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THE NEW TAPS ELECTRONICS*

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The current electronics for TAPS is more than 10 years old with the expected deficiencies of such an old hardware. To overcome these problems, a new 4 channel per module electronics has been designed which will replace and improve the currently used electronics. The main goals for the new design have been the need of a better handling, easier maintainance, improved performance and the capability to handle higher readout rates. A basic requirement was the compatibility with the HADES experiment to perform combined experiments. This is achieved by using similar VME-motherboards. The readout of a typical TAPS-BaF_2-signal comprises 4 QACs for the separate integration of the long and short scintillation components in two different ranges, a TAC and 2 LEDs for more sophisticated trigger conditions. A CFD is included to optimize the timing information. Several tests were performed with prototypes. Initial problems were identified and have been removed.

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1. Introduction

The new readout electronics for TAPS [2] is designed within the TAPS collaboration by the Giessen group in close collaboration with KVI, Groningen (The Netherlands) and the University of Basel. It is planned to employ the new read-out electronics for TAPS in joint experiments with the dilepton spectrometer HADES at GSI, Darmstadt, and future stand-alone experiments at various accelerator facilities. Therefore, the electronics has to be compatible with the general read-out and trigger concept of HADES, which requires in particular the complete digitization within 10μs. In addition, a highly compact electronics located directly near the detector modules including the complete digitization of the detector response will drastically

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reduce the installation time, avoid long signal cables and passive delays and should improve the overall performance significantly. The repair of the existing electronics is more and more limited by the lack of components which were designed and produced exclusively for TAPS.

2. Overview of the components

The concept is based on the VME-standard and accommodates modern requirements regarding data rate, resolution, flexibility and trigger selectivity. Based on a HADES compatible mainboard with a 13bit ADC and the VME-interface, the specially constructed piggyback is able to read out in parallel 4 channels of BaF_2-detectors (see figure 1).

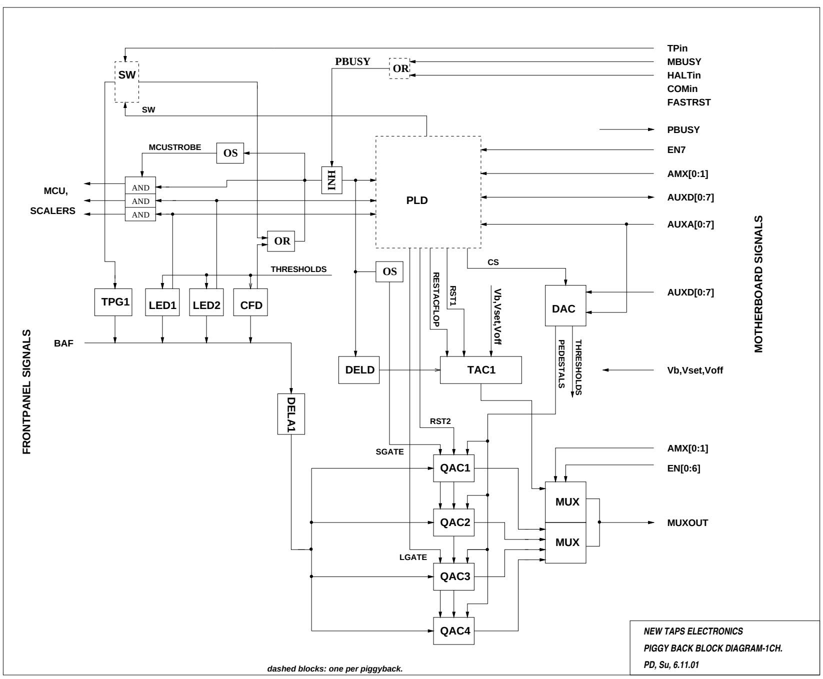

Fig. 1. Schematic block diagram of the piggyback designed for the read out of 4 channels. The upper part shows the digital control circuits for the analogue section (QACs and TAC) below.

Each channel is discriminated by a Constant Fraction Discriminator (CFD). Two separate Leading Edge Discriminators (LED) provide independent thresholds for more advanced trigger decisions. The CFD signal represents the main start signal. After a possible inhibit setting (initiated by a motherboard busy, *e.g.* during conversion of a precedent signal), the CFD signal is used in the PLD control functions and for generating the integration gates of the Charge-to-Amplitude Converters (QAC), which have to be set very accurately to allow pulse shape analysis. Each analog signal is integrated 4-fold: the BaF_2-signal is integrated over the total response time (long gate, typically 2μs) and during its fast component (short gate, typically 20ns), both with a high and a low gain. Exploiting the correlation of the fast scintillation component with the total light yield, such a pulse shape analysis allows to distinguish signals initiated by photons or hadrons. An analog Time-to-Amplitude-Converter (TAC) with a resolution per channel of approx. 50 ps delivers the timing information. Due to the fast operation in common stop mode no long delay of the logic timing signals is required.

