GOBIERNO DE ARAGON

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea NextGenerationEU

ITAINNOVA R&D activities for physics detectors

Instrumentation for the future of particle, nuclear and astroparticle physics and medical applications in Spain

6–7 of March 2023 , Barcelona

Dr. Fernando Arteche

Technology coordinator of Sustainable and advanced electrical technology

ITAINNOVA INSTITUTO TECNOLÓGICO DE ARAGÓN

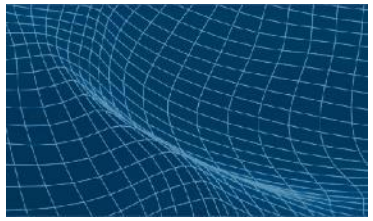
OUTLINE

- 1. Introduction
- 2. Past activities – expertise gained
- 3. ITAINNOVA current and future DRD plans
- 4. Main Collaboration / Synergies & Technology transfer
- 5. Facilities

1. INTRODUCTION

- ITAINNOVA (Instituto Tecnológico de Aragón) is a Public R&D Centre
- We develop research projects and provide technological services in cooperation with other public agents (other institutes and universities) and private agents (companies).
- We are based in Zaragoza
- Our annual budget is 20 M€: (80%-SF)
  - Annual investment is 2 M€
  - 280 Employees:18% are Doctors.

NEW MATERIALS AND COMPONENTS	MECHATRONICS SYSTEMS	SUSTAINABLE & ADVANCED ELECTRICAL TECHNOLOGIES	DIGITAL TECHNOLOGIES



1. INTRODUCTION

- During the last 14 years, ITAINNOVA has been involved in activities related to particle physics detectors.
- These activities have been focused on:
  - **Front end electronics (FEE) design**
  - **Electromagnetic interference phenomena** (EMI /EMC) **characterization** of physics detectors and facilities
  - **Power systems designs for physics detectors**
  - **Distributed clock systems design** for timing detectors
  - **RF instrumentation**
- 18 members of the team
  - 10 engineers (5 phD & 5 Master) – 1 finishing PhD
  - 7 technical staff giving support & 1 student (preparing his master thesis)
- **FTE involved in physics detectors per year - 5**

2. PAST ACTIVITIES – EXPERTISE GAINED

PREVIOUS PROJECTS

EU

- **AIDA 2020:** Advanced European Infrastructures for Detectors at Accelerators", Ref. **H2020-INFRAIA-2014-2015 – 654168**, Funding Agency: EU-H2020, Duration: 2015- 2019 PI: Dr. Laurent Serin, Type of participation: Investigator y **WP12 leader**
- **EMC studies for the DEPFET pixel detector at Belle II experiment**, Company: Max Planck Institute of Physics (Germany) MPI, **Principal investigator: Dr .Fernando Arteche**, Duration 2011-2016,
- **REWARD:** Real time Wide Area Radiation surveillance system" REF: **FP7- 284845**, 2011- 2014, Budget: 4 265 883 €. (ITAINNOVA´s Budget: 20.000 €.), **IP: Dr. Manuel Lozano**,

National

- **CMSRUN2-B:** PARTICIPACION EN EL EXPERIMENTO CMS DEL LHC-PIXEL UPGRADE PARA ALTA LUMINOSIDAD",Ref: **FPA2017-85155-C4-3R**, Ministerio de Ciencia e Innovación y Universidades, Duration: 2018-2020,, **IP: Dr.Fernando Arteche.**
- **CMSRUN2**: PARTICIPACION EN EL EXPERIMENTO CMS DEL LHC: RUN 2 Y UPGRADE DE ALTA LUMINOSIDAD" , Ref. **FPA2014-55295-C3-3R** ,Ministerio de Economía, Duración: 2015- 2017, Principal investigator: **Dr .Fernando Arteche**.
- **DET4HEP: I+D** en detectores para futuros Colisionadores" Ref. **FPA – 2010 – 22163 – C02-01**, Ministerio de Ciencia y Tecnología, Duration: 2011- 2013, **IP: Dr. Ivan Vila (IFCA**)

Regional

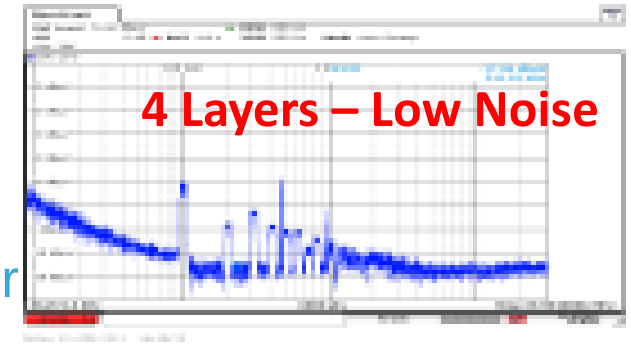
- **HDI4CMSPIX:** Desarrollo y diseño del HDI (High Density Interconnection board) basado en el RD53A readout chip para el nuevo detector de pixeles de CMS – Fase II", **Ref. LMP170_18 , DGA** , Duration: 2018- 2020**IP: Dr. Fernando Arteche**
- **Caracterización electromagnética y estudio de las medidas correctoras necesarias en el laboratorio subterráneo de Canfranc",** Company: ICTS- Laboratorio Subterráneo de Canfranc (Spain), Principal investigator: **Dr .Fernando Arteche**, Duration:2019-2021,

2. PAST ACTIVITIES – EXPERTISE GAINED

The REWARD project develops portable, intelligent radiation detectors (neutron & Gammas)

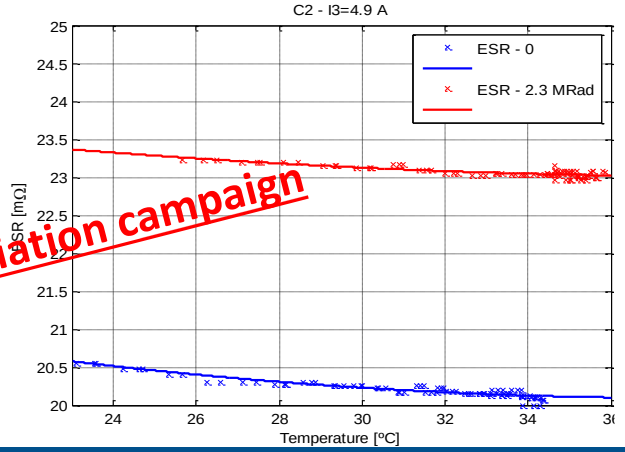
- **Design & Develop** 100 W **power unit for physics detectors**
  - UPS & low noise power unit

