

sPHENIX Annual MIE Review

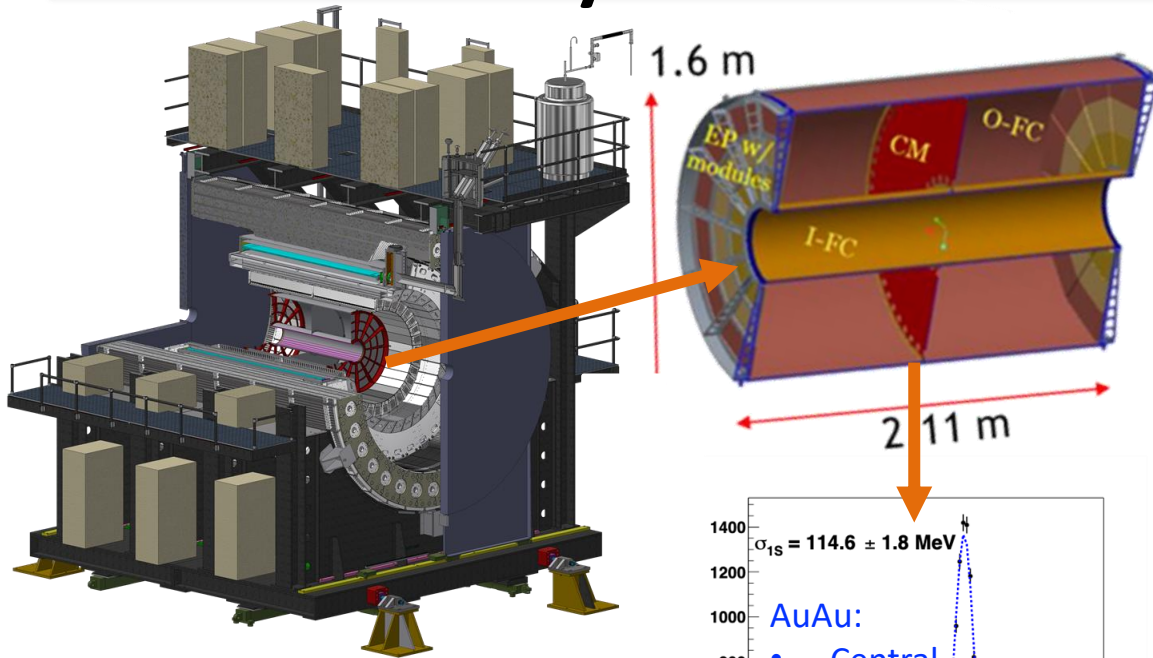
1.2 sPHENIX TPC

Thomas K. Hemmick

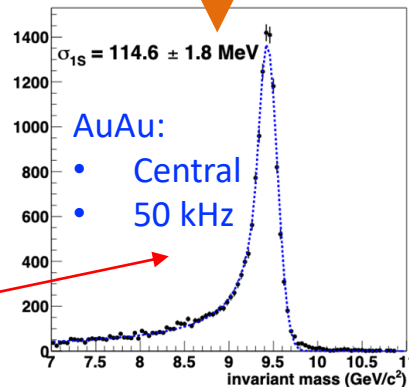
July 14-15, 2021

BNL

The Subsystem



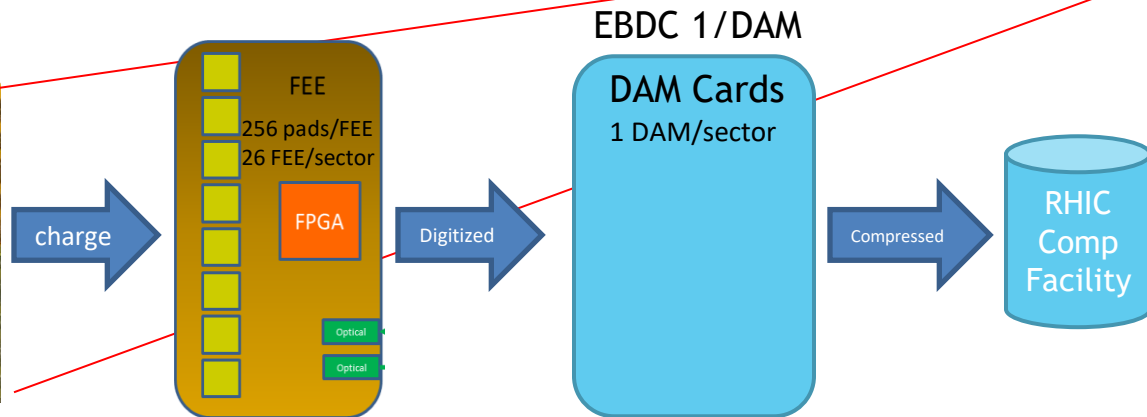
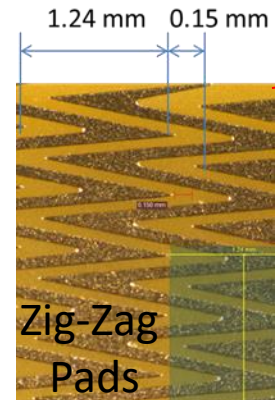
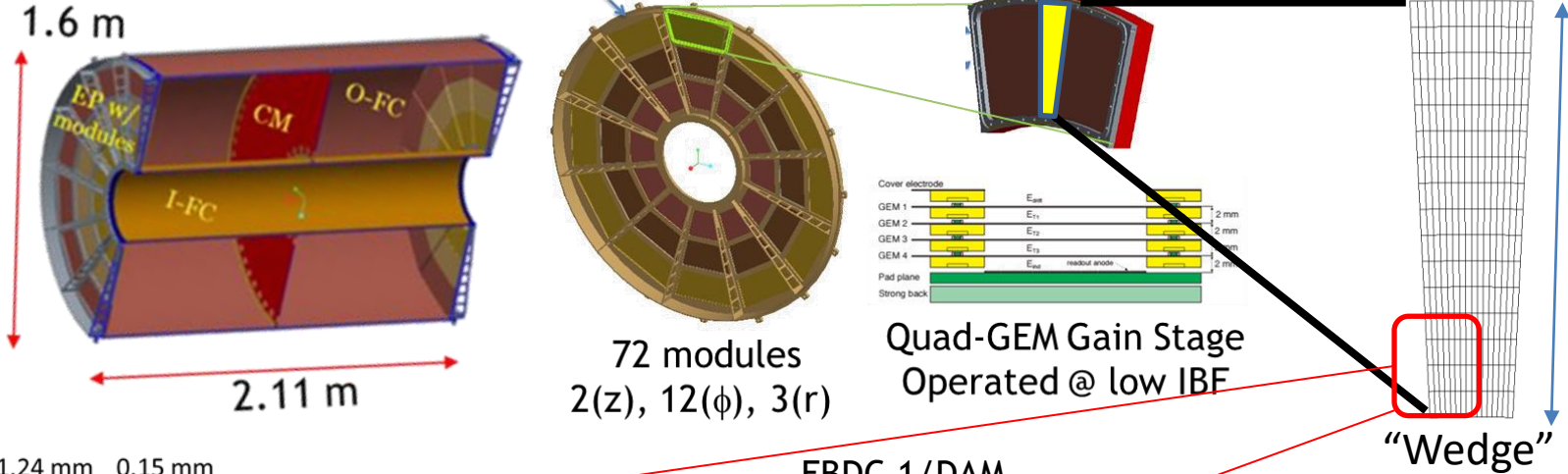
- A next-generation TPC operated in continuous readout mode using Gas-Electron Multiplier (GEM) avalanche w/ low Ion Back Flow (IBF).
- Front End Electronics (FEE) uses SAMPA chip (developed by ALICE).
- Data Aggregation Module (DAM) uses the FELIX board (ATLAS exp)²



