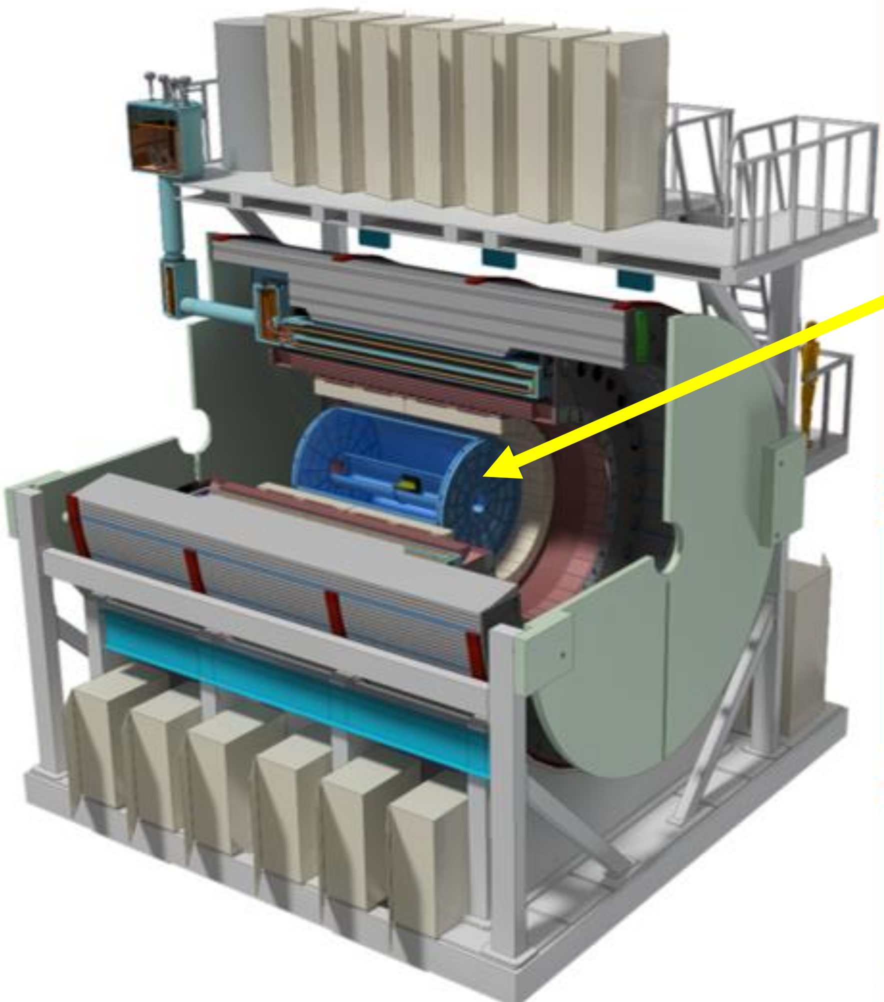
sPHENIX Director's Review



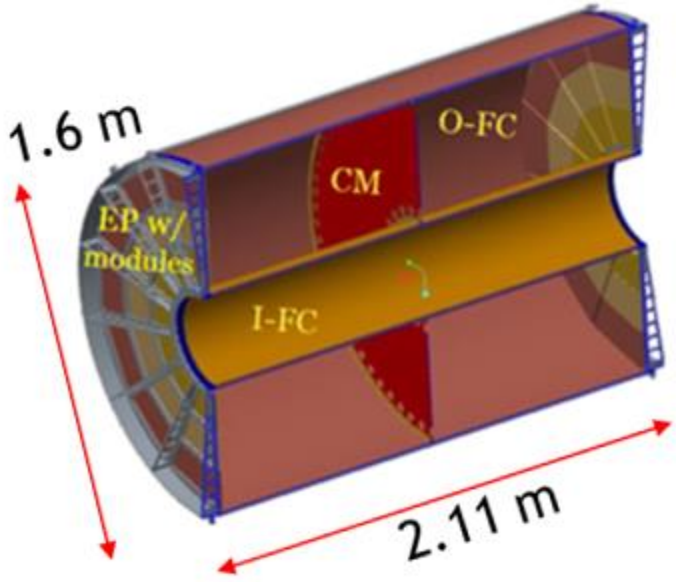
WBS	sPHENIX MIE Project Elements
1.1	Project Management
1.2	Time Projection Chamber
1.3	MAPS Telescope
1.4	Electromagnetic Calorimeter
1.5	Hadron Calorimeter
1.6	Calorimeter Electronics
1.7	DAQ-Trigger
1.8	Minimum Bias Trigger Detector

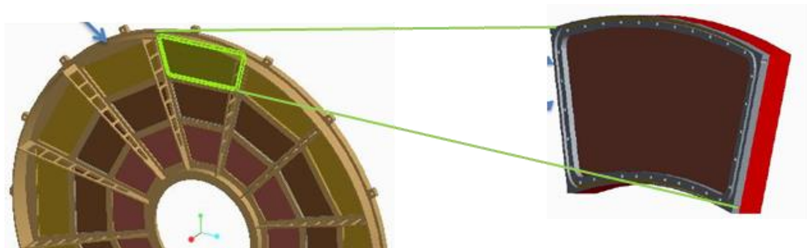
WBS	Infrastructure & Facility Upgrade
1.9	SC-Magnet
1.10	Infrastructure
1.11	Installation-Integration

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

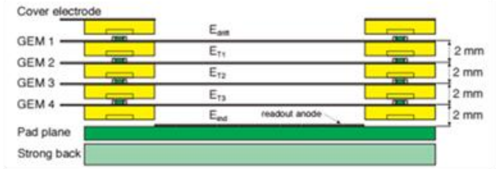
Thomas K. Hemmick
Stony Brook University
L2 Manager, sPHENIX TPC

sPHENIX TPC Mechanical Description





72 modules
2(z), 12(ϕ), 3(r)



Quad-GEM Gain Stage
Operated @ low IBF

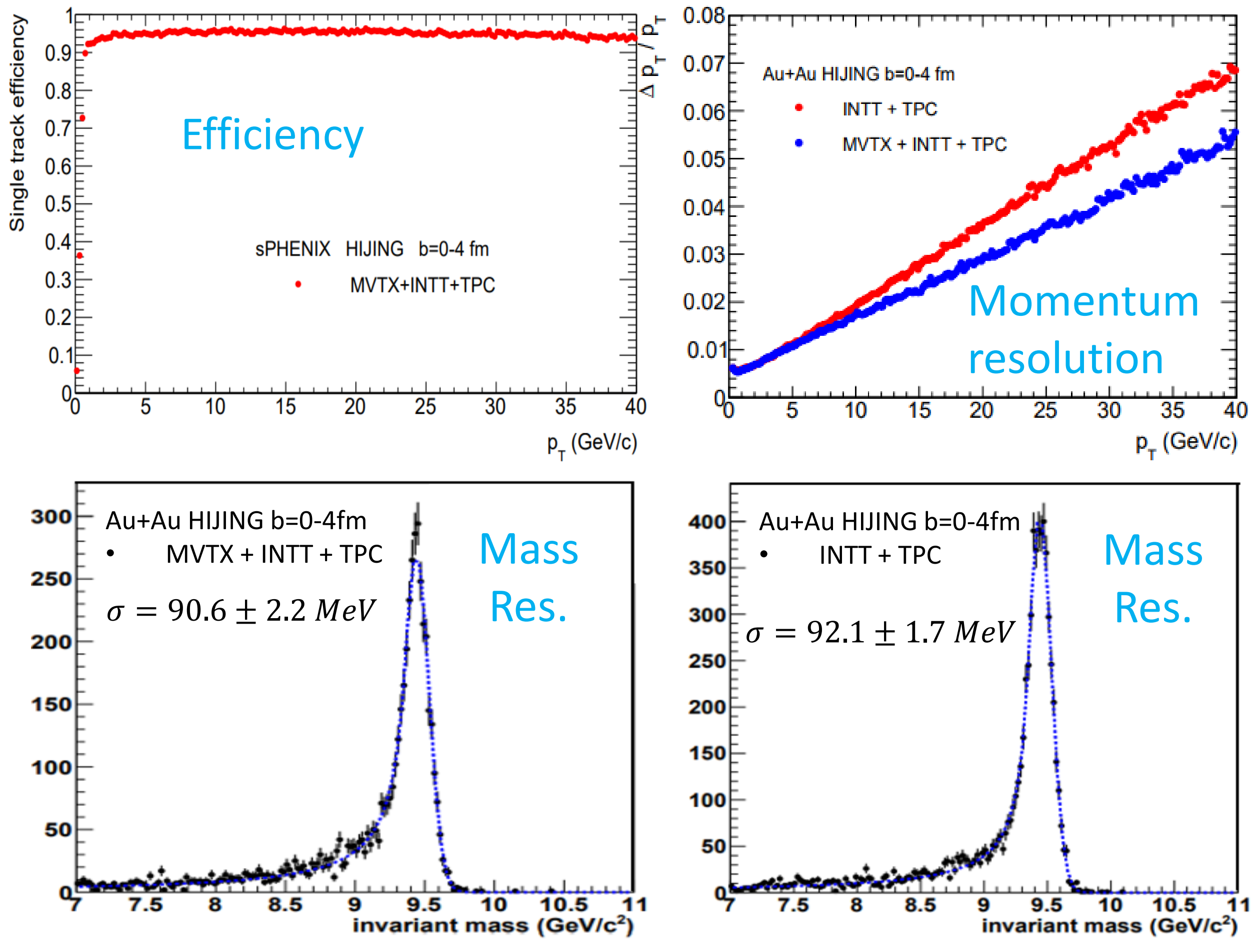
- Coverage
  - **20cm < r < 78 cm (leaves ~10cm room for future PID upgrade)**
  - $|\eta| < 1.1$ **implies 2.11 meter overall length**
  - **Full azimuthal coverage**
- Ne-based gas mixture ($Ne/CF_4/iC_4H_{10}$; 95:3:2) @ E_{drift} = 400 V/cm:
  - **high ion mobility/velocity to reduce space charge**
  - **low transverse diffusion for good position resolution.**
  - **Drift velocity plateau @ 400 V/cm.**
- Quad-GEM-based continuous readout for low Ion Back Flow

