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Cofinanciado por:

Developments of EnsarRoot Framework for Different Applications

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PIGE Experiment and Analytical Tools

PIGE is one of the **Ion Beam Analysis (IBA)** group of **analytical techniques** that is widely used in applications ranging from environment to cultural heritage. All IBA methods are non- destructive, highly sensitive and allow the detection of elements in depths ranging up to several hundreds of micrometers. The technique uses energetic ion beams to probe the surface of materials in order to determine the composition. Its multielemental analysis allows the **determination of the concentration** and an **isotopical differentiation for light elements**, i.e. Z<20.

The PIGE technique uses proton, deuteron, or α- beams at low energies up to 4 MeV to surmount the repulsive Coulomb barrier where low energy nuclear forces are involved. The basic mechanism is the formation of a compound nucleus in a highly excited state that de-excites by the emission of gamma rays [1][2]. Therefore, it is restricted to the **detection of gamma rays emitted** in inelastic scattering and (p,γ) and (p,αγ) nuclear reactions [3,4].

Nuclei Characterization and Data Analysis Routines

^{35}Cl	^{37}Cl
STABLE	STABLE
75.76%	24.24%

The **chlorine stable isotopes**, ^{35}Cl and ^{37}Cl, have not been hastily inspected, regarded as the lack of information in available IBNDL data sets for PIGE analysis. Our purpose is to **complete the cross sections** and **yields** data for these two isotopes **at low energies**. The experimental campaign has taken place at the CTN/IST Laboratory (Sacavém) using an HPGe detector.

Apart of the experimental simulation that has been carried out, different **methods** and **subroutines will be implemented** in the code to treat the experimental data and the simulated data. As a result, an exhaustive benchmark between the experiment and the different parts of the simulation including the analytical methods will be performed.

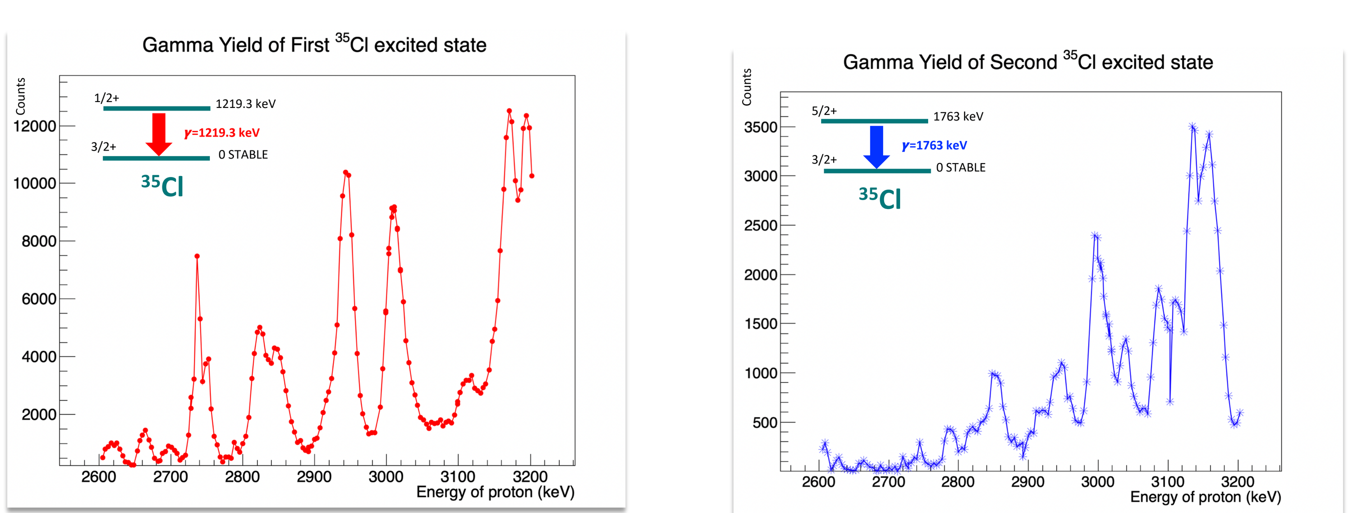

Fig.1,2. Experimental analysis of the ^{35}Cl first and second excited state from the reaction $^{35}Cl(p,p'\gamma)^{35}Cl$. (Preliminary Data)

