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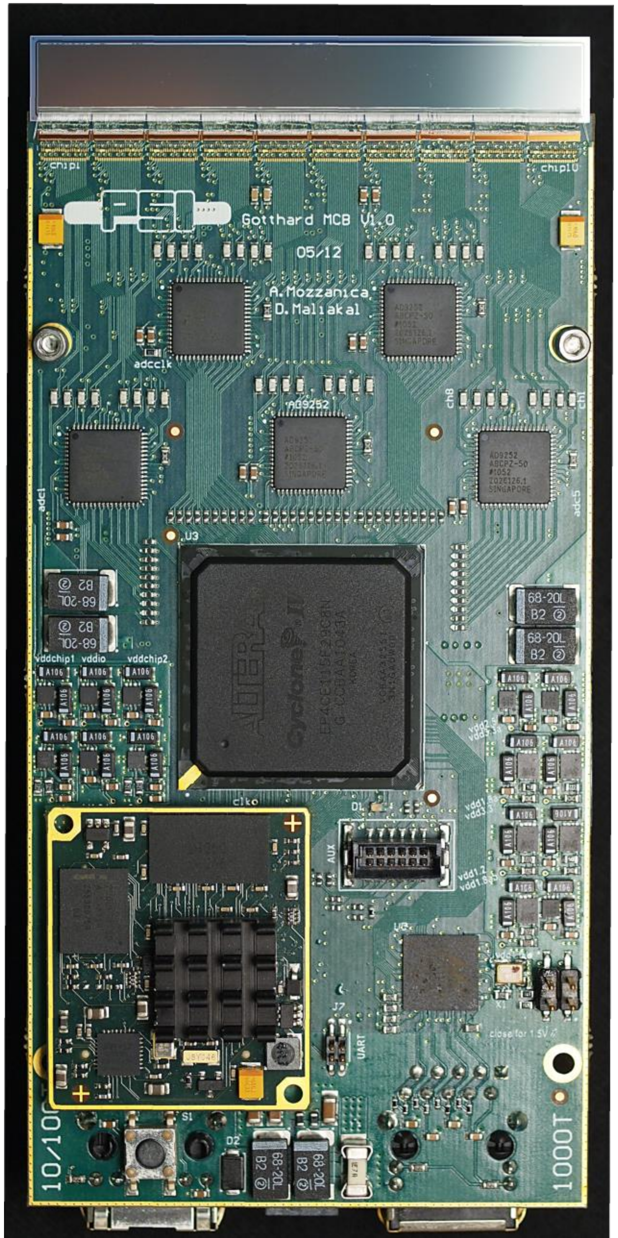
GotthardII development status

XDAC Meeting, 23.05.2016

GotthardI



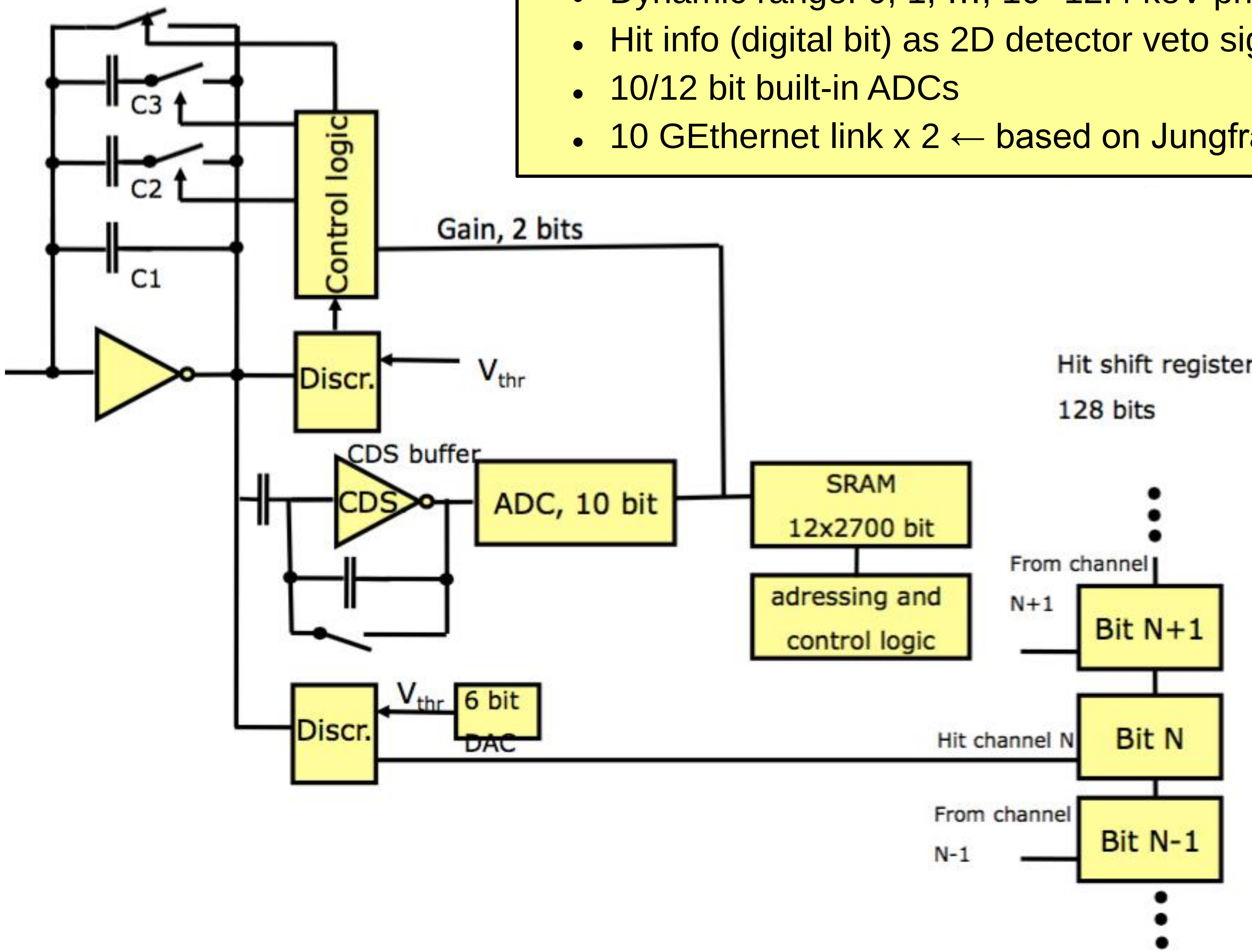
- 67mm x 130mm
- 50 μm pitch, 1280ch/module (same as MYTHEN)
- 10 chips, 4 analog outputs per chip
- 40 ADC channels @32Mhz,14bits
- Gbit Ethernet data transfer for readout
- 100M Ethernet for slow control/setup
- Fast readout (1MHz) with ~600 bunches per EU-XFEL train measurable (memory for ~350)
- 60kHz continuous frame rate
- Integration in detector class for software control (same as Jungfrau)
- Developed in collaboration with Desy
- Start with GotthardI and replace it with GotthardII

Outline

- The Gotthard-II
- Gotthard-1.5(&1.4) front-end characterization
  - Architecture
  - Test results
- Towards Gotthard-II and next submission:
  - New front-end
  - ADC status
- Summary

Reminder of Gotthard-II: Schematic

- 4.5 MHz frame rate ← bunch structure of the Eu-XFEL
- Dynamic range: 0, 1, …, 10^4 12.4 keV photons
- Hit info (digital bit) as 2D detector veto signal
- 10/12 bit built-in ADCs
- 10 GEthernet link x 2 ← based on Jungfrau read-out



