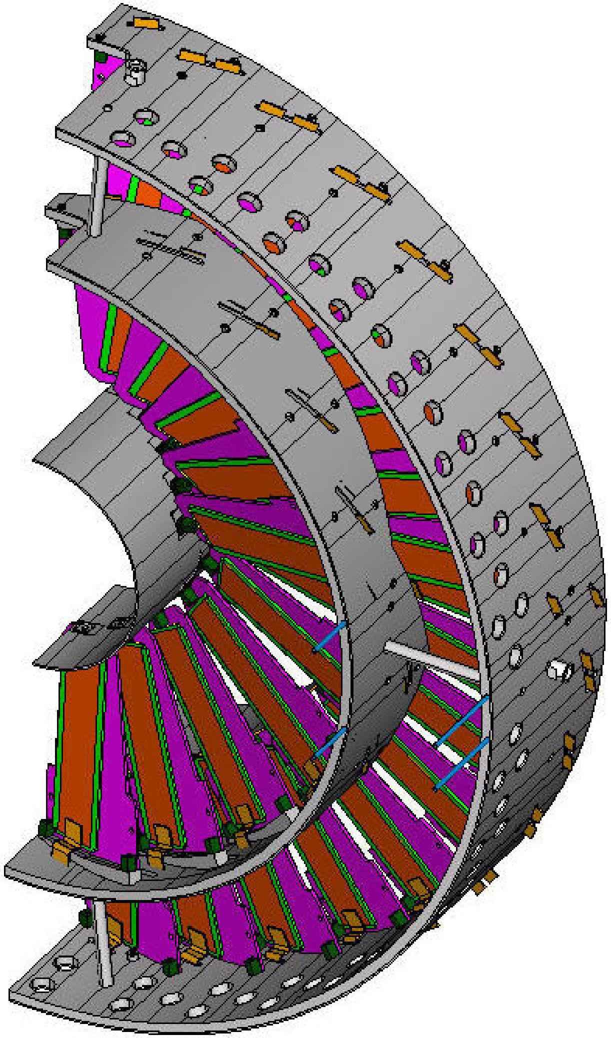
FPIX pixel module assembly

Kirk Arndt
on behalf of
US CMS Pixel Mechanics R&D at Purdue and Fermilab

Overview

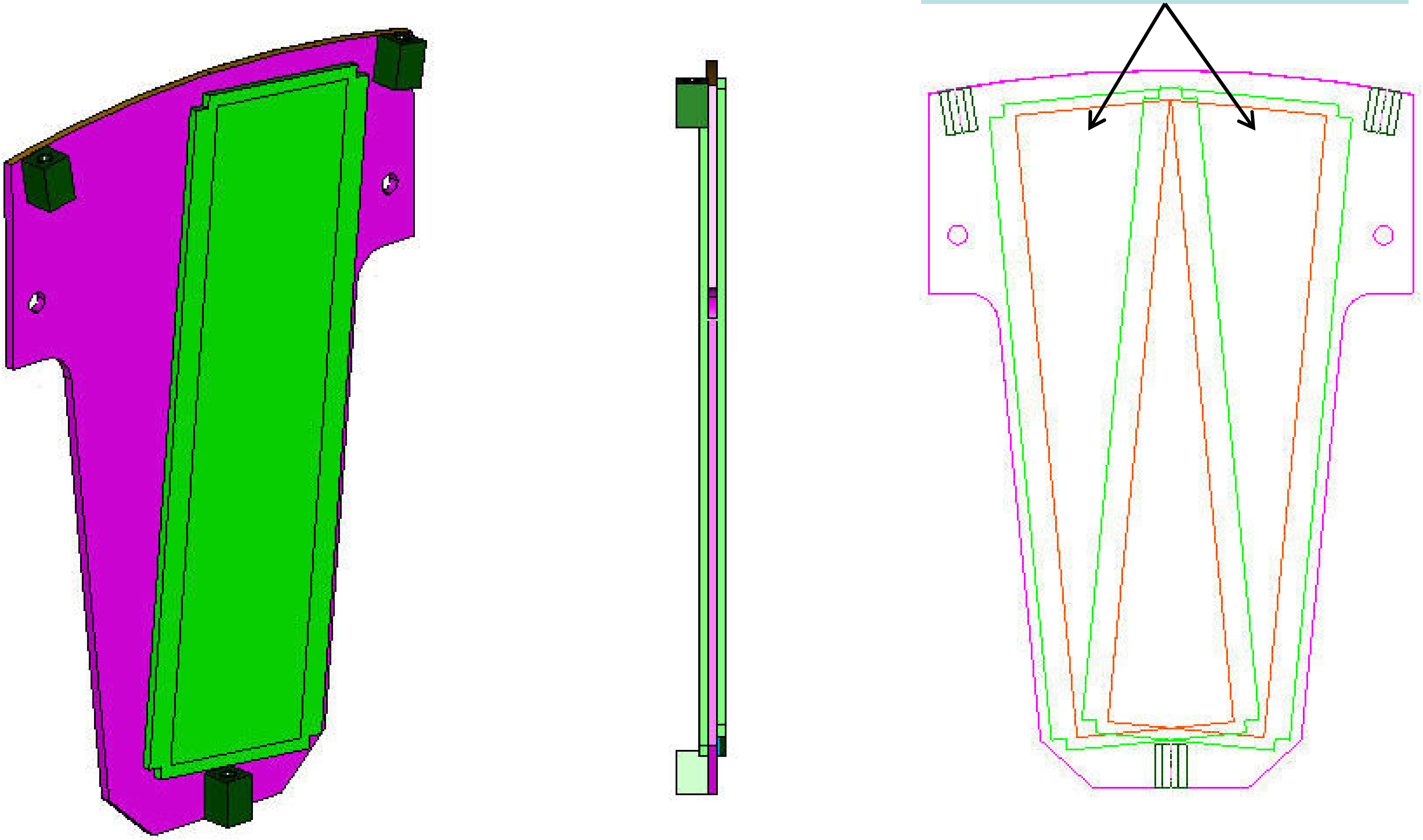
- Half-disk and blade conceptual design
- 2x8 module concept
- Automated module assembly status
- Adhesive study

