International Atomic Energy Agency

Introduction: Background, contents and objectives

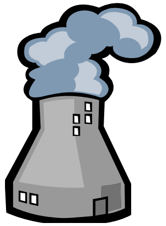
Naohiko Otsuka

IAEA Nuclear Data Section

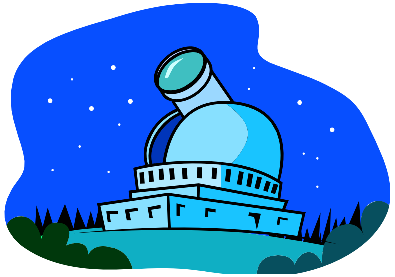
Nuclear Data for Application

- Nuclear energy systems (e.g., new design, critical safety)
- Dosimetry (e.g., neutron dose estimation)
- Shielding
- Medical isotope production
- Material analysis

etc.



(Also utilized in *basic science*,
e.g., astronuclear physics)



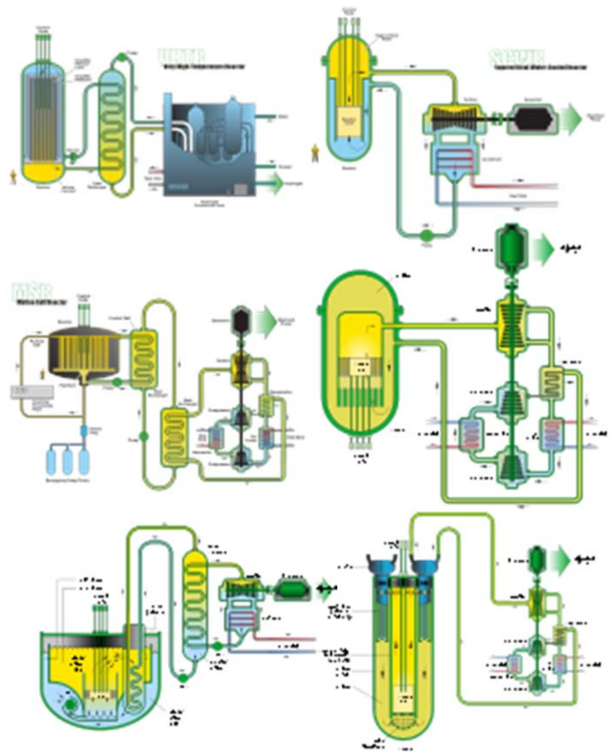
Generation IV Reactor (GEN IV - Next Generation)

GEN IV International Forum (GIF)

Argentine, Canada, China, EU, France, Japan, Korea, Russia, South Africa, Switzerland, UK, USA (Secretariat: NEA)

GEN IV Reactors (Rio de Janeiro, 2002)

- Very-high-temperature reactor (VHTR)
- Supercritical-water-cooled reactor (SCWR)
- Molten-salt reactor (MSR)
- Gas-cooled fast reactor (GFR)
- Sodium-cooled fast reactor (SFR)
- Lead-cooled fast reactor (LFR)

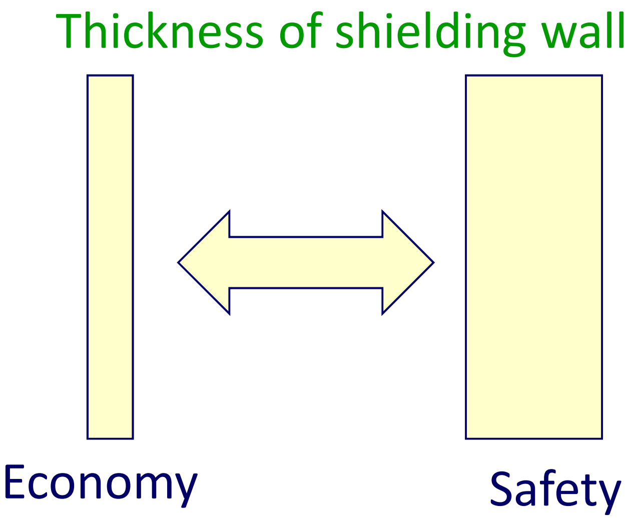


Images from Wikipedia

Highly Economical, Enhanced safety, Minimal waste, Proliferation resistant

Target Accuracy in New Reactor Design

Target accuracy is a concept to ensure *safe* and *economic* design of new reactor cores.



Example:

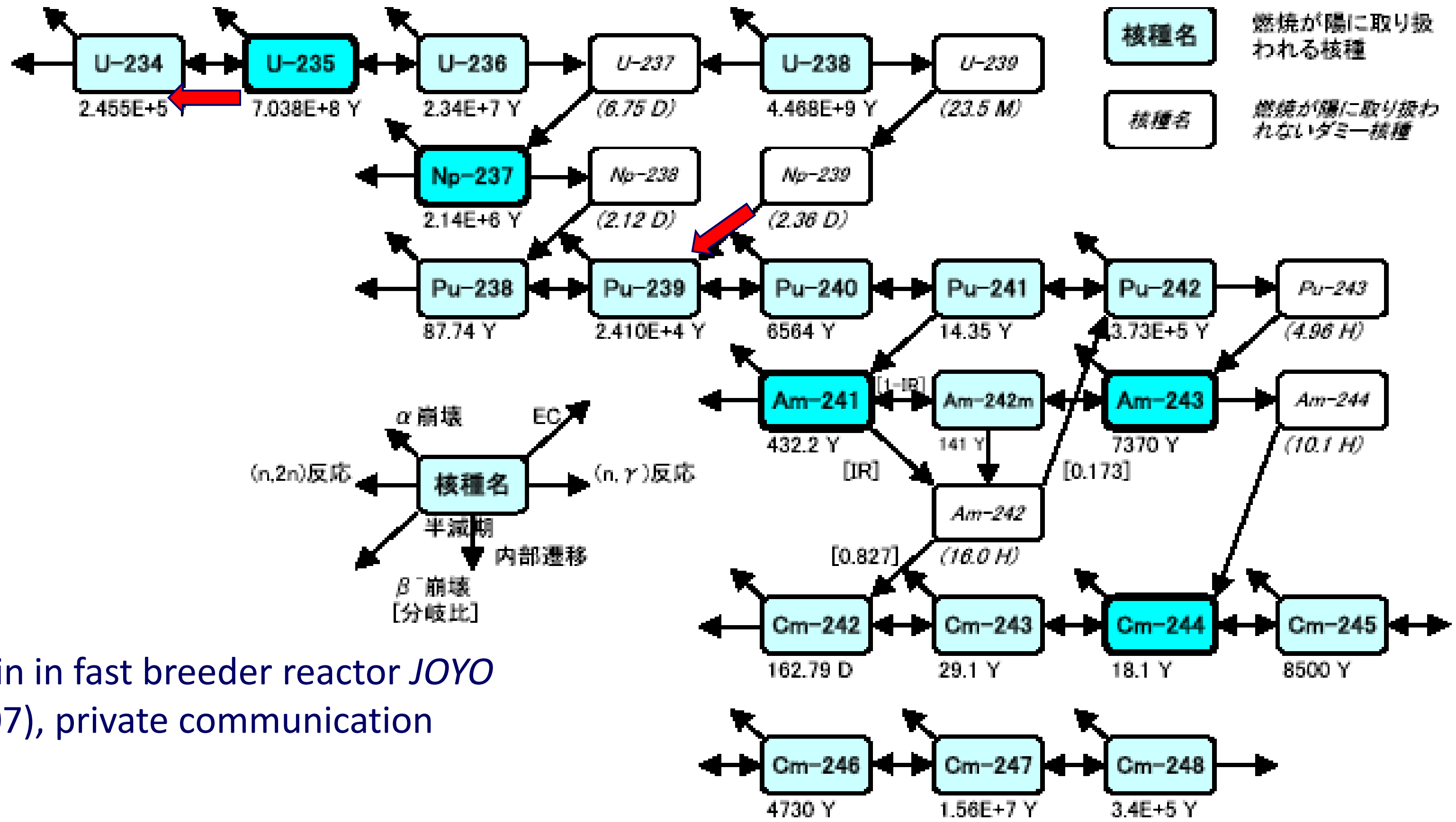
Target accuracies for design of a fast reactor core in Japan:

- Criticality (k_{eff}) - ±3% (1σ)
- Na void reactivity worth (± 20%, 2σ)
- Doppler reactivity worth (± 14%, 2σ)

...

