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Performance of shielded timing RPCs in a ^{12}C fragmentation experiment

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Abstract

We show the feasibility of large area timing RPC detectors for experiments dealing with fragmentation-like primary interactions and/or high detector multiplicities, without significative degradation of the detector capabilities. The tested prototype is constituted by three independent cells placed into grounded aluminium boxes, which reduce the cross-talk to the level of 0.4%. Each $2 \times 2 \times 60\,\mathrm{cm}^3$ box consists of a 4-gap glass–aluminium RPC.

At $200\,\mathrm{Hz/cm}^2$ the counters have shown a time resolution of $60\,\mathrm{ps} < \sigma_t < 80\,\mathrm{ps}$ with 3σ-tails below 8%. High mechanical robustness and homogeneity of the physical properties along the longitudinal direction of the detector were also observed.

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1. Introduction

The coverage of large areas with time of flight detectors is a demanding topic in modern physics. Although very young in this field, timing RPCs [1]

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have already demonstrated their capabilities: a large area RPC of $160 \times 10\,\mathrm{cm}^2$ was shown to be adequate for medium and low multiplicity experiments [2], and so far there have been different encouraging approaches [4–8] for timing 'RPC walls'. We have made this study emphasizing the main a priori 'shortcomings' of working with gaseous detectors, namely:

(i) Increase of the fraction of streamers in the presence of highly ionizing particles.
(ii) Cross-talk between cells, as it contributes through fluctuations of the voltage baseline which can effectively increase the occupancy of the cell or distort the time resolution of *real* coincident hits.

Following this line, we have tested a prototype in a physical environment constituted by particles coming from interactions of ^{12}C at $1\,\mathrm{GeV}/u$, generated at the GSI SIS in Darmstadt, Germany.

2. Detector design

The detector concept is shown in Fig. 1. It is constituted by three glass–aluminium RPC cells of 4 gaps, each of them delimited to a width of 0.3 mm with the help of nylon monofilaments. The three cells are electrically isolated from the neighbours, placed in aluminium boxes properly grounded while the glass is left electrically floating [3]. During the tests, the gas mixture used was 98.5% $C_2H_2F_4$ + 1% SF_6 + 0.5% iso-C_4H_{10} and the working point was set to 6.2 kV. The details about the signal amplification stage can be found elsewhere [4].

3. Experimental setup

The trigger scheme shown in Fig. 2 was performed with the help of 3 auxiliary scintillators A, B and C; two of them (A, B) are Bicron BC420, with a known resolution of 35 ps σ. We choose a symmetric scheme, that substantially reduces the bias introduced in the determination of the time resolution due to the different particle velocities (Fig. 2). The time definitions used are

$$T = \frac{T_\mathrm{A} + T_\mathrm{B}}{2} - T_\mathrm{rpc} \tag{1}$$

$$\delta(T)^2 = \frac{1}{2}(\delta(T_\mathrm{A})^2 + \delta(T_\mathrm{B})^2) + \delta(T_\mathrm{rpc})^2 \tag{2}$$

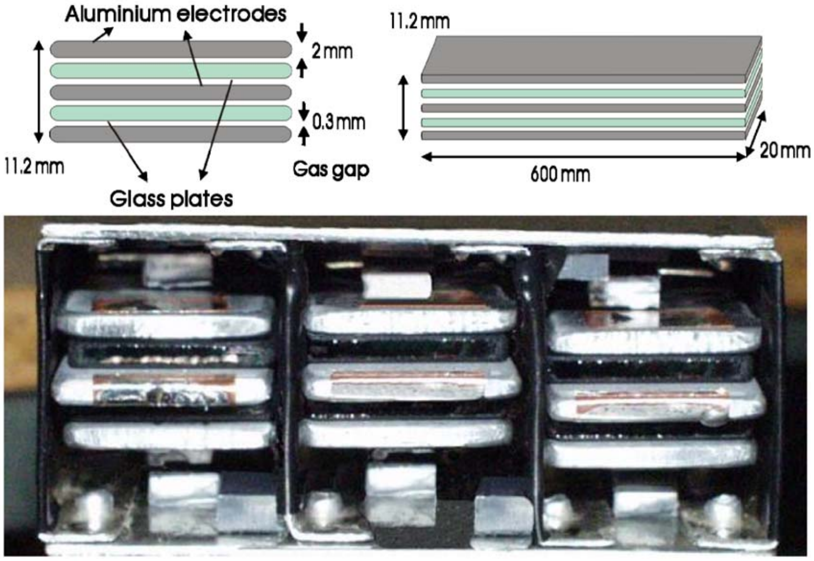

Fig. 1. Different perspectives of the detector together with a laboratory photo, showing the three RPC cells inside the metallic insulating box.

