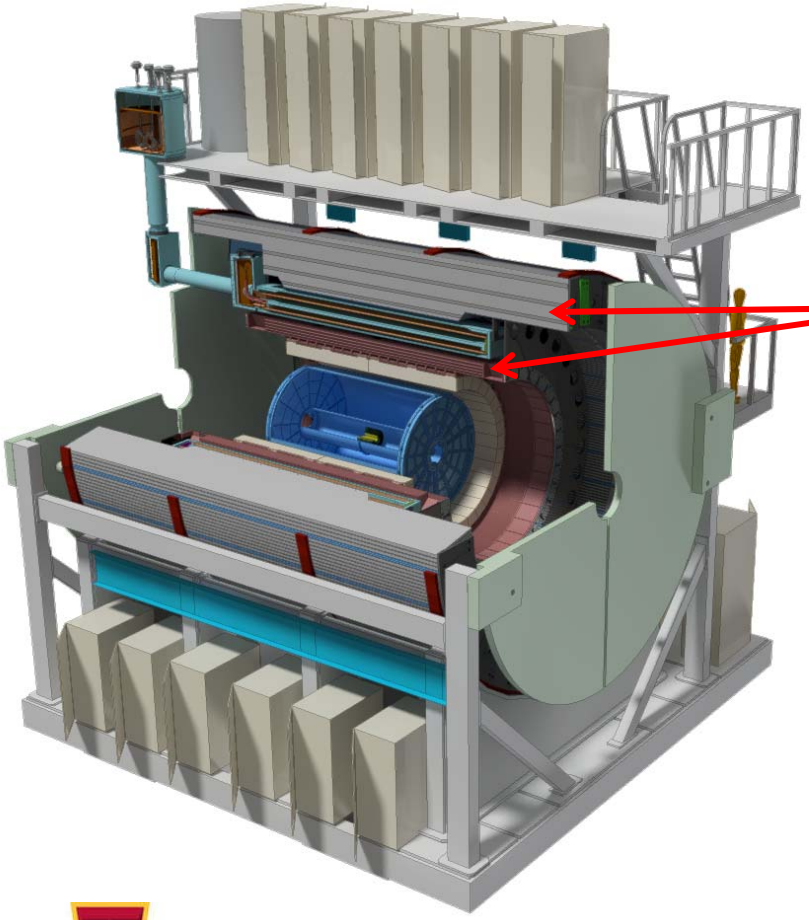
sPHENIX Director's Review



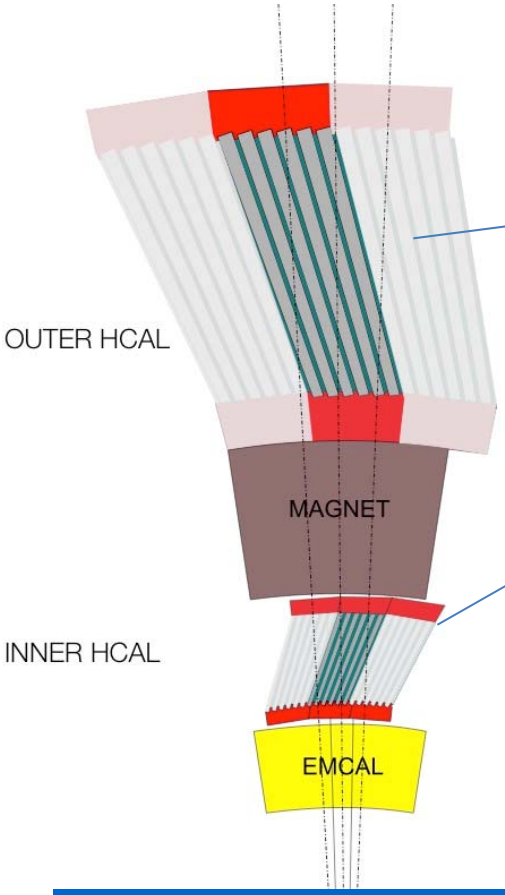
WBS	sPHENIX MIE Project Elements
1.1	Project Management
1.2	Time Projection Chamber
1.3	Electromagnetic Calorimeter
1.4	Hadron Calorimeter
1.5	Calorimeter Electronics
1.6	DAQ-Trigger
1.7	Minimum Bias Trigger Detector

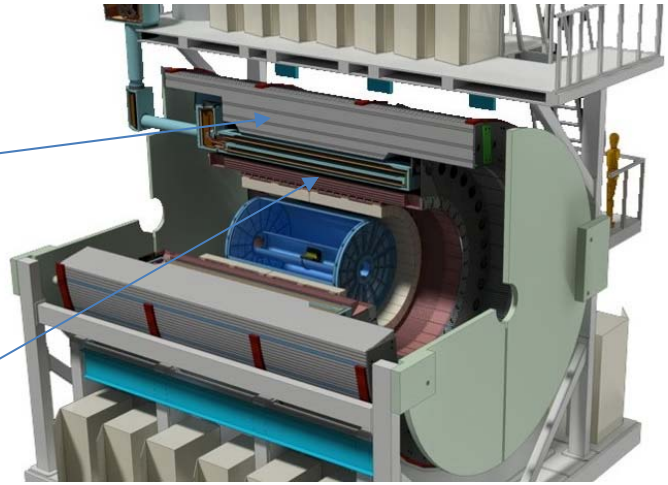
WBS	Infrastructure & Facility Upgrade
1.8	SC-Magnet
1.9	Infrastructure
1.10	Installation-Integration

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

John Lajoie
Iowa State University

sPHENIX HCAL Description





- Outer HCAL ≈3.5λ_I
- Magnet ≈1.4X_0
- Inner HCAL ≈1λ_I
- EMCAL ≈18X_0≈1λ_I

- HCAL steel and scintillating tiles with wavelength shifting fiber
  - **2 longitudinal segments.**
  - **An Inner HCal inside the solenoid.**
  - **An Outer HCal outside the solenoid.**
  - **$\Delta\eta$ x $\Delta\phi$ ≈ 0.1 x 0.1**
  - **3,072 readout channels**
  - **$\sigma_E/E < 100\%/\sqrt{E}$ (single particle)**
- SiPM Readout

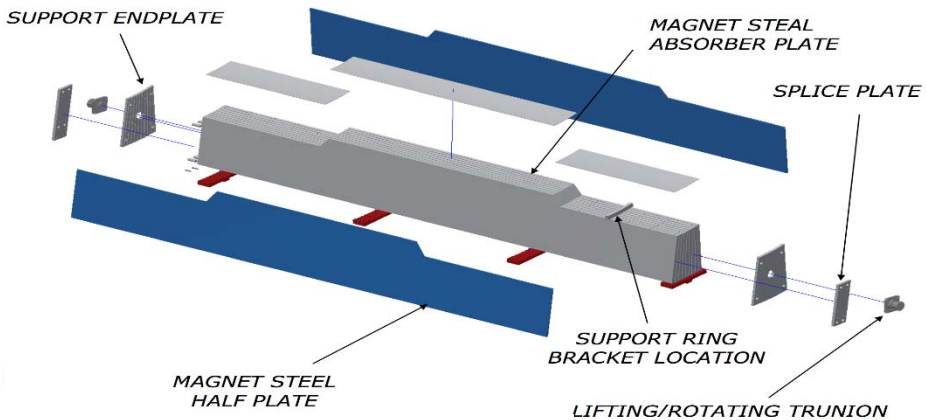
Outer HCAL Geometry

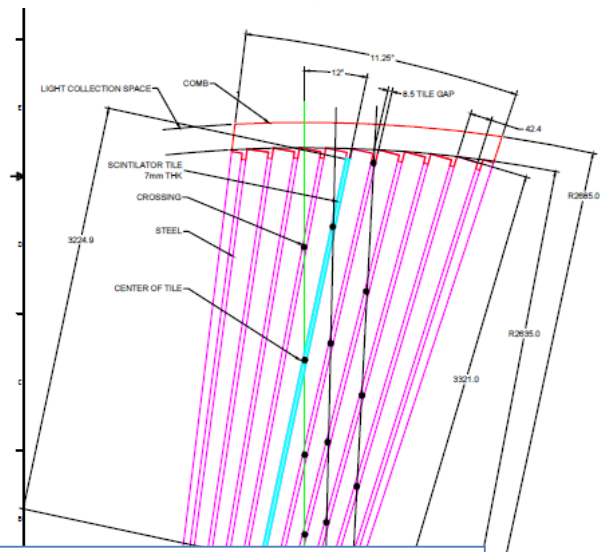
DELIVERABLE:
32 sectors - 1.9m inner radius, 2.6m outer radius

