sPHENIX Director's Review
WBS 1.8: Superconducting Magnet

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Collider-Accelerator Department

Aug 3, 2017

BNL

A little history …

- The Superconducting Magnet was originally built ~1997-98 for the BaBar Experiment at SLAC and used until BaBar ended in Apr. 2008.
- It was brought to BNL ~ Feb. 3 (near midnight), 2015.
- LESHC (Laboratory Environment, Safety & Health Com.)/PCSS (Pressure & Cryogenics Safety Sub-Com.) review (May 22, 2015) for the Cryo system
  - *13 action items generated & all 13 already closed out*
- ASSRC/ESRC (Accel. Sys./Experimental Safety Review Committee) review (Dec. 8, 2015) for the low-field test
  - *all action items closed out*
- Low-Field Test (100 A) was performed successfully on Mar. 22, 2016.
- ASSRC/ESRC review (July 6, 2017) for the High-Field Test

Original conductor/coil Specifications

~1.37 T in the High-Field Test

~1.4 T in sPHENIX

Table 1
Main characteristics of BaBar solenoid (as built)

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Main characteristics of BaBar solenoid (as built)

Central Induction	1.5T
Conductor peak field	2.3T
Winding structure	2 layers graded current density
Uniformity in the tracking region	± 3%
Winding axial length	3512 mm *at R.T*
Winding mean radius	1530 mm *at R.T.*
Operating current	4596 A
Inductance	2.57 H
Stored Energy	27 MJ
Total turns	1067
Total length of conductor	10 300 m

TABLE II
SUMMARY OF SPECIFICATION FOR STRANDS, RUTHERFORD AND FULL CONDUCTOR

Component	Characteristic	Value
Strand	NbTi	Nb 46.5 +/- 1.5 wt % Ti
	Filament size	< 40 μm
	Twist pitch	25 mm
	Cu/NbTi ratio	> 1.1
	Cu RRR	Final >100
	Wire diameter	0.8 mm ± 0.005
Rutherford	Transposition pitch	< 90 mm
	Number of strands	16
	Final size	1.4 x 6.4 mm2
Conductor	Al-RRR	>1000
	Dimensions:	
	Thin conductor	(4.93 x 20)±0.02 mm
	Thick conductor	(8.49 x 20)±0.02 mm
	Rutherford-Al bonding	> 20 MPa
	Al/Cu/NbTi ratio:	
	Thin conductor	23.5:1.1:1
	Thick conductor	42.4:1.1:1
	Edge curvature radius	> 0.2 mm
	Critical current @ T=4.2 K; B=2.5 T	12680 A

Heavily stabilized

~ 276% margin

⇒ High-Field Test (BaBar operating current ~ 4596 A) is planned to be done in Sept./Oct. 2017 [off-project].

Status of the High-Field Test [off-project]

- On June 30, 2017, the riggers have helped move/lift the Magnet Cryostat into the Flux Return steel box.
  - The Magnet Coil was initially slightly rotated (~0.5°) and we moved it up/rotated again ~July 7.
  - The Survey Group (C-AD) confirmed the alignment to be good ~July 11.
- Superconducting Magnet Div. electrical/mechanical groups are installing the Extension starting July 12.
- C-AD personnel are also responsible for assemblying/testing the front-end boards as well as the quench detection software. The software to transfer and store the data into the C-AD Control System is completed.
- C-AD Power Supply Group should finish modifying/testing the Power Supply this week and then we can move it to the test site.
- Cryo group (C-AD) will connect the Magnet to the Cryo system in Bldg. 912 after Extension/Valvebox & platform are installed.

sPHENIX Project and WBS

- WBS 1.8: Superconducting Magnet
  - 1.8.1: Magnet Management & Technical Oversight (K. Yip)
  - 1.8.2: Mechanical Disassembly, Transport & Reassembly (M. Anerella)
  - 1.8.3: Cryogenic Systems (R. Than)
  - 1.8.4: Power Supply & Quench Detection System (C. Schultheiss)
  - 1.8.5: Magnet Field Measurement (A. Franz/J. Haggerty)

Documentation Made Available to the Committee

- Basis of Estimate
  - https://docdb.sphenix.bnl.gov/cgi-bin/private/ShowDocument?docid=63
- WBS Dictionary:
  - https://docdb.sphenix.bnl.gov/cgi-bin/private/ShowDocument?docid=83
- Microsoft Project File:
  - https://docdb.sphenix.bnl.gov/cgi-bin/private/ShowDocument?docid=55