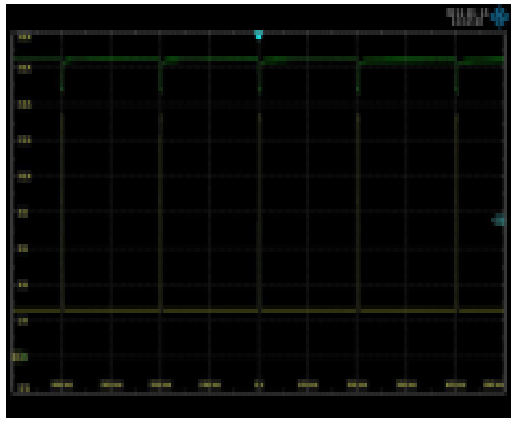
REWARD



FTD-ILD sub-detector for International Linear Collider

- **Design and develop a power pulsing system** based on supercapacitors



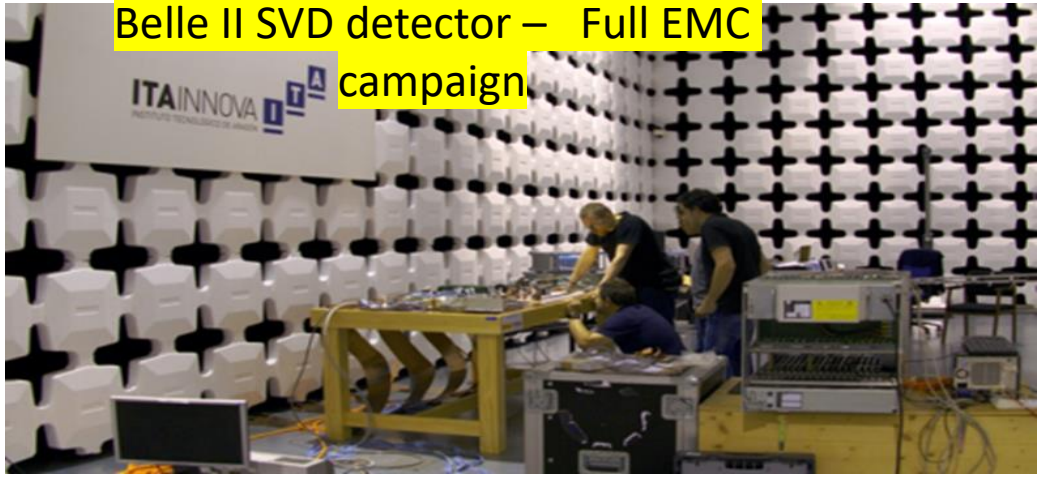


2. PAST ACTIVITIES – EXPERTISE GAINED

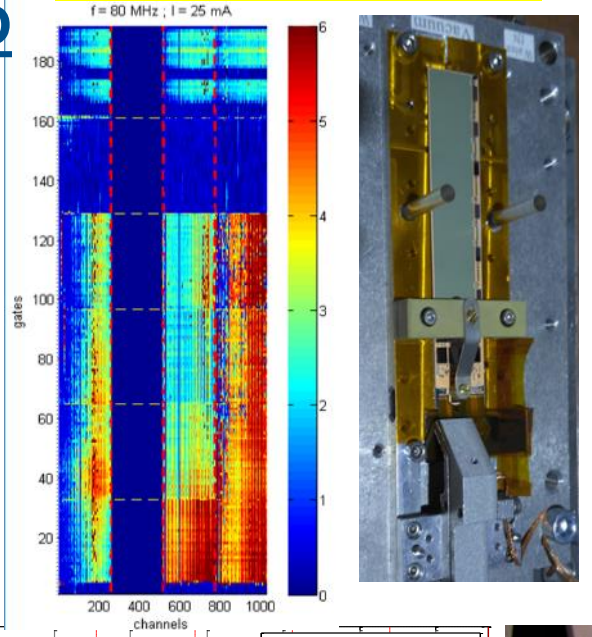
Belle II – SVD & DEPFET

- **EMI effects on sensors** (DEPFET- Double Side µstrip)
- **Nosie propagation effects on** multi-conductor **cables** (MTL models)
- EMC Belle II: **Electronics integration**

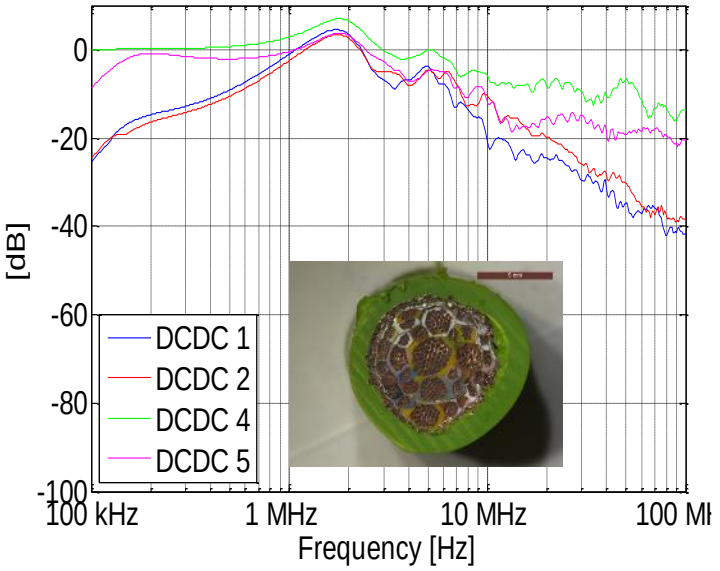
Belle II SVD detector – Full EMC campaign

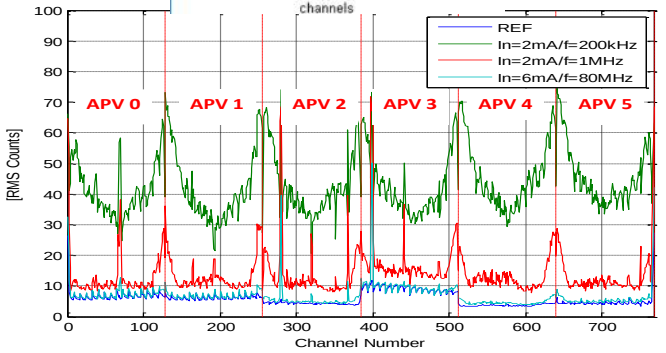


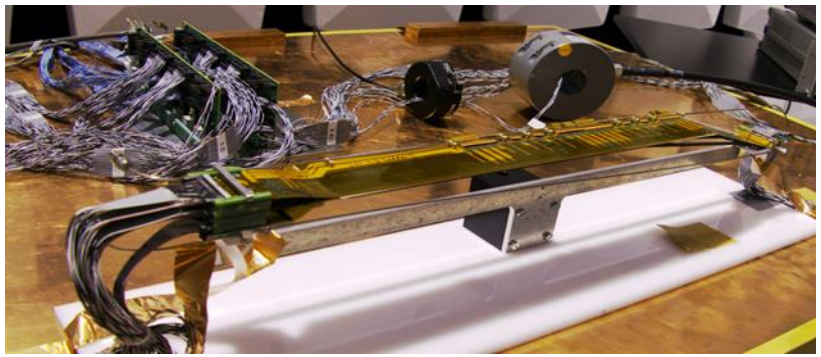
Belle II DEPFET detector
Noise sensor distribution



Noise distribution on Belle II DEPFET detector MS cable







Belle II SVD detector
Noise sensor distribution

2. PAST ACTIVITIES – EXPERTISE GAINED

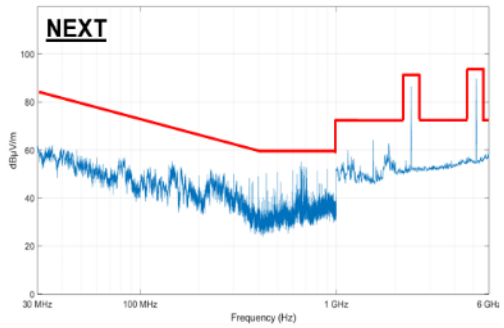
LSC – Laboratorio subterráneo de Canfranc

