Fermilab

Mu2e WBS 5.4 Upstream External Shielding DOE CD-2/3b Review

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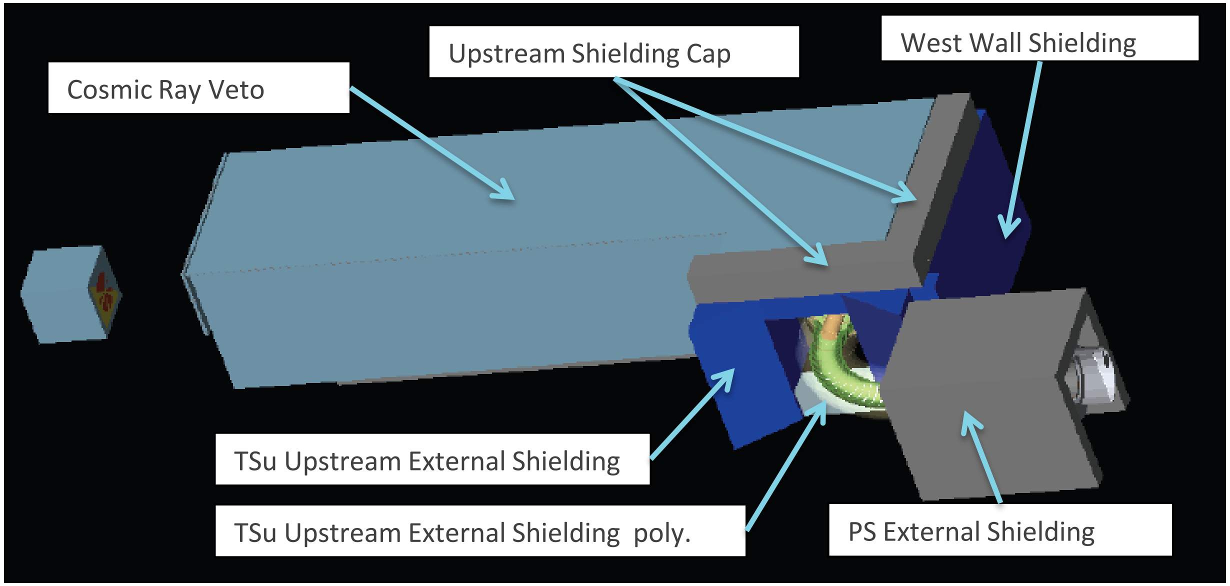
Muon Beamline Level 3 Manager

10/21/2014

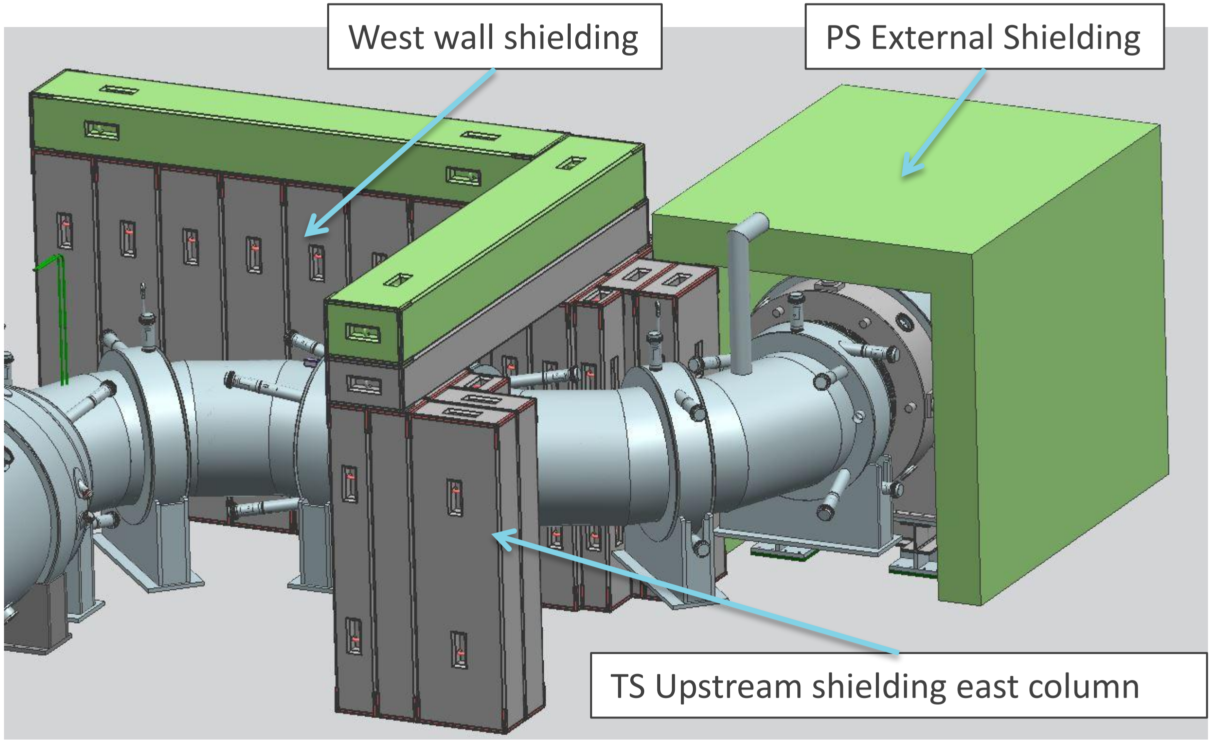
Physics Requirements

- The primary purpose of the Upstream External Shielding around the PS and TSu is to reduce the rate of particles incident on the Mu2e detectors
- The rate incident upon the Cosmic Ray Veto must be suppressed to a low enough level to support efficient and reliable operation of the CRV
- The Upstream External Shielding also isolates the primary proton beamline from the DS hall, providing a natural radiation zone break and serves as an element of the airflow control system for the Mu2e Experiment Hall



Design

The preliminary design of the Upstream External Shielding as viewed from the north east with the PS on the right hand side and the DS on the left hand side of the figure below. The grey blocks are high density barite concrete blocks, while the green elements are composed of normal density concrete.



PS External shielding:

–Concrete cave

–90 tons

–Cast under PS Hatch and move using rollers on floor track plates

TS Upstream wall and West wall shielding:

–High density (barite) concrete blocks capped with normal concrete blocks

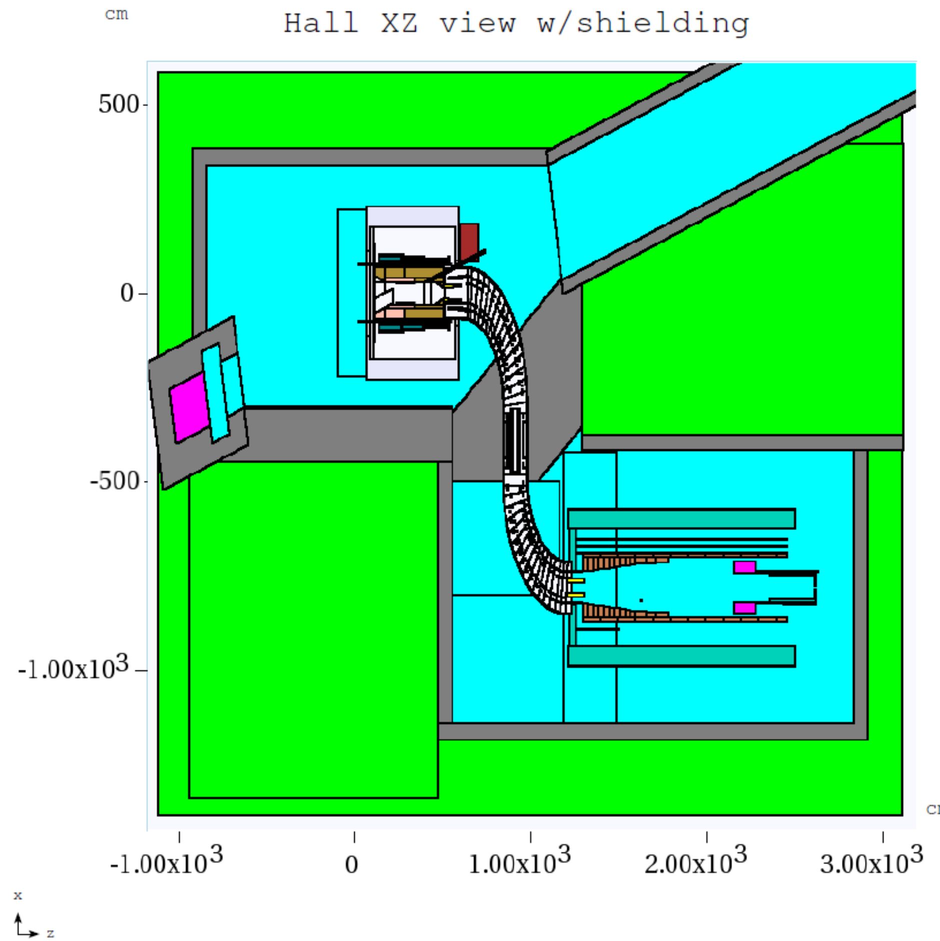
–242 tons high density concrete

–48 tons normal density concrete

Improvements since CD-1

- Introduced shielding around Production Solenoid
  - PS External Shielding
- As a result of the detailed background simulation studies, new design of shielding in the vicinity of the Transport Solenoids has been developed to reduce rates in the CRV to acceptable levels
- Large block type design was selected to simplify production and assembly/installation of the shielding, and access to the TS3 interface region

