IEC-217

Experimental Activities at IRMM

Activity Report May 2000

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EC - JRC, IRMM, B-2440, Geel, Belgium

Neutron Sources:

"GELINA" pulsed white n-source

thermal - 10 MeV ; high resolution

7 MV Van de Graaff

mono-energetic neutrons 0.1 - 20 MeV

Measurements recently completed or in progress.

GELINA

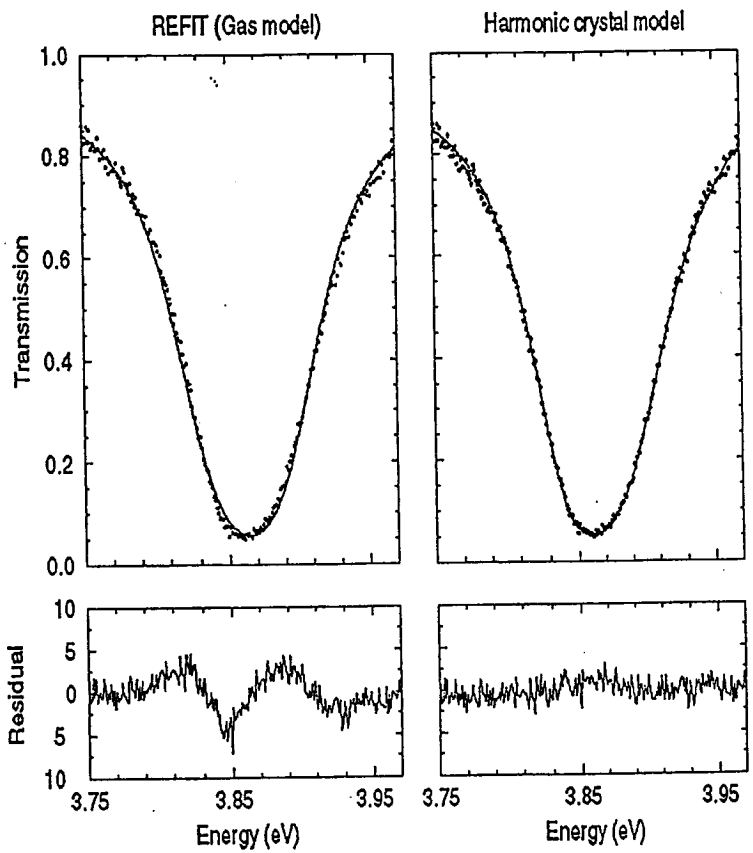
1. **Doppler broadening of neutron resonances.**
   P. Rullhusen, V. Gressier, P. Ribon, P. Siegler,
   C. Mounier (CEA), C. Zeyen (ILL),...

   Resonance measurements:
   earlier: U-metal , UO_2
   more recent: UO_3 , Hg_2Cl_2 , NpO_2 , Ta , Hf, 14 - 300 K
   analysis NpO_2 (low E_n resonances) with DOPUSH
   V. Gressier + D. Naberejnev, Ann.Nucl.Energy, to be publ.

   In progress: average transmission in the keV region
   77, 300, (900) K;
   Hf, ^{232}Th, ^{238}U;
   to be compared to predictions from (JEF, ENDF, JENDL).

   Planned:

   1. Low temperature measurements on $^{240}PuO_2$ and $^{242}PuO_2$
      sample preparation under way;
   2. resonance measurements at high temperatures (to 3000 K);



2. Cross section measurements for transmutation.

A. Lepretre, F. Gunsing, V. Gressier (CEA),
A. Brusegan, F. Corvi, E. Macavero (IRMM).

^{99}Tc (see contribution F. Gunsing):
total and capture cross sections En < 100 keV
resonance region: analysis with REFIT;
paper at Santa Fe conf. and submitted to Phys.Rev.C.

^{237}Np (see contribution F. Gunsing):
total and capture cross sections E_n < 3 keV;
resonance analysis of total cross section, En < 500 eV
(thesis V. Gressier); see also ADTTA, Praha 1999;
additional capture measurement planned at 15 m flight path;
low T transmission measurement (Doppler effect).

^{129}I:
base material (200 l of solution) arrived at IRMM;
sample preparation (PbI_2) to start.

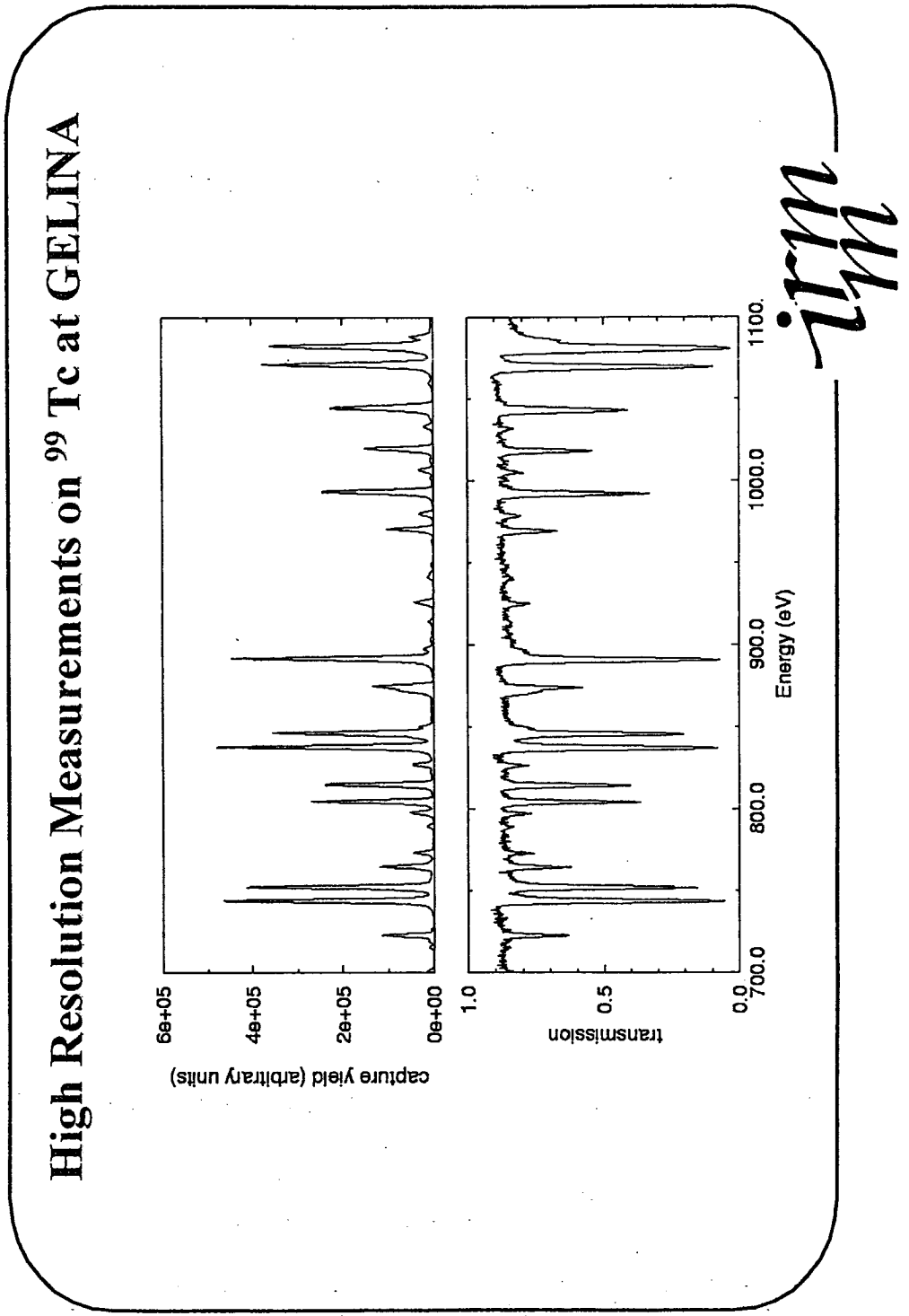
3. High resolution inelastic scattering.

