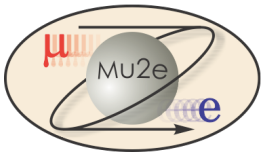
Fermilab

Mu2e CD-2 Review
8.4 Fibers

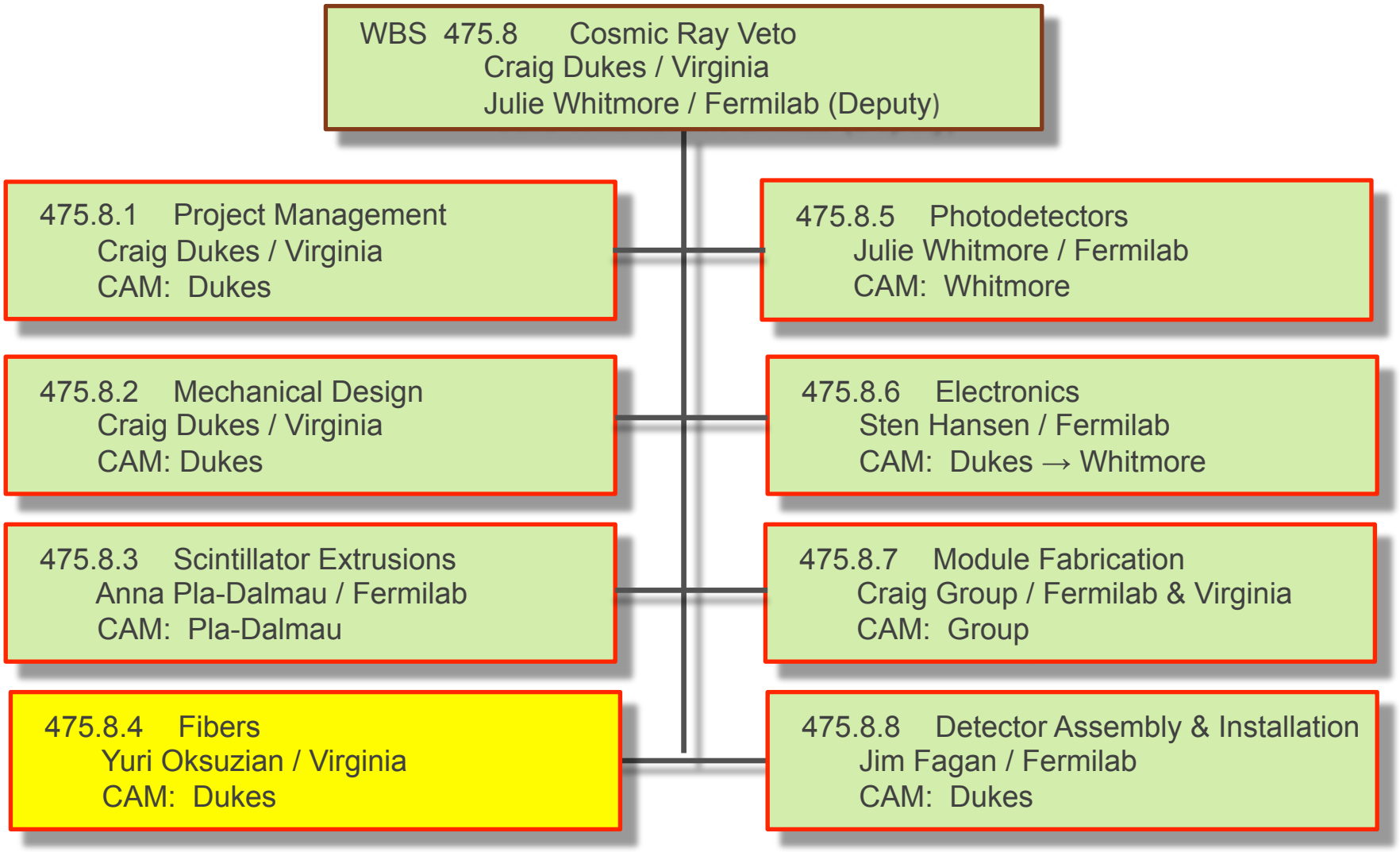


Yuri Oksuzian
Level 3 Manager
10/21/2014

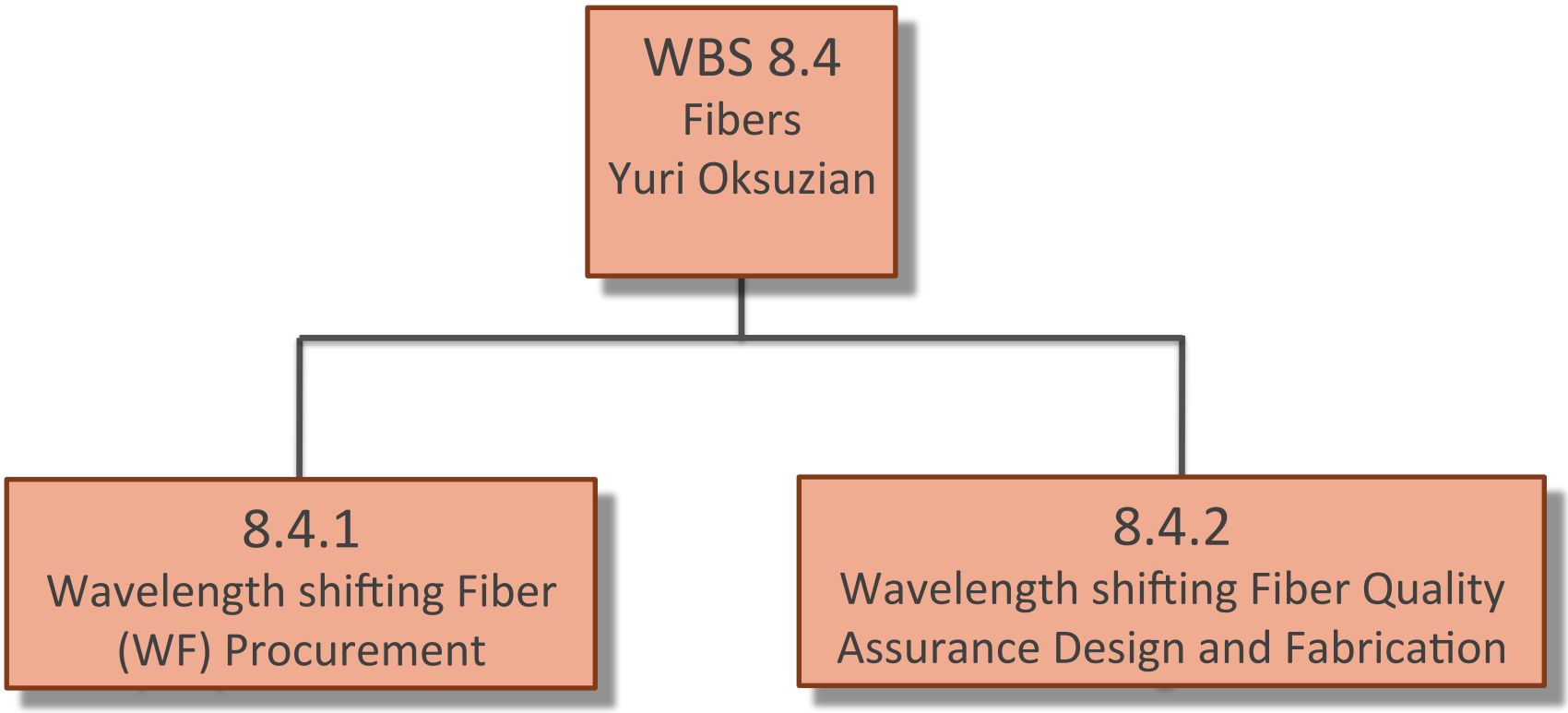
CRV Fiber team

- Yuri Oksuzian – L3 Manager
  - Research scientist at UVA
  - Ph.D. in 2010 – University of Florida on CDF
  - Member of NOvA experiment
  - Involved in CRV R&D since 2010
  - Light yield measurements with CRV prototypes
  - CRV dead-time estimates from the radiation sources
  - Radiation damage doses estimates for SiPM and plastic components
- Craig Dukes – CAM
- Dean Shooltz
  - Ph.D. in 2006 - Michigan State University
  - Experience with fibers on NOvA experiment

Organizational Breakdown



Organizational Breakdown



WBS Dictionary for 8.4

- **475.08.04.01 Wavelength shifting Fiber (WF) Procurement:** This task covers the specification, selection, procurement, and testing of wavelength shifting fibers for the prototypes and production counters.

- **475.08.04.02 Wavelength shifting Fiber Quality Assurance Design and Fabrication:** The purpose of this task is to develop the quality control testing procedures, and to design and fabricate the equipment for testing the wavelength shifting fiber.

