Noise contributions of AGIPD0.2 and AGIPD0.3

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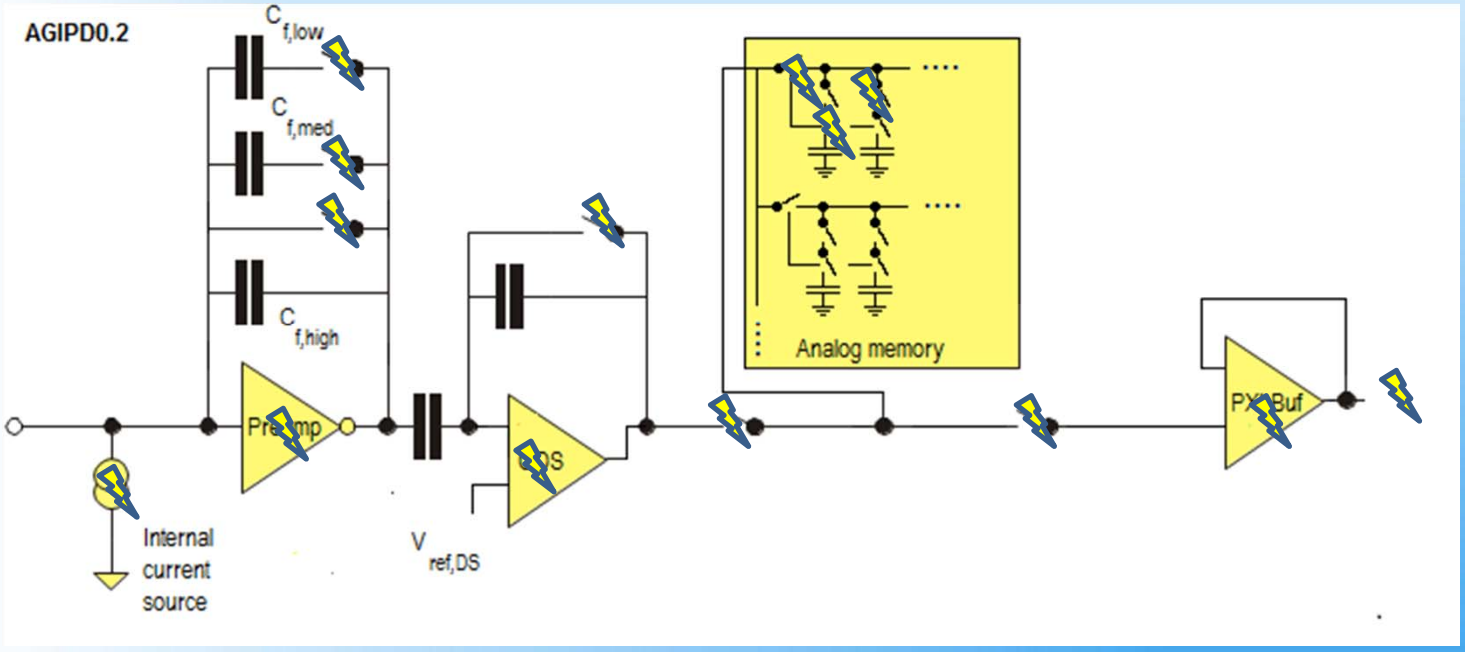
AGIPD0.2: Pixel schematics



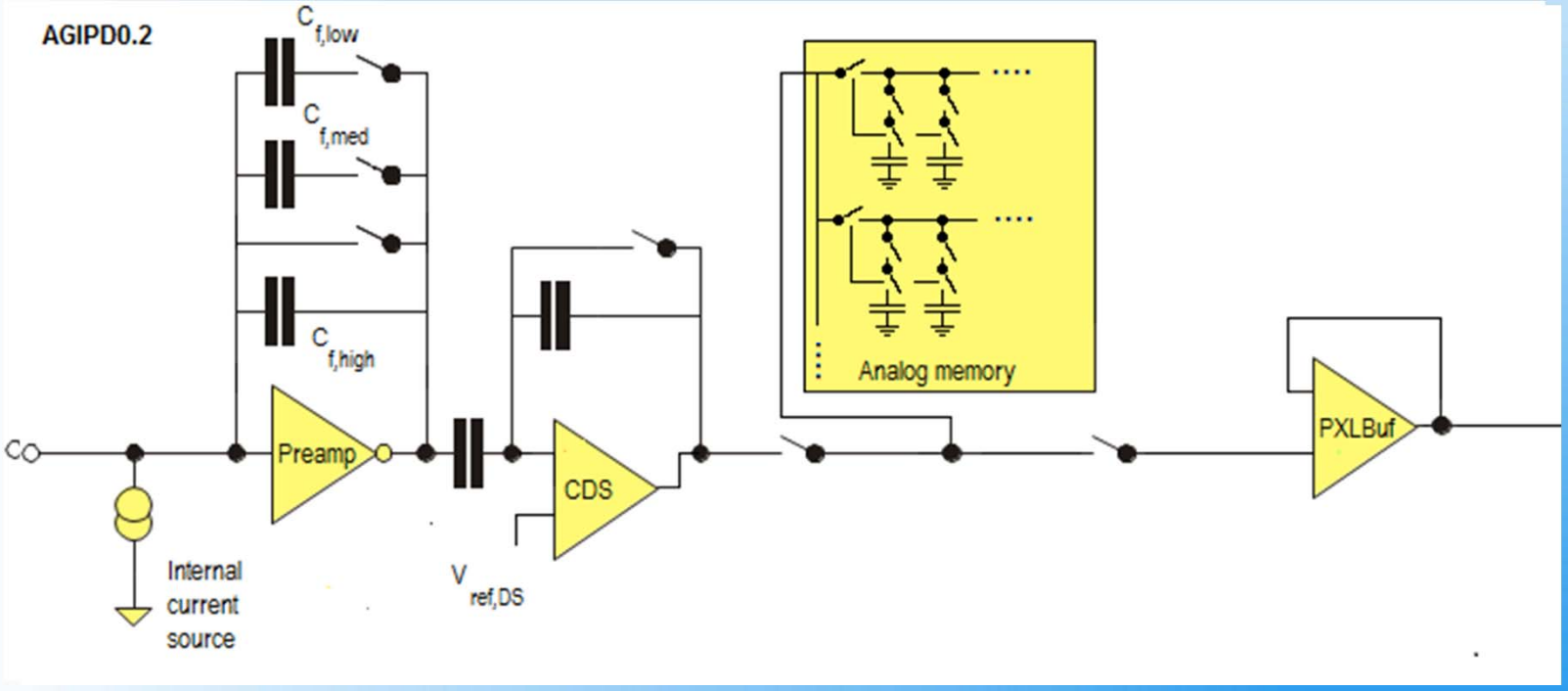
: Noise contributions

If the noise sources are independent:

$$\sigma_{overall}^{2} = \sigma_{Preamp}^{2} + \sigma_{CDS}^{2} + \sigma_{Pixelbuffer}^{2} + \sigma_{Offchipdriver}^{2} + \ldots\ldots$$

AGIPD0.2 (10 SCR)

10 SCR: 10 storage cells statically connected at output of CDS (NO write/read)



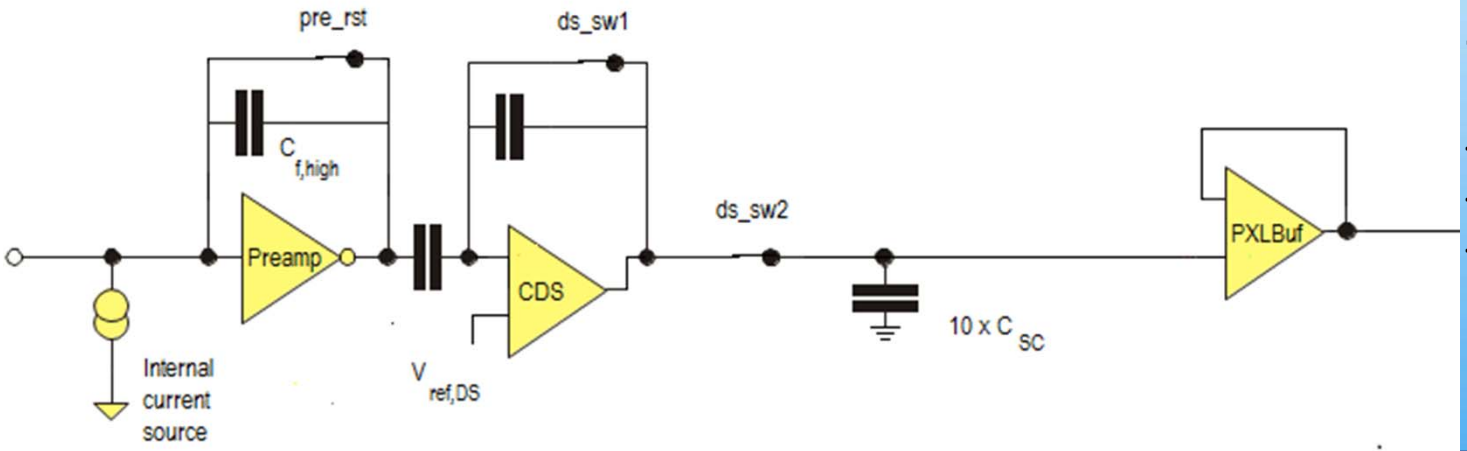
→Only high gain stage

→ No write/read, only 10 storage cells as filter capacitance at output of CDS

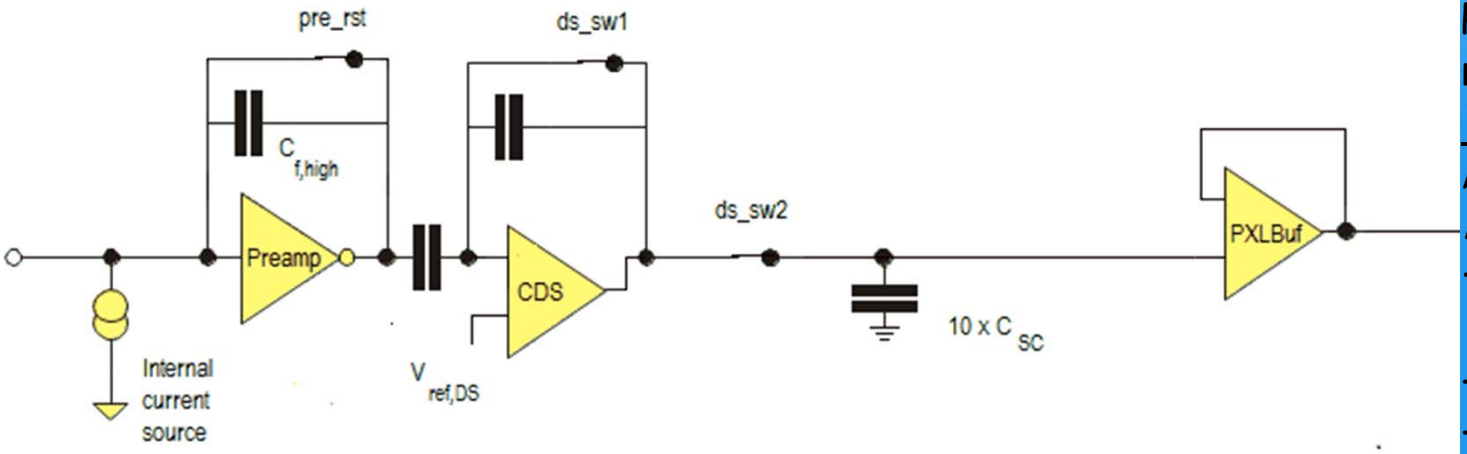
AGIPD0.2 (10 SCR): Measurement

AGIPD0.2 (simplified, 10 storage cells directly coupled with output)

Start: Preamp, CDS in reset



Start: Preamp, CDS in reset



Normal Measurement:

→Noise contributions:

- Preamp
- CDS
- Pixelbuffer

Noise contributions measurement:

Preamp always in reset:

→ Assumption: Preamp contribution is negligible!

