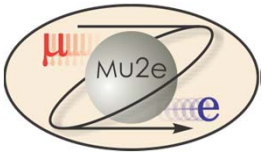
Fermilab

475.04.06 Magnet Power Supplies



Steven Hays

AD E/E Support Electrical Engineer

Mu2e CD-2/3b Review, October 21-24, 2014

Magnet Power Supply Team

- Steven Hays – L3 Manager Magnet Power Supplies
  - 38 years at Fermilab on Main Ring, TeV, Main Injector, Proton Source, Pbar, Beam Line systems and now Muon Campus power supply systems.
  - Tev Dump Switch lead designer, and TeV operation support
  - Pbar pulsed power supplies
  - Ramped power supplies for Main Injector
  - DC supplies for Muon Campus
- Engineering Group:
  - Matt Kufer Electrical Designer
  - Ryan Crawford AC Distribution Engineer
  - 5 electronic technicians

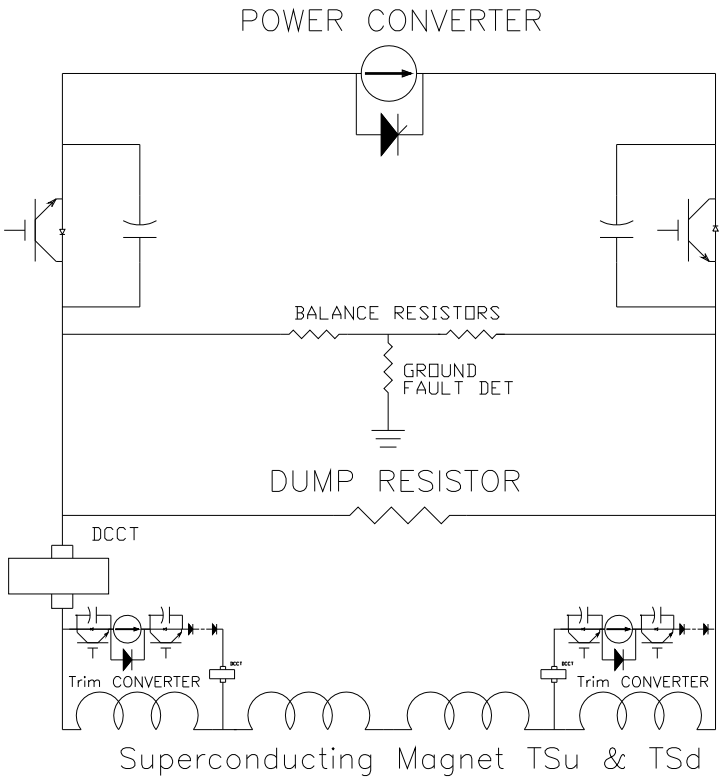
Requirements Magnet Systems

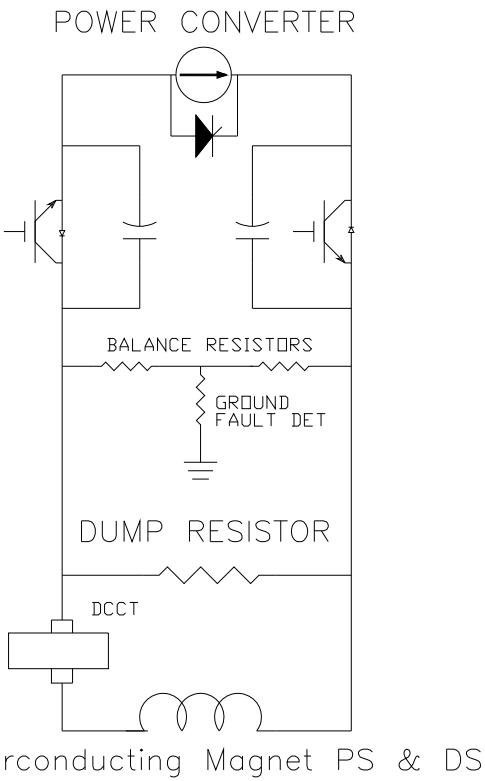
- Mu2e Power Supply Document 1237
  - Four main loops
  - Four trim loops, two on each TS magnet.
  - Energy Extraction on all main loops.

