PIXEL DETECTOR SERVICES

APRIL 10, 2000

LAWRENCE BERKELEY NATIONAL LABORATORY
E. ANDERSSEN, LBNL

Pixel Detector

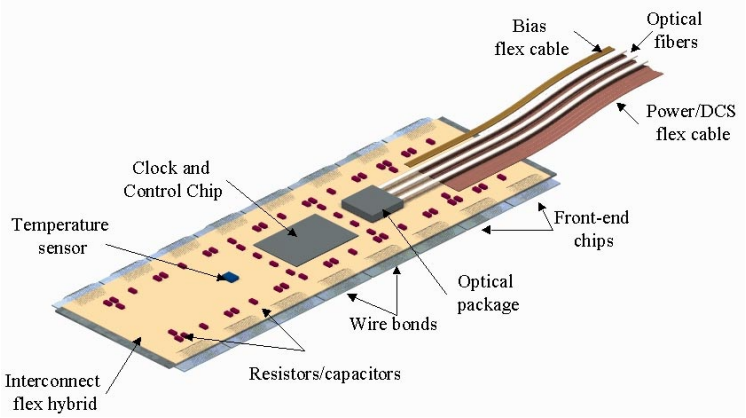
Overview

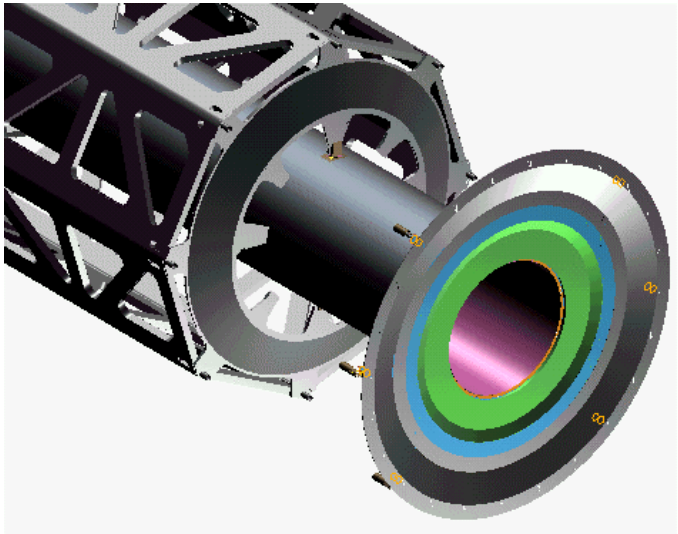
- **Pixel Detector in ATLAS**
  - What systems are serviced
  - Where do the services go
  - What are the constraints on the design
  - Who are the interfaces
- **Service Plant Description**
  - What are some of the cooling plant concerns
  - How is the cable plant defined
  - Conventional Cable design status
  - Low Mass Cable Design Status
- **Service Routing within Pixels**
  - Modeling and Prototype Status
  - Sector termination and fittings

Pixel Detector

Serviced Systems

- **Modules**
  - Electrical Power
  - High Voltage
  - Monitors/Slow Controls
  - Optical data and control links
- **Local Supports**
  - Refrigeration lines
  - Temperature sensors
- **Cooling/Thermal Sub-systems**
  - Heaters
  - Temperature monitors





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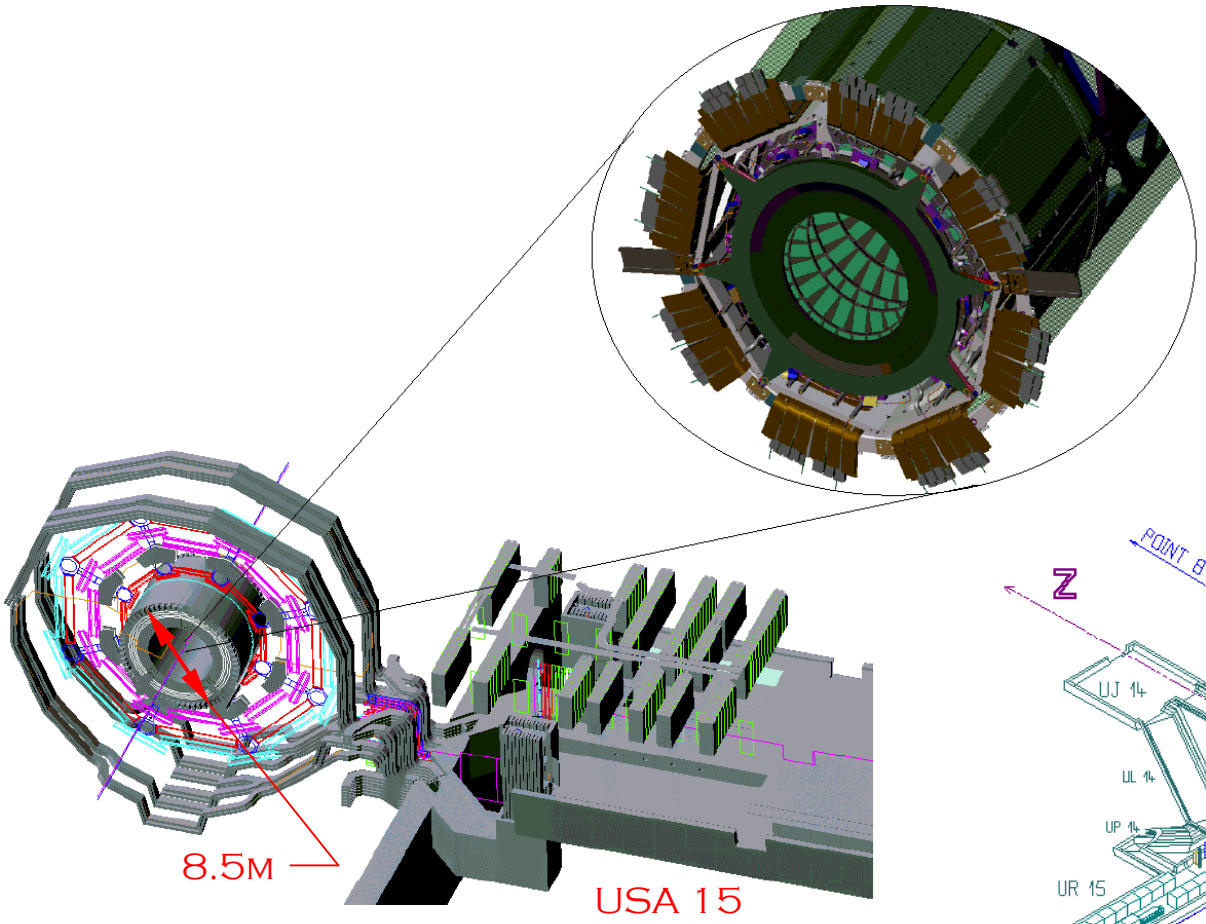
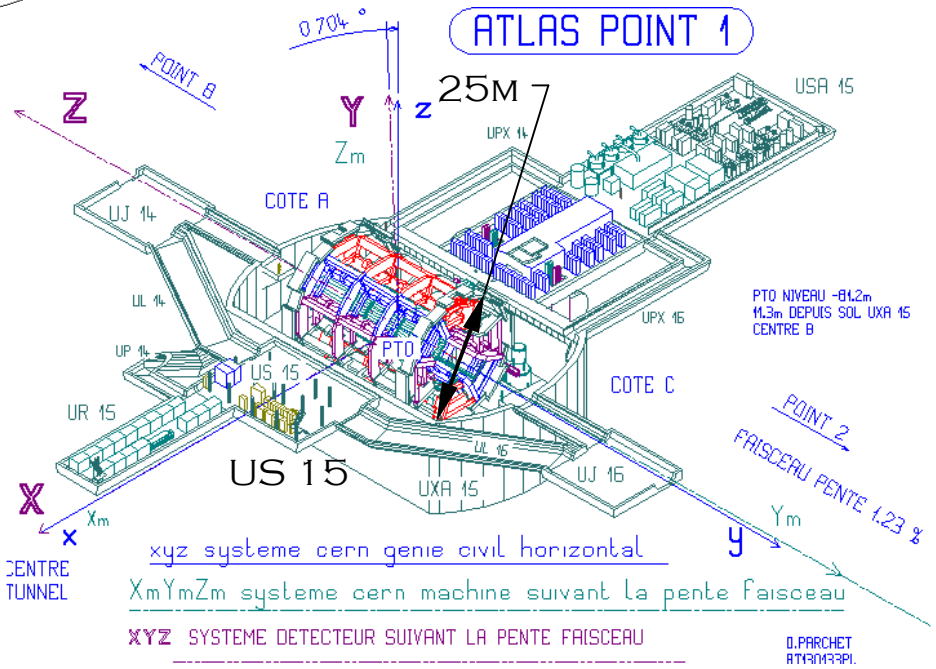
Pixels in ATLAS Cavern





Pixel Services have the furthest to go on their way to the racks.
Emphasis has been on USA 15, but interest in US 15 is growing

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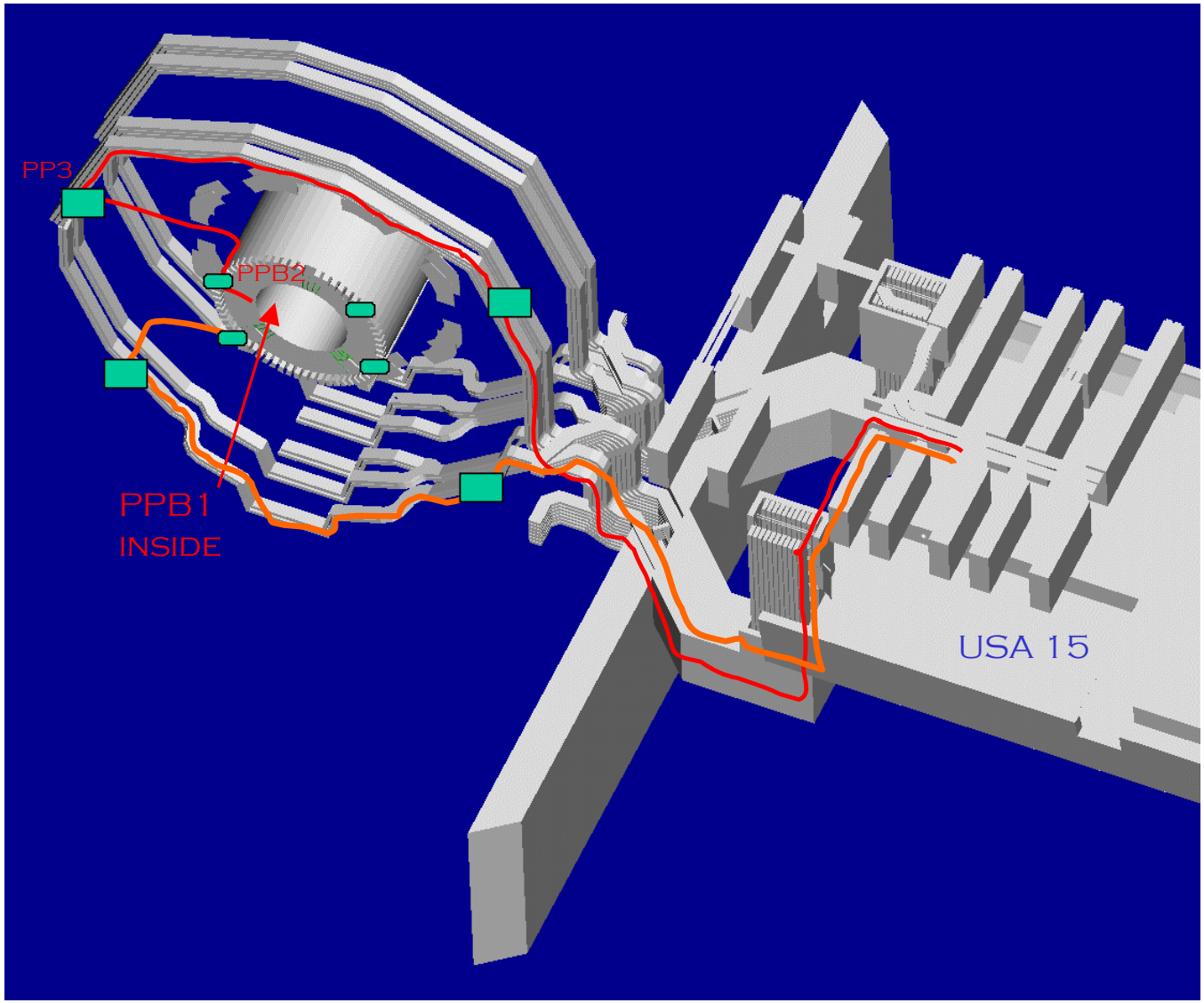
Service Plant Physical Layout



