Power and Grounding system implementations of ATLAS ITk

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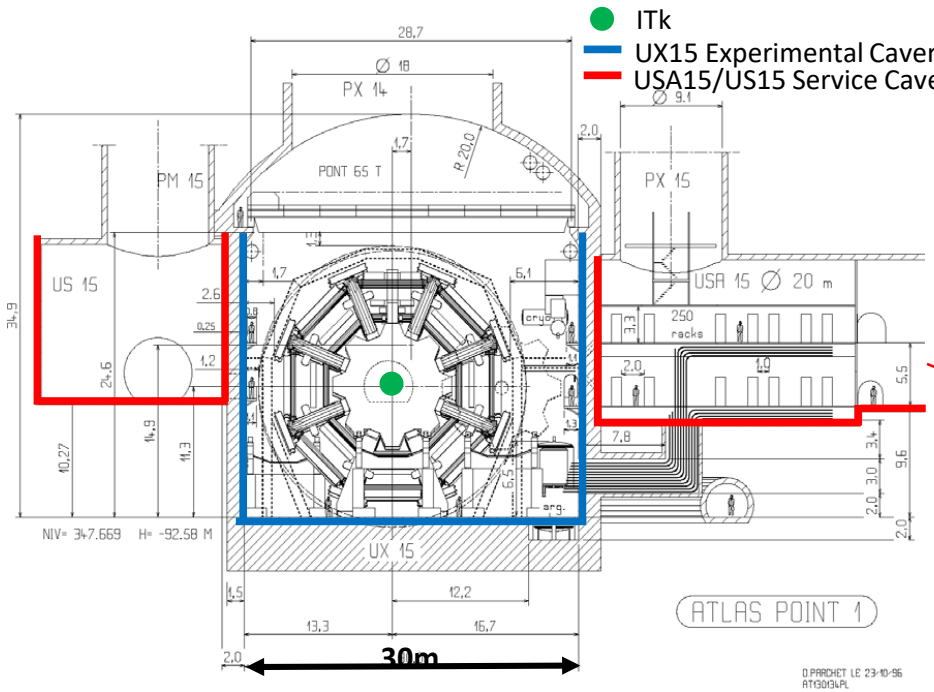
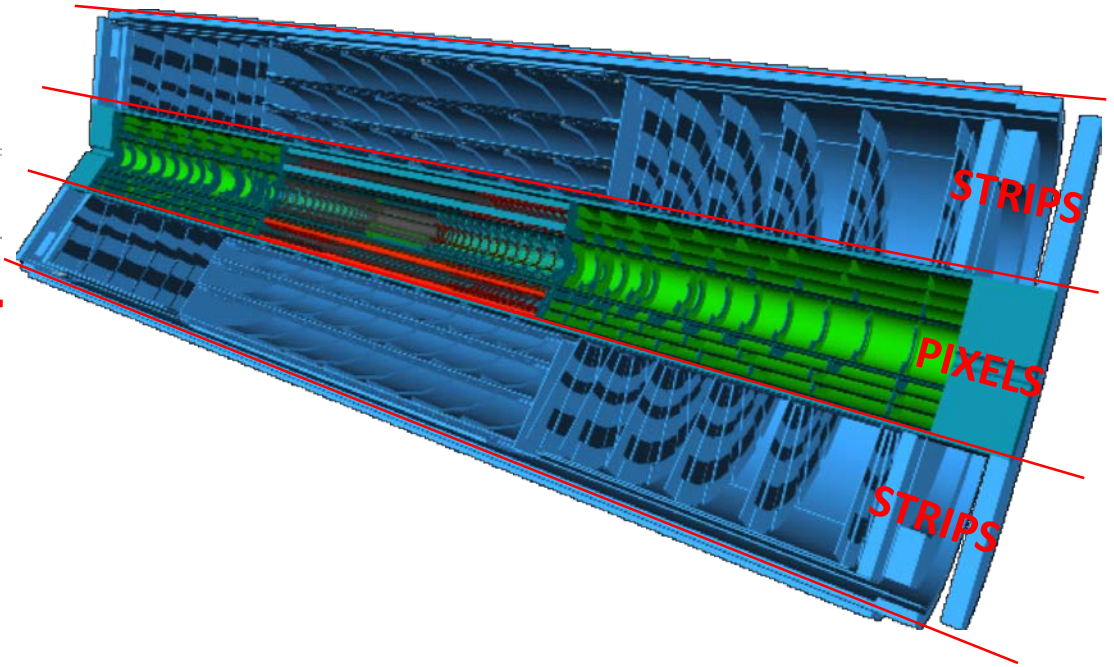
ATLAS ITk





Powering extends through over ~100 meters of electrical cables from both service caverns through the rest of the ATLAS subdetectors requiring special attention to grounding and shielding requirements throughout the entire extent of the system.

ITk Pixels Powering

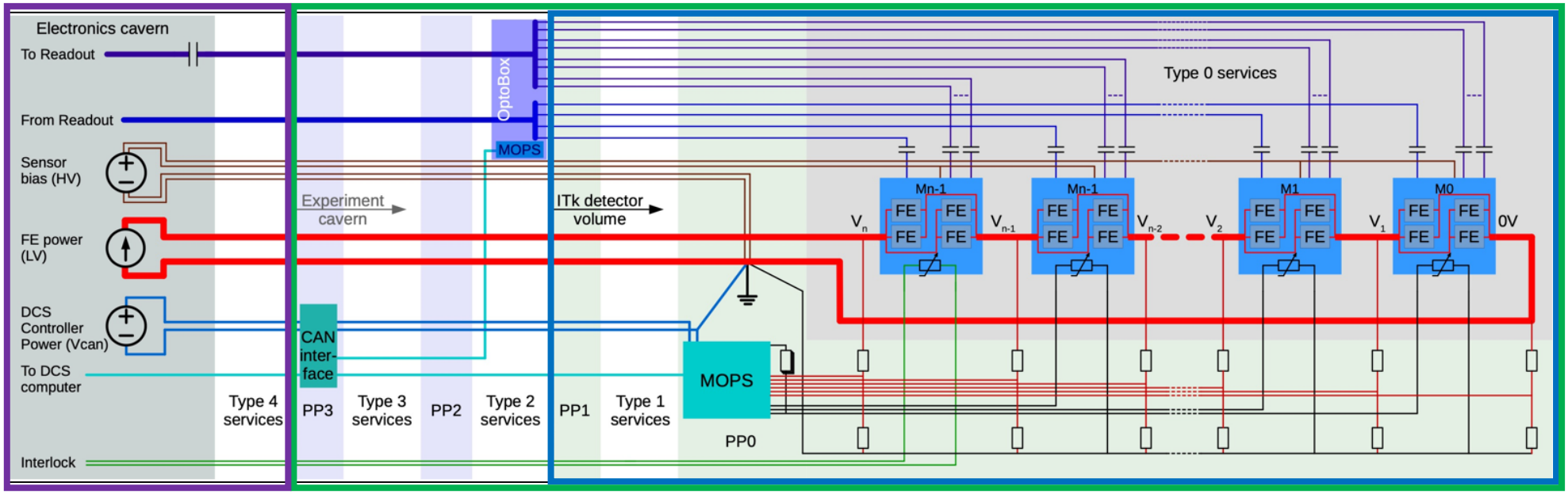
In order to minimise powering and cabling Pixels use:

- Serial Powering for LV
- Shared Parallel Powering for HV

8372 modules grouped in **912 SP chains,**
2004 HV channels

264 Type II cables
576 LV, 302 HV Type III cables

- USA15/US15 Service Caverns
- UX15 ATLAS Experimental Cavern
- ITk Volume



*Matthias Hamer, "*Serial power system implementation and test results", ACES 2020

ITk Strips Powering

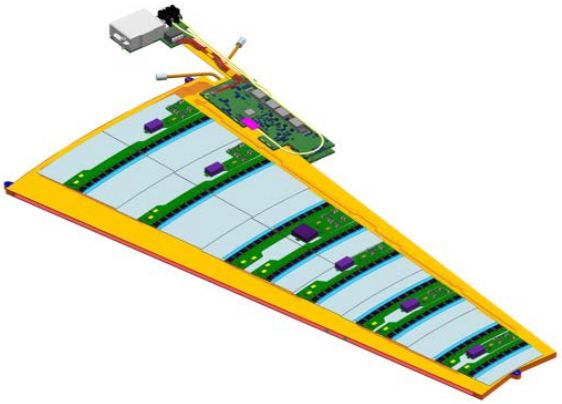
In order to minimise powering and cabling, Strips use:

