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ER1 High Speed Module: Sanity-check on maturity level of TID irradiations at DL.

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Outline

- First TID irradiation at DL
- Dose calibration
- Preliminary results on ER1
- Conclusion

- Disclaimer:
  - all the work to install, commission and calibrate the X-ray generator was funded by TD.

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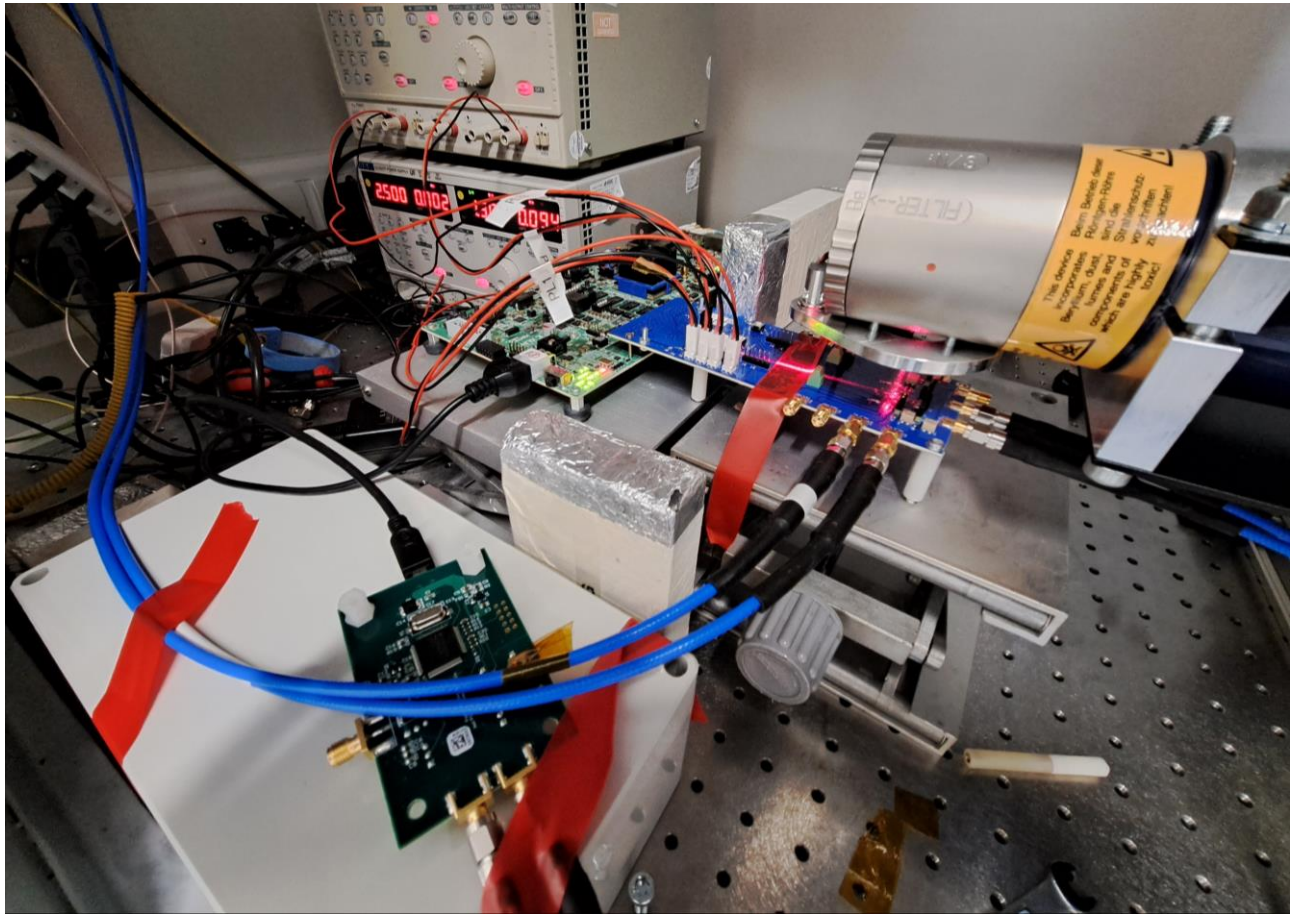
The TID irradiation at DL

- DUT:
  - ER1 High Speed module by RAL
- Irradiated up to 10MRad the
- Very first TID irradiation at DL!
- Data analysis complete:
  - Device is rad hard
- Very first irradiation, conservative on dose estimate!



