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# BEAM TESTS OF THE FIRST PROTOTYPE OF A CHERENKOV COUNTER FOR ALICE T0 DETECTOR

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## ABSTRACT

The first prototype of a Cherenkov counter consisting of a quartz radiator of rectangular shape 25x30x12 mm (30 mm along the particles' trajectories) and/or PMTs Hamamatsu R3432-01 and FEU-187 has been tested at proton/pion beam with 1.19 GeV/c momenta. Time resolution better than 50 ps (sigma) has been obtained for both types of the PMTs at different voltages. The dynamic range of both types of PMTs was measured with a pulsed laser (500 ps FWHM). For both types of the PMTs the dynamic range, with a time resolution better than 50 ps, exceeds 100, thus providing to cover the expected dynamic range for the ALICE experiment for p-p, Ca-Ca and Pb-Pb runs.

## 1. INTRODUCTION.

In our ALICE Internal note Nr.99-43 [1] we proposed to use an array of Cherenkov counters based on quartz radiators and fine-mesh phototubes as T0 detector for ALICE pretrigger, L0 ,and L1 triggers and for the TOF system. Our preliminary estimates of the time resolution of a Cherenkov counter consisting of a quartz radiator 3 cm long and a PMT Hamamatsu R5506 showed that a 50 ps resolution (sigma) can be achieved for minimum ionizing particles (mips). These estimates were based on our studies of the timing properties of fine-mesh phototubes Hamamatsu R3432-01, almost identical to R5506, and scintillation counters using these phototubes. In this paper we give the experimental results of beam test of the first prototypes of Cherenkov counters based on PMT R3432-01 and Russian FEU-187, similar to FEU-527.

## 2. EXPERIMENTAL SETUP.

For our tests we used the mixed pion/proton beam of ITEP and the experimental setup of the ALICE ITEP group, which was used in the ITEP studies of timing properties of PPCs for the ALICE TOF detector. The schematic diagram of the test beam setup is shown in Fig.1. The test beam facility includes the following detectors.

- Two identical scintillation START counters S1 and S2, located close to each other. Each detector consists of a PMT XP7229 and BC 408 scintillator 2x2x2.5 cm. The time resolution of each counter is about 50 ps and it was monitored permanently during each run by measuring the time distribution between S1 and S2.
- The scintillation counter S3 located at a flight distance 10 m from S1. TOF data between S1 and S3 which was also monitored permanently during a run gives the possibility to separate pions and protons (p = 1.19 GeV/c) with an efficiency close to 100%.
- Two identical scintillation counters F1 and F2 with 0.8x0.5x10 cm scintillators, limiting the beam size to 0.8x0.8 cm.
- Additional beam scintillation counters S4, L1 acting in coincidence with the other counters.
- The Cherenkov detector under study ( CHD), located at 2 m from S1.

The signals from S1, S2 were fed to a constant fraction discriminator inputs, whereas the signals from CHD were fed to a fast leading edge discriminator with a 60 mV threshold. All TDC channels were identical having a 50 ps/channel resolution. A 1024 channel QDC was used to measure the amplitude distributions of the CHD signals.

## 3. EXPERIMENTAL RESULTS.

For our Cherenkov counter prototype we used a one inch PMT Hamamatsu R3432-01 with a conventional borosilicate glass entrance window, and a quartz radiator. The radiator had a rectangular shape 25x30x12 mm. According to our estimates a 30 mm path length of a mip in a quartz radiator should give more than 100 photoelectrons in the visible spectral range assuming reasonable light collection efficiency. This amount of photoelectrons is sufficient to provide a time resolution not worse than 50 ps. We have also made some runs with a Russian fine-mesh phototube FEU-187 with a 30 mm diameter, produced by the "Electron" enterprise (St.Petersburg), which main parameters are very similar to those of the R3432-01. The same Cherenkov radiator was used in these runs. In both cases we used elastic optical glue in order to provide a good optical contact between the radiator and the PMT entrance window. The Cherenkov counter was aligned along the beam axis as shown in Fig.1.

All measurements were made at 1.19 GeV/c for both pions and protons.

Fig.2 gives an example of a TOF spectrum measured between CHD and S1. One can see that pions and protons are well separated.

Fig.3 shows a TOF spectrum measured between S1 and S3. The efficient discrimination between protons and pions enables us to analyze all experimental spectra measured with CHD and other detectors, separately for pions and protons. For example the S1 – S2 time distribution spectra are shown in Fig.4. Fig.4a gives the time distribution without pion/proton separation, Fig.4b and Fig.4c give the distributions for pions and protons separately. One can see that the time resolution of the START counters S1, S2 is slightly better for protons. In our calculations of the time resolution of the CHD we used this data separately for pions and protons.

Fig.5 gives the amplitude distributions of the CHD signals both for pions and protons without pion/proton separation. In average the relationship between amplitudes for pions and protons is 2.2 in accordance with their velocities ($\beta$ = 0.99 for pions and $\beta$ = 0.78 for protons). Good amplitude resolution for both types of particles (sigma = 8.5 % for pions, = 13% for protons) enables to estimate the average number of photoelectrons produced in both cases. Assuming that the amplitude resolution can be described by a Poisson distribution we obtain the lower limits for the number of photoelectrons emitted from the PMT photocathode for pions and protons. These values are N ~ 140 and N ~ 60 respectively, in good accordance with the ratio of the average amplitudes.