Environmental Background Simulations

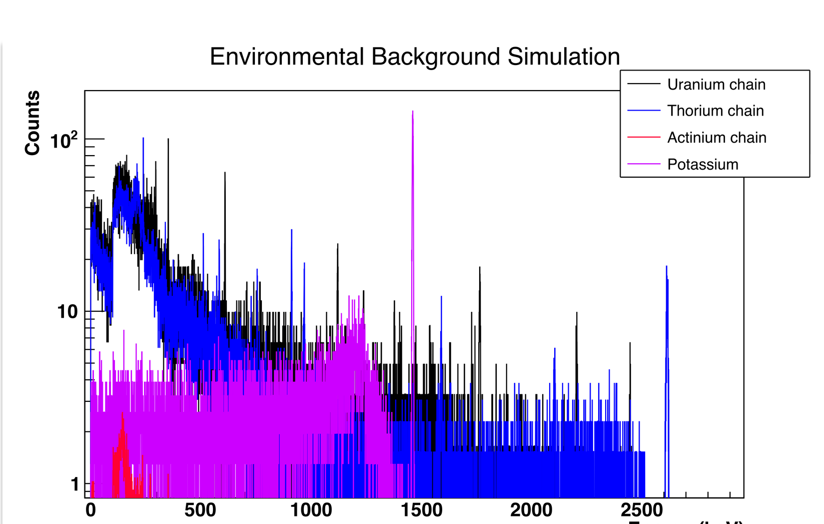

Fig.3. Contributions of the radioactive chains and the potassium decay in the simulation.

The **analysis of environmental radiation** is a challenging field, due to it varies depending on altitude, the type of soil, etc. All these variables and uncertainties make difficult to predict it at an specific region beforehand. In this work, we focused on the **simulation of the radioactive chains** and the **decay of ^{40}K**, taking into account all the gamma emissions from the nuclear decays (in Fig.3 all the contributions are plotted).

Afterwards, summing and only applying a factor scale for each chain, which depends on the environmental characteristics of the laboratory, the natural radioactivity is simulated and **comparable to the real data**, as we can observe in Fig.4.

The best asset of this Background Generators is that could be used with **any type of detector** placed in **different locations**.

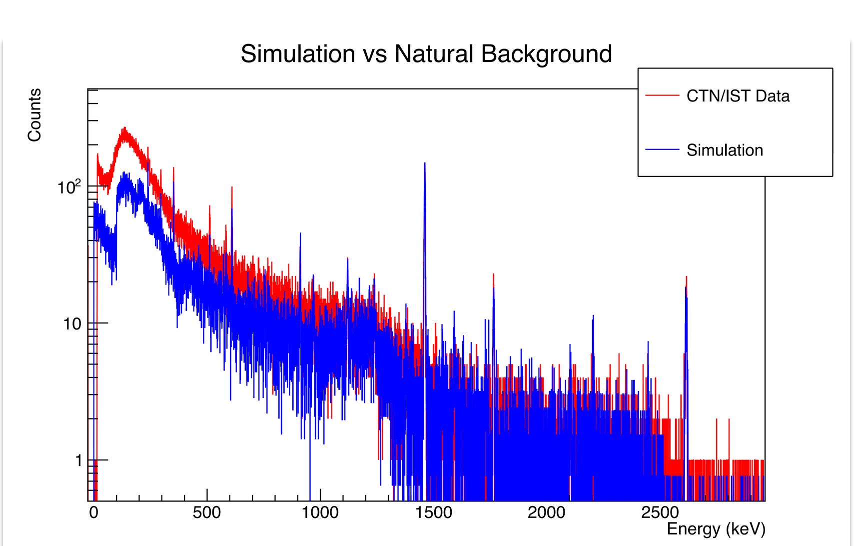

Fig.4. Benchmarking between the background simulation and the environmental background measured at CTN/IST.

Abstract

During the last years different branches of simulations and analysis tools have been created and developed within EnsarRoot framework. EnsarRoot allows the simulation of diverse setups and the creation of simulated data based on Virtual Monte Carlo platform and Geant4 transport engine. As well as, it allows that experimental and simulated data could be treated on equal footing using the same data routines.

As a result of its versatility, different nuclear areas have been investigated. In this poster, there are presented the last expansions of the code and its applications. There are two simulated experiments at CTN/IST (Lisbon): CALIFA Testing Experiment which objective was characterize the crystal response of the CALIFA detector for future experiments at GSI (Germany) and PIGE experiment with the aim of complete IBNDL data sets of some isotopes. In order to complement the previous simulations, some analysis and particle generators have been developed, such as, gamma generators which reproduces angular correlations or radioactive chains to reproduce the environmental background. Nowadays, we are working on some subroutines to treat the PIGE data.

EnsarRoot

EnsarRoot is a software framework used for simulations and data analysis of different experiments. It derives from FairRoot and FairSoft frameworks, so they are required in the installation process. EnsarRoot has a modular design with shared libraries. The simulation part is based on the Virtual Monte Carlo (VMC) concept and Geant4 as a particle transport engine [1,2].
The main advantage is the possibility of analyse experimental data using the same tools as simulated data, treating both equally to avoid additional bias. Different algorithms and methods prepared for data analysis have been already implemented and it is possible to extend them under user's requirements.

