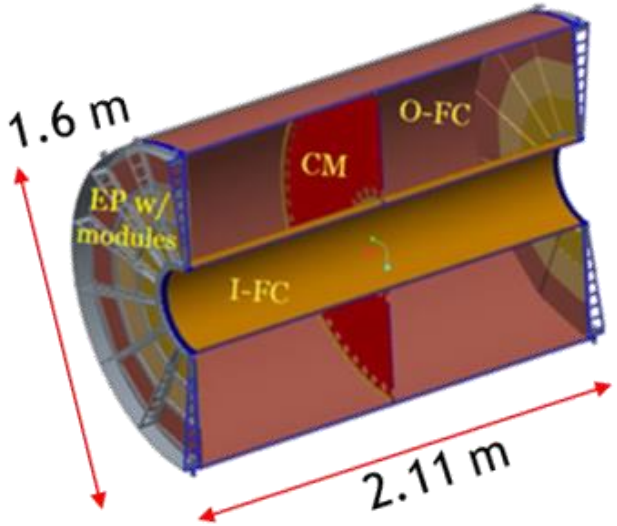
sPHENIX Director's Review
1.2.1 TPC Mechanics

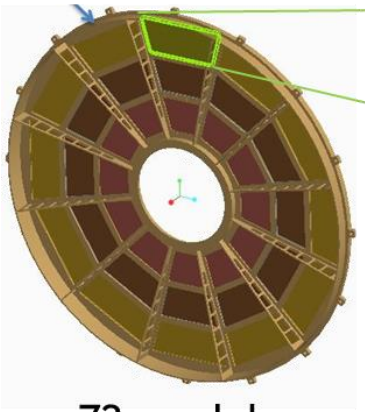
Klaus Dehmelt, Stony Brook University

August 2-4, 2017

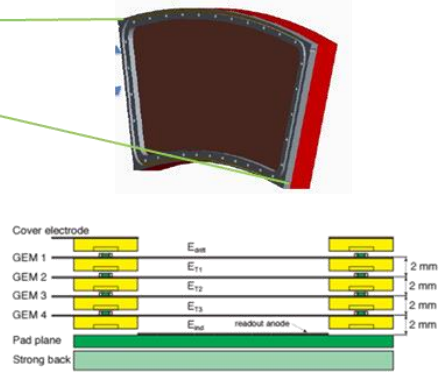
BNL

The Subsystem





72 modules
2(z), 12(ϕ), 3(r)



Quad-GEM Gain Stage
Operated @ low IBF

- WBS 1.2.1 - TPC Mechanics → Field Cage with full azimuthal coverage and $|\eta| < 1.1$

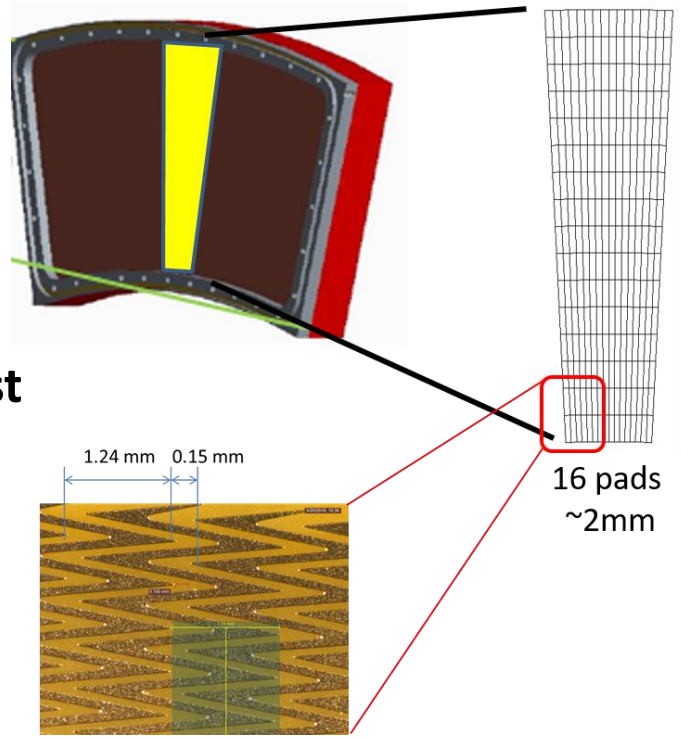
Outer Field Cage O-FC, R = 78 cm, L = 211 cm
Inner Field Cage I-FC, R = 20 cm , L = 211 cm

Central Membrane CM
Endplates EP, 2 in z
Modules, 12 in ϕ, 3 in r

- Modules based on Quad-GEMs for continuous readout and low Ion Back Flow IBF
- Present gas choice provides drift time of ~ 18 μs, single spatial point resolution < 250 μm, low IBF

The Subsystem Technical Overview

- Dimensions and designs dictated by
  - **Inner/outer radius → magnet and inner/outer detector design**
  - **Length → pseudorapidity**
  - **Design of field cages → minimum space and maximum stability**
  - **Design endplates → minimum material budget, maximum stability**
  - **Design modules → maximum integrity, least producibility, maximum performance**



Scope

- WBS 1.2.1 contains all elements that lead to the successful assembly of the TPC mechanics (WBS 1.2.1.8) and eventually make the TPC ready to install