1.8.1	Magnet Management and Technical Oversight	1330 days	2/1/17	6/2/22
1.8.2	Mechanical Disassembly, Transport Prep. And Reassembly of Valve Box	1110 days	7/17/17	12/30/21
1.8.3	Cryogenic Systems	1301 days	2/1/17	4/21/22
1.8.3.1	RHIC Interfacebox/Helium Transfer System / Platform 4.5K and LN2 Coldbox system	1274 days	2/1/17	3/15/22
1.8.3.2	LN2 supply transfer line system	1013 days	2/1/17	2/25/21
1.8.3.3	Warm Piping System	1254 days	4/6/17	4/19/22
1.8.3.4	Cryo Controls Hardware	1291 days	2/1/17	4/7/22
1.8.3.5	Cryo Controls Software	1211 days	6/9/17	4/21/22
1.8.4	Power Supply and Quench Detection Systems	754 days	2/1/17	2/11/20
1.8.4.1	AC/DC Power Distribution	739 days	2/1/17	1/21/20
1.8.4.2	Power Supply	754 days	2/1/17	2/11/20
1.8.4.3	Quench Detector and Dump Resistor	655 days	2/1/17	9/16/19
1.8.5	Magnet Field Measurement	991 days	1/2/18	12/21/21
1.8.5.1	Magnet Field Measurements Engineering and Design, Field Studies and Stress Analysis	513 days	1/2/18	1/23/20
1.8.5.2	Magnet Field Measurements Equipment Purchase and Fabrication	65 days	1/16/20	4/17/20
1.8.5.3	Magnet Field Measurements Installation and Test, Post-Test Field Studies and Stress Analysis	478 days	1/24/20	12/21/21

Magnet documentation status

- The Basis of Estimate (BOE) for 1.8 is in sPHENIX docdb (docid=63).
- An overview of the BOE looks like :

sPHENIX Detector
Relativistic Heavy Ion Collider
BASIS of ESTIMATE (BoE)

L2 Project Name	L2 WBS Number	L3 Project Name (Control Account)	L3 WBS Number
Magnet	1.8		

Work Package Name	WBS Number	Basis of Estimate Link
Magnet Management & Technical Oversight	1.8.1	Management & Oversight
Mechnical Disassembly, Transport & Reassembly	1.8.2	Disassembly & Assembly
Cryogenic Systems	1.8.3	Cryogenic Systems
Power Supply & Quench Detection Systems	1.8.4	Power Supply & Quench Detection
Magnet Field Measurement	1.8.5	Magnet Field Measurement

An example for the Basis of Estimate (Cryo)

- "Cryogenic Systems" is our largest "spender" and here is a part of it :

Description	Duration	Resources	Material	Labor	Total
Vendor Engineering and Design					
Engineering	45 days	PROF4 AD[10%],TECH3 PO D[15%],PROF3 AD[20%]	$0.00	$14,602.68	$14,602.68
Preliminary Design Review	1 day	PROF3 AD,PROF4 AD	$0.00	$1,553.12	$1,553.12
Detail dwg package	60 days	PROF3 AD[5%],PROF4 AD[2%]	$110,000.00	$2,156.16	$112,156.16
Final Design Review	2 days	PROF3 AD,PROF4 AD	$220,000.00	$3,106.24	$223,106.24
Long lead items order	1 day	PROF3 AD,PROF4 AD	$200,000.00	$1,553.12	$201,553.12
Drawings approvals	5 days	PROF3 AD,PROF4 AD	$50,000.00	$7,765.60	$57,765.60
Vendor Fabrication					
Raw Material procurement	45 days	PROF4 AD[2%]	$200,000.00	$750.96	$200,750.96
Main fabrication items	90 days	PROF4 AD[10%],PROF3 AD[10%]	$0.00	$13,978.08	$13,978.08
Final assemblies	30 days	PROF4 AD[1%]	$0.00	$250.32	$250.32
BNL Holdpoint witness	1 day	PROF4 AD	$200,000.00	$834.40	$200,834.40
Shipping	3 days	PROF4 AD[25%]	$120,000.00	$625.80	$120,625.80
Delivery and receiving					
Rigging/Truck Unloading	1 day	TECH3 AD	$0.00	$648.80	$648.80
Inspection	1 day	PROF4 AD	$0.00	$834.40	$834.40
Installation					
Rigging in place on piping supports	5 days	PROF4 AD[50%],CRAFT3[50%],PROF3 AD[50%],TECH3 AD[50%]	$0.00	$7,774.60	$7,774.60
Field joint welding to RHIC Interconnect	30 days	PROF4 AD[10%],PROF3 AD[10%],TECH3 AD[50%]	$0.00	$14,391.36	$14,391.36
Installation Cryo Mechanical MAGNET platform equipment	30 days	PROF4 AD[5%],PROF3 AD[5%],TECH3 AD	$0.00	$8,817.68	$8,817.68
Final pressure. leak check and reliefs install equipment shakedown	10 days	PROF4 AD,PROF3 AD,TECH3 AD	$0.00	$22,019.20	$22,019.20
Final pump and purge	10 days	PROF4 AD[5%],PROF3 AD[5%],TECH3 AD[50%]	$0.00	$4,020.56	$4,020.56

