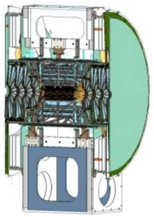
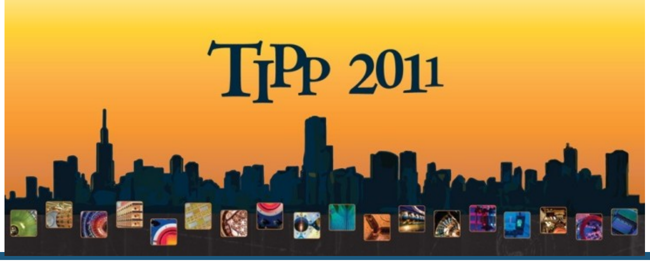
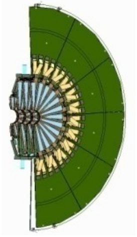






Mechanics and Assembly of the Silicon Vertex Detector for **PHENIX**

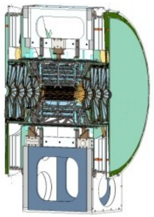
Walter Sondheim - *LANL*

Mechanical Project Engineer; VTX & FVTX Detectors

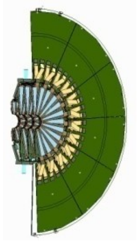
PHENIX

TIPP Conference, June 10, 2011

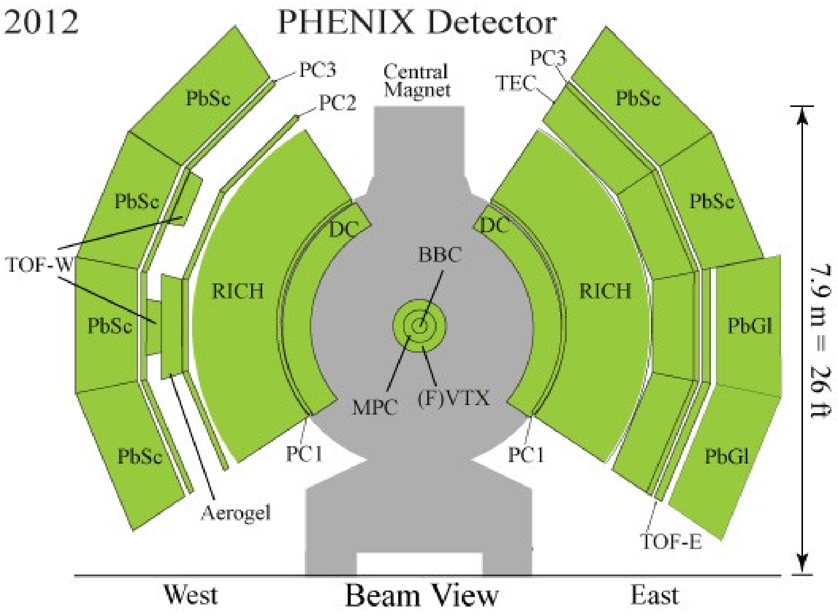
Los Alamos
NATIONAL LABORATORY



PHENIX Experiment at **RHIC:**

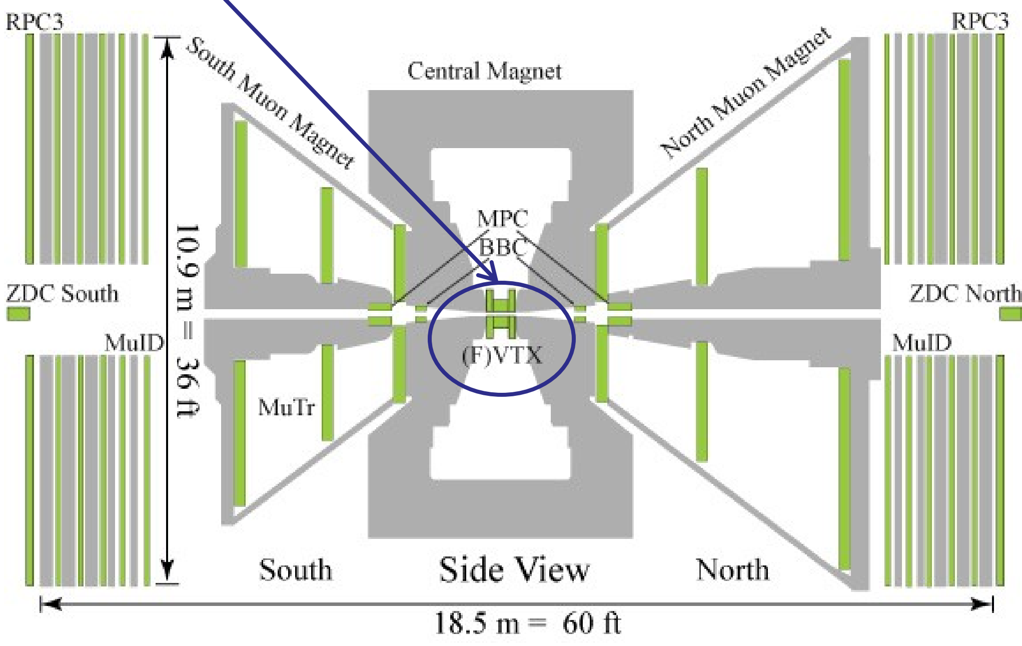


The **PHENIX** experiment at **RHIC** is now in its *11th* year of data taking. Experimental configuration for RUN in 2012:



