INSTITUTO TECNOLÓGICO DE ARAGÓN

Grounding & Shielding
Main issues
(electronics integration)

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OUTLINE

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- 2. Grounding
  - Recommendations
- 3. Noise sources
  - Switching converters
- 4. Noise victims
  - FEE
- 5. Conclusions

1. Introduction

- The electronics integration is an important task in a HEP experiment .
- The main goal is to ensure the correct performance of HEP detectors or experiments.
- Electronics integration is mainly defined by three elements:
  - Grounding strategy
  - Noise sources
  - Noise victims

2. Grounding

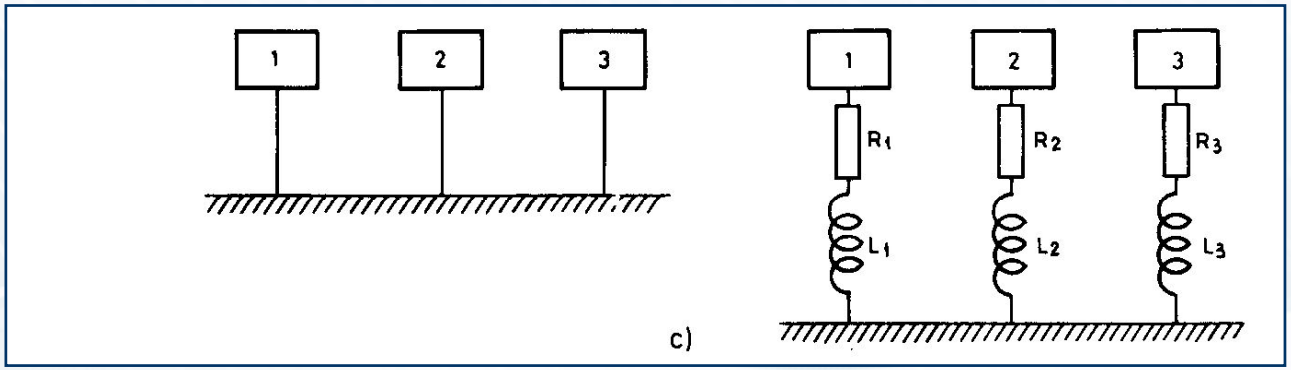
- What is a ground ?
  - It is a reference
    - Uniform reference voltage at any frequency
  - It is a structure to bypass currents
    - Fault (short circuits ..)
    - Noise
- Reasons for Grounding
  - Safety
  - Equipment protection
  - Equipment performance
- Golden rule:
  - ***"Make the system safe and then make it work "***

2. Grounding: Some recommendations

- **Selection of reference** (grid 3D or plane)
  - Detector & Experiment level
    - Reinforcement structure
    - Any metal structure
  - It should have low impedance from DC to High frequency
- **Safety ground & Equipment protection**
  - Laboratory codes and European directives.
    - Metal parts that can be energized – should be grounded
    - Ground connections - Bonding and straps
  - Ground path should be free of operational currents