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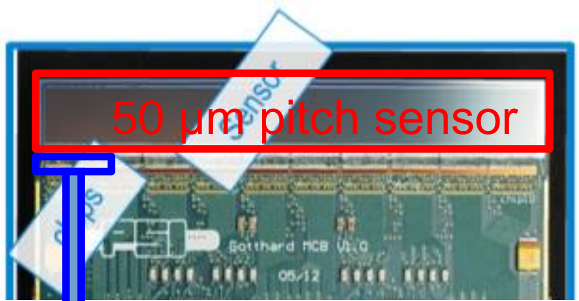
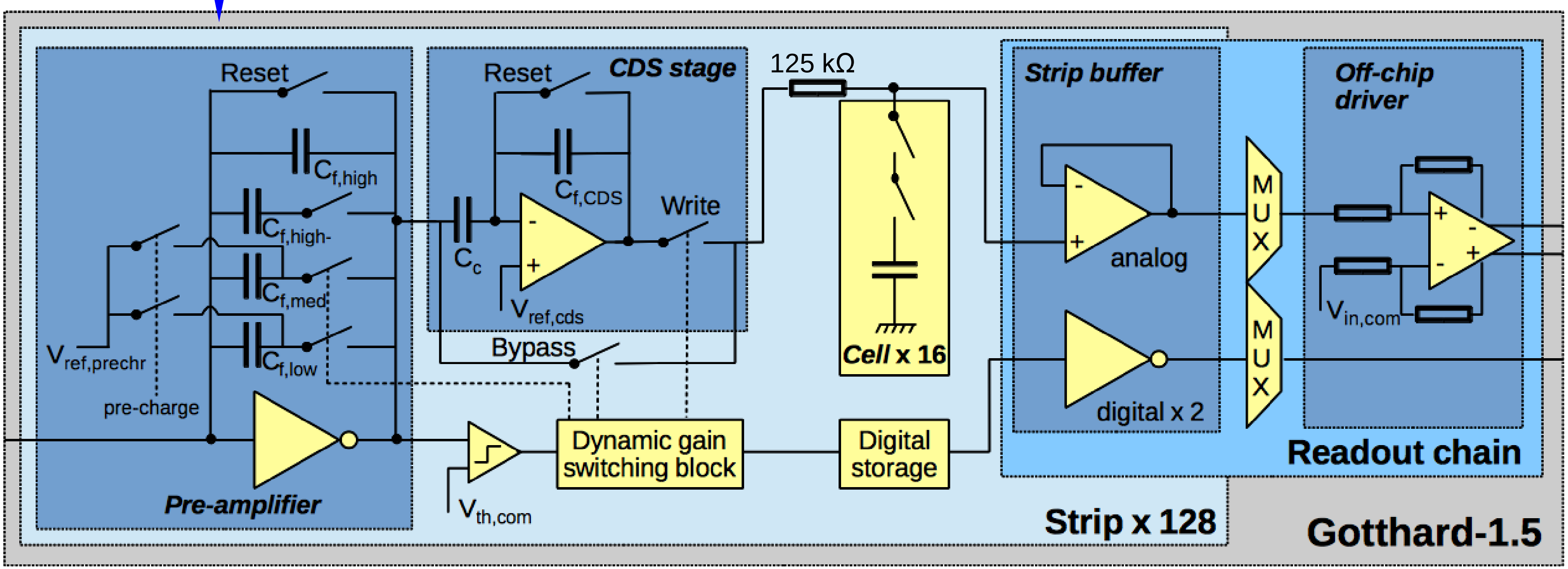
Gotthard-1.4&1.5 Architecture



ASIC

Key features:

- Dynamic gain switching (Jungfrau & AGIPD)
- Different high gain capacitor: HG0 and G0
- Med. & low gain capacitors pre-chargeable
- CDS bypass after gain switching
- Digital gain bit



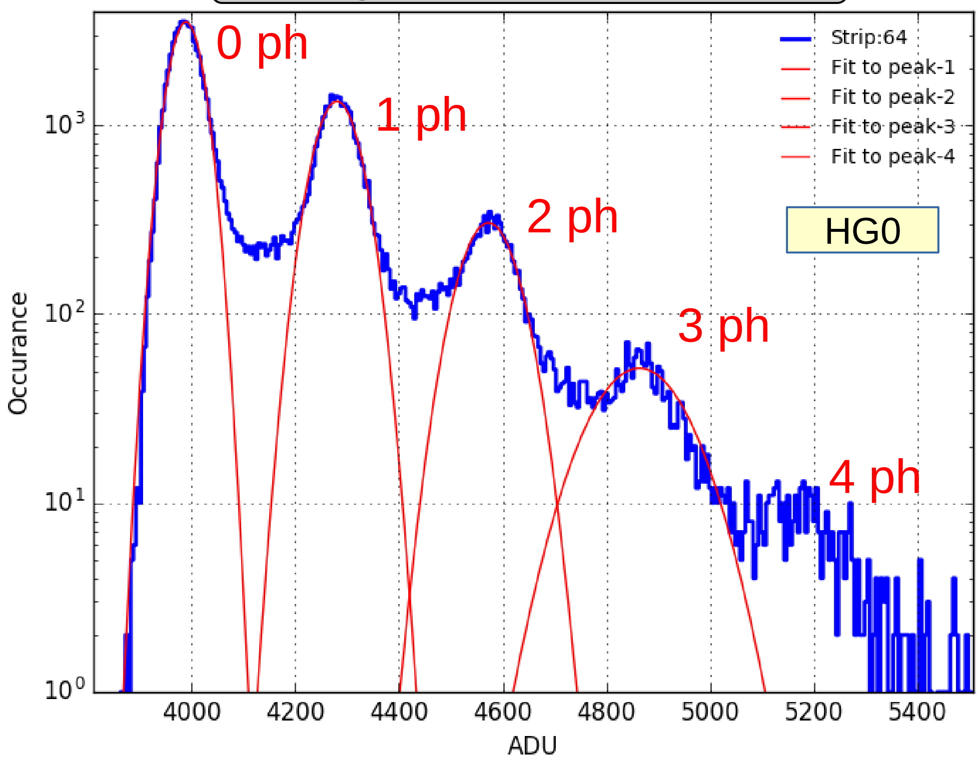
Less channels but similar complexity to the other integrating detector!

High gain: X-ray fluorescence

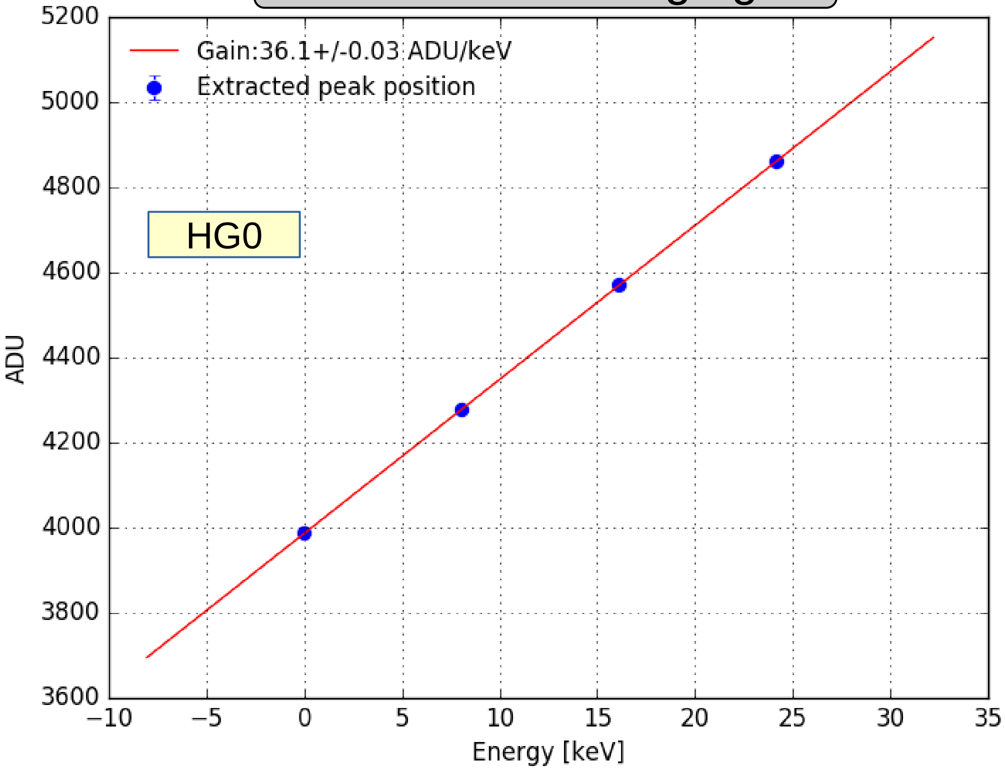
- Cu-target for fluorescence: $E_{ph} \rightarrow 8.05$ keV

