Fermi National Accelerator Laboratory

TM-1610

Radiation Measurements Inside the CDF Detector

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During the last CDF experimental period from 6/88 to 6/1/89, radiation measurements were made inside the detector on or near the beampipe using various types of monitors. The purpose of the tests was to help predict the radiation levels for future electronics which must be located close to the interaction area.

The results from two different types of monitors, PIN diodes and TLD's are reported in this paper. The TLD's (Harshaw/Filtrol type 700) are sensitive to X-rays, gammas, alphas, electrons, and protons. They are calibrated against a cesium source and corrected for nonlinear effects at higher radiation levels. The PIN diodes (Harshaw/Filtrol type DN-156) are sensitive only to neutrons. The devices are calibrated for 1 MEV neutrons and require correction factors for neutrons at other energy levels.

All of the monitors were placed just outside of the VTPC, but still inside the CDF magnetic field. The monitors were located 68 inches from the center of the interaction region as shown in Figure 1. The beam pipe is 2 inches in diameter. Therefore the closest monitoring points were on the beampipe or 1 inch from the beam.

Radiation Level versus Time

During the run, TLD's were placed at the same 2 locations inside the detector and replaced several times to monitor how radiation levels changed over the course of the run. Both monitors were on the beampipe at the east end of the detector, one located on the bottom of the beampipe and one located on the outside edge of the ring. Figure 2 shows the results of those measurements. Results have been normalized by dividing the measured radiation level by the delivered integrated luminosity for the time period during which the monitors were installed. As can be seen, over the course of the run the radiation exposure per unit of integrated luminosity generally decreased. For the first few months of the run, the radiation levels were relatively high, probably due to beam tuning. The accelerator was most stable from about January 1 through June 1. Thus not surprisingly, the third set of TLD's installed from 1/10 to 3/24 show low radiation levels. The last set of TLD's were not removed until 6/15 and include two weeks of low intensity main ring studies with no integrated luminosity after the end of the CDF run. Thus, the somewhat higher radiation levels for the last period of time is not unreasonable. Most of the

