Alignment of the Mu2e Experiment

Jana Barker
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Mu2e (Muon to Electron Conversion) Experiment

- Make muons at the production target
- Collect and transport them to the stopping target
- Search for muon to electron decay without neutrinos
Mu2e Alignment Challenges

• “Guess” of the target final position based on the Solenoid QC
• After initial alignment, solenoids will be welded to steel pads imbedded in reinforced concrete slab floor.
• Measuring energized magnets (magnet field mapping…)
  – Need nonmagnetic equipment: ceramic SMRs, nonmagnetic nests, so usage limitations
  – SMRs have to be held by gravity (disadvantages in high traffic areas) or glued on (the equipment has to be carefully and completely cleaned for later reliable use)
  – Measurement crew in magnetic field
• Measurement instruments must endure magnetic fields
• Iterative alignment of the Detector Train
Mu2e Reference Network

• The building was handed over in Jan. 2017
• Reference network was designed and simulated using SA and GeoPAN
  – using an “Exclude Obscured Points and Fabricate Measurements with Lines” MP [3]
  – measured with a AT401 LT, a DNA03 Leveling instrument, and a DMT Gyromat 2000 Gyrotheodolite
• To follow the Earth curvature, the Ellipsoidal height was held on measured points during the Least Square Adjustment of the terrestrial observations
Heavy Assembly Building Reference Network

- Used for precision assembly of the transport solenoid
Testing of the Leica AT403 in Magnetic Field

- No long-term effect or damage caused by 500 Gauss field
- That field causes problems with aiming at the targets => longer measurement time but possible
- After leaving 500 Gauss field, instrument came back to normal accuracy
Field Mapping System – Vibration Analysis

- Motivation:
  - Needs precise 3D magnetic field mapping to model charged particle trajectories
- Field Mapping System (FMS) maps the magnetic field of the solenoids.
  - Discrete translation on rails and discrete rotation of the propellers
  - Need to precisely know the location of the location of the magnetic field sensors
- Rigid mechanical coupling of the FMS needed to be proved
- Measured with three API LTs and used SA with UDP
Data processing in Python

Start: Text data files in

Same Sampling Frequency?

Yes

Find course offset: Min $\chi^2$ from shifting by discreet number of samples

No

Interpolate finer data stream to match sampling frequency

Find fine offset: Min $\chi^2$ from shifting (-1,1) sampling periods, Between-sample interpolation

Done, $\Delta t$ found to 0.1 to 0.5 sampling periods
Close-up of the vibrations of the system in X and Y axes (right-left and up-down) – third set of measurements
• Fast Fourier Transform was performed for identification of the vibration sources
FMS – Calibration Magnet

- Hall probes (magnetic sensors) need calibration in known field
- Magnet is mapped mechanically and compared to magnetic measurements (NMR probes)
- Magnet poles will be mapped using interferometer measurements (LT in IFM mode), used to find bisecting plane
FMS – EMMA

- Complex Field Mapping System’s software includes LT interface and calculations
- Cooperating with a software developing team on the correct approach, calculations, and interpretation of gathered data
Cold Mass Positioning System

• Communicates the Cold Mass position to the outside of the cryogenic vessel
• Three interferometric lasers on the flange monitor the position of the piston disc connected to the piston nest position on the Cold Mass
• Main metrology challenge is referencing the lasers to the fiducials
Transport Solenoid Test Unit 01

- TSUN01 is a unit consisting of 2 solenoid coils
- It’s the center part of TSU (The TS is made up of the TSU and TSD)
Transport Solenoid Test Unit 01 Measurements

- Quality Control and Referencing measurements were performed
- Mechanical and magnetic axes were measured and compared to the original CAD model
- Measurements are fitted to a CAD model which uses the Mu2e coordinate system
- Results, such as the magnetic axis, are used to recalculate the final position within the experiment
Production Target Measurements

- Developed new fiducial type: fitting into an 80/20 groove
- Production Target held by 6 spring loaded spokes
- Measured adjustability
- Repeatability of placing tested

https://youtu.be/SCI_jyeUels
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Thank you for your attention

Jana Barker

Fermi National Laboratory
jana@fnal.gov, X3098
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[8]