

Proposal Name: Ground Motion studies at NuMI. ¹

Classification (subsystem)

Beamline, interaction region stability.

Personnel and Institution(s) requesting funding

Northwestern University, Department of Physics and Astronomy:
Mayda Velasco (Assistant Professor),
Michał Szeleper (Research Associate),
Summer student.

Collaborators

FNAL: Shekhar Mishra, Vladimir Shiltsev.

Project Leader

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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.

The proposed studies were requested by the LC project leader at FNAL, Shekhar Mishra. They will be a continuation of the measurements carried out recently by the Northwestern group, which 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 will be made in the NuMI tunnel. We take advantage 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 proposed study has two main goals. First, carrying extended and more systematic measurements which will check the stability of the vibration amplitudes at different depths over

¹ Item ID 55: R & D list for NLC available in <http://www-conf.slac.stanford.edu/lcprojectlist/asp/projectlistbyanything.asp>.

long periods of time. This will allow a better control and more efficient averaging out of the daytime variation effects and a better study of other time dependences, before the actual depth dependence can be discerned with more accuracy. New measurements should also clarify the relatively few poorly understood features of the existing results. The second objective will be making a measurement in the first 150 ft under ground, which the previous study did not cover, but results provided motivation to do so.

The proximity of Northwestern to Fermilab allows us to go to the tunnel frequently in order to change the location of the probes, exchange storage disks and batteries for the equipment (whatever needed) and program data taking for the next period of time.

Broader Impact

We plan to hire a summer student to work on this project. The student will be hired from the SROP (Summer Research Opportunity Program) NU-minority program. This project may be a good opportunity for a young student to learn a variety of issues in modern experimental high energy physics, including both NuMI and LC issues, and to acquire some basic hardware and software skills.

In the past, we have already worked with both an undergraduate physics student and a prospective graduate student on ground motion projects.

Results of Prior Research

First test measurements were made in 2003 in the Aurora Mine, 200 ft below ground level, where measurements using a different equipment had already been made before (V. Shiltsev).

In spring 2004, the equipment was installed in the NuMI tunnel. Measurements were made at three locations inside the tunnel: in the NuMI target hall (depth ~ 150 ft), in the absorber hall (~ 280 ft) and in the MINOS near detector hall (~ 350 ft). Data taking lasted two weeks in total.

Measurements scanned effectively the frequency range of 0.1 - 50 Hz. From an offline data analysis, the following observations have been made:

- Vibrations below 1 Hz come mainly from natural sources. The vibration amplitudes vary slowly in time, but no regular pattern was observed within the timescale of the study.
- Dependence on depth of vibrations below 1 Hz seemed not be present, or could not be discerned outside the limits set by the natural time variations.
- Human activity is the main source of vibrations above 1 Hz. It presents significant day/night and weekday/holiday variations, amounting up to a factor of 3 in the total amplitude averaged over 30 minutes long intervals.
- Significant amount of vibrations above 1 Hz was due to local in-tunnel sources, many of them being strongly time dependent and irregular.

- Vibrations coming from surface sources were visible and their amplitudes depended on, besides depth itself, many details of the study location. These included, e.g., the distance to the nearest shaft or ventilation tunnel.
- Dependence on depth in the range of 150 - 350 ft below ground was found insignificant and possible to discern only after subtracting the vibrations from local sources. Since earlier studies revealed a drop by a factor of ~ 2 of the vibration amplitudes between ground level and 150 ft underneath, this precisely turned out to be the range where most attenuation happens.
- Vibrations in the vertical and horizontal directions were found similar to each other.
- Overall, vibration amplitudes were inside the tolerance limits of a linear collider, confirming earlier results from the NuMI target hall (DESY group, W. Bialowons et al.), from data collected with a different equipment.

Preliminary results were shown at the ICAR meeting in Argonne, May 2004 (see http://diablo.phys.northwestern.edu/~michals/mszleper_icar.pdf).

The final results were reported at the LC Workshop in Victoria, Canada, July 2004 (see http://diablo.phys.northwestern.edu/~michals/mszleper_victoria.pdf).

This research was funded by a grant from the state of Illinois to do accelerator development, ICAR.

