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Fast Quality Assurance (QA) Tests for LGAD Production

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- Devices & readout
- Measurements & analysis
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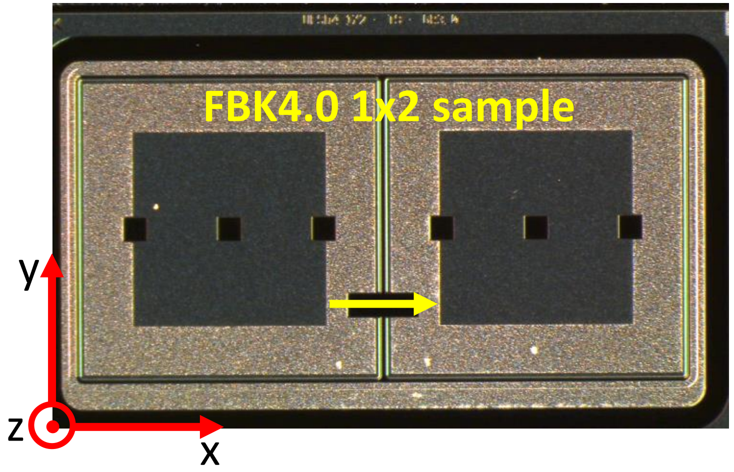
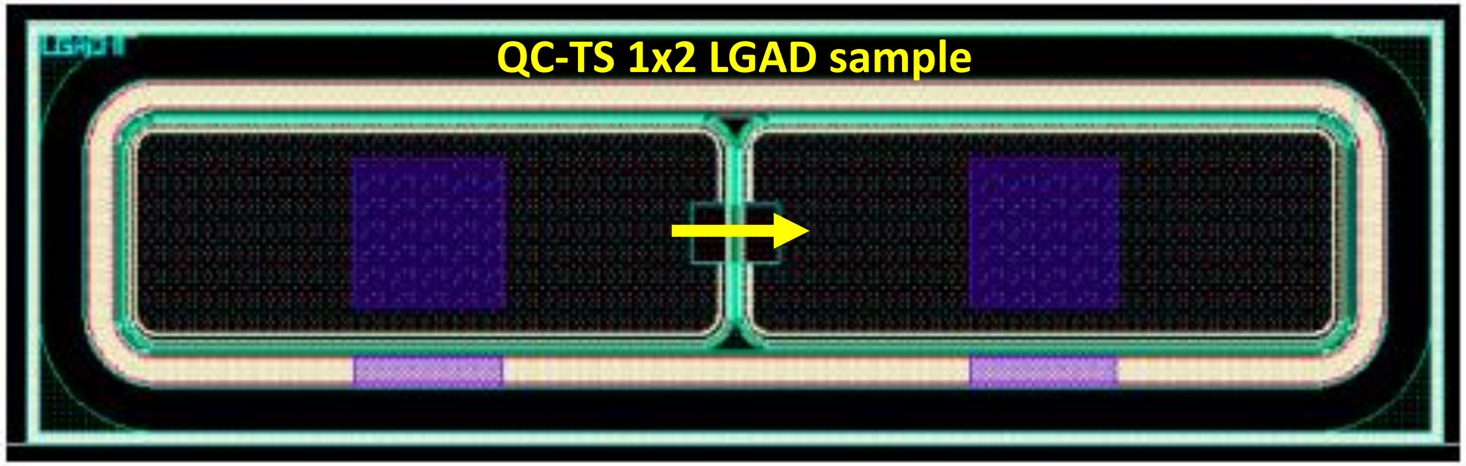
Motivation

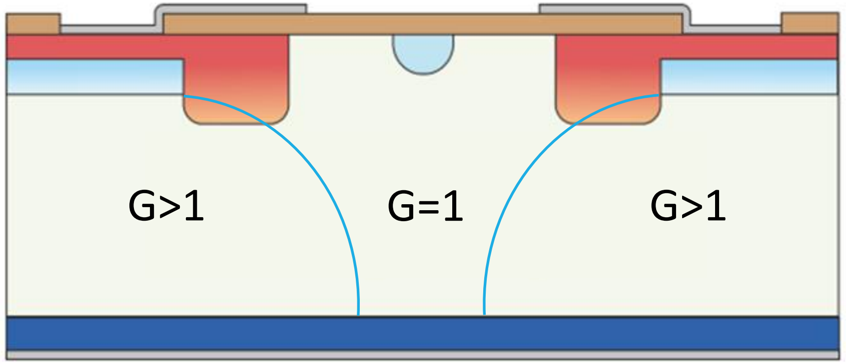
- During production phase of sensors for HGTD extensive Irradiation Tests (IT) will be done on each batch (50-200 wafers per batch)
- Typically several tests per batch planned
- Radiation hardness of LGADs is very sensitive to small variation in production (1% diff. in [B] makes a difference)
- IT are meant to provide info on radiation hardness
- The outcome of the IT will largely depend on statistics. Methods should therefore be:
  - simple & fast, to allow large number of samples measured with little resources
  - such that allow extraction of large number of sensor parameters from a single measurement
  - available at several sites
- CC/timing measurements with ^{90}Sr are slow & allow limited number of tests
- Proposal: use a Scanning-TCT set-up and a 1x2 LGAD array w/ opening in IP region
- Speed up the tests and provide reliable information on gain (and other important parameters)
- Idea from studies of PiN and LGAD structures shown before