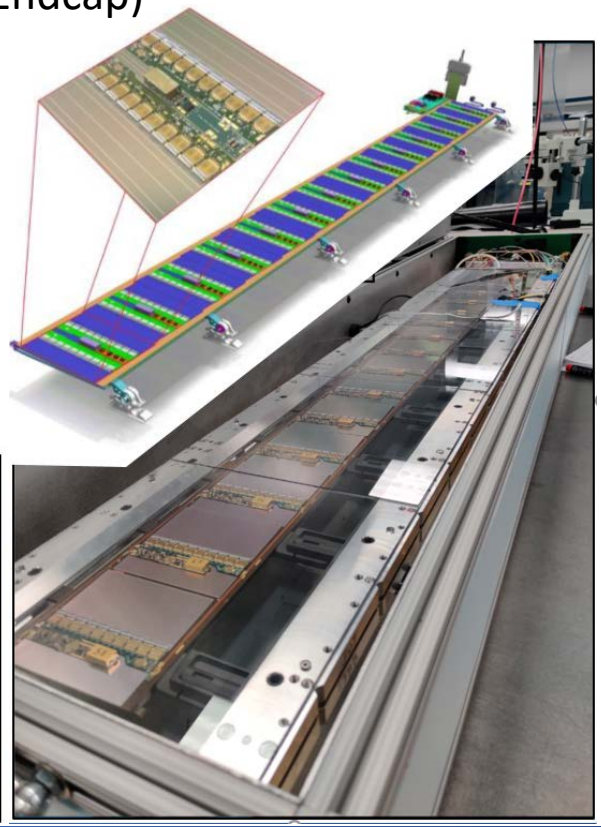
- One LV channel per Local Support (stave/petal) side (14 barrel modules, 9 endcap modules)
- DCDC scheme to reduce voltage drop: PS=48V, PP2=11V to the stave/petal, Module=1.5V
- Shared Parallel Powering for HV (bigger share for Outer Barrel and Endcap)

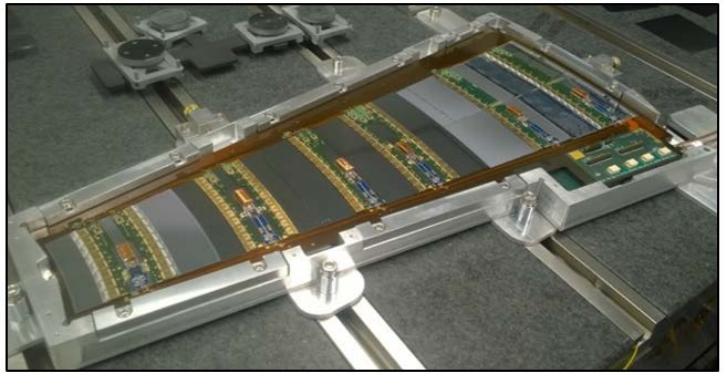
- 136 inner barrel staves
- 256 outer barrel staves
- 384 petals
- 1552 LV channels
- 3648 HV channels

Cables have different segmentations depending on the section:

- 776 Type I
- 392 Type II
- 1568 Type III







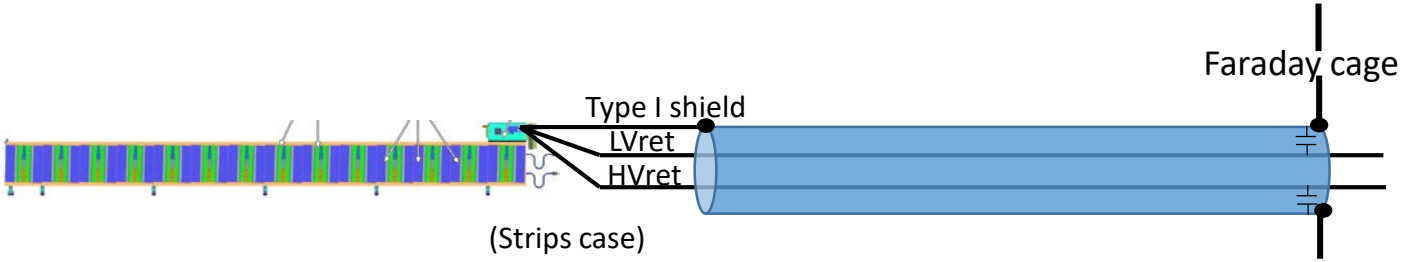
ITk Grounding and Shielding

ATLAS G&S policy:

- Each subdetector must be isolated from the others
- It must be located in a Faraday cage
- Power supply outputs must be floating
- Single connection to earth

ITk guidelines:

- The single connection to earth is at the Faraday cage
- Cable shields are extensions of the Faraday cage
- All conductive objects inside the Faraday cage must be referenced to it
- All conductors entering the Faraday cage must be filtered at entrance
- Different signal grounds (LVret and HVret) are independent up to each local structure (PP0/staves/petal/ring) where they connect together
- The local support reference to the Faraday cage is through the Type I cable shield

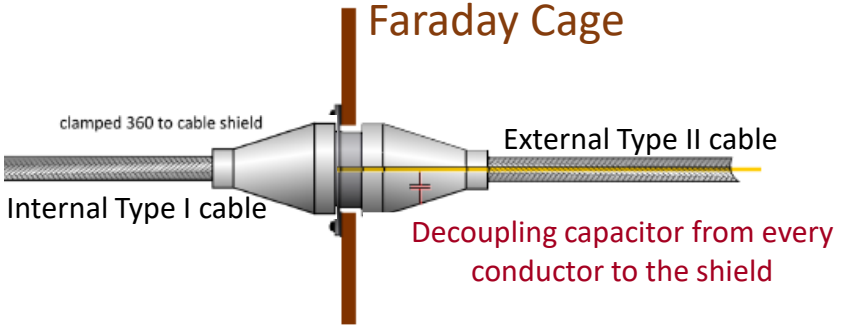


Pixel case:

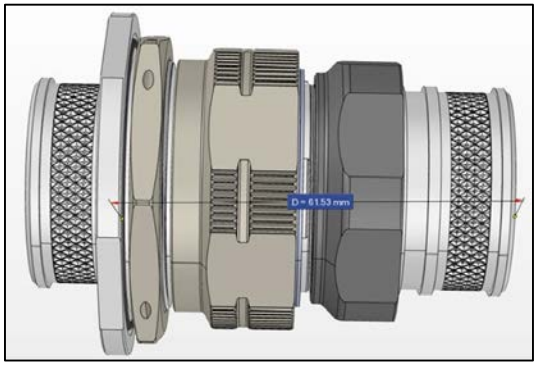
- Several cables (LV, HV, DCS)
- Connection to the Faraday cage through the DCS Type I shield

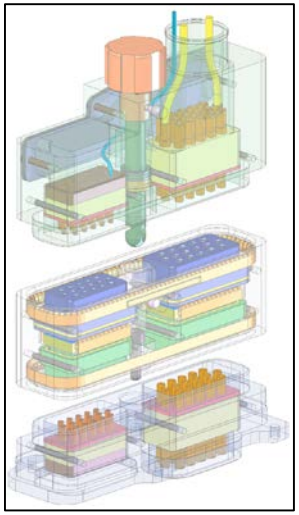
Importance of PP1

- Grounding location of the local supports and modules
- Cable shields are extensions of the Faraday cage (valid for Type I and Type II cables)
- All conductors entering the Faraday cage should be filtered at entrance



