Progress Report on the IAEA-CRP No. 13278

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OUTLINE OF PRESENTATION

- Introduction
- Status report on work performed in the last year
  - Testing of k0-IAEA software using SMELS
    Neutron spectrum characterization using MCNP
    Measurements of σ_o,Q_o

  Conclusions
- Acknowledgement

INTRODUCTION-CRP Plan as at 1st RCM

- Improve and validate methods for n-spectrum parameters
  - Acquisition of codes (MCNP5)
- Develop methodologies for accurate measurement of fission neutron σ_{ave}
  - Comparison with data libraries
- Re-measure constants (σ_o, Q_o) for NAA
  - As specified by CRP
- Testing of the k0-IAEA software
  - Using SRMs

1st RCM, 2005

Jonah

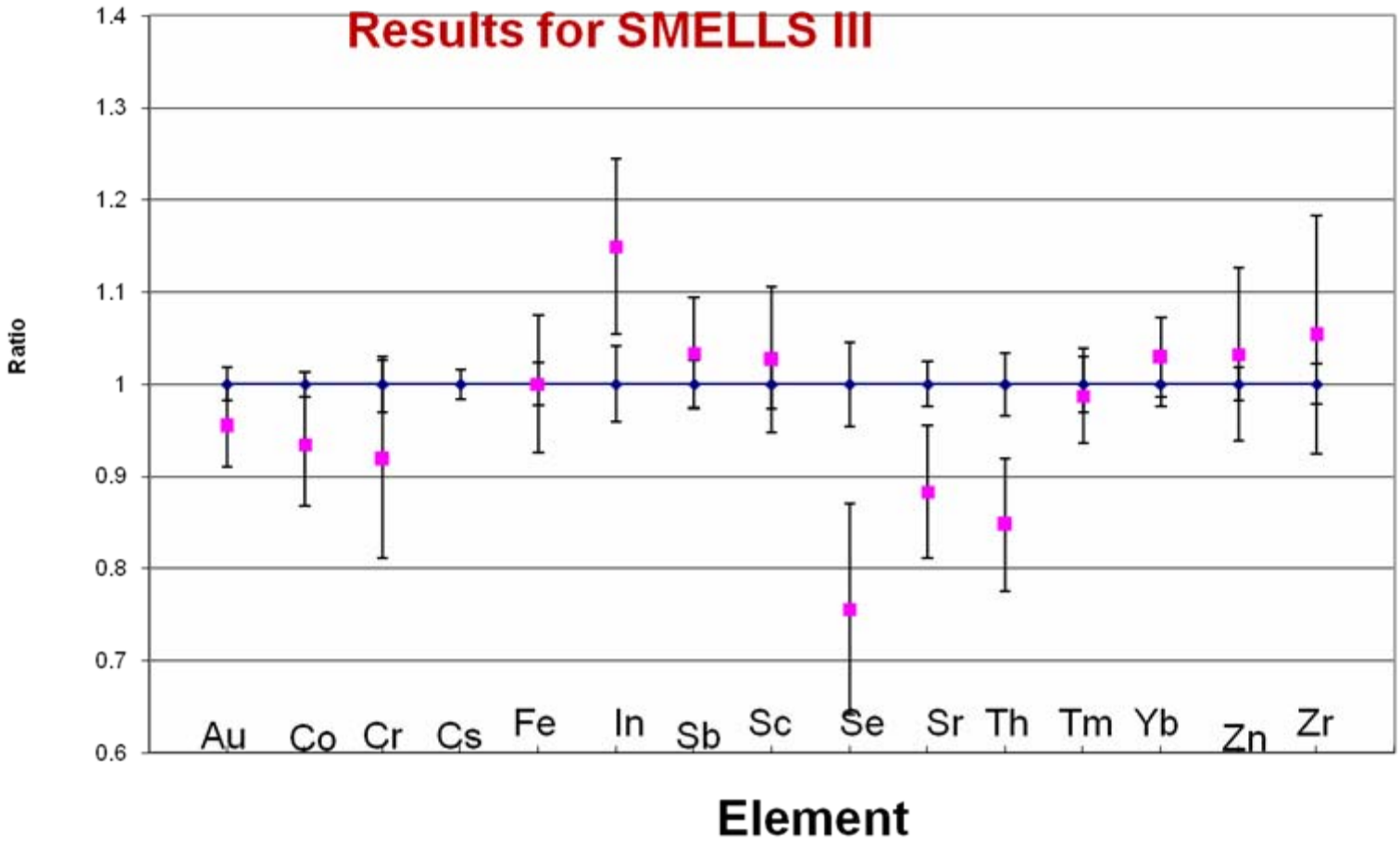
