KOPIO note tn02x, Novenber 2001

First experience from a scintillator tile test with wave length shifting fibre readout

Charged-particle veto R&D

Heinz Kaspar, Peter Robmann, Andries van der Schaaf, Simon Scheu, Peter Truöl
Physik-Institut der Universität Zürich, CH-8001 Zürich

1 Introduction

1.1 The Kopio charged-particle veto system

The purpose of the charge-particle veto system is the efficient identification of background processes in which an apparent $\pi^0 \to 2\gamma$ decay inside the decay volume is accompanied by charged particle emission. Examples of such background processes are, (i) $K_L \to \pi^+\pi^-\pi^0$, (ii) $K_L \to e^+\pi^-\nu\gamma$ in which the positron creates a second photon through Bremsstrahlung or annihilation in flight, (iii) $K_L \to e^+\pi^-\nu$ again followed by $e^+ \to \gamma$ whereas the π^- creates a photon through $\pi^- p \to \pi^0 n$. In all cases two particles with opposite electrical charge emerge. In all cases the events may also produce signals in other detector elements, like the barrel veto system. Detection efficiencies of 99.99% or better are required to keep these backgrounds below a few events in the final sample.

The charged-particle veto system will consist of two or three layers of plastic scintillator mounted inside the vacuum tank surrounding the decay volume. The detectors will be separated from the high-quality beam vacuum by a thin metallic foil.

1.2 Scintillator tile detectors with wls fibre readout

Combinations of 2-3 layers of scintillator tiles with dimensions typically 200×200 mm^2 and a thickness of $2.5 - 5.0$ mm may be used for the charged-particle veto system. The scintillation light would be extracted with the help of wave length shifting fibres running in grooves of 1 mm depth and 5-10 mm spacing. The fibres would be coupled to multi-channel hybrid photo-multipliers mounted on the outside of the vacuum tank. Detector prototypes with different combinations of scintillator tiles with varying groove pitch and scintillator thickness were tested in the beam at PSI. The final setup (Version 6, see Fig.4) was then also used to measure the number of photo-electrons with cosmic rays in the laboratory. In this note we summarize the experience gained with this prototype detectors from measurements done in spring 2001 (see also [1]).

2 Layout of the test detector

2.1 General layout of the prototype detector

Figure 1 shows a sketch of the prototype detector. The active area in the center has the dimensions of 150×100 mm^2. The scintillation light is extracted through 16 wave length shifting fibres. Both ends of the fibre bundle are then coupled to individual photomultipliers (see Fig 3). All 16 fibres have the same length of 920 mm.

