sPHENIX Director's Review:
1.2.7 TPC Support Systems

Robert Pisani, BNL Physics

August 3, 2017

BNL

TPC Support Systems Scope

From the WBS Definitions

- 1.2.7 **TPC Support Systems** TECHNICAL SCOPE: CONTAINS ALL TASKS WHICH ARE REQUIRED TO PROVIDE NECESSARY SUPPORT SYSTEMS FOR THE TPC: LASER, GAS, COOLING SYSTEM. WORK STATEMENT: PROVIDE ALL PARTS TO SUPPORT TPC OPERATION.
  - **1.2.7.1 TPC Laser System** Will be covered by Bob Azmoun
  - **1.2.7.2 TPC Gas System** TECHNICAL SCOPE: THIS ITEM CONTAINS ALL TASKS WHICH ARE REQUIRED TO IDENTITY COMPONENTS FOR THE TPC GAS SYSTEM AND PROCURE AND CONSTRUCT THE ELEMENTS OF THE SYSTEM. WORK STATEMENT: PROVIDE ALL PARTS TO PRODUCE THE GAS SYSTEM AND ASSEMBLE/INSTALL ALL PARTS.
  - **1.2.7.3 TPC Cooling System** TECHNICAL SCOPE: THIS ITEM CONTAINS ALL TASKS WHICH ARE REQUIRED TO IDENTITY COMPONENTS FOR THE TPC GAS SYSTEM AND PROCURE AND CONSTRUCT THE ELEMENTS OF THE SYSTEM. WORK STATEMENT: PROVIDE ALL PARTS TO PRODUCE THE GAS SYSTEM AND ASSEMBLE/INSTALL ALL PARTS.

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

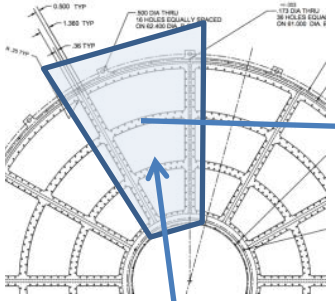
L2 Project Name	L2 WBS Number	L3 Project Name (Control Account)	L3 WBS Number
Time Projection Chamber	1.2	TPC Support Services	1.2.7

Work Package Name	WBS Number	Basis of Estimate Link
TPC Laser System	1.2.7.1	Laser-Summary
TPC Gas System	1.2.7.2	Gas-Summary
TPC Cooling System	1.2.7.3	Cooling-Summary

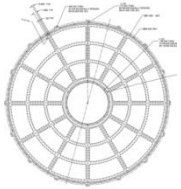
Cooling System Technical Design Drivers

•A Cooling System(1.2.7.3)- Cooling system need to be designed to remove 12kWatts of heat from the TPC Fee's which are located on the end caps of the TPC in side the SPhenix magnet. System to be operated below atmospheric pressure to prevent coolant leaks.