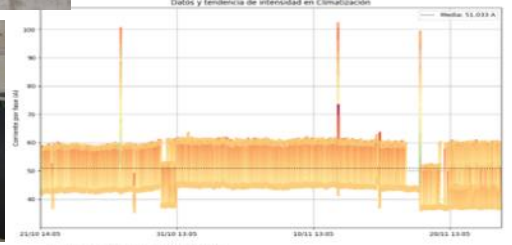
- **EMI characterization of scientific installation**

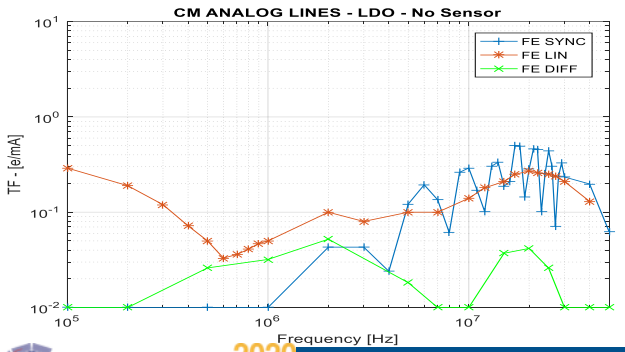
AIDA 2020 – Advanced European Infrastructures for Detectors at Accelerators

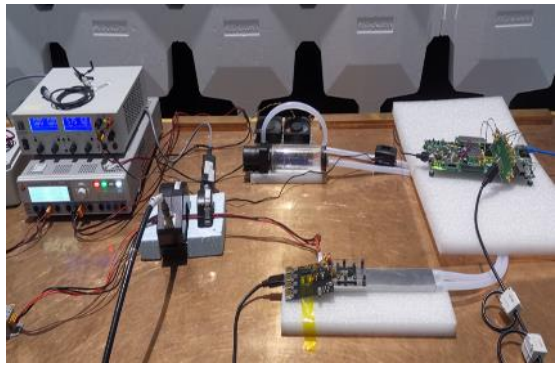
- **EMI of ROC** & Susceptibility to High E fields
- **TA facility for EMI characterization of physics detectors** - WP12 leader

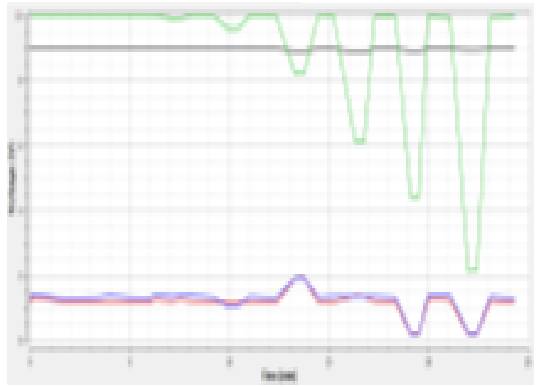
Noise characterization campaings at LSC

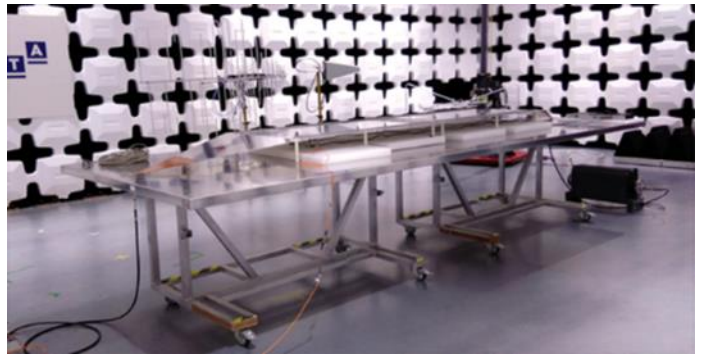












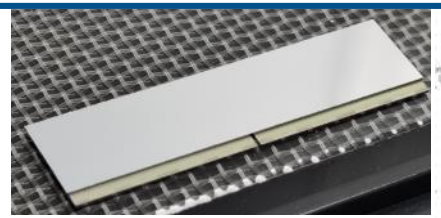
RD53 SCC – FE characterization

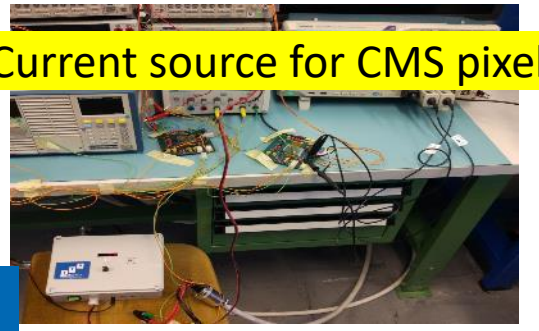
DOSFET – Dosimeter for synchrotron radiation facility (Elettra) & Laser Pulsed facility

2. "PAST" ACTIVITIES – EXPERTISE GAINED

CMS- PIXEL Phase II

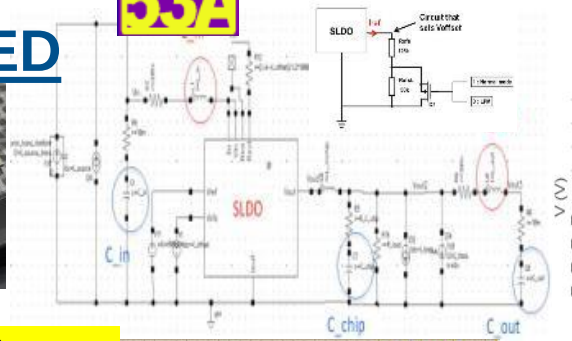
- HDI design
- RD53A chip design
- Current source design
- Serial powering – System design

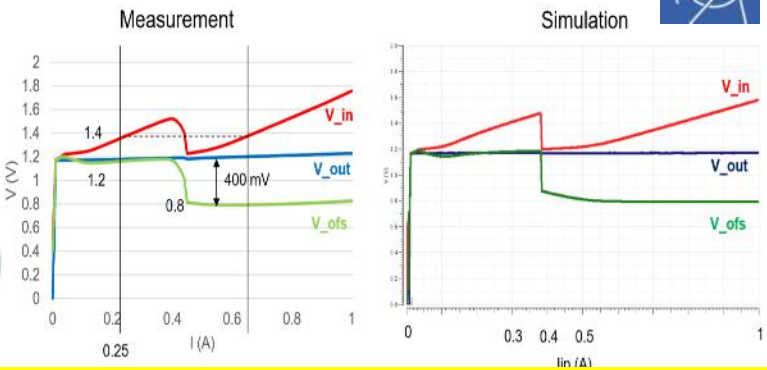


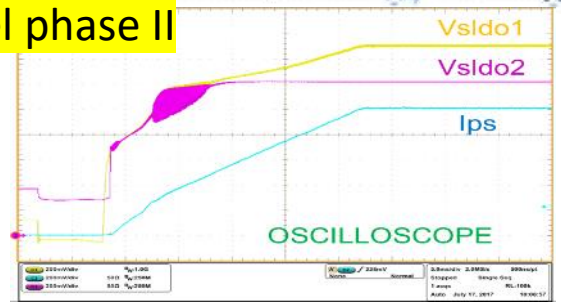


Current source for CMS pixel phase II

RD53 Low power mode (ITAINNOVA circuit)

