# GRUCON-2019: Calculation of Neutron Group Transition, Fission and Photon Production Matrices

**Tasks of work:**

1. To provide for the calculation of group transitions and photon production matrices,
2. To provide for the generation of vector and matrices in the GENDF and MATXS formats.


**Abstract**

A new module of the GRUCON code package, the SXAEXFM one, has been developed for the group neutron transitions and photon production matrices calculations with usage of the ENDF MF1, MF4, MF5, MF6, MF12, MF13, MF14, and MF15 data files, that contain yields and energy-angular distributions of neutrons and photons, produced in the neutron interactions. This module integrates functions of AEXXD and SXDXM modules with restricted possibilities, included to early versions of the package. Together with SXGXF (cross section moments, needed for resonance shielded cross sections and subgroup parameters calculations), SXGXFM (group photon cross sections and transition matrices calculation), and the THXXDS/DXEXD/SXDXM module chain (thermal scattering data processing), the AEXSXFM module provides complete set of data, needed for neutron-photon transfer calculations in usual nuclear reactor shielding applications.

To provide conversion of *F* and *M* internal data structures, used in GRUCON system as group vector and matrices containers, to the GENDF (for connection with NJOY processing system) and MATXS data formats (used by the TRANSX code, assigned to transport tables production for discrete-ordinates ($S_N$) and diffusion transport codes), two modules- convertors with corresponding names, namely, GENDF and MATXS, have been included to the package. The first one has been revised with aim to extend output options, the second module is a new one.

The report contains description of the new functionality of the GRUCON package, input data structures and calculation procedures for group data libraries preparation, some calculation results, demonstrating the new modules operability.


## 1. The SXAEXFM Module.

The SXAEXFM module prepares neutron group transition and photo-production matrices by integration of double-differential cross sections, reconstructed from pointwise cross sections and energy-angular distribution parameters. Data, needed to perform calculation, include:
1). The *S* structures with pointwise cross sections in all energy range in form, and *F* structures with pointwise cross section moments $< \sigma_x/(\sigma+ \sigma_o)^n >$ with n=0,1,2, obtained from the unresolved resonance parameters (if they exist) for required set of temperatures; data should be prepared by preprocessing modules, dedicated to reconstruction linearized pointwise cross sections from combination of cross section tables and parameters of resolved and unresolved resonances for required temperatures (*RXTXS, *SXIXS, *SXCXS, SXTXS, *UXDXF and *FXCXF modules),

2). The *A*, *E*, *AE*, *NU* structures for neutrons, and *AE*, *GP* and *GS* structures for photons, with energy-angular distribution parameters and yields; needed structures can be extracted directly from the ENDF file by the *ENDF module without preliminary preprocessing.

The functionality and calculation algorithms of the SXAEXFM module are very similar to the GROUPR module of NJOY, so, to simplify debugging, the architecture of the module SXAEXFM, namely, computational scheme, functional content, including the names of basic calculation subroutines, repeats the architecture of the GROUPR module. The difference is in content, because approach, implemented in the GRUCON for data storage and data access, is absolutely different. The system access functions allow to get necessary data without decoding the ENDF data records. It allows to use rigorous order of calculation, namely, to prepare feed function (reconstruct for parameters or interpolate initial tables) in tabulated form at the current energy point, to perform integration on secondary energies, to perform primary energies integration with cross section and weight function. The GETSED subroutine of GROUPR, for example, violates this order - interpolation is carried out after secondary energies integration on groups.

So, calculation scheme, implemented in the GETSED subroutine of SXAEXFM module, provides correct processing of two-dimensional tables by Method of Corresponding Energies (MCE), allowing to avoid non-physical results. Two-dimensional interpolation is performed by TERPY2 subroutine by method, described in the ENDF Manual [1], with arbitrary number of equal integral bins N (in current version N=100).

The resonance self-shielding of elastic scattering can be taken into account through temperature and dilution cross section parameters (similar to GROUPR).

The list control parameters of module is given in the Appendix A. Optionally, low part of energy distribution can be extended as sqrt(E) (ismooth = 1).

## 2. The GENDF and MATXS Modules.

The GENDF module, dedicated to read/write data in the GENDF format (internal files of NJOY), has been extended to include possibility to read/write photo-production and photo-atomic interaction vectors and matrices. Two types of data structures, *F* (cross section moments) and *M* (matrices), can be prepared/converted from/to GENDF file in binary or binary mode (see Appendix B).

The MATXS module is a new one, designed for converting of *F* and *M* structures to format of the same name. Presently only output option with formatted mode is implemented, but there exists a utility code, named BBC [3], that can be used to covert the MATXS files back and forth between BCD (i.e., formatted) and binary modes and to prepare library for TRANSX code [3]. Thus, the MATXS (similar to

MATXSR module of NJOY), opens possibility to generate working libraries through TRANSX for nuclear transport code, such as DANTSYS etc.

## 3. Verification procedure.

A number of materials from the ENDF/B-VIII.0 library has been processed by GRUCON and NJOY codes with aim to compare calculation results and verify the SXAEXFM module. The group vectors and matrices have been prepared in the N199/G42/P7 group structure (VITAMIN-B6) for neutron, thermal scattering (free gas) and photo-interaction cross sections in the GENDF и MATXS files. For easy comparison of intermediate results, the calculations through GRUCON were performed in 12 steps (tasks):

task01: reading ENDF material with linearization and correction options
task02: reconstruction cross sections in the required energy range
task03: Doppler broadening
task04: preparing particle production cross sections
task05: reconstruction cross section moments in the UR range
task06: preparing subgroup parameters from moments
task07: preparing unshielded group cross sections
task08: preparing shielded group cross sections
task09: preparing group transition and photo-production matrices
task10: preparing thermal scattering cross sections in free gas model
task11: preparing photo-atomic group cross sections and transition matrices
task12: converting to the GENDF and MATXS formats

Visual comparison has been performed by PLOTTAB code [4]. In Figures 1-6 are shown typical results with acceptable agreement, obtained for the Fe-56 material from ENDF/B-VIII.0 library. Groups are numerated in the energy descending order. However, there are cases, when disagreement is large enough. For example, in the low energy part of transition cross sections of neutrons from (n,2n) reaction, difference reaches value ~ 20% (see Fig.7).

The input decks for each task are given in the Appendix B.

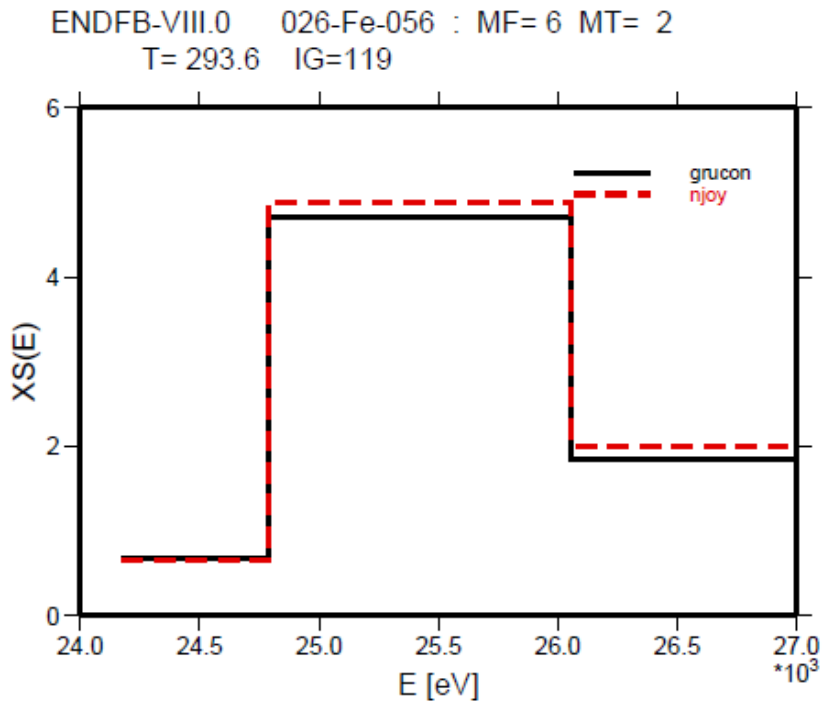


Fig.1 Fe-56: Group transitions due to elastic scattering in group 119.