INTRODUCTION-work done in years 1&2

- Participation in proficiency tests
- Characterization of NIRR-1 irradiation sites by experiment
- Detector calibration
- Determination of reactor neutron spectrum averaged cross section σ_f
- Installation & testing of the k0-IAEA Program
- Installation of MCNP5 & development of input model for NIRR-1

INTRODUCTION

- SCOPE OF WORK FOR THIRD YEAR
- Validation of NIRR-1 MCNP model for accurate neutron spectrum characterization using GRUPINT
- Finalize the testing of the k0-IAEA Program using SMELS
- Development of procedures for measurements of discrepant nuclear data

Results of SMELS by k0-IAEA Program



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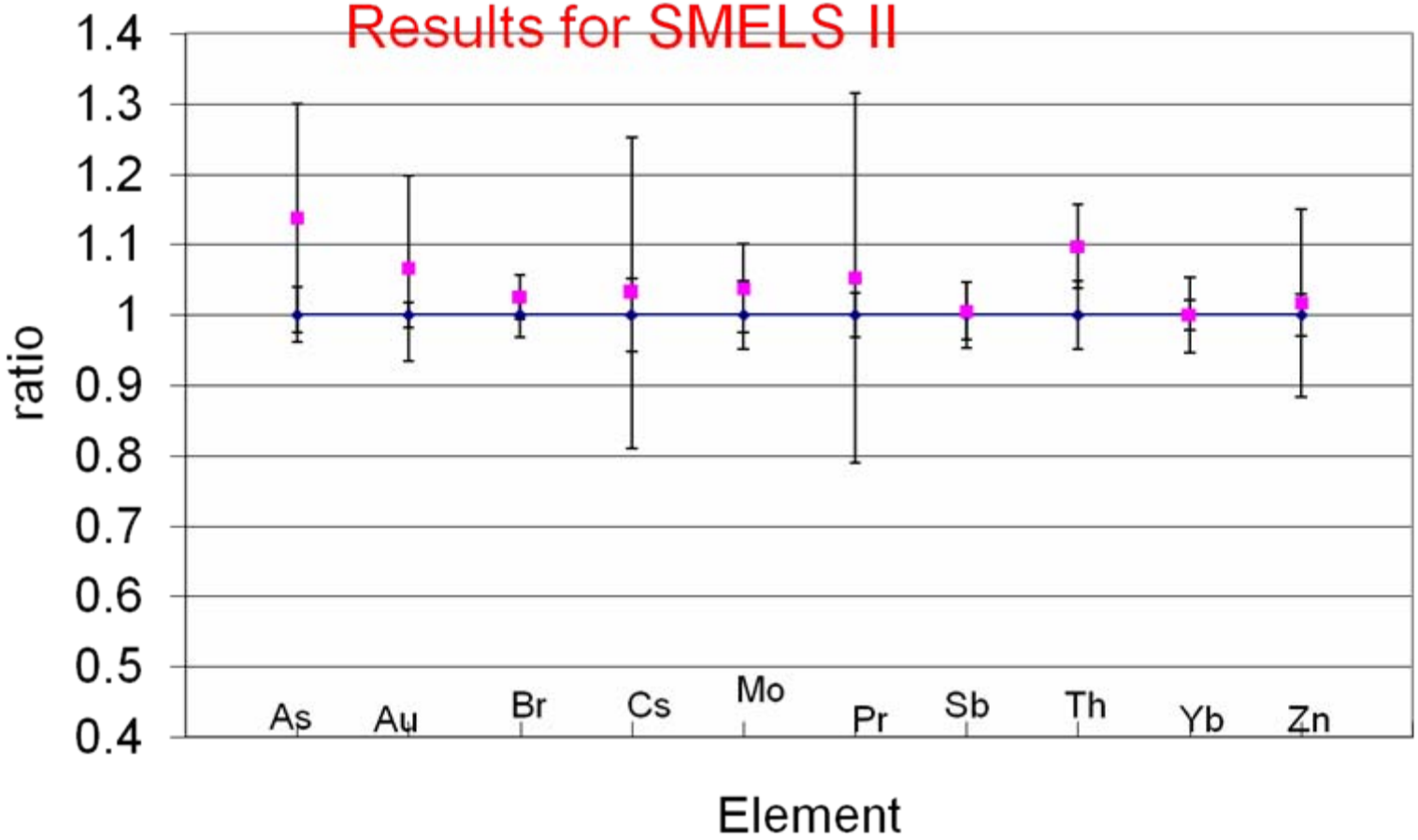