→Noise contributions:

- CDS
- Pixelbuffer

AGIPD0.2 (10 SCR): Measurement

Normal measurement:

$$\sigma_{overall}^2 = \sigma_{Preamp}^2 + \sigma_{CDS}^2 + \sigma_{Pixelbuffer}^2$$

Preamp in reset: (Assumption: Preamp noise contribution negligible)

$$\sigma_{overall}^2 = \cancel{\sigma_{Preamp}^2} + \sigma_{CDS}^2 + \sigma_{Pixelbuffer}^2$$

→Validated by measurements, when
a) switching off preamp (V_a=0)
b) resetting preamp

Preamp, CDS in reset: (Assumption: Preamp & CDS noise contribution negligible)

$$\sigma_{overall}^2 = \cancel{\sigma_{Preamp}^2} + \cancel{\sigma_{CDS}^2} + \sigma_{Pixelbuffer}^2$$

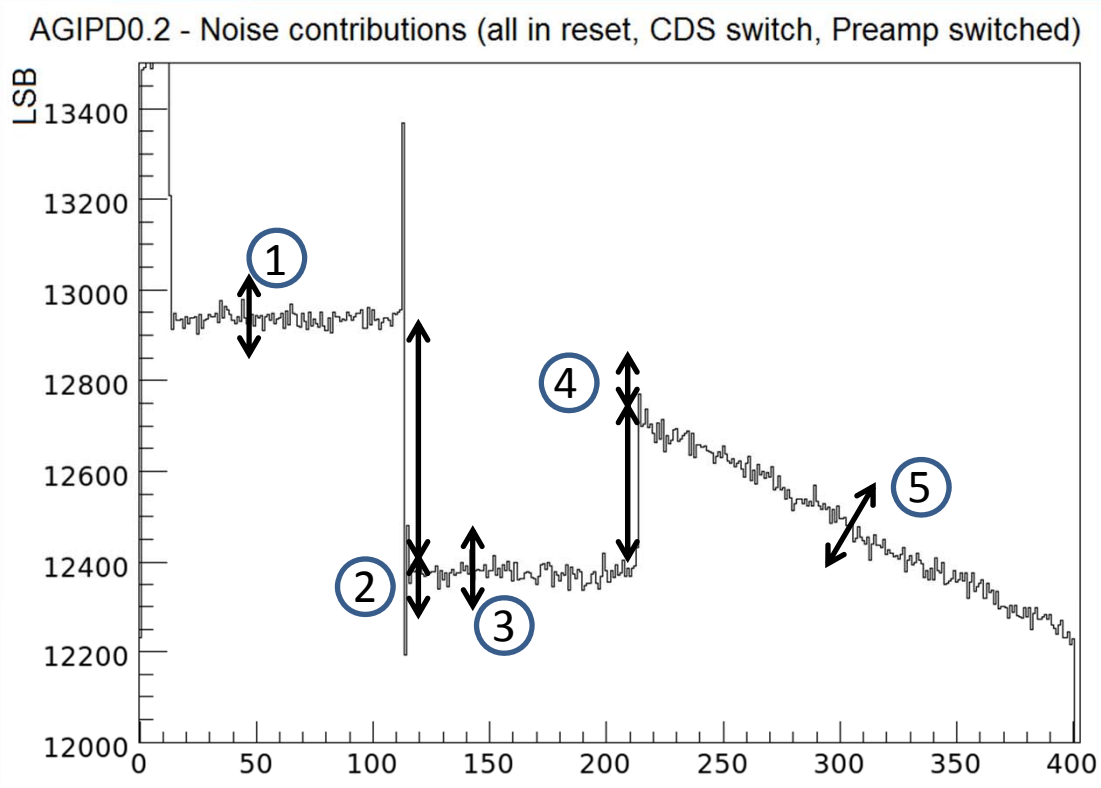
→CDS noise contribution: (Preamp in reset – Preamp, CDS in reset)

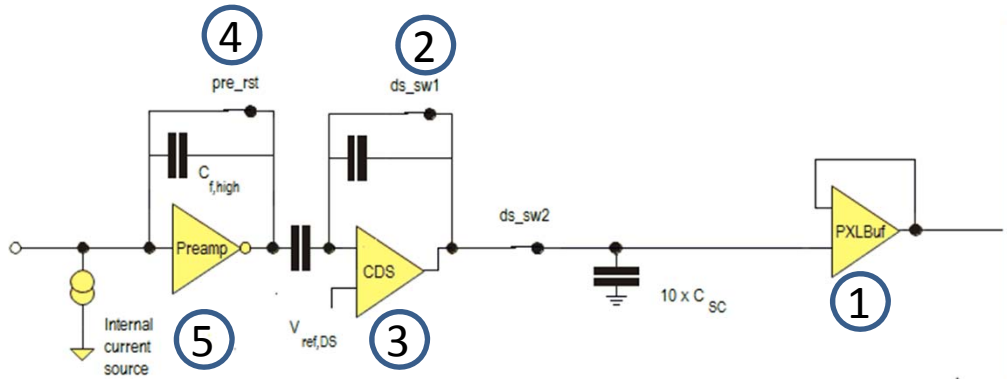
$$\sigma_{overall}^2 = \sigma_{CDS}^2 + \cancel{\sigma_{Pixelbuffer}^2} - \cancel{\sigma_{CDS}^2} - \cancel{\sigma_{Pixelbuffer}^2}$$

→Preamp noise contribution: (Overall – Preamp in reset)

$$\sigma_{overall}^2 = \sigma_{Preamp}^2 + \cancel{\sigma_{CDS}^2} + \cancel{\sigma_{Pixelbuffer}^2} - \cancel{\sigma_{CDS}^2} - \cancel{\sigma_{Pixelbuffer}^2}$$

AGIPD0.2 (10 SCR): Charge injection





1 **Noise Readout chain:**

$\sigma_{Readout\ chain}$= (5.75 ± 0.01)

2 **Injection CDS switch:**

Height= 564,7 LSB

$\sigma_{QInj,CDS}$= (14.01 ± 0.03)

3 **Noise CDS:** Strongly dominated

σ_{CDS}= (14.88 ± 0.02)

4 **Injection Preamp switch:**

Height= 346.5 LSB

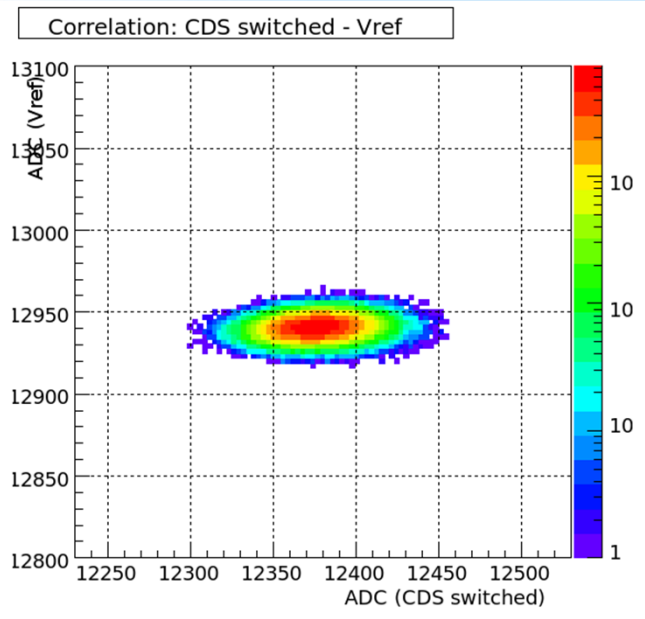
$\sigma_{QInj,Preamp}$= (18.78 ± 0.03)

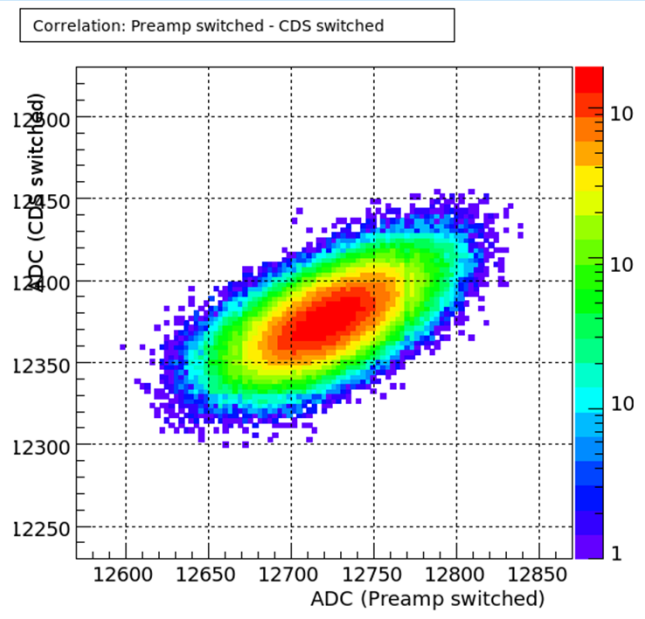
5 **Noise Overall:** Dominated

σ_{Preamp}= (23.23 ± 0.06)

(Typically removed by reset of CDS)