The slow control (adjustment of the DACs) as well as the digital readout of the discriminator status are handled by a Programmable Logic Device (PLD, XCR3256XL), positioned on the piggyback. In addition, it controls the long gate and the reset of the channels by using the first level trigger decision. If the stop signal for the TAC circuit does not arrive in the time window between 400ns and 600ns after the CFD signal, the PLD resets the corresponding detector channel.

3. First tests

An 8-channel prototype (4 boards comprising only 2 channels each on two-layer boards assembled with several plugins) was employed during a first test beam time at the MAMI tagged photon facility at Mainz. The in-beam test was performed to study the energy and time resolutions as well as the overall linearity. A detector array consisting of 7 TAPS BaF_2-detectors was exposed directly to the collimated tagged photon beam. The coincidence with a limited number of tagging channels selects a few incident photon energies distributed over the full energy range up to 800 MeV. Figure 2 presents the energy response of the detector array to incident photon energies between 70 and 800 MeV.

The analog signals have been integrated over 2 μs and digitized within a full dynamic range corresponding to 1 GeV. The line-shapes are fitted by the typical asymmetric response function (solid lines), see Ref. [1]. The deduced energy resolutions (σ) are shown as a function of incident photon energy in the same figure 2.

In a subsequent measurement the BaF_2-matrix, read out with the new TAPS electronics, was used in a parasitic experiment. In a joint operation, coincidences of the test unit have been recorded with the complete TAPS detector, which was arranged in a wall geometry and positioned at the opposite side of the beam (covering ca. 30% of 4π). The small detector array was

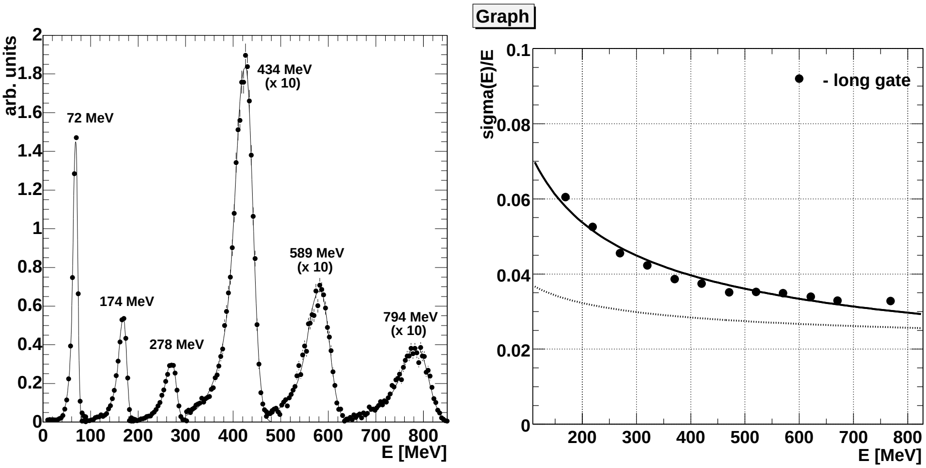

Fig. 2. Left: Experimental line-shapes for various incident photon energies determined in the detector array and recorded with the new electronics. Right: Energy resolution of the BaF_2-matrix measured for the long integration gate as a function of incident photon energy.

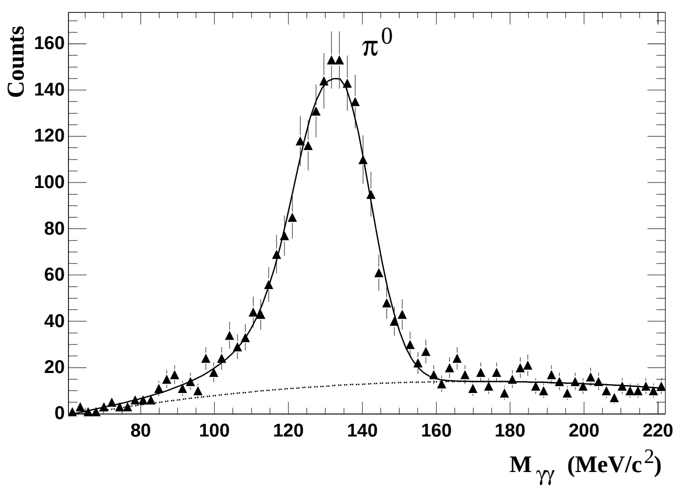

Fig. 3. Invariant mass spectrum deduced from $\gamma\gamma$-coincidence detected in the reaction γ+^{4}He showing a pronounced π^0 peak. One of the decay photons was detected in the small detector array read out with the new TAPS electronics. The solid line represents a fit with the known $\pi^0 \to \gamma\gamma$ line shape including the combinatorial background (dotted line).

