The FlashCam Project

A fully digital camera for future Cherenkov telescopes

TOPICS

Introducing FlashCam

Adaptations for the SST

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AGH University of Science and Technology

ETH Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

ecap Erlangen Centre for Astroparticle Physics

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FlashCam – a changeable camera

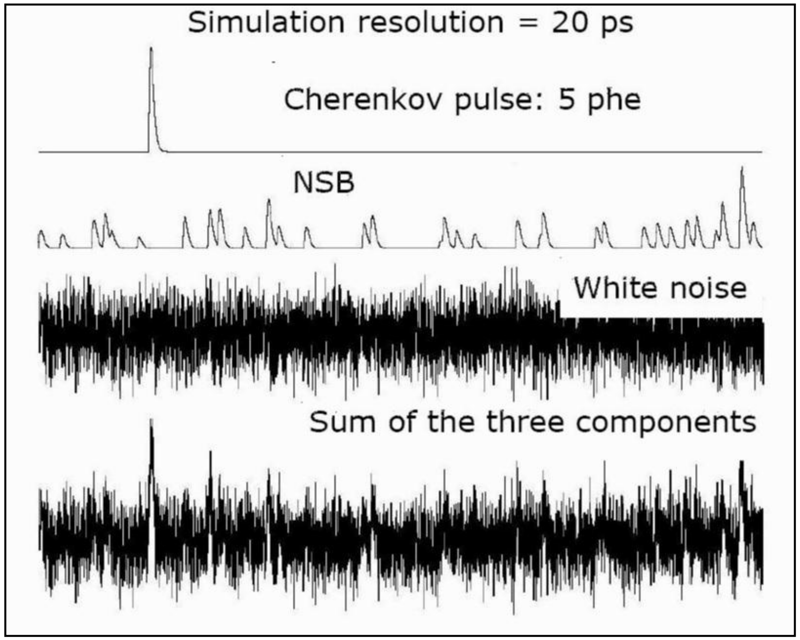
Properties of FlashCam

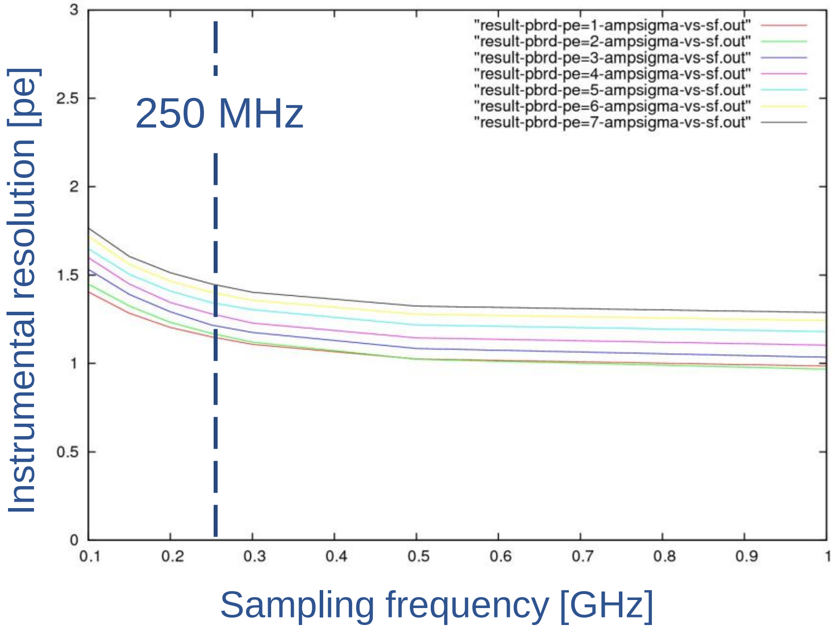
- Simple concept based on commercial available chips
- Trigger decision based on digitized signals
  - ⇨ no separate trigger path necessary
  - ⇨ programmable and flexible
- Low power (<0.5 W/channel) 12 bit FADCs currently only available up to sampling speeds of 250 MS/s
  - ⇨ extensive simulations incl. time jitter, night sky background etc. have shown that trigger performance applying digital trigger options is very competitive with higher (e.g. 2 GS/s) sampling speeds
  - ⇨ resulting data rate (~600 MB/s) allows to transmit the full pixel event information w/o data reduction over standard gigabit ethernet infrastructure (incl. commercial switches)

