Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

FY2025 NPP LDRD Type B Pre-Proposal

Understanding Single Event Burnout to empower future silicon detectors

Principal investigator:
Gabriele D’Amen [Physics Department]

FY2025 NPP LDRD Type B Pre-Proposal

Proposal title:

Understanding Single Event Burnout to empower future silicon detectors

Primary Investigator:

Gabriele D'Amen (PD)

Other Investigators:

Gabriele Giacomini (IO)
Thomas Kubley (CAD)
Alessandro Tricoli (PD)

Indicate if this is a cross-directorate proposal: Yes ___ No _X_

If yes, identify other directorates/organizations:

Proposal Term:

From: 10/1/2024 To: 9/30/2025 (1 yr)

FY2025 NPP LDRD Type B Pre-Proposal

Proposal title and brief abstract: *Understanding Single Event Burnout to empower future silicon detectors*

Silicon sensors with gain such as Low Gain Avalanche Diodes (LGADs) are often required to withstand enormous amount of radiation while maintaining acceptable performances. Particles interacting with highly biased irradiated sensors can produce irreversible damages known as Single Event Burnouts (SEBs), which represent one of the main limitations of silicon technology in high fluence scenarios. We plan to expose irradiated silicon sensors (LGADs) to a beam of 29 MeV protons produced at the BNL Tandem Van de Graaff, increasing the probability of SEBs. This work will shed a light into the mechanism of SEB and permanent radiation damages in general and drive the evolution of future silicon detectors in high-radiation environments.

Program: **HEP**

Return on investment:

- PI is eligible for Early Career Award
- Leads to new collaborations within RDC3 (US) and DRD3 (EU)
- Strengthen BNL position as one of the leaders of fast-timing silicon technology for HEP and NP applications

Broader impact on the activities at the laboratory:

- **within our group:** BNL aims to take a leadership role in future HEP colliders (see past awarded LDRDs)
- **within our department:** Huge impact on our EIC-oriented silicon development
- **within our directorate:** Strengthen inter-departmental collaboration

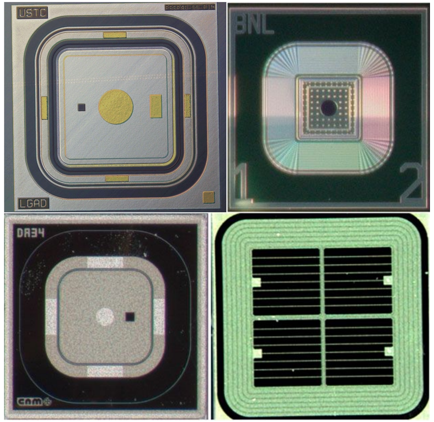
Total planned funding per year in FY25: 250k USD for FY25

Fast silicon sensors

Low Gain Avalanche Diodes…

- …are being extensively used in **HEP, NP, space applications**, etc.
- …will be central in future HEP (HL-LHC, FCC) and NP (EIC) experiments
- …can withstand **fluences** up to < 10^{15} n_{eq}/cm^2
- …can achieve excellent time resolution thanks to **interal gain**

LGAD sensors produced by various manufacturers



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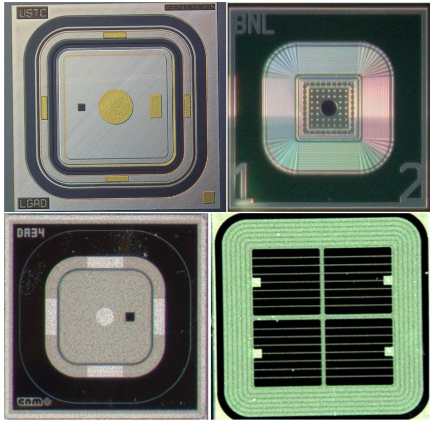

