News on radiation hardness studies for the CBM MVD

Tobias Bus, Benjamin Linnik, Michael Deveaux, Ali Yazgili

Institut für Kernphysik, Goethe Universität Frankfurt am Main

26.02.2018

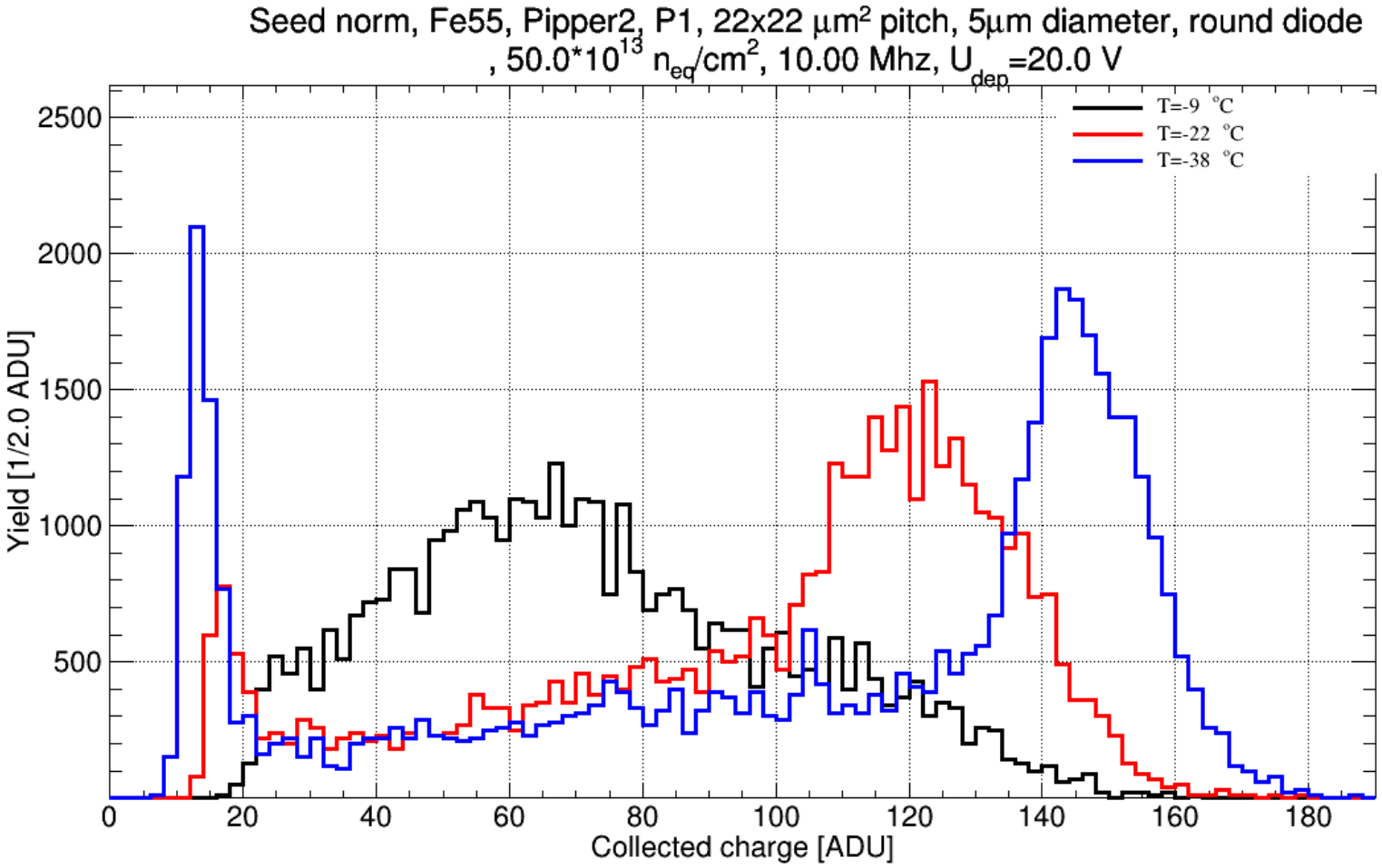
Leakage currents in MAPS

Leakage current:

- Adds shot noise
- May clear the signal from the pixel (more later)

Radiation tolerance: $5 * 10^{14} \frac{n_{eq}}{cm^2}$

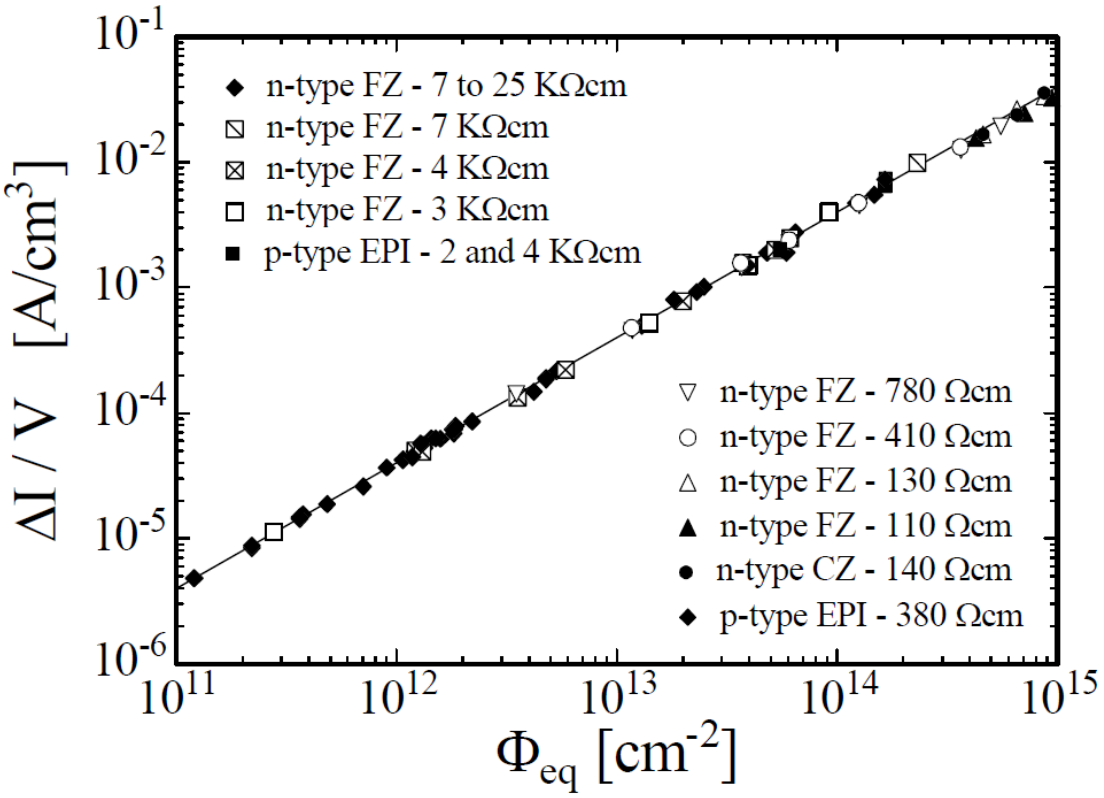
PIPPER-2: „Fully depleted“ MAPS with AC- coupling



Signal amplitude highly relies on temperature.
Charge clearing due to high leakage current?

Leakage current – What do we know?

Fully depleted PIN-diodes:



Which volume?