CDR version of Upstream External Shielding



Value Engineering since CD-1

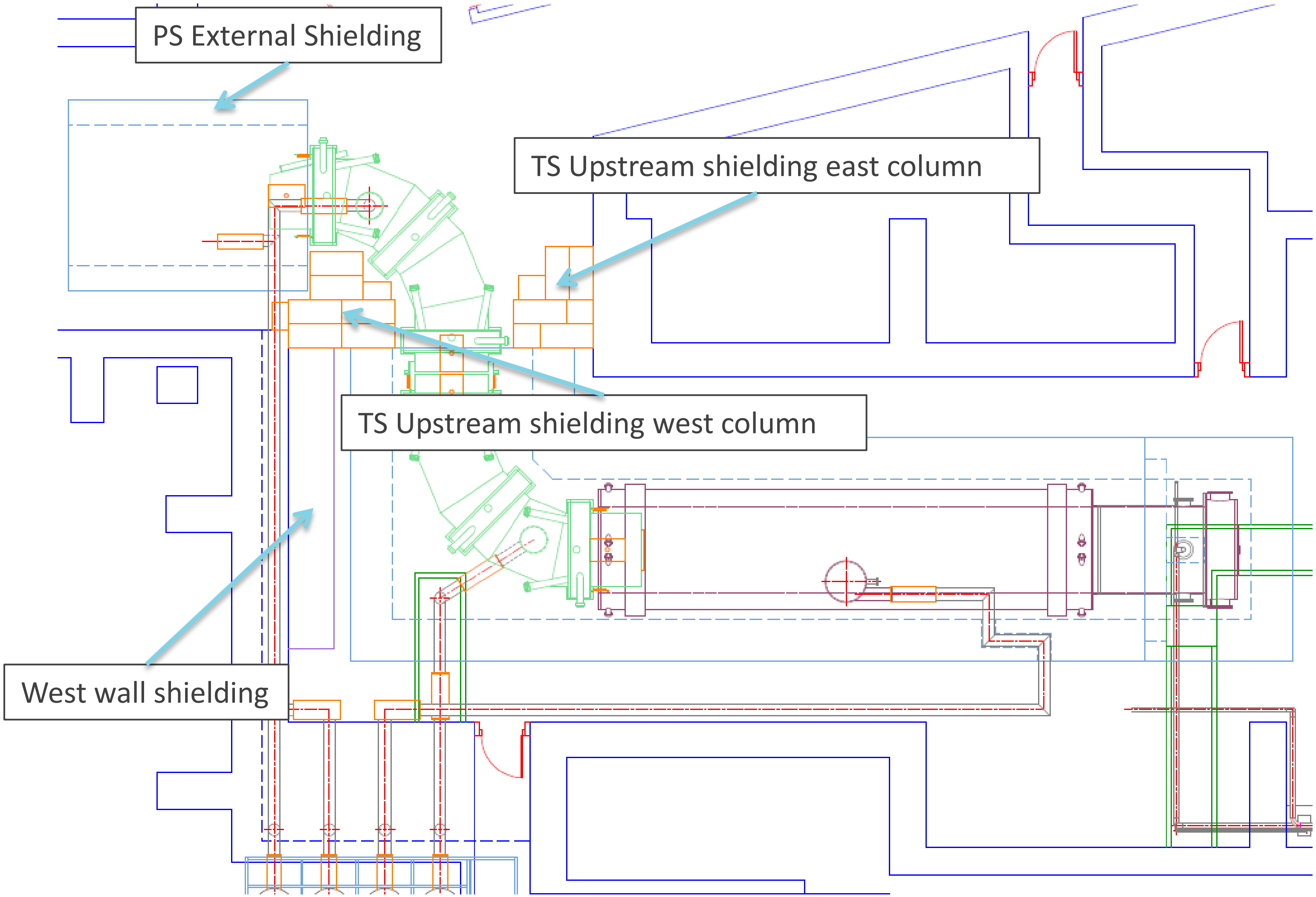
Shielding related optimizations:

- Investigate less expensive shielding materials
- Employ high density concrete instead of copper or stainless steel
- Plan to cast PS external shielding
- Plan for multiple use of same hydraulic system to move the shielding parts

Remaining work before fabrication

- Continue shielding value engineering effort
- Optimize design of shielding for reliefs and penetrations
  - Opening for TS
  - TSu services
  - West wall relief
  - Pipe Chase Alcove
- Finalize material choices
- Finalize engineering design
- Finalize installation techniques and sequence

Top view on Upstream External Shielding



Installation Plans/Sequence

- Cast the PS external shielding under the PS hatch
- After the electron source test is complete (and the solenoid coils are aligned)
  - Install west TS shield column
  - Finalize location of PS external shielding
  - Install east TS shield column
  - Install shielding below TS
  - Install TS external shielding cross beams
  - Isolate the primary beamline from the detector hall
  - Install shielding in west wall relief
  - After the CRV-U installation, install the west wall shielding and the upstream external shielding cap

Integration and Interfaces

- Upstream External Shielding has external interfaces to Accelerator, Conventional Construction, Solenoids, and CRV
- Internal interfaces to
  - Muon beamline vacuum system
  - Downstream external shielding
- Integration and interfaces addressed via
  - WBS dictionary and interface documents
  - Muon beamline meetings
  - Mechanical and electrical integration meetings

Quality Assurance

Quality Assurance in the muon beamline efforts relies upon 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
- Documentation of procedures
- Delivered materials will be inspected for conformance to the specifications

Risks

- Damage to surrounding elements during shielding installation
  - Design to mitigate this risk (standoffs)
- Shielding installation impacts beamline alignment
  - Civil construction plans mitigate this risk
- Constructed external shielding may not adequately suppress rates in the detector area, resulting in higher than anticipated background rates in the Cosmic Ray Veto
  - Ongoing simulations aimed at minimizing this risk

- The residual mitigated risks will not be realized within the project horizon, and must therefore be addressed if and when encountered

ES&H

- **FALL HAZARDS**
- **CRANE, HOIST AND FORKLIFT USE**
  - The external shield blocks are heavy objects, so during installation special care should be taken to follow Fermilab safety procedures for working with lifting equipment.
- **HYDRAULIC SYSTEM**
- **RADIATION HAZARDS**
- **MAGNETIC FIELDS**
- **ELECTRICAL HAZARDS**
- **CRYOGENIC HAZARDS**

Cost Table

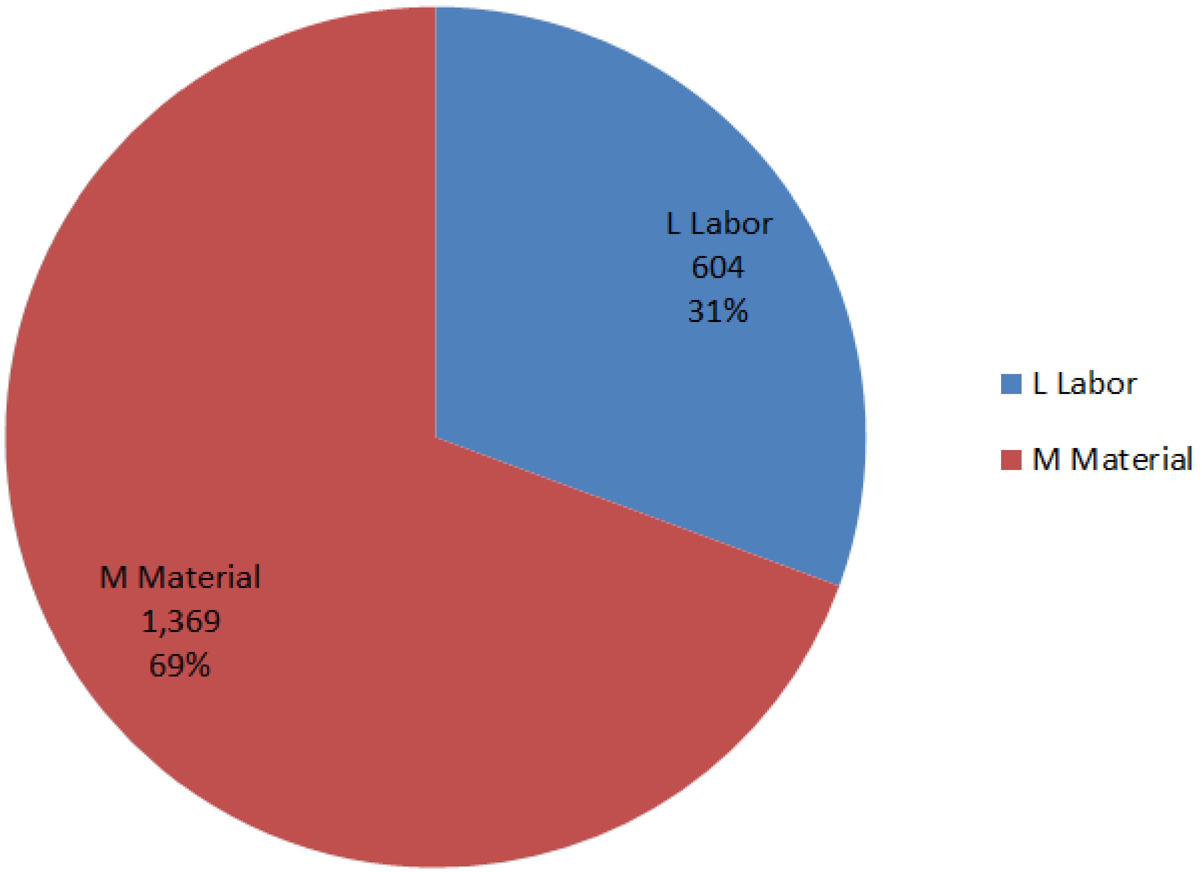
- WBS 5.4 Upstream External Shielding

Costs are fully burdened in AY k$

	Base Cost (AY K$)					
	M&S	Labor	Total	Estimate Uncertainty (on remaining budget)	% Contingency (on remaining budget)	Total Cost
475.05 Muon Beamline						
475.05.04 Upstream External Shielding						
475.05.04 Upstream External Shielding	1,369	604	1,973	808	47%	2,781
Grand Total	1,369	604	1,973	808	47%	2,781