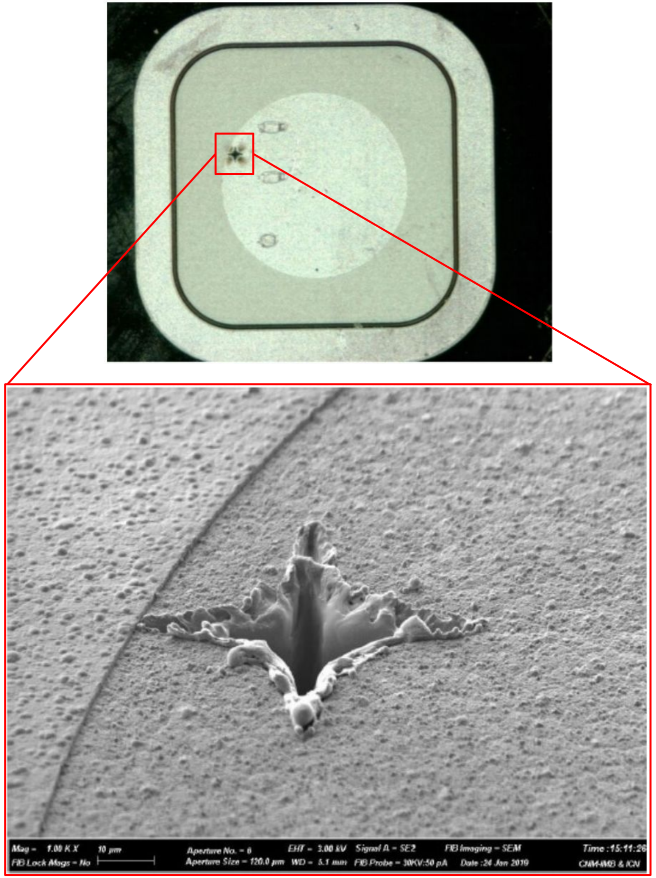

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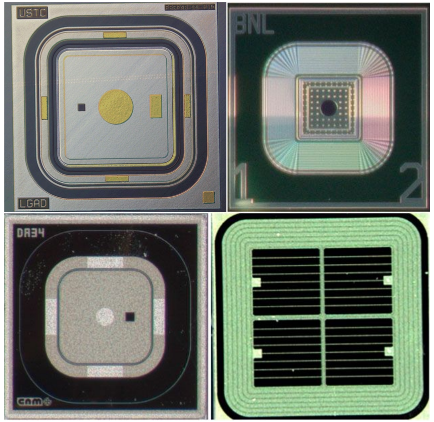
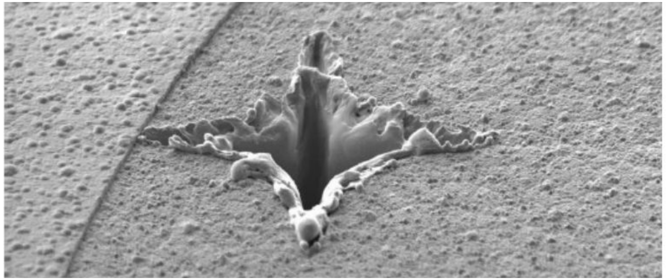
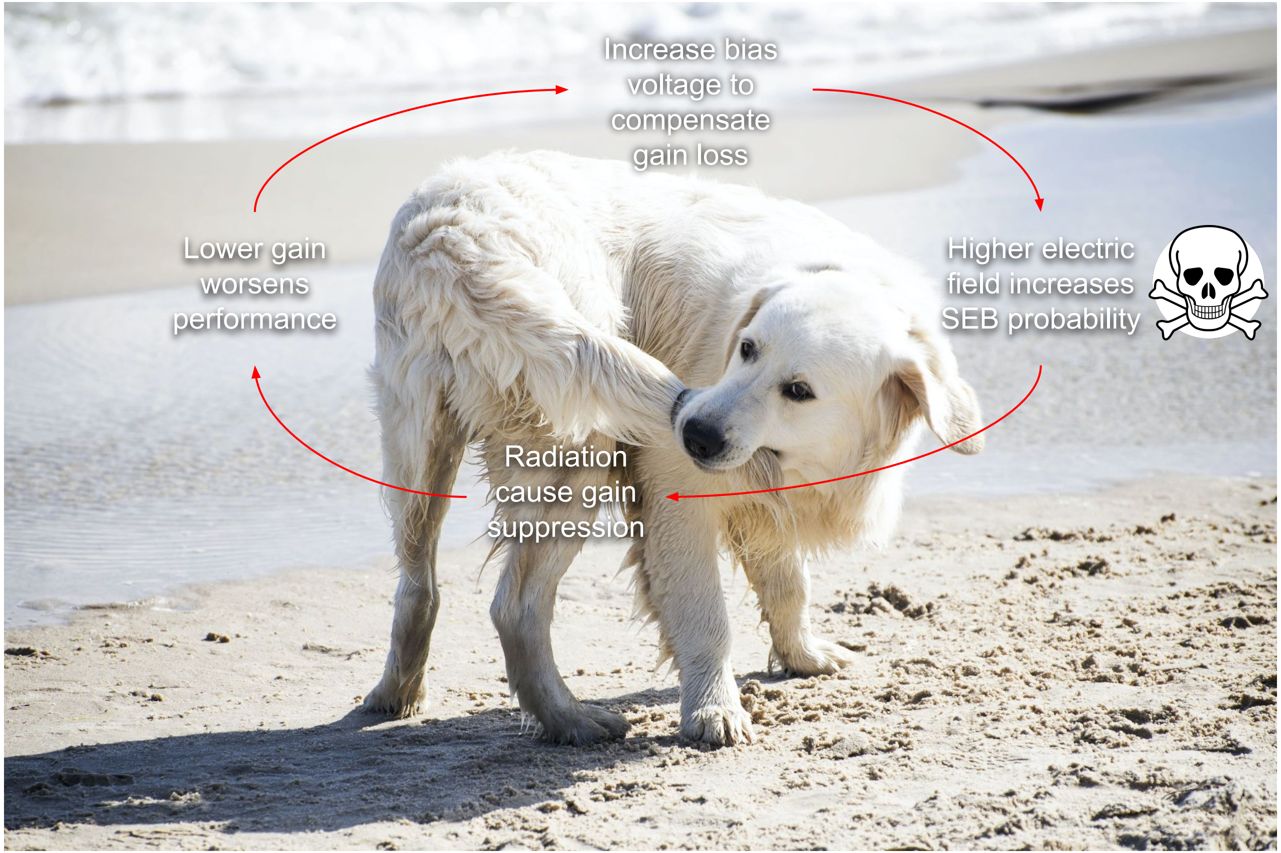




Ionizing radiation can create temporary damage (Gain Suppression) or permanent fatalities (**Single Event Burnout, SEB**)

- In high E^{dep} interactions, high local charge density is created, leading to **collapse of the local field** and avalanche breakdown
- Enough to **melt silicon** and destroy the sensor
- SEB probability depends on many factors (detector thickness, pad structure, incident angle, …) but mainly on **local electric field**
- **Death (crater)** observed in HPK 50 µm LGADs at V^{bias} > 600 V ($\gtrsim 10^{15}$ n_{eq}/cm^2)

The death spiral



Studies at Tandem VDG

State-of-the-art

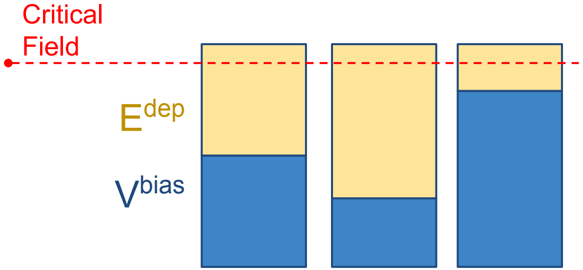
Studies of SEB performed using:

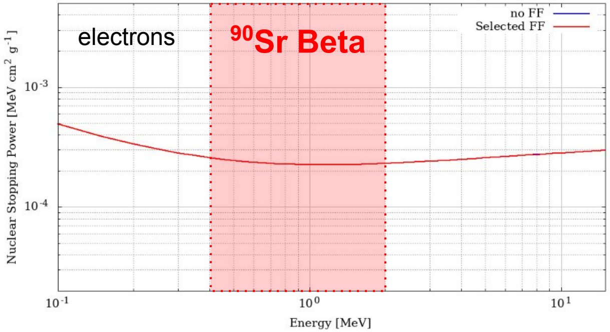
- Betas from ^{90}Sr
- **CERN SPS** (120 GeV pions)
- DESY high-energy electrons

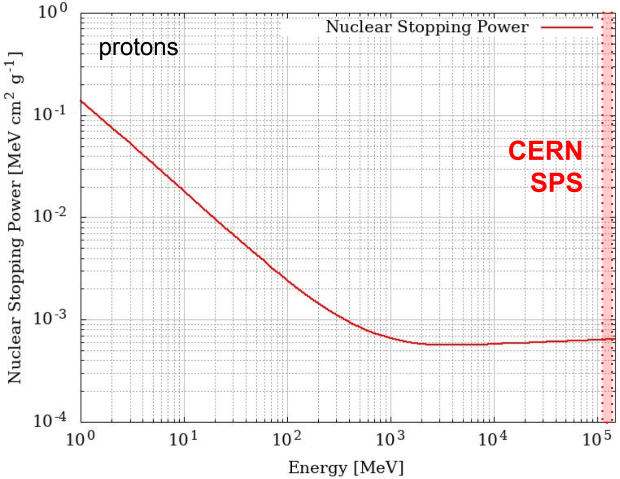
[New insight into gain suppression and single event Burnout effects in LGAD](#)

[Destructive breakdown studies of irradiated LGADs at beam tests for the ATLAS HGTD](#)

All studies use minimum ioninzing particles…but **deposited energy is a critical parameter!**







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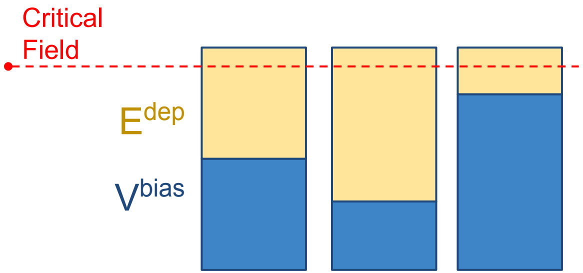
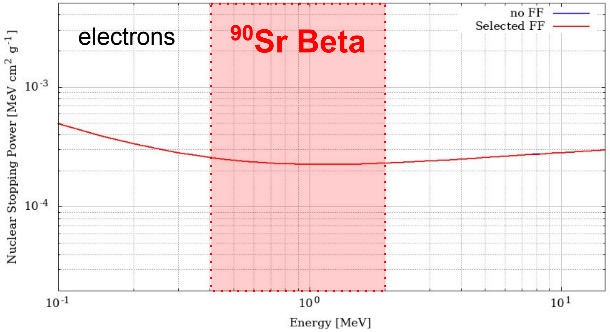
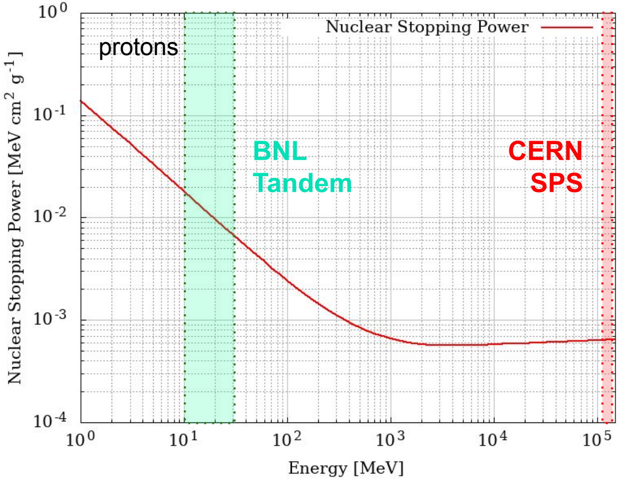
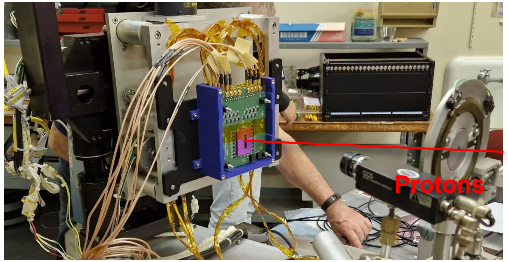