Segment system along the 12 sectors and remove 500 watts from each

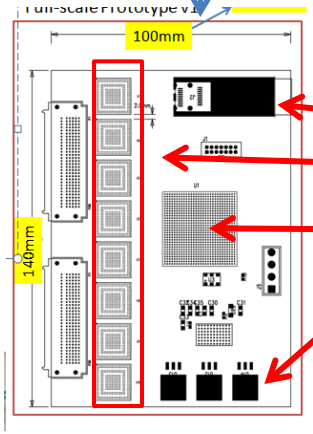


300 Fee Cards per End Cap:
Inner: 5/Module
Middle: 8/Module
Outer: 12/Module



Take heat out with chillers

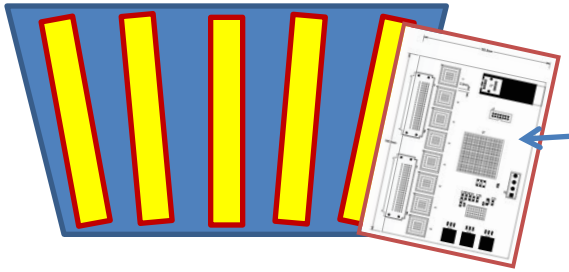
Chilled water sent to TPC



Heat Source

~1watt
~8Watts
~7watts (FPGA)
~3watts

Thermally coupled to the Fee Board

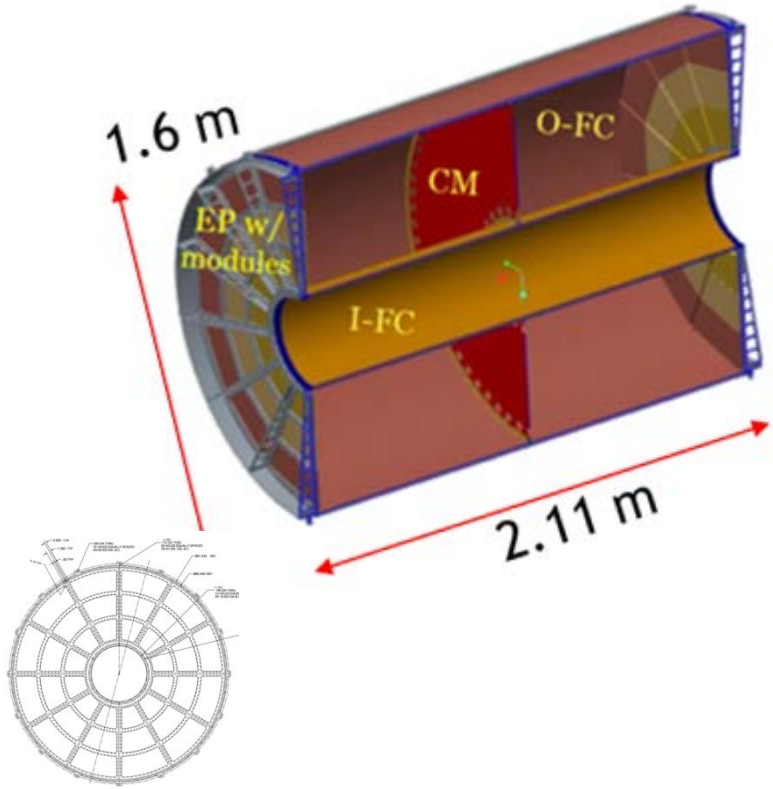


FEE estimated max ~20 watts per board

The Gas System Design Drivers

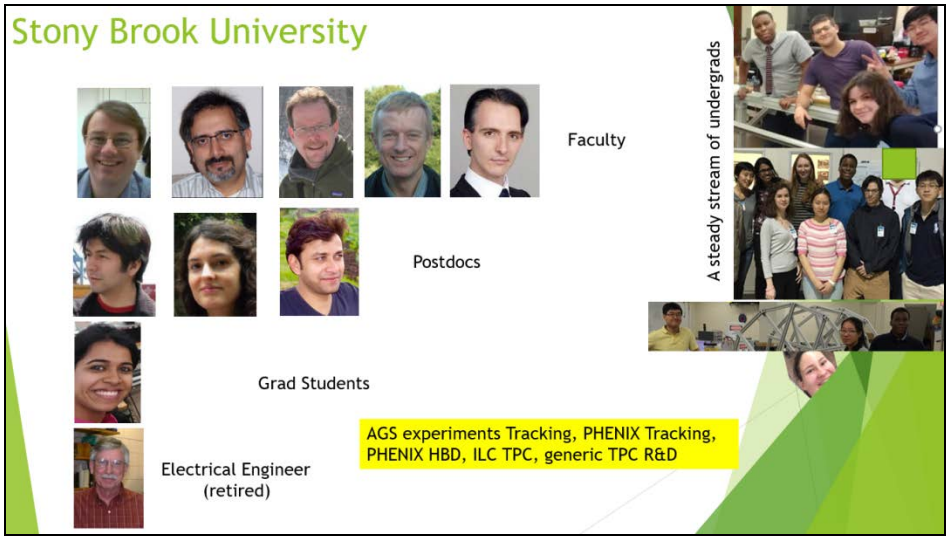
TPC Gas System Requirements

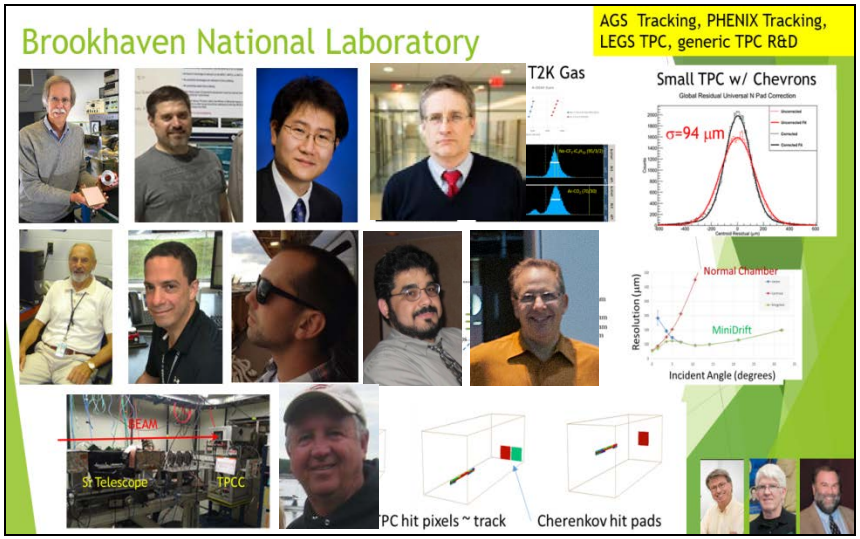
- •Neon based gas (minimize space-charge distortions by maximizing the positive ion drift velocity)
- •6 turnover a day
- •4000 liter volume
- •Slight overpressure above atmosphere
- •Compensate for changes in barometric pressure
- •High purity system
- •Recirculation required ($)
- •Remote monitoring
- •Alarmed

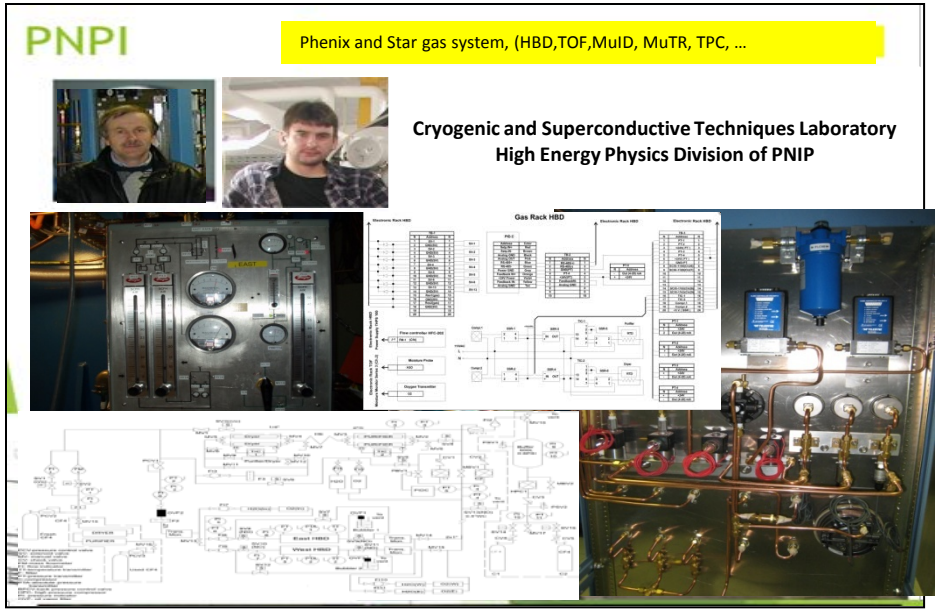


•A Gas System (1.2.7.2)--- High purity re-circulations system for a Ne based operating gas. System need to be operated at constant atmospheric pressure (0.5”w.c.) while turning over the gas volume (4000 liters) six times over 24hrs.

Subsystem Collaborators





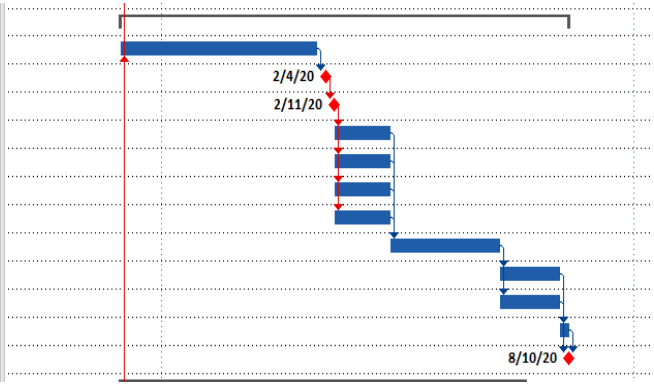


Some Key Personnel:

- Paul Giannotti – Principal Electrical Engineer (BNL)+20 Monitoring and alarms system experience.
- Don Lynch-- Chief Engineer (BNL)15 yrs thermal engineering experience, 20 yrs mechanical experience with BNL
- Robert Pisani—Physic Associate (BNL) 20+ years of gas systems and 10+ cooling systems experience.
- Carter Biggs --Sr Tech 20+ experience with technical support gas and cooling systems
- Dr. Leonid Kotchenda Sr Scientist (PNPI_20+ experience with gas system
- Dr. Peter Kravtsov Sr Scientist (PNIP)20+ experience with Gas systems
- Tom Hemmick Sr Scientist (SUNY SB) 20+ years gas detector experience
- Bob Azmoun Physics Associate +15 yrs experience gas detectors
- Sean Stoll Physics Associates +25 yr experience detectors and lasers.

