NEUTRON AND GAMMA-RAY SPECTROMETRY

Claudia OLARU

University of Bucharest
Faculty of Physics

Andreea-Elena COJOCARU

University of Craiova
Department of Physics

Supervisor: I.N. Ruskov

Technical Assistance:
D.N. Grozdanov
Wang Dongming

Determination of the angular distributions of the gamma-rays from the inelastic scattering of 14.1 MeV neutrons on ^{12}C by NaI(Tl) and BGO multi-detector systems

Claudia OLARU

University of Bucharest
Faculty of Physics

Contents

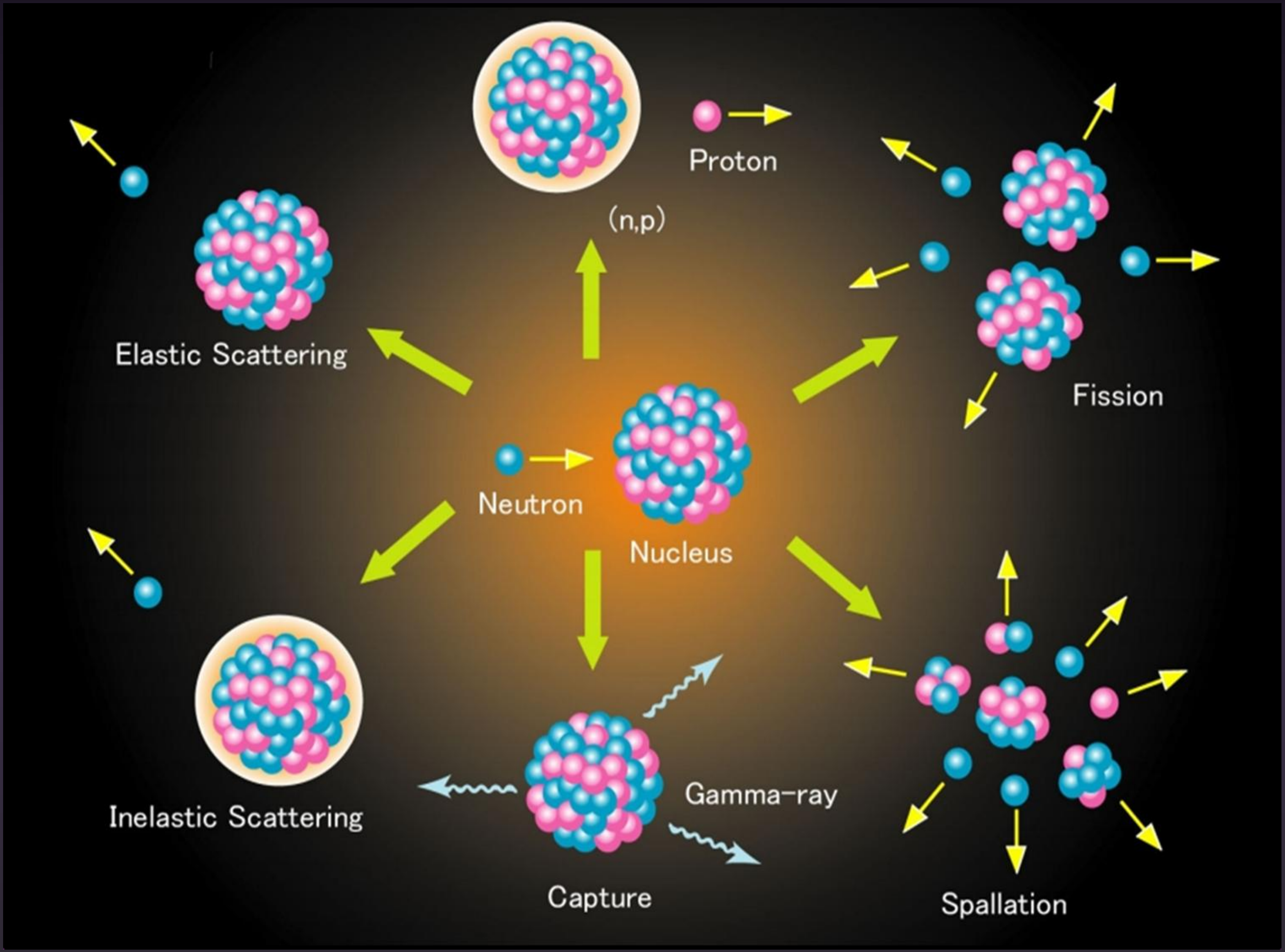
- What is neutron?
- Types of nuclear reactions produced by neutrons
- TANGRA setup
- Romashka vs. Romasha
- DAQ system
- Experimental results
- Conclusions

Neutron

- Particle found in the nucleus of the atom
- No electric charge
- Bound to the proton in the nucleus by the nuclear force
- Mass = 1.008 u
- Free neutrons are unstable ($t_{1/2}$ ~ 10.3 min)
- Negative magnetic momentum
- Spin = 1/2
- Formed by quarks (udd)

β decay: $n \longrightarrow p^{+} + e^{-} + \tilde{\nu}_e$

Free neutrons + Matter —interaction→ Nuclear Reactions



TANGRA

TAgged Neutron & Gamma-RAys

What is TANGRA ? Experimental setup

Why ? To investigate the 14.1 MeV neutron induced nuclear reactions on nuclei of different materials

How? Using the method of tagged neutrons

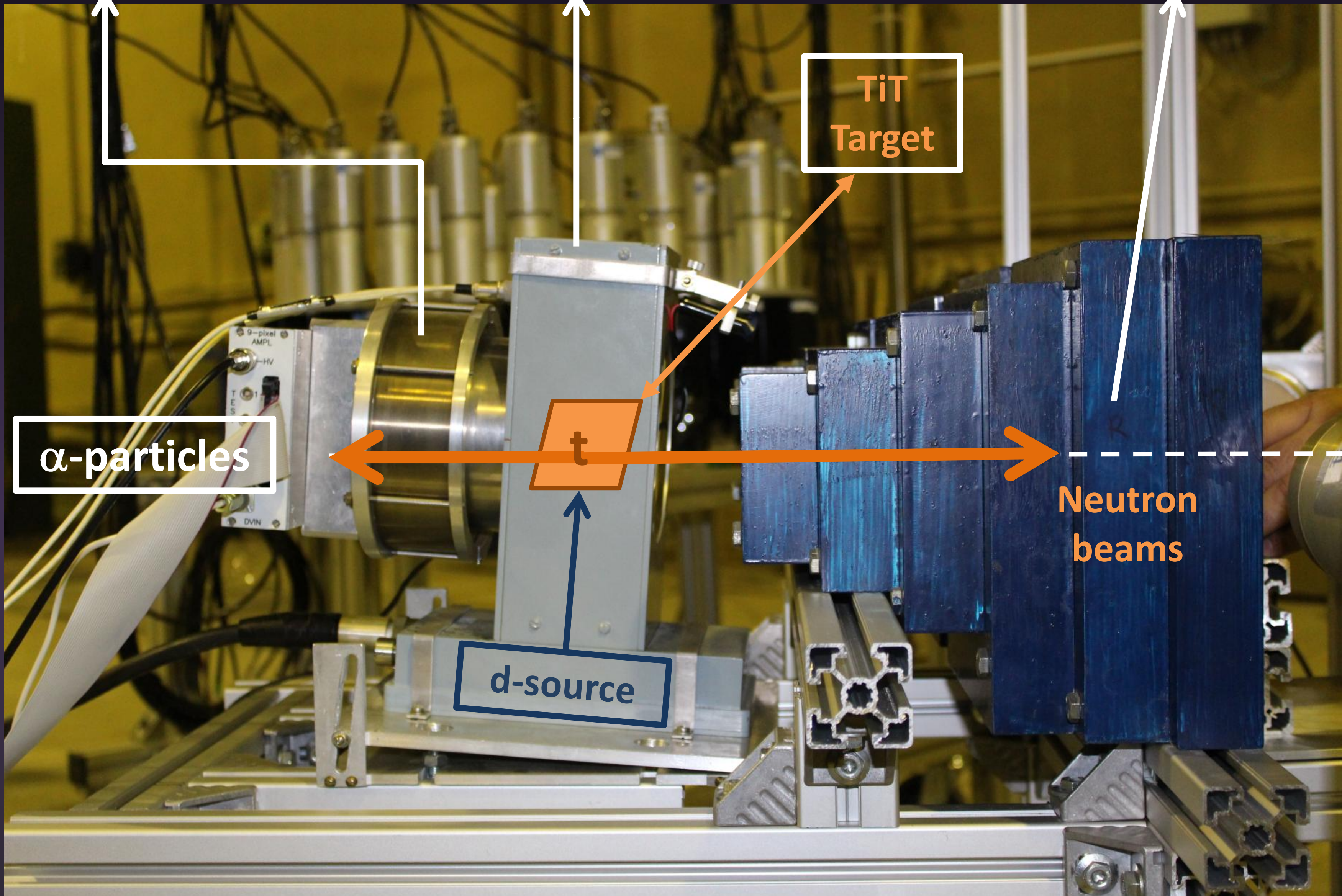
Where? At Joint Institute for Nuclear Research, Frank Laboratory of Neutron Physics