TPC v1 Field Cage Prototype
TPC v2 Field Cage
TPC Final Field Cage
TPC v1 Modules
TPC v1 Module Gas Enclosure
TPC v1 Module Common Mechanics
TPC v1a Module Prototype
TPC v1b Module Prototype
TPC v2 Modules
TPC v2 Module Gas Enclosure
TPC v2 Module Common Mechanics
TPC v2a Module Prototype
TPC Production GEM Acquisition
TPC High Voltage System
TPC Assembly

- Support structure → Infrastructure WBS 1.9.2.2
- Installation fixture → Installation/Integration WBS 1.10.2.8

Subsystem Collaborators

- CAM WBS 1.2.1 TPC Mechanics: Klaus Dehmelt (Stony Brook University)
  - **Research Scientist**

  Since 1999: HEP/HI Experiments: HERA-B (DESY-HERA), COMPASS (CERN-SPS), L3 (CERN-LEP), PHENIX (BNL-RHIC). Detector Systems: HERA-B Outer Tracker System (installation/commissioning), COMPASS-GEM Small Area Tracker (SAT) (design/construction/installation/commissioning), DESY-Large Prototype of a TPC (LC-TPC collaboration) (design/construction/installation/commissioning, management), PHENIX-Detector Council Member (Drift Chamber subsystem, 2011 – 2016), R&D: CsI-GEM RICH, large area GEM chambers, TPC Ion Back Flow
- L2 Manager WBS 1.2 TPC: Thomas K. Hemmick (Stony Brook University)
  - **Distinguished Teaching Professor**

  Since 1988: Heavy Ion Experiments: E814 (BNL-AGS), E877 (BNL-AGS), PHENIX (BNL-RHIC). Detector Systems: E814 drift/pad chambers (construction), E877 MWPC chambers (design/construction/management), PHENIX RICH (design/construction/management), PHENIX drift chambers (design/construction/management), PHENIX hadron blind detector (design/construction/management), PHENIX MPC-EX (construction). R&D: CsI-GEM HBD, CsI-GEM RICH, W-Si preshower, large area GEM chambers, TPC-Cherenkov hybrid, TPC Ion Back Flow
- John Cozzolino (CAD BNL)
  - **Senior engineer**

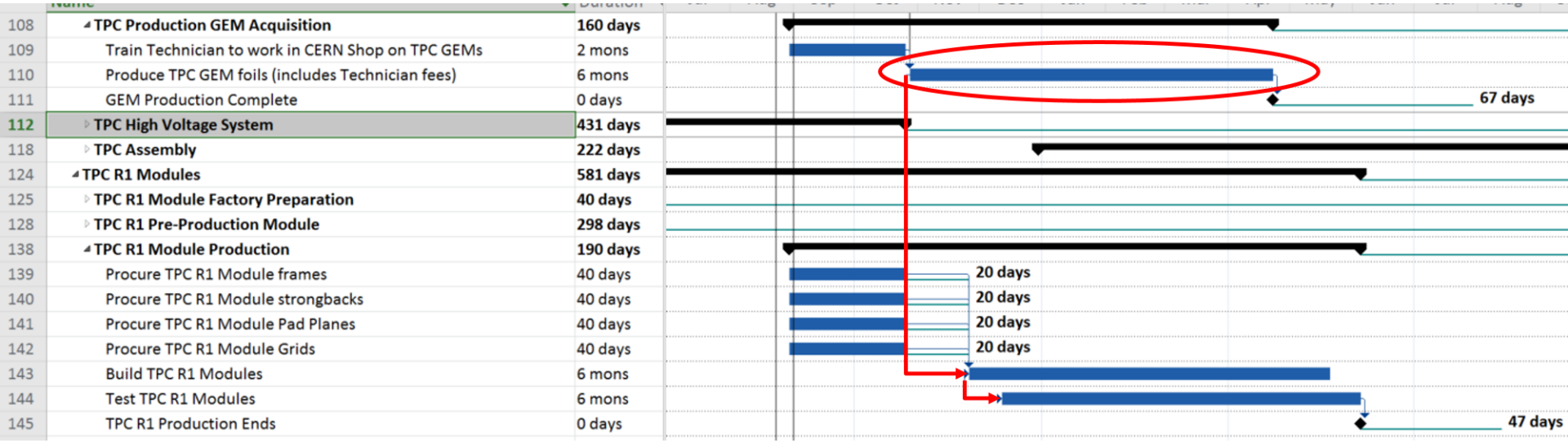
  25+ years involved in numerous aspects of the design development and construction of superconducting accelerator magnets. Specialized in computer-aided engineering analyses critical to the R&D, design and manufacture of such magnets primarily for RHIC at BNL and the LHC at CERN
- Steven Bellavia (CAD BNL)
  - **Senior engineer**

  25+ years performing mechanical analysis, design and fabrication of detectors, for PHENIX (1992-1995), RHIC (1998-present), NSRL (1999-2003) and LSST (2013-present)

