GEANT4 SIMULATIONS FOR THE ANALYSIS OF (n, γ) MEASUREMENTS AT n_TOF

J. Lerendegui-Marco[1,*], C. Guerrero[1], M. A. Cortés-Giraldo[1], J. M. Quesada[1]

1) Dep. Física Atómica, Molecular y Nuclear, Universidad de Sevilla, Facultad de Física, Apdo. 1065, 41080 Sevilla, España.
(*) e-mail: jlerendegui@us.es

1. INTRODUCTION

Neutron induced capture cross-section measurements rely either on post-irradiation activation analysis or on the detection of the prompt γ-rays emitted in the (n,γ) reaction. At the n_TOF facility [1], the study of the resonance structure is performed at a pulsed neutron source; a high energy resolution is obtained with the of Flight (TOF) technique.

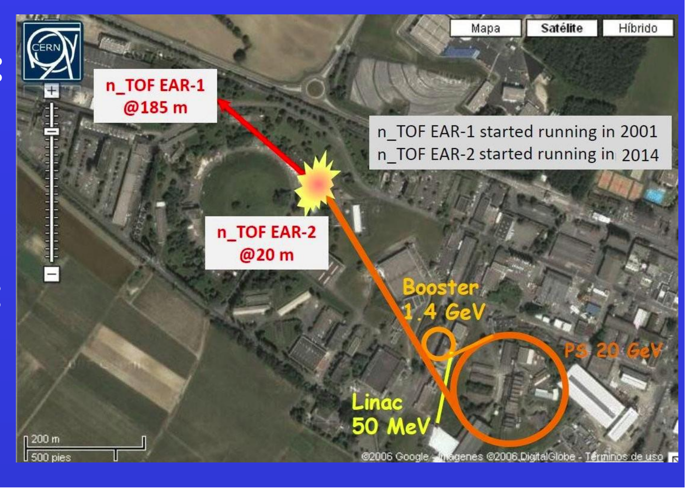
The radiative capture experiments are carried out either with a 40 BaF_2 crystal Total Absorption Calorimeter or with a set of C_6D_6 scintillators [2].

In the second approach, a lower neutron sensitivity and a simpler setup are counter-balanced by a more elaborated analysis procedure, the so called Pulse Height Weighting Technique, that requires a manipulation of the determined detector response.

The modeling of the detector response can just be done with help of Monte Carlo (MC) simulations. The goal of this work is to provide an overview of the analysis technique focusing on the detailed simulations performed with the Geant4 toolkit [3].

n_TOF @ CERN

- Neutrons generated by spallation in Pb with a 7ns pulsed beam of 20 Gev/c protons.
- Neutron Flux from thermal to GeV.
- Two Experimental Areas (EAR):
- **EAR1, @ 185m forward:**
  - $\Delta E/E = 3.\ 10^{-4}$ (1keV)
  - 4.10^5 n/pulse/cm^2
- **EAR2, @ 19m upwards:**
  - $\Delta E/E = 8.\ 10^{-3}$ (1keV)
  - 8.10^6 n/pulse/cm^2



2. TOTAL ENERGY DETECTION TECHNIQUE

EXPERIMENTAL SETUP

- Prompt gammas detected with Deuterized Benzene, **C_6D_6 scintillation detectors** and TOF registered.
- **Neutron flux monitors**: Charged particle detectors Cross-section standards ^{10}B(n,α) , ^{6}Li (n,α), ^{235}U(n,f)

PRINCIPLES

The **total energy detection principle[4]** requires the use of low efficiency detectors and it is based on:

I. Just one γ-ray per cascade detected:

$$\varepsilon \ll 1$$

II. Total efficiency α Energy Cascade:

$$\varepsilon_\gamma = \alpha E_\gamma \rightarrow \varepsilon_c = \sum_\gamma \alpha E_\gamma = \alpha E_c = \alpha(S_n + E_n)$$

