Fermilab

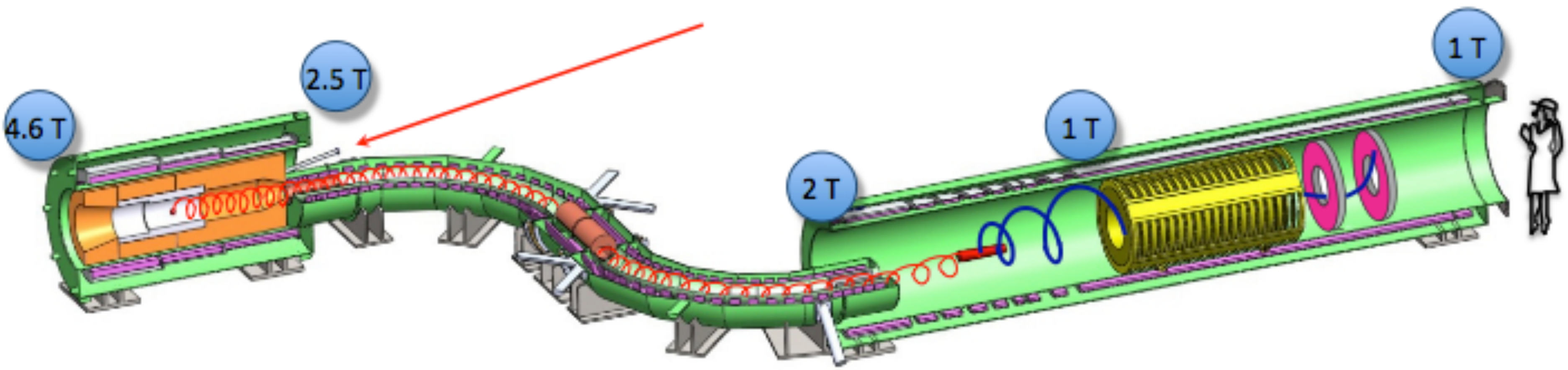
Mu2e CD-2 Review Target Station

Rick Coleman
L3 Manager Target Station
10/22/2014

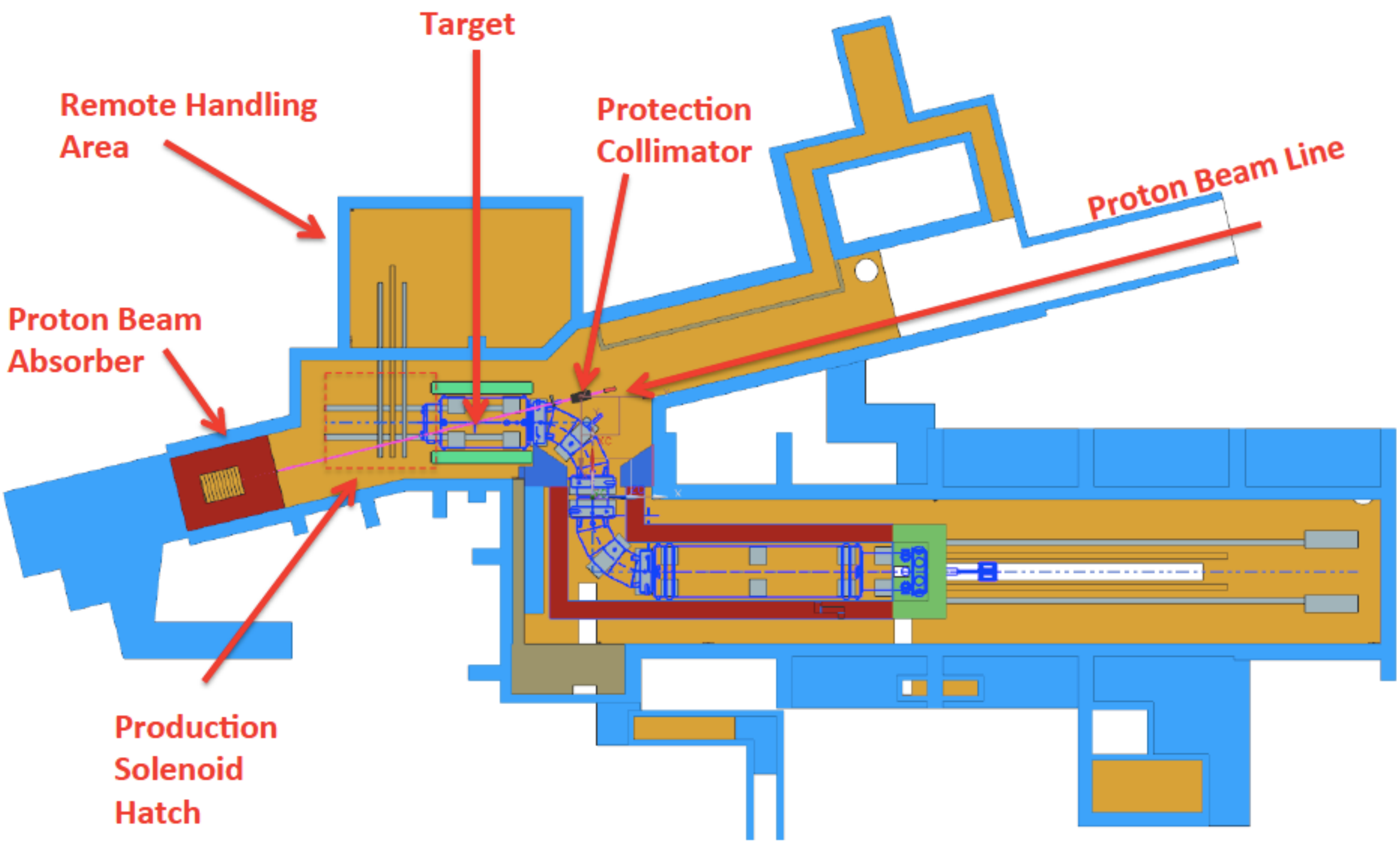
WBS 475.02.09 Target Station

- The Target Station
  - proton beam production target
  - heat and radiation shield (HRS)
  - target remote handling system
  - proton beam absorber
  - protection collimator

- There is a WBS task for each of above, plus one for simulations and one for technical documentation (& general support)



Overview of Layout



Requirements

- Mu2e Proton Beam Requirements (DocDB 1105)
  - 3.6 x 10^{20} protons on target over 3 years to obtain sensitivity
  - Repeat period > 864ns (lifetime of muons in aluminum stopping target)
  - 6 x 10^{12} protons/sec at 8 GeV delivered every 1.33 seconds, 0.3 duty factor
  - Transverse Spot Size 0.5 to 1.5 mm (rms), Divergence < 4 mr (rms)
  - For alignment & target scans +/- 1 cm and +/- 0.8 °
  - Low intensity for commissioning and special calibration runs

- Production Target Requirements (DocDB 887)
  - Maximize number of stopped muons (high Z material, small radius target and minimize target support structure material to reduce pion reabsorption)
  - Target Lifetime > 1 year to minimize interruptions to experiment, since target replacement time ~ 1 month
  - Target-Beam Alignment < 0.5 mm transverse, < 10 mr angle

Requirements

- Mu2e Proton Beam Absorber Requirements (DocDB 948)
  - Designed to absorb the primary proton beam and secondary particles left after the production target for normal beam over the experiment lifetime(10 yrs) and full beam power for 10 minutes in an accident condition
  - Placed far enough away from target to eliminate back-scattered particles from entering muon beam channel and allow access for target remote handling
  - No maintenance or service directly over lifetime
  - Maintain surface and ground water contamination below limits
  - Air activation from absorber must be below limits after cooled down
  - Minimize residual radiation during access
  - Shielding for the extinction monitor must be sufficient

- Protection Collimator Requirements (DocDB 2897)
  - With loss monitor instrumentation provide a means to abort the proton beam if it is missteered to provide protection for the solenoid systems
  - Provide an "out" position for target scans

Requirements

Mu2e Production Solenoid (PS) Heat and Radiation Shield (HRS) Requirements (Mu2e-doc-1092- G. Ambrosio, R. Coleman, V. Kashikhin, M. Lamm, M. Lopes, N. Mokhov, J. Popp, V. Pronskikh)

- Limit Magnet from Heat Load

  Limit the overall dynamic heat load in the PS magnet to less than 100 W.

  Limit the instantaneous heat load in any coil of the PS to less than 30 μW/gm.

- Prevent radiation damage to PS magnet materials

  Limit dose rate to the superconductor insulation and epoxy to less than 350 kGy/year.

- Geometry

  The heat shield must have sufficient inner aperture to preserve the muon yield

- Maintain electrical conductivity of superconducting cables and normal conducting quench stabilizing matrix

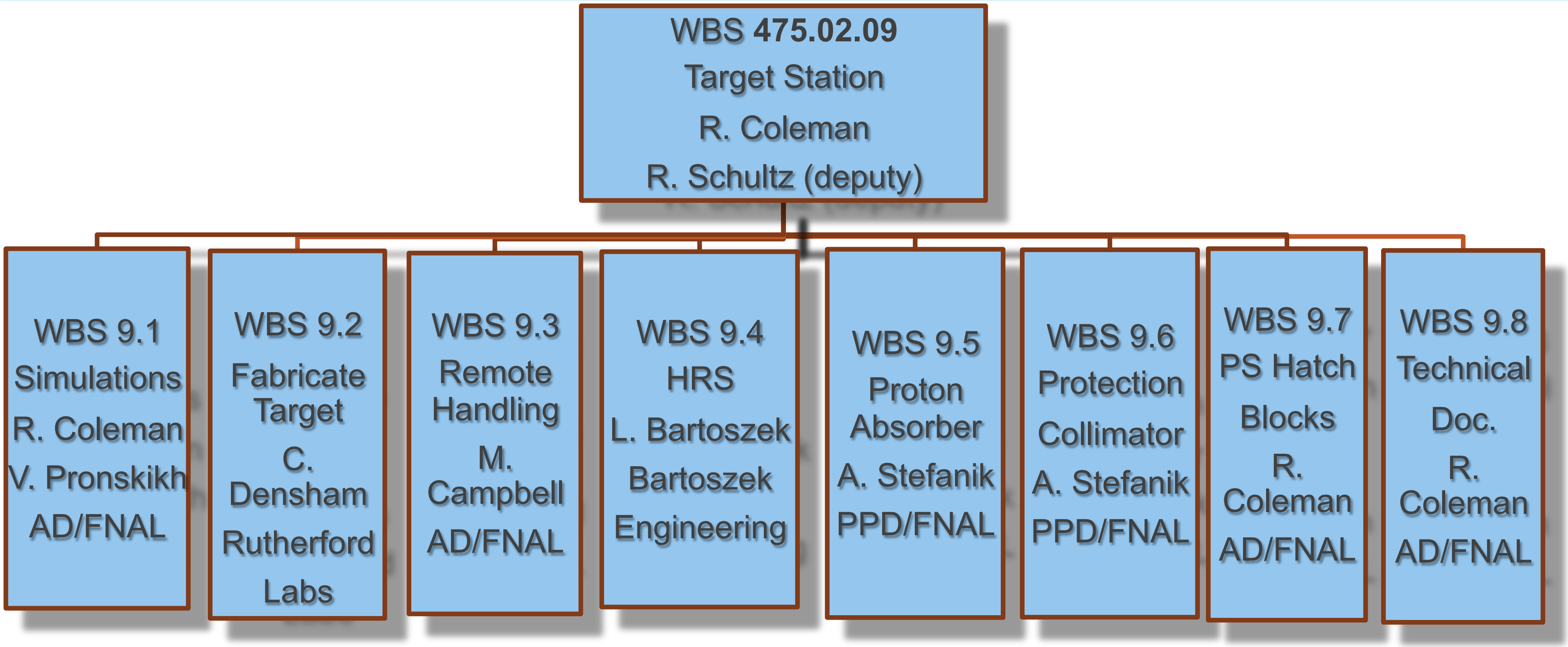
  Limit the DPA † experienced by the component metals of any PS superconducting cable to less than 4 to 6 $\times 10^{-5}$ DPA/year.

