CERN Physics Department PH-DT Detector Technologies

Characterization of Irradiated Silicon Strip Sensors

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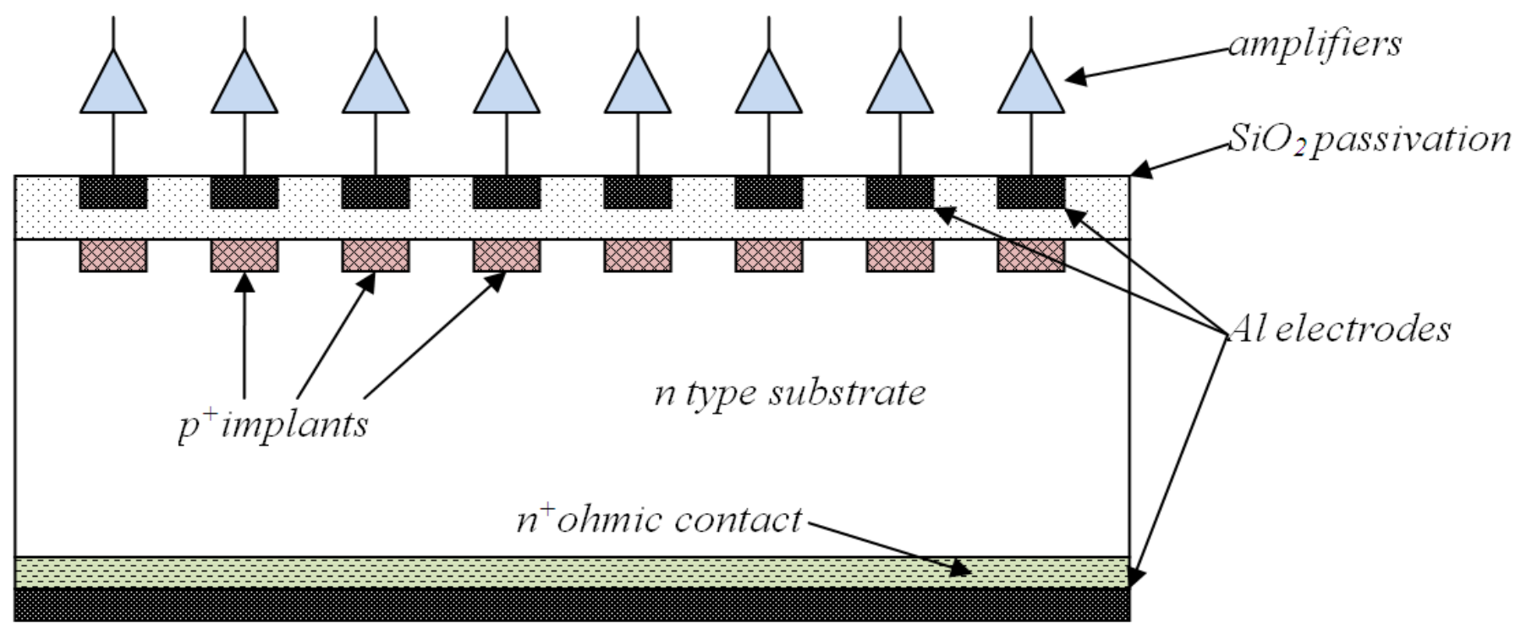
Signal formation in microstrip detectors – space charge effects

Why do we need to know the field shape inside the detector?

- The ionizing particles travelling through the silicon bulk lose energy producing electron/hole pairs, with an average energy loss of 3.6 eV/pair.
- The charged carriers drift in the detector under the effect of the electric field resulting from the applied bias



The current signal induced on one of the electrodes is given by:

$$i_k = -q\vec{v}\cdot\vec{E}$$

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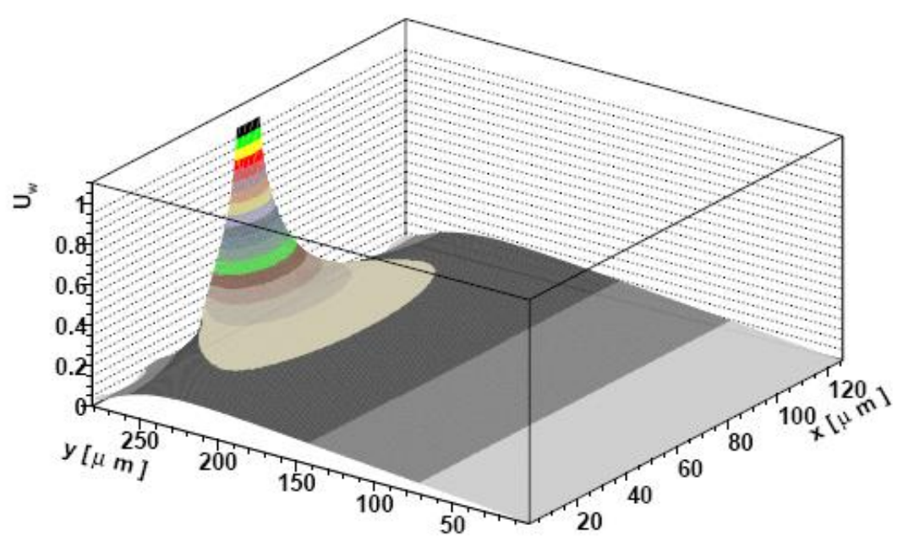
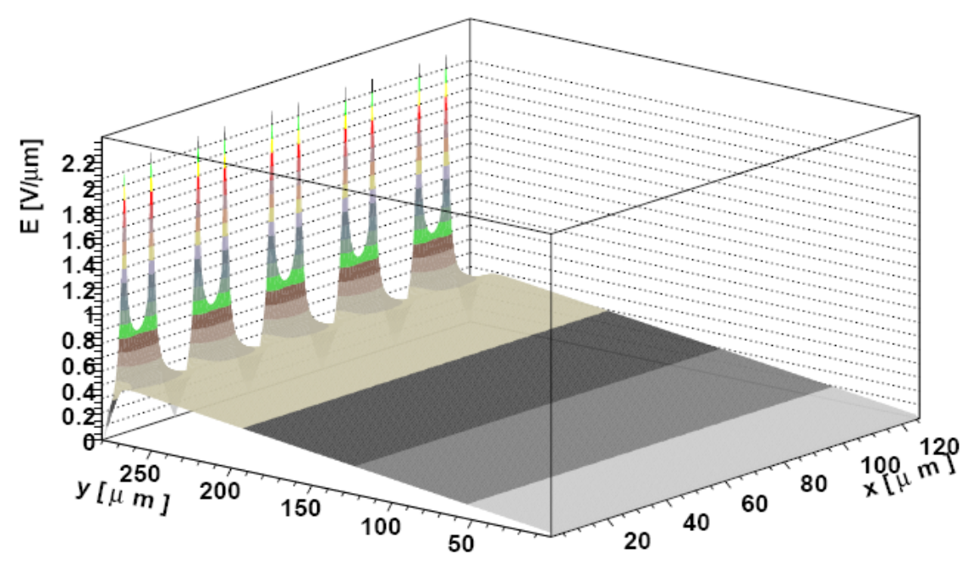
Where q is the electric charge, v is the instant velocity of the carrier within the bulk end E is a quantity called *weighting field* related only to the geometric characteristics of the detector.