Detection efficiency is independent of the actual cascade path

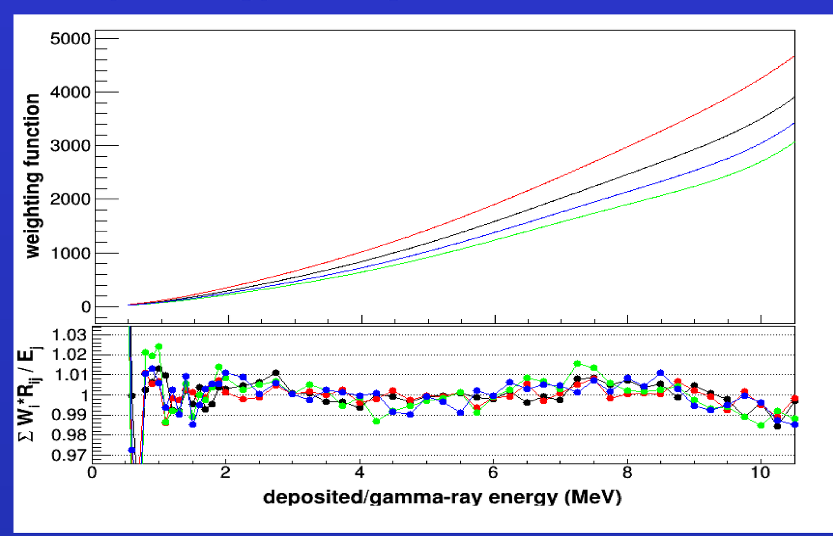
Condition II needs manipulation of the response:

$$R(E) = R_i \rightarrow W_i R_i$$

$W_i = W(E)$: Energy (pulse height) dependent factor, the so-called Weighting Function.

WEIGHTING FUNCTIONS

To determine the **Weighting Function (WF)**. The response of the detection setup to the range of gamma ray energy using **MC simulations**

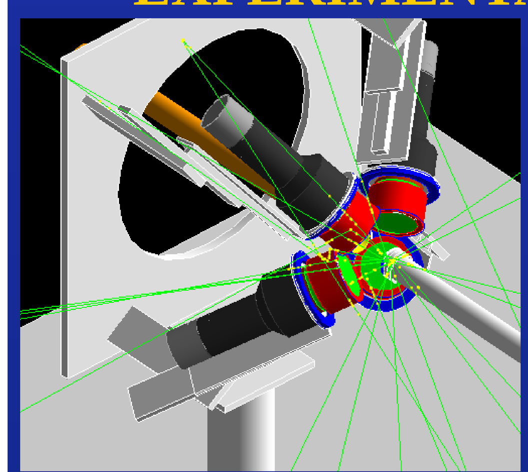


WF: 4th-6th order polynomials obtained with least-squares fit of several γ-ray responses $R_i(E_\gamma)$.

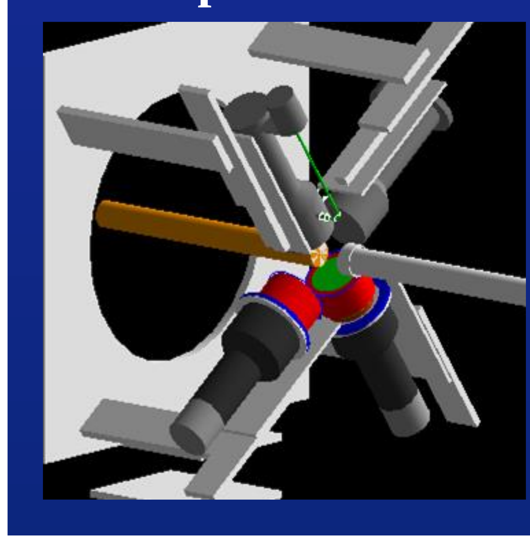
$$min \sum_j \left(\sum_i W_i R_i(E_{\gamma j}) - \alpha E_{\gamma j} \right)^2$$