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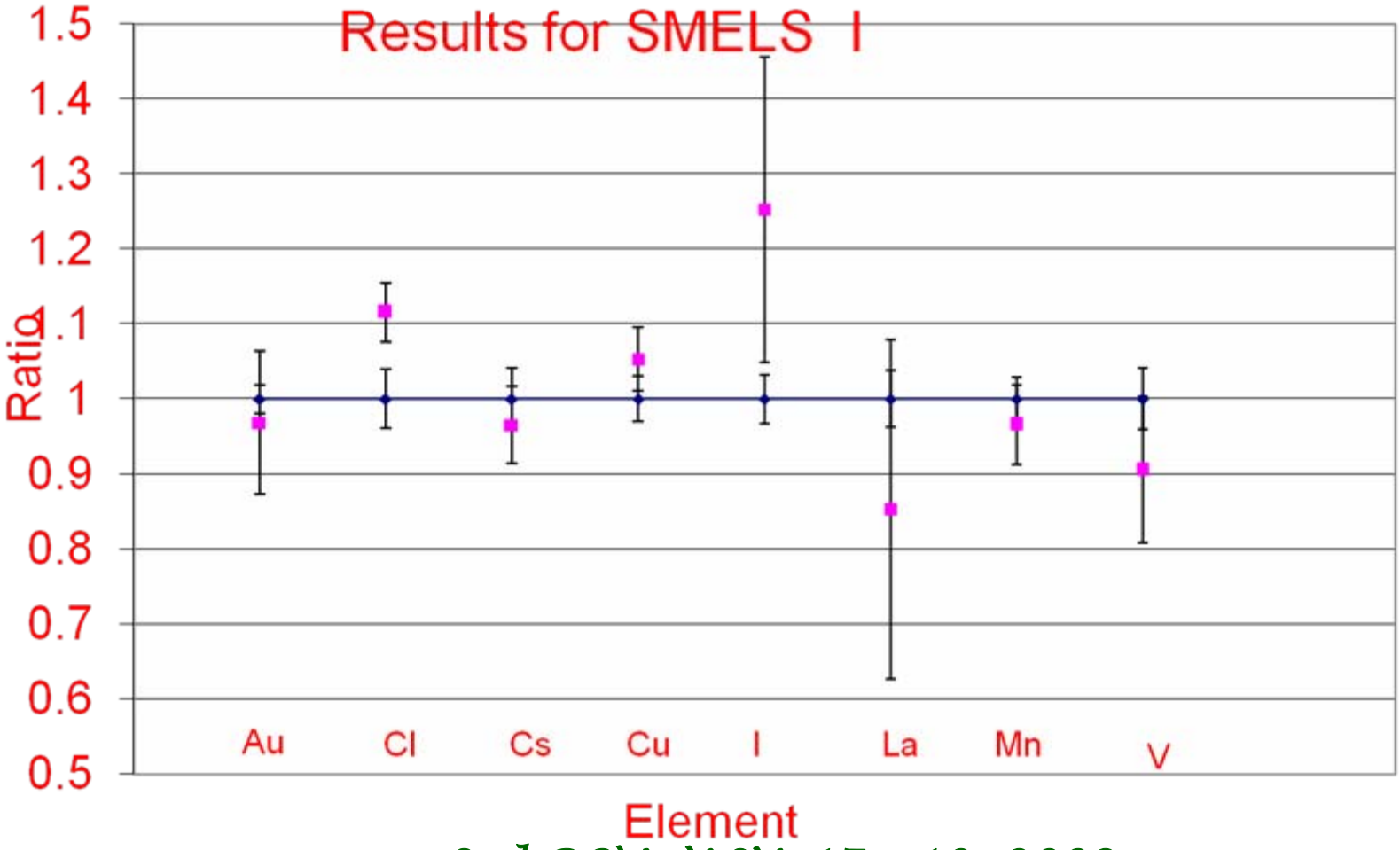


