Grounding & Shielding
Some Experiences from ATLAS

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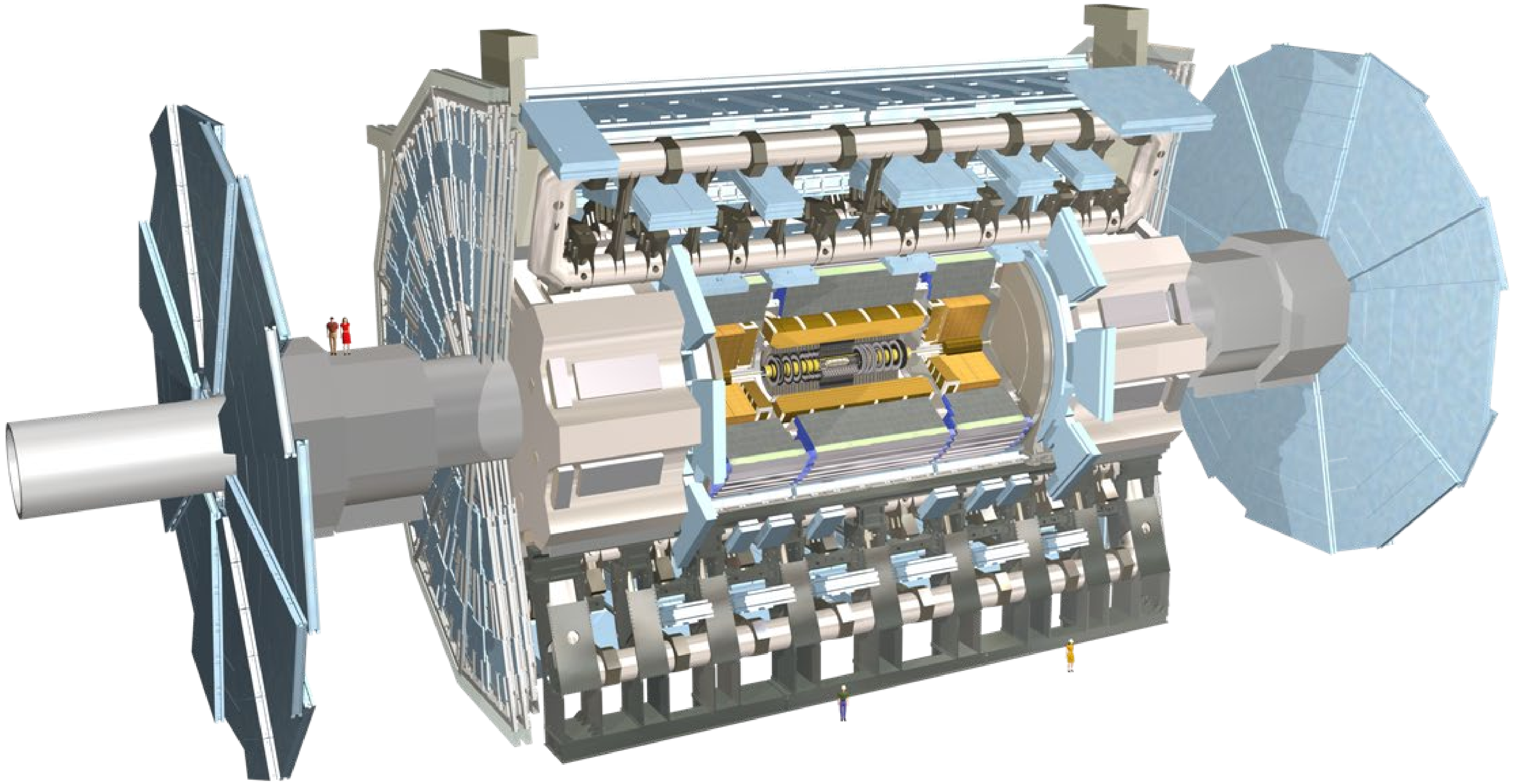
Context

- Currently the responsible person for the Grounding and Shielding (G&S) of the upgrade of the ATLAS Inner Tracker (ITk)
  - Advisor for developers
  - Reviewing G&S concepts of ITk components
- Talk covers the actual (sub-)detector G&S
- NOT covered is the overall grounding of the experiment
  - layout of grounding planes during construction, rack grounding, safety ground etc.
- Example is the new Inner Tracker ITk

ATLAS Experiment – Upgrade for High-Lumi LHC



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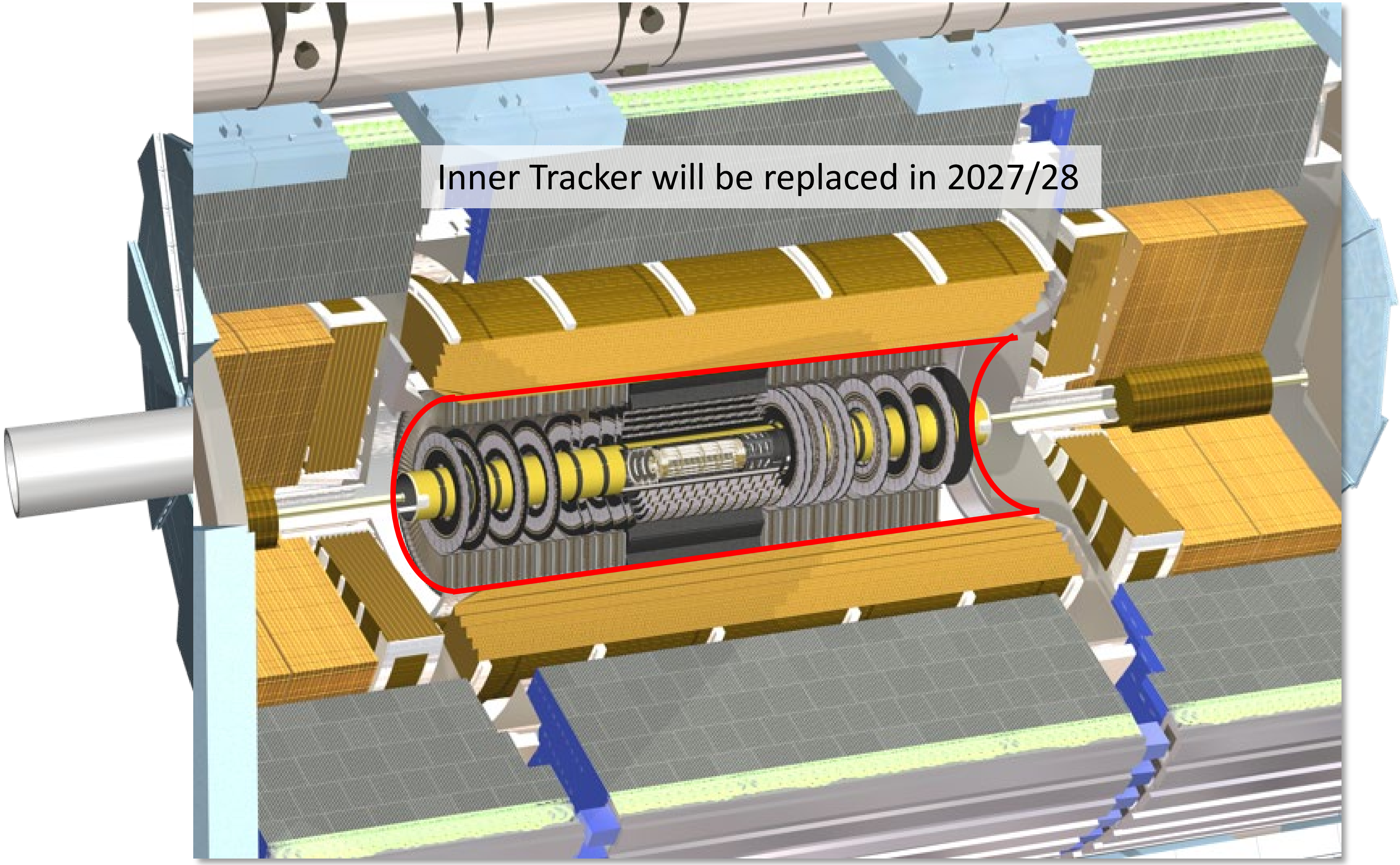

