Mu2e Accelerator Upgrades

Steve Werkema
Level 2 Manager: Mu2e Accelerator Upgrades
7/8/2014

Scope Overview

475.02.08.03 Extinction Monitor

475.02.09 Target Station

475.02.07 External (M4) Beamline

475.02.08.02 Extinction

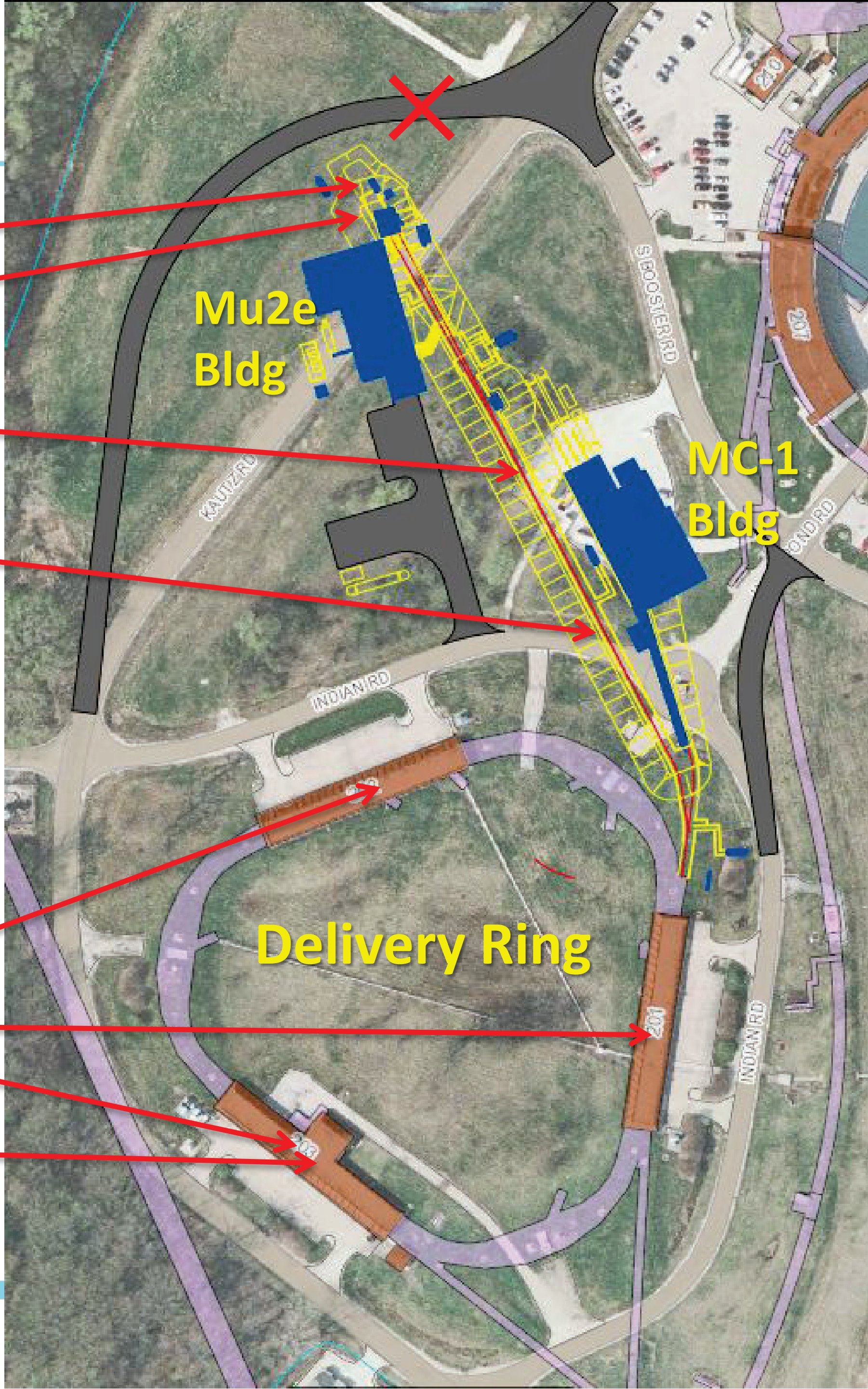
475.02.03 Instrumentation & Controls

475.02.04 Radiation Safety

Everywhere

475.02.05 Resonant Extraction

475.02.06 Delivery Ring RF



Not on the Mu2e Project

Accelerator Upgrade	Project
MI-8 beamline to Recycler Ring Injection	NOvA Project
Recycler Ring 2.5 MHz RF system	Recycler RF AIP
Delivery Ring 2.4 MHz RF Cavities	Recycler RF AIP
Single bunch extraction from Recycler Ring	Beam Transport AIP
Beamline aperture upgrades	Beam Transport AIP
AP1, AP2, AP3 to M1, M2, M3 conversion & upgrade	Beam Transport AIP
Beam transport instrumentation & infrastructure	Beam Transport AIP
Beam transport controls	Delivery Ring AIP
Delivery Ring Injection	Delivery Ring AIP
Delivery Ring Abort	Delivery Ring AIP
Delivery Ring infrastructure	Delivery Ring AIP
Delivery Ring Controls and Instrumentation	Delivery Ring AIP
D30 straight section reconfiguration	g-2 Project
Delivery Ring Extraction (except ESS)	g-2 Project
Extraction line (M4) to M5 split	g-2 Project
M4 beamline enclosure	MC Beamline Enclosure GPP

Requirements

The Mu2e Accelerator Upgrades are governed by seven requirements documents

- Proton Beam Requirements — Mu2e-doc-1105
- Beam Extinction Requirements — Mu2e-doc-1175
- Extinction Monitor Requirements — Mu2e-doc-894
- Production Target Requirements — Mu2e-doc-887
- Heat and Radiation Shield (HRS) Requirements — Mu2e-doc-1092
- Proton Absorber Requirements — Mu2e-doc-948
- Protection Collimator Requirements — Mu2e-doc-2897

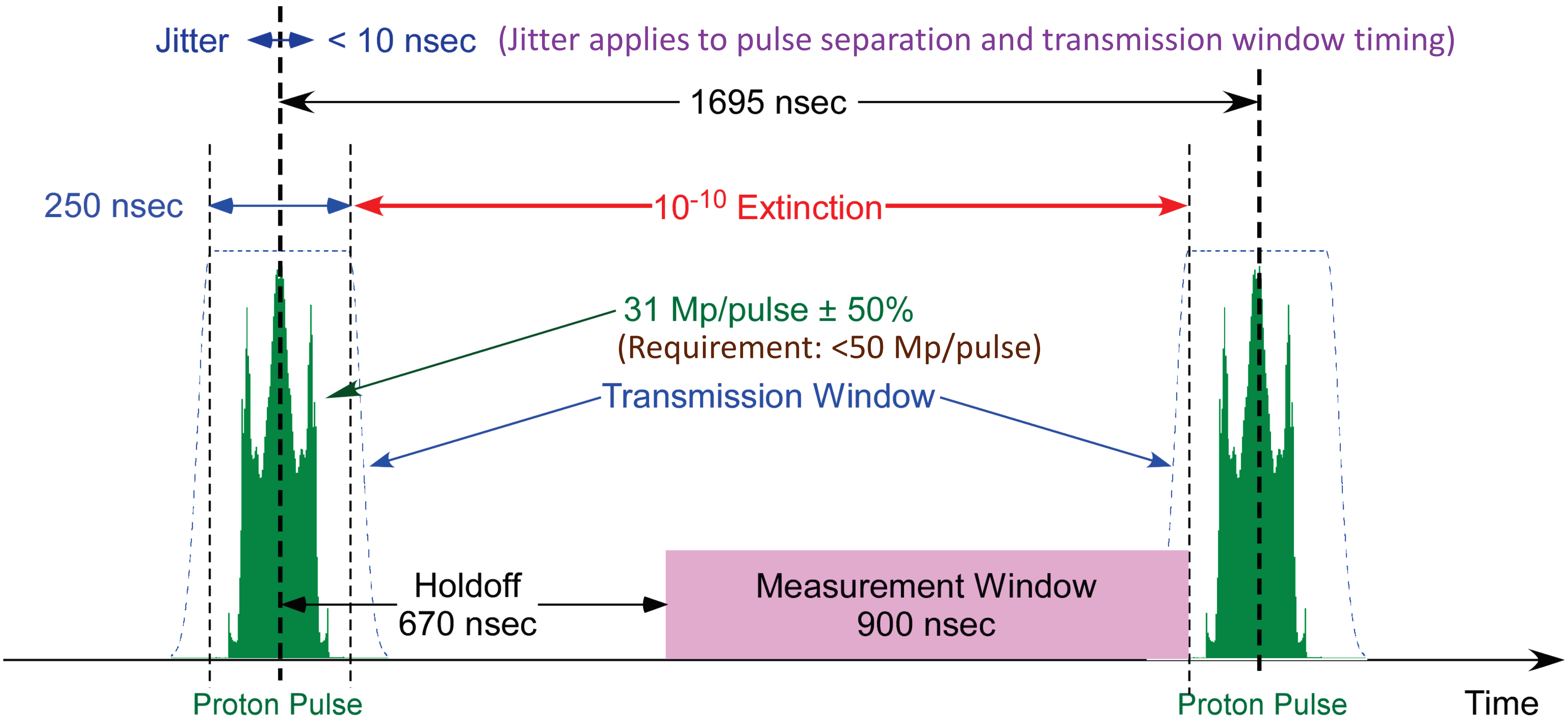
All of these documents are available on the review web site.

Proton Beam Requirements

	Parameter	Design Value	Requirement	Unit
	Total protons on target	3.6×10^{20}	3.6×10^{20}	protons
Time Structure	Time between beam pulses	1695	>864	nsec
Time Structure	Maximum variation in pulse separation	< 1	10	nsec
Time Structure	Spill duration	54	>20	msec
Time Structure	Beamline Transmission Window	230	250	nsec
Time Structure	Transmission Window Jitter (rms)	5	<10	nsec
Time Structure	Out-of-time extinction factor	10^{-10}	$\leq 10^{-10}$	
Intensity	Average proton intensity per pulse	3.1×10^{7}	$< 5.0\times10^{7}$	protons/ pulse
Intensity	Maximum Pulse to Pulse intensity variation	50	50	%
Beam Size	Minimum Target rms spot size	1	0.5	mm
Beam Size	Maximum Target rms spot size	1	1.5	mm
Beam Size	Target rms beam divergence	0.5	< 4.0	mrad

Proton Beam & Extinction Requirements

Two successive proton pulses on the Mu2e target (out of 32,000 per spill)

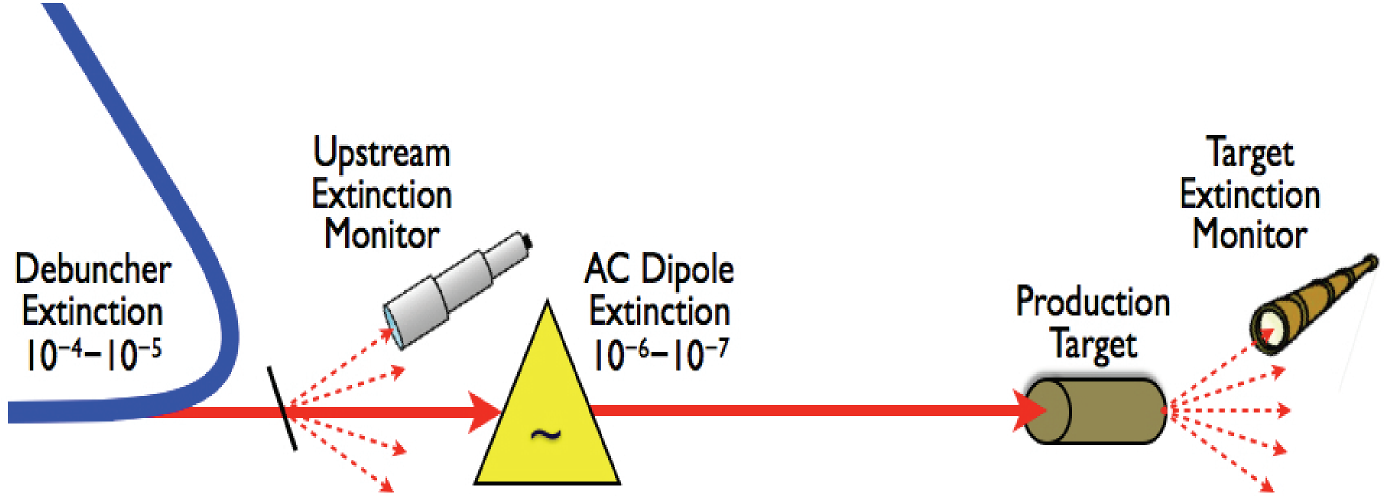


Extinction Monitor Requirements

Two Extinction monitors

- Upstream – fast, low sensitivity
- Target – slow, high sensitivity

Specification	Upstream Monitor	Target Monitor
Extinction sensitivity	10^{-5}	10^{-10}
Integration time	~10 s (< 2×10^{14} POT)	~1 hr (6×10^{16} POT)