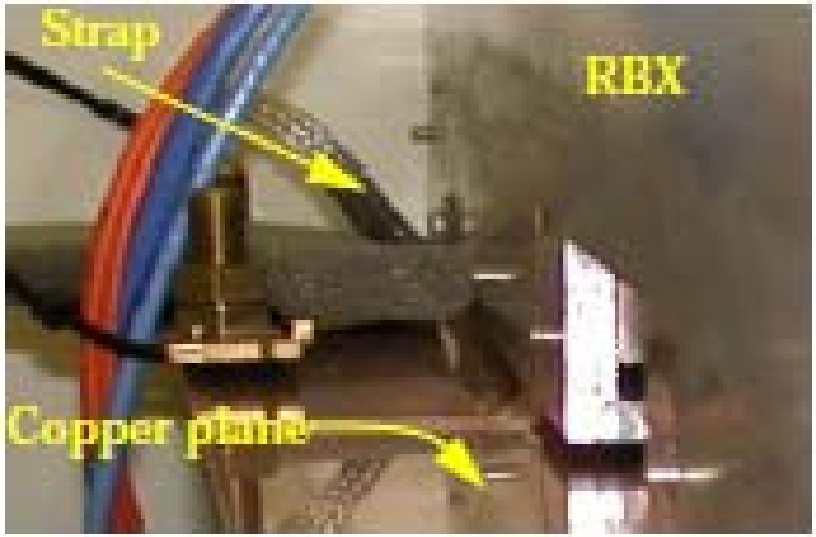
2. Grounding: Some recommendations

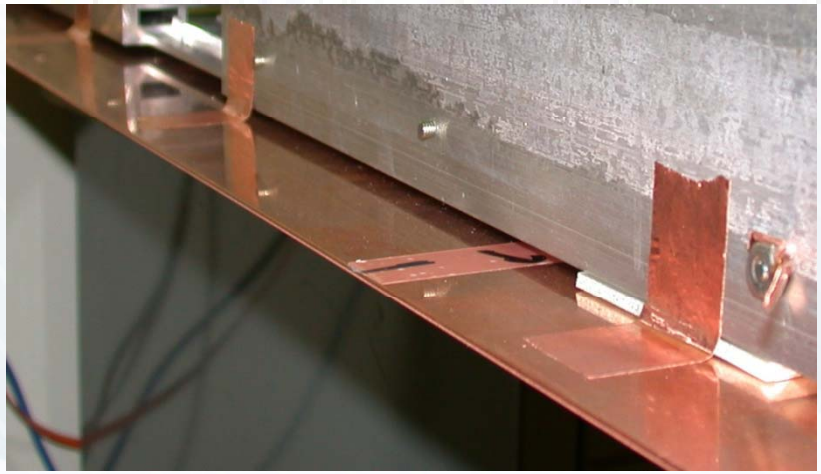
- **Ground to improve the equipment performance**
  - **Multipoint ground topology** is the preferred option
    - Multiple ground connection to ground
    - Digital and analog has to be grounded separate and later connected to common point at board level
    - Electronics , hardware and power parts should be grounded separately at module level and then connected together
  - **Ground connection has to be short**
    - It has to present low impedance path at high frequency



2. Grounding: Some recommendations

- **Low impedance connection example**
- One single connection a few cm
  - It resonates 14 MHz
- Multiple connections
  - It resonates above 50 MHz
- Main characteristics of multiple ground connections
  - They should be connected to:
    - Opposite corners of the equipment
    - The nearest points on the signal reference grids.
- Very special cases it can be done via capacitors
  - Several