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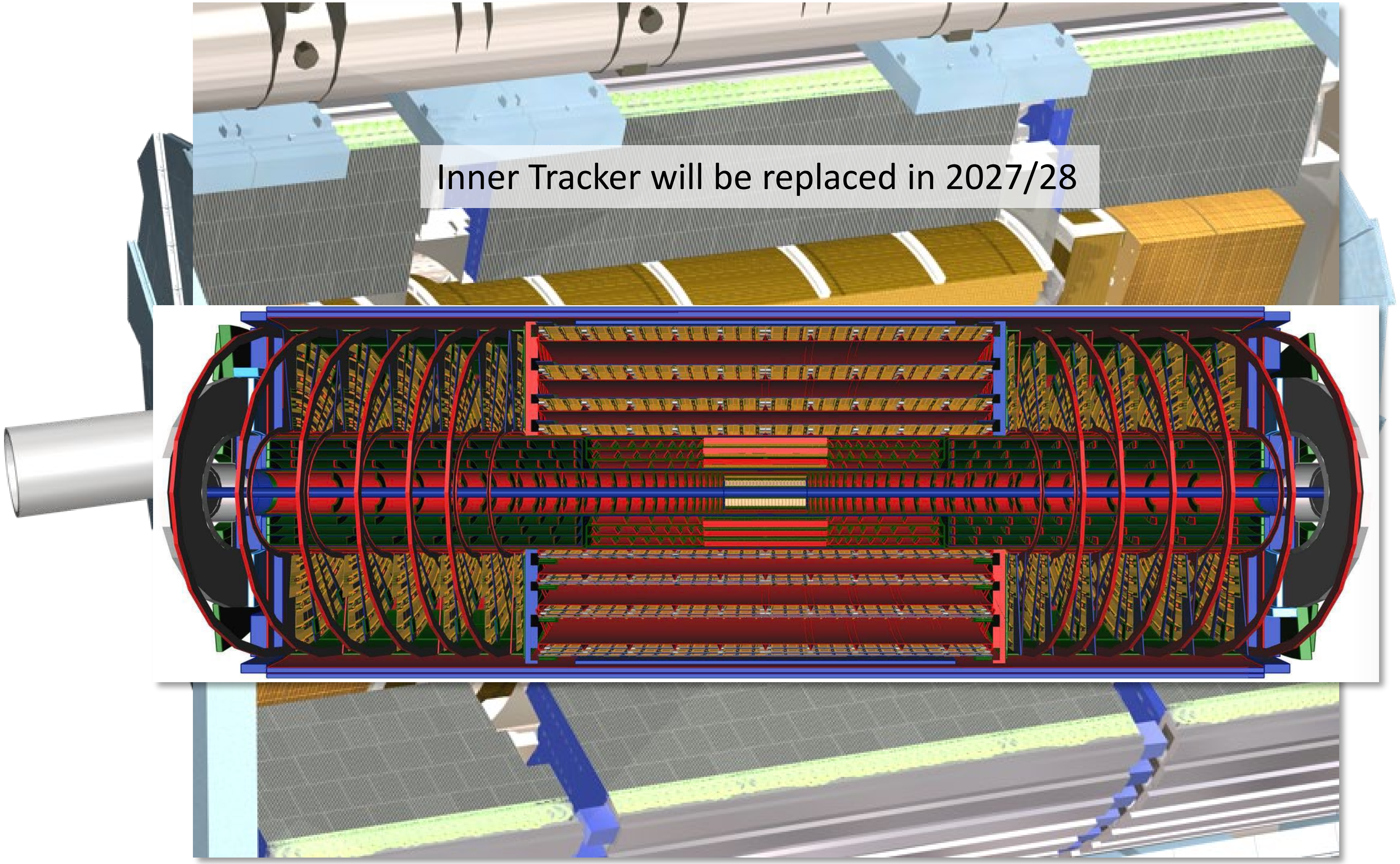

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ATLAS G&S Basics Tenets

General ATLAS rules defined in the late 1990s/early 2000s

- Star-like structure
  - Central grounding point at the detector level
- All detector systems are electrically isolated
  - No electrical connection between sub-detectors
  - E.g. the tracker is isolated from the calorimeter
- Each detector subsystem has only a single DC connection to ATLAS ground in order to avoid ground loops
  - For the Inner Tracker this connection is done at the detector level in the underground hall
- Each detector system is located in a Faraday cage