➔ RRR*> 100 , Annual warm-up to anneal

† DPA = Displacements per Atom

$$*RRR = \frac{\rho_{300K}}{\rho_{4.5K}}$$

Organizational Breakdown

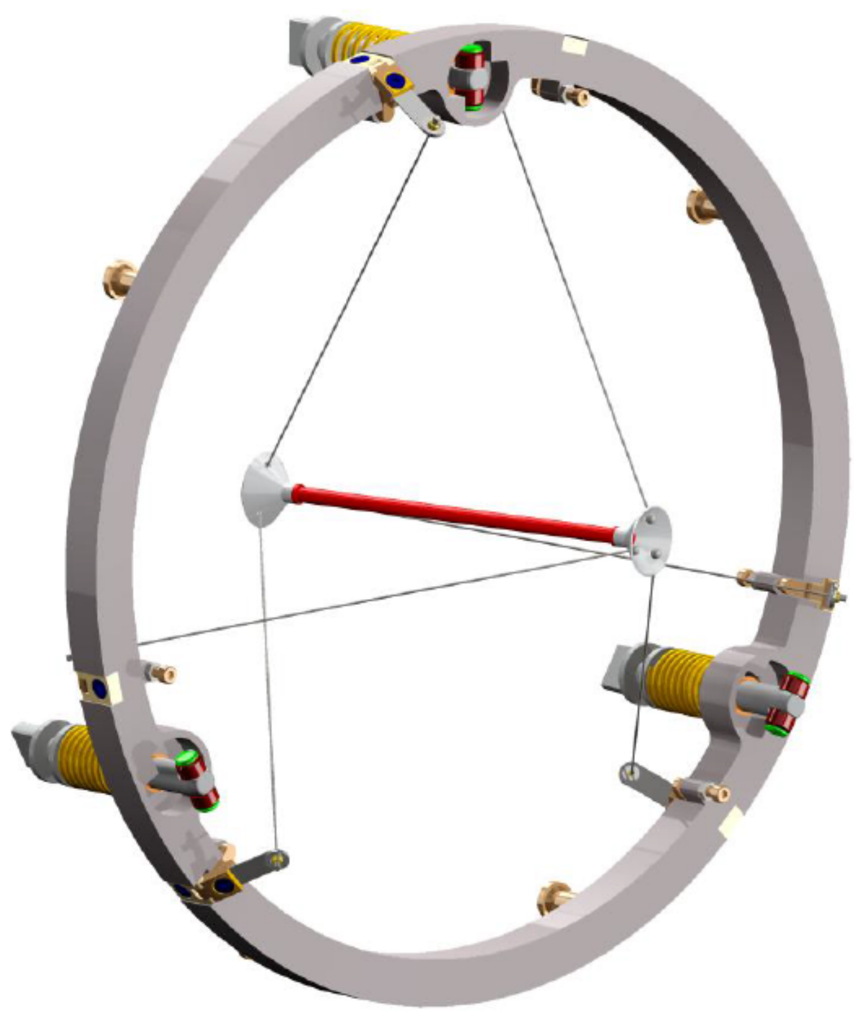


Target Station Team

- Steve Werkema, Vladimir Nagaslaev, Mike Campbell
  - L2 Manager, Deputy and Engineer
- Rick Coleman, Ryan Schultz
  - L3 Manager, Deputy
- Target- Rutherford High Power Targetry Group- Chris Densham, Peter Loveridge, Joe O'Dell, Roger Bennett, Otto Caretta
- Remote Handling- Mike Campbell
- Heat and Radiation Shield- Bartoszek Engineering- Larry Bartoszek
- Proton Beam Absorber and Protection Collimator- Andy Stefanik
- Simulations- V. Pronskikh, N. Mokhov, Y. Eidelman
- Radiation Safety & ES&H – A. Leveling, M. Wolters, D. Hahn
- Project Mechanical Engineer (Integration) - K. Krempetz
- Muon Beamline L2 Manager- G. Ginther
- University Collaborators- J. Popp, K. Lynch
- Alignment- H. Friedman

Target Design

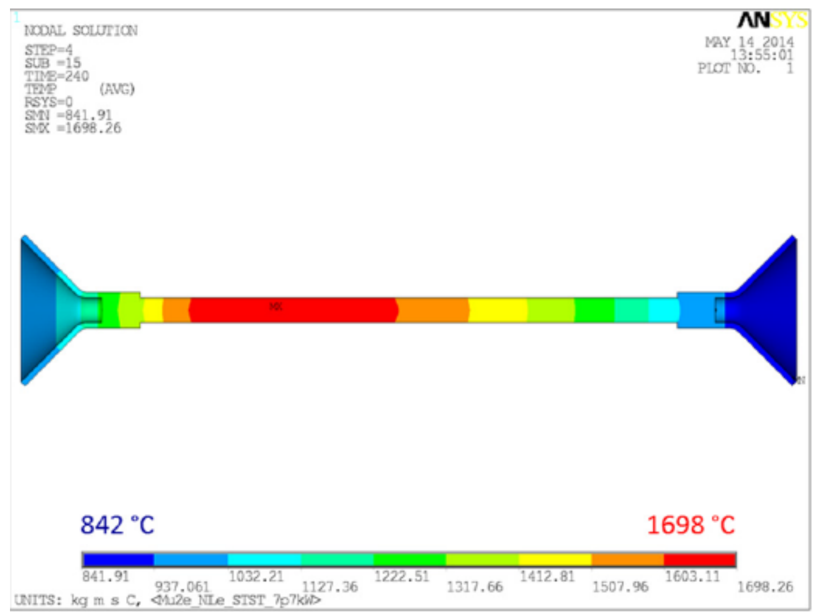
L=16 cm r=3.2 mm Tungsten Rod



High Power Targets

www.STFC.ac.uk

Doc db 2406
68 pages,
August 2012

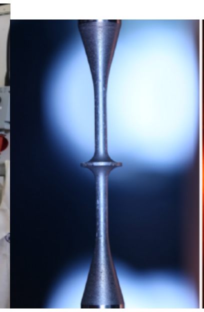
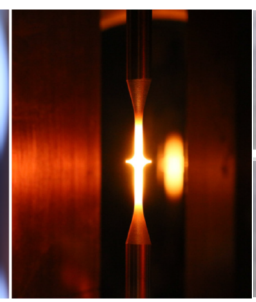
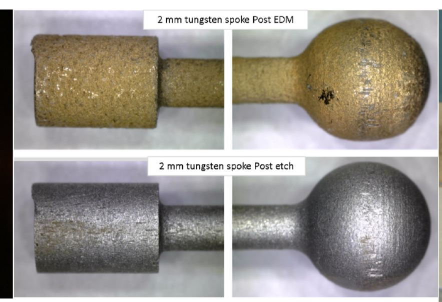


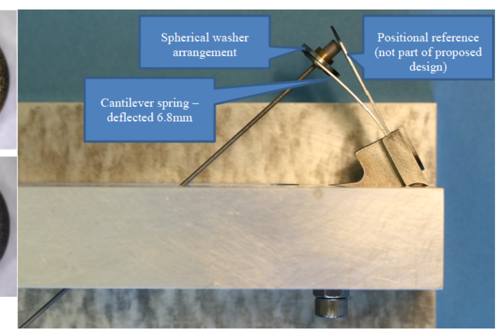
Target Design/R&D

STFC Rutherford Appleton Laboratory
High Power Targets group

Doc db 4305, 76 pages, June 2014 (2nd Contract)

- Completed Design, Testing, and Prototype work
  - Design shown on previous page
    - spoke tensioner, support ring detailed work
  - Measurements
    - vacuum vessel and equipment setup for testing
    - emissivity measurements at high T (5% verification of literature)
    - lifetime pulsed heating tests (fatigue)-OK for 4 yrs equivalent so far
  - Study of Creep in the Target Support- 6 micron elongation OK
  - Chemical Erosion Study (vacuum quality, oxidation) 1e-3 Torr not good enough, design is 1e-5 Torr
  - Spoke Prototyping (manufacturing, spring tests, adjustments)

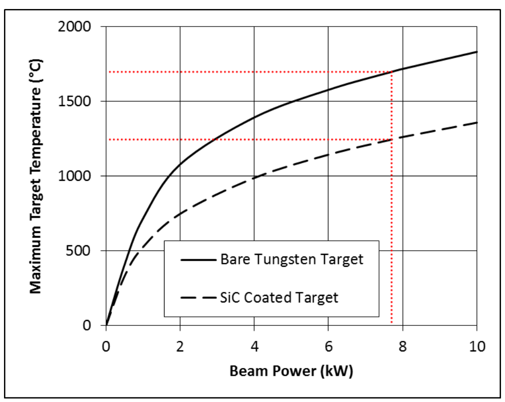





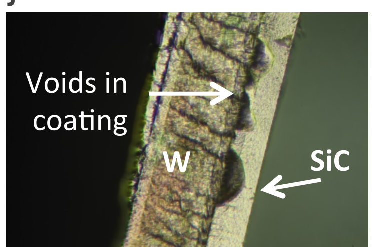


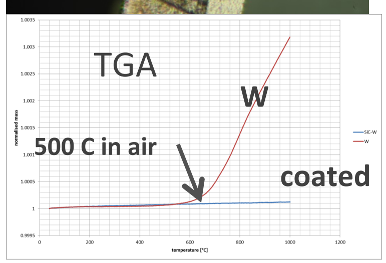
Target Design/R&D

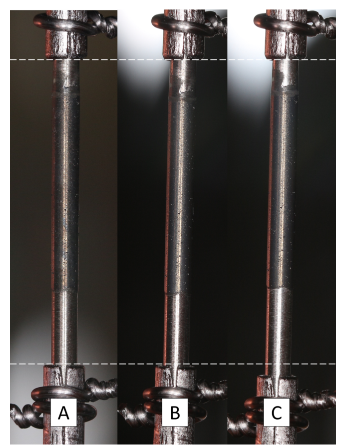
STFC Rutherford Appleton Laboratory
High Power Targets group

- 3rd Contract- started recently
  - Tungsten surface finish versus emissivity characterization
  - SiC coating/surface/oxidation/fatigue R&D, including:
    - Various surface treatment/coating R&D
    - Emissivity measurements of surface coatings
    - Medium vacuum (10^{-4} to 10^{-5} Torr) lifetime testing
    - Pulsed current fatigue testing for shaped test samples (horizontal test)
  - High temperature creep testing of spokes and spring tensioners
  - He cooling feasibility study and preliminary plant specification
  - Optimization of end joints







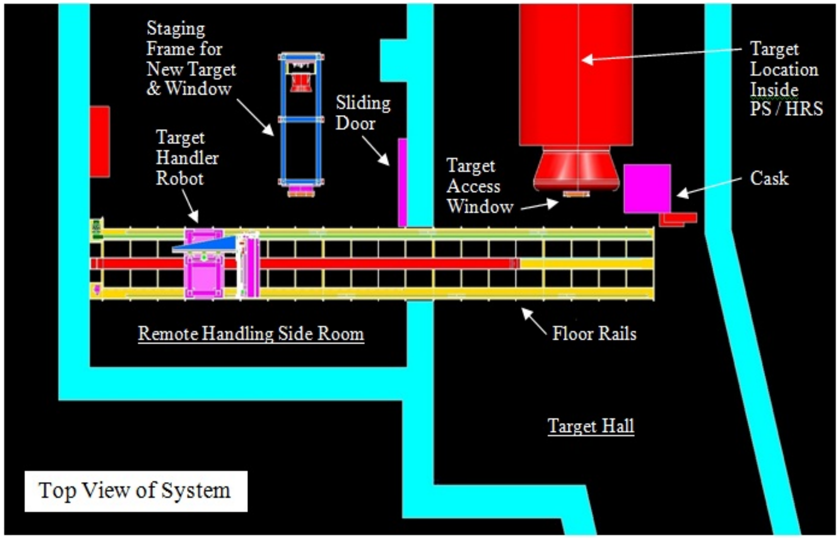


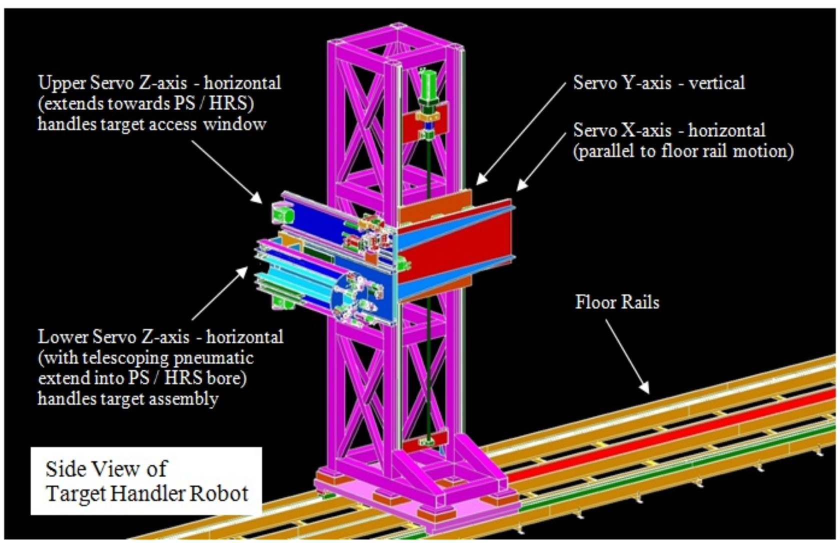
Thermal Cycles 1500 C

Baking 40 days

Target Remote Handling Design

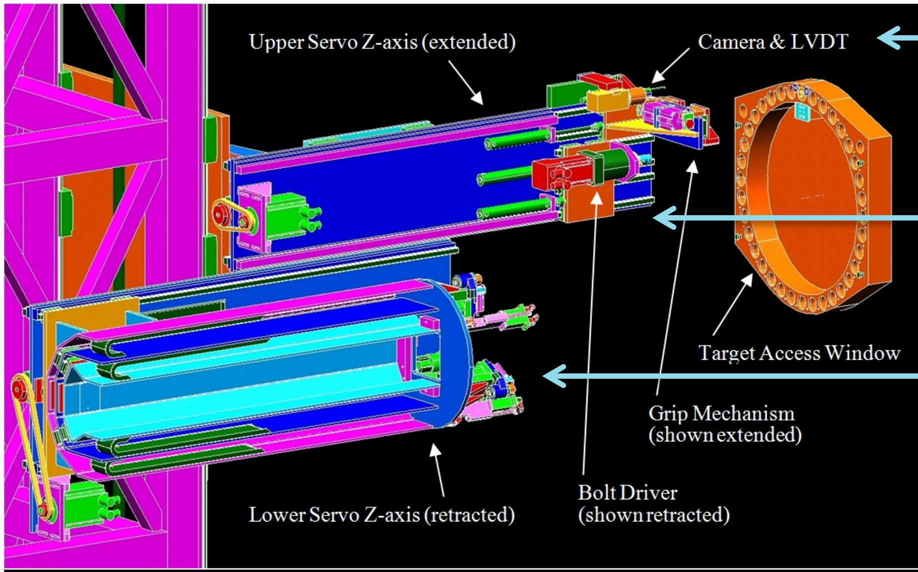
Mike Campbell/ FNAL





- Tasks
  - Enter Hall from RH room
  - Remove access window
  - Place window in cask
  - Detach/remove target
  - Place old target in cask
  - Obtain new target
  - Latch new target into place
  - Obtain new window
  - Bolt window in place
  - Exit Target Hall