The time resolution of the Cherenkov counter with the PMT R3432-01 at different PMT voltages is shown in Fig.6. The circles and triangles give experimental results calculated as $\sigma_{\mathrm{CHD}} = \sqrt{\sigma_{TOF}^{\ 2} - \sigma_{SI}^{\ 2}}$, where $\sigma_{TOF}$ is the experimental value extracted from the TOF distribution shown in Fig.2, and $\sigma_{S1}$ is equal to $\sigma$(S1-S2)/$\sqrt{2}$. All values were calculated for pions and protons separately.

These raw data do not give the intrinsic resolution of the CHD because we used a leading edge discriminator in the CHD channel, and the data need off-line correction. The two-dimensional distributions shown in Fig.7 were fitted by a second order polynomial. The time resolutions for pions and protons after off-line correction are given in Fig.6 (squares and rhombs). Fig.8 gives an example of fitting of experimental data by a Gaussian after off-line correction. The results given in Fig.6 show that the intrinsic time resolution of the Cherenkov counter is somewhat below 50 ps and does not change with the HV value between 1600V and 2466V, the dynamic range of the output amplitudes being about 15. This data agree very well with the data published by the PHENIX Hiroshima group [2].

In order to measure the dynamic range of a PMT we used a pulsed laser. The experimental setup, shown in Fig.9, was in this case somewhat different from that used in beam tests. In order to eliminate the contribution of electronics to experimental results we used constant fraction discriminators (CFD) in START and STOP channels of a time-to-amplitude converter with a 10 ps channel width. Since CFDs still have an amplitude related time walk comparable or even larger than the expected time resolution of a PMT, we kept the amplitudes of the signals coming from the PMT to the CFD input constant with a precision of about 10%. For this purpose we used a variable compensated RC attenuator at the input of the PMT, and a fast preamplifier.

Two runs of measurements were made using this experimental setup. In the first run we changed the intensity of the laser pulse (70 ps FWHM) using optical filters. The result of this run – the time resolution of the PMT used in the Cherenkov detector as a function of the number of photoelectrons is given in Fig.10. In the second run we used another laser with a 500 ps FWHM. The number of photoelectrons was fixed to be about 120-140 and the time resolution of the PMT was measured as a function of the applied HV. The results of this run are given in Fig.11. One can see that the time resolution of the PMT Hamamatsu R3432-01 remains stable (about 40 ps) in the wide dynamic range of the PMT output amplitudes (more than 120).

Similar measurements – beam tests and laser tests - were also made for two samples of Russian fine-mesh PMTs FEU-187. The beam tests with the same radiator gave a time resolution of a Cherenkov counter of about 50 ps for both PMT samples. One of the PMTs was also studied using a laser in order to estimate its dynamic range. The result of this test is shown in Fig.12, and it is similar to that obtained with R3432-01.

## 4. CONCLUSIONS.

The results of beam tests of the prototypes of Cherenkov counters based on quartz radiator 3 cm long and fine-mesh phototubes show that a time resolution better than 50 ps can be achieved for minimum ionizing particles for both Hamamatsu R 3432-01 and Russian FEU-187 phototubes.

The tests with a pulse laser show that both types of the PMTs have wide dynamic range (more than 100) thus covering the ALICE T0 requirements for p-p collisions, Ca-Ca collisions and Pb-Pb collisions.

Thus it seems feasible to cover the whole dynamic range of the PMT’s amplitudes using a constant fraction discriminator and other fast electronics as it was proposed in [1], with a dead time less than 50 ps. In this case the T0 signal and z-vertex signal will be generated not later than 25 ps after a collision occurs.

## REFERENCES

[1] V.A.Grigoriev et al. ALICE T0 start detector based on Cherenkov radiators and fine-mesh phototubes. ALICE/99-43, Internal Note/Trigger, 20 September 1999.

[2] K.Ikematsu et al. A start-timing detector for the collider experiment PHENIX at RHIC-BNL, Nuclear Instruments and Methods, A 411(1998), 238-248.