- Data, Clock, trigger, monitoring and control signal transmission via optical or shielded twisted pair cable
- Filtering required for all signal, monitoring, power lines entering/leaving the Faraday cage
- All conducting objects require grounding to avoid beam induced charge-up

ATLAS G&S Basics Tenets

originally from about 1997

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2000s

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ATLAS Policy on Grounding and Power Distribution

Introduction

As is well known from previous experiments, careful attention must be paid to the grounding and power distribution of each of the detector systems if they are to operate successfully at the low signal levels required. While this has been an important issue in previous experiments, it is an especially important issue for ATLAS given the large expense and time required to redo any system, and given the very large power in most systems. In this note, we outline the present ATLAS policy on grounding and power distribution. The primary content of this note is a set of proposed guidelines that have been arrived at via reasonably extensive consultation with each of the subsystems. The intent is that these guidelines must be followed unless specific approval for a deviation is granted by the Executive Board. Some discussion is also presented as to how the guidelines can be accomplished. It is expected that recommended implementations will become increasingly detailed after further discussion and thought and as experience in test beams and system tests provides additional information.

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General ATLAS … ontrol signal
2000s … wisted pair

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ATLAS project	Grounding of the ATLAS Experiment	
ATLAS Project Document No: **ATC-TE-ER-0002** **EDMS ID: 884827**	*Created:* **29 November 2007**	*Page:* **1 of 47**
	Modified: **VOID**	*Rev. No.* *1*

Grounding of the ATLAS Experiment

Documentation of the grounding architecture implemented in the ATLAS detectors, infrastructure and back-end systems.

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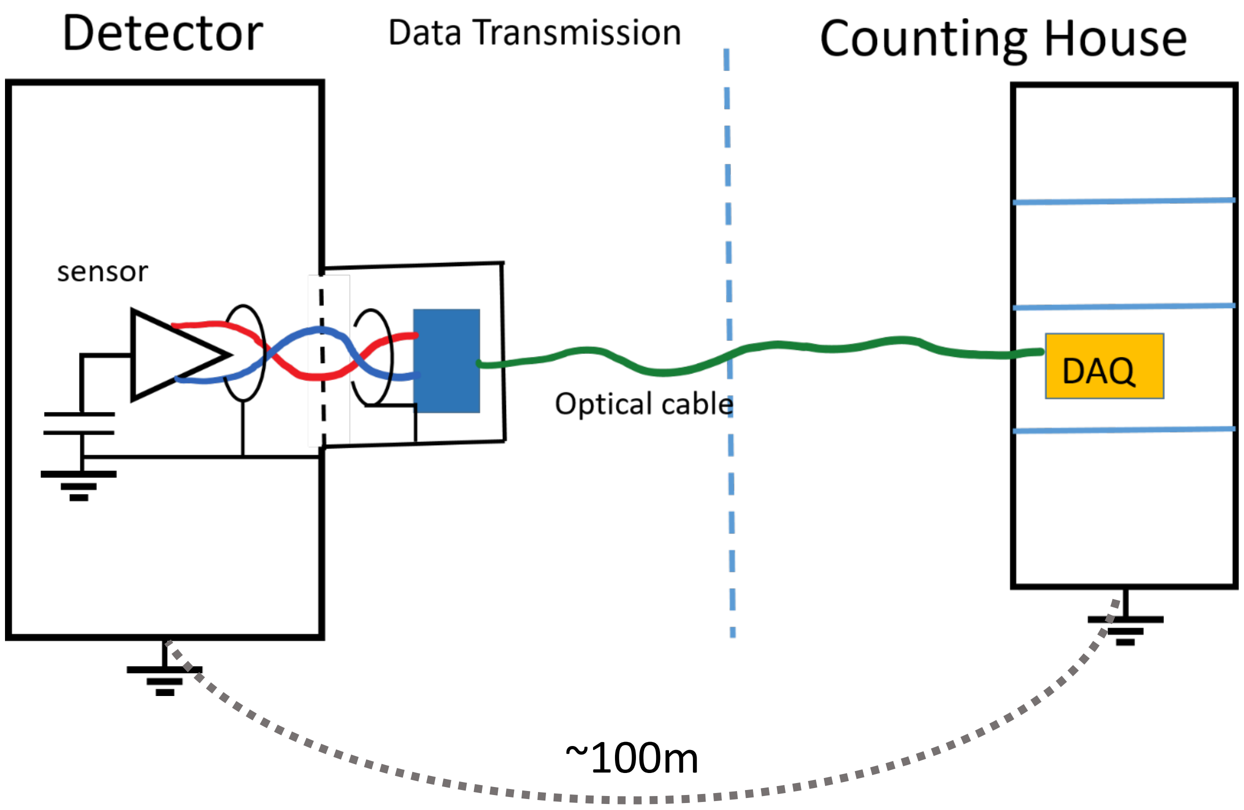
Implications

- All power supplies (LV and HV) are floating and only referenced to the corresponding Faraday cage
- All signals between the detector (front end) and electronic racks (back end) are only DC referenced on the detector (Faraday cage) side
- All cable shields are directly connected to the Faraday cage
- Split grounds required on the back end PCBs
  - Galvanic decoupling required (opto couplers, transformers or capacitors)
- All intermediate active/passive patch panels are only AC coupled to local ground
- AC connection required for shields at back end/intermediate patch panels
- Services (Cooling, safety, interlock …) require electrical decoupling
  - Cooling pipes: Electrical breaks and filtering to decouple from the cooling plant
  - Interlock: same rules apply as for power and signal lines
- All cables carrying clocked signals, require a shield inside the Faraday cage

G&S Sketch

- Detector as well as back-end electronics is grounded locally
- “Same” ground, but with ~100m distance
- Risk of a big ground loop



