Integration of the ATLAS Pixel Detector

March, 11 1999

US ATLAS Review

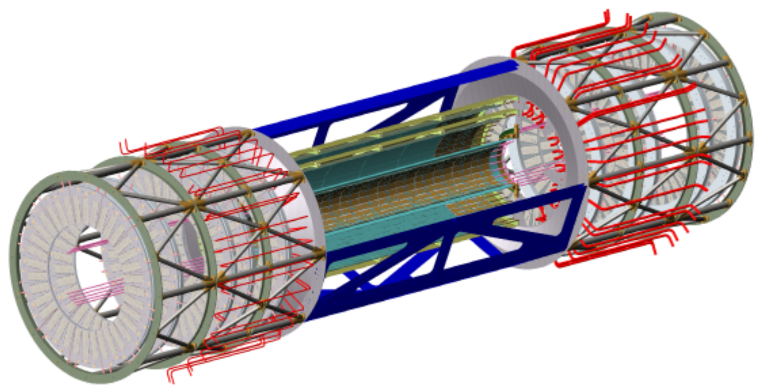
E. Anderssen, LBNL/CERN

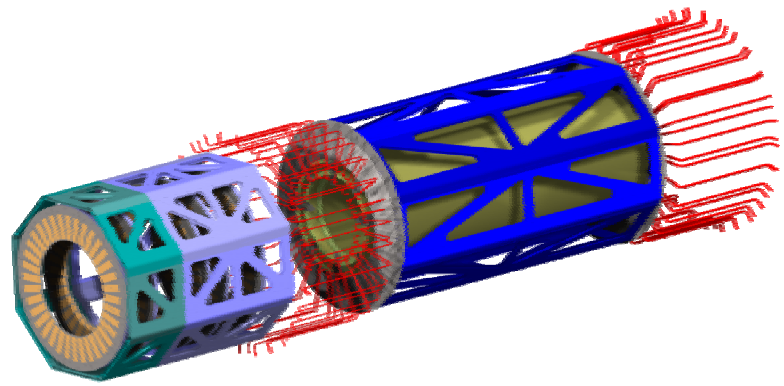
Overview

- **Overview of the structure**
  - General Layout
  - Global Support Elements
  - Local Support Elements
  - External Interfaces
- **Integration within Pixel Structure**
  - Integration areas
    - Structure
    - Interface
    - Services
  - Organization
    - Configuration Control
    - Work Packages Responsibilities
    - Schedule
- **Integration with the rest of ATLAS**
  - Interface Documents
  - Services
  - Installation and Maintenance

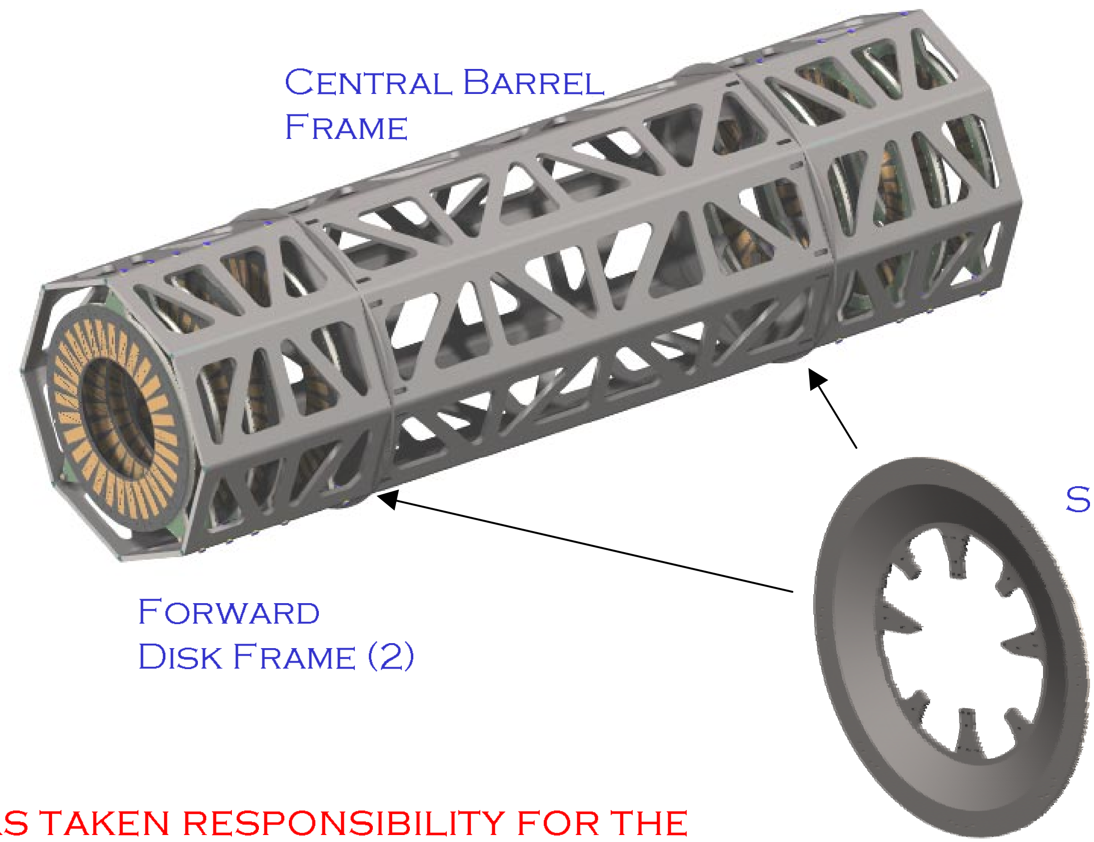
Brief History of Layout

- **Baseline Design in TDR has tubular truss end frames with disks that extend past Z=800**
- **Progression of design important to remember:**
  - Baseline in TDR
  - Costing
  - Analysis
  - Material Estimates
  - Structural Performance Baseline
- **Design changed to flat panel to reduce cost**
- **Changed again to Z<780 Layout of Disks for integration reasons**



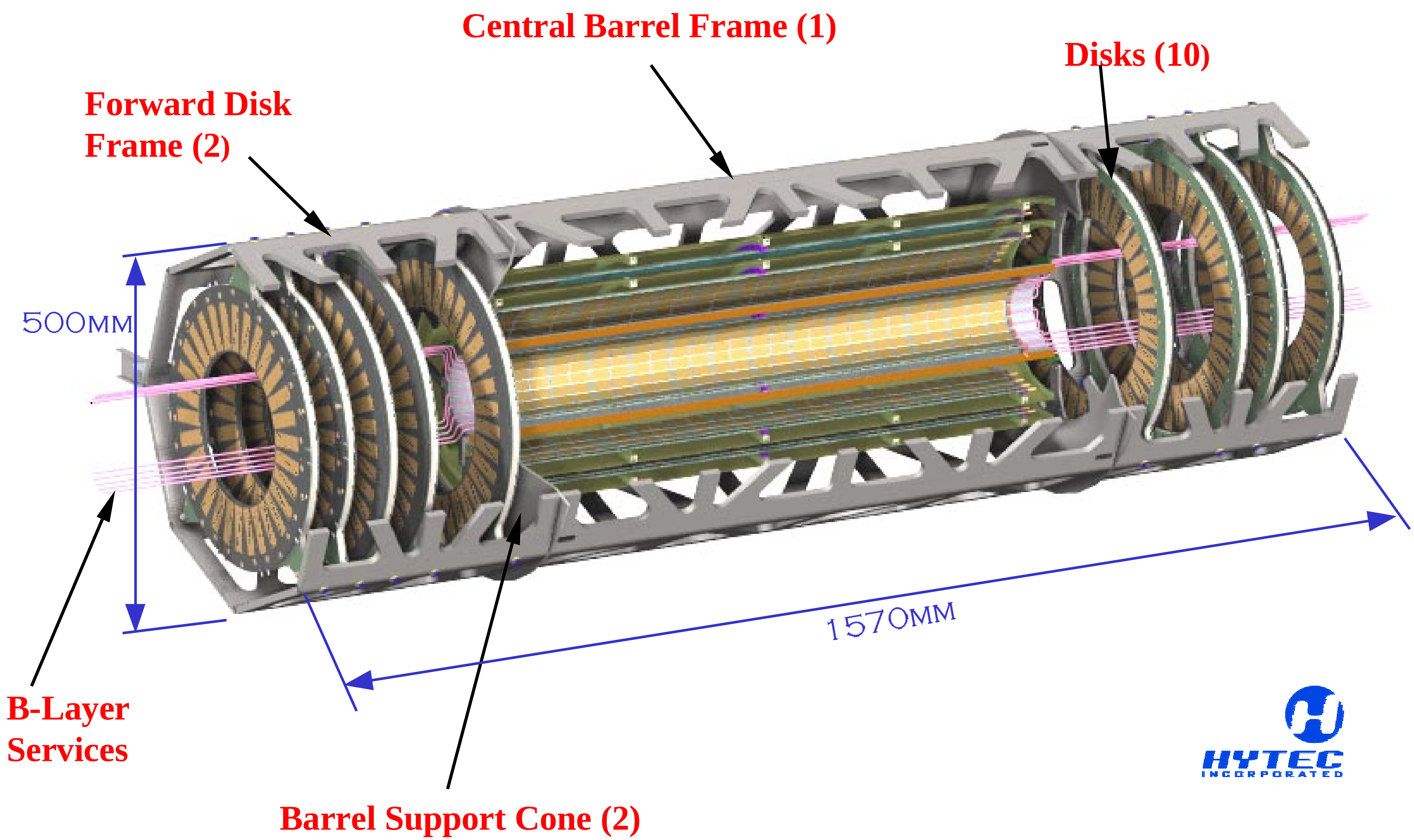


Global Support Structure

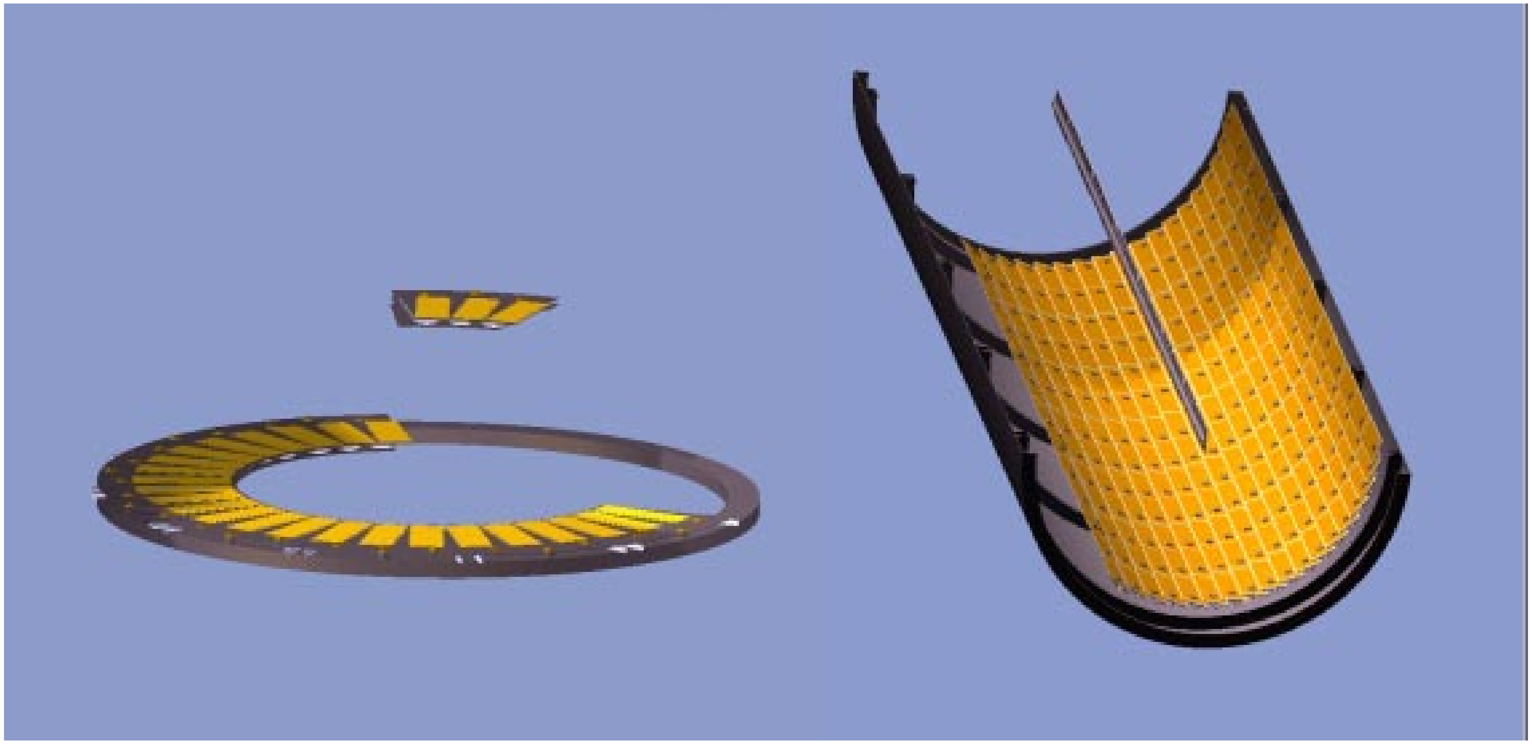


US ATLAS has taken responsibility for the Overall Pixel Global Support frame; specifically the articles shown:
Central and Forward frames, Support Cones and Disk Supports

Global Support Concept



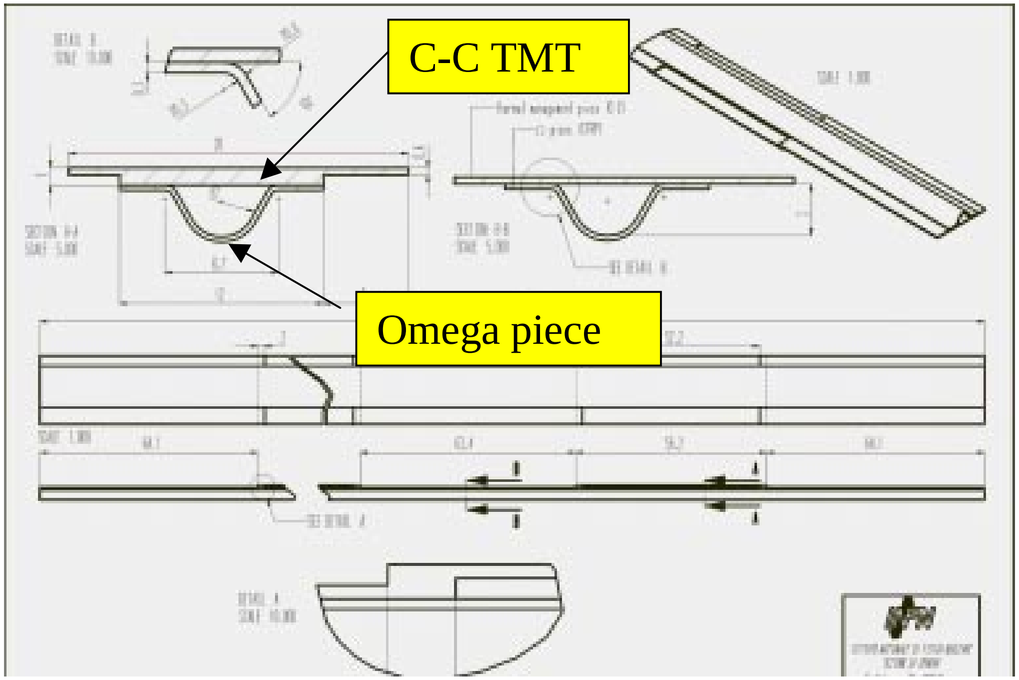
Disk and Barrel Global Support Sub-Structure

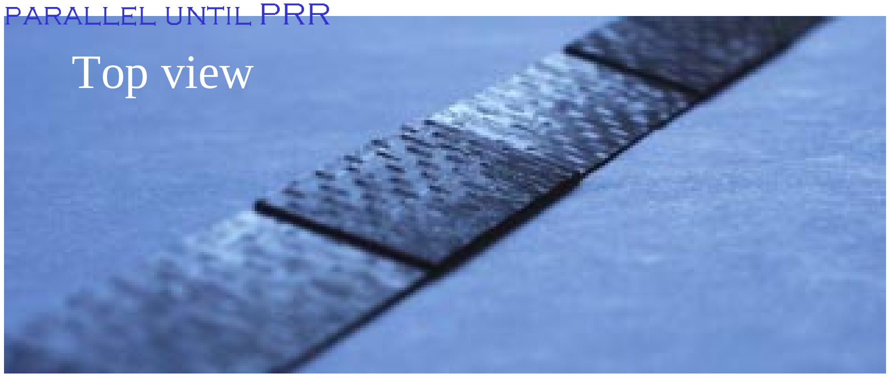


- **Disk Sectors and Barrel Staves are placed onto Disk Sector Supports and Barrel Half shells respectively**
- **Barrel Half shells and Disk Sector Supports are considered part of the "Global" support system**

Local Support (Stave) Baseline

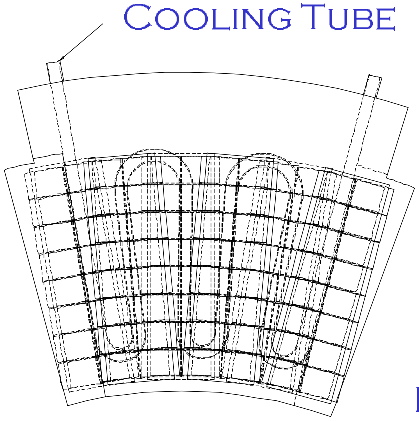
- cooling tube made of an Omega-shaped Graphite Cyanate Ester material glued to a Carbon-Carbon (C-C) Thermal Management Tile (TMT)
- TMT machined from a C-C plate and impregnated to seal porosity
  - Shingled Geometry accepted as baseline Jan99
  - Small layout change in disks necessary to accommodate this
  - Baseline design assumes evaporative cooling and under-pressure operation
  - Backup design to proceed in parallel until PRR



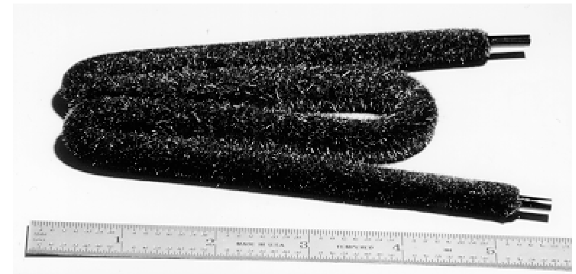


Sector Baseline

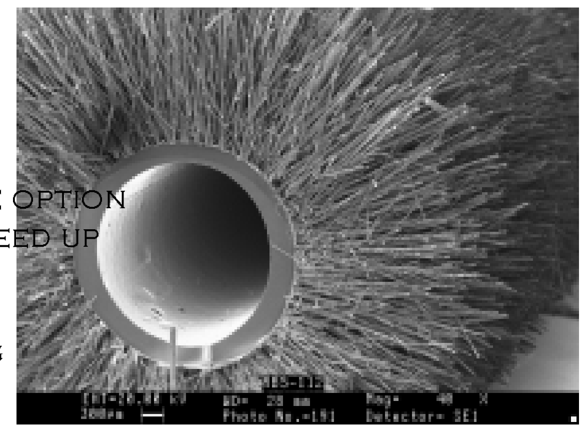
Cooling Tube



ESLI is on prototype #8 it is the first one with the newer 5 disk layout as defined in the TDR

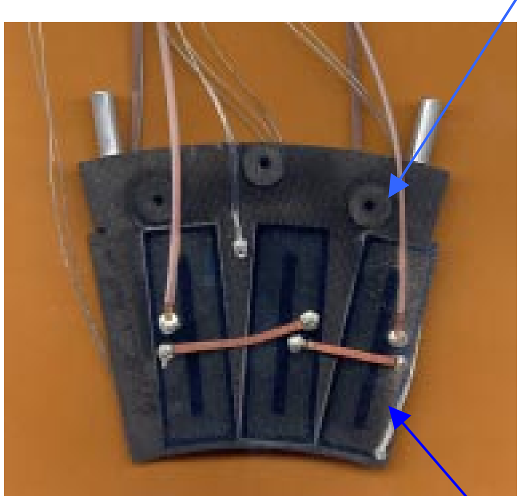


ESLI flocked glassy carbon Tube (Old 4 disk design)



Section through tube

Mounting Pads
(not shown above)

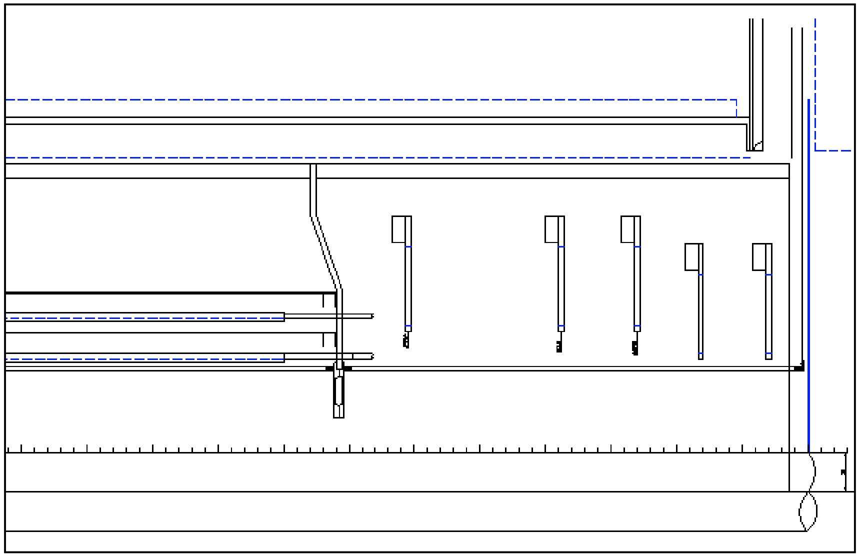


Heaters

Backup effort includes both CC tube option and aluminum tube options, will proceed up to PRR.

