The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

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Joint ICTP-IAEA Workshop on Nuclear Reaction Data for Advanced Reactor Technologies

19 - 30 May 2008

Cross Section Measurements and Uncertainties of Cross Section Data.

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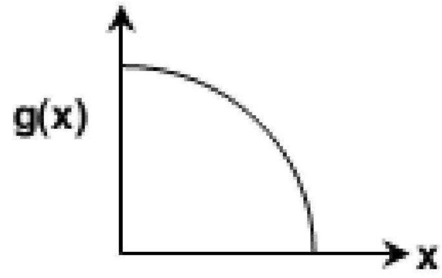
Simple Monte Carlo Example

Evaluate $G = \int_0^1 g(x)dx, \quad \text{with} \quad g(x) = \sqrt{1-x^2}$

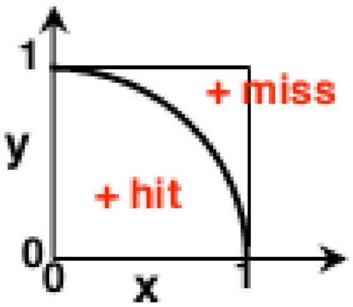


Simulation approach:

"darts game"

For $k = 1, \ldots, N$: choose $\hat{x}_k, \hat{y}_k$ randomly in (0,1),

if $\hat{x}_k^2 + \hat{y}_k^2 \leq 1$, tally a "hit"



$$G = [\text{area under curve}] \approx (1 \cdot 1) \cdot \frac{\text{number of hits}}{N}$$

- **Monte Carlo approach to particle transport**
  - Random Numbers are generated to solve particle transport
  - Vs. deterministic codes

  - Relies on:
    - Physics and particle transport equations
    - Data (cross sections) for the various process
      - Where data are not available relies on models

  - The history are tracked by generating random number (RN): so-called “random walks”
  - According to the value of the RN, the XS and the physics, the particle fate will be different
  - The source particle and possible secondary particles are tracked in the medium according to the geometry and composition
  - Quantities of interested (the so-called tallies) are computed

  - More info and documentation: http://mcnp-green.lanl.gov/

MCNP/MCNPX

MCNP is a code developed by LANL to simulate the transport of neutrons, gamma rays and electrons by the Monte Carlo method. It simulates a coupled transport, i.e., it also accounts for transport of secondary particle resulting the interaction of primary particles.

MCNPX extends the capacilties of MCNP to other particles (e.g. charged particles, heavy ions, pions etc.)

Problems that can be solved/Fields of application

- **Reactor calculations**
  - Burnup
  - Criticality
- **Medical application**
  - Radiography
- **Detector**
  - e.g. C6D6
- **High energy physics (MCNPX)**
- **Space applications**

MCNP users groups

Application	# Groups	Percent
Medical (BNCT, proton therapy, etc.)	50	15
Spacecraft, Cosmic Rays, SEE, propulsion	42	12
Detectors, experiments, Threat Reduction	39	11
ATW, ADS, Energy Amplifiers	37	11
Fuel cycles, beginning to end, including storage	32	9
Accelerator Shielding and Health Physics	28	8
Theoretical Physics	23	7
Neutron Production for Scattering	21	6
Isotope Production	14	4
Radiography	12	4
MCNPX/MCNP code development	11	3
Homeland Security	10	3
Materials studies (IFMIF)	6	2
Radioactive Ion Beams	5	1
Irradiation Facilities	4	1
Neutrino Targets	4	1
Light Sources, electron machines	3	1