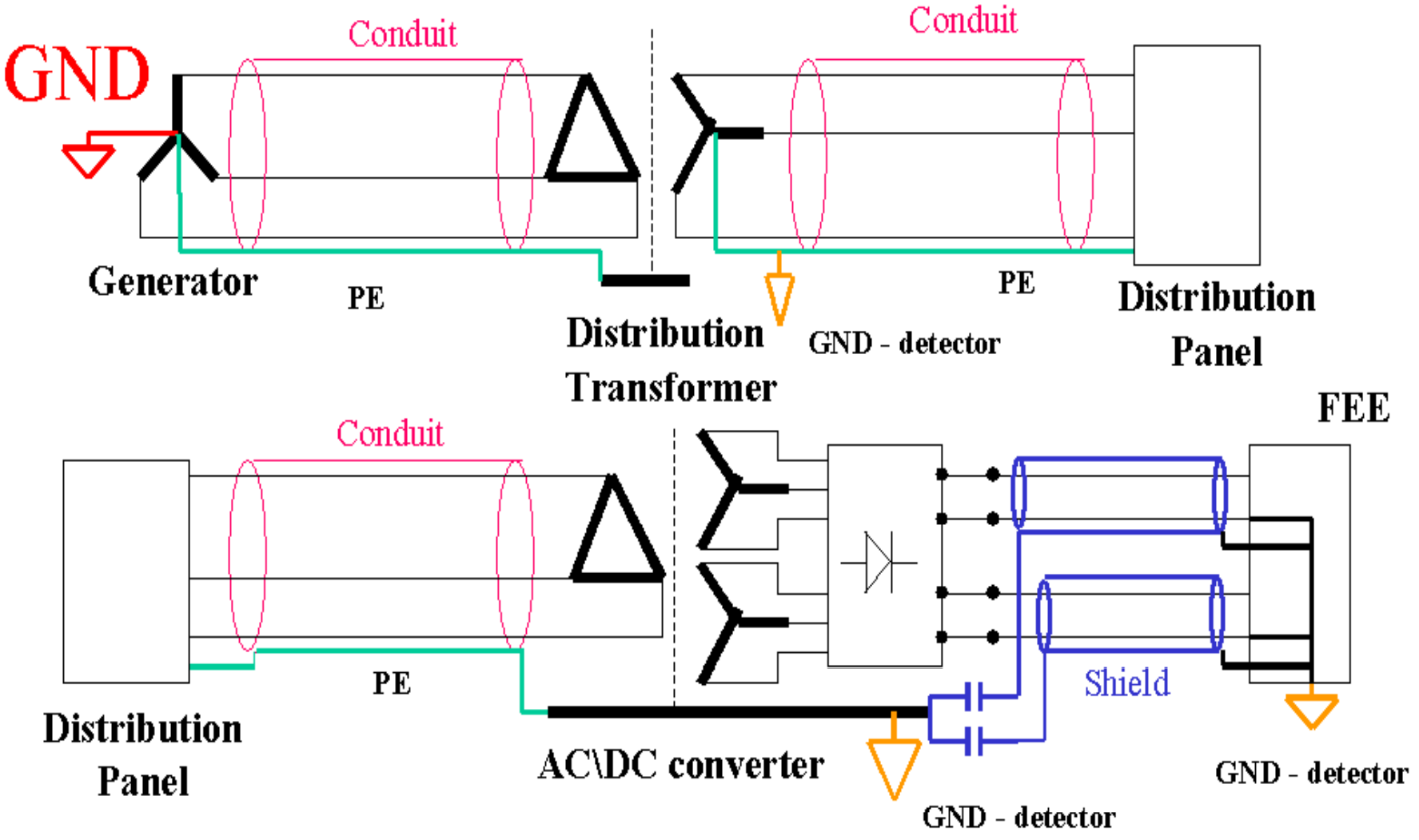


2. Grounding: Some recommendations

- **The grounding designs to improve the equipment performance can be tackled in two steps:**
  - At LF – Avoid ground loops
    - Detector is a kind of resistor divider where currents flows everywhere
  - At HF – Avoid noise currents pass through sensitive parts
    - Everything is connected (real or parasitic impedance) and designing a low impedance paths for these currents
- **It is recommended to have an schematic ground design first and later mechanical ground design**
  - Mechanical and electrical integration issues should be tackle at the same time.
- **All experiment subsystems has to present the same ground topology.**