Devices used



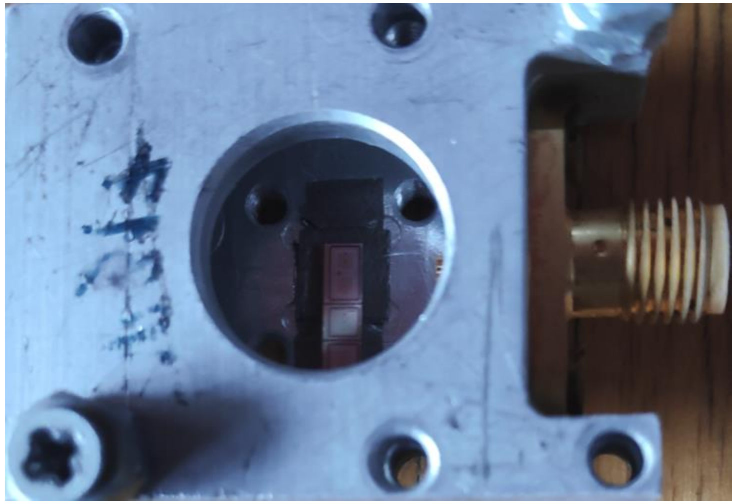


- Instead of separate PiN and LGAD structures
- 1x2 LGAD (IPD measurement) w/ opening in passivation in ATLAS HGTD QC-TS
- Gain only present on pads, no gain in IP region
- Single measurement, multiple parameters extracted
- Much faster check of irradiated samples than CC/timing

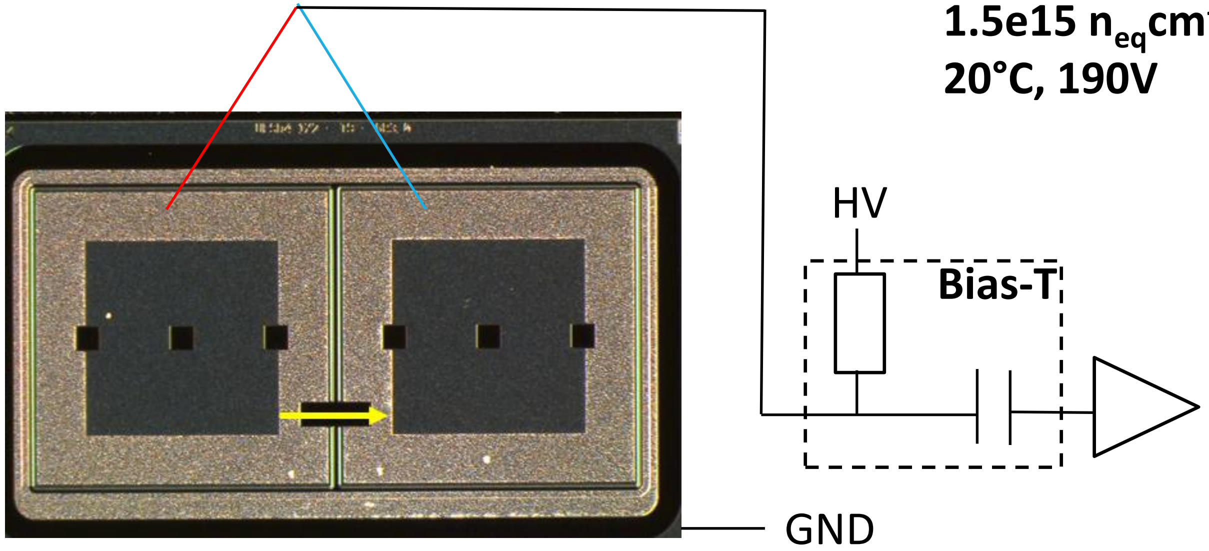


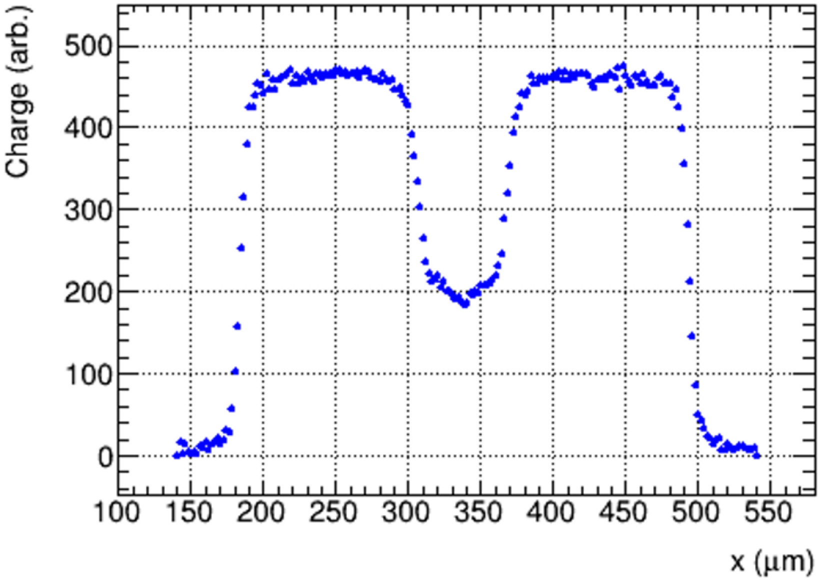
Readout of the LGADs

- Sensor mounted in simple Al housing and wire-bonded (two bonds)
- Single amplifier is used (explored also option with two amps)
- Scan over the opening in the IP region using an IR laser (1064nm)



