CONRAD P-3

TRIPOLI-4 solution for SIGMA graphite moderated Am-Be neutron field

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CONRAD-P3

/. Introduction – SIGMA facility

/. TRIPOLI-4 simulation – Φ(E), H*(10) and Hp(10)

/. Calculation results

/. Conclusions

/. Graphite facility SIGMA was set up at IRSN to provide a thermal neutron field for metrology and dosimetry purposes.

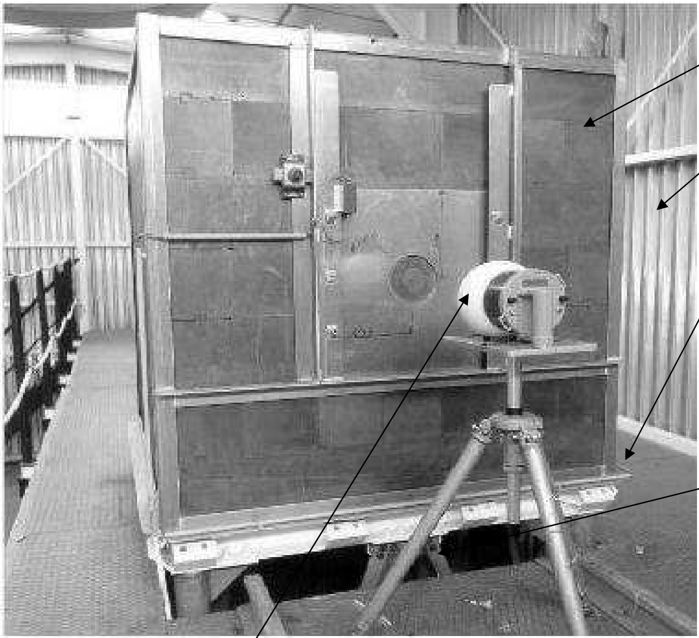
/. Six Am-Be sources were introduced into the graphite block.

/. To minimize the neutron background:

- Exp. hall: 12 m x 6 m x 4.5 m (high).
- Al wall: 2 x 0.25 cm thick.
- Graphite block: 2 m above the 20 cm thick concrete floor.
- Steel platform: 0.6 cm thick around the block.

/. A ref. position is defined at 50 cm from the graphite block.

CONRAD P-3 SIGMA graphite facility



/. At the ref. point, we calculate

- the neutron fluence rate,
- the neutron energy distribution and
- the ambient dose equivalent rate H*(10) with ICRP-74

in an ICRU sphere of 30 cm diameter.

/. Uncertainty calculation

- the wall and floor contribution (cf a bare graphite block model),
- the graphite density (perturbation run) and
- the Am-Be source density influence (two indep. runs).

TRIPOLI-4 simulation - Hp(10)

/. The "phantom present method" was applied to calculate the Hp(10, 0°) and Hp(10, 45°) at the ref. point.

/. A slab phantom (15 x 30 x 30 cm^3) of ICRU tissue.

/. A tally slice (0.01 x 10 x 10 cm^3) at 10 mm below the ref. point.

/. Coupled neutron and photon transport calculation was carried out to consider the photons generated inside the slab phantom.