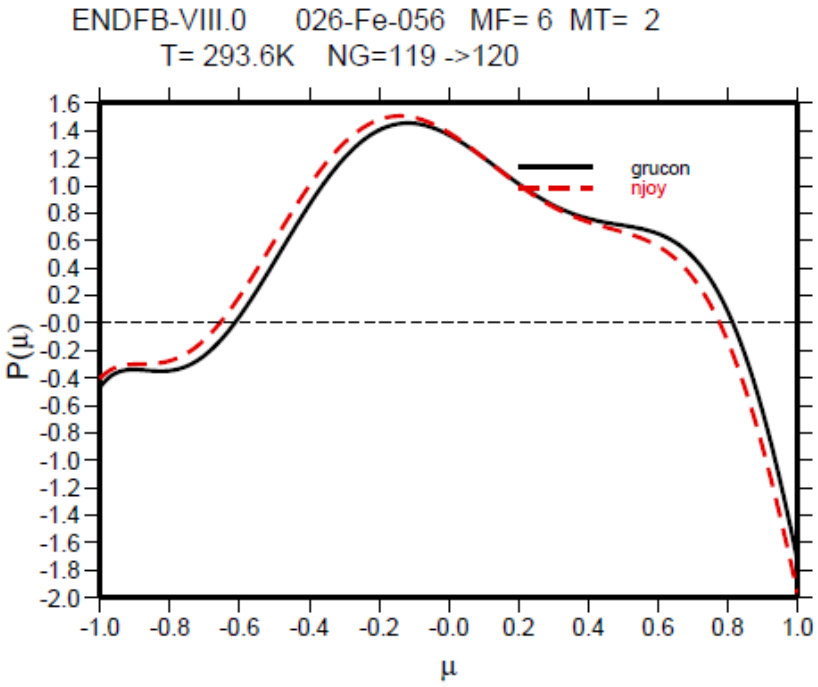


Fig.2 Fe-56: Angular distribution of elastic scattered neutron
for group transition 119 => 120

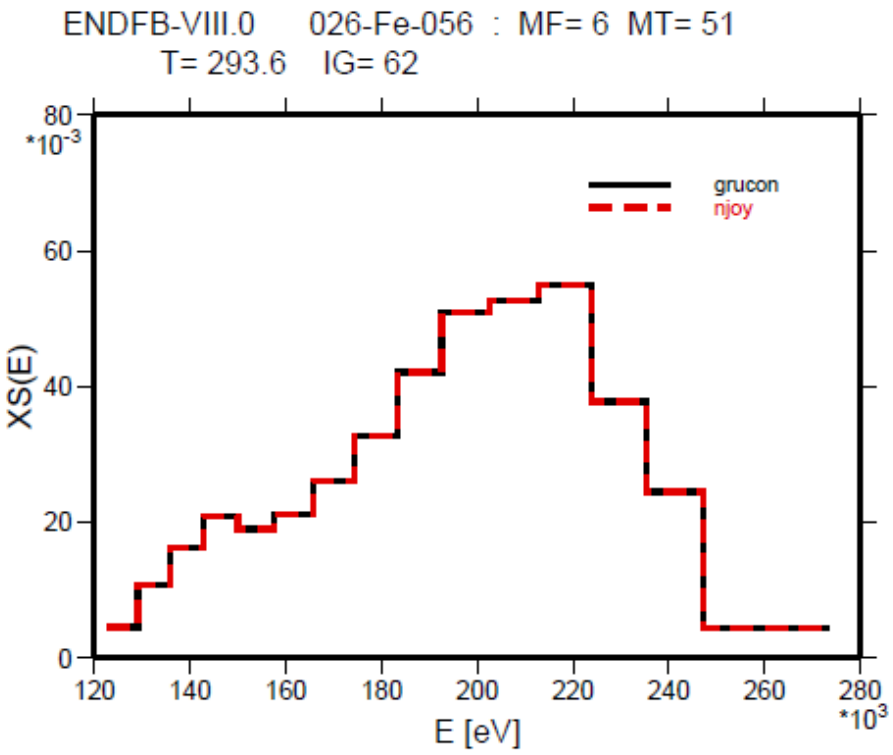


Fig.3 Fe-56: Transition cross section vector for group 62 of neutrons in $(n,n_1)$ inelastic scattering reaction

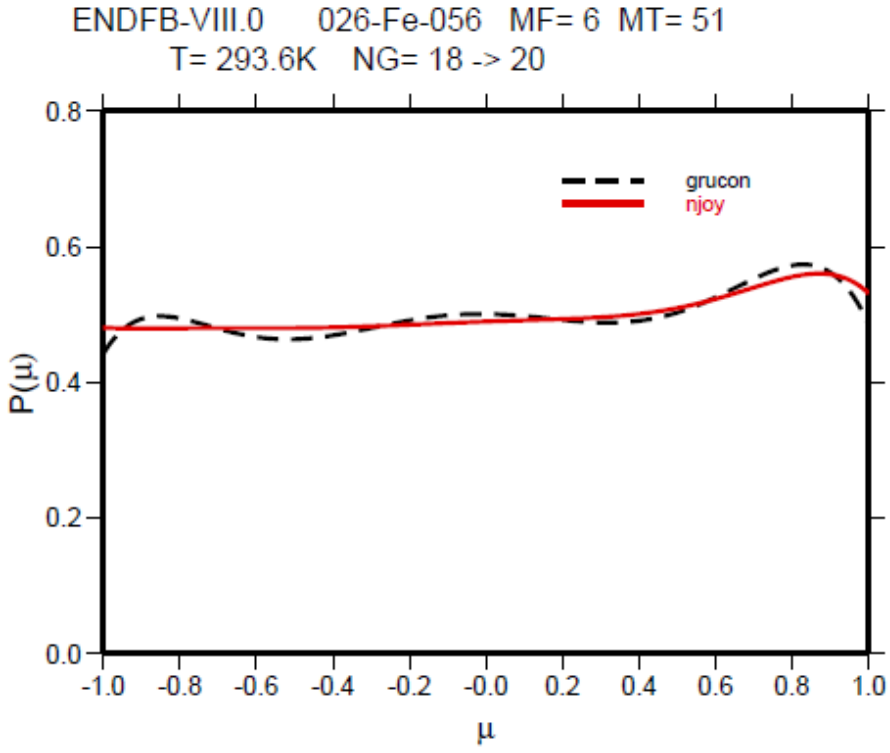


Fig.4 Fe-56: Angular distribution of $(n,n_1)$ inelastic scattered neutrons for group transition 18 => 20