Summary of SMELS Analysis

- SMELS were subjected to NIRR-1 routine procedures
- For SMELS I S1 & L2 were used
- For SMELS II & III, the 4 protocols were used
- Overall, results compare well with relative method (WINSPAN) and RVs
- For SMELS I, Cl & I are slightly higher than RVs
- For SMELS II, results are ok within limit of expt
- For SMELS III,
  - Se is far off RV
  - Sr & Th are slightly lower than RV
  - In value is higher than RV
- The k0-IAEA program has been successfully installed and tested with NIRR-1 facilities.

Neutron Spectrum Characterization

- Experimental and computational protocols were deployed for NIRR-1
- Measured data of f & α have been presented at 2nd RCM
- MCNP model of NIRR-1 has been developed – 2nd RCM
- Data of activation foils were sent to A. Trkov
- Neutron spectrum shape for NIRR-1 have been derived by GRUPINT – semi-empirically
- In the 3rd year a theoretical method was used to determine neutron spectrum data
- It is based on MCNP neutron spectrum and cross section data in 640 energy group structure, energy bin is relatively small
-

Neutron Spectrum Data by MCNP

- RR energy–dependent neutron flux density, φ(E), for reaction with σ(E) is given below as:

$$R = \int_0^\infty \varphi(E)\sigma(E)dE \qquad (1)$$

- For 640 energy group structure, energy bin is relatively small

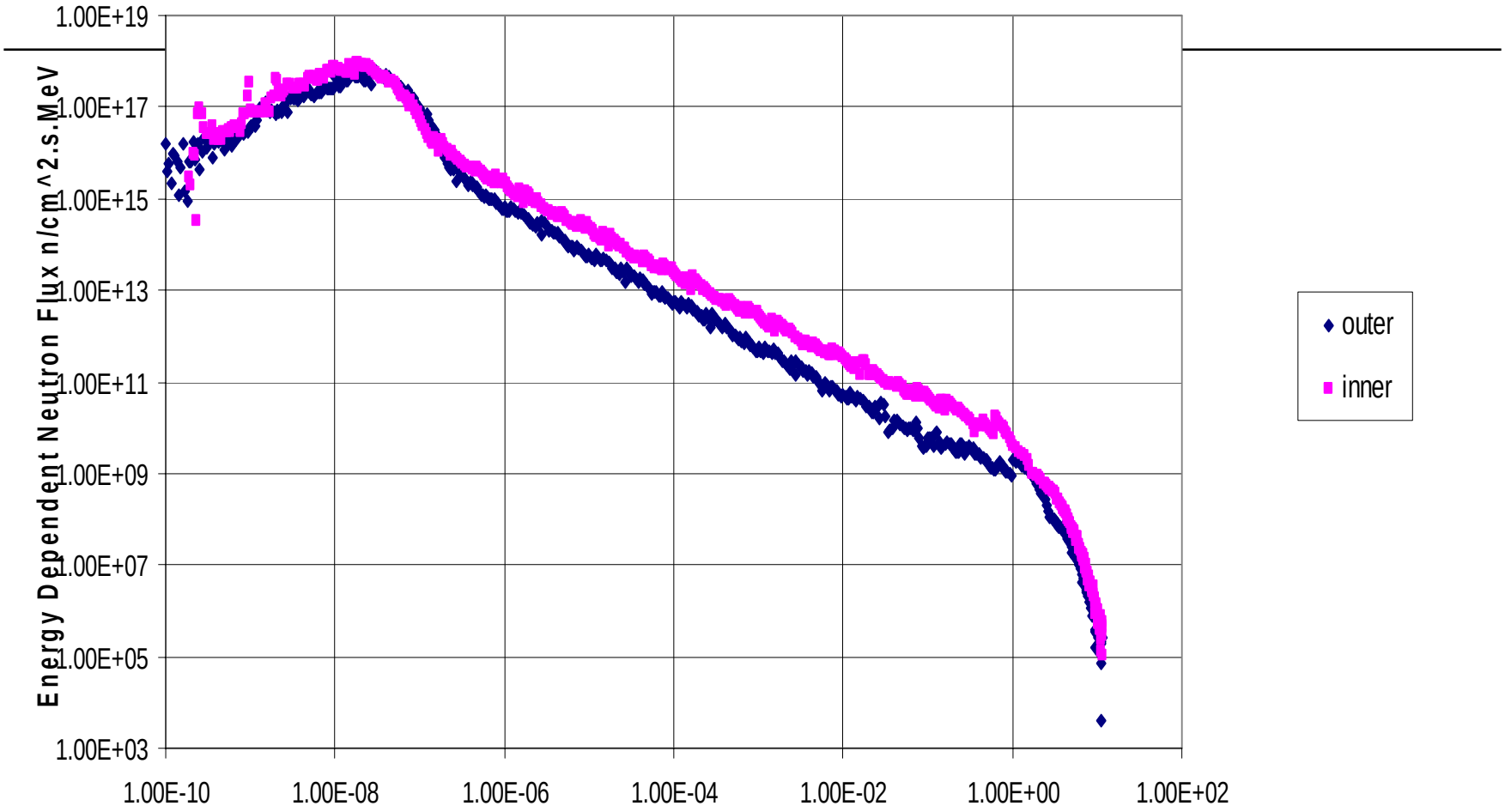
$$R = \sum_0^\infty \varphi(E)\sigma(E) \qquad (2)$$

- The φ(E) data were obtained from the standard MCNP output
- σ(E) data for (n,γ) reaction retrieved from ENDF-VI data libraries from the NDS, IAEA, Vienna, Austria.

