8/25/02

Summary of Beam Reflection Noise in the CNI Polarimeters

The RHIC CNI* polarimeters were successfully commissioned during the first polarized pp run in RHIC. The polarimeters make use of silicon strip detectors (SSDs) to detect recoil carbon nuclei, which are scattered by a polarized proton beam. A diagram of an SSD can be seen in Fig. 1. The detectors have a sensitive area of 24 mm by 10 mm, which is segmented into 12 strips of 2 mm by 10 mm. The SSDs are mounted on a feed-through and sit inside the polarimeter vacuum chamber. A pc board containing pre-amplifiers is mounted on the other side of the feed-through, outside of the vacuum chamber.

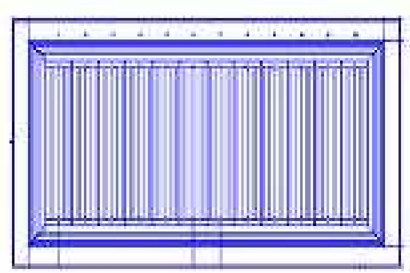

FIG. 1. Diagram of a silicon strip detector used in the RHIC CNI Polarimeters. The detector has a sensitive area of 24 mm by 10 mm and is segmented into 12 strips.

During the run a noise signal was noticed every time a proton bunch passed by the detectors. The signal was seen on all strips of all detectors, but the magnitude and shape of the signal varied for different strip orientations and for different strip positions within a detector. Fig. 2 shows the signal seen in one of the detectors, which had the strips oriented perpendicular to the beam

*CNI: Coulomb-Nuclear Interference

direction. On the top in Fig. 2, the signal from a strip on the right side of the detector is shown. The signal from a left side strip is shown on the bottom. The signals from either side of the detector look very similar, except the signals from the six strips on the left have the opposite sign with respect to the six strips on the right. All 12 strips have wires bonded to them to read out current. On the left side wires are bonded at the top of the strips, and on the right wires are bonded at the bottom of the strips. An initial explanation for this noise signal was that current was being induced on the wire bonding loops by the passing proton bunches. Also, the different wire bonding for right and left was thought to account for the opposite-signed signals that were observed. Another contribution to the different left and right signals may be the orientation of the pre-amplifier electronics. There are two seperate pre-amplifier printed circuit (pc) boards connected to each SSD. The two pc boards have opposite orientation with one board corresponding to six strips on the left and the other to the six on the right. The different orientation of the pre-amplifier electronics may also contribute to the different signals seen in the left and right sides of the detector.

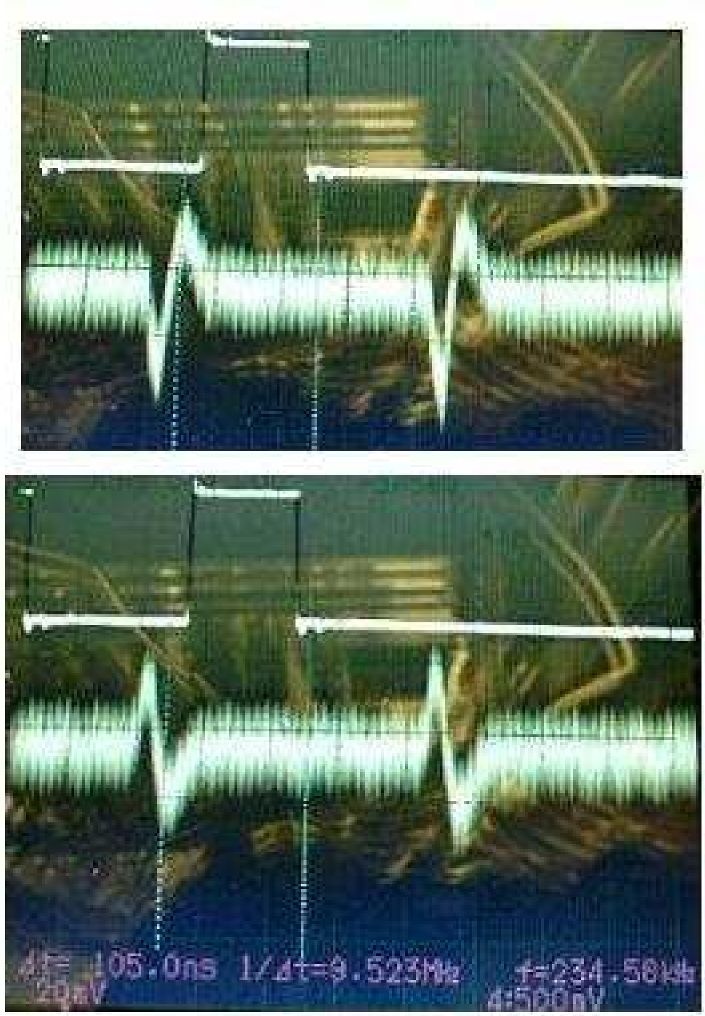

FIG. 2. The top oscilliscope trace shows the noise signal induced on a strip on the right side of a detector in the RHIC polarimeter. The bottom trace shows the same for a strip on the left.

