

Mu2e-experiment Overview

- **Project Rebaseline**
- **Stato dell'esperimento Solenoids**
 - Accelerator
 - Tracker
 - Calorimeter
 - CRV
- **Cost and Schedule**

S.Miscetti
Meeting with Referees
5-Sep-2022

Rebaseline of Project

- **The Project cannot be completed before the CD-4 milestone of 12/31/22.**
- There are two, largely independent, drivers of this delay
 1. The COVID-19 pandemic has significantly delayed the project completion date
 - Biggest impacts are to the Tracker, Transport Solenoid and Calorimeter
 2. Delays at General Atomics have pushed the project completion date beyond the CD-4 milestone
 - Impacts Production and Detector Solenoids.
 - Biggest indirect impact is to Muon Beamline.

Bottom Line Up Front

- Significant and impressive technical progress on all fronts
- Mu2e project cannot be completed before the CD-4 milestone or within TPC
 - COVID has significantly delayed field work on the TS, Accelerator and detectors
 - Replanned field work with COVID protocols has resulted in increased costs (more work stations/tooling, work inefficiencies, etc.)
 - COVID supply chain issues have resulted in cost increases and increased lead-times.
 - Critical path magnets (PS and DS) have been significantly delayed due to vendor performance issues
 - Lack of resources has caused schedule delays in completing designs and fabrication
 - Additional contingency draws result from underestimating design complexity
 - Schedule delays have turned into draws on contingency that will cause the project to exceed the TPC
- Original Project contingency has been depleted. Project will run out of funds by early Q2FY23.

Bottom Line Up Front

- A Project rebaseline is required
 - Project is 85% complete. **A new plan is in place, but additional time/money is needed to execute that plan to completion.**
 - TPC including estimate uncertainty and project risks: **\$316.0M**
 - Early CD-4 date of **June 20, 2025**
- Director Review done on May 2022
- OK for technical points
- A lot of recommendations for Cost/Schedule/Risks

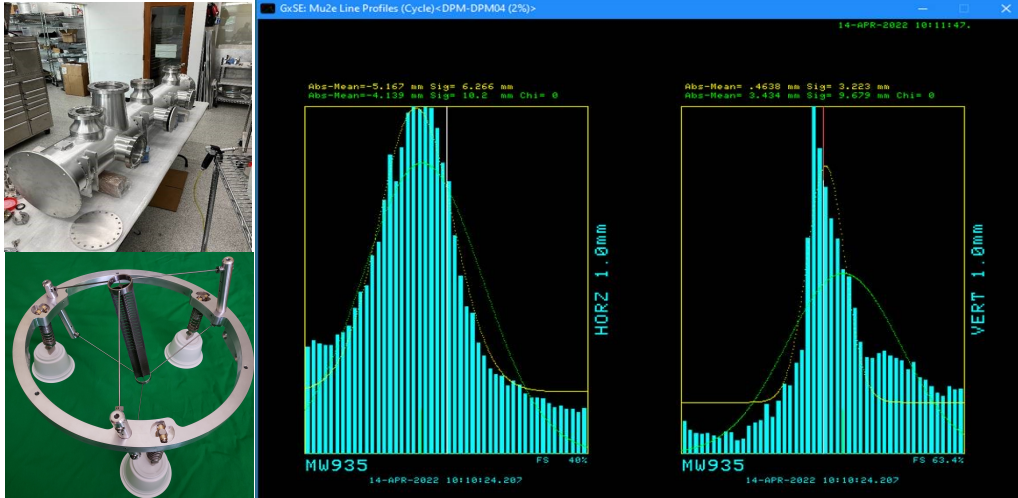
DOE IPR Rebaseline Review → 13-15 Sept/2022

ICE (Independent Cost Review) → 28 Sept/2022

475 – Mu2e project – Remaining Scope

	Level 2	% Complete	Major Remaining Scope by Accelerator L3
475.01	Project Management	88.4%	LOE
475.02	Accelerator	88.3%	Final focus, ESS, Extinction System, Extinction monitor
475.03	Civil Construction	99.2%	Concrete work for proton absorber albedo trap
475.04	Solenoids	85.2%	PS/DS payment milestones, TS assembly, QPS, Cryo & Solenoid installation
475.05	Muon Beam Line	55.3%	Vacuum system, Collimators, Proton absorbers, beam stop, stopping target monitor, detector support, shielding
475.06	Tracker	81.0%	Remaining panels/planes, electronics, tracker assembly, services, installation/integration
475.07	Calorimeter	83.8%	Disk assembly, electronics, source system, services, installation & integration
475.08	Cosmic Ray Veto	88.0%	Remaining modules, electronics, installation & integration of modules for detector KPP configuration
475.09	Trigger and Data Acquisition	87.3%	Readout fiber plant, servers, detector readout support
	Total	84.5%	

