WP4
Upgrade of Irradiation and Characterization Facilities

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AIDAinnova 2nd Annual Meeting - Plenary Session, ADEIT (Valencia, ES), 26 April 2023

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101004761.

Outline

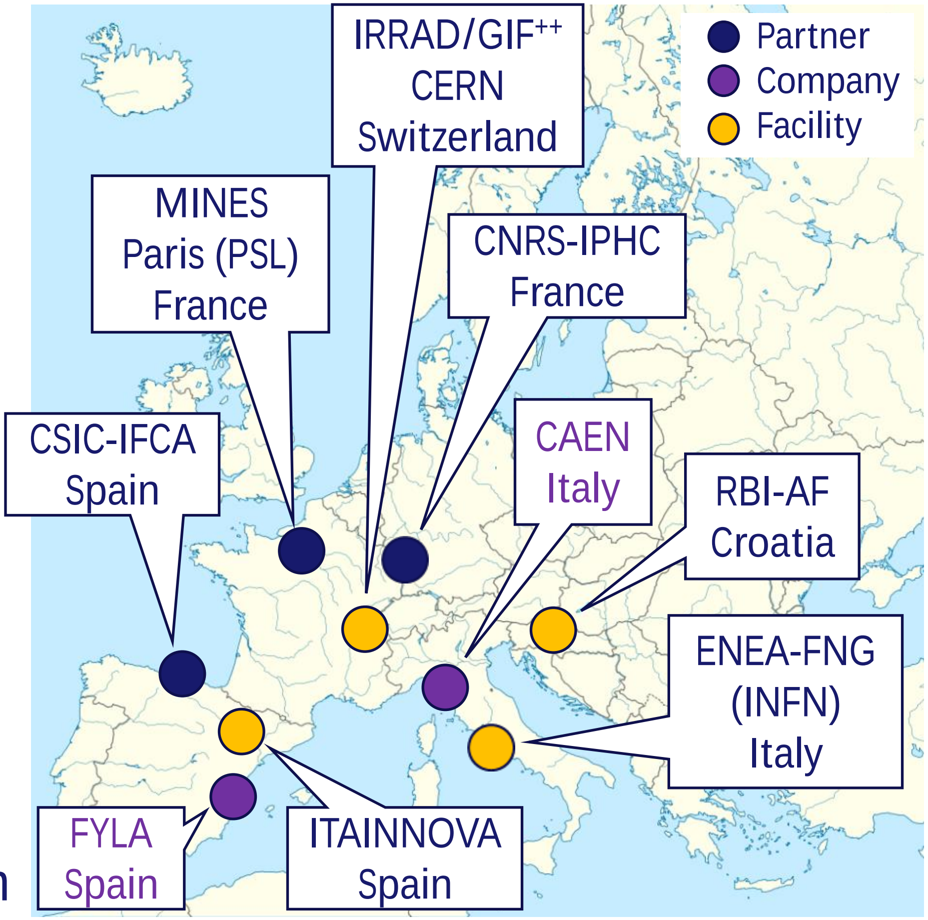
- Introduction to WP4
  - Goal, Structure, Partners, Organization, MS/D, etc.
- WP4 Parallel Session Summary
  - Task-by-task review
- Conclusion & Highlights

WP4 Goal

- Irradiation and characterization tests required for the R&D on next generation of particle detectors demand more accurate and reliable procedures, as well as a higher efficiency in their execution
- *The main goal of WP4 is to develop & standardize common tools for testing infrastructure to better support the next detector generation*
  - Improve facilities, systems and methods
- The activities are covered by different partners:
  - Academia
  - Industry
  - Research and Technology Organizations (RTOs)
- Good combination of partners aiming to improve the readiness of the detector support infrastructure to high TRLs

WP4 Structure & Partners

- Task 4.1: Task Coordination
  (CERN, ITAINNOVA)
- Task 4.2: Micro-beam Upgrade at RBI Accelerator Facility
  (RBI-AF)
- Task 4.3: Common Tools for Irradiation Facilities QC: Data Management, Traceability, Dosimetry and Activation Measurements
  (CERN, *MINES*(*), INFN, *ENEA*(*), CAEN)
- Task 4.4: Design & Development of a New Sensor Characterization System based on TPA-TCT Technique
  (CERN, CSIC-IFCA, FYLA)
- Task 4.5: Design & Development of a New Electronics Characterization System for EMC Control
  (ITAINNOVA(+), CNRS-IPHC)



(*) *Collaborating Institute*
(+) RTO

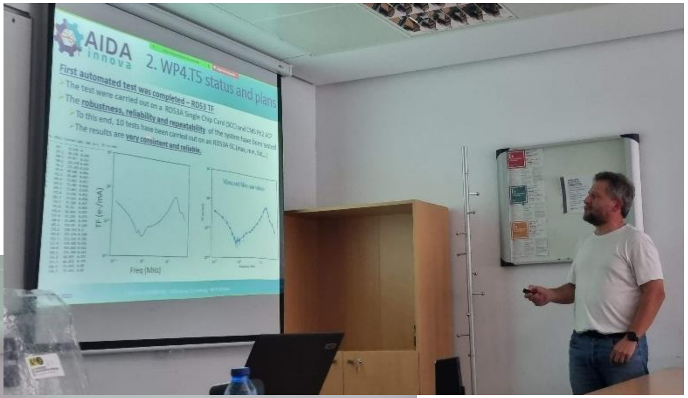
WP4 Milestones / Deliverables

Milestone or Deliverable	Description	Lead Beneficiary	Month
Task 2	Micro-beam upgrade at RBI accelerator facility (RBI-AF)		
MS12	Upgrade RBI-AF infrastructure for detector characterisation, SEE, micro hardness testing	RBI	M23
D4.1	Integrate the data acquisition and control system at RBI-AF	RBI	M40
Task 3	Common tools for irradiation facilities Quality Control: Data Management (DM), Traceability, Dosimetry and Activation measurements		
MS13	Define requirements, global architecture and design the extended DM system for ENEA-FNG and CERN-GIF++	CERN	M18
MS14	Extend IDM for FNG, GIF++ and communication with CAEN DigiWaste and CANBERRA Apex-Gamma Platforms	CERN	M36
MS15	Test RFID tagging for irradiation facilities	INFN	M42
D4.2	Evaluate Non-Ionizing Energy Loss (NIEL) of irradiation facilities with dedicated dosimeter structures	CERN	M42
D4.3	Deploy full prototype for irradiation facilities data management with sample tagging and spectrometry features	CAEN	M45
Task 4	Design & Development of a new sensor characterization system based on TPA-TCT technique		
MS16	Commission a complete TPA-TCT system	FYLA	M23
D4.4	Support the implementation of TPA-TCT systems and contribute to the evaluation of new sensors technologies	CERN	M46
Task 5	EMC Characterization		
MS17	Apply TF test bench to FEE prototypes	ITAINNOVA	M23
D4.5	Develop a conductive noise test bench for irradiation facilities	ITAINNOVA	M44

- 6 Milestones (MS): M18 – M42
  - M18: MS13 achieved
  - M23: MS12, MS16 submitted → being reviewed, to be released soon
  - M23: MS17 achieved
- 5 Deliverables (D): M40 – M46

