APDs progress

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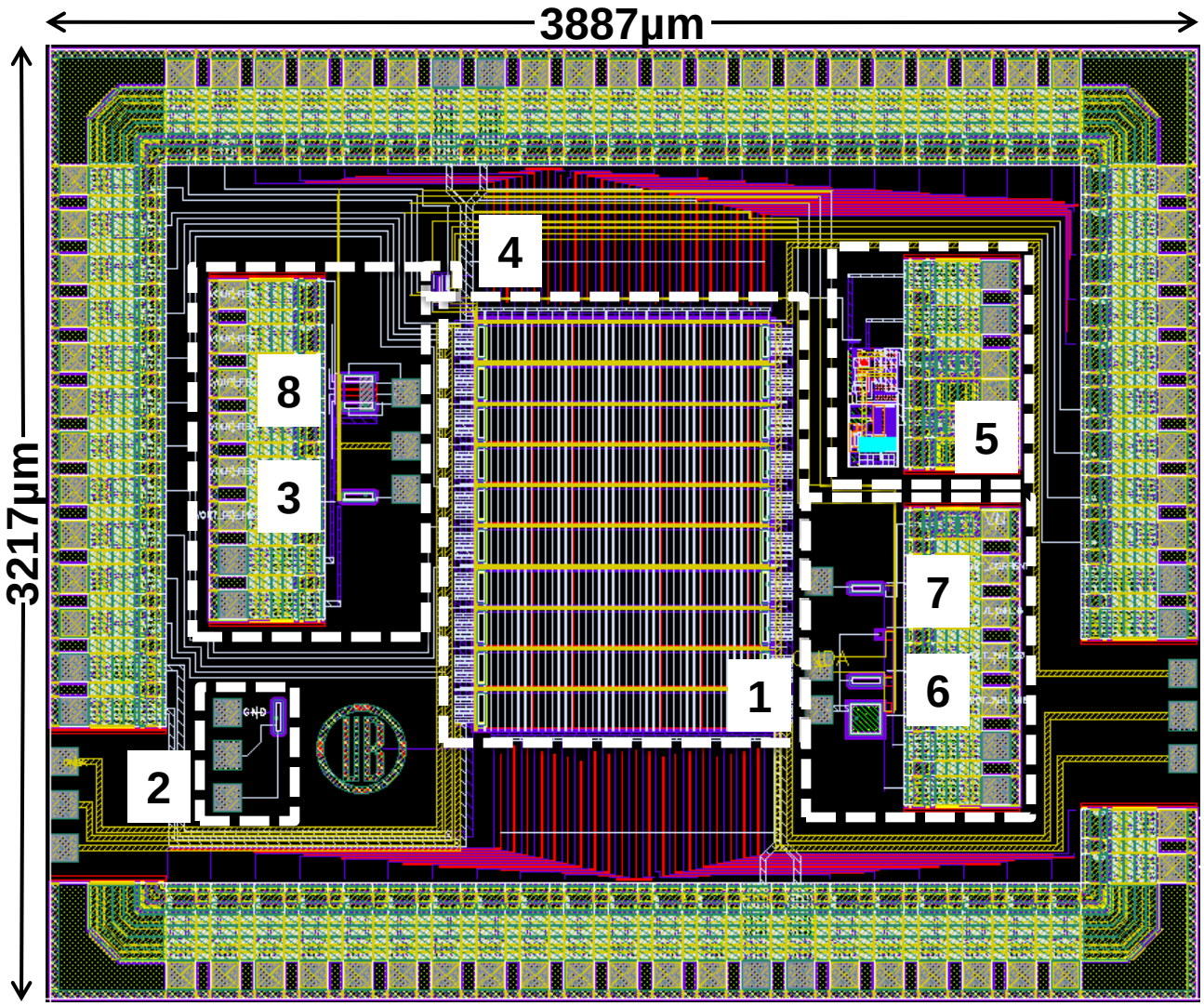
Outline

- **10 x 43 GAPD array**
  - Submitted chip
  - Pixel schematic
  - Results and test status
  - Some numbers
- **Irradiation test**
  - Expected damage
  - What to test
  - Where?

