LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
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From Bonner Spheres to a Single Smart Detector Approach for Neutron Field Characterisation

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LIP summer internship workshop 3-4 september 2026

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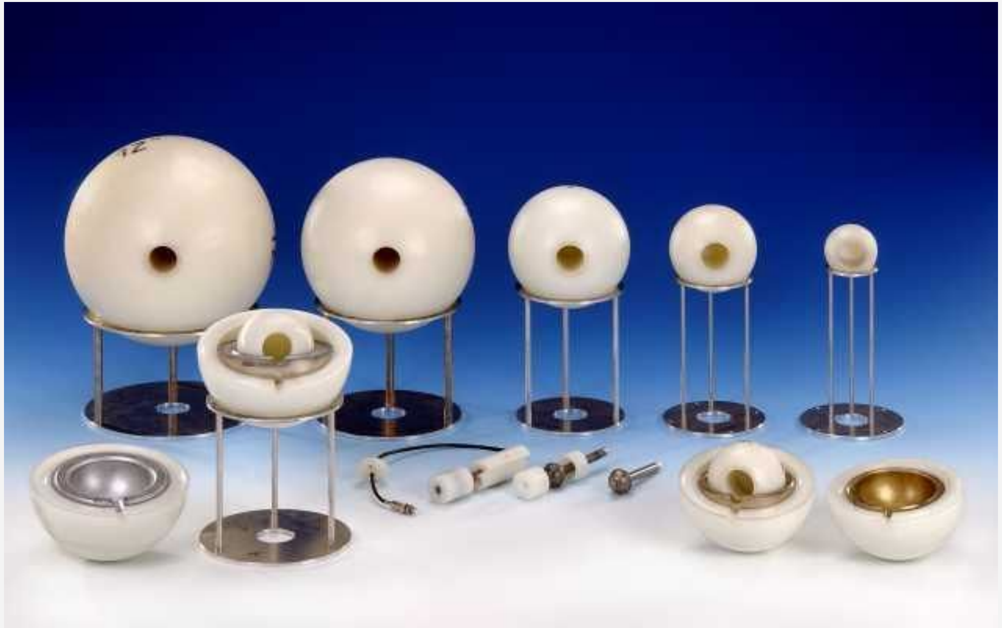
MOTIVATION

Neutron Spectrometry

Neutron fields can span a wide energy range, making the determination of their energy spectrum essential in applications such as:

- Radiation protection
- Nuclear physics and industry
- Medical applications



Different moderators ⟶ Different responses

Conventional Bonner Sphere Spectrometer

How Bonner Sphere Spectrometry Works

1. **Moderate**

   Neutrons enter a polyethylene sphere and are slowed down before reaching the central detector.

2. **Measure/ Neutron Detection**

   Different sphere sizes produce different energy-dependent detector responses.

3. **Reconstruct**

   The measurements from all spheres are combined to estimate the neutron energy spectrum .

Spectrum Reconstruction

$$\mathbf{M} = \mathbf{R}\boldsymbol{\Phi}$$

M : measurement vector
R: detector response matrix
Φ : incident neutron spectrum

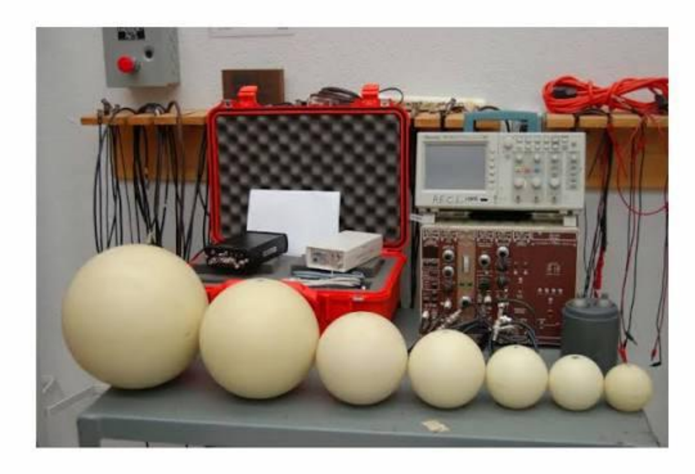
The Inverse Problem

Measured Responses + Response Matrix → **Reconstructed Spectrum**

GOAL / OBJECTIVES

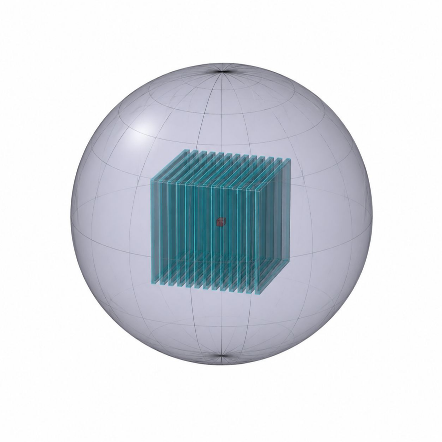
Evaluate an nRPC-based detector concept with HDPE moderation, using the conventional **Bonner Sphere Spectrometer** as a benchmark.