Model and inputs for *reactor design calculation* must be accurately prepared to meet the target accuracy.

Modelling of Reactor System (Burning Chain)



Burning chain in fast breeder reactor *JOYO*
Sugino (2007), private communication

An isotope to another isotope through *reaction* or *decay e.g.,*

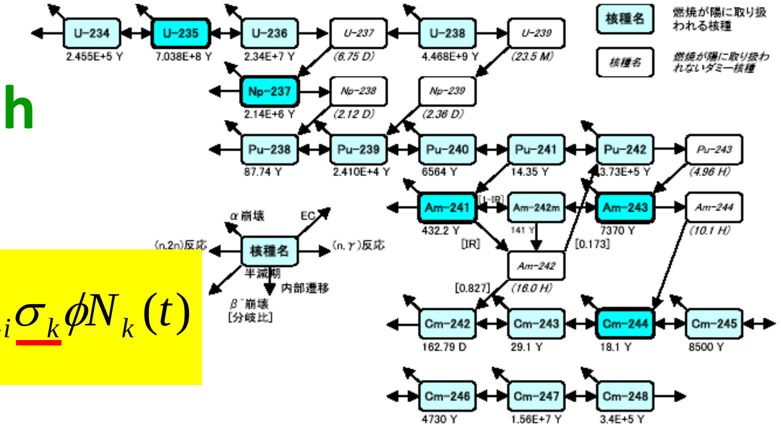
^{235}U(n,2n)^{234}U (reaction)

^{239}Np $\rightarrow$ ^{239}Pu + e^- + ν_e (β decay)

Nuclear Data to Solve Fission Energy System

Time evolution of the number of the *i*-th isotope ("burn-up equation")

$$\frac{dN_i(t)}{dt} = -(\underline{\lambda_i} + \underline{\sigma_i}\phi)N_i(t) + \sum_j f_{j\to i}\underline{\lambda_j}N_j(t) + \sum_k g_{k\to i}\underline{\sigma_k}\phi N_k(t)$$



Nuclear data as inputs for the coupled equations (i=1,n):

- σ_i: cross section for reaction from isotope i to other isotopes
- λ_i: decay constant for the isotope i ($\lambda = \ln 2 / T_{1/2}$).

Propagation of uncertainty from (independent) nuclear data $\{\Delta x_i\}$ to reactor parameters ΔX_{reac} in linear approximation:

$$\sum_i (S_i \cdot \Delta x_i) = \Delta X_{reac} ,$$

where $S_i = (\partial X_{reac} / \partial x_i)$ – "sensitivity coefficient".

Target Accuracy of Nuclear Data

Error propagation from nuclear data to reactor quantity:

$$\sum_i (S_i \cdot \Delta x_i) = \Delta X_{reac}$$

Target accuracy ΔX_{reac} and sensitivity coefficients $\{S_i\}$ constrain the target accuracies of nuclear data $\{\Delta x_i\}$.

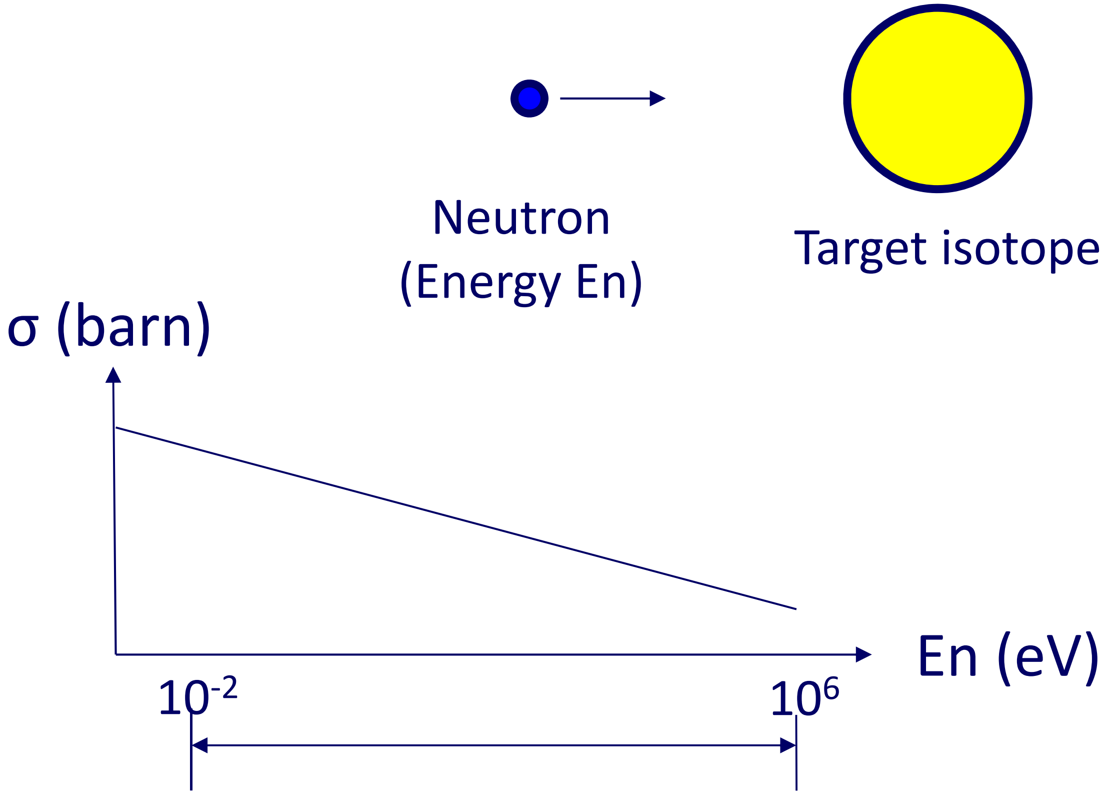
→ Motivation for nuclear data improvements by new experiments and evaluations

Table 30. ADMAB: uncertainty reduction requirements needed to meet integral parameter target accuracies

Isotope	Cross-Section	Energy range	Uncertainty (%)		
			Initial	Required	
				$\lambda=1$	$\lambda\neq1$ [a]
Pu238	σ_{fiss}	6.07 - 0.498 MeV	20	3	3
	ν	1.35 - 0. 183 MeV	7	3	3
Pu239	σ_{capt}	498 - 2.03 keV	12	4	3
	σ_{inel}	6.07 - 0.498 MeV	25	5	6
Pu240	σ_{capt}	183 - 67.4 keV	14	6	6
	σ_{fiss}	2.23 - 0.498 MeV	6	2	2
	ν	1.35 - 0.498 MeV	4	2	2
Pu241	σ_{capt}	1.35 - 0. 183 MeV	20	7	7
	σ_{fiss}	6.07 MeV-22.6 eV	15	2	2
Pu242	σ_{capt}	24.8 - 9.12 keV	35	10	10
	σ_{fiss}	6.07 - 0.498 MeV	20	4	4
Np237	σ_{capt}	498 - 0.454 keV	6	3	3
	σ_{fiss}	6.07 - 0.183 MeV	8	2	2
	σ_{inel}	2.23 – 0.183 MeV	25	5	6
Am241	σ_{capt}	1.35 MeV- 0.454 keV	8	2	2
	σ_{fiss}	6.07 – 0.183 MeV	10	1	1
	ν	6.07 - 1.35 MeV	2	1	1
	σ_{inel}	6.07 – 0.183 MeV	25	4	5
Am242m	σ_{fiss}	1.35 MeV- 9.12 keV	17	5	5
		[illegible]	[illegible]	[illegible]	[illegible]

