Status Report on Survey and Alignment Activities at FNAL

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Abstract

Survey and alignment activities at Fermilab since 2008 are presented with an eye towards future projects and challenges as we approach the post-Tevatron era. Fermilab has been changing its priorities to not just the energy frontier but also the intensity and cosmic frontiers. This challenges Alignment and Metrology Group to adapt and increase its versatility to many types of projects and measurements.

1. Introduction

Since the last IWAA in 2008, the Alignment and Metrology Group (AMG) has participated in three major accelerator shutdowns and in the construction of several major experimental projects in various stages of completion. The experimental projects that have been completed are Main Injector Neutrino Experiments for ν-A (MINERvA) and the Compact Muon Solenoid (CMS) FPIX project at LHC. Projects in progress include Dark Energy Camera (DECam), the NUMI Off- axis ν_e Appearance (NOvA) experiment and E906 (SeaQuest). Projects just getting started include Long Baseline Neutrino Experiment (LBNE) and Mu2e. The AMG is also involved with R&D activities such as High Intensity Neutrino Source (HINS) and Superconducting Rf (SRF). There is a proposal being considered at this time for a 3 year extension of the Tevatron (CDF and D0 experiments) essentially doubling the luminosity acquired since the beginning. This currently add some uncertainty to planning AMG's future projects. LBNE and NOvA are discussed in separate presentations

2. Booster Corrector Upgrade

In order to push the intensity limits of the Fermilab 8 GeV Booster, 48 multipole corrector magnets (Fig. 1) were installed and aligned during the 2008 and 2009 shutdowns. This includes horizontal and vertical dipoles, normal and skew quadrupoles, and normal and skew sextupoles. In addition to tracking the 15Hz cycle of the main, combined function magnets, the quadrupoles and sextupoles must swing through their full range in 1 ms during transition crossing. The magnet is made from 12 water-cooled racetrack coils and an iron core with 12 poles, dramatically reducing the effective magnet air gap and increasing the corrector efficiency.

Due to the complex geometry of the magnet a special alignment adapter (Fig. 2) had to be designed. This required significant testing to prove that the magnets would be aligned without a built in systematic error

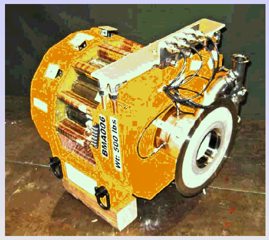

Fig. 1 Booster multipole corrector magnet

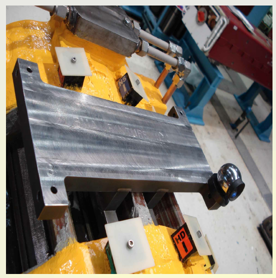

Fig. 2 Specially designed alignment adapter for Booster corrector magnets

3. SRF Beam Test Facility at NML

The RF unit test facility at New Muon Lab (NML) is a large facility with an expansion under construction at FNAL in support of Project X and ILC goals. This is currently the only U.S. facility capable of testing completed cryomodules at high accelerating gradients. In 2010 and 2011, the goals are to complete civil construction of the facility addition (Fig. 3), install a new gun, injector, test beam lines, and dump. They will also install and test a second cryomodule.

AMG support consists of densification of primary control network throughout the existing NML building and the addition (when completed), alignment of beamline components including Capture Cavity 2 (CC2), the Rf gun, and cryomodule referencing and alignment.

Fig. 3 Drawing of SRF Test Facility expansion currently under construction

4. HINS

The mission of HINS is to investigate accelerator technology with application in a high energy, high intensity superconducting Linac for the next generation of neutrino physics experiments or muon storage ring/collider R&D , including: operation of a high power klystron RF power source, testing high power Rf control components, testing conventional and superconducting Rf cavities, and ultimately construction and operation of a 65 MeV proton/H- linear accelerator.