## ACKNOWLEDGEMENTS

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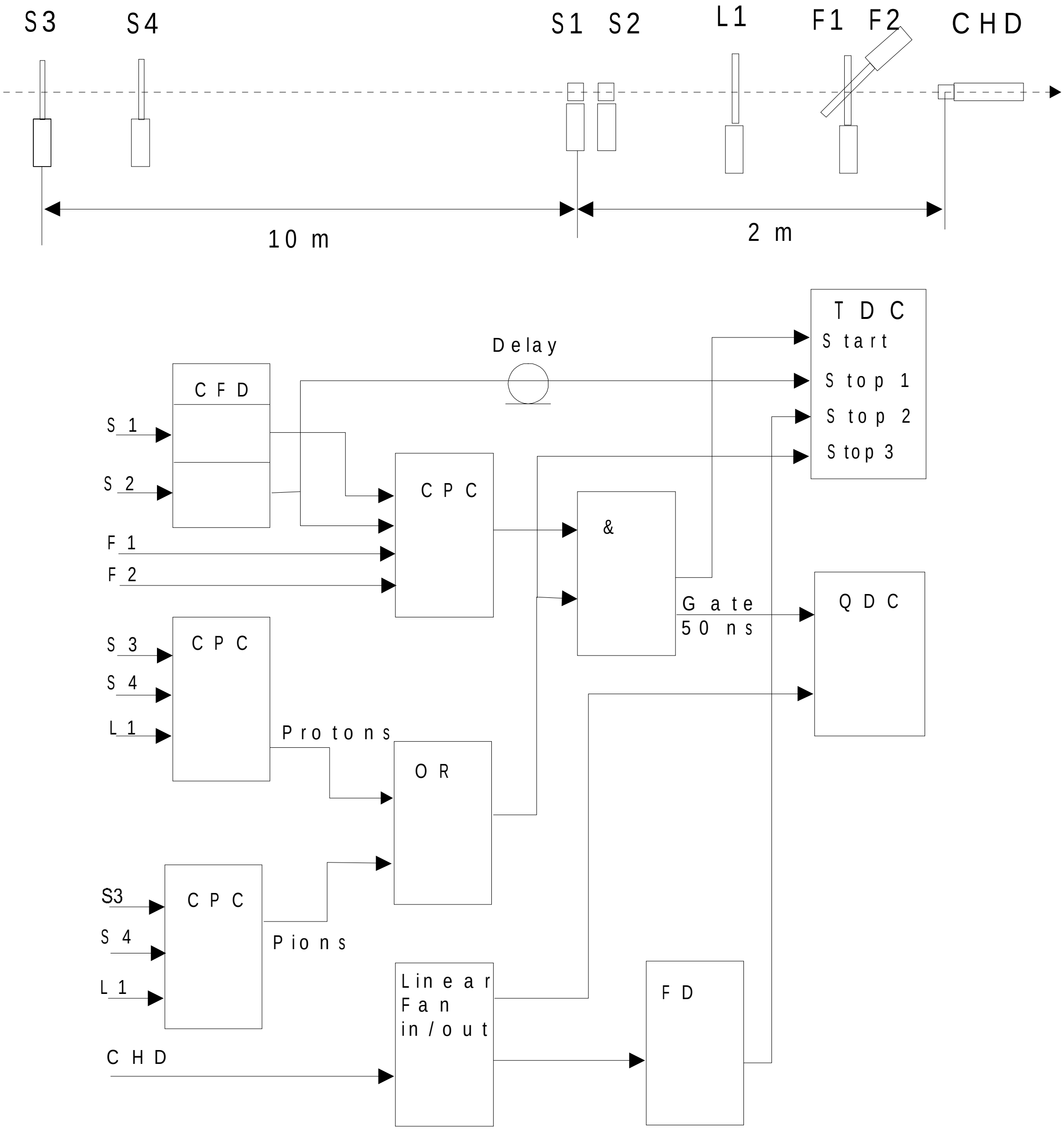


CPC- coincidence / priority circuit
FD - fast leading edge discriminator
CFD - constant fraction discriminator
S1,S2 - scintillation START detectors
S3 - scintillation counter
F1,F2 - Scintillation counters, limiting the beam
cross-section to 0.8 cm x 0.8 cm
S4,L1 - beam coincidence counters
CHD - Cherenkov detector