Readout of Detector Data

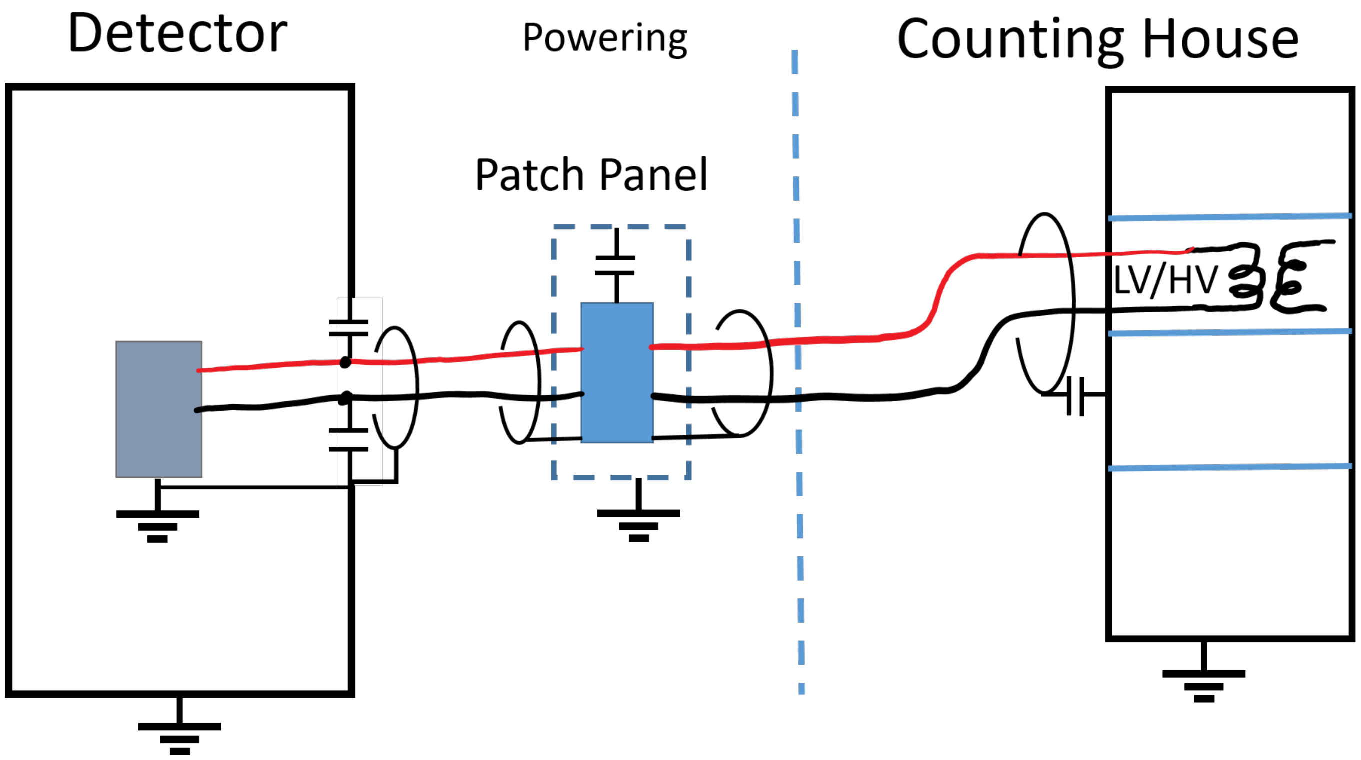
- Sensor signals are digitized at the detector level and converted and transmitted optically

→ Loop is broken

G&S Sketch (1)

Powering of active components

- Floating voltage/current source
- Powering lines run straight to or into the detector
  - Filtering to Faraday cage required
- Referenced at the detector level
- Shields are only AC coupled to avoid the ground loop



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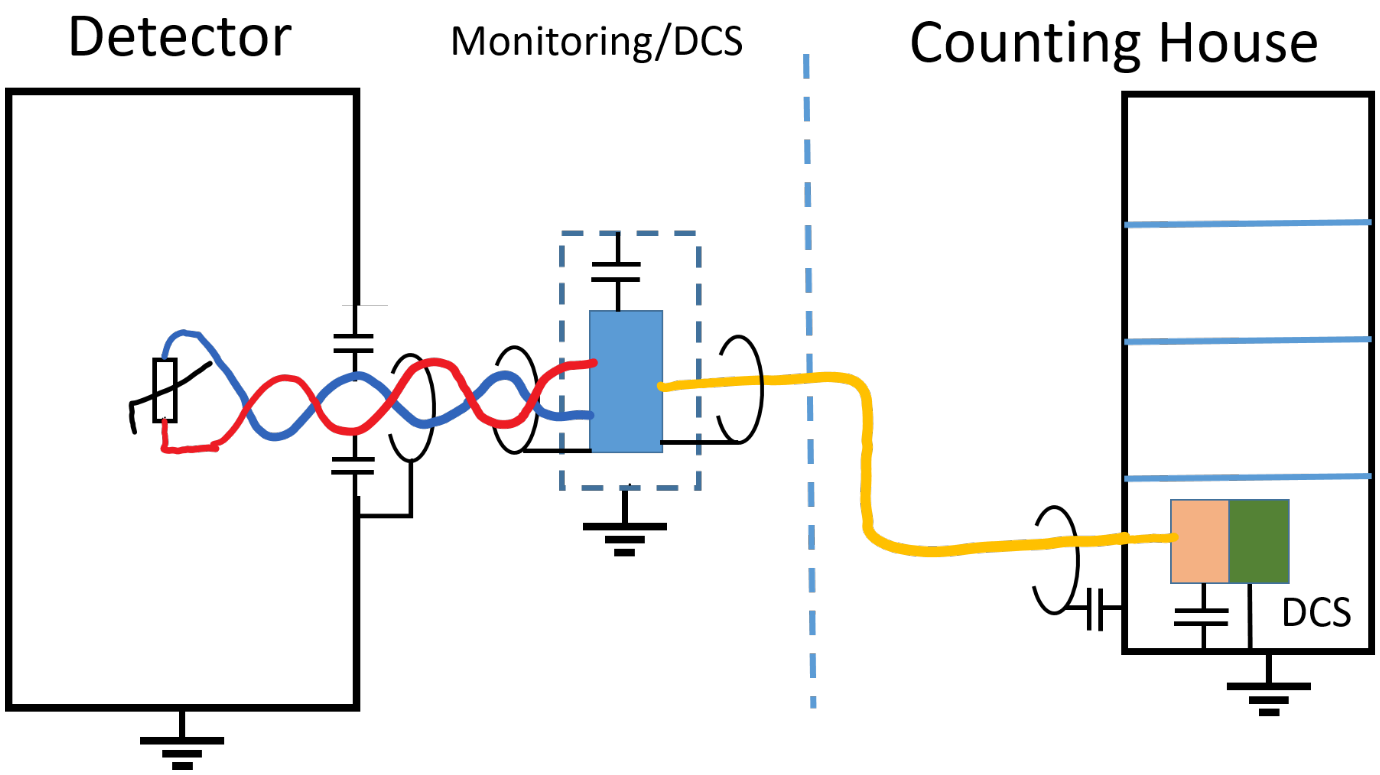
G&S Sketch (2)