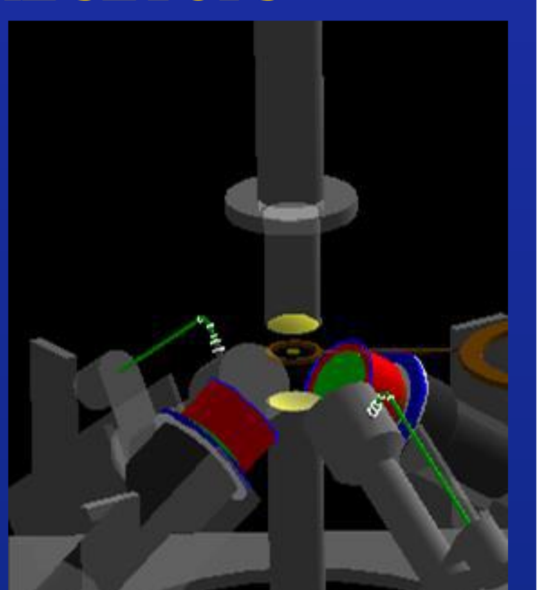
3. SIMULATIONS WITH GEANT4

SIMULATED EXPERIMENTAL SETUPS



Exp. Area 1



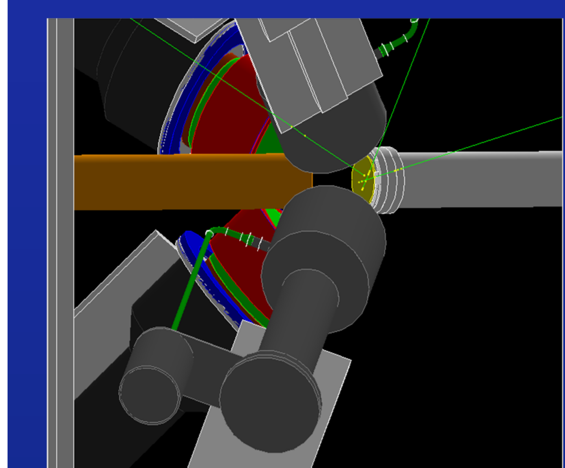


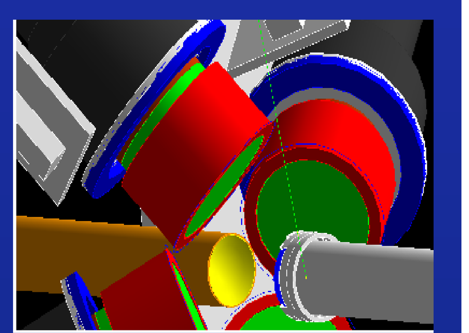
Exp. Area 2

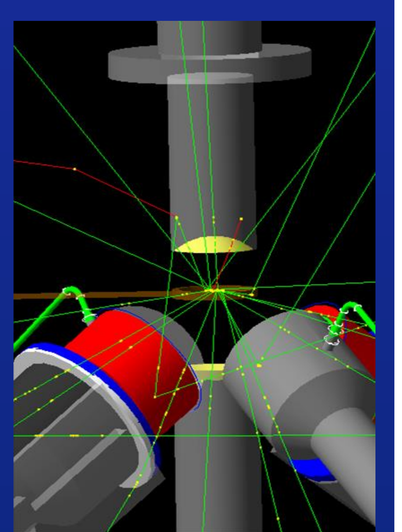
Flexible Application :

- Both experimental areas implemented
- Adjustable distances, orientation of detectors