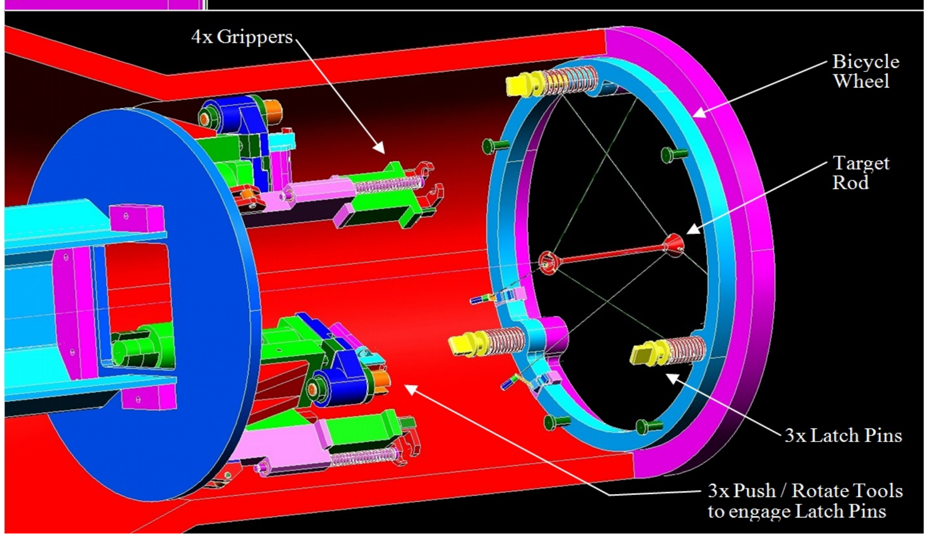
Target Remote Handling Design



Camera with machine vision software

Target Access Window
Upper Servo z-axis

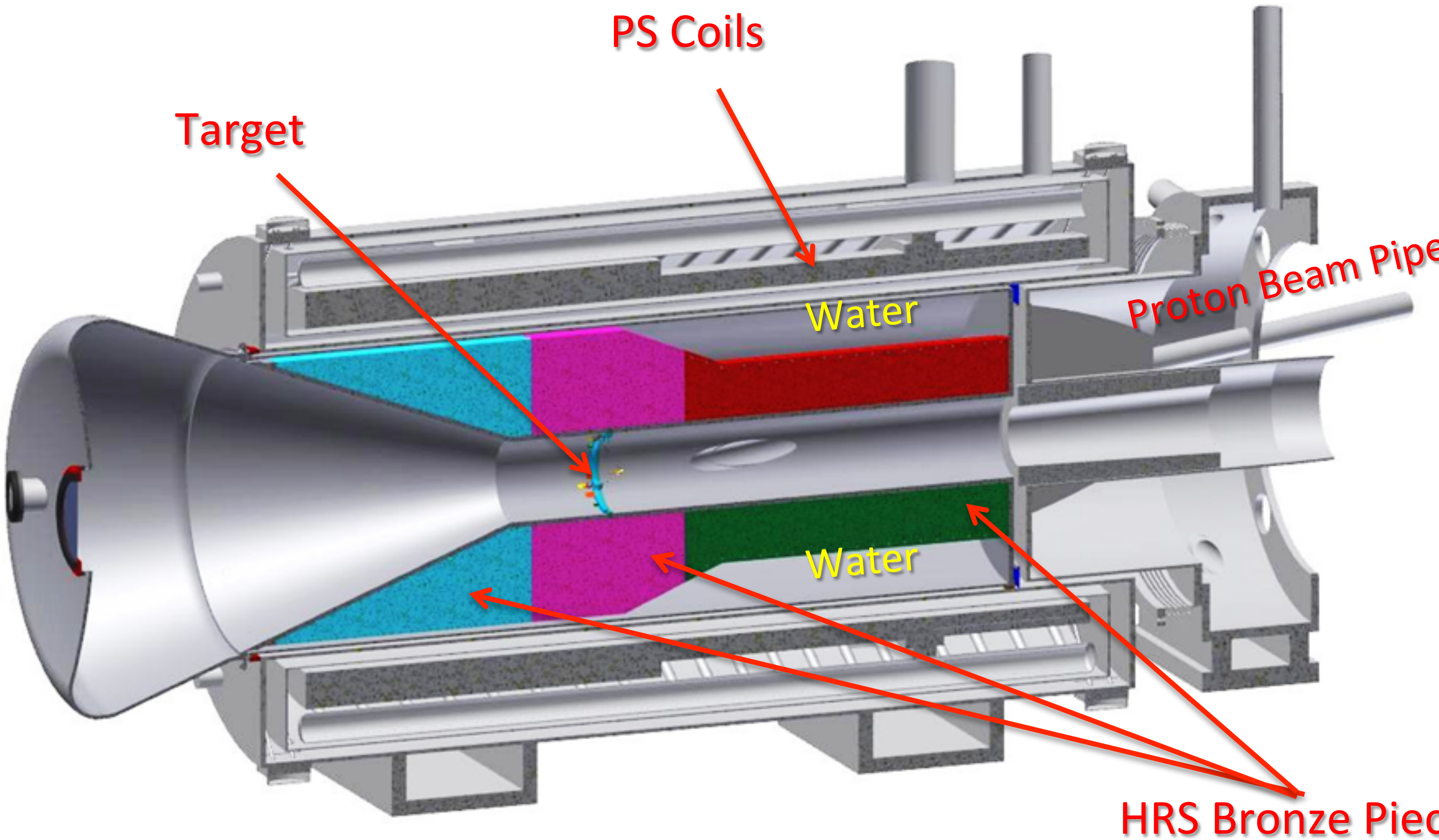
Target Interface Mechanism
Lower Servo z-axis



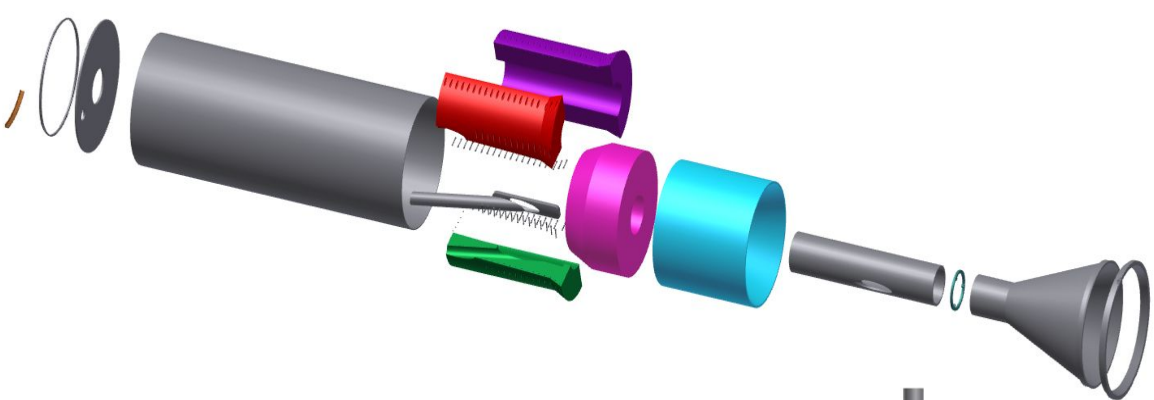
Target Interface Mechanism
Detailed View

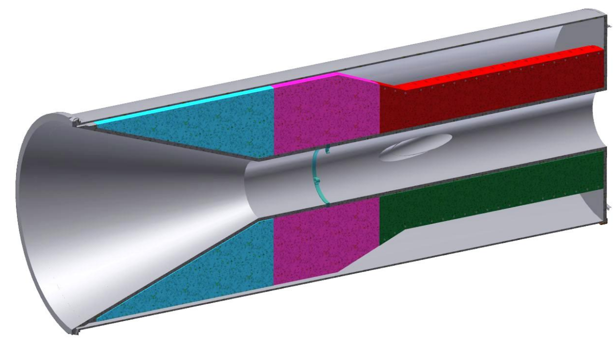
Heat & Radiation Shield Design

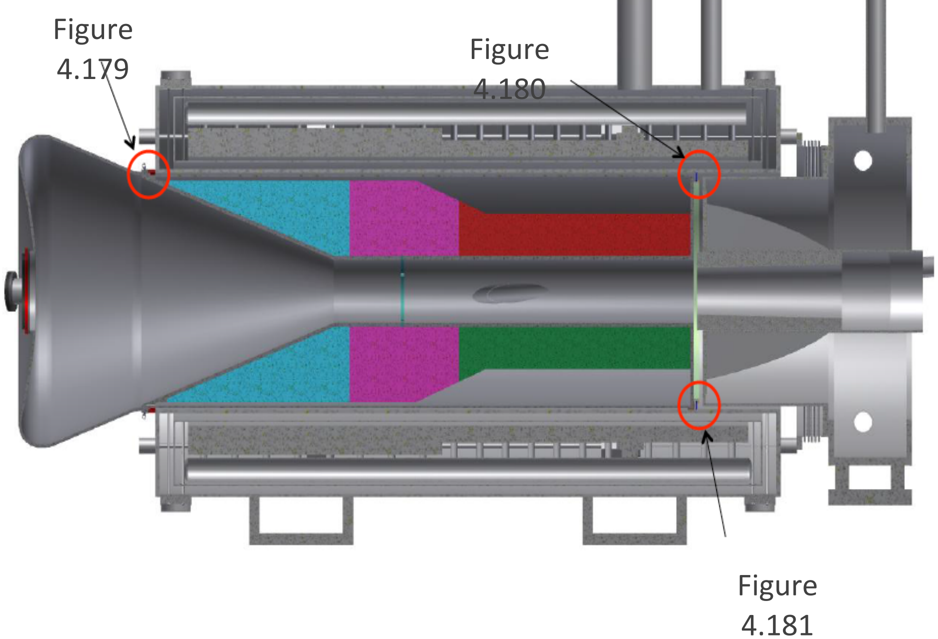
Bartoszek Engineering
Larry Bartoszek



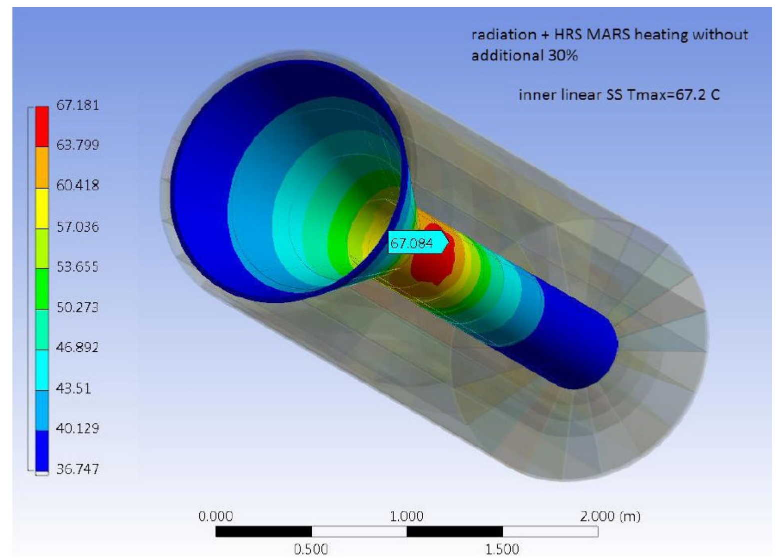
Heat & Radiation Shield Design



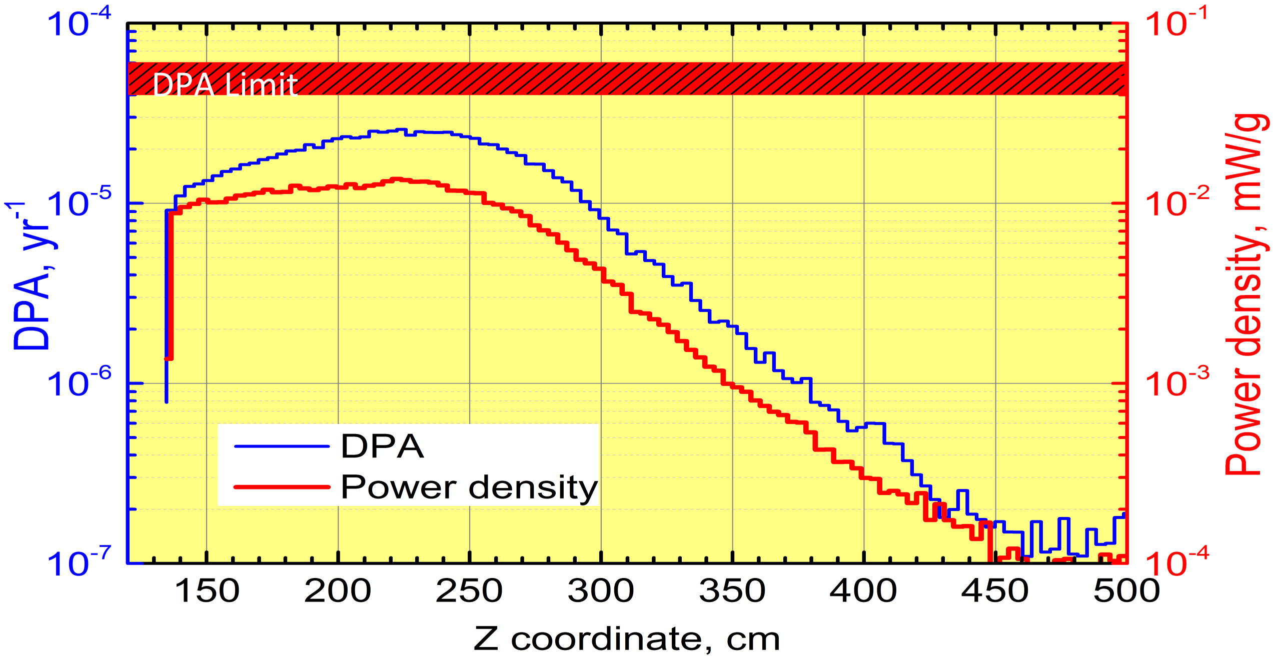




67° C max



Performance- HRS



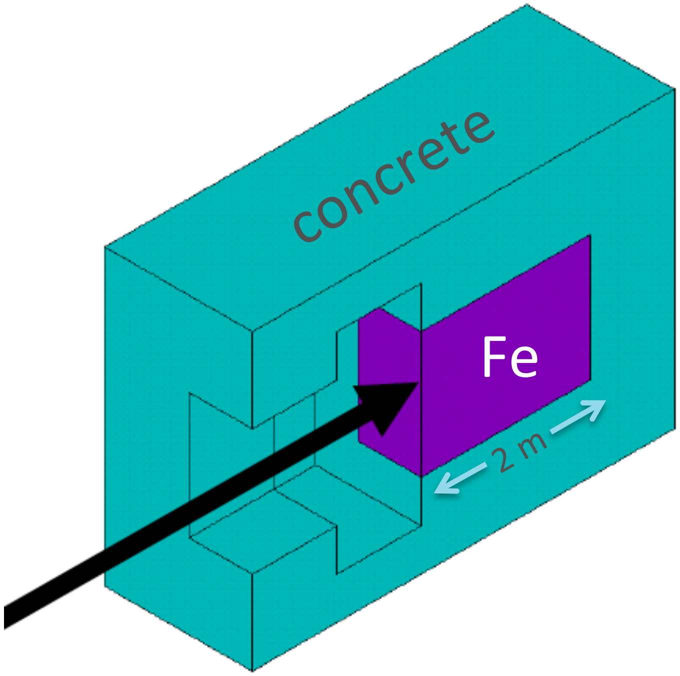
MARS Simulations
Vitaly Pronskikh

	Peak DPA/yr* [10^{-5}]	Peak Power Density [μW/g]	Absorbed Dose [MGy/yr]	**Years Before 7 MGy	Dynamic Heat Load [Watts]
Specification	4 to 6	30	0.35	20	100
Performance	2.4	13	0.26	27	24