Charged Tracking in sPHENIX:

- TPC provides **p-resolution**

The Subsystem Technical Overview



Item	Count
Field Cage	1
Modules	72
FEE	624
DAM	24
EBDC	24

Scope/Deliverables

- 1.2.1: TPC Mechanics
 - TPC Field Cage: v2 prototype; Final Field Cage
 - TPC Modules: prototypes; Assembly & Test Production.
 - TPC GEM Production: CERN Shop (mirroring ALICE production)
 - TPC High Voltage Systems: (GEM & Central Membrane)
 - TPC Assembly: (Modules, Electronics, Testing).
- 1.2.(2-4): Rn Factories (n=1, 2, 3a, 3b):
 - Factory Preparation; Pre-production GEM; Framed GEM Production
- 1.2.5: TPC FEE:
 - FEE v1 Prototype; FEE v2 Prototype; FEE Production
- 1.2.6: TPC DAM:
 - DAM v1 Prototype; DAM v2 Prototype; DAM Production
- 1.2.7: TPC Services:
 - Laser Calibration System; Gas System; Cooling System

Funding Source Key:

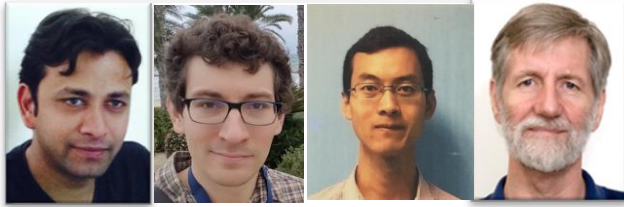
- OPC
- MIE

Subsystem Collaborators

Factory Managers



Additional Scientific



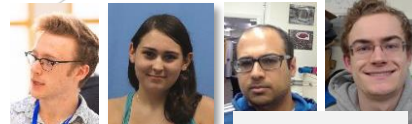
L2/L3- Management



Engineering



BROOKHAVEN NATIONAL LABORATORY



Students



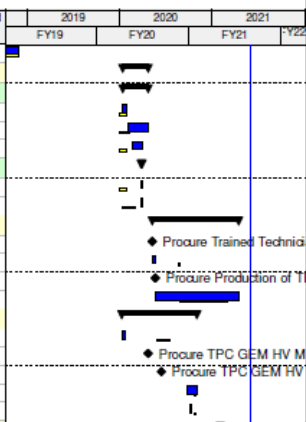
EE:



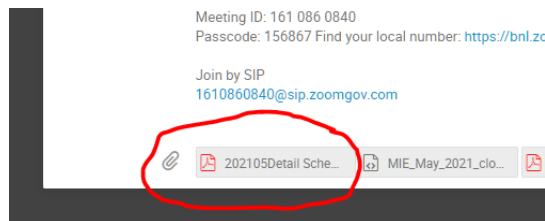
Schedule Overview



POM02 sPHENIX WBS 1.x, 2.x May 2021		IPD - MIE Detail Schedule											16-Jun-21 09:44							
Activity ID	Activity Name	Total Float	At Completion	Activity % Complete	Start	Finish	BL Project Start	BL Project Finish	Budgeted Labor Units	Budgeted Nonlabor Units	Budgeted Total Cost	BL Project Total Cost	BNL Acct Number	BNL Fund Source	2019		2020		2021	
															FY19	FY20	FY21	FY22		
S116300	Procure TPC v1b Module GEMs M&S		40	100%	01-Oct-18 A	30-Nov-18 A	01-Oct-18	30-Nov-18	0	0	0	0	16701	A-OPC						
	TPC v2 Modules		72		14-Jan-20 A	24-Apr-20 A	31-Dec-19	05-Mar-20	0	12900	14,679	14,679								
	TPC v2 Module Common Mechanics		72		14-Jan-20 A	24-Apr-20 A	31-Dec-19	12-Feb-20	0	2700	3,072	3,072								
S117700	Procure TPC v2 Module Grid Parts M&S		9	100%	14-Jan-20 A	28-Jan-20 A	31-Dec-19	29-Jan-20	0	500	569	569	16701	A-OPC						
S117400	Procure TPC v2 Module Frames M&S		58	100%	04-Feb-20 A	24-Apr-20 A	31-Dec-19	12-Feb-20	0	1000	1,138	1,138	16701	A-OPC						
S117100	Procure TPC v2 Module Strongback M&S		30	100%	18-Feb-20 A	31-Mar-20 A	31-Dec-19	29-Jan-20	0	1200	1,366	1,366	16701	A-OPC						
	TPC v2a Module Prototype		3		26-Mar-20 A	31-Mar-20 A	31-Dec-19	05-Mar-20	0	10200	11,607	11,607								
S118100	Procure TPC v2a Module Padplane M&S		3	100%	26-Mar-20 A	31-Mar-20 A	31-Dec-19	29-Jan-20	0	3700	4,210	4,210	16701	A-OPC						
S118400	Procure TPC v2a Module GEMs M&S		3	100%	26-Mar-20 A	31-Mar-20 A	08-Jan-20	05-Mar-20	0	6500	7,397	7,397	16701	A-OPC						
	TPC Production GEM Acquisition		236		07-May-20 A	17-Apr-21 A	12-Aug-20	02-Mar-21	0	172280	196,860	198,472								
S119700	Procure Trained Technician to work in CERN Shop on TPC GEMs - Contract Award(s)		0	100%	07-May-20 A			12-Aug-20	0	0	0	0		A-TEC						
S120000	Procure Trained Technician to work in CERN Shop on TPC GEMs - Delivery Acceptance		5	100%	14-May-20 A	20-May-20 A	19-Aug-20	25-Aug-20	0	39080	44,470	44,470	59702	A-TEC						
S119800	Procure Production of TPC GEM foils (includes Technician fees) - Contract Award(s)		0	100%	20-May-20 A			12-Aug-20	0	0	0	0		A-TEC						
S120100	Procure Production of TPC GEM foils (includes Technician fees) - Delivery Acceptance		226	100%	21-May-20 A	17-Apr-21 A	26-Aug-20	02-Mar-21	0	133200	152,390	154,002	59702	A-TEC						
	TPC High Voltage System		207		08-Jan-20 A	30-Oct-20 A	26-May-20	29-Oct-20	0	119072	138,191	138,191								
S120400	Procure TPC Membrane HV Cables - M&S		8	100%	08-Jan-20 A	20-Jan-20 A	26-May-20	21-Jul-20	0	600	683	683	59702	A-TEC						
S121200	Procure TPC GEM HV Membrane Power Supply - Contract Award(s)		0	100%	22-Apr-20 A			26-Aug-20	0	0	0	0		A-TEC						
S121100	Procure TPC GEM HV Power Supplies - Contract Award(s)		0	100%	15-Jun-20 A			26-Aug-20	0	0	0	0		A-TEC						
S121400	Procure TPC GEM HV Power Supplies - Delivery Acceptance		28	100%	22-Sep-20 A	30-Oct-20 A	23-Oct-20	29-Oct-20	0	107922	125,263	125,263	59702	A-TEC						
S121500	Procure TPC GEM HV Membrane Power Supply - Delivery Acceptance		5	100%	06-Oct-20 A	13-Oct-20 A	23-Oct-20	29-Oct-20	0	10550	12,245	12,245	59702	A-TEC						

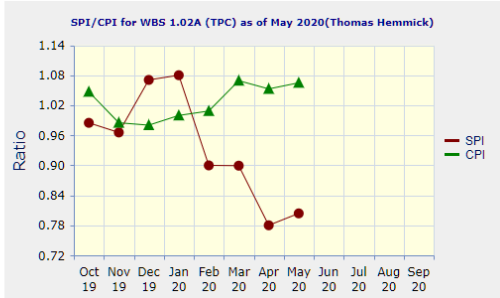
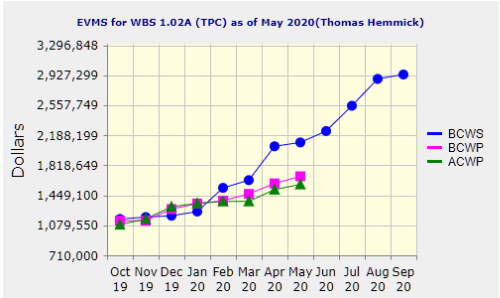


- Many tasks completed since the last review.
- Detailed sPHENIX P6 schedule progress available via Indico site:

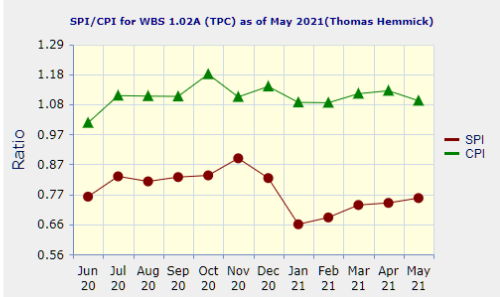
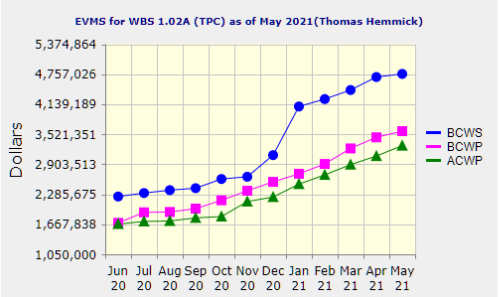