Monitoring and Control

- Sensor data (analog or digitized)
  - Run either straight to the counting house or an intermediate readout
- Control data are passed straight to the corresponding component at or in the detector volume
- All lines require filtering to the Faraday cage
- Clocked data require a shield inside the Faraday cage
- Shields are only DC coupled to the Faraday cage



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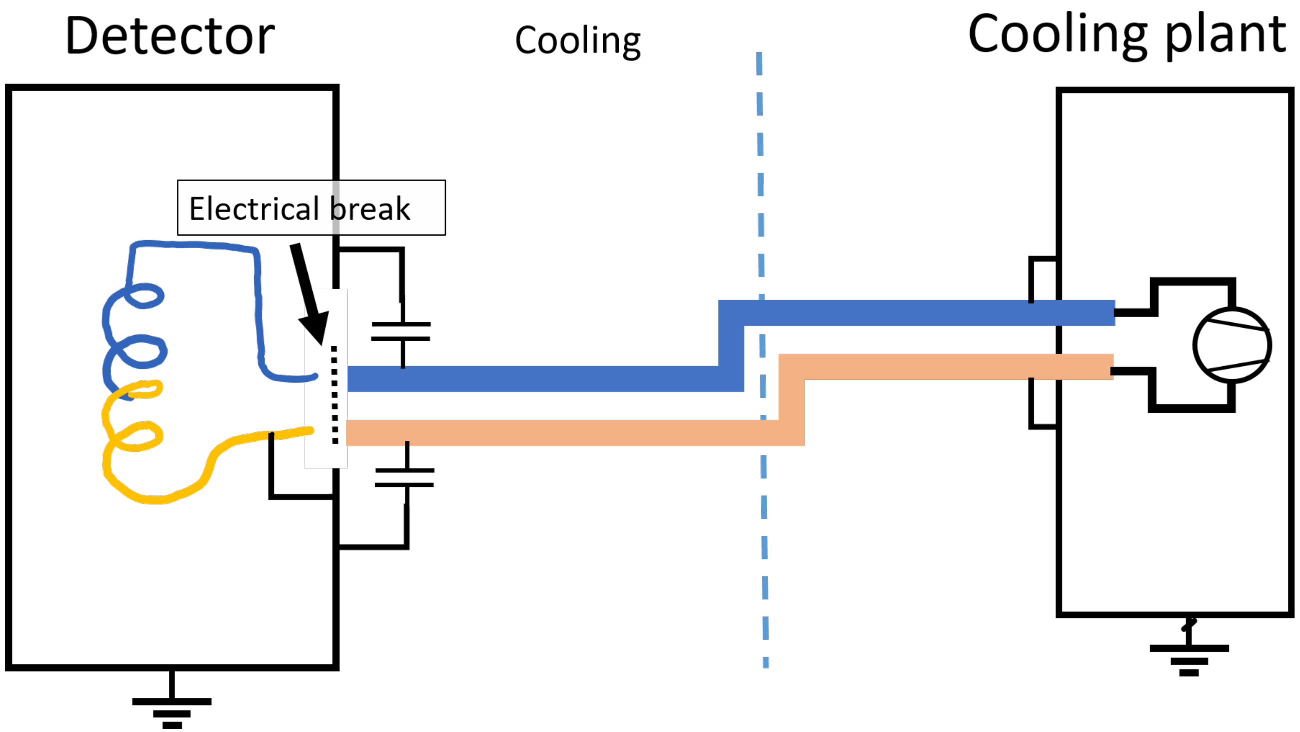
G&S Sketch (3)

Cooling

- Cooling pipes have to be isolated from the experiment to break the ground loop

  → electrical breaks (ceramic) inserted

- High frequency coupling through capacitors
- Cooling pipes inside the Faraday cage



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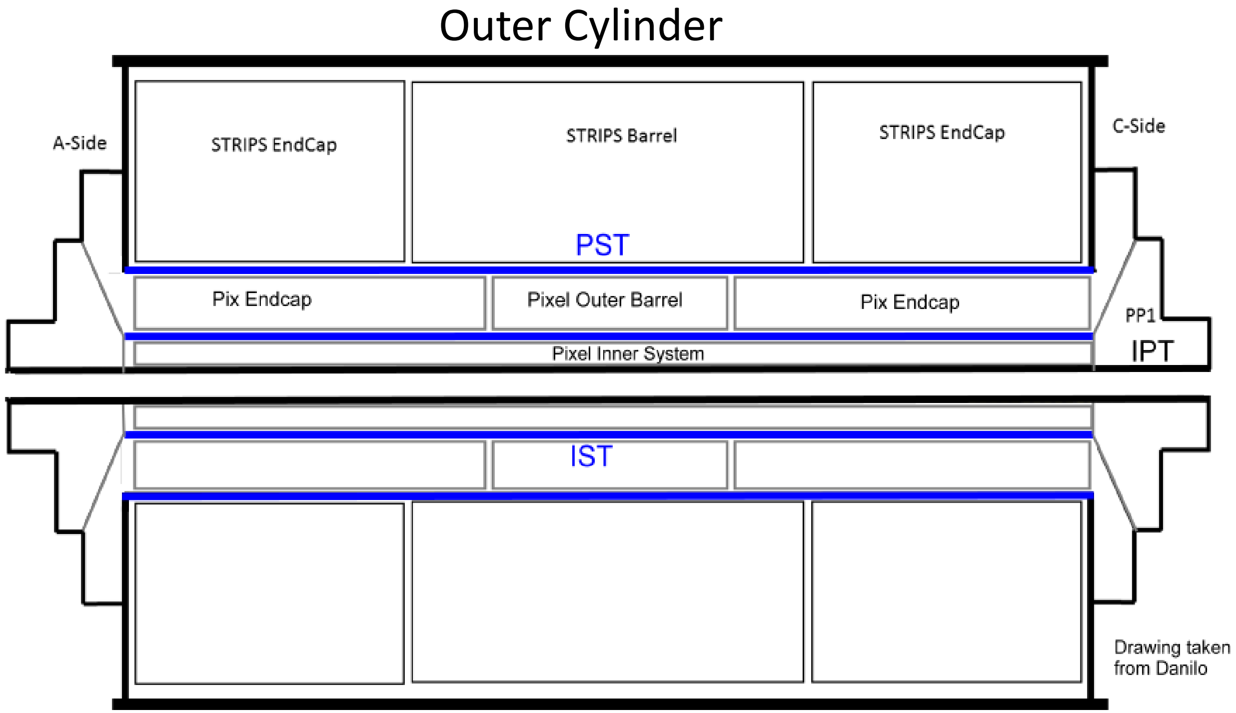
G&S Concepts applied to new Inner Tracker

