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Letter to STAR Spokesman

Letter of Intent

Time-of-flight in STAR

By

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November 4, 1999

Professor John Harris
Yale University
Wright Lab - P.O. Box 208124
272 Whitney Avenue
New Haven, CT 06520-8124

Dear Professor Harris,

As you know, Rice has a long-standing interest and investment in improving the TOF capability of STAR. We are already pursuing the development of a small patch of TOF using conventional technology. We, along with others, have repeatedly made the case, however, that a large scale implementation allowing event-by-event particle identification would strengthen STAR's scientific program significantly. The Bonner Lab group is strongly convinced that a large area, cost effective TOF detector is necessary for STAR to meet its goals. We have been working steadily over the past 18 months with our collaborators at CERN to prove that Multigap Resistive Plate Chambers (MRPC) can be the solution for STAR.

The purpose of this letter is to inform STAR and other parties who might be interested in the implementation of a TOF system in the STAR detector that the group at Bonner Lab intends to submit a proposal to construct a large area TOF detector using MRPC technology. It is our expectation that within two months we will have completed our ongoing R&D studies to optimize the physical detector design and associated electronics sufficiently to allow a complete proposal to STAR for consideration as an upgrade project.

Attached you will find a short Letter of Intent that provides more detail about our progress and plans.

Sincerely,

B. E. Bonner
Professor of Physics

J. B. Roberts
Professor of Physics

CY Letter and LOI: Distribution

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Letter of Intent

Concerning

A Time-of-flight System for STAR

RICE

Submitted to:

John Harris and STAR Management

With information copies to:

Tom Kirk and BNL Management
Dennis Kovar and DOE Management

Submitted by:

B. E. Bonner, G. Eppley, F. Geurts, W. J. Llope, G. S. Mutchler, T. Nussbaum, E. D. Platner, J. B. Roberts, P. Yepes.

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November 1, 1999

Time of Flight (TOF) – Background and Overview

For many years the Bonner Lab group has led the efforts towards implementing a Time-Of-Flight (TOF) system in STAR. The scintillator slat + PMT system, although conventional, has been demonstrated by us to meet the physics-driven design requirements. However, the cost for a full-scale system (~50 m^2) based on the Hamamatsu R5946 mesh dynode PMT is prohibitive. For this reason, our plan to implement a large-scale TOF in STAR has proceeded along more than one path. The recent discovery that we and our colleagues at CERN made on how to achieve superb timing from Multigap Resistive Plate Chambers (MRPC) has led to the possibility that this new technology can overcome the prohibitive cost problem for TOF in STAR. This LOI serves to document our present status and future plans regarding this breakthrough. First, however, let's review where we are on the PMT + scintillator option.

In order to ameliorate the problem of prohibitive PMT cost, we instigated a project that will lead to the fabrication of low-cost mesh dynode PMTs by Russian industry. We obtained support for this project in the past from several sources, including the non-proliferation funds from the ILAB program, DOE supplemental funds, and the DOE CRDF (Soros) program. With this support, we have developed and tested prototype Russian phototubes that are comparable to the Hamamatsu tubes. This work has been published[1,2] in Nuclear Instruments and Methods. A Cooperative Research and Development Agreement (CRADA) between Rice, BNL, Burle Industries, and two Russian companies, MELZ and ELECTRON, was approved about a year ago. At present, the paperwork is making its way through the appropriate chain at BNL. If this funding can be cleared and dispensed within the next few months, we stand to get a significant number of mesh dynode PMTs effectively for free. This would have a very positive impact on the possibility of implementing a significant patch of scintillator slat + PMT - based TOF. It is important to continue this project even though it must be regarded as a fallback position in case the MRPC option meets unanticipated difficulty.

In November 1998 we proposed that one of the installed CTB trays be replaced with a similar tray filled with ~50 TOF counters (PMT + scintillator design). After preliminary approval in May and preliminary funding in June, we began specific R&D efforts at Rice toward this STAR TOF Patch (TOFp). If the project receives final approval and we can find an additional ~120 k$, we expect to install the TOFp system during the March 2000 mid-run shutdown of RHIC. We should emphasize that this is a realistic schedule and one that we fully intend to meet.