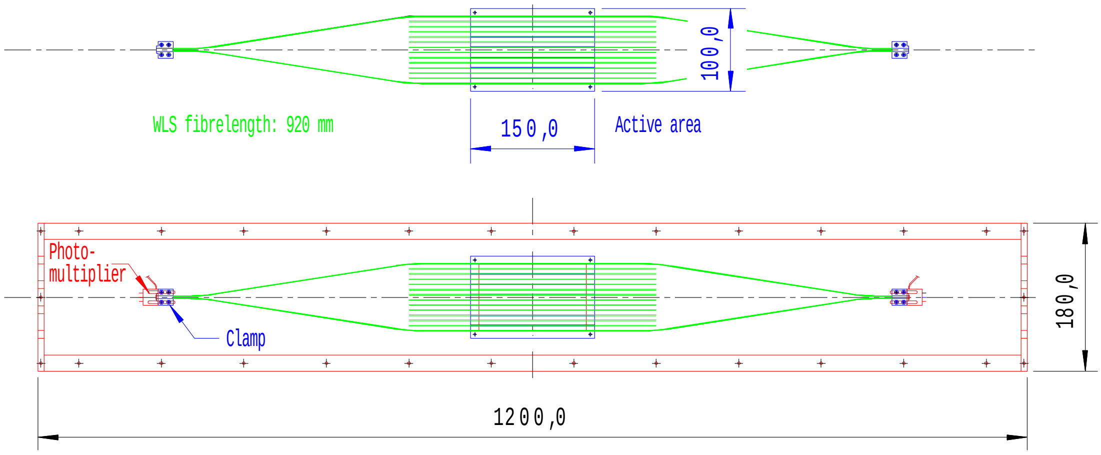

Figure 1: *Sketch of the prototype detector with the actual dimensions.*

To couple the fibres optically to the scintillator tiles we used optical grease. This allowed us to test different combinations of tiles with the same set of wls fibres. We only exchanged the scintillator tiles. For the final measurement we glued the fibres to the scintillator tiles. This setup was then also used to measure the photo-electron yield. The active area is wrapped with aluminum foil.

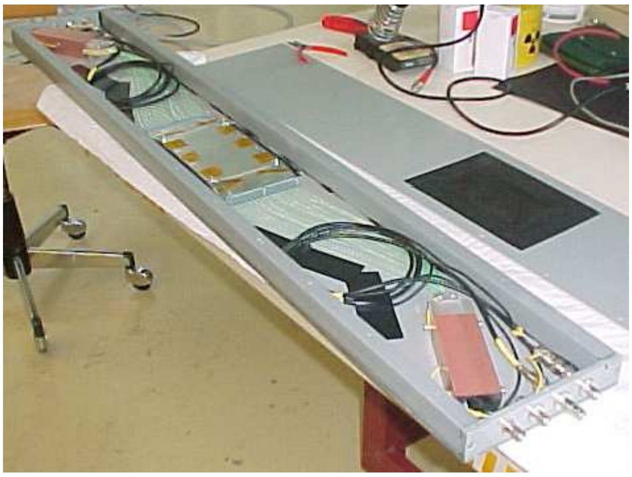

Figure 2: *Picture of the test detector with the active area in the center of the open box and the wls fibres which are connected to the photomultipliers.*

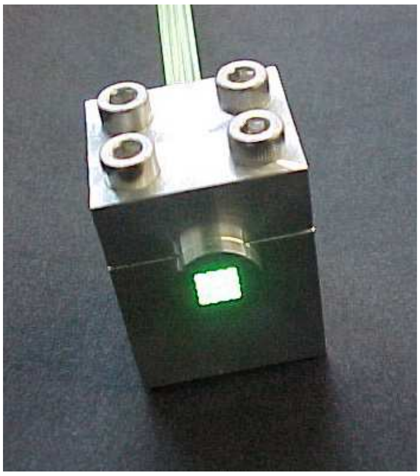

Figure 3: *Clamp which couples the 16 wls fibres to the photomultiplier.*

2.2 Layout and dimensions of the prototype detectors

Different types of scintillation tiles (see Fig.4) were tested to study the resulting signal pulseheights from both counters. We used tiles with a thickness of 2.5 and 5.0 and the pitch of the grooves was 5.0 mm and 6.25 mm. The size of the active area was 150 × 100 mm^2.