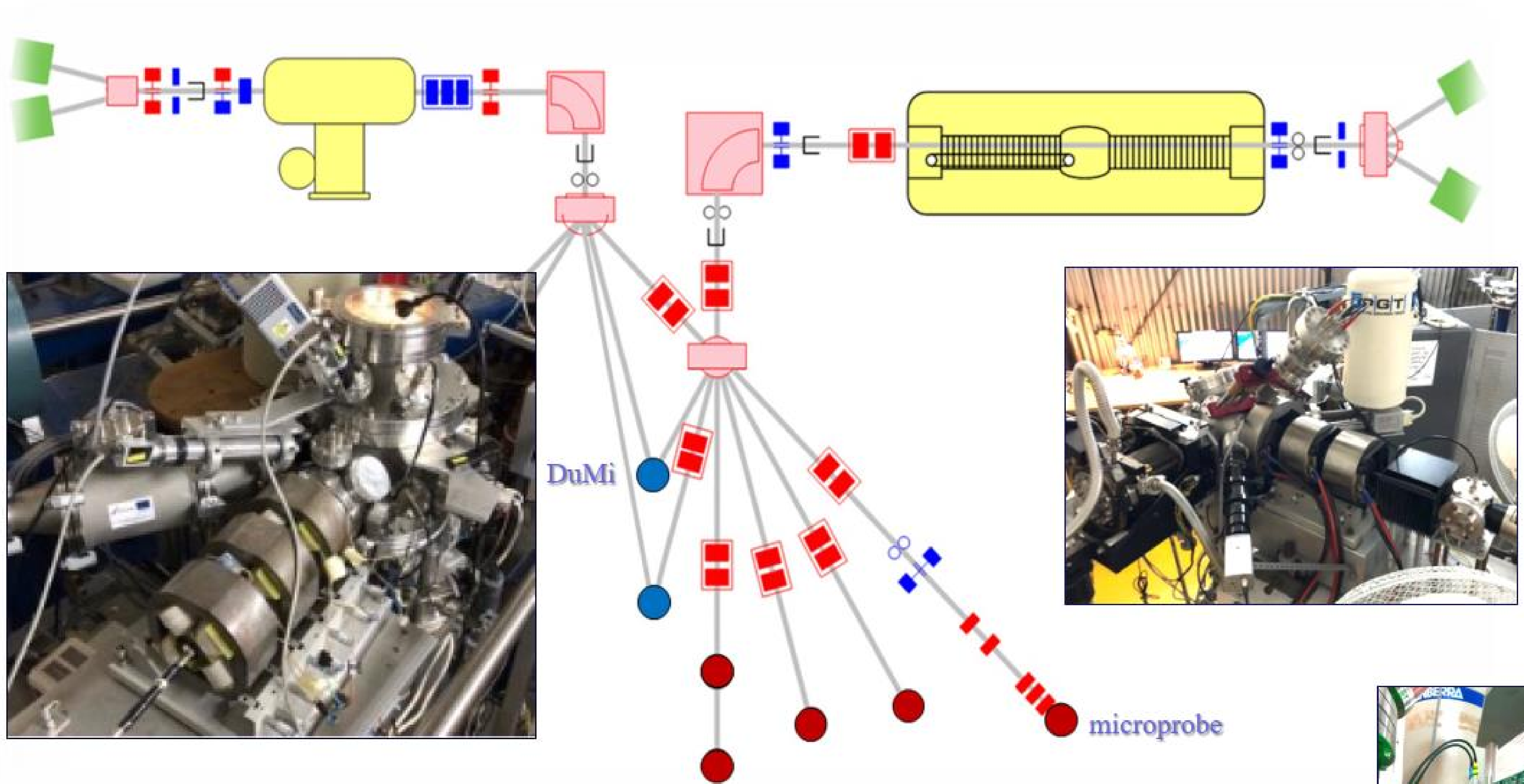
Task 4.1: Scientific Coordination

- WP4 session on Monday (15 participants including Zoom)
  - Task Leaders (TLs) reports



- 2 doc's for WP4 in Zenodo, some in the pipeline (review t.b.d by TLs)
- Discussion about usage of our improved/new infrastructures:
  - begin some periodical "book-keeping": number, type of users, etc.
  - useful for reporting and for new/future projects (e.g., EURO-LABS)

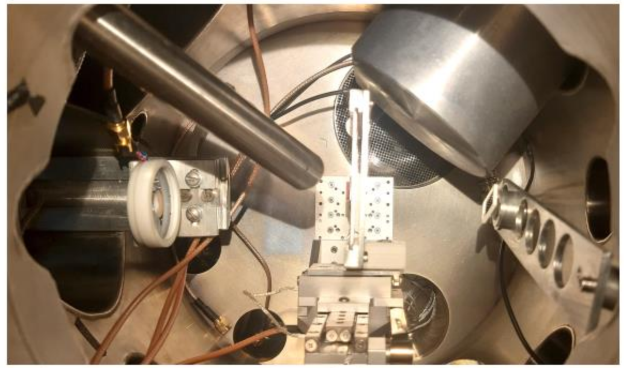
Task 4.2: Micro-beam upgrade at RBI accelerator facility



Detector characterization and precise irradiations are carried out by ion beam scanning microscopy. The lab has two microprobe end stations, providing microbeams (vacuum/ambient) with resolutions ranging from 120 nm to several um.

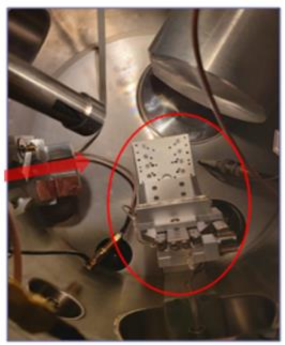
Task 4.2: Micro-beam upgrade at RBI accelerator facility

The components for the motorized stage were installed in the DuMi chamber.



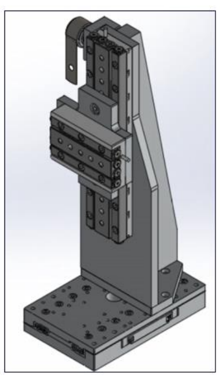
Precise motorised sample positioning and upgrade of related software MS12 (M23)

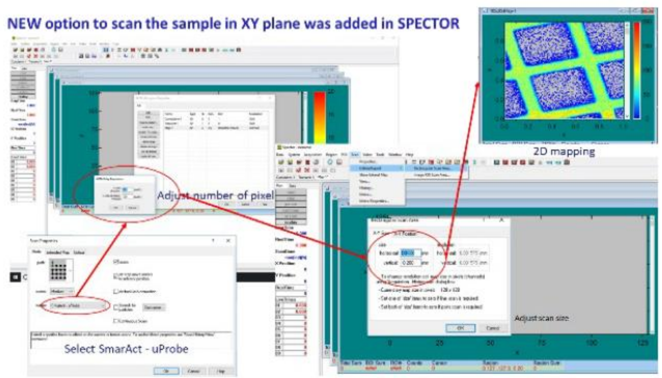
A sample holder is attached on the piezo-stage inside the vacuum chamber



The working range is extended to 100 x 100 x 50 mm.

The samples can be positioned at 90 deg and 60 deg with respect to the beam.

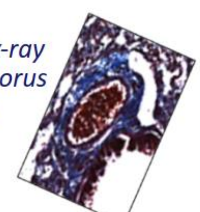


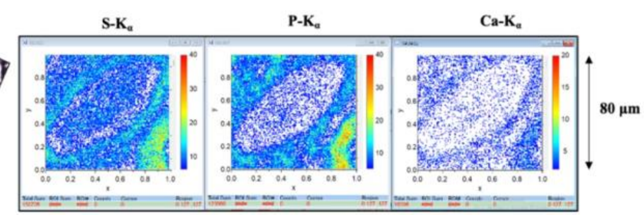


New option to scan the sample in XY plane was added in SPECTOR.

Extended 2D mapping capabilities, two dimensional mapping of IBIC charge collection efficiency on samples in vacuum has been extended from areas of few mm² to few cm² in controlled way.

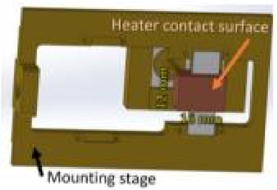
Two dimensional maps of PIXE x-ray intensity maps (Sulphur, phosphorus and calcium) from thin samples containing organic materials.

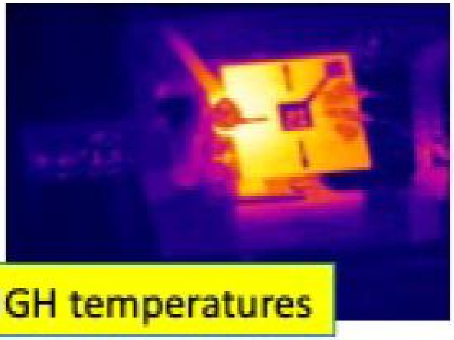




Task 4.2: Micro-beam upgrade at RBI accelerator facility

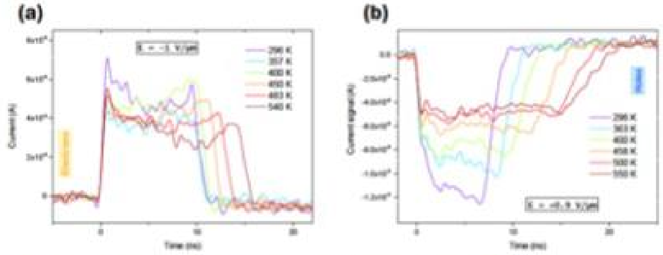
*Within RBI projects is the **study of detectors in extreme conditions**, i.e. radiation hard environments, high and low temperatures.*





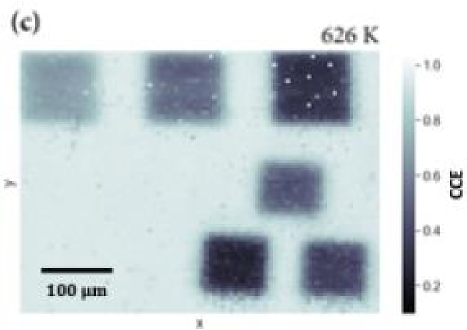
HIGH temperatures

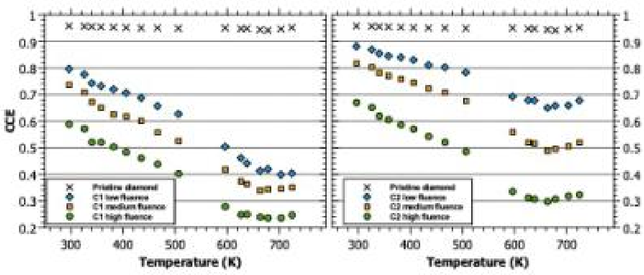
Resistive heating of detector: up to 450 C (diamond)



Kinetics of charge carriers was studied in elevated temperatures by means of TRIBIC technique.