TANGRA setup

Consists of:

- ING-27 neutron generator, with an incorporated 64-pixel α-particle detector
- Iron shielding collimator
- Sample for gamma-ray emission (neutrons interact with the sample's nuclei, producing the gamma-rays)
- A reconfigurable multi-detector setup, for detecting gamma-rays
- ADCM (used for DAQ), a compact and universal Digital Pulse Processing system for nuclear physics experiments

α-particle Detector ING-27 Neutron Generator Collimator (Fe)



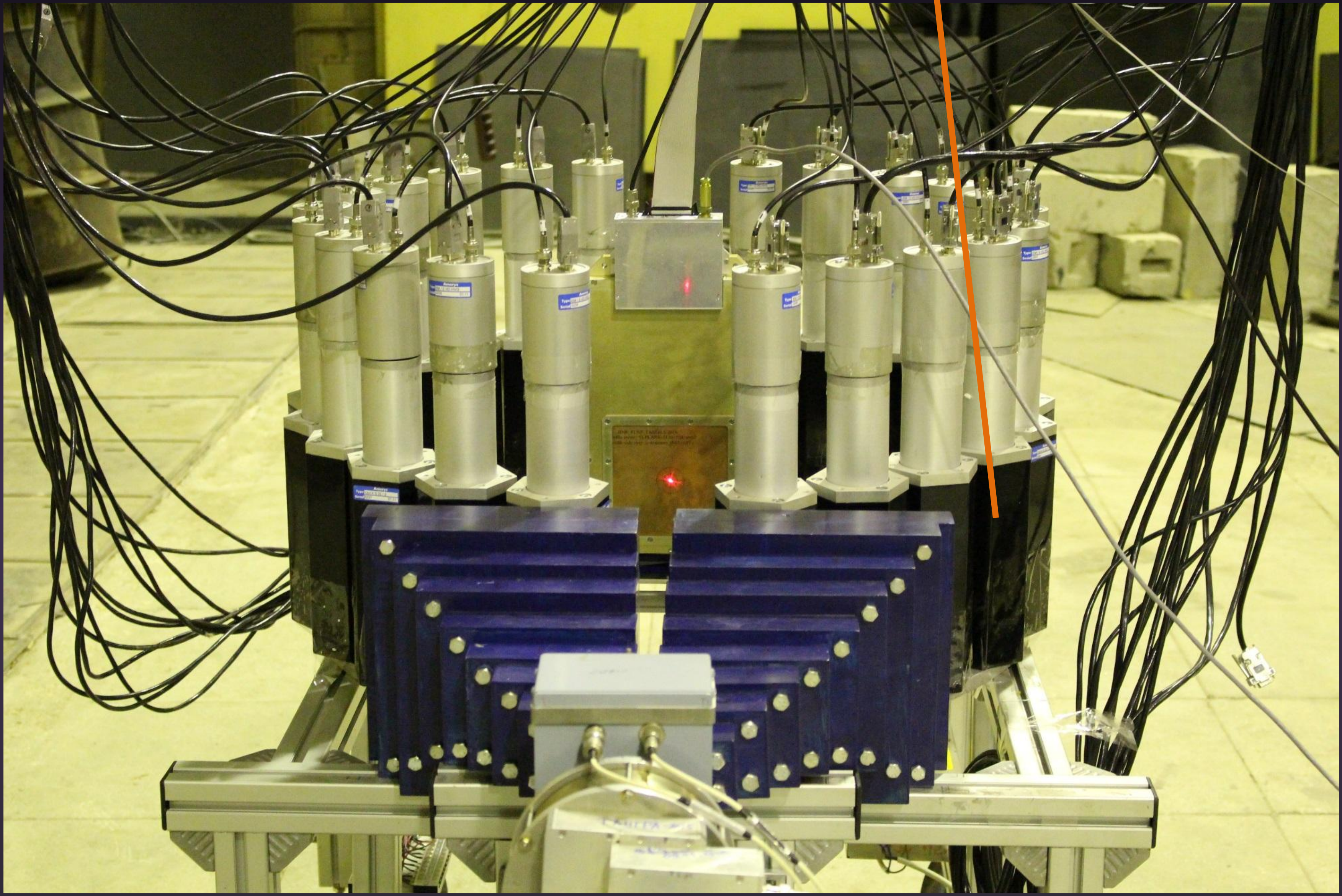
The fusion-fission reaction produces the 14.1 MeV neutrons:

$$d + t \longrightarrow \underset{3.5\ \text{MeV}}{\alpha} + \underset{14.1\ \text{MeV}}{n} \quad (Q=17.6\ \text{MeV})$$

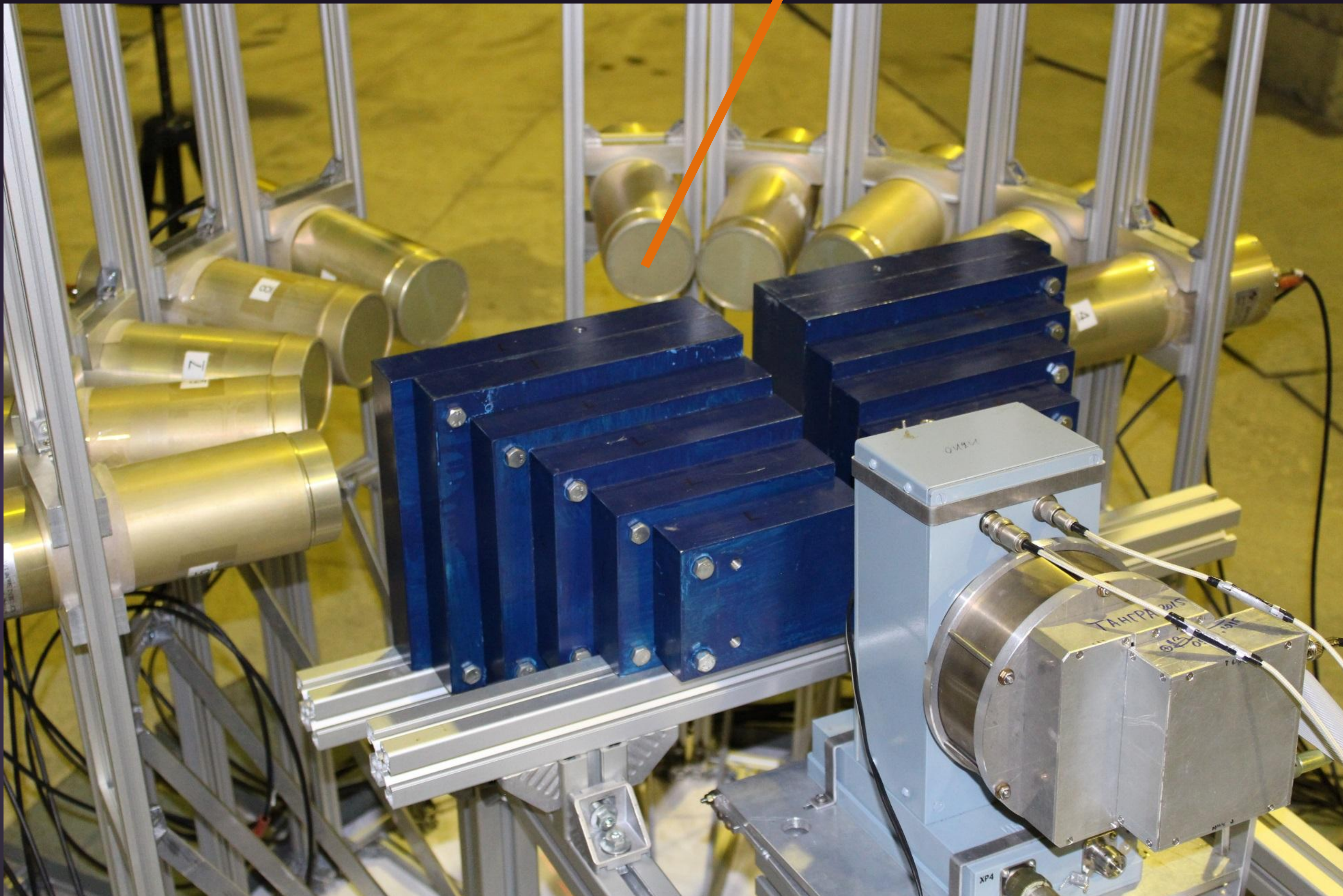
This experiment is based on the Tagged Neutron Method