Parameter	Unit	PS	TSu	TSTU x2	TSd	TSTD x2	DS
Nominal current	A	9200	1730	250	1730	250	6114
Peak field in coil	T	5.48	3.4		3.4		2.2
Inductance	H	1.58	4.77		3.79		1.40
Stored energy	MJ	66.8	7.1		5.7		26.1

Requirements Energy Extraction

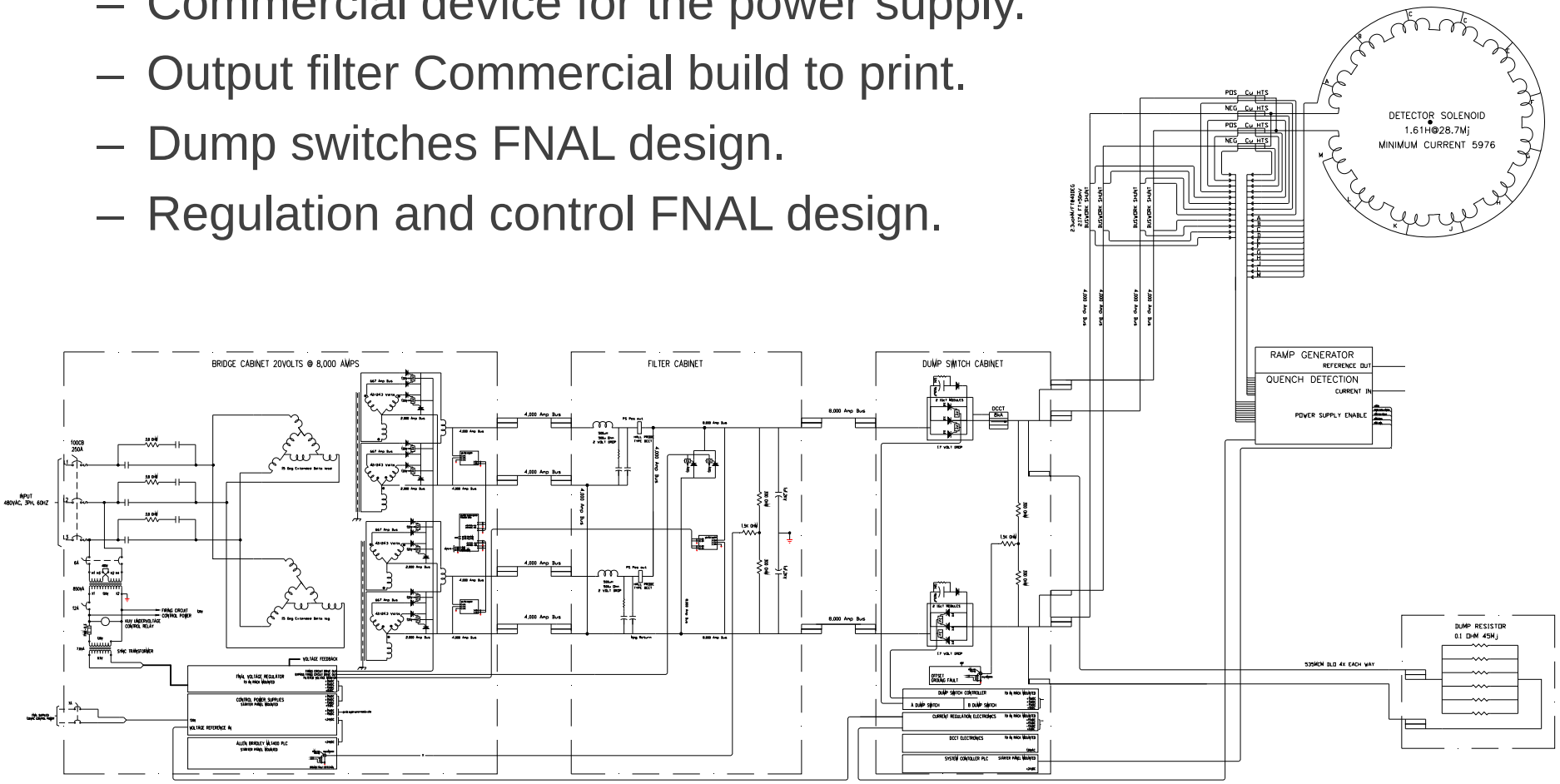
- The TS magnet loops with two trim power supplies, one on each end.
  - The main Dump Switch disconnects the power supply from the magnet.
  - Two small switches will be installed on the trim power supplies to isolated them from the magnet during a Quench/Dump.





Design DS shown, typical of all loops.

- BASIC POWER SUPPLY DESIGN
  - Commercial device for the power supply.
  - Output filter Commercial build to print.
  - Dump switches FNAL design.
  - Regulation and control FNAL design.



Improvements Since CD-1

- Updated the requirements document to clarify and better detail the minimum requirements of the power system.
  - Updated operating currents
  - Removed the Trim power supply requirement from the PS coil
  - Increased the number of Trim power supplies for the TSu and TSd magnets to two each.
  - Improved the wording for the Power Supply Function definition.