Proton Beam Absorber Design

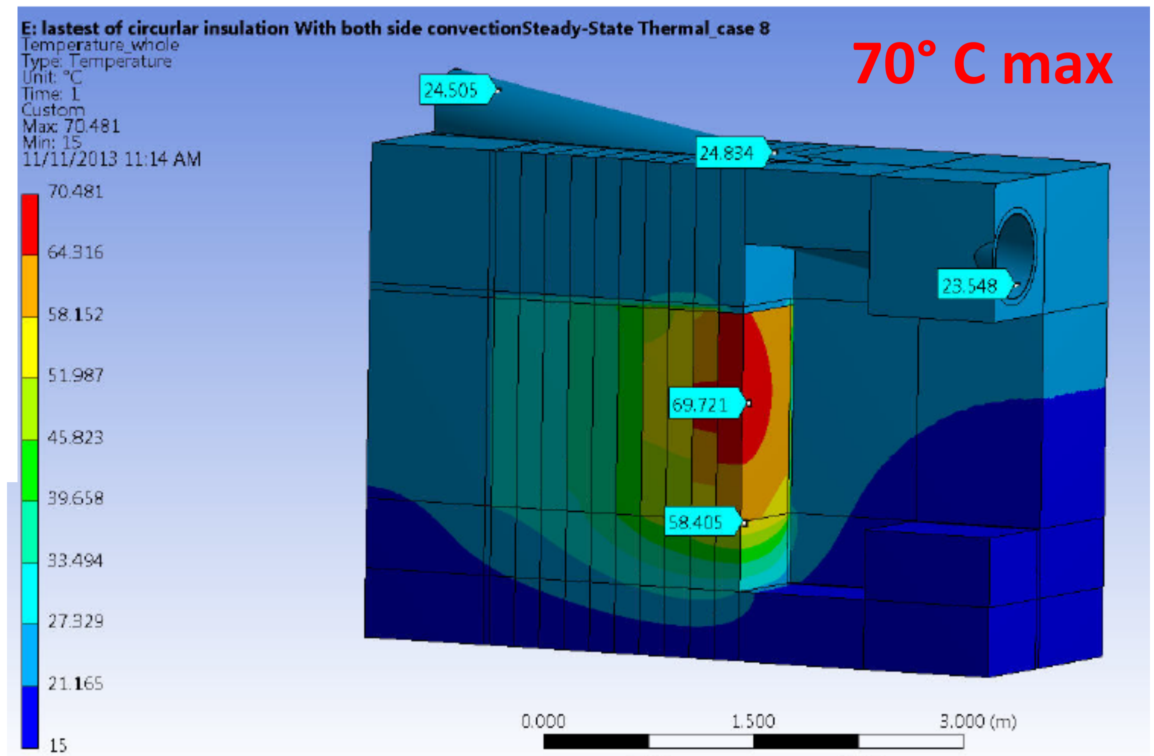
Andy Stefanik

Left Section View



Proton Beam

Fe core 1.5 m x 1.5m x 2 m



A. Lee

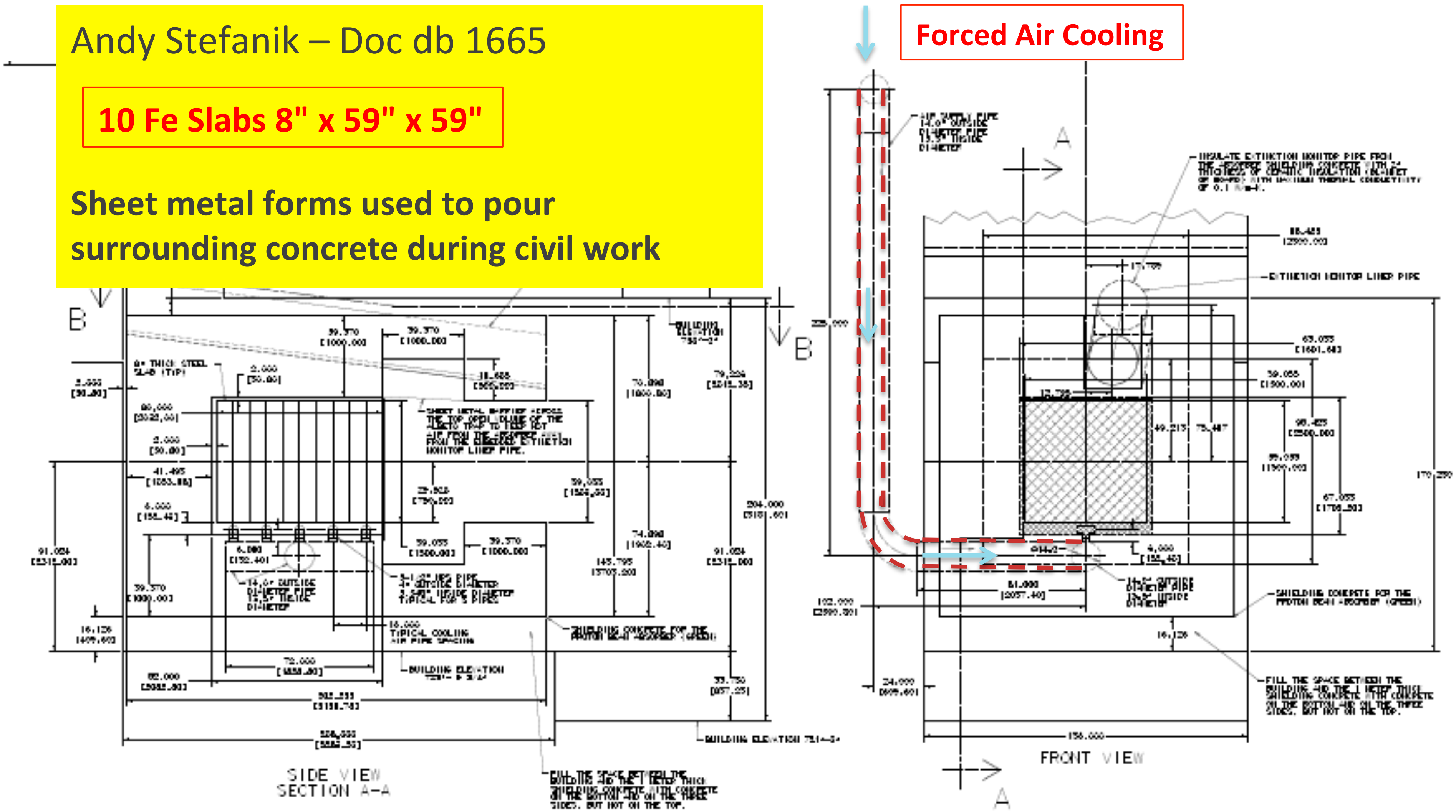
forced air cooling

Proton Beam Absorber Design

Andy Stefanik – Doc db 1665

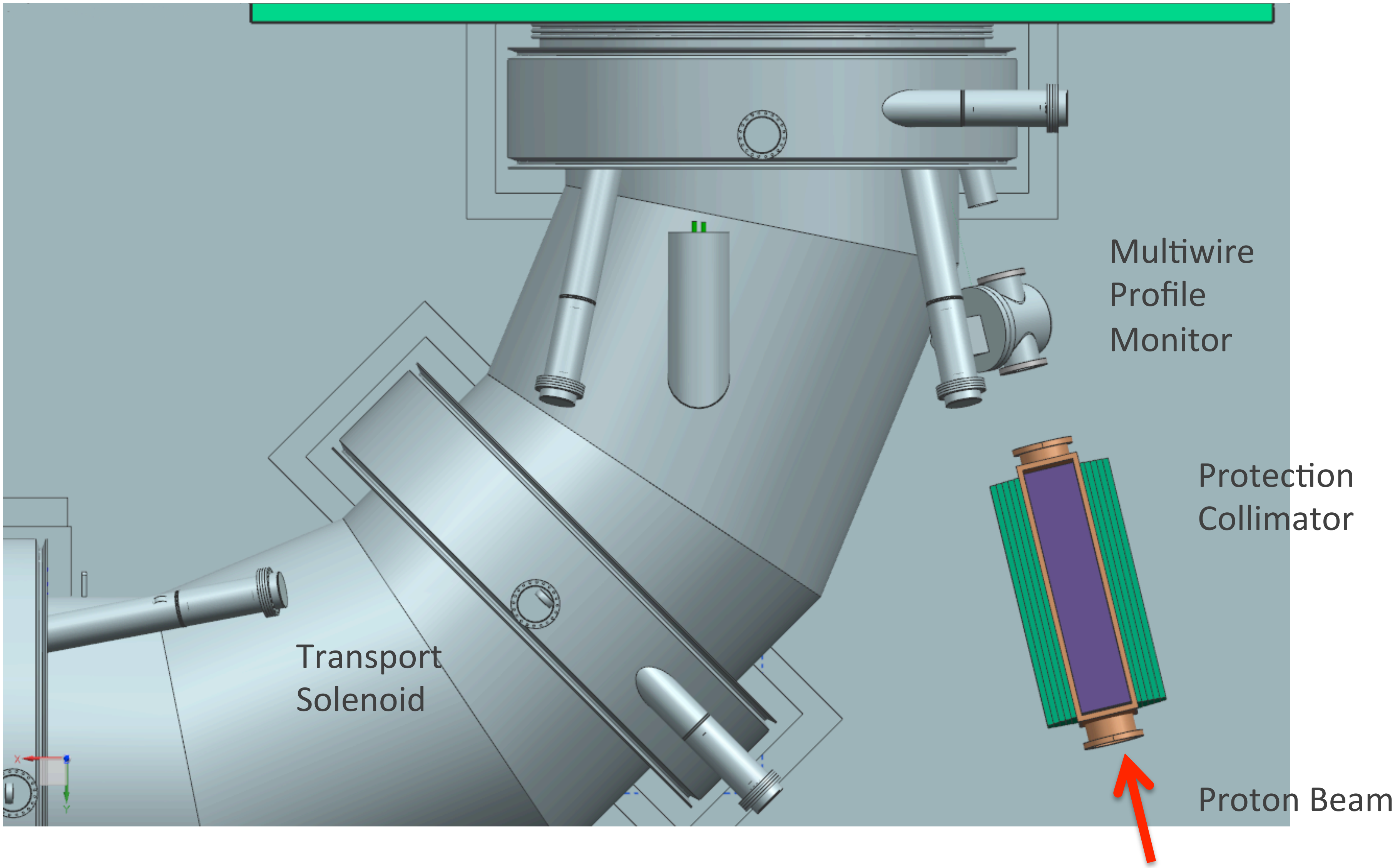
10 Fe Slabs 8" x 59" x 59"

Sheet metal forms used to pour surrounding concrete during civil work

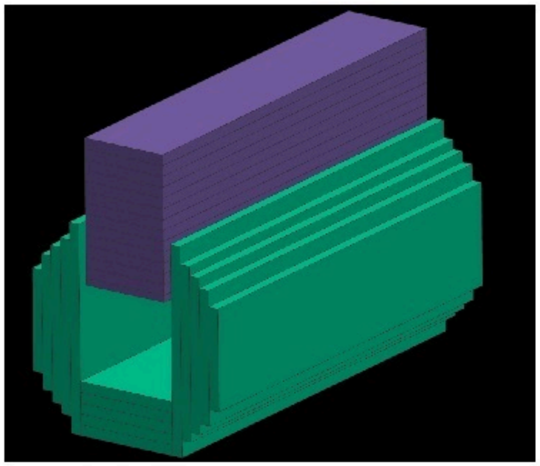


Protection Collimator Design

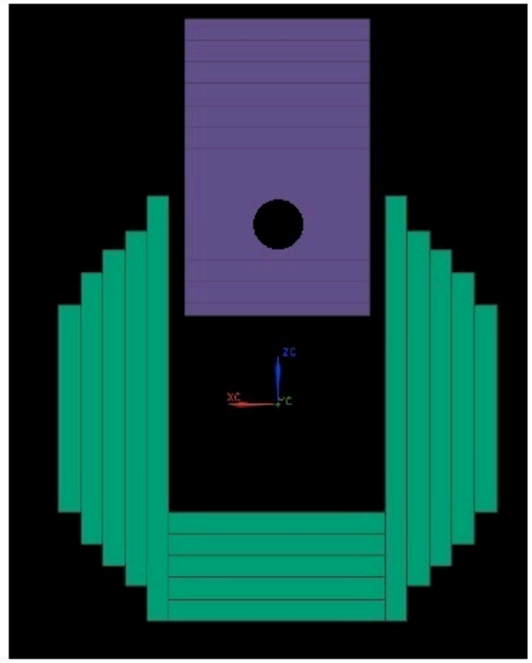
A. Stefanik



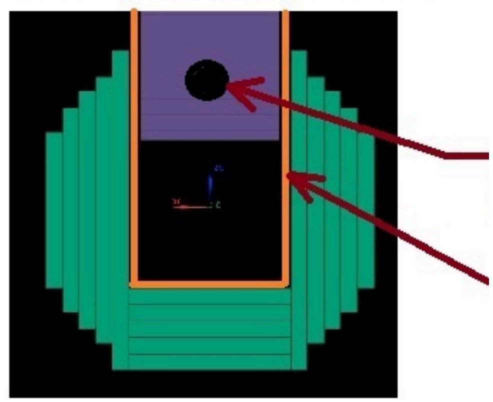
Protection Collimator Design



NEW CORE ISO VIEW. STATIONARY PART OF THE CORE IS GREEN. MOVING PART OF THE CORE IS PURPLE.