Facilities, Equipment and Other Resources

Northwestern has invested \$25K in equipment toward this project using ICAR funds (see Table 1). Preparations, including learning the hardware, setting up the software, and organizational issues, involved altogether over a year of work. All of the equipment has been tested and its performance studied. We have been advised by people who had done similar ground motion studies at other sites in the past (in particular A. Seryi of SLAC). An offline Fourier analysis program has been adapted to work in a Linux environment and to input the required data format. Software has been developed to facilitate data analysis.

2	broadband seismometers	\$6,500.00	\$13,000.00
2	seismometer cables	\$325.00	\$650.00
1	DL-24 data recorder w/ 1 GB microdrive	\$11,240.00	\$11,240.00
1	12V 33 Ah battery	\$175.00	\$175.00
1	control interface	\$700.00	\$700.00
1	power supply	\$160.00	\$160.00
	handling charge		\$5.00
	shipping and insurance		\$160.00
total			\$26,050.00

We foresee the same equipment and software resources could be used for the proposed study. A desirable upgrade would concern a pair of new removable data storage disks (2×8 Gb capacity), as explained below.

FY2005 Project Activities and Deliverables

All the equipment is presently stored at Northwestern University and needs to be transported to Fermilab and installed in the NuMI tunnel.

A series of short test measurements will be made in order to check the proper operation of the hardware and online software. The quality of the data will be checked off-line.

Measurements must be made at a few different places in the tunnel, including the NuMI target hall, the absorber hall and the MINOS hall. Exact locations and times will depend on the accessibility of the relevant parts of the tunnel and must be negotiated with the NuMI management. Each measurement will be 3-4 weeks long. This will require several short accesses to the tunnel in order to replace the data storage disk and reprogram data taking for the next period of time. Offline data analysis will proceed in parallel.

These measurements will reveal the long-term variations of the seismic activity in different frequency ranges. The results will allow to determine the maximum size of natural variations of the vibration amplitudes below 1 Hz and provide more comparative input to test the stability of the results above 1 Hz. A longer data taking period will permit to separate the proper dependence on depth from daily and other accidental variations.

An additional measurement will be made in a selected location within the first 150 ft below ground. Depending on the accessibility, this measurement may take one or more days, or more than one measurement may be actually made. The results will determine how fast the noise attenuation occurs in this region.

FY2006 Project Activities and Deliverables

N/A

FY2007 Project Activities and Deliverables

N/A

Budget justification: Institution 1

The timescale to complete the project is defined mainly by the length and number of measurements and will be close to 3 months. As offline data analysis will run mostly in parallel, it will not change timescales significantly. Currently, we have no grant to cover a Research Associate position for LC related R&D. We therefore request funding for 3 months of salary for a Research Associate.

We request funding for travel that will cover the full expenses of the participation in international conferences or workshops, for the research associate and the PI. For example, we will like to participate in the ILC SNOWMASS summer study this year. We anticipate that at

least two such participations in total will be worthwhile and reasonable. We also anticipate at least one visit for further discussions and consultation with ground motion experts in other labs within the US.

The proposed measurements will be made using essentially the same equipment and computing resources we have used in our previous study. However, as we want to extend our measurements to cover much larger periods of time (and for technical reasons, possibly increase the probing frequency), we will be collecting and storing much larger amounts of data. Consequently, for all practical purposes, having a more efficient system for data storage and transfer will be important. The simplest upgrade would consist of using a pair of removable data storage disks (2×8 Gb capacity). Large disk capacity will decrease the frequency of necessary human accesses to the equipment down to a manageable level, while using two disks will allow quick exchange of one with another without losing much data taking time.

Three-year budget, in then-year K\$

\$28,489

Institution: Northwestern University

Item	FY2005	FY2006	FY2007	Total
Other Professionals	\$11,531	0	0	11,531
Graduate Students	0	0	0	0
Undergraduate Students	0	0	0	0
Total Salaries and Wages	\$11,531	0	0	11,531
Fringe Benefits	2,579	0	0	2,579
Total Salaries, Wages and Fringe Benefits	\$14,110	0	0	14,110
Equipment	\$2,500	0	0	2,500
Travel	\$6,000	0	0	6,000
Materials and Supplies	0	0	0	0
Other direct costs	0	0	0	0
Institution 2 subcontract	0	0	0	0
Total direct costs	\$22,610	0	0	22,610
Indirect costs(1)	5,876	0	0	5,876
Total direct and indirect costs	\$28,489	0	0	28,489

(1) Includes 25% of first \$22,610 subcontract costs