Accelerator – 88% Complete



Remaining Scope

Complete assembly of 2 production ESS

Complete Extinction System AC Dipoles

Install Extinction Monitor System

Fabricate remaining beamline elements (ESS, Final Focus, AC Dipoles, power supplies, etc.)

Install HRS into the PS

Complete remote handling system controls, cart & RHR door

Challenges & Plans

Work with division heads to ensure availability of resources to execute remaining scope of work (MOA)

Continue to advocate for strong support of Operations for beam commissioning (e.g. resonant extraction studies)

Completed Scope

KPP Achieved - Demonstrated 8GeV proton beam transport to the M4 beamline diagnostic absorber

Prototype electrostatic septa (ESS) fabricated.
Production ESS components procured.

Extinction AC Dipole ferrites -100% delivered, mechanics procured. Extinction monitor sensors/readout assembled.

Production target fabricated. Prototype target handler mechanics complete.

Remaining work well understood

Solenoids – 85% Complete



Completed Scope

PS/DS designs complete. **100% PS coils fabricated.** DS coils 77% complete. (Vendor)

TS design complete. TS cold mass fabricated (vendor). All units passed acceptance tests at FNAL. **TSu/TSd cold masses and thermal shields assembled.**

PS/TSu cryogenic feedboxes installed. 8 transfer lines completed. 2/4 mid-run interconnects completed.

2/4 cryogenic feedboxes installed. All 8 transfer line segments in place. 3/4 midrun interconnects nearly complete

Remaining Scope

Complete DS coils. Complete PS/DS cold mass assemblies, cryostat, ship to Fermilab (Vendor). Install. Power test.

Cryostat TSu/TSd. Install. Power test.

Complete installation of cryogenic feedboxes and xfer lines. Complete connections to solenoids.

Complete Quench Protection System installation & programming. Complete field mapping programming.

Challenges & Plans

Working with vendor to mitigate further PS/DS schedule delays

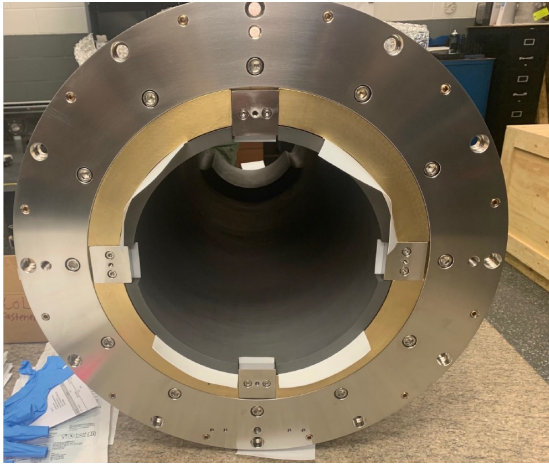
Work with division heads to maintain cryo tech support to mitigate cryo transfer line cost and schedule

Work with division heads to maintain solenoid engineering & tech support for TS assembly (MOA)

Identified replacement power supply L3. Working with divisions on identifying team for installation tasks (MOA).

Remaining technical scope well understood. Additional complexity reflected in replan.

Muon Beamline – 55% Complete



Completed Scope

Stopping target assembled

Procurement of collimators in progress, COL1 delivered

Bids for major component of Muon Beam Stop provided by potential vendors

Developing and testing readout for STM
Continuing to refine designs for STM infrastructure

Developed design for trench cable management system

Remaining Scope

Complete major collimator component procurements, and advance fabrication of antiproton stopping window housing

Get POs in place for major Muon Beam Stop components and for remainder of DS internal shielding