Quality Assurance

- The equipment being reused was part of the TeV in collider operation and maintained at a very high level so they are still valuable and usable.
- We will replace components that have limited life times
- Some modifications need to be done to the supplies to make them operate in two quadrant mode (+/- Voltage)

Risks

- The risk for reusing the type of equipment is reasonable and low and not included in the risk registry.
- We will be constructing new Dump Switches but they will be copies of a proven design used in the TeV.
- The trim power supplies are a new design but similar to other system used in the TeV.
- Magnetic coupling issues will need to be addressed during the detail design.

Performance

- The requirements for the power supply system is required to track at 10^{-3} and regulate at 10^{-4}, the Low Beta Quad System in the TeV operated at 10^{-5} .
- We can only be as accurate as the current measurement we make, The use of DCCTs and temperature regulated reference allow us to regulate to these levels.

Remaining work before CD-3

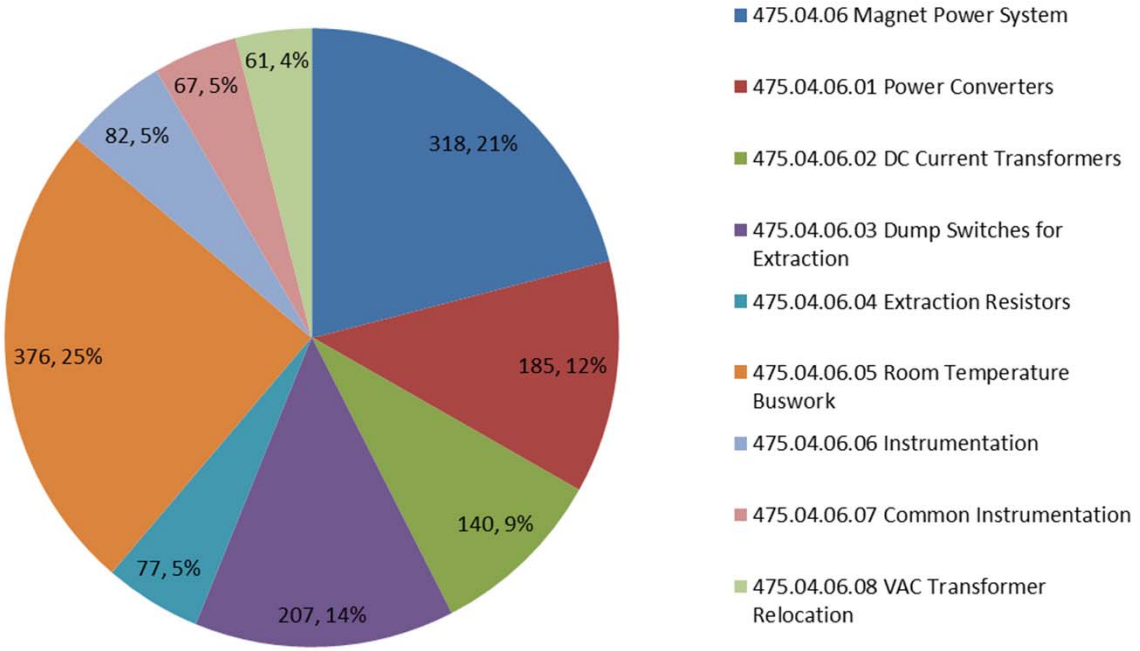
- Detailed Control Cable Drawings
- Detailed building layout
- Detailed design work the common controls

Cost Breakdown

- All Design time in the first level
- Installation management in each sub system