Basis of Estimate and Resource-Loaded Schedule

243	1.2.7.2	TPC Gas System	235 days	Fri 8/30/19	Mon 8/10/20	
244	1.2.7.2.1	Design TPC Gas Handling System	100 days	Fri 8/30/19	Tue 1/28/20	279
245	1.2.7.2.2	TPC Gas System Safety Review	0 days	Tue 2/4/20	Tue 2/4/20	244FS+5 days
246	1.2.7.2.3	TPC Gas System Design Review	0 days	Tue 2/11/20	Tue 2/11/20	245FS+5 days
247	1.2.7.2.4	Procure TPC Gas System mass flow meters	30 days	Wed 2/12/20	Wed 3/25/20	246
248	1.2.7.2.5	Procure TPC Gas System Analyzers (2 for redundancy)	30 days	Wed 2/12/20	Wed 3/25/20	246
249	1.2.7.2.6	Procure TPC Gas System scrubbers	30 days	Wed 2/12/20	Wed 3/25/20	246
250	1.2.7.2.7	Procure TPC Gas System oxygen and water sensors	30 days	Wed 2/12/20	Wed 3/25/20	246
251	1.2.7.2.8	Assemble TPC Gas System controls	60 days	Thu 3/26/20	Thu 6/18/20	247,248,249,250
252	1.2.7.2.9	Set up TPC Gas System computer control	30 days	Fri 6/19/20	Mon 8/3/20	251
253	1.2.7.2.10	Assemble and Plumb TPC Gas System	30 days	Fri 6/19/20	Mon 8/3/20	251
254	1.2.7.2.11	Install and Test TPC Gas System Interlocks	5 days	Tue 8/4/20	Mon 8/10/20	252
255	1.2.7.2.12	TPC Gas System Complete	0 days	Mon 8/10/20	Mon 8/10/20	254,253



The gas system cost is $107k before contingency and $135k after contingency.

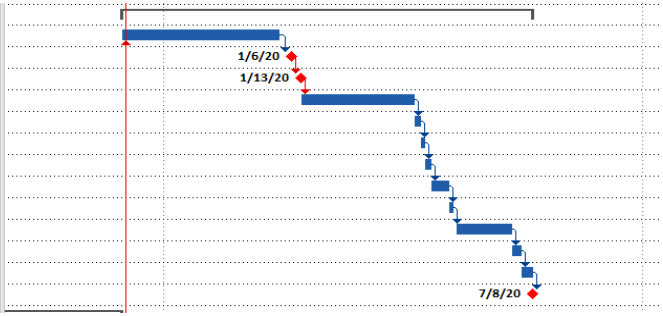
Gas System

Manufacturer quotes are either assessed as 20% or 25% contingency based upon past experience with long term price stability. All other items carry 40% contingency.

WBS	Item	Vendor	Total	Status	Basis of Estimate	Contingency	Item Contingency	Wt Contingency	Total	Contingency	Total w/ Contingency	Grand Total	Grand Total w/ Contingency
1.2.7.2												$106,755	$135,374
1.2.7.2.2								0.20	$8,975	$1,795	$10,770		
	Flowcontrollers		$4,500	Pending	Quote	0.20	$900						
	Power supply		$3,975	Pending	Web	0.20	$795						
	Cables		$500	Pending	web	0.20	$100						
1.2.7.2.3)								0.25	$28,300	$7,060	$35,360		
	Cf4 Analyzer		$14,000	Pending	past quote	0.25	$3,500						
	Iso Analyzer		$14,000	Pending	past quote	0.25	$3,500						
	Cables		$300	Pending	web	0.20	$60						
1.2.7.2.4								0.38	$6,550	$2,485	$9,035		
	Vessel		$5,000	Pending	experience	0.40	$2,000						
	Catalyst		$600	Pending	past quote	0.25	$150						
	Molecular sieves		$300	Pending	past quote	0.25	$75						
	Heater and temp controller	OMEGA	$650	Pending	estimate	0.40	$260						
1.2.7.2.5								0.25	$11,200	$2,840	$14,040		
	H2O analyzers		$7,000	Pending	web	0.20	$1,400						
	O2 Analyzers		$3,000	Pending	experience	0.40	$1,200						
	Cables		$1,200	Pending	quote	0.20	$240						
1.2.7.2.7								0.28	$20,375	$5,648	$26,023		
	Electronics Design	CSINO	$7,000	Pending	Past Cost	0.25	$1,750						
	Design Control Software	CSINO	$3,300	Pending	Past Cost	0.25	$825						
	Procure Gas system Electronic Crate	Allied	$1,000	Pending	Past Cost	0.25	$250						
	Procure Electronics Modules	CSino	$3,600	Pending	past cost	0.25	$900						
	Procure Hardware for electronics (Cabels,termanals,Etc)	Various	$2,600	Pending	Estimate	0.40	$1,040						
	Procure Gas System Control PC	Dell	$800	Pending	Web Quote	0.20	$160						
	Procure Power supplies	Omega	$1,200	Pending	estimate	0.40	$480						
	Procure Mounting hardware	McMaste	$200	Pending	estimate	0.40	$80						
	Procure Al Panels	McMaste	$140	Pending	estimate	0.40	$56						
	Procure Electronics Rack	Allied	$535	Pending	web quote	0.20	$107						
1.2.7.2.8								0.28	$31,355	$8,791	$40,146		
	Procure Stainless compression fittings	Swagelok	$6,500	Pending	old order	0.25	$1,625						
	Procure Stainless Tubing	Swagelok/	$3,400	Pending	old order	0.25	$850						
	Procure Monitoring instrumentation	Dwyer	$6,500	Pending	past order	0.25	$1,625						
	Procure Electronic Pressure Controller	Tescom	$2,400	Pending	web quote	0.20	$480						
	Procure Compressors (2)	Aid Dimer	$4,000	Pending	past quote	0.25	$1,000						
	Procure Stainless Solenoids	Parker	$3,600	Pending	estimate	0.40	$1,440						
	Procure Stainless Valves	Swagelok	$3,500	Pending	estimate	0.40	$1,400						
	Procure AL Panels	McMaste	$520	Pending	web quote	0.20	$104						
	Procure Mounting hardware	McMaste	$400	Pending	estimate	0.40	$160						
	Procure Electronics Rack	Allied	$535	Pending	Web Quote	0.20	$107						
1.2.7.2.9								0.00	$0	$0	$0		
	This is part of Computer control		$0	Pending	Experience	0.40	$0						

