduced set of data, assumed to be the best normalised average of all those available
- The last plot shows the experimental datasets with the final evaluation (plotted in purple)

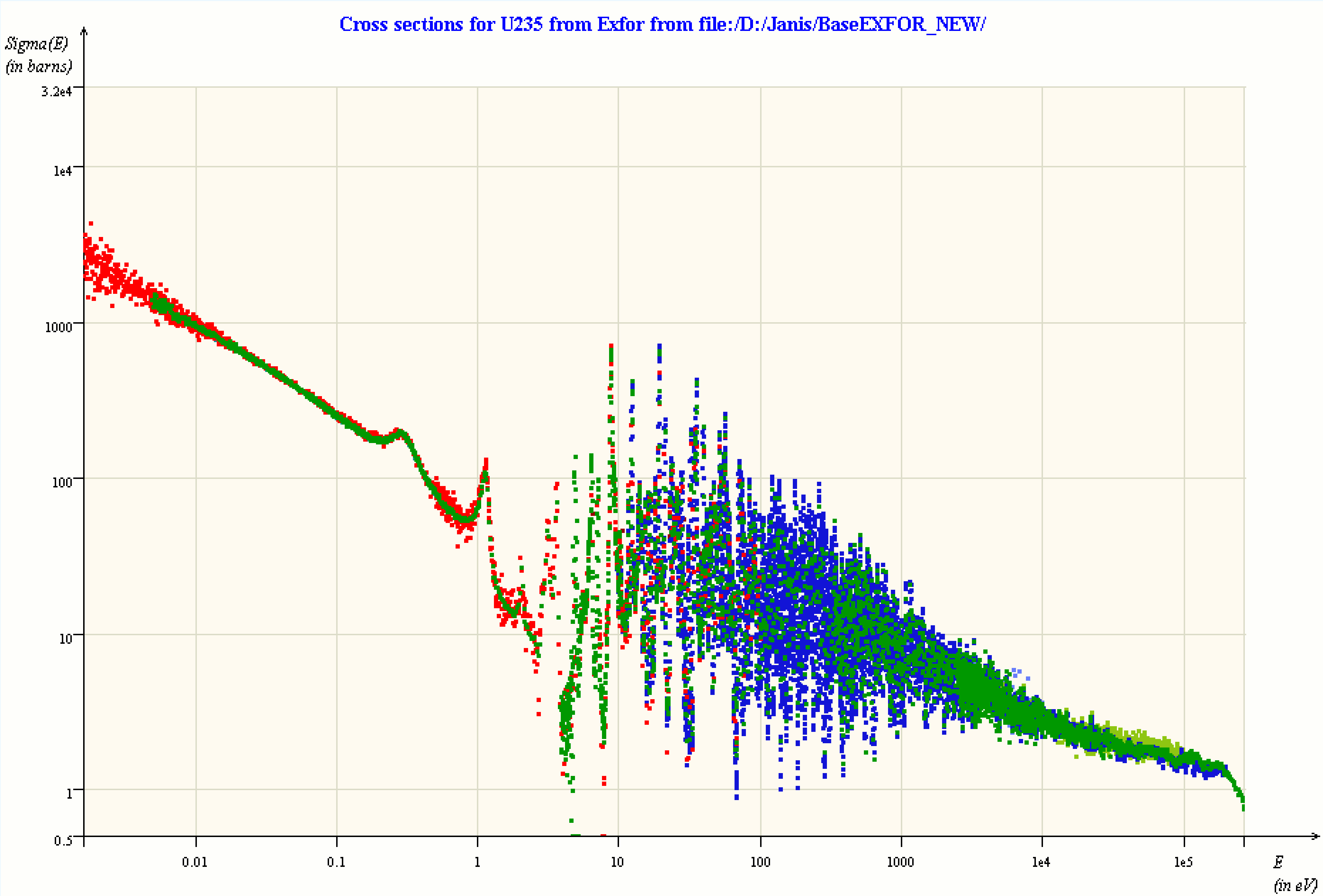
U-235 evaluation ($\leq$ 2.25 keV)

- Transmission data of Harvey et al. on the ORELA 18-meter flight path, with sample thickness of 0.03269 atoms/barn, cooled to 77 K (0.4 to 68 eV).
- Transmission data of Harvey et al. on the ORELA 80-meter flight path, with sample thickness of 0.00233 atoms/barn, cooled to 77 K (4 to 2250 eV).
- Transmission data of Harvey et al. on the ORELA 80-meter flight path, with sample thickness of 0.03269 atoms/barn, cooled to 77 K (4 to 2250 eV).

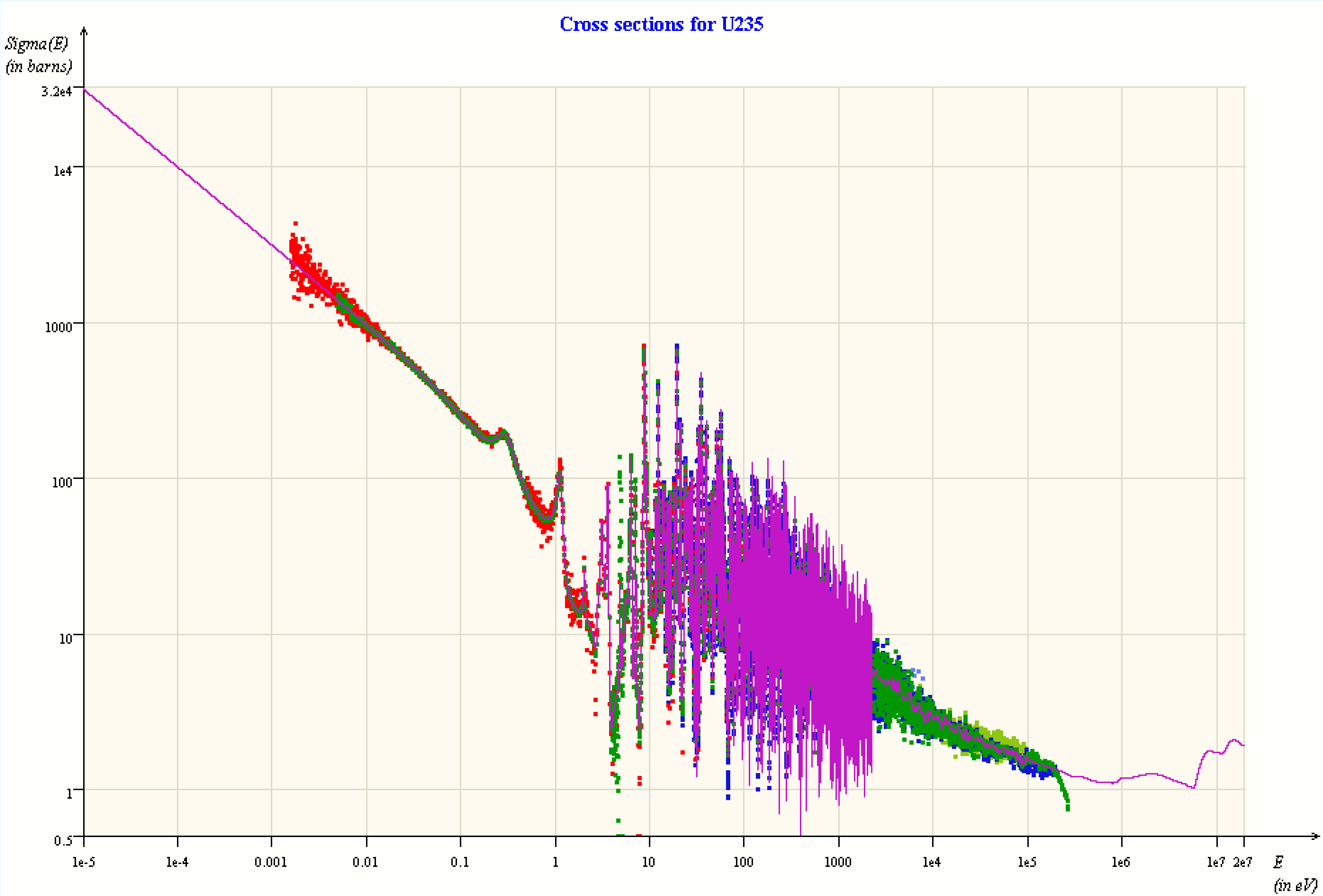
U-235 evaluation ($\leq$ 2.25 keV)

- Fission data of Schrack on the RPI Linac at 8.4-meter flight path (0.02 to 20 eV).
- Fission data of Wagemans et al. on the Geel 18-meter flight path (0.001 to 1.0 eV)
- Fission and capture data of Perez et al. on the ORELA 39-meter flight path (0.01 to 100 eV).
- Eta data of Weigmann et al (0.0015 to 0.15 eV).
- Absorption and fission data of Gwin at ORELA (0.01 to 4.0 eV).

Cross sections for U235 from Exfor from file:/D:/Janis/BaseEXFOR_NEW/
Sigma(E)
(in barns)
3.2e4
1e4
1000
100
10
1
0.5
0.01
0.1
1
10
100
1000
1e4
1e5
E
(in eV)



Cross sections for U235 from Exfor from file:/D:/Janis/BaseEXFOR_NEW/
Sigma(E)
(in barns)
3.2e4
1e4
1000
100
10
1
0.5
0.01
0.1
1
10
100
1000
1e4
1e5
E
(in eV)

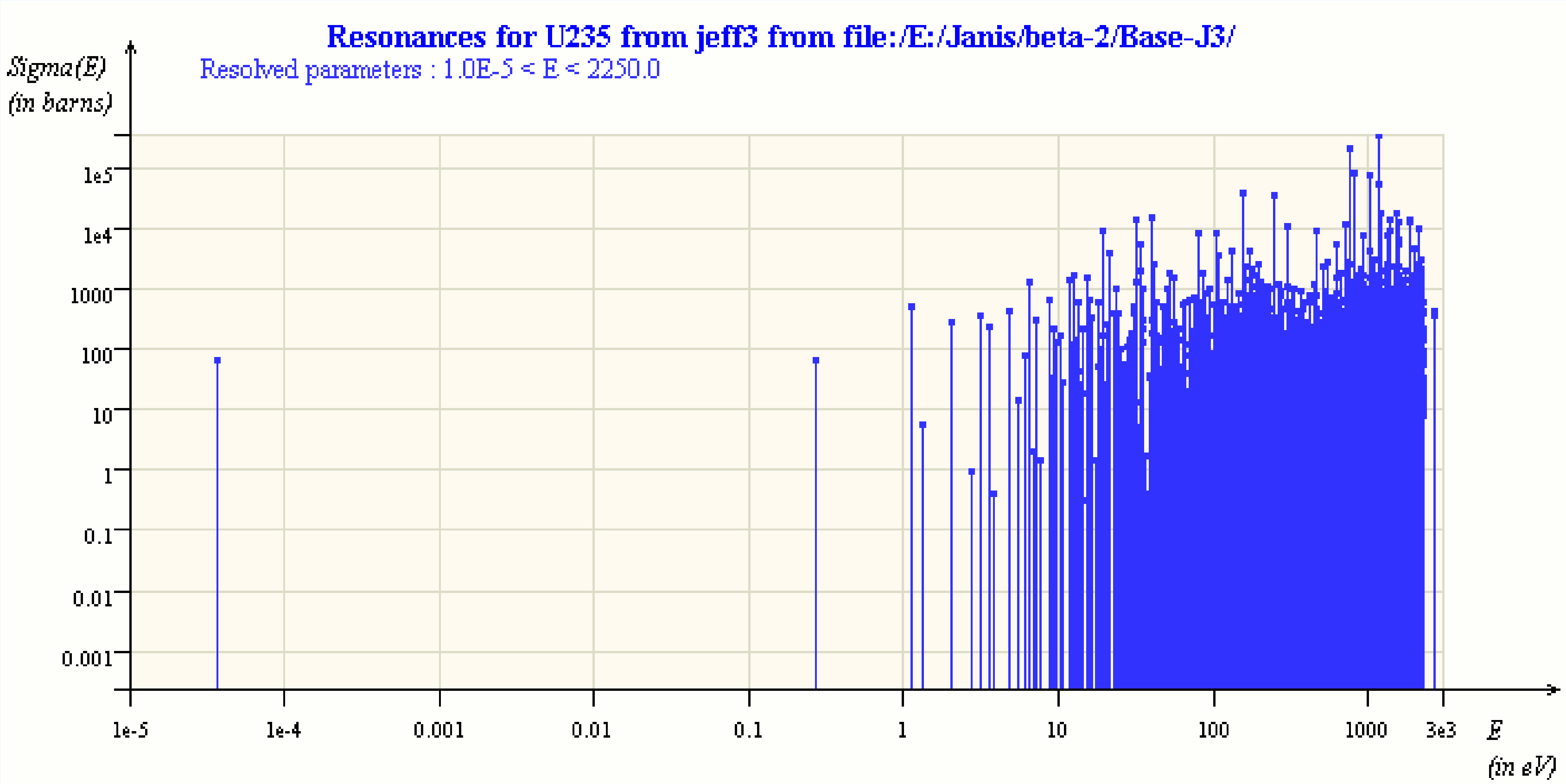


Cross sections for U235
Sigma(E)
(in barns)
3.2e4
1e4
1000
100
10
1
0.5
1e-5
1e-4
0.001
0.01
0.1
1
10
100
1000
1e4
1e5
1e6
1e7
2e7
E
(in eV)