Bonner Sphere Benchmark



Monte Carlo Modelling

nRPC + HDPE Model



DETECTOR MODEL

A set of Bonner Sphere configurations was modelled in ANTS3/GEANT4 to characterize their energy-dependent neutron response.

Simulation Configurations:

- 9 sphere diameters: 2.5”, 3”, 3.5”, 4”, 5”, 6”, 8”, 10”, 12”
- HDPE moderator surrounding a central neutron detector
- Identical source and simulation conditions
- Modelled in ANTS3/GEANT4

DETECTOR MODEL

A set of Bonner Sphere configurations was modelled in ANTS3/GEANT4 to characterize their energy-dependent neutron response.

Response Characterization:

- Each configuration produces an energy-dependent response Ri(E)
- The 9 responses from the response matrix R
- R is used for neutron-spectrum reconstruction

Monochromatic Spectrum

The response matrix was validated using monoenergetic neutron sources at 12 reference energies.

Monoenergetic Inputs:

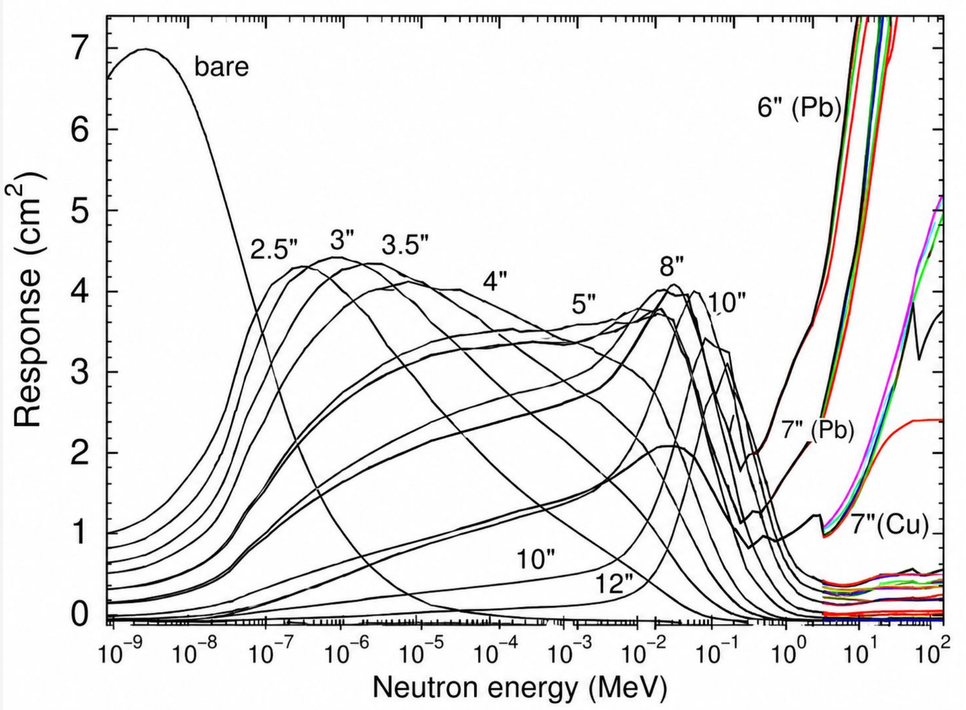
10^{-9} – 10^{2} MeV
12 energies

Expected behaviour:

- Different diameters => different Ri (E)
- Complementary energy sensitivity
- Combined responses => response matrix R

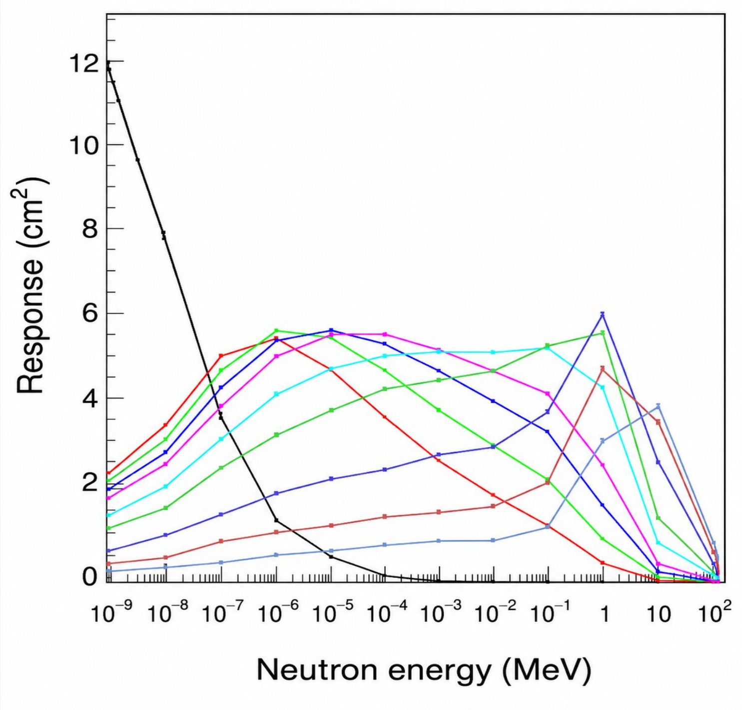
Monochromatic Spectrum

Published BSS Response Functions



Hu et al., Nucl. Instrum. Methods Phys. Res. A 940 (2019) 78–82. DOI: 10.1016/j.nima.2019.06.004