Fig.1. The test beam layout

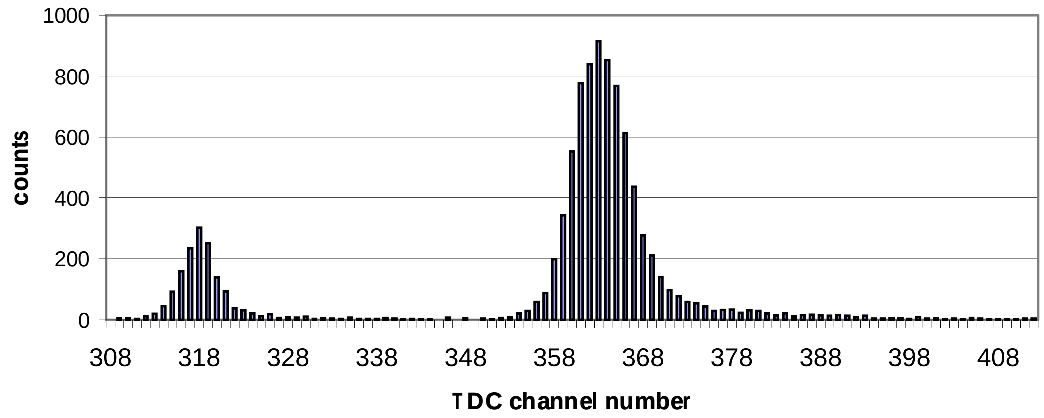


**Fig. 2. The TOF distribution for pions (left) and protons (right) between S1 and CHD.**

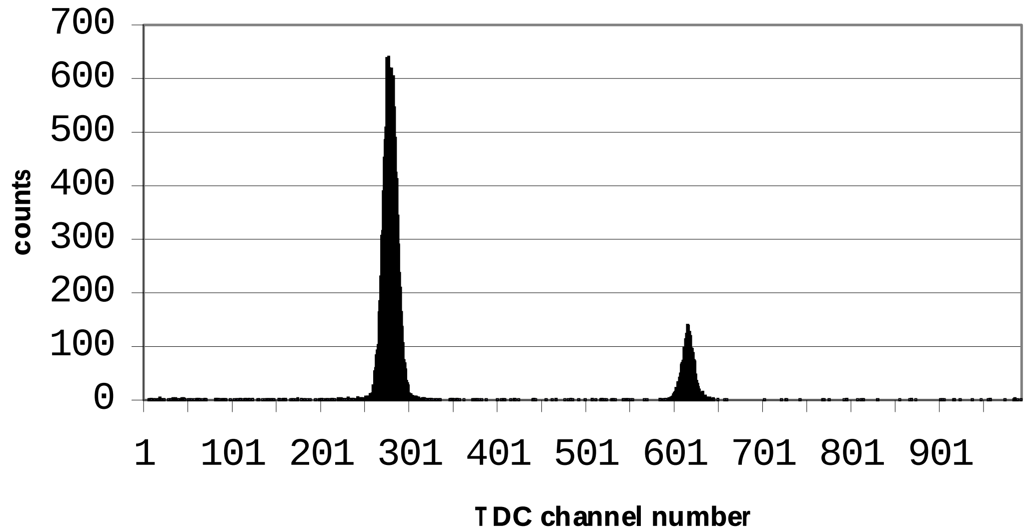


**Fig.3. The TOF distribution between S1 and S3 for protons (left) and pions (right).**

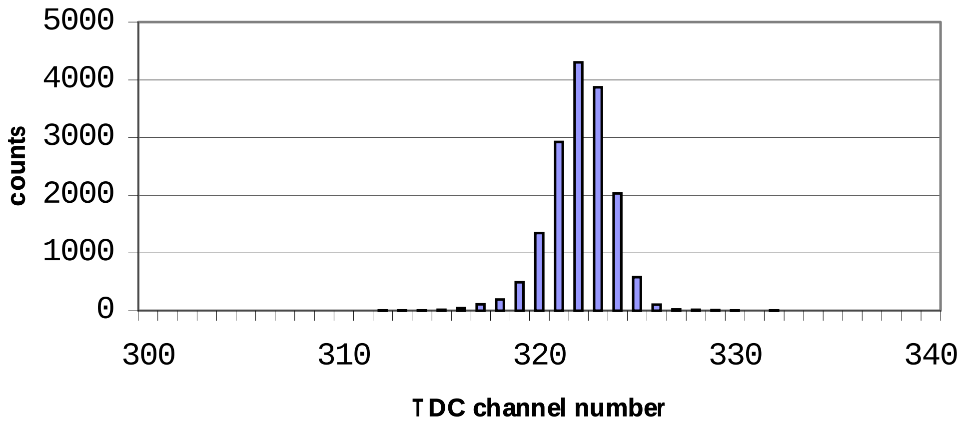


**Fig.4a. The S1-S2 time distribution without pion/proton separation (sigma 50ps).**

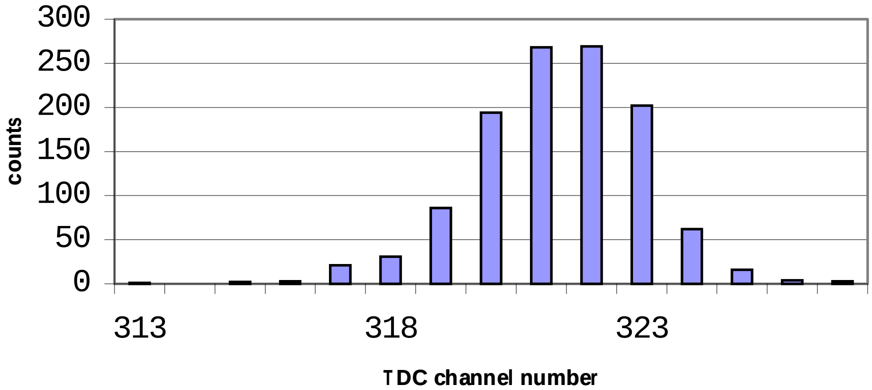


**Fig.4b. The S1-S2 time distribution for pions (sigma 56ps).**

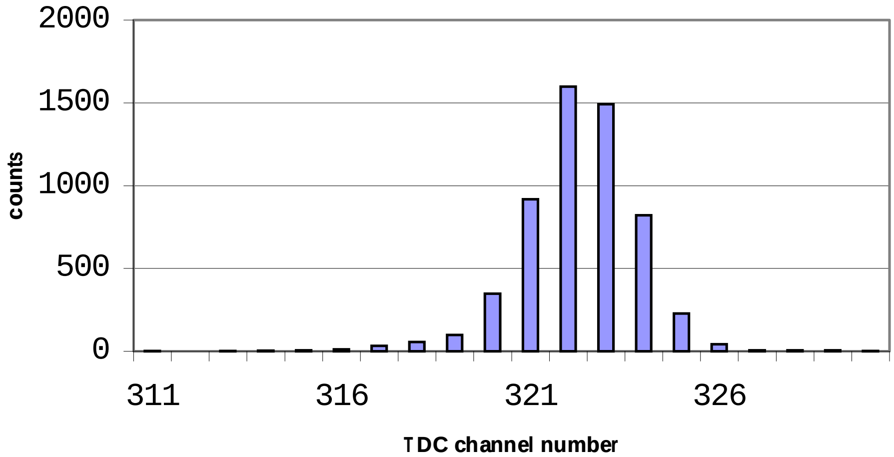