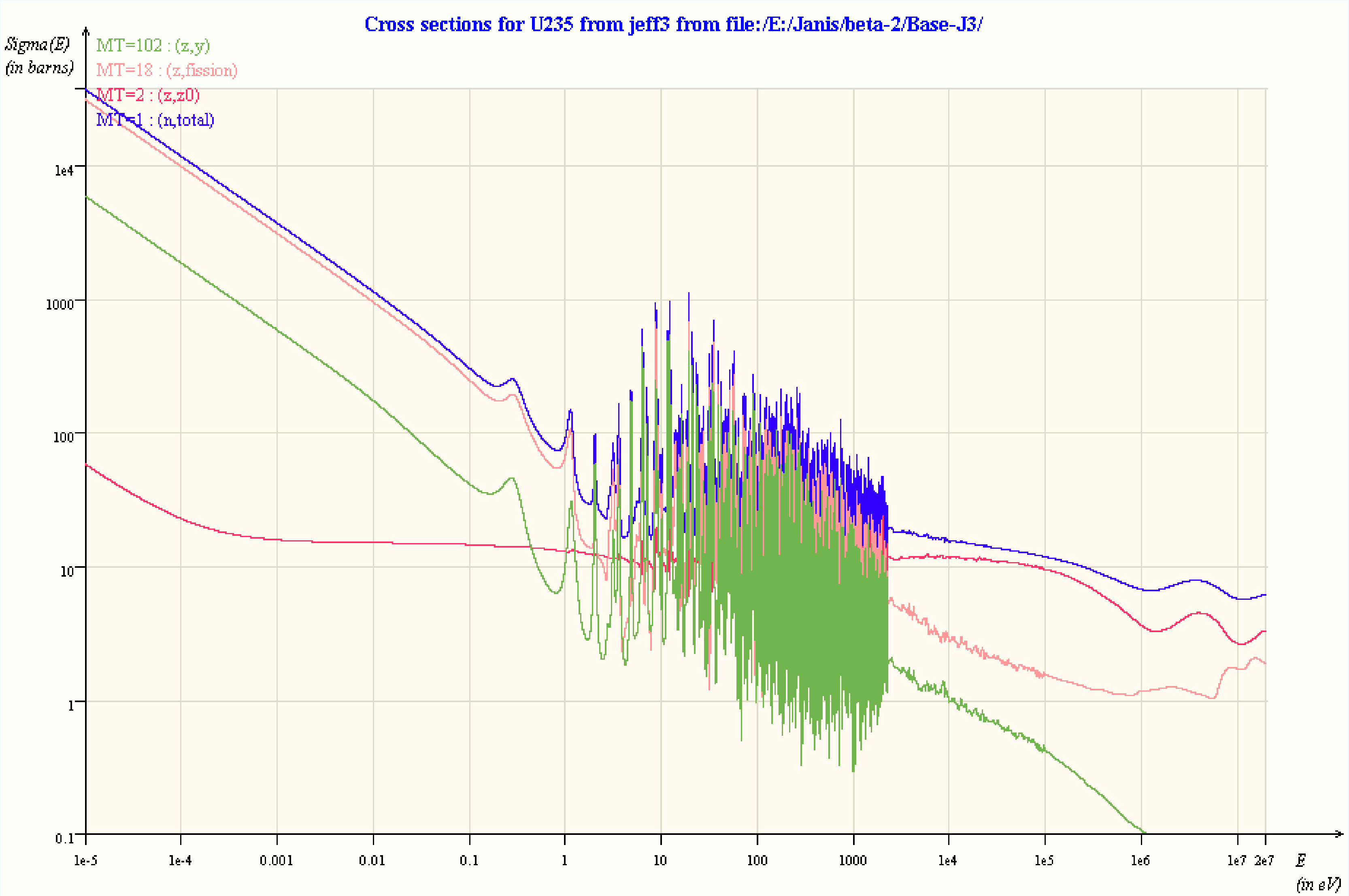
Data analysis

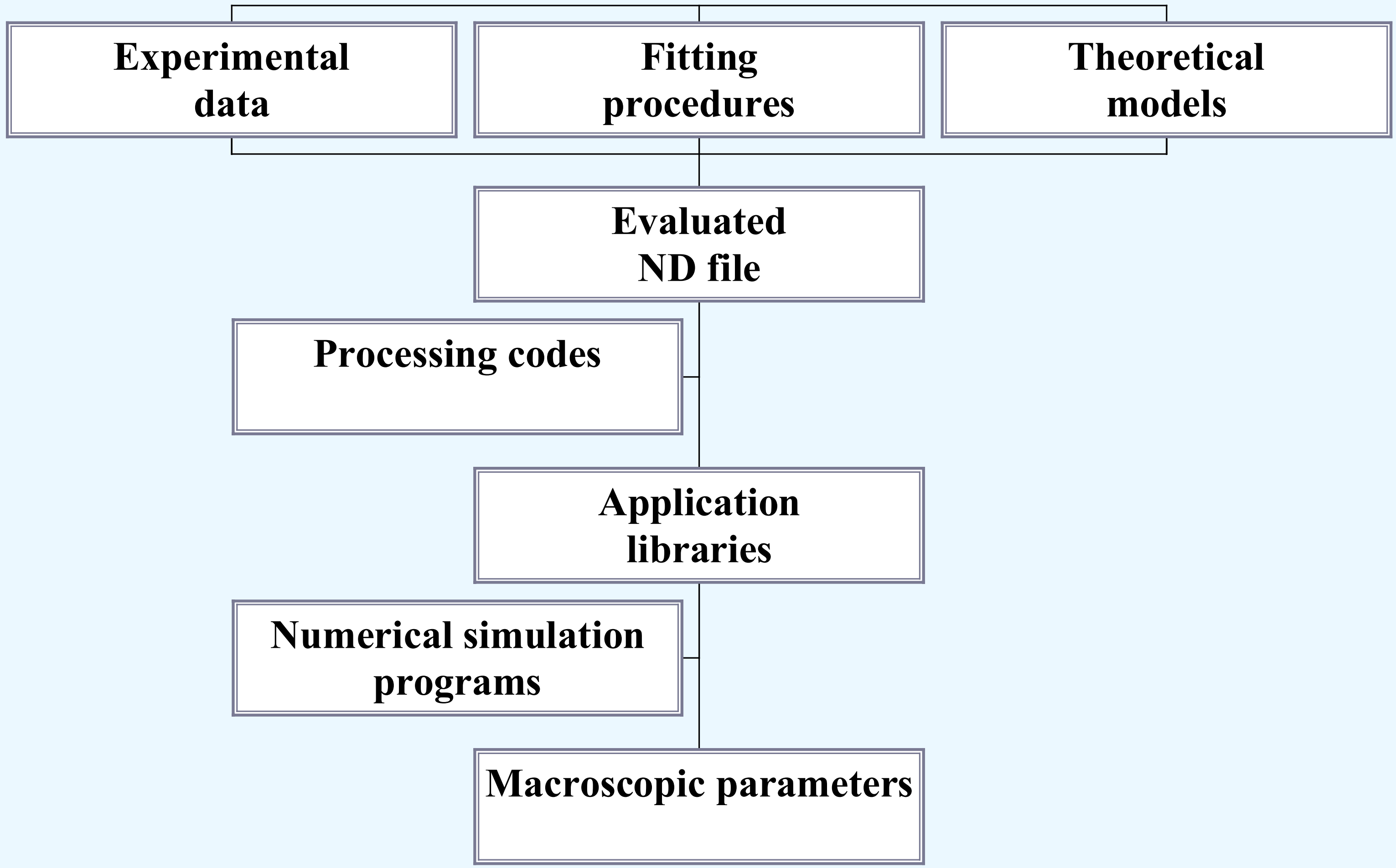
- Nuclear reaction theory (R matrix in the thermal and resonance range) is used to parameterize experimental data
- Probabilistic theory (Bayes theorem) allows the best fit to obtained for a series of measurements

U-235 evaluation (ORNL)



U-235 evaluation (ORNL)




Experimental data
Fitting procedures
Theoretical models
Evaluated ND file
Processing codes
Application libraries
Numerical simulation programs
Macroscopic parameters

Evaluated Data Files (1)

- **Evaluations (common format: ENDF-6):**
  - ENDF/B-VI, JEF2.2, EFF2.4, JENDL-3.2, CENDL-2.1, BROND-2.2
  - Initially for neutron induced reactions
  - General Purpose file: x-s, resonance parameters, angular and energetic distributions for E < 20 MeV
  - Special purpose files for Decay data, FP yields, Thermal scattering data...

Evaluated Data Files (2)

- **Extensions to higher energies (up to about 200 MeV for neutrons)**

- **Extensions to other particles**
  - **Proton, deuterium, alpha...**

Evaluated Data Files (3)

1	General information, neutron fission multiplicity
2	Resonance parameters
3	Pointwise cross-sections
4-6	Energy-angle correlations
7	Thermal Scatteing Data
8	Decay Data and Fission Product yields
30-40	Covariance data

Computer Programs

- **Analysis codes**
  - **Resonance range : SAMMY, REFIT...**
  - **Higher energies : ECIS, ALICE, CASTHY, CASCADE...**
- **Format and physics evaluation checks**
  - **ENDF utility codes (Brookhaven)**
- **Processing codes**
  - **NJOY , PREPRO, CALENDF**
- **Visualisation tools: JEF-PC, JANIS**

Code and model comparisons

- Average resonance parameters
- Fission cross-section calculations
- Coupled Channel Model Study
- Spherical Optical and Statistical Model Study
- Hauser-Feshbach calculations
- Intermediate Energy nuclear models
- Intra-Nuclear Cascade models

Conclusions - Evaluations

- The evaluation process involves:
  - taking data from many sources
  - analysis and comparison
  - theory to complement the available data
  - tools allowing checking/processing/benchmarking
- The final evaluation contains complete data for all reaction channels, all energies (<20MeV), i.e. cross sections, distributions, fission data, etc.

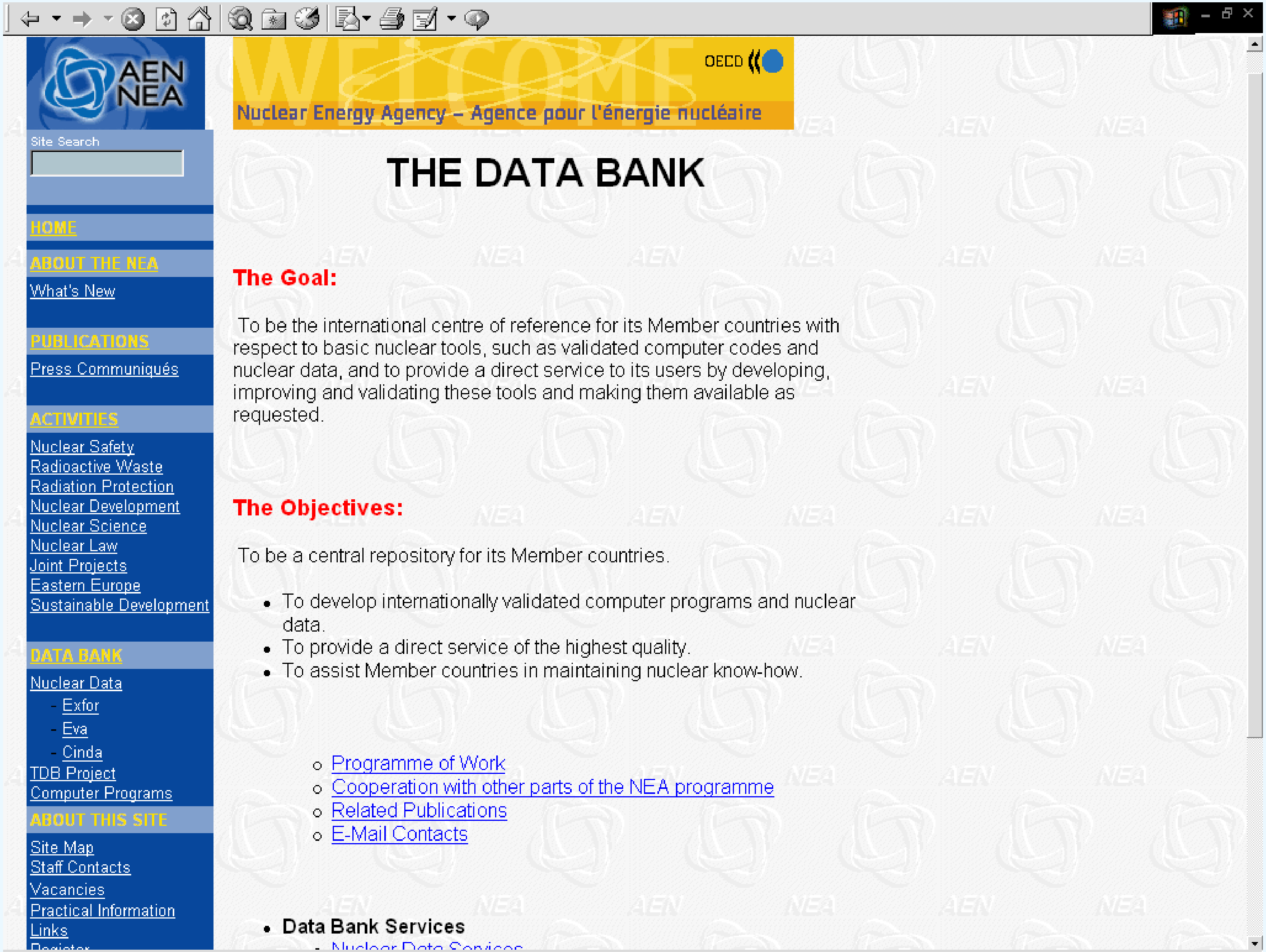
NEA Activities

- Gives centralised access to experimental data
- Overseas the JEFF evaluation project
- Sponsors the WPEC group (world-wide evaluation co-operation)
- Distributes ALL evaluated libraries and codes for processing/bench-marking etc.
- Carries out benchmark exercises for nuclear data and codes and provides training in their use

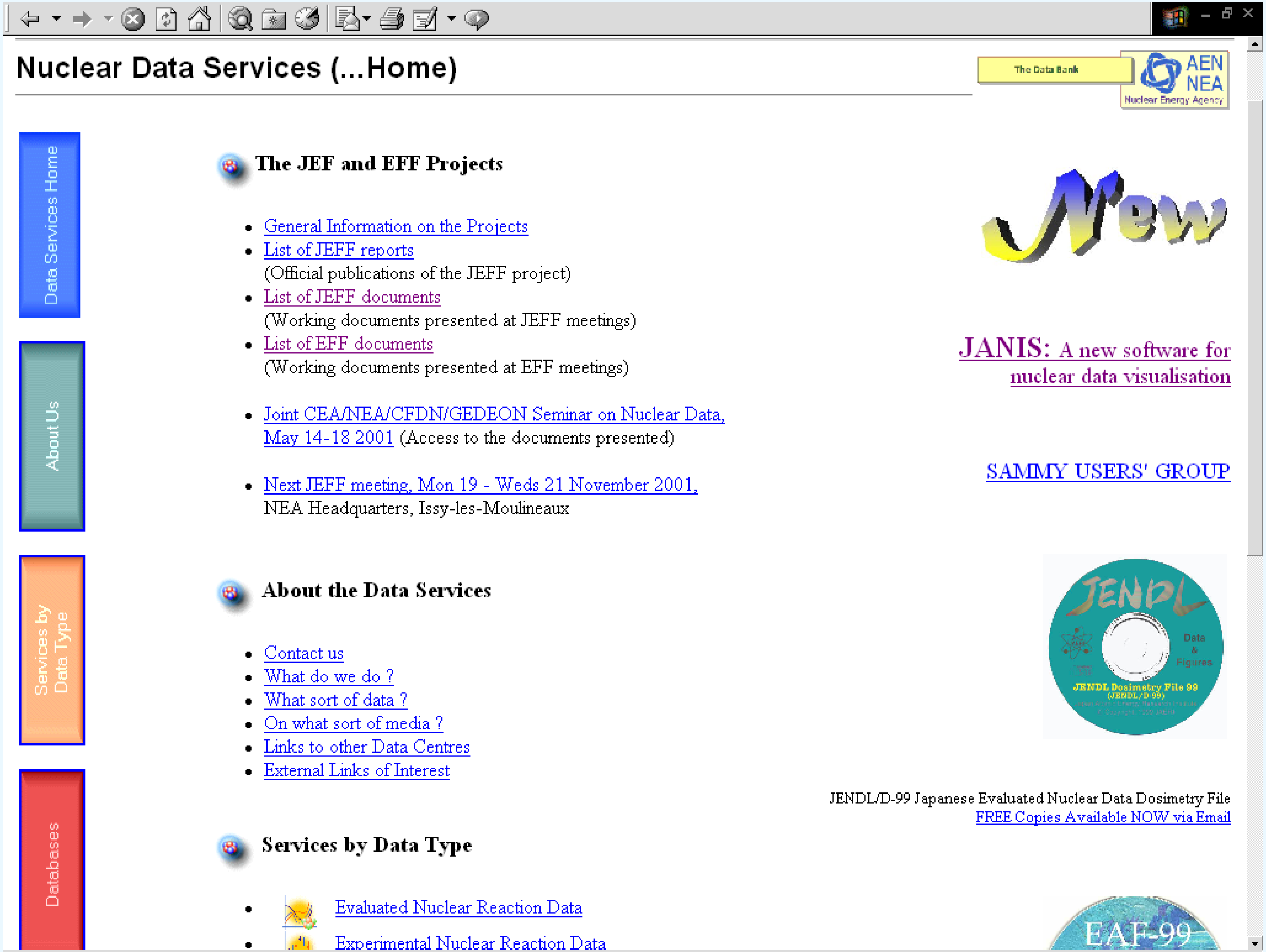
The role of the NEA Data Bank

- To be the international centre of reference for its Member countries with respect to basic nuclear tools, such as validated computer codes and nuclear data, and to provide a direct service to its users by developing, improving and validating these tools and making them available as requested
- Services are provided free of charge

http://www.nea.fr/html/databank



http://www.nea.fr/html/dbdata



Nuclear Data Services (...Home)

