Timing performance of the NectarCAM camera: paper outline

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Paper Outline

Timing performance of the NectarCAM camera

(NectarCAM collaboration)

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- SCOPE: describing results on timing precision and accuracy of NectarCAM
- Target journal: **NIM-A**
- Paper length (including 12 figures): 7 pages
- Corresponding authors: FB, H. Rueda
- Authors: opt-in procedure

Abstract

NectarCAM is a Cherenkov camera which is going to equip the medium-sized telescopes (MST) of the northern site of the Cherenkov Telescope Array Observatory (CTAO). NectarCAM is equipped with 265 modules, each consisting of 7 photo-multiplier tubes (PMTs), a Front-End Board and a local camera trigger system used for data acquisition". This paper addresses the timing performances of NectarCAM which are crucial to reduce the noise in shower images and improve the image cleaning as well as discriminate between gamma-ray photons and cosmic-ray background. The tests have been performed in a dark room using various light sources to illuminate the first NectarCAM unit. The timing precision and accuracy of the trigger arrival, of individual and multiple pixel signals have been studied and are shown to comply to CTAO requirements.

Introduction on NectarCAM

Aim of the paper

Description of the measurements and analysis

Results and verification of CTAO requirements

Keywords: NectarCAM, gamma ray, Cherenkov, CTA, timing resolution, PMT transit time, trigger

Paper content

1. **INTRODUCTION**
   - Introduction on CTA and NectarCAM
   - Aim of the paper and distinction between different timing uncertainties
2. **THE NECTARCAM CAMERA**
   - Camera readout
   - Camera trigger
3. **CAMERA TEST SETUP**
   - Description of the darkroom
   - Description of sources and their calibration
     - FFCLS, NSB and Laser sources
4. **TIME OF MAXIMUM**
   - Description of the two methods to estimate the time of maximum
5. **SINGLE PIXEL TIMING PRECISION**
   - Measurement, analysis and results
6. **PMT TRANSIT TIME**
   - Measurement, analysis and results
7. **GLOBAL TRIGGER TIMING ACCURACY**
   - Measurement, analysis and results
8. **CONCLUSIONS**

2. The NectarCAM camera

Camera readout

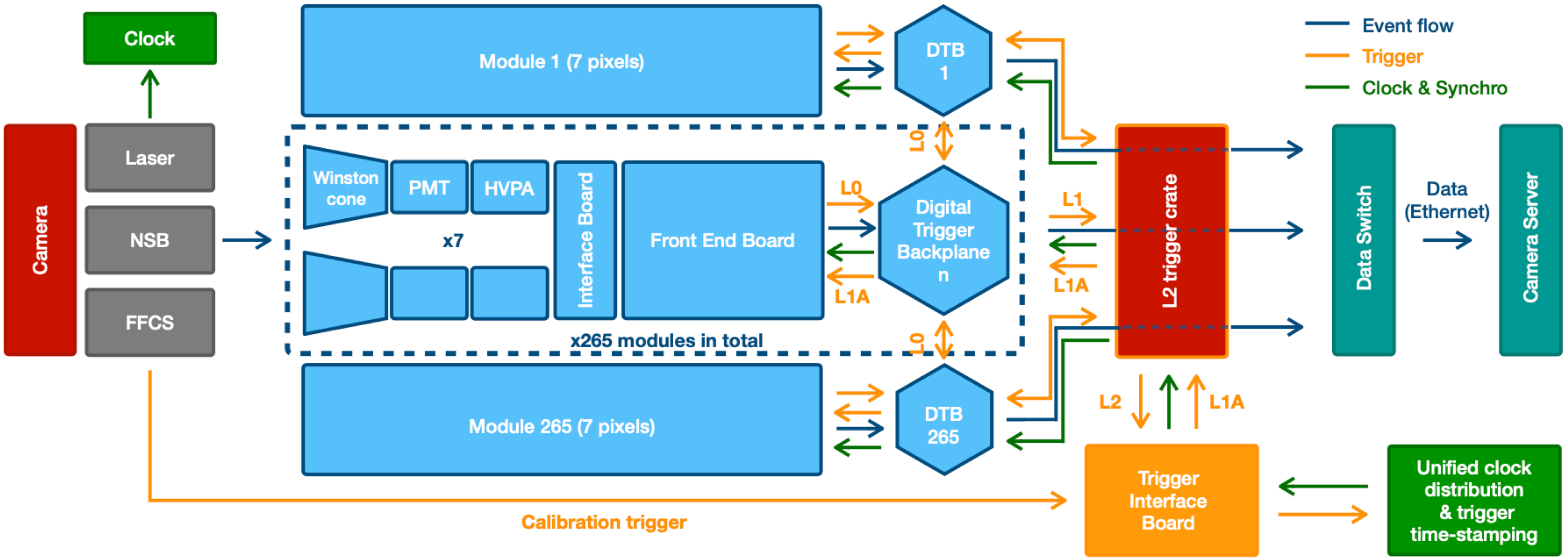

Figure 1: Schematic illustration of the signal and trigger chain of the NectarCAM camera. The light sources used in the dark room for the verifications described in this paper are also shown on the left.