- Faraday Cage
  - Made mainly out of Carbon Fiber Composite
  - Some metalized plastics (e.g PEEK)
  - Aluminum
  - RF gaskets required for the transitions
- Transitions are tricky for large CF structures usually made out of multiple parts
  - Conducting glue, co-cured copper pads and braided cables
- Even more complex: Pixel Modules of the ITk
  - Modules are serially powered (all on different potential)
    - Modules are isolated from their respective CF support structure
  - LV and HV require referencing
    - Central grounding point close to the Pixel modules



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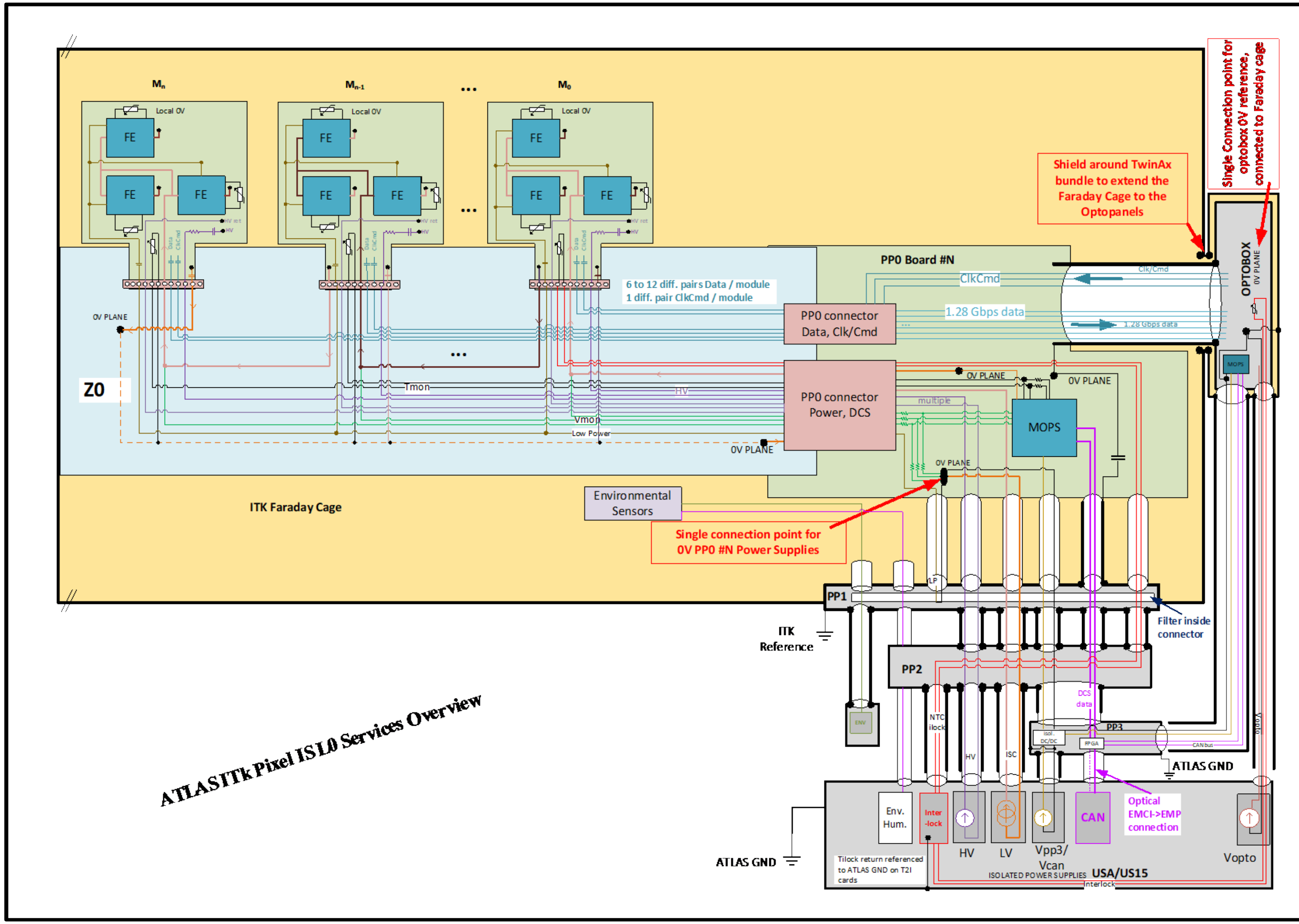
ITk Feedthroughs into the Faraday Cage

- Detector Data are on GBit transmission lines
  - Shielded twisted pair potted into Feedthroughs
- Services (LV,HV, DCS signals, interlock) share connectors
  - Custom made Connectors
  - Include the filter capacitors
  - Connects the shields to the Faraday cage

Example:
ITk Pixel Inner System

Includes signal, shields, services referencing …

Similar schematics requested for all (sub-)components during the review process



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Validation of the G&S Concept

- Development
  - Measure impedance of connections up to approx. 100 MHz to be below 10 Ohm for low impedance connections
    - Upper frequency depends on the sensitivity range of the Front-ends
  - This is difficult and requires a controlled environment, specialized tools and experience
  - Even more difficult for large scale CF-composites
    - Requires co-cured copper pads for contacts
  - Noise injection (capacitive or inductive) to validate immunity of the system
    - Very difficult to quantify noise level and signal/noise ratio
- Combined tests needed

- Quality Control of components
  - DC measurements (< 10 Ohm)
- The Ground Fault Monitor (GFM)
  - Device injects a constant current into the structure
  - Return current measured at single ground connection
  - Discrepancy triggers an alarm
- Ground Fault Monitor used during
  - Assembly of larger structures
  - Installation
  - Commissioning
- Problems should be discovered already at the production and latest assembly stage