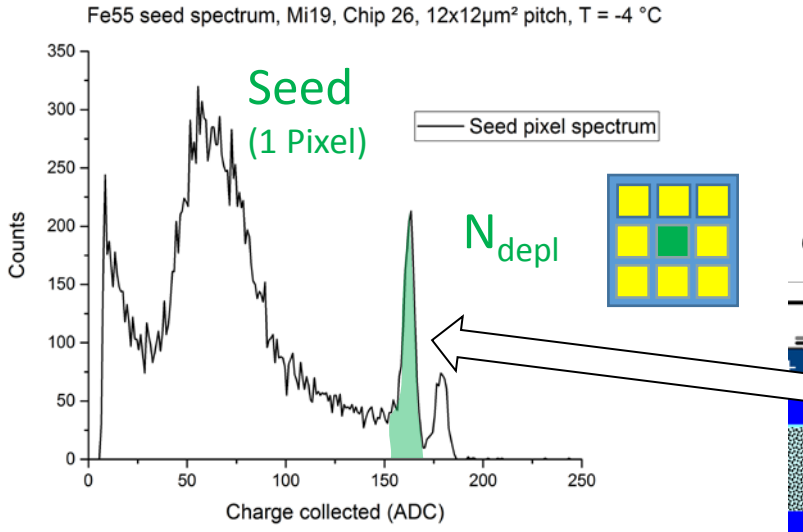
$$\Delta I = \alpha \cdot \Phi_{eq} \cdot V$$
$$\alpha \approx 4 \cdot 10^{-17}\ A/cm$$

Leakage current:
- scales with volume and radiation dose.
- does not depend on doping.

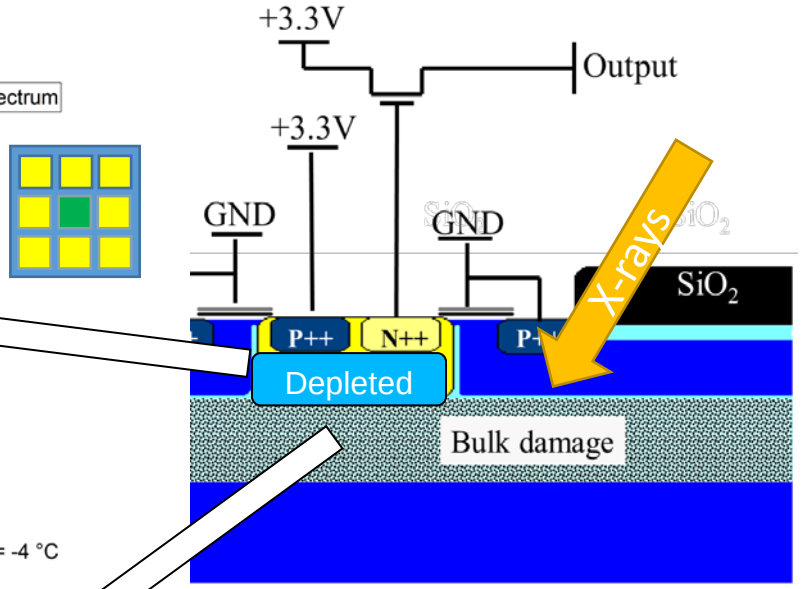
G. Lindström, NIM-A 512.1 (2004): 30-43

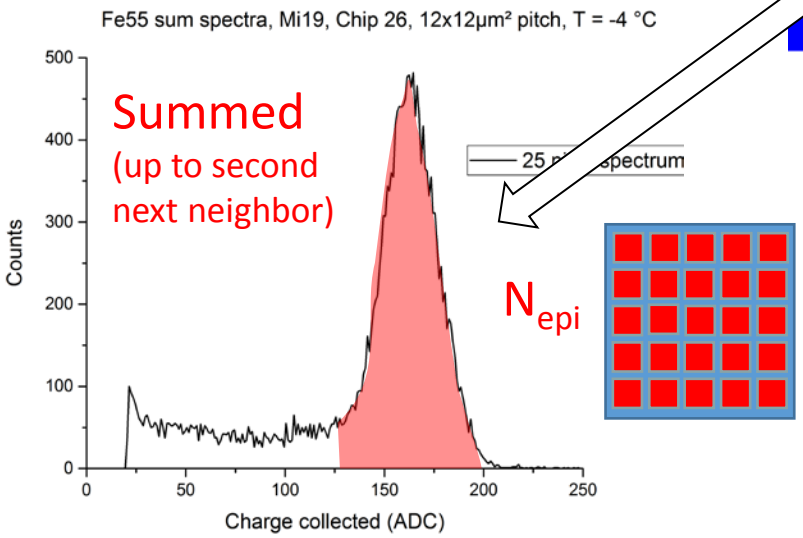
Known to hold for depleted sensors. MAPS are not (always) depleted.
⇒ Open issue: Valid for MAPS?
⇒ Measure leakage current

