Response of Acrylic to UV light

Quantifying the fluorescence response of the ultra-pure acrylic used in the DEAP-3600 dark matter detector

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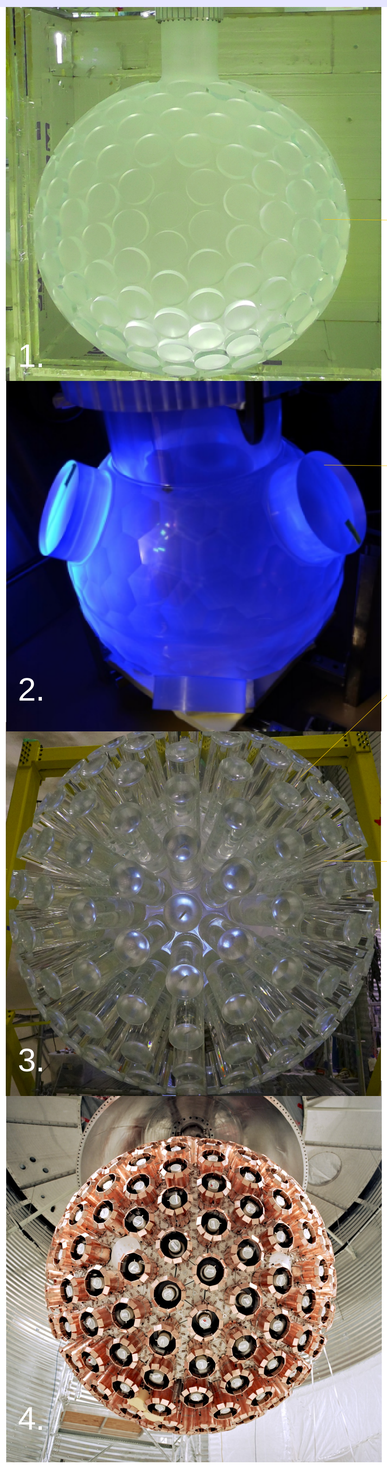
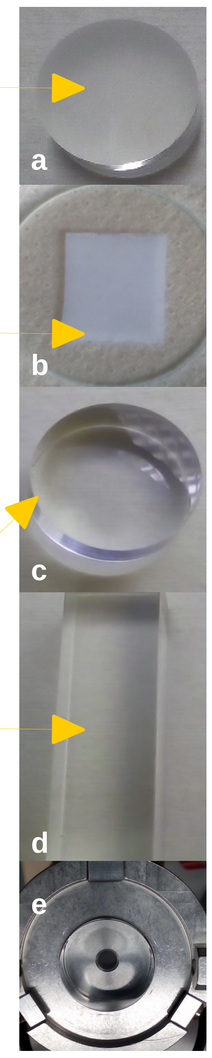
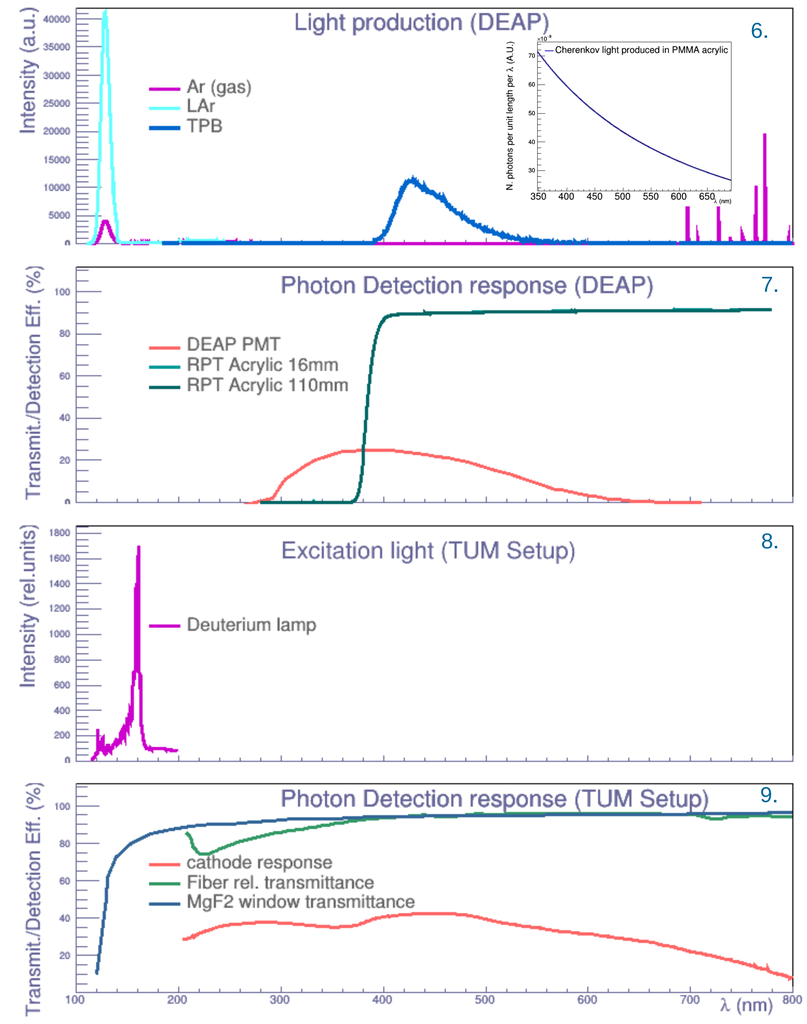




The DEAP-3600 detector combines custom-made ultra-pure and high transmittance acrylic with the wavelength shifter TPB.

