



APPENDIX A Calculating the error or uncertainty

According to the FLUKA simulation use Monte Carlo method which is a random process thus the calculation of the error or uncertainty of data using counting statistics from below equation:

$$\sigma^2 = \frac{1}{n(n-1)} \sum_{i=1}^n (N_i - \bar{N})^2$$

where

σ = the standard error

N_i = the number of counts from the simulations

$\bar{N}$ = the average of N_i

If z is a function of more other variables for instance $z = f(x, y)$

when $x = \bar{x} \pm \sigma_x$ and $y = \bar{y} \pm \sigma_y$

then we can calculate the error or uncertainty of z by:

$$\bar{z} = f(\bar{x}, \bar{y}),$$

$$\sigma_z = \sqrt{\left(\frac{\partial f(x, y)}{\partial x}\right)_{\bar{x}, \bar{y}}^2 \sigma_x^2 + \left(\frac{\partial f(x, y)}{\partial y}\right)_{\bar{x}, \bar{y}}^2 \sigma_y^2}$$

For example, $z = \frac{x}{y}$ to find σ_z by

$$\sigma_z = \sqrt{\left(\frac{\partial \left(\frac{x}{y}\right)}{\partial x}\right)_{\bar{x}, \bar{y}}^2 \sigma_x^2 + \left(\frac{\partial \left(\frac{x}{y}\right)}{\partial y}\right)_{\bar{x}, \bar{y}}^2 \sigma_y^2}$$

then

$$\sigma_z = \sqrt{\left(\frac{1}{\bar{y}}\right)_{\bar{x}, \bar{y}}^2 \sigma_x^2 + \left(\frac{-x}{\bar{y}^2}\right)_{\bar{x}, \bar{y}}^2 \sigma_y^2}$$

thus

$$\sigma_z = \sqrt{\frac{1}{\bar{y}^2} \sigma_x^2 + \frac{\bar{x}^2}{\bar{y}^4} \sigma_y^2}$$



APPENDIX B Example of the FLUKA input file of calibration neutron monitor

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*.....1.....2.....3.....4.....5.....6.....7.....8
TITLE          The calmon 70 cm(water 65 cm)
*.....1.....2.....3.....4.....5.....6.....7.....8
GLOBAL
GEOBEGIN
                                1.0
                                COMBNAME
                                0 -10          MC-Cad Test
*.....1.....2.....3.....4.....5.....6.....7.....8
* B03
  BOX B03      8.00      0.00     -83.00      3.00      0.00      0.00
                0.00     -68.00      0.00      0.00     -0.00     -3.00
* B04
  BOX B04      8.00      0.00     -86.00      2.82      0.00      1.03
                -0.00     -3.00      0.00     11.63     -0.00     -31.95
* B05
  BOX B05      8.00     -65.00     -86.00      2.82      0.00      1.03
                -0.00     -3.00      0.00     11.63     -0.00     -31.95
* B06
  BOX B06     -11.00      0.00     -83.00      3.00      0.00      0.00
                0.00     -68.00      0.00      0.00     -0.00     -3.00
* B07
  BOX B07     -11.00      0.00     -85.00      2.82      0.00     -1.03
                0.00     -3.00      0.00     -11.63     -0.00     -31.95
* B08
  BOX B08     -11.00     -65.00     -85.00      2.82      0.00     -1.03
                0.00     -3.00      0.00     -11.63     -0.00     -31.95
* B09
  BOX B09      22.50      0.00     -118.00     -45.00      0.00      0.00
                -0.00     -68.00      0.00      0.00      0.00      3.00
* B10
  BOX B10      19.00     -3.00     -118.00     -38.00      0.00      0.00
                -0.00     -62.00      0.00      0.00      0.00      3.00
* B11
  BOX B11      19.00     -18.00     -118.00     -38.00      0.00      0.00
                -0.00     -30.00      0.00      0.00      0.00      3.00
* B12
  RPP B12     -15.30      14.70      -3.00      0.00     -115.00     -102.00
* B13
  RPP B13     -12.30      11.70      -3.00      0.00     -112.00     -105.00
* B14
  RPP B14     -15.30      14.70     -68.00     -65.00     -115.00     -102.00
* B15
  RPP B15     -12.30      11.70     -68.00     -65.00     -112.00     -105.00
* BNK001
  RPP BNK001  -122.50     122.50     -166.00      79.00     -375.02     -155.02
* BNK002
  RPP BNK002   -82.50      82.50     -126.00      39.00     -372.02     -165.02
* BNM003
  RPP BNM003  -204.51    -122.51     -166.00     -126.00     -375.02     -209.02
* BNM004
  BOX BNM004  -204.51    -166.00     -375.02      0.00     122.00      0.00
                -40.00      0.00      0.00      0.00      0.00     166.00
* Box02
  RPP Box02   -11.00      11.00      -3.00      0.00     -89.00     -83.00
* Box03
  RPP Box03   -11.00      11.00     -68.00     -65.00     -89.00     -83.00
* Cyl01
  RCC Cyl01      0.00     -3.05     -67.00      0.00     -61.40      0.00
                2.50
* Cyl02
  RCC Cyl02      0.00     -1.15     -67.00      0.00     -65.20      0.00
                2.54
* Cyl03
  RCC Cyl03      0.00      0.00     -67.00      0.00     -67.50      0.00
                3.03
* Cyl04
  RCC Cyl04      0.00      0.00     -67.00      0.00     -67.50      0.00
                5.05
* Cyl05

