Summary of RPC TOF Test Results, Spring 2000

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Rice submitted a Letter of Intent in November 1999 expressing interest in developing a Time-of-flight (TOF) system for STAR. The system would exploit new technology developed at CERN using multi-gap resistive plate chambers (MGRPCs). Rice has been participating in this development for more than three years. The development of this technology has not reached a point where we can consider building a larger prototype as rapidly as we had originally anticipated. However, the most recent test results are still very encouraging. Crispin William's group from INFN-Bologna is leading the development of this technology for ALICE and we are actively participating with them. There is scheduled test beam time throughout the summer and fall. This is still a development project but we anticipate building a larger scale prototype detector for STAR in the near future.

Members of the Rice group are B. E. Bonner, G. Eppley, F. Geurts, J. Lamas-Valverde, W. J. Llope, G. S. Mutchler, T. Nussbaum, E. D. Platner, J. B. Roberts, P. Yepes. The STAR TOF group (see http://bonner-mac8.rice.edu/~TOF/default.html) is completing construction of a patch of scintillator TOF and Rice expects a number of the institutional members of this group will be interested in a larger RPC TOF project. In particular, the Chinese groups have expressed interest in the RPC TOF project and Huan Huang from UCLA has joined the TOF group to act as liaison with the Chinese groups.

The following contains VERY Preliminary results from recent tests and should not be placed in general distribution.

The STAR TOF group joined the ALICE TOF group for a test beam run at the T10 area at CERN from April 25 to May 17 and May 24 to June 4. The ALICE group built several 2 x 48 arrays of 2.8 x 2.8 cm cells and one 2 x 8 array for the tests. The STAR group built 4, 2 x 8 arrays of 3 x 3 cm cells. The ALICE group built a number of single cells to test various materials and the STAR group built a 3 x 3 cm single cell and 2, 7 x 7 cm single cells. A substantial portion of the actual operation of the test beam was provided by the STAR group.

The STAR group at the test beam consisted of Jose (Pepe) Lamas-Valverde, Geary Eppley, and Jabus Roberts, all from Rice University. Pepe is resident full time at CERN to facilitate this development project.

The TOF system at STAR would occupy the space now occupied by the central trigger barrel (CTB). One obvious design solution would be to install the TOF in the existing 120 aluminum CTB trays. The internal dimensions of a tray are 241.3 x 21.3 x 8.4 cm, length x width x depth. 2 x 6 arrays with 3 x 3 cm cells similar to the 2 x 8 arrays tested could be run across the width of the tray at two different alternating depths to allow readout of the signal from the side of the pads. This will allow positioning of the preamplifier and discriminator extremely close to the pad, desirable for good time resolution. With a 3 x 3 cm cell size, it would take 36, 2 x 6 arrays to fill a tray for a total channel count of 462 per tray.

There are two questions that must be addressed to be able to use larger pads and reduce the channel count. What is the optimum pad size determined from the physics requirements and can larger pads also produce good time resolution? If larger pads can be employed, 2 x 3 arrays of 6.3 x 6.3 cm cells can be run across the width of a tray. It would take 18 such arrays to fill a tray for a total channel count of 108 per tray. The final design is expected to fall within these two limits.

