STATUS OF MEDIPIX-3, PLANS FOR TIMEPIX-2

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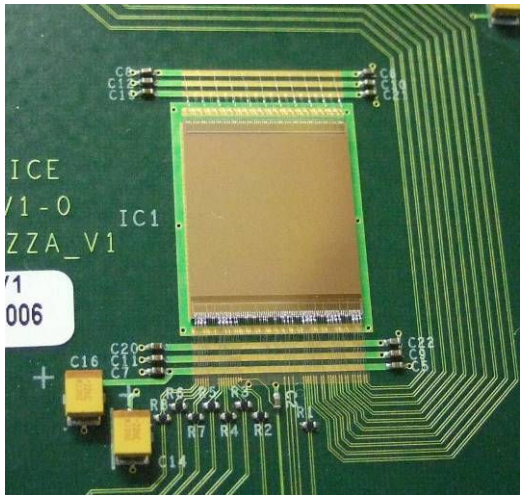
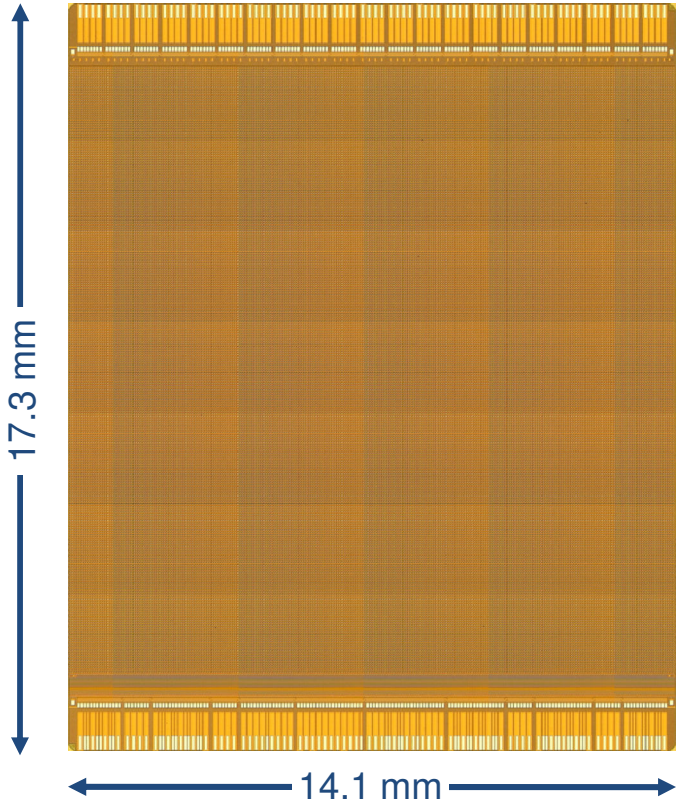
Medipix 3 - reminder

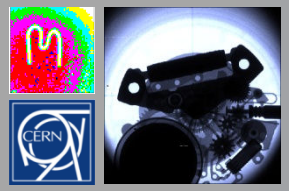
- Medipix3 builds on the success of Medipix2 as a single photon counting imaging chip
- Added Features
  - Analogue charge summing to keep all charge information
  - Spectroscopic mode with 8 threshold levels
  - Continuous readout mode (no dead time)
  - Increased counter depth increasing dynamic range
  - Increased readout speed
  - Increased radiation hardness from 130nm CMOS process



Status

- First engineering run (12 wafers of 100 chips) delivered early this year
- Wafer probing complete
- One wafer diced and bonded to PCBs
- Using the IC Tester data transfers speeds of 1.6 Gb/s were achieved
- Initial readout system working at low speed (USB from Prague)
- Electrical characterisation is almost completed
- Medipix3 readout integration in Pixelman is underway
- First bump bonded assemblies with wafers expected soon (~1 month)

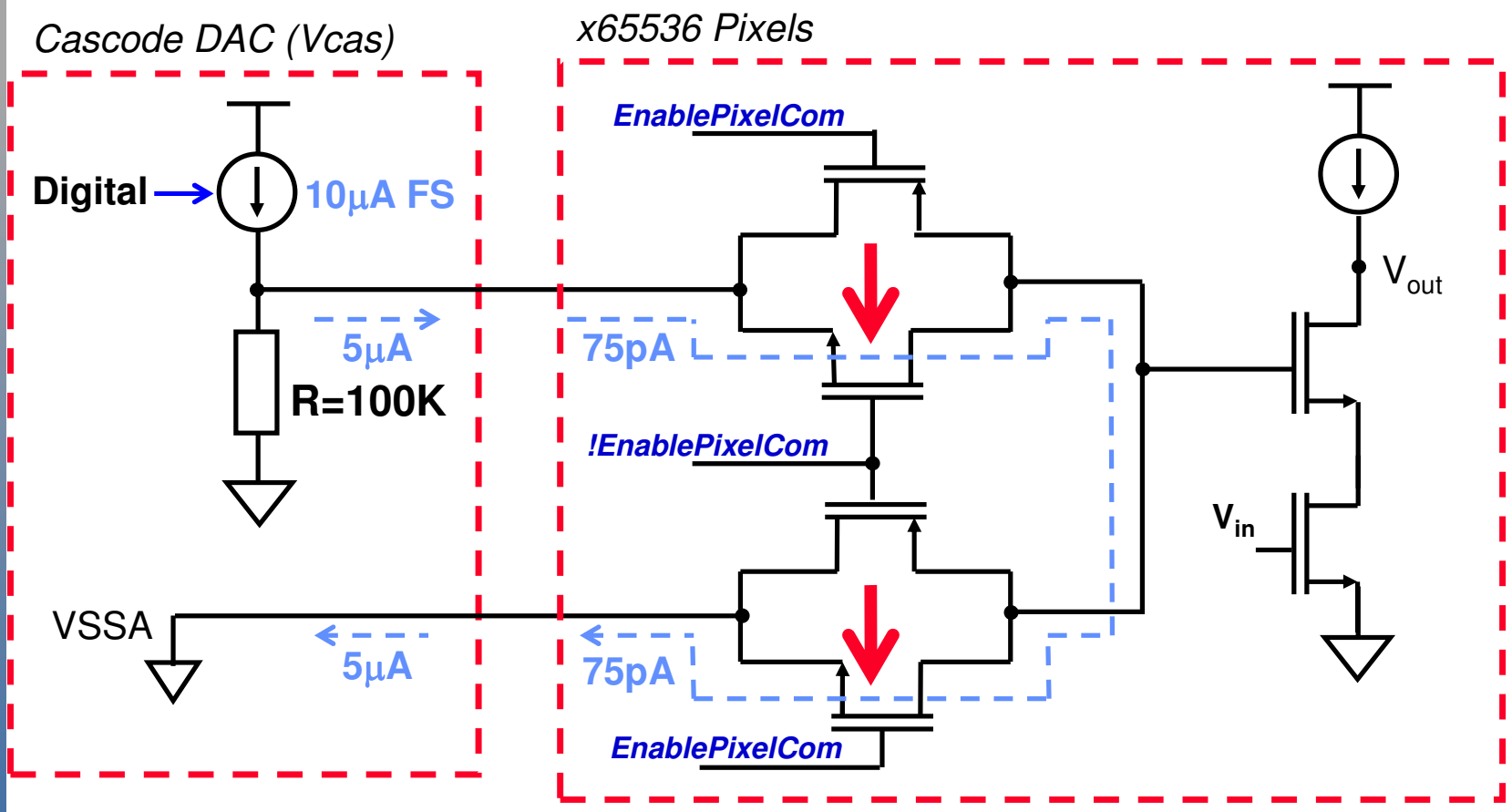




Electrical Characterisation Status

- Almost everything works as designed:
  - Complex pixel functionality: Charge summing, 8 independent thresholds, programmable counter depth
  - Expected ENC and minimum threshold has been measured as expected in all the different pixel modes
- Need to confirm the electrical characterisation with Medipix3 Si assemblies
- We found 2 issues with the chip
  - Cas and FBK DACs are not able to supply the designed nominal voltage
  - Continuous Read Write is not working correctly