Schedule Drivers

WBS 1.2.1.6 TPC Production GEM Acquisition

- 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



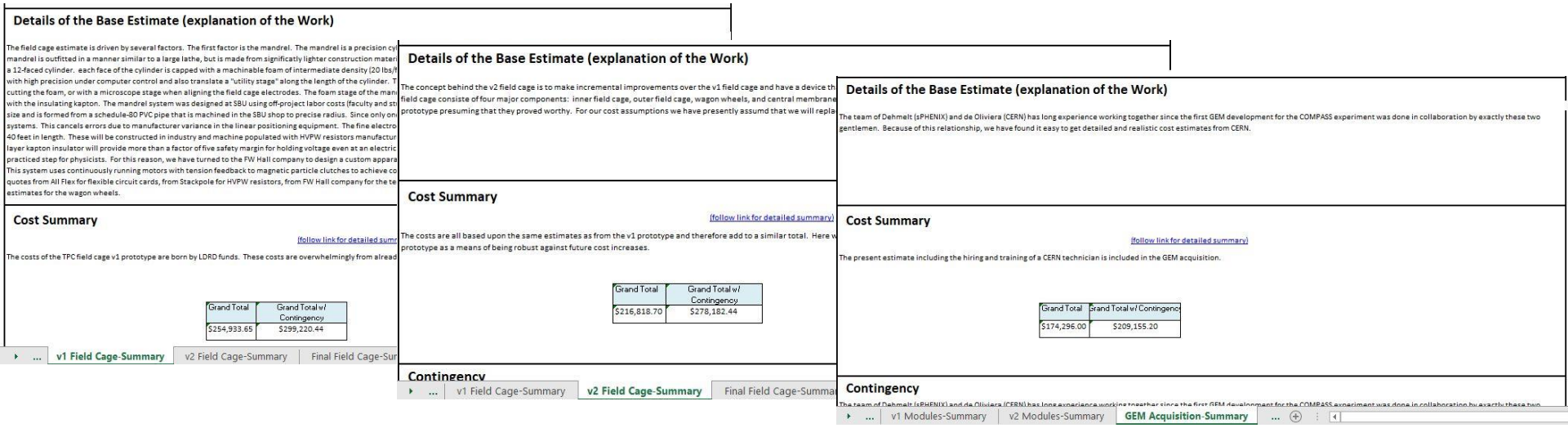
Cost Drivers

- Latest bottom-up cost estimate reveals the cost drivers to be
  - **WBS 1.2.1.1 TPC v1 Field Cage Prototype**
  - **WBS 1.2.1.2 TPC v2 Field Cage**
  - **WBS 1.2.1.6 TPC Production GEM Acquisition**
  - **Contingency at purchase-by-purchase level → weighted contingency**

Grand Total	Grand Total w/ Contingency
$254,933.65	$299,220.44

Grand Total	Grand Total w/ Contingency
$216,818.70	$278,182.44

Grand Total	Grand Total w/ Contingency
$174,296.00	$209,155.20



Basis of Estimate and Resource-Loaded Schedule

- WBS 1.2.1 contains 8 work packages

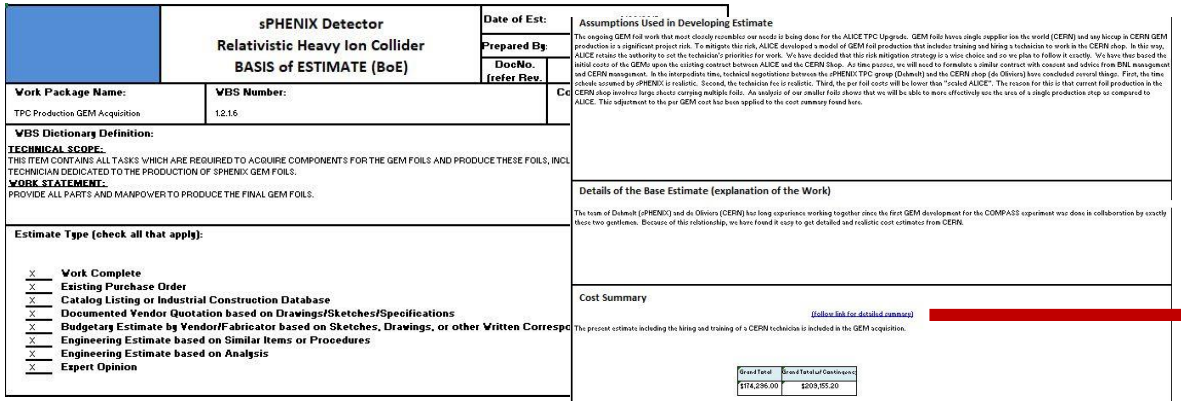
sPHENIX Detector
Relativistic Heavy Ion Collider
BASIS of ESTIMATE (BoE)

