

ITA activities in WP 7.1b: GaN based power converter for Serial Powering

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OUTLINE

- 01 Funding status**
- 02 Introduction to DRD7**
- 03 Activities 2023-2024**
- 04 Future plans & Fundings**
- 05 Summary**

1. Funding status

• 2023-2024 funding

- **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)**. Convocatoria de proyectos Multidisciplinares DGA 2021 Funding agency: Dirección General de Aragón, Budget 98.000€. PI: Dr.F. Arteché
- **CMSUPG:** “Actividades de ITAINNOVA para los” Upgrades” de alta luminosidad del LHC: Inner Tracker y Endcap timing layer”. Ref: PID2020-113705RB-C33 Funding agency: Ministerio de Ciencia e Innovación y Universidades, Duration: **2020-2024**, Budget: 243.000 €, PI: Dr. Fernando Arteché

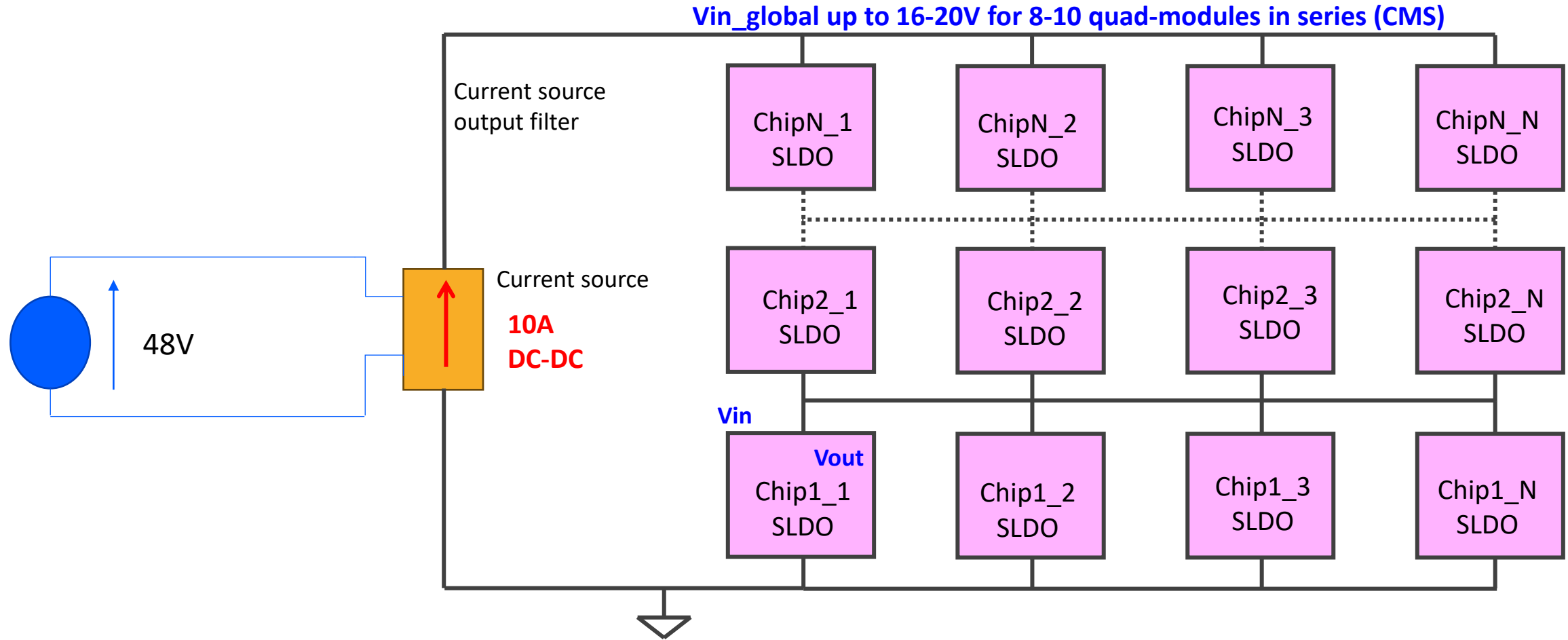
• 2025-2027 funding – Projects already granted (~3 FTE ~120 k€)

