Measurement of annihilation lifetime for positron burst

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High intensity positron bursts, with a time spread of few nanoseconds or even picoseconds, can be produced thanks to the development of positron trapping and femtosecond laser-induced positron techniques. Huge number of gamma photons will be released at almost same time, when the positron burst annihilates in the target. Because of the overflow of detector, it is impossible to pick out the time information for each annihilating γ-ray using conventional time-measurement nuclear detection technology. In this study, the method of a multi-detector array composed of enough independent detector cells, with high efficiency and accuracy, is first put forward to detecting the positron burst lifetime.

The performance parameters of timing resolution and counting efficiency for a PALS measurement by this method were simulated and tested in experimental. We found that the detection efficiency mainly depends on single γ detection efficiency of the detector cell and the intensity of the positron burst, the higher the efficiency of detector cell or the intensity of positron burst is, the larger detection efficiency the detector array system has. While the time resolution mainly depends on the burst time width and time resolution of detector cells.

When the burst detection efficiency of a detector cell is high enough, it is very likely to detect one more γ rays during one positron burst, and signals pile-up will occur. Due to the relatively long response time of detectors, pile-up leads to picking out the time information of the first photon that hits the detector only, and the information of other photons will be lost. Results showed that the positron lifetime value measured will be less than the true one with high pile-up level. In this work, we have analyzed the pile-up reason from three aspects—theoretical calculation, simulation and experiment. According to the results, the lifetime can be measured precisely by setting the signals' amplitude an upper-threshold corresponding to the energy of 511 keV. And the valid burst detection efficiency will be maximum (~37%), when the detector is at the position where the average number of γ-ray detected in a burst is only one.

In future, we plan to arrange 2048 detector cells on a hemisphere as the array. In order to detect lifetime efficiently and accurately, we found that once the properties of the detector cell and the intensity of the positron burst are fixed, the position and the valid detecting efficiency are determined. For example, for 3mm×3mm×5mm LYSO and 5000 e^+/burst with 33 Hz repetition frequency, the array radius is 54~85 mm and the typical counting rate can reach 2.5×10^4/s.

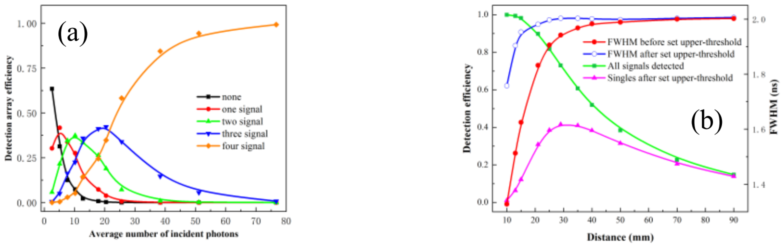

Figure (a) *Detection array efficiency as a function of the average number of incident photons.* **(b)** *FWHM of 2ns width burst and detection efficiency as a function of the detector distance.*

References

[1] B.Y. Wang *et al.*, *Nucl Instrum Methods Phys Res A*, **885**, 119~123 (2017).

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