The exciting new possibility for TOF in STAR involves a promising new technology for TOF detectors called the Multigap Resistive Plate Chamber (MRPC). It has long been recognized that RPCs are relatively inexpensive, have good position resolution, and make excellent trigger detectors. Historically RPCs have not provided precision timing information. As the width of the gas - filled gap in an RPC is increased, the signal from hits becomes larger, but the time resolution worsens. If one decreases the RPC gap width in an attempt to improve the timing performance, the signals become smaller and more susceptible to noise. Crispin Williams of CERN and INFN Bologna discovered that by stacking several (~5) thin-gap RPCs on top of each other the overall signal is increased five-fold, while the timing performance remained good, even better than a single small

[1] In-beam tests of proximity mesh dynode tubes for the STAR TOF subsystem, S. Ahmad, B. E. Bonner, W. Gere, G. S. Mutchler, P. Rambo, S. Toshkov, E. Platner, H. J. Crawford and J. M. Engelage, Nuclear Instruments and Methods **A330**, 416 (1993).

[2] Performance tests of Russian mesh dynode photomultiplier tubes, S. Ahmad, B. E. Bonner, W. J. Llope, G. S. Mutchler, E. Platner, H. Themann, M. Wright, P. Yepes *et al.*, Nucl. Instrum Methods A **400**, 149 (1997).

gap since the timing information comes from the earliest of the five gaps. The counters are stable and do not suffer from previous difficulties associated with the notoriously unstable Pestov counters. This configuration of a number of layers of thin-gap RPCs is attractive as a possible way to achieve a full STAR TOF system at a fraction of the cost for PMT – based options.

During the past three years, members of the Bonner Lab have collaborated with Crispin Williams at CERN. This has included several in-beam tests at CERN, with the goal of developing MRPC technology suitable for this application.

Multi-gap Resistive Plate Chambers for TOF

Introduction

As mentioned above, a potentially interesting option for a time of flight system for STAR is the multigap RPC design.[3,4,5] This possibility became apparent to us when members of the Bonner Lab High Energy Group worked in cooperation with Dr. Crispin Williams at CERN to explore the suitability of the MRPC as a multiplicity detector for the CMS endcap muon system, a US piece of the CMS detector. Two varieties of RPC were investigated and as a result a full scale MRPC suitable for use as one of the CMS endcap trigger sectors was assembled and tested at CERN. This chamber is huge, being 2.5 m tall and it has excellent efficiency. Somewhat to our surprise it also showed excellent time resolution[6] (<1 ns rms). This led us to further investigate the timing properties of RPCs. Recently a version was developed with very small gas gaps, the so-called micro-gap RPC[7] that has demonstrated amazingly good time resolution. We will present some of the results here and consider the suitability of this design for the STAR TOF system.

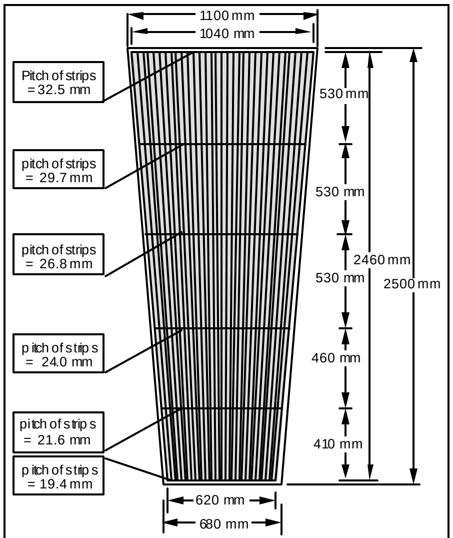

***Fig. 1**. Layout of pickup strips for the large chamber. The inter-strip gap was 1.5 mm.*

Geometric considerations

A short discussion of the very large MRPC will provide some background on how the detector works. The MRPC has electrodes on the external surfaces, with the anode on one side and the cathode on the other. This means that if the anode surface is divided into many strips, it is very easy to access the signal. The connection between the pickup strips and the electronics is very short, an ideal situation when working with the fast signals produced by the RPCs.

