Recent activities of the neutron standardization at KRISS

Neutron Spectrometry with BSS

Energy spectrum measurement of cosmic neutrons

KRISS have constructed the multi-sphere system for the neutron spectrometry (Bonner Sphere spectrometer), manufactured by Centronic Ltd., UK. The Bonner Sphere set has 10 spheres of 3", 3.5", 4", 4.5", 5", 6", 7", 9", 10", and 12" diameter and originally designed by PTB, Braunschweig.

To extend the energy range for the neutron spectrometry, we have constructed the extended Bonner spheres with copper and lead shell included. The response matrix is calculated by using MCNPx (Fig. 1).

	Inner PE sphere	Metal shell		Outer PE shell
	Diameter	material	Outer diameter	Outer diameter
C3P5S6	3”	Pb	5”	6”
C4P5S7	4”	Pb	5”	7”
C4U5S7	4”	Cu	5”	7”
C4P6S8	6”	Pb	6”	8”

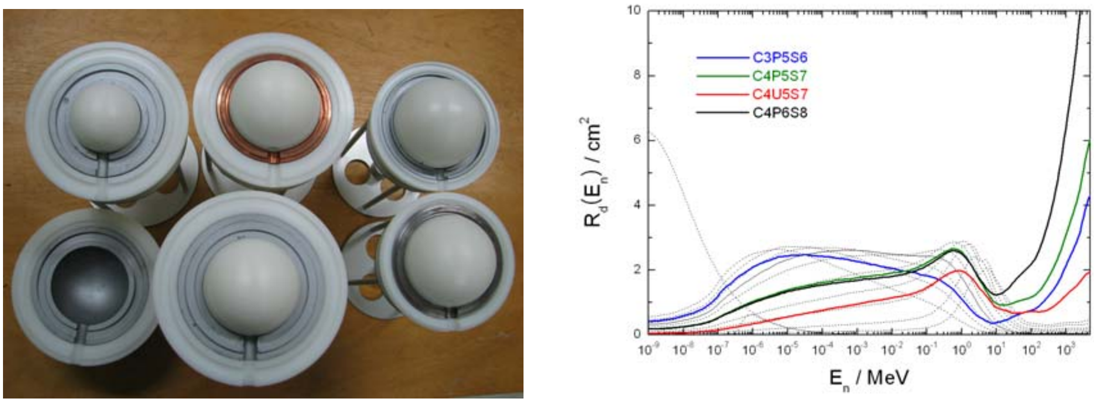

Figure 1 KRISS extended BSs and their response function

With the extended Bonner sphere set, we have measured the energy spectrum of cosmic neutrons in the site of KRISS for several months. The measurement position is at latitude 36.3916^o, longitude 127.3690^o and an altitude 142 m. Figure 2 shows the measured energy spectrum of cosmic neutrons.