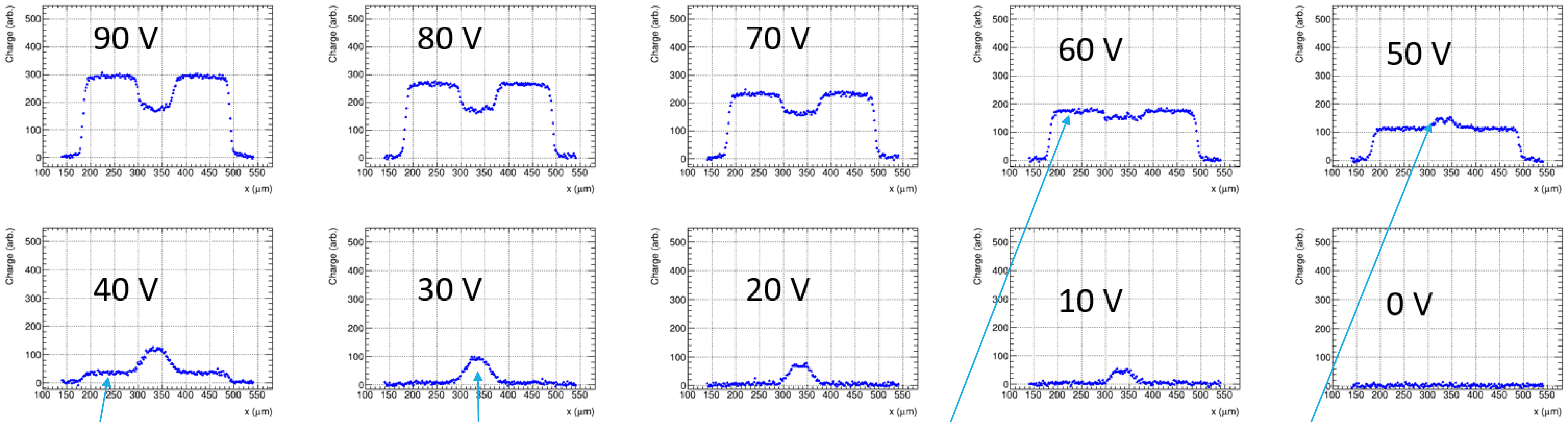
FBK4-W18
(deep C-GL)
1.5e15 $n_{eq}cm^{-2}$
20°C, 190V