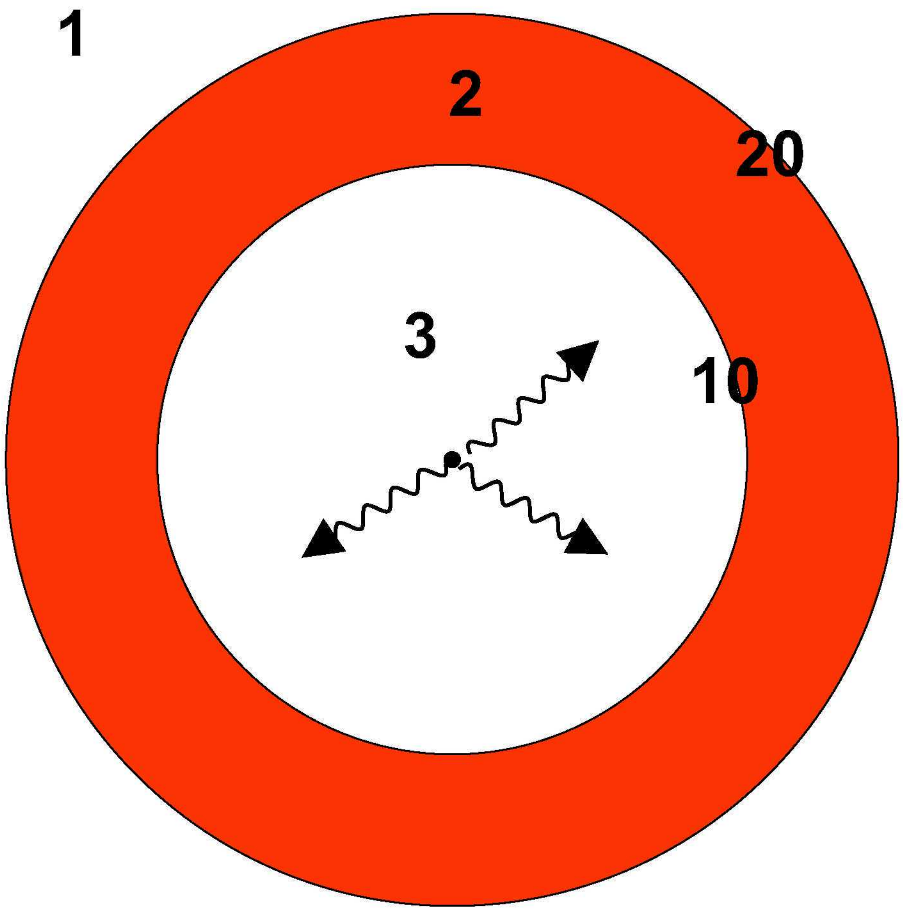
Overview

- **Examples**
  - Gamma ray transport
  - Neutron transport
- **Structure of the input file**
  - Cell
  - Surfaces
  - Materials (XS)
  - Source definition
  - Tally
  - Additional options
- **Output files**
  - Binary
  - Out file
  - Other files (mctal)

Tallies examples

F1:	Surface Current
F2:	Surface Fluence
F4:	Cell Fluence
F5:	Detector Fluence
F6:	Energy Deposition
F7:	Fission Energy Deposition
F8:	Pulse Height

Example 1 – gamma transport



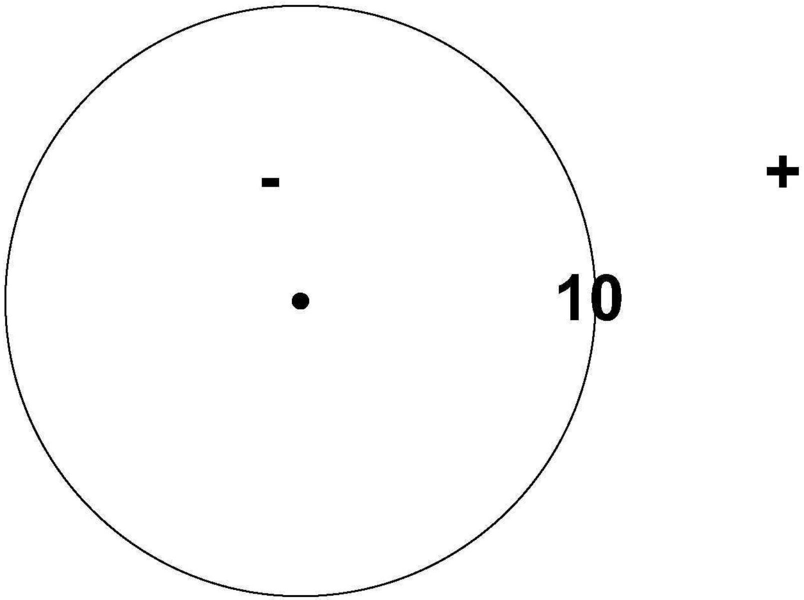
Point source in (0,0,0)
Isotropic source