Basis of Estimate and Resource-Loaded Schedule

256	1.2.7.3	TPC Cooling System	212 days	Fri 8/30/19	Wed 7/8/20	
257	1.2.7.3.1	Design TPC Cooling System	80 days	Fri 8/30/19	Fri 12/27/19	279
258	1.2.7.3.2	TPC Cooling System Safety Review	0 days	Mon 1/6/20	Mon 1/6/20	257FS+5 days
259	1.2.7.3.3	TPC Cooling System Design Review	0 days	Mon 1/13/20	Mon 1/13/20	258FS+5 days
260	1.2.7.3.4	Procure TPC Cooling Sys tem equipment(pumps,heat	60 days	Tue 1/14/20	Wed 4/8/20	259
261	1.2.7.3.5	Install TPC Cooling System pumps	3 days	Thu 4/9/20	Mon 4/13/20	260
262	1.2.7.3.6	Install TPC Cooling System heat exchanger	3 days	Tue 4/14/20	Thu 4/16/20	261
263	1.2.7.3.7	Install TPC Cooling System PH control	3 days	Fri 4/17/20	Tue 4/21/20	262
264	1.2.7.3.8	Install TPC Cooling System end cap manifolds	10 days	Wed 4/22/20	Tue 5/5/20	263
265	1.2.7.3.9	Install TPC Cooling System tanks	3 days	Wed 5/6/20	Fri 5/8/20	264
266	1.2.7.3.10	Install TPC Cooling System plumbing	30 days	Mon 5/11/20	Mon 6/22/20	265
267	1.2.7.3.11	Set up TPC Cooling System computer controls	5 days	Tue 6/23/20	Mon 6/29/20	266
268	1.2.7.3.12	Set up and Test TPC Cooling System interlocks	5 days	Tue 6/30/20	Wed 7/8/20	267
269	1.2.7.3.13	TPC Cooling System Complete	0 days	Wed 7/8/20	Wed 7/8/20	268



The cooling system cost is $66k before contingency and after $81k after contingency.

Cooling System

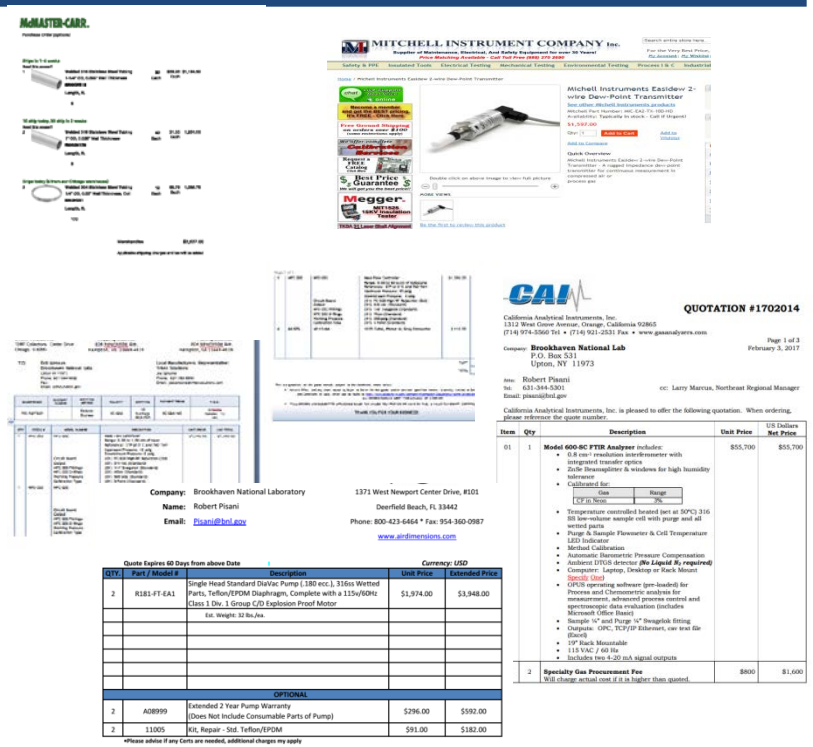
Manufacturer quotes are either assessed as 20% or 25% contingency based upon past experience with long term price stability. All other items carry 40% contingency.

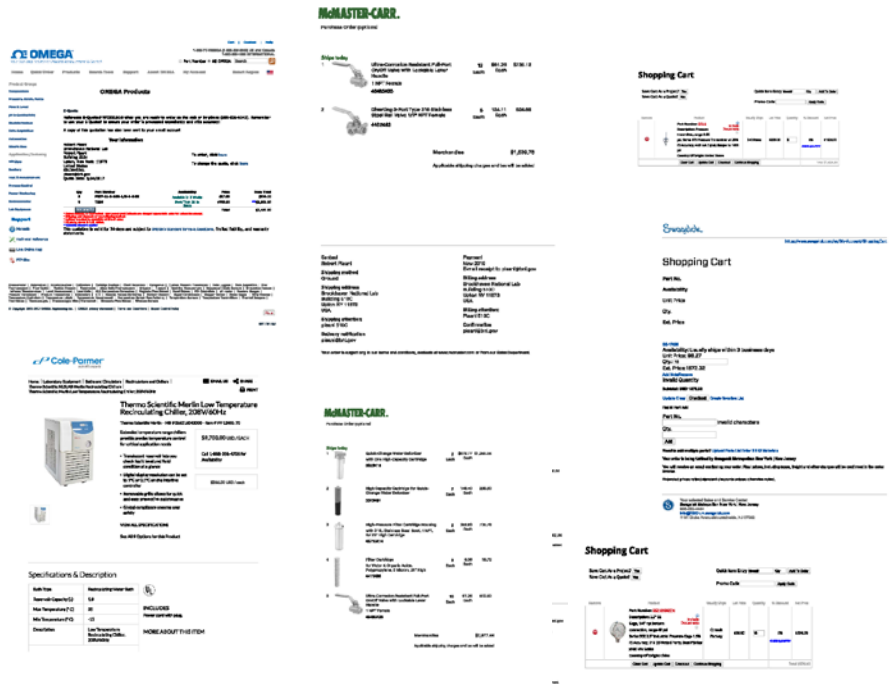
WBS	Description	Item	Vendor	Total	Status	Basis of Estimate	Contingency	Item Contingency	Wt Contingency	Total	Contingency	Total w/ Contingency	Grand Total	Grand Total w/ Contingency
1.2.7.3	TPC Cooling System												$66,499	$80,941
1.2.7.3.4	Procure TPC Cooling Sys tem equipment(pumps,heat exchanger, PH control, manifolds, tanks…)								0.21	$44,339	$9,368	$53,707		
		Chillers watt 10C(3)	Thermo Scientific Merlin	$32,000	Pending	Quote	0.2	$6,400						
		Deionizing filters (2)	McMaster	$1,644	Pending	web Quote	0.2	$329						
		Particle filters (3)	McMaster	$720	Pending	web Quote	0.2	$144						
		Valving for Chiller Switchover	McMaster	$825	Pending	Web Quote	0.2	$165						
		SS Manifolds (4) 12 port	MSC	$1,110	Pending	web quote	0.2	$222						
		Hardware (panel, brackets, mnts)	Mcmaster	$650	Pending	web Quote	0.2	$130						
		Flowmeter 24(SS) water	Dwyer	$1,315	Pending	web Quote	0.2	$263						
		Compression fittings SS (various)	Swagelok	$2,500	Pending	Quote + experience	0.4	$1,000						
		Bypass Valving at detector	McMaster	$1,550	Pending	web Quote	0.2	$310						
		Pressure gauges (8)	Dwyer	$450	Pending	Web Quote	0.2	$90						
		Manifold valving (24)	Swagelok	$1,575	Pending	web Quote	0.2	$315						
1.2.7.3.8	Install TPC Cooling System plumbing								0.23	$11,667	$2,626	$14,293		
		1 1/4" thin walled SS Lines	Mcmaster	$1,600	Pending	old Quote x inflation	0.25	$400						
		1" SS Thin walled Lines	McMaster	$1,450	Pending	old Quote x inflation	0.25	$363						
		5/16" SS Coil (0.250 ID Min)	McMaster	$1,200	Pending	web quote	0.2	$240						
		SS Pipe fittings	Mcmaster	$700	Pending	experience	0.4	$280						
		1 1/4" Braided lines (316 SS)	McMaster	$946	Pending	web quote	0.2	$189						
		Large Compression fittings SS	Swagelok	$3,750	Pending	web quote	0.2	$750						
		Poly lines to detector (Various)	MSC	$924	Pending	web Quote	0.2	$185						
		House Water Manifolding (brass)	McMaster	$1,097	Pending	Web Quote	0.2	$219						
1.2.7.3.9	Set up TPC Cooling System Interlocks and Safety System								0.23	$10,493	$2,449	$12,942		
		Pressure Transmitters (8 min)	Dwyer	$1,625	Pending	quote	0.2	$325						
		Transmitting Flowmeters (SS 1") (8)	Mcmaster	$2,050	Pending	Web Quote	0.2	$410						
		RTDs (8)	Omega	$550	Pending	Web Quote	0.2	$110						
		RTD transmitter+local read (7)	Omega	$2,986	Pending	Web Quote	0.2	$597						
		Electronic hardware	various	$1,750	Pending	estimate	0.4	$700						
		House water Monitor (pressure)	Various	$650	Pending	Web Quote	0.2	$130						
		Presure Relief Valves 1" (2) SS	Mcmaster	$882	Pending	web quote	0.2	$176						