Requirements

- Wavelength shifting (WLS) fiber collects the light from scintillator and transports the light to the photo-multiplier
- High performance and quality control

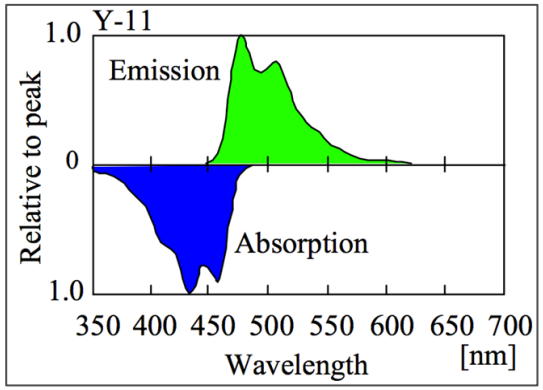
- Absorbs the blue light from scintillator and re-emits in green region

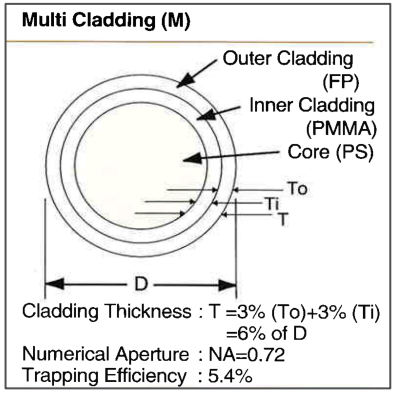
- Sufficient light yield, high trapping efficiency and long attenuation length

- Ionizing radiation damage levels have to be lower than 1kGy

Design

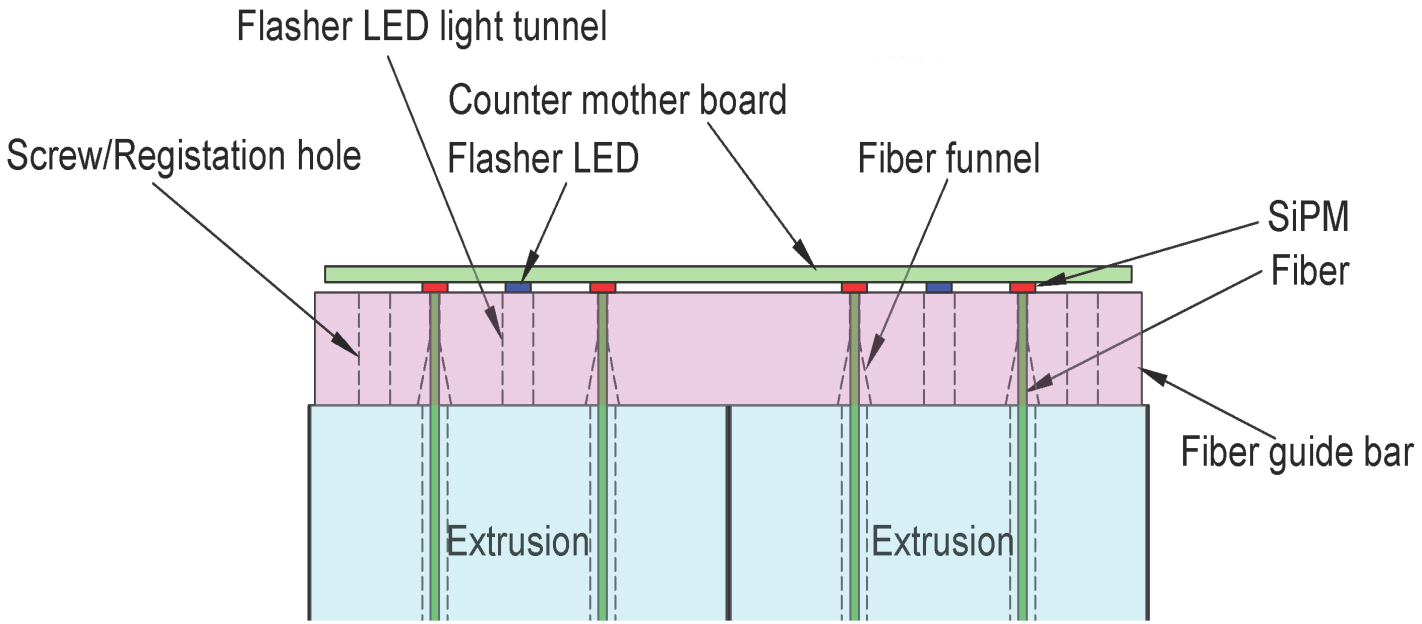
- Wavelength shifting (WLS) fiber collects the light from scintillator and transports the light to the photo-multiplier
- High performance and quality control
  - **Kuraray**
- Absorbs the blue light from scintillator and re-emits in green region
  - **Y11**
- Sufficient light yield, high trapping efficiency and long attenuation length
  - **1.4 mmD, non-S, multi-clad fiber with 175 ppm fluorescent compound**
- Ionizing radiation damage levels have to be lower than 1kGy
  - **The radiation levels are lower than 10 Gy**





