TÉCNICO LISBOA

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LIP

ProtoTera

PicoMonitoring: sub-ns FLASH beam monitoring with Si devices

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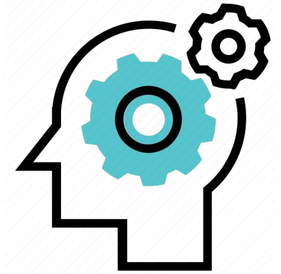
Beam Monitoring for FLASH Therapies Using Silicon Devices (LGADs)

Research Focus:

- Developing a beam monitoring system for FLASH proton therapy using Low Gain Avalanche Diodes (LGADs)

Why it Matters:

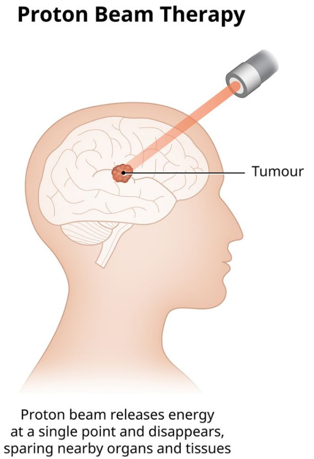
- **FLASH therapy** delivers ultra-high dose rates in very short bursts, requiring precise, real-time monitoring.



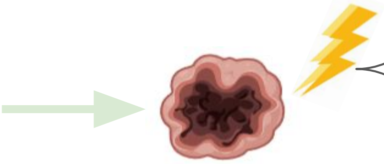
The Challenge:

- Beam monitoring in FLASH therapy is **highly demanding** due to the extreme fluence and fast timescales.
- Using **LGADs** for this purpose involves overcoming significant technical and design challenges to achieve accurate, time-resolved dosimetry.

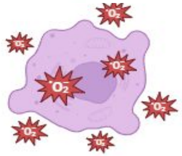
FLASH Therapy



Type of proton beam therapy

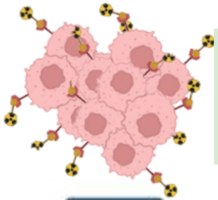


Better ratio Tumour Control Probability (TCP) vs the **Normal Tissue Complication** Probability (NTCP)



Reduce the **damage** of normal tissue

Same treatment dose

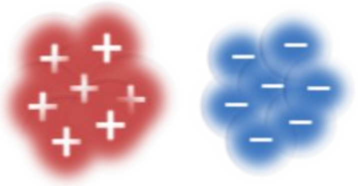


The **dose rate is >40 Gy/s** (**conventional** RT uses **~0.1 Gy/s**)

Shorter time intervals

FLASH Therapy

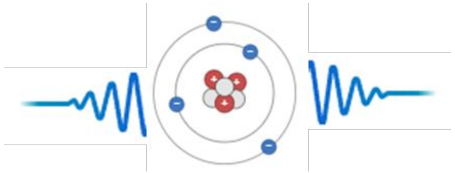
Ultra-high **Dose Rate**



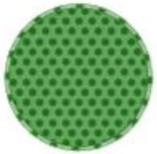
Extremely **high particle fluxes**

10^7 to 10^9 particles per pulse

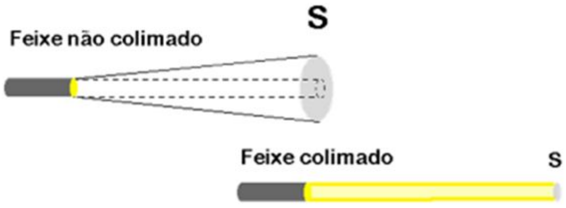
Typically **very short Time Between Pulses** intervals of microseconds to milliseconds



Each pulse lasts a **few microseconds** (~1-10 μs)



Very **high particle fluence**, often exceeding **10^12 particles per cm²** **within a single treatment**



The **beam can be focused** or **spread depending on the treatment plan**, typically in the range of 1-10 cm diameter for localized therapy

Dosimetry

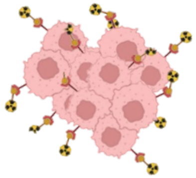
In standard radiation therapy, the methods are well-established.

But **due** to the **dose rate** and **short pulses dosimetry becomes a challenge** in FLASH therapy:

Accuracy

Quick response

Size



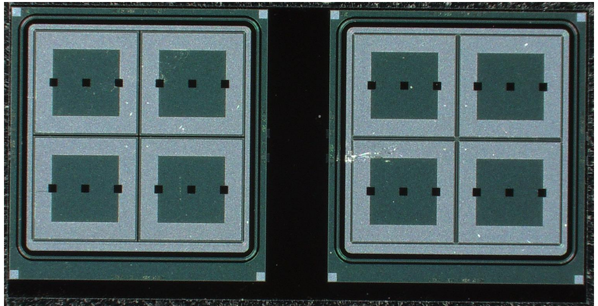
Radiation hardness

CERN - LHC

- **Large Hadron Collider (LHC)**
- **Increased Luminosity**
- **Proton-Proton Collisions**:
    - Protons are accelerated to nearly the speed of light and collide at extremely high energies.
    - These collisions allow scientists to study fundamental particles and forces, contributing to discoveries such as the Higgs boson.
- **Collision Experiments**:
    - The **ATLAS** and **CMS** detectors analyze the products of these high-energy collisions.