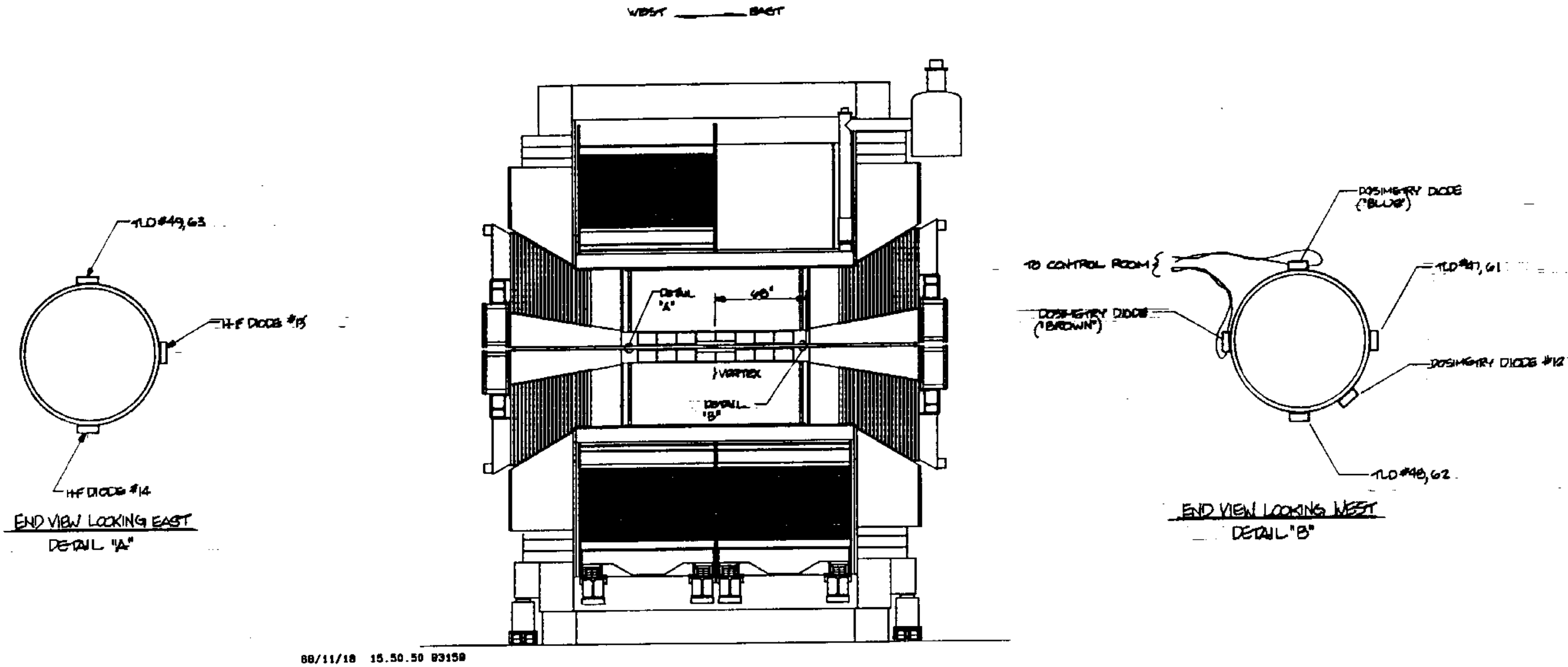

Figure 1 - Radiation Monitor Locations Inside CDF Detector

