PROPOSAL

To the

STAR Collaboration

For the construction of a

Single Tray of Multi-gap Resistive Plate Chamber Time-of-Flight for STAR

By the STAR TOF group*

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Proposal for a Single Tray of Multi-gap Resistive Plate Chamber Time-of-Flight for STAR

Introduction

The design philosophy of the STAR detector, unique among experiments at RHIC, is to create a large-acceptance detector capable of measuring and identifying a substantial portion of the particles produced in a heavy ion collision. The powerful statistical technique of multi-particle correlations can then be used to explore the dynamics of high-multiplicity events: event-by-event physics. In particular, a large-acceptance TOF subsystem, as envisioned from inception, will yield particle identification to probe the flavor composition of events. Two key observables are the K/π ratio – a measure of strangeness content – and the $\bar{p}/\pi$ ratio – gauging baryon density and chemical potential.

The design goal of the STAR detector has yet to be fully realized. Proposals to install a full barrel TOF[1] for the central region $-1 < \eta < 1$, now occupied by the CTB, have not been funded. The cost of this 6,000-channel scintillator-based TOF system using mesh-dynode phototubes at $1-1.5k/channel was judged to be too expensive. The expected occupancy in such a system was 30-40 %.

In the current STAR detector, large-acceptance particle identification is provided by the TPC and SVT. This allows measurement of the K/π ratio out to 0.6 GeV/c and proton identification out to 1.1 GeV/c. The addition of a TOF system with an overall time resolution of <100 ps extends the momentum range of these measurements to ~1.8 GeV and ~3 GeV, respectively.

A patch of scintillator-based TOF occupying one CTB tray or 1/120th the acceptance of the full system, TOFp[2] is now installed in STAR and will greatly extend the reach of particle identification over the limited coverage of a single tray. This, of course, will not allow extraction of the crucial event-by-event observables.

The STAR Long Range Plan[3] reiterates the original design goal and establishes completion of the EMC and completion of a large-acceptance TOF as the highest priorities.

A new technology was developed at CERN culminating in a proposal for TOF using multi-gap resistive-plate chambers (MRPC) for the ALICE experiment[4]. This proposal was submitted in late 1999 and accepted. In November 1999, members of the STAR collaboration who participated in the development efforts at CERN submitted a Letter of Intent to STAR management and DOE for an RPC TOF system in STAR[5]. Since that time we have pursued an extensive testing program on TOF modules constructed to be prototypes for detectors suitable for installation in STAR[6]. Results are included in this report.

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[1] mac8.rice.edu/~WJLlope/~STAR/~TOF/TOFprop.html; and /TOFpatch.htm; STAR Notes 36 (1992), 49 (1992), 50 (1992), 52 (1992), 207 (1995), 208 (1995)
[2] mac8.rice.edu/~TOF/Documents/TOFp.pdf
[3] rhic.physics.wayne.edu/~bellwied/long_range_3.ps
[4] alice.web.cern.ch/Alice/TDR/alice_tof.ps
[5] Letter of Intent, A Time-of flight System for STAR, November 1, 1999
[6] M.C.S. Williams, E. Platner, J. Roberts, et al., NIM **A434** (1999) 362; E. Cerron Zeballos, D. Hatzifotiadou, J. Lamas Valverde, E. Platner, J. Roberts, M.C. S. Williams, A Zichichi; Micro-streamers and the Microgap RPC,

The RPC TOF modules proposed for STAR consist of six 0.22 mm gas gaps between parallel glass plates. A schematic section through the module is shown in **Fig. 1**. The five inner glass plates have a thickness of 0.55 mm and the two outer plates are 2.0 mm. Graphite resistive ($\sim 10^5 \Omega$/square) electrodes applied to the outer surface of the outer glass provide a ~16 kV electric potential. A charged particle traversing the gas gaps creates an electron shower or avalanche that is seen as an image, through the resistive electrodes, on copper pick-up pads. The pads are separated from the electrodes by 0.35 mm mylar. The sudden appearance of the image on the pads generates a signal that is read out over twisted-pair cable. Since the total charge of this signal is small, ~100 fC, it must be amplified before being discriminated and digitized. Both the time and amplitude are digitized to allow slewing corrections.

