Mu2e WBS 5.9 Downstream External Shielding
Director's CD-2 Review

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Requirements

Shielding needs to be placed around the downstream Transport Solenoid (TSd) and the Detector Solenoid (DS) to limit the number of neutrons and gammas reaching the Cosmic Ray Veto Counter. This shielding will be supported on the lower level floor of the Mu2e Experiment Hall.

The Mu2e End Cap Shielding requirements and specifications are documented in Mu2e-doc-1371.

The downstream external shielding is designed to facilitate detection of the experimental signature events by reducing the experimental background rates. Physics requirements are:

- Reduce the neutron and gamma background incident upon the Cosmic Ray Veto (CRV) Counters.
- Allow a line of sight to the Muon Stopping Target Monitor (STM) and reduce the neutron and gamma background incident upon the STM.

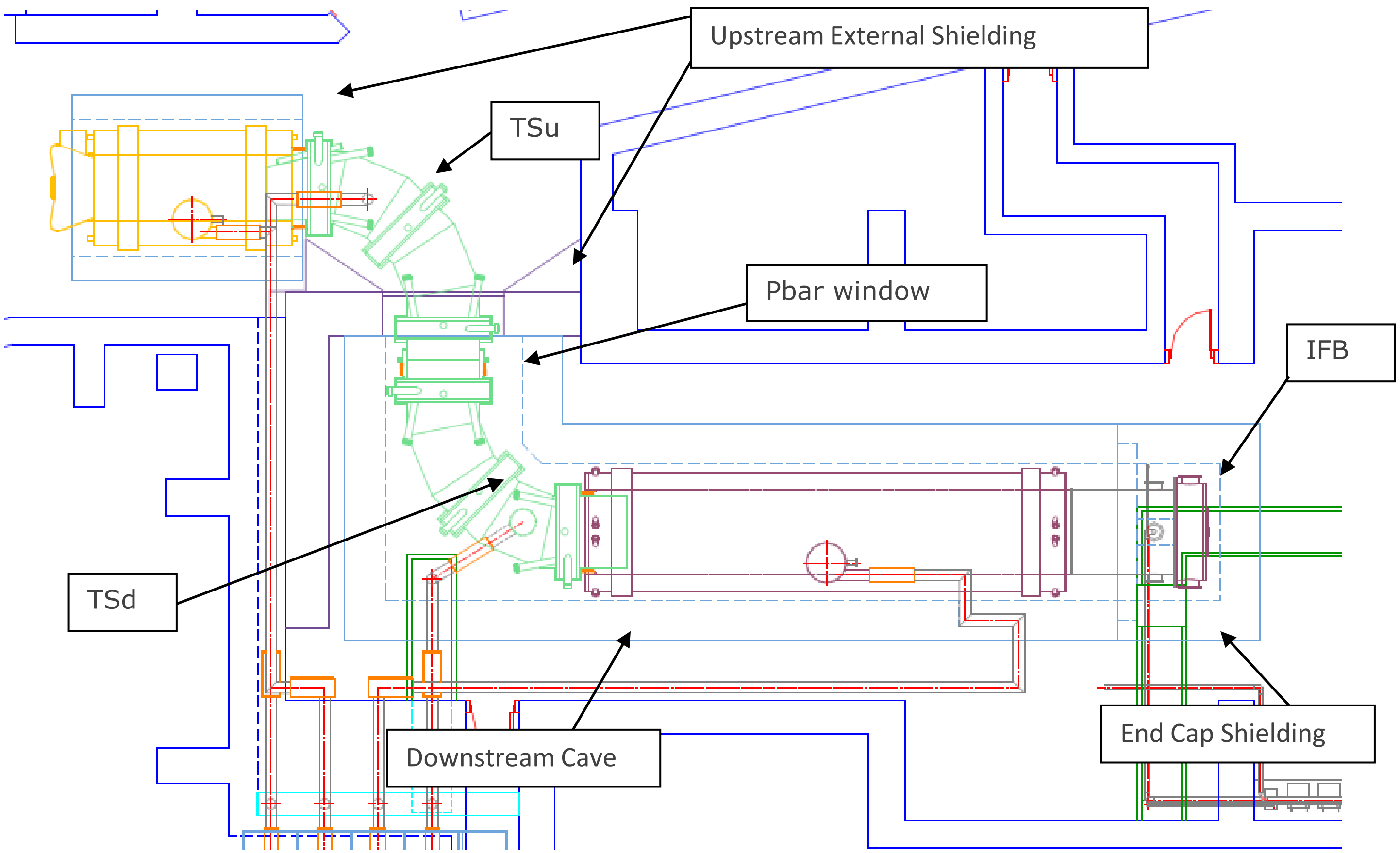
Requirements

In addition to the above physics requirements, the downstream external shielding must satisfy the following mechanical requirements:

- Provide a base for support of the CRV modules (as well as facilitate temporary storage of additional CRV modules removed from the upstream end during access to the pbar window at the TSu/TSd interface).
- Facilitate access to the Instrumentation Feedthrough Bulkhead (IFB) and the detector train inside the DS.
- Facilitate access to the pbar window and the collimator rotation mechanism located at the TSu/TSd interface.
- Accommodate passage of power, cryo and vacuum services to the DS while reducing rates of particles escaping through this penetration.
- Reduce rates of particles escaping through the TSd trench as appropriate.
- Reduce rates of particles escaping through the DS trenches as appropriate.
- Stay clear of the solenoids during installation, and satisfy the constraints imposed by the building geometry.
- Provide a relatively economical structure that is mechanically stable and servicable while allowing for adequate exit pathways.

Design

The Downstream External Shielding consist of two parts, the Downstream Cave and the independent End Cap Shielding. The Downstream Cave is placed around the TSd and DS, and the End Cap Shielding surrounds the downstream end of the muon beamline vacuum enclosure. All Downstream External Shielding is supported independently of the DS.