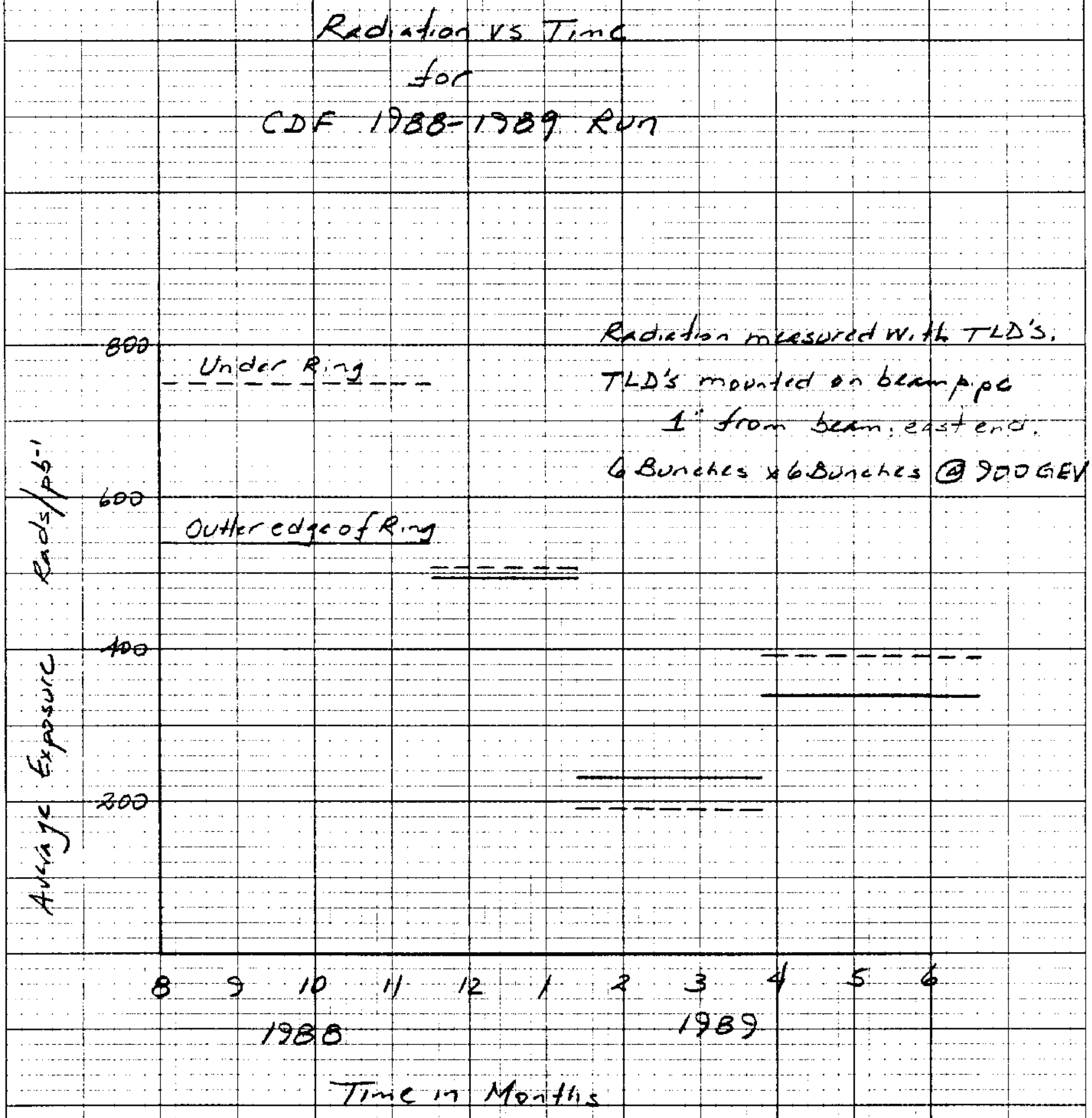

Figure 2

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