$\rightarrow$ Conversion gain [ADU/keV]

Histogram: 100,000 frames



Gain extraction: High gain

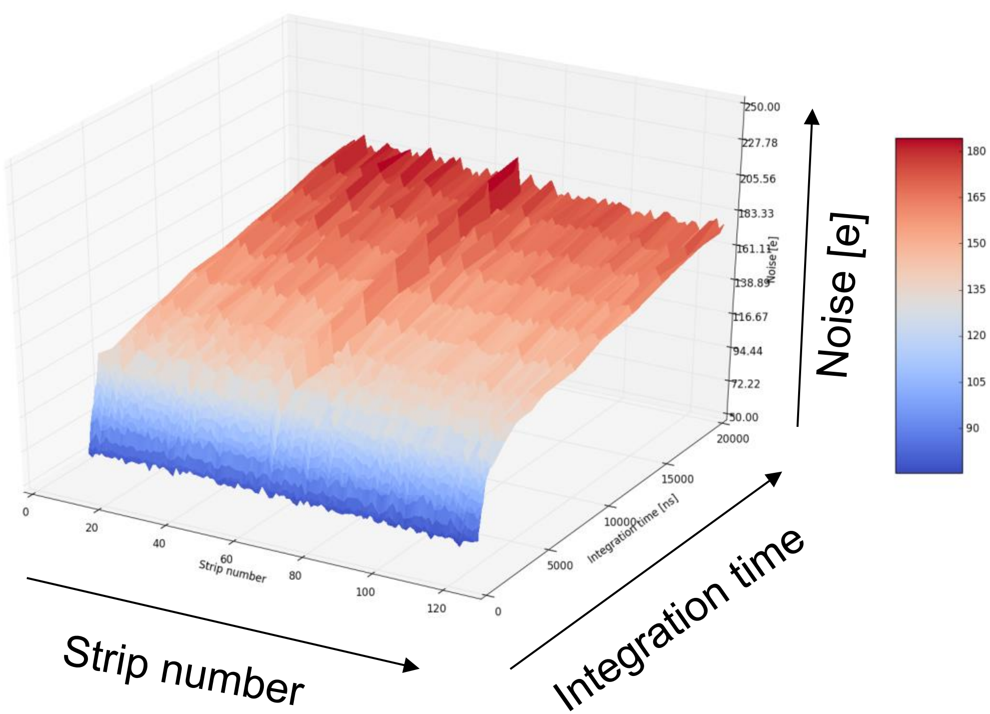


More coincident photons due to large detection area per channel!

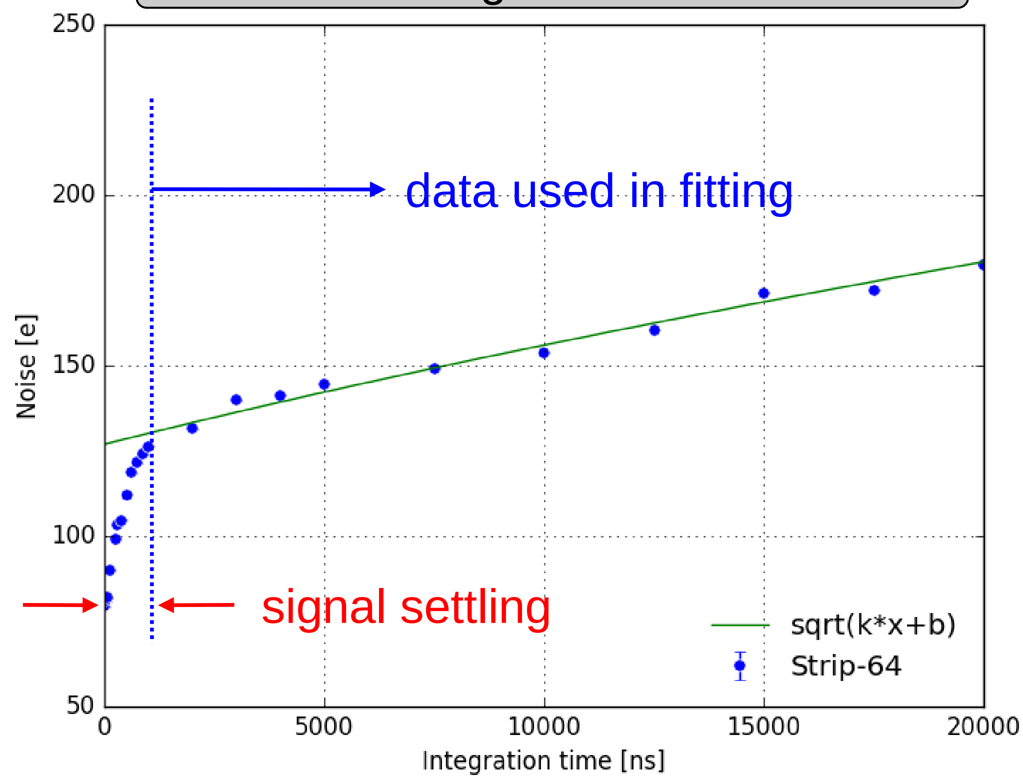
Noise vs. integration time

- Noise as function of integration time for HG0 with Cf=13.4 fF:
  - Integration time from 50 ns up to 20 µs
  - Fitting model: $Noise[ENC] = \sqrt{k \cdot t_{int} + b^2}$ with b intrinsic para. indep. t_{int}

Example for all strips



Noise vs. integration time for HG0

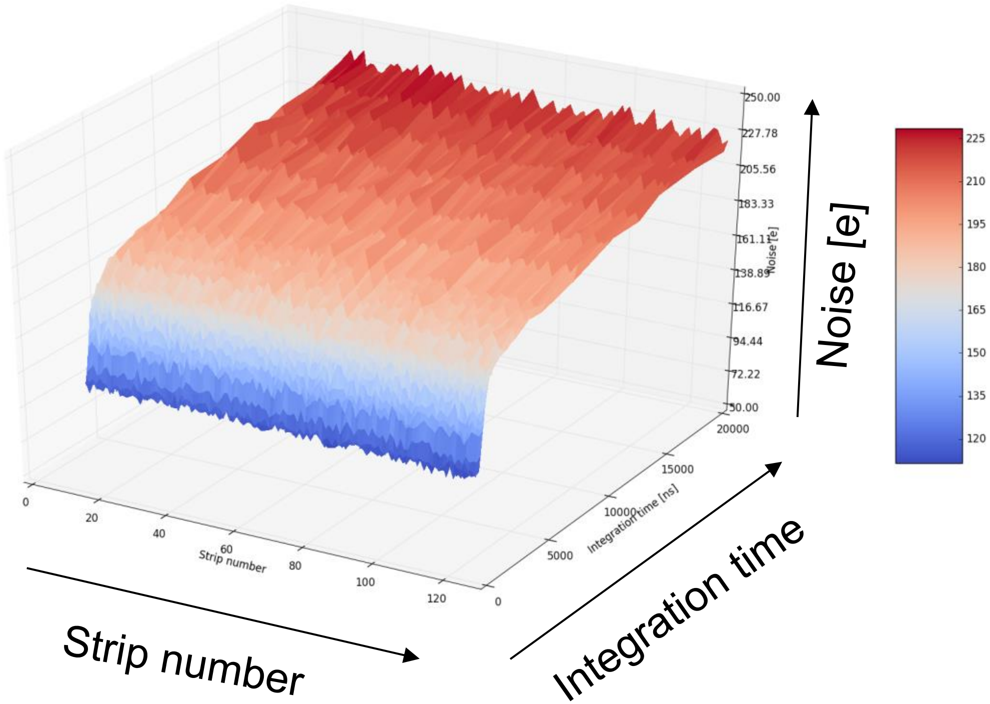


Noise HG0: ~ 125 e @ t_{int} = 100-150 ns (XFEL timing)