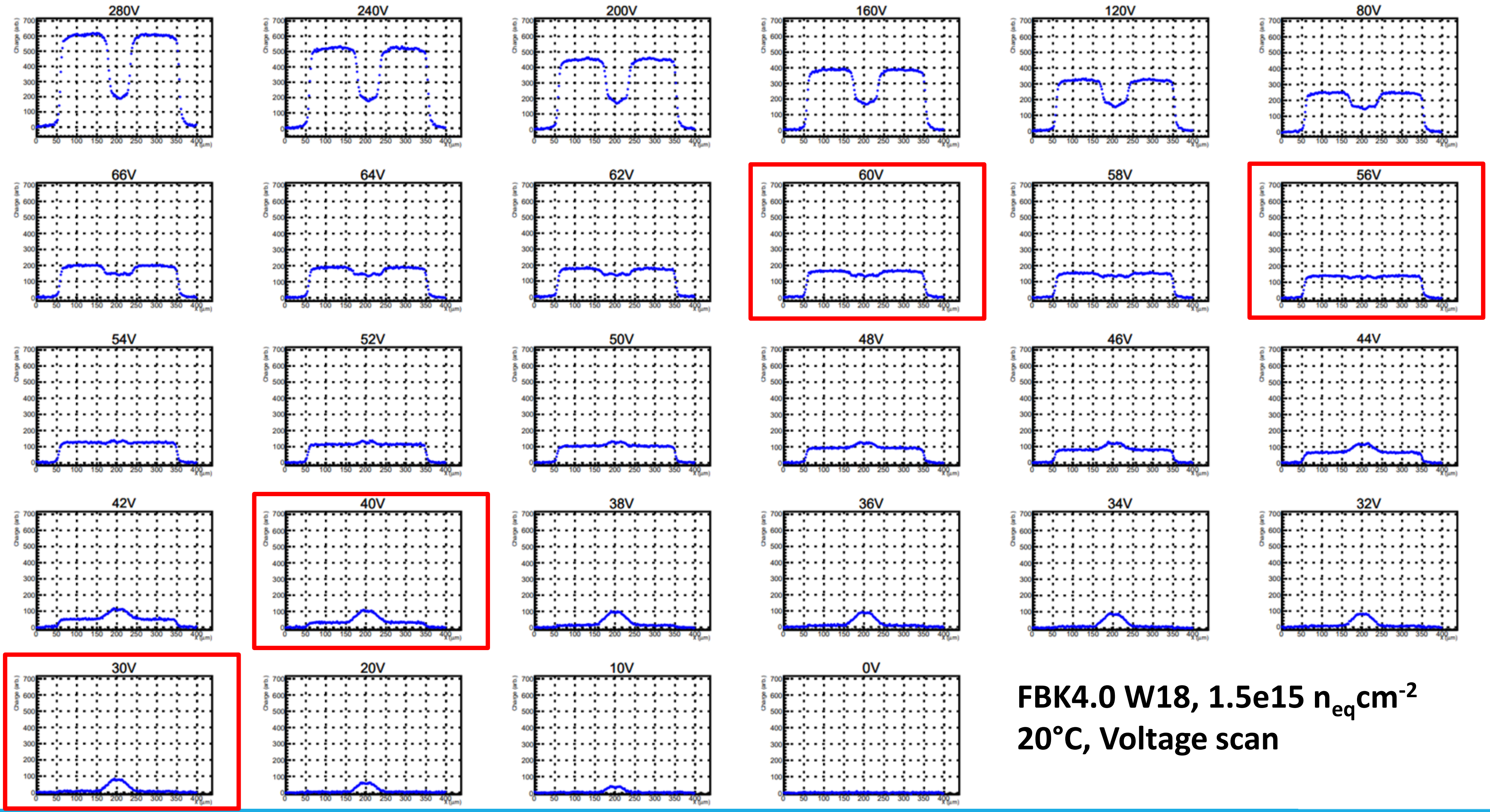
Measurement – before irradiation

FBK4.0 W18, 20°C, Voltage scan



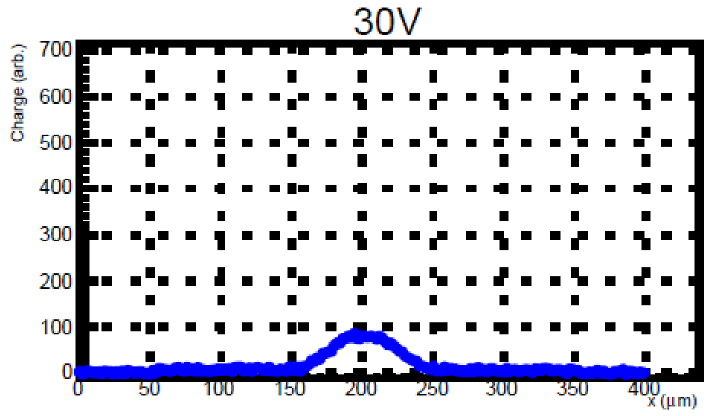
1. Depletion of "no gain" region – full depletion of active layer
2. Depletion of gain layer – appearance of signal in GL (agrees with CV)
3. Full depletion of the device
4. Gain increases