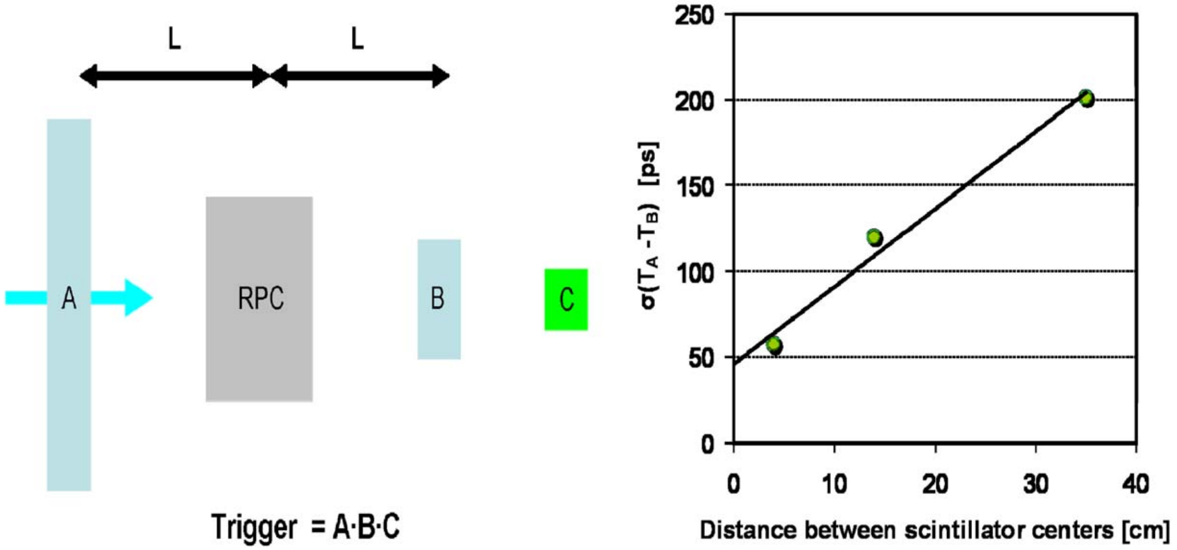

Fig. 2. Side view of the trigger setup. The arrow shows the particles incidence direction. The right figure shows the increase in the spread of the time measured between scintillators as a function of distance; beyond a few centimeters the time resolution is completely dominated by the velocity spread of the particles.

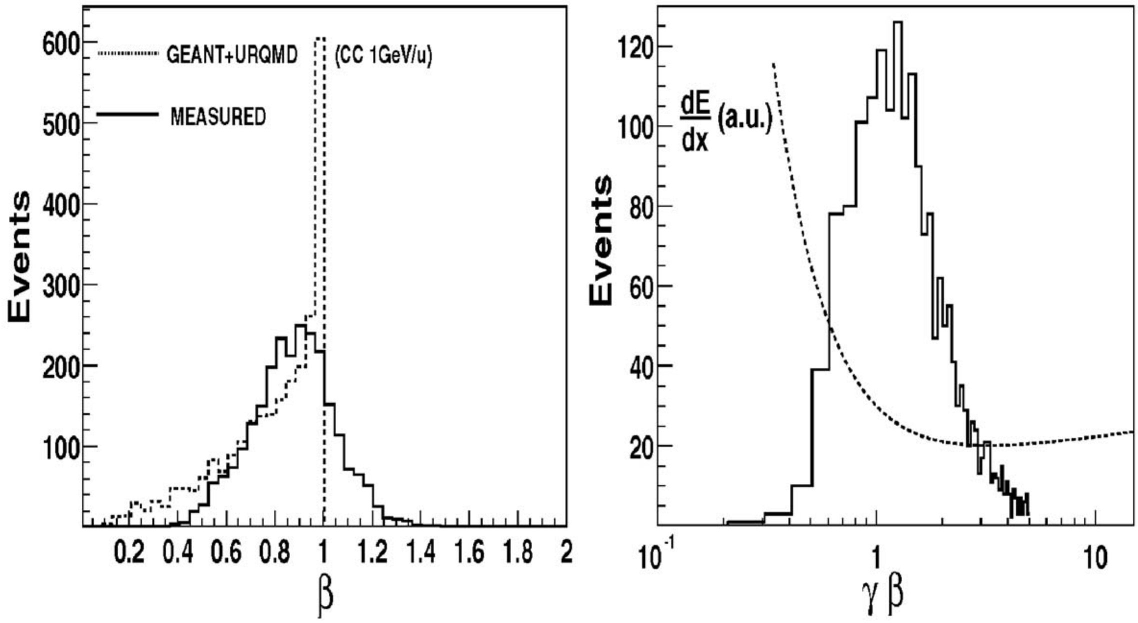

Fig. 3. Distributions of β and $\gamma\beta$ measured with the trigger scintillators, compared with the ones obtained from the HADES simulation toolkit [9]. Also shown superimposed the Bethe–Bloch curve for fluor in arbitrary units.

