Improving count rate capability of timing RPCs by increasing the detector working temperature

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Abstract - This communication describes test beam results, focusing on detection efficiency and timing precision, of common float glass timing Resistive Plate Chambers (tRPCs) exposed to a 2.7 GeV proton beam and operated at higher operational temperature in order to increase the count rate capability of the chambers, by exploiting the reduction in the resistivity of the glass electrode, one of the limiting factors. Results suggest that the count rate capability can be extended at least up to 1500 Hz/cm² when the detector is operated at 40.6 ºC without noticeable loss of efficiency or timing precision degradation with values of 90 % and 100 ps, respectively, for this specific timing RPC chamber arrangement.

1 - INTRODUCTION

tRPC have traditionally been used with relatively low particle flux (< kHz/cm²) due to the inherent limitation to the counting rate **imposed by** the commonly used **float glass electrode resistivity.** Since tRPCs are one of the main large-area timing detectors, extension of its counting rate capability is of great interest for future High Energy Particle (HEP) experiments, were the luminosity is expected to increase considerably.

Attempts have already been made to increase the count rate capability by **using materials with lower electrical resistivity** compared to the commonly used float glass, such as ceramics [1], [2], special glasses [3] or some technical plastics [4]. As a **result**, the operation of **small area detectors was successfully achieved**, but the **implementation** of the **medium/large area detectors failed** due to the lack of homogeneity of the materials, which present spurious low electrical resistivity paths, resulting in an unstable behavior of the detector. **Another possibility**, still very little explored, is to **decrease the resistivity** of standard float glass **by increasing the operational temperature of the detectors**, providing a ten-fold decrease in resistivity every 25 ºC.

$$\phi_{max} \leq \frac{\Delta V}{\rho d \bar{q}}$$

Φ_{max} = maximum particulate flux
ΔV = allowable voltage drop at the resistive electrode, which does not compromise performance.
ρ = electrode resistivity
d = electrode thickness
q = average charge per avalanche

Φ_{max} can be increased by decreasing ρ

ρ can be decreased by increasing temperature factor 10 every 25 ºC

2 – EXPERIMENTAL SETUP AND METHODS

- Four **Individually shielded strip-like tRPC** chambers [4], 750 mm long, widths of 22 and 44 mm and **glasses of thickness 1 mm (~4.10¹² Ωcm) and 2 mm (~1.10¹³ Ωcm)** with 0.270 mm gap width.
- **Gas box with controlled temperature.**
- Scintillator telescope as time reference.
- Both tRPC and the PMTs signals are fed to a fast FEE [5] read out by the TRB board [6] equipped with 128 multi-hit TDC (TDC-in-FPGA technology) channels with a time precision better than 20 ps.
- The chambers were operated in open gas loop with a mixture of 97% $C_2H_2F_4$ and 3% SF_6 and exposed to 2.7 GeV protons.

