Institut
"Jožef Stefan"
Ljubljana, Slovenija

Charge Collection Measurements in irradiated AMS CHESS 1 and TowerJazz CHESS 1 PonP HVCMOS Prototypes

ATLAS Strip CMOS Regular Meeting, 12 April 2016

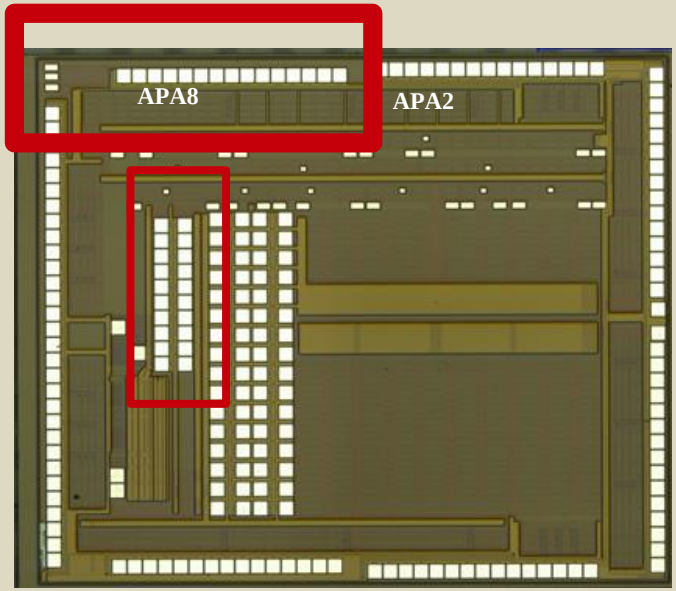
Bojan Hiti, Igor Mandić et al.
Jožef Stefan Institute, Experimental Particle Physics Department (F9)

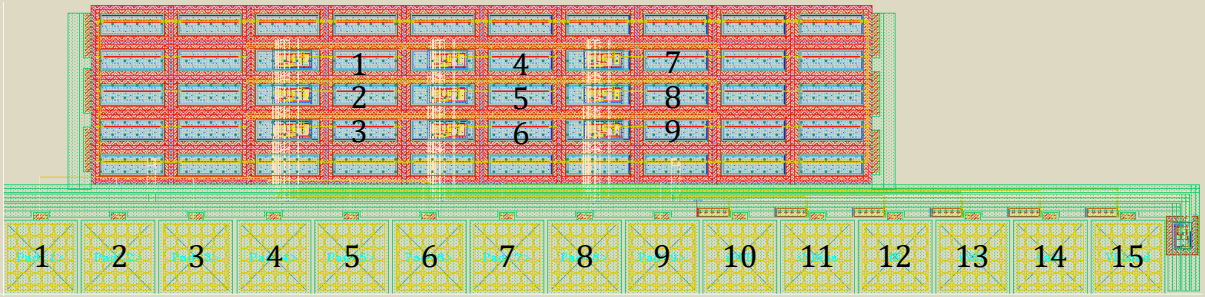
AMS CHESS 1 Sample

- 350 nm, 20 Ω, max. bias voltage 120 V, active pixels

- Irradiated at CERN PS in November 2015
  - low fluence (1 sample) – 3.3e14 neq cm^{-2}
  - high fluence (1 sample) – 4.8e14 neq cm^{-2}
  - annealed 80 min at 60°C

- Active pixel array for edge TCT:
  - APA08: 3x3 pixels, 800 x 45 μm^2
- Isolated amplifier array
  - comparison of responses at different fluences





exemplary layout of a 3x3 APA (200 x 45 μm^2)

Global DAC Settings

- Chip DACs in irradiated samples have to be tuned
  - For VPFB > 2500 mV no signal output
- Greater laser power compared to unirradiated sample needed

CONFIG 7	
VPLOAD	2100
VCASC	2600
VNSF	570
VN	1000
VBIAS	340
VPFB	2664

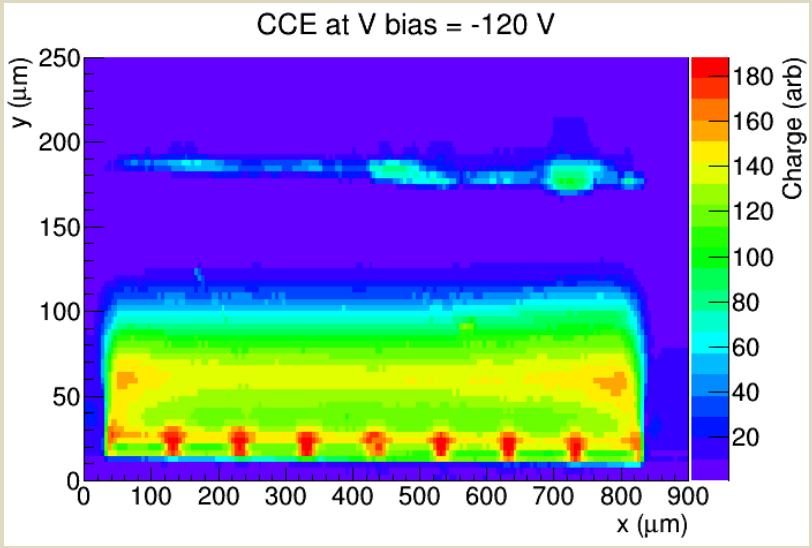
CONFIG 8 (standard)	
VPLOAD	2100
VCASC	2600
VNSF	750
VN	1000
VBIAS	150
VPFB	2700

