DRD3

Study of Deep Carbonated LGAD at IHEP

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2-12-2024

Outline

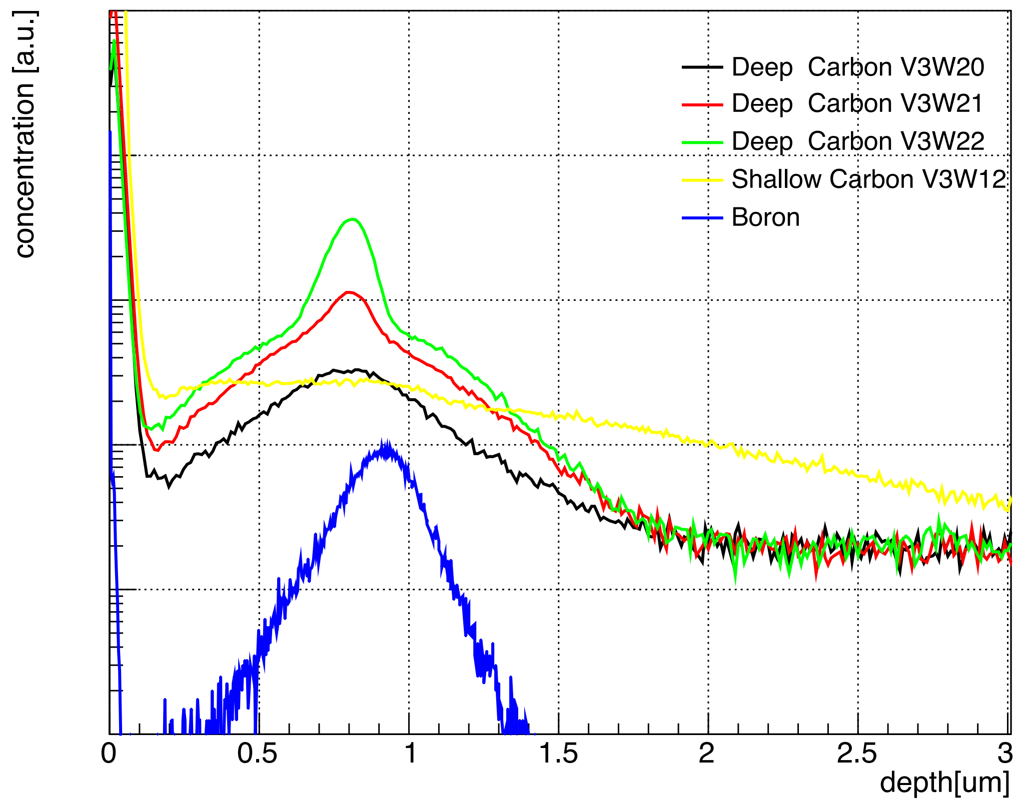
- Motivation
- General features
- Neutron irradiation
- Proton irradiation
- Comparison and conclusion

Motivation

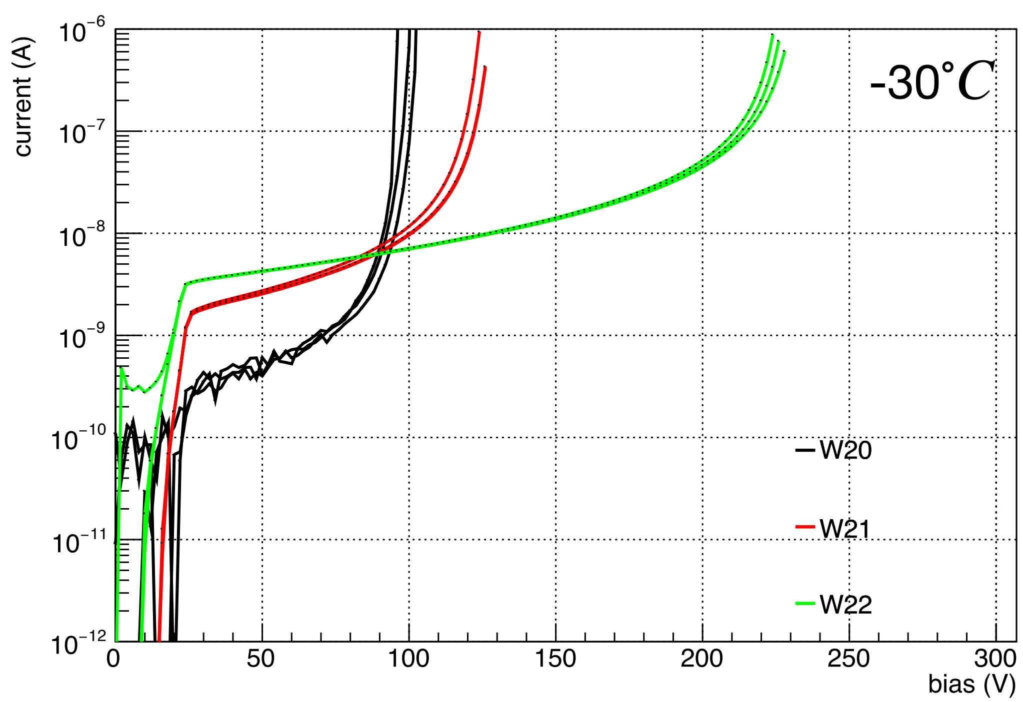
- Growing need for enhanced radiation hardness in detectors:
  - Low operation bias to suppress single event burnt down.
  - Survive from higher accumulated irradiation dose.
- Low gain avalanche detectors designed by IHEP shows good radiation tolerance.These detectors are:
  - Carbonated.
  - Different implantation depth for gain layer and Carbon.
  - High thermal load for Carbon.
- Explore different strategy with deeper implantation energy for Carbon.

