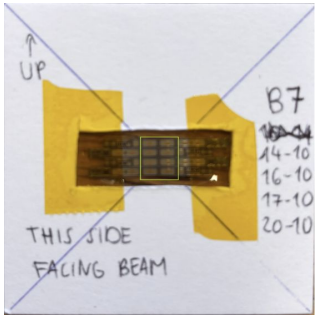
CYRIC 70 MeV measurements

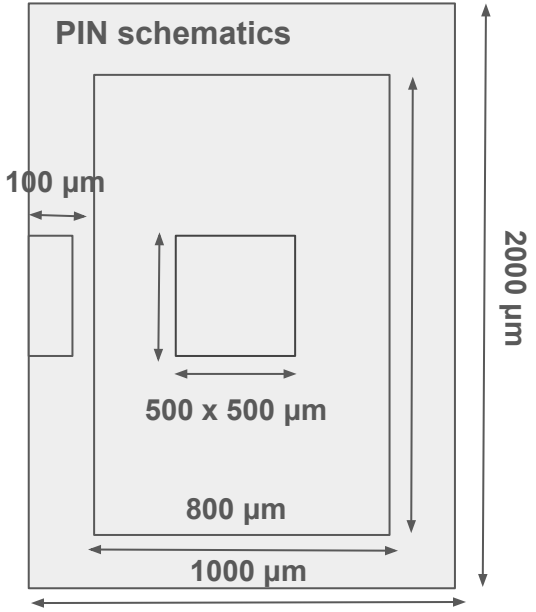




Calculation of the measured fluences:

- Φ_{eq} = ΔI (@ 20 ℃ annealed at 60 ℃ for 80 min) / αSd

ΔI is extracted from the current read at the V_{Fd} + 20 V (CV measurements of the PiN average is ~ 25 V)



α = 4 x 10^{-17} A/cm; S = 2.1 x 0.8 mm^2 and d = 50 µm

- Reverse bias is applied through the backplane
- The central PIN electrode is connected to the electrometer input
- The guard ring is connected to the voltage-source return (LO) and maintained at the same potential as the PIN electrode.

- Beam current: 1–1000 nA @ -15 ℃
- Beam diameter: ~5 mmφ (68% beam containment; σ ≈ 1.66 mm assuming a 2D Gaussian)
- Fluence determination: Aluminium foil activation via Na24 activity measured using a germanium γ-ray detector.
- Hardness factor: κ = 1.52 (ATLAS ITk reference; 0.7 used by CYRIC).
- More detail here : https://iopscience.iop.org/article/10.1088/1748-0221/10/06/C06008

Mounted on glass fiber plate?

Nominal fluences → what they measured at CYRIC

		ID	Target Nuetron Fluence (cm-2)	Actual Nuetron Fluence (cm-2)	Na22 activity (Bq)	Be7 activity (Bq)
SK-2026-Jun-3	3	HGTD B6	2.2E+14	2.40E+14	1.68E+01	1.27E+01
SK-2026-Jun-4	4	HGTD B7-22-10	4.5E+14	4.44E+14	3.10E+01	2.34E+01
SK-2026-Jun-5	5	HGTD B7-14-10	7.5E+14	7.63E+14	5.33E+01	4.02E+01
SK-2026-Jun-6	6	HGTD B7-9-10	1.0E+15	1.14E+15	7.94E+01	6.00E+01

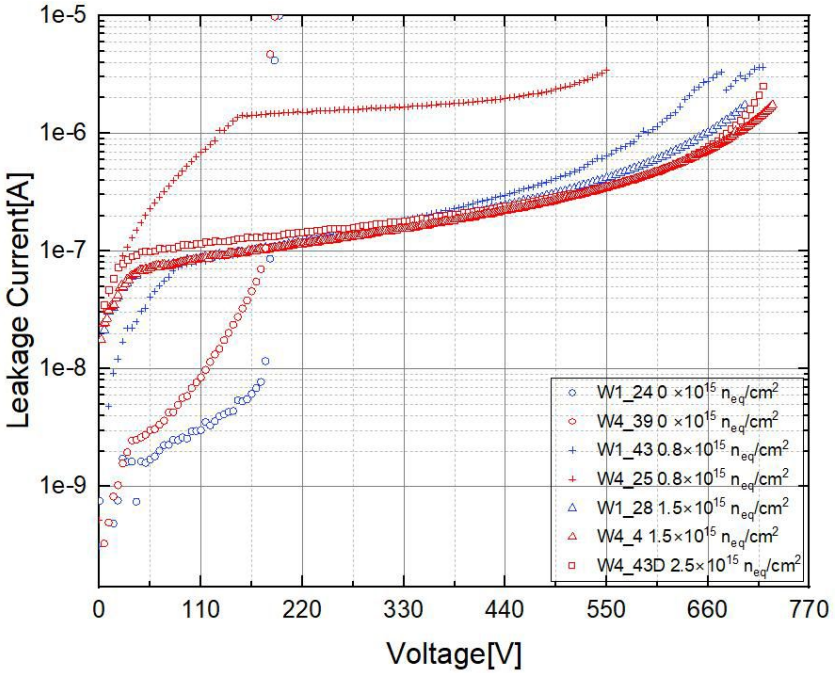
$$\Phi[1\,\mathrm{MeV n_{eq}/cm^2}] = \frac{N_{mes} e^{\lambda \Delta t}}{N_t \sigma \lambda E_{eff} \Gamma} \times 0.7$$

NOTICE!