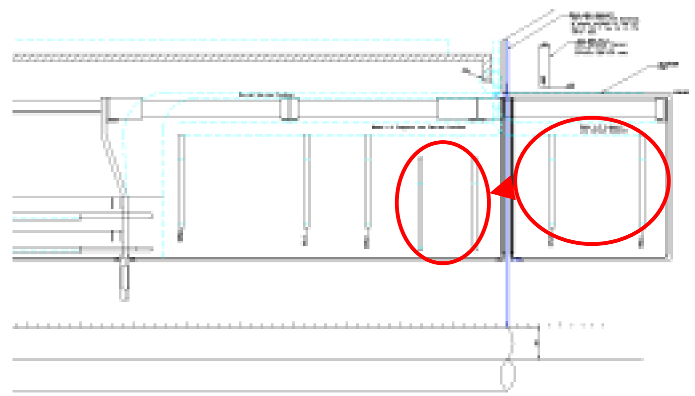
Results presented later this morning

Change to TDR Layout in Disk Region



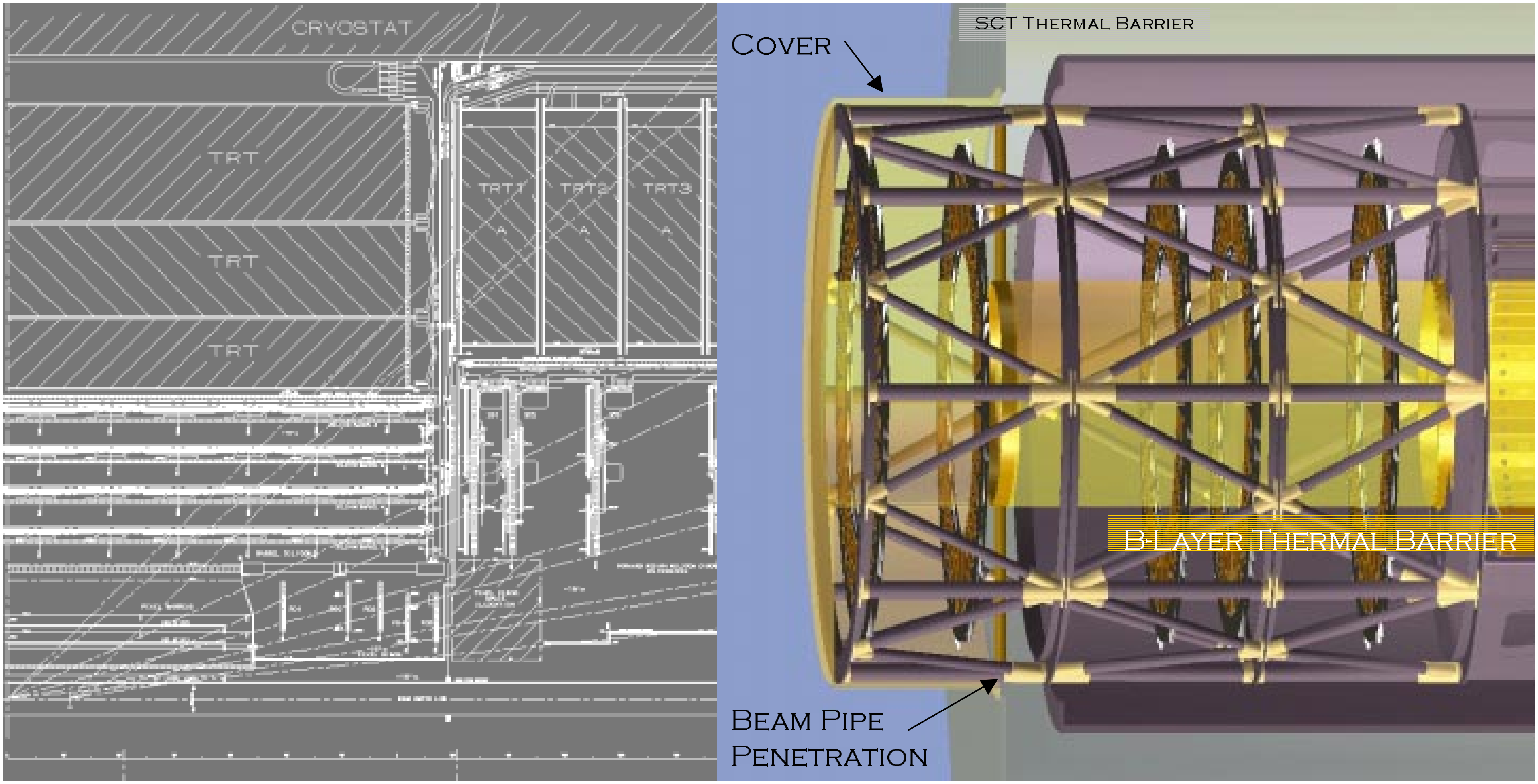
- **New Layout reduced number of disk modules by ~7%**
- **Eased integration with the beampipe**
- **Solved SCT Clash**

3 Barrel Layers	B-Layer	18 Staves
	Layer 1	42 Staves
	Layer 2	56 Staves
13 Modules per Stave		
	1508 modules	
5 Disks each end	1-3	12 Sectors
	4-5	10 Sectors
6 Modules per Sector		
	672 Modules	

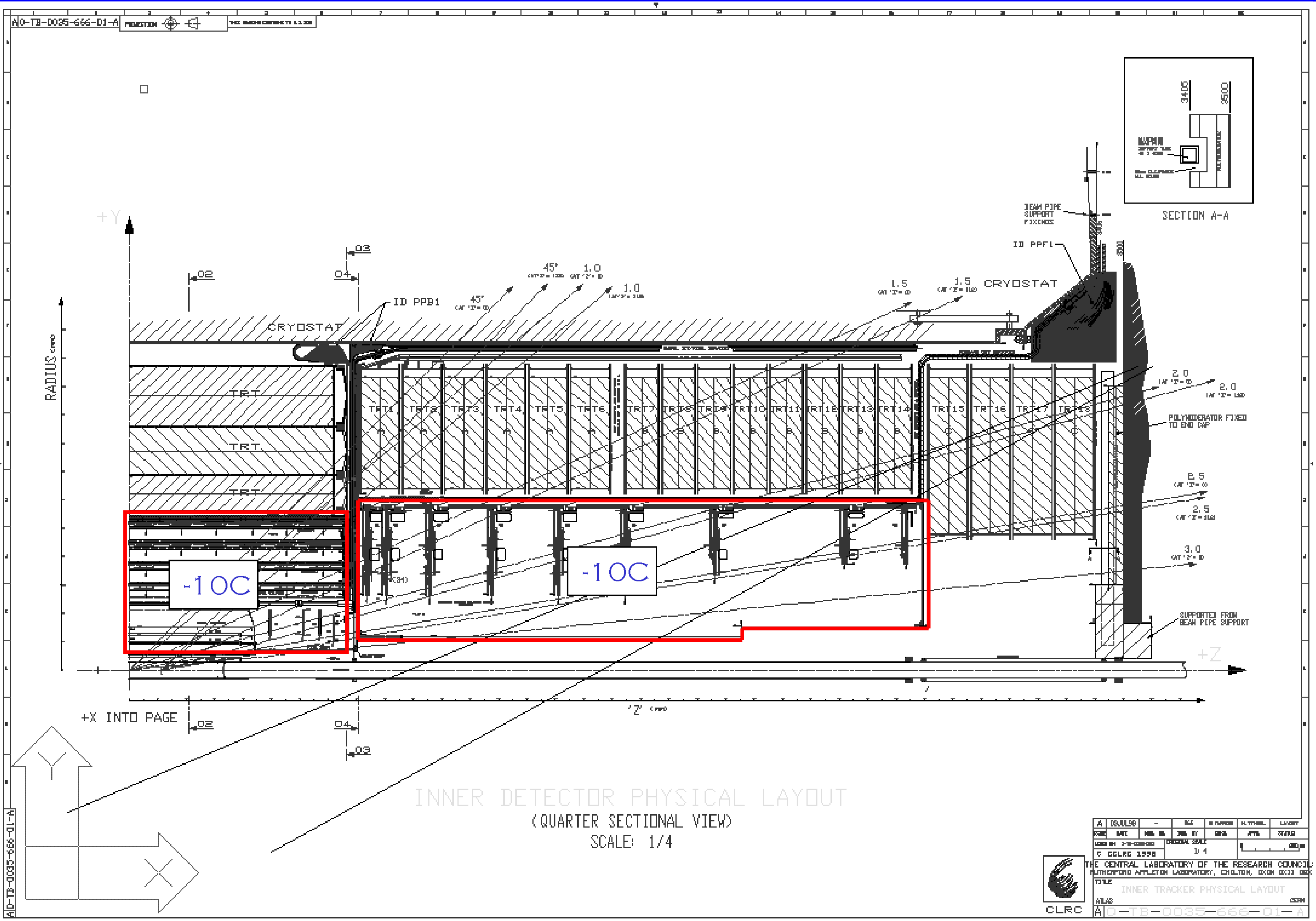


Old Baseline with change indicated

Local External Environment



Pixel Detector



Integration within the Pixel Structure

- **System Issues**
  - Structural Sub-elements
    - Performance criteria
    - Accuracy
  - Interface Control
    - Geometry/Envelope
    - Accuracy
    - Loads and Environment
  - Services
    - Cooling
    - Electrical
    - Implications for the Structures
- **Organization**
  - Configuration Control
  - Work Packages/Responsibilities
  - Schedule

Requirements/Specification Scheme

- **Mechanics should not significantly detract from inherent Pixel resolution**
  - Goal: 15μ inherent pixel resolution will be increased to no more than 18μ by mechanical uncertainties (neglecting track alignment which may reduce the 18μ)
- **Two possible approaches**
  - A.) Fabricate with loose tolerances and rely on track alignment (particles)
  - B.) Fabricate with very tight tolerances to minimize track alignment effort
- **Desire to fall closer to option B than A, but certainly in between**
  - Desire to use Stave as fundamental alignment unit to minimize track fitting effort for 1500 modules with 6 DOF

Tolerances presented are with view in mind that Stave is a well know unit

Relation of Assembly to Tolerances

Only fundamental requirements are Module placement, and Stability

Fundamental to Module but Unrelated to rest

- **Modules Placed on Local Support**
  - Minimum accuracy required for module to module registration
  - All modules are to E3σ, within 1 pixel width of desired position

Add in Quadrature

- **Modules Surveyed on Local Support**
  - Modules' Positions are determined relative to stave mounts and each other
  - CMM Accuracy limits fundamental accuracy of this measurement to E5 μ (one σ for CMM)
- **Local Support placed in Shell/Disk**
  - Last time to physically measure module location
  - CMM Accuracy limits fundamental accuracy here as well.

Change of State Not Statistical

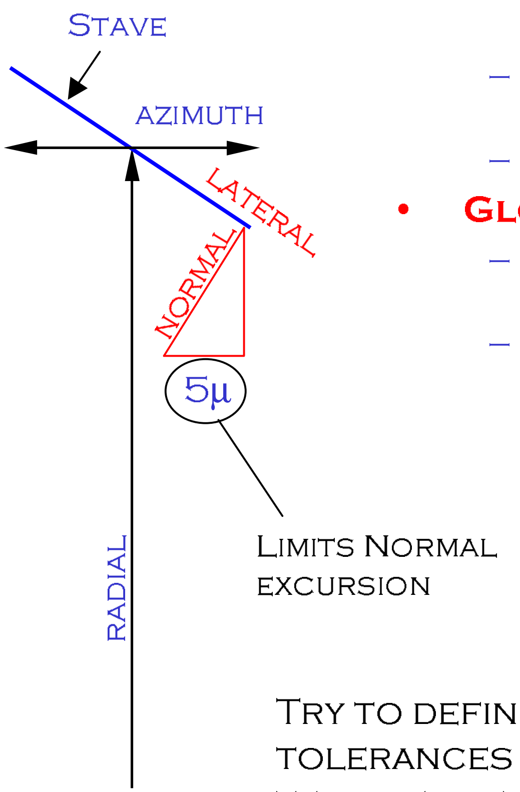
- **Powered on in operating environment (Flow, CME, CTE, etc)**
  - Changes location of modules from surveyed position
- **X-Ray survey in powered on condition**

Affects Fundamental Performance

- **Stability/Repeatability**
  - Gradient of stability motions should be less than accuracy/calibration-time-constant

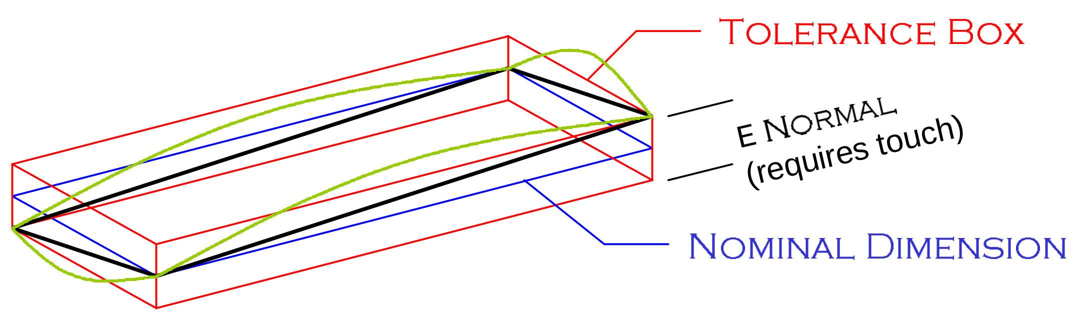
Consider that this rationale requires a thorough X-ray Survey

Map Global Tolerance to Stave Dimension
(Done also for Sector)



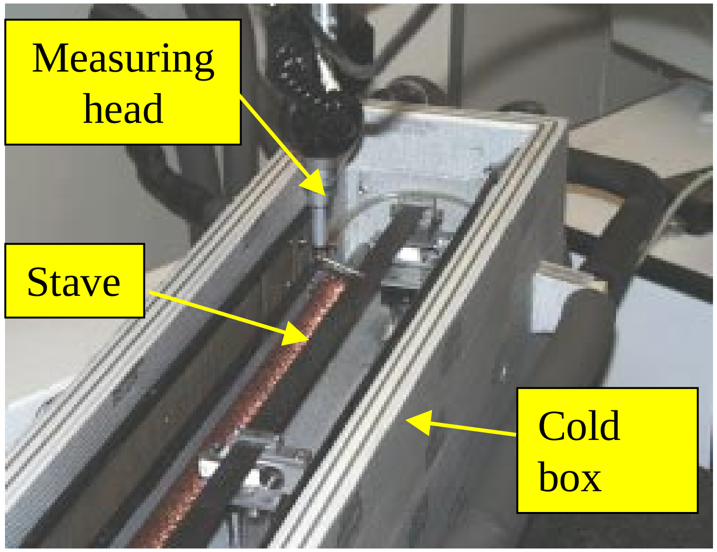
- **Global Tolerances based on 3 effects**
  - Tilt angle
    - δ(azimuth) = δRsin(tilt) (azimuth as linear dimension)
  - Module does not change dimension as it moves (ΔR maps to ΔΦ)
    - δ(azimuth) = δR(azimuth/R)
  - Low momentum tracks have bend radius (negligible)
- **Global Tolerances are mapped to stave coordinates**
  - Lateral Tolerance is approximately equal to Azimuth tolerances (projectively: cos(tilt) y 1)
  - Out of plane (normal) motion of stave maps to azimuth via tilt angle--azimuthal tolerance sets limit on out of plane motion, not Radial Tolerance