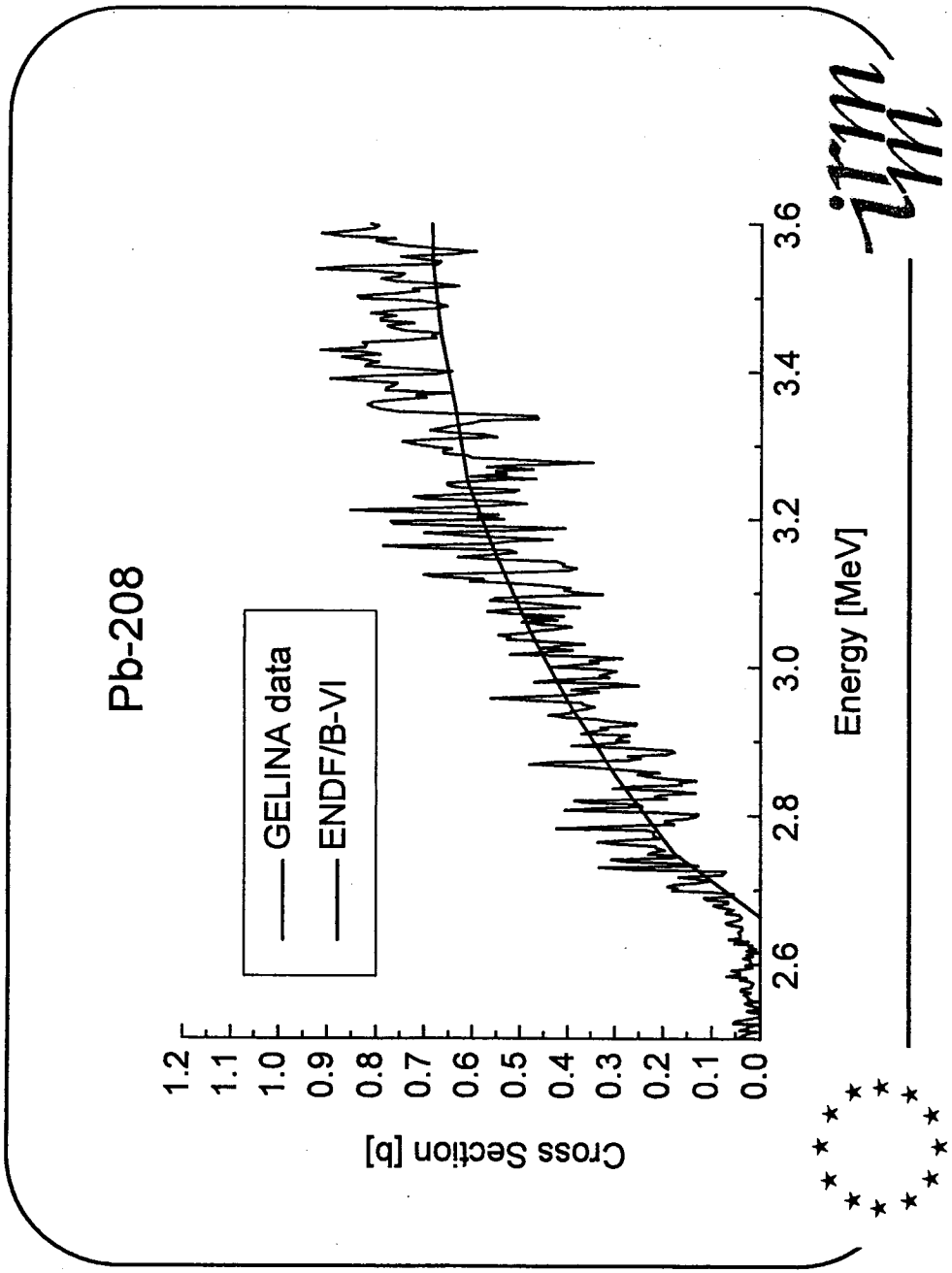
R. Shelley, A. Plompen.

Fe(n,n'): No news:
Additional measurements using HPGe detector "ongoing" at linac and Van de Graaff (pulsed mono-energetic neutrons);

^{208}Pb(n,n'):
Measurement done for E_n < 4 MeV; 200 m flight path;
additional pointwise measurements ongoing at Van de Graaff

planned: ^{52}Cr and/or ^{58}Ni.