E_γ = 1 MeV

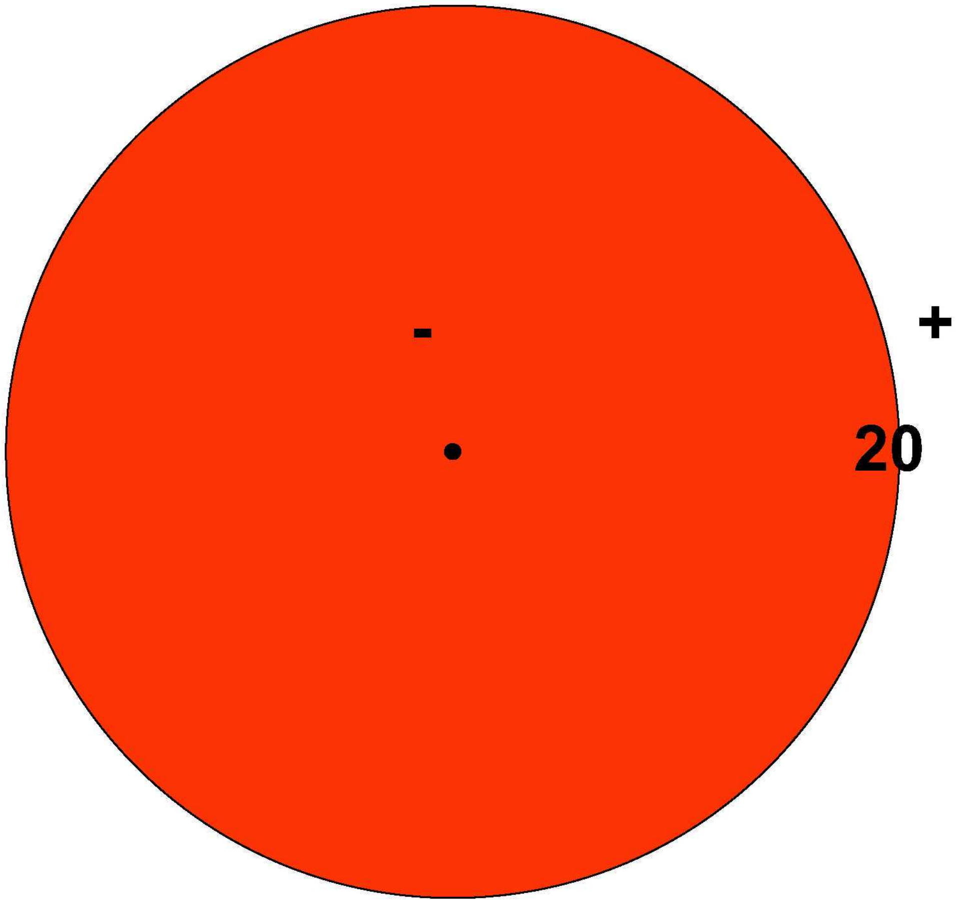
Response in a sphere
Deposited energy
R_{in}=10 cm R_{out}=15 cm