The Data Bank

AEN NEA Nuclear Energy Agency

Data Services Home

About Us

Services by Data Type

Databases

The JEF and EFF Projects

- General Information on the Projects
- List of JEFF reports
  (Official publications of the JEFF project)
- List of JEFF documents
  (Working documents presented at JEFF meetings)
- List of EFF documents
  (Working documents presented at EFF meetings)
- Joint CEA/NEA/CFDN/GEDEON Seminar on Nuclear Data, May 14-18 2001 (Access to the documents presented)
- Next JEFF meeting, Mon 19 - Weds 21 November 2001, NEA Headquarters, Issy-les-Moulineaux

New

JANIS: A new software for nuclear data visualisation

SAMMY USERS' GROUP

About the Data Services

- Contact us
- What do we do ?
- What sort of data ?
- On what sort of media ?
- Links to other Data Centres
- External Links of Interest

JENDL

JENDL/D-99 Japanese Evaluated Nuclear Data Dosimetry File
FREE Copies Available NOW via Email

Services by Data Type

- Evaluated Nuclear Reaction Data
- Experimental Nuclear Reaction Data

EAF-99

BASTRA meeting
05/12/2001

EVALUATION OF NEUTRON X-SECTIONS OF ^{233}Pa AND CREATION OF THE RESPECTIVE ND FILE

[1]A. Goverdovski, [2]O. Grudzievich, [2]D. Klinov, [1]V. Piksaikin

1- IPPE, Obninsk, Russia, 2- IAE, Obninsk, Russia

Presented by W. Furman on the behalf of the n_TOF collaboration

Why ^{233}Pa ?

and why now?

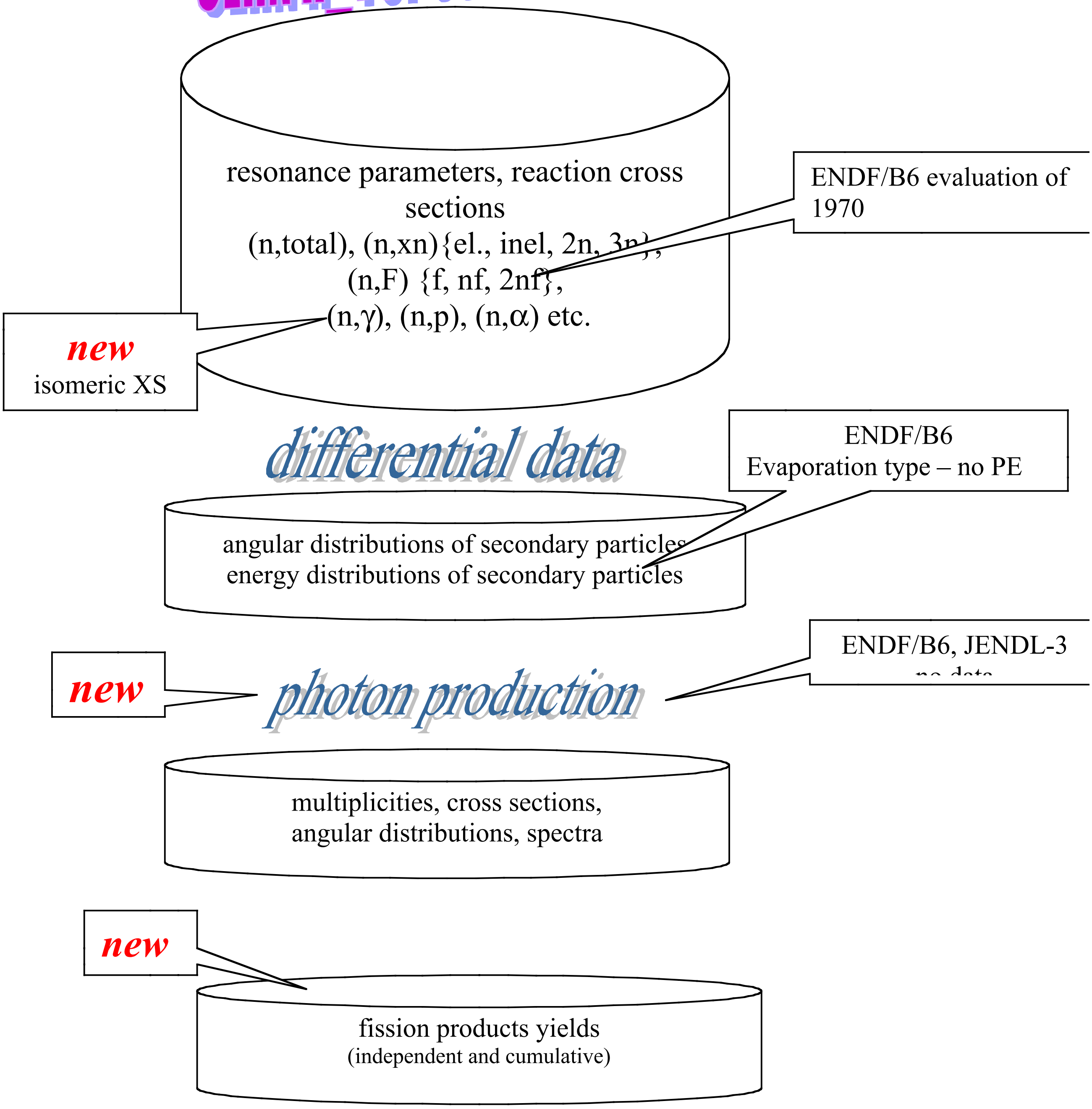
$$^{232}\mathrm{Th} + \mathrm{n} \rightarrow {}^{233}\mathrm{Th} \rightarrow {}^{233}\mathrm{Pa} \rightarrow {}^{233}\mathrm{U}$$

$$T_{1/2}\ ({}^{233}\mathrm{Pa}) = 26.97\ \mathrm{d}$$

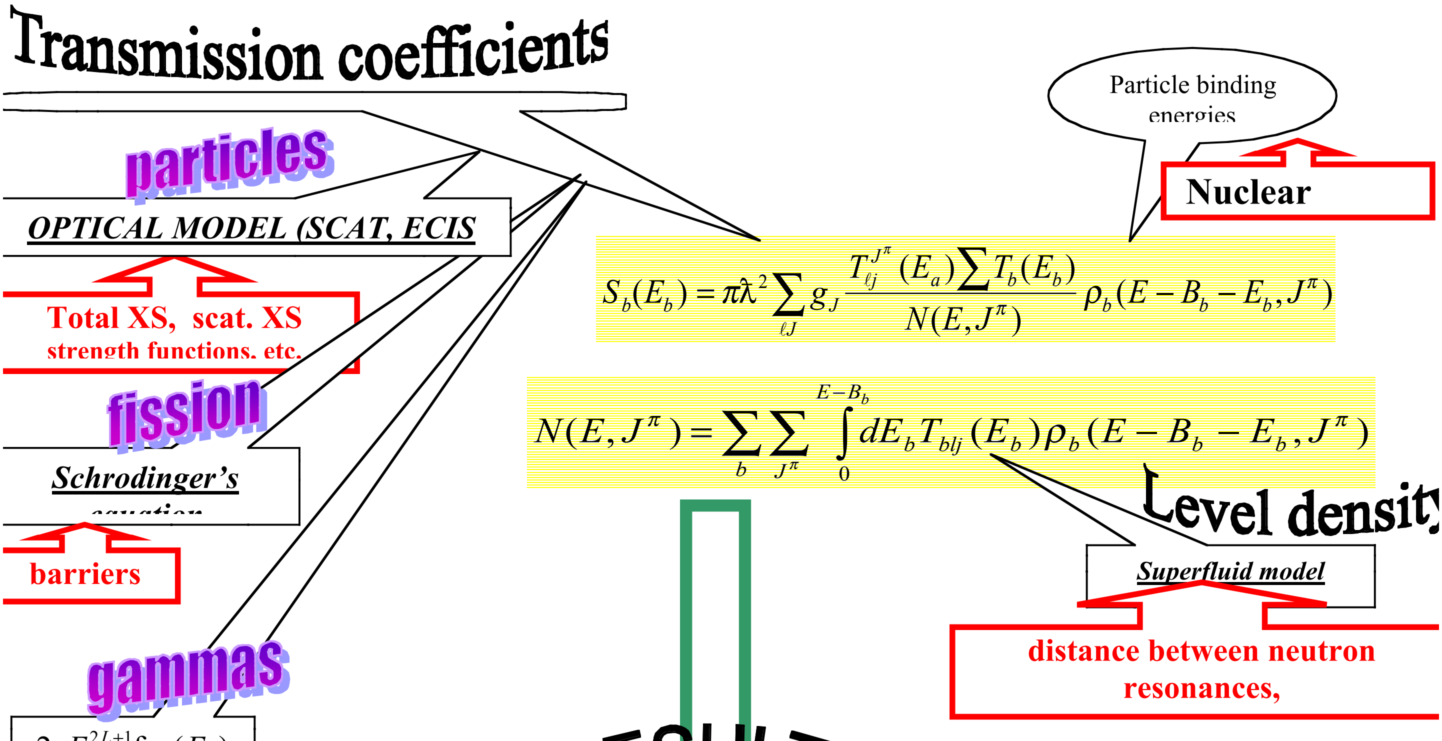
Target for experiments at n_TOF CERN facility - ?

So an evaluation of ND file for ^{233}Pa is very actual !

233-Pa EVALUATED NEUTRON DATA FILE
CERN n_TOF collaboration PS-213



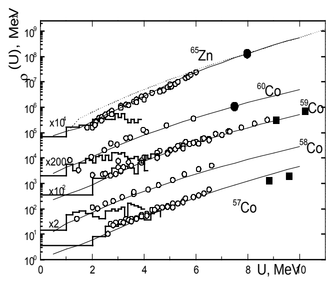
STAPRE code SYSTEM



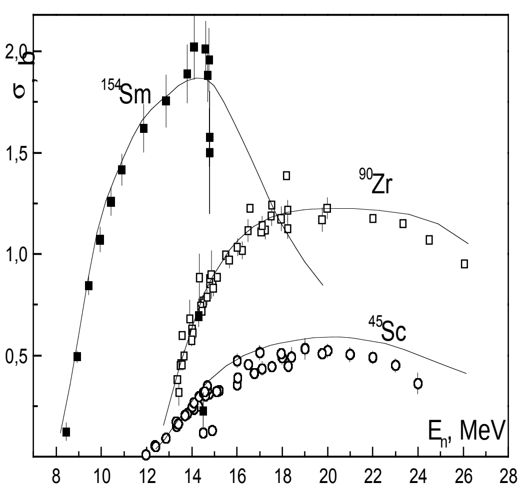
$$S_b(E_b) = \pi\lambda\!\!\!^{-2}\sum_{\ell J} g_J \frac{T_{\ell j}^{J^\pi}(E_a)\sum T_b(E_b)}{N(E,J^\pi)}\rho_b(E-B_b-E_b,J^\pi)$$

$$N(E,J^\pi) = \sum_b \sum_{J^\pi} \int_0^{E-B_b} dE_b T_{blj}(E_b)\rho_b(E-B_b-E_b,J^\pi)$$

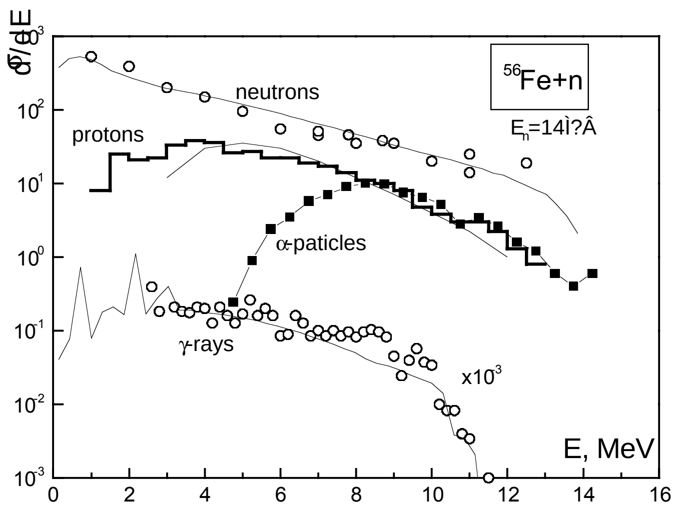
$$2\pi E_\gamma^{2L+1} f_{XL}(E_\gamma)$$



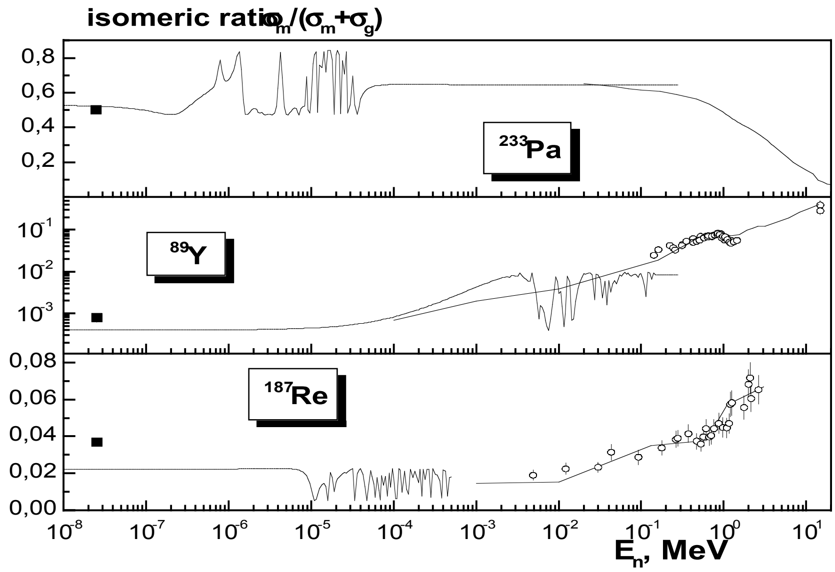
cross sections



spectra



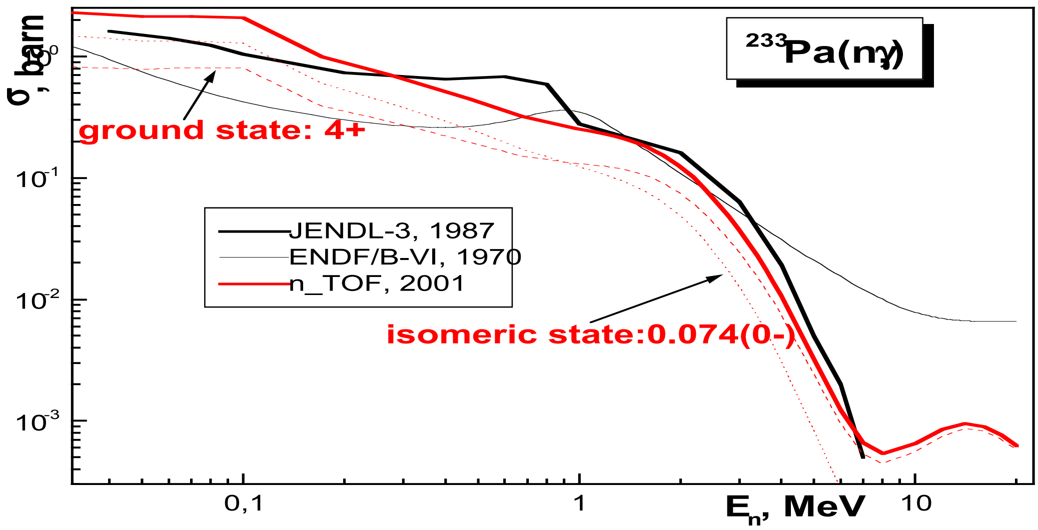
t is possible to fix the set of parameters for description of neutron radiative capture with aid of the energy dependence of the isomeric ratios



Isomeric ratios of neutron radiative capture by ^{187}Re, ^{90}Y and ^{233}Pa nuclei.