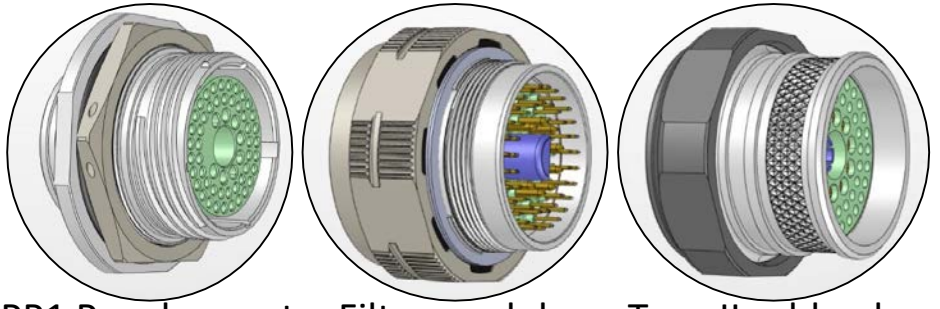
Pixels proposal





Strips proposal

PP1 Panel mount Filter Type II cable plug

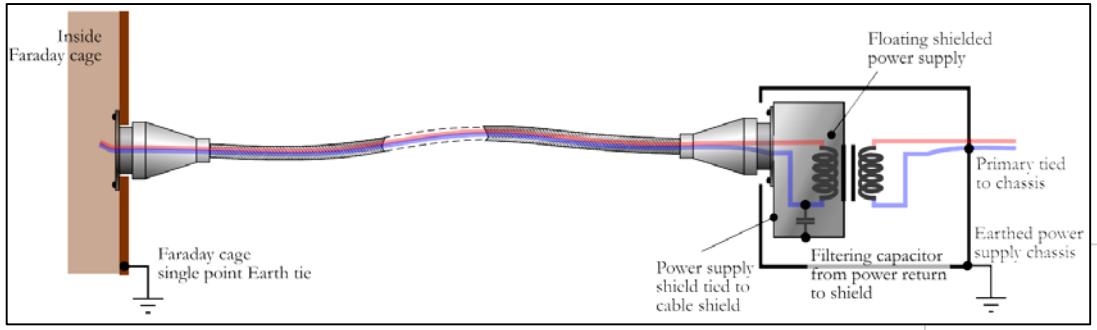


PP1 Panel mount Filter module Type II cable plug

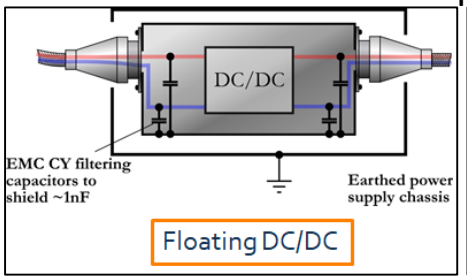
Cable shields

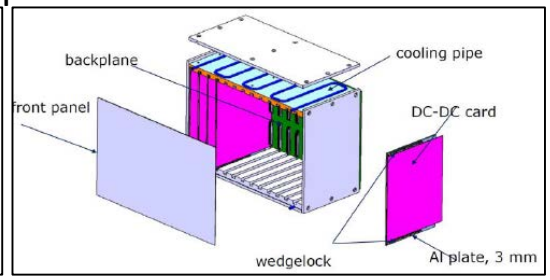
- The single connection to earth is at the Faraday cage
- Cable shields are extensions of the Faraday cage

Avoid big DC loops that can develop constant currents



Strips PP2

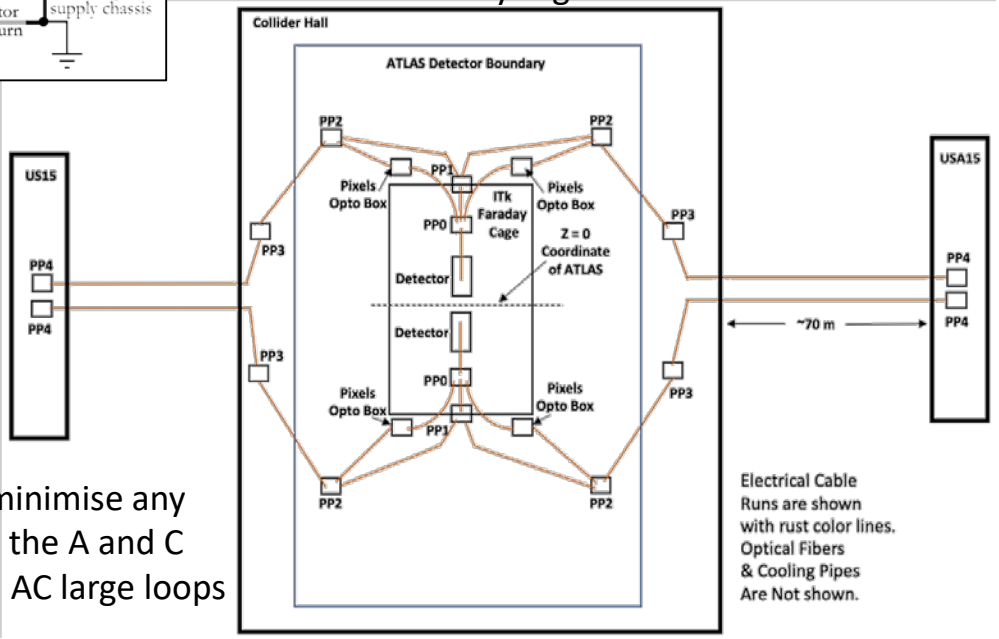




ITk requirements on cable shields:

- 25µm Al foil (fragile)
- Tinned copper or aluminum braid with minimum 80% coverage - the Al side of foil facing against the braid.

Possible noise on the cable shields between the two service caverns (different Mains) shunted at Faraday cage



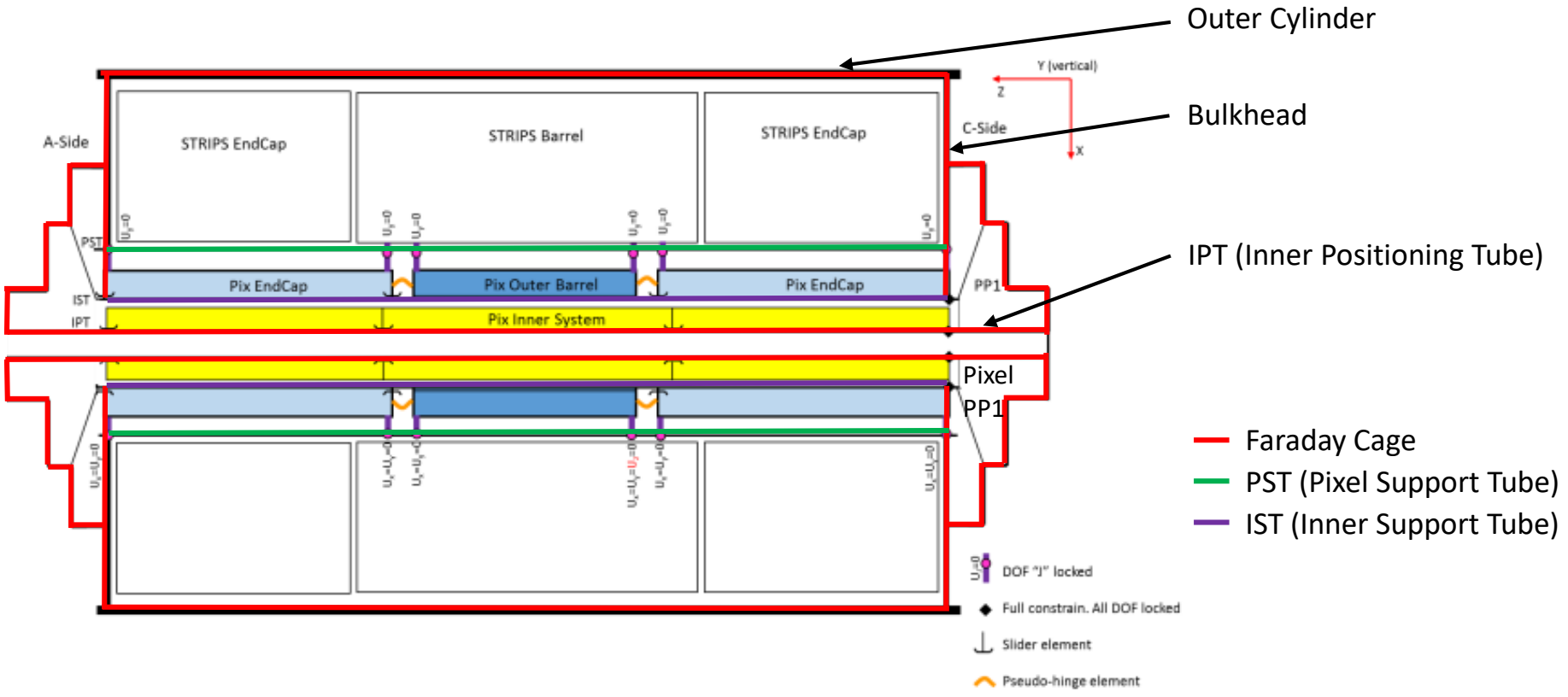
Care must be taken to minimise any cross coupling between the A and C sides of the ITk to avoid AC large loops