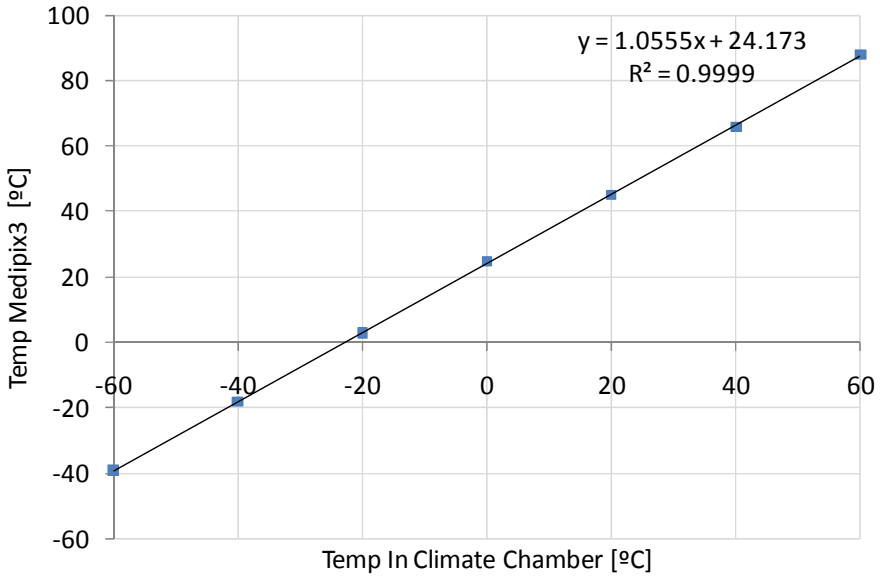
The “analog switches” (problem)



Due to radiation and temperature an increase in the leakage current of NMOS transistors is observed

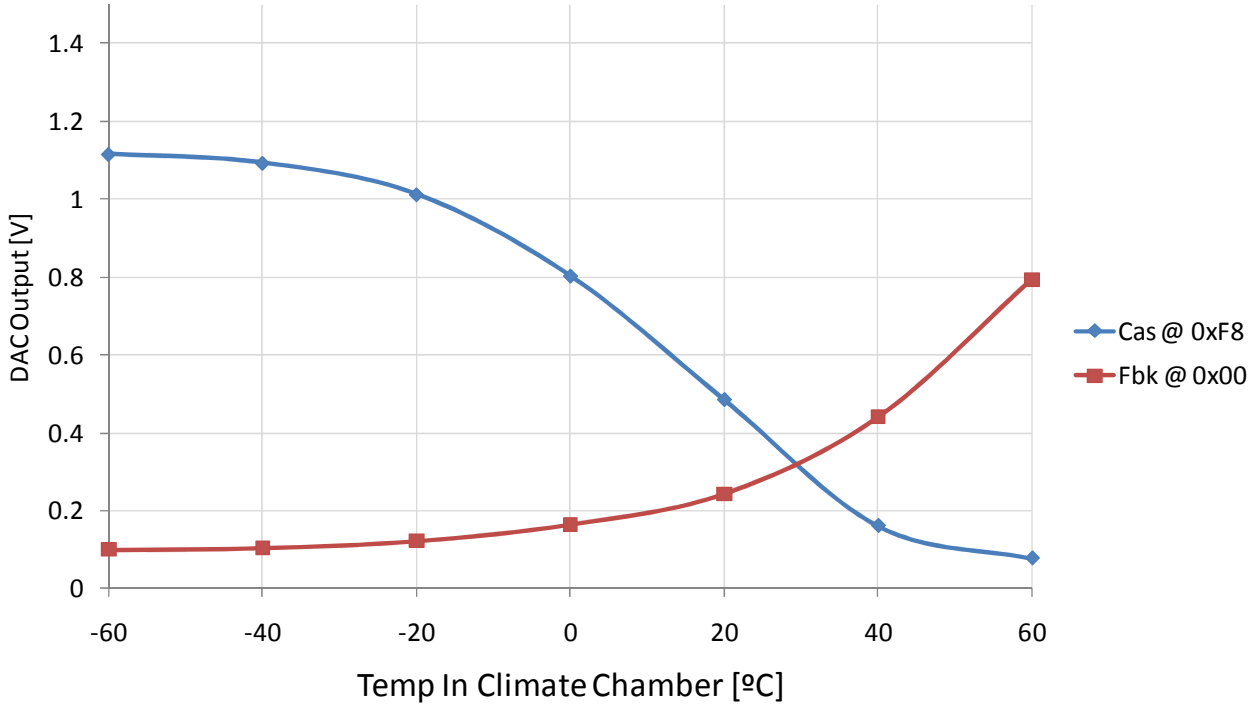
Temperature Measurements Setup

- The Medipix3 has an on-chip temperature sensor in the chip periphery
- At CERN we have available the Climatic Chamber ESPEC EGNX12-6CWL (-70 °C to +180 °C)
- Measurements covered the -60 °C to 60 °C range



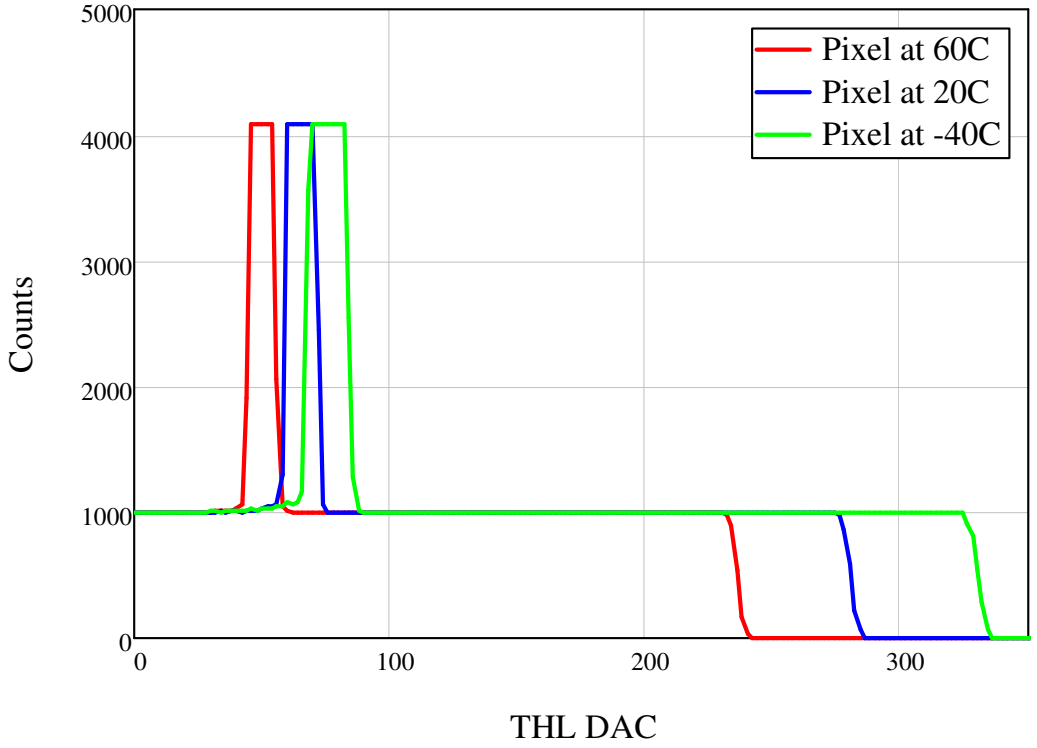
Vcas and Vfbk temperature sensitivity

- Vcas is pulled low since the current leakage path goes to GND
- Vfbk is pulled high
- The consequence of this is effect is that the operational biasing of the front end is not stable in temperature and it must be controlled carefully