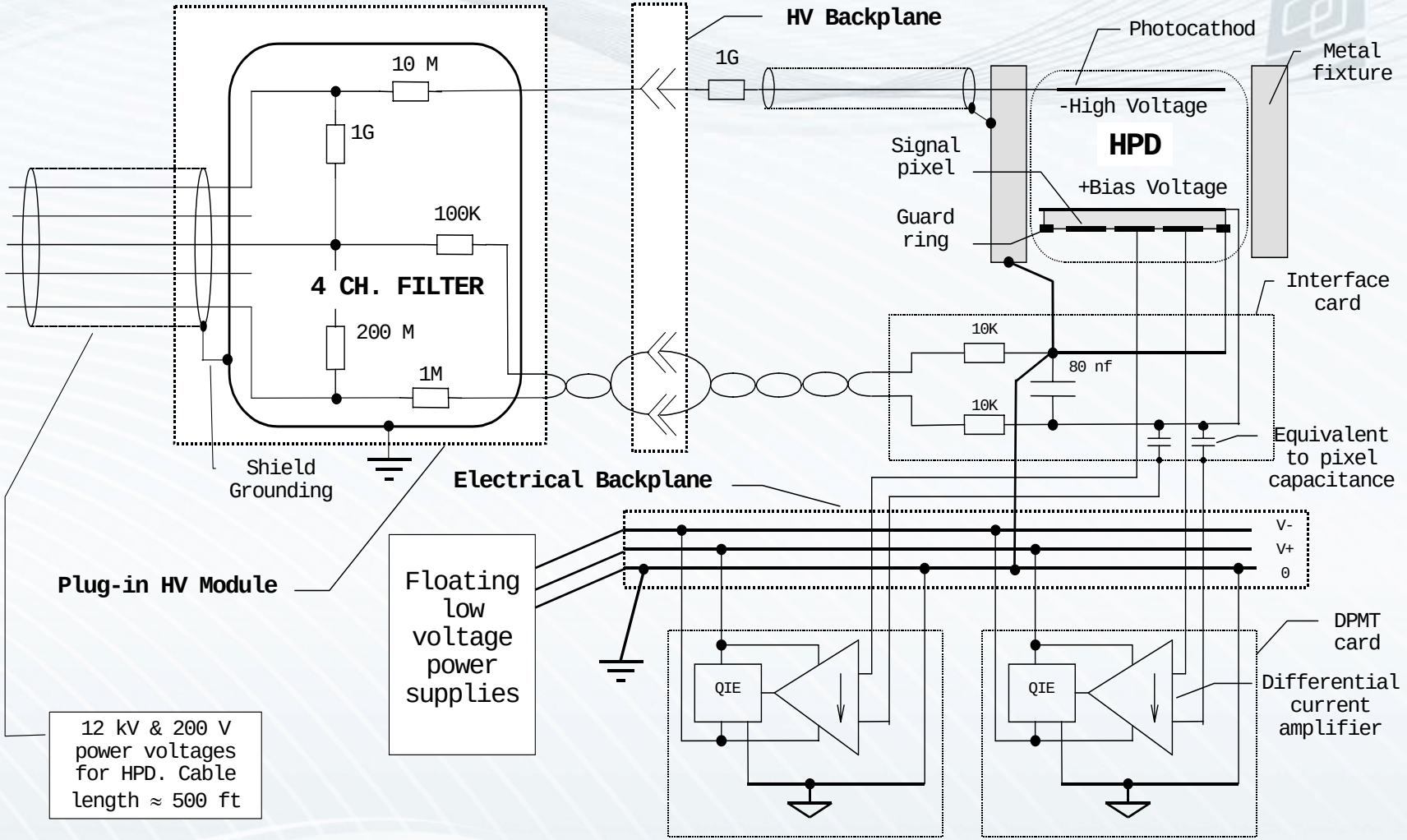
2. Grounding

Experiment level



2. Grounding

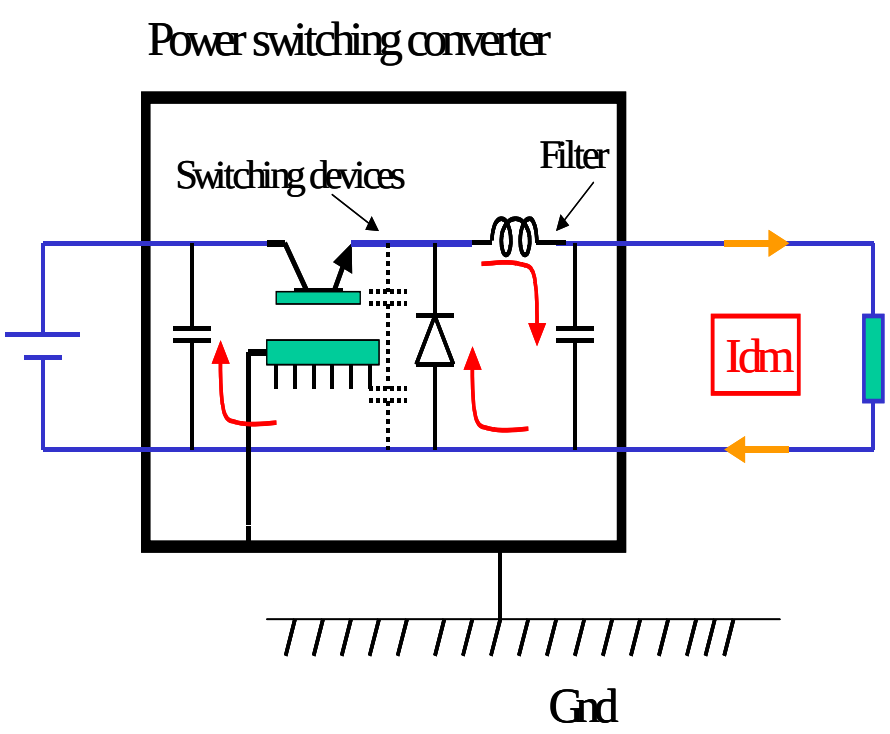
Sub-detector level

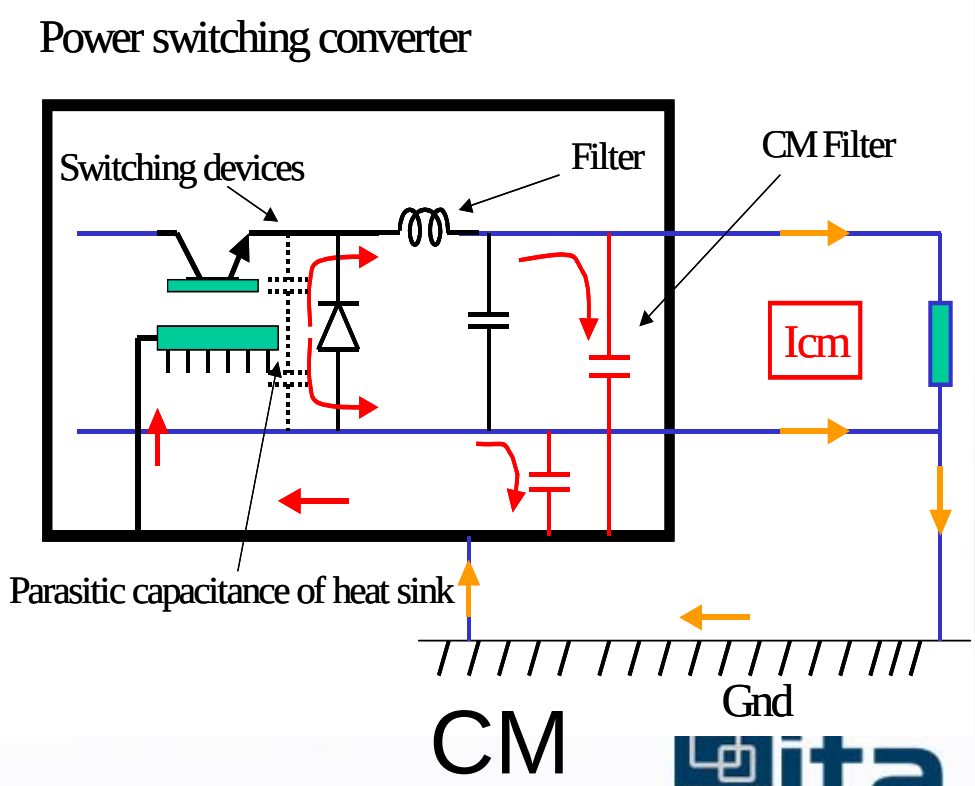


Global & System grounding policy have to be coordinated

3. Noise sources