Report NEA/WPEC-26 (OECD, 2008)

Neutron-Induced Reaction Cross Section



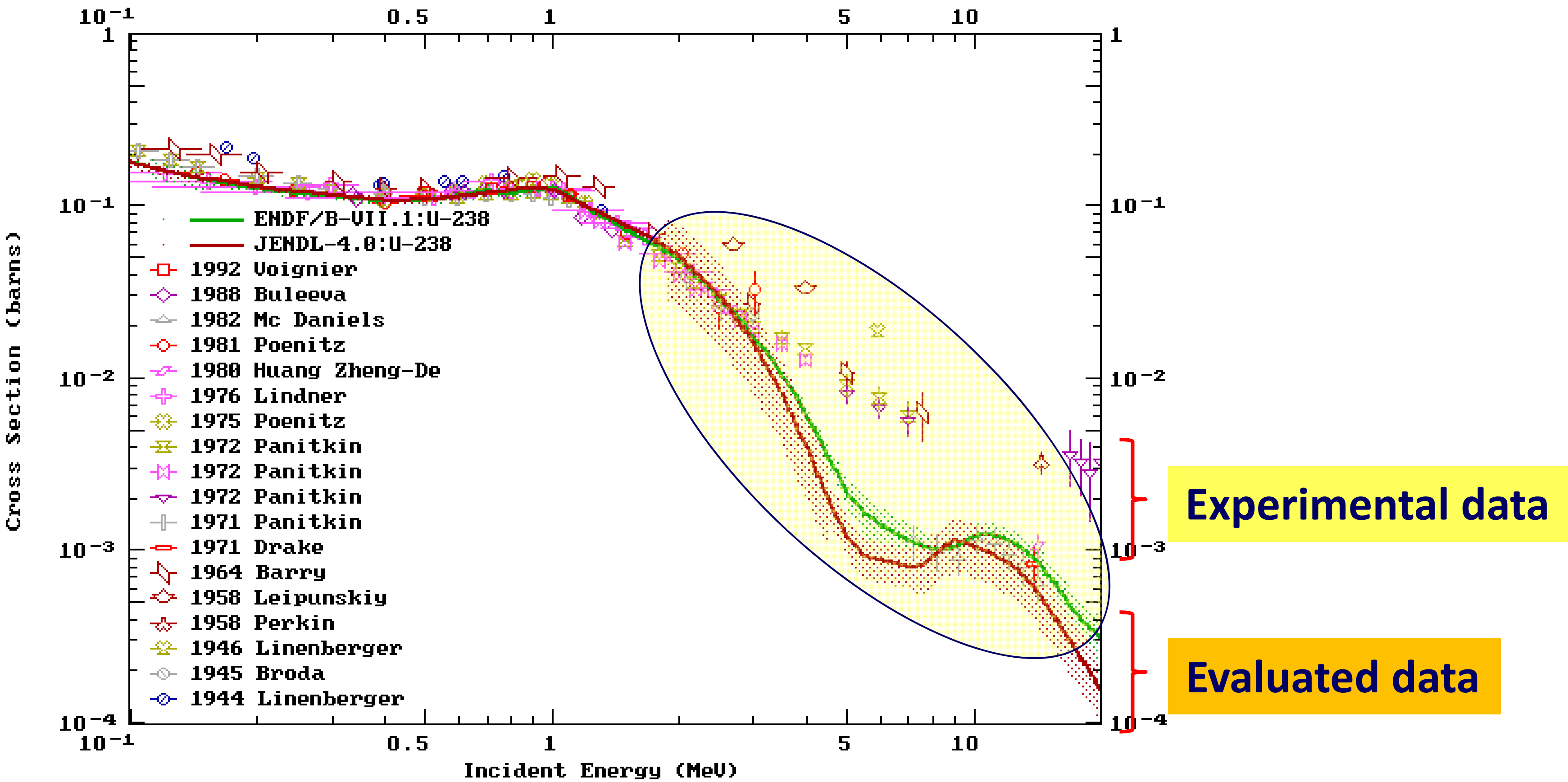
Energy range for fission reactor system

10^{-2} eV: Energy of thermal neutrons (room temperature)

10^{6} eV (=1 MeV): Energy of neutrons emitted during fission

Evaluation of Cross Section (σ)

^{238}U(n,γ)^{239}U (neutron capture by uranium-238) cross section



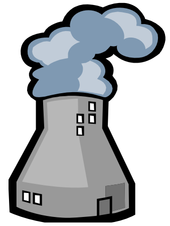
It is now common to provide evaluated cross sections with their uncertainties.

Uncertainties and Covariances for Evaluations

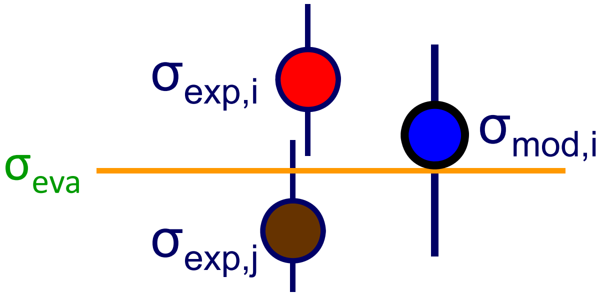
Experimental data $\{\sigma_{exp,i}\}$

Theoretical data $\{\sigma_{the,i}\}$

Evaluated data σ_{eva}



Reactor calculation



Least-squares with variance (standard deviation Δσ)

$$\chi^2=\Sigma_i (\sigma_{eva} - \boldsymbol{\sigma_{exp,i}})^2 / (\boldsymbol{\Delta\sigma_{exp,i}})^2 + \Sigma_i (\sigma_{eva} - \sigma_{the,i})^2/(\Delta\sigma_{the,i})^2 = \min$$

Least-squares with covariance (V)

$$\chi^2=\Sigma_{ij} (\sigma_{eva} - \sigma_{exp,i}) (\mathbf{V^{-1}_{exp,ij}}) (\sigma_{eva} - \sigma_{exp,j})+ \Sigma_{ij} (\sigma_{eva} - \sigma_{the,i})(V^{-1}_{the,ij}) (\sigma_{the} - \sigma_{the,i}) = \min$$

Experimental uncertainty $\Delta\sigma_{exp}$ and covariance V_{exp} are essential for proper weighting of each experimental data point σ_{exp} !

