Design of the GRETINA detector module

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The detector module is the highest cost item of GRETINA and is also the most critical to its performance. During the R&D phase, a large number of simulation studies have been carried out to determine the detector design parameters, such as the number and size of the segments, needed to achieve the required position resolution. Three prototype detectors with increasing complexity were purchased from Canberra/Eurisys. The development of these detectors helped to establish the design, cost, and performance of these highly segmented detectors. The detectors were tested to confirm and validate the simulation calculations and the results were used in the design of the production model.

In the production model, the Ge crystals will have an irregular tapered hexagonal shape with six longitudinal and 6 transverse segmentation giving 36 separated electrodes on the outside surface. The cylindrical crystal, before shaping, has a diameter of 8 cm and a length of 9 cm. During the conceptual design phase two major alternatives were considered. They are packing 3 vs. 4 crystals per cryostat, and using warm vs. cold field effect transistor (FET) for the preamplifier. The power dissipated by cold FETs in a 4-crystal configuration is large and it is not clear that it is possible to design a compact cryostat that can remove the entire heat load generated. Therefore, only three possible designs are left:

a) Three crystals with cold FETs
b) Three crystals with warm FETs
c) Four crystals with warm FETs

Following a detailed value engineering analysis, a decision was made to use the 4-crystal with warm FETs design. This study was made with input from the GRETINA engineering staff, the Detector Working Group, the Advisory Committee, and the detector manufacturer. Factors considered included performance, risk, cost and schedule to the GRETINA project as well as its operation and future extension to a full 120 crystal array (GRETA).

The use of warm FETs is based on the question of reliability and serviceability and the significant impact failures have on the array performance when in operation. The down time to replace a cold FET is about 9 days, because it requires a cycle of warm up, repair and cool down. Warming up a neutron damaged detector will degrade its resolution, and thus it would require additional time for annealing. With warm FETs the repair time is less than 1 day. This is a much shorter down time and the risk associated with FET replacement is also much less. In addition, the warm FET will have less liquid nitrogen consumption, better temperature stability, allowing easy upgrade and shorter production time. The warm FET will have higher noise which corresponds to an energy degradation of about 0.2 keV at 60 keV and 0.1 keV at 1 MeV. This is not significant compared to other effects such as Doppler broadening.

Packing 4-crystals in a single module requires the minimum number (2) of crystal types and only one type of module (all modules are identical) is needed. A 3-crystal design requires 4 types of crystal and 2 types of module. Thus from a fabrication point of view, the quad design is less expensive and requires less tooling. Due to its closer packing, it is evident that the 4 crystal design has consistently better efficiency and peak-to-total performance (although by only a small percentage) for the same solid angle coverage.

With the quad design, GRETINA will have 7 modules with a total of 28 crystals, and the triple design will have 9 modules with 27 crystals. Thus the total efficiency will be higher for the quad design. The total cost of the quad design is $100k less than the triple-warm design, and is $400k less than the triple-cold design. The advantages of the quad design become even more important as we look to a future continuation towards the full GRETA array.

The shape of the two types of irregular hexagon crystal were determined by optimizing the solid angle coverage under the constrains of the crystal size, the space for gaps and the cryostat walls. Figure 1 shows the optimal packing of the sphere using these two types of crystals.

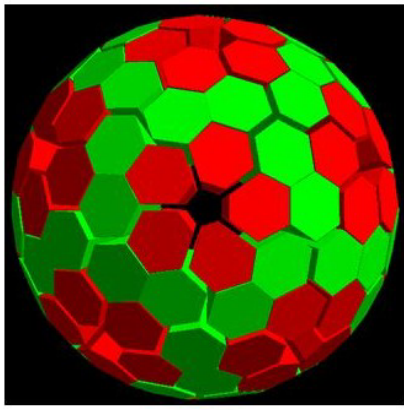

FIG. 1: Packing sphere with two types of GRETINA crystals.