The noise seen in RHIC limited the kinematic range to which the CNI polarimeters were sensitive. This noise problem is also expected to affect the performance of the new AGS CNI polarimeter. An effort has been made to understand the nature of this noise and also to understand the general noise environment in the AGS. In April 2002 an SSD and the pre-amplifier electronics were installed in an empty port in the C-20 region of the AGS. At this time the AGS was being used to accelerate high intensity proton beams of 6×10^{12} protons/bunch with 6 bunches. This intensity is about a factor of 50 times higher than that used for injecting polarized protons into RHIC, but the high intensity

beam provided an opportunity to explore any noise that may be unique to the AGS environment. Fig. 4 shows the signals induced on two of the strips of the SSD. The trace on Ch. 1 of the oscilliscpe shows the signal from a strip on the left side of the detector, and the trace on Ch. 3 shows the signal from a strip on the right. The signal shape differs from that which was seen in RHIC, but there are some similarities in the behavior. The signals in the AGS are not exact polar opposites as in RHIC, but the signals do change significantly from the right side strips to the left side strips. Fig. ?? shows the signal from two strips both on the left side of the detector. These look very similar. Again, this suggests that the different wire bonding for the left and right sides plays some role in the shape of the reflection signal that is seen. Also, from Figs. 4 and ?? one can see that the noise signals in the AGS have a period of 420 ns. This corresponds to the timing difference between bunches in the AGS and suggests that the signal is indeed caused when the bunches pass by the detectors.

