CALIF a Calorimeter for in-flight detection of γ-rays and light charged particles for the R^3B@FAIR experiment

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A calorimeter for in-flight detection of γ-rays and light charged particles is one of the main detection systems of the R^3B experiment [1] at FAIR. This detector will be used in most of the physical cases presented in the R^3B Technical proposal [1], though the requirements differ significantly from one case to the other. In some cases it is the γ-ray sum energy that is required ($\sigma(E_{sum})/\langle E_{sum}\rangle < 10\%$) , while in others the detector has to be able to provide γ-ray multiplicities($\sigma(N_\gamma)/\langle N_\gamma\rangle < 10\%$) and individual γ-ray energies (2-3 % ΔE/E) for spectroscopic purposes. As a key requirement the detector has also to act as the calorimeter for the target Silicon recoil detector described in [1, 2]. Hence the detector has to stop and measure the total energy of high-energy light charged particles, i.e. protons up to 300 MeV, with good energy resolution.

The main properties of this device, high total absorption efficiency ($\geq$ 80% for γ's at 15 MeV in the laboratory frame) and good angular resolution($\approx$ 1 deg for $\Theta \approx 35$ deg), are imposed by the very particular kinematics of energetic γ-rays (up to 30 MeV in the CM system) emitted by sources moving with relativistic velocities and by the typically low intensities of the secondary beams involved. In order to ensure these nominal values in all the angular domain, the polar angular segmentation and the thickness of the scintillation material will be variable. All these considerations determine the choice of the device geometry.

Several options are under study to guarantee the polar segmentation. In a first design, we propose a detector divided into small frustum-like crystals. The dimensions and type of scintillator used would depend on the γ-ray emission angle (finger-like solution). Each crystal will be coupled to an individual readout device, being the final angular resolution determined by the crystal entrance area. Another posible solution is based on larger area crystals coupled to several readout devices and where the final angular resolution will be deduced from the combined information from the different sensors. Finally, a third solution would consider two detection stages, the first one made of thin detectors with very high granularity, providing the angular resolution, and the second one with larger area and thick crystals ensuring the total absorption function.

Extensive simulations using the GEANT4 package and based on the first geometrical approach have been performed. In the present design (Figure 1), around 5000 crystals will surround the reaction target with a total length of 130 cm, 35 cm of internal radius and external variable radius ranging between 46-77 cm. We distinguish a central part or BARREL, with cylindrical shape, covering polar angles between 40 and 130 degrees, and an ENDCAP, with semi-spherical shape, for polar angles between 7 and 40 degrees. The crystals have the form of pyramidal frustum with rectangular base, with the axis orientated approximately towards a fixed point (the target, in coincidence with the center of coordinates of the system from which the polar angles are measured). The amount, size and form of the crystals are fixed to ensure the angular segmentation needed and to get a complete circle (ring). There are 5 different types of crystals in the BARREL and up to 24 in the zone of the ENDCAP, where at low polar angles, it is complicated to close a volume without gaps.

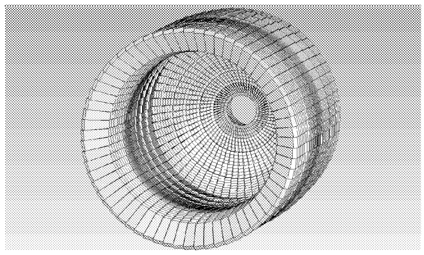

Figure 1: Graphical representation of a preliminary geometrical design of the R^3B calorimeter.

The selection of the appropriate scintillation material and readout device is another critical parameter that would determined the nominal energy resolution of the detector. Presently, several inorganic scintillators are under study, namely $LaCl_3$(Ce), $LaBr_3$(Ce), CsI(pure) and CsI(Tl). The first three materials have a rather good intrinsic resolution (in the order of 3% for 662 keV γ's) what coupled with an appropiated readout device will match the detector requirements. However, they present some disadventages: the first two are at present rather expensive and highly hygroscopic and the third one needs to be cooled down to LN2 temperatures to achieve this value. Those factors justify the study of CsI(Tl) crystals coupled to adecuate sensors (APD or PM) that with a moderate energy resolution (lower than 5% for 662 keV γ's) could be a plausible solution, at least for backward angles (BARREL).

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References

[1] http://www-land-gsi.de/r3b/docu/R3B-TP-Dec05.pdf.

[2] http://www.gsi.de/informationen/wti/library/scientificreport2005/FAIR-NUSTAR-R3B-01.pdf