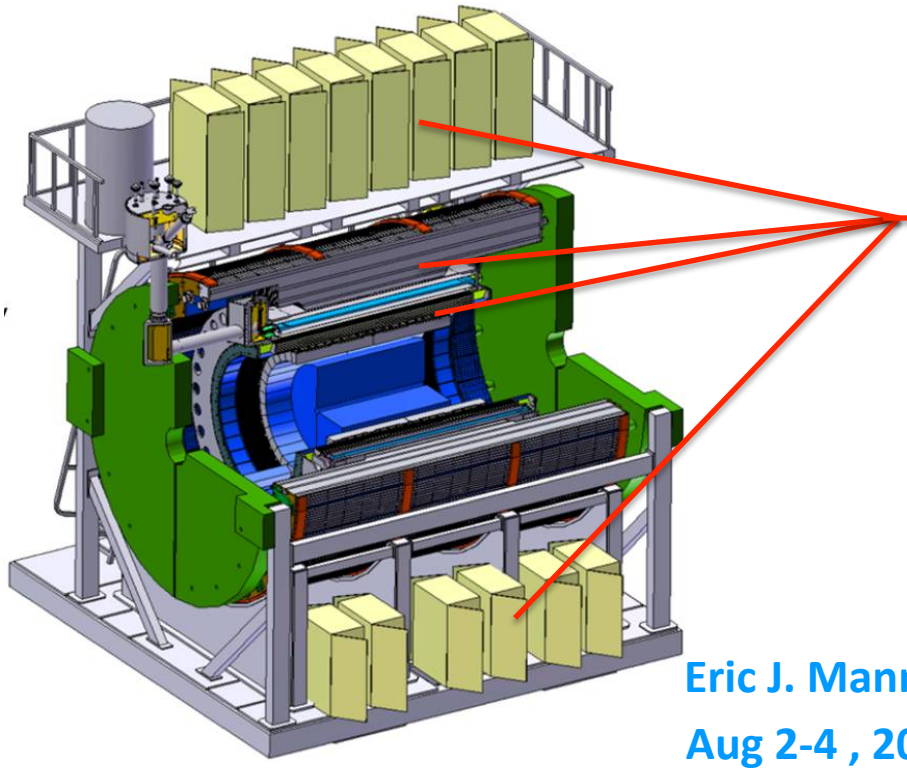
WBS 1.5 Calorimeter Electronics Directors Review



WBS	sPHENIX MIE Project Elements
1.1	Project Management
1.2	Time Projection Chamber
1.3	Electromagnetic Calorimeter
1.4	Hadron Calorimeter
1.5	Calorimeter Electronics
1.6	DAQ/Trigger
1.7	Minimum Bias Trigger Detector

WBS	Infrastructure & Facility Upgrade
1.8	SC-Magnet
1.9	Infrastructure
1.10	Installation-Integration

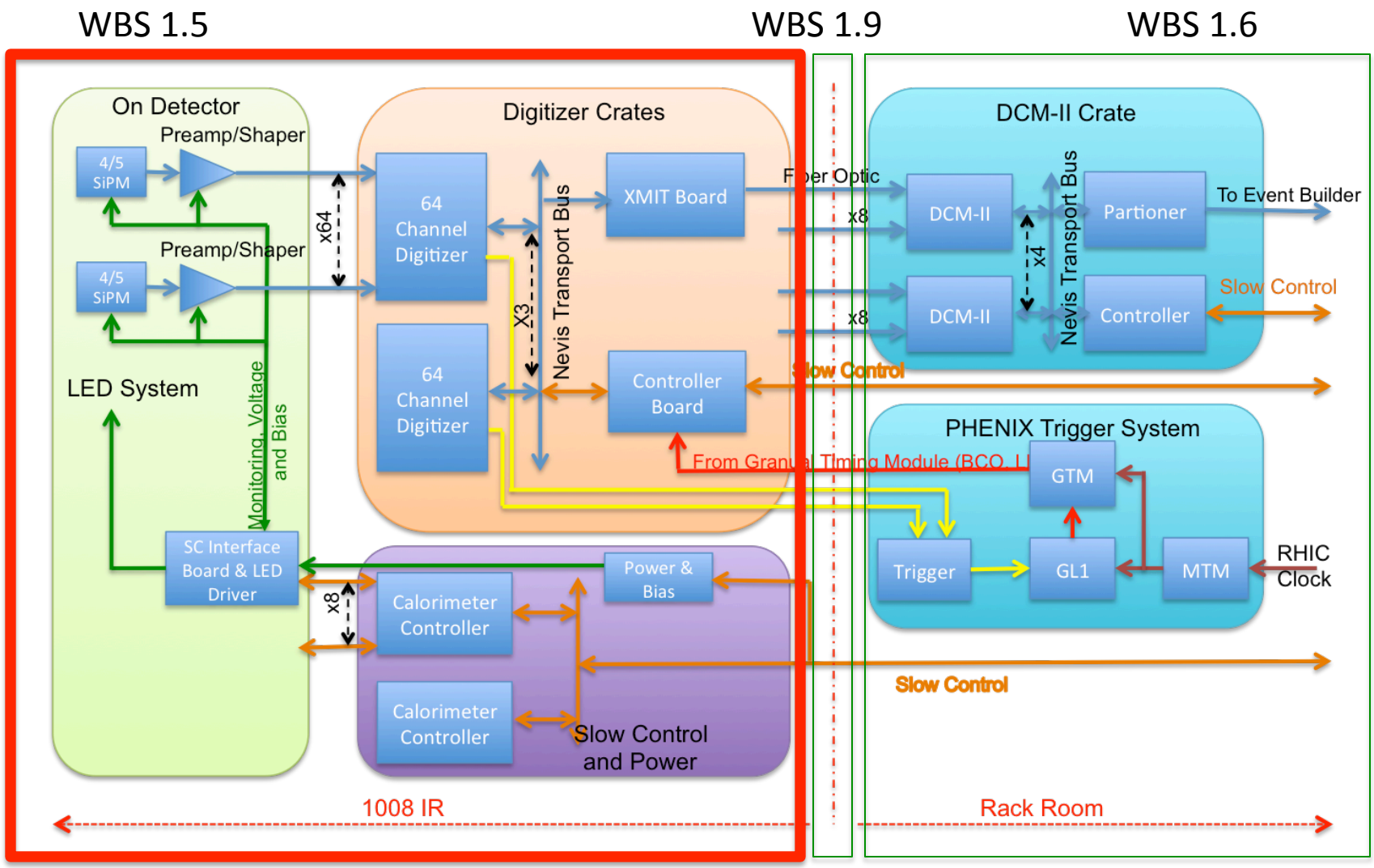
WBS	Parallel Activities
1.11	Intermediate Silicon Strip Tracker
1.12	Monolithic Active Pixel Sensor

Eric J. Mannel

Aug 2-4 , 2017

BNL

WBS 1.5 Electronics Overview-I



WBS 1.5 Electronics Overview-II

- "Common" design for both EMCal and HCal
  - Optical Sensor: Silicon Photomultiplier (SiPM)
  - Font End Analog Section:
    - Amplification/Shaping
    - Gain adjustment
    - Different packaging for EMCal and HCal.
  - Digital Backend Section:
    - Continuous waveform digitization
    - Trigger primitives
  - Common Low Voltage and Bias Voltage Systems