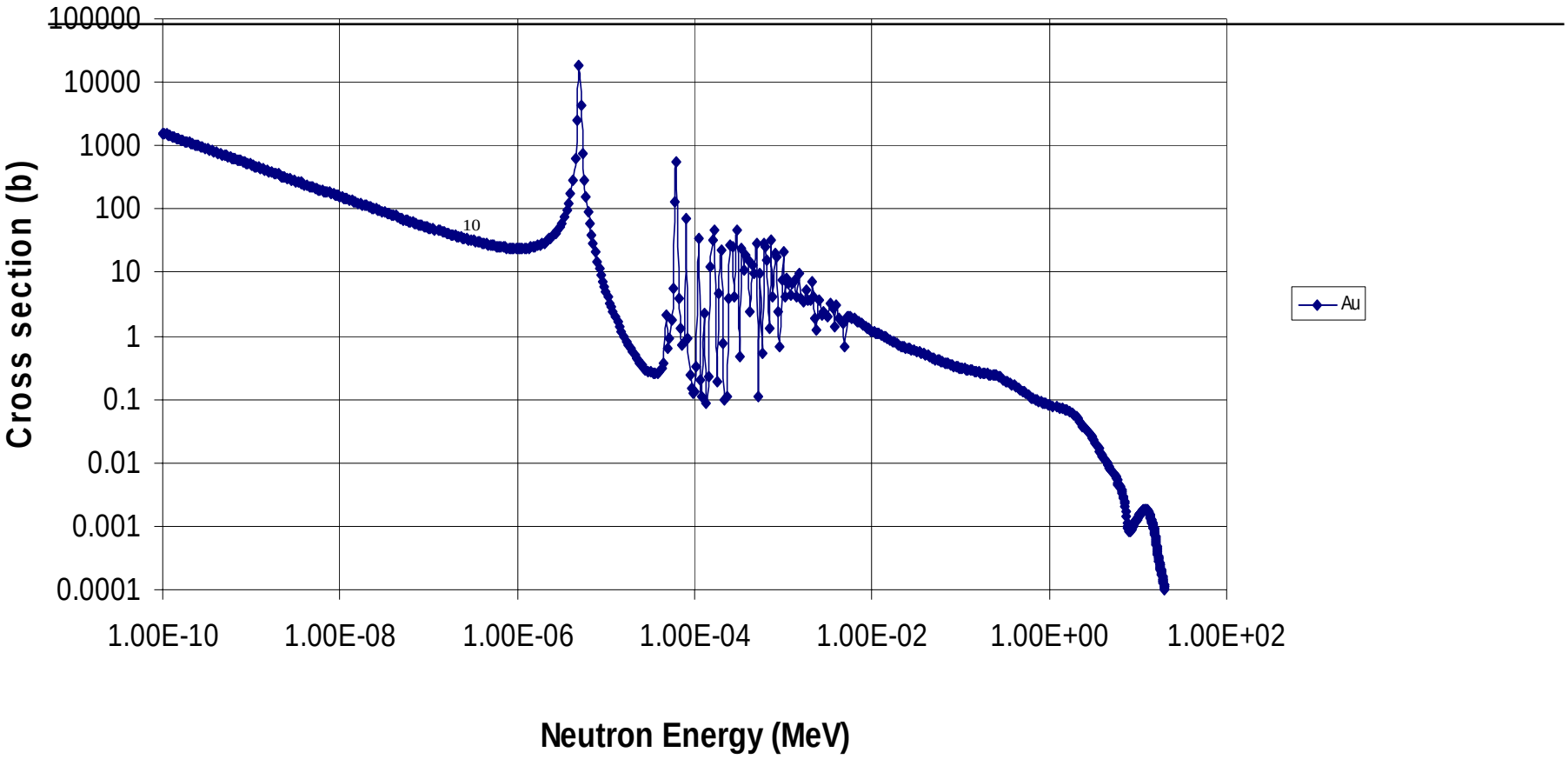
- *R_{Cd} data were calculated for E_{Cd} = 0.55 eV*

$$R_{CD} = \frac{\sum_{0}^{20MeV} \varphi(E)\sigma(E)}{\sum_{O.55eV}^{20MeV} \varphi(E)\sigma(E)}$$

A Comparison of MCNP Simulated Energy Dependent Neutron Flux in Inner and Outer Channels of NIRR-1



Cross section for 197Au(n,g)198Au Reaction



A comparison of RCd in inner channel

Reaction	R_{Cd} Inner irradiation channel		
	Measured	GRUPINT	This work
$^{197}Au(n,\gamma)^{198}Au$	2.12±0.02	2.13	2.01±0.07
$^{55}Mn(n,\gamma)^{56}Mn$	17.4±1.9	-	17.3±1.7
$^{64}Zn(n,\gamma)^{65}Zn$	8.15±0.16	8.43	-
$^{68}Zn(n,\gamma)^{69m}Zn$	5.63±0.08	5.70	-
$^{94}Zr(n,\gamma)^{95}Zr$	3.33±0.08	3.29	-
$^{235}U(n,\gamma)^{239}U$	-	-	1.15±0.03
$^{232}Th(n,\gamma)^{233}Th$	-	-	2.02±0.06
$^{58}Co(n,\gamma)^{59}Co$	-	-	8.05±0.85