CONFIG IRRAD	
VPLOAD	2100
VCASC	2600
VNSF	570
VN	1000
VBIAS	300
VPFB	2500

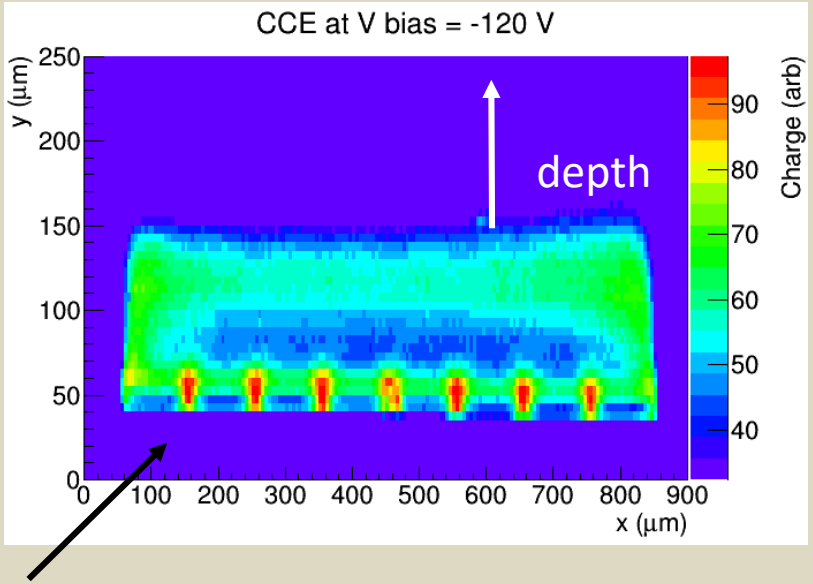
Low Fluence 2d E-TCT Scans

APA08 pixel 5

before annealing



after annealing

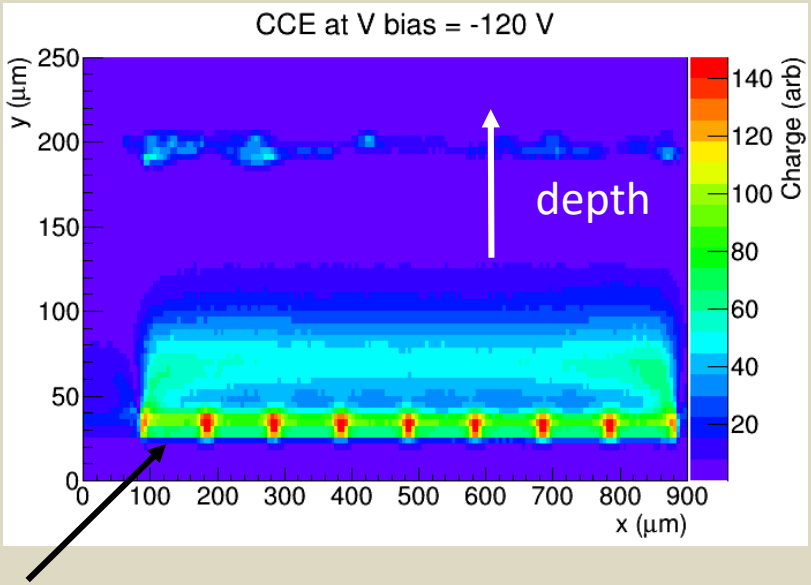


chip surface

High Fluence 2d E-TCT Scans

APA08 pixel 5

after annealing

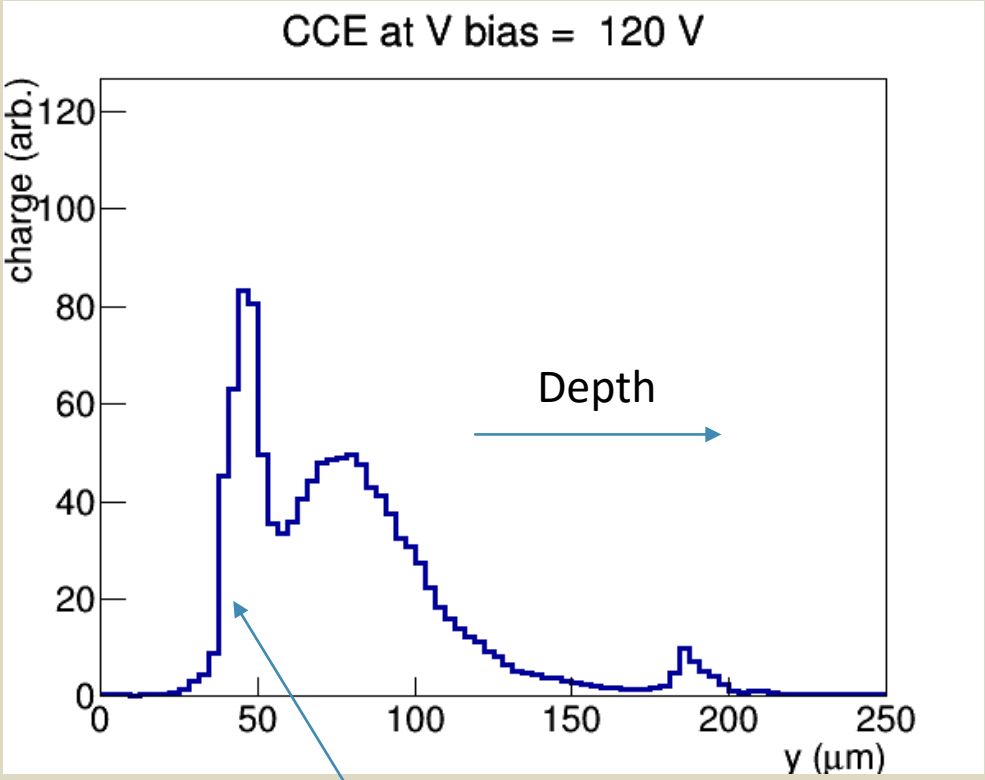


chip surface

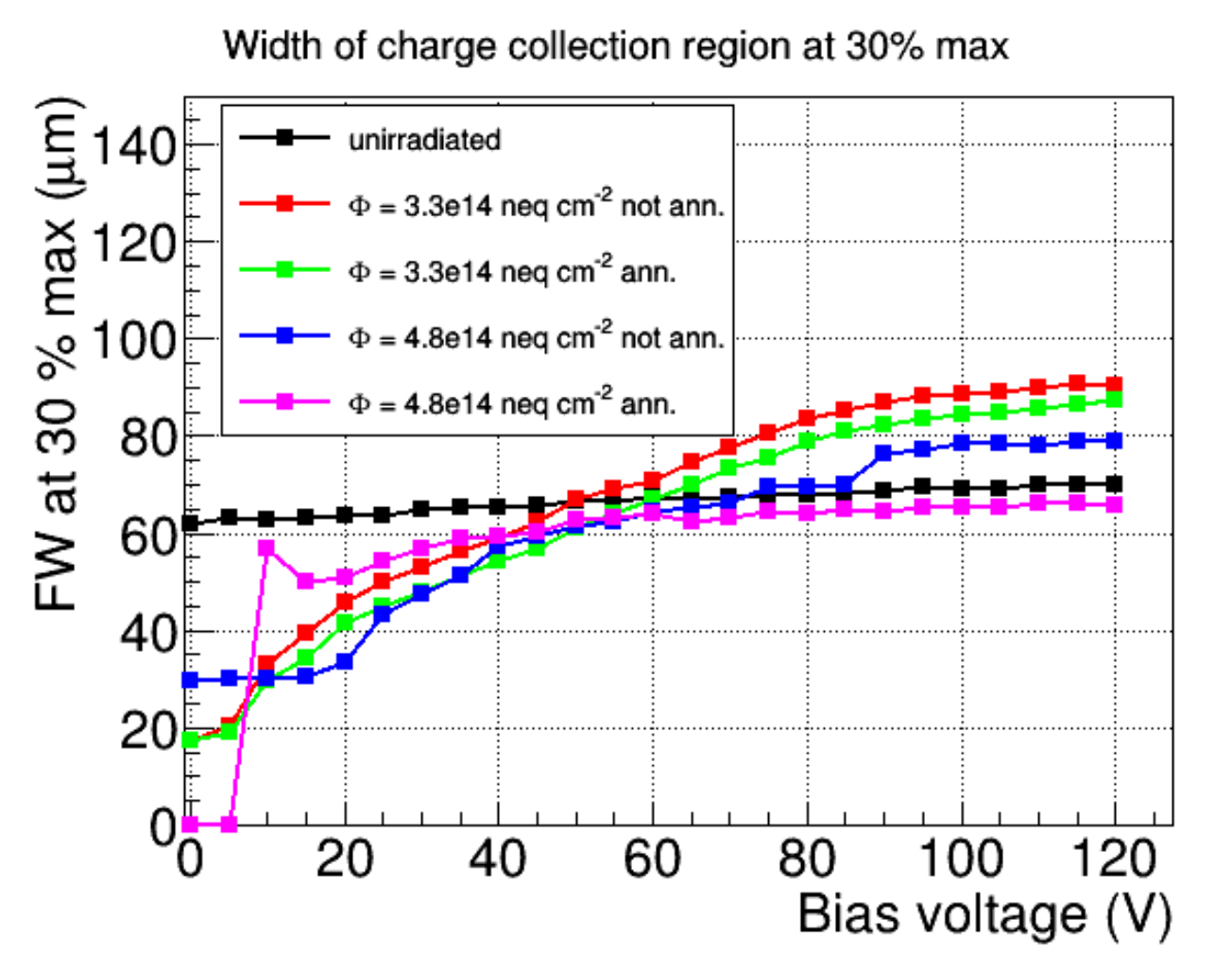
VPFB had to be changed
2500 mV → 2600 mV
after annealing

Size of the Depleted Region

- Width of depleted region calculated as Full Width at 30 % of charge collection profile
- Measured for different fluences and before/after annealing