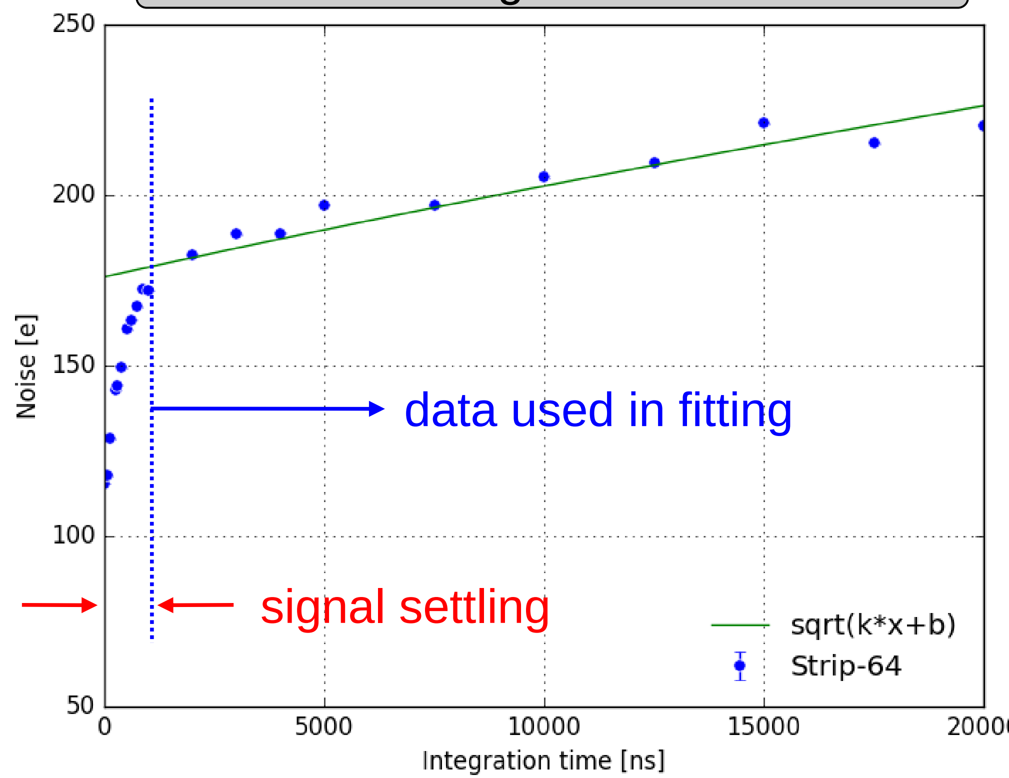
Noise vs. integration time

- Noise as function of integration time for G0 with Cf=46.4 fF:
  - Integration time from 50 ns up to 20 μs
  - Fitting model: $Noise[ENC]=\sqrt{k \cdot t_{int}+b^2}$ with b intrinsic para. indep. t_{int}