An example of Purchase Order of similar nature

56MHz 4.5K Cryogenic system and CeC 4.5K cryogenic system, each consisting of condenser cryostat and multiline vacuum jacketed bundle to the cavity cryostats plus 80L phase separator and 15 ft VJ transfer line section

Purchase Order

Business Unit:	BNL	PO Status:	Dispatched
PO ID:	0000227886		
Change Order:	4		

Header

PO Date:	10/15/2012		
Vendor Name:	KENDALL-001	Backorder Status:	Not Backordered
Vendor ID:	0000053125 Vendor Details	Receipt Status:	Partial
Buyer:	BERNATH,PHILIP J	Hold From Further Processing	
PO Reference:	Source From Req 0000227886		

Header Details | All RTV | Document Status
Header Comments... | Matching
Change Order | Activity Summary

Amount Summary

Merchandise:	1,103,807.00
Freight/Tax/Misc.:	0.00
Total:	1,103,807.00 USD

Lines Personalize | Find | View All | First 1-3 of 3 Last

Line	Item ID	Item Description	Category	PO Qty	UOM	Merchandise Amount		Status
1		Quiet Helium source with VJ li	ELCTR	1.0000	E	433,564.00	USD	Approved
2		Quiet Helium Source with VJ an	ELCTR	1.0000	E	665,119.00	USD	Approved
3		Addition of 3rd pipe run	ELCTR	1.0000	LT	5,124.00	USD	Approved

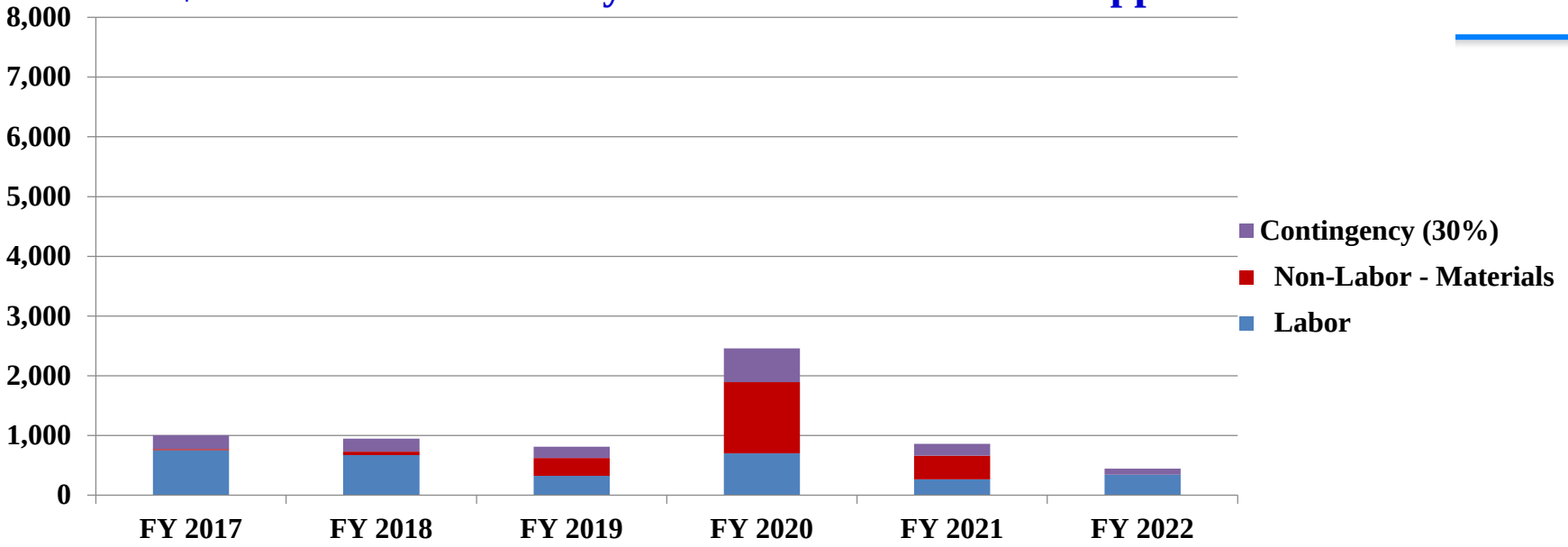
56MHz 4.5K Cryogenic system and CeC 4.5K cryogenic system with phase separator	
56Mhz Condenser Cryostat	
7 cryogenics valves	77,000
Helium vessel package with condenser cryostat	120,000
20 kW heater in vacuum jacket	25,000
Vacuum vessel	100,000
Platform/ support frame	30,000
Multilines Vacuum jacketed transfer line system, 20 ft	60,000
Reliefs and burstdisk	6,000
Thermal shield	15,000
	433,000
112Mhz Condenser Cryostat	
8 cryogenics valves	88,000
Helium vessel package with condenser cryostat	120,000
20 kW heater in vacuum jacket	25,000
Vacuum vessel	100,000
Platform/ support frame	30,000
Reliefs and burstdisk	6,000
Thermal shield	15,000
Multilines Vacuum jacketed transfer line system, 50 ft	155,000
80L phase separator	85,000
Segment 1: 1x1 bayonet ends, single line VJ 1/2" x 2" x ~18 ft long, LN2 VJ main LN2 dewar to inside bldg	18,000
	642,000