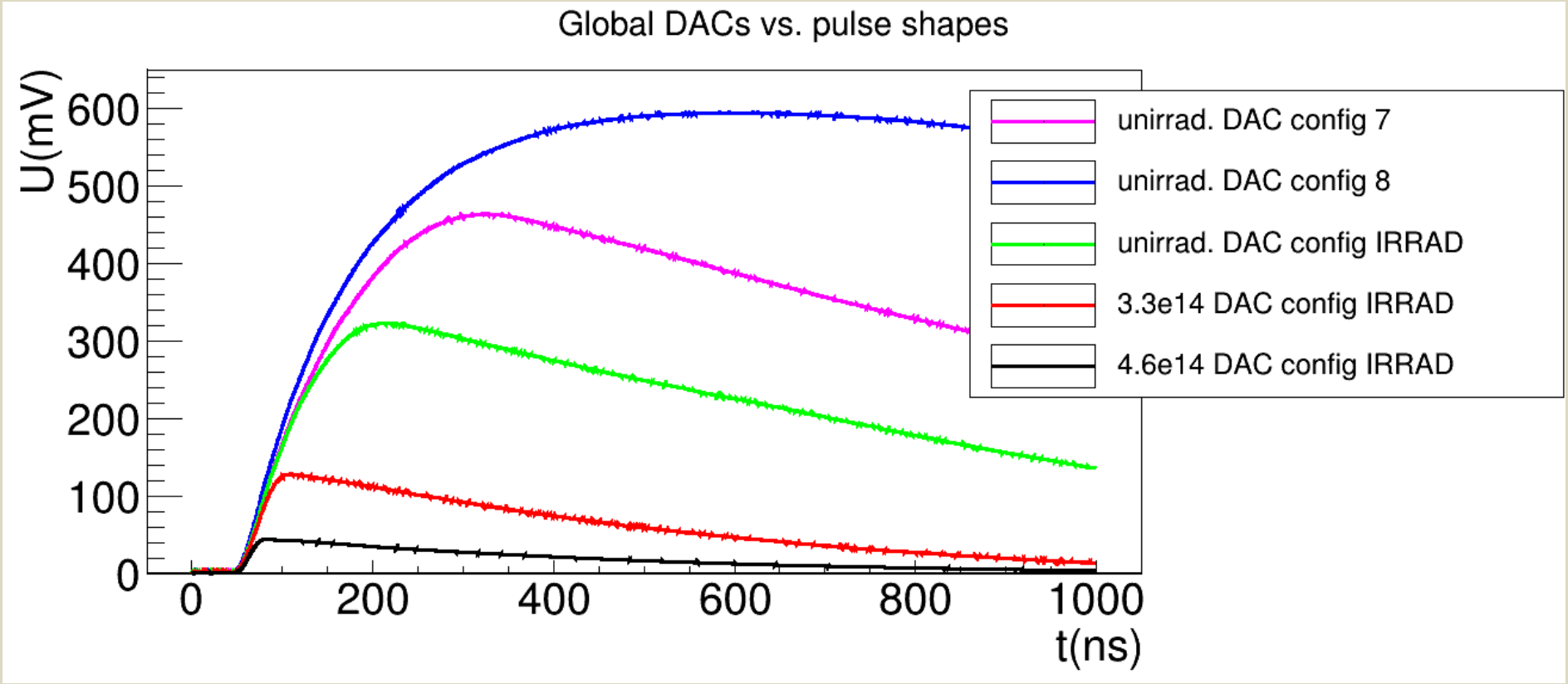


APA08 Depletion Depth vs. Bias



Reminder: Pixel Gain after Irradiation

- Pulse shape on 3 different samples measured (unirrad., low fl., high fl.)
- Same amount of light injected
- 120 V bias



Reasonable amount of charge collected from the sensor

➔ Gain reduces after irradiation

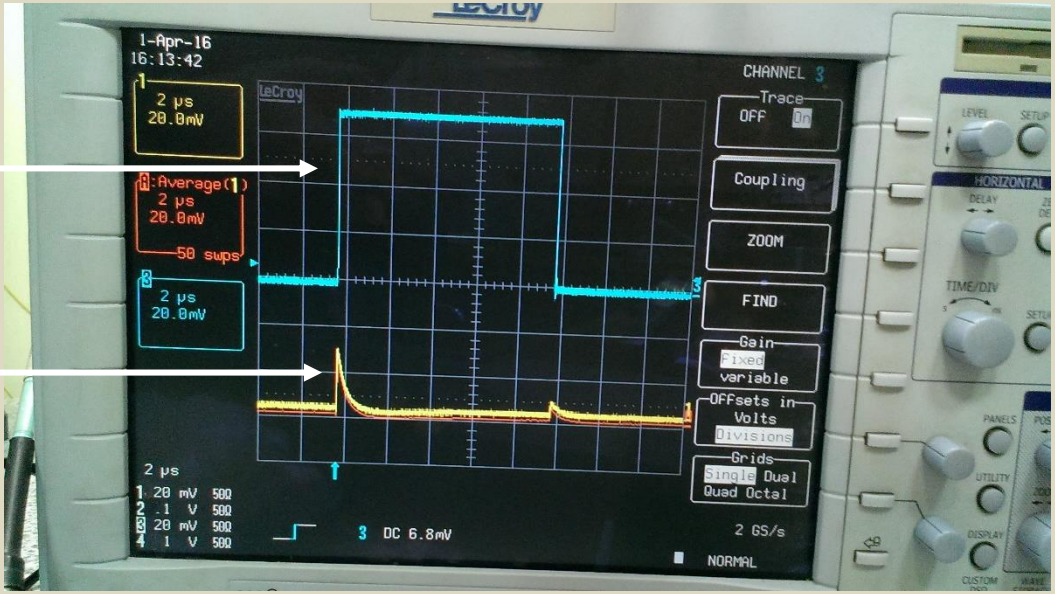
Gain on Isolated Amplifiers

- Cross check gain evolution with fluence on isolated amplifiers
  - 3 – 5 bonded isolated amplifiers on each sample (variation on chip 20 %)

- External pulse injection via 4 nF capacitance:
  - pulse amplitude 0 – 500 mV
  - step function, ON time 10 µs, frequency 1 kHz

U_in

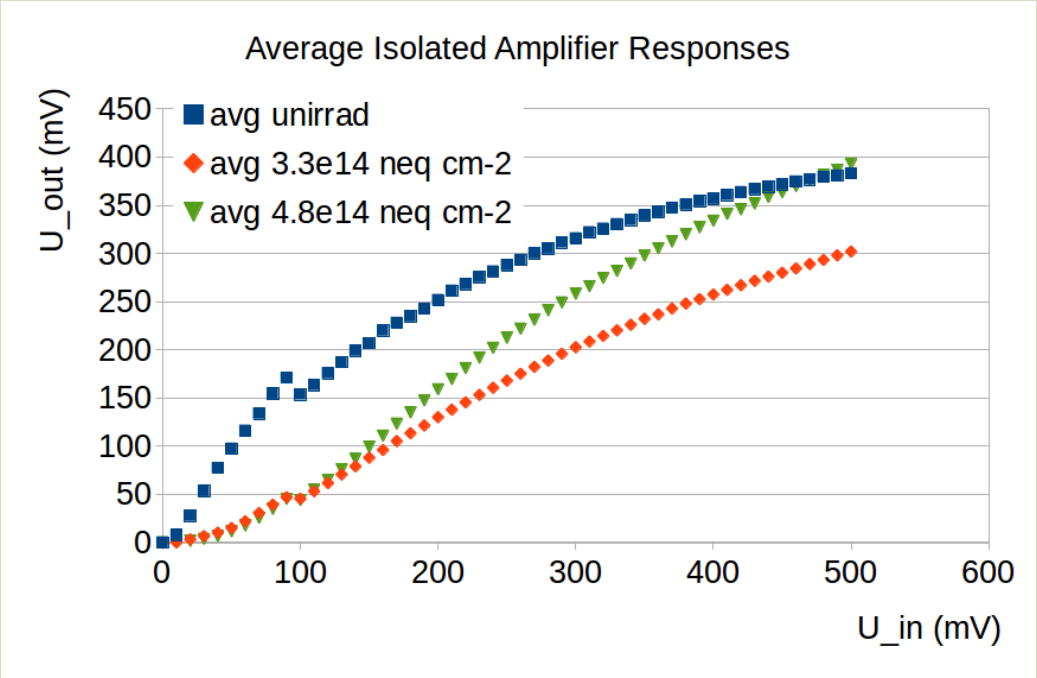
U_out



DAC CONFIG

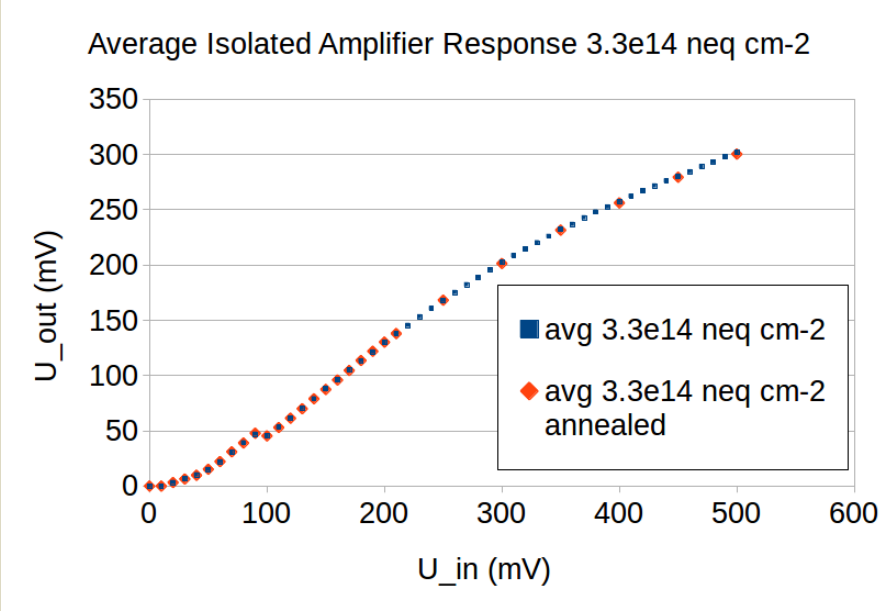
VPLOAD	2100
VCASC	2600
VNSF	570
VN	1000
VBIAS	340
VPFB	2200