General features before irradiation

SIMS profile

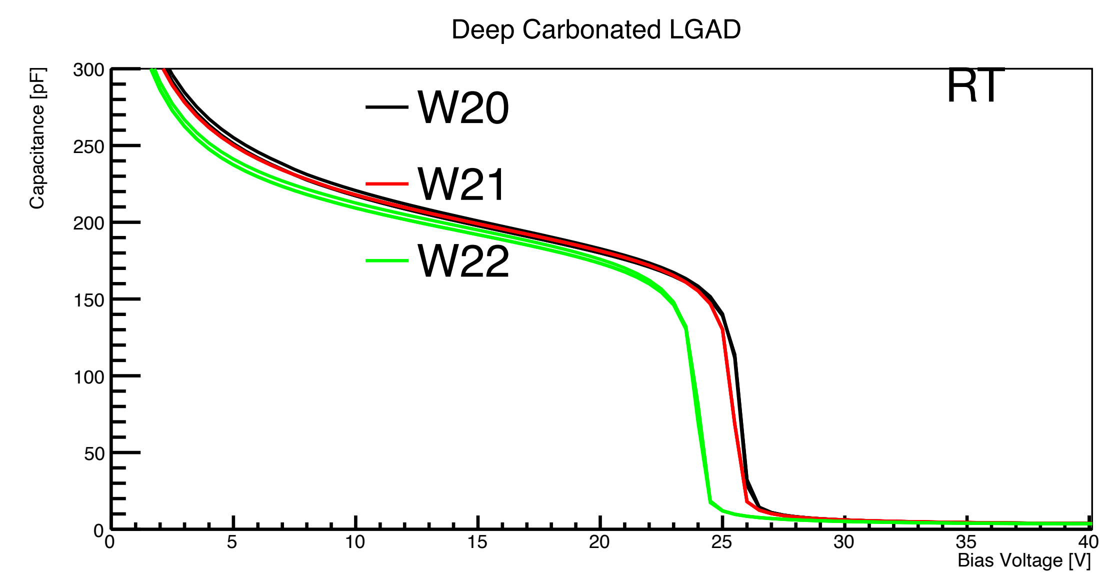


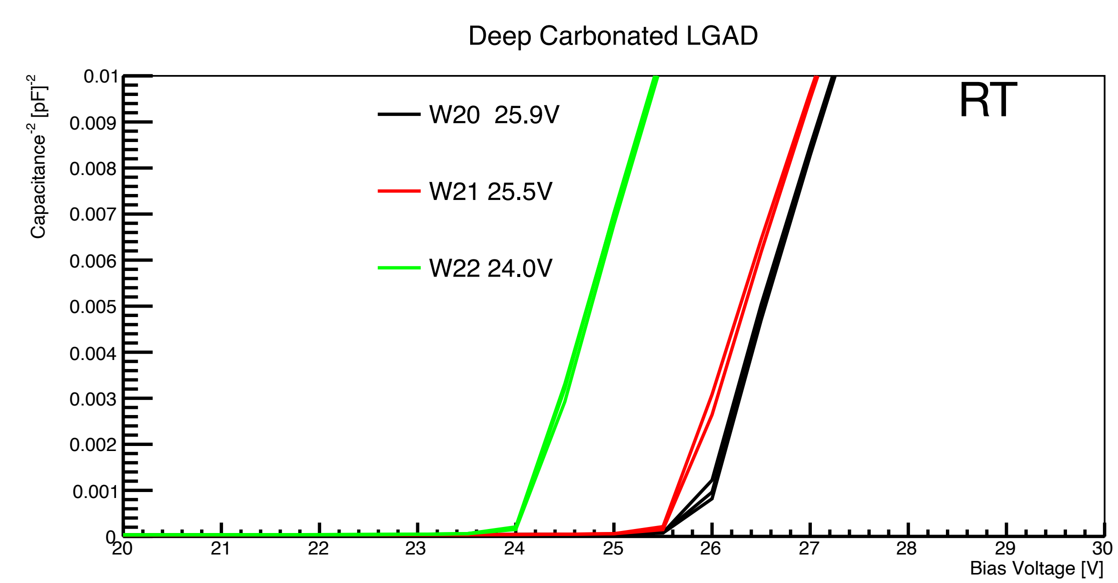
leakage current



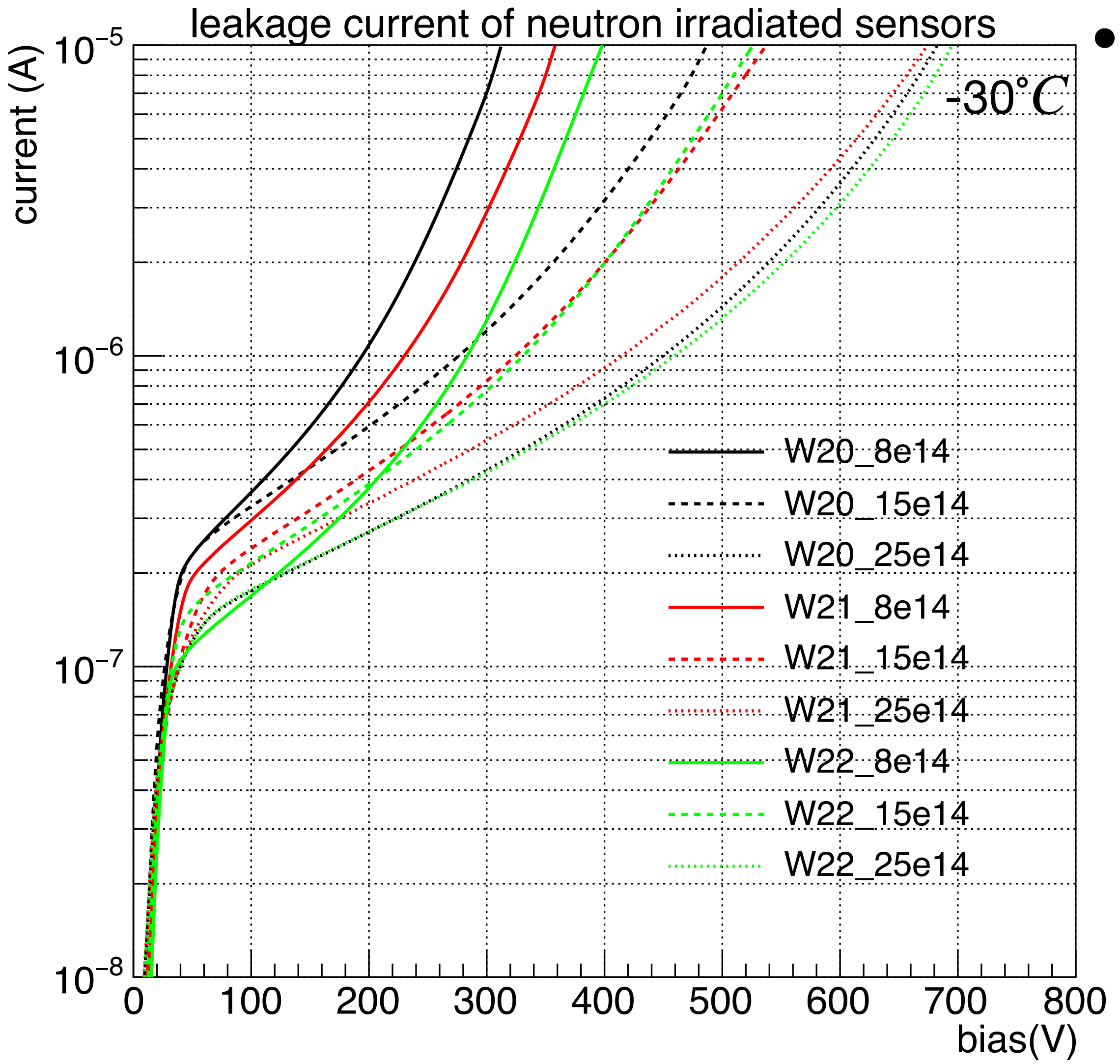
	W20	W21	W22
Vgl (V)	25.9	25.5	24 (-7%)
Vbd (V) (200nA)	100	120	220
Carbon dose (a.u.)	2	5	10

- W20 W21 and W22
  - Same Boron implantation depth and dose.
  - Same Carbon depth (close to boron) with different dose.
  - Leakage current (at -30˚C) and the breakdown voltage increase with Carbon density.
  - An initial acceptor deactivation is observed in W21 and W22.

