Radiation hardness of Carbon enriched LGAD sensor developed by IHEP-IME

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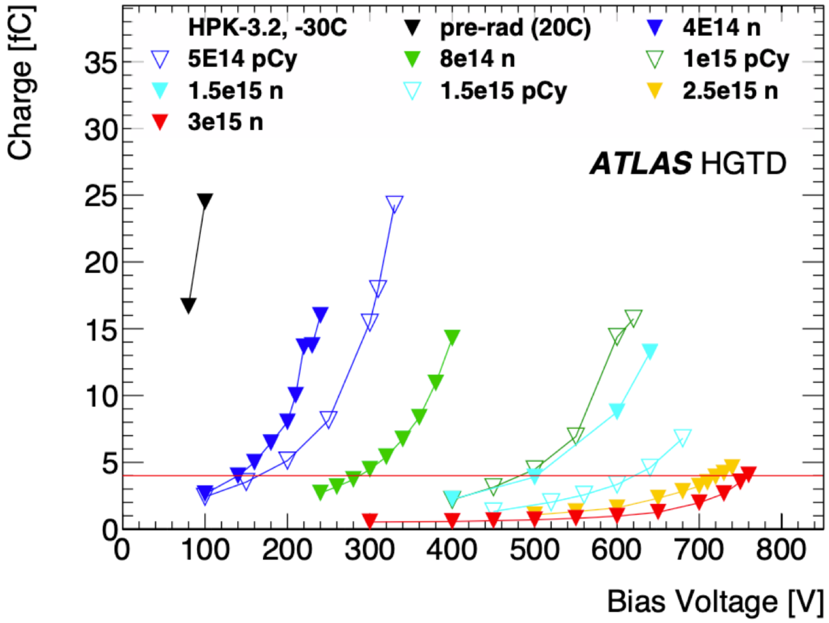
Radiation Concerns

Radiation Fluences ➔ acceptor removal ➔ loss gain ➔ compensate gain ➔increase bias voltage ➔ maintain charge & time resolution ➔ SEB (single event burnout)



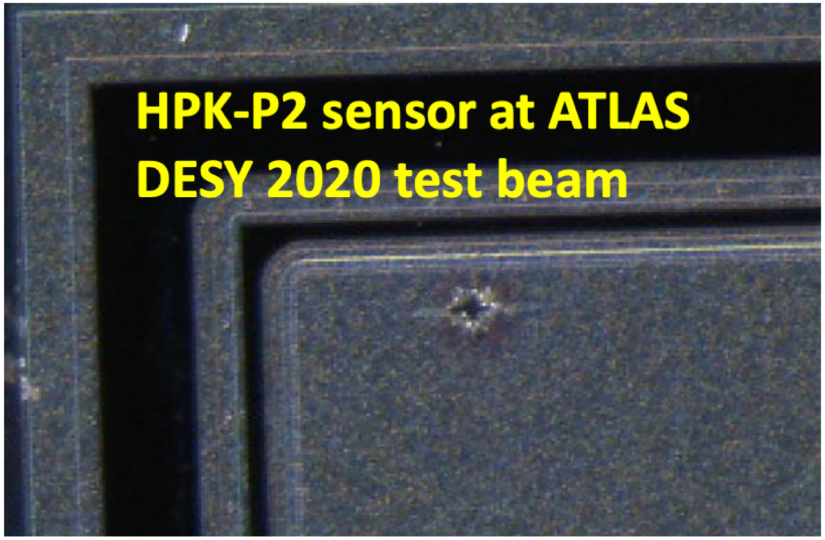
Collected charge as a function of bias voltage for different fluences for HPK-3.2. Target charge: **4 fC at 2.5 × 10^{15} n_{eq} cm^{-2}.**

HV stability in the beam:

- ➢ Bias voltages >700 V
- ➢ SEB risk for all sensors
- ➢ Permanent damage

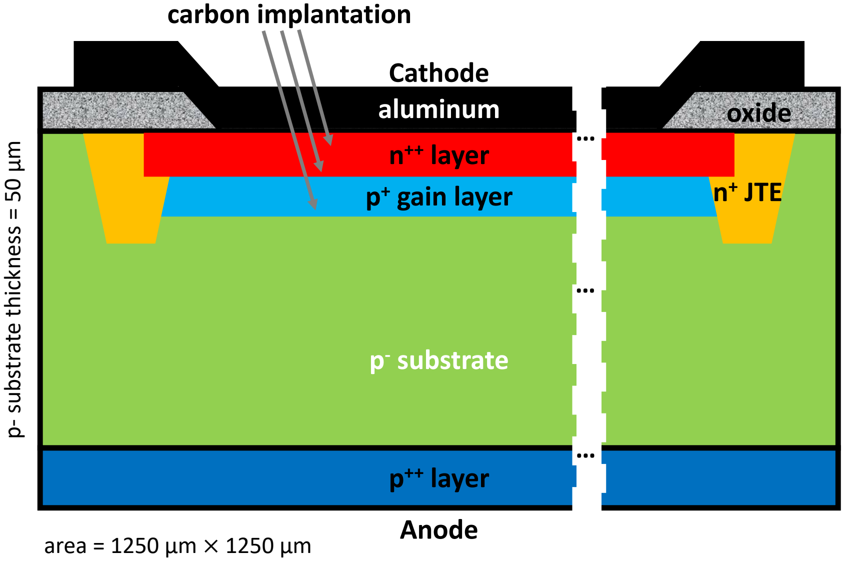
Solution:

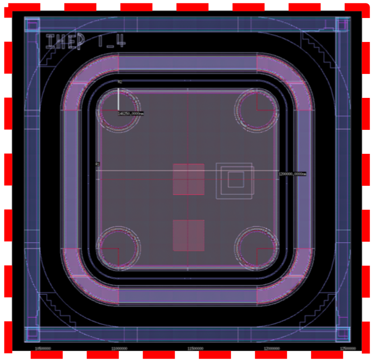
- ➢ Small acceptor removal factor
- ➢ Thicker sensor



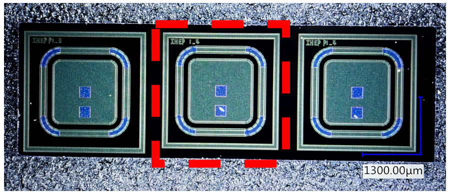
IHEP-IME LGAD Sensor Design

Wafer	Quadrant	Boron	Phosphorus
1	I	Medium	Low
1	II	High	Low
1	III	Medium	High
1	IV	High	High





IHEP-IMEv2 1_4 layout mask



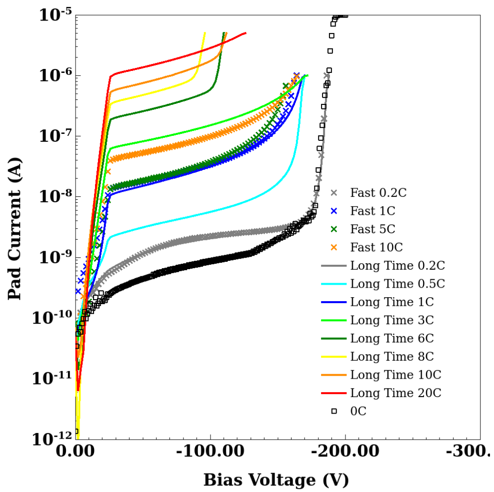
Test unit including a LGAD sensor and two PIN sensors

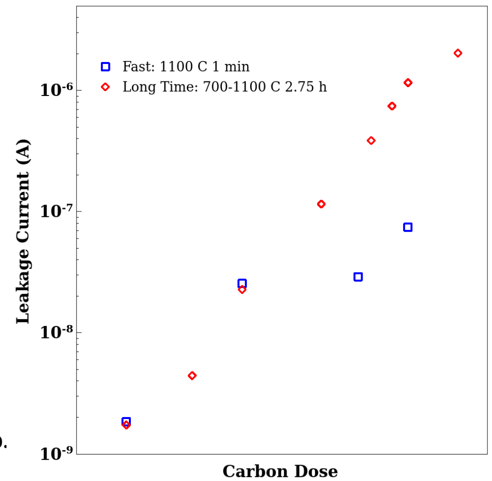
$$C_s + I \rightleftharpoons C_i \quad vs \quad B_s + I \rightleftharpoons B_i$$

