Studies of systematic effects of the AstroBox2 detector in online conditions

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After commissioning, the AstroBox2 detector [1] has been used already for several physics experiments. During some of the experiments systematic effects in the measured decay spectra have been observed and related to gain shifts due to the environment, the chemical nature of the isotope under investigation, and to the beam implantation rate [2].

Gas gain, especially in the exponential regime of a Micromegas, can be very sensitive to various changes in the detection medium such as gas impurity levels and gas density changes due to either pressure or temperature fluctuations. In the experimental cave which remains closed during the beam time, the temperature stabilizes during beam tuning and is monitored during experiments. To track possible gain drift we have implemented multiple independent ways to monitor the stability of the detector: (1) an α-source on an active side pad of the detector, (2) a separate chamber for a ~1 cm^2 Micromegas detector using an ^{55}Fe X-ray source at the gas exhaust, (3) a pulser in the AstroBox electronics, and (4) possible strong decay branches of the species under study. In most cases when the environment is under control, no gain shifts beyond the typical instrument resolution are observed. In case gain shifts are observed, those can be corrected by using the the simultaneously collected α-source data from an active side pad [2].

Within the present operating conditions in use with AstroBox2 the implanted ions if rapidly neutralized will exercise a Brownian motion and will be localized within a sphere of few mm of the stopping position at decay. However, for relatively low electron affinities with respect to the P5 constituents, the ions will drift towards the cathode. In some cases, such as βα-decay of ^{20}Na, we have observed a clear signature of decays occurring on the cathode: As shown in Fig. 1, ^{16}O recoils are clearly seen in data and in calorimetric measurement this is only possible from decay on a surface. The α will be deposited into the cathode while the ^{16}O recoil ionization is detected. In addition the drift time difference from the two pads indicates particle tracks mostly towards the anode. If the decay occurs in gas, there should be equal amounts of particle tracks towards the cathode, a signature missing from these data. Our observations [2] are in agreement from earlier studies done at GANIL in the 1990s [3] but would need a separate study to be fully characterized.

In the AstroBox experiments, when everything is under control, we have not observed any rate related effects up to about kHz total implant/decay rates (rates limited mostly due to amount of primary beam available). However, during one of our experiments the standard MKS piPC99 gas controller failed during the setup stage and we had to use instead the gas handling system used for the Oxford detector. During the run it became evident that unknown chemical history and component quality of this gas system, even after flushing for several days, brought up implant / decay related pulse height defect even at below kHz rates. This effect was localized into pads with highest implant rates which translates to

highest β-activity during the decay phase [2]. A separate study with proper gas handling system to study this effect with higher rates is under planning.

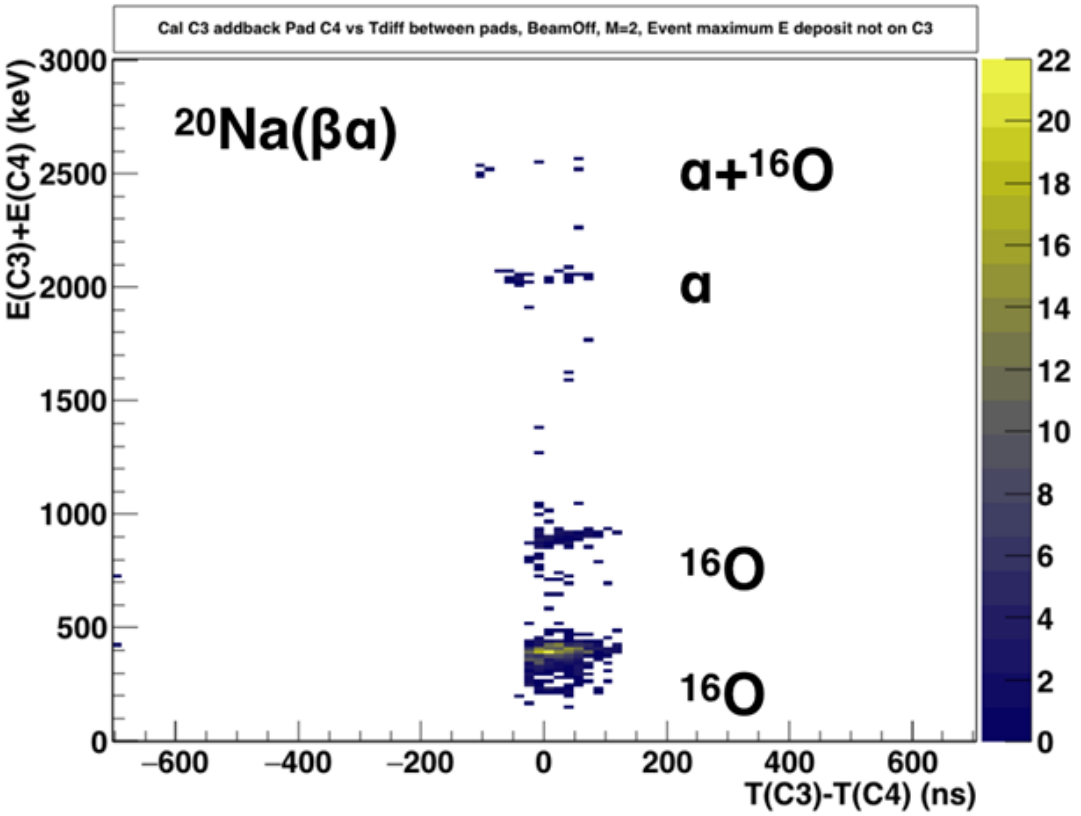

FIG. 1. The total decay energy collected with two neighboring pads from the central region (labeled C3 and C4) versus the time difference of the same pads in case of ^{20}Na measured with AstroBox2. Here the positive time difference in pad drift times corresponds to particle trajectory towards the anode and the negative time difference to a trajectory towards the cathode. The spectra are produced from beam off period with requirement of exactly two pads firing, and that the maximum energy deposition of the event is not on the pad where decay occurred.

[1] A. Saastamoinen *et al.*, Nucl. Instrum. Methods Phys. Res. B**376**, 357 (2016).

[2] A. Saastamoinen *et al.*, Nucl. Instrum. Methods Phys. Res. B (in press); DOI: 10.1016/j.nimb.-2019.05.026.

[3] B. Blank *et al.*, Nucl. Instrum. Methods Phys. Res. **A330**, 83 (1993).