- **CMSUPG2:** "Participation in the CMS experiment of LHC: IT and ETL upgrades for high luminosity, and ECFA DRDs" (Ref: PID2023-148418NB-C43), de la convocatoria 2023 de ayudas a "Proyectos de Generación de Conocimiento" **Funding agency: Ministerio de Ciencia e Innovación y Universidades, Duration: 2024-2027, Budget:182.000 €**, Principal investigador: Dr.Fernando Arteché.
- **PROTECT:** "Detectores Semiconductores de Vanguardia para Tomografía de Protones Avanzada en Terapia Oncológica con Protones" (Ref: PDC2023-145925-C33), correspondiente a la convocatoria de "Prueba de Concepto" dentro del programa Pert Chip 2023, **Funding agency: Ministerio de Ciencia e Innovación y Universidades, Duration: 2024-2025, Budget:83.925 €**, PI: Dr.Fernando Arteché..
- **Tecnologías avanzadas para la exploración del universo y sus componentes** (2022- 2025). Este proyecto dotado con un presupuesto de 5M€ (ITA 239.000€, IP: Fernando Arteché). **Funding agency: Ministerio de Ciencia e Innovación y Universidades**, Programa: Planes Complementarios del Plan de Recuperación, Transformación y Resiliencia-MMR.
- Additional support for EU Project EUROLABS – ITA is TA for EMC test for physics detectors - 2022-2026

1. Introduction

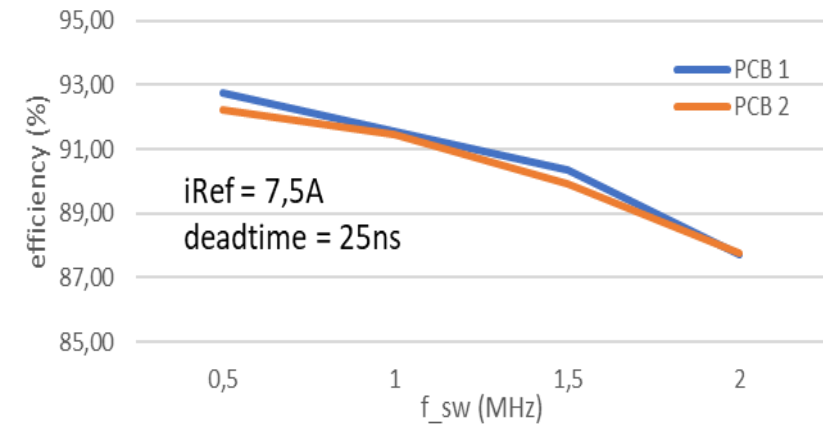
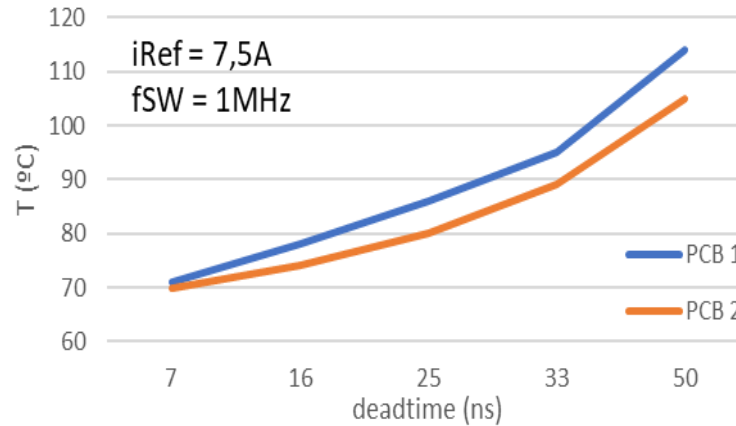
- The main goal of this task is to assess the feasibility of utilizing GaN-based DC-DC converters (current source) for serial powering applications (48V to ~24V / ~10A)
- Several critical issues have been identified to optimized the design of these units
 - Design implications associated to GaN switching
 - High frequency (~ 2 MHz) and short transition times (ns)
 - Precise Duty Control & deadtimes (High Resolution PWM modulator)
 - EMI filter design: Filter embedded in the PCB & magnetic components
 - Radiation hardness
 - Modular/Multiphase concept
- **Activities 2023-2024**
 - Design & Develop a preliminary prototype (2023)
 - Performance evaluation, regarding efficiency, dissipation and EMI testing (2024)
 - This evaluation also involved combined EMI testing in radiation environments