Half Disk = 11 inner + 17 outer blades ➡ 56 2x8 modules (672 for 6 full disks)



Identical blade used for both outer and inner half disk assemblies

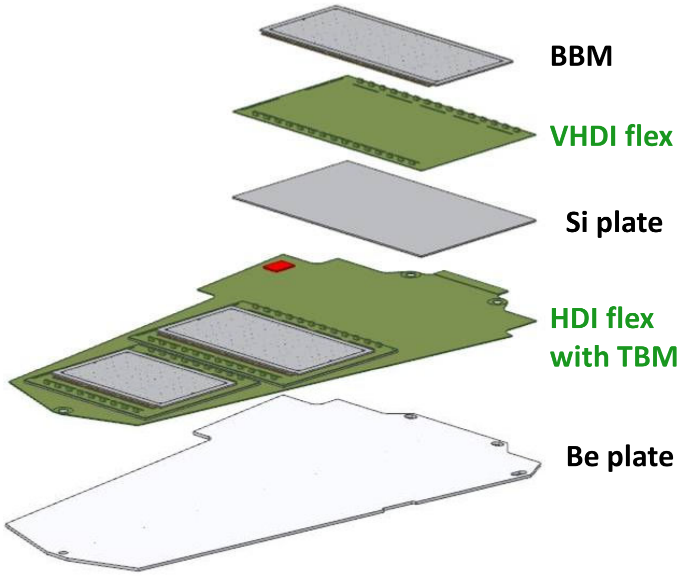
One 2x8 module on each side of blade substrate



Upgrade Pixel Module

current FPix

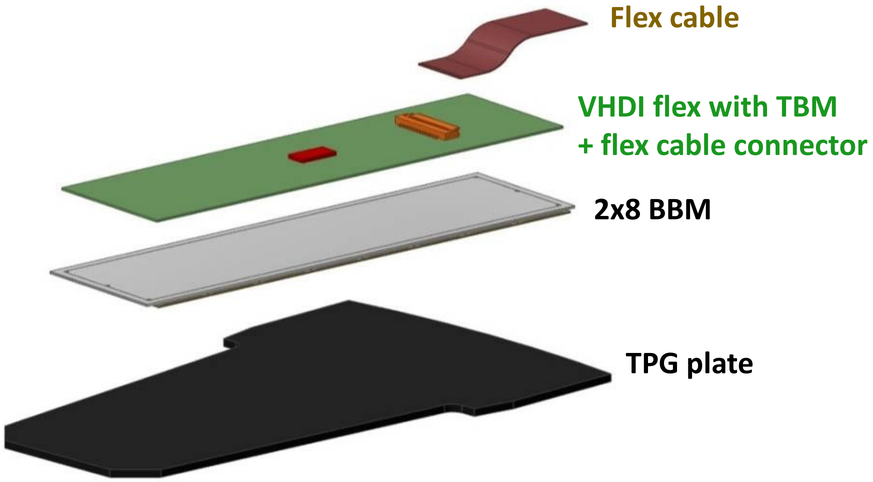
VHDI+Si plate+HDI+Be plate
+4 adhesive layers under BBM