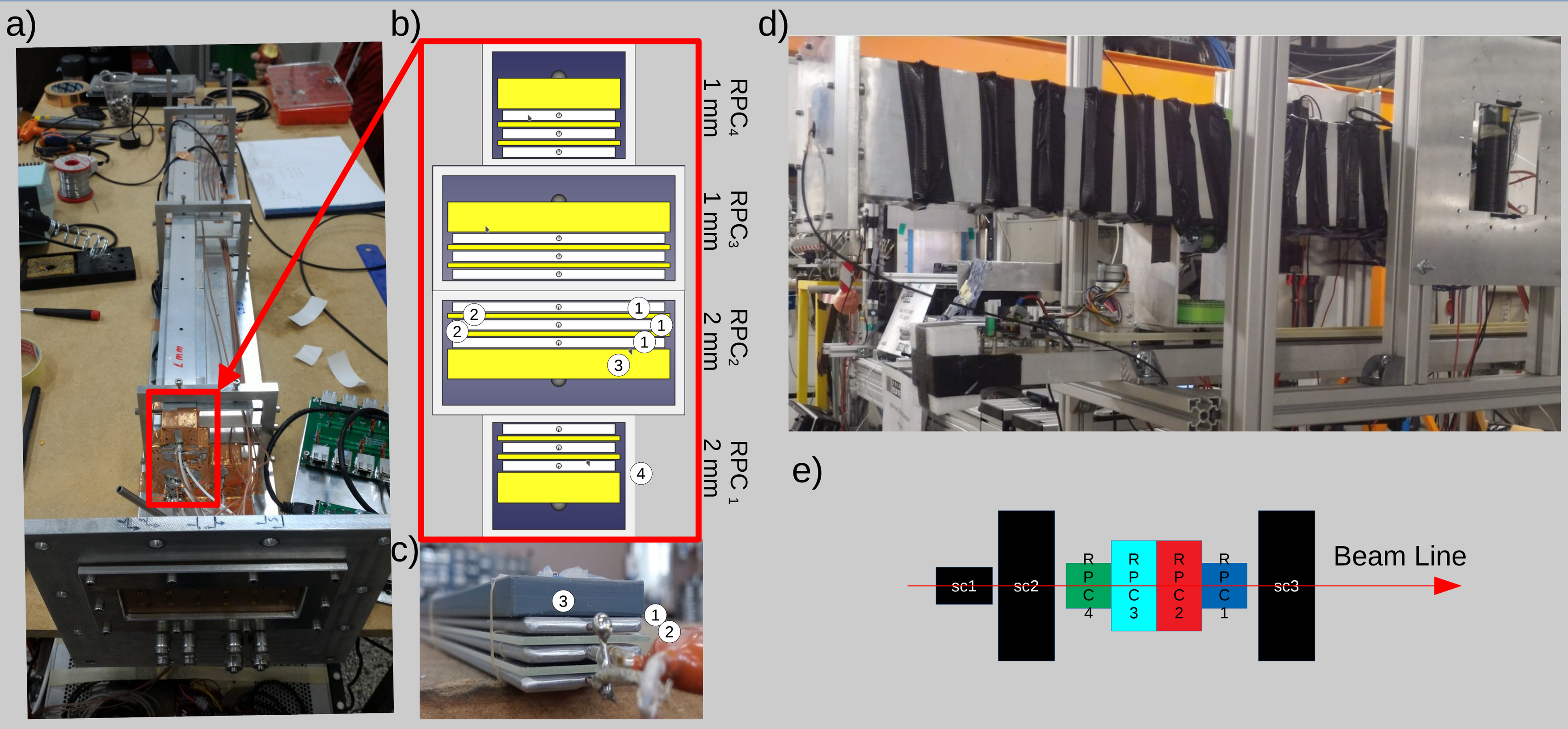
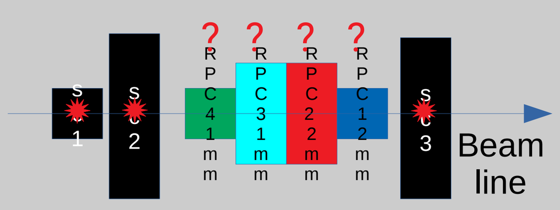


Figure 1. a). Internal arrangement of the tRPC chambers. b) Cross section of the four chambers arrangement. c) RPC chamber: 1 aluminum and 2 glass electrodes, 3 plastic support bar, 4 aluminum tube. d) Panoramic view of the setup in the beam line, showing the tRPC chambers gas box, surrounded by the heating wire, and the last scintillator of the telescope. e) Cross section of the scintillator and tRPC counters in the beam line.

Efficiency determination

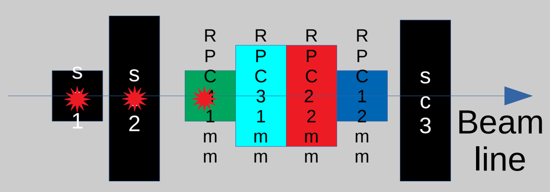
Request hits in the scintillators and check the RPC