From the Basis of Estimate

- Total and contingency estimates (FY17 $ Direct) :

			Material	Labor		Total	Total with Contingency
1.8.1	Management & Oversight		$0	$819,963		$819,963	$874,437
1.8.2	Disassembly & Assembly		$44,000	$159,664		$203,664	$327,129
1.8.3	Cryogenic Systems		$1,524,420	$990,277		$2,514,697	$3,269,106
1.8.4	PS & Quench Detection		$66,000	$147,724		$213,724	$268,803
1.8.5	Magnet Field Measurement		$7,000	$126,773		$133,773	$160,528
1.8			$1,641,420	$2,244,401		$3,885,821	$4,900,003

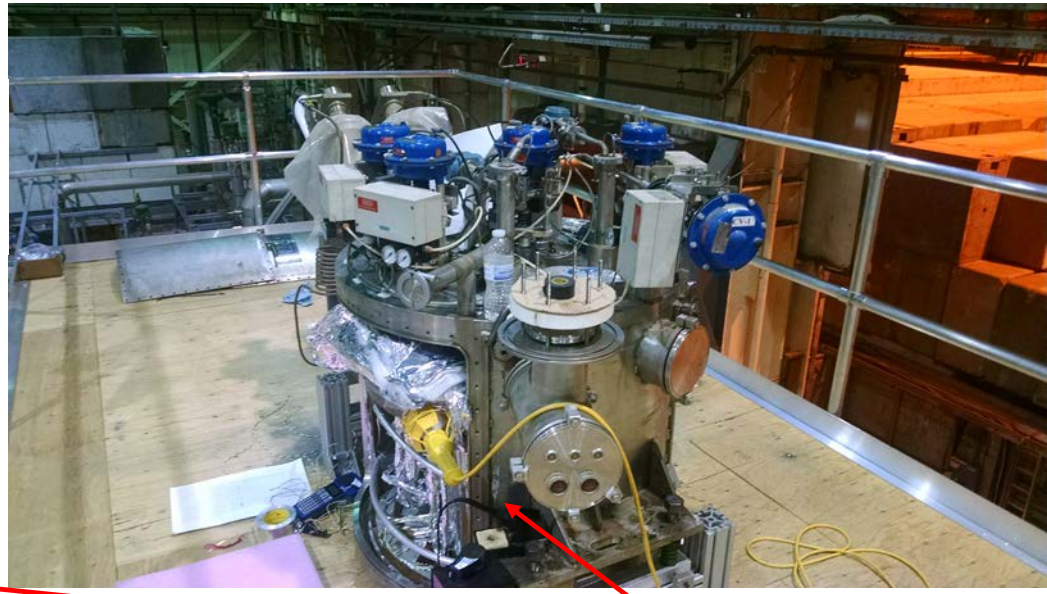
Baseline Scenario - 1.8 S/C Magnet
AY k$'s - with Extraordinary Construction Overhead Application