- Advance stage of design:
  - 3 Stages of prototypes, beam test.
  - Use "Off the Shelf" components- No custom ASICS
- Developing plans for radiation and magnetic field testing of front end boards in 2018

WBS 1.5 Technical Overview

- Silicon Photomultipliers:
  - Immune to magnetic fields
  - Susceptible to neutron damage: increased leakage current
  - 15 x 15 μm^2
  - Dynamic range: 10^4
  - Gain: 10^4
- Analog Front End
  - Common design for EMCal/HCal with different packaging.
  - Located “on” detector.
  - Shaping time of 30 nSec
  - Switchable gain
    - normal gain
    - x 16 for calibration
  - Differential analog drivers
  - LED calibration/test system
  - Monitoring of voltages, current and temperature
  - Gain adjustment via bias voltage
- Digitizer Back End
  - Identical for EMCal/HCal
  - Located “near” detector
  - 14 Bit ADC (12 bit effective)
  - 65 MHz maximum sampling frequency
  - 40 BCO latency for triggering
  - Maximum of 32 samples/ channel/event
  - 5 Event buffering
  - Generate trigger primitives based on 2x2 towers

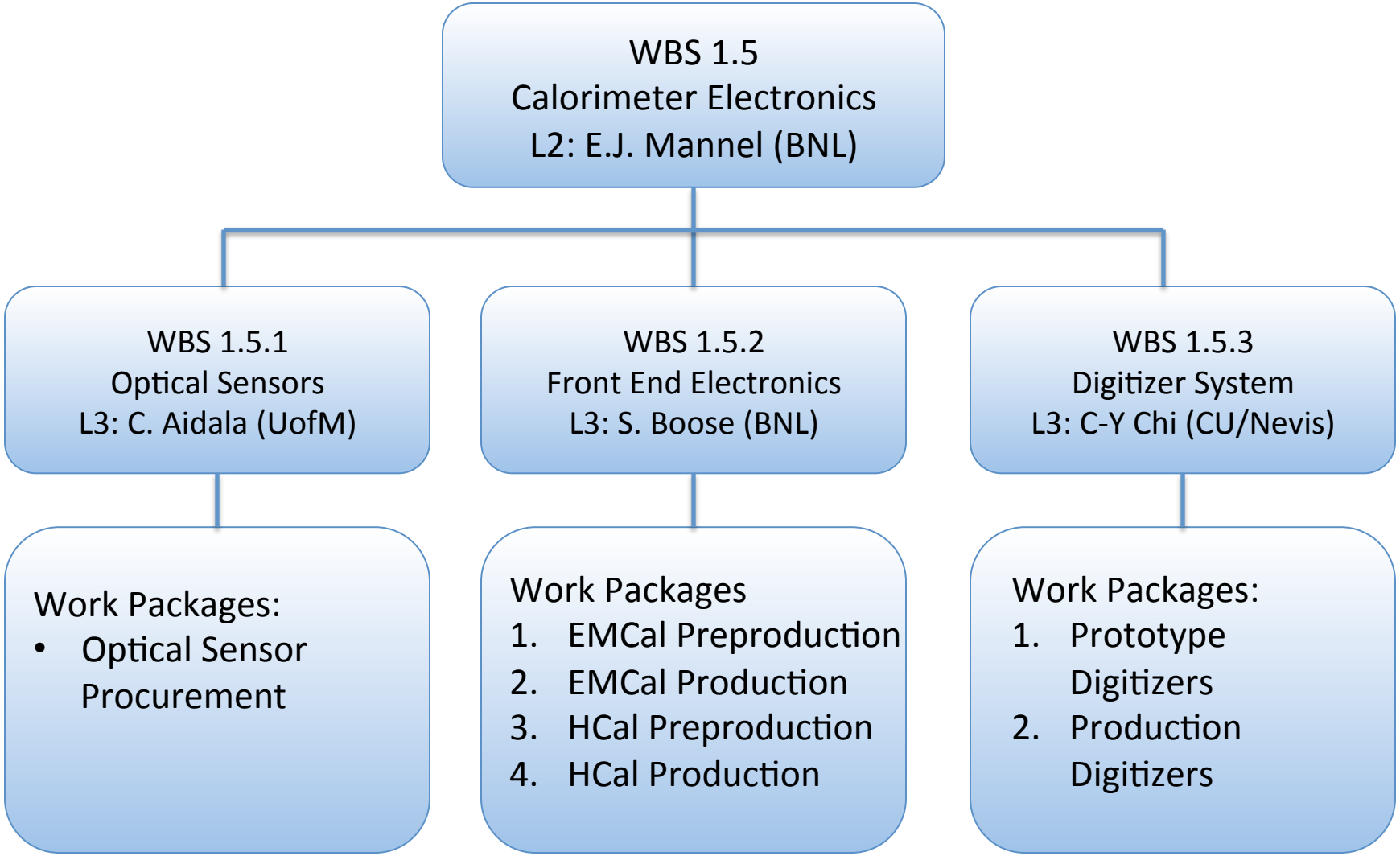
WBS 1.5 Boundaries

- Inside the Scope
  - Optical sensors for EMCal/HCal: 1.5.1
    - Test and Sort sensors
    - Lead: UofM (C. Aidala) with assistance from Debrecen, Augustana…
  - Front end analog electronics assembled and tested: 1.5.2
    - SiPM Daughter boards; Preamplifier/ Shaper boards
    - LED based calibration systems
    - Slow control and power systems
    - Internal signal and power cables
    - External Signal and Power cables to patch panels, digitizers and power supplies
    - Lead: BNL (S. Boose)
  - EMCal/HCal digitizer system assembled and tested: 1.5.3
    - Digitizer/XMIT/Trigger Trans. Boards
    - Crates and Crate controllers
    - Optical fiber to patch panels
    - Power Systems for digitizer crates
    - Lead: Columbia Univ (C-Y Chi)
- Outside the scope
  - Detectors: 1.3 EMCal/1.4 HCal
  - Installation of electronics on detector: 1.3 EMCal/1.4 HCal
  - Post-installation testing: 1.3 EMCal/1.4 HCal/Commissioning
  - Racks, AC power and safety systems:1.9 Infrastructure
  - EMCal Cooling: 1.3 EMCal/1.9 Infrastructure
  - Optical Fibers between IR and Rack Room: 1.9 Infrastructure
  - DAQ System: 1.6 DAQ

WBS 1.5 Scope

- WBS 1.5.1 Optical Sensors:
  - EMCal: 98304 SiPMS
  - HCal: 13824 SiPMs
- WBS 1.5.2 Front End Electronics:
  - EMCal: 24576 Channels
  - HCal: 3072 Channels
  - System consists of:
    - Analog preamplifier/Shaper/ Driver Circuit
    - LED Test Pulse
    - Monitoring (e.g.: Voltages, Temperatures, Current)
    - Bias and Low Voltage systems.
    - Internal signal and power cables
    - Crates for control modules
- WBS 1.5.3: Digitizer System
  - Common for EMCal and HCal
  - 27648 Total Channels
  - System consists of:
    - 432 Digitizer Boards
    - 144 XMIT Boards
    - 432 Trigger primitive transmitters
    - 36 Crates with controllers
    - Clock and Trigger distribution
    - Power supplies for 36 crates
    - 624 Patch Fibers
    - Crate Power Systems