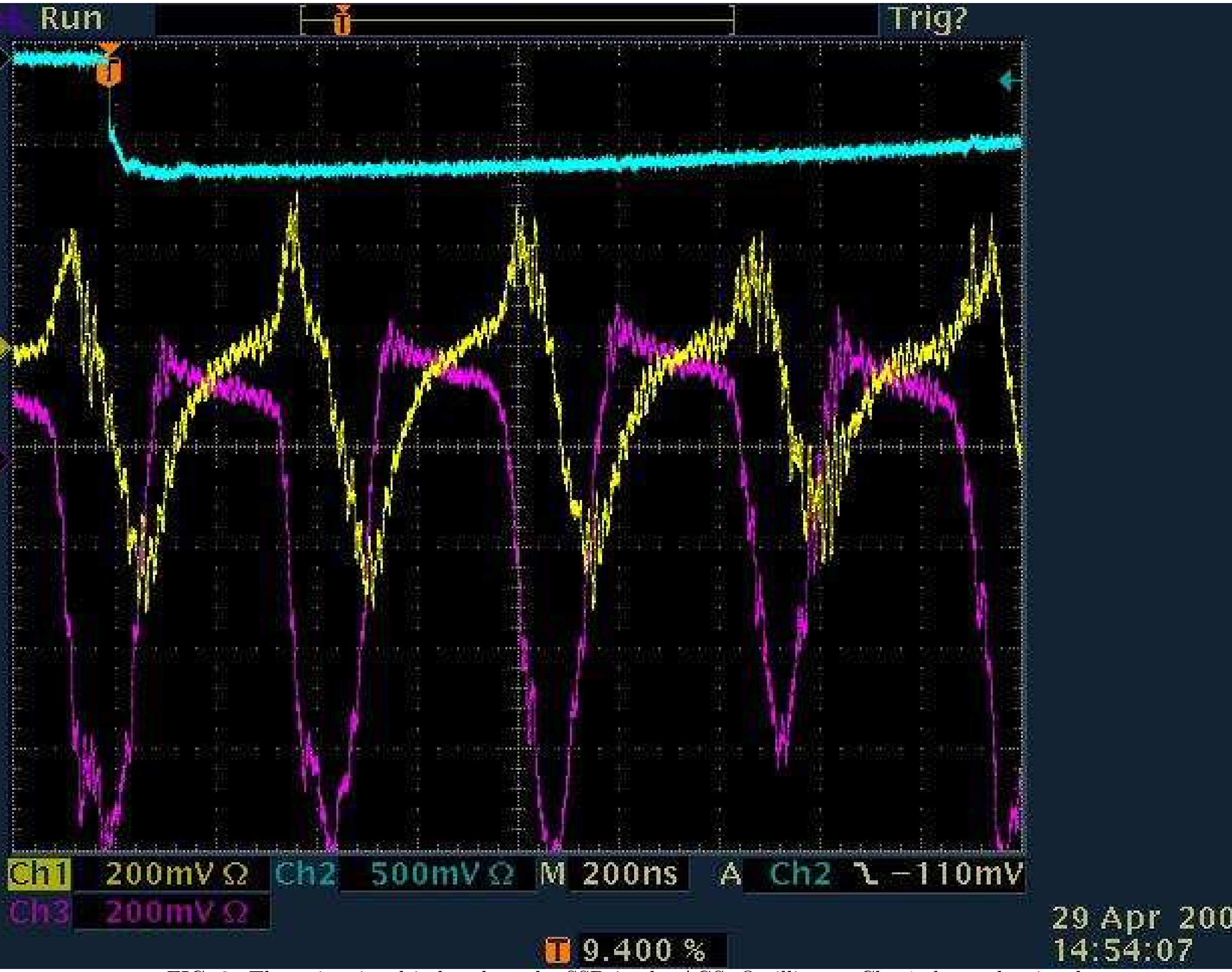

FIG. 3. The noise signal induced on the SSD in the AGS. Oscilliscope Ch. 1 shows the signal from a strip on the left side of the detector, and Ch. 3 shows the signal from a strip on the right. The AGS was running with 6 bunches, 6×10^{12} protons/bunch.

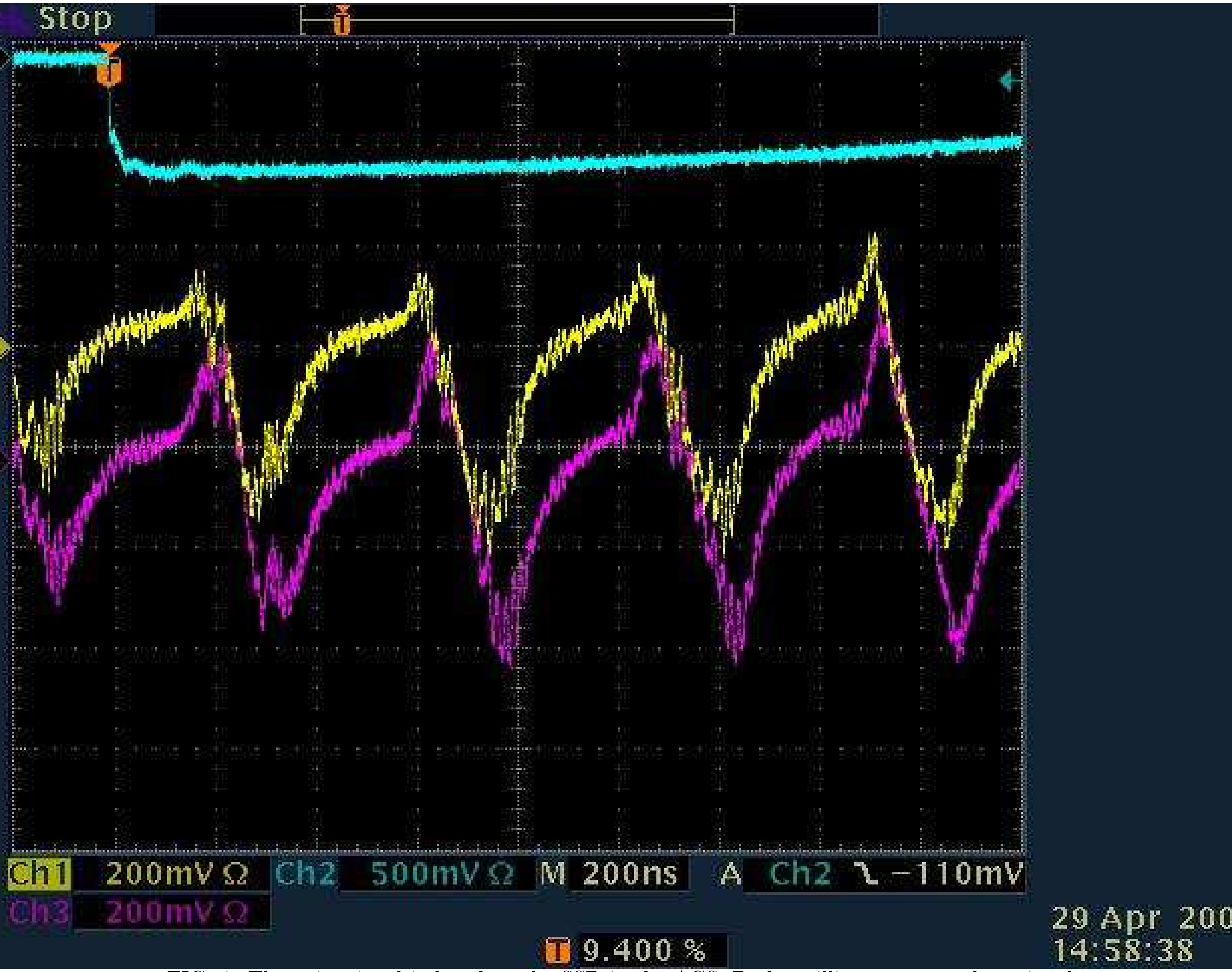

FIG. 4. The noise signal induced on the SSD in the AGS. Both oscilliscope traces show signals from strips on the left side of the detector. The AGS was running with 6 bunches, 6×10^{12} protons/bunch.

