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E.P. NOTE 19

Summary of MERL On-site and Off-site radiation Surveys For the 1999 Fixed Target Run

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Introduction

The Fermilab 1999 fixed target experimental program started stable beam operations in June 1999 and ended on the 17^{th} of January 2000. This note describes the results of on and off Fermilab site measurements and surveys of muon and neutron fluences due to the operation of the fixed target beam lines. The purpose of these surveys is to ensure that Fermilab operations are within the environmental and facility design limits, and radiation dose to the public and Fermilab employees is below the various regulatory requirements (FR99). These measurements were conducted using MERL, the Mobile Environmental Radiation Laboratory (El89).

During this Fixed Target run only three beam lines were operating, The KTeV experiment running on the Neutrino-Muon beam line, E-871 running on the Meson Center (MCenter) beam line, and the Meson Test (MTest) beam line that was used for testing detectors for several different experiments. MT runs were intermittent, and the beam line was operating during only a fraction of the Fixed Target run.

A Brief Description of the MERL Detectors

The muon detector consists of two overlapping plastic scintillator paddles with a one-inch thick aluminum plate in between to eliminate non-muon coincidence rates. For neutron detection a Long Counter is used. This detector consists of a BF_3 proportional tube within a paraffin enclosure. The paraffin jacket is fine-tuned to make the counter response to neutrons fairly constant over a wide range of energies up to 19 MeV (Kn79, Sl77).

Both scintillator paddles were tested and gain matched using gamma ray sources and muons downstream of KTeV experimental area. The Long Counter was calibrated with radioactive neutron sources and a gamma ray source. The Long Counter's detection threshold was raised until the signals produced by the gamma rays were not detectable.

A laptop computer with built-in modem and cell phone was used to connect to the Beams Division machines status display screen. This information was used to make sure that the beam was being delivered to the beam line under observation.

A Brief Description of the Measurements

For the 1999 Fixed Target run the accelerator beam spill length was 80 seconds with a 40-second flattop. Timing signals from the accelerators at the start and end of the flattop were used to generate gates for beam-on and beam-off (background) data acquisition. The number of protons per spill for each of the operating beam lines was also recorded.

The measurements were scheduled for stable periods of the beam line operations. The MTest measurements were hardest to plan since tests ran over short periods, and the beam line operated differently for each test.

An aerial map of the site was used to extrapolate the direct line of sight of the beam down stream of each beam line. This extrapolation spanned several roads on site and out to Roosevelt road on the northern boundary of the Fermilab site.

The measurements were done by scanning along the roads that crossed the line of sight of the beam lines. Each beam line was scanned over a distance of about 1000 ft., in 20 to 30 ft. steps. On Roosevelt road the measurements were done at 60-ft. intervals. Three measurements were made at each step, with each measurement lasting one beam cycle.

Discussion and Results

No significant neutron fluence was observed around or downstream of any of the operating beam lines.

The dose equivalent due to muons were calculated based on the assumption that 25000 muons per square centimeter of the muon detector is equivalent to one mrem. The uncertainties quoted are based on statistics only. The maximum value of muon dose equivalent at each location is given below.

1. KTeV

The muon cone from the KTeV target points upward. The rates observed at places other than down stream of the NM2 experimental area (Fig. 1.) are probably from the penumbra of the muon cone. That is the reason for not giving the distance from the source in the tables below. The results of the measurements for KTeV are given in the Table 1. The annual dose at each location is based on the total 1999 protons delivered to the KTeV experiment.

Table 1. Muon dose rate down stream of KTeV in the order of increasing distance from the target. Elwyn Road is the road to the east off of Powerline Road and Route 38.

