Mechanics and Assembly of the Silicon Vertex Detector for PHENIX

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

Vertex Region*

2 central arms; electrons, photons, hadrons
2 muon-spectrometer arms; muons

*VTX installed for current run cycle, FVTX next year’s run cycle
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
  - |η| 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

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
Improving 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*

Carbon Foam Core; Allcomp K3, 4.2mm thick

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

PEEK pieces

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
    - $\Delta T: 11.5^\circ C$*
      - $\Delta T: 23.0^\circ C$ with added metallic tube
    - Gravity sag < 2. microns
    - Pressure tested
    *Calculations using Nastran- Mat9 software

• **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

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TIPP Conference, June 10, 2011
**Space-frame and Barrel Mounts, exploded view:**

- **Pixel layer 1 & 2 barrel mounts**, M55J and Allcomp K3 Carbon foam, 3.6mm thick panel assembly
- **Center gussets**, CN60 cloth, 2.0mm thick
- **Stripixel layer 3 & 4 barrel mounts**, M55J and Allcomp K3 Carbon foam, 6.3mm thick panel assembly
- **Main beam (2)**, POCO Graphite, extension attaches FVTX detector
- **Space-frame flexure**, 1 of 3 on each half
- **Space frame shell**, CN60 cloth with EX1515 resin, 1.5mm thick

PHOENIX

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Space-frame component fabrication and assembly:

Space-frame shell: Vacuum jig machining cut-outs

Layer 2 barrel mount on assembly jig

Layer 4 barrel mount on assembly jig

All work at LBNL Composite Shop
FVTX detector:

- Silicon tracking in the forward regions of PHENIX;
  - $1.2 < |\eta| < 2.4$
  - $\Phi$ acceptance $= 2\pi$

- 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:

- **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
- **Hirose DF18 series connector**, 100 pin for large and 60 pin for small
- **Hirose H.FL series mini-coax** for bias
- **FPHX read-out-chips**, 13 on each side of sensor, 128 channels each, 410. microwatts per channel, 1.36 watts/wedge

Each wedge assembly is mounted to a station disk by 2 #2 screws and 2 locating pins. Separate ground connection point for Carbon.
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
Station Disk construction, Stations 2, 3 & 4 Large Disk:

- K13C2U uni-fiber face sheets, .40mm thick
- R=182.0mm
- 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
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.
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