

BLACK-BOX MONTE CARLO: IMPLICATIONS ON SIMULATION OF NEUTRON REACTIONS

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UNIVERSITY OF
SURREY

HOW BLACK IS BLACK

A REAL-LIFE EXAMPLE

2MeV NEUTRONS IN ^{27}Al

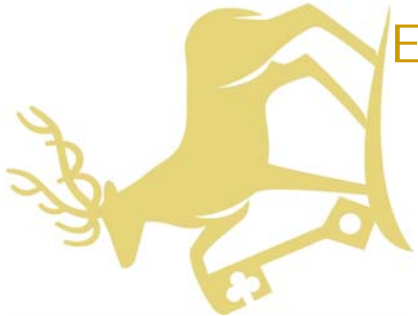
BETA-TESTING MCNPX's DELAYED GAMMA CAPABILITY

THERMAL NEUTRONS IN ^{10}B

GAMMA ENERGY ACCORDING TO MCNPX

GAMMA ENERGY ACCORDING TO FLUKA

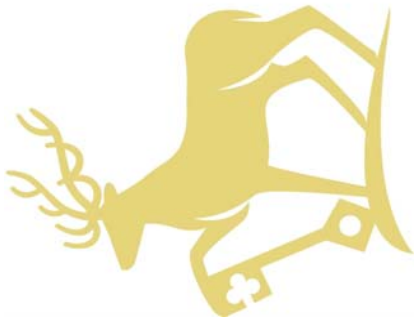
EFFECTS OF MULTIGROUP APPROXIMATION

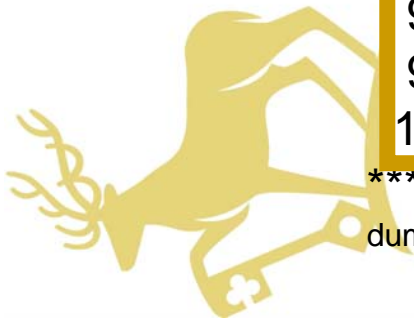


BLACK BOXES: HOW BLACK IS BLACK? A REAL-LIFE EXAMPLE.

MCNP output files

“300 lines of text... just ignore everything. Scroll down to the bottom, look for 2 columns of numbers and plot... that’s all you need.”





nps	mean	e
512000	4.2314E-07	0.0
1024000	3.3935E-07	0.0
1536000	3.1175E-07	0.0
2048000	3.1283E-07	0.0
2560000	3.6148E-07	0.0
3072000	3.3046E-07	0.0
3584000	3.1986E-07	0.0
4096000	2.8916E-07	0.0
4608000	2.8010E-07	0.0
5120000	2.5831E-07	0.2510 0.2020 0.0 52
5632000	2.6965E-07	0.0
6144000	2.4889E-07	0.0
6656000	2.4575E-07	0.0
7168000	2.5214E-07	0.0
7680000	2.7510E-07	0.0
8192000	2.7945E-07	0.0
8704000	2.7360E-07	0.0
9216000	2.6434E-07	0.0
9728000	2.5643E-07	0.0
10000000	2.5948E-07	0.0

dump no. 2 on file line1r nps = 10000000 coll = 6072911 ctm = 0.70 nrm = 65367545
13 warning messages so far.

FOLLOWING THAT ADVICE

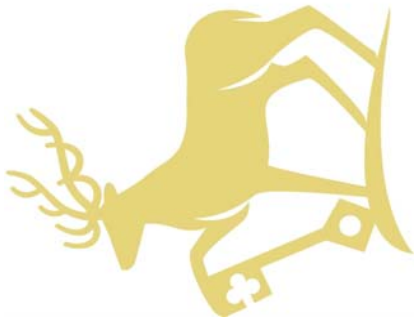
2 COLUMNS DATA

NEW VS

DISTANCE !!!

**ABSOLUTE
NONSENSE**

DATA ARE IN FACT
FLUCTUATION OF THE
MEAN AS THE NUMBER
OF HISTORIES
PROGRESSED !!!