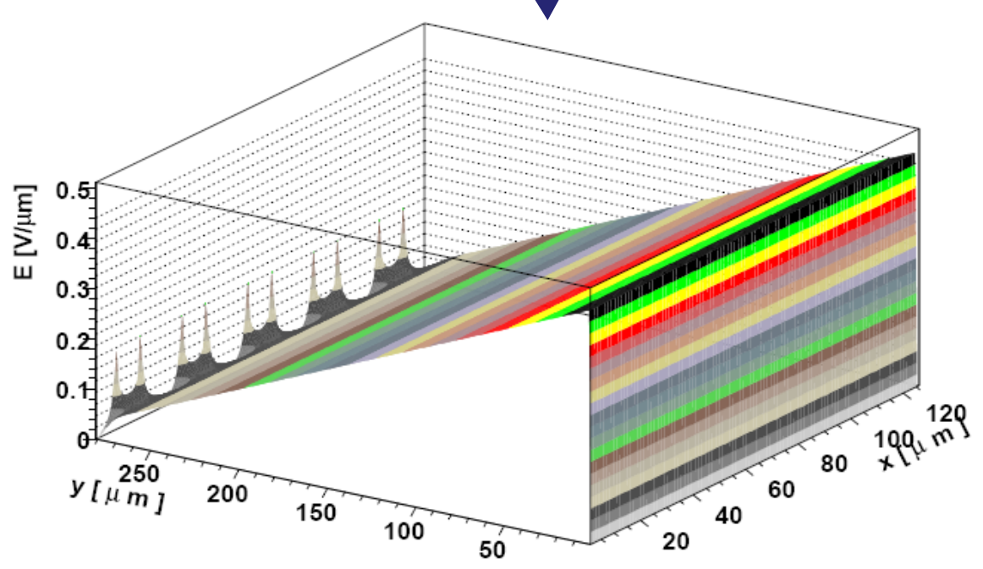


Weighting field for one strip of the sensor



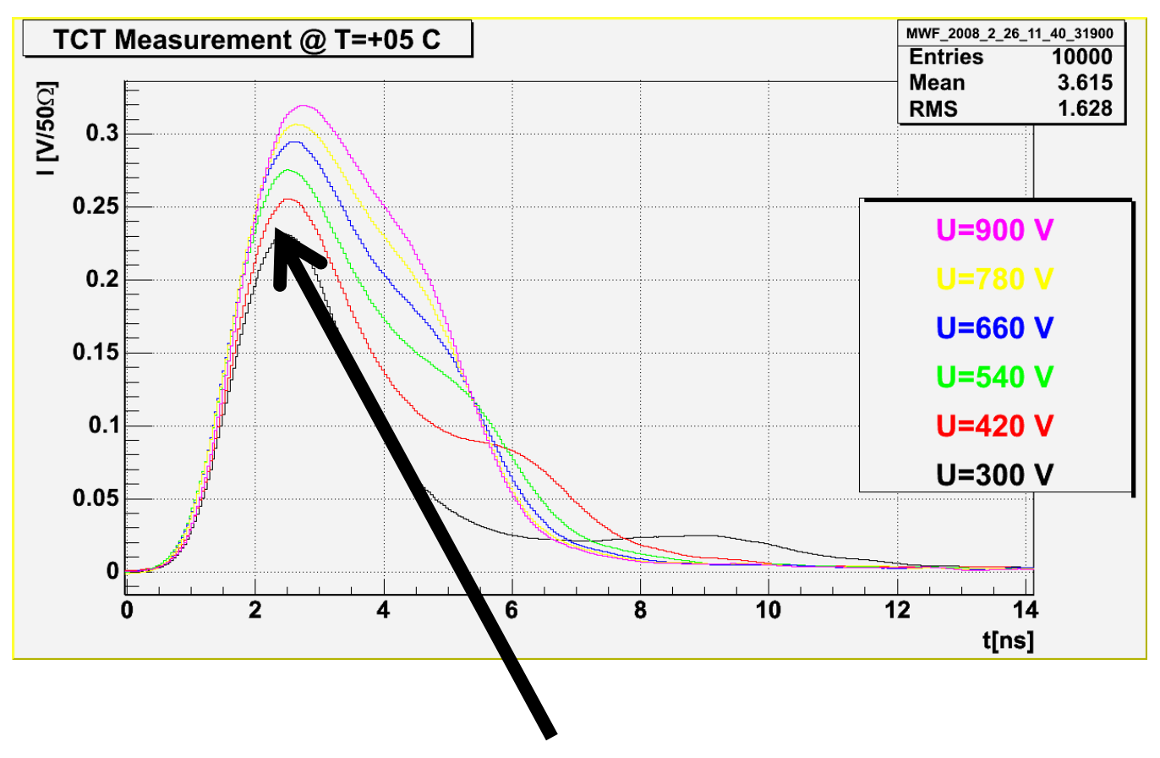
Before type inversion: the high electric field is on the same side as the high weighting field

In some cases, irradiation with different kind of particles can cause type inversion of the sensor bulk (from *n* to *p* or vice-versa). In this case the main junction can move on the other side of the sensor and the scalar product can be very low (plots: Gregor Kramberger)