ITk Faraday cage

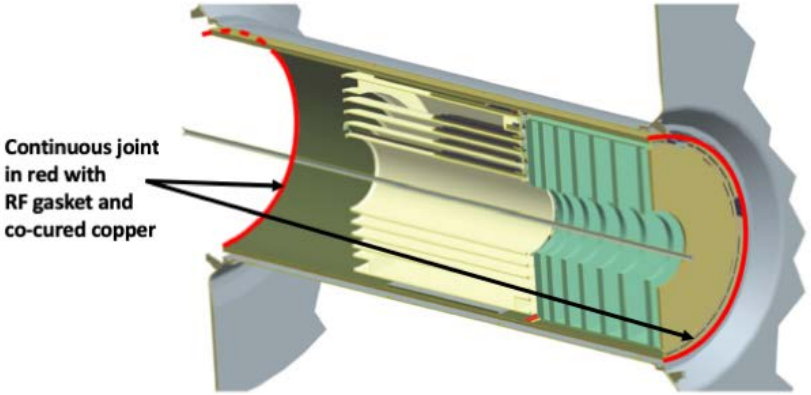
The Faraday cage

The entire ITk shares a unique and common electrical reference potential to earth

- Main parts are the Outer Cylinder, the two Bulkheads and the Inner Positioning Tube



ITk Faraday cage



For shielding effectiveness: 18µm copper, 25µm aluminium or 3.6mm CF

- OC foresees to have a layer of 35µm copper, with soldered seals between sections
- BHs foresee to have two layers (inner+outer) of 18µm copper, and a layer across width at high radius.
- IPT will do similarly (to be decided)

Earth tie can be at one of the Bulkheads, we need to check that there is very good connection Bulkhead to Bulkhead (<1 Ohm)

The enclosure needs to be as EM-hermetic as possible

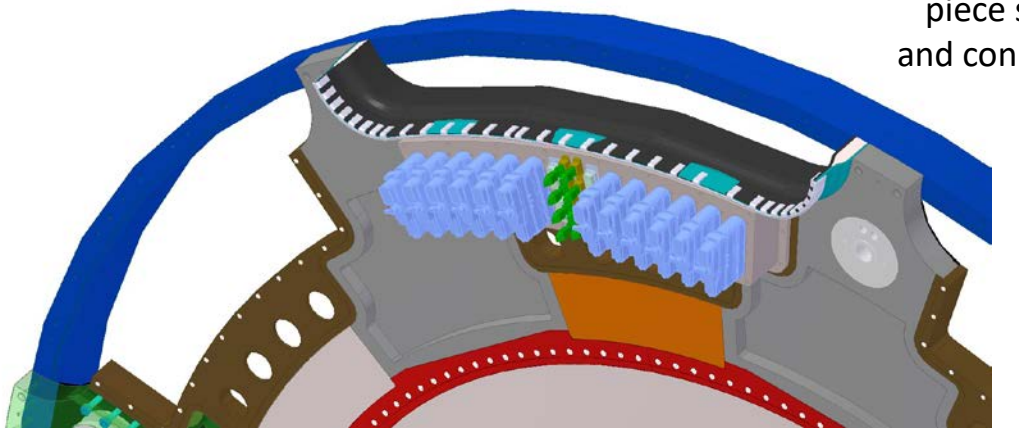
Special attention is taken at interfaces (OC/BH/PP1s) in order to minimise apertures

ITk Faraday cage – Interface OC/BH/PP1

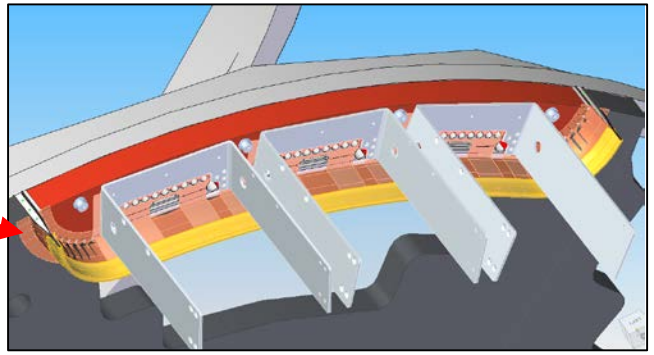
Outer Cylinder and Bulkhead interface at the 8 fingers of the BH.

- The contact is against the end flange of the OC.
- The flange will have a copper layer and RF gaskets between the flange to BH interface and between the flange and the OC interface.
- This copper layer will also be used for the connection to the Barrel Service Module (SM) and PP1

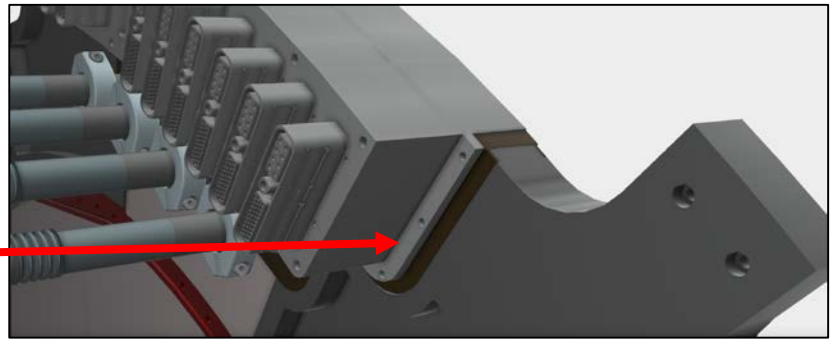
It is important to have a good electrical connection of PP1s to the Bulkhead



Strips Barrel PP1 with in-fill piece soldered to Cu foil and connecting to Bulkhead