4. **Capture cross sections.**
(collaboration with FZK)
P. Mutti, F. Corvi, A. Brusegan;
H. Beer, F. Kaeppeler (FZK),

Pb, Bi :
Resonance analysis of capture data with REFIT
up to 500 keV (^{207}Pb), 900 keV (^{208}Pb), 80 keV (Bi);
for Bi average sigma up to 300 keV.

Resonance parameters sent to NEA Data Bank
and PNPI, St. Petersburg
publication in preparation

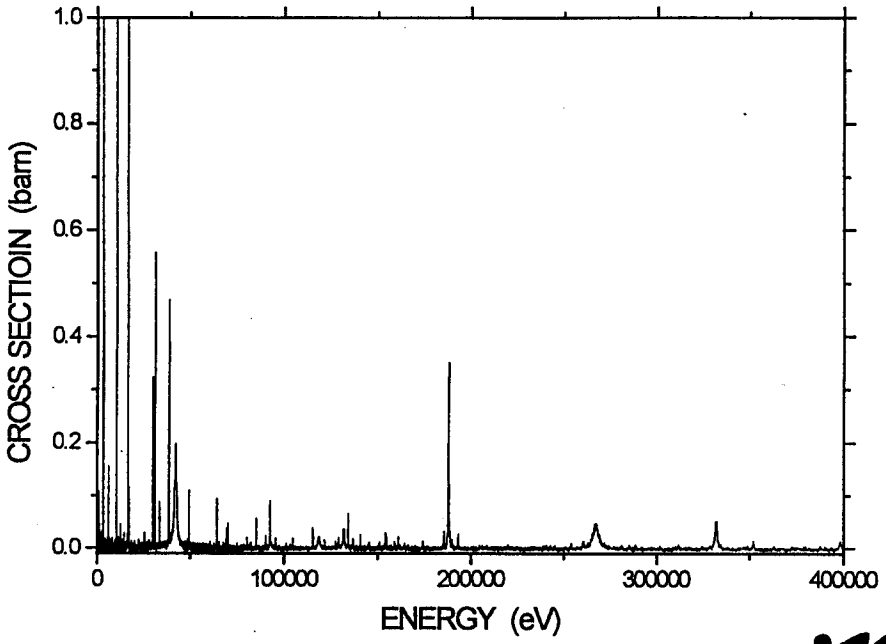
^{232}Th :
measurements (gamma detection)
done at FZK Van de Graaff;
first measurement at Geel linac done; data analysis started;
additional capture measurement planned at 15 m flight path;

measurement at Geel Van de Graaff (activation) in preparation.

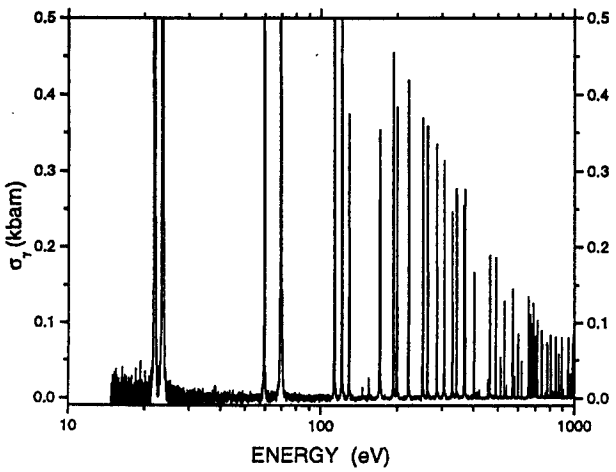
^{82}Kr, ^{84}Kr, ^{86}Kr :
measured (capture + ^{84}Kr transmission) at linac up to 200 keV;
preliminary analysis done for ^{84,86}Kr:
^{86}Kr discrepancy with activation data (FZK);
to check normalisation (Xe), additional measurement of
Xe total σ; analysis $E_n < 1$ keV: confirms older (Ribon) res.par.

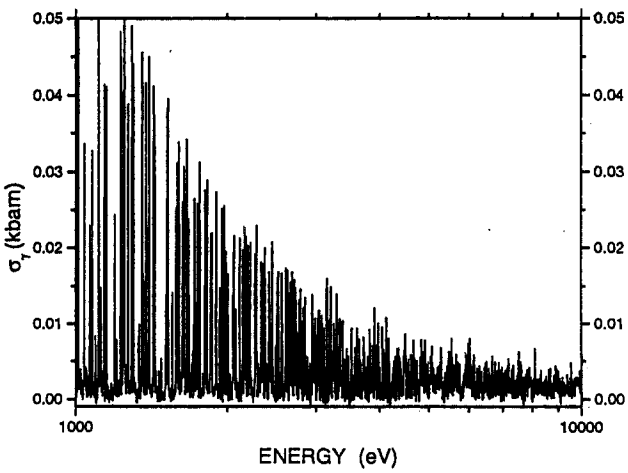
paper at Santa Fe conference and "Nuclei in the Cosmos VI".

^{207}Pb (n,γ)



^{232}Th (n,γ) - Cross Section





5. **^{239}Pu(n,f) mass- , TKE distributions in resonances.**
L. Dematte, F.-J. Hambsch, H. Bax.

Measurements in resonance region at linac;
no significant spin effect or variations in resonances
(in contrast to ^{235}U);
results presented at Seminar on Fission, Pont d'Oye

6. **^{235}U(n,f), ^{239}Pu(n,f) (tenary fission).**
(collab. U. Gent - IRMM): O. Serot , C. Wagemans.

ΔE(ion ch.)/E(s.b.) telescope to separate α and t.