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RCC Cyl105	0.00 9.65	-1.10	-67.00	0.00	-65.30	0.00
* Cyl106						
RCC Cyl106	0.00 17.50	3.90	-67.00	0.00	-75.30	0.00
* Cyl107						
RCC Cyl107	0.00 9.84	-71.41	-67.00	0.00	-7.30	0.00
* Cyl108						
RCC Cyl108	0.00 8.57	-71.73	-67.00	0.00	-6.98	0.00
* Cyl109						
RCC Cyl109	0.00 9.84	-78.71	-67.00	0.00	-0.32	0.00
* Cyl110						
RCC Cyl110	19.50 5.00	-2.00	-123.00	3.00	0.00	0.00
* Cyl111						
RCC Cyl111	-22.00 5.00	-2.00	-123.00	3.00	0.00	0.00
* Cyl112						
RCC Cyl112	-22.00 5.00	-65.00	-123.00	3.00	0.00	0.00
* Cyl113						
RCC Cyl113	19.50 5.00	-65.00	-123.00	3.00	0.00	0.00
* Cyl114						
RCC Cyl114	0.00 21.00	-65.00	-67.00	0.00	-3.00	0.00
* Cyl115						
RCC Cyl115	0.00 17.50	-65.00	-67.00	0.00	-3.00	0.00
* Cyl116						
RCC Cyl116	0.00 135.00	-35.00	-152.02	0.00	0.00	70.00
* Cyl117						
RCC Cyl117	0.00 134.80	-35.00	-151.42	0.00	0.00	69.70
* Cyl118						
RCC Cyl118	0.00 134.80	-35.00	-150.42	0.00	0.00	65.00
* Cyl119						
RCC Cyl119	0.00 21.00	0.00	-67.00	0.00	-3.00	0.00
* Cyl120						
RCC Cyl120	0.00 17.50	0.00	-67.00	0.00	-3.00	0.00
* Door						
BOX Door	-82.50 -40.00	-119.00 0.00	-375.02 0.00	0.00 0.00	87.00 0.00	0.00 207.00
* Sph01						
SPH Sph01	0.00	0.00	0.00	700000.00		
* Sph02						
SPH Sph02	0.00	0.00	0.00	500000.00		
* chips						
RCC chips	0.00 8.57	-74.00	-67.00	0.00	-2.11	0.00
* col01						
BOX col01	13.00 0.00	-7.50 -15.00	-118.01 0.00	15.00 0.00	0.00 -0.00	0.00 -30.00
* col02						
BOX col02	13.00 0.00	-44.50 -15.00	-118.01 0.00	15.00 0.00	0.00 -0.00	0.00 -30.00
* col03						
BOX col03	-28.50 0.00	-44.50 -15.00	-118.01 0.00	15.00 0.00	0.00 -0.00	0.00 -30.00
* col04						
BOX col04	-28.50 0.00	-7.50 -15.00	-118.01 0.00	15.00 0.00	0.00 -0.00	0.00 -30.00
* rock						
RPP rock	-400.00	367.00	-360.00	285.00	-575.02	-375.02
* roof						
RPP roof	-180.00	185.00	-220.00	145.00	-155.02	-152.02


