

Application of Monte Carlo Techniques to Dose Rate Calculations of Gamma Irradiation Facility



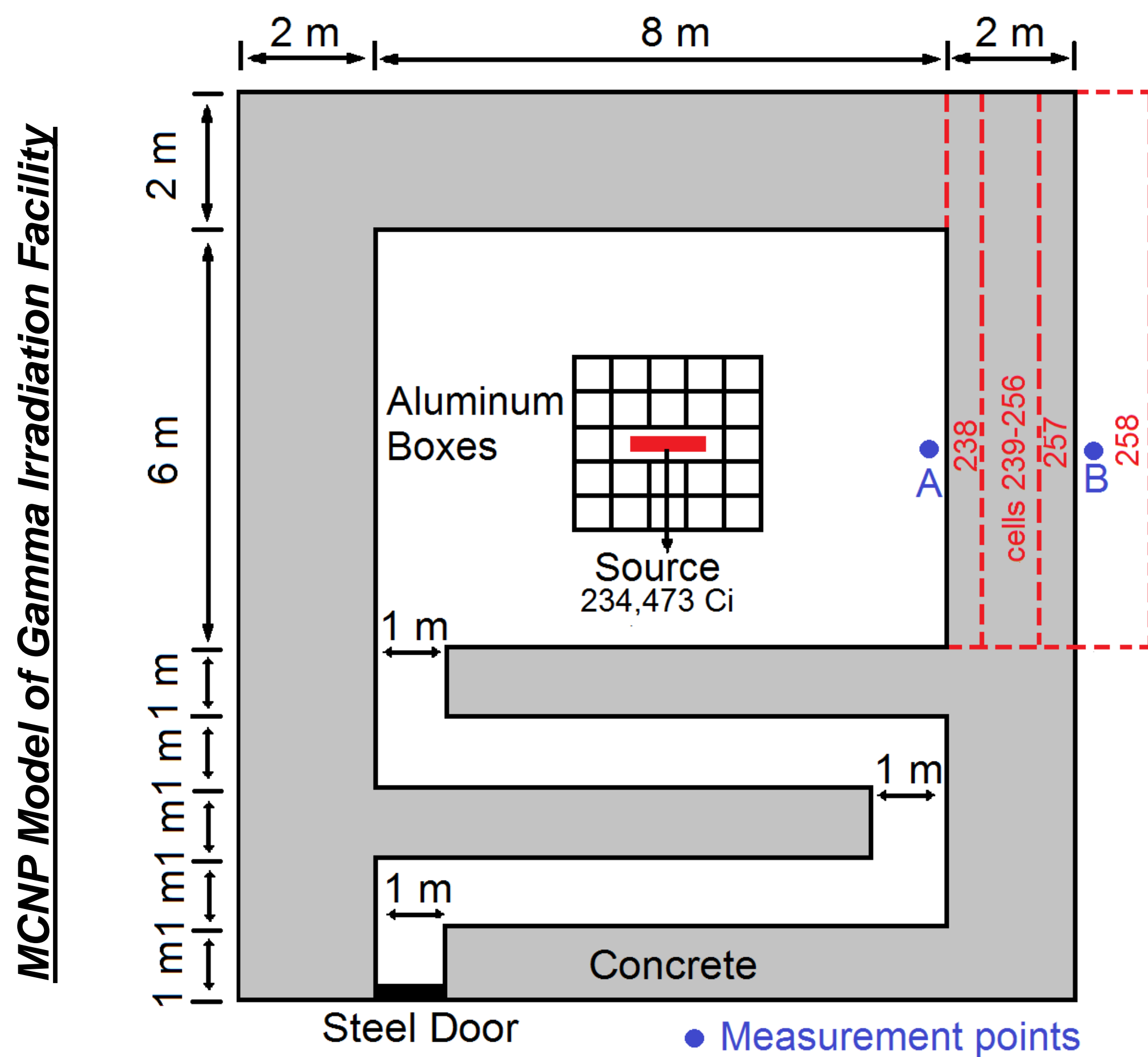
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MOTIVATION

- ◆ Dose calculations of gamma irradiation facility with Monte Carlo technique.
- ◆ Investigation of methods to reach reliable Monte Carlo results fast and effectively.
- ◆ Identification of variance reduction techniques and determination of key points on application.