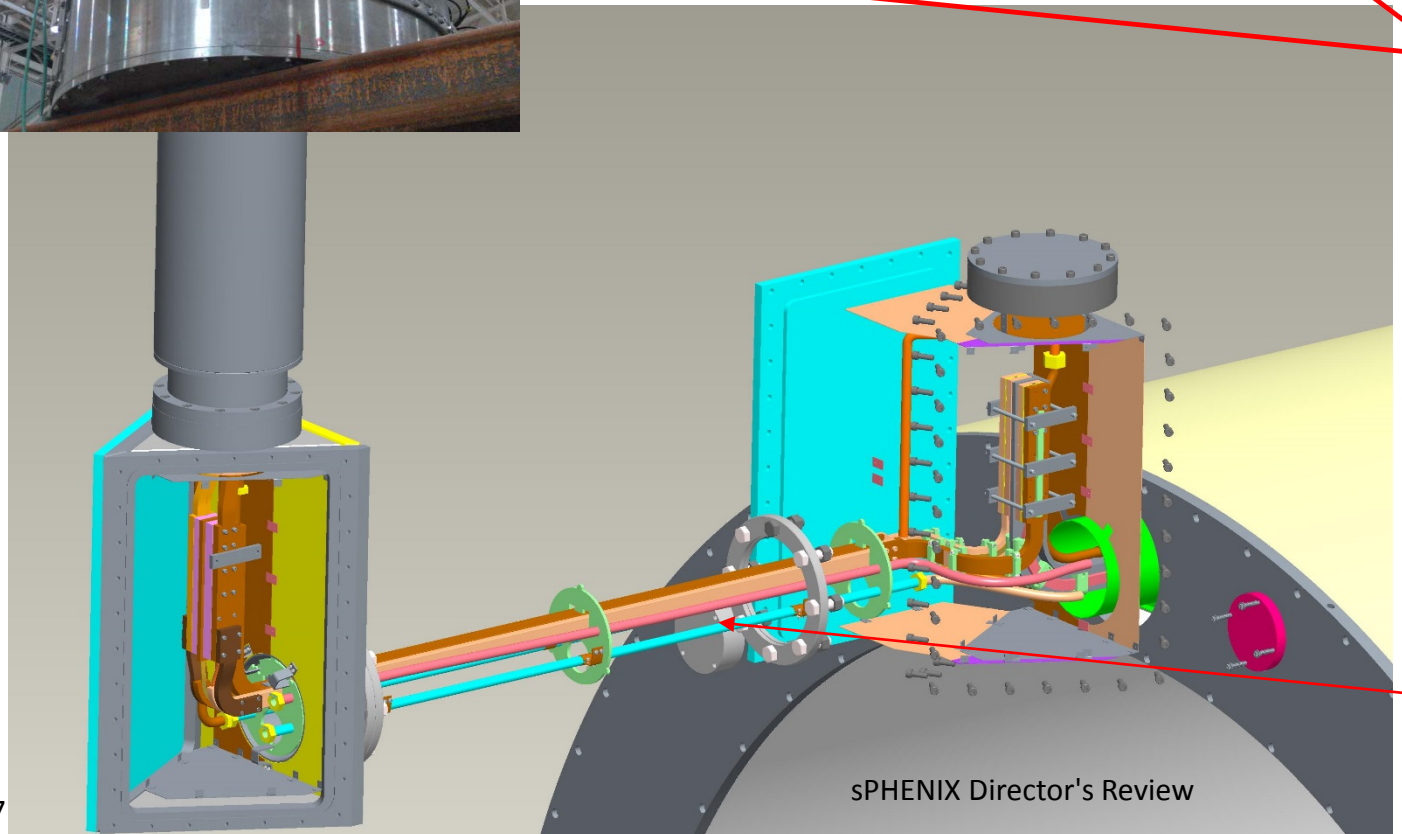
Baseline Scenario
AY k$'s - with Extraordinary Construction Overhead Application

Resource	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	FY 2022	Total
Labor	752	672	323	701	264	340	3,052
Non-Labor - Materials	19	55	300	1,189	396	0	1,959
Baseline Total	771	727	623	1,890	660	340	5,011
Contingency (30%)	231	218	187	567	198	102	1,503
MIE Total	1002	945	810	2457	858	442	6514

Resource	Baseline	Contingency	Total
Labor	3,052	916	3,968
Non- Labor	1,959	588	2,547
1.8 S/C Magnet	5,011	1503	6,514