2. The NectarCAM camera

Camera trigger

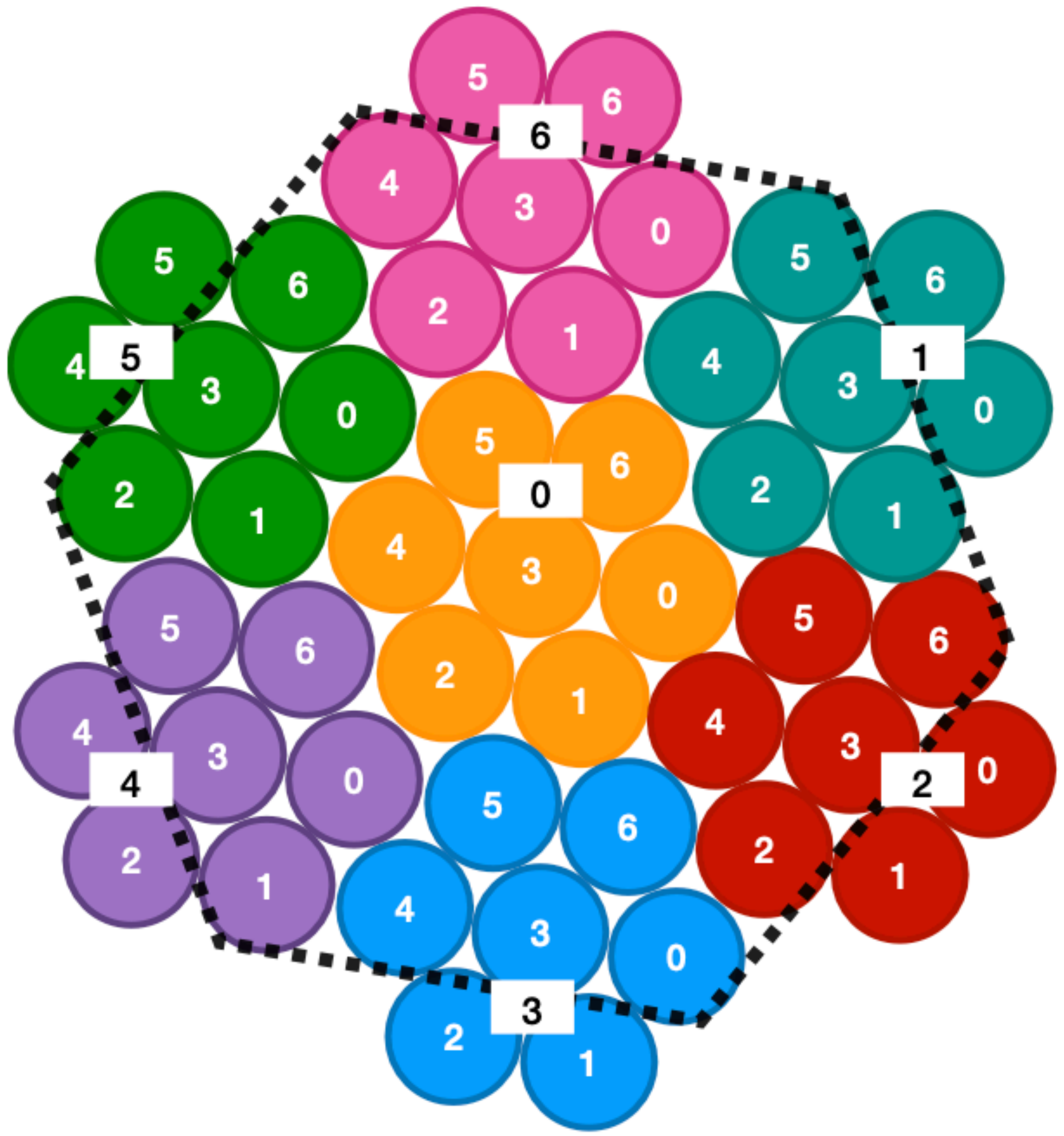

Figure 2: Schematic illustration of the 37 neighboring pixels where the L1 trigger is formed.

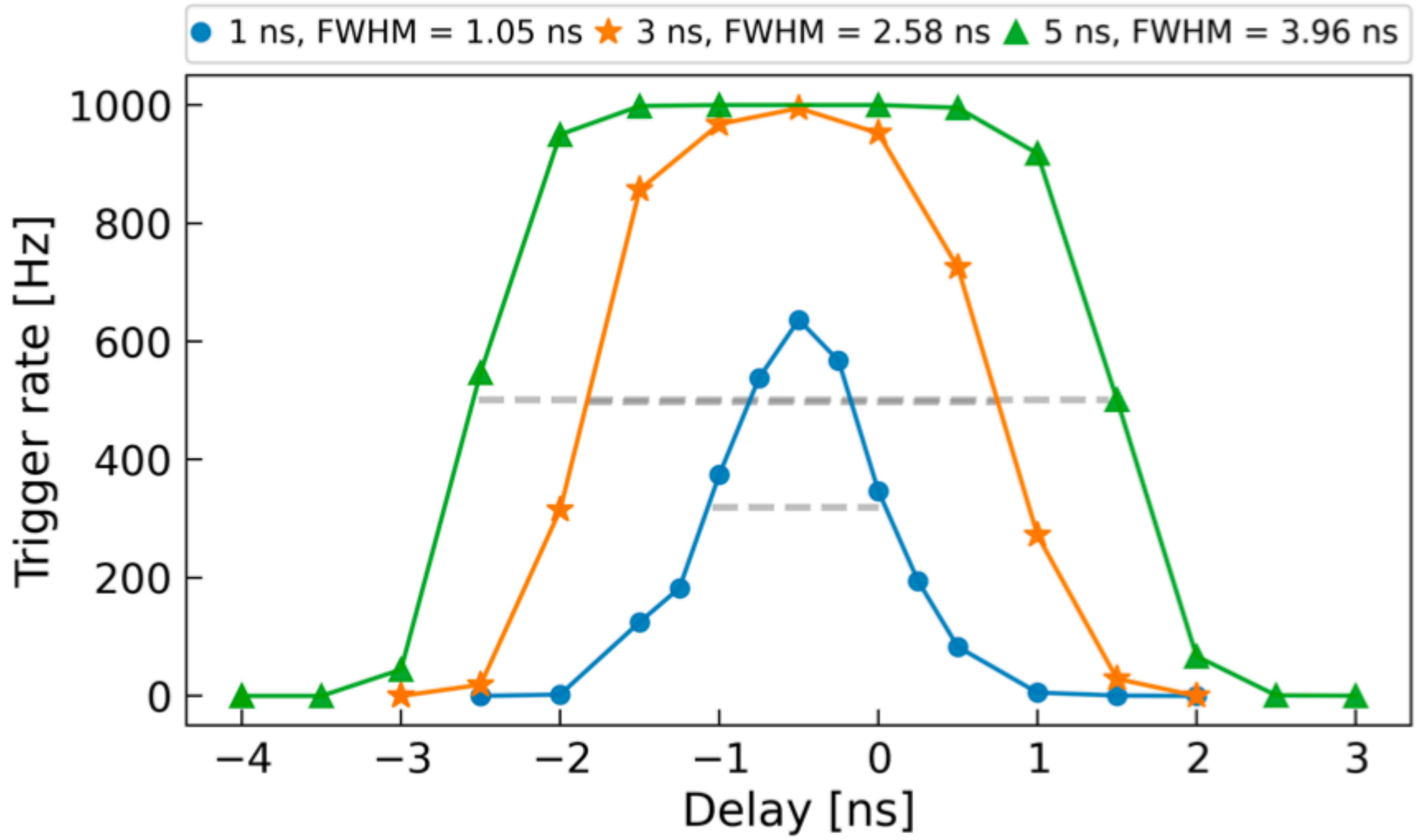

Figure 3: Trigger rate as a function of the time delay between 3 optical fibers injecting light directly into 3 pixels in 3 neighboring modules to test the 3NN trigger time window. The origin of the delay at 0 ns is arbitrary.