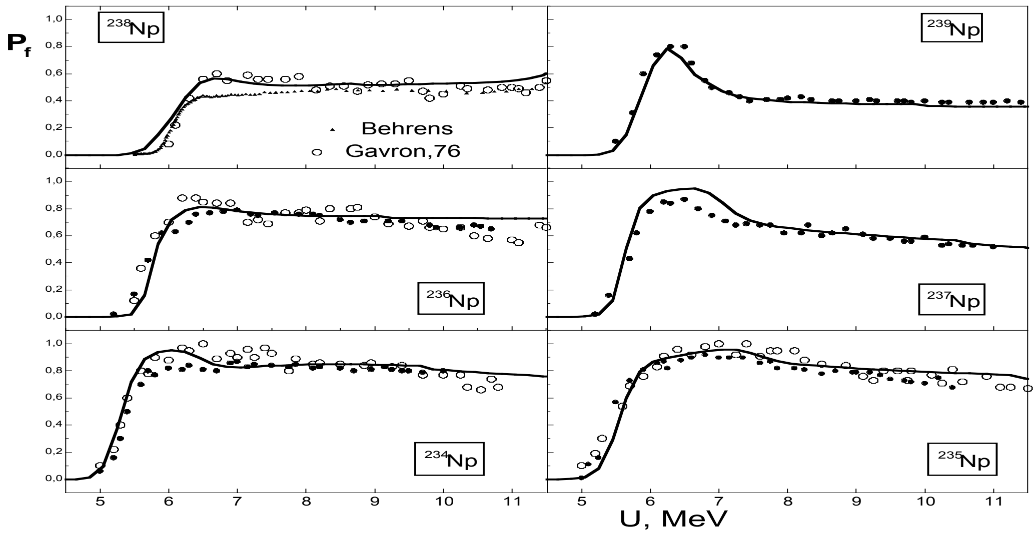
Curves – calculations on the basis of the statistical model with account for

So the predicted energy dependence of the neutron radiative capture cross-section on ^{233}Pa is next

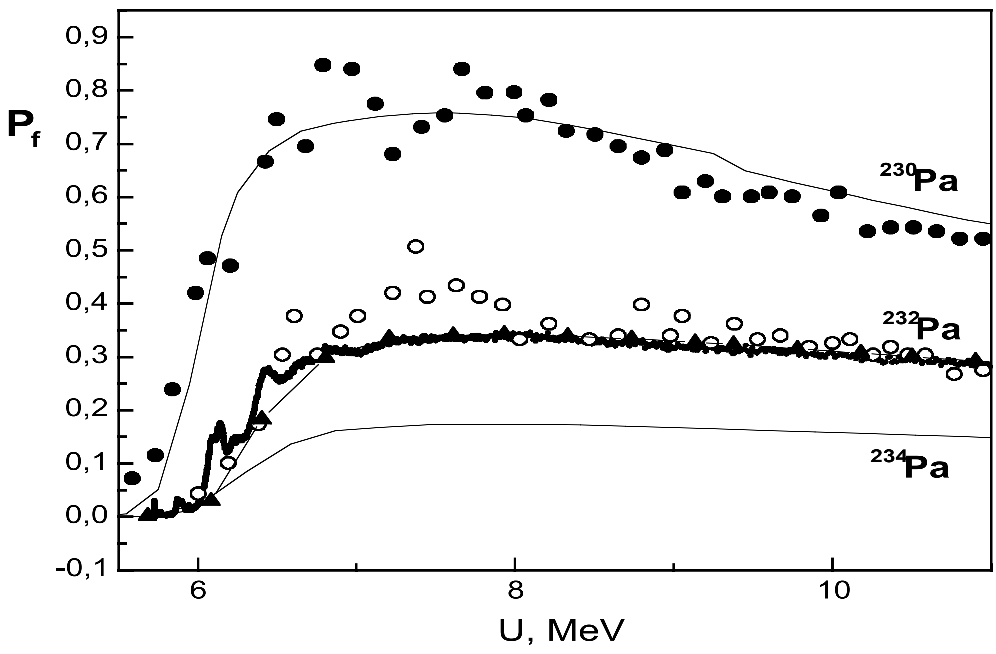


The cross-section of $^{233}Pa(n,\gamma)$.

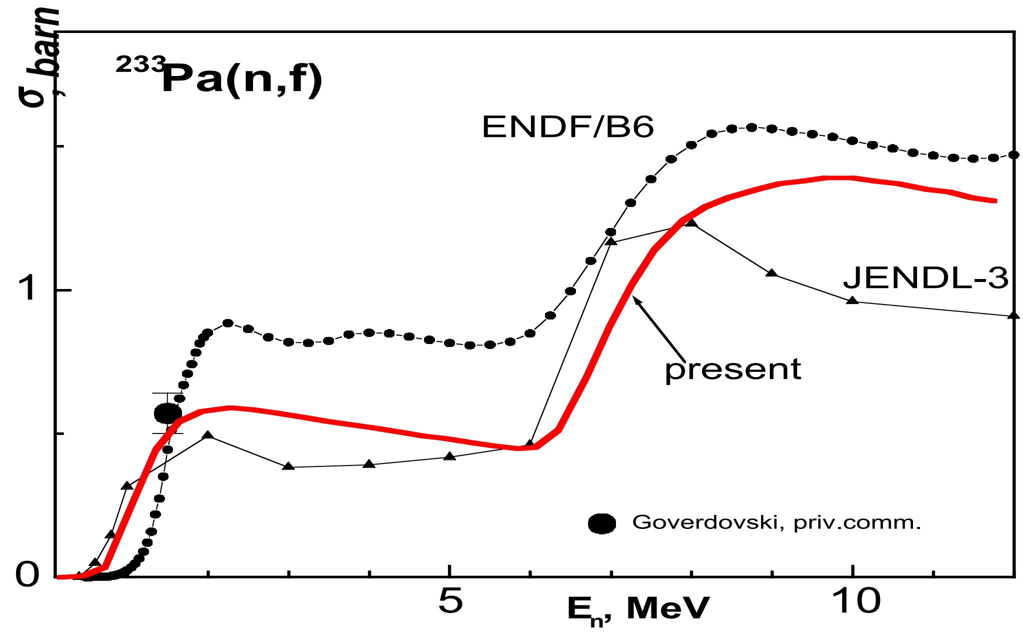
Fission cross-sections



Fission probabilities of neptunium isotopes in dependence of excitation energy of fissioning nucleus from the reactions (^{3}He,df), (^{3}He,tf) _ (n,f).
Points- experimental data from [6.7], curves – results of calculation.



Fission probabilities of the odd-odd Pa isotopes in dependence of excitation energy of fissioning nucleus Points – experimental data from [6.7], curves – results of present calculation.



The predicted cross-section of ^{233}Pa(n,f) reaction.

Current status of complete file of evaluated neutron data for ^{233}Pa

N	Stage	Status	What and Where ?
1.	exp. data compilation and analysis	done	resonance parameters
2.	libraries analysis	done	ENDF/BVI, JENDL-2, JEF-2
3.	theor. model verification and parameters fitting	done	STAPRE code system
4.	calculations of neutron XS's, analysis	done	
5.	complete file compilation	Done	
6.	file format testing	Done	CHEKR code
7.	physical testing	Done	FYZCON, PHYHE code
8.	file presentation	done	n_TOF Meeting

1ST MEETING OF THE CLUSTER for BASIC STUDIES FOR TRANSMUTATION

ISTC PROJECT : B70

Presented by S.CHIGRINOV

TEXT MISSING

DECEMBER 5, 2001

CERN, GENEVA, SWITZERLAND

REPORT on ISTC Projects:
540
1309
2213

On behalf of the authors presented by

N. Olsson

Cross sections for (p,f) and (n,f) at 20 – 200 MeV

V.P. Eismont et al., KRI

Past: ISTC #540 (1997 – 99)

- Thin-film breakdown counters (TFBC):
  - _ for ^{209}Bi, ^{232}Th, ^{233}U, ^{237}Np, ^{239}Pu, ^{243}Am (relative to ^{235,238}U)
  - _ for ^{181}Ta, ^{nat}W, ^{197}Au, ^{nat}Hg, ^{nat}Pb, ^{208}Pb (relative to ^{209}Bi)
  - All at 21 – 174 MeV

2. Frisch-gridded ionization chamber:
   - _ and fragment ang. dist. for ^{209}Bi, ^{232}Th, ^{238}U
   - All at 20 – 160 MeV

- Conclusions from ISTC #540:
   - Data for conceptual ADS OK, except for subactinides (around Pb)
   - Better standards needed; ^{235,238}U, ^{209}Bi (5 á 10%)
   - Further systematic studies needed for better modelling near Pb
   - (p,f) vs. (n,f) gives dependence on nuclear fissility

Present: ISTC #1309 (1999 – 2002)

- Focus on near Pb nuclei
- Pb-target in ADS: Fission contributes 10 – 15% of residual activity after 1 year cooling
- ^{209}Bi adopted as standard; _ should be improved
- Thus,
  - Measure _ for (n,f) and (p,f) on ^{205}Tl, ^{204,206,207,208}Pb, relative to ^{209}Bi(n,f) or (p,f)
  - Measure (n,f) and (p,f) under similar conditions
  - TFBC for cross sections
  - Frisch-gridded ionization chamber for _, LMT, angular-, energy- and mass distributions
  - Many targets simultaneously

Future: ISTC #2213 (2002 –)

- Measure (p,f) and (n,f)
- Natural tungsten and W-isotopes
- Similar experimental conditions
- Energy 50 – 200 MeV

ISTC Project # 1372

Complex Radiochemical and Activation Analysis of Long-lived Nuclear Waste Transmutation in Fast Reactors and in the Beams of High Energy Accelerators

Leading Institution: *SSC RF **IPPE** (Institute of Physics and Power Engineering, Obninsk).*

Supporting Institution ***JINR*** *(Joint Institute for Nuclear Research, Dubna)*

Foreign Collaborators
Prof. Waclaw Gudowski, Royal Institute of Technology, Department of Nuclear and Reactor Physics, Stockholm, Sweden,
Dr. Cornelis H.M. Broeders, Institute of Reactor Safety Forschungszentrum, Germany,
Dr. Ved P. Bhatnagar, European Commission Directorate General Research, Brussels, Belgium.

Project Duration 30 months . Expected start date 1 12.2001.

Total budget: 400,000 Euro.

Specific features

The specific feature of the ISTC Project 1372 "Complex Radiochemical and Activation Analysis of Long-lived Nuclear Waste Transmutation in Fast Reactors and in the Beams of High Energy Accelerators"
is that to the moment of the Project formulation we had already the set of the samples made of the separate isotopes of transuranium elements. The samples have been irradiated earlier in the industrial reactor BN-350 with fast neutron spectrum. The irradiation experiment conditions were described in detail, and also the control samples were kept safely containing the same isotopes, which have been irradiated in the reactor. At the moment these experiments are unique and can not be repeated at the industrial reactors in operation because the new safety regulations have been adopted, and these new rules make practically impossible to perform such experiments.

The investigation of the samples, irradiated in the reactor, the control samples and the samples irradiated in the high-energy accelerator beams using radiochemistry and nuclear physics methods will give the unique experimental data. These experimental data on a wide range of the isotopes being analysed in combination with theoretical investigations will increase the possibility of the reliable transmutation process evaluation and enable to have recommendations on the long-lived radioactive waste management.

Main tasks

1. Radiochemistry investigations and nuclear physics measurements of the isotope content changes in the samples of minor actinides, irradiated during several series of the experiments in the BN-350 reactor with fast neutron spectrum.
2. Investigations of actinide transmutation in BN-350 fast reactor.
3. Creation of complete data files with the evaluated neutron cross-sections for Pu-240, Np-237 and Am-241 isotopes up to 150 MeV.
4. Transmutation research in proton beams of the accelerating complex of the Laboratory of High of JINR.

Scope of activity

- Fabrication of radioactive targets for irradiation in the proton beams of the accelerator complex of the Laboratory of High Energies of the JINR; fabrication of radiators for solid-state track detectors from the depleted and enriched uranium mono-layers.

the radiochemical analysis of the samples irradiated in the reactor BN-350 for a content of fission fragments, heavy nuclide isotopes and the parent isotope residues after irradiation in the reactor;

- the investigation of the samples after the long term irradiation in the reactor with the nuclear physics methods (α-,β-,γ-spectroscopy and mass spectral methods);

- analysis of conditions and parameters of the samples irradiation in the reactor;

- - calculation of neutron fields and their changes during burn-up processes and the core re-loading; the expected nuclide composition of the samples;
- the evaluation of realistic errors;
- the comparison of theoretical and experimental results, self-descriptiveness evaluation of the experiments carried out;
- the conclusions about the neutron data accuracy for minor actinides and a reliability of actinide transmutation calculations in fast reactors.

The determination of generalised optical model parameters for calculation of cross-sections of elastic and inelastic interaction of neutrons and light charged particles with minor actinides' nuclei;

The selection of the optimal parameters of the pre-equilibrium evaporation model for description of angular distributions and spectra for neutrons and charged particles emitted by highly excited nuclei;

Development of the consistent fission model of actinides for calculation of multiple-chance fission cross-sections as well as spectra and fission neutron multiplicity.