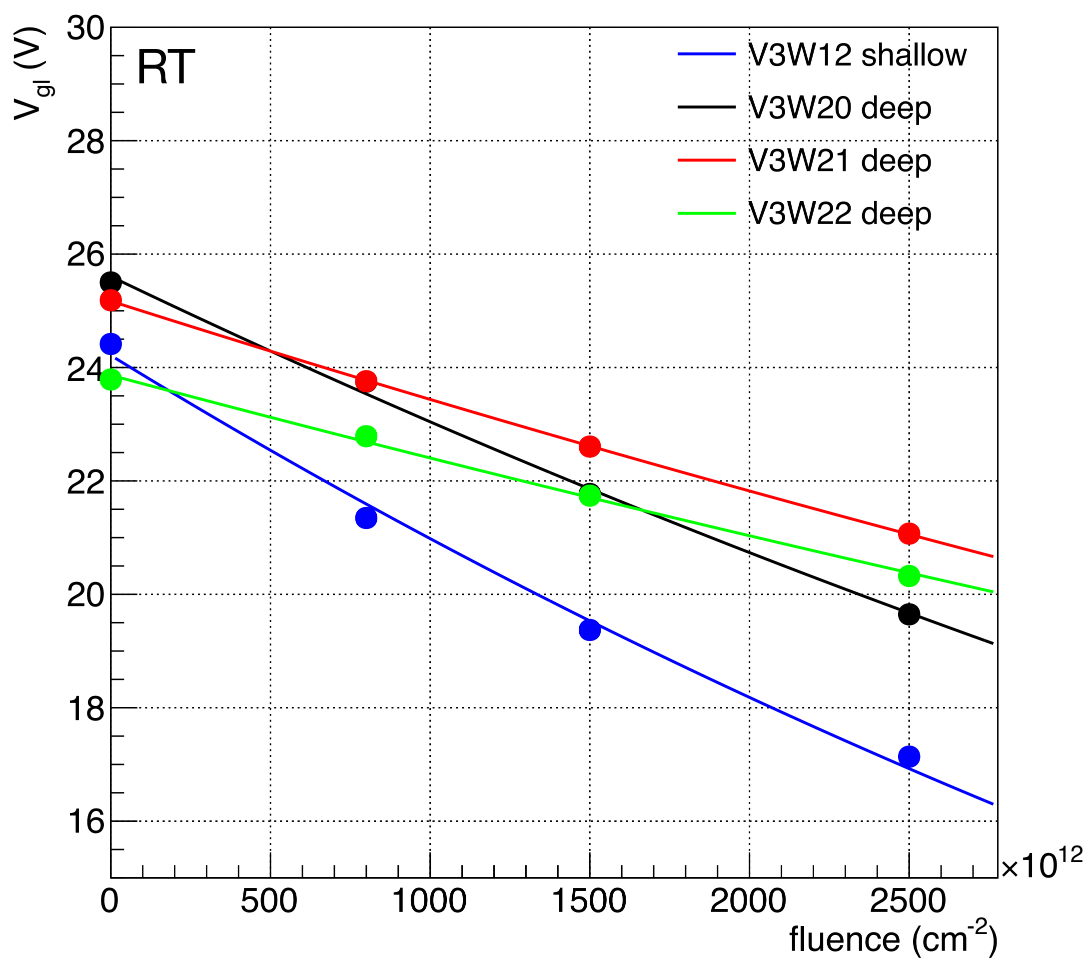




Electronic features of neutron irradiated sensors

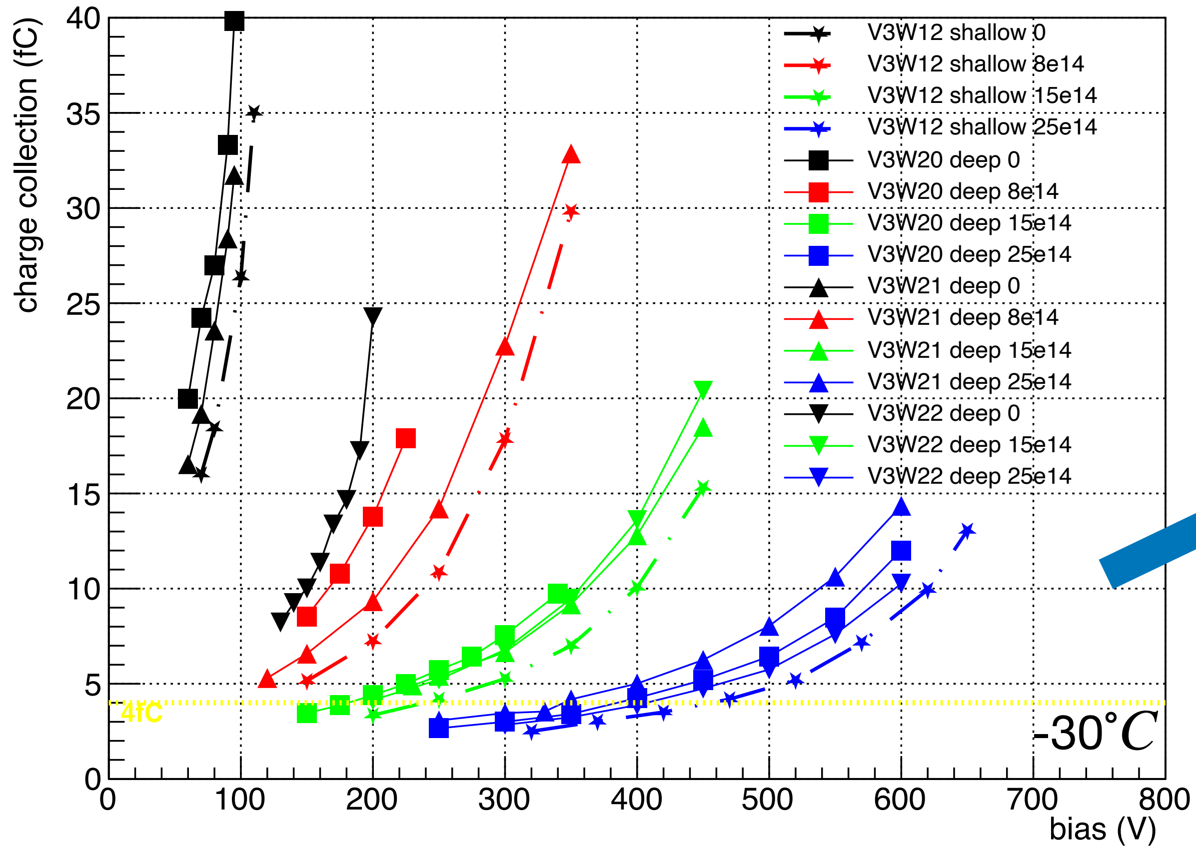


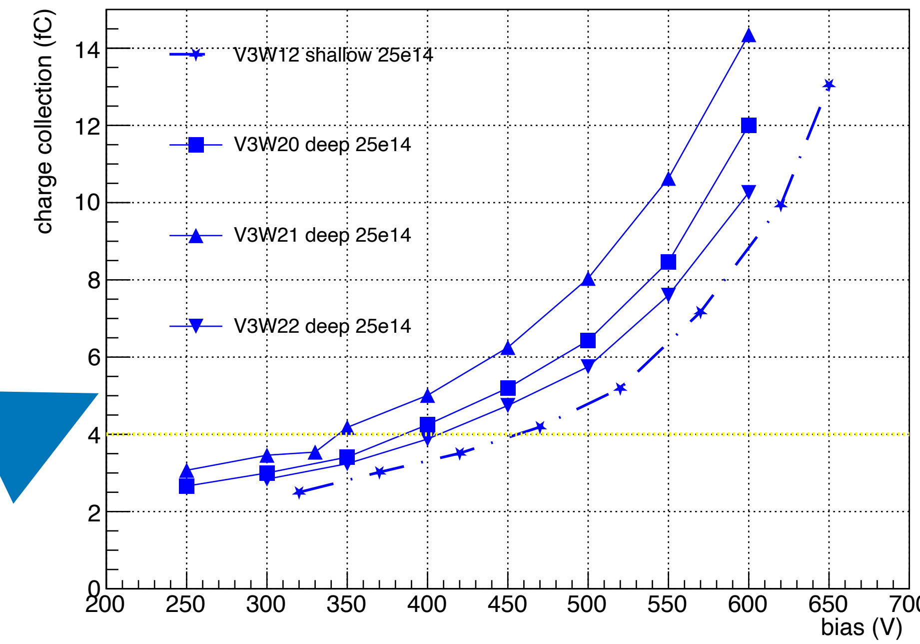
- The leakage current difference gradually become