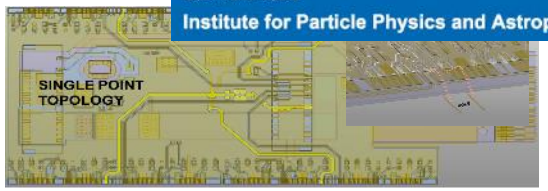


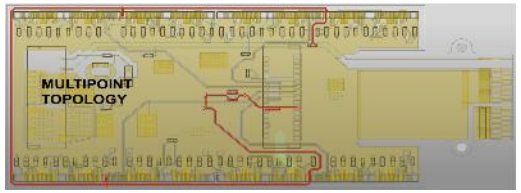


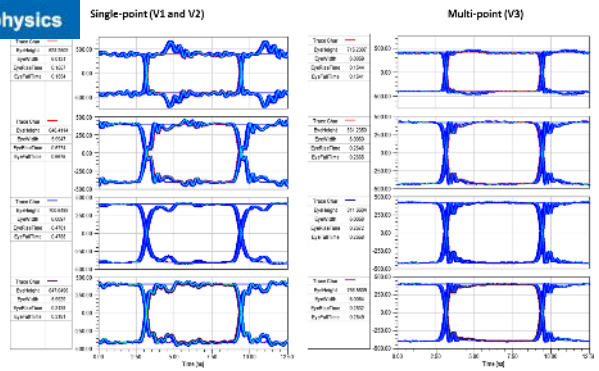


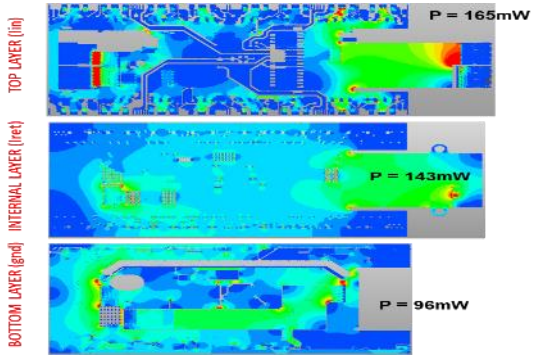
1x2 3D-RD53A based module prototype (IFCA,IMB & ITAINNOVA)

ETH zürich
Department of Physics
Institute for Particle Physics and Astrophysics









HDI design - Data transmission & power dissipation CMS pixel phase II

3. ITAINNOVA CURRENT & FUTURE DRD PLANS

- The group's activity will focus on activities similar to those carried out in the past (DRD7 & DRD3) but exploring new areas (DRD5) due to synergies and knowhow.
- These activities will be focused on:
  - **Front end electronics (FEE) design** for physics detectors (ASICs development-power stage, interconnection boards and electronics integration) **(DRD 7**)
  - **Electromagnetic interference phenomena** (EMI /EMC) **characterization** of physics detectors and facilities (**DRD 3 DRD 5 DRD7**)
  - **Power systems designs** (standard ,serial and power pulsing applications) (**DRD 7**)
  - **Distributed clock systems design** for timing detectors (**DRD 7**)
  - **RF instrumentation and Digital Signal Processing** covering system modeling, optimization and implementation of the LL RF chain for Accelerator & quantum technologies(**DRD 5**).
- The activity will be strongly aligned with Spanish groups and ECFA.

3. ITAINNOVA CURRENT & FUTURE DRD PLANS

ITAINNOVA's areas of interest within **DRD7** - Electronics and Data Processing

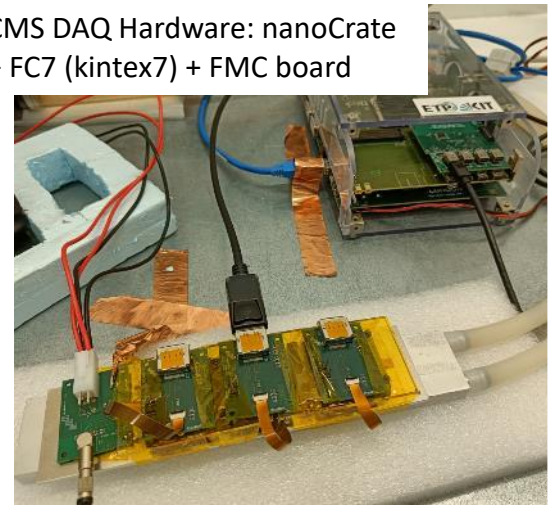
- **Front-End AISIC (Power stage models & protection circuits)**
  - High-granularity **pixel readout chip in 28nm** CMOS (DRDT 7.1, DRDT 7.2, DRDT 7.4) – **Power stage**
  - 3D integration technologies for high density interconnection of stacked layers of sensors and readout electronics, or for connection of ASICs and specialized PCBs (DRDT 7.1, DRDT 7.5); - **(HDI)**
- **Links, Powering and Interconnects. (HDI & Power converters)**
  - **Small form-factor power modules compatible with the HEP environment**, including optimized coils, capacitors, cooling interfaces, connectors and packages (DRDT 7.1, DRDT 7.4, DRDT 7.5) – **(HDI)**
  - **High conversion factor DC-DC converters** based on new processes and materials, and associated power management circuit blocks (DRDT 7.1, DRDT 7.2, DRDT 7.4, DRDT 7.5) – **(Power converters EMI control)**
- **Back-end Systems (Clock distribution systems & Power distribution & System Prototyping)**
  - Next-generation **pico-second precision timing distribution systems** to enable 4D-detectors (DRDT 7.3, DRDT 7.4).
  - **Large-scale and realistic technology demonstrators**, tracking relevant industry developments, with permanent integration **and test-facilities** (DRDT 7.1, DRDT 7.2, DRDT 7.5) – (**EMI & Detector prototyping & Power distribution**)