WBS 1.5 Organization



WBS 1.5 Organization

- Dr Eric Mannel (BNL)
  - HiRes Fly's Eye Project (1995-2011): Oversaw production, testing and operations of the HiRes-II FADC based electronics
  - PHENIX VTX/FVTX Electronics Project Engineer (2011-2016)
  - sPHENIX Calorimeter Electronics oversight (2015-Present)
- Prof. Christine Aidala (Univ. of Michigan)
  - PHENIX FVTX Electronics testing and assembly.
  - Long standing member of PHENIX and sPHENIX: Executive Council Member, Physics Convener
- Steve Boose (BNL)
  - PHENIX Electrical Engineer for 20+ years
  - Analog front end systems
  - Slow control and Monitoring systems
  - Power systems.
- Dr Cheng-Yi Chi (Columbia Univ./ Nevis labs)
  - PHENIX Electronics Design & Fabrication: DCMs, HBD, MPC, RPC…
  - Neutrino Digitizer Electronics: Mico-Boone, Short-Baseline Near Detector
  - ATLAS electronics

WBS 1.5 Schedule & Cost Drivers

- Schedule Drivers:
  - SiPM Delivery
- Cost Drivers:
  - SiPMS: CD-3A item $1.1M
  - EMCal Preamps: $0.4M
  - EMCal Cables: $0.4M
  - Digitizer Boards: $0.9M

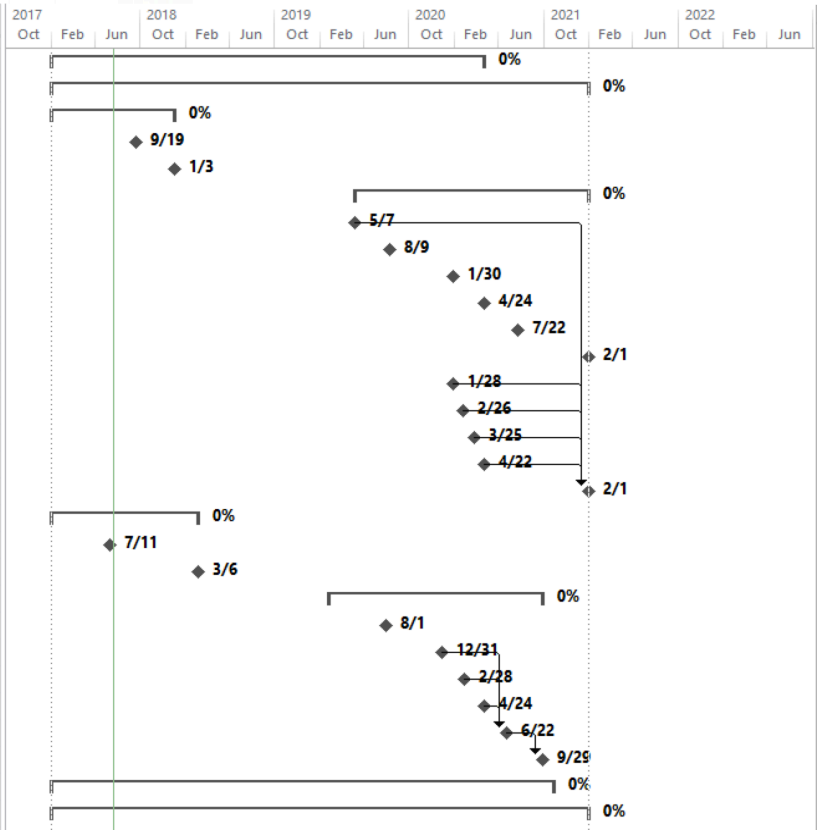
- Milestones:
  - Readiness & Safety reviews
  - Procurement start dates
  - Staged, scheduled deliveries
  - Task completion dates
- Fixed Cost in FY17 Dollars
- Average Contingency: ~30%

WBS	Name	Cost	Cost+Contingency
1.5	sPHENIX Calorimeter Electronics	4,454,789.35	5,837,669.02
1.5.1	Optical Sensors	1,095,896.80	1,526,605.52
1.5.2	Calorimeter Front End Electronics	1,681,198.58	2,220,200.41
1.5.2.1	EMCal Electronics: Preproduction Prototype	24,470.88	30,336.58
1.5.2.2	EMCal Electronics: Production	1,049,392.92	1,376,052.29
1.5.2.3	HCal Electronics: Preproduction Prototype	15,349.27	19,359.40
1.5.2.4	HCal Electronics: Production	591,985.51	794,452.14
1.5.3	Calorimeter Digitizer System	1,677,693.97	2,090,863.09
1.5.3.1	Calorimeter Digitizer: Preproduction Prototype	75,000.00	80,776.62
1.5.3.2	Calorimeter Digitizer: Production	1,602,693.97	2,010,086.47

WBS 1.5 Schedule- Partial

Milestones for Front End Electronics

WBS	Task Name	Fixed_Cost_sPHEN
1.5.1	**Optical Sensors**	**$1,095,500.00**
1.5.2	**Calorimeter Front End Electronics**	**$1,684,900.00**
1.5.2.1	**EMCal Electronics: Preproduction Prototype**	**$24,600.00**
1.5.2.1.14	Safety and Design Review Complete: EMCal Preproduction Electronics	$0.00
1.5.2.1.24	EMCal Electronics Review Complete: Preproduction Protoype	$0.00
1.5.2.2	**EMCal Electronics: Production**	**$1,042,100.00**
1.5.2.2.1	L3 Oversight: EMCal Electronics Production	$0.00
1.5.2.2.14	Production Readiness & Safety Review: EMCal Electronics	$0.00
1.5.2.2.22	25% EMCal SiPM Daughter Boards Delivered: Production	$0.00
1.5.2.2.23	50% EMCal SiPM Daughter Boards Delivered: Production	$0.00
1.5.2.2.24	75% EMCal SiPM Daughter Boards Delivered: Production	$0.00
1.5.2.2.25	100% EMCal SiPM Daughter Boards Delivered: Production	$0.00
1.5.2.2.27	25% EMCal Preamp and Interface Boards Delivered- Oroduction	$0.00
1.5.2.2.28	50% EMCal Preamp and Interface Boards Delivered- Production	$0.00
1.5.2.2.29	75% EMCal Preamp and Interface Boards Delivered- Production	$0.00
1.5.2.2.30	100% EMCal Preamp and Interface Boards Delivered- Pproduction	$0.00
1.5.2.2.32	EMCal Electronics Complete: Production	$0.00
1.5.2.3	**HCal Electronics: Preproduction Prototype**	**$15,500.00**
1.5.2.3.16	HCal Electronics Safety Review	$0.00
1.5.2.3.28	HCal Preproduction Electronics Complete	$0.00
1.5.2.4	**HCal Electronics: Production**	**$602,700.00**
1.5.2.4.16	Hcal Frontend Electronics Production Review	$0.00
1.5.2.4.25	25% Hcal SiPM & Preamp Boards complete: Production	$0.00
1.5.2.4.26	50% Hcal SiPM & Preamp Boards complete: Production	$0.00
1.5.2.4.27	75% Hcal SiPM & Preamp Boards complete: Production	$0.00
1.5.2.4.28	Hcal SiPM & Preamp Boards Complete: Production	$0.00
1.5.2.4.32	HCal Electronics Complete: Production	$0.00
1.5.3	**Calorimeter Digitizer System**	**$1,700,600.00**
1.5.4	**Project Management**	**$0.00**