Try to define tolerances in terms easy to measure on CMM



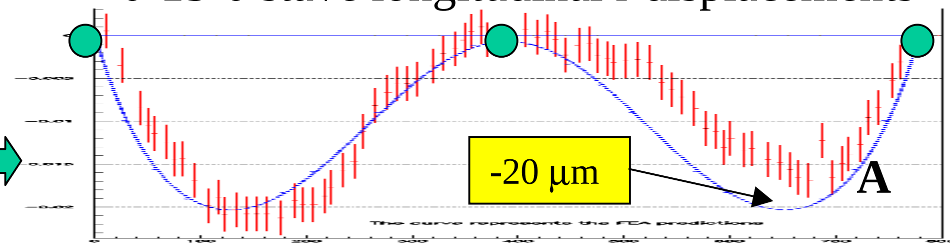
COOL DOWN STABILITY TESTS

CMM tooling

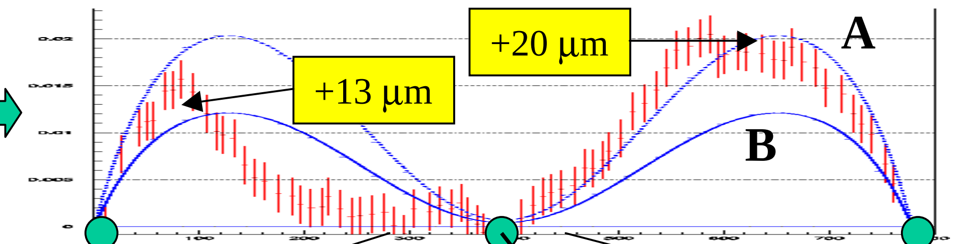


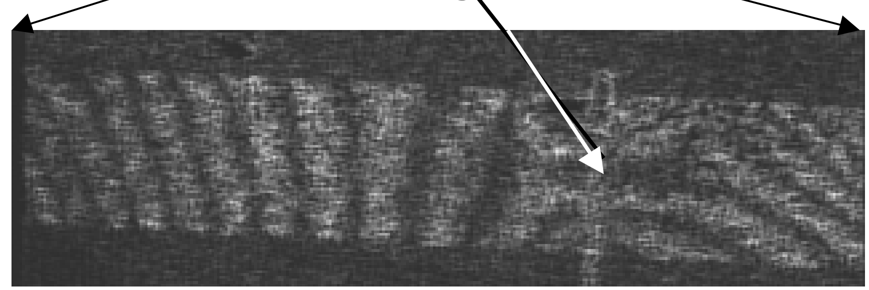
ESPI setup

0-15-0 stave longitudinal r displacements



0-90-0 stave longitudinal r displacements





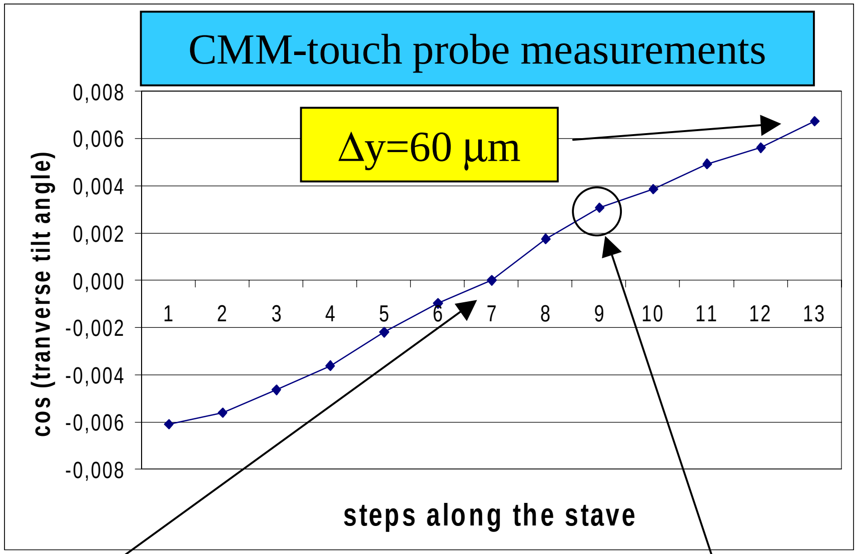
A curve: FEA surface impregnated TMT

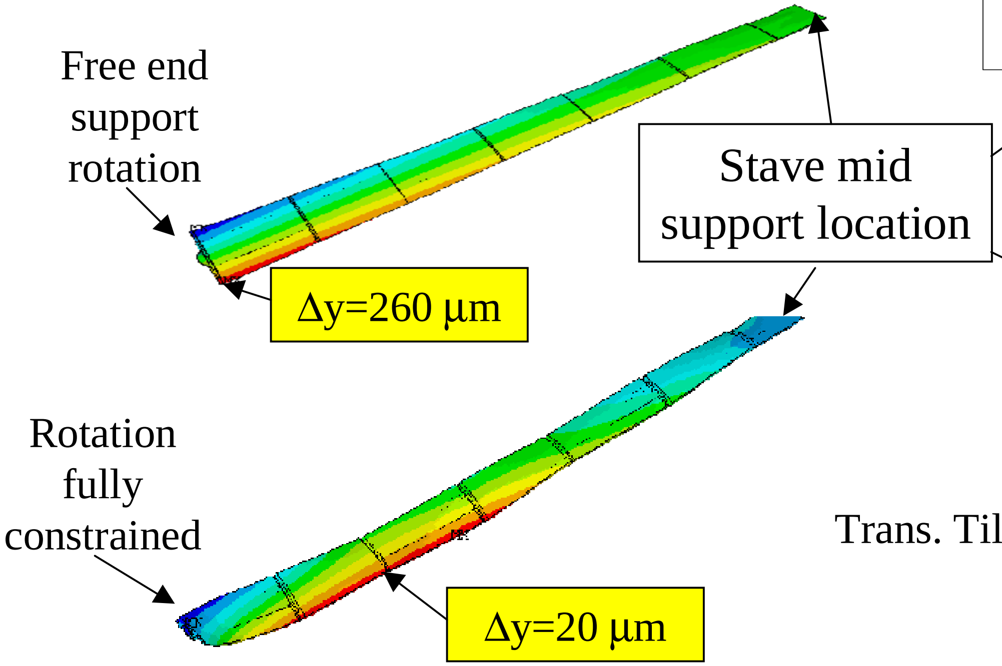
B curve: FEA deep impregnated TMT

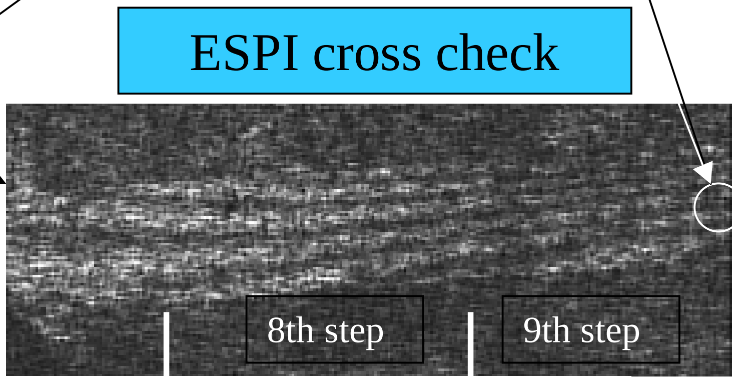
Support location

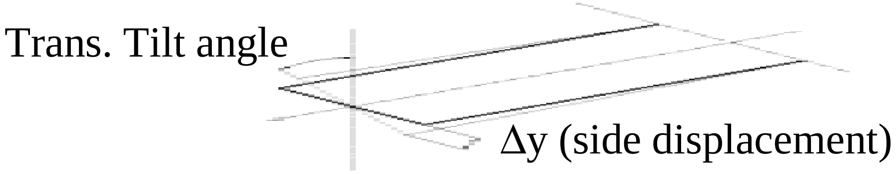
Cool-down tests: 0-15-0 stave twisting

- In addition to a normal deflection, the 0-15-0 omega stave also shows an undesirable twisting due the 15° CFRP layer
- A torque of 13Nmm is required to constrain rotation of the end of the stave
- With this constraint, the max side displacement due to tilting is within the specifications (20 μm)
- Need to factor Stave loads into Barrel Half Shell designs









Status of Specifications for Pixel Structures

- **Specifications for Stave and Sector to be written in the spirit of the preceding by June Pixel meeting for approval by the collaboration**
- **Similar Specifications are needed for the Disk Sector Support and Barrel half shells in the near term for prototype structures to be built--should follow readily from the specifications of the Stave and Sector**
- **Specification for the Global Support Structure is a more complex problem and requires integration efforts to proceed with external systems, as well as detailing of several internal interfaces, including Services**

Internal Interfaces of the Pixel Detector

Europe + PE

- Barrel (half-shell) to Stave
- Barrel to Support Cone

US + PE

- Support Cone to Central Barrel Frame
- Forward Frame to Central Barrel Frame
- Disk to Forward Frame
- Sector to Disk
- Global Support to SCT-TRT-Cryostat
- Service penetrations/Loads
- Thermal Barrier

These interfaces will ultimately affect the fit and accuracy of assembly of the detector and thus require control.

Configuration Control

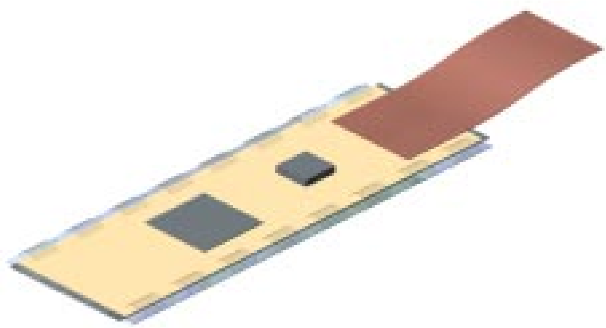
- **Baseline is necessary**
  - Standard Documents
  - Cad Data Exchange
- **Changes from baseline need to be documented**
  - Versioning
- **Centralization of information for "Current" design**
  - EDMS
- **Needs for communication are paramount**
  - Approval process
  - notification

Currently available Tools

- **EDMS**
  - Documents, all sorts
  - Will eventually replace CDD, all other databases for detector integration at CERN
- **CDD**
  - Engineering drawings
  - To be replaced by EDMS Fy99
  - Will not be used by Pixel Detector
    - implies slight delay of full functionality for drawings
- **Web Page**
  - Centralized Link information for rapidly changing data
  - All information of consequence should be put into EDMS
  - Up to institutes to maintain

EDMS will be the central location for ALL Pixel configuration in

PIXEL DETECTOR SERVICES



- **MODULE SERVICES**
  - POWER
  - CONTROL
  - SIGNAL
  - CONNECTORS/BREAKS

- **COOLING**
  - SUPPLY/RETURN
  - MANIFOLDING
  - TEMPERATURE SENSING
  - CONNECTORS/BREAKS

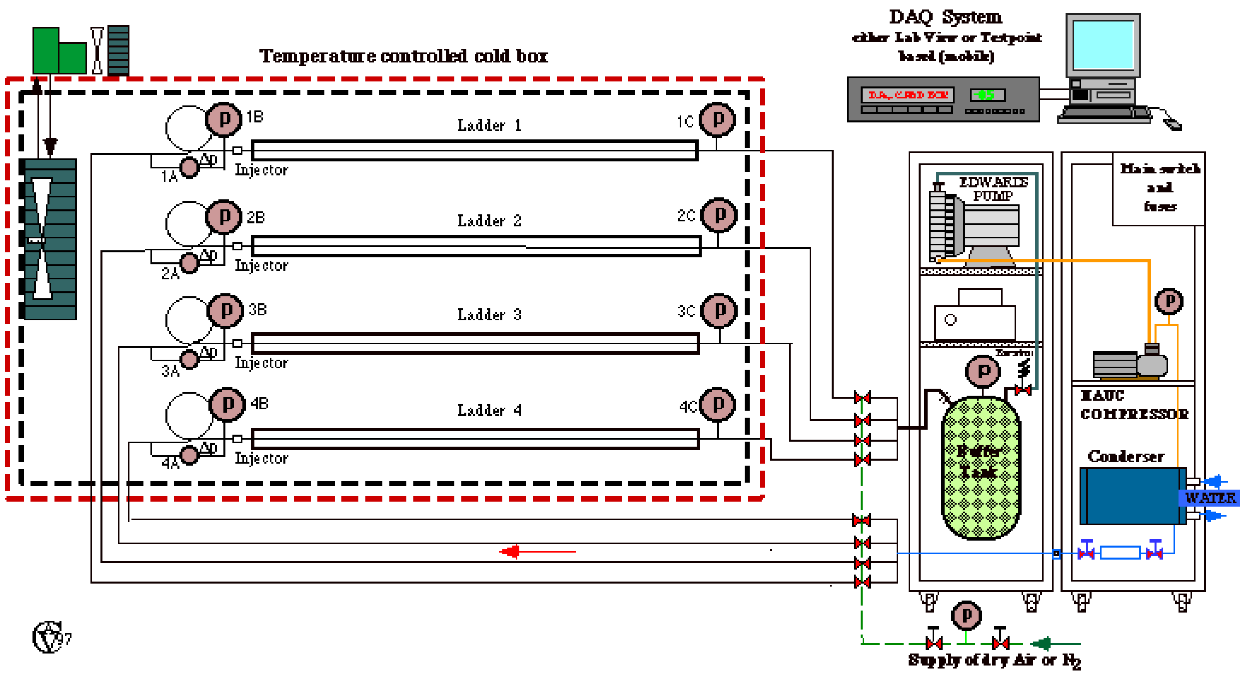
-MODULE SERVICES DOMINATE SERVICE VOLUME. THERE ARE 1946 MODULES COMBINED IN THE BARREL/FORWARD REGION, AND 234 IN THE B-LAYER.

-COOLING EXHAUST TUBES ARE THE LARGEST SINGLE ITEMS TO ROUTE

-B-LAYER SERVICES, WHILE SIMILAR, HAVE DIFFERENT MODULARITY AND ARE ROUTED DIFFERENTLY

PIXEL COOLING

Fluorinert Evaporative Cooling Setup at CERN - September 1998

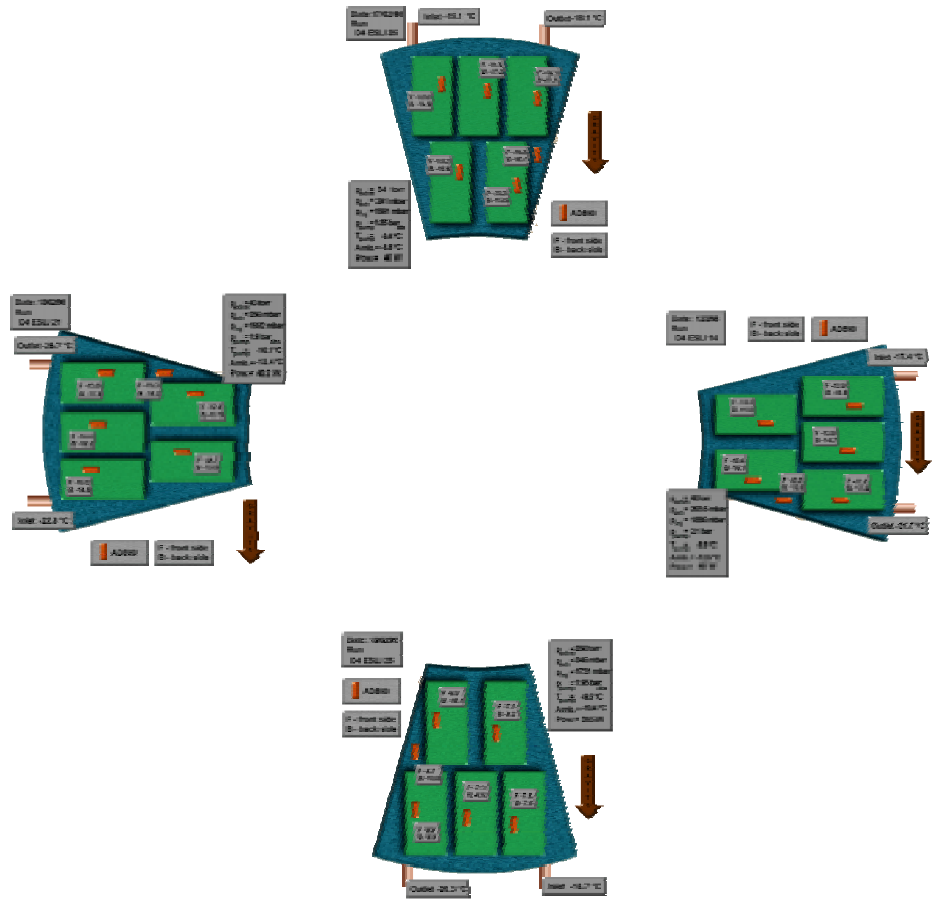


Schematic presented by G. Hallewell and V. Vacek

- EVAPORATIVE COOLING IS THE BASELINE FOR THE PIXEL DETECTOR
- PHASED COOLING PROGRAM UNDERWAY AT CERN TO DETERMINE OPERATING PARAMETERS--RESULTS FY99 TIMEFRAME
- NOT MUCH PROGRESS IN THE PAST YEAR
- ONLY HAVE ESTIMATED TUBING SIZES FOR TIME BEING

Proof of concept in Pixel Structures

- Evaporative C4F10 cooling has been shown to work in Pixel structures in tests at CPPM
- Disk sectors were tested in all orientations with a “realistic” 4m tubing routing showing satisfactory results
- All stave designs have been shown to work with evaporative cooling
- Thermal qualification at prototype manufacturing sites still use monophase fluid (methanol water, or Binary Ice) to test thermal performance of structures



Current Status ATLAS Inner Detector Cooling

- **CERN based Cooling group established, headed by Pixel collaborator**
  - Intent to establish proof of concept for SCT structures followed by determination of relevant engineering parameters to design system
  - Proof of concept phase hampered by dissent from SCT community, and too diverse an initial scope
  - Manpower is an issue
- **"Cooling Decision" slated for Late May '99**
  - Cooling review 26-28 May 1999
  - Selection of cooling media and type (monophase/evaporative) for Inner Tracker.
  - Unclear if enough information will be available in May timeframe to decide
- **Phase II starts after cooling review**
  - Full scale system development is planned
  - Subject to final approval at Cooling Review
  - Funding is mostly in place to proceed
  - Schedule is optimistic
- **Overpressure Operation a concern**
  - SCT desires cooling temps as low as -35C and pressures as high as 10bar (3bar exhaust pressure)

Current Cooling Inventory

- **Evaporative cooling is Pixel Baseline**
- **Space reserved for monophase coolant system**
  - Return line to PPB1 is 5.1mm, supply is 2.0mm
  - All tubes laid in at 5.1 to reserve space if monophase is required
- **Cooling modularity**
  - Two staves/sectors per circuit, except B-Layer, which has one circuit per stave
  - possibility of manifolding only exhaust under study (individual capillary supplies)
- **Return line sized based on single phase flow parameters**
  - Return line size under study for evaporative flow (two-phase flow)
  - Assumption that this is conservative
- **Connectors still need investigation**
  - Overpressure currently not foreseen in connector selection
  - Rad-hard connectors unavailable commercially for use at low radius

Barrel Layer 1	Barrel Layer 2	B-Layer	Disks	Totals	
56 Staves	42 Staves	18 Staves	56 Sectors	PPB1	PPF1
14 Supply	10 Supply	9 Supply	28 Supply	52 Supply	9 Supply
14 Return	11 Return	9 Return	28 Return	53 Return	9 Return

Module/Power supply Parameters

Power budget	W/cm^2		Power Supplies		AMPS	AMPS	VOLTS	WATTS	WATTS
Module	*0.540*			**Circuit**	**Current (Max)**	**Current (USED)**	**Voltage**	**Power(Max)**	**Power (NOM)**
Stave Pigtail	*0.059*	curr_scale	0.8	*Vcc*	0.75	0.6	1.5	1.125	0.9
.5meter PPB1	0.026			*Vddd*	1.5	0.75	3	4.5	2.25
TOTAL	**0.626**			*Vdda*	0.6	0.45	3	1.8	1.35
				PT100	0	0	0		
				Optical link	1.00E-05	1.00E-05	10	0	0
Active Area (cm^2)	*9.216*			VCSEL	1.00E-05	1.00E-05	4	0.0001	0.0001
				Bias Voltage	2.00E-03	1.60E-03	300	0.6	0.48
								Module Power	4.9801

- **Numbers used to size cables are "nominal" at the end of detector life**
  - Estimate based on current prototype electronics
- **Power budget normalized to active area**
- **Nothing can increase without negative impact (growth) in service cross-section**
- **Cable Performance requirements have not been considered**
  - Capacitance, noise rejection
  - performance of 140m chain
  - Impact on performance due to connectors
- **Cable Chain out to Racks has been sized and is being reviewed**
- **System test of full length cables with flex planned for summer 99**

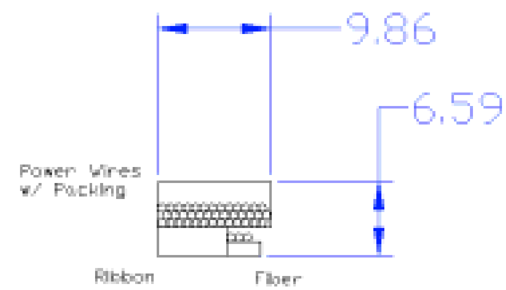
Circuit Sensitivity

Circuit	Current (Max)	Current (USED)
Vcc	0.75	0.6
Vddd	1.5	0.75
Vdda	0.6	0.45
PT100	0	0
Optical link	1.00E-05	1.00E-05
VCSEL	1.00E-05	1.00E-05
Bias Voltage	2.00E-03	1.60E-03

Sensitivity to changes in parameters

- **Current/Power**
  - Slight sensitivity for small changes
    - <10% (+/-)
- **Number of circuits**
  - It is likely to increase in the case of sense wires (doubles number of low power traces)
    - up to 30% increase
- **Noise Rejection**
  - Twisted pair doubles wire area
    - up to 50% increase
- **Fiber Modularity**
  - Currently connectors come modulo 12 which does not easily divide into 13 X 3
    - possible 5% increase

Bundle indicative of service cross section (Typ



Barrel Cone Bundle

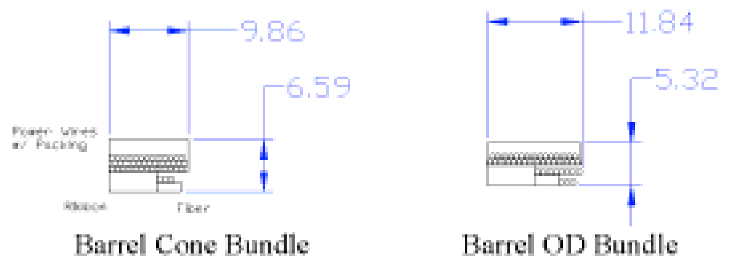
Module services may up to double in face area from current best estimates.