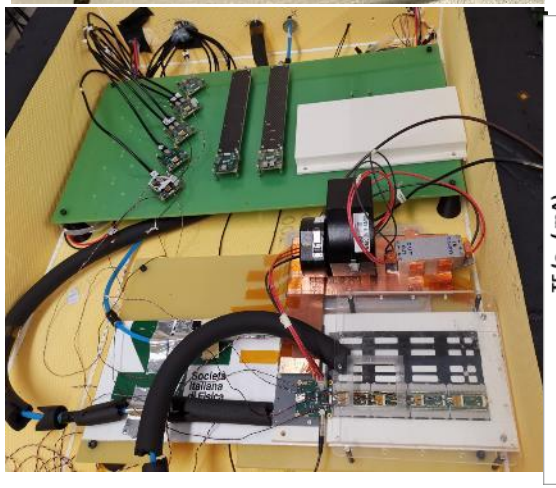
3. ITAINNOVA CURRENT & FUTURE DRD PLANS

ITAINNOVA's areas of interest within **DRD7** - Electronics and Data Processing

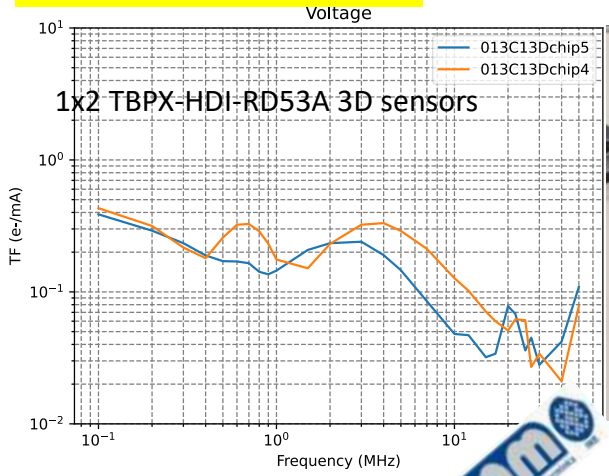
- **CMS phase II current activities**
  - CROC simulation models & ETROC testing **(FE AISIC)**
  - Pixel & ETL System prototyping - Electronics & DAQ **(Power/BKE)**
    - GaN based DC-DC
    - Serial powering
    - Hardware, gate-ware and firmware for ASIC/DAQ comm. and control.

CMS DAQ Hardware: nanoCrate + FC7 (kintex7) + FMC board

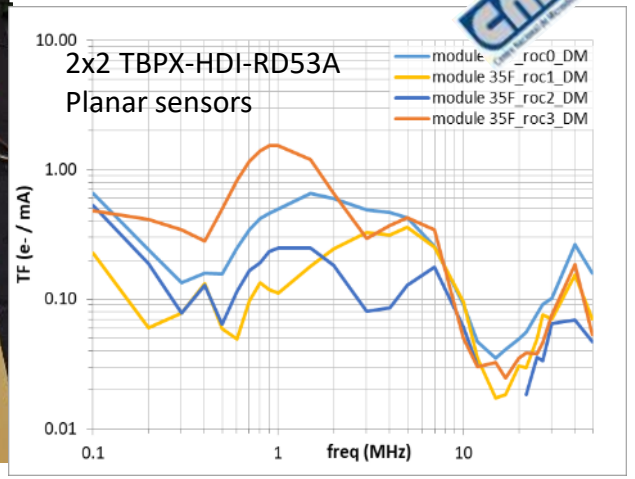


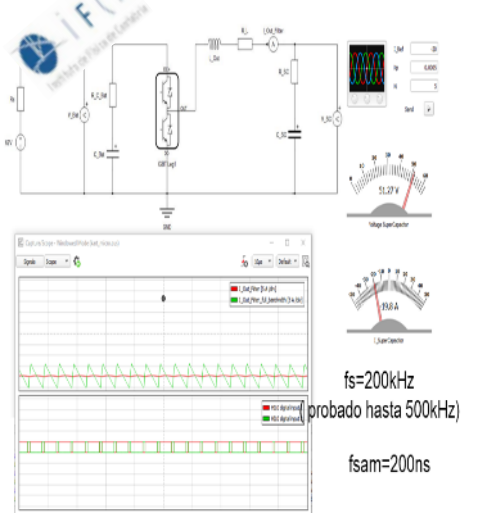


3D – RD53A based Serial Powering protoype (3 modules) – TF test at ITAINNOVA



HIL for GaN based DC-DC control board



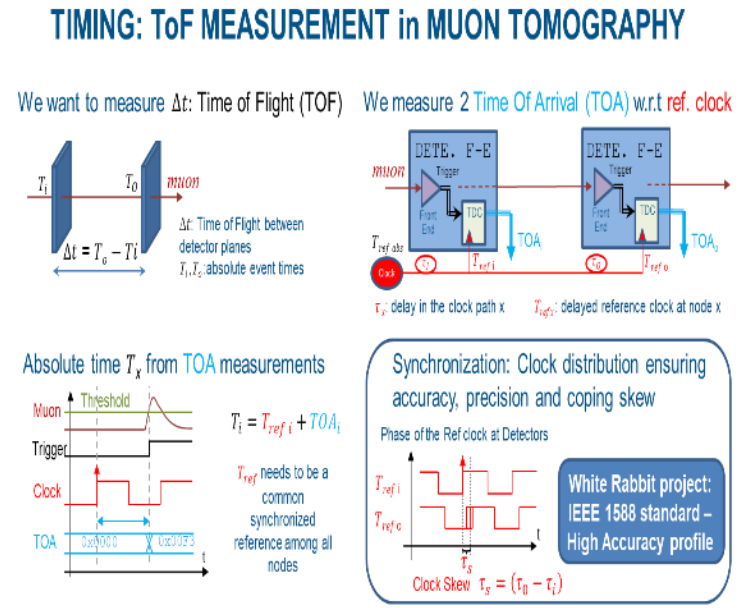


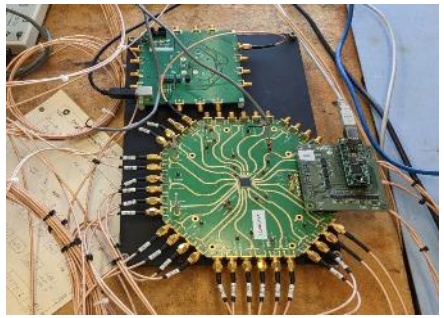
Plannar – RD53A based Serial Powering protoype (3 modules) – TF test at CERN (CMS TK Facility)

3. ITAINNOVA DRD ACTUAL & FUTURE PLANS

ITAINNOVA's areas of interest within **DRD7** - Electronics and Data Processing

- **TOMULGAD-4D: Distributed Clock network and power distribution system** design for the technology demonstrator of the Timing Muon Tomography concept- **Current activities (Back-end / Timing)**
  - High Accuracy and High Precision Timing sub-systems:
  - Dedicated system vs Scalable deterministic networks (White Rabbit - IEEE1588HA)
  - Versatile, scalable and portable clocking architecture
  - Prototype development