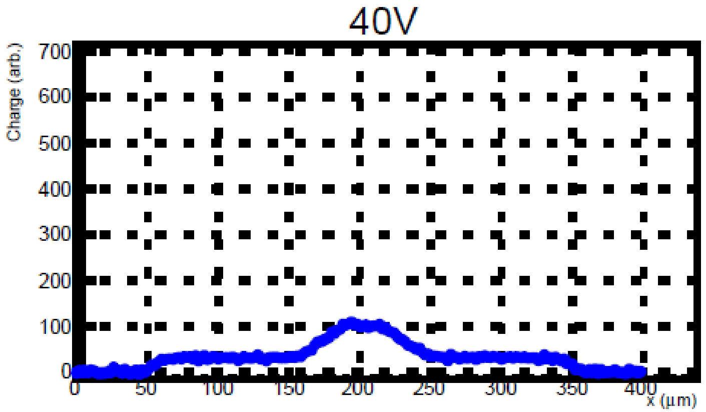
Measurement – after irradiation



FBK4.0 W18, 1.5e15 $n_{eq}cm^{-2}$
20°C, Voltage scan

Analysis





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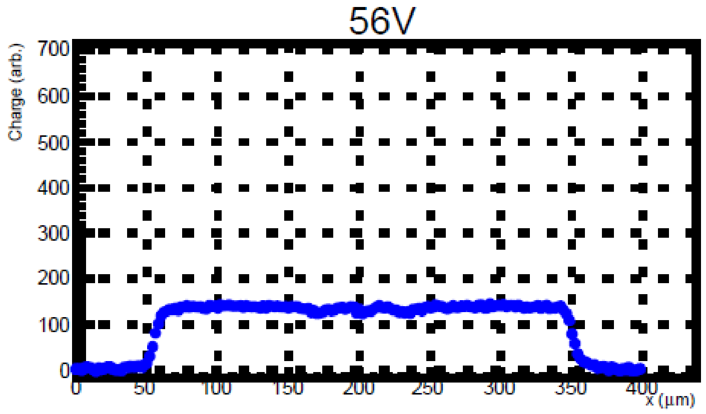
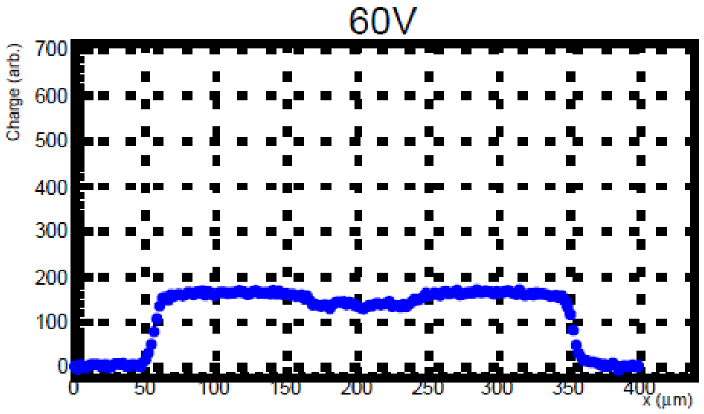
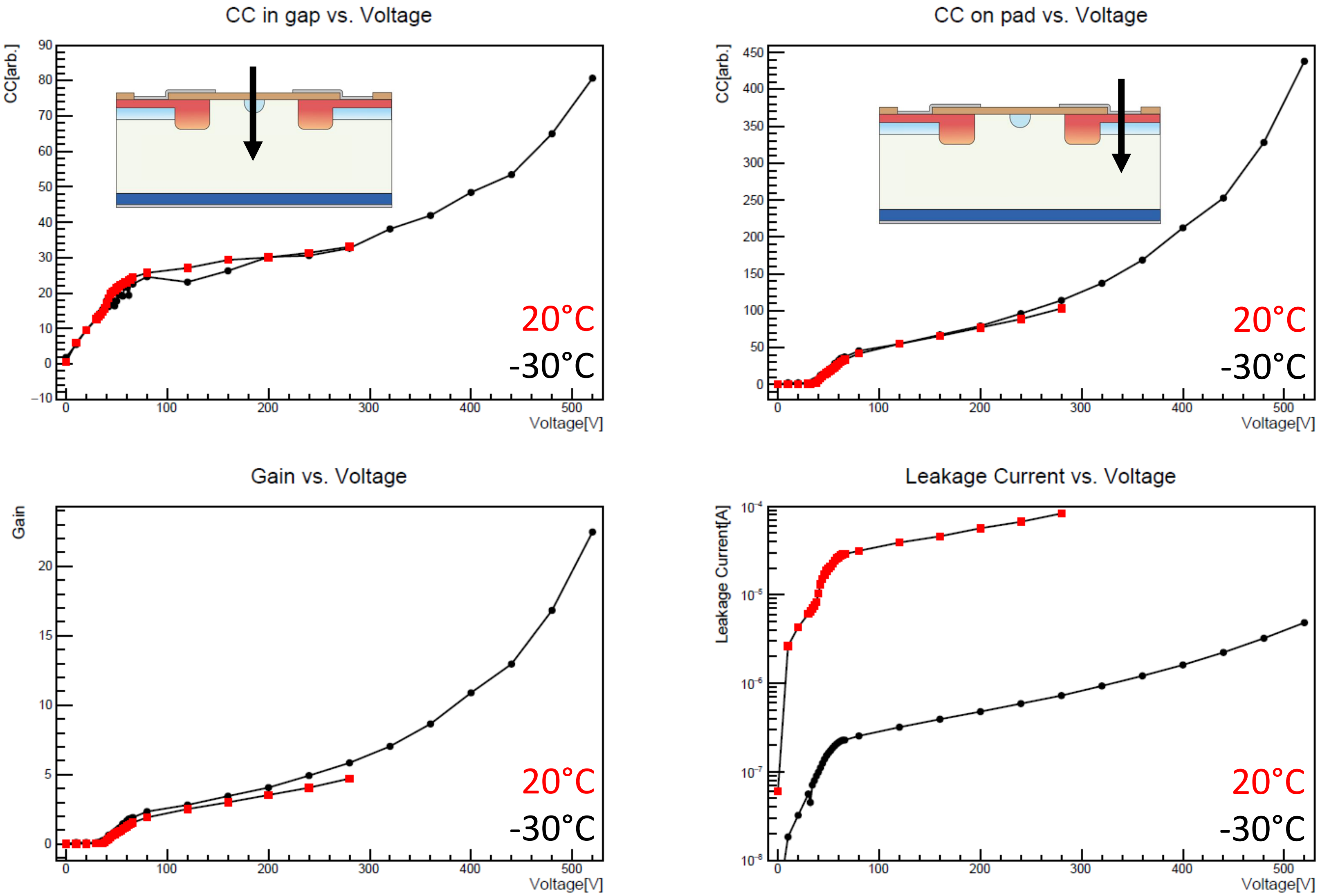




Extract parameters: CC in gap, CC on pad, I_{leak}, I_{gen}, G, V_{GL}, V_{FD}, IPD