2 central arms; electrons, photons, hadrons

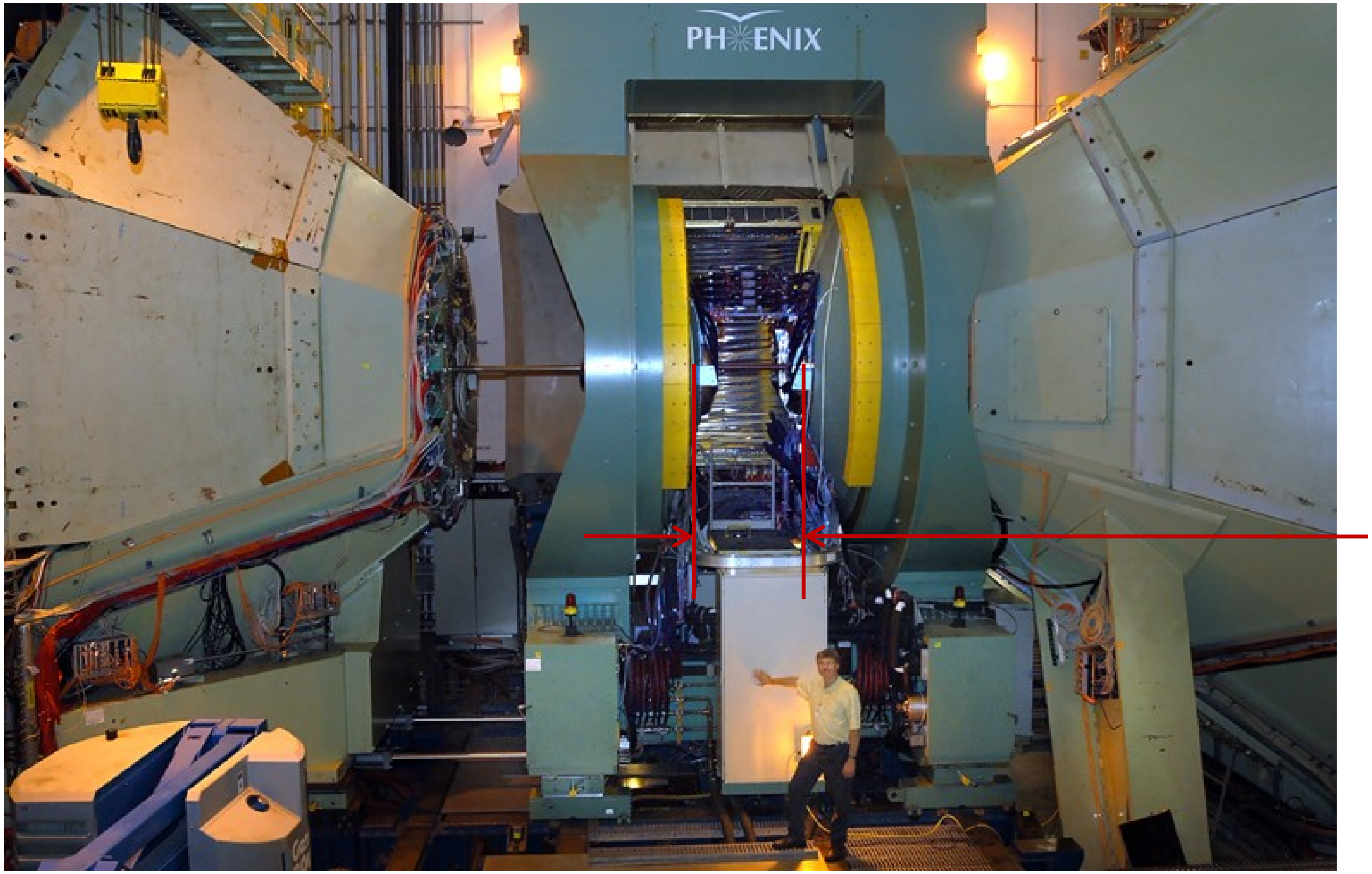
Vertex Region*



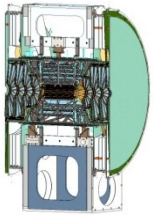
2 muon-spectrometer arms; muons

*VTX installed for current run cycle, FVTX next year's run cycle

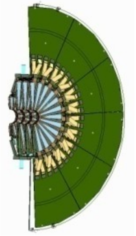
PHENIX Experiment at RHIC:



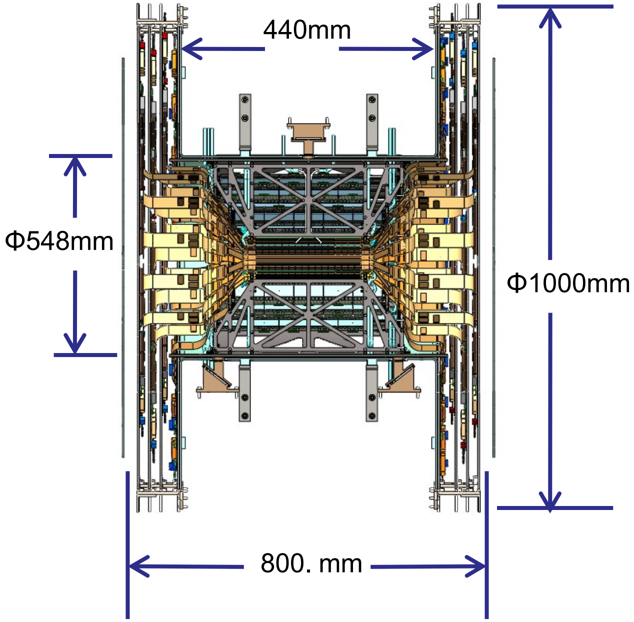
Available space for Vertex Detector 800.0 mm between the Central Magnet pole tips along the beam axis. The original 3.0 inch diameter Beryllium beam pipe was replaced with a 1.575 inch ID x .020 wall NEG coated Beryllium beam pipe, now installed for this run cycle.

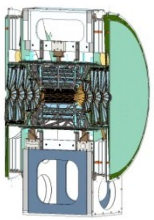


VTX Design Criteria:

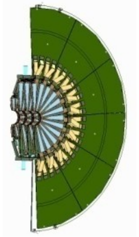


- VTX - Barrel Detector:
  - 2 pixel sensor layers at a radius = 25.0 and 50.0 mm
    - Fine granularity, low occupancy
      - 50μm x 450μm pixel size, ALICE LHCB1 read-out chip
      - AC Coupled read-out, required coolant temp. @ 10°C
        - » To avoid de-lamination
  - 2 stripixel layers at a radius = 100.0 and 140.0 mm
    - Unique sensor design from BNL Instrumentation
      - 80μm x 1000μm pixel pitch, SVX4 read-out chip
      - DC Coupled read-out, required cooling @ 0° C,
        - » Avoid increase leakage current from radiation damage
  - Φ acceptance ~ 2π
  - $|\eta|$ acceptance < 1.2
  - Dimensional structural stability to 25μm

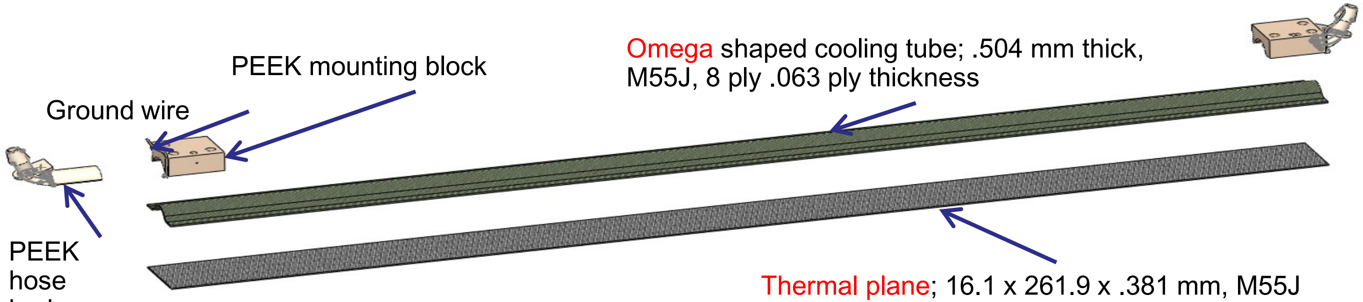




VTX - Pixel layers 1 and 2:



- Closest sensors to beampipe, radiation length should be kept to a minimum
  - Stave design uses Carbon composite technology, Omega shaped bonded to backside of thermal plane to create cooling channel. Bonded assembly must meet mechanical tolerance for flatness of 100. microns prior to bonding of sensor modules
  - Layers 1 & 2; 4 sensor modules per ladder, Layer 1 - 5 ladders layer 2 - 10 ladders per half barrel



PEEK mounting block

Omega shaped cooling tube; .504 mm thick, M55J, 8 ply .063 ply thickness

Ground wire

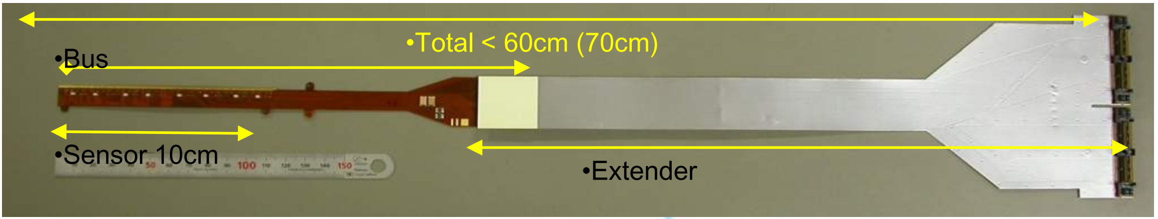
PEEK hose barb

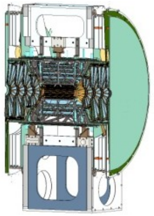
Thermal plane; 16.1 x 261.9 x .381 mm, M55J Graphite Cyanate Ester, 6 ply .063 ply thickness

Bonding agent HYSOL EA9394

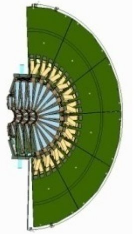
Assembled pixel stave: stave + sensors + readout chips + bus, readout is split in half – left bus and a right bus

Assembled pixel stave with bus extender attached, interface with SPIRO readout card