Location	Max. Dose (microrem/proton)	Max. Dose Error (microrem/proton)	Max. Annual Dose (millirem)	Max. Annual Dose Error (millirem)	%Max. Annual Dose Error
DS of NM2	3.78E-14	3.26E-16	23.8	0.20	0.9%
Stanfield Pass	5.86E-15	1.54E-16	3.68	0.10	2.6%
Lab G	9.04E-17	4.94E-17	0.06	0.03	54.7%
Eola Road	1.83E-16	1.10E-16	0.12	0.07	60.0%
DS of NML	1.33E-16	5.31E-17	0.08	0.03	39.8%
Elwyn Road	1.28E-16	5.23E-17	0.08	0.03	40.9%
Roosevelt Road	4.80E-17	5.38E-17	0.03	0.03	112.1%
Total KTeV protons=	6.29E+17				

2. MCenter

The muon beam from this beam line is pointed up, but I was still able to see the tails (penumbra) of the muon cone on Batavia (Fig.2), Wilson and Roosevelt roads.

Table 2. Muon dose rate down stream of MCenter in the order of increasing distance from the target. Batavia road is the road directly in back of MWest, MCenter and MP.

Location	Max. Dose (microrem/proton)	Max. Dose Error (microrem/proton)	Max. Annual Dose (millirem)	Max. Annual Dose Error (millirem)	%Max. Annual Dose Error
Batavia Road	2.39E-12	1.26E-14	61.10	0.32	0.5%
Wilson Road	7.16E-14	2.73E-15	1.83	0.07	3.8%
Roosevelt Road	2.32E-15	9.12E-16	0.06	0.02	39.3%
Total MCenter protons=	2.56E+16				

3. MTest

No discernible peak was observed from this beam line on site. On Roosevelt road, a muon peak along the line of sight of this beam line was observed, but only during BTeV detector tests (Fig. 3). Therefore, the site boundary value is a very conservative choice.

Table 3. Muon dose rate down stream of MTest in the order of increasing distance from the target.

Location	Max. Dose (microrem/proton)	Max. Dose Error (microrem/proton)	Max. Annual Dose (millirem)	Max. Annual Dose Error (millirem)	%Max. Annual Dose Error
Batavia Road	0	0	0.00	0.00E+00	0
Wilson Road	0	0	0.00	0.00E+00	0
Roosevelt Road	1.24E-14	2.07E-15	0.10	1.72E-02	16.7%
Total MTest Protons=	8.30E+15				

Conclusion

All the beam lines are designed so that the centerlines of muon plums produced at the target locations would not be along the surface. Most are designed for the muons to range out under the ground and some, like KTeV or MCenter are designed such that the muon cone will be exiting the ground at a steep angle, at an inaccessible location. Thus the measured values shown in the tables do not scale as the inverse-square of the distance from the source, since different parts of the muon cone are sampled at the measurement locations. The absence of neutron fluence associated with any beam is also associated with the shielding design of the facility.

MTest annual dose given above is based on the assumption that all the protons were delivered during the BTeV detector tests. However, the BTeV detector test took only a fraction of the above protons, and no significant muon fluence due to other test runs at MTest was detected. Note also that the results for the MTest beam line are specific to the 1999 run and should not be used to predict dose rate due to future operations of this beam line.

The dose to the public due to muons and neutrons generated by the operation of the Fixed Target beam lines was well below the regulatory limits.

References

FR99 Fermilab Radiological Control Manual (FRCM), 1999 revision.

El89 A. Elwyn, "Mobile Environmental Radiation Monitoring", Radiation Physics Note 76, February 1989.

Kn79 G. F. Knoll, "Radiation detection and measurement" (John Wiley and Sons, New York, 1979). A second edition of this text has been produced.

Sl77 D. R. Slaughter and D. W. Rueppel, "Calibration of a DePangher long counter from 2 keV to 19 MeV", Nucl. Instr. and Meth. 145 (1977) 315-320.