DIFFERENT WAYS OF EXTRACTING DATA FROM MCNPX SIMULATIONS

- STANDARD TALLIES

BLACK-BOX APPROACH
MORE POPULAR

- PTRAC

HIGHLY

MORE F

USEFUL AS PERFECT DETECTOR
TO DETECT PARTICLES WITHOUT

• PERTURBING PARTICLE TRACKS

• STOPPING THEM

• ENERGY DEPOSITION

Neutrons of ^{252}Cf fission spectrum started in ^{27}Al sphere of 16 cm radius

SIMPLE TALLY

CLOSES TO A REAL DETECTOR

TALLY WITH SPECIAL TREATMENT

PTRAC

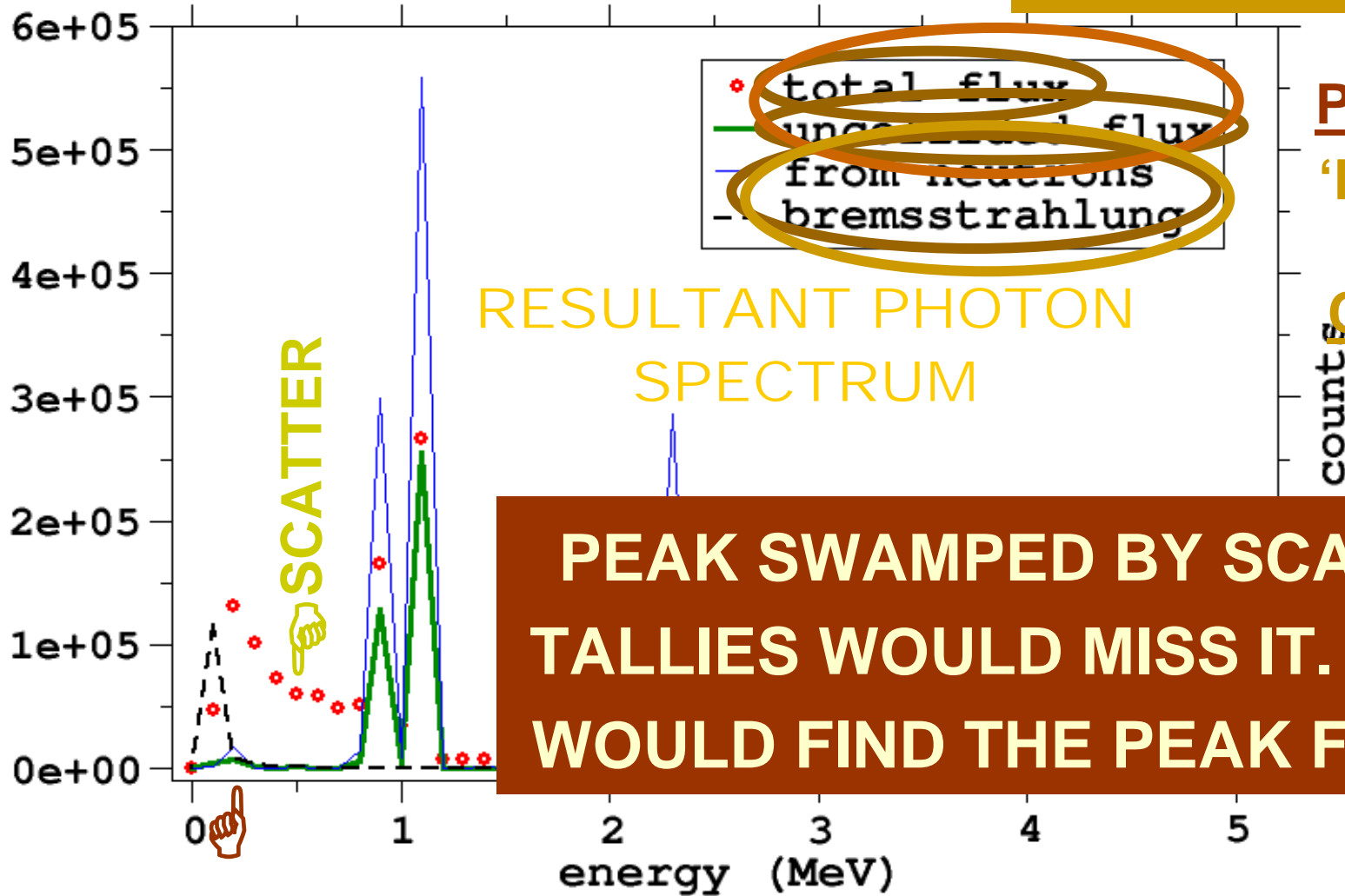
CAN DIFFERENTIATE VARIOUS COMPONENTS

'MEASURE'

PHOTON PRESENCE

'MEASURE'

PHOTON CREATION



RESULTANT PHOTON SPECTRUM

PEAK SWAMPED BY SCATTER.
TALLIES WOULD MISS IT. PTRAC
WOULD FIND THE PEAK FOR US.

BETA-TESTING MCNPX26D

2.0. DESCRIPTION

Note that the new developments and capabilities are developed cautiously, they are

The principal new capabilities are:


- Depletion
- CEM03
- Long file
- Tallies to
- Spherical
- Energy-t
- Charged
- Delayed-
- Criticality

A PRE-RELEASE TEST BY
SELECTED USERS TO GIVE
THE PRODUCT A
REAL-WORLD TEST.

2ND PHASE IN SOFTWARE
DEVELOPMENT: SAMPLE OF
AUDIENCE TRIES OUT
THE PRODUCT.

MCNPX DELAYED GAMMA OPTIONS

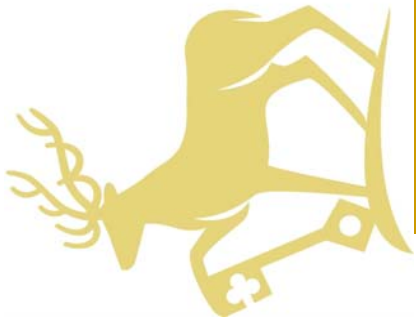
- MULTIGROUP EMISSION
- MULTIGROUP + LINE EMISSION
- LINE EMISSION (**stated as *fragile***)

 IN FACT
DOESN'T
WORK AT ALL

WE REPORTED 4TH FEBRUARY


SAME OPTION STILL
LISTED IN MANUAL OF
SUMMER RELEASE.
STILL DOESN'T WORK.

data are used for nuclides lacking line data.”

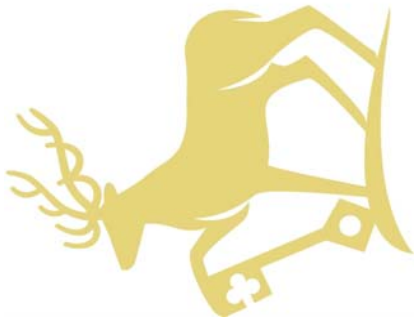


MCNPX DELAYED GAMMA OPTIONS

- MULTIGROUP EMISSION
- MULTIGROUP LINE EMISSION
- LINE EMISSION (**stated as *fragile***)

 IN FACT
DOESN'T
WORK AT ALL

PHYSICS INCREASINGLY ACCURATE
LEFT WITH TWO OPTIONS
COMPUTATION INCREASINGLY SLOW



MCNPX DELAYED GAMMA OPTIONS

- MULTIGROUP EMISSION
- MULTIGROUP + LINE EMISSION
- LINE EMISSION (**stated as fragile**)