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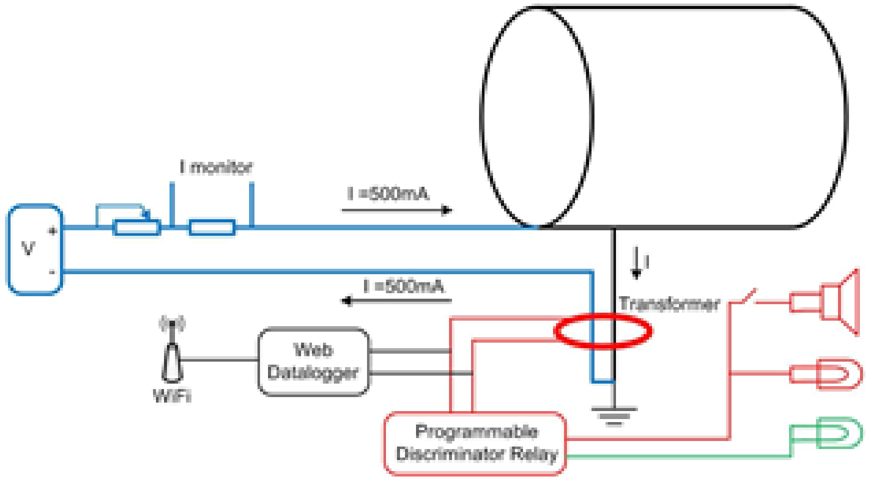

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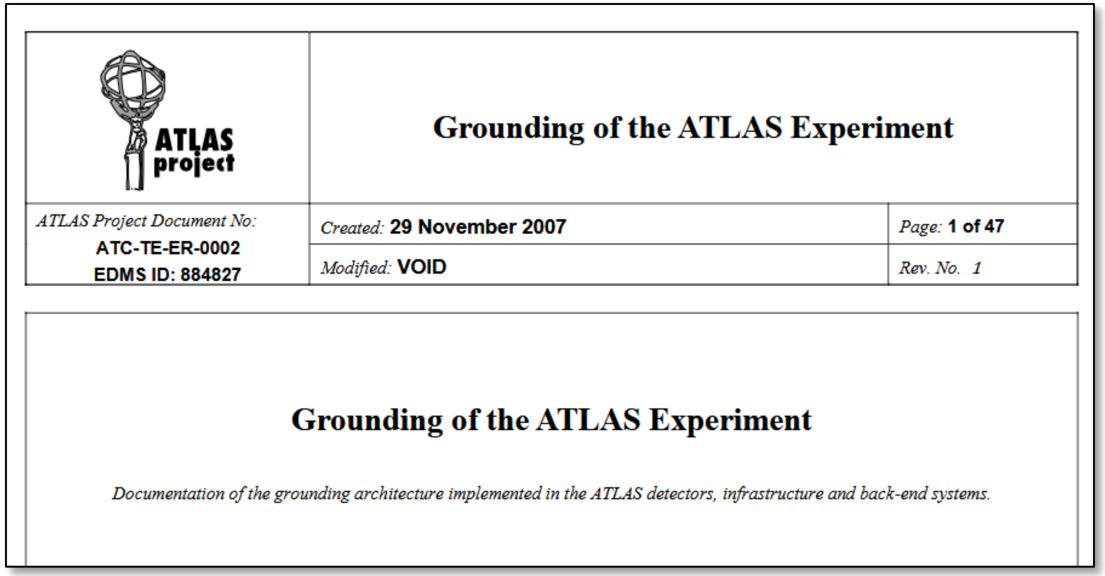
Spreading the Information - Documentation

- Rather complex writeups of G&S rules exist for ATLAS, Calorimeter, ITk …
- BUT: very difficult to reach non-experts!

  → created simplified introduction
- Start early to talk about the G&S requirements
- Should be taken into account for test setups



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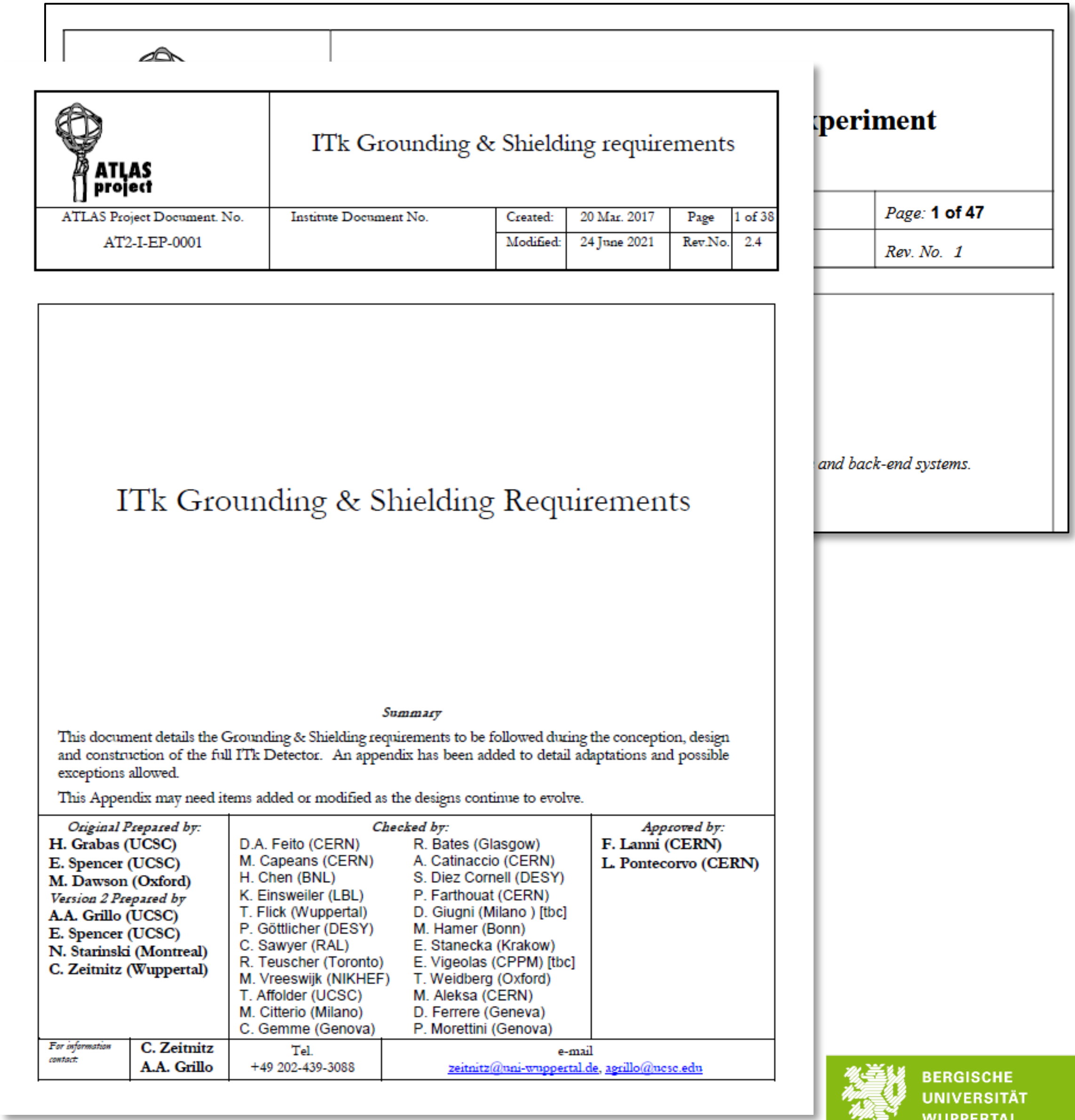

