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DOE PROGRESS REPORT

Silicon Drift Chamber studies for the RHIC STAR experiment

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Summary

This is a progress report covering the period 5/1/91-4/30/92 and a one-year budget request for the period 5/1/92-4/30/93 for the current DOE project "Silicon Drift Chamber studies for possible use at RHIC" being carried out at the University of Pittsburgh by T. J. Humanic (principal investigator) and two graduate students. Over the past year we have continued our testing of the UA6 1 X 1.8 cm^2 prototype (resulting in a paper accepted by NIM for publication in 1992) and designed a 4 x 4 cm^2 prototype detector for the RHIC STAR Silicon Vertex Tracker (SVT). In the next year this STAR prototype detector will be fabricated and tested to finalize the design for the detector that will be used in the SVT. The requested one-year budget to fund Pittsburgh's contribution to this work is $60K.

1. Introduction

In 1989 we received RHIC R&D funding to begin a study of the suitability of silicon drift chambers (SDC) for use in RHIC detectors. Within one year we were able to set up a testing laboratory at Pittsburgh, obtain (from P. Rehak at BNL) one of the few working SDC's in the world at that time (a 1 x 1.8 cm^2 prototype) and carry out some preliminary base-line measurements with this detector. In the following year we made the first two-hit resolution measurements and first measurements in a magnetic field with an SDC. This work has resulted in a recent publication [1] based on the two-hit resolution measurements (see Appendix). In collaboration with BNL, Pittsburgh is planning to carry out improved magnetic field measurements within the next few months. See the Appendix for a discussion of the theory of operation of SDC's.

In the Summer of 1990, the decision was made to use SDC's in the vertex detector for the RHIC OASIS detector. The Pittsburgh group played a leading role in designing this detector which eventually led to the design, in collaboration with BNL, of a prototype 4 X 4 cm^2 SDC. With the decision by the RHIC program advisory committee not to approve OASIS, Pittsburgh decided to join the RHIC STAR collaboration which was also planning to use SDC's in its Silicon Vertex Tracker (SVT). The "OASIS prototype SDC" was renamed the "STAR prototype SDC" which we are now in the first stages of fabricating (the masks are now being made).

After the masks are completed, LBL and BNL will independently fabricate prototype SDC's (about 20 total) for testing. Tests on these SDC's will then be carried out at Pittsburgh and LBL to evaluate their performance. Pittsburgh will also fabricate the PC boards on which the SDC's will be mounted and electrically bonded for the testing. In addition to the hardware testing, Pittsburgh has recently become involved in Monte Carlo studies to determine to what extent the SVT can be used as a stand-alone device for momentum reconstruction.

Section 2 gives a progress report for the period 5/1/91-4/40/92, section 3 describes our plans for the proposed budget period, and section 4 discusses the budget.

2. Progress Report for the Period 5/1/91-4/30/92

In the last year, the Pittsburgh group has made progress in three main areas: 1) refinement and publication of two-hit resolution measurements, 2) design of the STAR prototype SDC, and 3) preparations for improved magnetic field tests. The Pittsburgh group presently consists of the principal investigator (T. J. Humanic) and two graduate students (Rama Jayanti and Gintas Vilkelis). These three areas will now be discussed below.

a. Two-hit Measurements

In the high particle density environment of RHIC, the ability of an SDC to resolve close hits in space is crucial for good track reconstruction efficiency. This ability is particularly important for two-boson interferometry studies where close hits are most sensitive to the interference effect [2]. Thus one of our highest priorities has been to measure the two-hit resolution of our 1 X 1.8 cm^2 SDC and compare our measurements with theoretical predictions for these devices. Gatti et al. [3] have made two-hit resolution predictions for SDC's. Our two-hit measurements which will be published in NIM [1] are discussed in detail in the Appendix which is a copy of this NIM paper. Note that these measurements were carried out in Pittsburgh using our detector test setup, which is also described in detail in the Appendix.