- + allows scanning sensor with light for dead channel/bump connection tests
- + allows for removal of BBM (Bump-Bond Module) for ROC rework
- - VHDI and HDI (multilayer interconnect) layers between modules and cooling

Phase 1 FPix

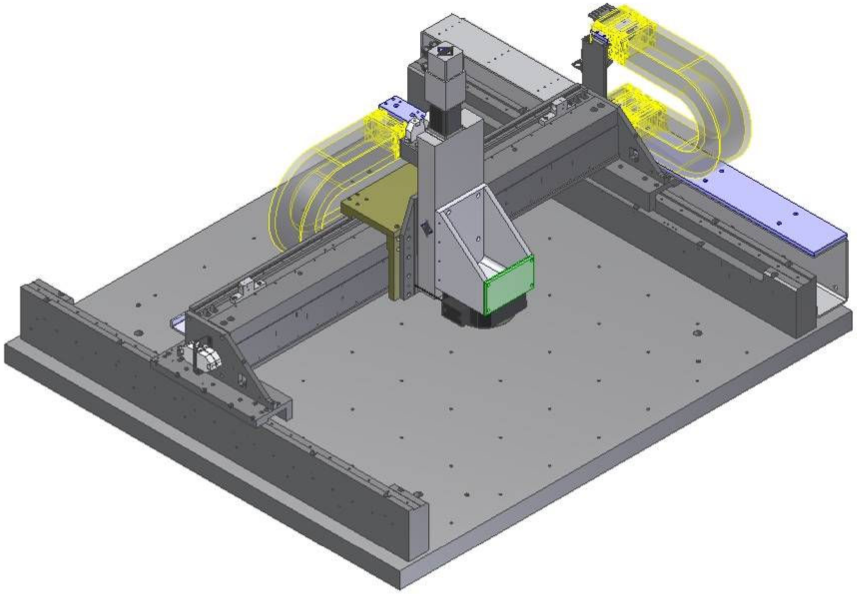
VHDI flex on top of module

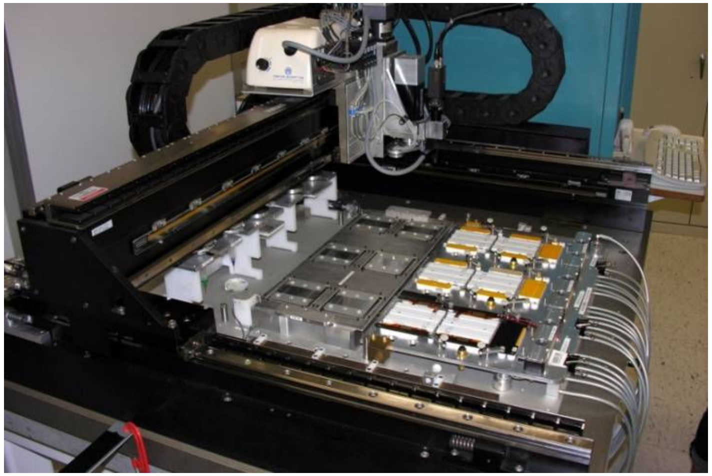


- + easier to assemble and test
- + BBM mounted directly on high heat transfer substrate for cooling
- + no Si plate + only one VHDI flex circuit = material reduction
- - VHDI inhibits scanning with light (use gamma rays instead) for bump connectivity tests

Automated module assembly and prototypes

- Will use robotic 'pick-and-place' machine with optics and glue dispensing for upgrade module assembly
- Could also be used for module placement on upgrade panels
- We're assisted by Dean White at UCSB to ensure compatibility of the tool holder with the gantries at UCSB (shown below), FNAL, CERN, etc.