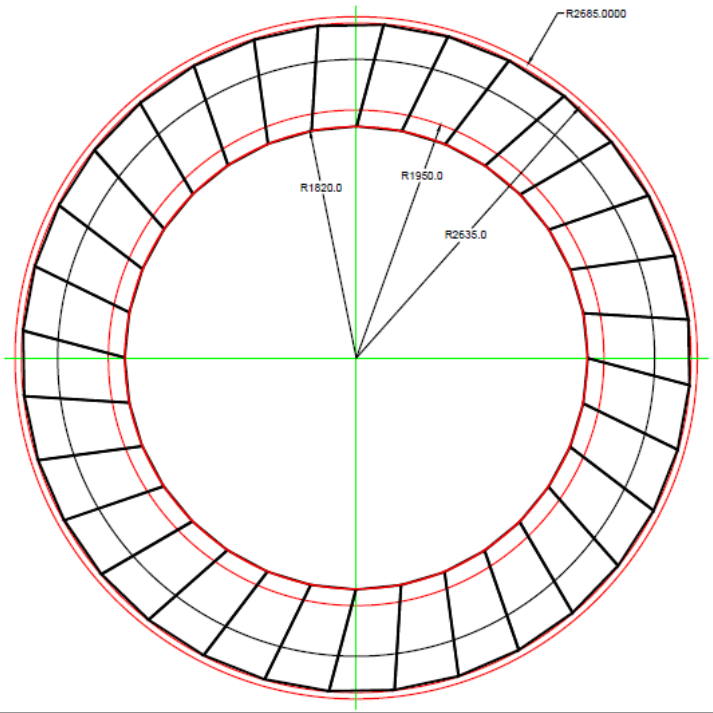
10 rows of 7mm scint. tiles (24 tiles per row), 12° tilt angle

Tapered 1020 steel plates ~26.1mm - ~42.4mm

Completed sector is 6.3m long, 13.5 tons





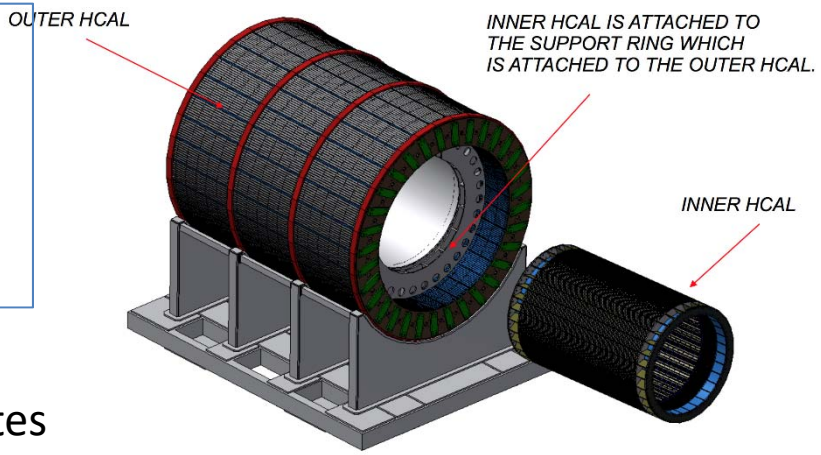


5 scintillators/tower
48 towers per sector
32 sector; 1536 channels
(7680 SiPMs)

Inner HCAL Geometry

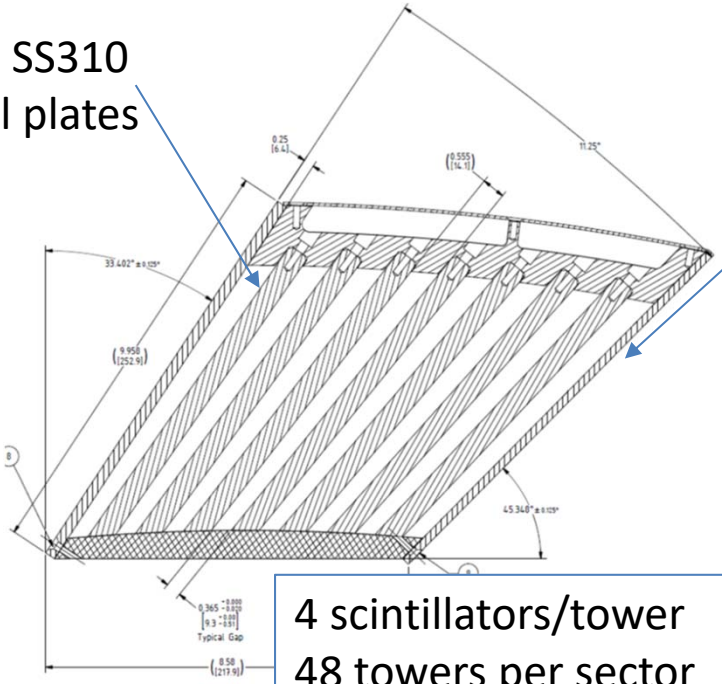
DELIVERABLE:
32 sectors - 1.16m inner radius, 1.37m outer radius
8 rows of 7mm scintillator tiles (24 tiles per row)
32° tilt angle, flat stainless steel plates ~10.2mm - ~14.7mm

Completed sector is 4.3m long, weighs ~ 1 ton

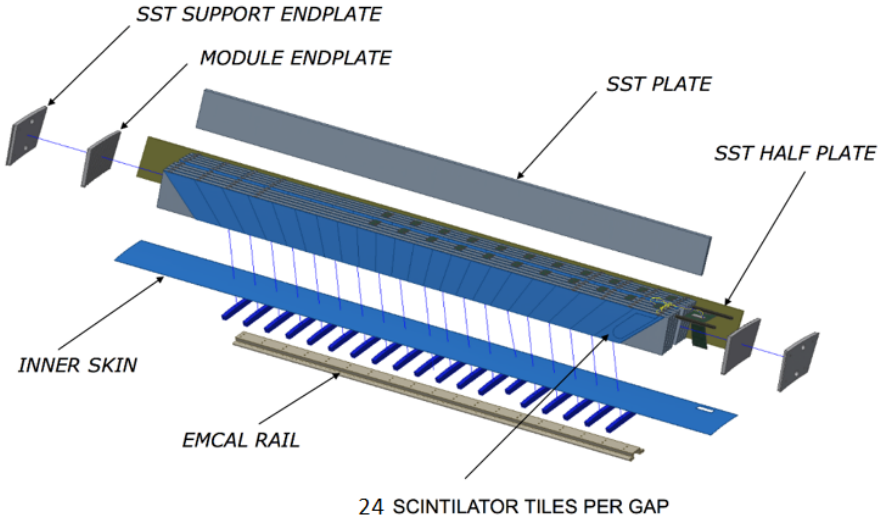


Flat SS310 steel plates

Half plates on sides



4 scintillators/tower
48 towers per sector
32 sector; 1536 channels
(6144 SiPMs)