Our approach

- Evaluate **SEB dependance on E^{dep}**
- Inject more charge by using lower energy protons
- Exploit local **Tandem Van De Graaff**
- Phase space unreachable with electrons or higher energy accelerators (SPS, FNAL, etc.)



Research milestones

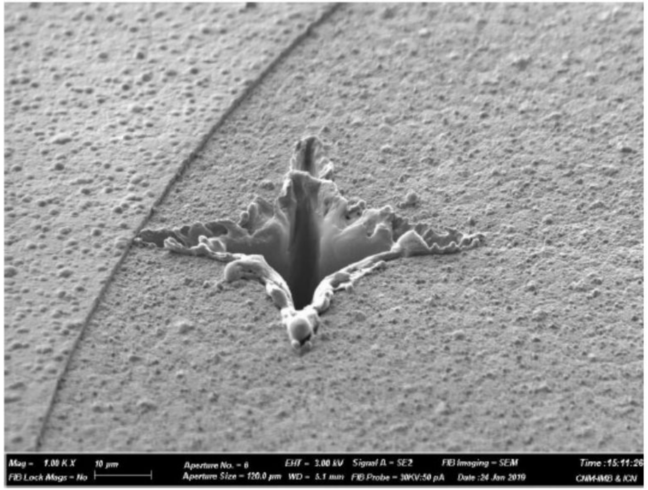
Q1	Q2	Q3	Q4
Irradiation of sensors from various manufacturers (HPK, BNL, FBK)	**Characterization** of irradiated silicon sensors	Preparation for test-beam; **Test beam at Tandem**	Data **analysis**
Simulation with GEANT4; Design and construction of **readout system**; Design and construction of **cooling** and **powering** system	Production of **mechanical structure**		**Paper** writing

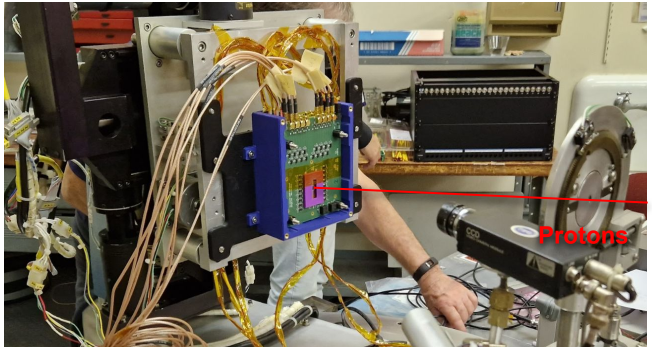
Cost breakdown

Sensor irradiation	free of charge
Miscellanea (cables, etc.)	10k USD
Electronics (readout boards)	20k USD
Labour (wirebonding, etc.)	20k USD
Power supply (for sensor bias)	20k USD
Beam time at Tandem Van de Graaff	50k USD
Multichannel readout system	80k USD
Labour cost	50k USD

Summary Slide

- Silicon sensors with gain are more and more commonly used to achieve excellent timing in HEP and NP experiments
- As radiation damage increases, the probability of a **fatal failure due to SEB** increases
- **SEB strongly limits the performance** achievable with silicon sensors
- We will **study the dependance of SEB on energy deposited** by ionizing radiation by using protons from the **BNL Tandem Van de Graaff** accelerator
- Will test a **large array of different LGADs** from various manufacturers, with different thicknesses, gain profiles, geometries





Deliverables

- Strenghten understanding of SEB and permament radiation damages
- Parametrize SEB probability at high E^{dep} as a function of parameters of the detector
- Publish the observed results
- Present the work at international conferences