Open issue: How to measure depleted volume



N_{depl}





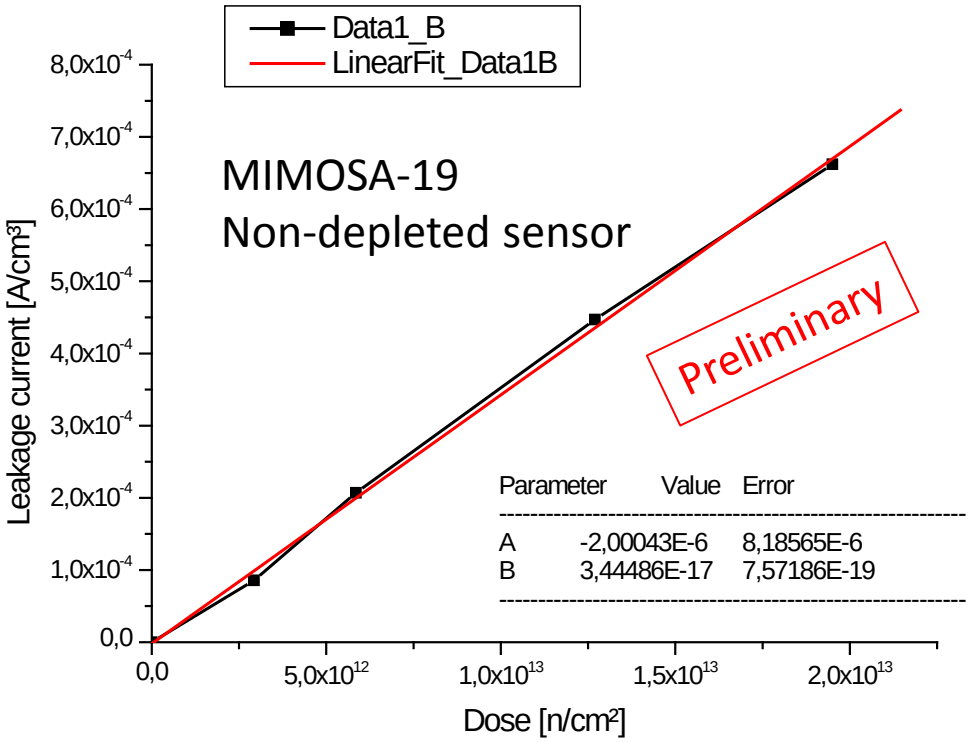
N_{epi}

Depletedvolume:

$$V_{depl} \approx \frac{N_{depl}}{N_{epi}} \cdot V_{pixel}$$

Known from design

Leakage current in MAPS?



Literature

$\alpha \approx 4 \cdot 10^{-17}\ A/cm$

Observed

$\alpha \approx 3.4 \cdot 10^{-17}\ A/cm$

Mismatch compatible with room temperature annealing.