Compilation of experimental data and available evaluations of reaction cross-sections for ^{240}Pu, ^{237}Np, and ^{241}Am in the energy range up to 200 MeV. Analysis of total, absorption neutron cross-sections and elastic neutron scattering angular distribution for incident neutron energies up to 150 MeV. Calculation and analysis of integral cross-sections for inelastic interactions of neutrons with nuclei.

Fission cross-section analysis. Theoretical modelling and calculations of fission cross-sections and the average number of neutrons per fission in the neutron energy range up to 150 MeV. Evaluation of prompt fission neutron spectra. Calculations of angular distributions, full spectra and fission neutron multiplicity.

Charged particle emission analysis. Calculations of the production cross-sections, spectra and angular distributions for protons, deuterons, tritons and α-particles in the incident energy range up to 150 MeV. Evaluated neutron data file formation for ^{240}Pu, ^{237}Np, and ^{241}Am up to neutron energies 150 MeV in the ENDF/B-VI format. Format and physical testing of the created files.

Measurements of the neutron spectra generated by high energy protons in the uranium-lead target. The determination of fission fragment yields with the use of solid-state track detectors and the gamma-activity measurement of activation detectors. Processing, analysis and interpretation of the experimental results. Experiments in proton beams in the energy range from 500 MeV up to 2000 MeV to research the radioactive waste transmutation: I-129, Np-237, Am-241, U-234, and Pu-238.

The simulation of the experiment conditions with the uranium-lead target in beams of the accelerator complex of LHE taking into account the target geometry and material, blanket and detectors, proton beam's energy and profile. The comparison of theoretical and experimental results and their interpretation. Experimental data analysis of neutron yields and energy deposition by the program package "Cascade LAHET and comparison with MCNPX" in neutron yields, spectra and angular distributions, the experimental data application for the complex "Cascade" advancement. Data base development on integral interactions of nucleons and mesons with nuclei.

The systematisation and analysis of data on actinide and fission product transmutation cross-sections in proton beams of high energy accelerators. Evaluation of reaction rates in the isotopes being transmuted, comparison with experimental results and predictions of various programs. The computer codes modification.

Expected results and their applications

The following scientific and practical results are expected during the project implementation:

- new methods of extraction, deep purification and analysis of radioactive nuclides;
- radioactive targets for the transmutation research in the high energy accelerators;
- radioactive samples and targets for the whole set of the experiments;
- procedures of a radio-nuclide composition research of various materials under fast reactor neutron irradiation based on the technique of needle and capillary type samples;
- experimental data on isotopic composition of the actinide samples after the long irradiation in BN-350 reactor;
- data for mathematical simulation in the fast reactor;
- experimental data on nuclide contents in the radioactive samples and targets after the irradiation by alternative methods;
-the analysis and comparison of the major nuclides concentration with the use of theoretical as well as experimental methods: radiochemical and nuclear physical ones;
-the complete files of the evaluated neutron cross-sections for Pu-240, Np-237, Am-241 at the neutron energies up to 150 MeV;
-the determination of transmutation parameters on the basis of the measurement results, calculation and theoretical analysis of the obtained experimental data,

reliability evaluation of constants, calculation methods of description and efficiency evaluation of the actinide transmutation processes in fast reactors;
- software testing for simulation of the transmutation processes in the heavy targets made of lead and natural uranium;
- models, calculation methods and the calculated cross-sections of the most important reactions induced by protons and high energy neutrons.
-

The confidence in successful realisation of these tasks is based on the experience accumulated during many years activity in the field of nuclear data evaluation:

-MENDL-2 and MENDL-2P activation data libraries, which contain more than 120,000 reactions induced by neutrons with the energies up to 100 MeV, and by protons with the energies up to 200 MeV for more than 500 stable and unstable nuclei, having the half-life more than 1 day, in the mass region from Al to Po, have been produced.

-The cross section evaluation for the reactions induced by neutrons and gamma-quanta on the most long-lived fission products in the energy region up to 50 MeV have been performed.

-The long-lived activity and residual product accumulation in the heavy metal liquid ADS targets have been estimated and used for the designing of the first lead-bismuth ADS 1 Mwt target manufactured in IPPE.

-In collaboration of IPPE with the Royal Institute of Technology the complete neutron and proton files of evaluated reaction cross sections in the energy region up to 150 MeV have been created for U-238, Th-232 and neutron file for Pu-239.

The results obtained during this project implementation can be used in Russia as well as in other countries which develop large-scale nuclear power and apply the nuclear engineering for solving the ecological problems.

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Nuclear data studies for ADS within ISTC Projects 609 (completed) and 1971 (new):

Neutron-induced fission of ^{233}U, ^{238}U, ^{232}Th, ^{239}Pu, ^{237}Np, ^{nat}Pb and ^{209}Bi relative to ^{235}U in the energy range 1-200 MeV

O.A. Shcherbakov[1], A.Yu. Donets[2], A.V. Evdokimov[2], A.V. Fomichev[2]
T. Fukahori[3], A. Hasegawa[3], A.B. Laptev[1], V.M. Maslov[4],
G.A. Petrov[1], S.M. Soloviev[2], Yu.V. Tuboltsev[5], A.S. Vorobyev[1]

Neutron-induced fission cross-sections of ^{240}Pu, ^{243}Am and W in the energy range 1-200 MeV

O.A. Shcherbakov[1], M.B. Chadwick[6], A.Yu. Donets[2], A.V. Fomichev[2],
R.C. Haight[6], A.B. Laptev[1], Yu.V. Tuboltsev[5], A.S. Vorobyev[1]

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[2] *V.G. Khlopin Radium Institute, 2-nd Murinski Ave. 28, 194021, St. Petersburg, Russia*
[3] *Nuclear Data Center/JAERI, Tokai-mura, Naka-gun, Ibaraki-ken, 319-1195, Japan*
[4] *Radiation Physics and Chemistry Institute, 220109, Minsk-Sosny, Belarus*
[5] *A.F. Ioffe Physico-Technical Institute, Polytekhnicheskaya 26, 194021, St. Petersburg, Russia*
[6] *Los Alamos National Laboratory, Los Alamos, New Mexico, 87545, USA*

The purpose of this projects is to obtain neutron fission cross-sections of ^{233}U, ^{238}U, ^{232}Th, ^{239}Pu, ^{237}Np, ^{nat}Pb and ^{209}Bi in case of Project 609 and ^{240}Pu, ^{243}Am and W in case of Project 1971 relative to ^{235}U by means of new measurements in the energy range from 1 MeV to 200 MeV. These isotopes have been chosen for present investigation according to the Nuclear Data Request List for new JENDL High Energy File (JENDL-3.3). The values of the cross-sections to be obtained are intended for use as nuclear data for accelerator-driven transmutation and energy production problem, as well as for the problem of secondary standard in intermediate energy region and some other applications. The Project 609 has been completed successfully and measured fission cross-sections have been published [1]. The Project 1971 is at the very beginning now.

The experimental part of the Projects includes: preparation of fissile targets, measurements, experimental data processing and production of the neutron induced fission cross-sections for isotopes mentioned above relative to ^{235}U in the energy range 1-200 MeV. The measurements are carried out at the time-of-flight neutron spectrometer GNEIS [2] in Gatchina based on the 1-GeV proton synchrocyclotron of PNPI used as a white neutron source. The fission cross-section ratios are measured simultaneously for several isotopes using two multiplate fission ionization chambers. For actinide targets, the threshold cross-section method and evaluated data below 14 MeV are used for normalization of the shape measurement data. For Pb, Bi and W targets, an absolute normalization of the measured cross-section ratios is done using the thickness of the targets and detection efficiencies. The values of fission cross-section ratio are obtained with statistical accuracy 1-3 % and systematic one 3-10 % and then convert to absolute cross-sections using the evaluated and recommended fission cross-section of ^{235}U.

At present, the world scientific community disposed only a few neutron sources suitable for the neutron fission cross-sections measurements at intermediate energies. Such measurements are very expensive and therefore have a high priority within the framework of international cooperation. Besides the scientists from institutions of CIS countries, the specialists from Japan Atomic Energy Research Institute were involved in the Project 609 and from Los Alamos National Laboratory will be involved in the Project 1971.

References:

1. A.Yu. Donets, A.V. Evdokimov, A.V. Fomichev, T. Fukahori, A. Hasegawa, A.B. Laptev, V.M. Maslov, G.A. Petrov, O.A. Shcherbakov, S.M. Soloviev, Yu.V. Tuboltsev, A.S. Vorobyev, *Int. Conf. Nucl. Data for Sci. and Tech.,* Oct. 7-12, 2001, Tsukuba, Japan. Abstracts, p. 1.3-O-16.
2. N.K. Abrosimov, G.Z. Borukhovich, A.B. Laptev, V.V. Marchenkov, G.A. Petrov, O.A. Shcherbakov, Yu.V. Tuboltsev, V.I. Yurchenko, *Nucl. Instrum. Meth.* **A242** (1985) 121.

ISTC Project #2002:
Experimental and theoretical studies of the yields of residual product nuclei produced in thin Pb and Bi targets irradiated by 40-2600 MeV protons

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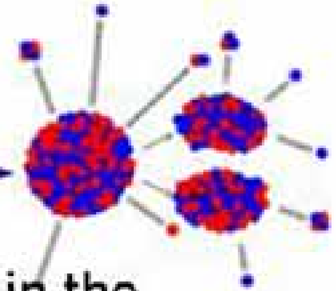
To be presented at

BASTRA Cluster Meeting of EC funded FP5 projects,
CERN, Geneva, Switzerland, December 5, 2001

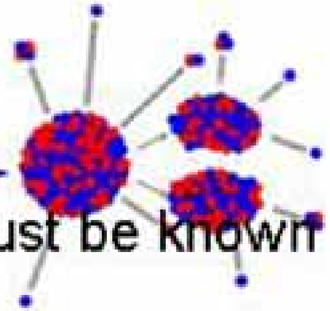
ISTC #2002: Objectives



Studying the physics of high-energy proton-matter interaction in the following three essential research lines:

- Experimental determination of the independent and cumulative yields (cross sections for production) of residual radioactive product nuclei in proton-irradiated ^{206}Pb, ^{207}Pb, ^{208}Pb, ^{nat}Pb, and ^{209}Bi within a minutely fractionated proton energy range, namely, at 0.04, 0.07, 0.10, 0.15, 0.25, 0.4, 0.6, 0.8, 1.2, 1.4, 1.6, and 2.6 GeV.
  - **Additional measurements: ^{197}Au (0.8GeV), ^{238}U(1.0GeV) to be compared with GSI inverse kinematic data**
- Simulation of the residual product yields by different codes (LAHET, CEM2k, INUCL, CASCADE, YIELDX etc.). Verification of the codes against the experimental data to be obtained under the Project, that is, we will estimate of the predictive power of the codes;
- Modifying the most widely used LAHET and CASCADE codes.

ISTC #2002: *Motivation*

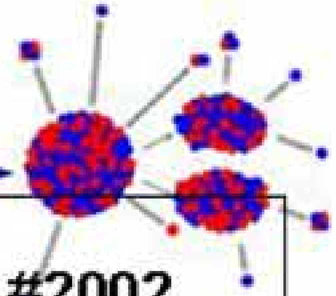


Fundamentally *novel parameters* of the target assemblies must be known reliably for ADS conceptual and engineering designs:

- Neutron yield and spectrum;
- Target neutronics;
- Energy deposition parameters of the target;
- Reaction product yields in the target. The yields define:
  - Activation of target and structure materials
    - Handling & maintenance
    - Alpha-activity (^{210}Po, ^{148}Cd, ...)
    - Long-lived nuclide accumulation
  - Radiation damage ⟶ Mechanical strength, Life time, Thermal stress
    - p, d, t, ^{3}He, ^{4}He gas production
  - Neutronic "poisoning"
  - Chemically-active nuclide accumulation

International code comparison by NEA auspice in 1996 (NSC/DOC(97)-1) emphasized that calculation of activation yields turns out to be <u>an extremely difficult task</u>

ISTC #2002: *Work plan*



ISTC / МНТЦ

Project | **#2002**

Experimental and theoretical studies of the yields of residual product nuclei produced in thin Pb and Bi targets irradiated by 40-2600 MeV protons

Irradiation modes and characteristics of the targets

Targets	Proton energy [GeV]										
	0.04	0.07	0.1	0.15	0.25	0.4	0.6	0.8	1.2	1.6	2.6
^{208}Pb	x	x	x	x	x	x	x	x	x	x	x
^{207}Pb	x	x	x	x	x	x	x	x	x	x	x
^{206}Pb	x	x	x	x	x	x	x	x	x	x	x
^{nat}Pb	x	x	x	x	x	x	x	x	x	x	x
^{209}Bi	x	x	x	x	x	x	x	x	x	x	x

Approximate isotopic composition of the targets

Targets	Isotopic composition, %				
	^{204}Pb	^{206}Pb	^{207}Pb	^{208}Pb	^{209}Bi
^{208}Pb	<0.01	0.87	1.93	97.2	-
^{207}Pb	<0.01	1.39	93.2	5.41	-
^{206}Pb	0.19	92.3	5.1	2.41	-
^{nat}Pb	1.4	24.1	22.1	52.4	-
^{209}Bi	-	-	-	-	>99.9

ITEP U-10 proton synchrotron

Two synchrotron extracted beams are used in irradiations:

- high-energy beam of protons with energies from 800 MeV to 2.6 GeV.
  - Section: an ellipsis with axes of about 25 mm and 15 mm;
  - Intensity: ~ $2 \cdot 10^{11}$ protons per pulse;
  - Extraction run duration: about 0.4 s.
- low-energy beam of protons with energies from 70 to 200 MeV.
  - Section: a circle with diameter of about 25 mm;
  - Intensity: ~ $5 \cdot 10^{9}$ protons per pulse;
  - Extraction run duration: about 50 ns.

The pulse repetition rate is about 15 pulses per minute in both beams.