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The facility

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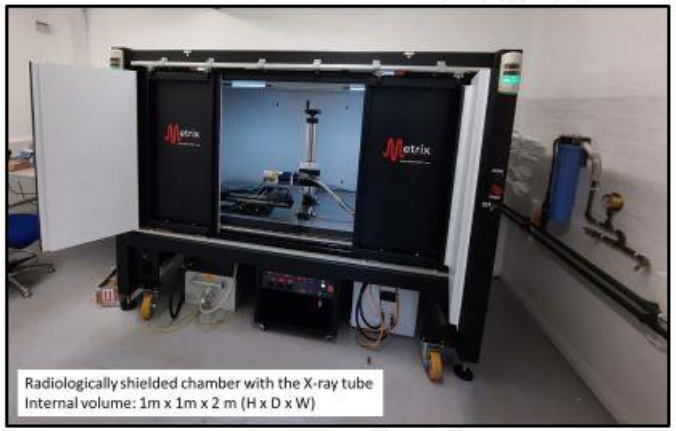
X-Ray Irradiation Facility

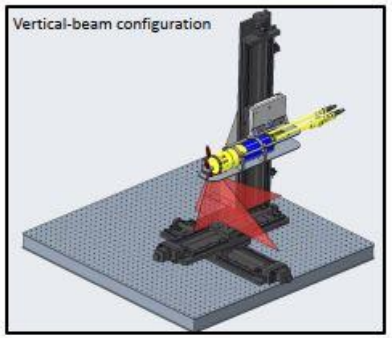


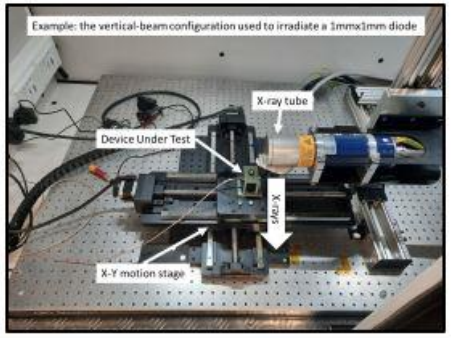
Electronic circuits used in many space, military, nuclear power systems and scientific particle-collider experiments may be exposed to various levels of ionizing radiation dose.

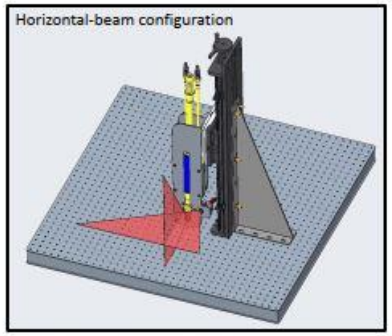
It is essential for the design and fabrication of such circuits that test methods are available to determine the vulnerability or hardness of electronics components to be used in such systems.

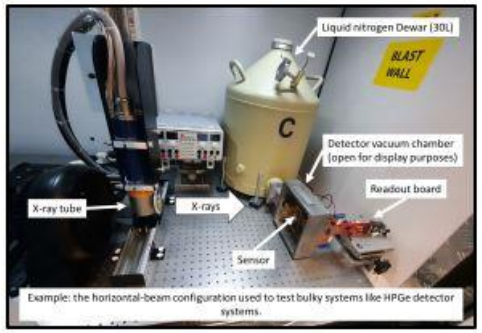
The X-ray generator has proven to be a useful ionizing radiation effects testing tool because:

- It offers a relatively high dose rate, in comparison to most cobalt-60 sources, thus offering reduced testing time.
- The radiation is of sufficiently low energy (≈10 keV) that it can be readily collimated. As a result, it is possible to irradiate a localised area in a device or on a wafer.

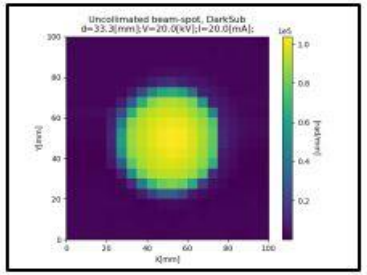








Tungsten X-ray tube specifications	
Tube Voltage	0 – 60 kV
Tube Current	0 – 50 mA
Total power	3 kW
Beam divergence	40 deg
Inherent filtration	1mm Be
Additional filters	2mm Al; 4mm Pb
Further external collimation possible	



Reference irradiation settings used for existing internal projects:
peak dose rate ~100 krad/min;
dose rate uniform within ~3% over an area of ~1cm x 1cm around the peak value;

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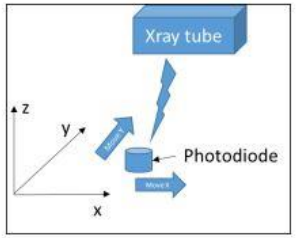
TID calibration

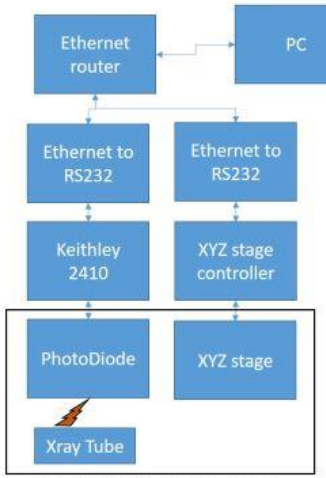
Setup: overview

The photodiode is mounted on the XYZ stage and it is moved on the XY plane (Zstage not fitted).
At each position, the current on the diode is measured via the HV pwr supply.
The current intensity on the photodiode is $\propto$ to incident radiation.