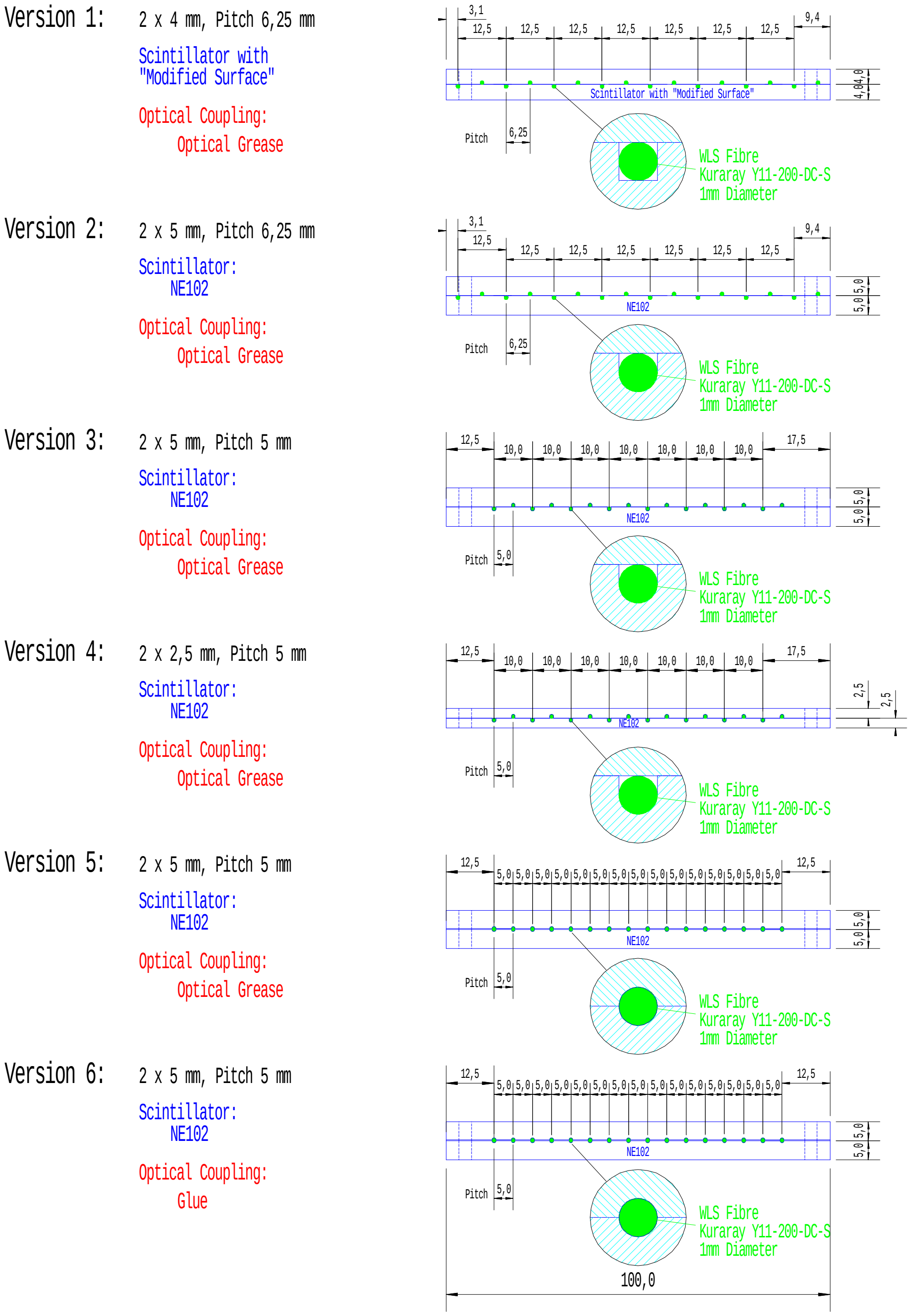

Figure 4: *Layout and dimensions of prototype detectors. The size of the active area is* 150 × 100 *mm*^{2}.

2.3 Scintillator, wls fibres and photomultiplier

The scintillating material used is NE 102. This is a general purpose plastic scintillator, where the emission spectra peaks at 423 nm. The wave length shifting fibre from Kuraray (Y11-200-DC-S) has an absorption spectra which peaks at 430 nm. The emission spectra has its maximum at 476 nm. It is a 1 mm diameter soft fibre with double cladding which provides a high light trapping efficiency. The minimal bending radius for the soft fibre is 20 cm. The photomultiplier S83062E from Burle is a 25 mm (1 inch) endwindow PMT with a 10-stage linearly focused alkaliantimonide dynode structure and a bialkali photocathode. The useful spectral range is 300 – 660 nm. The quantum efficiency in the peak region of the wls fibre emission spectra is typically 20 %.

