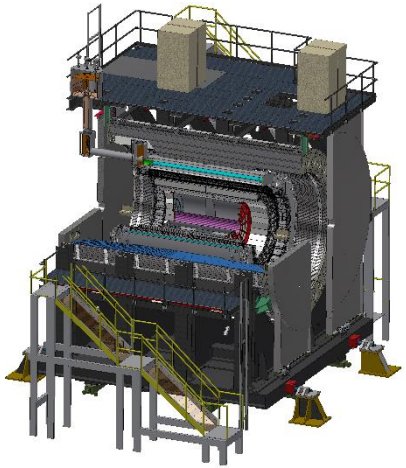
The sPHENIX Project

RHIC Program S&T Review

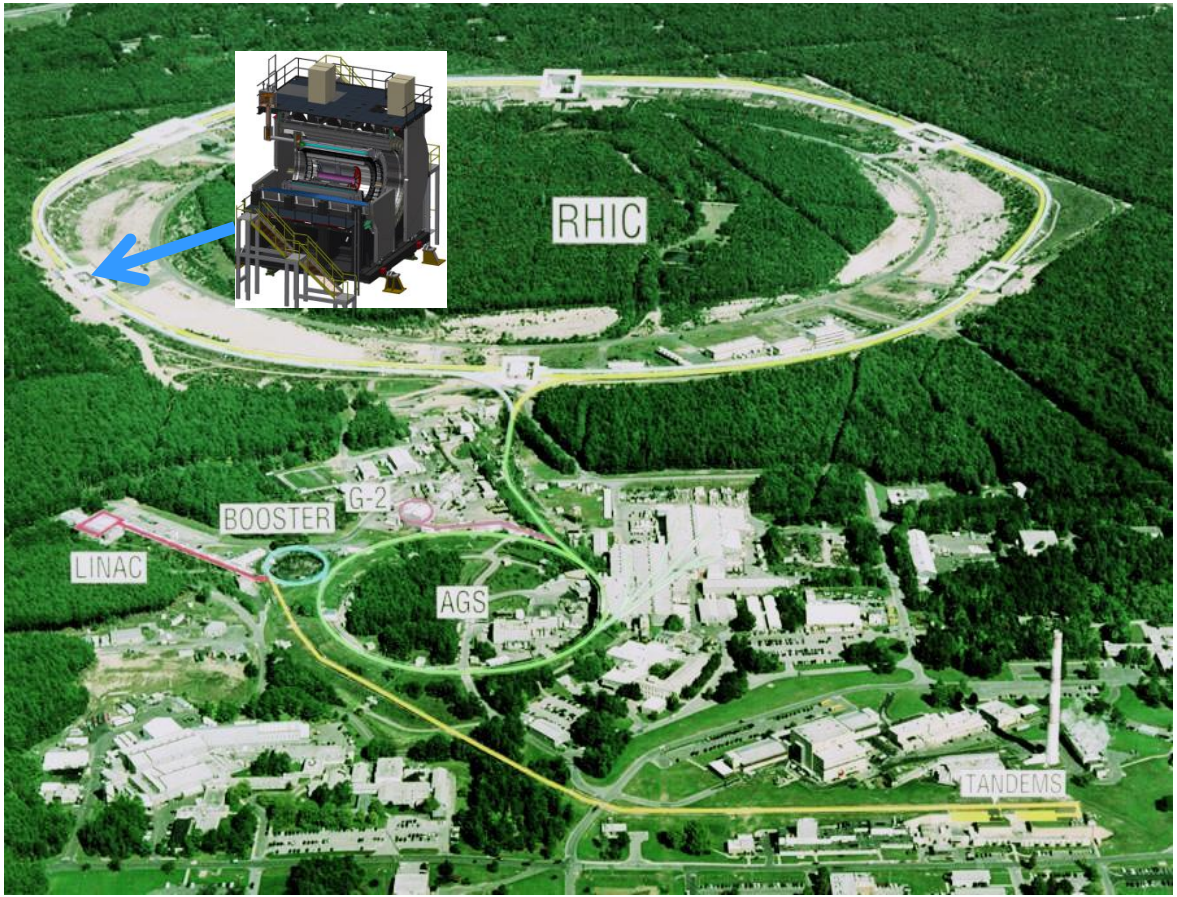
September 17-19, 2019

Brookhaven National Laboratory

Edward O'Brien



sPHENIX Overview



sPHENIX is a major upgrade to the PHENIX detector. It is a large-acceptance, high-rate detector for Heavy Ion physics that repurposes **>$20M** in existing PHENIX equipment, infrastructure and support facilities.

The detector is optimized to measure jet and heavy quark physics by incorporating a Time Projection Chamber, Electromagnetic and Hadronic Calorimeter with a high rate DAQ/Trigger and a 1.4 T solenoidal magnetic field.

MIE Baseline Scope

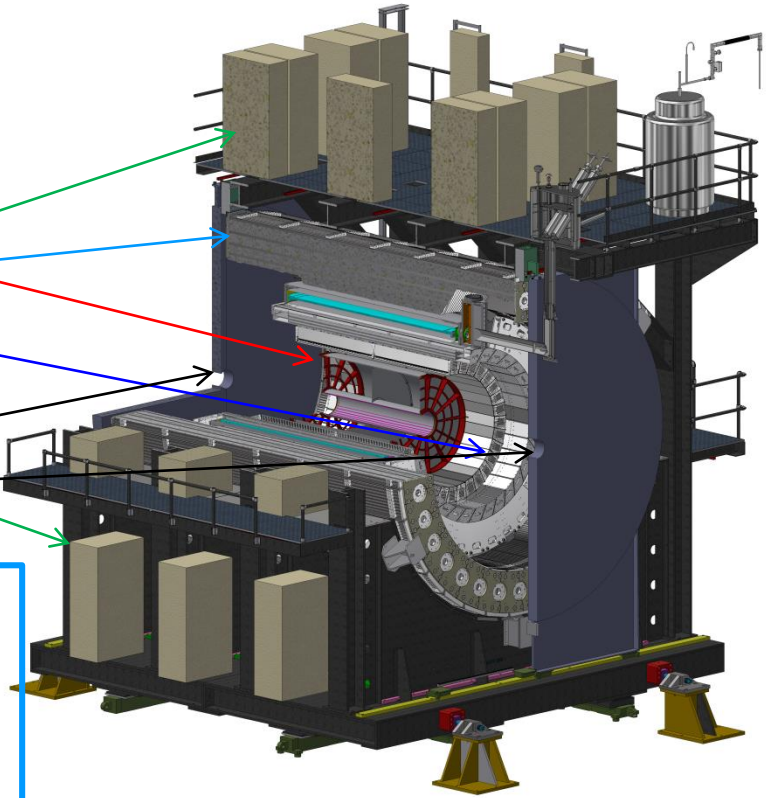
- A **Time Projection Chamber** (TPC), **Electromagnetic Calorimeter** (EMCal), and a **Hadronic Calorimeter** (HCal) all covering 2π in azimuth. The TPC and HCal have pseudorapidity coverage of $-1.1 \leq \eta \leq 1.1$. The EMCal has pseudorapidity coverage of $-0.85 \leq \eta \leq 0.85$.
- A **Minimum Bias Trigger Detector** (MBD).
- **Readout electronics** to fully instrument the **TPC, EMCal, HCal and MBD**.
- A **Data Acquisition** (DAQ) system with the capability to readout the TPC, EMCal, HCal and MBD with an event rate and data-logging rate commensurate with the sPHENIX physics goals.
- A DAQ/**Trigger** system that can provide minimum bias and energy cluster triggers at a rate necessary to carry out the sPHENIX physics program in AA, pA and pp collisions at RHIC.
- **Project Management** to carry the project scope through to a successful on time and on budget completion.

