Phoswich advances for R^{3}B in FAIR

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CSIC

MOTIVATION

R^{3}B

EURONS

The R³B (Reaction with Relativistic Radioactive Beams) experiment is part of the first stage of the FAIR project. In the R³B experiments, high energy nuclear beams, extracted from the Super FRS, will interact with a secondary target surrounded by a complicated detector set-up for a complete study in inverse kinematics of all reaction products, especially nuclei with very short half life are to be studied. The total absorption calorimeter, CALIFA (CALorimeter for In-Flight gamma detection) will be situated around the reaction target to determine the total gamma energy disintegration, the cascade multiplicity and the individual gamma energies, as well as to detect and determine the energy of protons of up to 300 MeV. Required characteristics are: high efficiency and good angular resolution.

Our objective is to contribute to the design of CALIFA's forward cap and we suggest an innovative solution using detectors made up of two new generation scintillators crystals layers stacked together, one after the other, in a phoswich configuration with only one common readout. Simulations show that the gamma deposit most of the energy in the first impact, for this reason, the material of the first detector layer must have good resolution. Second layer is used to fully absorb the gamma energy or in the case of first hit in the second layer as to veto that specific event.

PHOSWICH

For protons, two layers detector is also useful to determine the initial energy. When a proton go through a material, it slows continuously down leaving part of its energy along the track but it will deposit most of its energy in the final absorption process (Bragg peak). Because of that, instead of using one very long crystal (25-30 cm) it is possible to determine the initial energy for the energy loss in two shorter crystals e.g. 3cm $LaBr_3$(Ce) + 6 cm $LaCl_3$(Ce).

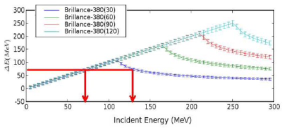


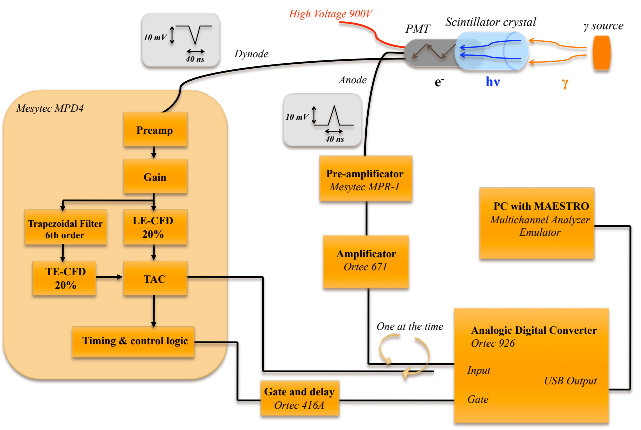
Fig. 1:.Protons: Deposited energy vs. incident energy. Two detectors are needed to solve the ambiguity of the signal.

Preliminary simulations of various combinations of materials LYSO, $LaBr_3$, $LaCl_3$ has shown that gammas deposit most of the energy in the first crystal, it's the reason why it is necessary that first crystal has a good energy resolution and that both crystals must be optically compatible i.e. the second layer crystal has to be transparent to the light emitted by the first layer.

The $LaBr_3$ and $LaCl_3$ crystals have very good energy resolution in the order of 3-4% for 662 keV gammas, according to Saint Gobain, the crystals manufacturer. In addition, these materials exhibit a very good light output production (from 32 ph/keV up to 63 ph/keV). Simulations show that detectors formed by 30 mm $LaBr_3$(:Ce) and 150 mm $LaCl_3$(:Ce) detect protons up to 280 MeV energy with a resolution better than 2%. It results this combination have enough E_γ and E_p resolution even if one take a shorter $LaCl_3$ crystal. However, the materials are hygroscopic and very expensive.

Experimental setup uses a phoswich detector made from of $LaBr_3$(:Ce) (30 mm) stacked with $LaCl_3$(:Ce) (50 mm) together with a Hamamatsu R5380 PMT. The aim of the second experiment is to distinguish the energy deposited in each individual crystal of $LaBr_3$ and $LaCl_3$ separately, and to compare the response of the crystal with GEANT4 simulations. The spectra are detected in each detectors with high efficiency and good resolution. Experimental results showed below indicate that such separation of the energy signals of the phoswich is possible with the appropriate electronic, even if the materials present very similar time response (τ_{LaBr3} = 16 ns ; τ_{LaCl3} = 28 ns).

EXPERIMENTAL SET-UP



The source used for the data acquisition was a Na^{22} source placed end-on at 10 cm from the crystal. The photons emitted by the scintillator crystal are collected by a photo multiplier tube. The anode signal goes via a preamp and an amplificator and further to the ADC to provide the energy signal. The dynode signal goes to a Mesytec MPD4 module which divide the signal in two: on part is sent to a trapezoidal filter and then loose is original shape, the other part is sent directly to a constant fraction. This treatment permit to give a TAC signal reflecting the decay time of the signal. This is useful in the case of the phoswich to know which crystal is emitting the signal. The MPD4 module also provide the gate signal used by the ADC for the time signal acquisition. From the ADC the data are sent to a PC running an emulated multichannel analyzer. The spectrum from the signal is the displayed and analyzed.