Tomulgad ad-hoc clocking

CERN WR2RF VME Card

WR SPEC Card

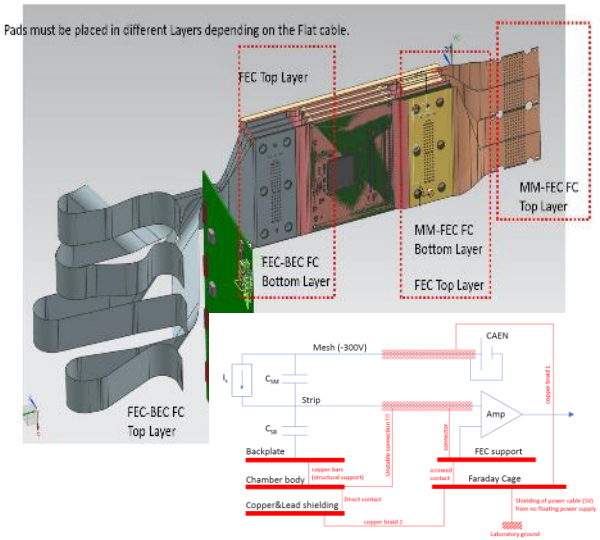
WR Switch

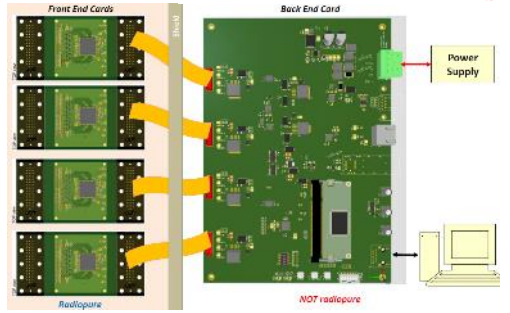
3. ITAINNOVA DRD ACTUAL & FUTURE PLANS

ITAINNOVA's areas of interest within **DRD7** - Electronics and Data Processing

- **PC-MMR current activities**
  - Development of **electronic instrumentation for pixel and timing** detectors based on LGAD and 3D sensors with **industrial applications (Back-end Systems – Timing & Prototyping)**
  - Implement **new integration strategies** for background reduction of Micromegas detectors **for BabyIAXO**, **based on** the analysis of the electronic architecture of the data acquisition system (**DAQ**) **with EMI/EMC criteria and assessment of a WR based** synchronization architecture.(**Back-end Systems – EMI & Timing**)
  - **Electromagnetic characterization of the TREX-DM** experiment site at the LSC and its interactions with BabyIAXO. .(**Back-end systems – EMI**)
- **AIDAINNOVA (**Advancement and Innovation for Detectors at Accelerators**) current activities – EU-H2020**
  - Portable test bench to perform in-situ EMC conducted emission measurements of DC-DC in irradiation facilities (**Powering & Back-end Systems – Power & EMI control**)

BabyIAXO electronics





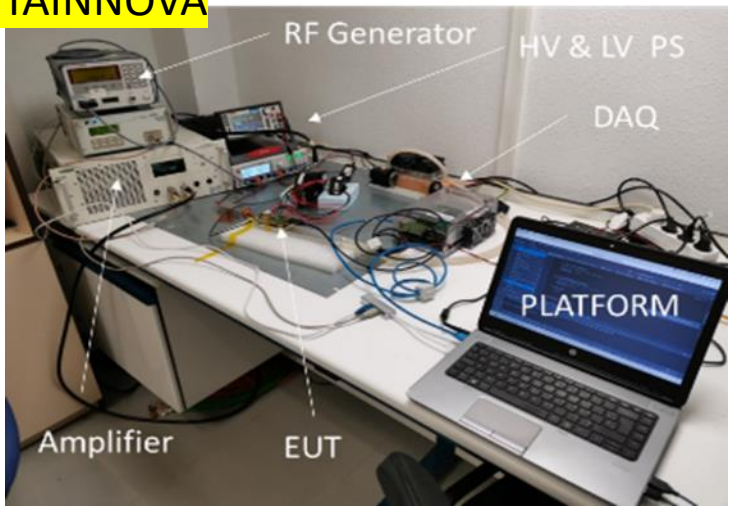
Barcelona RadioPure DAQ

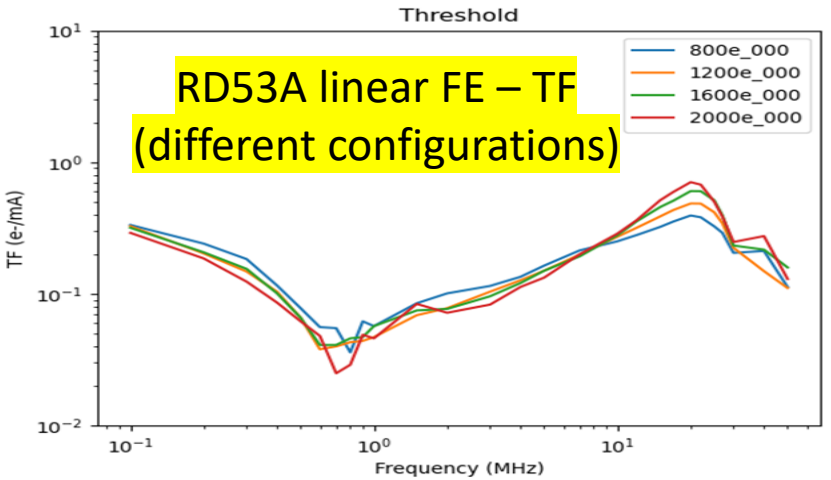
3. ITAINNOVA CURRENT & FUTURE DRD PLANS

ITAINNOVA's areas of interest within **DRD3** - Solid state detectors

- New characterization techniques and facilities of common interest - **EMI characterization of sensors**
- We have already submitted an **expression of Interest for participation in DRD3**
- **AIDAINNOVA current activities – EU –H2020**
  - ITAINNOVA are designing and development an automatic EMC test bench to measure the noise TF of physics detectors. (WP4 leader)
- **EUROLABs Current activities – EU – Horizon Europe**
  - ITAINNOVA is TA facility for EMI detectors characterizations
  - We will improve the EMI system test with a new cooling system

Automatic test bench for EMC-TF test at ITAINNOVA



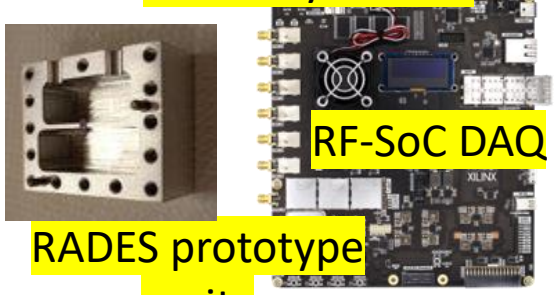


3. ITAINNOVA CURRENT & FUTURE DRD PLANS

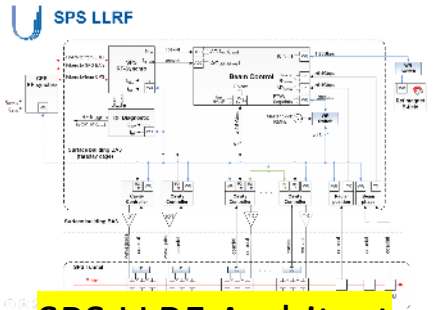
ITAINNOVA's areas of interest within **DRD5** – Quantum technologies

- **Technology transfer and development synergies for the superconducting roadmap**:
  - Packaging, EMI, environmental control.
  - RF Readout and subsystem control electronics
- Activities mainly focused on topic "DRDT5.2": Investigate and adapt state-of-the-art developments in quantum technologies to particle physics"
- **PC-MMR current activities**
  - Assessment of an RF-SoC based DAQ system as alternative to current heterodyne DAQ for RADES cavities for DM axion search.
- **Collaboration to CERN RF group (synergies accelerator & quantum technologies)**
  - RF DSP based on resampling for Accelerator derived Bunch Synchronous Clock data
  - Low noise Direct-sampling techniques for microwave frequencies

Heterodyne DAQ


RF-SoC DAQ

RADES prototype cavity



SPS LLRF Architect

3. ITAINNOVA CURRENT & FUTURE DRD PLANS

Current ITAINNOVA funding for DRD activities

CURRENT PROJECTS

EU

- **EUROLABs:** (EUROpean Laboratories for Accelerator Based Sciences) Horizonte Europa - 101057511 (**2022- 2026**).
- **AIDAinnova:** Advancement and Innovation for Detectors at Accelerators, H2020-101004761, **(2021- 2025**) , CERN (Suiza) y DESY (Alemania), **WP4 leader** and Steering Comitteee member.