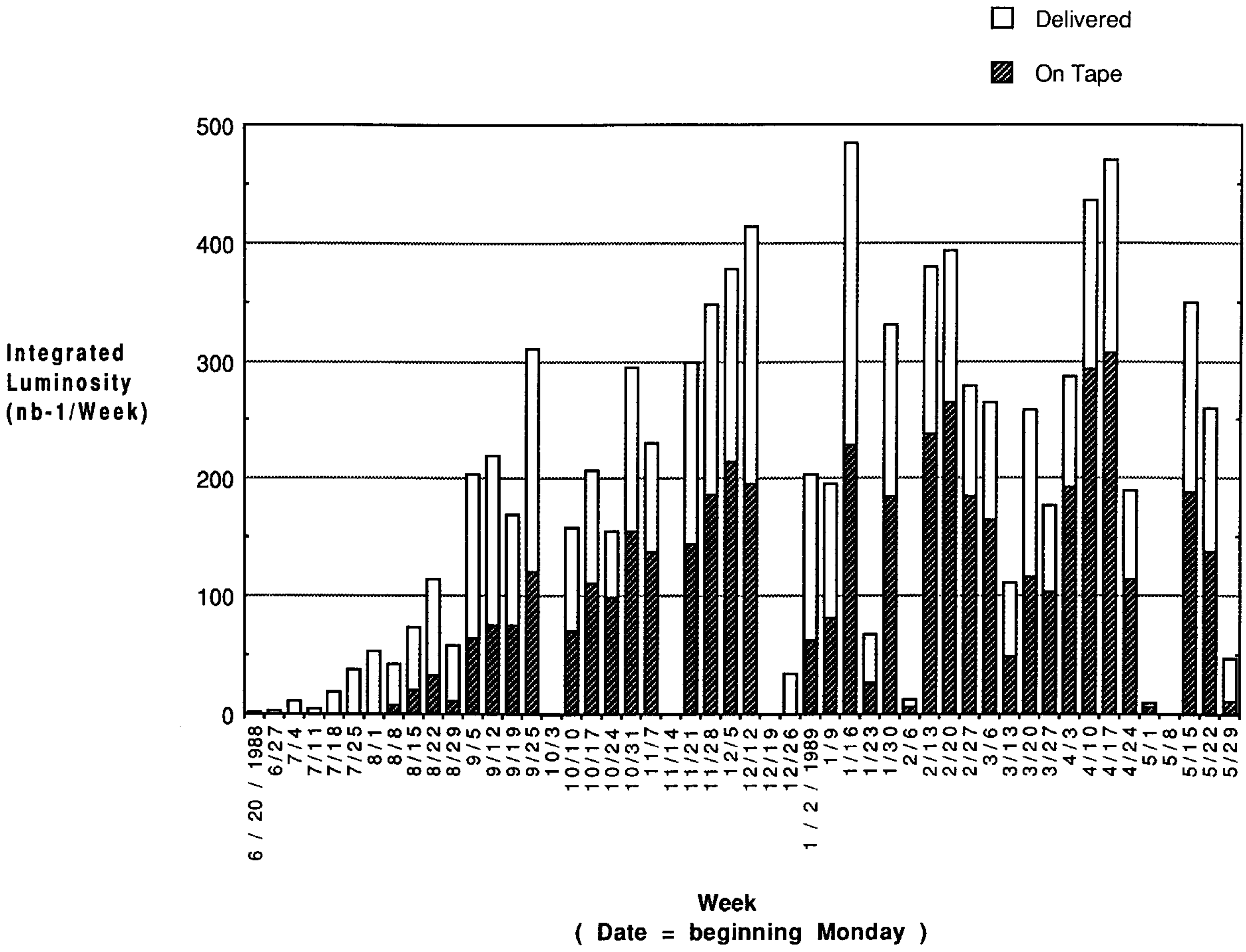
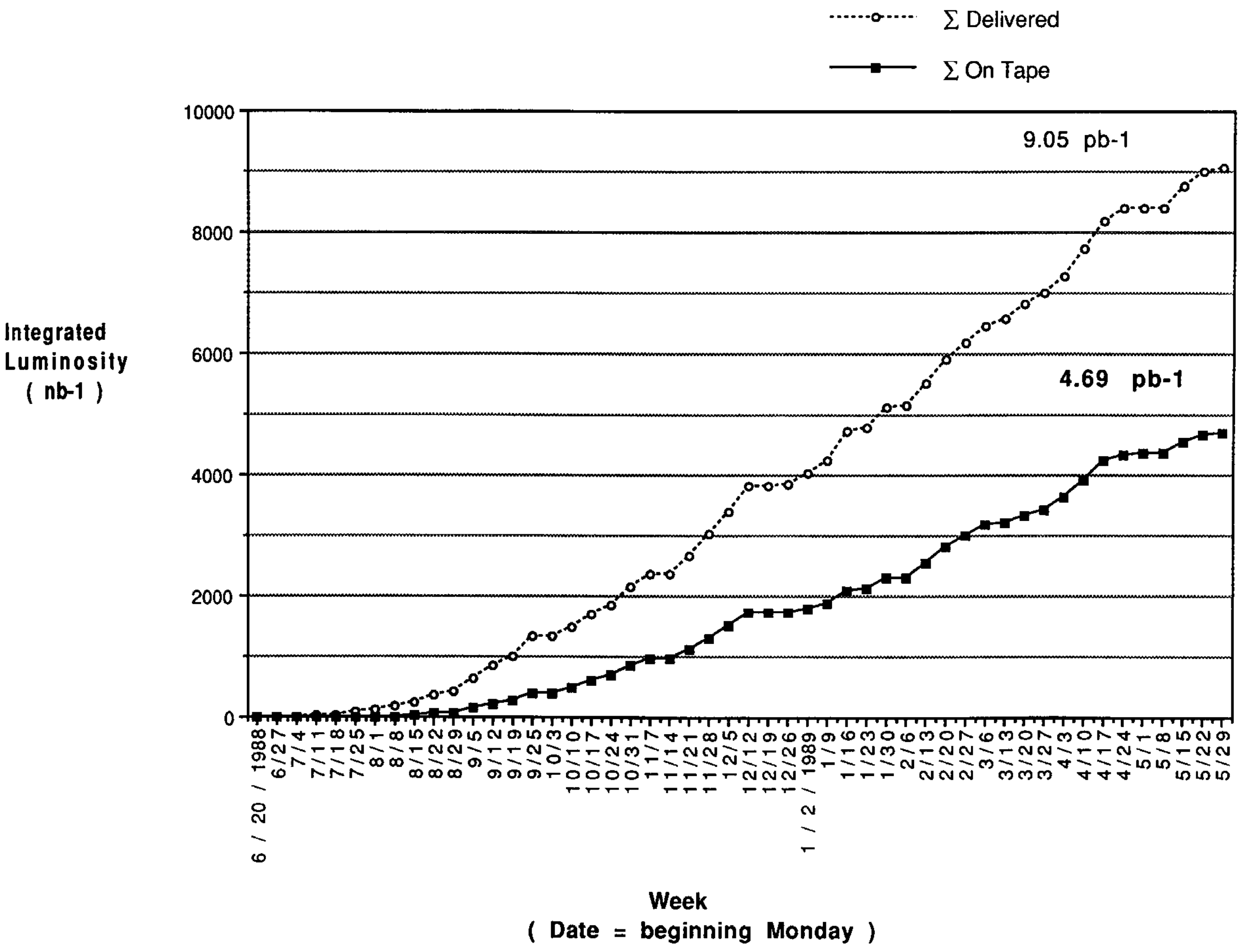

