Properties of Single Crystal Para-Terphenyl as Medium for High Resolution TOF Detector

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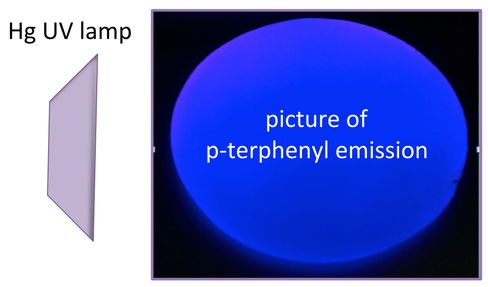
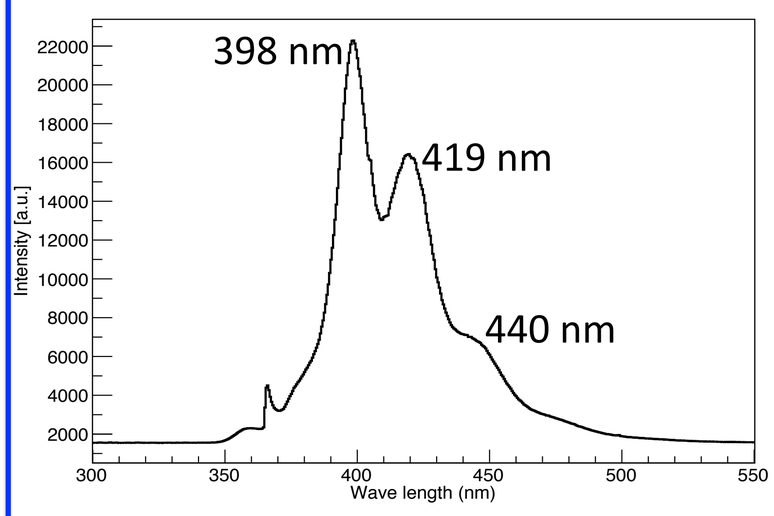
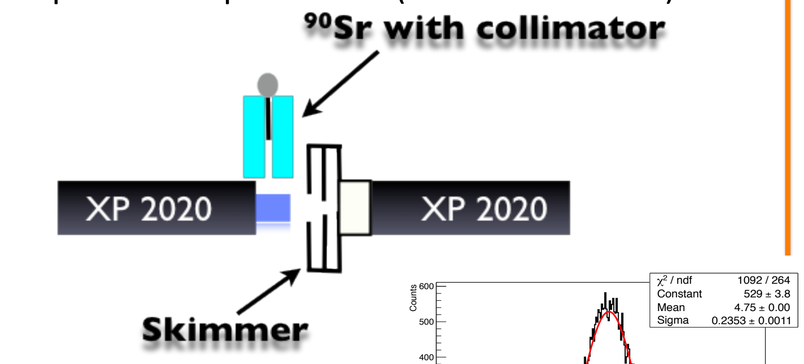
Abstract: In the last years organic scintillators have been largely investigated in order to achieve high light yield together with good time response. It has been showed [1] that pure organic compound with high quality crystalline structure can achieve both this goals. Among a large type of organic compound, para-terphenyl ($C_{18}H_{14}$) have proven to have practical applications as detector medium for particle physics. In this paper, the characterization of different sizes (1-3 cm) high quality mono-crystal p-terphenyl samples is presented. The optical and scintillation properties (emission spectrum, light yield, attenuation length, decay time) are investigated. Coupling a Silicon Photomultiplier-based readout system to the crystal, a small prototype for a high resolution TOF detector was built; the preliminary results, obtained on a 20x30x3 mm^3 sample, with dual-side read-out (Hamamatsu S10931-050P SiPMs) and irradiated with ^{90}Sr source, show a time resolution of ~35ps.

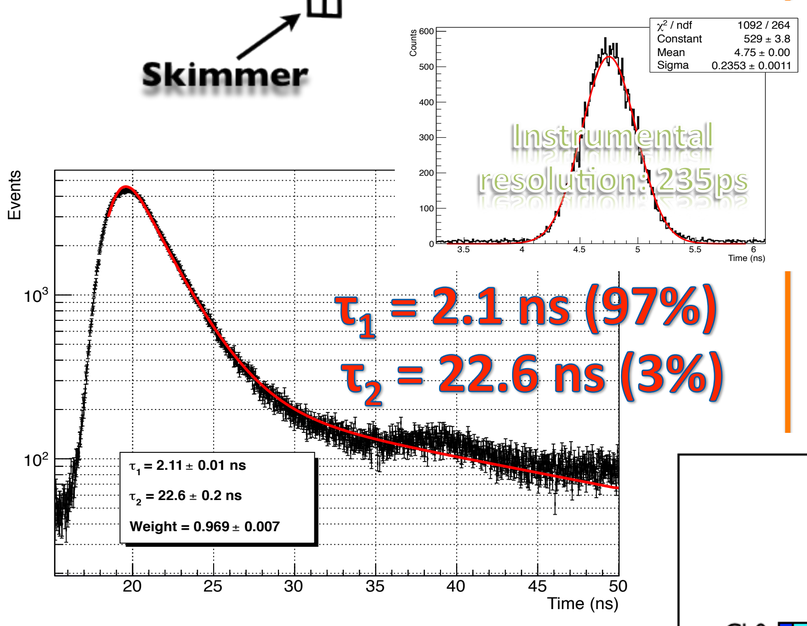
The emission spectrum has characteristic features with 3 peaks (namely: 398, 419 and 440 nm) and is slightly blue-shifted [1].