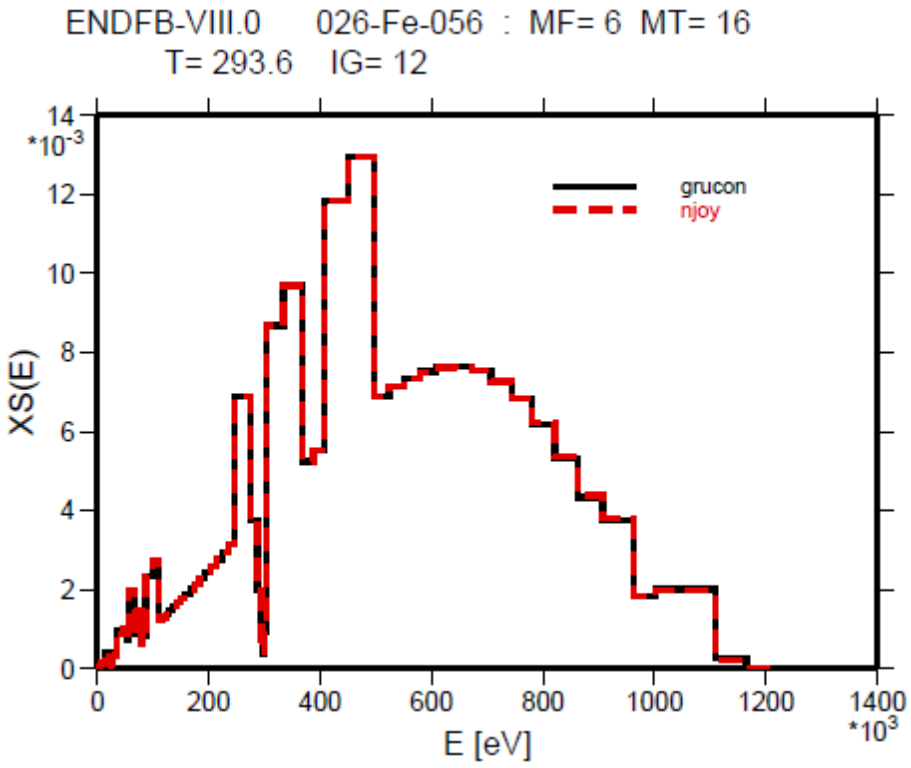


Fig.5 Fe-56: Group transitions of neutrons in (n,2n) reaction for group 12

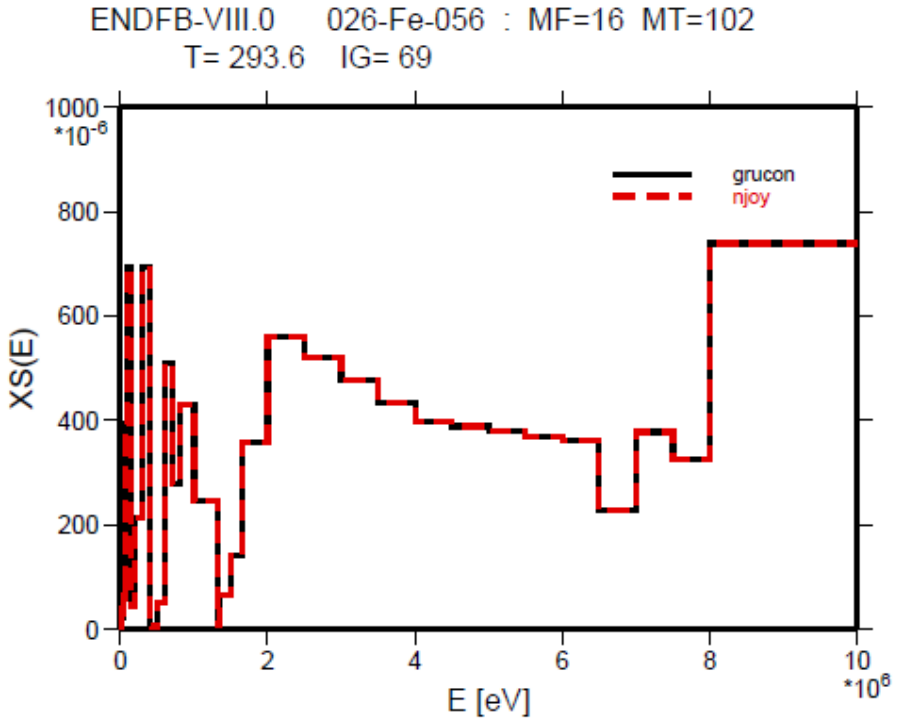


Fig.6 Fe-56: Photo-production in (n, γ) reaction for group 69

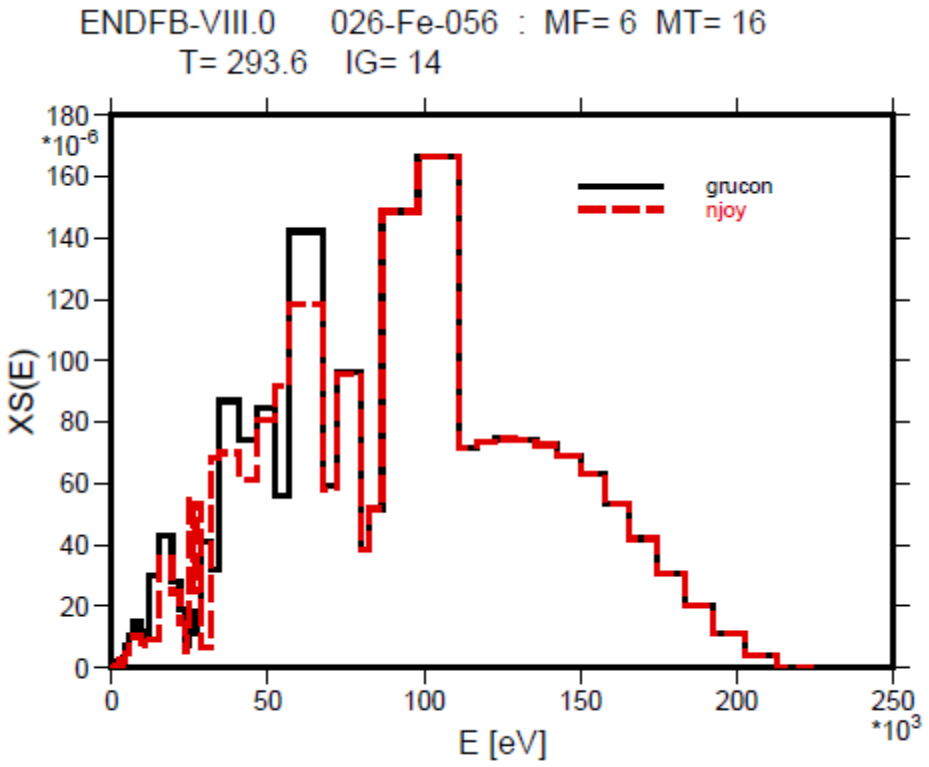


Fig.7 Fe-56: Group transition cross section of neutrons in (n,2n) reaction for group 14

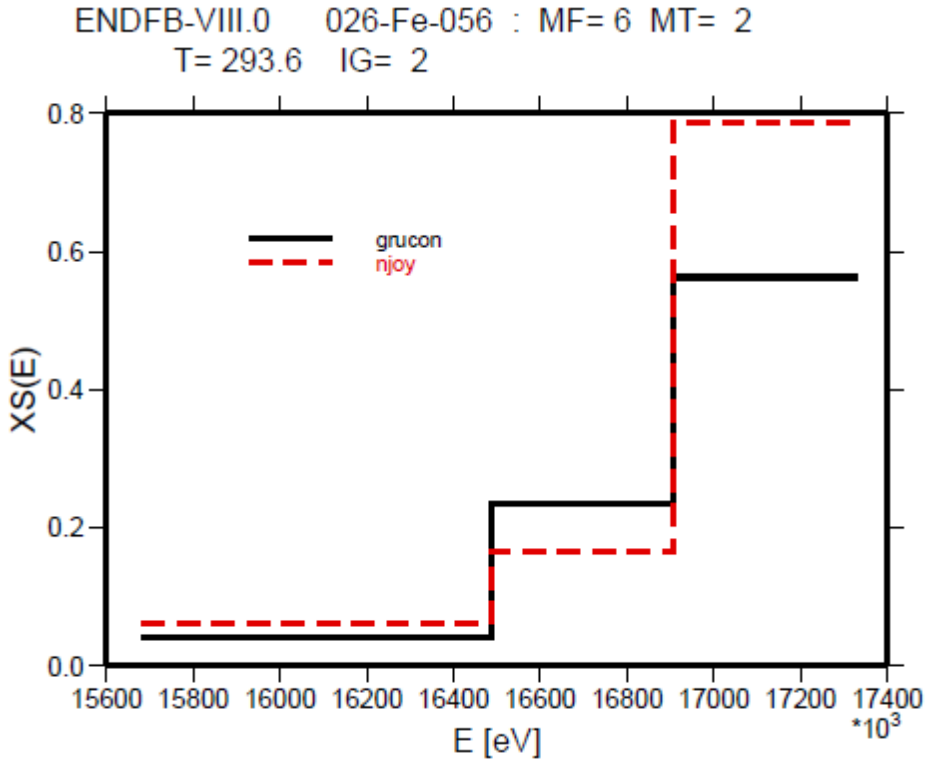


Fig.8 Fe-56: Group transition cross section of elastic scattered neutrons for group 2

## 4. Integral Testing.

To check operability of the new modules, two MATXS twin's library have been prepared by NJOY and GRUCON processing systems, and neutron and gamma leakage spectra from iron sphere R=30cm with Cf252 source (ALARM-CF-FE-SHIELD-001 [5]) have been calculated through TRANSX/ONEDANT codes. The results are shown in Figures 9,10.

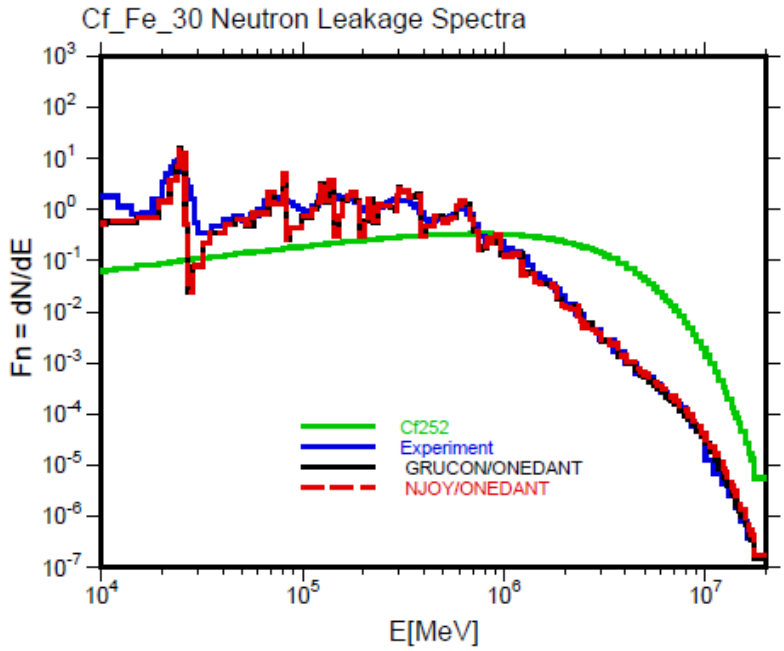


Fig.9 Comparison of neutron leakage spectra from iron sphere with source Cf-252

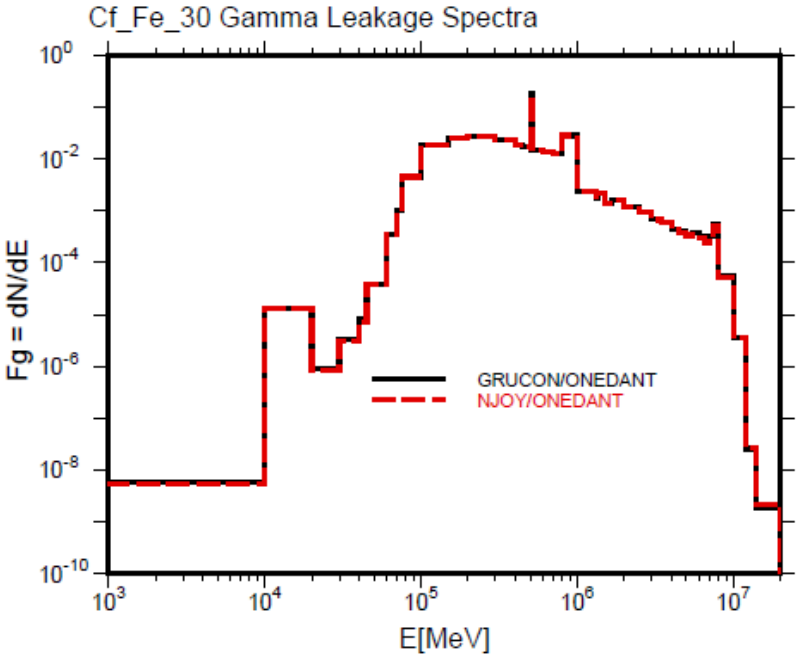


Fig.10 Comparison of gamma leakage spectra from iron sphere with source Cf-252

## Conclusion

Two new modules, SXAEXFM and MATXS, have been developed for GRUCON package with aim to supply group data for neutron-photon transport calculations and to generate working libraries for deterministic codes. In spite of their operability, inter-comparison results, obtained through NJOY and GRUCON processing codes, revealed in some cases essential disagreement between GRUCON/SXAXFM and NJOY/GROUPR modules, connected, probably, with difference in in integration and interpolation algorithms. The study of reasons, responsible for obtained differences in calculation results, should be continued.