Finalize detector support system component designs

Finalize DS endcap design (IFB and VPSP) and get procurement underway

Challenges & Plans

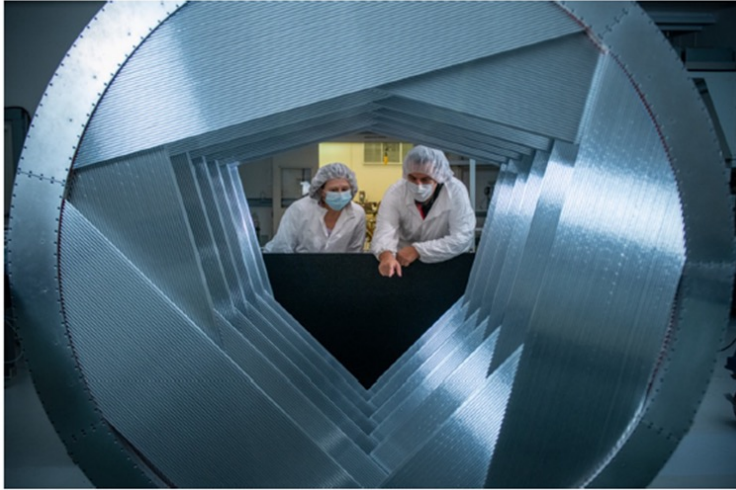
Working with detector subsystem leads to clarify and finalize detector services, feedthroughs and infrastructure interfaces

COVID related component cost escalation captured in RLS. Residual risk captured in risks.

Working with divisions to ensure availability of high-demand, key resources (MOA)

Identify and minimize potential for interferences (or other surprises) during the installation process

Tracker – 81% Complete



Completed Scope

Produced 92% of Tracker Panels

Produced 56% of Tracker Planes

Completed electronics designs

Demonstration of KPP quality cosmic tracks in VST

Remaining Scope

Complete production of Tracker Panels

Assemble Tracker Planes, Frame & Stations

Complete fabrication and installation of electronics (AMB, preamps, DMBs)

Complete infrastructure (HV, LV, gas & cooling)

Challenges & Plans

COVID impact to close-proximity fabrication work and supply chain issues included in replan.

Continue to work with vendors to mitigate electronics supply chain challenges. Electronics risk included in risk register & replan.

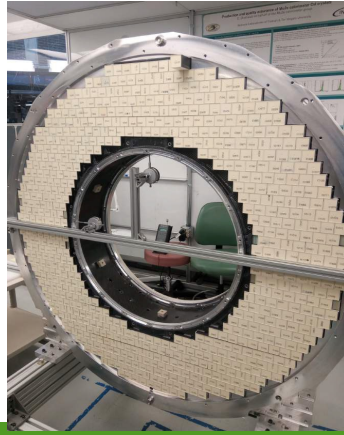
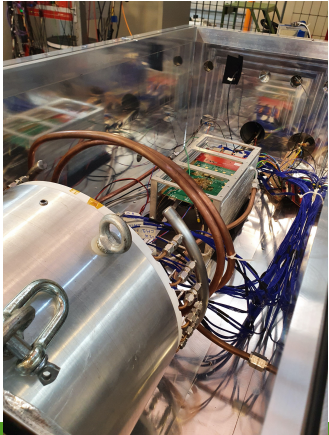
Retain experienced technical resources from university partners to support tracker assembly. Continue onboarding additional effort supported by Research funds.

5/9/2022

S

Panel/plane production well understood. Electronics risks captured in risk register & plan

Calorimeter – 84% Complete, DOE only



Completed Scope

All SiPMs glued. ROUs being assembled/tested

All mechanical parts fab'd/assembled @ INFN & FNAL

Source : **Al tube produced, Neutron gen. received**

Rad-hard FEE and cables production completed.
MB production started. Dirac V3 prototypes produced.

