

WP5 : Radiation effects testing with VHE ions

CERN, 20.01.2023 HEARTS Kick-off Meeting https://indico.cern.ch/event/1216205/



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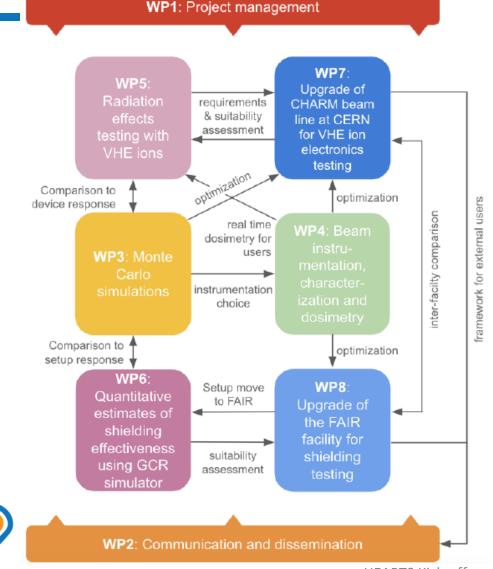
- Project: provide >100 MeV/n heavy ion beams to space users, to mimic the effects of Galactic Cosmic Rays (GCR) at ground level
 - penetration levels large enough to enable electronics testing in air, without the need of special preparation and at board and box level
 - Essential for the exploitation of high-end microelectronics technology in space, for e.g. onboard artificial intelligence or Big Data processing applications
- The suitability of the infrastructures for the testing and qualification of EEE devices (↑ TRL to 6-7) and electronic boards is a key aspect
- WP5: study of radiation effects induced by VHE heavy ions on a set of technologies representative of current state-of-the-art COTS electronics
 - Comparison with standard-energy heavy ions.
 - Hierarchical approach, based on three levels of complexity, will highlight different levels of details





In the Project

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- WP5 is strongly interconnected with the other work packages
 - WP3: comparison with simulation results

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- WP4: beam dosimetry
- WP7: facility development

HEARTS Kick-off meeting, CERN, 20.01.2023

Description of work: Tasks

- 1. Final review of VHE ion beam requirements for SEE testing
- 2. Analysis of ionization response in a PIN diode for beam quality assessments
 - 3. Suitability of the proposed VHE ion beams for 3D integrated device structures
 - 4. Validation of the VHE ion beams for industrial use with TRL 6-7 achievement
 - 5. Qualification of high-complexity devices
 - 6. Board-level testing





From 1st year

From 2nd year

From 3rd year



- Month 36: Achievement of TRL6-7 for electronics testing at the CHARM facility (MS14)
- Month 36: Achievement of TRL6-7 for electronics testing at GSI (MS15)
- Month 48: First-time heavy ion SEE qualification of highly-integrated electronic devices in Europe (MS16)
- Month 48: Release of guideline for SEE testing with VHE ion beams (MS17)





Timeline

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WP1	Project management																			
	Task 1.1: Project coordination and coordination	M1 M2 M3	M	4		M5		D1.1		M6					D	1.2, M7				D1.3
VP2	Communciation and dissemination																			
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	Task 2.2: Dissemination and outreach	M9 M10				D2.2									_			<u>↑</u>		D2.4
	Task 2.3: Knowledge transfer														D	2.3				
VP3	Monte Carlo simulations																			
	Task 3.1: Simulation of beam properties and detector characterization			I	I	I				D3.1										
	Task 3.2: Simulation of shielding materials and configurations for test set	U		instruction		stan	I			D3.1										
	Task 3.3: Simulation of GCR simulator			rume		dardi			III	D3.										
	Task 3.4: Simulations to ensure the reduction of uncertainties about the	4		ntatic		zatio	I			M 11	1					3.4				
/P4	Task 3.5: Understanding physical mechanisms of simple and medium-co			ň		2							II		D	3.5				
VP4	Beam instrumentation, characterization and dosimetry						0	0										t C		
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/P5	Radiation effects testing with VHE ions			-																
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	Task 5.4: Validation of the VHE ion beams for industrial use with TRL 6-7	requi					uiren	suita asses					- Ingu	holder er-test	imet D	5.4, M14, I	M15			
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/D.0	Task 5.6: Board-level testing	nts						~												D5.6
/P6	Quantitative estimates of shielding effectiveness with GCR s	51									. <u>e</u> †									
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	Task 6.2: Quantitative measurement of shielding effectiveness								¥		vork	Ţ	†	* *	′ ▼ D	6.2, M18, I	M19			
(D 7	Task 6.3: Radiobiological characterization									+	nt	Ţ	•		•	_				D6.3
'P7	Upgrade of CHARM beam line at CERN for VHE ion testing							ste												
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	Task 7.2: Achievement of the required beam parameters for microelectro						*	rdizat		D7.:		7	bility sme <u>nt</u>							
	Task 7.3: Framework for user access							lion			M20 *							1		D7.
/P8	Upgrade of the FAIR facility for shielding testing											++								
	Task 8.1: Framework for user access																	1		D8.
	Task 8.2: Installation of the GCR simulator in the APPA cave															•				D8.2
	Task 8.3: Test of the GCR simulator																			D8.3

Timeline (WP5)

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	Year	1						Γ	2										3										4														
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Final review of VHE ion beam requirements for SEE testing