Baseline Approved at PD-2/3

sPHENIX MIE (1.X)

WBS MIE

1.1 Project Management
1.2 Time Projection Chamber
1.3 EM Calorimeter
1.4 Hadronic Calorimeter
1.5 Calorimeter Electronics
1.6 DAQ/Trigger → **To counting house**
1.7 Minimum Bias Detector

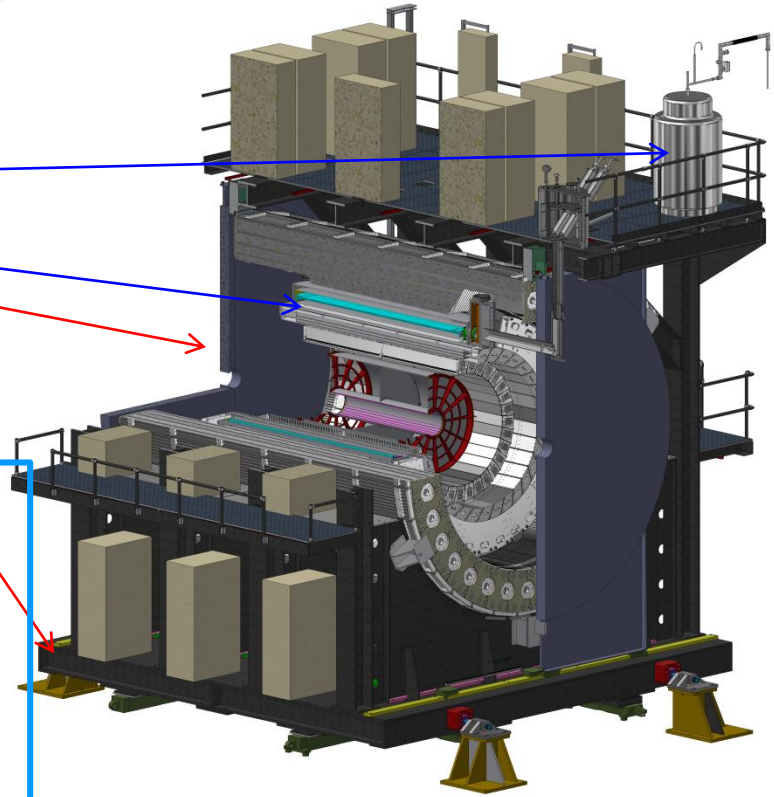


The final design of sPHENIX is driven by 3 principles:

- Design a detector to meet the Science Mission of measurements of Jets and Upsilons in RHIC environment
- Maximize cost effectiveness and utilize modern technologies where appropriate (SiPM, fast TPC readout)
- Build on existing $20M+ PHENIX infrastructure

sPHENIX Infrastructure and Facility Upgrade(2.X)

WBS	I&F Upgrade
2.1	I&F Management
2.2	SC Magnet
2.3	Carriage & Structural Components
2.4	Infrastructure
2.5	Installation & Integration



Three large M&S items:

- Barrel Magnet steel
- Carriage/Cradle/Poletips/Platform
- Cryogenics for 1008

Three main labor items:

- SC-Magnet
- Carriage/Cradle/Poletips/Platform(engineering design)
- Installation/Integration

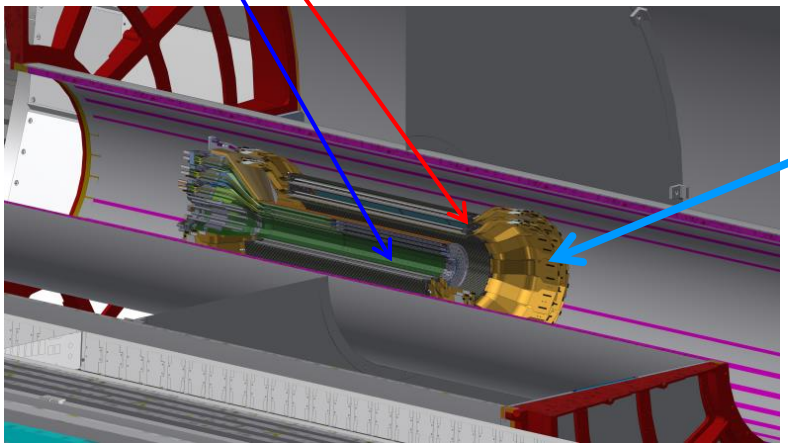
sPHENIX Silicon Detectors (3.X)

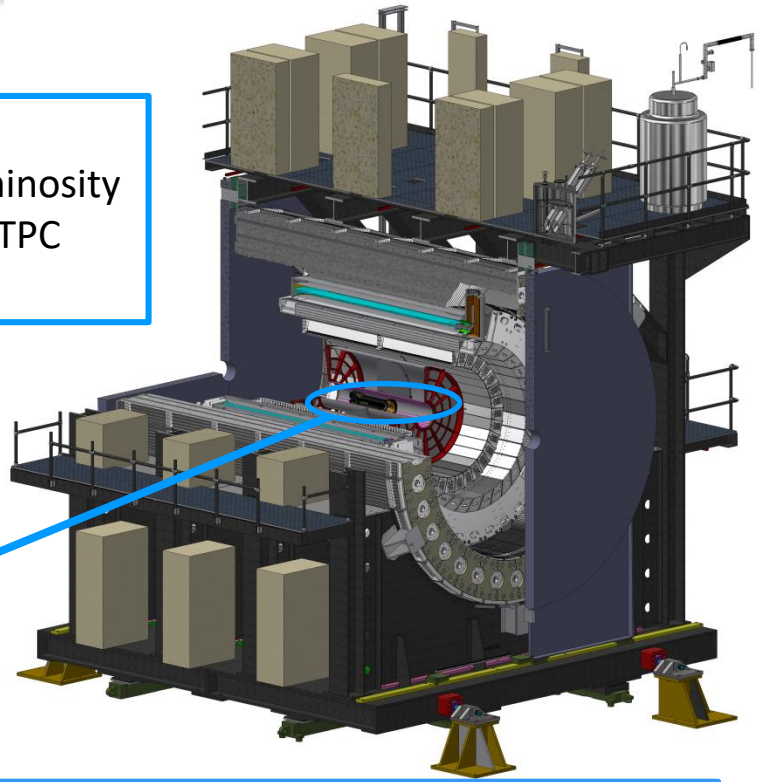
WBS Silicon Detectors

3.1 INTT

3.2 MVTX

- Enables flavor-tagged physics program
- Separates multiple vertices at high luminosity
- Provides tracking between vertex and TPC





INTT is an in-kind detector contribution from RIKEN

sPHENIX MIE Overview

TPC	Project Director	Last CD Achieved	% Complete	CPI	SPI
$27.0M AY	Edward O'Brien	PD-2/3 Pending	24.0% BCWP/BAC @ 7/31/2019	1.0	0.95

Scope

- Detector systems produced, tested and ready for installation: Time Projection Chamber w/ electronics, Electromagnetic Calorimeter w/ electronics, Hadronic Calorimeter w/ electronics, DAQ/Trigger, Minimum Bias Detector, Project Management

Not in scope

- SC-Magnet, Bldg/Det Infrastructure, Installation and System Commissioning

Schedule

- CD-0 received Sept 2016
- CD-1/3A received Aug 2018
- PD-2/3 review May 2019 (approval pending Sept 2019)
- Early completion Oct 2021
- PD-4 Dec 2022

Cost

- **$27.0M AY Total Project Cost including 28.7% contingency on ETC**

1008 Infrastructure & Facility Upgrade

TPC	Project Director	Last CD Achieved	% Complete	CPI	SPI
$29.5- 35.0MAY	Edward O'Brien	N/A	31.1% BCWP/BAC @ 7/31/2019	I&F: Pre-baseline	I&F: Pre-baseline

Scope

- SC-Magnet support including the Flux Return, Cryogenics into Bldg 1008, Detector Carriage/Cradle, other Bldg 1008 Infrastructure improvements
- sPHENIX Installation, Integration and System Commissioning is part of the scope

Updated RLS for 1008 Infrastructure and Facility

I&F Management and RLS integrated with the sPHENIX MIE

Schedule

- sPHENIX Upgrade Completion date December 2022
- First RHIC run of sPHENIX Feb 1, 2023

Cost

- **$32.3 M AY Point Estimate including 25% contingency on ETC**

MAPS Vertex Detector (MVTX)

TPC	Project Director L2 Manager	Status	% Complete
$4.75M AY	Edward O'Brien Ming Liu	BNL Capital Project: Approval pending addressing C&S review recommendations	Just started

Scope

- Three layers of Monolithic Active Pixel Silicon Sensors modeled on the ALICE Inner Tracking System, mechanical support system, electronics, assembly, integration and services.

