Rate capability and transient gain drop of a single photon timing detector

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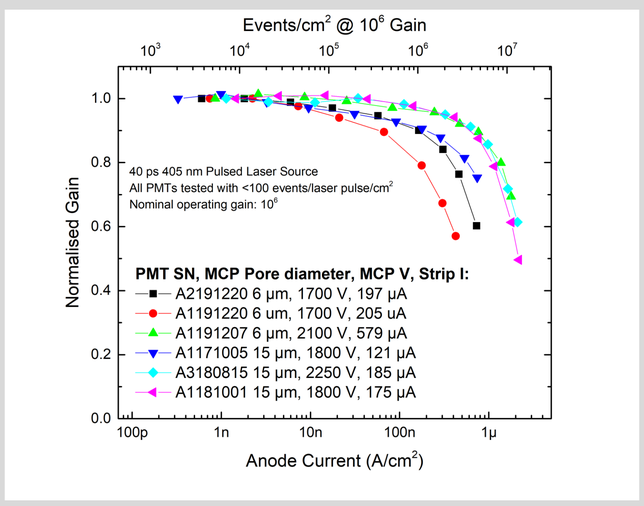
Multi-anode Microchannel Plate (MCP) detectors provide sub-30 ps timing, single-photon sensitivity, and modular designs. High-Energy Physics experiments, such as TORCH, demand higher photon rates and finer spatial resolution. This study measures the rate capability of multi-anode photomultiplier tubes (MAPMTs), including a custom 16 × 96-pixel device (0.55 mm pitch), to assess the lateral spread of transient gain loss.

When a photoelectron triggers an avalanche in the MCP, local charge depletion causes a temporary gain drop, reducing sensitivity. This suppression extends beyond the struck channel, affecting neighbours and broadening the effective dead time. Quantifying this spread is critical for optimizing MCP design and pixel pitch in high-rate particle physics applications.

Global Gain Saturation of Multi-anode PMT's Vs. MCP pore size

The plots demonstrates the global gain saturation of MAPMT's with varying MCP pore diameters, the graphs illustrates a correlation between bigger pore diameters and gain saturating at a higher photon rate. Plot 1b. further confirms this correlation by removing the dominating factor of the strip current by plotting the nominal gain vs. anode/ strip current.



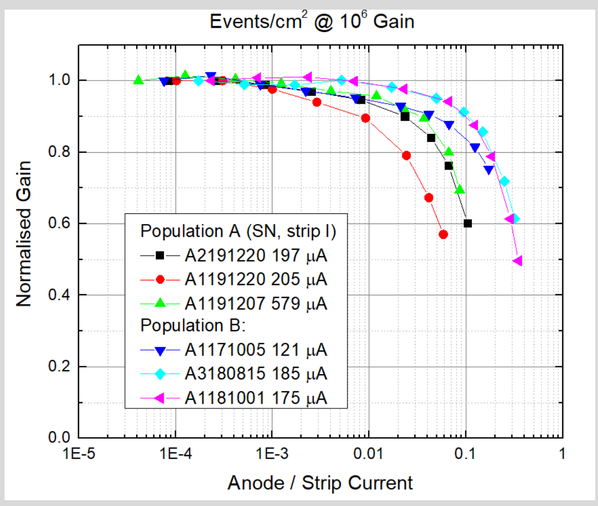


Figure 1a) and 1b) Illustrates the global gain saturation for multiple multi anode PMT's using microchannel plates with 6 µm and 15 µm diameter pores.

Global Gain Saturation Vs Local Gain Saturation for MAPMT's

These results illustrate the contrast between local and global saturation. In both plots, "previous Photek data" references experimental data whereby the entire active area of the cathode illuminated.

The remainder of the data points are taken by illuminating a masked area of the cathode of 0.326 cm^2 and operating the PMT at varying gains between 4.3 x 10^5 and 2.13 x 10^6, while increasing the repetition of rate of the laser.