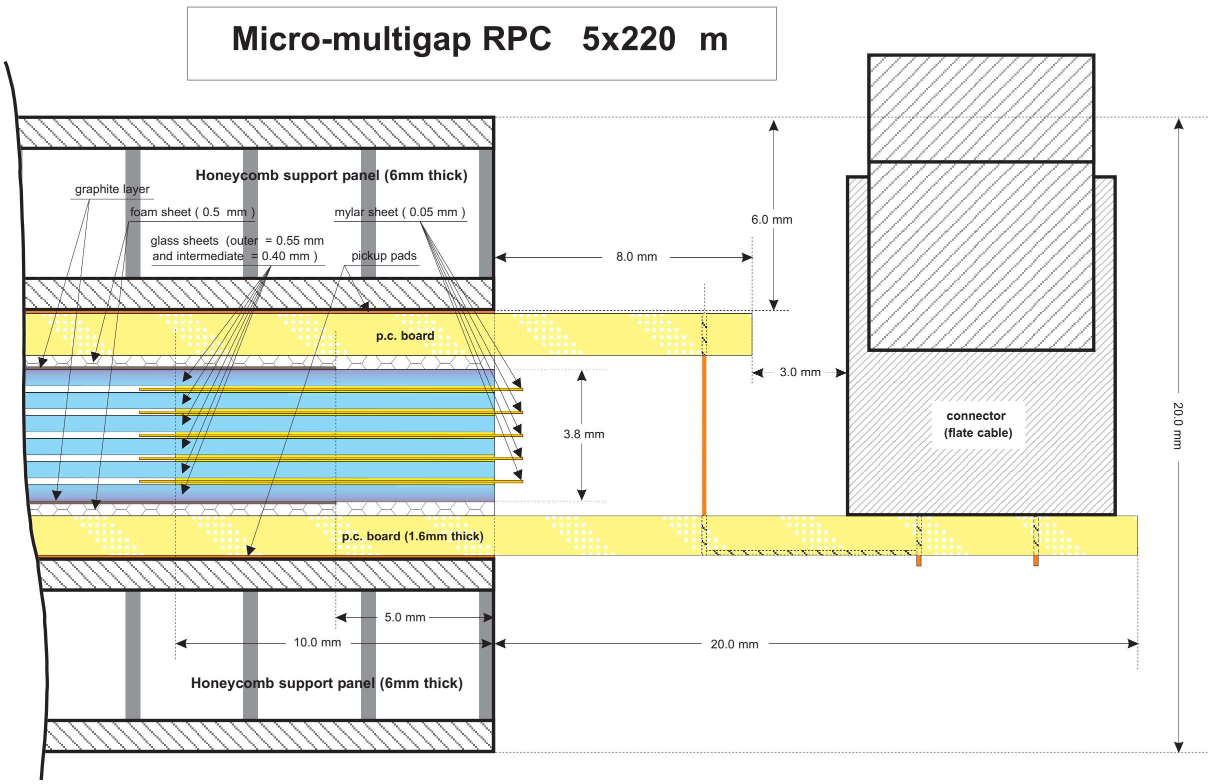

Fig. 1. A partial sectional view of a multi-gap RPC TOF module.