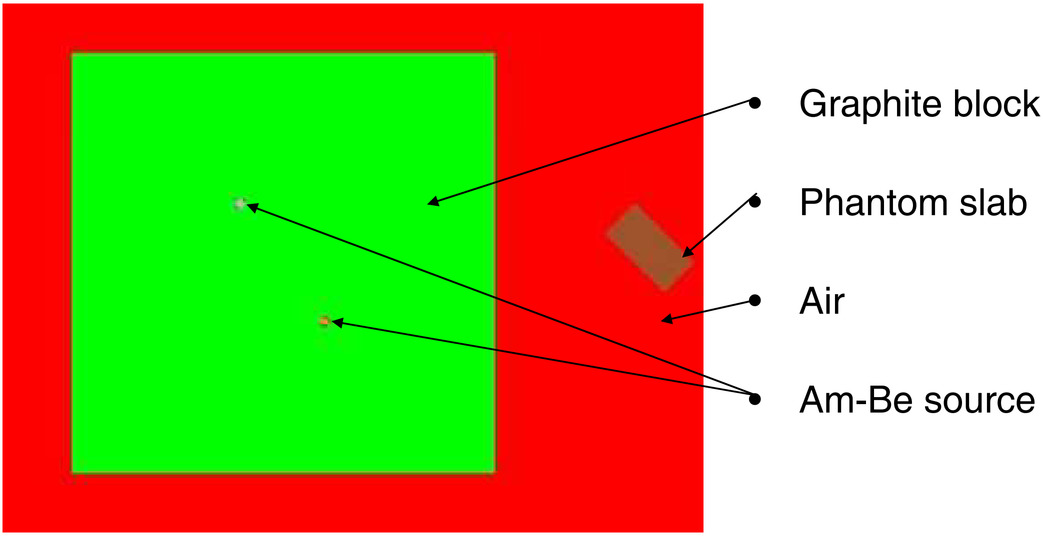


Fig 2. TRIPOLI-4 modelling - (X-Y view) for Hp(10, 45°) calculation.

TRIPOLI-4 Monte Carlo code

- Developed at CEA/Saclay, France.
- Used in radiation shielding, criticality safety, reactor physics and nuclear instrumentation.
- For neutron, photon and coupled n and γ simulation.
- **TRIPOLI-4.3 available from OECD/NEA databank** **http://www.nea.fr/abs/html/nea-1716.html**

Free training course – Apr. /2008

/. **GEOMETRY** (GRAF) **FING**

volume => pre-defined shapes

/. **COMPOSITION et GEOMCOMP**

=> pointer by volume no.

/. **SOURCE** (r, Ω, E, t)

=> intersection with source volumes

/. **SCORE** **(LIST_DECOUPAGE, REPONSES)**

=> **Volume** and surface for local results

/. **SIMULATION**

(Variance reduction, Perturbation…)

TRIPOLI-4 I/P Conrad-P3 **Geometry - 1**

TYPE 400	BOITE	1301.	901.	600.	/* Air */
TYPE 401	BOITE	1200.	303.	0.6	/* Platform - Steel */
TYPE 402	BOITE	150.	150.	0.6	/* hole in Platform */
TYPE 403	BOITE	0.5	600.	400.	/* west wall - Al */
TYPE 404	BOITE	1200.	0.5	400.	/* south wall - Al */
TYPE 405	BOITE	1200.	600.	20.	/* floor - concrete */
TYPE 501	BOITE	150.	150.	150.	/* Graphite block */

VOLU 400	COMB 400	0	0	0			FINV
VOLU 401	COMB 401	-40	0	-95.3	ECRA 1	400	FINV
VOLU 402	COMB 402	0	0	-95.3	ECRA 1	401	FINV
VOLU 403	COMB 403	560.25	-148.5	-95.0	ECRA 1	400	FINV
VOLU 404	COMB 404	-40.	151.75	-95.0	ECRA 1	400	FINV
VOLU 405	COMB 405	-40.	-148.5	-285.0	ECRA 1	400	FINV
VOLU 501	COMB 501	0	0	0	ECRA 1	400	FINV

```
TYPE 602  CYLZ    1.46425  3.2962      /* AmBe source  */

VOLU 601 COMB 601  -15 -10.5  18.2    ECRA 1 501 FINV
VOLU 602 COMB 602  -15 -10.5  18.2    ECRA 1 601 FINV
 .........

TYPE 802  BOITE  15.      30.    30.          /* ICRU slab phantom */
TYPE 803  BOITE    0.01  10.    10.           /* Tally slice in phantom */

VOLU 8020 COMB 802  132.5   0   0   FICTIF   FINV  /* phantom */
VOLU 8030 COMB 803  126.    0   0   FICTIF   FINV  /* Tally slice */

VOLU 802  ROTATION VOLU 8020      0 0 1
                    45                   125 0  0 ECRA 1 400 FINV
VOLU 803  ROTATION VOLU 8030 0 0 1
                    45                   125 0  0 ECRA 1 802 FINV


//   GRAF -100 -100  0.    1 0 0   0 1 0    250 250    1
```