Full scale testing of module power chain is necessary to determine the extent to which they may increase

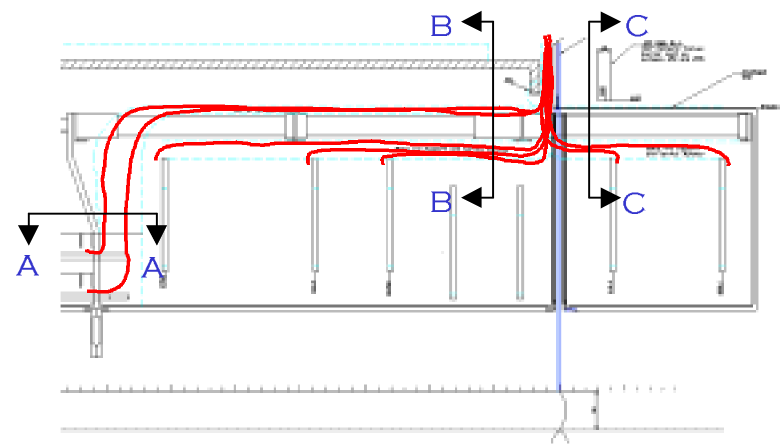
Cable Bundles as Defined in Pixel Volume

- **Bundles do not account for Phi Regrouping**
  - Bundles will need to be integrated and bunched in GAP region into 8 angular regions for external routing
- **Barrel Services are routed on the outside of the forward frame**
  - Bundles have services for up to 7 modules
- **Disk Services are routed inside of forward frame**
  - This has changed due to layout changes, but is still relevant and illustrative

Section AA Section BB



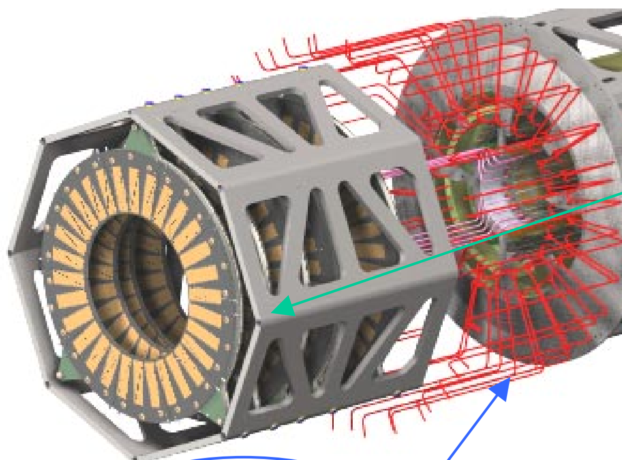
Same bundle, with aspect ratio modified

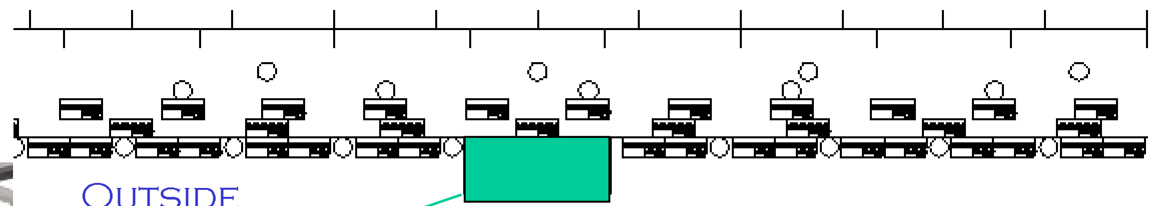


Pixel Detector Integration
E. Anderssen LBNL/CERN

Sections of "routed" Cables

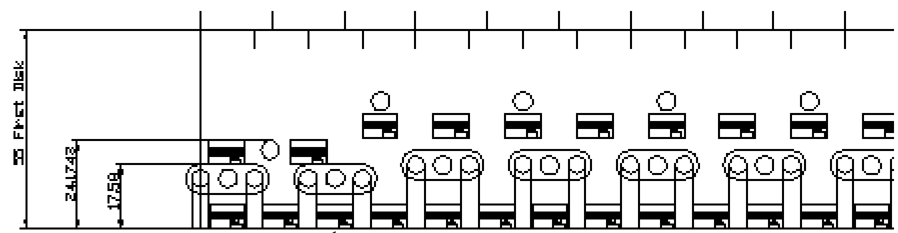
Services outside of frame have 10% circumferential margin for uniphase tube packing.





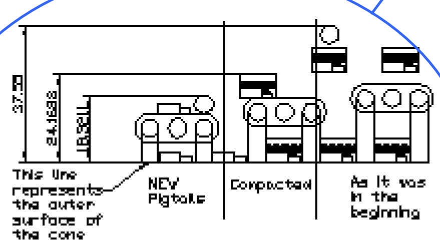
Outside Frame

15 X 40 support



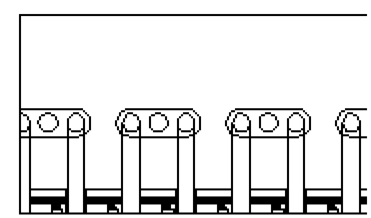
Barrel Layer 2

Cable width limited by pitch



Packing study for Barrel Services

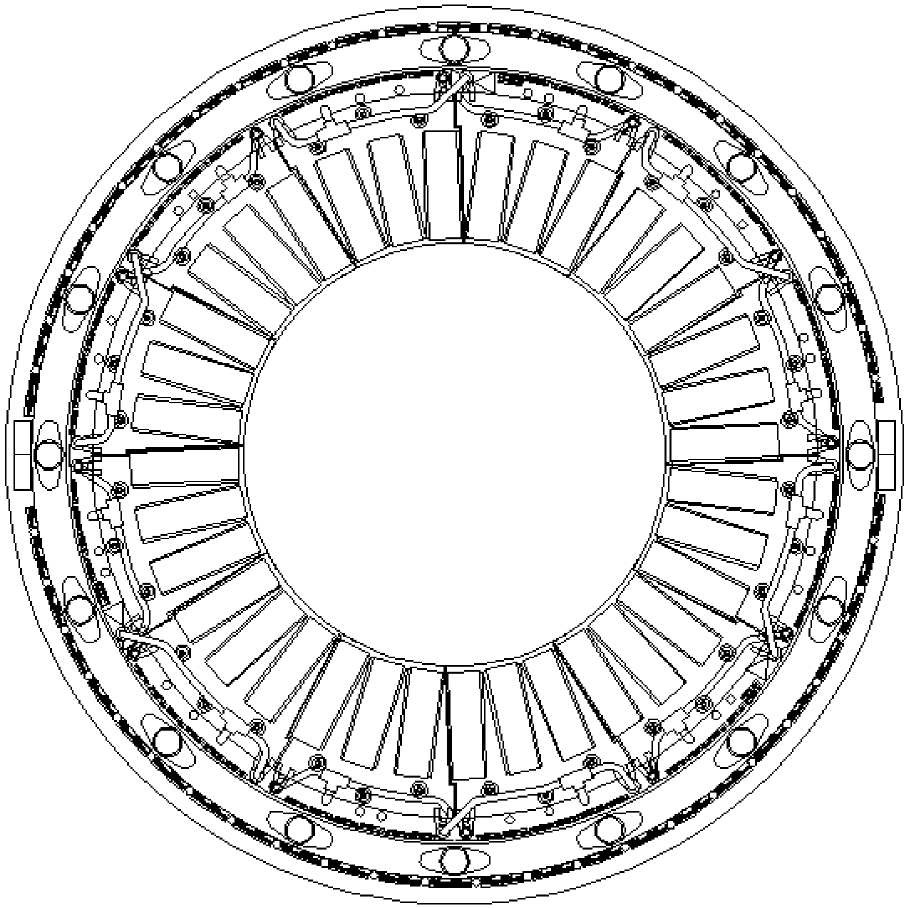
Services exiting barrel affect first disk position.

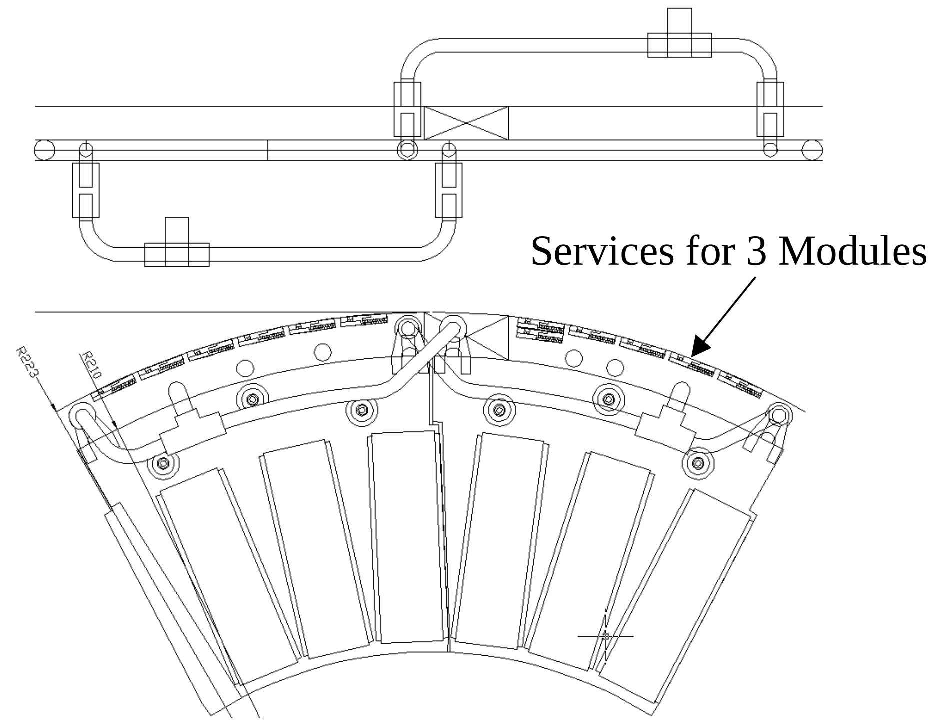


Barrel Layer 1

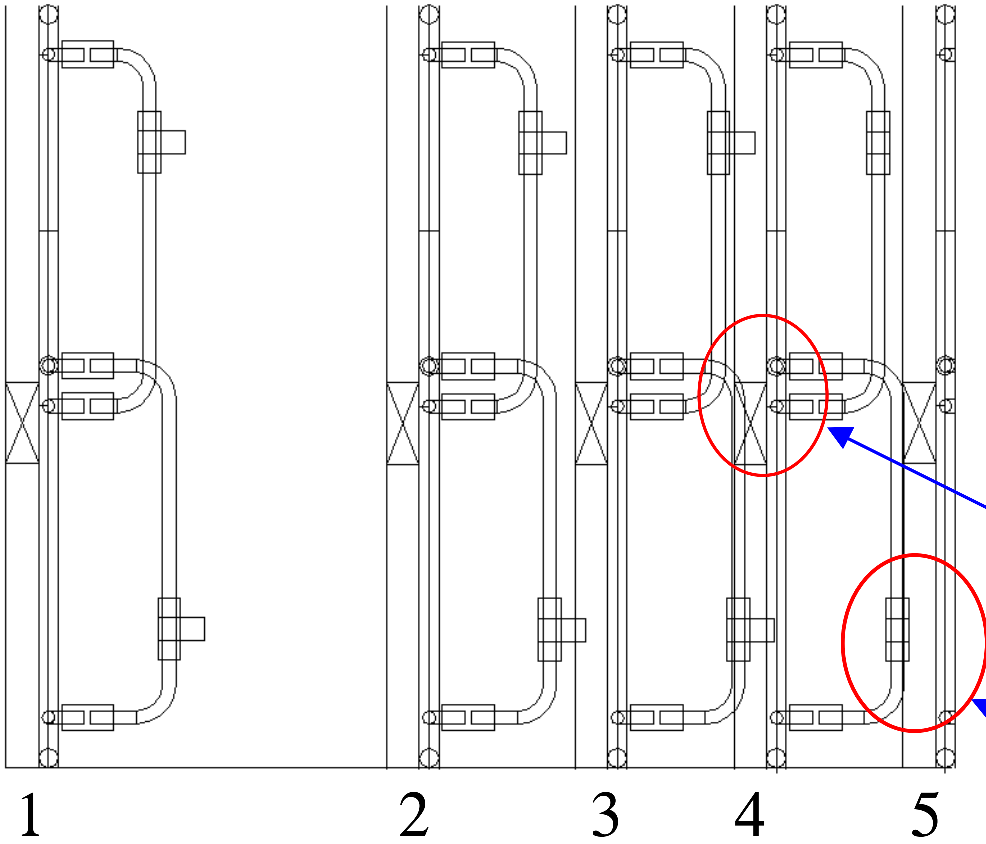
Service Packing inside frame

Space Frame was baseline for cable routing





Service/Layout interaction



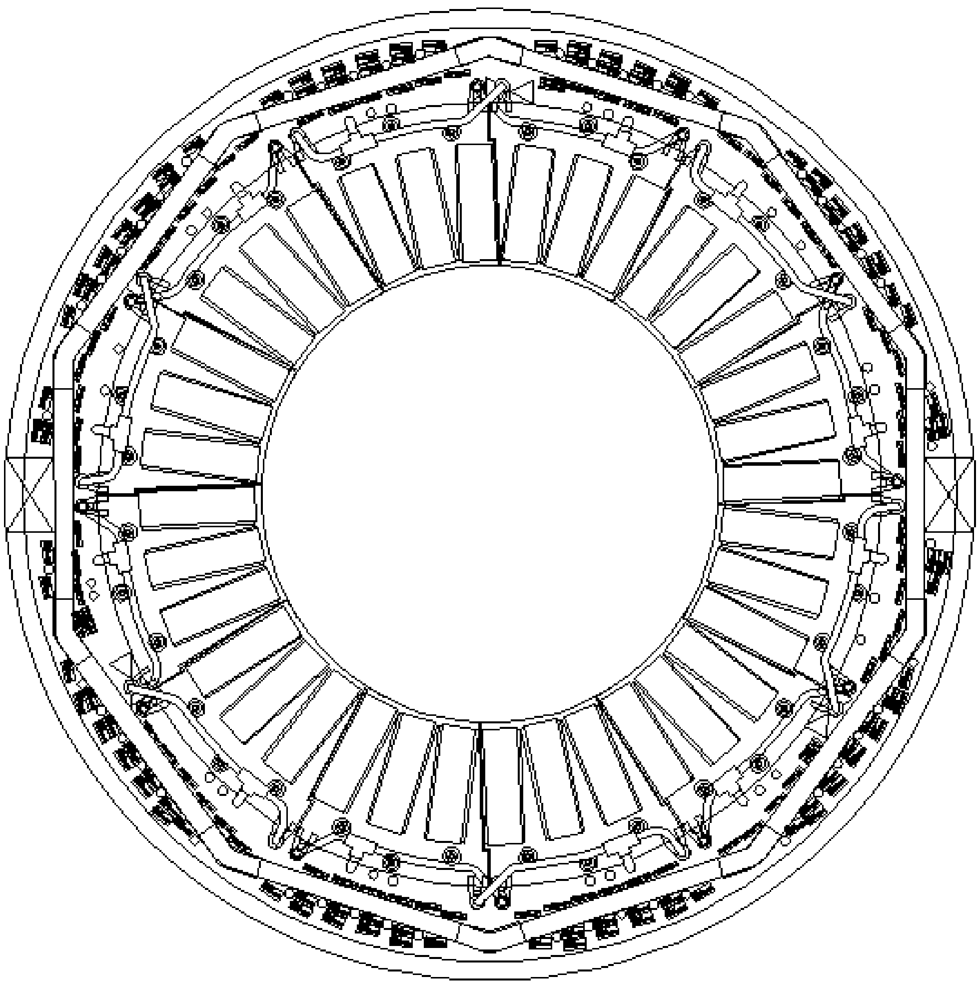
- Services affect layout by dissallowing tighter spacing of disks
- Disks 4/5 are smaller in diameter than 1-3
- Disk 5 overhangs SCT, not room to route services in Z

O.K. due to smaller radius of dis

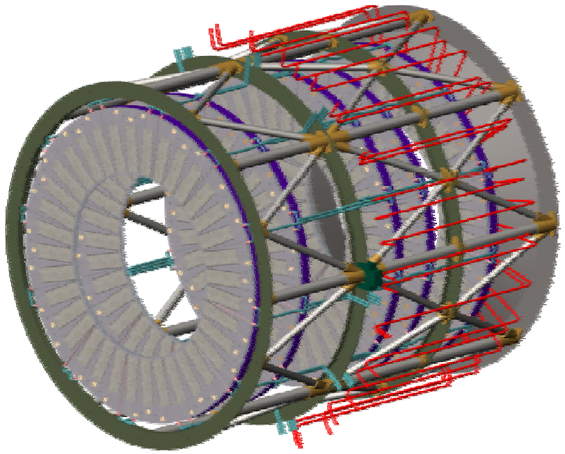
Questionable, likely requires mc complex routing to solve what a to be tight or actually interferi