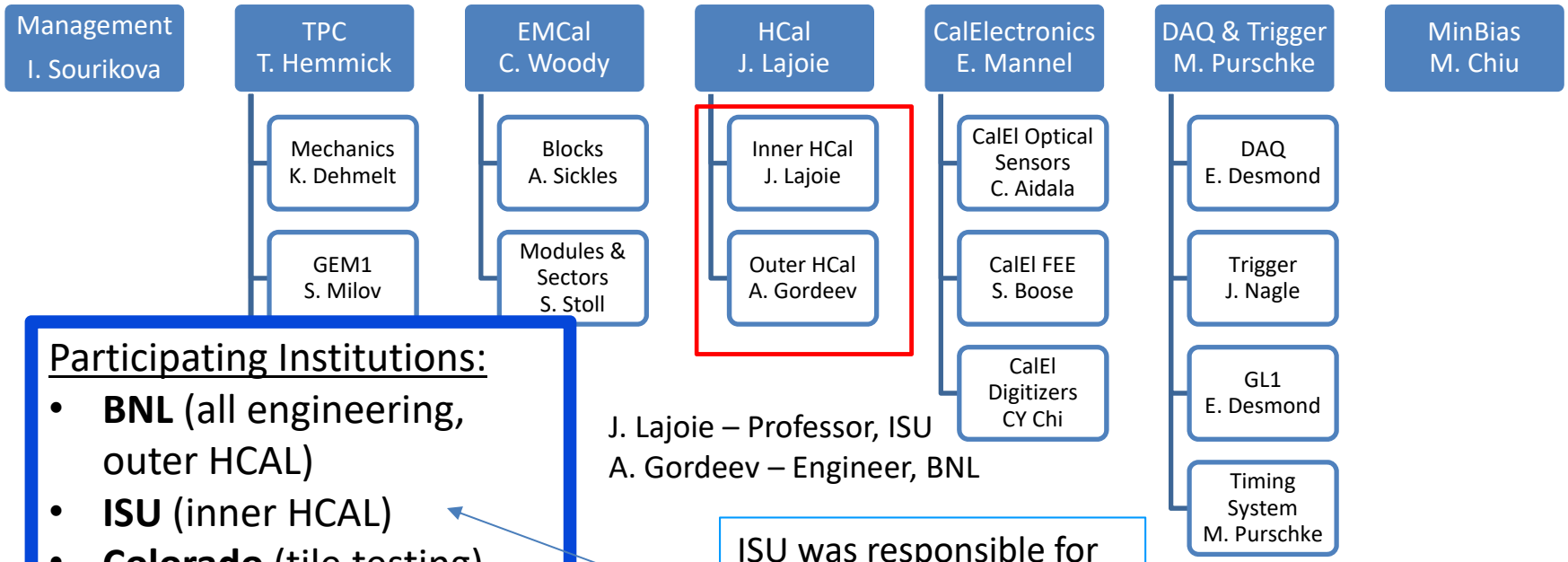
HCAL Performance Specifications

- HCAL performance driven by jet physics in HI collisions
- Uniform fiducial acceptance $-1<\eta<1$ and $0<\phi<2\pi$
  - **Extended coverage $-1.1<\eta<-1.1$ to account for jet cone**
- Absorb >95% of energy from a 70 GeV jet
  - **Requires 5.5 nuclear interaction length depth**
- Hadronic energy resolution of *combined* calorimetry:
  - $\frac{\sigma}{E} < \frac{100\%}{\sqrt{E}}$ **with constant term <15%**
  - **Gaussian response (limited tails)**
  - **Performance optimized/demonstrated in three test beams**
- Hadronic calorimeter doubles as flux return
  - **Inner HCAL non-magnetic**
  - **Outer HCAL magnetic (flux return)**

Design Drivers

- Why not a separate flux return?
  - **Simplified construction and support structures**
- Why an inner and outer HCAL segment?
  - **Size limitations set by existing interaction hall**
  - **Set by radius of BaBar solenoid, the design of the mechanical support for the detector, and overall cost effectiveness**
- Why a tilted plate design?
  - **A tilted plate design can provide a uniform acceptance, adequate energy resolution and simplified construction**
- How are the tilt angles chosen?
  - **Chosen to avoid channeling (tails in resolution function)**
- Why $\Delta\eta \times \Delta\phi \approx 0.1 \times 0.1$?
  - **Driven by occupancy in Heavy Ion collisions**
  - **Good match to scale of hadronic jets**

Level-2 Managers and CAMs



J. Lajoie – Professor, ISU
A. Gordeev – Engineer, BNL

Participating Institutions:

- **BNL** (all engineering, outer HCAL)
- **ISU** (inner HCAL)
- **Colorado** (tile testing)
- **GSU** (tile testing, outer HCAL)
- **WSU** (inner HCAL)
- **ACU** (inner HCAL)
- **Rutgers** (inner HCAL)
- In discussion with Russian institutions (MEPHI/IHEP/Kurchatov)

ISU was responsible for the PHENIX LL1 trigger and MPC-EX.

WSU has a wide range of experience in building detectors.

ACU worked on the PHENIX MuTR chambers.

HCAL Scope/Interface

Included in HCAL Scope		
WBS	**Item**	**Funding**
1.4.2	Inner HCAL	
1.4.2.1	Inner HCAL Sector Prototyping	OPC/PD/ISU
1.4.2.2	Inner HCAL Mechanical Structure	MIE
1.4.2.3	Inner HCAL Scintillating Tiles	MIE
1.4.2.4	Inner HCAL Sector Assembly, Testing, Integration	MIE
1.4.2.5	Inner HCAL Reception and Storage at BNL	MIE
1.4.3	Outer HCAL	
1.4.3.1	Outer HCAL Sector Prototyping	OPC/PD
1.4.2.2	Outer HCAL Mechanical Structure	MIE
1.4.2.3	Outer HCAL Scintillating Tiles	MIE
1.4.2.4	Outer HCAL Sector Assembly, Testing, Integration	MIE
Not Included in HCAL Scope		**Where Included**
Electronics, cables, power supplies, etc.		Cal. Electronics
SiPMs		Cal. Electronics
Installation Fixtures		Install./Integration
Support Structure		Infrastructure

Cost/Resource Drivers

- Steel is essentially a commodity material but precision machining is expensive
  - **Minimizing the volume of steel (HCAL radius) minimizes the cost**
- Scintillator tile production
  - **Surface flatness over long distances a key specification**
  - **Uniplast (T2K, PHENIX)**
    - **Wrapped tile thickness < 7.5mm, Uniplast can meet this spec.**
    - **FNAL/Elgen also investigated, Uniplast most economical for complete tile assemblies**
- Module Assembly and QA
  - **Outer HCAL to be assembled at BNL**
    - **Manpower, assembly location**
  - **Assemble inner HCAL at multiple university sites**
    - **Make use of university labor and facilities**
    - **Deliver assembled, cosmics tested sectors to BNL**