VST with Module-0, final FEE, MB, DIRAC v2 in vacuum

Procurement of service cable and feedthroughs

Remaining Scope

Complete assembly of disks (install crystals, instr. (racks, photodetectors, FEE, cooling, etc)

Complete cooling system design, fabrication & installation

Complete installation & commissioning of source system

Challenges & Plans

Increase INFN team presence @ FNAL to complete calorimeter assembly

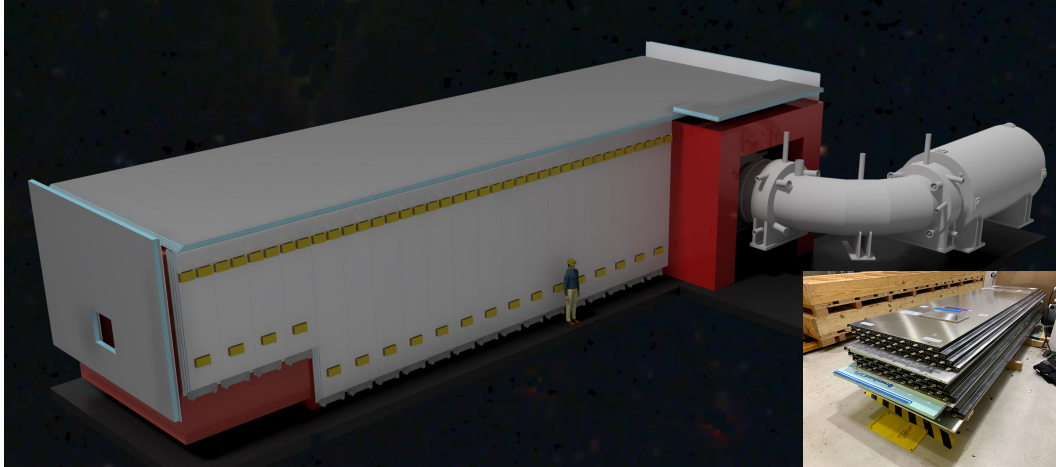
Recover/produce anew the missing FEE @ JINR

Complete production of DIRAC boards

Work closely with vendors to mitigate FPGA supply delay-chain. Electronics delays included in replan. Residual uncertainty included in risk register.



Cosmic Ray Veto – 88% Complete



Remaining Scope

Complete module fabrication (83/83)

Complete layout/firmware of FEB-II. Produce & test FEB-II.

Produce & test Readout Controller (ROC)

Test support structure design needed for CRR

Completed Scope

Successfully fabricated 68/83 modules (82%)

Support structure design completed

Successfully completed VST with FEB-I

Shipped all modules to Wideband (68/83)

Challenges & Plans

Complete development/fabrication of FEB-II. FEB design changed due to FPGA unavailability.

Electronics supply chain issues. Electronics delays included in replan. Residual uncertainty included in risk register.

TDAQ – 87% Complete

Partial DAQ room installation complete.

Working to mature the path forward to Mu2e Operations.



Remaining Scope

Stable operation DTC chain in DAQ room.
Purchase DAQ servers.

Support integration of detectors into Vertical Slice Tests (Round 2 (COVID)) for systems ...

Mature Mu2e Operations path.
Mature Offline and Run Info interface.

Server purchase, VST and HST support.
Scale up Hardware Event Building.

Integrate detectors into DAQ at Mu2e hall.

Completed Scope

Stable10-DTC chain at test stand.

Trigger processing time target achieved.

Partial DAQ room installation LIVE

Demo of 3-subsystem software chain.

Challenges & Plans

FPGA/firmware knowledge transfer to new hires

Background/Noise impact on Trigger processing benchmarked. Collaboration engagement is critical in continuing optimization.

Project Summary

Level 2 \$k	Actuals through March 31	Remaining Work (ETC)	New Level 2 Plan (EAC)	Estimate Uncertainty	% EU	Risks (90% C.L.)	Total Contingency	Total Contingency	%
475.01 Project Management	\$ 26,024	\$ 3,898	\$ 29,922	\$ 58	1.5%	\$ 4,195	\$ 4,253		109%
475.02 Accelerator	\$ 43,819	\$ 7,097	\$ 50,916	\$ 2,126	30.0%	\$ 109	\$ 2,235		31%
475.03 Civil Construction	\$ 18,594	\$ 150	\$ 18,744	\$ 39	26.2%	\$ -	\$ 39		26%
475.04 Solenoids	\$ 104,256	\$ 21,270	\$ 125,526	\$ 3,965	18.6%	\$ 4,028	\$ 7,993		38%
475.05 Muon Beamline	\$ 11,784	\$ 9,945	\$ 21,729	\$ 2,977	29.9%	\$ 1,607	\$ 4,584		46%
475.06 Tracker	\$ 17,864	\$ 4,766	\$ 22,630	\$ 944	19.8%	\$ 404	\$ 1,348		28%
475.07 Calorimeter	\$ 5,395	\$ 1,073	\$ 6,468	\$ 302	28.1%	\$ 170	\$ 472		44%
475.08 Cosmic Ray Veto	\$ 9,450	\$ 1,677	\$ 11,127	\$ 450	26.9%	\$ 41	\$ 491		29%
475.09 Trigger and DAQ	\$ 6,173	\$ 943	\$ 7,116	\$ 183	19.3%	\$ 232	\$ 415		44%
Grand Total	\$ 243,360	\$ 50,819	\$ 294,179	\$ 11,043	21.7%	\$ 10,787	\$ 21,830		43%

