FAST TIMING WITH 3D SILICON SENSORS

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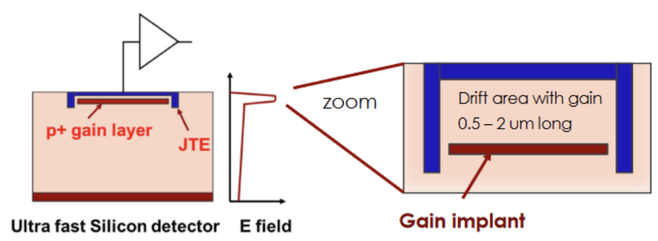
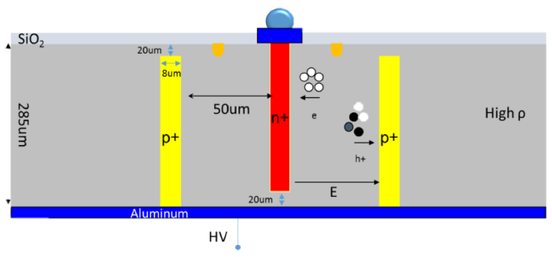
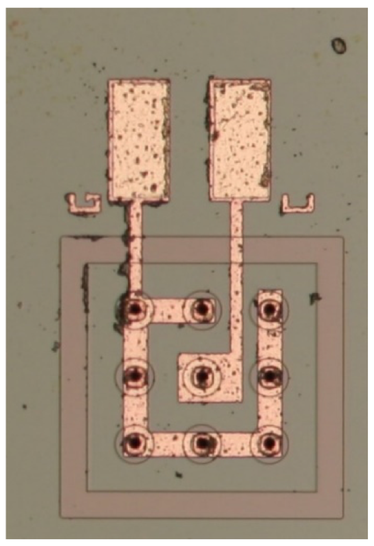
INTRO | LGADS AND 3D SENSORS

- Low Gain Avalanche Diodes (LGADs), foreseen as fast timing sensors in Phase-II LHC Upgrades at ATLAS and CMS
- Radiation hardness is an issue as gain implants degrade
- This study is part of a joint RD50 3D project

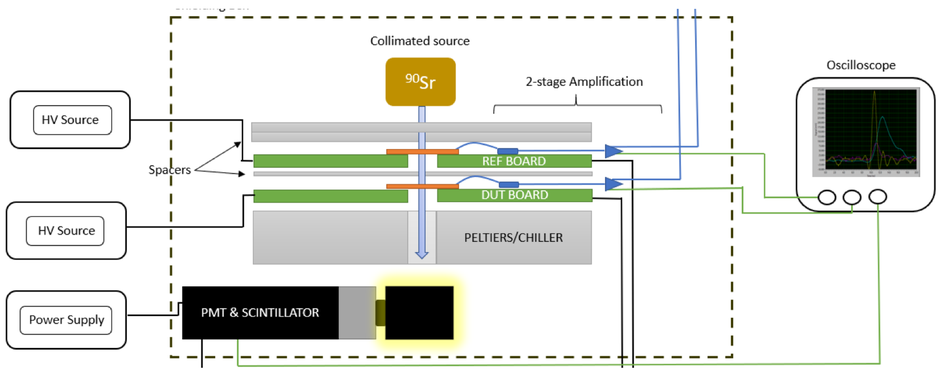


- 3D Sensors have columnar implants orthogonal to sensor surface
- 3Ds studied as radiation hard alterantive to LGADs
- LGADs unirradiated and irradiated up to $1.5 \cdot 10^{15}\ \mathrm{n_{eq}/cm^2}$
- 3Ds unirradiated and irradiated up to $5 \cdot 10^{15}\ \mathrm{n_{eq}/cm^2}$

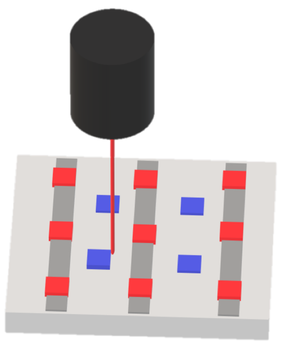




MEASUREMENT SETUPS | SOURCE AND LASER



- Signal from Sr90 source (e⁻ with $2\ \mathrm{MeV}$)
- LGAD as timing reference ($\sigma = 25.2 \pm 0.4\ \mathrm{ps}$)
- Single pulses, triggered by scintillator with PMT
- Data taken by fast oscilloscope
- Landau flcutuations as MIP-like signal is used



- Transient Current Technique (TCT) with pulsed IR laser orthognal to sensor surface
- Fibre splitter to have two pulses (reference and signal pulse both on DUT)
- Data taken by fast oscilloscope
- Laser pulses have constant energy → no Landau fluctuations

- Time resolution σ_t determined by jitter and time walk
- Jitter component σ_j determined by the rise time at the amplifier output $\mathrm{dV/dt}$ and the noise level σ_n
- Time walk component includes weighting field (or electric field) contribution, Landau fluctuations in signal
- Time walk depends strongly on sensor design