Recently, the objectives of the HINS 2.5 MeV beam test are to: verify the functionality of HINS Radio Frequency Quadrupole (RFQ) as an accelerator, make initial measurements of its output beam parameters, establish procedures and conditions for subsequent HINS 2.5 MeV beam operations. In January 2010, HINS successfully accelerated a proton beam to 2.5 MeV in a RFQ (Fig. 4) for the first time at Fermilab. "This new use of SRF technology enables efficient production of the intense proton beam that will give Project X its versatility as a front end for a muon collider or a neutrino factory. " [*Symmetrybreaking*, Volume 7, Issue 4, August 10, 2010]

AMG provided support by establishing a survey network throughout Meson Detector Building including ties to Fermilab Primary network and monitoring deformation surveys. The AMG also did QC and referencing of various components and alignment of beam line components including the Ion Source, Injector, and RFQ

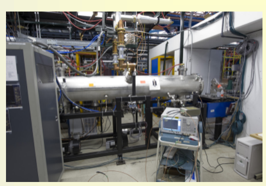

Fig. 4 HINS Radio Frequency Quadrupole

5. Mu2e

In November 2009, the Mu2e Project (Fig. 11) received CD-0 approval from the U.S. Dept of Energy. Mu2e is an experiment to search beyond the Standard Model for direct muon to electron conversion ($\mu^- N \rightarrow e^- N$) otherwise know as charged lepton flavor violation.

The proposed Mu2e detector solenoid is a complicated device combining a stopping target and absorber, one Tesla solenoid magnet, straw tracking detector, and electron calorimeter. The referencing and alignment tolerances are not fully understood but cannot be described as anything less than challenging. The production region is also challenging as it will take 2 x 10^{13} 8 GeV protons/sec and combines an extremely radioactive area with a 5 Tesla superconducting solenoid

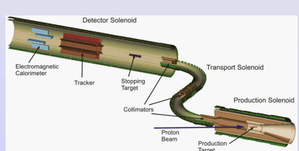

Fig 11 Proposed layout of new Mu2e project

Acknowledgements

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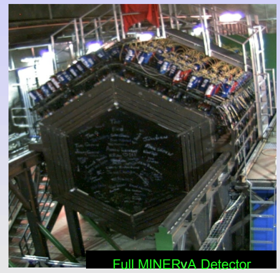
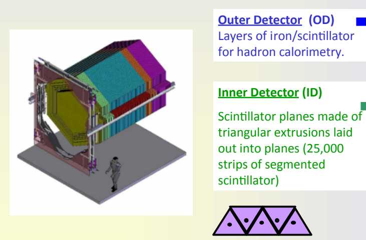
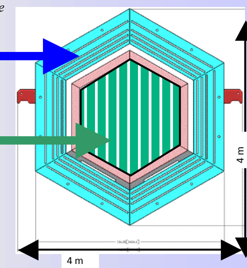


Fig. 5 Above: Completed MINERvA detector situated in front of the MINOS Near Detector. Fig. 6 Below: Conceptual views.





6. MINERvA

The MINERvA detector (Figs. 5, 6) is constructed of 120 modules separated into an inner detector (25k strips of extruced scintillator) and an outer detector for calorimetry. AMG had to determine the position of the inner detector relative to the beamline, position of inner detector scintillator after hanging, and the stability over time with a required accuracy of 1-2 mm.

AMG provided: quality control of components during assembly, monitoring of module component deformation during installation, analysis of the spatial geometry of all prototype components before/after hanging, and monitoring of stability. The results were that positions were able to be determined with a 0.5 mm accuracy and that the scintillator planes remained within relative and absolute tolerance. MINERvA is now taking data and expected to run until 2016.

