Services Design for the CMS Phase II Inner Tracker

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• Objective
• Cartridge design
  – Connectors
  – Putting it together
• Service cylinder
• Concluding remarks
CMS central beam-pipe (mid-section in beryllium)

Beam-pipe support "fishing rods" at Z = 3.3 m

CMS endcap beam-pipe

Beam-pipe connection flanges and bellow

Tracker Bulkhead Disk AKA PPO

IT installation/support rails in the ITST

Beam-pipe support collar, vertical (permanent) and horizontal (pivoting) supports at Z = 1.63 m

Double Dees

Beam interaction point

Inner Tracker Support Tube (ITST)
Challenges: Assembly of detectors to single service cylinder

- Tracker Barrel Pixel Detector (TBPX) comes from Italy
- Tracker Forward Pixel Detector (TFPX) comes from USA
- Each detector to be **tested independently** at its **own centers** before being shipped to CERN
- **Modularity** for detector design important to allow each detector to be **assembled and tested independently** when sharing the service cylinder at CERN
- Three detectors (TFPX, TFPX, TEPX) share the same space as phase 1 (FPIX and BPIX) with increased services for phase 2. Not a lot of space!!
CARTRIDGE ASSEMBLY: CONNECTORS
Propose stacked PCBs with Interposers for all non-HV wiring

Assembly hardware designed for PCBs between 1.6 and 3.2 mm thick. Would need special consideration for thinner boards, including analyzing flexing.

Samtec ZA1 Derating plot for all pins powered

Some argument about how much current per pin is really allowed. The plot is drawn for a maximum 30 C rise in a 75 C environment to avoid the material max of 105 C.

I propose operating near 15 C rise, limiting the current to around 200 ma per pin.
300 pin interposers for TFPX dee’s

- 300 pin interposer to be used; one per dee, **16 total**. 1 on each side of the service cylinder

- The interposer will wire
  - 8 amp serial power conductors
  - 4 amp serial power conductors
  - High voltage return conductors
  - DSS control temperature conductors
32 pin HV-in connectors for TBPX and TFPX

- In order to fit the HV in wires a new PCB was designed
- PCB uses electrical standard spacing needed for HV connections; however this takes up a lot of space
- 32 pin connector to accommodate for even dee. Same connector can be used for TBPX and TFPX to reduce number of parts at this stage
- **16 total** HV-in pcb boards for TFPX
100 pin port card mechanism power for TBPX and TFPX

- For each port card mechanism the power will be provided for all port cards 100 pin interposer
- This component has to be close to port card mechanism assembly
- Only placed on one side of service cylinder (mirrored side will not have this component)
- **8 total** for TFPX
MT-MT Fiber Optics Junction

- For each port card mechanism 2 fiber optic pairs needed
- A single 24 wire bundle per dee
- Fiber optic bundles are part of each cartridge and routed along service cylinder with each installation of a cartridge

Fanout 12 fiber pairs to 12 individual MT connectors. TFPX needs 10 of the 12.
CARTRIDGE ASSEMBLY: PUTTING IT TOGETHER
Design of DC-DC still ongoing. Shown is first design.

Each versalink has 2 pigtails each with 2 fiber optic cables into MT permanent connectors.
Port cards assembled to cartridge chassis

Fiber optic connector parts from US Conec, Ltd.
- MM Elite MT ferrule (17184)
- The individual guide pins (16735)
- The spring clamp (10405)

24 wire fiber optic fan out going out to PP0

24 fiber wires same connector to PP0
The power to all port cards for an even and odd dee for a cartridge is provided by a single 100 pin interposer sandwich.

The female pigtail shown connects to all port cards in this cartridge and exits out to service cylinder to make the mating connection.
Dees assembled on cartridge chassis

Female PCB’s for high voltage, serial power, temperature are wired

Dees are slid into slots in cartridge and screwed in place from top into square nuts on dee sandwich

Strain reliefs for wire bundles will be designed and be part of cartridge chassis
**Modular design**

- Same for all layers of TFPX reducing number of unique parts
- Cartridge used for TBPX port cards as well
- Speeds assembly
- Factorizes testing so assembly can be tested as a unit and inserted as a unit

Each pigtail bundle exits to either side of the service cylinder to attach to its male counterparts.

Wire connections to dees still under development.
Attaching cartridge to service cylinder

- Dee female fitting for cooling tubes connected to male fittings permanent on service cylinder
- Space available IF cooling needed for port cards
- 24 wire fiber optic bundle to PP0
- Permanent wires end to male PCB boards attached to service cylinder
### TFPX and TBPX available cross section area

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius of service cylinder in TEPX region</td>
<td>280.00</td>
<td>mm</td>
</tr>
<tr>
<td>Maximum usable height on service cylinder</td>
<td>13.00</td>
<td>mm</td>
</tr>
<tr>
<td>Height reserved for cover and cable management</td>
<td>1.00</td>
<td>mm</td>
</tr>
<tr>
<td>Angle occupied by each of two TEPX reserved areas on 180 degree cylinder</td>
<td>41.00</td>
<td>degrees</td>
</tr>
<tr>
<td>Width of slot in service cylinder</td>
<td>40.00</td>
<td>mm</td>
</tr>
<tr>
<td>Approximate angle equivalent of slot</td>
<td>8.20</td>
<td>degrees</td>
</tr>
<tr>
<td>Available area over 180 degrees (sum of 2 large openings)</td>
<td>5378.99</td>
<td>mm-sq</td>
</tr>
<tr>
<td>Area of each opening</td>
<td>2689.50</td>
<td>mm-sq</td>
</tr>
</tbody>
</table>