**Fig.4c. The S1-S2 time distribution for protons (sigma 47ps).**

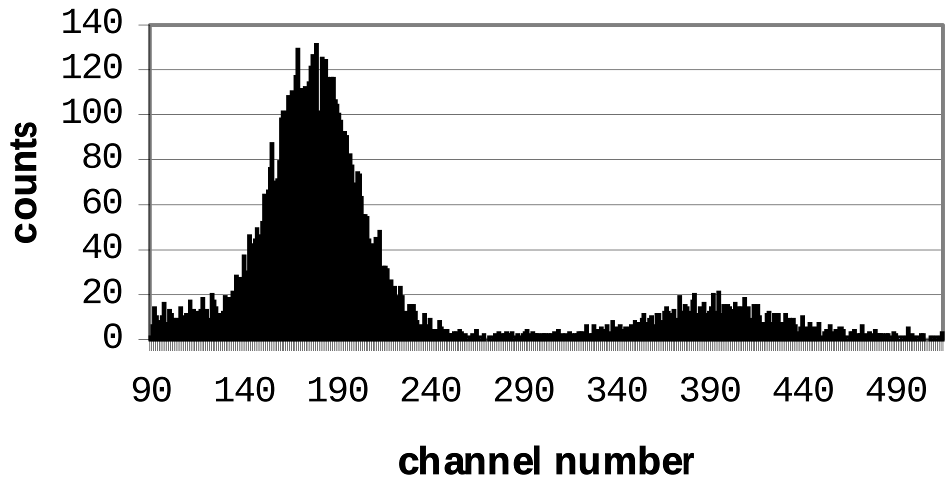


**Fig. 5. The amplitude distribution in CHD for protons and pions.**

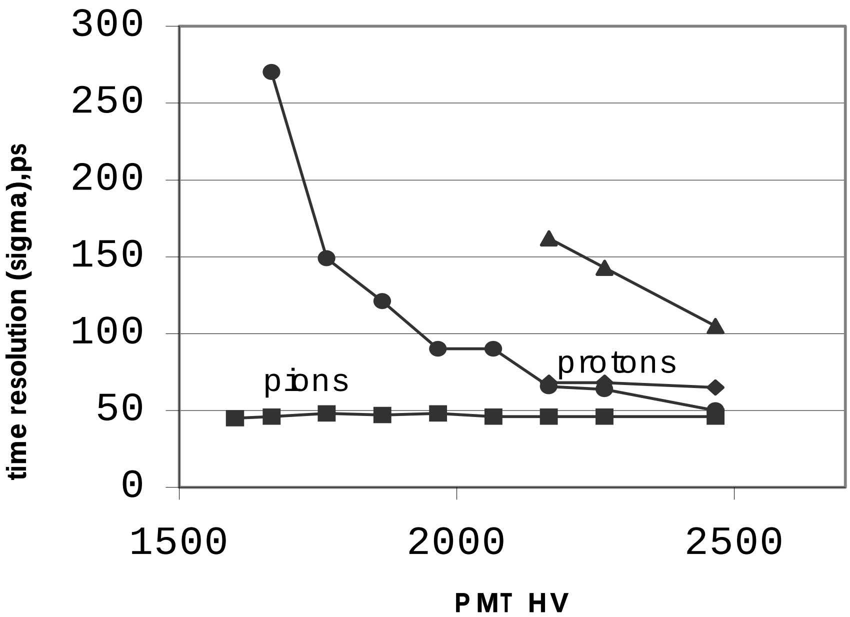


**Fig. 6. Time resolution of the Cherenkov detector for pions and protons as a function of the PMT HV.**

The triangles and rhombs correspond to the time resolution for protons in the uncorrected and corrected cases, respectively. The circles and squares correspond to the time resolution for pions in the uncorrected and corrected cases, respectively.