Example for all strips



Noise vs. integration time for G0

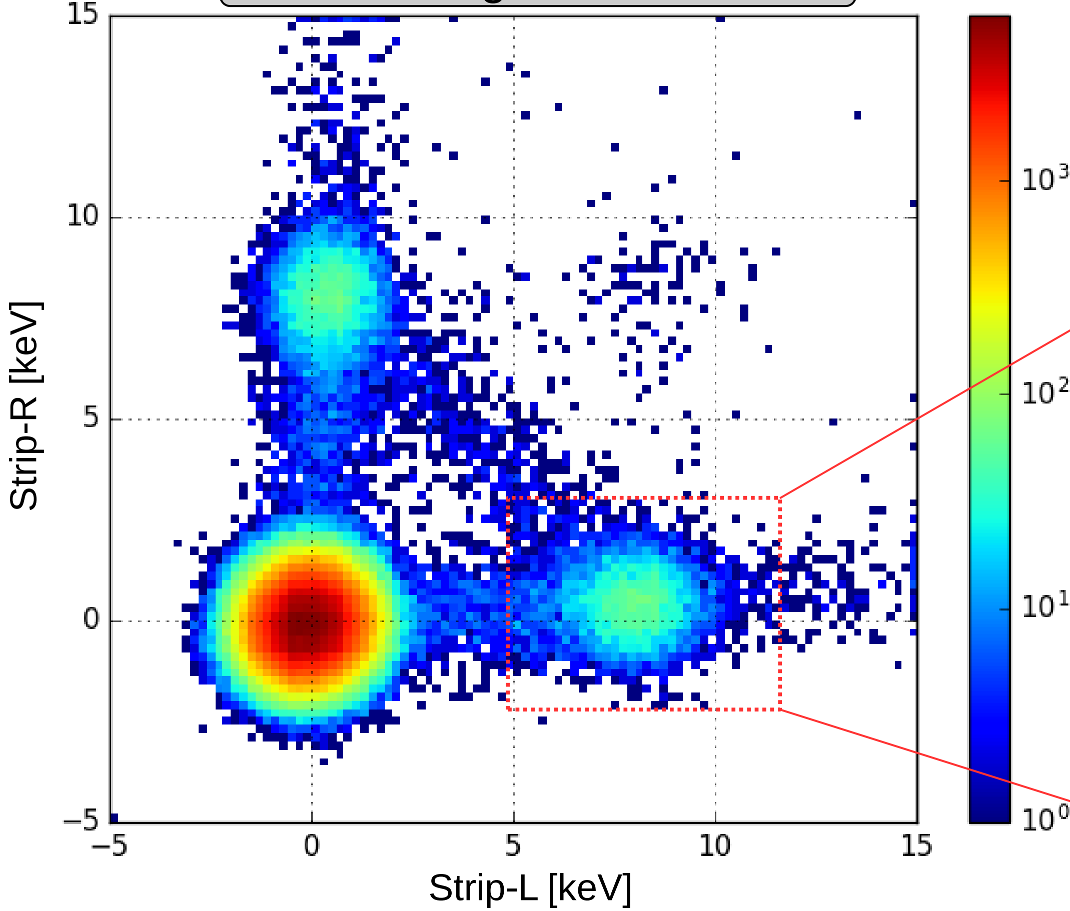


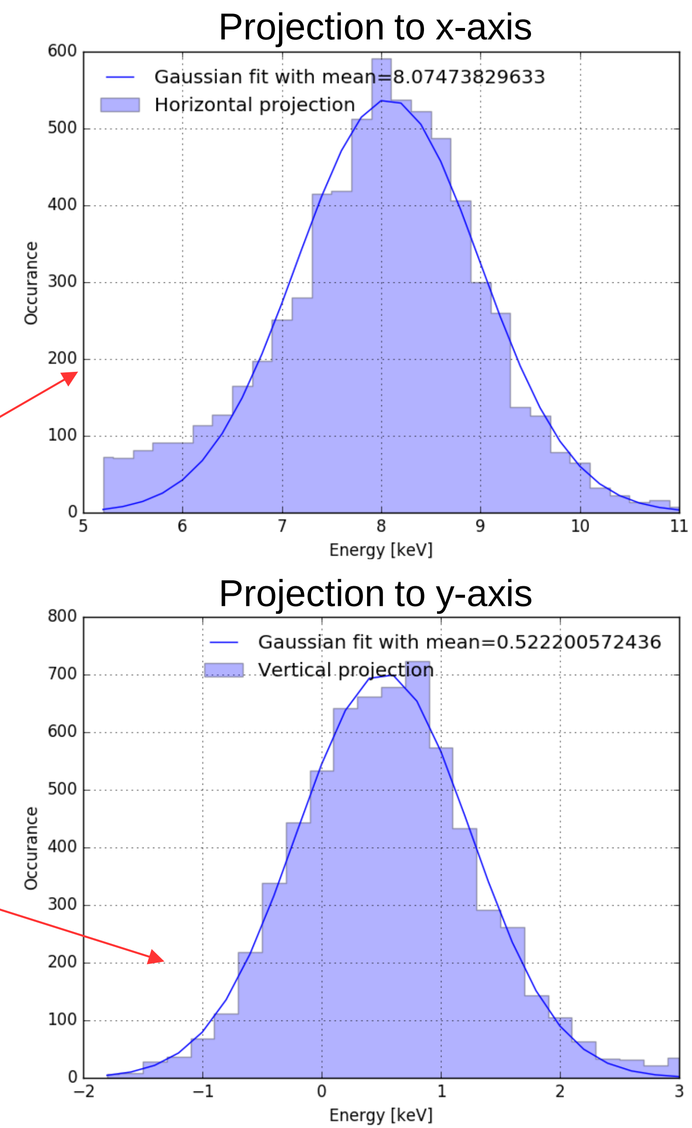
Noise G0: ~ 175 e @ t_{int} = 100-150 ns (XFEL timing)

Coupling: Low rate X-ray measurement

- Low rate X-ray measurement: 0 or 1 ph entry

2D histogram for HG0



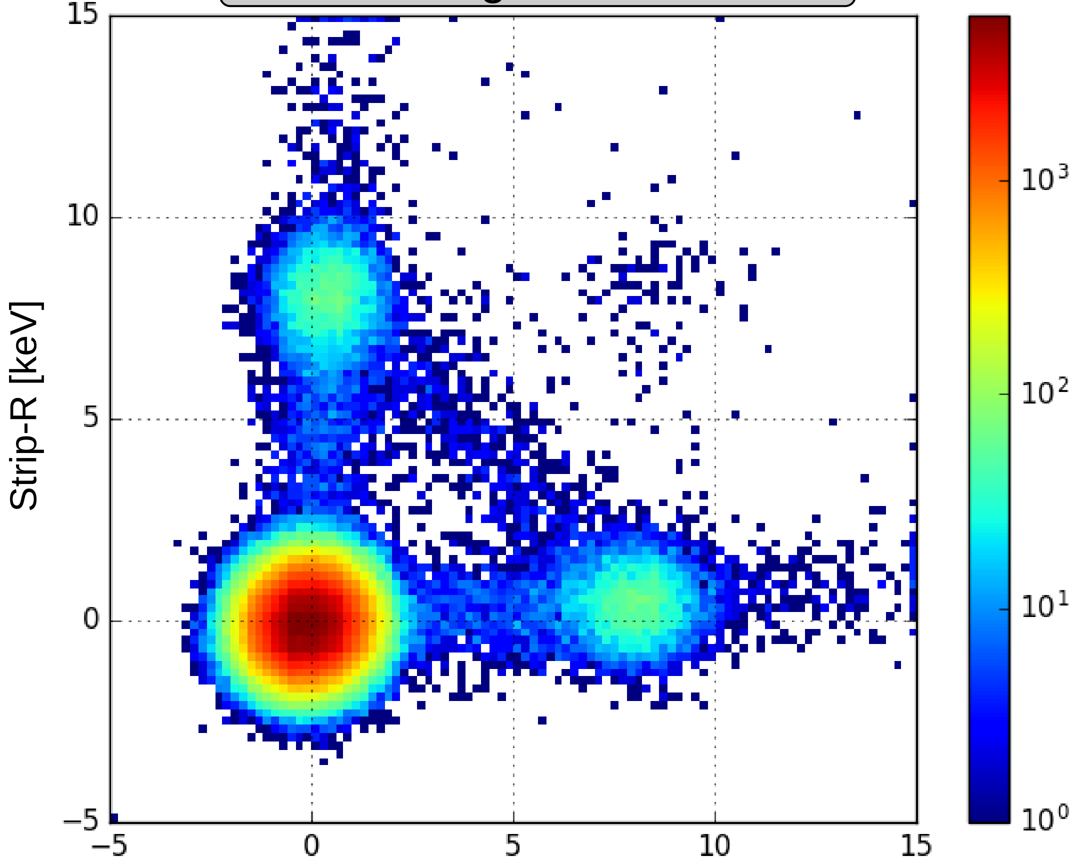


- Coupling: <u>6.5%</u> for HG0; <u>3.9%</u> for G0

Coupling: Low rate X-ray measurement

- Low rate X-ray measurement: 0 or 1 ph entry

2D histogram for HG0



Simple calculation/approximation:

interstrip cap. (239 fF)

$$Coupling = \underbrace{\frac{1}{A}}_{\text{DC gain (125)}} \cdot \frac{C_{int}}{C_f + \underbrace{C_{para}}_{\text{parasitic cap. (15 fF)}}}$$

HG0: 6.8 %; G0: 3.1%

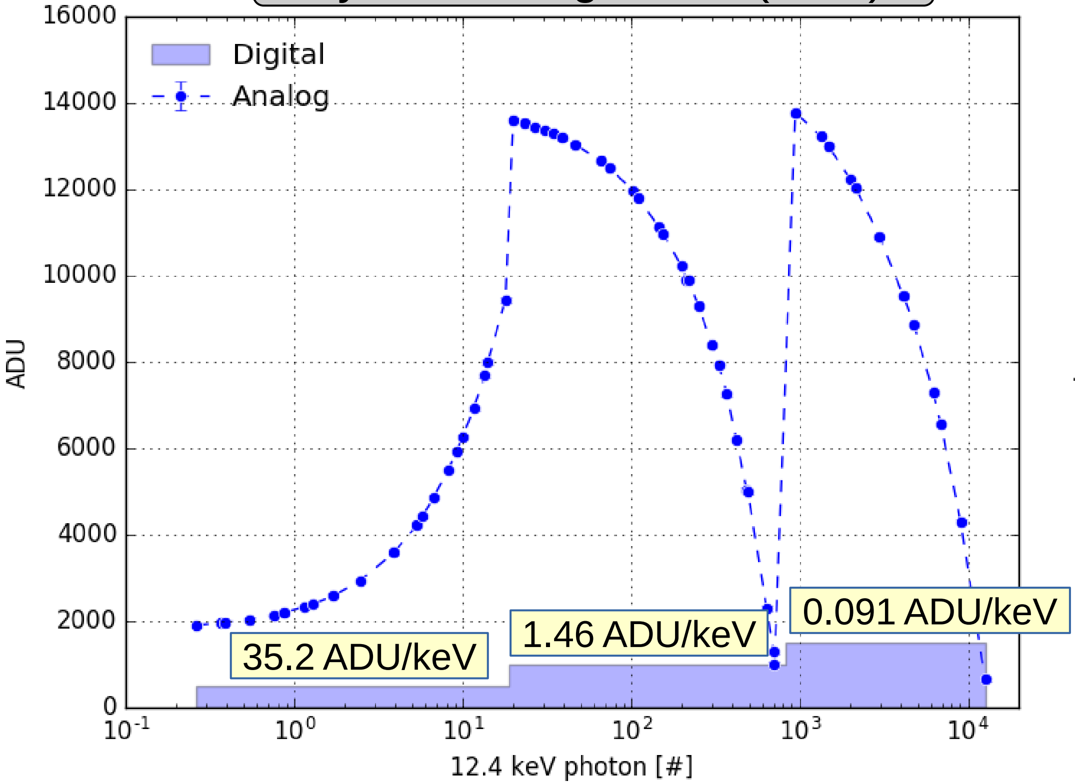
Good agreement with measurement!