METHODOLOGY

- **Analog Monte Carlo:** Natural laws are preserved.
- **Non-analog Monte Carlo:** Alters the nature to improve statistics in short period of time.

VARIANCE REDUCTION

- Point detector tallies did not pass 10 statistical checks performed by MCNP with Analog MC.
- Number of tracks entering into adjacent cells must be similar for good sampling.
- Geometric splitting/Russian roulette and energy splitting/roulette improve random walk sampling significantly either increasing number of particles moving to high importance regions by splitting or exterminating particles moving to unimportant regions.

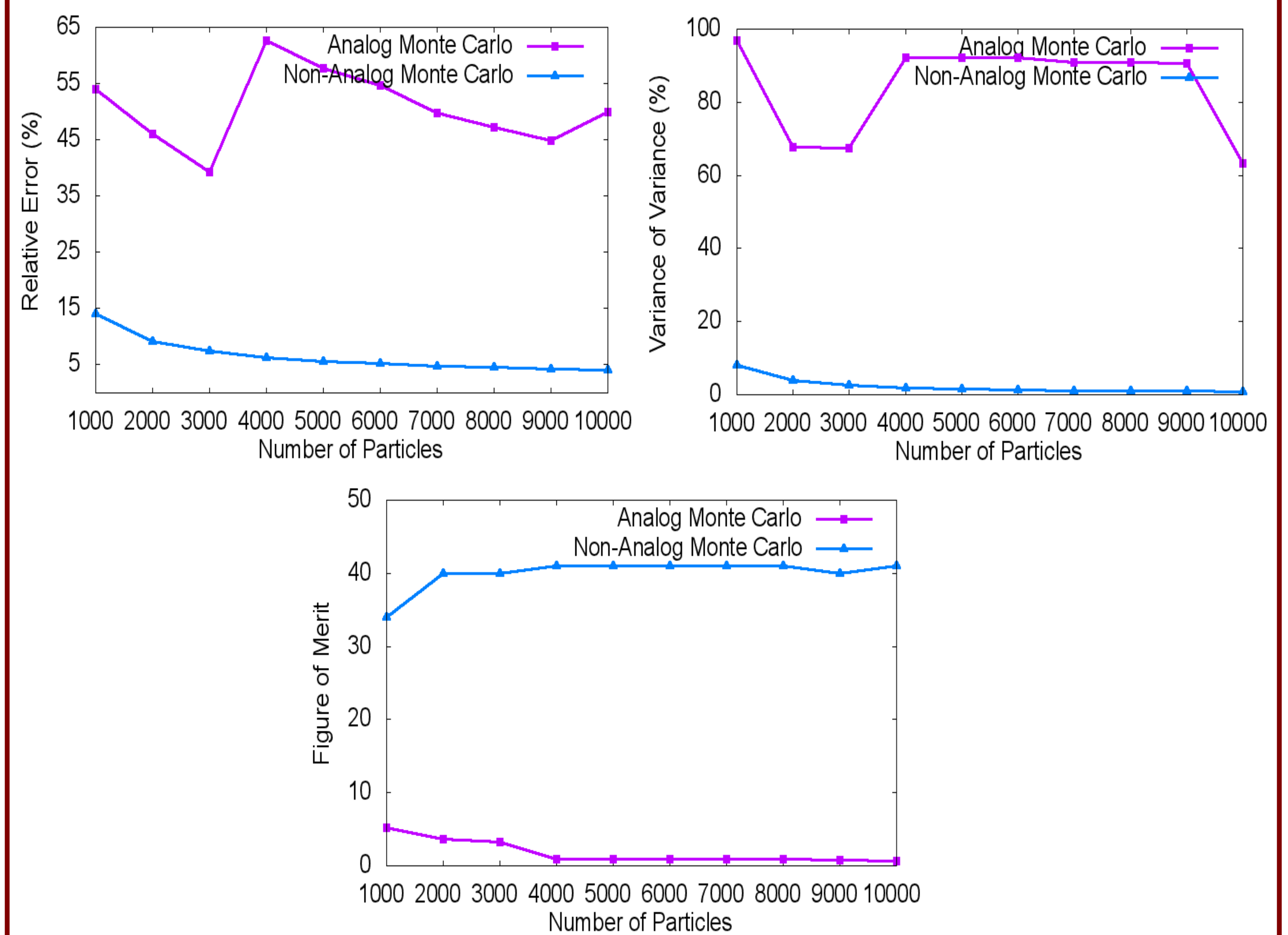
Tracks entering into cells of the side wall.