Hardness factor: κ = 1.52 (ATLAS ITk reference; **0.7** used by CYRIC)

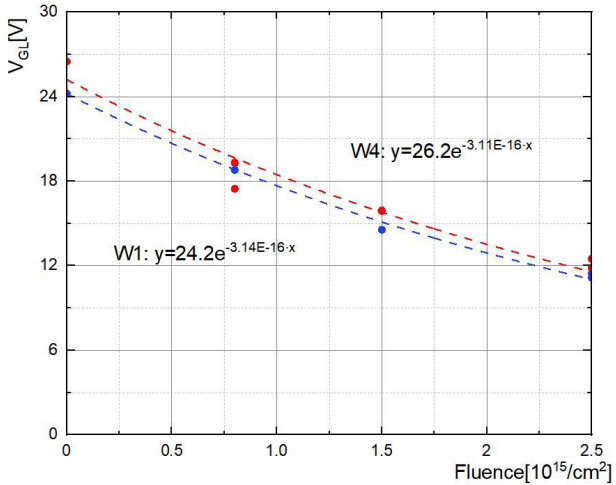
Comparison of results: China Spallation Neutron Source(CSNS)

- Beam energy: 80 MeV ; beam size: 20 x 20 mm^2



Here C_p = 3.15 !

wafer	p	n	c_p/c_n
W4	3.14	1.27	2.47
W1	3.11	1.06	2.93



Cardboard mounting → PIN leakage current and LGAD mapping

PIN: |I| at VFD + 20 V (µA)

PIN leakage curren 1×1 LGAD VGL

B6 · 1.5 × 10¹⁴ p/cm²

B6 8-10	PIN	0.400 µA	1×1 LGAD	—
B6 9-10	1×1 LGAD	23.77 V	PIN	0.395 µA
B6 10-10	PIN	0.400 µA	1×1 LGAD	23.93 V
B6 12-10	1×1 LGAD	23.97 V	PIN	0.397 µA

B7 · 3 × 10¹⁴ p/cm²

B7 22-10	PIN	0.740 µA	1×1 LGAD	23.27 V
B7 23-10	1×1 LGAD	23.25 V	PIN	0.733 µA
B7 24-10	PIN	0.704 µA	1×1 LGAD	23.47 V
B7 25-10	1×1 LGAD	23.13 V	PIN	0.718 µA

B7 · 5 × 10¹⁴ p/cm²

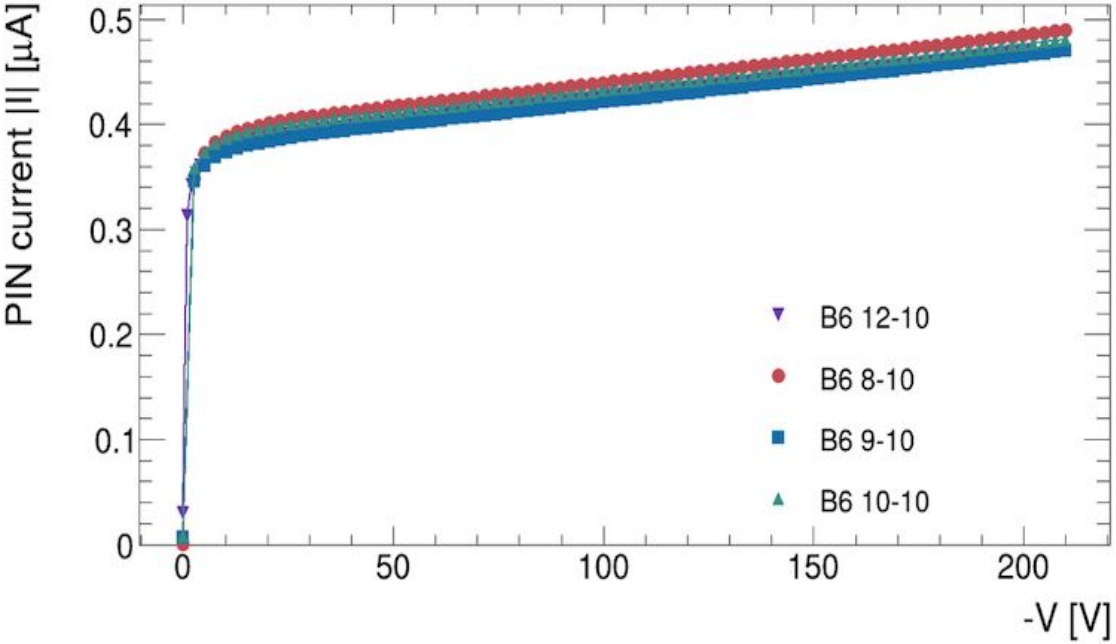
B7 14-10	PIN	1.233 µA	1×1 LGAD	22.10 V
B7 16-10	1×1 LGAD	22.20 V	PIN	1.200 µA
B7 17-10	PIN	1.250 µA	1×1 LGAD	22.17 V
B7 20-10	1×1 LGAD	22.00 V	PIN	1.095 µA

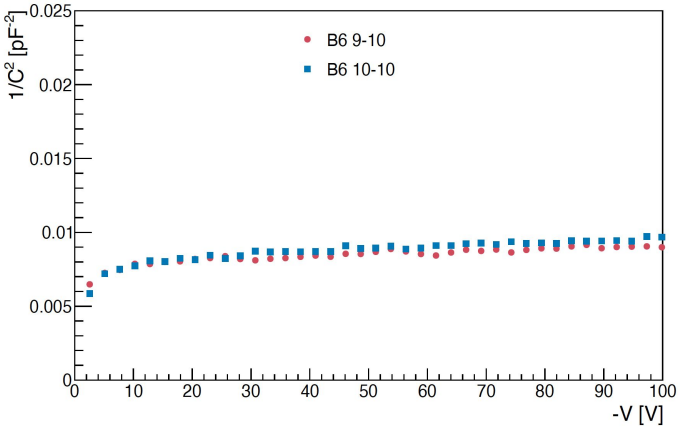
B7 · 7 × 10¹⁴ p/cm²

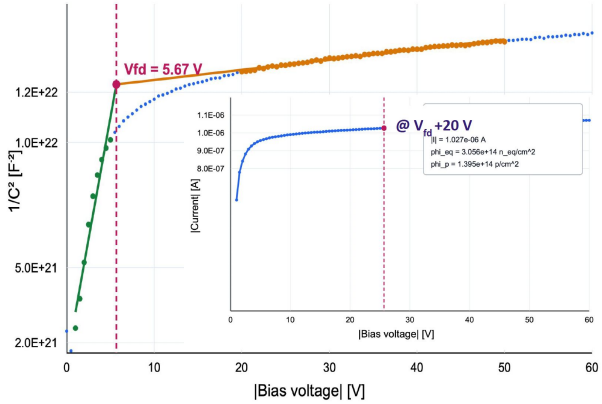
B7 9-10	PIN	1.600 µA	1×1 LGAD	21.37 V
B7 11-10	1×1 LGAD	21.47 V	PIN	1.600 µA
B7 12-10	PIN	1.800 µA	1×1 LGAD	21.00 V
B7 13-10	1×1 LGAD	21.43 V	PIN	1.550 µA

