PROGRESS REPORT ON NIR/13278/RBF: MEASUREMENTS OF PARTIAL CROSS SECTIONS USING NIRR-1 FACILITIES

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OUTLINE OF PRESENTATION

- BACKGROUND
- STATUS REPORT
  - Additional Characterized irradiation sites
  - MCNP Computational Model of NIRR-1 Measured Cross section Data
  - Testing of the k_0-IAEA Program
- PLAN FOR THE CRP
- CONCLUSIONS

BACKGROUND

- IAEA Research Contract No. 13278/RBF
- Scope
  - Participation in proficiency tests
  - Develop model to simulate NIRR-1 & validate by measurements
  - Implement the k_0-IAEA program for NAA
  - Perform spectrum characterization
  - Perform accurate measurements of cross section data

NIRR-1 CORE & IRRADIATION FACILITIES

- **Type: Tank-in-pool, low-power research reactor**
- **Fuel: 90% enriched uranium as U-Al_4 alloy with Al cladding**
- **Moderator/Coolant: Light water**
- **Core: Sealed, Sq cylinder diam. 23 cm and height 23 cm.**
- **Reflectors: Be annulus & disk**
- **Control rod: One central CR for start-up and shutdown**
- **Characteristics for NAA:**
  - **Stable flux**
  - **Poorly thermalized inner channels**

