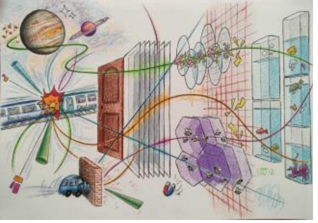
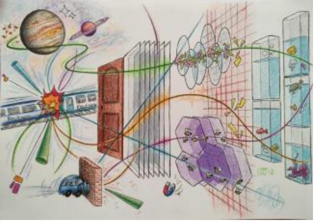


WG6: Wide bandgap and innovative sensor materials

Discussion

Xin Shi & Alexander Oh



WG6

- Rich agenda, thank you for your contribution!
  - Very active in SiC, exiting new developments.
  - GaN and Diamond also very active, hopefully more abstracts for next meeting.

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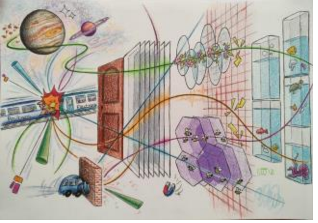
Time	Contribution	Speaker	Room	Slot
09:00	Effect of proton irradiation on the performance of 4H-SiC LGAD devices	Sen Zhao	4/3-006 - TH Conference Room, CERN	09:00 - 09:20
	Research on graphene-optimized silicon carbide detector	Dr Wang Congcong et al.	4/3-006 - TH Conference Room, CERN	09:20 - 09:40
	RD50 GaN Schottky Diodes Fabrication at IMB-CNM - Preliminary Results	Dr Joan Marc Rafí	4/3-006 - TH Conference Room, CERN	09:40 - 10:00
10:00	Observation of signal multiplication in neutron irradiated SiC detectors characterized using TPA-TCT	Dr Ivan Vila Alvarez	4/3-006 - TH Conference Room, CERN	10:00 - 10:20
	Characterization by IBIC of neutron irradiated SiC detectors at CNA	Carmen Torres Muñoz	4/3-006 - TH Conference Room, CERN	10:20 - 10:40
	Coffee Break		4/3-006 - TH Conference Room, CERN	10:40 - 11:10
11:00	Update on the RD50-SiC-LGAD Project	Andreas Gsponer	4/3-006 - TH Conference Room, CERN	11:10 - 11:30
	Characterisation of Diamond and SiC sensors with TPA and modelling of response	Huazhen Li	4/3-006 - TH Conference Room, CERN	11:30 - 11:50
	Establishment of a Silicon Carbide Source Test Setup and Initial Results	Roman Mueller	4/3-006 - TH Conference Room, CERN	11:50 - 12:10
12:00	The Study of SiC DC-LGAD and SiC AC-LGAD by Ultra-Violet Transient Current Technique (UV-TCT)	Tao Yang	4/3-006 - TH Conference Room, CERN	12:10 - 12:30
	Lunch Break		4/3-006 - TH Conference Room, CERN	12:30 - 13:30
13:00	Caribou: A versatile data acquisition system for silicon pixel detector prototyping	Tomas Vanat	500/1-001 - Main Auditorium, CERN	13:30 - 13:50
	Prototype of SiC-LGAD Detector	Xin Shi et al.	500/1-001 - Main Auditorium, CERN	13:50 - 14:10
14:00	Planar SiC diodes for material and radiation hardness studies	Thomas Bergauer	500/1-001 - Main Auditorium, CERN	14:10 - 14:30
	Discussion on WBG	Xin Shi et al.	500/1-001 - Main Auditorium, CERN	14:30 - 15:00
15:00				

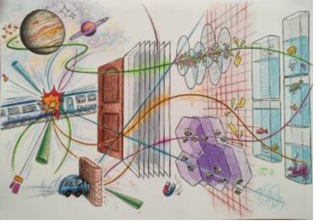


Work Package Status

Currently we have three proposal in CDS

Proposals (link):
- GaN for MIP detection - CERN-DRD3-PROJECT-2024-001
- SiC LGAD Detector - CERN-DRD3-PROJECT-2024-002
- 3D diamond detectors - CERN-DRD3-PROJECT-2024-003