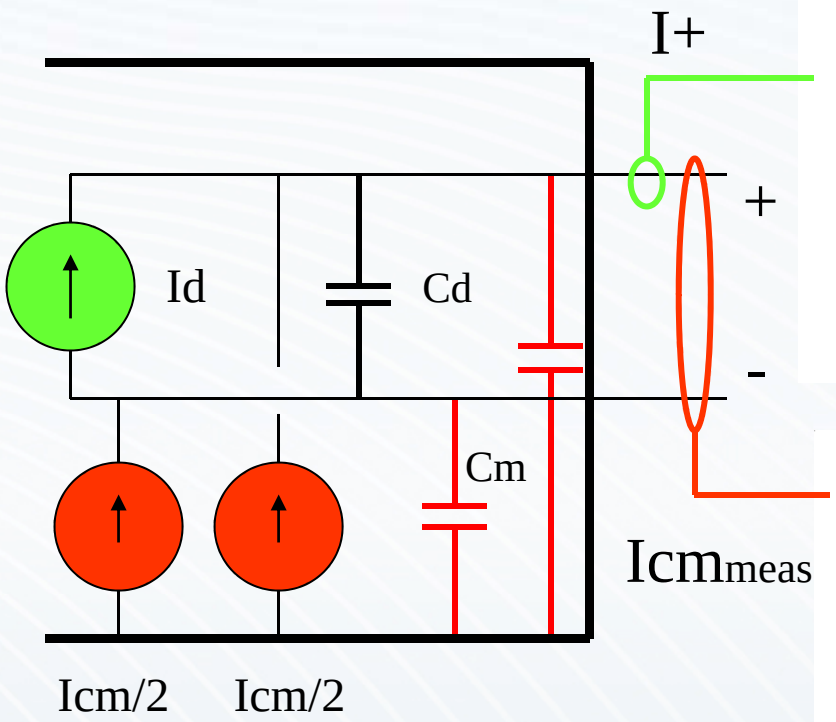
- Switching converters generates conducted noise
  - At the input & output
- It is generally the main noise source in HEP
- Two modes of noise emissions (kHz - MHz range)
  - **Common mode & Differential mode**