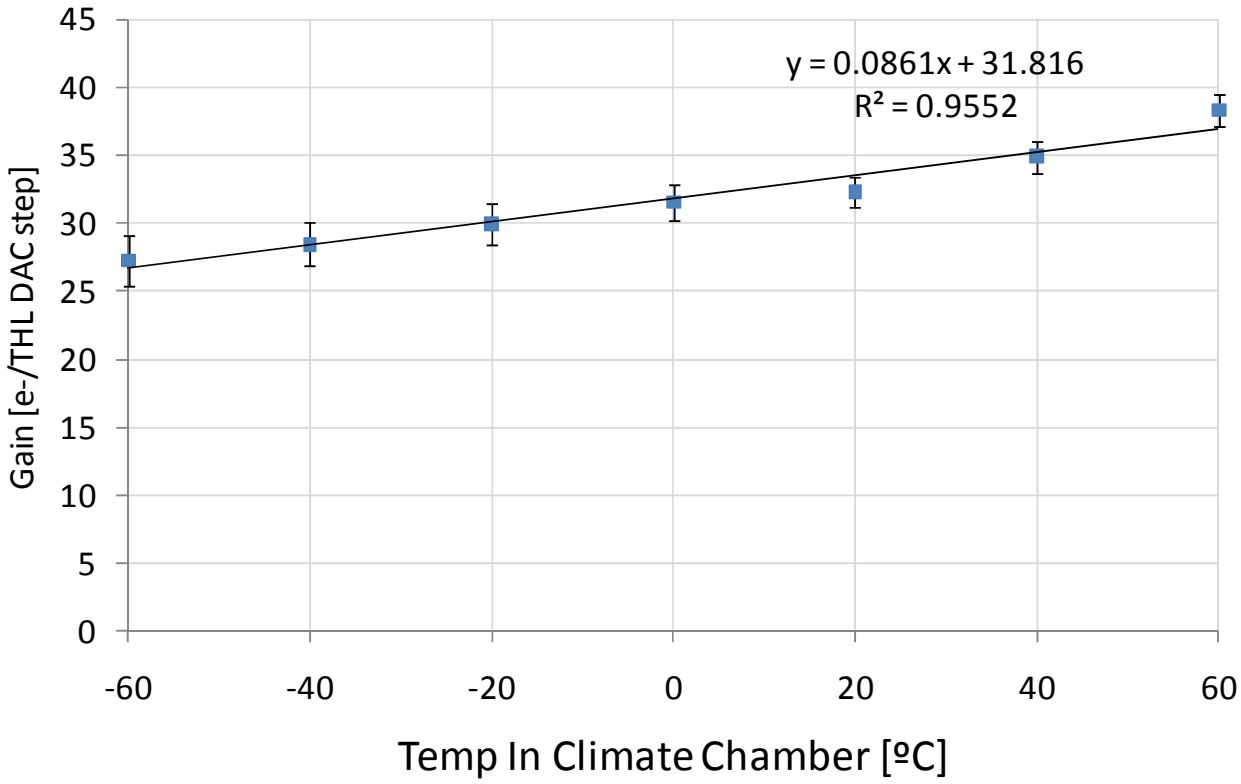
Temperature effects in one pixel

- The chip is operational in all the studied temperature range
- But, we observe variations on the noise, threshold position and gain



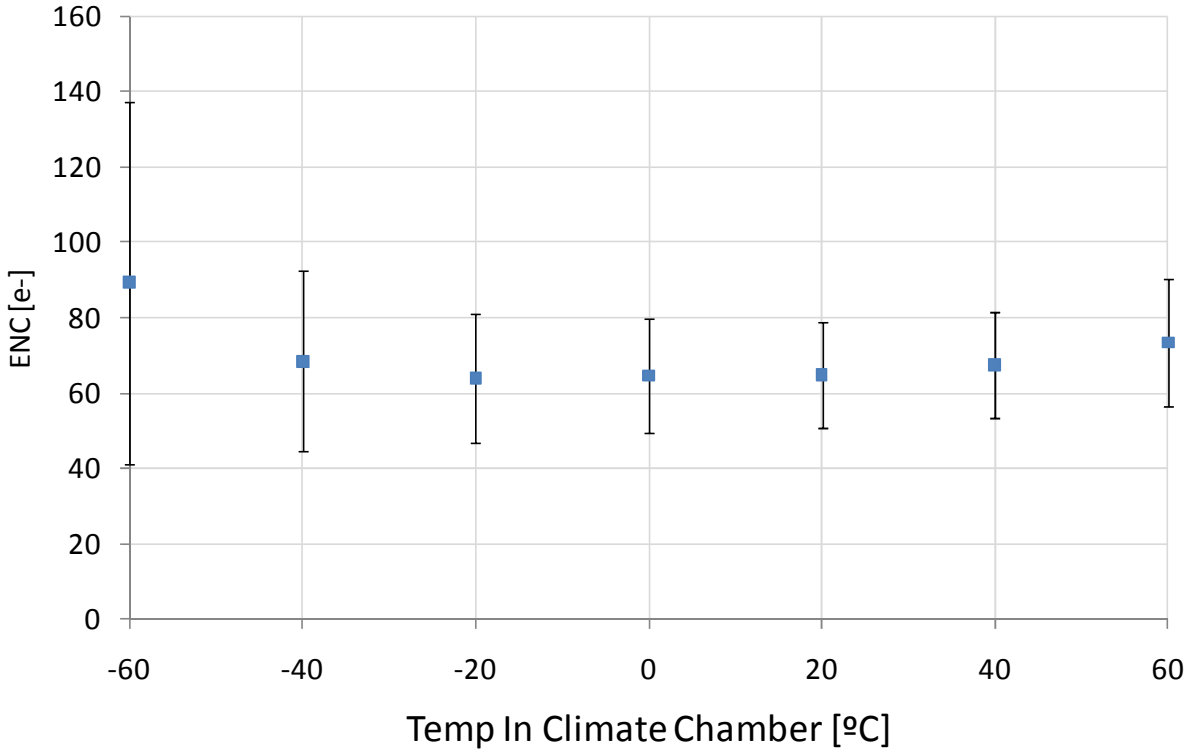
Pixel to pixel gain variation

- Gain variation (0.086 e^-/THL DAC step) is due to the Medipix3 shaper stage



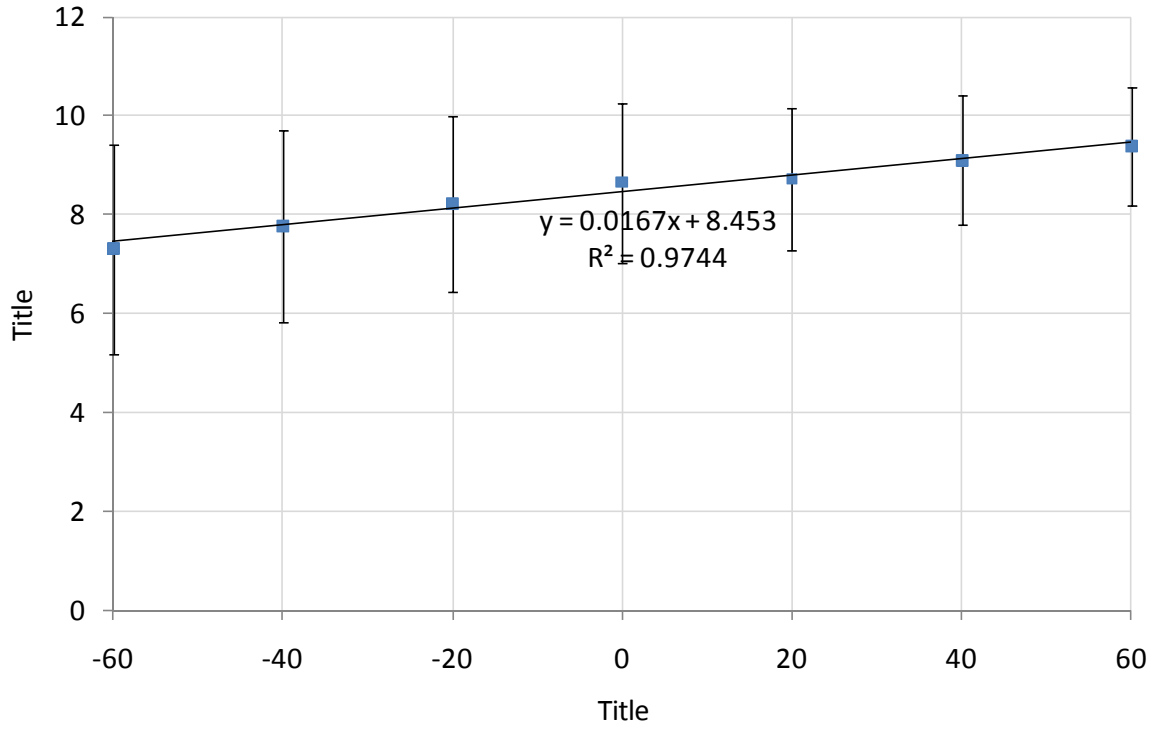
Overall pixel noise variation

- Noise is increasing at low temperature probably due the change in front end bias voltages Vcas and Vfbk



Overall threshold position shift

- Significant effect visible in the threshold position due to the variation on Vcas
- When the shaper's pol-zero cancellation circuit is activated the measured temperature sensitivity is 16.7 e^-/°C and 3.7 e^-/°C when it is switched off.