Previously, studies of diamond response after high dose irradiations and at high temperatures by means of resistive heating was carried out.

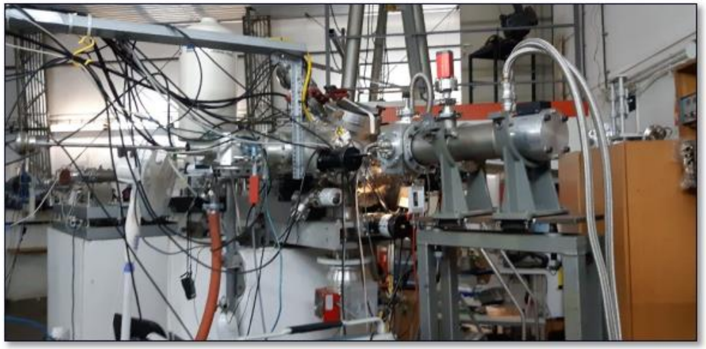




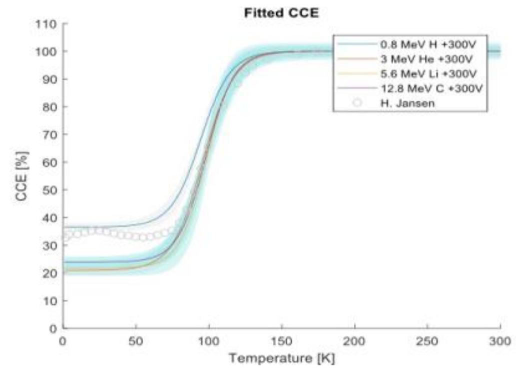
Response/annealing after irradiation was study up to 700 °C by employing IBIC.

Task 4.2: Micro-beam upgrade at RBI accelerator facility

*In Task 4.2 **sample cooling** was considered only for the old microprobe. Two different sample cooling options have been tested.*



Option A: Cooling to cryogenic temperatures with the use of a modified cryo-pump and resistive heating.

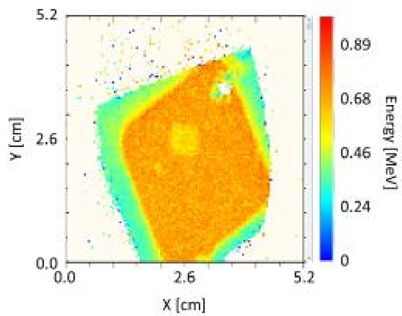


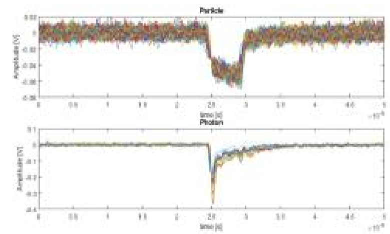
CCE drop significantly below 100 K due to exciton formation

Option B: Passive LN2 cooling.

IBIC study of detectors down to -4 °C

IBIC and TRIBIC characterization of diamond down to 38 K





A 300 um thick diamond detector, planned to be used at cryogenic temperature as a beam-loss monitor at DONES was studied at RBI →

Task 4.2: Micro-beam upgrade at RBI accelerator facility

Summary:

- ***Two precise motorized positioning*** *systems for long and short focus positions at the* ***DuMi*** *setup have been designed, related components procured assembled and tested.*
- *The existing home made data acquisition and control system* ***SPECTOR*** *has been* ***upgraded*** *to enable the control of the new piezoelectric motorized stage.*
- *Upgrade of the old microprobe with possibilities for sample cooling. Cryogenic and passive LN2 cooling have been installed and tested. Detectors can now be tested down to 38 K.*

Milestone MS12 *has been achieved*

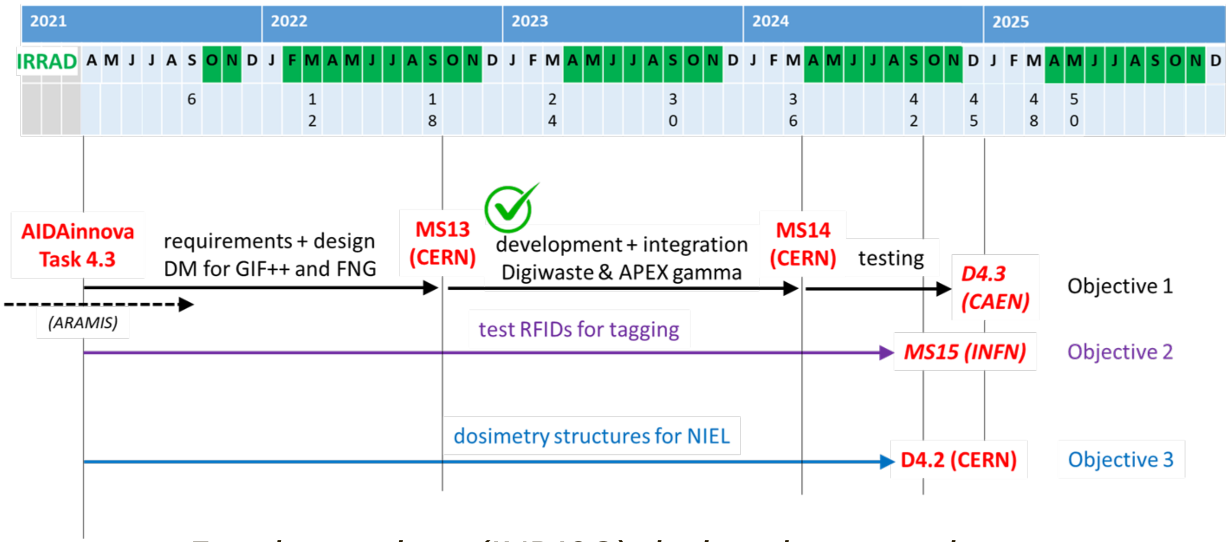
Future activities within Task 4.2:

- *Installation of precise target positioning system at the old microprobe*
- *Improvements of old microprobe cooling system for studies below 38 K.*

D4.1 (RBI) – M40: well on track

Task 4.3: Common Tools for Irradiation Facilities QC: Data Management, Traceability, Dosimetry, Activation Measurements

- Objective 1: Generalisation of the IRRAD Data Manager (IDM) system to new facilities
- Objective 2: Design and development of an integrated system prototype for induced activation and traceability data management
- Objective 3: Common dosimetry calibration set for cross-comparison of irradiation facilities



5 task meetings (INDICO) during the second year

Detector development, irradiation, characterization (CH)

Irradiation/testing of electronics (IT)

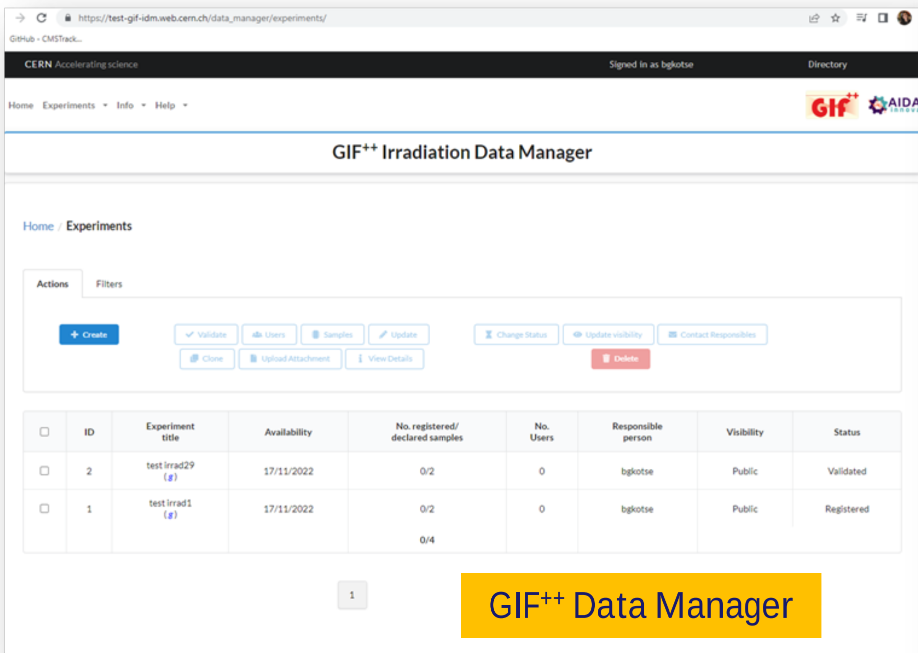
Electronic Instrumentation for Nuclear and PP (IT)