Timing precision determination

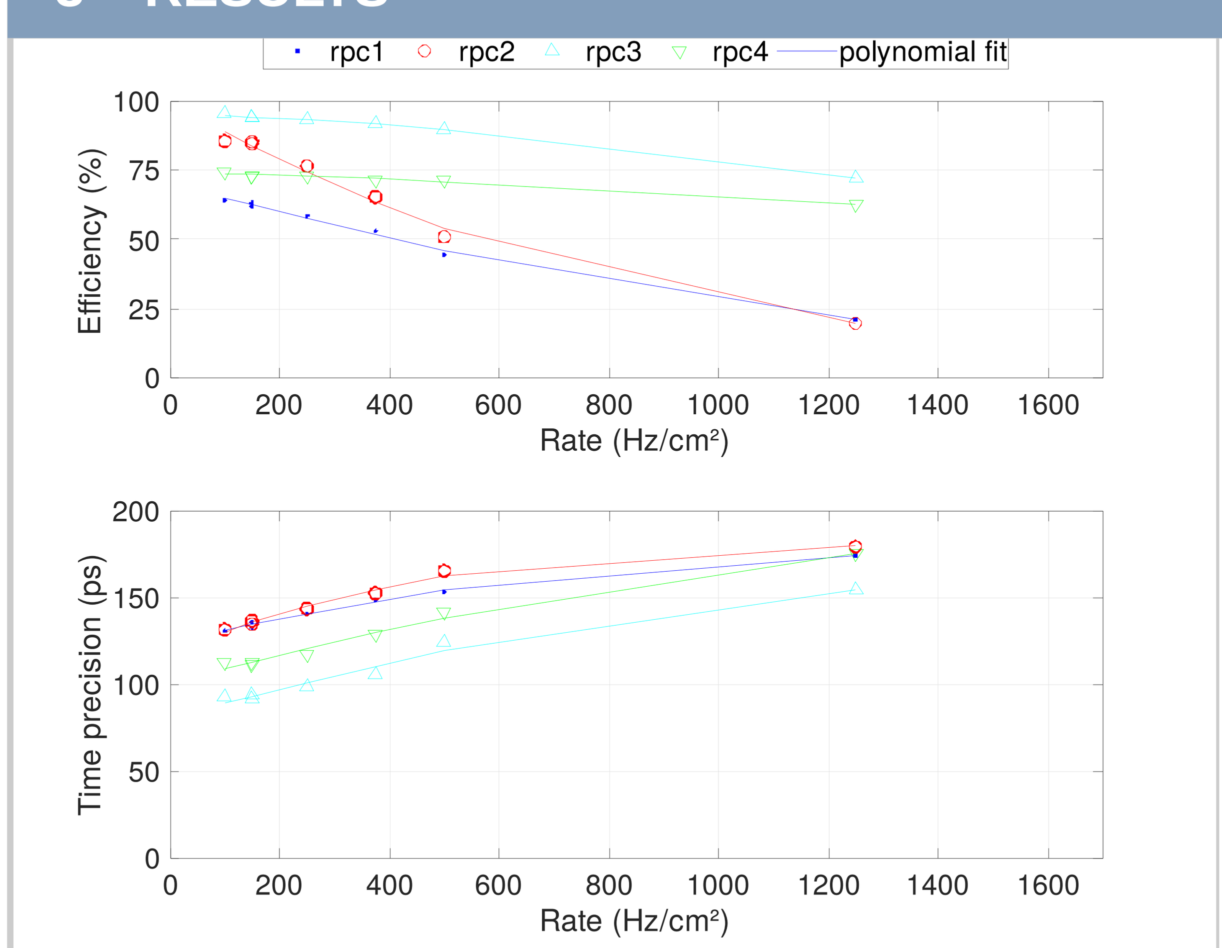
Compare RPC with scintillators 30 ps σ

$$\begin{pmatrix} 1 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 1 \end{pmatrix} \begin{pmatrix} \sigma(RPC)^2 \\ \sigma(SC1)^2 \\ \sigma(SC2)^2 \end{pmatrix} = \begin{pmatrix} \sigma(\Delta(RPCSC1))^2 \\ \sigma(\Delta(RPCSC2))^2 \\ \sigma(\Delta(SC1SC2))^2 \end{pmatrix}$$