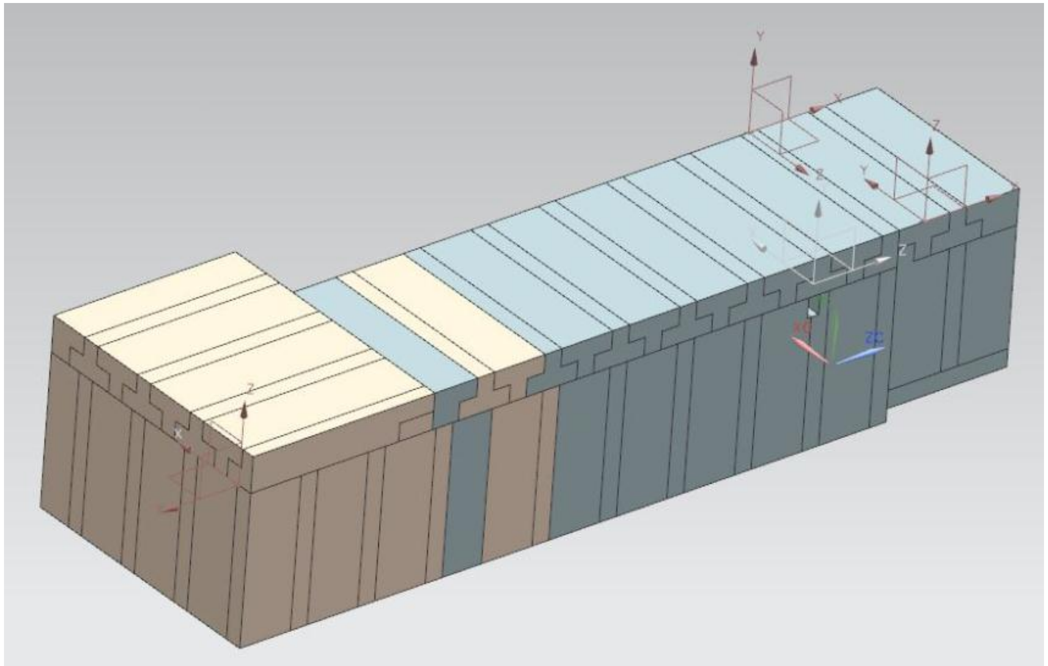


Design

The current design of the shielding requires 36 inch thick concrete to sufficiently suppress the rates at the CRV. The upstream (or TSd) end of the downstream cave, which surrounds the TSd is composed of high density (barite) concrete. The concrete blocks surrounding the muon stopping target region of the DS are also anticipated to be composed of high density (barite) concrete, while the remainder of the concrete blocks are normal density concrete.

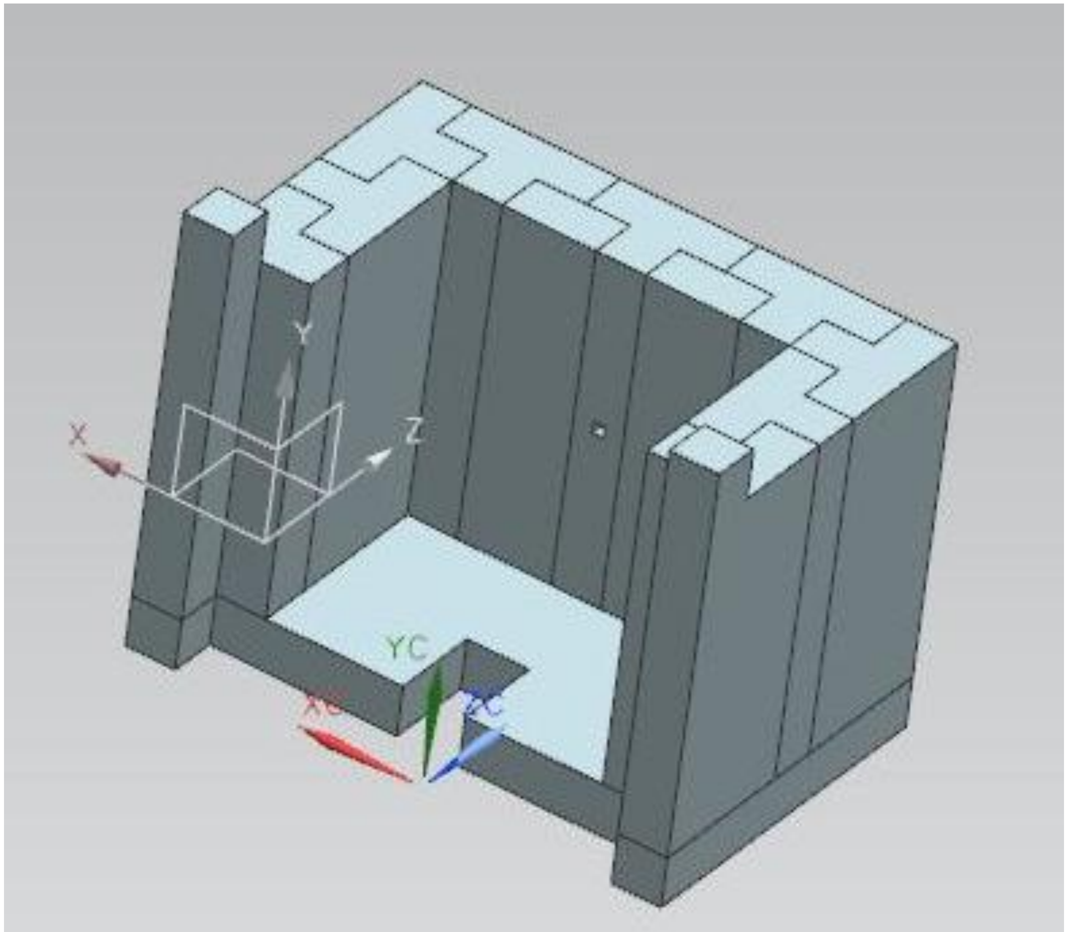
The downstream cave is composed of 409 tons of high density concrete and 312 tons of normal density concrete. The end cap shielding is composed of 117 tons of normal density concrete.