Data management SW, ontologies and ML (FR)

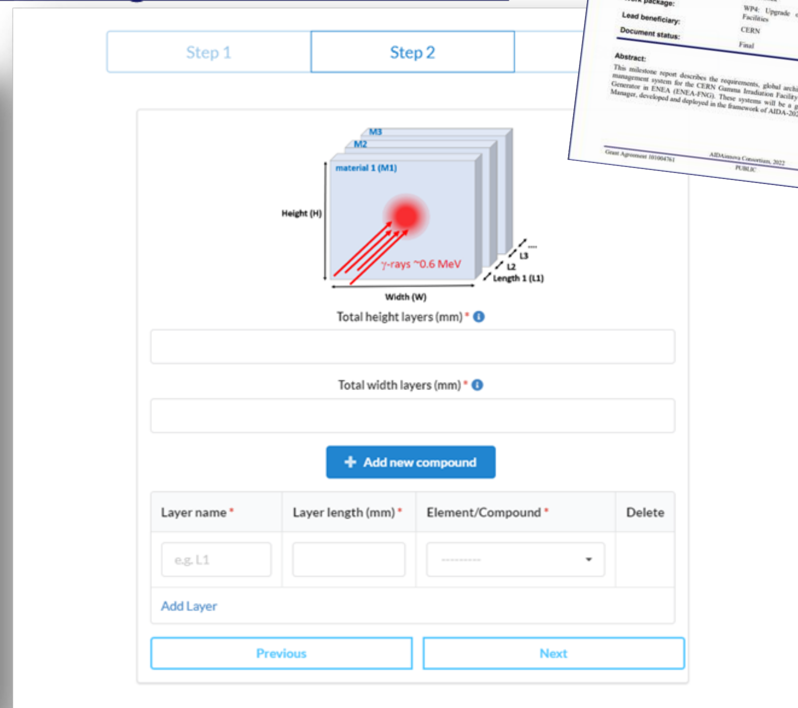
Task 4.3-1: Data Manager (DM) Extension for New Facilities

- Cloning and adapting IDM for GIF^{++} according to identified requirements (e.g., computation of photons attenuation factor, etc.)
- Deployment using the OpenShift platform
- Available in this link (CERN network): https://test-gif-idm.web.cern.ch/

MS13 (CERN)



GIF^{++} Data Manager



Task 4.3-2: Induced Activation & Traceability Management in IDM

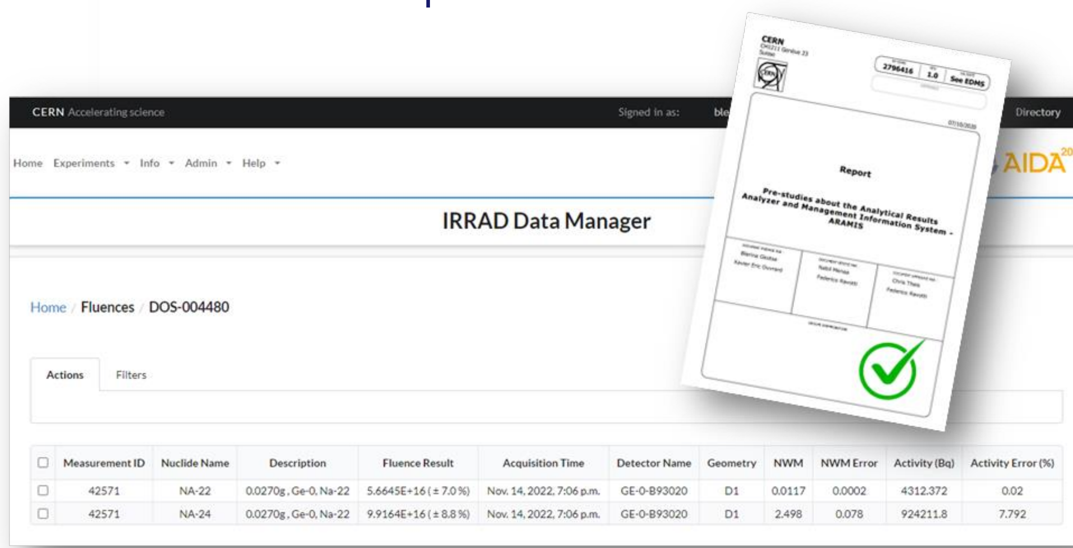
IRRAD Data Manager (IDM) Updates

- **New** CERN Single Sing-On (**SSO**) deployed
- IDM **user model changes** to adapt to the new SSO authentication
- Fixing new user notification for **EURO-LABS** information (complementary European Project for Transnational Access)
- Separating past/current experiments
- **Data privacy** notice published
- **Usability sessions** organized for new/improved functionalities

MS14 (CERN) – M36: well on track

Spectrometry project (APEX-Gamma)

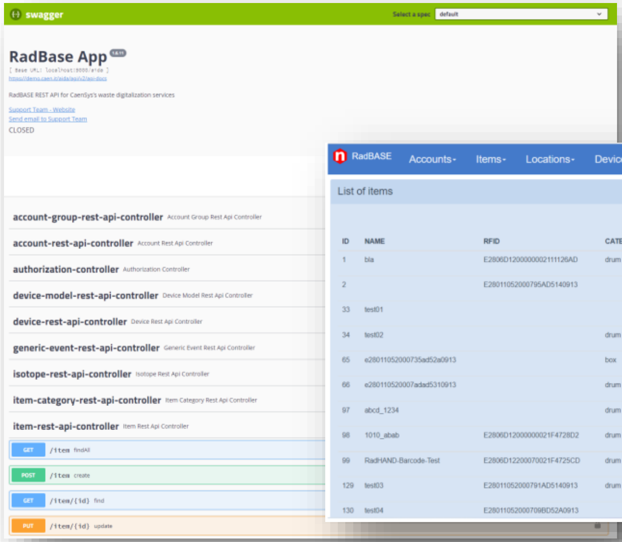
- Spectrometry data model and report finalised
  → ARAMIS report (CERN EDMS 2796416)
- Data model configured and integrated to IDM
- Communication with the spectrometry APEX-gamma database and IDM
- Calculation of proton fluence-related values in IDM

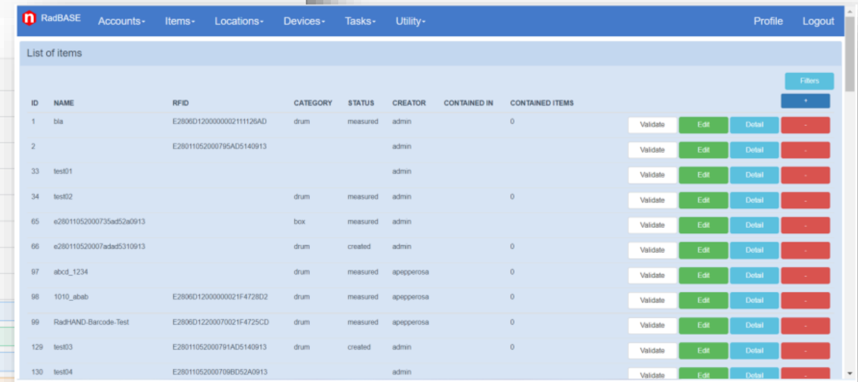


Task 4.3-2: Induced Activation & Traceability Management in IDM

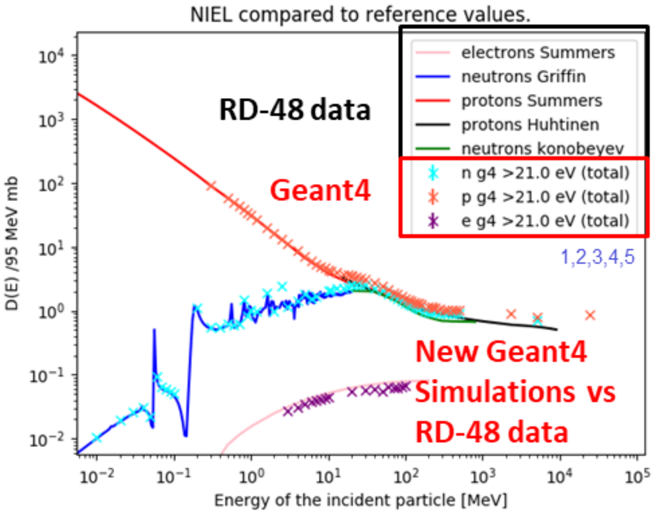
- CAEN RadBASE interface tested for CERN IRRAD
- Need to define the requirements for IDM integration
- RadHAND test with RadBASE at CERN planned end of May
- Two irradiation campaigns already performed for RFID tag:
  - IRRAD
  - ENEA-FNG (funded by RADNEXT TA)
- Test campaign with mix-field is under discussion (CHARM)