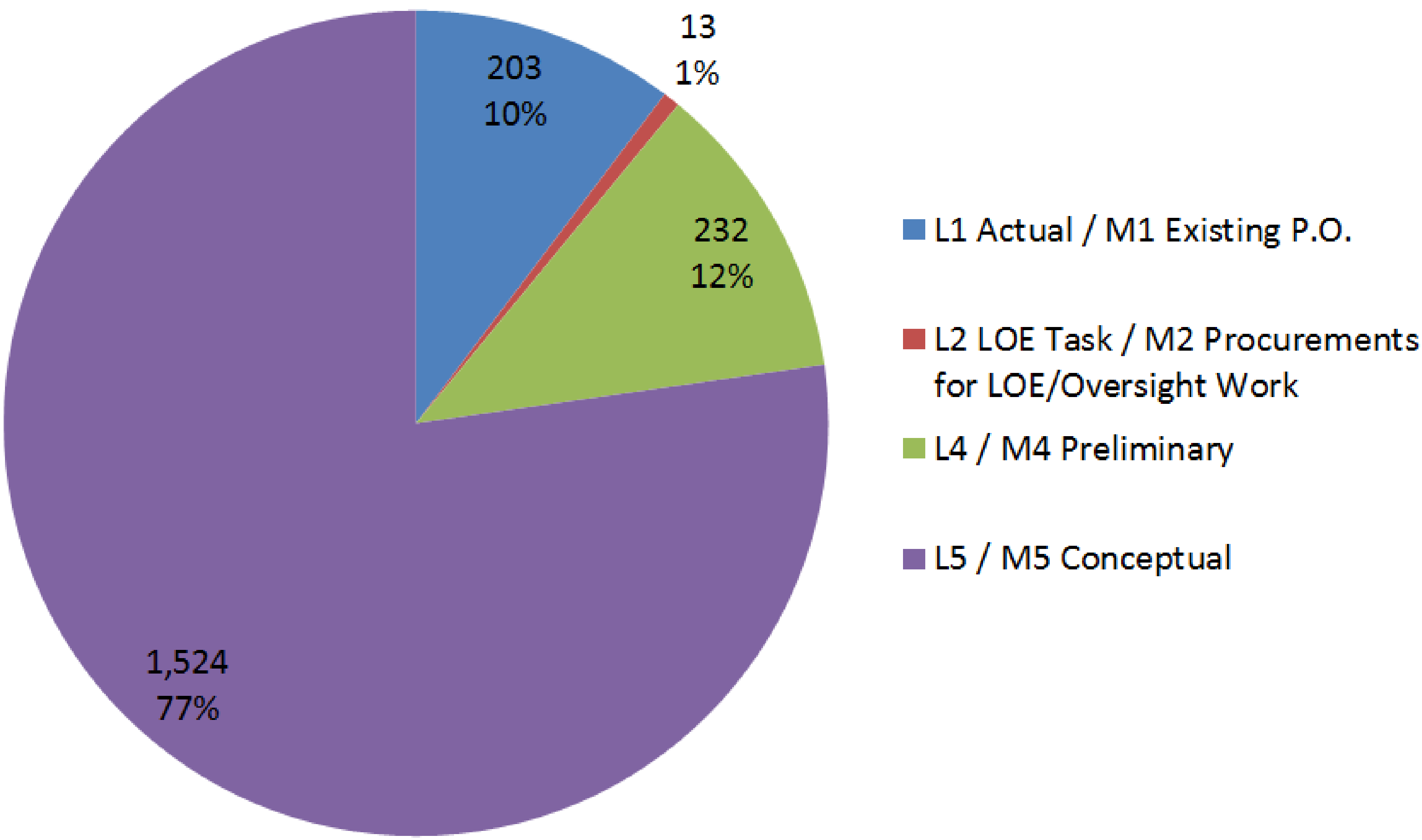
Cost Distribution by Resource Type

- Upstream External Shielding (AY k$)



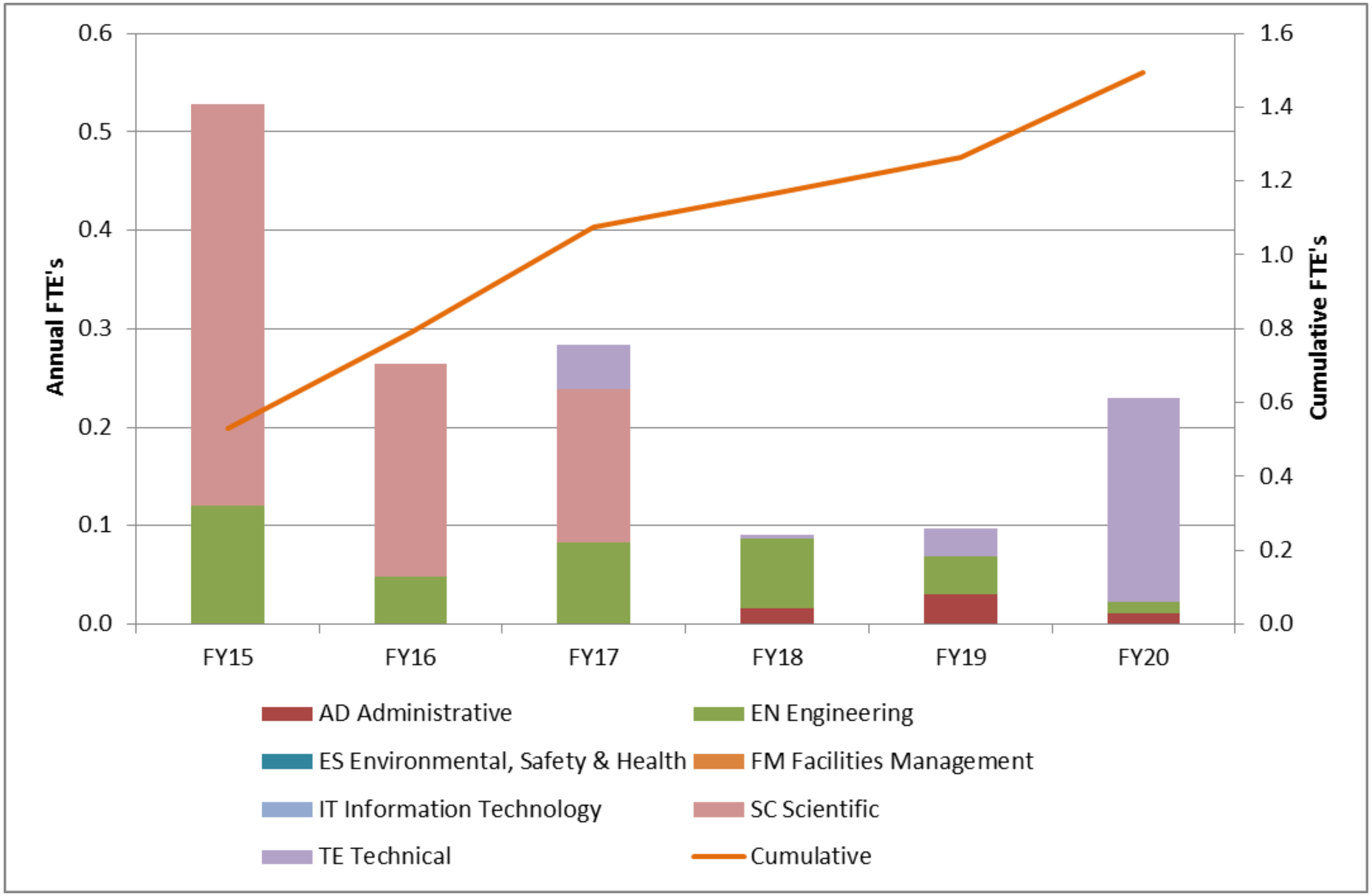
Quality of Estimate

- Upstream External Shielding Base Cost by Estimate Type in AY k$

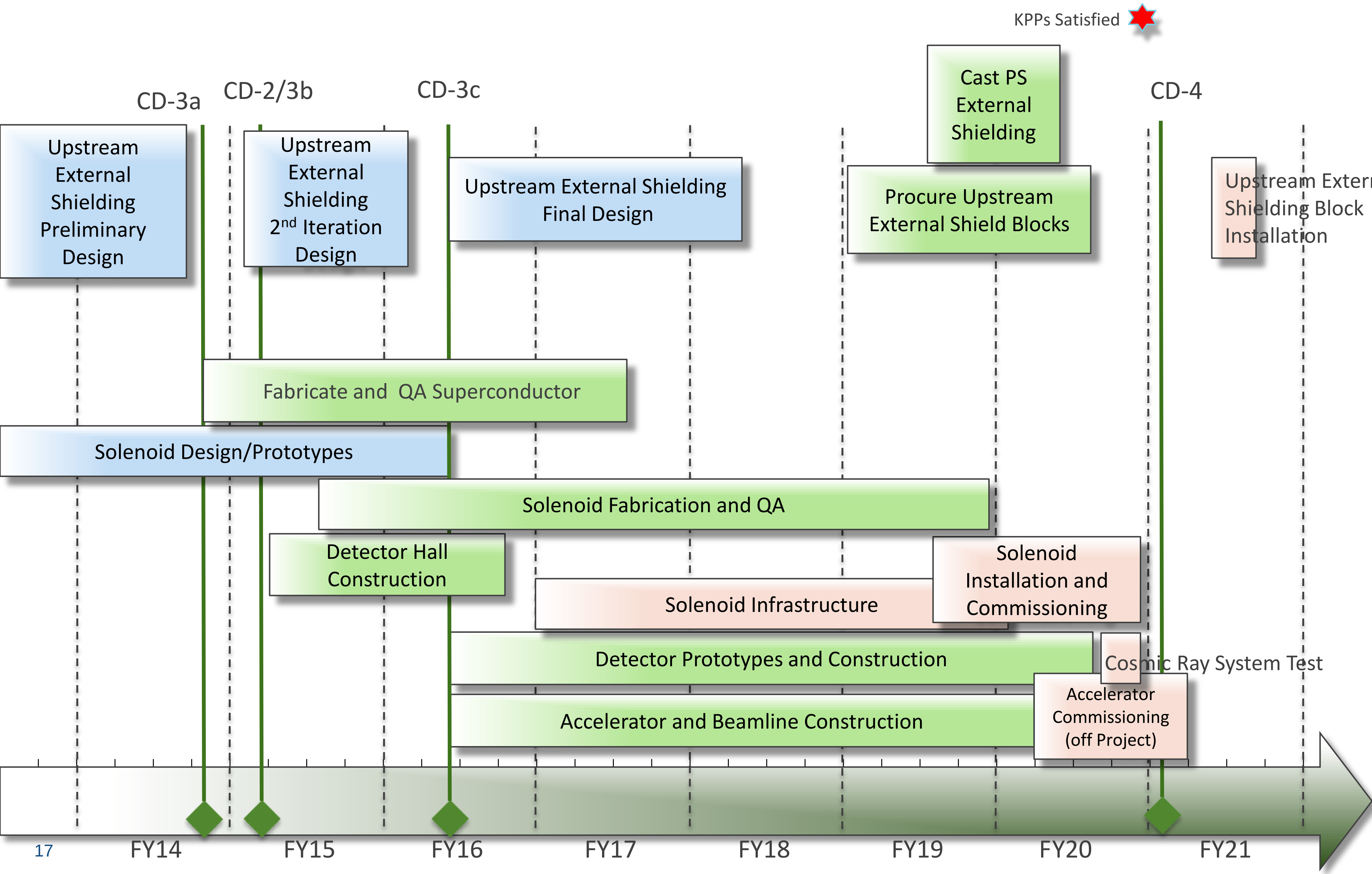


Labor Resources

- Upstream External Shielding FTEs by Discipline



Schedule


KPPs Satisfied
CD-3a
CD-2/3b
CD-3c
CD-4
Upstream External Shielding Preliminary Design
Upstream External Shielding 2nd Iteration Design
Upstream External Shielding Final Design
Cast PS External Shielding
Procure Upstream External Shield Blocks
Upstream External Shielding Block Installation
Fabricate and QA Superconductor
Solenoid Design/Prototypes
Solenoid Fabrication and QA
Detector Hall Construction
Solenoid Infrastructure
Solenoid Installation and Commissioning
Detector Prototypes and Construction
Cosmic Ray System Test
Accelerator and Beamline Construction
Accelerator Commissioning (off Project)
FY14
FY15
FY16
FY17
FY18
FY19
FY20
FY21