Worst case route is shown

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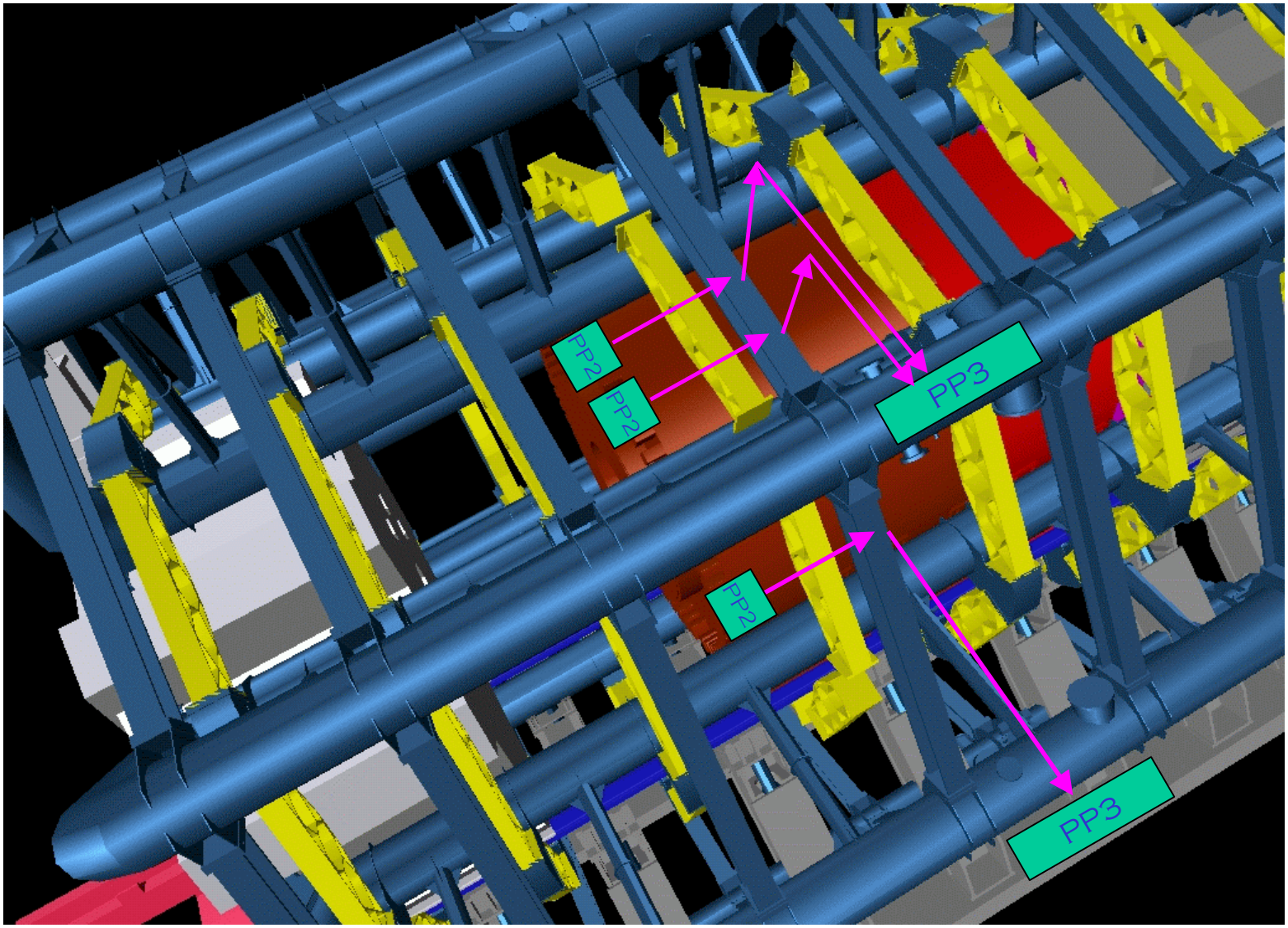
Integration within ATLAS Volume



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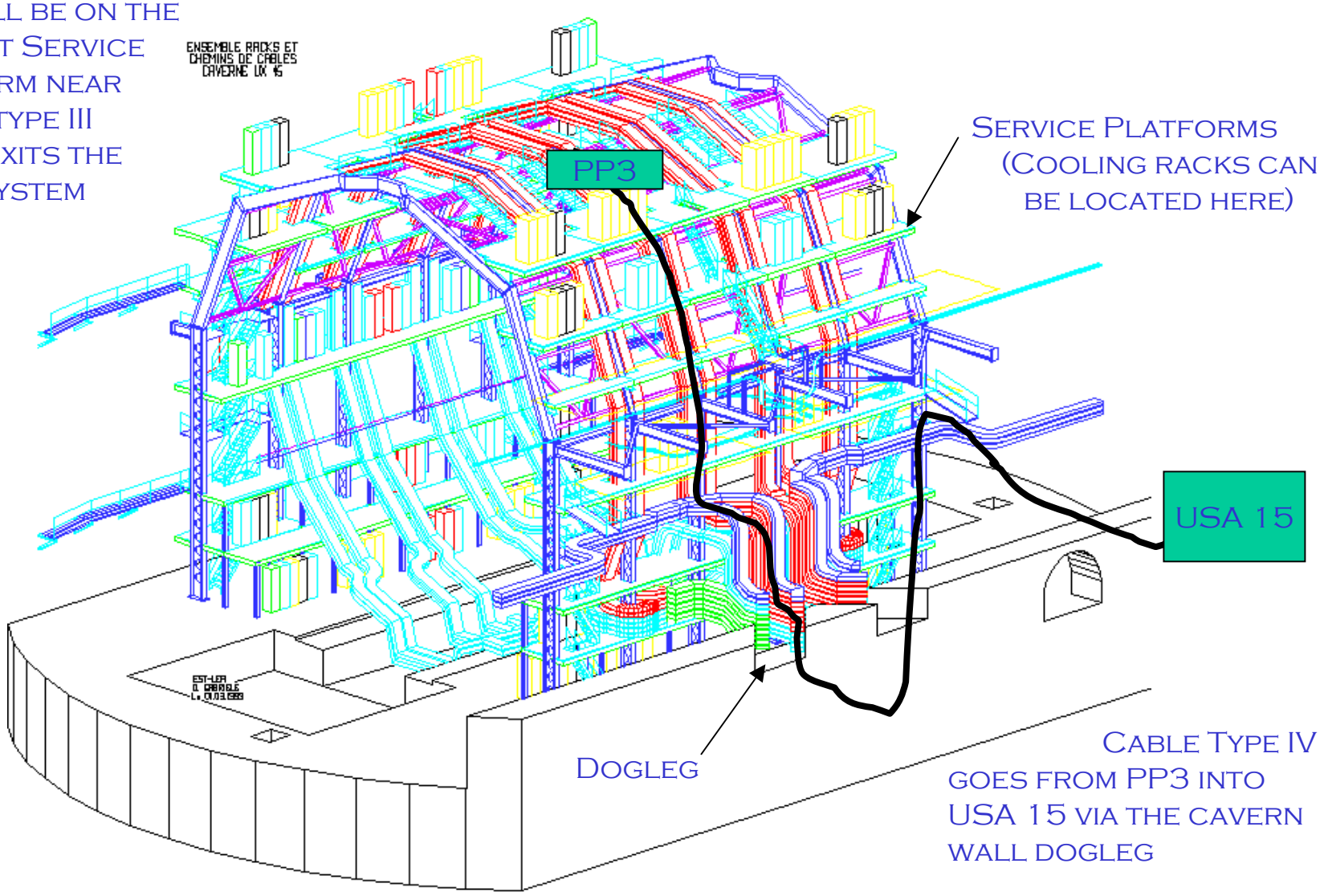
Cable Type IV Cable route

PP3 will be on the closest Service Platform near where type III cable exits the muon system



Several PP3's are distributed around the Circumference of ATLAS

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Constraints

- **Almost all constraints have an R^{-1} dependence**
  - Space
    - Patch panels are nightmarish-like the Bayou at night
  - Mass
    - Low mass cables, thin tubing at low radius
  - Power Dissipation/Thermal Neutrality
    - There is a global limit, but in the tighter spaces this is critical
- **Cooling System**
  - Static Head
    - Soft limit-traded against other constraints (optimal = 0)
  - Pressure Drop
    - Hard limit-based on physical laws
- **Power**
  - Voltage Drop
    - Electronics DV + Cable DV less than ill defined critical value (hard)
    - Power dissipation along various parts of route (soft)
- **Signal**
  - Latency
    - 132 beam crossings-latency budget of readout and trigger sum such that Fiber length needs to be monitored carefully

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Interfaces

- **Extra-Detector**
  - SCT_Pixel Thermal Volume
    - Pixel/SCT engineers
  - TRT-GAP/Cryostat Bore and Side
    - Inner Detector Services Working group (IDSWG)
  - PP2 to PP3 (through Muon Chambers)
    - ATLAS Technical Coord. Via IDSWG
  - ATLAS Cavern
    - ATLAS TC Via IDSWG
- **Intra-Detector**
  - Barrel Services
    - End of Barrel Shells
      - LBNL/Genova/Bonn
    - Frame Penetration
      - LBNL/Hytec
    - Strain Relief
      - LBNL/Hytec
  - Disk Services
    - Sector Termination
      - LBNL
    - Strain Relief
      - LBNL/Hytec
  - End of Frame
    - End-Plate Stiffener
      - LBNL/Hytec
    - Strain Relief
      - LBNL
    - Services Support Plate
      - Pixel/SCT Engineers