National

- **CMSUPG:** "Actividades de ITAINNOVA para los" Upgrades" de alta luminosidad del LHC: Inner Tracker y Endcap timing layer". **PID2020-113705RB-C33** (**2021- 2024**) , **IP: Dr.Arteche**
- **TOMULGAD:** Distributed Clock network and power distribution system design for the technology demonstrator of the Timing Muon Tomography concept. Ref.:PDC2021-121718-C33 , (**2022-2024**). Prueba de Concepto, **, IP: Dr.Arteche**
- **PC de Física**: **Tecnologías avanzadas para la exploración del universo y sus componentes (2022- 2025**). Planes Complementarios (PC-MMR)

Regional

- **GaNCap4CMS:** Diseño y desarrollo de un sistema de protección contra transitorios basados en fuentes de corrientes con transistores GaN y superCondensadores integrados para el nuevo detector de Pixeles de CMS – Fase II (Ref: LMP239_21). (**2021-2023**). **IP: Dr. Arteche**).

4. Main Collaboration /Synergies & Technology transfer

NATIONAL COLLABORATION

- We have been collaborating with **IFCA , IMB-CNM** on numerous research projects focused on physics detectors since 2008.
- Today, we are carrying out 5 projects together on various topics related to the DRD lines defined by ECFA.
  - DRD7, DRD3, DRD5
- We plan to continue coordinating our DRD activities with IFCA and IMB-CNM.
- Also, a long collaboration with UNIZAR - Elec
- The national cooperation will not be limited to these groups.
  - New collaboration are on going
- We have started to collaborate with CAPA – UNIZAR in the development of Baby IAXO and RADES experiment (DRD7-DRD5)
  - Plan complementario de física
  - We submitted recently a coordinated project.
- We plan to continue the collaboration with Laboratorio Subterráneo de Canfranc in EMI control. (DRD7)

4. Main Collaboration /Synergies & Technology transfer

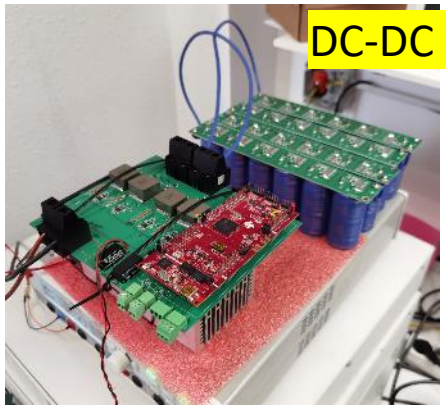
INTERNATIONAL COLLABORATIONS

- **CERN, Switzerland:** Collaboration agreement (KN3478) – Feb. 2017 / 1 Person at CERN for 1.5 years at Microelectronics group at CERN & IRRAD Group & starting novel support activity to SY-RF group
- **CMS experiment** - Collaboration since 2008 (Upgrades): ITAINNOVA became an associate Institute in 2012
- **RD53 Collaboration** - Read out chip design for CMS and ATLAS pixel upgrades – ITAINNOVA is member since 2018
- **ETHZ Zurich**, Switzerland (2017-Today)
- **Institut Pluridisciplinaire Hubert CURIEN (IPHC)/CNRS** (Strasbourg, France) – AIDAINNOVA H2020
- **FERMILAB, USA**: 1 Person will move to FERMILAB - Spring 2023
- **ECPE –** European Center of Power Electronics . ITAINNOVA became a Competence Center in 2019**.**
- **EUROPRACTICE Network** – ITAINNOVA has been admitted within europractice in 2022

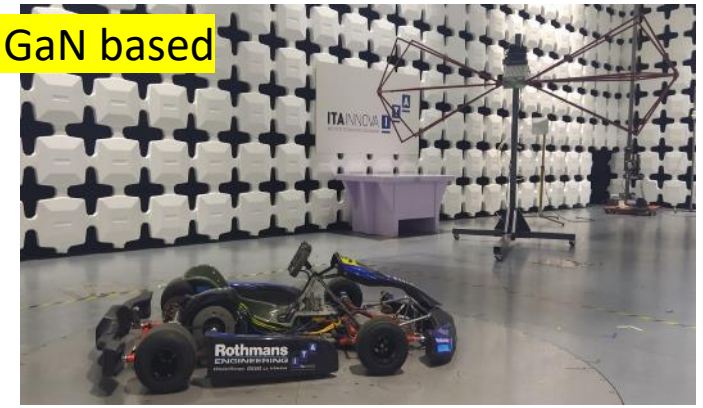
4. Main Collaboration /Synergies & Technology transfer

Synergies & Technology transfer

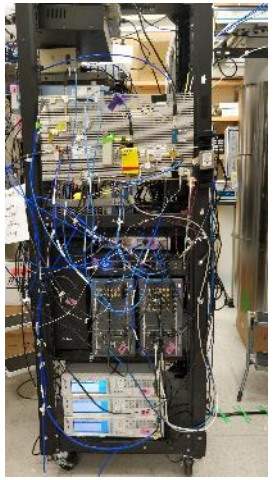
- The special characteristics of the institute and its proximity to industry may help the development of some of the DRD activities in which the group will collaborate.
  - ➢ They could benefit from synergies with industrial developments.
  - ➢ Some developments could be carried out taking into account aspects that simplify the technology transfer of the technological developments carried out by the cluster.



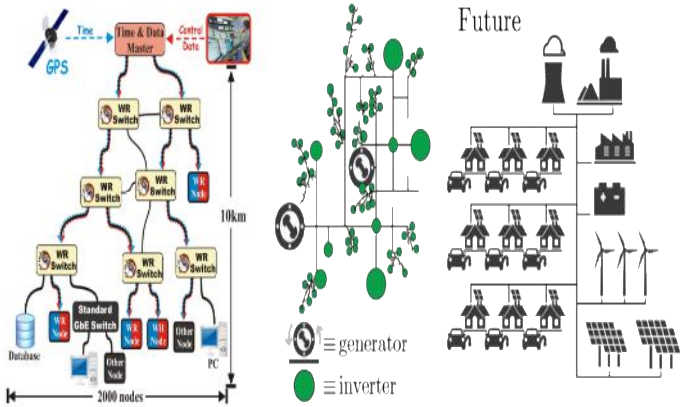
DC-DC GaN based



ITAINNOVA RF



Traditional RF Quant System



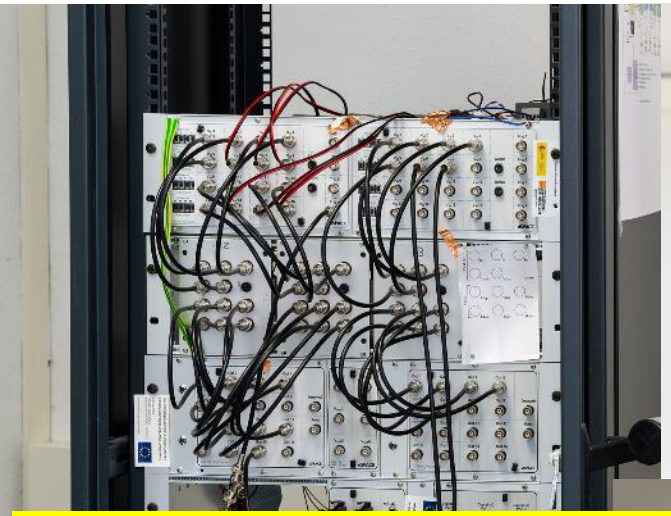
Synchronization of distributed power converters