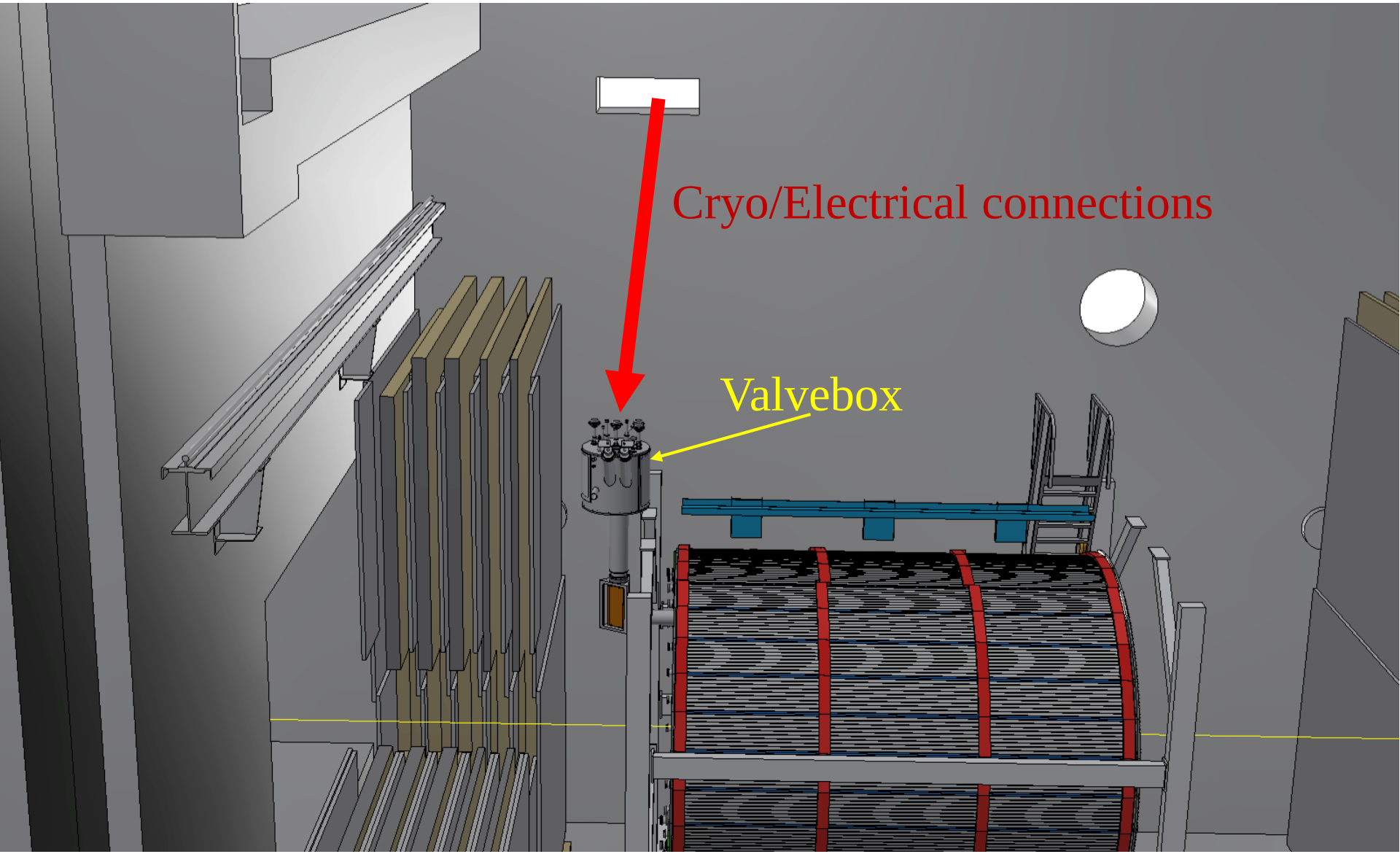


Valvebox

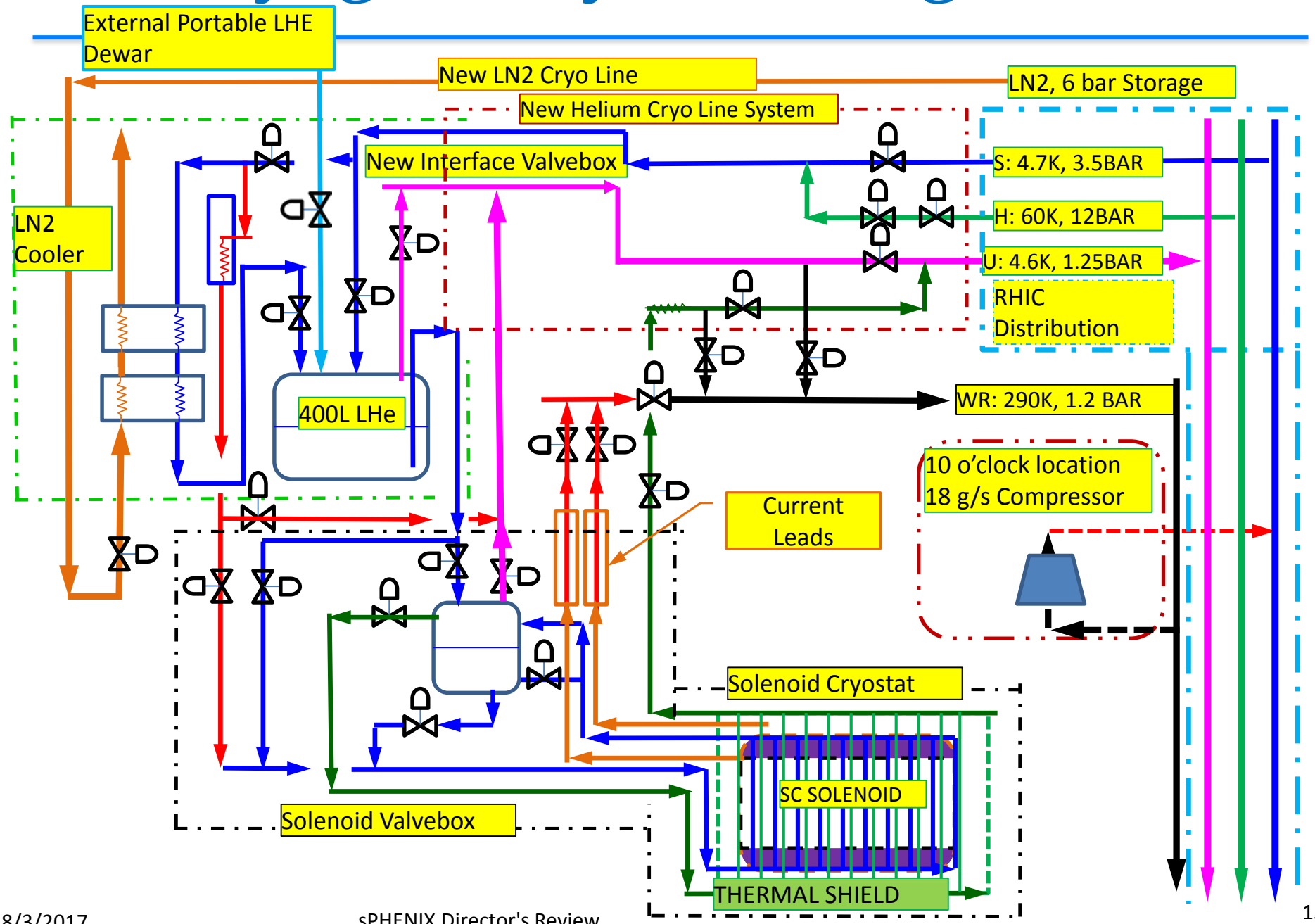


Extension

Depiction of sPHENIX Experimental Hall with Cryo/Electrical connection



Cryogenic System Diagram



Example of WBS Dictionary

1.8.3	1.8.3.3	1.8.3.3.4	Installation, warm piping systems	Install the warm piping, relief piping, and vents systems including its piping supports. Inspect, pressure test and leak test the piping system.
1.8.3	1.8.3.4		Cryo Controls Hardware	This item includes all tasks required to engineer and specify equipment for the control system hardware and to procure the equipment, build the control racks and procure or built other control panels / junction boxes. Procure the cables required between the racks and cryo equipment and interface to layout the cable trays. Complete the I/O check out and test the hardware working with the software.
1.8.3	1.8.3.4	1.8.3.4.1	Engineering and Design	Project Engineering & Management Execute procurement of these components and subsystems. Manage and interface with vendors during the procurement cycle, update schedule based on procurement progress. Procure instruments and controllers/conditioners, PLC and PLC chassis hardware, power supplies, racks and rack components, multi-conductor cables, Heater controls panels, junction box panels.
1.8.3	1.8.3.4	1.8.3.4.2	Procurement	Purchase various hardware components.
1.8.3	1.8.3.4	1.8.3.4.3	Installation: Cryo controls hardware	Install cable trays and pull cables. Install racks, junction boxes, cables, instruments, and wire-up Racks I/O to instruments, control panels, and control valves. I/O Testing and Check-out and shake down between rack and instruments and end to end check out between software and instruments/ equipment.
1.8.3	1.8.3.5		Cryo Controls Software	This item includes all tasks required to specify, engineer and program, and test the controls software required to control the cryogenic system for this project. The efforts required to complete this WBS item are described for the various subtasks as follows: Execute engineering/development, and deployment and testing of the control software for this project's cryogenic system.

