HPGe detector pumping/temperature history

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We report here a short history of "vacuum interventions" required to sustain our high-precision efficiency-calibrated HPGe detector, whose absolute efficiency was determined more than 15 years ago to a precision of ~0.15%, as initially reported in [1]. Over its lifetime, this detector has lost vacuum a number of times. In all cases, no major damage was done since the built-in protection circuitry ensured that the detector was shut-down whenever the crystal temperature rose above about -160°C. However, in order for us to effect repairs the detector had to be warmed to room temperature for a few days on each occasion. This could have affected the detector's efficiency calibration so we routinely verified its stability by measuring the activity of our "standard" precisely calibrated ^{60}Co source, which was used in the original calibration.

The first major vacuum failure occurred in 2002. Using a high-vacuum leak-checker, we were able to locate the leak at the bond between the Be window and the Al cap. While there was no mechanical problem with the bond, the epoxy wasn't able to maintain the vacuum. After contacting the manufacturer (ORTEC) we learned that a permanent fix would imply a brand-new cap for the crystal. Such a major overhaul would have tampered with the geometry of the HPGe and turned our detector into a good-but-uncalibrated one. To avoid this major inconvenience, we tried a less-radical fix: we patched externally the cap at the Al-Be contact. For this purpose, we used a manufacturer-recommended low-vapor-pressure epoxy. After leak-testing the patch, the HPGe was cooled to liquid-nitrogen (LN) temperature. The last important step of the repair consisted in the verification of the absolute efficiency with our ^{60}Co source. The relatively tedious work payed off: The repaired HPGe showed no change from the previously determined efficiency curve.

During the next 14 years, there were five more vacuum-loss incidents, each handled the same way and each leaving the detector's efficiency unaltered. However, starting in 2016, the seal of the Be window appeared to be in a less stable situation: during that year alone we performed four interventions. While each patch appeared to work, it nevertheless ended up in a vacuum loss after a few months.

In the spring of 2017, we completely removed all the old epoxy and added a thin fresh layer of low-vapor-pressure epoxy (see Fig. 1). Again, we leak checked, re-cooled the detector and returned it to use. At that point though, we started monitoring the temperature of the crystal, using the ORTEC calibrated thermal element. This allowed us to effectively monitor the pressure and prevent unexpected shut-downs. Subsequently when the temperature (consequently, pressure) rose to near the shut-down threshold (~-160°C), we intervened to pump the detector out. On no occasion was there any indication of a leak in the Be window seal. Fig. 2 shows the evolution of the crystal temperature after each pumping.

FIG. 1. Externally patched epoxy seal of the Be window in early 2017.

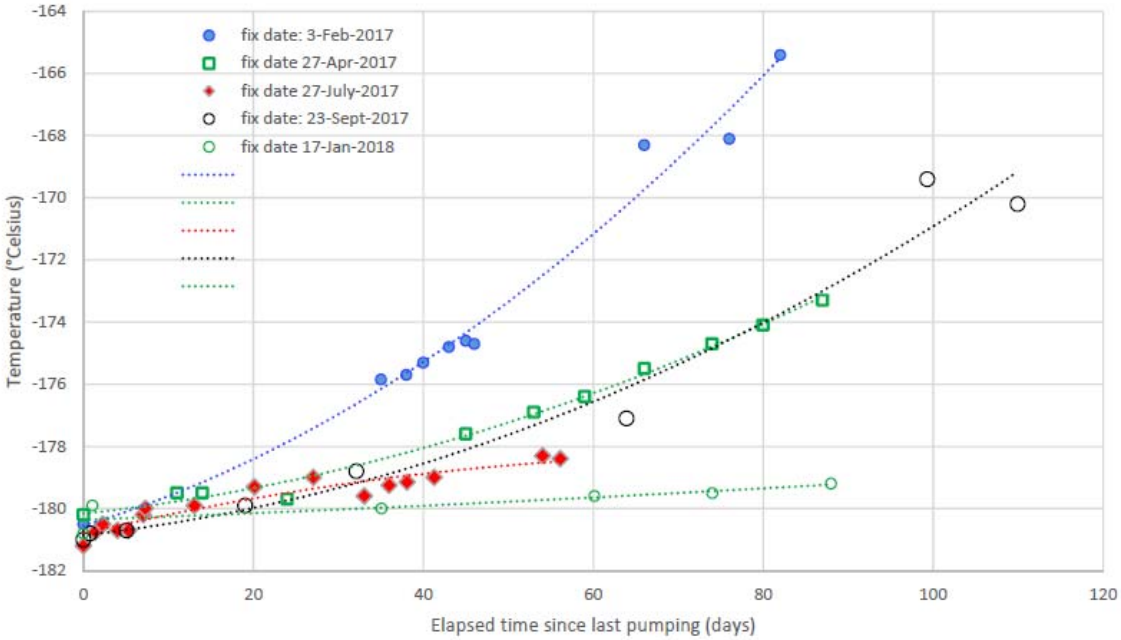

FIG. 2. Evolution of the HPGe temperature post vacuum-intervention in 2017 and 2018.

We performed three more (preventive) vacuum restorations during 2017. Since no significant leak was detected, we concluded that the increased heating rate was related to a reduced capacity of the molecular sieve to maintain the required high vacuum. As these interventions were preventive, we did not expect any negative impact on the detector's performance. However, each intervention increased the time required to bias the detector after cool-down: from a few minutes, to hours, then days. Thus, the last 2017 intervention required 4 steps to bias the HPGe to the nominal voltage of -4300 V: The step limits were -3200, -3700, -4100, and -4300 V. In each step we biased the detector to the maximum voltage it could sustain with normal energy-resolution, leaving it for several hours at that voltage before moving to the next step.

Clearly something had to be done to restore the effectiveness of the molecular sieve. Heating it to high temperature was out of the question since that would have seriously compromised our detector's performance, so in January 2018 we tried a "minimal" cure. With the detector operating normally, we stopped the LN cooling and brought the detector to room temperature while continuously pumping. We then continued pumping for five days, considerably longer than ever before. This time, after the detector had been cooled again it behaved normally: only a few minutes was required to bring the bias to the nominal -4300 V. Moreover, the evolution of the crystal temperature (see Fig. 2) indicates a partial restauration of the pumping capacity of the molecular sieve: The temperature increases at a rate of 0.1°C/week, much less than after previous fixes.

Because of the abnormal behavior in detector biasing observed in 2017 we became concerned that our efficiency calibration might have been affected. We are currently preparing for a high-precision evaluation of our HPGe absolute efficiency as it stands after the January 2018 fix.

[1] R.G. Helmer, J.C. Hardy, V.E. Iacob, M. Sanchez-Vega, R.G. Neilson, and J. Nelson, Nucl. Instrum. Methods Phys. Res. **A511**, 360 (2003).