B6 irradiated to 1.5e14 p/cm^2

- Chuck was cleaned, different configurations of the setup were tested, settling time was tested, the other probe station was used for verification, the Ileah of the GR was measured, systematic studies were done as well





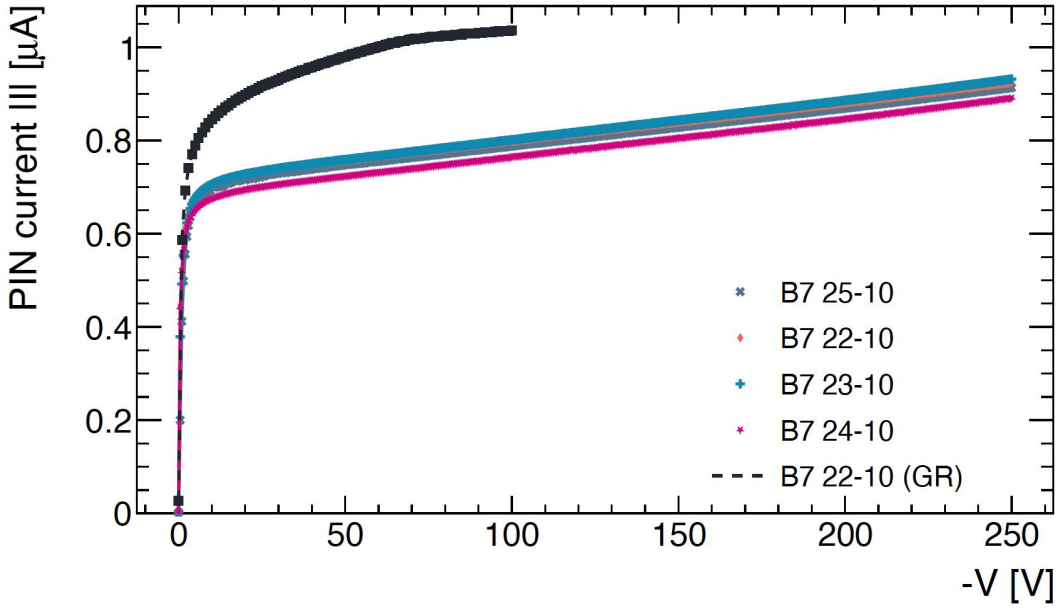


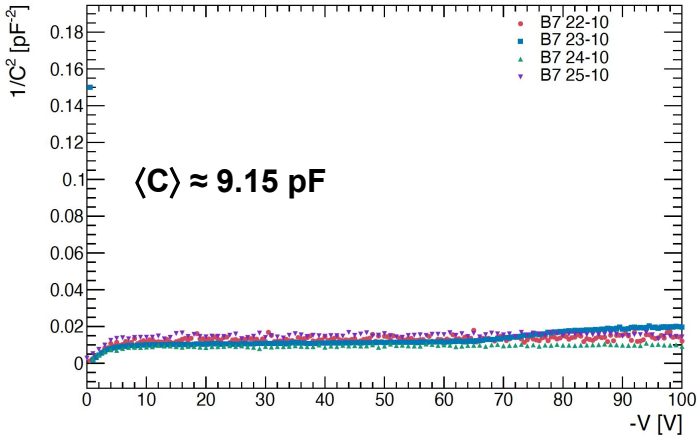
Reported fluence: **2.40 × 10¹⁴ neq/cm²** (CYRIC dosimetry)

Average measured fluence (4 samples): **⟨Φeq⟩ ≈ 1.19 × 10¹⁴ neq/cm²**

Observed variation from repeated measurements: ± 0.03 × 10¹⁴ neq/cm²

B7 irradiated to 3e14 p/cm^2





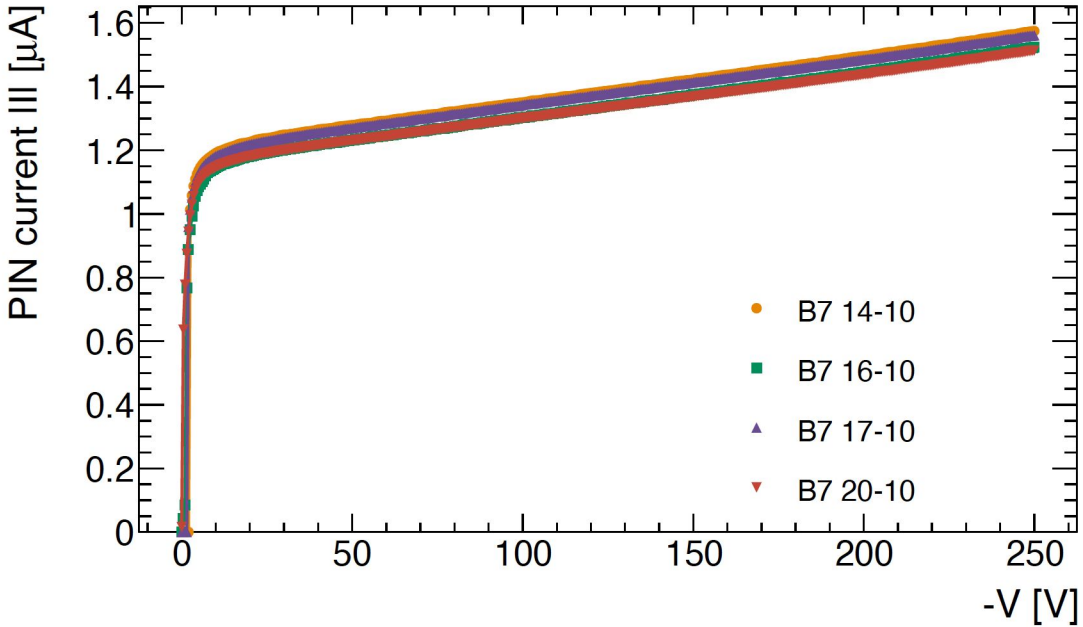
Reported fluence: **4.44 × 10¹⁴ neq/cm²** (CYRIC dosimetry)