The study during the AGS high intensity proton run helped to characterize the reflection signals that were being seen, but the origin of this noise was still not fully understood. Therefore, a proposal was made to use the new AGS CNI polarimeter vacuum chamber for further study of the reflection signals until

the time of its installation. A set up was constructed in which a wire was run through the center of the chamber. An SSD was mounted in the chamber, and current pulses were sent down the wire to simulate passing proton bunches. Fig. 5 shows the signal induced by a current pulse. There was no change seen in the signal when the bias voltage was changed or even completely removed. This was further evidence that the noise signal is due to a current induced on the wire bonding of the detector or on the read-out electronics rather than being associated with the silicon itself.

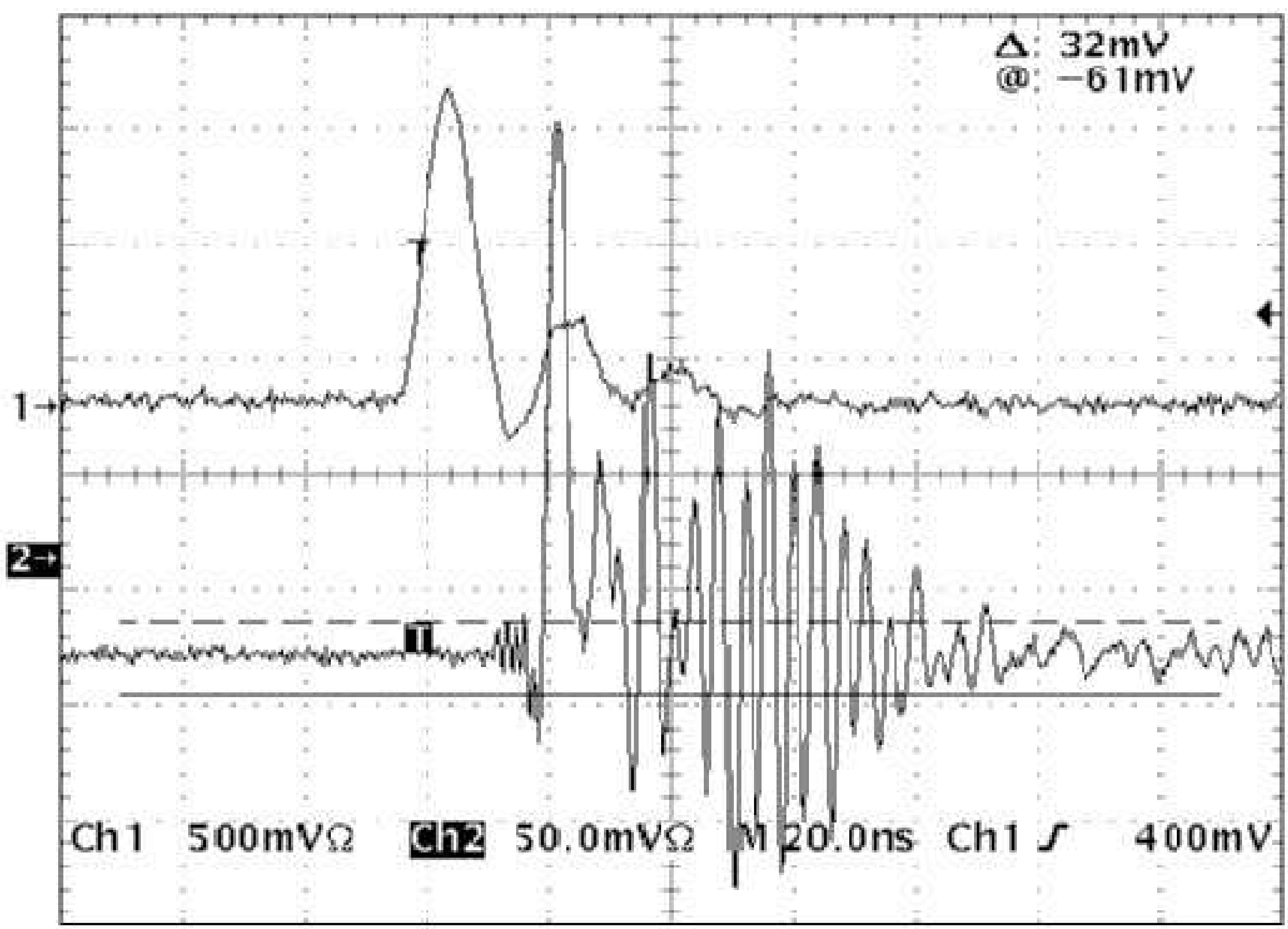

FIG. 5. Ch. 1 shows the 1.5 V, 15 ns wide current pulse sent down the wire. Ch. 2 shows the induced signal, ∼ 225 mV and ∼ 60 ns wide with ringing structure.