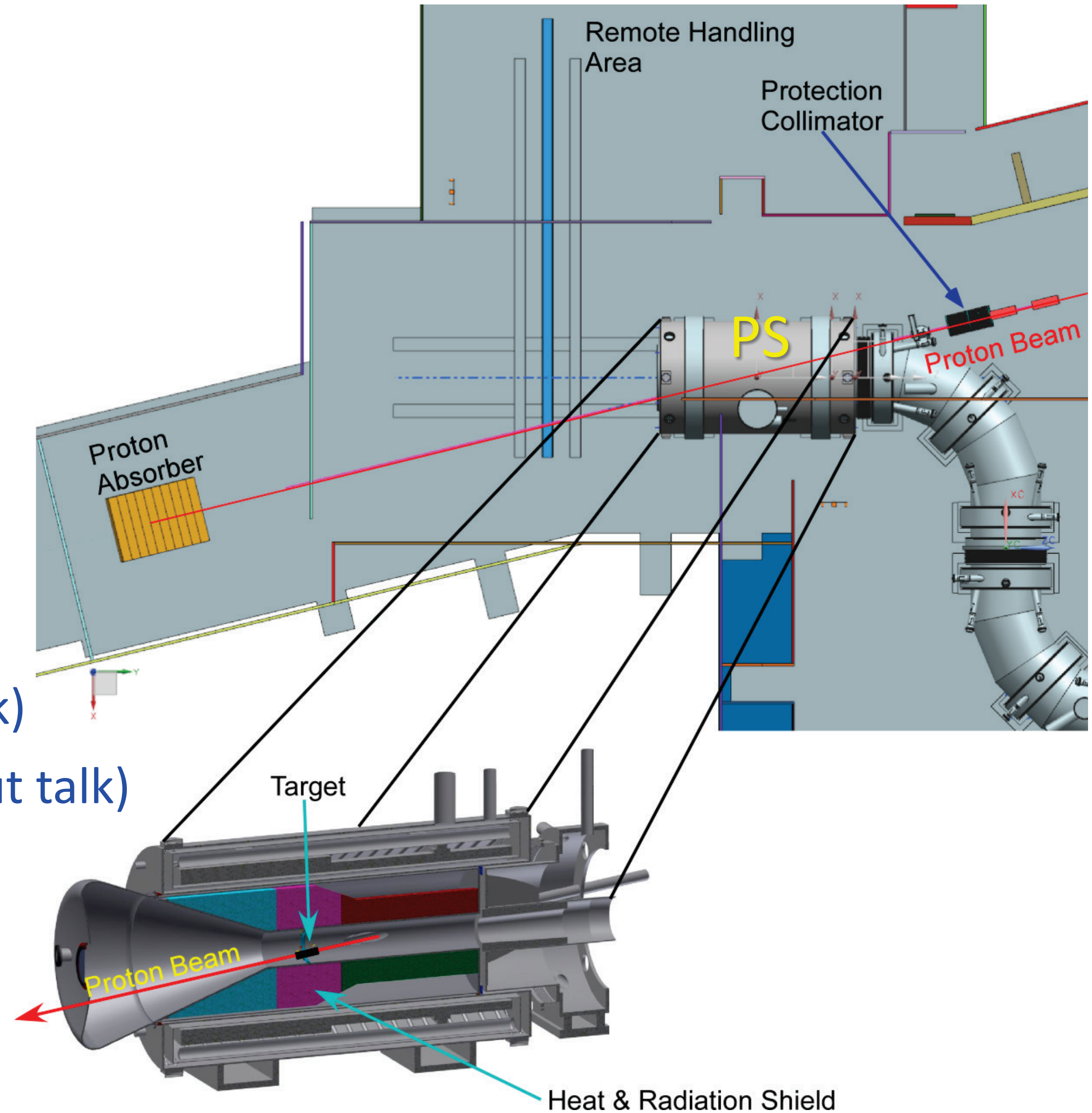


Target Station Requirements

Target Station Layout

There are four requirements documents governing target station components.

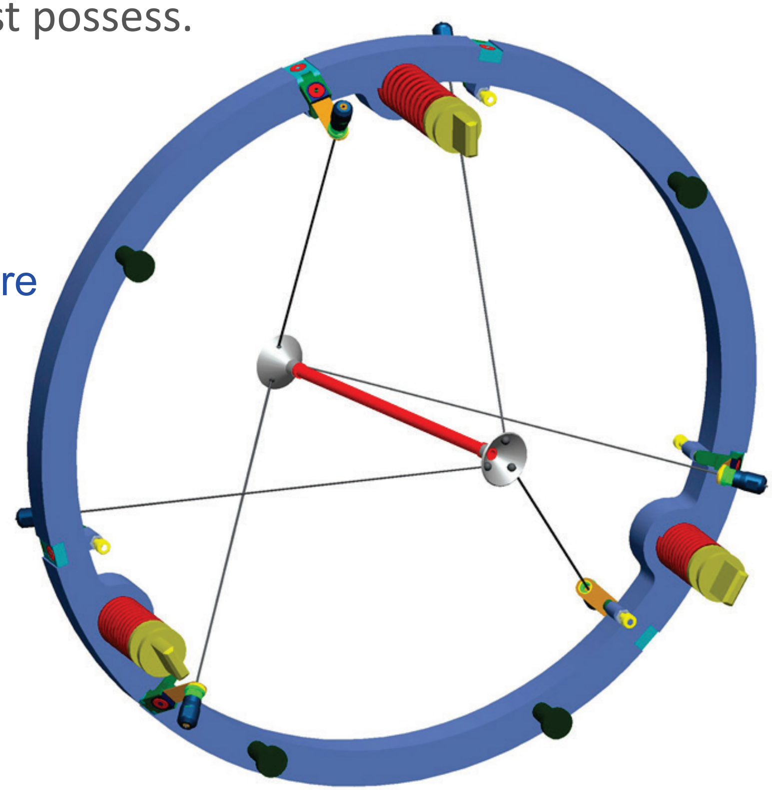
- Target
- Heat & Radiation Shield (HRS)
- Proton Absorber (breakout talk)
- Protection Collimator (breakout talk)



Production Target General Requirements

The target requirements document gives qualitative and quantitative specifications. Here are the general properties that the Mu2e proton target must possess.

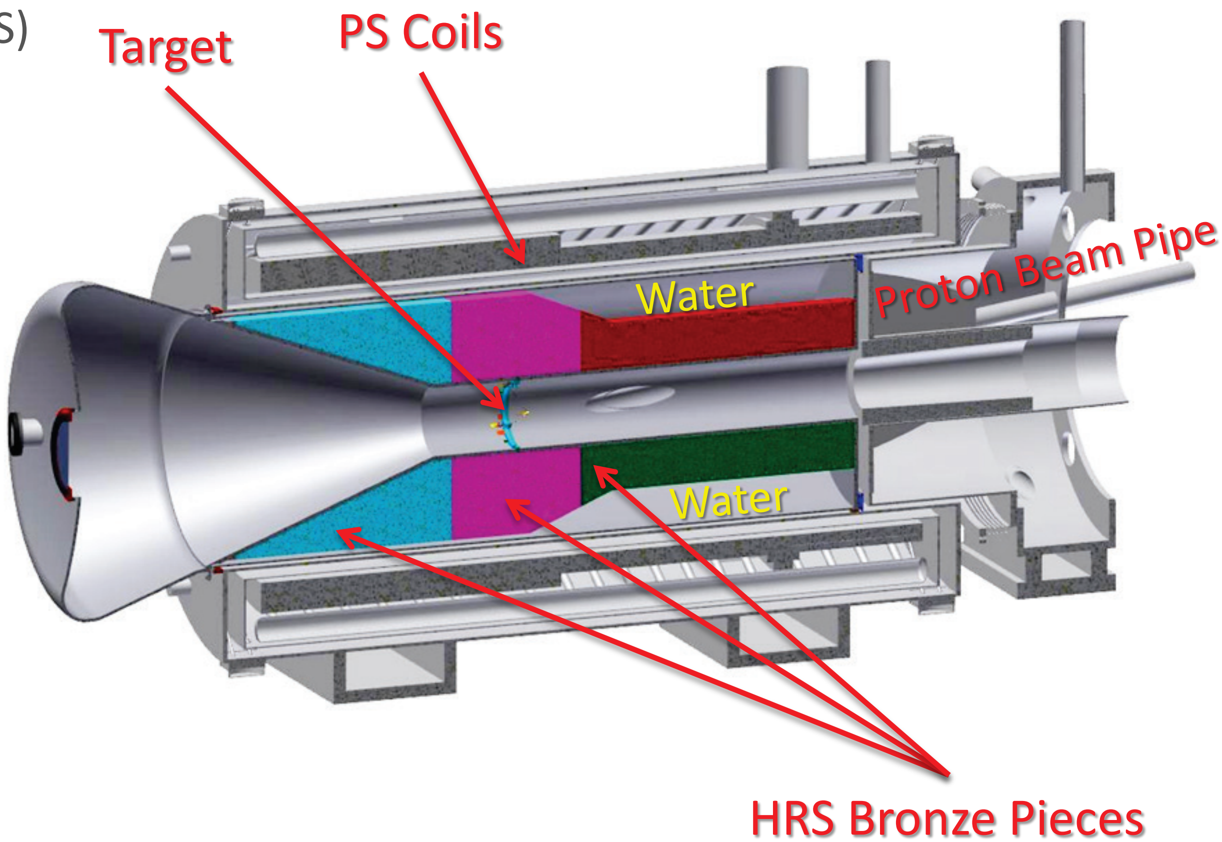
- Maximize pion yield
  - High Z, high density
  - Compact geometry to minimize reabsorption
  - Mechanically stable, low mass target support structure
- Survive (1 year lifetime) high radiation, high temperature environment
  - High melting point
  - Corrosion resistant
  - High emissivity (lower operating temp.)
  - Robust support structure
- Replaceability
  - Remote target handling system
  - Target support structure/target handling system must allow removal of spent target and precise positioning of replacement target



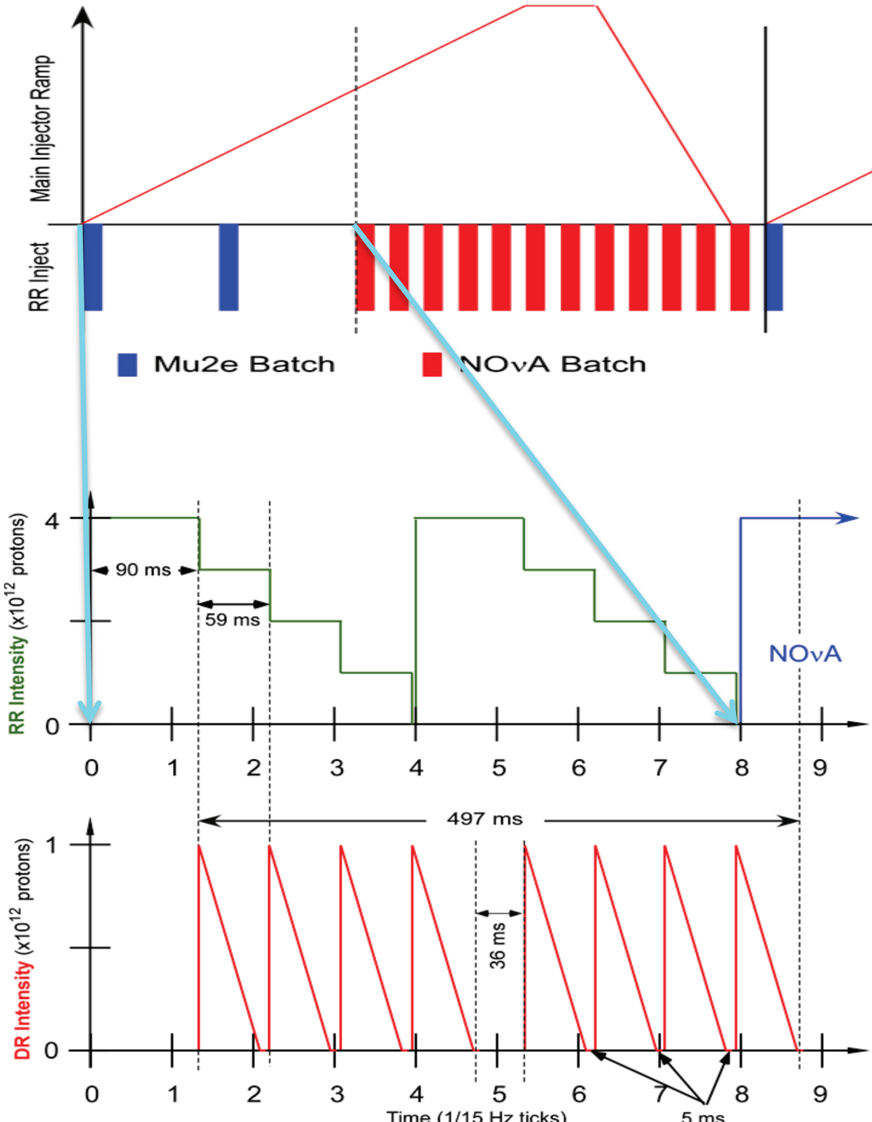
Radiatively cooled tungsten target and target support system