MS15 (INFN) – M42
D4.3 (CAEN) – M45





Task 4.3-3: Dosimetry cross-comparison (NIEL calibration set)



V. Subert PhD Thesis (synergy with EP-RD)

EP R&D

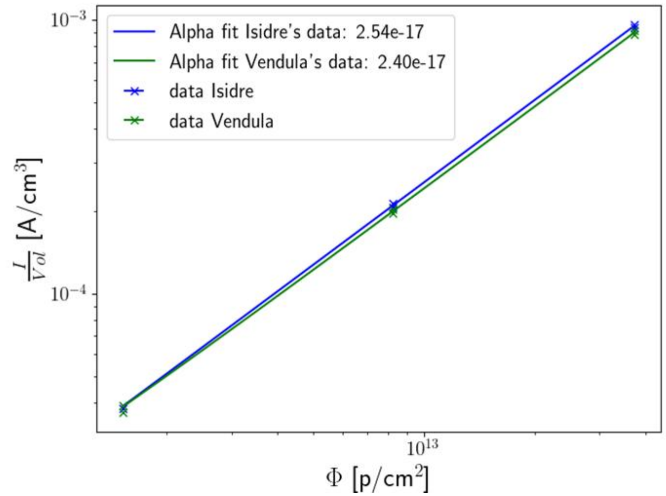
Revisiting NIEL concept ...

- NIEL curves in literature with Geant4 and FLUKA simulations successfully reproduced
- **Algorithm for identifying clustered versus point defect damage implemented** and qualitative agreement reached
- Further developments of **algorithm for damage differences between different particles** are envisioned

&

... NIEL Experimental Measurements

- Set of irradiated Si-diodes measured in IRRAD in 2018 (I. Mateu) and re-measured 4 years later (V. Subert)
- Results are in good agreement
- Evaluating possibility to perform new experiments

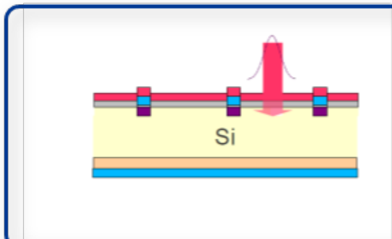


➔ Launch the production of a dedicated common set of dosimeter structures for cross-comparing the NIEL in various irradiation facilities

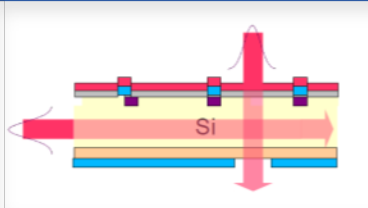
D4.2 (M42)

Task 4.4: TPA-TCT System Development

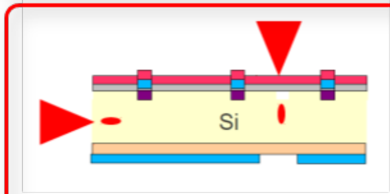
- **TCT:** Pulsed laser induced generation of charge carriers inside detector
  - Study of E-field in sensor, charge collection efficiency, homogeneity, ..
  - Benchmark simulation tools, e.g. signal formation,
  - Measure physics parameters e.g. mobility, impact ionization, ..



- **TCT (red laser)**
  - short penetration length (650nm = 1.9eV)
  - carriers deposited in a few µm from surface
  - front & back TCT: study electron & hole drift separately
  - 2D spatial resolution (5-10µm)



- **TCT (infrared laser)**
  - long penetration (1064nm = 1.17 eV)
  - similar to MIPs (though different dE/dx)
  - top and edge-TCT
  - 2D spatial resolution (5-10mm)



- **TPA-TCT (far infrared)**
  - No single photon absorption in silicon
  - 2 photons produce one electron-hole pair
  - Point-like energy deposition in focal point
  - **3D** spatial resolution (1.5 x 1.5 x 15 μm^3)

TCT "invented": 1996

edge-TCT invented within RD50: 2010

TCT commercialized: 2013

TPA-TCT: Proof of concept presented by RD50 in 2015

Table-top TPA-TCT laser commercialized: 2020/21

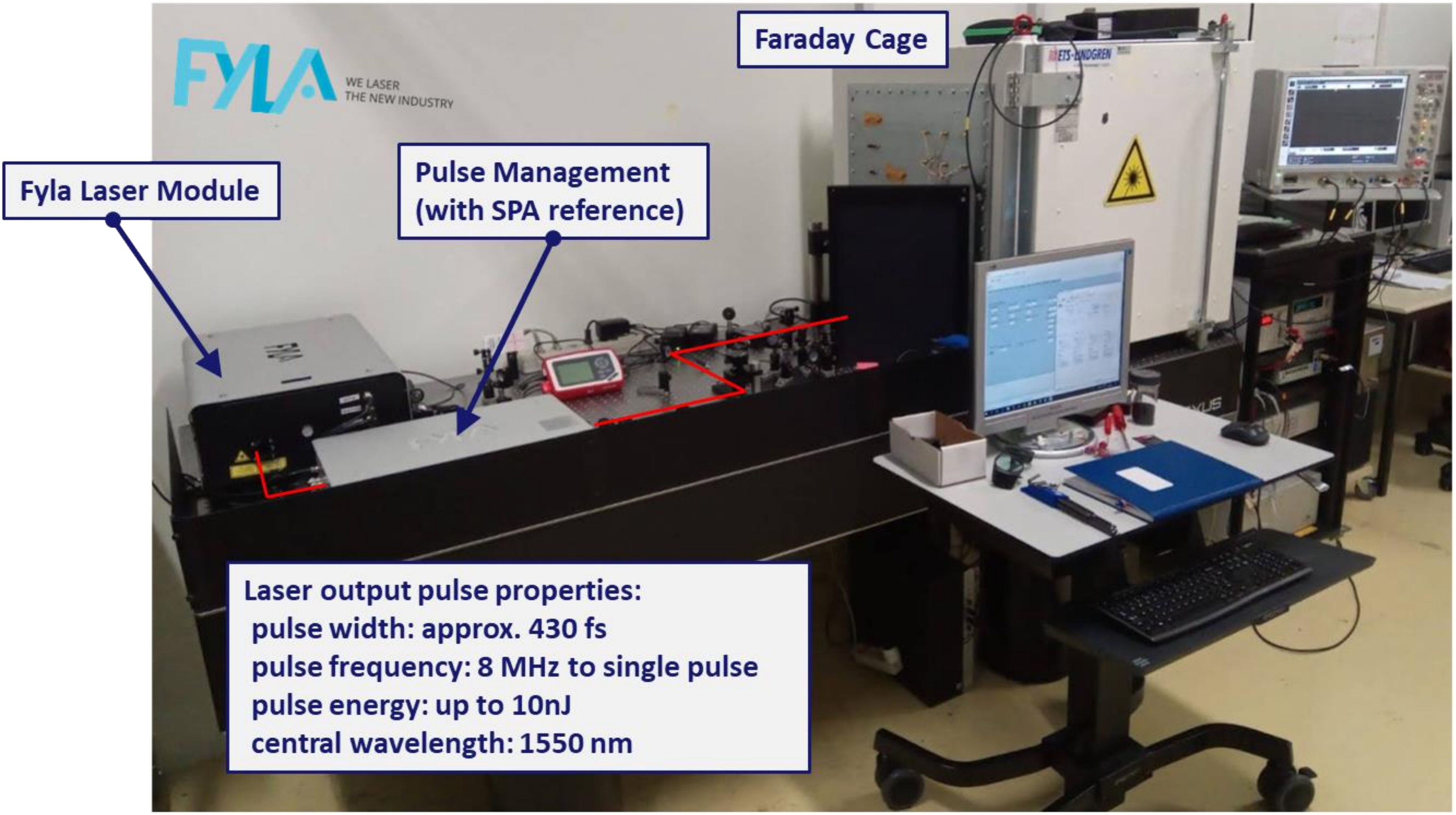
Table-top TPA-TCT system

AIDA innova RD50

All fiber based table-top TPA-TCT laser/system

Task 4.4: TPA-TCT System Development

- **CERN:** TPA-TCT at the Solid State Detectors (SSD) lab of the EP-DT group
  - Laser laboratory with interlocked access and personal protection equipment