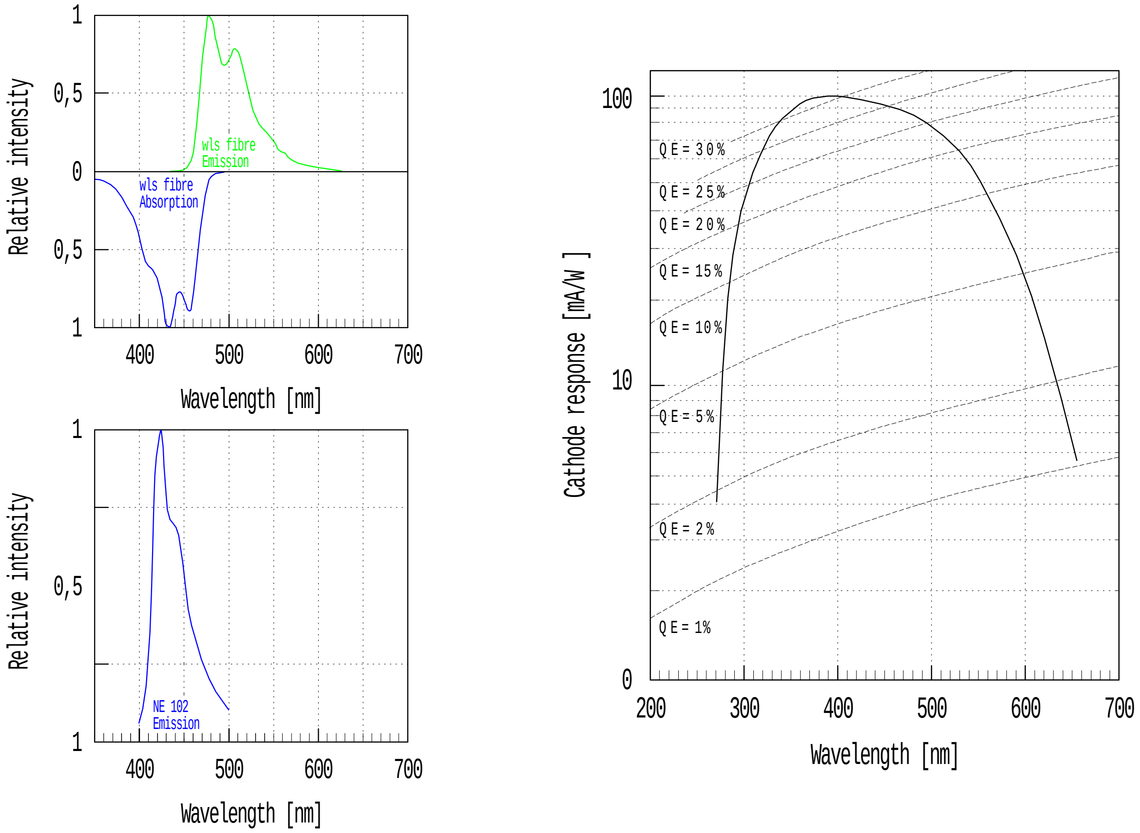

Figure 5: *The lower left figure shows the emission spectra of the scintillator NE 102. The absorption (lower) and the emission (top) spectra of the wls fibres is shown in the left picture on top. The quantum efficiency of the phomultiplier tube is given in the picture on the right.*

3 Yield of photo electrons

We measured the yield of photo electrons with cosmic rays (see Fig. 6). The observed number of photo-electrons ($\approx$ 100 in 10 mm scintillator) is compared with predictions in Fig.7.