Simple Evaluation: Averaging of Experimental Data

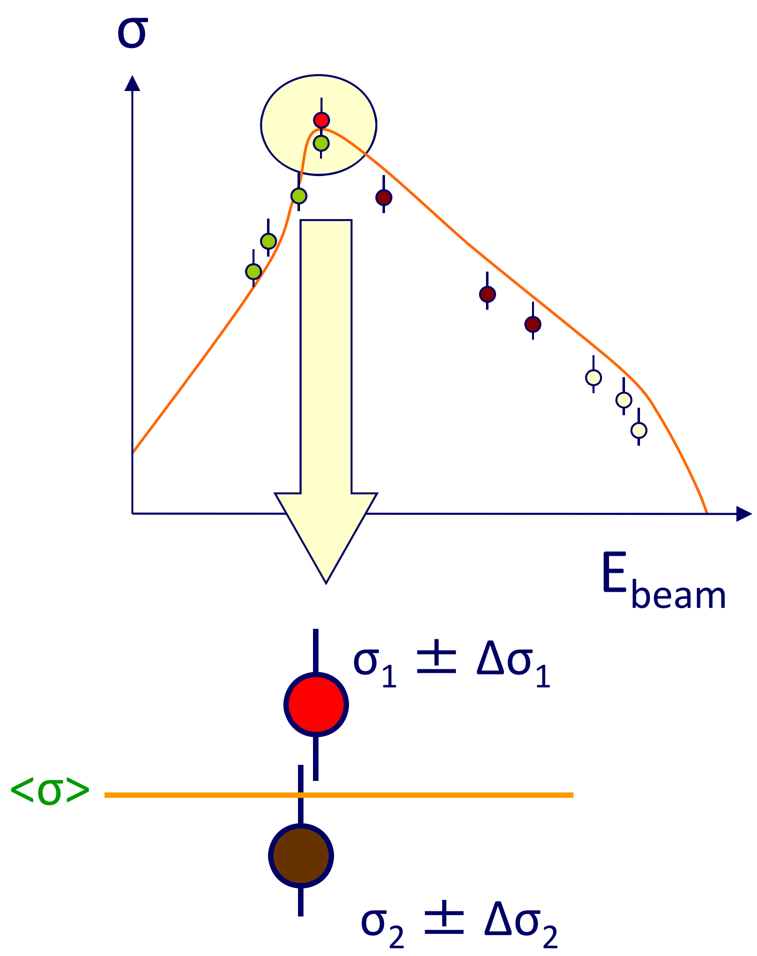
Evaluation of the best estimate from experimental data sets (averaging) for

$\sigma_1 \pm \Delta\sigma_1$ and $\sigma_2 \pm \Delta\sigma_2$.

If two experiments are independent (i.e., $cov(\sigma_1,\sigma_2)=0$), the least squares prescription gives

$$\begin{cases} \langle\sigma\rangle = (\sigma_1 w_1 + \sigma_2 w_2) / (w_1 + w_2) \\ (\Delta\langle\sigma\rangle)^2 = 1/(w_1 + w_2) \end{cases}$$

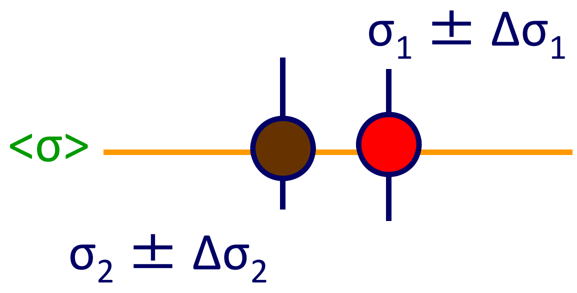
with $w_1 = (1/\Delta\sigma_1)^2$, $w_2 = (1/\Delta\sigma_2)^2$ (simple weighted mean).



Average from Two Independent Measurements

Formula:

$$\begin{cases} \langle\sigma\rangle = (\sigma_1 w_1 + \sigma_2 w_2) / (w_1 + w_2) \\ (\Delta\langle\sigma\rangle)^2 = 1/(w_1 + w_2) \\ \text{with } w_1 = (1/\Delta\sigma_1)^2 , w_2 = (1/\Delta\sigma_2)^2 \end{cases}$$



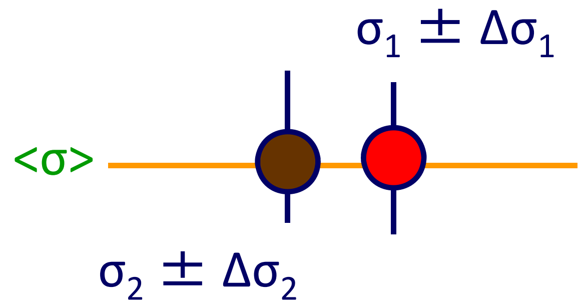
Example:

	Experiment 1	Experiment 2
σ	100.0 mb	100.0 mb
Δσ	5.0 mb (5%)	5.0 mb (5%)

The weighted average is 100.0 ± 3.5 mb (3.5%).
Averaging (i.e., repetition of the experiment) improved the uncertainty.

Partial Uncertainties – Numerical Example

$$\begin{cases} \sigma_1 = N_1 / (n_1\rho_1) \\ \sigma_2 = N_2 / (n_2\rho_2) \end{cases}$$



	Experiment 1	Experiment 2	Source of uncertainty
σ	100.0 mb	100.0 mb	
Δσ	5.0 mb (5%)	5.0 mb (5%)	Total ($5^2=4^2+3^2$)
$\Delta\sigma_N$	4.0 mb (4%)	4.0 mb (4%)	product *counting*
$\Delta\sigma_\rho$	3.0 mb (3%)	3.0 mb (3%)	sample density *counting*
$\Delta\sigma_n$	(negligible)	(negligible)	beam *counting* (assumed as negligible)
< σ >	100 ± 3.5 mb		

Repetition of *counting* (measurements of N, ρ, n) improves the uncertainty. (For random variable x, $\Delta x/x \sim x^{-1/2}$ for normal distribution.)

Uncertainty Determined by Other Measurement

Sometimes the same sample material is used by several experiments without repetition of sample density counting.

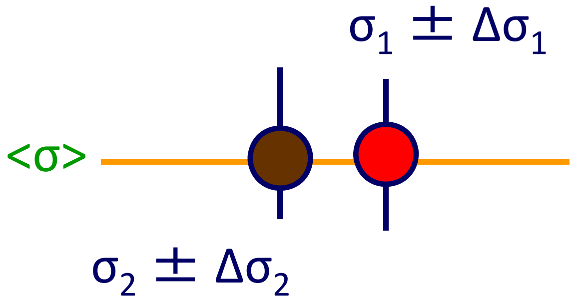
	Experiment 1	Experiment 2	Source of uncertainty
σ	100.0 mb	100.0 mb	
Δσ	5.0 mb (5%)	5.0 mb (5%)	total
$\Delta\sigma_N$	4.0 mb (4%)	4.0 mb (4%)	product counting
$\Delta\sigma_\rho$	3.0 mb (3%)		sample density counting (measured in Exp. 1 only)
$\Delta\sigma_n$	(negligible)	(negligible)	beam counting

The Exp. 2 assumed that $\rho_2=\rho_1$, namely
Probability density $P(\rho_1,\rho_2)= P(\rho_1)\delta(\rho_1-\rho_2)$, where δ is Dirac's delta function.

What is the influence of the assumption (correlation) on error propagation?