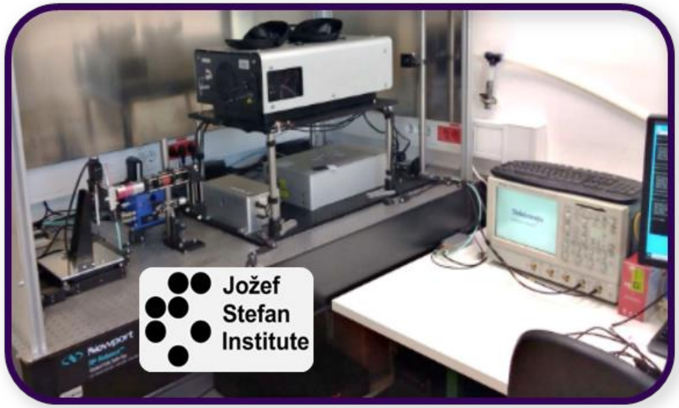
[M.Wiehe et al.: Development of a Tabletop Setup for the Transient Current Technique using Two-Photon Absorption in Silicon Particle Detectors, IEEE TNS, Vol.68, Issue.2, Feb.2021, pages 220-228]

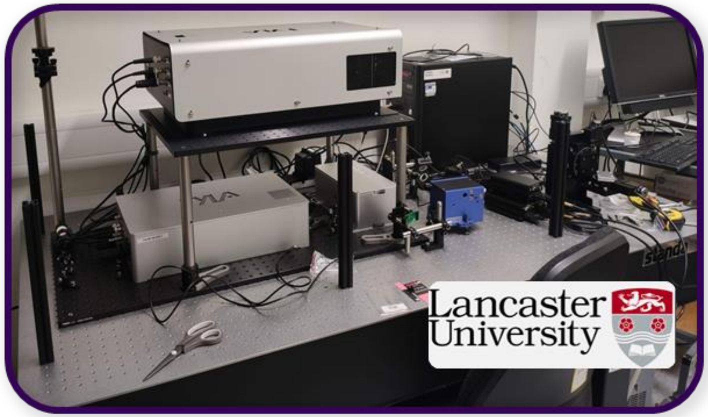
Task 4.4: TPA-TCT System Development

- **CERN:** TPA-TCT at the Solid State Detectors (SSD) lab of the EP-DT group
  - Laser laboratory with interlocked access and personal protection equipment
- TPA-TCT systems have been set up at several institutes with the LFC1500X laser

FYLA WE LASER THE NEW INDUSTRY

LFC1500X





[M.Wiehe et al.: Development of a Tabletop Setup for the Transient Current Technique using Two-Photon Absorption in Silicon Particle Detectors, IEEE TNS, Vol.68, Issue.2, Feb.2021, pages 220-228]

Task 4.4: Fiber-based TPA-TCT System

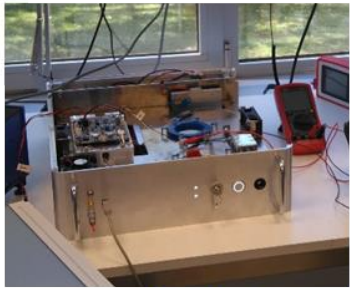
Current TPA-TCT system

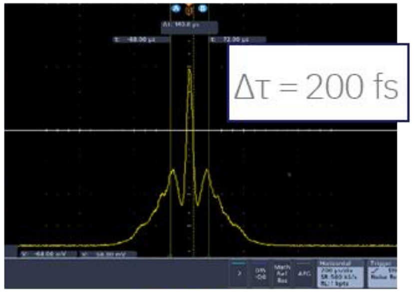
CURRENT
LFC1500X commercial model

AIDA INNOVA
Single box fully all-fiber

Fiber delivery

- **LPS:** Laser Pulse Source
  - All-fiber CPA femtosecond pulses generation
  - Pulse rep rate selection. **Single shot to 8 MHz**
- **LPM**: Laser Pulse Management module
  - Pulse energy modulation: **<10 pJ to > 10 nJ**
  - Synchronized shutter. **rise/fall time < 1 us**





Prototype January 2022

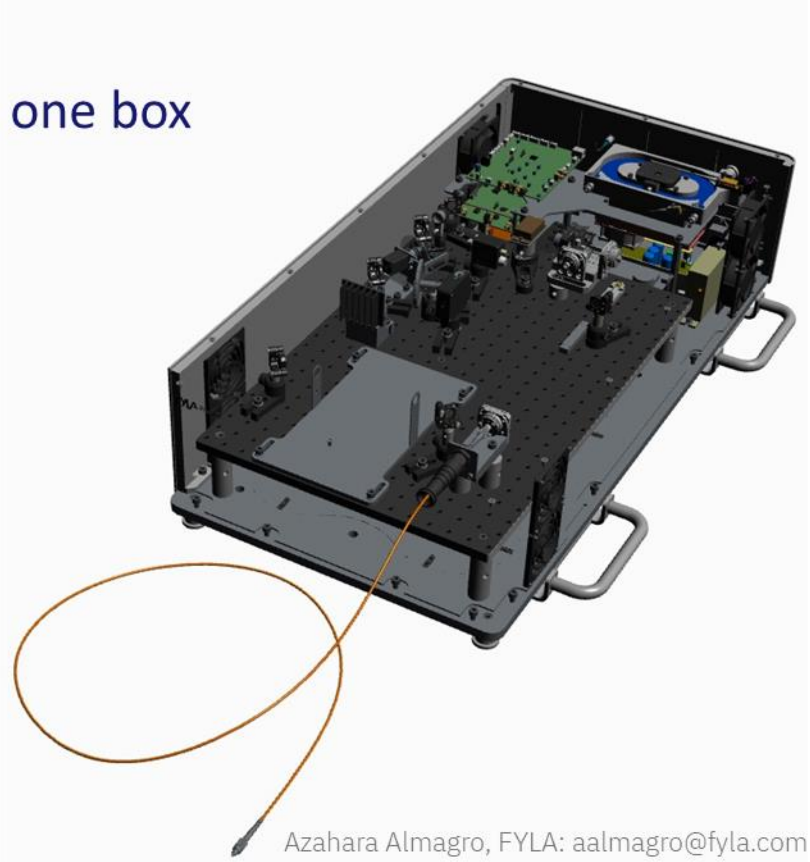
Details on the new design: A.Almagro-Ruiz, Fyla "**Towards an All-Fiber Femtosecond Laser System as Excitation Source in the TPA – TCT**", presented on 39th RD50 Workshop, November 2021, Valencia

- **LPS + LPM + D-SCAN** in single box fully all-fiber
  - Pulse duration goal < 100 fs
  - Fiber-based tunable dispersion compensation: < 100 fs to 1 ps
  - Fiber-pigtailed AOM functionalites:
    - Energy modulation; Pulse rep rate selection; Sync shutter
  - Dispersion-less fiber output

Task 4.4: Fiber-based TPA-TCT System

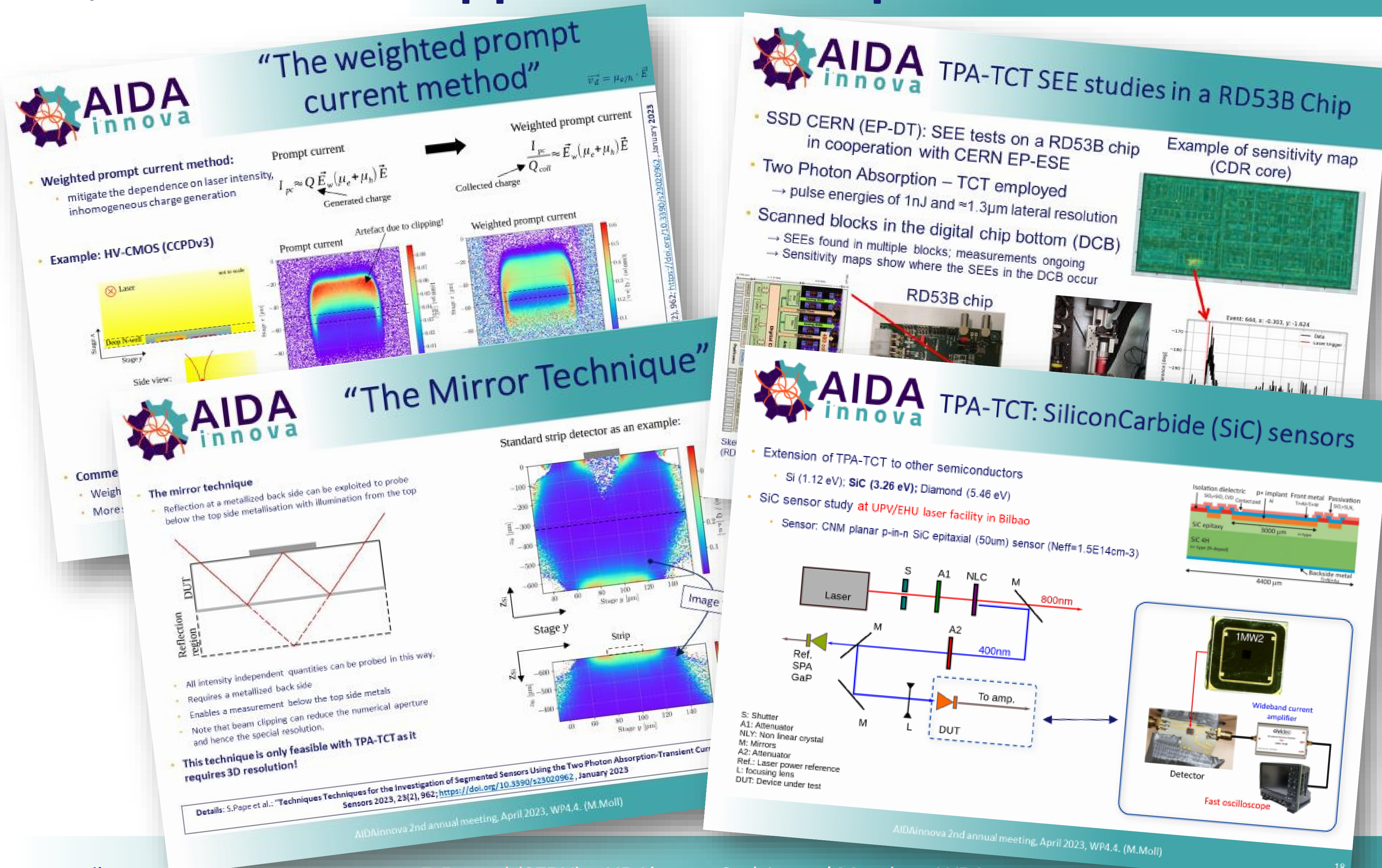
New design concept (2023): Compact laser system with fiber output