1. Introduction

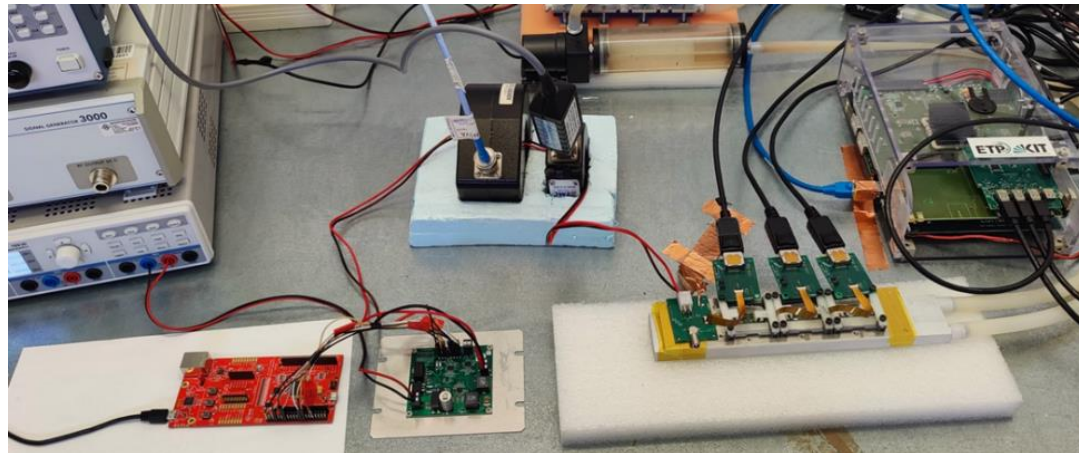


2. Activities 2023-2024

- The performance assessment of the preliminary prototype is completed.

