Report for: Ground Motion studies at NuMI.

Personnel and Institution(s)
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Collaborators
FNAL: Shekhar Mishra, Vladimir Shiltsev.

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Project Overview

Ground motion can cause significant deterioration in the luminosity of a linear collider. Vibration of numerous focusing magnets causes continuous misalignments, which makes the beam emittance grow. For this reason, understanding the seismic vibration of all potential LC sites is essential and related efforts in many sites are ongoing.

In this document we summarize the results from the studies specific to Fermilab grounds as requested by the LC project leader at FNAL, Shekhar Mishra in FY04-FY06. The Northwestern group focused on how the ground motion effects vary with depth. Knowledge of depth dependence of the seismic activity is needed in order to decide how deep the LC tunnel should be at sites like Fermilab. The measurements were made in the NuMI tunnel, see Figure 1. We take ad- vantage of the fact that from the beginning to the end of the tunnel there is a height difference of about 350 ft and that there are about five different types of dolomite layers.

The support received allowed to pay for three months of salary of Michal Szleper. During this period he worked a 100% of his time in this project. That include one week of preparation: 2.5 months of data taking and data analysis during the full period of the project in order to guarantee that we were recording high quality data.

Summary of Results

We extended our previous work and made more systematic measurements, which included detailed studies on stability of the vibration amplitudes at different depths over long periods of time. As a consequence, a better control and more efficient averaging out of the daytime variation effects were possible, and a better study of other time dependences before the actual depth dependence was obtained. Those initial measurements were made at the surface and are summarized in Figure 2.

All measurements are made with equipment that we already had (two broadband seismometers KS200 from GEOTECH and DL-24 portable data recorder).

The offline data analysis took advantage of the full Fourier spectra information and the noise was properly subtracted. The basic formalism is summarized if Figure 3.
The second objective was to make a measurement deeper under ground (Target hall, Absorber hall and Minos hall – 150 ft to 350 ft), which previous studies did not cover. All results are summarized in Figure 3 and 4.

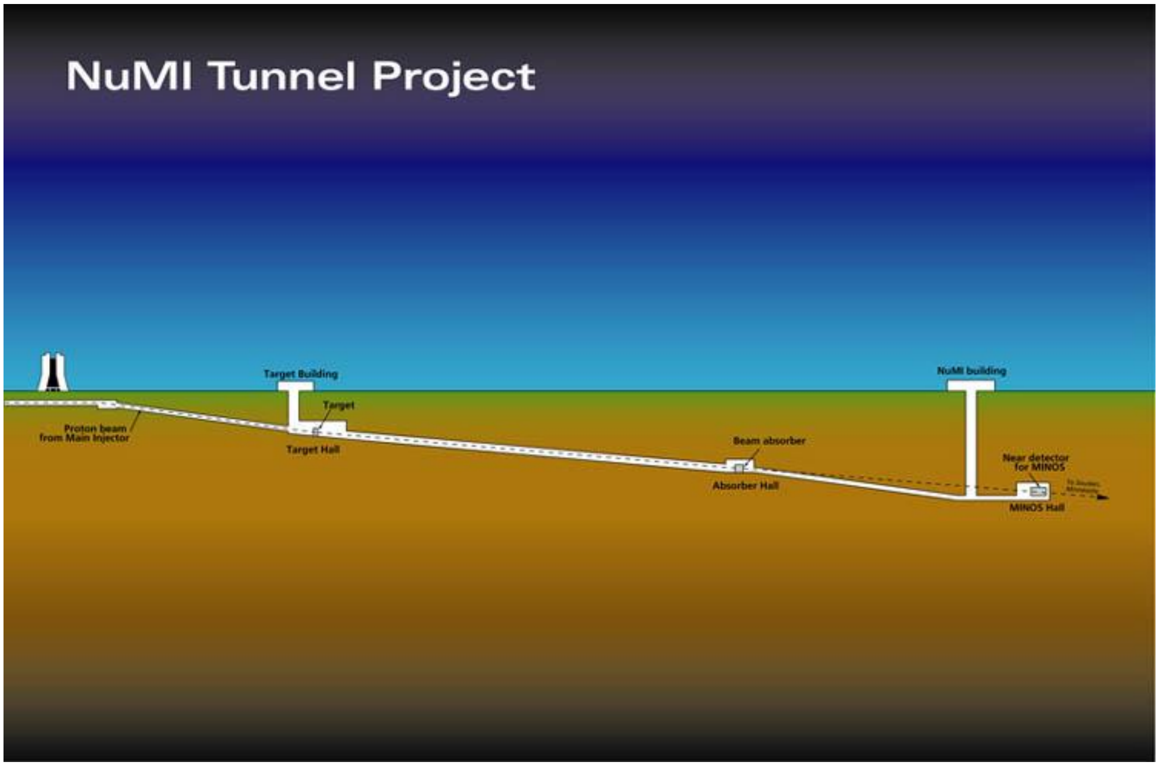

Figure 1: Schematic of NUMI tunnel at Fermilab.