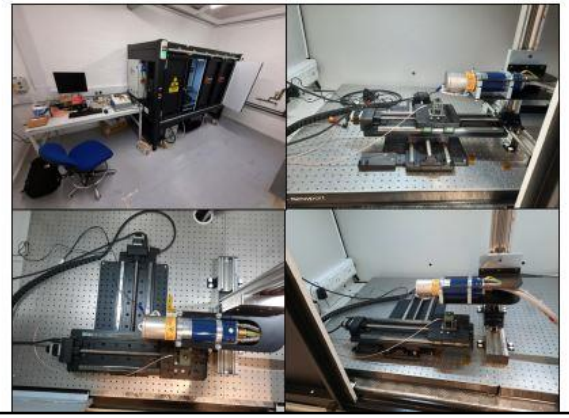
List of materials:
- XYZStage montion controller:
  - Optics Focus Instruments moc023220b
- X and Y stages:
  - Optics Focus Instruments mox06300
- Z stage: (not fitted)
  - Optics Focus Instruments mox06300b
- HV pwr supply:
  - Keithley 2410
- PhotoDiode:
  - OptoDiode AXUVHS5
- PC:
  - DELL Optiplex 745
  - DDTEC0133 (MAC ID: 00:1a:a0:57:13:9a)
  - IP address: 148.79.103.51
  - Additional Ethernet card (Mac ID: 78:32:1b:91:8a:b8)
  - OS: Ubuntu 22.04.2 LTS
- Ethernet router
- Ethernet cables;
- RS232 cables:
  - Male to female
- RS232 to Ethernet adapters
  - Startech NETRS2321P
- Coaxial cable Keithely2410 to PhotoDiode;
- PhotoDiode support (3D printer)



Logical sketch of the set-up



Radiologically shielded cabinet



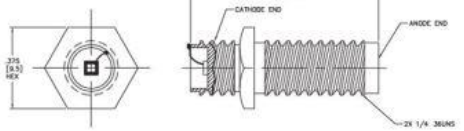
Setup: photodiode

- OptioDidoe Axuvhs5.
- Active area 1mmx1mm.
- This is the diode selected by CERN.
- We have three units of this type of diode:
  diode1: lot 111431
  diode2: lot 111431
  diode3: lot 112449

OPTO DIODE — Photodiode 1 mm² — AXUVHS5

FEATURES
- SMA Connector
- Ideal for Electron Detection
- Ultra-High Speed

Package Information



Dimensions are in inch [metric] units.

Electro-Optical Characteristics at 25°C

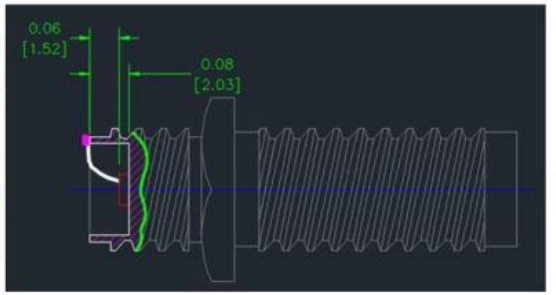
Parameters	Test Conditions	Min	Typ	Max	Units
Active Area	1 mm x 1 mm		1		mm²
Responsivity	(see graphs on next page)				A/W
Reverse Breakdown Voltage, V_R	I_R = 1 µA	55			Volts
Capacitance, C	V_R = 0 V		15	50	pF
Rise Time	RL = 50 Ω, V_R = 52 V			700	psec
Dark Current	V_R = 52 V		1	10	nA

Thermal Parameters

Storage and Operating Temperature Range	Units
Ambient[1]	-10°C to 40°C
Nitrogen or Vacuum	-20°C to 80°C
Lead Soldering Temperature	N/A

[1] Temperatures exceeding these parameters may create oxide growth on the active area.
Over time responsivity to low energy radiation and wavelengths below 150 nm will be compromised.

Maximum torque of 5 inch/pounds recommended.
Permanent damage will result if higher torque values are used and warranty is voided.



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Diode calibration at CERN

Procedure

- The reference diode (DA18) was irradiated for different tube currents:
  - To apply Vbias on diode: -50V.
  - Tube voltage: 40kV; Scan Tube current: 0-20mA in steps of 2mA.
    - First, to perform 10 readings of dark current.
    - Second, to open the shutter and expose the sensor to
      - To take two consecutive readings of current.
  - DA18 is not the AXUVHS5 diode.
  - DA18 is the older reference diode by Quantrad Sensor.
  - By using DA18 we followed the exact same procedure used
  - DA18 was biased at 50V.
- The three diodes from DL were also irradiated following the sa

The distance between diodes and the X-ra

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Results

The best values to calculate the IrradCoeff are those at a tube current of 20mA.