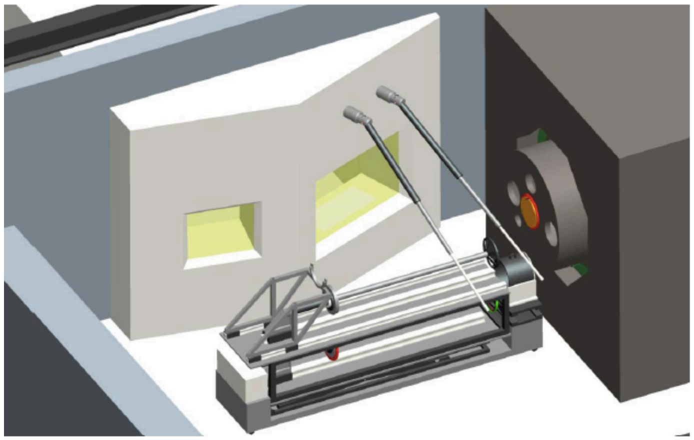
NEW CORE CROSS SECTION

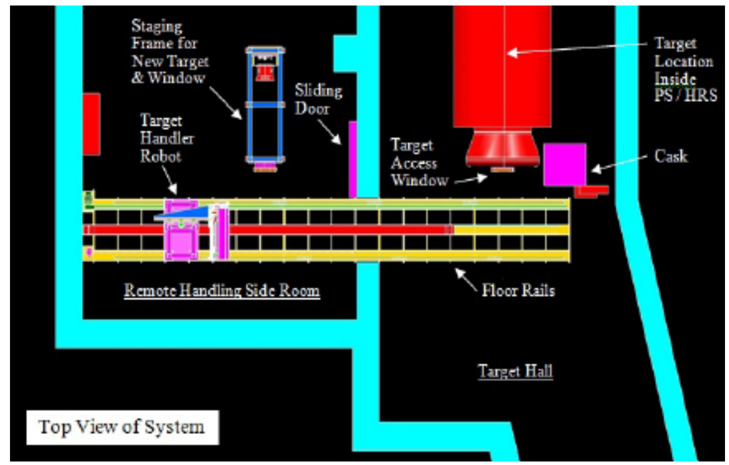


Changes since CD-1

- Target Remote Handling

Hot Cell and manipulator arms changed to current "robot" design

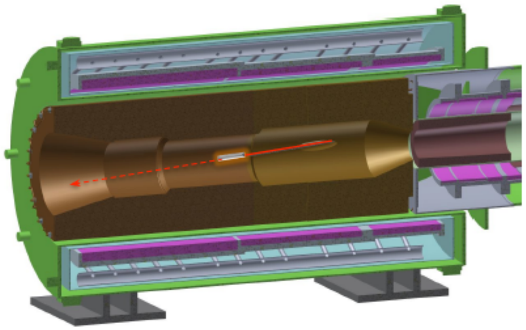


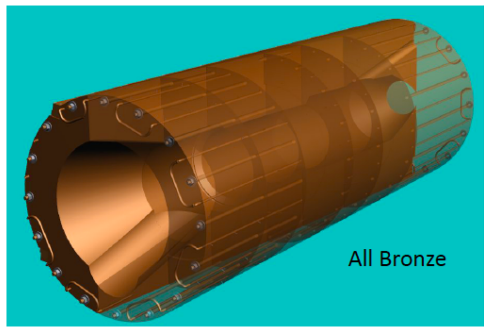


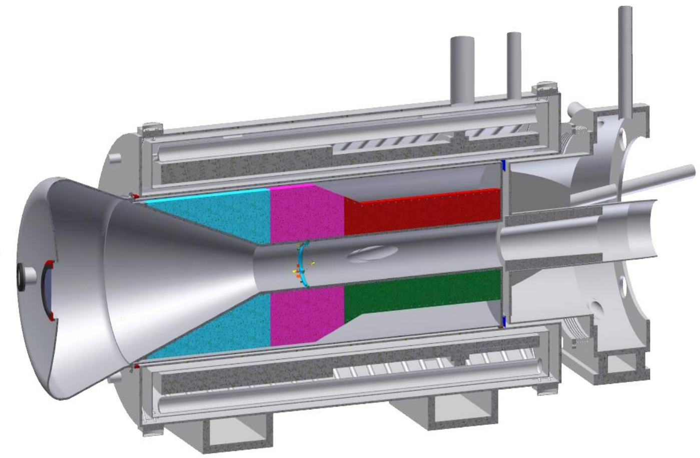
  - Move (Overall project beam power reduced by 3x for economics) -> from water-cooled to radiatively cooled target
  - Above removes the need for a longer plunger tool as shown on left
  - Responsibility of remote handling changed from contractor to FNAL
  - Started from discussions of a moveable hot cell
  - Minimize need for access through main PS hatch with temporary crane into high radiation area
  - Given building layout and large span to reach PS hatch, requires very large crane ($$$)
  - Minimize the need for massive shielding for hot cell/ manipulator arms (40 ton shield not shown in picture on left)

Changes since CD-1

- Heat & Radiation Shield







  - Mass of Bronze reduced from 41 tons to 31 tons
  - Water replaces some Bronze, serves as cooling & neutron shielding
  - Shape of Bronze simplified to cone plus cylindrical pipe, original had steps in radius, scalloped region
  - Stainless Steel liner -> Vacuum cleaner, vacuum surface area reduced
  - Concerns about water cooling lines contact in shield eliminated, number of pipe connections reduced

Value Engineering since CD-1

- Both design changes for Remote handling and HRS described on previous slides were motivated by Value Engineering
- Proton Beam Absorber design simplified, cost effective
  - Machined Al plates for core replaced with "boneyard" steel
  - Much of concrete around core poured in place during civil construction rather than using blocks
- Proton Collimator design simplified, cost effective
  - Motion of block inside vacuum changed, greatly reduces vacuum volume
  - Further work with look at larger reduction in mass of steel used

Value Engineering since CD-1- Rutherford Labs

- here is a list of the value of equipment RAL has used, or in some cases purchased specifically with no cost to the project:
-
- 1. Roger's 'little wire' test rig – c.£10k(?) of relevant costs not including pulsed psu
- 2. Vacuum pumps (turbo + scroll), gauges (Pirani + Penning + Controller/Display) - £9435
- 3. Pulsed PSU (components and much of the effort) c.£15k
- 4. DC power supply for emissivity measurements c.£2k
- 5. Induction PSU for future testing of prototype target £20k
- 6. Tensile test facility £300k
- 7. TGA test machine
- 8. Vac furnace for baking out and stress relieving – Run in a large vacuum furnace @ Culham ~ £500/day (capital cost ~ £50,000 ?)
- 9. Oscilloscope - £2240
- 10. DAQ system
- 11. Optical pyrometer
- 12. Digital pyrometer - £3175
- 13. Optical microscope - £5k
- 14. EDM capital costs (running costs only paid for?) Machine cost ~100k +VAT
- 15. Laser fin cutting (prototyping)
- 16. Advanced metrology facilities (3D co-ordinate measuring machine, profilometry, non-contact measuring machine etc) – A number of high value instruments
- 17. Graphtec datalogger - £2500
- 18. ANSYS multiphysics license - £45k purchase list price plus £8.4k pa support
- 19. Residual Gas Analyser – c.£5k

Risks

- **Poor quality vacuum reduces target lifetime due to chemical processes**
  - Erosion of the tungsten rod, supports and spoke material is expected due to oxidation and water vapor-induced corrosion from impurities in the vacuum. It is difficult to predict the erosion rate by these processes at the expected achievable vacuum level of 1×10^{-5} Torr due to uncertainties in the vacuum impurity constituents, uncertainties in the operating temperature as described above, and discrepancies and extrapolations in the data from different sources in the literature.
  - Mitigation strategy is the extensive RAL studies: measuring the effect, testing protective coatings, and exploring He cooling as an alternative.

- **Remote Handling needs redesign and cost increase if we abandon radiatively cooled target**
  - Mitigation strategy is to evaluate our option of above ground remote handling room with crane which has remote handling solution for either radiative or He cooled target.

Remaining work before CD-3

- Complete Proton Beam Absorber and install during civil construction next year
- Complete the HRS assembly and transportation fixture design
- Evaluate the option of an overhead remote handling room with crane coverage added above existing PS hatch
  - Civil bids done with and without underground RH room
  - A first pass of redesign of "robot" into several modules done
  - Detailed discussion with Accelerator Radiation Safety Group started
  - After costs are developed for overhead, planning a review
- Based on completed target R&D, decide on radiation cooled or He cooled target, modifications to RH, minimal if overhead solution is chosen

Quality Assurance

- Every part of the target will be thoroughly prototyped and tested off-line. A complete prototype will then be manufactured. All manufacturing and test methods will be thoroughly documented. The actual target supplied for experimental operation will use the same procedures as were developed for the prototype.

- Target Station sub-systems will be designed and built in accordance with the requirements of the Fermilab Engineering Manual. The design of these systems is monitored by in-progress design review during weekly meetings of the Target Station Group. The in-progress review is followed by a final project review. The design is documented in the requirements and specification documents, CAD model, and drawings. As-built dimensions will be checked against the fabrication drawings. Operation is verified as part of the fabrication process and again after installation.

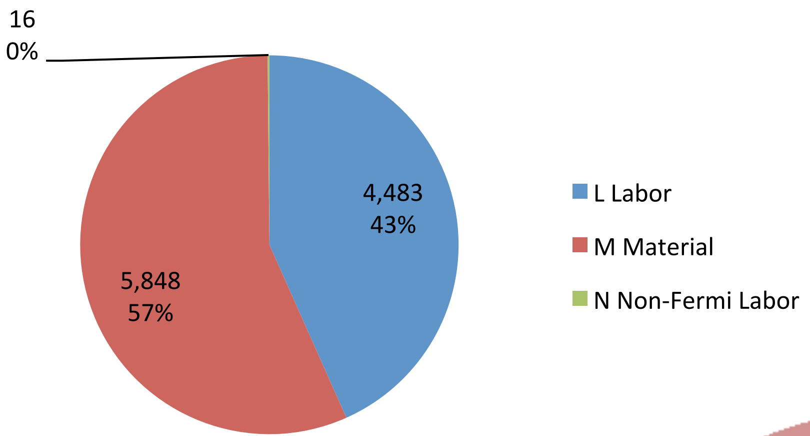
ES&H

- Mu2e Hazard Analysis Document doc-db 675 covers a complete list of topics
- Two members from ES&H group attend weekly Target Station meetings
- Radiation Safety is particularly important for the Target Station, including:
  - Prompt Dose
  - Residual Dose
  - Contamination
  - Air and Ground Water Activation

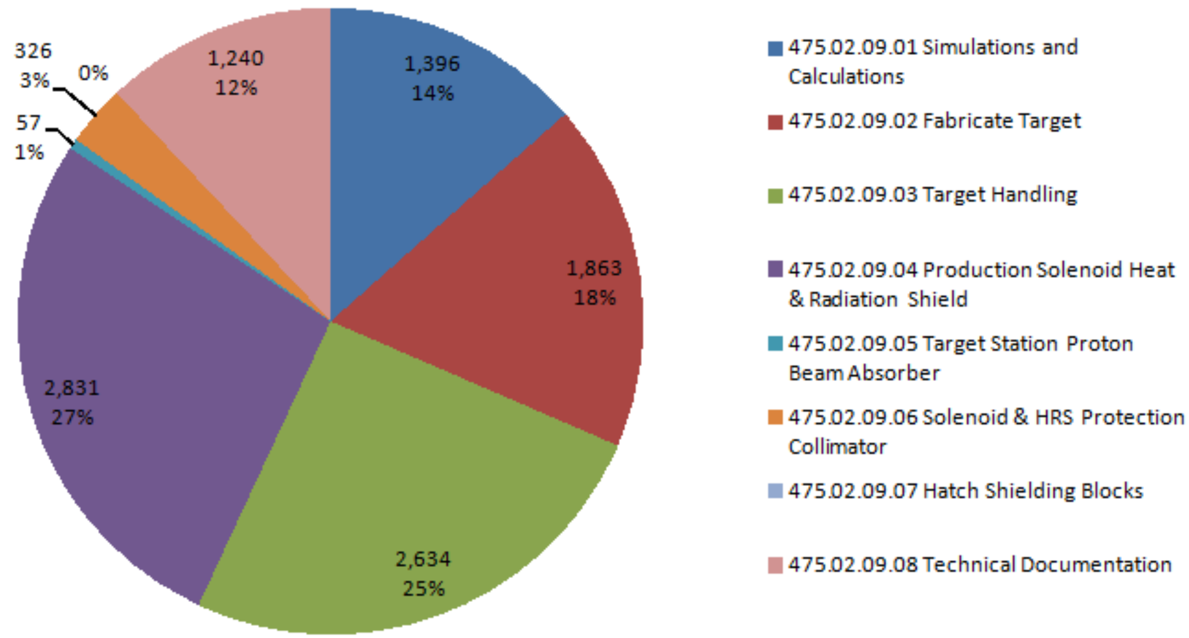
Cost Table

	Base Cost (AY K$)					
	M&S	Labor	Total	Estimate Uncertainty (on remaining budget)	% Contingency on (on remaining budget)	Total Cost
475.02.09.01 Simulations and Calculations	67	1,329	1,396	171	31%	1,567
475.02.09.02 Fabricate Target	1,863		1,863	497	41%	2,360
475.02.09.03 Target Handling	1,177	1,457	2,634	777	33%	3,410
475.02.09.04 Production Solenoid Heat & Radiation Shield	2,632	200	2,831	875	32%	3,706
475.02.09.05 Target Station Proton Beam Absorber		57	57	14	53%	71
475.02.09.06 Solenoid & HRS Protection Collimator	126	201	326	128	42%	454
475.02.09.07 Hatch Shielding Blocks					n/a	
475.02.09.08 Technical Documentation		1,240	1,240	245	22%	1,485
Grand Total	5,863	4,483	10,346	2,706	32%	13,053