Strips Endcap PP1 flap connects to Bulkhead using RF gasket

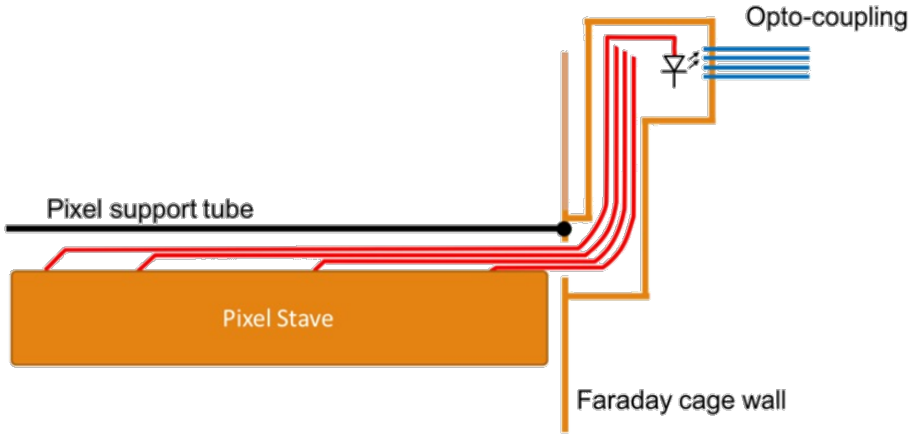


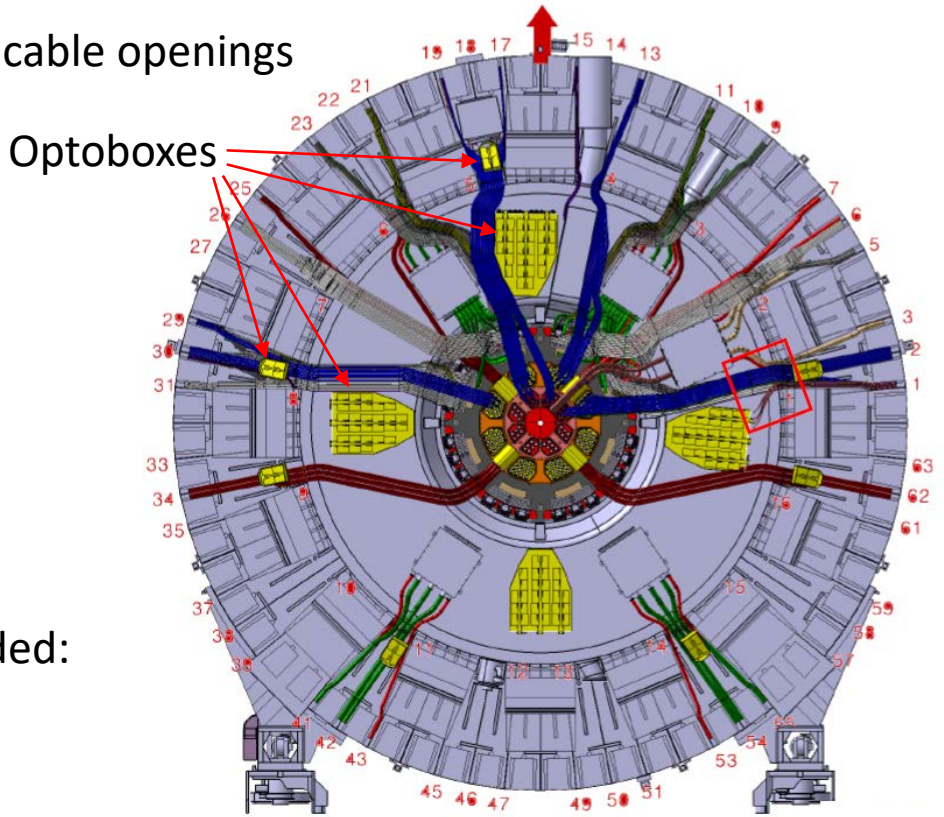
Pixel Optoboxes

Because of the very high radiation levels and mechanical constraints, the electrical to optical transceivers need to be placed outside of the Faraday cage. The Pixel data transmission needs to be electrical up to these optoboxes.

The Faraday Cage needs to be extended:

- Shield the data transmission cables and seal the cable openings
- Reference the optoboxes



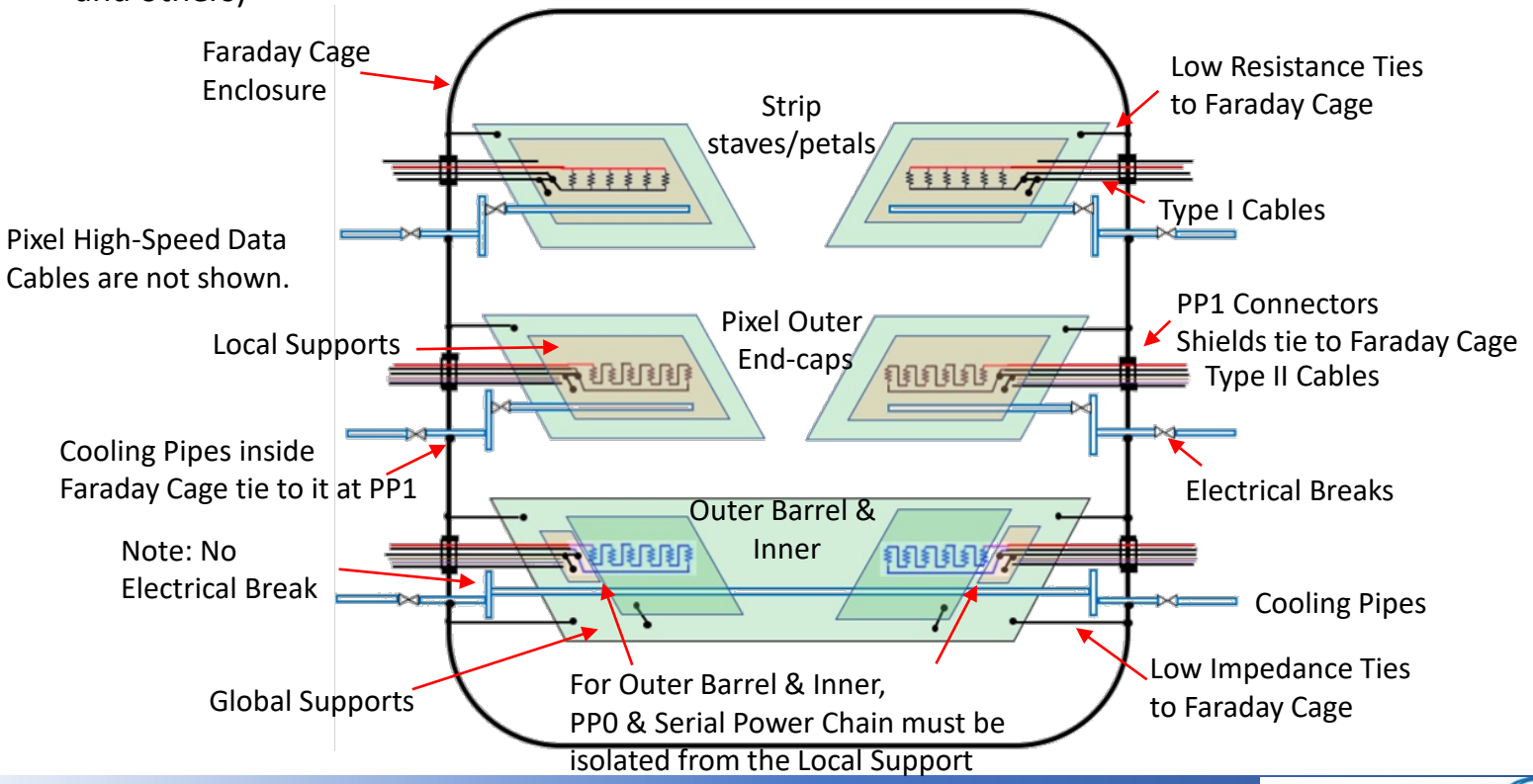


The high speed electrical data cables are shielded:

- DC referenced to the Optoboxes
- AC referenced to PP0 (modules)

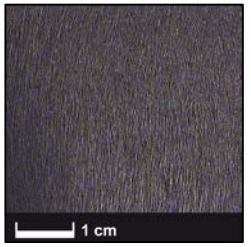
ITk grounding of Local Supports

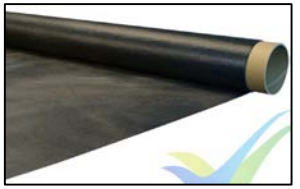
- Strip staves/petals and Pixel Outer endcap rings are grounded to their local supports, and they are isolated from the global supports
  - An electrical break in the cooling line keep them only referenced by Type I cable
- Pixel Outer and Inner Barrel have cooling pipes through various SP chain local supports
  - Local supports grounded together with cooling pipes to the global supports (modules isolated)
  - No inner electrical break needed (outer electrical breaks are always needed to avoid loops through cooling plant and others)

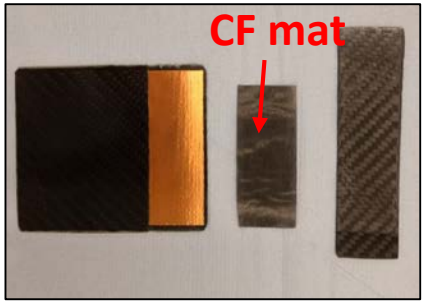


Carbon fibre joints

- All conductive objects inside the Faraday cage should be referenced to it
- Outer cylinder, bulkheads, and most of the global supports are made of carbon fibre.
- They need to be electrically referenced to avoid charge up.
- We differentiate:
  - Ancillary support structures: low resistance connection (DC) to PP1 < 20 Ohms. Ohmmeter checked.
  - Influential support structures: those close to stave/petals/rings. They must have a low impedance connection.
    - Low impedance connection (DC to 100MHz): < 10 Ohms to PP1
    - There must be one of these ties every ≤ 200 mm.
    - Check on prototype joints with dedicated equipment (AC)
    - Check on production parts with ohmmeter
- Electrical tests have been made on CF joints
- Epoxys: not reliable electrical connection for the needed values.
  - Even loaded with graphite powder (>20Ω)
- **CF mesh (non woven matt)** with non-conductive glue in between give good results (~Ω)
- Baseline for most of the joints. High force in structural joints.
- Back-ups: conductive glue and matt. Also, graphene sheet and glue.
- For influential CF joints in support structures (OC, BH) and as back-up:
  - **Co-cured copper** with RF gasket/washer (<1Ω)