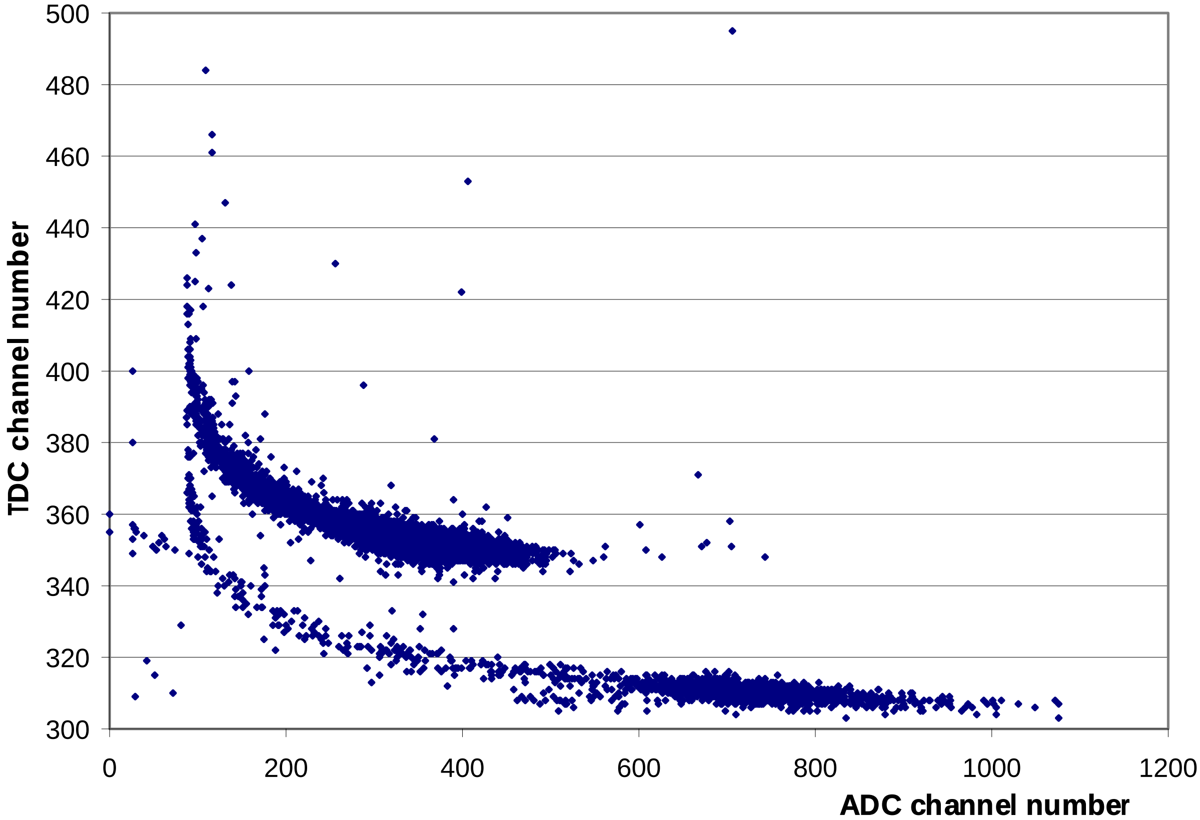


**Fig.7. Two-dimensional distributions of the TOF spectra for protons (upper) and pions (lower).**

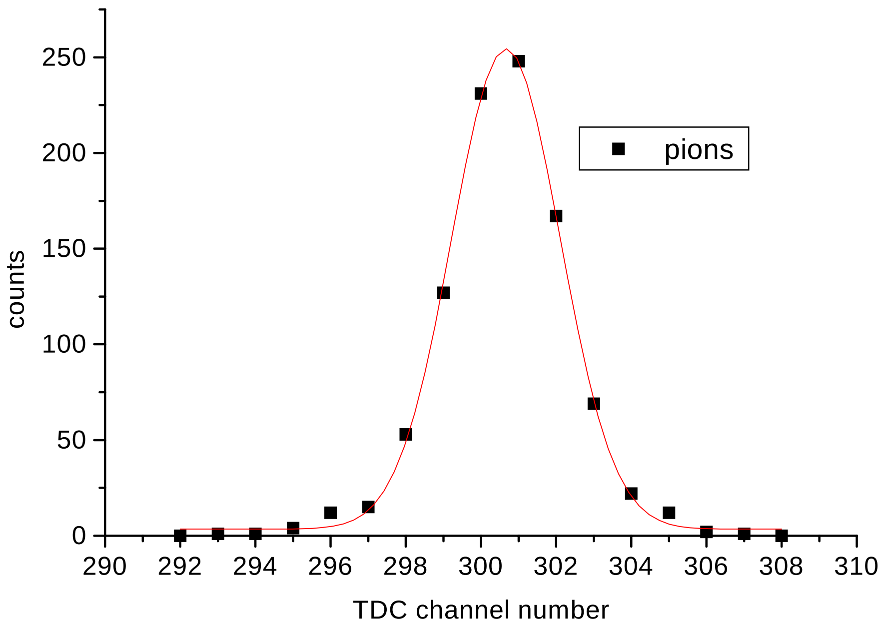


**Fig.8. The Gaussian fitting of the TOF distribution after off-line correction. Time resolution (sigma) = 47 ps, efficiency 98.4%.**

