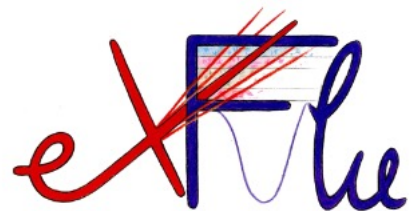


Radiation resistance of Carbon-Shield LGADs and comparison with standard carbonated LGADs

M. Ferrero, A. Fondacci, A. Morozzi, C. Hanna, D. Passeri, F. Moscatelli, G. Borghi, G. Paternoster, L. Lanteri, L. Menzio, M. Costa, M.C. Vignali, M. Boscardin, N. Pastrone, N. Cartiglia, R. White, R. Arcidiacono, R. Mulargia, S. Giordanengo, T. Croci, F. Siviero, V. Sola

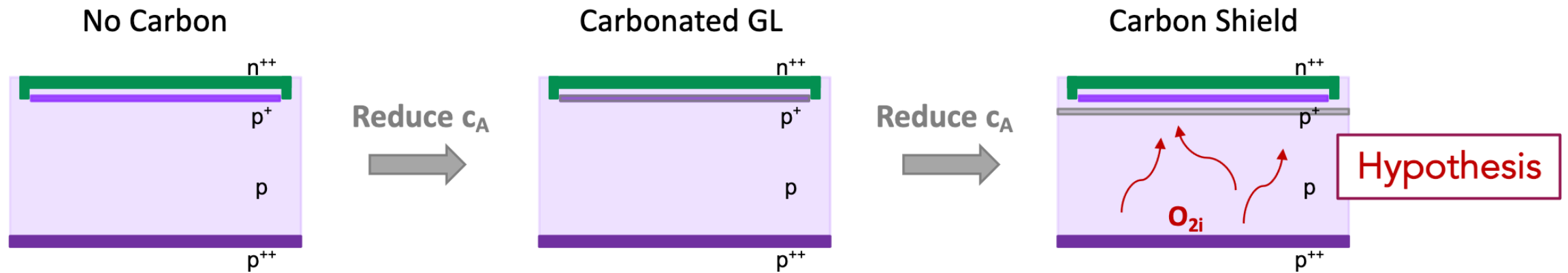


43rd RD50 Workshop
CERN
30/11/2023



Motivation - Carbon Shield strategy to further improve LGADs radiation hardness

A Carbon shield infusion underneath the gain layer volume to protect the gain implant from the diffusion of defect complexes from the bulk region and the support wafer



Hypothesis:

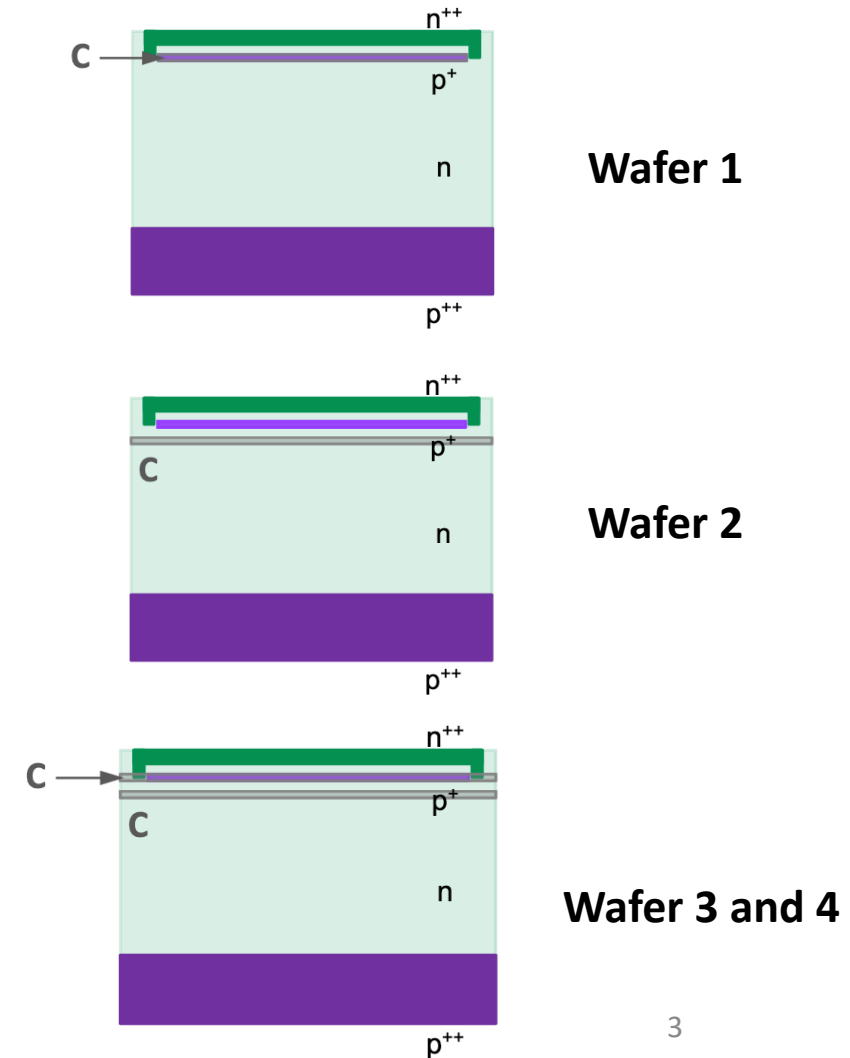
→ Defect complex can be captured by the Carbon atoms, preventing the removal of acceptors

