FAST READ-OUT OF THE COMPASS RICH CSI-MWPC PHOTON CHAMBER

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A new readout system for CsI-coated MWPCs, used in the COMPASS RICH detector, has been proposed and tested in nominal high-rate conditions. It is based on the APV25-S1 analog sampling chip, and will replace the Gassiplex chip readout used up to now. The APV chip, originally designed for Silicon microstrip detectors, is shown to perform well even with "slow" signals from a MWPC, keeping a signal-to-noise ratio of 9. For every trigger the system reads three consecutive in-time samples, thus allowing to extract information on the signal shape and its timing. The effective time window is reduced from ~3 μs for the Gassiplex to below 400 ns for the APV25-S1 chip, reducing pile-up events at high particle rate. A significant improvement of the signal-to-background ratio by a factor 5-6 with respect to the original readout has been measured in the central region of the RICH detector . Due to its pipelined architecture, the new readout system also considerably reduces the dead time per event, allowing efficient data taking at higher trigger rate.

I. Introduction

The COMPASS experiment [1] is dedicated to the study of the spin structure of nucleons and the spectroscopy of hadrons. It takes advantage of the 100-300 GeV muon and hadron beams delivered by the SPS (Super Proton Synchrotron) accelerator at CERN, with beam intensities reaching 10^8 part./s. The COMPASS detector is constituted by a fixed target, for instance a polarized target of ^{6}LiD, and a two stage spectrometer dedicated to the detection of particle at low and high momentum. A large part of the physics topics studied at COMPASS needs a good particle identification.

The particle identification is performed by a RICH detector [2] included in the first stage of the spectrometer, which has been designed to separate kaons and pions in the momentum range 5 - 50 GeV, with a large geometric acceptance (180 mrad x 250 mrad). Cerenkov photons produced in the radiator gas (80 m^3 of C_4F_{10}) are focused by a spherical mirror wall onto the photon detectors, consisting of 8 MWPCs with CsI photocathodes placed out of the acceptance. The MWPC photon chambers are equipped with two square CsI photocathodes of 72x72 pads detecting UV photons, they operate at a gain around 3.10^4. The read-out electronics is based on Gassiplex amplifiers which use a large integration time of ~3 μs, its long base line restoration time lead to a dead time of 5 μs. These two characteristics limit the performances of the RICH detector in a high intensity environment like COMPASS.

A global upgrade of the RICH detector has been proposed, separated in two projects: in the central region, the CsI-MWPC chambers will be replaced by multi-anode PMTs [3], and in the outer region a new electronics based on the APV25-S1 chips will replace the present one. This later project is described below.

II. Principle

The APV25-S1 chip [3] is a 128-channel preamplifier/shaper ASIC with analog pipeline, originally developed for the CMS Silicon microstrip tracker [4], and successfully adapted for the COMPASS Silicon [5] and GEM [6] tracking detectors. Its peaking time are adjustable in a wide range from 50 to 300 ns, opening the possibility to use the APV25-S1 to read "slow" detectors as MWPCs. The amplifier output amplitudes are sampled at a frequency of 40 MHz and stored in a 192 cells analog pipeline. When an event is triggered, the cells to read are multiplexed into a single differential output. In order to get timing information, two additional samples on the rising edge of the signal are read. The time gap between these individual samples can be varied in steps of 25 ns, depending on the shape of the input signal. For the RICH MWPCs, the sampling step size is settled to 150 ns.

A 10-bit flash ADC digitizes the multiplexed analog data stream from each APV25-S1 chip, and a FPGA performs on-line zero suppression. In order to match the form factor of the present RICH front-end cards, 4 APV25-S1 chips, each reading 108 RICH pads, are included in one front-end card. Three front-end cards are then connected into one ADC module.

III. Test beam results

A full system test with 12 front-end cards was performed in 2004 in both muon and hadron beams at intensities of 4.10^7 μ/s and 1.10^7 h/s. To this aim, half the area of one photon chamber (i.e. a full CsI photocathode) was equipped with APV front-end cards in the central region close to the beam.