Schedule Performance

Last Year



This Year



Date	SPI	CPI
Cumulative	0.75	1.09

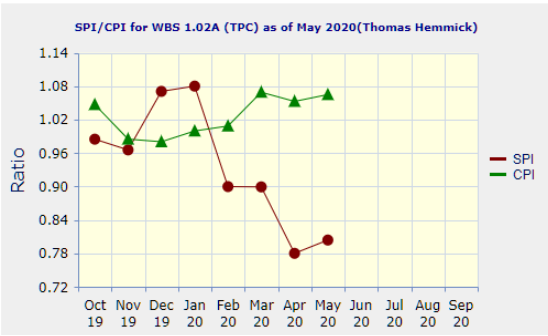
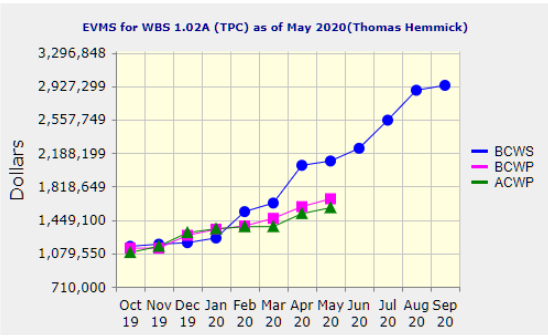
- 1.2.5 TPC FEE -506.6k\$
 - First articles received.
 - No impact presently.
- 1.2.6 DAM -224.2k\$
 - Orders Placed.
 - No impact presently.
- TPC Support Systems -278.4k\$
 - ~1/2 orders placed.
 - Components arriving.
 - No impact presently.

WBS 1.02A TPC (Thomas Hemmick [H5685])		Reporting Period: 5/1/2021 - 5/31/2021							
Current:	BCWS 64,109	BCWP 127,173	ACWP 214,001	SV in \$ 63,064	SV in % 98%	CV in \$ -86,828	CV % -68%	SPI 1.98	CPI 0.59
Cumulative:	4,762,916	3,585,188	3,286,624	-1,177,727	-25%	298,564	8%	0.75	1.09
At Complete:	BAC 5,026,775								

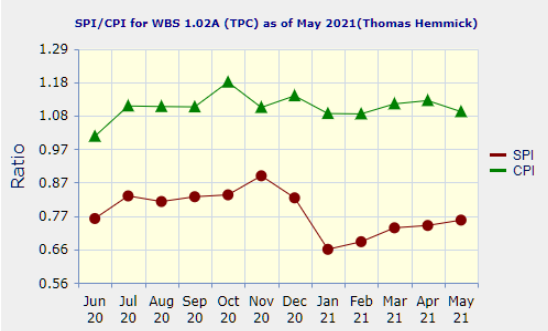
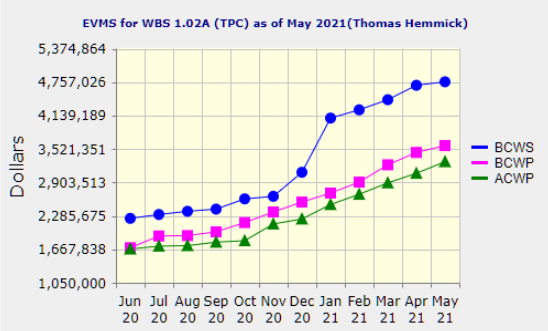
SV from electronics & services with no impact on overall schedule.

Cost Performance

Last Year



This Year



Date	SPI	CPI
Cumulative	0.75	1.09

No mitigations yet required

- Cost Variance Drivers
 - CPI of 1.09 quite good
 - Below threshold for variance reporting.
- Cost Items to go
 - FEE (now on order),
 - DAM (now on order),
 - Laser/Gas/Cooling

WBS 1.02A TPC (Thomas Hemmick [H5685])			Reporting Period: 5/1/2021 - 5/31/2021							
Current:	BCWS 64,109	BCWP 127,173	ACWP 214,001	SV in \$ 63,064	SV in % 98%	CV in \$ -86,828	CV % -68%	SPI 1.98	CPI 0.59	
Cumulative:	4,762,916	3,585,188	3,286,624	-1,177,727	-25%	298,564	8%	0.75	1.09	
At Complete:	BAC 5,026,775									

Remaining Tasks Overview



WBS	Desc	Progress	Remaining
1.2.1	Mechanics	100% Procured.	Assembly.
1.2.2-4	GEMs/Modules	100% Procured.	Assembly/Test
1.2.5	FEE	First Articles Procured	Procurement/Testing
1.2.6	DAM	On order; “known” (ATLAS, GSI)	Procurement/Testing
1.2.7.n	Services: Laser	All except diffuse laser.	Choose Laser Count*
	Gas	Reuse of existing components.	Reconfigure/Install
	Cooling	Recirculator arrived.	Configure/Install

*Details on later slides

Risks

Risk Identification			Risk Handling Plan (Mitigations)	Residual Risk (Post- Mitigation Assessment)										
Risk ID Number	Risk Title	IF/THEN	Risk Handling Plan (Mitigations)	Residual Risk	Low Cost Impact	Likely Cost	High Cost Impact	Low Schedu	Likely Schedu	High Schedu	Overall Impact Score	Expected Value	Average Expect	Basis of Impact Estimates How were cost and schedu
sPH_TPC_013	TPC FEE assembly is late	If TPC FEE assembly rate is lower than planned, then TPC FEE assembly could be behind schedule up to 3	Check P6 progress schedule monthly	10%	0	0	0	1	2	3	Negligible	0.00	0.00	Based on latest experience
sPH_TPC_014	TPC assembly is late	If TPC assembly rate is lower than planned, then TPC assembly could be behind schedule up to 3 mo.	Check P6 progress schedule monthly	10%	0	0	0	1	2	3	Negligible	0.00	0.00	Based on latest experience
sPH_TPC_015	TPC Lasers	If fiberoptic cable has to be 18 m long, then more diffuse lasers will be needed.	Keep track of latest design.	50%	20	40	80	0	1	1	Low	20.00	23.33	Based on latest experience
sPH_TPC_016	TPC FPGA replacement	If the project needs to change FPGA vendor, the purchase will cost more	Keep track of FPGA procurement.	100%	100	100	100	0	0	0	Moderate	100.00	100.00	Based on latest experience