Carbon competing for Interstitial with Boron

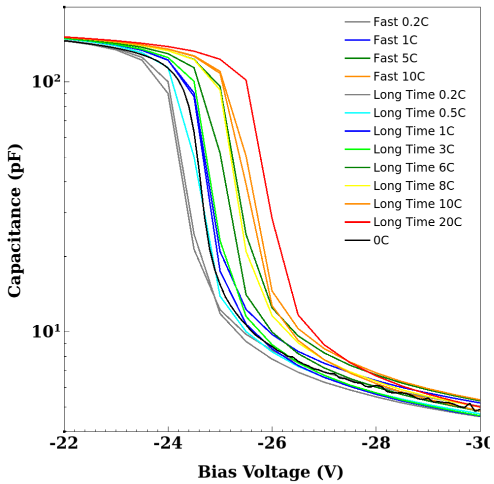
Wafer	Carbon	Thermal Process
4	0.2C-10C	Fast Annealing
7, 8	0.2C-10C	Long time Annealing

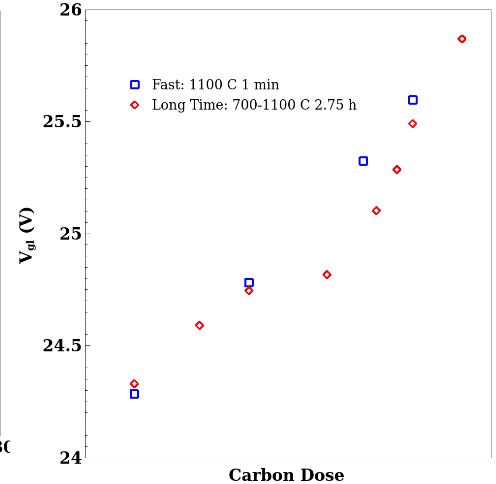
Sensor IV & CV

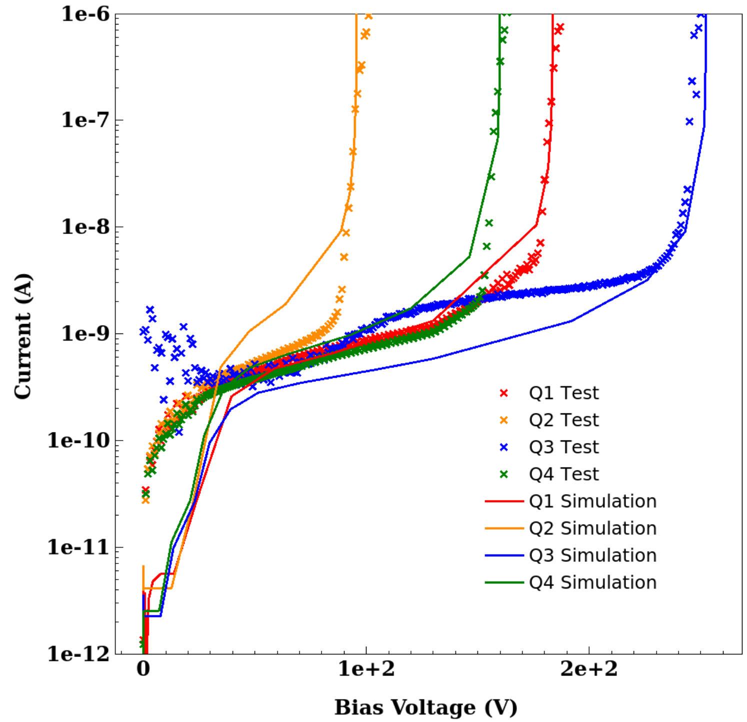




Carbonated Sensor: IV, CV, leakage current, and V_{gl}

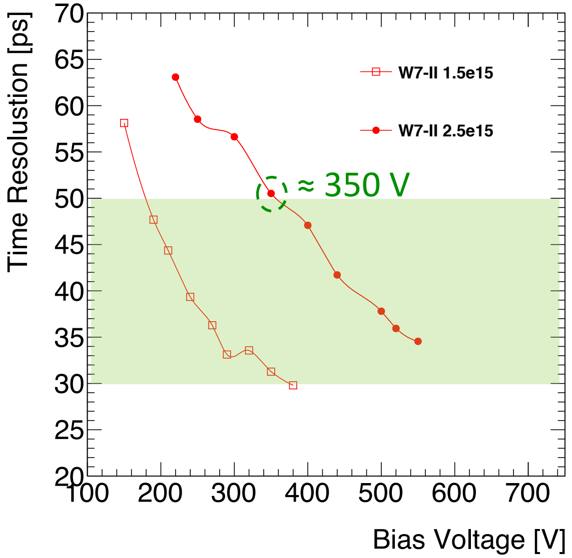


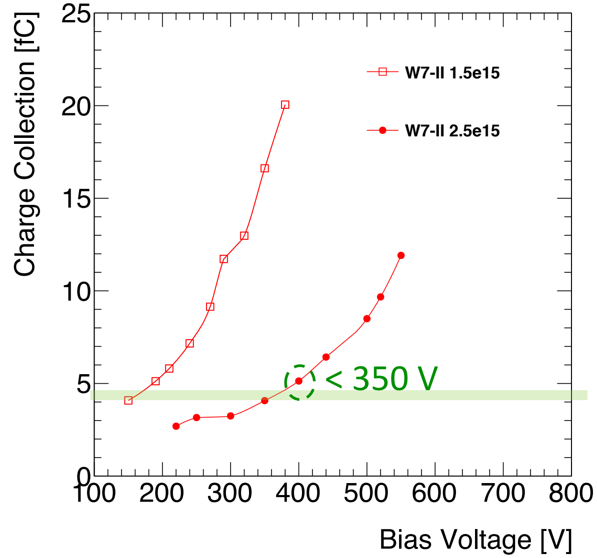