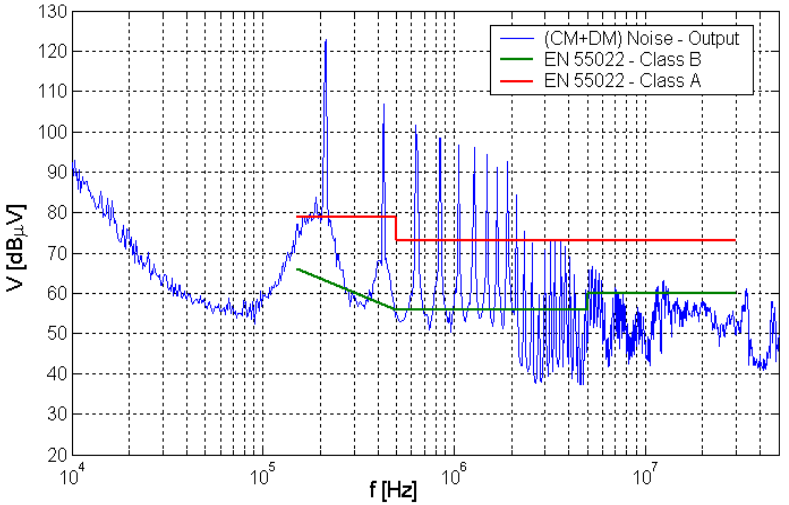


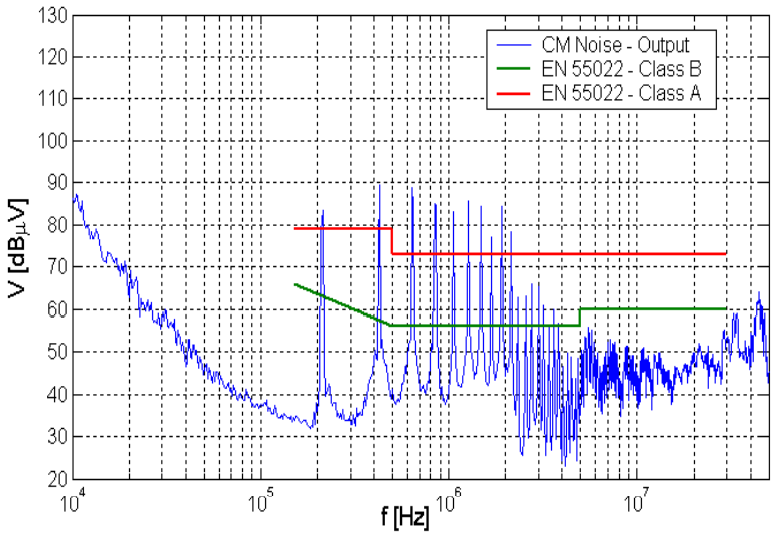


3. Noise sources

CMS - HCAL



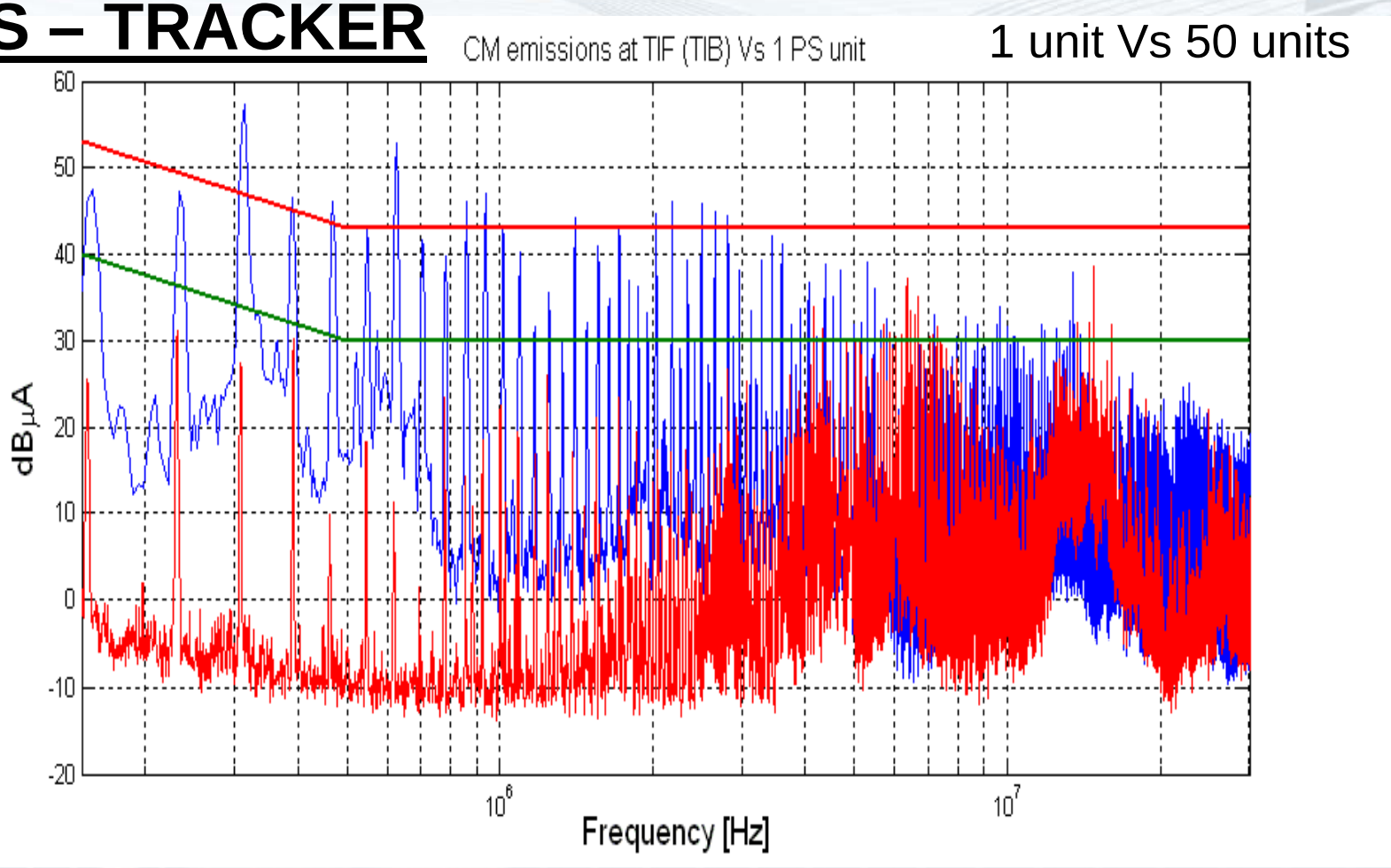




- **Output** currents – (ref. = 50 ohms)

3. Noise sources

CMS – TRACKER



- Multiple PS units may increase the noise level
  - Design issue

4.Noise victims

- The most sensitive component in HEP experiment is the FEE
- Noise components that deteriorates the FEE performance are:
  - Intrinsic thermal noise
  - EM noise
    - EM noise picked-up by the connection detector – FEE
    - EM noise picked-up by the connection FEE - Power supply

$$n_a(t) = n_{th}(t) + n_{in}(t) + n_{ps}(t) + \ldots$$

