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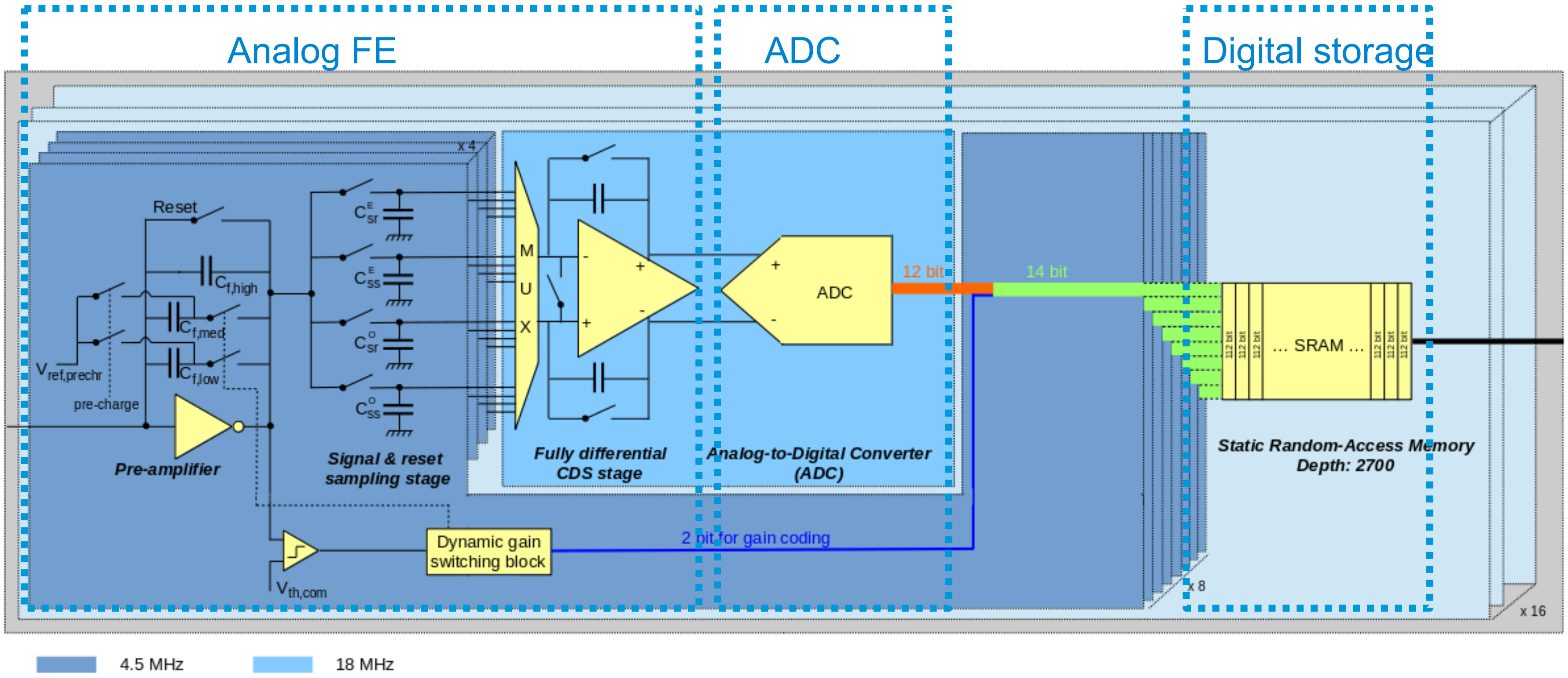
GotthardII Development Status

XDAC meeting, December 2017

Outline

- Gotthard overview
- Results from last MPW
- Calibration procedure
- First user experiment
- Next steps and Conclusions

Gotthard II overview



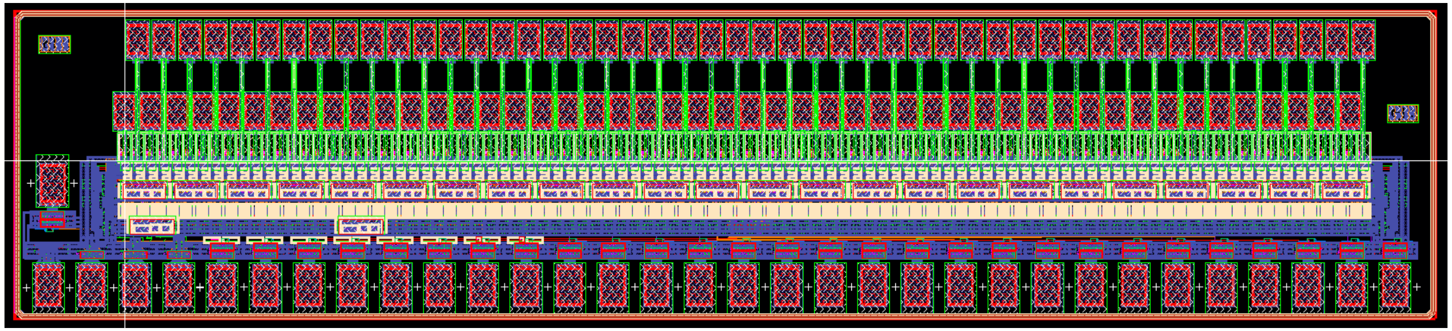
Goal:

- Development of a strip detector system for energy dispersive measurements capable of measuring all bunches in the trains
- Gain switching analogue front end, ADCs and SRAM, readout during gap between bunches

MPW submission in 03.2017

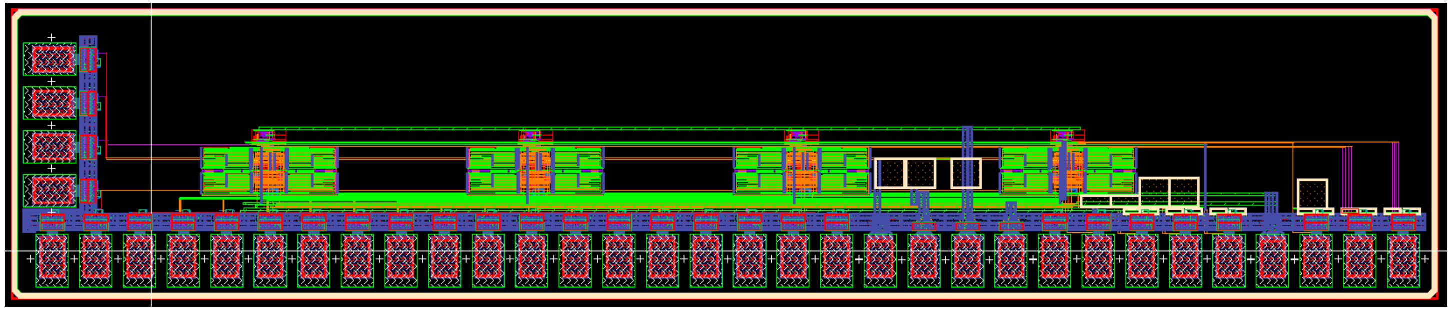
Analog front-end G-1.8:

Variations of designs



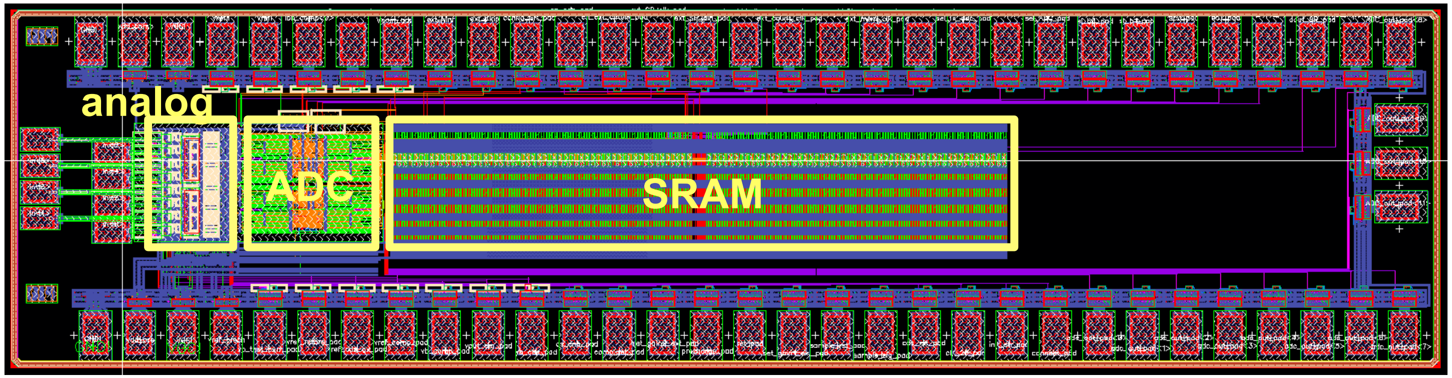
ADC-0.3:

Unit cap. 20, 30, 40 fF



Full chain G-1.9:

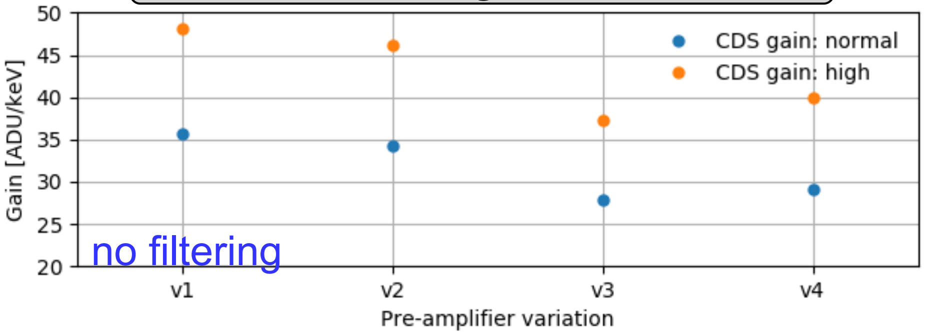
FE + ADC + SRAM

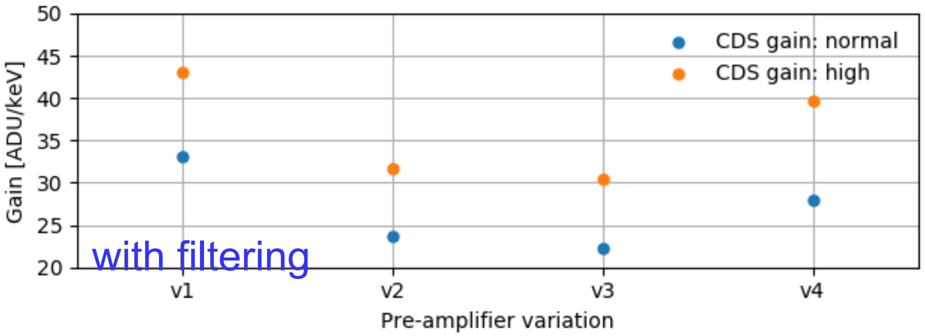


Gain and noise of G-1.8

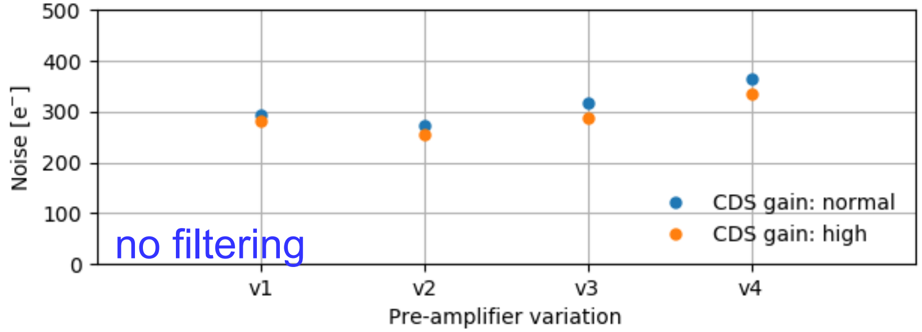
- Extraction from X-ray and dark measurements with 5 μs integration time

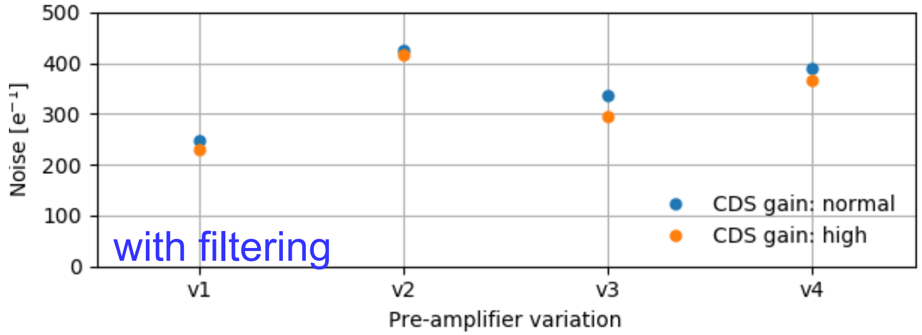
Conversion gain @ 1.2 V





Noise in electrons @ 1.2 V



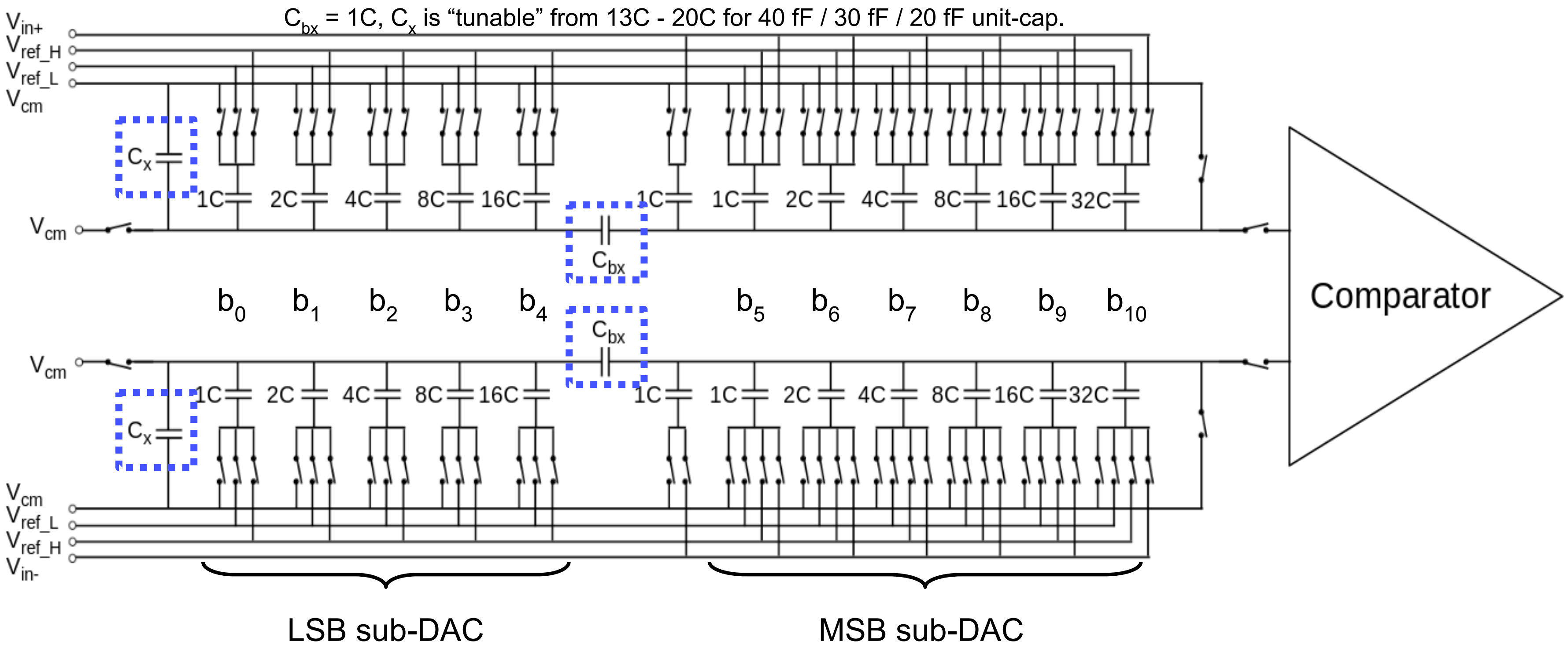


- Conversion gain ratio between CDS gain high and normal: 1.35 – 1.4
  - agree with the ratio of CDS gains [2.9/2.1 = 1.38]
- Noise: 220 - 250 e^- for per-amplifier v1 with filtering resistor [G1.7: 300-320 e^-]
  - Speed still to be confirmed