A field cage similar to STAR/ILC holding a gas/avalanche similar to ALICE/T2K

Performance Specifications

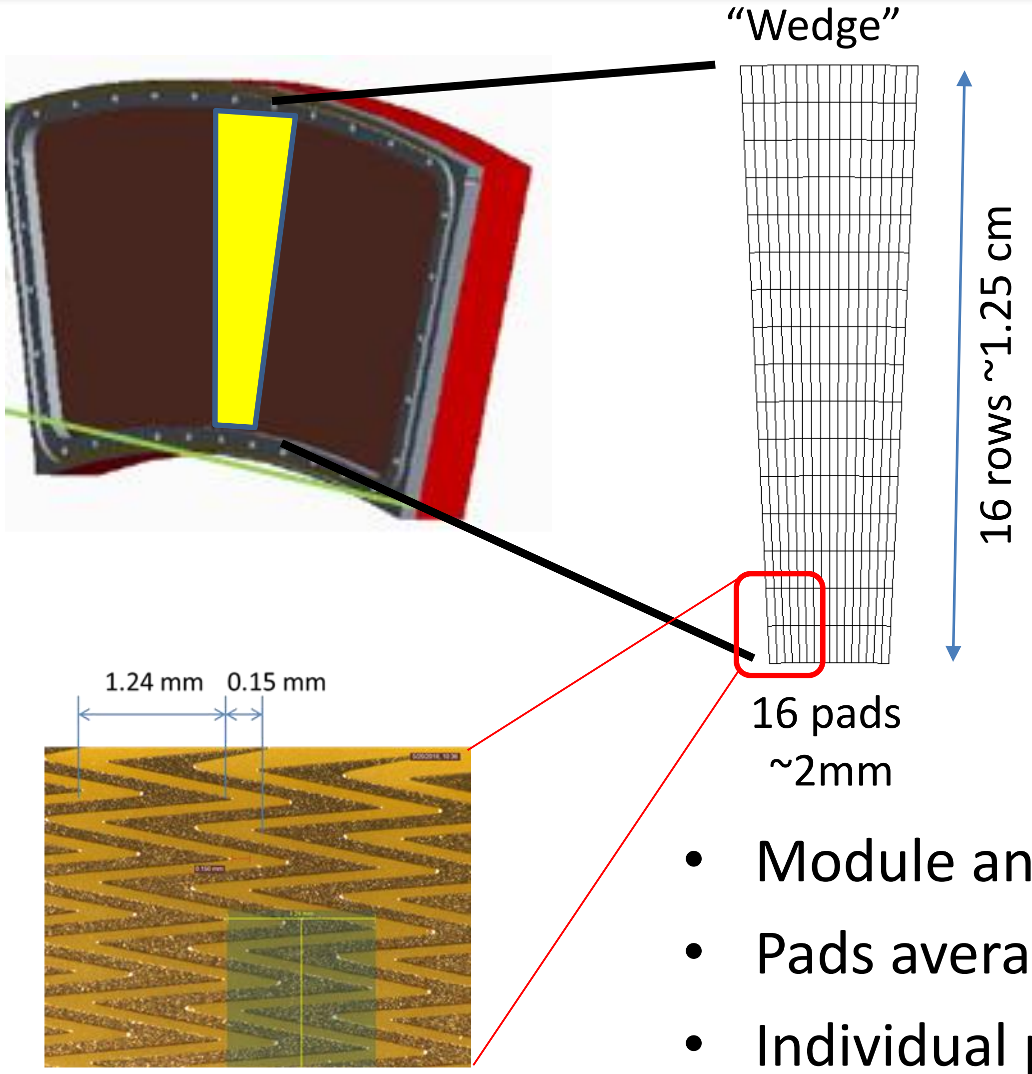
- Principle Performance Requirements:
  - **Provide excellent pattern recognition.**
  - **Separate the Upsilon States.**
- Hardware performance goals @ delivery:
  - **>90% of all channels fully functioning**
  - **Drift field >350 V/cm**
  - **eNoise(RMS) < 670 electrons.**
  - **Gain > 2000**
- Physics performance goals:
  - **Tracking efficiency > 90%**
  - **Purity > 95% below p_T= 10 GeV/c**
  - **Single spatial point resolution < 250 μm**
  - **Mass resolution(9 GeV/c^2) < 100 MeV/c^2**

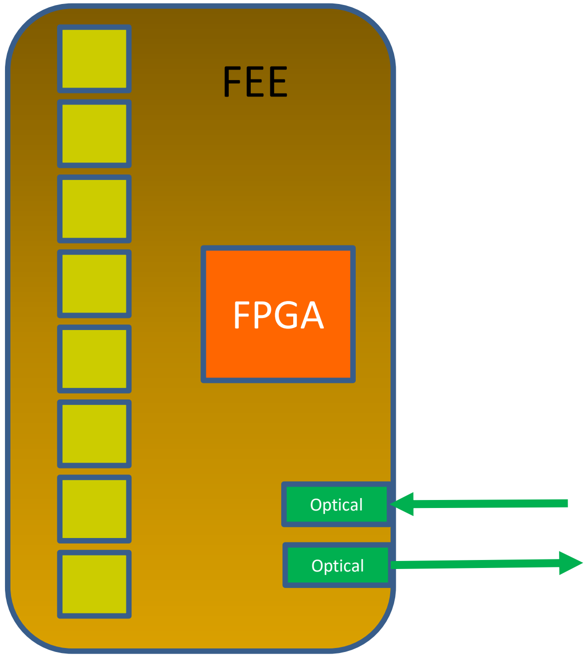
Simulation Studies of full tracking system



TPC has strict momentum resolution specs and no dE/dx resolution specs.

TPC On-Detector Electronics





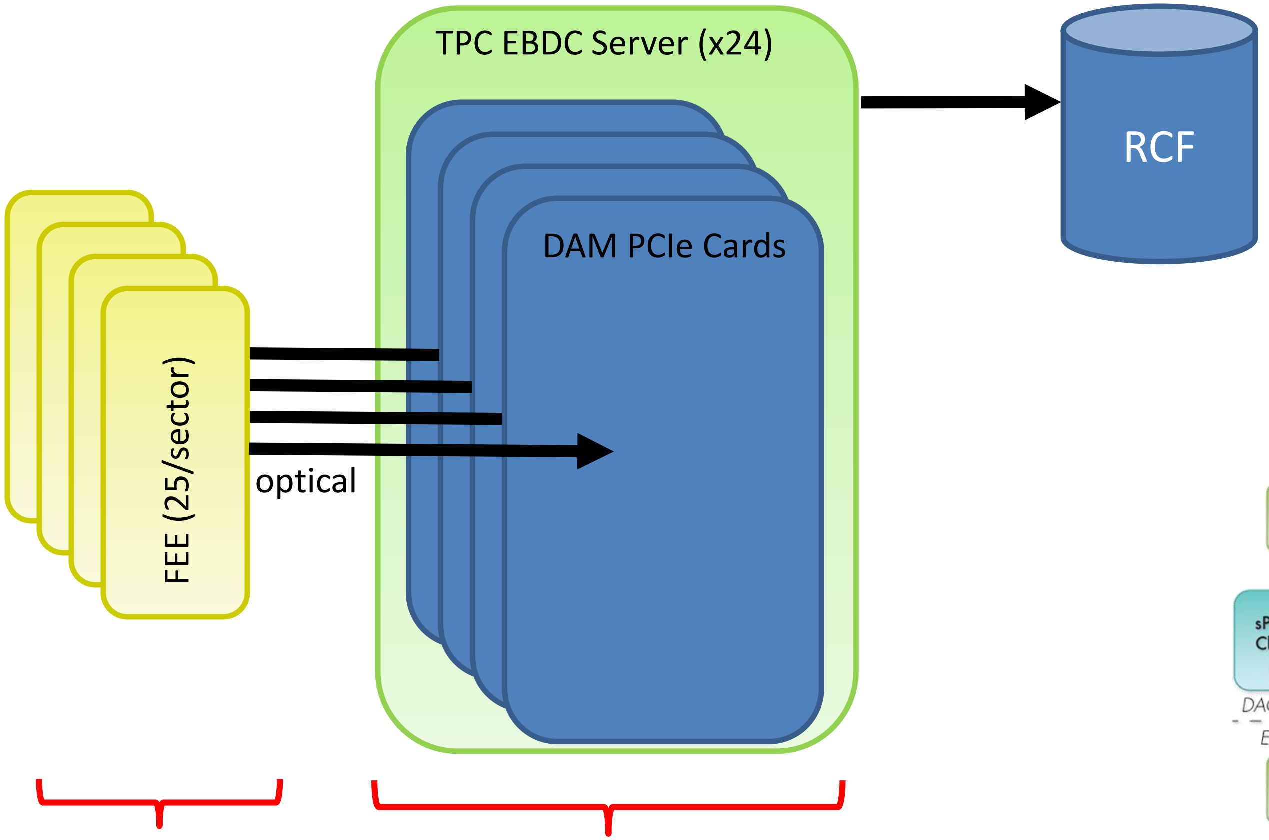
FEE card:

- Uses ALICE "SAMPA" chip
- SAMPA does zero suppression, but readout is triggerless.
- FPGA has minimal duty:
  - Convert SAMPA to 8b10b
  - Slow Controls.
- Data "processed" at later stage.
- Design minimizes onboard power and complexity.

- Module anodes segmented into 16x16 pad "wedges".
- Pads average 2mm x 1.25cm in size.
- Individual pads segmented as Zig-Zag or Chevron.
- Each FEE card supports a single wedge.

Similar (not identical) to STAR & ALICE SAMPA implementations

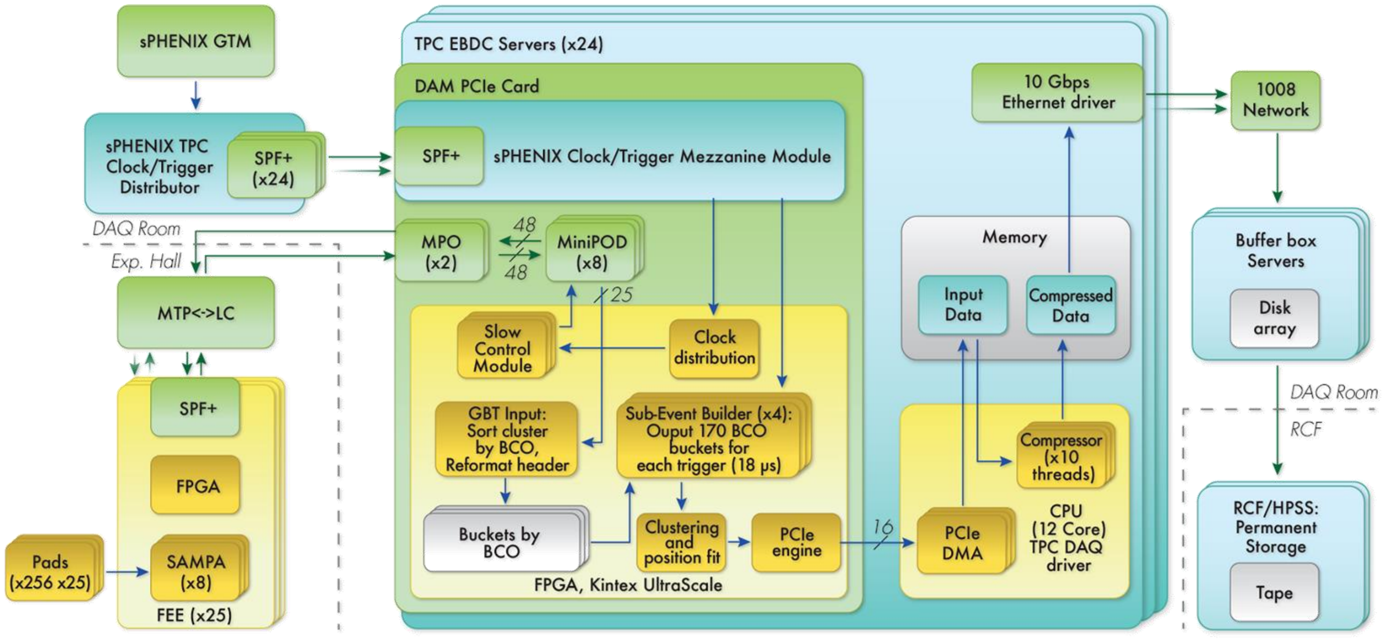
TPC Electronics Overview



On detector:
Custom sPHENIX implementation of SAMPA chip.