- Coupling: 6.5% for HG0; 3.9% for G0

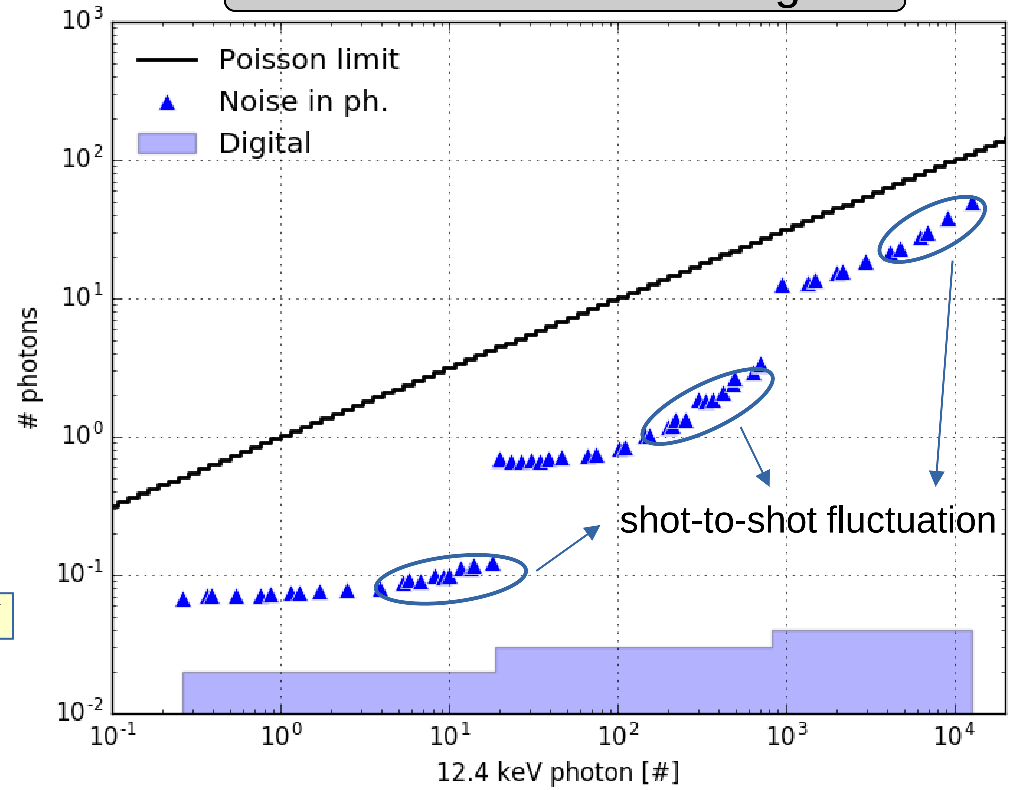
Dynamic range: Infrared laser

- Photon conversion based on high gain measured with X-rays
- Dynamic range up to 1.35×10^4 12.4 keV
- Noise below poisson limit: S/N > 14 for single photon detection

Dynamic range scan (HG0)