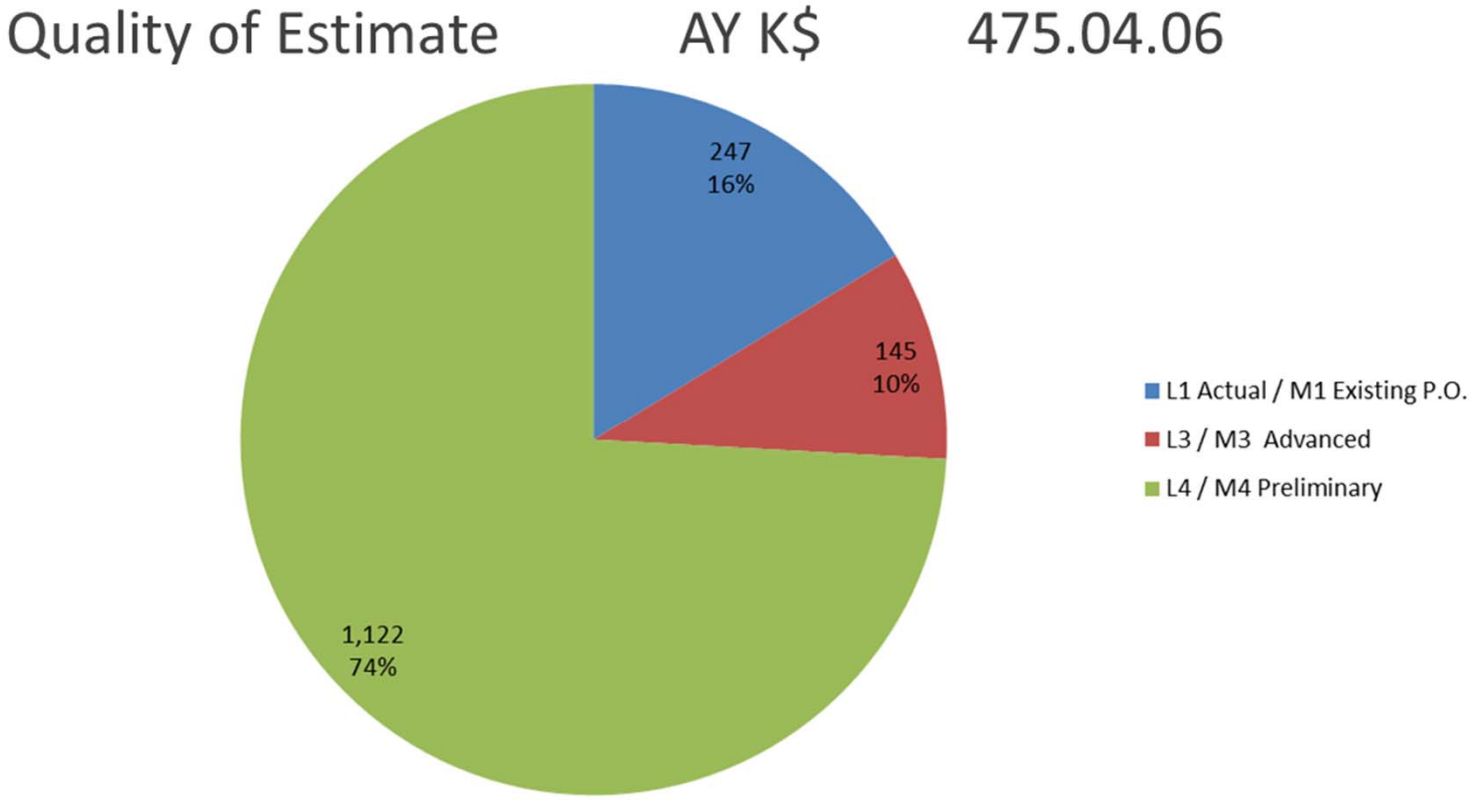
WBS Level 4 AY K$

Sum of Value WBS Level 4	Total
475.04.06 Magnet Power System	318
475.04.06.01 Power Converters	185
475.04.06.02 DC Current Transformers	140
475.04.06.03 Dump Switches for Extraction	207
475.04.06.04 Extraction Resistors	77
475.04.06.05 Room Temperature Buswork	376
475.04.06.06 Instrumentation	82
475.04.06.07 Common Instrumentation	67
475.04.06.08 VAC Transformer Relocation	61
Grand Total	**1,514**



Quality of Estimate

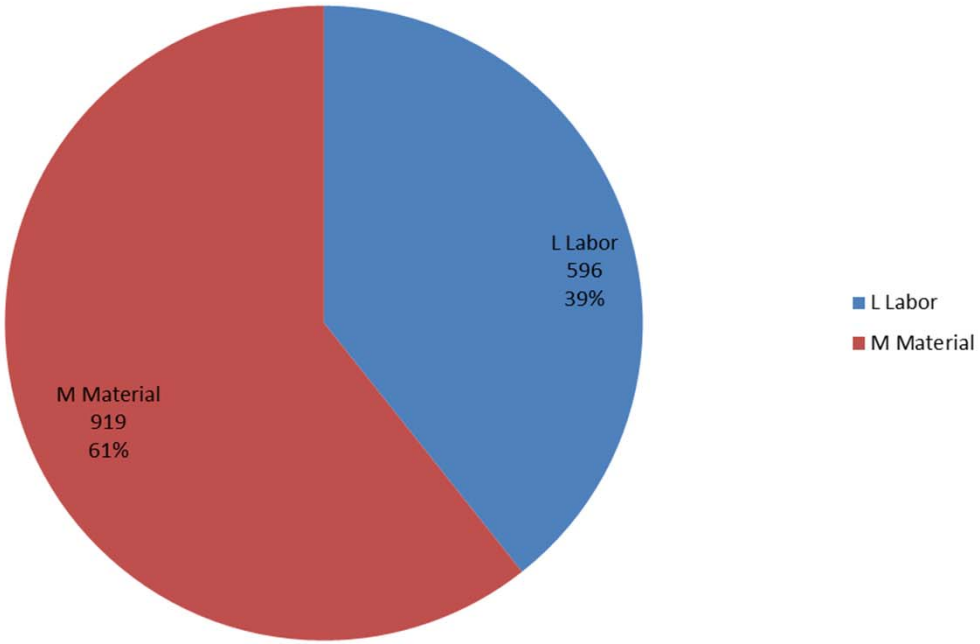
- All equipment based on existing designs and equipment on hand but need final design