Delivered
On Tape
Integrated Luminosity (nb-1/Week)
500
400
300
200
100
0
6 / 20 / 1988
6/27
7/4
7/11
7/18
7/25
8/1
8/8
8/15
8/22
8/29
9/5
9/12
9/19
9/25
10/3
10/10
10/17
10/24
10/31
11/7
11/14
11/21
11/28
12/5
12/12
12/19
12/26
1 / 2 / 1989
1/9
1/16
1/23
1/30
2/6
2/13
2/20
2/27
3/6
3/13
3/20
3/27
4/3
4/10
4/17
4/24
5/1
5/8
5/15
5/22
5/29
Week
(Date = beginning Monday)

Figure 3



Σ Delivered
Σ On Tape
9.05 pb-1
4.69 pb-1
Integrated Luminosity (nb-1)
10000
8000
6000
4000
2000
0
6 / 20 / 1988
1 / 2 / 1989
5/29
Week
(Date = beginning Monday)

Figure 4

radiation, however, is thought to come from the CDF run. Figures 3 and 4 provided by J. Cooper are included for reference. They show the integrated luminosity over the course of the run. Data from these figures was used to normalize the TLD measurements.

The exposure received by the third set of TLD's may represent a lower limit for running with 6 bunches on 6 bunches at 900 GEV. Radiation levels would then be increased from that limit by main ring tuning or setup losses or higher intensity levels.

Radial Distribution of Radiation

A large array of TLD's were installed to determine the radial distribution of radiation at the east end of the VTPC detector. TLD's were placed at 1", 2.5", 4", 6", and 8.5" from the center of the beam. The array which was installed from 3/24 to 6/15 included exposure from the end of the CDF run and 2 weeks of low intensity main ring tests. As mentioned before, most of the exposure is due to the CDF run. Figure 5 is a plot of the measured radiation levels. Data has been normalized to the 2.2 pb-1 which were delivered to CDF during that time period. As can be seen, near the beampipe radiation levels have an azimuthal dependence of almost 2 to 1. Radiation levels at the beampipe are highest on the inside of the ring. There are some anomalies such as the single high reading at 8.5" on the outside of the ring or 0 rads at 6". While these are not understood, they are thought to be related to human errors or mishandled TLD's.

Also apparent is the large dependence of radiation on radial position. Averaging those numbers from the array which are reasonably consistent with numbers from other devices at similar locations gives a picture of the radial dependence. Figure 6 plots the average radiation level versus distance from the beam. Empirically, the radiation is approximately proportional to (1/radius) to the 1.5 power. Shown on the bottom of Figure 6 is the expected location of the 4 layers of silicon and readout chips for the proposed CDF upgrade. From the inner location to the outer location there is about a 5:1 change in the radiation level. Radiation at the inner level is about 360 rads/pb-1 +/- 20% depending on the azimuthal angle. Thus for a run of 40 pb-1 delivered to CDF (as expected for the next run), a radiation level of about 14.4 Krads at the inner level can be expected. At the outer level, a radiation exposure of about 3 Krads can be expected.