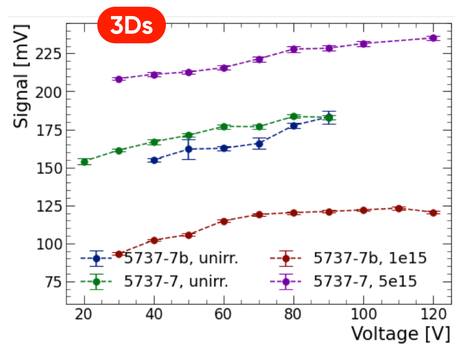
$$\sigma_t^2 = \sigma_j^2 + \sigma_{TW}^2$$

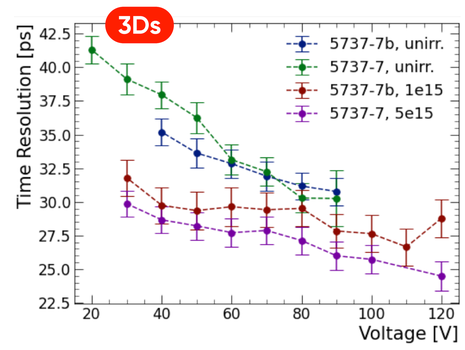
$$\sigma_j = \frac{\sigma_n}{|dV/dt|} \approx \frac{\sigma_n}{|S/\tau_p|} = \frac{\tau_p}{S/N}$$

RESULTS

3D pixel sensors

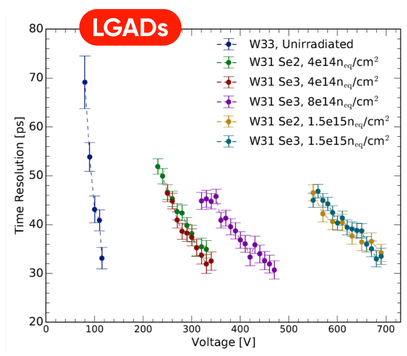
- Signal increases at lower fluence ($1 \cdot 10^{15}\ \mathrm{n_{eq}/cm^2}$), drops below initial signal level at higher fluence ($5 \cdot 10^{15}\ \mathrm{n_{eq}/cm^2}$)
- Caused by increased field due to radiation-induced increase of doping
- High Voltage stability grows after irradiation
- Time resolution in 3Ds increases with bias voltage, high fluence does not worsen it





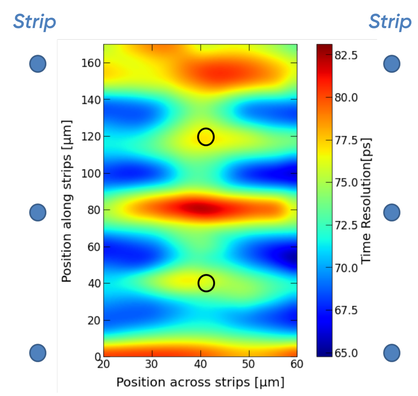
LGADs

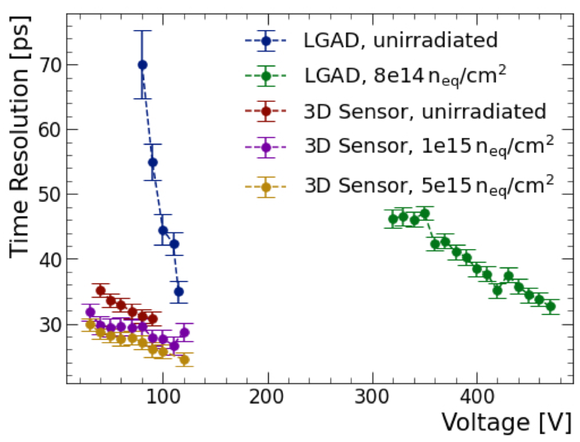
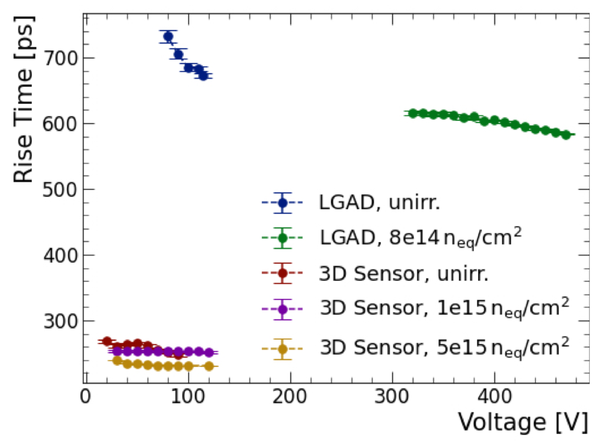
- With increasing fluence, much higher bias needed to keep time resolution. This works until HV limit is reached



3D strip sensors

- Average time resolution $75\ \mathrm{ps}$, worse than in 3D pixels due to much larger capacitance
- Metal strips connect junction columns strips not transparent for laser
- Measure position-resolved time resolution maps with TCT
- Map shows clear cell structure and correlation to electric field (slower at lower field points)
- Between junction columns resolution is worse
- Next to Ohmic columns resolution is worse



CONCLUSIONS & OUTLOOK

- With increasing fluence, LGADs need higher bias to keep up time resolution and rise time
- In 3D sensors, time resolution and rise time are hardly affected by radiation doses up to $5 \cdot 10^{15}\ \mathrm{n_{eq}/cm^2}$
- **3D sensors are a potential radiation hard alternative to LGADs**
- Dedicated fast 3D timing sensors made at CNM in Summer 2023, distributed Oct 23, with testing currently underway
- Initial IV/CV tests indicate sufficient HV tolerance