Milestones

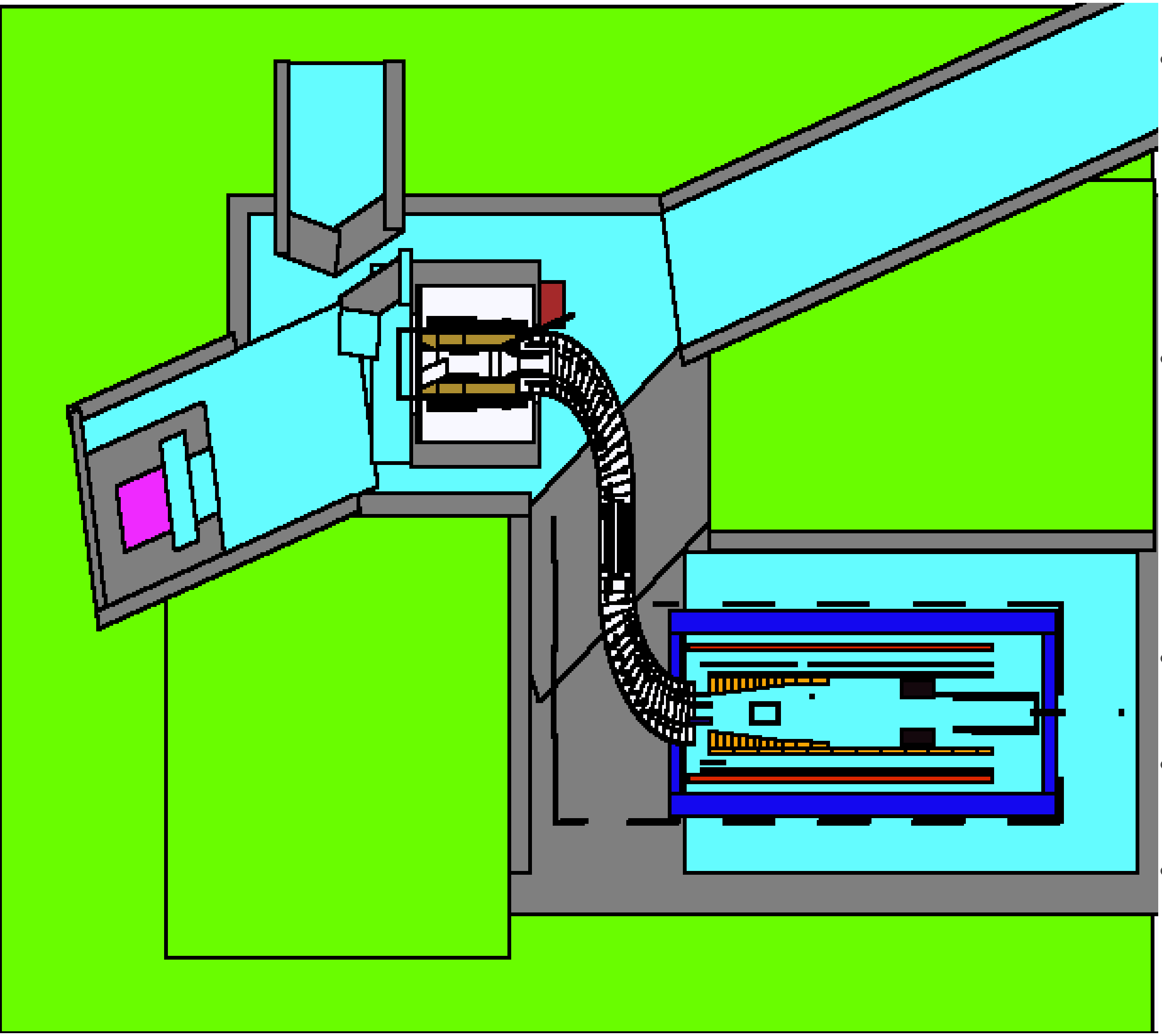
47505.4.001215	T5 - Muon Beamline External Shielding Preliminary Design 1st Iteration Complete	5/30/2014
47505.4.001235	T5 - 2nd iteration Upstream External Shielding Requirements and Specs Complete	6/17/2015
47505.4.001280	T5 - Upstream External Shielding 2nd iteration Design	11/18/2015
47505.4.001355	T5 - Upstream External Shielding ready for CD-3 Review	12/3/2015
47505.4.001356	T5 - CD-3 approval Muon Beamline External Shielding	2/23/2016
47505.4.001340	T5 - Upstream External Shielding ready for fabrication	1/26/2018
47505.4.010009	T5 - PS External Shielding Casting Complete	1/9/2020
47505.4.010010	T4 - PS External Shielding Casting Complete	3/10/2020
47505.4.009008	T5 - Upstream External Shield Wall Blocks at Fermilab	3/27/2020
47505.4.010011	T3 - PS External Shielding Casting Complete	4/10/2020
47505.4.030020	T4 - Upstream External Shielding Components at Fermilab	6/9/2020
47505.4.040000	T5 - Upstream External Shielding Ready for CD-4	6/9/2020

Summary

- The preliminary design of the Upstream External Shielding addresses the requirements to reduce particle rates on the detectors to an level which will allow reliable and efficient detector operation
  - 3-D model of the preliminary design for the TS Upstream External Shielding of Mu2e Beamline has been developed.
  - Additional simulations are anticipated to fully optimize the design of the Upstream External Shielding
- Cost estimate is complete and resource needs are understood
- Risks are understood and under control, and are being mitigated to the extent possible
- Upstream External Shielding is ready for CD-2

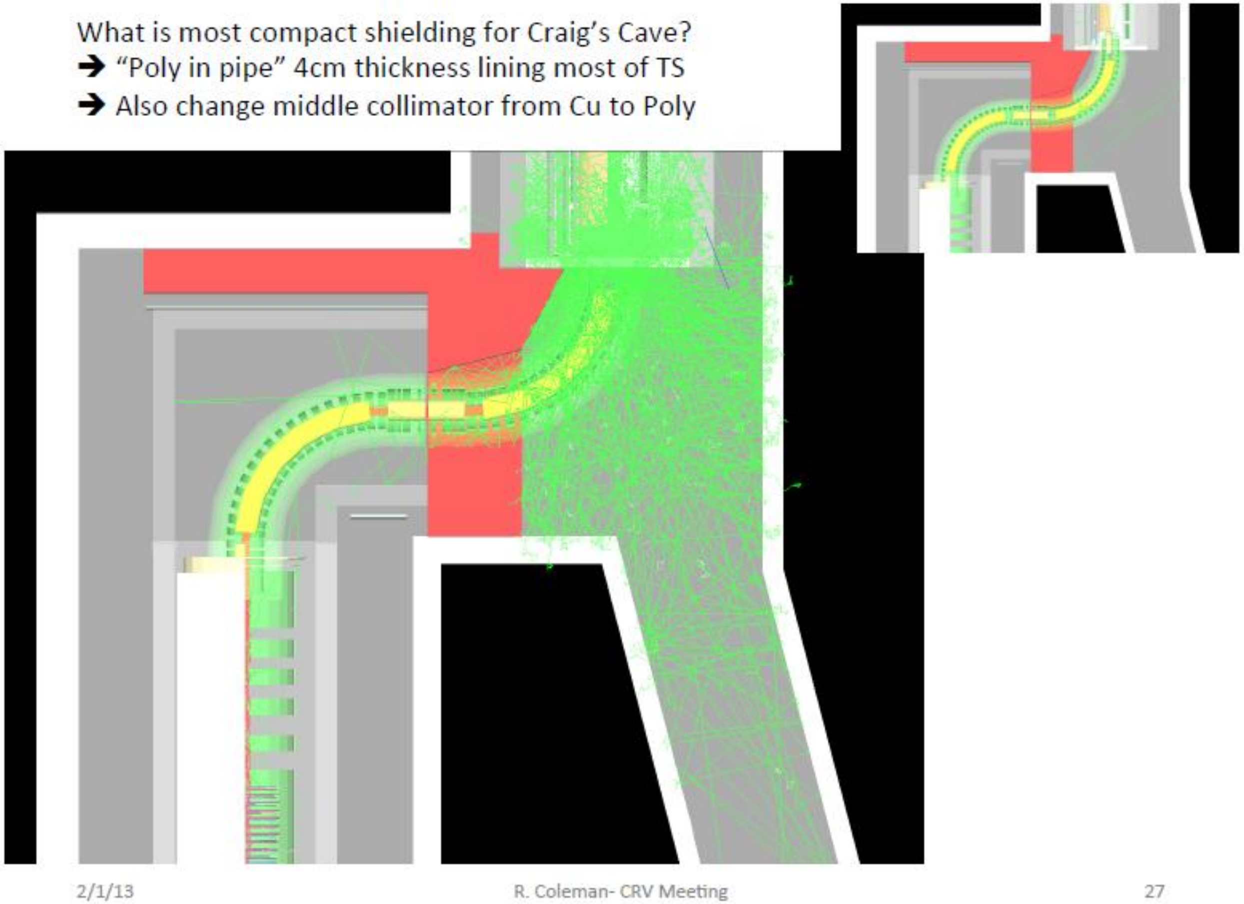
Backup slides

Early Neutron Task Force Model (Docdb 2788)