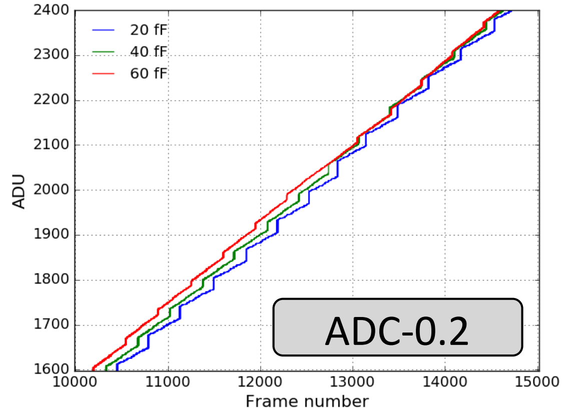
ADC architecture

12-bit SAR (successive approximation) ADC:

- Split-capacitor DAC array → reduced total capacitance and size
- critical points:
  - scaling of C_X: matching of banks for lower and higher bits
  - charging time of capacitors, more for higher bits (b_4 and b_9)
  - stability of V_{ref}

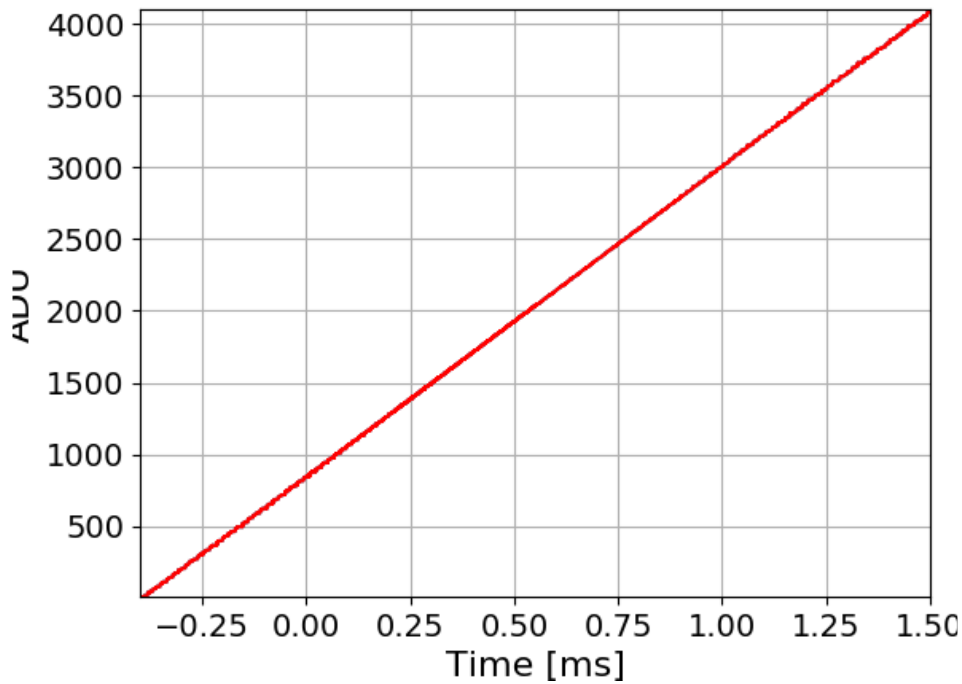


ADC 0.3 Test results

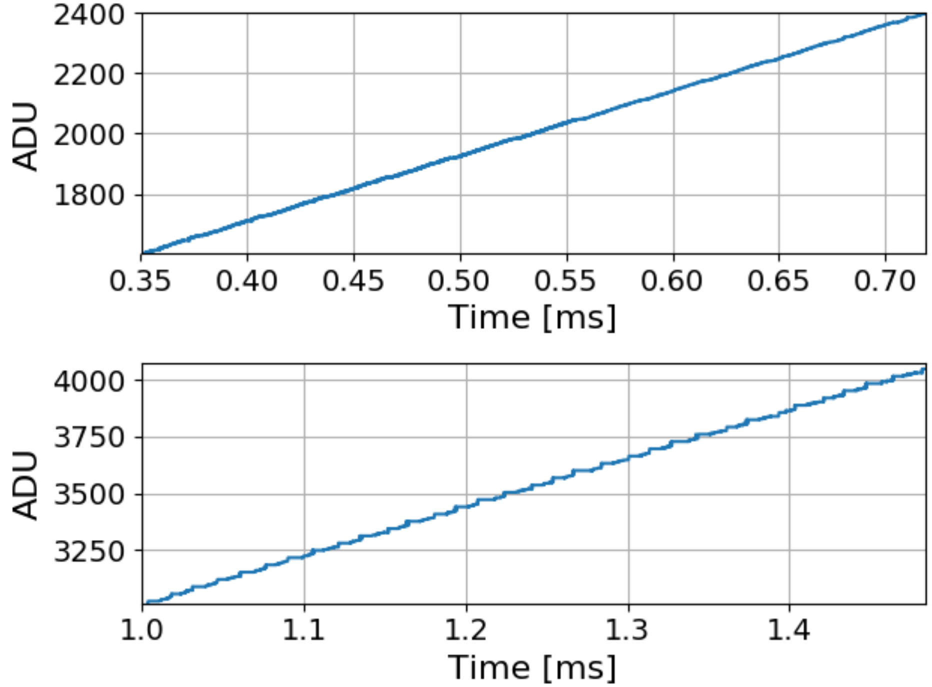


- Ramping curve: Linear voltage input covering entire range
  - Missing codes recovered compared to ADC-0.2
    - Over-compensation of the parasitic of C_{bx}
  - Stuck codes in center region due to over-compensation of the parasitic of C_{bx}

Ramping curve of ADC-0.3 (40 fF)



Center and boundary region



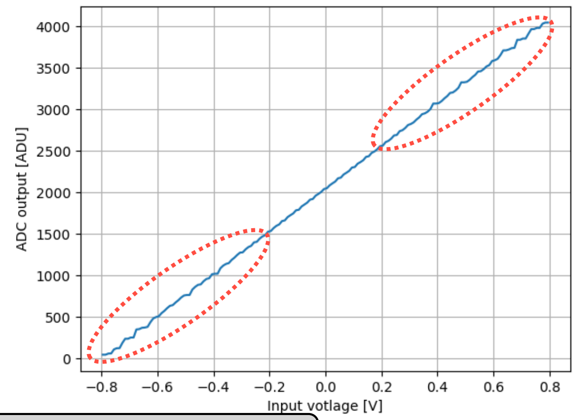
- Combination of <u>stuck and missing codes</u> + <u>noise</u> close to boundaries

