

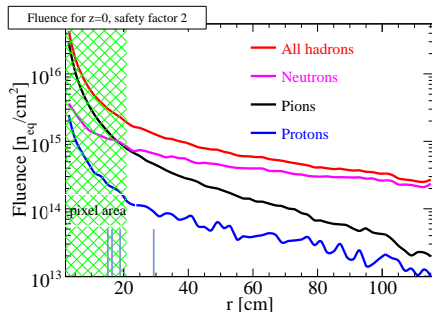
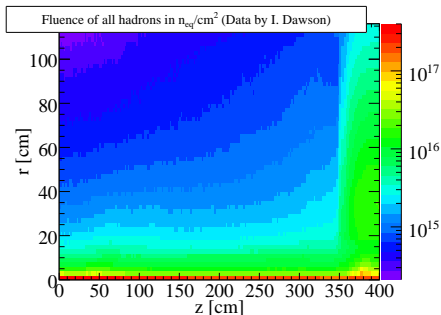
# CCE Measurements of Irradiated HPK-ATLAS07 n-on-p Sensors

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## Fluences in this irradiation campaign:

- Particle composition corresponding to 3 specific radii
- Fluences calculated for  $3000 \text{ fb}^{-1} \times \text{safety factor 2}$
- 2 detectors at each fluence
- Additional set of sensors measured at Liverpool to cross-check the results



## Pion irradiation

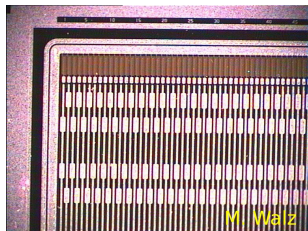
- Performed at PSI (Villigen) with 280 MeV Pions
- 16 days beam time for a maximum fluence of  $1.73 \times 10^{15} \pi/\text{cm}^2$
- Thanks to T. Rohe and M. Glaser

## Proton irradiation

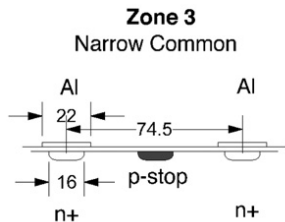
- Performed at KIT (Karlsruhe) with 25 MeV Protons
- Thanks to A. Dierlamm and W. de Boer

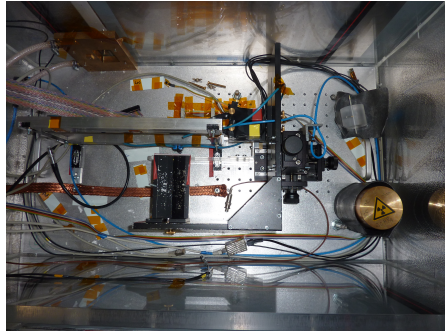
radius	pion dose	proton dose
18.9 cm	$9.3 \times 10^{14} \text{ n}_{\text{eq}}/\text{cm}^2$	$1.9 \times 10^{14} \text{ n}_{\text{eq}}/\text{cm}^2$
16.4 cm	$1.2 \times 10^{15} \text{ n}_{\text{eq}}/\text{cm}^2$	$2.6 \times 10^{14} \text{ n}_{\text{eq}}/\text{cm}^2$
15.1 cm	$1.4 \times 10^{15} \text{ n}_{\text{eq}}/\text{cm}^2$	$2.6 \times 10^{14} \text{ n}_{\text{eq}}/\text{cm}^2$

- Prototype detectors for the ATLAS Upgrade
- N-in-p strip sensors
- A detailed description can be found in Y. Unno et al., NIMA 636 S.24-30



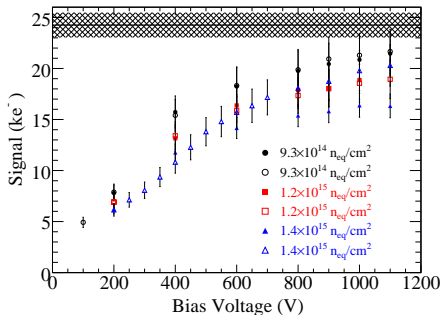
material	FZ-silicon, p-type
size	1 cm × 1 cm
thickness	320 μm
number of strips	104
length of strips	0.8 cm
pitch	74.5 μm
coupling	AC
strip isolation	p-stop
zone	3



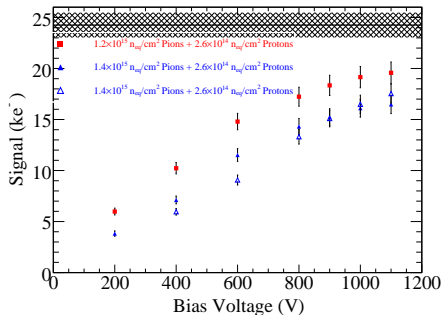


- Sr-90  $\beta$ -Source with 37 MBq leads to a measurement rate of up to 300Hz
- Cooling with a commercially available freezer to  $\sim -20^{\circ}\text{C}$
- Additional liquid nitrogen cooling for measuring at  $-60^{\circ}\text{C}$

after pion irradiation:



after pion and proton irradiation:



- Deposited charge in 320  $\mu\text{m}$  silicon:  $\sim 24 \text{ ke}^-$
- Not all detectors measured yet
- Next step will be the neutron irradiation



# Annealing Sensors at Different Temperatures



## Accelerated Annealing

$$\frac{\tau_a}{\tau_{ref}} = \exp \left[ -\frac{E_a}{k_B} \left( \frac{1}{T_{ref}} - \frac{1}{T_a} \right) \right]$$

$\tau_a$  &  $\tau_{ref}$   $\hat{=}$  time constant

$E_a$   $\hat{=}$  activation energy

$T_a$  &  $T_{ref}$   $\hat{=}$  annealing- & reference temperature

### Motivation:

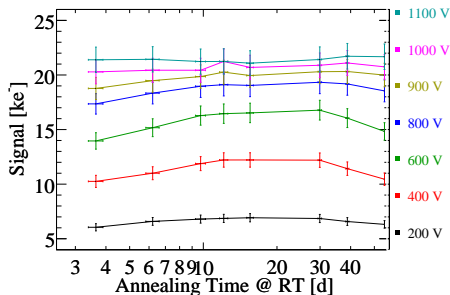
- The scaling is often applied in annealing studies. Usually one uses the activation energy that was determined in  $N_{eff}$  measurements.
- G. Casse found indications that the scaling is not generally applicable to CCE measurements.