The measurements were covering a frequency range between 0.1 to 50 Hz. The data was taken continuously for at least a period of two weeks in each of the locations.

We concluded that the dependence on depth is weak, if any, for frequencies above 1 Hz and not visible at all at lower frequencies. Most of the attenuation (factor of about 2-3) and damping of ground motion that is due to cultural activity at the surface is not detectable once we are below 150 ft underground. Therefore, accelerator currently under consideration can be build at the depth and there is no need to go deeper underground is built at Fermi National Laboratory.

- Power spectral densities from either probe $z_1(t), z_2(t)$:

  $$P_{ij}(f) = \int\int z_i(t) z_j(t') e^{-i\omega(t-t')} dt dt',$$

- Correlation between probes:

  $$C(f) = < P_{12} > / \sqrt{< P_{11} >< P_{22} >},$$

- Measure of intrinsic noise level - power spectrum of the difference:

  $$D(f) = | \int [z_1(t) - z_2(t)] e^{-i\omega t} dt|^2,$$

- The average vibration amplitude (RMS of vibration) for $f' > f$:

  $$A(f) = \sqrt{\int_{f_{max}}^{f} P_{ii}(f')\, df'}.$$

Figure 2: Fourier analysis used in the offline analysis of the data.

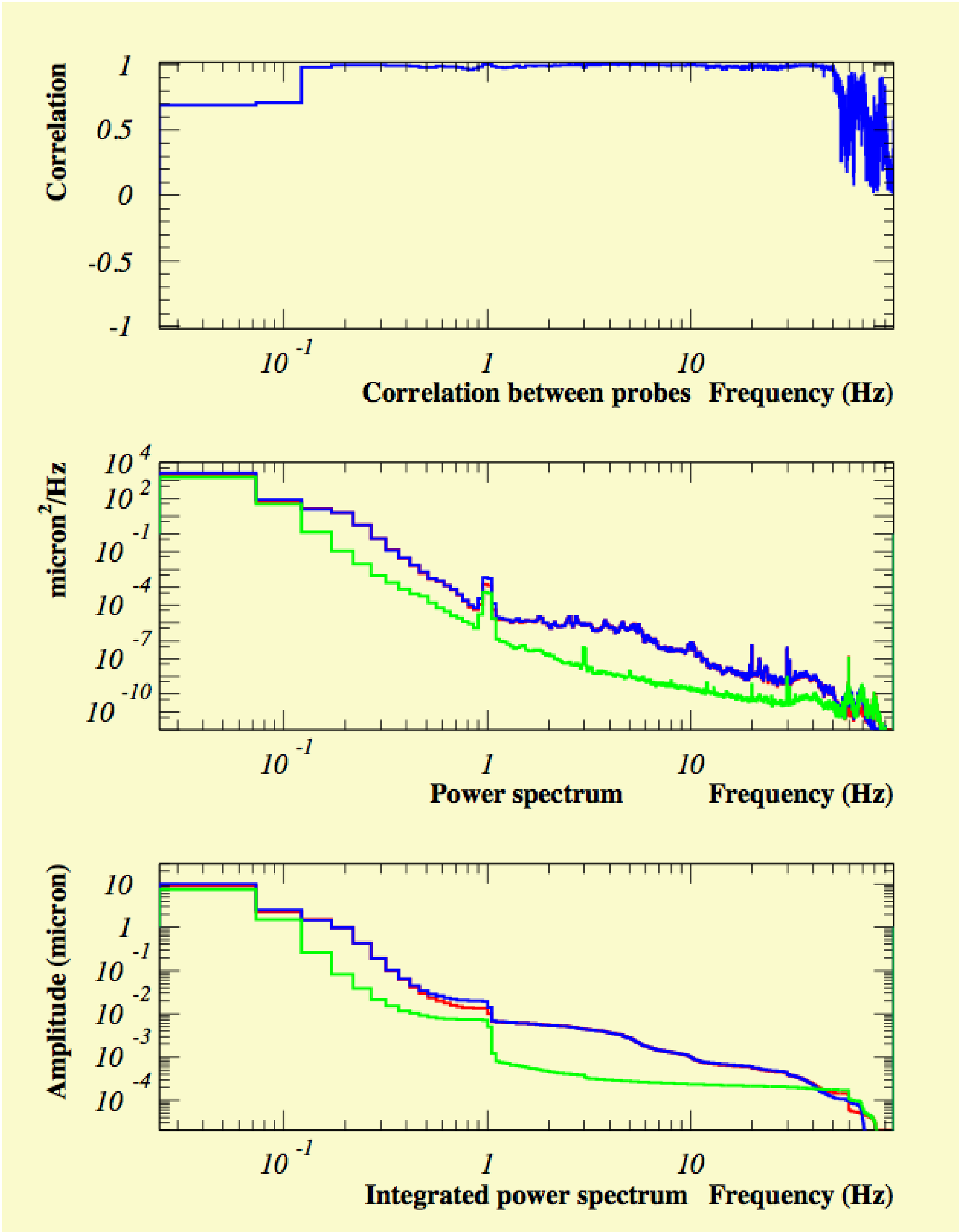

Figure 3: Measurement made at the surface.