The average noise achieved with the APV25-S1 chip depends on the amplifier and shaper time constants, and was found to be ~640 e^- for a setting corresponding to an optimal peaking time of 250 ns, compared to ~1000 e^- for the GASSIPLEX chip. The mean amplitude of the photon spectrum was found to be ~5800 e^-, corresponding to a signal-to-noise ratio (SNR) of 9. For comparison, the mean amplitude measured with the GASSIPLEX was determined to be ~8700 e^-. The lower value for the APV25-S1 corresponds to its larger “ballistic deficit” due to the shorter time constant, and it is well reproduced by simulation of the electronic circuit. Due to its lower noise figure the APV25-S1 can be operated at a lower threshold, which fully compensates the loss of integrated charge. As a consequence, the SNR figures for both readout systems are quite similar.

After reconstruction of a track in the spectrometer, the expected position and radius of a ring in the RICH is known assuming that the particle is a pion. Figure 1 shows the distribution of residuals, i. e. the difference between the radial distance of each cluster measured by the APV-equipped MWPC and the expected ring radius; clusters are selected cutting on cluster amplitude threshold and timing. The background under the signal was determined by combining clusters from one event with tracks from a different event. The signal-to-background ratio (SBR) determined by subtracting this background is 2.13, the number of clusters in the peak is 11.2 to be compared with respectively 0.35 ans ~12 for the GASSIPLEX under similar conditions.

The in-time signal shape can be scanned by artificially varying the latency of the trigger sent to the APV25-S1. Figure 2 shows the distribution of residuals versus latency. The time window of the APV readout deduced from this scan has a FWHM of 250 ns, and a full width of 375 ns. For comparison, the effective time window of the GASSIPLEX chip, determined from Monte-Carlo studies, was found to be ~3 μs. The time of the cluster can be also measured from the ratio of the second to the third samples of the signal. A time resolution better than 30 ns is achieved for clusters with high enough amplitude (corresponding to half of the clusters). Dead time is also improved with the APV electronics due to its analog

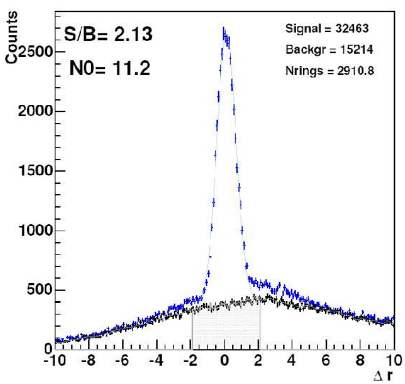

Figure 1: Distribution of residuals, i.e. the difference between measured cluster radial distance and expected ring radius, assuming that the particle was a pion.

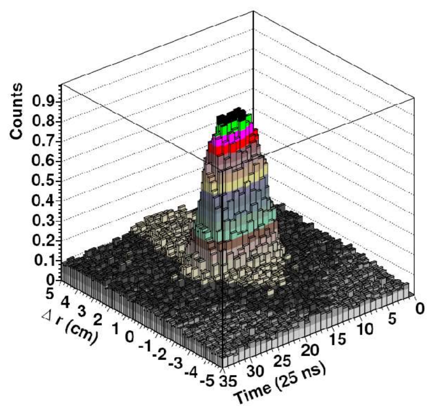

Figure 2: Normalized distribution of residuals versus latency, i.e. the time difference between passage of particle and sampling time.

pipelines architecture. With a 40 MHz read-out, the dead time is negligeable for a rate up to 40 kHz, and around 15% at 80 kHz.

IV. Summary and Outlook

A new analog readout system for the COMPASS RICH detector based on the APV25-S1 chip was proposed and tested in 2004. 5000 channels of the new system were successfully operated under realistic conditions in the central part of the detector, using both muon and hadron beams. As expected, the effective time gate was reduced to below 400 ns, leading to a significant improvement of the SBR as compared to the present readout system. The dead time is also improved in the new system. For 2005, the production of ~62000 channels of this new readout system is foreseen at a moderate cost of 5 Euro per channel. The installation of the new system is expected for early 2006 in order to be ready well in time for the 2006 beam start.

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