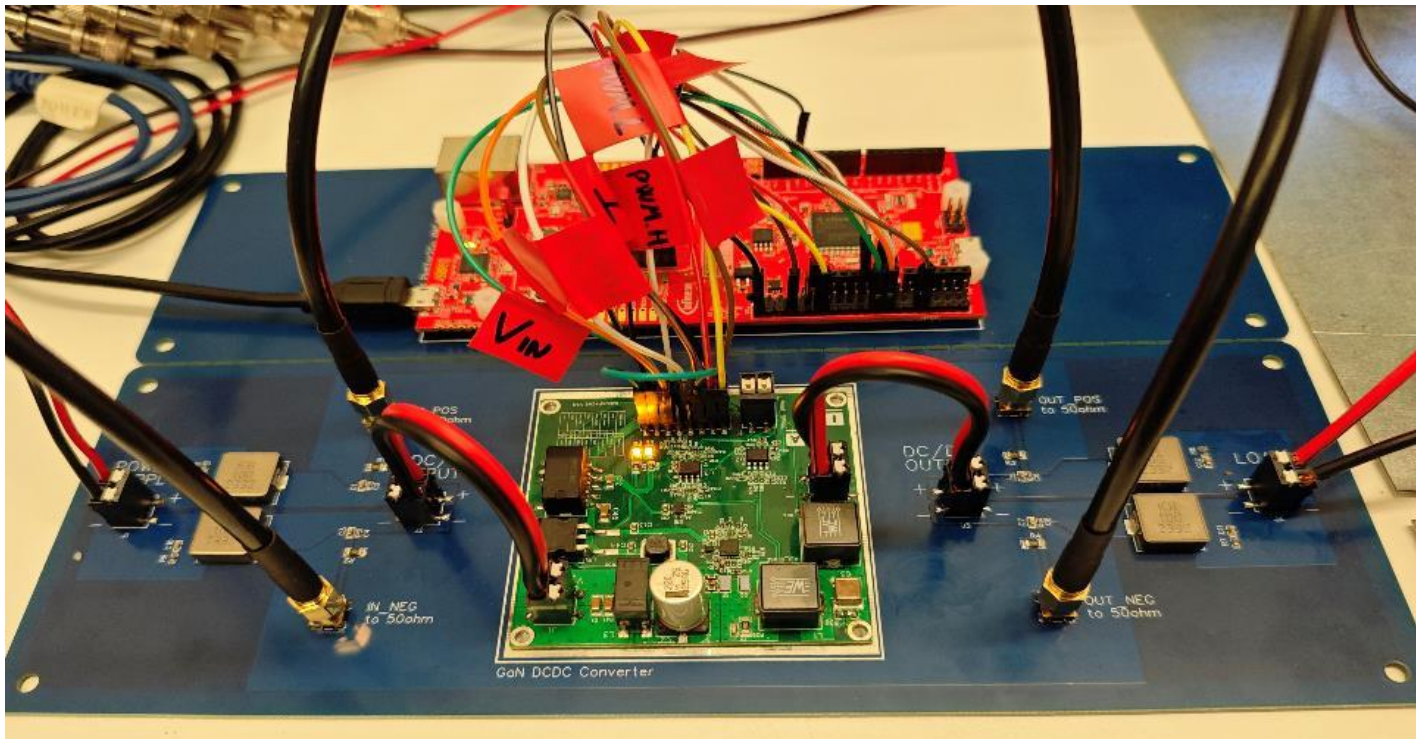


- The preliminary prototype was also tested on a real serial power chain during the noise TF characterization of 1x2 RD53A modules equipped with 3D sensors (IMB-CNM Barcelona) – CMS IT