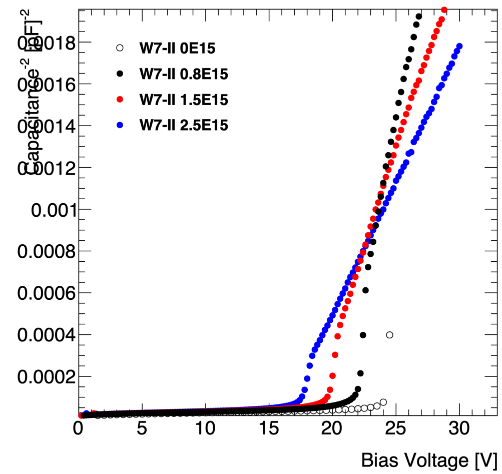


- Sensor simulation and test in good consistency
- Carbonated sensor:
  - Leakage current increase with carbon dose
  - V_{gl} slightly increase with carbon dose

Irradiated Sensor Test

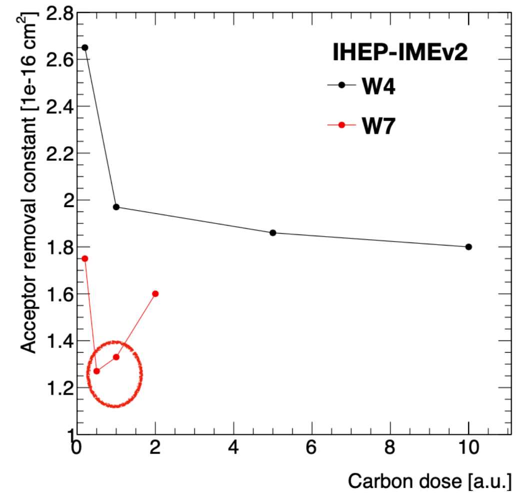






V_{gl} after different radiation dose

$$V_{\mathrm{gl}}\left(\mathrm{D_{rad}}\right) = V_{gl}(0)e^{c\times \mathrm{D_{rad}}}$$