Updated RLS for the MVTX as of July 2019

MVTX Management and RLS are integrated with sPHENIX MIE and I&F Upgrade

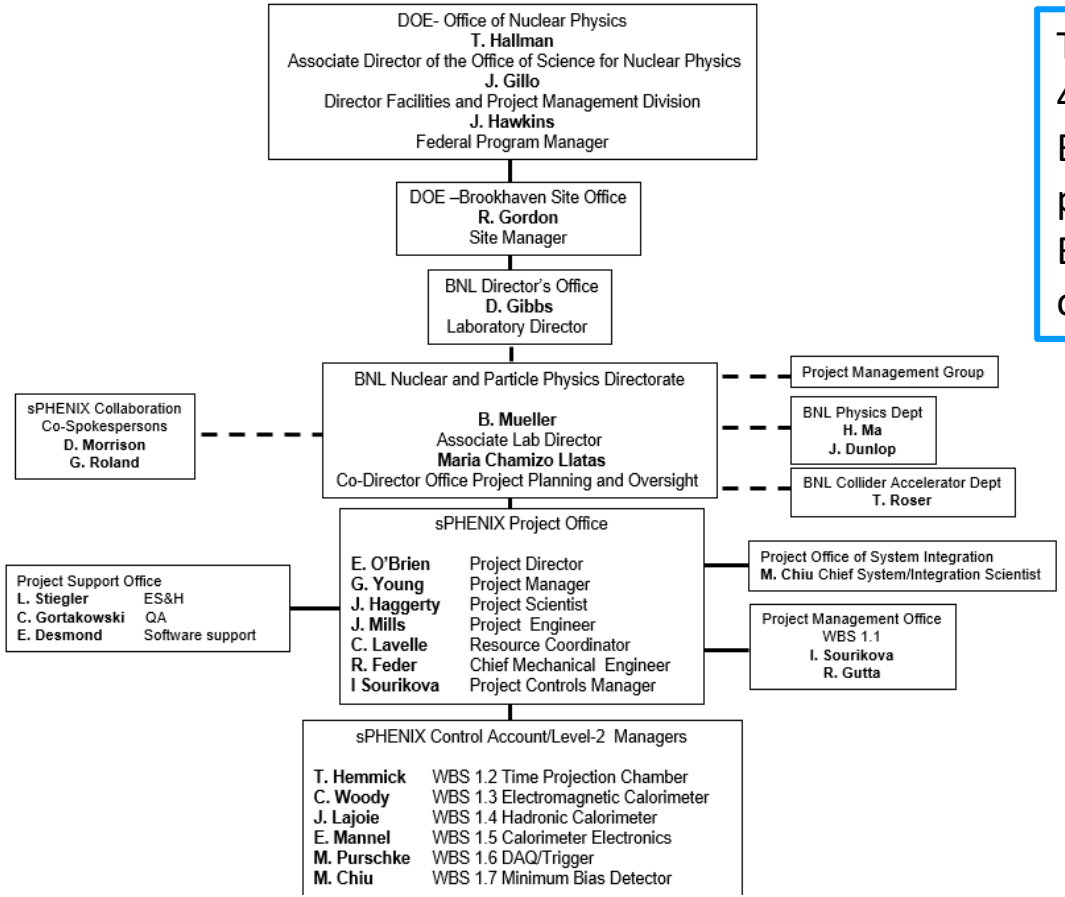
Schedule

- Expect approval Oct 2019
- sPHENIX Upgrade Early Completion date March 2022
- First RHIC run of sPHENIX Feb 2023
- Project Close Out Dec 2023

Cost

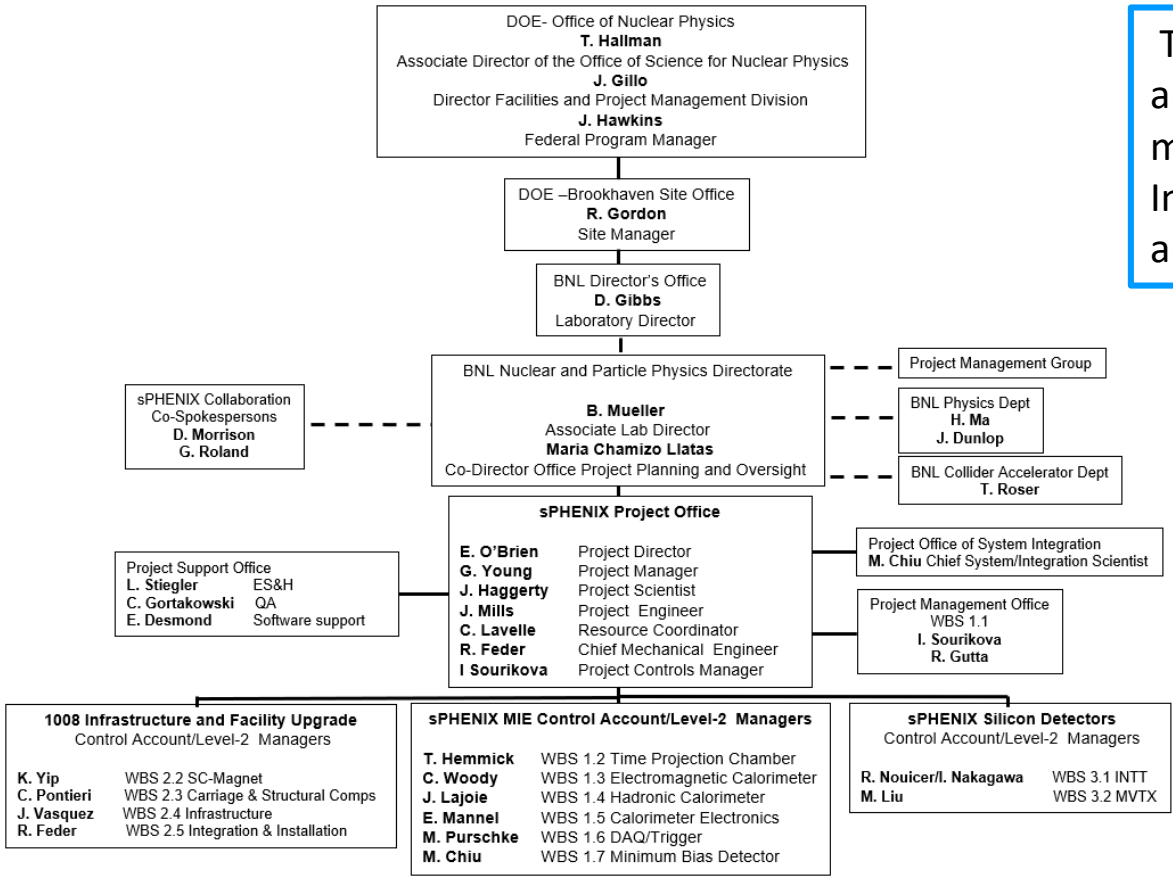
- **$4.75 M AY Total Project Cost including 28.6% contingency on ETC**

sPHENIX MIE Management Organization



The Org Chart varies from a DOE 413.3B project. There is no FPD in BHSO. The successful delivery of the project is the responsibility of the BNL Lab Director. DOE-OPA no longer oversees the Project.

sPHENIX MIE + Infrastructure & Facility + Silicon Detectors



The same management team with an expanded organizational structure manages the sPHENIX MIE, the 1008 Infrastructure and Facility Upgrade and the Silicon Detector Upgrades

Threshold & Objective KPP's

- The individual L2 components of sPHENIX are the MIE deliverables.
- KPP's are determined using bench tests, LED/Pulser/laser tests, and cosmics. Beam collisions are not needed to satisfy the KPP's.