Specifications

Number of pixels: 900 – 3600
Dynamic range: ~0.2 – 3000 PE
Local trigger rate: ~10 kHz
Storage of trace

FlashCam based on simulations for MST



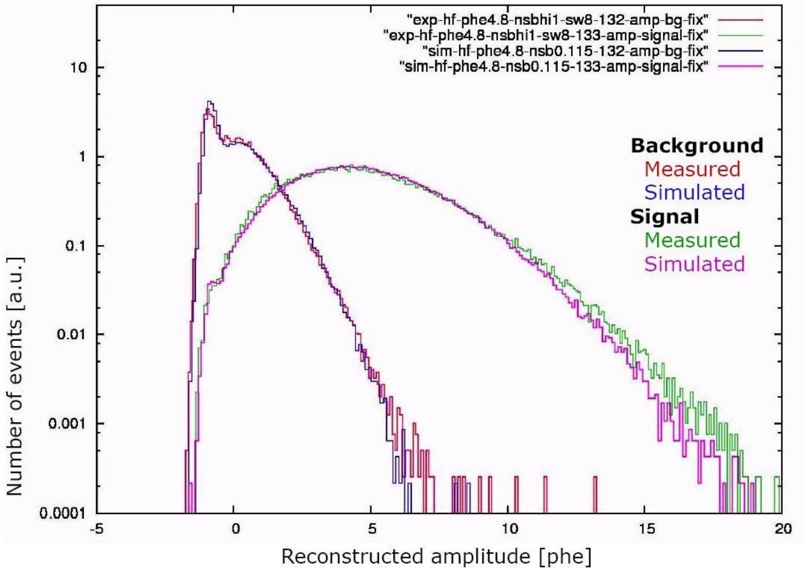


Simulation of 2 GS/s and 250 MS/s digitization

Resolution above 250 MS/s approx. constant

Simulations have shown: 250 MS/s digitization highly competitive

FlashCam based on simulations for MST

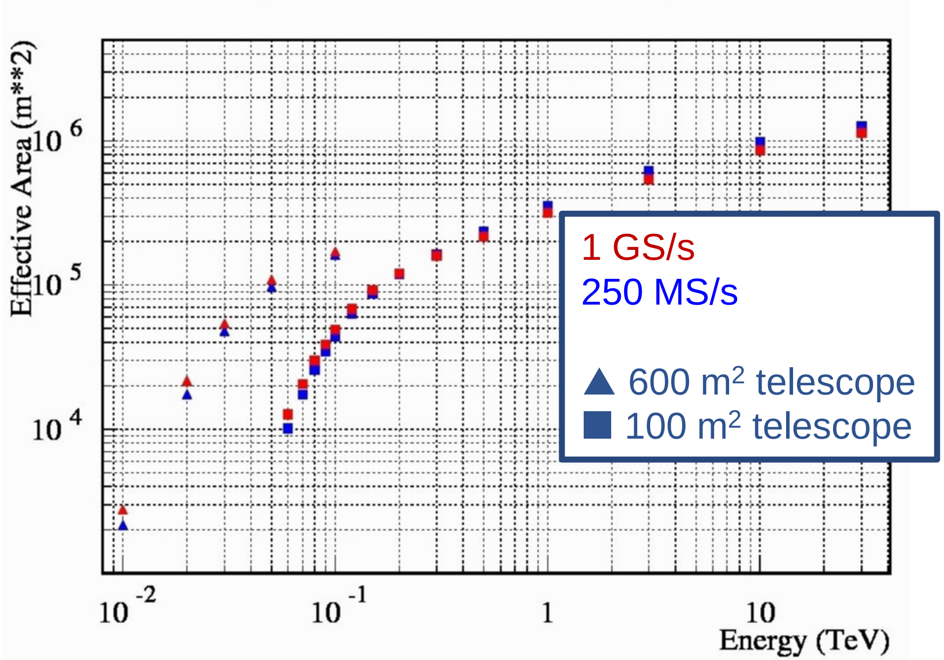


Comparison of measurements and simulation

Resolution at 2 GS/s and 250 MS/s with measurements shows that our simulations are OK