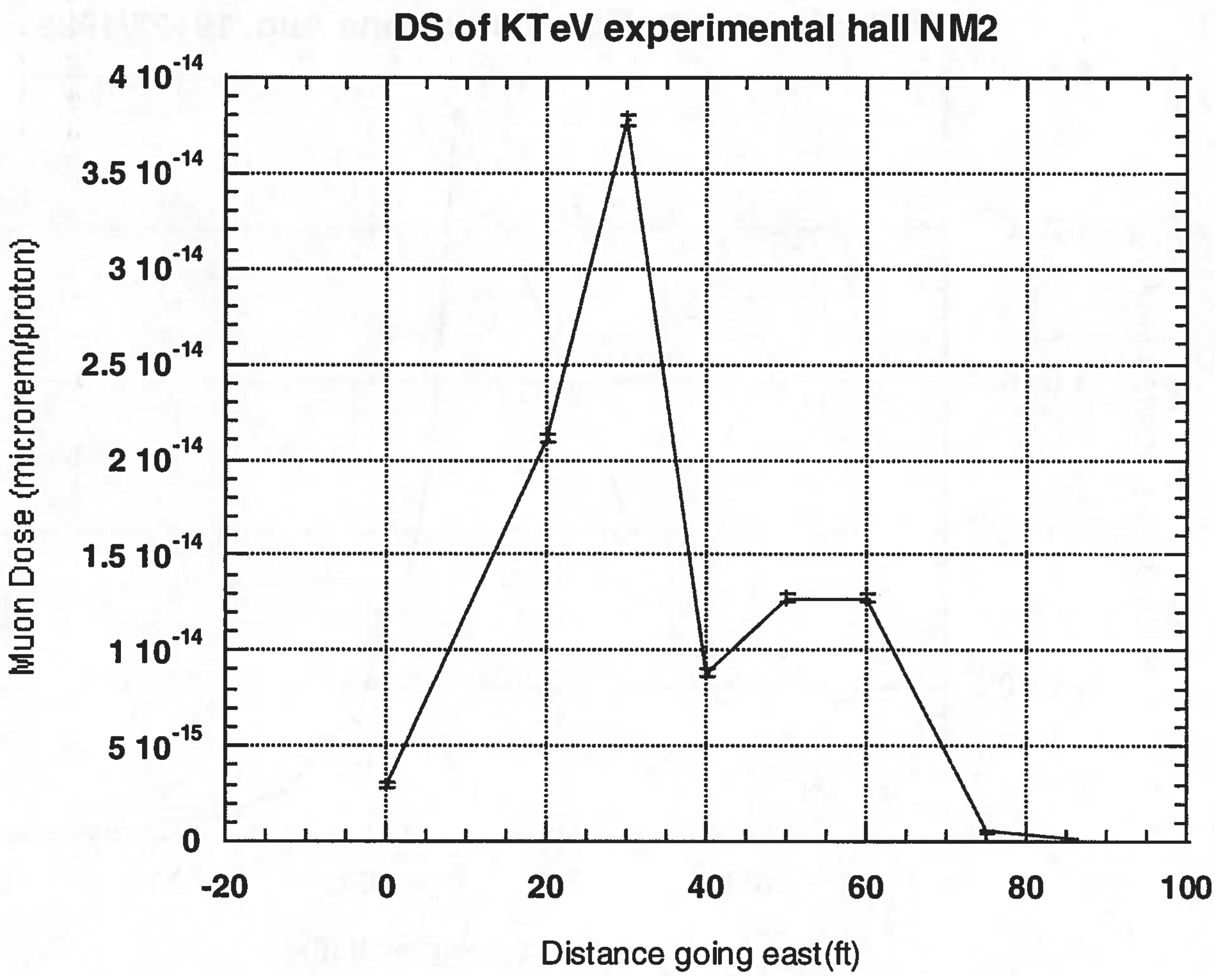

Figure 1. Muon dose rate outside the KTeV experimental area. The first point is where the back of the MERL was against the west wall.