WBS 1.5 CD-3A Items

- Optical Sensors: ~111k total devices
  - 98k for EMCal
  - 14k for HCal
- Catalog item from single vendor- Hamamatsu
  - Large Order, ~ $1M
  - Long lead time:
    - 1 Month to prepare documentation for order
    - 6 months to process purchase order, after documentation complete.
    - First delivery 3 months from AOR based on vendor estimate.
    - 10k devices per months over a ~1 year delivery period base on vendor estimate.
- Requires post delivery assembly, testing and sorting, ~2 months/10k devices, pipeline delivery.
- Required for assembly of HCal modules and EMCal sectors
  - ~2 month float for first EMCal SiPMs daughter boards to be delivered for installation in modules after post assembly testing

WBS 1.5 Dictionary

- Part of sPHENIX WBS Dictionary- Link
- Defined down to the work package level
- Definitions at the task level in the BOE Task Sheets
- Used as guideline for time/labor estimates

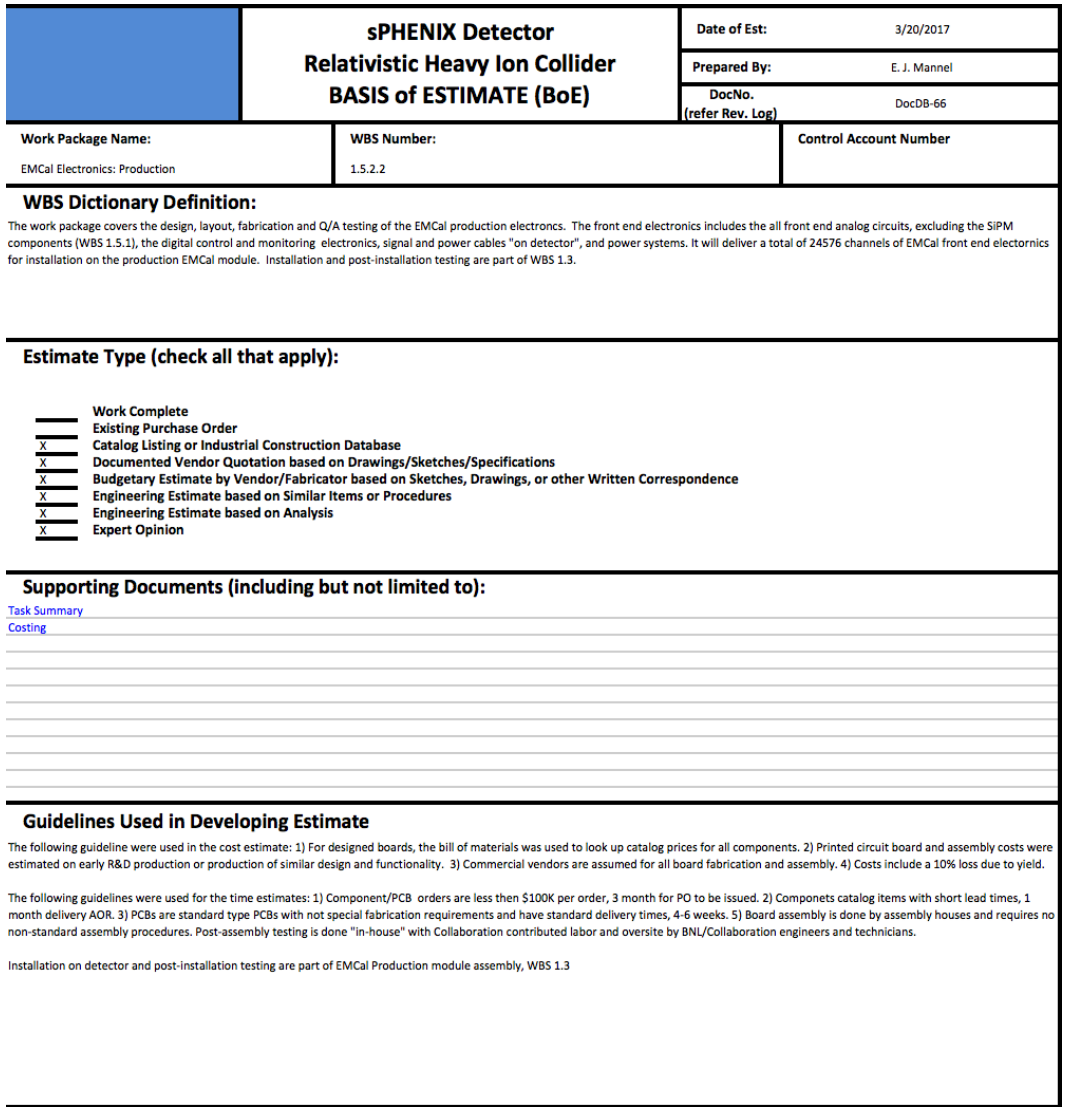
WBS L2	WBS L3	WBS L4	WBS L5	WBS Name	Dictionary Definition
1.5					
1.5				SPHENIX CALORIMETER ELECTRONICS	The Calorimeter Electronics for the sPHENIX Experiment at RHIC
1.5	1.5.1			Optical Sensors	This work packages covers the procurement and Q/A testing of the preproduction and production optical sensors for the EMCal and HCal detectors.
1.5	1.5.2			Calorimeter Front End Electronics	This covers the design, fabrication and Q/A testing of the preproduction and production calorimeter front end electronics.
1.5	1.5.2	1.5.2.1		EMCal Electronics: Preproduction Prototype	The work package covers the design, layout, fabrication and Q/A testing of the EMCal preproduction prototype electronics. It will deliver a total of 384 channels of EMCal frontend electronics.
1.5	1.5.2	1.5.2.2		EMCal Electronics: Production	The work package covers the design, layout, fabrication and Q/A testing of the EMCal production electronics. It will deliver a total of 24576 channels of EMCal frontend electronics.
1.5	1.5.2	1.5.2.3		HCal Electronics: Preproduction Prototype	The work package covers the design, layout, fabrication and Q/A testing of the HCal preproduction prototype electronics. It will deliver a total of 48 channels of HCal frontend electronics.
1.5	1.5.2	1.5.2.4		HCal Electronics: Production	The work package covers the design, layout, fabrication and Q/A testing of the HCal production electronics. It will deliver a total of 3072 channels of HCal frontend electronics.
1.5	1.5.3			Calorimeter Digitizer System	This covers the design, fabrication and Q/A testing of the preproduction and production calorimeter digitizer electronics.
1.5	1.5.3	1.5.3.1		Calorimeter Digitizer: Preproduction Prototype	This work package covers the final design, layout and fabrication for the preproduction digitizers needed for the sPHENIX EMCal and HCal detectors. The EMCal requires a total of 364 channels, and the HCal requires a total of 48 channels
1.5	1.5.3	1.5.3.2		Calorimeter Digitizers: Production	This work package covers the final design, layout and fabrication for the production digitizers needed for the sPHENIX EMCal and HCal detectors. The EMCal requires a total of 24576 channels, and the HCal requires a total of 3072 channels. The Digitizer System consists of the 64 channel ADC Digitizer boards, XMIT boards, Controller boards, Clock Masters Boards, Trigger Transmitter Modules, Crates, associated power supplies, and patch fibers from the digitizer crates to the local patch panel in the 1008 interaction region.