Services as routed

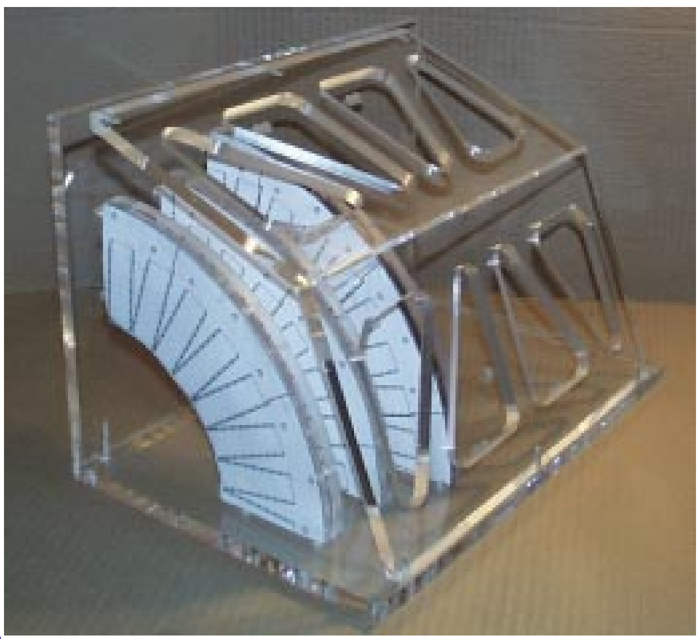
- Disk Manifolds have been laid in
- Service packing laid out for flat panel forward frame (10-sided shown--8-sided chosen)
- 3D model has been started with "realistic" manifolding and thoughts to strain relief
- Exit of barrel services from interior of frame need close attention
- Support cone likely to be added to present model



Remaining Issues

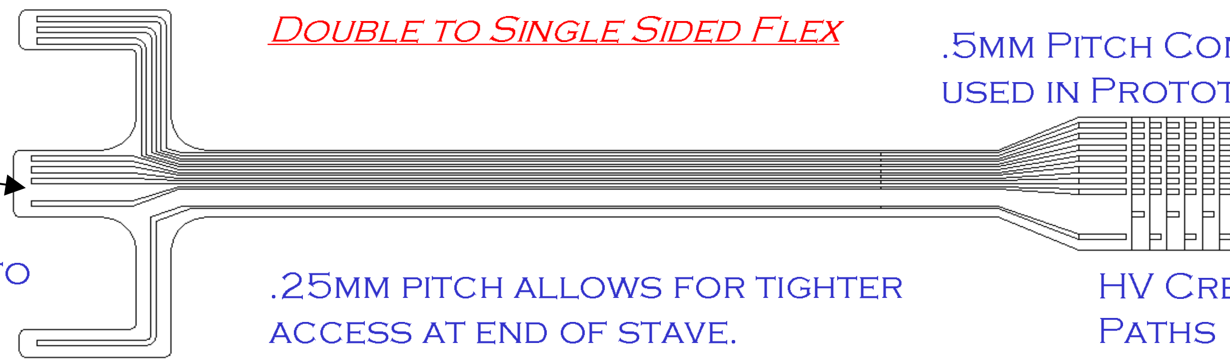


- **Patch Panels (!)**
  - Prototype of 1/4 tracker underway in Indiana and UC London
- **Routing needs to be re-done in 3-D**
  - Cable behaviour hard to capture in CAD
  - 3D non structural scale models have has been constructed
  - Route services on model, feedback into 3-D CAD
- **Forces need to be estimated**
  - Cooling tubes will respond to pressure and temperature variations--need to estimate loads
- **Couplings and Strain relief need to be investigated**
  - Assembly and subsequent attachment of services will couple the pixel detector to external detectors.
  - Flexible connections need to be rad-hard--looking at Nickel Bellows
- **Connectio**
  - Aluminu
  - Commer ... nd of Stave



Connections/Breaks/Termination

Double to Single Sided Flex



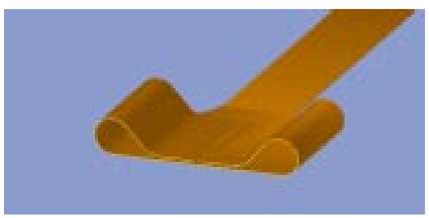
Double sided cable attaches here

Arms fold over to pick up top

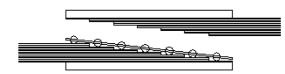
.5mm Pitch Contact used in Prototype

.25mm pitch allows for tighter access at end of stave.

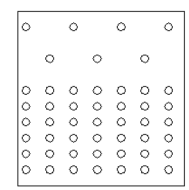
HV Creep Paths



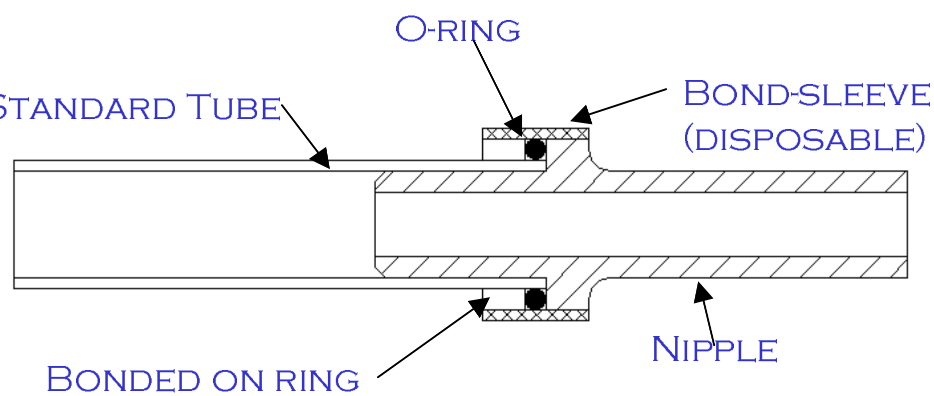
Up to 90 connections must be made at each end of every stave



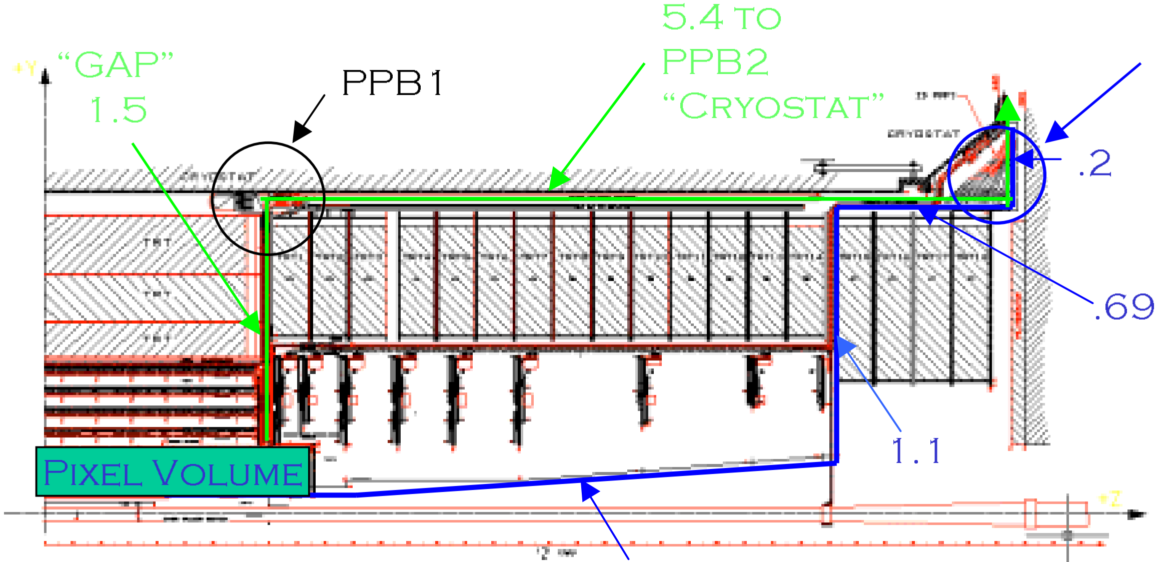
Ball Grid Array Contact Pad



Semi-permanent tube connector



A BRIEF LOOK AT EXTERNAL ROUTING



B-LAYER ROUTING IS SHOWN IN BLUE, THE REST OF THE PIXEL SERVICES ARE ROUTED ALONG THE GREEN PATH.

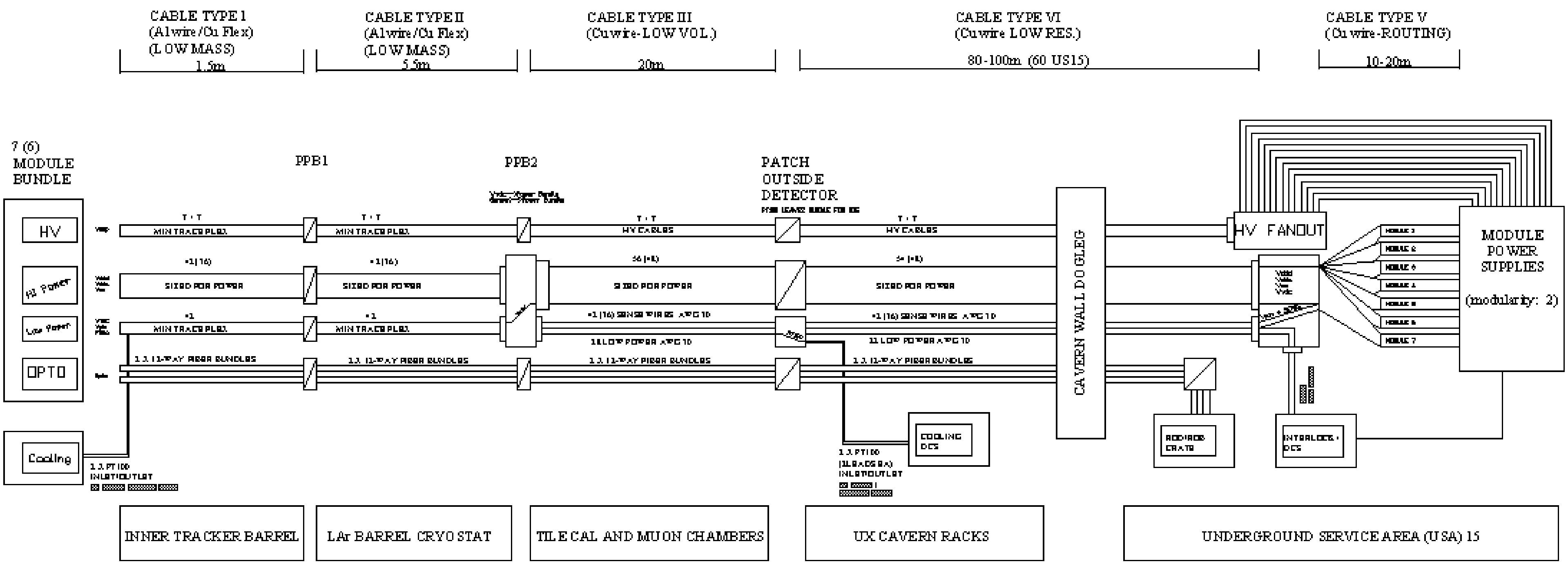
- POWER CABLES CHANGE SIZE AT PPB1 AND PPF1 FROM "TYPE 1" TO "TYPE 2"
- TYPE 1 IS SIZED FOR THE 1.5M RUN FROM INSIDE PIXEL VOLUME TO PPB1 THROUGH "GAP".
- TYPE 2 IS SIZED BASED ON ONLY 2.7M OF THE 5.4M RUN FROM PPB1 TO PPB2 ALONG "CRYOSTAT".
- THESE REGIONS WERE DEEMED MOST CRITICAL FOR BOTH SPACE AND DISSIPATION REASONS

POWER CABLES WERE SIZED BASED ON ACCEPTABLE VOLTAGE DROPS FOR THE GIVEN LENGTHS

B-LAYER CABLES ARE TYPE 1 CABLES OUT TO PPF1

CABLE PLANT

- **CABLES HAVE BEEN SIZED AND CONNECTORS SELECTED FOR PROTOTYPE CABLE CHAIN**
- **CABLES SELECTED BASED ON LOCAL OPTIMIZATIONS, E.G. MASS, VOLTAGE DROP**



PIXEL DETECTOR INTEGRATION
E. ANDERSSEN LBNL/CERN

LOW MASS CABLE DEFINITION

	Voltage		Current		Line Drop		Type I	Type II	Type III	Type IV	Type V	Pigtail
Power Supply	*Max*	*Nominal*	*Max*	*Nominal*	*Allowed*	*Worst Case*	*Actual*	*Actual*	*Actual*	*Actual*	*Nominal*	*Nominal*
VDD	6.000	3	2	1.5	2	2.046	0.409	0.371	0.269	0.547	0.200	0.250
VDDA	6.000	3	1.2	0.9	2	2.039	0.246	0.569	0.253	0.522	0.200	0.250
VCC	4.000	1.5	1.5	1.2	2	2.030	0.327	0.478	0.337	0.437	0.200	0.250
VVDC	-	4	-	0.2	-	2.530	0.415	1.493	0.056	0.116	0.200	0.250
VPIN	-	10	-	0.0005	-	-	-	-				
VDEPL	-	700	0.004	-	-	-	-	-				

Power Supply Current figures are for two modules in parallel. Line drops are two way, supply/return

TYPE I (7 Module) (ΔV nominal 0.4V/1.5m)

Cable	Circuit Name	Material/ Area for Nom ΔV mm^2	Nearest AWG	Trace Width mm	Conductor Area mm^2	ΔV	quantity	OD or Thickness mm	Width mm	PF = 2 Area mm^2	TYPE 1 Bundle Summary Packing Factor 2		
HV		*Copper Flex*			Cu						Width	Thickness	**Area**
	Vdepl	-		0.5	0.0125		14	0.10	3.00	8.40	21	0.4	**8.4**
Hi Power		*Aluminum Wire*			Al								
	Vddd	0.178	26	-	0.1550	0.409	14	0.51	0.51	7.28	42 Cables, each 0.51mmOD,		
	Vdda	0.076	26	-	0.1550	0.246	14	0.51	0.51	7.28	likely twisted pair.		
	Vcc	0.102	26	-	0.1550	0.327	14	0.51	0.51	7.28		**Area:**	**21.85**
Low Power		*Copper Flex*			Cu								
	Vvdc	-		0.5	0.0125	0.415	14	0.10	1.00	2.80			
Flex Foil	*Vpin*	-		0.5	0.0125	-	14	0.10	1.00	2.80			
0.025	*PT100 Module*	-		0.5	0.0125	-	14	0.10	1.00	2.80	Width	Thickness	**Area**
mm	*PT100 Cooling*	-		0.5	0.0125	-	0	0.10	1.00	0.00	21	0.4	**8.40**
OPTO		12-way Bundle									Width	Thickness	**Area**
	Fiber bundle			-	-	-	2	0.32	3.06	1.96	3.06	0.64	**1.96**

TYPE II (7 Module) (ΔV nominal 0.4V/5.4m)

Cable	Circuit Name	Material/ Area for Nom ΔV mm^2	Nearest AWG	Trace Width mm	Conductor Area mm^2	ΔV	quantity	OD or Thickness mm	Width mm	PF = 2 Area mm^2	TYPE 1 Bundle Summary Packing Factor 2		
HV		*Copper Flex*			Cu						Width	Thickness	**Area**
	Vdepl	-		0.5	0.0125		14	0.10	3.00	8.40	21	0.4	**8.40**
Hi Power		*Aluminum Wire*			Al						42 Cables, 7pairs each of		
	Vddd	0.570	20	-	0.6150	0.371	14	1.02	1.02	29.13	20,22and 24AWG wire, likely		
	Vdda	0.341	24	-	0.2410	0.569	14	0.64	0.64	11.29	twisted pair.		
	Vcc	0.451	22	-	0.3820	0.478	14	0.80	0.80	17.92		**Area:**	**58.34**
Low Power		*Copper Flex*			Cu								
	Vvdc	-		0.5	0.0125	1.493	14	0.10	1.00	2.80			
Flex Foil	*Vpin*	-		0.5	0.0125	-	14	0.10	1.00	2.80			
0.025	*PT100 Module*	-		0.5	0.0125	-	14	0.10	1.00	2.80	Width	Thickness	**Area**
mm	*PT100 Cooling*	-		0.5	0.0125	-	0	0.10	1.00	0.00	21	0.4	**8.40**
OPTO		12-way Bundle									Width	Thickness	**Area**
	Fiber bundle			-	-	-	2	0.32	3.06	1.96	3.06	0.64	**1.96**

Conventional Cables

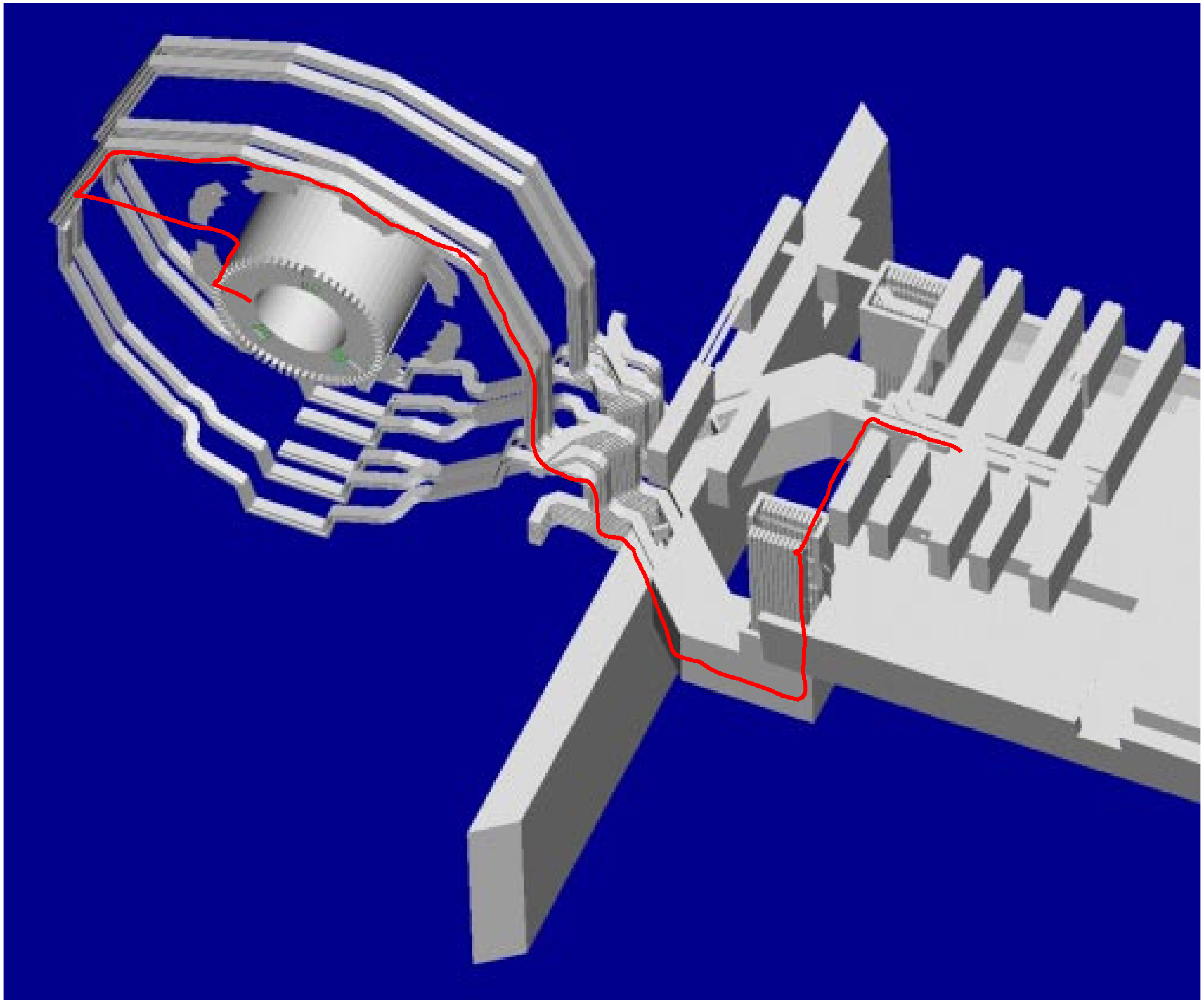
TYPE III (7 Module) (ΔV nominal 0.25V/20m)