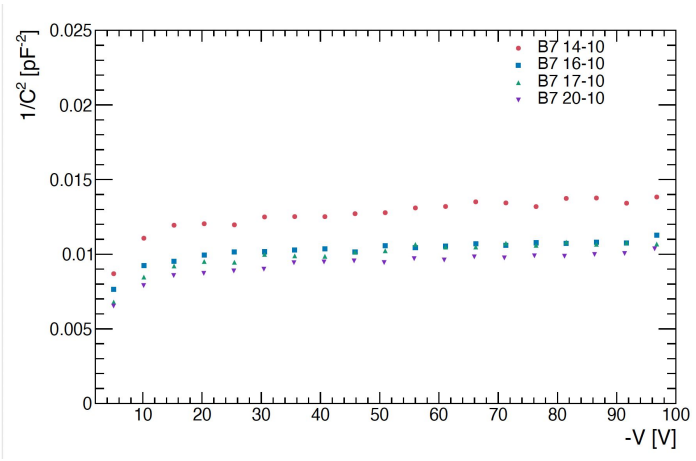
Average PIN-derived fluence (4 samples): **⟨Φeq⟩ ≈ 2.15 × 10¹⁴ neq/cm²**

Observed variation from repeated measurements: ~ ±0.07 × 10¹⁴ neq/cm²

- The guard-ring current was measured separately from the central PIN current.
- At approximately 100 V, I_{GR} *~1.03 μA* compared with I_{PIN} *~0.75 μA*
- The significant GR current suggests that current partitioning may influence the effective PIN collection area.
- The GR current may also contain surface and edge contributions → therefore, the active-area hypothesis remains unverified?

B7 irradiated to 5e14 ρ/cm²



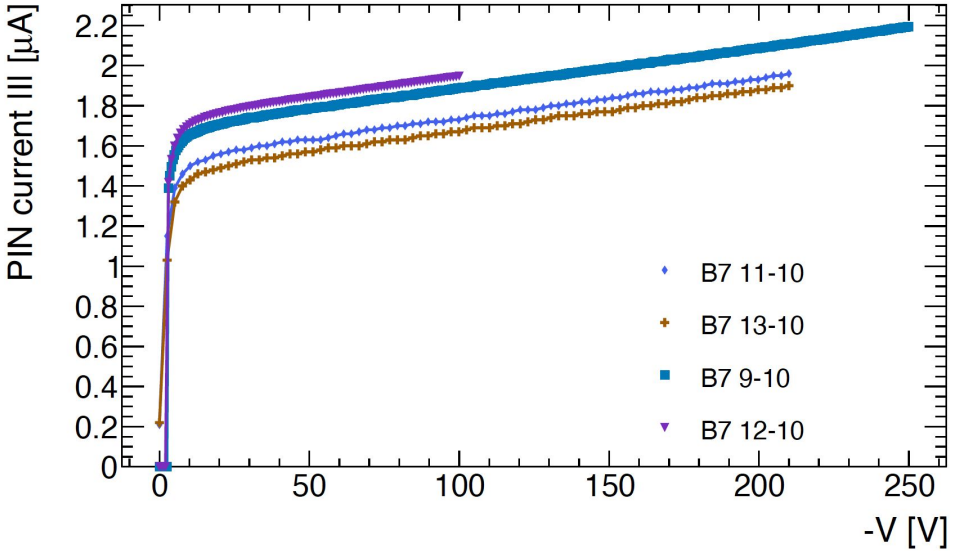


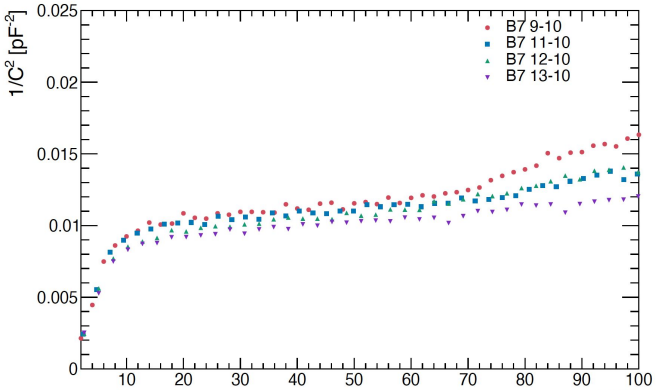
CYRIC-reported fluence: **7.63 × 10¹⁴ neq/cm²**

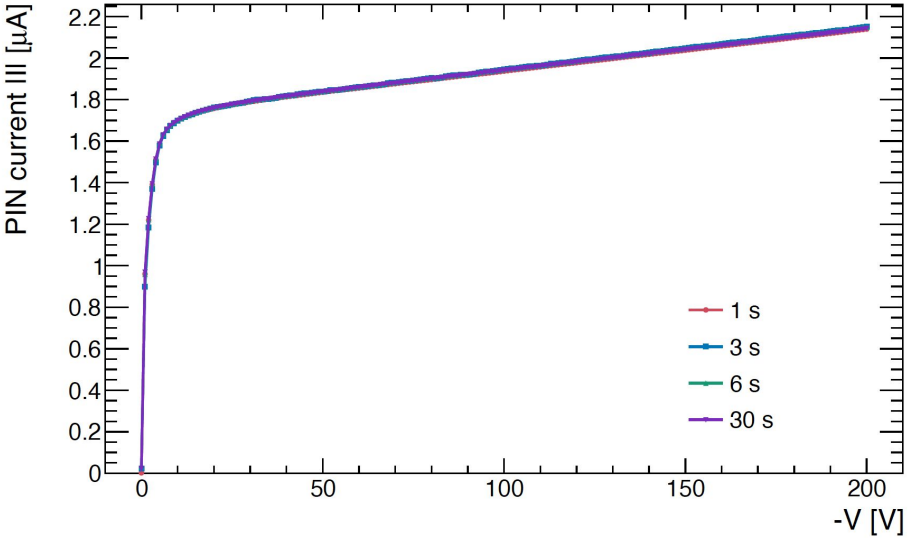
Average PIN-derived fluence (4 samples): **⟨Φeq⟩ ≈ 3.56 × 10¹⁴ neq/cm²**

