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# Design of CONAS Station for MCNPX Simulation

Hoang Sy Minh Tuan [a,b] and Gwang Min Sun [a,b*]
[a] *Korea Atomic Energy Research Institute, PO Box 105, Yuseong-gu, Daejeon 305-353*
[b] *University of Science and Technology, 217 Gajungro, Yuseong-gu, Daejeon 305-350*
[*] *Email: gmsun@kaeri.re.kr*

## 1. Introduction

The HANARO Cold neutron Research Facility (CNRF) construction project was formulated since early 2003. During the feasibility study, a user survey on cold neutron instruments, which includes SANS, TAS, TOF spectrometer, spin-echo spectrometer, neutron interferometer, powder-Laue diffractometer, etc., were performed. Beside these instruments, CNRF especially includes the neutron activation analysis instruments using the cold neutron beams.

At present, a Cold Neutron Activation Station (CONAS) has been under construction with a support by the National Research Foundation of Korea (NRF) since May 2010. CONAS consists of Neutron Depth Profiling (NDP) and Prompt Gamma Activation Analysis (PGAA) instruments. This project will finish in April 2012. In order to estimate the CONAS, the MCNPX code [1] was adopted in this study for estimating and optimizing the setup parameters of these instruments.

## 2. Experimental Setup

The CONAS was placed at the end position of CG1 and CG2B neutron guides. The CG1 guide was extended after a Vertical Reflectometer for the NDP and CG2B was newly installed for the PGAA. Both instruments have been under construction inside the CONAS concrete bio-shield.

### *2.1 Prompt Gamma Activation Analysis (PGAA) instrument*

The PGAA was designed to have a two spectrometer with its axis perpendicular together. Each spectrometer consists of an n-type HPGe detector, an annulus BGO detector and a rear catcher BGO detector. With this assembly detector, the spectrometer is able to operate in several modes such as normal, anti-coincidence and triple cases. A sample box was made from Teflon to reduce the gamma-ray background. Due to the high background in the PGAA analysis, these spectrometers have the lead shields and operate in the Compton suppression. The specifications of these detectors spectrometers were given in Table 1.

Table. 1 Specifications of the detectors.

| Detector | Crystal diameter (mm) | Crystal length (mm) | Hole diameter (mm) | Hole depth (mm) |
|---|---|---|---|---|
| HPGe-1 (*) | 60.2 | 72.5 | 8.0 | 66.0 |
| HPGe-2 (**) | 58.1 | 79.0 | 7.9 | 70.3 |
| Annulus BGO | 152.4 | 223.52 | 78.74 | |
| Catcher BGO | 71.628 | 35.56 | 37.592 | |

[*] The GMX40-76-S HPGe (SN 51-N32730A)
[**] The GMX40-76-S HPGe (SN 51-N42257A)

### *2.2 Neutron Depth Profiling (NDP) instrument*

The NDP consists of UHV sample chamber and semiconductor detectors. In future, we will install two micro-channel plate (MCP) detectors for a TOF-NDP technique inside this sample chamber. The body of the UHV sample chamber was made from iron material with 60cm diameter, 1cm thickness and 31.5cm height. This chamber has a bottom plate made from iron with 68cm diameter and 2cm thickness and a cover made from aluminum with 68cm diameter and 2.5cm thickness.

### *2.3 CONAS concrete bio-shield*

The CONAS bio-shield was made from high density concrete to prevent the radiations such as neutron, gamma-rays. The material composition and its density were given in Table 2. Concrete bio-shield was covered by 0.5cm iron shell when it was casted.

Table 2. The material composition of the CONAS concrete bio-shield.

| Material | Volume factor($m^3$) | Density (g/cc) |
|---|---|---|
| Cement | 0.1 | 2.2 |
| Water | 0.1 | 1 |
| $B_4C$ | 0.0 | 2.52 |
| Steel ball | 0.1 | 7.2 |
| Iron ore | 0.7 | 3.5 |
| Total | 1 | 3.70 |

## 3. Monte Carlo Simulation

MCNPX 2.7a was chosen for simulating the CONAS. The MCNPX is a general purpose Monte Carlo radiation transport code designed to track many particle types over broad ranges of energies. The new version of MCNPX code has integrated some advanced functions such as the pulse height tally in anti-coincidence mode, the mesh tally, speech up lattice, variance reduction and especially, the neutron-induced prompt and delays gamma-ray. With these useful functions, the MCNPX was suitable in this simulation to compare with other Monte Carlo codes.