Cable	Circuit Name	Material/ Area for Nom ΔV mm^2	Nearest AWG	Trace Width mm	Conductor Area mm^2	ΔV	quantity	OD or Thickness mm	Width mm	PF = 2 Area mm^2	TYPE 1 Bundle Summary Packing Factor 2		
HV		*Copper Wire*			Cu						Width	Thickness	**Area**
	Vdepl	-					7	1.00	1.00	14.00	7	2	**14**
Hi Power		*Copper Wire*			Cu						56 Cables, 42 pairs 16AWG and 14 pairs 14AWG wire likely twisted pair.		
	Vddd	0.178	14	-	1.9300	0.269	14	1.80	1.80	90.72			
	Vdda	0.076	16	-	1.2300	0.253	14	1.44	1.44	58.06			
	Vcc	-	16	-	1.2300	0.337	14	1.44	1.44	58.06			
	Vvdc	0.102	16	-	1.2300	0.056	14	1.44	1.44	58.06		**Area:**	**264.90**
Low Power		*Copper Wire*			Cu								
	Vpin	-	30	-		-	14	0.31	0.31	2.60	70 Cables each 0.305mmOD, 30AWG wire, likely twisted pair		
	SENSE	-	30	-		-	42	0.31	0.31	7.81			
	PT100 Module	-	30	-		-	14	0.31	0.31	2.60			**Area**
	PT100 Cooling	-	30	-		-	0	0.31	0.31	0.00			**13.02**
OPTO		12-way Bundle									Width	Thickness	**Area**
	Fiber bundle			-	-	-	2	0.32	3.06	1.96	3.06	0.64	**1.96**

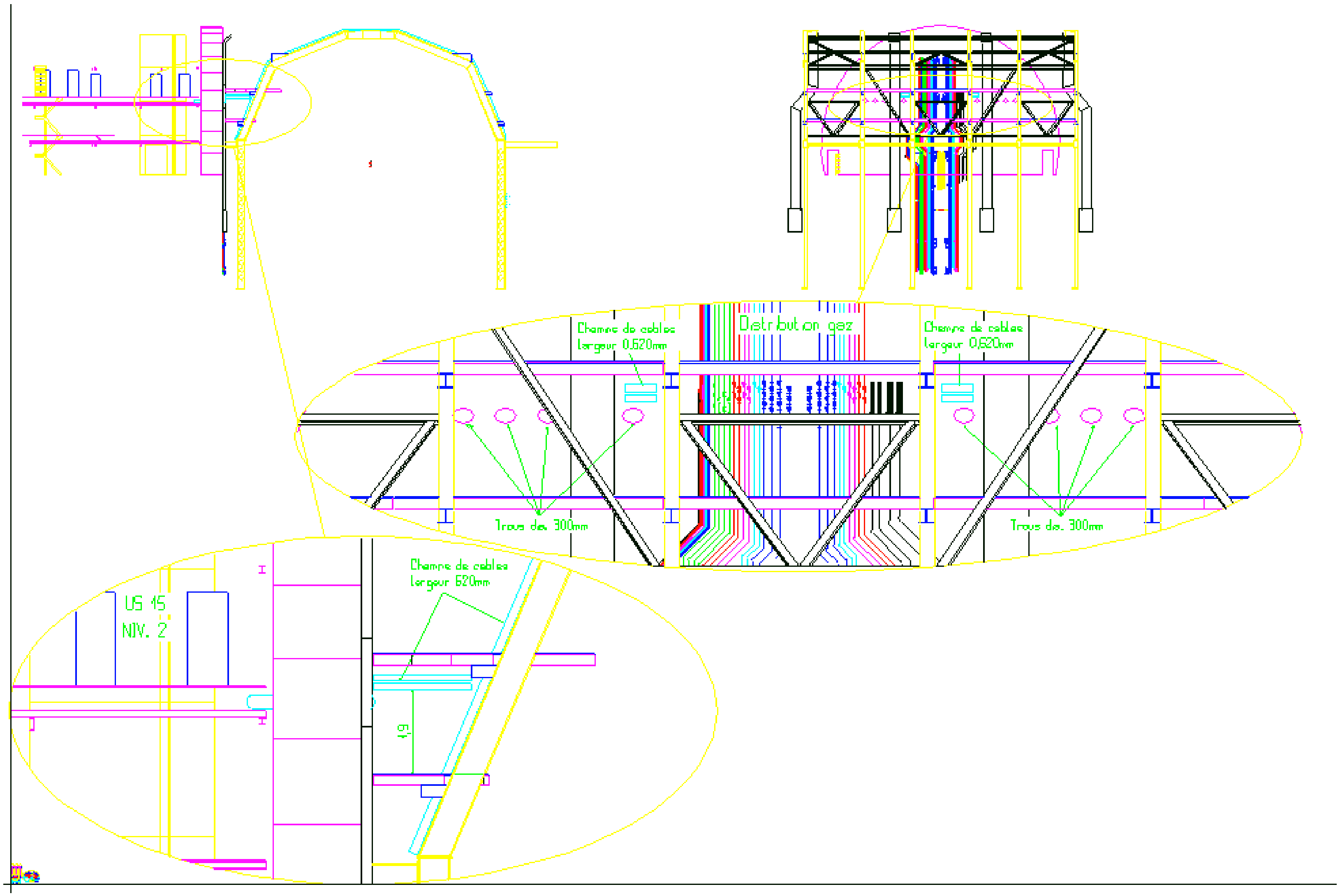
TYPE IV (7 Module) (ΔV nominal 0.50V/100m)

Cable	Circuit Name	Material/ Area for Nom ΔV mm^2	Nearest AWG	Trace Width mm	Conductor Area mm^2	ΔV	quantity	OD or Thickness mm	Width mm	PF = 2 Area mm^2	TYPE 1 Bundle Summary Packing Factor 2		
HV		*Copper Wire*			Cu						Width	Thickness	**Area**
	Vdepl	-					7	1.00	1.00	14.00	7	2	**14**
Hi Power		*Copper Wire*			Cu								
	Vddd	0.178	10	-	4.7400	0.547	14	2.83	2.83	224.25	54 Cables, 14 pairs each 12 and 10 AWG wire likely twisted pair.		
	Vdda	0.076	12	-	2.9800	0.522	14	2.24	2.24	140.49			
	Vcc	-	10	-	4.7400	0.437	14	2.83	2.83	224.25			
	Vvdc	0.102	12	-	2.9800	0.116	14	2.24	2.24	140.49		**Area:**	**729.48**
Low Power		*Copper Wire*			Cu								
	Vpin	-	30	-		-	14	0.31	0.31	2.60	70 Cables each 0.305mmOD, 30AWG wire, likely twisted pair		
	SENSE	-	30	-		-	42	0.31	0.31	7.81			
	PT100 Module	-	30	-		-	14	0.31	0.31	2.60			**Area**
	PT100 Cooling	-	30	-		-	0	0.31	0.31	0.00			**13.02**
OPTO		12-way Bundle									Width	Thickness	**Area**
	Fiber bundle			-	-	-	2	0.32	3.06	1.96	3.06	0.64	**1.96**

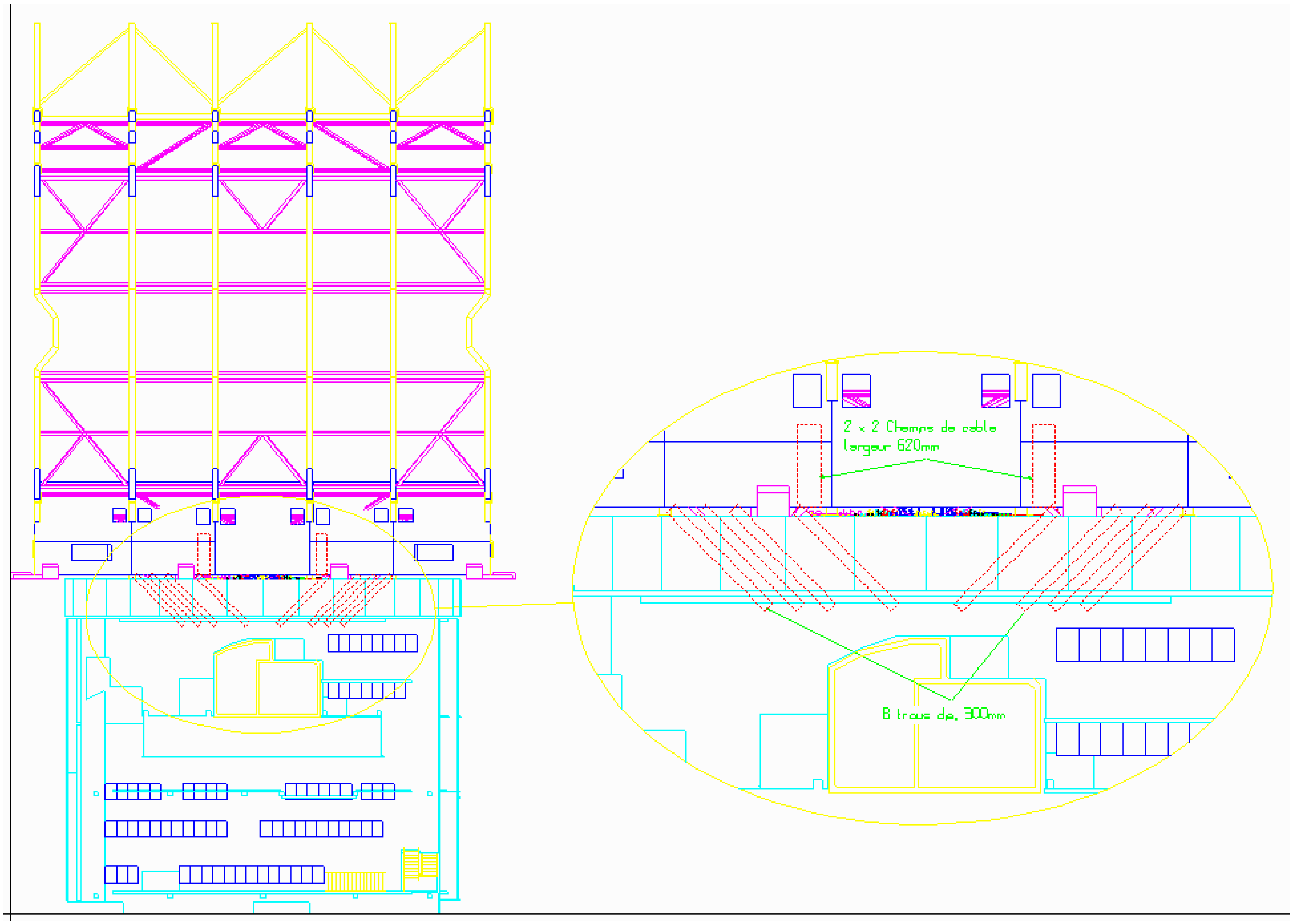
Worst Case Routing to the Racks (USA15)



US 15 Elevation



US15 as possible Rack Location



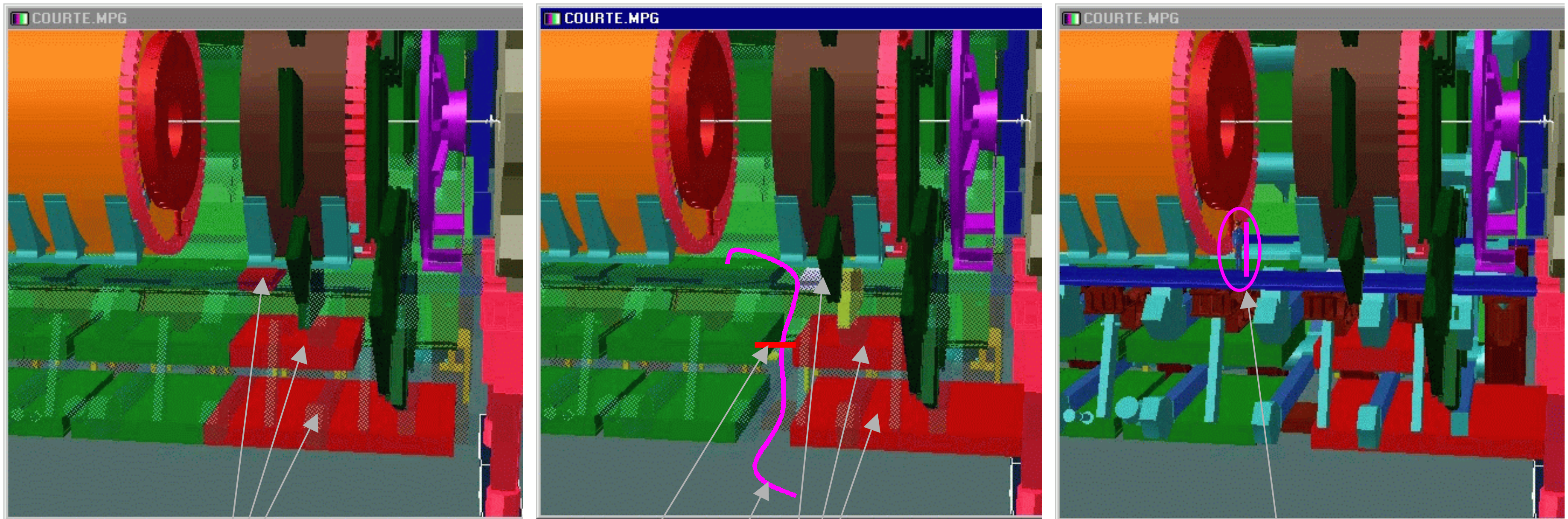
B-Layer Installation

- **Requirements/Necessity**
  - Beam Pipe bake-out
  - Finite Detector Life
- **Access**
  - Short Opening Scenario
- **Constraints**
  - Space limits
  - Alignment Grid in Forward SCT
  - Thermal Barrier
- **Tooling**
  - Description of Tooling
- **Beampipe**
  - Proposed changes to make installation easier

Removal of B-Layer is Necessary

- **Bake-out of Beam pipe**
  - Small Beampipe diameter leads to Vacuum instability
  - Bake out jacket will not fit with B-Layer in place
  - Bake out temperatures would destroy B-Layer
  - Bake out is necessary whenever vacuum is broken
- **Finite life of B-Layer**
  - The B-Layer is expected to survive the first 5 - 6 years as LHC ramps up luminosity
  - At full LHC Luminosity, expected life of the B-Layer could be as short as one year, but new data indicates that this may be excessive

ACCESS TO B-LAYER



1 METER

CHAMBERS INDICATED IN RED, CLOSED POSITION

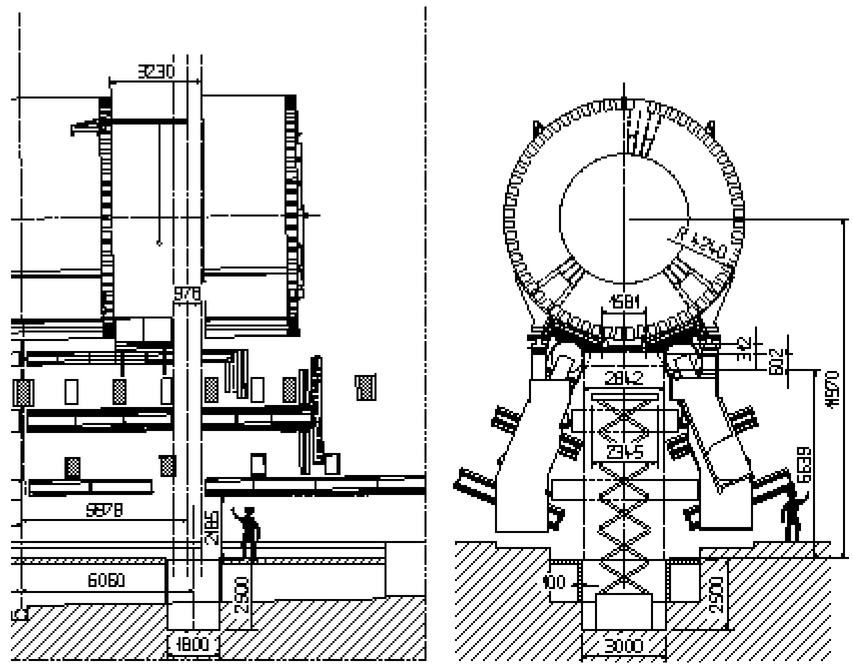
ACCESS

CHAMBERS IN OPEN POSITIONS
SMALLEST OPENING: 870MM

REFERENCE MAN-- MAGENTA BAR OF SAME HEIGHT SHOWN NEXT TO HIM

Constraints and Requirements

- **Work-Space Limitations**
  - Access Port is .7 X 1.5 Meters
  - Available Length is 3 Meters
  - Tool must weigh less than 200kg
- **Internal Constraints**
  - Beam pipe support at - 800mm
  - Alignment Paths in SCT Forward
- **Thermal Barriers**
  - 13 Deg C Dewpoint Cavern Air
  - Warm-up scenarios
- **Time**
  - Short Opening Schedule+
- **Common Tooling With Bake-Out Jacket should one be required**

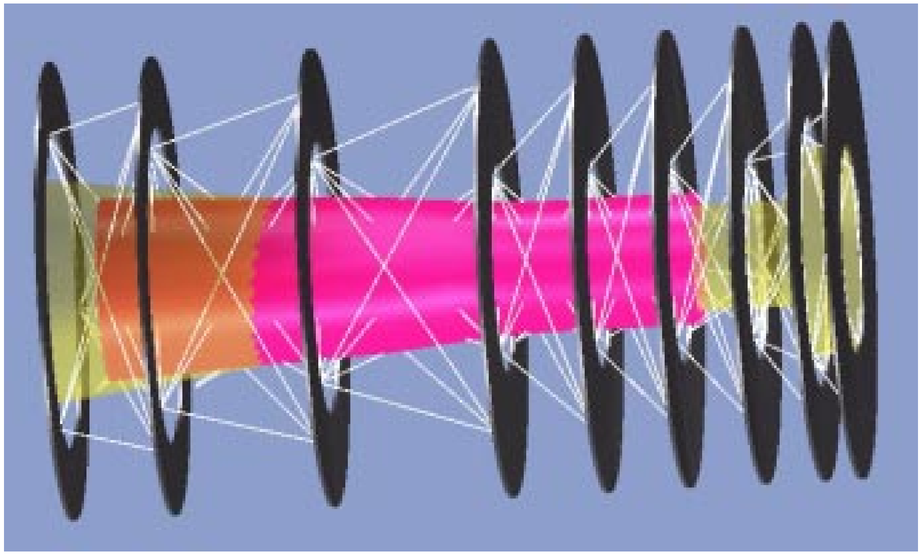


Thermal Barrier Requirements

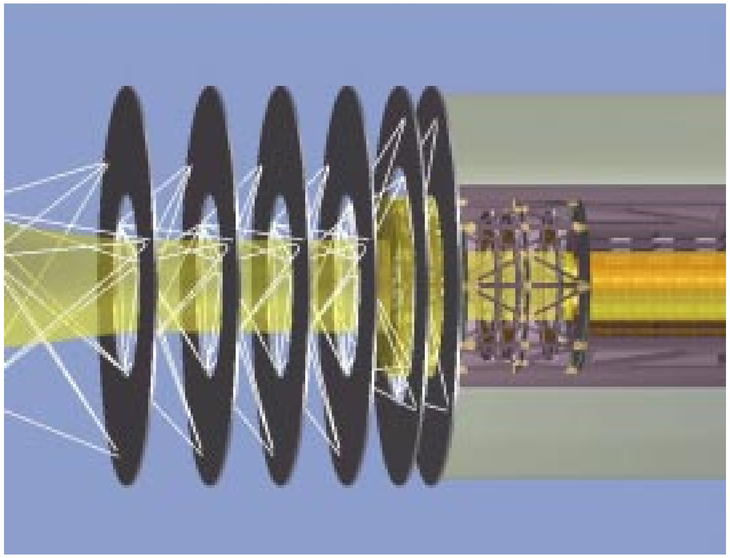
- The Volume for installing the B-Layer is filled with Cavern Air -- Dewpoint of 13 Deg C
- Detector Volume is as low as -15 Deg C-- Thermal Barrier must stand-off ~30 Deg C thermal gradient in minimal space
- Structure of Thermal Barrier minimized for X0
- No Condensation is allowed on any surface within the detector
- Design requires Knowledge of Installation and Removal Scenarios, Times and failure modes