Depleting also increases the leakage current

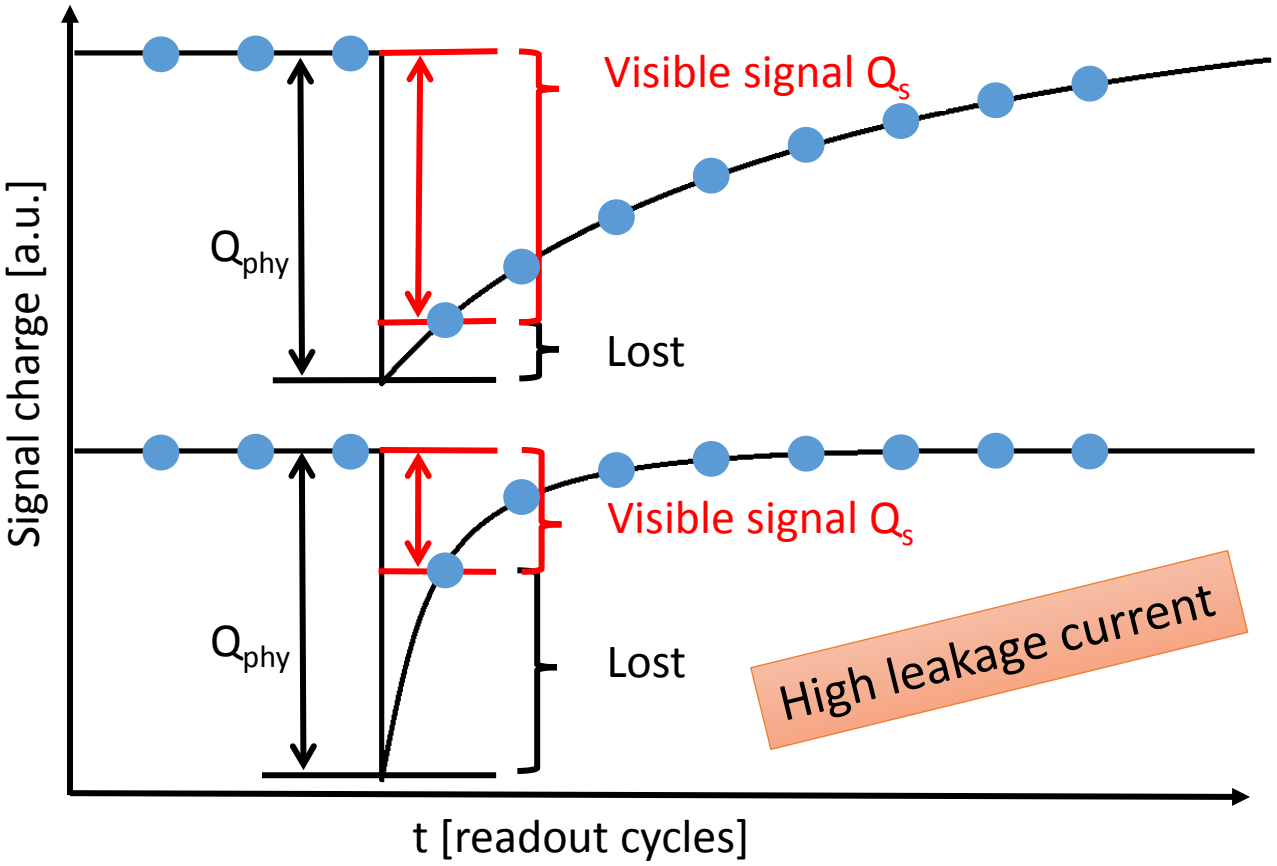
Depleted volume was used.

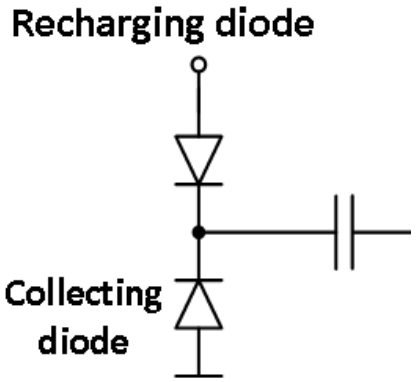
⇒ Epitaxial layer delivers mostly no leakage current.

⇒ Leakage current seems to scale with depleted volume.

Ali Yazgili, bachelor thesis, in progress

Leakage current in SB pixels





Collected charge

$$Q_S = Q_{Phy} \cdot \exp\left(-\frac{t}{\tau}\right)$$

Leakage current

$$\text{with } \tau \approx \frac{k_B\, T\, C}{e} \cdot \frac{1}{I_{leak}} \quad \text{with } C \approx 10 \text{ fF}$$

Requirementsfor good (>90%) signal:

$$\tau_{min} > 10\, t_{int} = 50\mu s$$

$$=> I_{Lmax} \approx 500 \text{ fA}$$

Clearing of the pixel is accelerated by radiation induced leakage current.
To obtain good signal leakage current must remain limited

Relevant for depleted sensors?