## Acknowledgments

I am grateful A.Trkov for posing the problem and supporting this work.

## References

1. Cross Section Evaluation Working Group, "**ENDF-6 Formats Manual, Data Formats and Procedures for the Evaluated Nuclear Data File ENDF/B-VI, ENDF/B-VII and ENDF/B-VIII**", BNL-2032018-2018-INRE, Brookhaven National Laboratory, edited by A. Trkov, M.W. Herman and D.A. Brown with contributions from N. Holden and G. Hedstrom (February 1, 2018)
2. A. Kahler, J.L. Conlin, A.P. McCartney, **NJOY2016**
   Los Alamos National Laboratory, Los Alamos, NM, USA,
   [Online] Available at https://njoy.github.io/NJOY2016/
3. R.E.MacFarlane, **TRANSX-2**: A code for Interfacing MATXS cross-Section Libraries to Nuclear Transport Codes. https://t2.lanl.gov/nis/codes/transx-hyper/TRANSX.html
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   [Online] Available at https://www-nds.iaea.org/plottab/
5. **International Handbook of Evaluated Criticality Safety Benchmark Experiments**, NEA/NSC/DOC(95)/03/VIII, Volume VIII, OECD NEA, Paris, France (2018)

**Appendix A. Control Parameters of Modules**

| **SXAEXFM: Calculation of Neutron Transition and Photon Production Group Matrices** | |
|---|---|
| **ZAP** | Z*1000+A charge and mass parameter of reaction product |
| **NMT** | Number of reaction ( 0 means “all reactions from the input data cluster”) |
| **NEGI** | Number of energy groups for incident particle |
| **NEGO** | Number of energy groups for secondary particle |
| **NIG** | Number of group sub-intervals |
| **IWF** | Weigthing function flag:<br>=1 read in smooth weight function<br>=2 constant<br>=3 1/e<br>=4 thermal (Maxwell) +1/e + fission (Watt) spectrum<br>=5 epri-cell lwr<br>=6 thermal (Maxwell) + 1/e + fission(Watt) + fusion<br>=7 same with temperature dependent thermal part<br>=8 thermal + 1/e + fast reactor + fission + fusion |
| **NTEM** | Number of temperatures |
| **NSIGZ** | Number of dilution cross sections |
| **LAN** | Flag of angular distribution representation ( 2 – Legendre polynomial coefficients) |
| **NORD** | Number of angular distribution parameters |
| **ISMOOTH** | Flag, used to control the extending of low-energy distribution part<br>= 0 – distribution should be used as is,<br>= 1 – perform extension |
| **MT(NMT)** | List of reaction types ( if NMT > 0) |
| **MIG(NIG)** | Serial number of the lower group in group sub-interval, |
| **MING(NIG)** | Scale used for sub-dividing group interval on multi-groups:<br>=1 – linear,<br>=2 – logarithmic |
| **MNG(NIG)** | Number of multi-groups in group for each sub-interval |
| **EPS** | Tolerance parameter |
| **TEM(NTEM)** | Temperature values ($^{o}$K) |
| **SIGZ(NSIGZ)** | Dilution cross section values (barns) |
| **WF(NWF)** | Weight function parameters |
| **EGI(NEGI+1)** | Group breaks for incident particle |
| **EGO(NEGO+1)** | Group breaks for secondary particle (if NEG > 0) |

| ***GENDF: Converting the *F* and *M* structures to the GENDF format** | |
|---|---|
| Command options:<br>&0 = real numbers with fixed f number of digits (default)<br>&1 = real numbers with increased precision<br>&2 = real numbers with maximum accuracy | |
| **±NTAPE** | Output unit for the GENDF tape and record mode:<br>>0 – formatted mode,<br><0 – binary mode |
| **NMAT** | Number of materials (0 = all materials) |
| **NTM** | Number of temperatures (0=all temperatures on tape) |
| **NMF** | Number of data classes (0 = all classes ) |
| **NMT** | Number of reaction types (0 = all reactions) |
| **MAT(NMAT)** | List of material numbers (if NMAT>0) |
| **MTM(NT)** | List of serial number of temperatures (if NTM>0) |
| **MF(NMF)** | List of data class numbers ( if NMF>0) |
| **MT(NMT)** | List of reaction type numbers (if NMT>0) |

| ***MATXS: Converting the *F* and *M* structures to the MATXS format** | |
|---|---|
| **NTAPE** | Output unit for the MATXS tape |