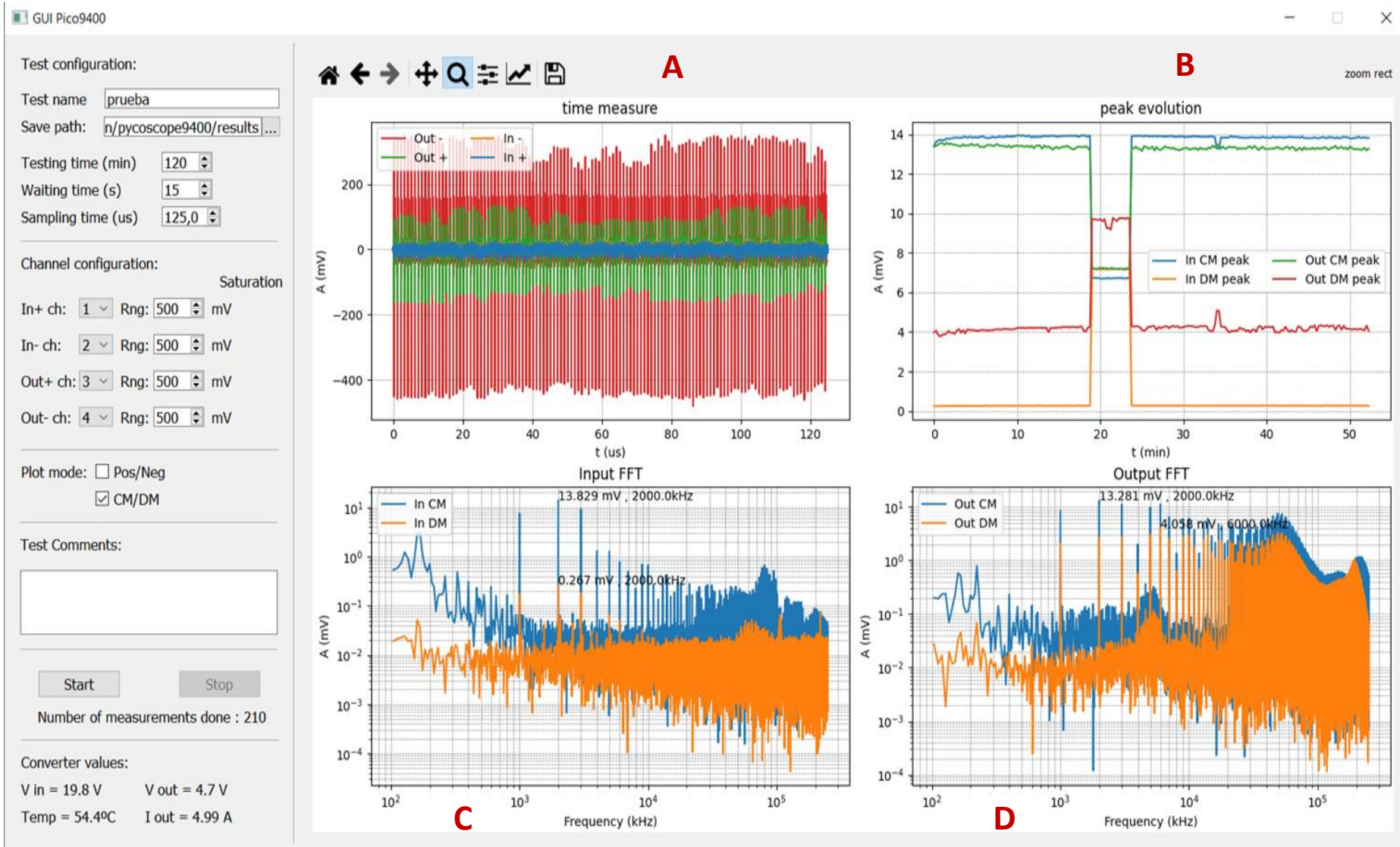
2. Activities 2023-2024

- The conducted EMI evaluation of the prototype was conducted using a specialized setup
 - The **setup is portable and fully automated**, allowing both time and frequency domain measurements.
 - It is highly effective for measuring transients related to power supplies (PS)
 - The system can also perform noise measurements during radiation campaigns (Measurements already performed at IPHC-Strasbourg, Nov2024) or temperature related tests.



The measurement system can be used by any other DC-DC converter design group. (collaboration & synergies)