TRIPOLI-4 I/P Conrad-P3 Composition - Geom

```
COMPOSITION  7
 DENSITY 300 AMBE        1.12
   3      AM241           0.08       BE9        0.909      O16     0.001

 DENSITY 300 GRAPHITE 1.70
   1      C_GRAPHITE  1.0

    ............................

GEOMCOMP
    GRAPHIT        1    501
    ALU            2                          403  404
    CONCRETE       1                          405
    STEEL          7    601 603 605 607 609 611      401
    AMBE           6    602 604 606 608 610 612

    ............................
```

```
LIST_SOURCE   6          NORME  1.9071e8              (neutron /sec)
   SOURCE COEFF 0.1591 NEUTRON   FACTORIZED
               FRAME        CARTESIAN
                            0. 0. 0.   1. 0. 0.   0. 1. 0.  0. 0. 1.
   VOLU  1         602
   GEOMETRIC_DISTRIBUTION    TABULATED
    TYPE F_UVW
    VAR_U X  2  -16.6  -13.4  VAR_V Y  2  -12.1  -8.9  VAR_W Z  2   14.9   21.5
    F_UVW    1
   ANGULAR_DISTRIBUTION   ISOTROPIC
   ENERGETIC_DISTRIBUTION SPECTRE  INTERPOLATED
           53  1      IN_NO_INTERPOLATION 52
                      4.14E-7 1.3091E-1                  (E-Mev  Intensity)
                      0.11      1.5182E-1
                      ........
                      10.82     1.7286E-3
   TIME_DISTRIBUTION DIRAC 0
   FIN_SOURCE
..................
```


TRIPOLI-4 I/P Conrad-P3 Score - Simulation

```
SCORE  6
    1 TRACK DECOUPAGE DEC_P3    VOLU LIST   1 803    (Fluence)
    2 TRACK DECOUPAGE DEC_P3    VOLU LIST   1 803    (Hp(10))
    ..........
    4 TRACK DECOUPAGE DEC_GAMA  VOLU LIST  1 803 (ICRP74)
    4 SURF  DECOUPAGE DEC_GAMA  FRONTIER  LIST  1  400 802
FIN_SCORE

SIMULATION
    BATCH 4000   SIZE 100000  EDITION 50
    PARTICULES 2 NEUTRON PHOTON
    PHOTON_NEUTRON_RATIO 10                  (Variance reduction)
FIN_SIMULATION
```

```
LIST_PERTURBATION  6
    PERTURBATION  DENSITY   1   GRAPHITE          (ρ=1.70 g cm3)
    VOL  LIST  1   501   FACT    1.0294           (ρ=1.75 g cm3)
    SCORE  LIST 1  1    MODE  DELTA    FIN_PERT   (Δ fluence rate)

    .......
FIN_LIST_PERT
```


Run TRIPOLI-4 in parallel mode

/. Execution :

*/home/…/bin/**linux**-intel/static_tripoli4-4.3* **(code)**

*-d **conrad-P3*** **(I/P)**

-s NJOY

-c /home/…/Env-4.4/t4path.endfb6 **(Library)**

-o conrad-P3.res **(O/P)**

*-p **fpara*** **(cpu list)**

-t bsd

// File ipara

PROCESS 4

process **monitor** ***tripoli4.3*** *cpu1*

process **collect** ***tripoli4.3*** *cpu1*

process task1 ***tripoli4.3*** *cpu1*

process task2 ***tripoli4.3*** *cpu2*

....