**Appendix B.**

```
::::::::::::::
task01.inp
::::::::::::::
! task01: read endf file with linearization and correction option
,in               ! enter local parameters
,in,1,endf        ! enter *endf control parameters
,in,2,s/i-s       ! enter *s/i-s control parameters
,in,3,extend      ! enter *extend control parameters
,in,4,write       ! enter *write control parameters
,1&1,20,data      ! read endf file with correction option
20,sel,21,s       ! select cross section data
20,sel,22,e&ae    ! select energy distribution parameters
20,sel,23,/s&e&ae ! select rest of data
21,2&1,24,s       ! linearize xs with threshold correction
22,3,24           ! add extended e- and ae-data
23,cp,24          ! add rest of data
24,con            ! print content
24,4              ! write tape21
,,,end
! ---------------------------------------
!    local parameters
*de:1.e-5,20.e6,
*eps:0.001
! ---------------------------------------
!    control parameters
*endf:ntape=20,nmat=0,nmf=0,nmt=0
*s/i-s:nint=2,*de,*eps
*extend:elow=40.,efact=0.84
*write:-21
```

```
::::::::::::::
task02.inp
::::::::::::::
! task02: reconstruct cross sections from resonance parameters
,in              ! enter local parameters
,in,1,read       ! enter control parameters for *read,
,in,2,s/c-s      ! *s/c-s,
,in,3,s/a-s      ! *s/a-s to prepare background xs,
,in,4,r/t-s      ! *r/t-s,
,in,5,u/d-s      ! *u/d-s,
,in,6,s/a-s      ! *s/a-s to prepare redundant xs,
,in,7,extra      ! *extra,
,in,8,s/e-s      ! *s/e-s,
,in,9,write      ! and *write modules
,1,20,data         ! read tape with endf data
20,sel&3,21,s    ! select xs
21,2,22,s          ! join xs in s structure
22,3,32,s,2        ! prepare background xs
20,4&20,32       ! add reconstructed xs in the RRR
20,5&20,32       ! add reconstructed xs in the URR
32,2,33,s,3        ! join resonance xs
22,6,33            ! add redundant xs
21,7&1,33        ! add all others
33,8&20,32,s     ! thin energy grid
32,con             ! print content
32,9               ! write tape with reconstructed xs
,,,end
! ---------------------------------------
!    local parameters
*de:1.e-5,20.e6,
*eps:0.001
! ---------------------------------------
!    control parameters
*read:ntape=-21
*s/c-s:ncom=0,ns=0,*de,*eps
*s/a-s:nop=4,
 li=0,2,0,102,
 lo=1,2,18,102,
 lop=0,0,0,0
*r/t-s:nfor=0,nt=1,*de,*eps,tem=0.
*u/d-s:nfun=0,nin=2,nt=1,*de,*eps,tem=0.
*s/a-s:nop=8,
 li=0,0,0,0,0,0,0,0,
 lo=4,16,17,103,104,105,106,107,
 lop=0,0,0,0,0,0,0,0
*extra:kdat=2,nmod=3,nr=5,lr=1,2,4,16,-18,102,-107
*s/e-s:*eps
*write:-22
```

```
::::::::::::::
task03.inp
::::::::::::::
! task03: doppler broadening
 ,in              ! enter local parameters
 ,in,1,read       ! enter *read control parameters
 ,in,2,read       ! enter *read control parameters
 ,in,3,s/e-s      ! enter *s/e-s control parameters
 ,in,4,s/t-s      ! enter *s/t-s control parameters
 ,in,5,write      ! enter *write control parameters
 ,1,20,data       !   read tape with endf data
 ,2,32,s,2            ! read tape with reconstructed xs
 32,3&20,33,s,3       ! thin energy grid
 33,4&20,32,s         ! doppler broaden
 32,3&20,33,s         ! thin energy grid
 33,con               ! print content
 33,5                 ! write tape with broadened xs
 ,,,end
 ! ---------------------------------------
 !    local parameters
*de:1.e-5,20.e6,
*ntem:4,
*tem:293.6,600.,1000.,2100.,
 *eps:0.001
 ! ---------------------------------------
 !    control parameters
 *read:ntape=-21
 *read:ntape=-22
 *s/e-s:*eps
 *s/t-s:*ntem,*de,*eps,*tem
 *write:-23
```

```
::::::::::::::
task04.inp
::::::::::::::
! task04: prepare particle production cross sections
,in              ! enter local parameters
,in,1,read       ! enter *read control parameters
,in,2,read       ! enter *read control parameters
,in,3,extra      ! enter *extra control parameters
,in,4,s/a-s      ! enter *s/a-s  control parameters
,in,5,prod       ! enter *prod control parameters
,in,6,s/c-s      ! enter *s/c-s control parameters
,in,7,s/e-s      ! enter *s/e-s control parameters
,in,8,write      ! enter *write control parameters
,1,20,data       ! read endf data
,2,32,s,2        ! read broadened xs
32,3&1,21,s      ! extract non-resonance xs
32,3,33,s,3      ! extract resonance xs
33,4,32,s        ! calculate nonelastic xs
21,cp,32         ! add non-resonance xs
32,5&20,33,s  ! calculate particle production xs
33,6,32,s        ! join in s structure
32,7,33,s        ! thin energy grid points
33,con           ! print content
33,8             ! write tape with particle production xs
,,,end
! ---------------------------------------
!    local parameters
*de:1.e-5,20.e6,
*ntem:4,
*tem:293.6,600.,1000.,2100.,
*eps:0.001
! ---------------------------------------
!    control parameters
*read:ntape=-21
*read:ntape=-23
*extra:kdat=2,nmod=3,nr=4,lr=1,2,18,102
*s/a-s:nop=6,
       li=1,2,1,2,18,102,
       lo=1,2,3,3,18,102,
       lop=0,0,1,2,0,0
*prod:nmt=1,*ntem,mt=202,-207,*eps,*tem
*s/c-s:ncom=0,ns=0,*de,*eps
*s/e-s:*eps
*write:-24
```

```
::::::::::::::
task05.inp
::::::::::::::
! task05: reconstruct cross section moments in the UR range
,in              ! enter local parameters
,in,1,read       ! enter *read control parameters
,in,2,u/d-f      ! enter *u/d-f control parameters
,in,3,f/c-f      ! enter *f/c-f control parameters
,in,4,write      ! enter *write control parameters
,1,20,data       ! read tape with endf data
20,2&20,21,f     ! reconstruct xs moments in URR
21,3,22,f        ! convolve xs moments
22,4             ! write tape with xs moments
,,,end
! ---------------------------------------
!    local parameters
*de:1.e-5,20.e6,
*ntem:4,
*tem:293.6,600.,1000.,2100.,
*nsigz:9,
*sigz:1.e-10,1.,1.e1,3.e1,1.e2,3.e2,1.e3,1.e4,1.e5,
*eps:0.001
! ---------------------------------------
!    control parameters
*read:ntape=-21
*u/d-f:nfor=0,nin=0,*ntem,nz=1,
       nl=-5,nh=4,*de,*eps,*tem,sigz=0.1
*f/c-f:nfun=100,nmat=0,ns=0,*nsigz,
        nl=-2,nh=0,*de,*eps,tr=0.,*sigz
*write:-25
```

```
::::::::::::::
task06.inp
::::::::::::::
! task06: prepare subgroup parameters from moments
,in              ! enter local parameters
,in,1,read       ! enter *read control parameters
,in,2,f/e-p      ! enter *f/e-p control parameters
,in,3,write      ! enter *write control parameters
,1,20,data       ! read tape with xs moments
20,2&20,21,f     ! calculate subgroup parameters
21,3             ! write tape with subgroup parameters
,,,end
! --------------------------------------
!    local parameters
*eps:0.001
! --------------------------------------
!    control parameters
*read:ntape=-25
*f/e-p:kg=0,nsub=4,ntyp=1,nmet=2,nopt=1,nset=0,
            nrel=1,kint=0,nmod=1,
            sigz=0.1,1.e10,*eps
*write:-26
```

```
::::::::::::::
task07.inp
::::::::::::::
! task07: prepare unshielded group cross sections
,in          ! enter local parameters
,in,1,read   ! enter control parameters
,in,2,read
,in,3,a/-s
,in,4,nu/-s
,in,5,s/-s
,in,6,extra
,in,7,s/i-s
,in,8,s/c-s
,in,9,s/a-s
,in,10,s/g-f
,in,11,f/-s
,in,12,s/a-s
,in,13,write
!----------- prepare main cross section table
,1,20,data    ! read endf data
,2,32,s,2     ! read reconsructed xs
20,3,21,s     ! calculate  mu,ksi,gamma
20,4,21       ! calculate nu-bar
32,5,33,s,3   ! unpack xs
33,6,32,s     ! extract resonance xs
33,6&1,22,s   ! extract all others
21,7,32       ! add nu,mu,ksi,gamma
32,8,33,s     ! join cross sections
33,9,32,s     ! prepare products xs and nu,mu,ksi,gamma
32,10,23,f    ! integrate
23,11,24,s    ! convert f to s
24,12,32,s    ! reconstruct nu,mu,ksi,gamma
32,7,33,s     ! linearize
22,cp,33      ! add non resonance
33,8,32,s     ! join
32,10,28,f    ! reintegrate to exlude threshold energies
28,13         ! write tape
,,,end
! ---------------------------------------
! define local parameters
*de:1.e-5,20.e6,
*ngn:199,
*egn:1.0000E-05,5.0000E-04,2.0000E-03,5.0000E-03,1.0000E-02,1.4500E-02,
