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PROGRESS REPORT

on

Silicon Drift Chamber Studies for the RHIC STAR Experiment

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by

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In the last year, the OSU group has made progress in all three of the areas in which we have taken our main responsibility for the SVT: A) design of STAR SDC prototypes, B) detector testing and radiation damage studies and C) Monte Carlo studies to determining the feasibility of using the SVT for boson interferometry measurements. These three areas will now be discussed below.

A) STAR SDC Prototype Design

In the Summer of 1991 Pittsburgh and BNL (Rehak) designed a 4 X 4 cm² 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. Vilkels of OSU/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. Fig. 3 shows a schematic representation of the STAR1 prototype.

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Figure 3. Schematic representation of the STAR1 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 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. The first STAR1 detectors were fabricated in August 1992. These have been wire-bonded to PC-boards and tested at several laboratories within the SVT group (see below).

In the last year, two new prototypes have also been designed by OSU (Vilkelis) in collaboration with BNL (Hobie Kraner), designated the STAR2 and STAR3 prototypes. The STAR2 prototype is an experimental "mini-guard" two-way drift detector. The STAR2 prototype is somewhat larger than the STAR1 in size, having an area of 6 cm x 6 cm, and also has the feature of being read out as two half-detectors as seen in Fig. 4. This has two main advantages: increased read-out speed due to smaller drift distances and lower applied drift voltages.

Figure 4. Schematic representation of the STAR2 prototype.

An additional advantage to the STAR2 "mini-guard" design is that the active area of the detector is rectangular instead of trapezoidal. This allows for easier tiling of the detectors on the SVT barrel and minimizes the overlapping regions of wafers which also minimizes the material through which the particles must traverse. Fig. 5 shows a blow-up of the actual AutoCAD drawing for the lower right corner of the STAR2 detector. In this figure the first 82 cathodes (horizontal lines) are labeled along with anodes 185 to 215. There are a total of 221 cathodes and 215 anodes per drift side. The "mini-guard" lines are seen as the almost vertical straight lines off to the extreme right of the diagram. This detector is now being fabricated at BNL and will be ready for testing within a month.

Figure 5. Expanded AutoCAD view of the lower right-hand corner of the STAR2 detector.

Figure 6. Schematic representation of the STAR3 prototype

Another prototype which has been designed by OSU/BNL is the STAR3 prototype which is a two-way drift version of STAR1. This detector, which is schematically shown in Fig. 6, has an area of 6 cm x 6 cm like STAR2 and the same advantages of a two-way drift detector. The disadvantage of STAR3 is that it has a trapezoidal active area, but its advantage is that it is a simple extension of a working design, i.e. STAR1, and thus has a high probability of working. The masks for this prototype have been finished and the detector itself will be fabricated near the end of this Summer.

B) Detector testing and radiation damage studies

As mentioned above, OSU is one of the three designated test labs for the STAR SVT project. The other two labs are at Wayne State University and the University of Texas, Austin. The main responsibility of OSU and WSU is to carry out general baseline testing of the prototype SDC's as they become available to ascertain their suitability for use in the SVT. Because there is some overlap of responsibilities and because of our geographic proximity, OSU and WSU collaborate closely on some measurements. UT has responsibility for the data readout of the SVT and in this capacity also maintains a detector test setup, although it is primarily geared toward data acquisition issues.

Fig. 7 shows a schematic diagram of the present OSU detector test setup. The main components of the test setup consist of the following:

- a pulsed Nd:Yag laser producing a fast (6ns width) pulse in the infrared (1064nm) suitable to simulate the effects of a minimum ionizing particle in the detector

- six channels of Nicolet 200Mhz time digitizers to digitize the signals from six readout anodes of the detector in 5ns bins to study their pulse shapes
- a PC that is connected to the digitizers via an RS-232 link that is used for further pulse shape analysis
- optics to focus the laser beam to a several micron spot on the detector
- a computer-controlled x-y stage to precisely position the detector under the laser beam to within one micron.

Figure 7. Present experimental setup used at OSU for SDC tests.

The infrared pulse from the laser is brought to the focussing optics via light fibers which help define the eventual size of the focussed spot on the detector and which, in groups of fibers, can be used to simulate multi-particle hits on the detector. The anode signals are then put through low-noise preamplifiers and gaussian shapers ($\sigma = 27$ ns). The gaussian signals, or the preamplifier signals directly depending on what is being studied, are finally digitized and stored onto disk by the digitizer-PC system for further analysis.

Fig. 8 shows digital scope signals from a STAR1 detector (#405) using the OSU laser setup for two different positions along the drift direction, 4.3 mm and 14.0 mm from the anodes. The applied drift voltage was 1800 V and the intensity of the laser was tuned to give an equivalent one-minimum-ionizing-particle response in the detector. The top signal is the direct preamplifier pulse, the middle signal is the preamplifier pulse differentiated (in software), and the bottom signal is the shaper output (vertical scale in volts, horizontal scale in microseconds). The peak position of the differentiated preamplifier pulse is seen to be reasonably close to the peak from the gaussian shaper.

Figure 8. Digital scope signals from a STAR1 detector for two positions of the laser along the drift direction. See text for explanation.