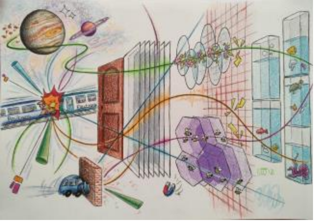
Additional projects / ideas (work package or CF project?):
- SiC radiation studies (lead HEPHY)
- Gain layer in diamond (lead Santa Cruz)
- Diamond defects for dark matter detection (lead UZH)



WG6: Research Goals

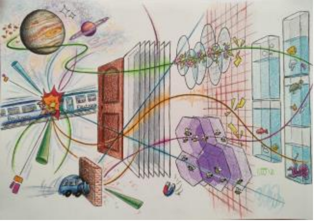
2024 – 2026

- RG 6.1: Development of small cell 3D diamond detectors
- RG 6.2: Fabrication of large area Diamond, SiC and GaN detectors, improve material quality and reduce defect levels
- RG 6.3: Improve tracking and timing capabilities of WBG materials
- RG 6.4: Apply graphene and/or other 2D materials in radiation detectors, understand signal formation



Work Package GaN

Report number	CERN-DRD3-PROJECT-2024-001
Title	**Title: Development of radiation-hard GaN devices for MIP detection**
Status	Draft
Author(s)	Koffas, Thomas (Carleton University (CA)) ; Griffin, Ryan (NRC) ; Noel, Jean-Paul (NRC) ; Walker, Alexandre (NRC) ; Mikestikova, Marcela (Czech Academy of Sciences (CZ)) ; Kroll, Jiri (Czech Academy of Sciences (CZ)) ; Rafi Tatjer, Joan Marc (Consejo Superior de Investigaciones Cientificas (CSIC) (ES)) ; Ceponis, Tomas (Vilnius University (LT)) ; Rumbauskas, Vytautas (Vilnius University (LT)) ; Bortoletto, Daniela (University of Oxford (GB)) ; Villani, Enrico Giulio (Science and Technology Facilities Council STFC (GB)) ; Gillberg, Dag (Carleton University (CA)) ; Chisholm, Andrew Stephen (University of Birmingham (GB)) ; Mandic, Igor (Jozef Stefan Institute (SI)) ; Hiti, Bojan (Jozef Stefan Institute) ; Malinauskas, Tadas (Vilnius University (LT)) ; Kadys, Arunas (Vilnius University (LT)) *Hide*
Publication	2024
Document contact	Contact: Thomas Koffas Email: Thomas.Koffas@cern.ch
Imprint	2024-07-12
Project	DRD3
Abstract	Gallium nitride (GaN) semiconductors are now commonly found in optoelectronic and high-power devices, e.g., light-emitting diodes (LEDs), lasers and high electron mobility transistors (HEMTs). GaN can also be used for detecting ionizing radiation under extreme radiation conditions due to its properties such as a wide bandgap (3.39 eV), large displacement energy (theoretical values averaging 109 eV for N and 45 eV for Ga), and high thermal stability (melting point: 2500 0C). Compared to narrower band-gap semiconductors such as silicon, GaN can operate at higher temperatures; while a comparison with other wide band-gap semiconductors, such as SiC, demonstrates GaN's higher electron mobility and potential for better carrier transport properties. In the proposal below, we provide the outline of a project that aims to exploit recent developments in GaN fabrication processes aiming at robust performances at harsh environments, e.g. high temperatures, and assess the potential of GaN as a meterial for the fabrication of radiation hard devices for MIP detection.
Submitted by	thomas.koffas@cern.ch

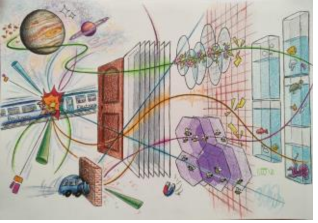


Work Package GaN

Report number	CERN-DRD3-PROJECT-2024-001
Title	
Status	
Author(s)	
Publication	
Document contact	
Imprint	
Project	
Abstract	
Submitted by	thomas.koffas@cern.ch