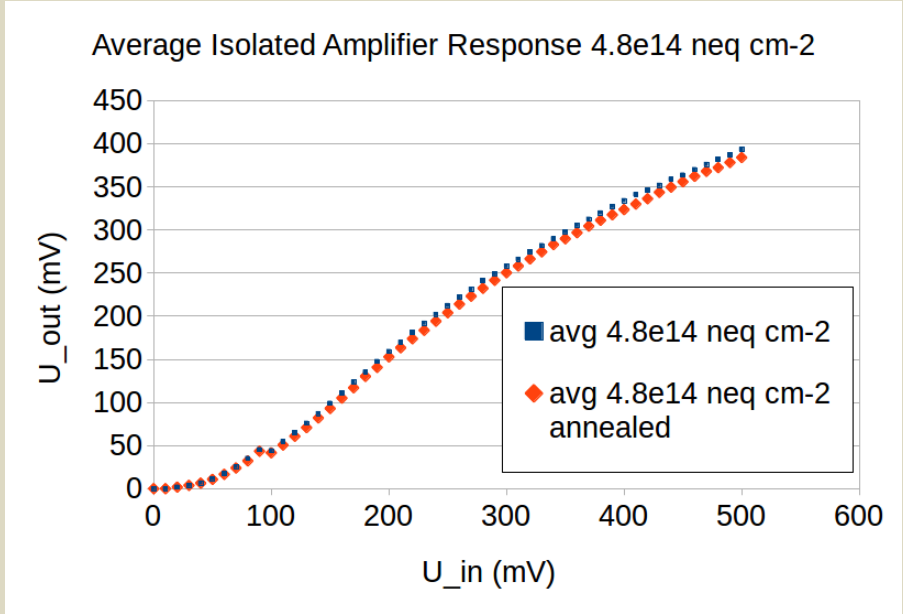
Gain on Isolated Amplifiers



- Factor 3 difference between unirrad. and irradiated samples in the low amplitude domain
- Can to some extent explain the drop in the gain after irradiation
- Does not explain the variation between low and high fluence

Annealing on Isolated Amplifiers





- No changes in the isolated amplifier response after annealing

TowerJazz CHESS 1 Sample

- 180 nm process
- epitaxial layer 1 kOhm cm, thickness 20 µm – for charge collection
- 2 chip designs: PonP, PonN – substrate type
- small collecting electrodes
- electronics in deep p-well

- We measure bulk properties with E-TCT

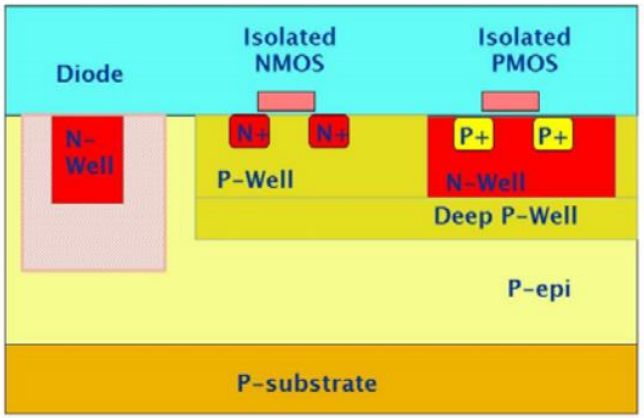


Figure 1. Cross-section of a PonP pixel

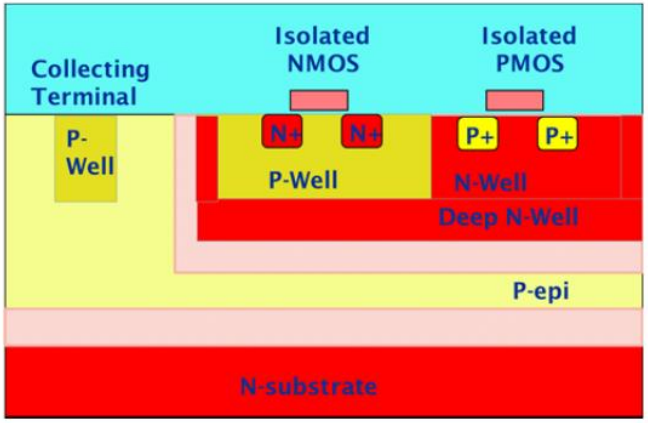
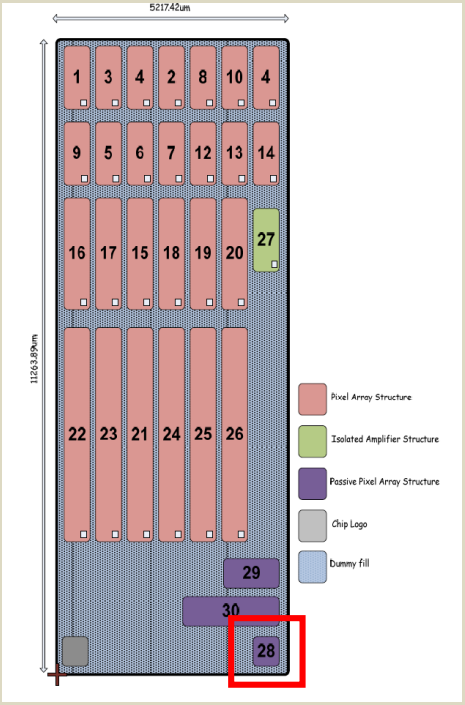
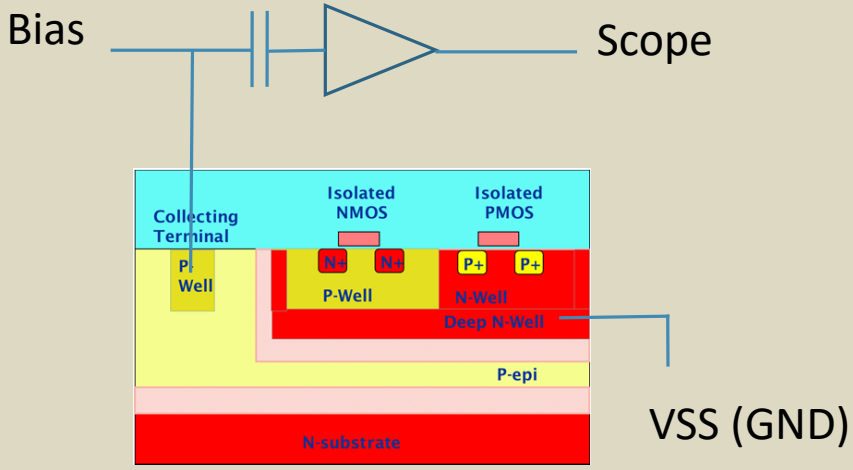