where $\delta(T_A) = \delta(T_B) = 35\,\text{ps}$. It is possible to obtain the resolution of the RPC from the measured value of $\delta(T)$, after subtracting the contribution of the scintillators (2).

The high scintillator resolution makes it possible to determine the $\gamma\beta$ distribution of the incident particles, in the range [0.3–5] (Fig. 3). According to the Bethe–Bloch curve for fluor (which is the dominant element in the gas mixture), at least a 5% of the total events deposited at least a factor 2 more energy than MIPS. No significant difference was observed when studying slow and fast particles separately.

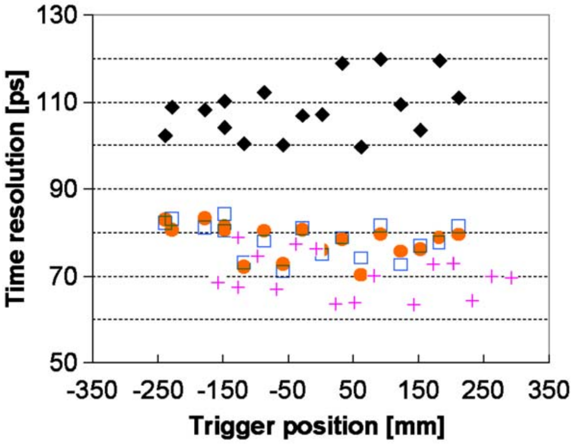

Fig. 4. Plot showing the high homogeneity along the detector length. Diamonds stand for non-calibrated (charge correlated) time resolution. Circles and crosses stand for the resolution of two different cells after subtracting $t-Q$ correlation as a 2-segmented linear function $t[\log(Q)]$. Squares must be compared with circles when getting calibration parameters from a fixed position.

4. Performance

We have given special attention to the calibration problem (i.e. time-charge decorrelation, see for instance Ref. [2]). On one hand, it was seen that time and logarithmic charge are correlated following 2 linear segments. On the other hand, the mechanical robustness and homogeneity of the detector give the possibility to get the calibration parameters from any position along the cell (these results are summarized in Fig. 4).

Position resolution is better than 6 mm σ, which is the minimum value achievable with the trigger setup used. Moreover, the systematic shifts of the position distribution since the TDC differential non-linearity and/or local inhomogeneities are below 2.5 mm (Fig. 5).

In Fig. 6 the behaviour of σ_t and 3σ-tails (tails beyond 3σ) is represented as a function of

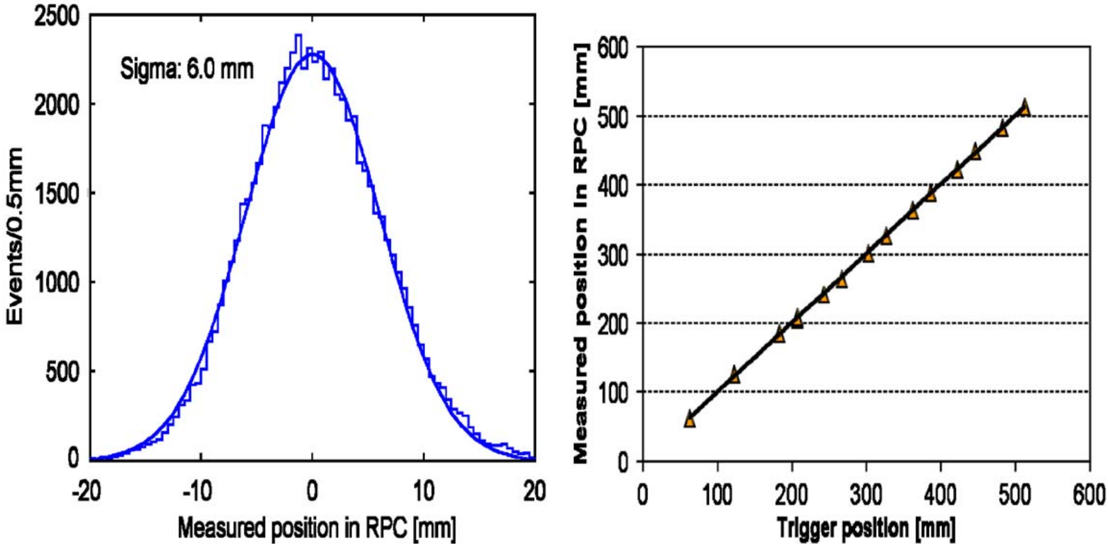

Fig. 5. Position resolution (left) and RPC position vs real position. Residuals are as small as 2 mm in the worst case.