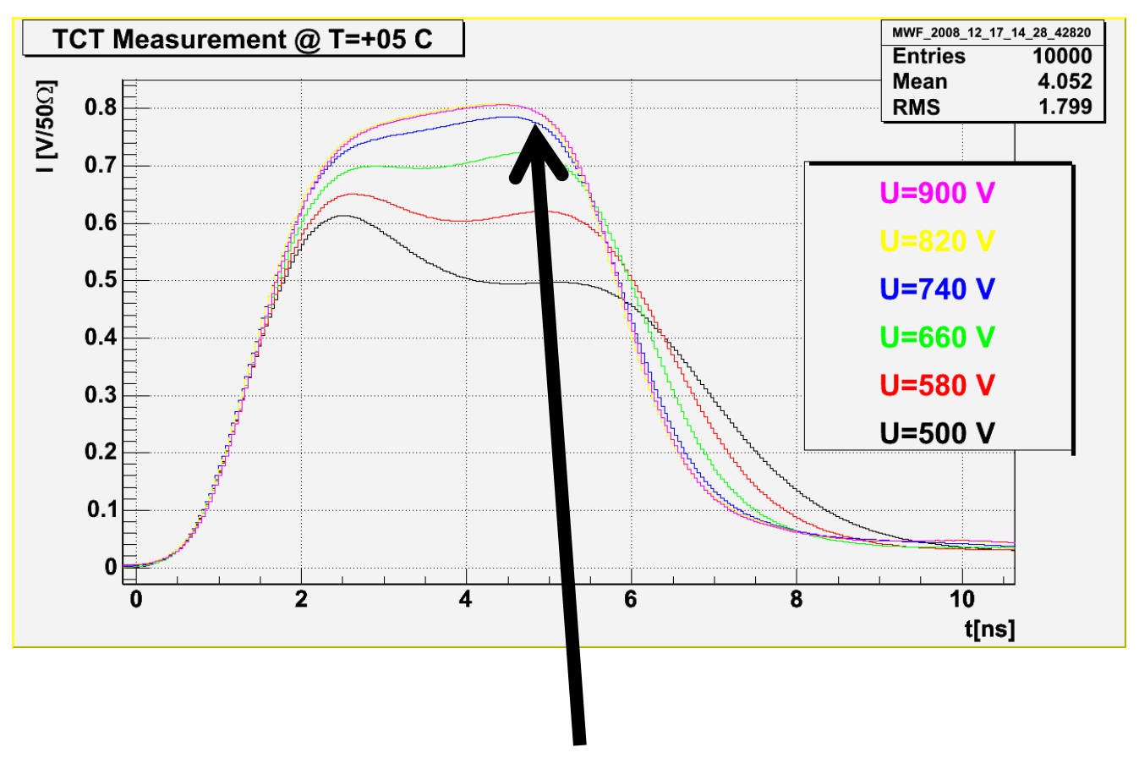


After type inversion: high electric field on the opposite side of high weighting field: vE scalar product is low->low signal