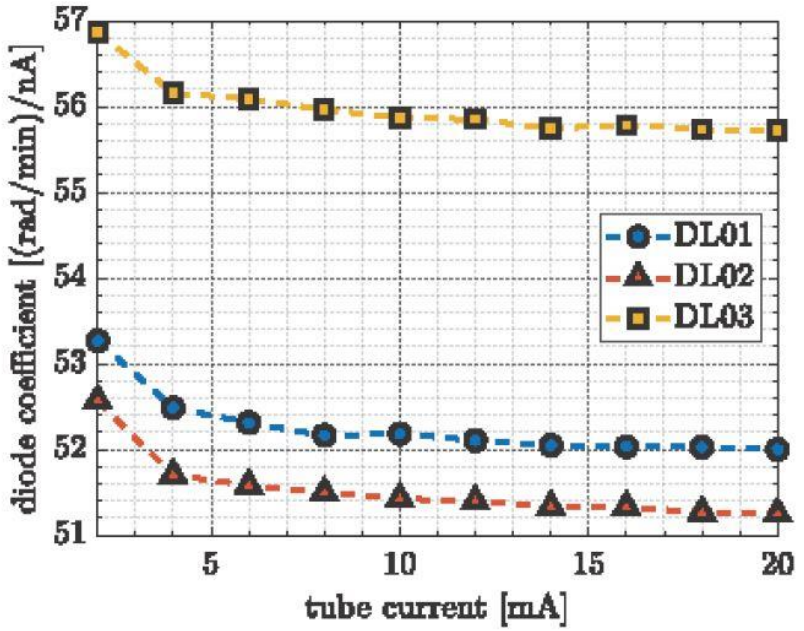
This is because the S/N ration is better for a more intense beam.

DL01 IrradCoeff = 52.0 rad/min/nA
DL02 IrradCoeff = 51.2 rad/min/nA
DL03 IrradCoeff = 55.7 rad/min/nA

Results for DL diodes are consistent with CERN's own AXUVHS5 diodes, which were calibrated following the same procedure.

DB02 51.86 rad/min/nA
DB03 52.00 rad/min/nA

DB01 170 rad/min/nA (considered dodgy by CERN)



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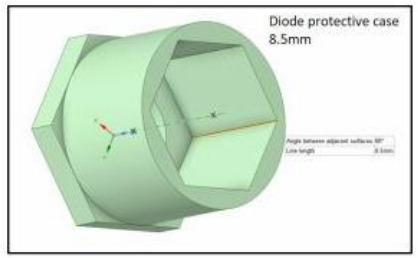
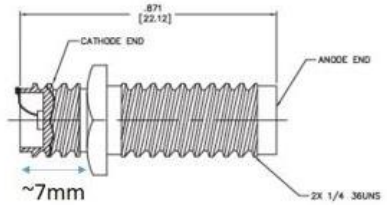
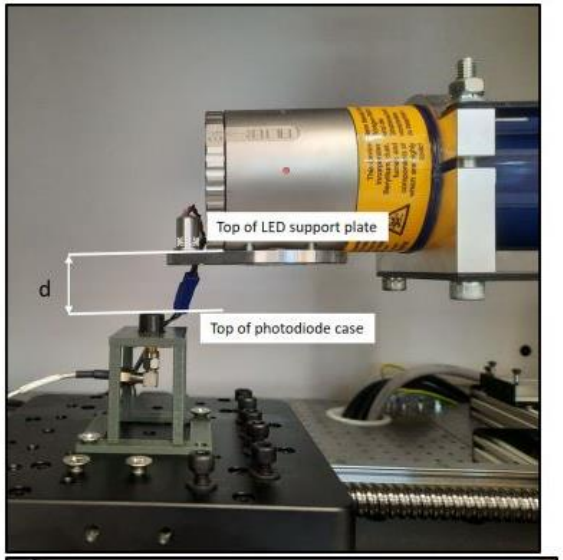
Dose estimate at DL

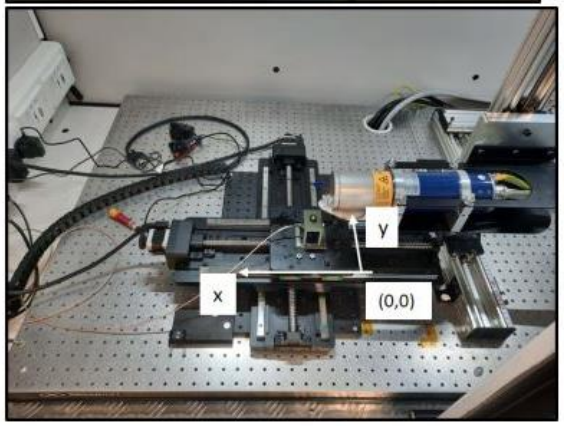
Setup: overview

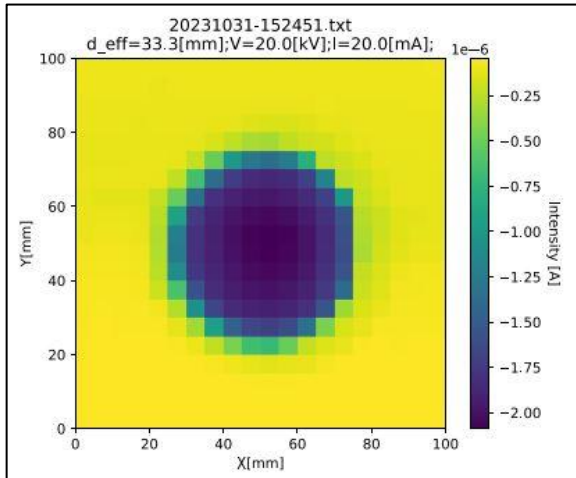
- The distance is measured:
  from the top of the LED support plate
  to the top of the diode protective case
- The effective distance (d_{eff}) to the top of the diode is calculated as:
  $d_{eff} = d + 1.52mm + 1.5mm$
  (i.e. $d_{eff} \sim d+3mm$)