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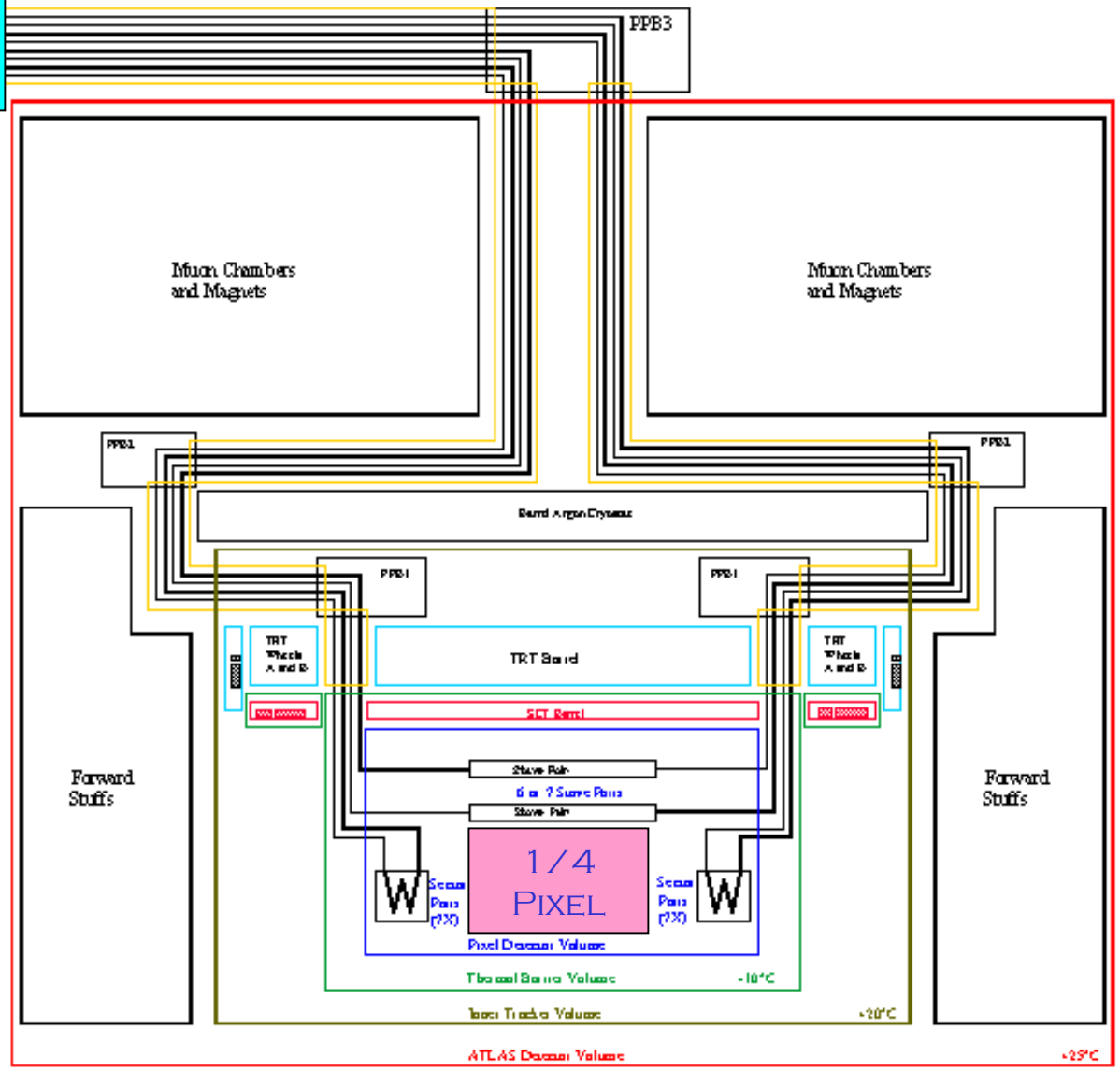
Tubing Layout

Pixel Cooling Rack



Tubes jump up in size at every patch panel, can be typed similarly by region type I to PPB1, type II to PPB2, etc...

Staves and Sectors are cooled in pairs, currently in series may revert to parallel

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Cooling Services

- **Routing of cooling tubes similar to that of cables**
- **Diameters are defined by Pixel Engineers in conjunction with Inner Detector Cooling Group at CERN**
- **Connectors preliminarily selected, but not optimal nor meeting all requirements**
  - Prototype connectors necessary at low radius
- **Auxiliary elements of tubing plant not well understood**
  - Tube insulation
  - Heat Exchanger(s)
  - Heaters
  - Temperature sensors
  - Fluid Sensors
- **Affects mostly space allocations**
  - Most of above named equipment is outside of Pixel volume, with the possible exception of heaters and temperature sensors
  - Uncertainty in Cooling plant has little impact on routing internal to pixels

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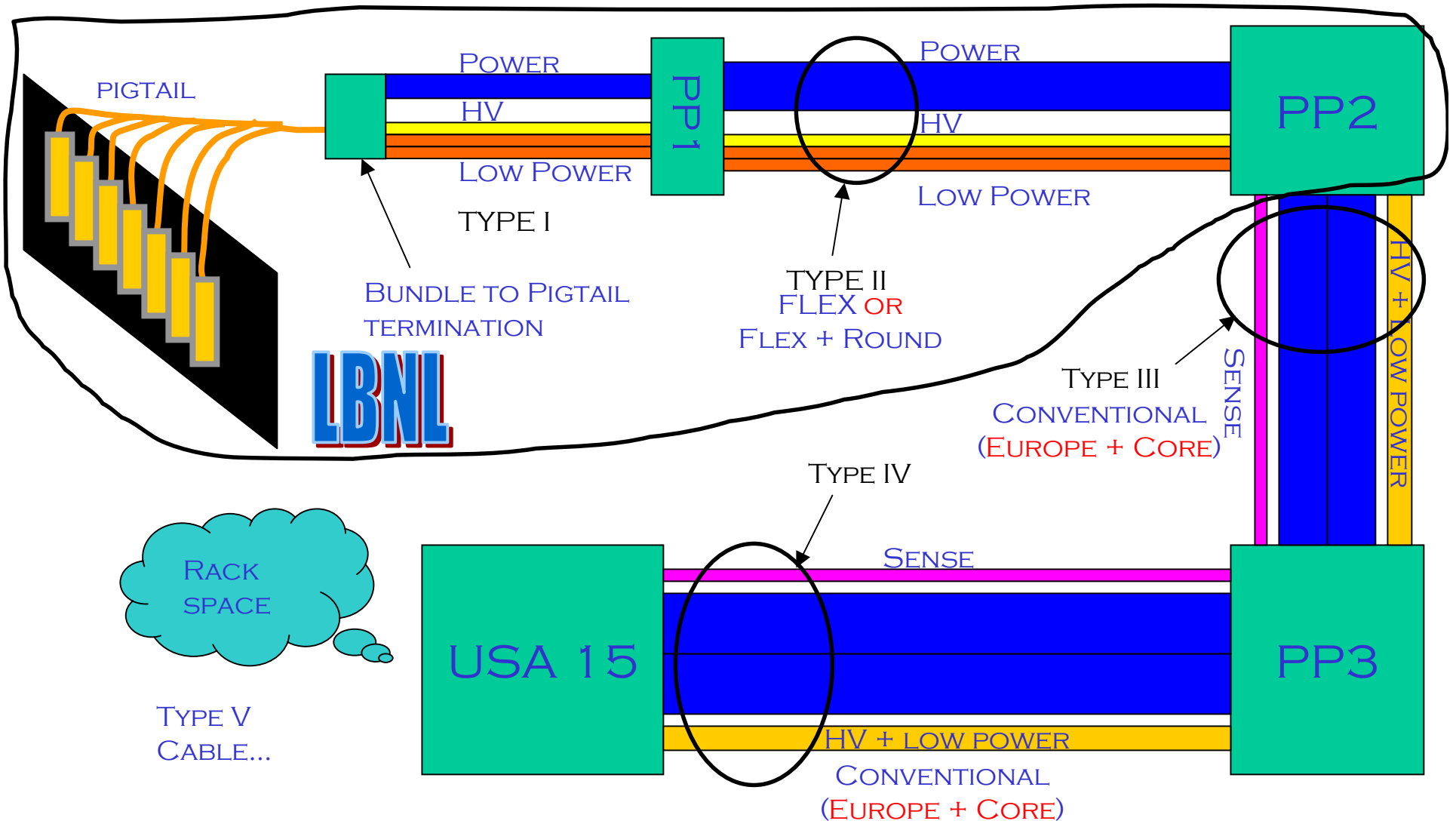
Cable Bundles Schematic



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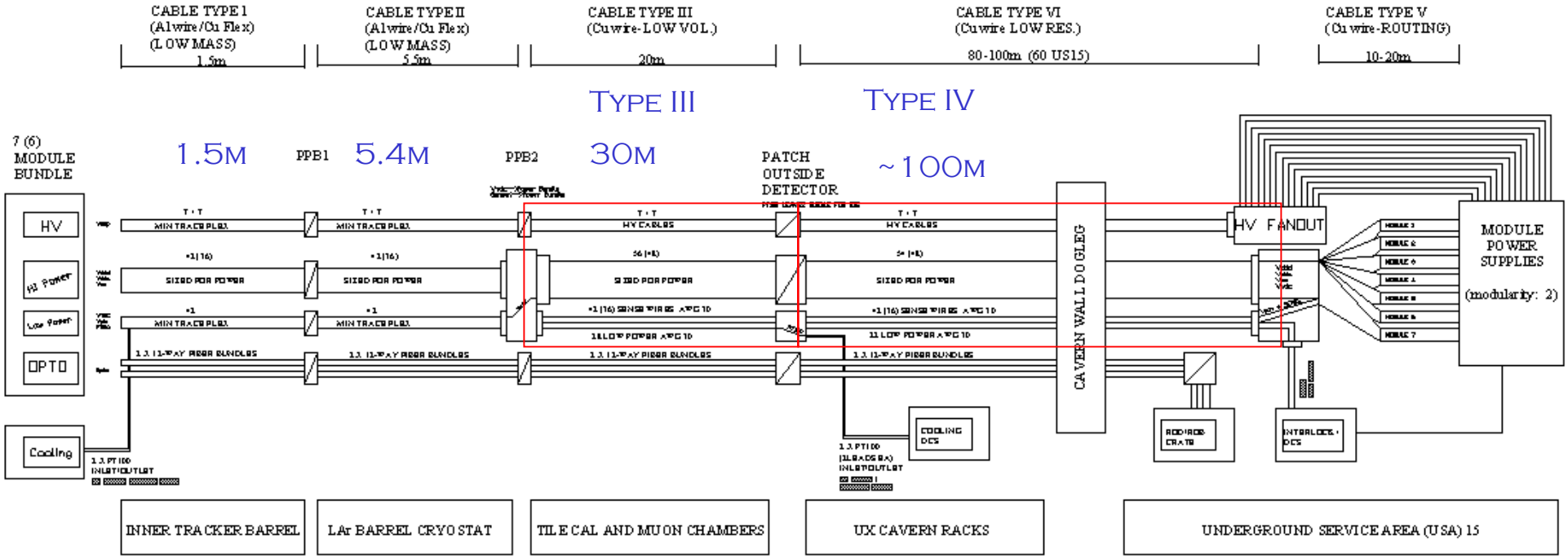
Cable Plant Overview

- **Cable Bundle services 6 or 7 modules**
  - 200 6way and 100 7 way bundles are required for the detector
- **Cable plant consists of Cable types 1-5 but not pigtail**
  - Pigtail is an HDI at end of Type 1 cable which disburses conductors to individual modules
  - Optical fibers shown here, but are routed separately from cables
- **Cables sized based on local optimizations (e.g. mass, space, voltage drop) for each region**