Estimate highest acceptable leakage current, e.g. for MAPS with 5µs integration time

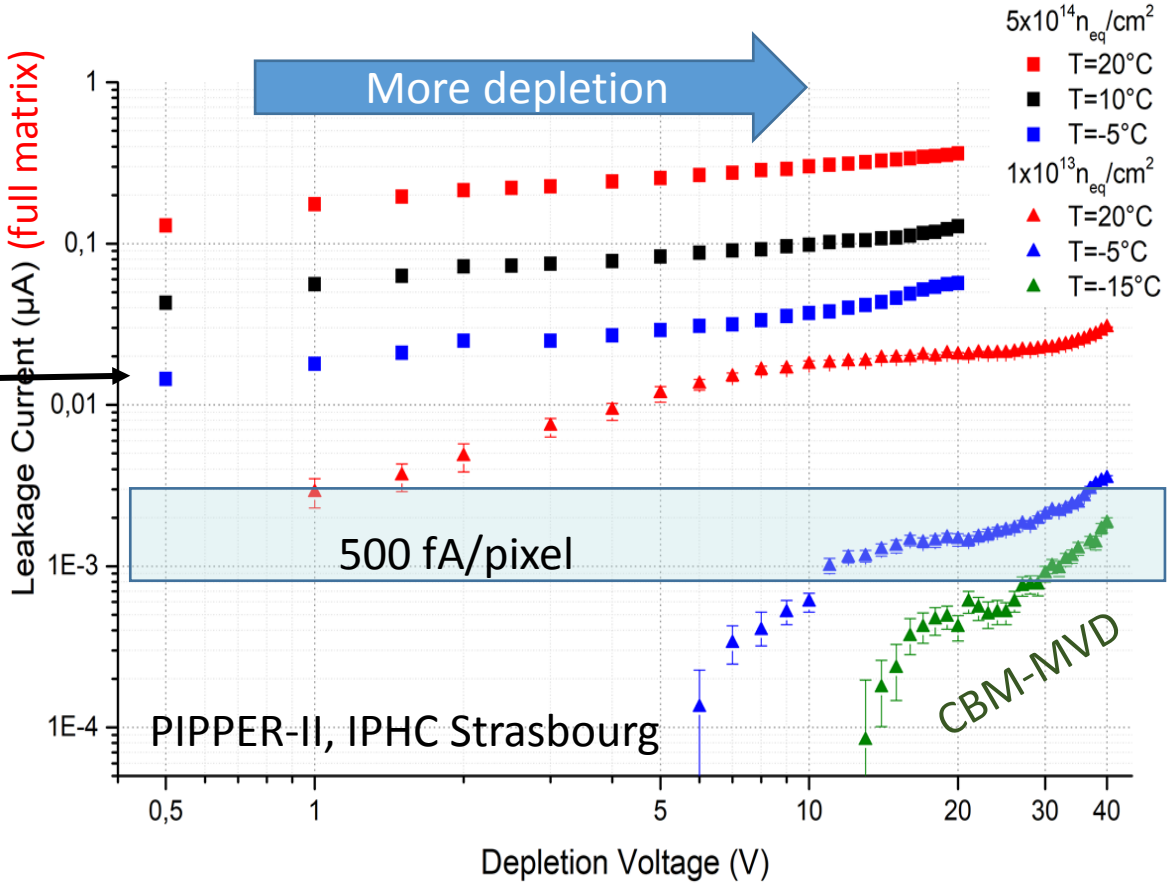
Requiredforgood>90% signal:

$$\tau_{min} > 10\ t_{int} = 50\mu s$$

$$=> I_{Lmax} \approx 500\ \text{fA} \pm \text{a factor}$$

Comparison with data:

- I_{leak} of heavily irradiated sensor exceeds limit.
- Cooling helps.



Conclusion: Depletion…

- Improves charge collection in heavily irradiated sensors.
- Increases leakage current of heavily irridiated sensors.

=> Fast readout and/or cooling is needed to exploit advantages.