C-Shield LGAD in EXFLU1 production

Split table

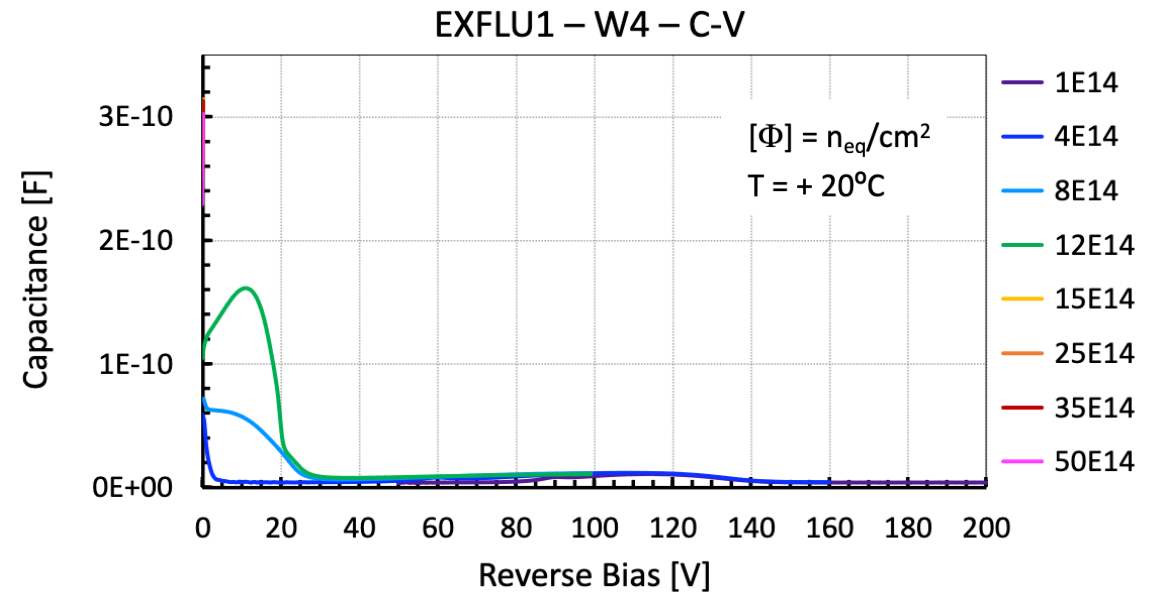
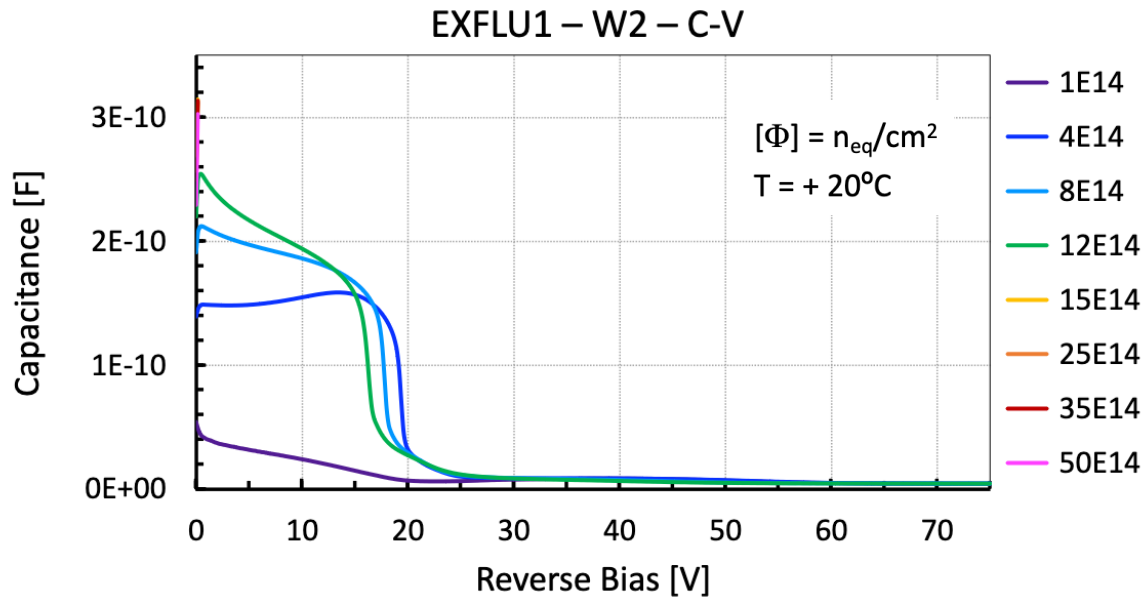
Wafer #	Thickness	p+ dose	C dose	C shield	Diffusion
1	45	1.14	1.0		CBL
2*	45	1.00		0.6	CBL
3*	45	1.16	1.0	0.6	CBL
4*	45	1.16	1.0	1.0	CBL

- The bulk of 45μm swapped to n-type
- Gain implant type: Shallow-CBL (no references in previous productions)
- One dose of carbon (1.0C) implanted into the gain implant
- **Carbon Shield obtained with a C-spray implant**
- Two doses of Carbon shield (1.0C and 0.6C)
- **W1: reference wafer (No C-Shield)**
W2: C-Shield only (No carbon into the gain implant)
W3 and 4: Carbon into the gain implant + C-Shield
- Irradiation campaign with neutrons up to fluences of $5 \cdot 10^{15} n_{eq}/cm^2$