Inductance induced instability

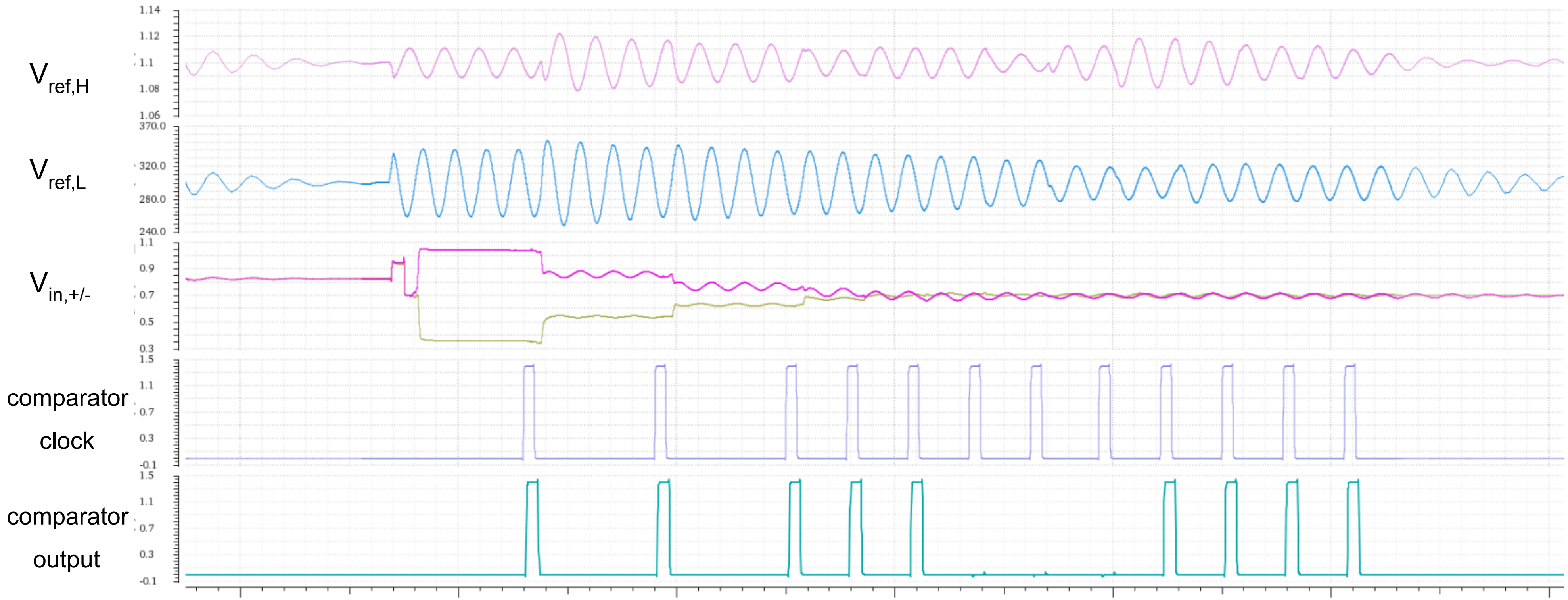
- Inductance due to wire-bonds to $V_{ref,H}$ and $V_{ref,L}$:
- Result in:
  1) Instability of $V_{ref,H}$, $V_{ref,L}$ and $V_{in,+/-}$
  2) "Noisy" output and potentially wrong decision

     at last few bits (small signals)

Simulated ramping curve

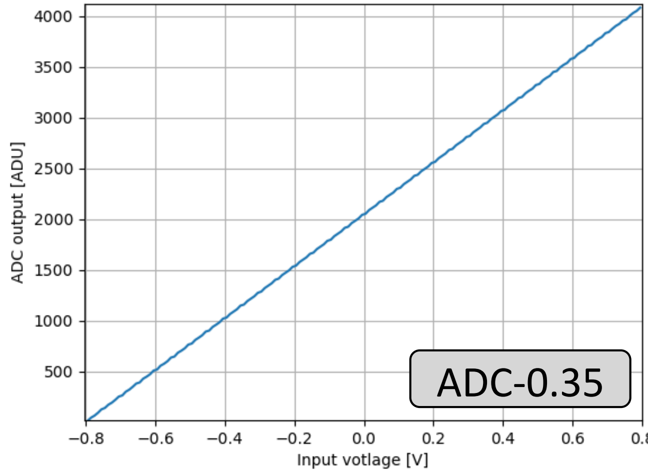


Simulation results for ADC-0.3 with inductance considered

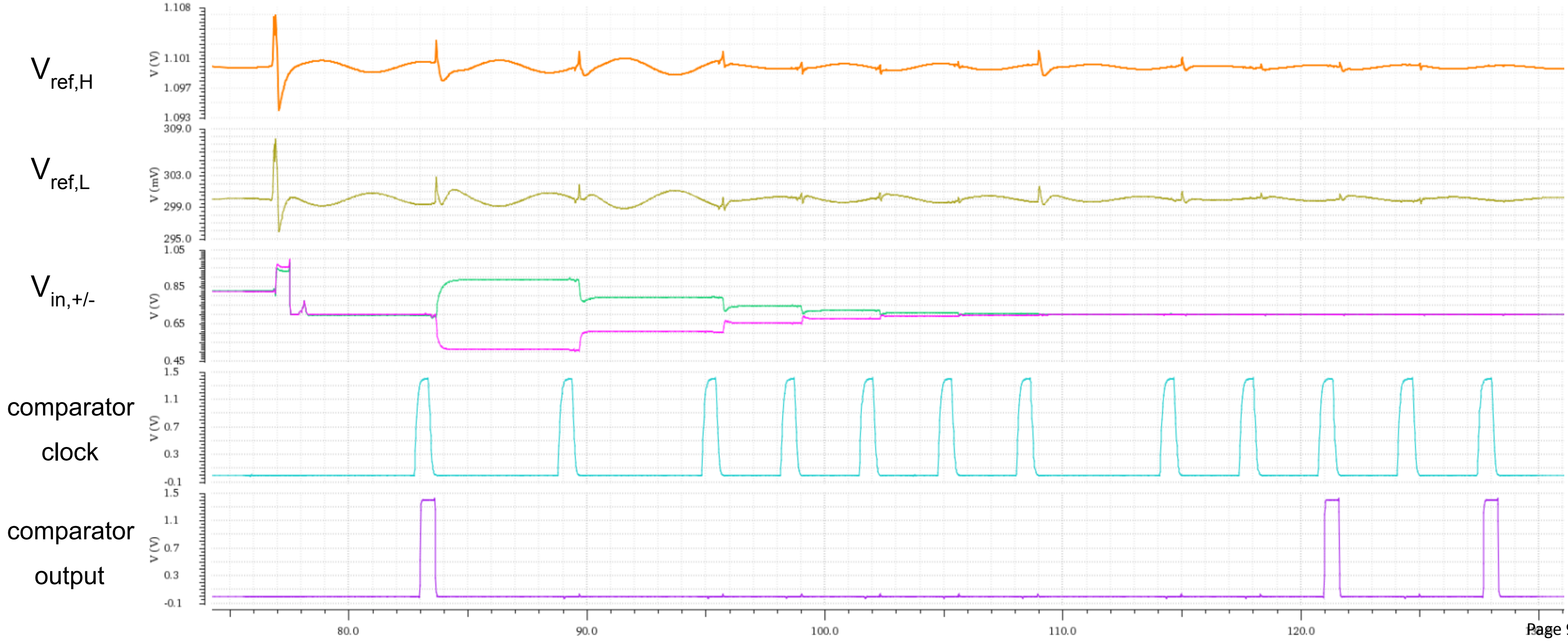


Solutions in new MPW

- Longer time before comparison made for bigger capacitors (bit-4) for signal settling purpose
- Decoupling capacitors to reduce the instability of the reference voltages



Simulation results for ADC-0.35 with inductance considered + decoupling capacitor implemented

