Low Gain Avalanche Detector (LGAD) for ATLAS and CMS Experiments

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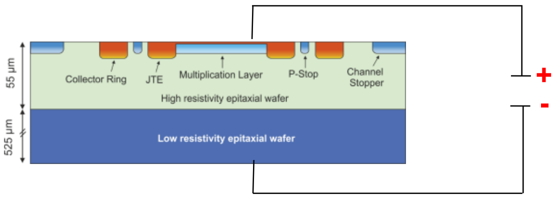
Abstract

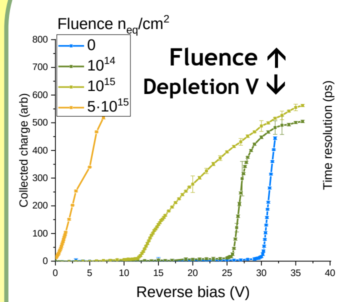
LGADs were proposed and fabricated for the first time by IMB-CNM. LGADs have intrinsic amplification (gain), enhanced by a p-type multiplication layer that promotes the avalanche mechanism. Their thin and low doped p-substrate (~50μm) ensures full depletion at a moderate voltage away from breakdown and a faster signal that maximises time resolution. LGADs are used in several applications, such as X-rays detection or biomedicine. In this project, these devices are meant to be used in the upcoming ATLAS and CMS experiments upgrade, providing the radiation resistance required for good performance.

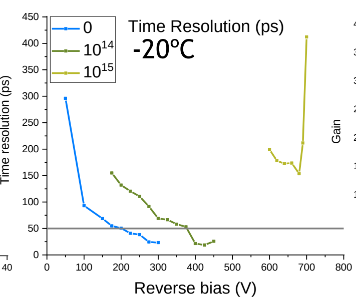
LGAD overview (Run13002)

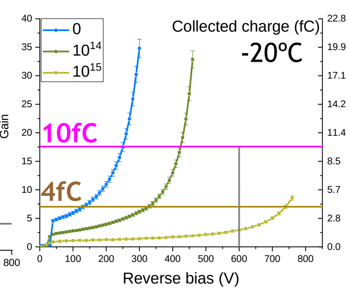


- Operating in **reverse mode** to deplete the bulk and allow charge collection.
- Moderately **p-doped (Boron) multiplication layer** that enhances avalanche mechanism, hence **gain** and good **time resolution**.
- Highly doped n+ implant and p+ epitaxial layer to collect charge.
- Three Boron implantation doses : 1.9, 1.95 and $2 \cdot 10^{13}/cm^2$. TCT measurements carried out for the last dose. LGADs pad area was 1.3x1.3mm².

TCT Measurements (IR Laser) after neutron irradiation

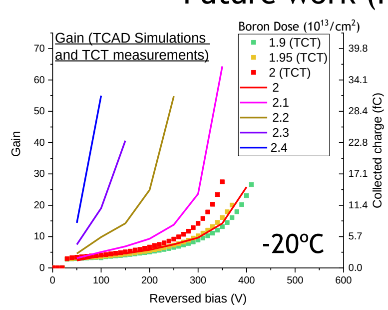


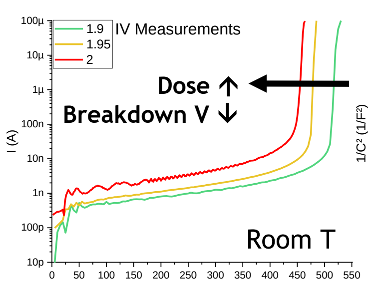


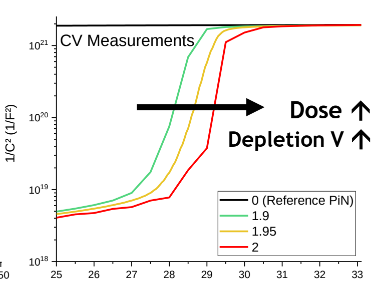


- Dopant concentration in the multiplication layer is reduced with irradiation fluence (**acceptor removal**), which **reduces gain** and **time resolution**.
- **ATLAS** and **CMS** **upgrade requirements** (set by the electronics):
  - **ATLAS:** A collected charge for a MIP of **4fC** after a fluence of $2.5 \cdot 10^{15}/cm^2$ at (max) **600V**.
  - **CMS:** A collected charge for a MIP of **10fC** after fluence of $1.5 \cdot 10^{15}/cm^2$ at (max) **600V**.

Future work (Run13840) and strategies to reach ATLAS and CMS upgrade requirements







- **Increasing the implantation dose** will increase the doping concentration of the p-multiplication layer, thus the **gain** but…
- … there's a catch : **LGADs need to be operational before and after irradiation**. Depletion voltage must be away from breakdown voltage : **a balanced dose value has to be found to meet ATLAS and CMS requirements**.

- Upcoming work for Run13840
  - Same fabrication process as Run13002 (**Epitaxial Wafers**).
  - LGADs' pad area ranging from 1x1 to 16x16mm².
  - 6 LGAD wafers with Boron implantation doses ranging up to $2.3 \cdot 10^{13}/cm^2$.
  - 4 LGAD wafers (dose $2 \cdot 10^{13}/cm^2$) with a thin layer of **implanted Carbon** (to study if the presence of C reduces the acceptor removal mechanism).
  - Measurements of Collected charge and time resolution with a **TCT** setup (IMB-CNM) and a **90-Sr** setup (IFAE).

Conclusions

LGAD production (simulation and fabrication), electrical characterization of the devices and TCT measurements (collected charge and time resolution) is carried out at IMB-CNM. Neutron irradiation and upcoming 90-Sr measurements are carried out, respectively, with the collaboration of Jozef Stefan Institute (Ljubjana) and IFAE (Barcelona). While the thinness of the devices is mandatory for timing applications, other parameters, such as implantation dose for dopants, need to be optimized to fulfil with the ATLAS and CMS upgrade requirements for radiation resistance.

References

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