3. Camera test setup

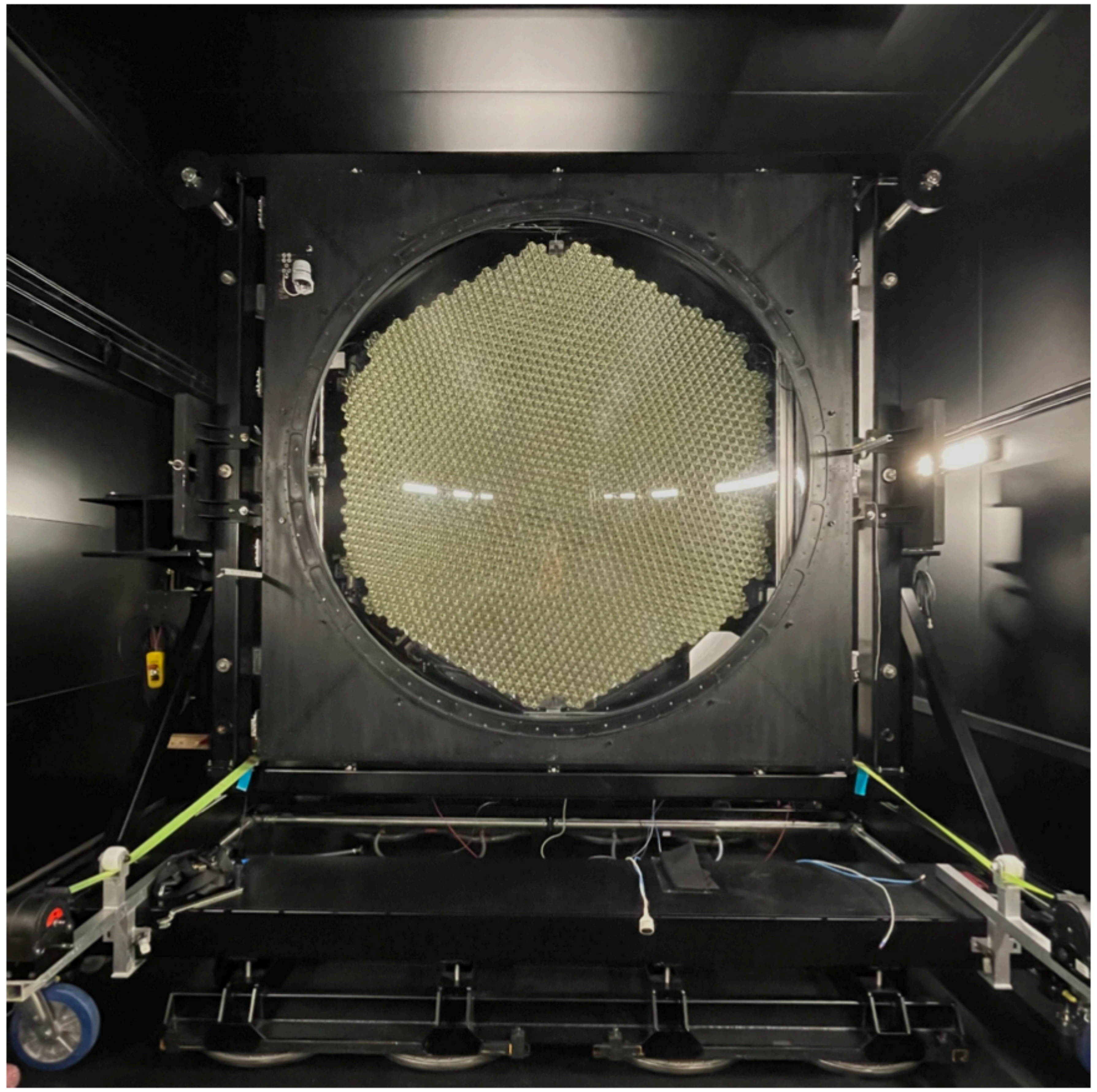

Figure 4: NectarCAM camera with entrance window in the dark room of CEA Paris-Saclay (France). The full camera is equipped with 1855 PMTs. The XY table for SPE calibration is visible in the lower right corner of the camera [8].