- **Compact** laser system: all modules in one box
- **Fiber output** delivery



Azahara Almagro, FYLA: aalmagro@fyla.com

Task 4.4: Technique Improvements & Application Examples



Task 4.4: TPA-TCT System Development

- WP4.4 - Design & Development of a TPA-TCT Sensor Characterization System
  - Scope: Development of a customizable and user friendly Two Photon Absorption – Transient Current Technique (TPA-TCT) system for the characterization and test of silicon devices.
  - Beneficiaries: CERN (task leader), CSIC-IFCA (Santander, ES), Fyla (Valencia, ES)
  - Deliverables/Milestones:
    - MS16 (M23 – February 2023) – Commissioning of complete TPA-TCT system [OK: MS report submitted]
    - D4.4 (M46 – January 2025) Publications & systems operational at several institutes [well on track]
  - Status April 2023:
    - Laser system:
    - Fyla free space laser systems at CERN, IFCA (Santander, ES), JSI Ljubljana(SI), NIKHEF(NL), Lancaster (UK)
      - Work of last 12 months: Systems operational and producing large amount of data (see examples and list of publications)
      - Goals for new compact laser and system developments re-defined:
        (2021/22) evaluation of full-fiber based system studied and finally abandoned in end of 2022;
        second design approach produced in the course of 2022: 2023 work started at Fyla on this new design
    - User community:
      - TPA-TCT lasers have been delivered to 5 HEP institutes, CERN/IFCA/Fyla provided consulting for setting up the systems
      - TPA-TCT common effort presented as example for collaborative efforts for new R&D collaboration (DRD3) in ECFA Detector R&D roadmap implementation plan.

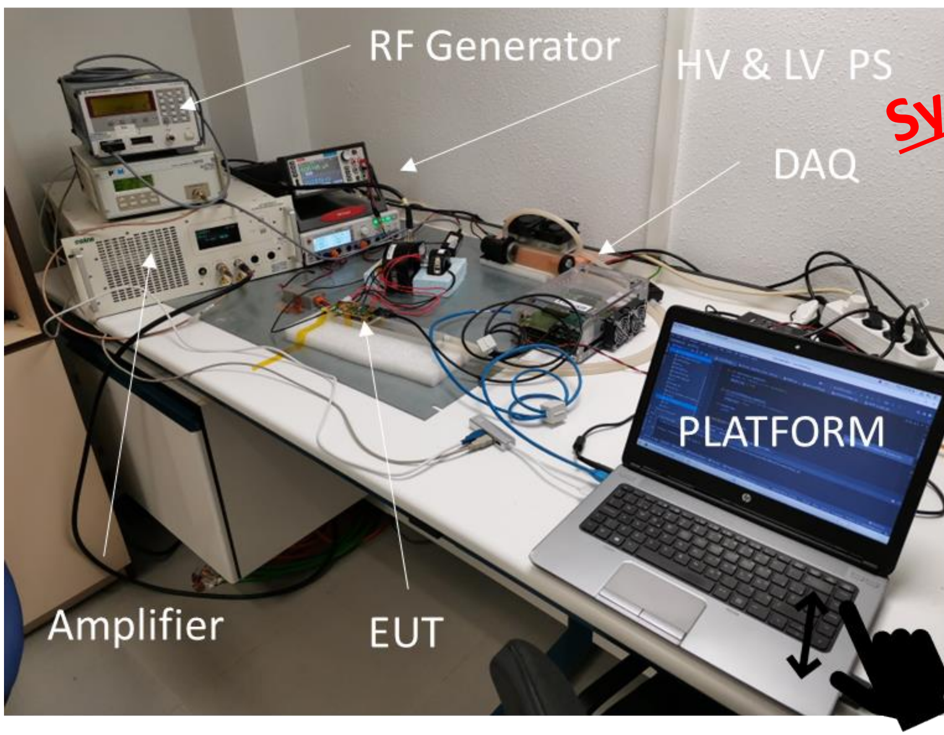
Task 4.5: Design & Development of a New Electronics Characterization System for EMC Control

- **Goal:** The main goal of this activity is to upgrade Electromagnetic Compatibility (EMC) tests in order to improve the support for detector electronics designers.
  - Noise studies were greatly demanded on previous AIDA 2020 project
- **Activities:** Two activities are planned
  - Design and develop an automatic EMC test bench to measure the noise transfer functions (TF) of physics detectors.
  - Design and develop a portable test bench to perform in-situ EMC conducted emission measurements of power units in irradiation facilities.
- **What is the novelty of the activity ?**
  - There are no systems to measure the TF of any detector against electromagnetic noise.
  - There is not any portable test bench to measure the noise emissions of DC-DC converters or small PS units during the radiation test campaigns.

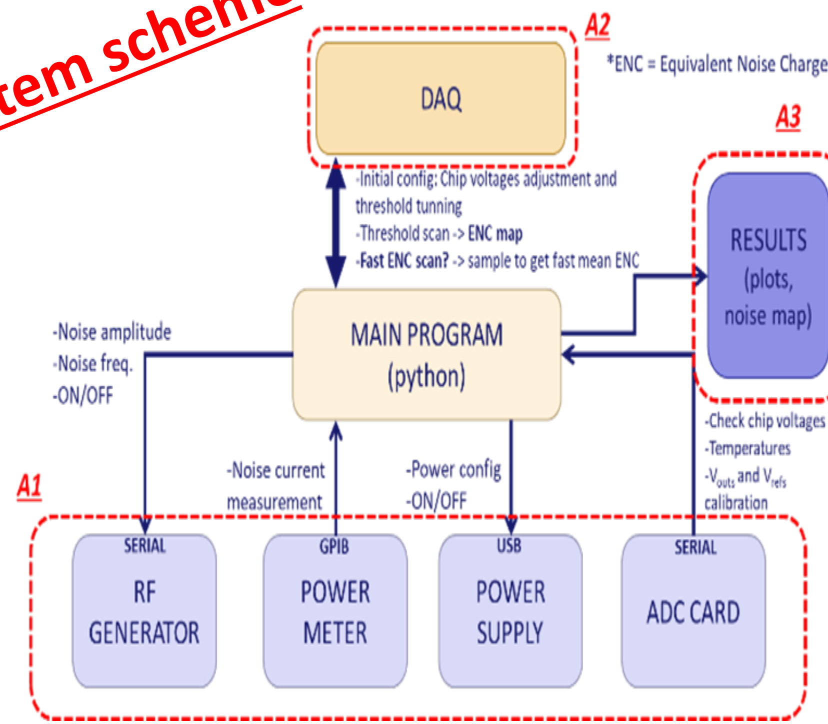
F. Arteche (ITAINNOVA)

Task 4.5: Design & Development of a New Electronics Characterization System for EMC Control

- During the first two years of the project, activities have focused on the design and development of an automatic EMC test bench to measure the noise transfer functions (TF) of physics detectors
    - System development is completed & tested (CMS IT phase II electronics)