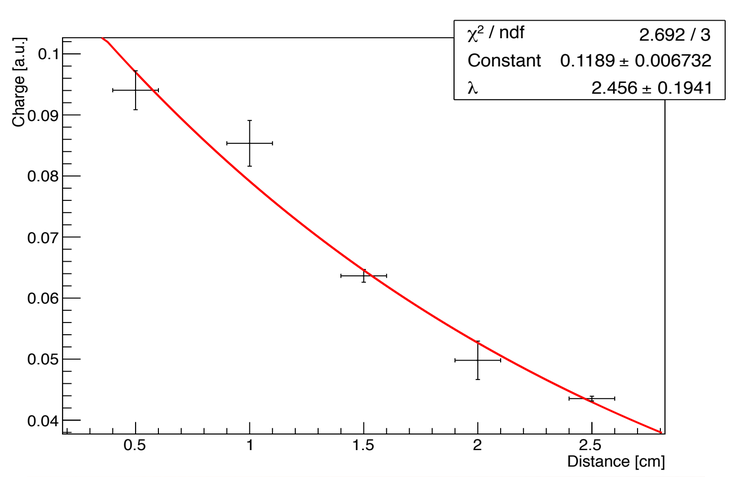


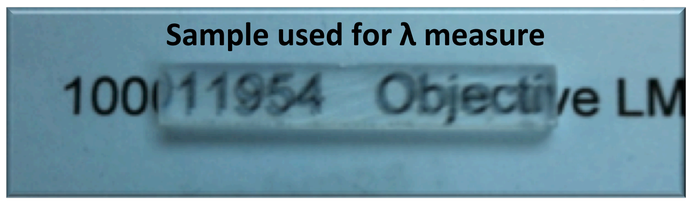
The decay time constants of p-terphenyl are measured by a standard start–stop timing method coupled with single photon detection [2] based on fast photomultiplier tubes (Photonis XP2020).