APPROXIMATION



IN FACT
DOESN'T
WORK AT ALL

WHERE THE

CONTINUOUS-

ENERGY CROSS

LIMITED

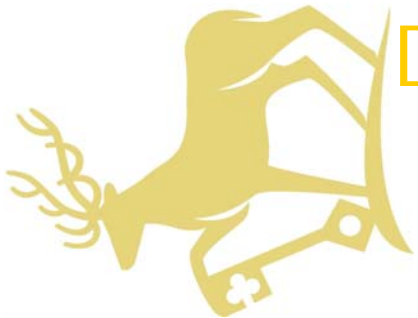
SECTION IS

CROSS SECTIONS

REPRESENTED BY

AVAILABLE

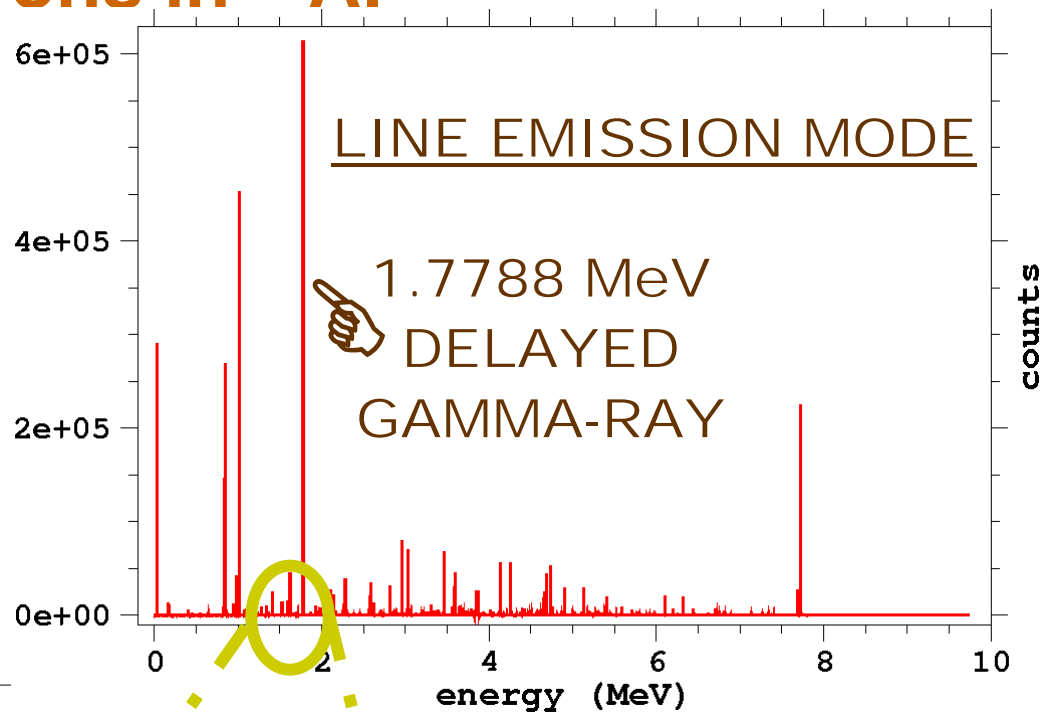
DISCRETE INTERVALS



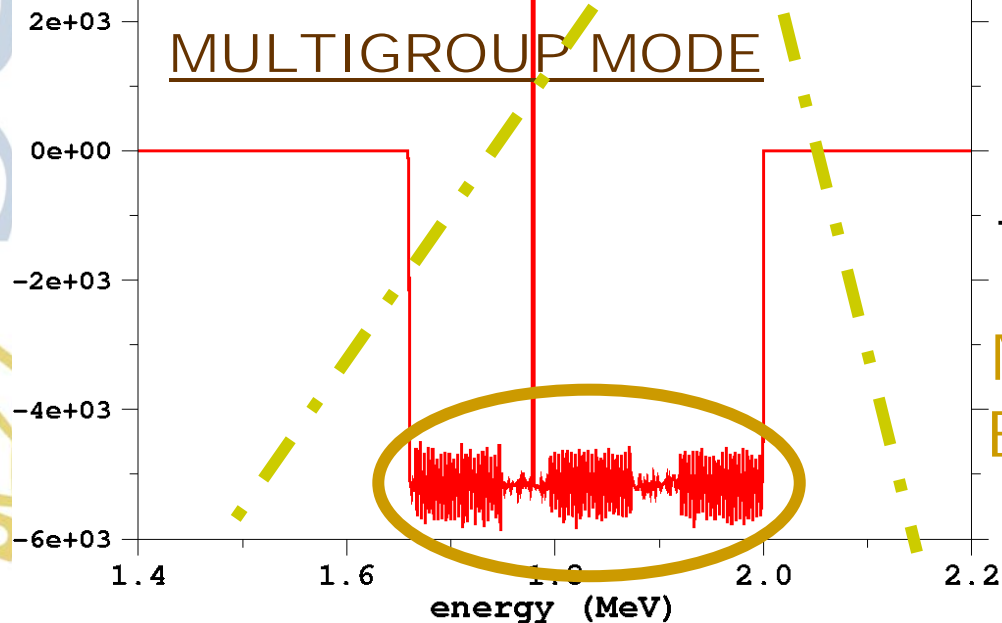
2 MeV neutrons in ^{27}Al

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LINE MINUS
MULTIGROUP



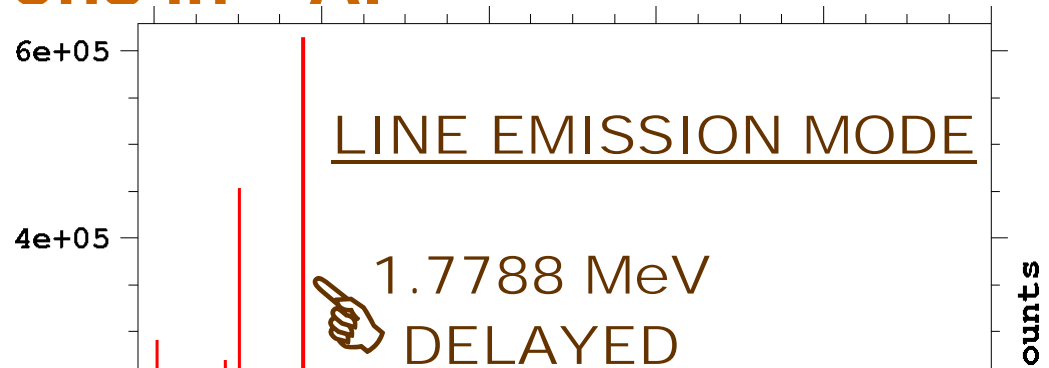
MULTIGROUP MODE



IDENTICAL
GAMMA-LINE
EXCEPT
SMEARED
INTO
THIS
REGION
MULTIGROUP
ENERGY BINS



2 MeV neutrons in ^{27}Al



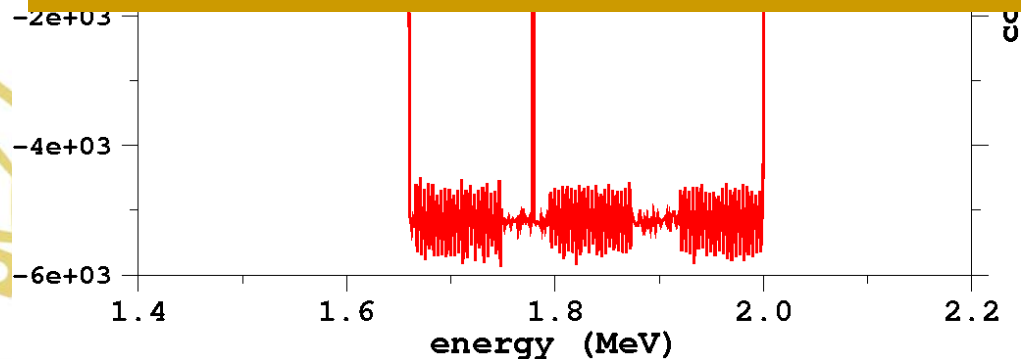
LINE vs MULTIGROUP CROSS SECTIONS

SO FAR SO GOOD:

MULTIGROUP FEATURE AS EXPECTED.

SPECTRA SEEM TO AGREE.

BUT ...



NEUTRON CREATION	tracks	weight (per source particle)	energy
source	1000000	1.0000E+00	2.00
nucl. interaction	0	0.	0.
particle decay	0	0.	0.
weight window	0	0.	0.
cell importance	0	0.	0.
weight cutoff	0	0.	0.
energy importance	0	0.	0.
dxtran	0	0.	0.
forced collision	0	0.	0.
exp. transform	0	0.	0.
ups	0	0.	0.
pho	0	0.	0.
(n, γ)	0	0.	0.
pro	0	0.	0.
del	0	0.	0.
tab	0	0.	0.
tot	0	0.	0.
neut	0	0.	0.