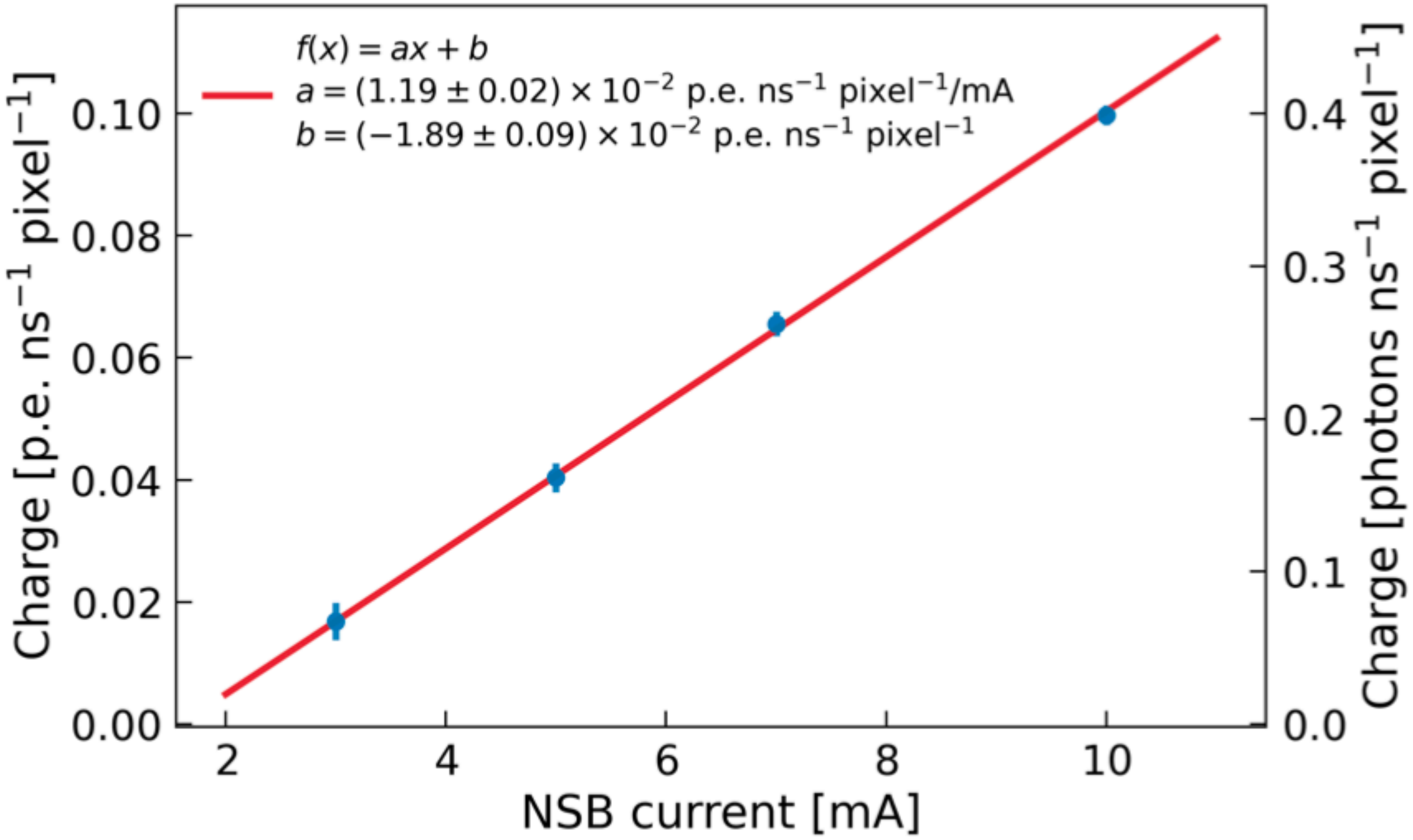

Figure 5: Calibration of the NSB light source. The number of photoelectrons per ns and per pixel is plotted as a function of the NSB current amplitude. The equivalent number of photons is shown on the right y-axis.

4. Time of Maximum

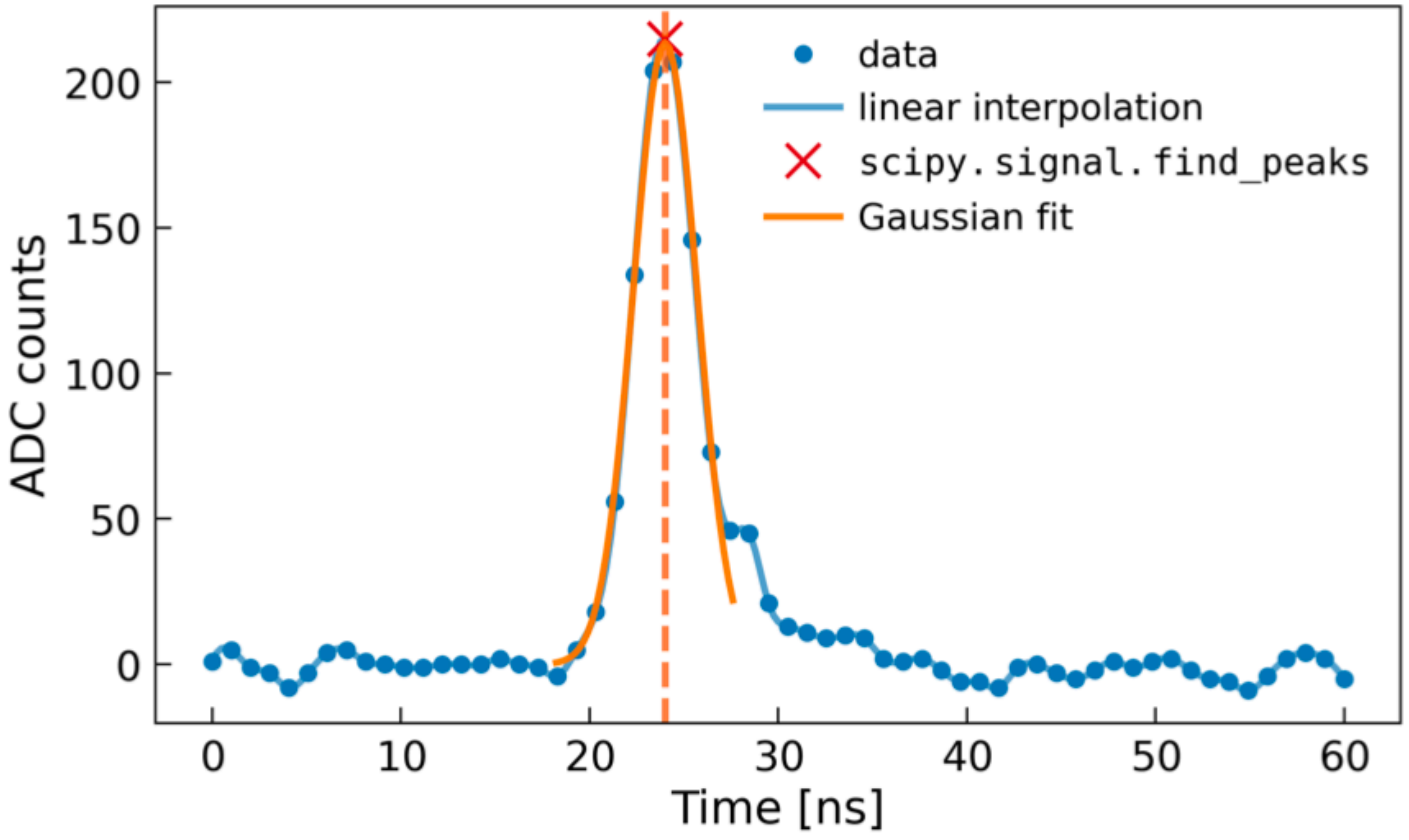

Figure 6: Waveform for one event after pedestal subtraction. The data points are interpolated using the **scipy** function (blue line). The two methods used to identify the TOM are shown. The red cross shows the maximum of the peak found with the **signal.find_peaks scipy** function. The orange curve represents the Gaussian fit. The vertical orange and red dashed lines show the TOM positions found with the first and second method, respectively.