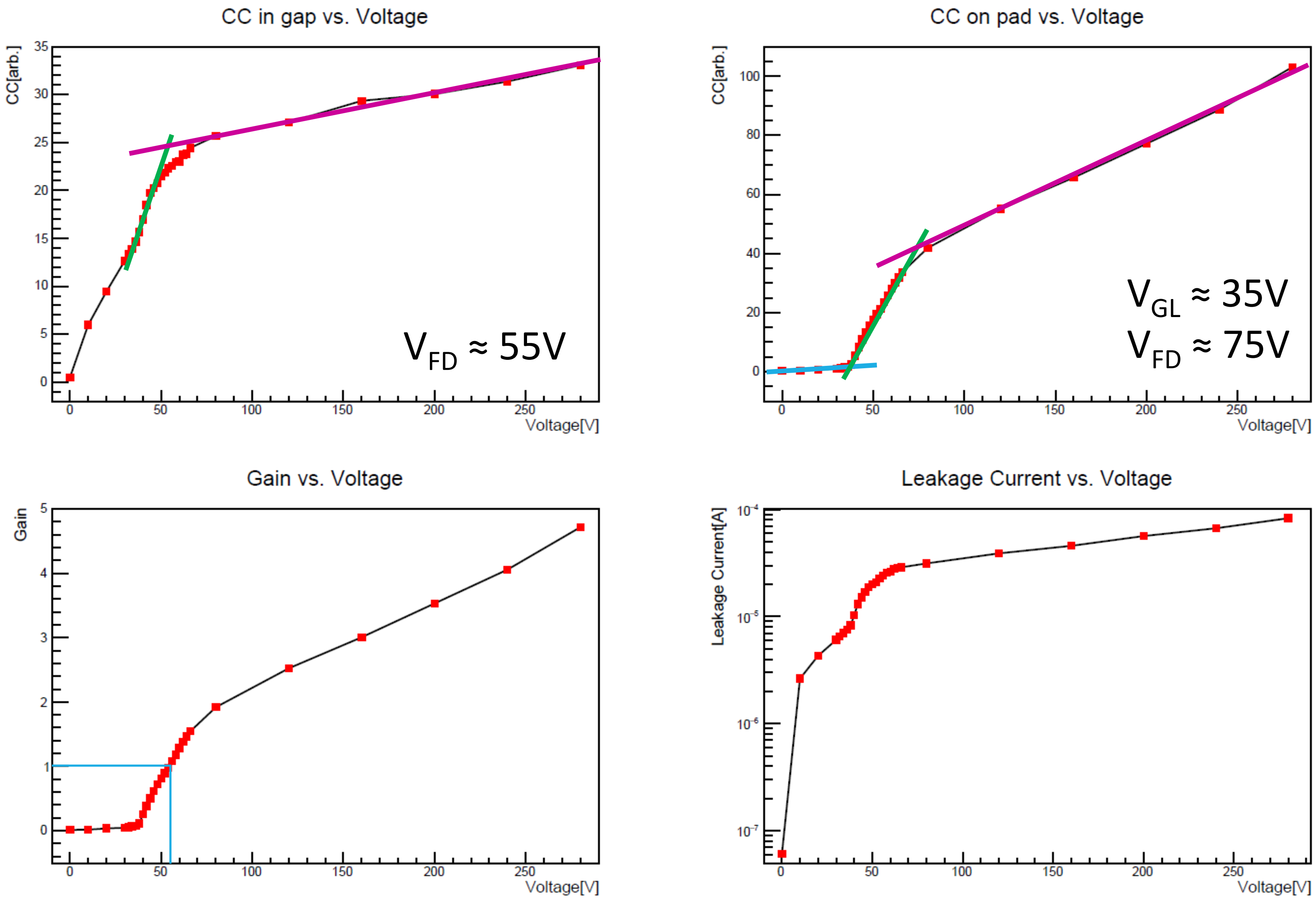
Analysis – temperature scan



FBK4.0 W18, 1.5e15

- Average of several points
- Scaled to correct for different laser intensities & absorption of IR light in Si
- No significant difference between 20°C and -30°C in important parameters (apart from of course I_{leak})

Extraction of parameters



- One scan → several parameters measured
- V_{GL}, V_{FD} extracted the same way as from CV
- Gives good picture of radiation hardness of entire device
- Analysis done with root script (can produce file ready for reporting to DB)

Conclusions

- Use TCT and a 1x2 LGAD array w/ opening in IP region on the ATLAS QC-TS for QA-IT
- At room temperature a full test takes around 2h – much faster than CC/timing
- An analysis script will produce the output for the database with all extracted parameters: I_{leak}, I_{gen}, G, V_{GL}, V_{FD}, IPD
- Very low values of gain can be measured at room temperature (with CC in ^{90}Sr gains at room temperature can not be observed due to noise)
- Need to assure a clear correlation between gain measured for a sample with CC/timing using ^{90}Sr at -30°C and $\approx V_{SEB}$ and the gain measured with TCT at room temperature
- Once the correlation is established we monitor the differences with respect to the “reference” sample