Top view of a prototype of MRPC for ToF

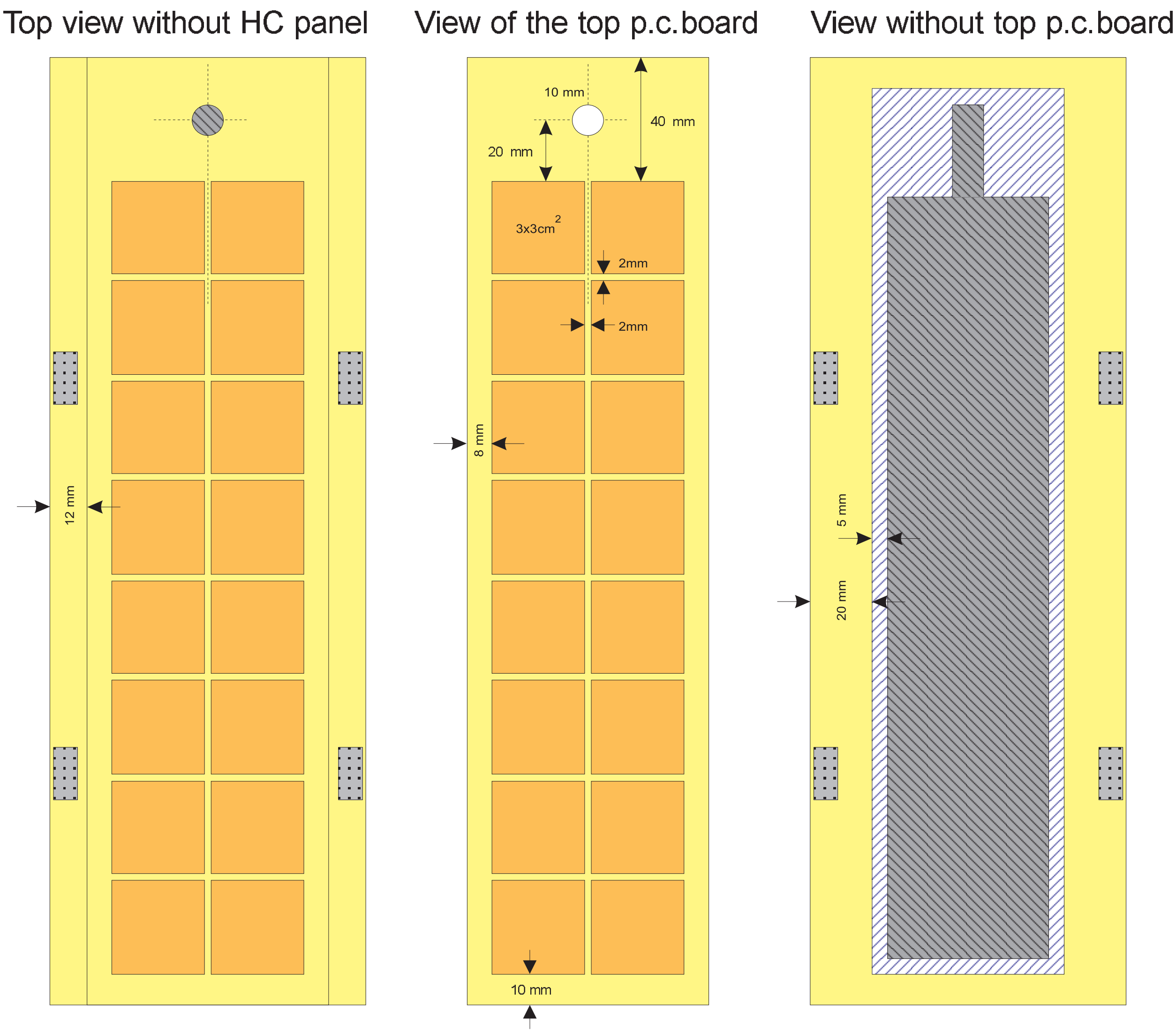

Fig. 2. The first two images show the p.c. boards with the copper pads. The third image shows the glass cell (light shading) sitting on the bottom p.c. board with the graphite H.V. electrode (darkest shading) shown on top of the top glass layer.

All cells used in the tests were five micro-gap cells, similar in design to the ALICE TOF TDR cell. In this design, the high voltage (HV) electrodes are thin, resistive graphite layers applied to the outer surface of the glass cell. (To get five gaps, six layers of glass are used and the outer glass is usually thicker to provide rigidity.) To get better adhesion of the graphite to the glass, a sand blasted glass was used for the outer surface. Also thinner glass was used for the outer and inner glass layers, 0.55mm and 0.4mm. Cells made with the thinner glass and sandblasted outer surfaces gave timing resolutions 2-3 times worse than in the TDR (77 ps.) Replacing the sandblasted outer glass with 0.62mm acid washed glass solved most of this problem. It was still suspected that there were possible deflections of the internal glass layers. Internal supports were added between the cells to reduce the span between supports. Cells of this type produce the best results in the May tests, results similar to those reported in the TDR.

Schematics of the 2 x 8 cell modules built by the STAR group are shown in Figs. 1 and 2. The module for which results are given, Rice 4, is identical to the schematic except that 0.62mm acid washed glass was used for the outer layers. Support between the glass layers was also provided at the inside corners of the pads. A picture of the test module seated in the gas box is shown in Fig. 3, top. Fig. 3, middle, shows the module installed in the beam line with front end discriminator cards attached. The front end cards were built for Rice at CERN following the ALICE design. Fig. 3, bottom, shows more of the beam line. To the right, ahead of the chamber are crossed scintillating strips attached to PMTs. A fourfold coincidence of crossed scintillator before and after the test module constitutes the trigger for the mostly pion beam.

Tabulated below are the charge corrected timing resolution for Rice 4 in picoseconds.

Cell no.	Card 1			Card 2		
	Fit	Start sub.	Jitter sub.	Fit	Start sub.	Jitter sub.
1	91	87	56	102	99	91
2	82	78	69	96	93	88
3	98	95	86			
4	88	84	78	85	81	77
5	110	107	94	87	83	63
6	121	118	107	85	81	70
7	130	128	117	115	112	107
8	120	117	109	149	147	141

Eight cells in one column are readout by one, eight channel front end card. Channel 3 of card 2 was not working. For each cell, the second timing entry is the sigma of the fitted time less the average resolution of the start counters, 25 ps. The third entry is also less the jitter of the preamplifier for that channel. The jitter in the preamplifiers used ranged from 26 to 67 ps.