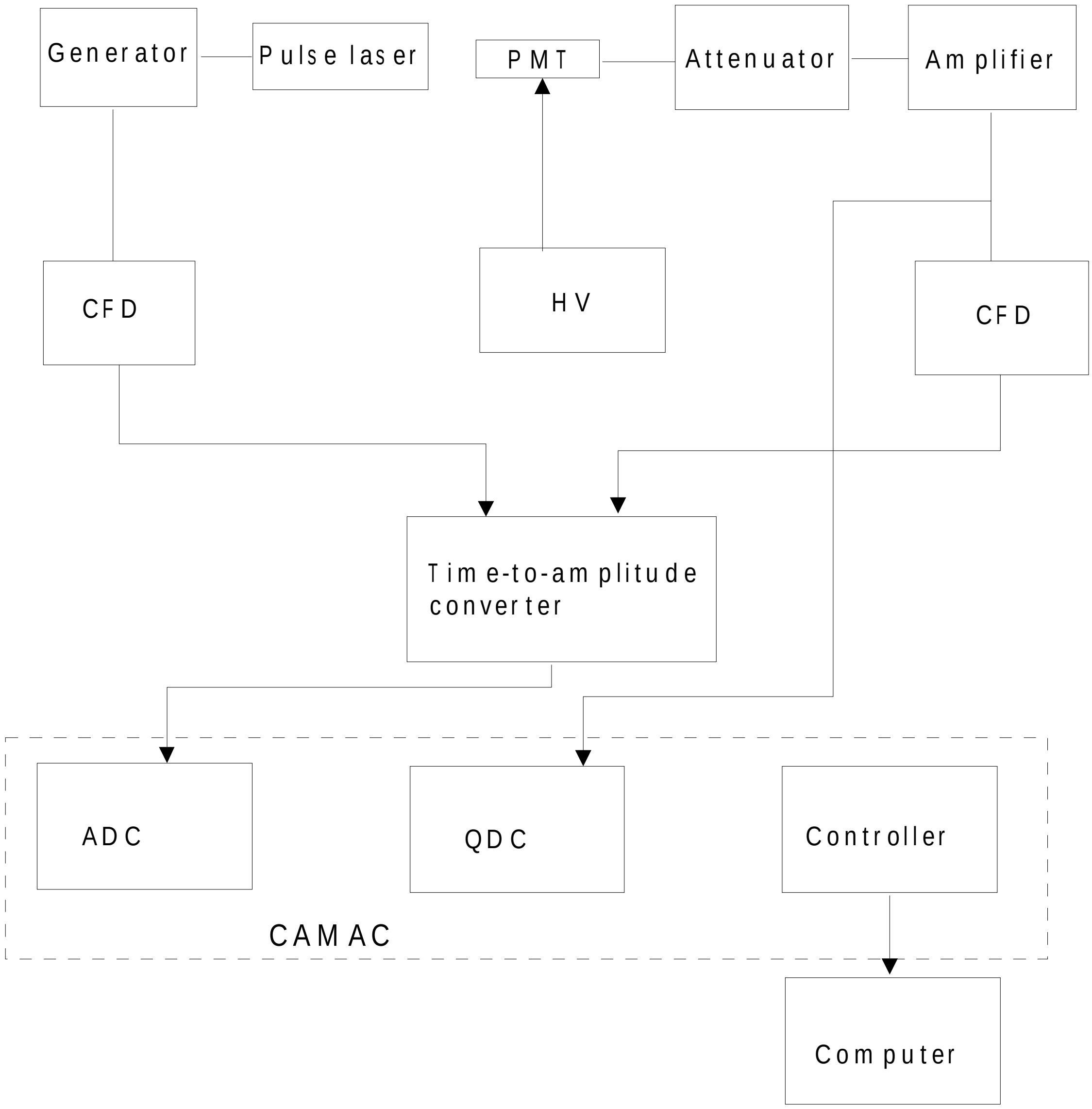


Fig.9. The experimental setup of the time resolution measurements of PMTs using a pulse laser

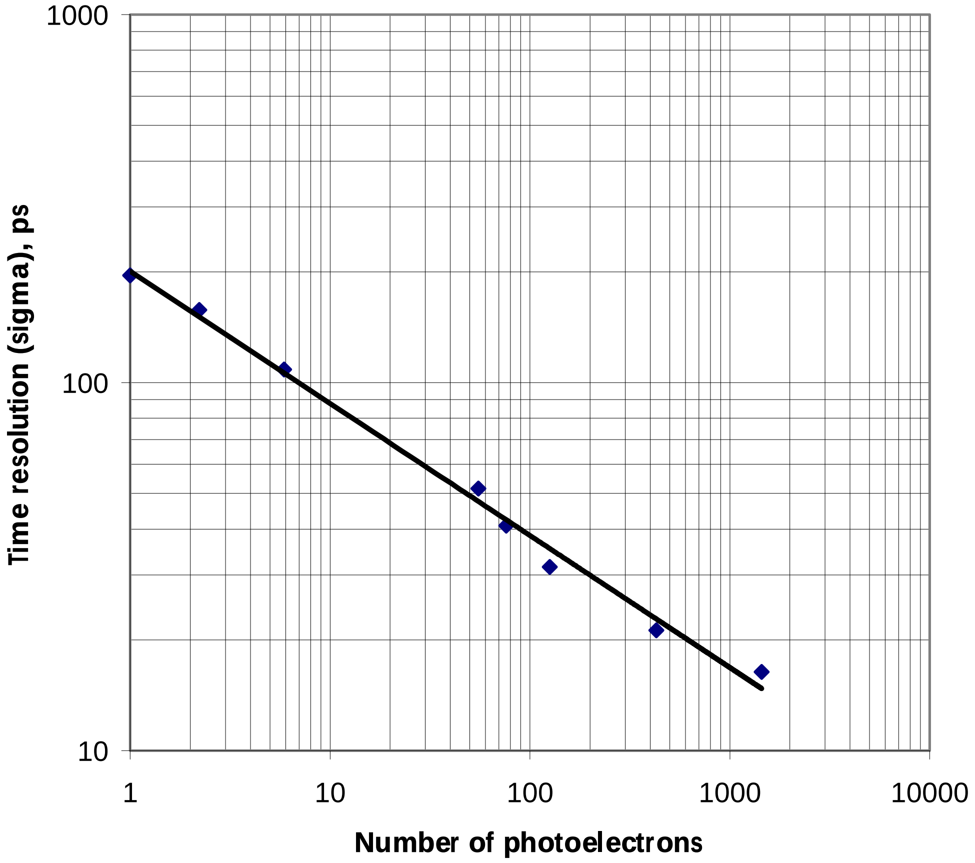


**Fig. 10. Time resolution of Hamamatsu R3432-01 PMT as a function of the number of photoelectrons measured with a pulse laser (680 nm, FWHM=70 ps)**