Exceeds TPC (\$274M)

Major Cost Increase Drivers (Diff):

PS/DS Vendor Delays, COVID-related impacts, underestimated design complexity, lack of resources

Major ETC: Complete remaining Solenoid, Accelerator & Detector fabrication/assembly;

muon beamline component fabrication & installation, detector installation & commissioning

Risks weighted by cost impact.

Schedule delays from impact to critical path (basically from Solenoid risks)

are spread over all subsystems.

Summary of Rebaseline Ask (Cost)

Charge #2

	Cost
EAC	\$294.2M
Estimate Uncertainty	\$11.0M
Risk based contingency (90%CL)	\$10.8M
Total	\$316.0M
COVID Impacts (Externals)	\$15.2M
Total (excl COVID Impacts)	\$300.9

FY21-FY25 funding profile: \$42.7M
 Total funding : 273.7+42.7 = \$316.4M

10% cap
 Original TPC*1.10 = \$301.0M is ~\$185k below

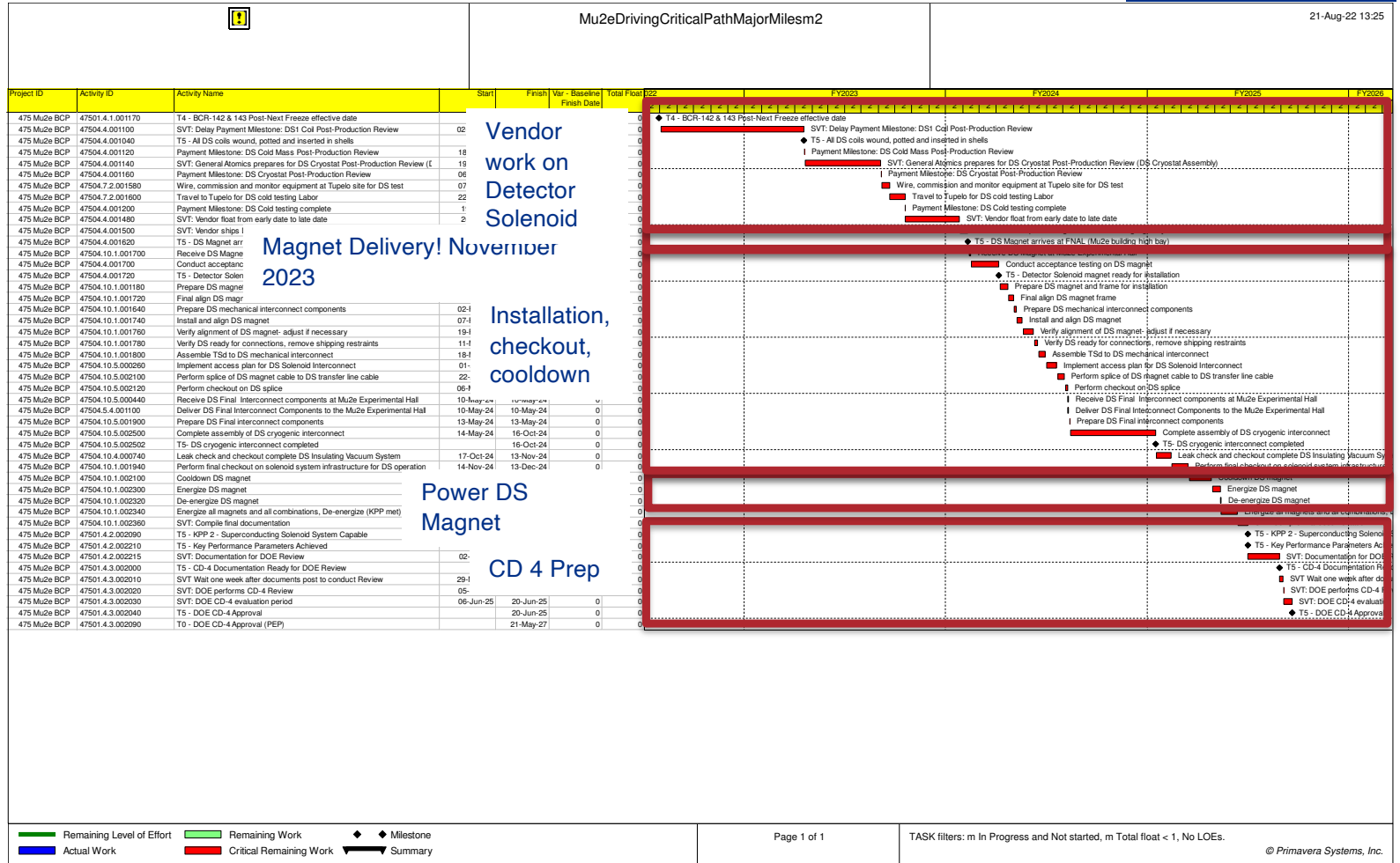
Mu2e Baseline TPC: \$273.677M	EAC: \$294.2M (incl COVID)
Obligations-to-Date: \$258M	Costs-to-Date (ACWP): \$248M
Remaining budget: \$16M	Costs-to-Go: \$50.8M (incl. \$9M of open commitments)