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

- Each work package is linked from the Title Page

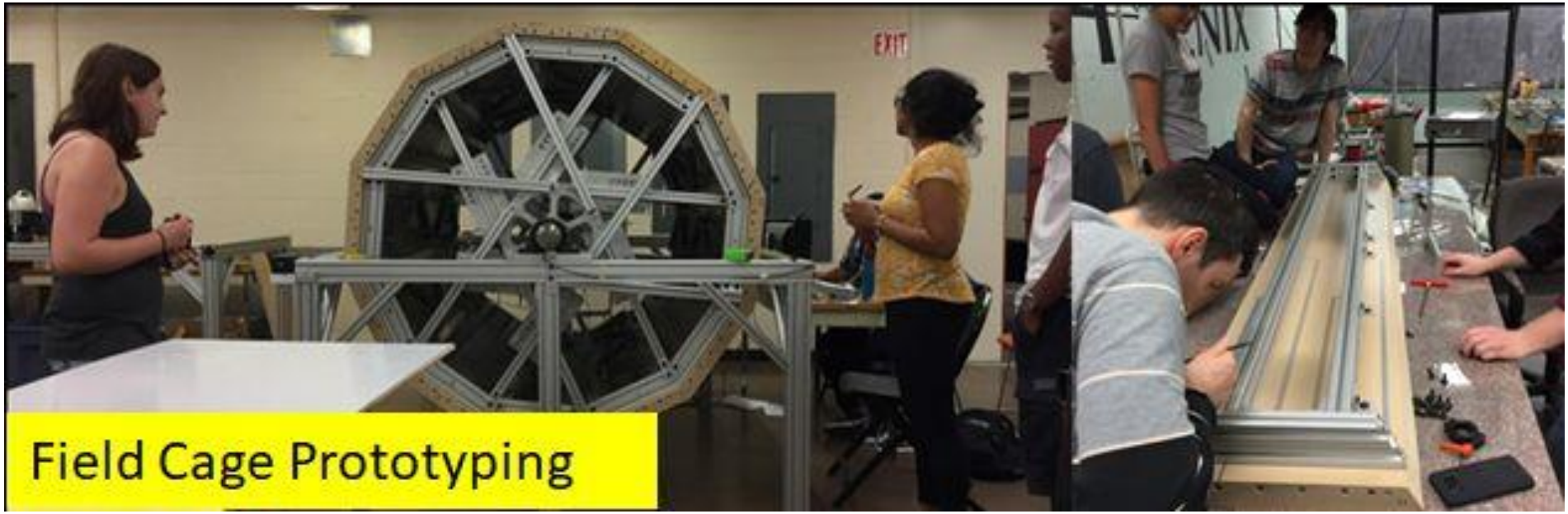
e.g.:



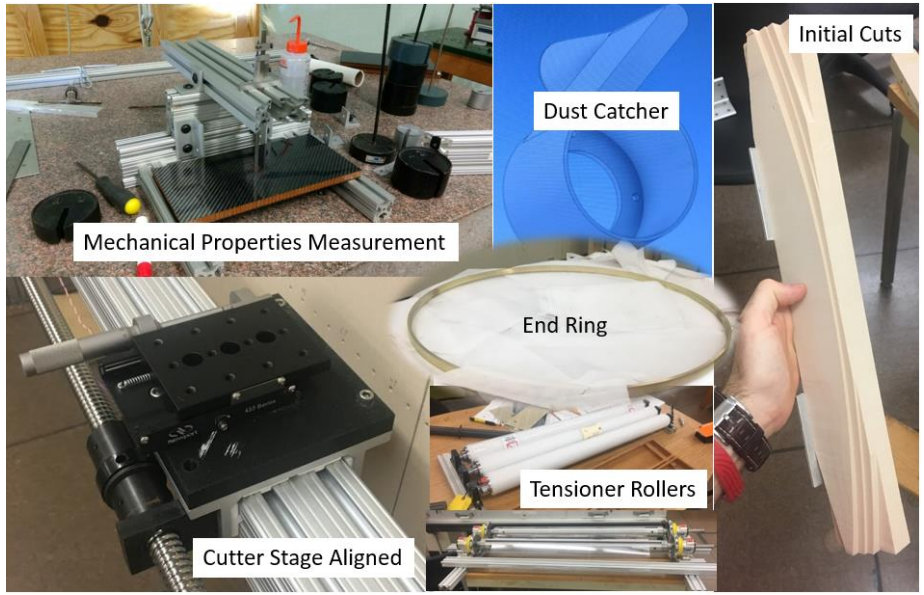
Link to detailed cost summary

- 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.**

Status and Highlights



- Outer Field Cage v1 prototype
  - **Mandrel being finalized**
  - **Start field cage production**