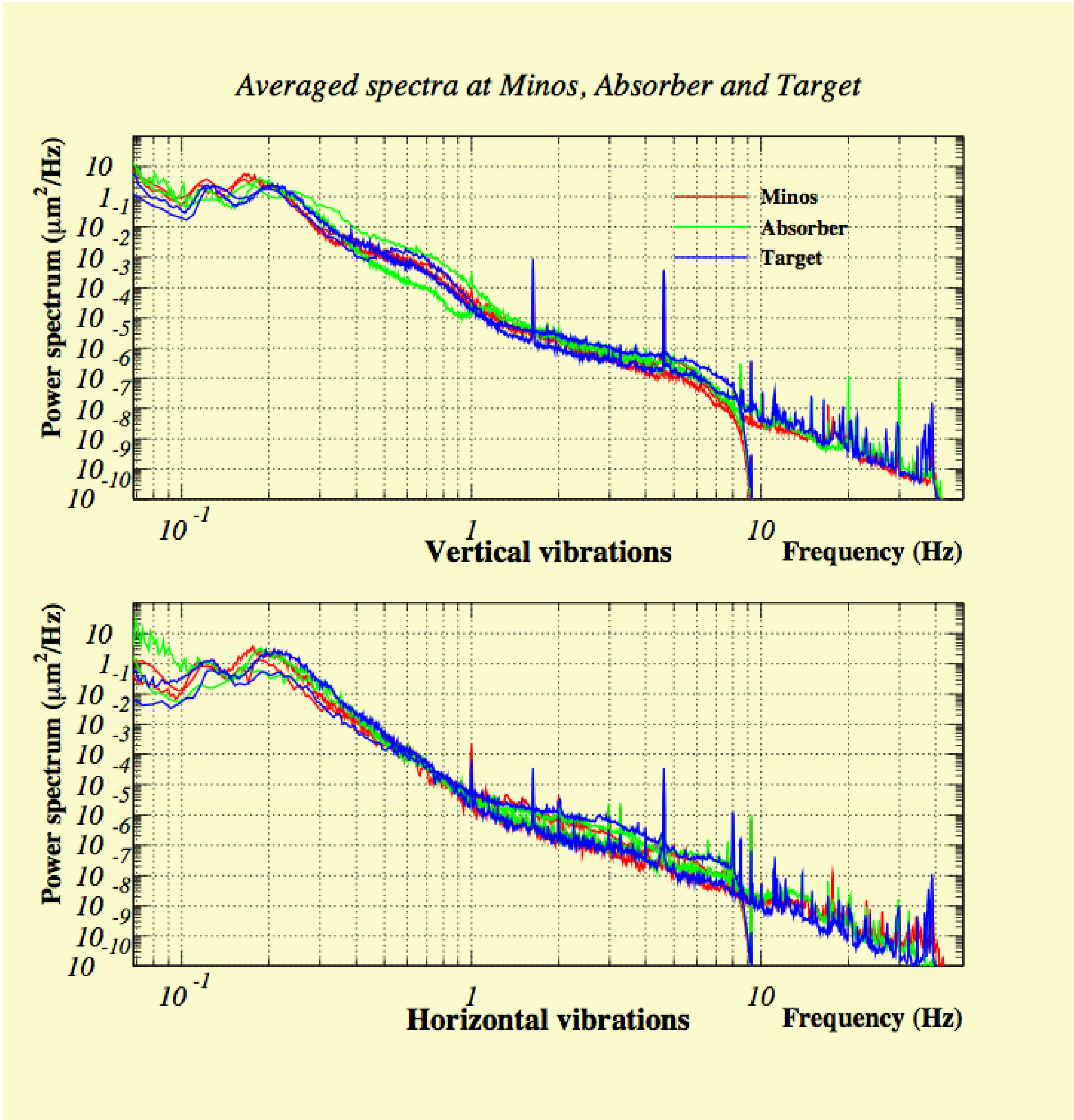

Figure 4: Time average spectra

