# Charge Collection efficiency measurements on thinned FZ Si diodes irradiated with Li ions

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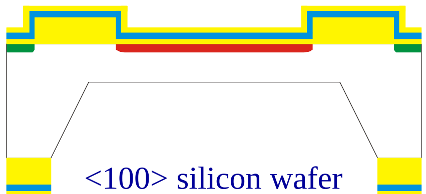
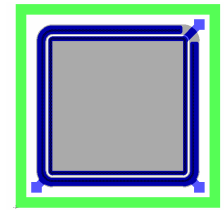
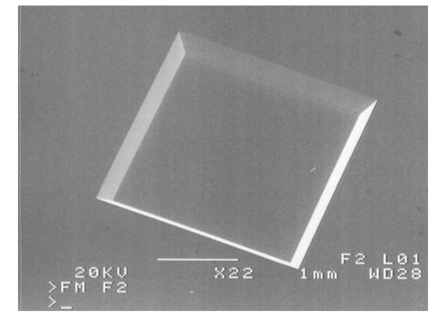
# SMART on FZ thinned devices (W=50-100 µm)

ITC-IRST, Trento

(E. Ronchin et al., NIM A 530 (2004) 134)






SEM: back view of a thinned device

Areas: 1 $mm^2$ - 20 $mm^2$ and I<1 $nA/cm^2$ at 20 V

1. Tetra Methyl Ammonium Hydroxide (TMAH) etching from back.
2. Phosphorous deposition and diffusion from back.
3. Metal deposition from back.

| charge collection efficiency studies | | | |
|---|---|---|---|
| **detector** | **thickness(mm)** | **Surface ($mm^2$)** | **devices** |
| **D50-1** | 50 | 3.5 | 1 |
| **D100-1** | 100 | 3.5 | 1 |
| **D300-1** | 300 | 3.5 | 2 |
| **D50-2** | 50 | 1.9 | 3 |
| **D100-2** | 100 | 1.9 | 3 |
| **D300-2** | 300 | 1.9 | 4 |

## First run

- FZ Si n-type, ρ> 6kΩcm
- Single Pad Diodes

**Second run on radiation hard materials planned in 2005**

## Irradiation performed on thin detectors

1. **58MeV Li ions in Padova, Legnaro, up to $64\times10^{12}$ Li/cm$^2$ (INFN Padova) equivalent to $5.4\times10^{15}$cm$^{-2}$ 24GeV/c protons.**

2. **SPS CERN with 24GeV/c p up to $10^{16}$cm$^{-2}$ on thinned detectors and epitaxial n-type 50mm, 50Wcm from ITME, processed by IRST-Trento. Detectors already irradiated, will be measured by the end of the year.**