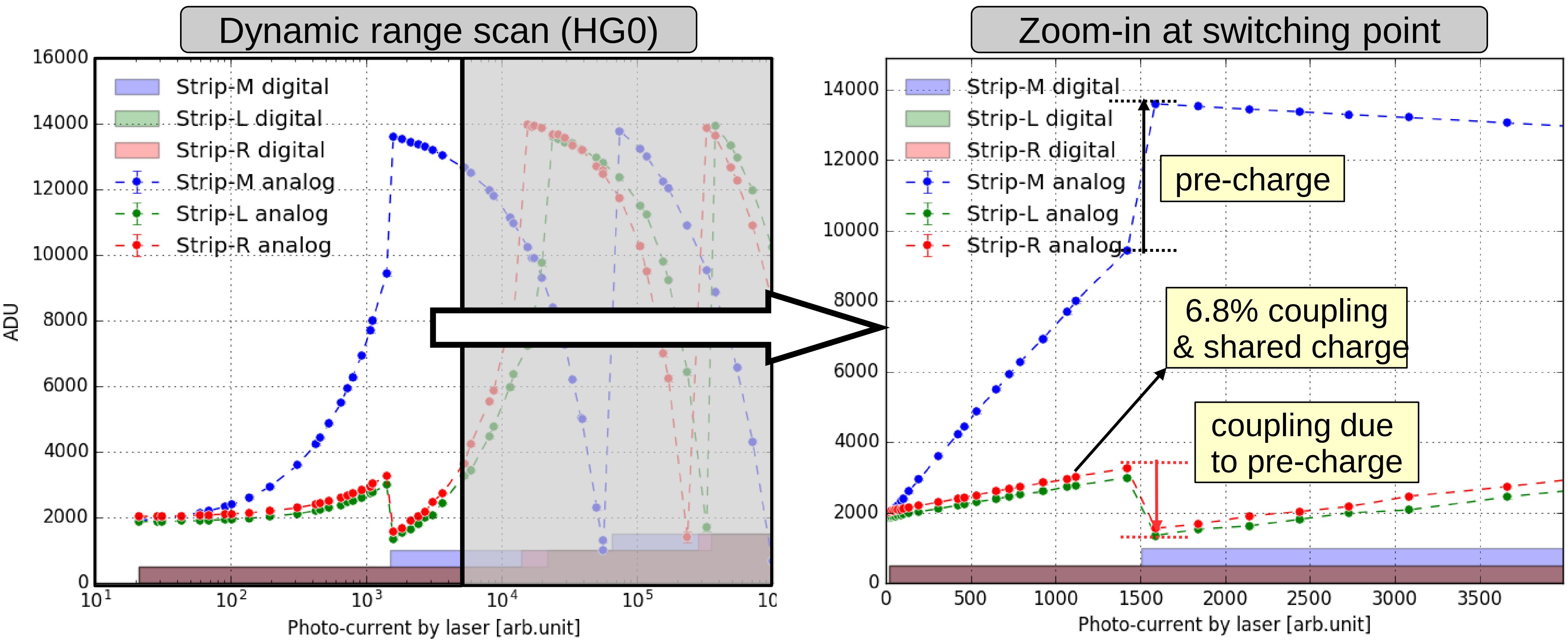
Noise in entire DR range



Resolution of 1 ph (H), 3 ph (M) and 55 ph (L) for 5σ separation

Coupling due to pre-charge: Measurement

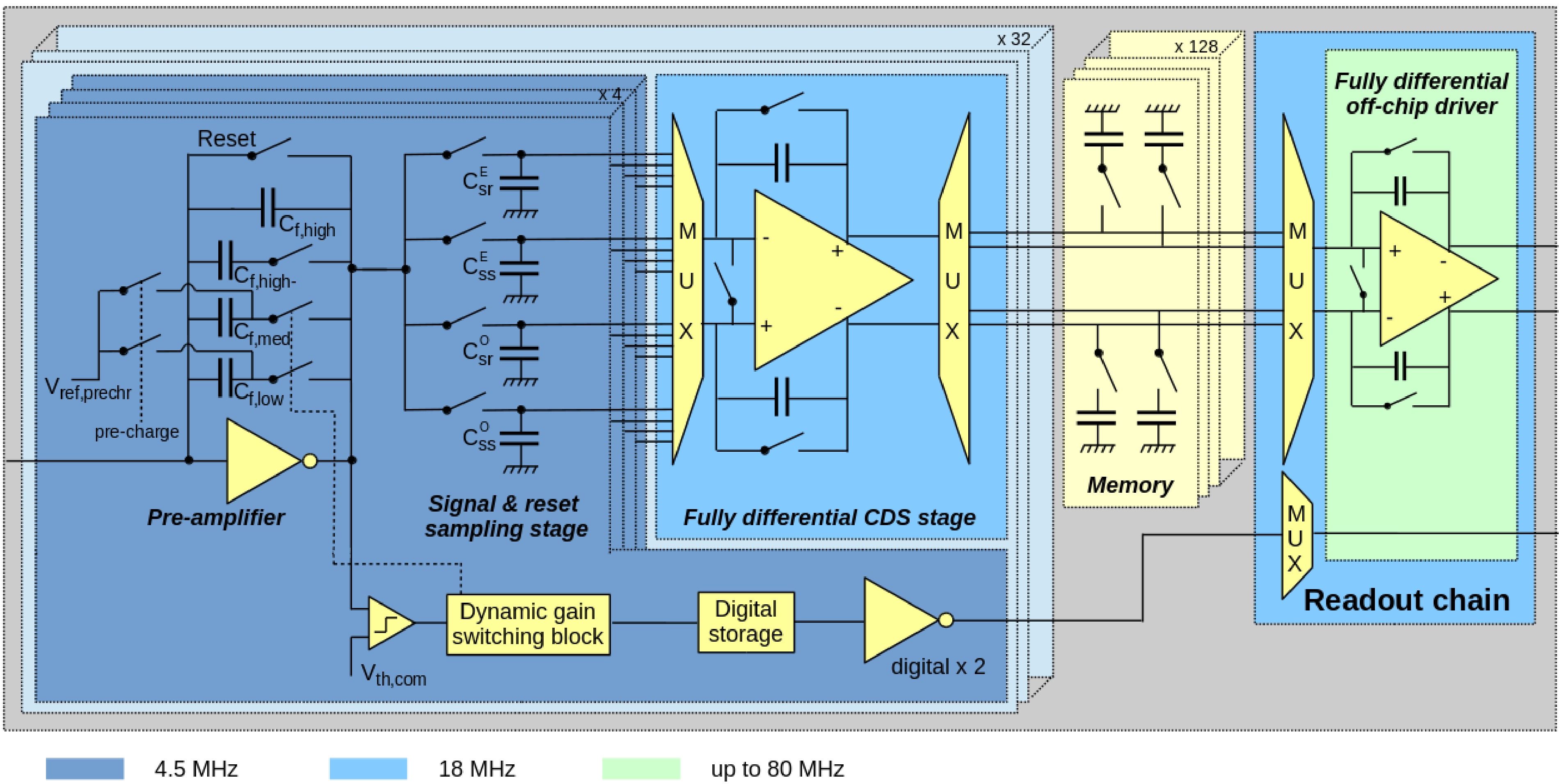
- Laser injection into a single channel
- Charge in neighbouring strip in high gain: <u>6.8% coupling</u> + <u>shared charge</u>
- Charge loss in neighbouring strips when injected channel switched



Schematic of new front-end

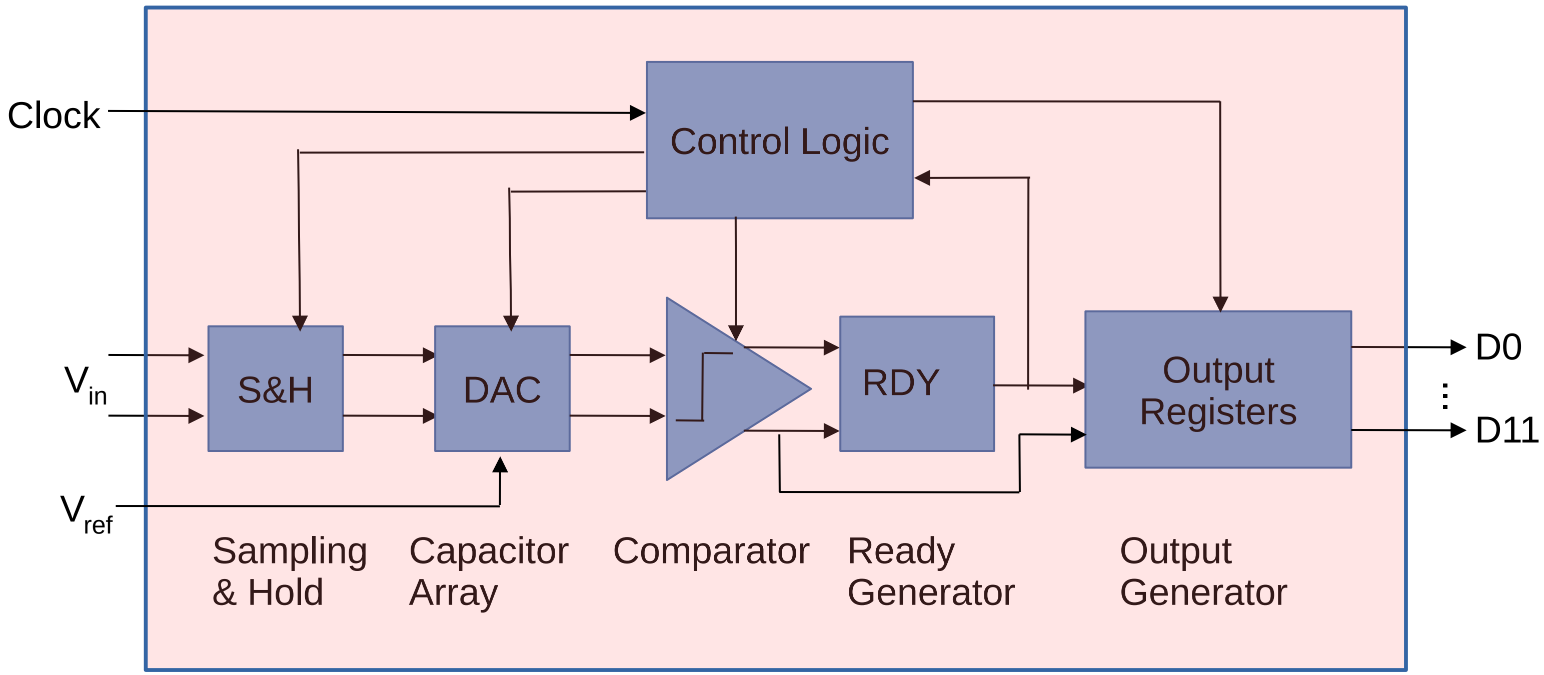
- Features of new frond-end:
  - high DC gain pre-amplifier
  - fully differential output

- continuous CDS sampling
- available for plugging build-in ADCs



ADC design progress

12 Bit Asynchronous SAR ADC with Charge Redistribution DAC



Specification:

- Resolution 12 bit
- Sampling frequency 20 MHz
- Power supply voltage 1.2V
- Input Signal Range ±0.8 V -> 1 LSB = 390 µV