Schedule and Calendar

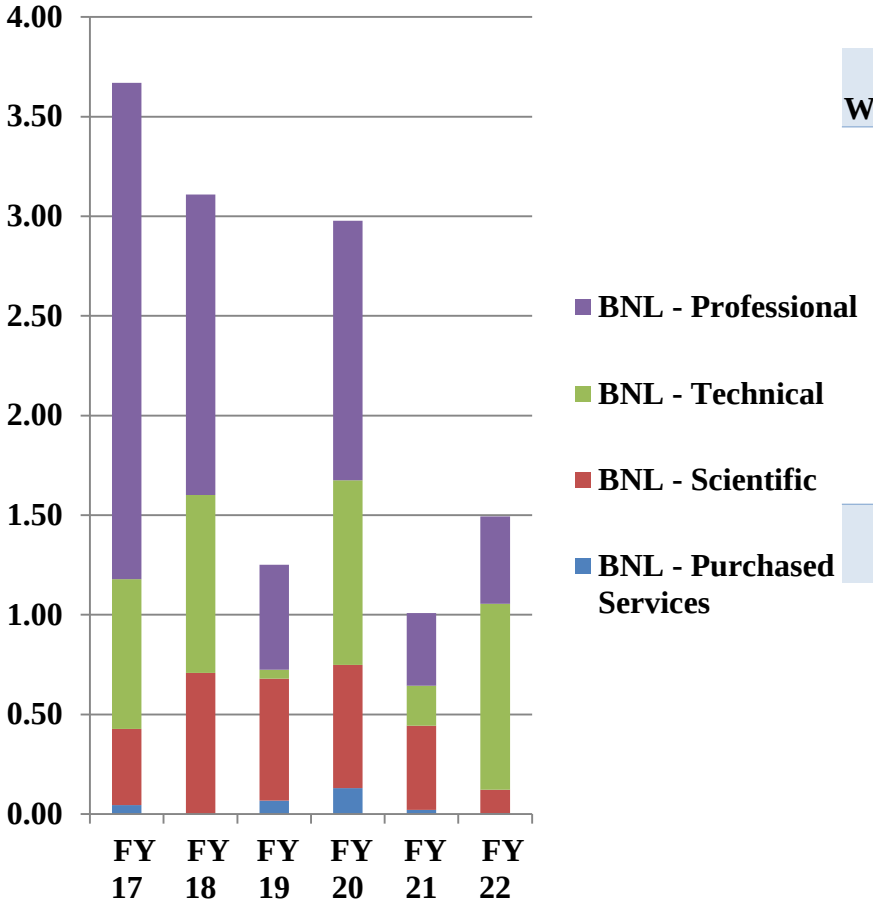
- The High-Field Test [off-project] is expected to be performed in Sept. - Oct.
  - The Booster (RF) Cavity (for "Low Energy RHIC electron Cooling") test may delay us from running even if we are all ready by September. We may need to negotiate with them. But this will not affect the sPHENIX project plan.

- Milestones :
  - 2018-6-15: Start ValveBox Disassembly
  - 2018-7-31: Coil Ready to Ship
  - 2020-1-23: Magnet (Field Measurement) Engineering & Design Complete
  - 2021-12-30: Complete Mechanical Support
  - 2022-3-15 : Installation (RHIC interface/He transfer system/Platform 4.5K/LN2 system) complete
  - 2022-4-7 : Cryo Hardware installed
  - 2022-6-2: Magnet is operational

- The Magnet, quench detector etc. will be sitting in Bldg. 912 until Fall 2021.

Superconducting Magnet Staffing

FTE Profile by Category



FTE Profile by Fiscal Year

WBS Level	Org Sort	Group	FY 17	FY 18	FY 19	FY 20	FY 21	FY 22
1.8	BNL	Purchased Services	0.05	0.00	0.07	0.13	0.02	0.00
		Scientific	0.38	0.71	0.61	0.62	0.42	0.12
		Technical	0.75	0.89	0.05	0.93	0.20	0.93
		Professional	2.49	1.51	0.53	1.30	0.36	0.44
	BNL Sum		3.67	3.11	1.25	2.98	1.01	1.49
Grand Total			3.67	3.11	1.25	2.98	1.01	1.49

1.8 Magnet – Risk Registry

Owner	WBS	Risk Name	Risk trigger (if)	Consequences (then)	Timeframe	Probability	Impact	Rank	Mitigation Plan
K. Yip	1.8 SuperConducting Magnet	Magnet does not work; cannot achieve specified field	Failure of magnet to reach field. Possible causes, Internal electrical failure, vacuum leak failure, cryo system failure, Power supply failure	Detector System can't resolve data without adequate magnetic field. Rework of magnet to correct deficiency is necessary	All	Low 10%	High: Cost ~$100-500K schedule 6-12 mos	Moderate	Full field test at bldg 912 prior to transport to bldg 1008 to proe out magnet performance, cryo, power supply and quench detection systems. Electrical check (warm) at 1008 to check for faults induced in shipping. Final full field/mapping test in 1008 IR.

- Extensive testing is being performed in order to remove risk.
  - We've completed 100 A test to show that it's superconducting.

- Available float (Fall 2017 to Fall 2021) provides adequate time for any repairs.