Coherent Neutrino Detection in the Year 2008

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Abstract. CoGeNT, a recent collaboration between Argonne National Laboratory, CANBERRA Industries, Lawrence Livermore National Laboratory, Pacific Northwest National Laboratory, Sandia National Laboratory, the University of Chicago and the University of Washington, aims at the detection of very faint ($\sim$100 eV) signals in devices massive enough ($\sim$1 kg) to allow searches for rare processes, using recently developed p-type point contact (PPC) germanium detectors. The broad range of applications for these detectors is succinctly described. Implications from their first underground operation are discussed. Finally, the status of an ongoing deployment at the San Onofre nuclear generation station, aiming at obtaining a first evidence for coherent (anti)neutrino interactions with nuclei, is briefly described.

We have recently reported on a new type of germanium detector [1] (Fig. 1). PPCs (p-type point contact), as we refer to them, feature an unprecedented marriage between large mass and low electronic noise, opening up more than a decade of low-energy (sub-keV) range to exploration with ultra-low background devices (Fig. 2). While our initial interest in the design was motivated by low-energy applications, we soon realized their strong potential for high-energy gamma background discrimination (Fig. 3) in next-generation double-beta decay projects such as Majorana [2].

The first PPC prototype [1] was operated early in 2008 in a shallow underground site (300 m.w.e.). This new laboratory is part of Chicago's Tunnel And Reservoir Project (TARP), sited 20 minutes from the UC campus. A full shield featuring a triple active veto was built around the detector. These runs revealed a low-energy source of background, now addressed. The collected data have nonetheless allowed to impose new limits on light WIMPs (Fig. 4), ruling out the very last possibility remaining for the DAMA modulation [3] to be caused by a standard WIMP halo. These results can be found in [4]. Besides their unmatched sensitivity to light WIMPs, PPCs are presently the only existing detector capable of testing the alternative hypothesis that light axion-like particles might be the cause for the DAMA effect. The detector is now taking data 25 m away from one of the reactors at the San Onofre Nuclear Generation Station (SONGS, Fig. 5). We expect to perform in this site a first observation of coherent neutrino-nucleus scattering, a process of great interest in fundamental and applied neutrino physics [1]. The large cross-section expected from this process can lead to a miniaturization in the mass of low-energy neutrino detectors by up to three orders of magnitude, enabling technological applications such as neutrino reactor safeguards.

PPC detectors are becoming increasingly popular within Majorana. The planned Majorana 60 kg demonstrator will feature at least two-thirds of its target mass as PPCs. Several PPCs have been successfully developed within the Majorana collaboration during 2007,

demonstrating reproducibility in their manufacture. One more, featuring upgraded electronics and based on a commercially-available BEGe crystal, is under construction for the University of Chicago group. A vigorous research program on improved front-end electronics is in progress: we envision realistic future energy thresholds lower than 100 eV. In other words, the energy resolution typical of a CCD, embodied in a large (∼1 kg) germanium gamma spectrometer.

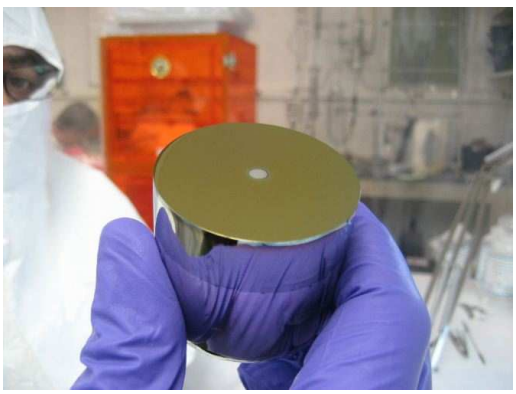

Figure 1. A view of the point contact region in a PPC germanium detector.

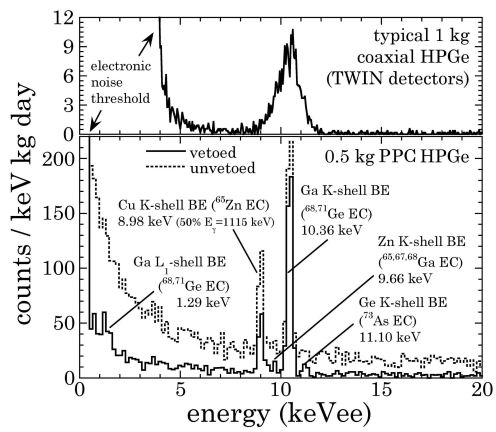

Figure 2. (from [4]) Improvements in threshold and resolution in a PPC design (bottom), compared to a typical coaxial HPGe (top). Cosmogenic peaks are clearly resolved in the PPC spectrum. BE stands for binding energy, EC for electron capture.