The two-hit measurements will be briefly described here. We simulated two particle hits using 8 ns pulses of 1064 nm light from a Nd:Yag laser which was split into two pulses using two light fibers. These fibers illuminated a microscope objective which was used to focus the light pulses to 20 micron spots on the SDC. The separation between the fibers at the microscope was adjustable using a precision set screw. The anode signal was preamplified and shaped (σ=27 ns) and fed into a 50 Mhz 7-bit digitizer. The digitized anode signal was then stored in an 8088-based computer and analysed off-line. Four adjacent anodes were instrumented in this way. The off-line analysis consisted of fitting two Gaussians to the two-hit anode signals and comparing the fitted positions of the peaks with the known positions of the light fibers having been set with the precision set screw mentioned above. Figure 2-1, which is excerpted from the Appendix, shows a comparison between our measured two-hit spacing errors (points) and that predicted by Gatti et al. [3] (curve). Plotted in this figure is the two-hit spacing error relative to the σ of the individual pulse width versus the relative pulse separation.

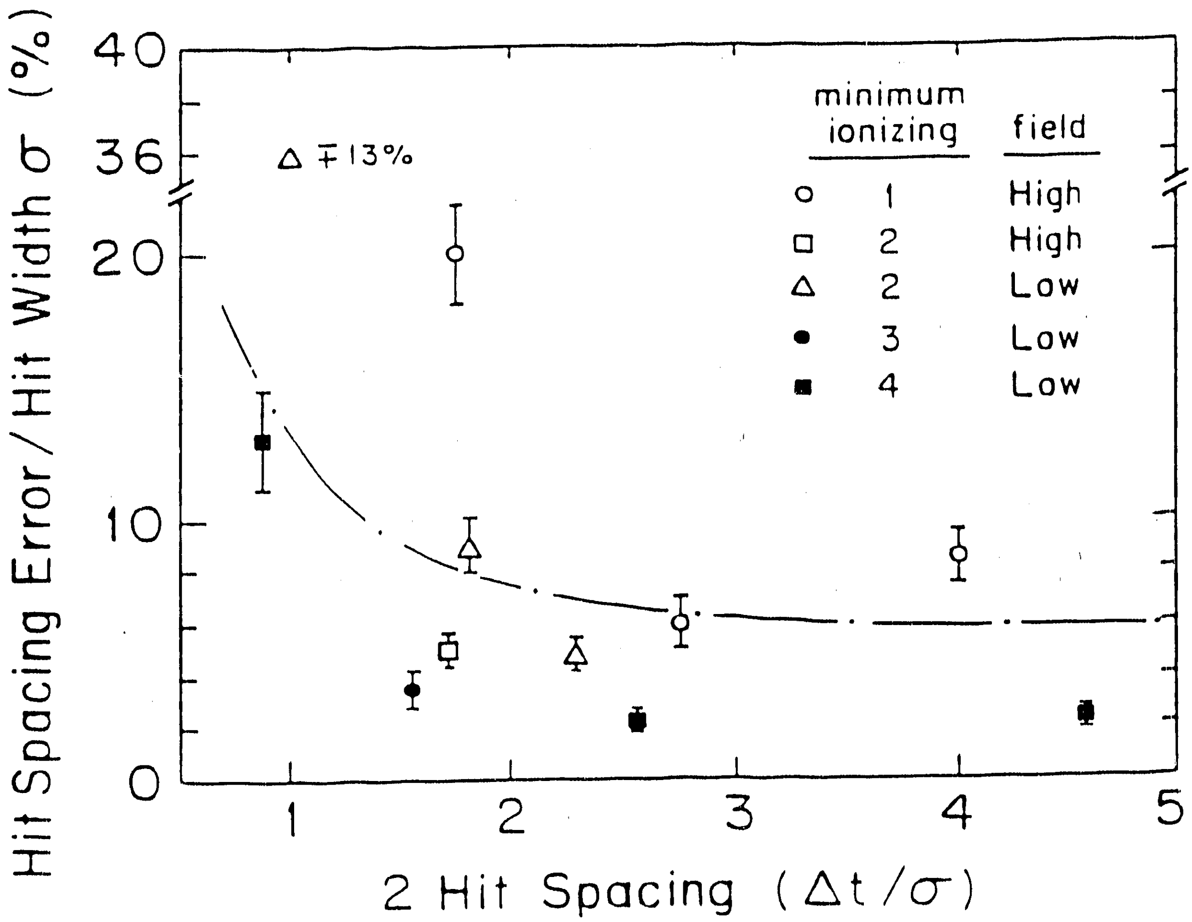

Figure 2-1: The measured spacing reconstruction uncertainty normalized to the single Gaussian waveform sigma versus the spacing normalized to the same. The prediction of Gatti et al. is shown as the curve.