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Definition of Bundles

- **A bundle powers 1/2 sector or 1/2 stave (6 or 7 modules)**
- **Cables within bundle can be divided into two categories--High and low power**
- **These can use different technologies to meet requirements**
- **A bundle is made of**
  - Power Cables for 6/7 modules
    - Vdd, Vdda, Vcc, Vvdc**
    - Flex or Round wire with conductor thickness and pitch sized for current
  - Control Cables for 6/7 modules
    - PT1000 (NTC), Iset0, Iset1, Reset, Vpin, Vvdc**
    - Minimum technological thickness and pitch conductor flex cable
  - High Voltage Cables for 6/7 modules
    - Vdet
    - nominally same flex technology as control, but meets HV requirements
- ****Special traces not so easily split into the above categories:**
    - Vvdc starts with control cables (I&II) and moves to power cables at PP2
    - Sense wires do not run all the way into the detector-start at PP2 (III&IV only)

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Module/Power supply Parameters

	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	4	2	1.52	2	2.067	0.415	0.376	0.272	0.554	0.200	0.250
VDDA	6.000	3.5	1.2	1.08	2	1.942	0.295	0.267	0.303	0.626	0.200	0.250
VCCA	4.000	1.75	1.5	1.44	2	1.982	0.393	0.357	0.258	0.525	0.200	0.250
VVDC	-	4	-	0.1	-	1.490	0.207	0.746	0.028	0.058	0.200	0.250
VPIN	-	10	-	0.0005	-	-	-	-	-	-	-	-
ISET0	-	-	-	-	-	-	-	-	-	-	-	-
ISET1	-	-	-	-	-	-	-	-	-	-	-	-
RESET	-	-	-	-	-	-	-	-	-	-	-	-
VDET	-	700	0.004	-	-	-	-	-	-	-	-	-

- **Numbers used to size cables are for worst case at the end of life**
  - Assume this is correct until further notice
- **Current quoted above is for Two modules in parallel (power supply)**
  - Voltage drop is for round trip
  - Sum of "Nominal" Voltage and "Worst Case" Line Drop not to exceed 6V?
  - Note problem on VDD
- **Cable Performance requirements have not been considered**
  - EMI more work than anticipated
  - Active or Passive Elements at PP2 or PP3 hard to assess without prototypes
  - Trying to get cable electrical simulation off ground at LBNL
- **Round/Twisted/Untwisted?**
  - Will purchase and prototype each
  - Have laid in twisted out to PP3 (most space)

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Conventional Cables (III & IV)

- **Cost is turning into primary constraint**
- **ROM cost estimate recently completed**
  - Vendor quote
  - Composite comparison from catalogs
  - Comparison with SCT
- **Clearly most expensive portion of service plant**
- **Cables sized for voltage drop not to exceed 6V at chip**
  - Leads to very large conductors
- **Every voltage has separate return for EMI purposes**
  - vastly increases the number of conductors
- **Sense wires run from power supplies up to PP2 only**
  - Power supply currently does not use sense wires
- **Must meet CERN fire safety regulations**
  - Leads to exotic insulator materials
  - Or: Requires testing of smoke qualities to verify acceptance

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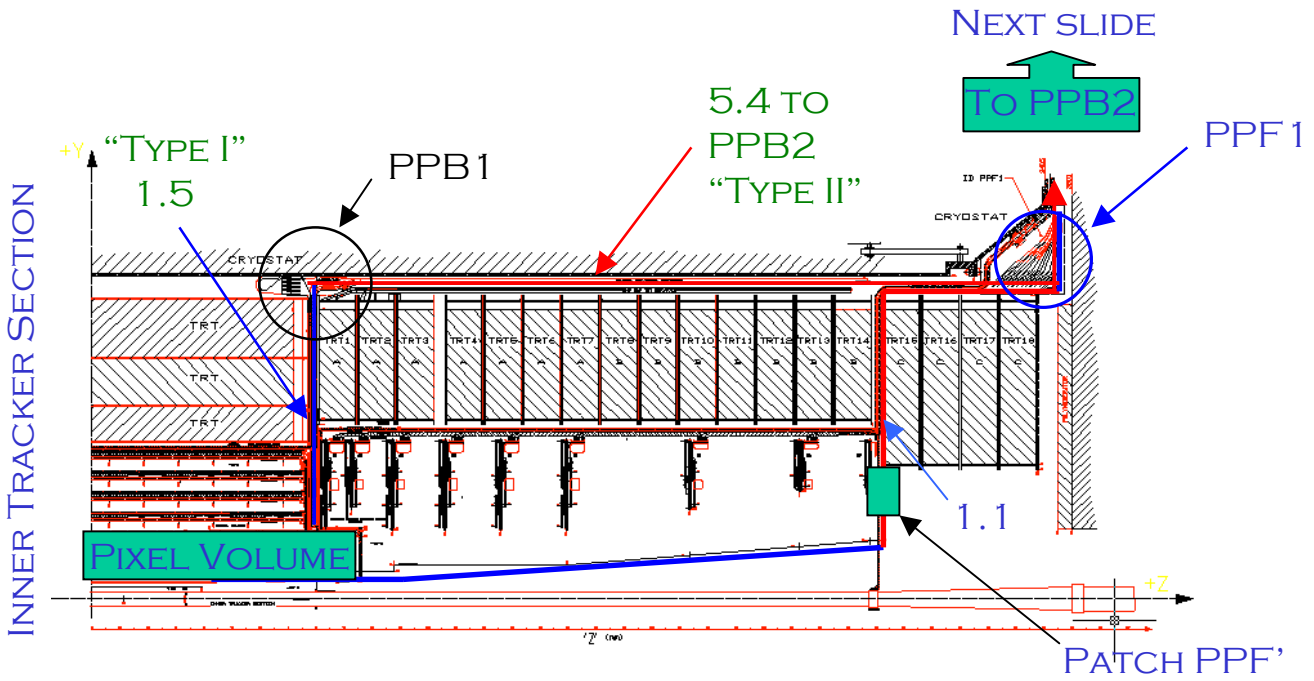
Cable Types I & II (low mass cables)



Type II cables are shown in Red, type I in Blue

B-Layer services are run along a different path than the rest of Pixel Services- change at PPF1

- Power cables change size at PPB1 and PPF1 from "Type 1" to "Type 2"
- LBNL (US) has taken responsibility for low mass cables
  - Uniquely qualified in collaboration
  - Well defined scope
- Prototype cables are being fabricated at LBNL presently
- Electrical test of realistic 150m cable chain to proceed this summer
  - Undecided whether all flex or combination of flex and twisted pair-wait for prototype cable sets and test results

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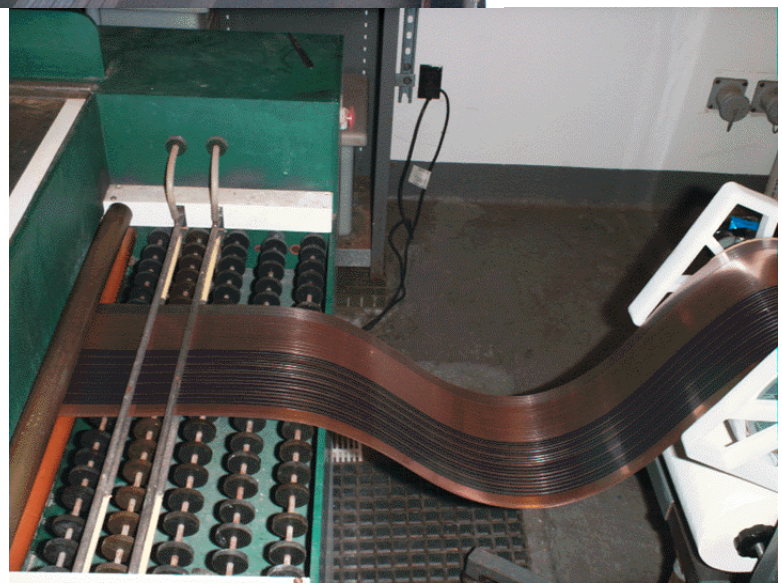
Low Mass Cables (Types I & II)

- **Cable technology split functionally**
  - Low current voltages **Control** and HV on minimum thickness conductor **flex**–SAME ART FOR BOTH TYPE I & II
  - High Current (Power) on either thick conductor **flex** or twisted pair **round** conductor
- **Definitions of components**
  - **Power** Cables for 6/7 modules
    - **Vdd**, **Vdda**, **Vcc**, **Vvdc****
    - Flex or Round wire with conductor thickness and pitch sized for current
    - Flex-Types I and II are each different art
    - Twisted pair option jumps in conductor size at PP1
  - **Control** Cables for 6/7 modules
    - **PT1000** (NTC), **Iset0**, **Iset1**, **Reset**, **Vpin**, **Vvdc****
    - Minimum technological thickness and pitch conductor flex cable
  - **High Voltage** Cables for 6/7 modules
    - **Vdet**
    - nominally same flex technology as control, but meets HV requirements

Prototype Electrical Cables



- **Flex Cables being produced at LBNL**
  - Tour of Bldg. 25 this afternoon
- **Wire option to be purchased**
  - funding recently approved
- **Artwork has All cable types in low mass bundles**
  - Types I&II power, Mintrace, HV
- **Prototype effort started with copper**
  - Copper remnants from STAR OFC
  - Shop really geared for Copper
  - quickly prove out staging and production aspects
- **Migrate to Aluminum**
  - Some STAR IFC materials available
  - Funding approved for materials
  - Experience with Al good in shops, but needs tuning with actual raw materials/chemicals

Electrical Prototypes Summary

- **Have had good success with fabrication of prototype cables**
- **Currently Fabricating Full length Cu-Kapton flex cable prototypes--right Resistance**
- **Selection of Material and process to alleviate labor and cost**
  - Photo-imageable, roll laminated coverlay available and seems to work well, need to test irradiate
  - Good exposure uniformity yields smaller need for inspection/touchup
- **Presently documenting process and labor to assess cost better**
- **Electrical prototypes could be available by end of april (types 1 and 2)**
  - Need to understand test needs to better gauge schedule
- **Conventional Cable prototypes available later this summer**

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Service Modeling and Mockup

- **Mini- and Full Model of Frame Penetration**
  - Used to verify packing factor, bend Radii, and estimate forces
- **Develop Cooling Tube Termination to Sector**
  - iterated about designs with aim to reduce pressure drops and number of joints in sector U-tube
  - Fittings for end of frame proposed
- **Route Disk Services and Barrel Services to end of Frame**
  - Established connectivity charts and naming conventions
  - Reserve Space for Connection of Electrical Services to Sector
  - Reverse First Disk
    - Chose Terminations which allowed first disk to reverse relatively painlessly
- **Inner Detector Services Mockup**
  - Full Scale of 1/8 of ATLAS Barrel out past PP2
    - Populate one PP2 in short term-LBNL to provide cable parts
    - Work out from Pix/SCT area to PP2 to understand cross-overs-longer term