Resource Type

- Material Cost driven by two large items: Copper & Dumps
- Labor driven by detail design and Dump Switch Construction

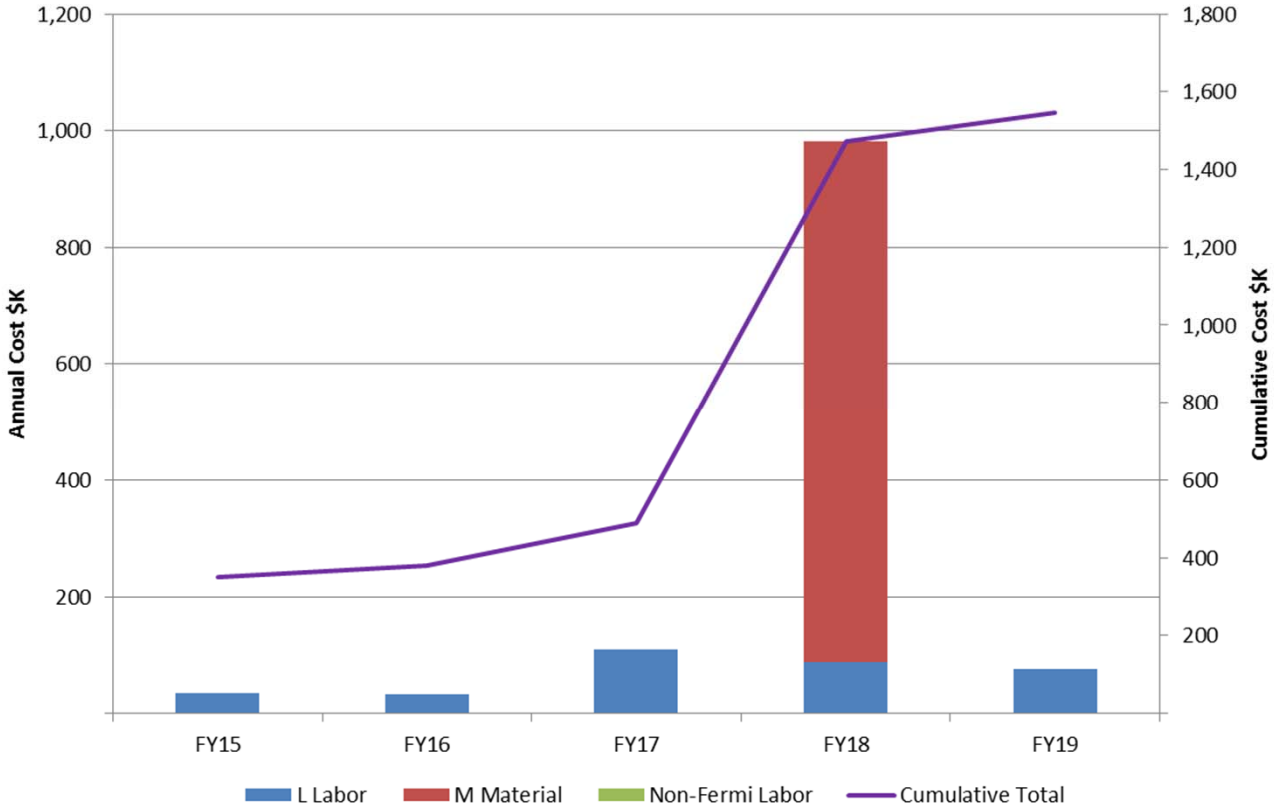
Resource Type AY K$ 475.04.06



LABOR AND MATERIALS

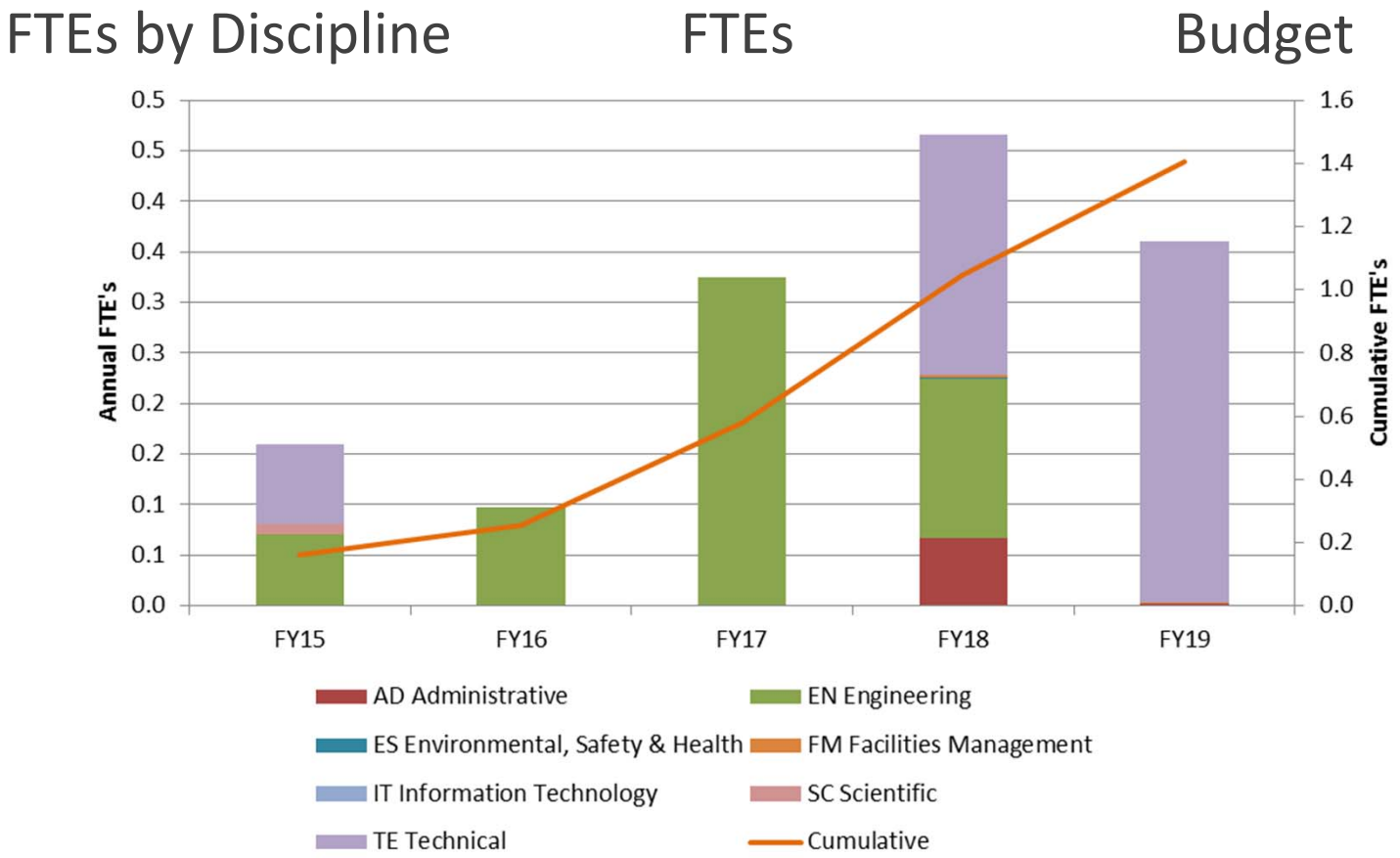
- Detailed design first followed by construction then we need a building to install equipment

Labor / Material Breakdown AY K$ Budget



FTE's by Discipline

- Detailed design to be completed then Tech will assemble and install in Service Building