RELEVANCE OF DETAILS



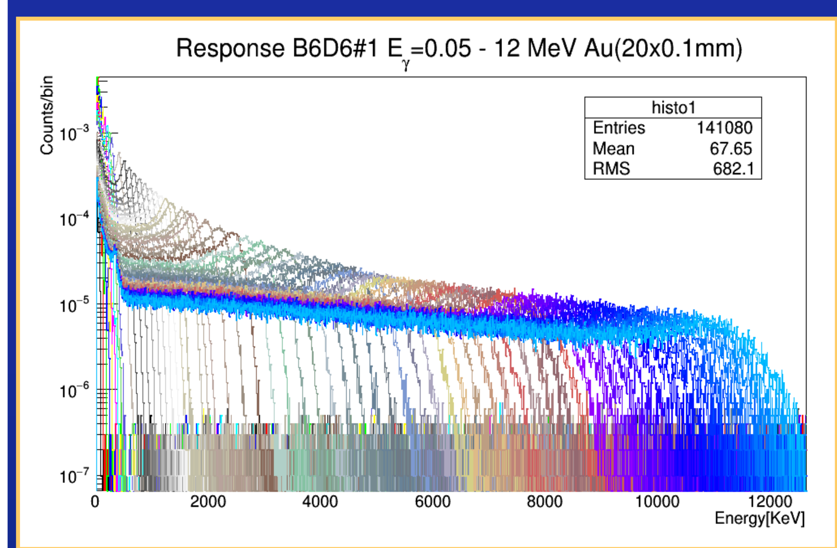




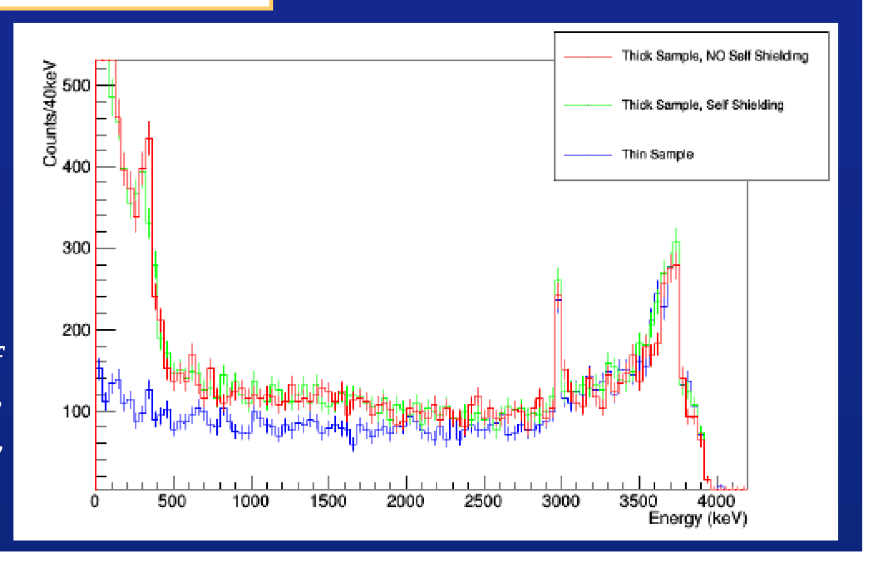
Factors affecting the response:

- Different detector models
- Dead materials detectors
- Effect of the g-ray transport in sample (materials & dimensions)
- Self-Shielding

EXAMPLES OF RESULTS



Simulated response of a C_6D_6 detector to 65 γ-ray energies including resolution broadening.



Effect of sample thickness and self shielding in the response of the detector to a 4 MeV γ-ray

4. SUMMARY

The analysis of the high accuracy (n,γ) cross-section measurements with C_6D_6 detectors includes an a-posteriori manipulation of the experimental response. In this stage of the analysis, detailed MC simulations are basic to reduce the uncertainties in the method.

This work presents the accurate implementation of the new experimental setup for radiative neutron capture measurements at n_TOF. This Geant4 tool is being used for the planning and analysis of the capture cross-section measurements of ^{171}Tm , ^{204}Tl and ^{242}Pu.

In addition, an effort has been done to release a flexible user-friendly version of the application [5] to facilitate the future analysis of neutron capture measurements with C_6D_6 detectors at n_TOF.

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