### Thin diodes studied in this work

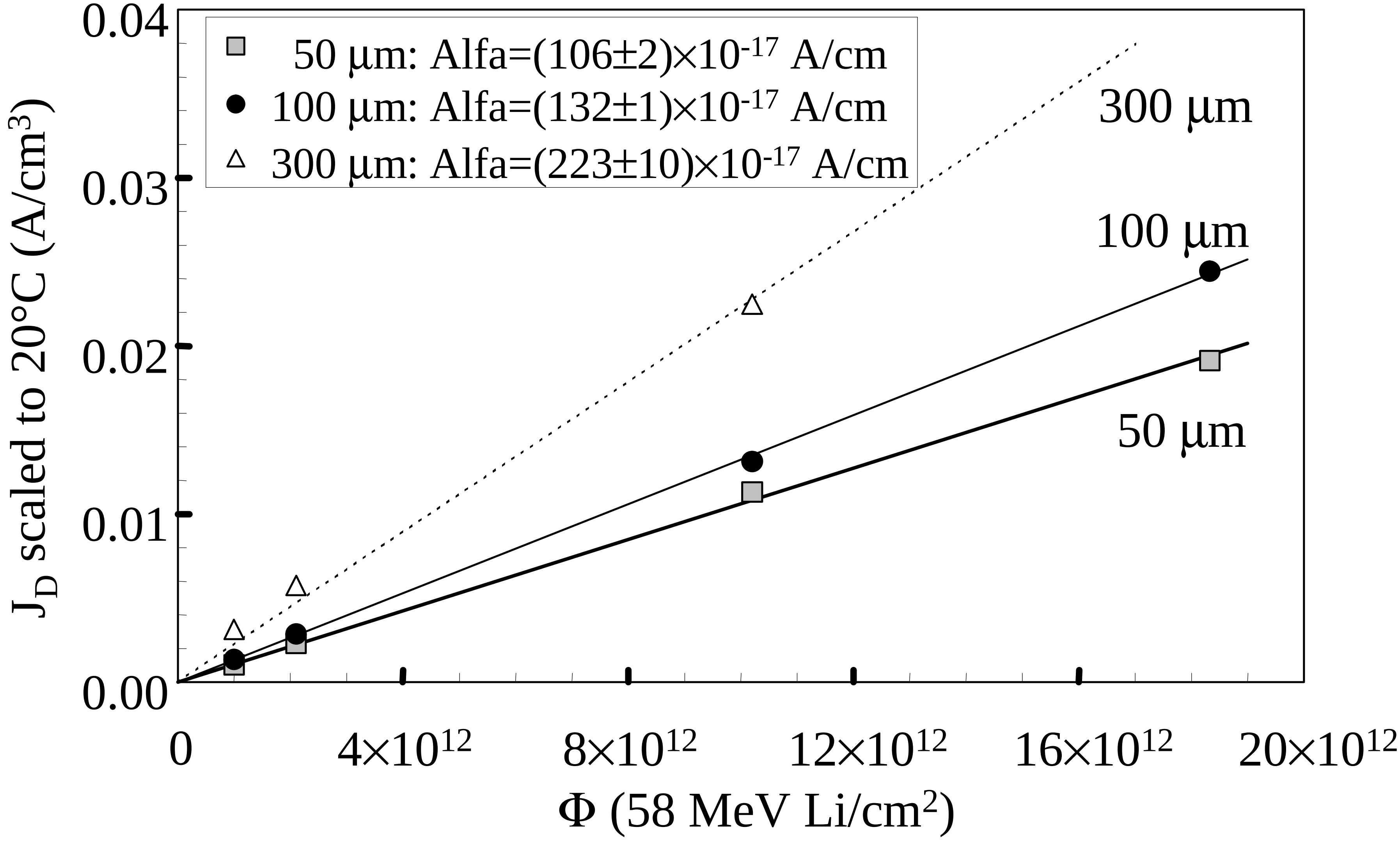
$10^{13}$ Li/cm$^2$ $\rightarrow$ 4.5 $\times10^{14}$ 1MeV n/cm$^2$ Padova Legnaro
$1.8\times10^{13}$ Li/cm$^2$ $\rightarrow$ $8.1\times10^{14}$ 1MeV n/cm$^2$

| Irradiated devices | | | |
|---|---|---|---|
| **detector** | **thickness(mm)** | **surface(mm$^2$)** | **devices** |
| **D50-2** | 50 | 1.9 | 1 |
| **D100-2** | 100 | 1.9 | 1 |
| **D300-2** | 300 | 1.9 | 2 |