Type inversion study with TCT measurements



Not type inverted -> Highest peak on the front contact of the detector

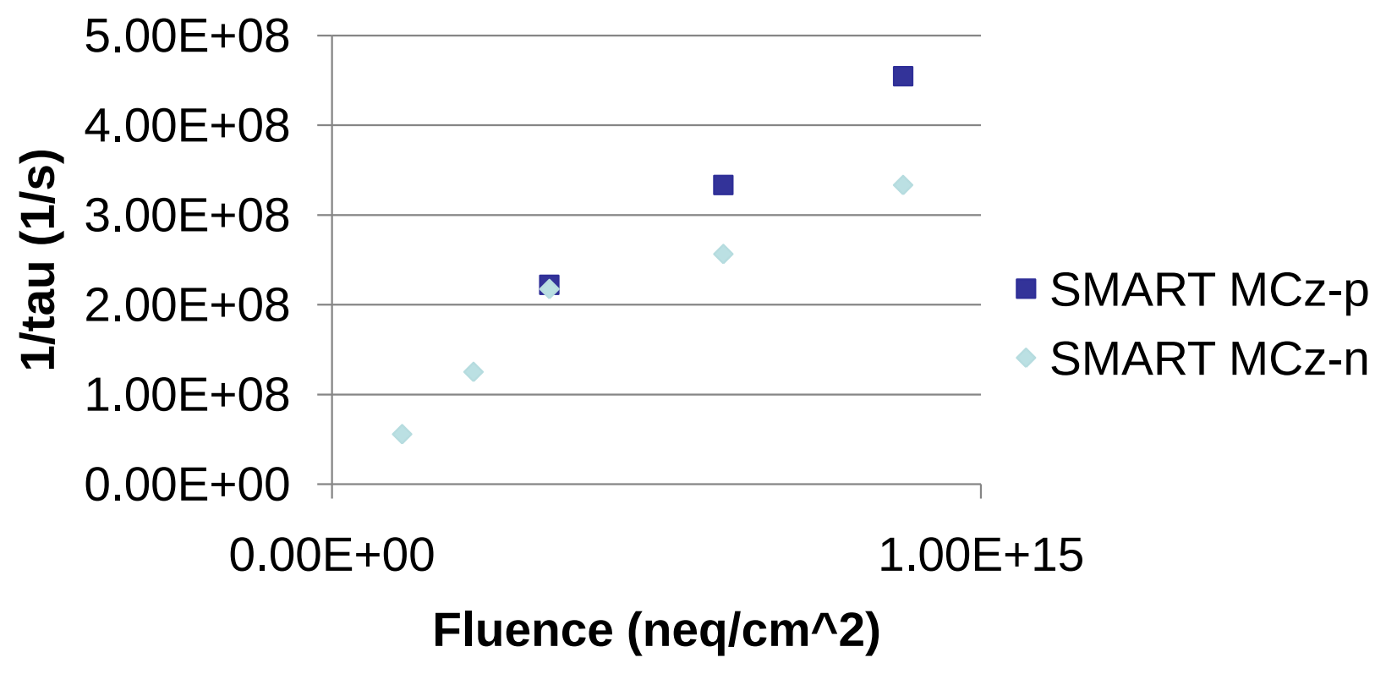


Type inverted -> Highest peak on the back contact of the detector

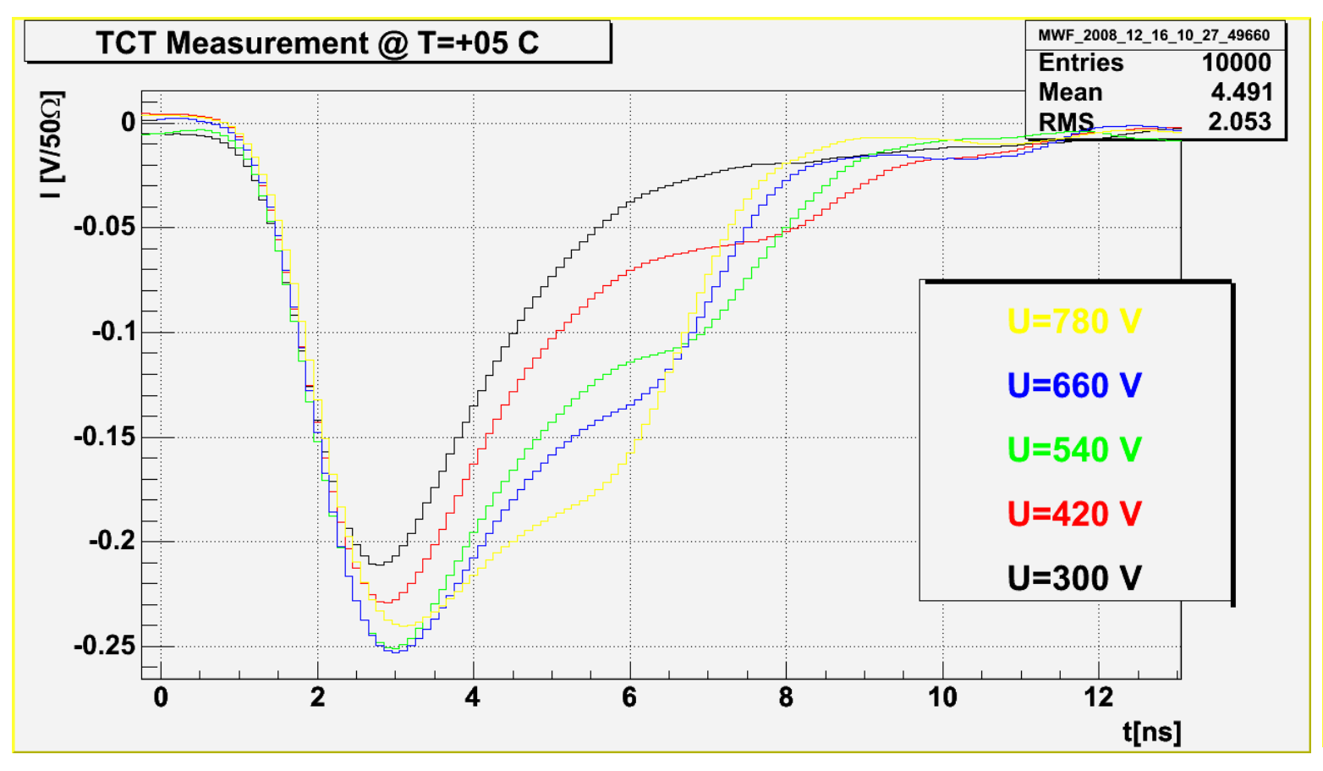
However the situation is not so trivial.

- The trapping of the carriers in defects localized in the silicon