400Mrad Irradiation

- **Used a calibrated X-ray machine (Seifert RP149)**
- **Beam profile is smaller than the Medipix3 → Two runs:**

On the Pixel Matrix 60Mrad

Threshold Variation

Gain Variation

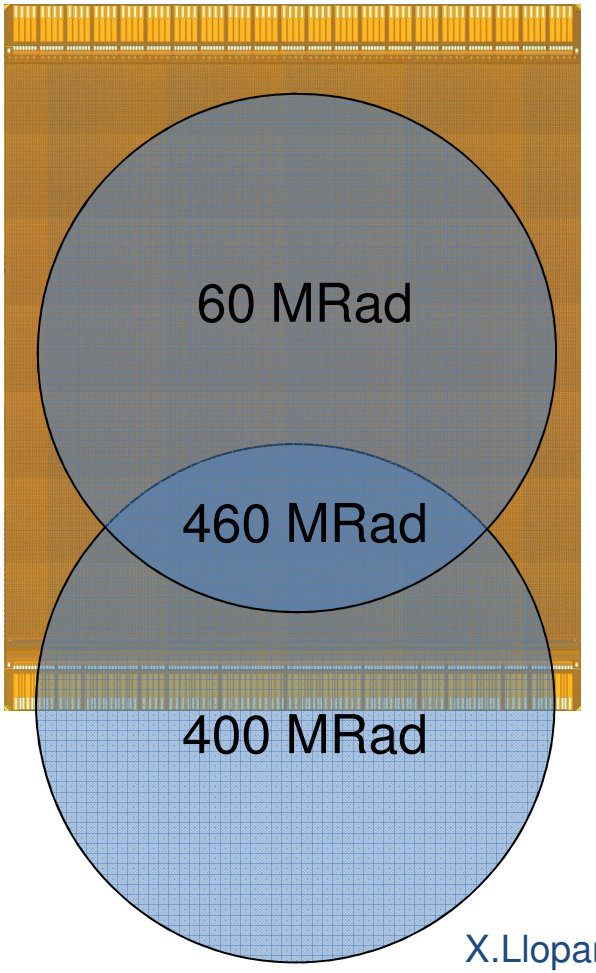
Noise Increase

On the Periphery 400Mrad

Check DACs

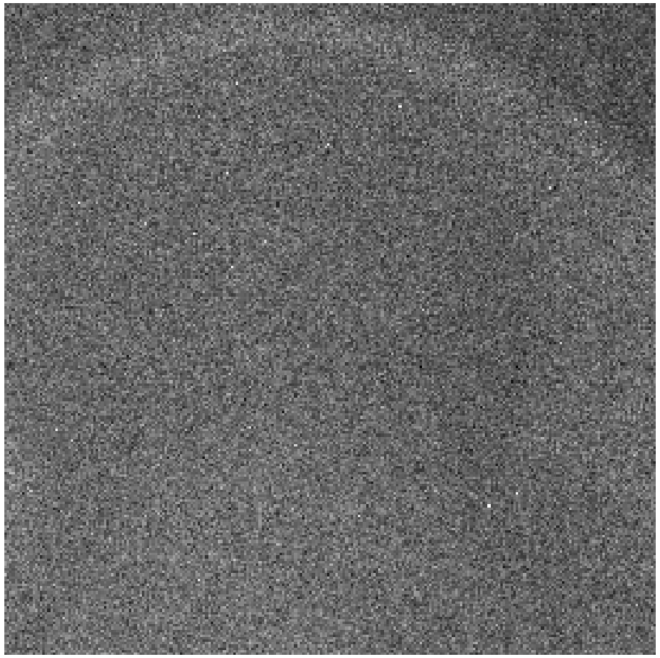
E-fuses

Logic functionality