The multi-pixel α-particle detector is measuring the time the α-particle reached the detector and the coordinates of the point where it hit the detector. As a result, the position of the associated neutron and its direction can be specified, thus the neutron is “tagged” and counted

"Romashka" gamma array/ 22 NaI(Tl) detectors



“Romasha” gamma array/ 10 BGO detectors ($Bi_4Ge_3O_{12}$)



The work with TANGRA setup consists of several experiments, leading to measuring the angular distribution of gamma-rays from the inelastic neutron scattering by the ^{12}C sample

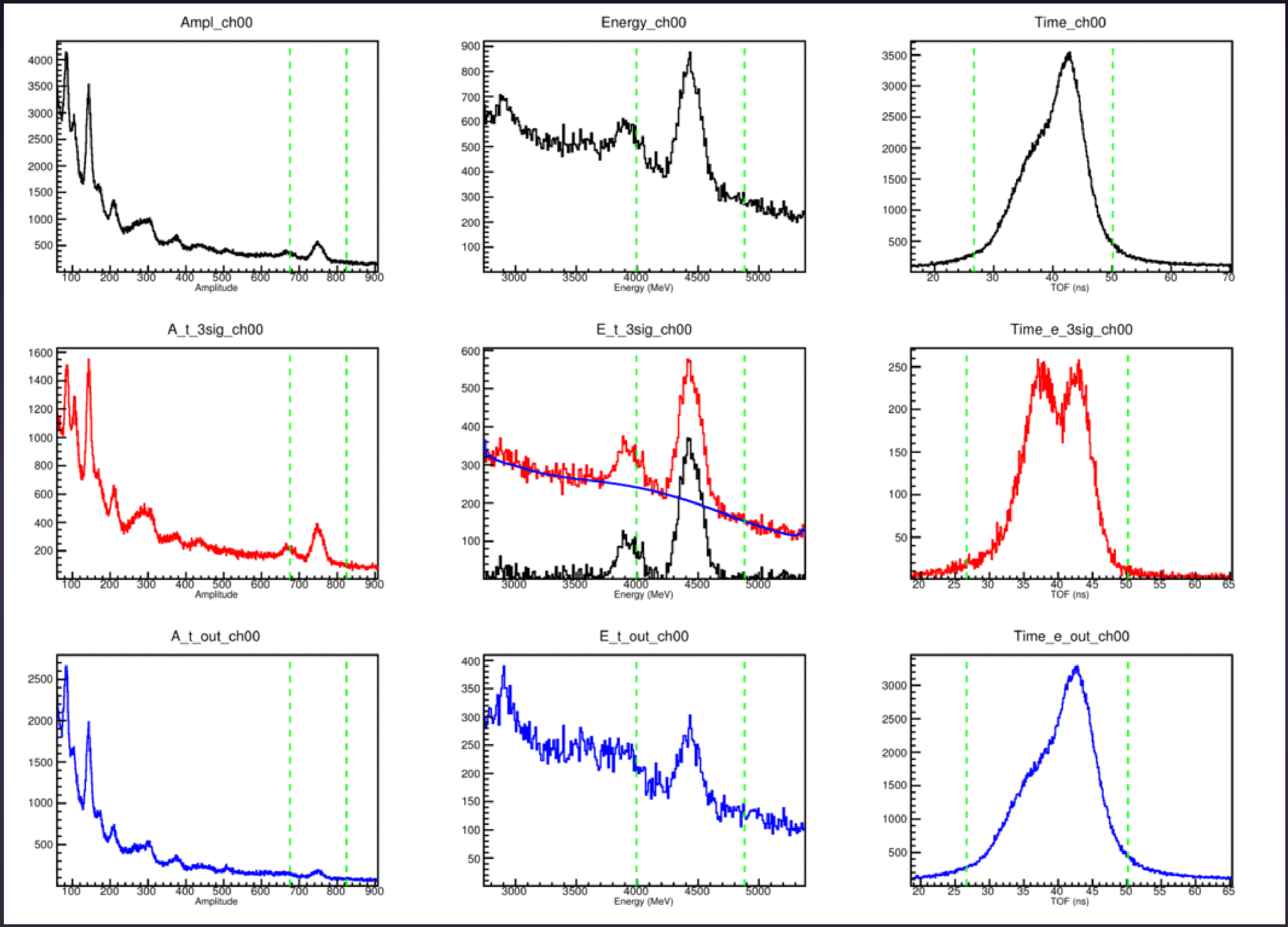
Initially, the gamma-rays were detected by the 22 NaI(Tl) multi-detector system "Romashka"

Now, instead of NaI(Tl) detectors, the BGO detectors are used. Using the new BGO multi-detector system, the probability of interaction of high-energy gamma-rays with the detector arises, thus the efficiency of the BGO detectors is higher than the one characterizing the NaI(Tl) detectors

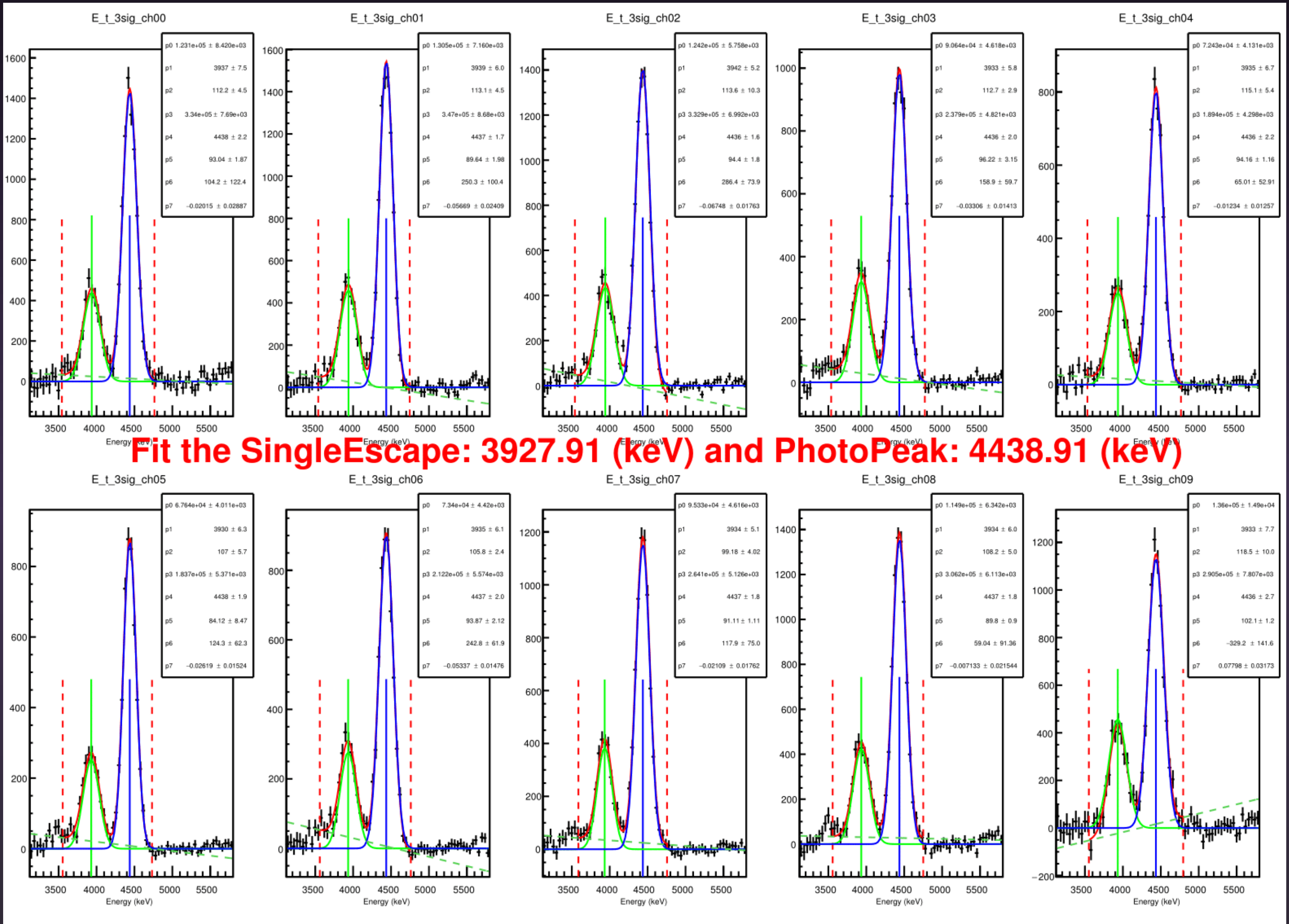
The signal processing and data collecting with "Romashka" and "Romasha" was done by a computerized 32-channel digitizer, using two ADCM16 (100MHz) ADC board