A second 2 x 8 cell array with 2.8 x 2.8 cm cells was also tested extensively and gave much more promising results. This chamber was constructed of 0.62 mm glass for all six layers and 250 micron plastic clad glass optical fibers were used between the cells to provide internal support.

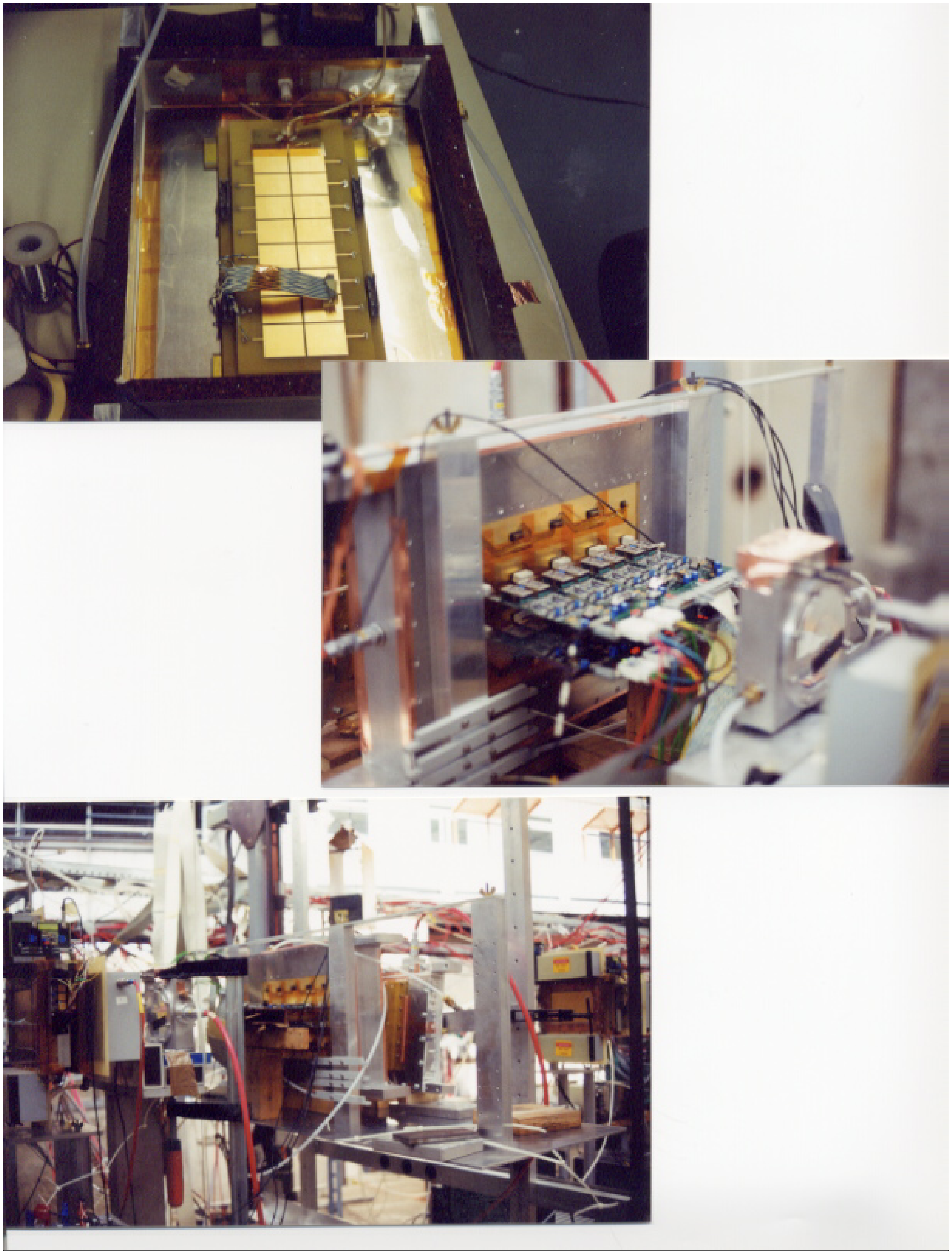

Fig. 3. The top picture is the test RPC TOF module RICE 4 in a gas Box. The middle picture shows the test module in the beam line with front end cards installed. The lower picture shows more of the beam line. The two of the start detectors, crossed strips of scintillator are visible to the right.