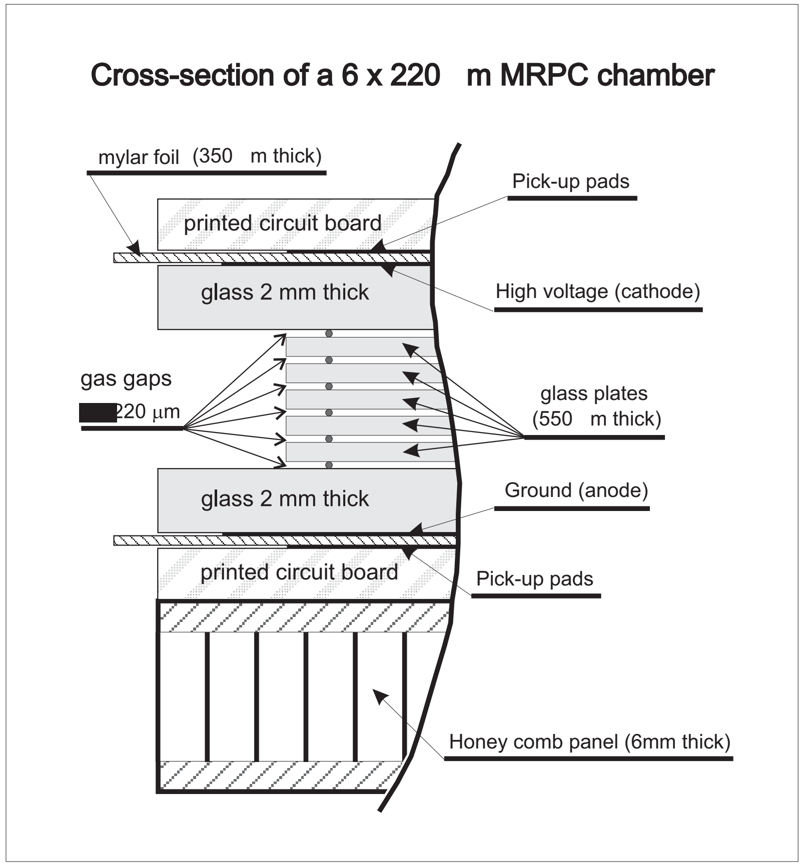

Fig. 1 *Cross section schematic view of a 6-gap RPC TOF module. The modules tested by STAR in the fall 2000 and proposed for installation into STAR are the same in this view.*

A detailed history of the development of RPC TOF may be found in Ref.[4] Following the successful development of RPC TOF with time resolution suitable for STAR[4,5] we began an intensive development and test program at CERN for RPC TOF modules specific to STAR. This development effort is in parallel and in conjunction with similar efforts for ALICE. The test beam results in spring 2000 were somewhat disappointing. In an effort to improve the time resolution and to reduce the amount of image seen on neighboring pads, thinner glass was used. This produced less-than-optimal time resolutions, 80-110 ps, because of (it is thought) non-parallel plates and non-uniform gaps created by stress from the strong electric field.

A significant step forward came in mid-year when members of the STAR group replaced the custom-designed amplifier on the front-end card with a circuit interfacing to the commercially available Maxim 3760 fast-current amplifier. This reduced the time jitter in the discriminator cir-

document in preparation; "The Multigap Resistive Plate Chamber as a Time-of-Flight Detector," A. Akindinov et al., (E. Platner, J. Roberts) Nucl. Instr. Meth. A 456, 16 (2000), B. Bonner, G. Eppley, J. Lamas-Valverde, W. J. Llope, T. Nussbaum, E. Platner, J. Roberts, E. Cerron Zeballos, D. Hatzifotiadou, N-Y. Kim, A. Semak, M.C.S. Williams, "A Multigap Resistive Plate Chamber Prototype for TOF for the STAR Experiment at RHIC, to be published in Procs. Of 9th Vienna Conf. On Instrumentation, Vienna, Feb. 19-23, 2001.

cuit to 20-30 ps from 40-50 ps. It also dramatically reduced the amount of correction for slewing. The uncorrected time resolution was improved from ~300 ps to ~100 ps.

The results from the fall tests are far more encouraging. The models tested all had thicker glass similar to **Fig. 1** and had internal support (fishing line) between the glass layers to restrict the glass from deflecting in the field. The STAR group produced and tested a 12-channel module and two 6-channel modules. The ALICE group built and tested three 96-channel modules. All channels tested in STAR and ALICE modules produced time resolutions of 50-80 ps, exceeding requirements for TOF in STAR. We conclude that the technology is now sufficiently stable and reproducible to propose production of a single tray of RPC TOF for installation in STAR to test a complete tray in the STAR beam environment. This should lead to proposal for a full implementation of RPC TOF.

The full barrel TOF for STAR has been informally assigned a budgetary goal of $3-5 million in Ref.[3] and by the spokesperson[7]. This is their judgment of what such a system is worth to STAR, given competing priorities. This will be the first use in an experiment of this technology for a large, high time resolution system. Since this technology has not been used in an experiment before, we think it is prudent to install a ~200-channel single tray in STAR to demonstrate that it works in place before proceeding to construction of a full $3-5 million system. Hence we present this proposal for a single tray of TOFr.