The signals from all the detectors are registered simultaneously in digitized form and are stored in a .root file on the hard disk of a personal computer for further analysis and data interpretation

Experimental results from ^{12}C (n,n'γ) using BGO "Romasha"

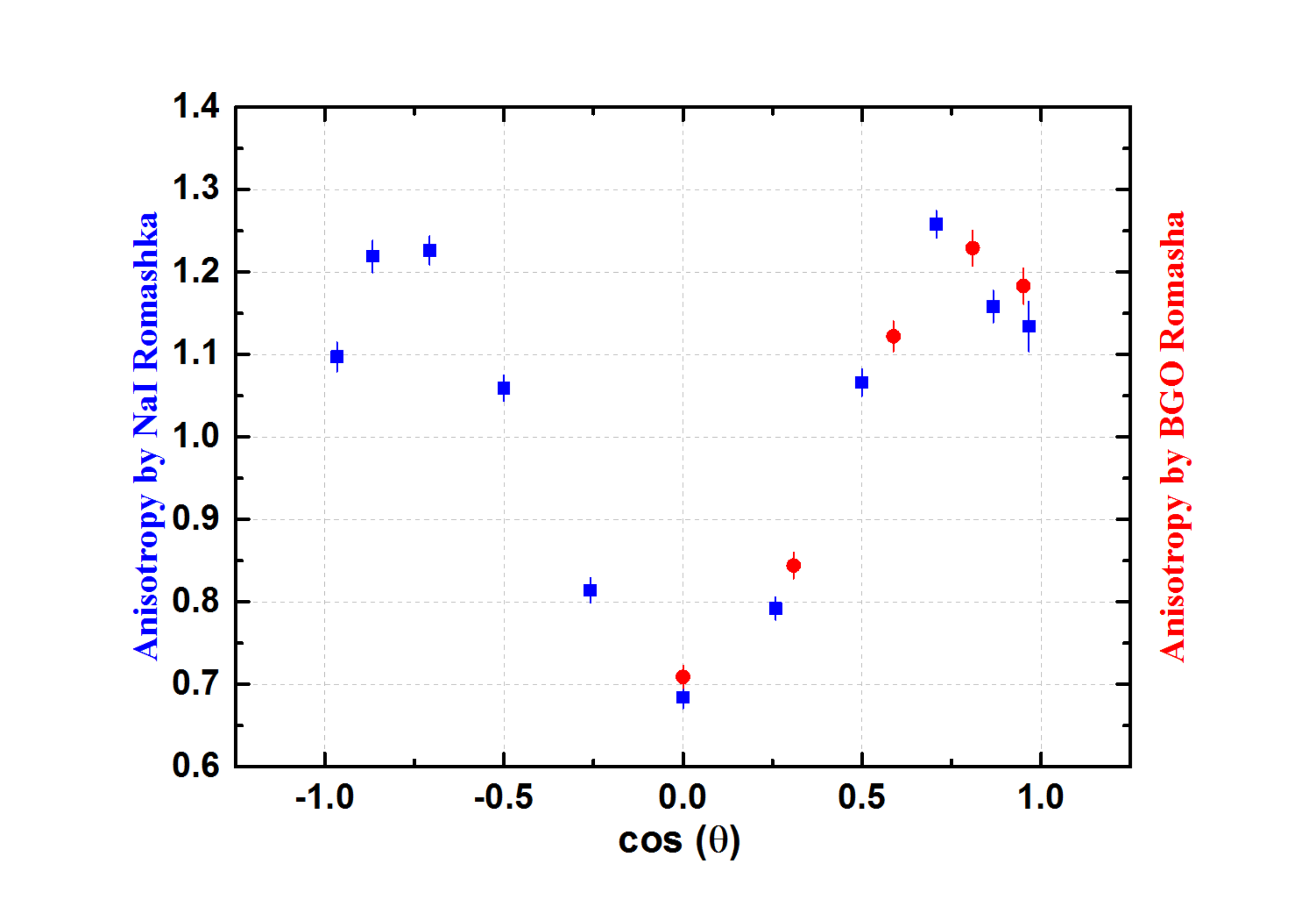


Energy spectra of 4.44 MeV gamma-ray from ^{12}C (n,n'γ)



Fit the SingleEscape: 3927.91 (keV) and PhotoPeak: 4438.91 (keV)

The Anisotropy of Gamma-Rays from ^{12}C (n,n'γ) by the two multi-detector systems



Conclusions

- TANGRA setup has been used for measuring the angular distributions of characteristic gamma-rays produced from the inelastic scattering of neutrons
- The angular distribution results obtained from “Romashka” have been compared with the results from the new multi-detector system “Romasha” for ^{12}C
- BGO detectors have a better efficiency for high-energy gamma-ray than the NaI(Tl) detectors

Simulation of the inelastic scattering of 14.1 MeV neutrons on ^{12}C and ^{14}N

Student:

Cojocaru Andreea – Elena

University of Craiova

Department of Physics

Supervisor:

Dr. Ivan N. Ruskov

Technical Assistance:

Wang Dongming

Joint Institute for Nuclear Research

Frank Laboratory of Neutron Physics

International Student Practice Stage 2 July 2017

Content of the presentation

- The Purpose of work
- Introduction: Why a simulation?
- TANGRA setup
- Simulation results
- Interpretation of the results
- The gamma–ray energy spectra

The purpose of work

- To obtain :
  - ➢ the characteristic γ - rays energy deposition
  - ➢ the angular distribution of γ - rays
  - ➢ the energy resolution of the detectors

  from simulating the production of γ - rays from the $^{12}C(n,n'\gamma)$ and $^{14}N(n,n'\gamma)$ reactions
- Comparing the gamma–ray energy spectra from NaI(Tl) and BGO spectrometers

Why a simulation?