Basis for BOE and RLS

- All components are standard off the shelf items.
  - 2 long lead time item, SiPMs & SiPM Bias Supplies,
  - No custom ASICs
  - “Standard” PCB fabrication and assembly
- Design work completed during R&D Phase
  - Use BOMs for component cost, scaled to larger orders
  - Use prototype fabrications costs, scaled to larger orders.
  - Working with some local vendors to “value engineer some assemblies.
- Standard lead times for placing orders
  - Time to prepare order documentation- 1 month typical
  - 2-6 months for PO to be issued based on expected order cost
  - Delivery times based on vendor estimates, engineering experience
- Three CAM Accounts/BoE Files as of July 2017
  - WBS 1.5.1: Optical Sensors
  - WBS 1.5.2: Front End Electronics
  - WBS 1.5.3: Digitizers

WBS 1.5 BoE Example: BoE Page 1

- Have detailed BOE for each work package, 7 Total:
- Identify what type of estimates were used in each work package
- Guidelines used for estimates, both cost and time
- Three BoE files as of July 2017
  - WBS 1.5.1: Optical Sensors
  - WBS 1.5.2: Front End Electronics
  - WBS 1.5.3: Digitizers



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

Date of Est:	3/20/2017
Prepared By:	E. J. Mannel
DocNo. (refer Rev. Log)	DocDB-66

Work Package Name:	WBS Number:	Control Account Number
EMCal Electronics: Production	1.5.2.2	

WBS Dictionary Definition:

The work package covers the design, layout, fabrication and Q/A testing of the EMCal production electroncs. The front end electronics includes the all front end analog circuits, excluding the SiPM components (WBS 1.5.1), the digital control and monitoring electronics, signal and power cables "on detector", and power systems. It will deliver a total of 24576 channels of EMCal front end electornics for installation on the production EMCal module. Installation and post-installation testing are part of WBS 1.3.

Estimate Type (check all that apply):

	Work Complete
	Existing Purchase Order
x	Catalog Listing or Industrial Construction Database
x	Documented Vendor Quotation based on Drawings/Sketches/Specifications
x	Budgetary Estimate by Vendor/Fabricator based on Sketches, Drawings, or other Written Correspondence
x	Engineering Estimate based on Similar Items or Procedures
x	Engineering Estimate based on Analysis
x	Expert Opinion

Supporting Documents (including but not limited to):

Task Summary
Costing

Guidelines Used in Developing Estimate

The following guideline were used in the cost estimate: 1) For designed boards, the bill of materials was used to look up catalog prices for all components. 2) Printed circuit board and assembly costs were estimated on early R&D production or production of similar design and functionality. 3) Commercial vendors are assumed for all board fabrication and assembly. 4) Costs include a 10% loss due to yield.

The following guidelines were used for the time estimates: 1) Component/PCB orders are less then $100K per order, 3 month for PO to be issued. 2) Componets catalog items with short lead times, 1 month delivery AOR. 3) PCBs are standard type PCBs with not special fabrication requirements and have standard delivery times, 4-6 weeks. 5) Board assembly is done by assembly houses and requires no non-standard assembly procedures. Post-assembly testing is done "in-house" with Collaboration contributed labor and oversite by BNL/Collaboration engineers and technicians.

Installation on detector and post-installation testing are part of EMCal Production module assembly, WBS 1.3

WBS 1.5 BoE Example: BoE Page 2

- Identify what is included in the BOE,
- What the total cost and cost + contingency
- Explain how the contingency was determined and the levels used.

Details of the Base Estimate (explanation of the Work)

This work package covers the preproduction design, layout, fabrication and Q/A testing of the EMCal frontend electronics. The design and layout stages covers all modifications to earlier prototype designs. Procurement covers obtaining all quotes, placing and tracking orders, and receipt of orders. Q/A testing covers the cost of all test equipment and the testing of the fabricated modules prior to installation. This workpackage also includes the controller boards required for HCal which are identical in design and functionality. Installation of electronics and post-installation are part of EMCal module assembly.

Cost Summary

Task	Cost Basis	Cost	Cost + Contingency
Parts Procurement	Catalogue/Quote/Eng Estimate	902,045.72	1,169,766.21
Board Assembly and Testing	Catalogue/Quote/Eng Estimate	147,347.20	206,286.08
Total Work Package Cost		1,049,392.92	1,376,052.29

Contingency

M&S Contigency Rules Applied

For Parts: M3 (20%) Based on BOMs for most recent prototypes
For Assembly: M4 (30%) Engineering estimate based on last round of prototype assembly.
For Cables: M4 (40%) Engineering estimate based on early prototype

Labor Contingency Rules Applied:

BNL Labor for design, layout, assembly oversight, and testing oversight: L3 (25%)
Univeristy Students for testing: L3 (25%)

WBS 1.5 Task Summary Example

Used to:

- Summarize cost at the task level
- Estimate labor requirements

WBS: 1.5.2.2
EMCal Electronics: Production
Date: 28-Feb-2017
Last Revision Date: 06-July-2017