W7-II Acceptor removal factor

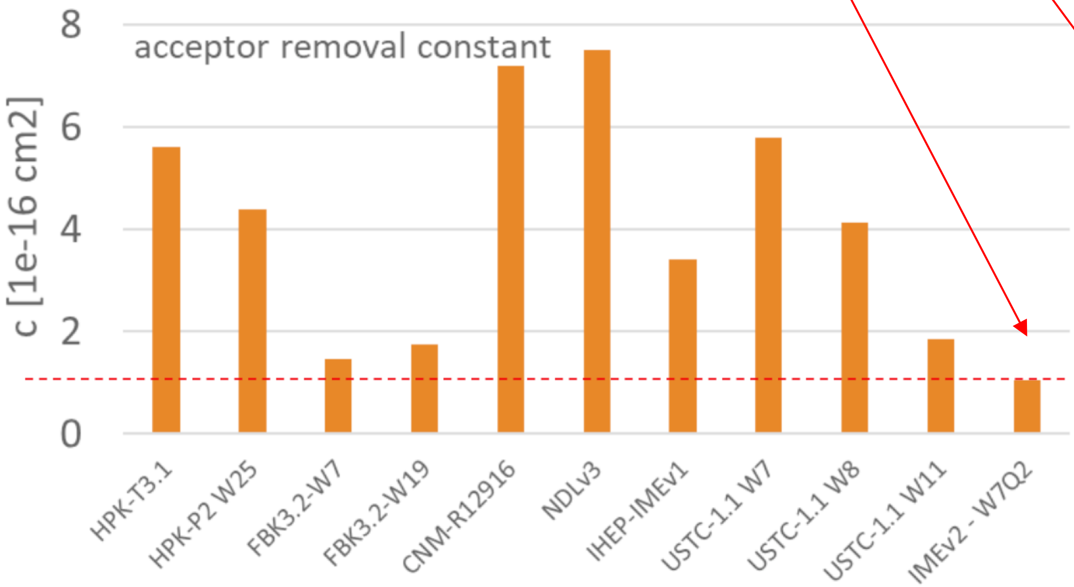
W7-II Sensor after $2.5 \times 10^{15}\ n_{eq}\ cm^{-2}$:

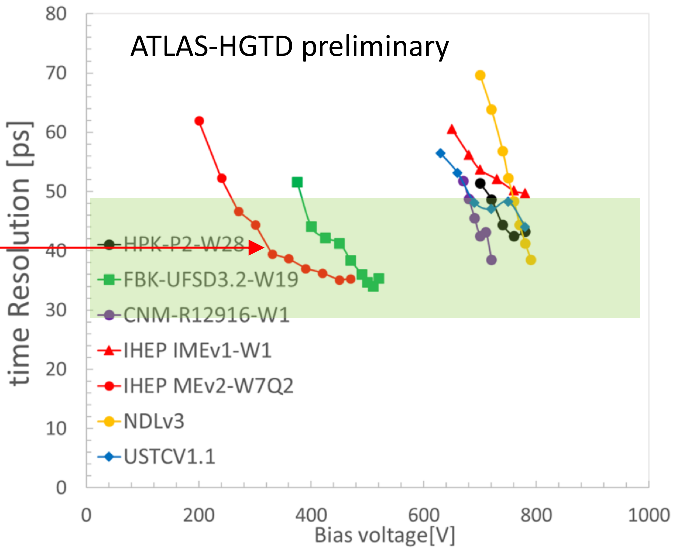
- collect 4 fC with bias voltage < 350 V
- Time resolution around 40 ps at 450 V
- Acceptor removal factor about 1.2
- Efficiency higher than 95% at 450 V

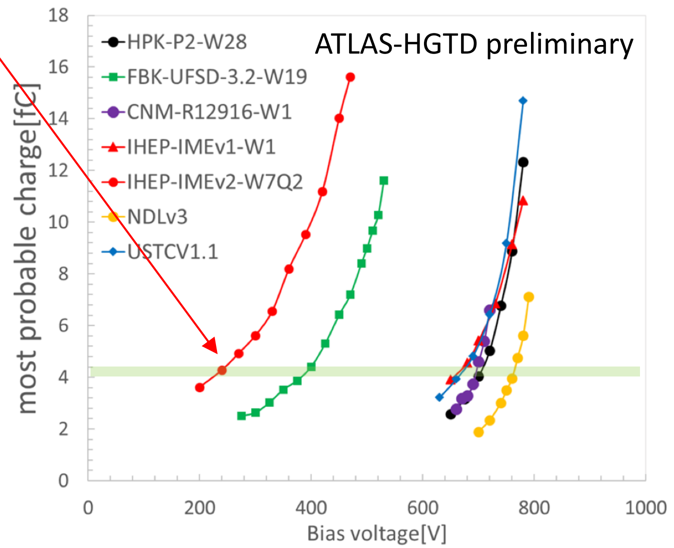
Radiation Campaign

Comparing with HPK, FBK, CNM, NDL, and USTC, IHEP-IMEv2 W7Q2 have the best radiation hardness.

- Smallest acceptor removal factor
- Lowest bias voltage for 30-50 ps time resolution
- Lowest bias voltage for 4 fC Charge Collection
- **Reach HGTD specifications for 2.5e15 with < 450 V**
- **Survived in the test beam several days with many millions of events at operational voltage**







Thanks for your listening!

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