Figure 2. Cross-section of a PonN pixel

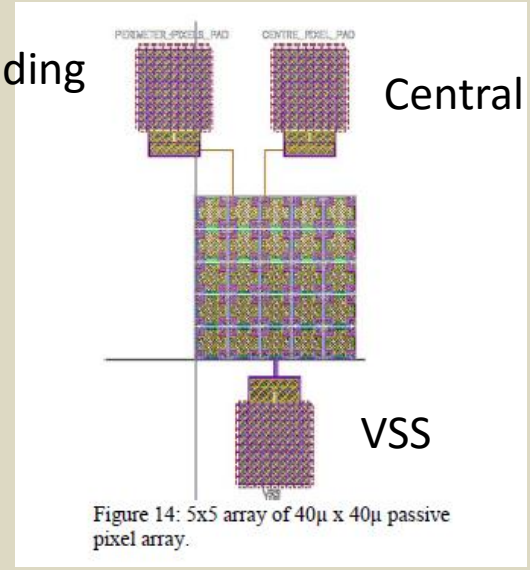
TowerJazz CHESS 1 PonN



structure 28
passive pixel array
pixel size 40x40 µm^2

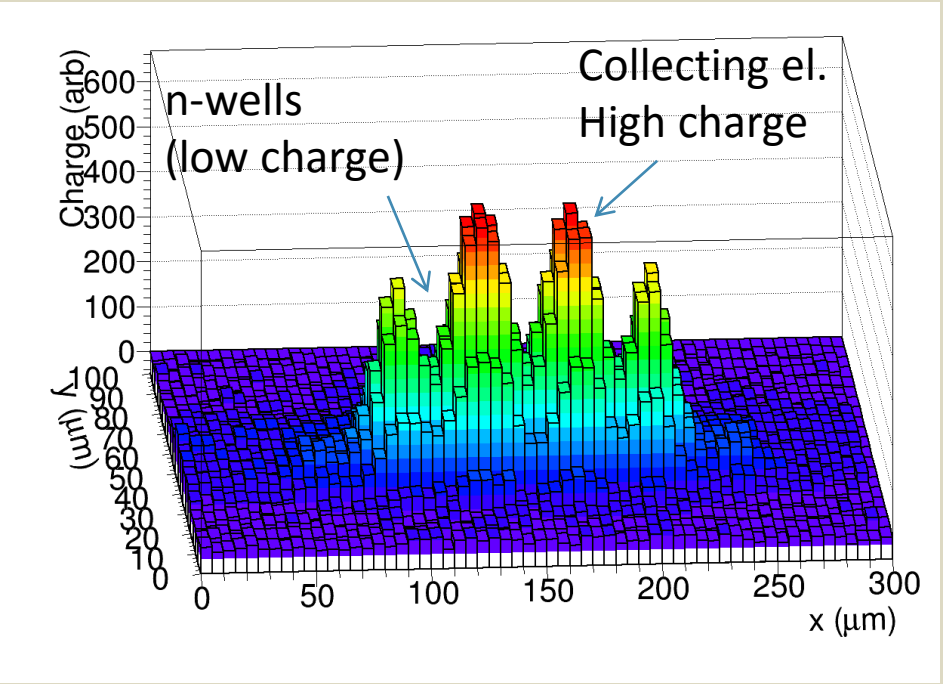


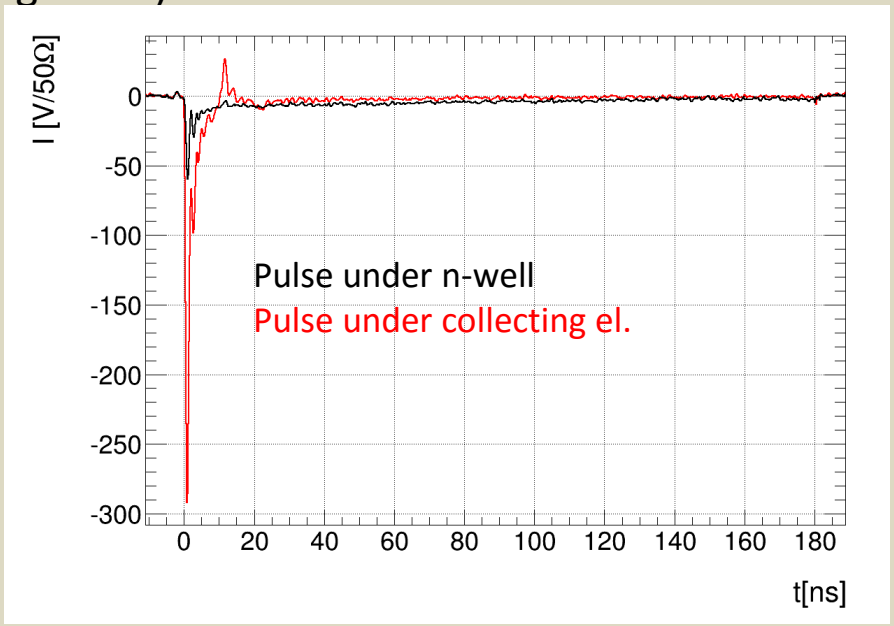
Surrounding 8 pixels



Charge Collection PonN

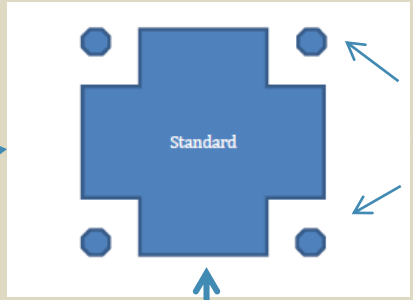
- high currents: 7 uA when collecting electrode at -1.5 V
- bias -1.5 V, 9 pixels read out, charge (25 ns integration)





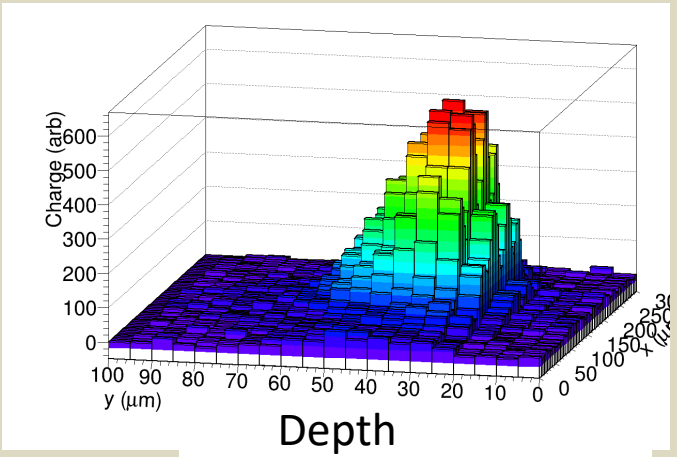
Pixel (top view):

N-well



Collecting electrodes

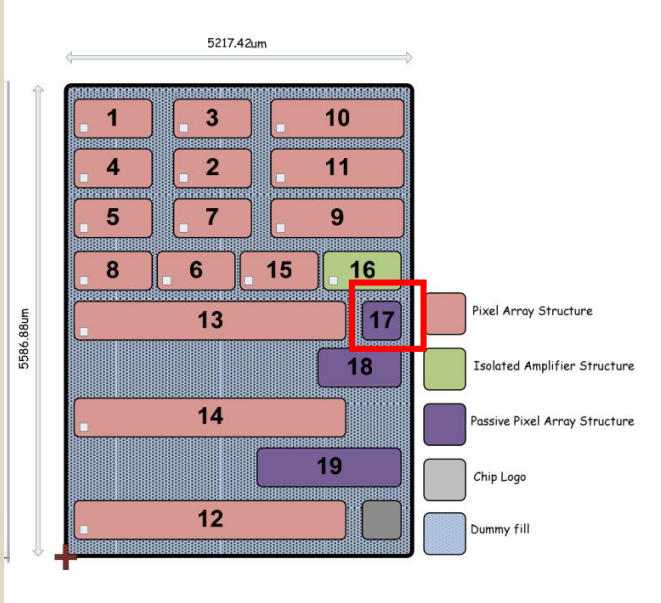
Laser beam direction



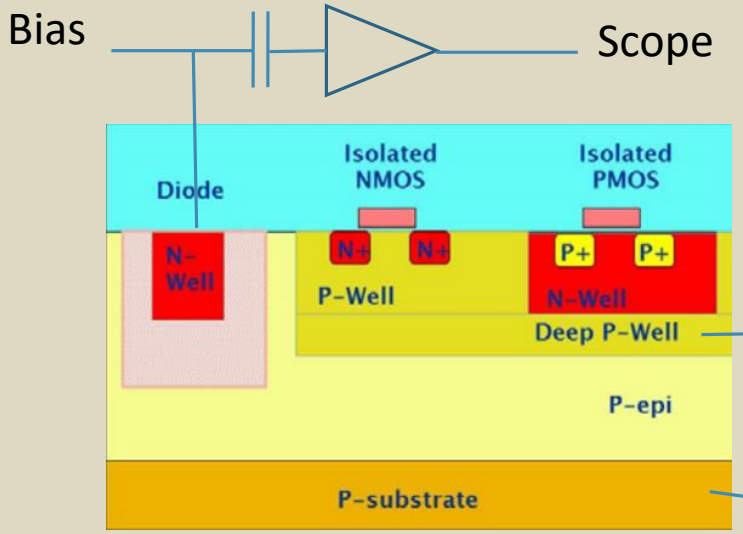
Depth

Active depth: ~ 20 um

TowerJazz CHESS 1 PonP



structure 17
passive pixel array
pixel size 40x40 μm^2

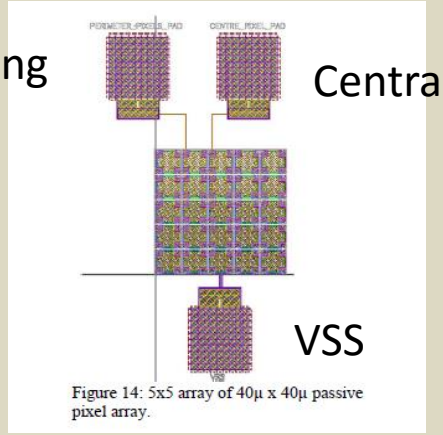


VSS (GND)

substrate (GND)