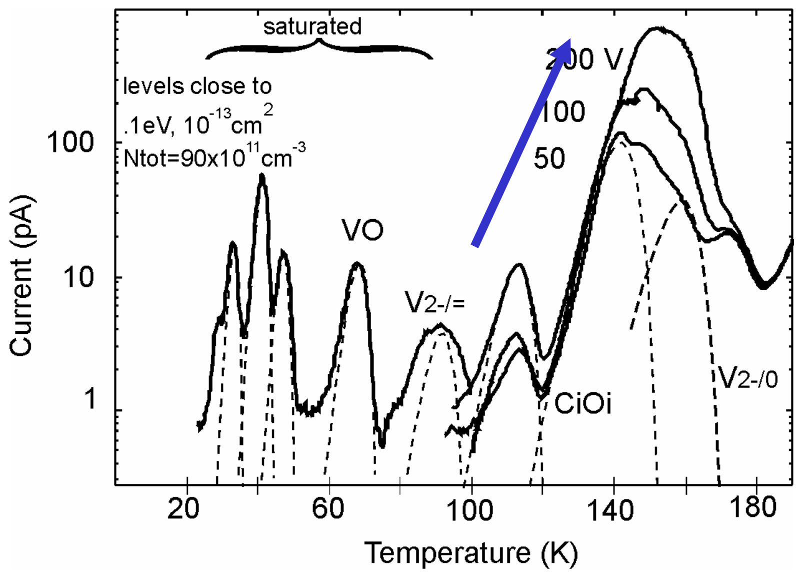
Annealing at *80°C* for *4* minutes
Stored at *-10°C*

*Hardness factor $Li^+$ vs. neutron: 45.08

# Scaling of leakage current after irradiation for different thickness
## Radiation hardness factor scales with dE/dx



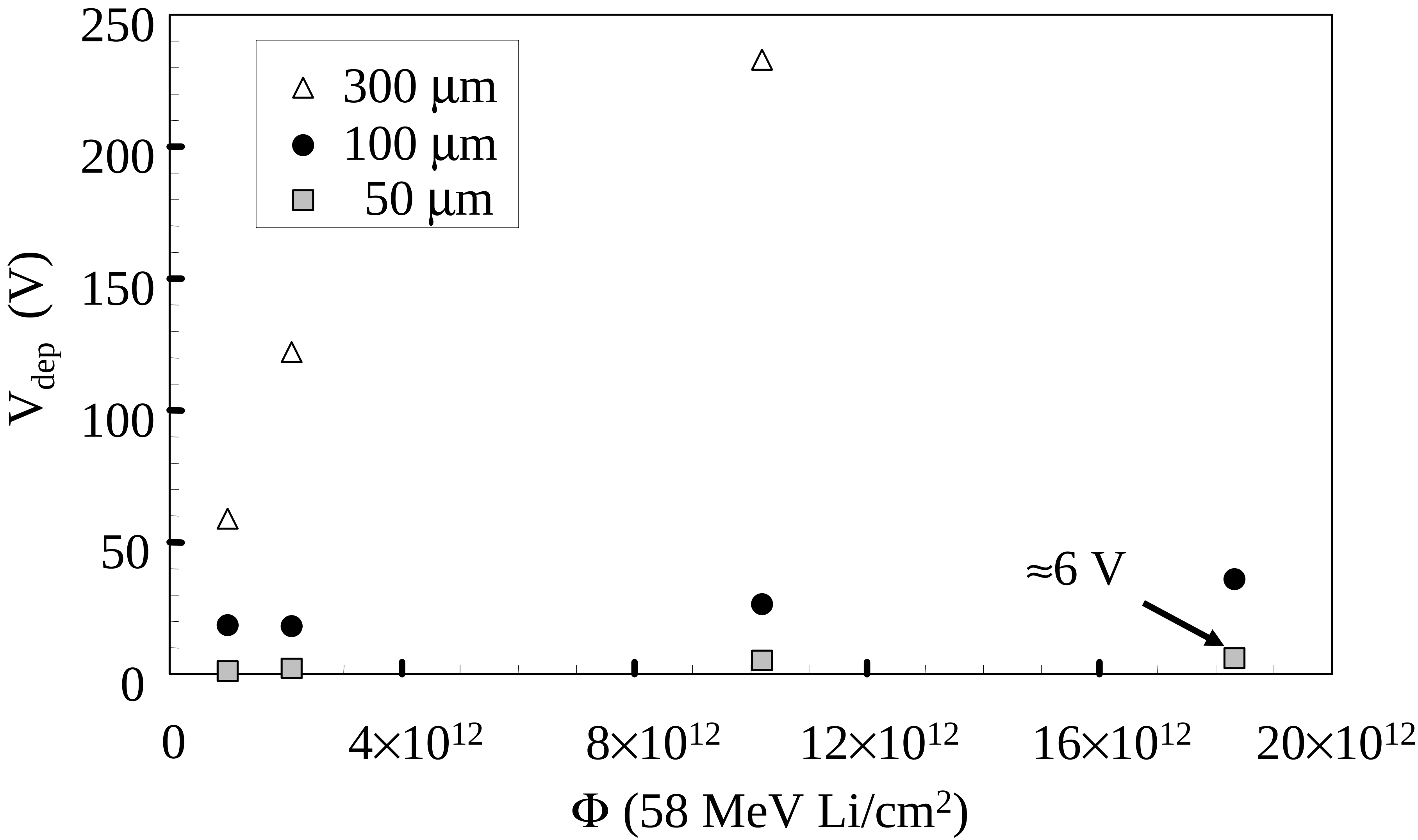
# Microscopic Analysis on thick Si irradiated with Li ions confirm this