In fact STAR will not be the first experiment to employ this technology. Members of the HARP collaboration joined us at the test beam at CERN last fall. After a successful fall test program, they are currently manufacturing 12 m^2 of RPC TOF. They are building dual double-gap modules using materials similar to those proposed here for STAR. They plan to install and begin using the detector in April. The granularity of the HARP system is much coarser than STAR, they have only 250 channels. Also, the required time resolution is much less. However, if their operation is successful, it will provide additional confirmation of the reliability of this technology.

Proposal

Module design

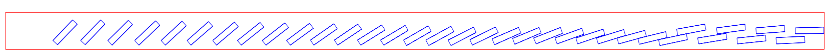

Fig. 2. *The profile view of 34 RPC TOF 6-channel modules in a CTB tray.*

A single tray of RPC TOF will replace a single CTB tray as the full barrel TOF will replace the full CTB. We plan to use the same tray modularity for the full TOF as in the current CTB. We plan to modify an existing spare CTB tray to hold the system. The tray would hold thirty-four 6-channel modules with each module rotated so that it faces the nominal interaction point as sketched in **Fig. 2**. The active area of each module is 6.1 cm x 20.0 cm ($\eta \times \phi$).

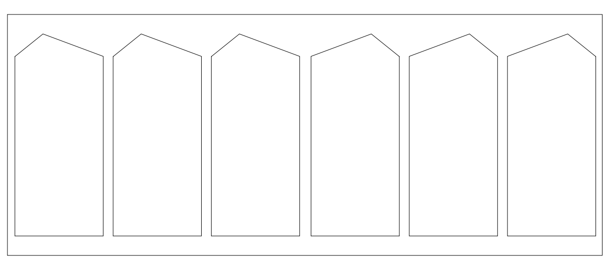

Fig. 3. *The layout for copper pick-up pads on a pc board for a 6-cell module.*

The individual pick-up pad size is 6.4 cm x 3.15 cm, as shown in **Fig. 3**. The

[7] email from John Harris to Billy Bonner, January 2001.

modules are overlapped slightly in η so that a particle coming from a primary vertex at $z = \pm$ 18 cm, 1σ, will always intersect the active area of at least one module, unless it is in a ϕ gap.

If we take the integration area of the CTB as the full azimuth and $|\eta| \leq 0.985$, the active area of the CTB covers 92.4 % of this area. (The value for η was selected somewhat arbitrarily to define a bound. It is the η of a point in the middle of the end plate of the CTB tray.) Most of the dead space in the CTB comes from the gaps in ϕ. The active area of the proposed TOF would cover 85.7% of this integration area. This reduction in acceptance is due to a 1 cm increase in the ϕ gap and the fact that gas and HV fittings preclude installing a module at the large η end of the tray.

The occupancy of such a system is 12-16 % for central collisions. This depends on the actual primary and secondary particle density at $\sqrt{s_{NN}} = 200\,GeV$, the albedo from the EMC, and the pad-to-pad cross talk in the final system.

Test beam results

A very similar 6-channel module was tested in the fall test beam. It had an active area of 6.5 cm x 19.5 cm and a pad size of 6.5 cm x 3.0 cm. The start-subtracted time resolution for this design was 62 ps, averaged for tracks uniformly distributed over the face of the pad. The proposed design is modified very slightly from this design to increase the acceptance and to attempt to get somewhat better time resolution at the edge of the pad. A module identical to the final design will be tested in-beam at CERN prior to construction of modules for the prototype.

Fig. 4a shows a typical pulse height distribution with the module operating at 15 kV. **Fig. 4b** shows the raw stop time distribution for a ~1 cm^2 beam spot centered at a point 5.0 cm from the pick-up edge of the pad. **Fig. 5a** shows the time versus amplitude scatter plot. The distribution is fitted with a 6th degree polynomial at low ADC values and a straight line at high values to provide a correction for slewing. **Fig. 5b** show the corrected time distribution. The Gaussian fits shown in Fig 4b and 5b give a sigma of 104 ps uncorrected and 62 ps corrected. After subtracting the jitter in the start time we obtain 99 ps uncorrected and 55

