X-ray flourescence setup and measurements of CMOS sensors

31st RD 50 Workshop
CERN

22.11.2017

Susanne Kuehn *CERN*,
Enrico Junior Schioppa *CERN*, Felipe Oliveira *Brazilian Synchrotron Light Laboratory*, Michael Kaemingk *New Mexico State University*, Christian Riegel *CERN*/University of Wuppertal
Sensor design@CERN: Thanushan Kugathasan, Cesar Augusto Marin Tobon, Heinz Pernegger, Petra Riedler, Walter Snoeys, Jacobus Willem Van Hoorne

Outline

- Idea of x-ray fluorescence measurements
- Details on the setup
- Details on the CMOS TowerJazz Investigator chip
- Measurements
- Summary

X-ray fluorescence method

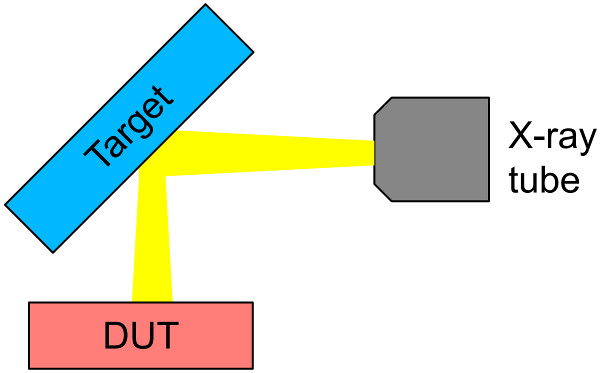
Many new pixel CMOS sensors to evaluate

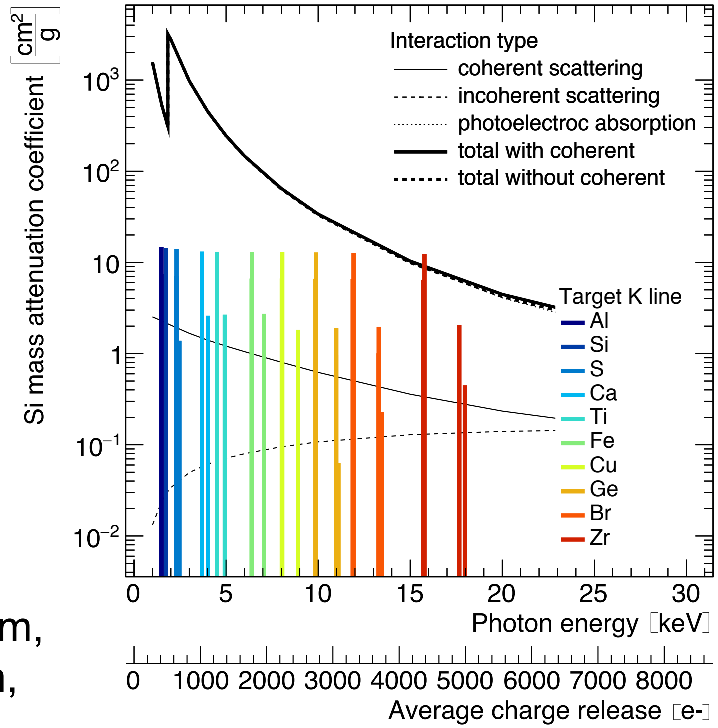
Method to calibrate and study the linearity of response of new sensors in the lab

→ **X-ray fluorescence method**

L.-D. Pohl et al., Obtaining spectroscopic information with the ATLAS FE-I4 pixel readout chip, Nuclear Instrum. Meth. A788 (2015), 49
D. Maneuski, Flourescence X-ray measurements

- X-ray from tube induces K_{α}- and K_{β} emission lines of target materials and gives access to a dense set of **monochromatic** lines in the keV-100 keV range measurements