- ADS, TAS M1-6
- Industrial partners will review the goals in terms of VHE ion beam parameters to be reached with the CHARM and GSI-FAIR upgrade (WP7-8)
- Other than parameters such as ion type, energy, LET and and range (and related accuracy), beam time availability (facility usable/bookable with reasonable delays) and commercial conditions of access (competitive with respect to European standard-energy ion facilities) will be included. Optimal trade-offs will be identified and submitted to the facilities

D5.1 (M6) Beam Requirements



Analysis of ionization response in a PIN diode for beam quality assessments

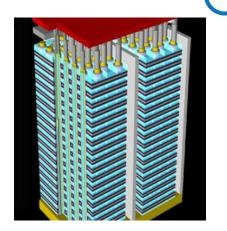
- UNIPD, M1-24
- **PiN diode**: simple and effective structure to study heavy ion beams. It provides precise measurements of energy deposition in semiconductor materials. Diagnostic tool to assess the quality of the provided beam in terms of purity and energy straggling (e.g. with degraders).
- Large experimental data set available with standard energy heavy ion beams.
- Monte Carlo model of the diode available (see also WP3)





Suitability of the proposed VHE ion beams for 3D integrated device structures

- UNIPD, M12-36
- **3D NAND Flash memories** the first and most successful example of 3D integration in the semiconductor industry
- Devices with **hundreds of layers** are now available and increasing, reaching tens of microns of thicknesss.
- VHE heavy ions are extremely useful for these technologies



D5.3 (M36) Beam suitability for 3D structures

D5.5 (M48) Impact of beam energy in SEE testing D5.6 (M48) SEE qualification guidelines for high complexity devices and board level testing





Validation of the VHE ion beams for industrial use with TRL 6-7 achievement

- ADS, CERN, M-12-36
- VHE SEE testing on devices which have already been characterized by the ADS at standard-energy heavy ion test facilities (e.g., UCL, RADEF)
- Previous tests carried out according to ESCC 25100 (package lid removal)
- Broad range of technologies will be tested:
 - High power diodes (Silicon or SiC)
 - High power MOSFETs (Silicon or SiC)
 - A stacked memory
 - all the dies will be tested as opposed to only the top die as customary with standard energy ions



Benchmark SRAMs from CERN

ingit complexity device

D5.4 (M36) Verification of beam parameter requirements

D5.5 (M48) Impact of beam energy in SEE testing

D5.6 (M48) SEE qualification guidelines for high complexity devices and board level testing



Description of work: Task 5.5

Qualification of high-complexity devices

- UNIPD, TAS, M24-48
- Graphical Processing Units (GPUs) and Field Programmable Gate Arrays (FPGAs) are two key enablers for on-board artificial intelligence
- Heavy-ion SEE qualification is very complex because of the very high power-consumption (standard energy ions require in-vacuum irradiations) -> in air irradiation is key
- UNIPD will perform a test campaign on a GPU
- TAS will perform a test campaign on a FPGA
- The results will be used together to compile recommendations and guidelines about SEE testing with very high energy ion beams



D5.5 (M48) Impact of beam energy in SEE testing

D5.6 (M48) SEE qualification guidelines for high complexity devices and board level testing



Description of work: Task 5.6

Board-level testing

- TAS, M24-48
- Board-level testing can enable the qualification of several devices by irradiating them simultaneously under the same beam.
- In some cases, and thanks to the properties of VHE ion beams, it can even be envisaged to test more complex systems that are made of a few electronic boards stacked on top of one another.
- The task will consist of testing electronic boards enabling power conditioning functionalities, which may be particularly sensitive to radiation.
- The objective of the task will be that of defining a methodology for testing these kinds of boards with a VHE ion beam that will be integrated in the suideline.

D5.6 (M48) SEE qualification guidelines for high complexity devices and board level testing





- D5.1 (M6) Finalised list of beam parameter requirements concurring to establish a TRL 6-7 for the CHARM facility
- D5.2 (M24) Validation of beam parameter quality of CERN and GSI infrastructures for testing of electronics
- D5.3 (M36) Verification of the beam parameter suitability for testing 3D structures
- D5.4 (M36) Verification of the compliance with beam parameter requirements and awarding of TRL 6-7
- D5.5 (M48) Implications of beam energy in single event testing for various levels of device integration
- D5.6 (M48) Guideline on SEE qualification procedures for high complexity devices and boardlevel testing with VHE ion beams



Key Personnel

- ADS:
 - R. Mangeret, M. Rostewitz
- TAS:
 - R. Mancini, S. Francola
- UniPD:
 - M.Bagatin, UniPD project leader
 - S. Gerardin, WP5 leader
 - A. Paccagnella, staff

Work package number	5.	Lead beneficiary	UNIPD								
Work package title	Radiation effects testing with VHE ions										
Participant number	1	3	4	5							
Short name participant	CERN	ADS	TAS	UNIPD							
Person- months per participant	2	19	4	16							
Start month	M1	End month	M48	10							



- Test board for radiation testing (FPGA and DC/DC)
- UniPD:
 - Electronic components for SEE testing (GPUs, FPGAs, PCB, cables, etc.)

Material Procurement

• TAS:

 Purchase of the components and test set-up development/upgrade (test sockets and PCBs, cables, test software etc.)







- Shared tool for documentation and deliverables
 - CERNBox
 - EDMS
- Main areas of collaboration among partners
 - Test plans
 - Data analysis
 - Deliverables
- Monthly 1-hour meeting
 - Discuss hardware/software choices/testing methods/results
 - Additional specific meetings for test campaigns, deliverables, ...
 - Zoom/Indico



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