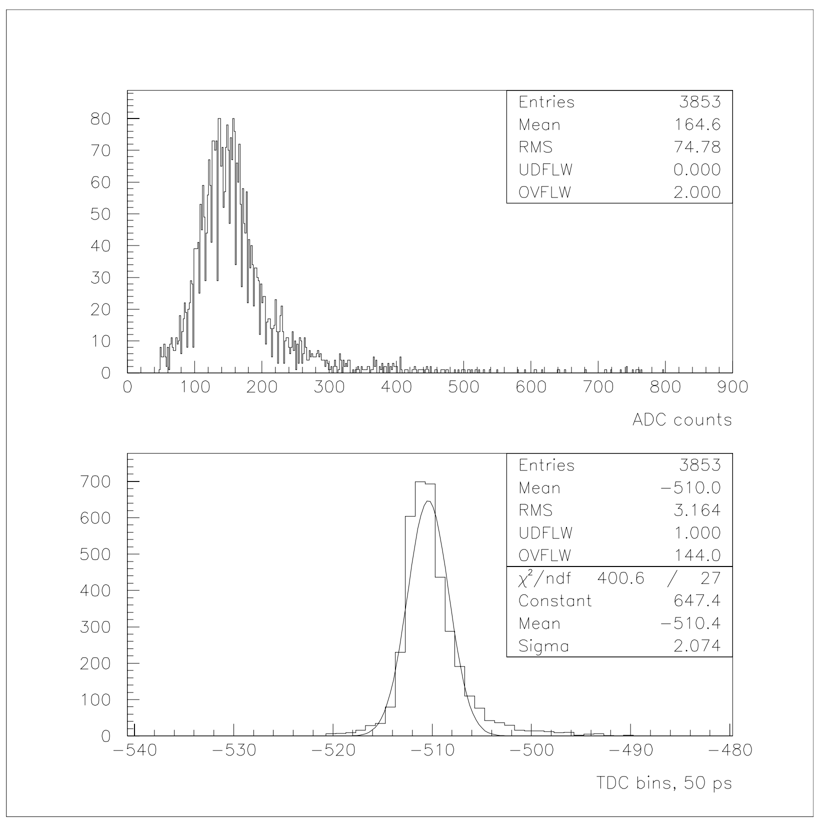

***Fig. 4a.** The ADC distribution for a 6-channel module at 15 kV.*
***Fig. 4b.** The raw stop time distribution in 50 ps bins for the same data.*

ps corrected. **Fig. 6a** shows the start-subtracted time resolution and the efficiency at various voltages with the beam in the same position as Figs. 4 and 5. The efficiency and time resolution are stable over 1 kV. **Fig. 6b** shows the time resolution for the beam centered at various positions on the pad for a voltage of 15 kV. The position is given in cm from the pick-up edge of the pad. The time resolution across the pad in the other (ϕ) direction is nearly flat except at the extreme edges. The time resolution for a track near an edge adjacent to a neighboring pad actually improves when the amplitude-weighted mean of the two times is used.

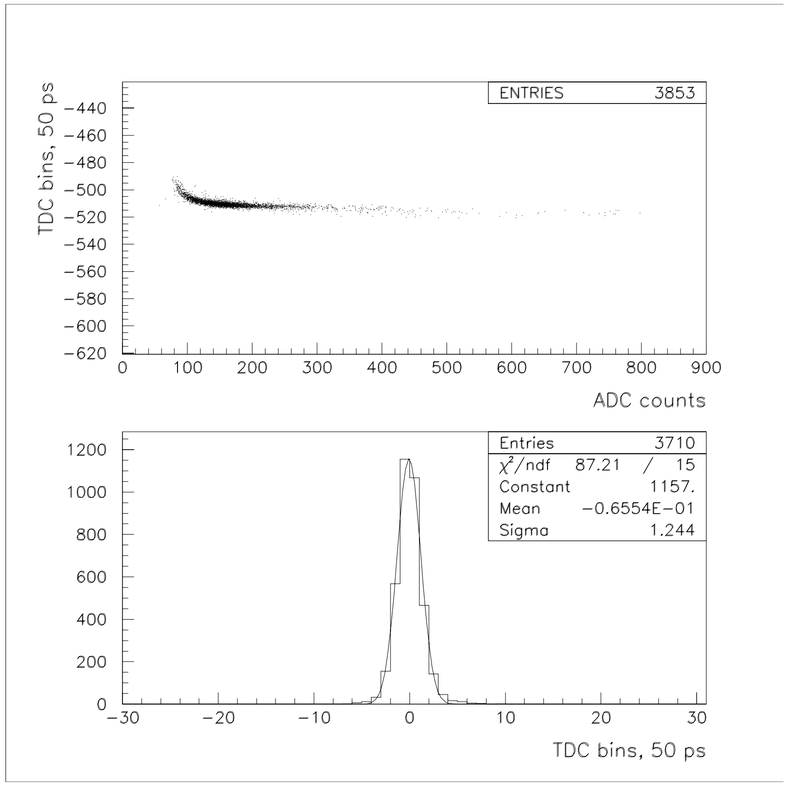

Fig 5a. A scatter plot of stop time versus ADC value for the same data as Fig. 4. ***Fig. 5b.*** *The slewing- corrected time distribution in 50 ps bins. The time resolution shown is 62 ps, 55 ps after subtracting the start resolution.*

