Advances in gaseous time-of-flight detectors

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Timing Resistive Plate Chambers (RPCs) are planar gaseous detectors made with a combination of metallic and resistive electrodes, delivering time resolutions around 50 ps σ and efficiency up to 99% for MIPs.
In this work we describe the development and test of an electrically shielded timing RPC array for crosstalk-free time measurements in high granularity time-of-fight (TOF) systems, as the Inner TOF Wall of the HADES experiment.

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1. Introduction

Timing resistive plate chambers (tRPCs) [1] are planar gaseous detectors made with a combination of metallic and resistive electrodes, which deliver time resolutions around 50 ps σ and efficiency up to 99% for MIPs. Advantages of this technique over the traditional scintillation-based approach include a lower cost per channel, compact mechanics and tolerance to the magnetic field.

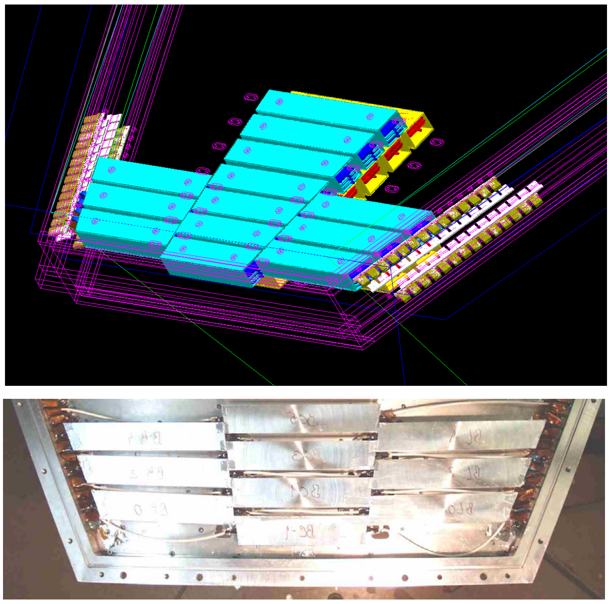
This technology has been developed into a variety of devices suited to different experimental needs, including large area [2] and position-sensitive [3] counters. The unusual operating principles of these detectors have been also subject to close scrutiny [4]-[6], while several experiments are researching, implementing or exploring tRPC TOF systems [7]-[10].

Recent results include operation under counting rates well beyond the previously accepted limits [11] and the development of electrically shielded arrays for crosstalk free time measurements in high granularity detectors, as described in this work.

2. The HADES Inner TOF wall

The HADES (High Acceptance Di-Electron Spectrometer [12]) experiment, located at the GSI institute in Darmstadt, Germany, is aimed at improving the understanding of nuclear matter at high densities.

A solution for the HADES Inner TOF Wall based on shielded timing RPCs [13] has been previously investigated ([14], [15]) in a fragmentation beam and found mostly adequate for the HADES requirements, except in what regards the rate capability.



a)

b)

Figure 1: General view of the detector internal structure corresponding to one HADES sextant a) and b) of the actual arrangement of the counters in one layer.

However, the single-plane design then considered proved to be inconvenient for mass production as it required the adherence to tight mechanical tolerances on all chamber components to ensure a sufficient geometric coverage.

Here we describe results from a similar test performed on a two-layer system of shielded timing RPCs with a very similar internal electrode structure. The staggered construction, while allowing for relaxed mechanical constraints, has the advantage of providing some degree of redundancy, very convenient for the auto-calibration of the system (see [15]) and, as shown below, for the elimination of timing tails (see also [3]). Simulations determined the optimum distribution of the detectors in three columnar regions for each sextant (HADES is divided into 6 sectors), as shown in Figure 1.

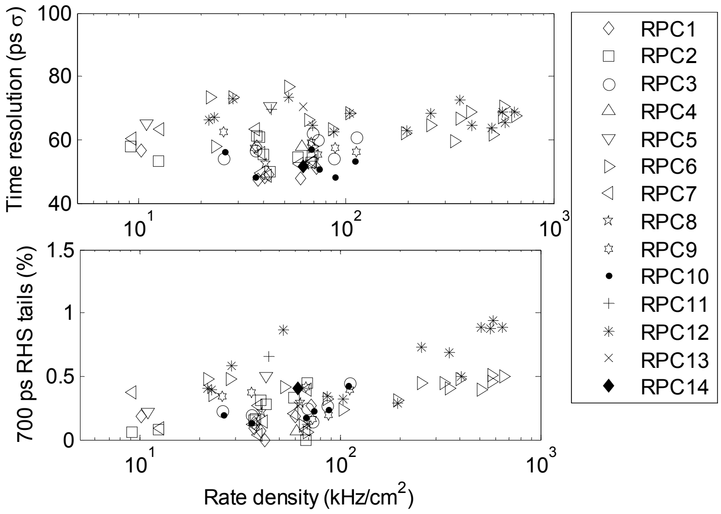


Figure 2: Time resolution and the 700 ps right hand side (RHS) tails (see Figure 3) for 14 individual counters as a function of the counting rate density. The time resolution ranges from 50 to 80 ps, with an average of 60.1 ps. The timing tails are mostly below 0.5 %.