smaller as irradiation dose increase.
- A deactivation observed at the beginning; W22 has the lowest removal factor.



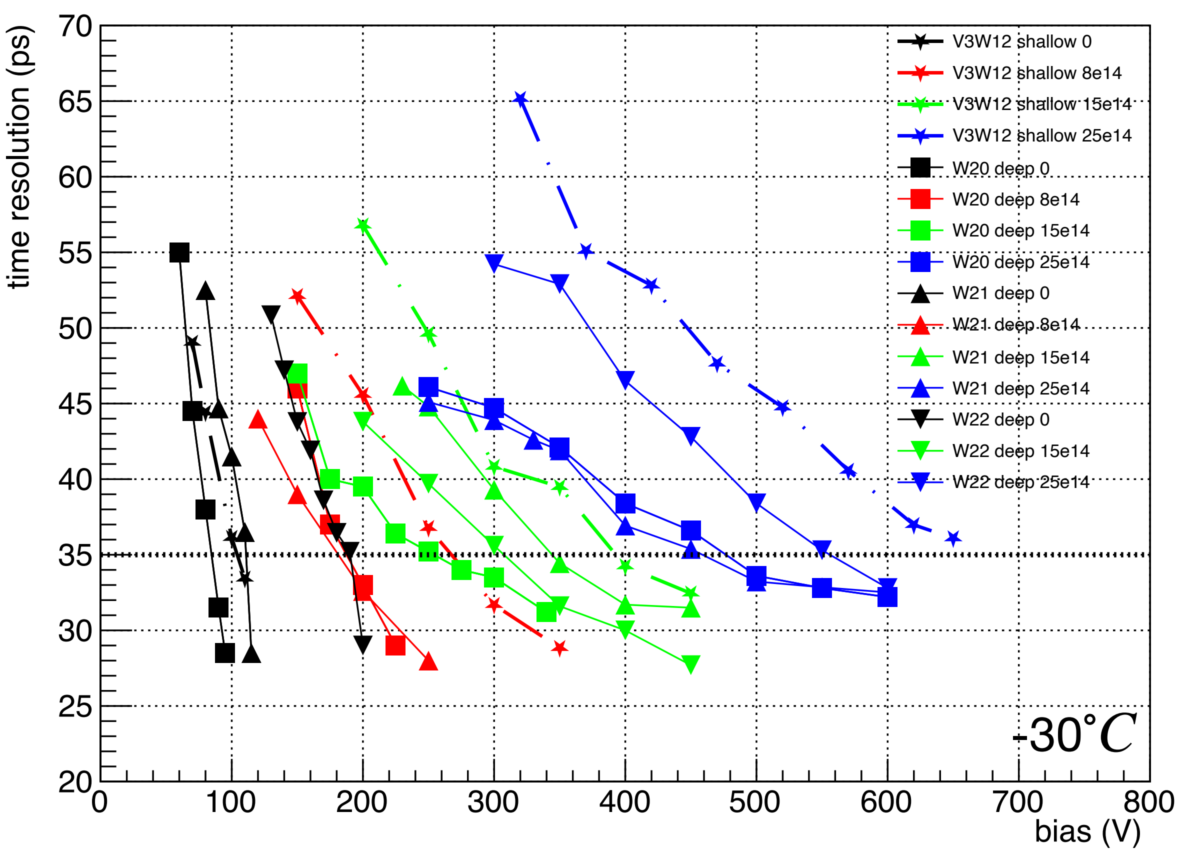
	W12	W20	W21	W22
Removal factor (x1e16 cm2)	1.31	1.05	0.71	0.63