Costs through June Status

Schedule & Critical Path

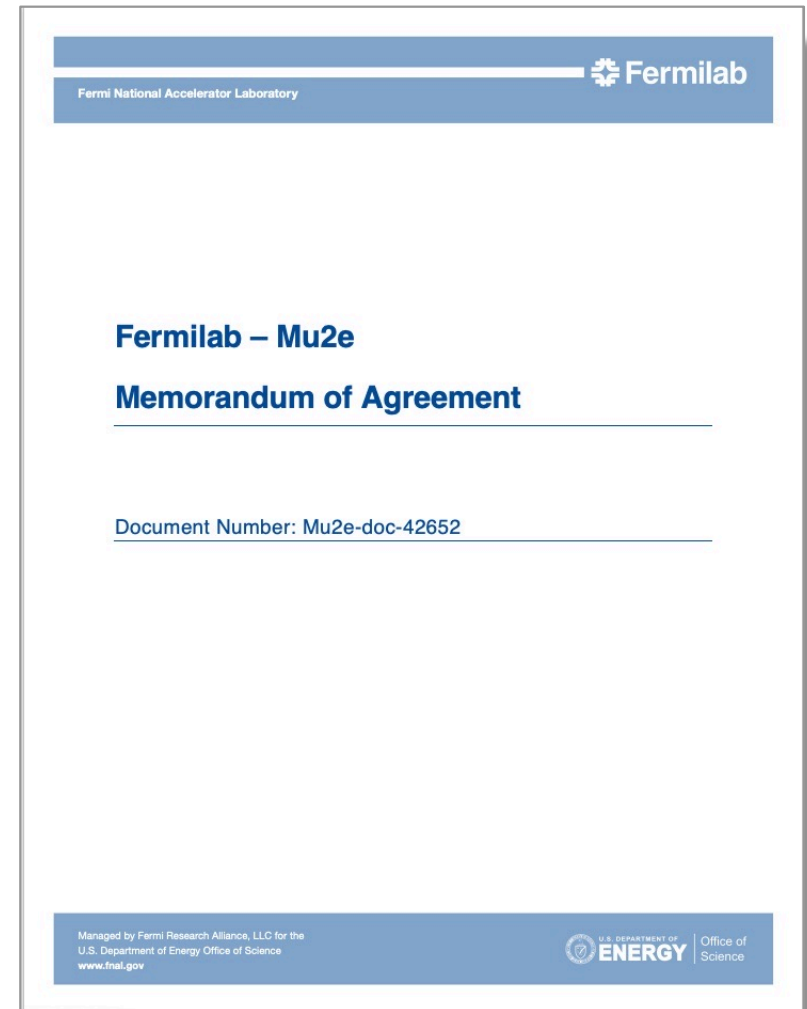
Charge #2

- Detector Solenoid Fabrication at the vendor
- Magnet Delivery November 2023
- Installation, Checkout, Cooldown
- KPP 3: Power DS Magnet
- CD 4 Preparation and Review