- FEE is the main schedule variance.
 - **Not yet impact.**
 - **Requires continual review.**
- TPC Module Assembly Rate
 - **SBU crew with long term experience (>15 years) and ample GEM supply.**
 - **Schedule assumes Mon-Fri module building, mitigate with weekend(s)**
- TPC Lasers
 - **Major light loss in laser system is in long fiber.**
 - **Long path requires more lasers**
- TPC FPGA Replacement
 - **Provenance of FPGA from vendor determined to be a risk.**
 - **New units ordered at 100% cost impact.**

Summary of Reviews

Prior Reviews

SAMPA V5 Review

Tuesday Aug 6, 2019, 10:00 AM → 1:00 PM US/Eastern
2-219 (Physics)

TPC GEM FDR/PRR

Tuesday Dec 17, 2019, 9:00 AM → 3:00 PM US/Eastern

Wayne State GEM Factory Validation

Tuesday Dec 17, 2019, 3:00 PM → 5:00 PM US/Eastern

sPHENIX DAM Production Readiness Review

Friday Feb 7, 2020, 10:00 AM → 12:00 PM US/Eastern

TPC R3 Padplane Design Review

Thursday Apr 16, 2020, 9:00 AM → 10:00 AM US/Eastern

TPC Preproduction FEE & PCB review

Monday Apr 20, 2020, 3:00 PM → 4:00 PM US/Eastern

SAMPA V5 Production Readiness Review

Wednesday May 27, 2020, 10:00 AM → 12:00 PM US/Eastern

AC and DC Power Distribution Preliminary Design Review

Wednesday Jun 17, 2020, 10:00 AM → 12:10 PM US/Eastern

sPHENIX TPC Transport Cart Final Design Review

Tuesday Jul 14, 2020, 2:00 PM → 3:30 PM US/Eastern

ESRC Review of sPHENIX AC and DC Power Distribution

Wednesday Jul 15, 2020, 10:00 AM → 12:10 PM US/Eastern

This Year

TPC Gas and Cooling Preliminary Design Review

Tuesday Aug 25, 2020, 10:00 AM → 12:00 PM US/Eastern

TPC Laser Calibration System Preliminary Design Review

Tuesday Aug 25, 2020, 2:00 PM → 4:00 PM US/Eastern

TPC Cooling FDR/PRR

Wednesday Dec 16, 2020, 9:00 AM → 11:00 AM US/Eastern

iHCAL, EMCAL and TPC Installation Engineering Review

Tuesday Dec 22, 2020, 9:00 AM → 3:00 PM US/Eastern

TPC Line Laser PRR

Friday Mar 19, 2021, 10:00 AM → 11:00 AM US/Eastern

ESRC Review of sPHENIX TPC

Monday Jun 21, 2021, 1:00 PM → 3:00 PM US/Eastern

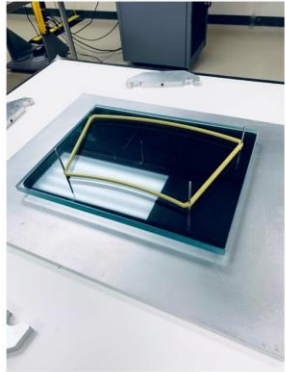
Remaining:

- Diffuse Laser PRR
- Expected August

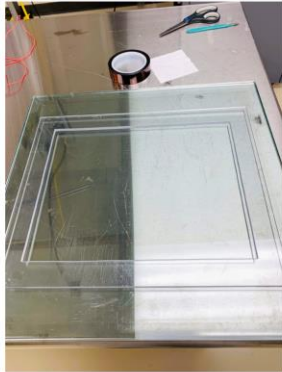
Status and Highlights



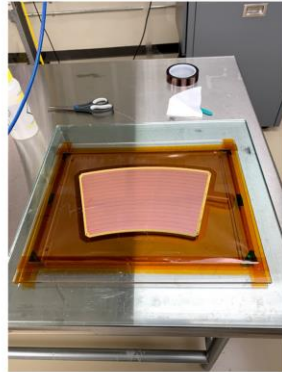
GEM Highlights



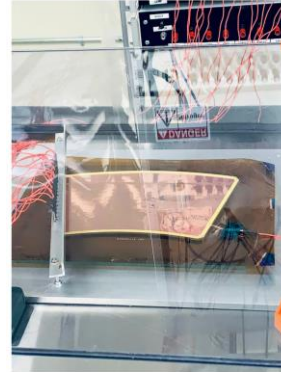
Base glass plate with precision holes, pins and GEM's frame



Stretching frame



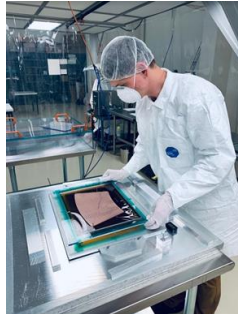
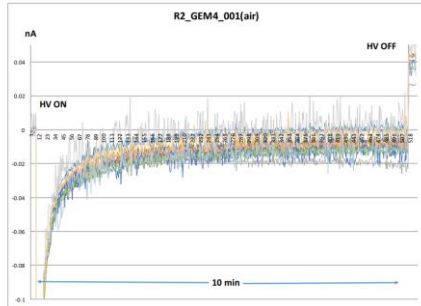
Stretching frame with framed GEM



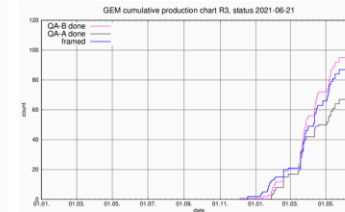
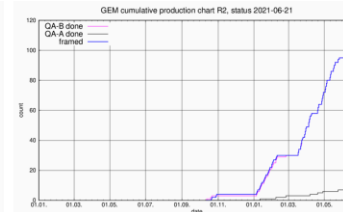
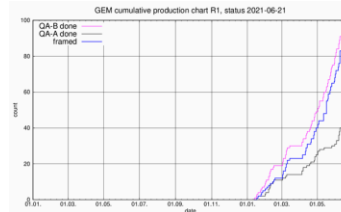
GEM connected to picoAmmeter for leakage current measurements