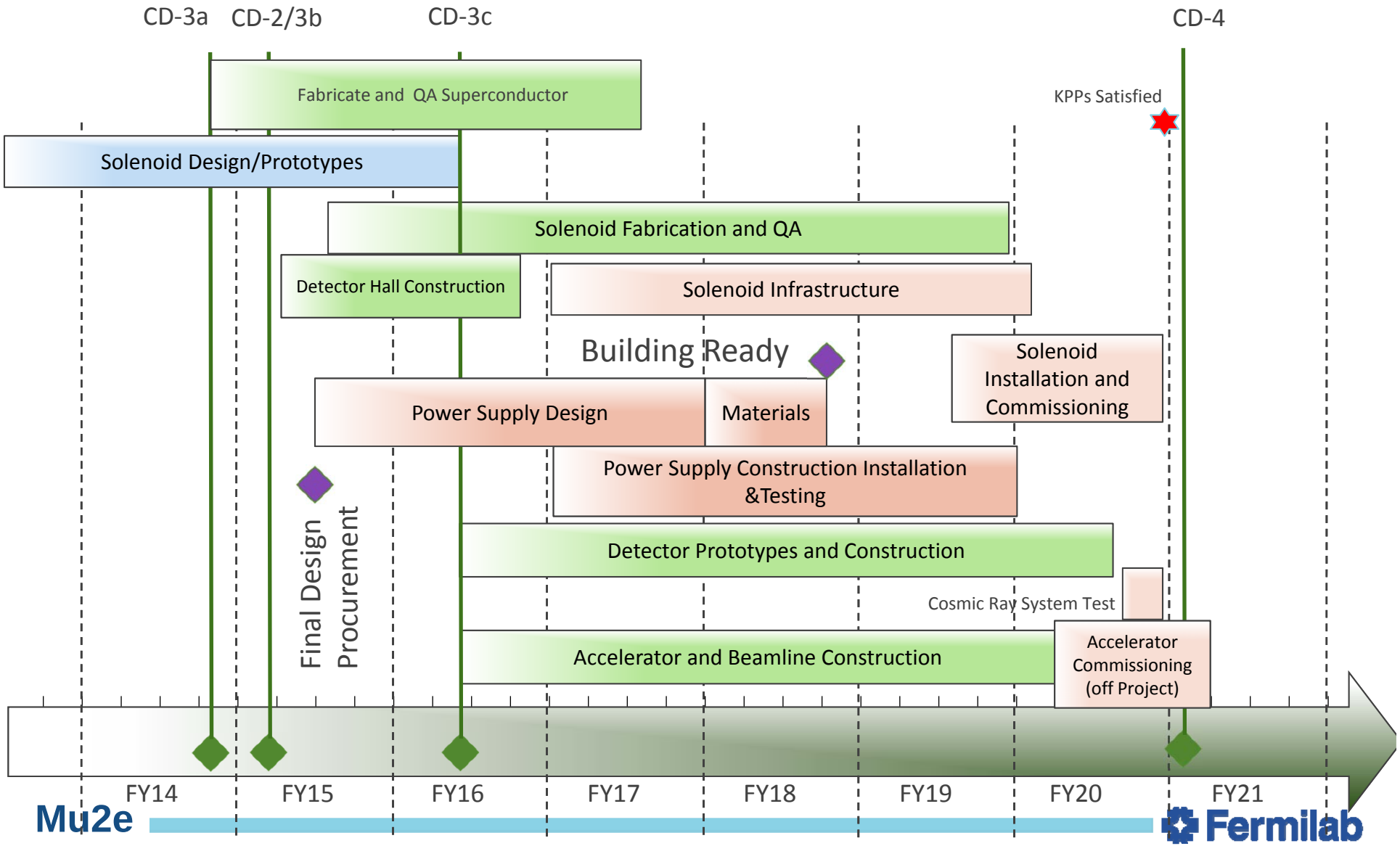


Cost Table

- Most of the labor consumed doing detailed design because we have equipment on hand and the new construction of equipment will be based on existing designs.

	Base Cost (AY K$)					
	M&S	Labor	Total	Estimate Uncertainty (on remaining budget)	% Contingency on (on remaining budget)	Total Cost
475.04.06 Magnet Power System						
475.04.06 Magnet Power System	25	293	318	28	68%	346
475.04.06.01 Power Converters	93	92	185	64	35%	249
475.04.06.02 DC Current Transformers	117	24	140	41	30%	182
475.04.06.03 Dump Switches for Extraction	166	42	207	82	40%	290
475.04.06.04 Extraction Resistors	54	23	77	24	31%	102
475.04.06.05 Room Temperature Buswork	316	60	376	87	23%	463
475.04.06.06 Instrumentation	41	42	82	28	34%	111
475.04.06.07 Common Instrumentation	55	12	67	21	31%	88
475.04.06.08 VAC Transformer Relocation	52	9	61	14	23%	74
Grand Total	919	596	1,514	390	32%	1,905