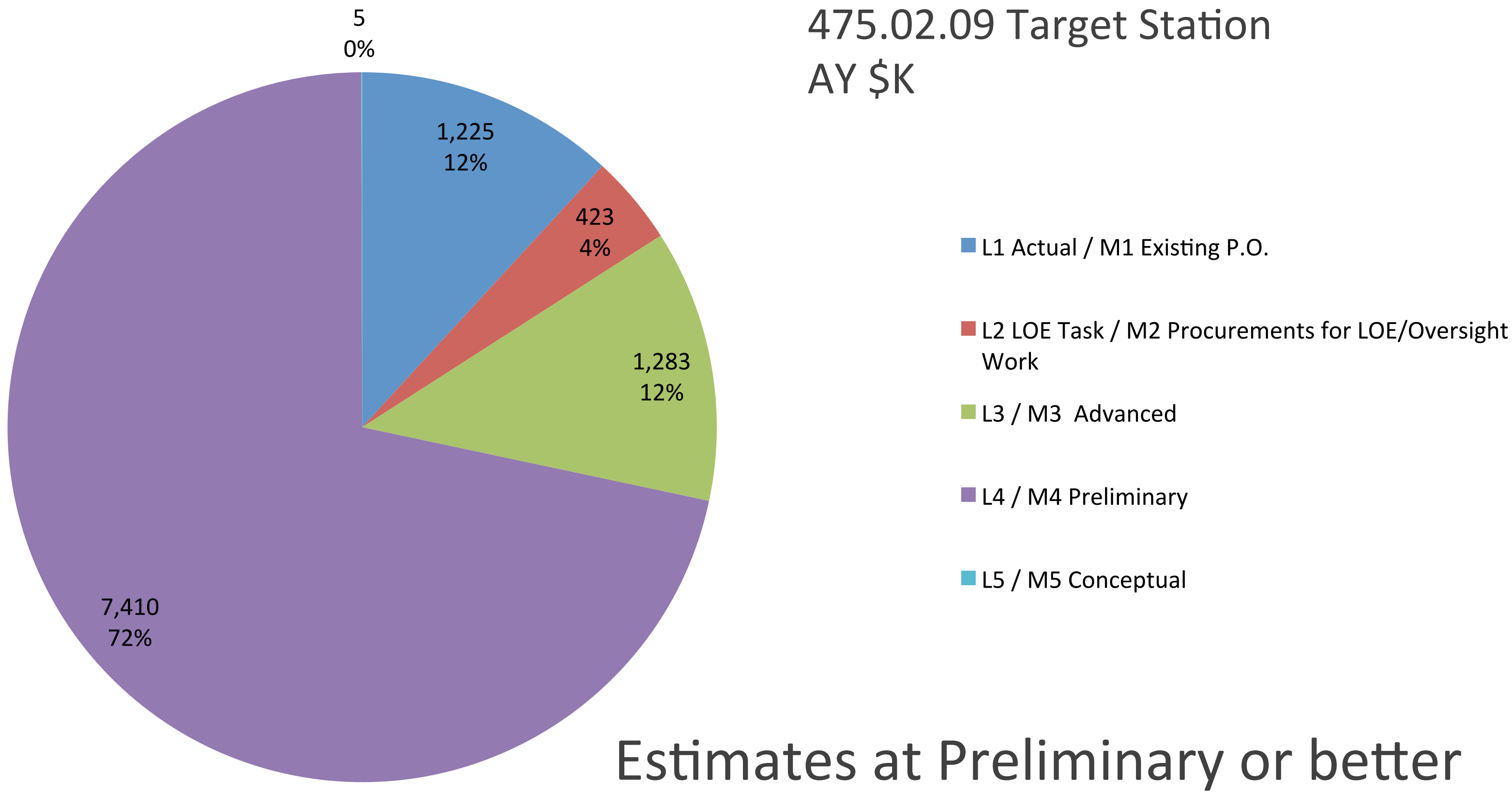
Cost Breakdown



475.02.09 Target Station
WBS Level 4
Base Cost in AY $K



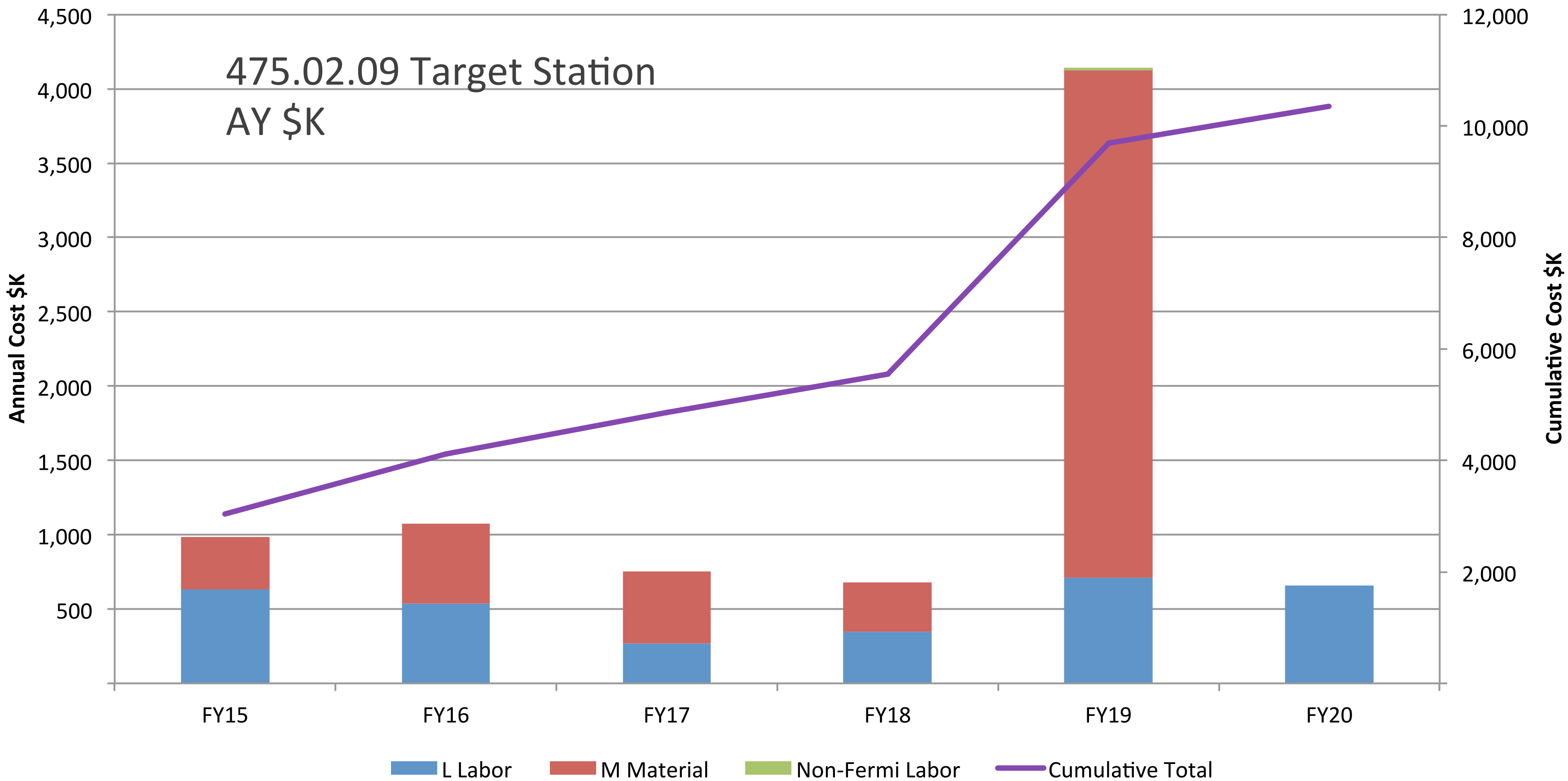
Quality of Estimate



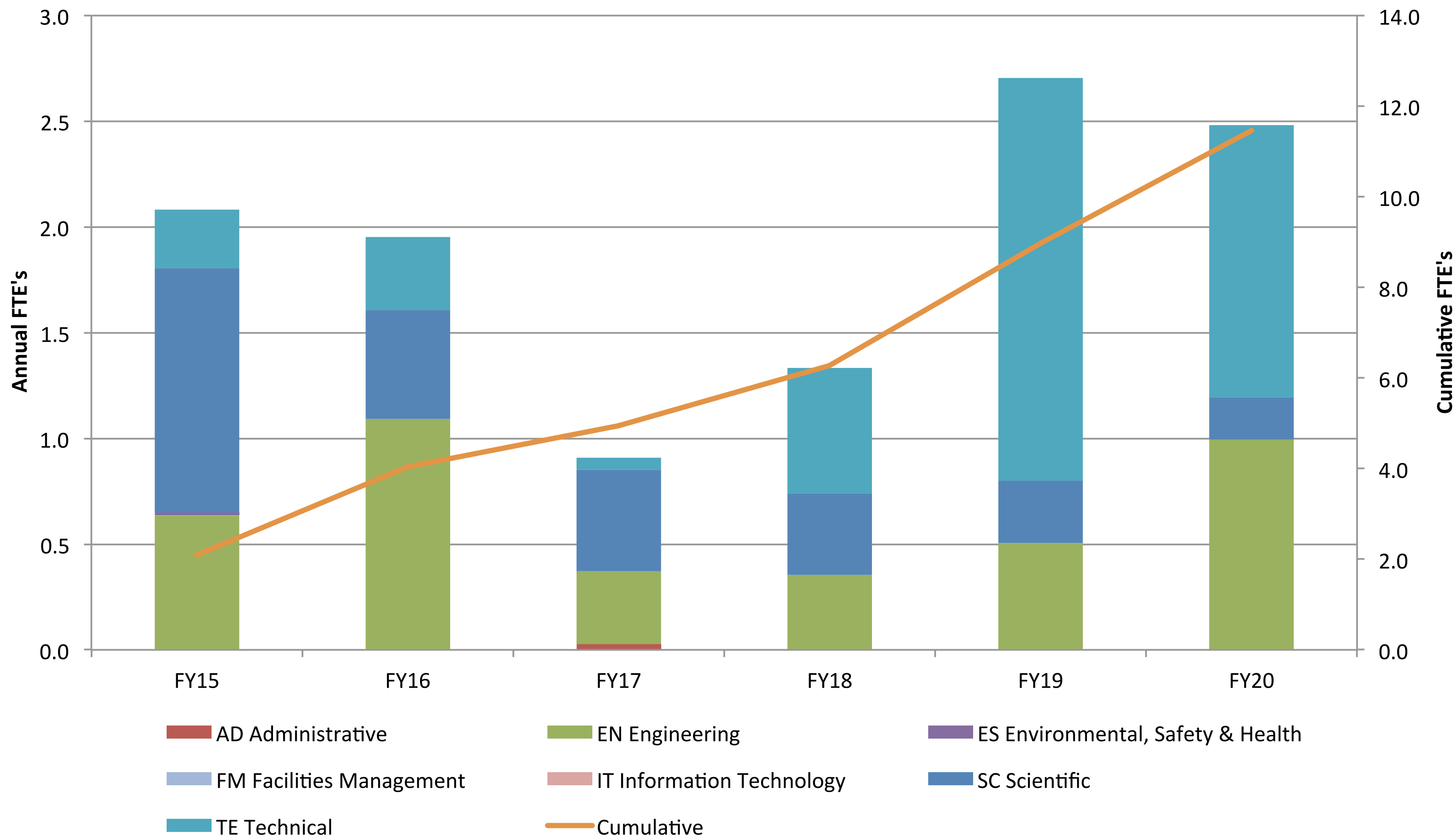
475.02.09 Target Station
AY $K

Estimates at Preliminary or better

Cost Breakdown by FY



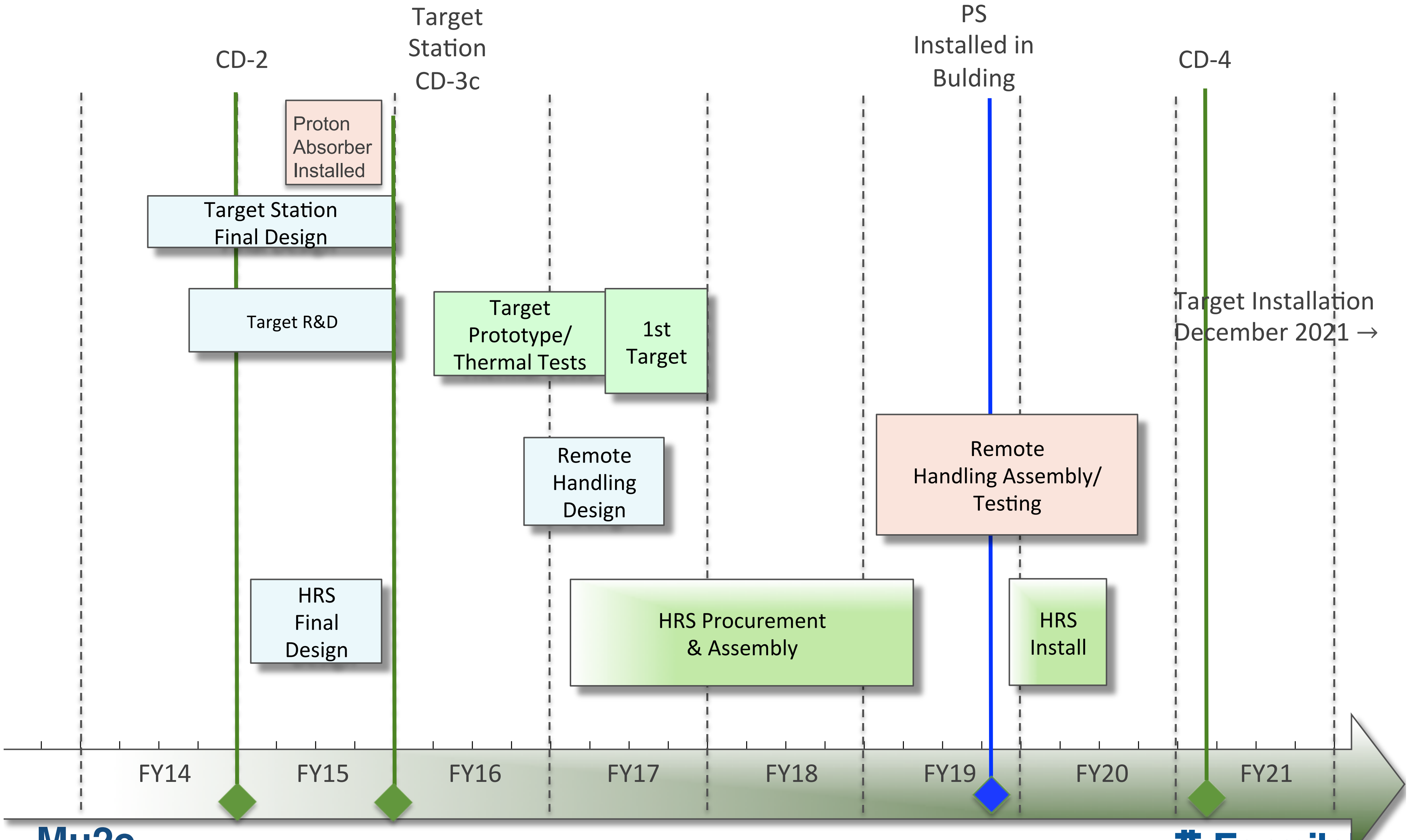
FTE's by Discipline



Milestones

Activity ID	
Accelerator - 9/2	10/Sep/2020 05:00 PM, Accelerator - 9/24/14 Baselir
Target Station	10/Sep/2020 05:00 PM, Target Station
47502.09.001000	
47502.09.001010	T5 - Target Station Preliminary Design Complete
47502.09.001020	T5 - Mu2e Target Station- Proton Beam Absorber Installation and Close-out Complete
47502.09.001030	T4 - Target Station Final Design Complete
47502.09.001040	T5 - DOE CD-3c Accelerator Target Station/HRS Approval
47502.09.001050	T5 - Mu2e Heat & Radiation Shield Installation Complete
47502.09.001051	T4 - Mu2e Heat & Radiation Shield Installation Complete
47502.09.001052	T3 - Mu2e Heat & Radiation Shield Installation Complete
47502.09.001053	T2 - Mu2e Heat & Radiation Shield Installation Complete
47502.09.001054	T1 - Mu2e Heat & Radiation Shield Installation Comp
47502.09.001060	T5 - Mu2e Production Target Station Systems Installation
47502.09.001070	T4 - Target Station Complete
Simulations and Calc	18/Mar/2020 05:00 PM, Simulations and Calculations
47502.09.01.001045	T5 - Target Station Final Design Simulations & Calculations Complete
47502.09.01.001200	T5 - Target Station Simulations and Calculations Complete
Fabricate Target	12/Oct/2018 05:00 PM, Fabricate Target
47502.09.02.001250	T5 - Decision on radiation cooled target feasibility and spec. coating / surface
47502.09.02.001255	T5 - Proton Target Final Design Complete
47502.09.02.001307	T5 - Proton Target Delivered to Fermilab
47502.09.02.001308	T4 - Proton Target Delivered to Fermilab
47502.09.02.001309	T3 - Proton Target Delivered to Fermilab
47502.09.02.001310	T2 - Proton Target Delivered to Fermilab
47502.09.02.001311	T1 - Proton Target Delivered to Fermilab
Target Handling	16/Jul/2020 05:00 PM, Target Handling
47502.09.03.001059	T5 - Final Decision on Target Remote Handling Configuration
47502.09.03.001150	T5 - Target Handling Final Design Complete
47502.09.03.001155	T5 - Start Target Handling Procurements
47502.09.03.001215	T5 - Start Fabrication of Target Handling System Parts
47502.09.03.001245	T5 - Start Assembly of Target Handling System
47502.09.03.001500	T5 - Target Handling Installation Complete
Production Solenoid	10/Sep/2019 05:00 PM, Production Solenoid Heat & Radiation Shield
47502.09.04.001146	T5 - PS Heat and Radiation Shield Design Complete
47502.09.04.001147	T5 - Start of HRS Procurement
47502.09.04.001160	T5 - Advanced procurement plan for HRS Complete
47502.09.04.001190	T5 - Readiness review for HRS complete
47502.09.04.001230	T5 - Vendor for HRS selected
47502.09.04.001260	T5 - PO issued for HRS
47502.09.04.001375	T5 - Heat and Radiation Shield Ready for Installation
47502.09.04.001395	T5 - Heat and Radiation Shield Installation Complete
Target Station Protor	21/Jan/2015 05:00 PM, Target Station Proton Beam Absorber
47502.09.05.001040	T5 - MARS Energy deposition for accident case
47502.09.05.001212	T5 - Target Proton Beam Absorber Design Complete
Solenoid & HRS Prot	27/Jun/2018 05:00 PM, Solenoid & HRS Protection Collimator
47502.09.06.001140	T5 - Protection Collimator Design Complete
47502.09.06.001145	T5 - Protection Collimator Procurement Start
47502.09.06.001265	T5 - Protection Collimator Fabrication Start
47502.09.06.001500	T5 - HRS Protection Collimator Fabrication Complete

Schedule



CD-2