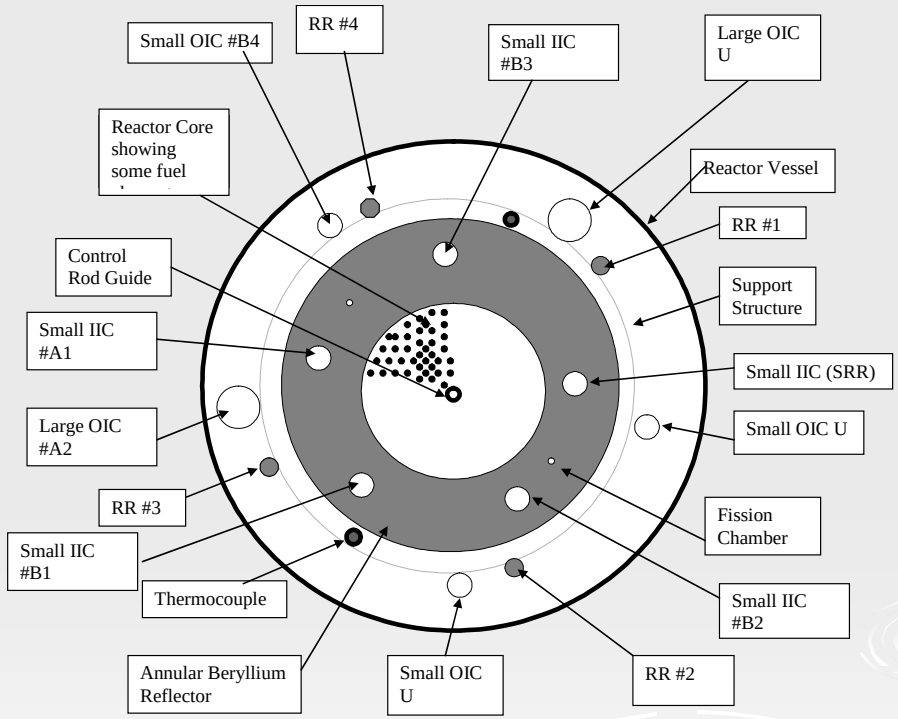
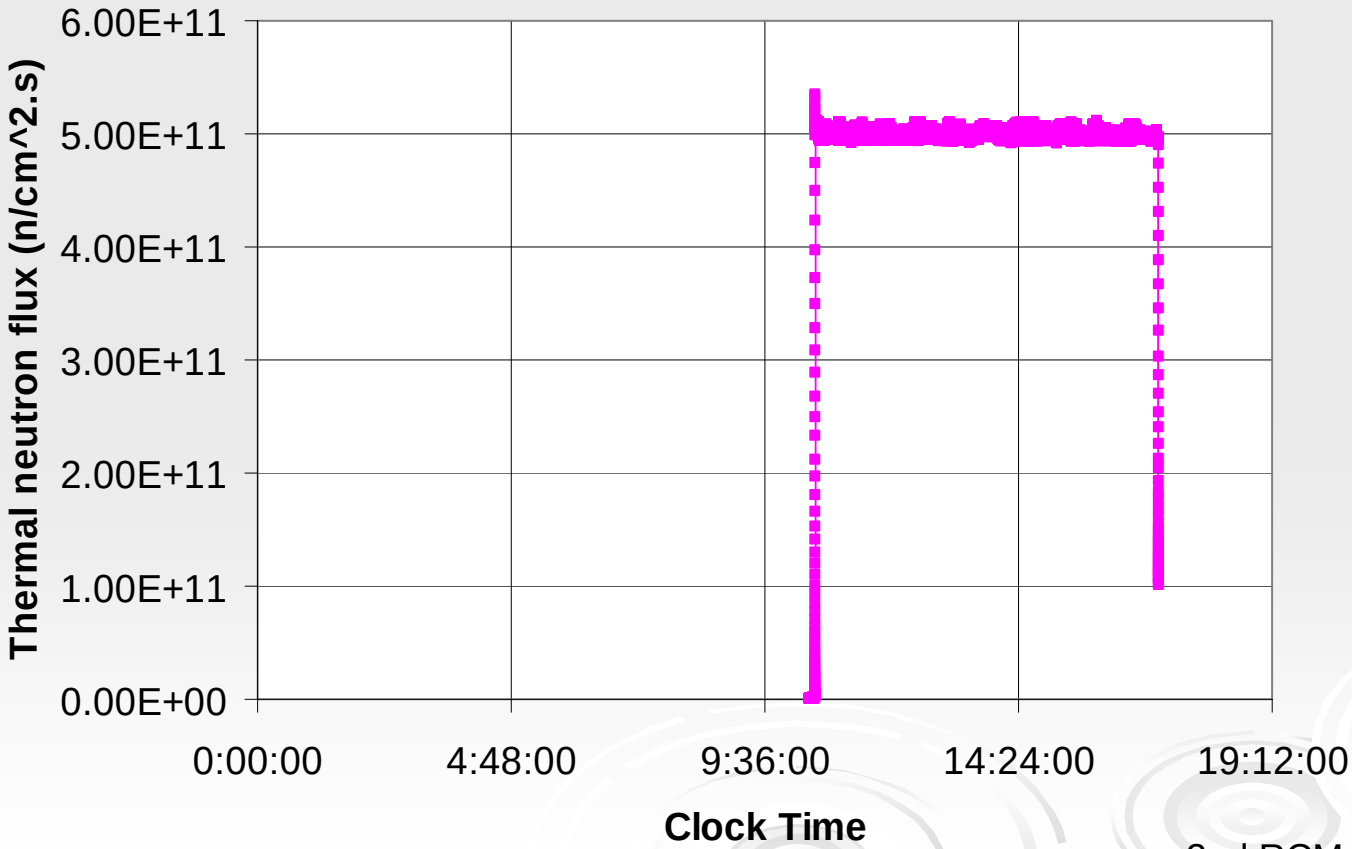


Fig. 1: Lay-out of NIRR-1 core showing irradiation channels and control devices

Neutron flux characteristics of the four connected NIRR-1 irradiation channels at CC setting of 5.0 x10^{11} n/cm^2.s

parameters	inner		outer	
	A1 (New)	B2	A2 (New)	B4
ϕ_{th} x10^{11} n/cm^2.s	4.96	4.89	2.40	2.45
ϕ_e x10^{10} n/cm^2.s	2.81	2.55	0.49	0.49
ϕ_f x10^{11} n/cm^2.s	0.96	1.0	0.16	0.17
α	-0.047	-0.52	0.024	0.029
f	18.4	19.2	49.7	48.3
ϕ_{th}/ϕ_f (f_f)	5.2	5.0	15.0	15.5
ϕ_f/ϕ_e (f_e)	3.54	3.84	3.33	3.12
$r(\alpha)\sqrt{T_n/T_0}$	0.0471	0.0459	0.0180	0.0183
T_n, (°C)	52.3	60.6	40.4	44.5