**M. Scaringella et al., NSS 2004, Rome**

- **Non uniform damage along the thickness due to different dE/dx ® $V_2$ related defects concentration increases along thickness**

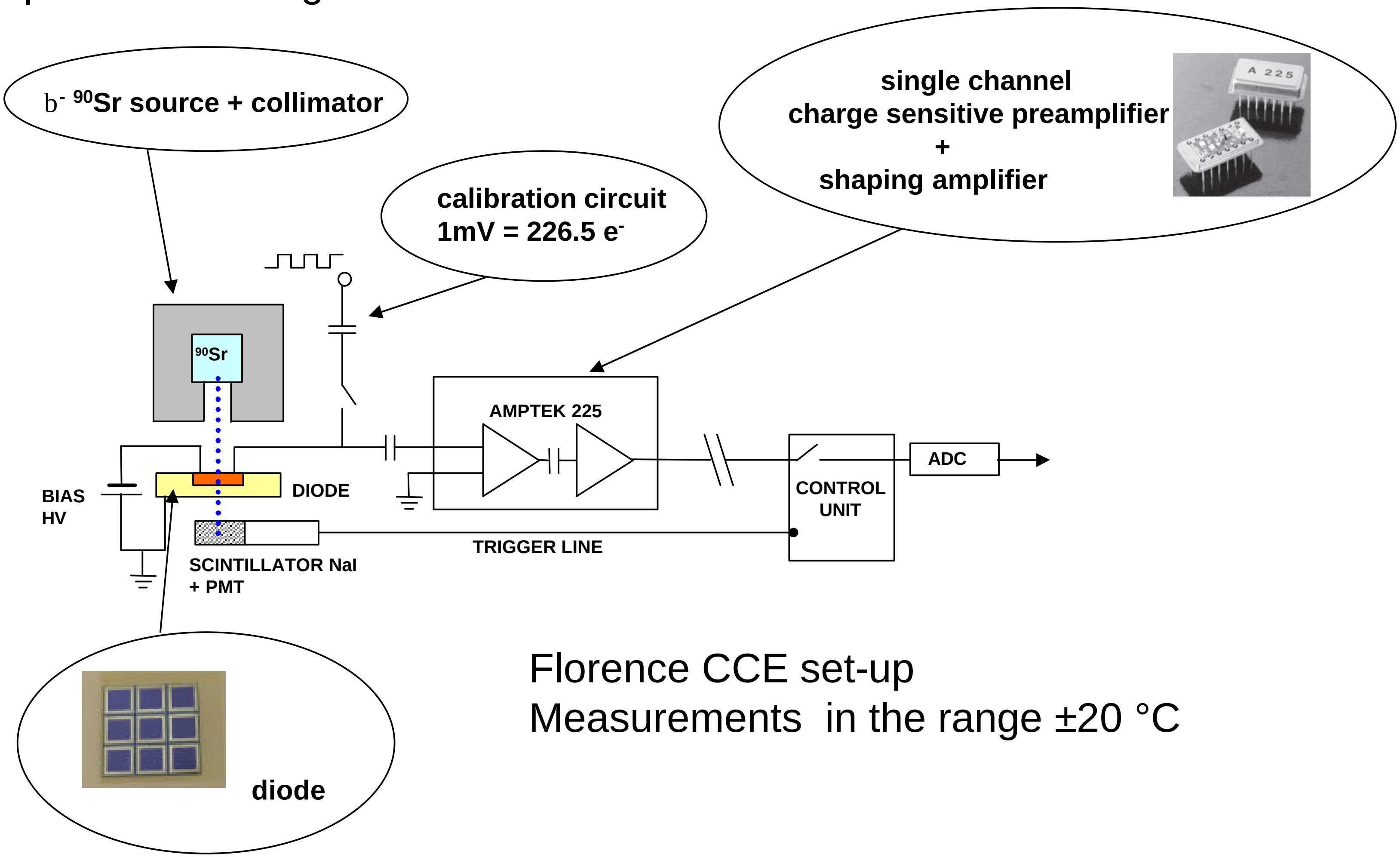
CV measured after irradiation + 4min at 80°C
F = 10kHz  T = ..°C