The pulsed wire tests continued with the following change being made. An aluminum shielding box was added to cover the pre-amplifier pc boards. The box was deemed necessary due to the high level of RF noise surrounding the AGS beam pipe. The addition of this box greatly reduced the amplitude of the reflection signal from the current pulse. Fig. 6 shows the signal after the addition of the box. One side of the box was removed while the signal in Fig. 6 was being measured. Removing the side from the box had no effect on the size or shape of the signal. This suggests that it is not the RF shielding that helps reduce noise levels. It is suspected that there may be a problem with the grounding of the pc board and the addition of the shielding box may provide a better ground connection to the vacuum chamber. This could contribute to the reduction of the noise level. A difference between the left and right was also observed during the pulsed wire tests. The reflection signal from strips on the right had a slightly lower amplitude than those on the left. The signal in Fig. 6 is from a left side strip. Fig. 7 shows a strip from the right side.

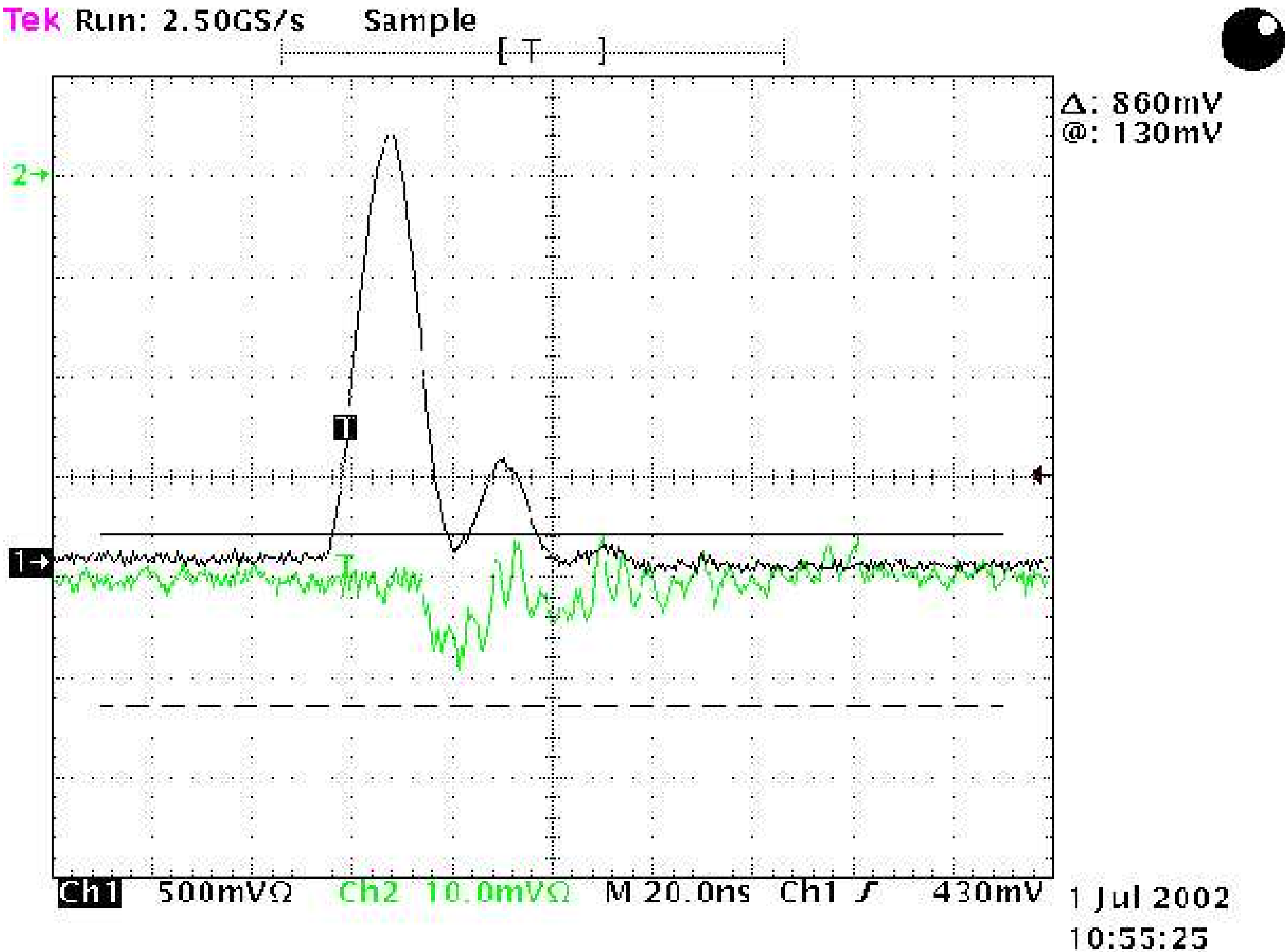

FIG. 6. Ch. 1 shows the 2 V, 25 ns wide current pulse sent down the wire. The induced signal is greatly reduced with the addition of the shielding box. The signal is shown on Ch. 2 with an amplitude of ∼ 10 mV. The signal is from a strip on the left side of the detector.