10 x 43 GAPD array

Submitted chip



1. 10 x 43 GAPD array
2. Test photodiode
3. Test pixel
4. Control signal generation circuit
5. Pad LVDS
6. Active inhibit pixel
7. Current mode pixel
8. 1 x 5 GAPD array with PAD layer

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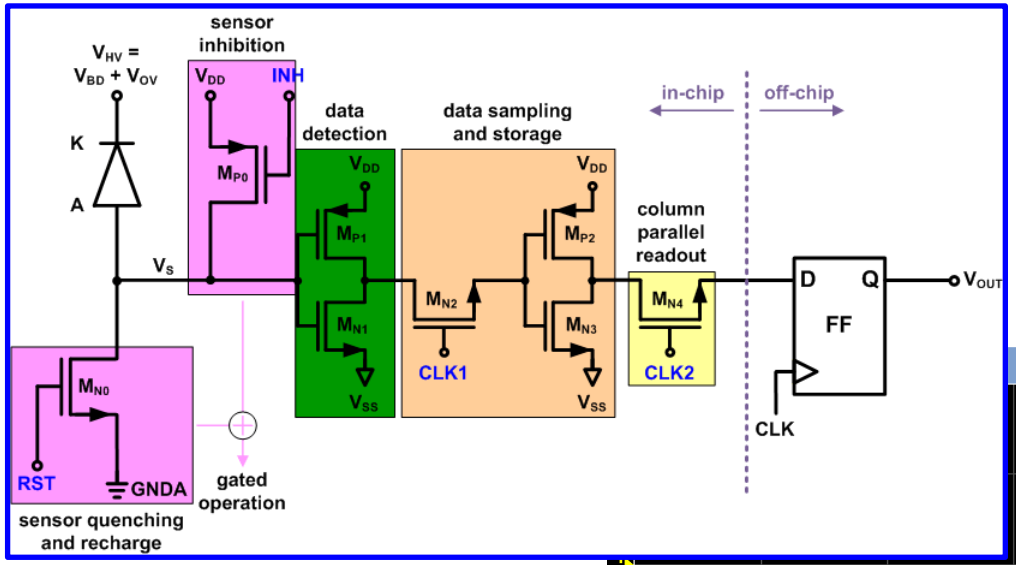
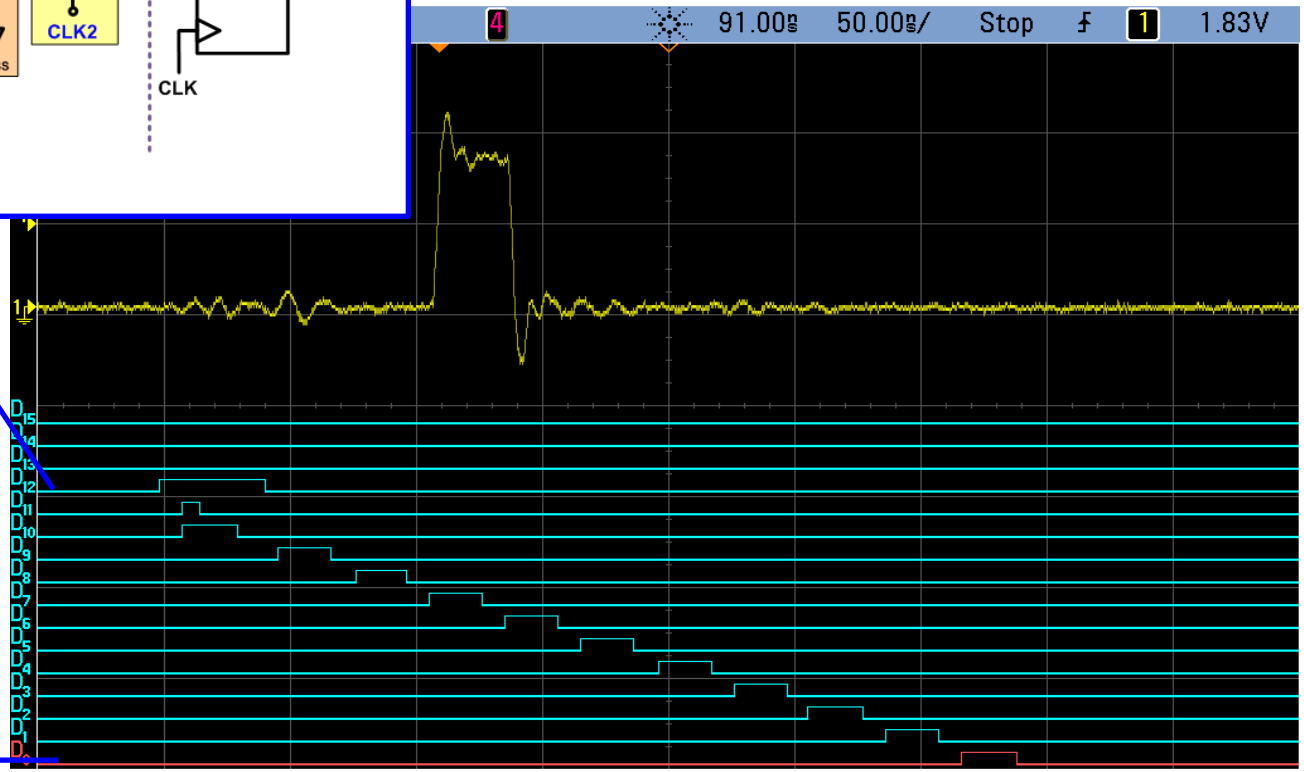
Pixel schematic