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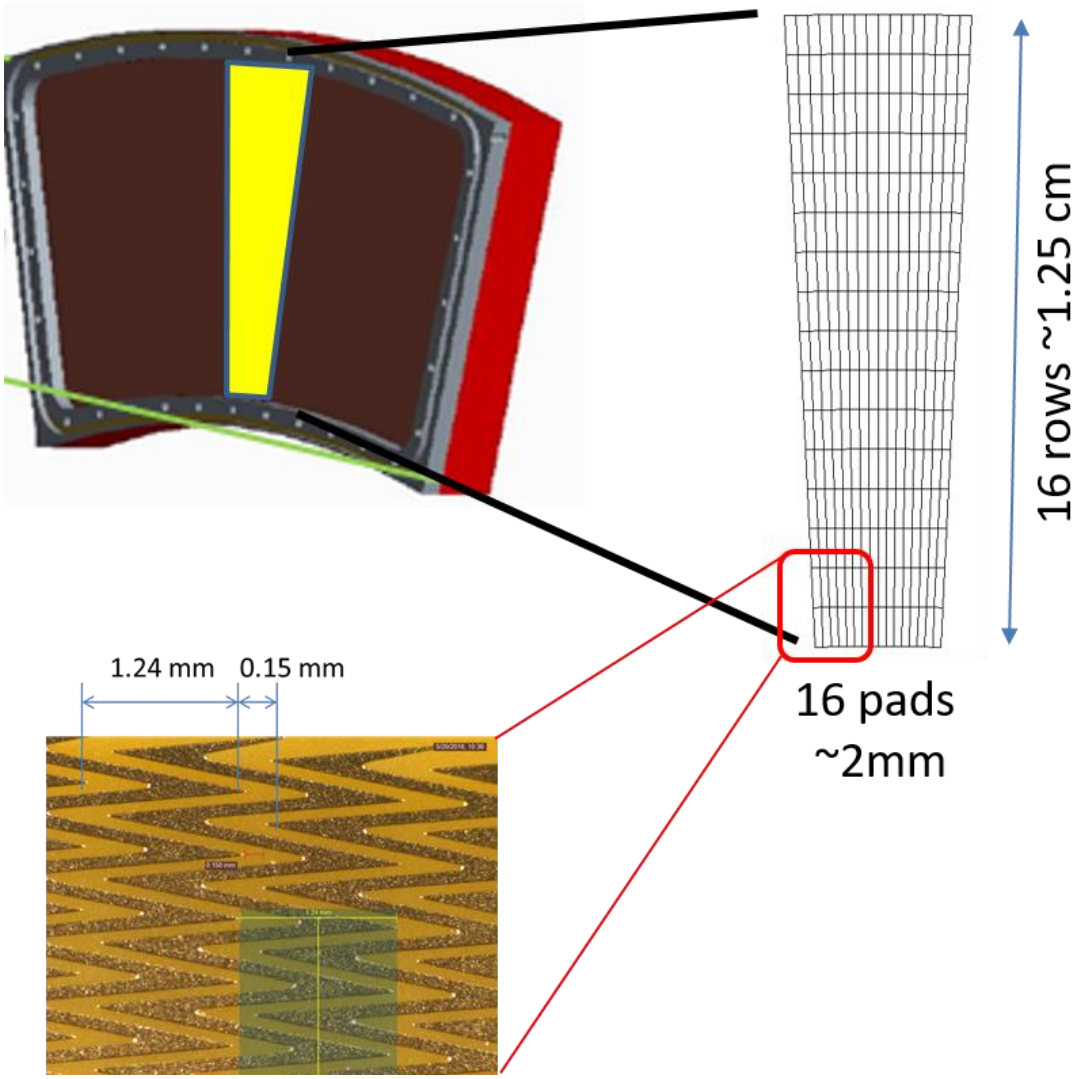
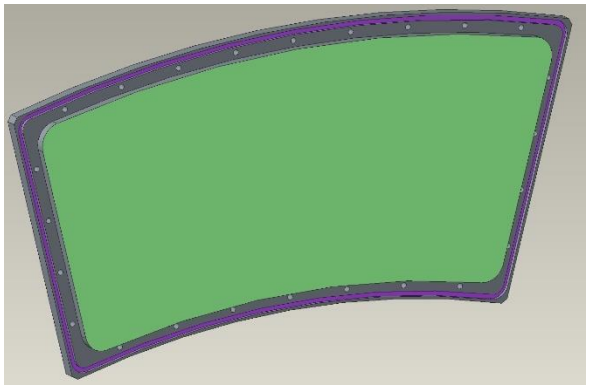


- TPC v1 modules
  - **Common mechanics designed → submit to SBU workshop**
  - **TPC v1a module prototype: GEM design finalized → submit to CERN workshop**
  - **Readout board with zig-zag shaped pads designed -> submit to provider**