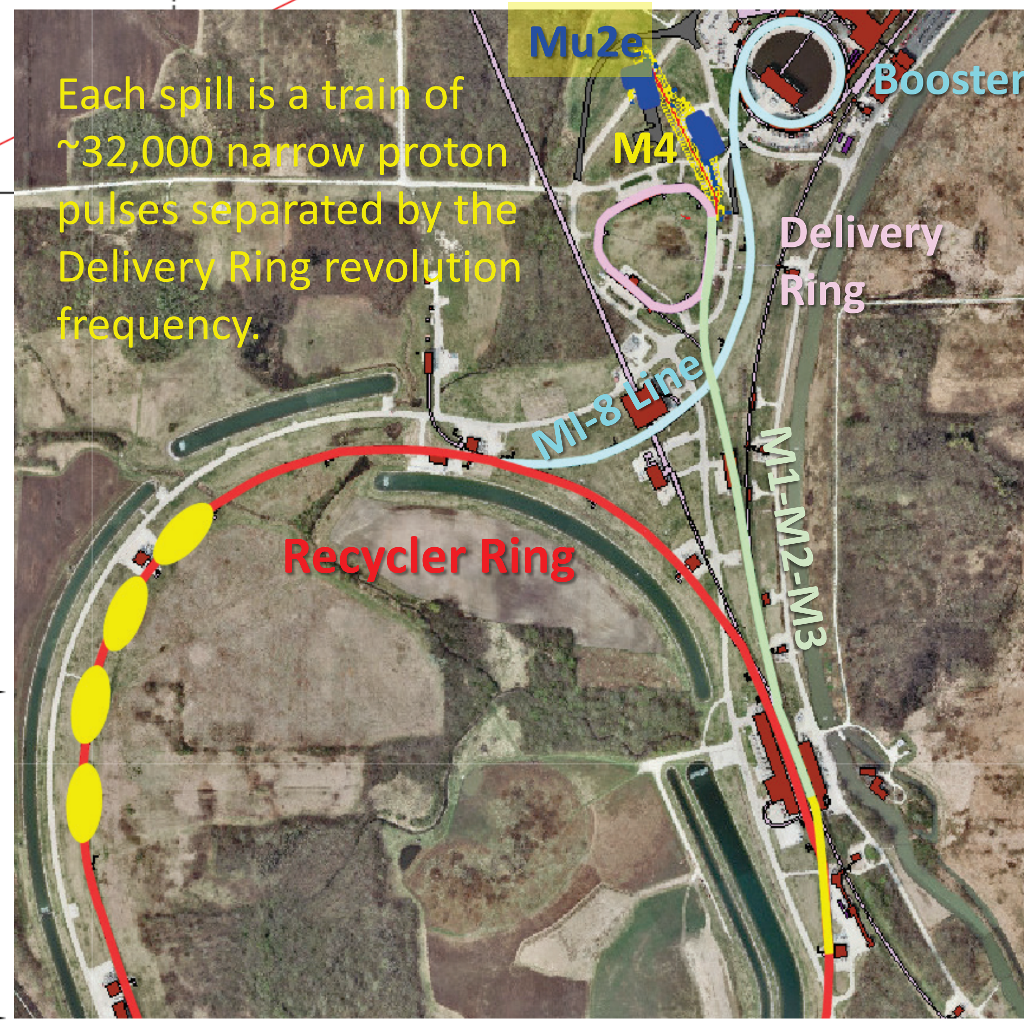
HRS Requirements Overview

- Limit Production Solenoid (PS) thermal exposure from heat radiated from target to acceptable levels
- Limit radiation dose and radiation damage to the Production Solenoid superconducting coils to acceptable levels
- Limit heat and radiation exposure of Transport Solenoid (TS) to acceptable levels
- Constraints on HRS design:
  - PS field quality
  - Quench induced eddy currents
  - Muon yield



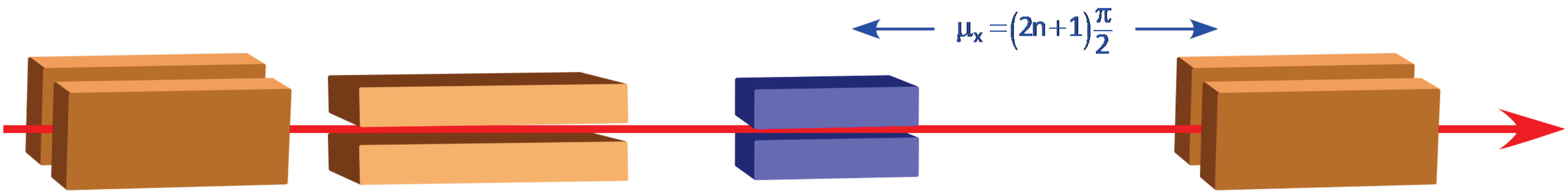
Design – Beam Time Structure





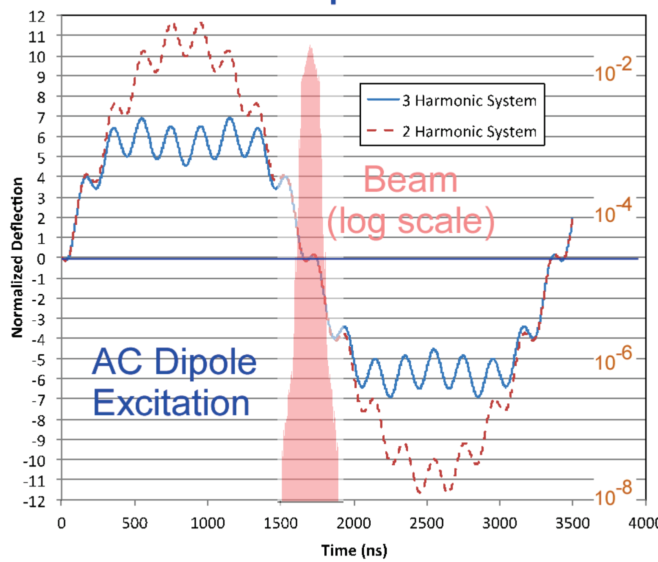
Each spill is a train of ~32,000 narrow proton pulses separated by the Delivery Ring revolution frequency.

Design – Extinction



AC Dipole

Upstream Horizontal and Vertical Collimation defines admittance



Out-of-time beam deflected into downstream collimator

Upstream Extinction:
$< 10^{-4}$

Downstream Extinction:
$< 10^{-10}$

Details in Eric Prebys' breakout talk

AC Dipole excitation is a superposition of three harmonics: 300 kHz, 900 kHz, and 4.5 MHz.

Extinction Performance

Two Models:

1. Beam time distribution from ESME longitudinal tracking model in the Delivery Ring.
2. G4Beamline tracking model of extinction section of the M4 beamline.

Results:

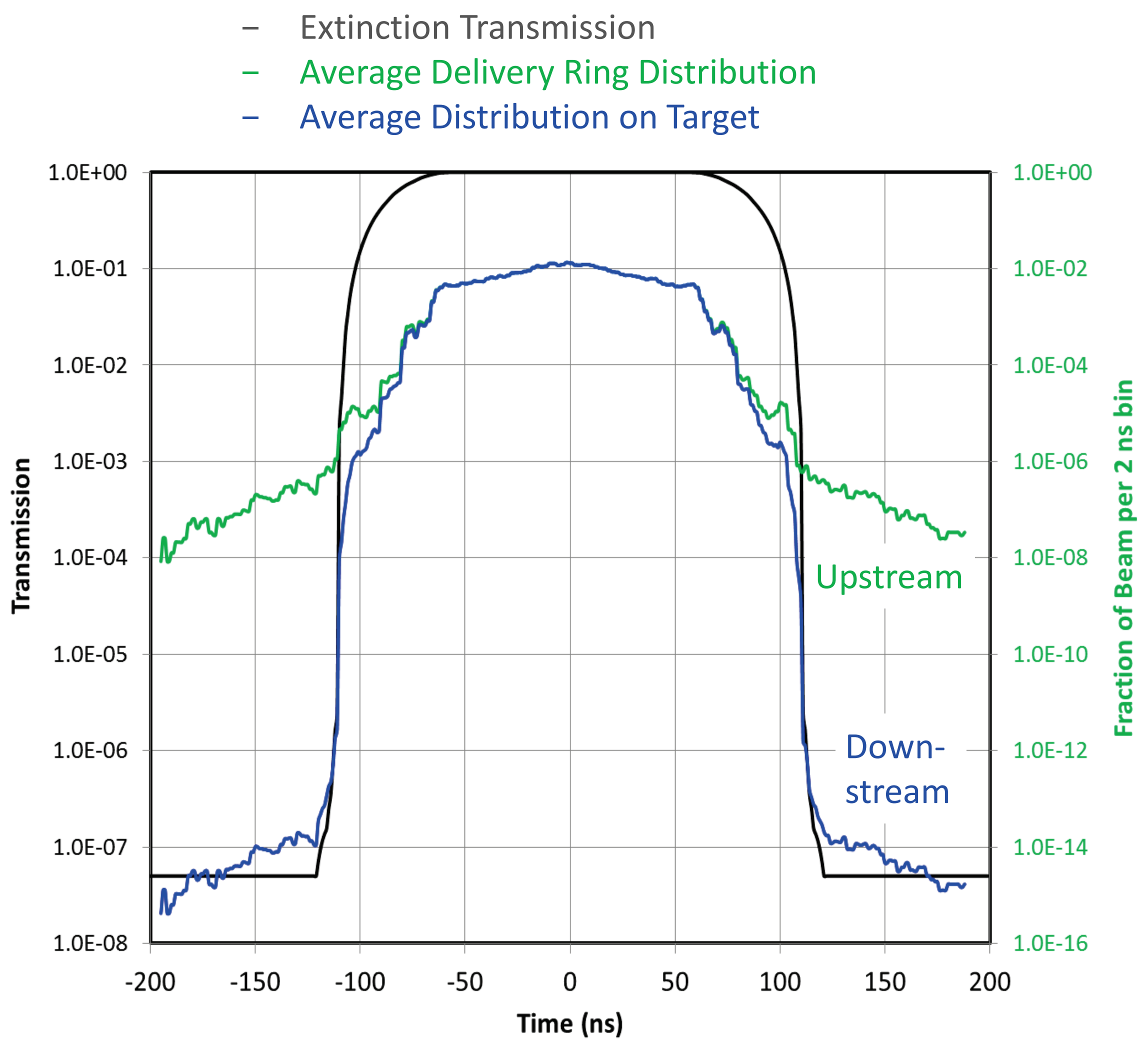
Upstream extinction: 1.6×10^{-5}

In-time beam transmission: 99.7%

Downstream extinction: 8×10^{-13}†

Extinction Requirement: 1×10^{-10}

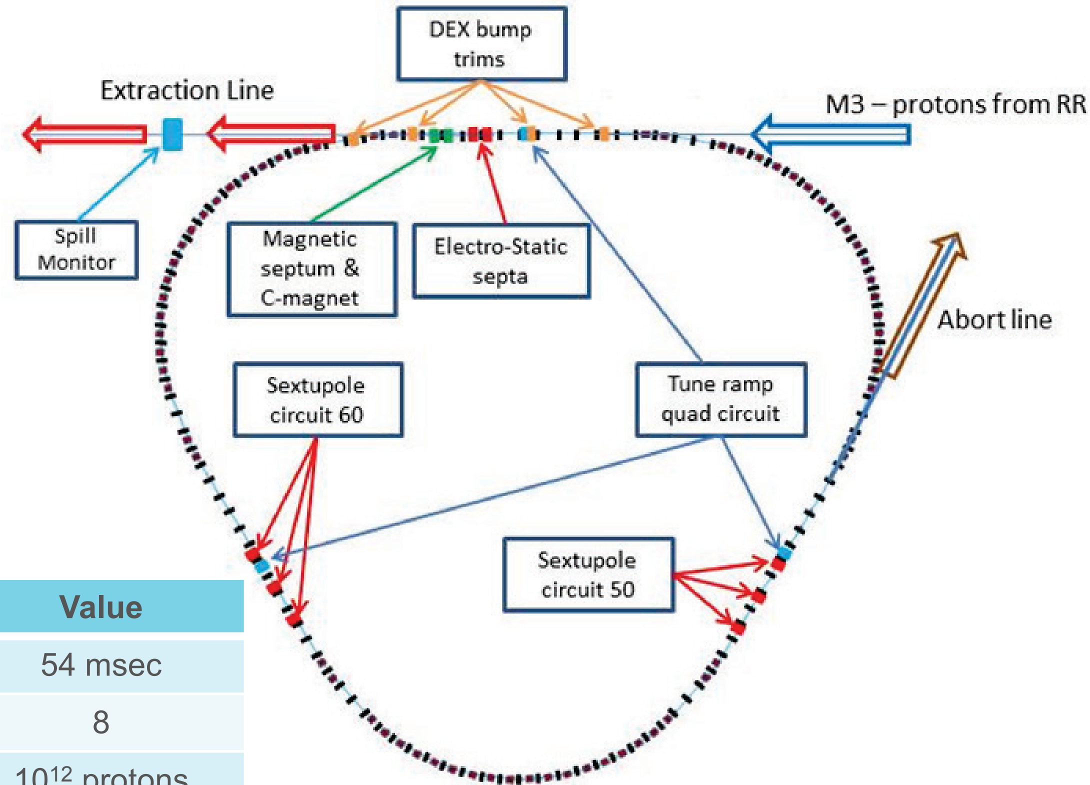
† This number assumes that there is no contribution from long transverse tails.