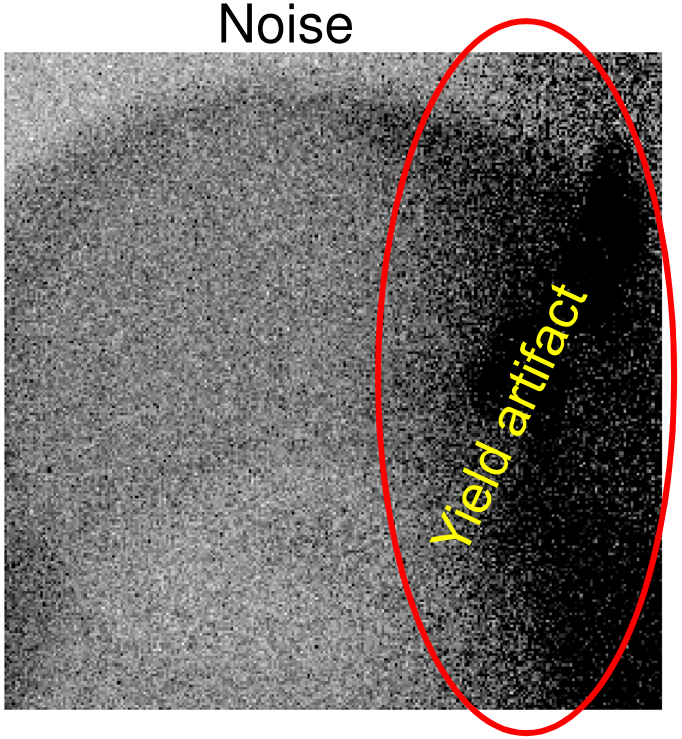


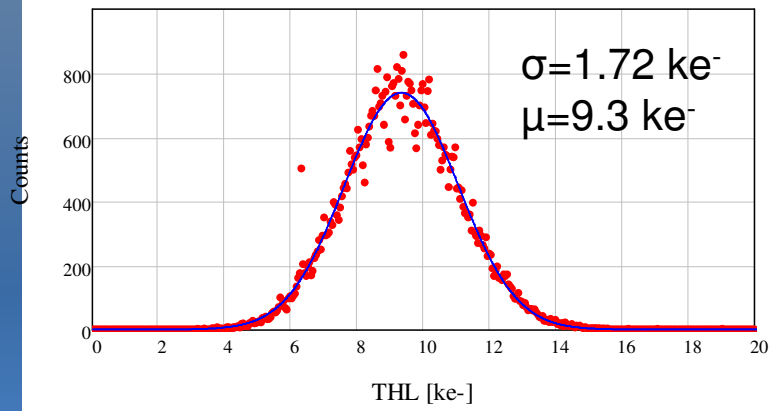
Performance after 460MRad

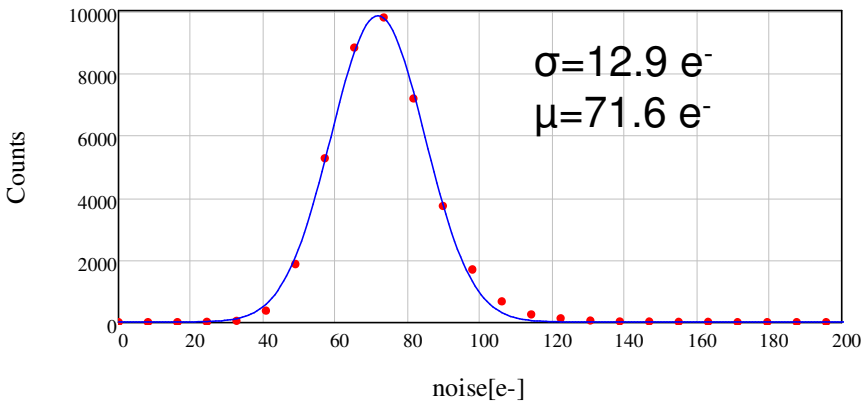
Threshold



Noise

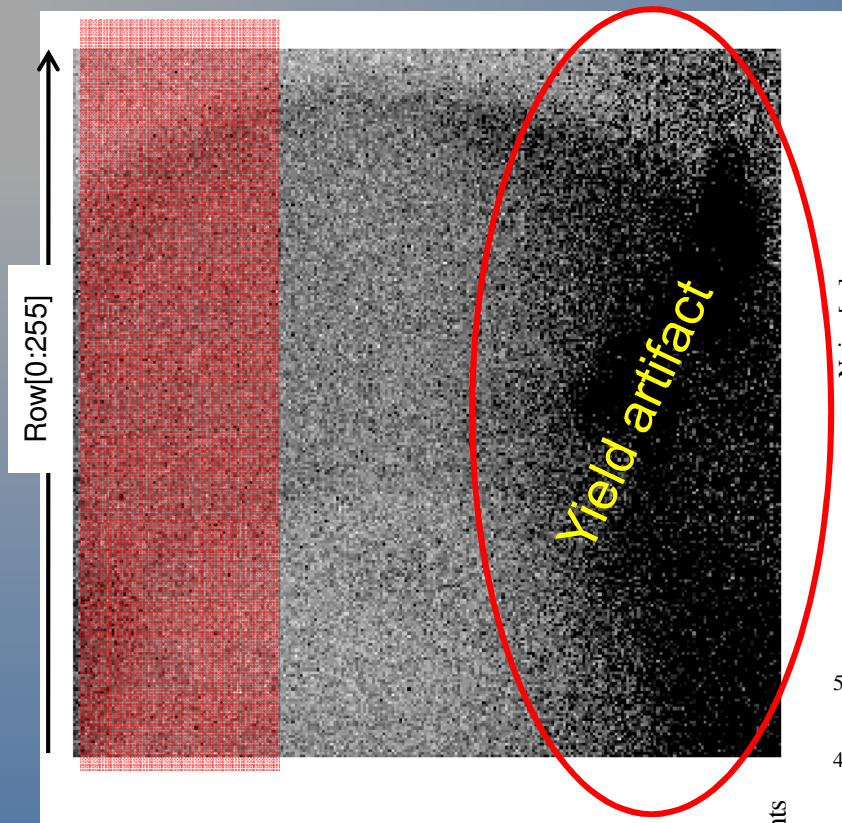


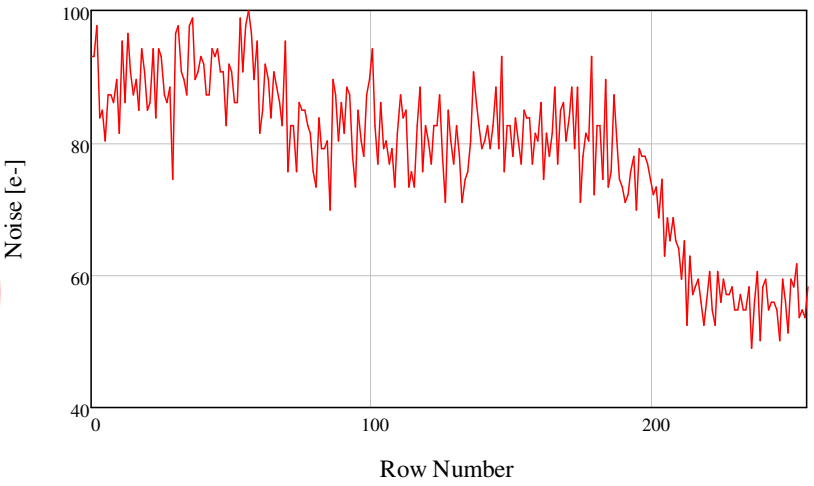




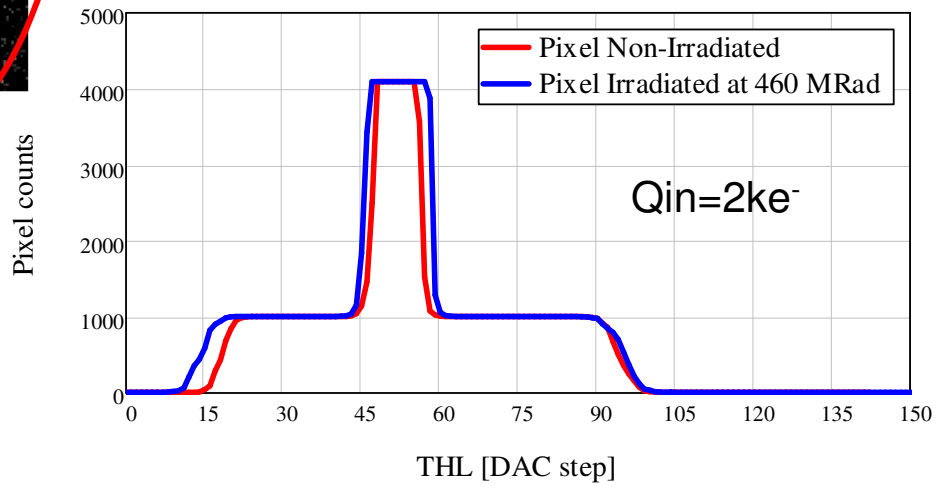
Threshold can be re-tuned using 5 bit equalisation