A comparison of Rcd in outer channel

Reaction	R_{Cd} Outer irradiation channel		
	Measured	GRUPINT	Theory
$^{197}Au(n,\gamma)^{198}Au$	4.27±0.06	4.68	4.12±0.11
$^{55}Mn(n,\gamma)^{56}Mn$	58.1±2.9	-	58.1±2.7
$^{64}Zn(n,\gamma)^{65}Zn$	31.3±1.0	31.4	-
$^{68}Zn(n,\gamma)^{69m}Zn$	18.8±0.7	18.2	-
$^{94}Zr(n,\gamma)^{95}Zr$	12.7±0.7	11.9	-
$^{235}U(n,\gamma)^{239}U$	1.51±0.04	-	1.49±0.07
$^{232}Th(n,\gamma)^{233}Th$	-	-	4.68±0.16
$^{58}Co(n,\gamma)^{59}Co$	-	-	29.9±1.4

A comparion of neutron spectrum data

•Parameters		•α		•f	
		•Expt.	•Theory	•Expt.	•Theory
	•Inner	•-0.052±0.002	•-0.056±0.004	•19.2±0.5	•17.2±2.8
	•Outer	•0.029±0.003	•0.023±0.007	•48.3±3.3	•46.6±3.6

Summary of spectrum characterization

- Measurement was based on Cd-ratio for multi monitor method
- GRUPINT is semi-empirical – a combination of computational methods with activation measurements
- Theoretical – a combination of computational methods with cross section data libraries
- Measured RCd data agree well with theory & GRUPINT
- RCd data were used to determine f and α parameters
- Data agree well, indicating the suitability of theory
- The theoretical method has been used to determine neutron spectrum parameters of NIRR-1 LEU core
- Method can be used for facilities that do not permit use of Cd

Measurement of Nuclear Data

- Measurement of reactor neutron spectrum averaged cross section data was performed – 1st & 2nd RCMs
- In the 3rd year measurements of σo & Qo were performed on basis of spectrum parameters
- Qo data are based measured RCd data according to

$$Q_O(\alpha) = \frac{f}{(F_{Cd}.R_{Cd} - 1).\frac{G_e}{G_{th}}}$$

- Data are compared with literature data

Measurement of Nuclear Data

Nuclide	Target material	Qo		σo (b)	
		This work	DC & S	This work	Mughahghab
^{48}Ca	Powder	1.21	1.3	0.85±0.24	1.09±0.07
72Ga	Powder	6.52±0.66	6.69	4.79±1.1	4.73±1.8
75Se	Powder	6.7±2.1	10.8	77.4±5.1	51.8±1.2
76As	Powder	13.9±0.4	13.6	4.38±0.33	4.23±0.08
95Zr	Foil	5.31±0.11	5.31	0.043±0.007	0.0499±0.0024
239U	Foil	101.6±2.5	103.4	2.73±0.03	2.68±0.019
197Au	Foil	15.6±0.3	15.7	98.7±0.1	98.65±0.09

Summary of nuclear data measurements

- Preliminary cross section measurements on some nuclides to assess NIRR-1 facilities
- 198Au & other data in good agreement
- 75Se deviates significantly-requires further investigation
- 115Cd, 197Hg, 153Gd, 131Ba, &134Cs are outstanding for lack of relevant target materials

CONCLUSIONS

- Validated NIRR-1 MCNP model for spectrum characterization – results in Ann. Nucl Energy, 2007
- Finalized determination of σ_f –results in Appl. Rad. Isot. 66, 2008
- Testing of k0-IAEA using SMELS – results in J. Radioanal. Nucl. Chem. 2009 (in press)
- A method for determination of neutron spect parameters by simulation has been developed
- Good agreement was found between measured and calculated data for NIRR-1 HEU core
- Further investigations on determination of Qo, σo are on going

ACKNOWLEDGEMENTS

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