Z Axis Variation

Little radiation monitoring was done on the west end of the CDF detector. TLD's in only one location were installed over the course of the run. Therefore it is hard to make a general comparison between the east and west end of the detector. Results of measurements on the west end

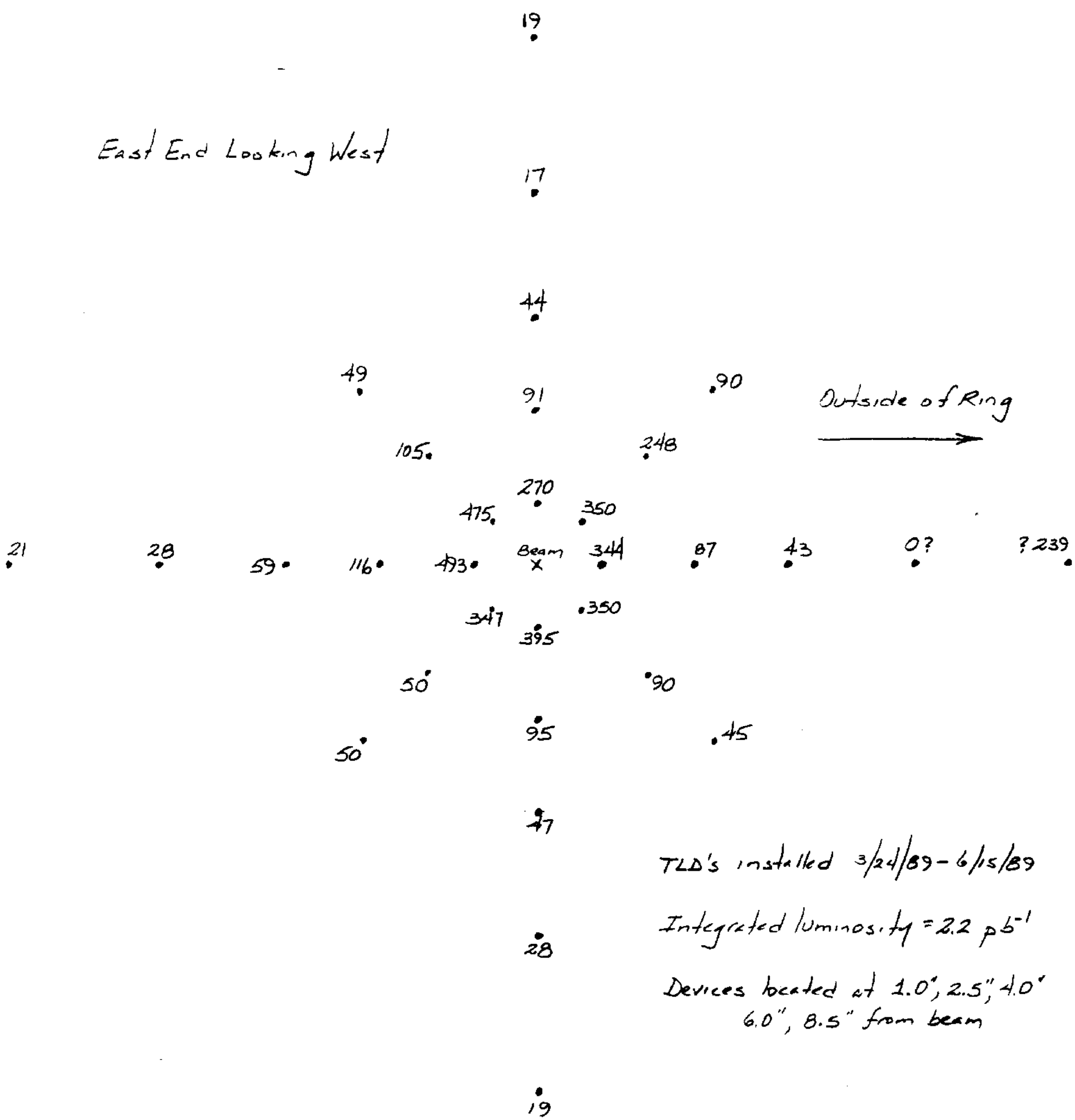


Figure 5- Radiation at East End of Detector