# Charge Collection Efficiency measurements

•It is a low noise charge integrator with
- shaping factor = 2.4μsec
- ENC = (280+5.6C/pF)e-

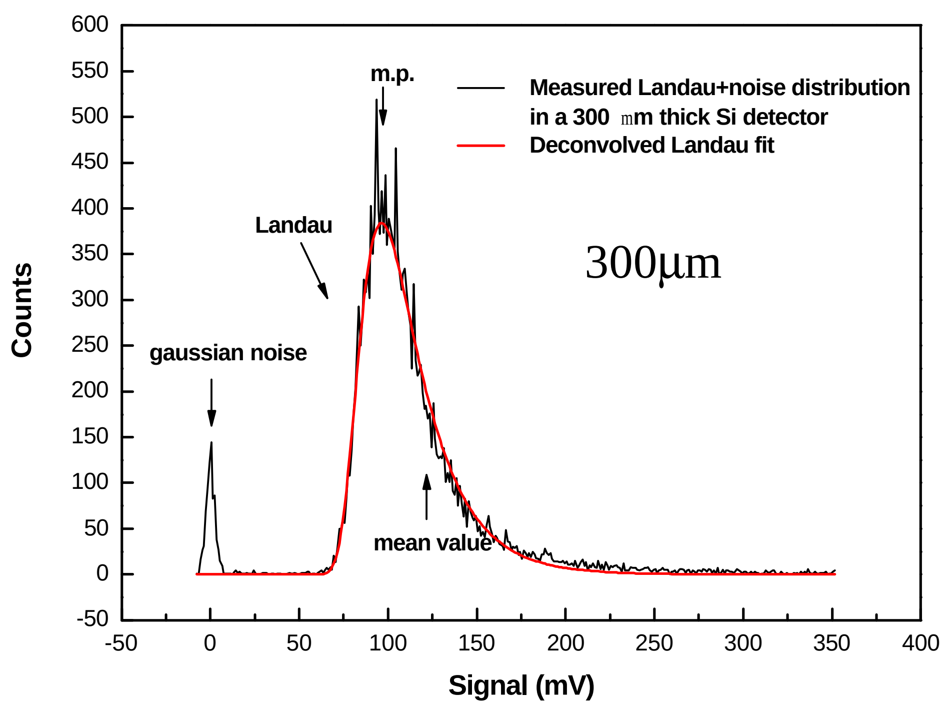
•It is optimized for single channel detectors