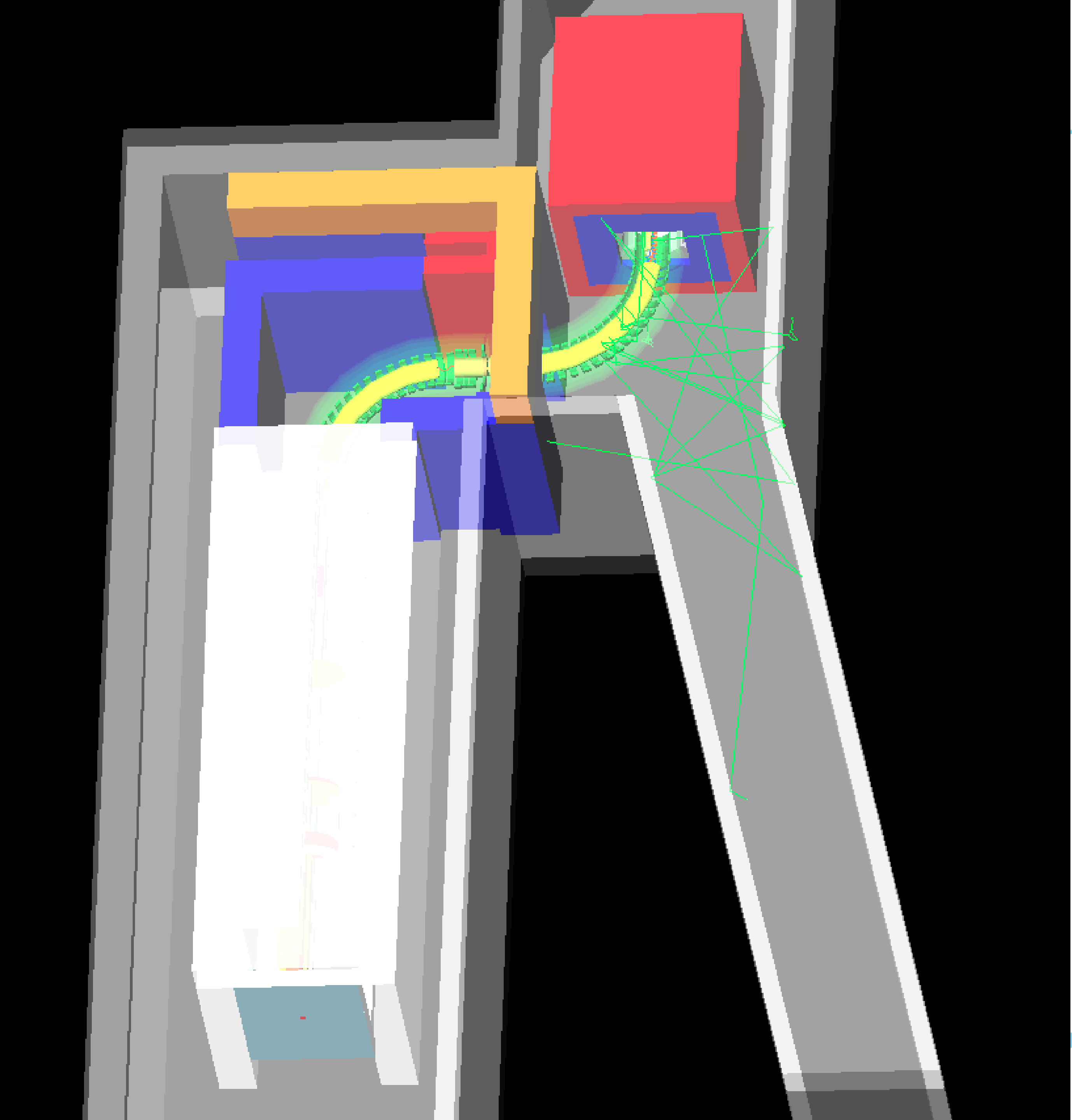


- The shielding consists of regular concrete (gray), “yoke” around the PS, “poured” around the TS, and the walls, floors, ceiling structures.
- The blue wall around the DS is heavy concrete. The DS has Li---Poly neutron absorbers both internal and external to the cryostat shown in orange.
- The light green is soil. The light blue is vacuum.
- The first collimator is copper with a small carbon liner.
- The middle collimator is also copper. The final collimator is polyethylene.