Cost Drivers

- Gas system
  - Purifier system—$10k
  - Gas Analyzers- $28k
  - Stainless Steel Parts -$9k
  - Controller $20k
  - Monitoring instrumentation $11k

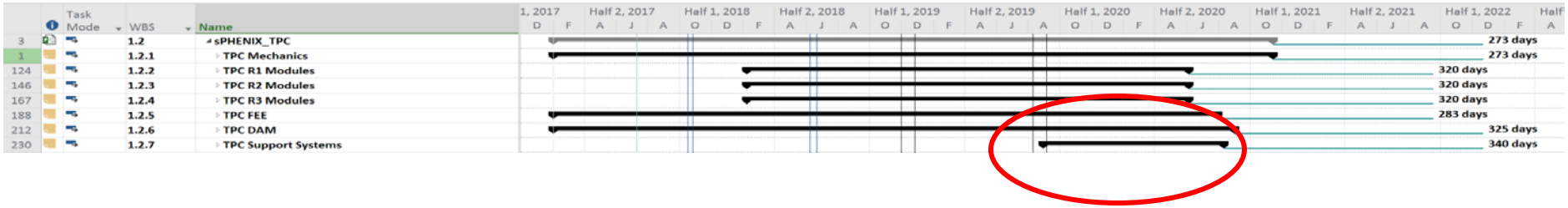
- Cooling system
  - Chillers $32k
  - Monitoring instrumentation -$11k
  - Stainless Steel parts –$12k





Key Times in the Schedule

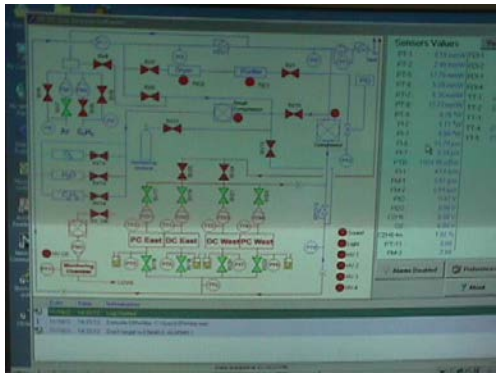
- Gas system
  - Design Winter 2019
  - Safety & Design Review Feb 2020
  - Procurement of parts Spring 2020
  - Assembly of system Summer 2020
  - System Complete August 2020
- Cooling System
  - Design Winter 2019
  - Safety & Design Review January 2020
  - Procurement of parts Winter/Spring 2020
  - Assembly of system Spring 2020
  - System Complete July 2020
- Laser system
  - Design Fall 2019
  - Safety & Design Review November 2019
  - Procurement Assembly of system Winter 2019/2020
  - Assembly of system Spring 2020
  - System Complete June 2020