Performance after 460MRad

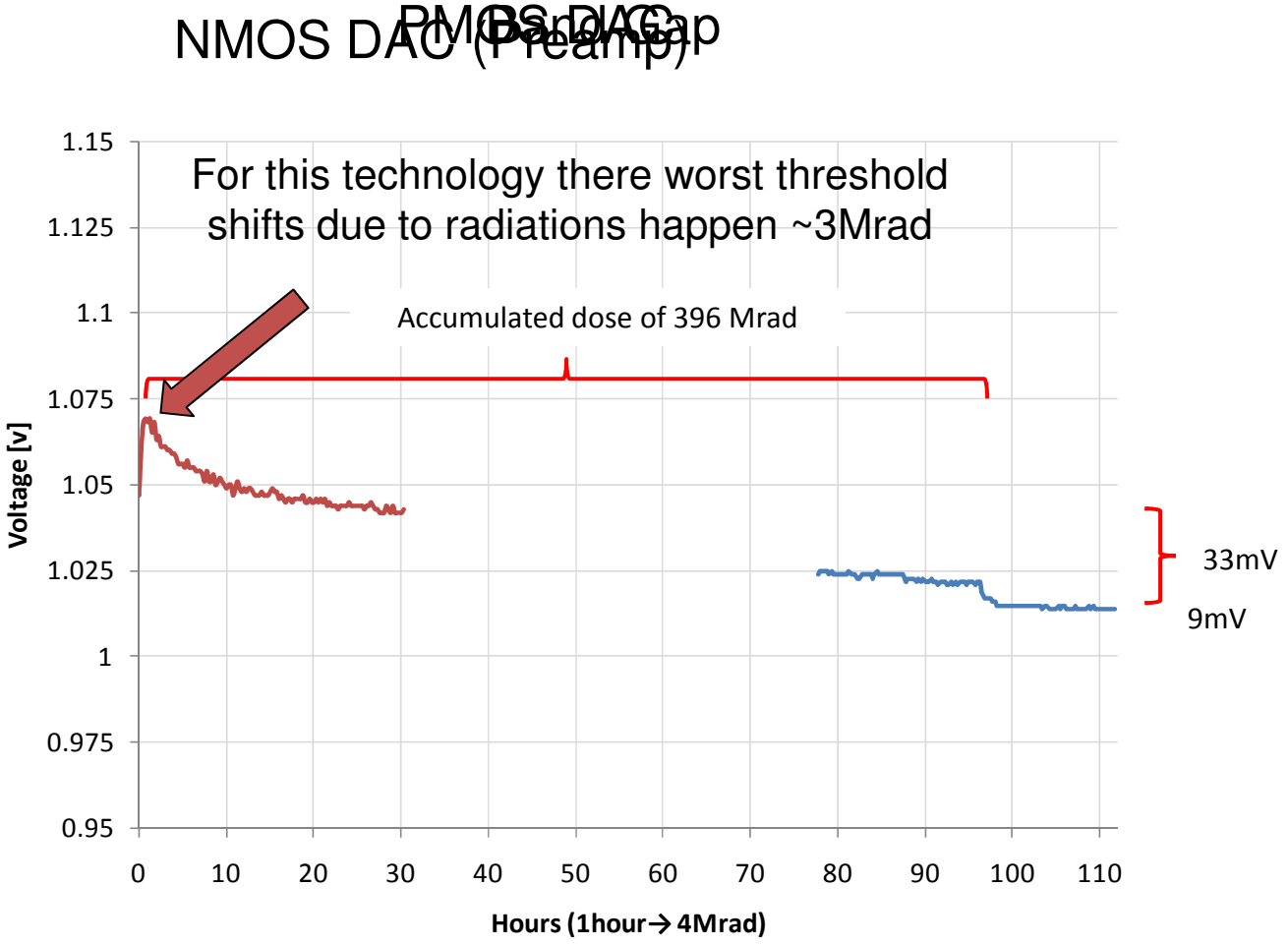




After 460MRad there is essentially no gain variation observed



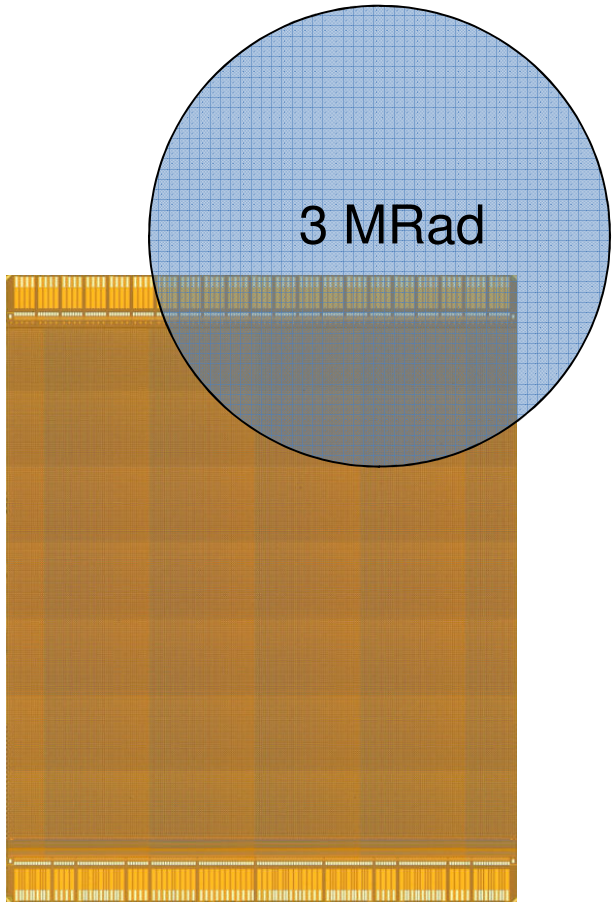
DAC Measurement



3MRad irradiation

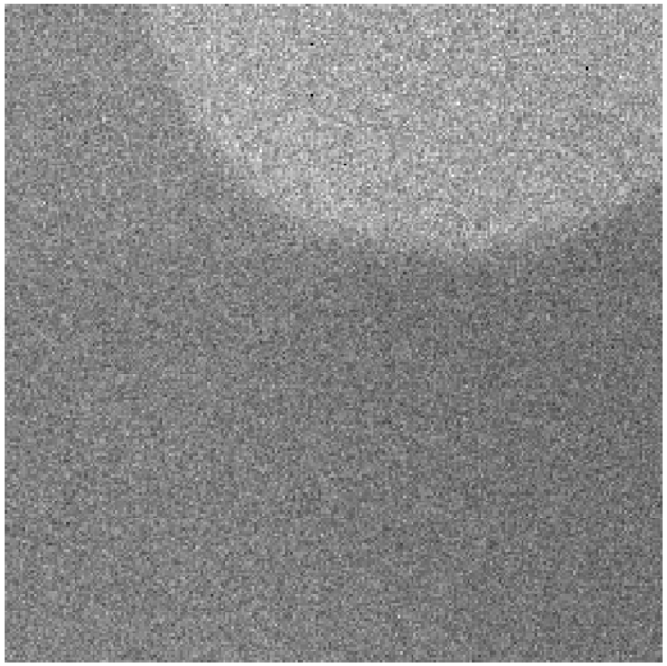
Worst effect at 3MRad, After this the effect of further radiation is much less.

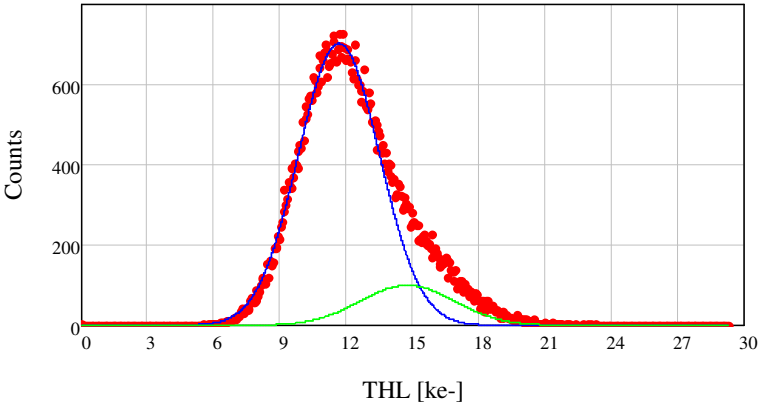
Irradiated a small area of the chip up to 3Mrad to try and keep Cas DAC working by only damaging a limited number of pixels