Another iteration by the Neutron Task Force



- Red material is a mixture of stainless steel and borated poly

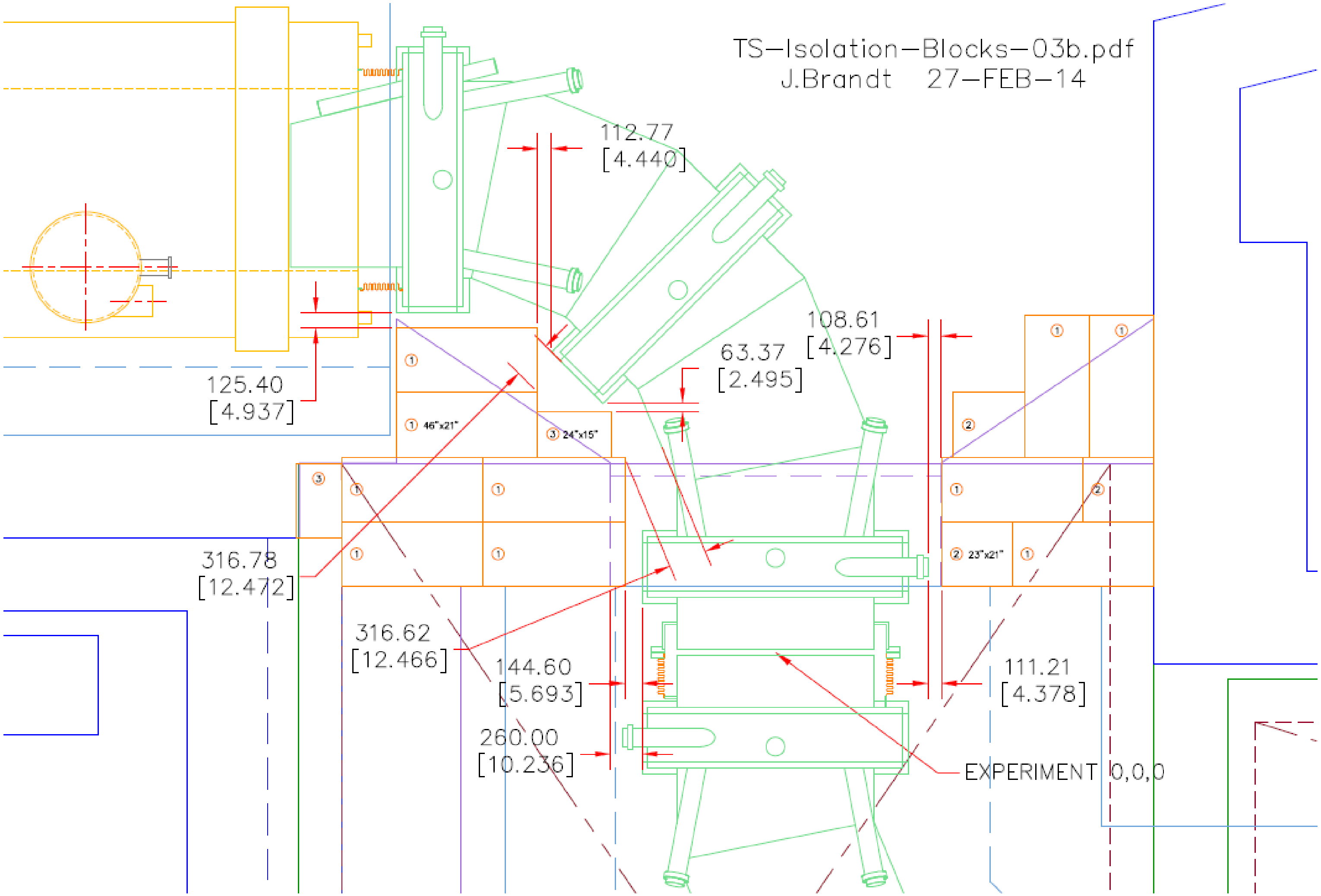


Neutron Task Force—Version II

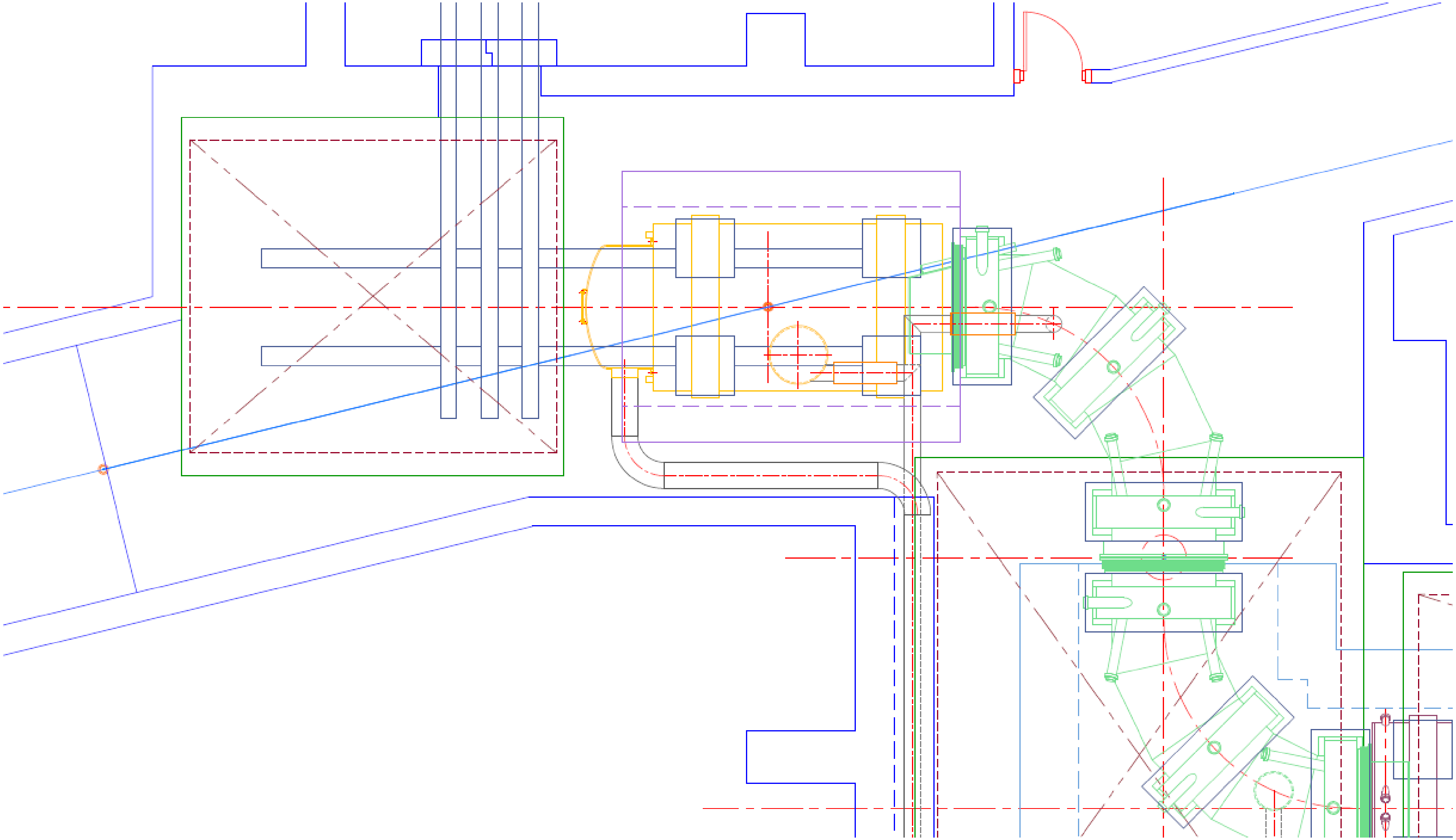
Summary of shielding material weights

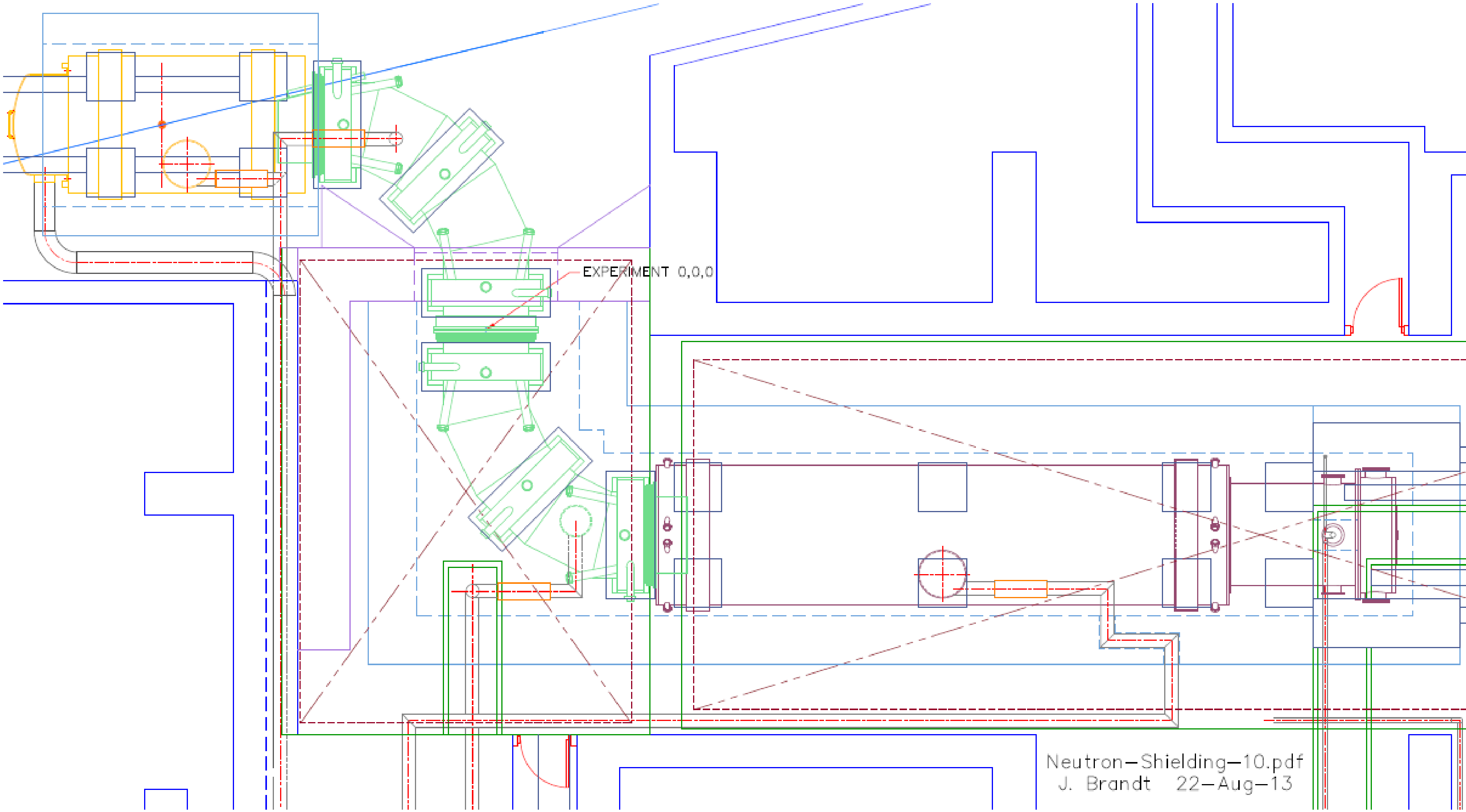
PS concrete	80T
Isolation wall	
Ba Concrete	150T
Concrete	29T
SS	64T
B poly	1T
TS concrete	215T
TS poly liner	1T
DS cave liner	22T
DS cave	509T
DS internal	9T
Total	1081T

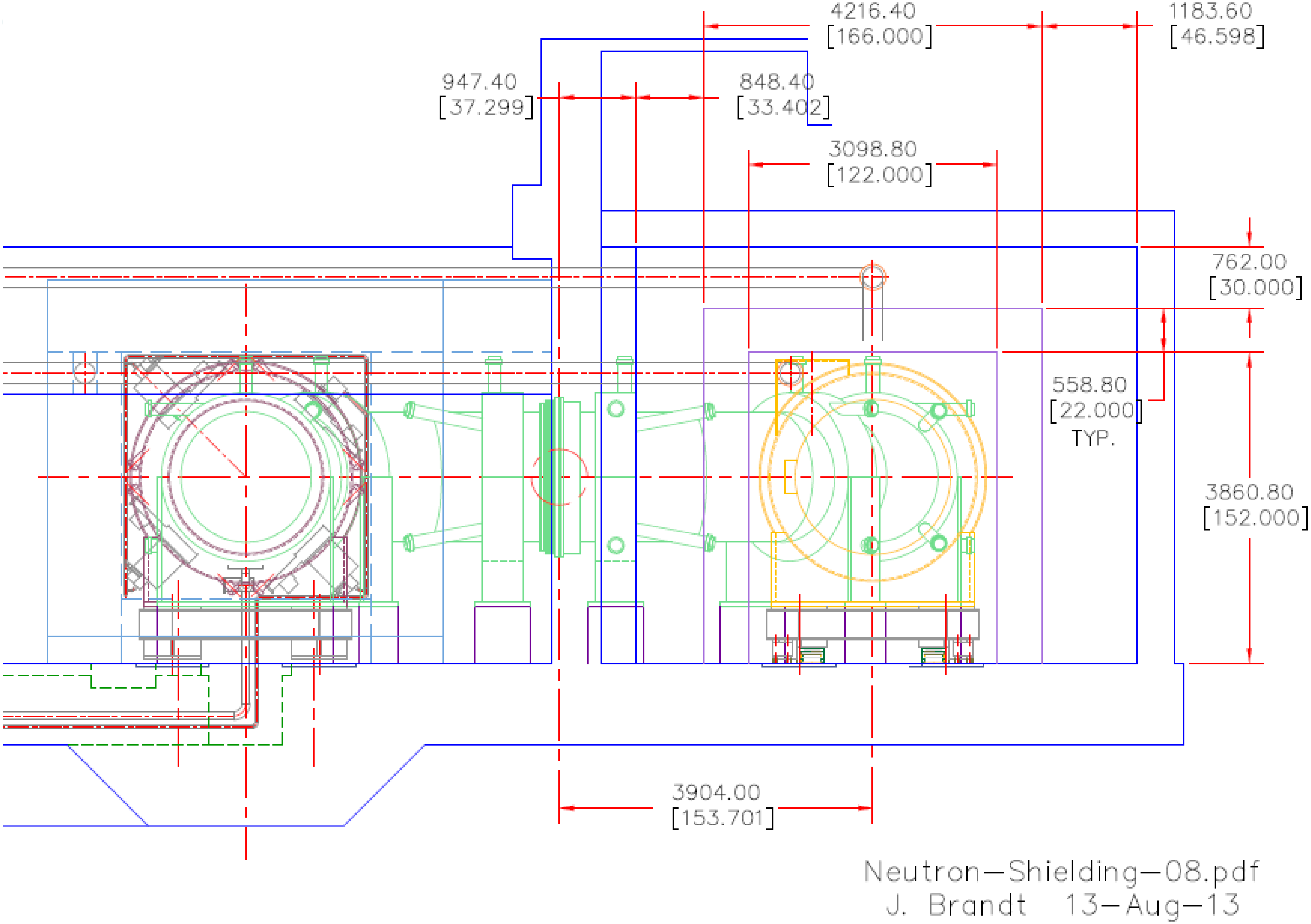
Top view on shielding blocks and theirs position dimensions



Vacuum and cryogenic supply tubes for PS




EXPERIMENT 0,0,0
Neutron-Shielding-10.pdf
J. Brandt 22-Aug-13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1183.60
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947.40
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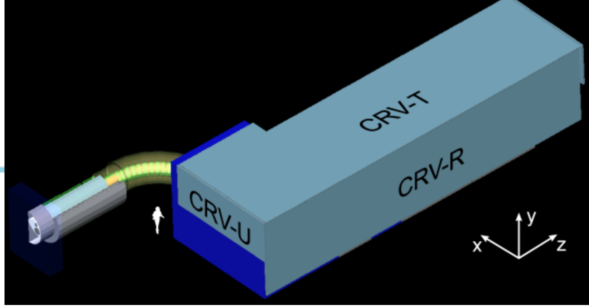
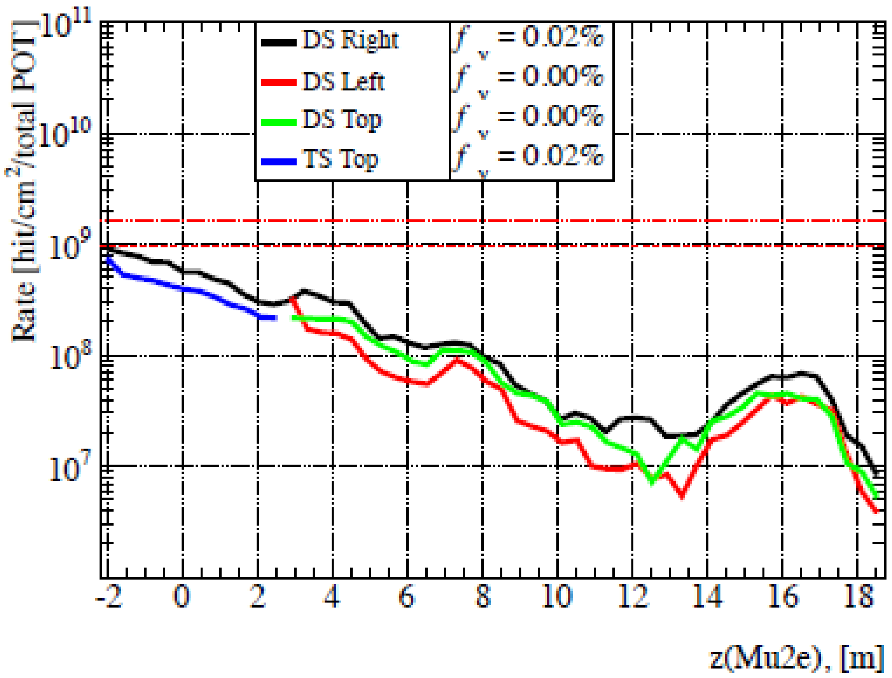
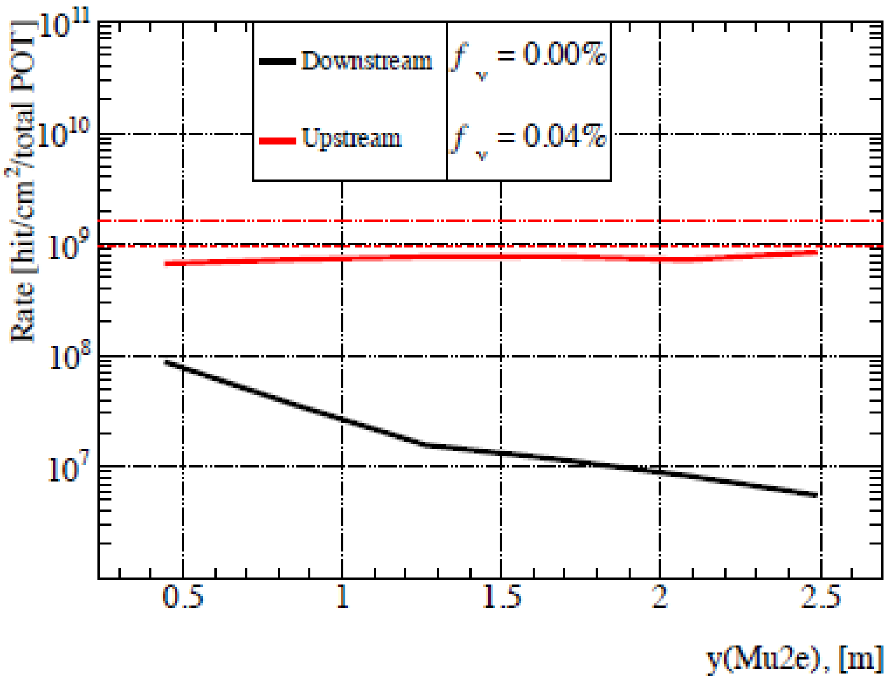
[30.000]
558.80
[22.000]
TYP.
3860.80
[152.000]
3904.00
[153.701]
Neutron–Shielding–08.pdf
J. Brandt 13–Aug–13