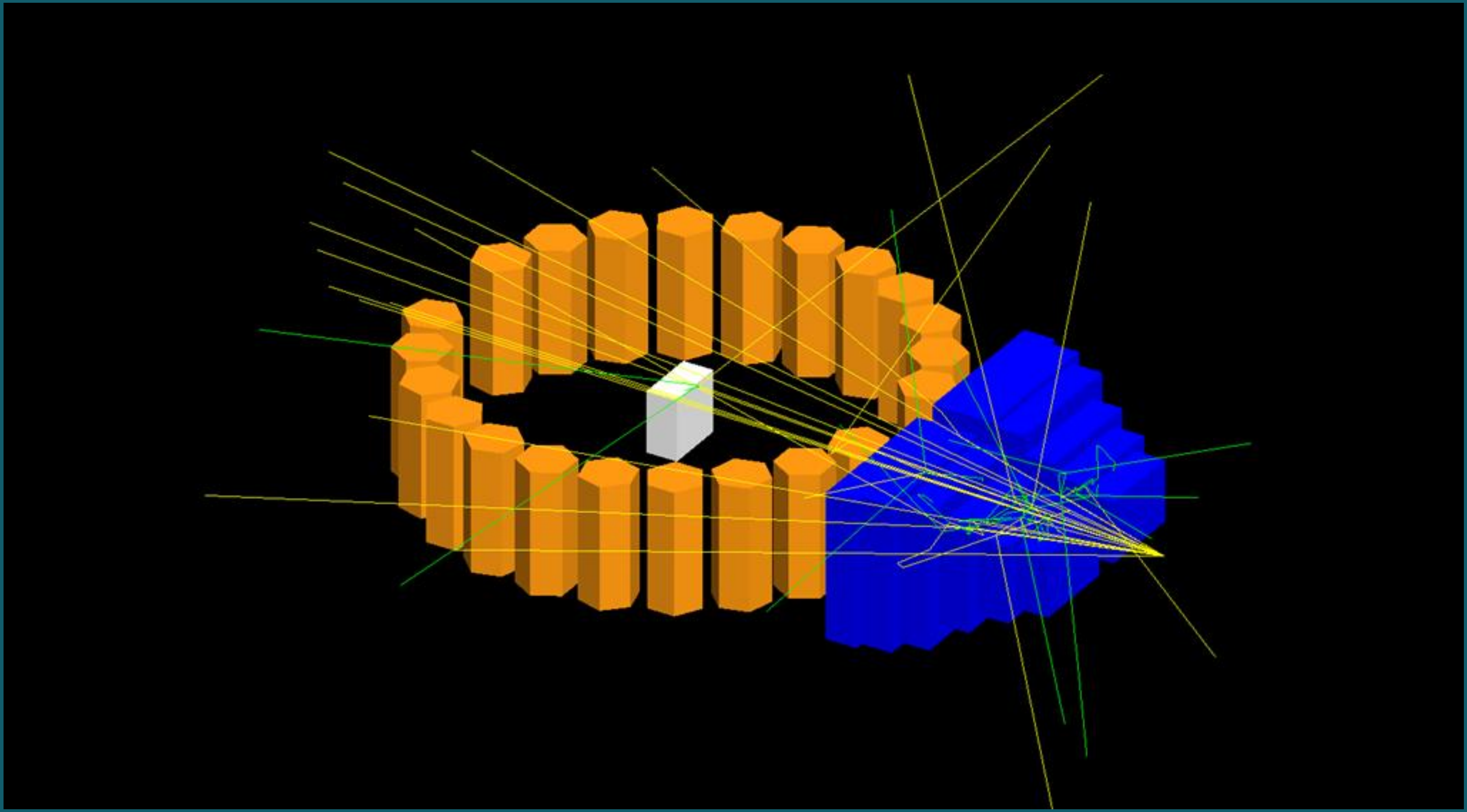
- The simulation:

➢ gives the possibility of creating different scenarios for the experiment

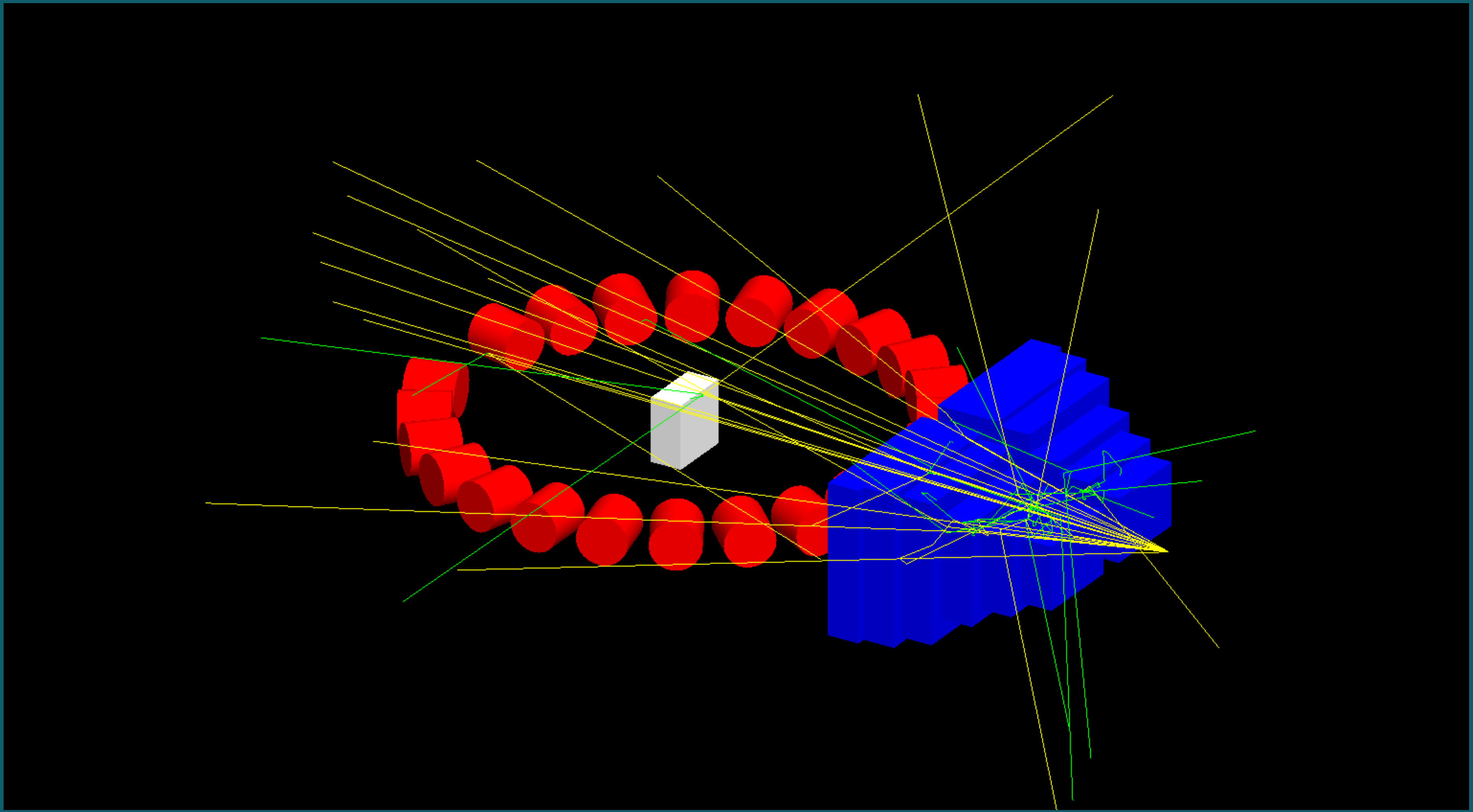
➢ optimizes the experimental setup

➢ estimates characteristics like angular distribution of γ - rays, energy deposition, detector energy resolution, efficiency of registration, etc.