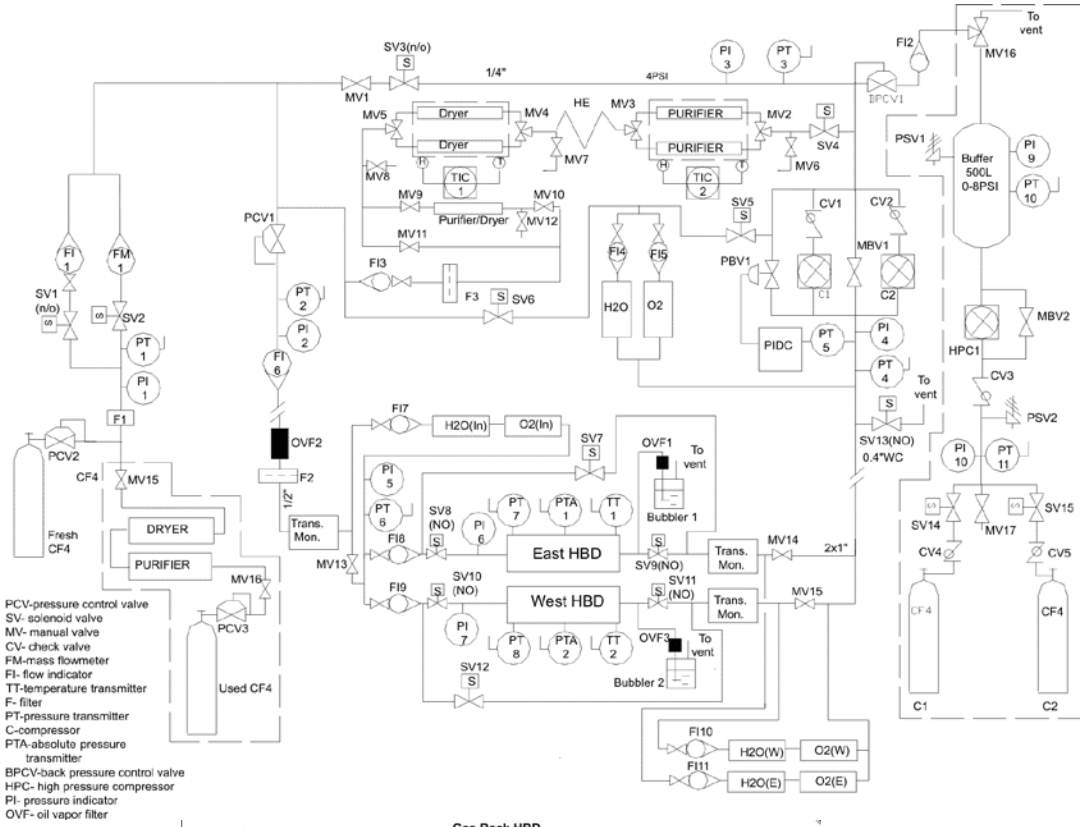


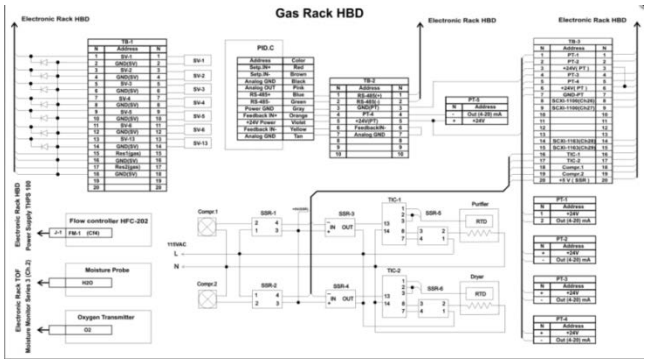
The Gas System Status

TPC Gas System

- Based on PHENIX HBD gas system designs
- Ne mixture (Ne/CF4/iC4H10; 95:3:2)
- Flowrate ~1m3/hr
- 1-2mBar (~0.5"w.c.) above atmosphere to +/- 1/8" w.c.
- Closed loop recirculation
- Analyzers to monitor mixture and impurities
- In line purifiers
- High purity system-all stainless
- PC Controlled
- Fully alarmed



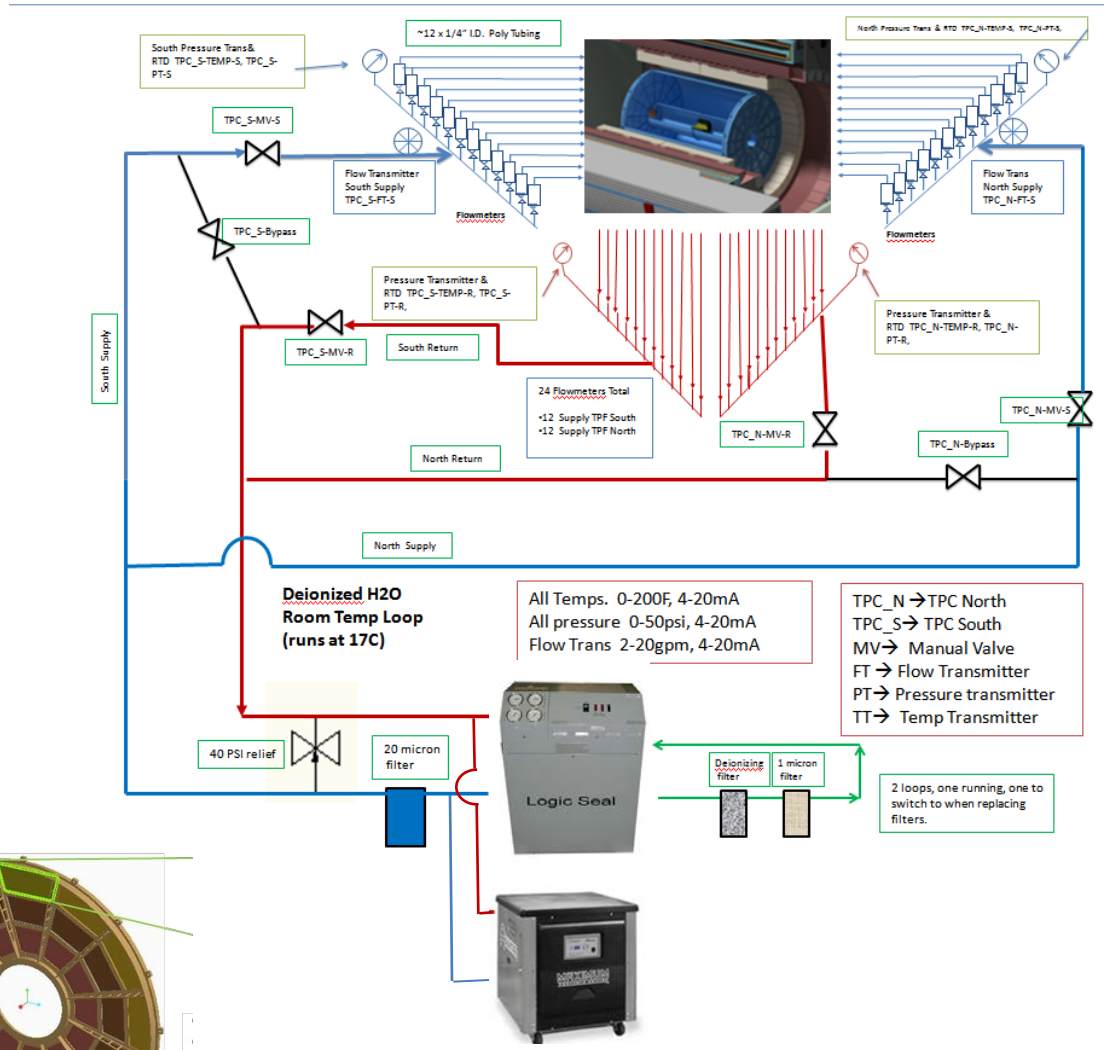


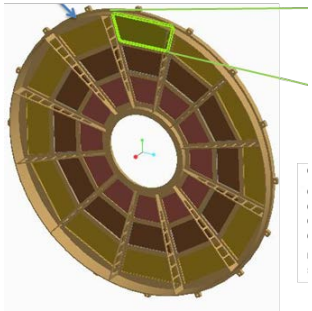


The Cooling System Status

TPC Gas System

- •Based on the PHENIX VTX/FVTX cooling system
- •Negative Pressure Loop
- •Modified for flow rate and load, and segmentation
- •Water based coolant
- •Closed loop
- •Purifier loops built in
- •Monitored and alarmed
- •24 channel system divided North and South
- •Redundancy built into the system.
- •Total heat removed 12kWatt





Summary

Gas System

- PHENIX hosted many high purity gas systems (HBD detector, mRPC, TOF, DC, PC, RICH, Mutr, Muid).
- The system will be designed with all stainless plumbing for highest purity and ample contamination monitoring.
- The TPC detector's needs are rather similar to the HBD ultra high purity system (even less stringent) and so we feel it is conservative to use the HBD system as a cost basis.
- We have highly experienced people collaborating on this. Many with 15 to 20+ years experience.
- The gas system cost is $107k before contingency and $135k after contingency. (From BOE & RLS)

Cooling System

- Our heat load is well understood, allowing for reasonable accuracy on the cost estimation. The heat load is significant enough that liquid cooling is required since gas cooling will be insufficient.
- The cost basis used is extrapolated using similar systems found in the PHENIX VTX/FVTX Cooling System
- We have a skilled set of people collaborating on this with 10 to 15 years experiences.
- The cost before contingency is $66k and after contingency is $81k.