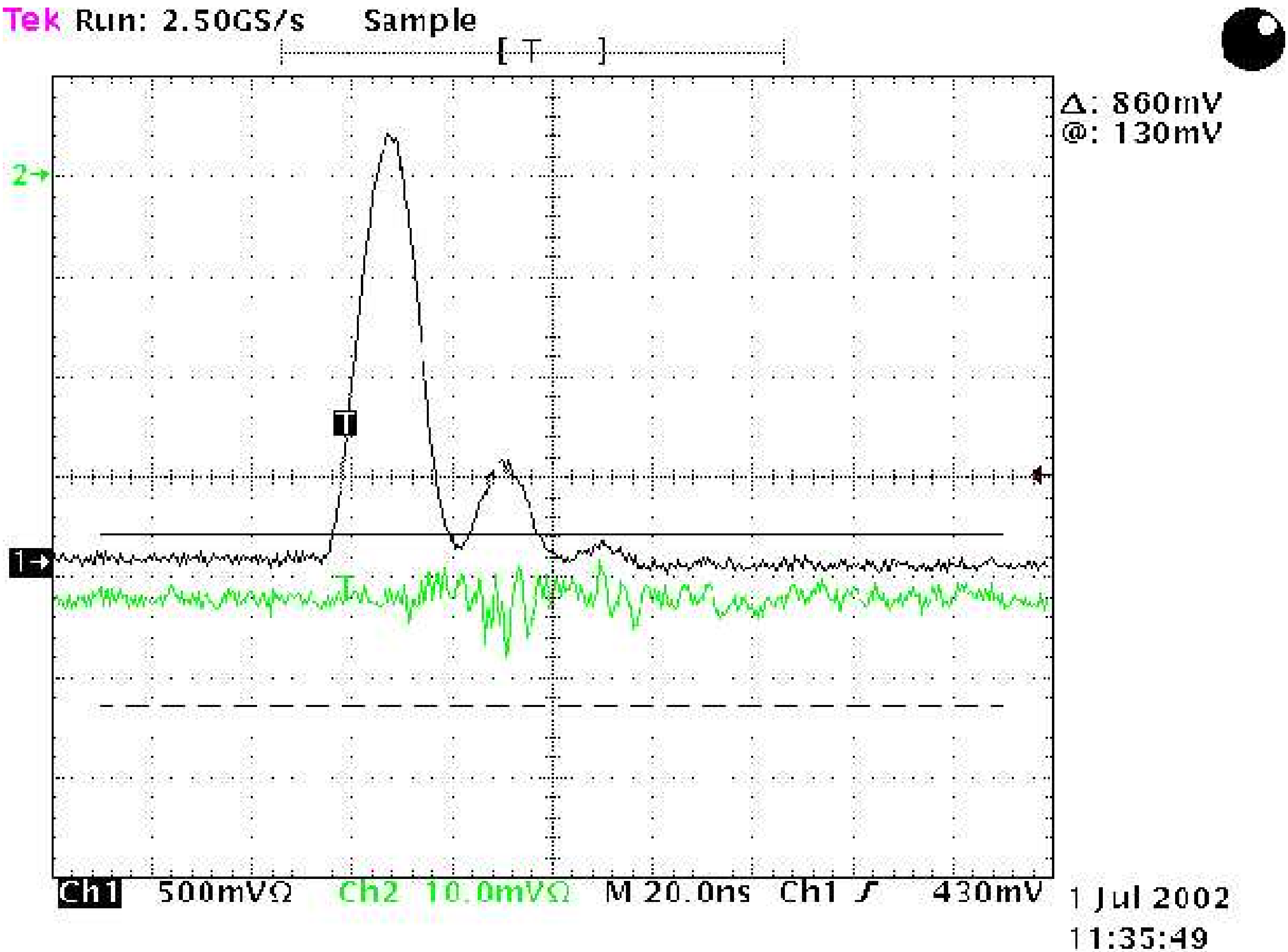

FIG. 7. The reflection signal from a strip on the right side of the SSD. Aluminum shielding box was in place.