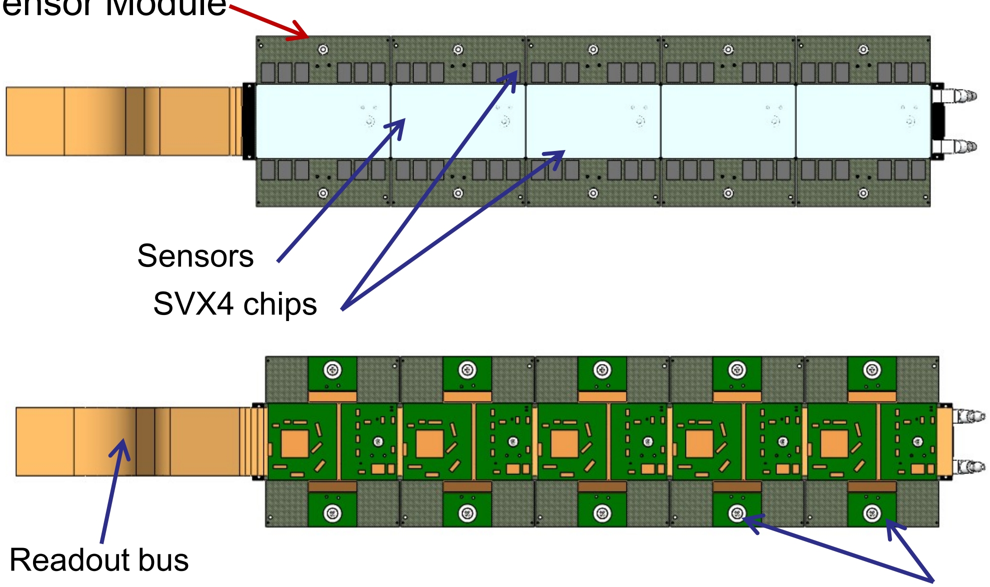




VTX - Stripixel layers 3 and 4:



- Improve track segment construction
  - BNL sensor design provides 2 dimensional, single sided readout
  - Readout uses FNAL’s SVX4 chip; 128 channels per chip, 340K channels for layers 3 & 4
  - Layer 3; 5 sensor modules per ladder, 8 ladder assemblies per half barrel
  - Layer 4; 6 sensor modules per ladder, 12 ladder assemblies per half barrel



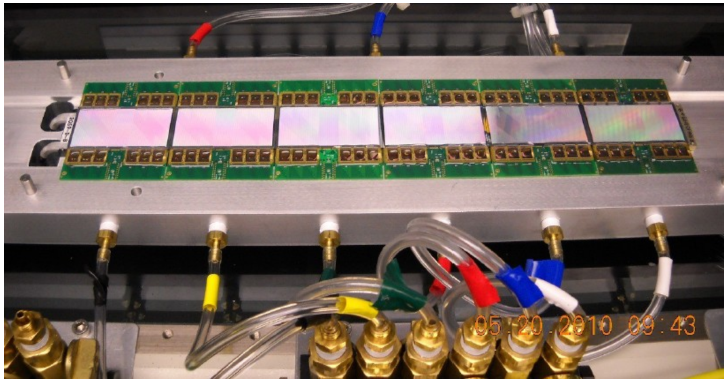
Sensor Module

Sensors

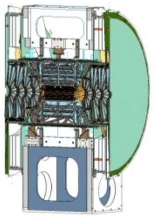
SVX4 chips

Readout bus

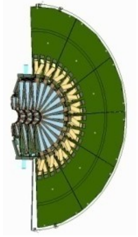
Interconnection between top layer and bus layer using PariPoser material



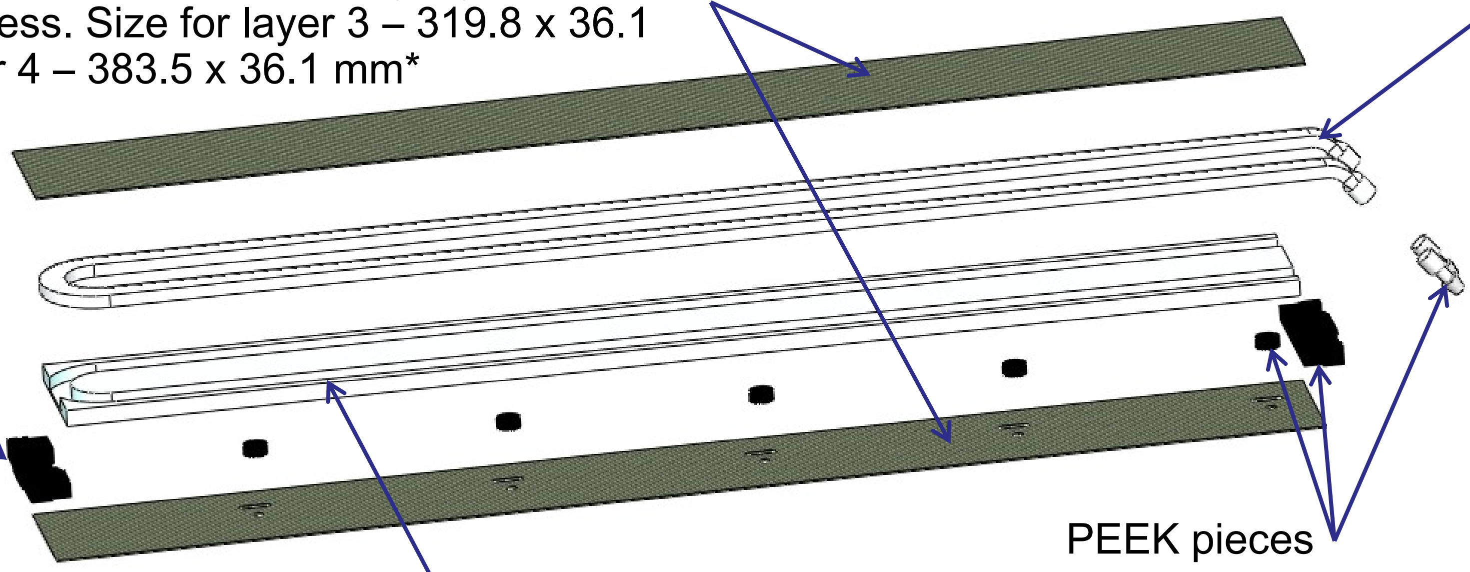
Layer 4 stave with sensor modules being located on stave using vacuum tooling, prior to bonding



Stripixel stave construction:



Layer 3 & 4 stave assembly: designed to allow for individual electronic modules and bus to be mechanically attached to stave backside – not bonded.



Face Sheets; K13D2U with EX1515 Cyanate Ester resin, .408mm thick, 6 ply layup, .063 ply thickness. Size for layer 3 – 319.8 x 36.1 mm, layer 4 – 383.5 x 36.1 mm*

Aluminum rectangular cooling tube; 3.18 x 6.35 x .38 wall (mm)

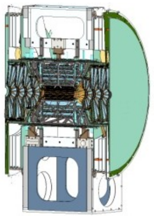
Aluminum end-block, grounds cooling tube

PEEK pieces

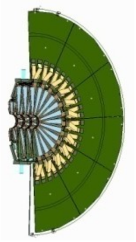
Carbon Foam Core; Allcomp K3, 4.2mm thick

Bonding agent HYSOL EA9396

*Layer 3 stave shown in exploded view, assembly flatness tolerance 100. microns



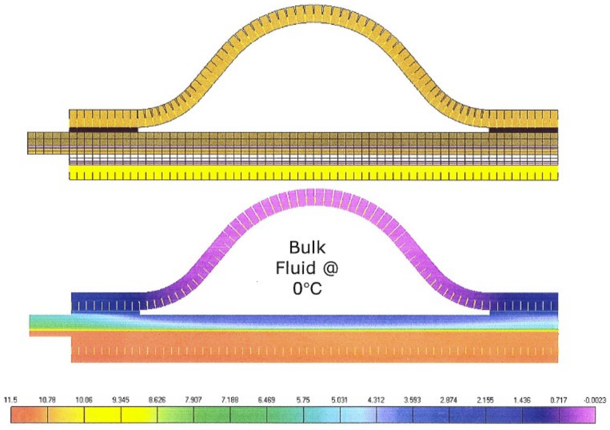
Thermal/Mechanical analysis:



•Pixel stave analysis

- Thermal load for pixel stave is 19.50 watts
- Each ladder's mass summary:
  - Structure/Si-detector/Readout chips 16.4 grams
  - Coolant: 6.5 grams (3M-NOVEC 7200)
  - Total:23.0 grams
  - ΔT:11.5°C*
    - ΔT:23.°C with added metallic tube
  - Gravity sag < 2. microns
  - Pressure tested