Control signals

- INH
- RST
- CLK1
- CLK2_0
- CLK2_1
- CLK2_2
- CLK2_3
- CLK2_4
- CLK2_5
- CLK2_6
- CLK2_7
- CLK2_8
- CLK2_9

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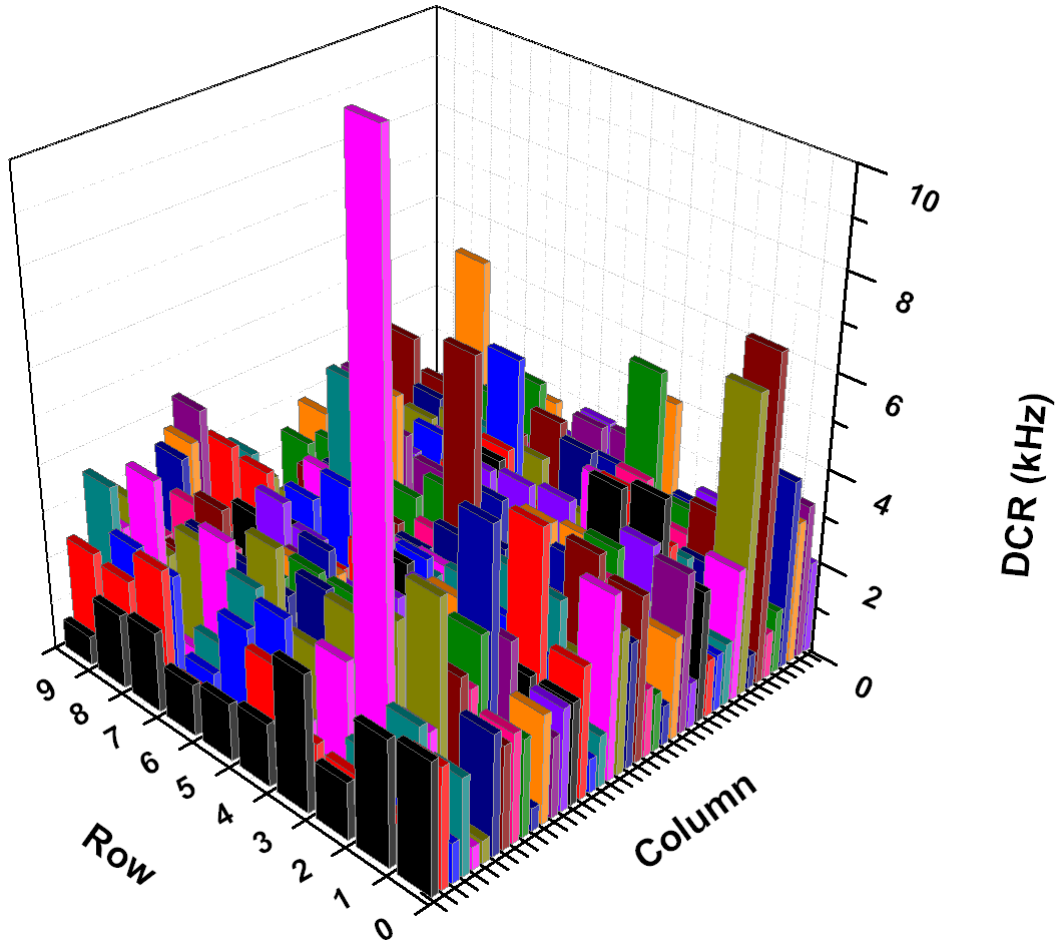
Results and test status