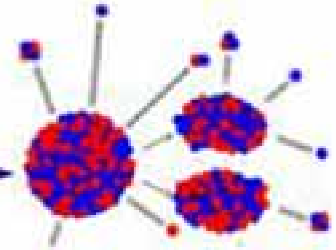
ITEP U-10 proton synchrotron: new beam

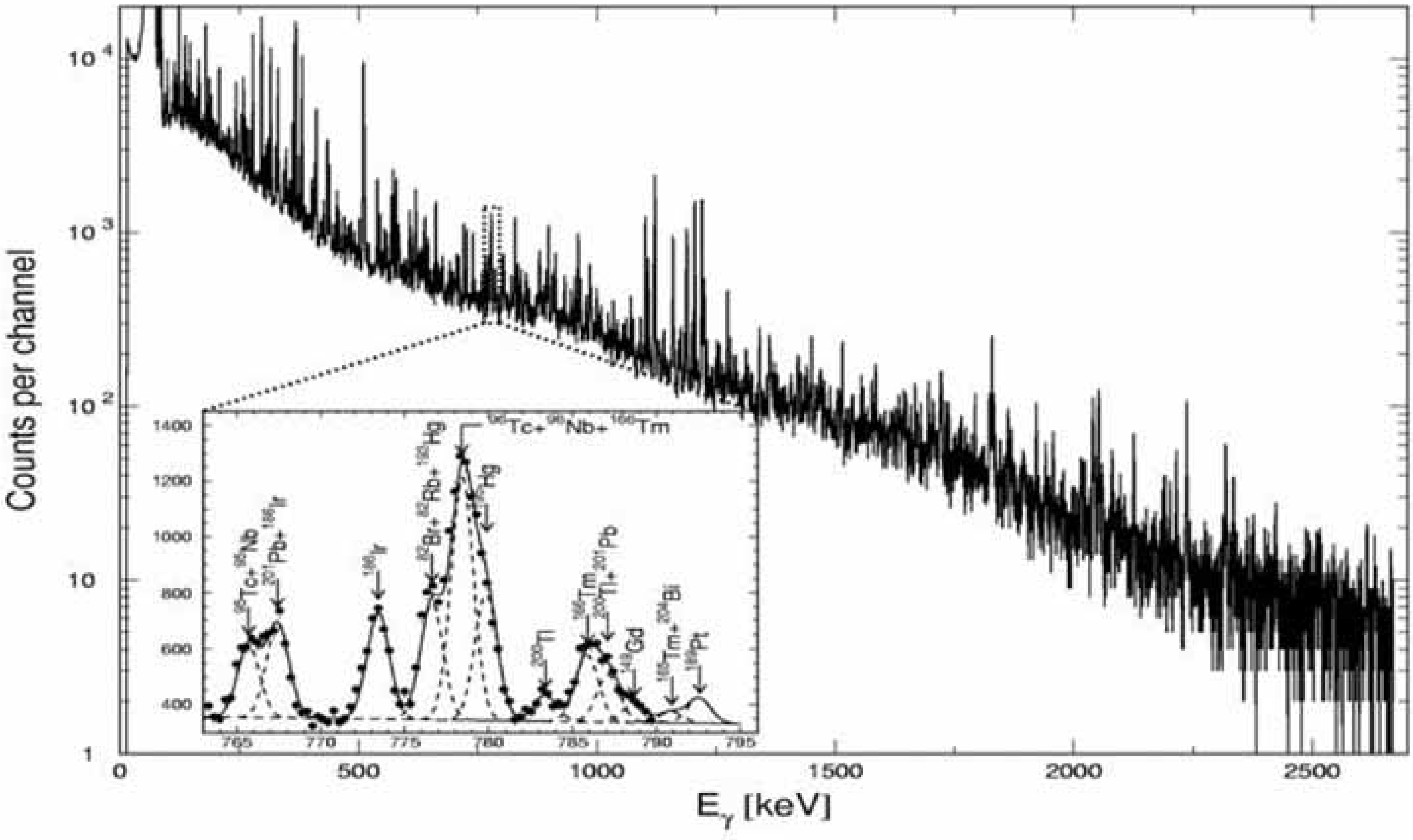
Third multi-function extracted beam is being mounted:

- Proton energy: 40-10000 MeV;
- Beam section: a circle of ~ 20 mm diameter;
- Intensity: $\sim 1 \cdot 10^{11}$ protons per pulse;
- Extraction runs: 1-4 50-ns bunches spaced 150 ns apart.

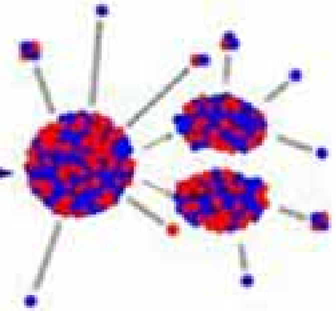
$\sim 5 \cdot 10^{13}$ protons are required for irradiating each of 55 targets to measure 10min - 30 years lifetime nuclides. This will take ~ 300 hours of accelerator operation time.

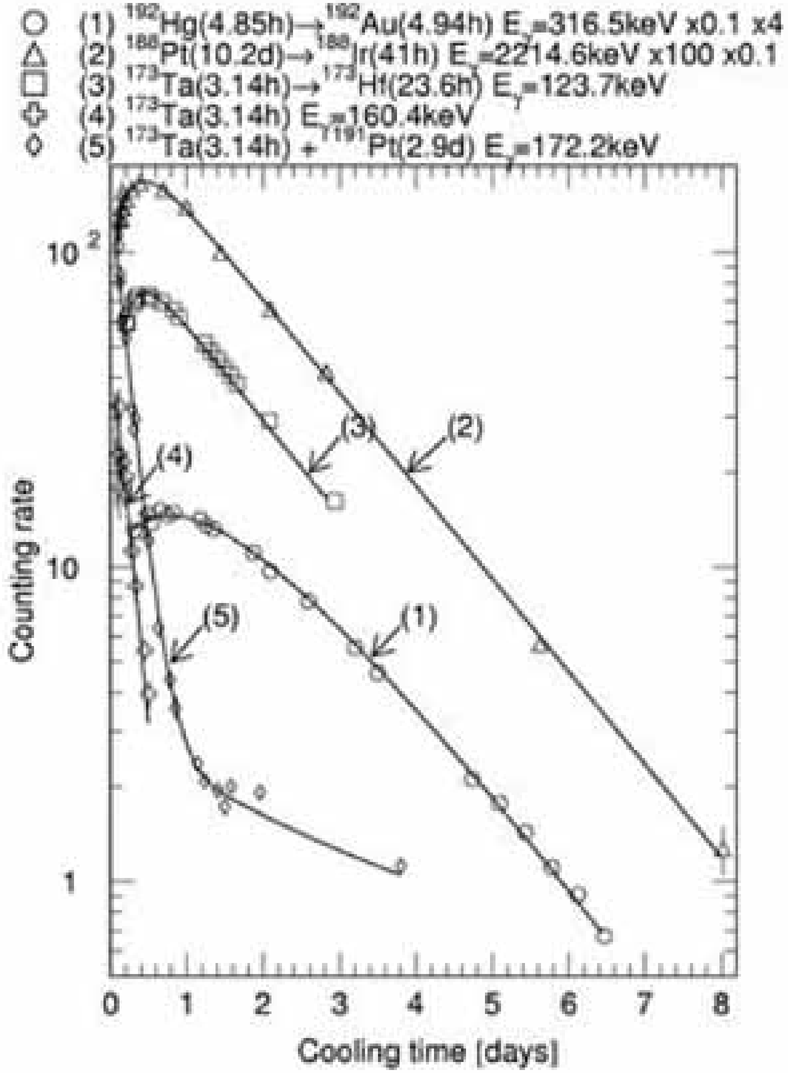
Gamma – spectra measurements





Cross sections determination





$$\sigma_1^{cum} = \frac{A_0}{\eta_1 \varepsilon_1 F_1 N_{Nu}} \cdot \frac{N_{At}}{N_T} \cdot \frac{F_{Nu}}{\lambda_{Nu}} \sigma_{st}$$

$$\sigma_1^{cum} = \frac{A_1}{\nu_1 \eta_2 \varepsilon_2 F_1 N_{Nu}} \cdot \frac{N_{At}}{N_T} \cdot \frac{\lambda_2 - \lambda_1}{\lambda_2} \cdot \frac{F_{Nu}}{\lambda_{Nu}} \sigma_{st}$$

$$\sigma_2^{ind} = \left(\frac{A_2}{F_2} + \frac{A_1}{F_1} \cdot \frac{\lambda}{\lambda} \right) \cdot \frac{1}{\eta_2 \varepsilon_2 N_{Nu}} \cdot \frac{N_{At}}{N_T} \cdot \frac{F_{Nu}}{\lambda_{Nu}} \sigma_{st}$$

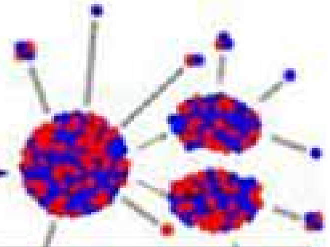
$$\sigma_2^{cum} = \sigma_2^{ind} + \nu_1 \cdot \sigma_1^{cum} =$$

$$= \left(\frac{A_1}{F_1} + \frac{A_2}{F_2} \right) \cdot \frac{1}{\eta_2 \varepsilon_2 N_{Nu}} \cdot \frac{N_{At}}{N_T} \cdot \frac{F_{Nu}}{\lambda_{Nu}} \sigma_{st}$$

Measurement Errors Components

Uncertainty:	[%]
γ-detection	0.2÷20
Decay Lifetime	<2
γ-line yield	<15
Spectrometer efficiency	3÷7
Monitor reaction	6÷9

Codes used in comparison



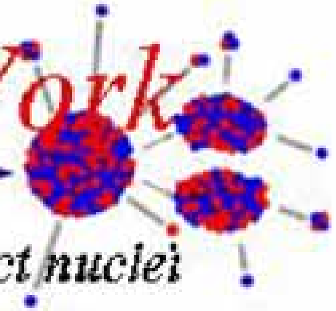
Code name	Author, Lab	Models used	Projectile Energy Range, GeV
CEM2k	S.G. Mashnik, JINR, Dubna. LANL	Dubna INC[1] (exciton), Preequilibrium Modified Exciton Model, Evaporation (Weisskopf-Ewing), Competition between Fission (Bohr-Wheeler) and Evaporation	0.01-5
CASCADE	V.S. Barashenkov, JINR, Dubna	Dubna INC, Evaporation (Bohr-Wheeler), Fission (Dubna version of Fong model)	<1000
INUCL	N.V. Stepanov, ITEP, Moscow	ITEP INC, Preequlibrium Exciton Model, Evaporation (Weisskopf-Ewing), Fission (Thermodinamical Model)	0.01-10
LAHET	R.E. Prael, LANL, NM	Bertini/ISABEL INC, Multustep Preequilibrium Exciton Model, Evaporation (weisskopf-Ewing, Dersner's code) or Fermi Breakup Model for light nuclei, Fission (RAL/ORNL models)	Bertini INC: <3.5 ISABEL: <1.0
YIELDX	R. Silberberg, C.H. Tsao	Semi-empirical formulae, fission allowed	>0.1

Codes that can be used by our collaborators:

ALICE	M.Blann, LLNL, CA	Hybrid Monte Carlo Simulation Model, Evaporation (Weisskopf-Ewing, Fermi/Kataria level densities), Fission (Bohr-Wheeler)	<0.4
GNASH	M.B. Chadwick, P.G.Young, LANL, NM	FKK[2] precompound Decay, Evaporation (Hauser-Fechbach), Fission (Bohr-Wheeler)	<0.2
NUCLEUS	T. Nishida et al., JAERI	Bertini INC, Evaporation (Weisskopf-Ewing), Fission (JAERI model)	<3.5
QMD	K.Niita et al., JAERI	Quantum-molecular dynamic model, Evaporation (Weisskopf-Ewing), Fission (Nakahara model)	<5.0

[1] INC – Intranuclear cascade, [2] FKK – Feshbach-Kerman-Koonin

ISTC #839-B *(I'99-XII'00)*: *Scope of Work*

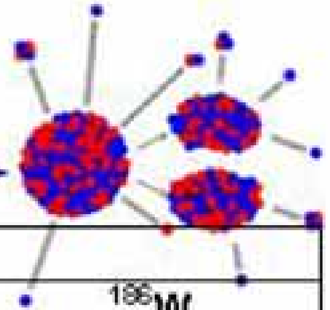


Experimental and theoretical studies of the yields of residual product nuclei produced in thin Pb and Bi targets irradiated by 40-2600 MeV protons

Proton Energy [GeV]	Targets															
	^{56}Fe	^{58}Ni	^{59}Co	^{63}Cu	^{65}Cu	^{93}Nb	^{99}Tc	^{182}W	^{183}W	^{184}W	^{186}W	^{nat}W	^{nat}Hg	^{208}Pb	^{232}Th	^{nat}U
0.1							+						+		+	+
0.2			+	+	+		+	+	+	+	+		+		+	+
0.8							+	+	+	+	+				+	+
1.0														+		
1.2			+	+	+		+						+		+	+
1.6			+	+	+		+	+	+	+	+				+	+
2.6	+	+	+	+	+	+						+	+			
ADS element	SM, Sh, TM	SM	SM	SM	SM	SM	FP	TM	TM	TM	TM	TM	TM	TM	Th-cycle	Fuel

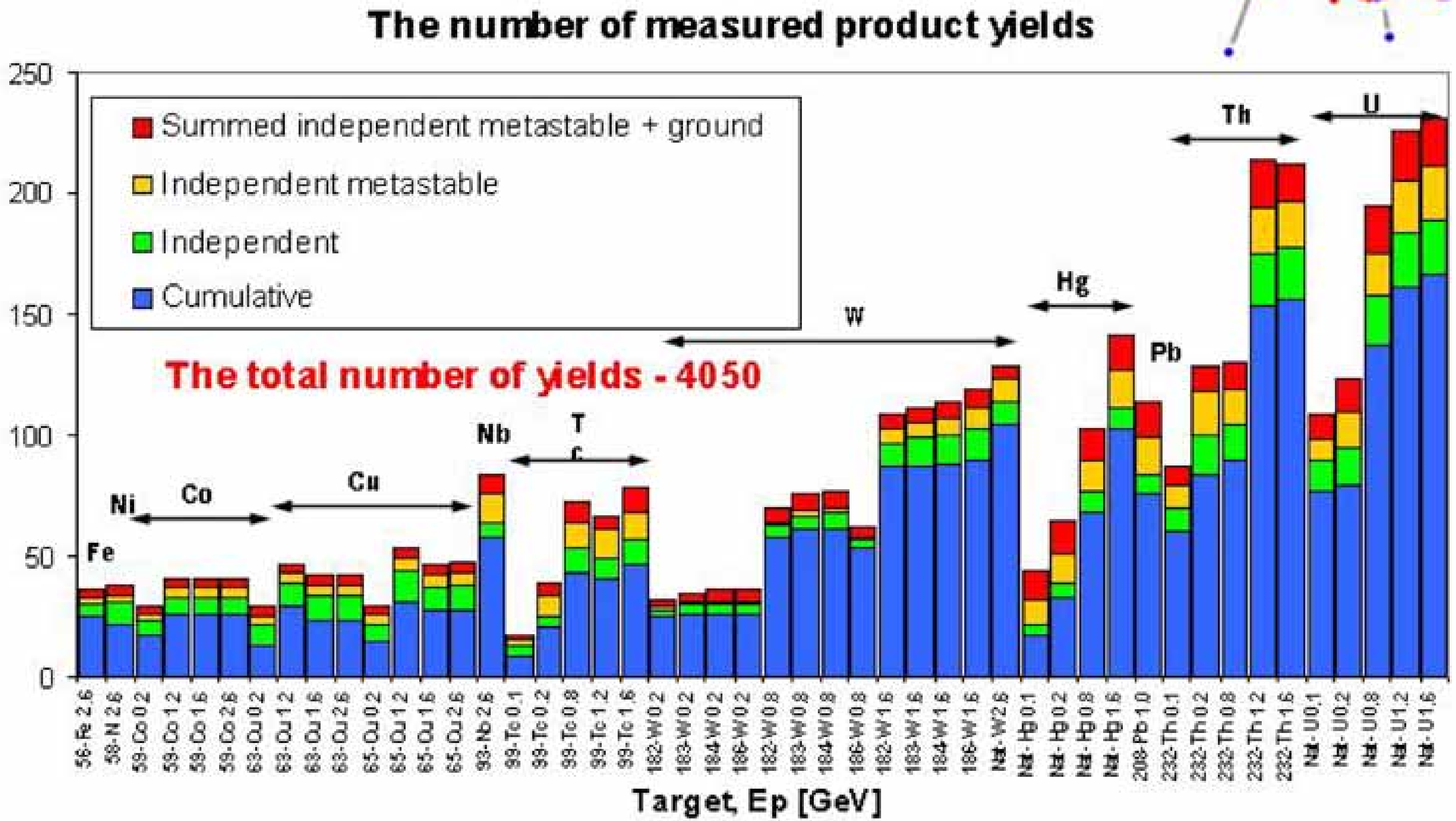
SM – Structure Material; Sh – Shielding Material; FP – Fission Product;
TM - Target material; Th - Th fuel cycle, breeding; Fuel - Fuel compositions