*Calculations using Nastran- Mat9 software

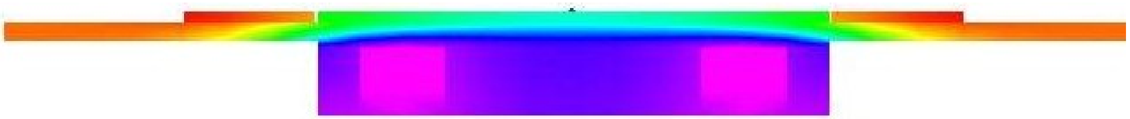


Mid-Span Section View

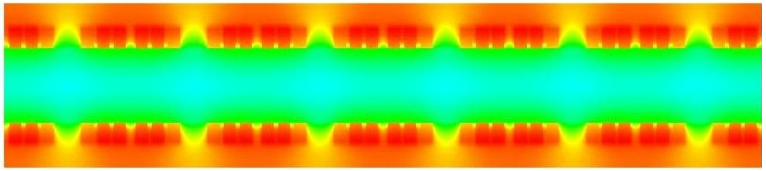
•Stripixel stave analysis

•Design goal to keep DC coupled sensors at 0°C:

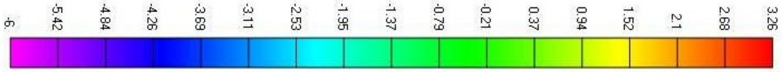
- •Coolant wall temperature at -6°C
- •Peak temperature 3.2°C
- •Temperature rise between coolant and sensor 5.55°C

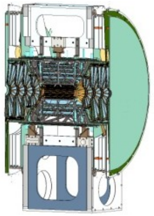


Cross section Temperature profile, layer 4 ladder

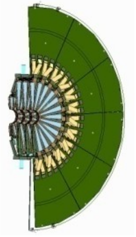


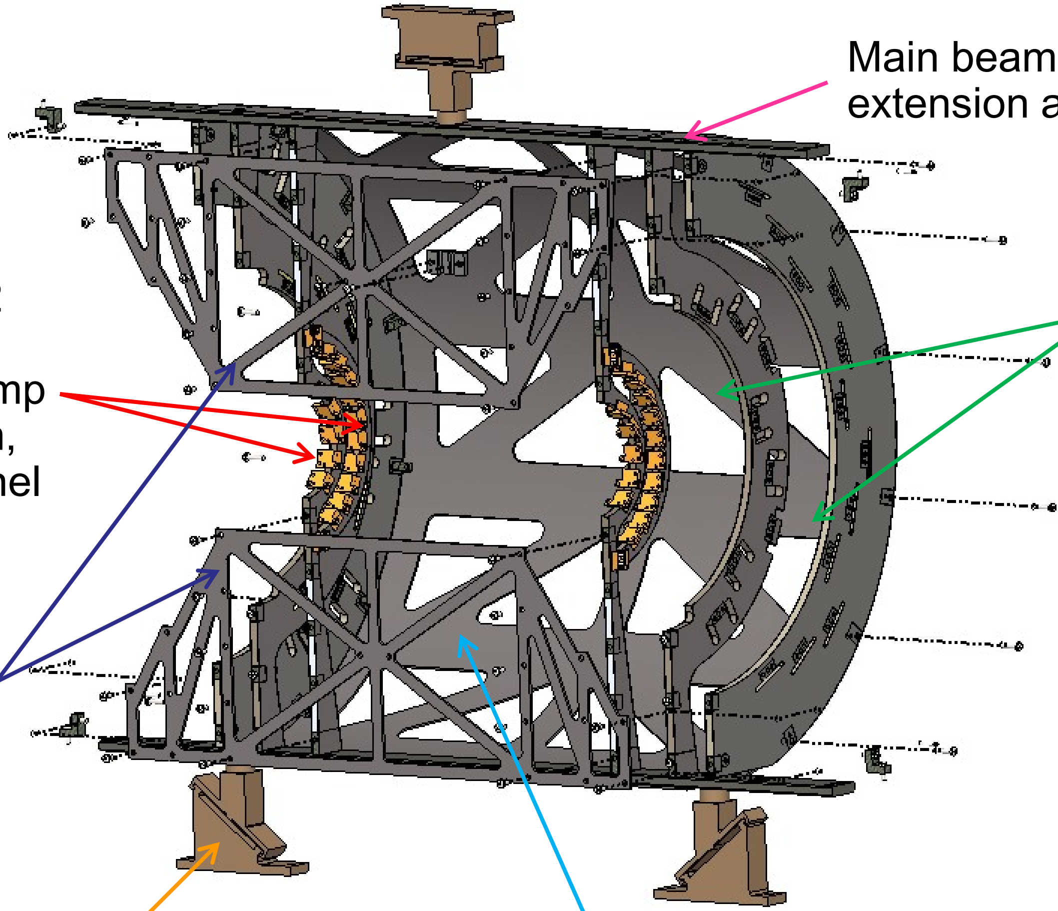
Surface temperature, layer 4 ladder





Space-frame and Barrel Mounts, exploded view:





Main beam (2), POCO Graphite, extension attaches FVTX detector

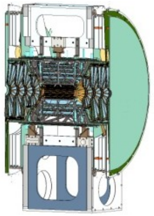
Stripixel layer 3 & 4 barrel mounts, M55J and Allcomp K3 Carbon foam, 6.3mm thick panel assembly

Pixel layer 1 & 2 barrel mounts, M55J and Allcomp K3 Carbon foam, 3.6mm thick panel assembly

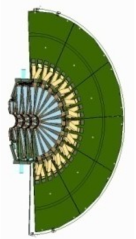
Center gussets CN60 cloth, 2.mm thick

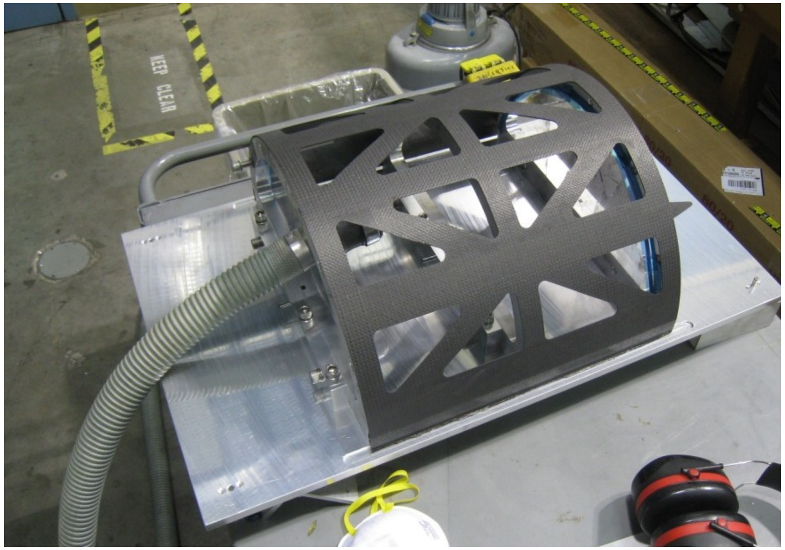
Space-frame flexure, 1 of 3 on each half

Space frame shell, CN60 cloth with EX1515 resin, 1.5mm thick

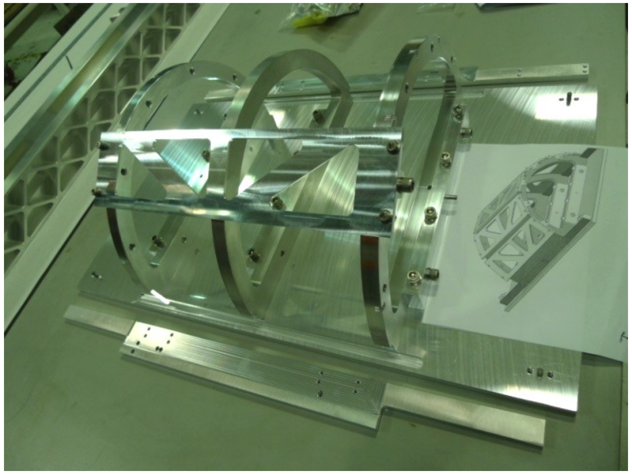


Space-frame component fabrication and assembly:

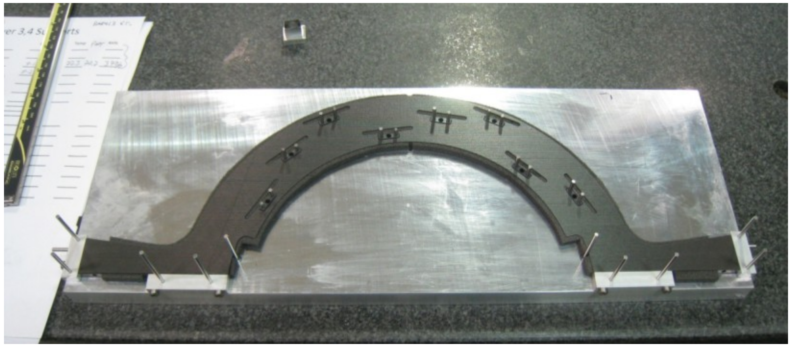




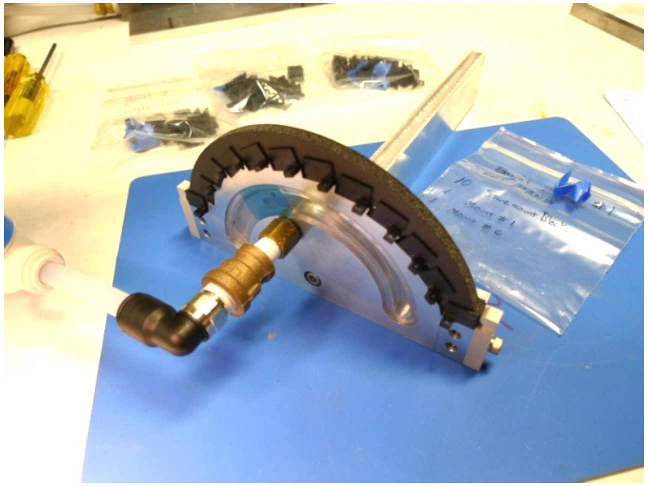
Space-frame shell: Vacuum jig machining cut-outs



Space-frame shell tooling

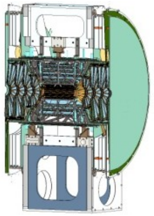


Layer 4 barrel mount on assembly jig

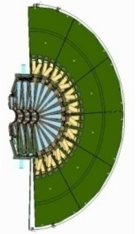


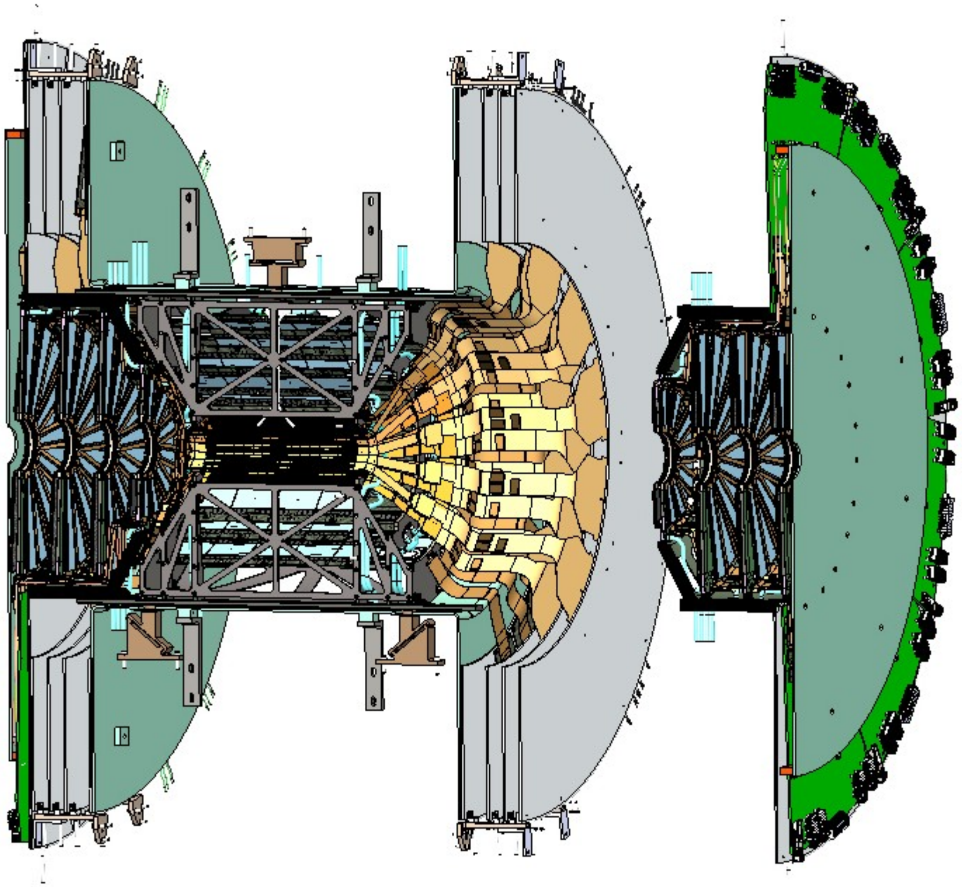
Layer 2 barrel mount on assembly jig

All work at LBNL Composite Shop



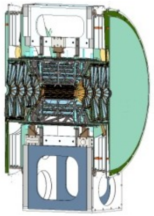
FVTX detector:



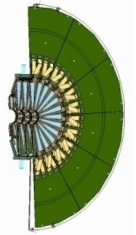


FVTX detector exploded view from VTX assembly

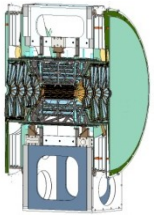
- Silicon tracking in the forward regions of PHENIX;
  - $1.2 < |\eta| < 2.4$
  - Φ acceptance = 2π
- Each FVTX assembly;
  - 4 tracking stations (Disks)
    - Silicon mini-strips, 2.8 – 11.2mm
    - 75. micron pitch (radial direction)
    - FPHX readout chip (FNAL design)
    - ~1.1M channels of readout



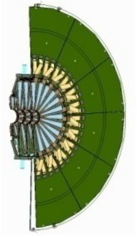
FVTX Station Disks:

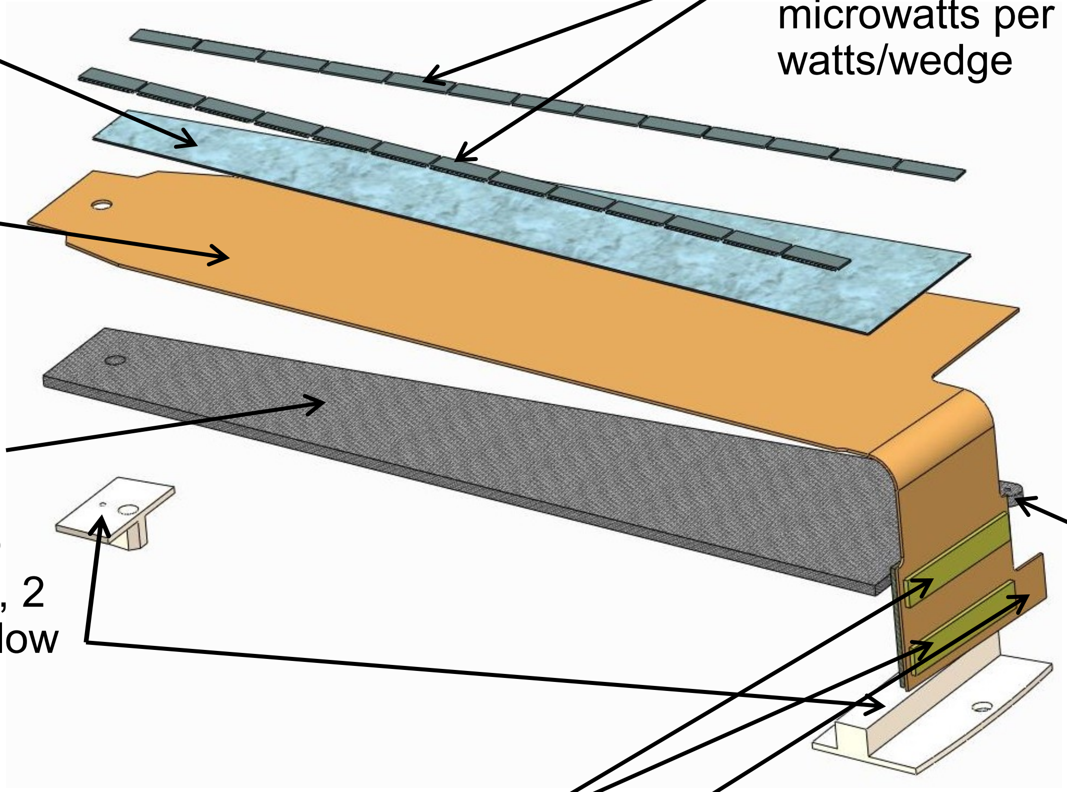


- View of a Station Disk assembly with large Wedges attached to both sides
- Each Wedge covers 15 degrees, each sensor covers 7.5 degrees, Wedges on both sides of Disk staggered by 7.5 degrees front to back – hermetic coverage in phi
- Each disk assembly is pressure tested to 30. psi, cycled 5 times
- The disk assembly bonding agent was Hysol EA9396