NEUTRON FLUX STABILITY of MNSRs



STATUS REPORT-MCNP Model

- The MCNP5 code was acquired and installed in a LINUX Cluster
- It has been used to determine the neutron energy spectrum in 640 energy groups
- The calculated n-spectrum data agree with measurements
  - 'Hardened spectrum' in inner channel

NIRR-1 HEU CORE BY MCNP CODE

- Geometry of NIRR-1 HEU core was created in a 3-D, Cartesian coordinate system.
- An MCNP input deck was constructed using detailed from SAR
- The deck was run as a KCODE source problem with ½ a million histories in 400 cycles with 50 inactive cycles skipped
- Tally setup for neutron flux in channels based on 640 energy groups

Core	Fuel Pins
347 Fuel Pins	Fuel Meat OD: 4.3 mm
3 Dummy Al Pins	Clad OD: 0.6 mm
4 Al tie rods	Clad Thick: 0.6 mm
1085g U-235	Fuel Height: 230 mm
90% Enr. U	U-235 per Pin: 2.88 g

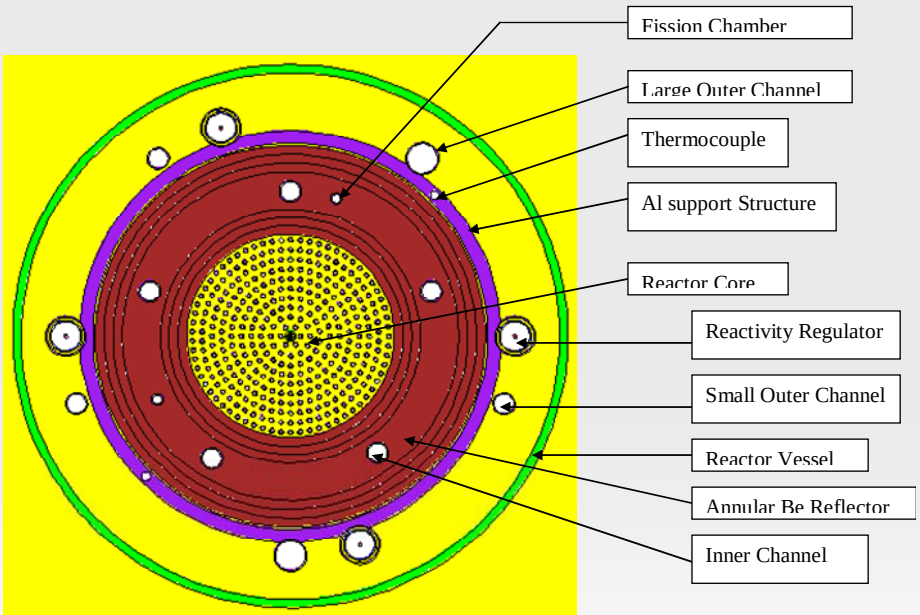
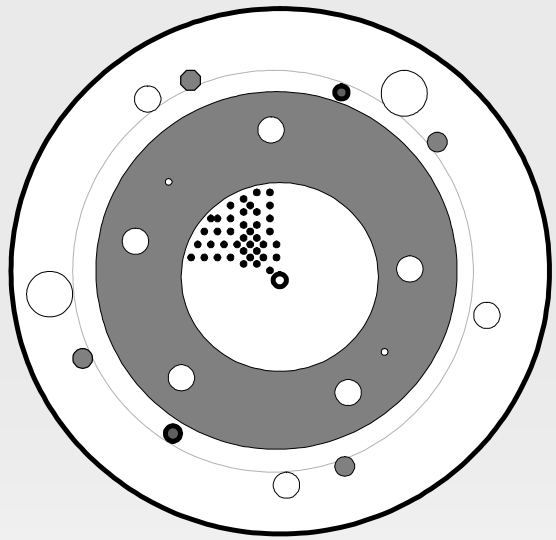
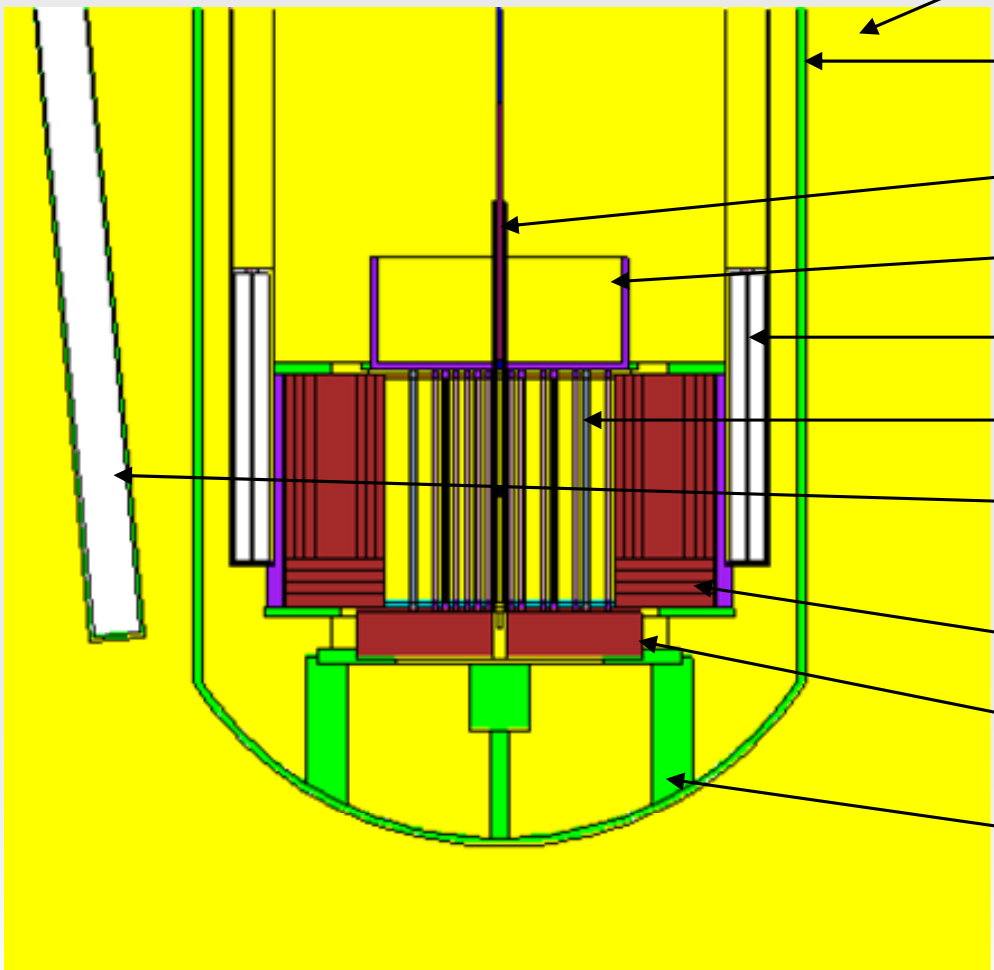
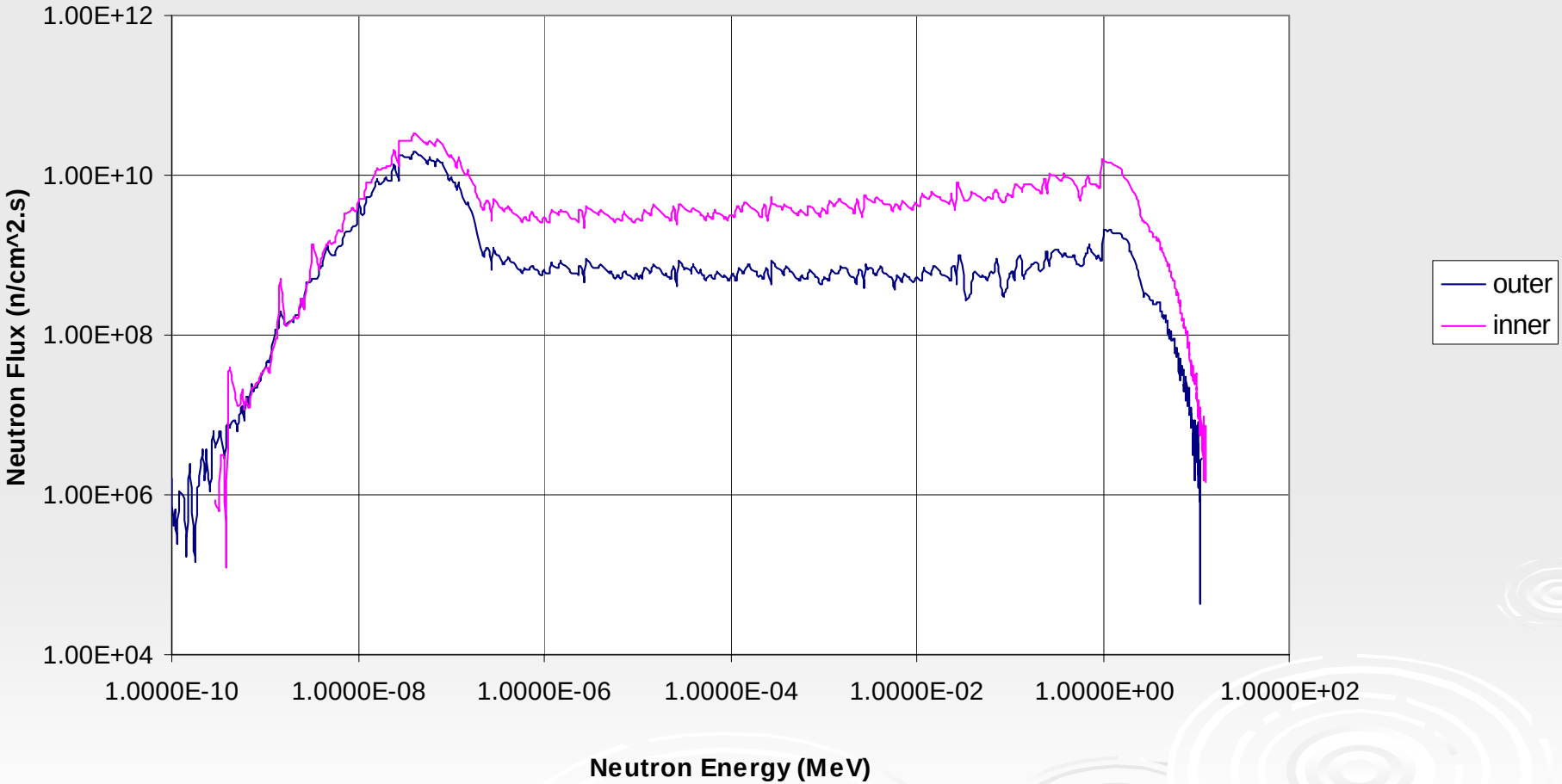