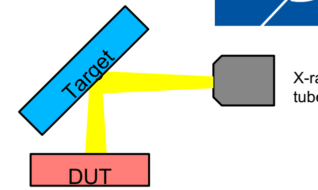


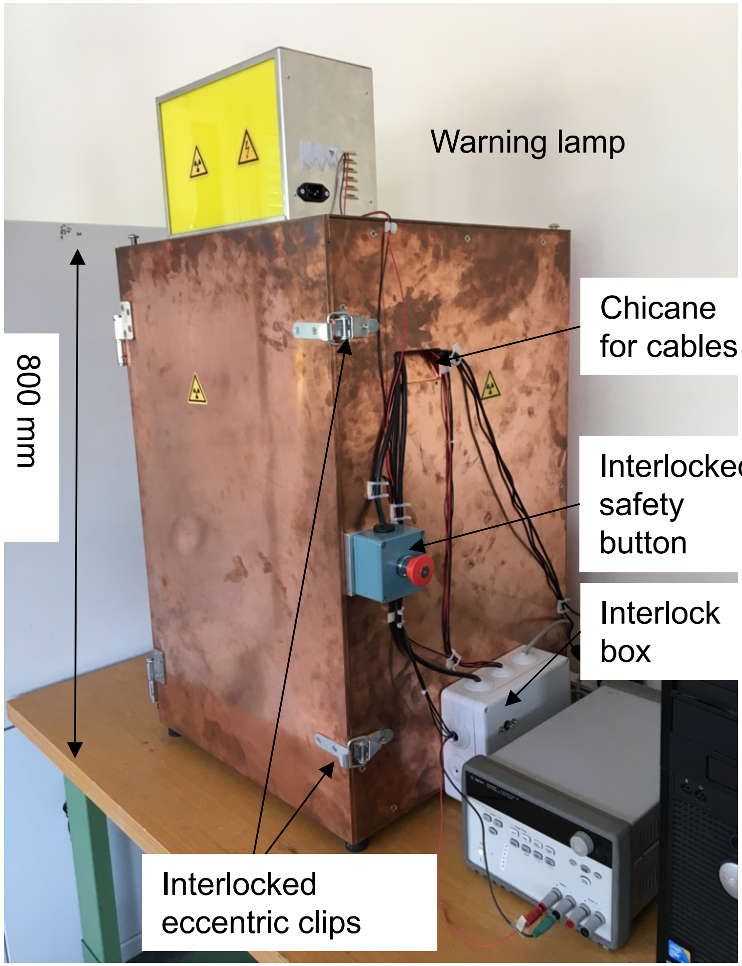
Courtesy: E. Jr. Schioppa

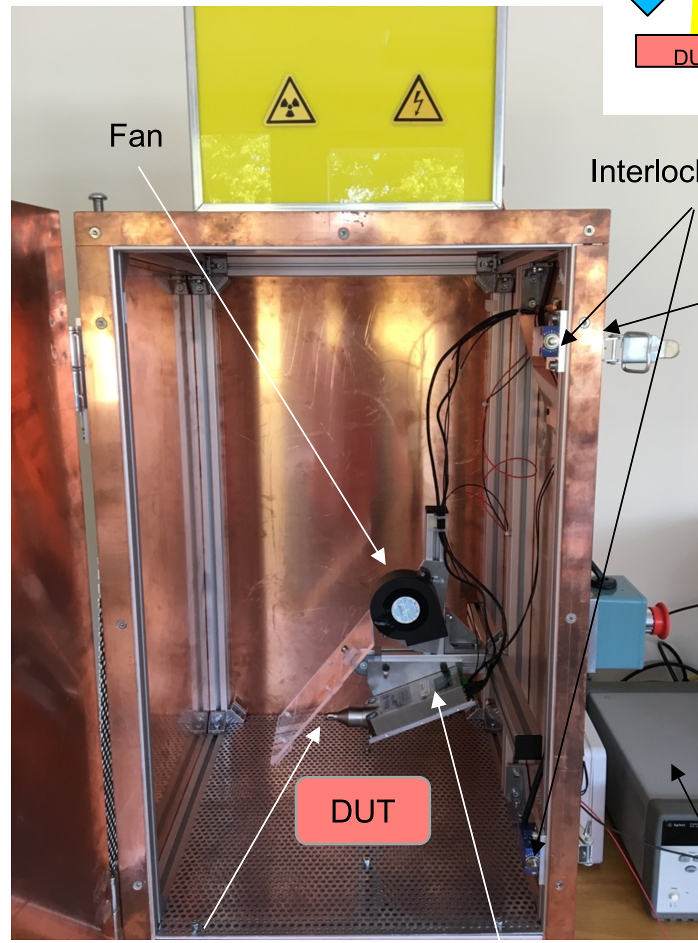
- Typical **target materials**: Al, Tin, Titanium, Molybdenum, Zinc, Manganese, Iron, Copper, Gemanium, Zirconium,
- Plus allows **measurements of charge spectra and energy resolution**