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* window1
  RPP win1 -122.50 -77.50 0.00 40.00 -248.02 -208.02
* window2
  RPP window2 -40.00 40.00 39.00 79.00 -248.00 -198.00
* window3
  RPP window3 -40.00 40.00 -166.00 -126.00 -248.00 -198.00
* window4
  BOX window4 122.50 -80.00 -248.00 0.00 80.00 0.00
               -40.00 0.00 0.00 0.00 0.00 50.00

END

* Reg # 1
* gas; assigned material: M34; mat # (34)
gas 5 +Cyl01
* Reg # 2
* counter; assigned material: H2O; mat # (36)
counter 5 +Cyl02 -Cyl01
* Reg # 3
* Blackhol; assigned material: Blackhole; mat # (1)
Blackhol 5 +Sph01 -Sph02
* Reg # 4
* Vacuum; assigned material: Vacuum; mat # (2)
Vacum 5 +Sph02 -Cyl06 -( +Cyl19 -Cyl20 +Box02 | +B03 | +B04 | +B05 |
      +B06 | +B07 | +B08 | +B09 -B10 | +B12 -B13 | +B14 -B15 |
      +Cyl10 | +Cyl11 | +Cyl12 | +Cyl13 | +Cyl14 -Cyl15 +Box03 | +B11 ) -(
      +Cyl07 -Cyl08 | +Cyl09 ) -col01 -col02 -col03 -col04 -( +Cyl16
      -Cyl17 ) -( +Cyl18 -col01 -col02 -col03 -col04 ) -roof -(
      +BNK001 -BNK002 -Door -win1 -window2 -window3 -window4 | +BNM003 |
+BNM004 )
      -rock -( +Cyl08 -chips )
* Reg # 5
* gap; assigned material: Nitrogen; mat # (7)
gap 5 +Cyl03 -Cyl02
* Reg # 6
* moderat; assigned material: POLY-CH2; mat # (27)
moderat 5 +Cyl04 -Cyl03
* Reg # 7
* producer; assigned material: Lead; mat # (17)
producer 5 +Cyl05 -Cyl04
* Reg # 8
* Reflect; assigned material: POLY-CH2; mat # (27)
Reflect 5 +Cyl06 -Cyl05 -Cyl04
* Reg # 9
* BASE; assigned material: SSTEEL; mat # (28)
BASE 5 +Cyl19 -Cyl20 +Box02 | +B03 | +B04 | +B05 | +B06 | +B07 | +B08 |
      +B09 -B10 | +B12 -B13 | +B14 -B15 | +Cyl10 | +Cyl11 | +Cyl12 |
      +Cyl13 | +Cyl14 -Cyl15 +Box03 | +B11
* Reg # 10
* Head; assigned material: Aluminium; mat # (10)
Head 5 +Cyl07 -Cyl08 | +Cyl09
* Reg # 11
* col01; assigned material: concrete; mat # (29)
col01 5 +col01
* Reg # 12
* col02; assigned material: concrete; mat # (29)
col02 5 +col02
* Reg # 13
* col03; assigned material: concrete; mat # (29)
col03 5 +col03
* Reg # 14
* col04; assigned material: concrete; mat # (29)
col04 5 +col04
* Reg # 15
* SWM; assigned material: IRONISOP; mat # (40)
SWM 5 +Cyl16 -Cyl17
* Reg # 16
* water; assigned material: H2O; mat # (36)
water 5 +Cyl18 -col01 -col02 -col03 -col04 -( +Cyl19 -Cyl20 +Box02 | +B03 |
+Box04 | +B05 | +B06 | +B07 | +B08 |
      +B09 -B10 | +B12 -B13 | +B14 -B15 | +Cyl10 | +Cyl11 | +Cyl12 |
      +Cyl13 | +Cyl14 -Cyl15 +Box03 | +B11)
* Reg # 17
* roof; assigned material: Wood; mat # (37)