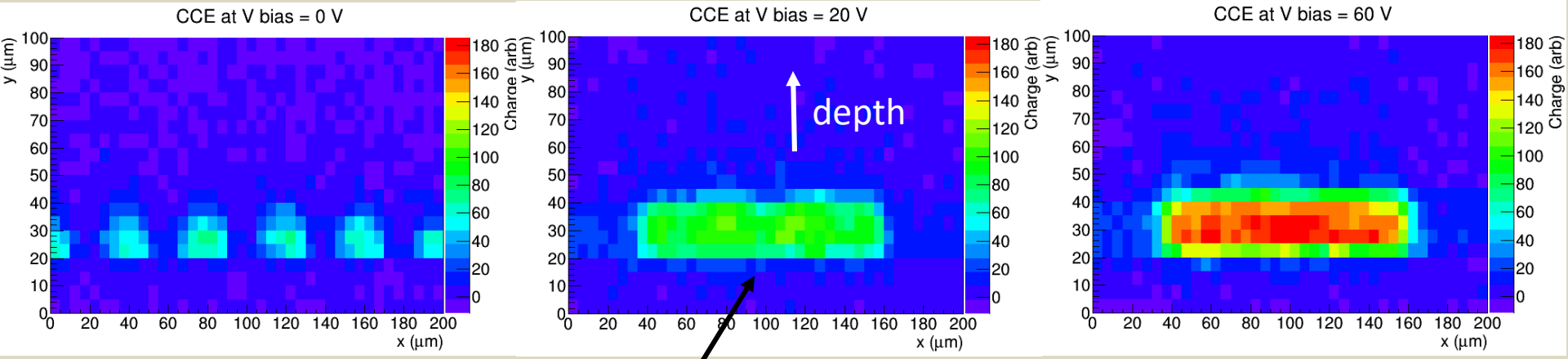
not correct bias configuration for active pixels

Surrounding 8 pixels



Charge Collection PonP

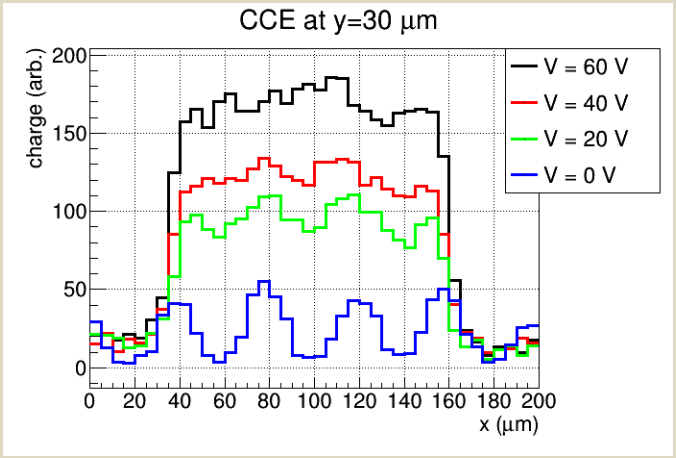
- bias voltage up to 60 V (current < 1 µA) – not correct bias configuration for active pixels
- 9 pixels read out, charge (25 ns integration)