The pulsed wire set up was dismantled in early July 2002, so that the carbon target holder could be installed in the vacuum chamber. After installation of the target holder was complete, the pulsed wire tests were resumed. At this time the shape of the reflection signal had changed with respect to the previous pulsed wire tests. The ringing structure that was previously seen was no longer present. Also, the reflection signal was now occurring at the same time as the

current pulse; whereas, previously the reflection signal trailed the current pulse by 15 ns. Fig. 9 shows the signal after the pusled wire set up was re-established. There were no known changes to the experimental set up that could have caused these changes in the reflection signal. The shielding box was replaced, and again adding the box significantly reduced the signal level (from 45 mV to 8 mV peak to peak). Fig. ?? shows a signal after the shield box was added. In addition to reducing the magnitude, adding the box also causes the sign of the signal to flip. Other systematic changes were also made during this study. The orientation of the detector was changed so that the silicon strips were approximately parrallel to the pulse wire. This change in orientation had no effect on the noise signals seen. Also, a copper mesh covering was added over the SSD. Adding the mesh had no effect on the signal.

The noise signals described above are not completely understood at the time of writing this document. However, these studies have given a characterization of the noise behavior. The noise pulses are clearly caused by the proton bunches passing by the silicon detectors. The addition of a shielding box placed around the preamplifier electronics reduces the noise level, and this suggest that the noise level may be related to a grounding problem with the preamplifier electronics. Future studies are planned to further the understanding of this noise problem.

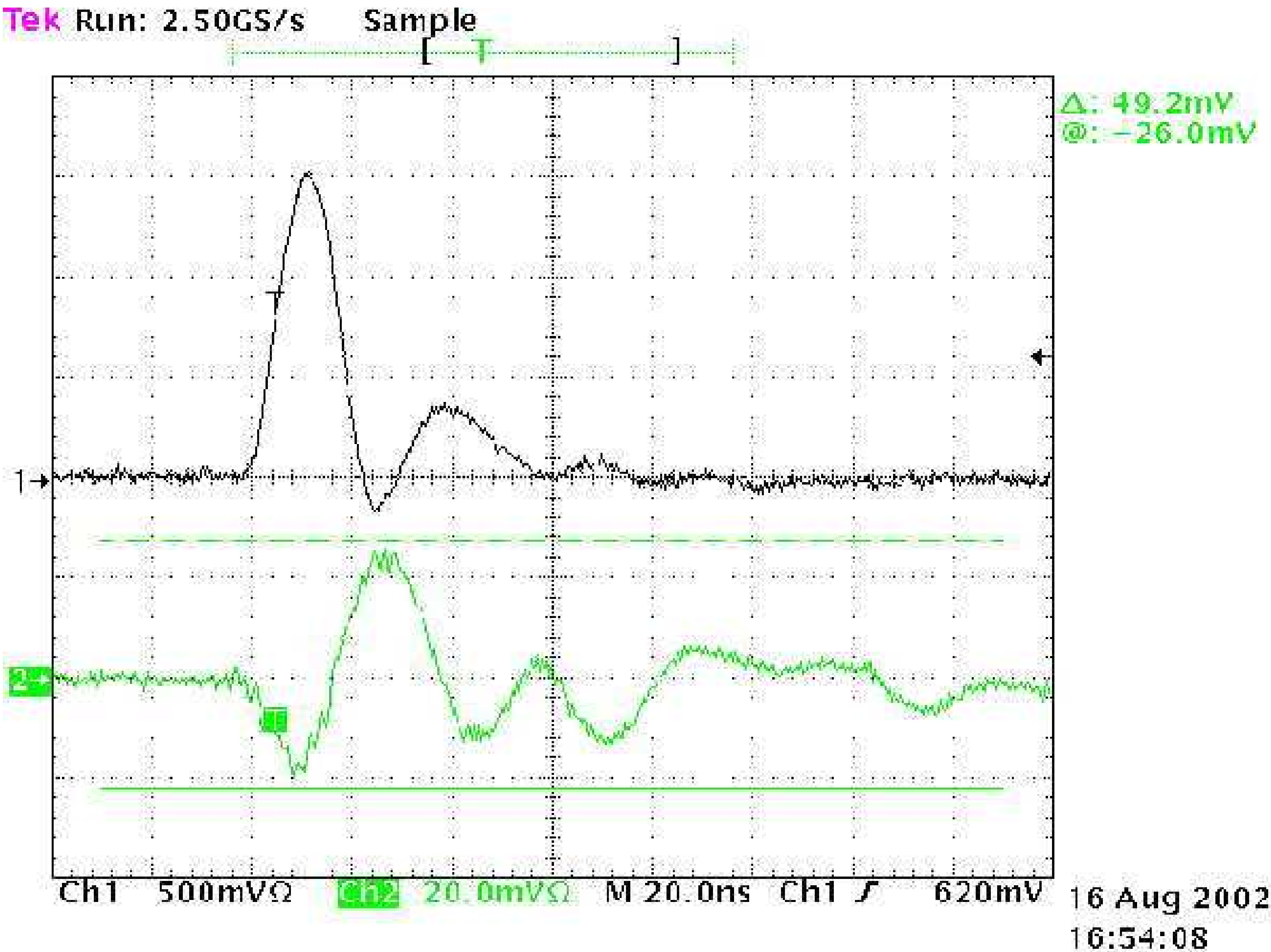

FIG. 8. Reflection signal from pulsed wire tests on Aug. 16, 2002 (after target holder installation). This signal does not have the ringing structure that was seen in previous tests. Also, there is no delay between the current pulse and the reflection signal. The shielding box was not in place for this measurement.