Tabulated below is the charge corrected timing resolution for the optical fiber spacer module, in picoseconds. The quantities shown are the same as in the previous table. The measured jitter in the preamplifiers ranged from 31 to 71 ps.

Cell no.	Card 1			Card 2		
	Fit	Start sub.	Jitter sub.	Fit	Start sub.	Jitter sub.
1	83	79	42	84	80	37
2	79	75	66	89	85	73
3	74	70	58	80	76	38
4	74	70	62	82	78	70
5	91	87	76	81	77	61
6	95	92	85	89	85	67
7	89	85	77	102	99	90
8	83	79	69	80	76	67

The raw TDC distribution for Rice 4, card 1 cell 2 is shown in Fig. 4, top. The overflow count represents chamber inefficiency. The efficiency for this cell was 97%. Efficiencies ranged from 95-97 % at HV plateau. The HV plateau is reached at 12-14 KV, depending on the chamber design. The efficiencies, and HV plateau were very similar for all cells in a given chamber. Fig 4, bottom, shows the raw ADC distribution for the same cell. The shapes of the distributions were all similar. Fig 5 shows the time versus charge distribution, and the charge corrected time distribution for the same cell. The raw time resolution is 1.63 TDC buckets or 82 ps. After subtraction of the 25 ps start time the resolution is 78 ps.

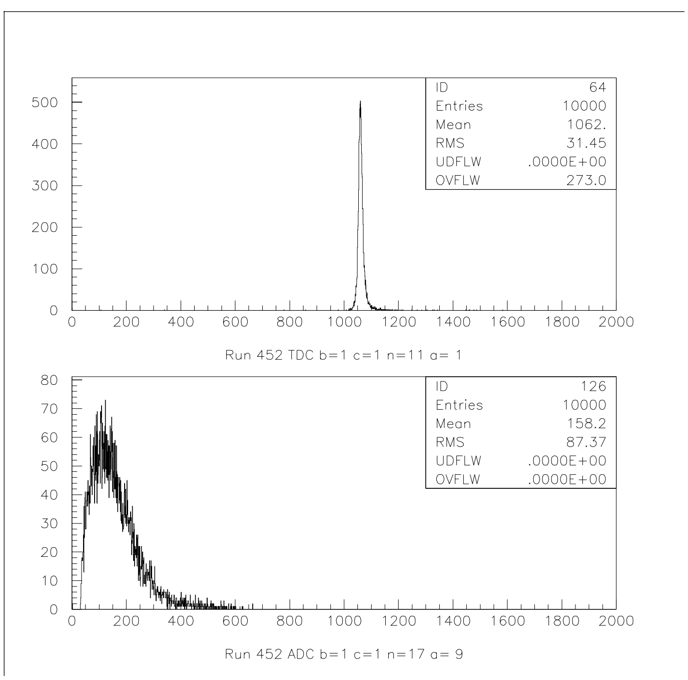

Fig. 4. (top) The raw TDC distribution for Rice 4 card 1 channel 2 is shown. The overflow count represents the chamber inefficiency. (bottom) The raw ADC distribution for the same cell.