System	Demonstration or Measurement	Threshold KPP's	Objective KPP's
Time Projection Chamber	Preinstall, Bench Test	≥ 90% live channels based on laser, pulser, cosmics	≥ 95% live channels based on laser, pulser, cosmics
Time Projection Chamber	Preinstall, Bench Test	Ion Back Flow ≤ 2% per GEM Module averaged over the active area of ea. GEM Module	Same
Time Projection Chamber	Preinstall, Bench Test w/cosmics	≥ 90% single hit efficiency / mip track, averaged over the active TPC volume	≥ 95% single hit efficiency / mip track
Time Projection Chamber Front End Electronics	Preinstall, FEE Stand-alone Bench Test	Cross talk ≤ 2% per channel, averaged over all channels	Same
EM Calorimeter	Preinstall, Bench Test	≥ 90% live channels based on LED, cosmics	≥ 95% live channels based on LED, cosmics
Hadronic Calorimeter	Preinstall, Bench Test	≥ 90% live channels based on LED, cosmics	≥ 95% live channels based on LED, cosmics
EM Calorimeter	Preinstall, Bench Test	Each sector with an absolute energy pre-calibration to a precision of ≤ 35% RMS	Same
Hadronic Calorimeter	Preinstall, Bench Test	Each sector with an absolute energy pre-calibration to a precision of ≤ 20% RMS	Same
Min Bias Trigger Detector	Preinstall, Bench Test	≥ 90% live channels based on laser. 120 ps/channels timing resolution w/ Bench Test	≥ 95% live channels based on laser. 100 ps/channels timing resolution w/ Bench Test
DAQ/Trigger	Event rate	10 kHz with random pulser	15 kHz with random pulser
DAQ/Trigger	Data Logging Rate	10 GBit/s with pulser	Same

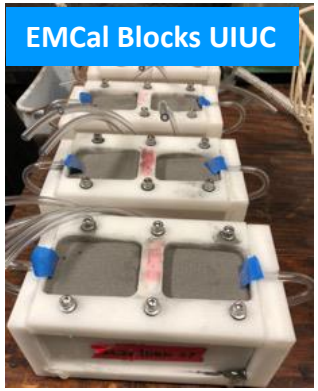
sPHENIX Accomplishments

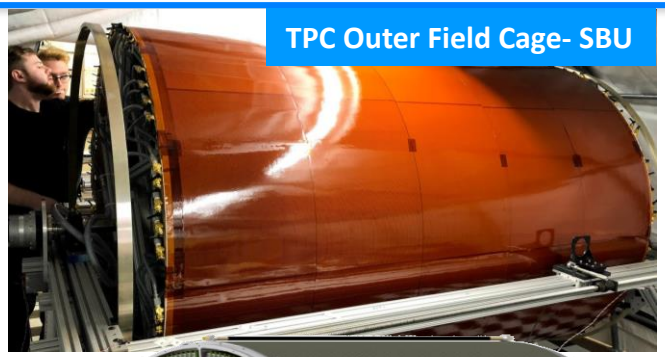
- **PD-2/3 approved by BNL POB subcommittee Sept 2019**. Waiting for Concurrence by BHSO/DOE-NP and Lab Director Approval
- **Successful sPHENIX MVTX Review July 2019**. Preparing MVTX PMP and addressing all recommendations.
- **All 32 Outer HCal Sectors/Magnet Flux Return now at BNL**.
- **All LLP's approved at CD-3A have been placed**. They are: 100k SiPMs, 2500km of Scintillating fiber for EMCal, 7000 Scin tiles for HCal, 19 metric tons of tungsten powder for EMCal.
- Partial delivery of LLP-1 orders, **60k/100k SiPMs**, have arrived at Univ. of Michigan. Partial deliver of LLP-2 scintillating fibers, **600/2500 km**, have arrived at UIUC. Fab work on LLP-3 scin tiles has started at vendor
- Assembly of **1st six OHCal sectors** begun with preproduction parts.
- **SAMPA v5 (TPC ASIC) engineering run** chip order ready for submission to vendor. Funds being transferred to SBU for order. FDR complete.
- **EMCal preproduction Sector 0 assembly complete**. Sector 1 blocks > 85% complete as UIUC.
- Bids for **Bldg 1008 Cryo Components** RFP ($1.1 M). Award process ongoing.
- **Carriage/Cradle FDR held in August**. Checking and sign-off of final drawings ongoing.
- R&D work progressing on all sPHENIX detector components.

sPHENIX Components

EMCal Sector-0 BNL

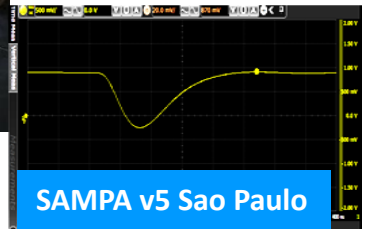
EMCal Blocks UIUC



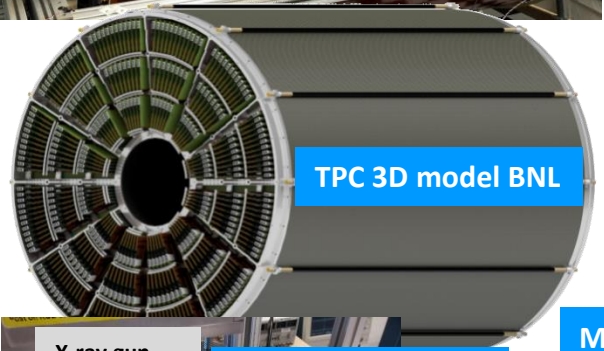


TPC Outer Field Cage- SBU

All OHCal Sectors/Flux Return BNL



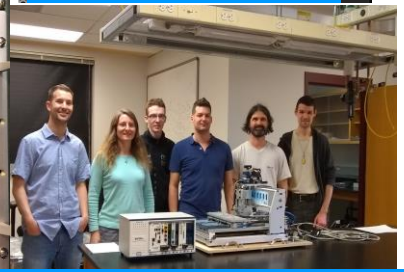
SAMPA v5 Sao Paulo



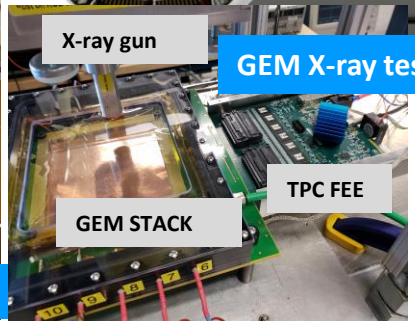
TPC 3D model BNL

HCal Tiles- Uniplast, GSU

Digitizer Crate Columbia U



SiPM Testing U Mich/Debrecen



GEM X-ray test BNL

MBD - RIKEN

OHCal Instrumented Sectors

Collaborators from Baruch, ISU, Lehigh, Ohio U, Rutgers & Wayne State working on instrumenting the first 6 sectors of the OHCal.