Project description

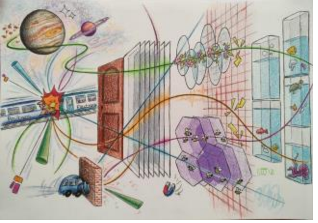
Gallium nitride (GaN) semiconductors are now commonly found in optoelectronic and high-power devices, e.g., light-emitting diodes (LEDs), lasers and high electron mobility transistors (HEMTs). GaN can also be used for detecting ionizing radiation under extreme radiation conditions due to its properties such as a wide bandgap (3.39 eV), large displacement energy (theoretical values averaging 109 eV for N and 45 eV for Ga), and high thermal stability (melting point: 2500 0C). Compared to narrower band-gap semiconductors such as silicon, GaN can operate at higher temperatures; while a comparison with other wide band-gap semiconductors, such as SiC, demonstrates GaN's higher electron mobility and potential for better carrier transport properties. In the proposal below, we provide the outline of a project that aims to **exploit recent developments in GaN fabrication processes aiming at robust performances in harsh environments, e.g. high-temperatures, and assess the potential of GaN as a meterial for the fabrication of radiation-hard devices for MIP detection**.



Work Package GaN

	Timeline of major deliverables					
		2025	**2026**	**2027**	**2028-2029**	**2030**
	WP/D-1: Improve material quality; GaN growth on bulk SiC or GaN substrate; increase thickness of epitaxial GaN layer			x		
	WP/D-2: Demonstrate radiation hardness to protons/neutrons at $>10^{16}$ neq/cm^2				x	
	WP/D-3: Improve existing infrastructure for TCAD modeling					x
	WP/D-4: Study high-temperature operation	x				
	WP/D-5: Study ageing			x		
	WP/D-6: Monolithically integrate transistors and sensors on same substrate					x

Table 1: Timeline of major deliverables for Phase-I



Work Package SiC (LGAD)

mailing list: drd3-wg6-sic-lgad@cern.ch

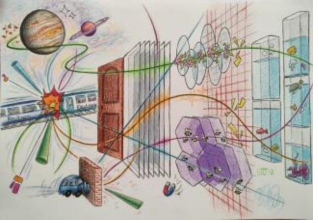
Information | Discussion (14) | Files

Report number	CERN-DRD3-PROJECT-2024-002
Title	**SiC LGAD Detector**
Status	Draft
Publication	2024
Document contact	Contact: Xin Shi Email: Xin.Shi@cern.ch
Imprint	2024-08-14
Project	DRD3
Abstract	Pixelated SiC LGAD device with both timing and position capabilities has the potential to address the 4D tracking in extreme fluence of future collider experiment. To improve the tracking and timing capabilities of SiC-LGAD device, this project proposes to fabricate the DC-coupled and AC-coupled LGAD SiC device with pixelated structures. These devices will be characterized by spacial and temporal resolution before and after proton/neutron irradiation up to fluences of 1e17 neq. The SiC properties after high fluence irradiation will be investigated with correlation of the detector performance.
Submitted by	xin.shi@cern.ch

Record created 2024-08-17, last modified 2024-10-29

Similar records

For details see Xin's talk



Work Package 3D Diamond

mailing list: drd3-wg6-PP-3ddiamond@cern.ch

Report number	CERN-DRD3-PROJECT-2024-003
Title	**Radiation hardness of 25um 3D diamond detectors**
Status	Draft
Author(s)	Oh, Alexander (The University of Manchester (GB))
Publication	2024
Document contact	Contact: Alexander Oh Email: alexander.oh@cern.ch
Imprint	2024-10-02
Project	DRD3
Abstract	The radiation hardness of diamond has been tested mostly in the planar configuration and only limited data is available on the radiation hardness on 3D devices down to 55um cell size up to 10^16 neq. The project proposes to investigate the radiation hardness of 25um cell size devices up to fluences of 10^17 neq, characterise devices in terms of charge collection properties and defect studies on the bulk material as well as on the graphitic electrodes. The results will show if 3D diamond detectors can in principle deliver a reliable detection signal up to fluences expected for the FCC-hh and will provide more insights into the radiation damage process in 3D diamond detector devices at extremely high fluences. CHANGE LINK: https://cds.cern.ch/submit/direct?sub=MBIGENSBM&GENSBM;_SBMNAME=DRD3%20Projects&GENSBM;_REPNUM=CERN-DRD3-PROJECT-2024-003
Submitted by	alexander.oh@cern.ch