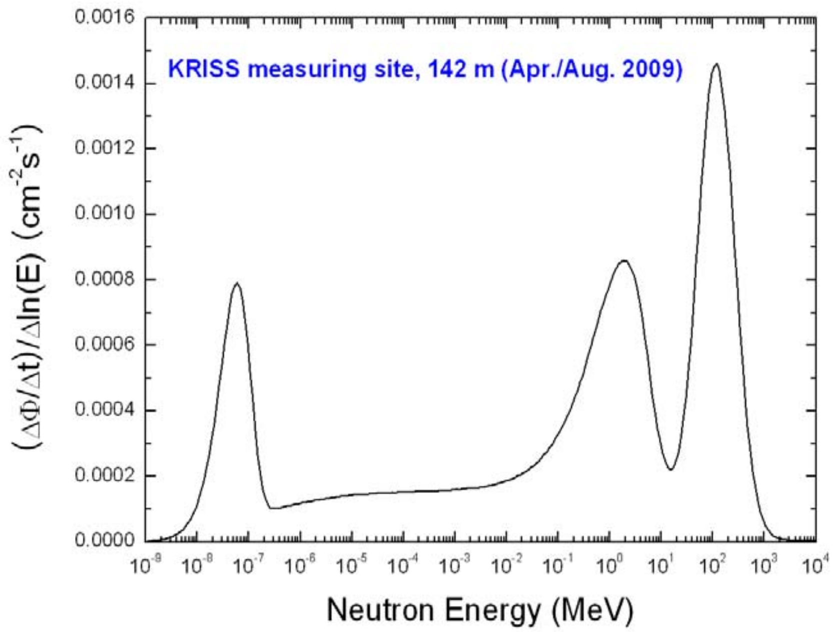

Figure 2 Cosmic neutron spectral fluence measured by KRISS-BS system

Neutron Spectrum Measurement at the underground

With the extended BS system, we have measured the neutron spectrum at the underground laboratory in Korea. The underground lab was located in the pumped storage power plant in the east part of Korea (Figure 3). The minimum depth from the ground is ~700 m.

The spectrum was measured for ~30 days. Figure 4 shows the pulse height spectrum of SP9 for ^{241}Am-Be source as a reference and one obtained in the underground lab. Figure 5 shows the neutron energy spectrum measured in the underground lab. The total neuron fluence is 0.242/cm^2/h which is about 1/143 compared to the ground.

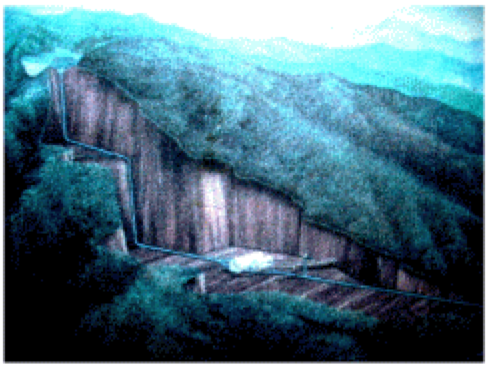

Figure 3 Underground Laboratory constructed in YangYang pumped storage Power Plantg

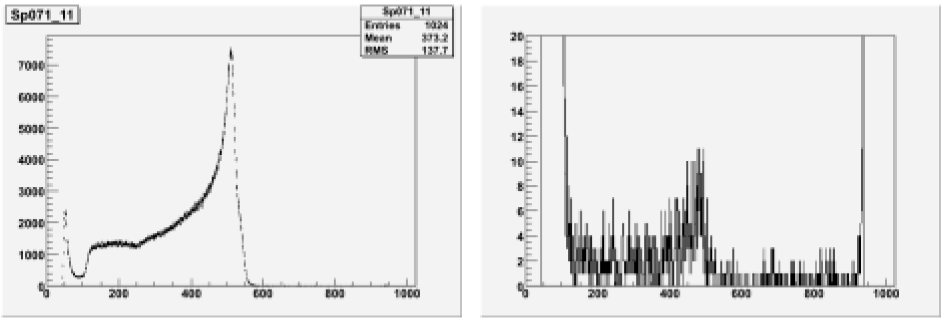

Figure 4 Pulse height spectrum of SP9 measured for ^{241}Am-Be source (left), one for the background neutron at YangYang (right)