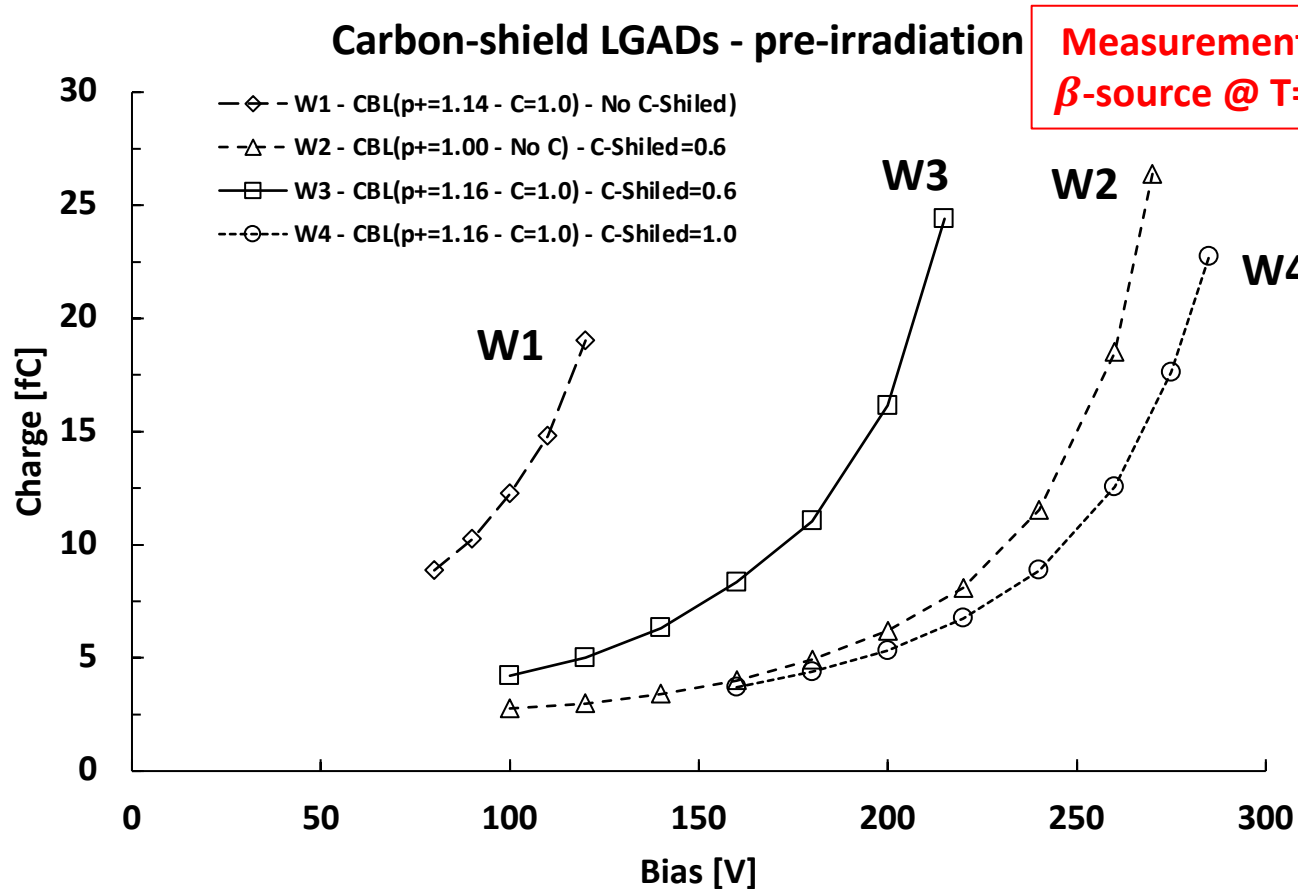
CV characteristics pre and post irradiation