The Downstream Cave (shown to the right) consists primarily of "T" shaped blocks. Concrete blocks are gray while Barite blocks are brown.



Design

End cap shielding block assembly as seen from the upstream end (looking towards the north east) prior to installation of the top blocks. The roof is not shown.



The End Cap Shielding will be supported underneath by Hilman rollers (not shown). The assembly will be detached from the Downstream Cave and rolled downstream for access to the components when they are removed for servicing (see WBS 5.10).

The slot shown at the bottom is needed to accommodate services from the Detectors.

Design

Tolerances and related constraints

The Downstream External Shielding is restricted on both the inside and outside surfaces (by the Detector Solenoid and CRV panels respectively), so block placement tolerances are important.

The location of the downstream cave is constrained on the upstream end by the upstream external shielding and on the north, west and south sides by the solenoids and on east side by the north south DS trench. Since the intent is to minimize line of sight cracks, the tolerances on the blocks and the spacing between blocks must accommodate these various constraints.

The Downstream Cave will include a side penetration to accommodate services for the Detector Solenoid, and the End Cap Shielding will include a penetration at bottom to accommodate services for the Tracker and Calorimeter.

Standard concrete block tolerances should accommodate the above cited assembly constraints.

Changes since CD-1

- Increased shielding around DS from 18 inches thick to 36 inches thick
- Include high density concrete around stopping target
- Extend cave to surround TSd (entirely high density concrete)
- Minimize cracks in downstream cave (introduced T-block design)
- Added penetration for DS services
- Exploring the impact of trenches on CRV performance

Value Engineering since CD-1

– Increase concrete thickness instead of higher density concrete in many places

– Eliminate stainless steel frame from DS cave

– Plan for multiple use of same hydraulic system with Upstream External Shielding and solenoid installation

Downselects

Explored many different shielding configurations and arrived at a one that addresses detector performance requirements

Performance

– Extensive simulations have been completed since CD1 to understand the necessary requirements for the Downstream External Shielding

– The Downstream External Shielding has been redesigned to achieve the performance goals dictated by the simulations

– See the CRV presentation in particular for a summary of the current performance of the external shielding

Remaining work before CD-3

- Continue simulations to further optimize configuration
- Continue value engineering efforts
- Complete testing of Barite composition for thermal and structural viability.
- Optimize design of shielding for penetrations
- Finalize structural components to install blocks into place
- Refine and finalize the installation procedures

Quality Assurance

- Quality Assurance in the Downstream External Shielding efforts will rely about the following tools :
  - Fermilab Quality Assurance Manual
  - Fermilab Engineering Manual
  - Documented engineering calculations and drawings
    - reviewed, approved and released
  - Verification of physics simulations
    - Comparisons between MARS and GEANT4
  - Prototypes and mockups as appropriate
  - Documentation of procedures
  - Delivered materials will be inspected for conformance to the specifications

Risks

- Schedule risk
  - Detector installation takes longer than anticipated
    - Primary mitigation is to continue refining the installation plan to account for new information and additional insights

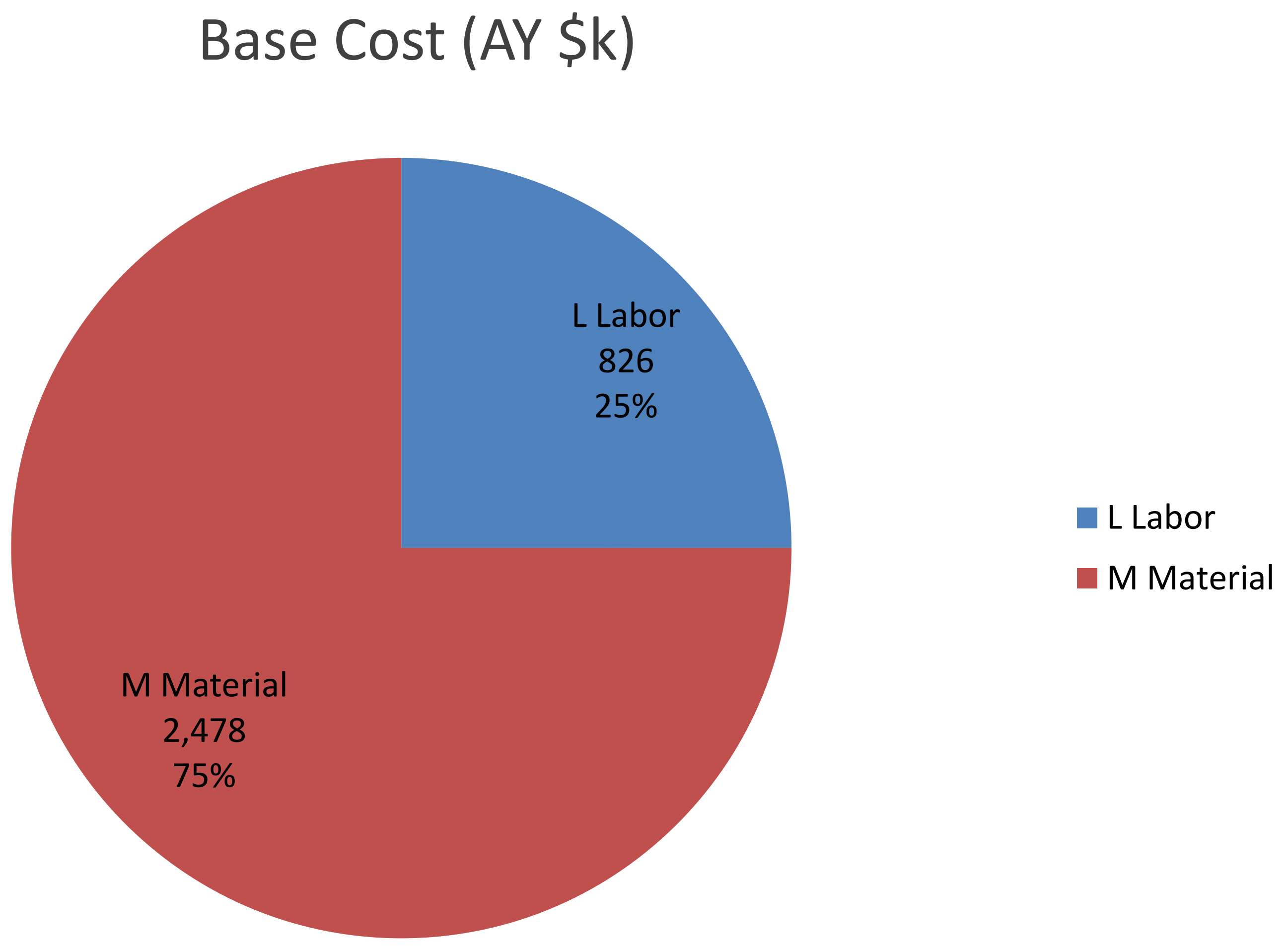
- Technical (and in schedule…)
  - Damage to surrounding elements during shielding installation
    - Mitigated via standoffs (to avoid damage)
  - Shielding installation impacts beamline alignment.
    - Mitigated by civil construction plans
  - Background rates in Cosmic Ray Veto higher than anticipated.
    - Simulation studies are ongoing to minimize this risk (but the residual risk will by necessity be transferred since the risks will not be realized during the project horizon.