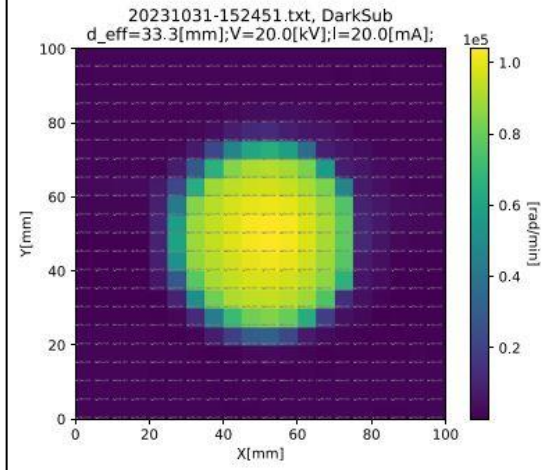


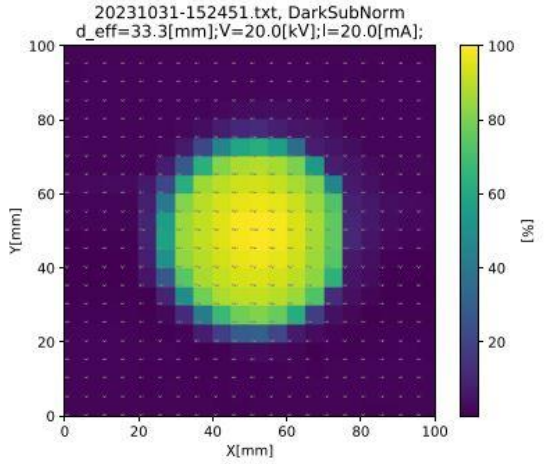












Good news;
We achieved 100krad/min (target) by using the calibrated diodes;
Dose is uniform within 3% in a 1x1cm2 area

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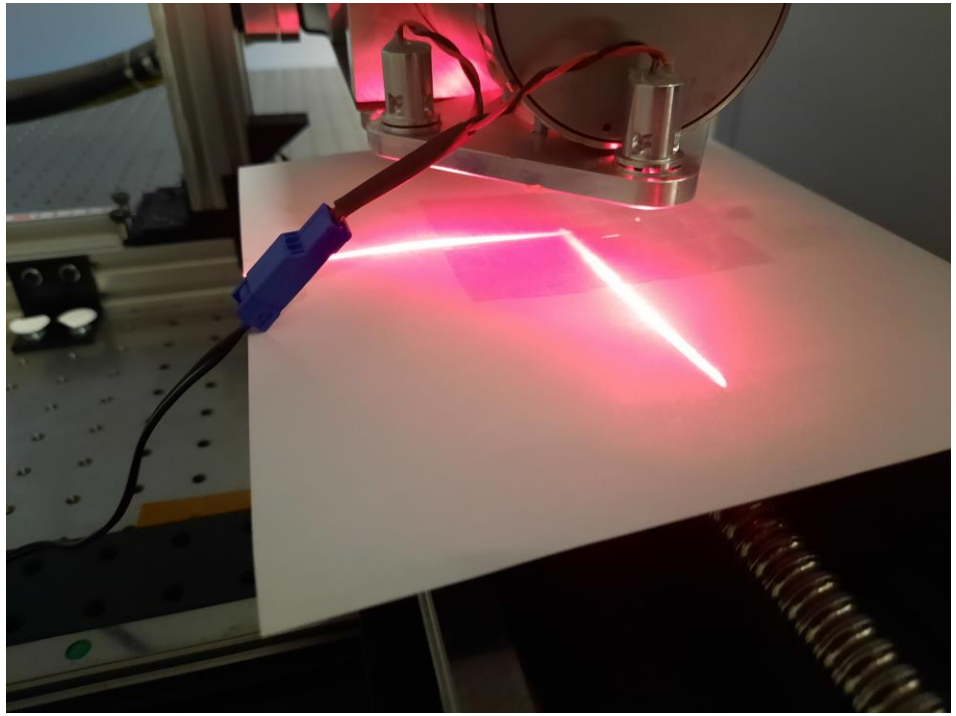
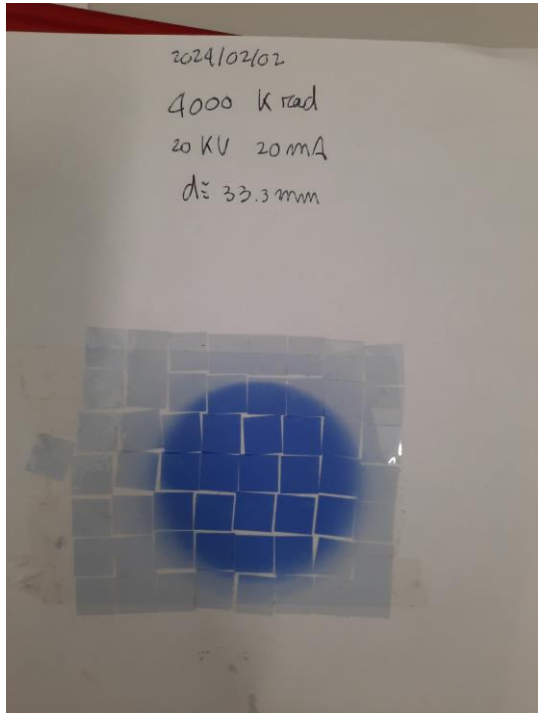
Radio-chromic foils