Resonant Extraction Design and Performance

The Mu2e project will install a Resonant Extraction System in the Delivery Ring.

- Two Electro-static septum modules
- Two families of harmonic sextupole magnets (6 magnets total)
- Three horizontal tune ramp quadrupole magnets
- RF-knockout based spill feedback and control
- Spill monitoring



Parameter	Value
Spill duration	54 msec
Number of spills in a supercycle	8
Full spill intensity	10^{12} protons
Number of protons extracted per pulse (turn)	3×10^{7}
Time between pulses (turns)	1.695 μsec
Reset time between spills	5 msec
Spill rate variations	< 50%
Extraction time duty factor	32%

Details in Vladimir Nagaslaev's breakout talk

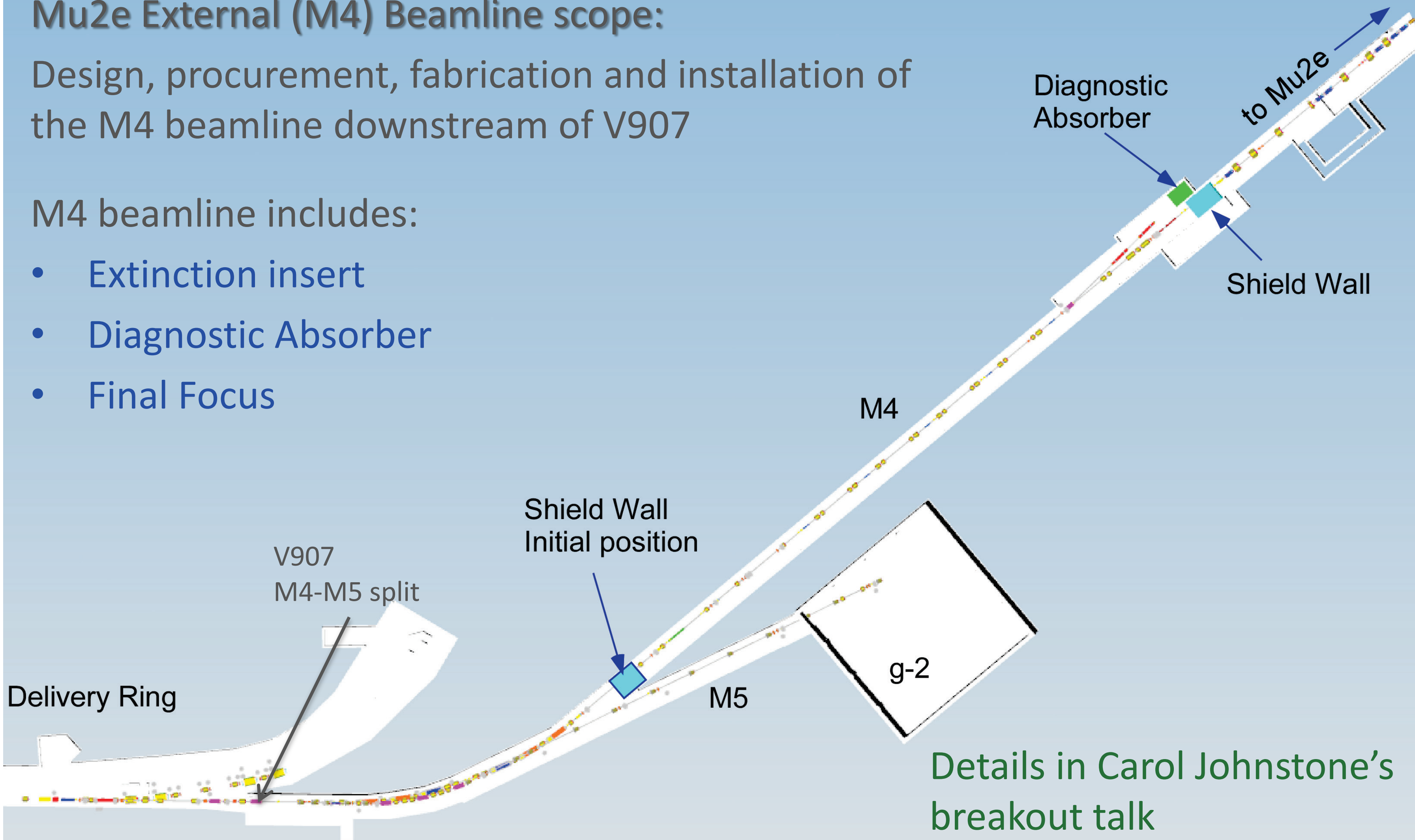
Design – External Beamline

Mu2e External (M4) Beamline scope:

Design, procurement, fabrication and installation of the M4 beamline downstream of V907

M4 beamline includes:

- Extinction insert
- Diagnostic Absorber
- Final Focus



Details in Carol Johnstone's breakout talk

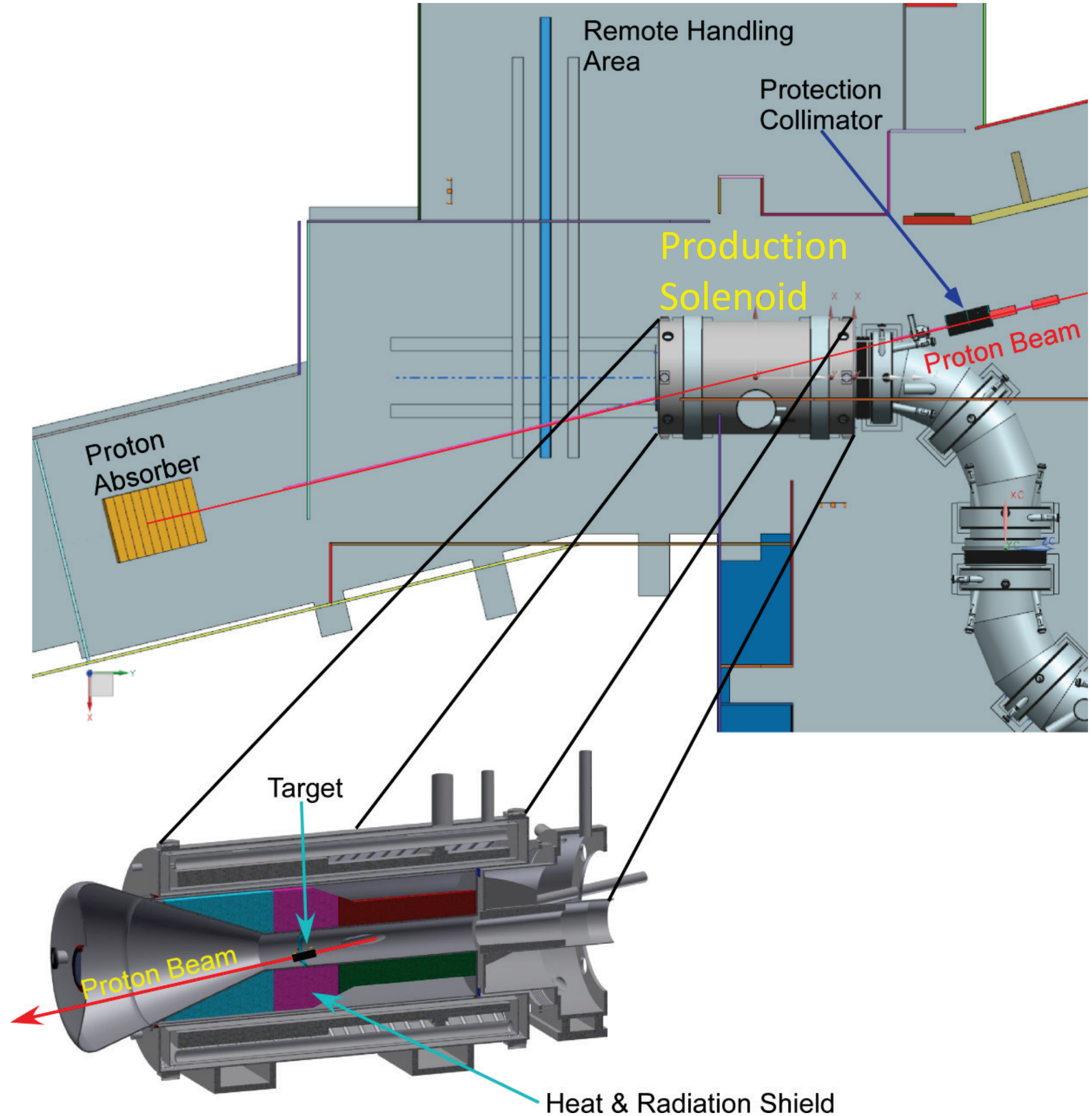
Design – Target Station

Proton Target

- Tungsten Rod: 16 cm (long) × 6 mm (diameter)
- Radiatively cooled
- Peak Operating temp.: ~1700°C
- Resides in PS vacuum ~10^{-5} torr

Heat and Radiation Shield (HRS)

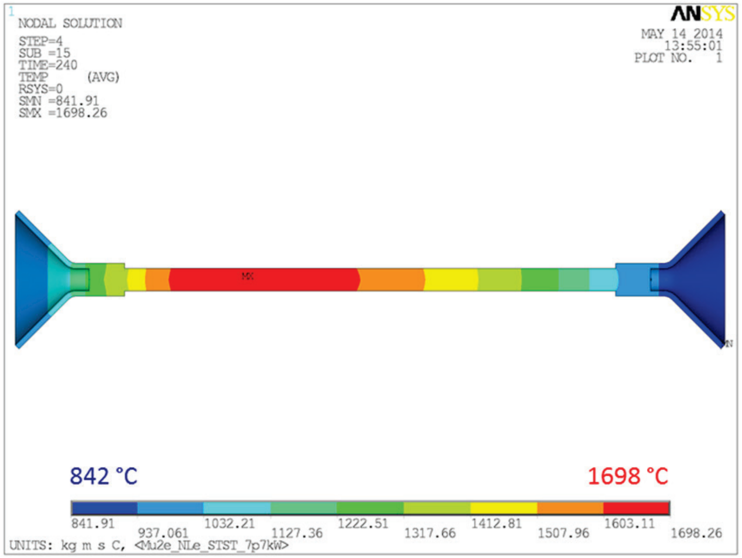
- Lines the inside of the PS cryostat
- Isolated from muon beamline vacuum
- ~37 tons of bronze, stainless steel, and water