All electronics for 6 sectors at BNL. Waiting for delivery of a few sheet metal parts to light tight and test OHCal sectors w/ cosmics

sPHENIX Baseline Budget Profile

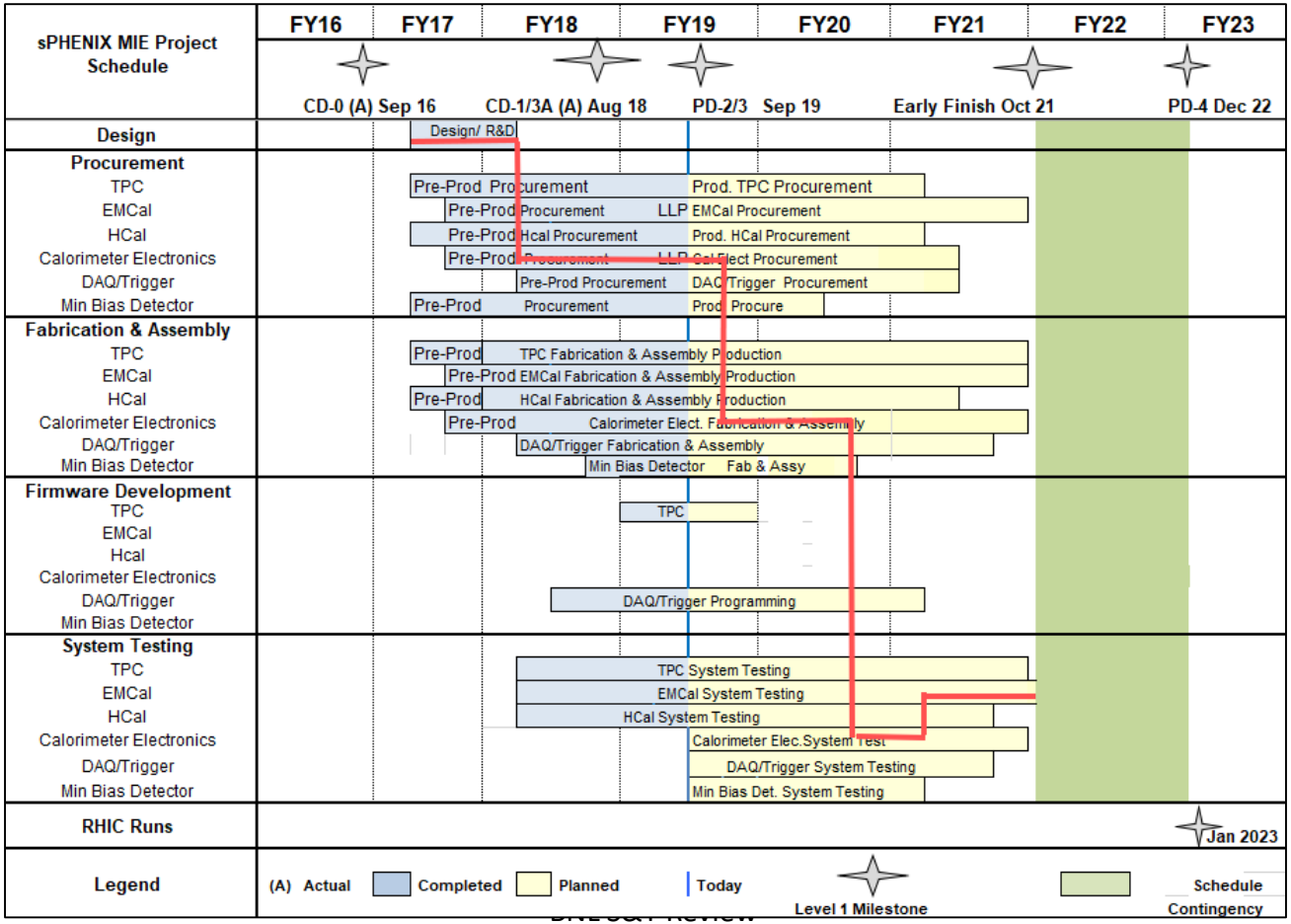
Requested Funding Profile **At Year K$**								
	Prior Yrs	**FY17**	**FY18**	**FY19**	**FY20**	**FY21**	**FY22**	**Total**
R&D		1,513	4,260	350				**6,123**
CDR		100	200					**300**
PED								
Pre-ops								
TEC				**5,310**	**9,524**	**5,530**	**213**	**20,577**
OPC		**1,613**	**4,460**	**350**				**6,423**
Total Project Cost		**1,613**	**4,460**	**5,660**	**9,524**	**5,530**	**213**	**27,000**

The Baseline Budget Profile

Cost Baseline at Level 2

Cost Baseline K$		
WBS	**Level 2 WBS Description**	**Baseline**
1.01	Project Management	$1,952
1.02	Time Projection Chamber	$4,170
1.03	EM Calorimeter	$5,196
1.04	Hadron Calorimeter	$4,069
1.05	Calorimeter Electronics	$5,373
1.06	DAQ/Trigger	$1,240
1.07	Min Bias Trigger Detector	$170
	Performance Measurement Baseline	**$22,169**
	Contingency	$4,831
	Total Project Cost	**$27,000**

Baseline Critical Path



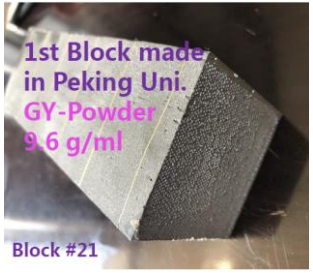
L1 and L2 Milestones in the PMP

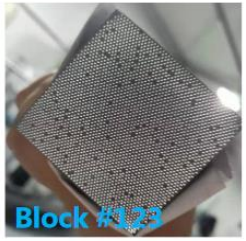
WBS	Level 1 & 2 Project Milestones	Date
1.01.01	**Approve Project Baseline and Construction PD2/3**	19-Sep
1.02.02.02	TPC Module Factories Preproduction Readiness Review	19-Dec
1.03.02.03.02	EMCal Preproduction Sector 0 Assembled	19-Dec
1.02.06.02	TPC DAM Production Readiness Review	20-Feb
1.05.02.03	HCal Preproduction FEE Complete	20-Apr
1.05.02.01	EMCal Electronics Preproduction Complete	20-May
1.03.01.03.01	EMCal W Powder Acquisition Complete	20-Jun
1.03.02.03.03	EMCal Prod. Readiness Review Blocks/Modules/Sectors Complete	20-Jul
1.02.05.03	SAMPA ASIC Performance Accepted	20-Sep
1.05.01	EMCal/HCal SiPM Sensor Procurement Complete	20-Oct
1.05.02.04	HCal SiPM Boards Assembly Complete	20-Nov
1.02.06.03	TPC DAM Felix 2.0 Production Complete	21-Jan
1.06.02.03	Trigger LL1 Preproduction complete	21-Feb
1.05.02.02	EMCal SiPM Boards Production Complete	21-Mar
1.04.04.02	First Outer HCAL Sector Ready to Install	21-Apr
1.04.01	Inner HCAL Ready for Installation	21-Apr
1.02.01.06	GEM Production Complete	21-May
1.06.01.03	DAQ Production: DAQ Ready for Operation	21-May
1.03.01.03.01	EMCal Scintillating Fiber Acquisition Complete	21-May
1.05.02.04	HCal Electronics Complete: Production	21-Jun
1.02.05.04	TPC FEE Production Complete	21-Jul
1.05.02.02	EMCAL Electronics Complete	21-Jul
1.05.03.02	Calorimeter Electronics Complete	21-Jul
1.07	Min Bias Detector Ready to Install	21-Sep
1.06.03.03	GL1 Ready to Operate	21-Sep
1.04.04.02	Last Outer HCAL Sector Ready to Install	21-Oct
1.02.01.08	TPC Ready to Install (Assembly Complete)	21-Oct
1.06.02.04	LL1 Trigger Production Complete	21-Oct
1.06.02.04	LL1 Ready to Operate	21-Oct
1.02.06.03	TPC DAM Production Complete	21-Oct
1.03.02.03.03	EMCal Ready to Install	21-Oct
1.01.01	Early Project Completion	21-Oct
1.01.01	**Approve Project Closeout PD-4**	22-Dec