In Rads per pb^{-1}

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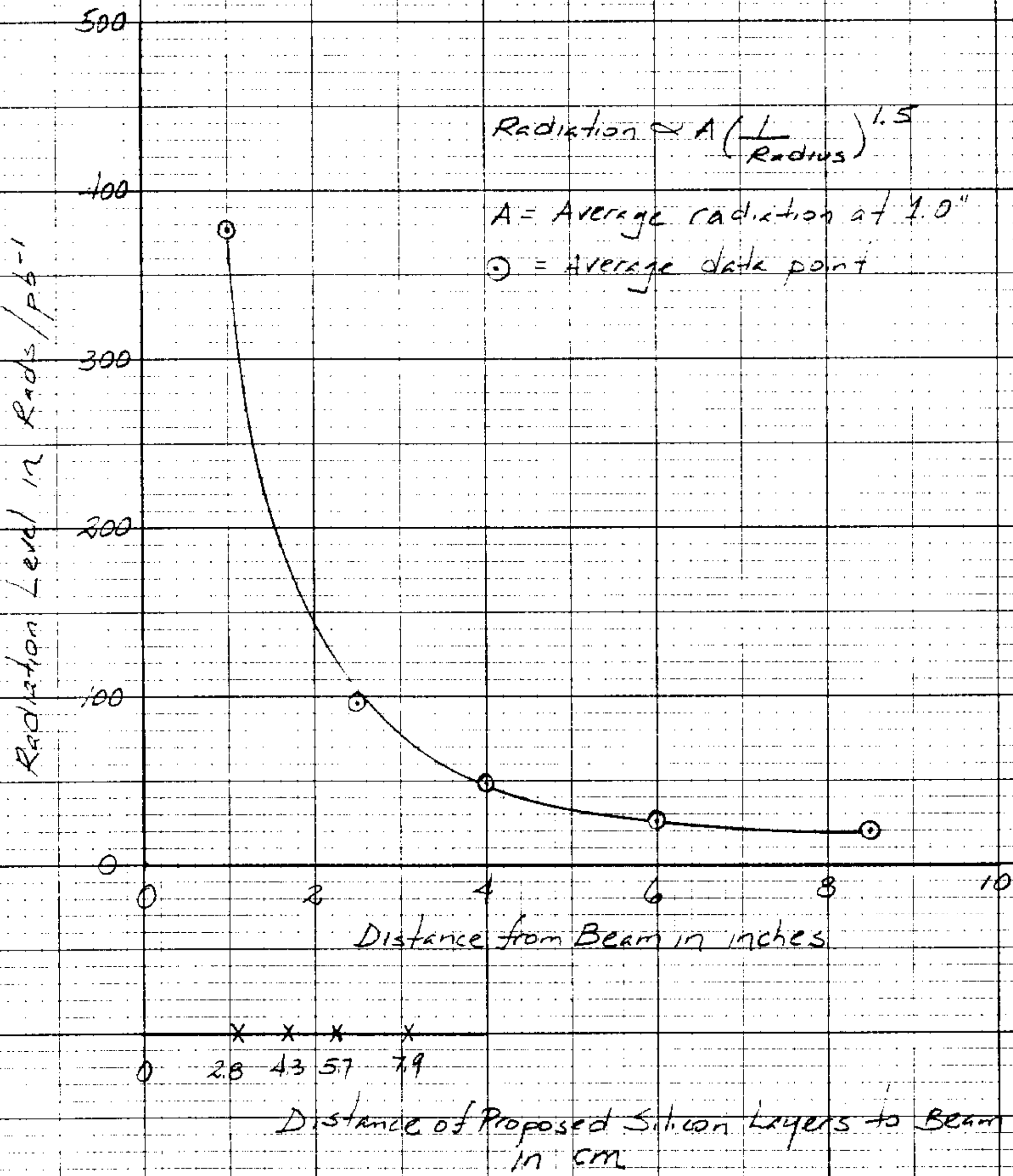

Figure 6 - Radiation vs Radial Distance

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are given in Table 1. The same general trend seen on the east end is present on west end. Specifically, the radiation exposure per inverse picobarn decreases as the run continues.