5. Single pixel timing precision

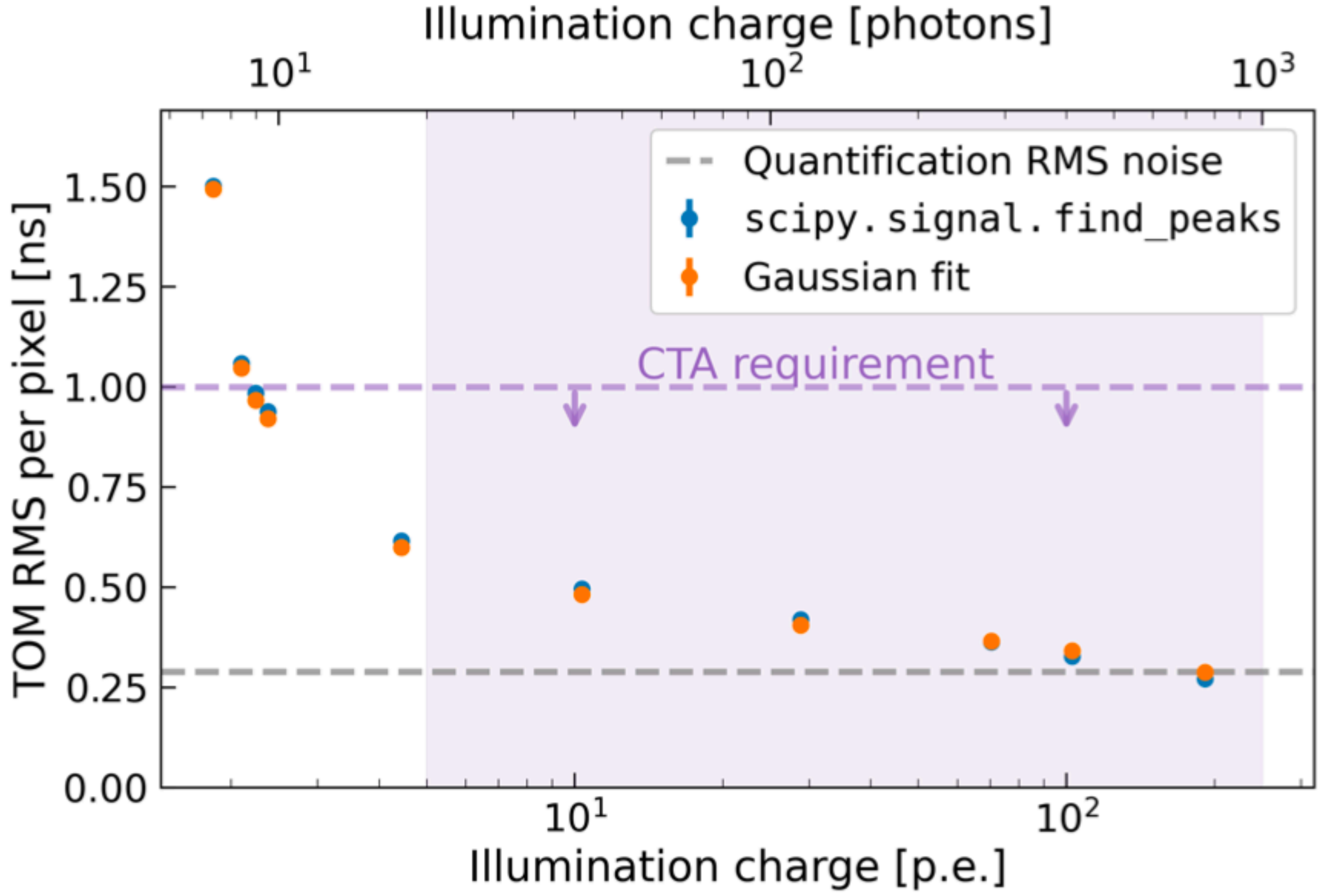

Figure 7: Timing precision per pixel (in ns) as a function of the charge of the illumination signal (in photoelectrons and photons on the bottom and top of the x-axis, respectively). The timing resolution is given by the mean of the RMS distribution over all the 1855 pixels. Both methods are shown (in blue and orange). The gray dashed line shows the quantification (RMS) noise given by $\frac{1}{\sqrt{12}}$ ns. The dashed violet line shows the 1 ns requirement limit to be valid between 20[5] and 2000[500] photons [photoelectrons] (violet area). The errors on the RMS have been obtained by a bootstrapping method.