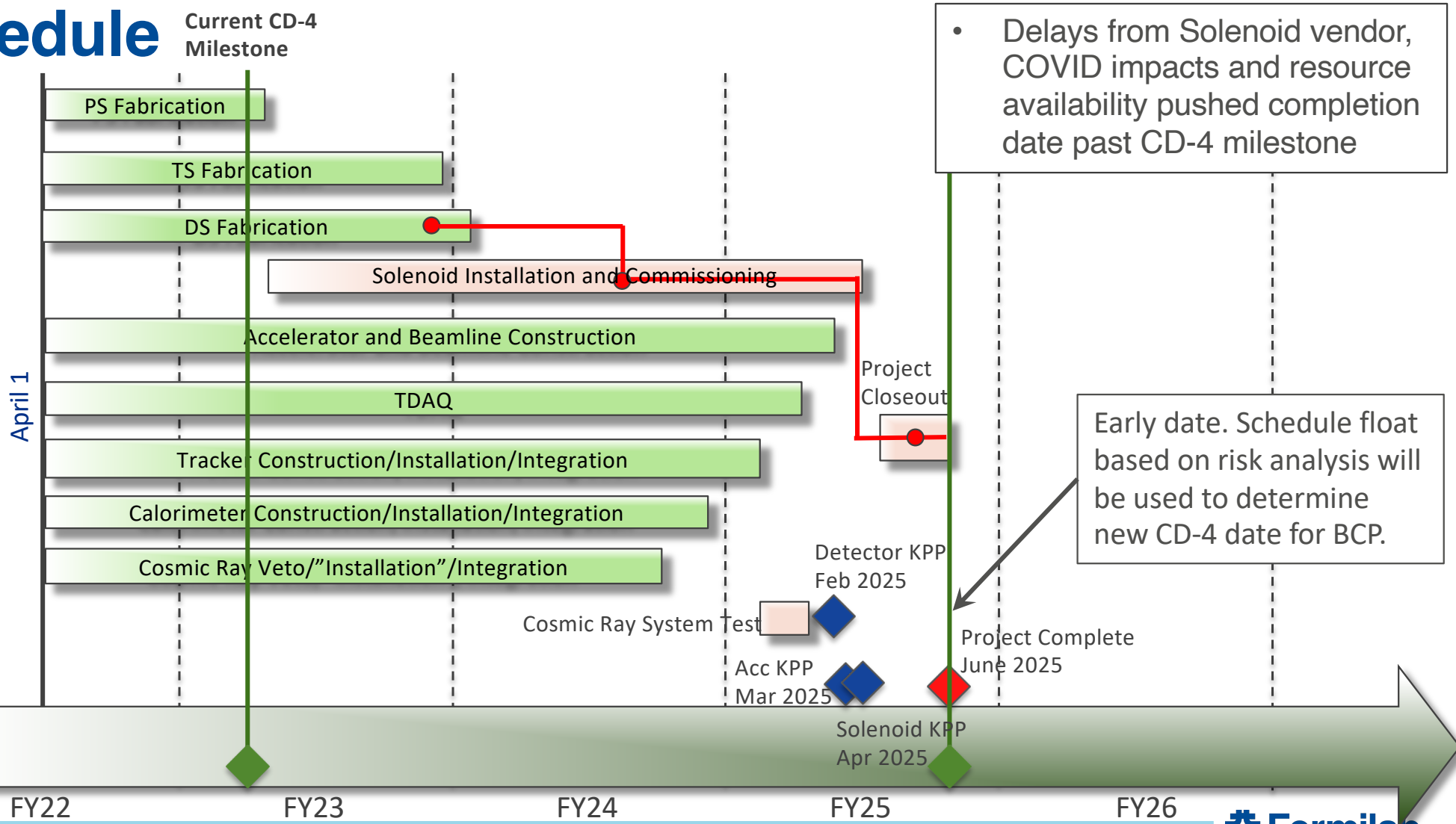
Memorandum of Agreement

- A Memorandum of Agreement (MOA) between the Mu2e Project and the Laboratory has been written and agreed to by all parties.
 - Communicates Project resource needs to the laboratory
 - Allows for resource planning by both the Lab and the Project (in the case of lab resource shortfalls)
 - Helps to ensure strong support going forward



Schedule

Current CD-4 Milestone



- Delays from Solenoid vendor, COVID impacts and resource availability pushed completion date past CD-4 milestone

Early date. Schedule float based on risk analysis will be used to determine new CD-4 date for BCP.

