MINERνA Project (FNAL e938)'s Mexico Contribution

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Abstract. The MINERνA Project (http://minerva.fnal.gov) (Main INjector ExpeRimentνA) is an experiment that uses Fermilab NuMI line. Its main goals are measure the interactions neutrino (antineutrino)-Nucleon at low energies, improve neutrino oscillation studies, study the strong dynamics between nucleons and between nuclei (nucleons) and neutrinos, and between nuclei (nucleons) and anti-neutrinos. I report on the current status of MINERνA experiment, studies currently under way, studies that can be done, and the Mexican (Universidad de Guanajuato) participation in MINERνA experiment.

1. Introduction

Mexican group, at Universidad de Guanajuato, in November 2007 started MINERνA collaboration (http://minerva.fnal.gov). Universidad de Guanajuato MINERνA collaborators in the past three years are: Professors Julian Felix and Gerardo Zavala; PhD students Zaida Urrutia, Aaron Higuera and Ranferi Gutierrez; Msc students Edgar Valencia, Aaron Higuera and Jorge Castorena; and Bsc students Cesar Capetillo, Luis Balcazar and Maria Cristina Zarazua. Our group, including our students, contributed to installation and commissioning of the MINERνA detector, which was completed in March 2010 and to construction and operation of the MINERνA test beam experiment which completed its data taking in July 2010. Many of our students have already obtained degrees from the work on MINERνA: Aaron Higuera, Jorge Castorena graduated getting their MSc degrees in physics based on commissioning of the test beamline and the MINERνA tracking prototype detector, respectively. Julio Cesar Capetillo and Luis Alfonso Balcazar had graduated with BSc degrees in mechanical engineering with projects on the MINERνA test beamline. Edgar Valencia will graduate in March 2011 with an MSc thesis on the three dimensional simulation of the dipole MINERνA Magnets. Maria Cristina Zarazua will receive a BSc in 2011 in part based on work comparing MINERνA detector simulations and data.

A key part of the experience of each of these students has been a period of residence at Fermilab which is realized through generous support for the students from Fermilab. Professors

Felix and Zavala also are working to improve the experience for the students on campus at Universidad de Guanajuato. We are working towards installation of small cluster of computers for data analysis for MINERνA collaboration. A more ambitious future plan is to develop a high energy detector laboratory for teaching and research, which includes a nearly completed laboratory for high performance computation. Part of the student work in this lab will be analysis of MINERνA data and MINERνA Monte Carlo simulations.

Since neutrino interaction first measurement in 1956, the field on neutrino physics has increased in both experimental and theoretical efforts and in interest. These are some of the actual problems in neutrino physics: The nature of neutrino -Dirac or Majorana-: Is the neutrino exactly equal to the anti-neutrino? The mass of the neutrino. The CP violation in the lepton sector. The mixing parameter. The oscillation of neutrinos.

Some of the proposed experiments in the world, to study neutrinos, are as follows: MINOS(http://www-numi.fnal.gov/); BooNE(http://www-boone.fnal.gov/); K2K(http://neutrino.kek.jp/); T2K(http://jnusrv01.kek.jp/public/t2k/); NOνA(http://www-nova.fnal.gov/); OPERA(http://www.nu.to.infn.it/exp/all/opera/); LBNE(http://lbne.fnal.gov/); and MINERνA(http://minerva.fnal.gov/). More accurate, and technical, information about these experiments are in their respective web page. MINERνA experiment is an international collaboration, it comprehend 21 institutions and 80 physicists from USA, Russia, Mexico, Peru, Chile, Brazil.

In the next sections, I describe MINERνA collaboration and emphasize on Mexican contribution accomplishments.

2. MINERνA Project

The project MINERνA (Main INjector ExpeRimentνA) is an experiment that uses the Fermilab NuMI line. The main goals of MINERνA experiments are: To measure neutrino (antineutrino)-nucleon cross sections, at low energies, with high statistics, to improve neutrino oscillation measurements. To measure interactions neutrino-nucleus -and to measure interactions anti neutrino-nucleus.- as a whole. This process is called coherent neutrino-nucleus scattering. Figure 1 shows MINERνA Main detector. Additionally a test beam detector was constructed and commissioning to obtain calibration parameters for MINERνA detector. Figure 2 shows MINERνA test beam line.