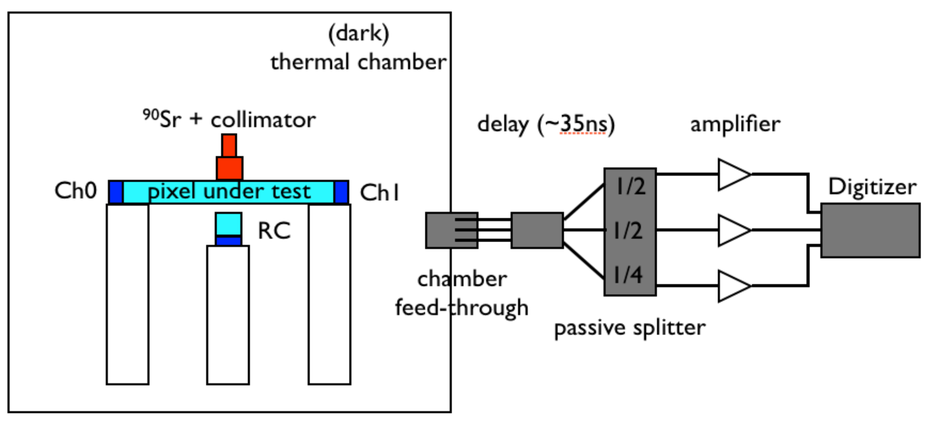




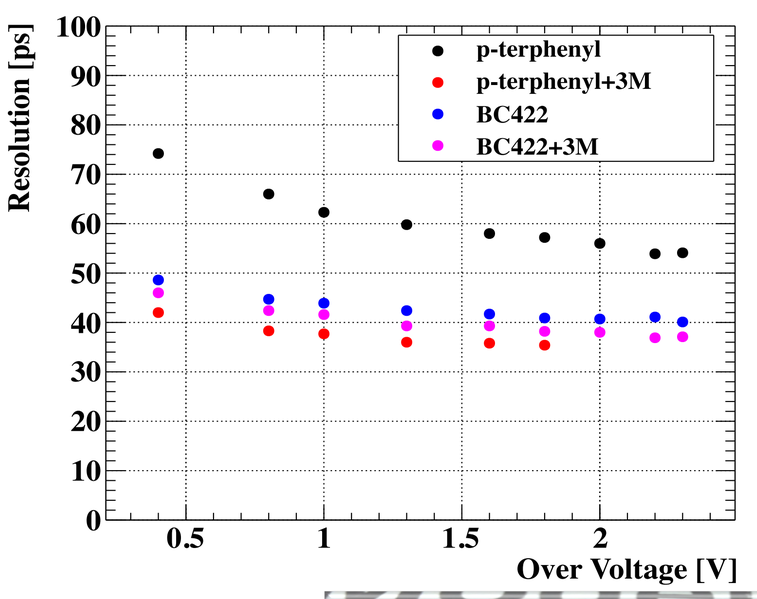
An attenuation length of 2.45 cm was found. Being this attenuation length close to slab size, the measurement has to be compared with ones of larger sizes for a reliable determination.

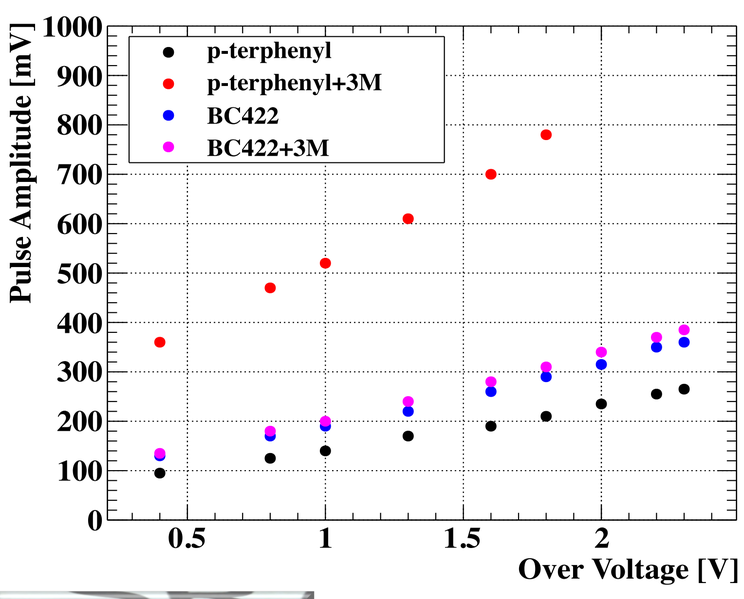


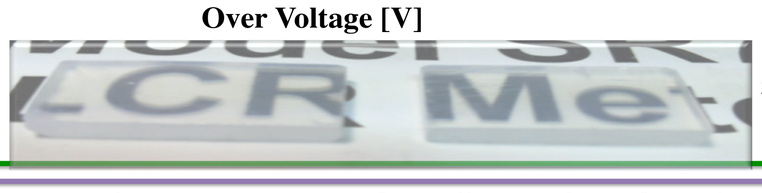




Time resolution and relative light yield of p-terphenyl detector of 20x30x3 mm^3 size sample, with dual-side read-out (Hamamatsu S10931-050P SiPMs) by excting with electrons from ^{90}Sr source. In order to have a reliable comparison with a standard scintillator, a same size sample of BC422 plastic scintillator was prepared and measured as well.







Sample used for timing reso measurement

The quality of the surface has a strong influence on performances:

- without any wrapping, p-terphenyl has low amplitude and worst resolution, due to light losses at the optical surface;
- with 3M film wrapping, light is recovered and p-terphenyl shows very good resolution and huge pulse amplitude.
- A resolution of 35ps was obtained in the best configuration, to be compared with 38ps for BC422 in the same conditions (10% improvement).
- An estimation of the light yield can be done by comparing pulse amplitude for p-terphenyl and BC422: p-terphenyl shows a x3 more LY with respect to standard plastic scintillator.

Conclusions: a preliminary characterization of small samples of single crystal p-terphenyl shows good performances for TOF detector applications. Emission spectrum well matches peak sensitivity wave length of SiPMs (like ASD-NUV-SiPM3S-P). Attenuation length of ~2.5cm is enough for many practical applications. Fast decay time and huge light yield permits to have optimum timing resolution performances: a comparison with a standard plastic scintillator (BC422) shows an improvement of 10% in timing resolution. Further studies are ongoing: we expect to improve time resolution by means of an improvement in the crystal surface polishing .

References:
[1] S. V. Budakovsky et al., Functional materials, 16(1):86 (2009).
[2] L. M. Bollinger, G. E. Thomas Rev. Sci. Instrum. 32, 1044 (1961)

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