Trigger simulations

Time jitter, NSB, and other studies show that 250 MS/s together with digital trigger options is competitive with higher sampling rates



Camera architecture: Overview

Separation of PDP and ADC, Analogue signal over CAT5/RJ45

→ allows adaption of various photon detectors and pitches and avoids electronics at the focal plane (weight)

Horizontal integration

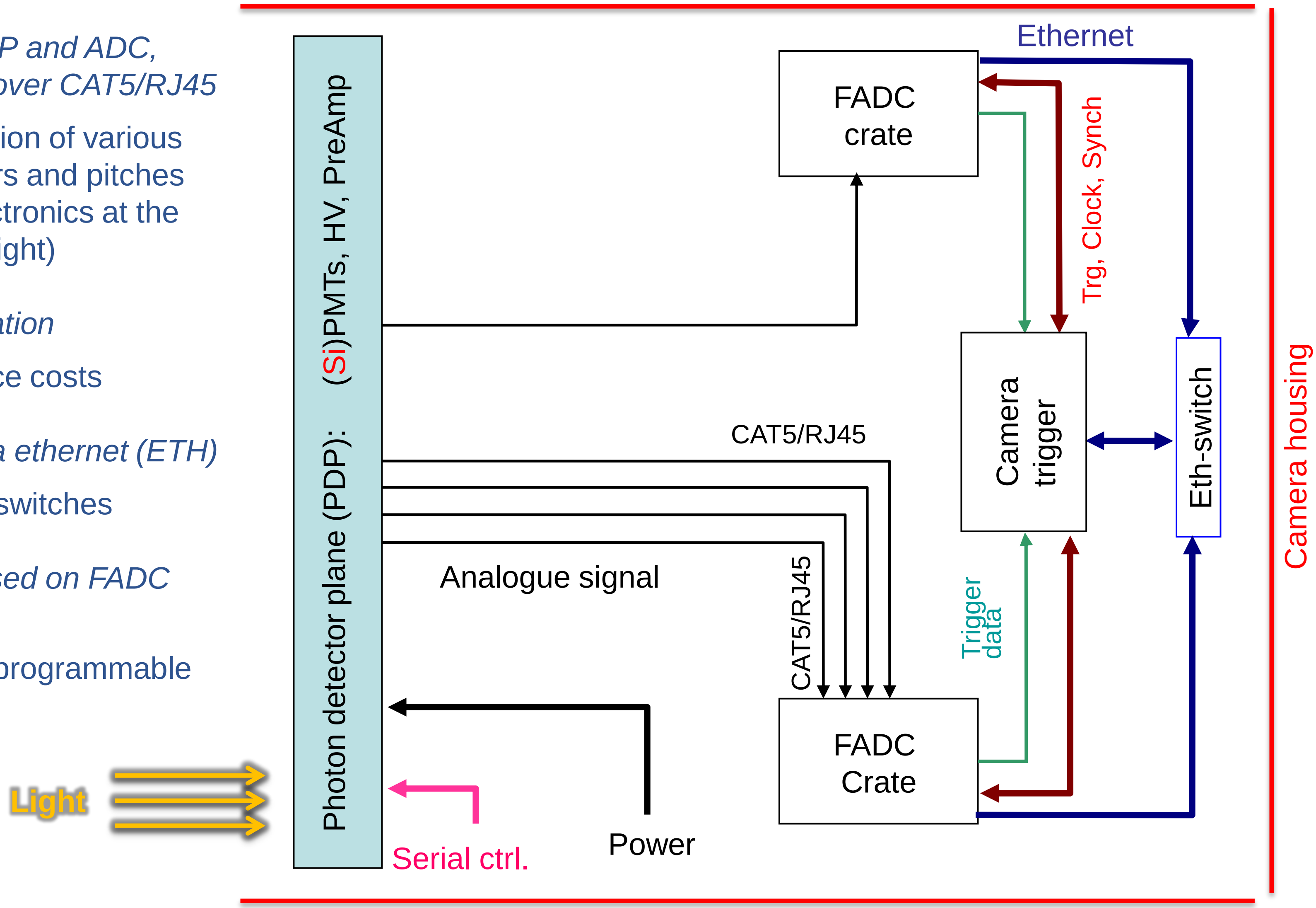
→ should reduce costs

Data transport via ethernet (ETH)