Counting House:
Combination of re-used boards for DAM and commodity PCs.

- FEE (sPHENIX Development)
  - **256 channel SAMPA→optical (no processing)**
- DAM (use e.g. BNL/ATLAS FELIX board)
  - **Data Aggregation Module.**
  - **Aligns, Clusters, Compresses (Triggers?) Data.**
- EBDC (purchase commodity PC)
  - **Commodity PC, houses one sector of DAM cards.**

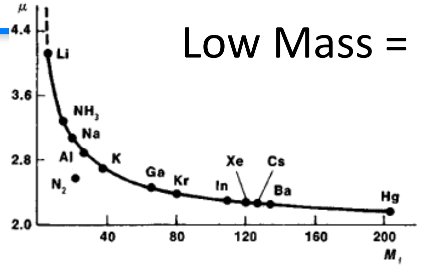


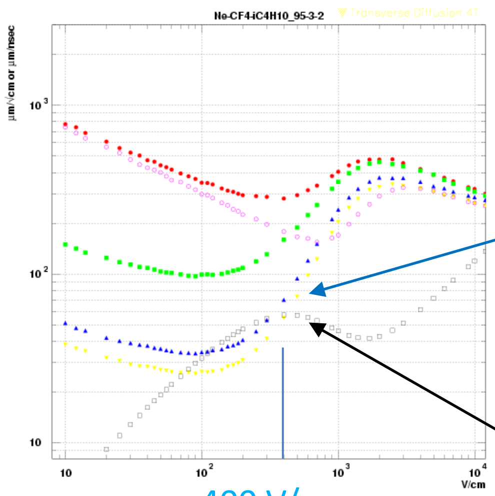
24 sectors, 144k Pads and 600 FEEs in total
1 sector, 25 FEEs per DAM for readout

Design Drivers

- Gas Choice
  - **The gas must be Neon-based to minimize space-charge distortions by maximizing the positive ion drift velocity.**
  - **Use of a "cold" quench minimizes transverse diffusion and thereby improves the single point position resolution.**
- Drift field
  - **Ion drift velocity is directly proportional to E, indicating that the large electric fields are optimal (400 V/cm).**
  - **Our candidate gas has a drift velocity plateau coincident with the desired drift field thereby minimizing environmental influence (T, P, E) on calibration.**
- Micro-Pattern Gas Detector for low Ion Back Flow
- Simple FEE w/ continuous readout (SAMPA)
  - **Elimination of data processing "on-detector" minimizes complexity and power consumption of FEE card.**
- DAM adopt design from off-project development
  - **Digital programmable data processing is such a common need that both the ALICE-CRU and the ATLAS-FELIX boards appear more than capable of filling our needs.**

Low Mass = High Mobility

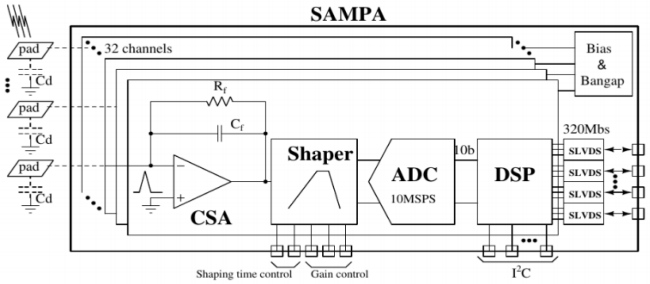


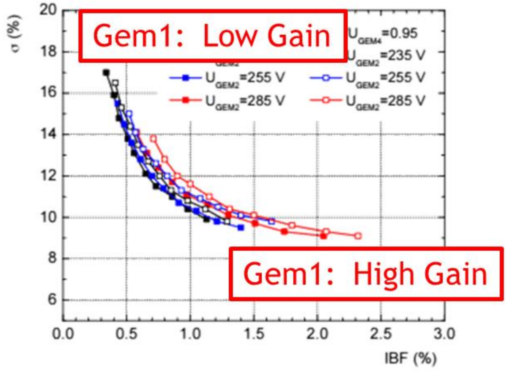


Low Diffusion

Drift Velocity Plateau

400 V/cm





TPC Scope/Interface

Included in TPC Scope		
WBS	Item	Funding
1.2.1.1	v1 Field Cage & Module Prototype	LDRD
1.2.1.2	v2 Field Cage & Module Prototype	OPC
1.2.1.7	TPC High Voltage Systems	PHENIX/EQUMIE
1.2.2.1 1.2.3.1 1.2.4.1	Site Prep for Production Factories	OPC
1.2.2.3 1.2.3.3 1.2.4.3	TPC Module Production	EQUMIE
1.2.5.1-2	FEE Prototype v1 & Pre-Production Prototype	OPC
1.2.5.3	FEE Production (incl. LV-PS, cable fiber)	EQUMIE
1.2.6.1-2	DAM Prototype v1 & Pre-Production Prototype	OPC
1.2.6.3	DAM Production & EBDC Procurement	EQUMIE
1.2.7.1	TPC Laser System	EQUMIE
1.2.7.2	TPC Gas System	EQUMIE
1.2.7.3	TPC Cooling System	EQUMIE
Not Included in Scope		Where Included
Installation Fixtures		Install./Integration
Support Structure		Infrastructure

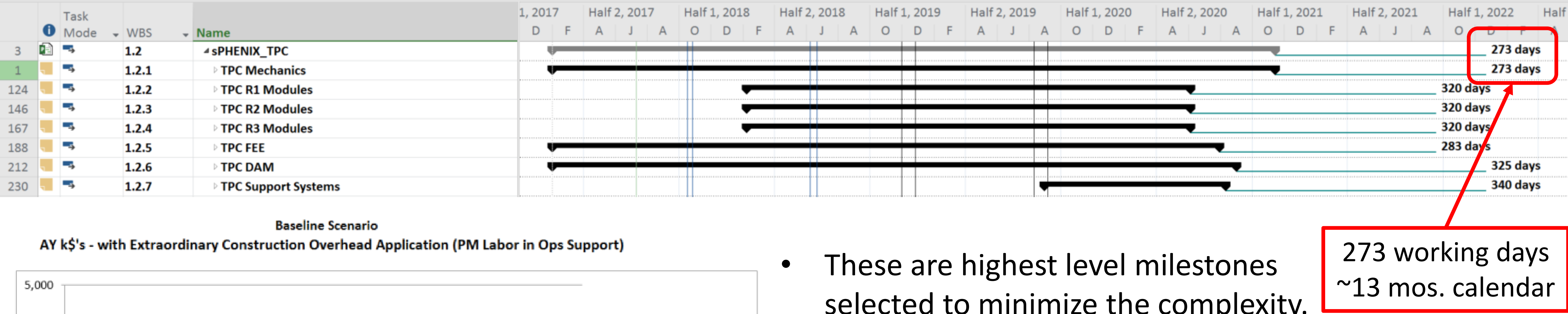
WBS Structure and Control Accounts

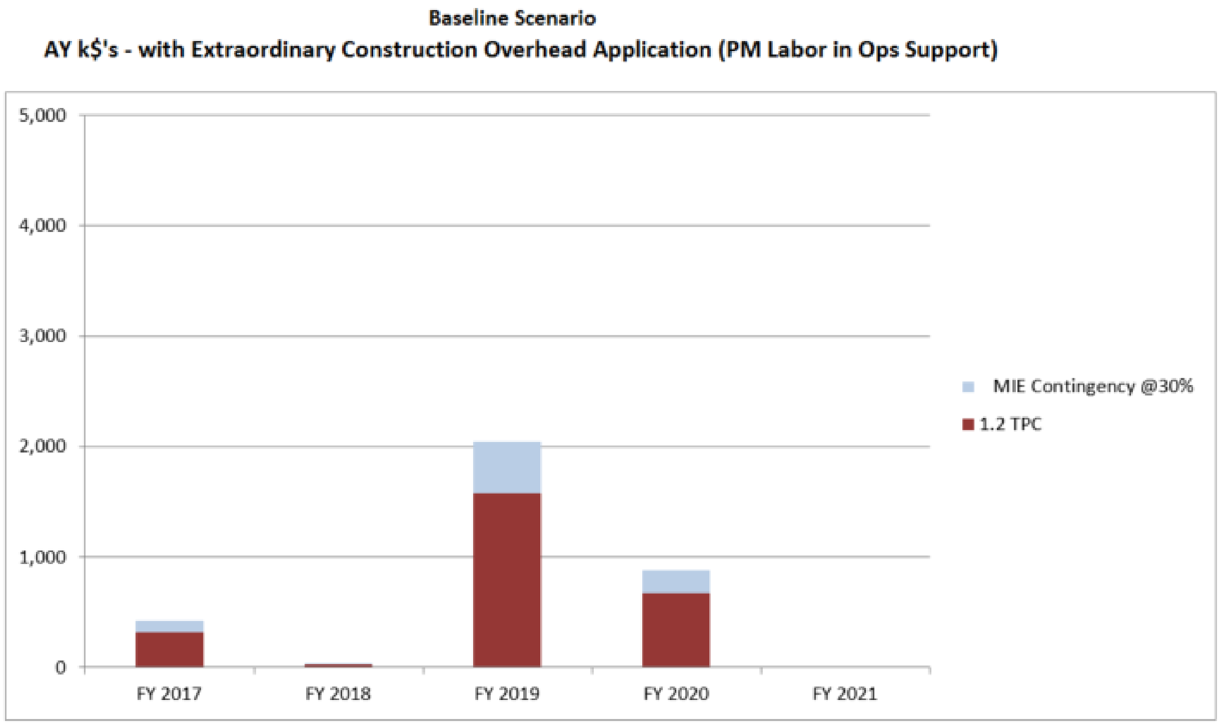
- **1.1 Management** — I. Sourikova
- **1.2 TPC** — T. Hemmick
  - Mechanics — K. Dehmelt
  - GEM1 — S. Milov
  - GEM2 — V. Green
  - GEM3 — V. Riabov
  - TPC FEE — T. Sakaguchi
  - TPC DAM — J. Huang
  - TPC Support — R. Pisani
- **1.3 EMCal** — C. Woody
  - Blocks — A. Sickles
  - Modules & Sectors — S. Stoll
- **1.4 HCal** — J. Lajoie
  - Inner HCal — J. Lajoie
  - Outer HCal — A. Gordeev
- **1.5 CalElectronics** — E. Mannel
  - CalEl Optical Sensors — C. Aidala
  - CalEl FEE — S. Boose
  - CalEl Digitizers — CY Chi
- **1.6 DAQ /Trig** — M. Purschke
  - DAQ — E. Desmond
  - Trigger — J. Nagle
  - GL1 — E. Desmond
  - Timing System — M. Purschke
- **1.7 MinBias Det** — M. Chiu

Key: **L2 Managers** | **CAMs**

- TPC DOE reporting level set at L3
- WIS/Vanderbilt/PNPI are factories for the R1,R2, & R3 modules.
  - **Each institution builds & tests all modules/spares of a single size.**
  - **Mapping of module size to institution is TBD.**
- Work packages and activities are located beneath each WBS L3.

Schedule and Cost Profile Overview





- These are highest level milestones selected to minimize the complexity.
- Lower level milestones include design reviews and production readiness reviews.
- Overall schedule for TPC has 13 months float, which is longer than the sPHENIX float, meaning we are not on the critical path for sPHENIX completion.

