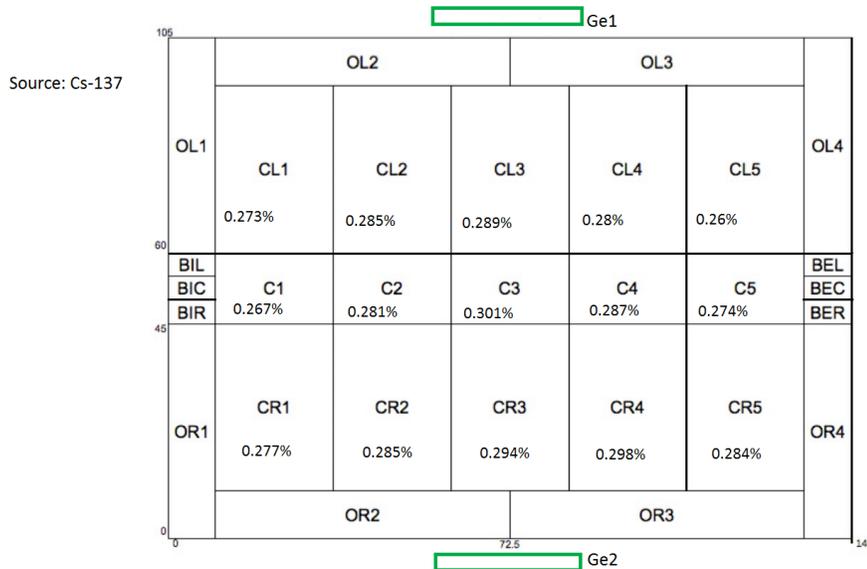


## Gamma efficiency measurements for the AstroBoxII with two HPGe detectors

R. Chyzh, A. Saastamoinen, and R.E. Tribble

Proton-gamma capture reactions,  $X(p, \gamma)Y$ , play an important role in stellar environments like X-ray bursts or novae [1-3]. Reactions like  $^{22}\text{Na}(p, \gamma)^{23}\text{Mg}$ ,  $^{12}\text{C}(p, \gamma)^{13}\text{N}(\beta^+)^{13}\text{C}$ , and  $^{16}\text{O}(p, \gamma)^{17}\text{F}(\beta^+)^{17}\text{O}$  are particularly important in the novae explosions [1-3]. These reactions are characterized by the location and the strength of proton resonances. Many of the important resonances lie just above the proton separation threshold  $S_p$  and they can be studied by indirect methods such as proton decay after a  $\beta$ -decay. In this case we populate the important states by means of  $\beta$ -decay. This will necessarily bring a problem of dealing with  $\beta$ -background. The AstroBoxII was specially designed for this purpose and it allows to reduce  $\beta$ -background dramatically and opens up an opportunity to measure proton energies of just a few hundred keV [4] [6]. It is a new detector that is an improvement over the original AstroBox[5]. While measuring low proton energy is the main task for the AstroBoxII, doing gamma spectroscopy helps to answer some important questions about the studied resonances. If we have a state that lies above  $S_p$  that can undergo proton decay, it is important to know whether or not this state decays directly to the ground state or to some excited state, which in turn de-excites by emitting gamma rays. By doing proton and gamma measurements in coincidence we can reliably answer that question. The gamma efficiency is needed to determine if the amount of observed coincident protons and gammas agree. Another important problem



**FIG. 1.** Gamma efficiency distribution for different pads in the AstroBoxII.

that can be addressed by doing gamma spectroscopy is answering a question about branching ratios of the resonances that lie just above  $S_p$ . A state can decay either by proton emission or gamma emission. To tell how much gamma emission there is relative to proton emission we need to know the efficiency of gamma detection. For this purpose we used two gamma sources:  $^{137}\text{Cs}$  with a single gamma line at 661.7 keV,

primarily for the efficiency measurements for every pad in the AstroBoxII and  $^{152}\text{Eu}$  for efficiency versus energy measurements.

The results for  $^{137}\text{Cs}$  are presented in the Fig 1. Two HPGe detectors were placed on the left and on the right side along the beam axis as close to the AstroBoxII as possible. The source ( $^{137}\text{Cs}$ ) was hung on a string that was attached to each individual pad. In each pad we see the combined efficiency from both HPGe detectors. As expected we get the highest efficiency (around 0.3%) in the central pads.

After that we repeated the same measurement with a  $^{152}\text{Eu}$  source. Using multiple gamma lines from the source we obtained efficiency curve for the central pad C3.

In Fig 2. it is clear that the efficiency of the gamma detection for the HPGe detectors falls exponentially with energy. Also it is worth mentioning that one the HPGe detectors (Ge2) displayed a little bit better efficiency than the other (Ge1). That can be partially explained by the fact that the positioning of the two detectors relative to the AstroBoxII is not exactly the same.

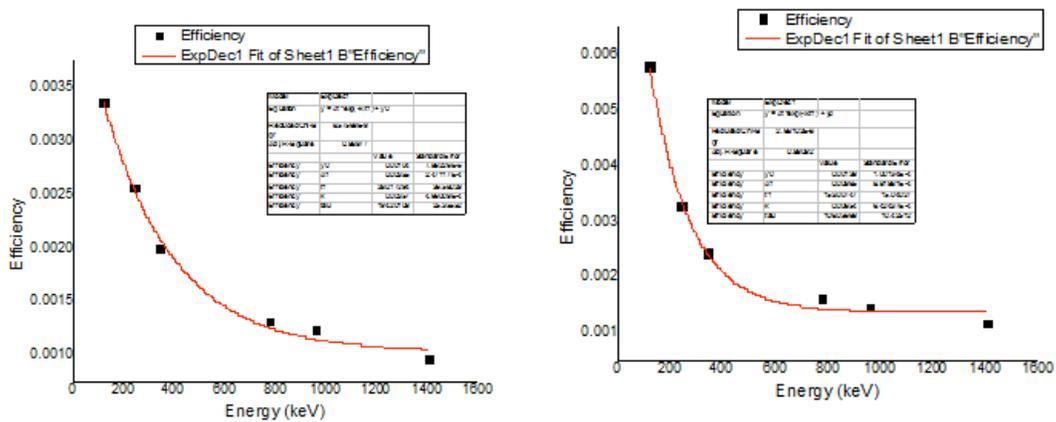


FIG. 2. Efficiency curves for the first (on the left) and the second (on the right) HPGe detectors.

- [1] J. Jose and C. Iliadis Rep. Prog. **74**, 096901 (2011).
- [2] J. Jose and M. Hernanz Eur. Phys. J. A **27**, Supplement 1, 107 (2006).
- [3] J. Jose, M. Hernanz, and C. Iliadis Nucl. Phys. **A777**, 550 (2006).
- [4] A.Saastamoinen *et al.*, Nucl. Instrum. Methods Phys. Res. **A376**, 357 (2016).
- [5] E. Pollacco *et al.*, Nucl. Instrum. Methods Phys. Res. **A723**, 102 (2013).
- [6] A.Saastamoinen *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2014-2015) p. IV-33; R. Chyzh *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2015-2016) p. IV-35.