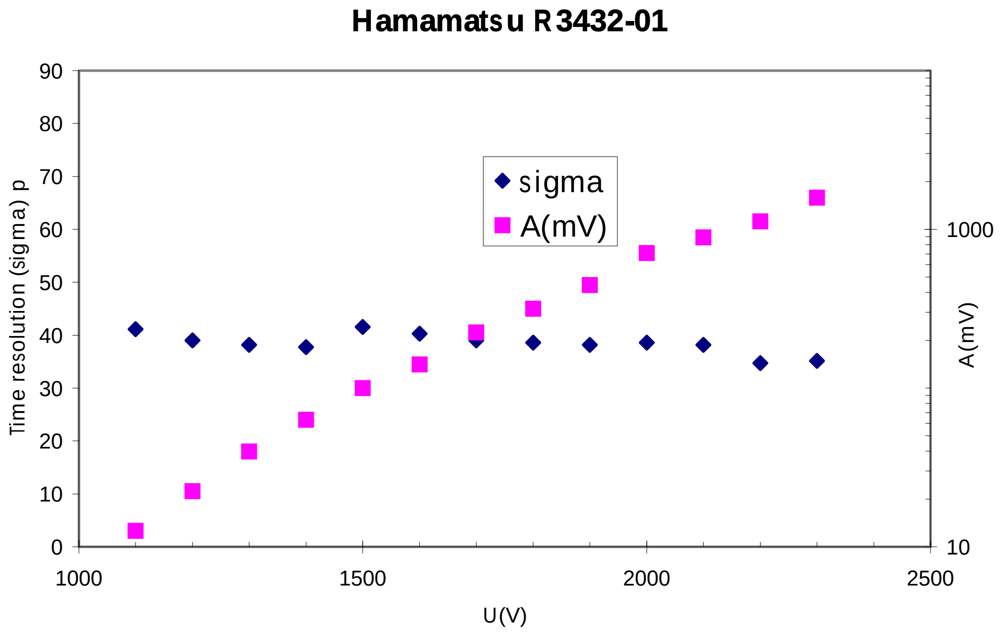


**Fig 11. Time resolution and amplitudes of the output signals of the Hamamatsu R3432-01 PMT as a function of the HV at a fixed number of emitted photoelectrons (~120), measured with a 500 ps pulse laser.**

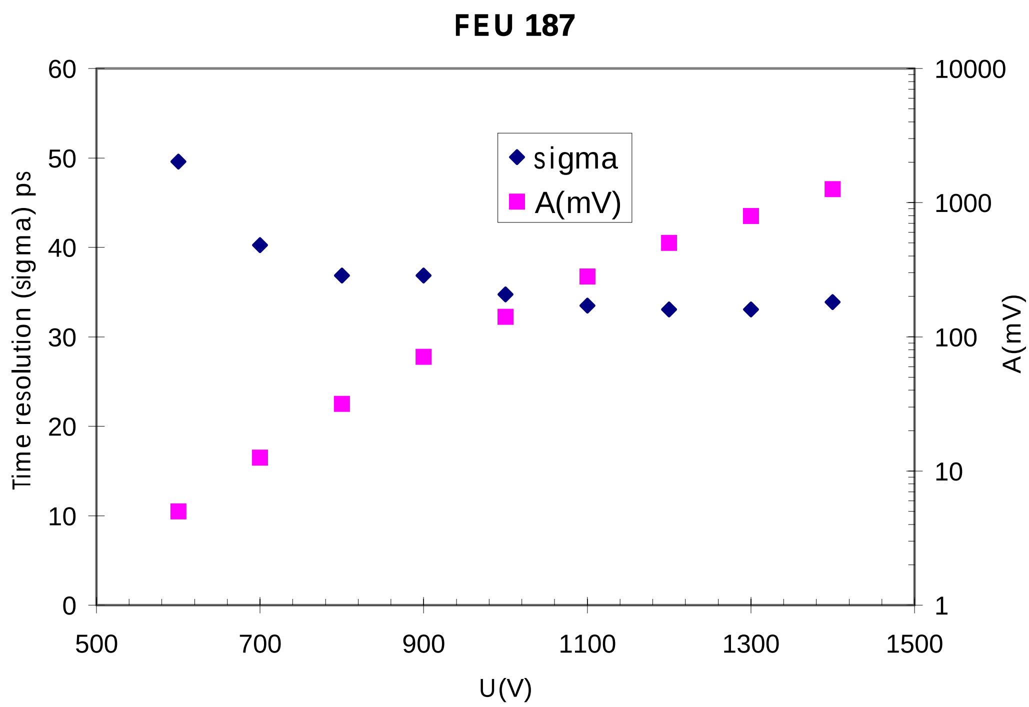


**Fig 12. Time resolution and amplitudes of the output signals of the FEU-187 PMT as a function of the HV at a fixed number of emitted photoelectrons (~120), measured with a 500 ps pulse laser.**