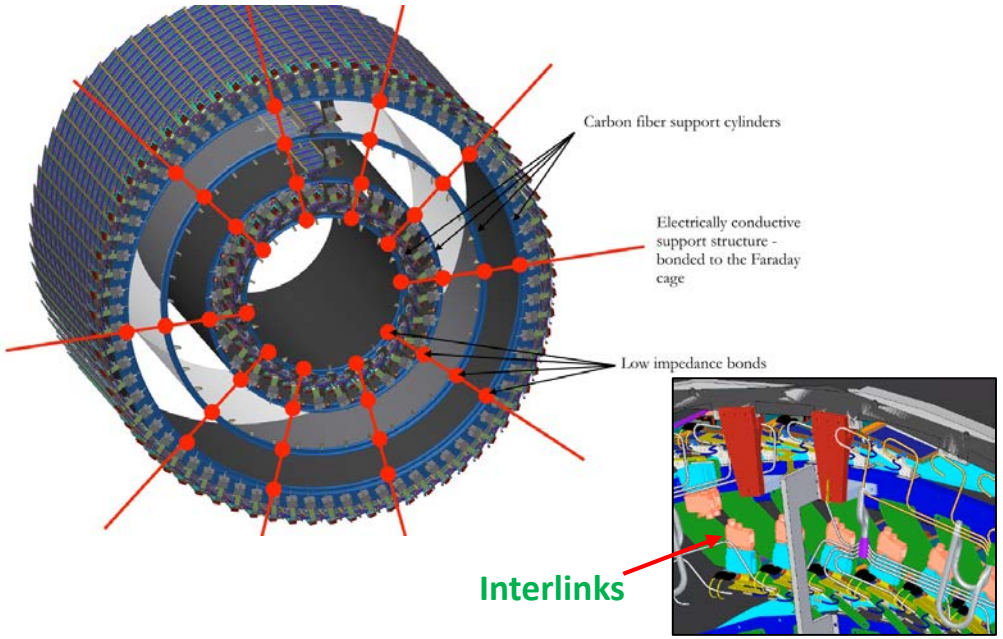


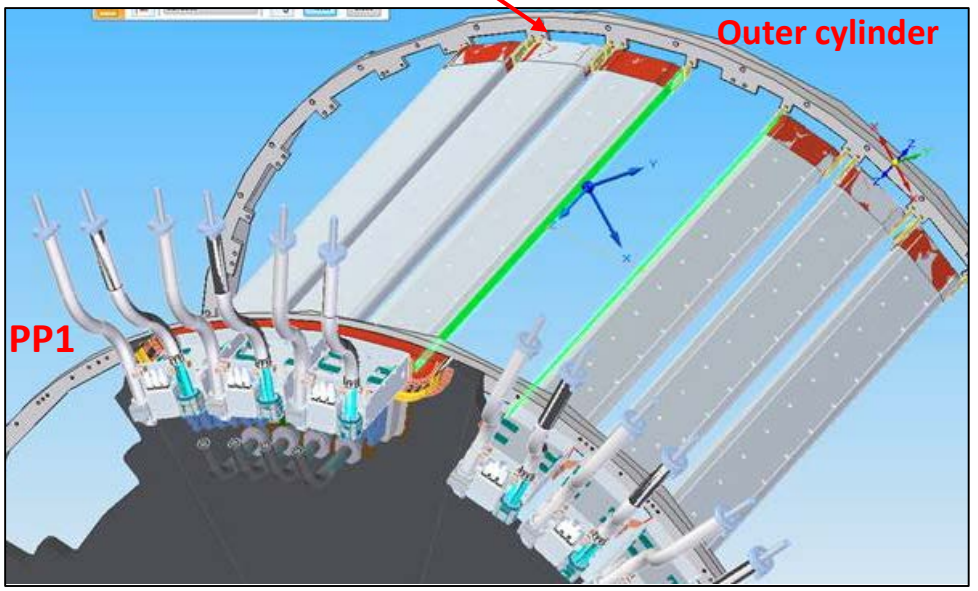




Strip Barrel Global Supports

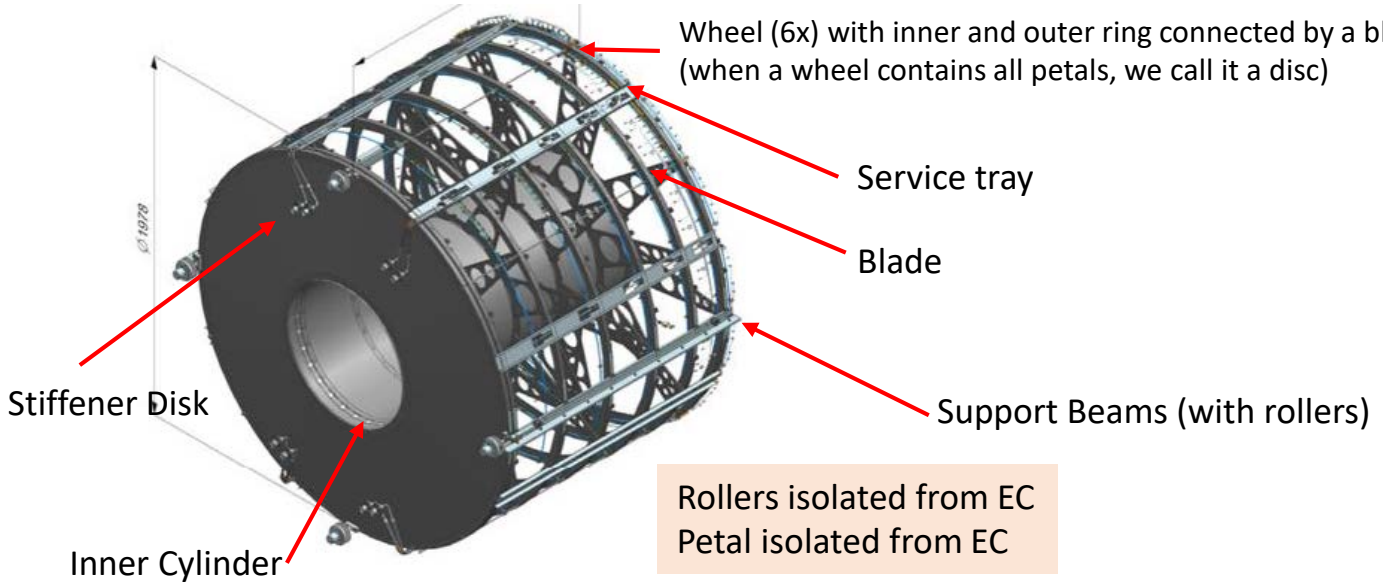
- The 4 barrel cylinders have a very large area and go from +Z to –Z .
- They represent a possible coupling to the staves:
  - Low impedance connection to both ends of the Faraday cage.
  - Low impedance between cylinders, each end of the interlinks.
  - Outermost cylinder connected to SM trays (Type I)
    - Litz wire each <20cm (interlink ~12cm)
  - The barrel supports to the OC (brackets) should be insulated. Only connection is to PP1s.

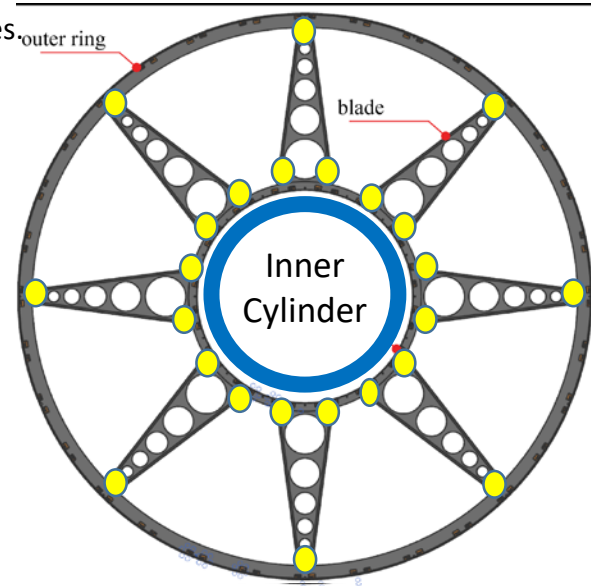




Strip Endcap Global Supports

- Most of the supports are considered low resistance.
  - Blades have limited area and they are at >9mm from the petals
  - Only the Stiffening disk can be considered low impedance, even at >40mm from the petals.
- Implementation:
  - Cable trays and cooling pipes should be connected with low impedance to PP1.
  - Pipes will be the connecting to PP1.
  - Outer ring of the disks should have low resistance to the 4 pipes per disk.
  - Blades and inner rings should have low resistance to the outer rings.
  - Stiffening disk should be connected low resistance to the 24 pipes, which will make a low impedance.
- The inner cylinder should be connected to the stiffening disk.
- The 4 EC supports to the rails should be insulated (ceramic bearings). The only connection will be to PP1s.