Thank you for your attention

Backup Slides

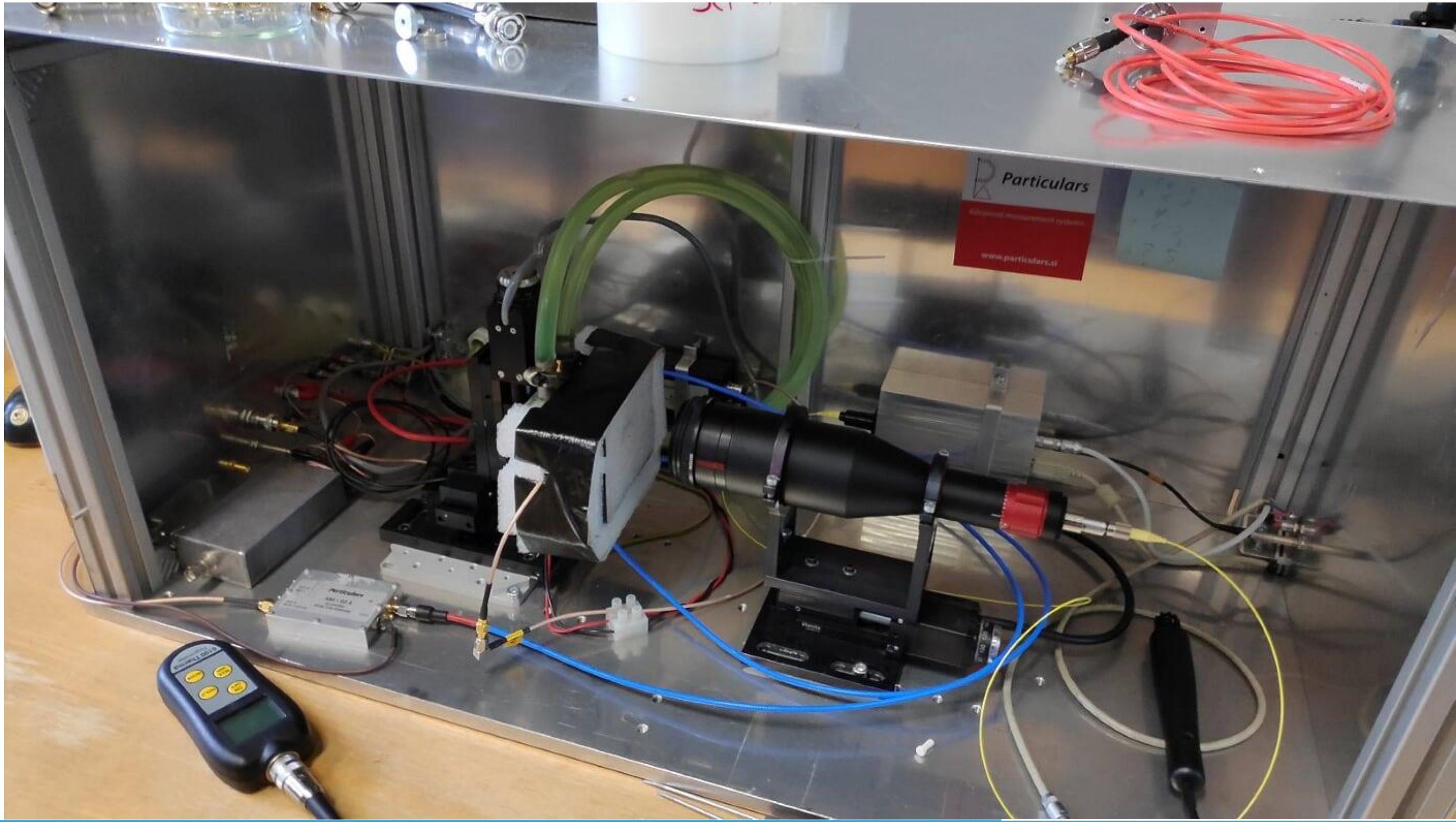
Experimental setup

Scanning TCT

- XYZ tables
- IR laser – focused beam of (8-10μm in waist)
- HV and readout through Bias-T
- Both pads connected to one amplifier

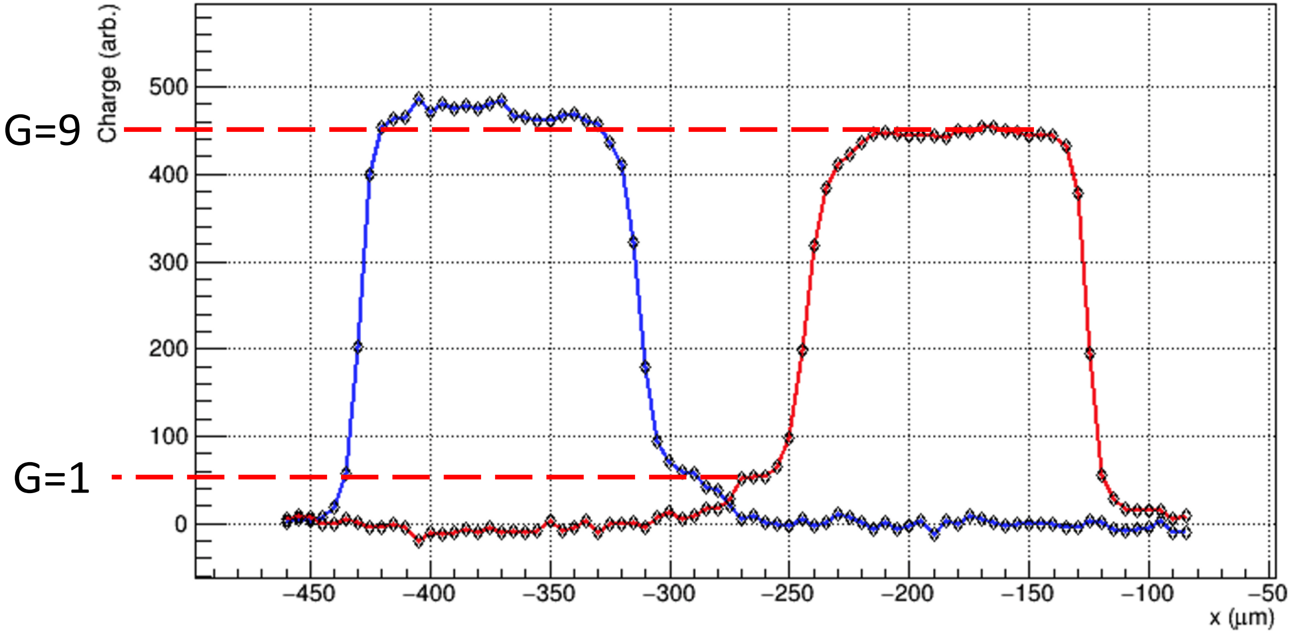
Operating conditions:

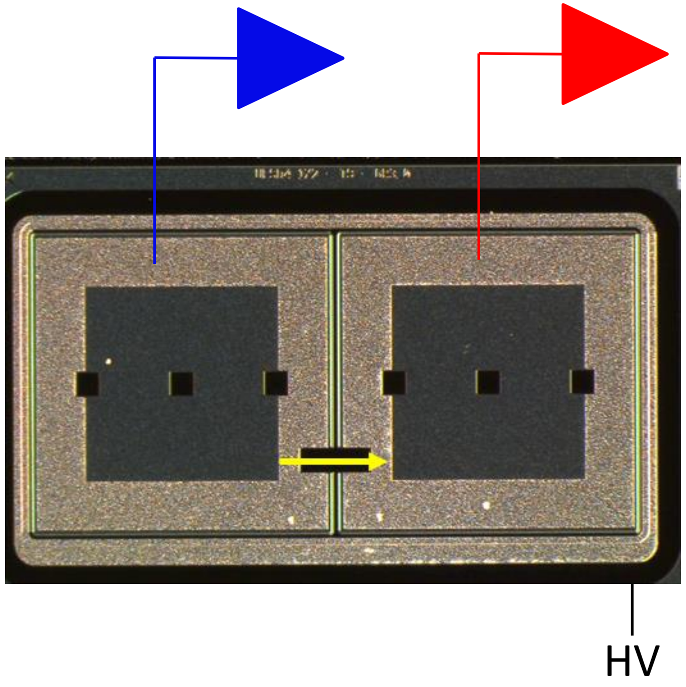
- **Temp. control from 40°C to -30°C**
- Insulation cap
- Closed environment
- Dry air (dew point well below measuring temperature)