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roof 5 +roof
* Reg # 18
* BUNKER; assigned material: concrete; mat # (29)
BUNKER 5 +BNK001 -BNK002 -Door -win1 -window2 -window3 -window4 | +BNM003 |
+BNM004
* Reg # 19
* rock; assigned material: BASALT; mat # (38)
rock 5 +rock
* Reg # 20
* chips; assigned material: POLY-CH2; mat # (27)
chips 5 +chips
* Reg # 21
* air; assigned material: Nitrogen; mat # (7)
air 5 +Cyl08 -chips

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END

GEOEND

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*...+...1...+...2...+...3...+...4...+...5...+...6...+...7...+...8
*MATERIAL      Z      A      Density      FLUKA#      ionize      isotope      ElemLAY#
*...+...1...+...2...+...3...+...4...+...5...+...6...+...7...+...8
MATERIAL      1.0      1.00794 0.0000837      3      1.0HYDROGEN
LOW-MAT      3      1.0      -3.0      296.0      HYDROGEN
MATERIAL      2.0      3.00      1.2E-4      4      3.0HELIUM-3
LOW-MAT      4      2.0      +3.0      296.0      HELIUM-3
MATERIAL      6.0      12.0107      2.0      6      CARBON
LOW-MAT      6      6.0      -2      296.0      CARBON
MATERIAL      7.0      14.0067 1.2506E-3      7      NITROGEN
LOW-MAT      7      7.0      -2.0      296.0      NITROGEN
MATERIAL      8.0      15.9994 1.429e-03      8      OXYGEN
LOW-MAT      8      8.0      16.0      296.0      OXYGEN
MATERIAL      12.0      24.305      1.740      9      MAGNESIU
LOW-MAT      9      12.0      -2.0      296.0      MAGNESIU
MATERIAL      13.0      26.982      2.70      10      ALUMINUM
LOW-MAT      10      13.0      27.0      296.0      ALUMINUM
MATERIAL      26.0      55.847      7.877      11      IRON
LOW-MAT      11      26.0      -2.0      296.0      IRON
MATERIAL      14.0      28.086      2.33      14      SILICON
LOW-MAT      14      14.0      -2.0      296.0      SILICON
MATERIAL      82.0      207.2      11.35      17      LEAD
LOW-MAT      17      82.0      -2.0      296.0      LEAD
MATERIAL      11.0      22.98977 0.971      19      SODIUM
LOW-MAT      19      11.0      +23.0      296.0      SODIUM
MATERIAL      20.0      40.08      1.550      21      CALCIUM
LOW-MAT      21      20.0      -2.0      296.0      CALCIUM
MATERIAL      28.0      58.693      8.90      25      NICKEL
LOW-MAT      25      28.0      -2.0      296.0      NICKEL
MATERIAL      6      CARBON      1.52      26      CELLOSE
COMPOUND      6      CARBON      10      HYDROGEN      5      OXYGENCELLOSE
MATERIAL      0.94      27      POLY-CH2
COMPOUND      2.0      HYDROGEN      1.0      CARBON      POLY-CH2
MATERIAL      7.9      28      SSTEEL
COMPOUND      -0.69      IRON      -0.01      CARBON      -0.20      CHROMIUMSSTEEL
COMPOUND      -0.10      NICKEL      0.0      0.0      0.0      0.0SSTEEL
MATERIAL      1.457      29      HCELLOSE
COMPOUND      5      CARBON      12      HYDROGEN      5      OXYGENHCELLOSE
MATERIAL      1.366      30      LIGNIN
COMPOUND      9      CARBON      10      HYDROGEN      2      OXYGENLIGNIN
MATERIAL      1.8421E-3      31      CO2
COMPOUND      1.0      CARBON      2.0      OXYGEN      CO2
MATERIAL      24.0      51.996      7.18      32      CHROMIUM
LOW-MAT      32      24.0      -2.0      296.0      CHROMIUM
MATERIAL      19.0      39.098      0.862      33      POTASSIU
LOW-MAT      39      19.      -2      296.0      POTASSIU
MATERIAL      7.5259E-4      34      HE97CO23
COMPOUND      -0.97      HELIUM-3      -0.03      CO2      HE97CO23
MATERIAL      0.0      0.0      2.35      35      CONCRETE
COMPOUND      -0.01      HYDROGEN      -0.001      CARBON      -0.529107      OXYGENCONCRETE
COMPOUND      -0.016      SODIUM      -0.002      MAGNESIU      -0.033872      ALUMINUMCONCRETE
COMPOUND      -0.337021      SILICON      -0.013      POTASSIU      -0.044      CALCIUMCONCRETE
COMPOUND      -0.014      IRON      CONCRETE
MATERIAL      1.0      36      H2O
COMPOUND      2.0      HYDROGEN      1.0      OXYGEN      H2O
MATERIAL      0.0      0.0      0.72      37      WOOD
COMPOUND      -50.00      CELLOSE      -25.00      HCELLOSE      -25.00      LIGNINWOOD