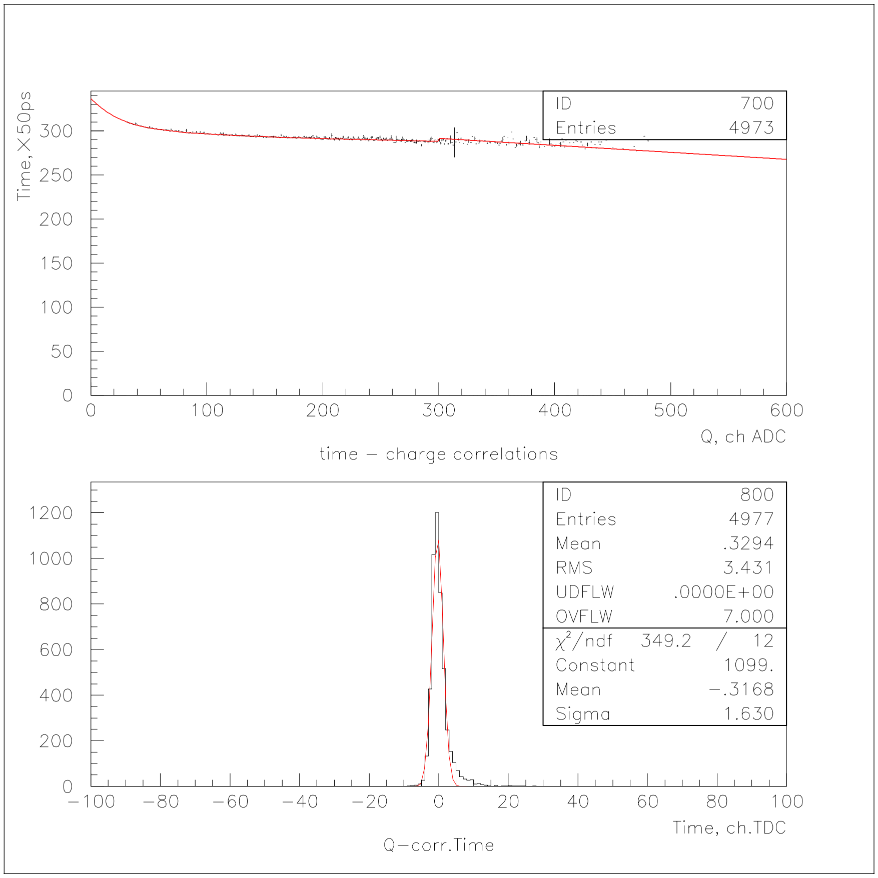

Fig. 5. (top) The time versus charge distribution for Rice 4 card 1 channel 2 is shown. This information is used to correct the raw time distribution. (bottom) The charge corrected time distribution for the same cell. The sigma is 1.63 or 81.5 ps.

The current front end cards use a custom designed Russian preamplifier. It is not currently easy to get more of these. Rice has been testing commercially available preamplifiers and preliminary tests at Rice showed that a Maxim MAX 3760 showed excellent rise time and jitter. We designed an interface card for the preamp to be used with the existing front end cards and sent two to CERN for testing with actual chambers. A test of the first preamp at CERN indicates that it should work with the chamber and gave a jitter of 17 ps, about half that of the current preamps. We subsequently sent a total of 9 preamplifier cards to CERN for testing with data. We are waiting for the results.

Rice has already designed a high precision and very compact Leading Edge Discriminator board for use as the FEE in the STAR TOFp System. These boards were *optimized for STAR* in both size and performance, and they outperform all commercially available discriminators that have much larger NIM or CAMAC profiles. The rise time of the timing signal output by the TOFp FEE is ~0.5ns, which should be compared to 2-3ns rise times from commercial discriminators. The intrinsic “stop” resolution of these boards is 5-10 ps more precise than existing commercial units. The dead time is 70ns, which is appropriate for STAR. Timing cross talk, which incredibly is extremely common in all but a few commercial units, does not exist in the TOFp FEE by design. The boards are fused and meet all BNL/RHIC Safety regulations. They will be used in STAR with the TOFp System for the first time in the RHIC 2001 Run, and are available for consideration as the heart of the MGRPC TOF FEE. The only modification necessary is the inclusion of the precision preamplifier (discussed above). There is also the possibility of including TDC chips on these boards as well, which would simplify the MGRPC TOF cabling. These chips are being developed at CERN, and the latest prototype of this chip should be available for testing in October, 2000.

A new 2 x 48 cell array from the ALICE group and a 2 x 8 array from the STAR group as well as number of single cells are currently in the beam line awaiting tests. Test beam time is scheduled from now through July 17 and throughout the fall. Our future plans are very dependent on the results of the current tests but our thrust will be to continue to explore possibilities with larger pad sizes and to build and test modules that would exactly fit in a CTB tray.

We continue to be optimistic but stress that this is still a development project.