IP and gain measurement – 2 amps

FBK4.0 – W9 Type9 (not irradiated) at 100V and 293K





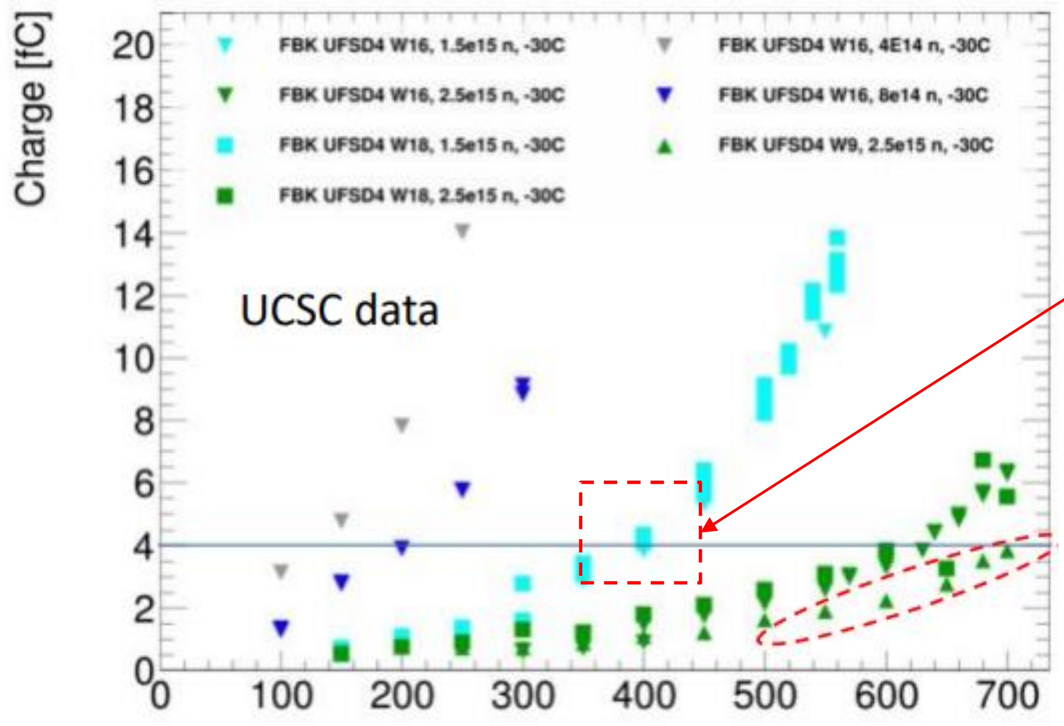
A good agreement with measured charge in CC setup.

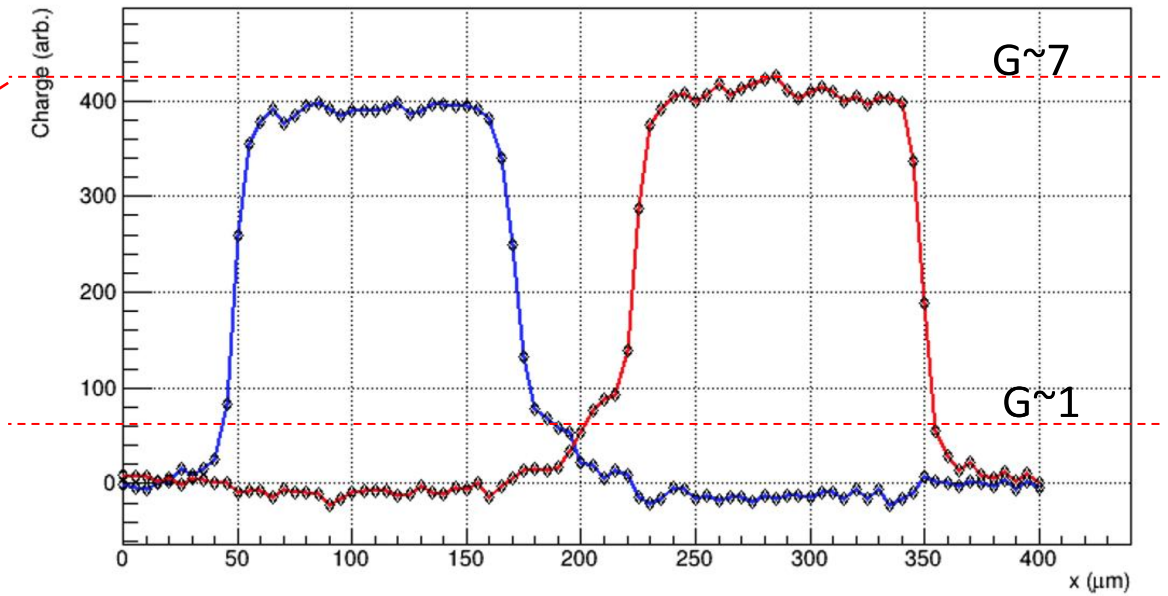
FBK4.0 correlation of TCT with ^{90}Sr

Note UCSC CC measurement shows 4fC for that sample type with ^{90}Sr!

FBK4.0 – W18 deep GL design at 400 V and 243 K , Type9 IP 1.5e15 cm^{-2}

G=7 ; Q~4 fC





Addition to: Extraction of parameters

$I_{leak} = I_{gen} \times G$; $G = G@V_{FD(gap)}$

Usually we don't know the gain, but with this method we do and we measure the leakage current. So we can also extract the generation current.
At low gain values, the current gain is the same as charge gain (up to about G=4 for this fluence).