     2.1000E-02,3.0000E-02,4.0000E-02,5.0000E-02,7.0000E-02,1.0000E-01,
     1.2500E-01,1.5000E-01,1.8400E-01,2.2500E-01,2.7500E-01,3.2500E-01,
     8.0000E-01,8.7643E-01,1.0000E+00,1.0400E+00,1.0800E+00,1.1253E+00,
     1.3000E+00,1.4450E+00,1.8554E+00,2.3824E+00,3.0590E+00,3.9279E+00,
     5.0435E+00,6.4760E+00,8.3153E+00,1.0677E+01,1.3710E+01,1.7604E+01,
     2.2603E+01,2.9023E+01,3.7266E+01,4.7851E+01,6.1442E+01,7.8893E+01,
     1.0130E+02,1.3007E+02,1.6702E+02,2.1445E+02,2.7536E+02,3.5357E+02,
     4.5400E+02,5.8295E+02,7.4852E+02,9.6112E+02,1.2341E+03,1.5846E+03,
     2.0347E+03,2.2487E+03,2.4852E+03,2.6126E+03,2.7465E+03,3.0354E+03,
```

```
     3.3546E+03,3.7074E+03,4.3074E+03,5.5308E+03,7.1017E+03,9.1188E+03,
     1.0595E+04,1.1709E+04,1.5034E+04,1.9305E+04,2.1875E+04,2.3579E+04,
     2.4176E+04,2.4788E+04,2.6058E+04,2.7000E+04,2.8501E+04,3.1828E+04,
     3.4307E+04,4.0868E+04,4.6309E+04,5.2475E+04,5.6562E+04,6.7379E+04,
     7.1998E+04,7.9499E+04,8.2503E+04,8.6517E+04,9.8037E+04,1.1109E+05,
     1.1679E+05,1.2277E+05,1.2907E+05,1.3569E+05,1.4264E+05,1.4996E+05,
     1.5764E+05,1.6573E+05,1.7422E+05,1.8316E+05,1.9255E+05,2.0242E+05,
     2.1280E+05,2.2371E+05,2.3518E+05,2.4724E+05,2.7324E+05,2.8725E+05,
     2.9452E+05,2.9721E+05,2.9849E+05,3.0197E+05,3.3373E+05,3.6883E+05,
     3.8774E+05,4.0762E+05,4.5049E+05,4.9787E+05,5.2340E+05,5.5023E+05,
     5.7844E+05,6.0810E+05,6.3928E+05,6.7206E+05,7.0651E+05,7.4274E+05,
     7.8082E+05,8.2085E+05,8.6294E+05,9.0718E+05,9.6164E+05,1.0026E+06,
     1.1080E+06,1.1648E+06,1.2246E+06,1.2874E+06,1.3534E+06,1.4227E+06,
     1.4957E+06,1.5724E+06,1.6530E+06,1.7377E+06,1.8268E+06,1.9205E+06,
     2.0190E+06,2.1225E+06,2.2313E+06,2.3069E+06,2.3457E+06,2.3653E+06,
     2.3852E+06,2.4660E+06,2.5924E+06,2.7253E+06,2.8651E+06,3.0119E+06,
     3.1664E+06,3.3287E+06,3.6788E+06,4.0657E+06,4.4933E+06,4.7237E+06,
     4.9659E+06,5.2205E+06,5.4881E+06,5.7695E+06,6.0653E+06,6.3763E+06,
     6.5924E+06,6.7032E+06,7.0469E+06,7.4082E+06,7.7880E+06,8.1873E+06,
     8.6071E+06,9.0484E+06,9.5123E+06,1.0000E+07,1.0513E+07,1.1052E+07,
     1.1618E+07,1.2214E+07,1.2523E+07,1.2840E+07,1.3499E+07,1.3840E+07,
     1.4191E+07,1.4550E+07,1.4918E+07,1.5683E+07,1.6487E+07,1.6905E+07,
     1.7332E+07,1.9640E+07,
*iwgn:4,
*wgn:0.125,0.025,8.2085E+05,1.273E+06,
*eps:0.001
! ---------------------------------------
! control parameters
*read:ntape=-21
*read:ntape=-23
*a/-s:*eps
*nu/-s:*eps
*s/-s:ns=0,ntem=1,tem=293.6
*extra:kdat=2,nmod=3,nr=4,lr=1,2,18,102
*s/i-s:nint=2,*de,*eps
*s/c-s:nmat=0,ns=0,*de,*eps
*s/a-s:nls=12,
      lsi=2,251,2,252,2,253,18,452,18,455,18,456,
      lso=251,251,252,252,253,253,452,452,455,455,456,456,
      nop=0,3,0,3,0,3,0,3,0,3,0,3
*s/g-f:nfun=1,*ngn,nig=1,nr=0,nsigz=0,nl=0,nh=0,
       nng=1,nsg=1,nmg=1,*iwgn,*eps,*wgn,*egn
*f/-s: nr=0,km=0,kt=0,kp=0
*s/a-s:nls=12,
      lsi=251,2,252,2,253,2,452,18,455,18,456,18,
      lso=251,251,252,252,253,253,452,452,455,455,456,456,
      nop=0,4,0,4,0,4,0,4,0,4,0,4
*write:ntape=-27
```

```
::::::::::::::
task08.inp
::::::::::::::
! task08: prepare moments for shielded group cross section calculation
,in ! enter local parameters
,in,1,read ! enter control parameters
,in,2,read
,in,3,read
,in,4,redef
,in,5,s/-s
,in,6,s/c-s
,in,7,s/a-s
,in,8,s/g-f
8,,9,f/g-f
,in,10,fxcxf
,in,11,write
!----------- prepare main cross section table
,1,20,data   ! read endf data
,2,32,s,2    ! read reconstructed cross sections
,3,21,f      ! read cross section  moments
21,4,22,f    ! redefine mt102 to mt101
32,5,33,s,3  ! unpack cross sections
33,6,32,s    ! join
32,7,33,s    ! calculate mt101
33,8&20,32,f ! integrate
22,9,32
32,10,33,f
33,9,32,f
32,11
,,,end
! ---------------------------------------
! define local parameters
*de:1.e-5,20.e6,
*ngn:199,
*egn:1.0000E-05,5.0000E-04,2.0000E-03,5.0000E-03,1.0000E-02,1.4500E-02,
     2.1000E-02,3.0000E-02,4.0000E-02,5.0000E-02,7.0000E-02,1.0000E-01,
     1.2500E-01,1.5000E-01,1.8400E-01,2.2500E-01,2.7500E-01,3.2500E-01,
     8.0000E-01,8.7643E-01,1.0000E+00,1.0400E+00,1.0800E+00,1.1253E+00,
     1.3000E+00,1.4450E+00,1.8554E+00,2.3824E+00,3.0590E+00,3.9279E+00,
     5.0435E+00,6.4760E+00,8.3153E+00,1.0677E+01,1.3710E+01,1.7604E+01,
     2.2603E+01,2.9023E+01,3.7266E+01,4.7851E+01,6.1442E+01,7.8893E+01,
     1.0130E+02,1.3007E+02,1.6702E+02,2.1445E+02,2.7536E+02,3.5357E+02,
     4.5400E+02,5.8295E+02,7.4852E+02,9.6112E+02,1.2341E+03,1.5846E+03,
     2.0347E+03,2.2487E+03,2.4852E+03,2.6126E+03,2.7465E+03,3.0354E+03,
     3.3546E+03,3.7074E+03,4.3074E+03,5.5308E+03,7.1017E+03,9.1188E+03,
     1.0595E+04,1.1709E+04,1.5034E+04,1.9305E+04,2.1875E+04,2.3579E+04,
     2.4176E+04,2.4788E+04,2.6058E+04,2.7000E+04,2.8501E+04,3.1828E+04,
     3.4307E+04,4.0868E+04,4.6309E+04,5.2475E+04,5.6562E+04,6.7379E+04,
     7.1998E+04,7.9499E+04,8.2503E+04,8.6517E+04,9.8037E+04,1.1109E+05,
     1.1679E+05,1.2277E+05,1.2907E+05,1.3569E+05,1.4264E+05,1.4996E+05,
     1.5764E+05,1.6573E+05,1.7422E+05,1.8316E+05,1.9255E+05,2.0242E+05,
     2.1280E+05,2.2371E+05,2.3518E+05,2.4724E+05,2.7324E+05,2.8725E+05,
```

```
     2.9452E+05,2.9721E+05,2.9849E+05,3.0197E+05,3.3373E+05,3.6883E+05,
     3.8774E+05,4.0762E+05,4.5049E+05,4.9787E+05,5.2340E+05,5.5023E+05,
     5.7844E+05,6.0810E+05,6.3928E+05,6.7206E+05,7.0651E+05,7.4274E+05,
     7.8082E+05,8.2085E+05,8.6294E+05,9.0718E+05,9.6164E+05,1.0026E+06,
     1.1080E+06,1.1648E+06,1.2246E+06,1.2874E+06,1.3534E+06,1.4227E+06,
     1.4957E+06,1.5724E+06,1.6530E+06,1.7377E+06,1.8268E+06,1.9205E+06,
     2.0190E+06,2.1225E+06,2.2313E+06,2.3069E+06,2.3457E+06,2.3653E+06,
     2.3852E+06,2.4660E+06,2.5924E+06,2.7253E+06,2.8651E+06,3.0119E+06,
     3.1664E+06,3.3287E+06,3.6788E+06,4.0657E+06,4.4933E+06,4.7237E+06,
     4.9659E+06,5.2205E+06,5.4881E+06,5.7695E+06,6.0653E+06,6.3763E+06,
     6.5924E+06,6.7032E+06,7.0469E+06,7.4082E+06,7.7880E+06,8.1873E+06,
     8.6071E+06,9.0484E+06,9.5123E+06,1.0000E+07,1.0513E+07,1.1052E+07,
     1.1618E+07,1.2214E+07,1.2523E+07,1.2840E+07,1.3499E+07,1.3840E+07,
     1.4191E+07,1.4550E+07,1.4918E+07,1.5683E+07,1.6487E+07,1.6905E+07,
     1.7332E+07,1.9640E+07,
*ntem:4,
*tem:293.6,600.,1000.,2100.,
*nsigz:9,
*sigz:1.e-10,1.,1.e1,3.e1,1.e2,3.e2,1.e3,1.e4,1.e5,
*iwgn:4,
*wgn:0.125,0.025,8.2085E+05,1.273E+06,
*eps:0.001
! ----------------------------------------
! control parameters
*read:ntape=-21
*read:ntape=-23
*read:ntape=-25
*redef:ntyp=3,nl=2,nli=102,102,nlo=101,102
*s/-s:ns=5,*ntem,ls=1,2,18,102,-117,102,*tem
*s/c-s:nmat=0,ns=0,*de,*eps
*s/a-s:nls=5,lsi=1,2,18,102,-117,102,
             lso=1,2,18,101,102,
             nop=0,0,0,1,0
*s/g-f:nfun=1,*ngn,nig=1,nr=0,*nsigz,nl=-2,nh=0,nng=1,nsg=1,
       nmg=1,*iwgn,*eps,*sigz,*wgn,*egn
*f/c-f:nfun=0,nmat=0,ns=0,*nsigz,
       nl=-2,nh=0,*de,*eps,tr=0.,*sigz
*write:ntape=-28
```

```
::::::::::::::
task09.inp
::::::::::::::
! task09: prepare group transition and production matrices
,in ! enter local parameters
,in,1,read ! enter control parameters
,in,2,read
,in,3,read
,in,4,sxaexfm
,in,5,write
,1,20,data
,2,21,s
,3,21
21,4&20,22,m
22,5
,,,end
! ----------------------------------------
! define local parameters
*de:1.e-5,20.e6,
*ngn:199,
*egn:1.0000E-05,5.0000E-04,2.0000E-03,5.0000E-03,1.0000E-02,1.4500E-02,
     2.1000E-02,3.0000E-02,4.0000E-02,5.0000E-02,7.0000E-02,1.0000E-01,
     1.2500E-01,1.5000E-01,1.8400E-01,2.2500E-01,2.7500E-01,3.2500E-01,
     8.0000E-01,8.7643E-01,1.0000E+00,1.0400E+00,1.0800E+00,1.1253E+00,
     1.3000E+00,1.4450E+00,1.8554E+00,2.3824E+00,3.0590E+00,3.9279E+00,
     5.0435E+00,6.4760E+00,8.3153E+00,1.0677E+01,1.3710E+01,1.7604E+01,
     2.2603E+01,2.9023E+01,3.7266E+01,4.7851E+01,6.1442E+01,7.8893E+01,
     1.0130E+02,1.3007E+02,1.6702E+02,2.1445E+02,2.7536E+02,3.5357E+02,
     4.5400E+02,5.8295E+02,7.4852E+02,9.6112E+02,1.2341E+03,1.5846E+03,
     2.0347E+03,2.2487E+03,2.4852E+03,2.6126E+03,2.7465E+03,3.0354E+03,
     3.3546E+03,3.7074E+03,4.3074E+03,5.5308E+03,7.1017E+03,9.1188E+03,