MOSFET: Charge injection





$\sigma_{Readout\ chain} = (5.75 \pm 0.01)$

$\sigma_{QInj,CDS} = (14.01 \pm 0.02)$

$\sigma_{CDS} = (14.88 \pm 0.02)$

$(5.75^2 + 14.01^2)^{1/2} = 15.14$

$\sigma_{CDS} = (14.88 \pm 0.02)$

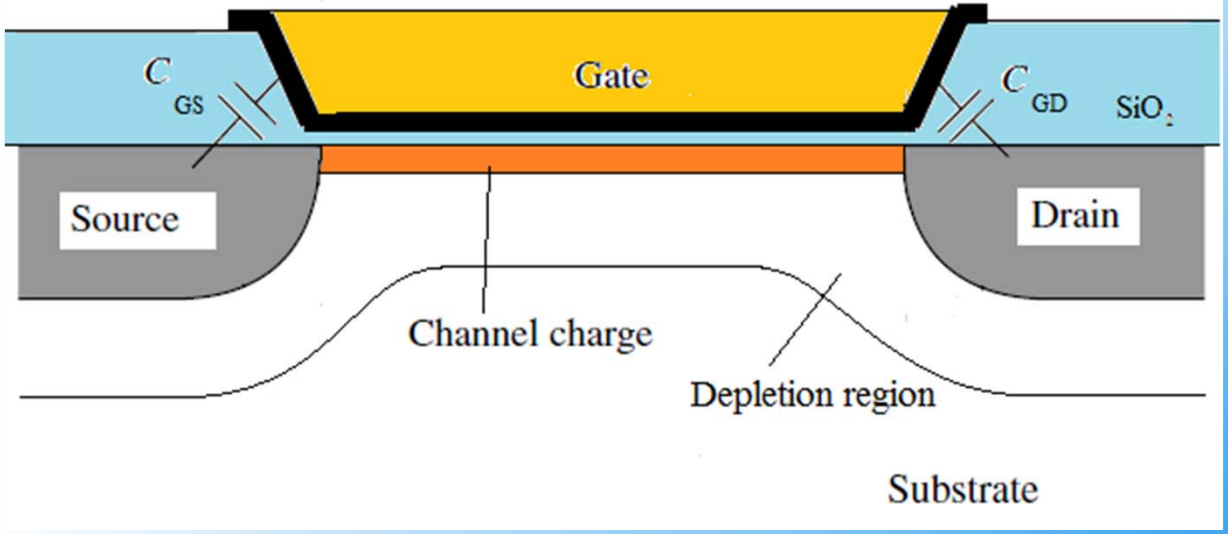
$\sigma_{QInj,Preamp} = (18.78 \pm 0.04)$

$\sigma_{Preamp} = (23.23 \pm 0.06)$

$(14.88^2 + 18.78^2)^{1/2} = 23.96$

→ Both charge injection processes are almost independent of each other! Thus, NO common movement of baseline…

MOSFET: Charge injection



AGIPD0.2 Preamp switch:

- L=0.12 um
- W = 11 um
- C_{GS}= 7.9 fF
- C_{GD}= 5.9 fF
- V_D=V_S=0.826 V
- V_G=1.5 V

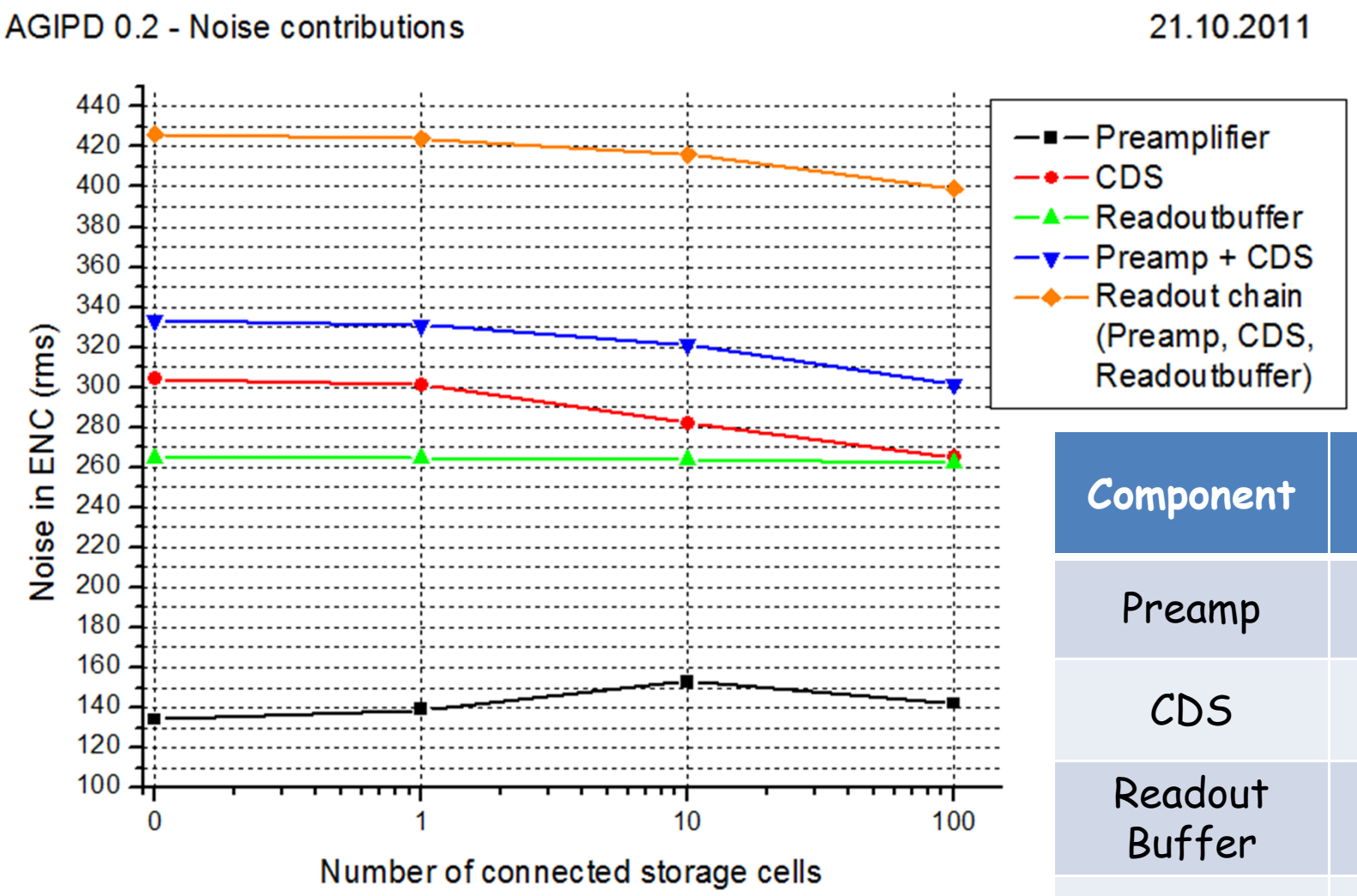
Where	Charge (e^-)
Channel	163125
C_{GS}	33279
C_{GD}	24854

Voltage jump after Preamp switching:

346.5 LSB = 21.1 keV = 5836 e^-

→ Main contributor unclear… (Channel, C_{GS} ,…)

AGIPD0.2 (10 SCR): Results

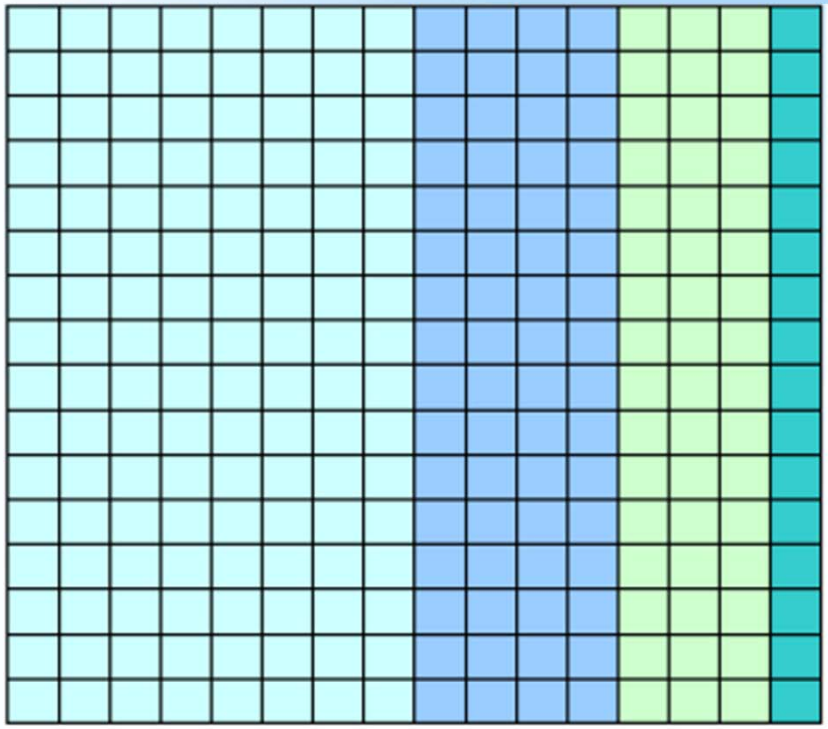


Component	ENC (10 SC, No Oversampling)
Preamp	153 e^-
CDS	251 e^-
Readout Buffer	273 e^-
Σ (20x oversampled)	401 e^- (281 e^-)

→Filter capacitance at the output of CDS improves noise performance

AGIPD0.2 (10 SCR): Results

Oversampling = Averaging at the output of ADC over several samples
→ Improving the noise performance

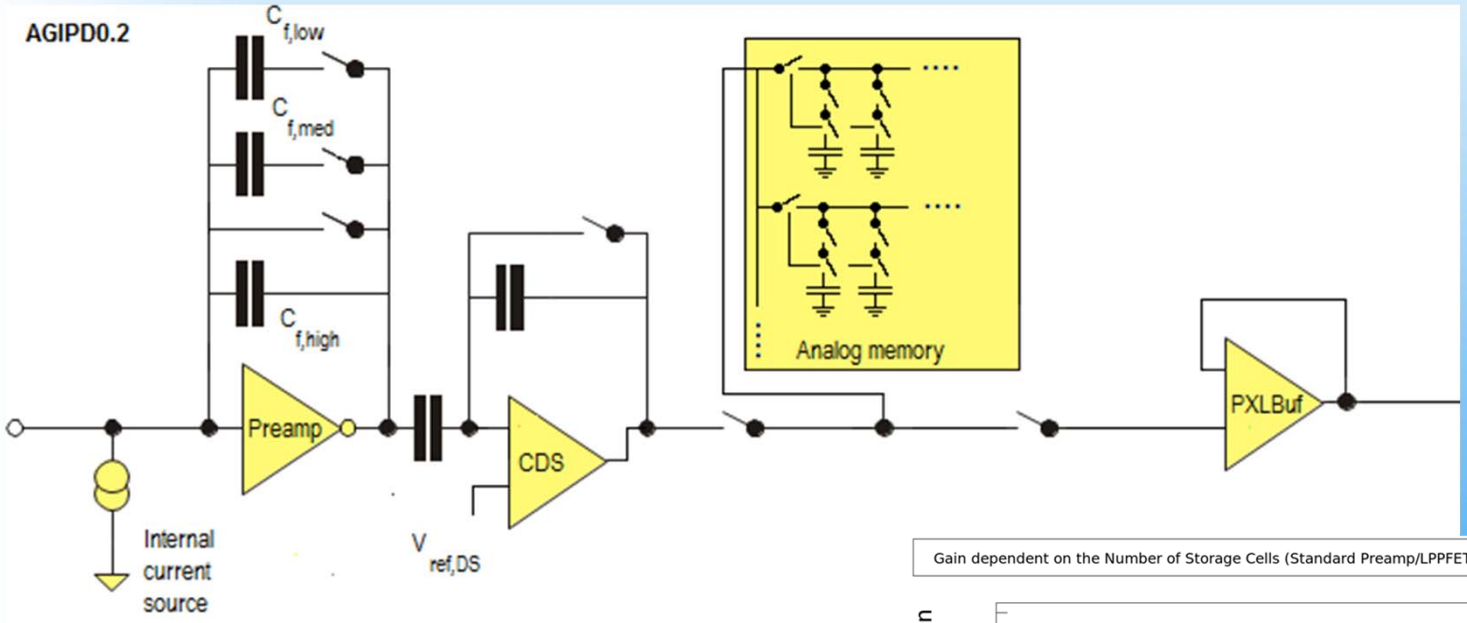


Categories of Test Structures:

- standard preamplifier (SP) (W=8u)
- fast preamplifier (FP) (W=16u)
- SP with protection diode
- SP with buffered cells (10 x 8)

	Noise (100 ns) in ENC (with photons)	*Gain (High gainstage)* (with current source)	*Linearity (High gainstage) (rms)*
Standard Preamplifier (SP)	**318 ± 30**	**253.86 ± 0.04**	**0.29%**
Fast Preamplifier (FP)	**307 ± 22**	**249.0 ± 1.1**	**0.27%**
SP with Protection Diode	**331 ± 30**	**250.5 ± 2.8**	**0.61%**

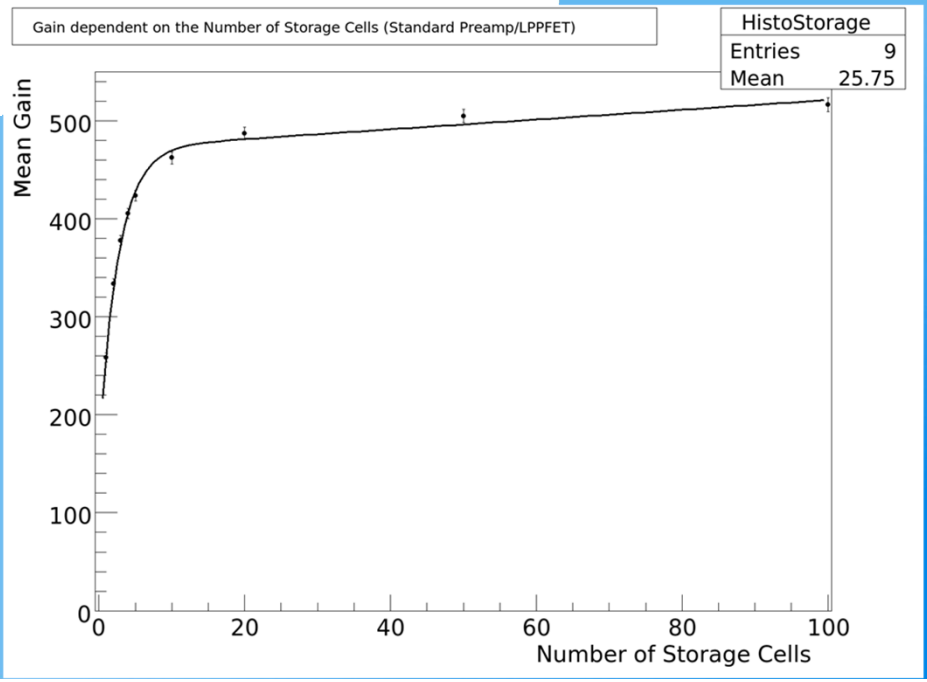
AGIPD0.2 (1 SC W/R)



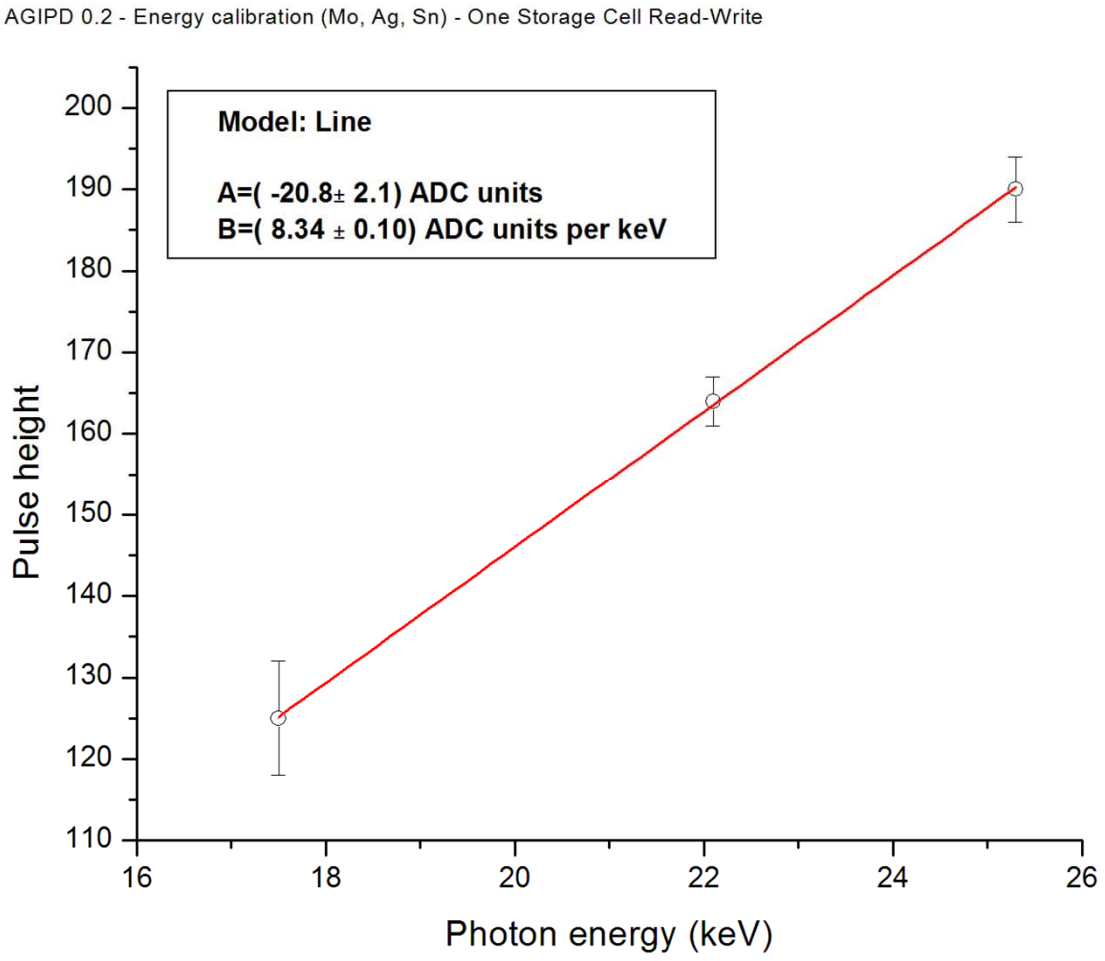
Loss of pulseheight, due to voltage sensitivity at PXLBuffer input

→ Bus between storage cell and PXLBuffer will be partially charge up with charge stored in storage cell

→ Heigher noise in ENC



AGIPD0.2 (1 SC W/R):

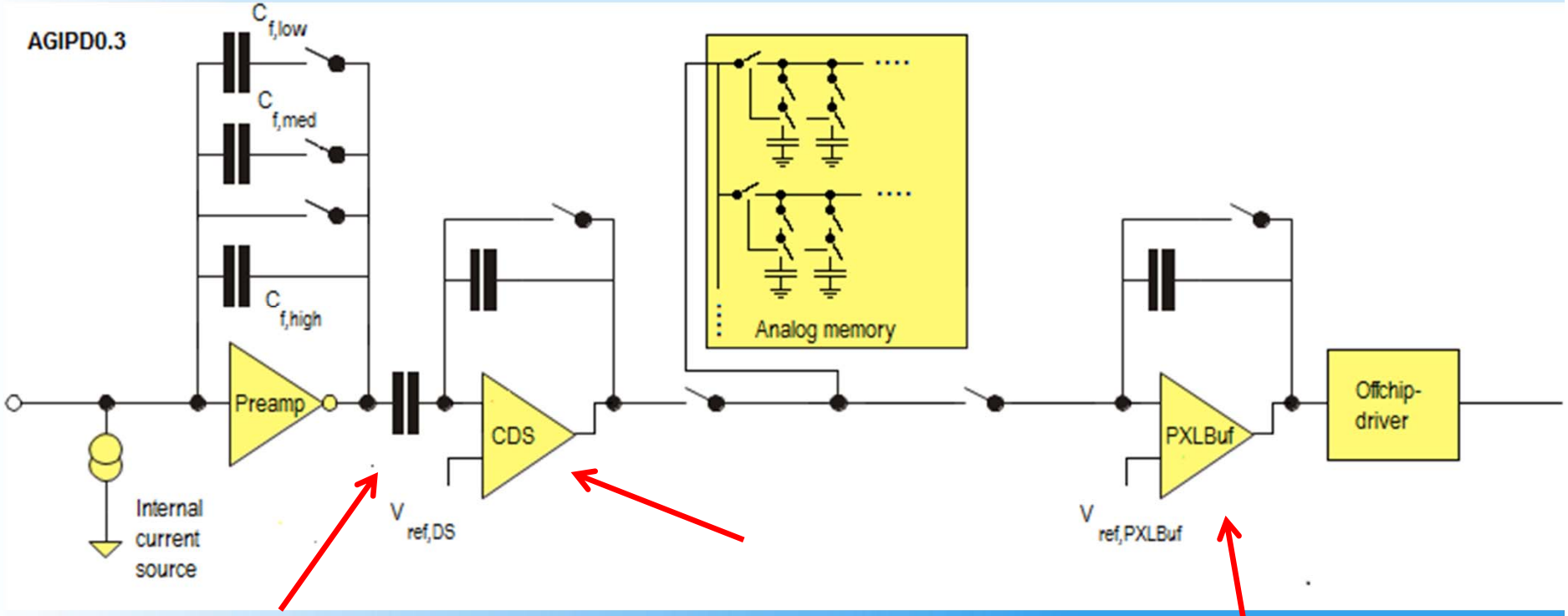


→ Gain reduced by ~ 50 % (10 SCR: 16.4 ADC/keV)

Component	ENC (One SC, No Oversampling)
Preamp	212 e^-
CDS	258 e^-
Readout Buffer	561 e^-
Σ (20x oversampled)	654e^- (413 e^-)

→ AGIPD03 features a different CDS and RO Buffer

AGIPD0.3 (1 SC W/R):