neut	0	0.	0.
total	0	0.	0.
net	0	0.	0.

2 MeV neutron source

NEUTRON CREATION	tracks	weight (per source particle)	energy
source	1000000	1.0000E+00	2.0000E+00
nucl. interaction	0	0.	0.
particle decay	0	0.	0.
weight window	0	0.	0.
cell importance	0	0.	0.
weight cutoff	0	0.	0.
energy importance	0	0.	0.
dxtran	0	0.	0.
forced collision	0	0.	0.
exp. transform	0	0.	0.
ups	0	0.	0.
pho	0	0.	0.
(n, γ)	0	0.	0.
pro	0	0.	0.
del	0	0.	0.
tab	0	0.	0.
tot	0	0.	0.
neut	0	0.	0.
neut	0	0.	0.
total	0	0.	0.
net	0	0.	0.

LINE MODE

MULTIGROUP MODE

OVER-PRODUCE

UNDER-PRODUCE

LINE MODE SAYS 0.6M,
 MULTIGROUP MODE SAYS 1.8M.
 WHICH IS RIGHT? PROBABLY NEITHER!
 THE ANSWER IS UNDERSTOOD TO BE
 SOMEWHERE IN BETWEEN!

PHOTON	tracks	weight (per source particle)	energy
source	0	0.	0.
nucl. interaction	0	0.	0.
particle decay	614766	6.1477E-01	1.0935E+00
weight window	0	0.	0.
cell importance	0	0.	0.
weight cutoff	0	0.	0.
energy importance	0	0.	0.
dxtran	0	0.	0.
forced collision	0	0.	0.
exp. transform	0	0.	0.
from neutrons	3951409	3.9514E+00	1.0169E+00
bremstrahlung	2178504	2.1785E+00	2.0689E-01
p-annihilation	530190	5.3019E-01	2.7093E-01