Measured points are shown for one to four times minimum ionizing (simulated by varying the laser pulse intensity). All measured points are seen to fall near or below the predicted error except for the one-minimum-ionizing point below 2-σ separation, which is twice the predicted error. In terms of actual positions, Gatti et al. predict position errors of about 25 microns or less at 500 micron separation (i.e. 2-σ) or greater which we also measure except for our 500 micron separation point which gives a 50 micron error. As discused in the Appendix, this could be due to sampling errors.

b. STAR SDC Prototype Design

In the Summer of 1991 Pittsburgh and BNL (Rehak) designed a 4 X 4 cm^2 prototype SDC for the OASIS detector, the design of which was taken over by STAR when OASIS was cancelled as mentioned above. The design of the electrode and guard-ring layout was done by G. Vilkelis of Pittsburgh working at BNL under the supervision of P. Rehak on a SUN-based CAD system. The anode region has been designed by Rehak and incorporates two transistors in a Darlington pair configuration directly integrated on half of the anodes for a first stage of low-noise amplification. Figure 2-2 shows a schematic representation of the STAR SDC prototype.

Note that the active area of the detector is trapezoidal in shape with a lower width of 4.5 cm, an upper width of 3.5 cm, and height of 4 cm. This shape is determined by the requirement that the voltage at the (negative) high voltage end must be given a finite distance to drop to ground to avoid unwanted surface currents and sparking. The "useful active area" is defined as the rectangle 3.5 cm wide and 4 cm high---anodes in this width will be instrumented. The readout anode pitch is 250 microns resulting in 140 anodes being read out per detector. The detector thickness is 250 microns. As mentioned above, only half of the anodes will have the implanted Darlington-pairs. This is to insure that if the higher-risk-of-production Darlington-pair anodes fail, the prototype can still be used in the more conventional preamplifier readout mode. Although the rest of the prototype design was finished by the end of last Summer, the anode region design (with Darlington pairs) was more problematic. Near the beginning of February 1992, the problems with the anode region design were solved and a mask of the detector layout is now being made by an outside vendor.