^{235}U resonance region: publ. Nucl. Phys. A587 (1995) 1;

^{239}Pu resonance region: measurements (α) completed;
no strong (<10%) variation tern/bin; paper at Pont d'Oye

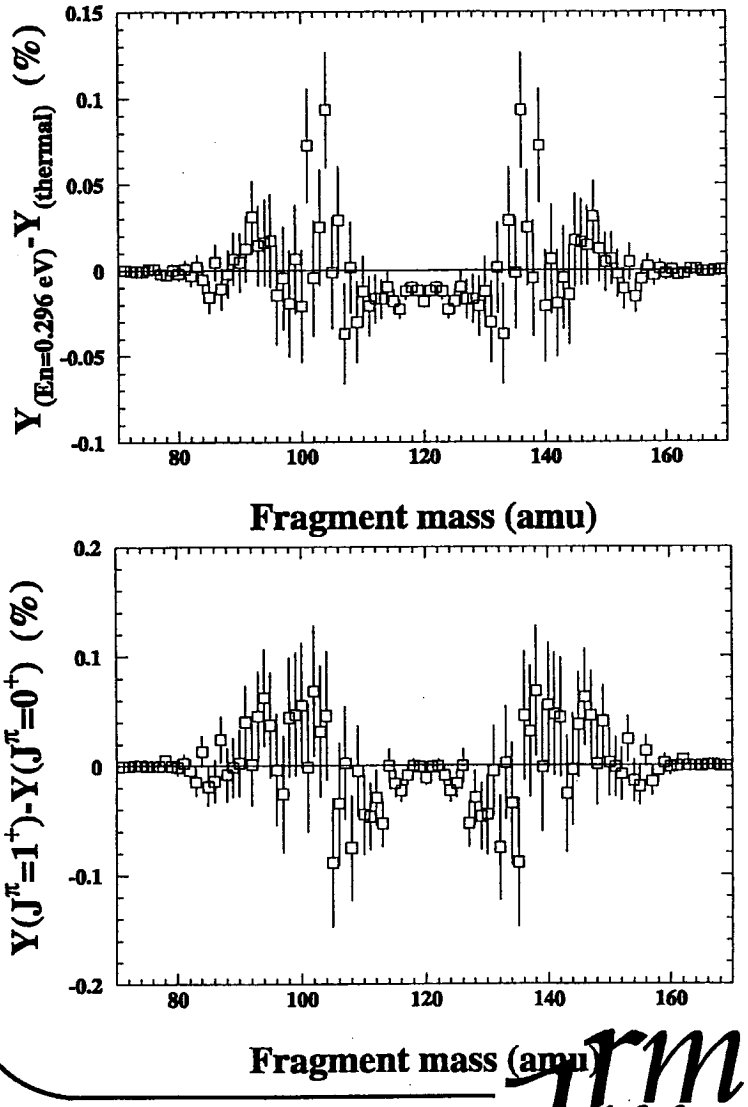
measurements to 30 keV ongoing.

7. **Ternary fission (α , t): spont. Fission.**
(collaboration Univ. Gent – IRMM – ILL)
O. Serot and C. Wagemans, P. Geltenbort.

Pu isotopes: LCP (α) emission correlated with S(α-decay)
and with contribution of standard-II mode;
published Nucl. Phys. A641 (1998) 34;
^{240}Pu, ^{242}Pu t emission started;

^{247}Cm(n,f) and ^{248}Cm(sp.f.): measurements ongoing;
preliminary results presented at Pont d'Oye;
planned: **^{245}Cm(n_{th},f)** at ILL for comparison with ^{246}Cm(sp.f.)

Difference in the mass distribution



Résults obtained at ILL

Thermal fission cross sections

Isotope	JEF – 2.2	ENDF/B6	JENDL-3.2	This Work
^{234}U	465	465	6.2	300 ± 20
^{236}U	46.9	47.2	61.3	0.3 ± 1

8. **^{234}U(n,f).**
(collaboration Univ. Gent – IRMM – ILL)
O. Serot, C. Wagemans, J. Wagemans, P. Geltenbort.

First measurement of thermal cross section done at ILL:
$\sigma = (300 \pm 20)$ mb; publ. Nucl. Sci. Eng. 132 (1999) 308
measurements 10 meV to 1 keV at linac:
10 meV < E_n < 1 eV : $\sigma \sim 1/v$; confirms ILL value;
paper (Nucl. Sci. Eng.) being prepared.

9. **^{236}U(n,f).**
(collaboration Univ. Gent – IRMM – ILL)
O. Serot, J. Wagemans, C. Wagemans, P. Geltenbort.

Measurements done at ILL; preliminary result:
σ(therm) < 1.3 mb (literature: ≈50 mb)
paper submitted to Nucl. Sci. Eng.
planned: σ(n,f) in resonance region at linac.

10. **Analysis of previous measurement:**

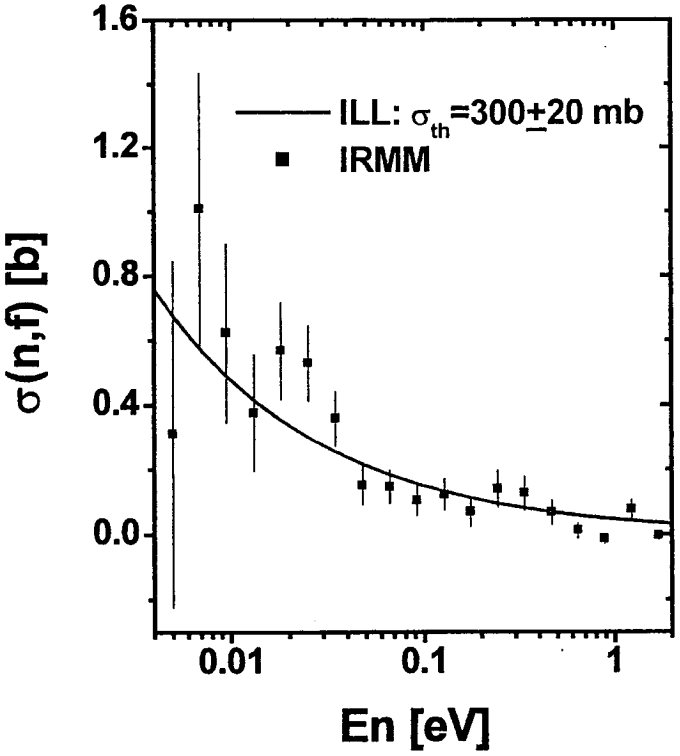
Al(n,n') high resolution data.
S. Kopecky, R. Shelley.

SAMMY-analysis of inelastic and total σ (E_n< 2 MeV);
resonance parameters and σ-files sent to NEA Data Bank;
see report to JEFF meeting May 2000.