WBS	Task	Task Description	Duration (d)	Scientist		Engineer		Designer		Technician		Trades		Student		Materials and Supplies	Materials and Supplies + Contingency	Risk Code	
				FTE	days	FTE	days	FTE	days	FTE	days	FTEs	days	FTEs	days			Labor	Material
1.5.2.2.18	Procure components: EMCal Interface Board: Production.	This task covers the procurement of all components need for assembly of the EMCal Interface board. Deliverables are assembly kits and documentation necessary for final assembly	80 days			0.25	16			0.5	24					27,478.69	32,974.42	L3	M3
1.5.2.2.19	Procure Internal EMCal Signal and Power Cables: Production	This task covers the procurement of all the signal and power cables that are installed inside the EMCal 1/2 sectors.	220 days	0.25	24	0.25	24			0.2	30					11,193.60	15,671.04	L3	M3
1.5.2.2.20	Procure External EMCal Signal and Power Cables, Controller Crates and Power Systems: Production	This task covers the procurement of all external power and signal cables, crates and power systems needed for installation in the IR	220 days	0.25	24	0.25	24			0.2	30					430,694.66	601,906.22	L3	M3
1.5.2.2.21	Assemble and Test SiPM Daughter Boards : Production.	This task covers the assembly and testing of the EMCal SiPM daughter boards required for production of EMCal electronnics . Deliverables are the SiPM Daughter boards for the full detector	310 days	0.5	44	0.5	44			0.5	66			1	140	54,067.20	75,694.08	L3	M3
1.5.2.2.22	25% EMCal SiPM Daughter Boards Delivered: Production	Milestone	0 days																
1.5.2.2.23	50% EMCal SiPM Daughter Boards Delivered: Production	Milestone	0 days																
1.5.2.2.24	75% EMCal SiPM Daughter Boards Delivered: Production	Milestone	0 days																
1.5.2.2.25	100% EMCal SiPM Daughter Boards s Delivered: Production	Milestone	0 days																
1.5.2.2.26	Assemble and Test EMCal Preamp and Interface Boards: Production	This task covers the assembly and testing of the EMCal Preamp and Interface boards required for the production EMCal electronics . Deliverables are the Preamp and Interface boards for the ful EMCal detector	80 days			0.25	16			0.5	24			0.6	20	84,480.00	118,272.00	L3	M3
1.5.2.2.27	25% EMCal Preamp and Interface Boards Delivered	Milestone	0 days																
1.5.2.2.28	50% EMCal Preamp and Interface Boards Delivered	Milestone	0 days																
1.5.2.2.29	75% EMCal Preamp and Interface Boards Delivered	Milestone	0 days																
1.5.2.2.30	100% EMCal Preamp and Interface Boards Delivered	Milestone	0 days																
1.5.2.2.31	Assemble and Test Calorimeter Controller Boards: Production-EMCal+Hcal	This task covers the assembly and testing of the EMCa/HCal Controller boards required for the production EMCal/HCal detectors . Deliverables are the Controllers for both the EMCal and HCal.	80 days			0.25	16			0.5	24			0.6	20	8,800.00	12,320.00	L3	M4
1.5.2.2.32	EMCal Electronics Complete: Production	Milestone	0 days																
1.6.1	Total Cost:			2.50	137	7.35	339	2.25	83	3.40	247	0.00	0	2.20	180	1,049,392.92	1,376,052.29		

WBS 1.5 BoE Example: System Cost

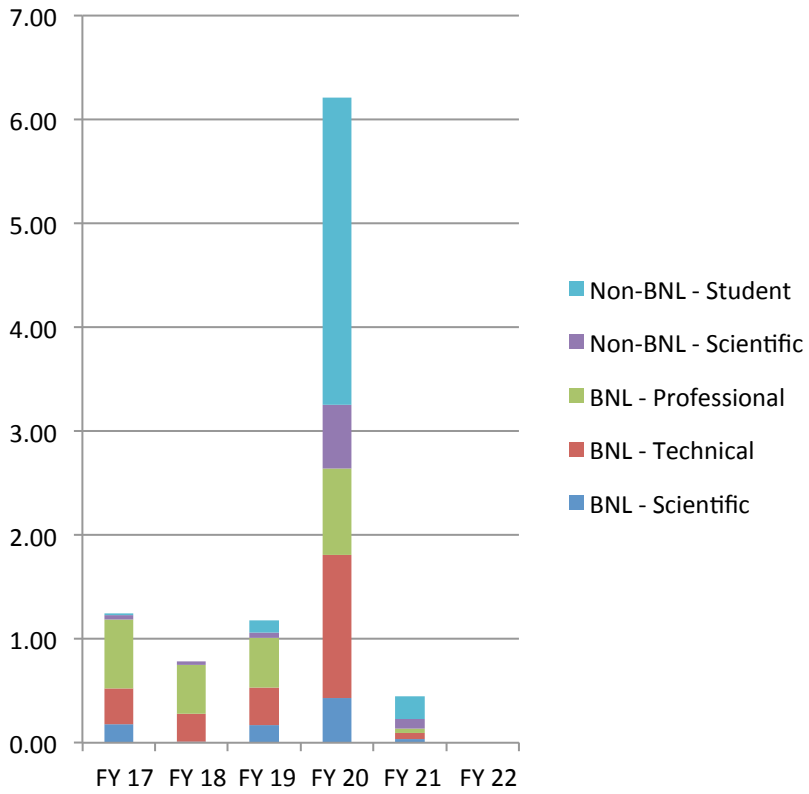
- Costs are estimated at the task level
- Based on:
  - Number of modules required
  - BOMs for prototype boards
- Cost contingency 20% for components, 40% for assembly,
- Includes 10% loss due to yield estimates

WBS 1.5.2 System Costs
Date: 5-Mar-2017
Last Revision Date: 01-June-2017

	Module	Quantity	Cost	NRE	Total Cost	Total Cost + 10%	Contingency	Total Cost + Contigency
Production								
	SiPM Daughter Boards- Parts	6,144	3.95		24,282.75	26,711.02	0.20	32,053.23
	SiPM Daughter Boards- Assembly	6,144	8.00		49,152.00	54,067.20	0.40	75,694.08
	SiPM Daughter Boards- Total				73,434.75	80,778.22		107,747.31
	EMCal Preamp Boards- Parts	1,536	217.38		333,902.16	367,292.38	0.20	440,750.85
	EMCal Preamp Boards- Assembly	1,536	100.00		38,400.00	42,240.00	0.40	59,136.00
	EMCal Preamp Boards- Total				372,302.16	409,532.38		499,886.85
	EMCal Interface Boards- Parts	384	439.49		35,159.43	38,675.38	0.20	46,410.45
	EMCal Interface Boards- Assembly	384	100.00		38,400.00	42,240.00	0.40	59,136.00
	EMCal Interface Boards- Total				73,559.43	80,915.38		105,546.45
	EMCal/HCal Controller Boards- Parts	80	312.26		24,980.62	27,478.69	0.20	32,974.42
	EMCal/HCal Controller Boards- Assembly	80	100.00		8,000.00	8,800.00	0.40	12,320.00
	EMCal/HCal Controller Boards- Total				32,980.62	36,278.69		45,294.42
	EMCal Controller Crate	4	1,211.71		4,846.84	5,331.52	0.20	6,397.83
	EMCal Power Supplies	1	120,736.00		120,736.00	132,809.60	0.40	185,933.44
	Test Pulse Splitter	4	1,000.00		4,000.00	4,400.00	0.40	6,160.00
	EMCal Cables- Internal	1	10,176.00		10,176.00	11,193.60	0.40	15,671.04
	EMCal Cables- External	1	261,957.76		261,957.76	288,153.54	0.40	403,414.95
	Misc Total				401,716.60	441,888.26		617,577.26