Electronic features of neutron irradiated sensors



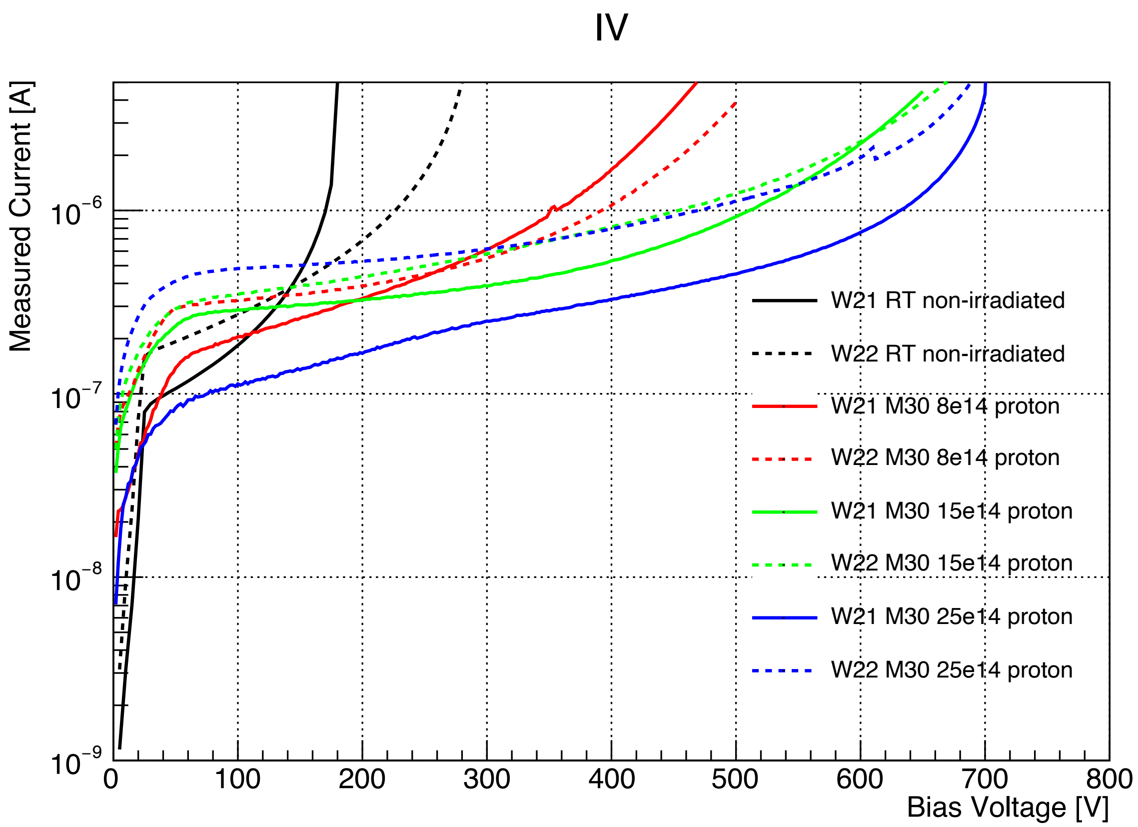


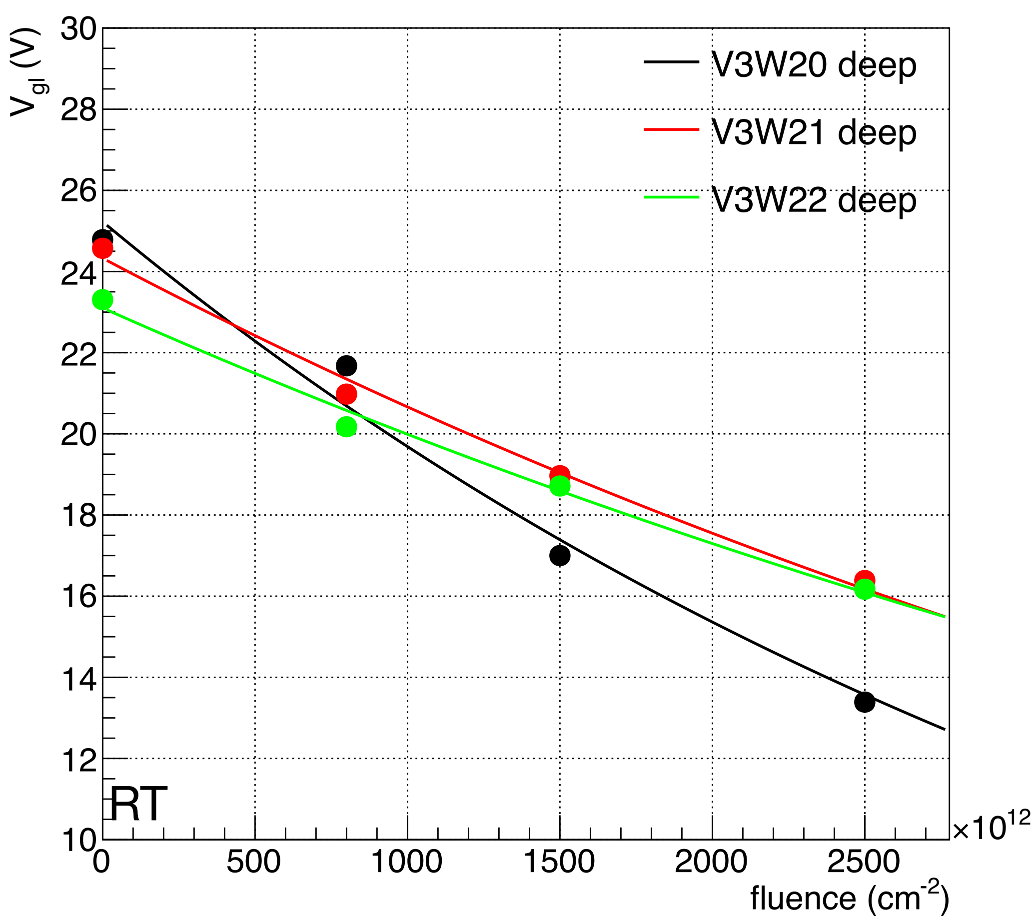
Wafer	W20	W21	W22	W12
4fC bias	380 V	340 V	410 V	460V



- 4 (3 deep Carbon + 1 shallow Carbon) with same Boron layer.
    - Deep Carbon overall better than shallow Carbon.
    - W20 and W21 are close, W22 needs a higher bias voltage at the very beginning (due to deactivation).
    - The sensors performance don’t directly decided by the removal factor.