ES&H

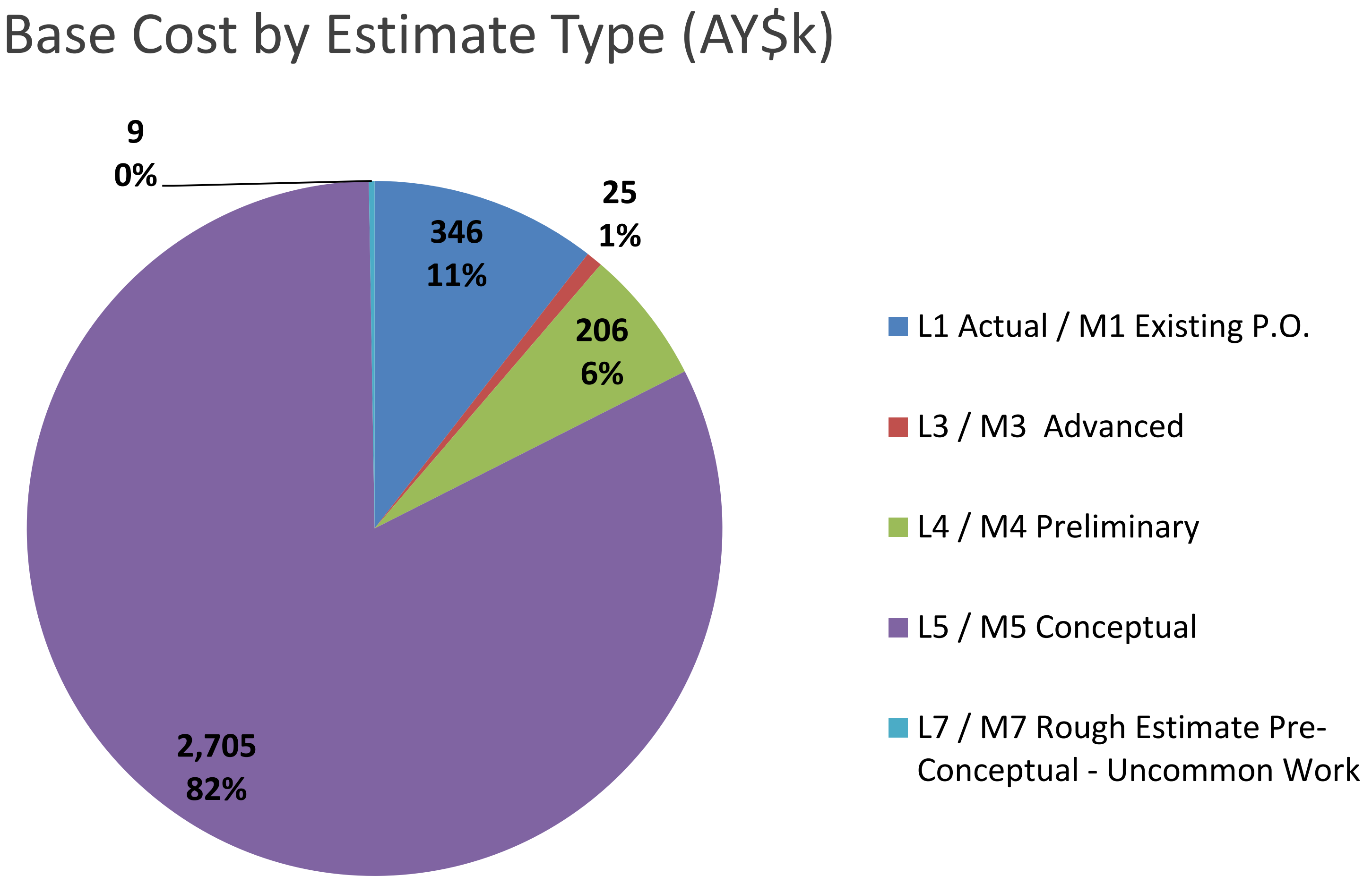
To perform Downstream External Shielding activities safely will require appropriate planning (JHA), attention to ES&H considerations and FESHM and FRCM requirements

- Accessing confined space FESHM 5063
- Crane, hoist, and forklift use FESHM 5021
  - Including lifts beyond direct crane coverage
- Fall Hazards FESHM 5066
- Magnetic fields FESHM 5062.2
- Electrical hazards FESHM 5042
- Hydraulic and perhaps pneumatic systems (and potential stored energy)
- Radiation hazards FRCM
  - Activation by beam
- And possibly ODH
  - FESHM 5064