Design

- The fiber is glued to the fiber guide bar and loose along the counter
- The fiber guide bar is fly cut
- The total amount of WLS fiber needed:
  - 760 (320) m of 1.4 (1.8) mmD fiber for prototypes
  - 1,600 m for 2 medium sized pre-production modules
  - 63,000 m for production modules, including wastage



Changes since CD-1

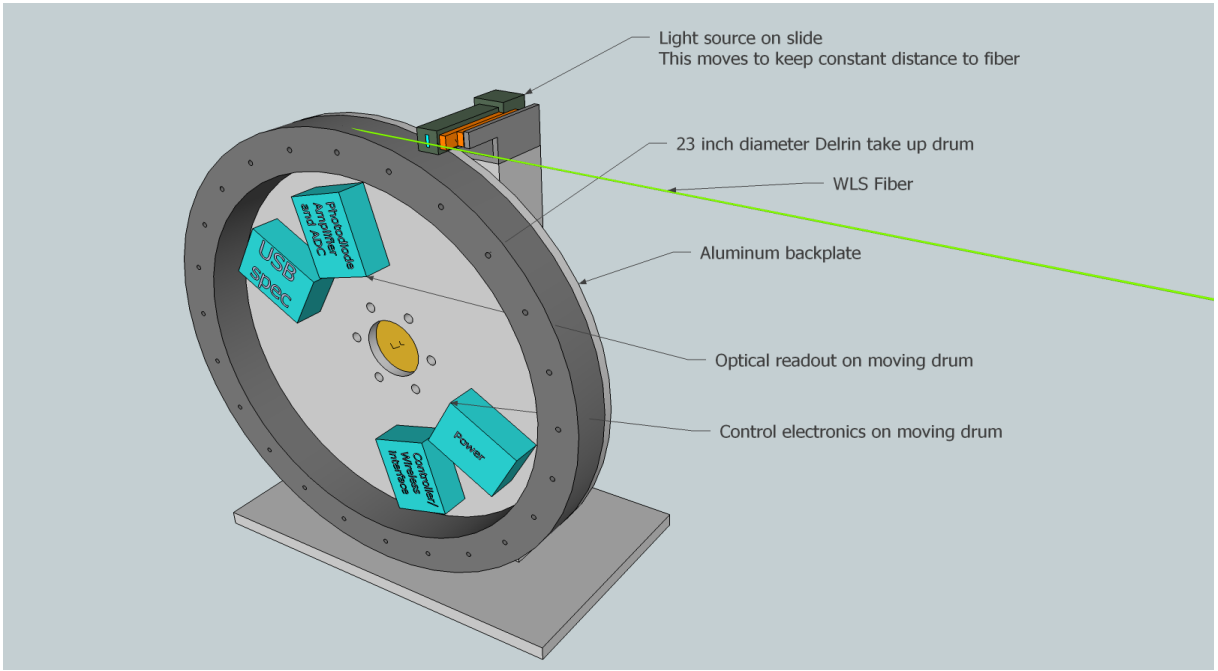
- The baseline fiber thickness was 1.0 mmD at CD-1
- The latest test beam results with di-counter prototypes suggest we need 1.4 mmD fiber to reach required light yield
- The QA test jig design has been modified to accommodate thicker fiber

Remaining work before CD-3

- Produce fiber QA test jig
  - Evaluate the prototype fiber
- Select the fiber size, using the measurement with prototypes
  - Part of “Mechanical Design”

Quality Assurance

- Former MSU technician has designed the fiber test jig
- Extract up to 25 meters of fiber from a factory supply spool
- Stimulate the fiber with a blue LED light source during the extraction
- Measure light output by two different readout devices:
  - Spectrophotometer (spectral attenuation)
  - Large-area photodiode (absolute scale and attenuation)



Risks

- Light yield is not sufficient
  - Increase the diameter of the fiber
- Kuraray goes off the market
  - Switch to Saint-Gobain fiber
- Opportunity
  - Higher than expected light yield (example: better SiPM)

Risks

Risk ID	Docdb #	Type	Title	Date	Probability	Point Estimate (cost k$)	Point Estimate (prob)	Expectation Value (cost k$)
VETO-122	3402	Threat	Need to use inferior fibers	FY15-FY20	Low	$50	20%	$10
VETO-159	4260	Threat	Photoelectron yield does not meet requirements	FY15	Low	$150	20%	$30
VETO-162	4250	Opportunity	Photoelectron yield exceeds requirements	FY15	Medium	$(100)	50%	$(50)

- Light yield is not sufficient
  - Increase the diameter of the fiber
- Kuraray goes off the market
  - Switch to Saint-Gobain fiber
- Opportunity
  - Higher than expected light yield (example: better SiPM)

Cost Table: CRV

	Base Cost (AY K$)					
	M&S	Labor	Total	Uncertainty (on remaining budget)	% Contingency (on remaining budget)	Total Cost
475.8.1 Project Management	267	178	445	75	21%	520
475.8.2 Mechanical Design	135	3	138	24	38%	162
475.8.3 Scintillator extrusions	567	462	1,029	209	25%	1,238
475.8.4 Fibers	**462**		**462**	**106**	**24%**	**568**
475.8.5 Photodetectors (SiPMs)	464	305	769	190	41%	959
475.8.6 Electronics	1,314	407	1,720	511	33%	2,231
475.8.7 Module Fabrication	1,482	8	1,490	466	35%	1,956
475.8.8 Detector assembly and installation	127	81	208	64	35%	273
475.8.9 Conceptual Design/R&D	258	252	511		0%	511
475.8.99 Risk Based Contingency				318	-	318
Grand Total	5,077	1,696	6,773	1,963	38%	8,735

Note: Labor Fermilab only;
Univ. labor captured in M&S.