No information on gain implant can be extracted from C-V measurements



Acceptor removal can't be estimated from C-V measurements

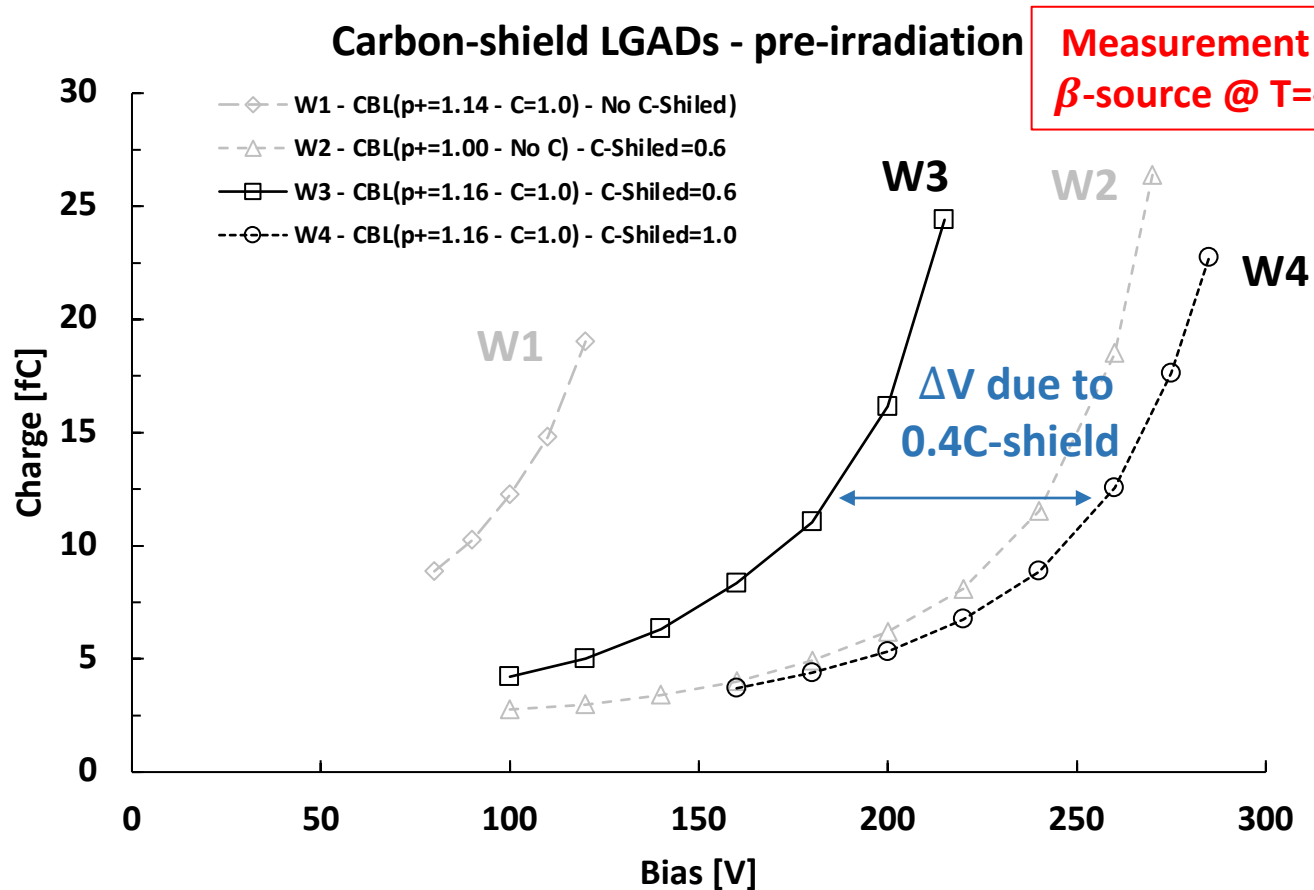
Pre-Irradiation CC measurements



➤ Large spread in Charge-Bias curves due to strong Boron Inactivation in presence of C-Shield implant.

Wafer #	Thickness	p+ dose	C dose	C shield	Diffusion
1	45	1.14	1.0		CBL
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Pre-Irradiation CC measurements

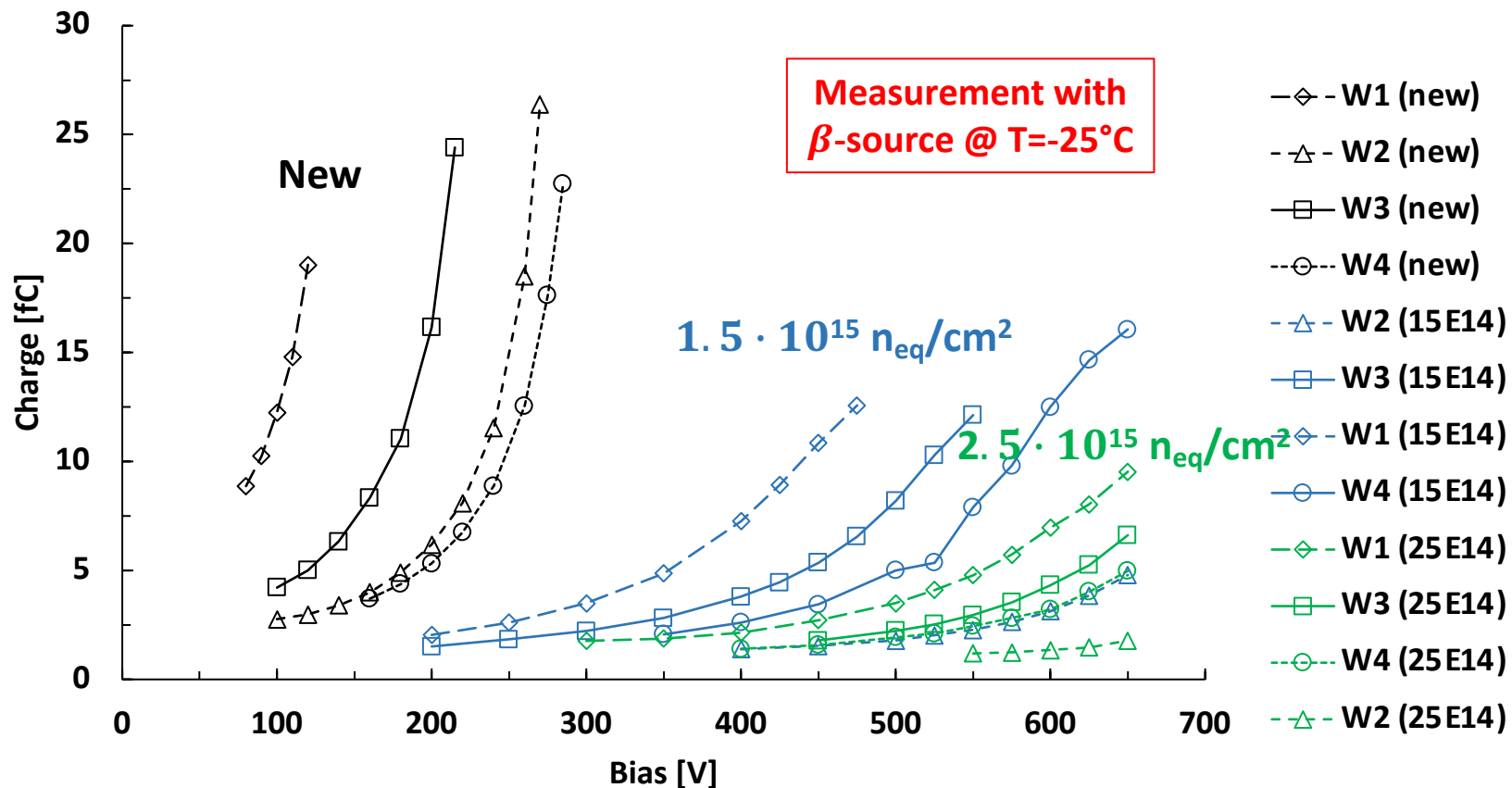


Wafer #	Thickness	p+ dose	C dose	C shield	Diffusion
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- Large spread in Charge-Bias curves due to strong Boron Inactivation in presence of C-Shield implant.
- Comparison between W3 and W4 quantifies the effect of C-Shield in term of Boron inactivation.