Observed variation across repeated measurements: approximately ±0.46 × 10¹⁴ neq/cm²

B7 irradiated to 7e14 ρ/cm^2







CYRIC-reported fluence: **1.14 × 10¹⁵ neq/cm²**

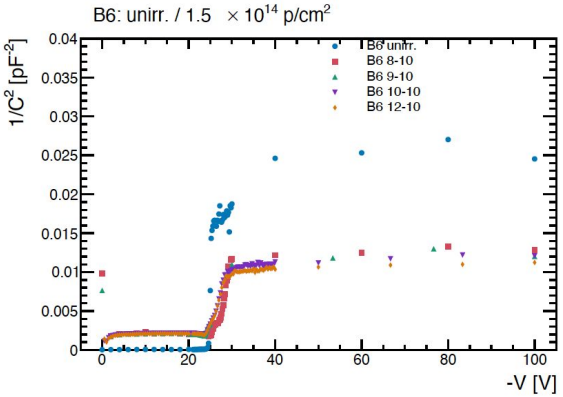
Average PIN-derived fluence (4 samples):

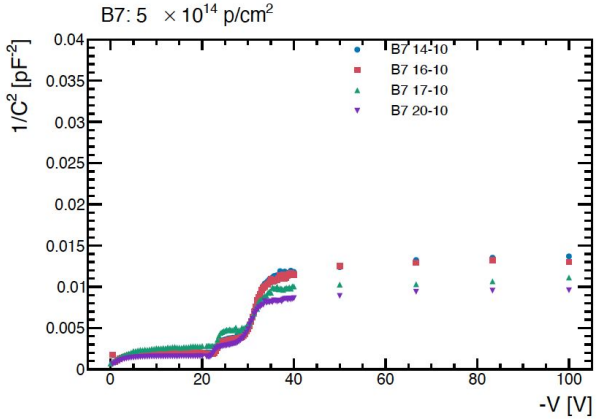
⟨Φeq⟩ ≈ 4.87 × 10¹⁴ neq/cm²

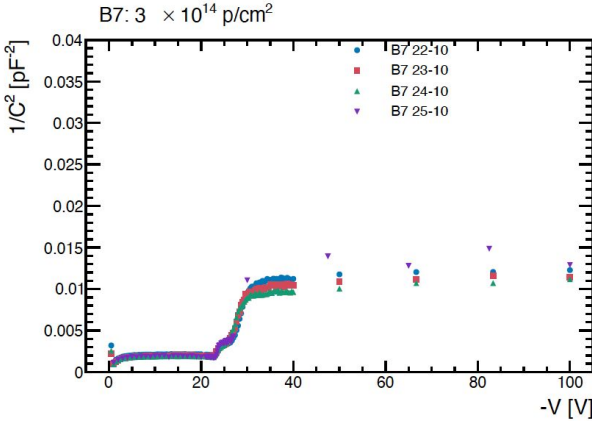
Observed variation from repeated measurements:
approximately ±0.45 × 10¹⁴ neq/cm²

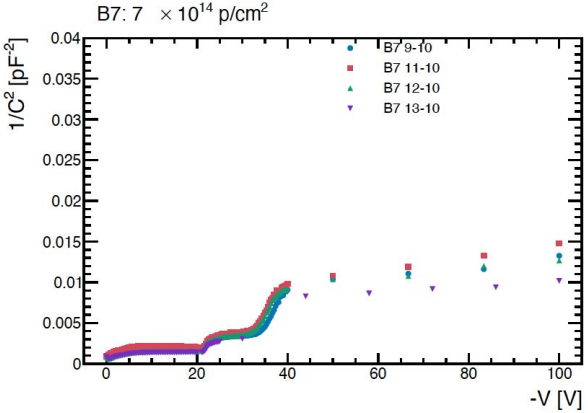
No significant settling-time dependence observed

