CEPA: A $LaBr_3(Ce)/LaCl_3(Ce)$ phoswich array for detection of high energy protons and gamma radiation

J. Sánchez del Río[1], M.J.G. Borge[1], J.A. Briz[1], M. Carmona-Gallardo[1], A. Charpy[2], *E. Casarejos[3], D. Cortina-Gil[4], J. Benlliure[4], H.T. Johansson[2], E. Nácher[1], H. Álvarez-Pol[4], T. Nilsson[2], A. Perea[1], B. Pietras[4], G. Ribeiro[1], J. Sánchez[1] and O. Tengblad[1]*

[1]Instituto de Estructura de la Materia, CSIC Madrid; [2] Chalmers Univ. Technology, Göteborg, [3]Universidad de Vigo, [4]Universidad de Santiago de Compostela

The 'Forward EndCap' of CALIFA [1] should cover the polar angle region between the beam pipe i.e. 6^{O} to 43^{O}, where the CALIFA barrel takes over the detection. This region concentrates 58.3% of the total γ rays emitted by a source moving at the nominal value of 0.82c and where Doppler shift boosts the energy to 1.5 – 2.5 times its value in the Centre of Mass frame.

Working towards a final design an endcap (CEPA) is proposed that should satisfy these requirements. To be able to compensate for the mentioned Lorenz boost, a high segmentation is needed and an energy resolution due to this effect of $\Delta E/E$=3.75 % has been used as a design effort. The CEPA is divided into 10 branches of 5 alveoli, each alveoli is sub-divided into 15 slots to hold the individual crystals. In total the CEPA amount to 750 individual crystals of truncated pyramidal shape. The active detection coverage of the CEPA detector for the mention solid angle is more than 80%.

As the detector is to detect high energy protons up to 400 MeV as well as gamma radiation up to 30 MeV, a phoswich configuration of 4 cm $LaBr_3(Ce)$ + 6 cm $LaCl_3(Ce)$ long crystals was decided. This configuration makes the CEPA work as a telescope detector ΔE_{LaBr3}-E_{Tot} for protons up to 200 MeV or as a double energy loss detector $\Delta E_{LaBr3}+\Delta E_{LaCl3}$ for protons of higher energies.

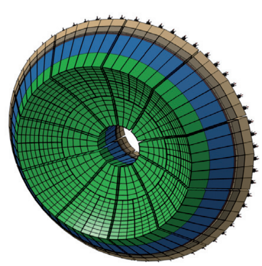

Figure 1: CEPA design.

For the design efforts, Montecarlo simulations were performed to especially study the efficiency for high energy protons, gamma resolutions, and to optimize the crystal length. The optimal phoswich crystal length of 10 cm (4+6 cm) was determined as a compromise between high gamma absorption efficiency (calorimeter) and proton spectroscopy up to the very high proton energies (400 MeV) [2]. By the use of the phoswich configuration, an analytical method that consists in representing the energy deposited in the $LaBr_3$ crystals vs the energy deposited in the whole calorimeter allows to resolve high energy protons. In these 2D histograms one can clearly distinguish the protons that are stopped in the first crystal, the ones that continue and stop in the second crystal and the ones that punch through even the second crystal. These results are shown in Fig. 2, that display the 2D spectrum resulting from the simulated $^{12}C(p,2p)^{11}B$ reaction at 400 MeV of initial kinetical energy when detecting coincident pairs of protons.

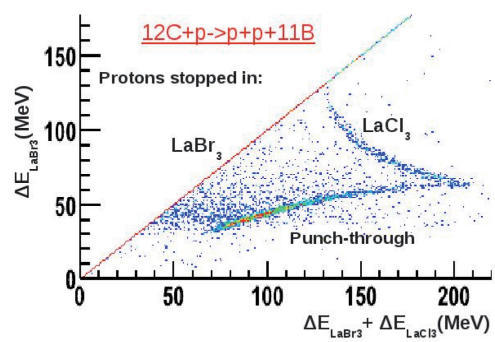

Figure 2: 2D spectrum of the protons from simulation of $^{12}C(p,2p)^{11}B$ reaction at 400 MeV/u.

Experimental tests for high energy protons (200 - 1000 MeV) were performed during the S406 experiment (Characterization of NEUland prototypes, described elswhere in this scientific report) in November using a prototype module consisting of 2x2 phoswich $LaBr_3(Ce)/LaCl_3(Ce)$ rectangular crystals array, placed at 18º from the beam. The geometrical dimensions of this 10 cm long array is 4 cm of $LaBr_3$ coupled with 6 cm of $LaCl_3$. The analysis of these data is ongoing.

References

[1] D. Cortina-Gil et al., GSI SCIENTIFIC REPORT 2011.

[2] O. Tengblad et al., Nucl. Inst. and Meth. in Phys. A704 (2013) 19-26.

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