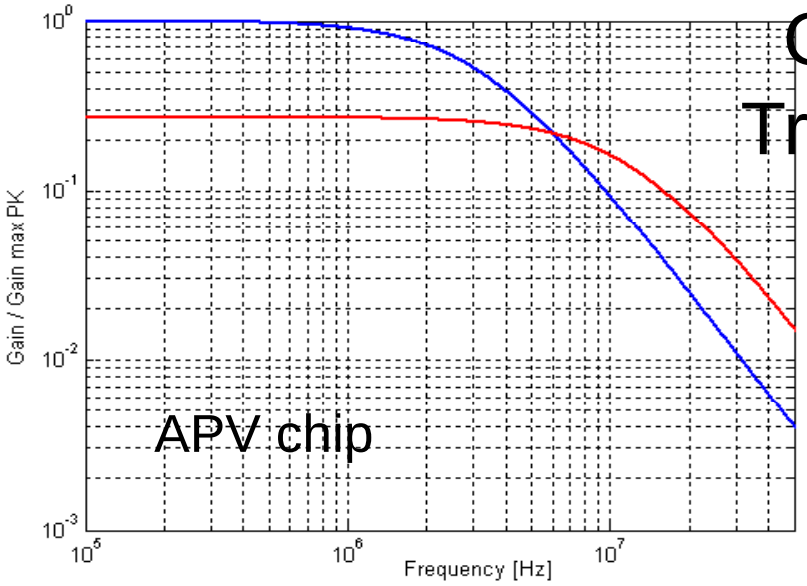
4.Noise victims

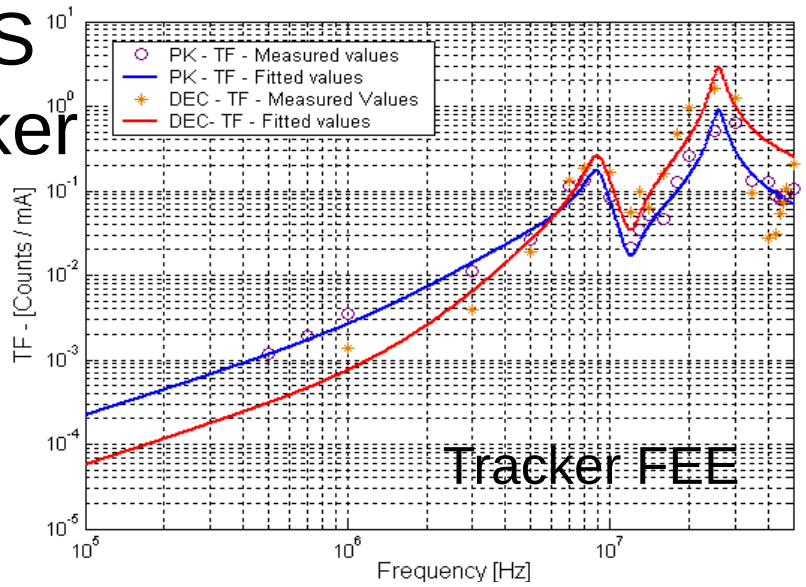
- This noise defines the minimum signal level that the FEE can process
  - Thermal noise dominant effect (by design)
  - EM noise has to be characterized and minimized
- EM noise contribution depends on two factors
  - It depends on Front End Amplifier frequency response.
  - Coupling mechanisms (coupling network) between EM noise and output of the FEE.
- EM noise contribution is not constant.
  - It may change from hundreds kHz to several tenths of MHz
  - FEE characterization to EM noise help to improve the FEE immunity (identify weak areas & frequencies).