Accidental CRV rates

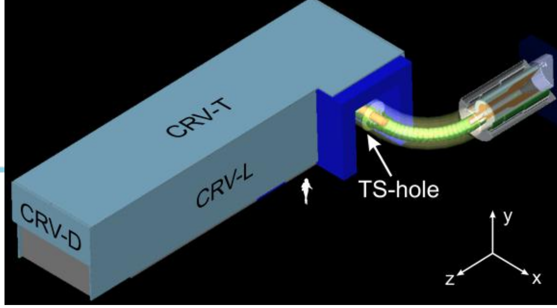


- Accidental hit rates per unit area over the entire running period. Dashed and dotted red lines correspond to 1% and 5% fractional dead time assuming uniform flux distribution.
- CRV deadtime requirement is ≤ 10%





Semi-correlated CRV rates



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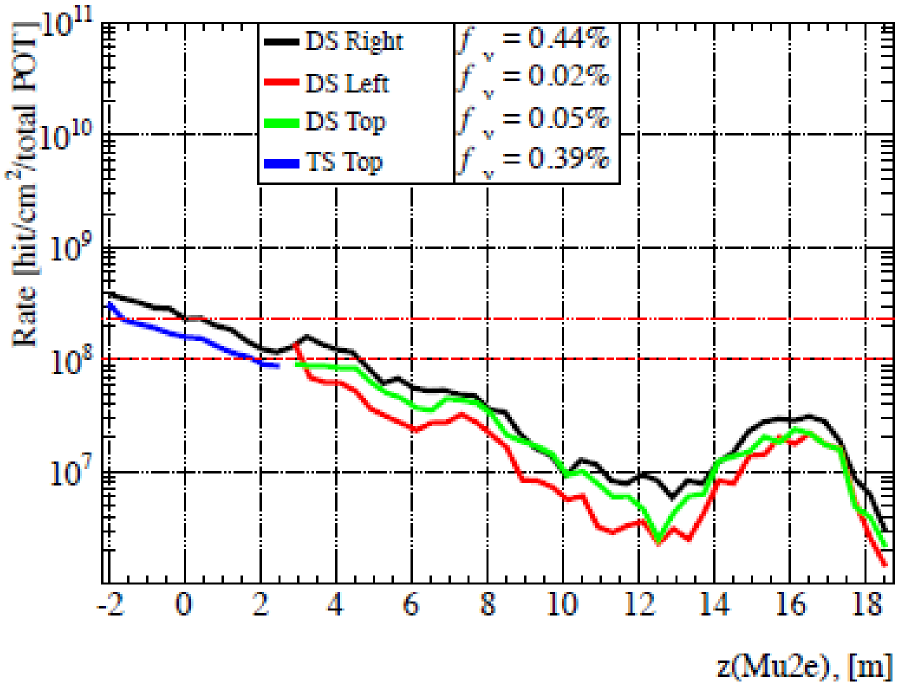
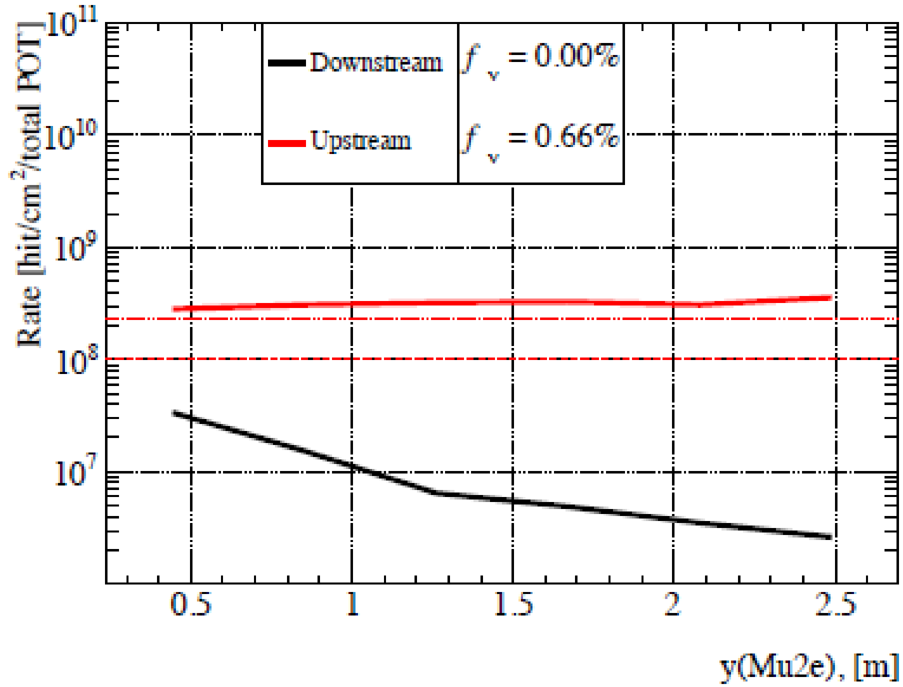
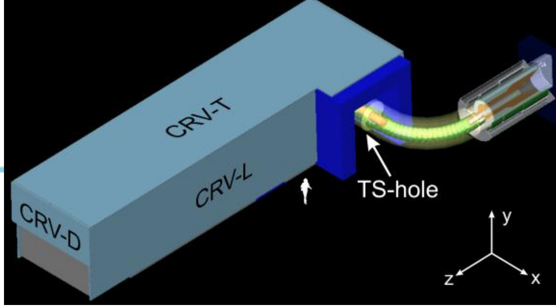