Used radio chromic foils to estimate the dose with an independent method.

Awaiting reading results from radiology services…

Dose will be estimated in H2O dose equivalent, to convert in SiO2

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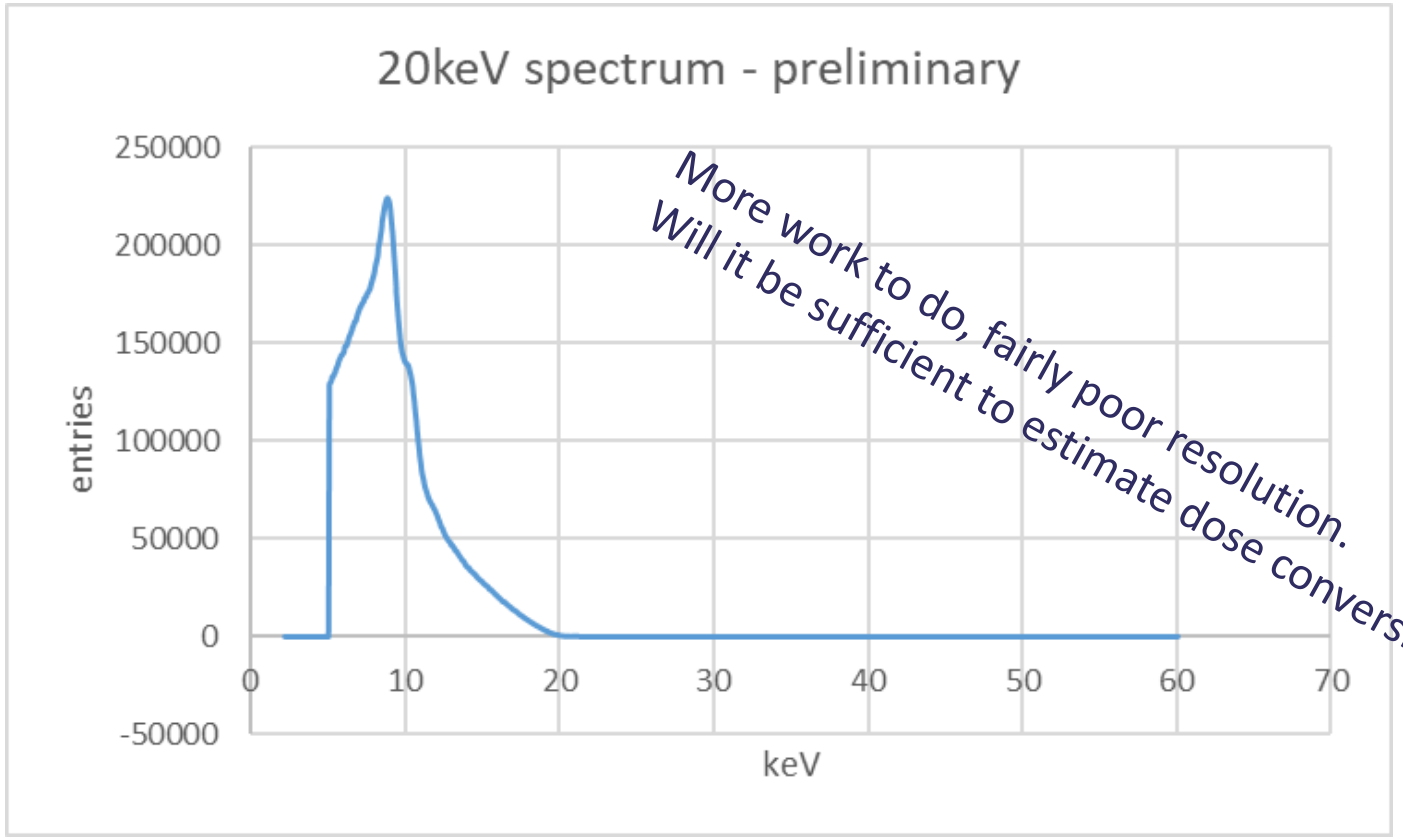
X-ray spectrum