(n, γ) IN ²⁷Al PROMPT

SAME: ok

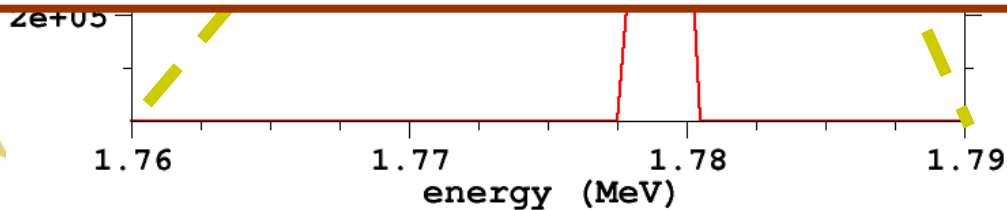
ZOOM IN FOR

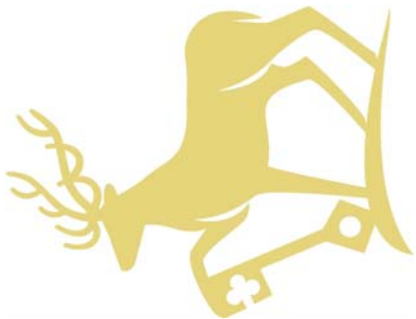
LINE EMISSION MODE

DOUBLE-SAMPLING OF
DELAYED GAMMA IN ²⁷Al

MCNPX SHOULD EITHER HAVE
REFUSED TO RUN, OR
AUTOMATICALLY SWITCHED ONE
EMISSION OFF, OR AT LEAST GIVEN
A WARNING MESSAGE

The delayed gamma
 $^{28}\text{Al} \rightarrow ^{28}\text{Si} + \beta^-$
data form these two ZAIDs (FRA02). [MCNPX manual]



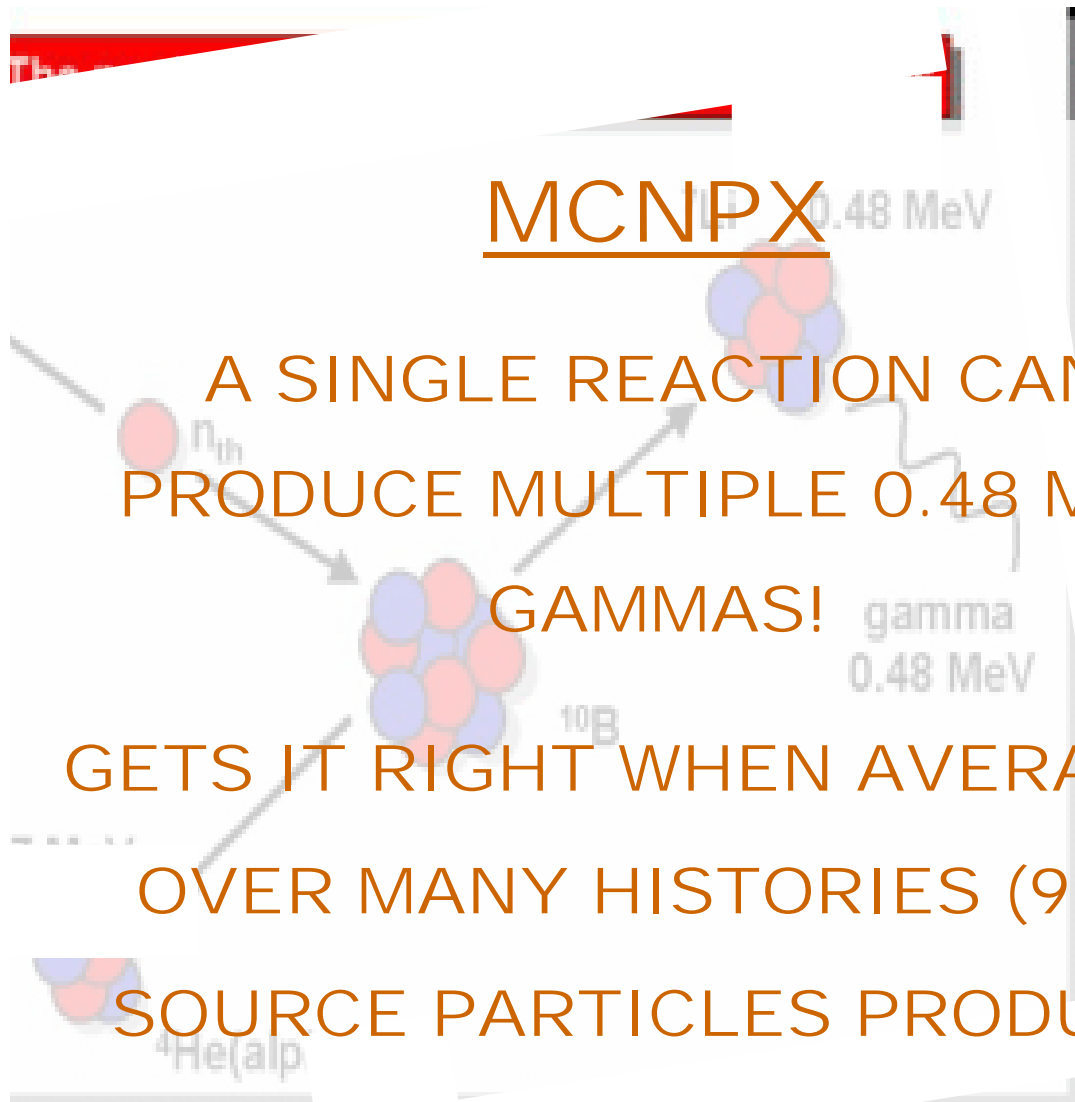
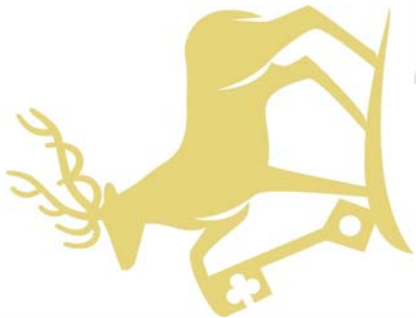


THERMAL NEUTRONS IN A
HOMOGENEOUS SEA OF ^{10}B

WHAT DO WE EXPECT OF
THE GAMMA SPECTRUM?

What do we get from a
FLUKA[‡] simulation?