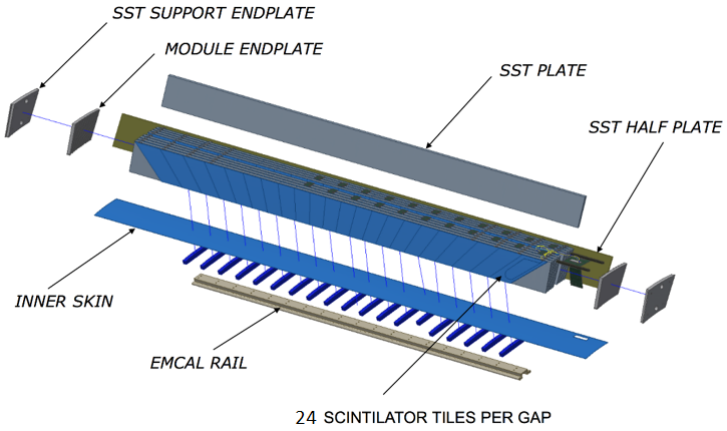
CD3a Request

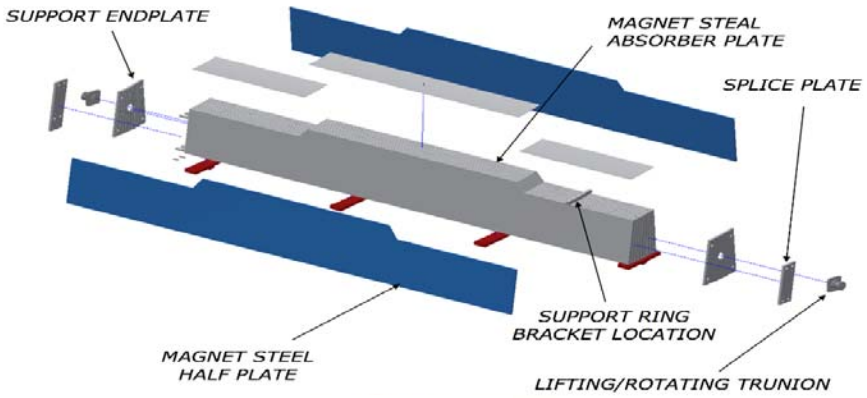
- The following CD-3a purchases are under WBS 1.4:
  - **Outer HCAL steel ($5.3M)**
  - **Scintillating tiles (outer HCAL: $1.8M)**
  - **sPHENIX is/will be ready for this authorization:**
    - **Outer HCAL design is complete; mech. prototype underway**
    - **Outer HCAL performance measured to be within sPHENIX specifications in multiple test beams**
    - **Tile designs complete; Uniplast ready for production after last prototype run (ongoing)**

- Impact of CD-3a request:
  - **Without the CD-3a funding authorization we will be unable to meet the sPHENIX schedule for first physics run in early 2023**

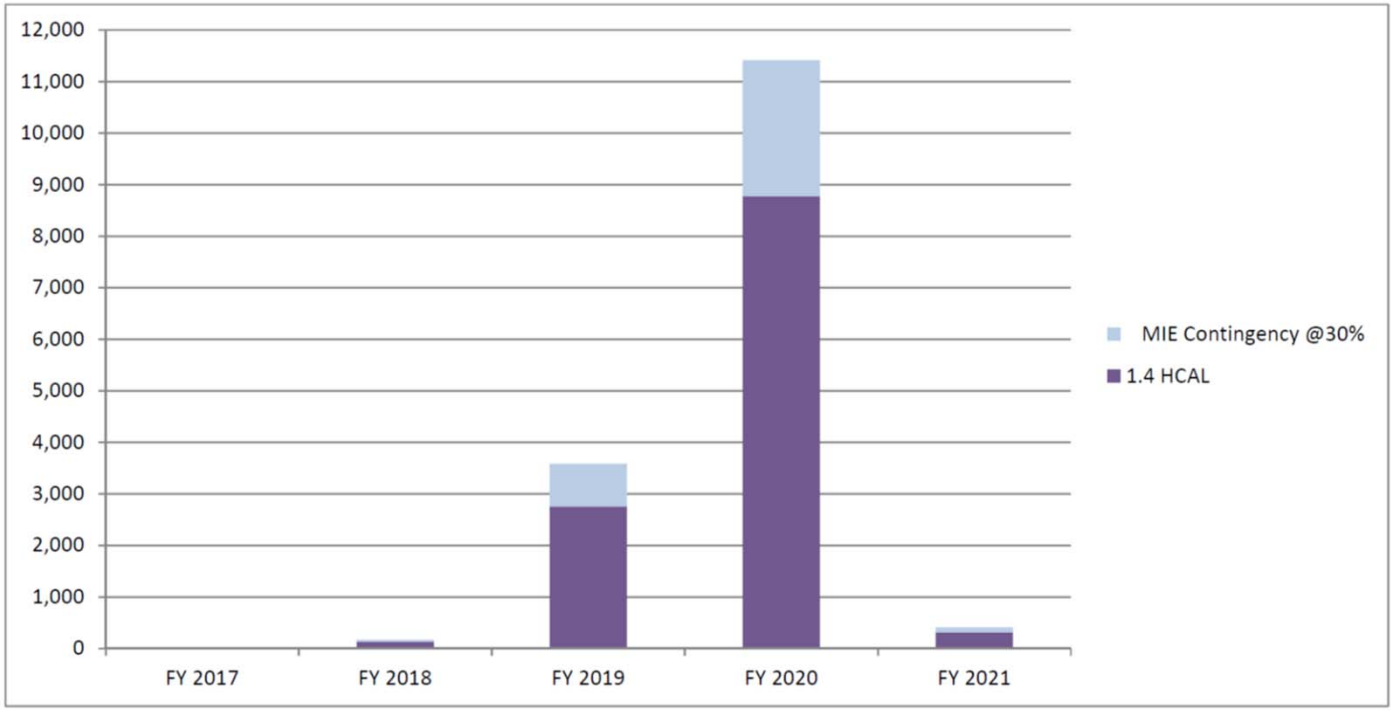
Timeline of Major Tasks

- **Sector Mechanical Prototypes: 3-9/2017**
- **Prototype v2.1 Test Beam: 2/2018 – 3/2018**
- **Outer HCAL Production: 9/2019 – 1/2021 (CD3a)**
- **Inner HCAL Production: 2/2020 – 7/2021 (CD3b)**





HCAL Budget Profile



Baseline Scenario

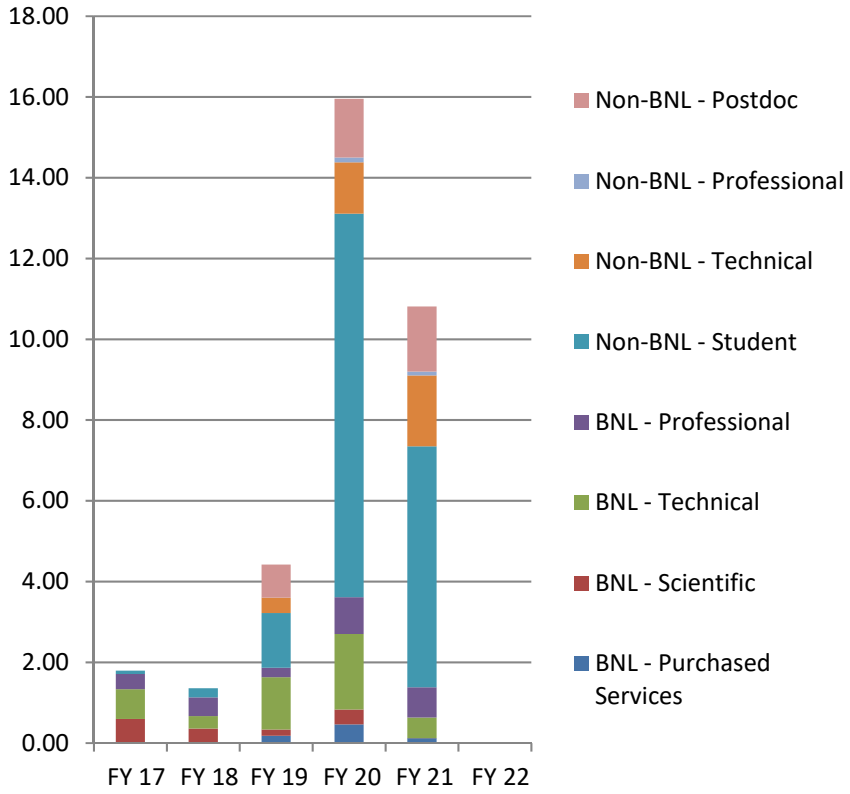
AY k$'s - with Extraordinary Construction Overhead Application (PM Labor in Ops Support)

WBS	SYSTEM	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021	Total
1.4	**HCAL**	15	129	2,752	8,777	313	11,986
	MIE Contingency @30%	5	39	826	2,633	94	3,596
	MIE Total	20	168	3578	11410	407	15582