Cross sectional area limiting factor at larger OD of service cylinder. White area within 12mm boundaries is available space for both TFPX and TBPX services plus 1mm cover.
<table>
<thead>
<tr>
<th>IT Services Placeholder Values</th>
<th>New wire diameters</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>dia. from IT services V1.4 (mm)</th>
<th>New diameter of cable (mm)</th>
<th>count TBPX –Long only</th>
<th>count TFPX</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 amp SP conductors</td>
<td>2.2</td>
<td>1.53</td>
<td>28 (0L1,0L2,12L3, 16L4)</td>
<td>64 (2 in per dee, 2 out per dee)</td>
</tr>
<tr>
<td>4 amp SP conductors</td>
<td>1.7</td>
<td>1.10</td>
<td>20 (6L1,14L2,0L3,0L4)</td>
<td>64 (2 in per dee, 2 out per dee)</td>
</tr>
<tr>
<td>HV conductors</td>
<td>1.1</td>
<td>0.56</td>
<td>240 (30L1, 70L2, 60L3, 80L4)</td>
<td>432 (22 ODD, 32 Even)</td>
</tr>
<tr>
<td>HV return conductors</td>
<td>1.1</td>
<td>0.56</td>
<td>24 (3L1,7L2,6L3,8L4)</td>
<td>64 (4/dee)</td>
</tr>
<tr>
<td>Temperature conductors</td>
<td>0.5</td>
<td>0.5</td>
<td>48 (6L1, 14L2, 12L3,16L4)</td>
<td>128 (8 wires/dee)</td>
</tr>
<tr>
<td>LpGBT power conductors</td>
<td>(? (1.524))</td>
<td>1.10</td>
<td>86 (2 wires/port card)</td>
<td>160 (2 wires/port card)</td>
</tr>
<tr>
<td>Fiber optic cables</td>
<td>?</td>
<td>0.5 (guess)</td>
<td>9 (3L1,3L2,1L3, 2L4)</td>
<td>16 (1/dee)</td>
</tr>
<tr>
<td>Port Cards</td>
<td></td>
<td>43 (15L1,14L2,6L3, 8L4)</td>
<td>80 (5/dee)</td>
<td></td>
</tr>
<tr>
<td>Cooling tubes</td>
<td>2.2</td>
<td></td>
<td>20 (loops 1L1, 2L2,3L3, 4L4)</td>
<td>32 (2/dee)</td>
</tr>
</tbody>
</table>

Need to reduce wire diameters or type of wire to reduce total area taken up by the services
Connectors placed on the service cylinder for TFPX are mirrored so that odd and even dee side of service cylinder is similar (no port card interposer on odd dee side).

For TFPX each connector is near the port card assembly exit on the service cylinder.

Wires for male connectors attached to service cylinder are flushed and permanent to service cylinder. TBPX services are placed on top of TFPX permanent services.

<table>
<thead>
<tr>
<th></th>
<th>300 pin interposer</th>
<th>100 pin interposer</th>
<th>HV-in PCB board</th>
<th>Cassette/port card assemblies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Even</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Odd</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>8</td>
<td>16</td>
<td>8</td>
</tr>
</tbody>
</table>
• Dressed service cylinder ready for either TBPX or TFPX dees installation
• Either detector can be assembled independently

• Interface flange holding the cantilevered TBPX detector
• Same mechanism holds the wheels for the service cylinder (wheel mechanism from BPIX phase 1)
• Cooling lines run under wires to remove heat for services wires and possibly begin the onset of boiling (need to verify total heat load)
• Capillaries could connect to detector dees directly with tube step up happening inside service cylinder (not much coiling at PP0). Working on this
• Space available for cooling loops for port cards IF needed. Working on this as well 😊
Due to space constraints and to reduce material near z=0 region TBPX port cards are installed inside TFPX service cylinder

- 50 total port cards in 5 cartridge like assemblies
- Cartridges with layer of red fiber optic cables used only to show TBPX port card cartridges. Each TBPX port card cartridge has e-link interposer and port card power interposer
The last port card assembly is successfully placed between layers 3 and 4 of TFPX by moving TFPX layer 3 closer to Z=0 by 15 mm.

New length to last port card assembly is **0.85m** (length of E-Link cable longer due to routing in R; not shown).

To keep TBPX e-links connections within 1m due to manufacturer limits, routing of cabling will need to be optimized. Otherwise last port card assembly can be placed on top of TBPX L4.
• TBPX cooling lines (green), high voltage, serial power, and temperature run directly to PP0 from the detector (space for intermittent connectors if needed is possible)
• E-links run on top of TBPX wires and into each port card location (1 through 5) possibly using an interposer as interface between TBPX cartridge and service cylinder
• TBPX cartridges can be tested with detector and installed with detector following same testing technique for TFPX
Integration space constraint changes can be reached: Theoretically

- Models show best case scenario 2.53mm between connectors to upper boundary limit (not optimized)
- Wiring (due to smaller ID changes) and cooling (still under discussion) show space may be enough. Mockups needed to verify
Inner Composite plate removed

- Additional carbon fiber layup with modules already glued and wired is used (pre-assembled)
- Tubes, foam, carbon fiber structure behind remains the same
- Easy to remove-fast installation/maintenance
- More mass due to additional layer of carbon fiber, thermal contact material (under study), nuts and bolts (materials also being studied)
- Thermal interface must be studied
- Design of removable layer must be optimized to hold the weight of modules and wiring with minimal deflection
- Lots of work to bring this idea to fruition
Concluding remarks

- New cartridge design to allow modular installation of TBPX and TFPX shown as a possibility
- Design of removable inner ring for odd dee is under development
- Testing and simple mockups construction to begin this summer to verify CAD models, test installation procedure and material selection
THANK YOU!
QUESTIONS?

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