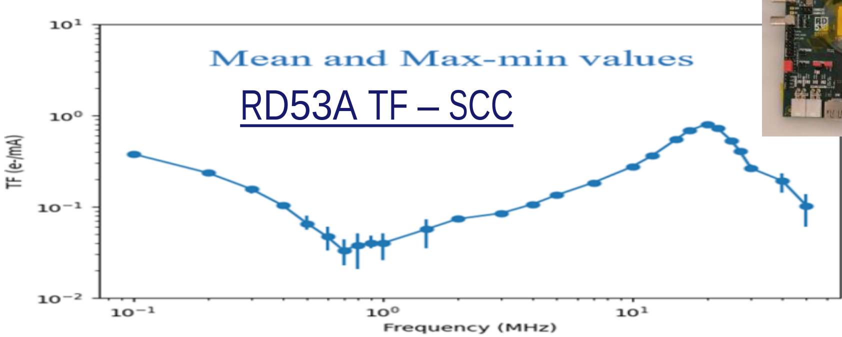


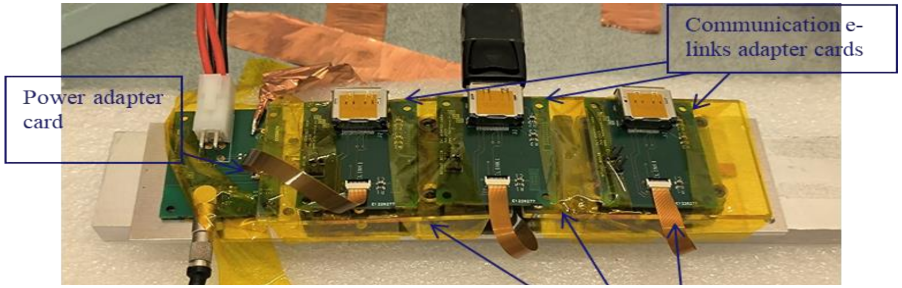
System scheme

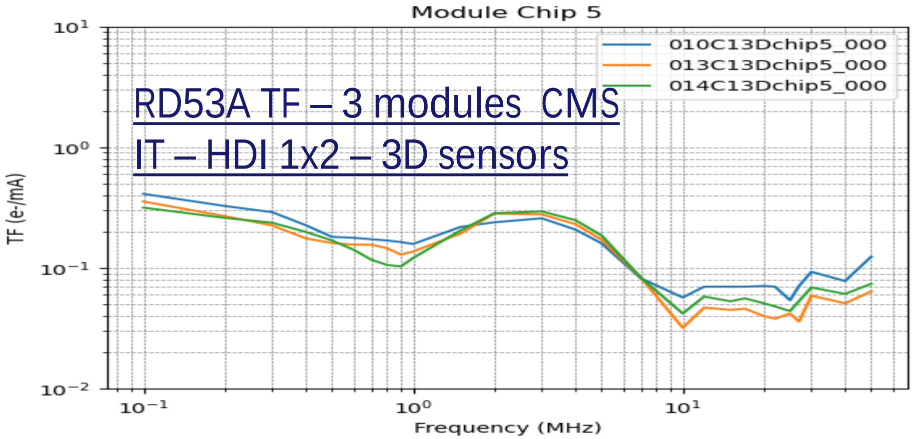


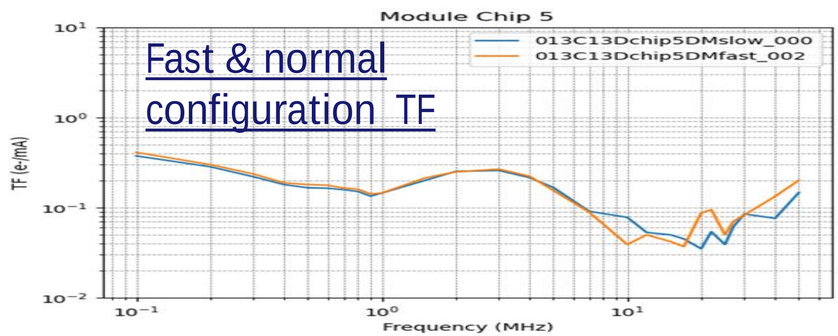
Task 4.5: Design & Development of a New Electronics Characterization System for EMC Control

- The system is compatible with various DAQ systems
  - It has been specifically tested with BDAQ53 (ATLAS) and CMS Ph2 ACF (CMS).
- The system includes a configurable function to increase testing speed
- The system has been already tested with simple and complex scenarios
  - System robustness & system potential





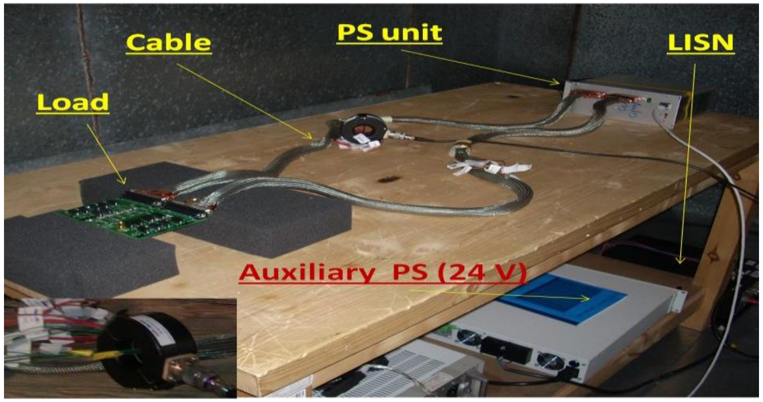




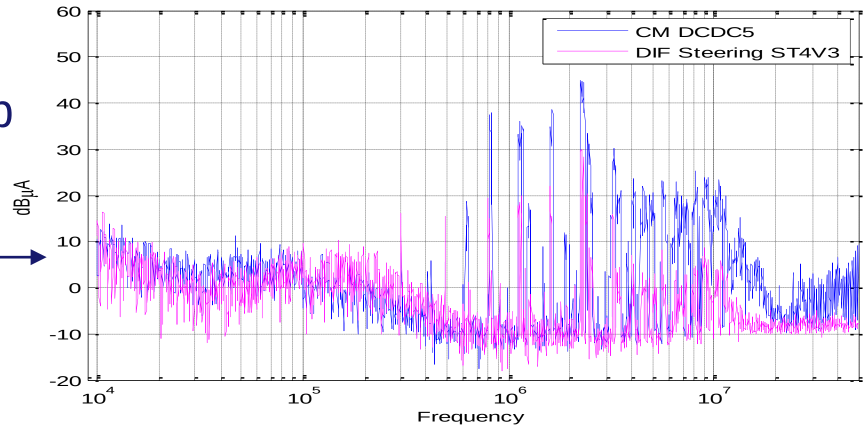
Task 4.5: Design & Development of a New Electronics Characterization System for EMC Control

- This activity has now been completed.
  - MS17 has been achieved
- It is a very valuable tools to perform many noise studies
  - EUROLABS project will benefit from this developments (TA facility)

- Our next steps involve designing and developing a portable test bench to perform in-situ conducted EMC emission measurements of power units in irradiation facilities



Old setup



Conclusion & Highlights

- Irradiation and characterization tests require:
  - More accurate and reliable procedures, a higher efficiency in their execution, automation and systems integration
- WP4 aims to develop & standardize common tools for testing infrastructure and better support the next detector generation R&D
  - Improve facilities, systems and methods
- Very positive feedback collaborating with companies within WP4:
  - actively contributing to the tasks, maintaining close collaboration
  - Their availability and interest in solving issues (technical and in the field of IPs) was impressive. *E.g., need to re-define "too ambitious" specifications, posing technical difficulties in developing a commercial product*, etc.
- Progresses have been presented in all activities:
  - 4 MS technically achieved: review of the last two MS reports being completed
  - synergies with other projects (RADNEXT, EURO-LABS, etc.)

Conclusion & Highlights

Achievements highlights at the end of the second year of AIDAinnova:

- Task 4.2:
  - MS12 submitted (precise sample positioning, upgrade of related controls at DuMi)
  - Work continue extending sample cooling capabilities and precise positioning at old ion microprobe setup
- Task 4.3:
  - MS13 achieved (specifications for DM extension)
  - Work continue for DigiWaste platform integration, deployment of DM systems, NIEL
- Task 4.4:
  - MS16 submitted (commissioning of complete system), 5 laser systems delivered
  - Work continue to strengthen the user community, compact laser goals re-defined
- Task 4.5:
  - MS17 achieved (automatic TF meas. system completed)
  - Work continue to develop a portable test bench to be used in irradiation facilities

Advancement and Innovation for Detectors at Accelerators

WP4
Upgrade of Irradiation and Characterization Facilities

Fernando Arteche (ITAINNOVA), Federico Ravotti (CERN)

AIDAinnova 2nd Annual Meeting - Plenary Session, ADEIT (Valencia, ES), 26 April 2023

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101004761.