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
1.2	TPC	323	31	1,575	675	0	2,604
	MIE Contingency @30%	97	9	473	203	0	781
	MIE Total	420	40	2048	878	0	3385

WBS	SYSTEM	Baseline	Contingency(30%)	Total
1.2	TPC	2,604	781	3,385

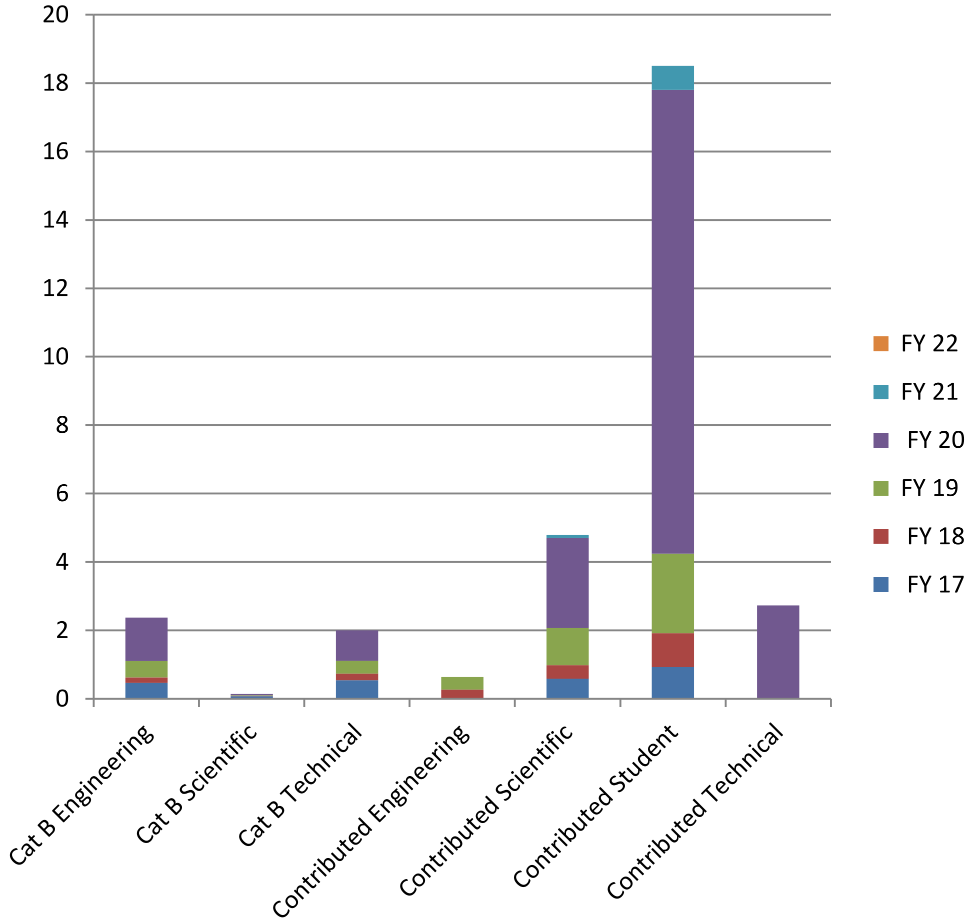
Schedule Driver: GEM Production

ID	Name	Duration
108	TPC Production GEM Acquisition	160 days
109	Train Technician to work in CERN Shop on TPC GEMs	2 mons
110	Produce TPC GEM foils (includes Technician fees)	6 mons
111	GEM Production Complete	0 days
112	TPC High Voltage System	431 days
118	TPC Assembly	222 days
124	TPC R1 Modules	581 days
125	TPC R1 Module Factory Preparation	40 days
128	TPC R1 Pre-Production Module	298 days
138	TPC R1 Module Production	190 days
139	Procure TPC R1 Module frames	40 days
140	Procure TPC R1 Module strongbacks	40 days
141	Procure TPC R1 Module Pad Planes	40 days
142	Procure TPC R1 Module Grids	40 days
143	Build TPC R1 Modules	6 mons
144	Test TPC R1 Modules	6 mons
145	TPC R1 Production Ends	0 days

- Factory production follows a Start-Start relationship to GEM production.
- Module assembly takes less time than GEM production (PHENIX HBD experience).
- GEM schedule drives module production schedule and TPC overall schedule.

Labor Profile

- FTE Profile by Category



- FTE Profile by Fiscal Year

Row Labels	FY 17	FY 18	FY 19	FY 20	FY 21	FY 22
Cat B	**1.08**	**0.37**	**0.87**	**2.21**	**0.00**	**0.00**
Engineering	0.47	0.16	0.48	1.28	0.00	0.00
Scientific	0.07	0.01	0.02	0.04	0.00	0.00
Technical	0.54	0.20	0.37	0.89	0.00	0.00
Contributed	**1.51**	**1.65**	**3.78**	**18.92**	**0.79**	**0.00**
Engineering	0.00	0.27	0.36	0.00	0.00	0.00
Scientific	0.59	0.39	1.09	2.63	0.08	0.00
Student	0.92	0.99	2.33	13.56	0.70	0.00
Technical	0.00	0.00	0.00	2.73	0.00	0.00
Grand Total	**2.59**	**2.02**	**4.65**	**21.12**	**0.79**	**0.00**

WBS Dictionary Example

- All sPHENIX WBS Dictionary entries host their “master version” in WBS file.
  - **Extracted at will into pdf version for readability.**
  - **Robust against numbering updates as the project files evolve.**
- Task descriptions all include:
  - **Technical Scope**
  - **Work Statement**
- Present Status: 100% Complete and Up-to-date.

Example from the pdf Version

1.2					
1.2				**SPHENIX TPC**	The Time Projection Chamber for the sPHENIX Experiment at RHIC
1.2	1.2.1			**TPC Mechanics**	TECHNICAL SCOPE: THIS ITEM CONTAINS ALL TASKS WHICH ARE REQUIRED TO IDENTITY COMPONENTS FOR THE TPC PROTOTYPE VERSION 1/2, PERFORM R&D, DESIGN AND CONSTRUCT THE ELEMENTS OF THESE PROTOTYPES AND THE FINAL TPC INCLUDING THE HV SYSTEM. WORK STATEMENT: PROVIDE PROTOTYPES: V1/2 FIELD CAGE PROTOTYPE; V1/2 MODULE PROTOTYPING, INCLUDING GAS ENCLOSURE, COMMON MODULE MECHANICS, MODULE PROTOTYPE, V2 FIELD CAGE MODIFICATIONS, SITE PREP FOR PRODUCTION FACTORIES.
1.2	1.2.1	1.2.1.1		**TPC v1 Field Cage Prototype**	TECHNICAL SCOPE: THIS ITEM CONTAINS ALL TASKS WHICH ARE REQUIRED TO IDENTITY COMPONENTS FOR THE TPC FIELD CAGE PROTOTYPE VERSION 1, PERFORM R&D, DESIGN AND CONSTRUCT THE ELEMENTS OF THIS PROTOTYPE. WORK STATEMENT: PROVIDE PROTOTYPE: FIELD CAGE V1 PROTOTYPE.
1.2	1.2.1	1.2.1.2		**TPC v2 Field Cage**	TECHNICAL SCOPE: THIS ITEM CONTAINS ALL TASKS WHICH ARE REQUIRED TO IDENTITY COMPONENTS FOR THE TPC FIELD CAGE PROTOTYPE VERSION 2, PERFORM R&D, DESIGN AND CONSTRUCT THE ELEMENTS OF THIS PROTOTYPE. WORK STATEMENT: PROVIDE PROTOTYPE: FIELD CAGE V2 PROTOTYPE.
1.2	1.2.1	1.2.1.3		**TPC Final Field Cage**	TECHNICAL SCOPE: THIS ITEM CONTAINS ALL TASKS WHICH ARE REQUIRED TO IDENTITY COMPONENTS FOR THE TPC FINAL FIELD CAGE, PERFORM NECESSARY MODIFICATION TO THE V2 FIELD CAGE. WORK STATEMENT: PROVIDE PROTOTYPES: MODIFY V2 FIELD CAGE PROTOTYPE AND TESTING, INCLUDING PROCURING PARTS THAT HAVE BEEN DEVELOPED DURING PROTOTYPING.
1.2	1.2.1	1.2.1.4		**TPC v1 Modules**	TECHNICAL SCOPE: THIS ITEM CONTAINS ALL TASKS WHICH ARE REQUIRED TO IDENTITY COMPONENTS FOR THE GEM READOUT MODULE PROTOTYPE VERSION 1, DESIGN AND CONSTRUCT THE ELEMENTS OF THIS PROTOTYPE. WORK STATEMENT: PROVIDE GEM READOUT MODULE V1 PROTOTYPE AND MATERIAL/EQUIPMENT TO PRODUCE THE MODULES.
1.2	1.2.1	1.2.1.4	1.2.1.4.1	**TPC v1 Module Gas Enclosure**	TECHNICAL SCOPE: THIS ITEM CONTAINS ALL TASKS WHICH ARE REQUIRED TO IDENTITY COMPONENTS FOR THE GAS ENCLOSURE OF A

Basis of Cost Estimate (standard sPHENIX format)

Example: 1.2.1 TPC Mechanics

sPHENIX Detector Relativistic Heavy Ion Collider BASIS of ESTIMATE (BoE)			
L2 Project Name Time Projection Chamber	**L2 WBS Number** 1.2	**L3 Project Name (Control Account)** TPC Mechanics	**L3 WBS Number** 1.2.1

Work Package Name	WBS Number	Basis of Estimate Link
TPC v1 Field Cage Prototype	1.2.1.1	TPC v1 Field Cage Prototype
TPC v2 Field Cage	1.2.1.2	v2 Field Cage-Summary
TPC Final Field Cage	1.2.1.3	Final FIeld Cage-Summary
TPC v1 Modules	1.2.1.4	v1 Modules-Summary
TPC v2 Modules	1.2.1.5	v2 Modules-Summary
TPC Production GEM Acquisition	1.2.1.6	GEM Acquisition-Summary
TPC High Voltage System	1.2.1.7	High Voltage System-Summary
TPC Assembly	1.2.1.8	Assembly-Summary

Title Page

Links to L4 Summary

sPHENIX Detector Relativistic Heavy Ion Collider BASIS of ESTIMATE (BoE)		
Date of Est:	3/28/2017	
Prepared By:	Thomas K. Hemmick	
DocNo. (refer Rev. Log)	docdb link 44	
Work Package Name: TPC v1 Modules	**WBS Number:** 1.2.1.4	**Control Account Number**

WBS Dictionary Definition:

TECHNICAL SCOPE:
THIS ITEM CONTAINS ALL TASKS WHICH ARE REQUIRED TO IDENTITY COMPONENTS FOR THE GEM READOUT MODULE PROTOTYPE VERSION 1, DESIGN AND CONSTRUCT THE ELEMENTS OF THIS PROTOTYPE.
WORK STATEMENT:
PROVIDE GEM READOUT MODULE V1 PROTOTYPE AND MATERIAL/EQUIPMENT TO PRODUCE THE MODULES.