Due to the complex geometry of CONAS, the Visual Editor [2] and MCAM [3] tools were used to simplify its design to make the MCNPX input deck. In the simulated mode, it takes so long running time to simulate the full particle tracks. To solve this problem, the MCNPX was installed on a cluster with 32 processors using the Red Hat operating system and apply the variance reduction techniques in MCNPX.

Figure 1 illustrates the 3D modeling of the CONAS station. This model was made by editing the MCNPX input and render by MCAM.

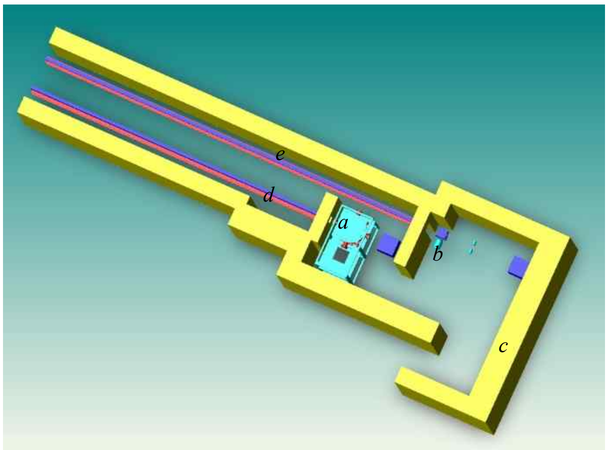

*Fig. 1 The 3D modeling of the CONAS station. (a)NDP, (b) PGAA, (c) concrete bio-shield, (d) CG1 neutron guide, (e) CG2B neutron guide.*

Figure 2 and 3 show the zoom in of the PGAA detector with sample box and the UHV sample chamber, respectively.

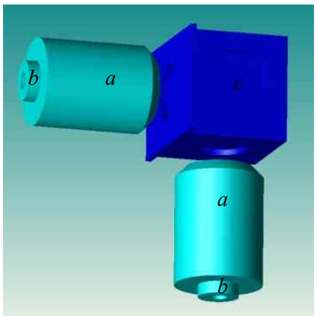

*Fig. 2 The zoom in of the PGAA detector with sample box in MCNPX model. (a)Annulus BGO detector, (b) Catcher BGO detector, (c) Sample box.*

The neutron beam profiles including energy and spatial distributions at the end of the neutron guide were already determined in the previous study [4]. And the material data in MCNPX input deck referred to R.G. Williams III's report [5].

### *3.1 Estimation of equivalent and absorbed doses inside the CONAS station*

The equivalent and absorbed doses inside or outside of the bio-shield were estimated. In MCNPX, Tally type F4, F6 and *F8 can be used to estimate absorbed dose and tally type F2 can be used to estimate equivalent dose on the basis of the KERMA approximation. With choice of TMESH tally option, the estimated dose can be graphically displaying on rectangular grid overlaid on top of the standard problem geometry.

### *3.2 Simulation of PGAA*

The full energy peak efficiency of HPGe detectors in PGAA system were calibrated in a wide energy range from 0.06 to 11 MeV. The prompt gamma-ray spectra in normal, anti-coincidence and triple mode were simulated by applying anti-coincidence and activation options.

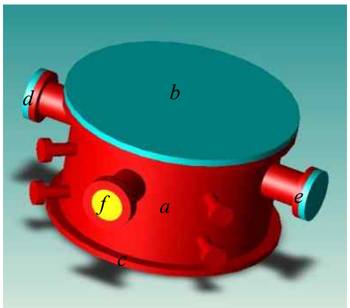

*Fig.3 The zoom in of the UHV sample chamber in MCNPX model. (a)Body chamber, (b) cover, (c)bottom plate, (d)input neutron beam port, (e) output neutron beam port, (f) window port.*

### *3.3 Simulation of NDP*

Residual energy of Charged particle from the sample after neutron capture reaction was recorded for the depth profiling of the elements of interest. If activated by the 7th entry on the PHYS:N card, the optional neutron capture ion algorithm performs neutron capture in $^3$He, $^6$Li, and $^{10}$B to produce protons, tritons, deuterons, and/or alphas according to the following Table 3:

Table 3. The reaction list in NDP simulation.

| Isotope Reactions | Isotope Reactions |
|---|---|
| $^3$He | n($^3$He,h)t<br>n($^3$He,d)d |
| $^6$Li | n($^6$Li,t)a |
| $^{10}$B | n($^{10}$B,g)a |

## 4. Conclusions

The MCNPX models were extremely useful for the following: simulated efficiency, prediction of the neutron-induced prompt gamma-ray spectrum, estimation of the absorbed dose and NDP profile by MCNPX model. These results will be used to compare with measured data.

## Acknowledgments

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