Record created 2024-10-02, last modified 2024-11-05

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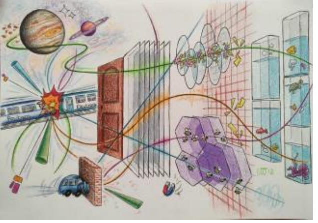


3D diamond technology for 10^{17} neq

- **Project Goals**:

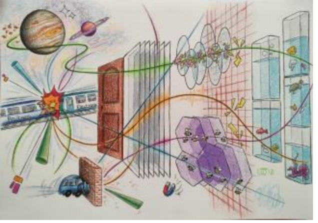
  Demonstrate the radiation hardness of 3D Diamond detector technology for fluences of 10^{17}neq and beyond.

  Develop a 25um cell size 3D diamond detector.

  Investigate charge multiplication.

Adresses
WP 3.2 (4d dtracking)
WP 3.3 (extreme fluences)

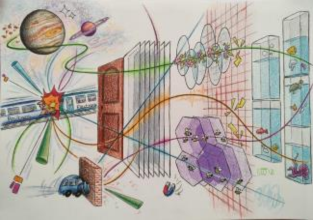
WG6 research goals <2027	
	Description
RG 6.1	Development of small cell 3D diamond detectors (cages / interconnects, base length 25 μm) and possible exploitation of impact ionization



Work Packages
Additional projects proposals

- **Planar SiC Schottky Diodes**
  - Studying Material properties, traps, irradiation effects, annealing
  - Towards a Radiation Damage Model
  - **Proposal**:
    - irradiation study with commercially available SiC-Schottky diodes on the short term
    - Production of planar Schottky and pn-junction diodes

- **HEPHY Vienna**: irradiation campaign, lab measurements, test beam @ Medaustron, TCAD simulations
- **INFN Perugia**: TCAD simulation, lab measurements
- **FBK**: production of Schottky and pn-junction 4H-SiC diodes
- **INFIM Romania** (Ioana Pintilie): defect investigations, FTIR and Hall measurements
- **INFN Torino**



Work Packages
Additional projects proposals

- Investigation of impact ionization in doped diamond devices (Simone Mazza)
  - Impact ionization holds promise to enable radiation-hard minimum-ionizing particle detection for diamond sensors.
  - Impact ionization have been observed for diamond sensors, but very little specific information is available about diamond's impact ionization properties.
  - **Study**, enabled by precision doping techniques, to separately determine these properties for electrons and holes.
  - **Explore** the prospects for tuning these properties through manipulation of the diamond semiconductor bandgap.

- Graphene electrodes on SiC sensors
  - Low temperature ohmic contact.
    - (reduce the contact barrier between metal and SiC)
  - Used as a transparent electrode
  - Improve charge collection uniformity
  - Increase charge collection rate

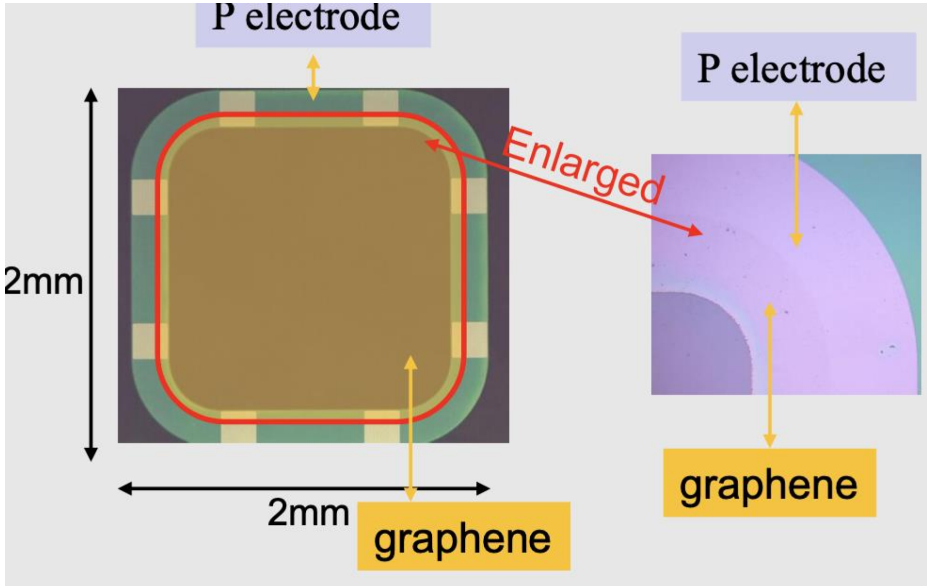
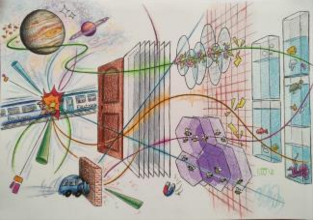