Correlated CRV rates



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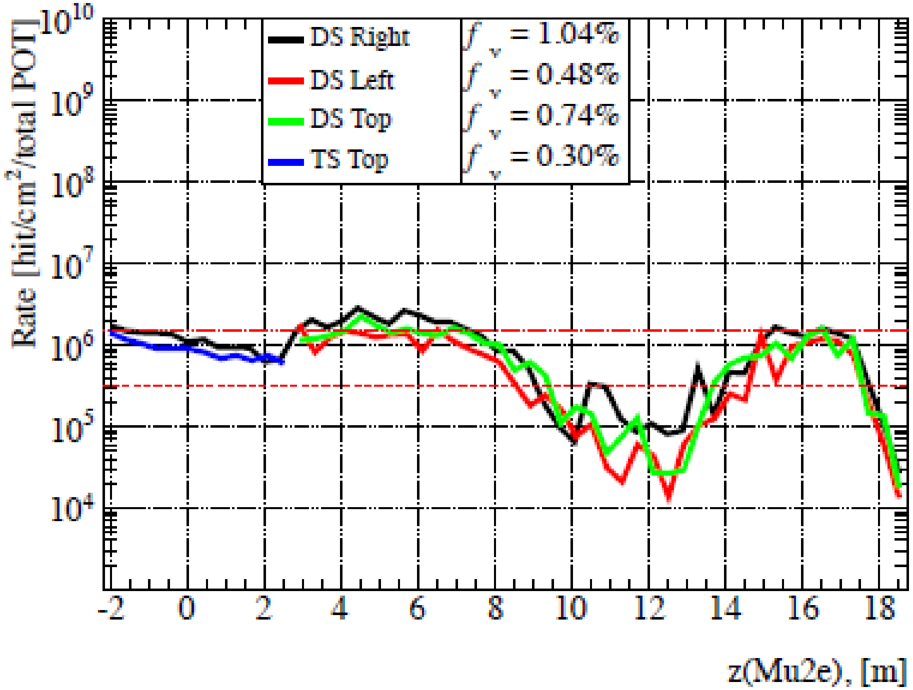
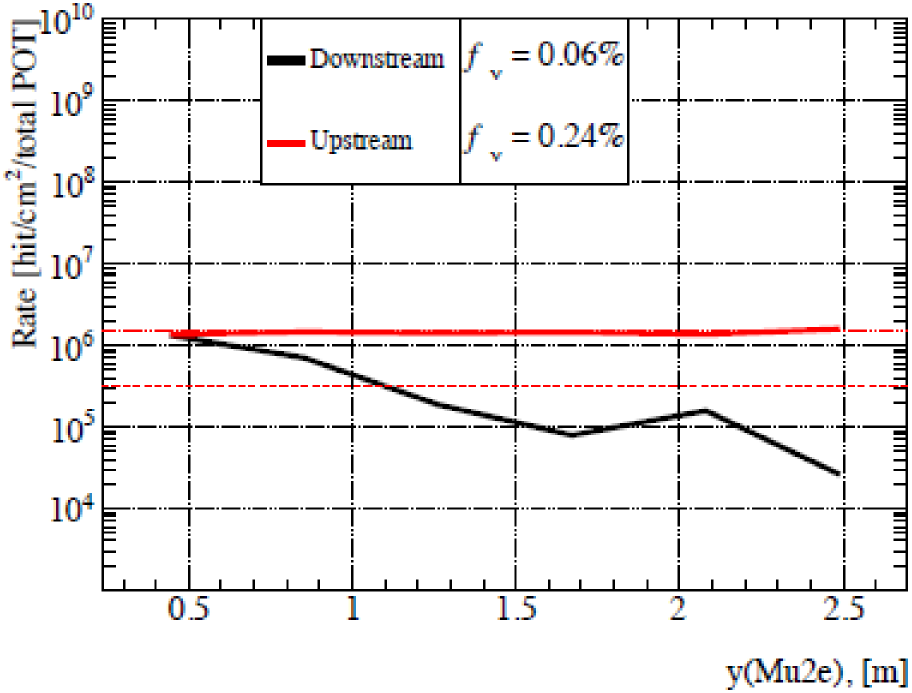
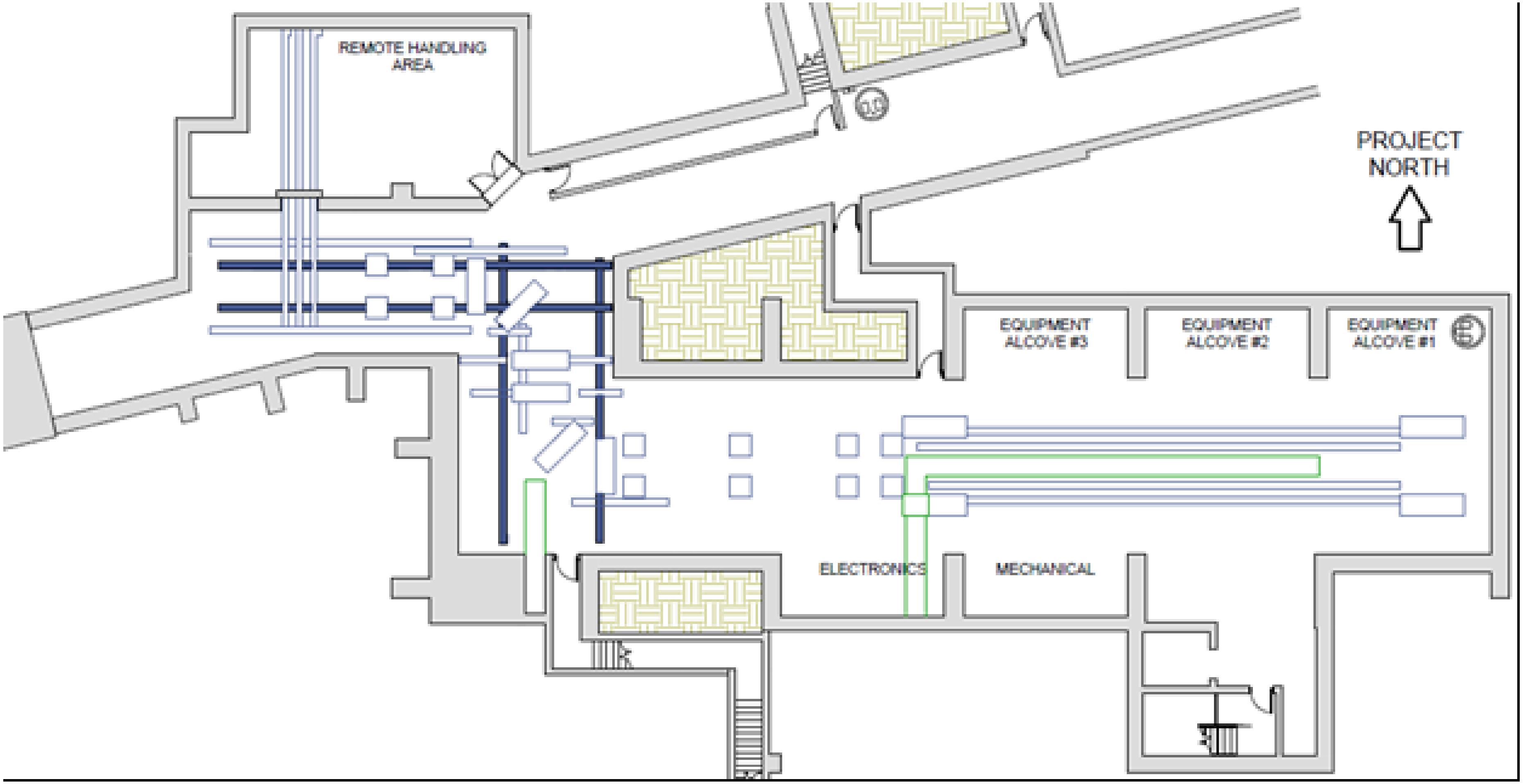
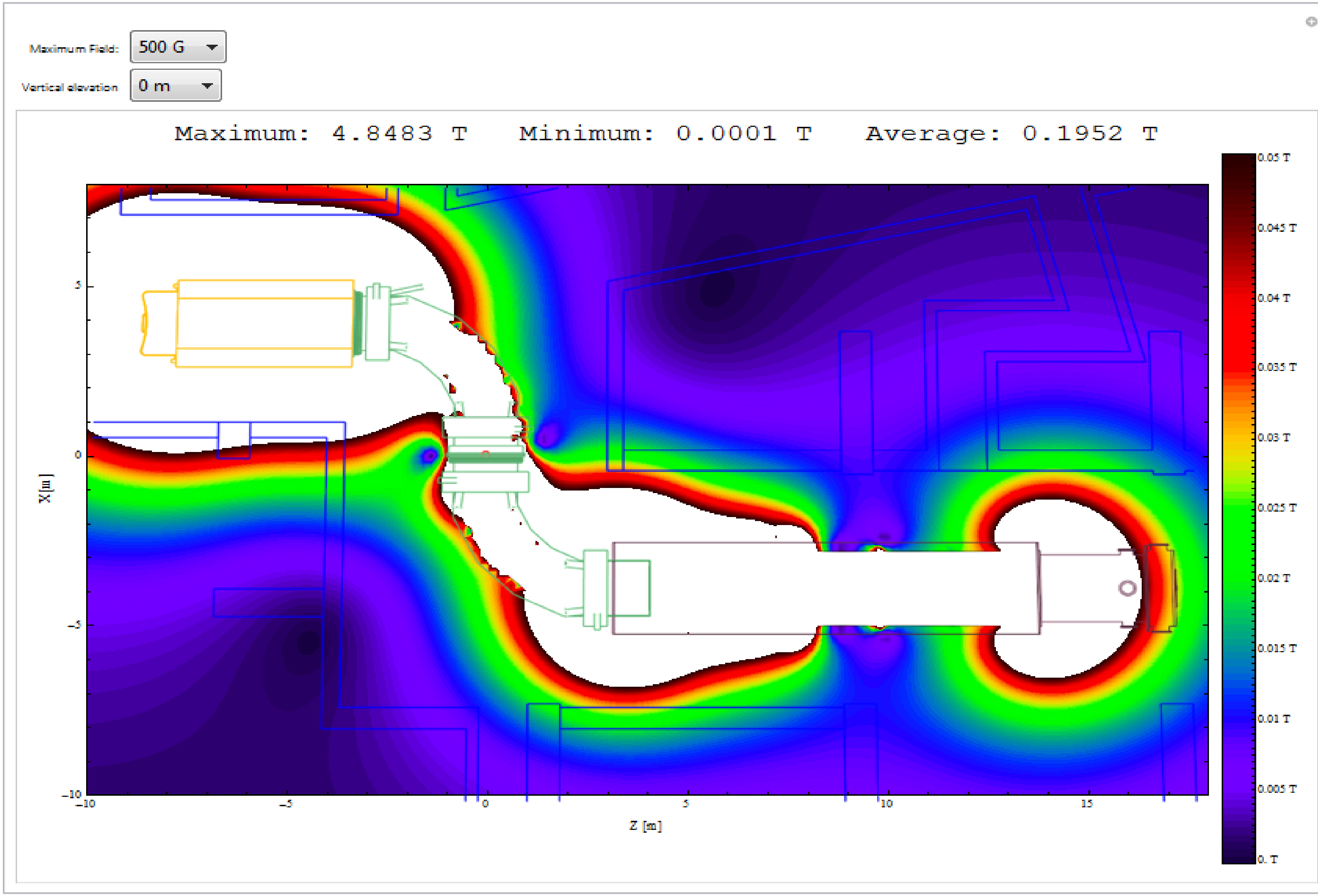




Floor track plate layout





Maximum Field: 500 G
Vertical elevation 0 m
Maximum: 4.8483 T Minimum: 0.0001 T Average: 0.1952 T
X [m]
Z [m]
0.05 T
0.045 T
0.04 T
0.035 T
0.03 T
0.025 T
0.02 T
0.015 T
0.01 T
0.005 T
0. T

Upstream External Shielding Blocks Parameters

Upstream External Shielding Blocks								
							TOTAL CUBIC FEET	
BLOCK LABEL	SHAPE	MATERIAL	(CU. FT.)	BARITE	CONCRETE	# OF BLOCKS	BARITE	CONCRETE
BRP-152	R	BARITE	85.0	18694		10	849.7	
BRQ-152	R	BARITE	42.5	9347		3	127.5	
BRR-152	R	BARITE	31.7	6967		1	31.7	
BRR-132	R	BARITE	27.5	6050		1	27.5	
BRN-264	R	BARITE	138.8	30536		1	138.8	
BRW-175	R	BARITE	128.7	28307		8	1029.3	
CRN-262	R	CONCRETE	167.7		24315	2		335.4
CRW-262	R	CONCRETE	163.4		23700	2		326.9
Total			**0.0**			**28**	**2204.5**	**662.3**
MAX				**30536**	**24315**			
Sub-total		**BARITE**				**24**	**2,204**	
Sub-total		**CONCRETE**				**4**		**662**

Barite Concrete

Engineering Compendium on Radiation Shielding Volume II   Jaeger et al

- Barite ore as the heavy aggregate
- Densities of around 3.5 gm/cm^3 or 220pcf
- Main difficulty is procurement of the ore
  - The best US barite in the past is from a min in Sweetwater Tennessee, which is now closed
  - Missouri is another source
  - There are a few western mines, but the ore is of inferior quality
- Barite concrete contains up to 75% $BaSO_4$
- Has been used extensively in the construction of very high activity cells and protective walls around accelerators
- It has become a fairly extensively used shielding material
- The behavior of barite aggregates in concrete is similar to that of silococalcereous aggregates in standard concrete and no special problems have been encountered regarding the selection and proportioning of the ingredients in the concrete.
  - 90 day compressive strength from 3500 to 5000 psi
- If a concrete of higher density is desired in certain cases, the barites can be combined with even denser aggregates

Barite concete mix studied for Nova

Client: Fermi National Accelerator Laboratory
Project: Heavyweight Concrete
Contact: Mr. Ron Cypret
Submitter: Mr. Ron Cypret

CTL Proj. No.: 390535
CTL Proj. Manager: J. Hidalgo
Approved by: W. Morrison
Date: August 28, 2007

Mix #3: Mix Proportions, Fresh Properties of Fermi-Lab Heavyweight Concrete Mix

Parameter, units per cubic yard	Fermi-Lab
CTLGroup Lab Cement (Lot. 18L0091), lbs	564
Rad Ban Coarse Aggregate SSD, lbs	2840
Rad Ban Fine Aggregate SSD, lbs	2327
Water, lbs	300.0
Water, gallons	36
Glenium 3030, BASF fl oz/cwt	5.0
w/c ratio	0.53
Fresh Concrete Properties	
Slump, in.	4.00
Density, pcf	219.5
Air Content, %	2.1
Average Compressive Strength (psi) *	
7 days	5390
14 days	5540
28 days	5990
Average Flexural Strength (psi)	
7 days *	620
14 days **	640
28 days **	740
Average Direct Shear (psi)	
28 days *	790

* Average of three samples.
** Average of two samples.

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Building Knowledge. Delivering Results.

Labor / Material Breakdown (AY k$)