- ~85% framing complete.
- Passing QA >90%
 - R1 95.1%
 - R2 94.5%
 - R3 97.2%

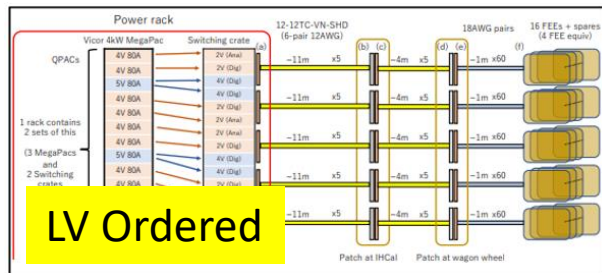
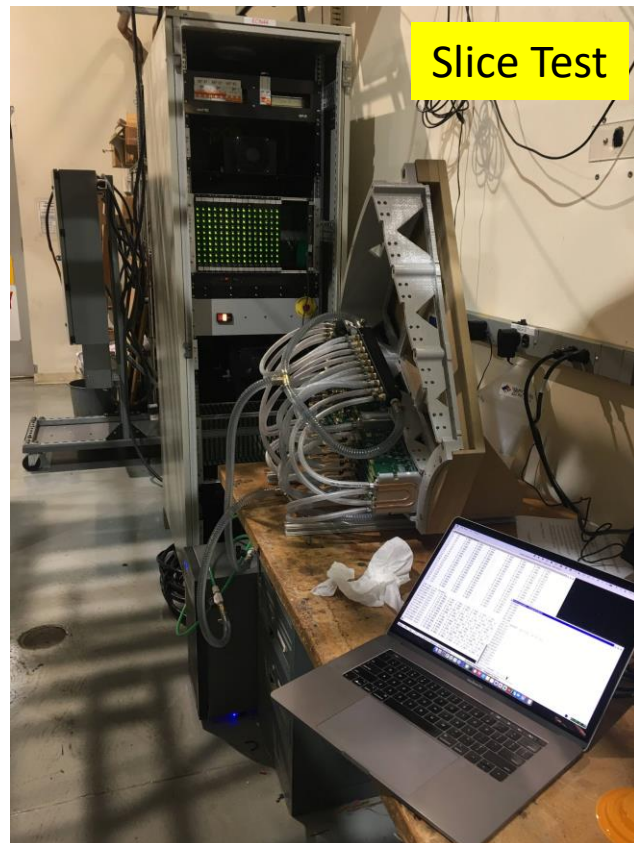
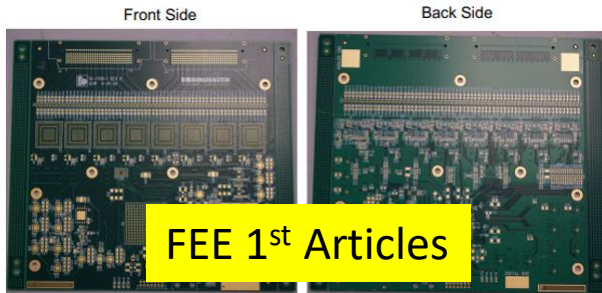
GEM4



2021-06-29	R1					R2					R3				
flavor	G1	G2	G3	G4	sum	G1	G2	G3	G4	sum	(V+T)G1	(V+T)G2	(V+T)G3	(V+T)G4	sum
produced	36	30	33	38	137	35	30	29	35	129	35	35	32	30	132
QA-B done	26	24	29	24	103	28	26	27	28	109	25	30	26	25	106
QA-B passed	26	24	29	19	98	27	25	25	26	103	23	29	26	25	103
QA-B yield	1.00	1.00	1.00	0.79	0.951	0.96	0.96	0.93	0.93	0.945	0.92	0.97	1.00	1.00	0.972
framed, ok	26	24	29	19	98	28	26	27	28	109	23	26	26	27	102
framing fraction of prod.	0.72	0.80	0.88	0.50	0.715	0.80	0.87	0.93	0.80	0.845	0.66	0.74	0.81	0.90	0.773

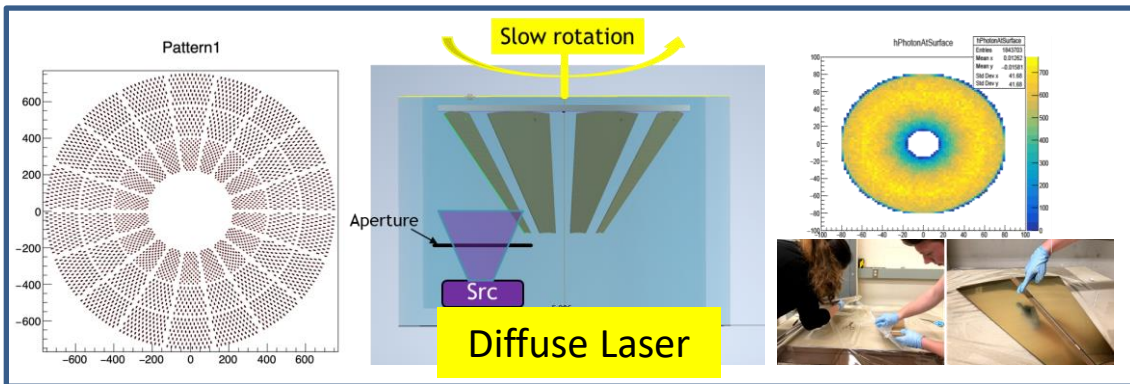
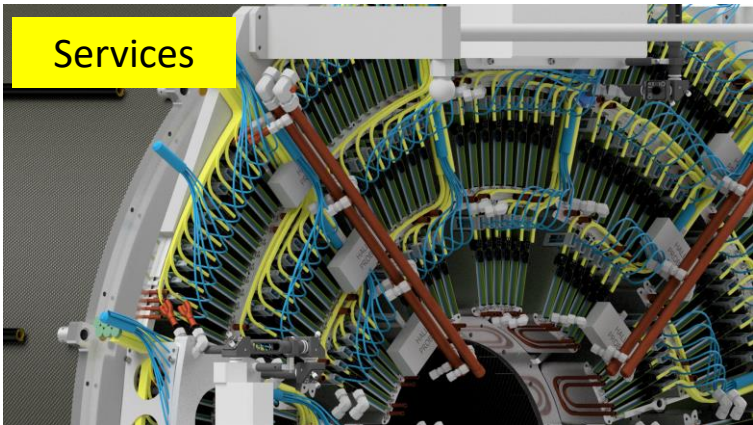