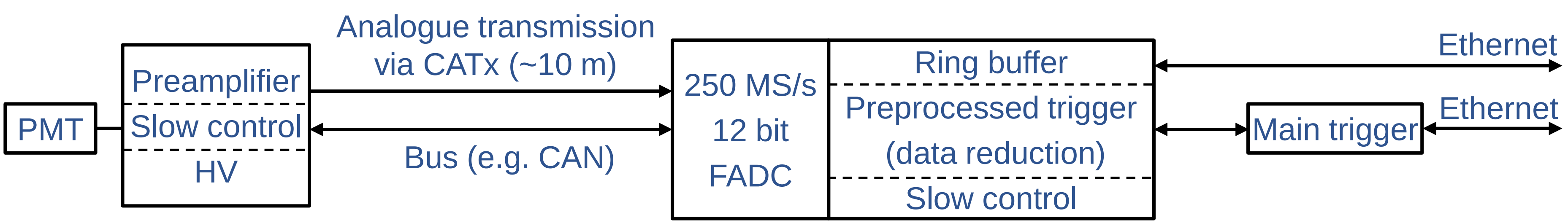
→ commercial switches

Digital trigger based on FADC data

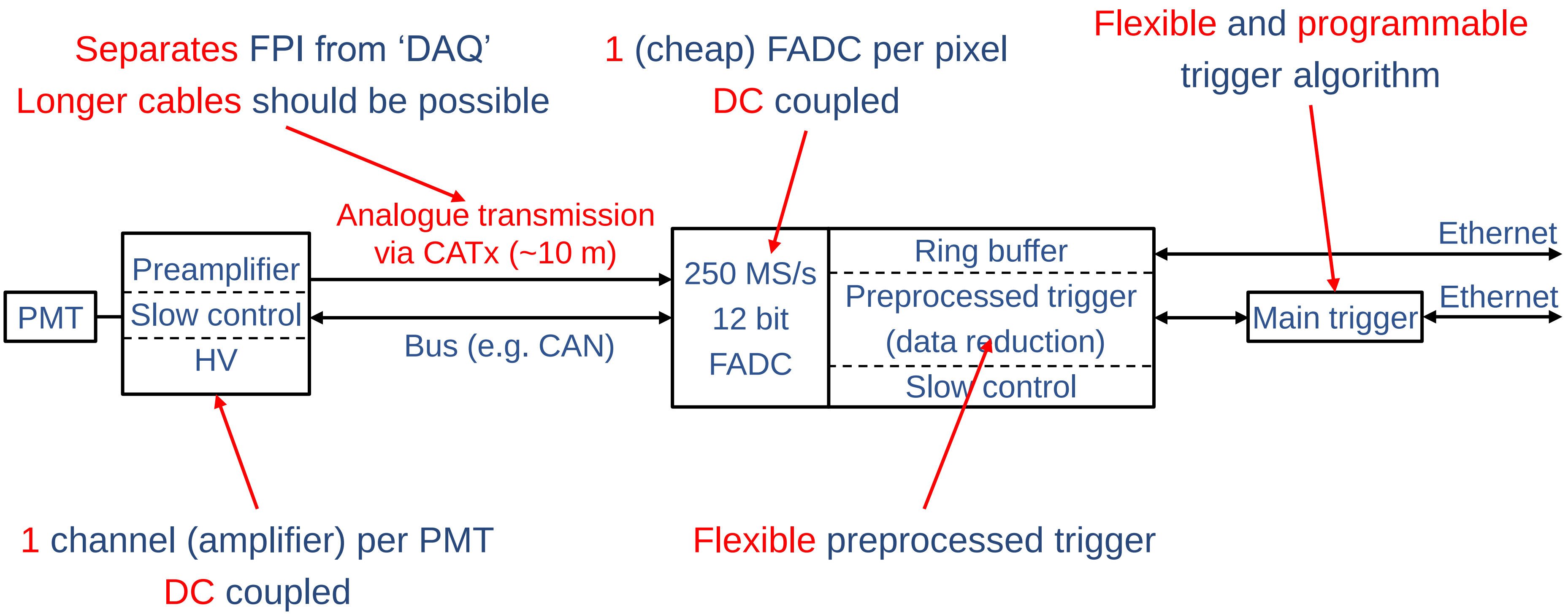
→ flexible and programmable



Camera architecture: Detailed view