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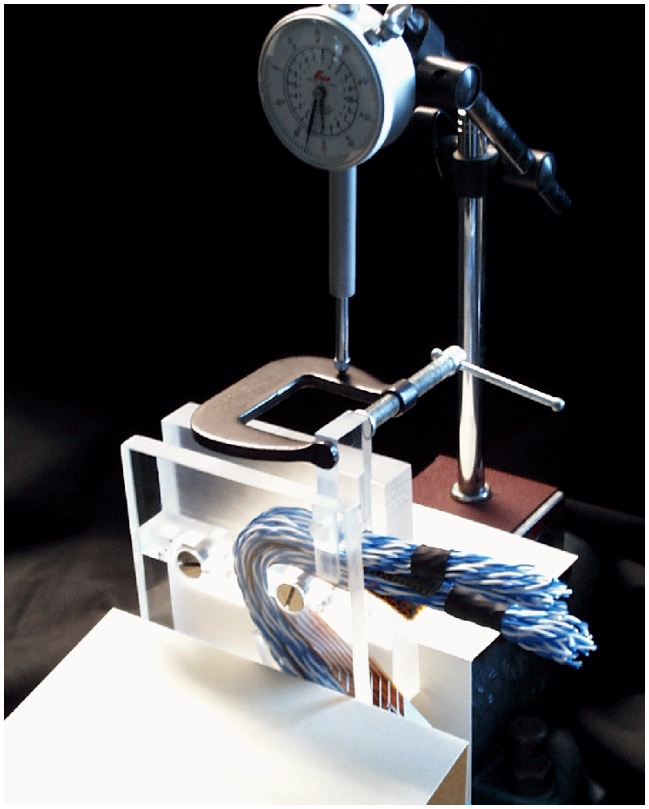
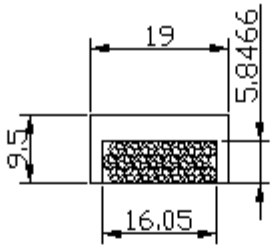
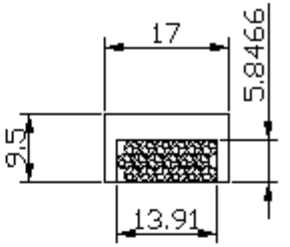
Wire Bundle Dimension used in CAD



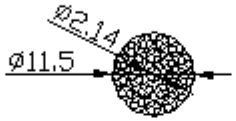
Packing Factor 2

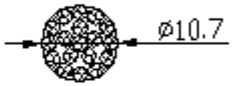
PF=2 ==>9.5 X 19 = 180.5
PF~0 ==>5.85 X 16.1 = 94.2





NASA Standard
Wire harness Ø





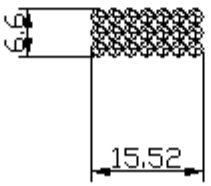
42 Wires
21 Twisted Pair
7 Module Bundle

36 Wires
18 Twisted Pair
6 Module Bundle

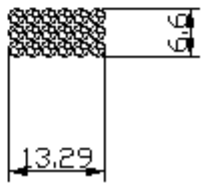
Pi*D^2 /4 = 3.14*(11.5)^2/4 = 103.9
11.5 = [(4/3.14) * (21) * (2.14)^2 * (1.08)]^(1/2)
NASA HarnessØ = √[(4/π)*(number of wires)*(wire dia)^2*(weighting factor)]

Weighting Factor ~ 1.08 on top of
circle to square conversion

- **Packing Factor Verified~ $1.08D^2$** (D is swept diameter of twisted pair)
  - Corresponds to PF=2.75 X {face area} where {...} is the face area of the wires in the twisted pair
  - Backed out of Nomograph in NASA std.
  - Provides ~20% give in packing
- **Bend Radius in CAD models easily met**



NASA Equlv.
Square
Bundles



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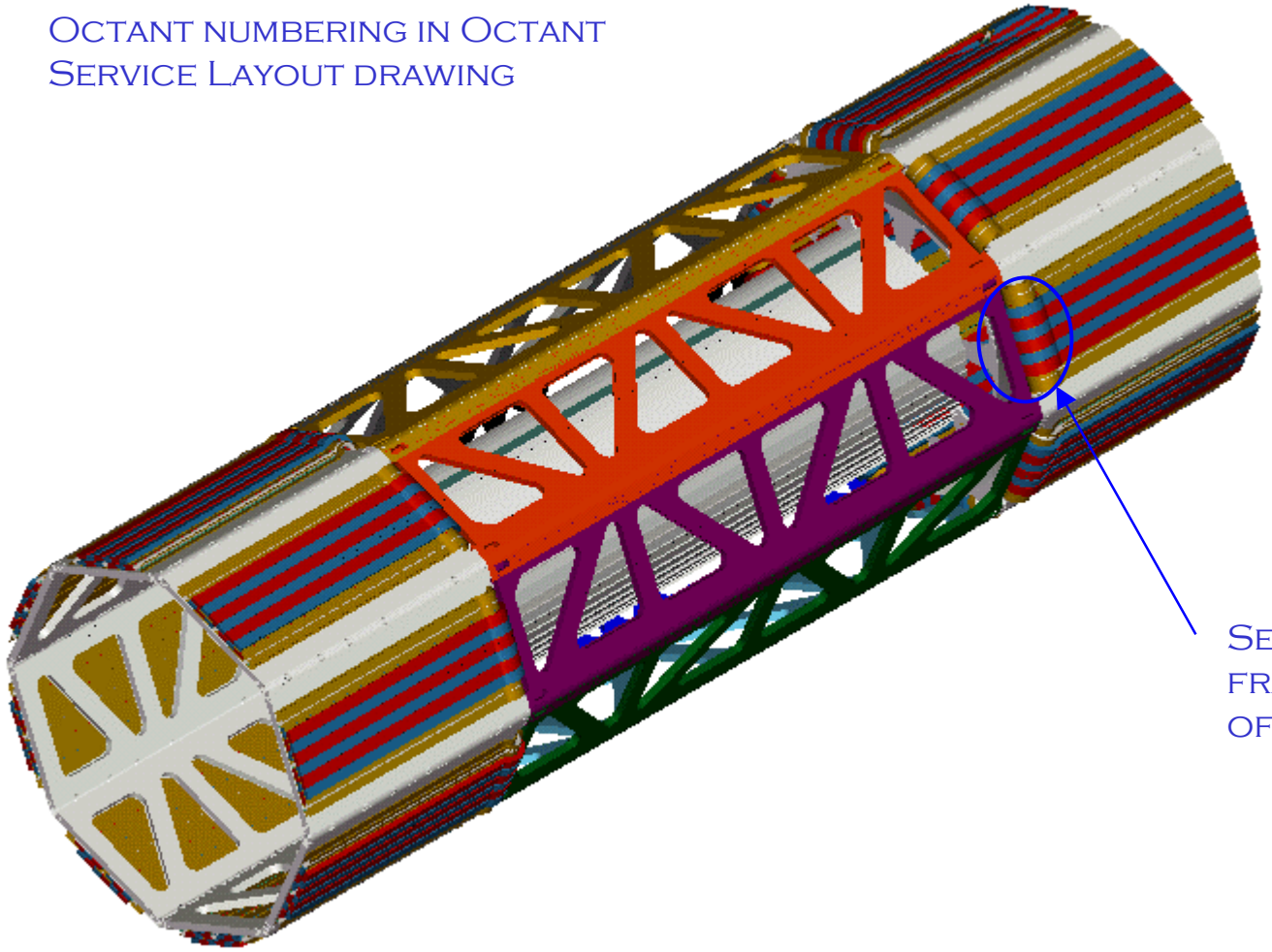
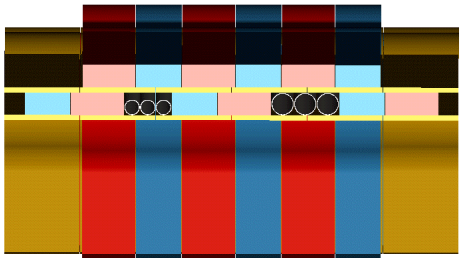
Barrel Services

Frame Panel Colors Correspond to Octant numbering in Octant Service Layout drawing



Service Bundles penetrate frame and proceed to end of frame

Bundles defined for both Evaporative and Monophase



Bundle End View (Monophase)

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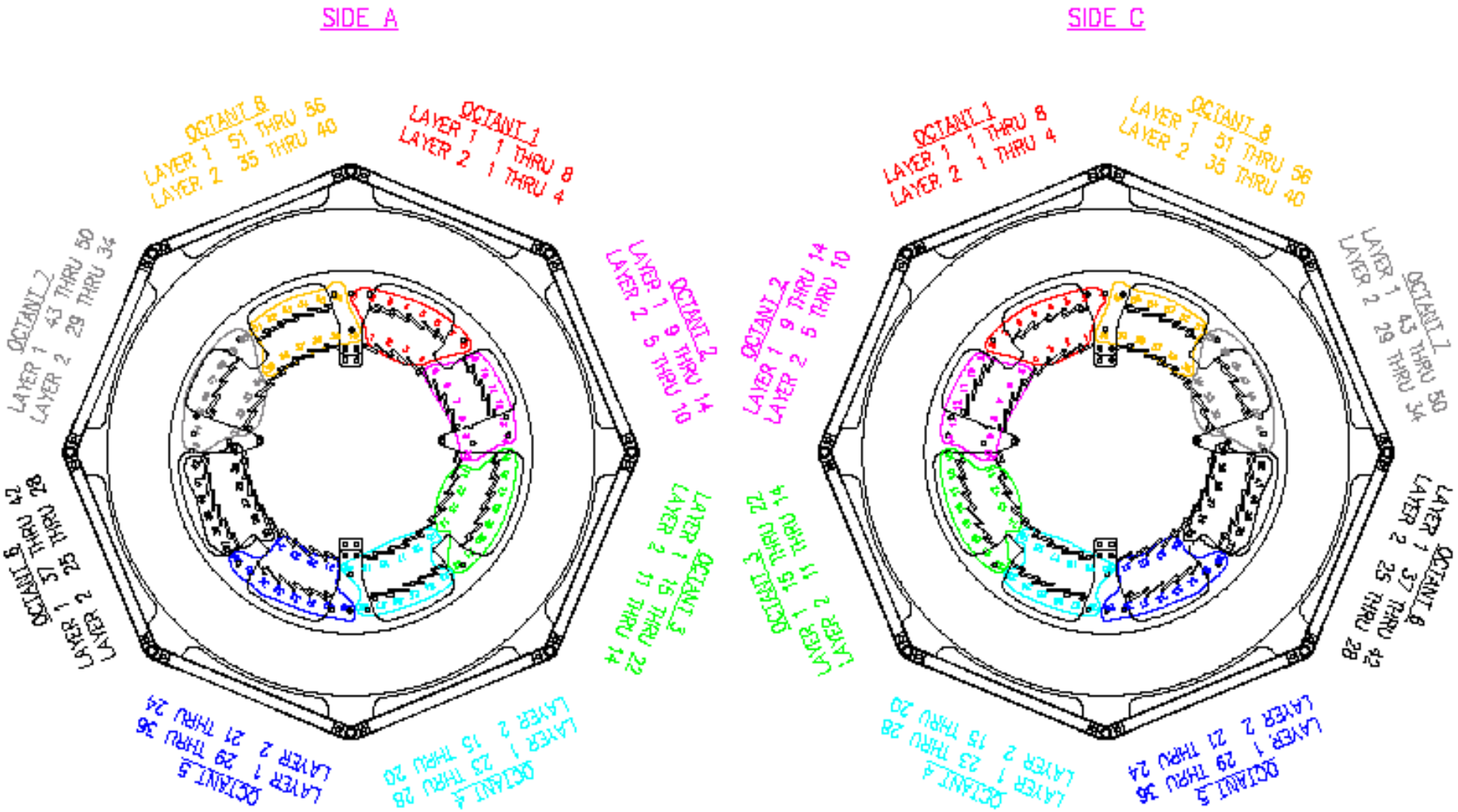
Octant Layout