Target Station CD-3c
PS Installed in Bulding
CD-4
Proton Absorber Installed
Target Station Final Design
Target R&D
Target Prototype/ Thermal Tests
1st Target
Target Installation December 2021 →
Remote Handling Design
Remote Handling Assembly/ Testing
HRS Final Design
HRS Procurement & Assembly
HRS Install
FY14
FY15
FY16
FY17
FY18
FY19
FY20
FY21

Summary

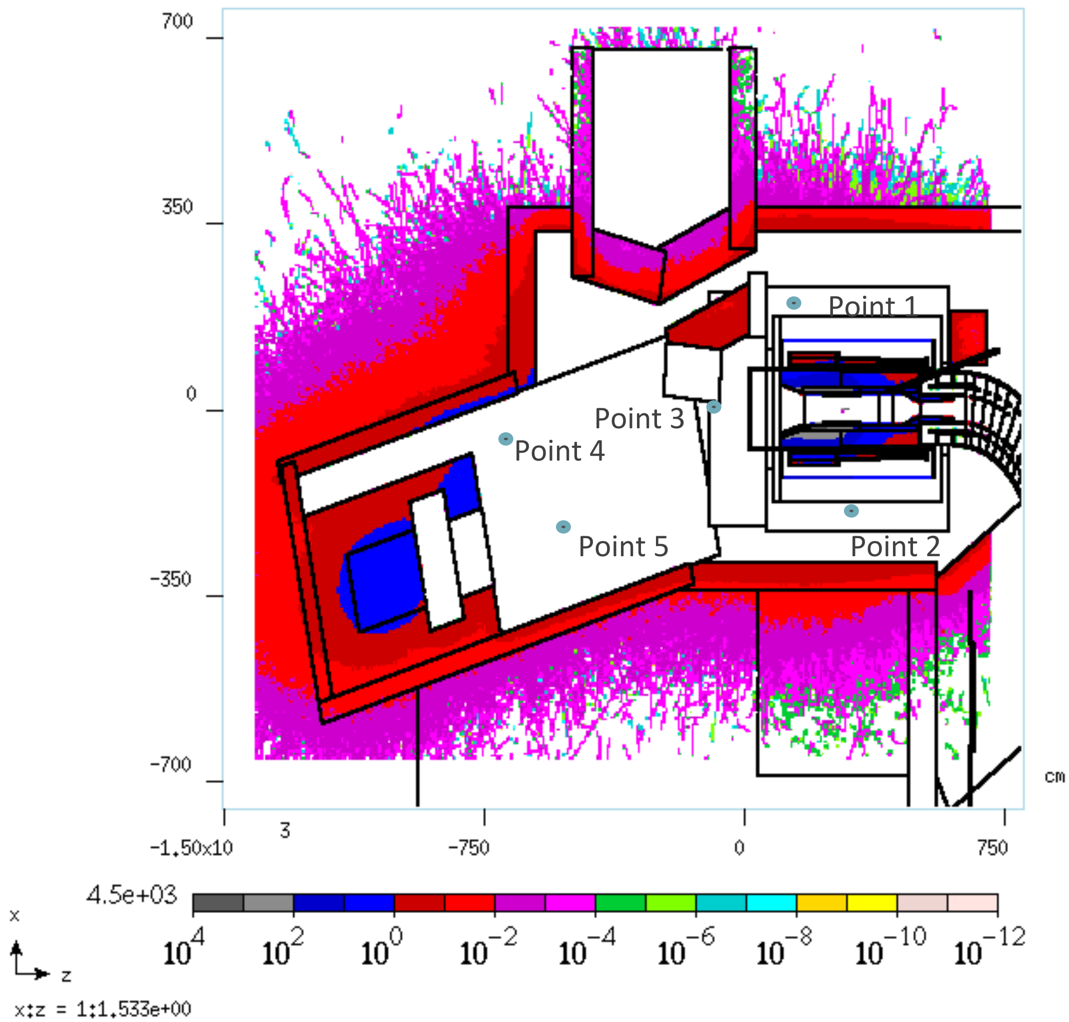
- The Target Station Design is well integrated with the Solenoids, Muon Beam line, Civil Construction, and Radiation Safety
- A preliminary design is complete
- A review and choice is needed on the remote handling scheme
- R & D is well underway to decide on target choice- radiative or convection cooled
- We are ready to baseline our schedule

Backup Slides

Milestones

475.02BL-5.09 Target Station				
47502.09.001000	T5 - Target Station Conceptual Design Complete		28-Jun-12 A	T5
47502.09.001010	T5 - Target Station Preliminary Design Complete		30-Apr-14 A	T5
47502.09.05.001040	T5 - MARS Energy deposition for accident case	02-Jun-14*		T5
47502.09.05.001212	T5 - Target Proton Beam Absorber Design Complete		25-Aug-14	T5
47502.09.06.001140	T5 - Protection Collimator Design Complete		5-Nov-14	T5
47502.09.03.001059	T5 - Final Decision on Target Remote Handling Configuration		9-Dec-14	T5
47502.09.02.001250	T5 - Decision on radiation cooled target feasibility and spec. coating / surface		2-Jan-15	T5
47502.09.001020	T5 - Mu2e Target Station- Proton Beam Absorber Installation and Close-out Complete		15-Apr-15	T5
47502.09.001030	T4 - Target Station Final Design Complete		20-Aug-15	T4
47502.09.04.001146	T5 - PS Heat and Radiation Shield Design Complete		20-Aug-15	T5
47502.09.01.001045	T5 - Target Station Final Design Simulations & Calculations Complete		20-Aug-15	T5
47502.09.001040	T5 - DOE CD-3c Accelerator Target Station/HRS Approval	24-Feb-16		T5
47502.09.04.001147	T5 - Start of HRS Procurement	3-Oct-16		T5
47502.09.04.001160	T5 - Advanced procurement plan for HRS Complete		4-Oct-16	T5
47502.09.04.001190	T5 - Readiness review for HRS complete		26-Oct-16	T5
47502.09.04.001230	T5 - Vendor for HRS selected		27-Jan-17	T5
47502.09.03.001150	T5 - Target Handling Final Design Complete		31-Jan-17	T5
47502.09.02.001255	T5 - Proton Target Final Design Complete		21-Apr-17	T5
47502.09.06.001145	T5 - Protection Collimator Procurement Start	2-Oct-17		T5
47502.09.02.001307	T5 - Proton Target Delivered to Fermilab		13-Oct-17	T5
47502.09.06.001265	T5 - Protection Collimator Fabrication Start	14-Nov-17		T5
47502.09.04.001260	T5 - PO issued for HRS		1-Dec-17	T5
47502.09.06.001500	T5 - HRS Protection Collimator Fabrication Complete		27-Jun-18	T5
47502.09.03.001155	T5 - Start Target Handling Procurements	1-Oct-18		T5
47502.09.03.001215	T5 - Start Fabrication of Target Handling System Parts	1-Oct-18		T5
47502.09.03.001245	T5 - Start Assembly of Target Handling System	13-Feb-19		T5
47502.09.04.001375	T5 - Heat and Radiation Shield Ready for Installation	21-Feb-19		T5
47502.09.001050	T5 - Mu2e Heat & Radiation Shield Installation Complete		10-Sep-19	T5
47502.09.04.001395	T5 - Heat and Radiation Shield Installation Complete		10-Sep-19	T5
47502.09.001051	T4 - Mu2e Heat & Radiation Shield Installation Complete		11-Nov-19*	T4
47502.09.001052	T3 - Mu2e Heat & Radiation Shield Installation Complete		11-Dec-19*	T3
47502.09.01.001200	T5 - Target Station Simulations and Calculations Complete		18-Feb-20	T5
47502.09.001070	T4 - Target Station Complete		16-Jul-20	T4
47502.09.001060	T5 - Mu2e Production Target Station Systems Installation and Close-out Complete		16-Jul-20	T5
47502.09.03.001500	T5 - Target Handling Installation Complete		16-Jul-20	T5