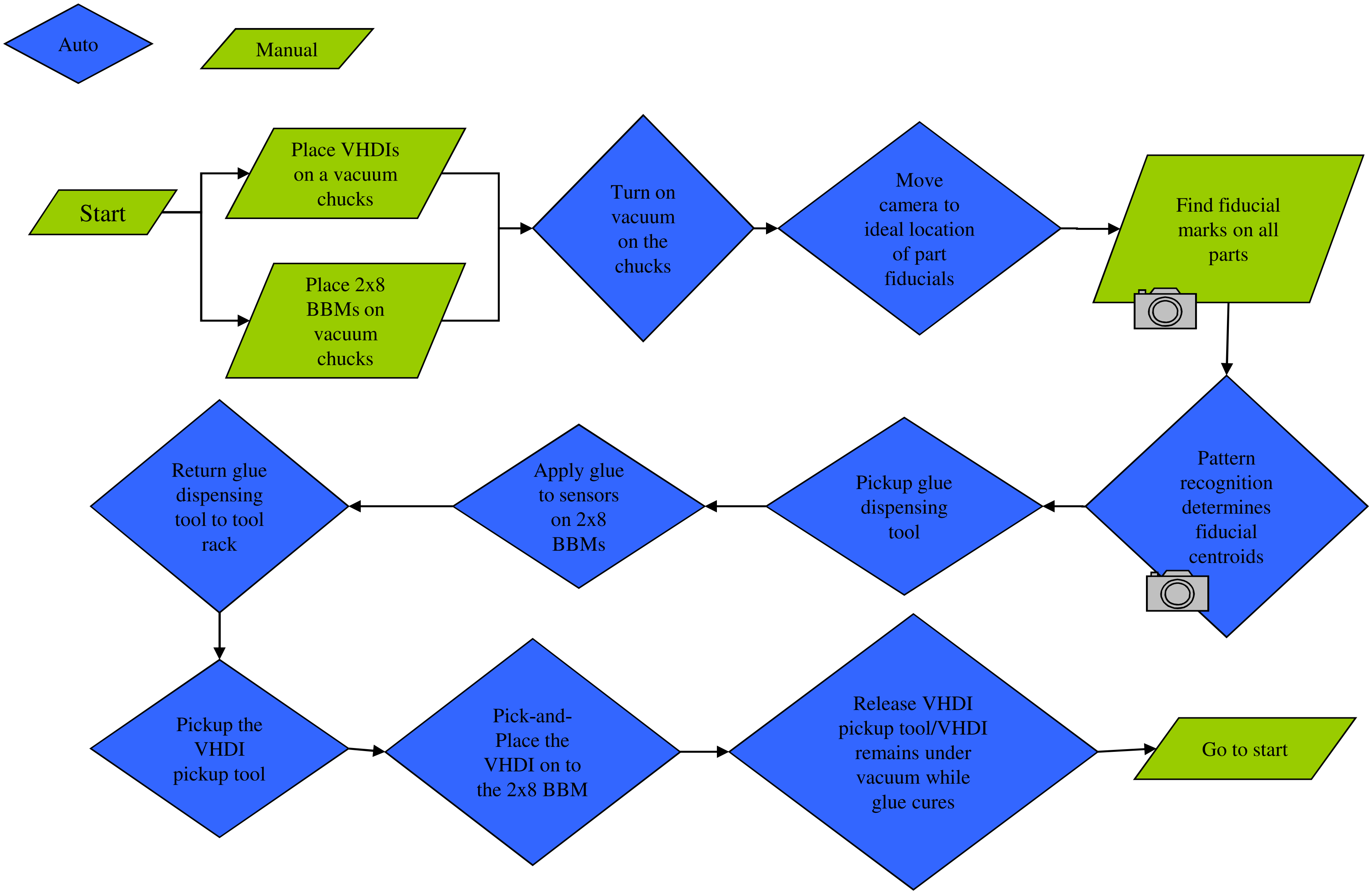




Status

- Gantry Positioning System (shown above), purchased with stimulus funding, delivery to Purdue in ~late November
- Will integrate camera/optics (already delivered), pattern recognition software, vacuum pick-up tool and glue dispensing to the motion control system
- Code development, process development, and prototype module assembly will be performed before production module assembly begins