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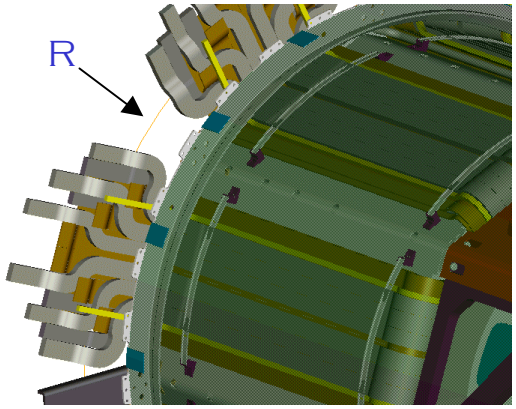
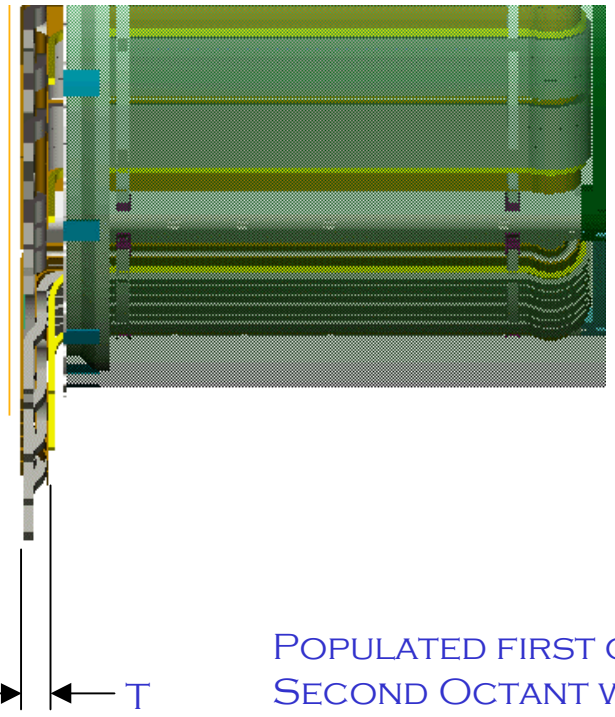
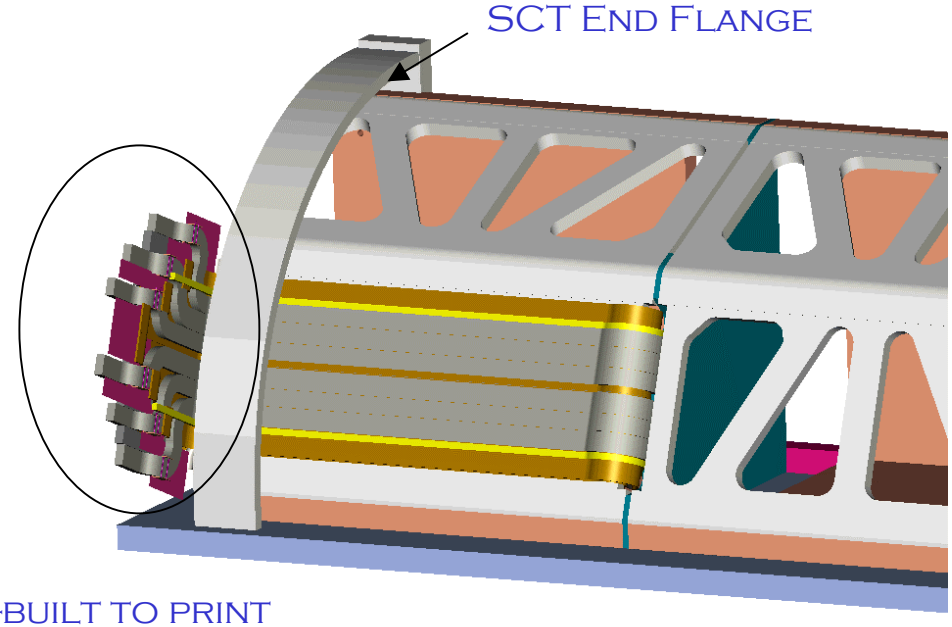
End Frame Model



Weaving is needed to get Wires from layer 2 down to layer one past the flex cables

- **Goal of routing is to reduce "T" to one layer as quickly in "R" as possible**
- **SCT Ring is already included--need also to include End-Plate Stiffener and Thermal Screen to better capture Envelopes**
- **Model will be on display this afternoon**





Populated first octant-built to print
Second Octant will push to see if bundles can pack to smaller R

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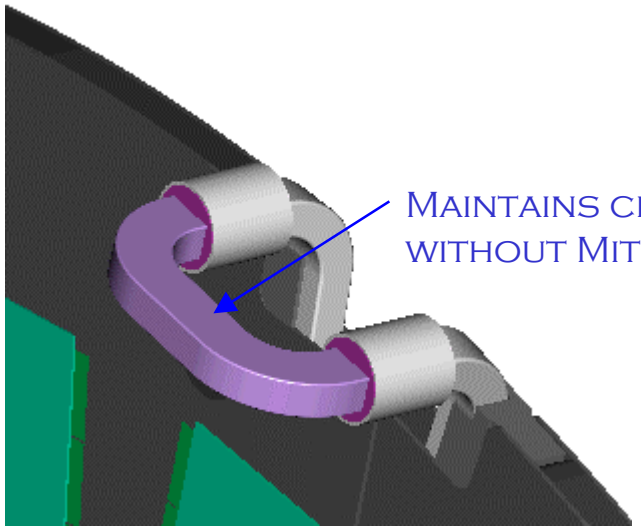
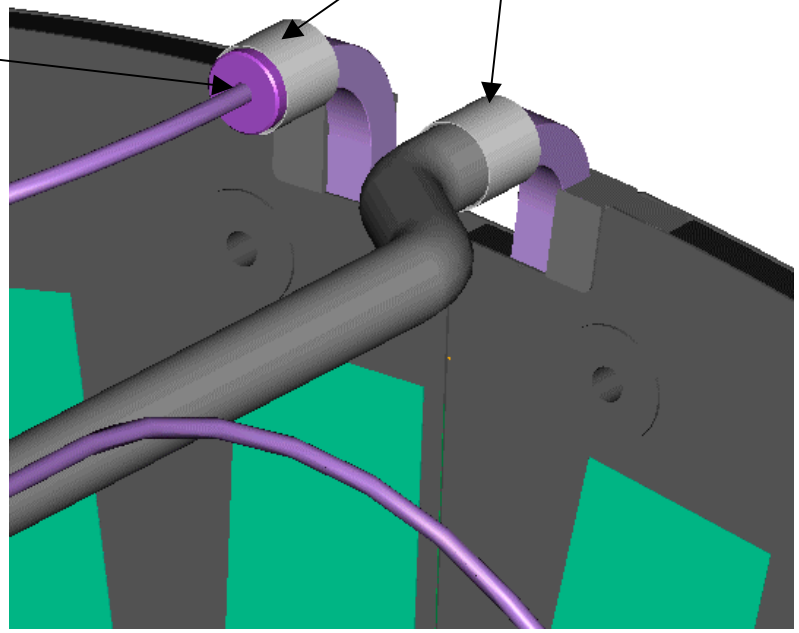
Service Termination

- **Minimize Pressure Drop**
  - Investigated several options-final choice fit best in layout
- **Sectors will be tested with Monophase system for thermal Coupling**
  - Needs to be compatible with both until Sector is installed
- **Tubing will be Glued to Sector**
  - Minimize number of joints
  - Make long enough to service/repair





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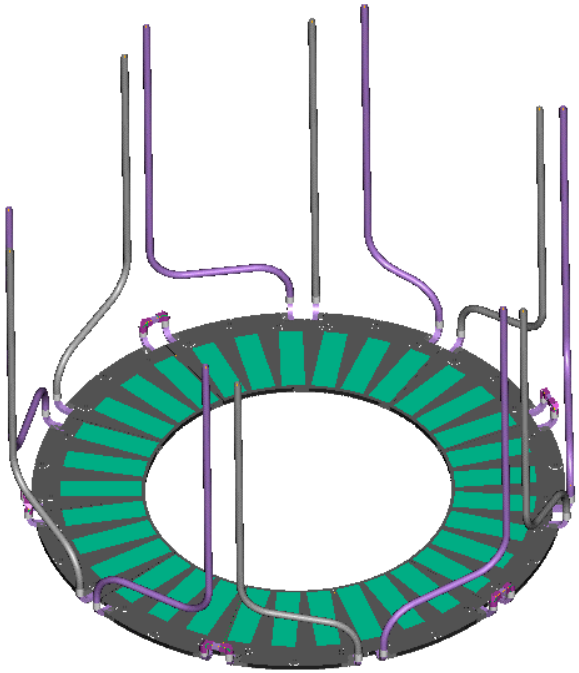
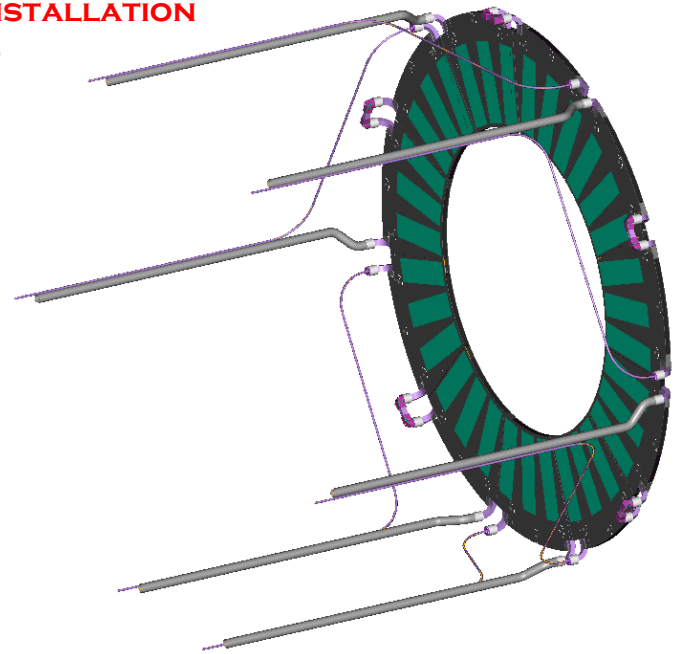
Tube Design Philosophy

- **Look to make all tubes 2D bent shapes**
- **Build sufficient complexity into models from start to allow adjustment**
  - Each Tube is dog-legged and has adjustment in all degrees of Freedom
  - Started with tubing sets-ended with custom tubes for each circuit
  - Most cables are still the same-disk 5 excepted
- **Monophase and Evaporative have diverging routing philosophies**
  - Evaporative wants to group supply and return together for a given circuit
  - Monophase wants supplies and returns grouped in bundles (opposite)
- **Common rules I've imposed to ease integration and installation**
  - No penetration or trapping of support elements is allowed
  - Specified Min Bend radii for tubes and cables
  - Cooling circuits enter and leave the same frame octant
  - Equal number of Circuits per Octant