EXPERIMENTAL RESULTS OF $LaBr_3$ $LaCl_3$ AND PHOSWICH CRYSTALS

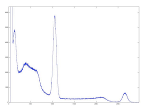


Fig 1: Na^{22} spectrum obtained with $LaCl_3$ crystal

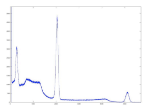


Fig 2: Na^{22} spectrum obtained with $LaBr_3$ crystal

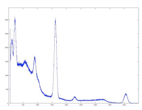


Fig 3: Na^{22} spectrum obtained with Phoswich crystal

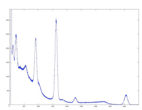


Fig 4: Na^{22} spectrum constructed with the spectra from $LaBr_3$ and $LaCl_3$

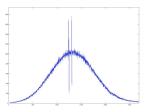


Fig 5: Time output with $LaCl_3$ crystal

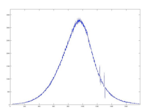


Fig 6: Time output with $LaBr_3$ crystal

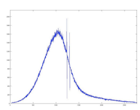


Fig 7: Time output with phoswich crystal

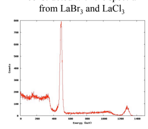


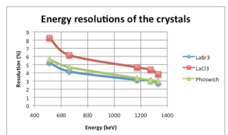
Fig 8: Na^{22} spectrum obtained by simulation of a $LaCl_3$ with GEANT4

The different figures represent energy output and time output for the different crystals and a re-construction made from the individual $LaBr_3$ and $LaCl_3$ crystals. The spectra all result from a 1000 seconds acquisition. The energy re-construction have been made using the spectra obtained with the singles crystals and adding them taking into account the ratio between the photopeaks from $LaBr_3$ and $LaCl_3$ in the phoswich spectrum. The time outputs obtained has not be sufficient in order to make a separation of the signal coming from one or other crystal in the case of the phoswich. One of the reason of the difference with the others experimental (see below) results is the constant fraction used: 20%. However we can observe that the time resolution of the $LaBr_3$ seems to be better than the time resolution of the $LaCl_3$. Clearly more investigation and improvements of the electronic circuit to be used is needed. This work is going on.

The figure 8 is one example of the results obtain with the GEANT4 simulation. The spectrum is almost the same than the real one (figure 1). The principal difference is the peak missing at low energy due to X-ray.

The following table regroup the energy resolution of the three crystals at different energies using γ sources of Na^{22}, Co^{60} and Cs^{137}:

Source	γ Energy	Resolution		
	keV	$LaBr_3$	$LaCl_3$	Phoswich
Na^{22}	511	5,23	8,26	5,63
Cs^{137}	661,65	4,16	6,16	4,68
Co^{60}	1173	3,13	4,67	3,33
Na^{22}	1274	3,06	4,39	3,08
Co^{60}	1332	2,69	3,83	2,98



The energy resolution in the case of the phoswich is always under 5% in our acquisition. However as the contact between the PMT and the scintillator is always problematic and it can still be improved, but the relative trend with energy is good, and shows that the phoswich combination does not disturb the resolution.

PHOSWICH PREVIOUS EXPERIMENTAL RESULTS

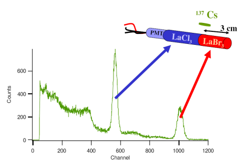


FIG 9: PHOSWICH ENERGY SPECTRUM

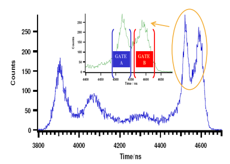


FIG 10: PHOSWICH TEMPORAL SPECTRUM

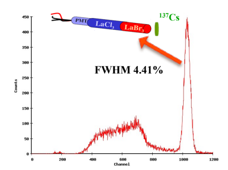


FIG 11:ENERGY SPECTRUM WITH GATE B

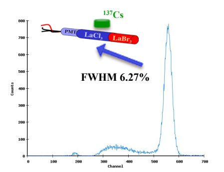


FIG 12:ENERGY SPECTRUM WITH GATE A

In a previous experiment, using a different electronic set-up, it has been possible to separate the two spectra of the phoswich, one from the $LaBr_3$ crystal and one from the $LaCl_3$.

Figures numbers 9 and 10 represent energy and temporal spectra for a Cs^{137} source in the position shown in the figure. In the second figure the gate which have been used for the time discrimination of the signals are represented. The third figure represents the energy spectrum obtained using the B gate and with the source in front of the crystal, that means that only the energy signals coming from the $LaBr_3$ crystal have been represented. Changing again the position of the cesium source, as shown in figure 12, and using the A gate in the temporal spectrum, the energy spectrum coming from the $LaCl_3$ is obtained.