ADDITIONAL MATERIAL

Summary of Rebaseline Ask (Schedule)

Charge #2

	Schedule	Comments
Early Finish Date	June 2025	
Schedule Risk (90% CL)	27.2 months	Based on risk analysis (90% CL)

WBS 475. Evolution of Project Costs (k\$)

Charge #3

Major Cost Increase Drivers (Diff):

PS/DS Vendor Delays, COVID-related impacts, underestimated design complexity, lack of resources

Major ETC:

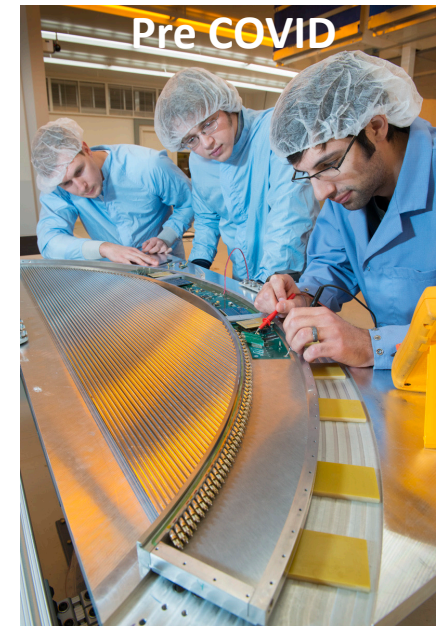
Complete remaining Solenoid, Accelerator & Detector fabrication/assembly; muon beamline component fabrication & installation, detector installation & commissioning

WBS	CD2 (March 2015 BAC)	CD3 (June 2016 BAC)	Current BAC	Diff (Current - CD2)	ETC
475.01	\$ 21,604	\$ 23,357	\$ 29,923	\$ 8,319	\$ 3,898
475.02	\$ 39,762	\$ 41,012	\$ 50,916	\$ 11,154	\$ 7,097
475.03	\$ 21,331	\$ 20,605	\$ 18,744	\$ (2,587)	\$ 150
475.04	\$ 90,490	\$ 92,376	\$ 125,526	\$ 35,036	\$ 21,270
475.05	\$ 19,596	\$ 19,828	\$ 21,729	\$ 2,133	\$ 9,945
475.06	\$ 11,645	\$ 12,075	\$ 22,630	\$ 10,985	\$ 4,766
475.07	\$ 4,861	\$ 4,927	\$ 6,468	\$ 1,607	\$ 1,073
475.08	\$ 6,919	\$ 7,801	\$ 11,127	\$ 4,208	\$ 1,677
475.09	\$ 5,018	\$ 5,393	\$ 7,117	\$ 2,099	\$ 943
Grand Total	\$ 221,226	\$ 227,373	\$ 294,179	\$ 72,953	\$ 50,819

Exceeds TPC (\$274M)

COVID Delays overall impacts

- COVID has had a significant impact on all aspects of the project.
 - Shutdowns
 - Reduced staff on site that continues
 - **COVID safe working protocols**
 - Social distancing – impacts efficiency
 - Masks
 - Additional work planning requirements – impacts efficiency
 - **Quarantines – Have hit us many times**
- Activities that used to take 8 hours now typically take 11 – 12 hours
 - ~ **70% efficiency**



COVID other Impacts

- Mu2e is a mature Project that depends on completing field work
- Largest impacts to **detector systems and Transport Solenoid**
- Biggest impact is to Tracker panels because of close proximity work
 - Panel production model involves a large crew of undergrads
- Significant impact to Calorimeter due to recall of INFN personnel to Italy
 - Continue to have problems getting INFN colleagues back to Fermilab
- CRV module construction at Virginia impacted by limited availability of undergraduates and social distancing requirements.
- **Acceptance testing of TS modules and cold mass construction significantly impacted by shutdown, occupancy limits, social distancing and COVID quarantines. Now this is OVER**
- COVID occupancy limits likely to persist at least through the summer.