Dates Exposed	Integrated Luminosity	Radiation Level	Exposure (R/pb-1)	Location (1" from beam)
8/1/88-11/14/88	2.4pb-1	1800R	750	Top of beampipe
11/22/88-1/10/89	1.6pb-1	1000R	625	Top of beampipe
1/10/89-6/15/89	5.0pb-1	2495R	499	Top of beampipe

Table 1 - West End Radiation

A comparison of the absolute value of the radiation exposure on the east and west ends is more difficult due to the limited number of TLD's used. However, comparison of the values in the above table to the levels shown in Figure 2, show that the exposure rates for the 2 ends are within a factor of 2 of each other.

Neutron Measurements

PIN diodes were installed along with the TLD's in many locations to measure neutron radiation. See Figure 1. Some diodes were installed with remote readout capability while others had to be removed to be measured. The diodes with remote readout had to be checked with the magnet deenergized. Presence of the magnetic field gave highly inaccurate readings.

Neutrons change the forward drop characteristic of the PIN diode. For the types of exposures encountered there is little annealing within the diodes. Thus the changes in the diode forward drop at a fixed current level provide a permanent measure of the neutron dose. Results of the PIN diode measurements are shown in Table 2. As can be seen, there is substantially less radiation per inverse picobarn than measured by the TLD's. The TLD's are insensitive to neutrons whereas the PIN diodes are only sensitive to neutrons.

Again, there does not appear to be a significant difference between radiation measured by the PIN diodes at the east and west ends of the detector. (Probably less than a factor of two.) However, the neutron radiation does drop rapidly with radius. The relationship appears to be reasonably consistent with the (1/radius) to the 1.5 power observed with the TLD's.

The energy of the neutrons is thought to be relatively low. The uncertainty of the neutron energy spectrum makes absolute measurement of the neutron radiation level also uncertain. The present diodes are calibrated for a spectrum centered around 1 MEV. If the neutron energy was 25 MEV instead, the radiation levels would be approximately twice that which is reported. Since the radiation levels are already low, this uncertainty is not considered significant at the present time.

Dates Installed	Integrated Luminosity	Radiation Level	Exposure R/pb-1	Location
8/1/88 - 1/25/89	4.0pb-1	35R	8.7	East end, top of beampipe, 1" from beam
8/1/88 - 1/25/89	4.0pb-1	40R	10	East end, inside of ring, 1" from beam
1/25/89 - 6/15/89	5.0pb-1	35R	7	East end, top of beampipe, 1" from beam
1/25/89 - 6/15/89	5.0pb-1	30R	6	East end, inside of ring, 1" from beam
11/22/88 - 6/15/89	6.6pb-1	90R	13	East end, 135° from top of beampipe, 1" from beam
11/22/88 - 6/15/89	6.6pb-1	50R	7.5	West end, inside of ring, 1" from beam
11/22/88 - 6/15/89	6.6pb-1	50R	7.5	West end, bottom of pipe, 1" from beam
3/24/89 - 6/15/89	2.2pb-1	6R	2.7	East end,top of beampipe,2.5" from beam
3/24/89 - 6/15/89	2.2pb-1	6R	2.7	East end, outside of ring, 2.5" from beam
3/24/89 - 6/15/89	2.2pb-1	6R	2.7	East end, bottom of pipe, 2.5" from beam
3/24/89 - 6/15/89	2.2pb-1	6R	2.7	East end, inside of ring, 2.5" from beam

Table 2 - Neutron Radiation Measurements

Summary

Exposure rates inside the detector were found to decrease over the course of the 1988 - 1989 run. Thus care during the early part of a run could reduce the overall exposure of critical electronics mounted inside the detector.

The exposure rate inside the detector near the beampipe was found to be proportional to (1/radius) to the 1.5 power. Electronics placed close to the beampipe can be expected to receive substantially more radiation than other electronics placed only a few more centimeters away from the beam. Sensitive electronic devices such as CMOS chips could behave quite differently depending on their location near the beampipe.

The neutron radiation level appears to be quite small compared to the overall radiation present. Ionizing radiation which is more damaging to CMOS devices is more prevalent inside the CDF detector.

Acknowledgements

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