Electronics Highlights



Services Highlights

Services



A: Steady-State Thermal

Temperature

Type: Temperature

Unit: °C

Time: 1

4/7/2020 4:45 PM

30.427 Max

28.824

27.221

25.618

24.015

22.412

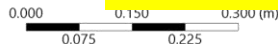
20.809

19.206

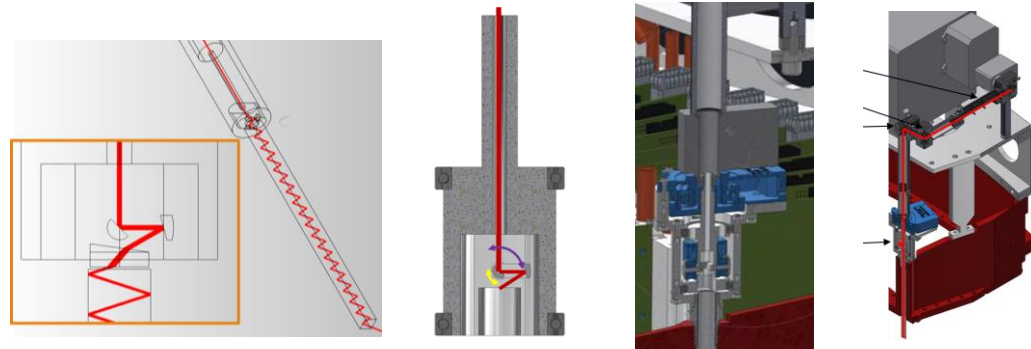
17.603

16 Min

Cooling



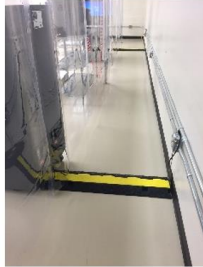
Line Laser



TPC ES&H

Hazard mitigation examples from GEM framing factories:

Examples: Trip Hazards



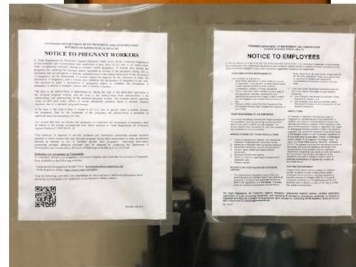
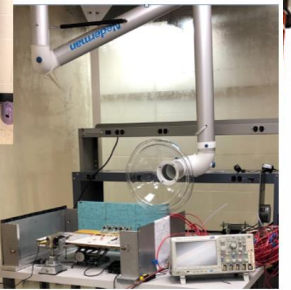
Site-specific Awareness



Personal Protective Equipment



Compressed Gas Safety



Temple: <https://www.temple.edu/ehrs/>

TPC QA Plan

- sPHENIX QA follows BNL-SBMS (Standards-Based Management System).
 - Project Director manages the project and is responsible for achieving performance goals.
 - **L2 Managers** implement the Plan w/in their subsystem and report issues to the Project Director.
 - QA Representative: (1) Ensures QA is established/maintained (2) Provides oversight/support.
- Aspects of the sPHENIX TPC QA Plan include:

- **SOW (Statement of Work)**
- **Documented Procedures**
- **Signed Drawings**
- **Data Management**
- **Inspection & Test.**

These documents on Interface Control are available:

SPHENIX-doc-#	Title	Author(s)	Topic(s)	Last Updated
171-s1	ICD_010_A_FMC_INE	Mickey Chau	Interface Control	21 Mar 2019
203-s1	ICD_042_Racks_Cables	Mickey Chau et al.	Interface Control	19 Mar 2019
202-s1	ICD_041_A_MVIX	Mickey Chau et al.	Interface Control	19 Mar 2019
201-s1	ICD_040_A_INTT	Mickey Chau et al.	Interface Control	19 Mar 2019
200-s1	ICD_039_A_Jandf	Mickey Chau et al.	Interface Control	19 Mar 2019
199-s1	ICD_038_A_INE	Mickey Chau et al.	Interface Control	19 Mar 2019
198-s1	ICD_037_A_MAG	Mickey Chau et al.	Interface Control	19 Mar 2019
197-s1	ICD_036_A_MBD	Mickey Chau et al.	Interface Control	19 Mar 2019
196-s1	ICD_035_A_DAOTrg	Mickey Chau et al.	Interface Control	19 Mar 2019
195-s1	ICD_034_A_CalEl	Mickey Chau et al.	Interface Control	19 Mar 2019
194-s1	ICD_033_A_HCal	Mickey Chau et al.	Interface Control	19 Mar 2019
193-s1	ICD_032_A_PMBAL	Mickey Chau et al.	Interface Control	19 Mar 2019
192-s1	ICD_031_A_TPC	Mickey Chau et al.	Interface Control	19 Mar 2019
191-s1	ICD_030_A_PMBAL	Mickey Chau et al.	Interface Control	19 Mar 2019
190-s1	ICD_029_A_PMBAL	Mickey Chau et al.	Interface Control	19 Mar 2019
189-s1	ICD_028_A_MVIX_Jandf	Mickey Chau et al.	Interface Control	19 Mar 2019
188-s1	ICD_027_A_MVIX_INE	Mickey Chau et al.	Interface Control	19 Mar 2019
187-s1	ICD_026_A_INTT_Jandf	Mickey Chau et al.	Interface Control	19 Mar 2019