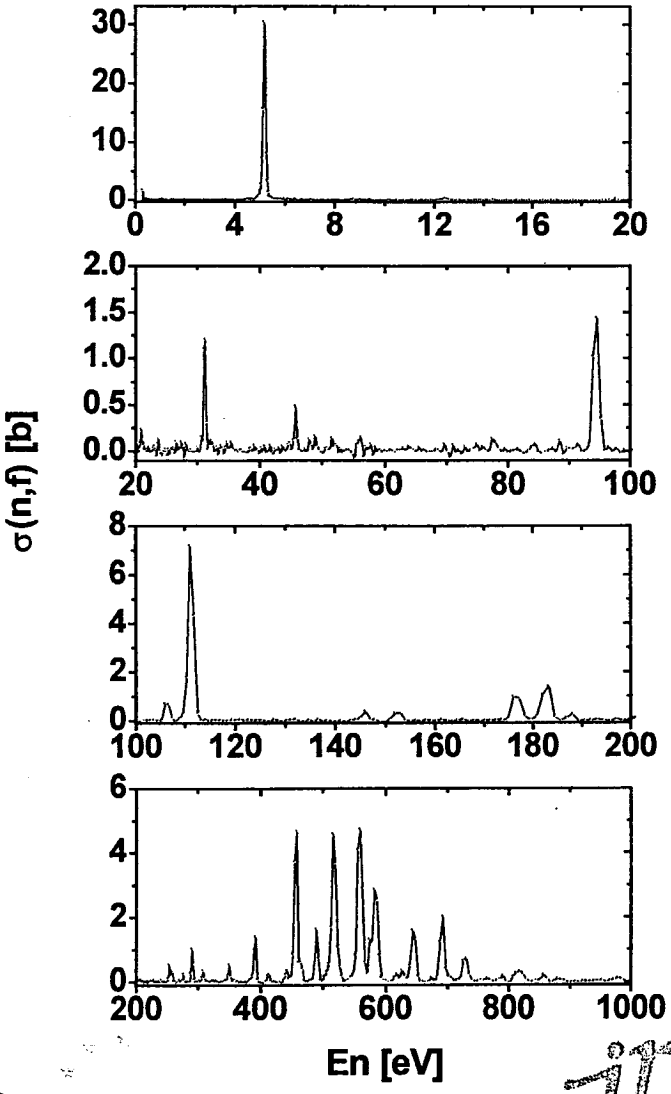
^{61}Ni total cross section.
A. Brusegan

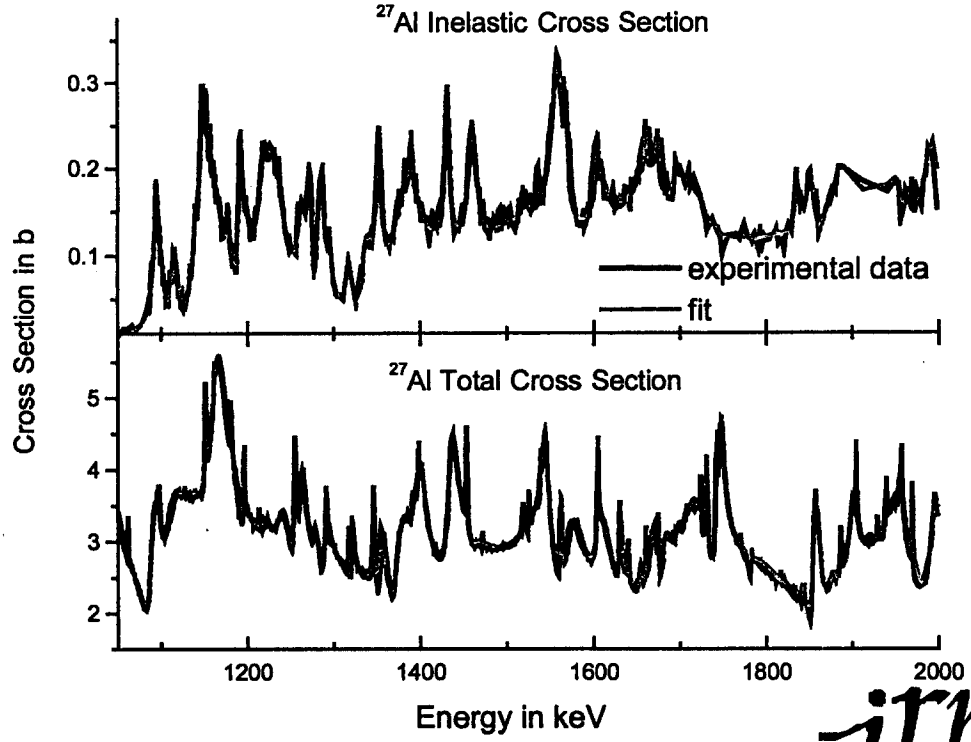
Analysis of earlier measurement with REFIT (E_n < 150 keV).

Determination of the $^{234}U(n,f)$ Cross-Section in the thermal region



Determination of the $^{234}U(n,f)$ Cross-Section in the resonance region





7 MV Van de Graaff

(mono-energetic neutrons 0.1 - 20 MeV)

- activation cross sections
- inelastic scattering (t-o-f to separate elast./inelast.)
- fission data (cross sections, fragment yields)

Activation

- activation of components (ADS, transmut. facility,...)
- fast way to obtain information on (n,2n), (n,p), (n,α)

Van de Graaf : measured >30 reactions

15 MeV < E < 21 MeV

(collaboration FZJ, ANL, JAERI)

Measurements at Van de Graaff.

1. **Activation cross sections.**
(collaboration KFA, Julich - ANL - IRMM)
A. Plompen, A. Fessler, P. Reimer,
D.L. Smith (ANL), S. Qaim (KFA).