X-ray fluorescence setup at CERN

4 mm thick copper wall box with interlock system and x-y-z source mount



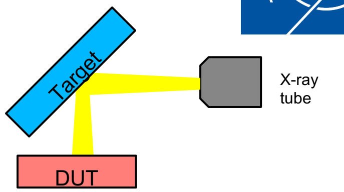


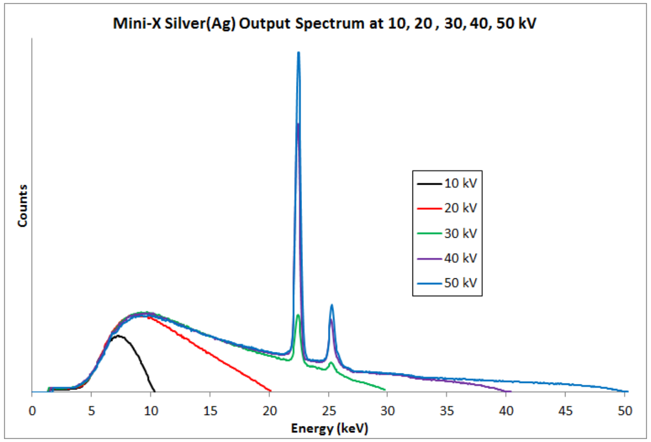


With support from L. Tluosos, J. Alozy,
M. Abbas and CERN EP-DT-EO

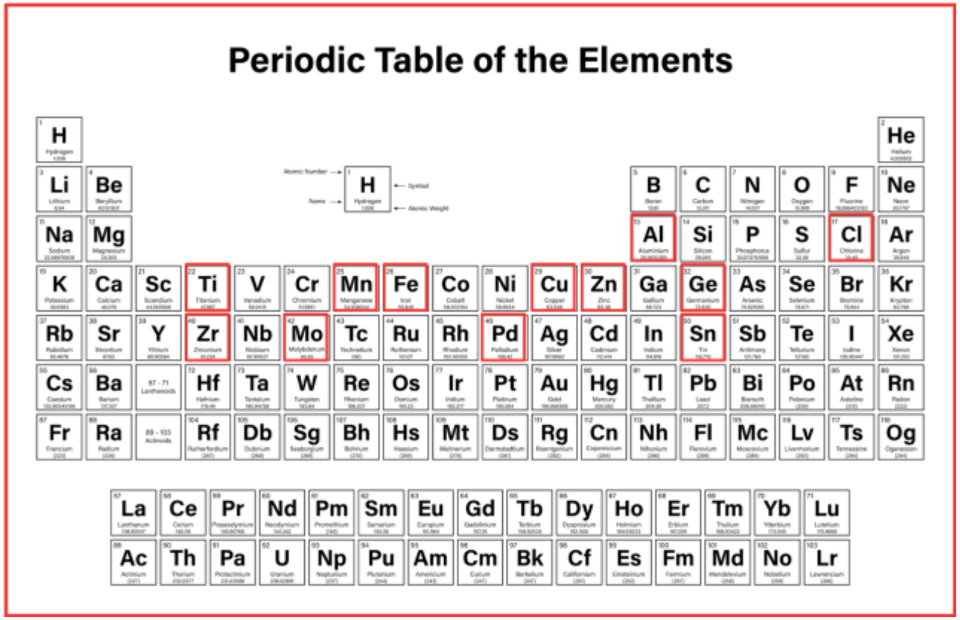
X-ray fluorescence setup at CERN ctd’

- Portable X-ray source: AMPTEK Mini-X with Ag transmission target
  - Max. 4 W (HV:10 kV to 50 kV, current: 5 μA to 200 μA), controlled via USB
  - 10^6 counts per s/mm^2 (30 cm distance)