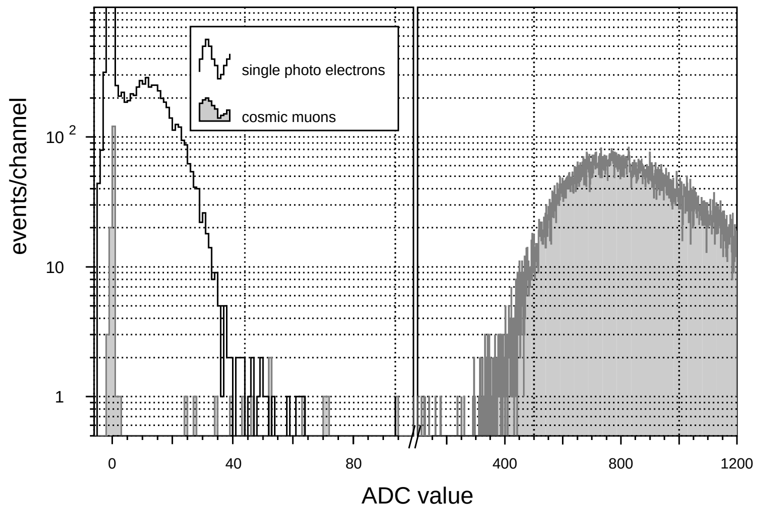

Figure 6: *The pulseheight spectrum measured in a cosmic muon test for a scintillator module with embedded fibres is compared to the distribution for single photo electrons. Note the change of scale near channel 100.*

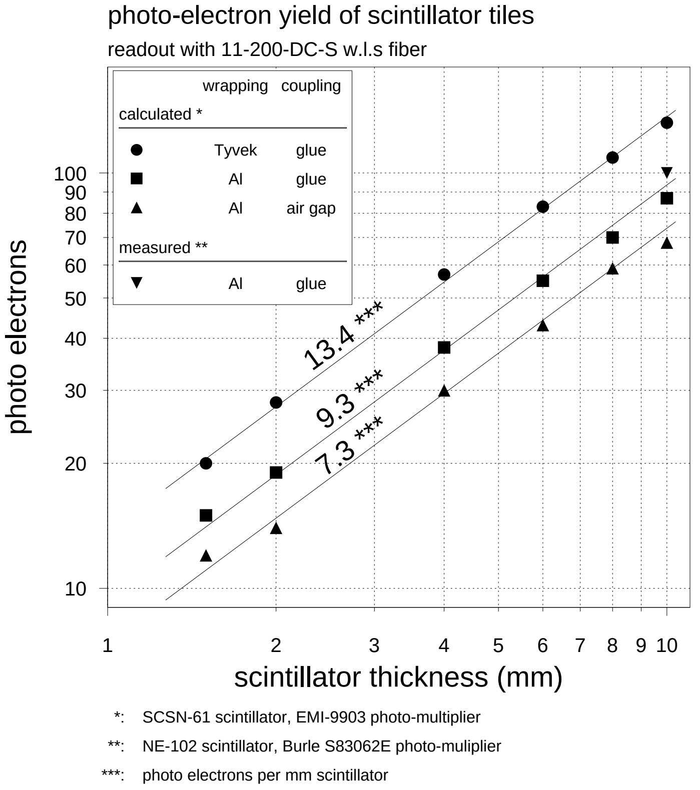

Figure 7: *Mean number of photo electrons for minimum-ionising particles crossing a scintillator tile with embedded wave length shifting fibres. Our measured value is compared with predictions for similar configurations studied for the proposal [2].*

4 Setup and data taking with beam at PSI

Figure 8 shows the experimental setup which consists of

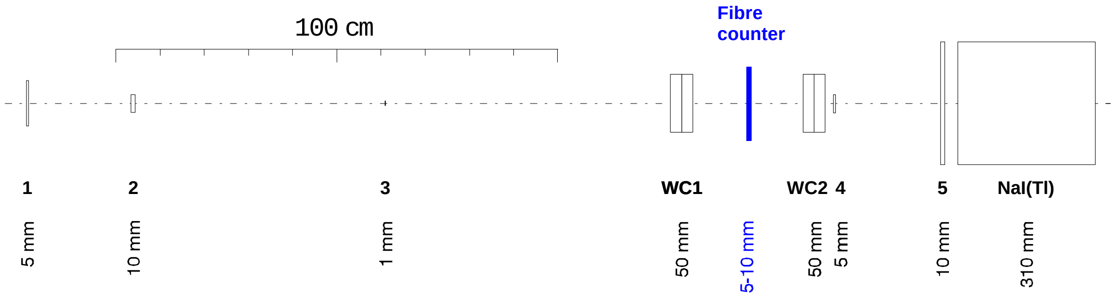

Figure 8: *Experimental setup for the measurements of the prototype detectors. 1-5: plastic scintillation detectors; WC1/2: x-y proportional wire chambers with 1mm wire spacing. The prototype fibre counter is mounted between the wire chambers. The values on the bottom denote the thickness of the corresponding detector. The beam extracted from the πM1 channel at PSI enters from the left.*