WBS 1.5 Labor Profile

- FTE Profile by Category

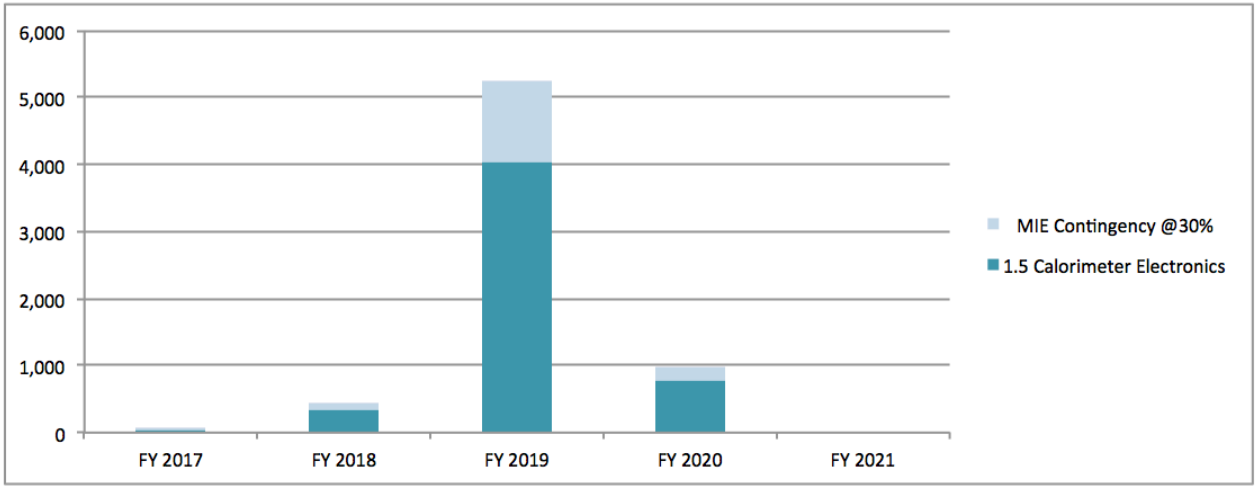


- FTE Profile by Fiscal Year

WBS Level	Org Sort	Group	FY 17	FY 18	FY 19	FY 20	FY 21	FY 22
1.5	BNL	Scientific	0.18	0.01	0.17	0.43	0.04	0.00
		Technical	0.34	0.27	0.36	1.38	0.06	0.00
		Professional	0.66	0.47	0.47	0.84	0.04	0.00
	BNL Sum		**1.19**	**0.75**	**1.01**	**2.64**	**0.13**	**0.00**
	Non-BNL	Scientific	0.04	0.03	0.05	0.61	0.09	0.00
		Student	0.02	0.00	0.12	2.96	0.22	0.00
	Non-BNL Sum		**0.06**	**0.03**	**0.17**	**3.57**	**0.31**	**0.00**
Grand Total			**1.25**	**0.78**	**1.17**	**6.21**	**0.45**	**0.00**

WBS 1.5 Cost Profile

Baseline Scenario
AY k$'s - with Extraordinary Construction Overhead Application (PM Labor in Ops Support)



Baseline Scenario
AY k$'s - with Extraordinary Construction Overhead Application (PM Labor in Ops Support)

WBS	SYSTEM	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	Total
1.5	**Calorimeter Electronics**	52	351	4,051	767	0	5,221
	MIE Contingency @30%	16	105	1,215	230	0	1,566
	MIE Total	68	456	5266	997	0	6787

WBS	SYSTEM	Baseline	Contingency(30%)	Total
1.5	**Calorimeter Electronics**	5,221	1566	6,787

Includes escalation and overhead

WBS 1.5 Risk Registry

			sPHENIX Risk Registry						
2	Owner	WBS	Risk Name	Risk trigger (if)	Consequences (then)	Timeframe	Probability	Impact	Rank	Mitigation Plan
18	E. Mannel	1.5 Cal Electronics	Delay in SiPM Delivery	SiPM order not placed on schedule or vendor unable to meet production schedule	Delay in assembly of HCal and EmCal SiPM daughter boards. Potential delay in HCal and EMCal module assembly	Procurement	Moderate: 50%	Low: Schedule delay 2-3 months	Low	Closely monitor the procurement stage.
19	E. Mannel	1.5 Cal Electronics	Delay in testing of SiPMs	SiPM Delivery not placed on schedule or vendor unable to meet prodcution schedule	Delay in assembly of HCal and EMCal SiPM daughter boards. Potential delay in HCal and EMCal module assembly	Production	Moderate: 50%	Low: Schedule delay 2-3 months	Low	Increase number of testing stations. Identify additional collaborators who can contribute to the testing program. Streamline testing program.
20	E. Mannel	1.5 Cal Electronics	Delay in Assembly of HCal Daughter boards, Preamps, Interface boards, LED	Procurement of components, issuing of orders.	Potential delay in HCal module assembly and testing	Production	Moderate: 25%	Low: Schedule delay 2-3 months	Low	Staged partial deliveries of boards. Use multiple assembly houses
21	E. Mannel	1.5 Cal Electronics	Delay in assembly of EMCal Daughter boards, Preamps or Interface boards	Procurement of components, issuing of orders.	Potential delay in EMCal module assembly and testing	Production	Moderate: 25%	Low: Schedule delay 2-3 months	Low	Staged partial deliveries of boards. Use multiple assembly houses

- Risk analysis based on risk matrix document- See Irina's talk
- Standard for sPHENIX

Table 3: Impact Assessment Matrix for Project-Level Global Risks

Impact / Risk Area	Low	Moderate	High
Cost:	≤ $250K	≤$500K	>$500K
Schedule:	Delays Level 2 milestone or Project critical path by ≤3 month	Delays Level 2 milestone or Project critical path by ≤6 months	Delays Level 2 milestone or Project critical path by >6 months
Scope/Technical:	Negligible, if any, degradation.	Significant technical/scope degradation.	Baseline scope or performance requirements will not be achieved.

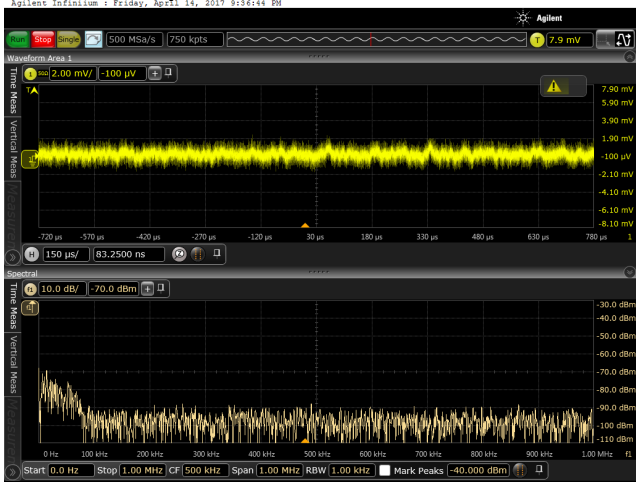
Table 6: Risk Classification Matrix

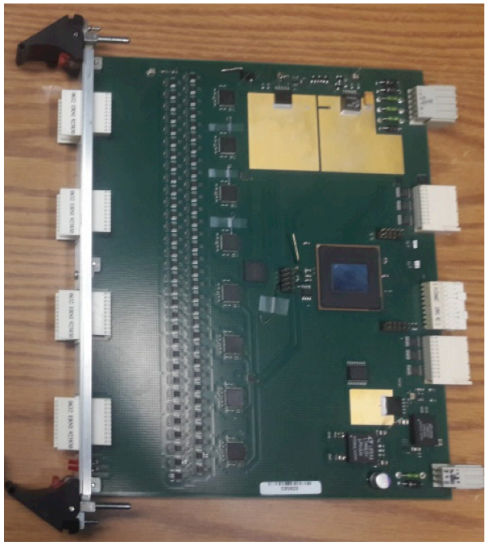
	Impact		
Probability	Low	Moderate	High
High (probability > 75%)	Moderate	High	High
Moderate (25% < probability < 75%)	Low	Moderate	High
Low (probability < 25%)	Low	Low	Moderate