bulk causes a reduction in the signal as the charge cloud travels through the bulk.
- The signal thus, after a time *t* is reduced by a factor $e^{t/\tau}$, where τ is the avarage lifetime of the carrier before it is recombinated in one of the trapping centres.

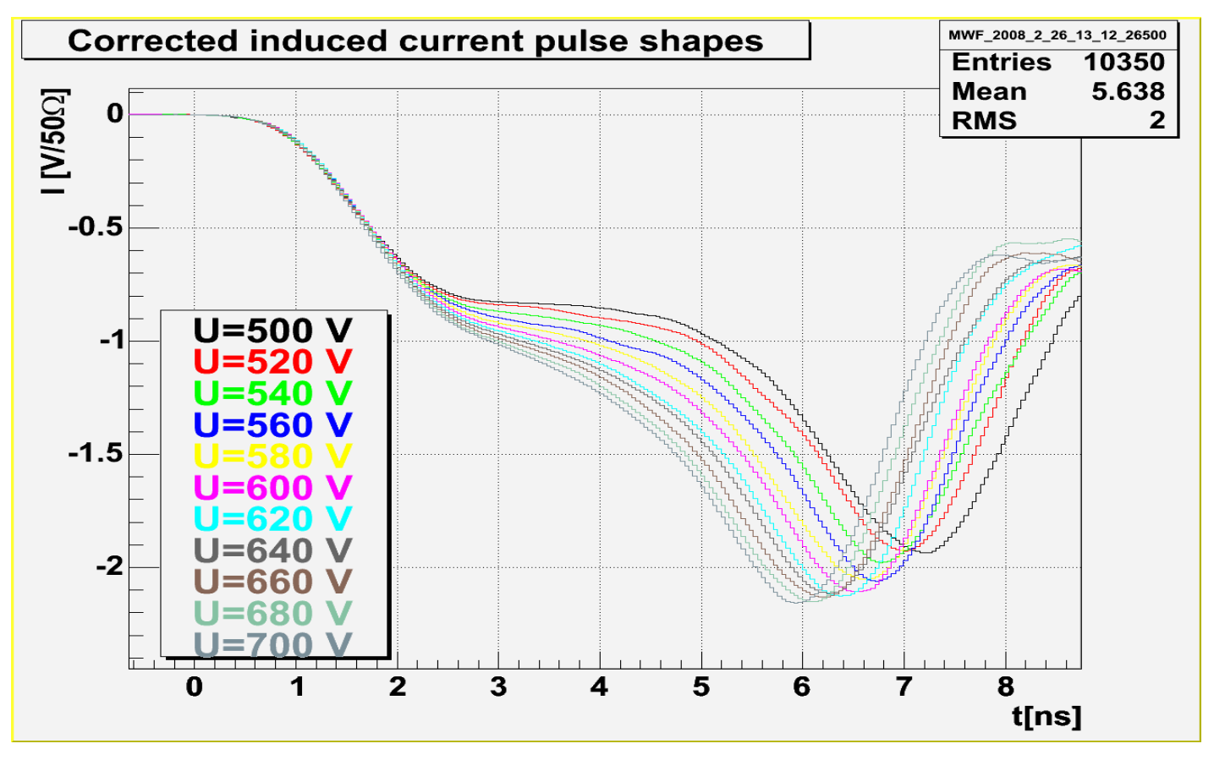
Trapping time depends on irradiation fluence and on particle type.