Fig. 1 A geometric diagram of NIRR-1 in the x-y plane from MCNP

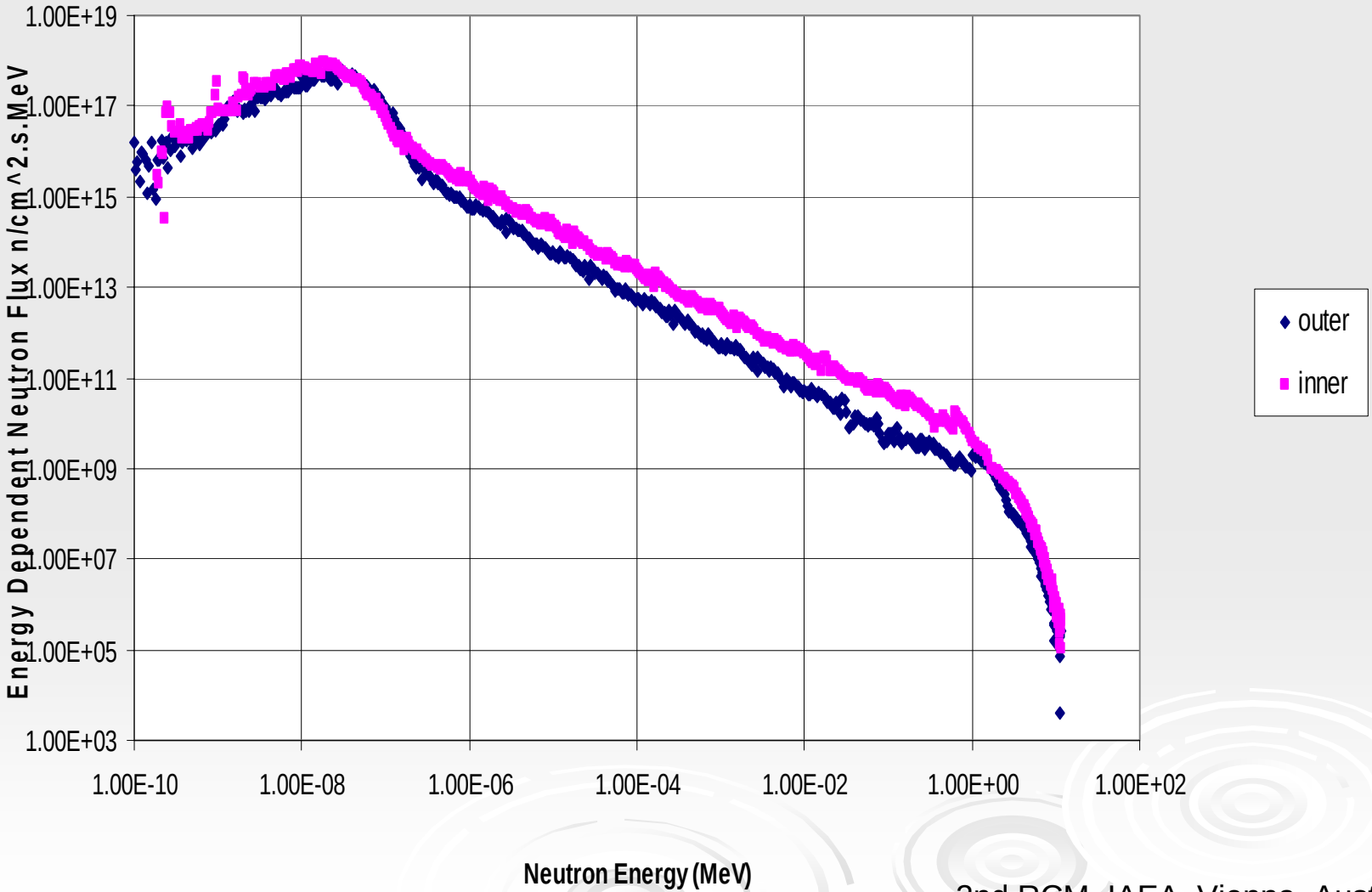



Pool Water
Reactor Vessel
CR Fully Withdrawn
Shim Tray
Reactivity regulator
Core with Fuel Pins
Slant Tube
Annular Be Reflector
Bottom Be Reflector
Al Support Structure

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



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



A Comparison of Neutron Spectrum Parameters

Parameter	Inner		Outer	
	MCNP	Meas.	MCNP	Meas.
Thermal-to-epithermal (f)	20.0	19.2	51.8	48.3
Thermal-to-fast ($f_{T)}$	4.6	5.0	18.8	15.5

Results of Fission Spec. Av. Cross section

Reaction	This work		CALAMAND (IAEA 1974)	JENDL (2002)
	σ_f (mb) relative to σ_f $^{27}Al(n,p)$	σ_f (mb) relative to $I_o(\alpha)$ $^{97}Au(n,\gamma)$		
$^{27}Al(n,p)^{28}Mg$	4.20±0.2	4.45±0.25	4.0±0.45	4.28
$^{27}Al(n,\alpha)^{24}Na$	0.93±0.05	0.98±0.06	0.73±0.05	0.69
$^{28}Si(n,p)^{28}Al$	6.83±0.22	6.85±0.21	6.4±0.8	6.13
$^{29}Si(n,p)^{29}Al$	3.98±0.16	3.98±0.20	3.3±0.2	2.99
$^{30}Si(n,\alpha)^{27}Mg$	0.16±0.01	0.15±0.01	0.155±0.02	0.131
$^{46}Ti(n,p)^{46}Sc$	12.5±0.7	13.4±0.9	12.5±0.9	13.10
$^{47}Ti(n,p)^{47}Sc$	16.6±1.1	17.8±1.5	20.0±2.3	17.75
$^{54}Fe(n,p)^{54}Mn$	85.5±4.9	91.4±5.2	82.5±5	81.85
$^{58}Ni(n,p)^{58}Co$	120.0±5.9	128.0±8.8	113±7	107.2
$^{64}Zn(n,p)^{64}Cu$	49.7±2.1	53.1±4.0	31.0±2.3	-