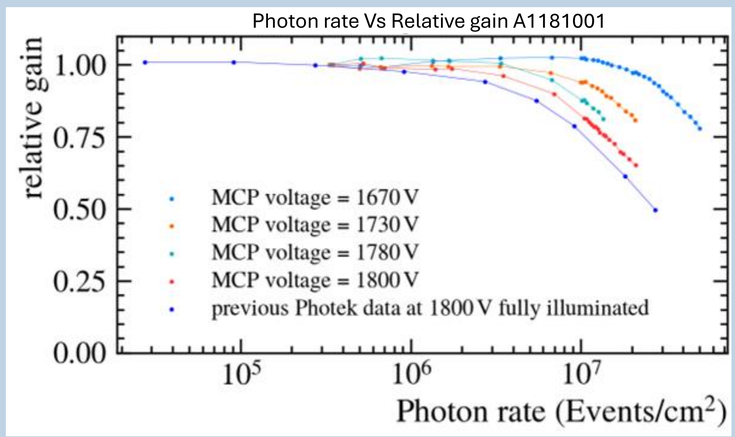


Figure 2a) Demonstrates gain saturation occurs more readily when operating the PMT at higher gain

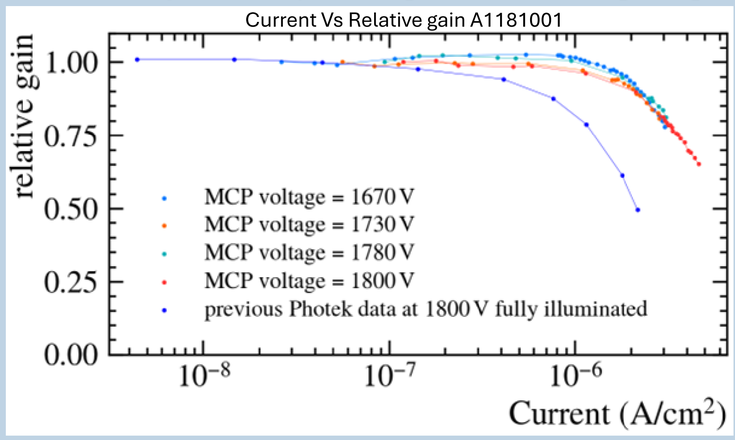


Figure 2b) depicts the contrast between a globally illuminated cathode and illuminating a masked area of 0.326 cm^2.

Local gain saturation with an image intensifier

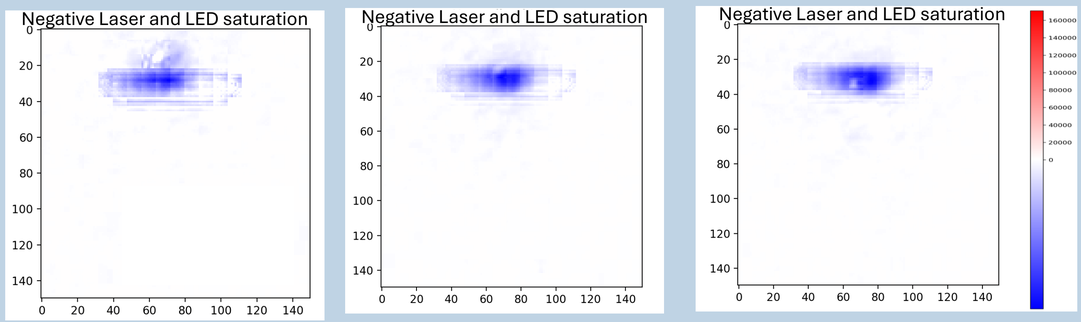
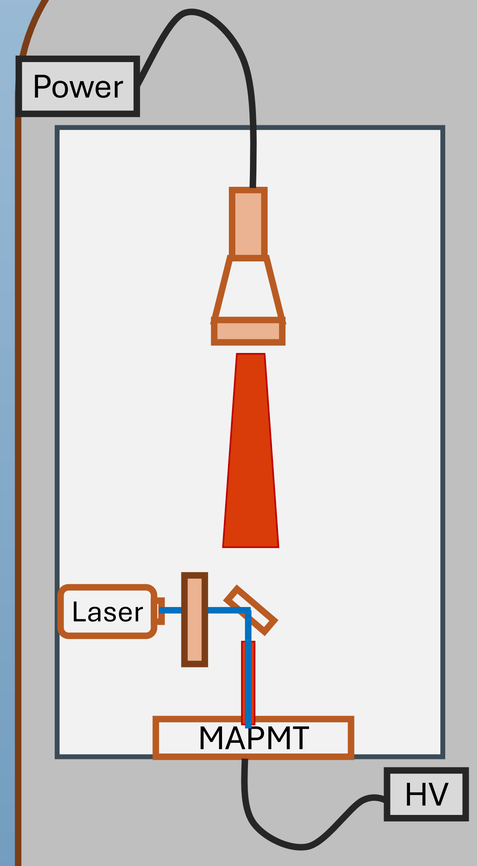


Figure 3) Plots demonstrate the local saturation on an image intensifier as a 405 nm laser is moved vertically through an illuminated masked 1mm^2 area

Plot 3 shows saturation of an illuminated area using a laser at three positions, subtracting the unsaturated image and laser, shows the saturated area as negative in the plots above.