- The tau factor depends on the inverse of the irradiation fluence, but at higher fluences a saturation of trapping has been observed.
- Trapping can affect heavily a current profile.
- Correction takes place by interpolating the current pulse with an $e^{t/\tau}$ function.
- After correction, a pulse profile may show type inversion that was not evident before.



Before trapping correction…

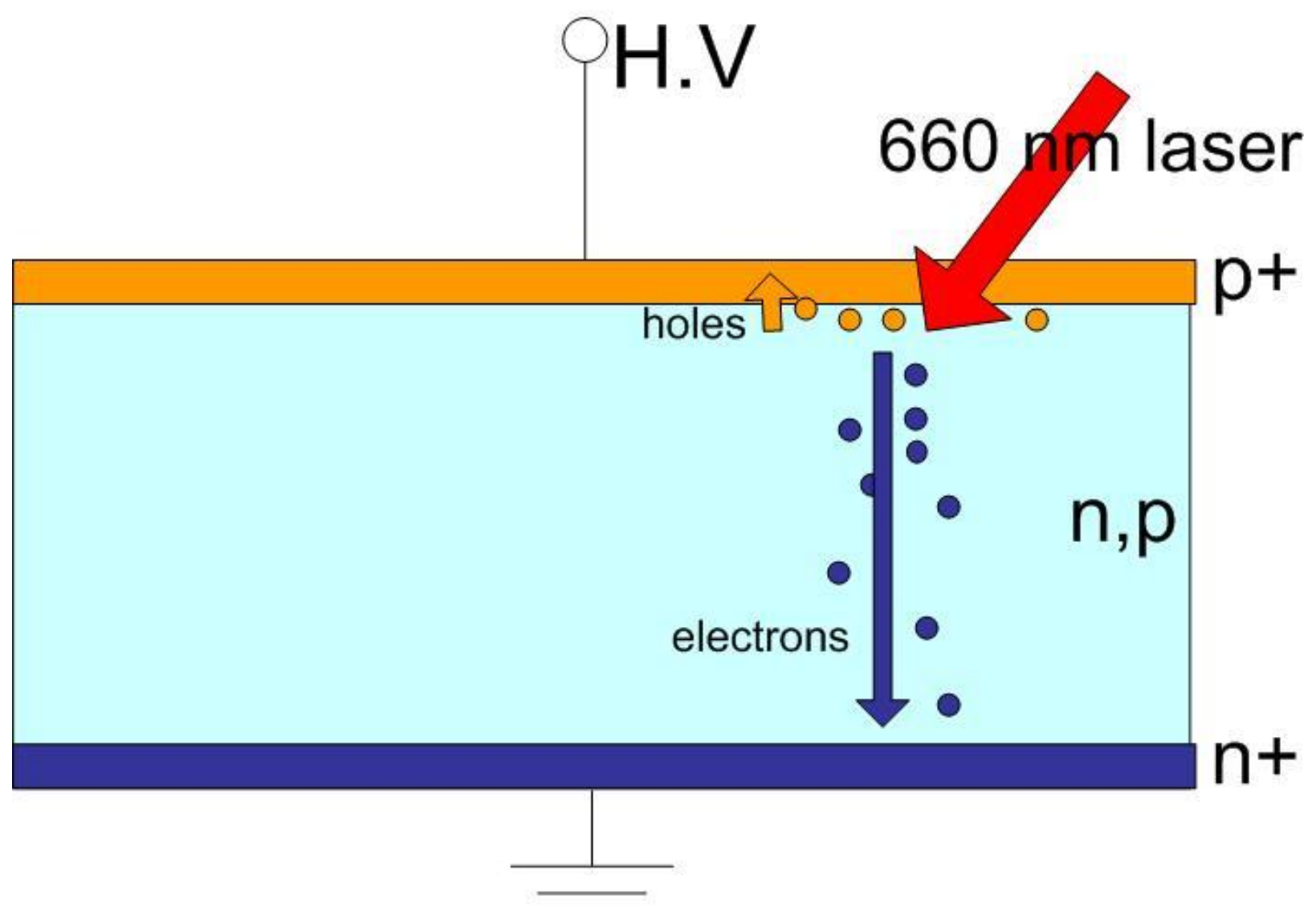


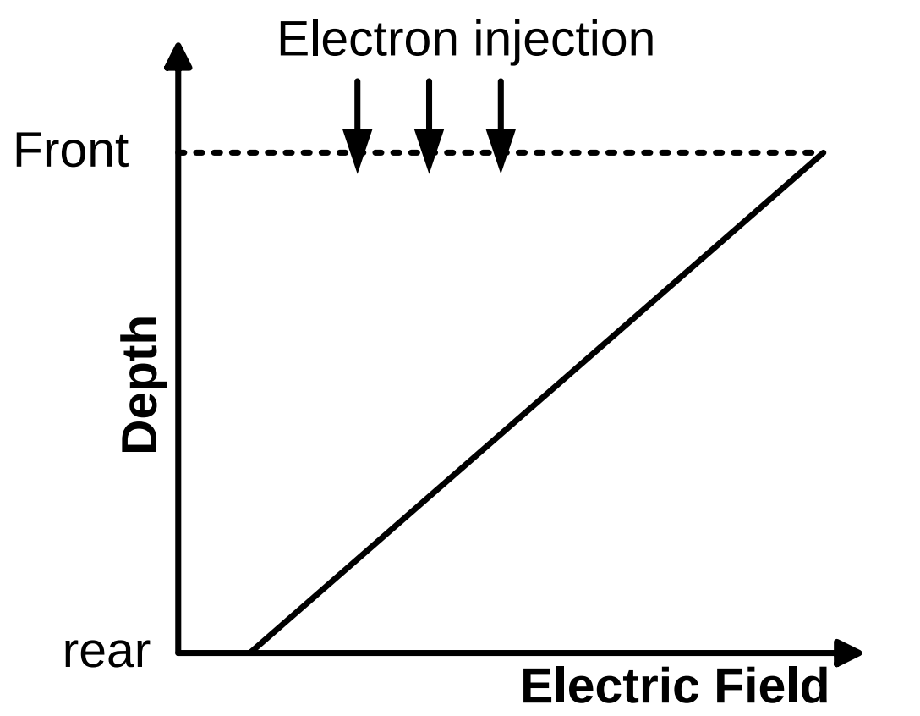
After trapping correction…

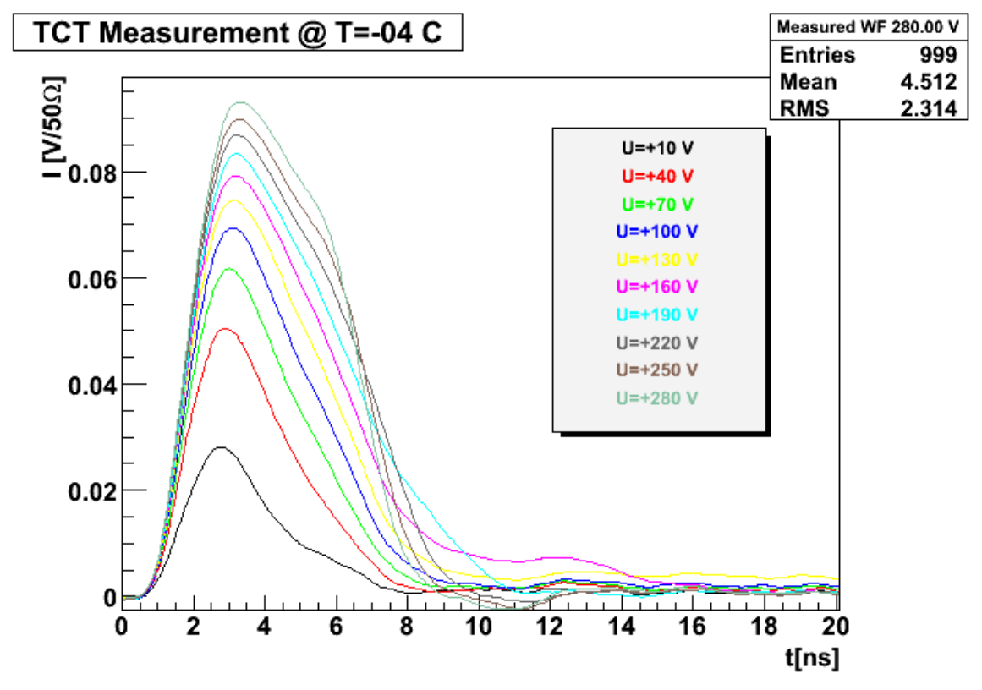
TCT measurements

- Laser injection produces carrier pairs close to the detector surface
- Signal generated by just one type of carriers