A particle defining telescope (counters 1-3 and $x - y$ multi-wire proportional chambers WC1 and WC2) followed by a veto system consisting of two plastic scintillation detectors (4 and 5) and a NaI(Tl) crystal.

Data were taken at beam momenta of 185 MeV/c for negative polarity. The beam intensity was kept below $\approx 5 \times 10^3$ s^{-1} with the help of slits along the πM1 beam line and by detuning the first quadrupoles of the channel. The trigger for data readout required signals in counters 1 and 3. Amplitude and time information for all scintillation detectors, the wire hits in WC1/2 and the phase with respect to the 50 MHz cyclotron r.f. signal were recorded. The latter information was used offline to discriminate between pions, muons and electrons in the beam.

5 Measured pulseheights for the different prototype detectors

In Figure 9 we compare the adc values for the setup version 1 to the setup version 2 for electrons.

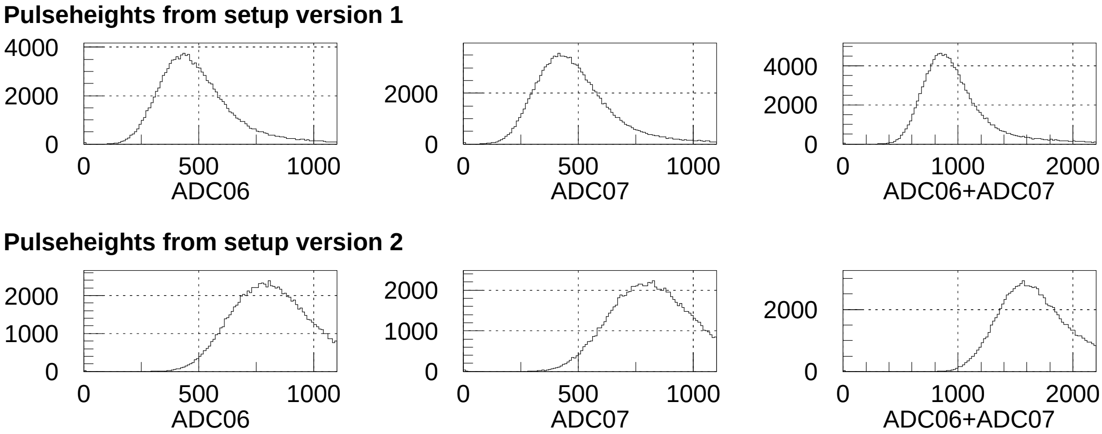

Figure 9: *The measured pulseheight spectrum from version 1 compared to version 2.*

The pulseheight increases by a factor of 2. The light yield of the scintillating material used in version 1 seems to be lower than the one in NE 102. We also have to mention that the grooves in version 1 have a different shape (see Fig.4) compared to the others. But nevertheless this can not explain the dramatic difference.