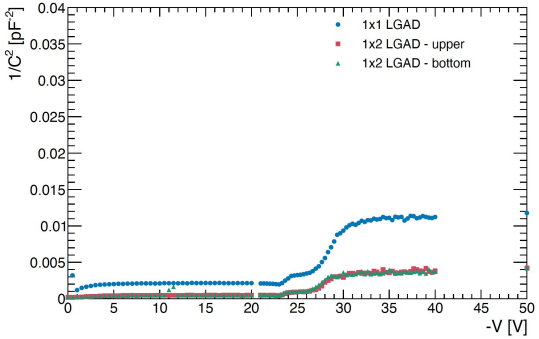
Depletion of the gain layer

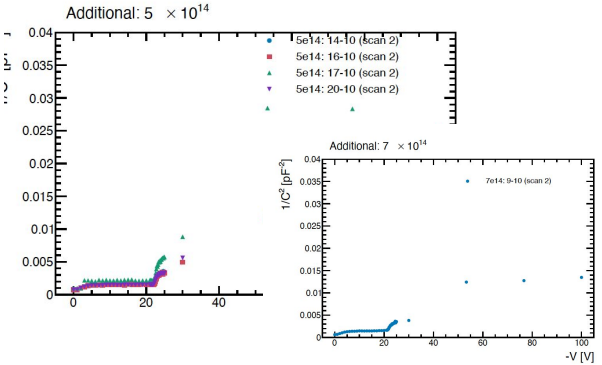








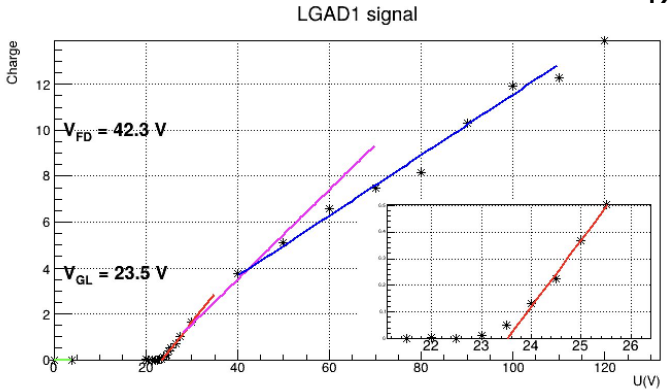


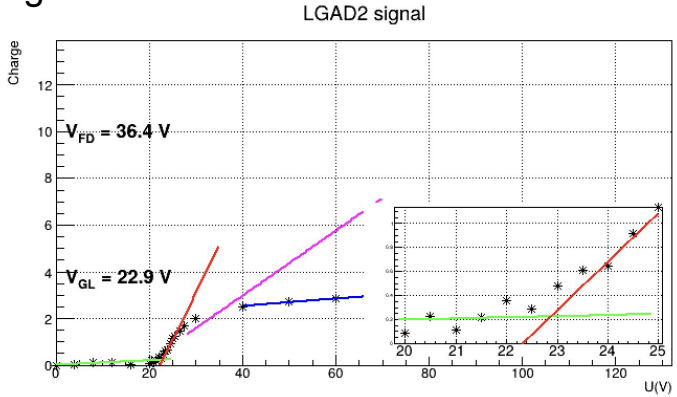


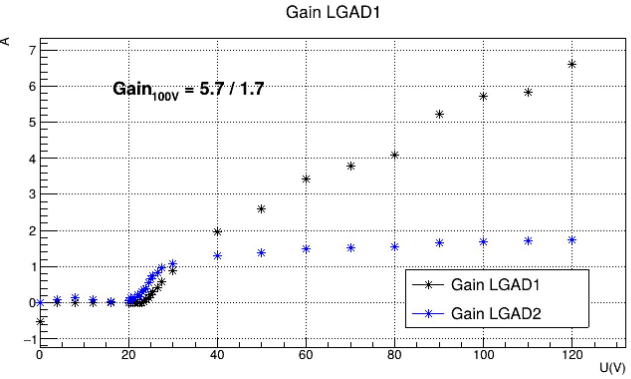
- Unirradiated : $V_{GL} \approx 25.0$ V
- 1.5×10^{14} p/cm²: $\langle V_{GL} \rangle \approx 23.89$ V
- 3×10^{14} p/cm²: $\langle V_{GL} \rangle \approx 23.28$ V
- 5×10^{14} p/cm²: $\langle V_{GL} \rangle \approx 22.12$ V
- 7×10^{14} p/cm²: $\langle V_{GL} \rangle \approx 21.32$ V

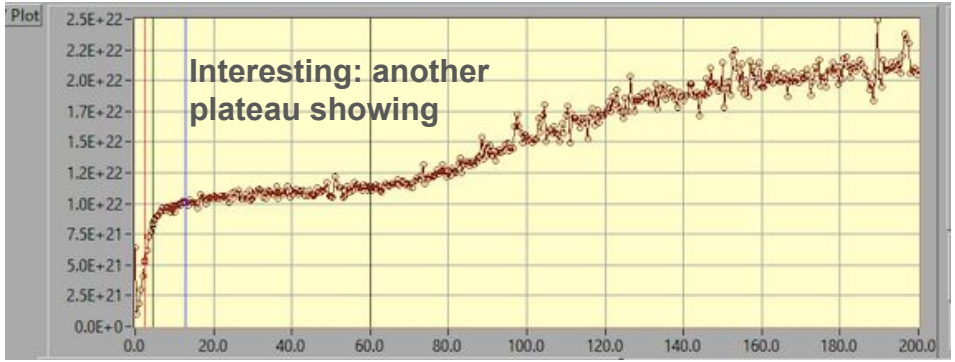
TCT results for B7 24-10 @ 2.15 × 10^{14} n_{eq}/cm^2