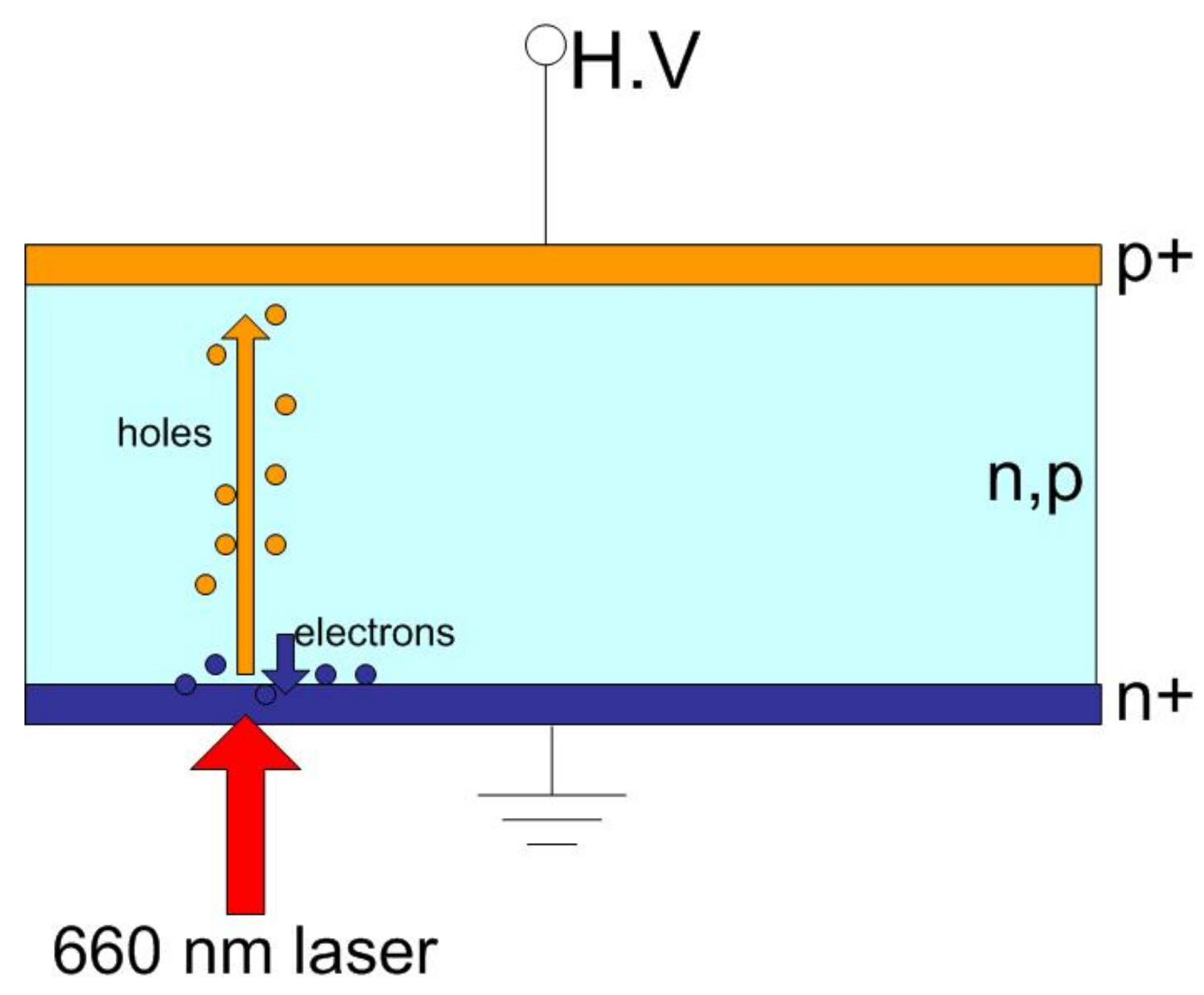
Front Illumination

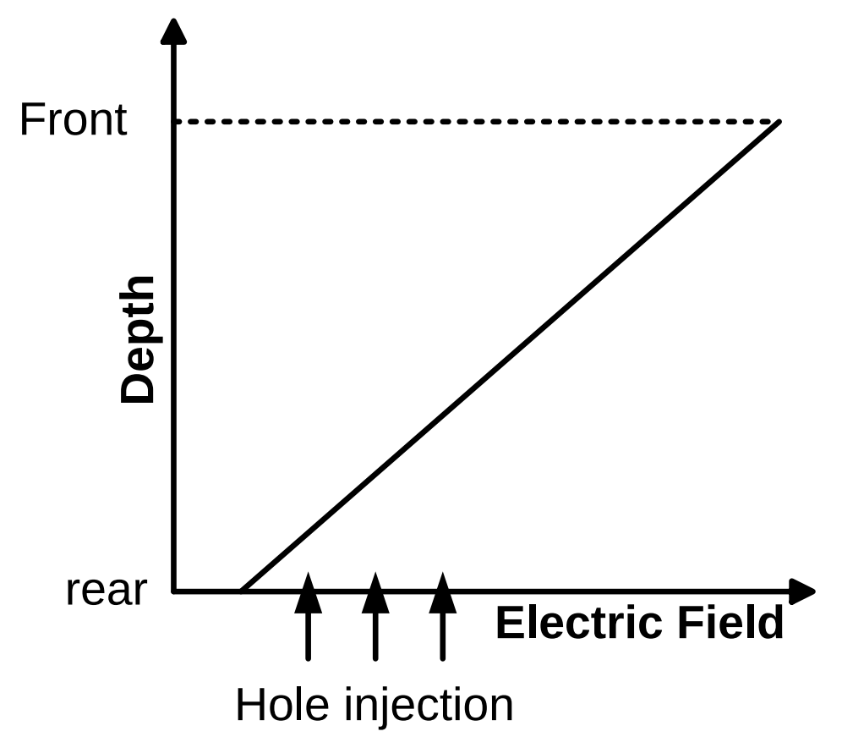


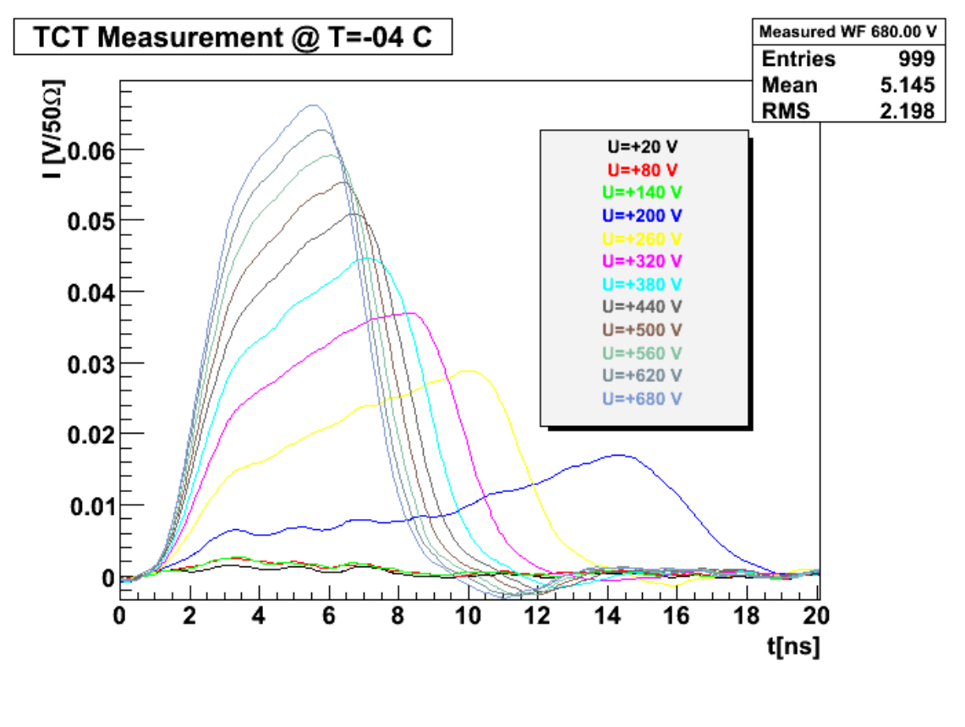




Back Illumination

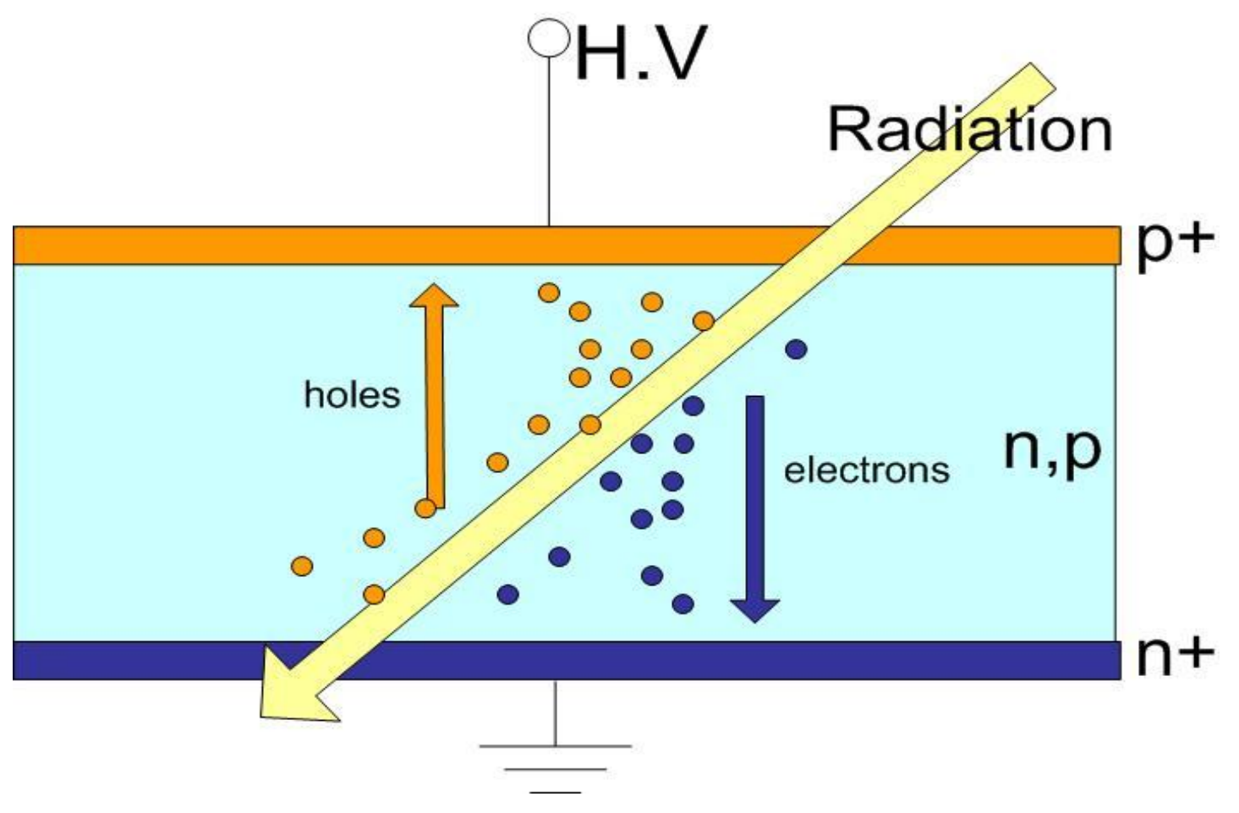






CCE measurements on strips

- Relies on the same principles as TCT measurements, but the aim is to get the integrated charge of the whole pulse
- To generate e-h pairs, one uses infrared laser or a beta source, which penetrates throughout the whole detector thickness
- The signal is generated by both types of carriers



Two different options are available for studing the CCE response of a strip detector

Option 1: Analog readout using an oscilloscope