Large Wedge construction:





FPHX read-out-chips, 13 on each side of sensor, 128 channels each, 410. microwatts per channel, 1.36 watts/wedge

Silicon sensor, 320. microns

HDI, 334. microns

Carbon back-plane, 1.56 mm, K13D2U with EX1515 resin

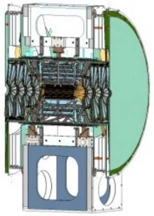
Spacers – POCO graphite, AXM5Q, 2 versions of each low and high profile

Each wedge assembly is mounted to a station disk by 2 #2 screws and 2 locating pins

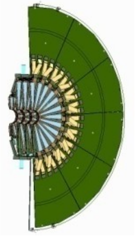
Separate ground connection point for Carbon

Hirose DF18 series connector, 100 pin for large and 60 pin for small

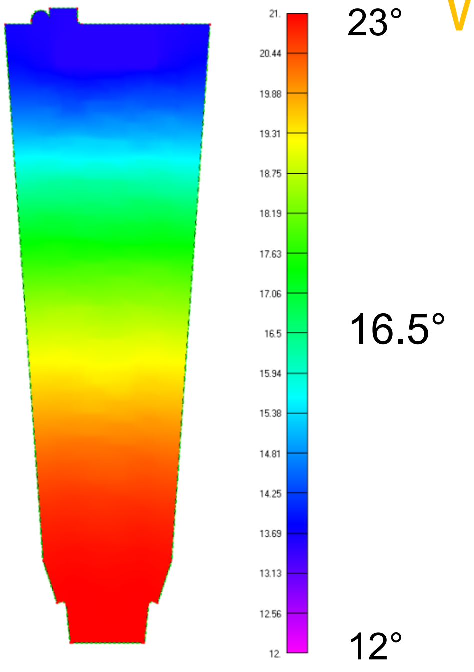
Hirose H.FL series mini-coax for bias



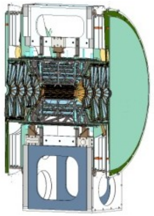
Large Wedge analysis:



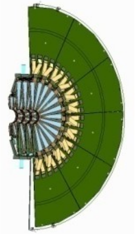
- Thermal path for heat generated on large Wedge
  - Delta T on large Wedge is ~7.47 degrees C
  - Heat from FPHX chips passes through HDI into Carbon backplane – through POCO graphite thermal block to Station Disk where coolant flows around perimeter – NOVEC 7200 coolant
  - Delta T from Disk to Wedge ~ 8. degrees C
  - In analysis a temp constraint was set to keep peak FPHX chip temp at 21 degrees C
  - Bonding of all elements of Wedge assembly, made using Arclad 7876 transfer adhesive, 50. micron thick

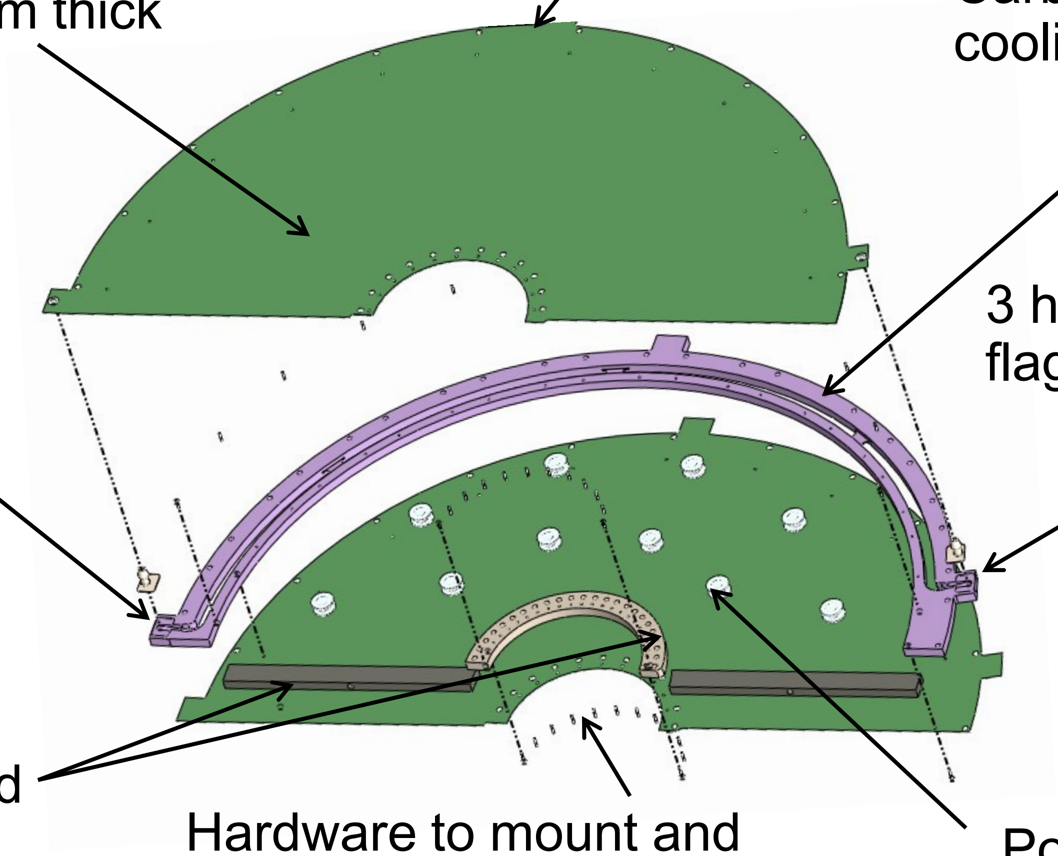


410 μW/Channel
Base Temperature 13.53° C



Station Disk construction, Stations 2, 3 & 4 Large Disk:





R=182.0mm

K13C2U uni-fiber face sheets, .40mm thick

Carbon loaded PEEK cooling channel

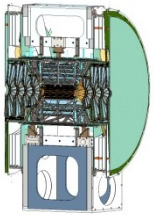
3 holes for alignment flags around perimeter

Mounting tab to Cage, one of three

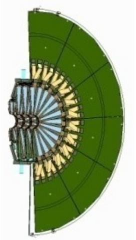
Carbon loaded PEEK pieces

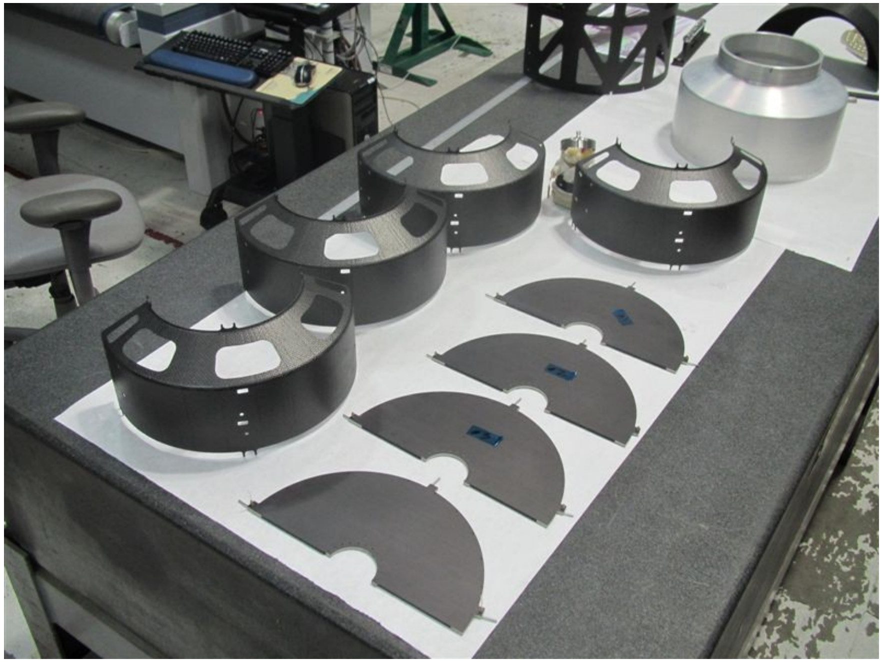
Hardware to mount and align Wedges to Disk