WBS	**SYSTEM**	**Baseline**	Contingency(30%)	**Total**

HCAL 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
1.4	BNL	Purchased Services	0.00	0.00	0.18	0.46	0.12	0.00
		Scientific	0.60	0.36	0.16	0.37	0.00	0.00
		Technical	0.74	0.31	1.29	1.87	0.51	0.00
		Professional	0.38	0.47	0.23	0.91	0.75	0.00
	BNL Sum		**1.71**	**1.13**	**1.87**	**3.61**	**1.38**	**0.00**
	Non-BNL	Student	0.08	0.23	1.35	9.50	5.97	0.00
		Technical	0.00	0.00	0.38	1.27	1.76	0.00
		Professional	0.00	0.00	0.00	0.12	0.10	0.00
		Postdoc	0.00	0.00	0.82	1.46	1.61	0.00
	Non-BNL Sum		**0.08**	**0.23**	**2.55**	**12.34**	**9.43**	**0.00**
Grand Total			**1.79**	**1.36**	**4.42**	**15.95**	**10.81**	**0.00**

BoE Summary Page (Example)

	sPHENIX Detector Relativistic Heavy Ion Collider BASIS of ESTIMATE (BoE)	Date of Est: 4/26/2017 Prepared By: John G. Lajoie DocNo. (refer Rev.

Work Package Name:	WBS Number:	Control Account Number
Inner HCAL Mechanical Structure	1.4.2.2	

WBS Dictionary Definition:

TECHNICAL SCOPE:
THIS ITEM CONTAINS ALL TASKS WHICH ARE REQUIRED TO IDENTITY COMPONENTS FOR THE INNER HCAL MECHANICAL STRUCTURE, DESIGN AND CONSTRUCT THE MECHANICAL ELEMENTS OF THE INNER HADRONIC CALORIMETER.
WORK STATEMENT:
PROVIDE INNER HADRONIC CALORIMETER MECHANICAL STRUCTURE.

Estimate Type (check all that apply):

____	Work Complete
X	Existing Purchase Order
____	Catalog Listing or Industrial Construction Database
____	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
____	Expert Opinion

Supporting Documents (including but not limited to):

Click for detailed summary

Guidelines Used in Developing Estimate

The primary cost element of the work package, the inner HCAL mechanical structure, is costed based on a vendor bid/quote through Iowa State University. The quotation was for the initial prototype, funded through ISU funds. This cost estimate was based on a highly evolved design of the inner HCAL mechanical structure, and while we expect some small changes before production, we do not anticipate any changes that should significantly affect the overall cost. An additional quote for a similar cost was obtained by Wayne State University. The contingency for this large item is therefore estimated at 20%.

All labor in this work package (BNL engineering and design) are costed at current BNL rates with a 20% contingency. We justify the contingency based on the advanced state of the design and the engineers estimate of the work remaining.

The inner HCAL supprt ring is based on an engineering estimate at with a 40% contingency. It is not anticipated that special lifting fixtures should be required.

This estimate assumes that the mechanical assemblies will be subcontracted by BNL two Universities, which will contract for the manufacture of the inner HCAL sectors. The University overhead is estimated at 26% and is included in the fixed cost in lines 1.4.2.2.10.1 and 1.4.2.2.11.1

- Developed from the ground up, using best estimates/quotes available at this time.
- All cost items implemented in standard sPHENIX BoE form.
- Detailed calculations separate out MIE and non-MIE labor, etc.

Sector Prototypes

Strecks visit – 7/2017

Outer HCAL absorber plates

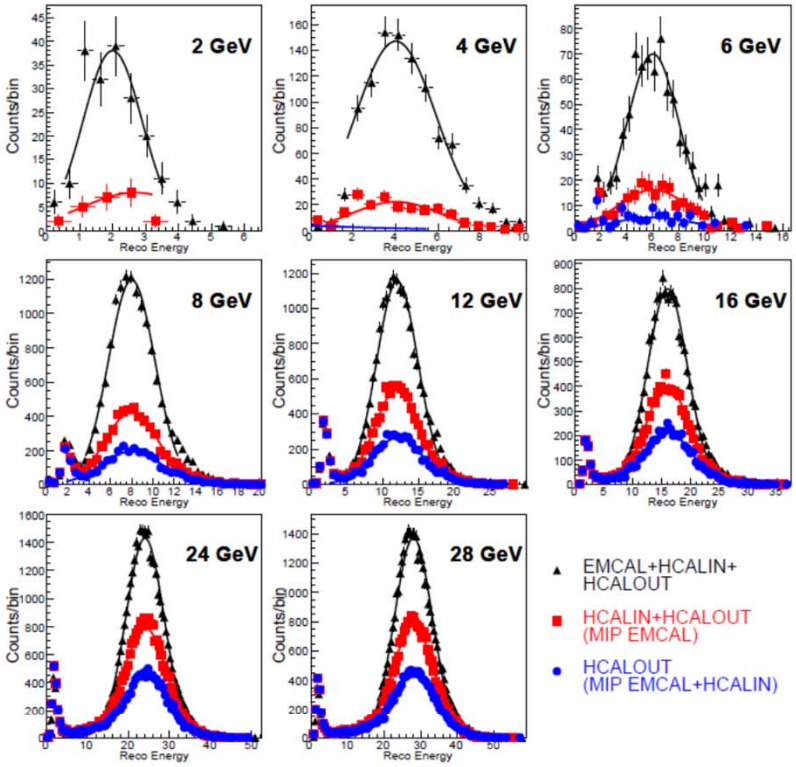
TSI/Ames visit 6/2017

(inner HCAL protoype funded by ISU)

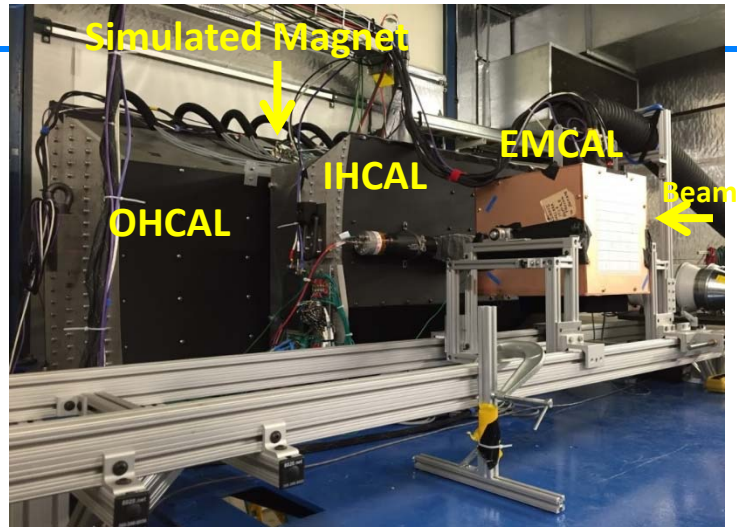
Full sector prototypes underway – Will be used to identify key issues to optimize manufacturing and reduce machining time/effort. Mechanical deflections and tolerances measured as a function of temperature, to be compared with finite element analysis.