[‡] *developed by INFN & CERN*



MCNPX

A SINGLE REACTION CAN
PRODUCE MULTIPLE 0.48 MeV

GAMMAS! gamma
0.48 MeV

GETS IT RIGHT WHEN AVERAGED

OVER MANY HISTORIES (94%

SOURCE PARTICLES PRODUCE

0.48MeV GAMMAS)

 **EXPLANATION**

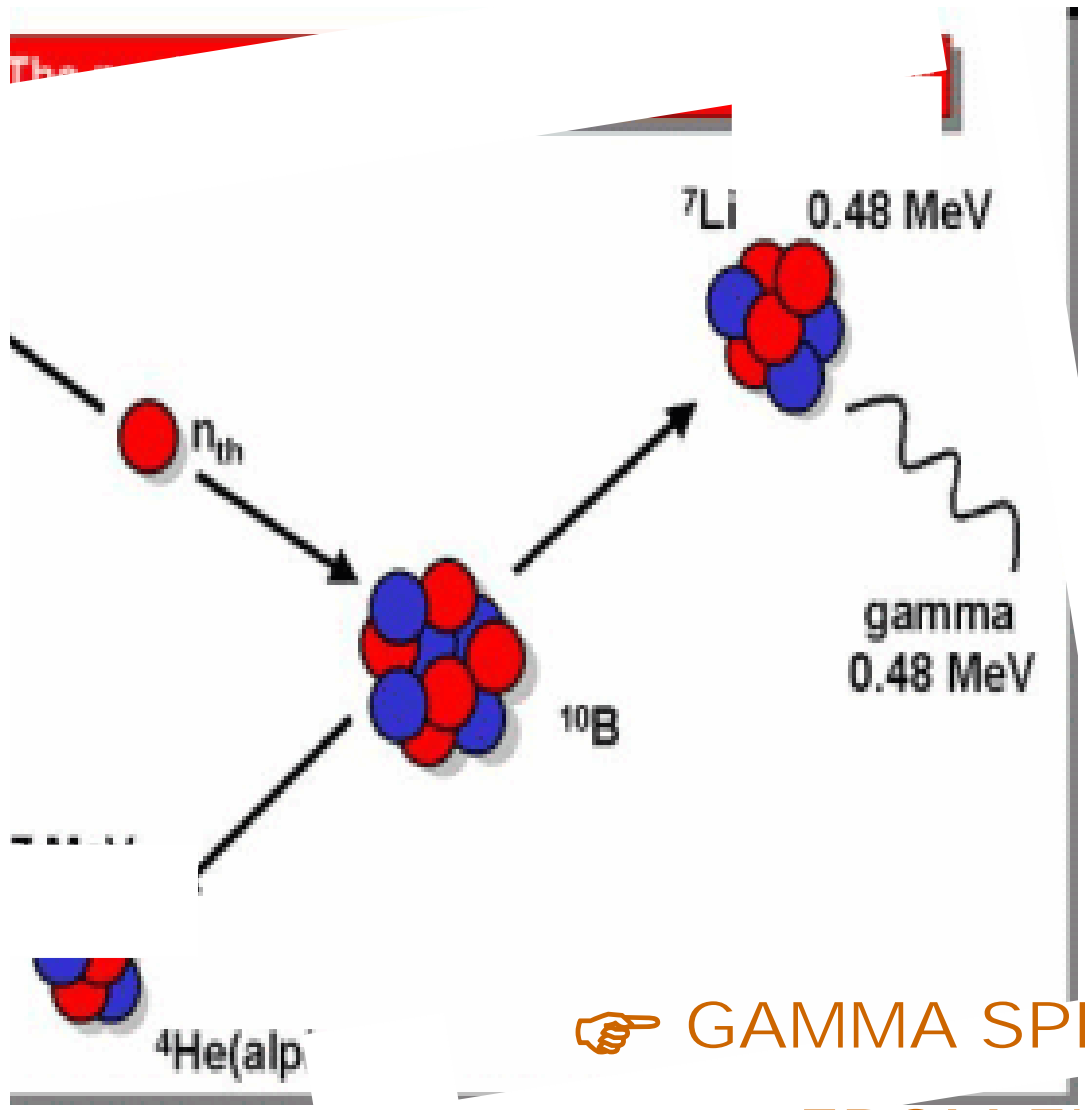
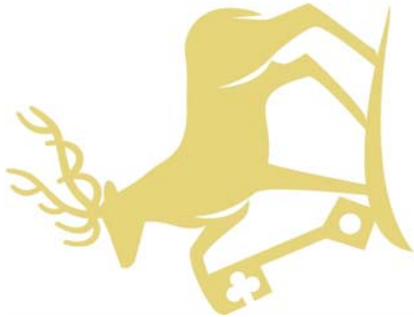
deviation from physical reality: the emission of secondary gamma rays from neutron collisions. In fact, in MCNP secondary photons are sampled independently from the type of neutron collision. For example, it is possible for a neutron in a collision with uranium to generate fission photons in the course of an elastic scattering. This technique provides correct answers when we consider the average outcome of a large number of histories, and it is well suited for biased calculations, but it fails when considering the single history [2]. This is a severe drawback in the simulation of correlation measurements in which the experimental quantity of interest is the delay between particles emitted by a single event [1,3].

In this paper we describe the MCNP-PoliMi

of the standard MCNP code. A major deviation to the standard code is introduced by inverting the order of photon production and neutron production.