### Samples:

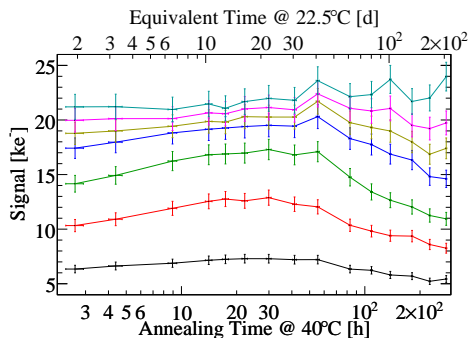
- 3 HPK sensors were annealed at 22.5°C, 40°C und 60°C
- All of them were irradiated with the same dose:  
 $1.1 \times 10^{15} n_{eq}/cm^2$  25 MeV Protons
- Estimated  $V_{fd} \sim 900$  V



annealing at room temperature:

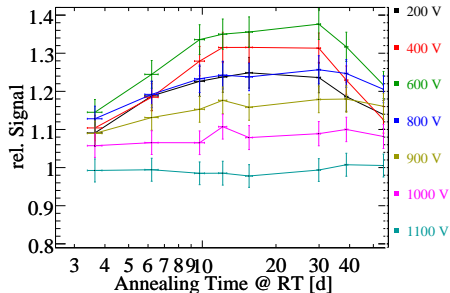


at 40°C:

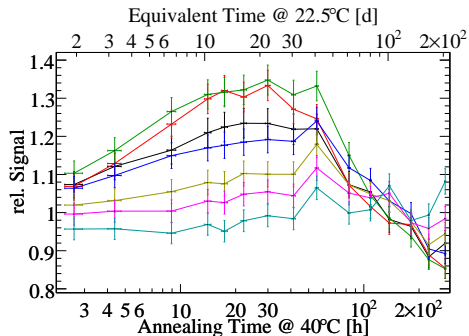


- Annealing @ 40°C scaled to 22.5°C using  $E_a = 1.31$  eV from long term annealing
- Annealing is beneficial for the first 50 h @ 40°C
- Beginning charge multiplication after 280 h for  $V \geq 900$  V?

annealing at room temperature:

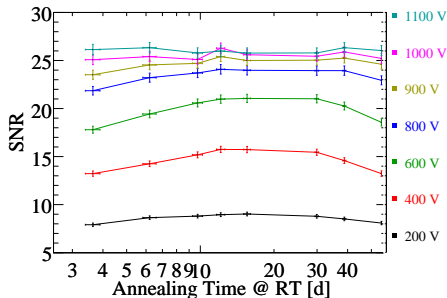


at 40°C:

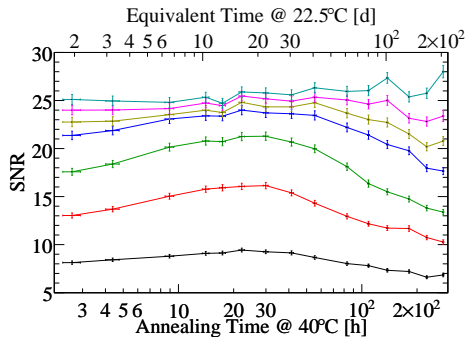


- Data points are normalised to a measurement before the first annealing step
- Significant increase in collected charge for  $V < 900\text{V}$

annealing at room temperature:



at 40°C:

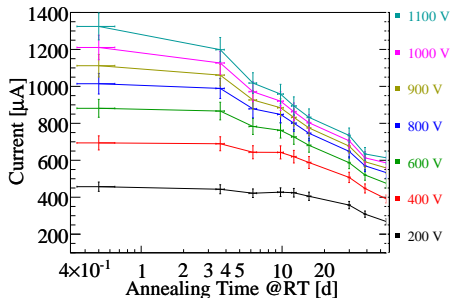


• Shape similar to CCE curve  $\Rightarrow$  noise did not change significantly

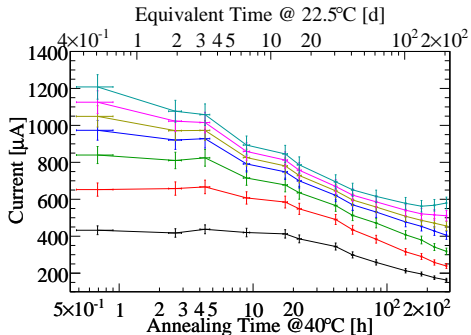
# Leakage Current (scaled to 20°C)



annealing at room temperature:



at 40°C:



- Slight increase in leakage current after 180h @ 40°C for high voltages
- Could be another indication of charge multiplication



## Mixed Irradiation

- The pion and proton irradiation steps were done
- Neutron irradiation in Ljubljana will be the last step

## Accelerated Annealing

- First indication of charge multiplication after 280h @ 40°C
- Will we see the same effect after 200 days at room temperature?
- More room temperature measurements need to be done
- An annealing series with an identical sensor will be done with an annealing temperature of 60°C
- No deviation in the scaling found so far