     1.0595E+04,1.1709E+04,1.5034E+04,1.9305E+04,2.1875E+04,2.3579E+04,
     2.4176E+04,2.4788E+04,2.6058E+04,2.7000E+04,2.8501E+04,3.1828E+04,
     3.4307E+04,4.0868E+04,4.6309E+04,5.2475E+04,5.6562E+04,6.7379E+04,
     7.1998E+04,7.9499E+04,8.2503E+04,8.6517E+04,9.8037E+04,1.1109E+05,
     1.1679E+05,1.2277E+05,1.2907E+05,1.3569E+05,1.4264E+05,1.4996E+05,
     1.5764E+05,1.6573E+05,1.7422E+05,1.8316E+05,1.9255E+05,2.0242E+05,
     2.1280E+05,2.2371E+05,2.3518E+05,2.4724E+05,2.7324E+05,2.8725E+05,
     2.9452E+05,2.9721E+05,2.9849E+05,3.0197E+05,3.3373E+05,3.6883E+05,
     3.8774E+05,4.0762E+05,4.5049E+05,4.9787E+05,5.2340E+05,5.5023E+05,
     5.7844E+05,6.0810E+05,6.3928E+05,6.7206E+05,7.0651E+05,7.4274E+05,
     7.8082E+05,8.2085E+05,8.6294E+05,9.0718E+05,9.6164E+05,1.0026E+06,
     1.1080E+06,1.1648E+06,1.2246E+06,1.2874E+06,1.3534E+06,1.4227E+06,
     1.4957E+06,1.5724E+06,1.6530E+06,1.7377E+06,1.8268E+06,1.9205E+06,
     2.0190E+06,2.1225E+06,2.2313E+06,2.3069E+06,2.3457E+06,2.3653E+06,
     2.3852E+06,2.4660E+06,2.5924E+06,2.7253E+06,2.8651E+06,3.0119E+06,
     3.1664E+06,3.3287E+06,3.6788E+06,4.0657E+06,4.4933E+06,4.7237E+06,
     4.9659E+06,5.2205E+06,5.4881E+06,5.7695E+06,6.0653E+06,6.3763E+06,
     6.5924E+06,6.7032E+06,7.0469E+06,7.4082E+06,7.7880E+06,8.1873E+06,
     8.6071E+06,9.0484E+06,9.5123E+06,1.0000E+07,1.0513E+07,1.1052E+07,
     1.1618E+07,1.2214E+07,1.2523E+07,1.2840E+07,1.3499E+07,1.3840E+07,
     1.4191E+07,1.4550E+07,1.4918E+07,1.5683E+07,1.6487E+07,1.6905E+07,
```

```
     1.7332E+07,1.9640E+07,
*ngg:42,
*egg:1.0000E+03,1.0000E+04,2.0000E+04,3.0000E+04,4.0000E+04,4.5000E+04,
     6.0000E+04,7.0000E+04,7.5000E+04,1.0000E+05,1.5000E+05,2.0000E+05,
     3.0000E+05,4.0000E+05,4.5000E+05,5.1000E+05,5.1200E+05,6.0000E+05,
     7.0000E+05,8.0000E+05,1.0000E+06,1.3300E+06,1.3400E+06,1.5000E+06,
     1.6600E+06,2.0000E+06,2.5000E+06,3.0000E+06,3.5000E+06,4.0000E+06,
     4.5000E+06,5.0000E+06,5.5000E+06,6.0000E+06,6.5000E+06,7.0000E+06,
     7.5000E+06,8.0000E+06,1.0000E+07,1.2000E+07,1.40000E+07,2.0000E+07,
     3.0000E+07,
*ntem:4,
*tem:293.6,600.,1000.,2100.,
*nsigz:9,
*sigz:1.e-10,1.,1.e1,3.e1,1.e2,3.e2,1.e3,1.e4,1.e5,
*iwgn:4,
*wgn:0.125,0.025,8.2085E+05,1.273E+06,
*nord:7,
*eps:0.001
! ----------------------------------------
! control parameters
*read:ntape=-21
*read:ntape=-23
*read:ntape=-26
*s/ae-fm:mzap=100,nmt=0,*ngn,*ngg,nig=1,*iwgn,
    *ntem,*nsigz,lan=2,*nord,ismooth=1,
     mig=1,ming=1,mng=1,
    *eps,*tem,*sigz,*wgn,*egn,*egg,
*s/ae-fm:mzap=0,nmt=0,*ngn,*ngg,nig=1,*iwgn,
    *ntem,*nsigz,lan=2,*nord,ismooth=0,
    mig=1,ming=1,mng=1,
    *eps,*tem,*sigz,*wgn,*egn,*egg
*write:ntape=-29
```

```
::::::::::::::
task10.inp
::::::::::::::
! task10: prepare free gas scattering group cross sections and matrices
,in,,          ! enter local parameters
,in,1,read     ! enter control parameters
,in,2,th/-ds
,in,3,d/e-d
,in,4,s/g-f
 4,,5,s/d-m
,in,6,write
,1,20,data      ! read endf file
20,2&1,21,ds    ! prepare free gas distribution
21,3,22,d       ! integrate secondary energies
21,4,23,f       ! calculate group averaging cross sections
21,5&22,23      ! calculate group transition matrices
23,6            ! write to tape
,,,end
!--------------------------------------------------
!    local parameters
*de1:1.e-5,10.,
*de:1.e-5,5.0435,
*ngn:199,
*egn:1.0000E-05,5.0000E-04,2.0000E-03,5.0000E-03,1.0000E-02,1.4500E-02,
     2.1000E-02,3.0000E-02,4.0000E-02,5.0000E-02,7.0000E-02,1.0000E-01,
     1.2500E-01,1.5000E-01,1.8400E-01,2.2500E-01,2.7500E-01,3.2500E-01,
     8.0000E-01,8.7643E-01,1.0000E+00,1.0400E+00,1.0800E+00,1.1253E+00,
     1.3000E+00,1.4450E+00,1.8554E+00,2.3824E+00,3.0590E+00,3.9279E+00,
     5.0435E+00,6.4760E+00,8.3153E+00,1.0677E+01,1.3710E+01,1.7604E+01,
     2.2603E+01,2.9023E+01,3.7266E+01,4.7851E+01,6.1442E+01,7.8893E+01,
     1.0130E+02,1.3007E+02,1.6702E+02,2.1445E+02,2.7536E+02,3.5357E+02,
     4.5400E+02,5.8295E+02,7.4852E+02,9.6112E+02,1.2341E+03,1.5846E+03,
     2.0347E+03,2.2487E+03,2.4852E+03,2.6126E+03,2.7465E+03,3.0354E+03,
     3.3546E+03,3.7074E+03,4.3074E+03,5.5308E+03,7.1017E+03,9.1188E+03,
     1.0595E+04,1.1709E+04,1.5034E+04,1.9305E+04,2.1875E+04,2.3579E+04,
     2.4176E+04,2.4788E+04,2.6058E+04,2.7000E+04,2.8501E+04,3.1828E+04,
     3.4307E+04,4.0868E+04,4.6309E+04,5.2475E+04,5.6562E+04,6.7379E+04,
     7.1998E+04,7.9499E+04,8.2503E+04,8.6517E+04,9.8037E+04,1.1109E+05,
     1.1679E+05,1.2277E+05,1.2907E+05,1.3569E+05,1.4264E+05,1.4996E+05,
     1.5764E+05,1.6573E+05,1.7422E+05,1.8316E+05,1.9255E+05,2.0242E+05,
     2.1280E+05,2.2371E+05,2.3518E+05,2.4724E+05,2.7324E+05,2.8725E+05,
     2.9452E+05,2.9721E+05,2.9849E+05,3.0197E+05,3.3373E+05,3.6883E+05,
     3.8774E+05,4.0762E+05,4.5049E+05,4.9787E+05,5.2340E+05,5.5023E+05,
     5.7844E+05,6.0810E+05,6.3928E+05,6.7206E+05,7.0651E+05,7.4274E+05,
     7.8082E+05,8.2085E+05,8.6294E+05,9.0718E+05,9.6164E+05,1.0026E+06,
     1.1080E+06,1.1648E+06,1.2246E+06,1.2874E+06,1.3534E+06,1.4227E+06,
     1.4957E+06,1.5724E+06,1.6530E+06,1.7377E+06,1.8268E+06,1.9205E+06,
     2.0190E+06,2.1225E+06,2.2313E+06,2.3069E+06,2.3457E+06,2.3653E+06,
     2.3852E+06,2.4660E+06,2.5924E+06,2.7253E+06,2.8651E+06,3.0119E+06,
     3.1664E+06,3.3287E+06,3.6788E+06,4.0657E+06,4.4933E+06,4.7237E+06,
     4.9659E+06,5.2205E+06,5.4881E+06,5.7695E+06,6.0653E+06,6.3763E+06,
     6.5924E+06,6.7032E+06,7.0469E+06,7.4082E+06,7.7880E+06,8.1873E+06,
```

```
     8.6071E+06,9.0484E+06,9.5123E+06,1.0000E+07,1.0513E+07,1.1052E+07,
     1.1618E+07,1.2214E+07,1.2523E+07,1.2840E+07,1.3499E+07,1.3840E+07,
     1.4191E+07,1.4550E+07,1.4918E+07,1.5683E+07,1.6487E+07,1.6905E+07,
     1.7332E+07,1.9640E+07,
*ntem:4,
*tem:293.6,600.,1000.,2100.,
*nsigz:9,
*sigz:1.e-10,1.,1.e1,3.e1,1.e2,3.e2,1.e3,1.e4,1.e5,
*iwgn:4,
*wgn:0.125,0.025,8.2085E+05,1.273E+06,
*nlord:7,
*eps:0.001
!-------------------------------------------------
!    control parameters
*read:-23
*th/-ds:mtref=221,iel=0,natom=1,nint=2,*ntem,*nlord,ntype=2,
   *de,*eps,*tem
*d/e-d:zap=100,*ngn,nig=1,mig=1,ming=1,mng=1,
       *de,*eps,*egn
*s/g-f:nfun=1,*ngn,nig=1,nr=0,*nsigz,nl=-2,nh=0,
      *eps,*sigz,*wgn,*egn
*write:-30
```

```
::::::::::::::
task11.inp
::::::::::::::
! task11: prepare photo-atomic group cross sections and transition matrices
,in ! enter local parameters
,in,1,endf ! enter control parameters
,in,2,sxixs
,in,3,sxgxfm
,in,4,write
,1,20,data
20,2,21,s
21,3,22,fm
22,4
,,,end
! ---------------------------------------
! define local parameters
*de:1.e-5,30.e6,
*ngg:42,
*egg:1.0000E+03,1.0000E+04,2.0000E+04,3.0000E+04,4.0000E+04,4.5000E+04,
     3.0000E+05,4.0000E+05,4.5000E+05,5.1000E+05,5.1200E+05,6.0000E+05,
     7.0000E+05,8.0000E+05,1.0000E+06,1.3300E+06,1.3400E+06,1.5000E+06,
     1.6600E+06,2.0000E+06,2.5000E+06,3.0000E+06,3.5000E+06,4.0000E+06,
     4.5000E+06,5.0000E+06,5.5000E+06,6.0000E+06,6.5000E+06,7.0000E+06,
     7.5000E+06,8.0000E+06,1.0000E+07,1.2000E+07,1.40000E+07,2.0000E+07,
     3.0000E+07,
*lord:7,
*eps:0.001
! ---------------------------------------
! control parameters
*endf:ntape=20,nmat=0,nf=2,nmt=0,mf=23,27
*s/i-s:nint=2,*de,*eps
*s/g-fm:*ngg,nwg=3,lang=2,*lord,nmt=0,*eps,*egg
*write:ntape=-31
```

```
::::::::::::::
task12.inp
::::::::::::::
! task12: write *f* and *m* structures to the gendf and matxs tapes
,in,1,read       ! enter control parameters
,in,2,read       !
,in,3,gendf      !
,in,4,gendf      !
,in,5,matxs      !
,1,20,data       ! read neutron data
,2,21,data       ! read photon data
20,3             ! write to the gendf neutron data file
21,4             ! write to the gendf photon data file
20,cp,22,data    ! merge neutron and photon data
21,cp,22         !
22,5,,ENDFB8_0   ! prepare matxs file
,,,end
! --------------------------------------
!    control parameters
*read:-27,
*read:-28,
*read:-29,
*read:-30
*read:-31
*gendf:40,nmat=0,ntm=0,nmf=0,nmt=0
*matxs:50
```