placed at a scattering angle of 100° with respect to the photon beam and was read out by a TAPS acquisition system. Figure 3 presents the identification of π^0-mesons from the reaction $\gamma + {}^4$He based on an invariant mass analysis. The invariant mass has been deduced from pairs of decay photons under the condition that one photon was identified in the small detector array. The figure demonstrates the overall performance of the new read-out, which included the reconstruction and calibration of the electromagnetic shower and the clean separation of photons via time-of-flight and pulse-shape analysis. The achieved time resolution of 200 ps (σ) is comparable to the typically value obtained with the current electronics.

4. Problems with nonlinearity

The tests described above have shown the functionality of the new electronics, but the detailed analysis of the response of the individual modules has revealed a non-linearity of the measured energy towards higher energies. Laboratory tests with test pulses, simulating the shape of BaF_2-signals, have been performed, whereby the pulse height has been varied with a high precision attenuator.

The investigations, covering a maximum attenuation factor of 52 dB, have shown a non-linearity in case of the long integration component of approx. 8% over a full range of 800 MeV (figure 4) measured with the piggyback used in the MAMI experiment. In the lower part of the spectrum a fully linear response of the charge integration is found while deviations occur at higher energies.

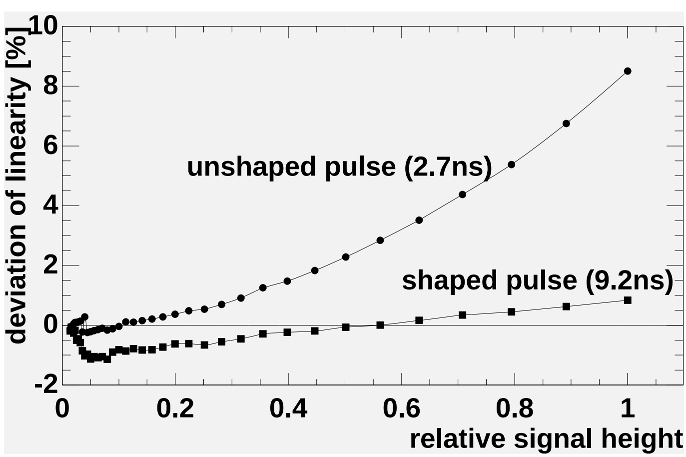

Fig. 4. The measured deviation from linearity shown for an unmodified BaF_2-signal (risetime = 2.7 ns) as a function of relative signal amplitude. Maximum values up to 8% have been determined. After shaping leading to an increase of the risetime to 9.2 ns, the maximum non-linearity is reduced down to 1.1%

The deviation from the linearity has been calculated by the following procedure: A linear fit has been applied to the 20 lowest data points. The absolute error is given by the deviation of the experimental data from the fitted line. In a similar way, the relative error corresponds to the ratio of (absolute error/fit-value)*100%.

After a series of detailed investigations the reason causing such a strong non-linearity has been attributed to the fast rise time of the BaF_2-signal. The used QAC chip can not handle such fast signals. When applying a signal shaping circuit increasing the rise time to 9.2 ns, in contrast to a former value of 2.7 ns — measured at the input stage of the QAC — the nonlinearity is reduced to a value as low as 1.1% (see figure 4).

5. Summary and outlook

A prototype of the new very compact read-out electronics for the photon spectrometer TAPS has been designed and operated in two first test experiments detecting high energy photons in a subarray consisting of 7 BaF_2-detectors. In comparison to the current electronics, the new concept is easier to handle, provides full compatibility for a joint TAPS/HADES operation and allows higher rates of fully digitized detector signals (> 90kHz). The first tests with prototype boards are very promising [3]. The implementation of the prototype set-up into the fully operating TAPS systems documents the overall functionality. The identification of neutral mesons via an invariant mass analysis documents the capability of a clean photon reconstruction. The reason for the significant non-linearity of the energy response has been identified and a practicable solution has been tested. As a next and final step, the design and production of a 4-channel multilayer piggyback is in preparation. The mass production, in collaboration with the group of R. Bassini, University of Milan, Italy and the company CAEN, Italy, should be started early 2002 to allow a complete read out with the new electronics for the joint CRYSTAL BALL/TAPS experiment at MAMI in summer 2003.

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