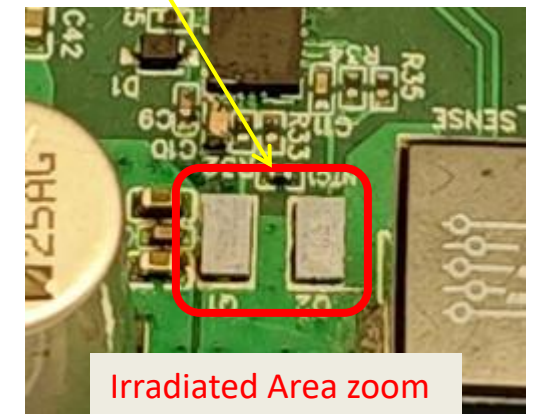
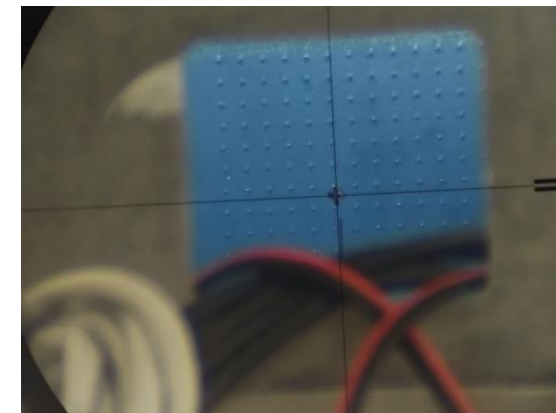
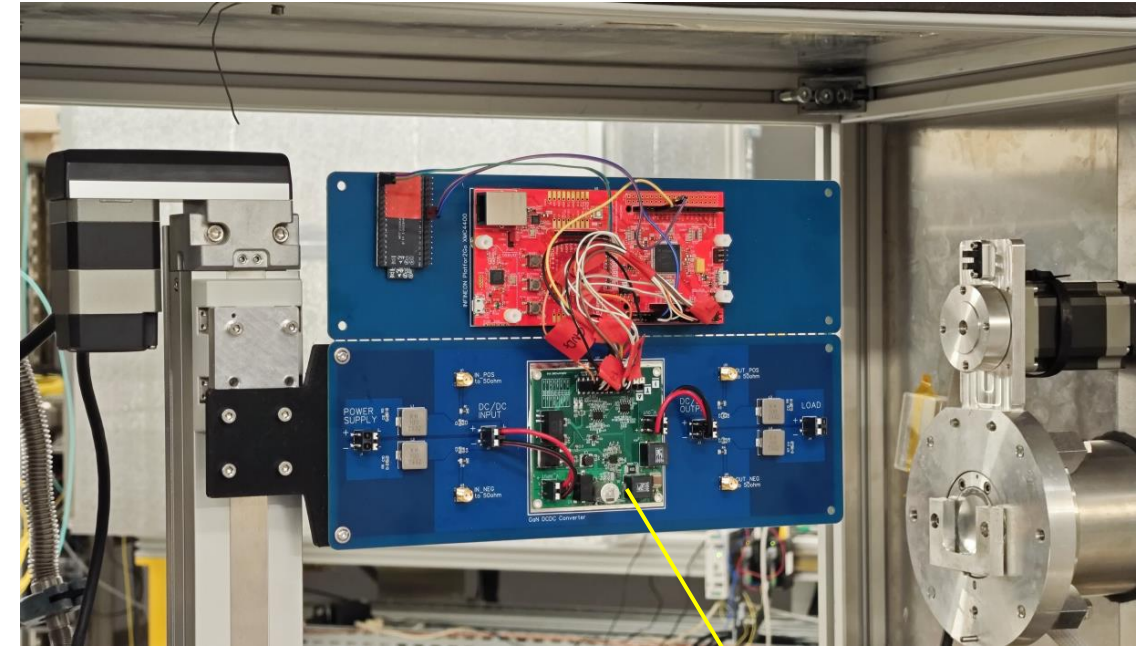
2. Activities 2023-2024



- A. Time domain measurements
- B. Evolution of the maximum peak of all measurements over the test (1hour)
- C. CM & DM at the input (last measurement)
- D. CM & DM at the output (last measurement)