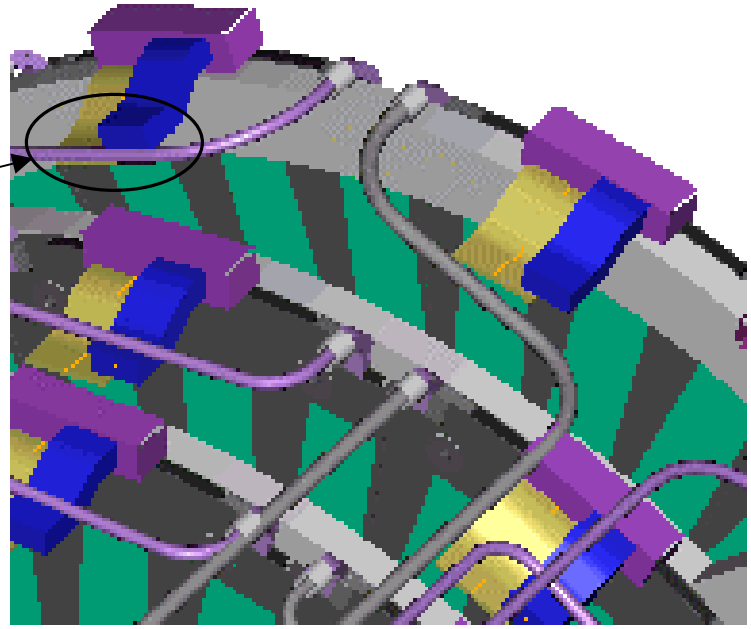


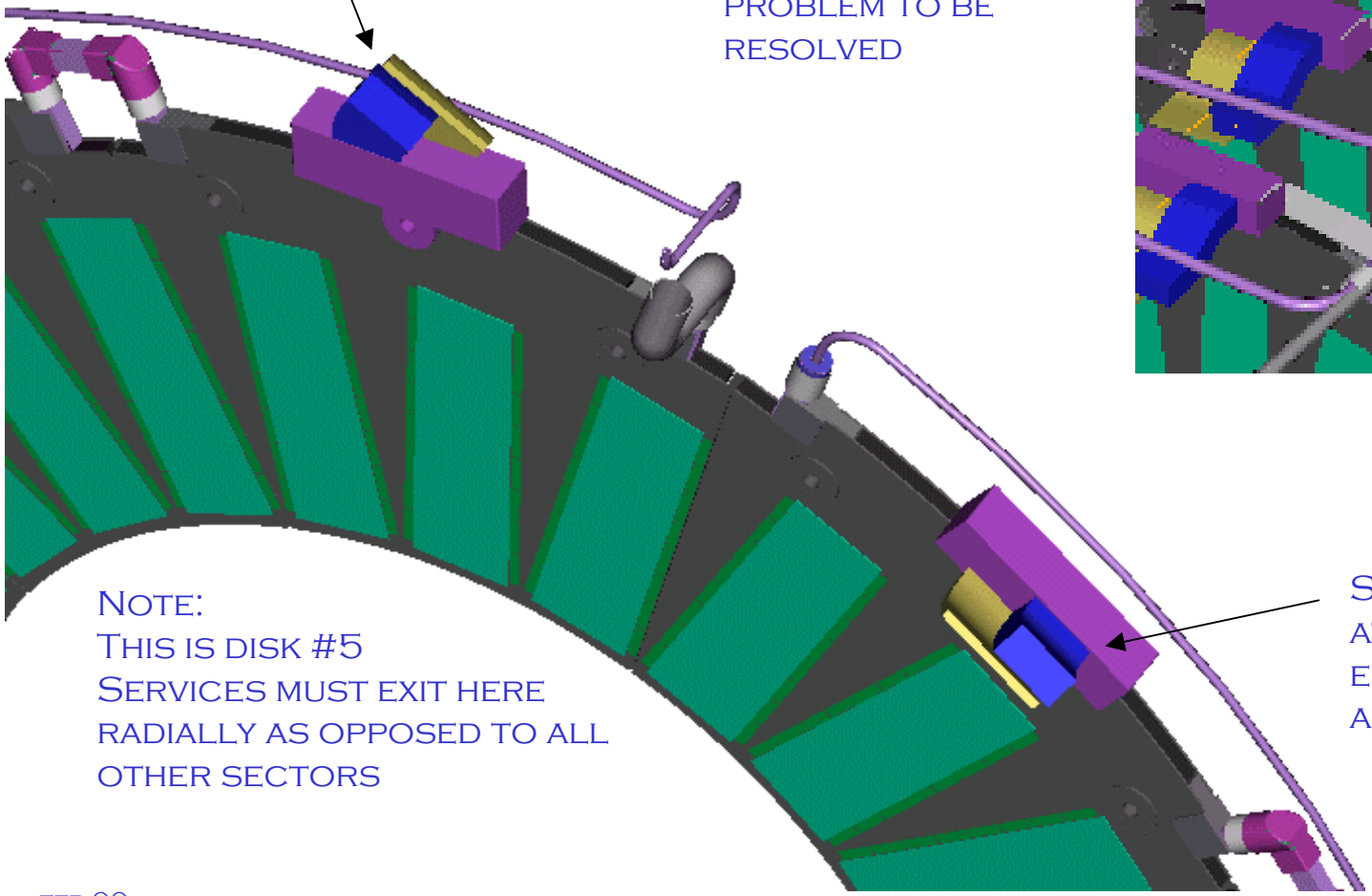
Pixel Detector

Cable Termination

Routing to pass by mounting ear of end plate Stiffener

This is type of problem to be resolved





Note:
This is disk #5
Services must exit here radially as opposed to all other sectors

Simple block reserved at top of every sector equal to sum of widths and heights of cables

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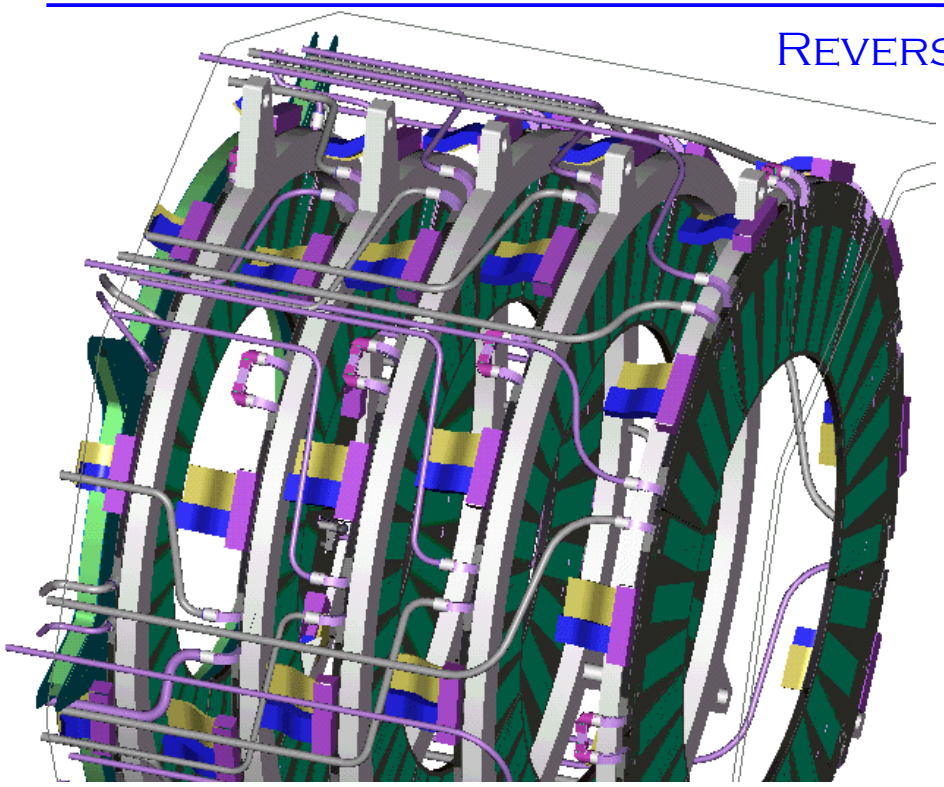
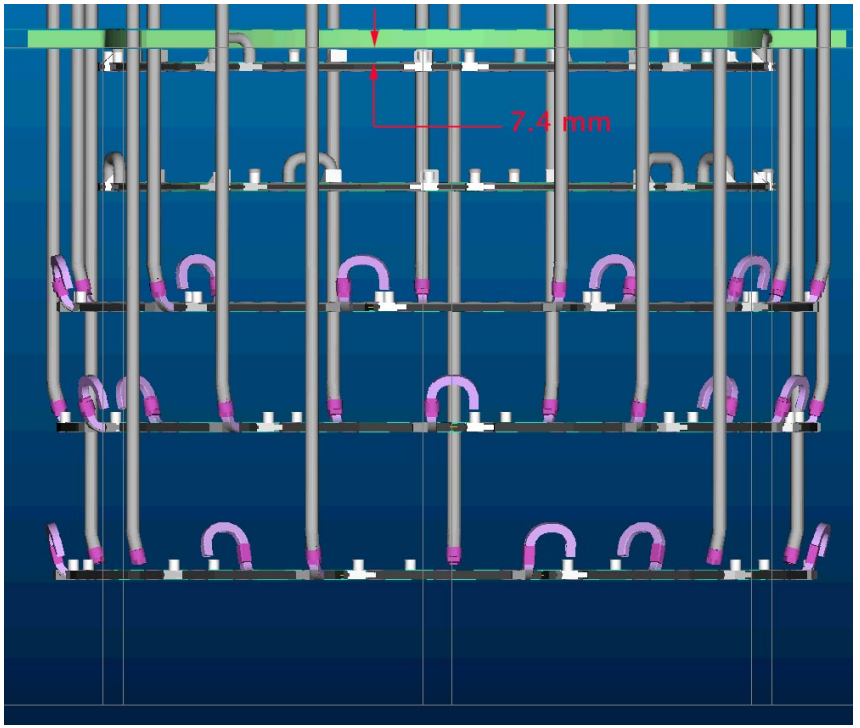
Reverse Disk 1





- **Disk 1 has been reversed (support ring on other side)**
- **Gives more room for Barrel Service Exit and Termination**
- **Uses common sector design**
- **Some problems**
  - Cable Termination on First disk
  - Slight asymmetry to mounting (accurate face of sector)