The rate capability was extended by warming the detector to 33 ºC, following previous encouraging studies [16].

3. Beam test of a shielded timing RPC array

For the purpose of this test a full size gas enclosure (one HADES sextant) was equipped with 24 counters placed in the region of highest track density. The beam setup and front-end

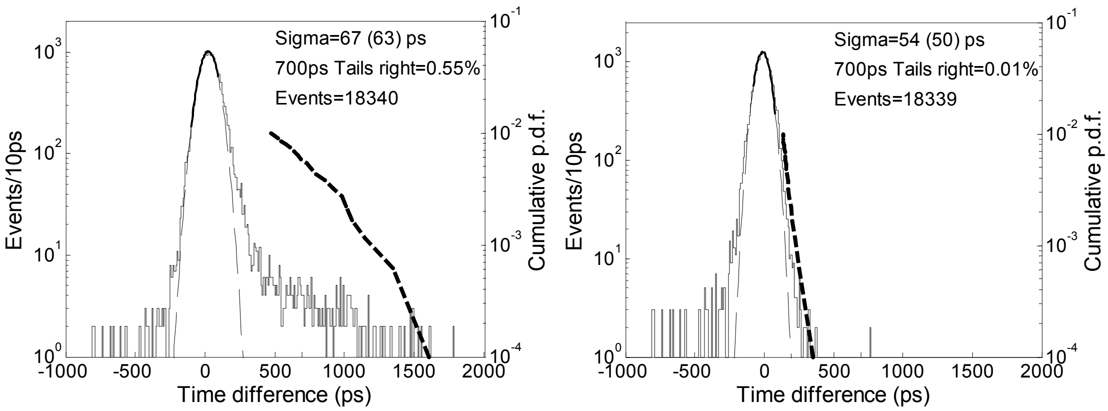


Figure 3: a) Typical time distribution, emphasizing the residual timing tails described by the cumulative probability density function (p.d.f - thick dashed line). b) The staggered design allows for some degree of redundancy, which provides a very strong tail suppression for those particles measured twice, along with some resolution improvement. The figures in parenteses correspond to the resolution after quadratic subtraction of the contribution of the reference scintilators.

electronics were similar to those described in [14].

The time resolution and timing tails were measured on 14 counters, with the results shown in Figure 2. The time resolution ranges from 50 to 80 ps σ, with an average of 60.1 ps. There is very little dependence on counting rate (compare with [15]), evidencing the positive results of the "warm glass" technique [16].

The fraction of events exceeding the average time by more than 700 ps (700 ps right hand side (RHS) tails) is mostly below 0.5 %. These tails are correlated with the smaller signal amplitudes and may be due, for instance, to edge effects on the detector or to the propagation characteristics of the timing comparator. However their exact origin is not understood at this moment.

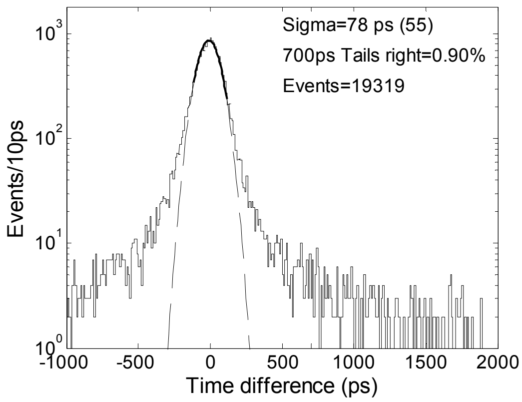


Figure 4: Time difference between two superimposed, neighbouring RPCs measuring twice the same particle. The figure in parenteses corresponds to the resolution of a single counter. The good resolution and moderate tails suggests a moderate degree, if any, of crosstalk effects.

The staggered design allows for some degree of redundancy, which provides strong tail suppression by taking the earliest time for those particles measured twice, along with some resolution improvement [3], as it may be appreciated in Figure 3.

By taking time data between two of such partially superimposed, neighbouring, RPCs, an integral resolution measurement was performed over the whole counter length. The excellent time resolution and unaffected timing tails shown in Figure 4 demonstrates a good uniformity of response and negligible crosstalk effects.

A different kind of crosstalk tests were performed in the laboratory by disconnecting from the high voltage supply 25% of the chambers and measuring the rate of pulses in these chambers when compared with the rates on their active neighbours. Typically such ratio was lower than 1% and the observed crosstalk pulses were mostly related to background pulses (eventually isolation leaks) and rather independent from radiation-induced effects.

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