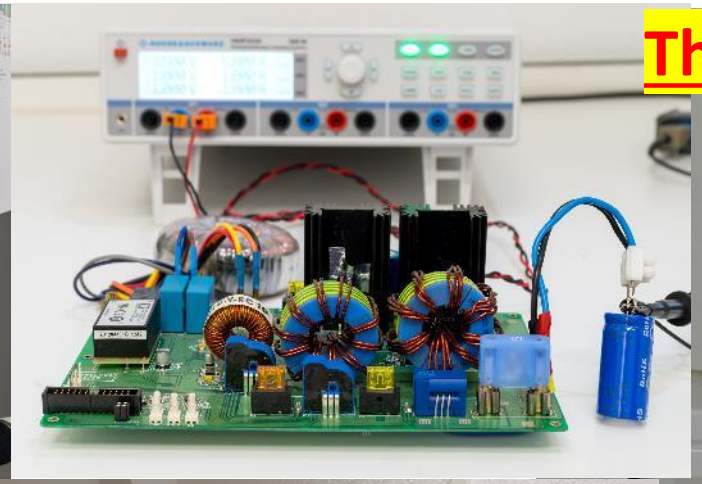
GOBIERNO DE ARAGON

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea NextGenerationEU

5. FACILITIES





Power Electronics & Instrumentation Lab

Boards designs

Power supplies

Electronic loads (160A)

Programming controllers

PSIM, Cadence tools &MATLAB / Simulink

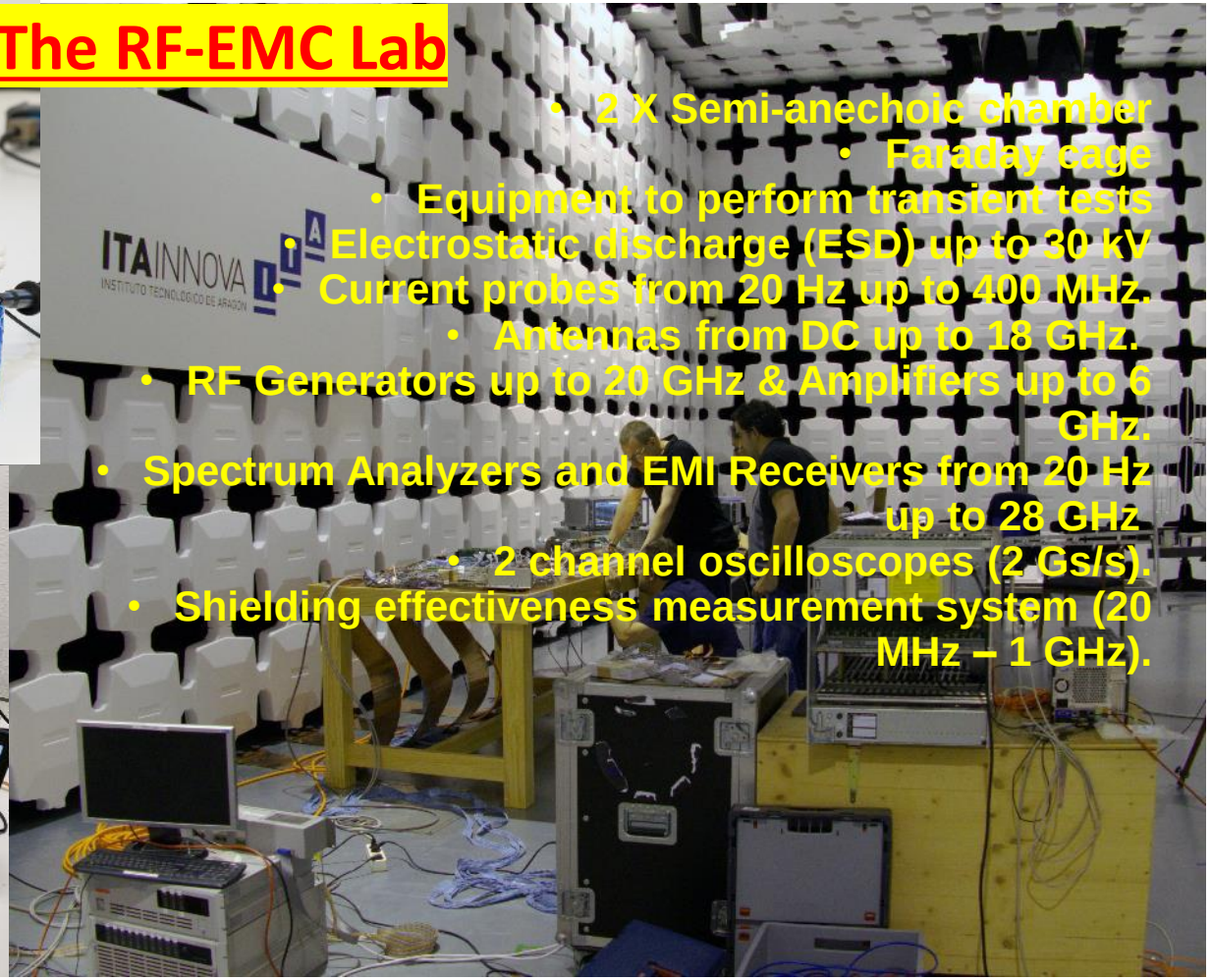
Texas Instruments platforms

Xilinx FPGA and SoC, RF-SoC development cards and ancillary elements

White Rabbit dev-kits and Low Jitter switch

dSpace & Typhoon platforms for rapid protyping.

The RF-EMC Lab



- 2 X Semi-anechoic chamber
- Faraday cage
- Equipment to perform transient tests
- Electrostatic discharge (ESD) up to 30 kV
- Current probes from 20 Hz up to 400 MHz.
- Antennas from DC up to 18 GHz.
- RF Generators up to 20 GHz & Amplifiers up to 6 GHz.
- Spectrum Analyzers and EMI Receivers from 20 Hz up to 28 GHz
- 2 channel oscilloscopes (2 Gs/s).
- Shielding effectiveness measurement system (20 MHz – 1 GHz).

ITAINNOVA INSTITUTO TECNOLÓGICO DE ARAGÓN

GOBIERNO DE ARAGON

Plan de Recuperación, Transformación y Resiliencia

Financiado por la Unión Europea NextGenerationEU

Thank you

ITAINNOVA
INSTITUTO TECNOLÓGICO DE ARAGÓN