Details in Rick Coleman's breakout talk

Target Station Performance

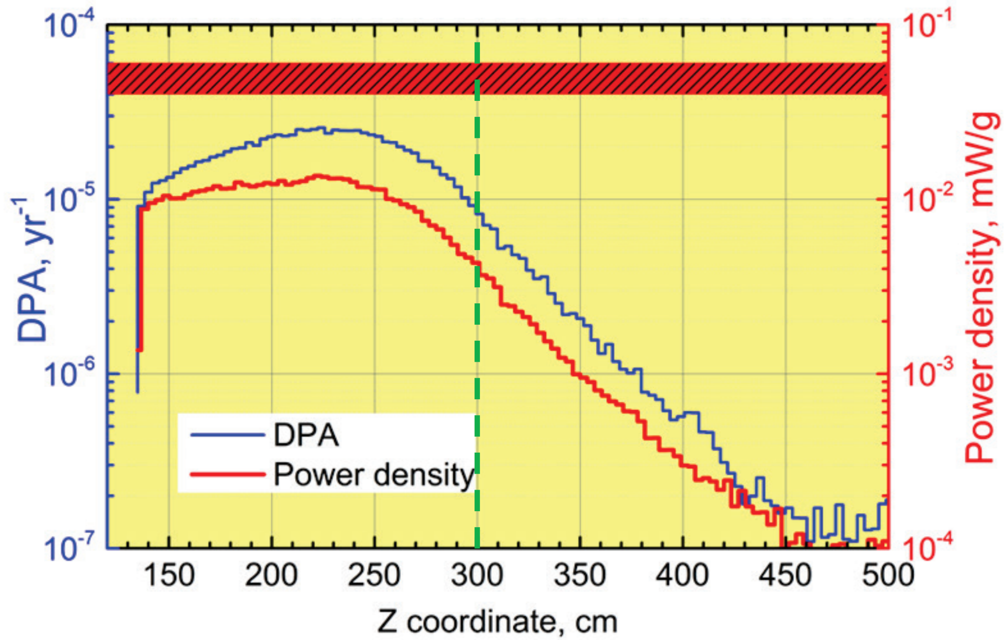
Target Performance



Steady-state target temperature distribution

- RAL completed numerous ANSYS and Fluka simulations for thermal and mechanical stress and mechanical stability
- Completed 4 years equivalent design pulsing on vacuum test stand at RAL to assess mechanical durability (stress and fatigue)
- Ready to begin tests of corrosion effects

HRS Performance



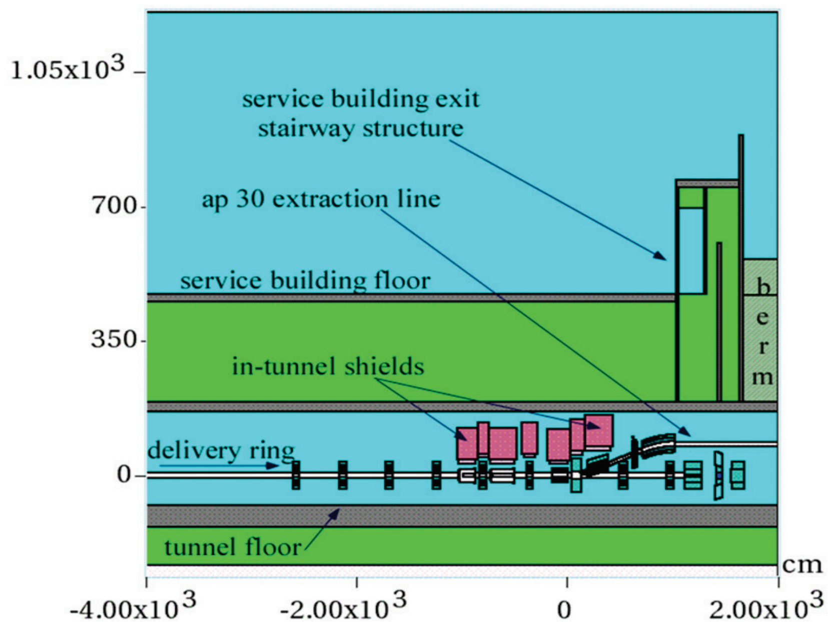
MARS Simulation:
Peak DPA and Power Density in the PS coils as a function of position along PS axis.
Target is at z = 300 cm.

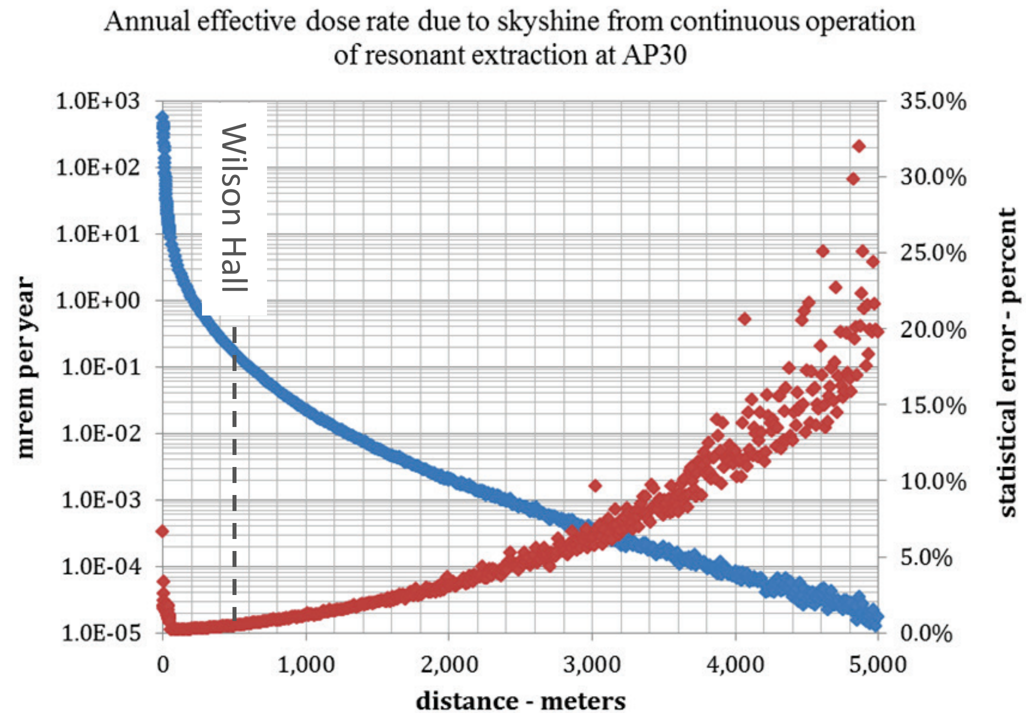
DPA Requirement: < 4-6×10^{-5} DPA/yr
Power Density Requirement: < 30 μW/g

Radiation Safety Design and Performance

The basic components of the Mu2e Accelerator Radiation Safety Upgrades are:

- Supplemental shielding of known loss points
- Total Loss Monitor (TLM) system of interlocked detectors to preclude unacceptable dose rates outside of beam enclosures





Extensive MARS modeling of beam losses during Mu2e operation has shown that the Mu2e Radiation System prevents unacceptable external radiation dose rates

Details in Tony Leveling's breakout talk

Design – Other Accelerator Systems

Also included in the Mu2e Accelerator Upgrades are:

- Accelerator Controls and Instrumentation
  - Basic services for new facilities (FIRUS, phone, Ethernet, ACNET, SEWS)
  - M4 beamline controls and instrumentation
  - Delivery Ring Abort controls
  - Delivery Ring beam intensity and tune measurement instrumentation
  - Details in Brian Drendel's breakout talk
- 2.4 MHz Delivery Ring RF System
  - Low level and High level systems
  - Cooling system
  - RF Cavity provided by the Recycler AIP
  - Details in Joe Dey's breakout talk

Design Status

The following level 3 sub-projects have completed their engineering design:

- 475.02.03 Instrumentation and Controls
- 475.02.04 Radiation Safety
- 475.02.06 Delivery Ring RF

We are asking for CD-3 for these three sub-projects

The following level 3 sub-projects are presenting a preliminary design:

- 475.02.05 Resonant Extraction — CD-3: March 2016
- 475.02.07 External Beamline — CD-3: December 2014
- 475.02.08 Extinction and Extinction Monitoring — CD-3: December 2014
- 475.02.09 Target Station — CD-3: September 2015

Changes since CD-1

WBS

- Combined the former 2.03 (Transport & Delivery Ring) and 2.11 (Operations Preparation) into the present 2.03 (Instrumentation and Controls)

Resonant Extraction

- Change from outward extraction to inward extraction
- Septum wire versus foil plane downselect
- Extraction resonance downselect

Radiation Safety

- Received active shielding waiver (allows use of interlocked detectors)
- Received preliminary approval for the use of TLMs (Allows retirement of $2M risk)
- Received approval of the Mu2e preliminary shielding assessment

Changes since CD-1 (Continued)

Extinction

- Eliminated need for "internal" extinction
- Changed from two AC dipole harmonics to three
- Beamline extinction section configuration change:
  - CD-1 Design: AC-Dipole followed by 5 collimators
  - CD-2 Design: H + V Collimators → AC Dipole → H Collimator

External Beamline

- Changed extraction to the diagnostic absorber from vertical to horizontal
- Changes to accommodate extraction direction change
- Changes to accommodate reconfiguration of the extinction section

Target Station

- HRS redesign:
  - CD-1 Design All Bronze located inside the muon beamline vacuum
  - CD-2 Design Bronze, Stainless Steel, and water located outside of the muon beamline vacuum
- Remote handling re-design

Value Engineering since CD-1

- Reduced amount of external beamline instrumentation by allowing for the early use of final focus section instrumentation for commissioning the extinction section
- Reduced cost of 2.4 MHz RF high level system by planning the procurement of the 8 kW final amplifiers from an outside vendor rather than having these amplifiers built at Fermilab
- New extinction section configuration uses two fewer collimators
- Acquisition of most of target materials testing equipment from off-project sources (RAL)
- Attempt to lower HRS costs by removing material at downstream (TS) end

Downselects

- Adopted foil plane electro-static septum design over the wire plane option
- Decision to forgo any further consideration of 2nd integer resonant extraction as the extraction resonance for the Delivery Ring
- Selection of an Extinction Monitor design by the Mu2e collaboration and the Mu2e project

Remaining work before CD-3

Resonant Extraction

- Build power supply prototype for ramped magnets (quadrupoles, sextupoles, DEX bump dipoles)
- Power supply prototype tests at MTF with existing magnets
- Electro-static septum High Voltage feed-though prototype tests in vacuum

External Beamline

- External Beamline optics design change to accommodate extinction section reconfiguration
- Complete vacuum system design

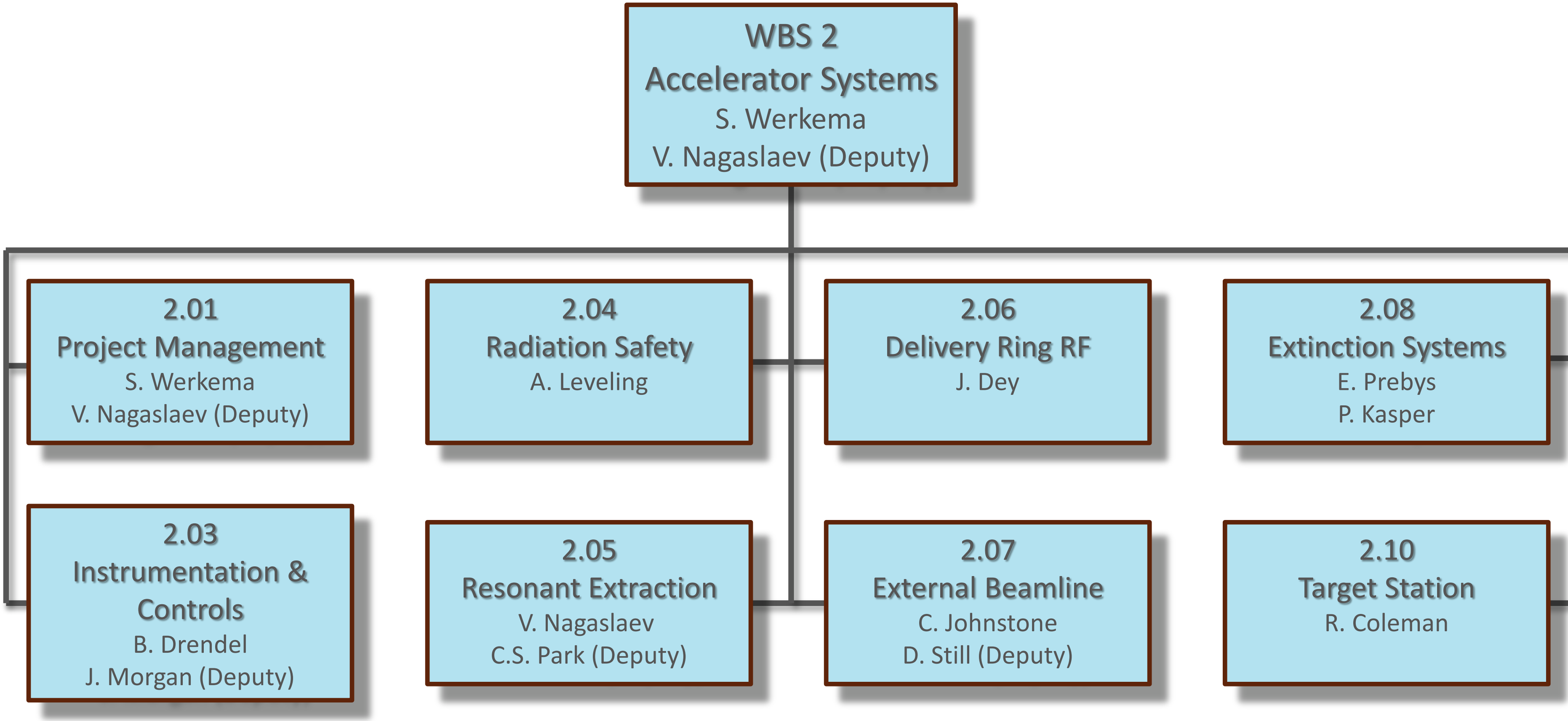
Extinction & Extinction Monitoring

- Complete Extinction simulations in final configuration
- Complete assessment of Extinction Monitoring backgrounds (fake out-of-time events)