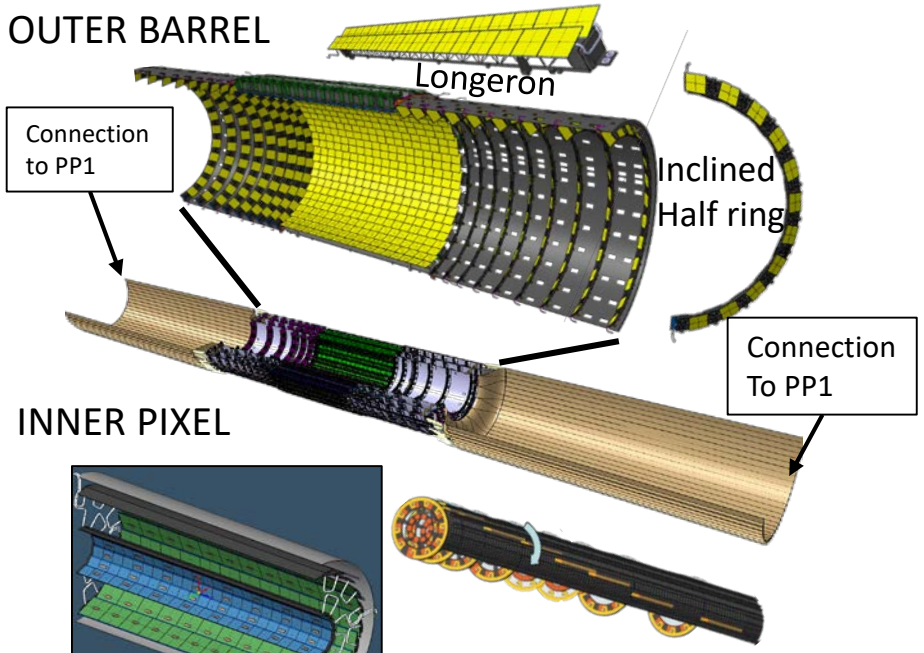




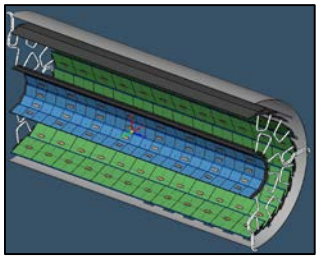
Pixel Global Supports

- **Outer barrel and Inner Pixel**
  - Low impedance connections to PP1 and between:
    - Cooling pipes
    - Local supports: longerons, inclined half ring, inner barrel supports
    - Global supports: different shells
  - Electrical components must not be referenced to local supports. Modules isolated >1MΩ DC to previous.

OUTER BARREL

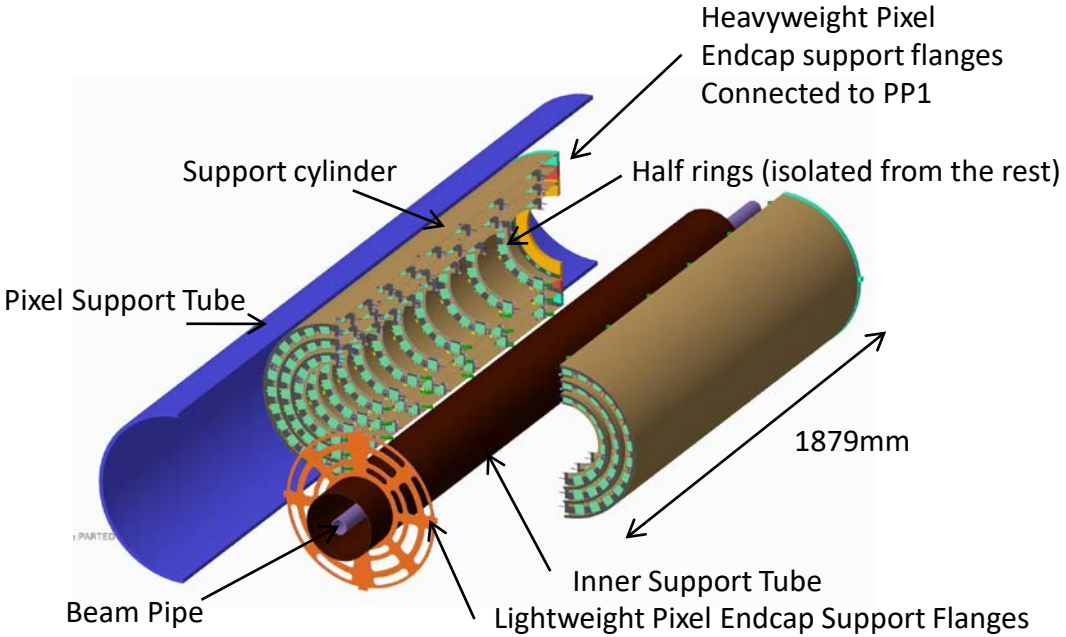


INNER PIXEL



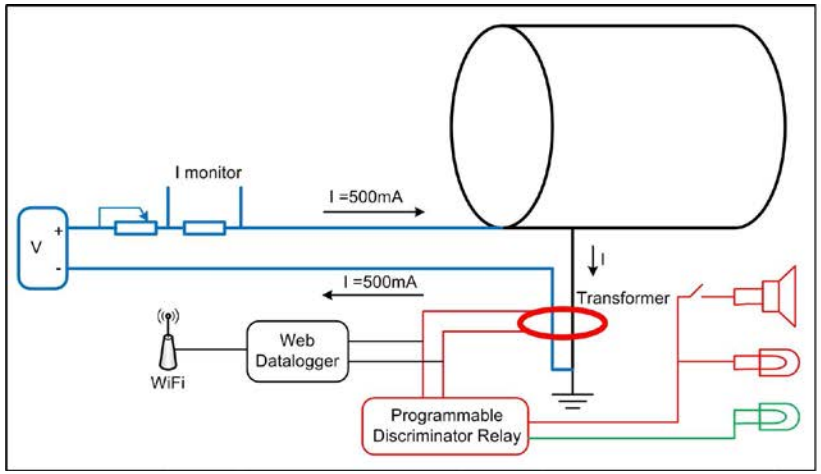
- **Outer endcap**
  - Half ring connected to PP0
  - Isolated from Support cylinders
  - Cooling pipes have electrical break before half ring
  - Low impedance Support cylinders, flanges and PP1

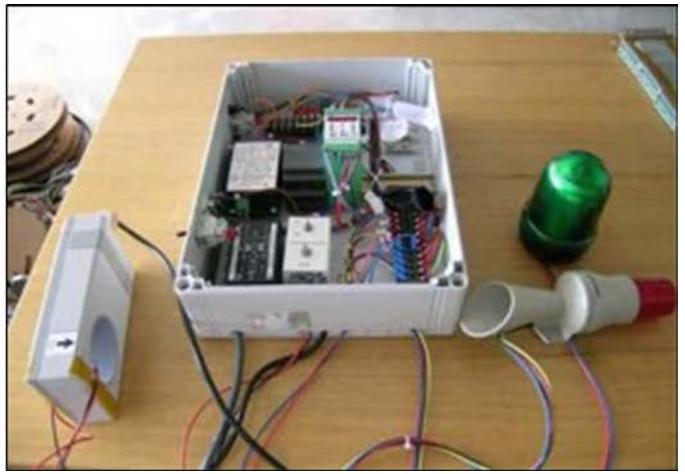
OUTER ENDCAP



G&S Validation

- We have worked in order that designs are consistent with the G&S requirements.
- Further checks on specific joints will be done.
- During fabrication and integration, the DC resistance of the various ties will be checked and those items that must be floating relative to others will be checked.
- It is not practical to check AC impedance in a similar way, a specific lab instrument is needed for this. Therefore, that validation will rely on the design checks. Prototype joints will be checked at a dedicated lab. Then, during integration of final parts, DC checks on them will give a cross-check.
- A further check will be provided during integration. A ground fault monitor will be provided at each integration site to monitor if any extra, unwanted ground connection is made during the integration process.