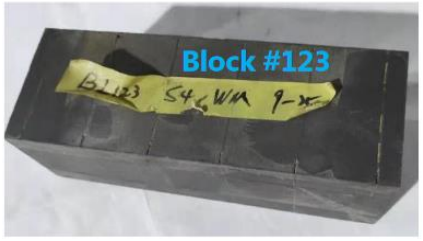
sPHENIX Scope Restoration: High Eta EMCal

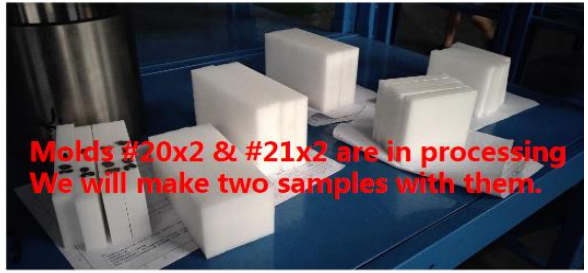
The sPHENIX EMCal had an eta coverage reduction from -1.1< η <1.1 to -0.85< η <0.85 during a cost cutting exercise in 2017

- **sPHENIX Collaborating Institutions Fudan Univ. and Peking Univ. are building the high eta blocks reduced in the cost cutting exercise. Progress on block building in China to date look good.**
- **Electronics for the Chinese blocks to be supplied out of the sPHENIX spare electronics pool funded by RHIC Exp Ops.**







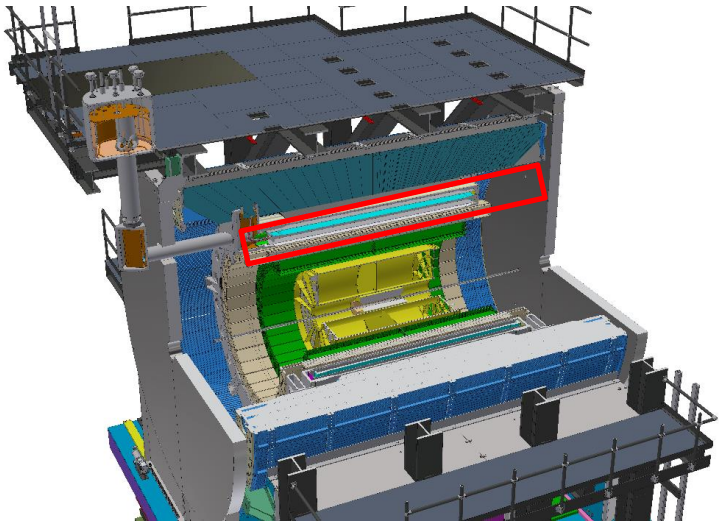


EMCal block fabrication at Fudan University

sPHENIX Scope Restoration: Inner HCal

Instrumentation for the Inner HCal was eliminated as part of the 2017 cost cutting exercise

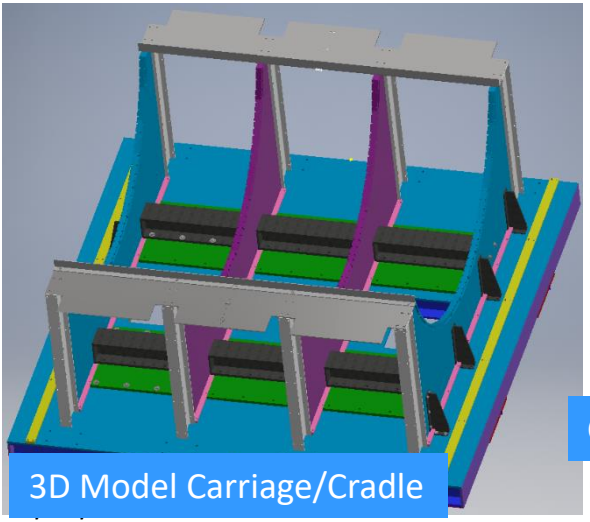
- **Efforts to apply to NSF for funding, and/or to identify international contribution contributions were not successful**
- **Propose to build IHCal scintillating tiles and electronics as a small BNL capital project**



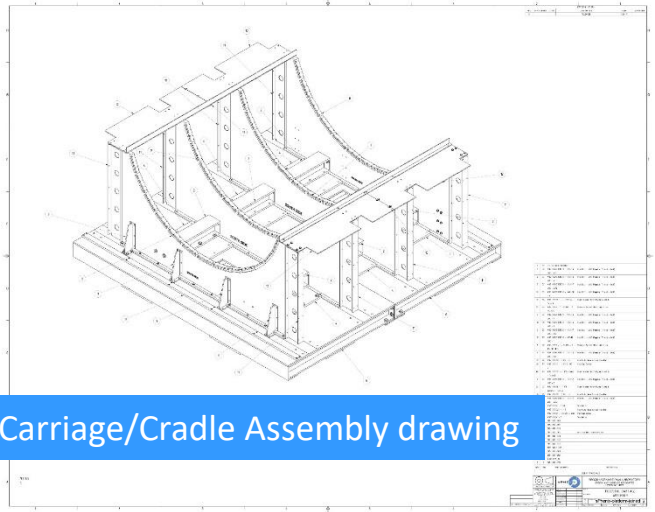
Mechanical prototype IHCal built by ISU

Carriage/Cradle for sPHENIX (2.X)

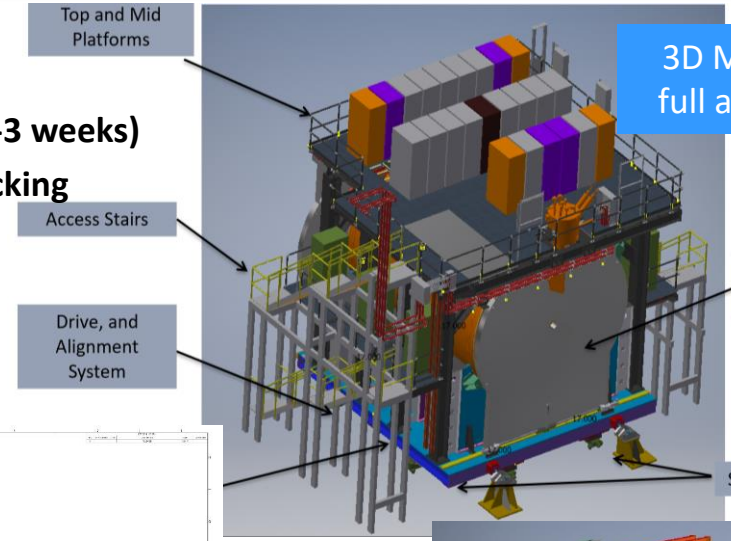
- Final Design Review held 8/7/2019
  - **Received FDR memo 9/10 (being reviewed)**
  - **100% Cradle Carriage drawings are in checking stage (2-3 weeks)**
  - **90% Prepared weldment cradle package -ready for checking**
  - **Starting work on the SOW**
- Base Platform drawings are 95% complete
- Upper Platform drawings are 80% complete
- End Caps drawings are 35% complete