Electronic features of proton irradiated sensors

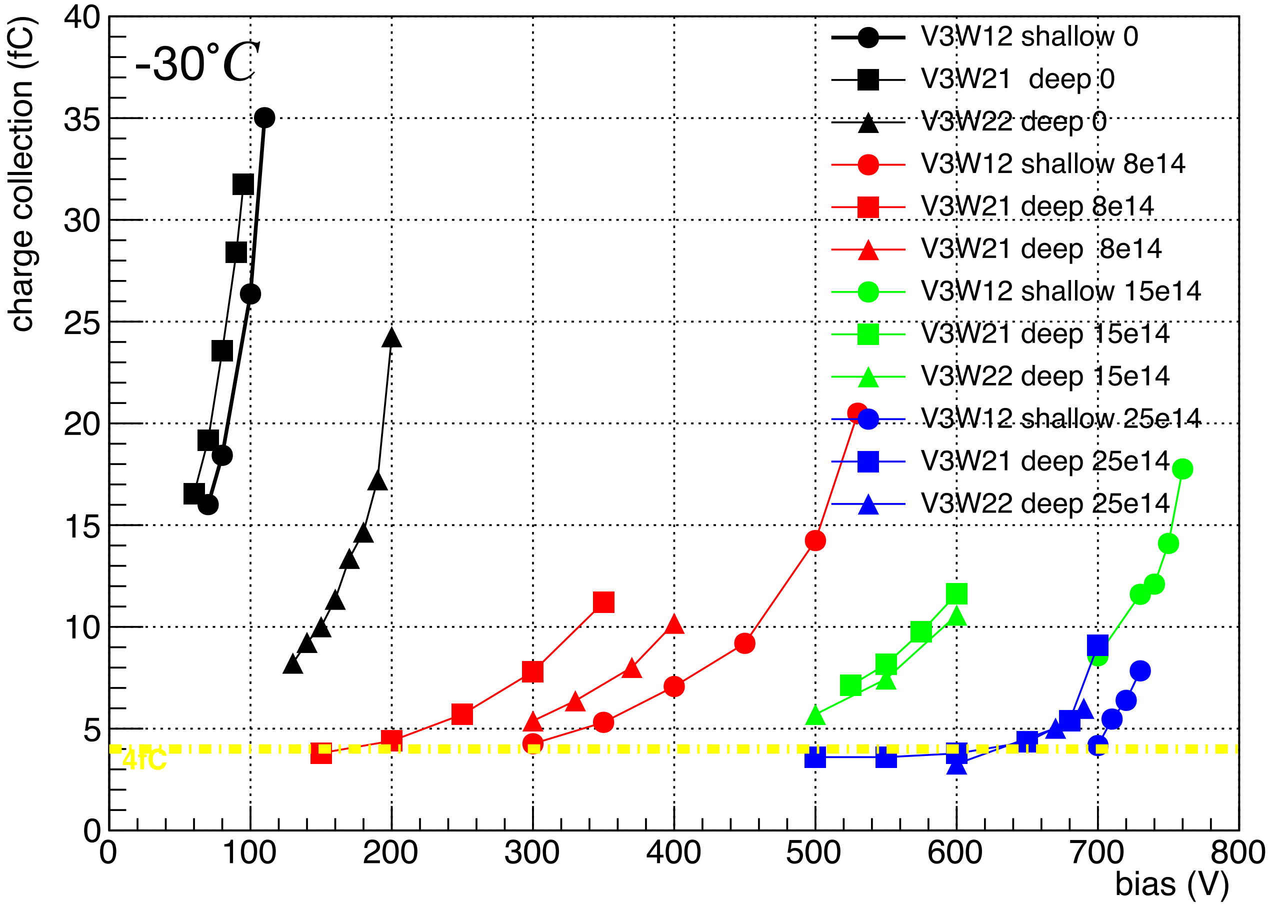


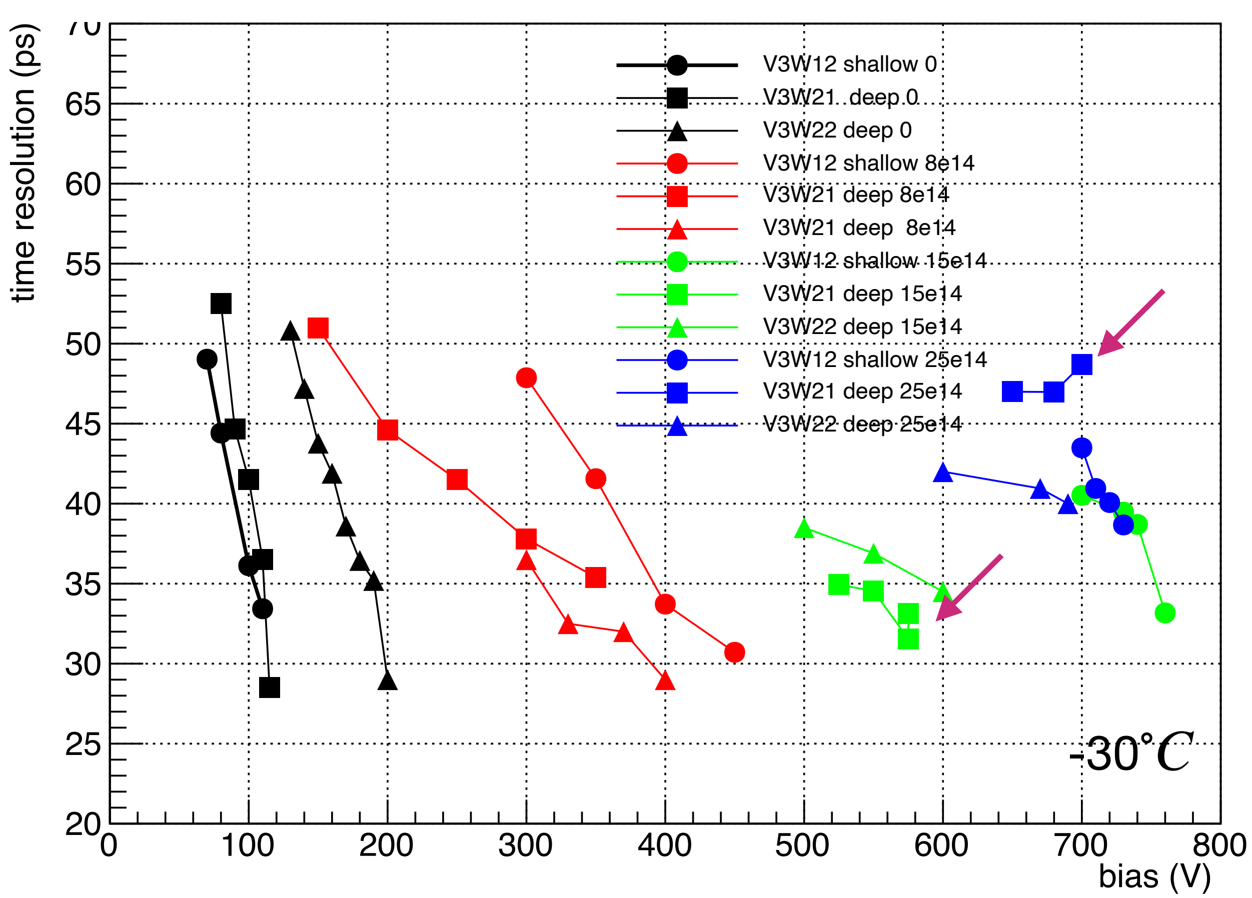


- Irradiated with 80MeV proton (hardness factor ~1.58) with n_eq up to 25e14/cm2.
- W22 leakage current greater than W21 before/after irradiation.
- Order of removal factors same as neutron irradiation case, with large absolute value.

	W20	W21	W22
Proton Removal factor (x1e16 cm2)	2.48	1.63	1.44
Neutron Removal factor (x1e16 cm2)	1.05	0.71	0.63

Electronic features of proton irradiated sensors





3 (2 deep carbon + 1 shallow carbon) with same boron layer.

- Deep carbon overall better than shallow carbon.
- At low irradiation dose, the advantage of deep ones are clear while for extremely high irradiation dose, the difference is narrowed, both W21/W22 and W12 need >600V to get a moderate charge collection.
- Up to very high irradiation dose, the time resolution increase with bias.