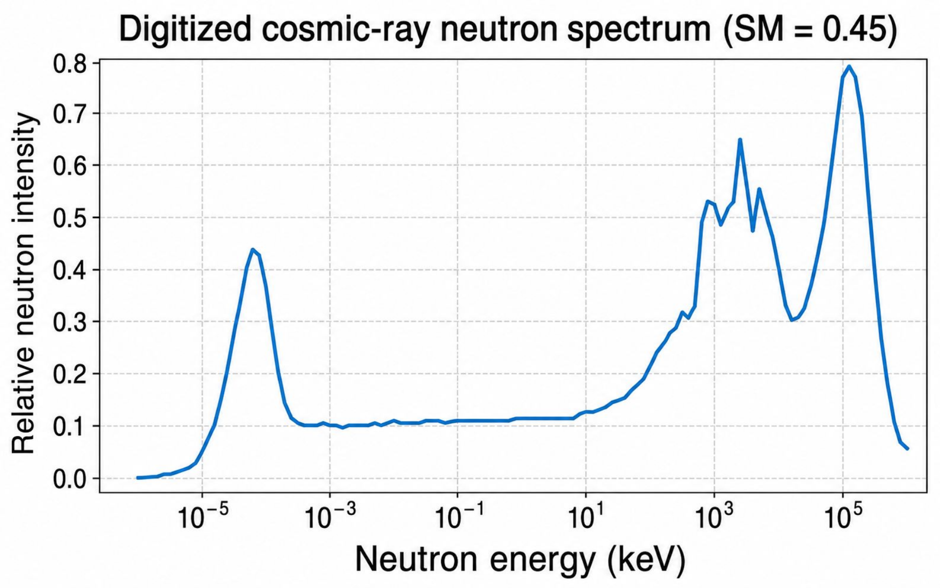
Simulated Response Functions



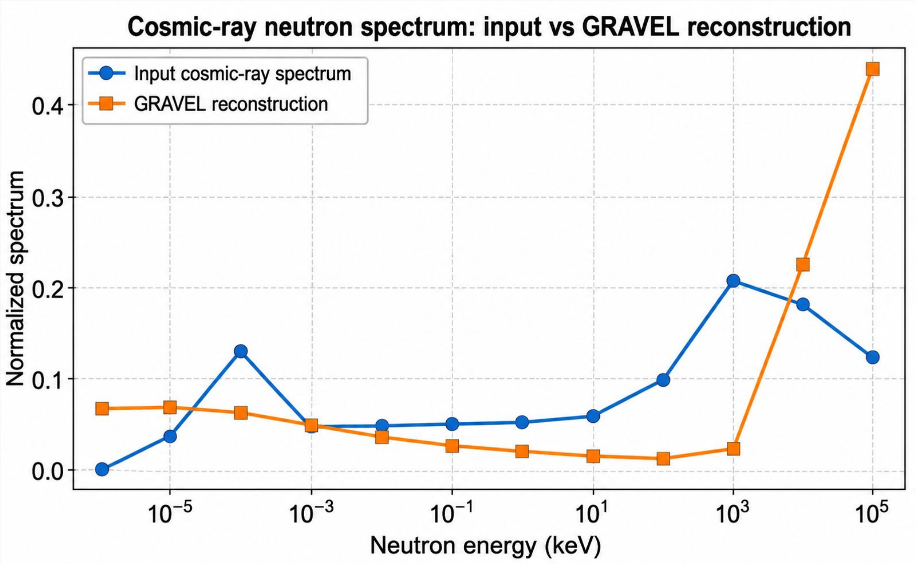
This work — ANTS3/Geant4

Cosmic Ray Neutron Spectrum

Input Neutron Spectrum



GRAVEL Reconstruction



The reconstructed spectrum was folded back through the response matrix and reproduced the detector measurements within approximately **2.4% maximum residual**.

CONCLUSIONS AND OUTLOOK

Conclusions

- Monte Carlo framework established for **detector response characterization.**
- Response functions generated over a **wide neutron energy range.**
- Response matrix successfully applied to **neutron spectrum reconstruction.**

Outlook

- Use the developed simulation framework to **optimise the detector design.**
- Improve **detection efficiency and energy discrimination.**
- Optimise the energy-dependent detector response to enable **reliable neutron spectrum reconstruction.**

THANK YOU FOR YOUR ATTENTION!