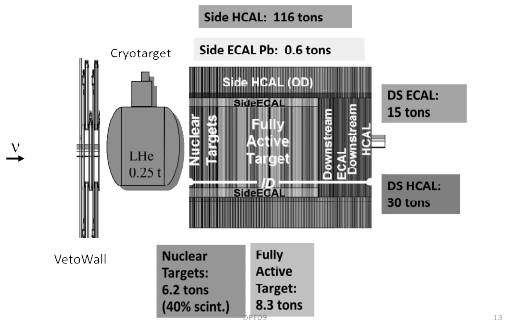

Figure 1. Layout of Minerva main detector.

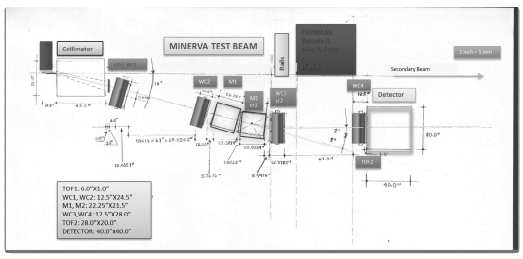

Figure 2. Layout of Minerva test beam line.

2.1. MINERνA Current Status

Both detectors are assembled and taking data. By March, 2010, the MINERνA main detector was completed and commissioned; the MINERνA test beam detector was completed and commissioned by July, 2010. MINERνA Monte Carlo is under current development and improvement. Figure 3 shows MINERνA main detector completely installed; and Figure 4 shows MINERνA test beam line completely installed.

Figure 3. Photo of MINERνA main detector installed.

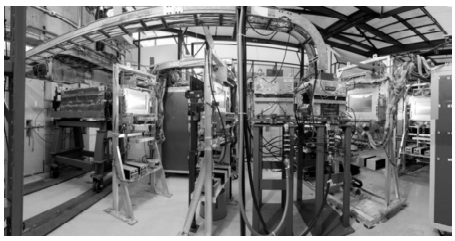

Figure 4. Photo of MINERνA test beam line completely installed.

The main MINERνA detector is 105 meters under ground in the line of Fermilab NUMI, upstream of MINOS detector.

The main characteristics of MINERνA detector are as follows: It is fine grained scintillator, 120 segmented planes, time resolution is about 4 ns, spatial resolution about 3 mm, covers a wide atomic numbers -He, C, H2O, Fe, Pb-. It has recorded 1.37 $\times$ $10^2$0 POT; and can perform $\frac{d\sigma}{dE}$ measurements in QE, DIS, and sπ production modes.

MINERνA detector is running in two different modes: antineutrino beam, and neutrino beam. And at three different energies: Low energy configuration, the most probable energy is around 3 GeV, and the rate of production data is about 60 000 events/tone-$10^2$0 POT. Medium Energy configuration, the most probable energy is around 7.0 GeV, and the rate of production data is about 230 000 events/tone-$10^2$0 POT. High Energy configuration, the most probable energy is around 12.0 GeV, and the rate of production data is about 525 000 events/tone-$10^2$0 POT. The neutrino flux is known with 5% of uncertainty.

MINOS detector gives muon momentum and charge.

Figure 5 and Figure 6 give another views of MINERν detector.

2.2. MINERνA Physics

The physics topics, among others, that MINERνA can address are the following: Rock muons, Michel electrons. Neutrino oscillations. Neutrino physical properties. Quasi elastic interactions. Resonances. Baryon polarization. Coherent production of pions. Interactions neutrino

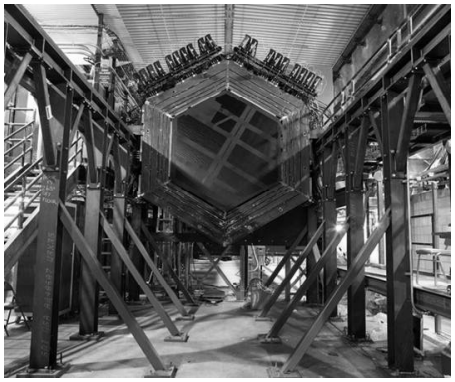

Figure 5. Another view of MINERνA main detector installed.