-Easy to realize with standard lab equipment and custom electronics

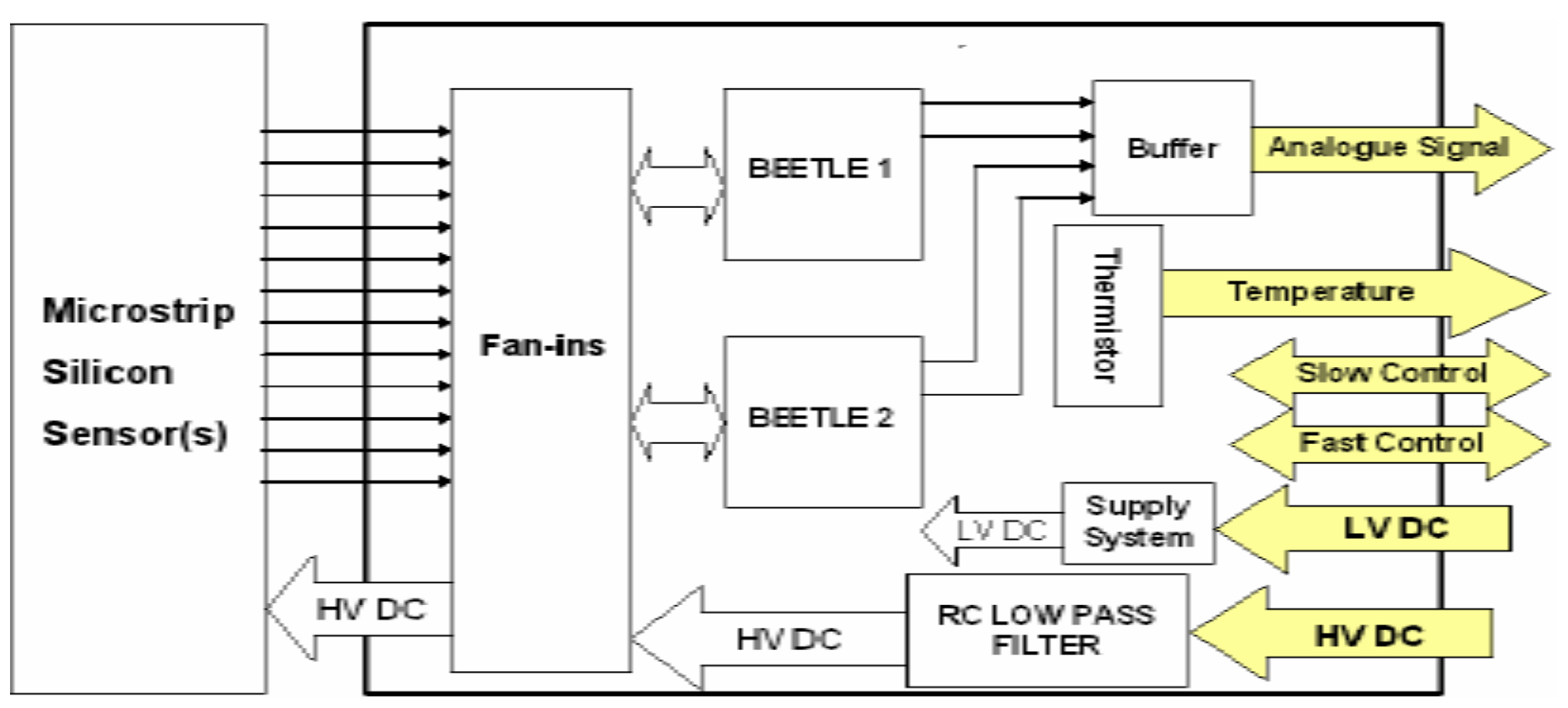
-Significant difference with the sensor arrangement in the final detector system

-Transmissions lines too long (significant loss on a signal which is in the order of the fC

Option 2: Alibava readout

-Much closer to “real-life” situation, with a detector front end that uses sdandard chips (Beetle, already used in LHCb) and a daughter board that can be placed close to the sensor

-“Coarser” electronics resolution



Further info: http://www.cern.ch/SSD and http://www.cern.ch/RD50

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