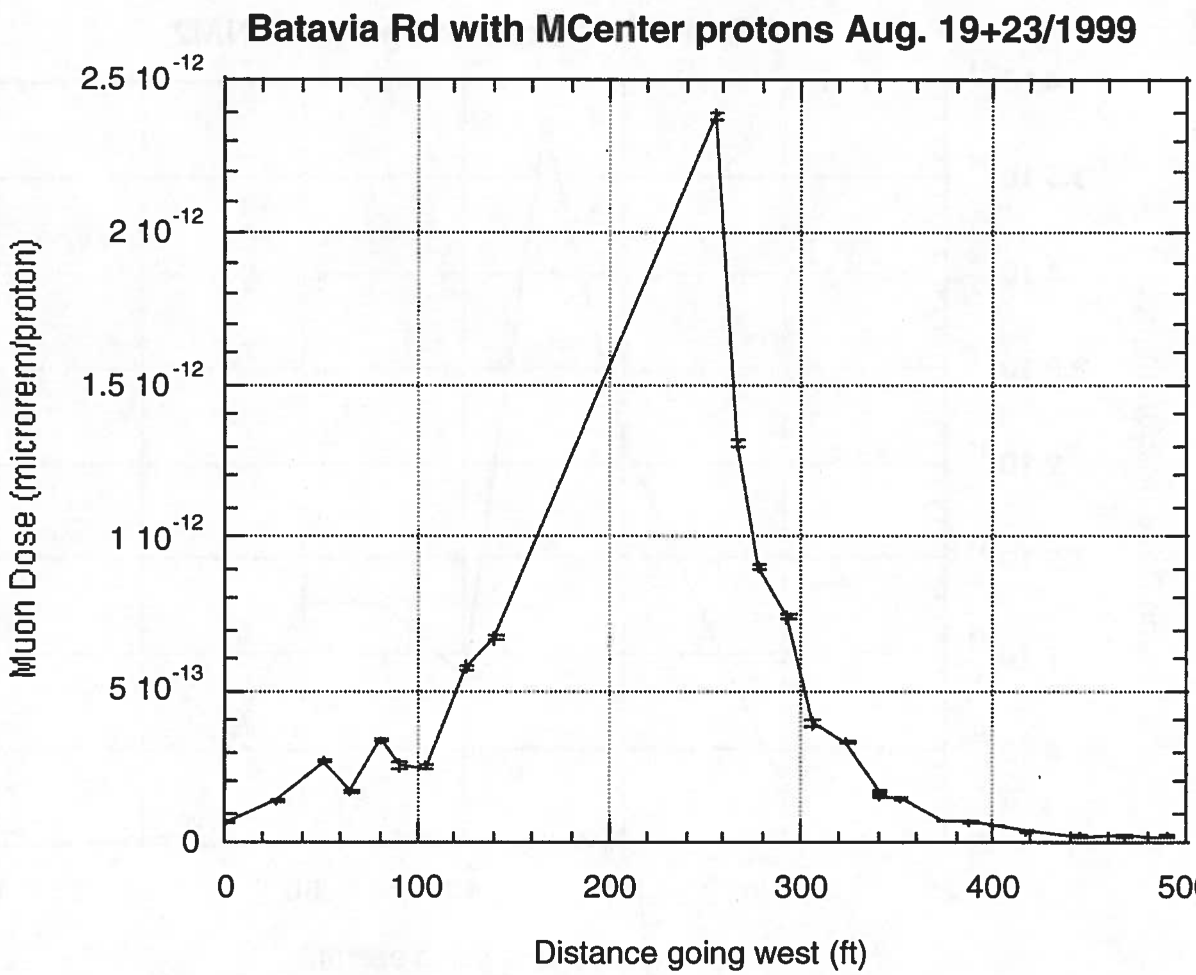

Figure 2. Muon dose rate on Batavia road downstream of MCenter experimental area.