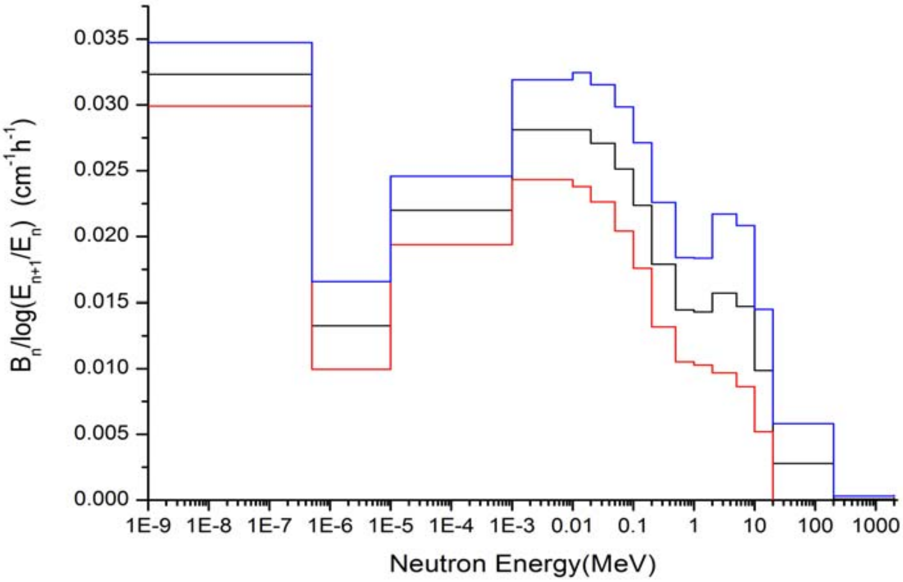

Figure 5 The neutron energy spectrum measured by BS at YangYang underground lab. The black histogram is the central value of the spectrum and the blue and red histogram represents the uncertainty of each bin (*k* = 1).

^{197}Au foil-based Bonner sphere system

We have constructed the activation foil-based Bonner sphere system with ^{197}Au foil and

KRISS Bonner spheres including the extended Bonner spheres for high energy neutrons. The response functions were calculated by using MCNPX and the response stabilities of the system were studied. The neutron incidence normal to the foil surface was sensitive to the foil position in Bonner sphere while the response of parallel or isotropic incidence was stable within 1%. Masses and responses have no linearity so the response matrix should be chosen properly with foil mass. We measured the spectral neutron fluence rate of ^{252}Cf and ^{241}AmBe sources at KRISS with both ^{197}Au foil-based Bonner spheres and SP9-based Bonner spheres. The results show that the neutron fluence rate and the ambient dose equivalent rate are well agreed within 2% and 4%, respectively.

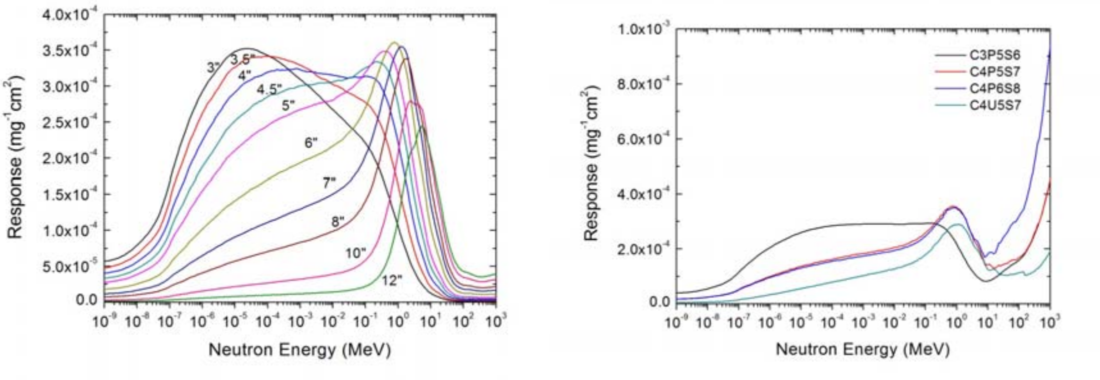

Figure 6 KRISS ^{197}Au foil-based Bonner sphere response function

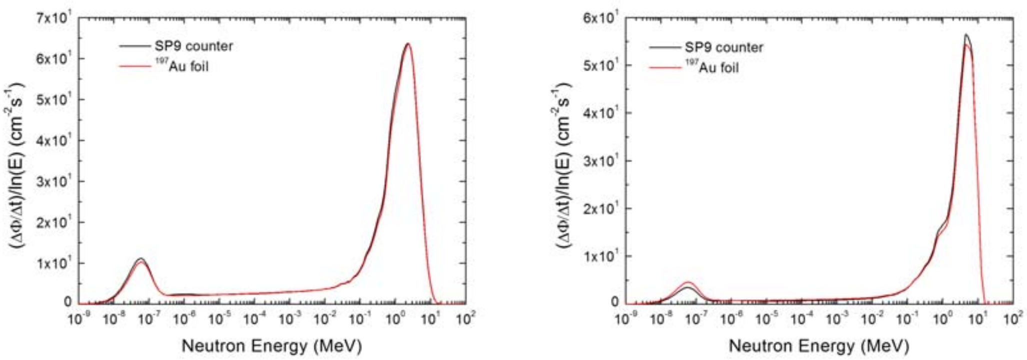

Figure 7 Unfolding results of ^{252}Cf (left) and ^{241}AmBe (right)

Neutron Metrology

Long counter for neutron fluence measurement

We have produced Long counter for neutron fluence measurement shown in Figure 8. Also, we calculated its response function and effective center. Figure 9 shows the calculated efficiencies and effective centers for various neutron energies and also shows the measured ones for ^{252}Cf and ^{241}Am-Be.