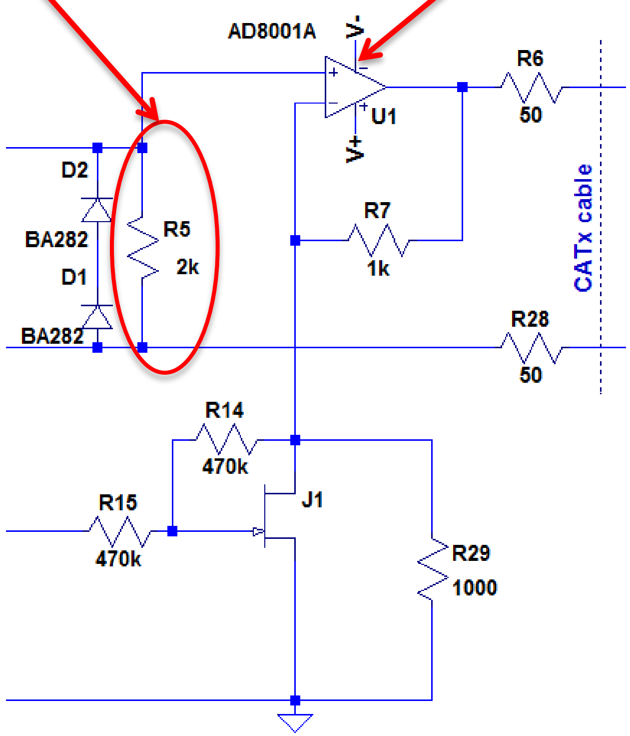
Camera architecture: Detailed view



Preamplifier

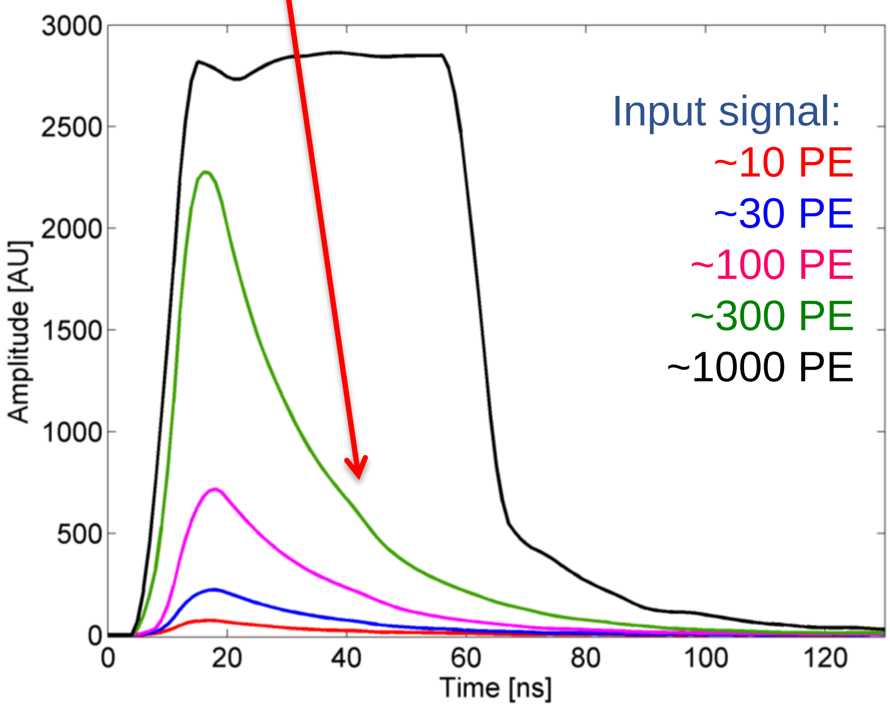
Major difference:
1-2 kΩ input resistor
(compared to 50 Ω)