C_6D_6
BaF_2

Example 1 – gamma transport



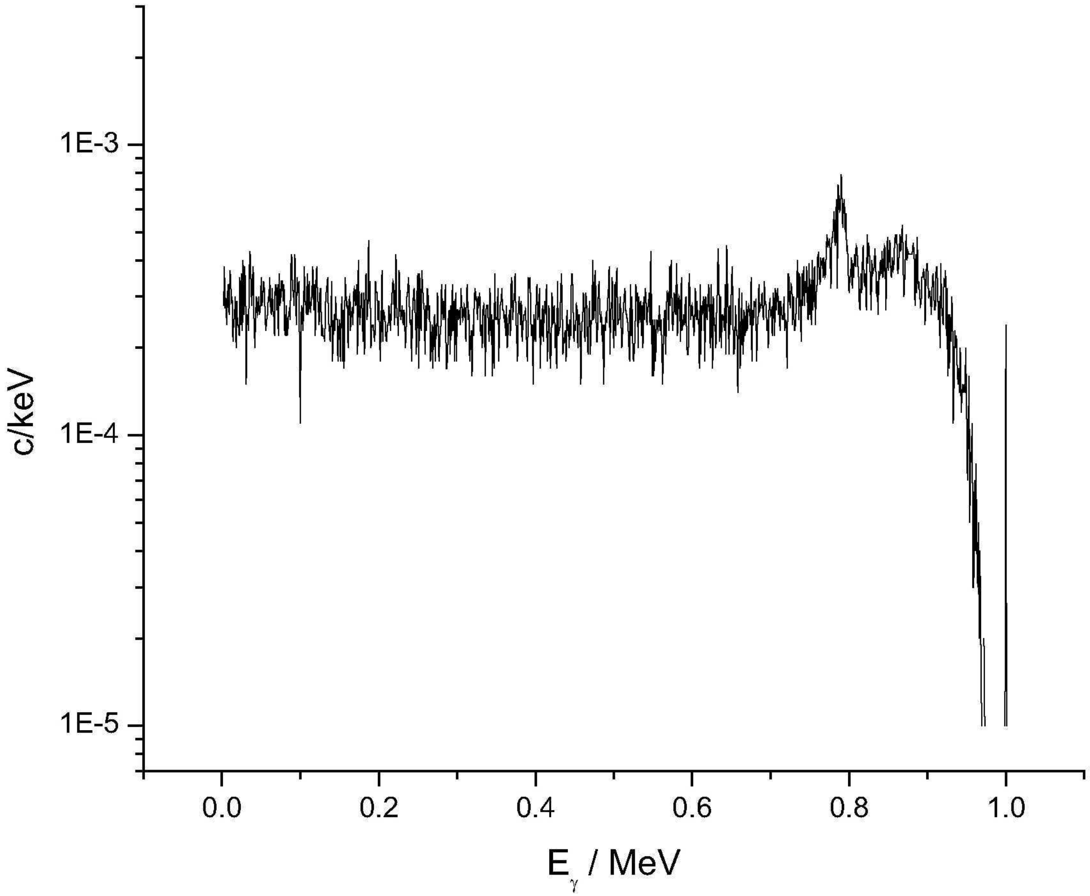
Example 1 – gamma transport



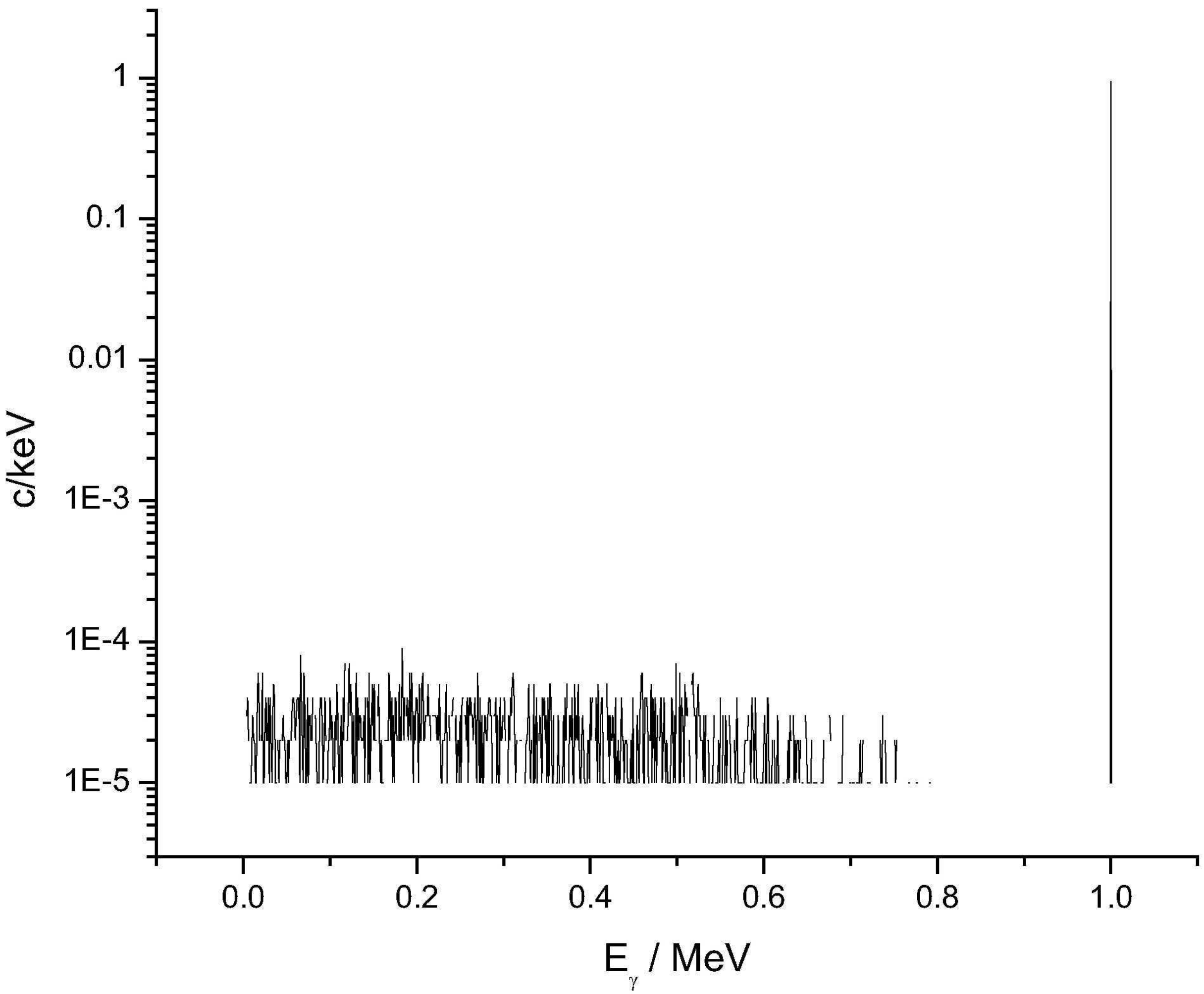
Input 1


```
example 1: g source response for c6d6
c
c ---------------------------------------------------------------------
1   0              20                  imp:n,p,e=0            $ univers
2   1 -1.00       -20 10               imp:n,p,e=1            $ univers
3   0             -10                  imp:n,p,e=1            $ univers
c

c ---------------------------------------------------------------------
c surface definitions for PM
10    so    10.0          $ global univers
20    so    15.0          $ global univers
c ---------------------------------------------------------------------

c ---------------------------------------------------------------------
MODE P E
c ---------------------------------------------------------------------
c     ZZAAA   AT1    ZZAAA AT2
M1     6012   0.5    1002  0.496   1001  0.004                  $ c6d6
c ---------------------------------------------------------------------
SDEF  ERG=1 PAR=2 POS=0 0 0
c
c ---------------------------------------------------------------------
F8:P,E  2
E8     0 999I 1.0          $ 1 keV/bin
c ---------------------------------------------------------------------
NPS    1e5
```