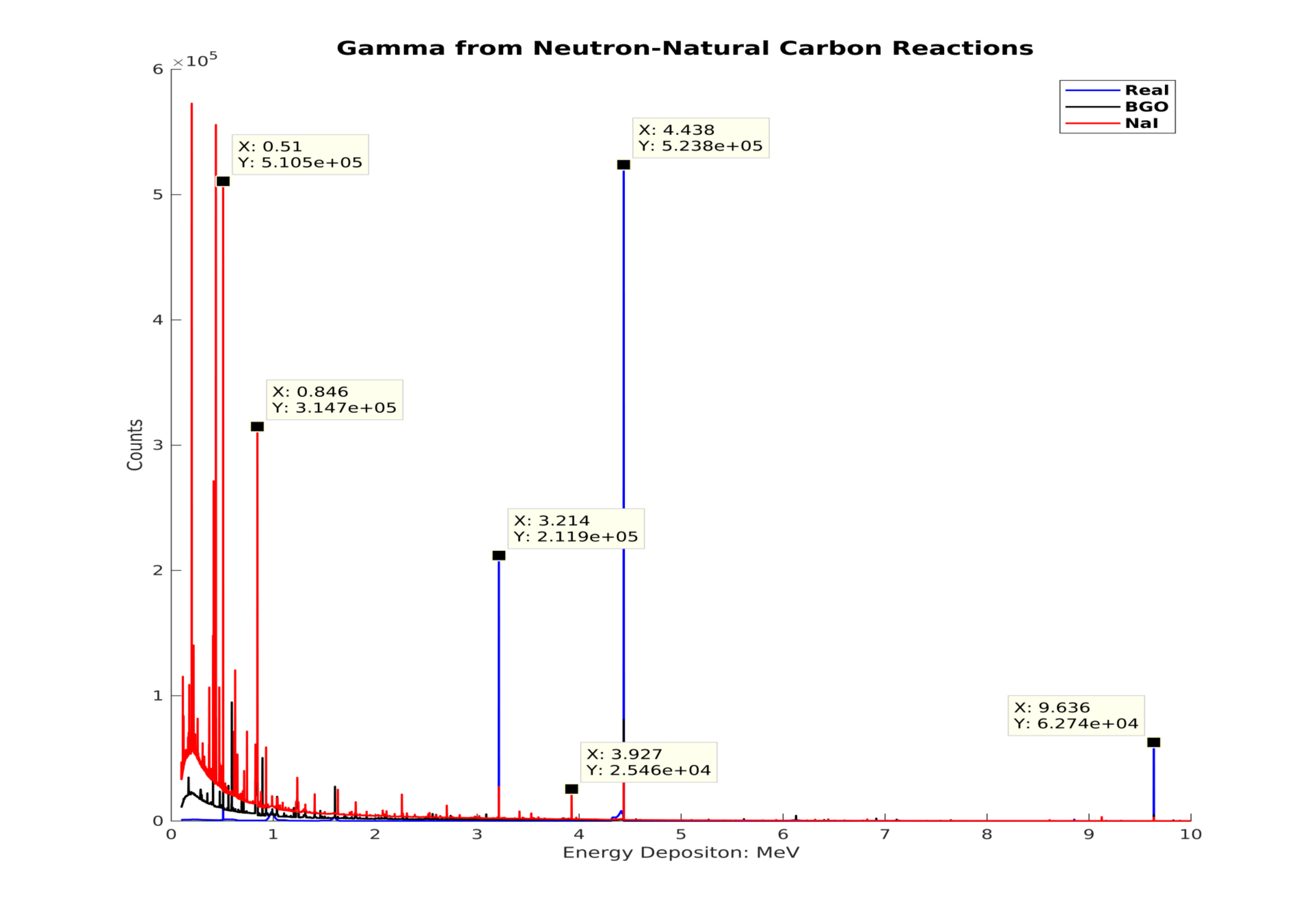
TANGRA Setup
- 22 NaI gamma-ray spectrometer -
ROMASHKA



TANGRA Setup
22 BGO gamma–ray spectrometer – ROMASHA



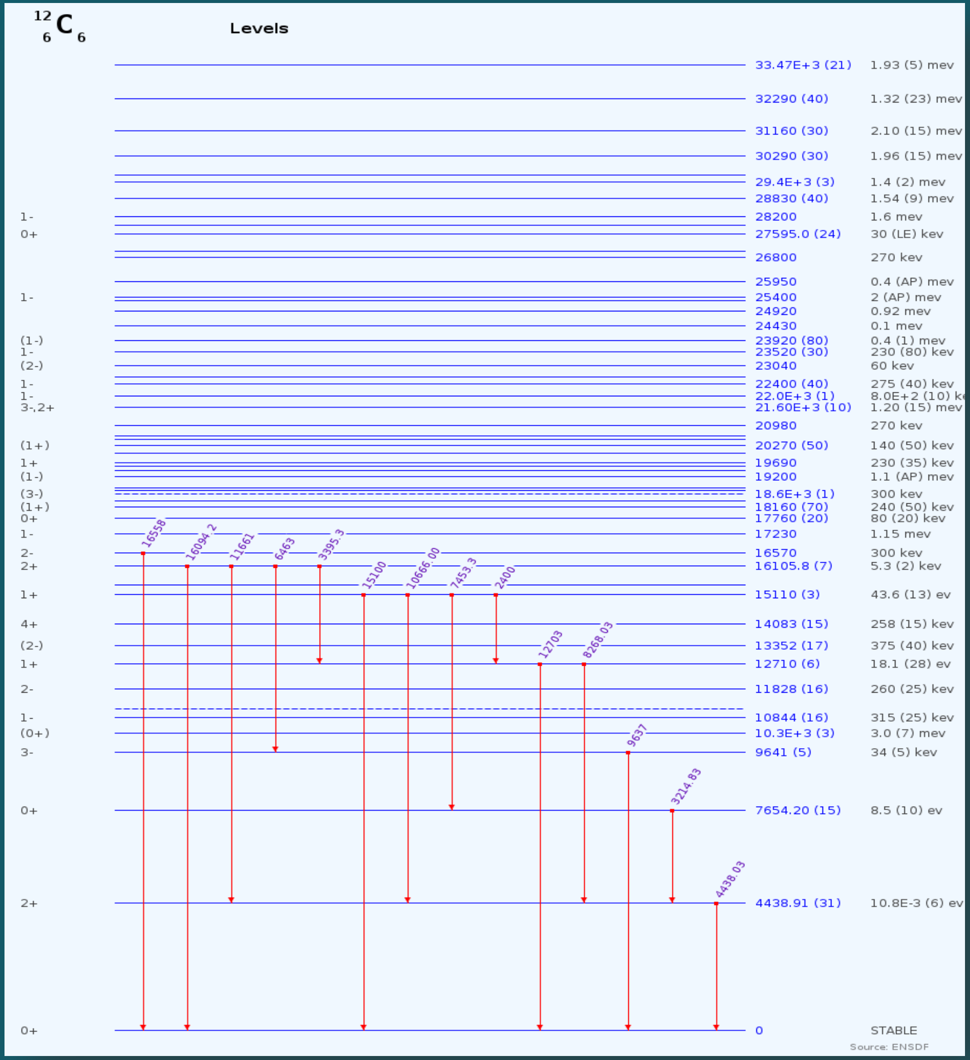
Simulation Results
Gamma - rays from $^{12}C(n,n'\ \gamma)$