CALIFA Testing Experiment

The purpose of this project is to **simulate the detailed setup** of an experiment done at CTN/IST (Lisbon) in November 2016, studying $^{27}Al(p,\gamma)^{28}Si$ reactions at proton energies below 3 MeV. The experiment allows a rich identification of ^{28}Si excited states, giving us the possibility to **study angular correlations** in the decay of high energy states and a **characterization of the response of the CsI(Tl) crystals** of CALIFA (CALorimeter for In-Flight detection of gamma-rays and high energy charged pArticles) with high energy gamma rays [5]. The Fig. 5 shows the setup simulation of the experiment

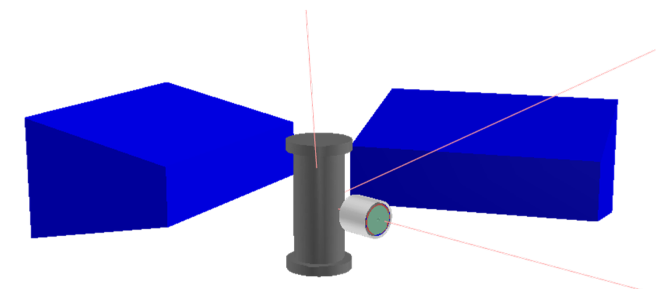

Fig.5. Artistic view of the CALIFA Testing Exp. Simulation. Including two units of CALIFA detector (gathering 64 crystals), an HPGe detector, and some inactive parts as the reaction chamber.

The Simulation of Angular Correlated Gamma Cascades

The **gammas** produced in the de-excitation of the parent nucleus of the reaction studied are affected by the spin-parity of it, therefore they are emitted with a certain **angular correlation** [6]. In order to reproduce this effect in our simulation, we have developed a specific **Angular Correlated Gamma Cascade Generator**. The three main components that we included are: the Energy of gammas, the Branching Ratios and the Angular Correlations for each energy level.

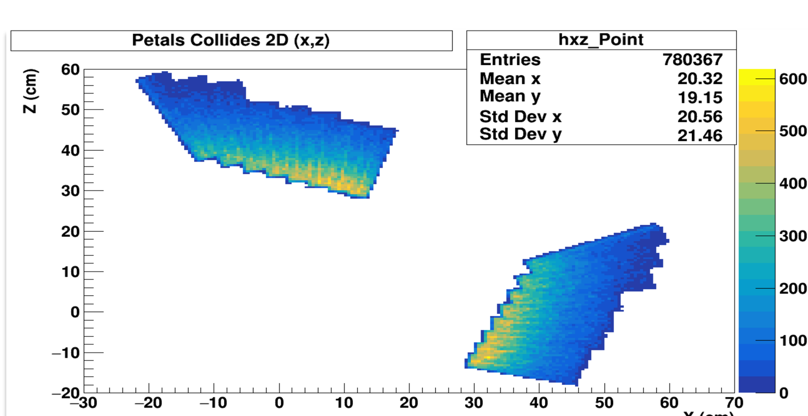

Fig.6. Number of gammas arriving to each crystal of the CALIFA petals.

As we observe in Fig. 6, the **angular coverage** of each crystal depends on its position and on its intrinsic shape, therefore, some corrections have been done using isotropic simulations to obtain the real angular dependence plotted in Fig.7. In this figure, each dot represent **one crystal signal** and they **fit with the theoretical angular correlation function** (green line).

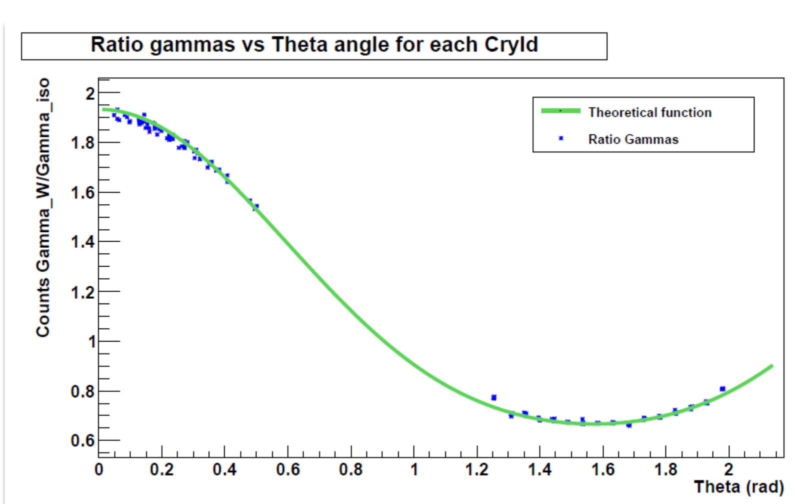

Fig.7. Simulation of Gamma Angular Correlations using the developed Gamma Cascade Generator and the Theoretical Angular Correlation function.

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