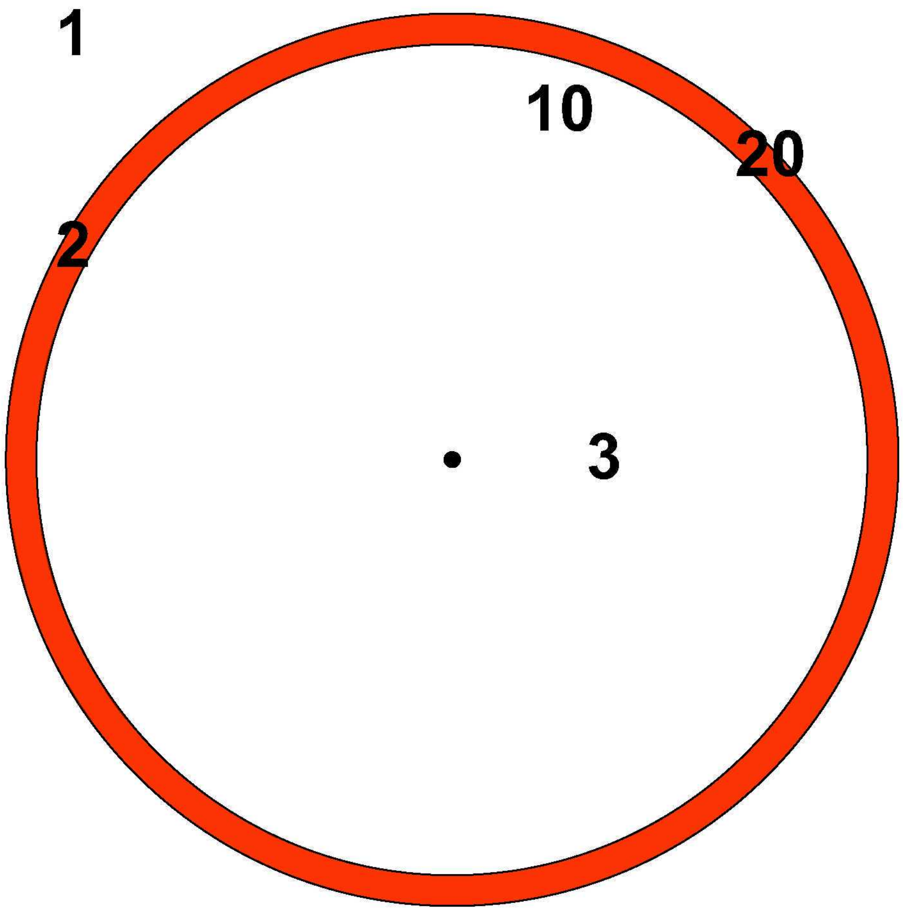
Example 1 – c6d6 result



Example 1 – BaF2 result



Example 3 – neutron transport



Point source in (0,0,0)
Isotropic source

E_n = 0.1-1 MeV

Flux in a sphere vs E
Flux through surfaces
R_{in}=10 cm R_{out}=10.5 cm

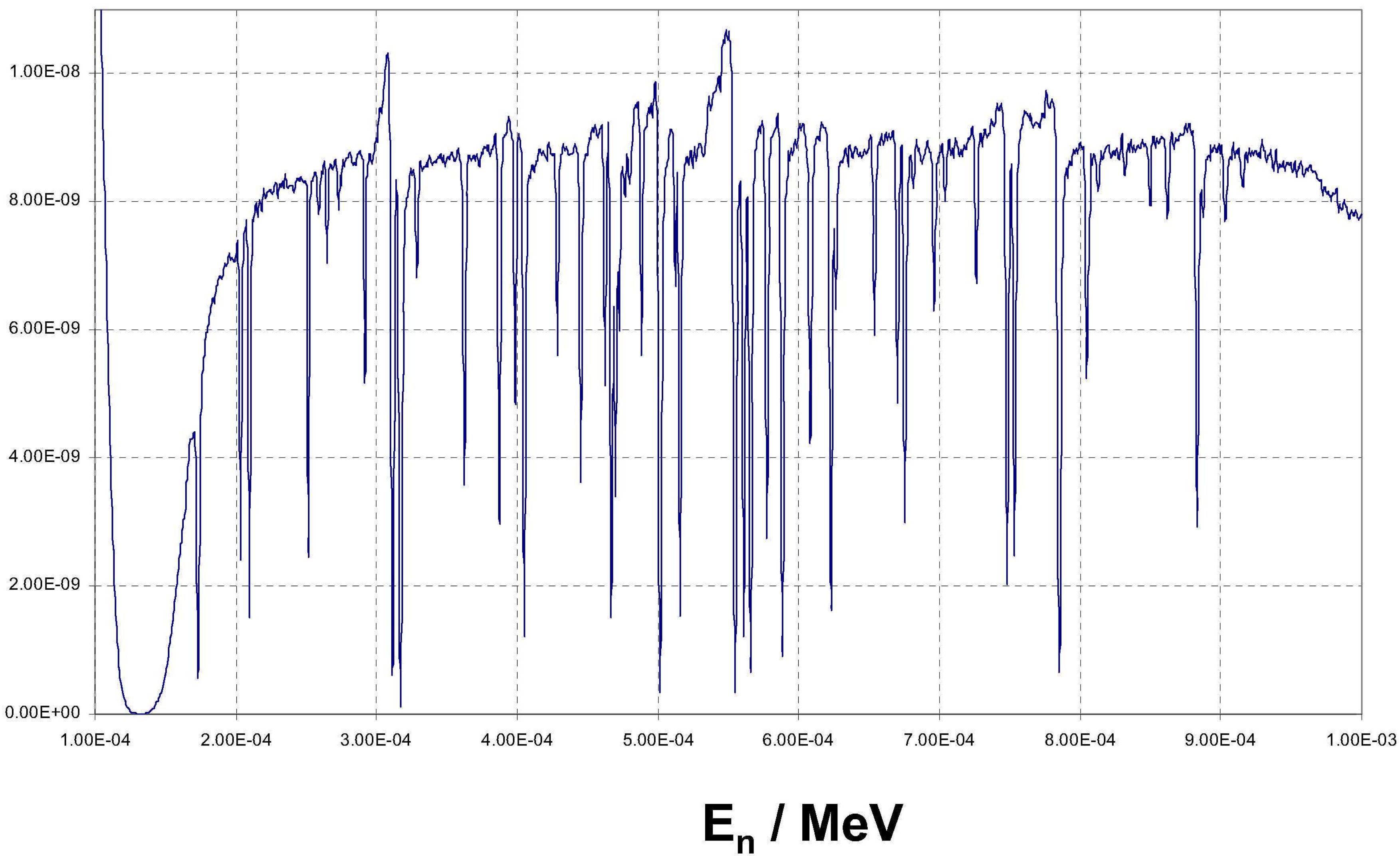
Co+Ag

φ(E) spectrum ?

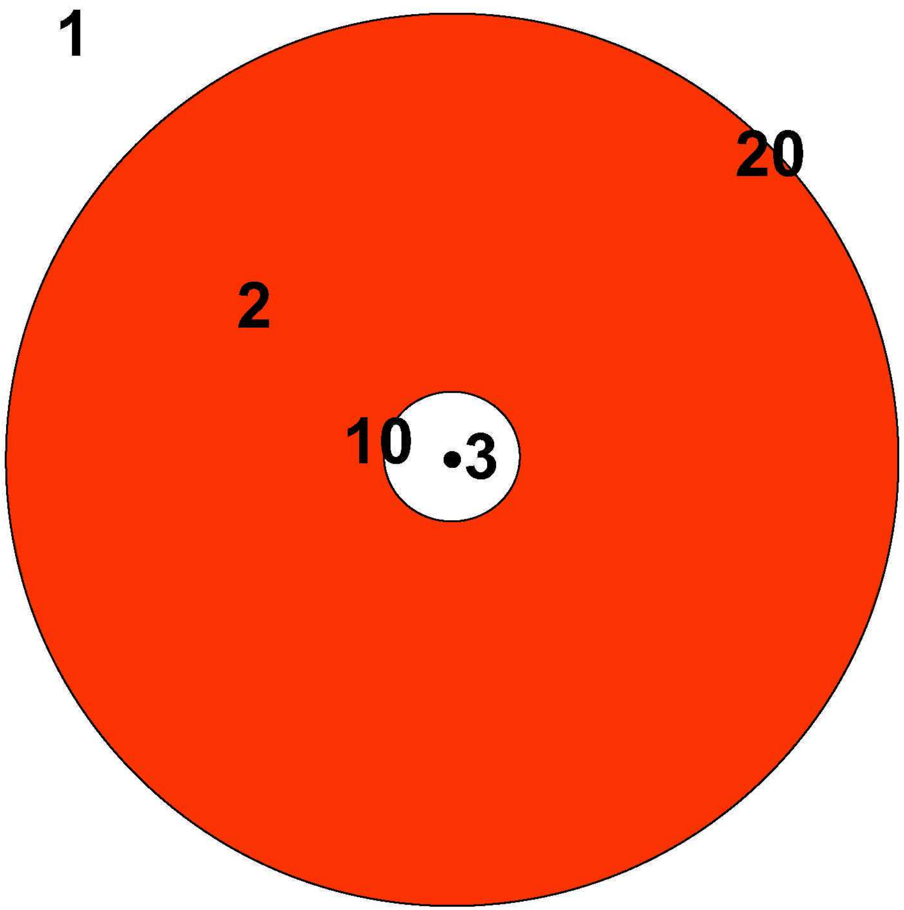
Input 2


```
example 1: n transport response for co+ag
c ------------------------------------------------------------------------
1   0              30                  imp:n,p,e=0           $ univers
2   1 -8.90       -20 10               imp:n,p,e=1           $ univers
3   0             -10                  imp:n,p,e=1           $ univers
4   0             20 -30                  imp:n,p,e=1           $ univers

c ----------------------------------------------------------------------
c surface definitions for PM
10    so    10.0         $ global univers
20    so    10.5         $ global univers
30    so    100.0

c -----------------------------------------------------------------------
MODE N
M1    27059  1.0                                      $ Co
c ----------------------------------------------------------------------
SDEF  ERG=D1 PAR=1 POS=0 0 0
SI1 H .1 1
SP1    0 1
c -----------------------------------------------------------------------
F12:n  30                     $surface flux 2
T12    1.0e00 999I 1.0e03                                 $ 10 ns bins
c -----------------------------------------------------------------------
NPS    1e07
```