Interpretation of the results

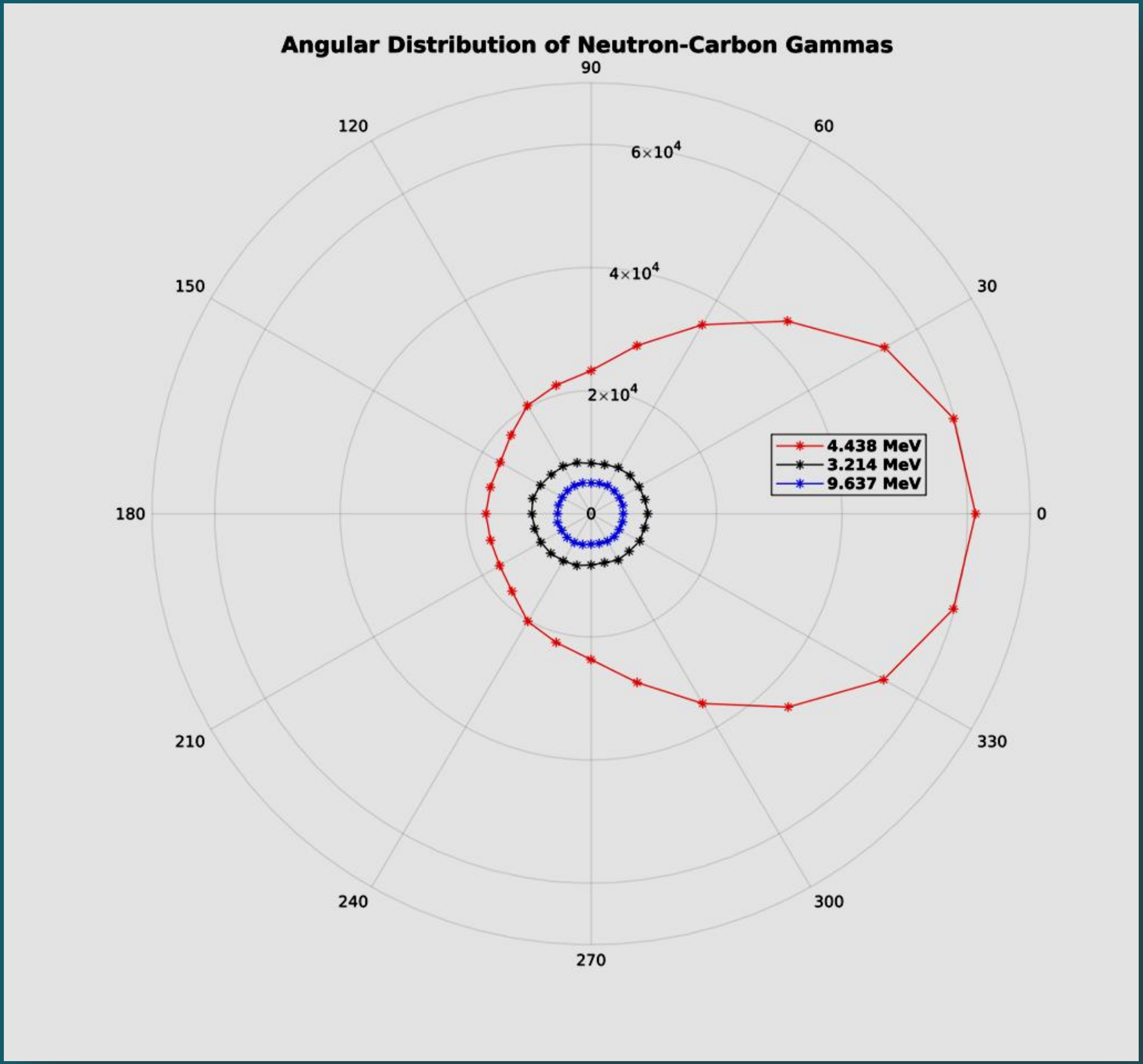
^{12}C

- **4.438 MeV** peak is due to the inelastic scatter of neutrons with ^{12}C crystal
- **0.51 MeV** peak is due to the positron annihilation
- **0.846 MeV** peak is due to the neutrons interacting with the Fe collimator
- **3.214 MeV** peak is due to the transition from second to first level
- **3.927 MeV** peak is due to single escape
- **9.636 MeV** peak is due to the transition from third to ground level

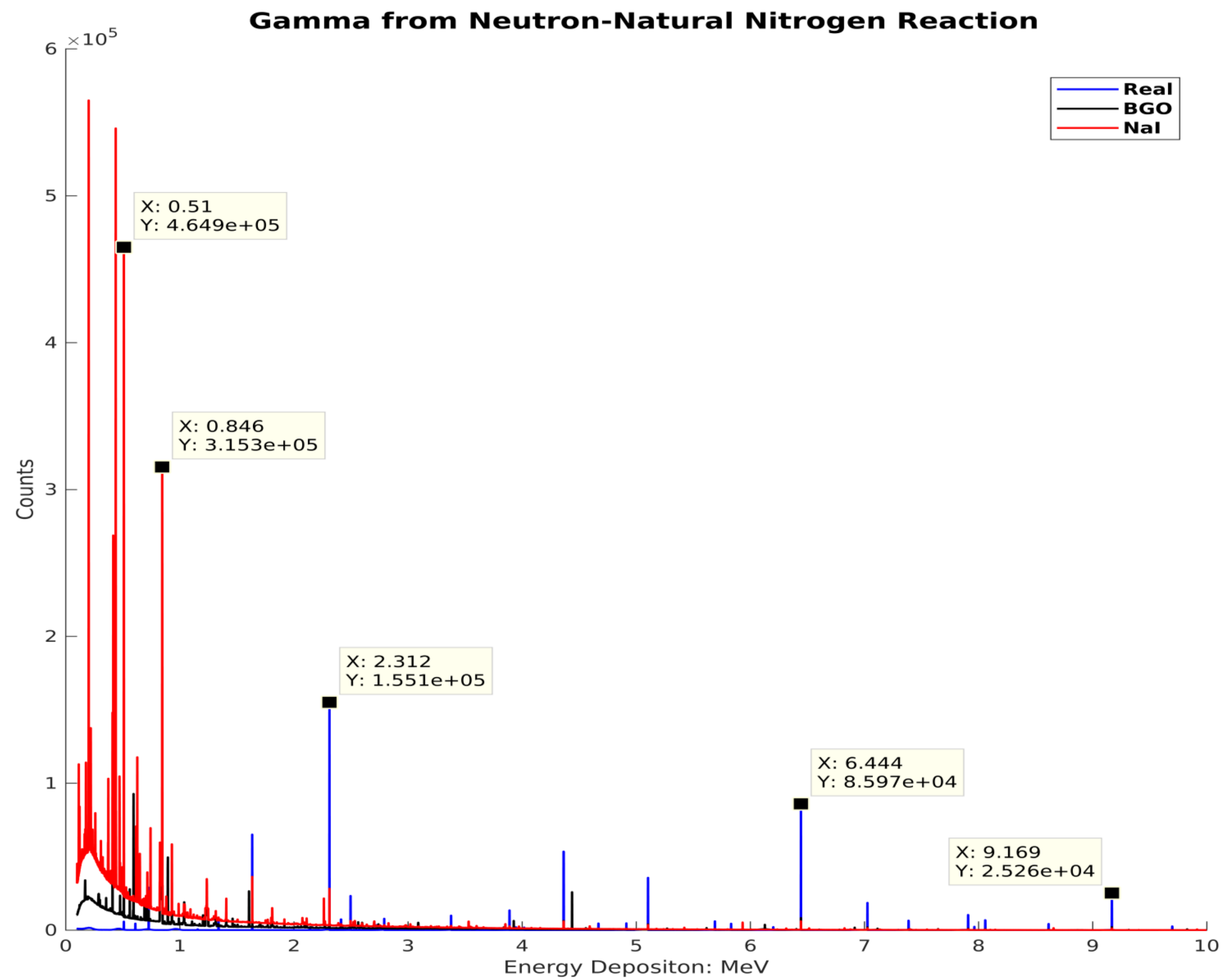


https://www-nds.iaea.org/relnsd/vcharthtml/VChartHTML.html

Angular distribution of γ–rays from $^{12}C(n, n'\gamma)$



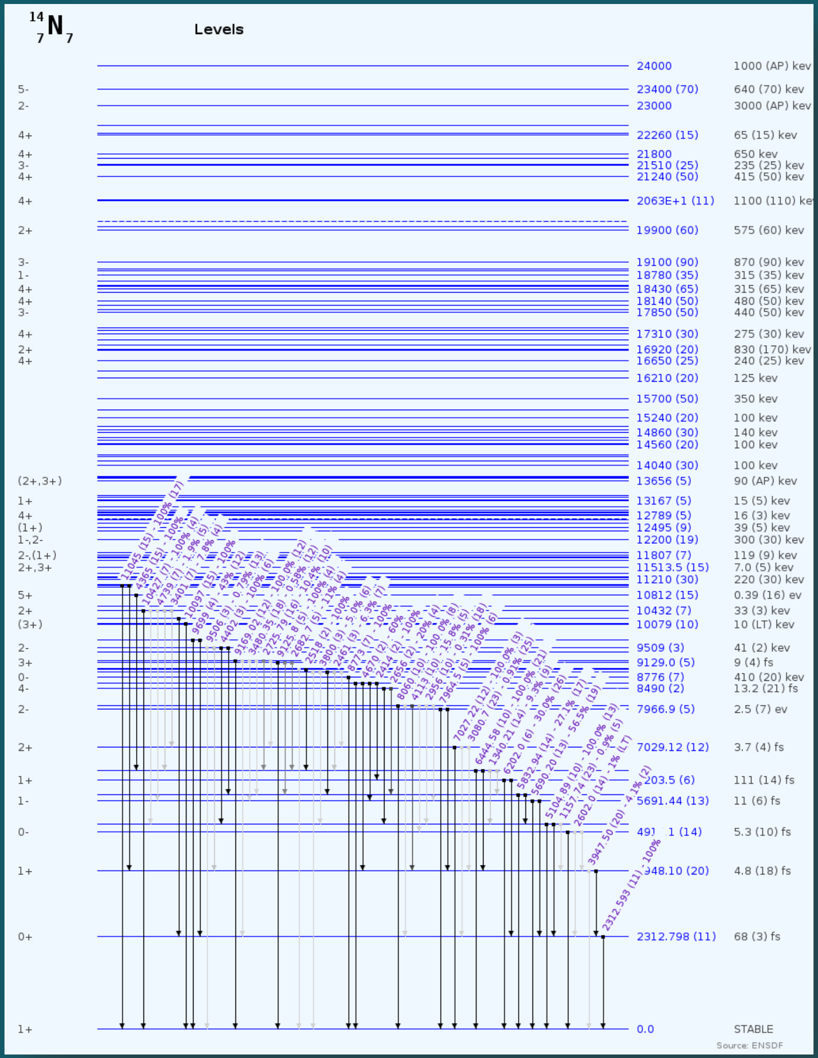
Simulation Results Energy spectra of γ-rays from $^{14}N(n, n'\gamma)$