GRAPH

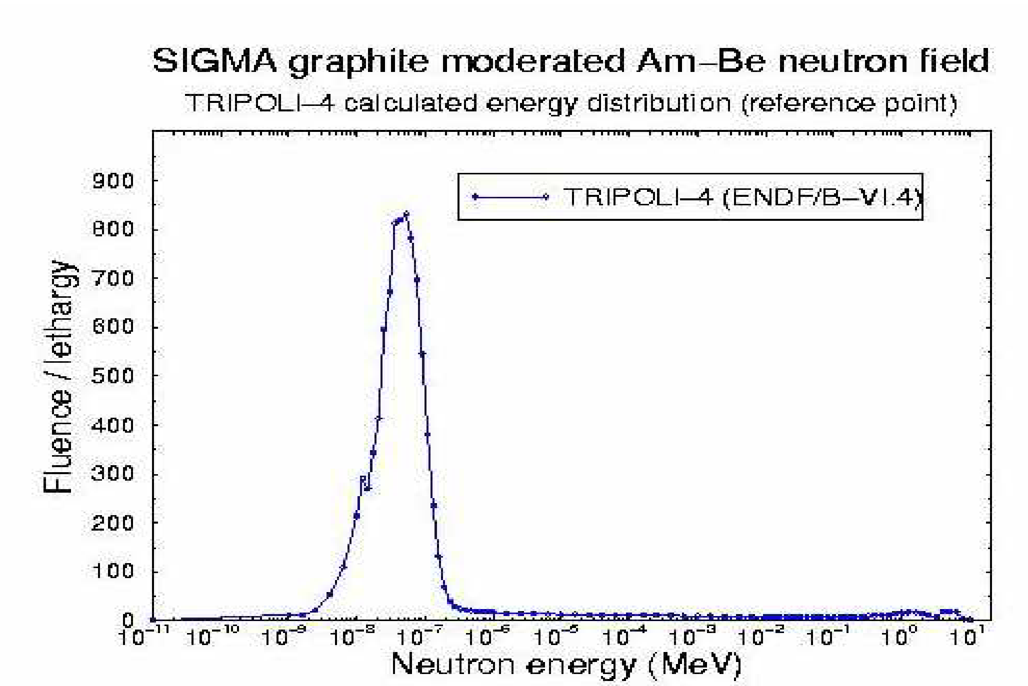
collect <-> tach1

collect <-> tach2

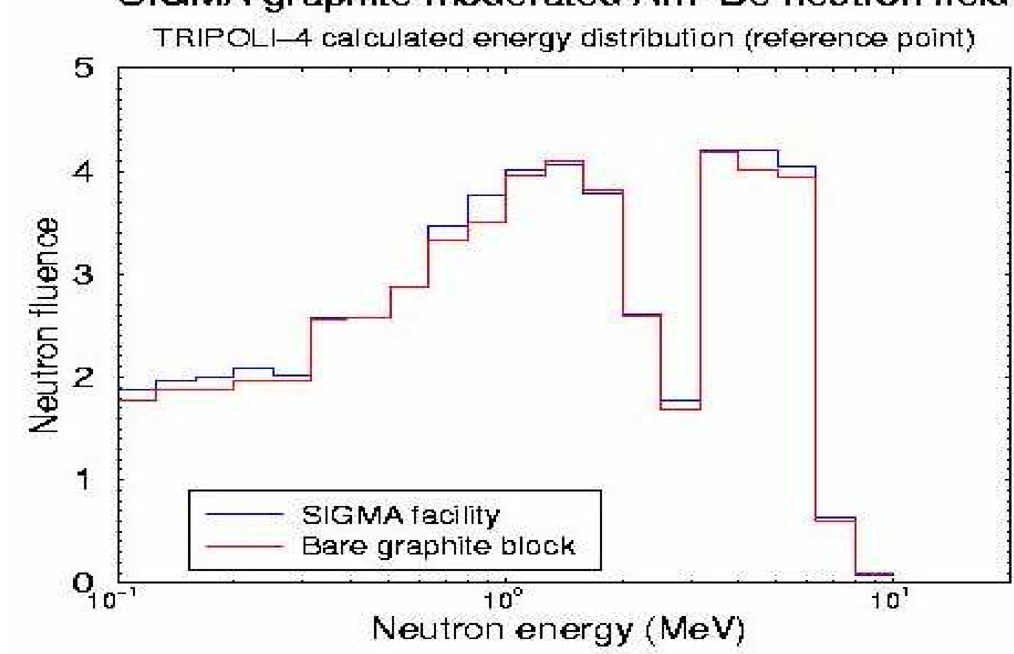
....