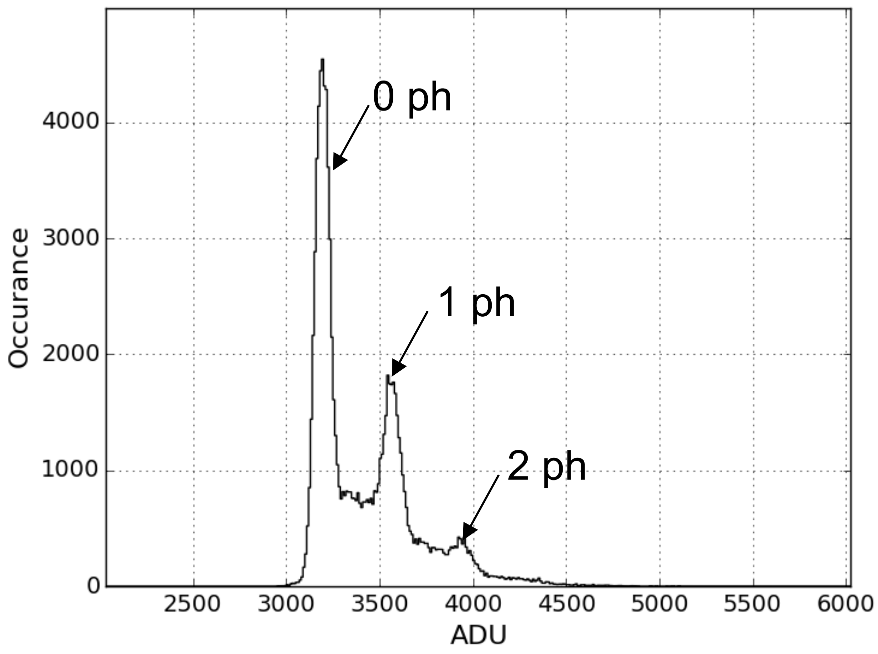


Gotthard calibration procedure

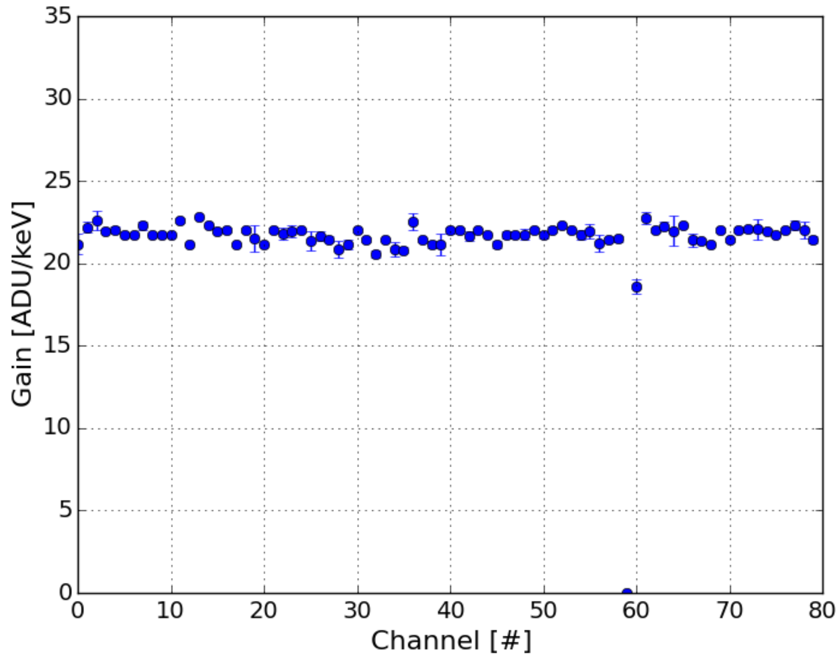
Step-1: Conversion gain from X-ray photons

- Conversion gain with Mo-fluorescence photons [17.5 keV]
  - Histogram of input data
  - Multi-peak fitting (0, 1, 2 photons) and gain extraction

Histogram: Fit to 3 peaks



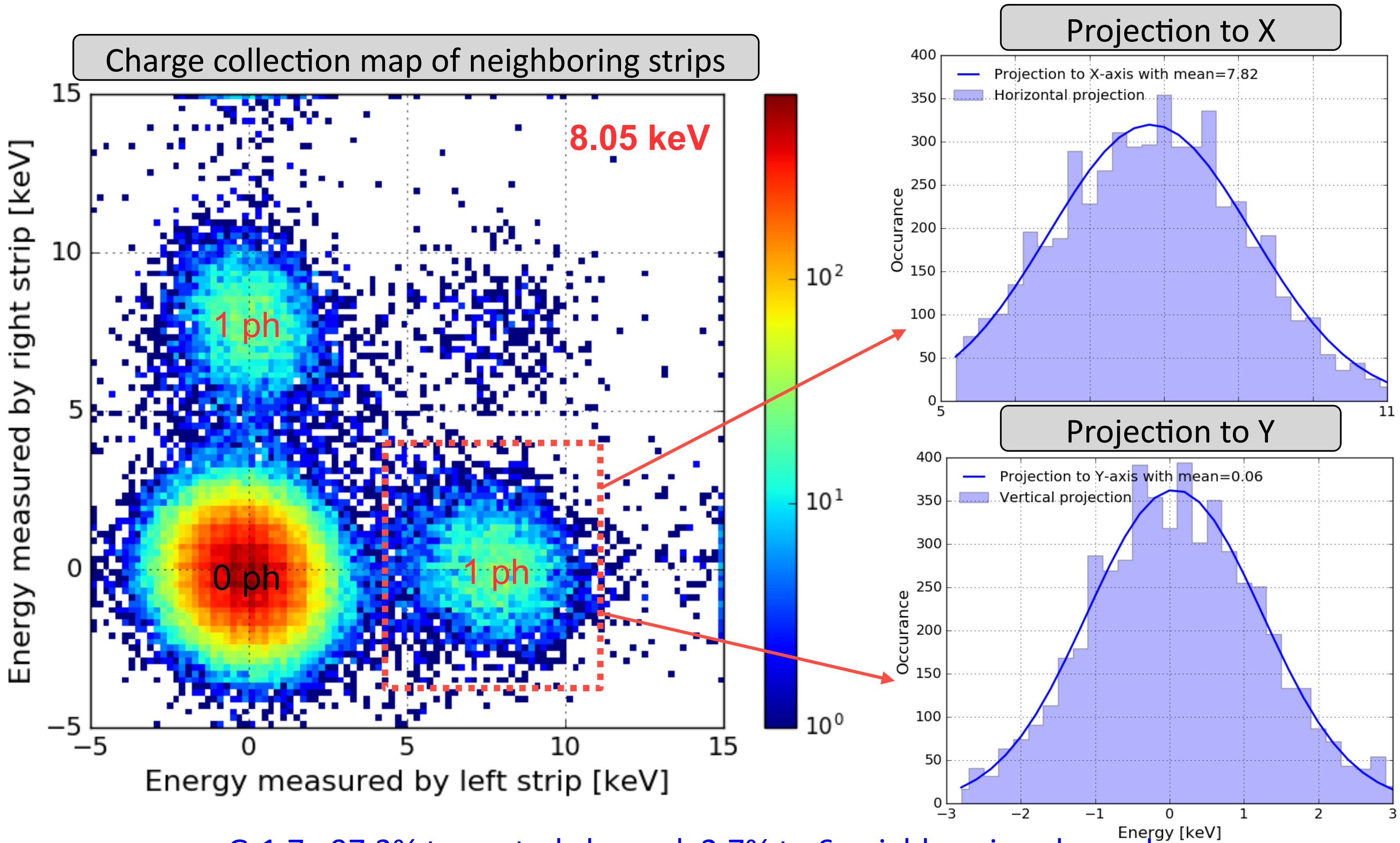
Measured gain over channels



Coupling has to be taken into account!