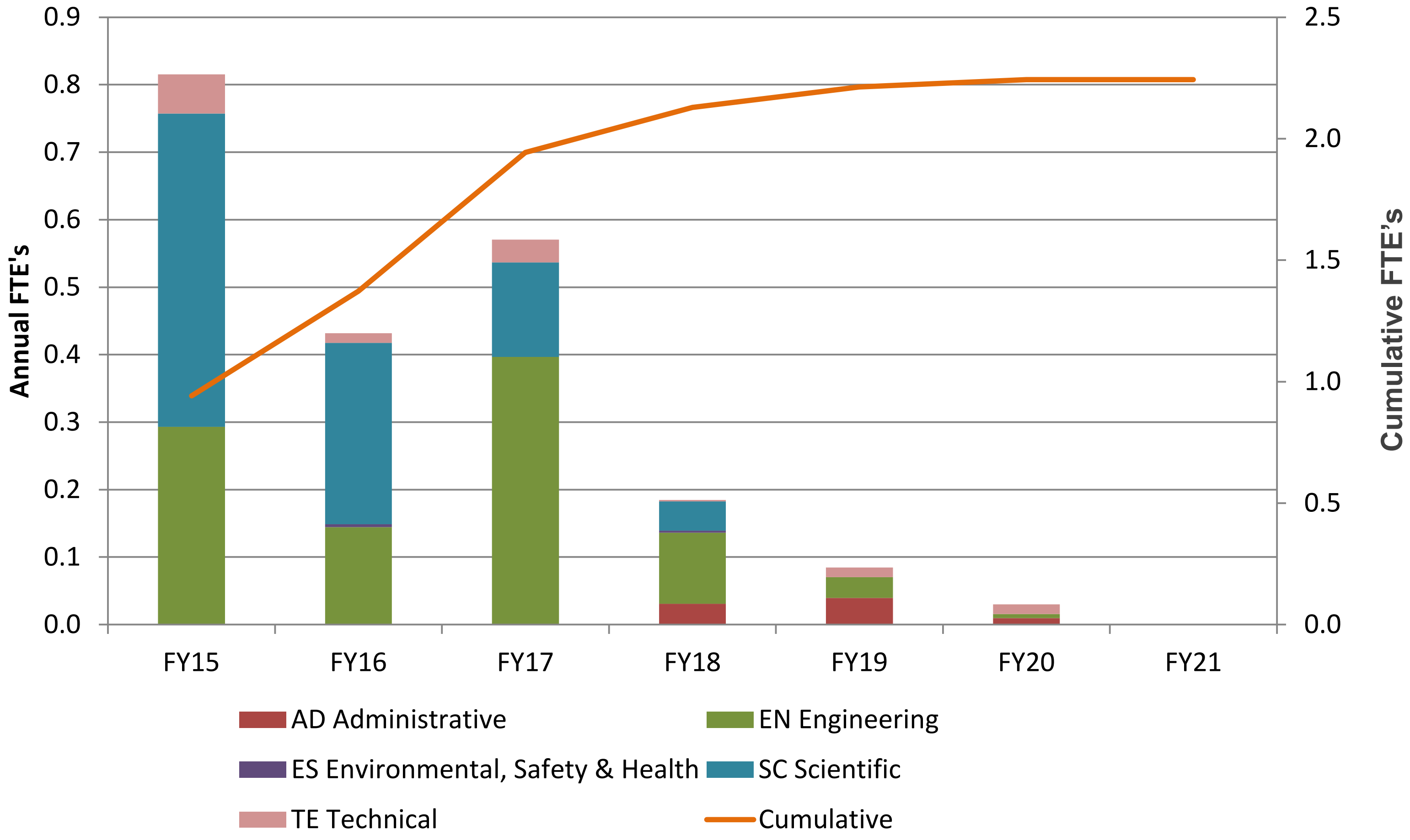
Cost Distribution by Resource Type



Quality of Estimate



Labor Resources by FY



Cost Table

WBS 5.9 Downstream External Shielding

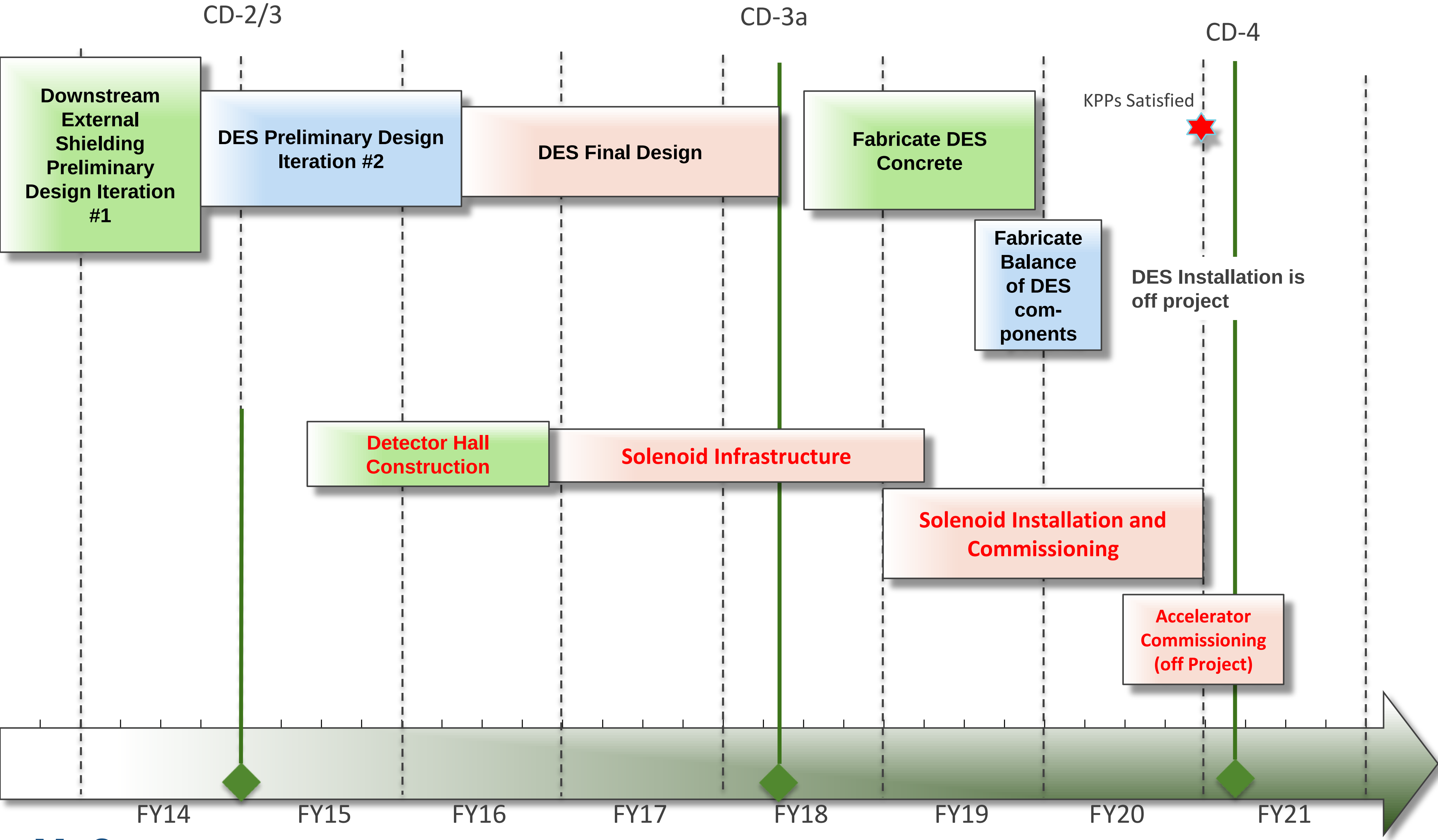
Costs are fully burdened in AY k$

	Base cost (AY k$)					
	M&S	Labor	BAC	Estimate Uncertainty (on remaining costs)	% Contingency on ETC	Total
475.05 Muon Beamline						
475.05.09 Downstream External Shielding	2,478	826	3,304	1,339	45%	4,642
Grand Total	**2,478**	**826**	**3,304**	**1,339**	**45%**	**4,642**

Major Milestones

Activity ID	Milestone Name	Milestone Date
47505.9.001915	Downstream External Shielding ready for CD 3a Review	January 29, 2018
47505.9.001916	CD 3a Approval Downstream External Shielding.	February 15, 2018
47505.9.010001	Advanced Procurement Plan for DES Concrete Fabrication Complete	February 19, 2018
47505.9.010005	Vendor for DES Concrete Fabrication Selected	May 8, 2018
47505.9.061010	Downstream External Shielding arrives at FNAL	February 03, 2020
47505.9.061020	Downstream External Shielding ready for CD-4	February 17, 2020

Schedule



CD-2/3
CD-3a
CD-4
Downstream External Shielding Preliminary Design Iteration #1
DES Preliminary Design Iteration #2
DES Final Design
Fabricate DES Concrete
KPPs Satisfied
Fabricate Balance of DES com-ponents
DES Installation is off project
Detector Hall Construction
Solenoid Infrastructure
Solenoid Installation and Commissioning
Accelerator Commissioning (off Project)
FY14
FY15
FY16
FY17
FY18
FY19
FY20
FY21