Fig.2 Graphene /4H-SiC PIN detector

Contact Person
wangcc@ihep.ac.cn



Work Packages
Additional projects proposals

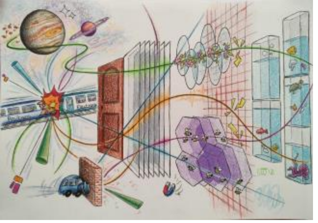
How to effectively improve charge collection rate and time resolution?
1. Using graphene to reduce the contact barrier and improve the P-ohmic contact performance
2. Graphene is used as an electrode

How to reduce graphene defects?
1. Transfer graphene to direct growth graphene on SiC

Readout electrical board and readout ASICs?
1. Improve signal-to-noise ratio
2. impedance mismatch

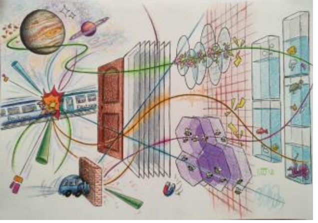
Effect of irradiation on the performance
1. Effects of different irradiation types on 4H-SiC devices
2. Understanding of temperature dependence

No.	Title	Description	Start date	End date	Institutions
Di.1	Fabrication of Graphene/SiC PIN	Fabrication of Graphene/SiC PIN	1/2025	8/2025	IHEP
Di.2	Fabrication of Graphene/SiC LGAD	Fabrication of Graphene/SiC LGAD	8/2025	12/2025	IHEP
Di.3	Electronics Readout	Development of the readout single board and ASICs	6/2025	12/2025	IHEP, IAT
Di.4	Characterization	IV, CV, Charge collection, time resolution test	1/2026	12/2026	IHEP, JLU, IAT
Di.5	Irradiation	Irradiation Graphene/SiC devices	1/2027	6/2027	IHEP
Di.6	Study of Irradiation Defects	Analysis of device defects caused by different types of irradiation	1/2027	6/2027	IHEP, IAT



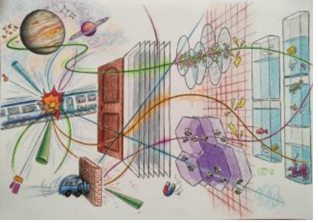
Work Packages
Additional projects proposals

- <u>Other developing ideas:</u>
  - Dark matter detection with diamond defects (N-vacancy complex?).
    - See Vagelis talk yesterday about Si CCD using this principle.
  - Use exciton production/decay in cryogenic diamond as sensitive phonon detectors for dark matter detection?
    - Long lifetime of excitons in diamond.
    - Can pump exciton population with laser?



Towards WPs

- Synergies between existing proposals
  - E.g: Many SiC activities on-going, merge LGAD and Schottky?
- Continue regular meetings every month.
  - At least 2-3 meetings between the two DRD3 meetings
  - Exchange common items progress
  - Make detailed technical discussion happen
  - Coordinate DRD3 agenda
- Will be announced with e-group: drd3-wg6-non-silicon@cern.ch
- Dedicated project proposal meetings category: https://indico.cern.ch/category/18916/



Questions?

Comments, Suggestions, Questions:

drd3-wg6-conveners@cern.ch

Webpage:

https://drd3.web.cern.ch/wg6

Mattermost:

https://mattermost.web.cern.ch/drd3/channels/wg6-general