# Advances in Monte Carlo methods in Radiation Transport*

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**Introduction:** Monte Carlo (MC) technique is widely employed for solving practical radiation transport problems. This technique is based on the simulation of a "history of a particle" which accounts for the absorption as well as energy transfer mechanisms. Such simulations are useful in predicting the radiation field strengths around the radiation sources thereby enabling control of exposures happening in the nuclear fuel cycle facilities. MC simulation requires copious quantity of random numbers in the range (0 to 1) and the probability density functions (PDF) which need to be deduced from Evaluated Nuclear Data File (ENDF). The main difficulty in the case of neutron transport with point cross sections is the number of data points are voluminous and vary widely from one nuclide to the other. In the present work, the usage of computer memory in handling voluminous data is optimized by the use of dynamic allocation and de-allocation. MC codes known to consume a lot of CPU time, which can be reduced considerably by adopting unionized energy grid method and efficient search algorithm.

## Materials and Methods:

Major components of Monte Carlo methods are:

- Random number generator (RNG)
- Sampling theory
- Scoring
- Error estimation
- Variance reduction techniques

First two components where in the advances have been made are reported in sequel.

## Results and Discussions:

The following are the advances[1] attempted in the present work in reducing the CPU time and memory storage for handling data.

**Random number generators-CPU time optimization:** In the literature[2] a large number of RNGs are available which satisfies minimal statistical tests. For selecting a fast RNG which takes minimum CPU time, several RNGs are tested for the time required to generate 100 million random numbers, and the representative results presented in table.1. Currently Monte Carlo simulations are done on parallel machines, which uses the following RNG.

**Where** is i+k th random number,
i and k are integers, g is the multiplier, c is the additive term.

**Table.1.Random number generating functions with time for 100 million random numbers**

| S.N | Random number generator<br>(s is the seed of RNG) | Time taken(s) |
|---|---|---|
| 1 | r4_random(s1,s2,s3) | 9.6250 |
| 2 | R4_uni(s1,s2) | 7.0156 |
| 3 | R8_random(s1,s2,s3) | 11.3906 |
| 4 | R8_uni(s1,s2) | 8.0625 |
| 5 | R4_uniform_01(s) | 5.2655 |
| 6 | R4_uniform_02(s) | 8.5156 |
| 7 | R4_uniform_03(s) | 18.0124 |

**Dynamic allocation of memory:** To store and access unstructured data which varies widely from one nuclide to another, it consume a large amount of computer memory in conventional programming method. However, the use of "**ALLOCATABLE**" statement, allows the user to dynamically allocate the required memory space. Further, the statement of "**DEALLOCATE**" enables one to reuse the same memory again and again for different purposes.

**Unionized energy grid method:** In sampling of nuclide and type of reaction taking place it is required to search the large data table of nuclides. This can be avoided by using the unionized energy grid. The CPU time can be improved by the use of unionized energy grid method and by following the improved search algorithms. Thus saving CPU time.

**Search algorithms:** At each interaction point it is required to compute the total and individual reaction cross-section of all nuclides present, by searching huge data table. For instance in a table of length 1 billion to search at fag end on a computer operating at 1 million operations per second, it requires 1000 seconds. While the binary search requires only 32 µs. Thus the use of Binary search algorithms reduces the CPU time drastically.
The advances reported here if adopted in future MC codes will make them attractive over other codes.

## References:

*This work carried out under BRNS Project:
"Development of indigenous Monte Carlo code for estimation of $k_{eff}$ in nuclear fuel cycle facilities.
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2. Press W.H. et al., (1992), “Numerical Recipes in Fortran, The art of scientific computing”. second Ed. P-266-320.