Modification to Weighted Average Formula

Weighted average without correlation exists



$$\begin{cases} \langle\sigma\rangle = (\sigma_1 w_1 + \sigma_2 w_2) / (w_1 + w_2) \\ \text{with } 1/w_1 = (\Delta\sigma_1)^2,\ 1/w_2 = (\Delta\sigma_2)^2 \\ (\Delta\langle\sigma\rangle)^2 = 1/[(\Delta\sigma_1)^2 \cdot (\Delta\sigma_2)^2] / [(\Delta\sigma_1)^2 + (\Delta\sigma_2)^2] \end{cases}$$

100 ± 3.5 mb

Weighted average with correlation (same sample density)

$$\begin{cases} \langle\sigma\rangle = (\sigma_1 w_1 + \sigma_2 w_2) / (w_1 + w_2) \\ \text{with } 1/w_1 = (\Delta\sigma_1)^2 - \mathrm{cov}(\sigma_1, \sigma_2),\ 1/w_2 = (\Delta\sigma_2)^2 - \mathrm{cov}(\sigma_1, \sigma_2), \\ (\Delta\langle\sigma\rangle)^2 = [(\Delta\sigma_1)^2 \cdot (\Delta\sigma_2)^2 - \mathrm{cov}(\sigma_1, \sigma_2)^2] / [(\Delta\sigma_1)^2 + (\Delta\sigma_2)^2 - 2\mathrm{cov}(\sigma_1, \sigma_2)] \end{cases}$$

100 ± 4.1 mb

Impact of Correlated Source of Uncertainty

	Experiment 1	Experiment 2
σ	100.0 mb	100.0 mb
$\Delta\sigma$	5.0 mb (5%)	5.0 mb (5%)
$\Delta\sigma_N$	4.0 mb (4%)	4.0 mb (4%)
$\Delta\sigma_p$	3.0 mb (3%)	3.0 mb (3%)
	(counted in both experiments)	
$\Delta\sigma_n$	(negligible)	(negligible)
$<\sigma>$	100 ± 3.5 mb	

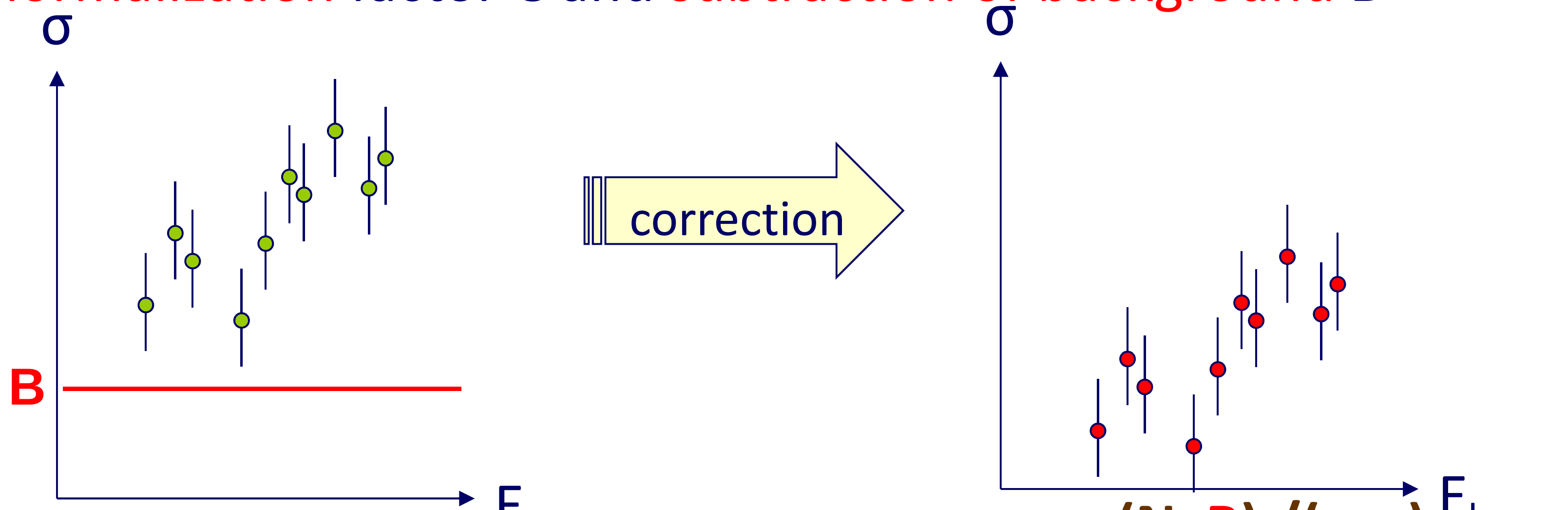
Experiment 1	Experiment 2
100.0 mb	100.0 mb
5.0 mb (5%)	5.0 mb (5%)
4.0 mb (4%)	4.0 mb (4%)
3.0 mb (3%)	
(counted in one experiment)	
(negligible)	(negligible)
100 ± 4.1 mb	

Conclusion:

Uncertainty is less improved if a primary measurable was not determined independently.

Correlation within Single Experiment

Example: Cross section measurement at various beam energy with renormalization factor **C** and subtraction of background **B**

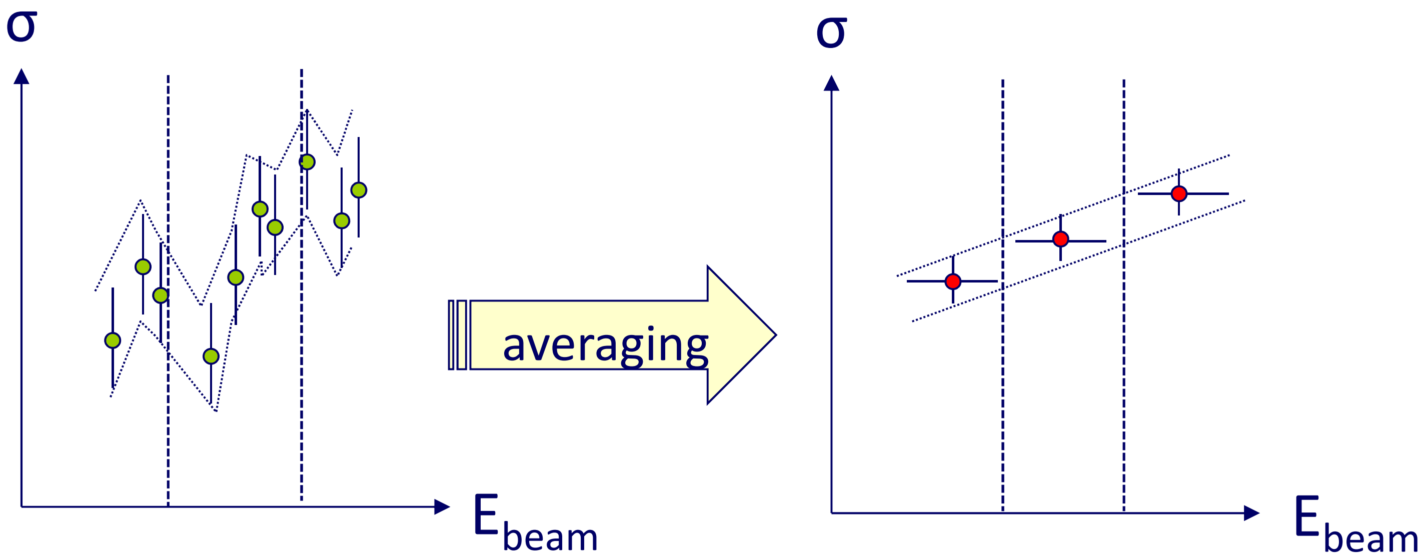


$$\sigma_i = N_i /(n_i\rho_i) \qquad \sigma_i = (N_i - B) /(n_i\rho_i)$$

Typical correlated source within one experiment

- Common sample characterization(n)
- Common normalization factor (C)
- Common background subtraction (B)