- V_{BD} = 18.9V
- DCR:
  - A few kHz for most of the pixels
  - Minimum ~ 100Hz
  - Maximum ~ 13kHz
  - Measured @ V_{OV} = 1.8V



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Some numbers

- **ILC pair induced backgrounds (FTD, 4th layer) → 0.002 hits/cm²/BX**
  - For a pixel area of 20μmx100μm → $4 \cdot 10^{-8}$ hits/pixel/BX
  - For a train of 2820BXs → **$1{,}128 \cdot 10^{-4}$ hits/pixel/train**

- **GAPD intrinsic noise → DCR_{mean} = 10kHz (per pixel)**
  - noise counts = DCR · time observed
    - noise counts = 10000
    - time observed = 1 train = 2820BXs · 337ns/BX = $9{,}503 \cdot 10^{-4}$ s
  - $noise\ counts_{train}$ = **9,503 noise counts/pixel/train**

- **SNR (free running)**
  - **SNR = $1{,}186 \cdot 10^{-5}$!!!!**

Some numbers

- **Time gated ?**

- **ILC pair induced backgrounds (FTD, 4th layer) → 0.002 hits/cm²/BX**
  - **1,128·10⁻⁴ hits/pixel/train**

- **GAPD intrinsic noise → DCR_{mean} = 10kHz (per pixel)**
  - noise counts = DCR · time observed
    - noise counts = 10000
    - time observed = 1 train = 2820BXs · 10ns/BX = 2,82·10⁻⁵ s
  - $noise\ counts_{train}$ = **0,282 noise counts/pixel/train**