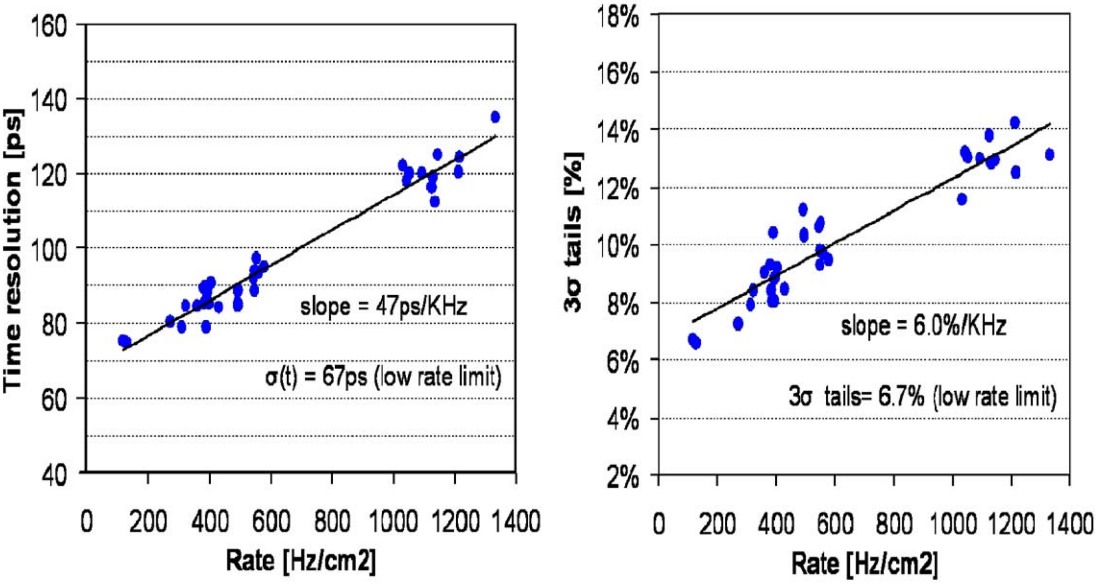

Fig. 6. Behaviour of time resolution and tails beyond 3σ, as a function of rate.

rate R. They can be parameterized as $\sigma_t = 67 + 47 \times \frac{R}{\mathrm{kHz/cm^2}}$ [ps] and 3σ-tails $= 6.7 + 6.0 \times \frac{R}{\mathrm{kHz/cm^2}}$ [%].

The behaviour of the system efficiency is $\varepsilon = 87 - 15 \times \frac{R}{\mathrm{kHz/cm^2}}$ [%], below the expected value for this kind of detector [2]. This is compatible with the fact that the projected trigger area over the RPC was larger than the cell width, also covering the shielding dead zones. We estimate this 'dead zone' per cell to be of the order of 3 mm. Assuming a cell width close to 20 mm, the expected geometric efficiency for perpendicular incidence (as chosen for the measurements) would be $\varepsilon \sim 1 - 3/20 \sim 85\%$, compatible with the results obtained.

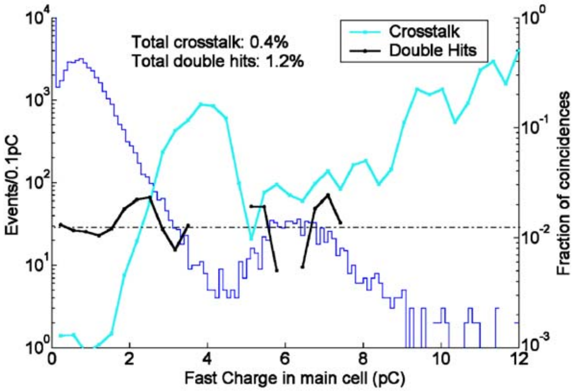

Fig. 7. Fraction of cross-talk and coincident hits in neighbour cell (right axis) as a function of the fast charge in main RPC (left axis). Double hit probability do not show any significant dependence with charge, as expected, whereas the probability of cross-talk is much higher for streamers.