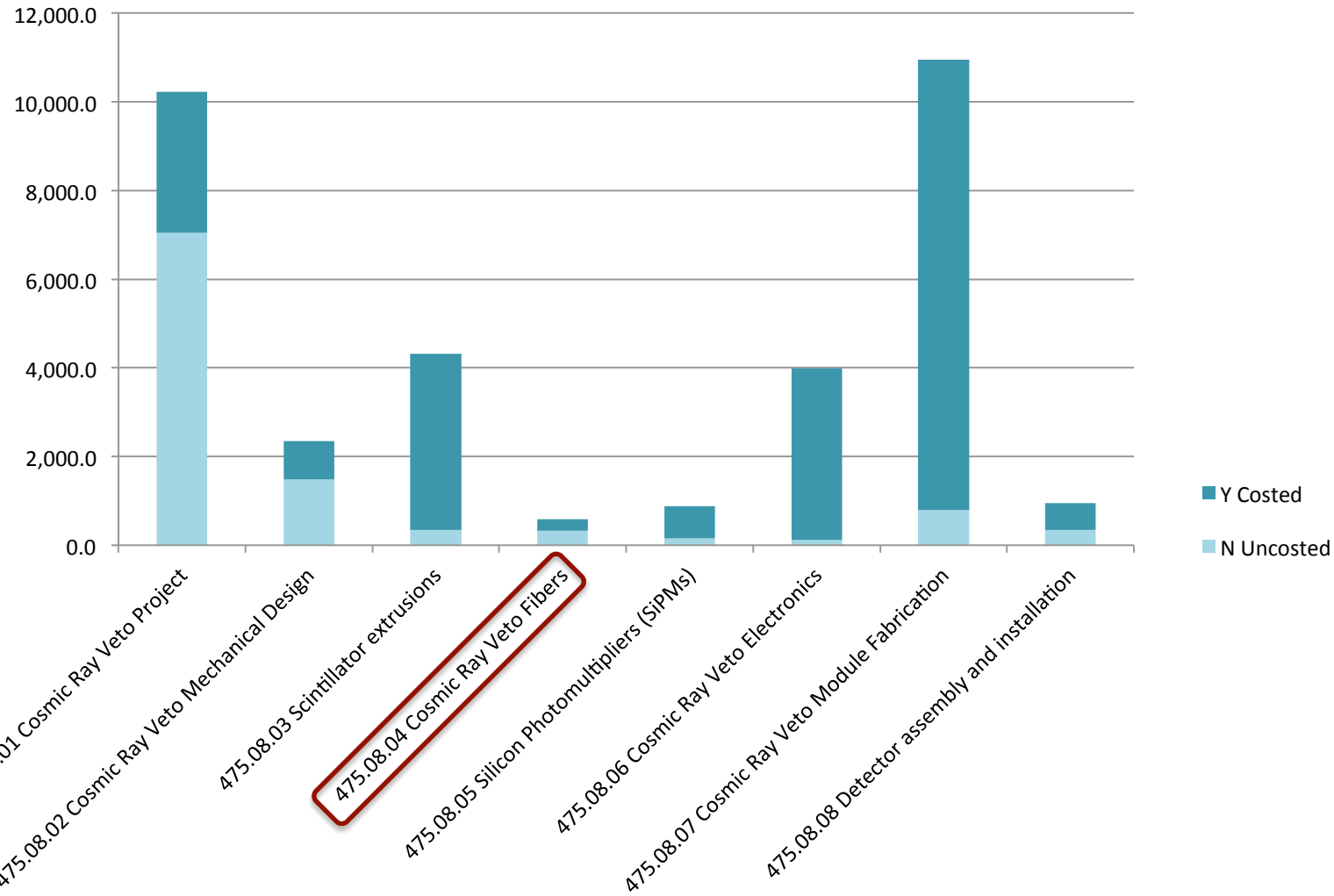
Costs are fully burdened in AY $k
Includes actuals