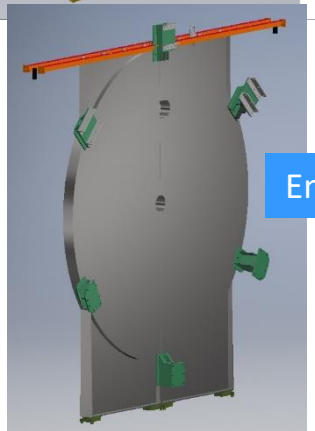
3D Model Carriage/Cradle



Carriage/Cradle Assembly drawing



3D Model of full assembly

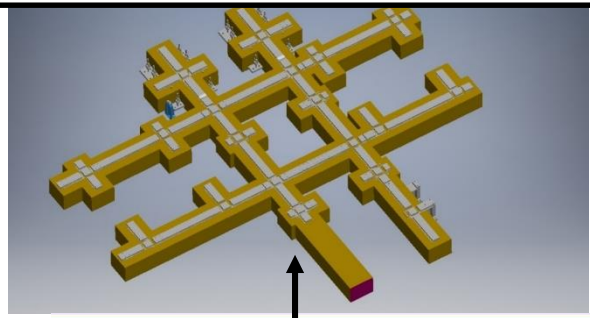


End Caps

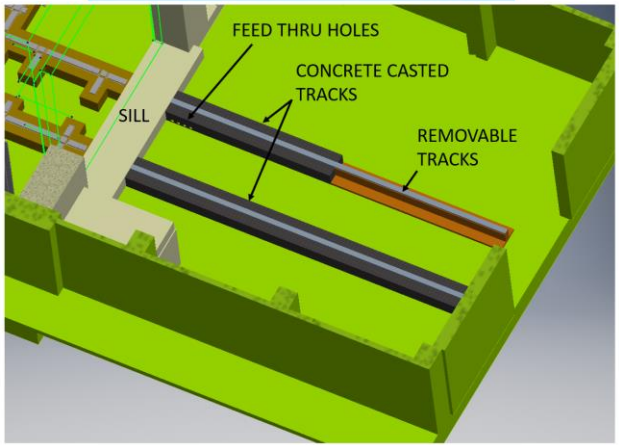
Bldg 1008 Track Modification (2.X)

- Continued detailed analysis of track modifications
- Timeline
  - Fall 2019- Design track system, Begin to remove items in IR after North magnet job is complete (2 weeks per C. Biggs)
  - Spring 2020- bidding process
  - Summer 2020- Construction begins

Tracks were designed to handle 450 tons, not the 900 tons we require for sPHENIX

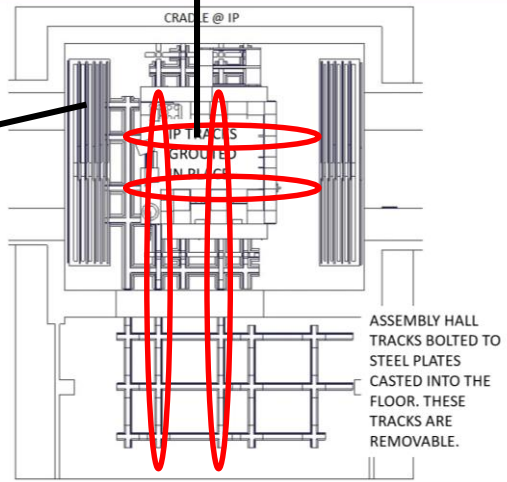


PROPOSED ASSEMBLY HALL TRACKS



- IR tracks will be cast in concrete.
- Piping/cable tray/track will need to be removed
- Removing these items will open up access to underneath the carriage base

EXISTING TRACK CONFIGURATION



Summary

- Successful MIE PD-2/3 Review in May 2019
  - **Project team/Organization in place**
  - **Baseline is set**
  - **Scope, schedule, and cost well defined and realistic**
  - **All review recommendations addressed**
  - **Project Management Plan written**
  - **Awaiting approval/concurrence by BNL/DOE**
- All CD-3A procurements have been placed. Many components starting to arrive.
- Advanced preproduction prototypes exist. R&D continues
  - **EMCal Sector 0 complete**
  - **HCal Sectors 1-6 instrumented**
- Plan in place to restore earlier calorimeter reductions due to 2017 cost cutting exercise.
  - **Plan includes both BNL and international contributions.**
- Good Progress on Infrastructure and Facility Upgrade
  - **Barrel magnet flux return sectors all at BNL**
  - **Major cryogenic component purchases under way**

Back Up

Ultimate Performance Parameters

UPP's unchanged from those approved at CD-1/3A and in PPMP

Ultimate Performance Parameters
Upsilon (1S) mass resolution $\leq$ 125 MeV
$\geq$ 90% Tracking Efficiency
$\leq$ 10% momentum resolution at 40 GeV /c
$\leq$ 150% / $\sqrt{E_{jet}}$ jet-energy resolution for R=0.2 jets
$\leq$ 8% single photon energy resolution at 15 GeV

UPP measurements made at 10% central Au+Au RHIC events at average RHIC store luminosity

Cost Performance Report as of the 7/31/19

sPHENIX

1. CONTRACTOR	2. CONTRACT	3. PROGRAM	4. REPORT PERIOD
a. NAME Brookhaven Science Associates	a. NAME sPHENIX	a. NAME sPH MIE 1907	a. FROM (YYYYMMDD) 2019 / 07 / 01
b. LOCATION (Address and ZIP Code) Brookhaven National Laboratory	b. NUMBER	b. PHASE	b. TO (YYYYMMDD) 2019 / 07 / 31
	c. TYPE / d. SHARE RATIO	c. EVMS ACCEPTANCE NO X YES (YYYYMMDD)	

5. CONTRACT DATA

a. QUANTITY	b. NEGOTIATED COST	c. ESTIMATED COST OF AUTHORIZED UNPRICED WORK	d. TARGET PROFIT/FEE	e. TARGET PRICE	f. ESTIMATED PRICE	g. CONTRACT CEILING	i. DATE OF OTB/OTS (YYYYMMDD)
1	0	0	0	0	0	0	

6. ESTIMATED COST AT COMPLETION

	MANAGEMENT ESTIMATE AT COMPLETION (1)	CONTRACT BUDGET BASE (2)	VARIANCE (3)
a. BEST CASE	0		
b. WORST CASE	0		
c. MOST LIKELY	0	0	0

7. AUTHORIZED CONTRACTOR REPRESENTATIVE

a. NAME (Last, First, Middle Initial)	
O'Brien, Edward	
c. SIGNATURE	d. DATE SIG (YYYYMMDD)

8. PERFORMANCE DATA

CA (3) ITEM (1)	CURRENT PERIOD: BUDGETED COST WORK SCHEDULED (2)	BUDGETED COST WORK PERFORMED (3)	ACTUAL COST WORK PERFORMED (4)	VARIANCE SCHEDULE (5)	VARIANCE COST (6)	CUMULATIVE TO DATE: BUDGETED COST WORK SCHEDULED (7)	BUDGETED COST WORK PERFORMED (8)	ACTUAL COST WORK PERFORMED (9)	VARIANCE SCHEDULE (10)	VARIANCE COST (11)	AT COMPLETION: BUDGETED (14)	ESTIMATED (15)	VARIANCE (16)	Cumulative SPI	Cumulative CPI
1.01A Project Management	32,352	32,247	15,159	-105	17,088	1,428,124	1,428,124	1,427,822	0	302	1,951,679	1,951,679	0	1.00	1.00
1.02A TPC	209,194	136,065	136,396	-73,129	-331	961,838	862,880	894,083	-98,959	-31,203	4,169,636	4,169,636	0	0.90	0.97
1.03A EMCal	182,951	22,460	49,195	-160,491	-26,735	1,653,135	1,420,636	1,380,943	-232,500	39,692	5,196,092	5,196,092	0	0.86	1.03
1.04A HCal	1,407	2,117	12,665	710	-10,548	624,743	694,880	739,816	70,137	-44,937	4,068,518	4,068,518	0	1.11	0.94
1.05A Calorimeter Electronics	171,436	111,362	113,600	-60,075	-2,238	785,585	792,290	819,225	6,705	-26,935	5,373,219	5,373,219	0	1.01	0.97
1.06A DAQ & Trigger	0	0	1,002	0	-1,002	25,972	25,972	27,157	0	-1,184	1,240,177	1,240,177	0	1.00	0.96
1.07A MinBias Trigger Detector	77,229	44,020	0	-33,208	44,020	99,148	99,148	34,287	0	64,860	170,170	170,170	0	1.00	2.89
b. COST OF MONEY	0	0	0	0	0	0	0	0	0	0	0	0	0		
c. GENERAL AND ADMINIS	0	0	0	0	0	0	0	0	0	0	0	0	0		
d. UNDISTRIBUTED BUDGET											0	0	0		
e. SUBTOTAL	674,568	348,271	328,018	-326,297	20,253	5,578,545	5,323,929	5,323,334	-254,616	595	22,169,490	22,169,490	0	0.95	1.00
f. MANAGEMENT RESERVE											4,830,510				
g. TOTAL	674,568	348,271	328,018	-326,297	20,253	5,578,545	5,323,929	5,323,334	-254,616	595	27,000,000				