Step-2: Extraction of fractional charge

- Strip-to-strip coupling / fractional charge: X-ray fluorescence measurement



- G-1.7: 97.3% to central channel, 2.7% to 6 neighbouring channels

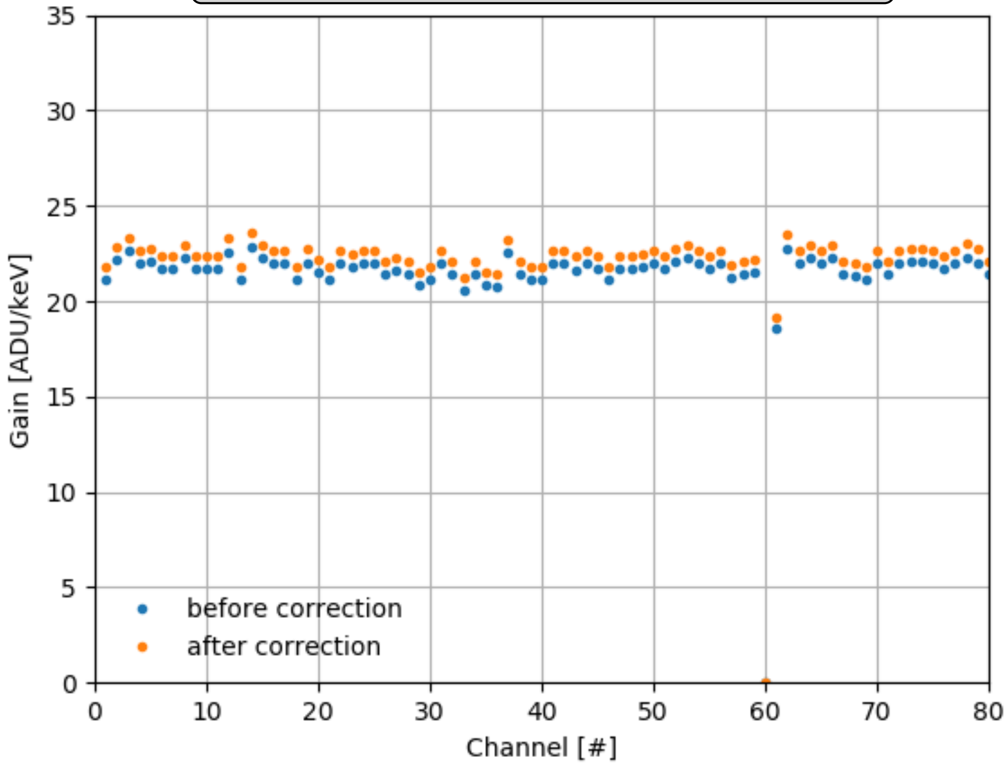
Accuracy relies on good statistics! Better current source implemented in final ASIC!

Step-3: G0 determination

- G0 determination:
  - Fractional charge (or charge fraction in center strip) calculated from coupling factor
  - G0 = Conversion gain/fractional charge

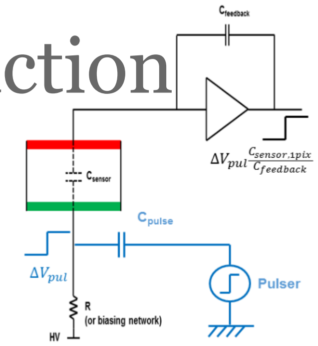
$$Q^i = \frac{(A+1)\cdot(C_f + C_{para})}{(A+1)\cdot(C_f + C_{para}) + C_{inp}} \cdot Q^{tot}$$

G0 w/o corrections over channels



Correction is necessary, otherwise all gains G0 & G1 & G2 can be under-estimated!

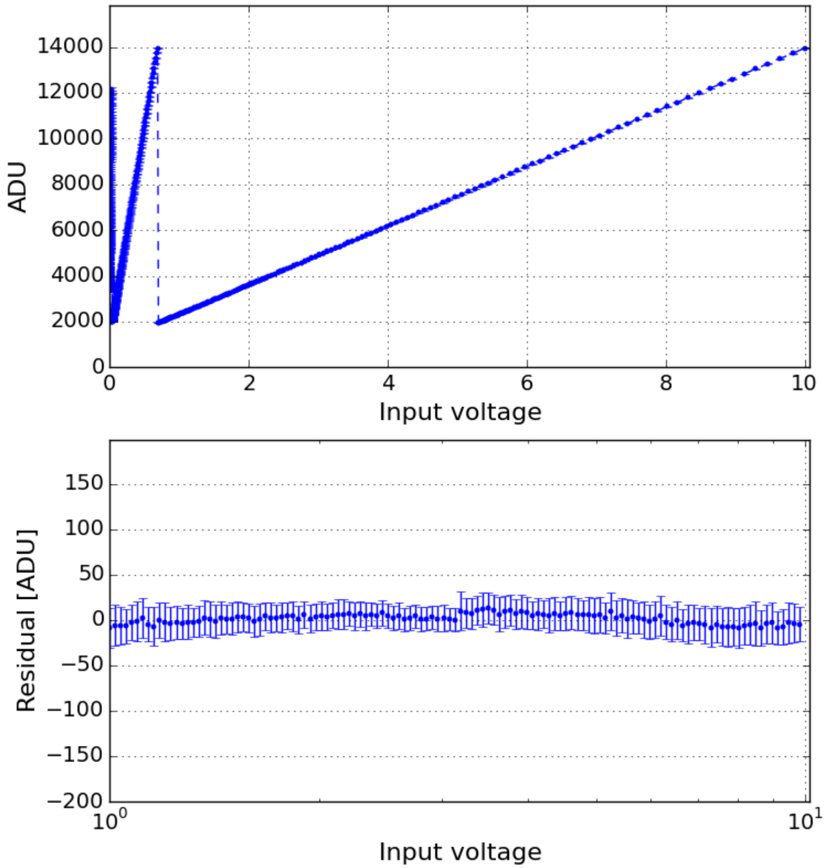
Step-4 & 5: DR scan + G1/G2 extraction (1)



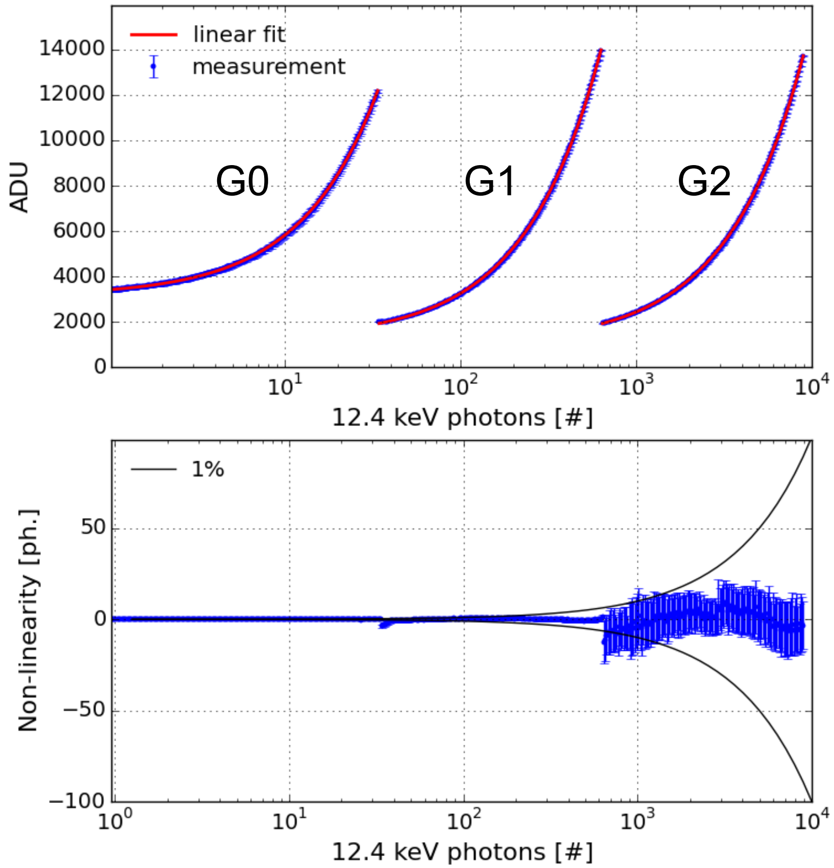
D. Mezza, JINST11 C11019

- Dynamic range curve for one channel (Ch-26) using <u>backside pulsing</u>
  - ADU as function of input voltage (wave generator)
  - Conversion to photons: ADU/V → ADU/keV