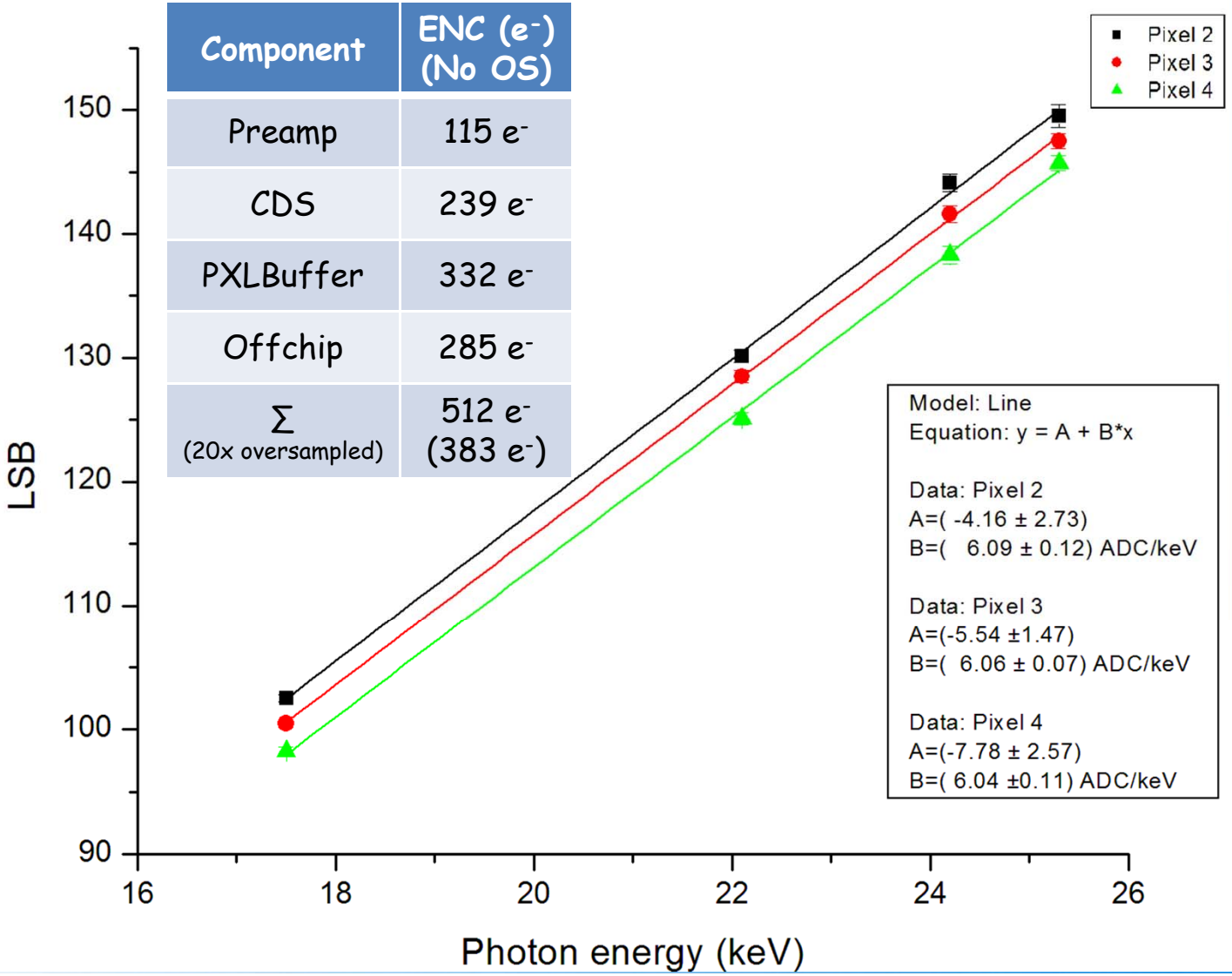
Changes in AGIPD0.3:

- Different PXLBuffer, now charge sensitive
- Different CDS with better noise performance
- Two coupling capacitances
  → Twice the gain to be expected (measured ~80 %)

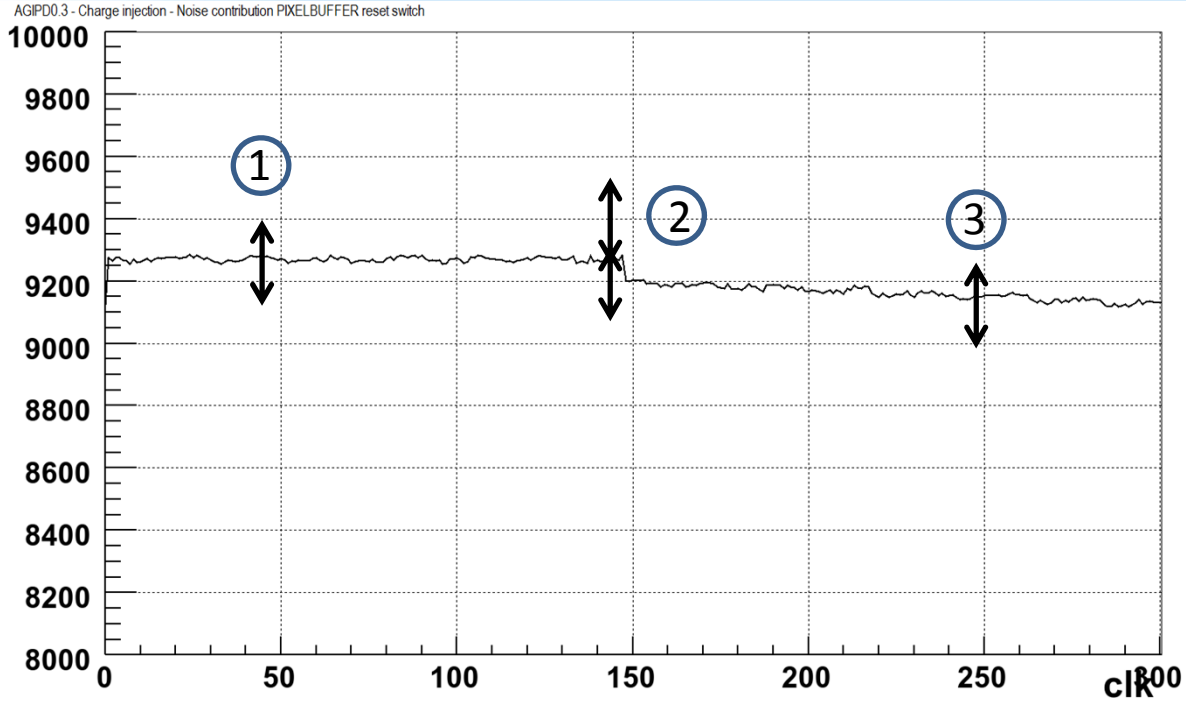
AGIPD0.3 (1 SC W/R): Noise

AGIPD0.3 - Energy calibration - Integration time: 400 ns - Fluorescence: Mo, Ag, In, Sn - Sensor bias: 120 V

Component	ENC (e^-) (No OS)
Preamp	115 e^-
CDS	239 e^-
PXLBuffer	332 e^-
Offchip	285 e^-
Σ (20x oversampled)	512 e^- (383 e^-)



AGIPD0.3 (1 SC W/R): Charge injection



1. Noise Offchip:

$\sigma_{Offchip} = (1.98 \pm 0.01)$

2. Injection PXLBuf switch:

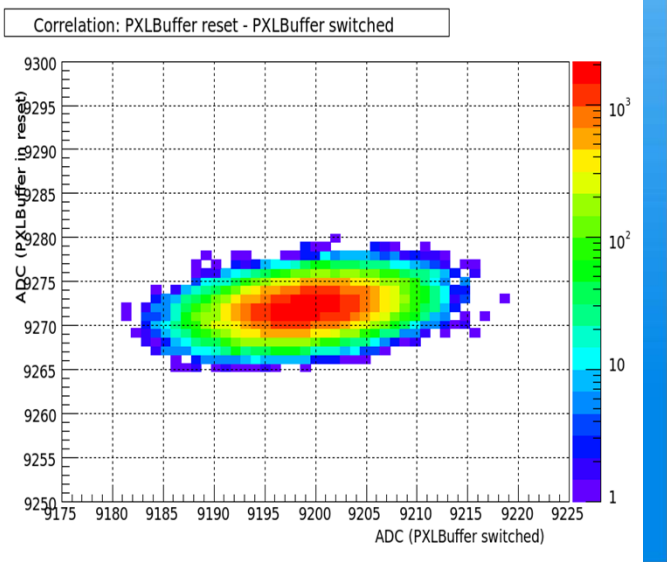
$\sigma_{QInj,PXB} = (4.34 \pm 0.01)$

3. Noise PXLBuffer:

$\sigma_{PXLBuffer} = (4.48 \pm 0.01)$

$(1.98^2 + 4.34^2)^{1/2} = 4.77$

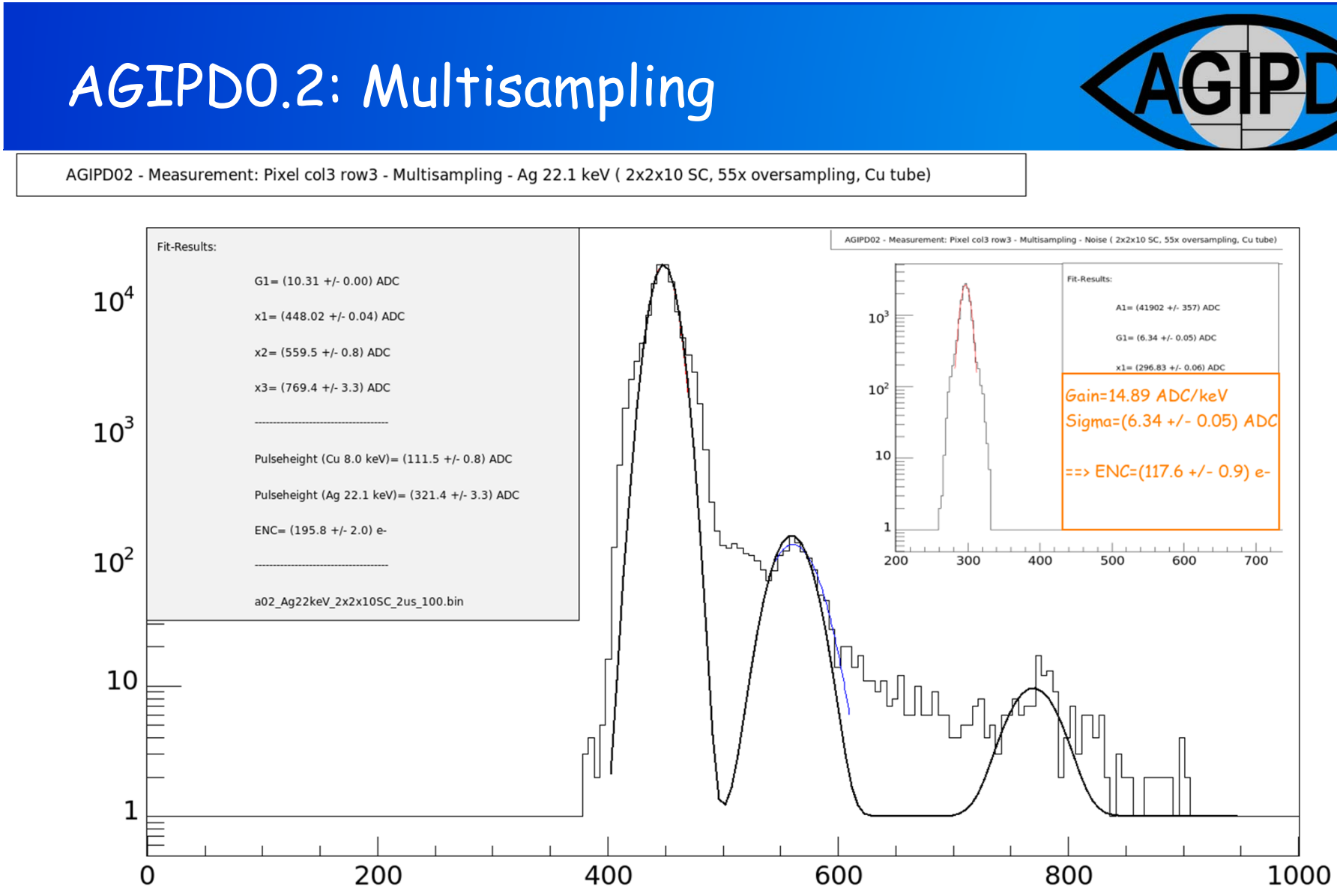
→ Again: Almost uncorrelated!