6. PMT transit time

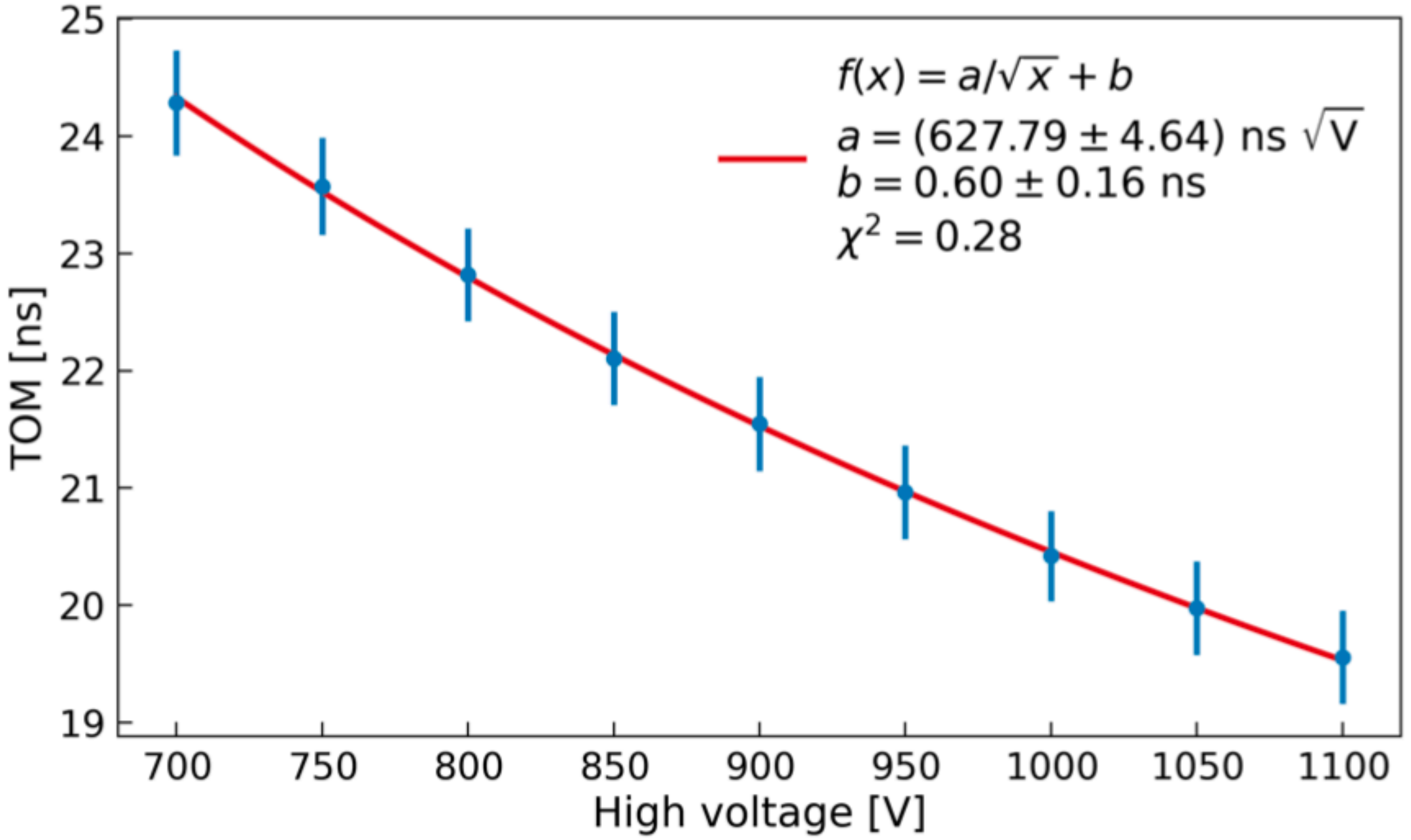

Figure 9: PMT transit time versus voltage for one pixel. The y-axis shows the TOM over ~1000 events in the camera as a function of the high voltage applied to all PMTs. The linear least squares fit is shown in red.

6. PMT transit time

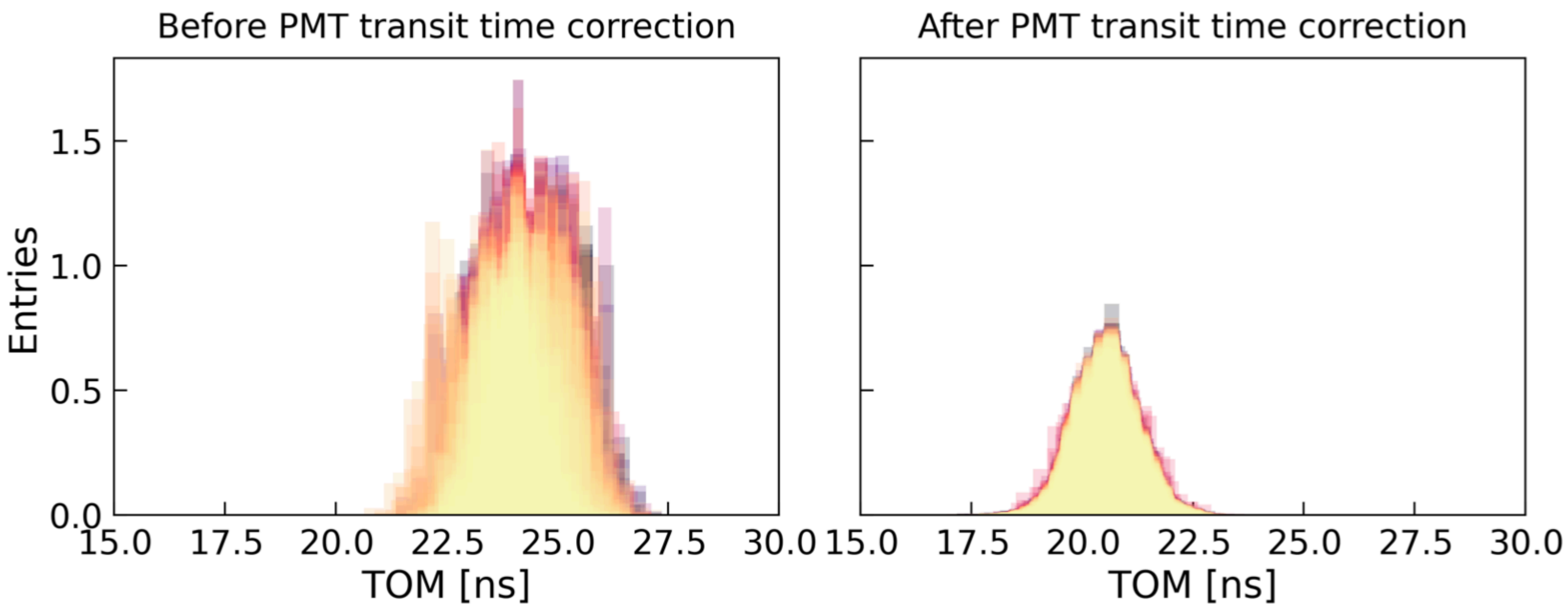

Figure 8: Mean time of maximum distribution for pixels before (left plot) and after (right plot) the PMT transit time correction for a light illumination of ~ 70 p.e. and for a uniform high voltage of 700 V for all the pixels.