Process flow for the assembly 2x8 BBM and VHDI using automated assembly machine



Module development - Adhesives study

Status

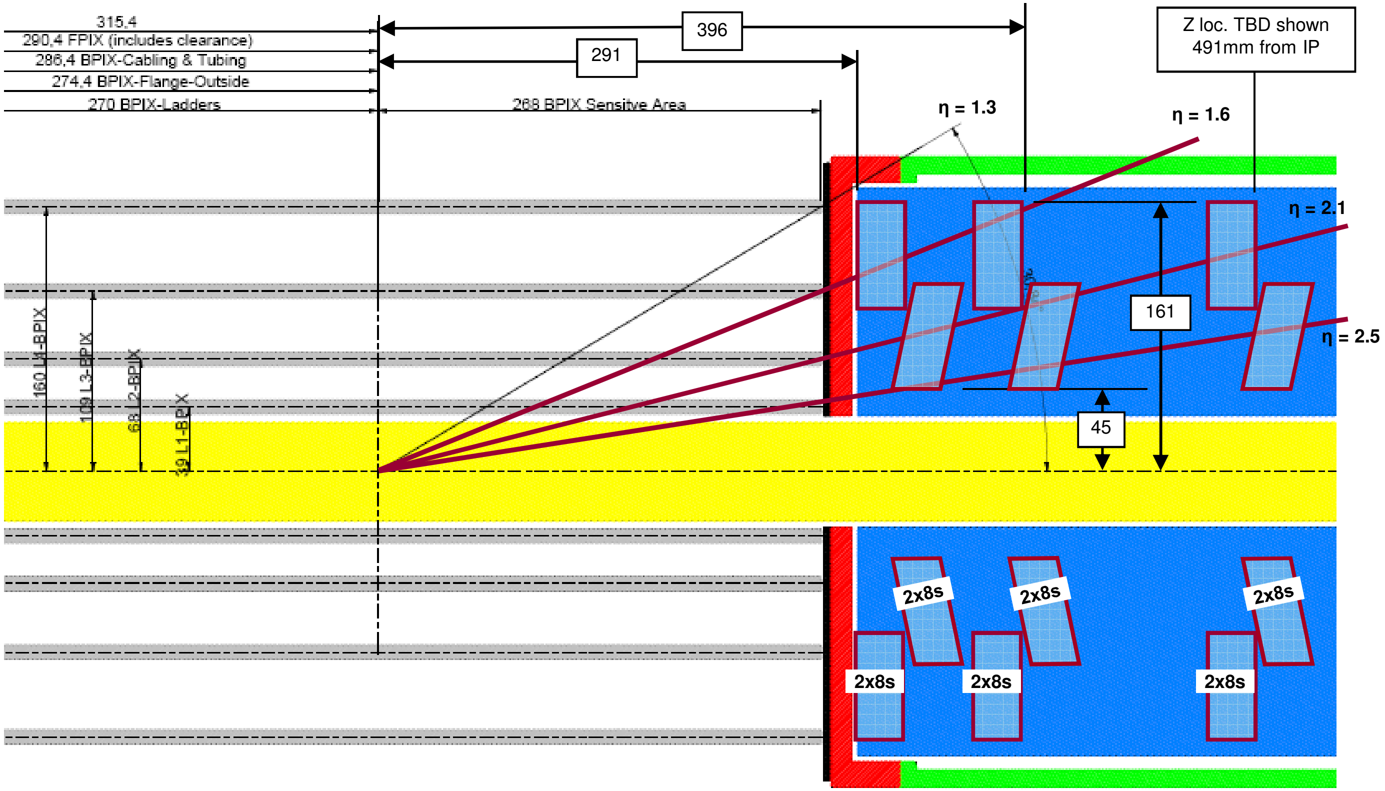
- Specifications for adhesives and materials have been set.
- Reviewed the extensive work that has been carried out (by CERN and others) on radiation effects in polymers.
- Performing a market survey of adhesives for pixel module assemblies that meet requirements for SLHC (including adhesives used in current LHC detectors – ALICE, ATLAS, CMS, LHCb and TOTEM).
- Several candidate adhesive/thermal interface materials selected for testing so far.
- Plan to build test samples and evaluate mechanical properties of module assembly candidate adhesives and thermal interface materials after irradiation.
- Need to consult with CERN experts regarding best evaluation method.

FPIX adhesive sample for tensile testing after irradiation

Plan for Phase 1 FPix Module Assembly Development

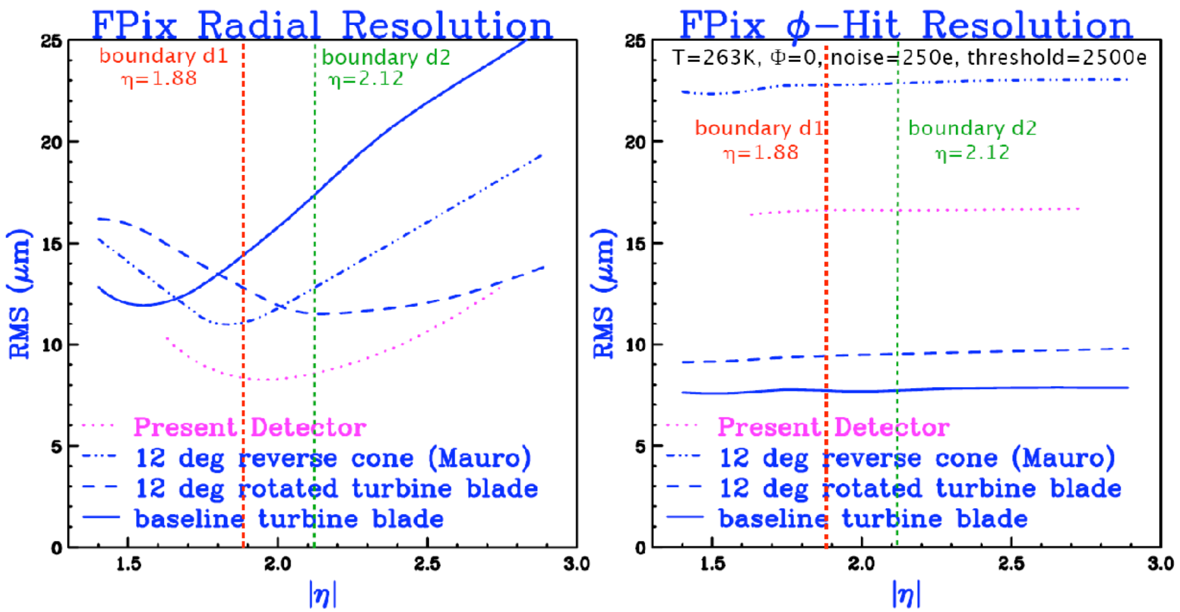
- Obtaining materials and tooling for prototype Phase 1 module assembly.
- In FY10, once a baseline design for modules is set for FPIX, we will assemble mechanical grade Phase 1 module prototypes to evaluate adhesives, interconnects, and develop assembly tooling and procedure.