Target Station

- Complete target testing
- Build prototype target and support system
- Reassessment of target handling

Organizational Breakdown



Quality Assurance

Mu2e Accelerator Upgrades Quality Assurance involves all of the following:

- Use of Governing Lab and Project QA Standards
  - Fermilab Quality Assurance Manual (QAM)
  - Fermilab Engineering Manual
  - Mu2e Quality Management Plan (Mu2e-doc-677)
- Design Verification and Validation
  - Reviews
  - Prototype testing
  - Beam testing
- Procurement & Fabrication Acceptance testing

Risks

- ACCEL-011 Inadequate AD Engineering Resources
  - ◊ Schedule risk due to delayed application of appropriate resources to scheduled tasks
  - ◊ Mitigation: Employ engineering services from outside of Fermilab (RAL, Bartoszek Engineering). Close and constant communication with Lab management regarding resource needs and schedule implications
- ACCEL-015 Injection damper required for Delivery Ring
  - ◊ Orbit control in the beam lines may not adequately control trajectory and may lead to emittance dilution
  - ◊ Mitigation: Build injection damper ($185k)
- ACCEL-033 Inability to move magnets to the M4 enclosure before g-2 operation
  - ◊ Inability, due to funding or schedule constraints, to stage magnets in the downstream M4 enclosure prior to g-2 beam operations
  - ◊ Mitigation: Removal and re-installation of M4 temporary shield wall during shutdowns. Installation of magnets via cranes through M4 hatch. ($400k)

Risks (Continued)

- ACCEL-038 Radiatively cooled target will not survive in the beam
  - ◊ Determination, during the final design phase, that a radiatively cooled target will not have the required one year lifetime.
  - ◊ Mitigation: Adoption of a cooled target design ($175k)
- ACCEL-151 Redesign the Remote Handling System for Water cooled target
  - ◊ Redesign of remote handling system required due to a determination that a radiatively cooled target will not have the required one year lifetime.
  - ◊ Mitigation: Modification of remote target handling system to accommodate the additional complexity of a cooled target and associated plumbing. ($3.3 M)
  - ◊ This is, by a significant margin, our most expensive risk.

ES&H

Accelerator beam enclosures

- Electrical hazards from exposed bus work.
- Mechanical hazards (sharp edges, protruding fixtures)
- Radiation hazards
  - Potentially lethal doses during beam operation
  - Residual radioactivity after beam operations
  - Radioactive surface and air contamination

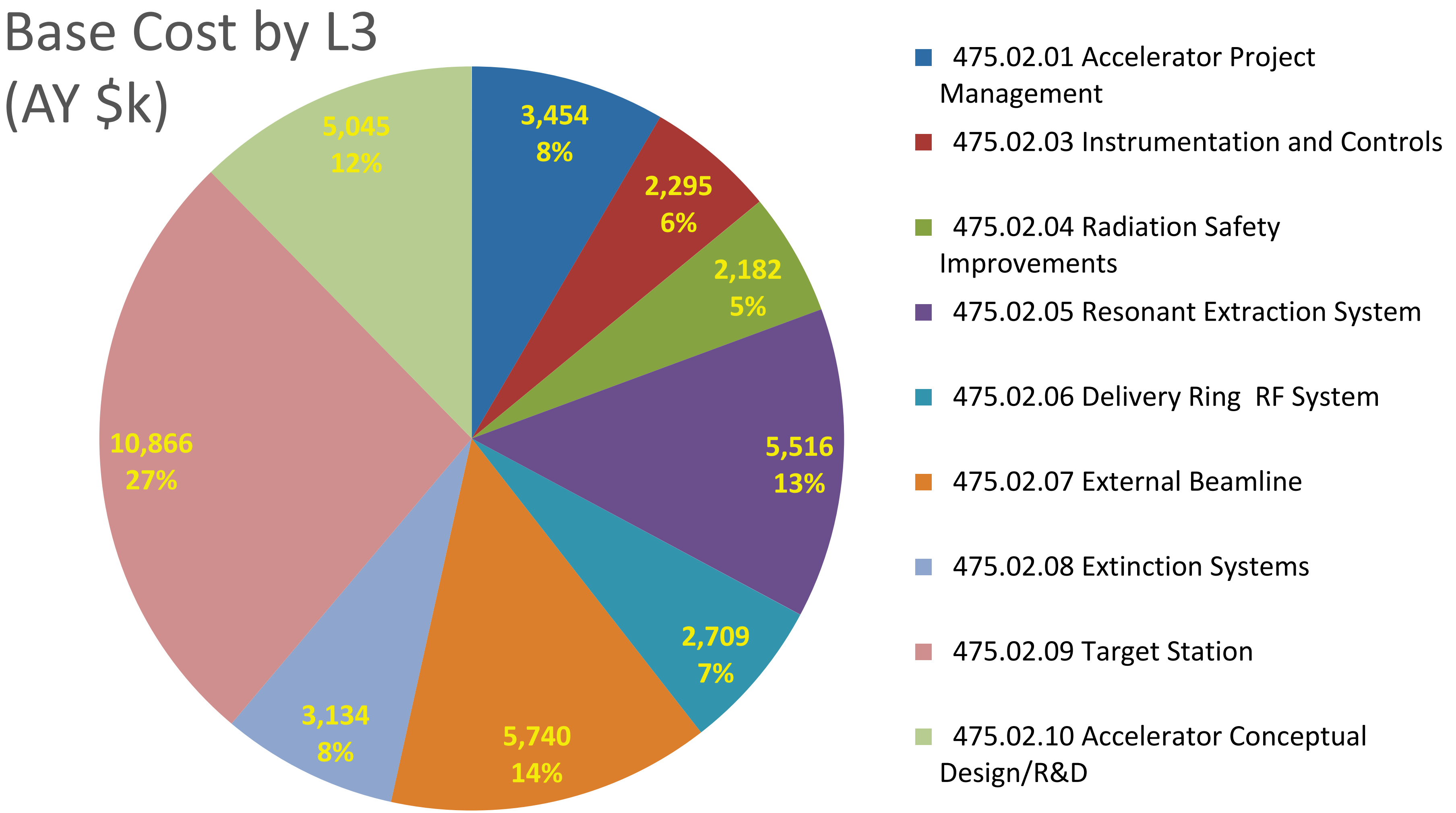
Above ground hazards

- Radiation dose rates in excess of continuous occupancy limits during beam operation in Muon Campus service buildings, on or near associated Muon Campus beamline berms, and in the vicinity of the Mu2e proton target and the associated proton beam absorber.

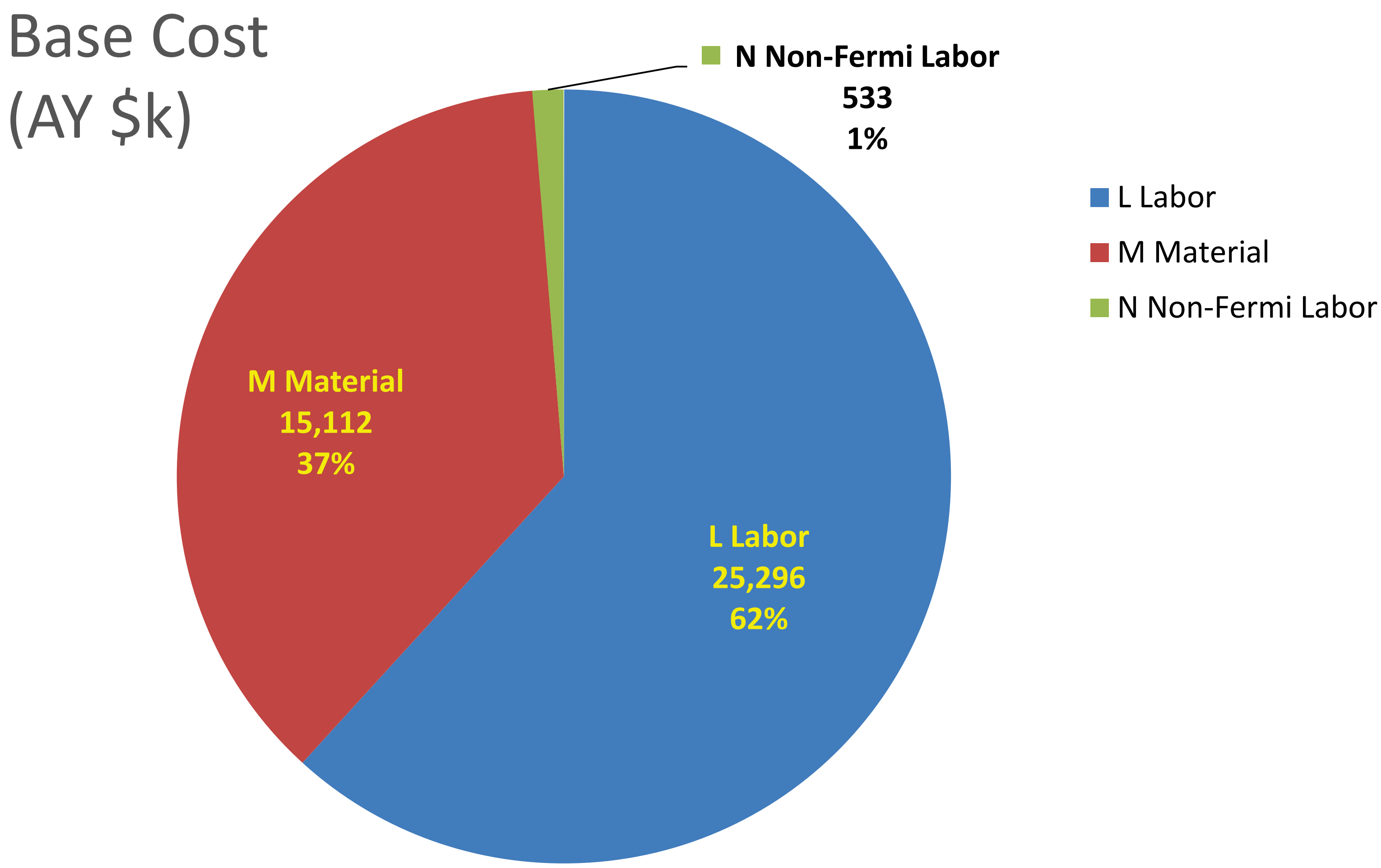
➢ Radiation safety is a significant part of the Mu2e Project – it is a level 3 sub-project of Mu2e Accelerator Upgrades.

➢ These hazards are all discussed in the Mu2e Hazard Analysis Report (Mu2e-doc-675).