ADU vs. voltage



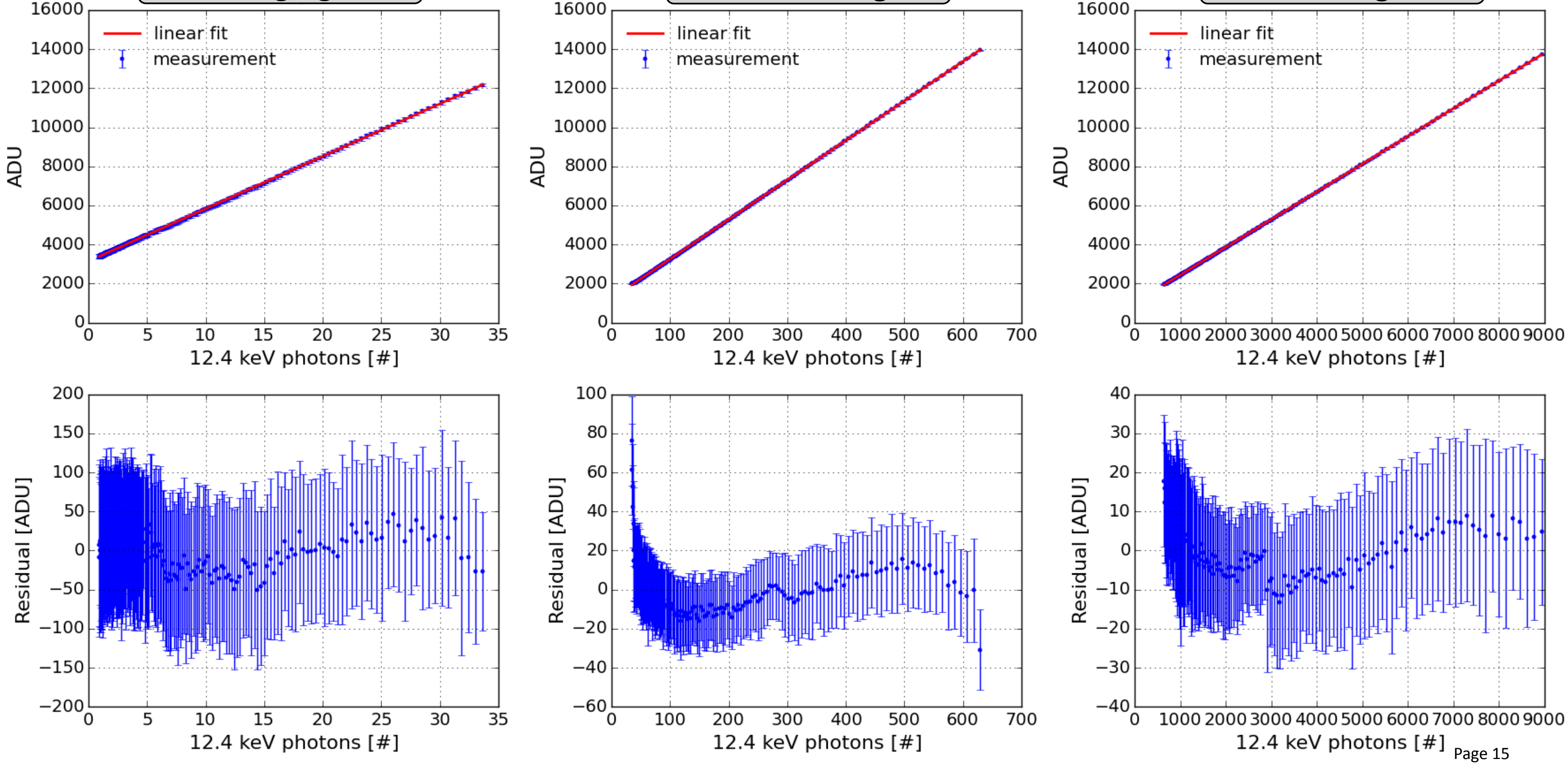
ADU vs. photons



Step-4 & 5: DR scan + G1/G2 extraction (2)

- Dynamic range curve for one channel (Ch-26): Individual gain stages
  - ADU as function of input voltage (wave generator)
  - Conversion to photons: ADU/V → ADU/keV

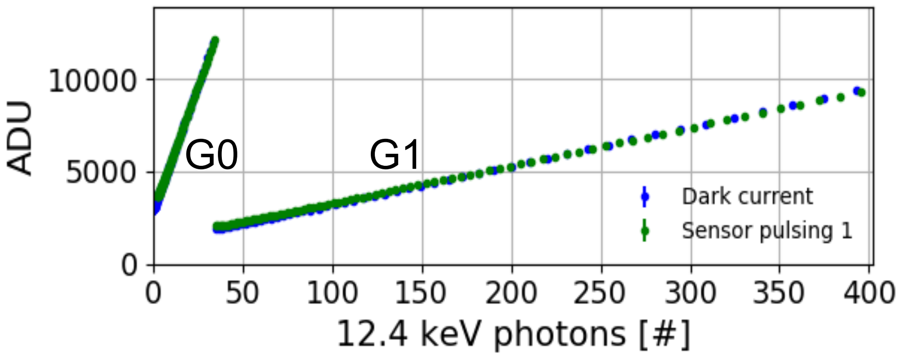
G0: High gain | G1: Medium gain | G2: Low gain