Isolation checks during installation:

- PP0/staves/petals
- External pipes
- Global structures
- Other infrastructure

Thank you

Further information:

A. Grillo et al., ITk Grounding & Shielding requirements, EDMS AT2-I-EP-0001

R.L. Bates et al., The ATLAS SCT grounding and shielding concept and implementation, JINST 7 (2012) P03005

ITk Strips Powering – Outer Staves and Petals cable segmentation

For 1 LS/EC stave/petal:

- 2 LV channels

(one per side)

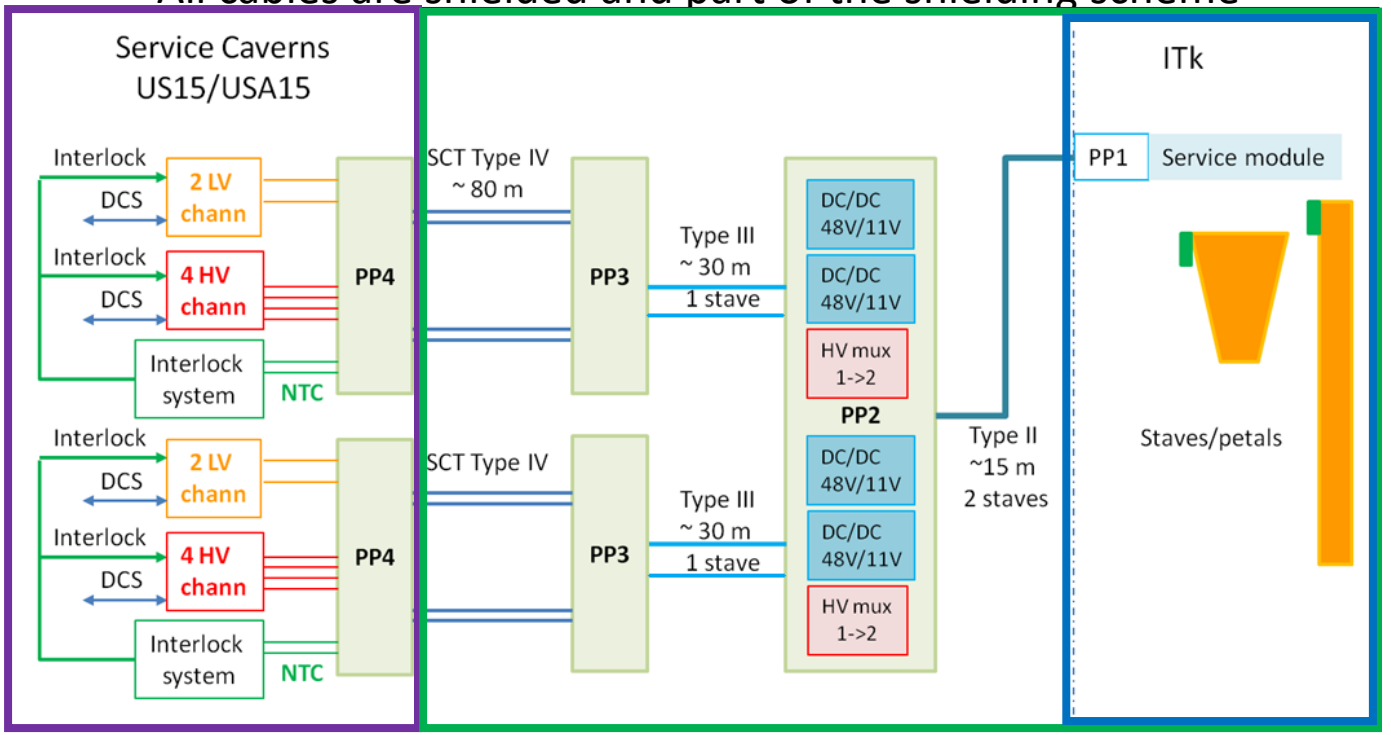
- 4 HV channels

(2 per side, multiplexed at PP2 to have 4 per side)

1 LS/EC needs:

- 4 SCT Type IV cables
- 2 new Type III cables (one per side)
- ½ new Type II cable (one cable for 2 staves to save space)
- 1 new Type I cable

All cables are shielded and part of the shielding scheme



- USA15/US15 Service Caverns
- UX15 ATLAS Experimental Cavern
- ITk Volume

Same cable flavour for SS and LS/EC: Type IV, TypeIII, Type I (Service Module)
Different cable flavour for SS and LS/EC: PP4, PP3, PP2, TypeII
Inner Barrel has Short Strip (SS) Modules
Outer Barrel has Long Strip (LS) Modules

ITk Strips Powering – Inner Staves cable segmentation

For 1 SS stave:

- 2 LV channels

(one per side)

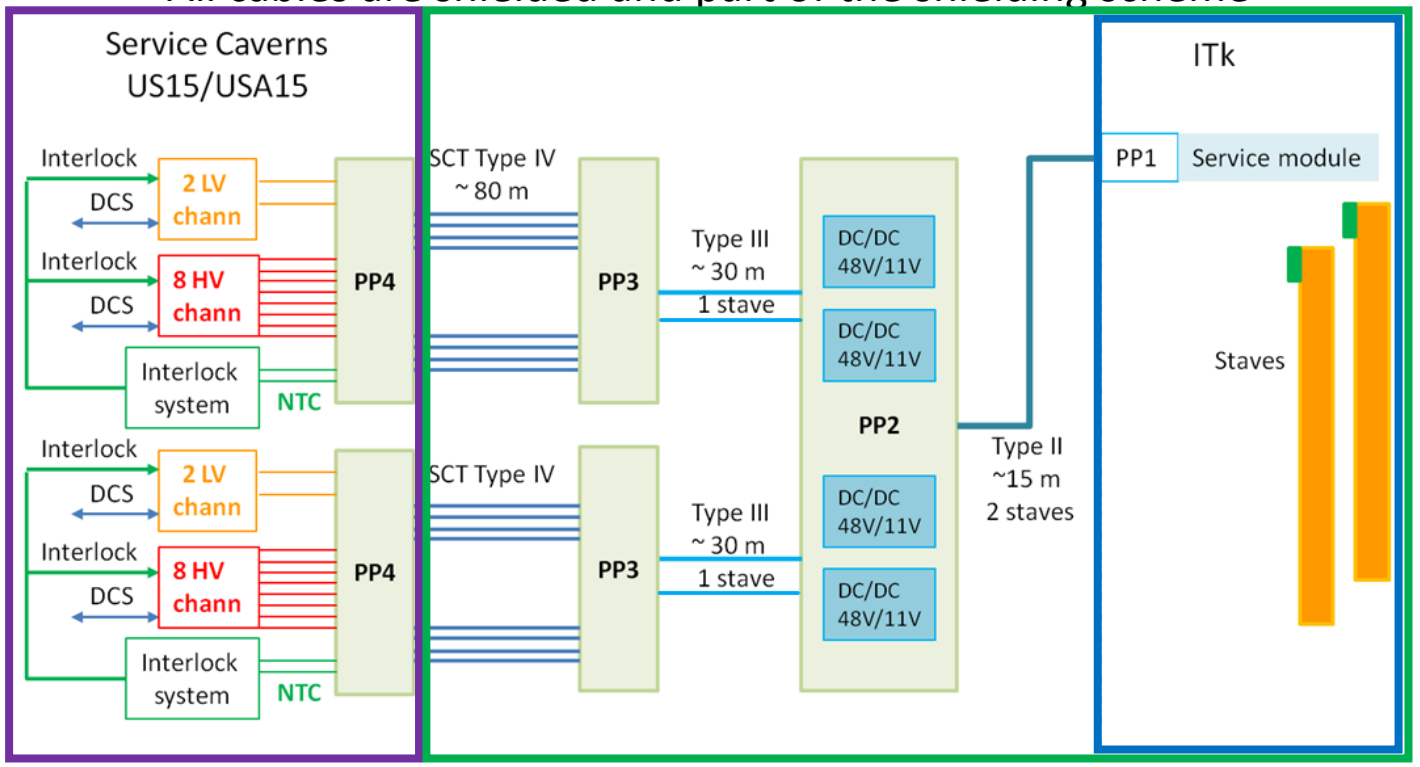
- 8 HV channels

(4 per side)

1 SS needs:

- 8 SCT Type IV cables
- 2 new Type III cables (one per side)
- ½ new Type II cable (one cable for 2 staves to save space)
- 1 new Type I cable

All cables are shielded and part of the shielding scheme



- USA15/US15 Service Caverns
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