Backup slides



With separate inner and outer blade assemblies, it’s possible to optimize the layout of each to obtain excellent resolution in both the azimuthal and radial direction throughout the FPix acceptance angle.

An inverted cone array combined with the 20 deg Rotated Vanes for the inner blade assemblies results in better radial resolution at large eta (see diagram above).



Proposed FPix geometries were studied by Morris Swartz (JHU) using the detailed Pixelav simulation currently used to generate reconstruction templates. Five geometries were studied: the current design, the Rotated Vane, 20° and 30° 'Fresnel Lens' (with castellated modules) layouts, and a 12° inverted cone array of Rotated Vanes.

The Rotated Vane design (labeled 'baseline turbine blade' in the above plots) has excellent azimuthal (phi) resolution (better by x2 compared to the current FPix detector); however, the radial resolution is worse for high eta.

The Fresnel Lens layouts perform worse compared to the current detector geometry.

Tilting the blades in the Inner Assemblies into inverted cones (labeled '12 deg rotated turbine blade' above) improves the high-eta radial resolution and only slightly worsens the high-eta azimuthal resolution. The radial resolution curves break along the vertical dotted lines at the eta between the Outer and Inner Blade Assemblies.

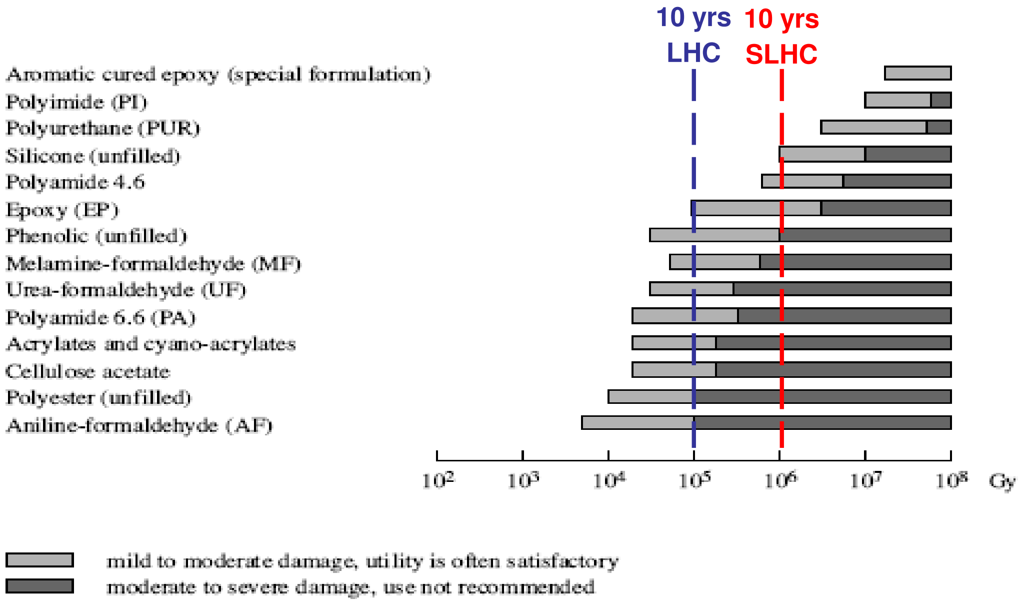
Summary of Blade Thermal FEA results

150% heat load 7.3 W

Configuration #	1	2	3	4	1
Substrate	cf/TPG/cf	cf/TPG/cf	cf/TPG/cf	cf/TPG/cf	Beryllium
Cooling at ends	outer	both	outer	both	outer
HDI position within module	top	top	bottom	bottom	top
Max temp at sensor	-24.8	-27.9	-22.3	-25.4	10.5
ΔT across the whole blade	5.2	2.1	7.7	4.6	40.5
ΔT across TPG	4.4	1.3	4.4	1.3	40.1
ΔT across CF facing	4.6	1.6	4.7	1.6	40.1
ΔT across sensor	3.4	0.9	2.9	0.6	29.6
ΔT across the mid-cut section	1	0.9	3.4	3.4	