Estimate Type (check all that apply):

- X Work Complete
- X 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):

(see Electronic BoE file [docdb] for supporting documentation

Assumptions Used in Developing Estimate

Although there is NO plan to change the interface between the field cage (speficically the wagon wheel) and the modules themselves, we nonetheless assume that this is possible. Therefore prototype modules are assumed to either be compatable with the v1 or the v2 field cage prototype and not with both. Therefore the definition of THIS workpackage to to produce prototype modules that are compatible with the v1

- One file for each L3 item (7 files for TPC):
  - **TPC Mechanics; R1; R2; R3; FEE; DAM; Services.**
  - **The "Nav" page contains one link for each L4 item.**
    - **L4 – Summary page.**
    - **L4 – Details page.**

Summary Page Example

sPHENIX Detector Relativistic Heavy Ion Collider BASIS of ESTIMATE (BoE)	
Date of Est:	3/28/2017
Prepared By:	Thomas K. Hemmick
DocNo. (refer Rev. Log)	docdb link 44

Work Package Name:	WBS Number:	Control Account Number
TPC v1 Modules	1.2.1.4	

WBS Dictionary Definition:

TECHNICAL SCOPE:
THIS ITEM CONTAINS ALL TASKS WHICH ARE REQUIRED TO IDENTITY COMPONENTS FOR THE GEM READOUT MODULE PROTOTYPE VERSION 1, DESIGN AND CONSTRUCT THE ELEMENTS OF THIS PROTOTYPE.
WORK STATEMENT:
PROVIDE GEM READOUT MODULE V1 PROTOTYPE AND MATERIAL/EQUIPMENT TO PRODUCE THE MODULES.

Estimate Type (check all that apply):

- X Work Complete
- X 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

Cost Summary

(follow link for detailed summary)

The costs of the TPC field cage v1 prototype are born by LDRD funds and total $255k without contingency and $299k with contingency. These costs are overwhelmingly from already purchased items, which is what has driven the contingency down.

Assumptions Used in Developing Estimate

As compared to the scale of prior TPCs used in heavy ion physics (STAR, ALICE), the major difference in the sPHENIX TPC is its size (less than 1/2 the length and diameter of STAR) and requirements for precision. Both of these requirements drive the design of the field cage into the direction that we have chosen. The small size of the TPC (stretching radially from 20cm-78cm) necessitates that we waste no radial space. Therefore, the TPC design requires that the field defining electrodes and the gas containment wall be a single structure using only 0.6 inches of radial space. Furthermore, to allow the region of high electric field quality to reach as closely as possible to the field cage walls, we have turned to an extremely fine-pitched electrode structure for the field cage. The period of the electrode structure is only 2.8 mm, which is nealry a factor of four smaller than STAR or ALICE. Furthermore, we have turned to the use of surface mount resistors to match the fine structure of the field cage electrodes. The risk of using small resistors is avoided using the newly-developed HVPW (High Voltage Pulse Withstanding) devices designed to withstand lightning strikes. These are small enough that they can be present directly in the gas volume and not create significant disturbance to the electric field. The principal blessing of the realtively small size of the TPC is that the end plates (referred to as "wagon wheels" in the engineering drawings) can be hogged from a single piece of aluminum, thereby eliminating MANY places that would be vulnerable to gas leaks. We have assumed that this part of the project cost will be entirely covered using LDRD funds.

Level of Detail intended to be "standalone"
(don't need CDR to read BoE)

Details of the Base Estimate (explanation of the Work)

The field cage estimate is driven by several factors. The first factor is the mandrel. The mandrel is a precision cylindrical mold that will be used to form that radius of the inner and outer field cage barrels. The mandrel is outfitted in a manner similar to a large lathe, but is made from significatly lighter construction materials. For the outer field cage barrel, the mandrel is formed by a bicycle-spoke design supporting a 12-faced cylinder. each face of the cylinder is capped with a machinable foam of intermediate density (20 lbs/ft^3). Harmonic drive motors with magnetic strip position feedback rotate the mandrel cylinder with high precision under computer control and also translate a "utility stage" along the length of the cylinder. The utility stage is equipped either with a variable speed high torque brushless DC motor when cutting the foam, or with a microscope stage when aligning the field cage electrodes. The foam stage of the mandrel additionally functions as a vacuum head securing the field cage electrodes prior to capping with the insulating kapton. The mandrel system was designed at SBU using off-project labor costs (faculty and students). The mandrel assembly for the inner field cage is significantly simpler due to its smaller size and is formed from a schedule-80 PVC pipe that is machined in the SBU shop to precise radius. Since only one mandrel is in use at any given time, the motor and positioning hardware is shared by the two systems. This cancels errors due to manufacturer variance in the linear positioning equipment. The fine electrodes are to be manufacturer by the All-Flex company, that specializes in long circuit cards up to 40 feet in length. These will be constructed in industry and machine populated with HVPW resistors manufactured by Stackpole electronics, the leader in HVPW technology. Bench tests have shown that an 18-layer kapton insulator will provide more than a factor of five safety margin for holding voltage even at an electric field strength of 400 V/cm. However, laying up 18 layers onto a large cylinder is not a well-practiced step for physicists. For this reason, we have turned to the FW Hall company to design a custom apparatus to deliver kapton at constant tension and "press" out bubbles during the winding process. This system uses continuously running motors with tension feedback to magnetic particle clutches to achieve constant tension. Because the mandrel systems are complete, the costs are dominated by the quotes from All Flex for flexible circuit cards, from Stackpole for HVPW resistors, from FW Hall company for the tensioning apparatus, from ATLAS Tool for the field cage end rings, and from engineering estimates for the wagon wheels.

Links to Details

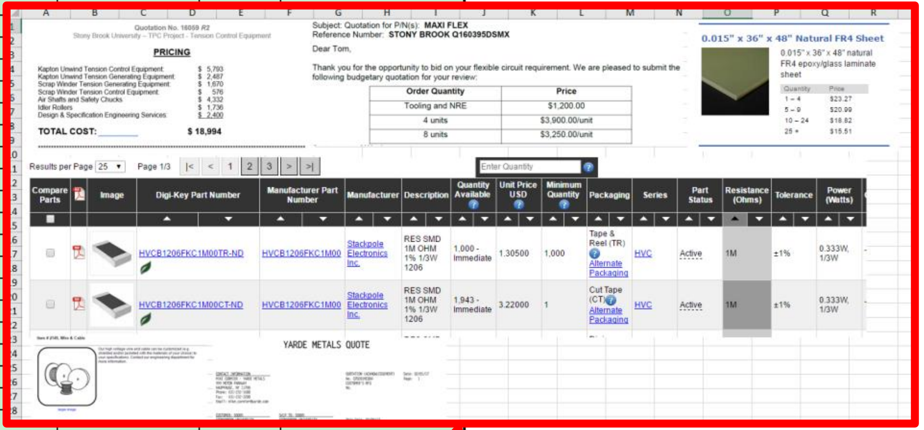
WBS	Description	Item	Vendor	Total	Status	Basis of Estimate	Contingency	Item Contingency	W
1.2.1.4	TPC v1 Modules								
1.2.1.4.1.2	Procure TPC v1 Module Gas Enclosure Parts								
		Gas		$5,000	Pending	Recent Purchase	0.20	$1,000	
				$3,000	Pending	Experience	0.40	$1,200	
1.2.1.4.2.2	Procure TPC v1 Module Strongback								
				$1,200	Pending	SBU Shop Quote	0.20	$240	
1.2.1.4.2.4	Procure TPC v1 Module Frames								
				$1,000	Pending	Sbu Shop Quote	0.20	$200	
1.2.1.4.2.6	Procure TPC v1 Grid Parts								
				$500	Pending	SBU Shop Quote	0.20	$100	
1.2.1.4.3.2	Procure TPC cv1a Module Padplane								
		PadPlane	Somacis	$1,718	Pending	Vendor Quote	0.20	$344	
1.2.1.4.3.4	Procure TPC v1a Module GEMs								
		GEM Mask	CERN	$1,500	Pending	Recent Purchase	0.20	$300	
		GEMs	CERN	$5,000	Pending	Experience	0.40	$2,000	
1.2.1.4.4.2	Procure TPC v1b Module Padplane								
		PadPlane	Somacis	$1,718	Pending	Vendor Quote	0.20	$344	
1.2.1.4.4.4	Procure TPC v1b Module GEMs								
		GEM Mask	CERN	$1,500	Pending	Recent Purchase	0.20	$300	
		GEMs	CERN	$5,000	Pending	Experience	0.40	$2,000	

- Within each file 2 pages per L4 item:
  - **Summary page explains BoE Details and Assumptions.**
  - **Intended to be readable without additional documents open and at the ready.**
  - **Summary pages link to Details pages**

Details Page Example

NOTE: LDRD Captured in Project Files…Lots of green

WBS	Description	Item	Vendor	Total	Status	Basis of Estimate	Contingency	Item Contingency	Wt Contingency	Total	Contingency	Total w/ Contingency	Grand Total	Grand Total w/ Contingency
1.2.1.1	TPC v1 Field Cage Prototype												$254,934	$299,220
1.2.1.1.3	Procure TPC v1 Mandrel Parts								0.03	$66,846	$1,899	$68,745		
		HVPF Boards	Sierra Express Circuits	$12,565	DELIVERED		0.00	$0.00						
		8020 parts	McMaster-Carr	$7,959	DELIVERED		0.00	$0.00						
		Clean Hood Motor Repair	Grainger	$555	DELIVERED		0.00	$0.00						
		Tooling for Mandrel Table	McMaster-Carr	$775	DELIVERED		0.00	$0.00						
		Optical readout for DVM (IBF)	Mouser	$80	DELIVERED		0.00	$0.00						
		FR4520 tooling Foam	General Plastics	$4,362	DELIVERED		0.00	$0.00						
		2" diameter 9' long shaft	Technico	$335	DELIVERED		0.00	$0.00						
		RSF-14B-30-F100-24B	Harmonic Drive	$1,330	DELIVERED		0.00	$0.00						
		SHA32A161SG-B12BLV-10S17b-AN	Harmonic Drive	$4,674	DELIVERED		0.00	$0.00						
		T-slotted framing 8020	McMaster-Carr	$4,278	DELIVERED		0.00	$0.00						
		Laminate Trimmer	Grainger	$155	DELIVERED		0.00	$0.00						
		Position Encoders	Renishaw	$1,202	DELIVERED		0.00	$0.00						
		Adhesive, lab supplies	McMaster-Carr	$1,440	DELIVERED		0.00	$0.00						
		Lead Screw	Lin Tech	$3,456	DELIVERED		0.00	$0.00						
		2" flanged Collars for motor/encoder	McMaster-Carr	$372	DELIVERED		0.00	$0.00						
		USB microscope	Microscope Store	$143	DELIVERED		0.00	$0.00						
		Motor Controllers	Copley Controls	$1,637	DELIVERED		0.00	$0.00						
		SM encoder	Automation Direct	$67	DELIVERED		0.00	$0.00						
		SM motor	MicroMo	$253	DELIVERED		0.00	$0.00						
		Wire/connectors	DigiKey	$352	DELIVERED		0.00	$0.00						
		PS for translation motor (24 V 24 A)	Automation Direct	$415	DELIVERED		0.00	$0.00						
		PS for shaft motor (48 V 24 A)	Acopian	$1,170	DELIVERED		0.00	$0.00						
		Motor Controller Access. Kits	Copley Controls	$276	DELIVERED		0.00	$0.00						
		Web Tension Applicator Toolset	F.W. Hall Company	$18,994	Pending	Manufacturer Quote	0.10	1899.4						
1.2.1.1.6	Procure TPC v1 Outer Field Cage Parts								0.08	$70,067	$5,263	$75,330		
		Honeycomb	Plascorp	$1,621	DELIVERED		0.00	$0.00						
		Striped circuit cards	All-flex	$23,400	Pending	Manufacturer Quote	0.20	$4,680.00						
		3 mil kapton 44" x 108 LF	Dunmore	$21,780	DELIVERED		0.00	$0.00						
		3 mil kapton 22" x 108 LF	Dunmore	$20,350	DELIVERED		0.00	$0.00						
		FR4 outer sheets 4' x 4'	ePlastics	$1,146	Pending	Manufacturer Quote	0.20	$229.16						
		HVPW resistors	DigiKey	$1,170	Pending	Manufacturer Quote	0.20	$234.00						
		High Voltage Cable	Dielectric Sciences	$600	Pending	Web Search	0.20	$120.00						
1.2.1.1.9	Procure TPC v1 Inner Field Cage Parts								0.09	$28,799	$2,680	$31,479		
		Striped circuit cards	All-flex	$12,000	Pending	Manufacturer Quote	0.20	$2,400.00						
		3 mil kapton 44" x 108 LF	Dunmore	$7,260	DELIVERED		0.00	$0.00						
		3 mil kapton 44" x 108 LF	Dunmore	$8,140	DELIVERED		0.00	$0.00						
		FR4 Sheets 4' x 4'	ePlastics	$229	Pending	Manufacturer Quote	0.20	$45.83						