7. Global pixel timing precision

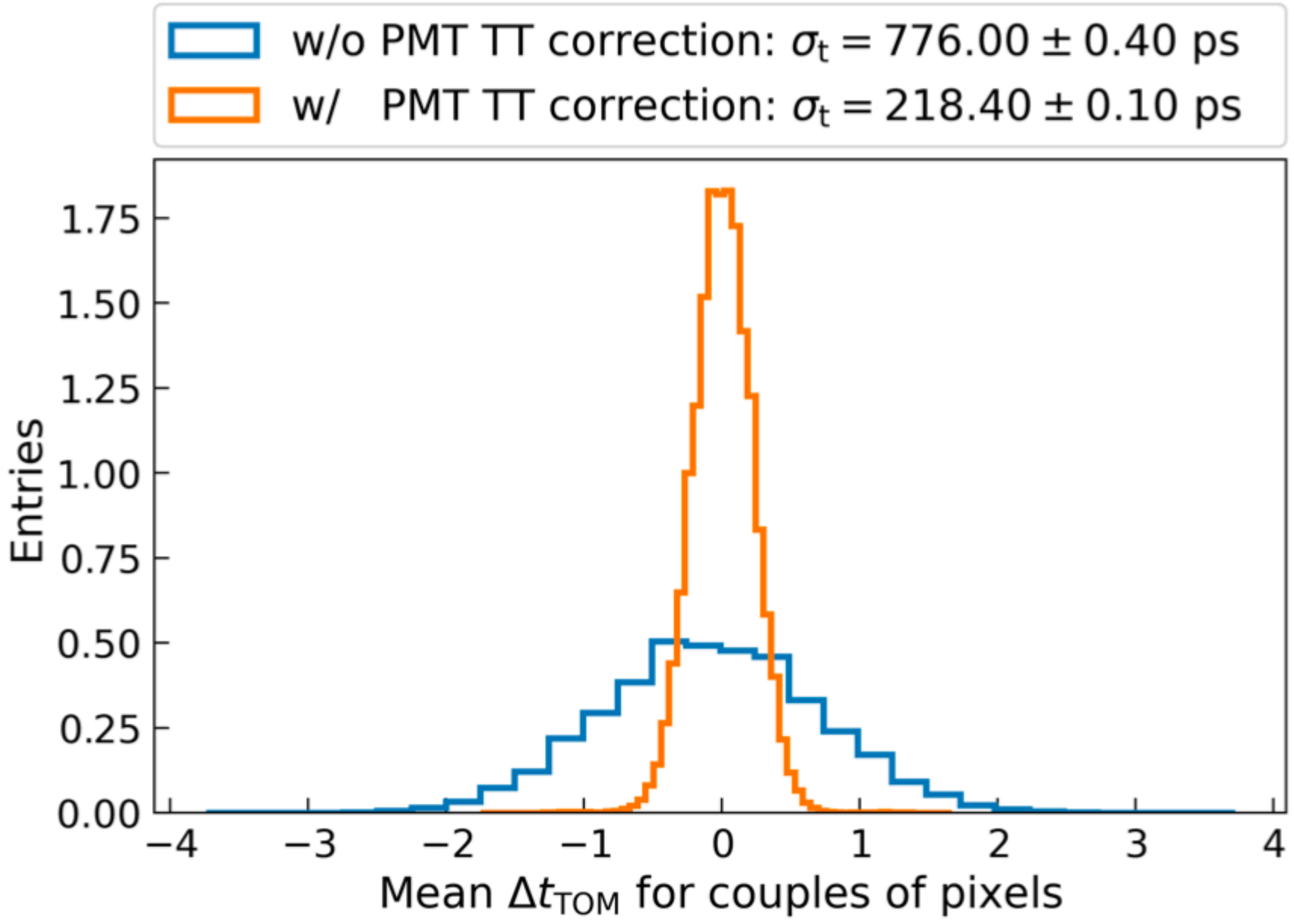

Figure 10: Distribution of the mean difference between the time of maximum value for each couple of pixels over all the events. The distributions with and without PMT transit time correction are shown in orange and blue, respectively.

