



Mu2e Accelerator

Diktys Stratakis Mu2e Collaboration Meeting June 13, 2025

Outline

- Introduction and scope
- Project Status
 - Resonant Extraction
 - External Beamline
 - Extinction Monitor
 - Target
- Briefly discuss commissioning
- Summary



Accelerator 6 focus areas

475.02.06 Delivery Ring RF

Accelerator systems required to deliver resonantly extracted 8 GeV proton beam from the Muon Campus to the Mu2e proton target.

475.02.03 Instrumentation & Controls

475.02.05 Resonant Extraction

201 **Delivery Ring** M-3 Beamline Λ **MI-8 Beamline** -2 Beam Commissio off-project

475.02.08 Extinction Monitor

475.02.09 Target Station

475.02.07 External (M4) Beamline

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External beamline: Overview



A magnet is used to deflect out-of-time beam into a downstream collimator.

The Mu2e experiment has very stringent limits on the amount of beam that appears between pulses



Major Components for Extinction

- AC Dipole Magnet
- AC Dipole Magnet Power Supplies
 - High Frequency ~ 4.4MHz
 - Lower Frequency ~ 300kHz
- Extinction Collimators [3] (removes unwanted particles)
- Extinction Monitoring



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AC Dipoles

- We will fabricate **three** AC dipoles
- So we need three (lid + baseplate +cover) sets. One set will be used as spare.
- Lid and covers will be fabricated at Fermilab
- For the **baseplates** we will use the ones provided by the vendor



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AC Dipole #1

AC Dipole #1 fabrication complete (May 2024)

Three, 1 m segments





AC Dipole #1: Fabrication

- After successful vacuum check, cover of magnet #1 was installed
- Dipole was flipped and placed on a permanent stand
- Baking began in January and revealed that the magnet meets our vacuum specs







AC Dipole #1: Power Testing

• Each 1-meter section of the magnet #1 was tested at 300kHz and 4.4MHz. Both meet specification and are consistent with the 1 m prototype results.

52.3

300kHz Thermal tests images

Section #2 on 3/4/24

- Then we power-tested the whole AC dipole #1
 - Results look good for both frequencies week



Section #1 on 9/1/23







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AC Dipole #2: Fabrication

- Fabrication of AC Dipole # 2 completed on October 2024
 - It took a few days to build the whole magnet!
- Lid #2 was placed on top of magnet; magnet was flipped and placed in a permanent stand
- In a similar fashion to Dipole # 1, this magnet was baked, vacuum checked & power tested



AC dipole final assembly + spare

- A spare magnet has been also fabricated and power tested
 - Currently awaiting baking and vacuum checks
- Capacitor covers for all magnets have been also fabricated and are installed
 - AC Dipole #1 and #2 fabrication is final!











AC Dipole – Transportation

- In May, AC dipoles #1 and #2 were transported to the M4 • beamline enclosure
- They are ready for installation

Cable pulls and electrical distribution work











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tunnel

M4 Final Focus Scope

- Upper-Level component & vacuum installation is complete.
- Lower-Level Vacuum & Trim Magnet Installation is complete
 - Pending leak check .

COMPLETE

 M4 power supply ORC and power supply testing still need to be completed
COMPLETE
COMPLETE



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Mu2e Target

Final Focus Section

Extinction & Diagnostic

Absorber Section

protons

HBend Section

Common Section G-2 and mu2e

Resonant extraction: Magnet installation plan



<u>Second</u> production ESS replaced prototype on November 2024

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Accel Technical Progress: Resonant Extraction

Electrostatic Septum ESS2-02 Transfer to Operations

28 October 2024

- October 2024: Transfer to ops signed
 - Mu2e-docdb-50802
- November 2024: Moved to Muon Campus
- December 2024: Conditioning/Testing started





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Operational ESS2 set in Delivery Ring





Electrostatic septa conditioning in the Muon Campus

- Electrostatic Septa conditioning began late December 2024
- Paused during Holidays
- Both septa approached their target value later in January 2025



ESS2 Voltage ESS1 Voltage

ESS1 Spark Counter ESS2 Spark Counter

Resonant Extraction Remaining Scope

Fluorinert skid

- Circulation & filtering of FC-40 through the ESS HV feedthroughs
- Skid rack to be built in the service building
- Piping system has been installed during Shutdown-2024
- Will complete in Summer 2025
- Good progress so far

Piping towards service building



Skid layout



Skid model





Technical progress – Target station

- Heat and Radiation Shield (HRS) is ready for installation; we met the T5 milestone
- The HRS has been moved temporarily to the Remote Handling Room and awaiting PS Delivery
 - Installation Plan Mu2e-doc-44716
- Thermocouple conduit work completed (later slide)









Mu2e Extinction Monitor

Upstream collimator is oriented along the direction of beam from the proton target

Pixel Interface Board PIB



Entrance collimator work

- As of late 2024: Upstream collimator was secured in a fixture that rested on blocks from the beam dump
- Feb. 2025: First, temporary hangers were installed and a rough alignment followed
- Mar/ April 2025: Permanent installation followed and is completed
- Thermocouple conduit work for target station completed as well







alignment followed;

Exit collimator work

• April 2025: Permanent installation followed and is completed

March 2025: First, temporary hangers were installed and a rough















Extinction Monitor Collimator: Concrete pour





Extinction Monitor Collimator: Concrete pour

Concrete Pour

- Concrete formwork installation nearing completion
- Concrete pour to start next week
- Concrete work finishes end of June







Beam commissioning

- Have a noticeable beam time for the first time:
 - Beam to DR since May 9, expect to run until shutdown ~July 9
- Established Circulating Beam in the Delivery Ring & tune up.
- Established Beam to the Delivery Ring Abort.
- Established resonant extracted beam to the M4 diagnostic absorber.



Profiles of beam at M4 Diagnostic Absorber



Resonantly Extracted Beam

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Commissioning the Slow Extraction

1. Improved significantly the beam quality:

• Transmission efficiency to DA. SX losses about 5%. Still there are additional losses that need to be curtailed.

2. Spill Regulation system (FPGA board):

- Drives the Q-ramp supply to control the squeeze.
- The fast regulation PID loop has been tested.



Circulating beam and Extracted beam. Significant ripples due to ripple in the quad supplies. Spill Duty factor over 60%. For the debugging purposes spill start is delayed after injection.

Commissioning the Slow Extraction

- Due to improved efficiency and higher extraction intensity, were able to see for the first time beam profiles in all multiwire monitors in the beam line
- Now we can steer the beam in the beamline.





Commissioning the Slow Extraction

- We successfully tested the multispill mode of extraction
- 4 spills delivered within 250msec
- This mode requires all the accelerator chain working in sync and in close concert.



Beam intensities on the scope. Trace 1 – circulating beam in the DR; trace 2 – SpillMonitor



Summary

- Accelerator project scope is ALMOST complete
- Both production AC dipole magnets are in the tunnel
 - Power supply work ongoing
- Both production septa installed and in operation.
- Extinction collimators (entrance and exit) are installed
 - Concrete pour done by end of June
- Very good progress in beam commissioning
 - We resonantly extracted beam
 - We improved our instrumentation capabilities so that we can monitor and correct beam imperfections