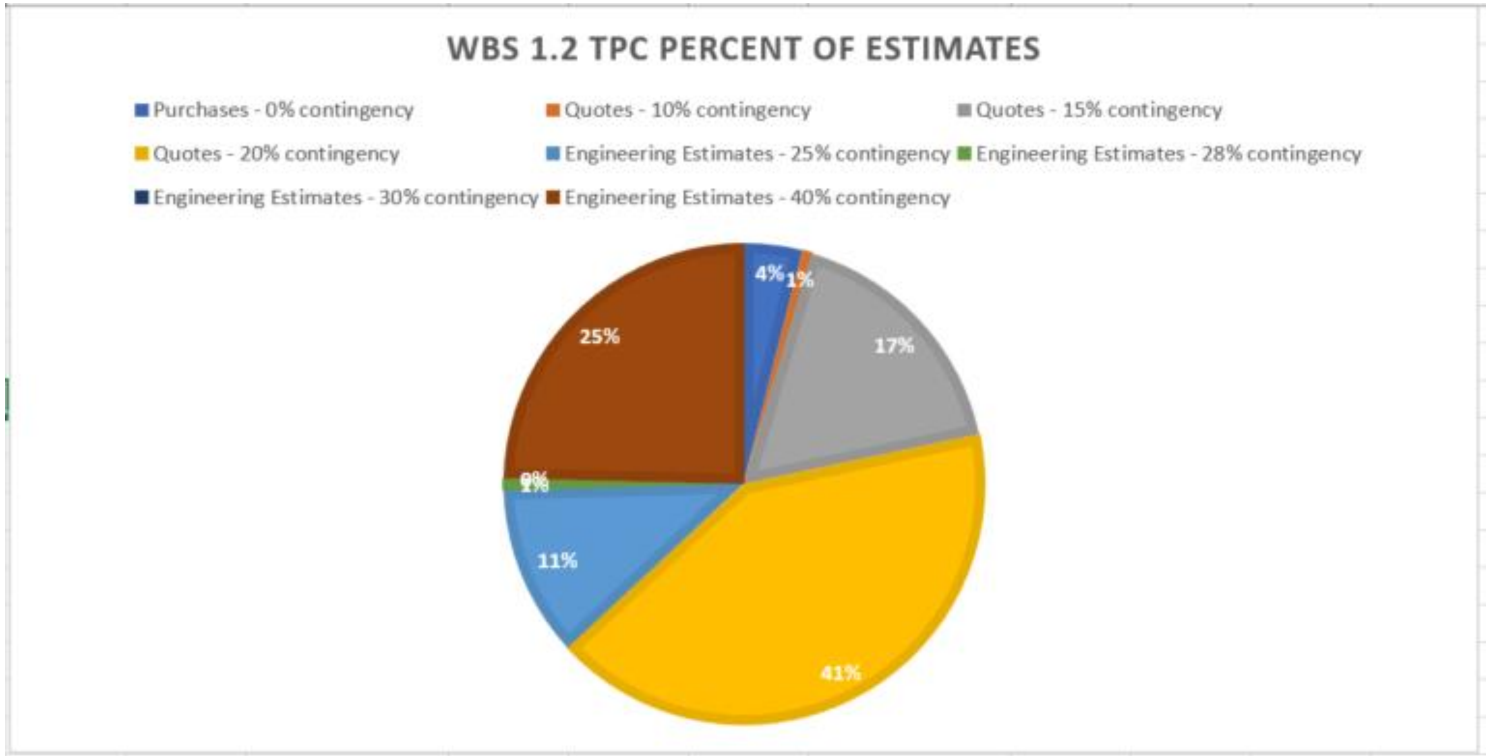
Item-by-Item Contingency

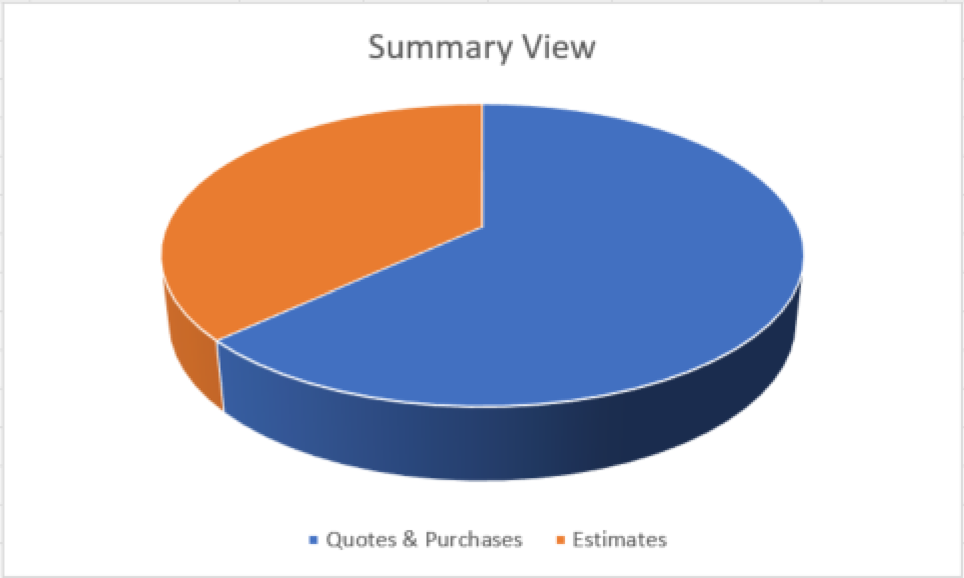
Basis of Estimate	Contingency	Item Contingency
	0.00	$0.00
	0.00	$0.00
Manufacturer Quote	0.10	1899.4
	0.00	$0.00
Manufacturer Quote	0.20	$4,680.00
	0.00	$0.00
	0.00	$0.00
Manufacturer Quote	0.20	$229.16
Manufacturer Quote	0.20	$234.00
Web Search	0.20	$120.00
Manufacturer Quote	0.20	$2,400.00
	0.00	$0.00
	0.00	$0.00
Manufacturer Quote	0.20	$45.83
Manufacturer Quote	0.20	$234.00

- Details pages are purchase-by-purchase for each L5 WBS item.
- Color code: Green=Delivered; Yellow=Quoted; Red=Estimate
- Color code also indicates level of item-by-item contingency.

Links to Quotations

Contingencies Summary

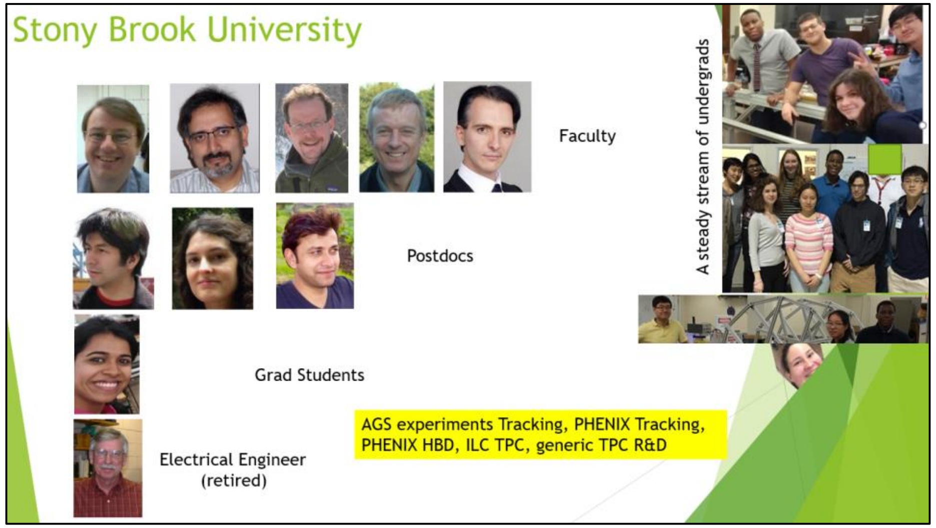


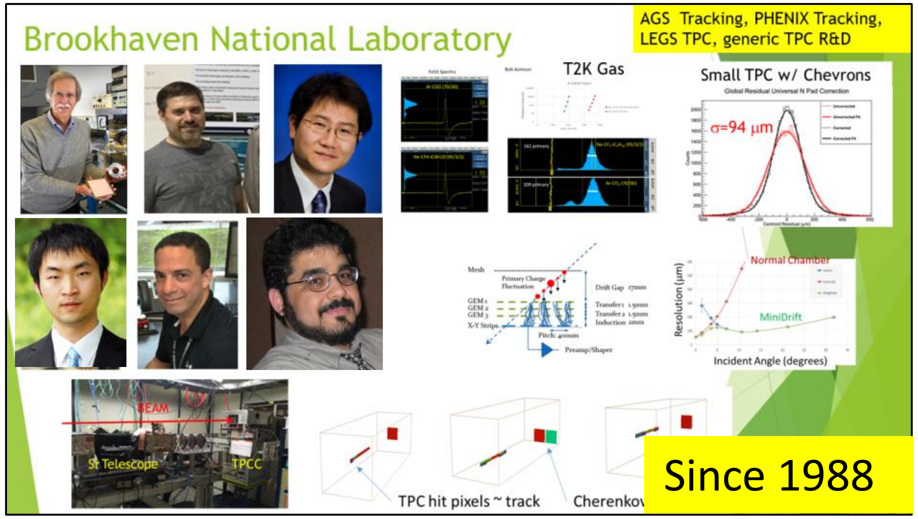


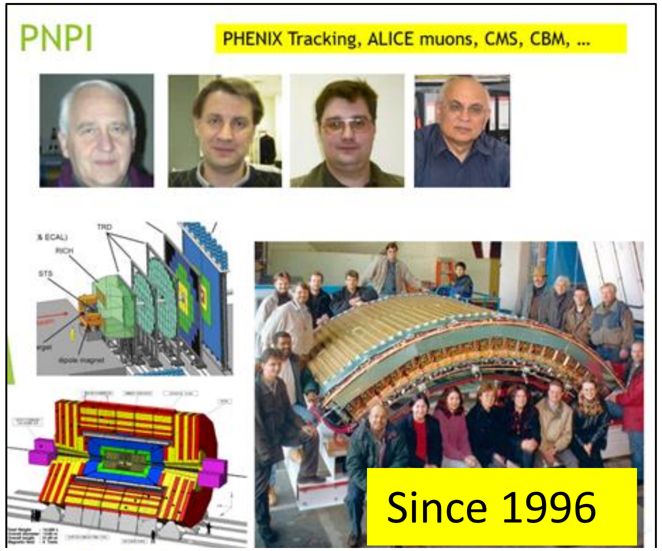
Subsystem	WBS 1.2 TPC Percent of Estimates
Purchases - 0% contingency	4%
Quotes - 10% contingency	1%
Quotes - 15% contingency	17%
Quotes - 20% contingency	41%
Engineering Estimates - 25% contingency	11%
Engineering Estimates - 28% contingency	1%
Engineering Estimates - 30% contingency	0%
Engineering Estimates - 40% contingency	25%