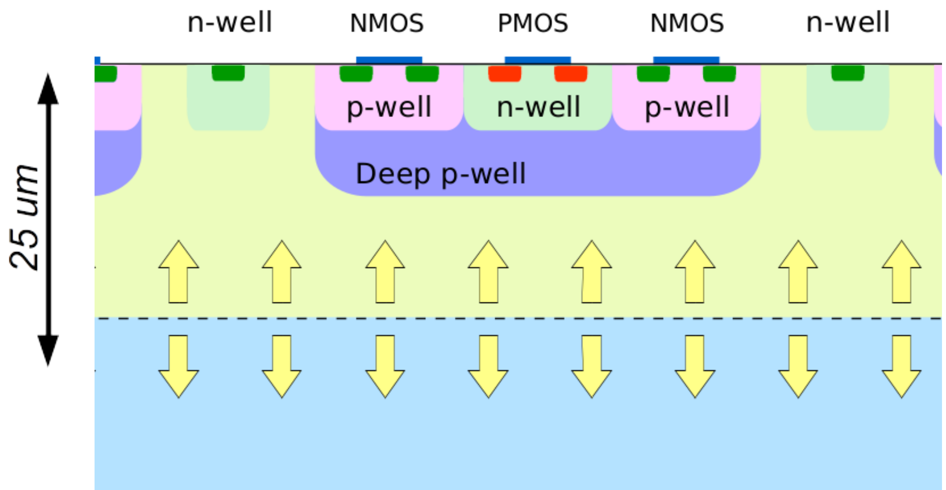


- Target materials: potentially two calibration energies per target



CMOS Sensor: TowerJazz 180nm technology

- The modified process with high efficiency after irradiation



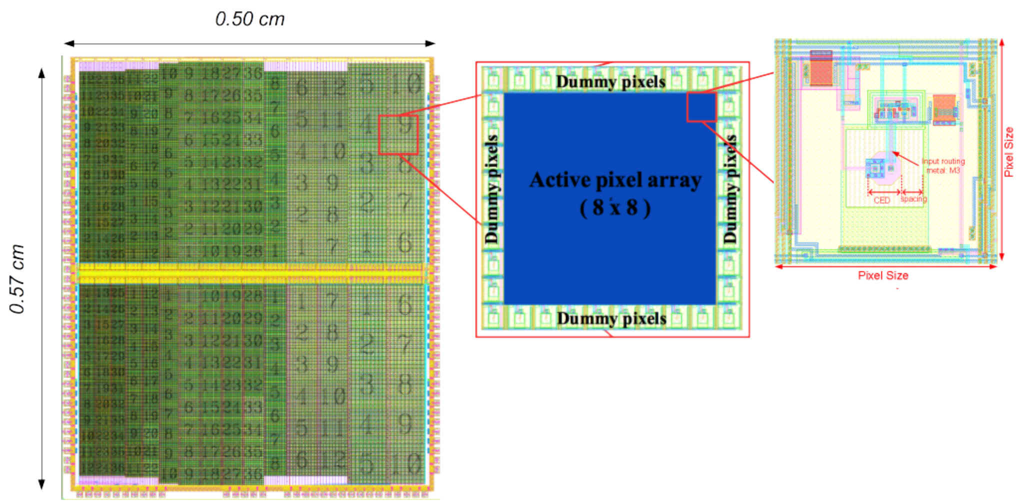
Courtesy: E. Jr. Schioppa

- Low input capacitance (~fF) at the collection electrode
- Large S/N ratio can be achieved
- Fast signals

➢ A planar junction extends across the full pixel surface
➢ Charge collected in depleted volume

H. Pernegger et al., First tests of a novel radiation hard cmos sensor process for depleted monolithic active pixel sensors, JINST 12 (2017) P06008