1x1 LGAD Vgl is ~ 23.5 V

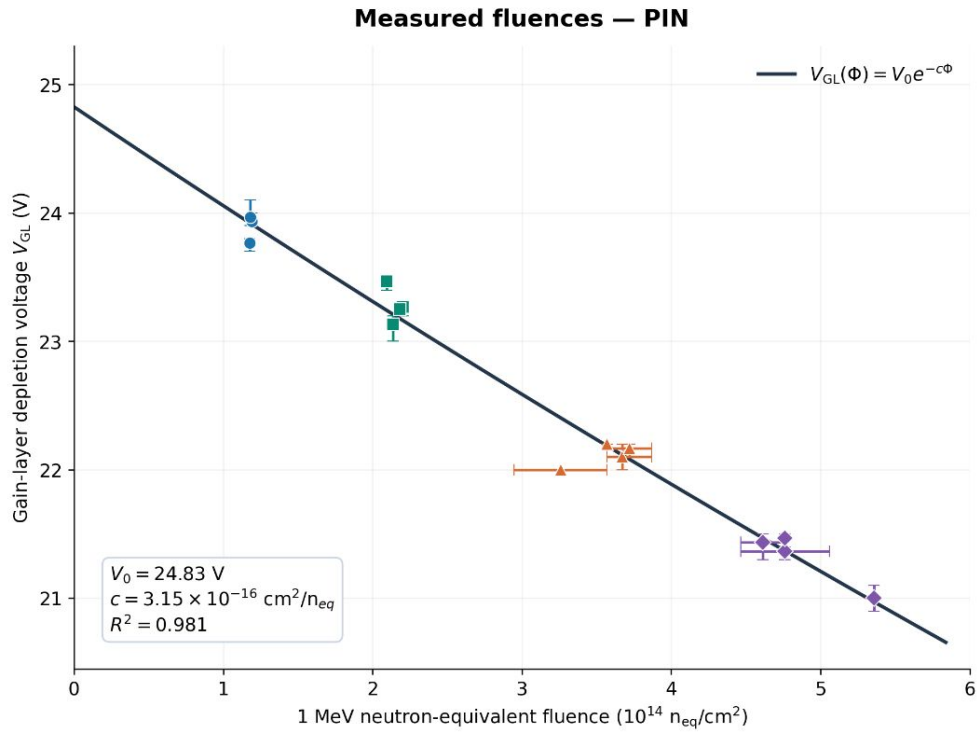


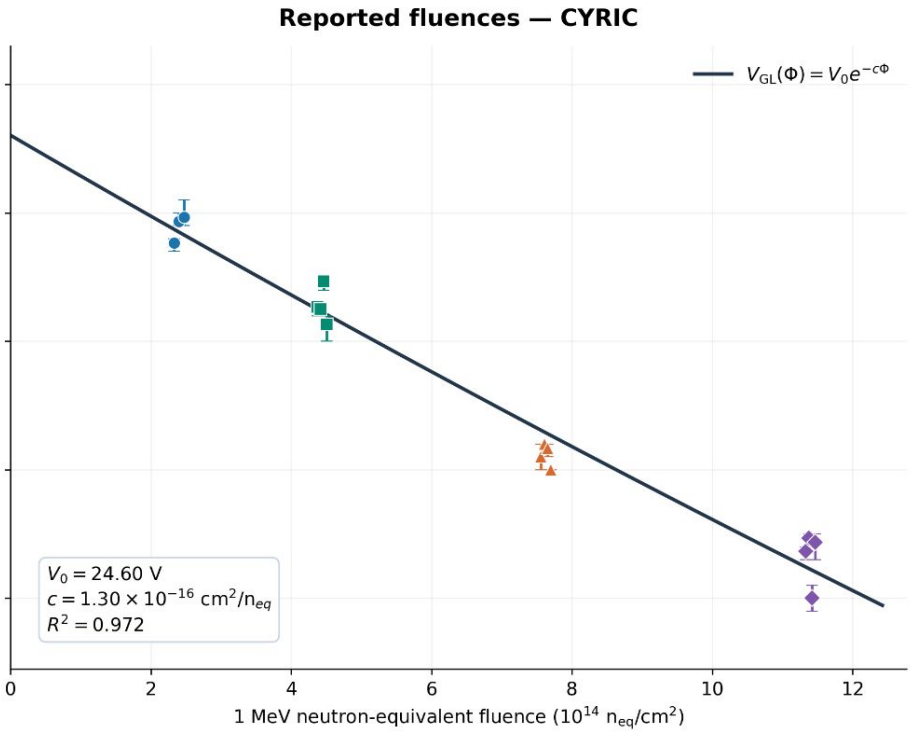




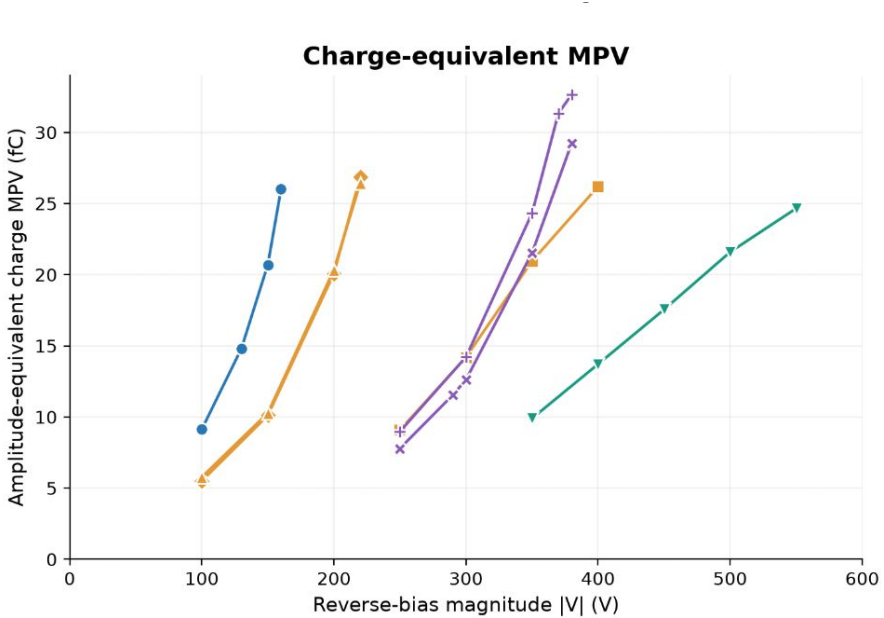


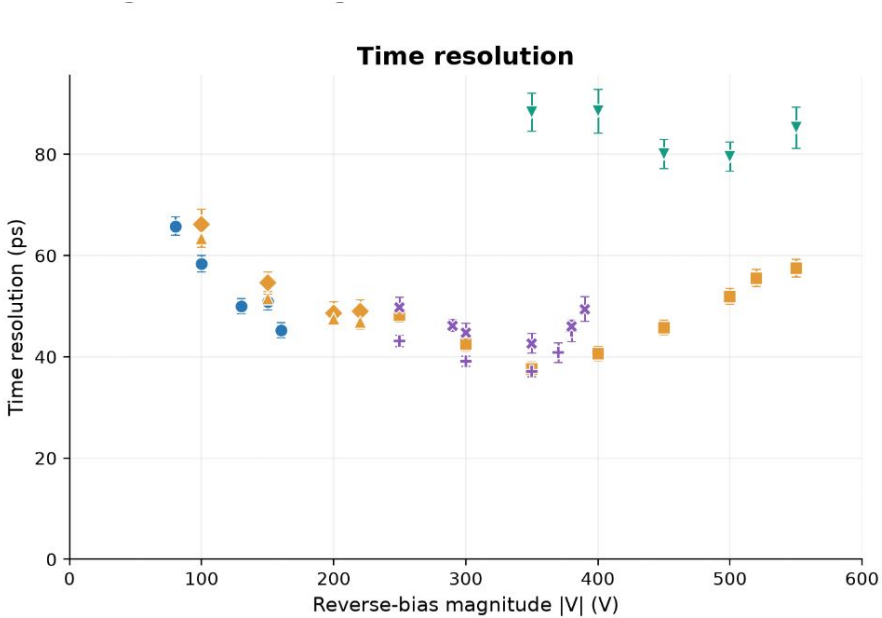
Acceptor removal





Collected charge and time resolution measurements





B6 12-10 (PIN 1.19)
B7 23-10 (PIN 2.15)
B7 23-10 retest (PIN 2.15)
B7 25-10 (PIN 2.15)
B7 17-10 (PIN 3.56)
B7 12-10 (PIN 4.87)
B7 11-10 (PIN 4.87)

Where could the CYRIC–PIN fluence discrepancy come from?