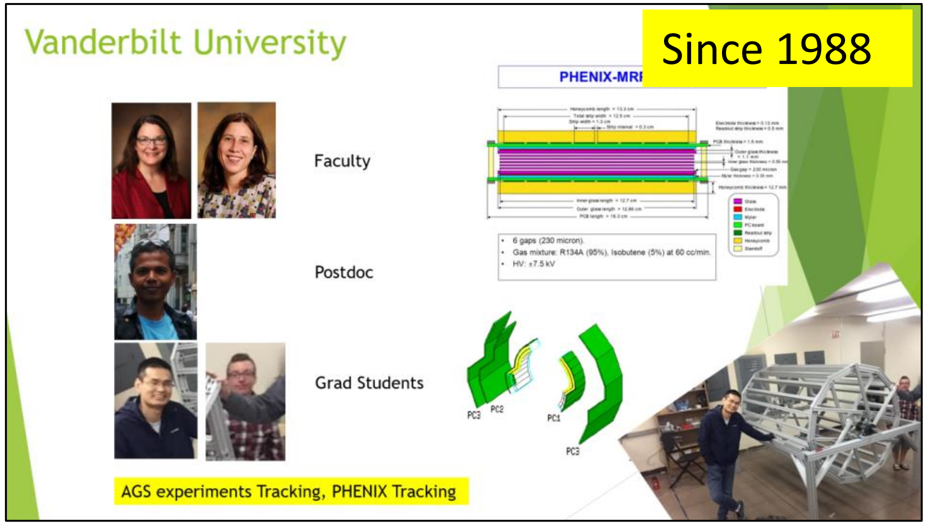
- The detailed view on the left breaks up each category by its contingency value.
- The summary view rolls up purchases/quotes vs estimates.

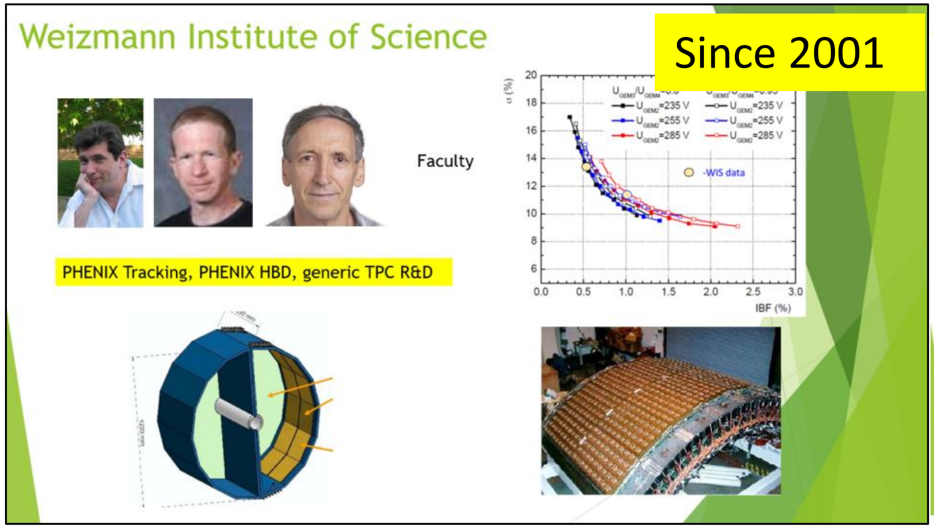
Collaborating Institutions and Technical Experience

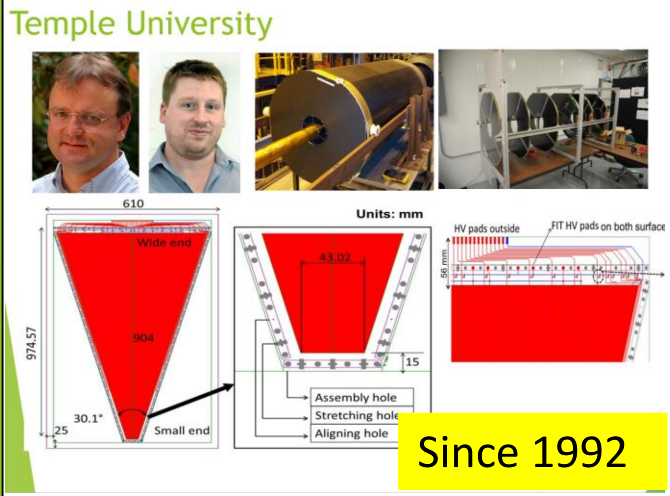












Broad technical expertise in gas chambers and specifically with GEMS used in formulating the BOE for the sPHENIX TPC

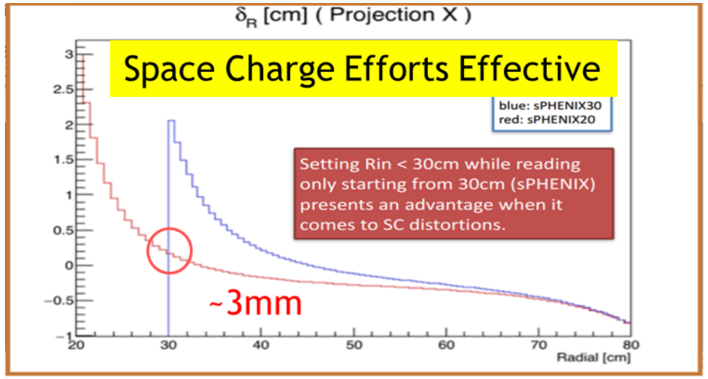
NOTE: Yellow boxes indicate time period over which these institutions have worked closely with the sPHENIX TPC L2 Manager.

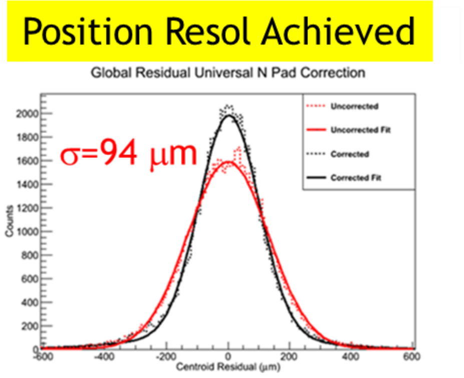
Risk Analysis

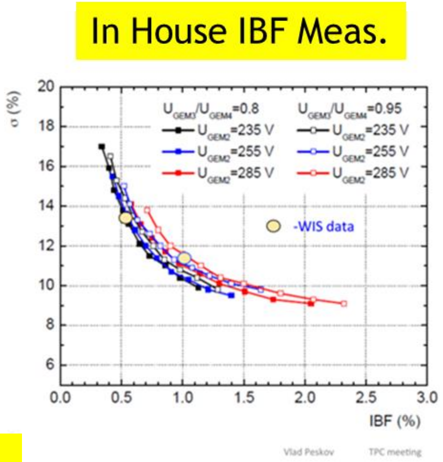
T. Hemmick	1.2 TPC	Procure v1a GEMs	Delivery date on v1-shapes GEMs leaves less than one month before magnet test.	The test will require that we use existing GEMs which will be 10x10cm^2. This will require a special module to adapt the smaller square GEMs to the	R&D Phase	20%	Cost $10k for square-GEM adapter parts	Low	In case the proper GEMs for the v1a prototype are not in hand, an adapter plate will be requires to fit an existing GEM-stack to allow the magnet test to proceed.
T. Hemmick	1.2 TPC	Performance failure of v2 prototype	The v2 prototype fails in any performance criterion that requires more thasn trivial re-design.	If the v2 prototype fails, then there will need to be a v3 prototype added to the cycle.	R&D phase	5%	Schedule: 2 months of float lost. Cost:$15k (only gain	Moderate	We will add a design cycle of a smaller device than the full sized field cage if the v1 prototype fails. We will proceed on v2 only after success of the small version.
T. Hemmick	1.2 TPC	Failure or delay of CERN production	Factories wait upon GEM foil delivery and suffer schedule shifts.	The factory production of modules is critical path and will directly affect schedule.	production	10%	Schedule: 3-5 months	Moderate	We will monitor carefully the success of CERN foil production and will hire a technician who will exclusively work on producing GEM foils for our project. If delays still occur, we will seek a second vendor.
T. Hemmick	1.2 TPC	SAMPA Chip Failure	SAMPA chips fail to match performance specifications.	Affects delivery of the TPC since FEE must be applied before delivery.	production	2%	Schedule: Unknown since mediation	Moderate	ALICE and STAR shall be forced to mitigate the situation and if not, alternatives such as the sALTRO and DREAM chips must be considered.

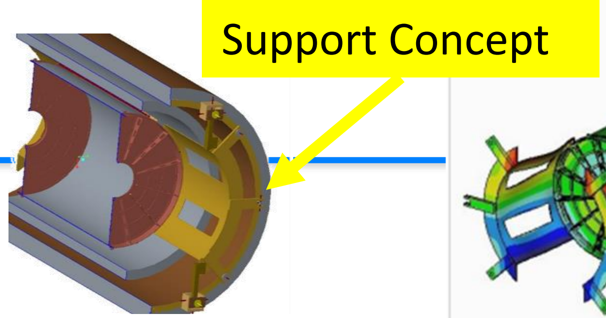
- The table above is an excerpt from the sPHENIX risk registry.
- Recent successes of bench tests of pre-production SAMPA chips have reduced the SAMPA chip risk from high to moderate.