A comparison of proton and neutron irradiation results

	W20	W21	W22
Proton Removal factor (x1e16 cm2)	2.48	1.63	1.44
Neutron Removal factor (x1e16 cm2)	1.05	0.71	0.63
C_p/C_n	2.36	2.30	2.29

- For 80MeV proton irradiation and reactor neutron irradiation, an average c_p/c_n of 2.32 is obtained.
- With the increase of carbon density, decrease of removal factor is obtained from both neutron and proton irradiation.
- However, W22 with the lowest factor can not obtained a best charge collection/temporal resolution.

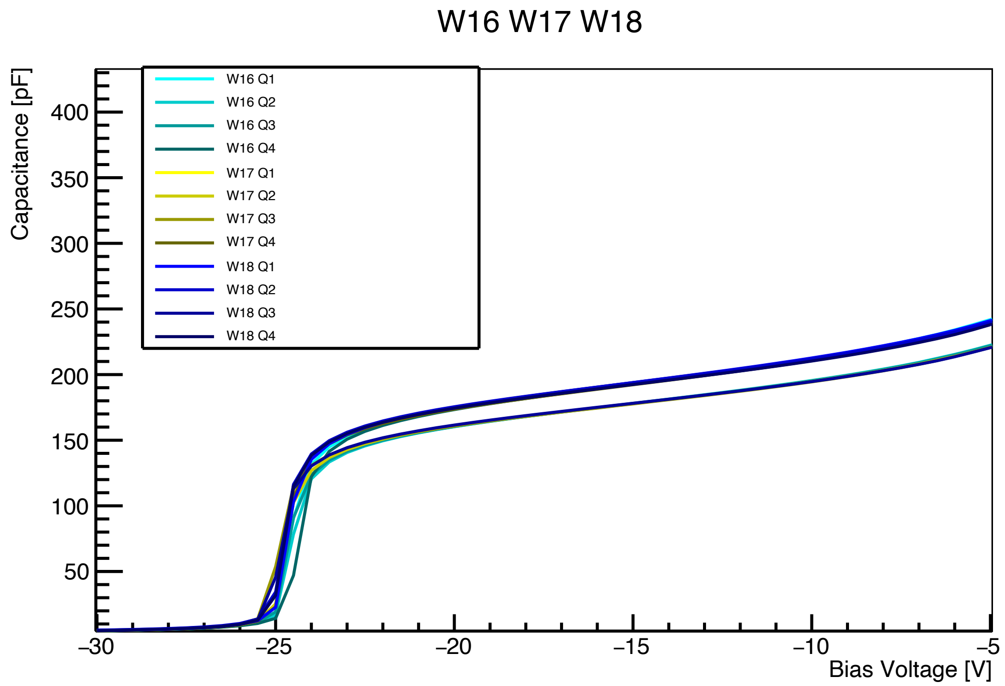
Summary

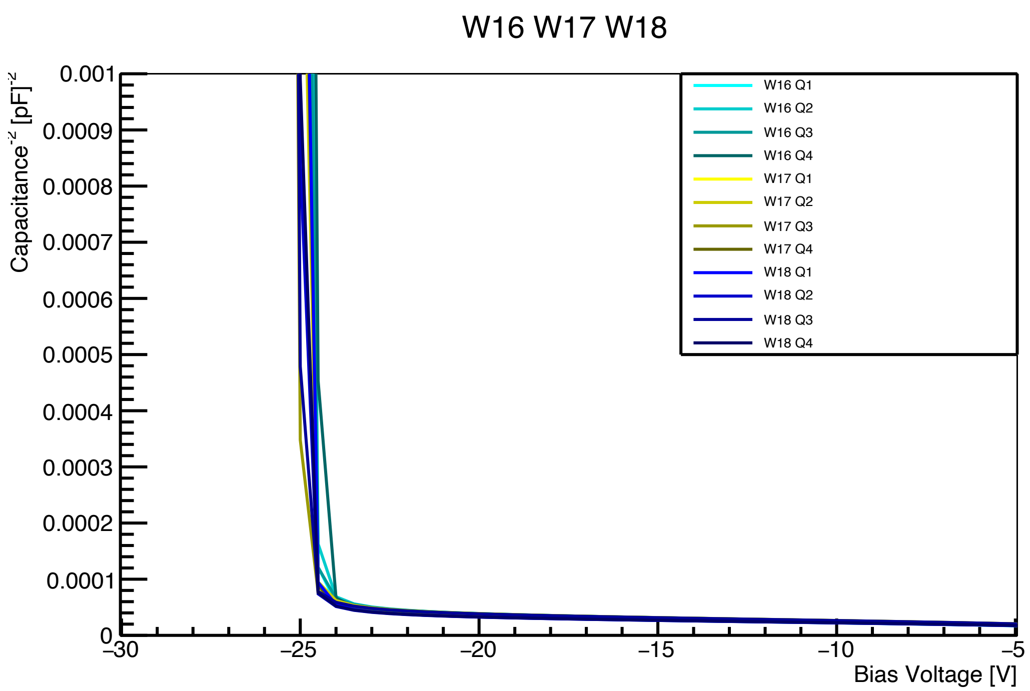
- LGAD with gain layer and carbon implanted in a similar depth was studied.
  - Improvements results from a higher carbon density benefits the removal factors and cc/tr.
  - The Carbon also leads to suppressing the gain layer active Boron, while the c factors might remain low, the cc/tr can be worsen(from W22).