c. Improved Magnetic Field Study

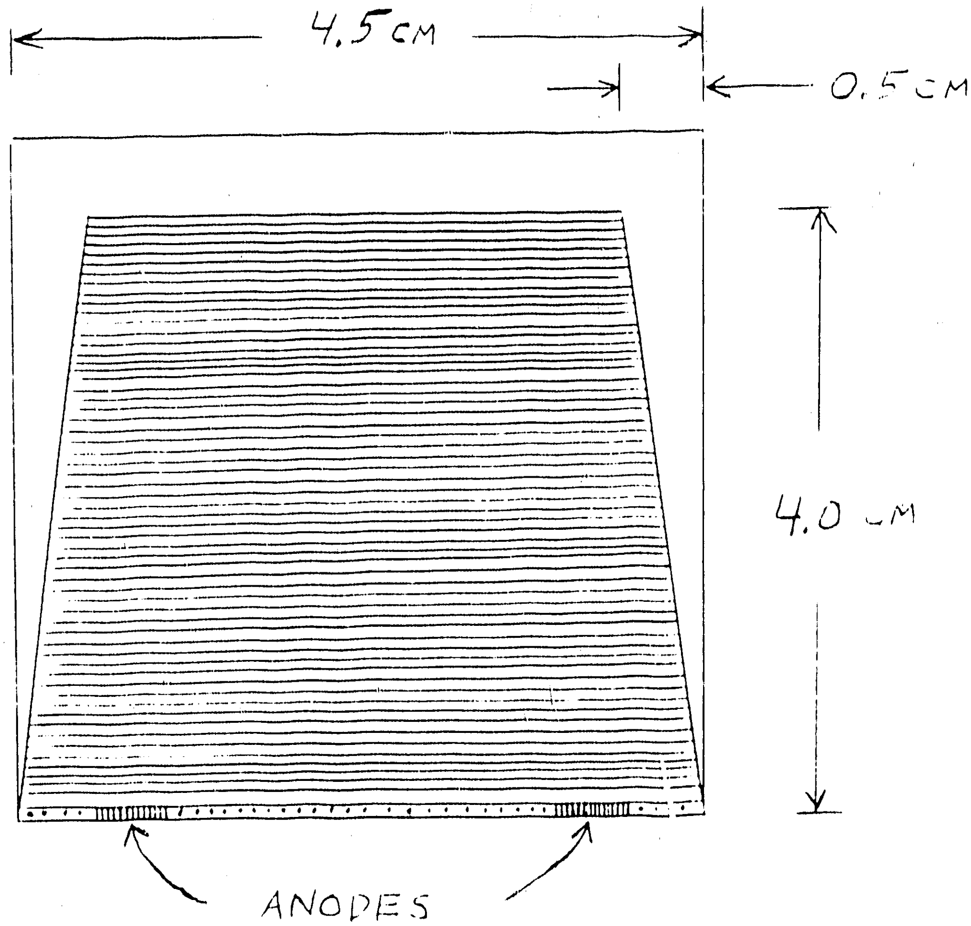

Figure 2-2: Schematic representation of the STAR SDC prototype.

The performance of SDC's in the environment of high magnetic fields is another important consideration in determining whether they are useful as tracking devices in magnetic spectrometers. Theoretically, one expects that if the magnetic field is normal to the surface of the detector, the path of an electron moving toward a readout anode will be deflected by a constant angle called the Hall angle, θ_H. The Hall angle is related to the applied magnetic field, B, by

$$\tan(\theta_H) = \mu_H B$$

where μ_H is called the Hall mobility. We have measured the Hall mobility as a function of B-field and E(drift)-field for our 1 X 1.8 cm^2 SDC, the results of which are shown in

Figure 2-3. This measurement was performed at Pittsburgh using a NMR magnet (1 T maximum) to generate the B-field and our Nd:Yag laser setup to simulate particle hits. If we ignore the measurements at B of 0.1 T which we expect have large systematic errors, we see that μ_H is independent of B, as expected, but has a significant dependence on the applied drift field, E. Since it is known that μ_H is temperature dependent [4] [5], we suspect a heating effect due to the implanted resistive divider on the SDC which causes more heating the larger the applied drift field.

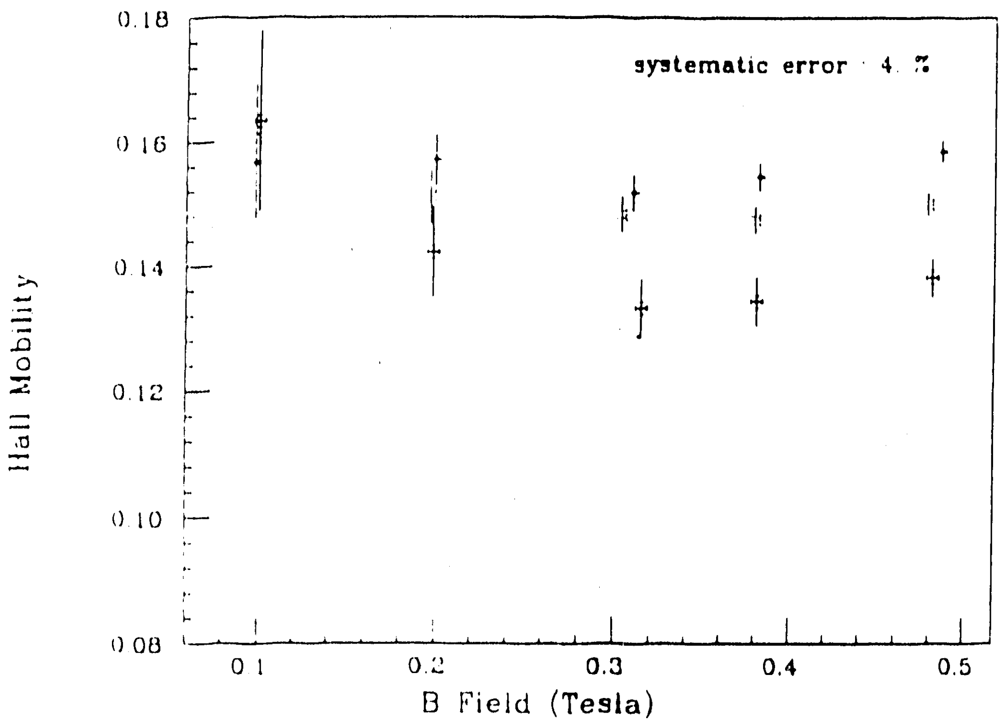

Figure 2-3: Hall mobility versus B-field and drift field. Circle--185 V/cm, Star--295 V/cm, Cross--531 V/cm. Note that B is perpendicular to the surface of the SDC