Cost Table: CRV

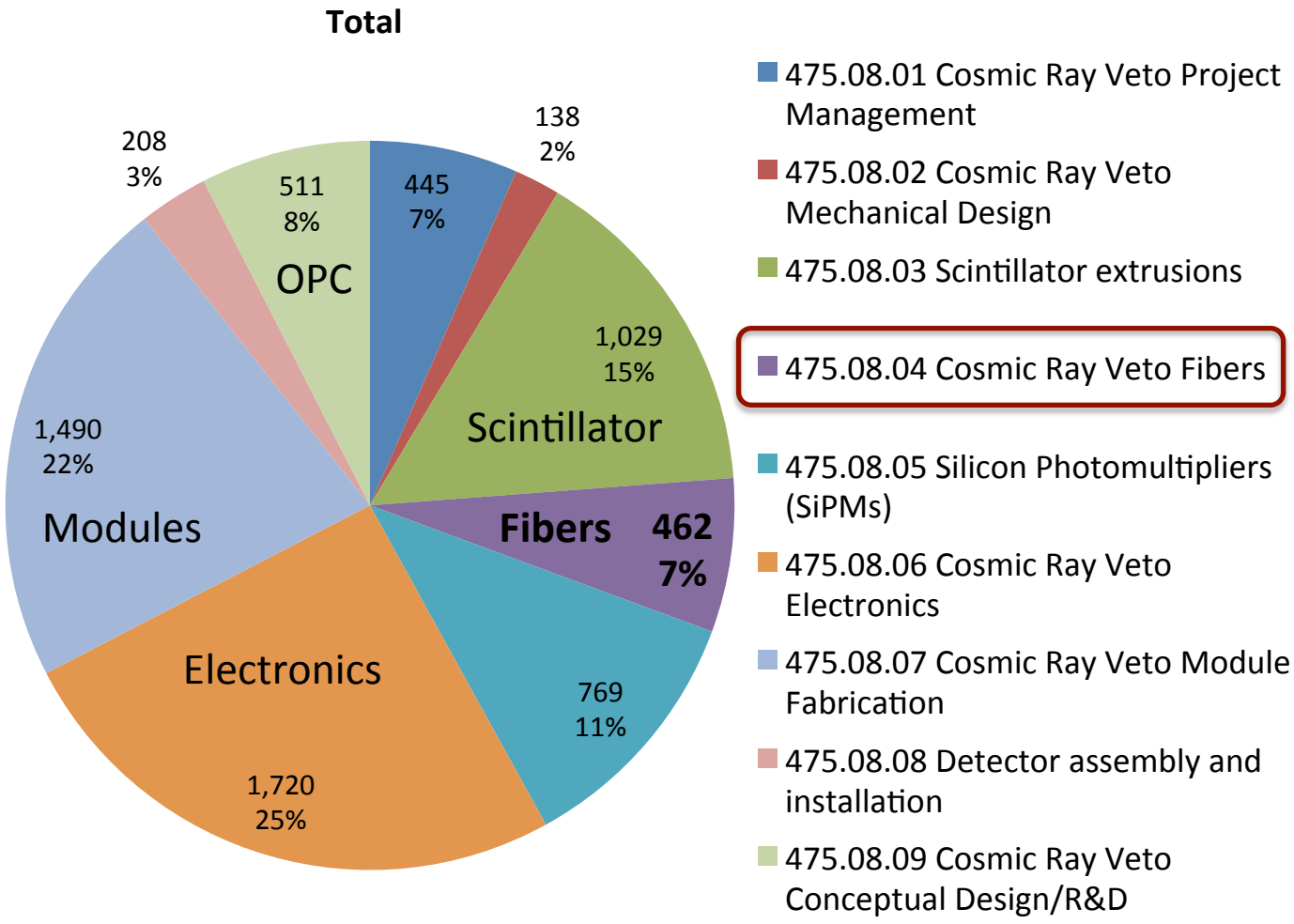
Mu2e Cost Book	October 10, 2014	CD-2/3b DoE Review					
WBS	Direct Labor Hours	Direct Non-Fermi Hours	Direct M&S	B A C	Estimate Uncertainty	Total	Contingency on remaining budget
475.08 Cosmic Ray Veto	20,394	24,189	3,846,811	6,772,668	1,962,633	8,735,302	38%
475.08.01 Cosmic Ray Veto Project Management	4,785	6,103	138,842	445,056	74,716	519,773	21%
475.08.01.02 Preliminary & Final Design (Post CD-1; PED)	1,548	1,765	91,960	181,062	21,918	202,979	25%
475.08.01.03 Implementation & Close-out (Post CD-3; Line Item)	3,237	4,337	46,882	263,995	52,799	316,794	20%
475.08.02 Cosmic Ray Veto Mechanical Design	31	2,760	106,532	137,940	24,112	162,052	38%
475.08.02.01 Detector Design		640	60,110	64,761	9,261	74,023	54%
475.08.02.02 Fabricate and test Counter Prototypes	27	1,540	28,653	55,036	14,851	69,887	32%
475.08.02.03 Cosmic Ray Veto Simulations	4	580	17,769	18,143		18,143	-
475.08.03 Scintillator extrusions	5,948	32	449,229	1,028,891	209,322	1,238,213	25%
475.08.03.01 Die design and procurement	1,388	32	125,057	234,195	36,982	271,177	36%
475.08.03.02 Scintillator extrusion production	4,561		324,172	794,695	172,341	967,036	24%
475.08.04 Cosmic Ray Veto Fibers		616	430,223	462,325	105,992	568,318	24%
475.08.04.01 Waveshifting fiber (WF) procurement		596	416,273	447,881	104,548	552,428	24%
475.08.04.02 WF quality Assurance design and fabrication		20	13,950	14,445	1,444	15,889	11%
475.08.05 Silicon Photomultipliers (SiPMs)	2,631	332	406,763	769,193	189,941	959,134	41%
475.08.05.01 Silicon Photomultipliers (SiPMs) procurement	312	212	374,341	444,617	147,962	592,579	36%
475.08.05.02 Silicon Photomultipliers (SiPMs) quality assurance design	2,319	120	32,423	324,576	41,979	366,555	80%
475.08.06 Cosmic Ray Veto Electronics	3,113	2,857	976,891	1,720,262	510,552	2,230,815	33%
475.08.06.01 Counter Mother Boards	335	1,453	210,584	350,098	86,024	436,122	29%
475.08.06.02 Front-end Boards	2,258	340	566,551	988,896	267,959	1,256,855	29%
475.08.06.03 Readout Controllers	40	904	174,539	268,023	86,145	354,168	33%
475.08.06.04 Integration with DAQ	480	160	25,217	113,246	70,424	183,670	80%
475.08.07 Cosmic Ray Veto Module Fabrication	663	11,152	1,005,146	1,489,982	465,611	1,955,593	35%
475.08.07.01 Design and fabricate assembly station		891	123,161	163,040	61,674	224,714	47%
475.08.07.02 Assembly Station Quality assurance design and fabrication	663	440	83,421	105,795	23,448	129,243	65%
475.08.07.03 Fabrication of Module Parts		80	413,000	453,551	93,061	546,612	21%
475.08.07.04 Module Production, Testing, Shipping		9,084	379,564	741,324	276,258	1,017,582	41%
475.08.07.05 Breakdown of Module Factory		657	6,000	26,272	11,170	37,442	43%
475.08.08 Detector assembly and installation	797	337	95,367	208,353	64,385	272,738	35%
475.08.08.01 Test Installation	224			20,643	7,225	27,867	35%
475.08.08.02 Recieve Production Modules at Fermilab	188	177		18,022	6,308	24,330	35%
475.08.08.03 Detector Assemly and Installation: Cosmic Ray Test Stand	289	160	3,000	36,411	10,870	47,281	80%
475.08.08.04 Module Support Structure	96		92,367	133,277	39,983	173,260	30%
475.08.09 Cosmic Ray Veto Conceptual Design/R&D	2,426		237,818	510,665		510,665	-
475.08.09 Cosmic Ray Veto Conceptual Design/R&D	2,426		237,818	510,665		510,665	-
475.08.99 Risk Based Contingency					318,000	318,000	-
475.08.99 Risk Based Contingency					318,000	318,000	-
Grand Total	**20,394**	**24,189**	**3,846,811**	**6,772,668**	**1,962,633**	**8,735,302**	**38%**