TPC Support Laser System

by Bob Azmoun

From the WBS Definitions

- 1.2.7 **TPC Support Systems** TECHNICAL SCOPE: CONTAINS ALL TASKS WHICH ARE REQUIRED TO PROVIDE NECESSARY SUPPORT SYSTEMS FOR THE TPC: LASER, GAS, COOLING SYSTEM. WORK STATEMENT: PROVIDE ALL PARTS TO SUPPORT TPC OPERATION.
  - **1.2.7.1 TPC Laser System** TECHNICAL SCOPE: THIS ITEM CONTAINS ALL TASKS WHICH ARE REQUIRED TO IDENTIFY COMPONENTS FOR THE TPC LASER CALIBRATION SYSTEM AND PROCURE AND CONSTRUCT THE ELEMENTS OF THE SYSTEM. WORK STATEMENT: PROVIDE ALL PARTS TO PRODUCE THE LASER CALIBRATION SYSTEM AND ASSEMBLE/INSTALL ALL PARTS.

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

L2 Project Name	L2 WBS Number	L3 Project Name (Control Account)	L3 WBS Number
Time Projection Chamber	1.2	TPC Support Services	1.2

Work Package Name	WBS Number	Basis of Estimate Link
TPC Laser System	1.2.7.1	Laser-Summary
TPC Gas System	1.2.7.2	Gas-Summary
TPC Cooling System	1.2.7.3	Cooling-Summary

•A Laser System(1.2.7.1)- Lasers can be used to produce ionization in the TPC volume that provides both a source of signals and a calibration. This includes pattern applied to the central membrane (STAR) as well as direct laser transmission through the gas (STAR and ALICE). In the case of STAR and ALICE, the lasers going through the gas are directed via fibers and mirror bundles to criss-cross planes at several Z locations. The fiber bundles take radial space that both STAR and ALICE can afford. Due to the small size, sPHENIX cannot afford to have a bundle running along Z. Therefore we shall use two solutions to laser calibration. First, we will shine diffuse laser light onto the patterned central membrane. Second, we will allow for angled\trajectories of laser light emanating from between the modules traveling at various angles through the gas. While not ideal it is a better solution than losing radial space.

Preliminary Laser System Concept

PURPOSE

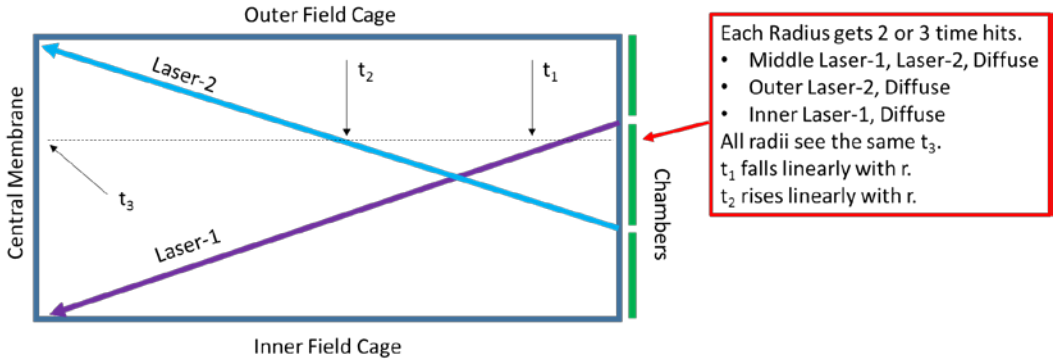
- Determine drift velocity throughout TPC volume
- Determine electric field distortions
- Determine precise alignment of field cage w.r.t. endcap and magnetic field

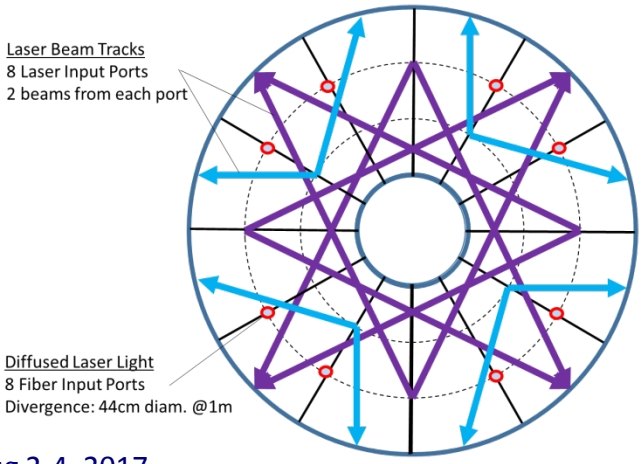
DESIGN CONSTRAINTS

- No radial space available for laser system → driven by TPC momentum spec.
- Only input ports available are on endcap (12 outer + 12 inner)→Planes of laser tracks not possible (ala STAR and ALICE), but angles tracks are. Also, can illuminate central membrane ala STAR.
- Pattern on central membrane shall be dots (ala ILC) not lines (ala STAR), as lines only allow space charge distortion determinations perpendicular to the lines → dots provide for more info.
- The laser system WILL include diffuse illumination (cheap) and MIGHT include laser beam tracks from the endcaps

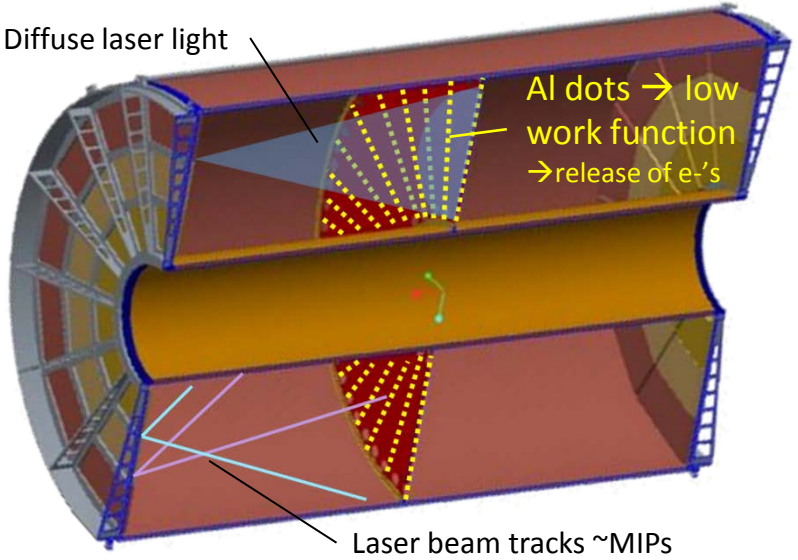
Three varieties of laser sources (266nm, 80mJ/pulse):

1. Diffuse laser targeting central membrane.
2. Laser going from R=60cm to R=20cm
3. Laser going from R=40cm to R=80cm





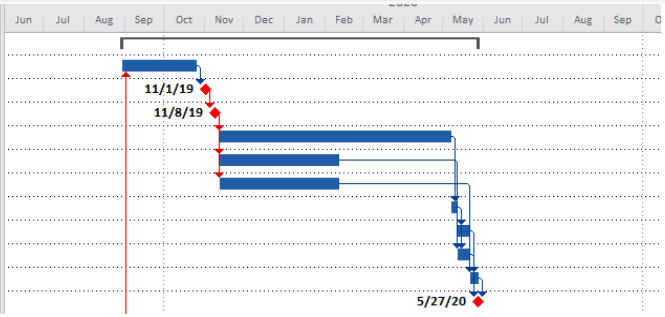
TPC End-cap



More complex picture in 3D!