Summary: Noise

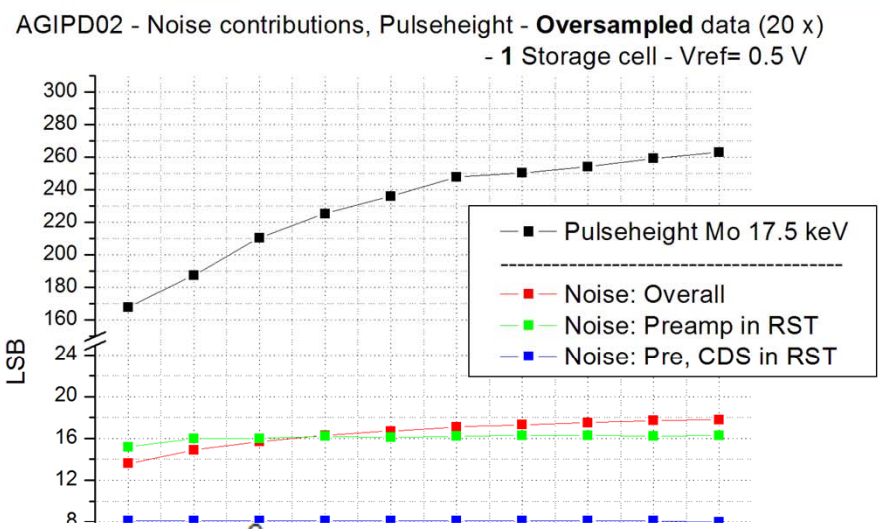
Component	AGIPD0.2	AGIPD0.2	AGIPD0.3
	10 SCR, std preamp 200 ns, $V_{ref,DS}$= 0.6 V	1 SCWR, std preamp, 2 µs, $V_{ref,DS}$= 0.6 V	1 SC W/R, 200 ns, $V_{ref,DS}$= 0.5 V
Preamp (Reset switch contribution)	153 ± 1 (317 ± 2)	212 ± 3	115 ± 3
CDS (Reset switch contribution)	251 ± 2 (236 ± 2)	258 ± 3	239 ± 5
Readout chain *(PXLBuffer²+Offchip²)* (Reset switch contribution)	273 ± 2	561 ± 7	438 ± 7 (197 ± 4)
Σ (oversampled)	401 ± 2 (281 ± 2)	654 ± 8 (413 ± 5)	512 ± 10 (383 ± 8)
Remarks	-Overall noise of standard preamp + protection diode: 438 ± 8 (325 ± 5) -Gain (ADC/keV)= 16.38 ± 0.10	-Overall noise of Standard preamp + protection diode: 661 ± 8 (422 ± 5) -Gain (ADC/keV)= 8.34 ± 0.10	- Readoutbuffer: (PXLBuf: 332 ± 7) (Offchip: 285 ± 6) -Gain (ADC/keV)= 6.09 ± 0.12

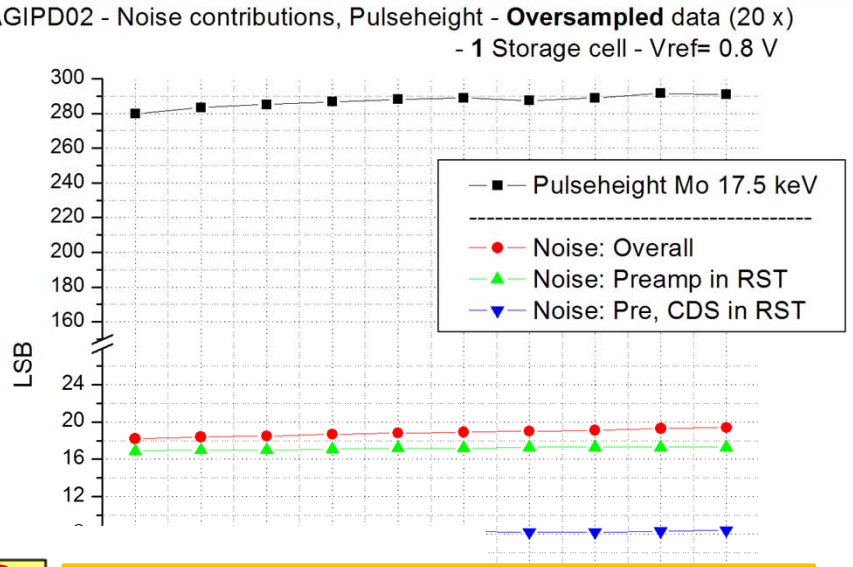
AGIPD0.2: Multisampling

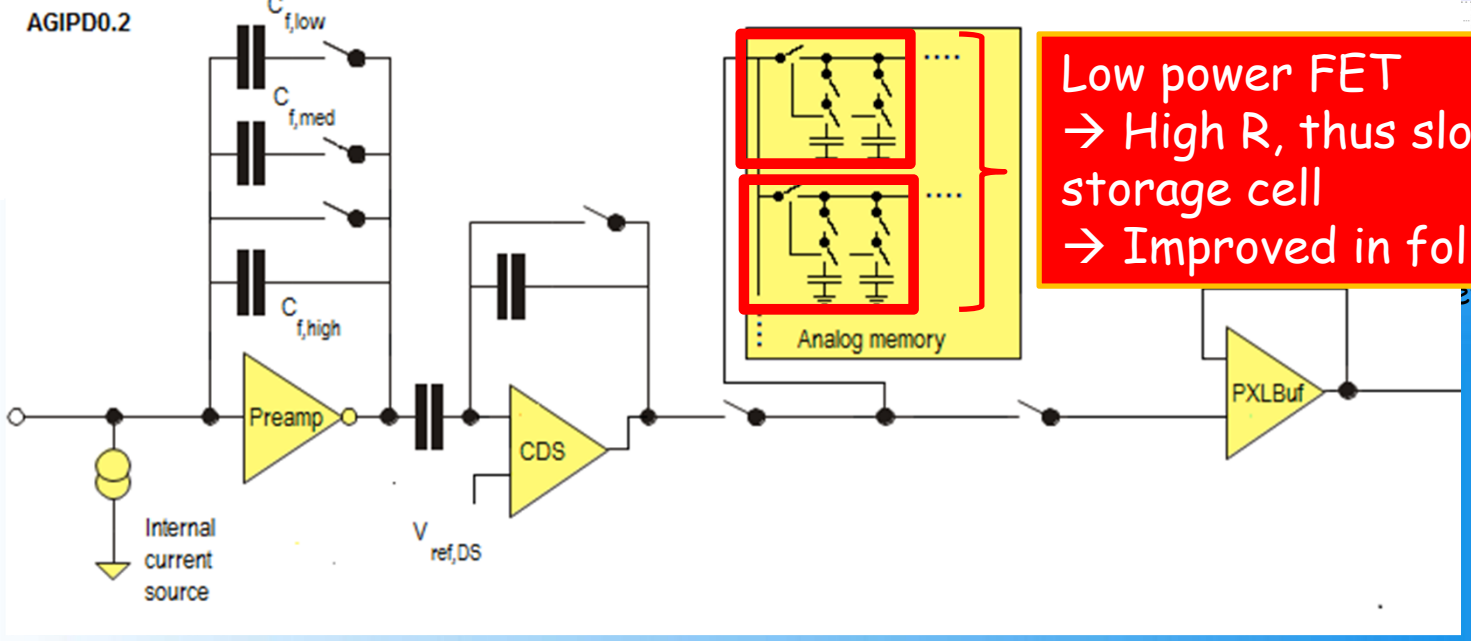


- Sampling before AND after integration → Multisampling of CDS stage
- Sampling with storage cell column switch → Less charge injection