A consistent factor-of-two scale difference across four irradiation groups

OBSERVED **CYRIC / PIN = 2.02 – 2.34**

Both compared as 1 MeV neutron-equivalent fluences

01

Effective PIN current-collection volume

Assumed A = 1.68 mm²; the scales would require ~0.72–0.83 mm² if other factors are correct.

The central-electrode / guard-ring collection and depleted thickness should be verified?

02

Leakage-current damage calibration

The inferred fluence depends on ΔI, α, temperature correction and annealing history.

Is the temperature during annealing correct?

03

CYRIC fluence reporting / conversion

whether “actual neutron fluence” is already Φeq and which proton hardness factor was used.

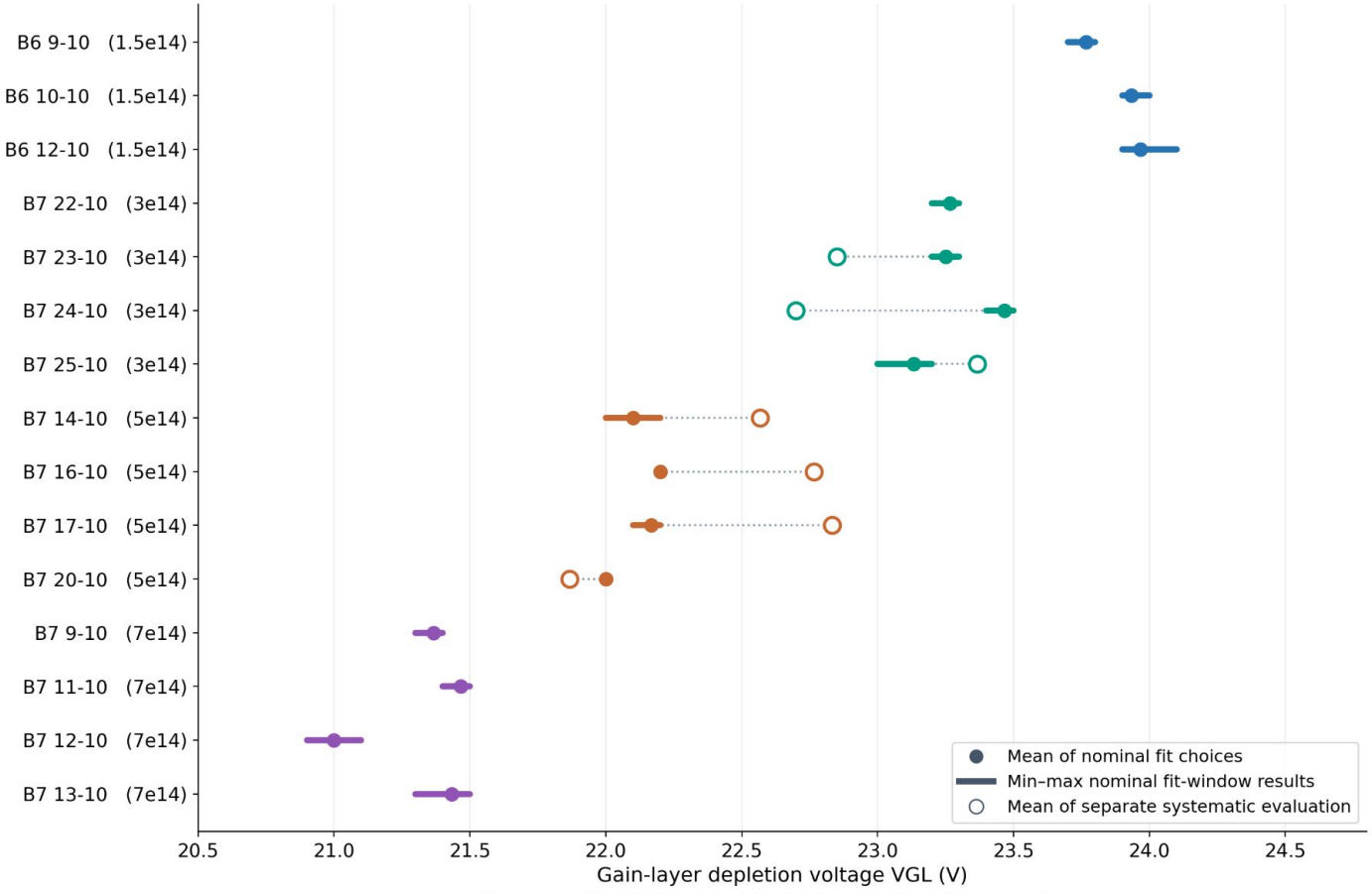
Request the original dosimetry definition, foil calibration and κ. The factor is important as different values are reported

04

Dose delivered to the mounted samples

Beam uniformity, sample positioning and spatial dose differences may contribute.

Cross-check irradiation map, sample layout and monitor-foil positions.


B6 9-10 (1.5e14)
B6 10-10 (1.5e14)
B6 12-10 (1.5e14)
B7 22-10 (3e14)
B7 23-10 (3e14)
B7 24-10 (3e14)
B7 25-10 (3e14)
B7 14-10 (5e14)
B7 16-10 (5e14)
B7 17-10 (5e14)
B7 20-10 (5e14)
B7 9-10 (7e14)
B7 11-10 (7e14)
B7 12-10 (7e14)
B7 13-10 (7e14)
Mean of nominal fit choices
Min–max nominal fit-window results
Mean of separate systematic evaluation
20.5
21.0
21.5
22.0
22.5
23.0
23.5
24.0
24.5
Gain-layer depletion voltage VGL (V)