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*-----
MATERIAL          0.0      0.0      3.00      38      0.0      0. BASALT
COMPOUND        -0.0900      IRON    -0.0700  ALUMINUM  -0.0600  MAGNESIUBASALT
COMPOUND        -0.2400     SILICON  -0.0700   CALCIUM  -0.4700   OXYGENBASALT
*-----
MATERIAL          0.681      39
COMPOUND          8.0  HYDROGEN      5.0      CARBON
MATERIAL          4.2755      40
COMPOUND        -50.00  ISOPRENE    -50.00      IRON
MAT-PROP         0.973      260.0    296.0      3.0      40.0      0. LOWNTEMP
*...+...1...+...2...+...3...+...4...+...5...+...6...+...7...+...8
ASSIGNMAT  HE97CO23      gas
ASSIGNMAT    SSTEEL    counter
ASSIGNMAT  BLCKHOLE  Blackhol
ASSIGNMAT   VACUUM    Vacuum
ASSIGNMAT  NITROGEN      gap
ASSIGNMAT  POLY-CH2    moderat
ASSIGNMAT    LEAD    producer
ASSIGNMAT  POLY-CH2    Reflect
ASSIGNMAT    SSTEEL      BASE
ASSIGNMAT  ALUMINUM    Head
ASSIGNMAT  CONCRETE    col01
ASSIGNMAT  CONCRETE    col02
ASSIGNMAT  CONCRETE    col03
ASSIGNMAT  CONCRETE    col04
ASSIGNMAT  IRONISOP      SWM
ASSIGNMAT    H2O      water
ASSIGNMAT    WOOD      roof
ASSIGNMAT  CONCRETE    BUNKER
ASSIGNMAT  BASALT      rock
ASSIGNMAT  POLY-CH2    chips
ASSIGNMAT  NITROGEN      air
*...+...1...+...2...+...3...+...4...+...5...+...6...+...7...+...8
DEFAULTS
DELTARAY          0.0001      80      1.04      3.0      40.0      1.0NOPRINT
IONFLUCT          0.0      0.0      1.0      3.0      40.0      1.0
EMFFLUO           0
PHOTONUC        1111.0      0.0      0.0      3.0      40.0      1.0
MUPHOTON         1.0      0.0      0.0      3.0      40.0      1.0
PAIRBREM         3.0      0.0      0.0012      3.0      40.0      1.0
EMFCUT          -0.001      0.0001      0.0      1.0      20.0
*BEAM            -1.E-01      0.0      0.0      400.0      400.0      1.0NEUTRON
*BEAMPOS          0.0      -38.0      500.0
BEAM             800.
SOURCE
*
*...+...1...+...2...+...3...+...4...+...5...+...6...+...7...+...8
USERDUMP          100      49      7.0      1.0
RANDOMIZE          1.0
START            10000000.0
STOP

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