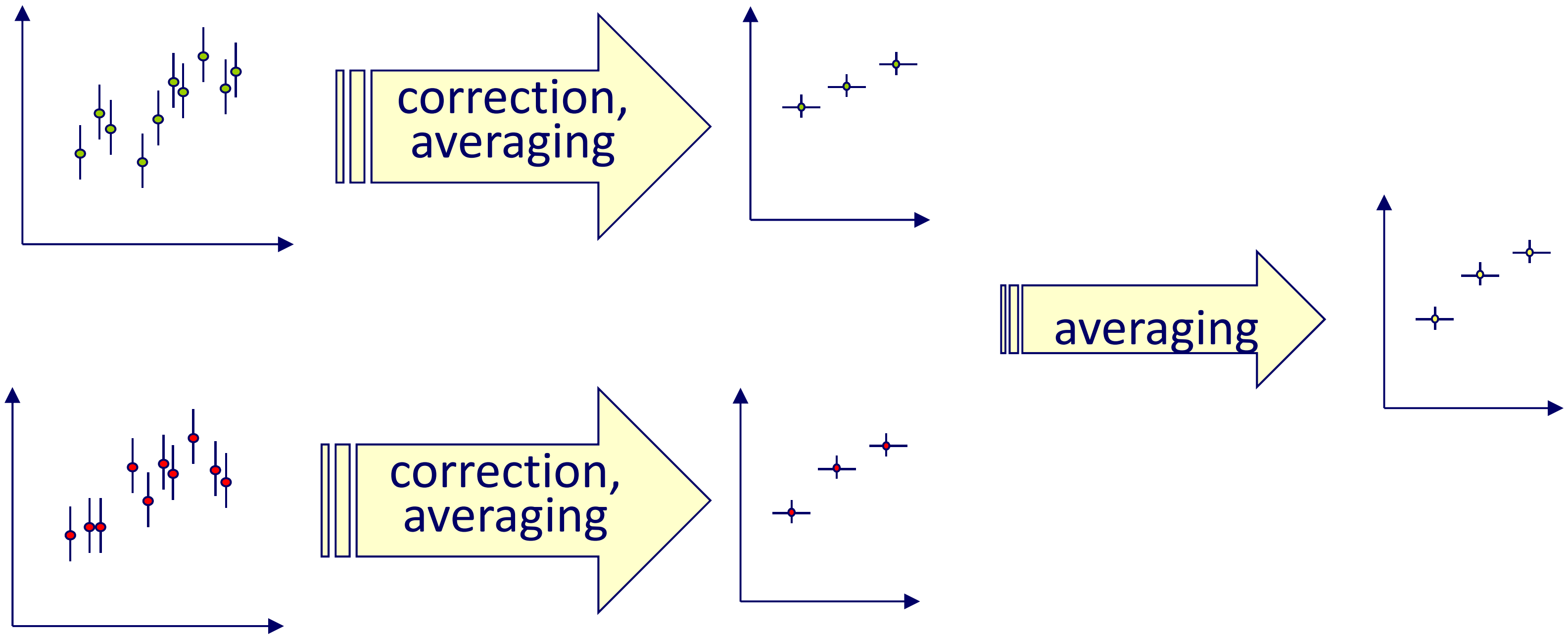
Average within Single Experiment



Statistical fluctuation visible. Uncorrelated uncertainty dominant.

Statistics (fluctuation) improved. Correlated uncertainty dominant.

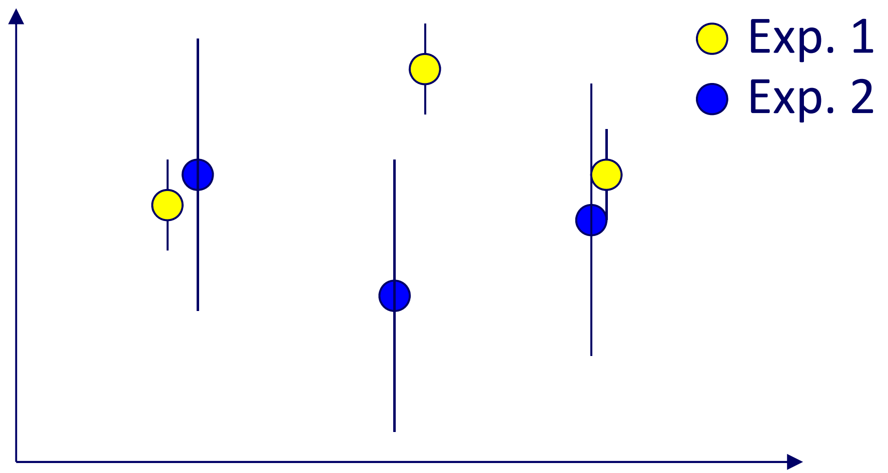
Correlation in Various Steps of Data Reduction



Information on uncertainties and correlation performed by experimentalists are essential for further evaluation.

→ **EXFOR Compilation!**

Which Data Sets Shall We Trust?



Which data set is better? We cannot answer if components considered in each set is not known.

EXFOR compilers are responsible to avoid this trouble.

Documentation: Journal Article

$^{51}V(n,p)^{51}Ti$ cross sections published in a journal (Ann. Nucl. Energy)

Ann. nucl. Energy, Vol. 11, No. 12, pp. 623–627, 1984
Printed in Great Britain

0306-4549/84 $3.00 + 0.00
Pergamon Press Ltd

MEASURED ACTIVATION CROSS SECTIONS BELOW 10 MeV FOR THE $^{51}V(n,p)^{51}Ti$ AND $^{51}V(n,\alpha)^{48}Sc$ REACTIONS

D. L. Smith, J. W. Meadows and I. Kanno*
Applied Physics Division, Argonne National Laboratory, 9700 South Cass Ave., Argonne,

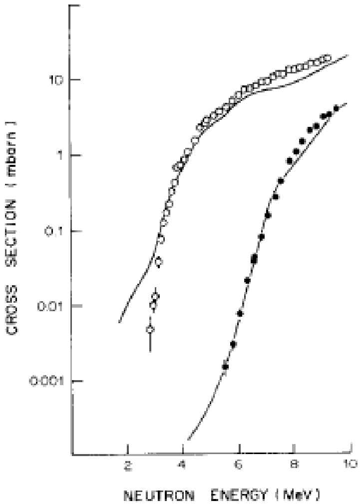


Table 2. Sources of experimental error

Source	Magnitude (%) $^{51}V(n,p)^{51}Ti$	Magnitude (%) $^{51}V(n,\alpha)^{48}Sc$
Random Errors		
Exposure, waiting and count times	0.2	N[a]
γ-Ray yield	0.3–47.8	0.5–22.6
Fission yield	0.7–1.5	0.1–0.2
Extrapolation correction	1–2	0.5
Background fission correction	N–3[a]	1–3
Background activation	0.2–1.2	N–0.5[a]
Geometric corrections	1.5	1.5
Systematic Errors		
Decay half-life	0.1	0.1–0.2
^{238}U content of monitor deposit	2	2
^{51}V content of the samples	0.2	0.2
U deposit thickness correction	0.8	0.8
γ-Ray counting efficiency	2.4	1
γ-Ray decay branch factor	1	N[a,b]
Orientation of sample for counting	N[a]	N[a,b]
Neutron-source properties	2	2
Room-return fission events	N[a]	N[a]
Neutron-scattering corrections	1.4–2.1	1.3–1.6
Geometric corrections	1.5	1.5
Average neutron energy determination	0.5–19.5	2.6–12.2

[a] N = negligible.
[b] Uncertainty included in γ-ray counting efficiency determination.

Sources of uncertainty

Because of the size limitation, uncertainties are often expressed by their ranges (not for each data point).

Documentation: Laboratory Report (Full Info.)

Same experimental work documented in a laboratory report.