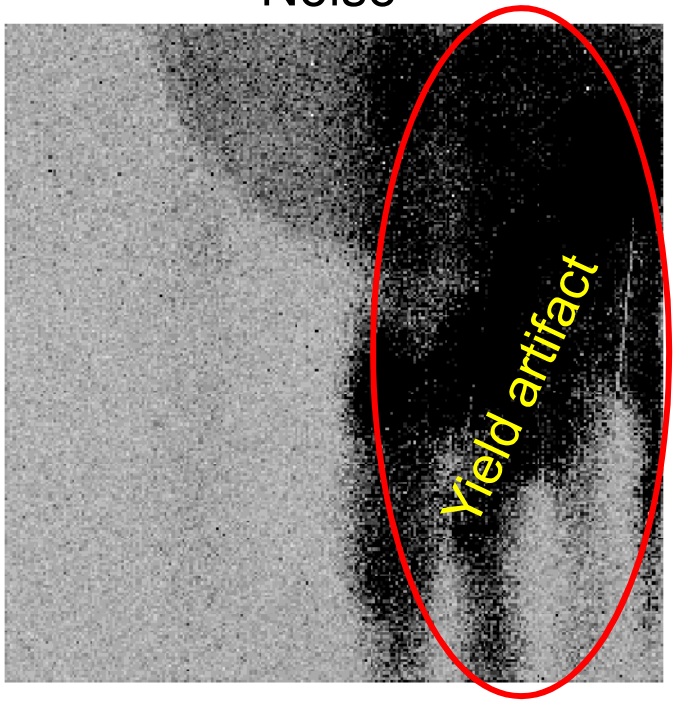
General behavior after 3 Mrad

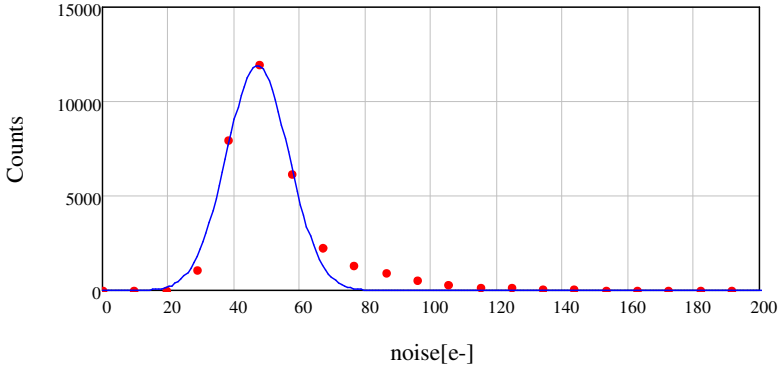
Threshold



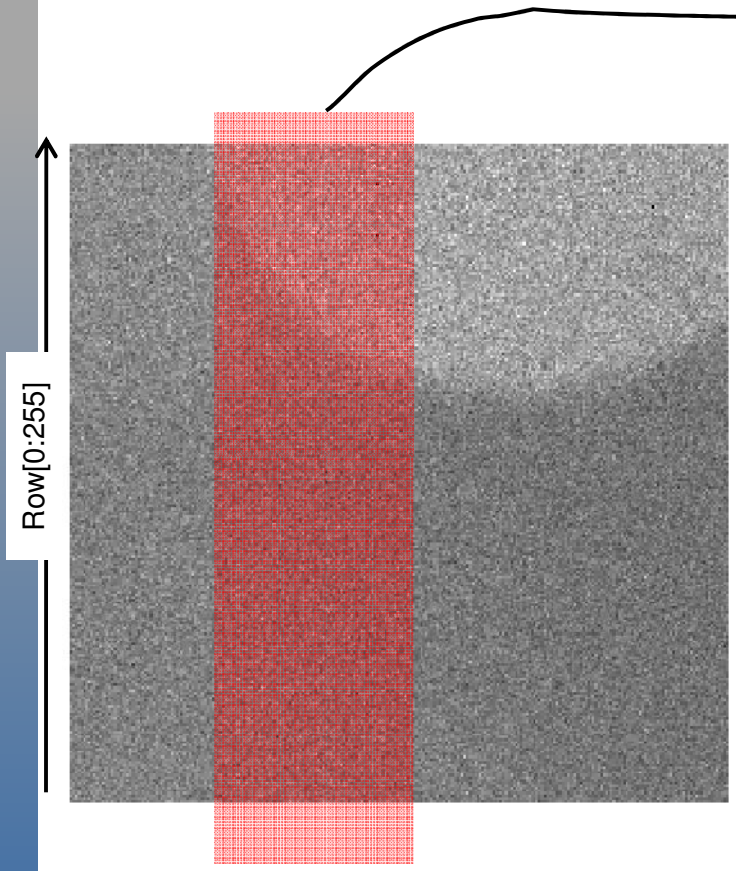


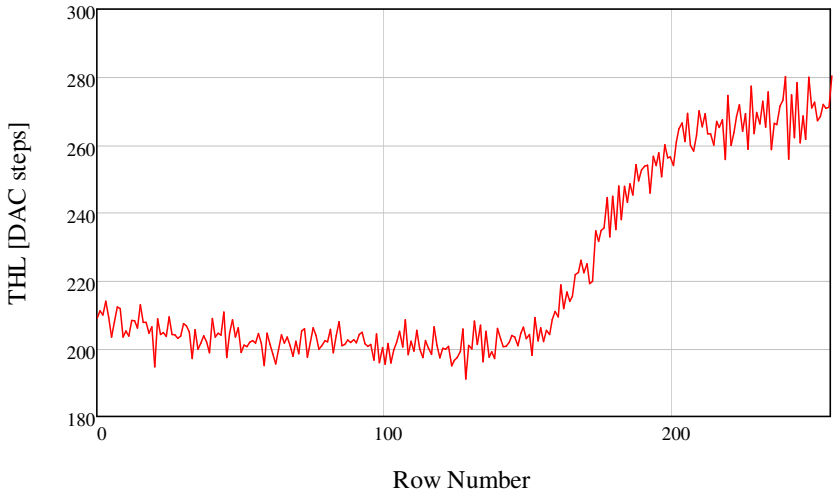
Noise





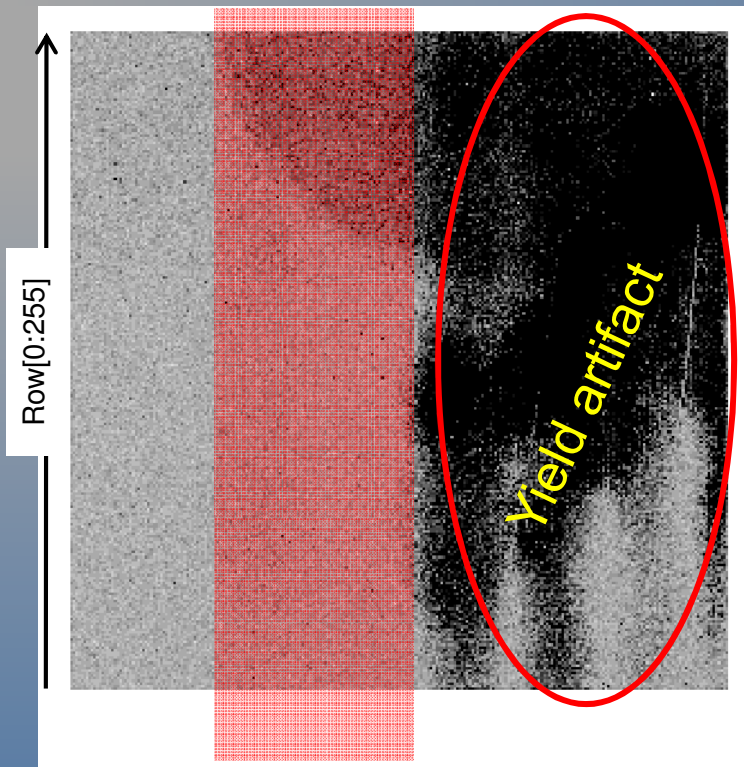
Overall threshold position variation

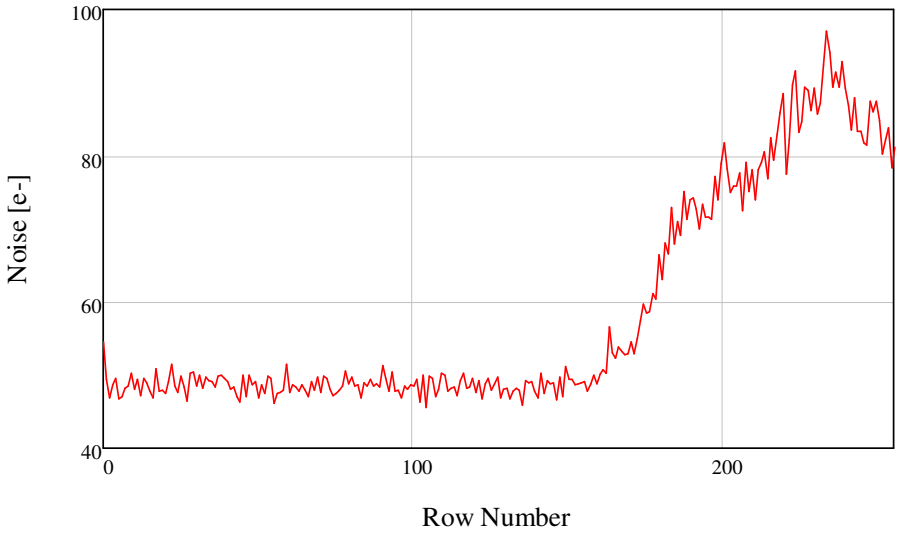




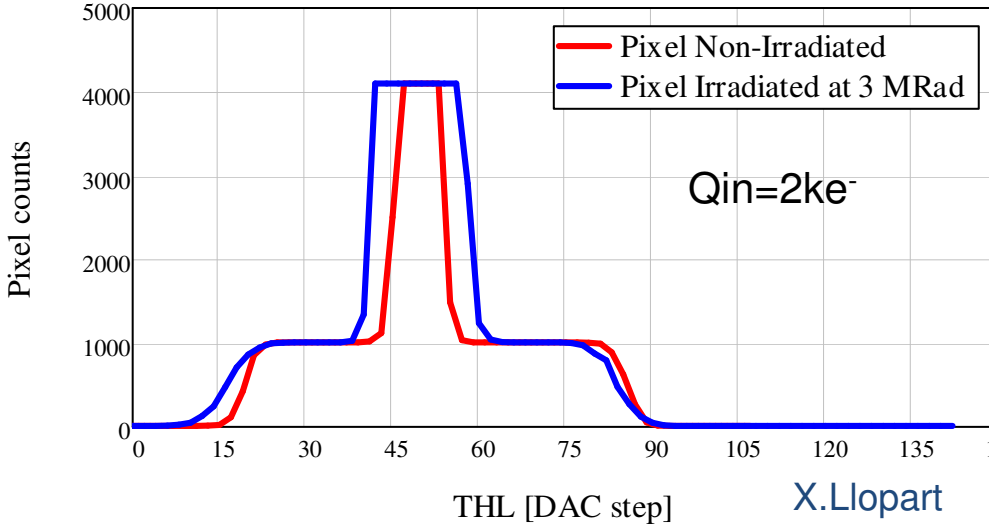
Main contributor is the protection diode. In order to minimize the pixel to pixel threshold variation Ikrum is set to 16nA which indicated that the leakage of this diode at 3Mrad is ~5 to 10 nA.
This is the worst radiation operation point.