Post-Irradiation CC measurements

Carbon-shield LGAD - UnIrr. and Irr. @ 1.5 and $2.5 \times 10^{15} \text{ n}_{\text{eq}}/\text{cm}^2$

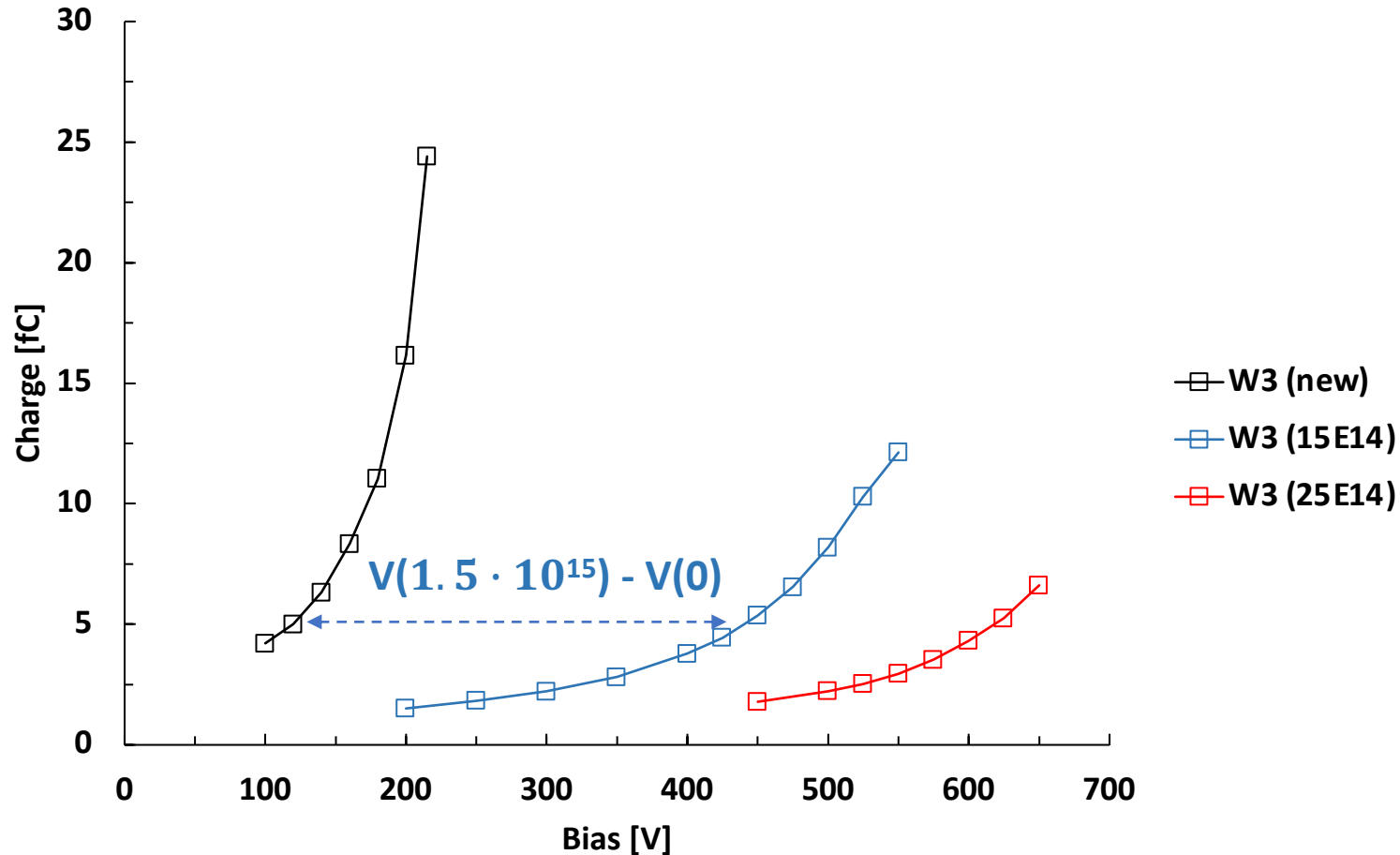


Large spread in pre-Irradiation Charge-Bias curves will make post-irradiation comparison difficult between wafers.