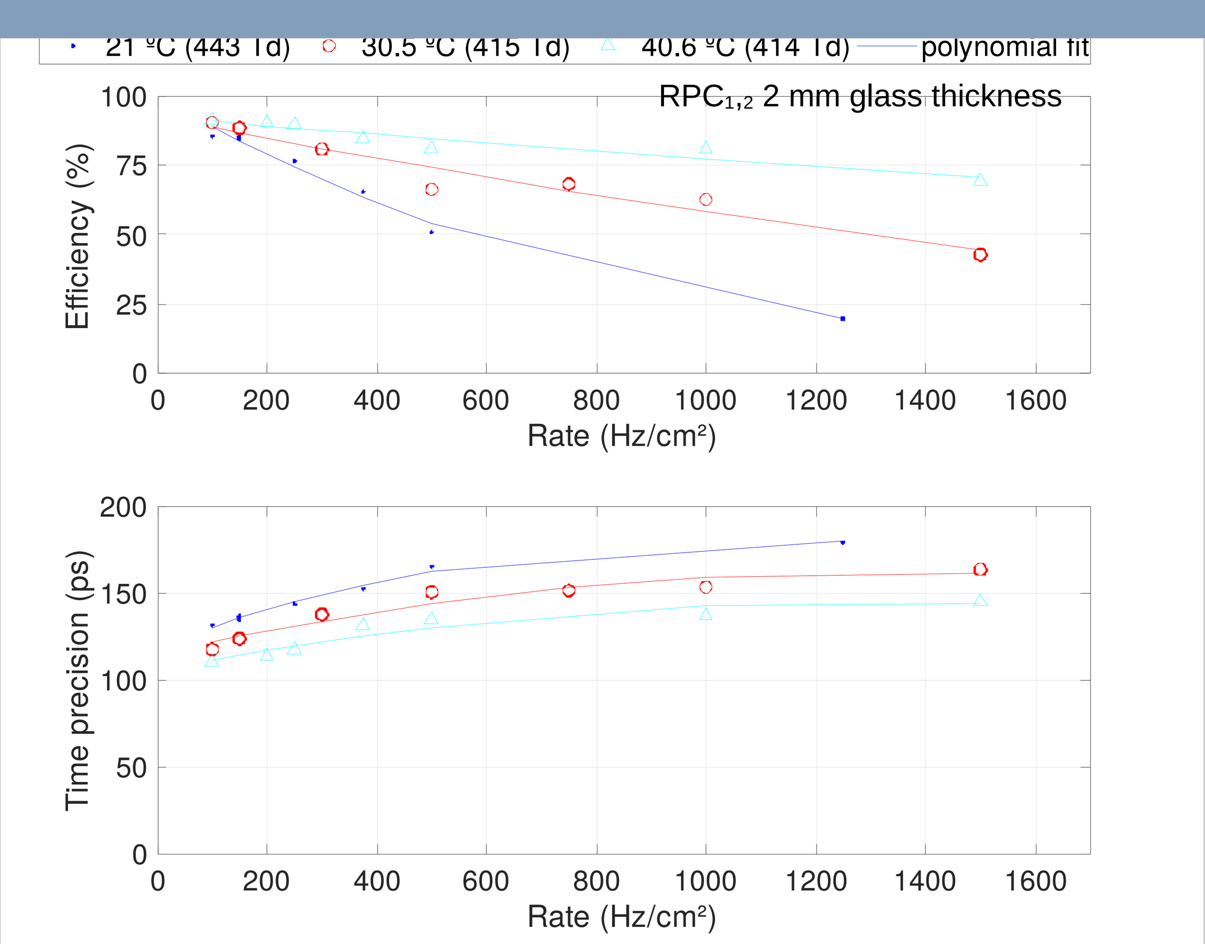


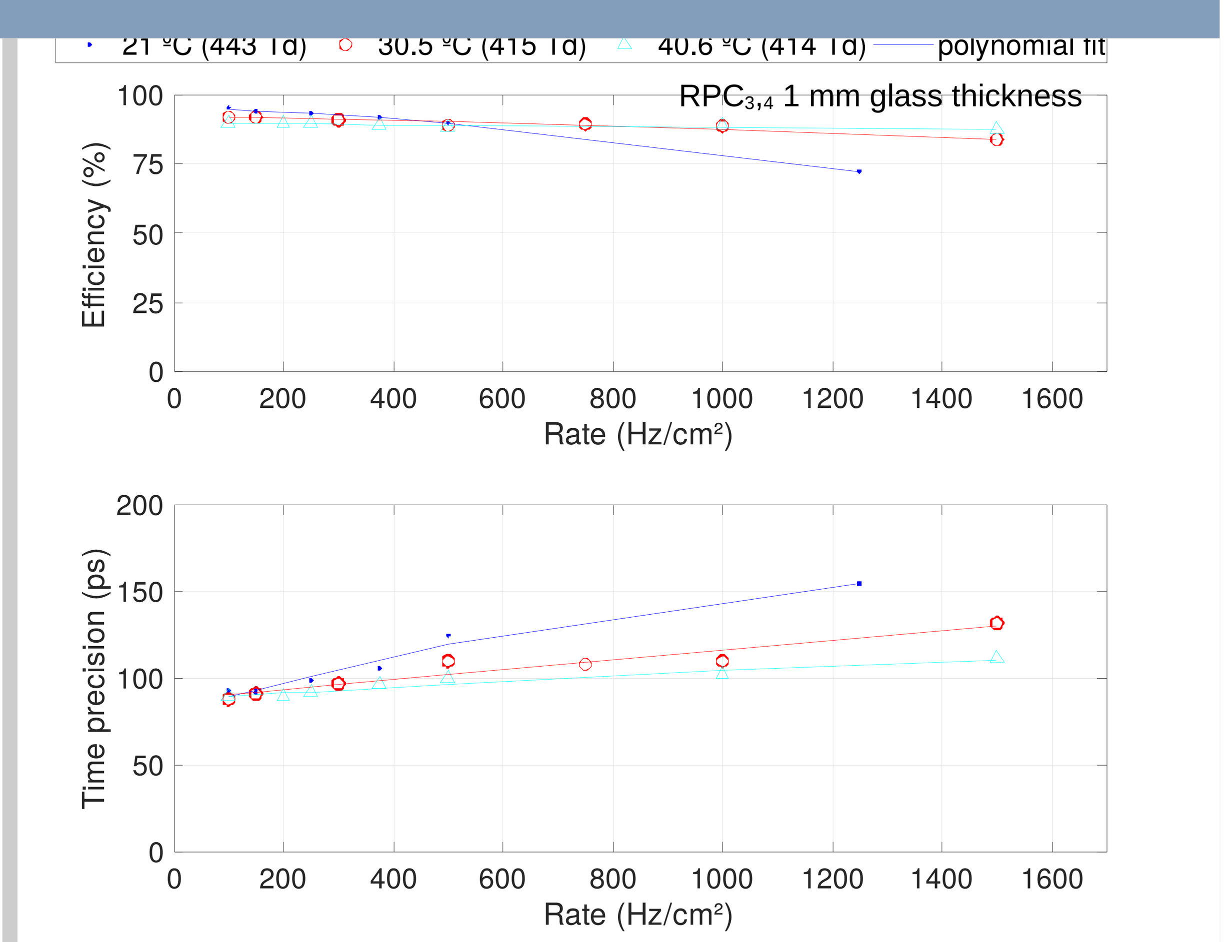
Time from RPC and scintillators are corrected by charge. Walk correction.

3 – RESULTS



Efficiency and **timing precision** as a function of the incident particle flux density at a working temperature of 21 ºC and reduced electric field of 443 Td. It is observed that the tRPCs with **2 mm glass (RPC_2 and RPC_1) lose efficiency much faster and have a worse timing precision.** This difference is due to two factors. On the one hand the **thickness** of the glass and on the other hand the **resistivity** itself which is 2 - 3 times lower in the 1 mm glass, giving in combination a **factor of 4 - 6 in resistance.**





Efficiency and **timing precision** for RPC_2 (2 mm thick glass) and RPC_3 (1 mm thick glass) chambers as a function of the incident particle flux for three **different working temperatures 21 ºC, 30.5 ºC and 40.6 ºC. The efficiency recovery, with increasing operating temperature** (due to decreasing resistivity), **is evident,** becoming basically independent of the incident particle flux (at least up to 1500 Hz/cm²) for a temperature of 40.6 ºC for RPC_3. The improvement for RPC_2 is smaller due to the higher resistance of the glass. Time precision for the same conditions mentioned for efficiency. Again, **the recovery in timing precision is observed as the operating temperature increases**, remaining at a level of approximately 100 ps up to 1500 Hz/cm² for RPC_3.

4 – CONCLUSIONS

We have shown that **increasing the working temperature of a tRPC can substantially improve its counting rate capability.** In particular, individually shielded strip-like tRPC chambers with an active area of 750 x 44 mm equipped with 4 gaps of 0.270 mm, show the same efficiency, 90 %, and approximately the same timing precision, 100 ps, over a range of incident particle fluxes up to 1500 Hz/cm² when their working temperature is raised to 40.6 ºC. This contrasts with a 20 % loss of efficiency and a worsening of temporal precision of more than 60 ps when operated at 21 ºC.

FCT Fundação para a Ciência e a Tecnologia
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