The large chamber was wedge shaped to meet the CMS requirements. The layout of the strips is shown in **Fig**. **1** and the cross section in **Fig**. **2**. This was the chamber that proved to have surprisingly good time resolution. The next phase of R&D for developing the RPC for fast timing consisted of building a small multi-gap (5 gaps) chamber. It proved to have (with conventional electronics) a time resolution in the 70-80 ps range. This gratifying result led us to pursue this as a possible option for STAR TOF.

[3] E. Cerron Zeballos *et al.*, Nucl. Inst. Meth. **A374** (1996) 132.
[4] E. Cerron Zeballos *et al.*, Nucl. Inst. Meth. **A381** (1996) 569.
[5] E. Cerron Zeballos *et al.*, Nucl. Inst. Meth. **A381** (1996) 569.
[6] A very large multigap resistive plate chamber, M.C.S. Williams, E. Platner, J. Roberts, *et al.*, NIM **A434** (1999) 362.
[7] Micro-streamers and the microgap RPC, E. Cerron Zeballos, D. Hatzifotiadou, J. Lamas Valverde, E. Platner, J. Roberts, M.C. S. Williams, A Zichichi, document in preparation.

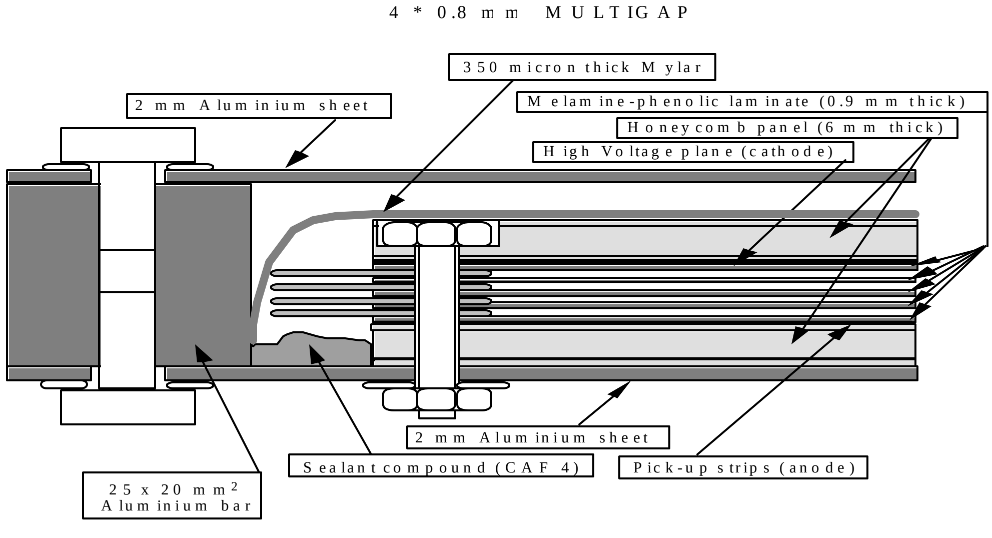

Fig. 2. *Cross-section of micro-gap RPC showing detail at edge.*

We are continuing this effort in cooperation with our CERN colleagues to optimize timing with different detector geometries and specialized electronics. In particular, we have constructed at Rice both five-gap and ten-gap chambers using a specialized slightly conductive glass that, because of its flatness and smoothness, should produce improved time resolution. In addition we are developing much faster electronics (~0.2 ns rise time) with the possibility of multi-threshold discrimination[8]. This type of discrimination has been shown to produce <40 ps time resolution with Pestov counters being considered at the time for TOF in ALICE. In **Fig. 3** we show pulses from two five-gap chambers. Note that the rise times are about ½ ns and the total pulse width is no more than 4 ns. We expect that the time resolution that we will measure in-beam in two weeks will be 50 ps or better.