COMPARISON OF RESULTS

Element	**NIST-1633b WINSPAN**	**C.V.**	**NIST-1633b k0-iaea**
Al (%)	14.4±0.2	15.05±0.27	11.1±0.21
Ti (%)	0.77±0.05	0.791±0.014	0.86±0.17
Ca (%)	1.48±0.22	1.51±0.06	BDL
Mg (%)	0.87±0.18	0.482±0.008	0.58±0.12
K (%)	1.6±0.2	1.95±0.03	2.4±0.3
Cl (%)	-	-	0.025±0.007
V (ppm)	345±15	295.7±3.6	277.3±20.8
Mn (ppm)	118.4±1.5	131.8±1.7	127.9±7.7
Dy (ppm)	12.1±0.7	17	10.6±1.8
Sr (ppm)	-	1041±14	1126±124

PRELIM RESULTS

Element	BITUMEN WINSPAN	BITUMEN k0-iaea	COAL-NIGER WINSPAN	COAL-NIGER k0-iaea
Al (%)	2.14 ± 0.06	1.3 ± 0.04	2.78 ± 0.08	1.51± 0.05
Ti (%)	0.19 ± 0.03	0.17 ± 0.02	0.23 ± 0.04	0.23 ± 0.03
K (%)	0.16 ± 0.06	0.32 ± 0.09	0.25 ± 0.04	0.60 ± 0.14
Fe (%)		2.0 ± 0.1		-
Na (%)	0.0097 ± 0.0009	0.014 ± 0.5	0.041 ± 0.003	0.056 ± 0.002
Cl (%)		0.027 ±0.004		0.057 ± 0.008
V (ppm)	29.6 ± 2.9	21.4 ± 3.9	28.0 ± 3.0	22.1 ± 2.7
Mn (ppm)	42.5± 3.1	51.2 ± 2.5	10.8 ± 1.1	8.6 ± 2.7
Dy (ppm)	1.16 ± 0.17	3.0 ± 1.1	5.06 ± 0.31	1.3 ± 0.3
U (ppm)	2.59 ± 0.45	-	5.19 ± 0.79	5.5 ± 0.5
As (ppm)	3.59 ± 0.61		1.86 ± 0.19	
Sb (ppm)				0.62 ± 0.07
La (ppm)	15.7 ± 0.8	14.2 ± 0.6	31.5 ± 1.3	25.6 ± 0.5
Sm (ppm)	2.91 ± 0.27		5.35 ± 0.49	
Sc (ppm)		4.0 ± 0.2		12.0 ± 0.3
Cs (ppm)		1.7 ± 0.4		
Eu (ppm)	0.48 ± 0.07	0.82 ± 0.14	0.70 ± 0.08	-
Co (ppm)		9.3 ± 2.1		
Yb (ppm)	1.03 ± 0.13		3.61 ± 0.73	1.35 ± 0.32
Br (ppm)	1.41 ± 0.2	1.4 ± 0.2	1.05 ± 0.20	1.65 ± 0.18

CRP PLAN

- Perform further validation of measured n-spect parameters by MCNP code
- Continue measurement of fission neutron σ_{ave}
- Perform measurements of σ_o & I_o
- Testing of the k0-IAEA software by the SMELS

CONCLUSIONS

- 2 additional channels of NIRR-1 facilities have been characterized
- Version 1.40 of the MCNP5 code has been installed on a LINUX cluster for spectrum characterization
- Version 3.12 of the k0-IAEA program has been installed and tested for routine NAA
- Performed Fission Spec Av cross data
- To develop procedures for measurements of σ_o & I_o by Cd-ratio method in irradiation channels of NIRR-1

Thanks for your attention !