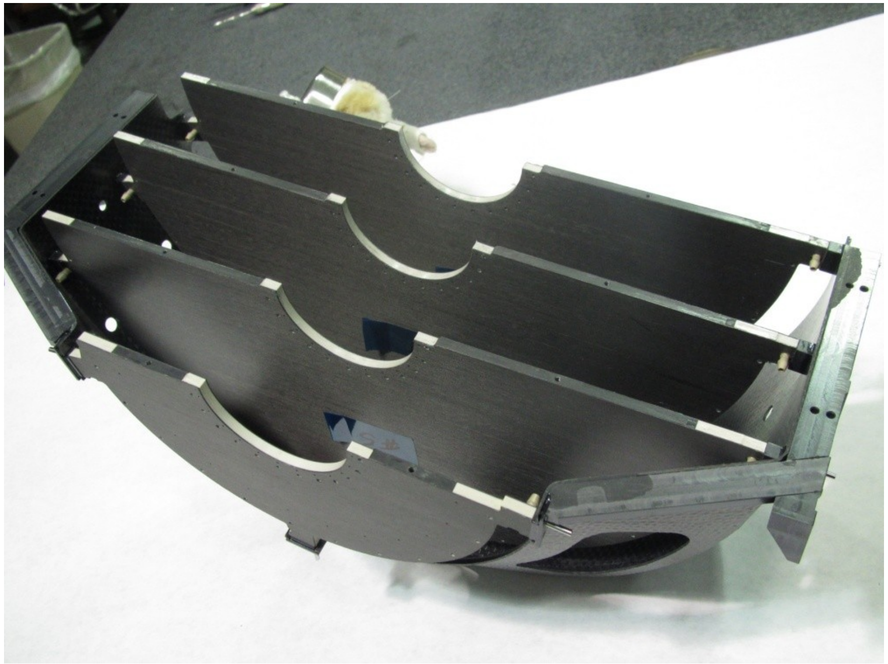
Polyimide “bobbins”



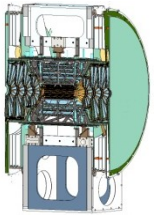
FVTX construction:



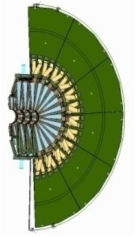


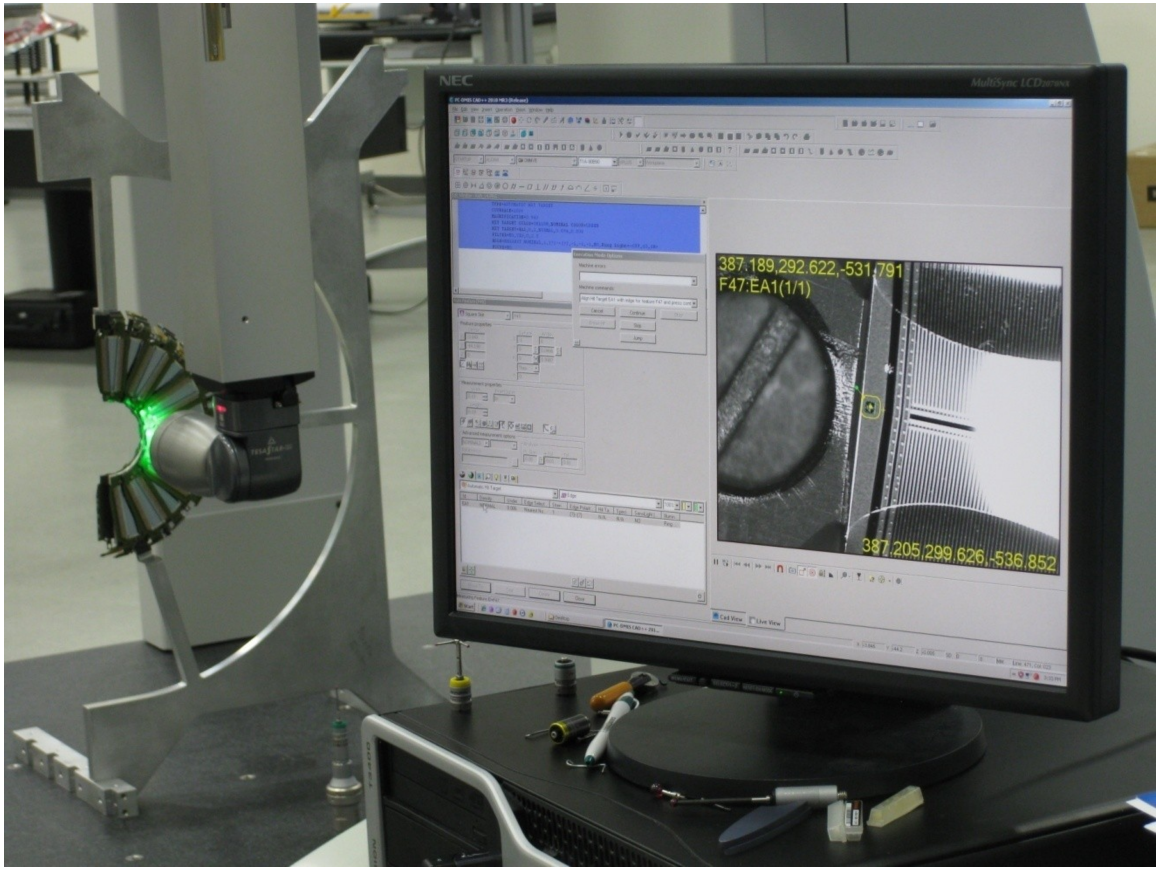


- FVTX cages and station disks being fabricated, tested and assembled at the LBNL composite shop.

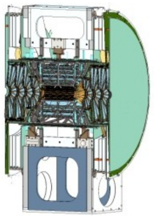


Metrology, FVTX wedge disk:

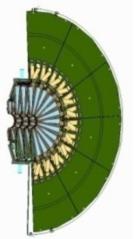


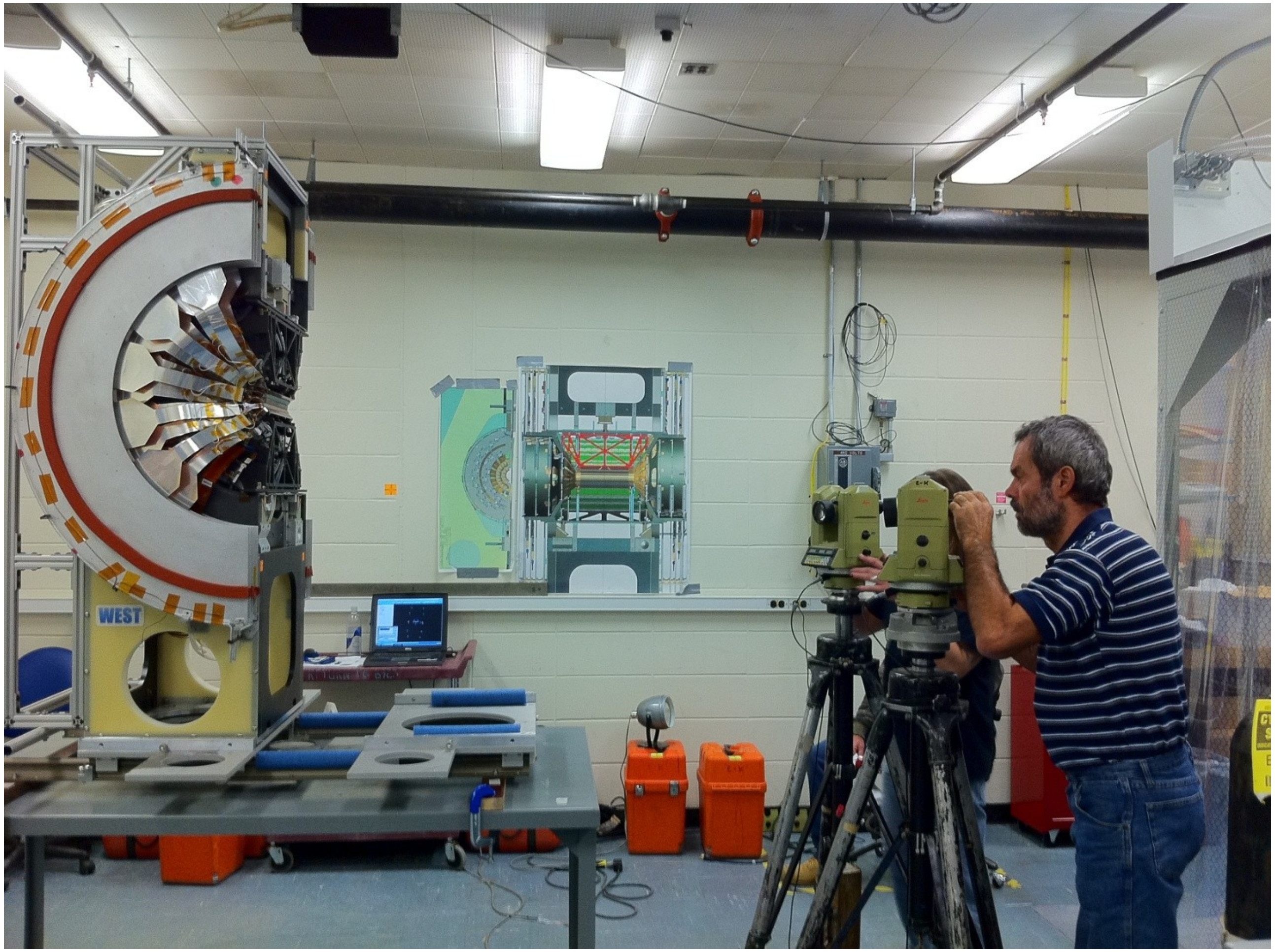


One of 6 -100. micron cross-hair targets on Silicon wedge sensor used to verify relationship of sensors on a disk to 5.08 microns in X-Y and 12.27 microns in Z

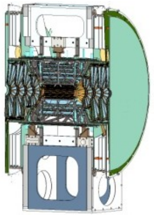


Metrology, Half VTX assembly:

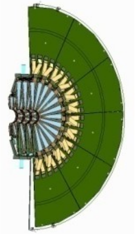


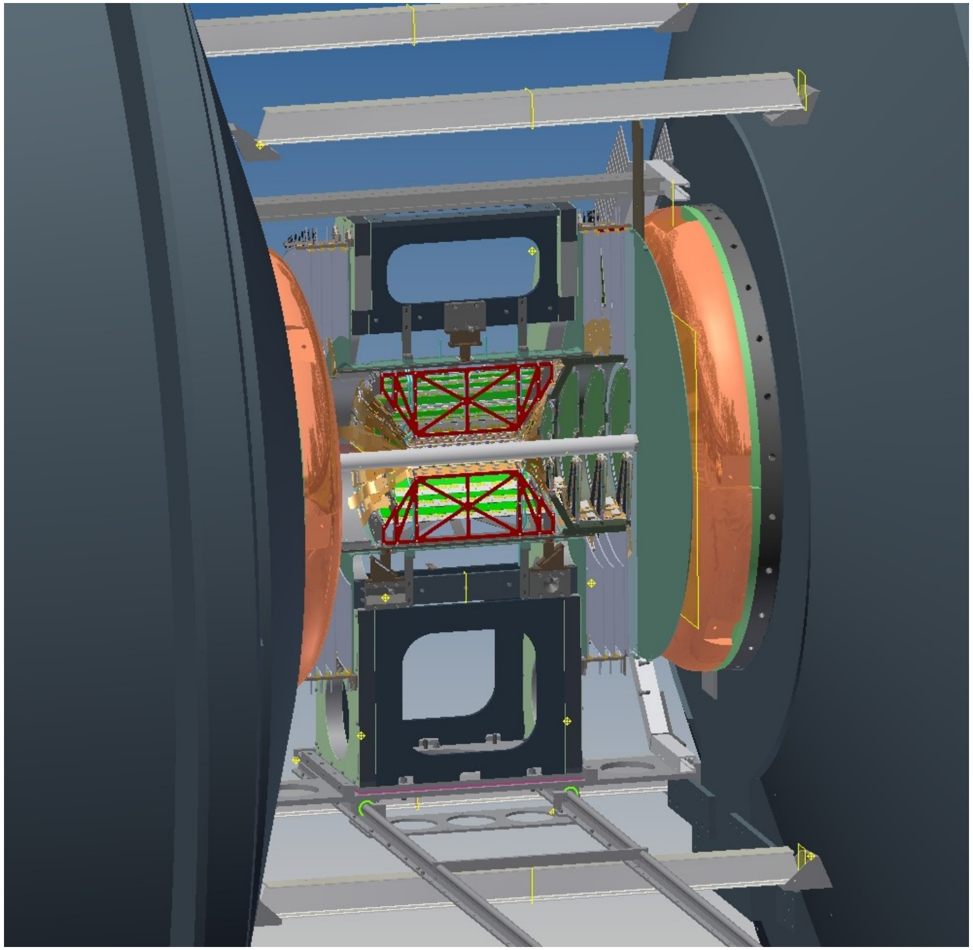


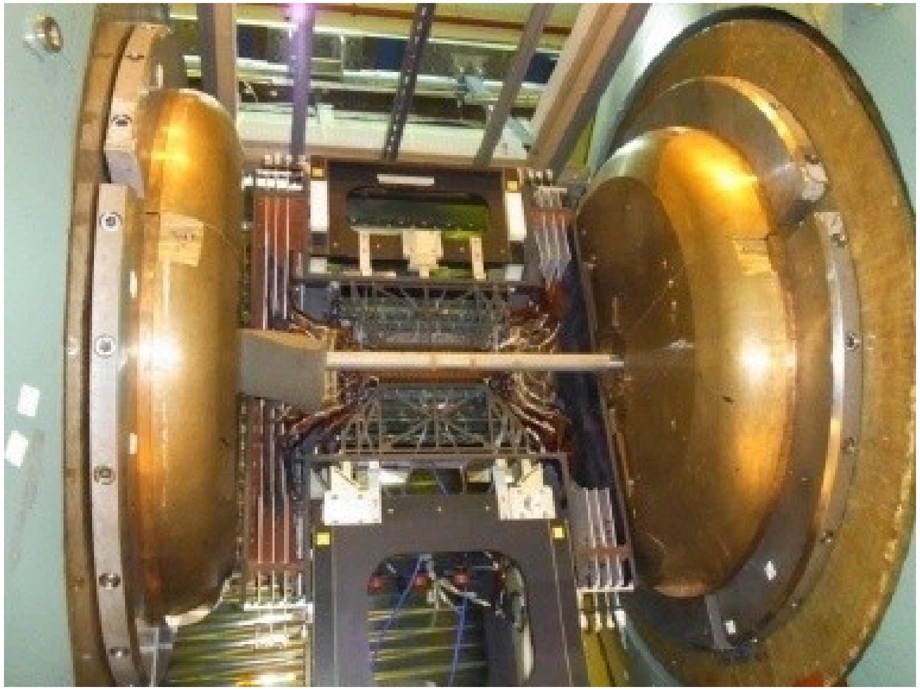
Half VTX assembly being optically surveyed: all ladders to global monuments in assembly. These will again be surveyed in relationship to monuments in the PHENIX hall. Expected detector positioning will be known to ~50. microns in the hall.



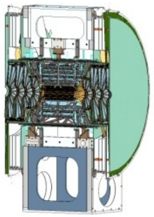
CAD vs. As-Built:



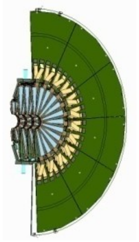




Demonstration of importance of constructing an accurate CAD model of experimental assemblies, installation of VTX proceeded just as modeled without any conflicts.



VTX & FVTX collaboration institutions:



- Brookhaven National Laboratory
- Columbia University
- Ecole-Polytechnique
- Iowa State University
- Kyoto University
- Los Alamos National Laboratory
- New Mexico State University
- Oak Ridge National Laboratory
- RIKEN
- Riken-Brookhaven Research Center
- Stony Brook University
- University of New Mexico