At the center of the DEAP-3600 detector is a spherical cryostat (Ø170cm) made out of ultra-pure acrylic. The cryostat is shown in *Fig.* ***1*** during construction and currently contains the 3300kg of liquid argon that forms the dark matter target. The inner surface of the vessel (AV) was sanded with a resurfacer in order to remove deposited radon daughters. A rough acrylic sample of the AV is shown in *Fig*. ***a*** and its transmittance is shown in *Fig.**7***. The inside of the acrylic cryostat is coated with a thin layer of the wavelength shifter TPB, which shifts UV light into the blue spectral region, as shown in *Fig*. ***2,*** where a small scale test vessel is lit with a 265nm UV lamp. A 1.9µm thick layer of TPB vacuum evaporated on glass is shown in *Fig.* ***b***. Its emission spectrum is shown in *Fig.* ***6***. Attached to the acrylic cryostat are 255 light guides (LG) made out of acrylic chosen for its superior optical transmittance. The LGs are shown in *Fig*. ***3*** and a sample of it is shown in ***c.*** A sample of this acrylic with bond used to attach the light guides is shown in *Fig*. ***d.*** A PMT is coupled to the end of each light guide, as shown in *Fig.* ***4***. The PMTs observe the LAr volume through the 50cm of acrylic, looking for a scintillation signal. The scintillation signal of LAr and its shift by TPB are shown in *Fig.* ***6***. The response of the PMT is shown in ***7***. In *Fig.**e**, a* cylindrical sample is shown inside the sample holder, which was specially designed to measure the acrylic samples and the TPB sample with the same geometry, allowing for the comparison between measurements.

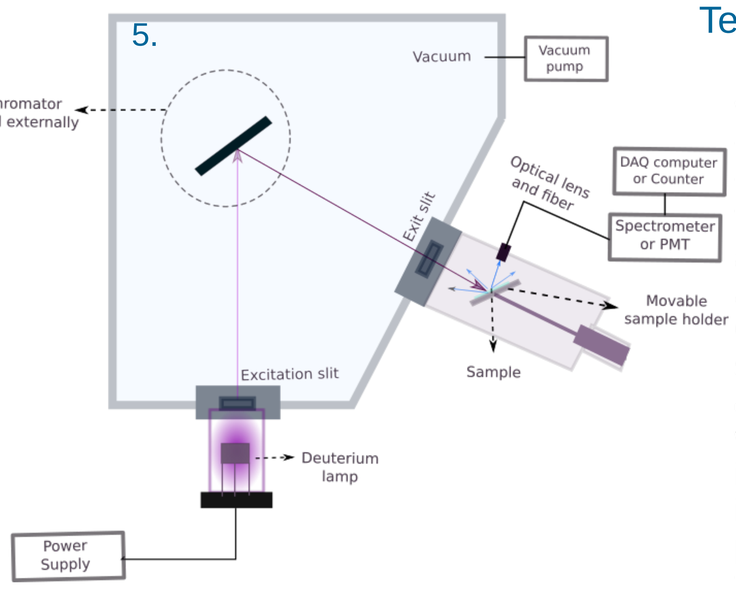


Several studies done on acrylic (PMMA) indicate its fluorescence

The fluorescence of acrylic has been reported by [1-5] for excitation light above 355nm. This response can be however different for acrylic produced by different manufacturers, since its fluorescence could be due to impurities, additives or lab processes. This response also may vary for lower excitation wavelengths. We measured, to the best of our knowledge, the response of acrylic to VUV light for the first time.

Fluorescence search region

In the DEAP detector, fluorescence of acrylic could be induced by: i) the scintillation of LAr or argon gas (*Fig.* ***6***) hitting acrylic that is not coated with TPB (neck); ii) Cherenkov light created in the acrylic (shown in the inset). The fluorescence search region is defined by the optical transmittance of the detector materials, shown in *Fig.* ***7***.