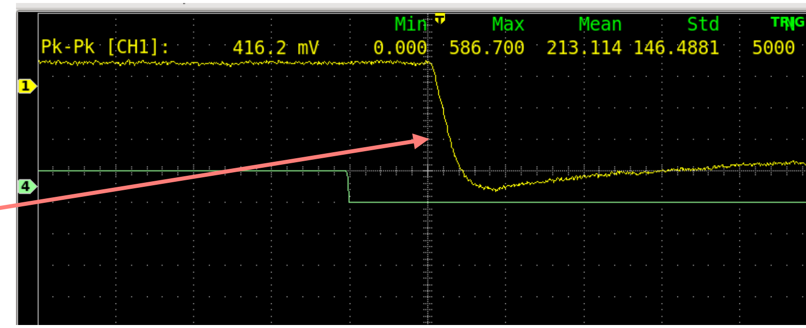
- TowerJazz Investigator 1 chip



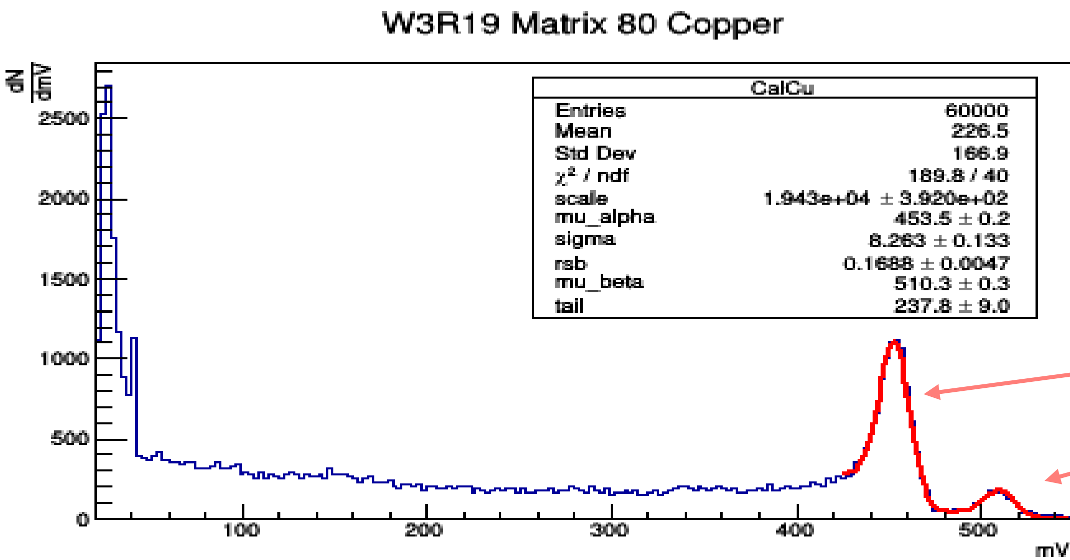
- Many different mini-matrices differing in geometry & front-end
- 4 matrices measured with pixel size of 28 × 28 μm^2 and 30 × 30 μm^2 and different depth of p-well

Measurements

- Test of 4 matrices with 3 target materials (unirradiated)
- Bias voltage 6 V
- Single pixel read out with Cividec C2HV amplifier, pulse amplitude proportional to charge
- 60000 events for each of the matrices for each of the target materials and wave-forms fitted



→ Charge spectra from X-ray emission



Maximum deep PW, 28 × 28 μm²

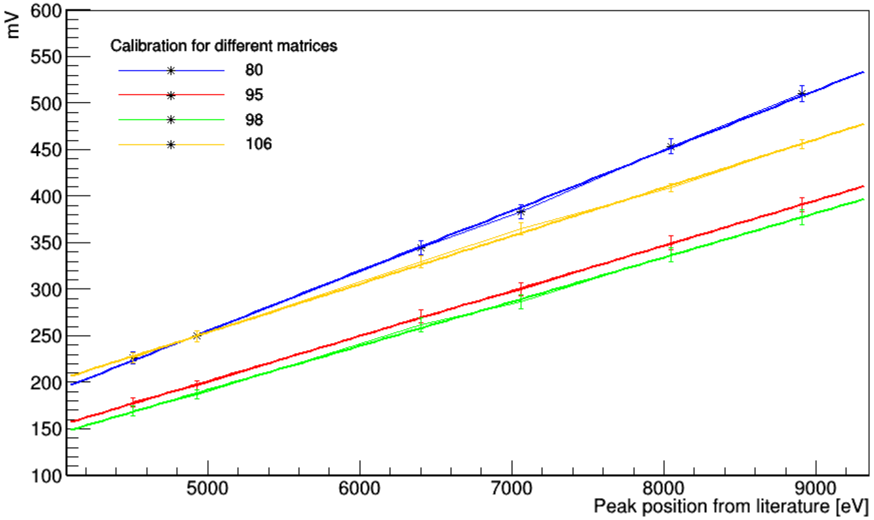
Materials	$K_\alpha[keV]$	$K_\beta[keV]$
Titanium (Ti)	4.512	4.933
Iron (Fe)	6.405	7.059
Copper (Cu)	8.046	8.904