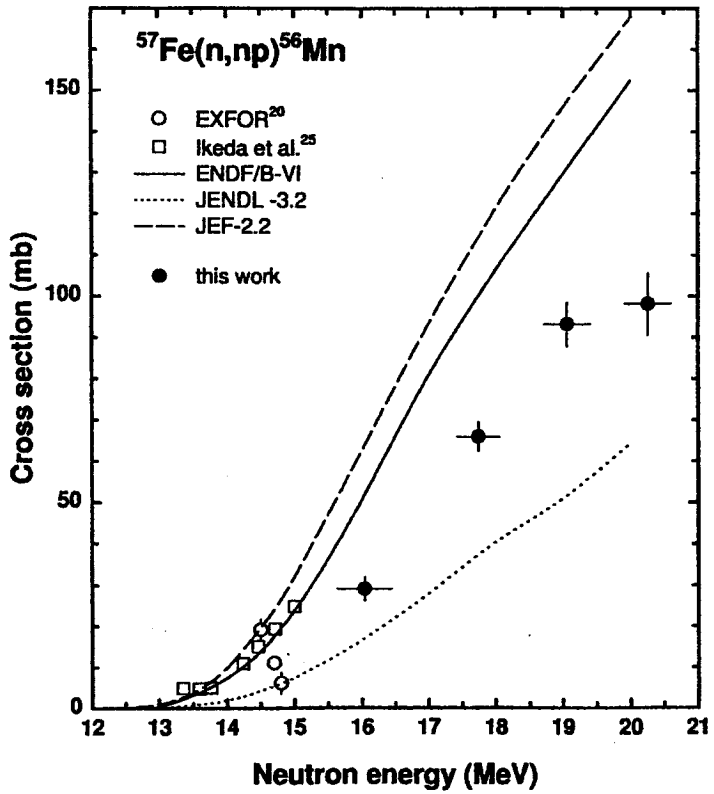
Cross sections for 30 short-lived activ. prod., 16-21 MeV;
(9-12 MeV at Julich); publications:

1. Measurement of (n,xp), (n,α) and (n,2n) cross sections from 16 to 20 MeV for isotopes of F, Na, Mg, Al, Si, P, Cl, Ti, V, Mn, Fe, Nb, Sn and Ba by the activation technique: Nucl.Sci.Eng. (2000) ;

2. Neutron-induced activation cross sections: measurements and model sensitivity: PHYSOR-2000, Pittsburg.

Measurements done on many further reactions,
among them: ^{47}Sc production from V+n ; $^{99}Tc(n,p),(n,\alpha)$;
ongoing: cross sections for long-lived activ. products,
e.g. $^{94}Mo(n,p)^{94}Nb$, $^{204}Pb(n,p)^{204}Tl$;
systematics of p-emission from Mo-isotopes;
WPEC subgroup:
"Neutron Activation Cross Section Measurements from Threshold to 20 MeV for the Validation of Nuclear Models and their Parameters"

Neutron Activation Cross Section Measurement at IRMM



irmm

2. ^{238}**U(n,n')**
(collaboration with RPCPI, Minsk)
C. Goddio, A. Plompen; V. Maslov(RPCPI).

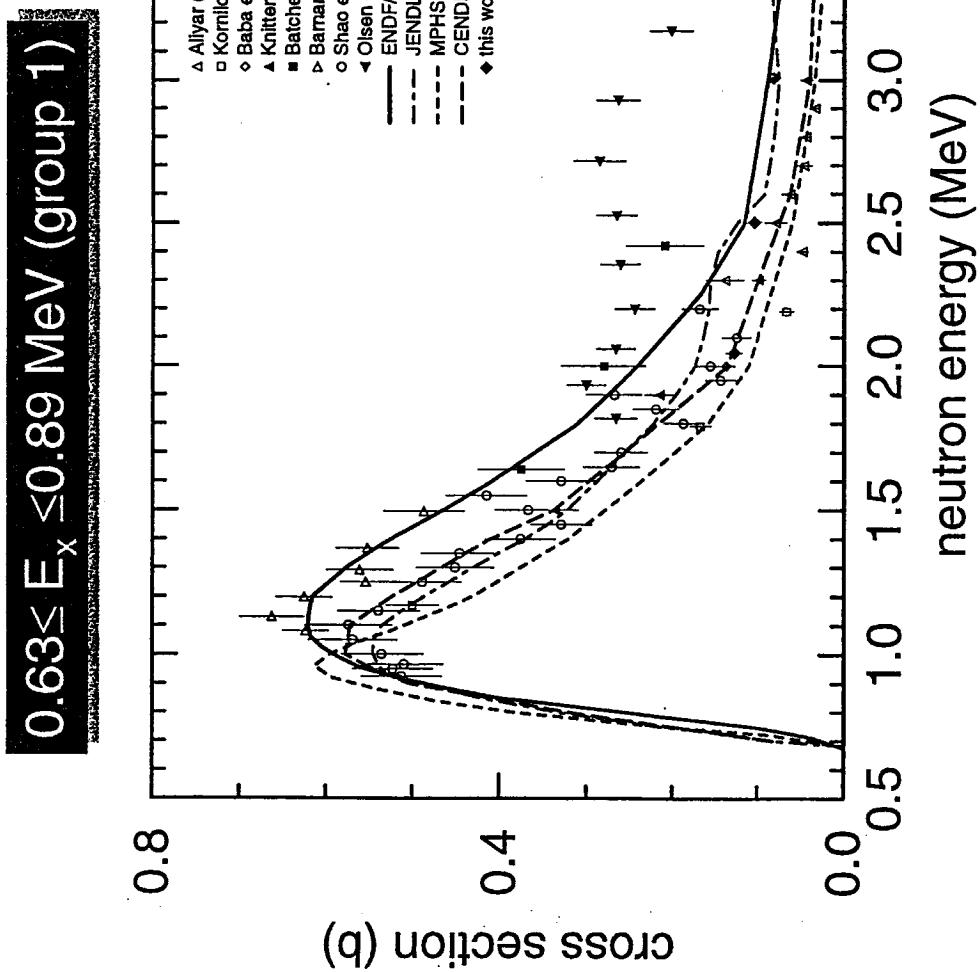
Measurements done E_n 2 - 3.5 MeV (gap in data);
determined cross sections for **groups** of levels [MeV]:
0.63-0.89 / 0.89-1.32 / 1.32-1.67 / 1.67-2.20 / 2.20-2.79;
status report WPEC subgroup 4 (**M. Baba**);
papers PHYSOR-2000, Pittsburg, and ISINN-8, Dubna;
new ISTC proposal "Actinide Nuclear Data Evaluation"
(V. Maslov + A. Plompen)

3. ^{238}**U(n,f) mass- and kinetic energy distributions.**
F. Vives, F.-J. Hambsch, H. Bax.

Twin gridded ion chamber;
measurements E_n = 1.2-5.8 MeV:
changes of mass-distribution (contribution of standard I)
and TKE; analysis in terms of Brosa model;
published: Nucl. Phys. A 662 (2000) 63.