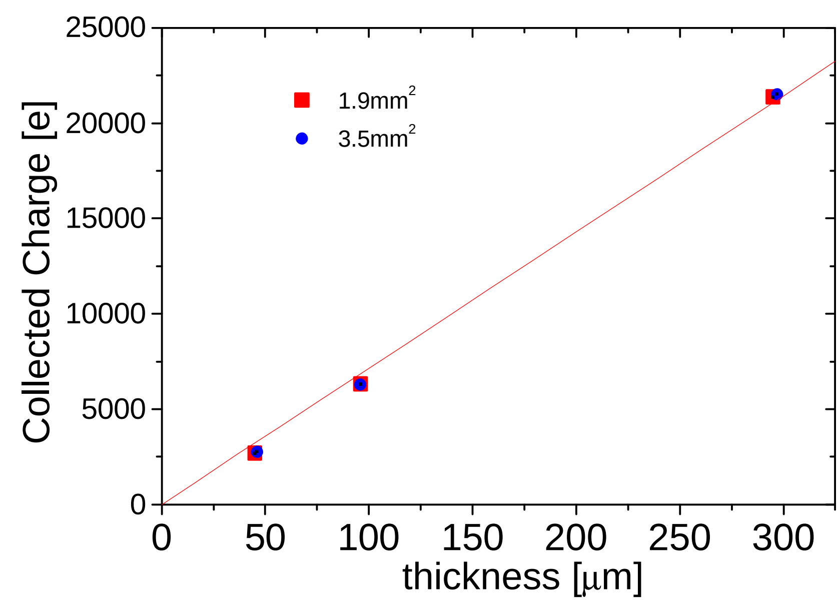



Florence CCE set-up
Measurements in the range ±20 °C

# Charge Collection Efficiency before irradiation on 50-300mm diodes

| Non irradiated | thickness (mm) | $V_{CV}$ (V) | $V_{CCE}$ (V) | $N_{eff}$ ($10^{11}$ $cm^{-3}$) | Collected charge [e] | $I_{sat.}$ ($A/m^3$) |
|---|---|---|---|---|---|---|
| **D50-a** | 45±2 | 1.25 ± 0.3 | 0.7 ± 0.1 | 9 ± 3 | 2680± 140 | 0.5 ± 0.1 |
| **D100-a** | 96 ± 2 | 1.8 ± 0.2 | 1.4 ± 0.5 | 3.5 ± 0.5 | 6300± 150 | 0.4± 0.1 |
| **D300-a** | 295 ± 3 | 17 ± 1 | 13.5 ± 0.5 | 2.5 ± 0.5 | 21350± 150 | 0.4± 0.1 |
| **D50-b** | 46 ± 2 | 1.3 ± 0.2 | 0.8 ± 0.1 | 9 ± 3 | 2760± 150 | 0.3± 0.1 |
| **D100-b** | 96 ± 2 | 1.4 ± 0.2 | 1.4 ± 0.5 | 2.5 ± 0.5 | 6280± 150 | 0.3± 0.1 |
| **D300-b** | 297 ± 3 | 16.5 ± 1 | 14 ± 1 | 2.5 ± 0.5 | 21500± 150 | 0.4± 0.1 |