BackUp

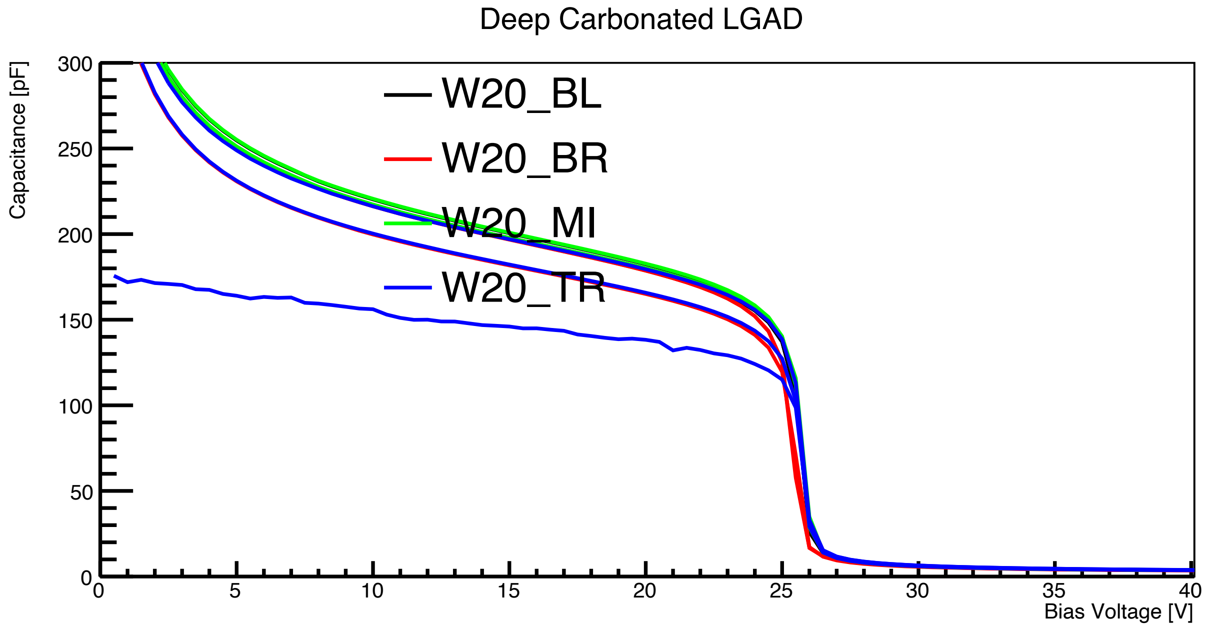
Vgl of shallow/deep carbon sensors

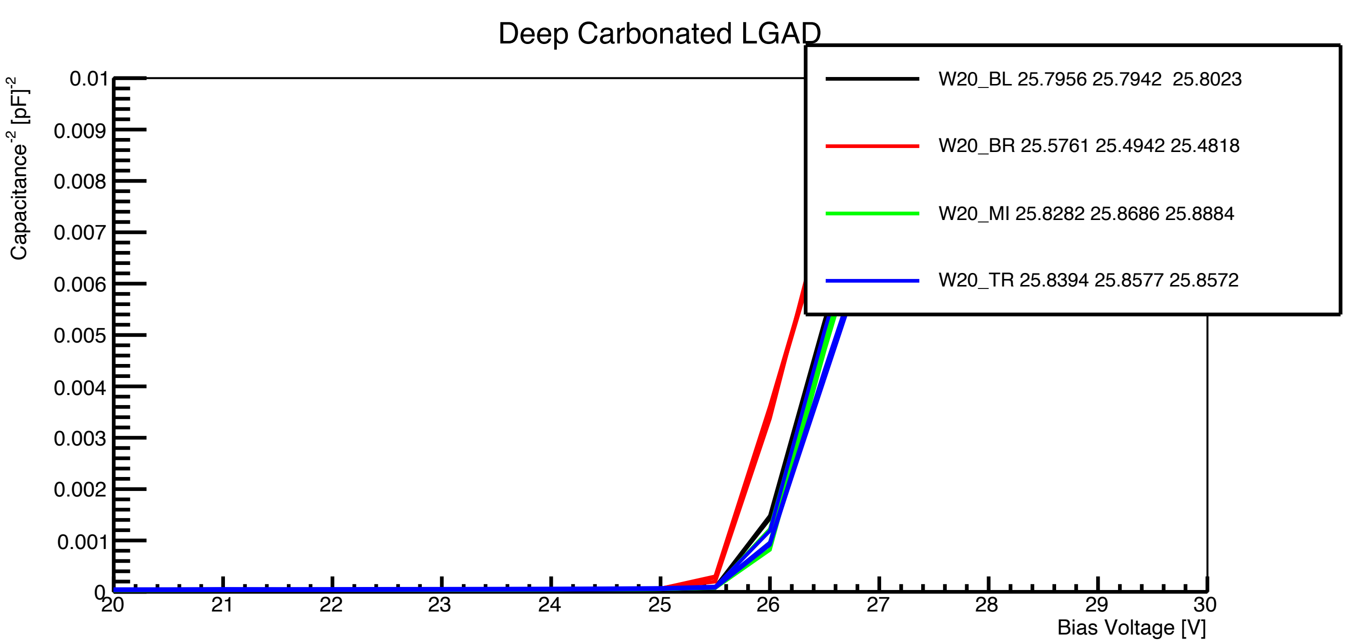
Shallow





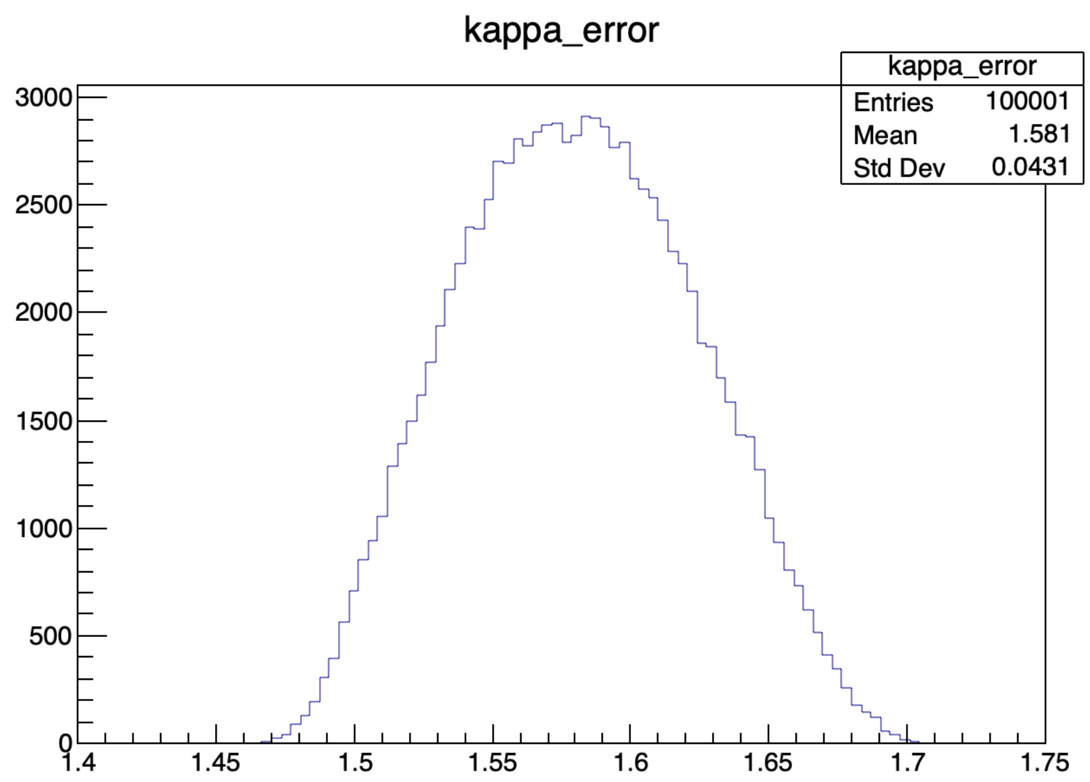
Deep





Hardness factor

Device	PIN1	PIN2	PIN3
Fluence (p/cm2)	7.59E+12	6.07E+14	1.14E+15
Vfd (V)	5	25	50
I_leak (Average)	3.7E-08	3.16E-06	6.19E-06
I_leak range	4v-10v	20v-30v	40v-60v



- The hardness factor (or κ) is 1.581 on average (1.47-1.71), which is 13% higher than the NIEL value we used when calculating c factor.