Basis of Estimate and Resource-Loaded Schedule

	WBS	Task Name	Duration	Start	Finish	Predecessors
231	1.2.7.1	TPC Laser System	184 days	Fri 8/30/19	Wed 5/27/20	
232	1.2.7.1.1	Design TPC Laser System	40 days	Fri 8/30/19	Fri 10/25/19	279
233	1.2.7.1.2	TPC Laser System Safety Review	0 days	Fri 11/1/19	Fri 11/1/19	232FS+5 days
234	1.2.7.1.3	TPC Laser System Design Review	0 days	Fri 11/8/19	Fri 11/8/19	233FS+5 days
235	1.2.7.1.4	Procure TPC laser(s)	120 days	Tue 11/12/19	Wed 5/6/20	234
236	1.2.7.1.5	Procure TPC optics with mirrors	60 days	Tue 11/12/19	Tue 2/11/20	234
237	1.2.7.1.6	Procure TPC mirror bundles with supports	60 days	Tue 11/12/19	Tue 2/11/20	234
238	1.2.7.1.7	Install TPC lasers	3 days	Thu 5/7/20	Mon 5/11/20	235
239	1.2.7.1.8	Install TPC Laser safety interlocks	8 days	Tue 5/12/20	Thu 5/21/20	238
240	1.2.7.1.9	Install TPC Laser optics with mounts	8 days	Tue 5/12/20	Thu 5/21/20	236,238
241	1.2.7.1.10	Install TPC mirror bundles and supports	3 days	Fri 5/22/20	Wed 5/27/20	240,237
242	1.2.7.1.11	TPC Laser System Complete	0 days	Wed 5/27/20	Wed 5/27/20	241,239



TPC Laser Components and Hardware

- Table below is updated from docdb
- More quotes than before (few weeks ago)
- Same Total as before
- ~$7K lower contingency than before
- The full cost of the laser system is now $144k before contingency and $180k after contingency.
- Manufacturer quotes are either assessed as 20% or 25% contingency based upon past experience with long term price stability. All other items carry 40% contingency.

Cost Drivers:

- Laser (~$77K)
- Beam Splitter (~$15K)
- Beam conduit system (~$17K)
- TPC laser beam window/ 2-way splitter (~$15K)

We have costed the laser system to include both membrane illumination and laser beam tracks so as to capture the highest estimate.

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
1.2.7.1	TPC Laser System												$144,177	$179,760
1.2.7.1.2	Procure TPC laser(s)								0.2	$77,177	$15,435	$92,612		
		Laser	Newport	$77,177	Pending	Manufacturer Quote	0.2	$15,435.40						
1.2.7.1.3	Procure TPC optics with mirrors								0.4	$50,000	$13,348	$63,348		
		Fibers	Fiberguide Ind.	$2,527	Pending	Manufacturer Quote	0.2	$505.40						
		Beam Splitter	CVI Optics	$14,925	Pending	Manufacturer Quote	0.2	$2,985.00						
		ND filters	Thor Labs	$936	Pending	Manufacturer Quote	0.2	$187.20						
		Waveplates	Thor Labs	$240	Pending	Manufacturer Quote	0.2	$48.00						
		Beam stearing optics	Thor Labs	$1,020	Pending	Manufacturer Quote	0.2	$204.00						
		Optical table	Thor Labs	$2,636	Pending	Manufacturer Quote	0.2	$527.20						
		Photodiodes	Thor Labs	$351	Pending	Manufacturer Quote	0.2	$70.20						
		Power meter	Thor Labs	$2,738	Pending	Manufacturer Quote	0.2	$547.60						
		Fiber couplers	Thor Labs	$7,888	Pending	Manufacturer Quote	0.2	$1,577.60						
		Beam conduit		$16,739	Pending	Experience	0.4	$6,696						
1.2.7.1.4	Procure TPC mirror bundles with supports								0.4	$15,000	$6,000	$21,000		
		Window/2-way splitter		$15,000	Pending	Experience	0.4	$6,000						
1.2.7.1.6	Design and implement TPC Laser safety interlocks								0.4	$2,000	$800	$2,800		
				$2,000	Pending	Experience	0.4	$800						

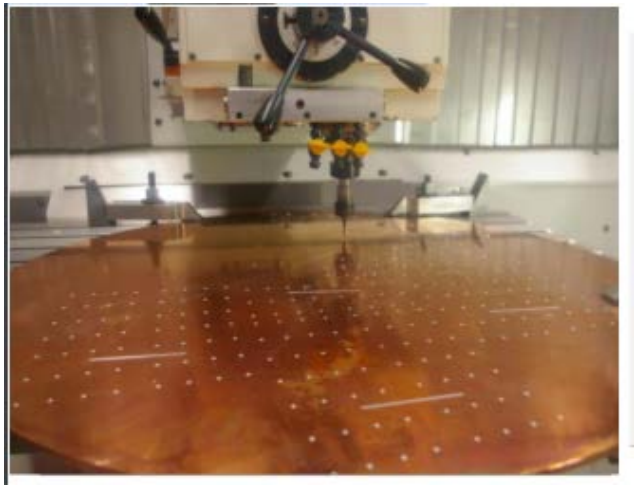
Summary

TPC Laser System

- We will base the calibration system on the STAR and ALICE laser calibration systems for the purpose of alignment and to directly measure the degree of space charge distortion
- Concept: illuminate pattern on membrane to liberate charge and possibly shoot beams into TPC volume to simulate tracks from MIPS
- We have costed the laser system to capture the highest estimate
- The full cost of the laser system is $144K before contingency and $180K after contingency.
- We have a skilled set of people in the collaboration and department with more than 10 to 15 years experience

Back Up

ILC Prototype TPC Laser System



Laser class:	IV	Divergence:	< 1 mrad
Laser type:	Nd:YAG	Pulse width:	≤ 6 ns
Wavelength:	266, 532, 1064 nm	Diameter of the Laser pulse y_0:	1.5 mm
Power:	60 mW	Repetition rate:	$5 - 20$ Hz
Energy:	3 mJ