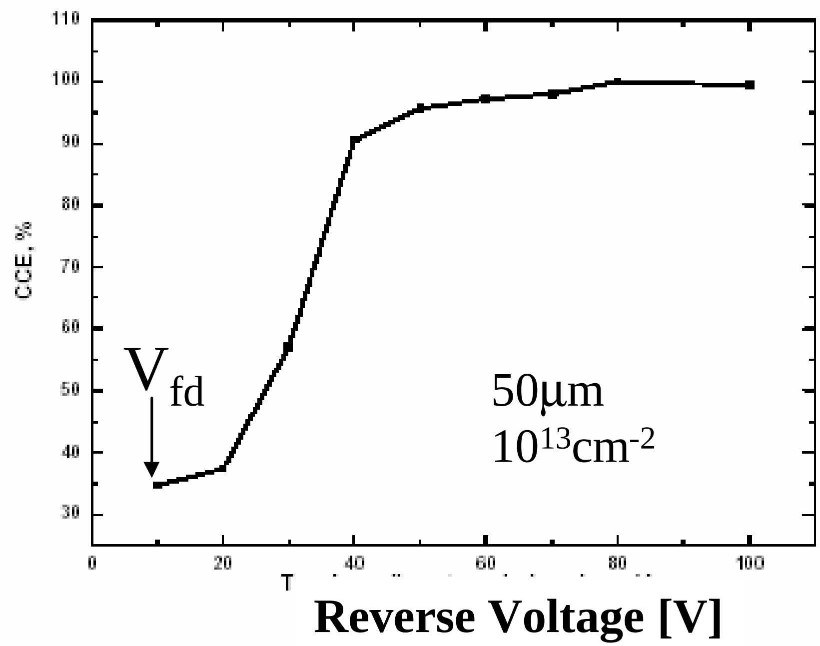



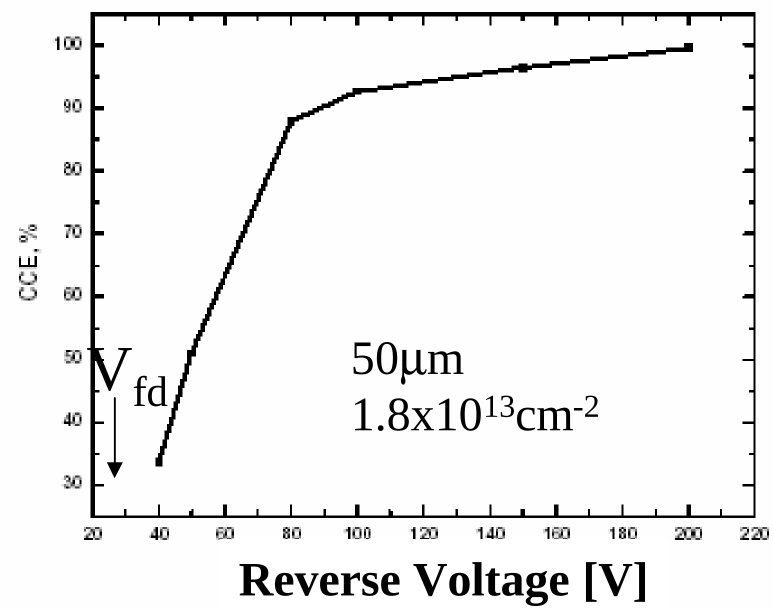
## After the maximum fluence of irradiation now studied ($8x10^{14}$ 1MeV $cm^{-2}$)

**100% CCE @ -20°C**

**<u>Need to overdeplete the detector</u>: $V_{CCE} >> V_{CV}$**

**After max fluence: $V_{CCE}$ = 75V (50mm) ; $V_{CCE}$ = 230-300V (100mm)**




- **Comparison with epitaxial diodes in progress**

# Conclusions

Si thin detectors have been tested before and after irradiation with 58MeV Li ions up to the fluence of $1.8 \times 10^{13} cm^{-3}$, corresponding to $8 \times 10^{14} cm^{-2}$ 1MeV neutrons.

Full cce has been measured with β-source and low noise electronics at –20°C with 100μm and 50μm thick detectors.

Reverse voltage needed to maximize the collected charge is much higher than the full depletion voltage measured with C-V. More studies are in progress to explain this behaviour.

Measurement will be extended by the end of the year on thin detectors irradiated up to $10^{16}$ 24GeV p / $cm^2$ at CERN.

Comparison will be carried out with epitaxial detectors produced on 50μm, 50Ωcm detectors produced on ITME materials by IRST-Trento.