4. ^{237}**Np(n,f):**
F. Vives, F.-J. Hambsch, H. Bax.

Re-analysis of mass- and kinetic energy distributions;
paper submitted to Nucl. Phys.


0.63≤ E$_x$ ≤0.89 MeV (group 1)
Aliyar (1988)
Kornilov et al. (1995)
Baba et al. (1990)
Knitter et al. (1971)
Batchelor et al. (1965)
Barnard et al. (1966)
Shao et al. (1986)
Olsen et al. (1979)
ENDF/B-VI (1977)
JENDL-3.2 (1994)
MPHS (1998)
CENDL-2.1 (1998)
this work
cross section (b)
0.8
0.4
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
neutron energy (MeV)

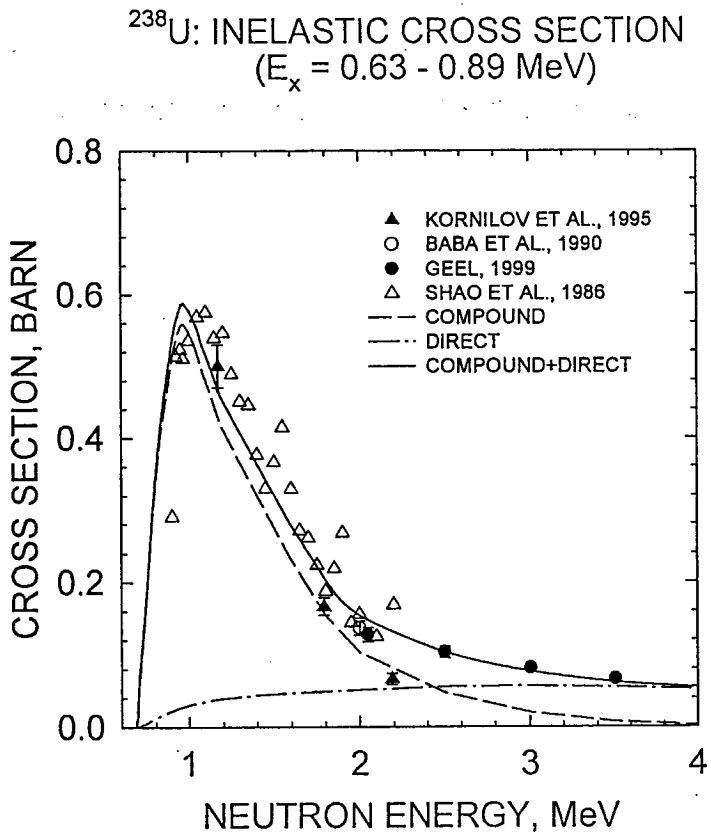

^{238}U: INELASTIC CROSS SECTION
(E$_x$ = 0.63 - 0.89 MeV)
KORNILOV ET AL., 1995
BABA ET AL., 1990
GEEL, 1999
SHAO ET AL., 1986
COMPOUND
DIRECT
COMPOUND+DIRECT
CROSS SECTION, BARN
0.0
0.2
0.4
0.6
0.8
1
2
3
4
NEUTRON ENERGY, MeV

FIG. 1

5. **Prompt fission neutron spectra: ^{252}Cf(s.f.), ^{235}U(n,f)**
N. Kornilov, A.B. Kagalenko, F-J. Hambsch

Related to WPEC subgroup;
re-analysis of older experimental data suggests
≈10% contribution of fission neutrons;
paper submitted to Physics of Atomic Nuclei.

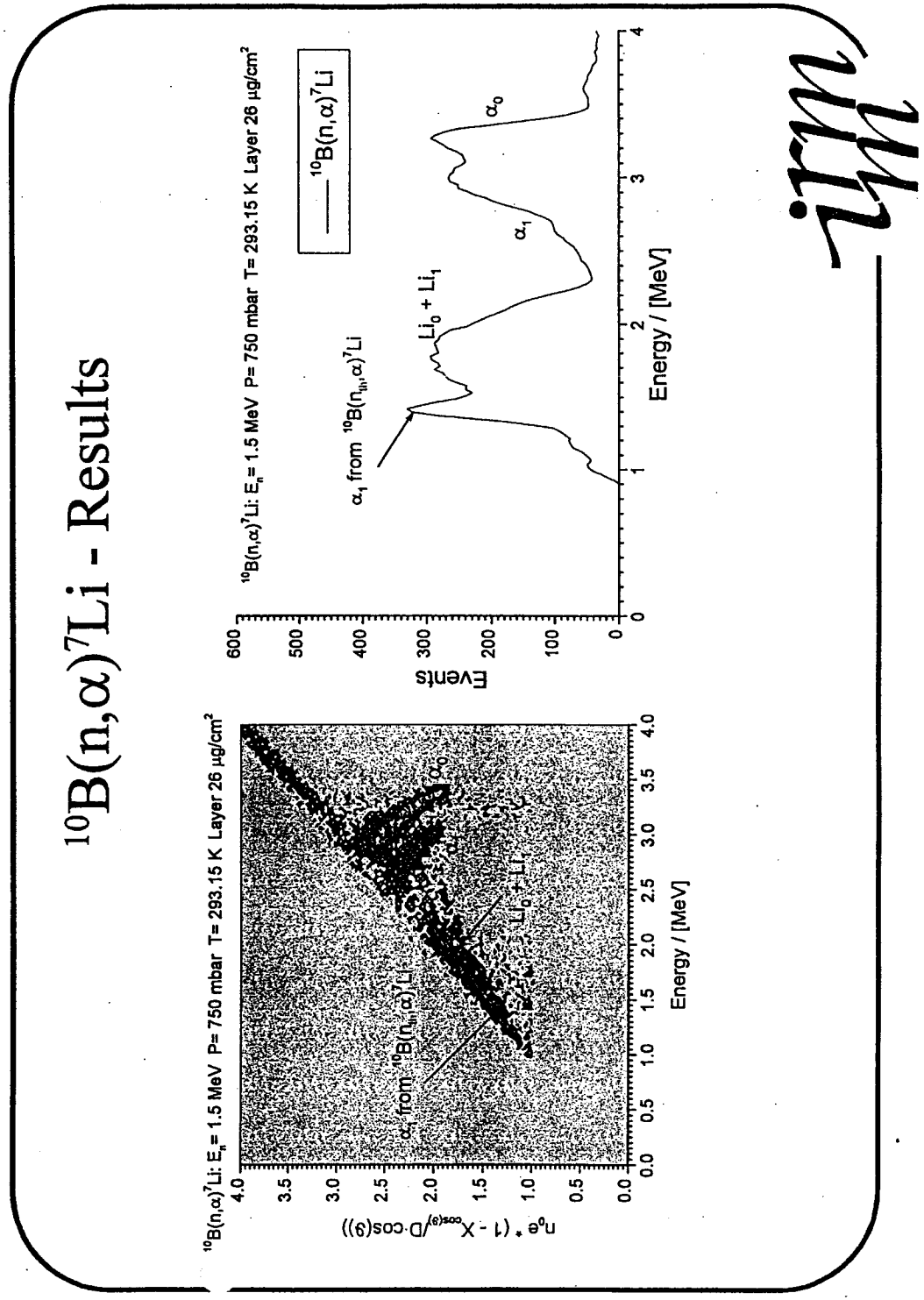
6. **Neutron multiplicity distribution as function of fragment mass for s.f. of ^{252}Cf, ^{244}Cm, ^{248}Cm:**
V. Kalinin, O. Shcherbakov, F-J. Hambsch
(ISTC project)