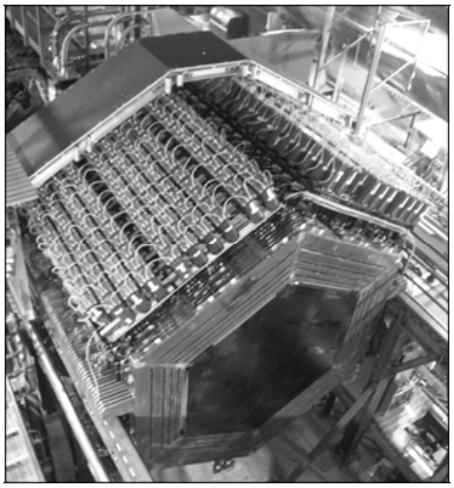

Figure 6. Another view of MINERνA main detector installed.

e-nucleon. Interactions neutrino nucleon (H20, He, Pb, C, Fe). Neutral currents. Charged Currents.

Figure 7 and Figure 8 show some real data.

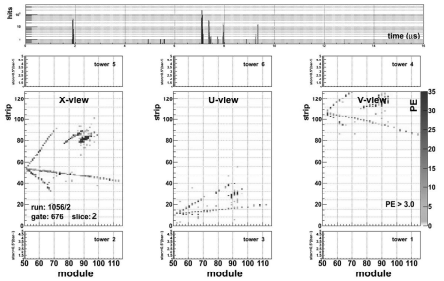

Figure 7. MINERνA data.

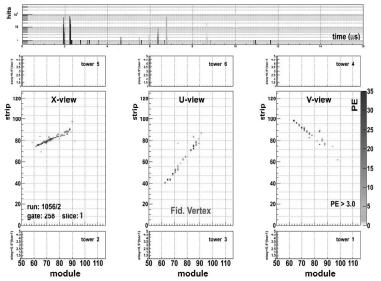

Figure 8. MINERνA data.

Figure 9 and Figure 10 show some real data.

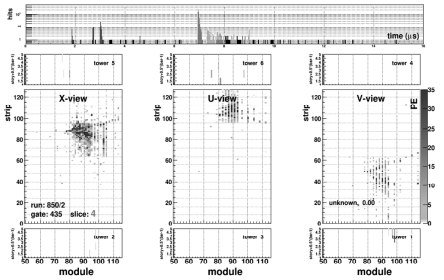

Figure 9. MINERνA data.

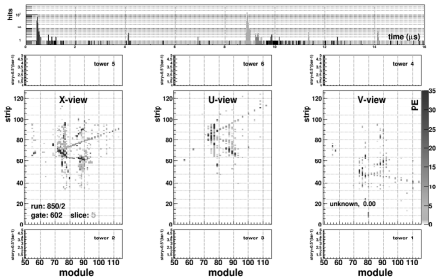

Figure 10. MINERνA data.

Figure 11 and Figure 12 show some real data.

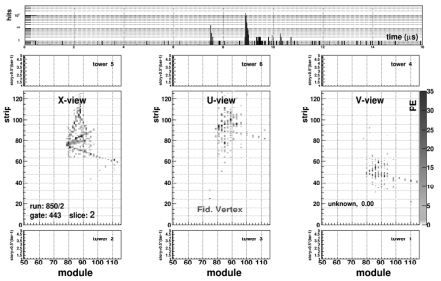

Figure 11. MINERνA data.

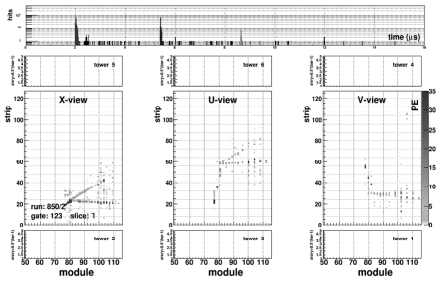

Figure 12. MINERνA data.

Figures 13 and 14 show some Monte Carlo data.

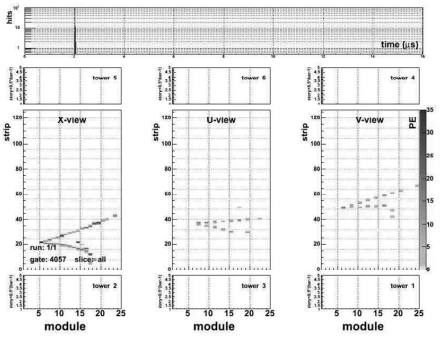

Figure 13. MINERνA Monte Carlo data.

