Status of the CALIFA/R^{3}B calorimeter*

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CALIFA (the CALorimeter for In Flight detection of γ rays and light charged pArticles) is one of the key detectors of the R^{3}B experiment. It surrounds the reaction target and is optimised according to the exacting requirements given by the ambitious physics program proposed for the R^{3}B facility [1]. CALIFA is a versatile detector and will be used in a wide spectrum of experiments. In certain spectroscopy experiments, high γ-ray energy resolution (5% at 1 MeV) as well as multiplicity determination is required. In other experiments the goal is to attain calorimetric response with high efficiency. Part of the complexity arises from the reaction kinematics which leads to large Lorentz boosts and broadening of the detected γ rays peaks, i.e. effects that the detector should be able to account for. Charged particles of moderate energy, e.g. protons up to 300 MeV, should also be identified with an energy resolution better than 1%.

In order to meet these targets the detector is divided into two sections, a "Forward EndCap" covering polar angles between 7-43.2^o and a cylindrical "Barrel" section that provides angular coverage up to 140.3^o. The Technical Design Report (TDR) [2] of the Barrel section was recently approved (January 2013) by FAIR, following the recommendation of the Expert Committee for Experiments (ECE)[1]. The adopted technical solution consists of 1952 CsI(Tl) crystals, readout by Large Area Avalanche Photodiodes (LAAPDs), and a very compact geometry (internal radius 30 cm) in order to maximise the calorimetric properties. To optimize the detector efficiency and to minimize energy straggling for inter-crystal proton scattering, the passive material must be kept at an absolute minimum. These demands have lead to an in-depth investigation of the best crystal housing, support structures and overall mechanical design.

The coupling of LAAPDs to CsI crystals was found to fulfil many of the R^{3}B programme's most challenging demands. Their ability to meet the energy resolution requirement has been proven via an extensive R&D program using standard radioactive sources. The performance over a wide dynamic range has been investigated via irradiation of smaller size prototypes with proton beams at 25 (MLL, 2011), 180 (TSL, 2009), 200 and 400 MeV (GSI, 2012). Readout support for the photosensors is provided by Mesytec MPC-16B preamplifiers, which feature an online temperature-gain correction. A custom digital FEBEX electronic support system, envisaged for use in the final CALIFA setup is currently undergoing tests. In addition to the compact, high performance design, this approach takes advantage of the different CsI decay times for pulse shape analysis for particle identification. The FEBEX setup is highly flexible and allows for easy reprogramming of the FPGA online processing to suit individual experimental requirements [3].

Detailed simulations of the response of the CALIFA Barrel have been performed within the R3BROOT analysis framework in order to guide the progression through each stage of the development process. These simulations have been validated by comparison to experimental data for a number of smaller scale prototypes for both γ-ray and proton irradiation over a wide range in energy.

The next milestone as described in the TDR is the construction of the CALIFA Demonstrator. The Demonstrator will have a modular configuration of 8 petals each comprising 20 alveoli. The Demonstrator will cover a polar range of 32.5 – 65°, with 4 types of alveoli/crystals and 3 segments of 2 alveoli in the azimuthal direction and 10 alveoli in

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[1] Decision adopted in the ECE first meeting in November 2012

polar direction. The design provides a significant section of the final calorimeter and will ultimately be incorporated into CALIFA [4]. In addition to detector characterisation, the Demonstrator is intended for use in a real experimental campaign. In Figure 1 an artistic view of the CALIFA Demonstrator is shown.

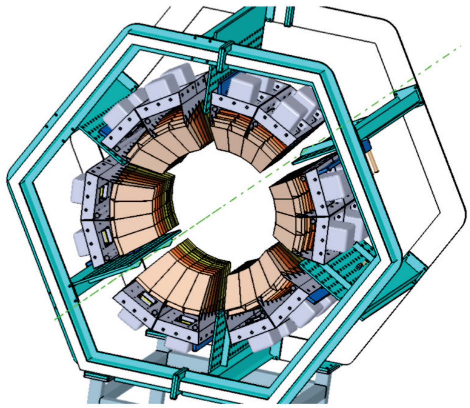

Figure 1: An artistic impression of the CALIFA Demonstrator.

We are in parallel working on the R&D towards an optimal solution for the "Forward EndCap" section. This polar region will be subject to high energy charged particles in addition to γ rays boosted to several times their energy in the projectile rest frame. The long CsI(Tl) crystals employed for the CALIFA Barrel section would fulfil the R^3B physics requirements for the EndCap section, however this option would suffer from incident charged particles undergoing a large number of inelastic reactions, significantly reducing the full energy peak efficiency. This restriction may be overcome by the use of a phoswich concept with two, relatively short, high performance scintillator layers which provide two ΔE measurements as charged particles pass through them. From these measurements the particle's incident energy can be determined. This approach reduces the detector volume significantly and several phoswich options are currently under investigation.

One such concept proposes a combination of two novel scintillation materials: 4 cm of $LaBr_3$(Ce) followed by 6 cm $LaCl_3$(Ce). This configuration works as a telescope, the first section ($LaBr_3$(Ce)) provides a ΔE measurement whereas the total E is obtained by the two consecutive energy loss measurements ($\Delta E\ LaBr_3 + \Delta E\ LaCl_3$). An initial small size prototype consisting of an array of 2x2 phoswich $LaBr_3$+$LaCl_3$ elements, formed by rectangular crystals, was recently irradiated with high energy protons (GSI, 200-1000 MeV). Data analysis is currently under way.

We have also progressed towards the final design of the segmentation of the Forward EndCap. The large segmentation present in the Barrel must be preserved in order to retain the spectrometric capabilities. A dedicated design

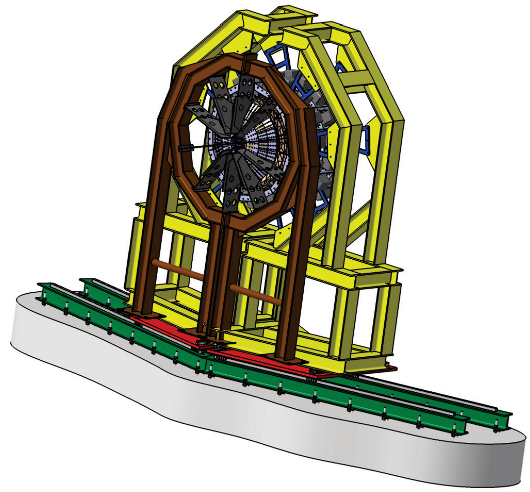

Figure 2: An artistic representation of the complete CALIFA calorimeter.

places frustum shaped crystals into 10 branches, each one containing 5 alveoli. The alveoli are sub-divided into 15 sectors holding individual crystals which results in a total of 750 crystals. The performance of this system has been studied by means of Monte Carlo simulations [5].

Figure 2 shows an artistic conception of CALIFA where both sections: Barrel and Forward EndCap, are mounted on a common platform. CALIFA is currently entering a very exciting period, with the full implementation and commissioning of the CALIFA Demonstrator expected in the first quarter of 2014. The submission of the TDR for the forward section is foreseen by the end of 2014. According to our plans the complete CALIFA should be installed and operational in the R^3B cave by the end of 2016.

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