## Appendix C. Integral testing. Iron sphere. Input decks for leakage calculation

### Input deck for TRANSX code

```
Cf_Fe_30
0 15 0 1 2 1 0 2 0 0 0 0 /
199 6 203 0 0 2 2 12 0 0 /
*~/.local/DATA/MATXS/ENDFB8_0/N199G42/matxs.b80 */
*shell* *air*
*shell* 293. 1. 1 1.e5 /
*air* 293. 1. 1 1.e5 /
1 1 *Fe54* 4.193464e-3  free /
1 1 *Fe56* 7.2232176e-2 free /
1 1 *Fe57* 1.834209e-3  free /
1 1 *Fe58* 2.73406e-4   free /
1 1 *Mn55* 9.56984e-4   free /
1 1 *Si28* 4.96887e-4   free /
1 1 *Si29* 2.13098e-5   free /
1 1 *Si30* 1.40473e-5   free /
1 1 *C*    7.885327e-4  free /
2 2 *C*    7.05098e-9   free /
2 2 *N14*  3.32114e-5   free /
2 2 *O16*  1.27446e-5   free /
*stop*
```

**Input deck for ONEDANT code**

```
    1    0    0
Cf_Fe_30
/
/ **** block i ****
igeom=3 ngroup=199 isn=32
niso=2 mt=2 nzone=2
im=3 it=358
maxscm=400000 maxlcm=4000000 t
/
/ **** block ii ****
xmesh=0.
      1.3
      30.
      75.;
xints=13
      300
      45;
zones=0
      1
      2;
t
/
/ **** block iii ****
lib= macrxs
balxs=0
writmxs=macbcd
t
/
/ **** block iv ****
matls=isos assign=matls
t
/
/ **** block v ****
ievt=0 ith=0 epsi=0.00001 isct=5
sourcp=1 xsectp=1 fluxp=0 balp=0 source=
 1.28125E-05 5.55862E-06 7.20057E-06 2.14139E-05 3.48857E-05 2.43909E-05
 3.01445E-05 3.75720E-05 4.62457E-05 1.26492E-04 8.42956E-05 1.01518E-04
 2.67133E-04 3.74802E-04 5.17026E-04 7.00027E-04 9.30782E-04 1.21589E-03
 1.56365E-03 1.98096E-03 2.47467E-03 3.05079E-03 3.71210E-03 4.45994E-03
 1.66671E-03 3.62166E-03 6.19666E-03 7.17544E-03 8.21583E-03 9.30952E-03
 1.04521E-02 1.16218E-02 1.28113E-02 2.91896E-02 3.37669E-02 3.78955E-02
 2.03085E-02 2.11081E-02 2.17481E-02 2.23531E-02 2.27879E-02 2.31619E-02
 1.55688E-02 3.93000E-03 3.90966E-03 7.85339E-03 1.57366E-02 2.36555E-02
 2.36073E-02 2.34796E-02 2.32766E-02 2.29857E-02 2.26205E-02 2.22224E-02
 2.17780E-02 2.12625E-02 2.06401E-02 2.00695E-02 1.94698E-02 1.88635E-02
 1.81508E-02 3.42668E-02 1.35024E-02 1.80619E-02 1.47641E-02 1.41082E-02
 1.34325E-02 1.27891E-02 1.21776E-02 1.15721E-02 1.09745E-02 1.04049E-02
 9.85610E-03 9.30961E-03 8.79439E-03 8.31405E-03 1.52430E-02 1.34986E-02
 6.15435E-03 5.79207E-03 1.05405E-02 9.27665E-03 1.00131E-03 3.67370E-04
 7.70331E-04 2.07024E-03 3.94156E-03 7.14700E-03 3.23224E-03 3.01906E-03
```

```
 2.82185E-03 2.63968E-03 2.46639E-03 2.30061E-03 2.14857E-03 2.00268E-03
 1.87383E-03 1.74318E-03 1.62761E-03 1.51476E-03 1.41509E-03 1.31838E-03
 1.22412E-03 1.14206E-03 2.52410E-03 2.11110E-03 7.08026E-04 5.19635E-04
 1.25892E-03 7.47265E-04 1.65608E-03 5.90671E-04 8.50351E-04 7.07780E-04
 7.95339E-04 2.82986E-04 3.63403E-04 1.57457E-04 9.67206E-05 1.27826E-04
 6.03710E-05 5.80242E-05 1.60907E-04 2.29486E-04 3.46275E-04 2.39236E-04
 7.42123E-05 9.32402E-05 1.14650E-04 7.88329E-05 5.46163E-05 2.38866E-05
 1.31158E-05 1.12736E-05 9.71772E-06 4.34745E-06 4.04437E-06 7.26983E-06
 6.31163E-06 1.22018E-05 8.32593E-06 5.76786E-06 3.95274E-06 2.70579E-06
 1.96979E-07 1.35688E-07 9.25864E-08 6.41213E-08 4.37320E-08 2.97337E-08
 2.05362E-08 1.43191E-08 9.77129E-09 6.72626E-09 4.65176E-09 3.16927E-09
 2.18945E-09 1.50306E-09 1.01878E-09 7.01168E-10 4.89302E-10 3.34947E-10
 1.07619E-10 1.22225E-10 3.03662E-11 2.63591E-11 2.59330E-11 7.65787E-11
 4.44853E-11 6.40652E-11 2.94719E-11 4.52547E-11 1.45442E-11 3.70399E-11
 1.85716E-11 1.54144E-11 1.71600E-11 1.57675E-11 1.18538E-11 8.83028E-12
 5.87187E-12 5.34562E-12 5.56350E-12 3.11400E-12 1.34988E-12 1.17365E-12
 9.05605E-13 5.51648E-13 3.16313E-13 2.74400E-13 1.11315E-13 3.32175E-14
 4.70735E-15
sourcx=1.,357r0.;
ibl=1 ibr=0
t
```