2. Activities 2023-2024

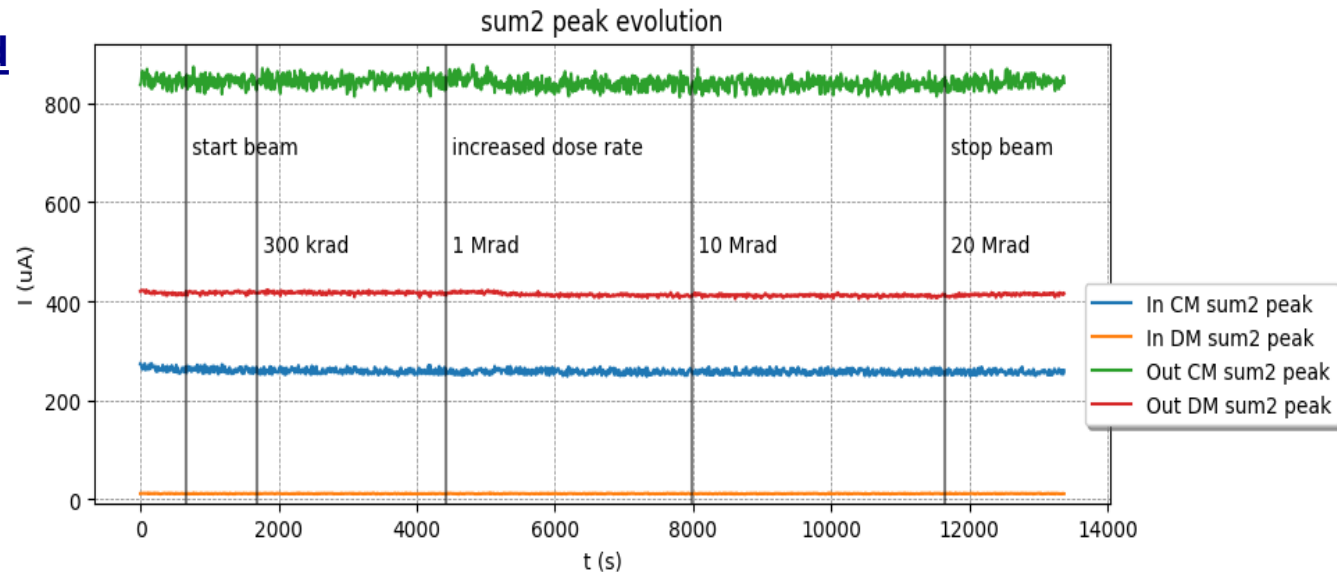
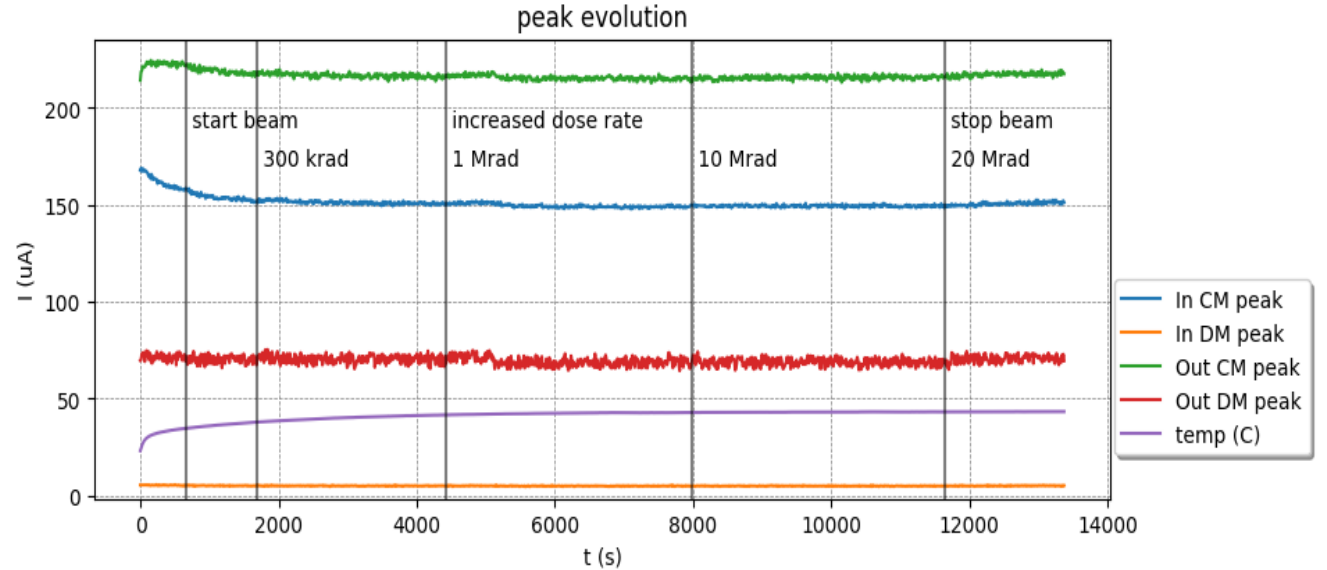
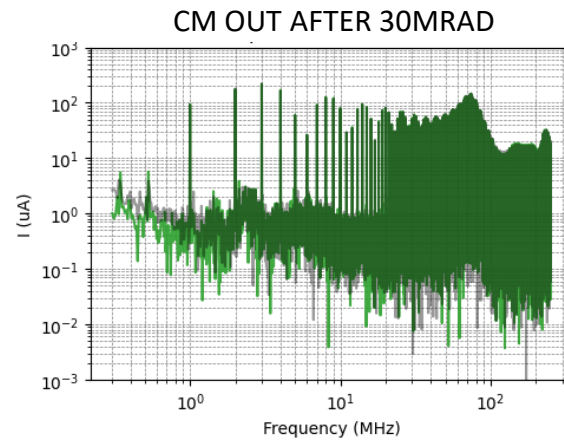
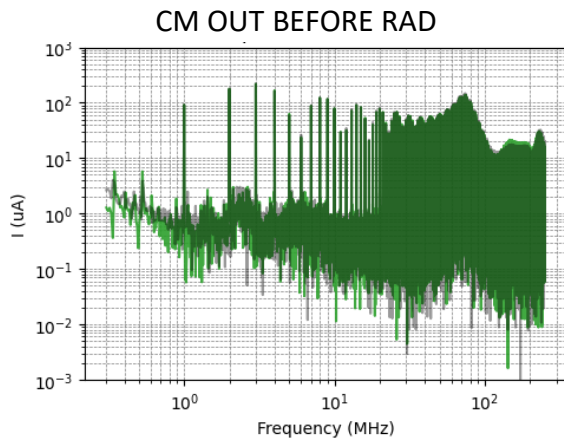
- Radiation campaign at IPHC - Strasbourg – 25 MeV cyclotron
- - Only GaN transistors were irradiated