Wafer #	Thickness	p+ dose	C dose	C shield	Diffusion
1	45	1.14	1.0		CBL
2*	45	1.00		0.6	CBL
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Figure of merit for post-irradiation comparison

Carbon-shield LGAD - Unirr. and Irr. at 1.5 and 2.5E1015 neq/cm2



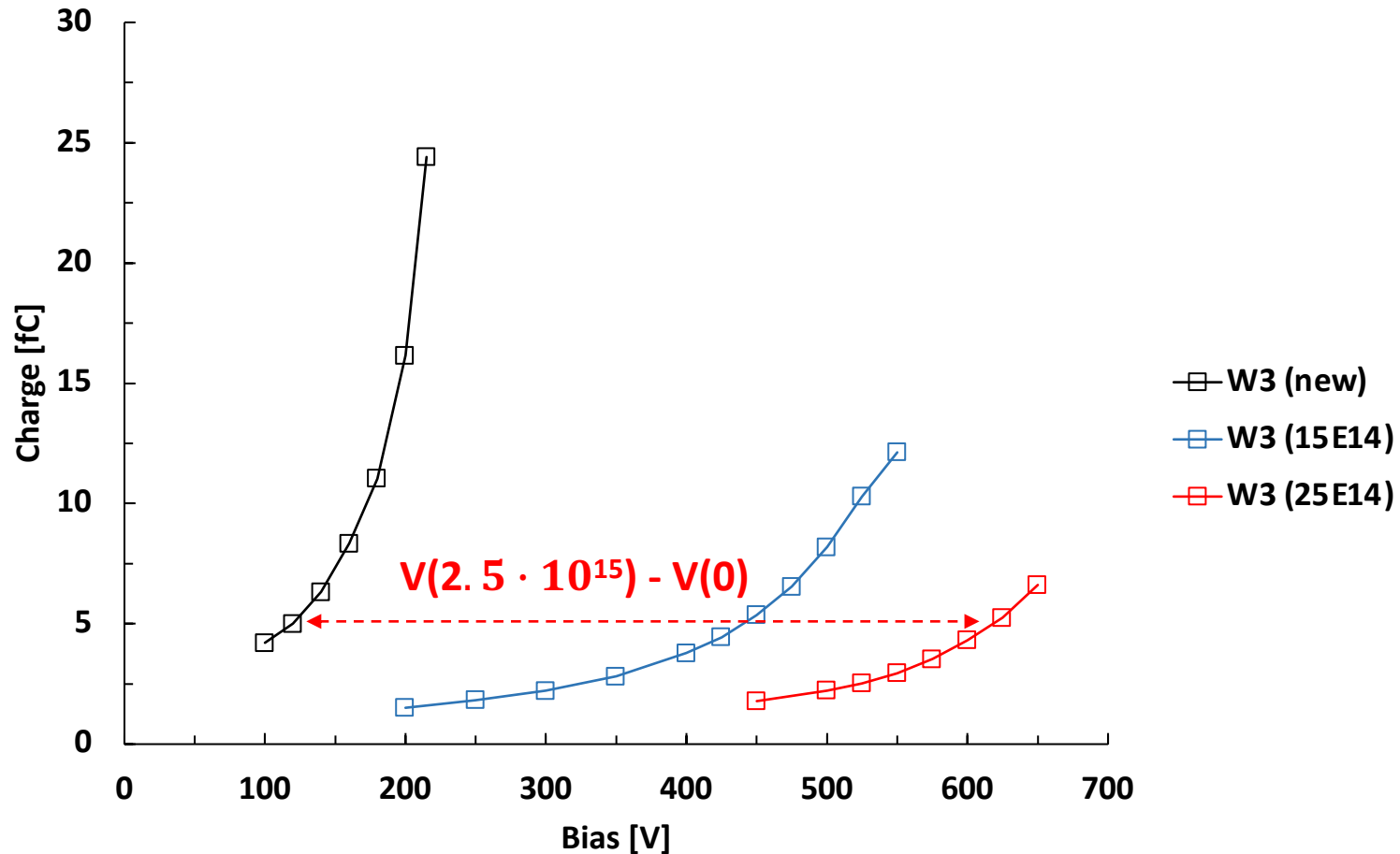
ΔV @ fixed value of charge

$$\Delta V(@ \text{ fixed } Q) = V(\phi) - V(0)$$

➤ ΔV computed at 5fC and at two fluences ($1.5 \cdot$ and $2.5 \cdot 10^{15}$ n_{eq}/cm^2)

Figure of merit for post-irradiation comparison

Carbon-shield LGAD - Unirr. and Irr. at 1.5 and 2.5E1015 neq/cm2



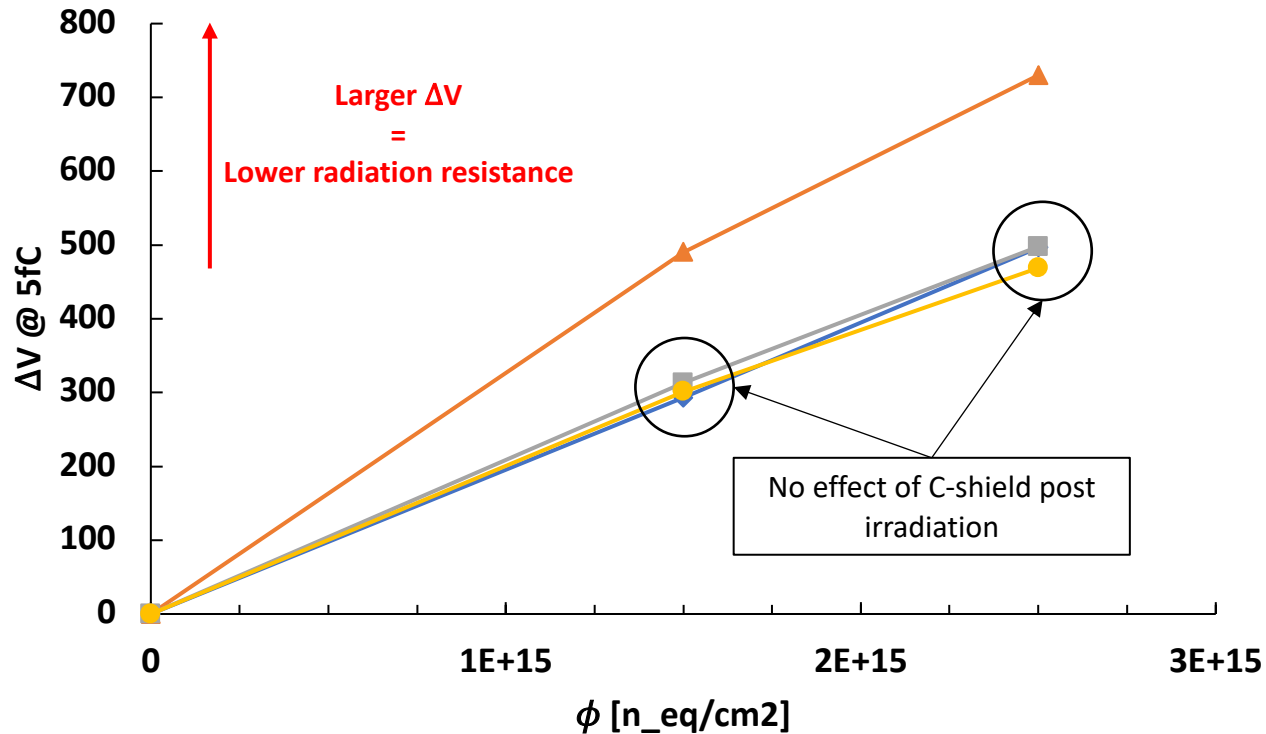
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Effect of Carbon-Shield on radiation hardness of LGADs