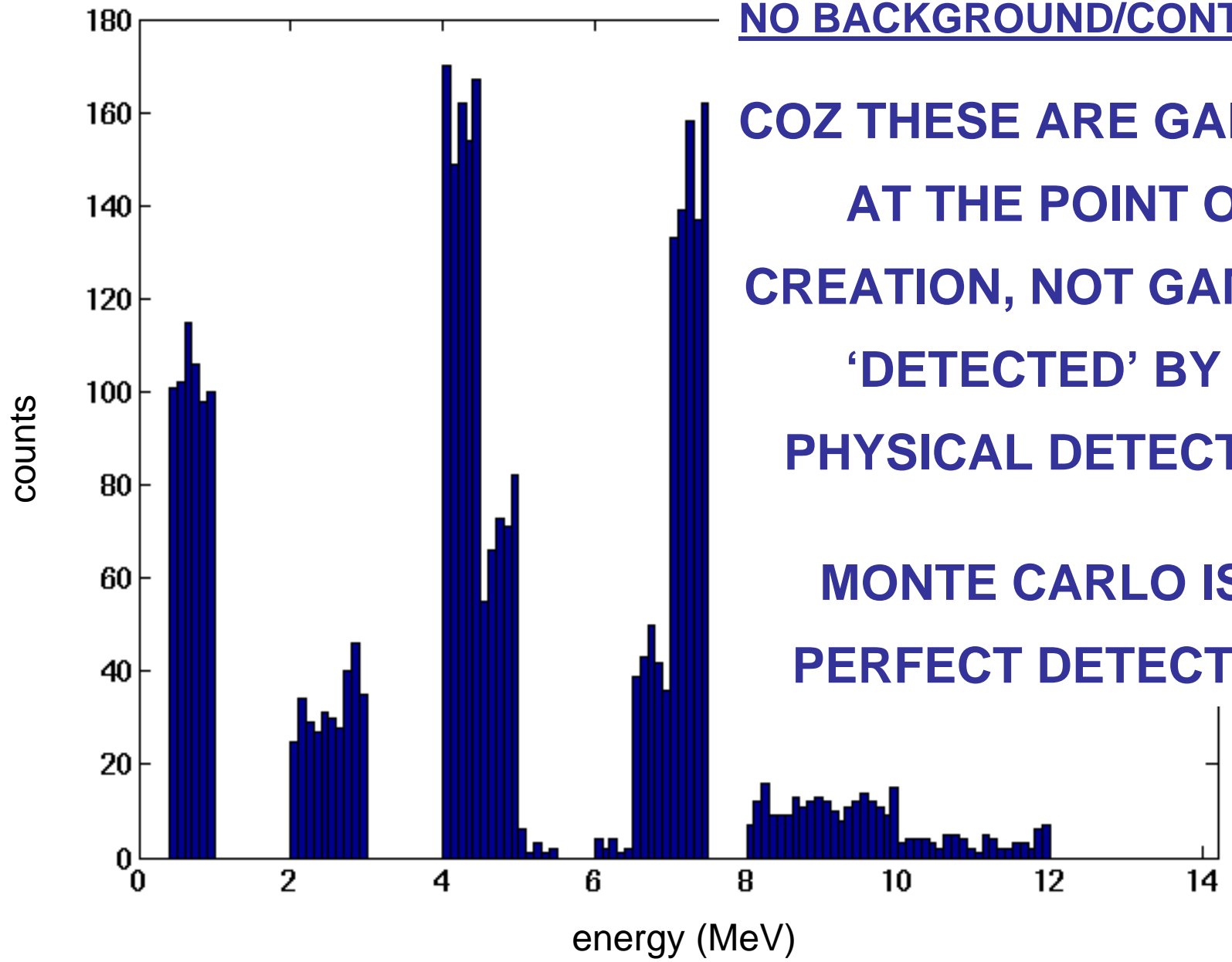
The MCNP-PoliMi code is used for particle tracking. This means that the weight of each particle is equal to one to each of the particles born at the source and to each of the particles born at a collision. With this method, particles have weight equal to one when they escape or are absorbed, making the process simpler to model.

The modifications to the standard code for transport can be grouped in two categories: the first concerns secondary particle production, whereas the second concerns