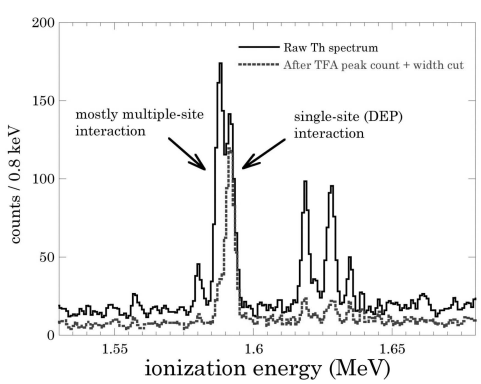

Figure 3. (from [1]) Natural Thorium irradiation of a PPC detector and effect of pulse-shape cuts on rejection of multiple-site events (see text). The energy resolution appears slightly degraded due to the limited resolution of the digitizer employed (8 bit).

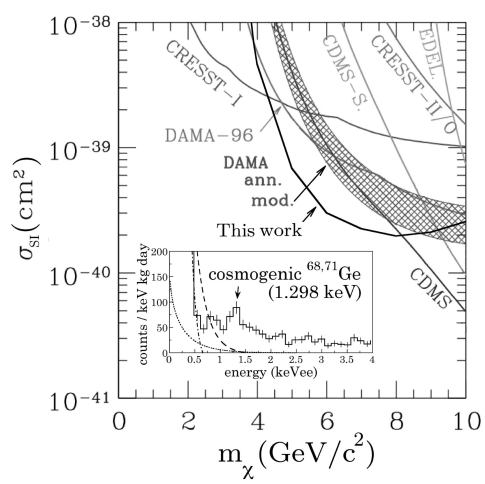

Figure 4. (from [4]) New limits on spin-independent couplings from light WIMPs, from a shallow underground run of the first PPC prototype (see text).

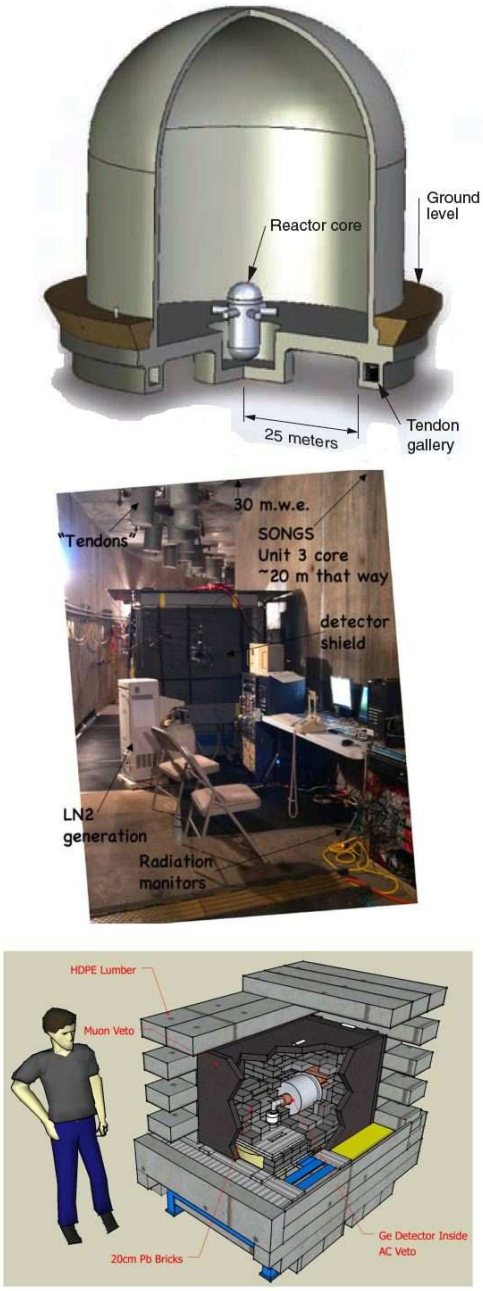

Figure 5. Top: "Tendon" galleries are commonly found along the periphery of power reactor containment domes. The term makes reference to the endings of the steel reinforcement cables that criss-cross the structure. Middle: the experimental setup for our ongoing attempt at coherent neutrino detection. Galleries like these combine a high (anti)neutrino flux ($\sim 10^{13}$ ν/cm^2 s) with the background reduction benefits from a $\sim$30 m.w.e. overburden. Liquid nitrogen is generated from air in situ. Bottom: shield design. A triple active veto is combined with several layers of passive shielding. A low-efficiency external muon veto is not shown in the diagram, but visible in the photograph.

References

[1] Barbeau P S, Collar J I and Tench O 2007 Large-Mass Ultra-Low Noise Germanium Detectors: Performance and Applications in Neutrino and Astroparticle Physics *J. Cosmol. Astropart. Phys.* JCAP09(2007)009.

[2] Elliott S R *et al.* 2008 The Majorana Project *Preprint* arXiv:0807.1741.

[3] Bernabei R *et al.* 2008 First results from DAMA/LIBRA and the combined results with DAMA/NaI *Preprint* arXiv:0804.2741.

[4] Aalseth C E *et al.* 2008 Experimental constraints on a dark matter origin for the DAMA annual modulation effect *Preprint* arXiv:0807.0879.