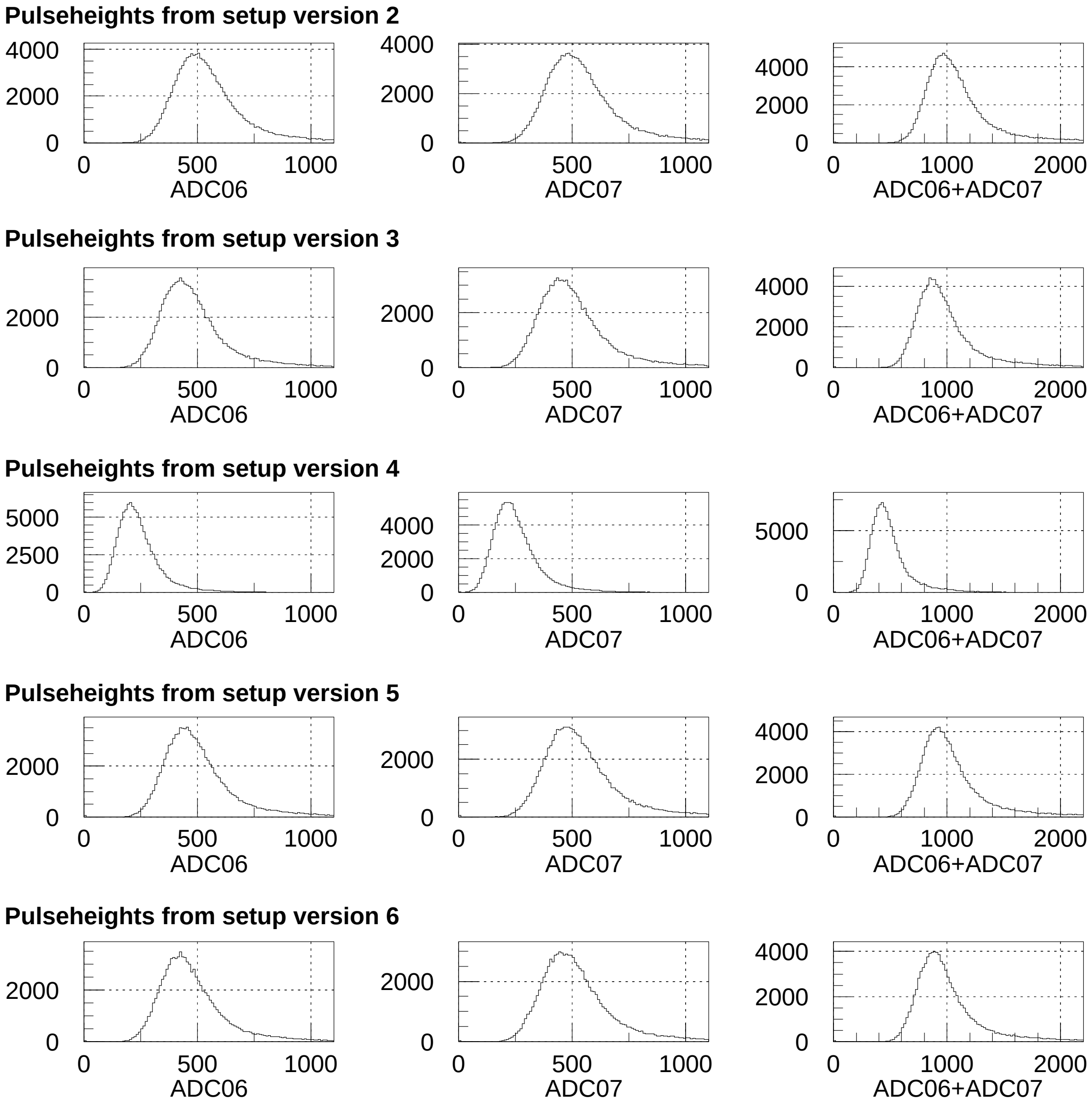

Figure 10: *The measured pulseheight spectrum from versions 2,3,4,5,6.*

Figure 10 compares the pulseheights for the versions 2-6, again for electrons. Here the signals are attenuated to adjust the pulseheight to the range of the adc. For version 4 the pulseheight changes obviously because of the thinner - by factor of 2 - scintillator.

References

[1] *Measurements on the response of plastic scintillator to charged pions at 185 - 360 MeV/c*, KOPIO note tn027, October 2001.
The note is avalaible at *http://pubweb.bnl.gov/people/rsvp/*

[2] *Rare Symmetry Violating Processes, KOPIO section*,
Technical design report submitted to the National Science Foundation to construct the MECO

and KOPIO experiments, June 2001, appended to request.
The proposal (1999) is avalaible at *http://pubweb.bnl.gov/people/rsvp/*