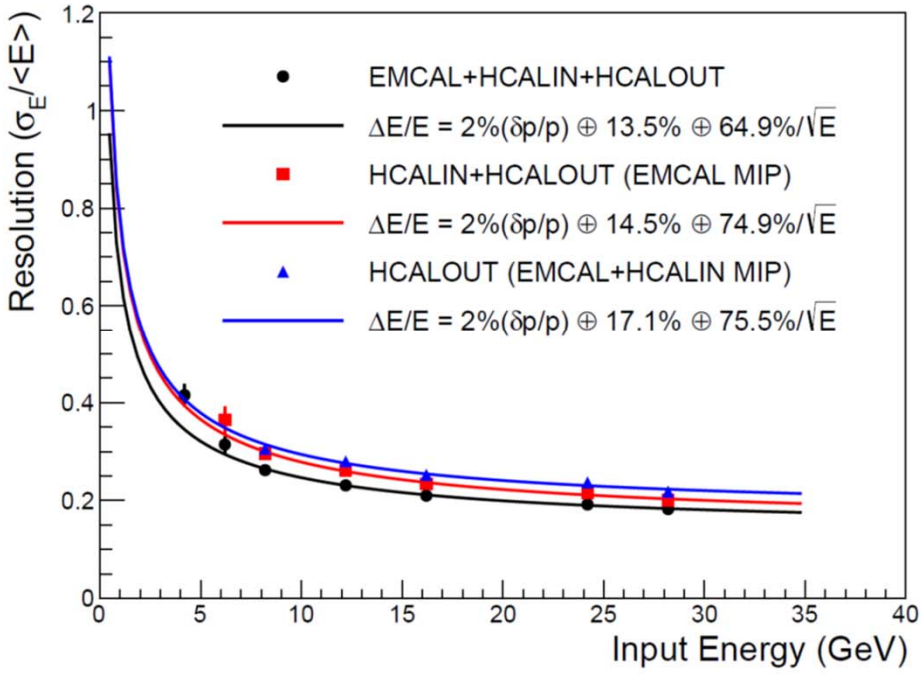
Performance

Three test beams (2014/15/16):



In all cases, the combined system meets the sPHENIX spec!





Risk Registry/Issues and Concerns

1.4 HCal	Loss of scintillating tile provider (Uniplast)	Uniplast is unable to engage in or complere the production contract	Schedule delay in the procurement of rthe scintillating tiles, along with corresponding delays in inner and outer HCAL assembly.	Moderate	Explore alternate scintillator vendors (FNAL, Elgin, IHEP).
1.4 HCal	Unable to produce inner HCAL in SS310 in a cost effective manner	Evaluation of inner HCAL prototype yields higher than anticipated production costs	Schedule delay in finalizing the design of the inner HCAL; re-engineering required.	Moderate	Investigate value-engineering designs and alternate materials (brass); will require re-engineering.
1.4 HCal	Unable to identify suitable site(s) for inner HCAL assembly (scint. and electronics)	No participating University site can idetify the space resources for assembly.	Schedule delay to set up assembly site at BNL	Low	Investigate possibility of assembly (scintillator and electronics) at BNL.

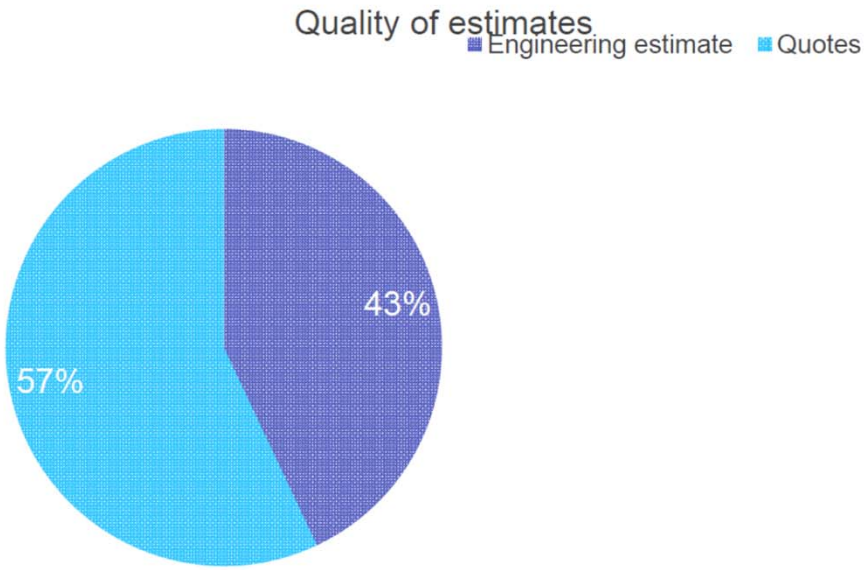
Risk registry currently includes three major items, two of which are rated at moderate risk.

Back Up

Quality of Estimate

HCal

SUBSYSTEM	PERCENT OF ESTIMATES	CONTINGENCY
Engineering estimate	43	0.40
Quotes	57	0.20
Average contingency		0.29



RLS/BoE Guidelines

- The Outer HCAL mechanical structures will be purchased fully assembled and delivered to BNL.
  - **Assembly at BNL will continue with BNL technicians and collaboration labor**
    - **Populate with scintillator and electronics, test and provide initial cosmics calibration.**

- The Inner HCAL will be assembled at two (or more) University sites.
  - **ISU, WSU and ACU have expressed interest**
  - **Sector assemblies provided by local vendors, populated with scintillator and electronics by University labor**
  - **Shipped to BNL, tested after shipping and stored.**

  - **IHEP Protovino investigating construction alternatives**

Basis of Estimate Documents

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

L2 Project Name	L2 WBS Number	L3 Project Name (Control Account)	L3 WBS Number
Hadronic Calorimeter	1.4	Inner HCAL	1.4.2

Work Package Name	WBS Number	Basis of Estimate Link
Inner HCAL Mechanical Structure	1.4.2.2	Inner HCAL Mechanical Structure
Procure Inner HCAL Scintillating Tiles	1.4.2.3	Procure Inner HCAL Scintillating Tiles
Inner HCAL Sector Assembly, Testing and Integration	1.4.2.4	Inner HCAL Sector Assembly, Testing and Integration
Inner HCAL Sector Reception and Storage at BNL	1.4.2.5	Inner HCAL Sector Reception and Storage at BNL

Outer HCAL summary page is similar...