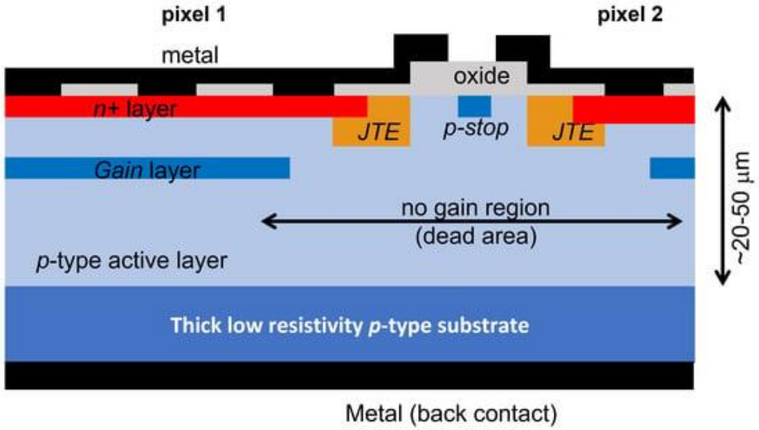
LHC Detector Upgrades & Novel Sensors

- **ATLAS** and **CMS** are **upgrading their detectors**
- **Increased Radiation Exposure**: The higher luminosity will expose the detectors to large fluxes of particles and higher doses of radiation, necessitating advancements in sensor technology.
- New sensors are being developed with:
  - **Timing resolution** better than **100 picoseconds** (for precise tracking of particle interactions).
  - **Radiation tolerance** up to **2 MGy** (to withstand extreme conditions in the collider).
- **Low Gain Avalanche Detectors (LGAD)**:
  - LGADs are silicon-based devices specifically designed to handle high radiation environments while providing excellent timing resolution.
  - These detectors play a critical role in ensuring accurate measurement in upgraded experiments.



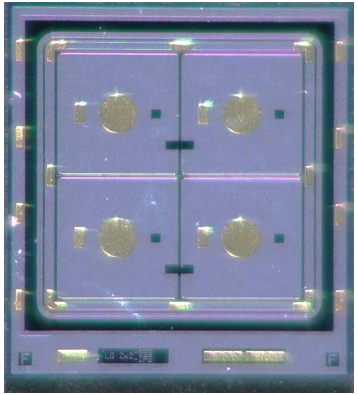
LGAD

- **Detects Charged Particles**: LGADs are designed to sense and measure the passage of **charged particles** with **high precision**
- **Provides Time-Resolved Measurements**:
  - They offer **excellent timing resolution** (better than 100 picoseconds), making them ideal for tracking particle interactions with great accuracy
- **Amplify Signal**:
  - Through internal avalanche multiplication, LGADs amplify small signals, allowing for the detection of even **low-energy particles**
- **Used in High-Energy Physics & Medical Applications**:
  - Crucial in experiments like those at CERN like ATLAS and CMS and also explored for **time-resolved dosimetry** in **medical fields** such as FLASH therapy.



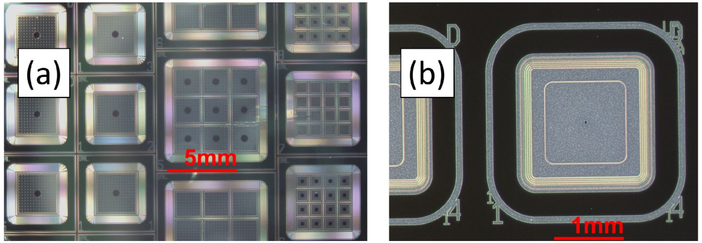
LGAD - Characteristics

- **Gain Factor**: Typically 10-20, providing signal amplification while maintaining low noise.
- **Fast Response Time**: Excellent time resolution, better than 100 ps.
- **Thin Active Layer**: 20–50 µm, enabling quick charge collection for fast particle detection.
- **Radiation Tolerance**: Can withstand high levels of radiation, making them suitable for use in harsh environments like particle accelerators.
- **Sensitive to Charged Particles**: Optimized for detecting fast particles such as protons, electrons, and ions.
- **Low Capacitance**: Contributes to reduced electronic noise and better signal quality.
- **High Spatial Resolution**: possess a spatial resolution of 1.3 mm by 1.3 mm.



Fluence and LGAD in FLASH Therapy Beam

- **Beam Fluence in FLASH:** Typically around 10^{12} particles per cm^2.
- **LGAD Size:** LGADs are small, usually just a few millimeters in area (much smaller than 1 cm^2).
- **Fewer Particles Hit LGAD**:
  - Due to the small size of the LGAD, the number of particles hitting it is much lower than the total beam fluence.
  - For example, if the LGAD is only a few mm^2, it will be hit by far fewer than 10^{12} particles.
- **Counting Individual Particles**:
  - The reduced number of particles allows the use of the LGAD to count individual particle hits.
  - This is key for precise, time-resolved dosimetry in FLASH therapy, where measuring high-speed particle interactions accurately is critical.
- **Advantage**: By detecting fewer particles, the LGAD can provide detailed data on the beam's characteristics, without being overwhelmed by the full fluence.



Pictures of the front side of LGAD devices fabricated at BNL

Current Phase and Future Improvements

- **Current Phase:**
  - We are in the **proof-of-concept** stage, where beam interference from the LGAD is not a major concern
  - The goal is to validate LGADs capability to count particles and work as a good **dosimetry** in FLASH therapy
- **Next Steps:**
  - LGADs are mounted on a thick carrier wafer for:
    - Mechanical support during fabrication
    - Ohmic contact for signal integrity
  - Possibility to remove carrier wafer to reduce device mass and minimize beam interference
  - Explore designs and optimize resolution and device characteristics

Thanks for your attention