Saturation is a documented feature



Power consumption ~40 mW / ch

- Saturation sets in at ~200 PE (~ 8 LSB / PE) => signal gets broader
- Long tail due to large input resistor

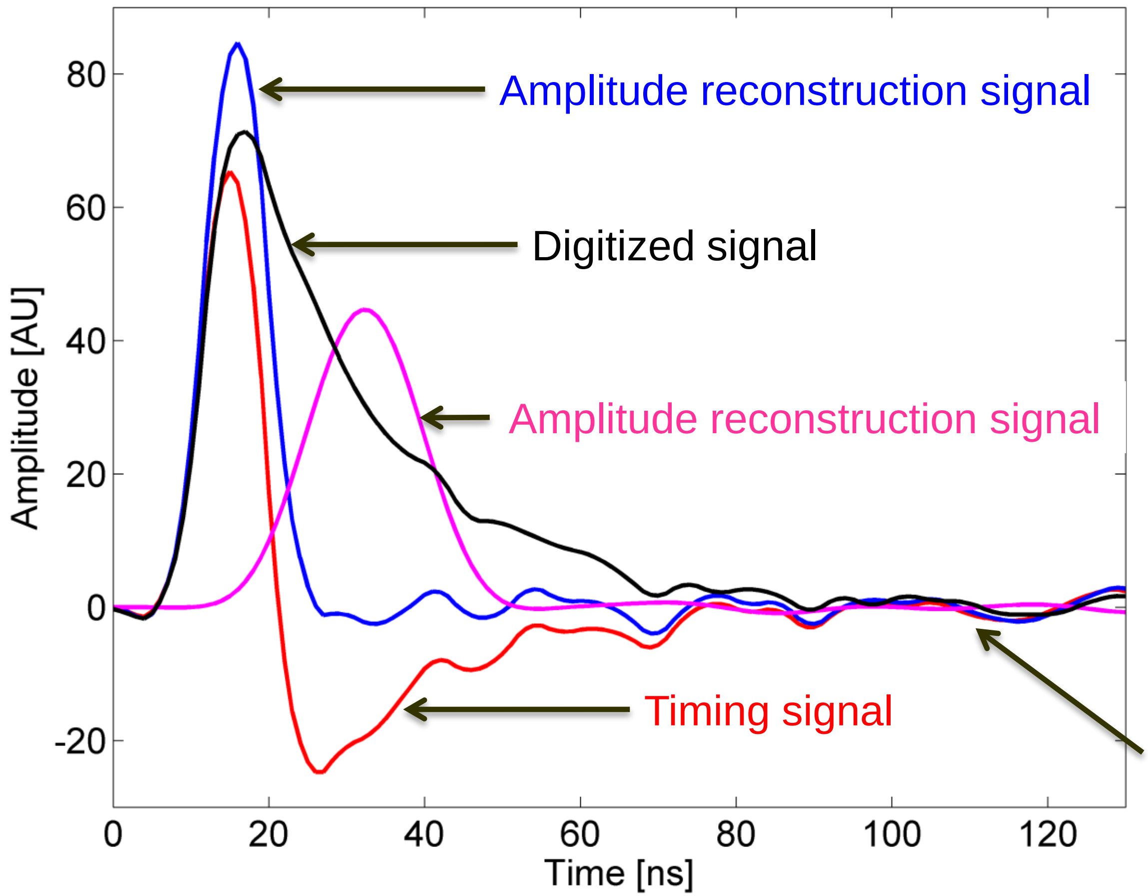


Measured signals interpolated and smoothed
Resolution 1 ns / step

Preamplifier / Deconvolution

Measured with FlashCam demo board

10 PE equivalent input pulse



Signals are integrated. Amplitude is given by the maximum of the signal.