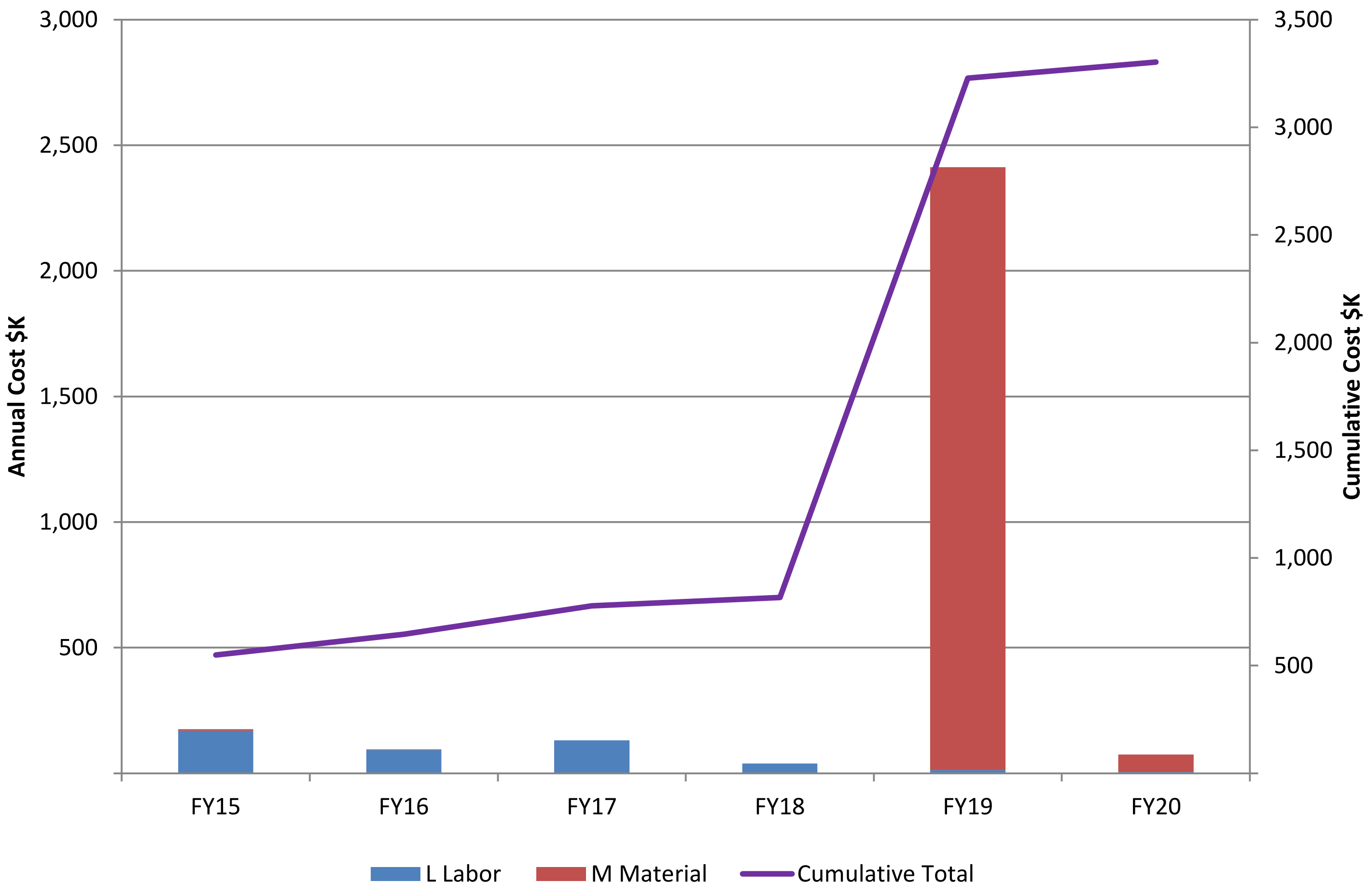
Summary

- Have made substantial progress since CD-1
  - Many designs have been significantly refined/optimized
    - Shielding wall thickness
    - Block shapes and materials changed
    - Installation procedure refined
  - Preliminary designs meet the current requirements from simulations

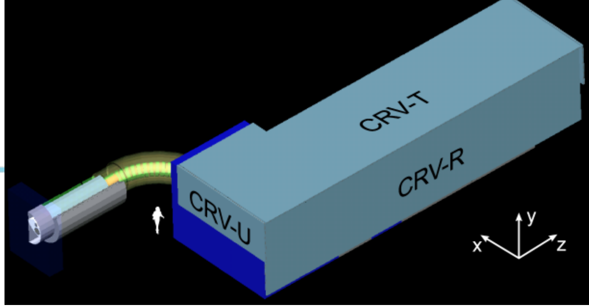
- Still several tasks to complete
  - Continue refining/optimizing the desitn via simulation studies.
  - Verify Barite material properties.
  - Refine installation procedure.
  - Continue working with CRV and STM interfaces.