Costs are fully burdened in AY $k

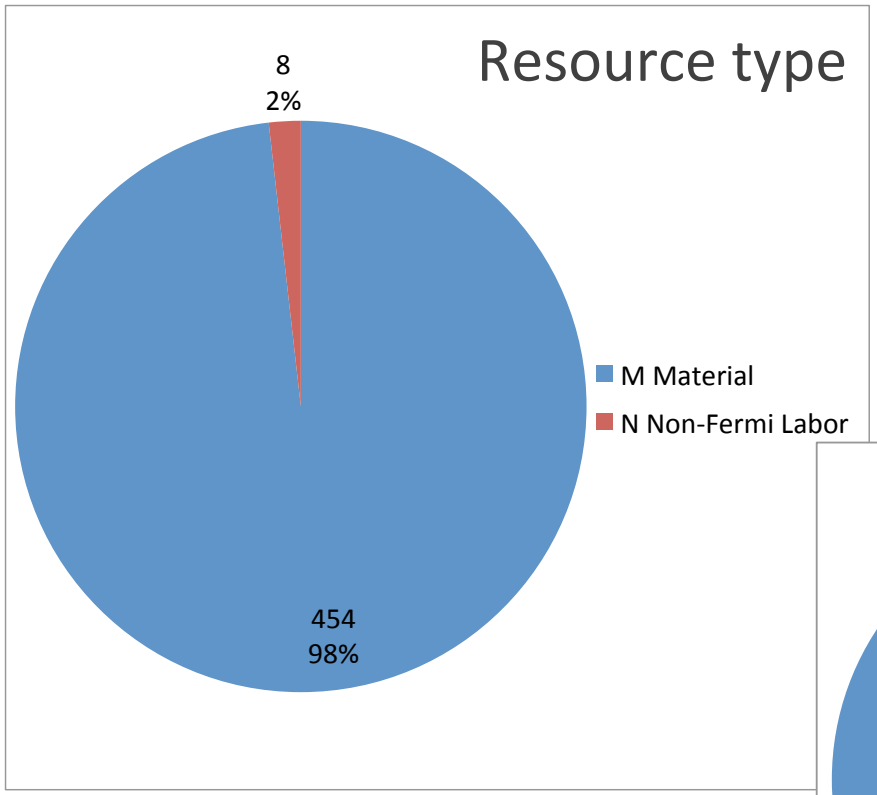
Costed / Uncosted Labor by Hours

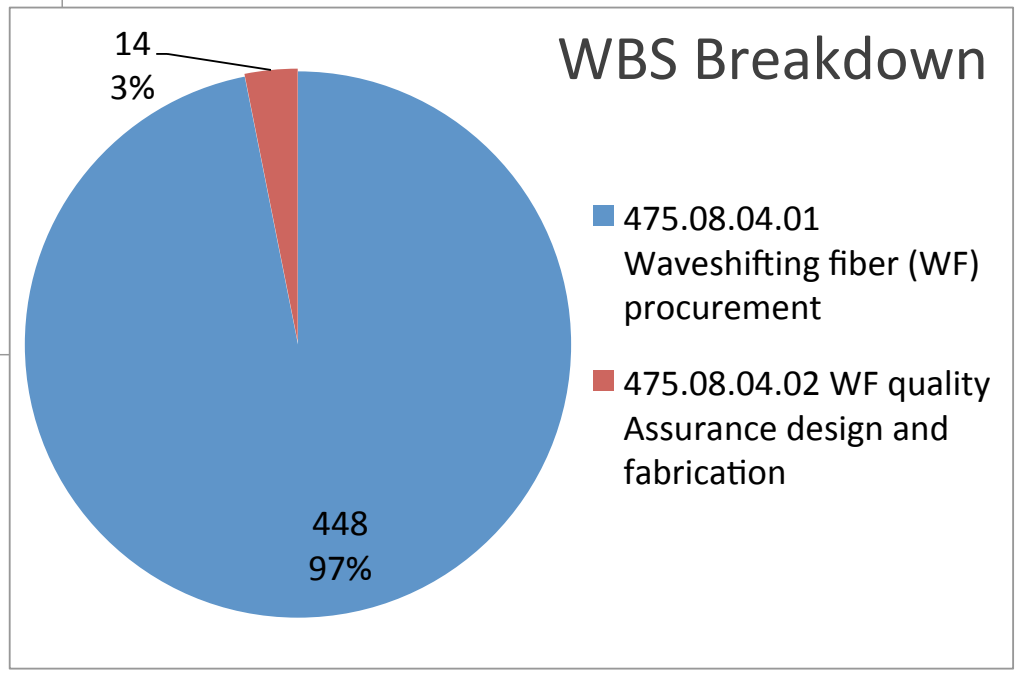


Cost Breakdown: Sub-Project

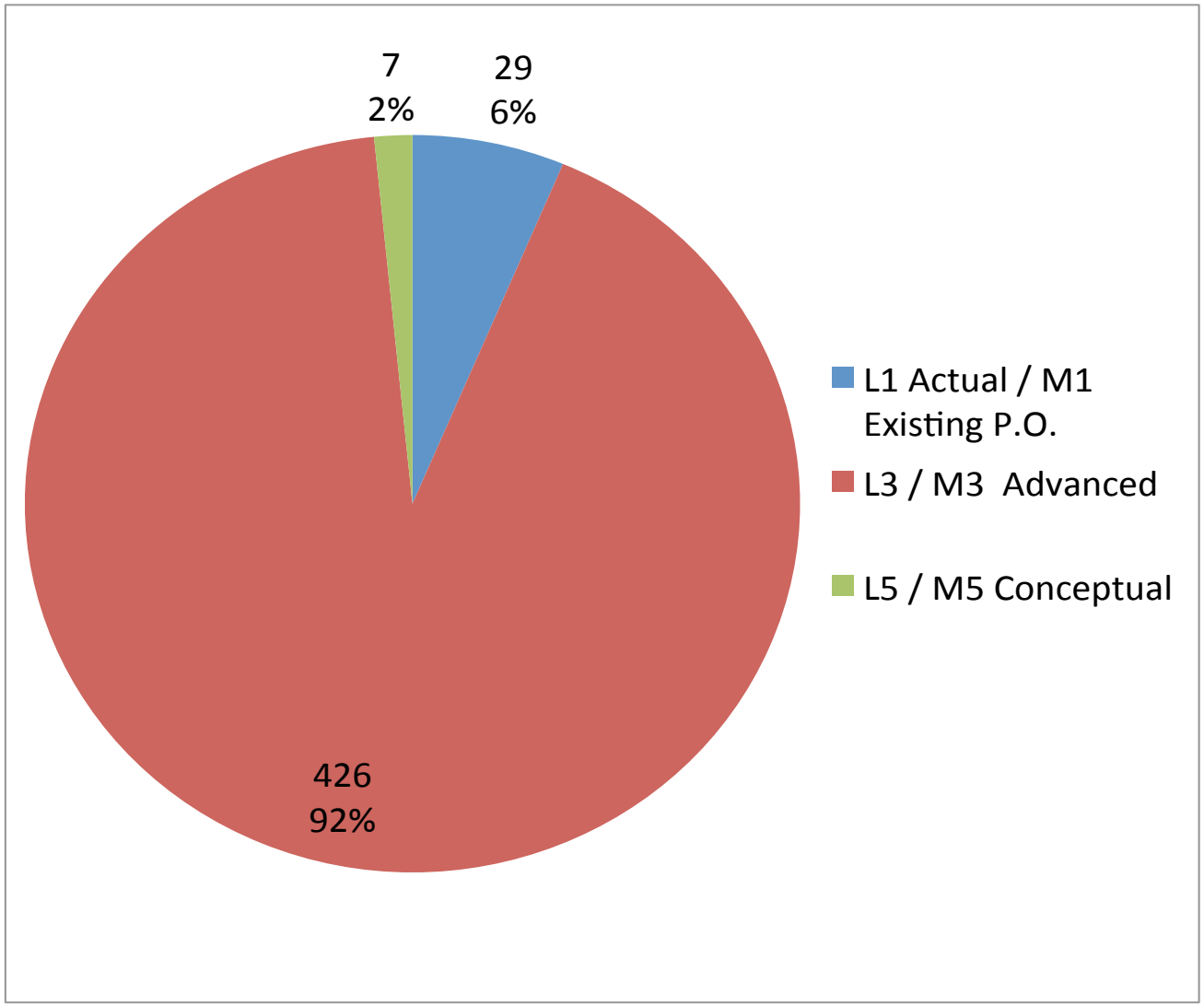


Cost Breakdown

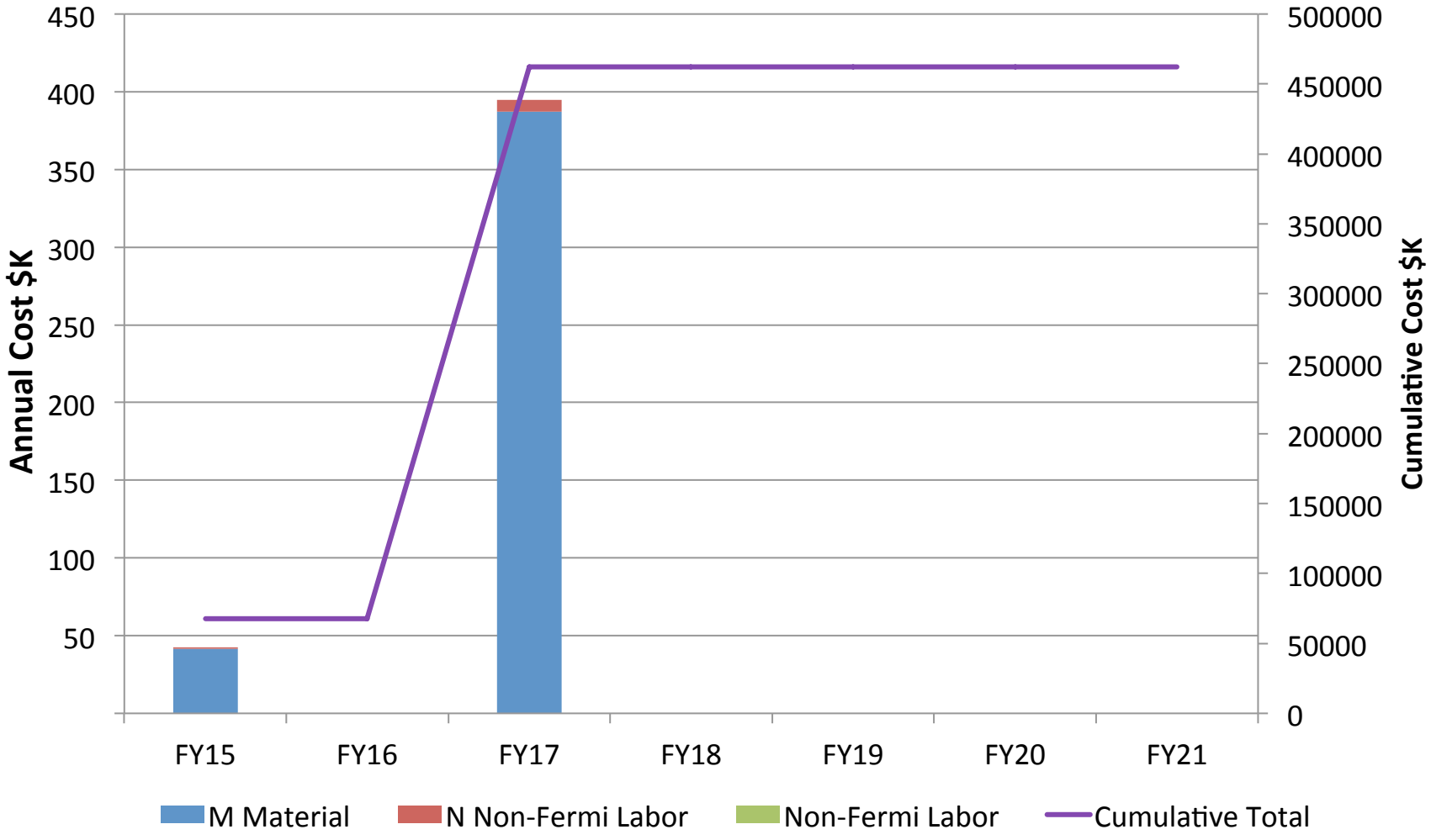




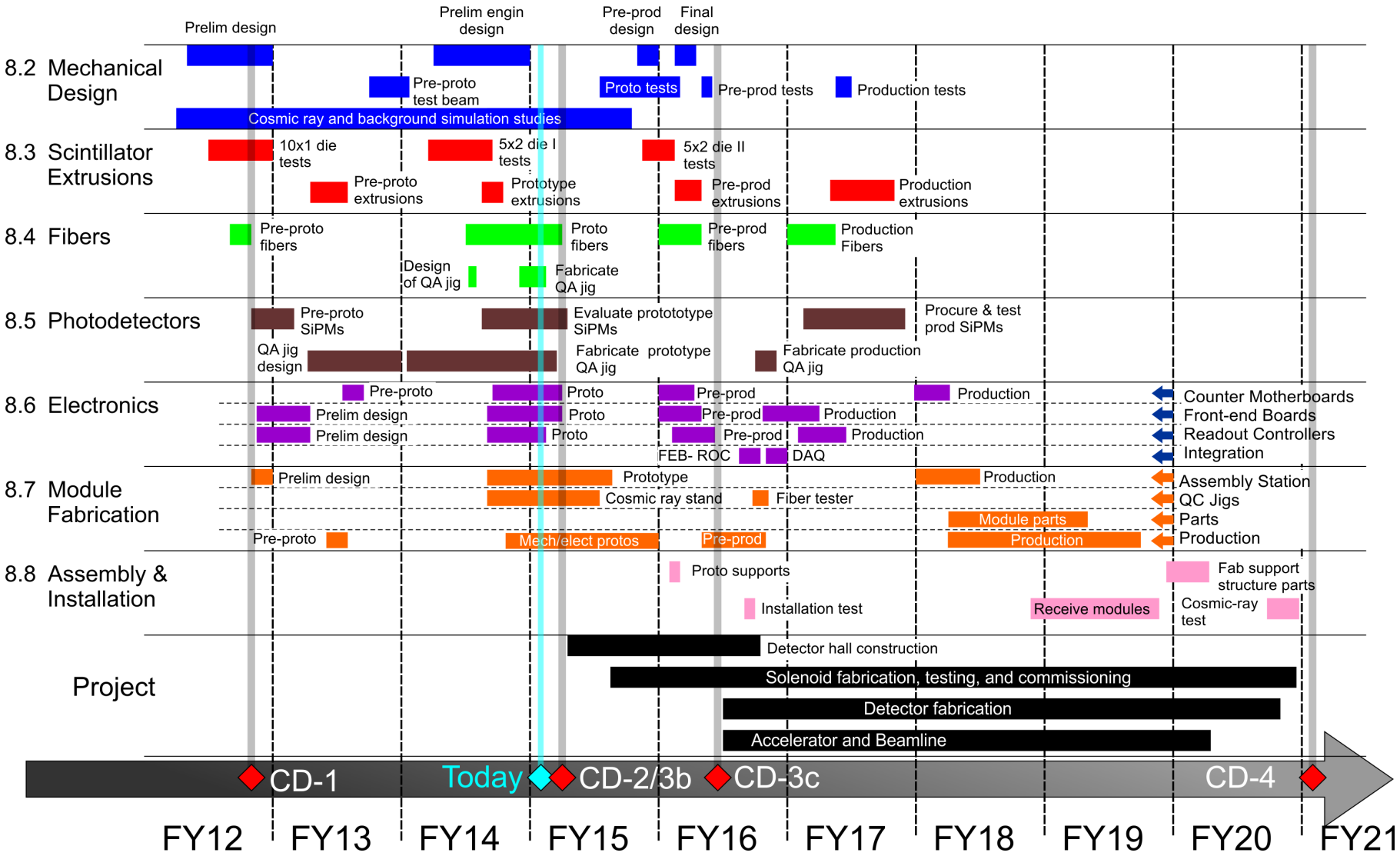
Quality of Estimate



Labor/Material Breakdown by FY



Schedule


Prelim design
Prelim engin design
Pre-prod design
Final design
8.2 Mechanical Design
Pre-proto test beam
Proto tests
Pre-prod tests
Production tests
Cosmic ray and background simulation studies
8.3 Scintillator Extrusions
10x1 die tests
5x2 die I tests
5x2 die II tests
Pre-proto extrusions
Prototype extrusions
Pre-prod extrusions
Production extrusions
8.4 Fibers
Pre-proto fibers
Proto fibers
Pre-prod fibers
Production Fibers
Design of QA jig
Fabricate QA jig
8.5 Photodetectors
Pre-proto SiPMs
Evaluate prototype SiPMs
Procure & test prod SiPMs