Cost Distribution by L3

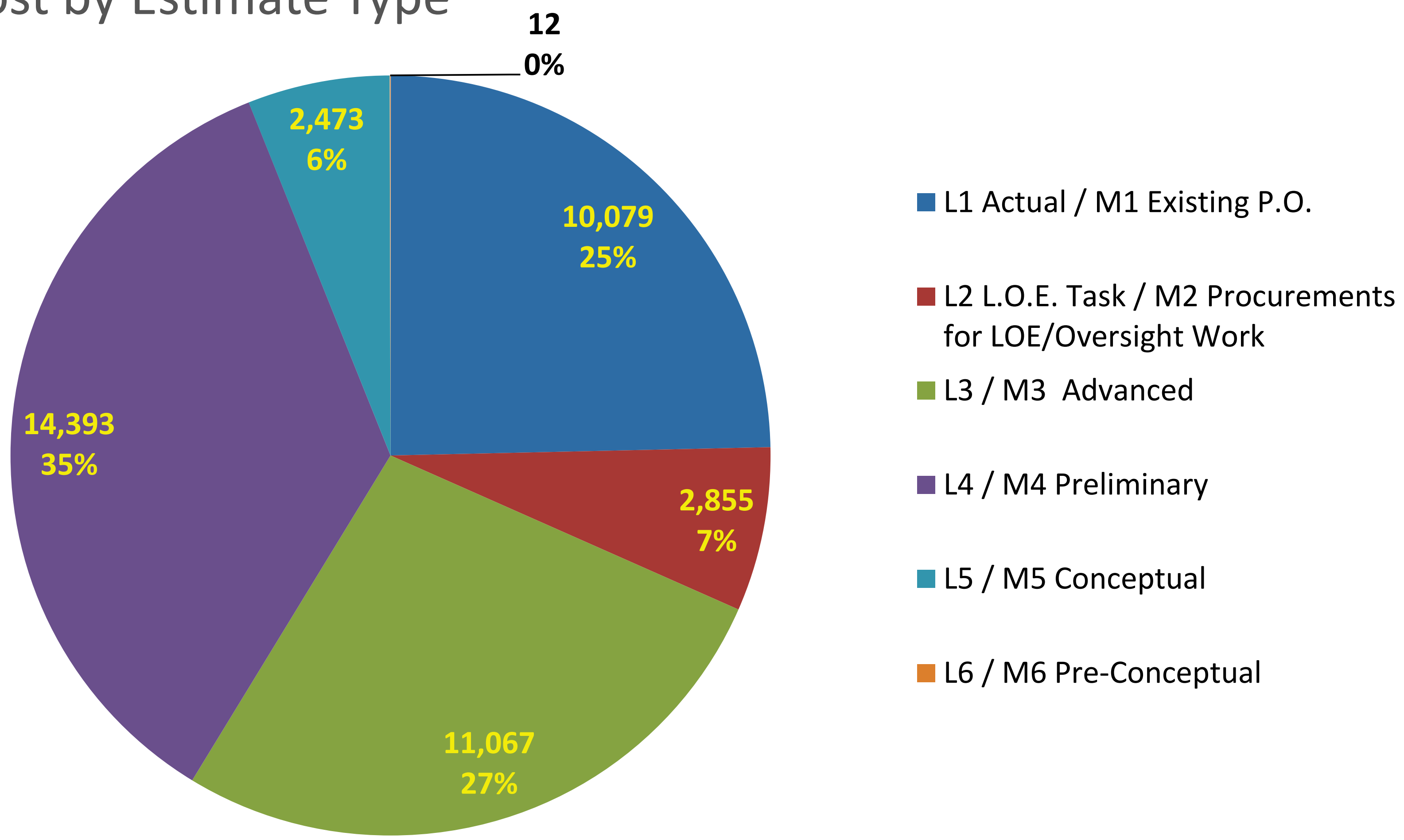


Cost Distribution by Resource Type



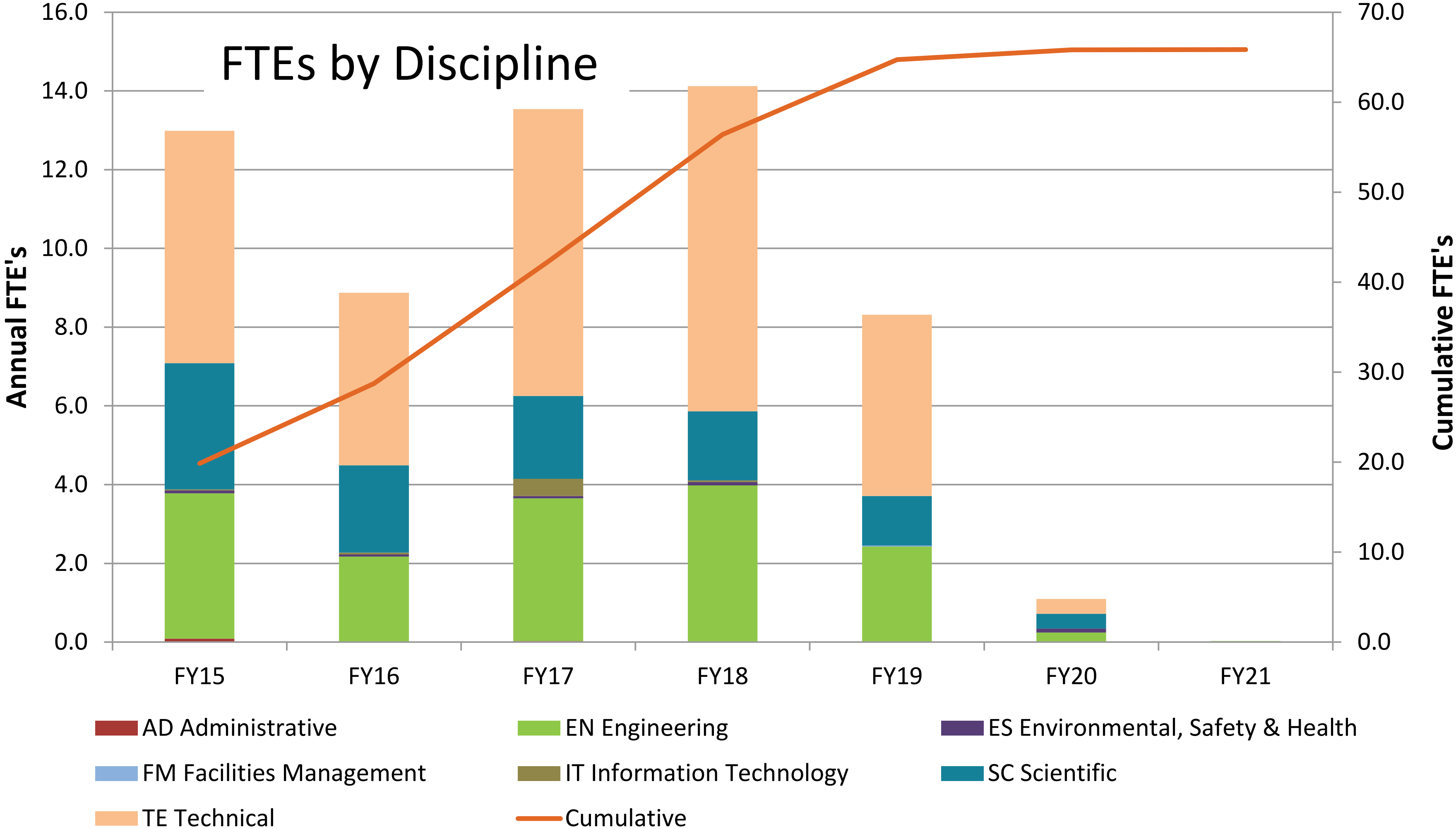
Quality of Estimate

Base Cost by Estimate Type (AY $k)



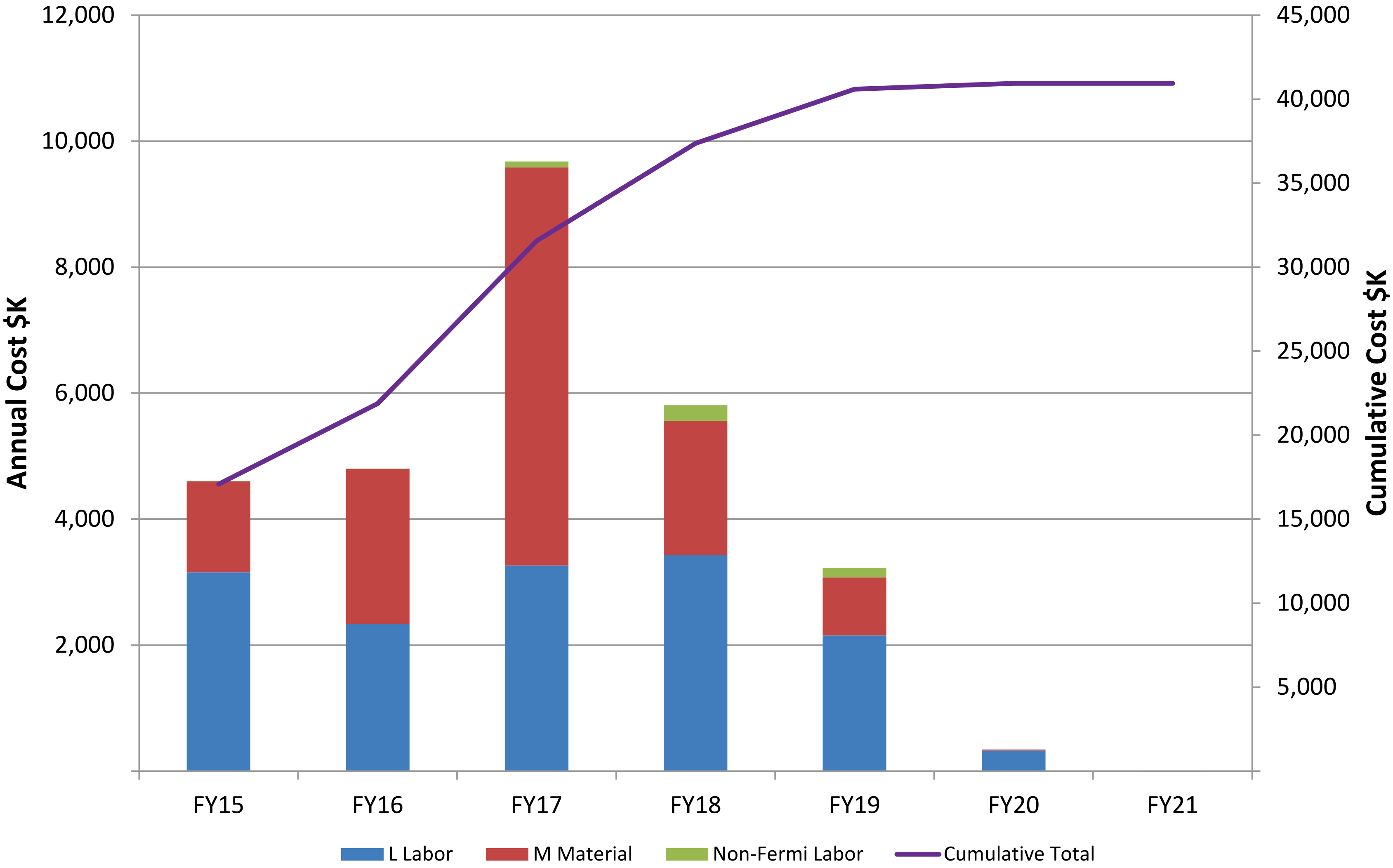
Contingency Rules are in Mu2e-doc-459
(available on the review web site)