From a knowledge of the position of the laser spot and the corresponding drift time obtained by fitting the shaper output or the frequency-filtered differentiated preamplifier output, one can obtain a plot of drift time versus position for the SDC being tested. This is shown using both the shaper and preamplifier outputs in Fig. 9 for STAR1 detector #405, measurements having been carried out at the OSU test setup. Both plots look virtually identical. The reason we are studying both shaper and preamplifier outputs is to determine what advantage there might be for the SVT to depart from its present baseline of using active shapers in the readout electronics to making the electronics chain shaperless. This is still under study, but from Fig. 9 it looks promising.

Figure 9. Time versus distance plots from OSU laser testing of STAR1 detector #405.

Examining the shapes of the plots in Fig. 9 further, one sees that detector #405 is not a perfect silicon drift chamber. Although the detector is quite linear from a distance of about 7 mm from the anodes and outward, having a slope of $1.78 \mu\text{s/cm}$, between 5-7 mm there is a "kink" in the plot. In the region from 0-5 mm the plot is fairly linear with a slope close to $1.78 \mu\text{s/cm}$, but there are some small but clear non-linearities in this region also. We have probed the region from 5-7 mm, making I-V measurements, and have concluded that the resistors of the wafer-implanted resistive divider in this region are too small, indicating a local non-homogeneity in the way the resistive divider was implanted. Note that some STAR1 detectors that have been tested have not shown these "kinks" and have linear drift time vs. distance plots over the entire length of the detector.

One reason that OSU has been particularly interested in this "slightly defected" detector is that because of its defect, it is considered expendable and thus is a good candidate for radiation testing. Having established the baseline performance of #405, we have recently carried out a program of incremental radiation exposures of #405 followed by laser testing after each exposure to see the effects of these radiation dosages on the detector's performance. We have exposed the detector to the γ -rays coming out of a high-activity ^{60}Co source located at the OSU Nuclear Reactor Facility. It is estimated that 1krad of γ -ray exposure is roughly equivalent to the radiation dose seen by a silicon drift chamber in the SVT after one year of RHIC running. We have exposed the detector to integrated dosages of 1krad, 5 krad, and 10 krad. The measurements are still being analysed but some preliminary results exist. Fig. 10 shows a comparison of the voltage versus cathode # probed on the detector before irradiation and after a 5 krad exposure. Note that the two plots are not plotted on exactly the same scales. If we look in the range from cathode #30-50 we see a "kink" that corresponds to the same position on the detector as the "kink" seen in Fig. 9. Curiously, after exposure to the γ -radiation the kink is seen to flatten out somewhat, and the small non-linearities from cathode #0-30 also flatten out. Apparently the radiation has "improved" the detector, at least in this respect. It still remains to analyze our laser test for this irradiation to verify that the time-vs.-distance "kinks" also flatten out. Another preliminary result is that after 10 krad the detector is still working, but with reduced signal amplitude out of the anodes. Much work remains to analyze this data.

Figure 10. Voltages probed on detector #405 versus cathode # before irradiation and after a 5 krad γ -ray irradiation.

C) Monte Carlo studies for feasibility of boson Interferometry with the SVT.

Boson interferometry is expected to be an important tool at RHIC in determining the size and lifetime of the interaction region, and therefore as a probe of the space-time dynamics of the collision³. Since we at OSU have been interested for a long time in boson interferometry⁴, we have taken the responsibility in the SVT group to investigate to what degree this detector can be used to carry out boson interferometric measurements. This study is in progress. Using an event generator and SVT software to track particles through the detector and reconstruct their momenta we have extracted some preliminary plots for the momentum-difference distribution in various variables important for interferometric analyses and for the momentum resolution for pions in the detector. Fig. 11 shows the momentum-difference distributions for RHIC Au-Au collisions in the variables $Q_{\text{invariant}}$, Q_{Tout} , Q_{Tside} , and $Q_{\text{longitudinal}}$. The horizontal scale is in GeV/c. As is seen the acceptance of the SVT for these variables is more than sufficient to carry out a correlation measurement since for source sizes expected to be seen at RHIC the Bose enhancement is confined to the region less than several hundred MeV/c.

Figure 11. Momentum-difference distributions for RHIC Au-Au collisions in the variables $Q_{\text{invariant}}$, Q_{Tout} , Q_{Tside} , and $Q_{\text{longitudinal}}$. The horizontal scale is in GeV/c.

Fig. 12 shows the corresponding resolution plots for $Q_{\text{invariant}}$, Q_{Tout} , Q_{Tside} , and $Q_{\text{longitudinal}}$. The best resolution is obtained for the Q_{Tside} variable and has a value of $\sigma = 27$ MeV/c. In some respects, the Q_{Tside} variable is the most important one to measure well since it is expected to have a radius parameter conjugate to it that contains information most directly associated with the geometry of the source. Typically one would hope for $\sigma < 20$ MeV/c in order to carry out a valid interferometric analysis, so we are looking into ways of making cuts to the data (e.g. momentum cuts) to minimize σ . We have also started looking at KK interferometry with the SVT.

Figure 12. resolution plots for $Q_{\text{invariant}}$, Q_{tout} , Q_{tside} , and $Q_{\text{longitudinal}}$.

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