ISTC #839-B: Targets

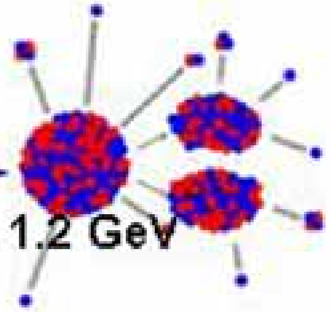


Target	Isotopic composition [%]				
	^{180}W	^{182}W	^{183}W	^{184}W	^{186}W
^{182}W	<0.03	90.7	5.71	2.62	0.97
^{183}W	0.07	4.62	73.3	20.08	1.93
^{184}W	0.3	1.9	3.9	90.3	3.6
^{186}W	<0.02	0.66	0.49	2.45	96.4
^{nat}W	0.126	26.31	14.28	30.64	28.64
^{232}Th	100				
^{nat}U	^{233}U-0.0055; ^{235}U-0.72; ^{238}U-99.2745				
^{99}Tc	100				
^{59}Co	100				
^{63}Cu	^{63}Cu – 99.6; ^{65}Cu - 0.4				
^{65}Cu	^{63}Cu - 1.3; ^{65}Cu - 98.7				
^{nat}Hg	^{196}Hg-0.14; ^{198}Hg-10.02; ^{199}Hg-16.84; ^{200}Hg-23.13; ^{201}Hg-13.22; ^{202}Hg-29.80; ^{204}Hg - 6.85.				
^{56}Fe	^{54}Fe-0.3; ^{56}Fe-99.5; ^{57}Fe-0.2; ^{58}Fe-<0.05.				
^{58}Ni	^{58}Ni - 99.8; ^{60}Ni - 0.19; ^{61}Ni - <0.01; ^{62}Ni - 0.01; ^{64}Ni - <0.01.				
^{93}Nb	100				
^{208}Pb	Pb – 97.2; ^{207}Pb – 1.93; ^{206}Pb – 0.87; ^{204}Pb < 0.01.				

ISTC #839-B: Results of measurements



ITEP-JAERI data comparison

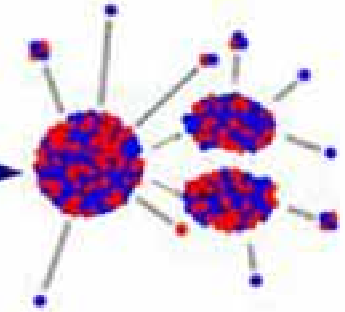


The experimental yields of ^{63}Cu, ^{65}Cu(p,x) reaction products at E_p = 1.2 GeV measured at ITEP and JAERI (sampled yields).

Product	$T_{1/2}$	Type	^{63}Cu			^{65}Cu		
			ITEP	JAERI		ITEP	JAERI	
			GC2518	VHTRC	FNS	GC2518	VHTRC	FNS
^{65}Zn	244.26d	i	1.73+-0.13	-	-	-	-	-
^{63}Zn	38.47m	i	1.32+-0.25	-	-	1.33+-0.21	-	-
^{62}Zn	9.26h	i	0.219+-0.020	0.33+-0.08	-	0.481+-0.053	0.45+-0.14	-
^{64}Cu	12.700h	i	61.4+-4.7	-	-	-	-	-
^{61}Cu	3.333h	c	5.42+-0.62	-	-	14.9+-1.7	-	-
^{60}Cu	23.7m	c	1.08+-0.08	-	-	3.46+-0.25	-	-
^{62m}Co	13.91m	$i_{(m)}$	1.63+-0.11	-	-	-	-	-
^{61}Co	1.650h	c	6.52+-0.86	-	-	5.29+-1.92	-	-
^{60}Co	5.2714y	$i_{(m+g)}$	16.8+-1.2	-	17.0+-1.9	9.27+-0.68	-	9.5+-1.1
. . . .								
^{34m}Cl	32.00m	$i_{(m)}$	0.329+-0.030	-	-	0.585+-0.050	-	-
^{38}S	170.3m	c	0.073+-0.008	-	-	-	-	-
^{29}Al	6.56m	c	1.32+-0.14	-	-	1.13+-0.14	-	-
^{28}Mg	20.91h	c	0.251+-0.018	0.26+-0.05	-	0.195+-0.014	0.18+-0.05	-
^{27}Mg	9.462m	c	0.452+-0.068	-	-	0.503+-0.074	-	-
^{24}Na	14.9590h	c	1.61+-0.13	1.98+-0.23	-	1.73+-0.12	1.68+-0.19	-
^{22}Na	2.6019y	c	1.12+-0.11	-	0.98+-0.14	1.39+-0.20	-	1.34+-0.24
^{7}Be	53.29d	i	4.50+-0.42	5.0+-0.6	4.5+-0.6	5.47+-0.51	5.3+-0.7	5.7+-0.7

Mean deviation from ITEP data [%]	12	3		14	4

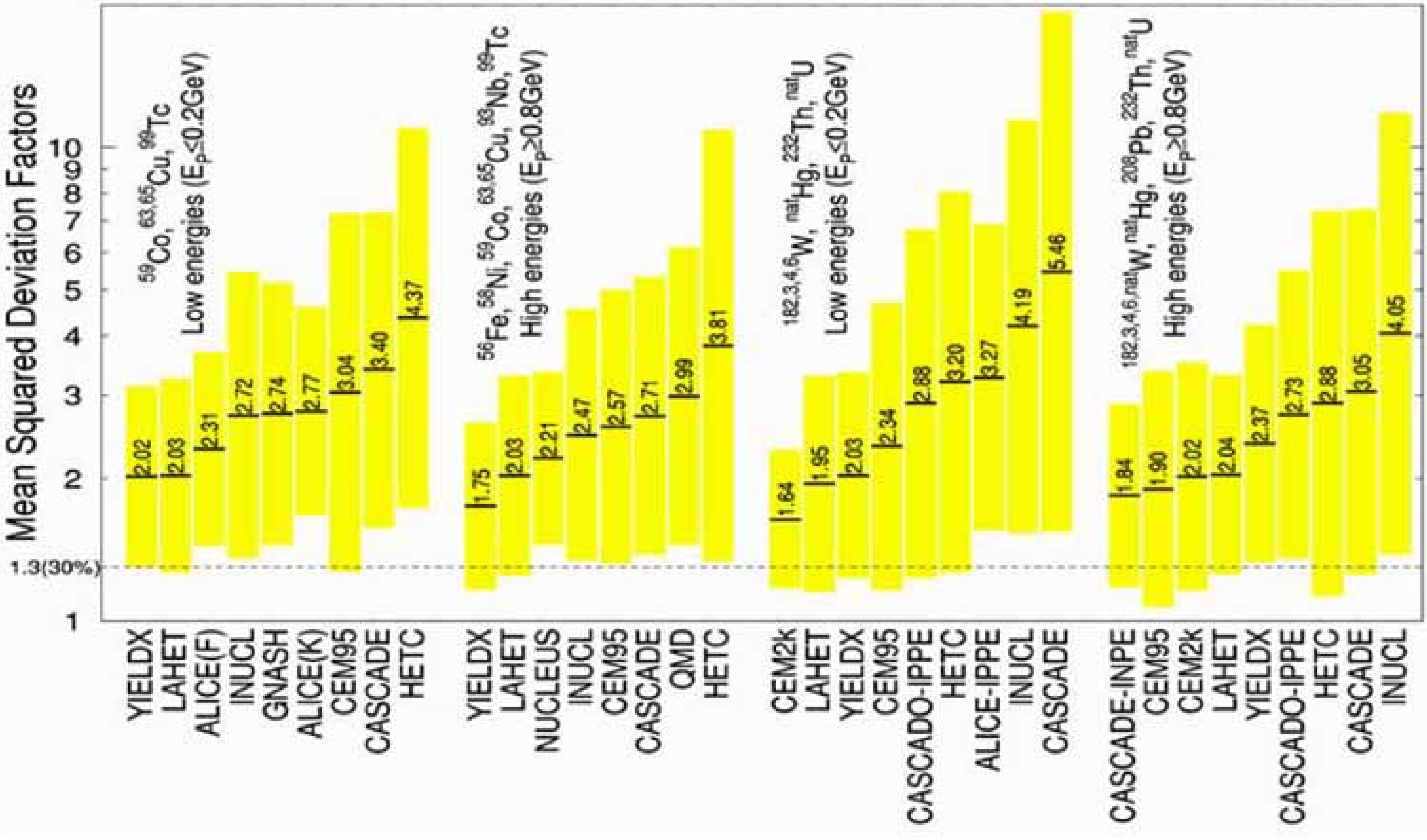
ITEP-GSI data comparison



ITEP measured residual nuclide yields in ^{208}Pb irradiated with 1.0GeV protons together with GSI and ZSR data (sampled yields)

Product	T1/2	Type	ITEP	GSI, Darmstadt	ZSR, Hannover
^{206}Bi	6.243d	i	4.60+-0.29	-	5.36+-0.67
^{205}Bi	15.31d	i	6.20+-0.40	-	7.09+-0.90
^{204}Bi	11.22h	$i_{(m1+m2+g)}$	5.29+-0.80	-	6.03+-0.95
^{203}Bi	11.76h	$i_{(m+g)}$	4.84+-0.59	-	-
^{204m}Pb	67.2m	$i_{(m)}$	11.0+-1.0	-	-
^{203}Pb	51.873h	c	31.5+-2.1	28.7+-3.1	-
^{201}Pb	9.33h	c	26.9+-2.4	20.4+-1.9	-
^{200}Pb	21.5h	c	18.2+-1.2	18.2+-2.0	27.8+-3.5
^{198}Pb	2.4h	c	8.9+-2.1	14.0+-1.3	-
^{197m}Pb	43m	c	17.9+-4.0	-	-
			. . .		
^{82m}Rb	6.472h	$i_{(m)}$	2.73+-0.30	-	-
^{82}Br	35.30h	$i_{(m+g)}$	2.17+-0.14	1.55+-0.24	2.62+-0.50
^{75}Se	119.779d	c	1.33+-0.09	1.18+-0.19	1.61+-0.20
^{74}As	17.77d	i	1.86+-0.18	1.66+-0.27	2.24+-0.28
^{59}Fe	44.472d	c	0.91+-0.08	0.69+-0.11	1.05+-0.14
^{65}Zn	244.26d	c	0.79+-0.19	0.42+-0.07	0.66+-0.17
^{46}Sc	83.79d	$i_{(m+g)}$	0.35+-0.06	-	0.37+-0.05
Mean deviation from ITEP data [%]				**32**	**24**

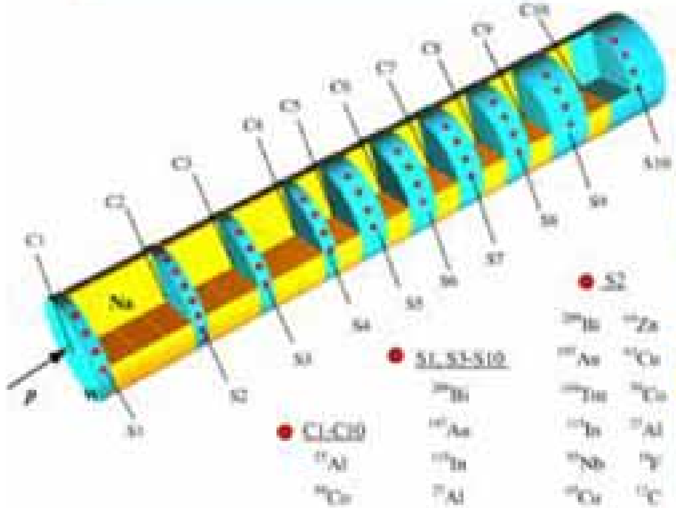
Unified comparison



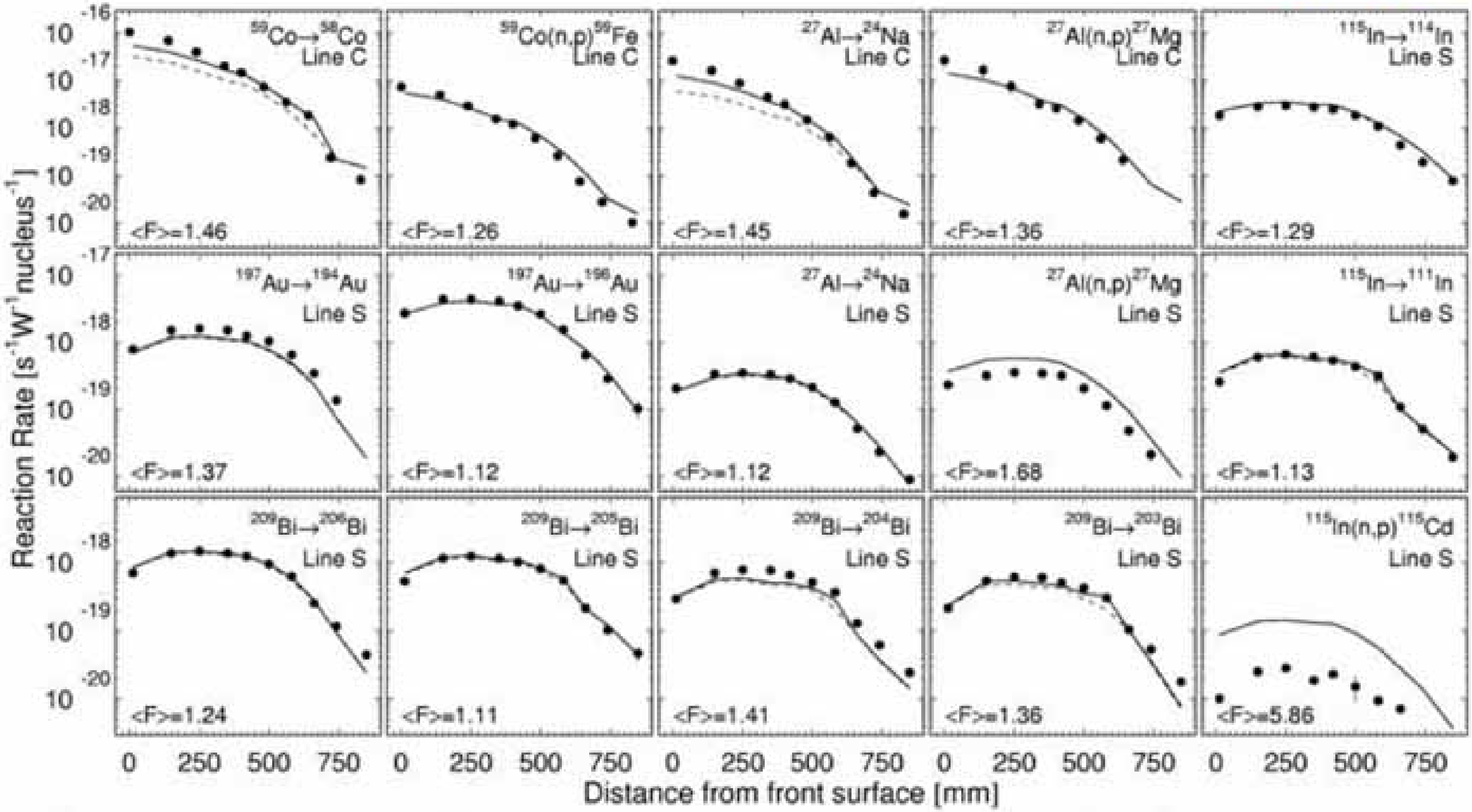
ISTC #1145 (III'99-VI'01): *Scope of Work*

- The various threshold reactions have been measured inside and outside a 0.8 GeV proton-irradiated thick W-Na target of Ø150xL900mm dimensions;
- The spectra of secondary neutrons from the 0.8 and 1.6 GeV proton-irradiated «thin» W (Ø50x30mm) and Na (Ø60xL200mm) targets have been measured;
- The fission cross sections have been estimated for seventeen isotopes (^{235}U, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{244}Pu, ^{241}Am, ^{242m}Am, ^{243}Am, ^{243}Cm, ^{244}Cm, ^{245}Cm, ^{246}Cm, ^{247}Cm, ^{248}Cm) in the NaF-ZrF$_4$ salt blanket micromodel.