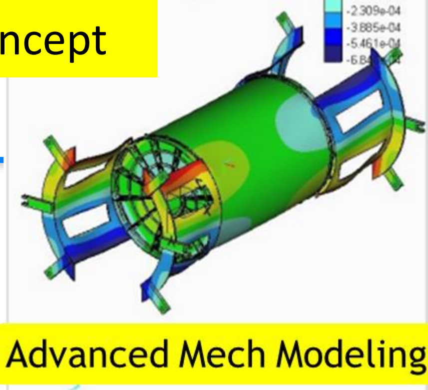
Status of design, generic R&D, OPC

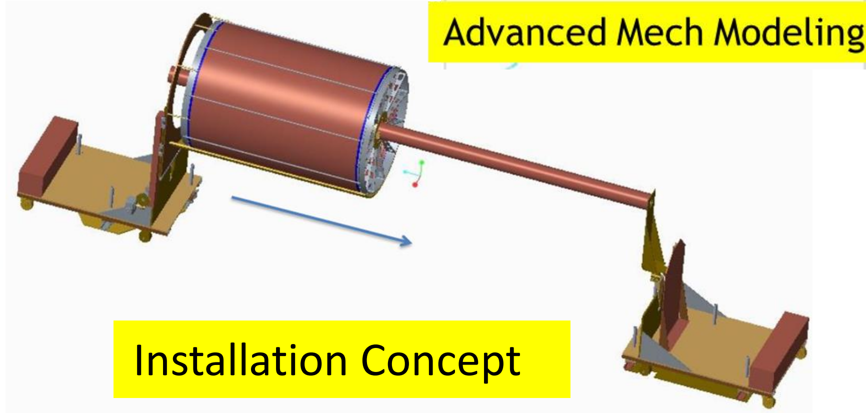


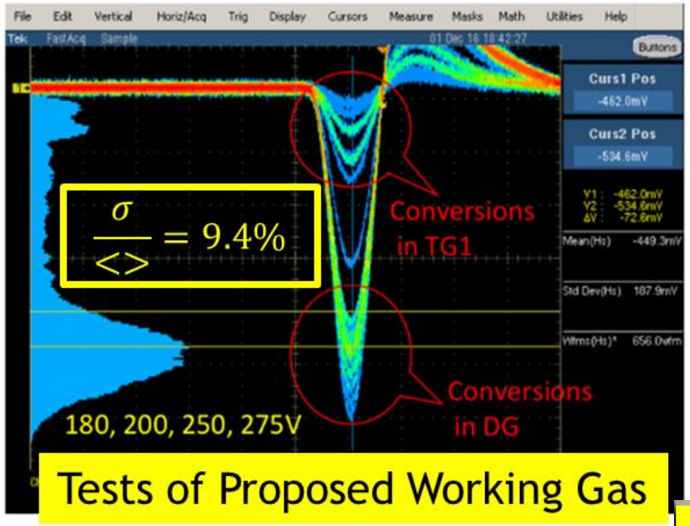


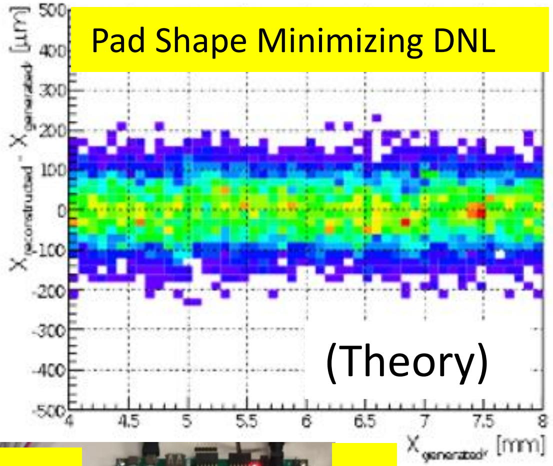


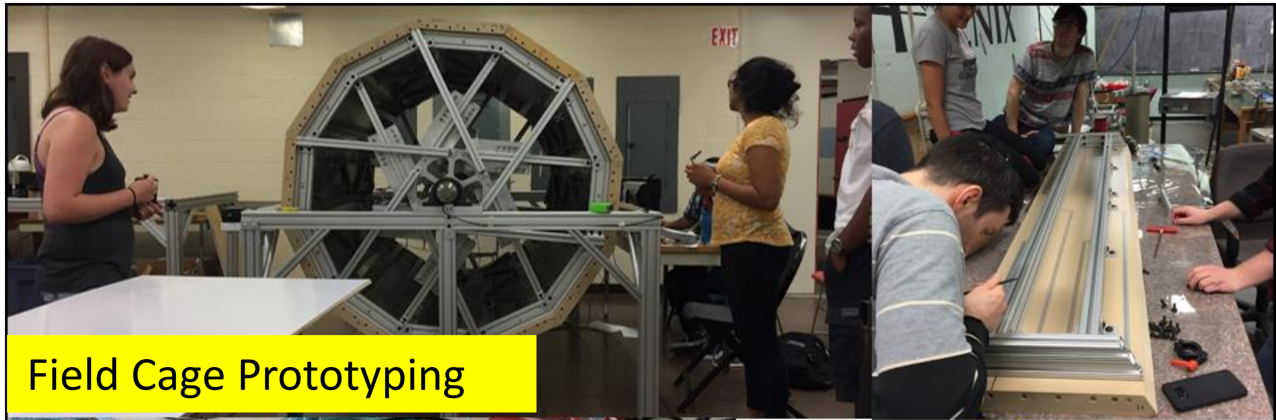


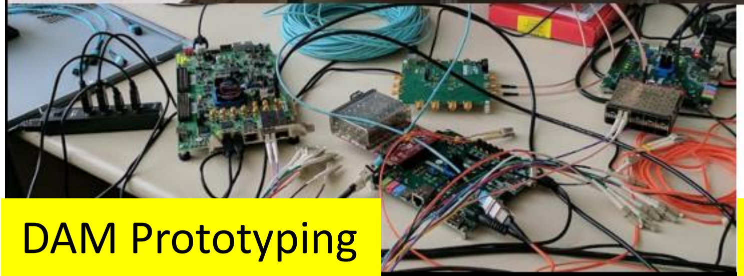


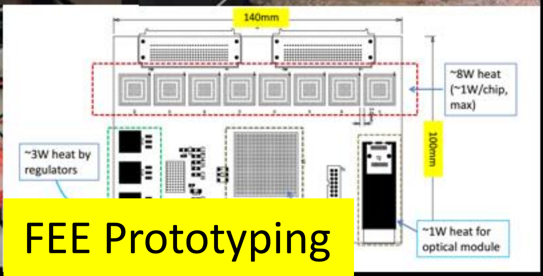












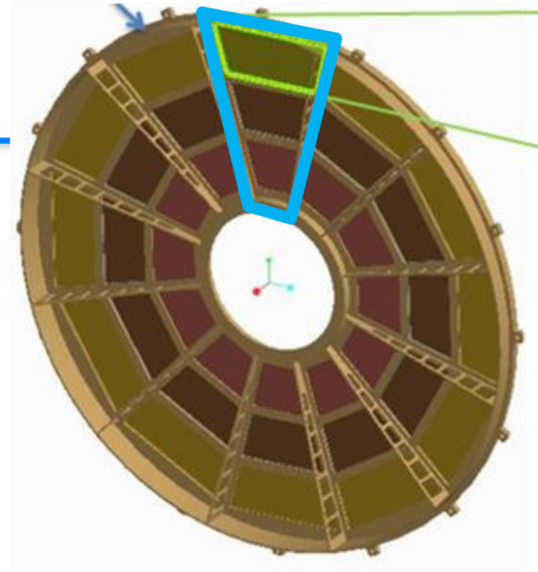
Issues & Concerns

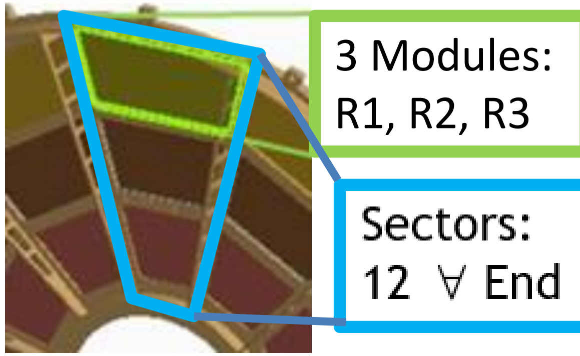
- GEM production is sole source at CERN
  - **TechEtch (former US vendor) would consider restarting production after receiving a purchase order.**
  - **TechEtch previously demonstrated poor corporate memory on GEM foil production.**
  - **Technical level contacts (Rui de Oliviera –CERN; Klaus Dehmelt – sPHENIX) indicate costs and schedule fit well within sPHENIX plans.**
  - **Need to move to formal agreement with CERN quickly (discussion ongoing)**
- SAMPA Chip has passed bench tests, but production run does contain minor changes.
  - **Header trouble in triggered mode (not our concern)**
  - **Noise a little higher than anticipated (~OK for our needs)…no affirmative changes to front end planned.**
  - **Good News: iTPC (STAR using SAMPA) progress excellent, implemented.**
  - **Becoming more likely that MPW3 (final run) will be good for sPHENIX.**
- Lowest IBF point for quad-GEM has stability issues @ ALICE.
  - **sPHENIX much finer HV segmentation; much shorter leads.**
  - **R&D efforts show significant IBF performance improvement using field termination grid.**
  - **Bench tests required for confirmation.**

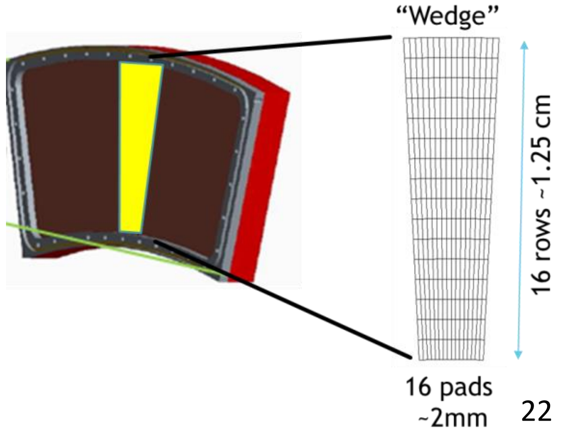
Back Up

Numerology of the Subsystem

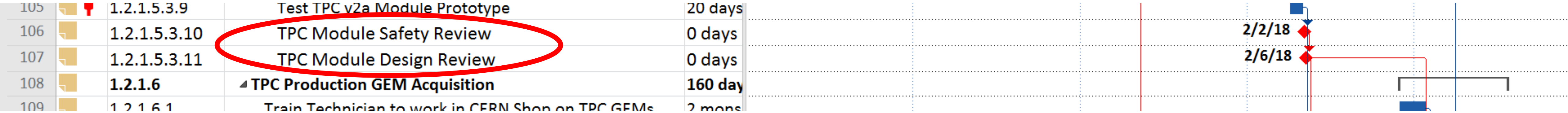
Item	Comment	Total
η coverage	Match magnet	+/- 1.1
ϕ coverage	Full azimuth	2π
Endcaps	1 @ each end	2
Sectors	12 for each endcap	24
Modules	3 for each sector: R1, R2, R3	72
Wedges	R1: 5 wedges R2: 8 wedges R3: 12 wedges	600
FEE	1 @ each wedge	600
DAM	CRU Option: 3/sector FELIX Option: 1/sector	72 24
EDBC	1 for each sector	24
SAMPA	8 for each FEE	4800
Channels*	32 for each SAMPA	153,600







Safety and Design Reviews



- Safety and Design Reviews are uniformly scheduled throughout the TPC project:
  - These follow every final prototype completion
    (gather information on updates before executing pre-production)
  - They also follow every pre-production step
    (demonstrating application of prior review advice).
- Safety reviews always precede Design reviews to allow for possible of design changes due to safety concerns prior to any design review.