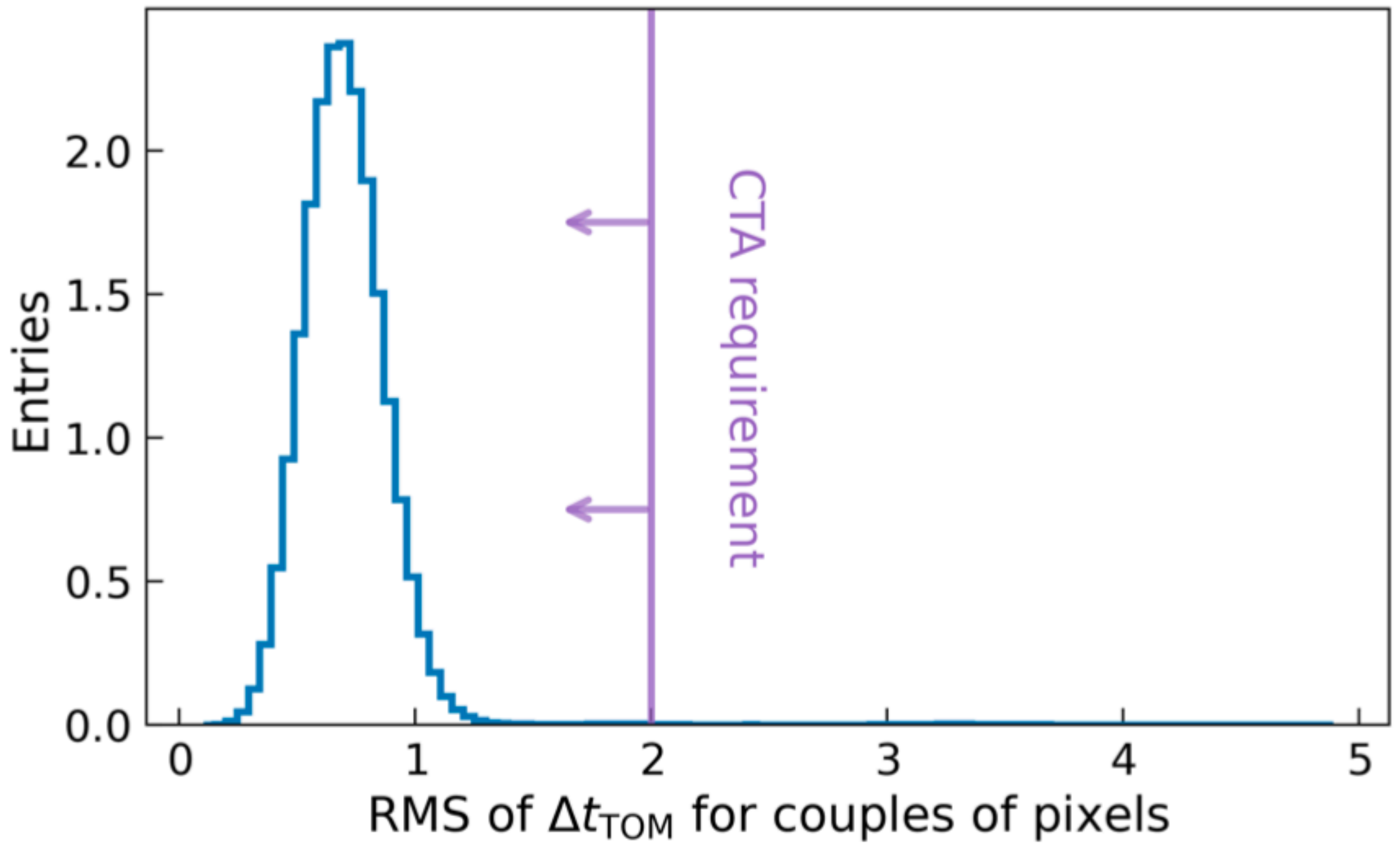

Figure 11: RMS distribution of the time of maximum difference between all pairs of pixels after applying the PMT transit time correction. The CTA requirement is shown at 2 ns.

8. Camera trigger timing accuracy

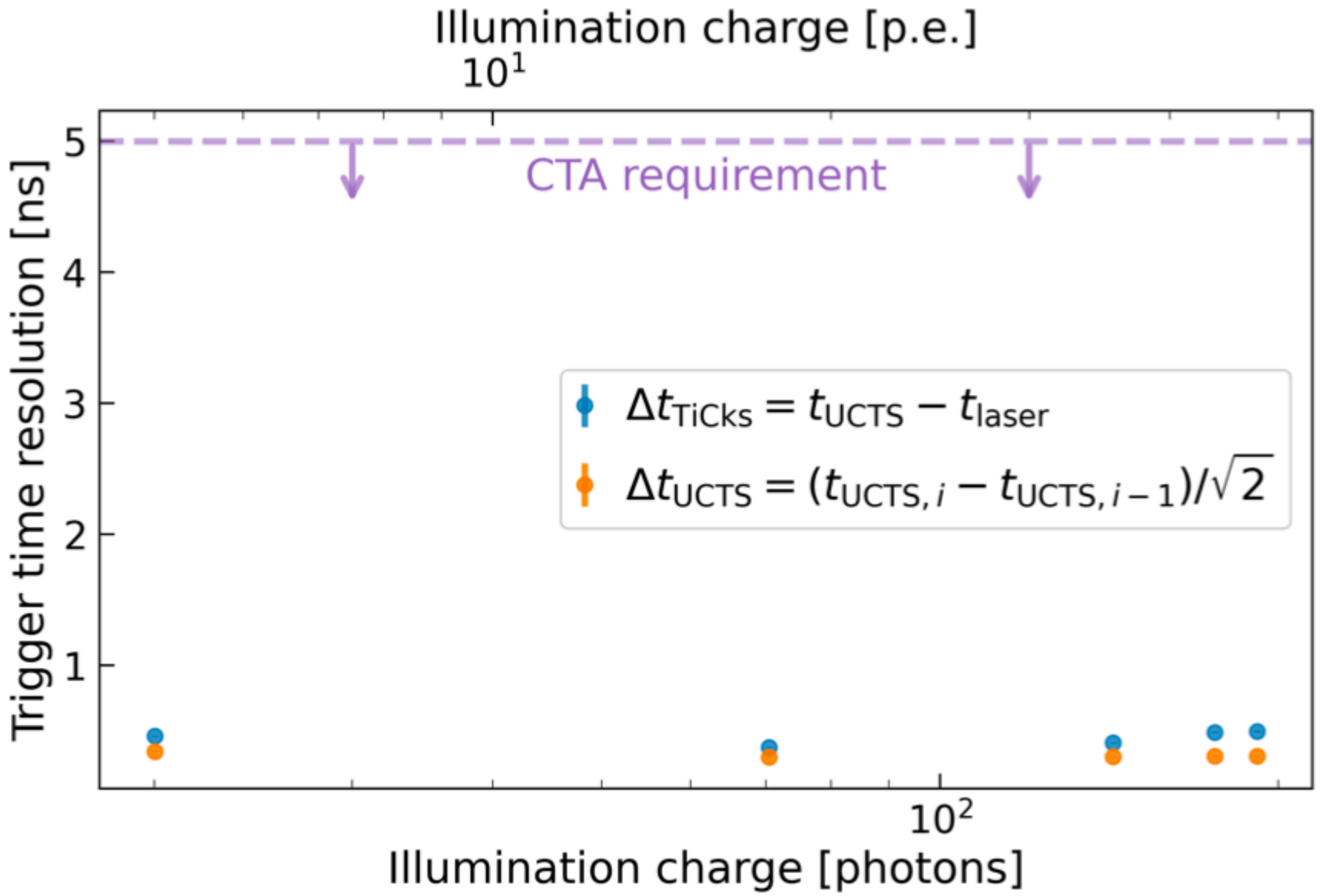

Figure 12: Camera trigger precision in ns as a function of the charge of the illumination signal (in photons and photoelectrons on the bottom and top of the x-axis, respectively) using two different methods. The CTA requirement of 5 ns for the camera timing resolution is also shown by the violet dashed line.

Summary and Outlook

- Paper about timing resolution of NectarCAM
- Title: "*Timing performance of the NectarCAM camera*"
- Description and results about the 4 main timing measurements connected to CTAO requirements:
    - timing accuracy and systematic uncertainties for each single pixel and for the full camera, performance of the camera trigger
- Description of the NectarCAM readout, trigger and calibration sources
- Target journal: **NIM-A**
- Mature paper draft within the NectarCAM WG → opt-in procedure for author list
- To be sent to SAPO in two weeks