ANL/NDM-85

MEASUREMENT OF THE $^{51}V(n,p)^{51}Ti$ REACTION CROSS SECTION FROM THRESHOLD TO 9.3 MeV BY THE ACTIVATION METHOD*

by

Donald L. Smith, James W. Meadows and Ikuo Kanno**
June 1984

All partial uncertainties are Given for each data point. But they are not computer readable.

Table 3: Explicit Values for Variable Error Components[a]

Data Point[b]	K_2	K_3	K_4	K_5	K_6	S_{11}	S_{12}
1	47.8	0.8	2.0	N[c]	N[c]	2.0	14.9
2	20.4	0.8	2.0	N	N	2.1	7.9
3	15.7	0.8	2.0	N	N	2.1	19.5
4	6.2	0.7	2.0	N	N	2.0	14.8
5	4.2	0.7	2.0	N	N	1.9	10.2
6	2.5	0.7	2.0	N	N	1.9	6.6
7	2.2	0.7	2.0	N	N	1.9	4.9
8	1.8	0.7	2.0	N	N	1.9	6.3
9	1.5	0.7	2.0	N	N	1.9	5.5
10	1.2	0.7	2.0	N	N	1.9	7.0
11	1.0	0.7	2.0	N	N	1.9	3.6
12	1.0	0.7	2.0	N	N	1.9	3.6
13	1.0	0.7	2.0	N	N	1.9	1.7
14	0.9	0.7	2.0	N	N	1.9	2.1
15	0.8	0.7	2.0	N	N	1.9	4.9
16	0.7	0.7	2.0	0.1	N	2.0	2.3
17	0.7	0.9	2.0	0.2	N	2.0	0.5
18	0.7	1.0	2.0	0.2	N	2.0	1.3
19	1.1	1.5	1.0	0.5	0.3	2.0	2.0
20	1.0	1.5	1.0	0.5	0.3	1.9	4.2
21	0.8	1.3	1.0	0.5	0.3	1.9	2.4
22	0.7	1.2	1.0	0.6	0.2	1.9	1.9
23	0.7	1.2	1.0	0.7	0.2	1.9	3.2
24	0.6	1.2	1.0	0.8	0.3	1.8	2.6
25	0.6	1.2	1.0	1.0	0.3	1.8	2.5
26	0.5	1.1	1.0	0.8	0.2	1.8	1.8
27	0.5	1.0	1.0	0.8	0.3	1.7	1.5
28	0.5	1.0	1.0	0.8	0.3	1.7	1.3
29	0.4	0.9	1.0	0.9	0.3	1.7	1.2
30	0.4	0.8	1.0	1.0	0.3	1.6	1.1
31	0.4	0.9	1.0	1.0	0.3	1.6	1.1
32	0.4	0.8	1.0	1.0	0.3	1.6	1.1
33	0.4	0.8	1.0	1.0	0.3	1.6	1.0
34	0.3	0.8	1.0	1.5	0.5	1.6	0.9
35	0.4	0.7	1.0	1.5	0.5	1.6	0.9
36	0.3	0.7	1.0	2.0	0.6	1.6	0.9
37	0.3	0.8	1.0	2.0	0.6	1.5	0.9
38	0.3	0.7	1.0	2.0	0.7	1.5	0.9
39	0.3	0.7	1.0	2.0	0.8	1.5	0.9
40	0.3	0.8	1.0	2.5	0.9	1.5	0.8
41	0.3	0.8	1.0	2.5	0.9	1.4	1.1
42	0.3	0.7	1.0	2.5	0.9	1.4	1.0

Documentation: EXFOR entry

```
SUBENT        12898002   20120710
BIB                  4         32
REACTION   ((23-V-51(N,P)22-TI-51,,SIG)/(92-U-238(N,F),,SIG))
...
FLAG       (1.) 7Li(p,n)7Be source
           (2.) 2H(d,n)3He source
ERR-ANALYS Uncertainty due to orientation of sample for counting
            was treated as negligible.
           (ERR-T)      Total uncertainty
           (ERR-S)      Total random uncertainty in ratio
           (ERR-SYS)    Total systematic uncertainty
           (ERR-1,,,U)  Exposure, waiting and counting times(0.2%)
           (ERR-2,,,U)  0.320-MeV gamma ray yield      (0.3-47.8%)
           (ERR-3,,,U)  Fission yield                    (0.7-1.5%)
           (ERR-4,,,U)  Extrapolation correction             (1-2%)
           (ERR-5,,,U)  Background fission correction         (<3%)
           (ERR-6,,,U)  Background activation            (0.2-1.2%)
           (ERR-7,,,U)  Geometric corrections                (1.5%)
           (ERR-8,,,F)  51Ti decay half life                 (0.1%)
           (ERR-9,,,F)  238U content of monitor deposit        (2%)
           (ERR-10,,,F) 51V content of samples               (0.2%)
           (ERR-11,,,F) Uranium deposit thickness correction(0.8%)
           (ERR-12,,,F) Gamma-ray counting efficiency        (2.4%)
           (ERR-13,,,F) 51Ti gamma-ray decay branch factor     (1%)
           (ERR-14,,,P) Neutron source properties              (2%)
           (ERR-15,,,P) Neutron scattering corrections  (1.4-2.1%)
           (ERR-16,,,F) Geometric corrections                (1.5%)
           (ERR-17,,,F) Average neutron energy          (0.5-19.5%)
COVARIANCE ERR-14:
            No correlation between p+7Li and and d+D points.
            Otherwise correlation coefficient=100-10 dE
            (dE: energy difference in MeV)
           ERR-15:
            Correlation coefficient=100-10 dE
            (dE: energy difference in MeV)
...
ENDBIB              32          0
```

```
ERR-1      ERR-7      ERR-8      ERR-9      ERR-10     ERR-11
ERR-12     ERR-13     ERR-14     ERR-16
PER-CENT   PER-CENT   PER-CENT   PER-CENT   PER-CENT   PER-CENT
PER-CENT   PER-CENT   PER-CENT   PER-CENT
 0.2        1.5        0.1        2.         0.2        0.8
 2.4        1.         2.         1.5
ENDCOMMON            6          0
DATA                14         45
EN         EN-RSL-FW  DATA       ERR-S      ERR-SYS    ERR-T
ERR-2      ERR-3      ERR-4      ERR-5      ERR-6      ERR-15
ERR-17     FLAG
MEV        MEV        NO-DIM     PER-CENT   PER-CENT   PER-CENT
PER-CENT   PER-CENT   PER-CENT   PER-CENT   PER-CENT   PER-CENT
PER-CENT   NO-DIM
  2.856     0.095      9.075 E-06 47.9       15.6       50.4
 47.8       0.8        2.0                               2.0
 14.9       1.
  2.957     0.094      1.966 E-05 20.6        9.2       22.6
 20.4       0.8        2.0                               2.1
  7.9       1.
  3.057     0.094      2.575 E-05 15.9       20.1       25.6
 15.7       0.8        2.0                               2.1
 19.5       1.
  3.158     0.092      7.369 E-05  6.7       15.5       16.9
  6.2       0.7        2.0                               2.0
 14.8       1.
  3.258     0.090      1.441 E-04  4.9       11.2       12.2
  4.2       0.7        2.0                               1.9
 10.2       1.
  3.359     0.087      2.354 E-04  3.6        8.1        8.9
  2.5       0.7        2.0                               1.9
  6.6       1.
  3.459     0.087      3.210 E-04  3.4        6.7        7.5
  2.2       0.7        2.0                               1.9
  4.9       1.
  3.560     0.087      4.130 E-04  3.2        7.8        8.4
 ......
```

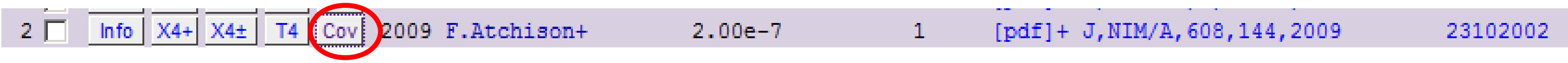
Full information is available in computer readable form!!