9. RECONCILIATION TO CONTRACT BUDGET BASELINE

	(10)	(11)	(14)	(15)	(16)
a. VARIANCE ADJUSTMENT	0	0			
b. TOTAL CONTRACT VARIANCE	-254,616	595	0	0	0

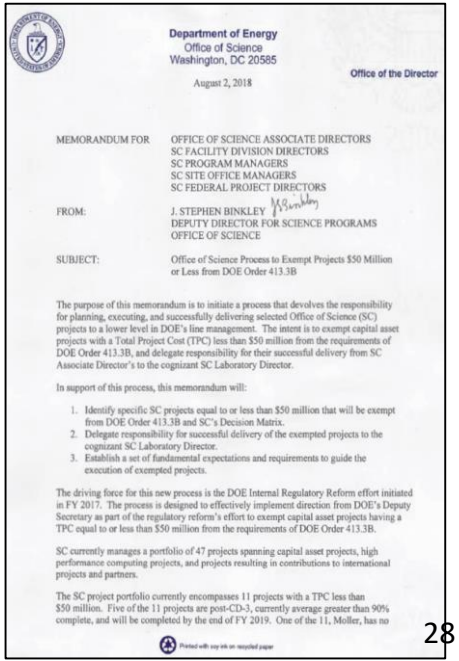
CLASSIFICATION (When Filled In)

16,846,156	ETC
16,845,561	BCWR
28.7%	% conting
24.0%	% complete
25.2%	Planned

Change in DOE-SC Rules for MIE's with TPC's ≤ $50M

DOE SC Memo on Project Management dated August 2, 2018

- Raised threshold for application of DOE Order 413.3B from $10M to $50M for SC projects.
- sPHENIX was on the DOE SC list of projects impacted by the change.
- Delegation for managing these projects now the responsibility of Laboratory Director
- DOE-OPA no longer responsible for managing these projects.
- ONP prepared guidance document for NP Oversight
- BNL has generated a procedure to address the management of sub $50M MIE's.
- BNL Procedure in process of being added to SBMS Project Management – Management System.
- DOE will assign a PEMP goal to BNL to hold them accountable for the successful execution of the project.



Department of Energy
Office of Science
Washington, DC 20585

Office of the Director

August 2, 2018

MEMORANDUM FOR: OFFICE OF SCIENCE ASSOCIATE DIRECTORS
SC FACILITY DIVISION DIRECTORS
SC PROGRAM MANAGERS
SC SITE OFFICE MANAGERS
SC FEDERAL PROJECT DIRECTORS

FROM: J. STEPHEN BINKLEY
DEPUTY DIRECTOR FOR SCIENCE PROGRAMS
OFFICE OF SCIENCE

SUBJECT: Office of Science Process to Exempt Projects $50 Million or Less from DOE Order 413.3B

The purpose of this memorandum is to initiate a process that devolves the responsibility for planning, executing, and successfully delivering selected Office of Science (SC) projects to a lower level in DOE's line management. The intent is to exempt capital asset projects with a Total Project Cost (TPC) less than $50 million from the requirements of DOE Order 413.3B, and delegate responsibility for their successful delivery from SC Associate Director's to the cognizant SC Laboratory Director.

In support of this process, this memorandum will:

1. Identify specific SC projects equal to or less than $50 million that will be exempt from DOE Order 413.3B and SC's Decision Matrix.
2. Delegate responsibility for successful delivery of the exempted projects to the cognizant SC Laboratory Director.
3. Establish a set of fundamental expectations and requirements to guide the execution of exempted projects.

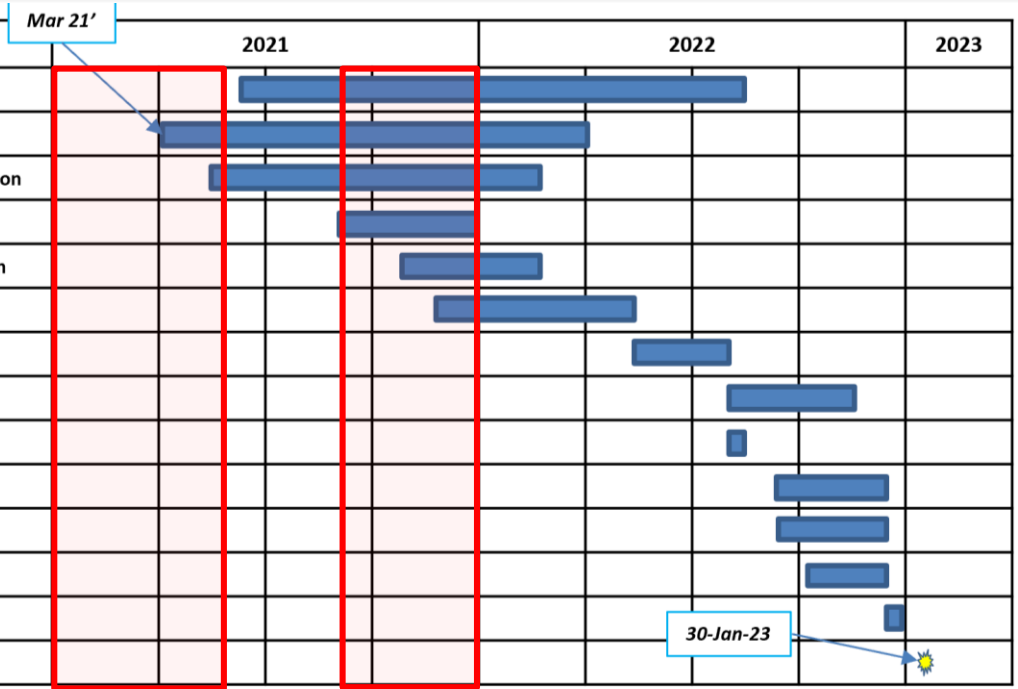
The driving force for this new process is the DOE Internal Regulatory Reform effort initiated in FY 2017. The process is designed to effectively implement direction from DOE's Deputy Secretary as part of the regulatory reform's effort to exempt capital asset projects having a TPC equal to or less than $50 million from the requirements of DOE Order 413.3B.

SC currently manages a portfolio of 47 projects spanning capital asset projects, high performance computing projects, and projects resulting in contributions to international projects and partners.

The SC project portfolio currently encompasses 11 projects with a TPC less than $50 million. Five of the 11 projects are post-CD-3, currently average greater than 90% complete, and will be completed by the end of FY 2019. One of the 11, Moller, has no

sPHENIX Installation/RHIC Run Schedule

Installed Component	Scope of installation	Calendar Year
Infrastructure	Safety, Cryo, Line Electric, Gas and cooling, other services	
Cradle-Carriage	Base → OHCAL and Magnet → Structure → Pole Tips	
Outer HCAL	13 Sectors → Magnet → 19 Sectors → Cables → Commission	
Magnet	Install and align → prep cryo and electric	
Inner HCAL	Assemble barrel → Insert and align → cable → Commission	
EMCAL	Assemble in iHCAL bore → services → Commission	
sPHENIX move to IR	Move into IR → connect magnet → field mapping	
TPC	Install → Align → Services → Commission	
Beam Pipe	Install, Support, Bake	
INTT	Install → Align → Services → Commission	
MVTX	Install → Align → Services → Commission	
MBD	Install → Align → Services → Commission	
Full System Commission		
Start of RHIC Run		



RHIC Run 2021—January 2021-May 2021

RHIC Run 2022—September 2021-December 2021