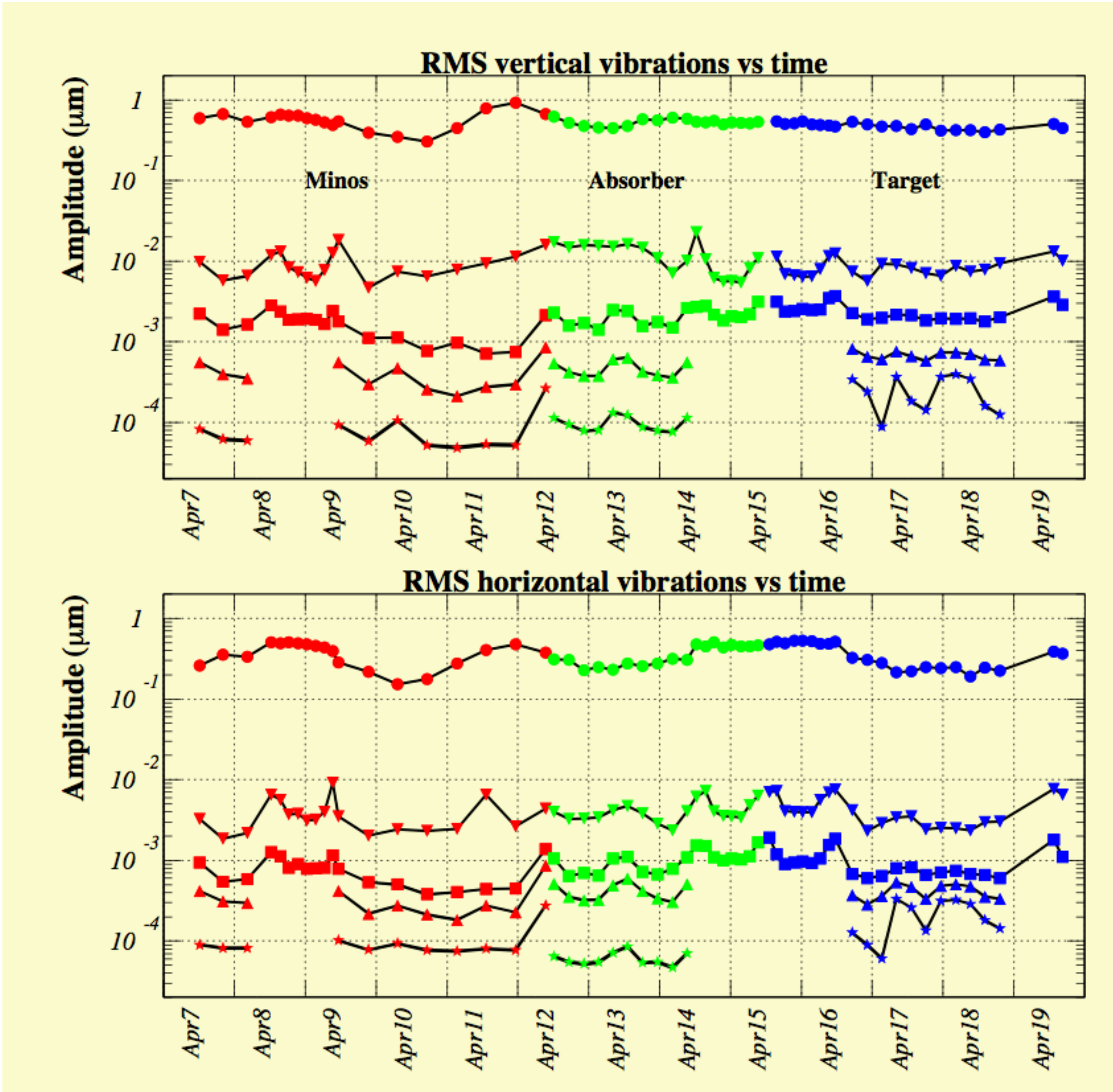

Figure 5: Width of vibration as a function of time.