Backup Slides

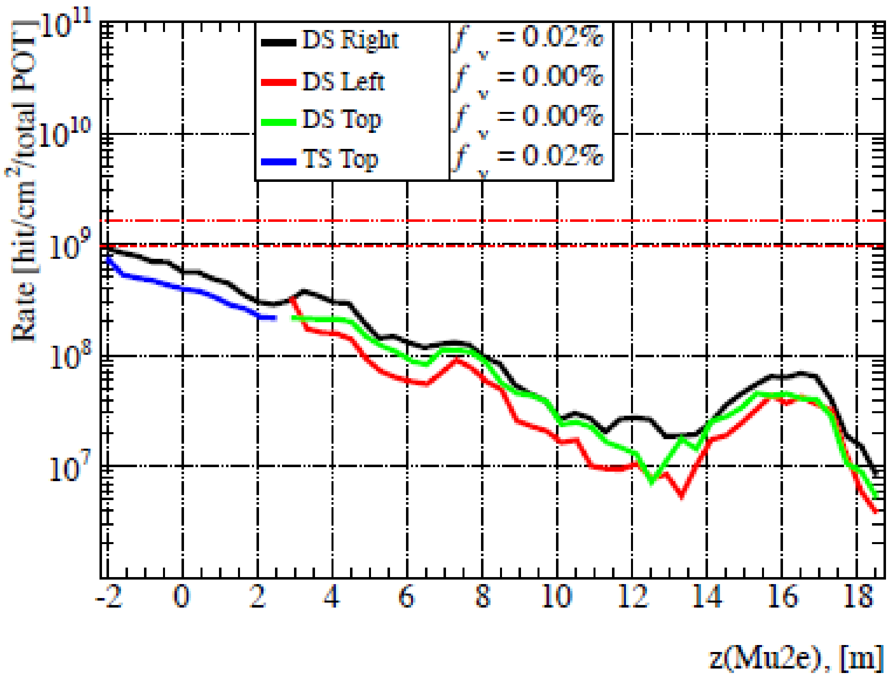
Labor/Material Breakdown

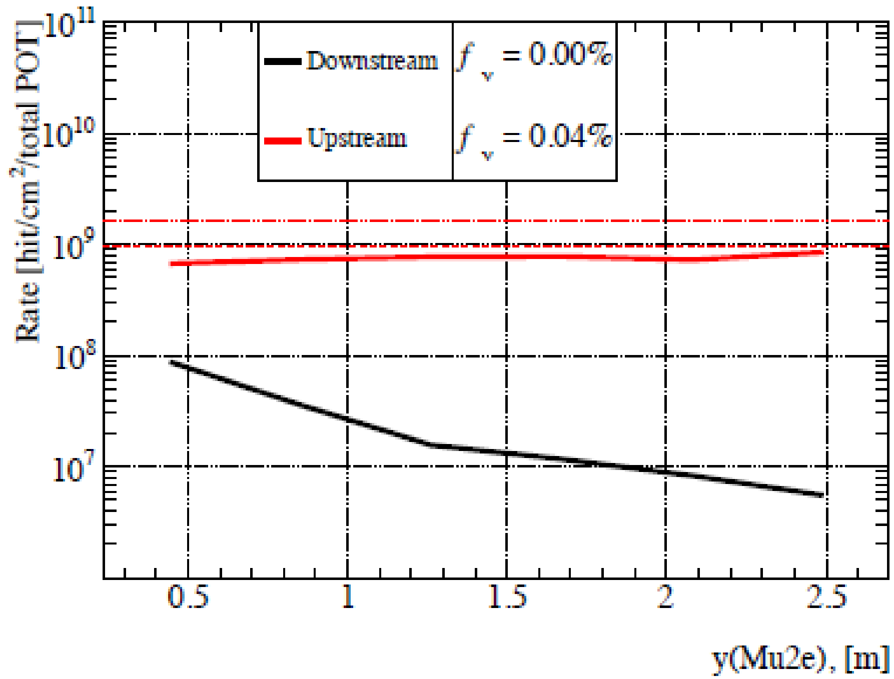


Accidental CRV rates

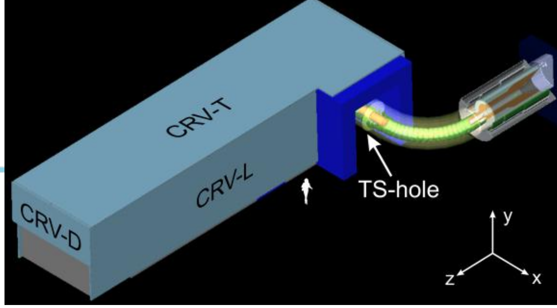


- Accidental hit rates per unit area over the entire running period. Dashed and dotted red lines correspond to 1% and 5% fractional dead time assuming uniform flux distribution.





Semi-correlated CRV rates



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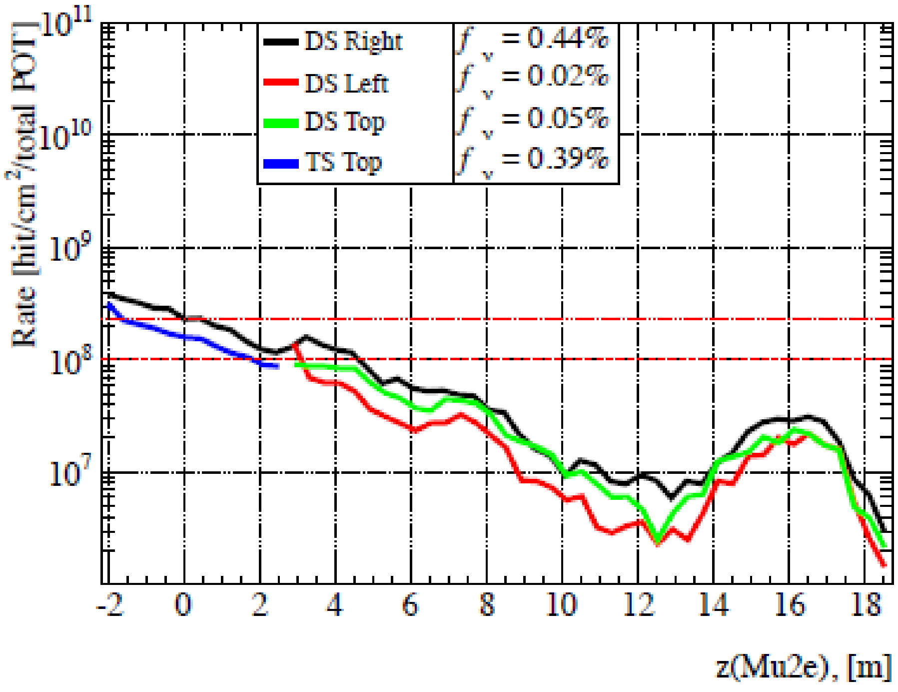

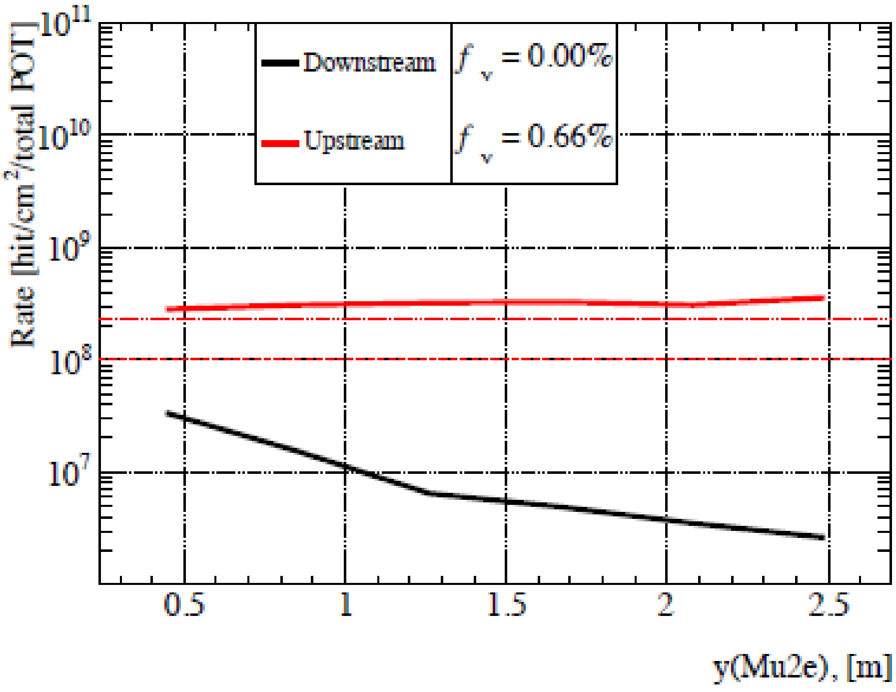

Correlated CRV rates

- Correlated hit rates per unit area over the entire running period. Dashed and dotted red lines correspond to 1% and 5% fractional dead time assuming uniform flux distribution.