FIN

TRIPOLI-4 calculation results - 1



Thermal neutrons contribute 89 % in $\Phi(E)$ and



Fast neutron component from Am-Be (α,n) sources.

TRIPOLI-4 calculation results - 3

Am-Be density (1.120 g cm-3)

	TRIPOLI-4	TRIPOLI-4 / MCNP5*
Φ(E) (cm-2 s-1)	1813.2 +/- 1.6	1.010 +/ - 0.003
H*(10) (mSv/h)	146.8 +/- 1.2	1.001 +/ - 0.008
All Scatter (cm-2 s-1)	76.5 +/- 2.1	?

Am-Be density (0.207 g cm-3)		MCNP5*
Φ(E) (cm-2 s-1)	1788.0 +/- 1.5	
Density effect**	0.986 +/- 0.001	0.982 +/ - 0.006

* Results from: R. Tanner

Reference point 50 cm from the graphite block	TRIPOLI-4 results	
Fluence rate (n cm^{-2} s^{-1}) Reference graphite ρ = 1.70 g cm^{-3}	1813.2 +/- 1.6	
Perturbation calculation	Δ fluence rate	Fluence rate change in %
ρ increases to 1.75 g cm^{-3}	-31.2 +/- 0.8	-1.7 %
to 1.73 g cm^{-3}	-18.3 +/- 0.4	-1.0 %
to 1.71 g cm^{-3}	-6.02 +/- 0.1	-0.3 %
ρ decreases to 1.69 g cm^{-3}	+5.96 +/- 0.1	+0.3 %
to 1.67 g cm^{-3}	+17.7 +/- 0.4	+1.0 %
to 1.65 g cm^{-3}	+29.4 +/- 0.8	+1.6 %

Hp(10, 0°) calculation results

Centre of tally slice was placed in the ICRU phantom slab. It was at 10 mm below the reference point and 50.1 cm from the graphite block.	TRIPOLI-4 results	Remark
Hp(10, 0°) rate (µSv/h)		
(1.1) Neutron contribution	123.99 +/- 2.02	
(1.2) Total secondary γ-ray contribution	16.30 +/- 0.24	
(1.3) γ-ray from background scatter	7.56 +/- 0.04	
(1.4) γ-ray from slab phantom	8.74 +/- 0.24	(1.2) – (1.3)
Hp(10, 0°) = (1.1) + (1.4)	132.7 +/- 2.0	Ref. R. Tanner
Total dose equivalent rate [illegible]	[illegible]	

Centre of tally slice was placed in the ICRU phantom slab. It was at 10 mm below the reference point and 50.1 cm from the graphite block.	TRIPOLI-4 results	Remark
Hp(10, 45°) rate (μSv/h)		
(2.1) Neutron contribution	97.74 +/- 2.08	
(2.2) Total secondary γ-ray contribution	12.63 +/- 0.18	
(2.3) γ-ray from background scatter	7.35 +/- 0.04	
(2.4) γ-ray from slab phantom	5.28 +/- 0.18	(2.2) – (2.3)
Hp(10, 45°) = (2.1) + (2.4)	103.0 +/- 2.1	Ref. R. Tanner
Total dose equivalent rate received by tally slice from six Am-Be neutron sources = (2.1) + (2.2)	110.4 +/- 2.1	

Conclusions

/. TRIPOLI-4 Monte Carlo code is a useful simulation tool to analyse the neutron field of SIGMA graphite facility and the dosimetry quantities for radiation protection application.

/. It is important to obtain the converged results in P-3 simulation both on thermal neutrons and on fast neutrons.

/. Number of thermal collisions per neutron history is high (~ 450) and the dose from fast neutrons is important for P-3 calculation,

=>

The 64-bit TRIPOLI-4 parallel computation becomes interesting to decrease the simulation uncertainty and the simulation time.

/. More study on Hp(10) calculation is necessary.