- Needed to convert dose from H2O to SiO2



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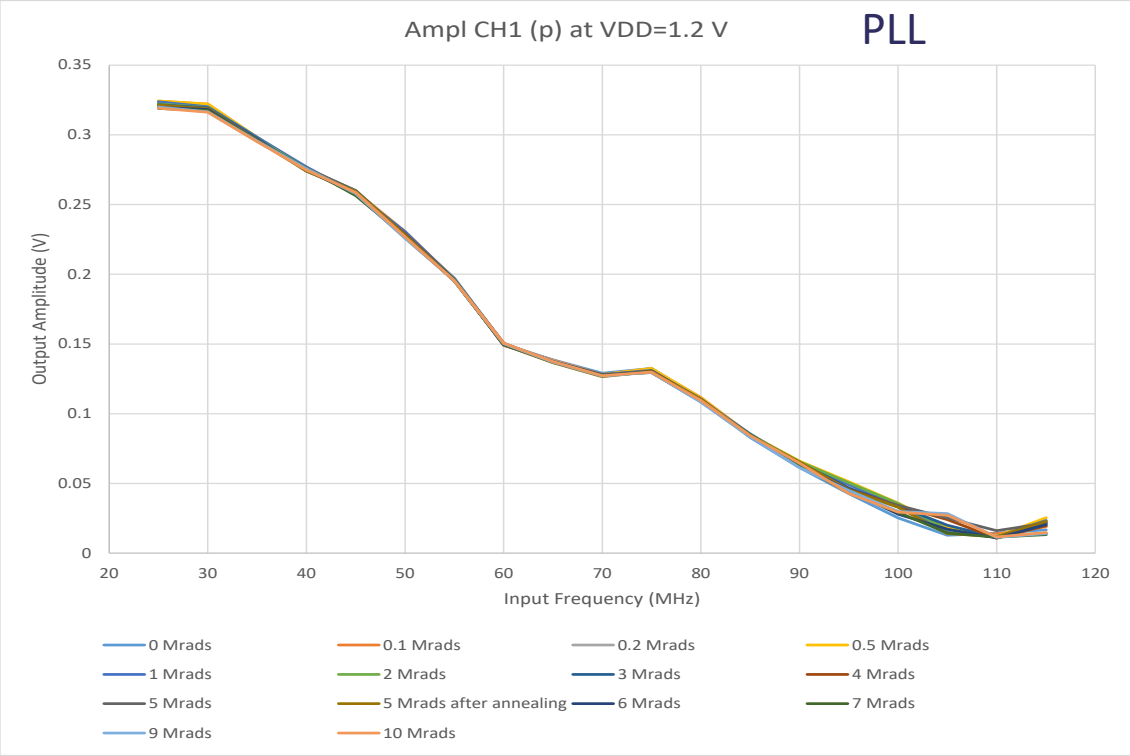
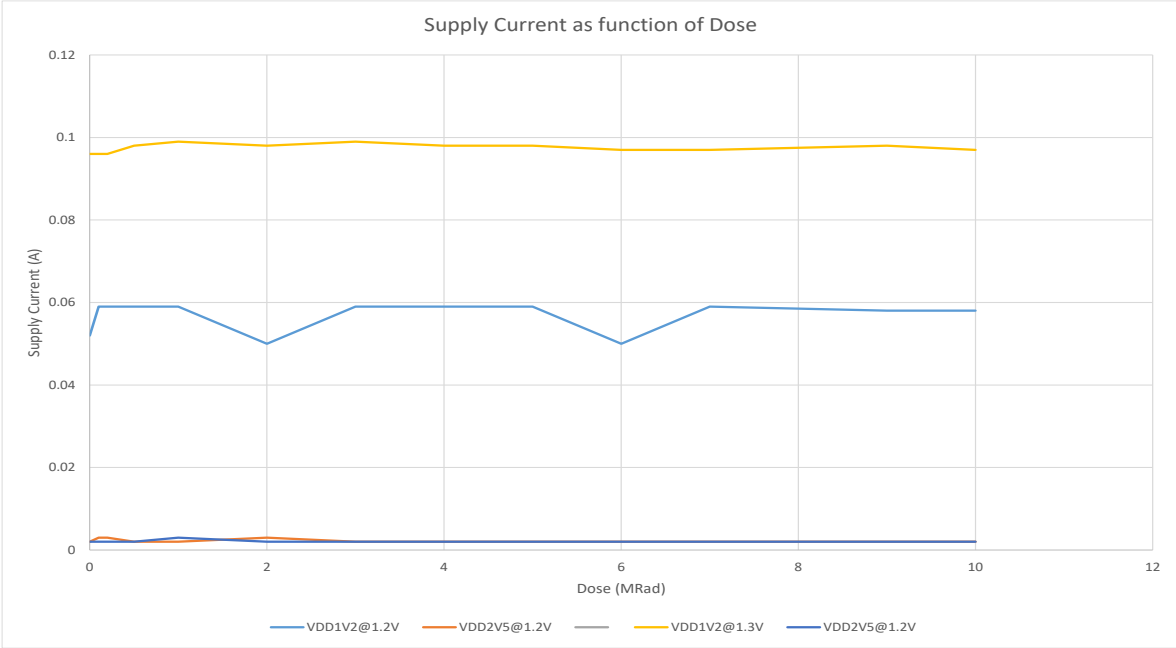
ER1 DUT, irradiation results