Data analysis in progress;
^{244}Cm, ^{252}Cf: good agreement with earlier data
^{248}Cm: unique data;
paper at Pont d'Oye

7. **^{10}B(n,α) and branching ratio α_0/α_1 :**
F.-J. Hambsch, A. Goepfert, H. Bax.

Gridded ion chamber; measurements at 1.0, 1.5, 2.0 MeV
angular distribution measurement needed;
done at Van de Graaff (MeV region, rel. to ^{238}U(n,f))

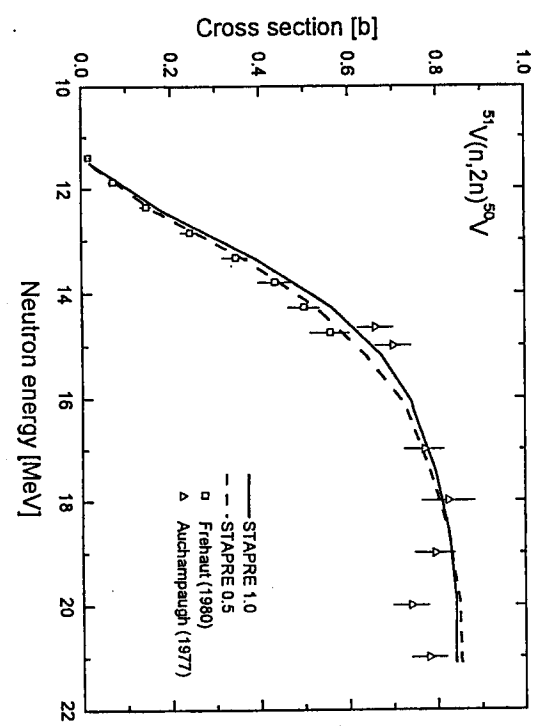
measurements at linac (keV region, rel. to ^{235}U(n,f))
started;
paper describing experimental method: Nucl. Instr. Meth. A.

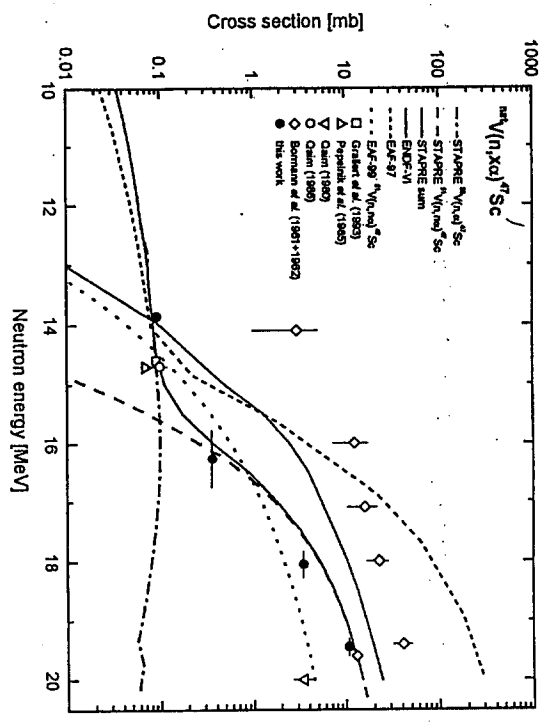


Collaboration with PECO

collaboration with pre-accession states (Romania, Hungary, Bulgaria)

- **measurement of activation cross sections**
- **measurement of (n,γ) and (n,n') x-sections**
- **evaluations related to IRMM experim. (start: Avrigeanu (NIPNE) evaluations ^{51}V**





Uppsala University: TSL:

(Nils Olsson)

sector focussed cyclotron, protons:
100 MeV (isochr. mode), 180 MeV (synchrocycl. mode);
quasi-monoenergetic neutrons from ^{7}Li(p,n), 20-180 MeV

Work partly within HINDAS (TSL, PSI, KVI, UCL, GSI, FZ-Jülich)

n-p scattering: still 10 - 15 % deviation from previous data at 180°

n elastic scattering (50-180 MeV) with the SCANDAL facility: for optical potential for intermediate energy neutrons; C, Pb, ...

σ(n,xp) using modified SCANDAL, for ADS applications: Fe, Pb

σ(n,ch.p.) with MEDLEY facility (8 telescopes for ch.p. up to 100 MeV) for various applications (ADS, dosimetry, therapy)

University of Hannover

(R. Michel, S. Neumann, ...)

Measurements performed in collaborations with
(radiochemical work at Hannover) :
TSL, LNS, PSI, UCL, CERN, LANL ;
BLC, Bordeaux , Köln , FZ-Jülich , PTB , ...

Activation σ's at intermediate energies (E < 180 MeV) at TSL, UCL
many nuclides from C to Pb

Production of radioactive (and stable) isotopes by protons (α's)
(E < 2.6 GeV) at TSL, LNS, PSI, CERN, LANL
for ADS (e.g. W, Pb, Bi, U, Th) and cosmology