WBS 1.5 Prototypes

- Most devices in advanced stage of development- Three prototype stages to date with beam tests
- Cost estimates based on prototype designs
- Analog modules used as part of T-1044
- Low technical risk

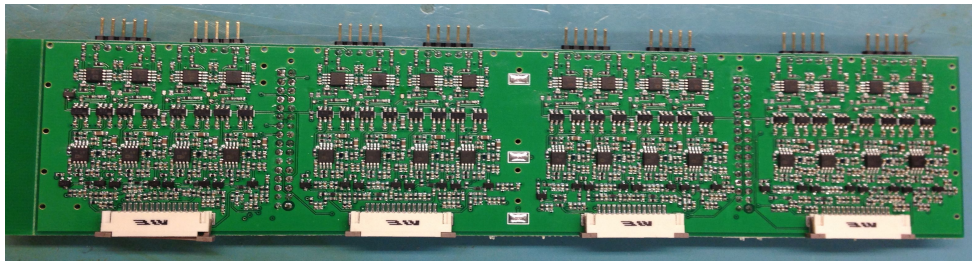
Preamp Noise Measurement





Digitizer Module

2x8 EMCal Preamp Module



Summary

- Costs & Schedule are well defined based on prototype designs
- Concerns:
  - SiPM Procurement:
    - Single vendor, long lead time
    - Will need to monitor purchase process closely
  - SiPM Testing/Assembly
    - Critical for EMCal/HCal performance
    - Tied to SiPM delivery schedule
    - Monitor schedule closely, multiple test facilities
    - Value Engineer assembly process with potential assembly house(s)
    - Multiple testing sites
  - Front End Electronics Assembly & Testing
    - Needed for EMCal Sector/HCal assembly
    - Closely monitor schedule
    - Early design of test procedures, value engineering
- Very mature design, minimal technical risks, tight schedule.

Back Up

WBS 1.5: Detailed Cost Estimate

Used to estimate board costs
Based on prototype BOMs
Catalog pricing/Vendor budgetary quotes

A	B	C	D	E	F	G
Sphenix WBS 1.5.3: Digitizer Crate Controller						
8/10/15						
DESCRIPTION	MANUFACTURER	PART NO.	QUANT.		UNIT COST	MODULE COST
PC BOARD	PAL PILOT	cal_crate_control	1	Pal PILOT	70.95	70.95
NRE	PAL PILOT	cal_crate_control	1	Pal PILOT	0.00	0.00
DIODE	VISHAY	SA24A-E3/54	1	DigiKey	0.27	0.27
1A, LOW DROPOUT CMOS LINEAR REGULATOR	ANALOG DEVICES	ADP1706ARDZ-1.2R7	1	Arrow	1.09	1.09
1A, LOW DROPOUT CMOS LINEAR REGULATOR	ANALOG DEVICES	ADP1706ARDZ-2.5R7	1	Arrow	1.09	1.09
TRANSCEIVER	AVAGO	AFBR-59R5LZ	1	Arrow	29.99	29.99
FERRITE BEAD - 0805 - 330 OHM	MURATA	BLM21PG331SN1D	4	DigiKey	0.02	0.08
CAPACITOR - 0402 - .001 MFD (1nf) - 50V	CALCHIP	GMC04X7R102K50NT	2	DigiKey	0.03	0.06
CAPACITOR - 0402 - 0.01 MFD (10nf)	CALCHIP	GMC04X7R103K50NT	15	DigiKey	0.03	0.45
CAPACITOR - 0402 - 0.1 MFD (100nf) - 16V	CALCHIP	GMC04X7R104K16NT	42	DigiKey	0.02	0.84
CAPACITOR - 0402 - 0.1 MFD (100nf) - 16V	CALCHIP	GMC04X7R104K16NT	2	DigiKey	0.02	0.04
CAPACITOR - 0603 - 0.1 MFD (100nf)	CALCHIP	GMC10X7R104K25NT	3	DigiKey	0.02	0.06
CAPACITOR - 0805 - 10 MFD, 16V, X5R	CALCHIP	GMC21X5R106K16NTLF	2	DigiKey	0.06	0.11
CAPACITOR - 0805 - 1 MFD, 16V, X7R	CALCHIP	GMC21X7R105K16NTLF	1	DigiKey	0.03	0.03
CAPACITOR - 0805 - 4.7 MFD - 25V	CALCHIP	GMC21X7R475K25NT	2	DigiKey	0.04	0.09
CAPACITOR - 1206 - 10 MFD - 25 VDC - X5R	MURATA	GRM31CR61E106KA12L	2	DigiKey	0.09	0.19
CAPACITOR - 1206 - 4.7 MFD, 50 VOLT, X5R	TAIYO YUDEN	UMK316BJ475KL-T	1	DigiKey	0.10	0.10
CAPACITOR - 1210 - 10MFD - 16V - Y5V	CALCHIP	GMC32Y5V106Z16NT	2	DigiKey	0.06	0.12
CAPACITOR - 1210 - 100 MFD - 6.3 V - X5R	MURATA	GRM32ER60J107ME20L	1	DigiKey	0.34	0.34
CAPACITOR - 1210 - 10 MFD, 50 VOLT, X5R	TAIYO YUDEN	UMK325BJ106KM-T	1	DigiKey	0.25	0.25
CONNECTOR - LEMO RA	LEMO	EPL.00.250.NTN	2	DigiKey	5.32	10.64
QUAD RECEIVER	NATIONAL	DS90LV048ATMTC/NOPB	3	Arrow	1.31	3.93
1 TO 10 LVDS CLOCK DISTRIBUTION	NATIONAL	DS90LV110ATMT/NOPB	2	Arrow	4.00	8.00
CYCLONE 2	ALTERA	EP2C5Q208C7N	1	Arrow	18.63	18.63
1 Mbit SERIAL CINFIGURATION DEVICE	ALTERA	EPCS4SI8N	1	Arrow	13.80	13.80
Right Angle Female Connectors For Daughter Cards: Type C - Press fit 55 pins	ERNI	354865	2	Arrow	2.17	4.34
Right Angle Male Power Modules For Daughter Cards - 3 pins	ERNI	114402	1	Arrow	2.60	2.60
ERMET - ZD 10 ROW	ERNI	973046	2	Arrow	5.16	10.32
2 AMP FUSE	LITTLEFUSE	0251002.MRT1L	1	DigiKey	0.31	0.31
SOCKET PIN	AMP/TYCO	2-5331272-7	2	Arrow	0.25	0.49
HOLE_PANEL		HOLE_PANEL	3	DigiKey	0.00	0.00
LOW SKEW, 1 TO 2 DIFFERENTIAL TO LVCMOS / LVTTL FANOUT BUFFER	IDT	ICS83026BMI-01LF	1	Digikey	5.85	5.85
2:4, LVDS Output Fanout Buffer	IDT	8SLVD1204-33NLGI	1	Digikey	10.21	10.21
JTAG	SAMTEC	TSW-105-07-G-D	1	DigiKey	0.21	0.21
LED	LUMEX	SSL-LX24731ID	2	DigiKey	0.18	0.36