Recent Update

Doc. No. _____ Rev. _____

PREPARED BY: W.J. Llope, Oleg Grachov
Sign/Date: XX/XX/XX

APPROVED BY: _____
Sign/Date: XX/XX/XX

Procedures for GEM Framing and Testing

Date	Description
04/19/2019	first issue

Brookhaven National Laboratory
Brookhaven Science Associates

Number: sPHENIX-005
Version: 3

STATEMENT OF WORK (SOW)
for the
sPHENIX TPC END CAPS (WAGON WHEELS)
QA Category: A-3

Brookhaven National Laboratory
Upton, New York

Version: 3
June 26, 2018

sPHENIX Project

Approved by: _____ Date: 6/26/18

John Cozzolino
sPHENIX TPC Project Engineer
Brookhaven National Laboratory

Donald Lynch
sPHENIX Chief Mechanical Engineer
Brookhaven National Laboratory

James Miller
sPHENIX Project Engineer
Brookhaven National Laboratory

Edward O'Brien
sPHENIX Project Director
Brookhaven National Laboratory

Lori Stager
ER&H Coordinator
Brookhaven National Laboratory

Date: 6/26/18



Manufacturer:
-- 246 item inspection report.

Post-delivery:
-- Verification by BNL Survey

NOTE: All procedures undergo revision from time to time. Any reference herein to any other procedure implies the latest revision, unless otherwise stated.

OUTSTANDING ECN NUMBERS	INTERPRET IN GENERAL ACCORDANCE WITH ASME Y14.24	SUPERCONDUCTING MAGNET DIVISION	BROOKHAVEN NATIONAL LABORATORY BROOKHAVEN SCIENCE ASSOCIATES UPTON, N.Y. 11973
	UNLESS OTHERWISE SPECIFIED	J. COZZOLINO 322016	TITLE: sPHENIX TPC END RING
	DIMENSIONS ARE IN INCHES DECIMAL TOLERANCES ARE: ±.01 ±.02 ±.03 ±.04 ±.05 ±.06 ±.08 ±.10 ±.12 ±.15 ±.20 ±.25 ±.31 ±.37 ±.45 ±.56 ±.69 ±.87 ±.109 ±.138 ±.175 ±.226 ±.288 ±.361 ±.451 ±.568 ±.716 ±.901 ±.113 ±.144 ±.183 ±.233 ±.297 ±.377 ±.477 ±.600 ±.750 ±.938 ±.119 ±.150 ±.191 ±.243 ±.308 ±.388 ±.491 ±.616 ±.775 ±.975 ±.123 ±.157 ±.200 ±.255 ±.324 ±.408 ±.519 ±.657 ±.834 ±.105 ±.134 ±.172 ±.219 ±.278 ±.351 ±.441 ±.558 ±.700 ±.875 ±.109 ±.140 ±.180 ±.230 ±.291 ±.364 ±.454 ±.571 ±.714 ±.890 ±.111 ±.142 ±.182 ±.232 ±.293 ±.366 ±.456 ±.573 ±.716 ±.891 ±.111 ±.142 ±.182 ±.232 ±.293 ±.366 ±.456 ±.573 ±.716 ±.891	T. HELMICK 326117 S. BELLAVIA 326117 M. ANERELLA 326117 D. LYNCH 326117 M. CHUC 326117 H. HOCKER 326117	SIZE: E DRAWING NUMBER: 205-0300-0010 REV: A
	125 FINISH BREAK SHARP EDGES .030 MAX. .015 MAX.		SCALE: 1:3 WEIGHT: 16 LB SHEET TOP

Issues and Concerns

Risk Identification			Risk Handling Plan (Mitigations)	Residual Risk (Post- Mitigation Assessment)										
Risk ID Number	Risk Title	IF/THEN	Risk Handling Plan (Mitigations)	Residual Risk	Low Cost Impact	Likely Cost	High Cost Impact	Low Schedu	Likely Schedu	High Schedu	Overall Impact Score	Expected Valu	Average Expect	Basis of Impact Estimates How were cost and schedu
sPH_TPC_013	TPC FEE assembly is late	If TPC FEE assembly rate is lower than planned, then TPC FEE assembly could be behind schedule up to 3	Check P6 progress schedule monthly	10%	0	0	0	1	2	3	Negligible	0.00	0.00	Based on latest experience
sPH_TPC_014	TPC assembly is late	If TPC assembly rate is lower than planned, then TPC assembly could be behind schedule up to 3 mo.	Check P6 progress schedule monthly	10%	0	0	0	1	2	3	Negligible	0.00	0.00	Based on latest experience
sPH_TPC_015	TPC Lasers	If fiberoptic cable has to be 18 m long, then more diffuse lasers will be needed.	Keep track of latest design.	50%	20	40	80	0	1	1	Low	20.00	23.33	Based on latest experience
sPH_TPC_016	TPC FPGA replacement	If the project needs to change FPGA vendor, the purchase will cost more	Keep track of FPGA procurement.	100%	100	100	100	0	0	0	Moderate	100.00	100.00	Based on latest experience

- Diffuse Laser Purchase & Placement
 - Light budget for central membrane is fixed.
 - Principle light loss depends upon fiber length.
 - If the laser placement requires an 18 meters fiber, more lasers must be purchased.
 - Under active study with integration group.
 - 50% residual risk.

- The TPC has maintained thus far small cost variance.
- The TPC has suffered some schedule variance:
 - **Dominated by electronics & services**
 - **Replan testing and installation to improve parallelization.**
 - **No impact as yet.**
 - **Within float for all other items, no action req'd.**
- Retired most risks.
- Added risk for diffuse laser procurement.

Back Up