These requirements lead to an active thermal barrier requiring heat input on the exterior surfaces to meet boundary conditions

Thermal Barriers and Forward Region Space

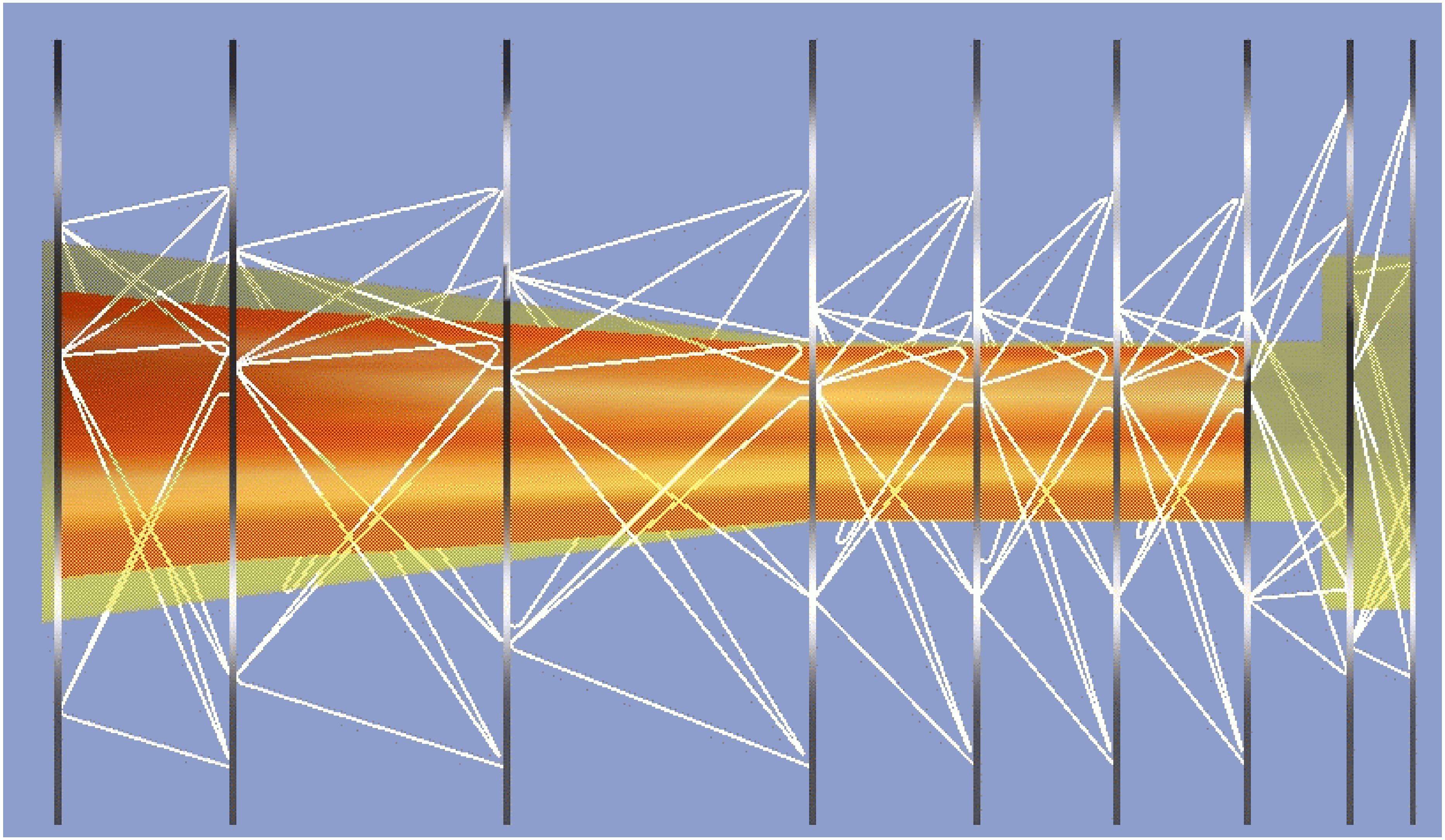


Gold "Cylinder" cone is Forward Region Thermal Barrier. Red cone is Inner Envelope of Current Alignment Grid.

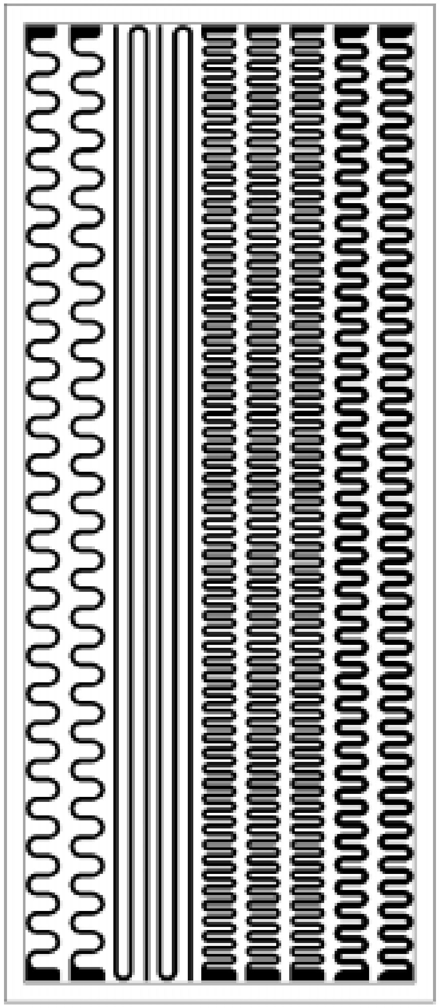


B-Layer tooling must fit inside of Thermal Barrier, which must fit inside of Forward Alignment Grid

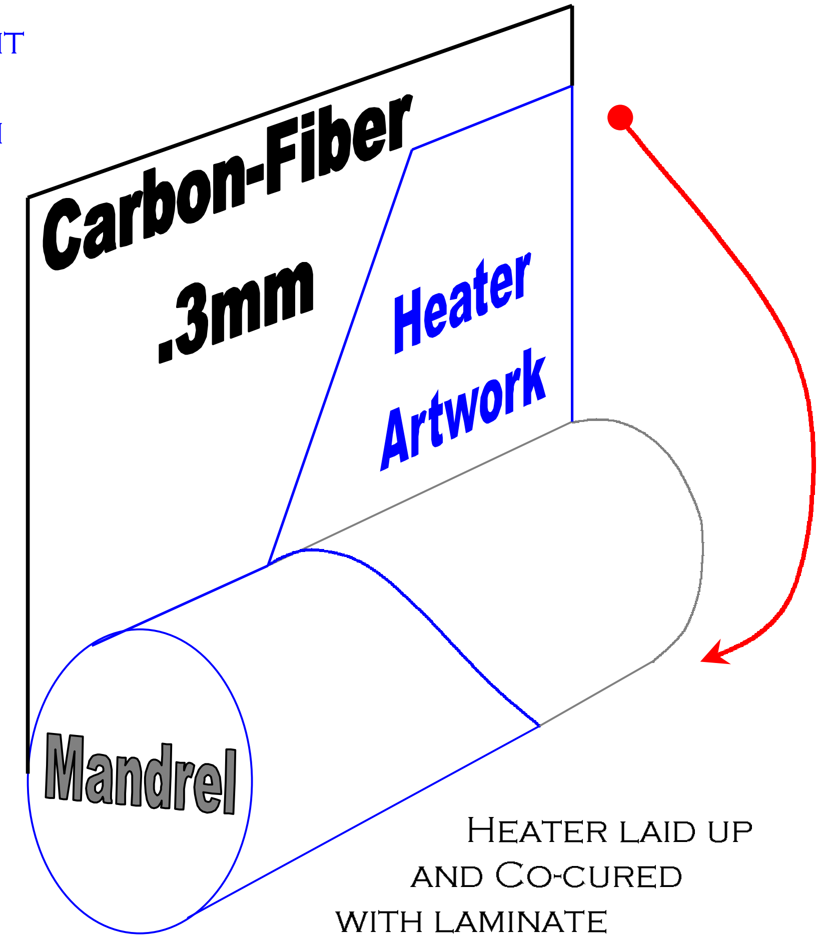
Thermal Barrier is designed to have a warm exterior surface above the dewpoint.
To achieve this with a minimum of thickness and material the exterior is heated actively.



Thermal Barrier Construction



Test Artwork for current Limit testing. Left Sets have equivalent radiation lengths. Slightly more heat is required at penetrations and boundaries



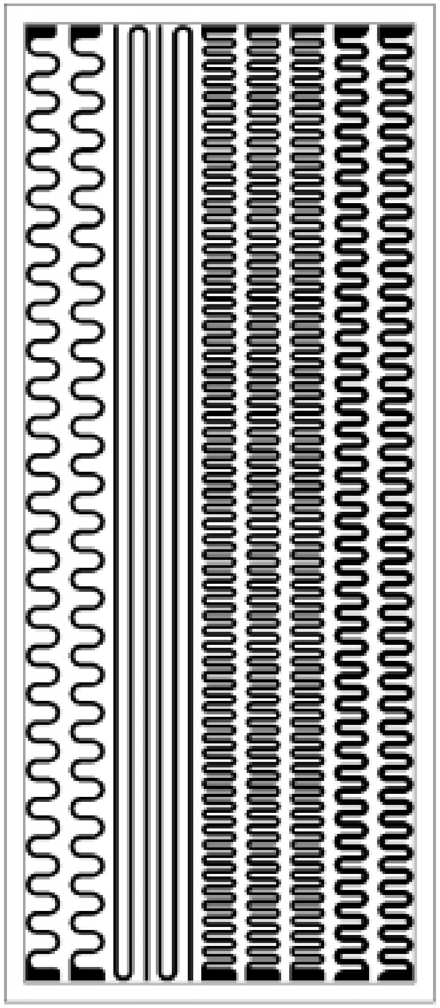
Test program on:
Double-Sided Al-Kapton
20micron AL
50micron Kapton

Heater patterns etched in one side

Heater laid up and Co-cured with laminate

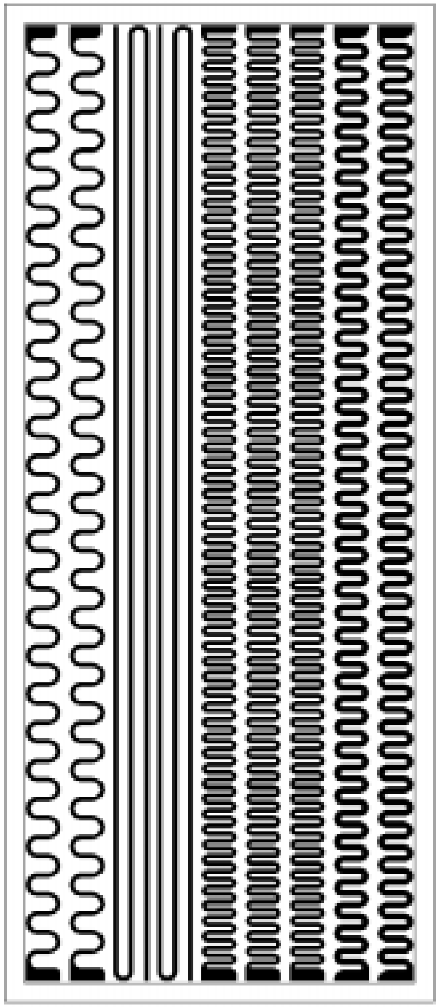
Design goal:
1-Amp / trace
2 traces / square cm
(traces have 5mm pitch)

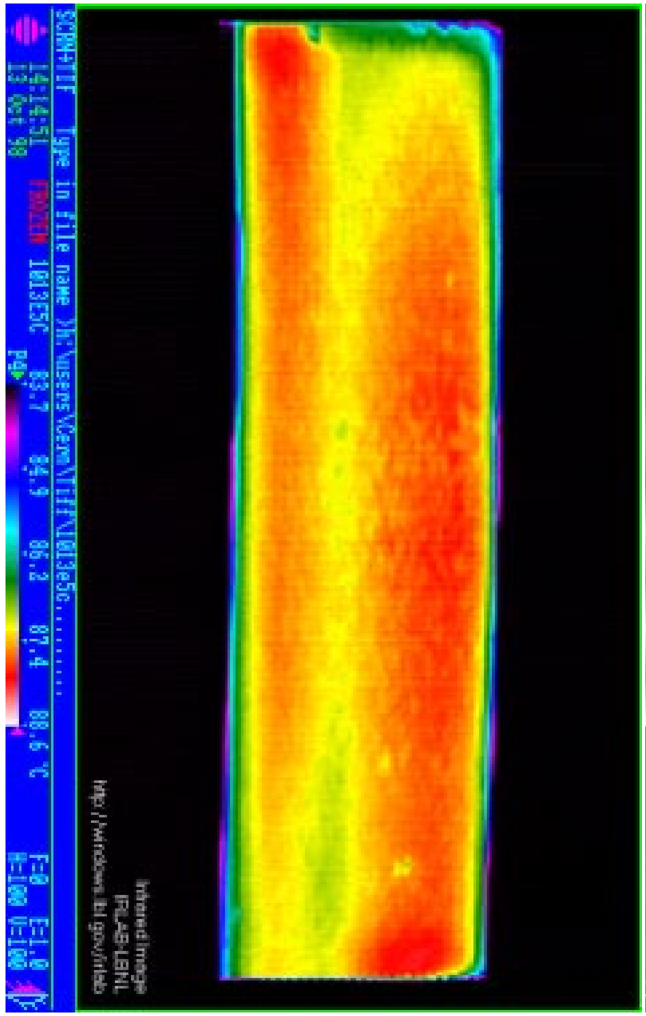
Test Results

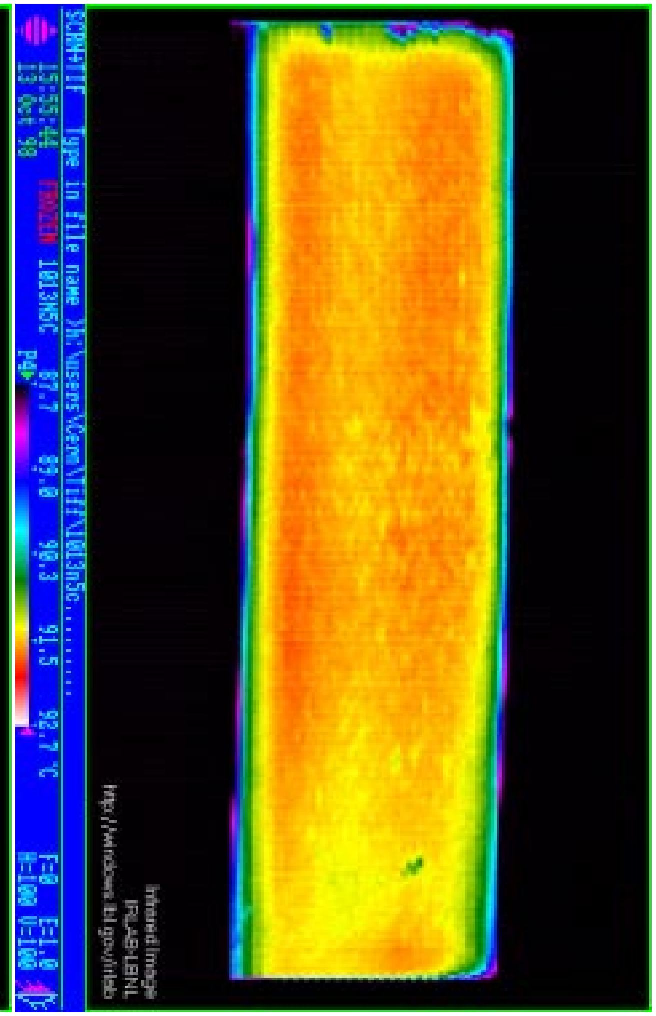


Test heaters fail at over 30X the required power density
IR Camera results show uniform operating temperatures