$V_{ref,DS}$: Writing signal to storage cell

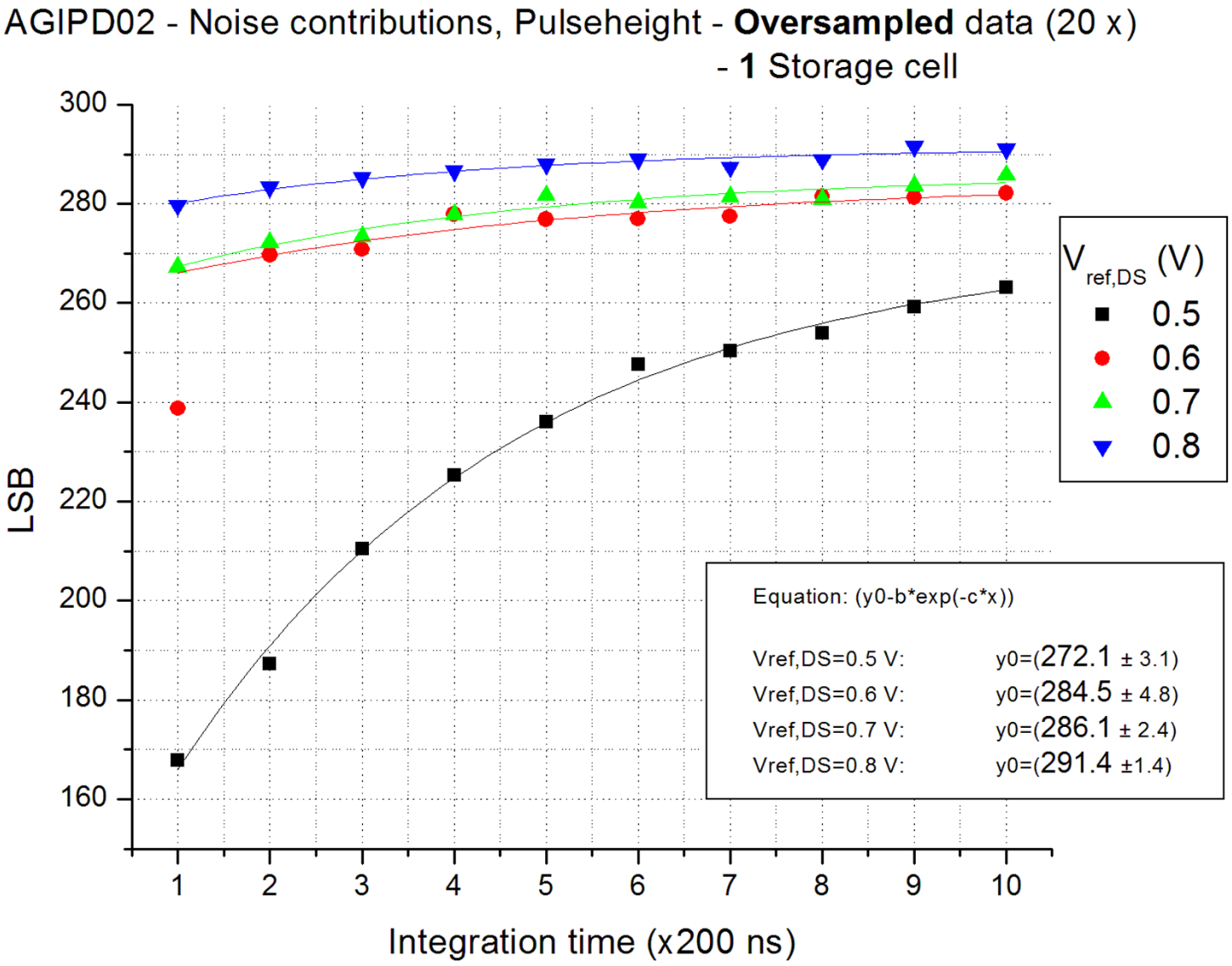




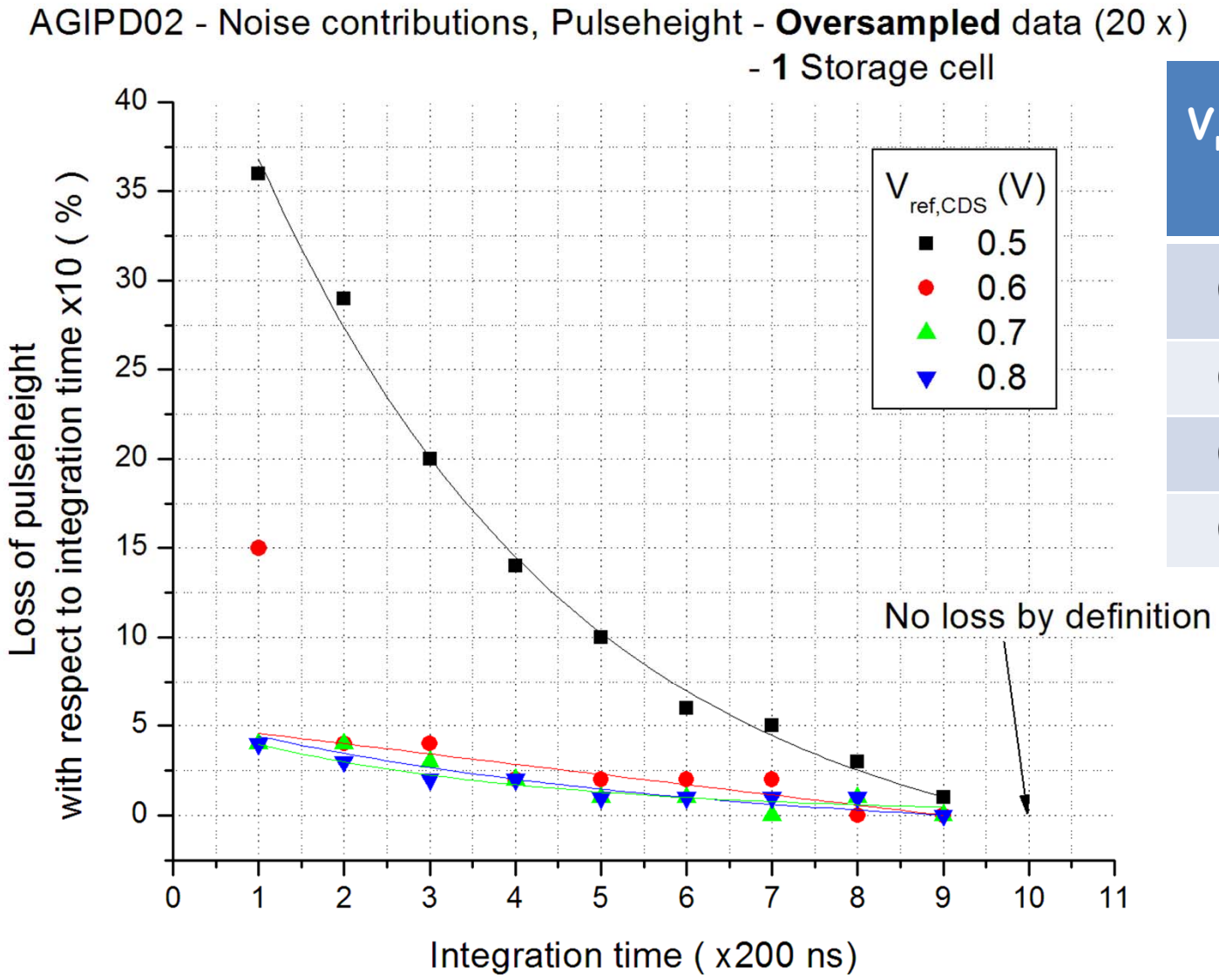


Low power FET
→ High R, thus slow charging of storage cell
→ Improved in following chips

$V_{ref,DS}$: Writing signal to storage cell



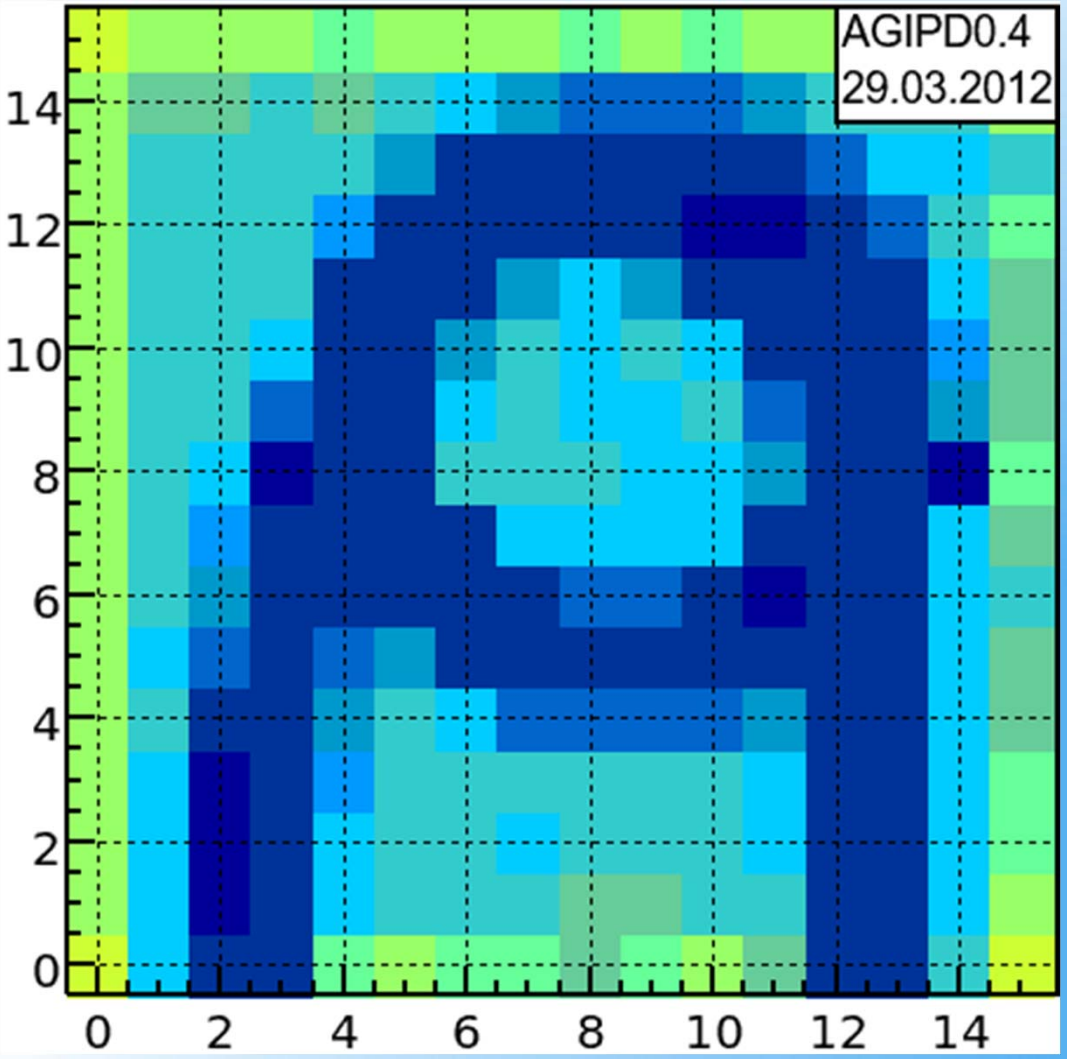
$V_{ref,DS}$: Writing signal to storage cell



$V_{ref,DS}$ (V)	Relative loss of dynamic range (%)
0.5	0 (reference point)
0.6	14
0.7	33
0.8	52

First results of AGIPD0.4

It works….