Residual Dose PS Hall-

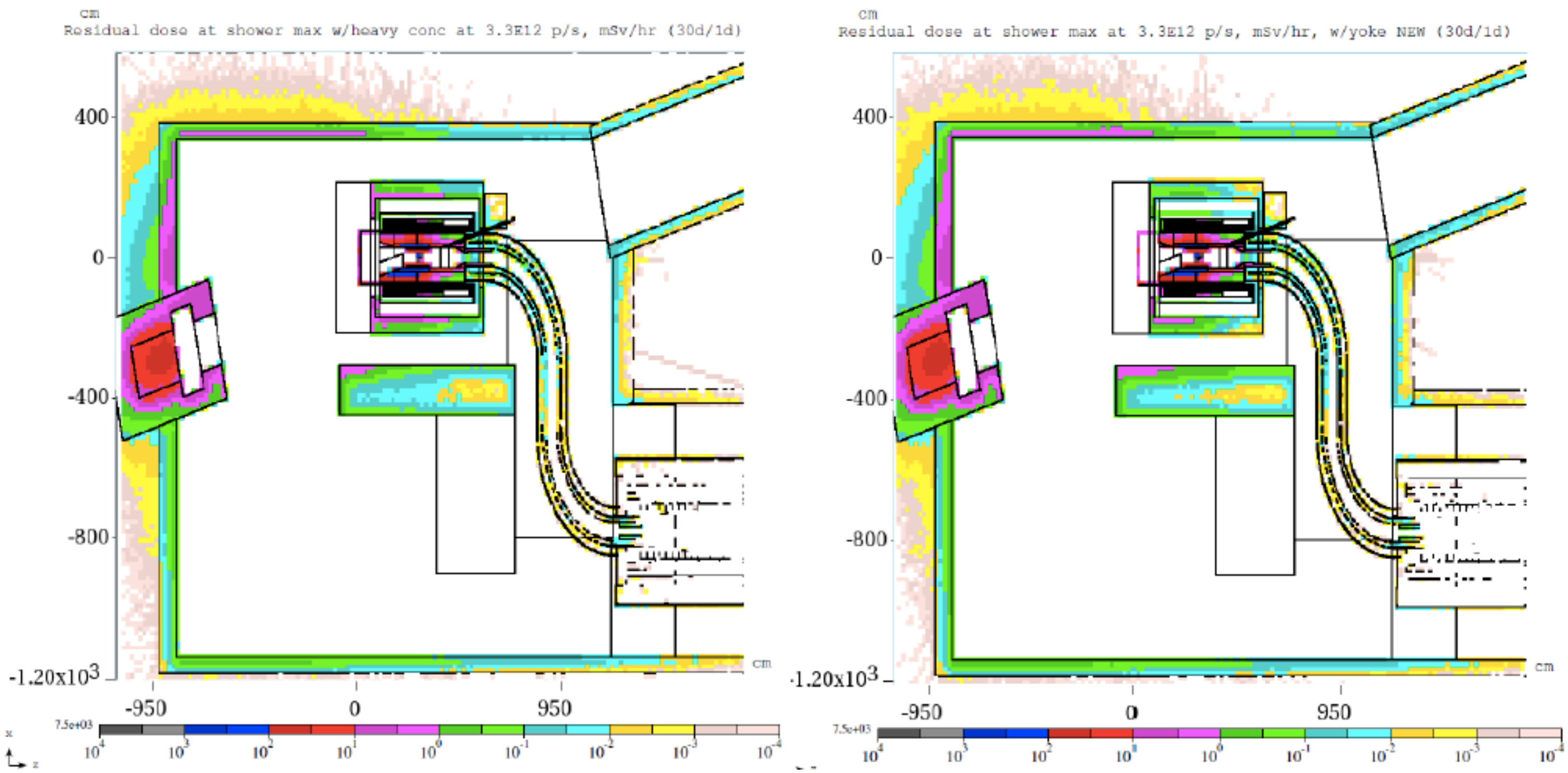


30 Days Irr, 1 Day Cool	(mrem/hr)
Point 1	596
Point 2	1087
Point 3	32816
Point 4	2269
Point 5	2473
30 Days Irr, 7 Day Cool	
Point 1	55
Point 2	101
Point 3	3035
Point 4	210
Point 5	229
365 Days Irr, 1 Day Cool	
Point 1	692
Point 2	1261
Point 3	38066
Point 4	2631
Point 5	2868
365 Days Irr, 7 Day Cool	
Point 1	147
Point 2	269
Point 3	8105
Point 4	560
Point 5	611

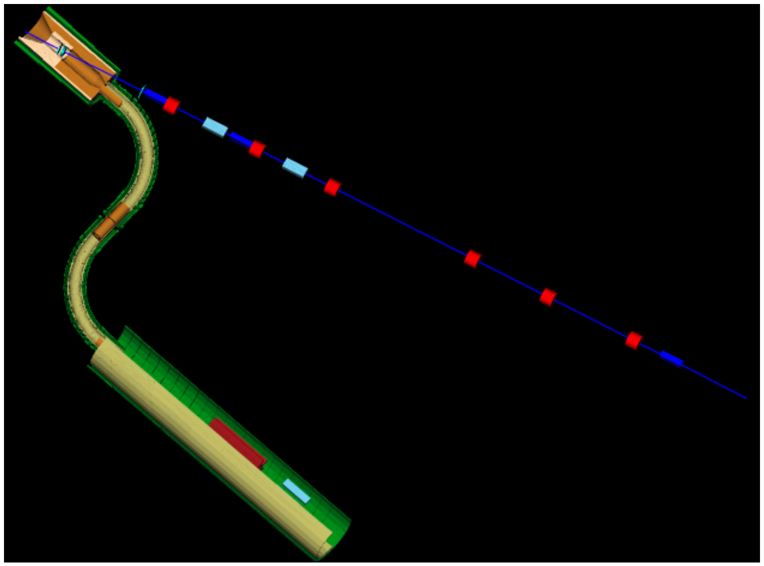
N. Duff, doc db 2717

Target Hall Radiation Levels

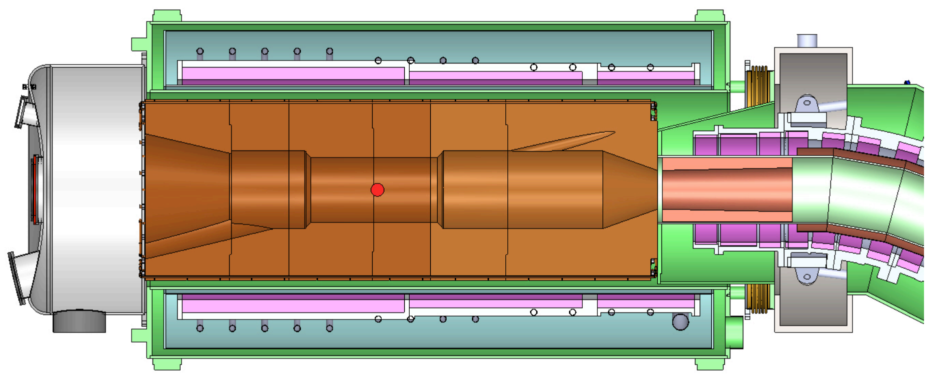
Residual dose w/concrete and w/ iron, mSv/hr

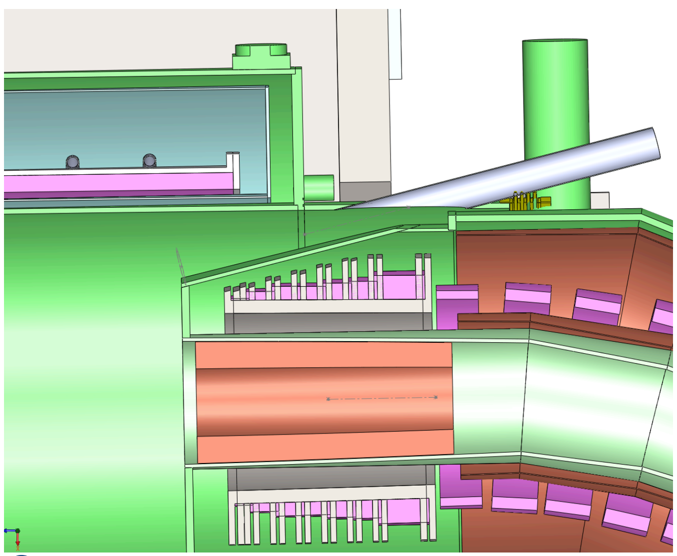


Proton Beam Through Solenoids



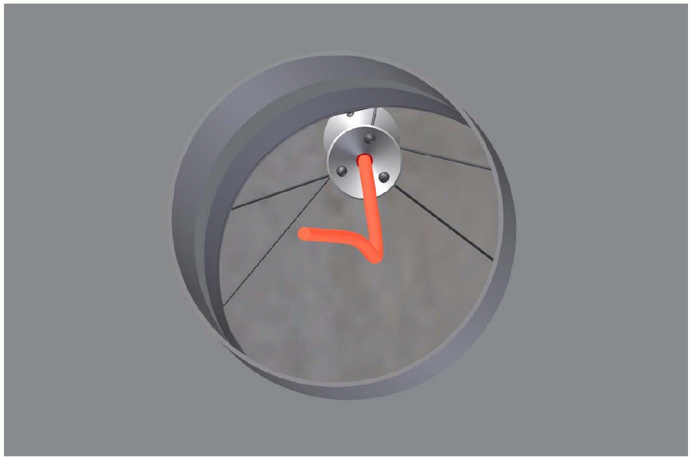
T. Page



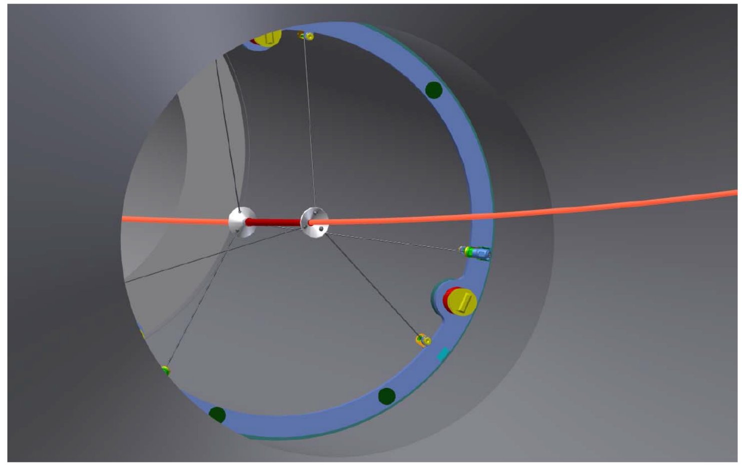


Proton Trajectory in Engineering Model

This view looks proton downstream through the holes in the TS and HRS

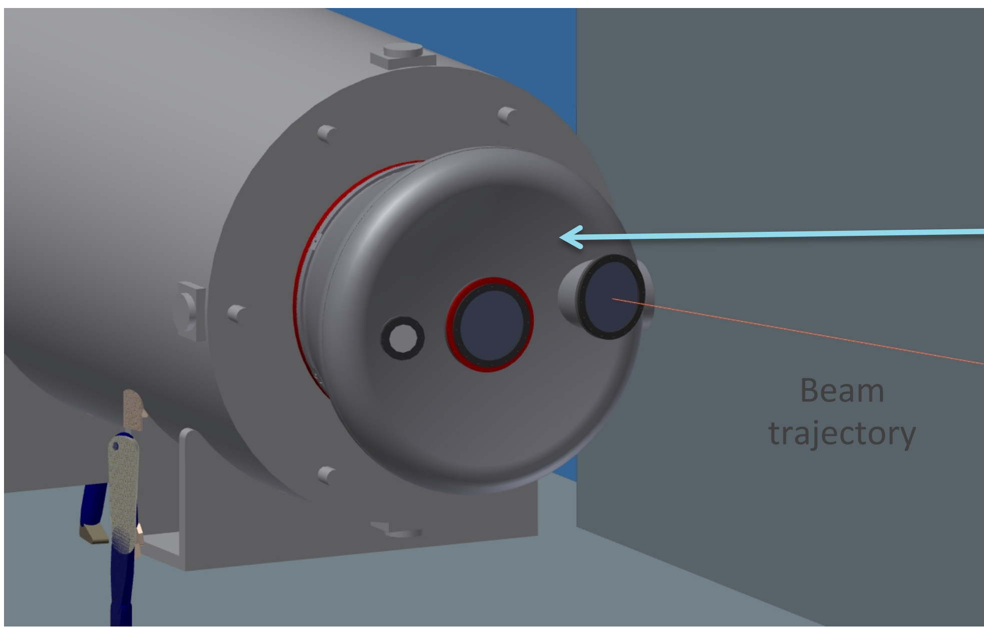


This view shows the proton beam exiting the target



L. Bartoszek
Check of Trajectory

Other checks by:
A. Stefanik
T. Page
J. Brandt



PS endcap

Target Alignment/Tolerances Summary

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°

Alignment Details

The alignment strategy to accomplish these requirements is:

- The target/supports/mounting must be quite stable and reproducible during target change relative to the PS. The tolerance on the manufactured target rod dimensions should be: length = +/- 2 mm and radius= +/- 0.1 mm. The target position relative to the PS must be stable to about ±0.25 mm during operation, taking into account distortions due to thermal cycling from ambient conditions when the beam is turned on. The target support structure and remote handling system must allow replacement targets to be placed within about ±0.25 mm of the first.

- The relative alignment of the target with respect to the PS axis is not as critical as the target-beam alignment. The muon yield is very insensitive to transverse [5] or motion along the z axis up to several cm. There is a potential background for ~100 MeV electrons, if the target source is more than 2 cm below the nominal elevation [6]. The relative alignment of the target to the PS axis should be +/- 5 mm transversely and +/- 1 cm along the PS axis.

- The PS axis must be aligned transversely to the proton beam to within: +/- 5 mm in position and +/- 0.2 degrees in angle. The angular requirement is set by the narrow channel available to the proton beam to pass through the transport solenoid entrance beam pipe which is 4.75" inner diameter about 3 m upstream of the target. Given the target z location, this pipe sets an angular acceptance of +/- 1 degree. The muon yield is much less sensitive to the angle [7].

The proton beamline has the ability to adjust the transverse position +/-1 cm and +/- 0.8 degrees at the target. If the alignment moves outside the range allowed by the beamline adjustment then the beam-PS alignment must be corrected.

Proton Beam Absorber Design