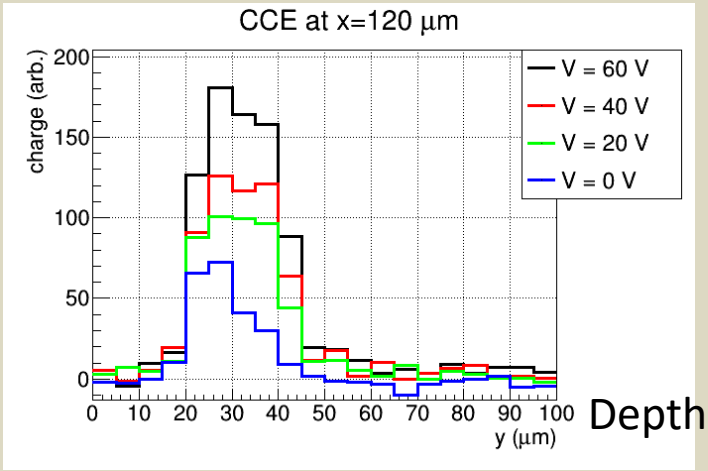


cross section x

chip surface

cross section y

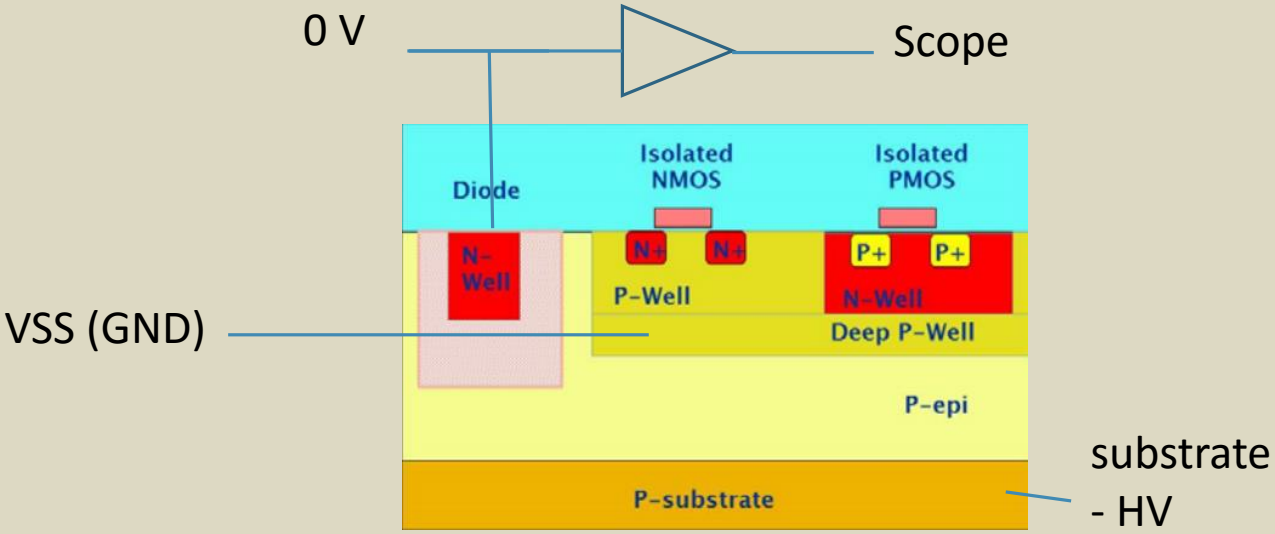




Depth

Active depth: approx. 20 µm

Correct bias configuration for PonP



High leakage current
1 µA at -2.5 V

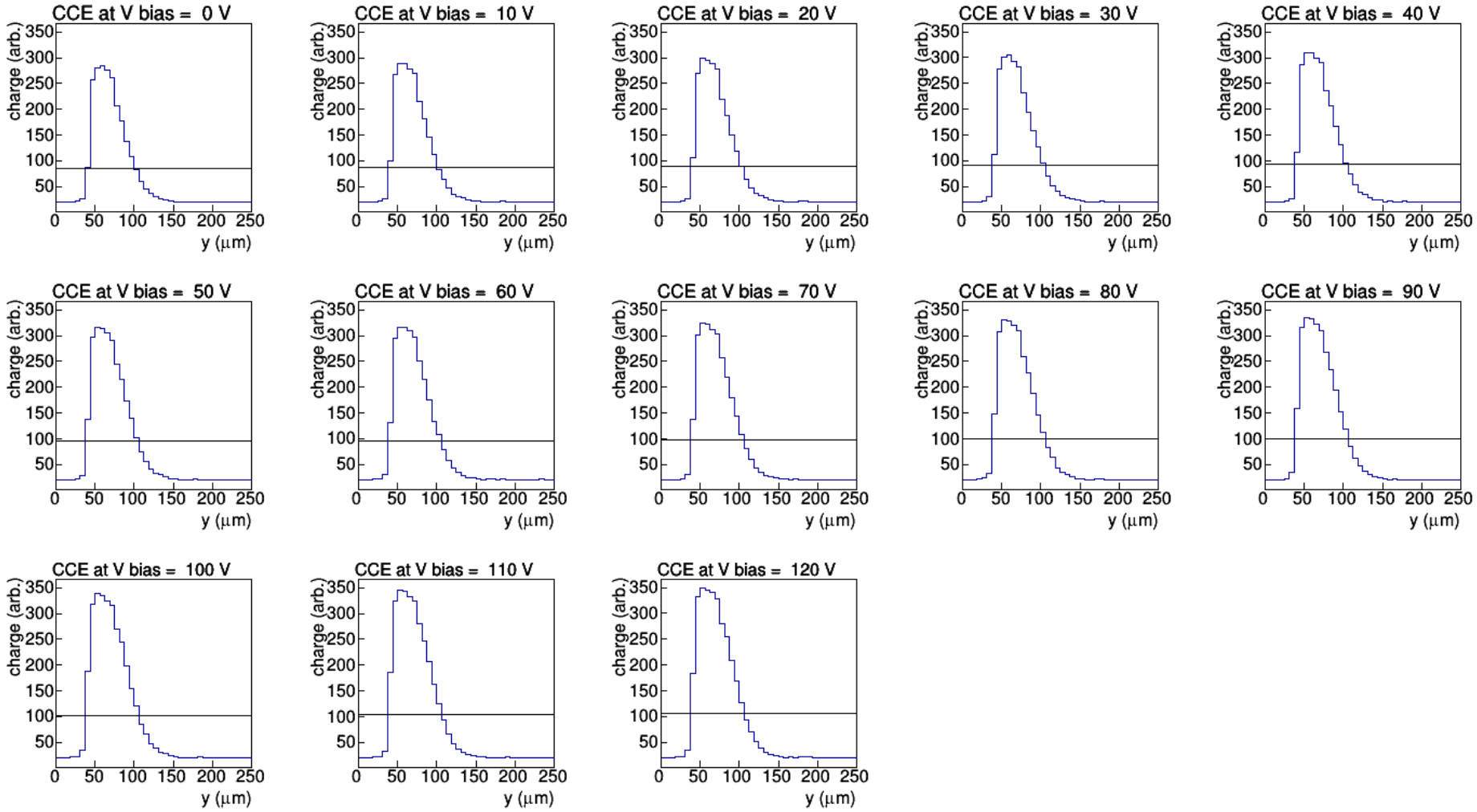
Conclusion

- AMS CHESS 1
  - measured charge collection in proton irradiated sample + annealing
  - isolated amplifier tests indicate gain drop after irradiation, however not conclusive

- TowerJazz CHESS 1
  - first E-TCT measurements done with PonN and PonP
  - observed signal from the entire epitaxial layer
  - Feature sizes in agreement with design values
  - High leakage currents

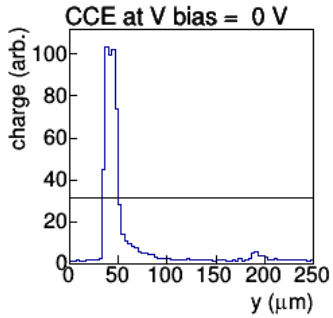
AMS Charge collection profiles – unirradiated