ATLAS project	ITk Grounding & Shielding requirements				
ATLAS Project Document No. AT2-I-EP-0001	Institute Document No.	Created:	20 Mar. 2017	Page	1 of 38
		Modified:	24 June 2021	Rev.No.	2.4

ITk Grounding & Shielding Requirements

Summary

This document details the Grounding & Shielding requirements to be followed during the conception, design and construction of the full ITk Detector. An appendix has been added to detail adaptations and possible exceptions allowed.

This Appendix may need items added or modified as the designs continue to evolve.

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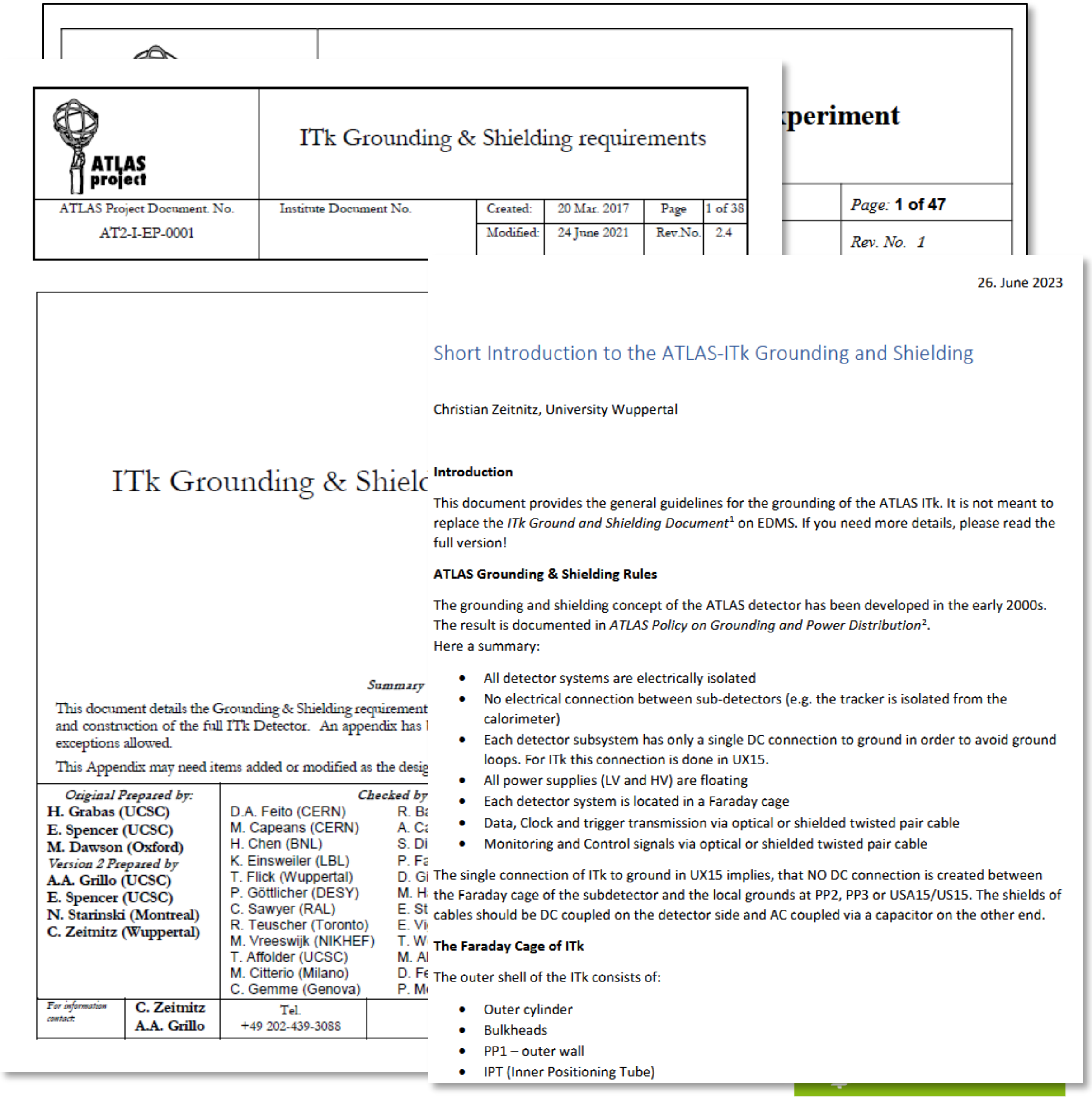

Conclusions

- Need general and easy to understand rules
- ATLAS: documentation came too late (2007)
- Had lots of discussions with “users” aka physicists, engineers
  - Physicists often miss the basic understanding of this topic
  - Multiple repetitions of concepts and solutions needed
- Especially complicated to address G&S wrt the global mechanics (Faraday cage)
  - Impact on the choice of CF composite
  - Transitions between parts and materials

- Advisor(s) needed to help with the implementation of the rules
  - Discuss options for the implementation
  - Often very practical questions
    - How to make good contact with CF?
    - Impedance measurements up to what frequency?
    - How to inject noise?
    - How to do Quality Control?
    - etc.
- Group of people needed to try out materials and methods and to recommend solutions
- Knowledgeable reviewers needed