Using the KRISS-LC, we performed fluence measurements for ^{241}Am-Be and ^{252}Cf sources and evaluated the neutron emission rate from the measured fluence rate. The emission rate evaluated by fluence measurement was in good agreement with its certified value.

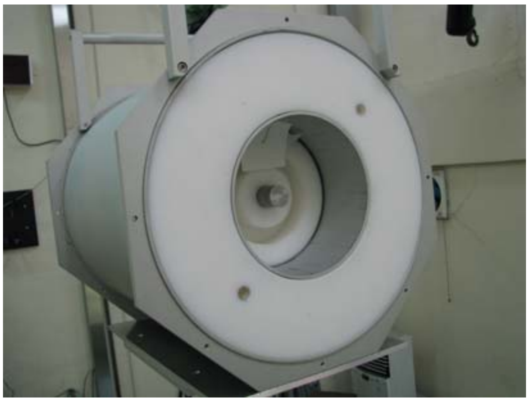

Figure 8 Long counter constructed by KRISS

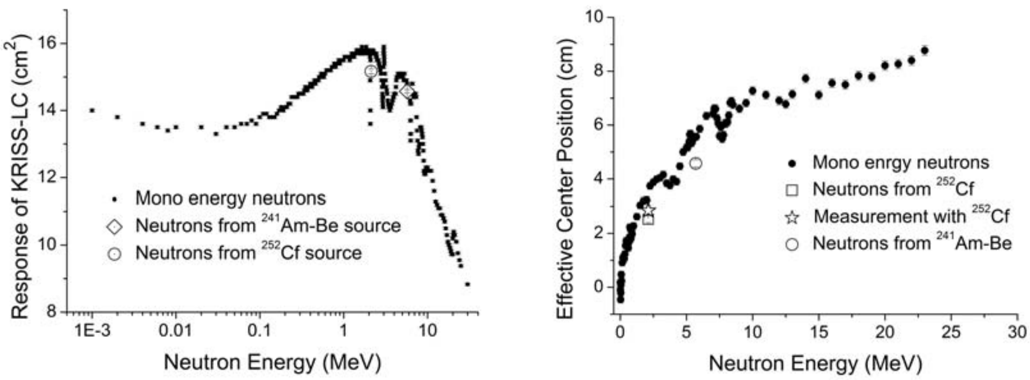

Figure 3 The response (left) and effective center (right) for each incident neutron energy.

Comparison between the fluence measurement using the KRISS-LC and the emission rate measurement by using the manganese sulfate bath

Source	Count rate (1/s)	Response	ϕ (1/(cm^2·s))	r_c (cm)	r_s (cm)	Emission rate (LC)	Emission rate (Mn)	Ratio (1-Mn/LC)
^{241}Am-Be	11.6 (2.4%)	14.6 (0.4%)	0.80 (2.4%)	4.58 (0.14)	150	2.40×10^5 (2.4 %)	2.33×10^5 (0.9 %)	+2.9 %
^{252}Cf	2052.8 (0.4%)	15.2 (0.5%)	135 (0.6%)	2.52 (0.13)	175	5.36×10^7 (0.6 %)	5.26×10^7 (0.76 %)	+1.9 %
^{252}Cf	29.41 (1.58%)	15.2 (0.5%)	1.94 (1.7%)	2.52 (0.13)	150	5.67×10^5 (1.7 %)	5.82×10^5 (0.69 %)	-2.7 %

Neutron Emission rate measurement with Manganese sulphate bath

Manganese Sulfate Bath was installed at KRISS in 1988 and used as a primary standard for the absolute measurement of Neutron Emission rate of radionuclide neutron sources. The diameter of the bath is 125 cm and the volume of the bath is 1.0226×10^6 cm^3. The aqueous solution of Manganese sulfate is circulated with the flow rate of ~10 cc/minute to the position of the gamma detector (NaI(Tl) crystal of 1.5" x 1.5"). The maintenance of Manganese sulphate bath is one of the most important tasks of KRISS. Table shows the chemical parameters measured at year 2004 and 2009, which are very stable for 5 years. Also, table shows the neutron emission rate of neutron sources measured at 2005 and 2009. The emission rates for both measurements are well agreed except for Cf252-II. Cf252-II is manufactured about 20 years ago, and it would be due to the ^{250}Cf (half life is 12.5 year) included in the Cf source.