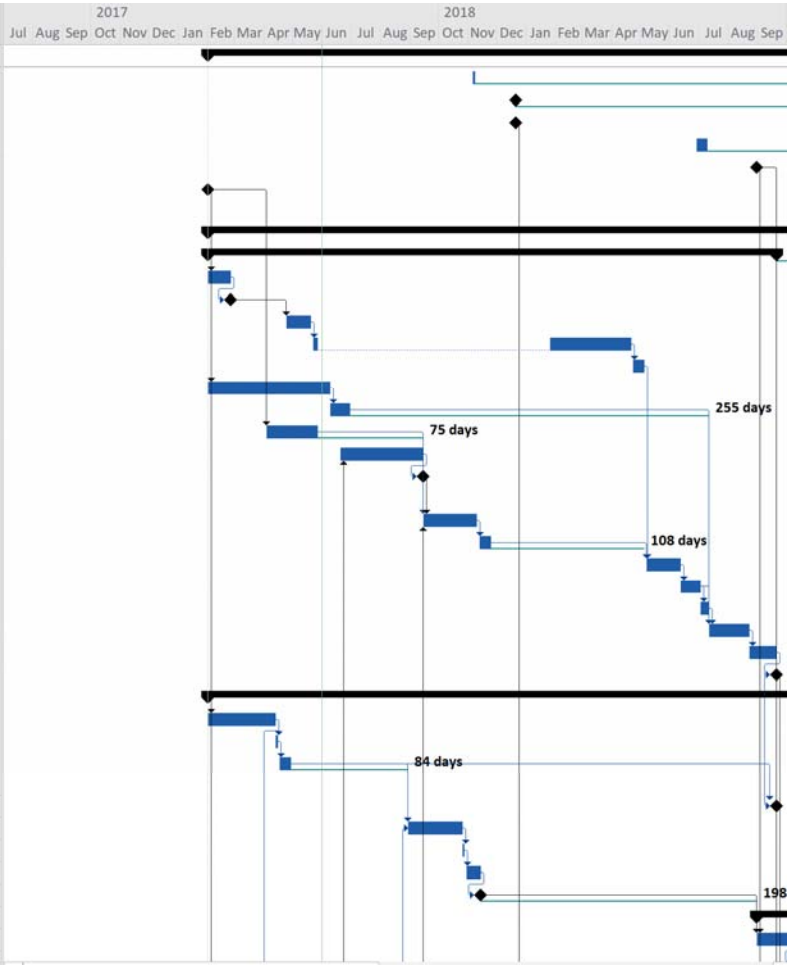
WBS Dictionary

1.4					
1.4				**SPHENIX HCAL**	The Hadronic Calorimeter for the sPHENIX Experiment at RHIC
1.4	1.4.1			**Inner HCAL**	TECHNICAL SCOPE: THIS ITEM CONTAINS ALL TASKS WHICH ARE REQUIRED TO DESIGN AND CONSTRUCT THE INNER HADRONIC CALORIMETER. WORK STATEMENT: PROVIDE INNER HADRONIC CALORIMETER.
1.4	1.4.1	1.4.1.1		**Inner HCAL Sector Prototyping**	TECHNICAL SCOPE: THIS ITEM CONTAINS ALL TASKS WHICH ARE REQUIRED TO PROTOTYPE AND TEST THE INNER HADRONIC CALORIMETER. WORK STATEMENT: PROTOTYPE AND TEST THE INNER HADRONIC CALORIMETER DESIGN
1.4	1.4.1	1.4.1.2		**Inner HCAL Sector Mechanical Structure**	TECHNICAL SCOPE: THIS ITEM CONTAINS ALL TASKS WHICH ARE REQUIRED TO IDENTITY COMPONENTS FOR THE INNER HCAL MECHANICAL STRUCTURE, DESIGN AND CONSTRUCT THE MECHANICAL ELEMENTS OF THE INNER HADRONIC CALORIMETER. WORK STATEMENT: PROVIDE INNER HADRONIC CALORIMETER MECHANICAL STRUCTURE.
1.4	1.4.1	1.4.1.2	1.4.1.2.1	**Procure Inner HCAL End Rings**	TECHNICAL SCOPE: THIS ITEM CONTAINS ALL TASKS WHICH ARE REQUIRED TO DESIGN AND MANUFACTURE THE INNER HCAL END RING MECHANICAL STRUCTURE. WORK STATEMENT: PROVIDE INNER HADRONIC CALORIMETER END RING STRUCTURE.
1.4	1.4.1	1.4.1.2	1.4.1.2.2	**Procure Inner HCAL Sector Mechanical Structure (Vendor #1)**	TECHNICAL SCOPE: THIS ITEM CONTAINS ALL TASKS NECESSARY TO PROCURE THE MECHANICAL ELEMENTS OF THE INNER HADRONIC CALORIMETER FROM VENDOR #1. WORK STATEMENT: PROCURE THE INNER HADRONIC CALORIMETER MECHANICAL STRUCTURE FROM VENDOR #1.
1.4	1.4.1	1.4.1.2	1.4.1.2.3	**Procure Inner HCAL Sector Mechanical Structure (Vendor #2)**	TECHNICAL SCOPE: THIS ITEM CONTAINS ALL TASKS NECESSARY TO PROCURE THE MECHANICAL ELEMENTS OF THE INNER HADRONIC CALORIMETER FROM VENDOR #2. WORK STATEMENT: PROCURE THE INNER HADRONIC CALORIMETER MECHANICAL STRUCTURE FROM VENDOR #2.
1.4	1.4.1	1.4.1.3		**Procure Inner HCAL Scintillating Tiles**	TECHNICAL SCOPE: THIS ITEM CONTAINS ALL TASKS WHICH ARE REQUIRED TO DESIGN THE INNER HADRONIC CALORIMETER SCINTILLATING TILE ASSEMBLIES. WORK STATEMENT: PROVIDE THE DESIGN FOR INNER HCAL SCINTILLATING TILES
1.4	1.4.1	1.4.1.4		**Inner HCAL Sector Assembly, Testing and Integration**	TECHNICAL SCOPE: THIS ITEM CONTAINS ALL TASKS WHICH ARE REQUIRED TO ASSEMBLE THE INNER HADRONIC CALORIMETER SECTORS. WORK STATEMENT: PROVIDE INNER CALORIMETER SECTORS, READY FOR INSTALLATION INTO SPHENIX
1.4	1.4.1	1.4.1.4	1.4.1.4.1	**Inner HCAL Sector Assembly, Testing and Integration (Area #1)**	TECHNICAL SCOPE: THIS ITEM CONTAINS ALL TASKS NECESSARY TO ASSEMBLE THE INNER HADRONIC CALORIMETER SECTORS AT UNIVERSITY AREA #1. WORK STATEMENT: ASSEMBLE THE INNER HADRONIC CALORIMETER SECTORS AT UNIVERSITY AREA #1.

Detailed WBS Dictionary available, based on MS Project file.

Resource Loaded Schedule

	Task Mode	WBS	Name
1		**1.4.1**	**HCAL Management**
3		1.4.1.1	DOE OPA CD-1/CD-3a Review
5		1.4.1.2	CD-1 Authorization
6		1.4.1.3	CD-3a Authorization
8		1.4.1.4	DOE OPA CD-2/3 Review
10		1.4.1.5	CD-2/3 Authorization
11		1.4.1.6	WBS Start for Ongoing Tasks
12		1.4.1.7	HCAL Project Complete
13		**1.4.2**	**Inner HCAL**
14		**1.4.2.1**	**Inner HCAL Sector Prototyping**
15		1.4.2.1.1	Inner HCAL Prototype 2.0 Test Beam Operation
16		1.4.2.1.2	Complete Inner HCAL Prototype v2.0
17		1.4.2.1.3	Design Test Beam Prototype v2.1
18		1.4.2.1.4	Fabricate Test Beam Prototype v2.1
19		1.4.2.1.5	Assemble Test Beam Prototype v2.1
20		1.4.2.1.6	Produce Inner HCAL Mechanical Prototype v2.1 Sector
21		1.4.2.1.7	Ship Inner HCAL Mechanical Prototype v2.1 to BNL and Inspect
22		1.4.2.1.8	Build Tile Test Box/Fixture
23		1.4.2.1.9	Procure Scintillating Tiles for Inner HCAL Test Beam Prototype v2.1
24		1.4.2.1.10	Award Procurement for Scintillating Tiles for Inner HCAL Test Beam Prototype v2.1
25		1.4.2.1.11	Fabricate Inner HCAL Prototype v2.1 Tiles & Ship to BNL
26		1.4.2.1.12	Inspect Inner HCAL Prototype v2.1 Scintillating Tiles
27		1.4.2.1.13	Install Scintillating Tiles in Inner HCAL Prototype v2.1
28		1.4.2.1.14	Inner HCAL Prototype v2.1 Calibration
29		1.4.2.1.15	Ship Inner HCAL Prototype v2.1 to FNAL
30		1.4.2.1.16	Inner HCAL Prototype v2.1 Test Beam Operation
31		1.4.2.1.17	Incorporate Feedback from Prototype into Inner HCAL Design
32		1.4.2.1.18	Complete Inner HCAL Prototype v2.1
33		**1.4.2.2**	**Inner HCAL Sector Mechanical Structure**
34		1.4.2.2.1	Final Design of Mechanical Structure of Inner HCAL Sector
35		1.4.2.2.2	Internal Review of Inner HCAL Sector Mechanical Design
36		1.4.2.2.3	Address Issues from Internal Review of Inner HCAL Sector Mechanical Design
37		1.4.2.2.4	Inner HCAL Sector Final Mechanical Design Complete
38		1.4.2.2.5	Design Inner HCAL End Rings
39		1.4.2.2.6	Internal Review of Inner HCAL End Rings
40		1.4.2.2.7	Address Issues from Internal Review of Inner HCAL End Rings
41		1.4.2.2.8	Inner HCAL End Rings Design Complete
42		**1.4.2.2.9**	**Procure Inner HCAL End Rings**
43		1.4.2.2.9.1	Procurement for Inner HCAL End Rings



RLS includes fixed cost, paid labor and non-MIE labor, and University overheads.