3MRad Noise and Gain Result





In this worst case situation the noise is still less than 100e$^-$ and the gain variation is still minimal



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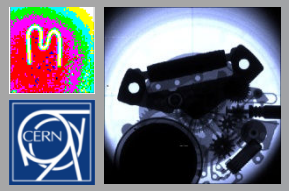
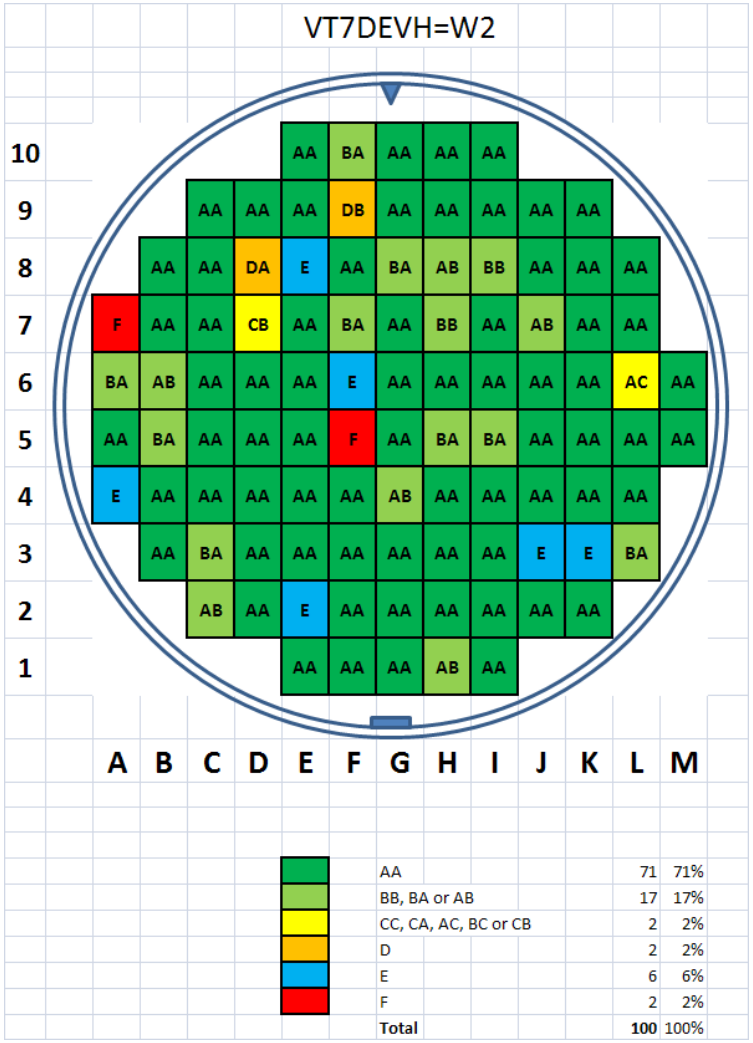
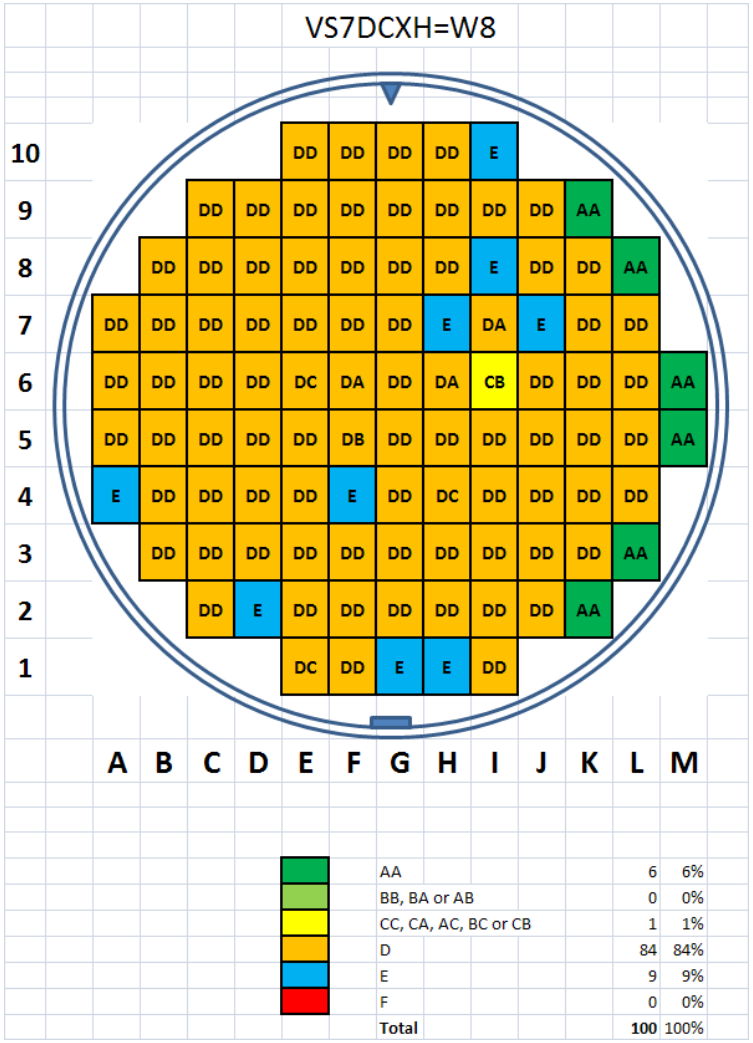


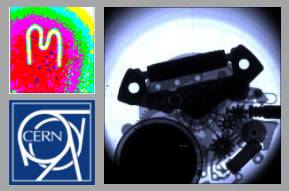
Wafer Probing Summary

Name	#	AA	Bs	Cs	Ds	E	F	# Chips	Where
VK7DG2H	0							100	CERN/diced
VT7DCWH	1	27	10	11	45	3	4	100	CERN
VT7DEVH	2	71	17	2	2	6	2	100	Bump bonding
VV7DFAH	3	33	18	6	32	7	4	100	CERN
VN7DE0H	4	57	18	2	15	8	0	100	Bump bonding
VU7DCVH	5	18	5	1	63	10	3	100	CERN
VW7DF9H	6	36	18	4	30	6	6	100	CERN
VQ7DCZH	7	61	18	2	8	6	5	100	Bump bonding
VS7DCXH	8	6	0	1	84	9	0	100	CERN
VU7DDCH	9	47	21	2	16	12	2	100	CERN
VL7DFJH	10	33	19	7	36	5	0	100	CERN
VW7DDAH	11	48	22	5	15	9	1	100	CERN
		437	**166**	**43**	**346**	**81**	**27**	**1100**	
		39.7%	15.1%	3.9%	31.5%	7.4%	2.5%	100.0%	

Best and worst wafer

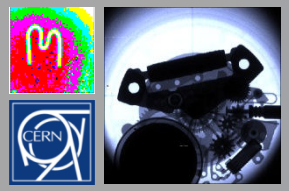






Conclusions

- The electrical characterisation of the chip is basically completed
- By monitoring the chip temperature and the radiation effects through Vcas line the chip is practically insensitive to radiation large temperature fluctuations
- Only remaining issue is to understand the failure mechanism of the CRW mode
- Yield results are very encouraging given the complexity of such chip
- First Si assemblies will be available shortly and will be use to confirm electrical measurements



Towards Timepix2

- In the Medipix3 collaboration there is a growing interest in Timepix2
- It might be possible to fund this development with the Medipix3 funds
- Main specs:
  - Pixel to measure TOT and Arrival time information simultaneously
  - <2ns time resolution
  - Triggered readout
  - Sparse and very fast readout
- Many building blocks used in Medipix3 can be reused for a new chip
- Start of design depends on available experienced man-power