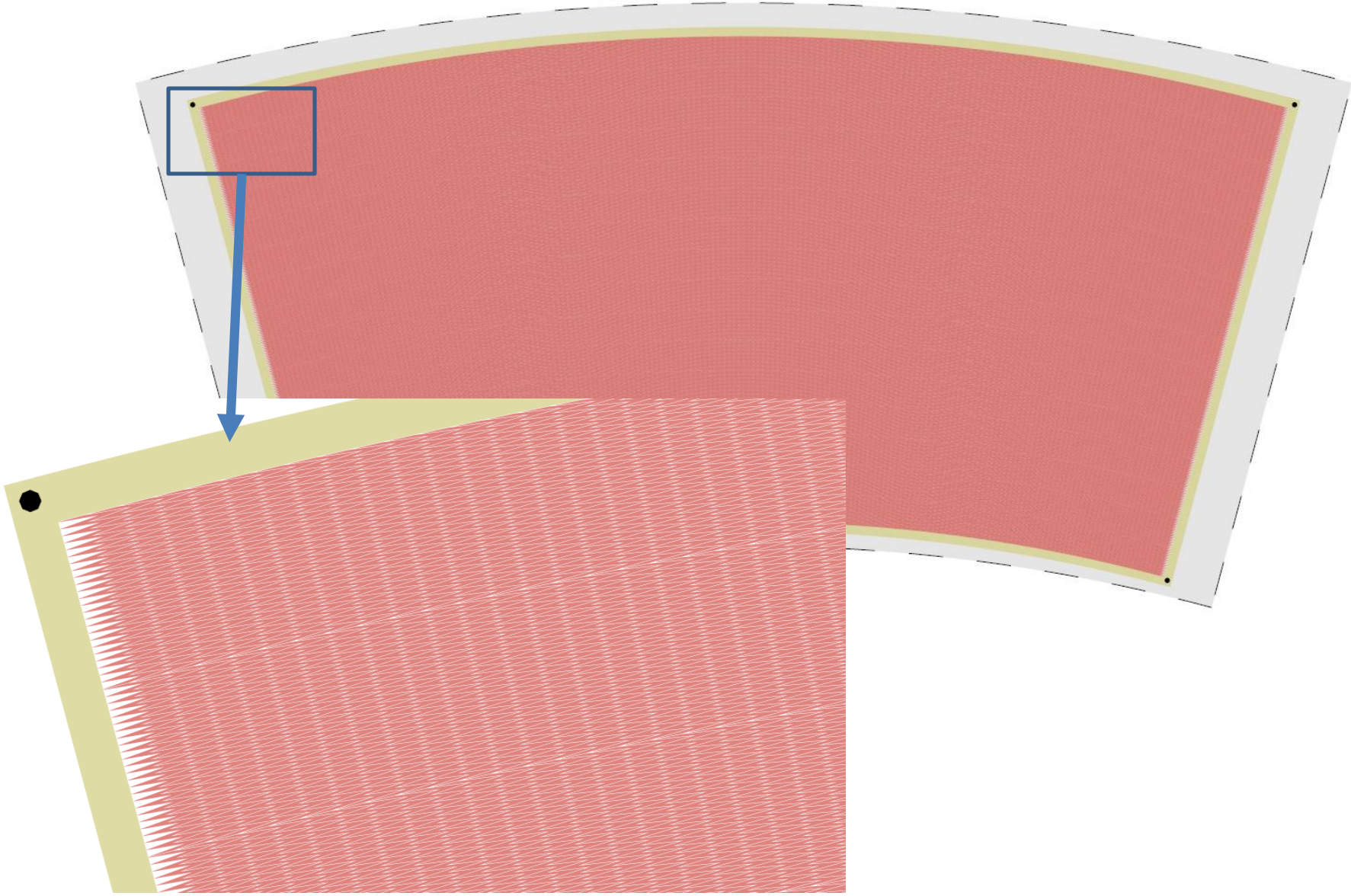


Issues and Concerns or Summary

- Issues and concerns
  - **GEM production exclusively at CERN**
  - **Mitigated by hiring technician exclusively for sPHENIX production**
  - **Big GEM production (ALICE TPC, CMS) completed in 2017/2018**
- Summary
  - **All WBS items in BoE well understood**
    - **Purchases, quotes, contracts, analysis, experience**
  - **All WBS items have contingencies on a very mature level**
  - **Risk items on a very low level**
  - **Tasks are well progressing**
    - **TPC O-FC v1 prototype nearly completed**
    - **TPC Modules v1 well on track**

Back Up

Status and Highlights



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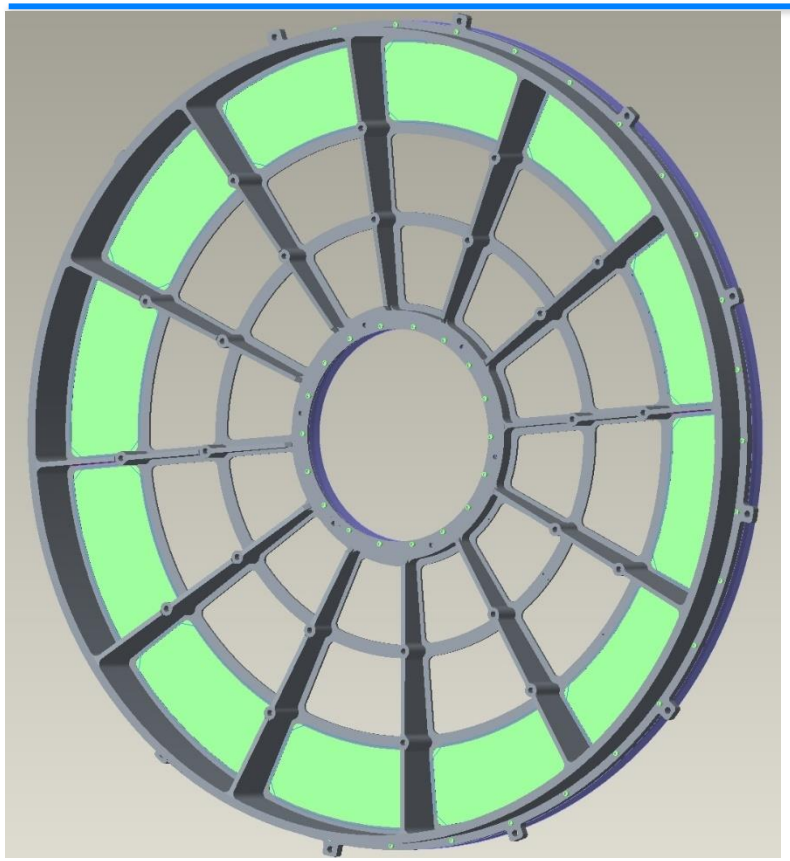