4.Noise victims

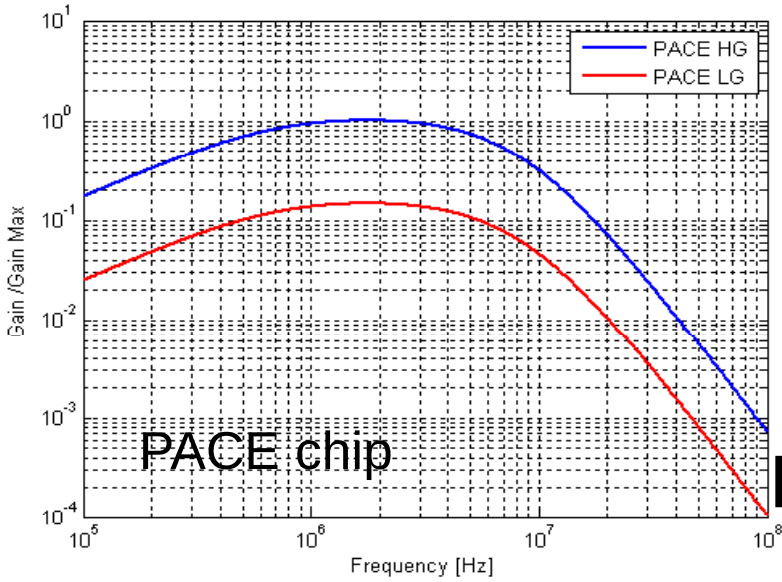
Frequency response

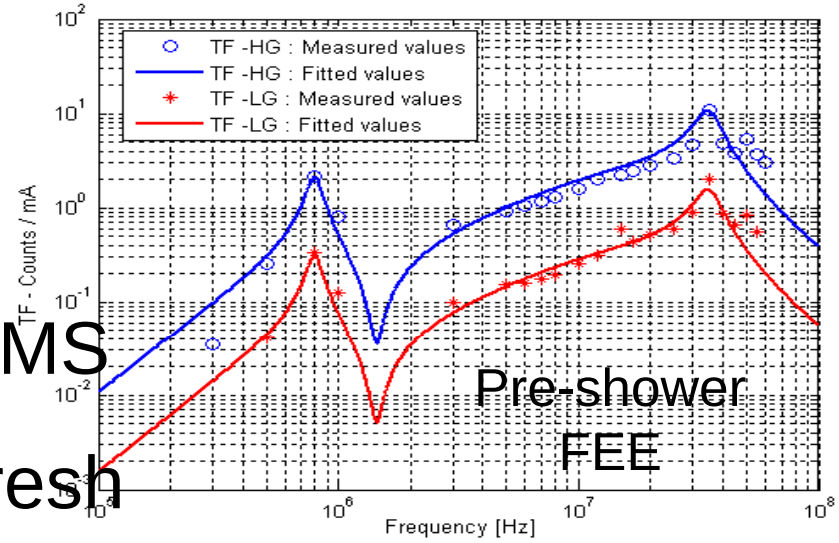
CMS Tracker





CMS Presh





5 CONCLUSIONS

- The main elements of electronics integration has been presented.
- **Grounding strategy:**
  - It has to cover safety and performance issues (LF & HF)
  - It should involves all disciplines – Mechanical , electrical……
    - All disciplines has to be coordinated – **UNIQUE ENTITY**
  - It has to be coordinated between sub-systems.
    - It saves money, time and “discussions between groups”.
  - It should be designed to work from DC to MHz
- **Noise sources**
  - Switching power converters are one of the main noise sources
  - SMPS emits noise form kHz to several tenths of MHz
  - Number of PS may increase system noise a lot.
- **Noise victims**
  - FEE is the main noise victim in any HEP experiment.
  - FEE is sensitive to noise from kHz to several tenths of MHz.
  - Do not forget noise contributions due to EM noise