- **SNR (10ns gate on)**
  - **SNR = 4·10⁻⁴ !!!!**

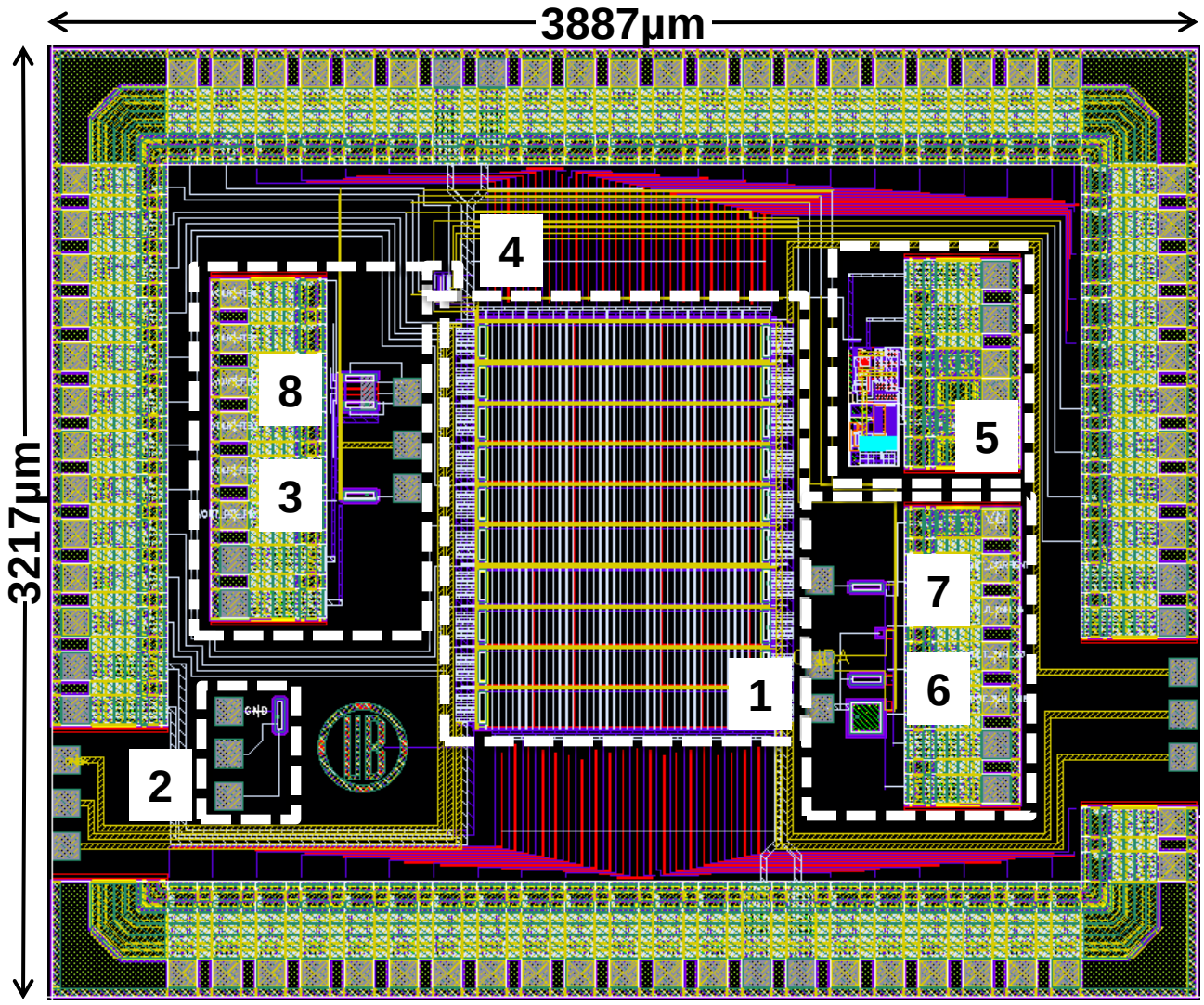
Some numbers

- **CLIC pair induced backgrounds → 0.02 hits/cm^2/BX**
  - For a pixel area of 20μmx100μm → $4 \cdot 10^{-7}$ hits/pixel/BX
  - For a train of 312BXs → **$1{,}248 \cdot 10^{-3}$ hits/pixel/train**

- **GAPD intrinsic noise → DCR_{mean} = 10kHz (per pixel)**
  - noise counts = DCR · time observed
    - noise counts = 10000
    - time observed = 1 train = 312BXs · 0,5ns/BX = $1{,}56 \cdot 10^{-7}$ s
  - $noise\ counts_{train}$ = **$1{,}56 \cdot 10^{-3}$ noise counts/pixel/train**

- **SNR (free running)**
  - **SNR = 0,8 !!!!**

Further reduction of the noise



1. 10 x 43 GAPD array
2. Test photodiode
3. Test pixel
4. Control signal generation circuit

with minimum t_{obs} = 1ns

6. Active inhibit pixel
7. Current mode pixel
8. 1 x 5 GAPD array with PAD layer

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Irradiation test

Expected damage

- **What we learn from the literature…**
  - [Carrara-2009]

4mGy/sec
800mGy/sec

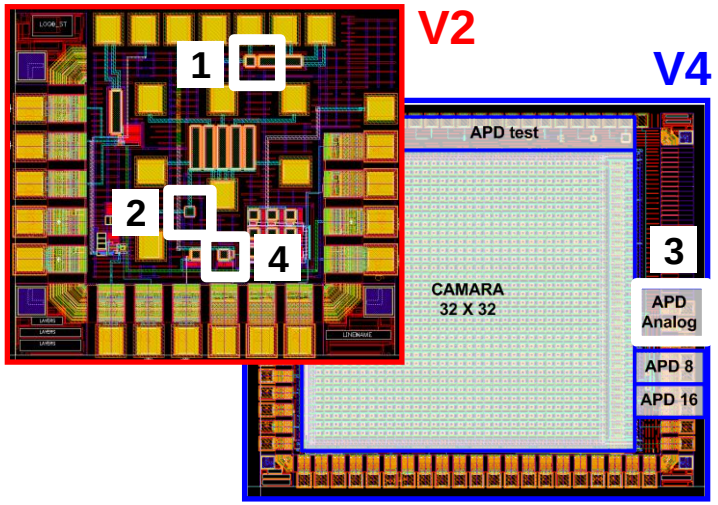
Centre	Irradiation type	Source	Fluence/ Flux	Dose (Si)	Initial DCR	Final DCR	DCR after Annealing (anneal time, temp)
ESA-ESTEC (Netherlands)	Gamma	Co60	41.6 mGy/s	14 kGy	153	13487	276 (172 h, 80° C)
			797.5 mGy/s	300 kGy	128	N/A	25877 (1500 h, 20° C)
Univ. Inst. for Radiation Physics (Switzerland)	X *	Comet-Yxlon TU320-D03	4.3 AsV^2	0.25 mGy	204	N/A	204 (1 min, 20° C)
			324 AsV^2	0.25 mGy	204	N/A	204 (1 min, 20° C)
			900 AsV^2	0.5 mGy	204	N/A	204 (1 min, 20° C)
Paul Sherrer Inst. (Switzerland)	Proton	Accelerator	$1.8x10^7 p/cm^2/s$ (11MeV)	400 Gy	140	6298	3884 (10 d, 20° C)
			$8.3x10^7 p/cm^2/s$ (60 MeV)	400 Gy	142	6290	1299 (21 d, 20° C)