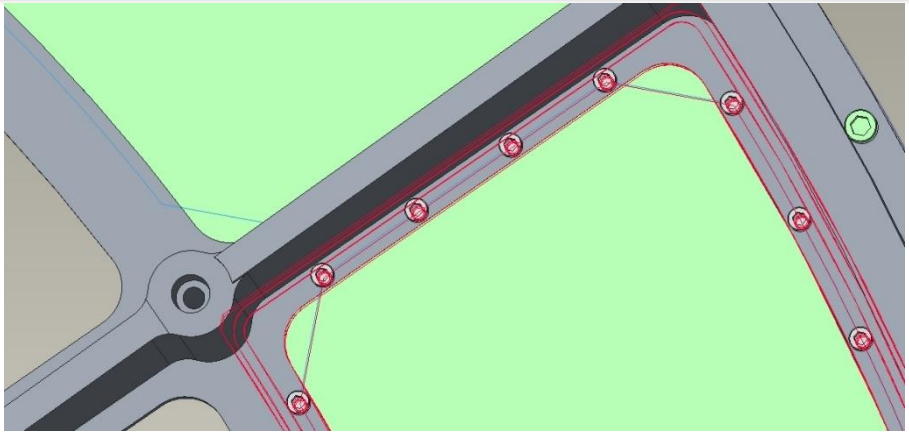

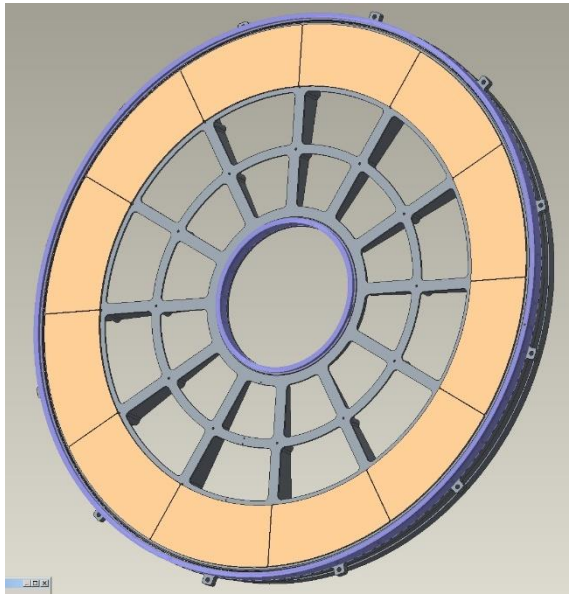

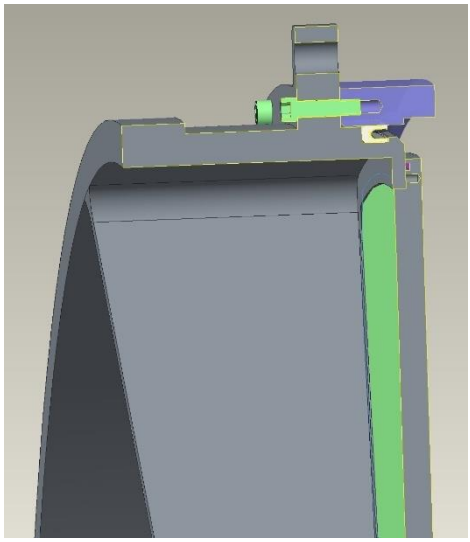

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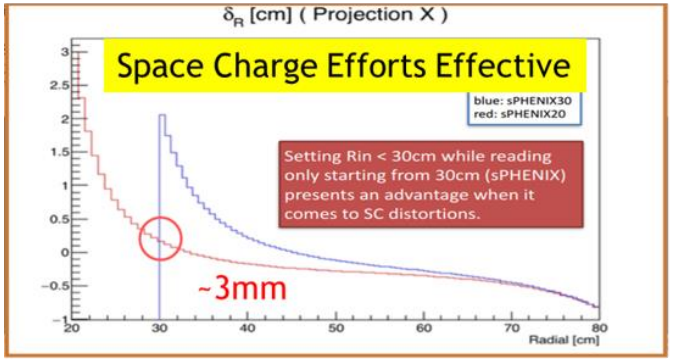
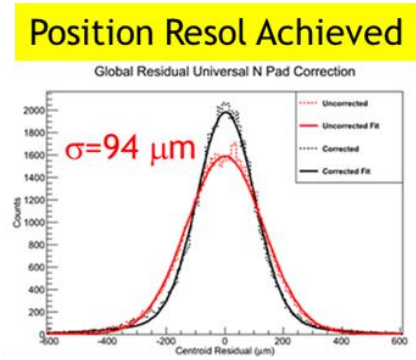
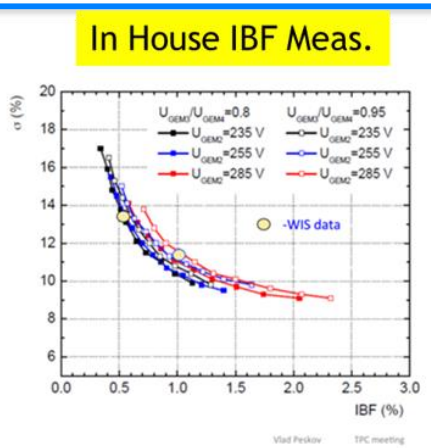
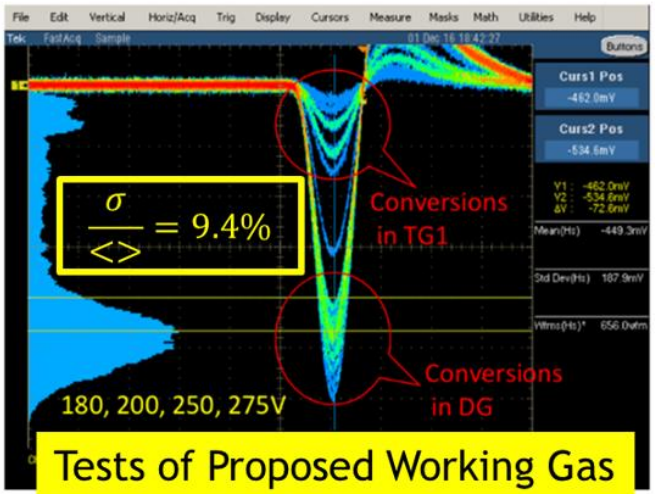
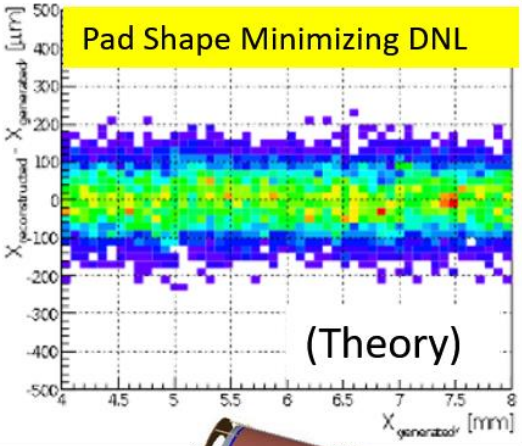
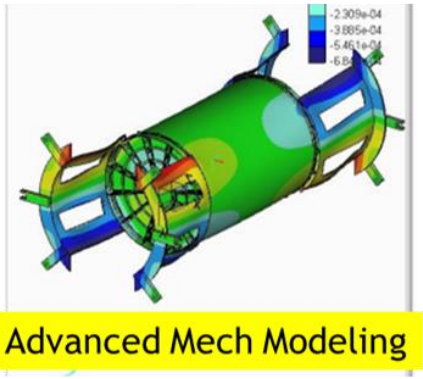