	2004	2009	Difference
Mn Concentration(g/g)	0.017 026 5 (0.16%)	0.017 128 (0.4%)	0.6%
Density g/cm3	1.0459	1.044 12	0.17%
N(H)/N(Mn)	341.44 (0.16%)	339.32 (0.4%)	0.6%
# density of Mn N(Mn)	1.952×10^{20} (0.16%)	1.960×10^{20} (0.4%)	0.41%
Measurement efficiency	3.253×10^{-4} (0.3%)	3.169×10^{-4} (0.3%)	2.58%

	Neutron capture probability by ^{55}Mn		Neutron emission rate			
	Year 2004	Year 2009	2004 (old)		2009 (new)	1 - old/new
			Ref. date: 2004. 4. 1.	Ref. date: 2009. 9. 1.	Ref. date: 2009. 9. 1.	
Cf252-I (M11)	0.1051	0.1057	2.051×10^8 (0.60%)	4.958×10^7 (0.74%)	5.010×10^7 (0.63%)	1.03%
Cf252-II (X.224)	0.1048	0.1055	1.950×10^6 (0.62%)	4.714×10^5 (0.76%)	5.386×10^5 (0.62%)	12.5%
AmBe-I (X.14)	0.1019	0.1025	1.229×10^7 (0.61%)	1.218×10^7 (0.61%)	1.227×10^7 (0.63%)	0.74%
AmBe-II (X.2)	0.1026	0.1032	2.325×10^5 (0.76%)	2.305×10^5 (0.76%)	2.344×10^5 (0.98%)	1.66%

Plans

1. **Bonner Sphere Spectrometer**

   We plan to measure the cosmic neutron spectrum at ~1000 m altitude. Also, we continue to establish the procedure of neutron spectrum with a passive BSS using gold foil.

2. **Neutron Spectrometry with LSC(Liquid Scintillation Counter)**

   Because the energy resolution of BSS is very much limited, we are preparing LSC (liquid scintillation counter) system for the high resolution neutron spectrometry.

3. **Thermal neutron field**

   We are planning to construct the thermal neutron field with graphite pile and ^{241}Am-Be source. We have already prepared about 1.2 x 1.2 x 1.2 m^3 of pure graphite and 2 ^{241}Am-Be source of ~10^7 n/s.

4. **APMP comparison for the calibration of ambient dose equivalent meter**

   The protocol is under preparation for the APMP comparison for the calibration of ambient dose equivalent meter.

Staff Members

Three research scientists and one research associate are fully involved for the neutron standardization.

- Hyeonseo Park, ph.D in Nuclear Physics
- Jung Ho Kim, ph.D in Nuclear Physics

- Kil-oung Choi, master in Chemistry
- Ji Yeon Gwak, master in Nuclear Physics

Facilities

- **Radioactive neutron sources**
  two ^{252}Cf source : the emission rates of ~2 x 10^7 n/s and ~2 x 10^5 n/s
  three ^{241}Am-Be source : the emission rate of two ~1.2 x 10^7 n/s, and ~2 x 10^5 n/s
- **Low background neutron irradiation room** : size of 6.7 x 7.6 x 6.4 m^3
- **Manganese Sulphate Bath system for neutron emission rate measurement**
- **Bonner sphere system with 10 PE spheres**
- **4 extended Bonner spheres with Pb and Cu shells**
- **Neutron detectors**
  Long counter with one He-3 proportional counter and one BF_3 proportional counter
  three REM counter(two EG&G Ortec LB123 and one Studsvik 2002A),
  two H_2 proportional counter
  Liquid scintillation detector (BC501a)
  two BF_3 proportional counter

Publications and Communications

- **International**

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