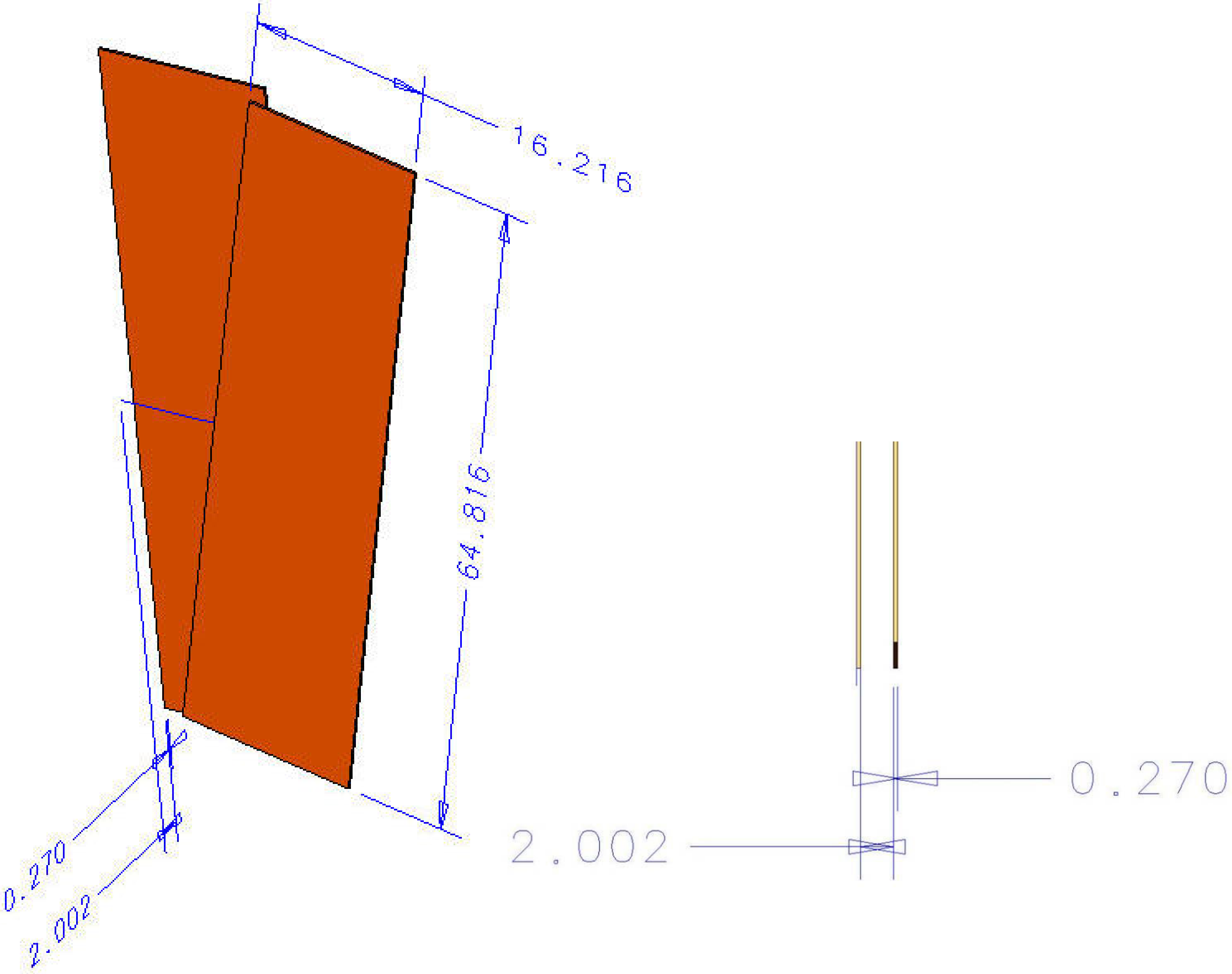
Note: Heat sink tempeaturea = -30

Radiation resistance of adhesives



- Extensive work has been carried out on radiation effects in polymers, mainly for nuclear reactor applications and radiation processing.
- Radiation damage studies of organic materials (at CERN in the 1990’s) produced the table above with approximate radiation levels up to which category adhesives can be used.
- The relative radiation resistance of a number of different materials indicates that high temperature resins are extraordinarily resistant to radiation.
- The adhesive-substrate interface (composed of ionic and physical bonds) is not usually sensitive to radiation – typically no degradation is observed until the polymer itself (covalent bonds) degraded.
- This is a general guideline - environmental conditions such as temperature, humidity, and dose rate, as well as additives influence the radiation behavior of materials.