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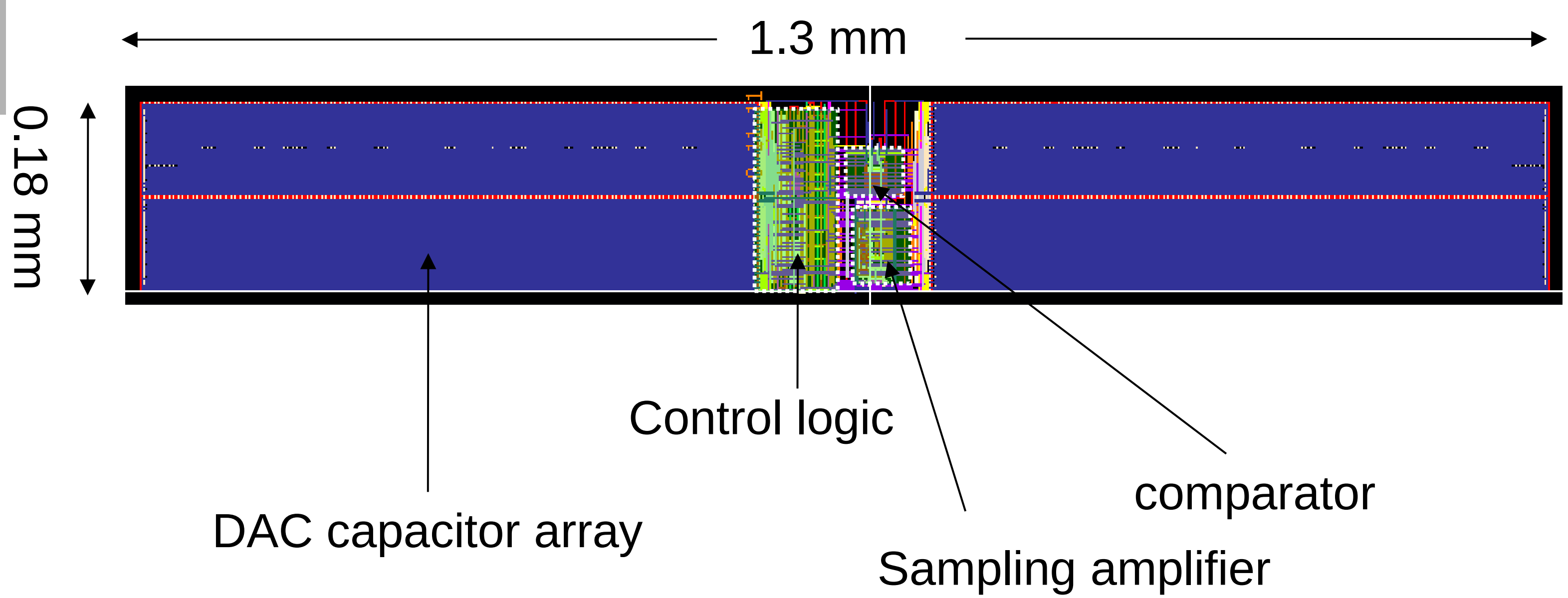

Specification:

- Resolution 12 bit
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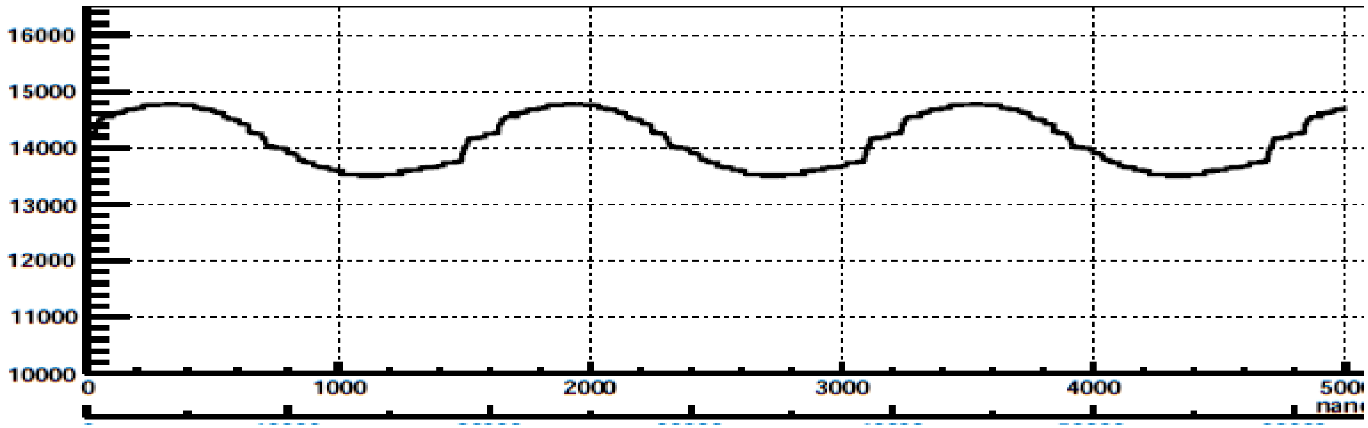
ADC progress: Measurement result

Measurements show that the ADC is working basicly



However

- The sampling Frequency < 8 MHz . The comparator is slower due to the parasitic RC of layout
- Had problems reproducing this with simulations using extracted parasitics, works now problem: comparator speed
- The last 4 LSBs are not stable, sometimes bits are missing: problem with comparator ready signal

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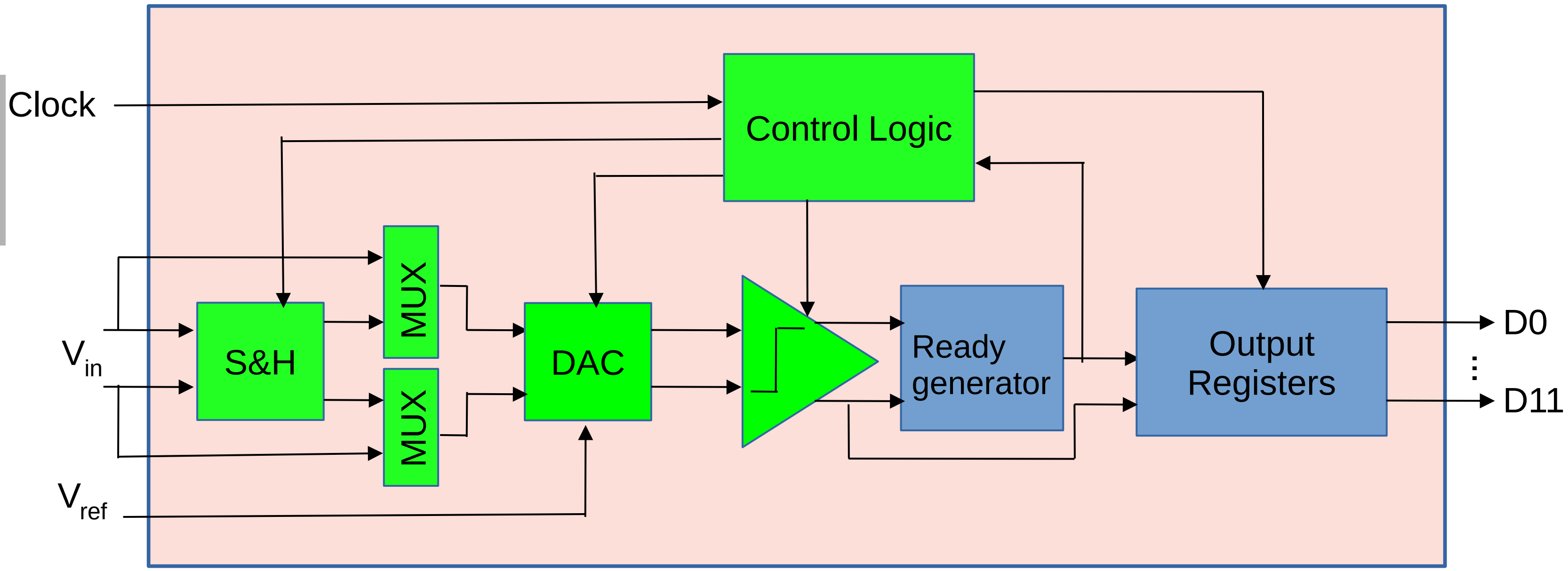
ADC progress: The redesign



Redesign of the ADC

- The comparator will be faster to achieve 20 MHz sampling frequency
- Insert adjustable delay in the control logic for debugging.
- The input can be fed into the comparator directly if the noise from the S&H is really a problem
- The redesign will be taped out in July 2016

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Summary

- Gotthard-1.5(&1.4) characterized
  - Noise: 125 e for HG0, 175 e for G0
  - Dynamic range up to 1.35 x 10^4 12.4 keV ph
  - Settling time: 500 ns – 600 ns limited by a resistor
  - Coupling in high gain: 6.8% for HG0, 3.9% for G0
  - Charge loss in neighbouring channel due to switching/precharge: 2.4 x 12.4 keV ph
- Next submission in July
  - New analogue front end with High DC gain pre-amplifier
  - ADC complete redesign with faster comparator and variable delay after comparator ready signal
- Next steps
  - MPW with memory end of this year/early next year
  - Engineering run mid 17