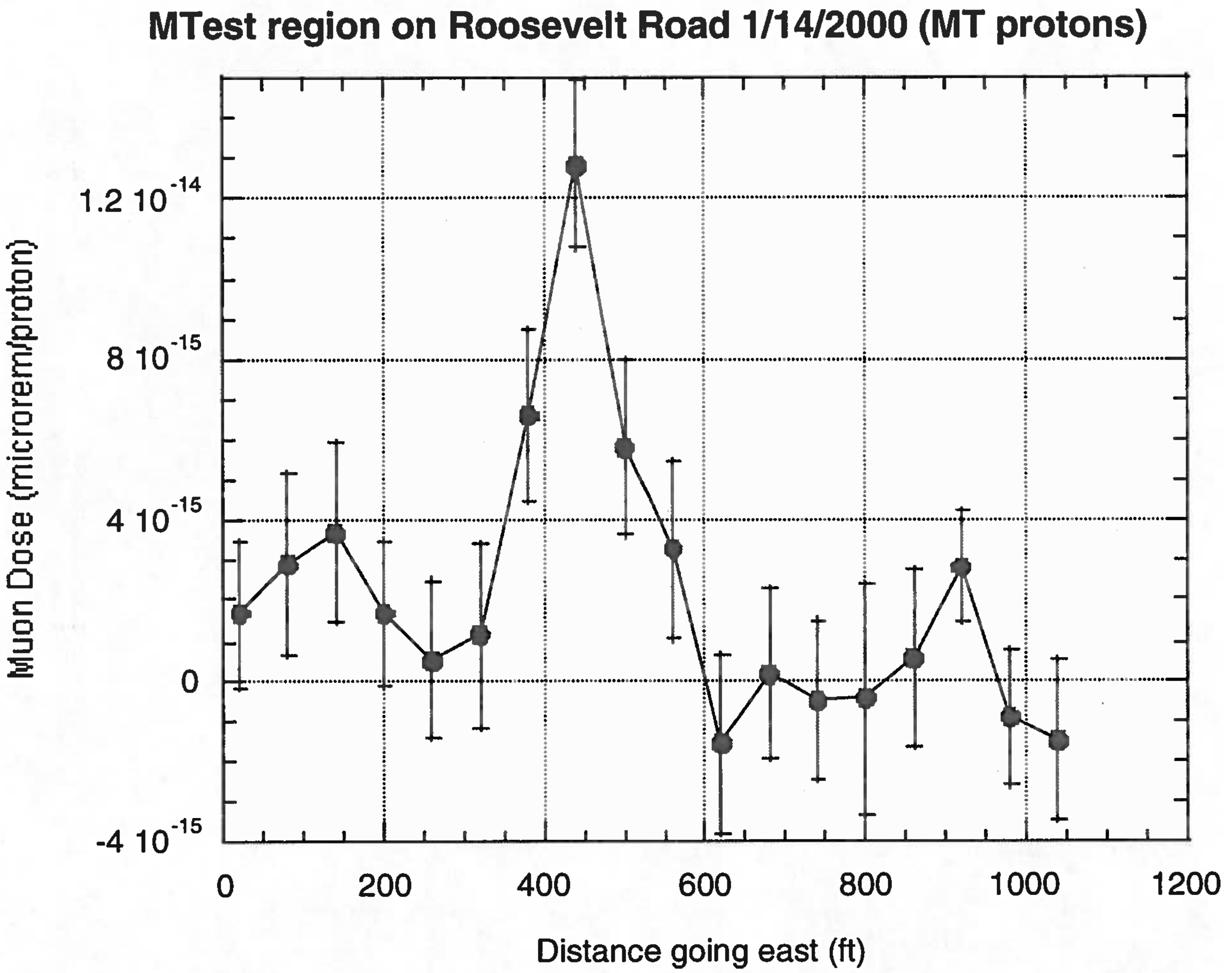

Figure 3. Muon dose rate on Roosevelt road downstream of MTest experimental area during the BTeV detector test. The small pick on the right is along the line of sight from MCenter.