Irradiated DUT1;
~100krad/min (peak nominally 104krad/min)
Target doses (SiO2):
0Mrad; 0.1Mrad; 0.2Mrad; 0.5Mrad;
1Mrad to 10Mrad in step on 1Mrad





No obvious damage on DUT1;
Either in PLL block or CTLE block;

Conclusion

- X-ray facility installed and commissioned;
- TID calibrated with CERN procedure;
- ER1 DUT irradiated, no visible damage
- Independent calibration w radio chromic foils [awaiting results]
- ToDo:
  - To repeat MLR1 irradiations on site (comparison with CERN irradiations)
  - To irradiate more ER1 DUTs? (Irradiate until device breaks?)

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Thank you

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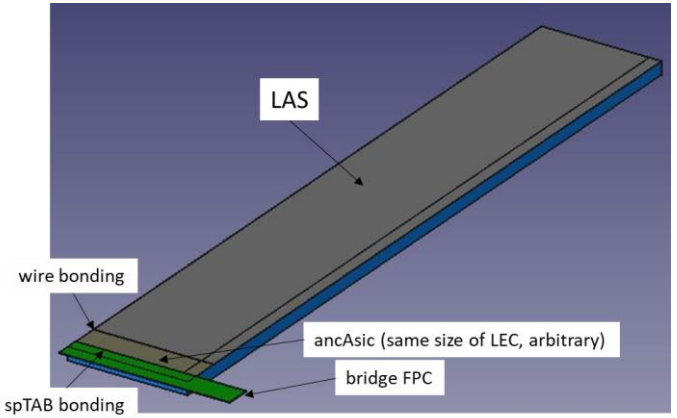
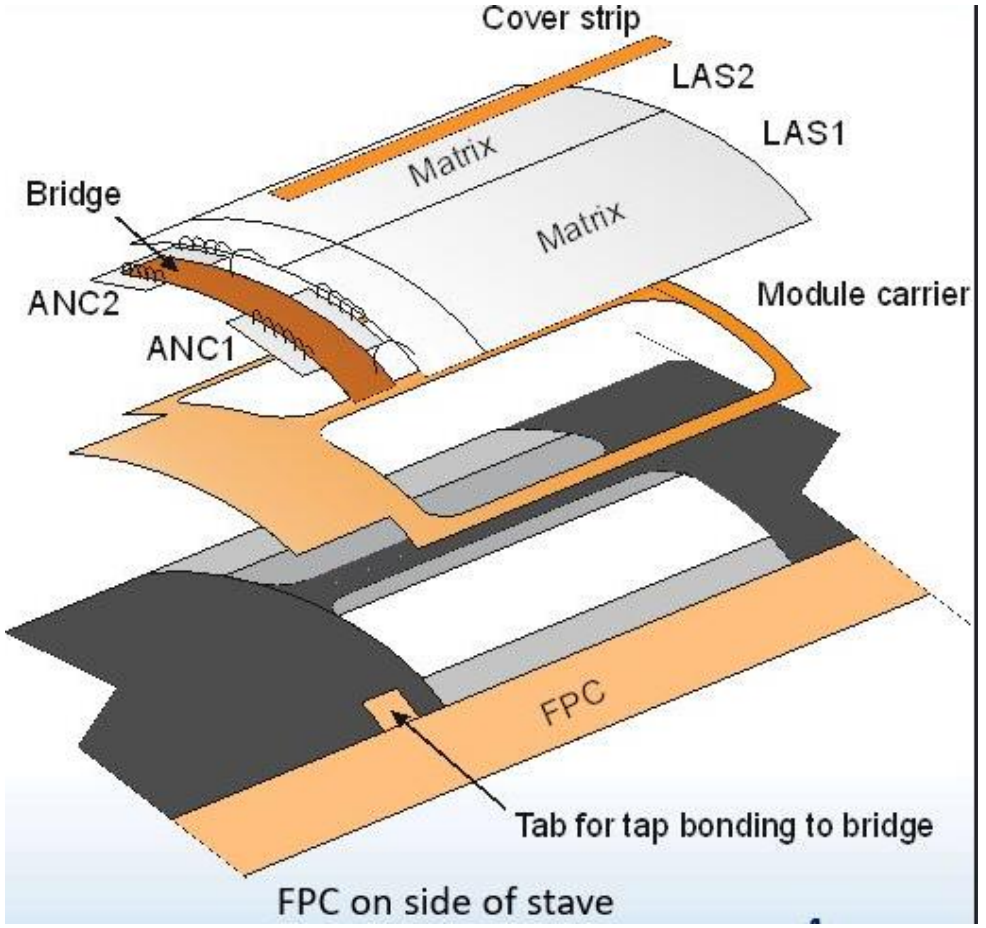
Module definition Vs AncASIC layout

- AncAsic form factor;
- Pads on AncAsic to/form LAS;
- Pads on AncAsic to/from end-stave services;
- (Speculative) Redistribution layer on AncAsic;





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