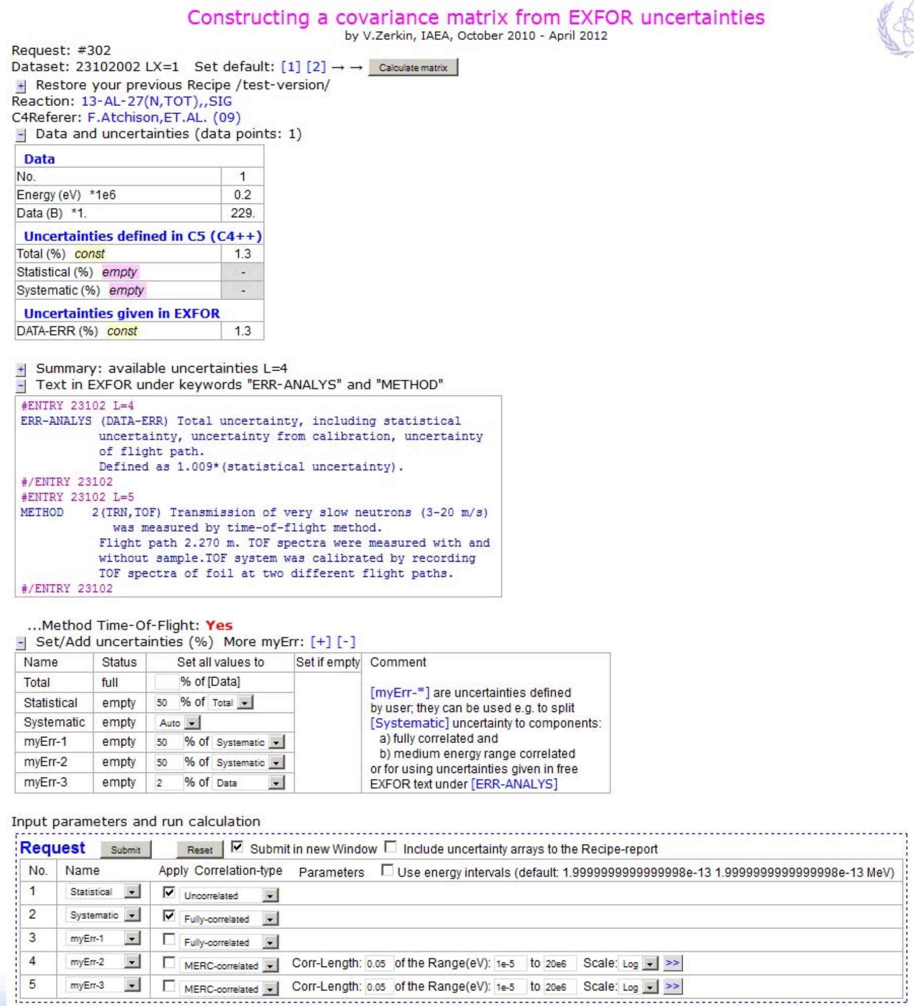
New EXFOR Formats for Correlation Properties

	Corr.	8.96 MeV	9.46 MeV
σ		21.71 mb	98.13 mb
$\Delta\sigma_{total}$		0.99 mb	7.24 mb
$\Delta\sigma_{intensity}$	Corr.	0.49 %	
$\Delta\sigma_{half\text{-}life}$	Corr.	0.39 %	
$\Delta\sigma_{efficiency}$	Corr.	1.5%	
$\Delta\sigma_{statistics}$	Uncorr.	0.33 mb	2.10 mb

```
ERR-ANALYS (ERR-T) Total uncertainty
           (ERR-1,C)gamma intensity        (0.49%)
           (ERR-2,C)half-life              (0.39%)
           (ERR-3,C)absolute HPGe efficiency(1.5%)
           (ERR-S,U) statistics
ENDBIB               8          0
COMMON               3          3
ERR-1      ERR-2      ERR-3
PER-CENT   PER-CENT   PER-CENT
 0.49       0.39        1.5
ENDCOMMON            3          0
DATA                 5          9
EN         EN-ERR     DATA       ERR-S      ERR-T
MEV        MEV        MB         MB         MB
  8.96      0.09        21.71     0.33        0.99
  9.46      0.13        98.13     2.10        7.24
```

New NDS EXFOR Web Tool to Construct Covariances





New tools to construct and manipulate covariance matrices from EXFOR are available!

Background of This Workshop

- Evaluators have to provide evaluated cross sections with their uncertainties / correlations for future applications – e.g., nuclear energy, dosimetry.
- The evaluation of uncertainties / correlations strongly relies on those in experimental data.
- New formats and new tools for EXFOR are ready.
- EXFOR compilers (not evaluators!) are responsible to collect necessary information from experimentalists.
- Compilers should know what will be useful for evaluators.

Contents of the Workshop (27 – 28 August)

Contents:

- **Basic concepts** - probability distribution, mean, (co)variance etc.
- **Error propagation** – linear combination, linear approximation
- **Evaluation** - least-squares analysis, weighted average
- **Topics** – tools (Viktor), activation (Valentina, Sandor), transmission (Olena)

Goal:

- To understand basic concepts.
- To understand the usage of experimental covariance by users.
- To understand correlation information must be in EXFOR.

Contents of the Workshop (27 – 28 August)

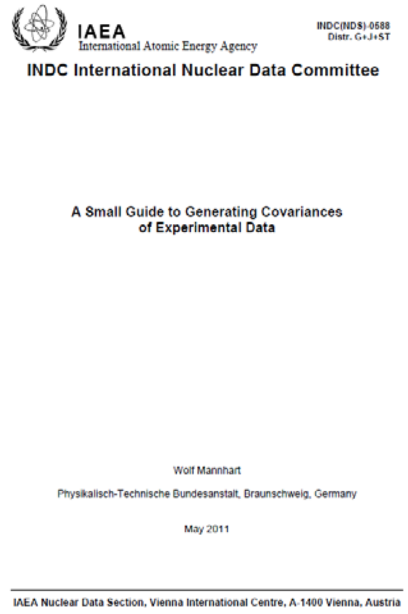
Remarks:

- Though I want to introduce concepts without equations, it is difficult within limited preparation time.
- It is probably not necessary to follow all equations.
- Correct my slides if you find any mistake (even after workshop)
- It is rather important to understand the role of variables (input for evaluators) which must be identified by EXFOR compilers in articles!

References

[WM2011]

W. Mannhart, “A small guide to generating covariance of experimental data”, INDC(NDS)-0588 Rev. (2013).



[DS2012]

D.L.Smith, N.O., “Experimental nuclear reaction data uncertainties: Basic concepts and documentation, Nucl. Data Sheets.**113**(2012)3006.

Social Event (28 August 19:00~)

U4→U1 →35A

Contents of the Workshop (29 – 30 August)

Contents:

- ***New* tool** – GDgraph Ver.5.0 released by CNDC.
- **Updated tools** – CNPD (EXFOR Edit, InpGraph), JCPRG (GSYS), NDS
- **Feedback from software users** - NDPCI

Goal:

1. To understand new functions of these tools.
2. To provide feedback, bug reports to developers (face-to-face discussion is easier to discuss software issues!)