In order to eliminate this heating effect, we have obtained a 1 X 1.8 cm^2 prototype SDC which was fabricated without an implanted resistive divider (an off-chip divider is used instead). Another improvement to the measurement will be the use of a more powerful, wider gap magnet at BNL (achiving B-fields up to 2 T). This measurement at BNL, which will be done in collaboration with P. Rehak, is scheduled to take place at the end of March 1992, before the beginning of the budget request period.

3. Plans for the Period 5/1/92-4/30/93

For the upcoming budget period, Pittsburgh's SDC activities will be shifted away from being generically motivated to being directed toward the fabrication and use of the STAR SVT. This will be accomplished within three activities: 1) fabrication of STAR SDC prototypes, 2) prototype testing and evaluation, and 3) Monte Carlo simulations of the SVT to study stand-alone tracking.

As mentioned above, once the prototype masks are produced, BNL and LBL will carry out the fabrication of twenty or so SDC wafers from these masks. Although Pittsburgh will not be directly involved in the fabrication of the silicon detector wafers, one of our responsibilities will be the fabrication of the PC boards onto which the silicon wafers will be supported and electrically bonded. We are well suited to this task since expertize exists at Pittsburgh to make high-density PC boards via our CDF/Fermilab group. This group has experience in making PC boards for silicon strip detectors and has agreed to teach/help us with this task. As several bonders also exist at Pittsburgh, we will also take part in electrically bonding the detectors (This is a task we already carried out several years ago when we bonded three 1 X 1.8 cm^2 SDC wafers to PC boards.).

Once the detectors are mounted and bonded onto PC boards, some will be distributed to LBL and some will remain in Pittsburgh. LBL and Pittsburgh will then test the SDC prototypes to evaluate their performance based on criteria mutually agreed upon between the two institutes. This will speed up testing and allow for cross-checking of each others results.

The third activity Pittsburgh will take part in is to carry out Monte Carlo studies of the SVT to evaluate in what regions of phase space it can act as a stand-alone tracker. Because of the small radius of the SVT, this is only expected to be possible for "soft" particles.

The personnel involved in these activities will be T. J. Humanic (principal investigator, 20-30%), Gintas Vilkelis (Graduate Student, 100%) and Rama Jayanti (Graduate Student, 50%). Jayanti has been working in the group since Summer 1991 and has obtained experience in SDC testing. She is spending 50% of her time on my other reseach project, the CERN NA44 experiment. Vilkelis has been working in the group since 1989, first as an undergraduate researcher and later part-time as a graduate student. As he has finished his graduate course work and passed his Comprehensive exams, Vilkelis will work full time on this project starting May 1, 1992. Jayanti will take the major responsibility for PC board fabrication and bonding and Vilkelis will take major responsibility for the Monte Carlo studies. All personnel will take part in the prototype testing. Bescause of his experience with SDC's, Vilkelis will visit LBL for about one month in May to help with their SDC test program.

4. Budget Request for 5/1/92-4/30/93

As seen in the attached budget sheet, the budget request for the 5/1/92-4/30/93 period is $60K. This provides 18 months of graduate student support, travel to BNL and LBL, materials, shop charges, and overhead. The overhead rate at Pittsburgh has recently increased from 43% to 47%. The materials costs are for fabrication and bonding of PC boards and miscellaneous electronics costs. The shop costs are also related to the PC board fabrication since some help will be needed from the electronics shop for this.

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2. T. J. Humanic et al., "Pion Interferometry with Ultrarelativistic heavy-ion collisions from the NA35 experiment," Z.Phys.C38, 79 (1988).
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4. C. Jacoboni et al., Solid-State Elect. 20, 77 (1977).

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