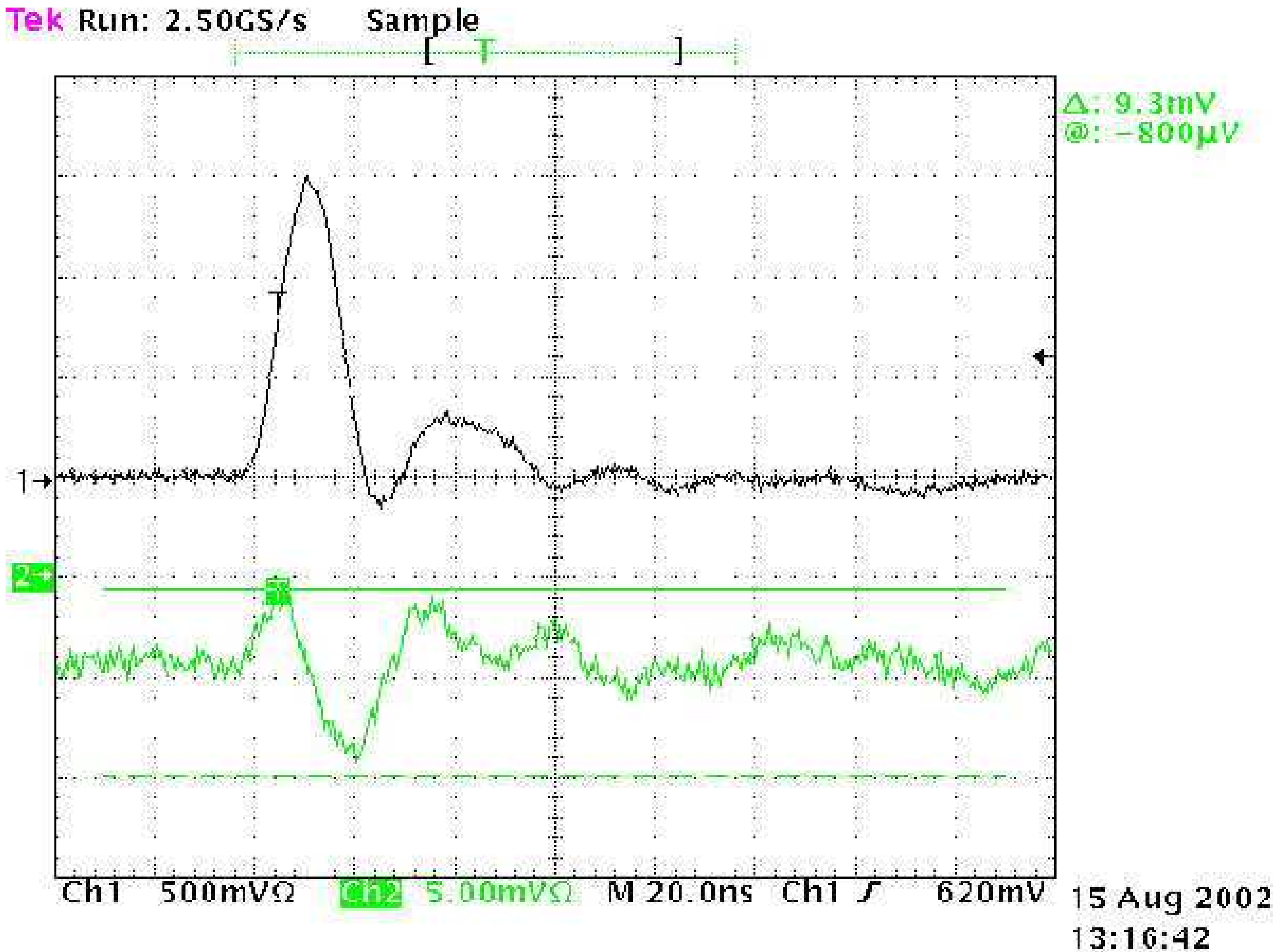

FIG. 9. Reflection signal from pulsed wire tests on Aug. 16, 2002 (after target holder installation). Adding the shielding box reduces the amplitude of the signal and also flips the sign of the signal.