| Cell | Case A | Case B | Case C | Cell | Case A | Case B | Case C |
|------|--------|--------|--------|------|--------|--------|--------|
| 238 | 1079 | 1126 | 1618 | 249 | 0 | 469 | 1474 |
| 239 | 456 | 1180 | 1717 | 250 | 0 | 339 | 1511 |
| 240 | 152 | 1257 | 1901 | 251 | 0 | 232 | 1420 |
| 241 | 55 | 1217 | 1814 | 252 | 0 | 206 | 1589 |
| 242 | 14 | 1235 | 1907 | 253 | 0 | 212 | 1367 |
| 243 | 2 | 1019 | 1576 | 254 | 0 | 264 | 1316 |
| 244 | 1 | 844 | 1264 | 255 | 0 | 407 | 1476 |
| 245 | 0 | 875 | 1357 | 256 | 0 | 427 | 1669 |
| 246 | 0 | 812 | 1386 | 257 | 0 | 524 | 1842 |
| 247 | 0 | 812 | 1717 | 258 | 0 | 637 | 1599 |
| 248 | 0 | 585 | 1533 | | | | |

Case A: Analog Monte Carlo, **Case B:** Geometric Splitting/Russian roulette, **Case C:** Case B+ Energy splitting/roulette.

- Variance reduction techniques specific to desired tally further improve statistics. Detector contributions, forced collision, and energy physics cutoff are useful methods for point detector tally.

VARIANCE REDUCTION



Statistical improvement of point detector tally at measurement point B.

- 10 statistical checks of MCNP being passed.
- Relative error < 5% and variance of variance < 10%.
- FOM ((RE²Time)⁻¹) as high as possible with constant value.
- Equivalent statistics as analog Monte Carlo of 10,000,000 particles with non-analog Monte Carlo of 10,000 particles.
- 1997 ANSI/ANS photon flux to dose rate conversion factors to obtain dose rate at point A and B.

RESULTS

- ✓ For well sampled Monte Carlo simulation tracks entering into adjacent cells have to be uniform.
- ✓ Geometric splitting/Russian roulette and energy splitting/roulette techniques improve random walk sampling effectively.
- ✓ Application of variance reduction techniques appropriate for desired output (tally) helps the output to pass statistical checks and ensures reliable results in a short period of time.
- ✓ Variance reduction reduces number of histories significantly.
- ✓ Dose rate at point A is 12.9 Sv/h and at point B is 6.05 pSv/h.
- ✓ Gamma irradiation facility is very well shielded.

References

- [1] Jaeger, R.G., Blizard, E.P., Chilton, A.B., 1970, Engineering Compendium on Radiation Shielding, Springer-Verlag, Berlin, Heidelberg, New York, Volume III, 478p.
- [2] Oliveira, C., Salgado, J., and Ferro de Carvalho, A., (2000) Dose rate determinations in the Portuguese Gamma Irradiation Facility: Monte Carlo simulations and measurements, Rad. Phys. Chem., 58, 279.
- [3] Carter, L. L. and Cashwell E. D., (1975) Particle Transport Simulation with the Monte Carlo Method, Technical information Center, USERDA, Springfield VA, USA.
- [4] Briesmeister J., (1997) MCNP - A general Monte Carlo Particle Transport Code LA 1265-M Version 4B, Los Alamos National Library, Los Alamos, New Mexico, USA.
- [5] Booth, T. E., (1985) A sample problem for variance reduction in MCNP, LA-10363-MS, Los Alamos National Laboratory, Los Alamos, New Mexico, USA.

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