Constant energies

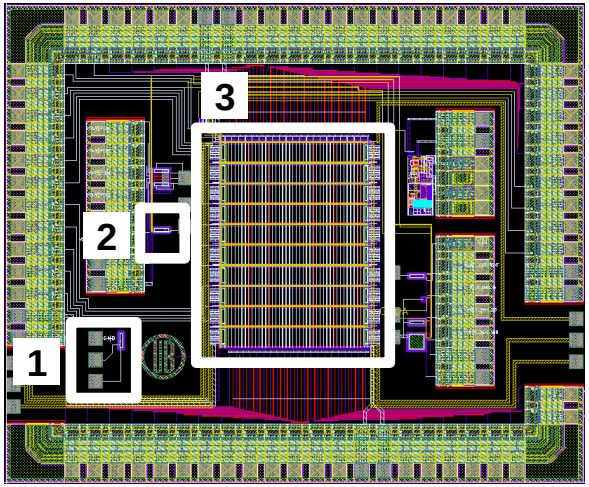
Tab. 2. Irradiation experiment summary. The median DCR is reported in Hz at room temperature. Photon detection and afterpulsing probabilities, and maximum frame rate remained unchanged after all three types of irradiation. The final DCR, when reported, was measured with the sensor still being irradiated. *Note: X-ray measurements were performed with an excess bias of 3.3 V rather than 2.8 V.

What to test

- **130nm ST-Microelectronics**
  1) 1 sensor (APD only) with n-well (20µm x 20µm)
  2) 1 sensor (APD only) with STI (20µm x 20µm)
  3) 1 analog pixel (APD + electronics)
  4) 1 digital pixel (APD + electronics)



- **0.35µm HV-AMS**
  1) 1 sensor (APD only)
  2) 1 digital pixel (APD + electronics)
  3) 10x43 array (APD + electronics)



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Where?

Centre name	Location	Radiation type	Price	Contact
Univ. de Santiago de Compostela (USC)	Santiago de Compostela	• Co60 (1.17MeV, 1.33MeV) • 11 krad/hour (area 12x12cm^2) • 20 rad/hour (area 2.4x2.4m^2), minimum dose	250€/day	Abraham.Gallas @cern.ch
Centro Nacional de Aceleradores (CNA)	Sevilla	• Protons (<18MeV) • Neutrons (<9MeV) • Co60 (1.17MeV, 1.33 MeV), starting at 09/2011	400€/day	cna@us.es or ymorilla@us.es
Instalación de Irradiación NÁYADE	CIEMAT (Madrid)	• Different rates and different total doses (no more information available)	600€/working day 800€/day 2000€/week 8000€/month	pedro.valdivieso @ciemat.es
ISOTRON	England	• Co60 <u>Type 1:</u> • 200krad/hour, all the pins shortcircuited • 20k → 40k → 80k → 160k → 320krad <u>Type 2:</u> • 2krad/hour (1 week), irradiation under a bias	<u>Type 1:</u> 600€ + transport <u>Type 2:</u> 2000€ + transport	richard.sharp @isotron.com
Cyclotron Research Centre	Louvain (Belgium)	• No information available	640€/hour	guy.berger @uclouvain.be

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