Irradiated Area zoom

2. Activities 2023-2024

- 1st run: dose rate of 2Mrad/h up to 1Mrad
- 2nd run: dose rate of 10 Mrad/h up to 30Mrad total dose
- Input/Output DM and CM noise is measured every 10 seconds throughout the entire test (100kHz-250MHz)
- Post-processing to analyze dose rate effects:
 - Maximum peak evolution
 - Quadratic sum of X highest peaks (total energy)
- Specific frequency ranges can also be analyzed
- **No clear changes in emissions detected up to 30MRad**
- Temperature effects during warm-up



3. Future plans

- **New improved 48V current source prototype is being designed focused in several aspects:**
 - “COTS” design. Only commercial components are used.
 - Size reduction (first design was a concept for testing):
 - Increased switching frequency and optimized dead-time -> there is still some room for improvement (up to ~5MHz)
 - Multi-level design is being analyzed (flying capacitor 3-level converter) -> lower losses and ripple
 - Optimized input (C-L-C) and output filter (L-C-L or L-C-L-C-L) (inductance is the largest component)
 - As a current source, relatively high inductance is needed for output current stability. Serial powering has proven reliable even with low inductive current sources.
 - Optimized auxiliary elements (auxiliary supplies, connectors, ...).
- **Modular / Multiphase concept (special attention will be paid to this concept in 2025)**
 - Power scalability and reduced output ripple
 - Communication / synchronization of units (timing distribution) – linked with our activity in DRD7.3 timing detectors
- **Precise control in high frequency switching**
 - Full digital control (microcontroller) -> limited resolution and control speed
 - Hybrid analog – digital control is being studied (rad hard)

4. Summary

- ITA's activities in DRD7.1b are in progress.
- ITA is working on the feasibility of a radiation-tolerant and EMI-optimized GaN-based DC-DC converter for serial powering.
 - A first prototype has already been developed, analyzed, and extensively tested to ensure its performance and reliability.
 - Portable EMI test system successfully developed, radiation-tested, and now available for other research groups
- Main plans for next years
 - New optimized converter prototype is being developed focusing on size reduction and modularity (paralleling and synchronization)
- Funding is secured for the coming years thanks to three projects that have already been approved by Spanish government (Ministerio de Ciencia e Innovación y Universidades)



¡Thank you!



This project has received funding from the GANCAP4CMS PC Física, CMSUPG and CMSUPG2 projects