Active Sensor Check Plates



Material Budget Estimate

Item	**Current (%RL)**	**Upgrade (%RL)**
Sensors+ ROCs	0.50	0.50
VHDI+substrate+ components	0.93	0
HDI+substrate+ components	0.80	0.70
Cooling channel + coolant	1.25	0.04
Outer & inner ring	0.68	0.48
Total per blade	**4.16**	**1.72**

The goal of reducing the material by 50% is feasible, primarily by removing the VHDI and by using CO2 cooling for a x10 reduction in the mass of the cooling channels and coolant.

Material Candidates for Substrate

	Density g/cc	Modulus, E_ab Gpa	Modulus, E_c Gpa	Strength Mpa	Thermal K_ab W/m-K	Thermal K_c W/m-K	cte_ab ppm/K	cte_c ppm/K	Rad L, X0 cm
Porous Materials									
fuzzy C, 5% pr	0.11	-	-		-	55	-	1.0	406.7
carbon foam, low density	0.25	0.9			15	20	3.5		170.8
SiC foam, 8% packing ratio	0.26	2.8	2.8		11	11	2.2	2.2	166.1
RVC foam (vitreous C)	0.30	0.1	0.1	0.3	0.5	0.5	2.2	2.2	142.3
carbon foam, medium density	0.35	3.0		-1.6	20	25	3.5		122.0
carbon foam, high density	0.45	5.0		-3.5	25	40	3.5		94.9
poco-foam, 25% pr	0.55	20.7	20.7	-2.07	45	135	2.5	2.5	77.6
rohacell	0.03	0.0	0.0	1	0.0	0.0	37.0	37.0	1497.7
Solid Non-metalic Materials									
pyrolitic graphite, PGS	1				600	15.0	0.9	32.0	42.7
peek	1.32	3.6	3.6	92.9	0.2	0.2	46.8	46.8	35.0
CoolPoly E5101 (PPS)	1.70	13.0	13.0	45.0	20	20	15.0	15.0	26.5
CFRP (M46J-epoxy)	1.61	18.1	7.3		56	0.7	0.0	30.2	26.5
glassy C	1.65	20.0	20.0		5	5	3.0	3.0	25.9
CFRP (K13C2U-epoxy)	1.75	483.0	6.2		320	0.5	-1.0	26.0	24.4
CFRP (K139-EX1515)	1.76	154.0	6.4		63	0.4	-0.8	30.4	24.3
Poco graphite ACF-10Q	1.77	11.0	11.0	69.0	60	60	7.6	7.6	24.1
C-C composite (carbon fiber/carbon matrix)	1.80	152.0	4.8		225	150	2.0	2.0	23.7
SiC	3.21	466.0	466.0	-3900	40	40	3.3	3.3	8.1
G10 (glass fiber/epoxy)	1.8	17.2		262.0	0.3	0.3	11.9	11.9	19.4
pyrolitic graphite, TPG	2.26	18.7*	0.0		1700*	10	-1.0	25.0	18.9
Alumina Silicate	2.80			17.5	1.2	1.2	2.9	2.9	14.2
Vespel SP1 Polyimide	1.43	2.4	2.4	87.3	0.3	0.3	54.0	54.0	31.9
CVD Diamond	3.51	1000.0	1000.0	400.0	2000	2000	1.0	1.0	12.0
DLC (diamond-like carbon) coating									
Solid Metalic									
Be	1.85	290.0	290.0	276	145	145	11.6	11.6	35.4
AlBeMet	2.10	200.0	200.0	192	210	210	13.9	13.9	16.1
BeO	2.90	345.0	345.0	138000	330	330	7.6	7.6	13.3
Aluminum Nitride (AIN)	3.26	331.0	331.0	-2100	165	165	4.5	4.5	10.3
silicon	2.33	110.3	110.3	-120	120	120	2.6	2.6	9.4
aluminum 6061-T6	2.76	69.0	69.0	379	237	237	23.4	23.4	8.9
stainless steel 304	7.86	200.0	200.0	517	16	16	15.1	15.1	1.8
copper 101	8.94	129.7	129.7	350	391	391	17.6	17.6	1.4