Heater Uniformity

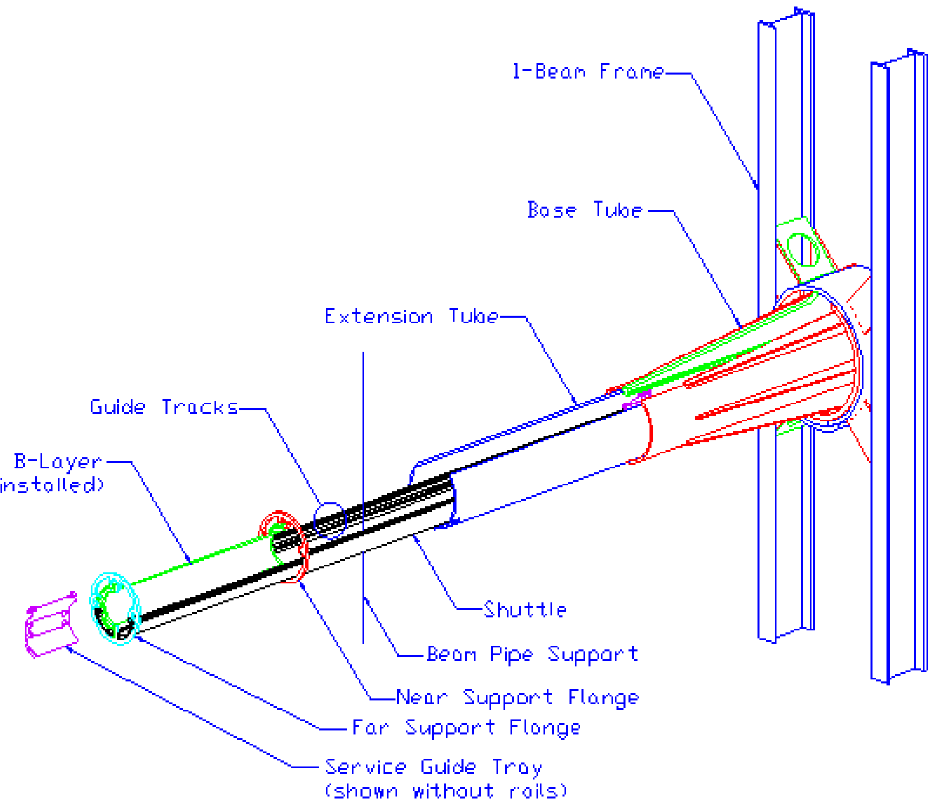




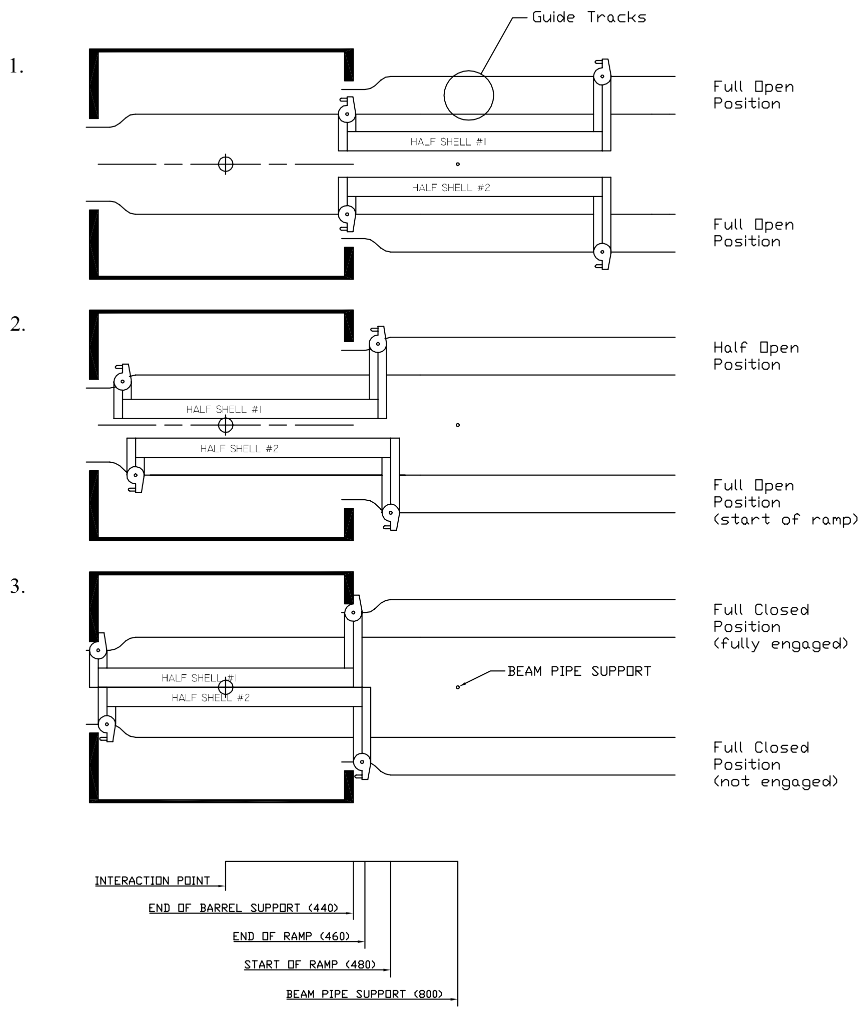


PIXEL ENGINEERING

B-Layer Installation Tooling



PRINCIPLE OF OPERATION



- B-LAYER IS INSTALLED ON SHUTTLE IN GUIDE TRACKS IN RETARDED POSITION (POSITION 1)
- B-LAYER IS ARTICULATED AROUND BEAM PIPE SUPPORT BY SLIDING IN TRACKS (POSITION 2)
- FLANGES ON B-LAYER INCLUDES REGISTRATION FOR GUIDE TRACKS AS WELL AS LOCATING PINS TO REGISTER WITH PIXEL DETECTOR (POSITION 3)

Current and Proposed Layouts

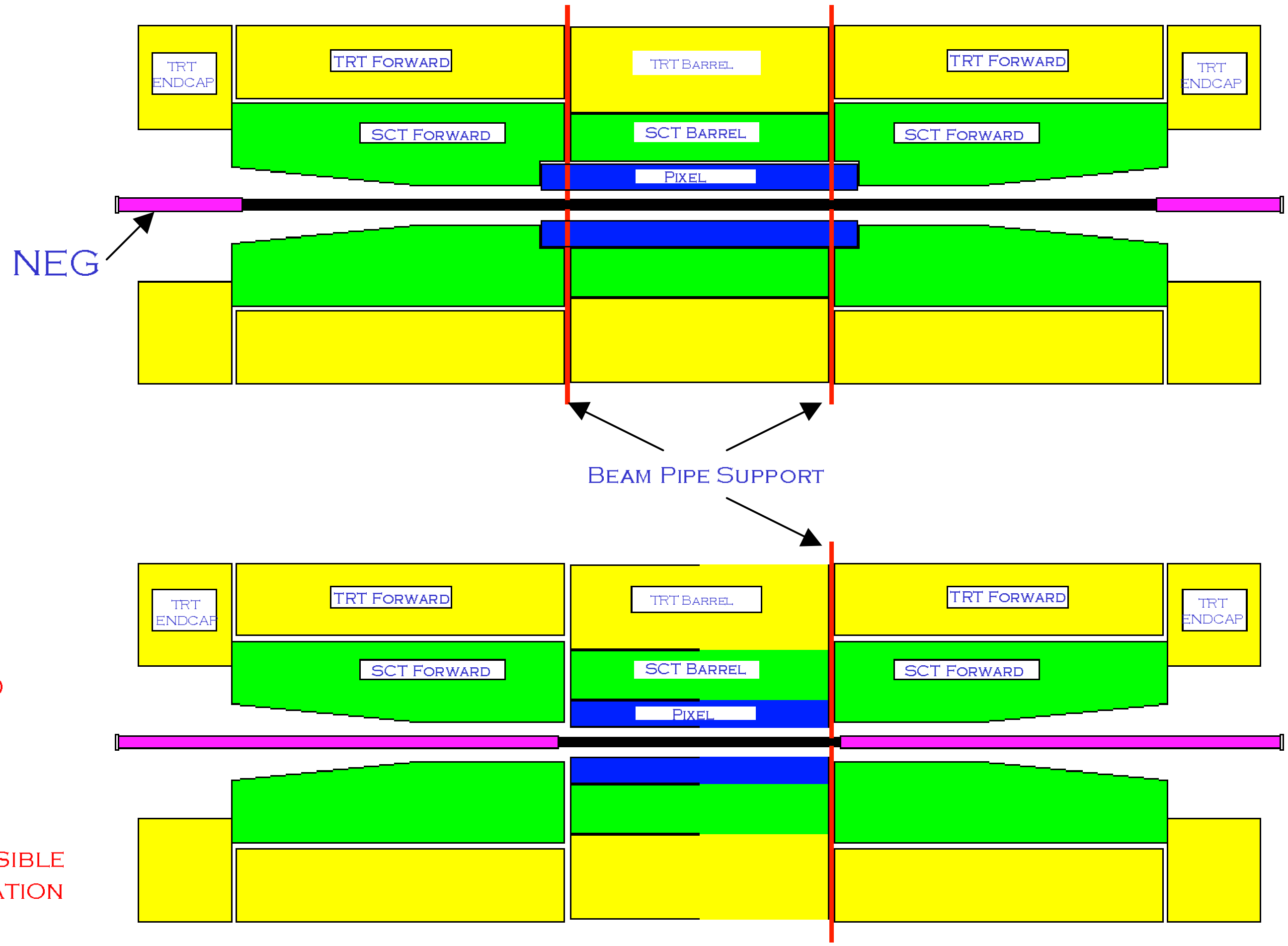
Current Layout:

- 2 Supports
- NEG at Ends

Proposed Layout

- 1 Support Removed
- NEG Extended In

Pixels shown in possible shrunken configuration
-NOT OFFICIAL



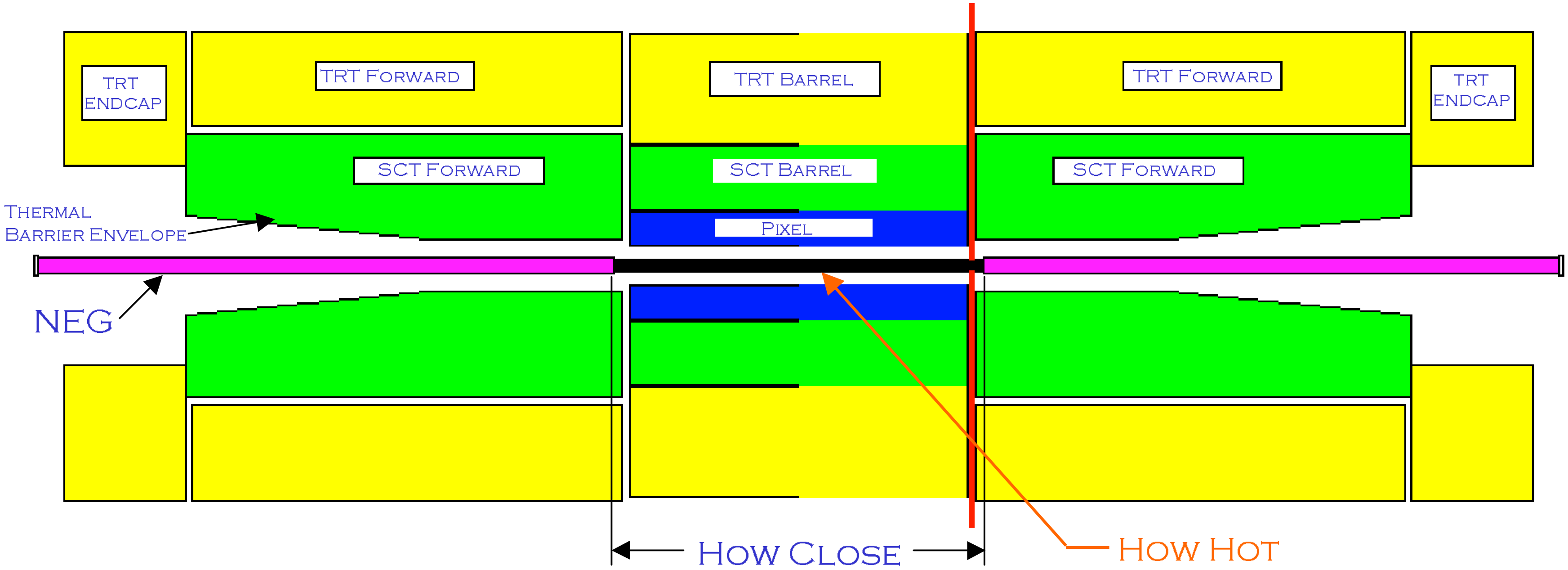
Current Layout Problems

- **B-Layer is installed in independent Half-Shells**
  - Half-shells are less rigid, so more material is required to design satisfactory B-Layer structure
  - Tooling is complex to actuate Half-Shells together Around the Beam-pipe support from 3meters away
- **B-Layer is removed whenever there is a bakeout**
  - B-Layer can last for the first 6 years of operation without removal
  - Each removal of B-Layer risks possible damage to ID
- **Frequent B-Layer removal requires Thermal Barriers**
  - B-Layer removal and bakeout require extended access to bore of Silicon Tracker and Pixels which are nominally -15 Deg C (negative)
  - Uncertainty in access times and frequency require thermal barriers to allow trackers to stay cold at all times/warm-up scenarios are ill-defined

Benefits of Proposed Layout

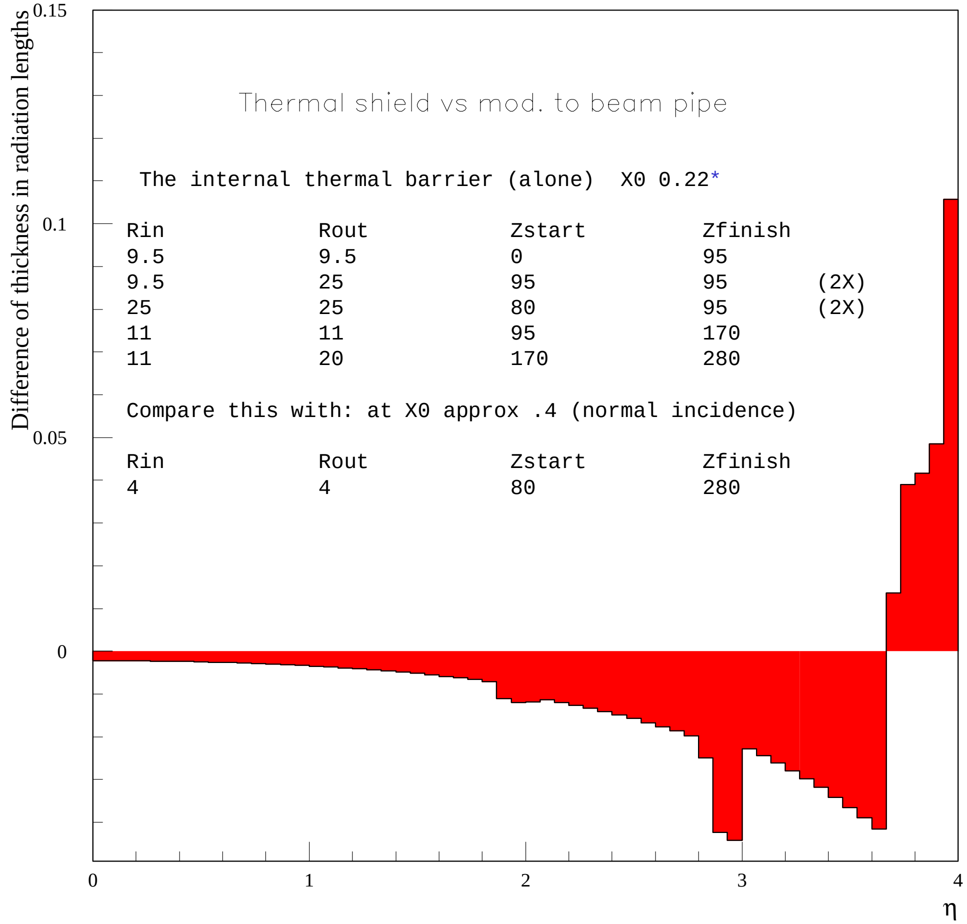
- **Removal of one Beampipe support simplifies B-Layer design**
  - B-Layer can be made full cylinder reducing mass
  - Tooling for B-Layer insertion can be simplified
    - Does not need to actuate around support
- **Extension of NEG toward IP reduces or removes Bake-out requirements**
  - Reduces frequency of B-Layer removal
  - No bakeout tooling is necessary (further simplifies B-Layer tooling)
  - Possible to do without thermal barriers
    - Due to reduction in frequency and time of accesses
- **Use of NEG Jacket to support B-Layer during installation**
  - Load/Positioning transferred to Pixel Detector upon insertion via rails
    - B-Layer is under 5kg–current estimate with services is less than 3kg
  - Simplifies further the installation tooling for B-Layer (less to bring through already impossible access port)
  - Reduces time to install B-Layer, further increasing the likelihood of removing the thermal barriers

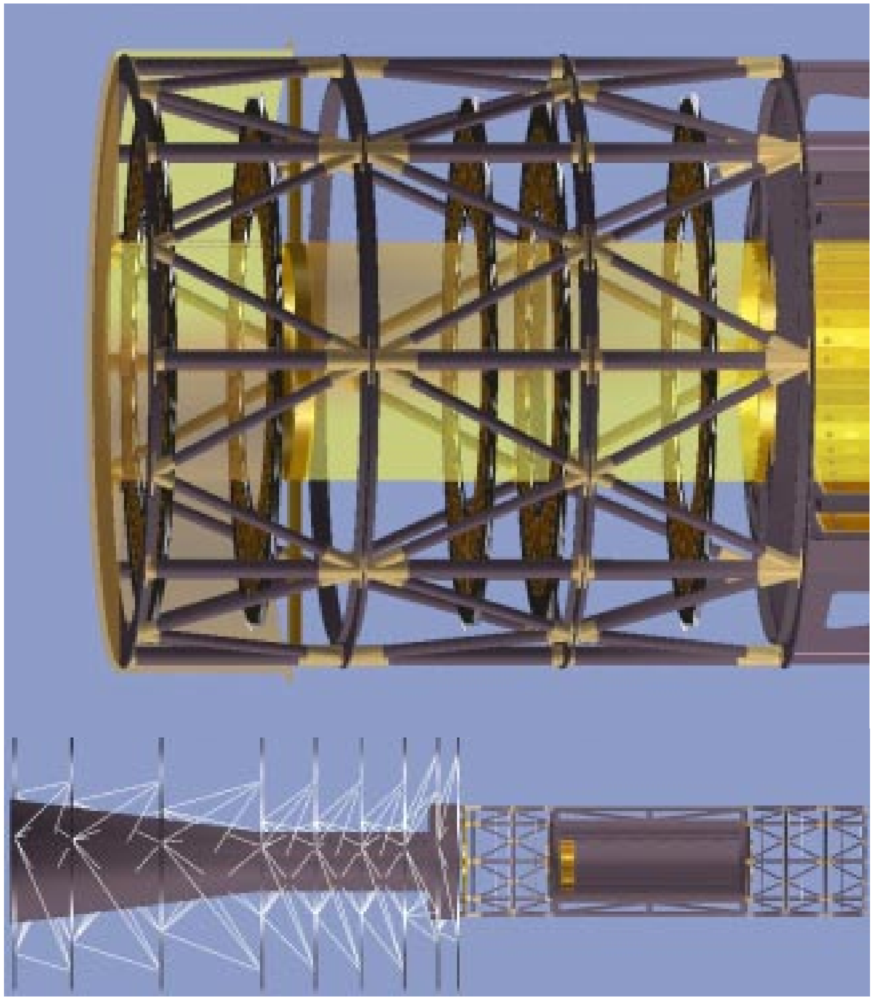
Need to Study:



- **Benefits of the New Layout are only possible if certain parameters are within acceptable limits**
  - How close to IP must the NEG come to never bakeout the beampipe?
  - During NEG reactivation, How Hot does the center section get?
  - With added mass of extended NEG, is one beampipe support feasible?
  - Can a reduction of mass at low eta be traded off with increases at high eta? (can thermal barrier requirements be relaxed/removed?)

ESTIMATED MATERIAL TRADEOFFS





*BOTTOM FOUR LINES (TAKEN ONCE) REPRESENT SCT FORWARD THERMAL BARRIER WHICH IS LIKELY TO BE .3% TO .35% X0, NOT THE .22 QUOTED, THIS IS THEREFORE SOMEWHAT CONSERVATIVE

Current Work

- **Work to study sectional stability of beam pipe**
  - Work mandated by ATLAS EB
  - Contract to be placed with Hytec Inc for feasibility study
- **Work on Mass Optimized NEG insulation Jacket/Heaters**
  - Be or CF vacuum sleeve with MLI and kapton-foil heater
  - Current designs for AE region radiate less than 15W/meter-length
- **Work to reduce Activation temperature of NEG**
  - Current study to reduce activation temp to 200C from 300C, Cern, (LBNL?)
- **Work to coat NEG on inside of Beampipe**
  - Addresses material compatibility issues
- **Thermal Barriers preliminary design with integrated heater**
  - Heaters prototyped and successfully tested
- **Work on B-Layer Design**
  - Current design optimizes rigidity of half shells, single beampipe support requires reinvestigation of this
  - Request for impact study of services coming out one side made by Pixel Community
- **Work on B-Layer Tooling**
  - Cantilever design is Pixel TDR baseline
  - Permanent Rails in Detector are being investigated

Beampipe issue Summary

- **Possible Benefits**
  - Simplify B-Layer Tooling
  - Reduce B-Layer Mass
  - Reduce B-Layer Removal Frequency
  - Remove Thermal Barriers in Inner Tracker Bore
  - Never bake out
  - Remove B-Layer only at end of detector life time
- **Tradeoffs**
  - Increased Mass in Far forward
  - Hot Beam Pipe next to B-Layer
    - Possible reduction in B-Layer Life
    - Increase in B-Layer cooling mass/complexity