All the results obtained have been simulated by the LAHET Code System and MCNP code with the use of the ENDF/B-VI, JENDL-3.2, MENDL2, MENDL2p nuclear data libraries.

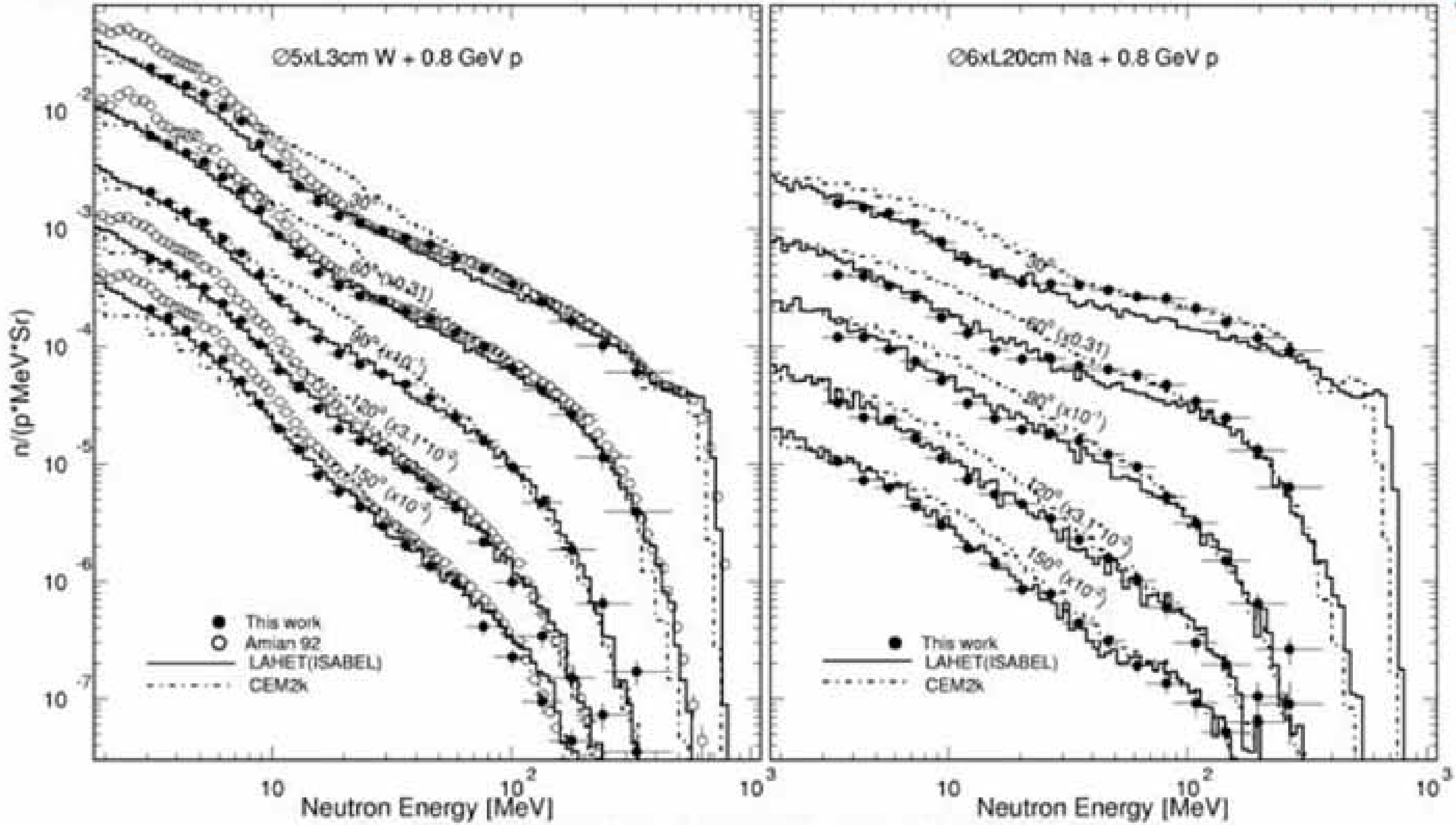


ISTC #1145: W-Na target



Reaction rates on W-Na thick targets irradiated with 0.8 GeV protons:
dots – experiment, lines – LCS+MENDL calculation

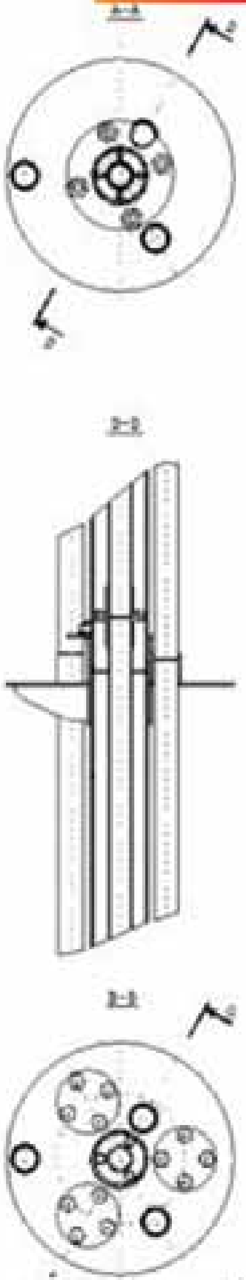
ISTC Project #1145: Neutron Spectra

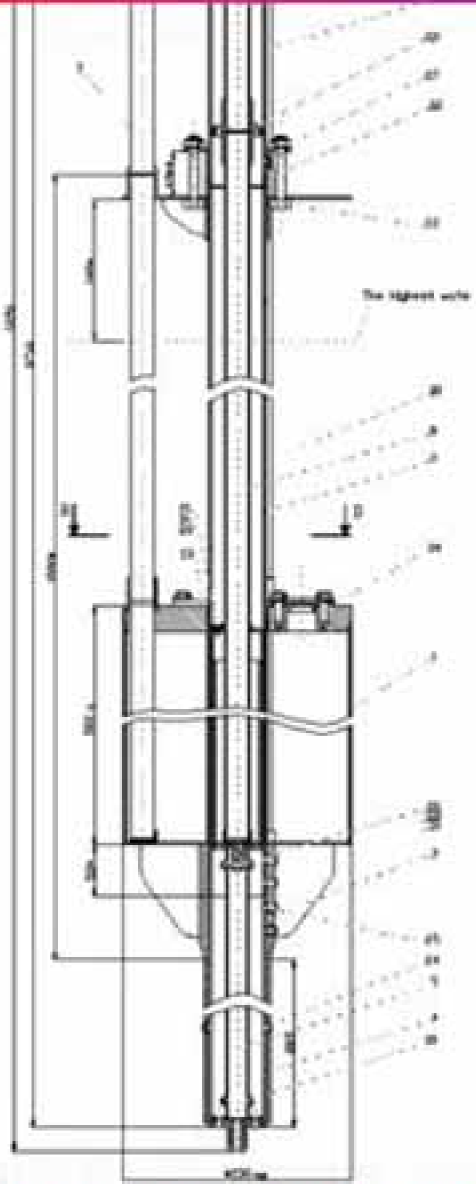


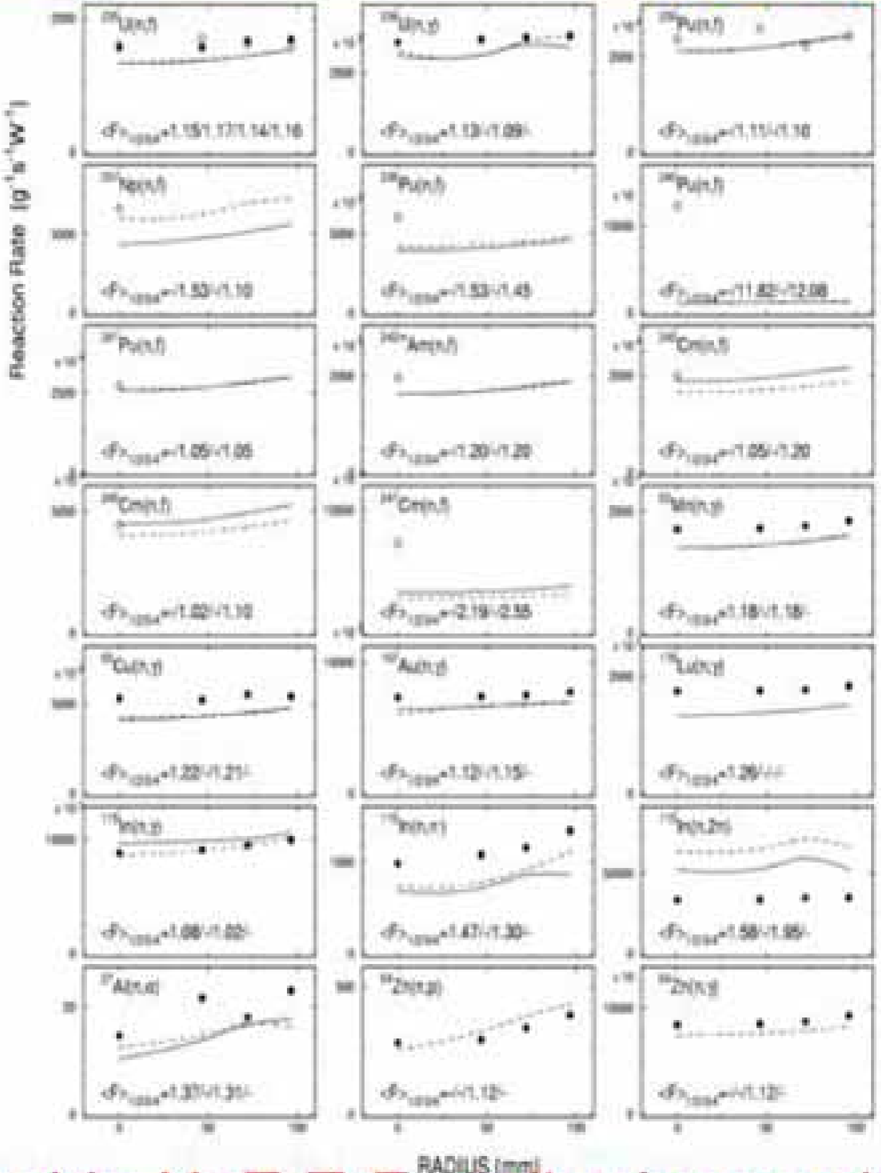
Neutron Spectra from W and Na targets:

Dots – experiment; lines – LAHET, CEM2k calculations

ISTC #1145: NaF-ZrF_4 salt micromodel







Actinide reaction rates inside NaF-ZrF_4 salt micromodel

P.Pavlopoulos

BASTRA

"*connecting people*"

coherently !!!

Round Table Discussion on the needs of Nuclear Data studies for ADS and their coverage by FP5 and other projects.

BASTRA Objectives

- Determine Nuclear Data needs for ADS and Review the cross sections which are :
  - Already existing;
  - Being acquired within FWP5 & ISTC;
  - Planned.
- Quality assurance plan for the Nuclear Data to be implemented into an ADS Database:
  - Methods, standards, norms and success metrics **BOTH** for Experimental Data and Theoretical Models (data descriptions);
  - Identify data being critical to the industrial design;
  - Benchmark TRANSPORT codes and tools !

ADS Nuclear Data Requirements

- ADS Nuclear Data Needs !
  - List of (Z,A) isotopes for ADS with explicit motivation ;
  - Needed reaction mechanisms ;
  - Energy domain ;
  - Parameter space.
- Input DATA for the ADS-Database !
  - Status of experimental data:
    - Quality on resolution, continuous energy range, normalisation etc.
    - Completeness

- Identify the REASONS for the existing DataBase discrepancies ; *Why need of "vitamines" ?*
- Universal criteria for the acceptance of Experimental Data in any compilation ; *Can't depend from the "evaluator", since Experimental Data are to costly !*
- More horizontal interactions between different theoretical activities, including the models and theoretical inputs used in TRANSPORT codes. *Include the necessary pion and kaon production, include FLUKA as simulation code of reaction rates.*

- Quality assessment for Data and Computational Tools !
  - Routines and Data used inside TRANSPORT codes;
  - Simulation tools;
  - Evaluators [?] *Continuation of the Joint n_TOF, JEF & NEA Workshop series.*
  - SENSITIVITY Analysis !
- Exchange of Experimental Techniques !
  - i.e. Radiochemical analysis of the nTOF Pb target.

Next Steps

- Identify members and goals of the 3 WG:
  - Review ND objectives of 5th FWP & ISTC.
    - *H. Aït Abderrahim, E.Gonzalez, J.-P.Meulders, P.Pavlopoulos, R.Soule, B. Carluec, L.Cinotti, …………*
  - Sensitivity Studies.
    - *C.Broeders, E.Gonzalez, Y.Kadi, ………………...*
  - Simulation Tools and Theoretical Models.
    - *A.Ferrari, H.Leeb, J.Cugnon, A.Koning, A.Nourri, P.Pavlopoulos, E. Gonzalez…….*
- Investigate for resources necessary to operate the WGs
- Finance young scientists through MC fellowships & other means (?)