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In-beam measurements of the HADES-TOF RPC wall

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ABSTRACT

A full size prototype of the new inner High-Acceptance DiElectron Spectrometer (HADES)-TOF wall based on Resistive Plate Chambers (RPCs) was mounted and exposed to secondaries from C reactions on Be and Nb targets at 2 AGeV kinetic energy and typical HADES particle fluxes. The tested sextant is constituted by 187 individual 4-gap glass–aluminium shielded RPC cells distributed in three columns and two layers, covering an area of 1.26 m^2.

An average timing resolution of 73 ps σ was measured with 99% intrinsic efficiency, on a random location, and moderate timing tails, along with an average longitudinal position resolution of 7.7 mm σ, in the range from a few Hz/cm^2 up to 80 Hz/cm^2 without noticeable degradation of performance. Additionally, the matching efficiency was estimated using the tracking system of HADES, yielding an average value of 97.5%.

1. Introduction

HADES (High-Acceptance DiElectron Spectrometer) at GSI-SIS [1] is a second-generation dielectron detector, divided into six identical sectors (or sextants), built after pioneering but puzzling results obtained by DLS at the Bevalac in the early 1990s [2]. Its main aim is to explore the phase diagram of nuclear matter at moderate temperatures and nuclear densities, where modifications of the particle masses are predicted due to the partial restoration of the chiral symmetry of QCD [3]. SIS energies of few AGeVs are well suited for studying such a phenomenon since the conditions are not yet sufficient to produce Quark Gluon Plasma. HADES has launched its experimental program and meanwhile confirmed the DLS results [4,5]. It needs, however, to be upgraded in order to be able to explore for the first time in this energy regime the heavy Ni–Ni and Au–Au systems in the dielectron channel.

A solution for the HADES Inner TOF Wall based on shielded timing Resistive Plate Chambers (RPCs) [6] has been previously investigated [7–9] in a fragmentation beam and found adequate for the HADES requirements. Here we present the results for a prototype of a fully instrumented sextant mounted at the nominal position and exposed to the realistic particle environment present at the HADES experiment.

2. Setup

Data were taken with an RPC sector (sextant) exposed to secondaries from reactions of a C beam of 2 AGeV, with an effective spill duration of ~6 s, on Nb and Be targets. A detailed description of the structure can be found in Ref. [10]. It was mounted on its support (see Fig. 1) and placed approximately at the nominal position, between the Pre-Shower (RPC downstream) and the MultiWire Drift Chambers(MDC) detectors, see Fig. 2. The RPC was operated with a gas mixture composed of 90% $C_2H_2F_4$ and 10% SF_6 under a continuous gas flow of 50 cc/min at a nominal High Voltage of 5800 V. One hundred and sixty two cells, distributed in 27 rows, were read out by the Front End

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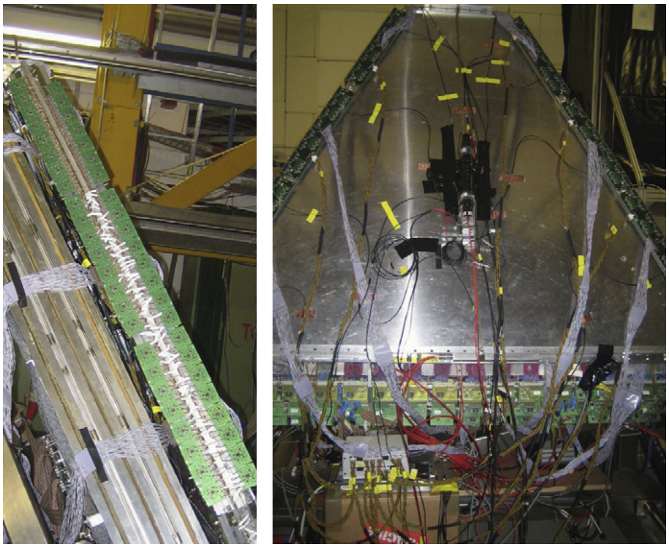

Fig. 1. Lateral and front view of the RPC sector on its support, standing over the Pre-Shower detector.