5. Cross-talk

Cross-talk between channels seems to be a real problem for high multiplicity environments [6]. We have performed two separated analyses. First of all it is shown that the total amount of pure cross-talk (events with time signal and without charge) is kept below 0.5% (Fig. 7). Secondly, we have studied how the signals belonging to two hits in coincidence in neighbouring cells (double hits) can interfere. Due to the intrinsic low multiplicity of the ^{12}C reactions, the amount of double hits in each cell was of the order of 1.2% (Fig. 7). However, according to HADES simulation package, this value can be increased up to $\sim 40\%$ for collisions of $AuAu$ at 1 GeV/u as it is expected in

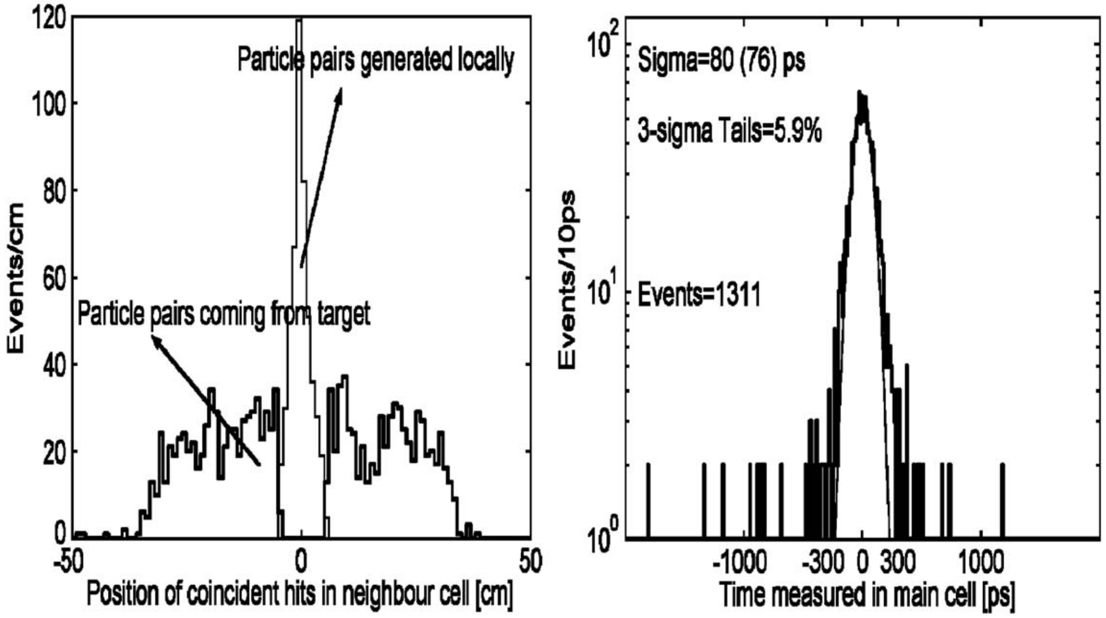

Fig. 8. Left plot shows the position of hits in the neighbour cell whenever the main cell has been fired. It shows a clear peak at trigger position (0 cm) that can be attributed to local production of particles. Subtracting these events, the sample is dominated by coincident pairs coming from the target (right), not showing any significative resolution degradation (between parentheses the resolution after subtracting the intrinsic resolution of the scintillators (2)).

the future[1] [9]. In such a case, for a 40% of the total events, the cross-talk between neighbouring cells could result in fluctuations of the signal baseline, introducing stochastic contributions to the resolution. Although double hits were highly improbable in our sample, the total amount of around 2×10^6 events taken become a statistically significant sample of more than 10^3 events after cuts and file selection, as it is shown in Fig. 8. No degradation is observed in the time resolution measured for such events.

6. Conclusions

We have proposed a solution based on shielded RPCs for environments with high multiplicities of particles and for values of the momentum $\gamma\beta$ in a wide range [0.3–5]. The prototype is robust and highly homogeneous; among other advantages, this allows us to simplify the calibration procedure, making it possible to take the calibrating parameters from any single position along the longitudinal direction of the detector. At rates of $200\,\mathrm{Hz/cm^2}$ time resolution is in the range $60\,\mathrm{ps} < \sigma_t < 80\,\mathrm{ps}$ with 3σ-tails below 8% and the position resolution is better than 6 mm. To avoid the dead regions due to insulating boxes, a 2-layer scheme is suggested for real applications, resembling the prototype proposed in Ref. [10].

A detector with the characteristics quoted above has been shown to fulfill the requirements of the HADES collaboration.

Acknowledgements

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[1] $20\%/\mathit{cell} \times 2$ *neighbour cells* $= 40\%$ in the case of central events, for the granularities proposed for HADES.

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