👉 GAMMA SPECTRUM FROM FLUKA

FLUKA: GAMMA SPECTRUM FROM THERMAL NEUTRONS IN ^{10}B

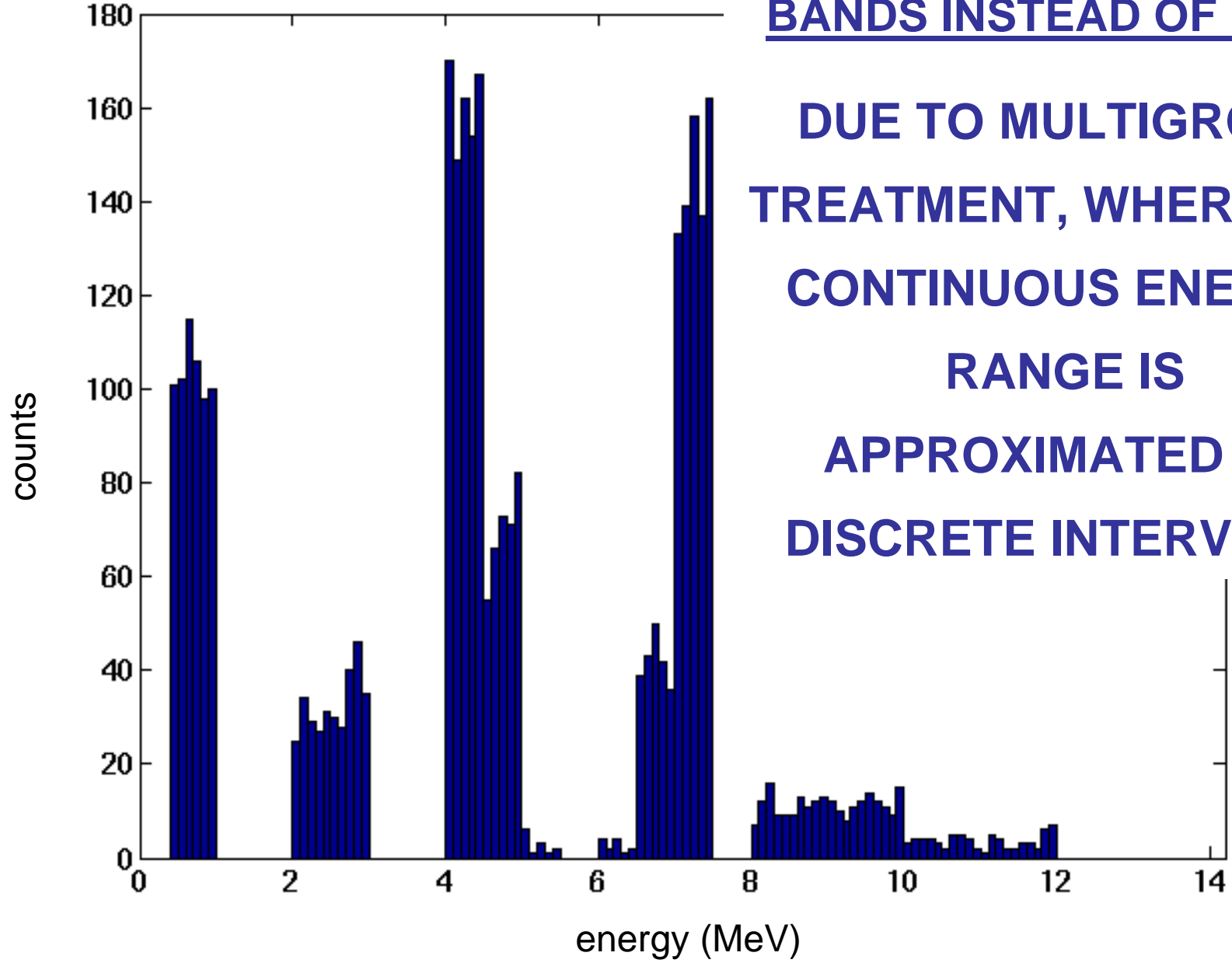


NO BACKGROUND/CONTINUUM

COZ THESE ARE GAMMAS
AT THE POINT OF
CREATION, NOT GAMMAS
'DETECTED' BY A
PHYSICAL DETECTOR.

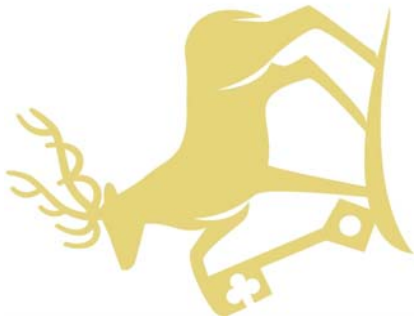
MONTE CARLO IS A
PERFECT DETECTOR!

FLUKA: GAMMA SPECTRUM FROM THERMAL NEUTRONS IN ^{10}B



BANDS INSTEAD OF LINES

DUE TO MULTIGROUP TREATMENT, WHERE THE CONTINUOUS ENERGY RANGE IS APPROXIMATED AS DISCRETE INTERVALS.



Hi Mary,

there are two neutron cut-offs in FLUKA. 1.960E-02 GeV is the cut-off for high-energy neutrons, below which the special multigroup treatment starts. With the present version it cannot be changed: it could be changed only when using a different library for low-energy neutrons (one with a different maximum energy). This cut-off is changed with PART-THR, but only when allowed by the low-energy neutron library

The second cut-off, which is changed with LOW-BIAS, is the real cut-off. It is not expressed in energy, but as a neutron group number. Look carefully in the output:

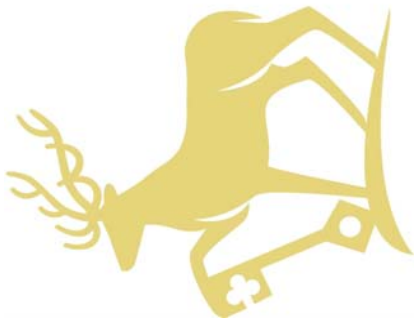
The first cut-off is reported as follows:
Cut-off kinetic energy for NEUTRON transport: 1.960E-02 GeV

And the second cut-off as follows: (here the group cut-off has been set as 73 for regions 1 and 2 - which means no cut-off at all - and group 65 in regions 3 and 4)

Region number	Particle importances Fluka part.	importances EM part.	RR factor Low en. n.	Cut off group	N.A. abs. group
1	1.0000	1.0000	1.0000	73	72
2	1.0000	1.0000	1.0000	73	72
3	1.0000	1.0000	1.0000	65	72
4	1.0000	1.0000	1.0000	65	72

Here the group cut-off has been set as 73 for regions 1 and 2 - which means no cut-off at all - and group 65 in regions 3 and 4, which means 7.3375E-09 GeV (see energy group structure in the Manual).

Alberto



THERMAL NEUTRONS IN A HOMOGENEOUS SEA OF ^{10}B

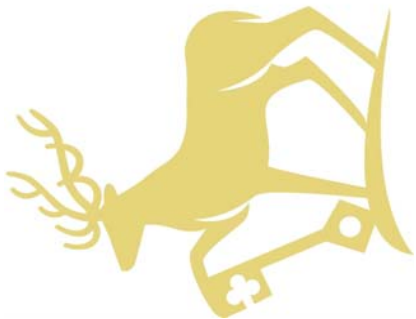
**THINGS TO LOOK AT BEFORE
MODELLING COMPLICATED &
INHOMOGENEOUS GEOMETRIES**



NOT THE SAME DUE TO APPROXIMATIONS

What do we get from a
FLUKA[‡] simulation?

**SHOULD KNOW THIS BEFORE
LOOKING AT FLUX OR DOSE**



MORE ON EVENT-BY-EVENT SIMULATIONS

TO BE PRESENTED AT THE
AMERICAN NUCLEAR SOCIETY
INTERNATIONAL MEETING
11-15 NOV WASHINGTON

***Chin & Spyrou 2007 Event-by-event Monte
Carlo tracking of neutron-nucleus collisions
in neutron detectors Trans ANS***