Labor Resources



Mu2e

Labor and M&S by FY



Cost Table

WBS 2 Accelerator

Costs are fully burdened in AY $k

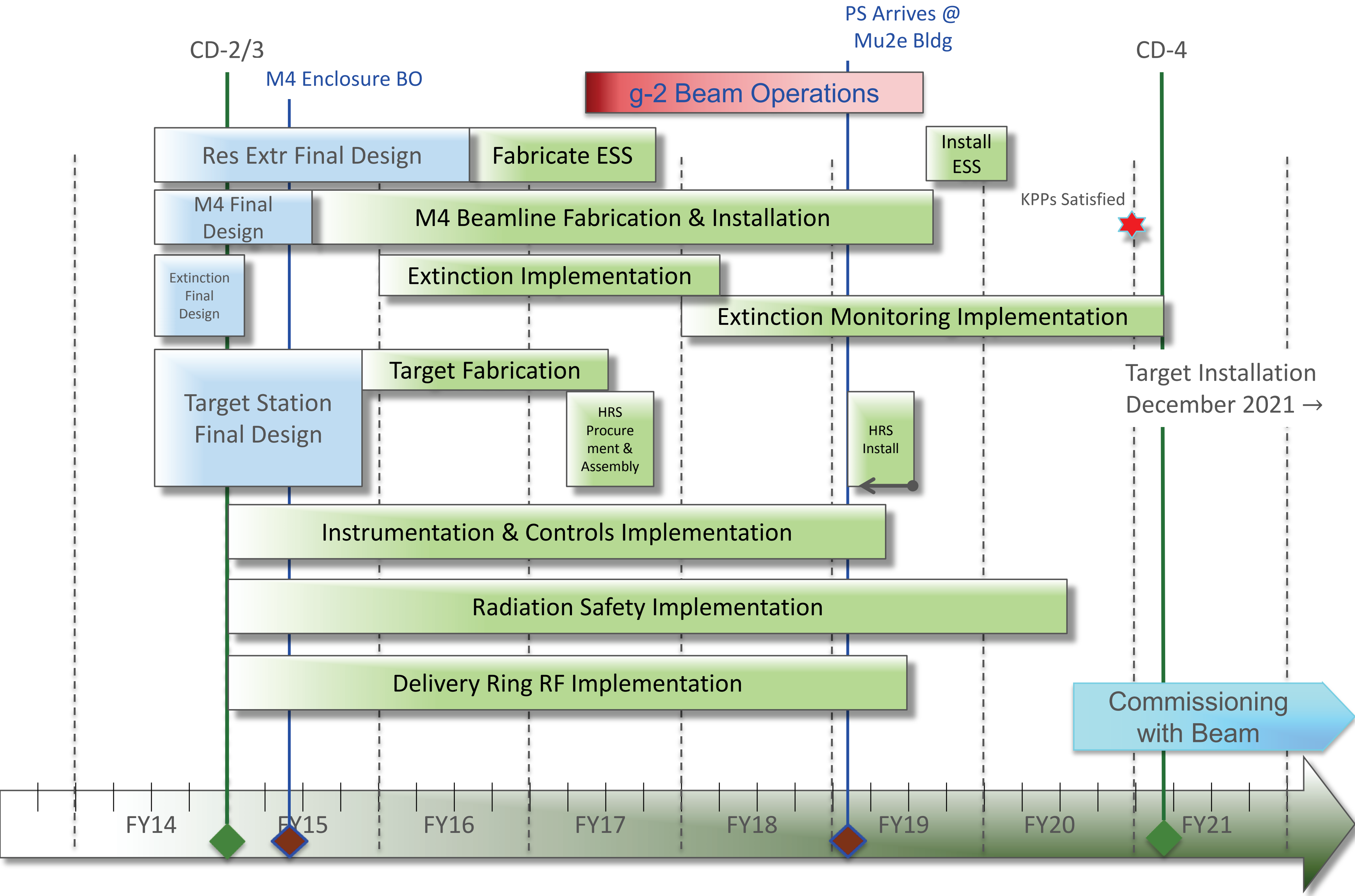
	M&S	Labor	Base Cost	Estimate Uncertainty	% Contingency on ETC	Total
475.02.01 Accelerator Management	73	3,381	3,454	342	14%	3,795
475.02.03 Instrumentation and Controls	772	1,523	2,295	522	26%	2,817
475.02.04 Radiation Safety Improvements	1,149	1,033	2,182	608	32%	2,790
475.02.05 Resonant Extraction System	1,853	3,663	5,516	1,649	34%	7,165
475.02.06 Delivery Ring RF System	754	1,954	2,709	565	23%	3,273
475.02.07 External Beamline	2,800	2,941	5,740	1,439	28%	7,180
475.02.08 Extinction Systems	1,400	1,735	3,134	701	27%	3,835
475.02.09 Target Station	6,185	4,681	10,866	2,919	31%	13,785
475.02.10 Accelerator Conceptual Design/R&D	660	4,386	5,045	0	0%	5,045
Risk Based Contingency				982		982
Total	**15,645**	**25,296**	**40,941**	**9,726**	**32%**	**50,668**

Mu2e

Major Milestones

Activity ID	Milestone Name	Milestone Date
47502.01.02.001020	Preliminary Design Tasks Complete	May 14, 2014
47502.01.02.001050	Start of Implementation (DOE approval of CD-2/3)	October 1, 2014
47502.08.001070	Mu2e External Extinction System Final Design Complete	October 28, 2014
47502.08.001072	Mu2e External Extinction Monitoring System Final Design Complete	November 6, 2014
47502.07.001020	Mu2e External Beamline Final Design Complete	February 18, 2015
47502.07.001050	M4 External Beamline Enclosure Complete (by GPP)	June 9, 2015
47502.09.001030	Target Station Final Design Complete	September 15, 2015
47502.05.001040	Resonant Extraction System Final Design Complete	March 2, 2016
47502.09.04.001230	Vendor for HRS selected	January 5, 2017
47502.03.001060	Delivery Ring AIP Complete	March 30, 2017
47502.06.001030	RF Cavity installed	March 30, 2017
47502.08.001080	Mu2e Extinction System AC Dipole & Power Supply Installation and Close-out Complete	September 18, 2017
47502.05.001060	Resonant Extraction System Implementation & Close-out Complete	September 4, 2018
47502.09.001050	Mu2e Heat & Radiation Shield Installation Complete	November 19, 2018
47502.07.001220	Mu2e External Beamline Installation Schedule Complete	January 7, 2019
47502.06.001020	Delivery Ring RF Implementation and Closeout Complete	June 21, 2019
47502.09.001070	Target Station Complete	October 28, 2019
47502.01.03.001100	Implementation Tasks Complete (Ready for Verification that KPP Criteria are met)	March 17, 2020

Schedule



CD-2/3
M4 Enclosure BO
PS Arrives @ Mu2e Bldg
CD-4
g-2 Beam Operations
Res Extr Final Design
Fabricate ESS
Install ESS
M4 Final Design
M4 Beamline Fabrication & Installation
KPPs Satisfied
Extinction Final Design
Extinction Implementation
Extinction Monitoring Implementation
Target Station Final Design
Target Fabrication
HRS Procurement & Assembly
HRS Install
Target Installation December 2021 →
Instrumentation & Controls Implementation
Radiation Safety Implementation
Delivery Ring RF Implementation
Commissioning with Beam
FY14
FY15
FY16
FY17
FY18
FY19
FY20
FY21

Accelerator Breakout Schedule

Tuesday	3:10 – 5:00 pm	Black Hole (WH2NW)

- Overview of Procedures (Steve Werkema) 10 min
- Radiation Safety (Tony Leveling) 30 min
- Resonant Extraction (Vladimir Nagaslaev) 30 min

Wednesday	8:00 – 9:30 am	Black Hole (WH2NW)

- Target Station (Rick Coleman – video link with RAL) 45 min
- Instrumentation & Controls (Brian Drendel) 30 min

Wednesday	9:45 – 11:30 am	Black Hole (WH2NW)

- External Beamline (Carol Johnstone) 30 min
- Delivery Ring RF (Joe Dey) 30 min

Wednesday	12:30 – 2:00 pm	Black Hole (WH2NW)

- Extinction & Extinction Monitoring (Eric Prebys) 30 min

Summary

- Final Design Complete for:
  - Accelerator Instrumentation and Controls
  - Radiation Safety
  - Delivery Ring RF
- Preliminary Design Complete for:
  - Resonant Extraction
  - External Beamline
  - Extinction and Extinction Monitoring
  - Target Station
- The design of Mu2e Accelerator Upgrades meets or exceeds the requirements of the Mu2e Experiment
- Costs and Schedule are sufficiently well understood that we are ready to establish our CD-2 baseline.

Backup Slides

Proton Target Positioning Requirements

Target dimension tolerances

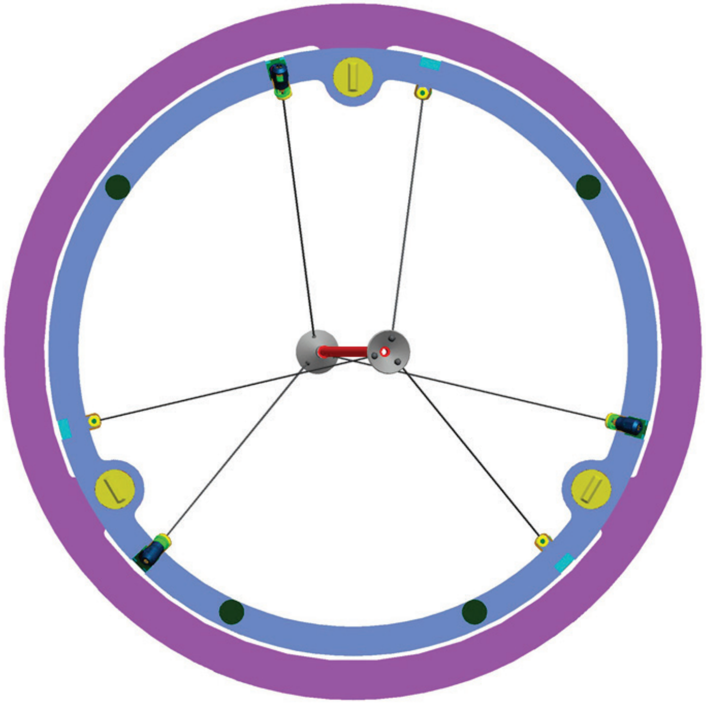
- Target Length = 16 cm ±2 mm
- Target Radius = 3 mm ±0.1 mm

Alignment of target with respect to PS/HRS

- Replacement target positioning repeatability: ±0.25 mm
- Transverse placement w/resp. to PS axis: ±5 mm
- Longitudinal placement along PS axis: ±10 mm

Alignment of target with respect to the proton beam:

- Transverse beam positioning requirement: ±0.5 mm
- Horizontal and vertical angle alignment: ±0.2°



Nominal target and support structure and HRS inner wall viewed along the solenoid axis, looking in the proton beam direction.

The target is centered vertically in the HRS.

The target points horizontally off-axis by 14° (toward proton beam left) relative to the support ring in order to be properly aligned with the beam

PS Heat and Radiation Shield General Requirements

1. Production Solenoid Heat and Radiation protection
   a) Limit the continuous power delivered to the cold mass
   b) Limit the local heat load allowed anywhere within the superconducting coils
   c) Limit the maximum local radiation dose to the superconductor epoxy over the lifetime of the experiment
   d) Limit the damage to the superconductor's aluminum stabilizer and copper matrix
2. Production Solenoid field quality should not be degraded by materials used in the HRS
3. Production Solenoid forces during a quench should be minimized by the choice of HRS materials, if possible. The HRS electrical resistivity must be high to limit forces from eddy currents during a quench.
4. Transport Solenoid (TS1 coils) Heat and Radiation protection (see #1 above)
5. HRS thermal cooling system should limit the temperature on the surface of HRS. The inner surface holds the target support. The outer surface is adjacent to the PS cryostat and in contact in a few locations.
6. The HRS must also be adaptable to the design of a remote handling system for the pion production target.
7. Muon Yield should not be reduced significantly by the inner bore size of the HRS.
8. An acceptable shield design must avoid any line-of-sight cracks between components that point from the target to the inner cryostat wall and thus the magnet coils.

PS Heat and Radiation Protection Requirements

	Dynamic Heat Load [Watts]	Peak Power Density [μW/g]	Max. Lifetime Radiation Dose [MGy]	Peak DPA/yr [10^{-5}]
Specification	< 100	30	7*	4 to 6†
Estimated HRS Performance	24	13	5.2	2.4

* 7 MGy is a conservative limit on coil epoxy exposure, 10% of shear modulus lost due to radiation damage.

† This is the DPA damage per year from which RRR degrades to 100. After this RRR reduction we must warm-up and anneal.

Definitions:

DPA = Displacements per Atom (unit of radiation damage)

$RRR = \frac{\rho_{300°K}}{\rho_{4.5°K}}$ = Residual Resistivity Ratio (want to be < 100)

Proton Beam Absorber Requirements

Purpose: The proton beam absorber stops non-interacting primary beam and secondary particles downstream of the proton target.

Proton Absorber parameters for various beam conditions:

	Primary Beam	Diagnostic Beam	Accident Condition
Beam Power	8 kW (on target)	0.8 kW	8 kW
Total No. of Protons	$8{\times}10^{20}$*	$2{\times}10^{19}$	$2{\times}10^{19}$
Duration of beam	Long Periods	Long Periods	< 10 min

Other Requirements:

- Absorber shielding sufficient to protect extinction monitor equipment from prompt radiation
- Absorber will include an albedo trap to protect PS hall equipment from secondary neutrons from absorber
- Sufficiently well shielded to protect workers in adjacent spaces from residual beam-off radiation
- Ground water and air activation less than FRCM limits

* Note: this is more than twice the required number of POT for physics running

Mu2e

Protection Collimator Requirements

Purpose: prevent any interaction of primary proton beam with the HRS, PS cryostat, or PS coils that could result in significant thermal energy deposition or radiation damage.

Requirements:

- The Protection Collimator must be able to absorb full design beam power for at least 50 msec*
- The Protection Collimator must be able to continuously dissipate the energy deposited by the absorption of beam halo particles during normal operation
- The Protection Collimator inside diameter must be less than 80 mm (for elimination of extinction monitor backgrounds)
- Must be able to move out of the beam for target scans
- Must be constructed of non-magnetic materials (due to proximity to PS and TS)

*The TLM radiation safety system will remove the beam permit in less than 50 msec if all of the beam is being lost in this device

Risks transferred to FNAL Operations

Risk ID	Description
ACCEL-012	Mu2e beam commissioning delayed.
ACCEL-017	Radiation levels outside of Mu2e facility too high.
ACCEL-022	Large beam loss from Resonant Extraction.
ACCEL-035	Failure of extinction system to sufficiently eliminate out of time beam
ACCEL-152	Need to install additional Delivery Ring tunnel shielding (list B)
ACCEL-150	Need to install additional DR tunnel shielding (list C)
ACCEL-037	Extinction monitor fails to perform to requirements.
ACCEL-041	Heat and radiation shield insufficient to protect the Production Solenoid