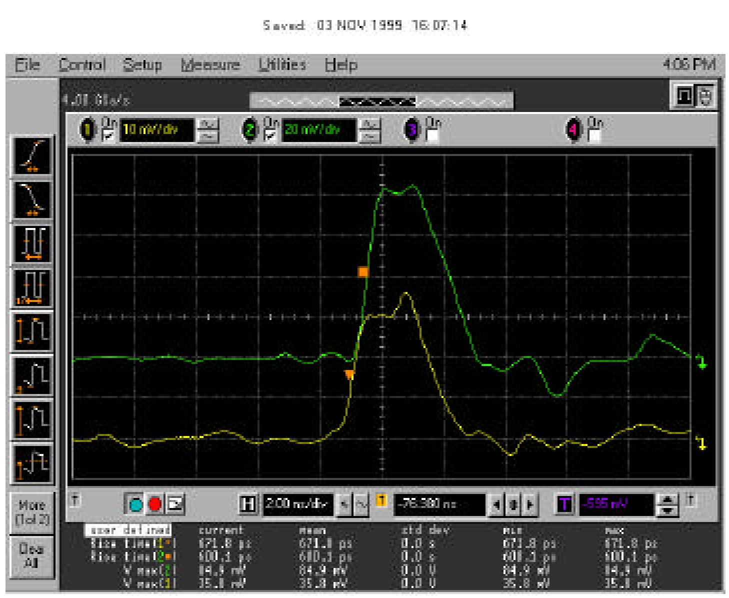

Fig. 3. *The two scope traces show the amplified outputs arising from a triggered cosmic ray passing through two five-gap chambers built at Bonner Lab. The horizontal time scale is 2 ns/div.*

Currently scintillator-PMT TOF systems with the appropriate electronics produce time resolutions in the 50-80 ps range, at best, after pulse height and other timing parameter corrections are implemented. We have shown that the multi-gap RPC with standard electronics achieves comparable resolution. We are confident that with optimized detector and electronic

[8] Third workshop on electronics for LHC experiments, 1998, pp 238-241.

designs even better timing will be achieved.

The cost of time digitizing electronics for RPC vs. PMT TOF systems in the small quantities affordable with PMT-based designs would be comparable. However, the cost of PMTs, HV bases and scintillator is far higher than the glass, mechanical support and front-end electronics needed for RPCs. Since this cost is small it is feasible to build detectors with far more elements (>10K). This leads to the possibility of building specialized custom integrated electronics that would be many times less expensive per channel than that used with the PMT based systems. At CERN, the ALICE collaboration is developing just such an integrated circuit time digitizing system for use with MRPC TOF. It appears feasible to build a TOF system for STAR with much finer pixellation than originally planned, at far lower cost, and with better time resolution. We expect to maintain our close contacts with the CERN developments and to take full advantage of any progress that would benefit our project.

Plans for the future

We expect to continue our R&D to examine the capability and suitability of the microgap RPC as a TOF detector for STAR. The schedule of our activities during the next year is briefly and tentatively given here. During the next month we will test several five- and ten-gap counters built in the Bonner Lab in beam at CERN. In addition we will test several counters made at CERN by our collaborators. Issues that will be investigated include rate capability and radiation hardness. Optimization of number and size of gaps will also be done. In particular we will investigate the desirability of using lower resistivity glass to improve rate capability. We intend to expose for an extended period one of the microgap RPCs to the intense radiation environment provided by the Gamma Radiation Facility (GIF) at CERN.

Layout of electronics that is capable of preserving the anticipated unprecedented time resolution will proceed in parallel. In two months we should have sufficient information to allow us to prepare a detailed proposal that will be submitted to STAR for consideration as an upgrade project. We expect that this will proceed in several stages, the first of which would be the construction of a fully instrumented single tray filled with approximately 96 cells. If approval is forthcoming and funding in the neighborhood of $200K can be found, we could have a fully tested tray ready for installation by next fall. If that proves successful, then we would expect to propose replacing much of the CTB with an RPC TOF system.

We will be actively recruiting members of STAR who would be interested in joining us in this exciting new development.