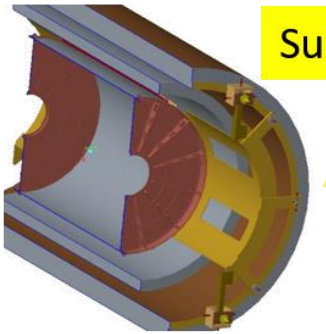


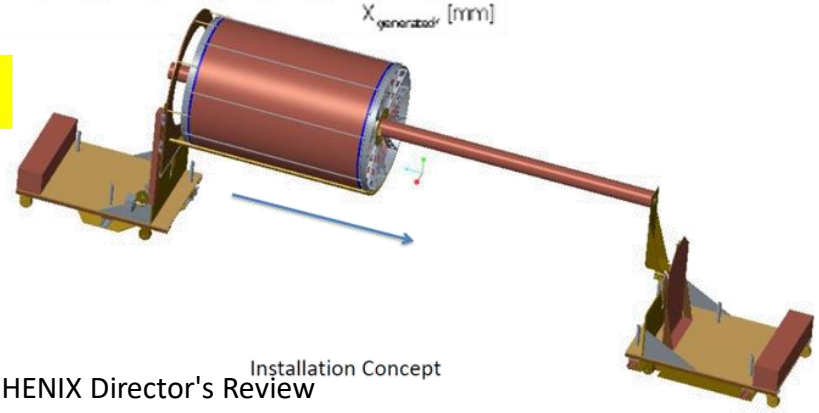






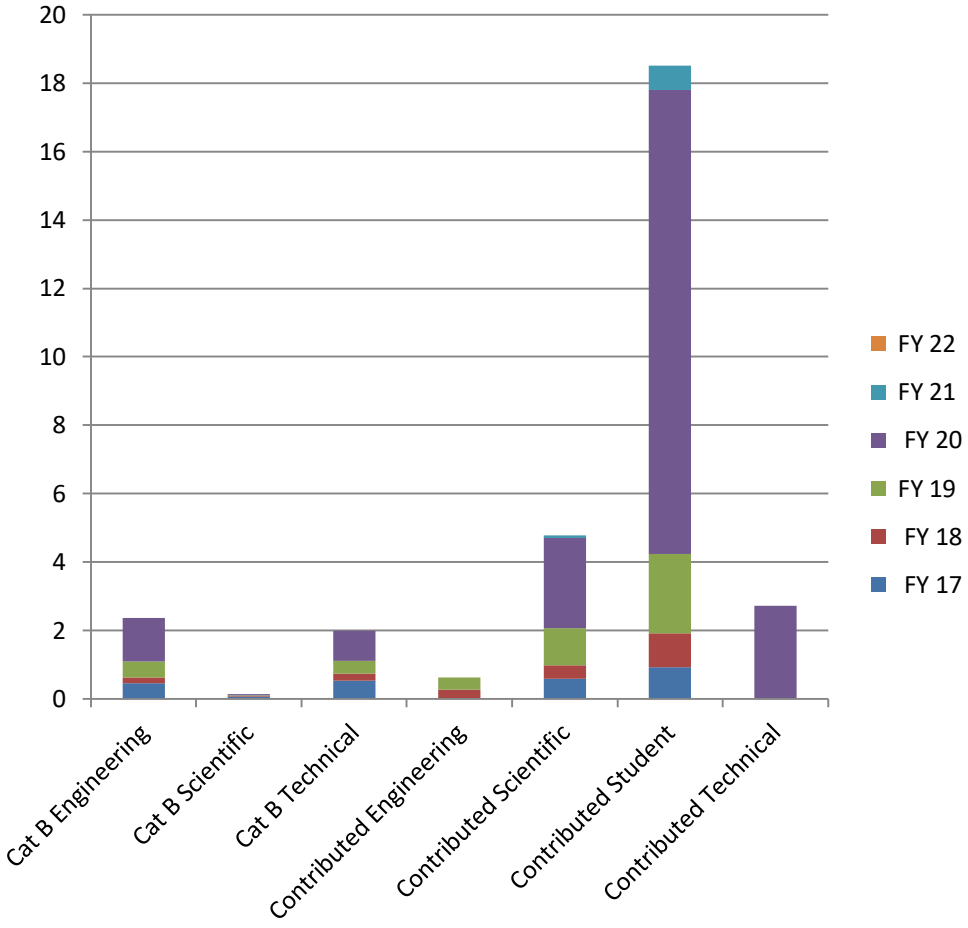






Labor Profile

- 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**

Risk Analysis

Excerpt of risk registry for WBS 1.2

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.