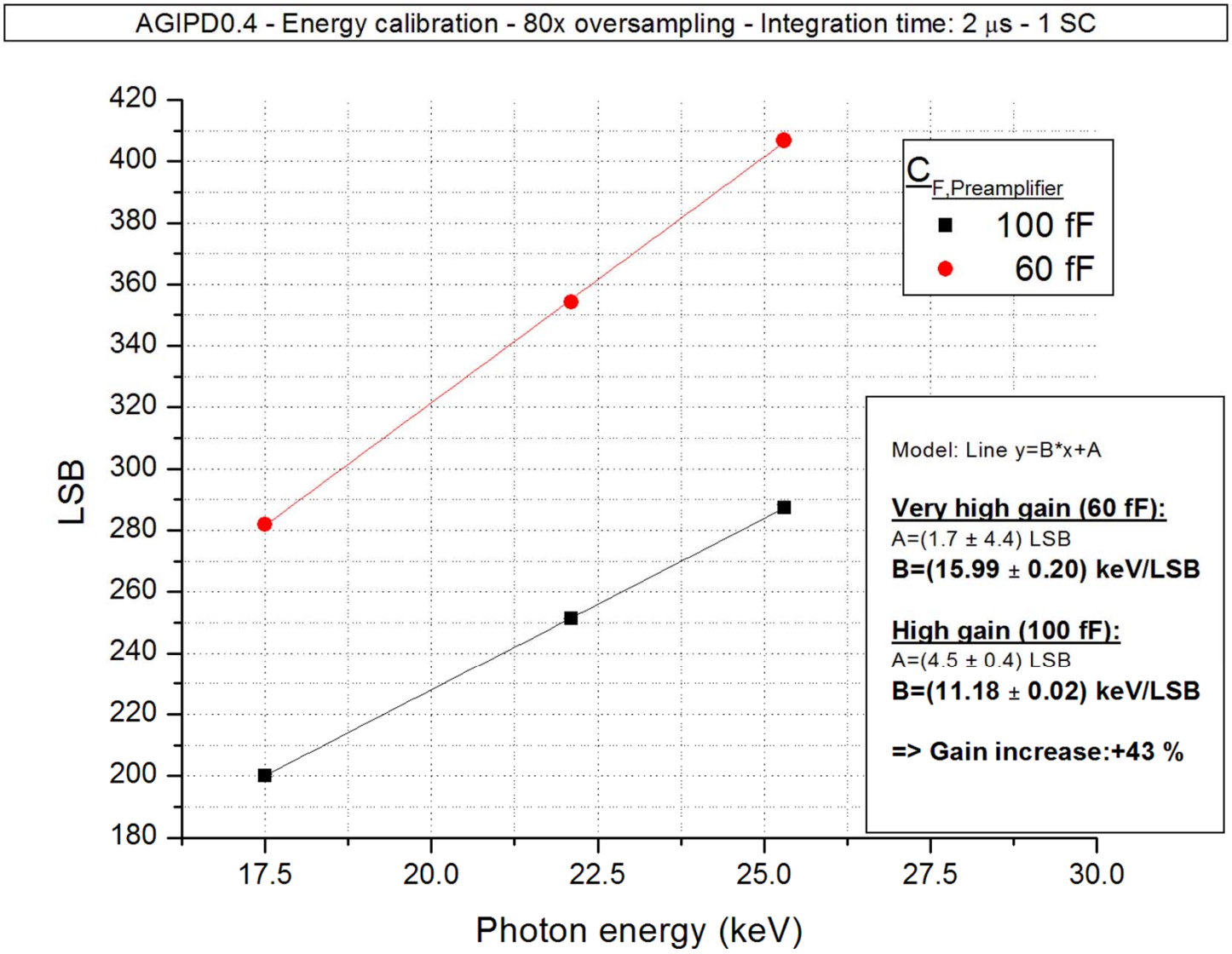


- Illumination of solder in X-ray box @ 25 keV
- Pedestal corrected

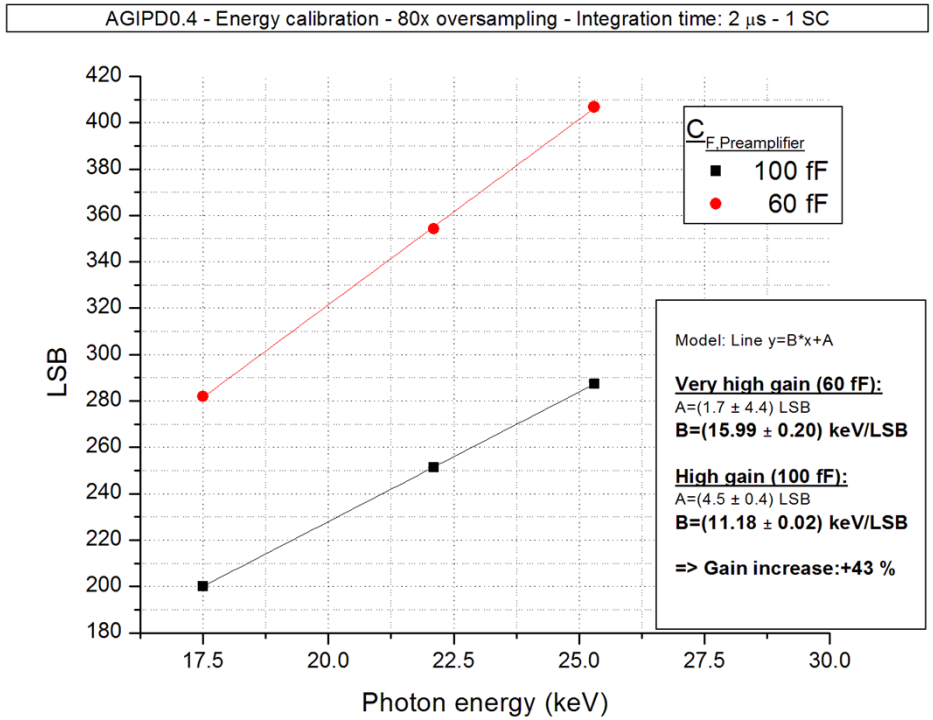
What do we expect?
What do we have?

Worry	Reason	Approach (applied at AGIPD0.4?)
Noise is too high	-(AGIPD0.2) Main contributor to overall noise is reset switch noise of CDS (ds_sw1) -(AGIPD0.3) Gain is too low	→Different CDS stage, rather complicated resetting scheme (yes) → Multisampling approach (doublesampling CDS stage) (no, but we investigate that)
Gain is too low (AGIPD0.3)	-(AGIPD0.2) Due to voltage write/voltage read partial loss of charge in storage cell into charging of bus →Loss of signal (~50 % for 1 SC W/R with respect to 100 SC W/R) -(AGIPD0.3) No signal amplification at offchip driver (@AGIPD0.2 ~x2) Signal loss between Pixelbuffer and Offchip driver of ~20 %	→ Charge write/voltage read: Already applied at AGIPD0.3 (yes) →Different scheme to drive the signals off the pixel/chip (yes) → (AGIPD0.4) Very high gain mode (C_f=60 fF)

AGIPD0.4: Energy calibration



AGIPD0.4: Energy calibration



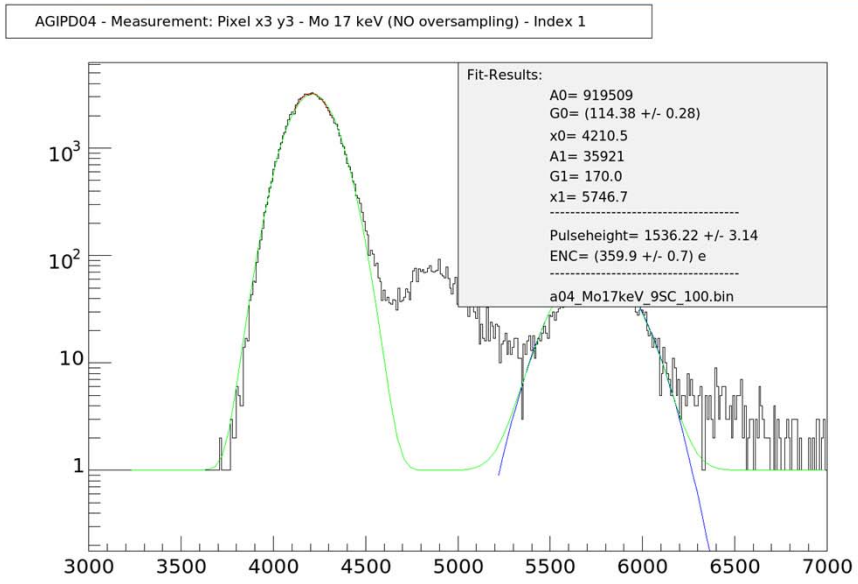
	AGIPD0.2 10 SCR	AGIPD0.2 1 SCRW	AGIPD0.3 1 SCRW	AGIPD0.4 1 SCRW (100 fF)	AGIPD0.4 1 SCRW (60 fF)
Gain (ADC/keV)	16.38 ± 0.10	8.34 ± 0.10	6.09 ± 0.12	11.18 ± 0.02	15.99 ± 0.20

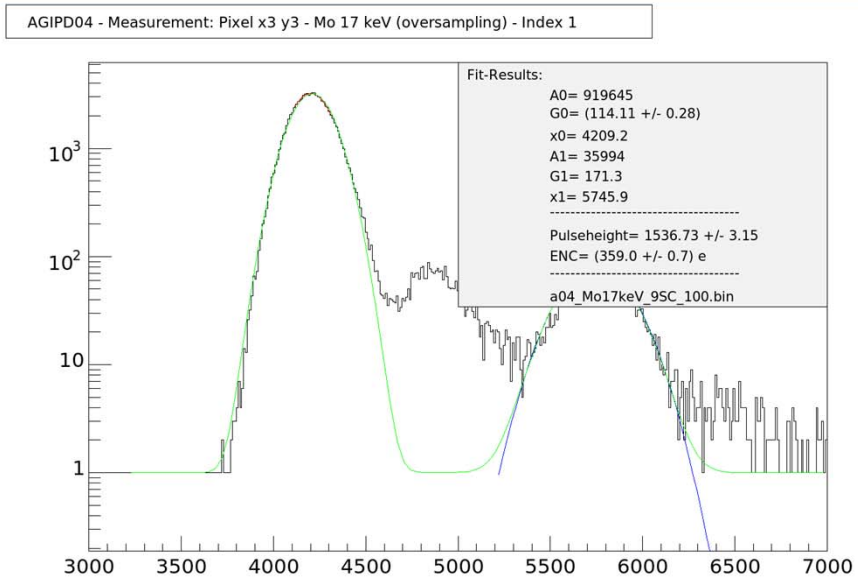
AGIPD0.4: Noise

Contribution	High gain preamp (100fF) (oversampled)	Very high gain preamp (60fF) (oversampled)
Preamp	210 ± 3	150 ± 3
CDS	221 ± 2	133 ± 2
Readout chain (Reset switch)	311 ± 1 (191 ± 1)	225 ± 3 (144 ± 1)
Σ	436 ± 1 (394 ± 1)	301 ± 4 (270± 3)

	AGIPD0.2 10 SCR	AGIPD0.2 1 SCRW	AGIPD0.3 1 SCRW	AGIPD0.4 1 SCRW (100 fF)	AGIPD0.4 1 SCRW (60 fF)
Noise (ENC) (oversampled)	401 ± 2 (281 ± 2)	654 ± 8 (413 ± 5)	512 ± 10 (383 ± 8)	436 ± 1 (394 ± 1)	301 ± 4 (270± 3)

AGIPD0.4: 9 storage cells





# Storage cells	Pulseheight (Mo 17.5 kev) (ADC)	Pulseheight (per storage cell) (ADC)	Noise (ADC)	Noise (per storage cell) (ADC)	ENC (e^-)
1	200.1	200.1	15.9	15.9	393.6 ± 1.2
9	1536.2	170.7 (-14.7 %)	114.4	12.7 (-20.1 %)	359.0 ± 0.7

Summary: AGIPD noise contributions

Component	AGIPD0.2 (std preamp)	AGIPD0.2 (std preamp)	AGIPD0.3	AGIPD0.4 ($C_{f,high}$=100 fF)	AGIPD0.4 ($C_{f,high}$=60 fF)
	10 SCR, 200 ns, $V_{ref,DS}$= 0.6 V	1 SC W/R, 2 µs, $V_{ref,DS}$= 0.6 V	1 SC W/R, 200 ns, $V_{ref,DS}$= 0.5V	1 SC W/R, 200 ns, $V_{ref,DS}$= 0.65 V	1 SC W/R, 200 ns, $V_{ref,DS}$= 0.65 V
Preamp (Reset switch)	153 ± 1 (317 ± 2)	212 ± 3	115 ± 3	210 ± 3	150 ± 3
CDS (Reset switch)	251 ± 2 (236 ± 2)	258 ± 3	239 ± 5	221 ± 2	133 ± 2
Readout chain *(PXLBuffer²+Offchip²)* (Reset switch)	273 ± 2	561 ± 7	438 ± 7 (197 ± 4)	311 ± 1 (191 ± 1)	225 ± 3 (144 ± 1)
Σ (oversampled)	401 ± 2 (281 ± 2)	654 ± 8 (413 ± 5)	512 ± 10 (383 ± 8)	436 ± 1 (394 ± 1)	301 ± 4 (270 ± 3)
Gain (ADC/keV)	16.38 ± 0.10	8.34 ± 0.10	6.09 ± 0.12	11.18 ± 0.02	15.99 ± 0.20