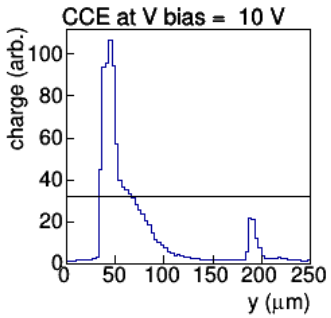
unirradiated

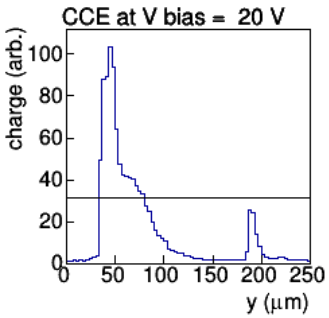


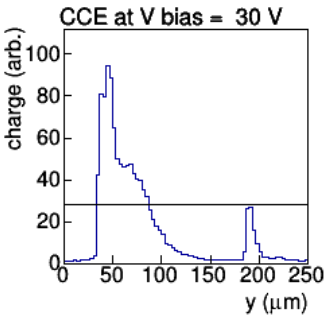
AMS Charge collection profiles – 3.3e14

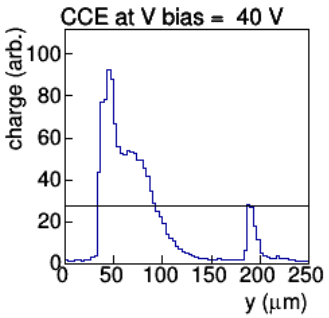
3.3e14 neq cm^{-2}, not annealed

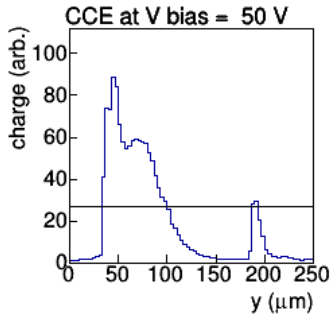


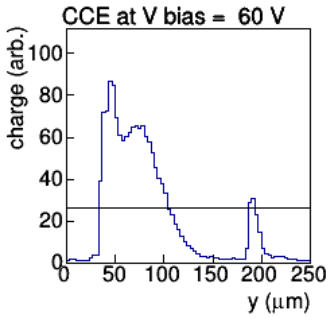


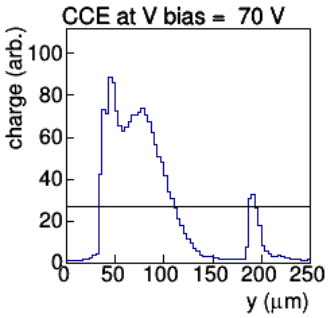


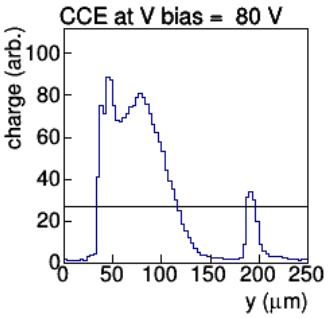


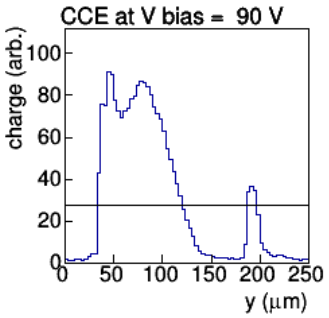


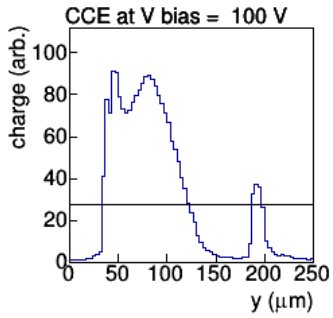


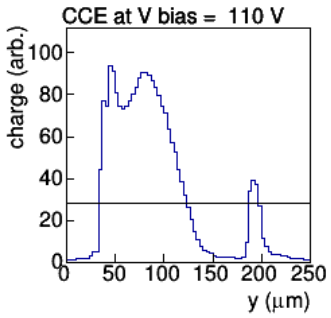


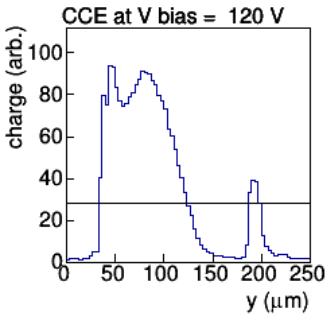






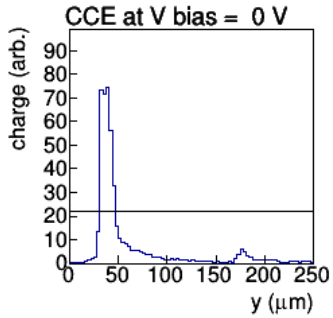


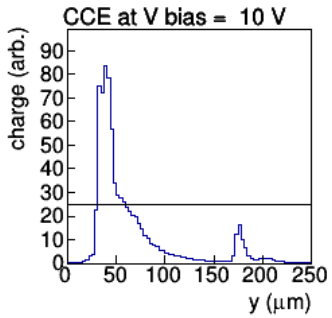


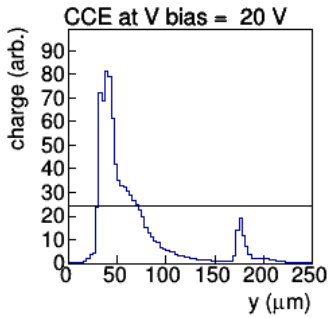


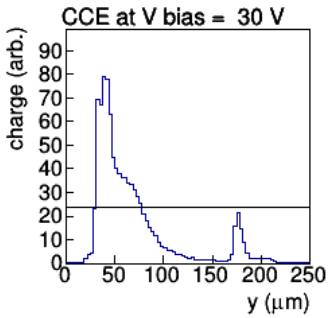
AMS Charge collection profiles – 3.3e14

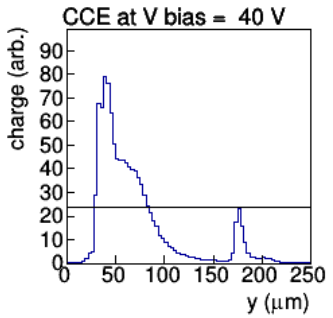
3.3e14 neq cm^{-2}, annealed

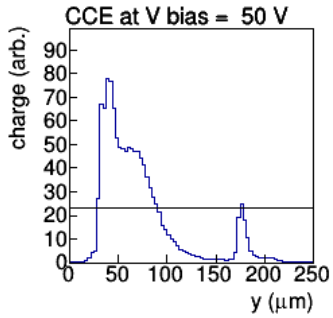


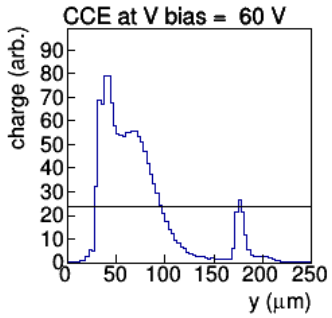


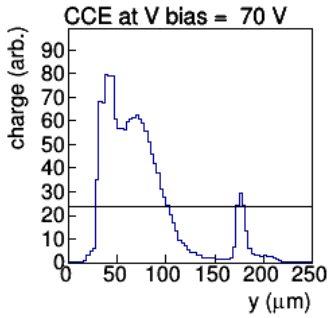


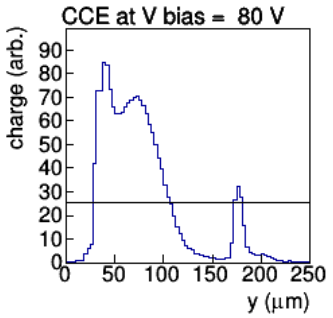


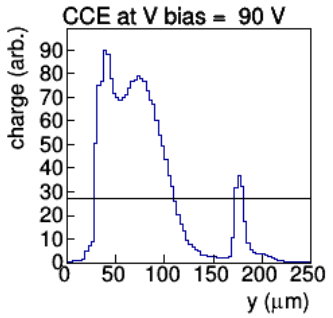


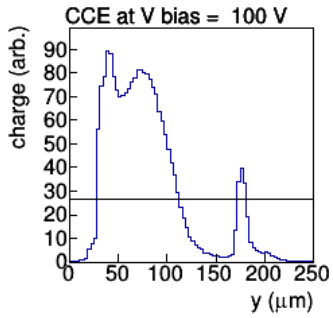


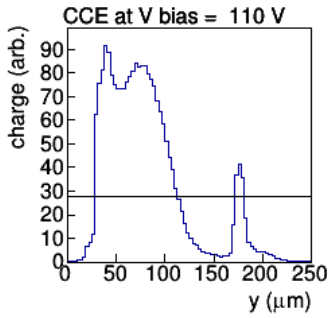


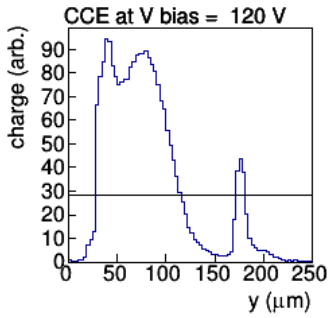






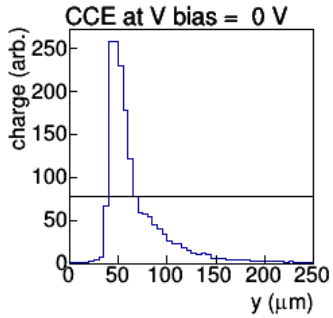


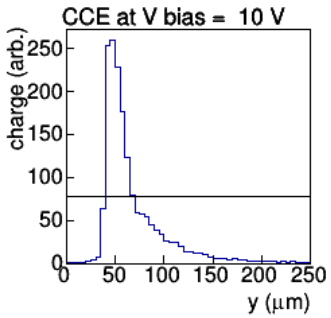


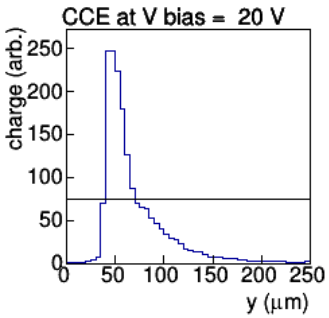


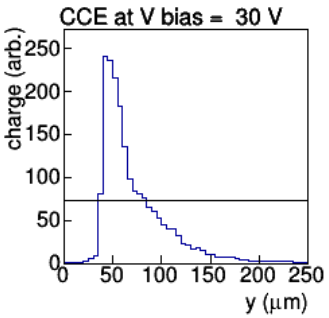
AMS Charge collection profiles – 4.8e14

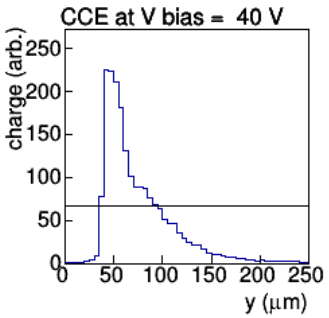
4.8e14 neq cm^{-2}, not annealed

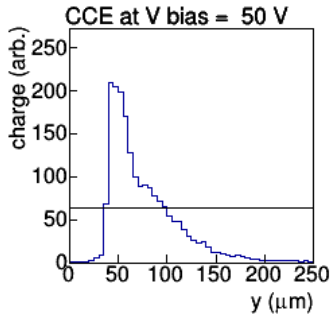


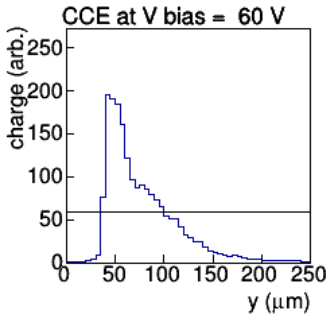


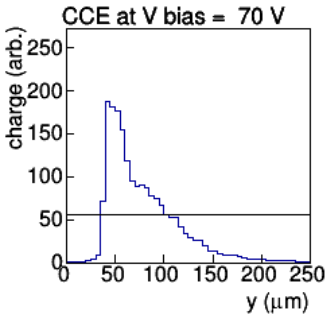


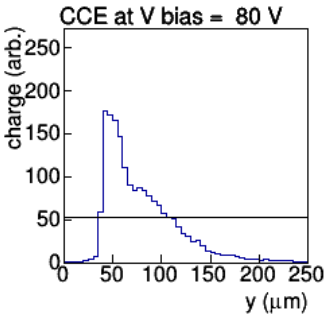


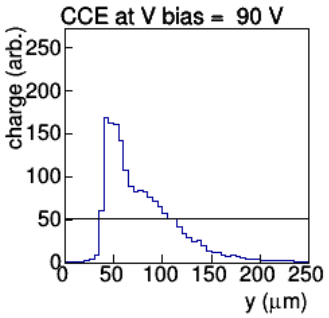


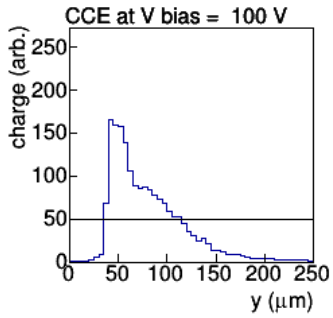


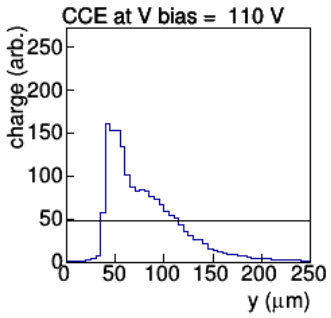


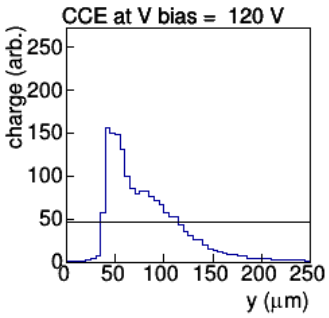












AMS Charge collection profiles – 4.8e14

4.8e14 neq cm^{-2}, annealed