Interpretation of the results

^{14}N

- **2.312 MeV** peak is due to the inelastic scatter of neutrons with ^{14}N
- **0.51 MeV** peak is due to the positron annihilation
- **0.846 MeV** peak is due to the neutrons interacting with the Fe collimator
- **6.444 MeV** peak is due to the transition from the ninth level to the first
- **9.169 MeV** peak is due to the transition from third level to the first level



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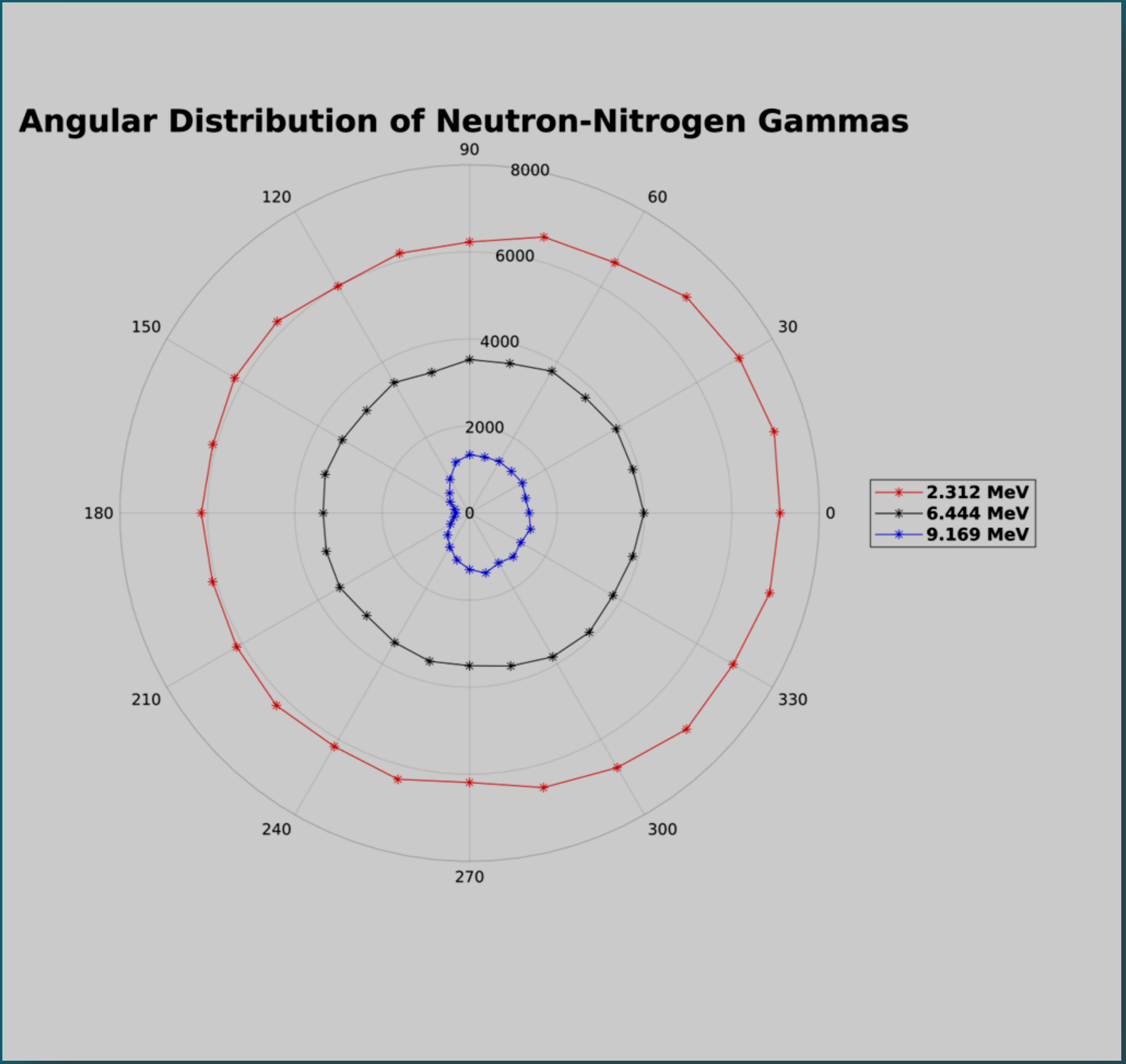
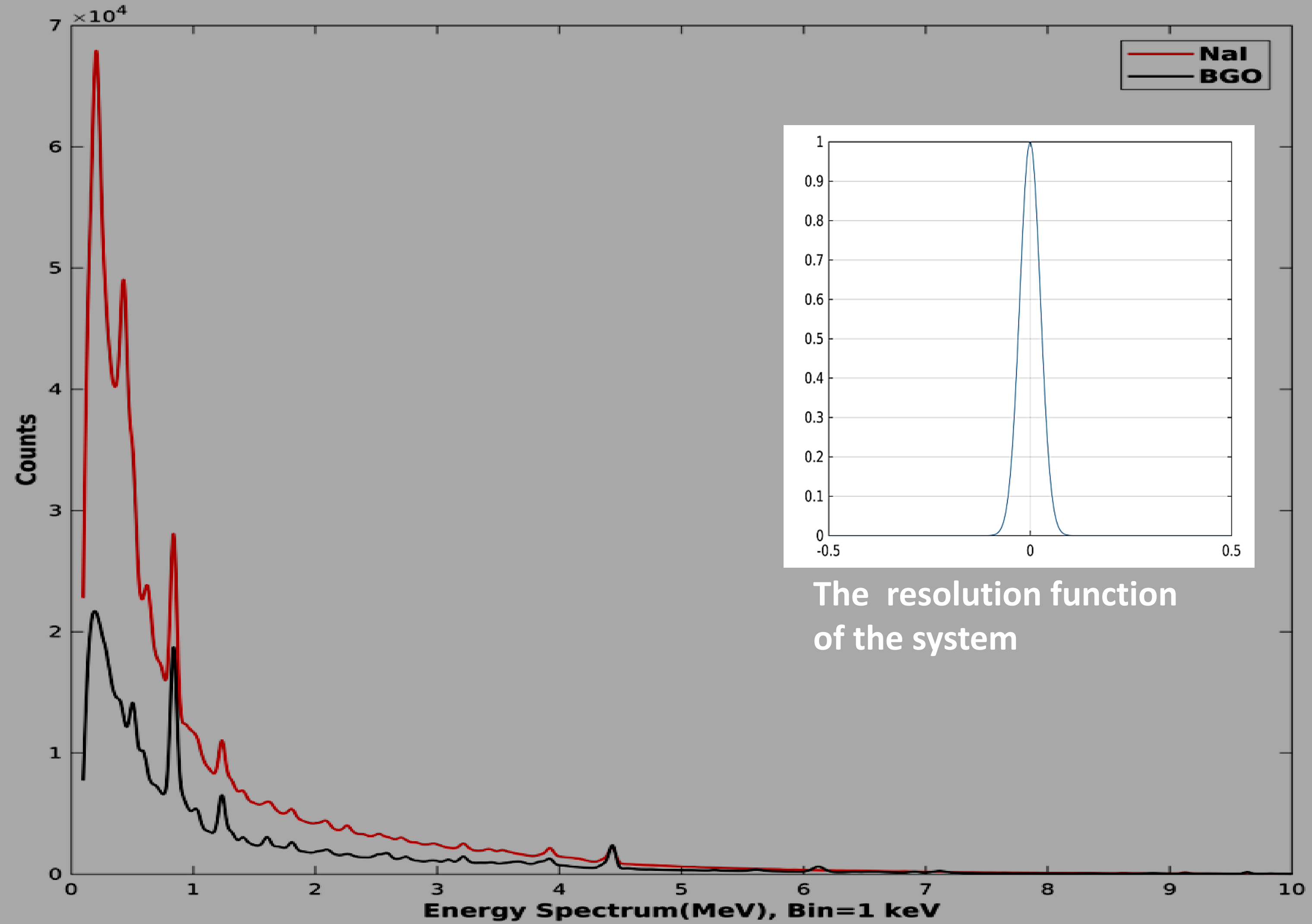
Angular Distribution of γ - rays from $^{14}N(n, n' \gamma)$



The Energy Spectra of γ-rays



The resolution function of the system

Thank you for attention!