Carbon-Shield LGADs - ΔV @ 5fC



- ◆ W1
- ▲ W2
- W3
- W4

- The same value of ΔV (@5fC) for wafers 1, 3 and 4 demonstrates the ineffectiveness of carbon-shield
- W2 is less radiation resistant than W1/3/4. W2 demonstrates that the effect of the C-shield is not comparable with the carbon implanted into the gain region.

Wafer #	Thickness	p+ dose	C dose	C shield	Diffusion
1	45	1.14	1.0		CBL
2*	45	1.00		0.6	CBL
3*	45	1.16	1.0	0.6	CBL
4*	45	1.16	1.0	1.0	CBL

Conclusion and hypothesis of ineffectiveness of C-shield

- Carbon-shield doesn't improve the radiation hardness of LGADs.

hypothesis of ineffectiveness of C-shield:

- Carbon shield doesn't screen the drift of bulk defects from the bulk towards the gain implant
- The acceptor removal is a localized mechanism; only defects created in the gain region participate in acceptor removal mechanism.

Acknowledgements

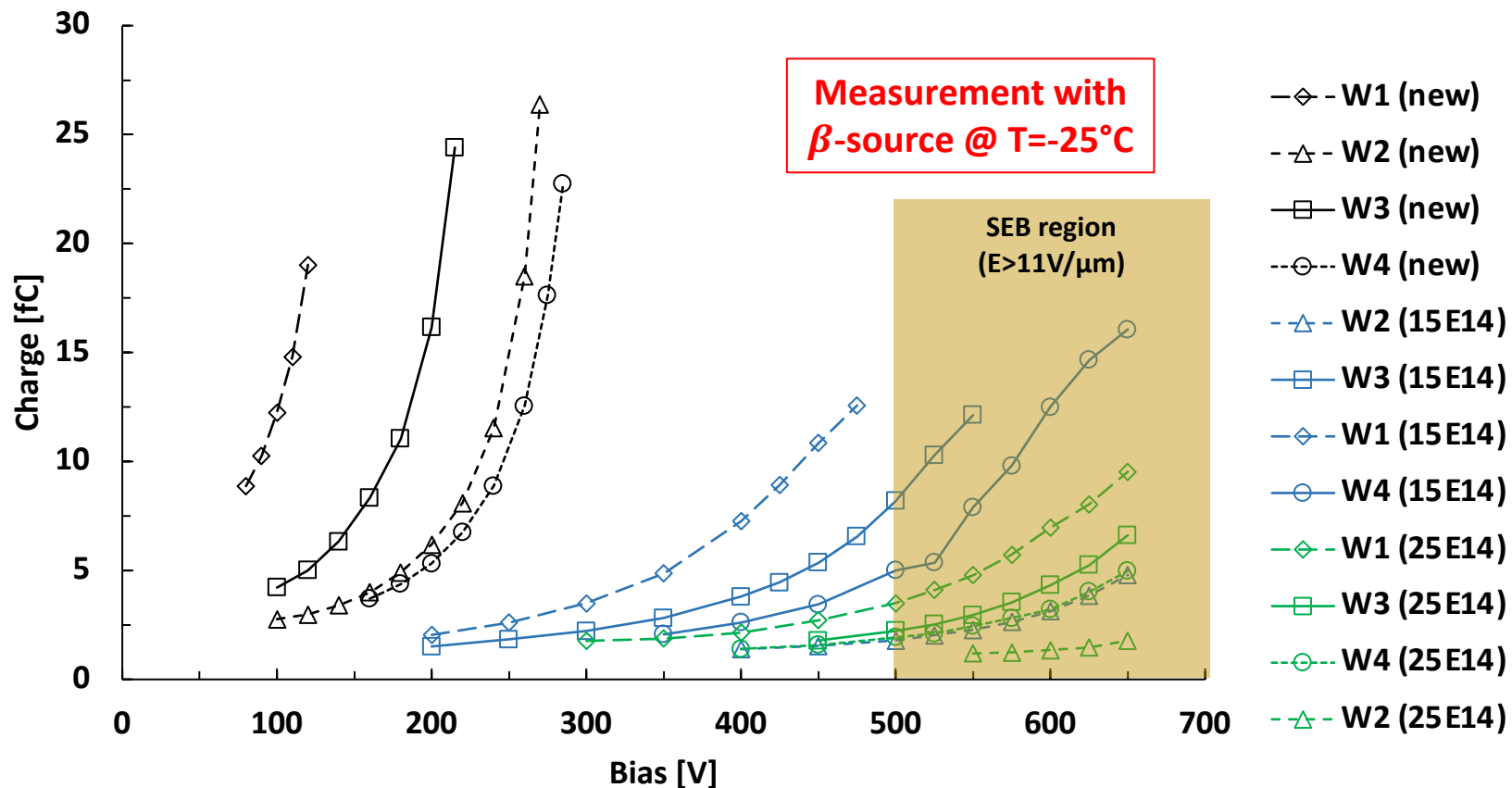
We kindly acknowledge the following funding agencies and collaborations:

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- RD50, CERN
- AIDAInnova, WP13
- Compagnia di San Paolo
- Ministero della Ricerca, Italia, PRIN 2017, progetto 2017L2XKTJ – 4DinSiDe
- Ministero della Ricerca, Italia, PRIN 2022, progetto 2022RK39RF – ComonSens
- European Union's Horizon 2020 Research and Innovation programme, Grant Agreement No. 101004761

Backup

Post-Irradiation CC measurements

Carbon-shield LGAD - UnIrr. and Irr. @ 1.5 and $2.5 \times 10^{15} \text{ n}_{\text{eq}}/\text{cm}^2$

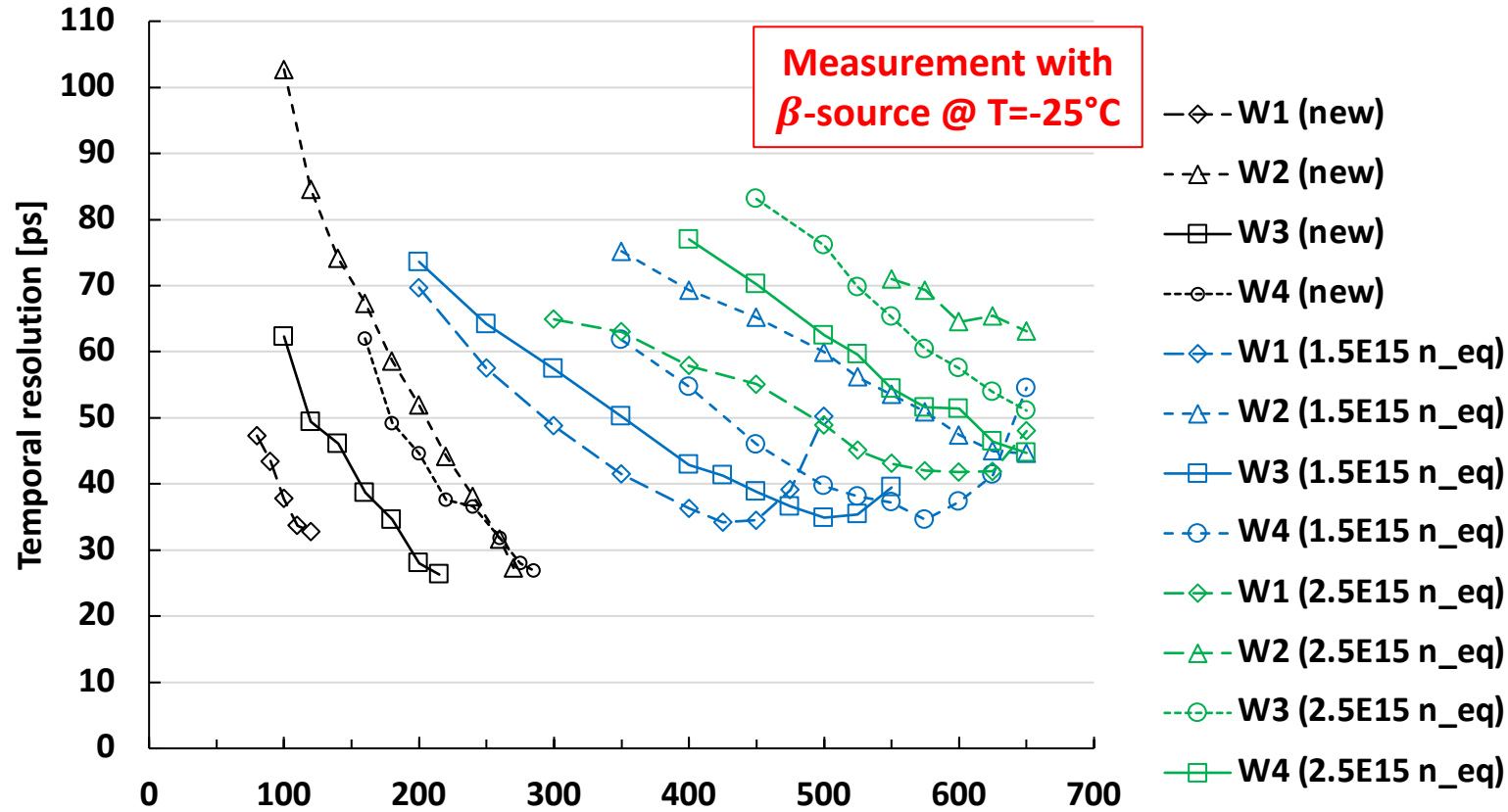


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Time resolution

Carbon-shield LGAD - Unirr. and Irr. @ 1.5 and 2.5E1015 neq/cm2



Wafer #	Thickness	p+ dose	C dose	C shield	Diffusion
1	45	1.14	1.0		CBL
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