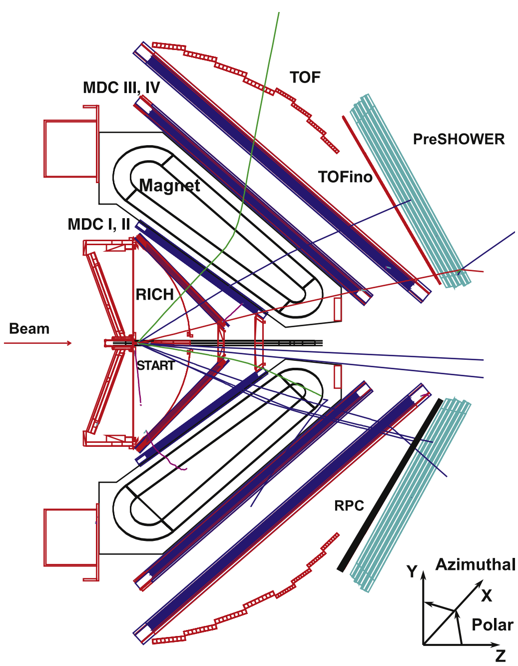

Fig. 2. Sketch of the HADES spectrometer with the beam entering from the left. Downstream from the target there are RICH, inner MDCs, magnet, outer MDCs, TOF, TOFino and Shower detectors. The RPC is shown on its position during beam time.

Elecronics (FEE) and Data Acquisistion System described in Refs. [11,12]. The last four rows of cells in the region at high polar angle were not read out due to a technical problem. Additionally, some of the electronic channels, on random locations, were not operative.

The last outer MDC (MDCIV) was operational together with the Pre-Shower detector belonging to the same sector, allowing for the selection of reference particle tracks over the RPC wall. The magnet and the RICH were off. In order to provide a reliable reaction trigger, we operated the present TOF and TOFino walls (with the exception of the sector instrumented with the RPC) with a low-bias trigger in multiplicity larger than 4 ($\langle N\rangle \simeq 10$). We also ran low statistic triggers with two reference scintillators as in Ref. [8].

3. Methods

3.1. Definition of the reference tracks and alignment

A set of reference tracks was defined as those tracks that matched both the MDC tracking system and the Pre-Shower detector within a window of $\Delta X_{match} = \pm 35$ mm in X (along the azimuthal angle) and $\Delta Y_{match} = \pm 35$ mm in Y (along the polar angle).

Due to the non-standard position of the RPC, a few centimetres backwards from the nominal position, it was necessary to make a careful alignment. This was done by minimizing differences between the position of the reference tracks on the RPC plane and the position given by the RPC itself, X_{res} and Y_{res}. The RPC hits were associated with a given track selecting the one at the minimum distance R_{res}, defined as $R_{res} = \sqrt{X_{res}^2 + Y_{res}^2}$. The complete procedure can be summarized as follows:

(i) X and Y position of a reference track given by the RPC was calculated as

$$X_{rpc} = \frac{t_l - t_r}{2} v_{prop} + X_{offset} \quad (1)$$

where t_l and t_r are the measured times left and right for each cell, v_{prop} is the signal propagation velocity in the cell and X_{offset} is an offset calculated individually for each cell. Y_{rpc} was calculated as the centre of the hit cell obtained from its physical position. The propagation velocity was calculated as

$$v_{prop} = \frac{2D}{W(t_l - t_r)} \quad (2)$$

where $W(t_l - t_r)$ is the width of the distribution of $t_l - t_r$ and D is the physical dimension of the cell.

(ii) The RPC was aligned by centering and minimizing the rms of the X_{res} and Y_{res} distributions. The free parameters in this procedure are Z (RPC position downstream along the sector rails), Y (RPC position along the polar angle) and Θ (angle that quantifies the deviations from the perfect parallelism with respect to the Pre-Shower). The other three free parameters needed for positioning a volume in space were assumed to be fixed for the sake of different symmetries.

(iii) After the alignment procedure, the propagation velocity was re-obtained by correcting the remaining residual dependence of X_{res} with X. Small deviations from the previously obtained value were identified and corrected.

3.2. Matching and intrinsic efficiencies

The matching efficiency is obtained on a given region as the ratio of the number of RPC hits, within a position window $\Delta Y = \pm 35$ mm and a time window ΔT of 400 ns, and the number of reference tracks. T represents the time with respect to the trigger signal given by the TOF + TOFino wall (no start detector available). This time does not represent a time of flight but can be used to suppress random matches.

The intrinsic efficiency is calculated as the fraction of RPC hits in coincidence with the scintillators, within a time window of 400 ns.

The matching efficiency is shown in two different representations. The 2D representation, which corresponds to the efficiency as a function of X and Y, and the 1D representation, which corresponds with the projection of the 2D representation on the Y axis.