Basis of Estimate (Detail)

- Summary pages linked to detailed costs spreadsheet, identifying cost and contingency for every item (fixed, paid labor and non-MIE labor)
- Deeper calculations separate out MIE and non-MIE labor, etc.

WBS	Task Name	Item	Vendor	Cost	Basis of Estimate	Contingency	Total w/Contingency
1.4.2.2	Inner HCAL Sector Mechanical Structure						
1.4.2.2.1	Final Design of Mechanical Structure of Inner HCAL Sector						
		Eng. Design Labor	BNL	$15,198.00	Engineering Est.	0.2	$18,237.60
1.4.2.2.2	Internal Review of Inner HCAL Sector Mechanical Design						
		Eng. Design Labor	BNL	$4,910.40	Engineering Est.	0.2	$5,892.48
1.4.2.2.3	Address Issues from Internal Review of Inner HCAL Sector Mechanical Design						
		Eng. Design Labor	BNL	$3,428.40	Engineering Est.	0.2	$4,114.08
1.4.2.2.5	Design Inner HCAL End Rings						
		Eng. Design Labor	BNL	$9,825.60	Engineering Est.	0.2	$11,790.72
1.4.2.2.6	Internal Review of Inner HCAL End Rings						
		Eng. Design Labor	BNL	$4,910.40	Engineering Est.	0.2	$5,892.48
1.4.2.2.7	Address Issues from Internal Review of Inner HCAL End Rings						
		Eng. Design Labor	BNL	$3,428.40	Engineering Est.	0.2	$4,114.08
1.4.2.2.9.1	Procurement for Inner HCAL End Rings						
		Eng. Design Labor	BNL	$5,907.60	Engineering Est.	0.2	$7,089.12
1.4.2.2.9.3	Manufacture Inner HCAL End Rings						
		Eng. Design Labor	BNL	$8,899.20	Engineering Est.	0.2	$10,679.04
		End Rings		$50,000.00	Engineering Est.	0.4	$70,000.00
1.4.2.2.9.4	Inspect Inner HCAL End Rings						
		Tech. Labor	BNL	$11,398.40	Engineering Est.	0.2	$13,678.08
1.4.2.2.10.1	Procurement for Inner HCAL Sector Mechanical Structure (Vendor #1)						
		Eng. Design Labor	BNL	$11,121.12	Engineering Est.	0.2	$13,345.34
		University Overhead	ISU	$56,004.00	University Off-Campus Rate 26%		$77,532.00
1.4.2.2.10.3	Inner HCAL Sector Mechanical Structure First Article Delivery (Vendor #1)						
		Eng. Design Labor	BNL	$8,899.20	Engineering Est.	0.2	$10,679.04
		Inner HCAL Sector		$43,640.00	Quotation (Prototype)	0.4	$61,096.00
1.4.2.2.10.4	Design and procure Inner HCAL Sector acceptance testing tooling (Vendor #1)						
		Eng. Design Labor	BNL	$6,837.60	Engineering Est.	0.2	$8,205.12
		Manufacture Tooling		$5,000.00	Engineering Est.	0.4	$7,000.00
		University Tech Labor	ISU	$2,000.00	Engineering Est.	0.2	$2,400.00
1.4.2.2.10.5	Inner HCAL Sector Mechanical Structure First Article Acceptance Testing (Vendor #1)						
		Eng. Design Labor	BNL	$2,735.04	Engineering Est.	0.2	$3,282.05
		University Tech Labor	ISU	$4,000.00	Engineering Est.	0.2	$4,800.00
1.4.2.2.10.6	Inner HCAL Sector Mechanical Structure production and assembly (Vendor #1)						
		Eng. Design Labor	BNL	$16,686.00	Engineering Est.	0.2	$20,023.20
		University Tech Labor	ISU	$4,500.00	Engineering Est.	0.2	$5,400.00
		Manufacture Sectors		$654,600.00	Quotation (Prototype)	0.4	$916,440.00
1.4.2.2.10.7	Inner HCAL Sector Mechanical Structure Acceptance Testing (Vendor #1)						
		Eng. Design Labor	BNL	$16,686.00	Engineering Est.	0.2	$20,023.20
		University Tech Labor	ISU	$6,300.00	Engineering Est.	0.2	$7,560.00
1.4.2.2.11.1	Procurement for Inner HCAL Sector Mechanical Structure (Vendor #2)						
		Eng. Design Labor	BNL	$11,121.12	Engineering Est.	0.2	$13,345.34
		University Overhead	ACU	$56,004.00	University Off-Campus Rate 26%	0	$77,532.00
1.4.2.2.11.3	Inner HCAL Sector Mechanical Structure First Article Delivery (Vendor #2)						
		Eng. Design Labor	BNL	$8,899.20	Engineering Est.	0.2	$10,679.04
		Manufacturing Cost		$43,640.00	Quotation (Prototype)	0.4	$61,096.00
1.4.2.2.11.4	Design and procure Inner HCAL Sector acceptance testing tooling (Vendor #2)						
		Eng. Design Labor	BNL	$6,837.60	Engineering Est.	0.2	$8,205.12
		Manufacture Tooling		$5,000.00	Engineering Est.	0.4	$7,000.00
		University Tech Labor	ACU	$2,000.00	Engineering Est.	0.2	$2,400.00
1.4.2.2.11.5	Inner HCAL Sector Mechanical Structure First Article Acceptance Testing (Vendor #2)						
		Eng. Design Labor	BNL	$2,735.04	Engineering Est.	0.2	$3,282.05
		University Tech Labor	ACU	$4,000.00	Engineering Est.	0.2	$4,800.00
1.4.2.2.11.6	Inner HCAL Sector Mechanical Structure production and assembly (Vendor #2)						
		Eng. Design Labor	BNL	$16,686.00	Engineering Est.	0.2	$20,023.20
		Manufacture Sectors		$654,600.00	Quotation (Prototype)	0.4	$916,440.00
		University Tech Labor	ACU	$4,500.00	Engineering Est.	0.2	$5,400.00
1.4.2.2.11.7	Inner HCAL Sector Mechanical Structure Acceptance Testing (Vendor #2)						
		Eng. Design Labor	BNL	$16,686.00	Engineering Est.	0.2	$20,023.20
		University Tech Labor	ACU	$6,300.00	Engineering Est.	0.2	$7,560.00

Total Cost	$1,602,088.00	
Total Cost + Contingency	$2,234,456.00	
Contingency Fraction	0.39	
Total Labor	$33,600.00	
Total Labor + Contigency	$40,320.00	
Total Fixed	$1,568,488.00	0.98
Fixed + Contingency	$2,194,136.00	0.98
Total non-MIE Labor	$193,836.32	
Total non-MIE Labor + Contingency	$232,603.58	
University #1 Overhead Basis (Labor)	$215,400.00	
University #1 Overhead Basis + Contingency (Labor + Contingency)	$298,200.00	
University #1 Overhead Total on Basis (26% of basis)	$56,004.00	
University #1 Overhead Total on Basis + Contingency (26% of basis + contingency)	$77,532.00	
University #2 Overhead Basis (Labor)	$215,400.00	
University #2 Overhead Basis + Contingency (Labor + Contingency)	$298,200.00	
University #2 Overhead Total on Basis (26% of basis)	$56,004.00	
University #2 Overhead Total on Basis + Contingency (26% of basis + contingency)	$77,532.00	

Engineering Strecks Visit (5/2017)

Outer HCAL Mechanical Prototype on track for delivery to BNL by end of summer.

Inner HCAL Prototype (TSI Ames)

Full sector prototype completed – Engineering visit 6/26/2017. Identified key issues to optimize manufacturing and reduce machining time/effort. Mechanical deflections and tolerances measured as a function of temperature, to be compared with finite element analysis. (Prototype funded by ISU.)