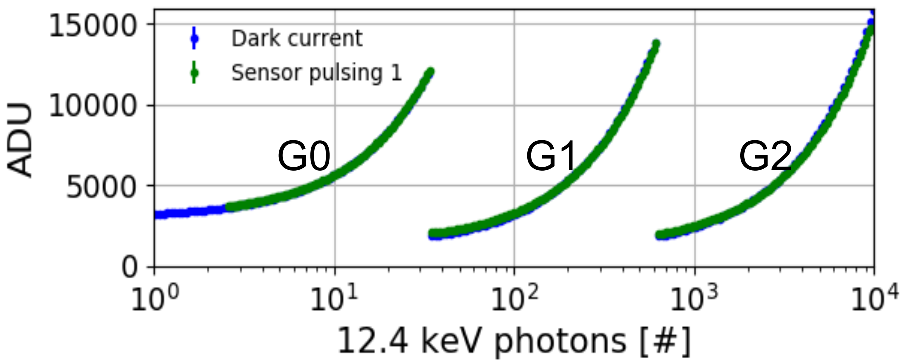


Dynamic range and G0/G1/G2

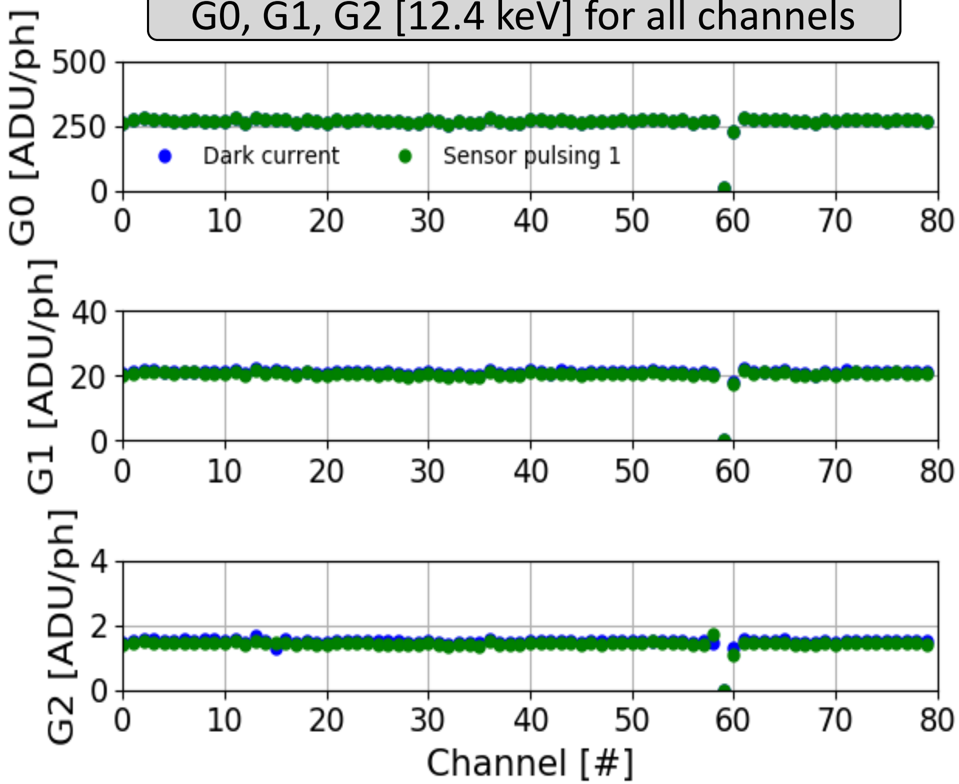
- Dynamic range for one channel [Channel: 26]
  - Overlap curves from backside pulsing, sensor leakage current
  - “Relatively” good overlap between sensor dark current and backside pulsing

Dynamic range with different methods



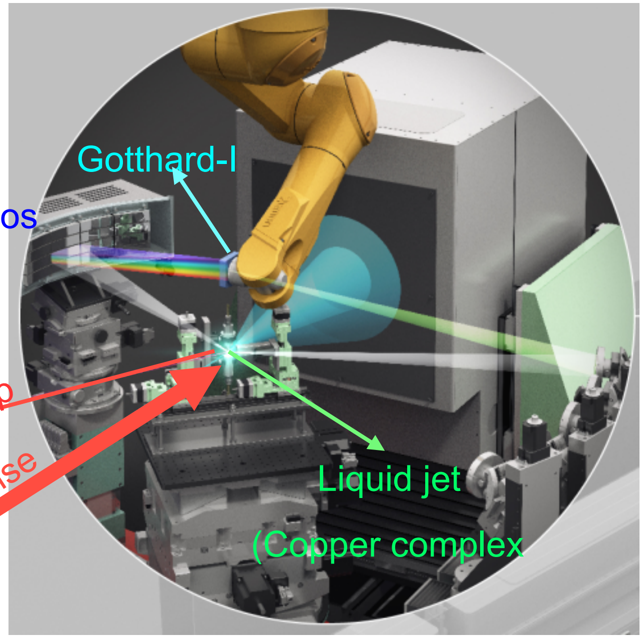


G0, G1, G2 [12.4 keV] for all channels

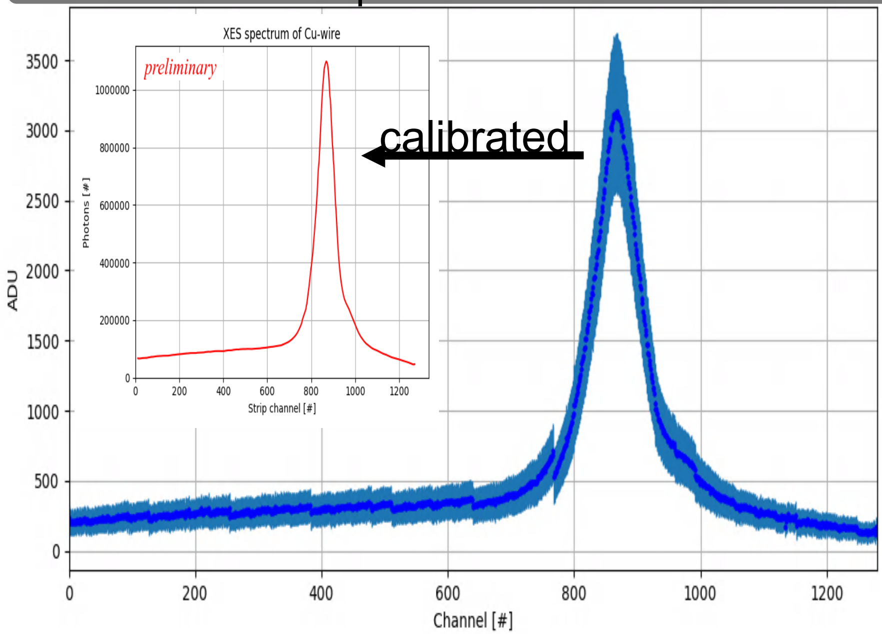


First user experiment at FXE using Gotthard I

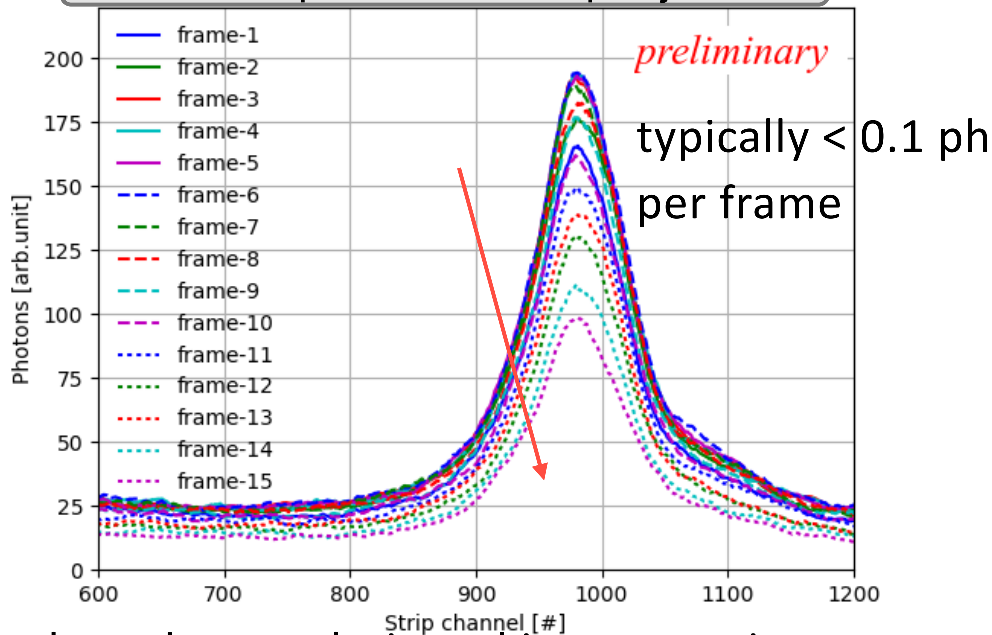
- XFEL.EU bunch structure
  - 1.125 MHz repetition rate
  - Bunches in a train: 30
  - Bunch train repetition: 10 Hz
  - X-ray energy: 9.3 keV



First Gotthard-I spectrum at XFEL 29.09.2017



XES spectrum from liquid jet



User work on data analysis and interpretation

Next steps and Conclusions

- Design of full scale chip (128 channels)
- Continue testing of last test structures from MPW
  Speed test of analogue FE and more tests of ADC
- Test of test structures from Nov 17 MPW to select ADC and analogue FE for final chip
- Submission of full chip
- Start design of readout board
- Build first module
- Test of final chip and module (end 18)

- Calibration procedure defined – verification ongoing

- First user experiments at FXE using Gotthard-1.0:
  - On-site calibration possible using a copper wire
    - Copper wire → pedestal correction + gain correction needed
  - XES spectrum measured

Wir schaffen Wissen – heute für morgen