Example 3 – flux attenuation by co+ag



Example 2 – neutron transport



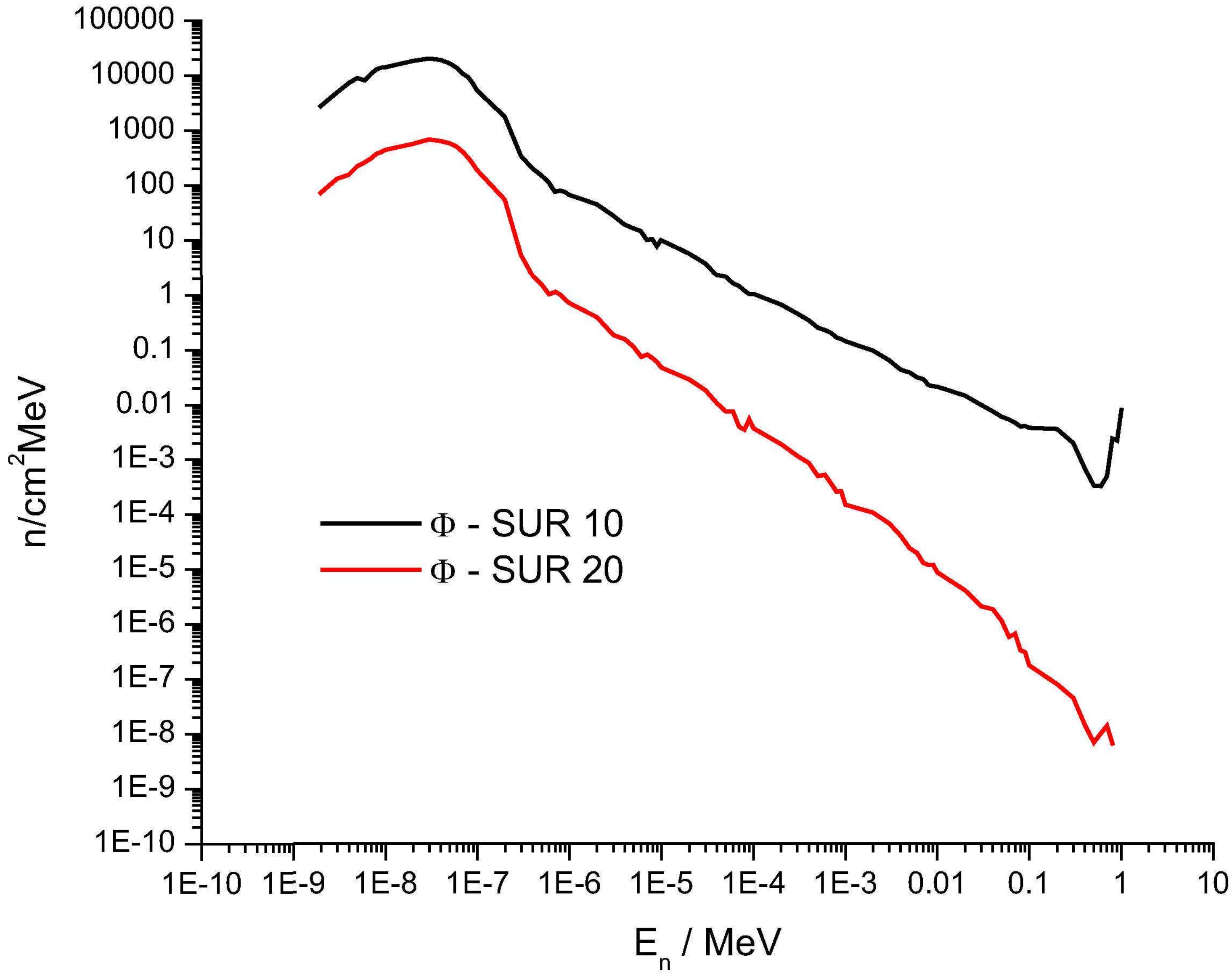
Point source in (0,0,0)
Isotropic source

E_n = 1 MeV

Flux in a sphere vs E
Flux through surfaces
R_{in}=10 cm R_{out}=50 cm

H_2O

Example 2 – flux through surfaces



Example 2 – flux in volumes