Local gain saturation with a MAPMT



Plot 4a shows pulse height distributions with varying laser trigger rates where the peak is the electron gain. Plots 4a and 4b conclude local gain saturation from a 2 x 64 readout of an MAPMT with an 8 x 64 anode. The plot 4c shows local saturation of a single pixel instrumented.

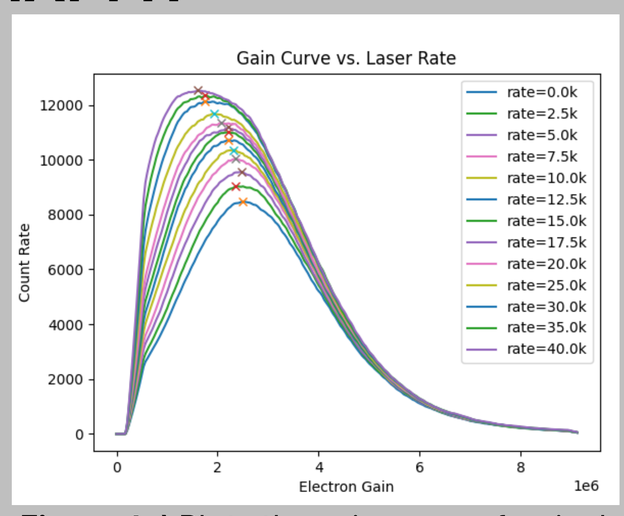


Figure 4a) Plots the gain curve of a single column with varying laser trigger rates

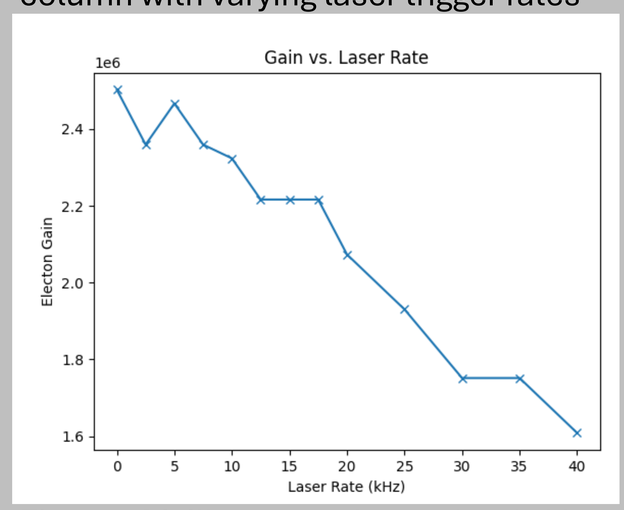


Figure 4b) Illustrates the peak gain Vs the laser trigger rate

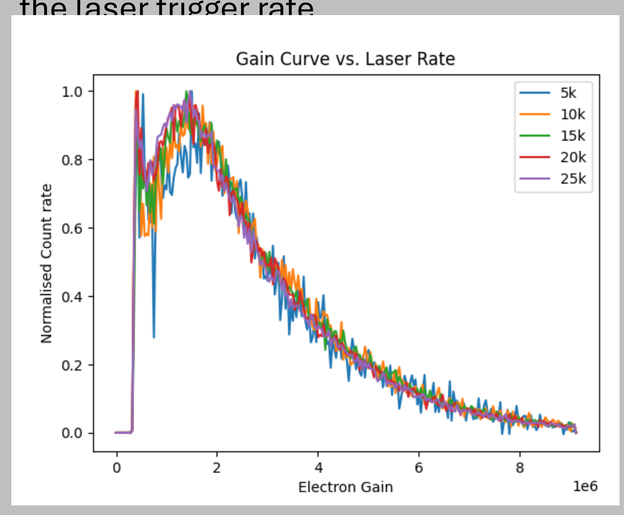


Figure 4c) Depicts the gain curve of a single pixel with varying laser trigger rates

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