→ High resolution allows to see K_α- and K_β lines separately

Noise about 3.6 mV

Results of unirradiated chip

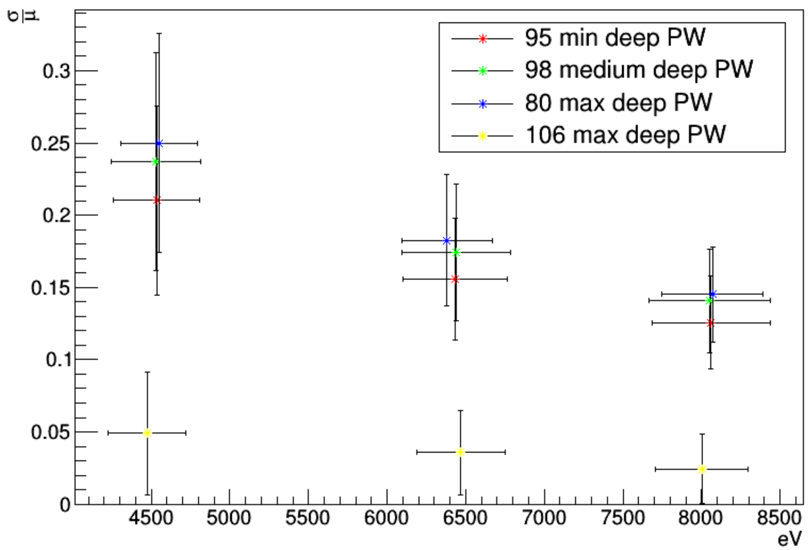
- Gamma peak positions versus literature values



- Matrix 80 (maximum deep PW),
- Matrix 95 (minimum deep PW) and
- Matrix 98 (medium deep PW) with 28 × 28 μm²
- Matrix 106 (maximum deep PW) with 30 × 30 μm²

➢ Linearity of gain
➢ Slightly higher gain for matrix 80 and also matrix 108 with maximum deep P-well

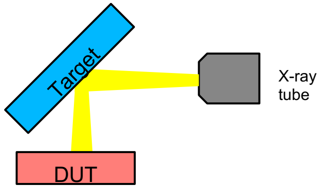
- Energy resolution for K_α-energies



➢ Matrix 106 with larger pixel size has a better energy resolution (around 0.05 ± 0.04)
➢ Matrix 80 with maximum deep PW around 0.25 ± 0.08

Summary

- X-ray flourescence setup installed and commissioned at CERN
- Ready to be used with new sensors
- Unirradiated CMOS Sensor Matrices from TowerJazz Investigator1 chip characterized with three target materials
  - Linear gain and good energy resolution measured
  - Matrix 80 has a higher gain (0.065 ± 0.002)
  - Matrix 106 has a better energy resolution (0.05 ± 0.04)
  - Low noise in the setup
- More measurements with several target materials ongoing
- Upgrade of setup for irradiated sensors in preparation



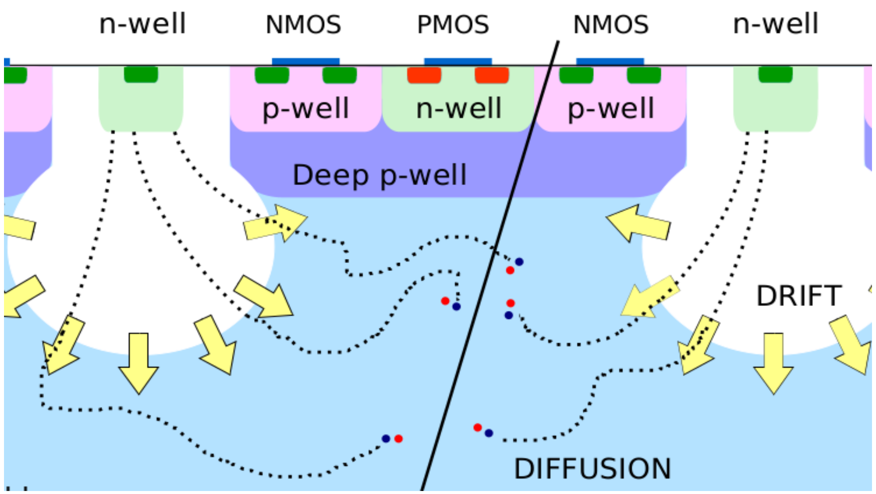
Thanky you!

Thank you to Enrico and the Summer students Felipe and Michael!

Spare

TowerJazz 180nm CMOS technology

- The standard process



Difficult to obtain full lateral depletion
Not radiation hard