Mechanical design, tray

The interior height of a CTB tray is 8.5 cm. To rotate the modules so that they face the interaction point and to leave room for gas and HV distribution requires 7.8 cm. This dimension will define the gas box for the RPC detectors. The FEE would sit on "top" of the gas box and be shielded from electronic noise. If power consumption is sufficiently low, it can be air-cooled. If not, it can be cooled with chilled water like TOFp. The prototype TOF tray needs to be installed where no EMC module exists. Since the signals from the prototype will be distributed by coaxial cable, the integration space of the EMC module must be encroached upon to get the TOF cables out.

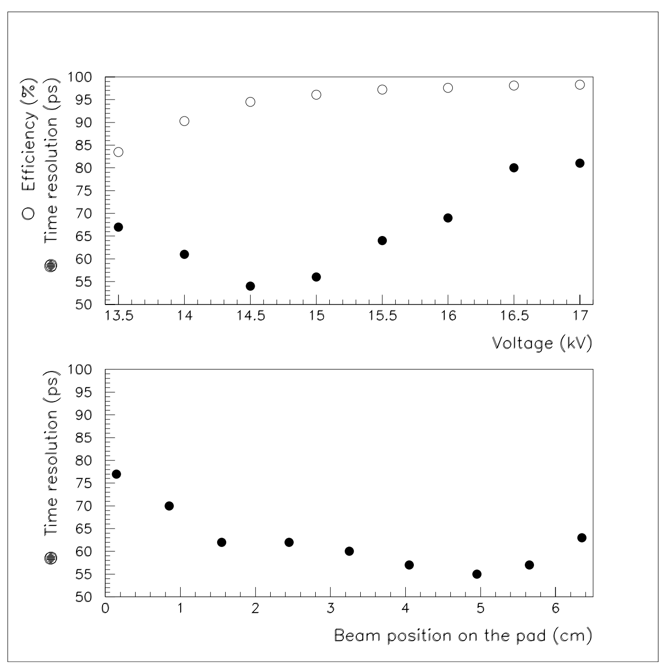

Fig. 6a. *The efficiency and time resolution for the 6-channel module at various voltages.* **Fig. 6b.** *The start-subtracted time resolution for various beam positions on a pad for the same module.*

Front-end electronics (FEE)

The FEE needs to amplify and discriminate the signal and send a pulse to the TDC and provide an analog output to the ADC. Since the successful fall test beam results, we have actively been developing FEE for RPC TOF. Two designs are currently being prototyped. Testing at the cosmic ray test stand at Rice is expected to begin soon. One design uses discreet components and the other, the Maxim

3760 amplifier and a commercial comparator. One design will be selected for the final prototype design by June 1. We are also monitoring the latest development efforts for RPC-TOF FEE at ALICE and HARP.

The prototype TOF will not have the onboard fast TDC and ADC and signal distribution system required by a full barrel TOF. We will instead connect from the onboard FEE by coaxial signal cables to borrowed ADCs and TDCs in a crate on the south platform in a manner similar to the existing TOFp.

Interface to trigger and daq

RPC TOF will share the interface to trigger and DAQ with TOFp. For the full barrel TOF, we would plan to issue a 7-bit sum for each half unit of rapidity representing the logical sum of all channels above threshold. This output would replace the 8-bit ADC sum from the CTB slats as input to the first layer of DSMs in the Level 0 trigger. This output should provide better discrimination for pp and peripheral triggers and equal discrimination for central triggers. The efficiency of single-track triggers for peripheral and pp collisions may actually be improved in spite of a 7 % lower geometric acceptance. We do not plan to include this trigger functionality in the prototype system. This will have negligible impact on the current trigger.

Low voltage

Low voltage, ± 5 V, will be supplied by a power supply on the south platform.

High voltage

We plan to supply ± 8 kV to the tray from a supply on the platform. The total current load based on test beam measurements should be ~1 micro-amp.

Gas system

The chamber operates un-pressurized on a mixture of 90 % $C_2H_2F_4$, 5 % i-C_4H_{10}, and 5 % SF_6. We plan to mix the gas and to vent the return to the atmosphere. The expected flow rate is 5 l/hour. We can experiment with lower flow rates.