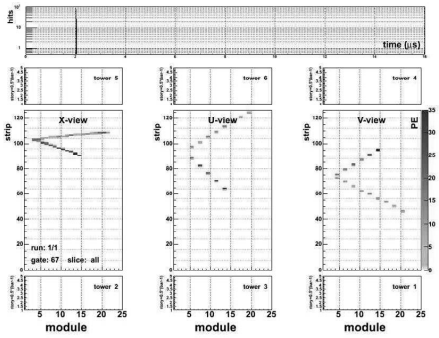

Figure 14. MINERνA Monte Carlo data.

3. Mexican Participation

The Mexican group participating in MINERνA collaboration, so far, is from the Universidad de Guanajuato. We participate since 2007, and currently this group includes two professors -Gerardo Zavala and Julian Felix-, two Ph. D students, one MsC student and five Bachelor students.

Figure 15 shows some students, and professor, at Fermilab.

3.1. MINERνA Detector

Mexican group participated in assembling the MINERνA detector (one MsC student and one Ph. D student), in the plane detector (two BsC students), in data taking (the whole group) and in the analysis of data (the whole group).

3.2. MINERνA Test Beam Line

The group from Guanajuato has participated in the Test Beam Line doing the following: planning (Julian Felix), designing (Julian Felix), installing (Julian Felix), studying the time of flight

Figure 15. Students and Professors at Fermilab.

(Zaida Urrutia, Julian Felix), designing a Cerekov detector (Luis Balcazar, Julio Capetillo, Julian Felix), simulating the magnets (Julian Felix, Edgar Valencia), taking data and analyzing data (the whole group).

More details about MINERνA dipole magnets simulations are given by Edgar Valencia paper, in this proceedings.

3.3. Data Processing

The infrastructure we are creating for data processing, both, real data and Monte Carlo data. The cluster assembled in Leon, in Guanajuato, and the small one at Leon.

To process and analyze data we have created a prototype of cluster, formed by 5 laptops, see Figure. We have installed Condor (http://www.cs.wisc.edu/condor/) and we are testing it. It has 9 processors with different speed, 9 GB of Ram, 1.5 TB hard disk space, and a local network of 10/100 MHz transferred speed.

Figures 16 and 17 show a prototype of cluster operated with condor.

Also we have created two clusters, almost similar, to connect as a GRID -260 processors,

Figure 16. Universidad de Guanajuato cluster prototype, one view.

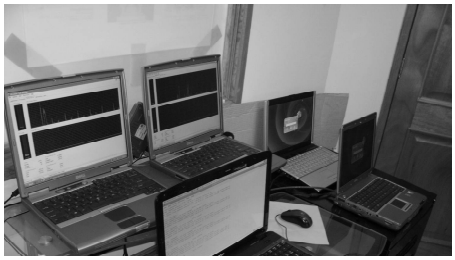

Figure 17. Universidad de Guanajuato cluster prototype, another view.

300 GB of memory, and 10 TB of storage. With these, we are planning process the data and analyzed data.

3.4. Data Analysis

Lambda polarization studies are possible in MINERνA data. Neutrino (nucleon) going to Lambda0 X; anti neutrino (nucleon) going to Lambda0 X. The polarization is measured by fitting to straight line the cosine of the angle between proton momentum from Lambda 0 and the normal of the production plane, in the coordinate system where Lambda 0 is at rest.

Aaron Higuera, Ph. D. Student, is working on neutrino-nucleus targets interactions. He is measuring cross section of the neutrino target interactions as function of neutrino energy and atomic mass (He, H2O, Pb, C, Fe).

Zaida Urrutia is working on vertex activity. What happens on the vertex of interaction of the neutrino and the target?

4. Conclusions

Mexican group has participated on MINERνA detector installation, on Test beam line, on Data analysis, on data processing.

These activities have impacted on the creation of infrastructure -a laboratory for particle physics, and two clusters and one GRID for processing and analyzing data- and human resources -BSc, MSc, and PhD students-. This collaboration will continue for some years ahead.

5. References

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[5] Communication using neutrinos. By MINERνA Collaboration. To be send to Nature Letters.

6. Acknowledgements

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MINERνA Collaboration (http://minerva.fnal.gov).