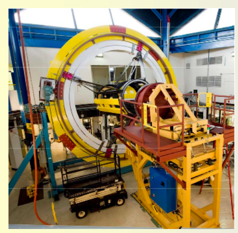


Fig. 7 DECam Test Stand

7. Prototype Assembly of the Dark Energy Camera (DECam)

A prototype assembly (Fig. 7) of the Dark Energy CAMera (DECam) is being assembled at Fermilab before transporting the device to its final destination. The DECam is the primary instrument used in the Dark Energy Survey. It is a 570 megapixel camera with a huge 2.2 degree field of view. The camera will be mounted at the prime focus of the Blanco 4m telescope at the Cerro-Tololo International Observatory (CTIO) in Chile.

The AMG supported the assembly process of the support structure. For instance the pillow blocks at about 4m elevation supporting the ring structure required precision alignment for a smooth rotation in the bearings. Also the concentricity of the ring structure was measured with respect to the outer ring and the bearing shaft. Both were found to be within tolerance for this prototype. Throughout this process AMG made extensive use of the API laser tracker and SA software analysis tools.

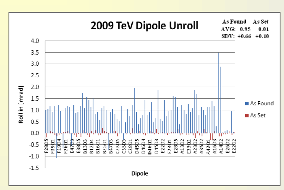


Fig. 8 2009 TeVatron roll data

8. Tevatron Status

The Tevatron has been Fermilab's workhorse for the past 25 years supplying the D0 and CDF detectors with colliding beams of protons and anti-protons that led to the discovery of the top quark in 1995. One of the limiting factors for improved luminosity in the Tevatron is the quality of the dipole roll alignment. Ideally the dipole roll should be in the range of 1 mrad or less. Due to the effects of hydro-static pressure on the tunnel enclosure and long-term settlements the dipole roll is drifting out of this range over time. Fig. 8 shows the measurements for the 2009 shutdown. It is the AMG's task to flatten the largest rolled dipoles during the annual machine shutdown periods.

During the 2009 shutdown the average dipole roll of the as found data sample was 0.95 mrad with a standard deviation of 0.66 mrad. After un-rolling these dipoles the average roll was 0.01 mrad with a standard deviation of 0.1 mrad. Similar results were found in 2010 with an average of 0.71 mrad and a standard deviation of 0.68 mrad prior to un-rolling the magnets. These values were 0.00 mrad and 0.1 mrad for the average and standard deviation respectively after the operation of un-rolling the magnets.

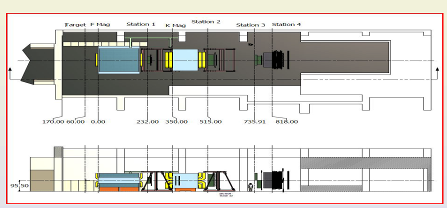


Fig. 9 SeaQuest Target and Experimental Hall layout

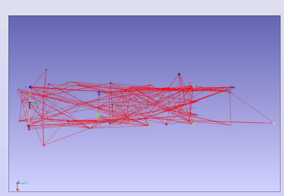


Fig. 10 SeaQuest Target and Experimental Hall control network

9. SeaQuest Drell-Yan Experiment (E906)

A new fixed target experiment SeaQuest performing measurements of the flavor asymmetry of antiquarks in nucleons is currently under construction. This project will make use of the 120 GeV proton beam produced by the Main Injector. It requires many upgrades to existing beam lines and a new target hall layout. For that the AMG needed to status many existing beam line components and return this information back to the physics for the creation of the new lattice data to transport the proton beam from the source to the target hall. The existing network in the target hall has been expanded and surveyed (fig. 10). The analysis shows a point accuracy on the order of 0.080 mm.

Summary

Over the last two years, the Alignment and Metrology Group has participated in many different types of projects and has adapted to Fermilab's new initiatives in the intensity and cosmic frontiers. In the future, the group will need to adapt even more as Fermilab expands its horizons beyond the traditional on-site accelerator and beamline roles to more off-site projects such as telescopes and deep underground neutrino detectors. They will also face ever more demanding tolerances and stability requirements in less controlled environments.