QA jig design
Fabricate prototype QA jig
Fabricate production QA jig
8.6 Electronics
Pre-proto
Proto
Pre-prod
Production
Prelim design
Proto
Pre-prod
Production
Prelim design
Proto
Pre-prod
Production
FEB- ROC
DAQ
Counter Motherboards
Front-end Boards
Readout Controllers
Integration
8.7 Module Fabrication
Prelim design
Prototype
Production
Cosmic ray stand
Fiber tester
Module parts
Pre-proto
Mech/elect protos
Pre-prod
Production
Assembly Station
QC Jigs
Parts
Production
8.8 Assembly & Installation
Proto supports
Fab support structure parts
Installation test
Receive modules
Cosmic-ray test
Project
Detector hall construction
Solenoid fabrication, testing, and commissioning
Detector fabrication
Accelerator and Beamline
CD-1
Today
CD-2/3b
CD-3c
CD-4
FY12
FY13
FY14
FY15
FY16
FY17
FY18
FY19
FY20
FY21

Milestones

47508.4.1.001035	T5 - Pre-production waveshifting fiber tested	T5	9/24/2015	Prototypes have been evaluated, the design has been modified based on their performance, and work can begin on pre-production prototypes.
47508.4.1.001060	T5 - Production waveshifting fiber tested	T5	2/21/2017	All production waveshifting fiber has been procured and tested.

Integration and Interfaces

- Fibers are integrated with other CRV L3s
  - Progress and details are discussed at CRV weekly meetings
- Some interfaces require coordination
  - Fiber diameter depends on the design (8.2)
  - Fibers is the key component of module fabrication (8.7)

- Interfaces
  - Interfaces DocDB #1551
  - Attend weekly CRV meetings

Summary

- The requirements and the design for WLS fibers are well understood
- The baseline fiber: Kuraray, 1.4 mmD, 175 ppm, non-S type
- We plan to produce the prototype to select the final fiber size
  - Fiber for prototypes has been received
- The QA test jig will be produced this Fall. The QA procedures are well understood.
- Fermilab has long history with WLS fibers