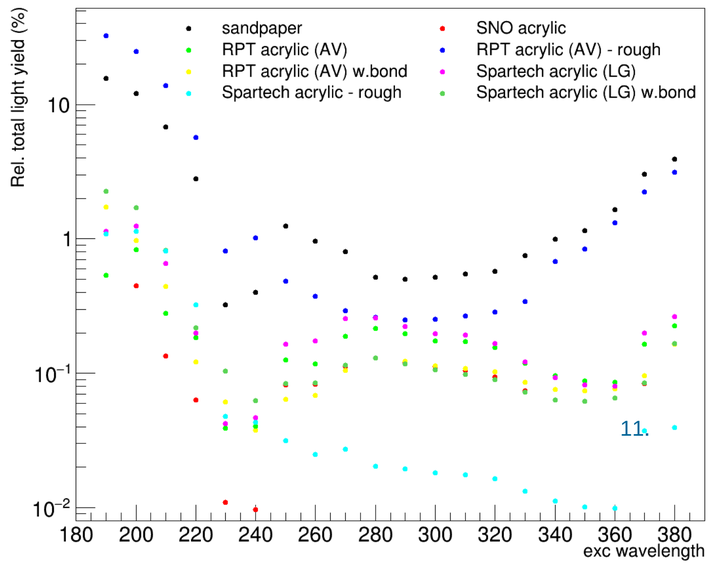


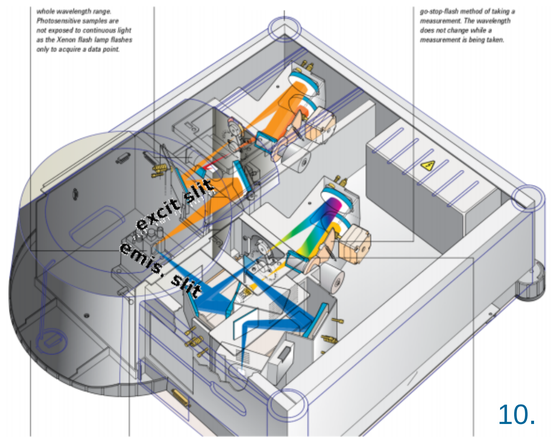
Tests at a level of 0.1% of TPB fluorescence with the TUM fluorescence Setup:

We built a test-stand to quantify the fluorescence response of acrylic relative to TPB for excitation wavelengths from 130 to 160nm. The TUM fluorescence Setup is shown in *Fig.* ***5*** and is composed of a deuterium lamp, a grating and a light detector which either consisted of an Ocean Optics spectrometer or a PMT. The spectrum of the deuterium lamp is shown in *Fig.* ***8***. A monochromator is used to select a specific wavelength from this spectrum and to guide it into the sample. As fluorescence emits light isotropically, some of the possible fluorescence photons will be collected by the lens. They are then transmitted through an optical fiber toward the light detector. The transmittance of the fiber is shown in *Fig.* ***9***. With the spectrometer, we found no fluorescence response from the acrylic and were able to put a limit at 1% relative to the TPB sample (*Fig. b*). In order to achieve an even better sensitivity, we performed wavelength-integrated measurements using a PMT. The PMT is composed of a S20 cathode and a Magnesium fluoride window. Its photosensitivity is shown in *Fig.* ***9***. With this setup, we were able to measure the fluorescence of the acrylic samples at a level of 0.1% of the wavelength shifting efficiency of a 1.9µm thick layer of TPB. The sensitivity of these measurements was limited by stray light in the 180 to 200nm region and by possible fluorescence of the lens or of other contaminations. We quantified the level of stray light and other background fluorescence sources by measuring the samples with air inside the chamber, by measuring the empty chamber and with the measurements of a plasma cleaned aluminium disc.

Results

For excitation with 130nm (~λ_{LAr}) photons and with 160nm (the most intense light available with the deuterium lamp) we were able to place a limit on the fluorescence response of acrylic in the 390 to 680nm region of 0.22% relative to the TPB sample. The relative light yield by the acrylic samples and by the sandpaper in the fluorescence measurements with the Cary Eclipse spectrophotometer for excitation with 190 to 380nm light (covering most of the wavelength region from Cherenkov light in the acrylic) is shown in *Fig.* ***11***. The light detected for excitation with 260 to 380nm photons could not be explained by either stray light or fluorescence of the filters.





Cary Eclipse Spectrophotometer

As the range of the grating of the TUM setup only goes up to approx. 200nm, a commercial spectrophotometer was used to quantify the fluorescence response for excitation wavelengths from 190 to 380nm. The Cary Eclipse spectrophotometer is shown in *Fig.* ***10*** and its source of excitation light is a xenon flash lamp. The sensitivity of this device was limited by stray light and fluorescence of the filters, which were seen in the measurements of the aluminium plasma cleaned reference sample.

References

[1] Aigars Piruska et al. The autofluorescence of plastic materials and chips measured under laser irradiation. *Lab Chip, 5, 13481354, 2005.*
[2] Kenneth R. Hawkins and Paul Yager. Nonlinear decrease of background fluorescence in polymer thin-films a survey of materials and how they can complicate fluorescence detection in mtas. *Lab Chip, 2003, 3, 248252.*
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[4] Hamed Shadpour et al. Physiochemical properties of various polymer substrates and their effects on microchip electrophoresis performance. *J. of Chromatography A, 1111 (2006) 238251.*
[5] Yann Molard et. al. Red-NIR Luminescent Hybrid Poly(methyl methacrylate) Containing Covalently Linked Octahedral Rhenium Metallic Clusters. *Chem. Eur. J. 2010, 16, 5613 5619.*