Schedule

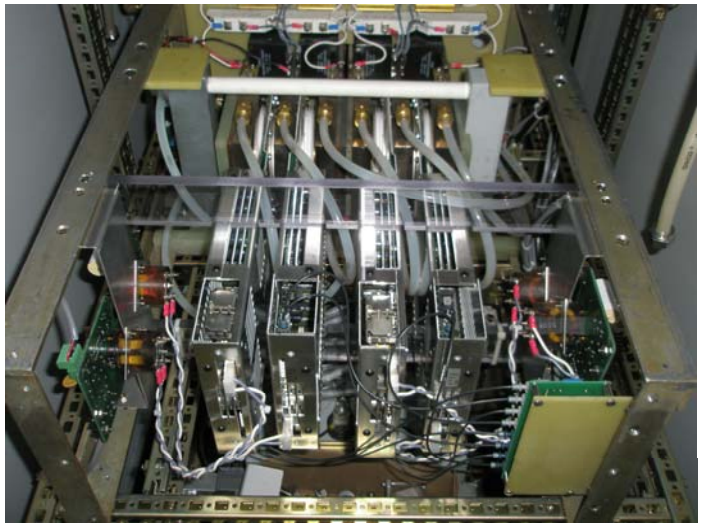

CD-3a
CD-2/3b
CD-3c
CD-4
Fabricate and QA Superconductor
KPPs Satisfied
Solenoid Design/Prototypes
Solenoid Fabrication and QA
Detector Hall Construction
Solenoid Infrastructure
Building Ready
Solenoid Installation and Commissioning
Power Supply Design
Materials
Power Supply Construction Installation &Testing
Final Design
Procurement
Detector Prototypes and Construction
Cosmic Ray System Test
Accelerator and Beamline Construction
Accelerator Commissioning (off Project)
FY14
FY15
FY16
FY17
FY18
FY19
FY20
FY21

Summary

- By reusing existing power supplies most of the large dollar and long lead time items are on hand.
  - We will not be able to move equipment until we have the service building constructed.
  - We will need to coordinate the installation in the building with other large equipment being installed.
- The major cost in both M&S and Labor will be spend on constructing new Dump Switches and Bus work.
- We are ready to move forward on the final design.

Power Supplies Components being used

- 375kW supplies for PS & DS



Electronic Dump Switch

50kW supply system for TSx

Remaining work before CD-3 extra detail

- Detailed Control Cable Drawings
  - Power Supply to Regulator/Controller
  - Regulator/Controller to Quench Protection
  - Dump Controller to Quench Protection
- Detailed building layout
  - Power Supply, Filter and Dump Switch floor plan
  - Cable tray routing
  - Bus Work routing
- Detailed design work the common controls
  - Water monitoring system that is common to all magnet loops.
  - Independent overcurrent monitors for all loops.
  - UPS system monitors.

Quality Assurance extra detail

- The equipment being reused was part of the TeV in collider operation and maintained at a very high level so they are still valuable and usable.
  - All regulation and control circuits were replaced with FNAL designs to improve the reliability early in operation.
- We will replace components that have limited life times
  - Electrolytic Capacitors in all control circuits
  - Electrolytic Capacitors in Filter bank
  - Internal low level control power supplies
- Some modifications need to be done to the supplies to make them operate in two quadrant mode (+/- Voltage)
  - We will install new proven design firing circuits for all the SCRs in the high current supplies to add the Bypass device.
    - We will replace the existing 3 circuit boards with new four circuit boards.
- High current testing will be done in AD lab before installation.

Risks extra detail

- The risk for reusing the type of equipment is reasonable and low and not included in the risk registry.
  - The Low Beta Systems operated at very close to the same level as they will in the experiment.
  - The 375kW power supplies are designed to operate at 7,500 amps each and we will only use them at 6,114 for DS and 4,600 for PS (two in parallel).
  - The TSx supplies will be 50kW supplies that are designed for 2,500 amp operation and will be used at 1,730 amps.
- We will be constructing new Dump Switches but they will be copies of a proven design used in the TeV.
- The trim power supplies are a new design but similar to other system used in the TeV. Magnetic coupling issues will need to be addressed during the detail design.

ES&H Extra Details

- All of this equipment will require written Lock Out Tage Out “LOTO”s because we have multiple input power sources and stored energy in the magnets.
- The Power Supply, Filter and Dump Racks are all separate cabinets that will require interlocking in addition to the written LOTOs.
  - These LOTOs will be written by AD E/E Support and be part of the department training and qualification process.
  - On large Super Conducting load we normally manage access using a registered Key system to ensure that the systems are turned Off in a controlled way. This Key system will defined by E/E support but issued by the Main Control Room in conjunction with Experiment Control Room.