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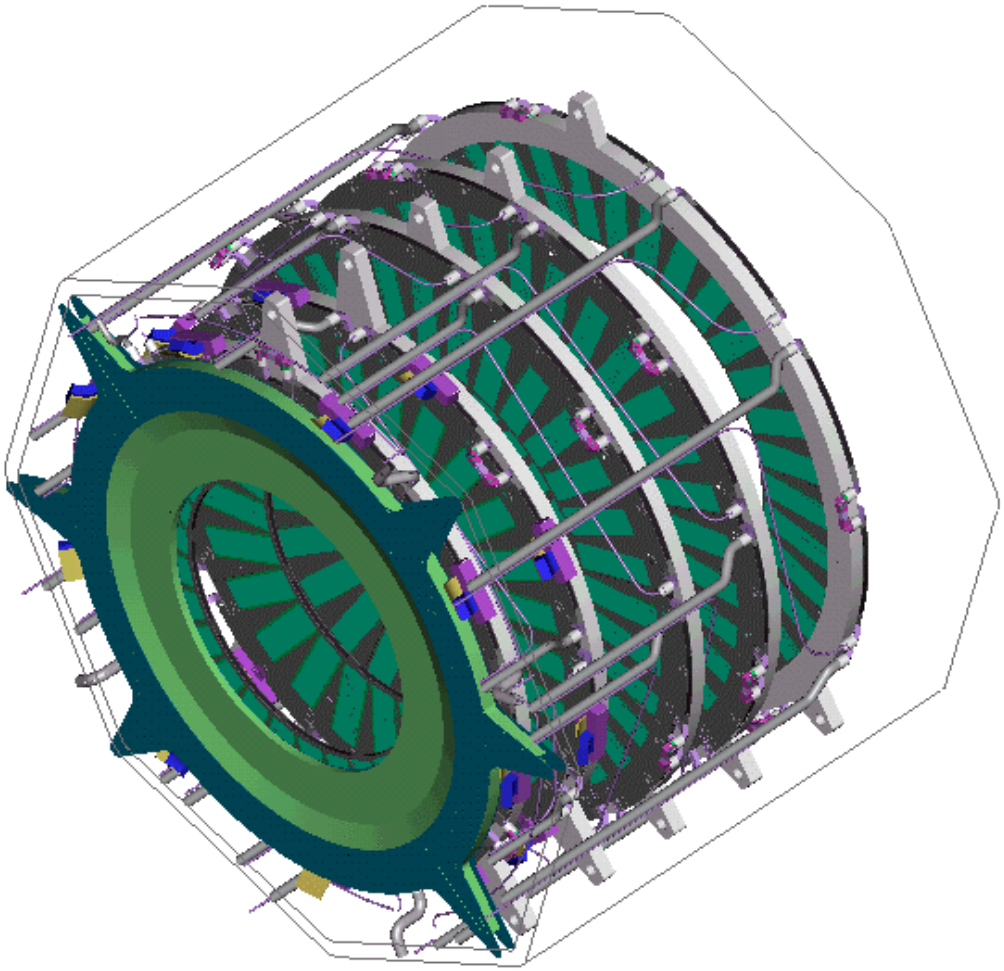
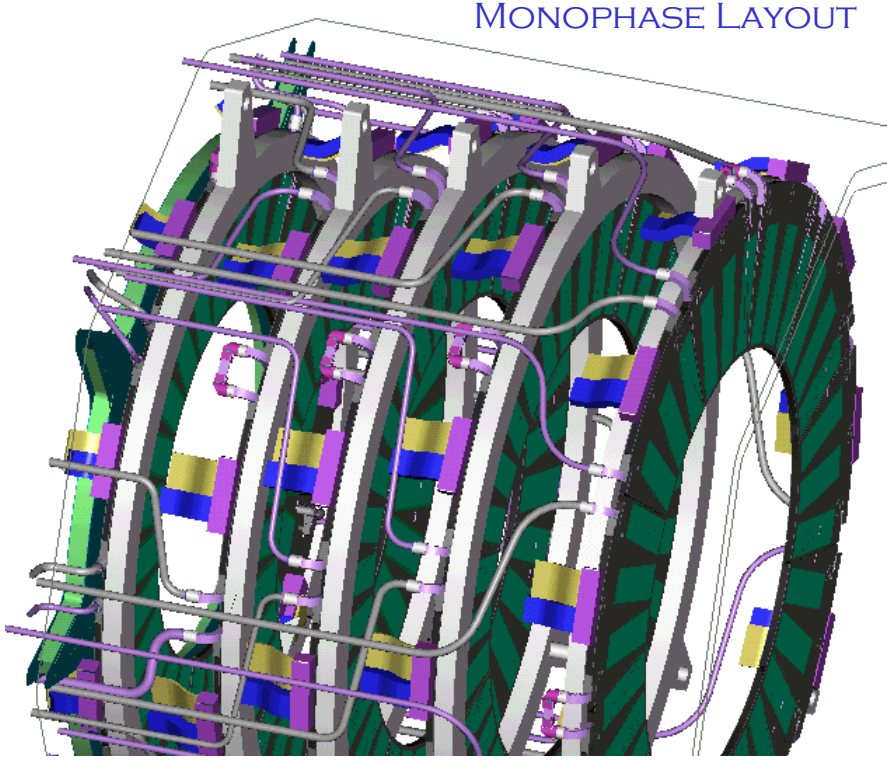
Tube Route Optimization



Evaporative Layout

Monophase Layout



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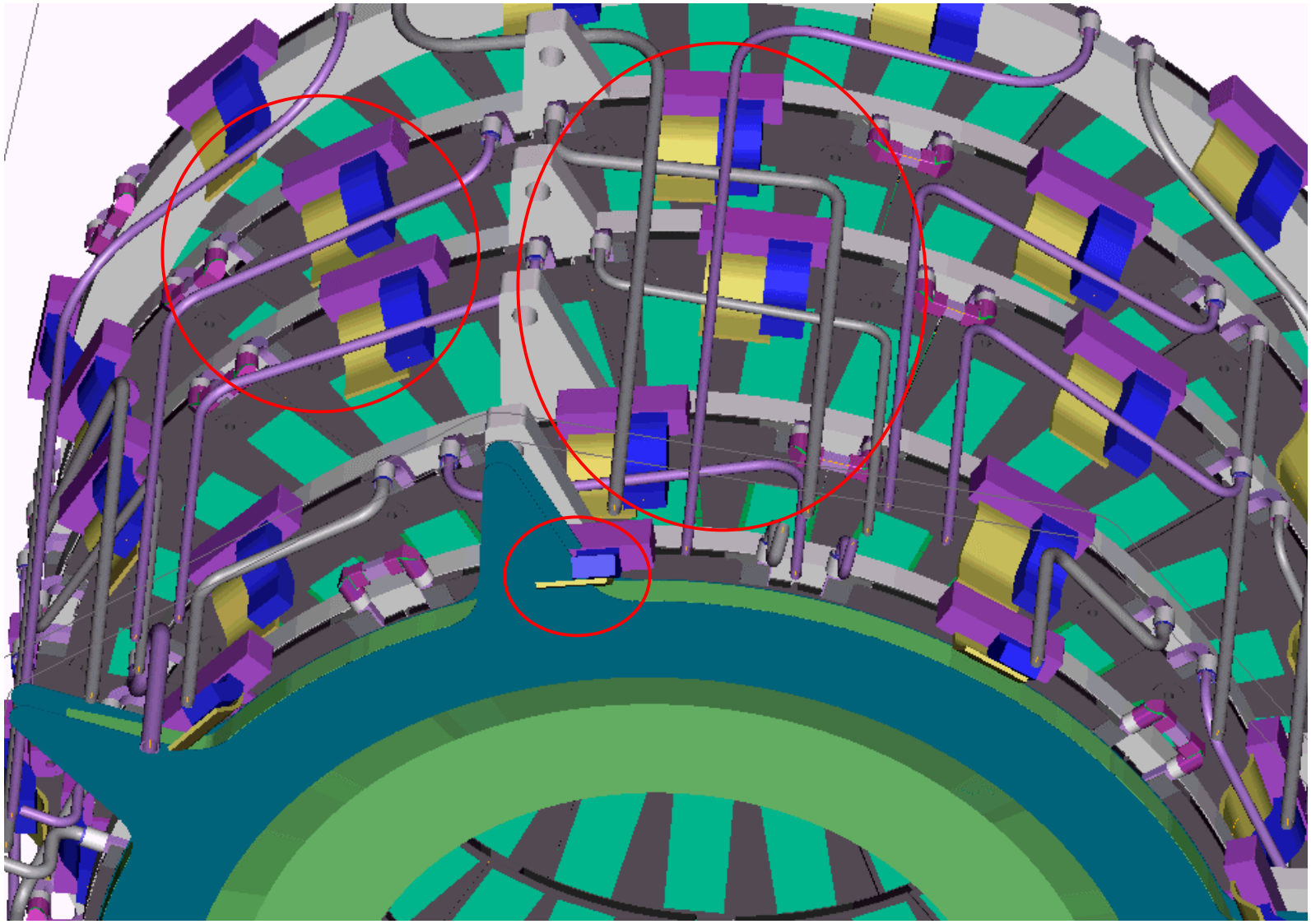
Monophase v.s. Evaporative

- **Evaporative Layout is very clean**
  - Capillaries allow for easy routing
  - Overall Tube length is shorter due to easier routing of Exhaust
  - Haven't put cables into evaporative model yet
- **Monophase is Crowded, but feasible**
  - Same Octant rule contributes to longer tube lengths
  - Tubing is harder to route out
  - Many obvious interferences with cable volumes, but maybe same in evaporative
- **Evaporative Cooling is Baseline Design**
  - Monophase Model stemmed from effort spent to develop routing for evaporative cooling
  - Optimization for both layouts still needs to be advanced significantly
- **Cables need to be added to both models**
  - Cursory inspection indicates that neither solution makes it easy for the cables currently
  - Pigtail should be developed which balances well with tubing constraints
  - Will develop tubing further prior to pigtail design

Pixel Detector

Cables Added



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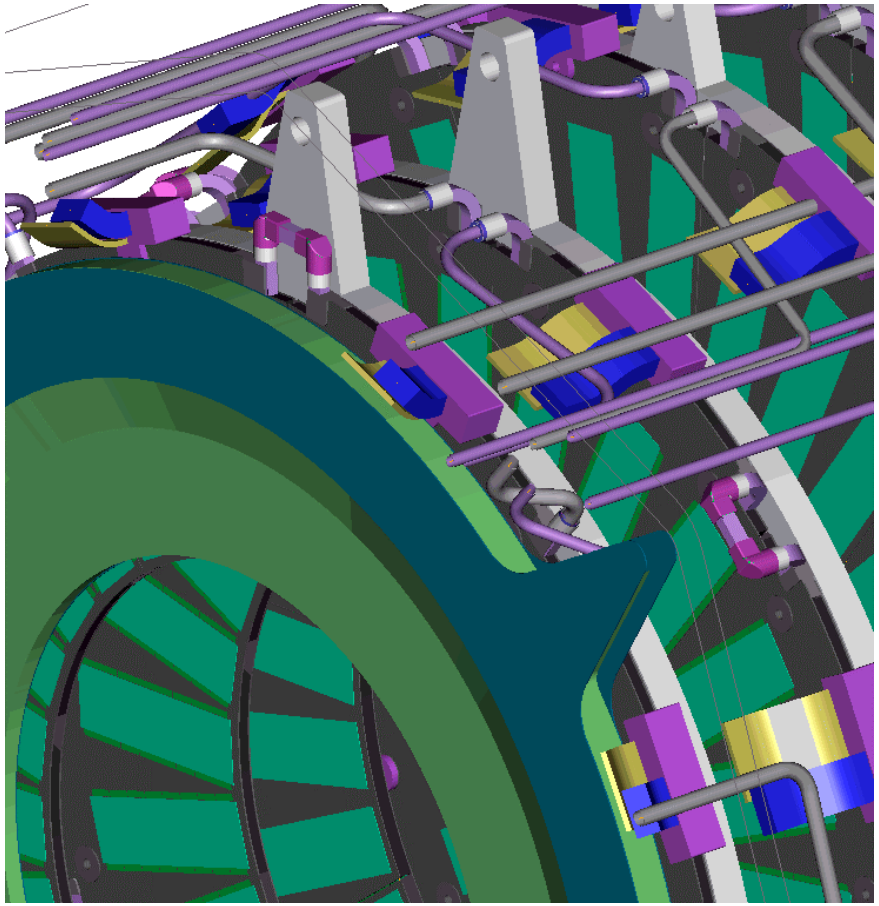
End of Frame routing

- **Need to have all services routed to end of frame to integrate with End-Plate Stiffener**
  - Tubes will need fittings for installation purposes
  - All Services will be strain relieved at this point by the End-Plate
- **Room is extremely tight in this area-envelopes established for assembly reasons**
  - Services have 15mm to make bend at end of frame (Z-envelope 798 (-3))
  - R-Envelope is 254mm
  - Need to finish layout pronto to figure if envelopes are sufficient
- **Only one of the two cooling options will be routed beyond this point**



Pixel Detector

Conclusion

- Service Layout proceeding full speed ahead
- Next step is to integrate Disk and Barrel Services
- Physical modeling of services coming along, so far good correlation of CAD with Reality
- Eventually will have to drop one of the cooling systems from the CAD modeling effort--this is doubling the amount of work.
- Electrical prototypes presently de-prioritized to mechanics effort--can change this, but need reason to
- Conventional Cable cost is higher than anticipated
  - Types III & IV are primary cost drivers