10 ns FWHM corresponds to an effective integration window of 10 ns

Total noise ~1.3 LSB
~0.7 LSB from ADC alone
ADC driver gives large contribution

Preamplifier / Clipping

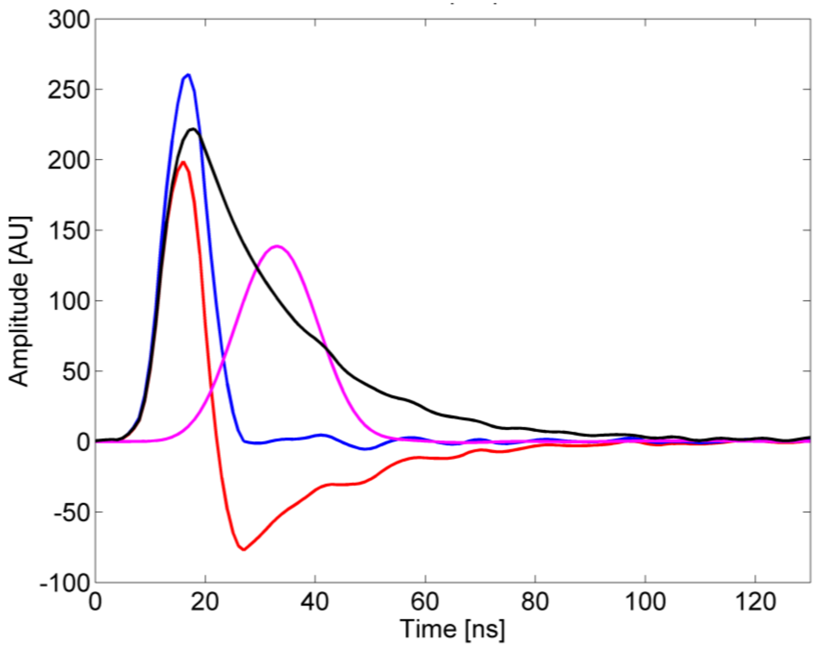
Measured with FlashCam demo board

- Digitized signal
- Timing signal
- Amplitude signals (10 ns width)
- Amplitude signals (20 ns width)

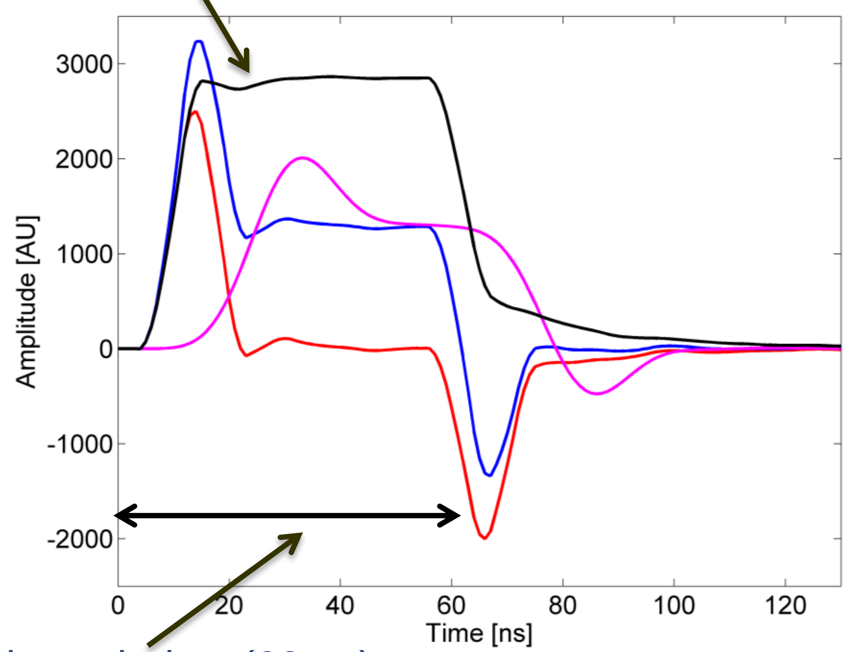
Saturation 'mode':

- Amplitude signals no longer useable
- Integrate digitized signal over 200 ns window in FPGA and subtract baseline for amplitude reconstruction (3000 PE signal is ~120 ns)

30 PE equivalent input pulse



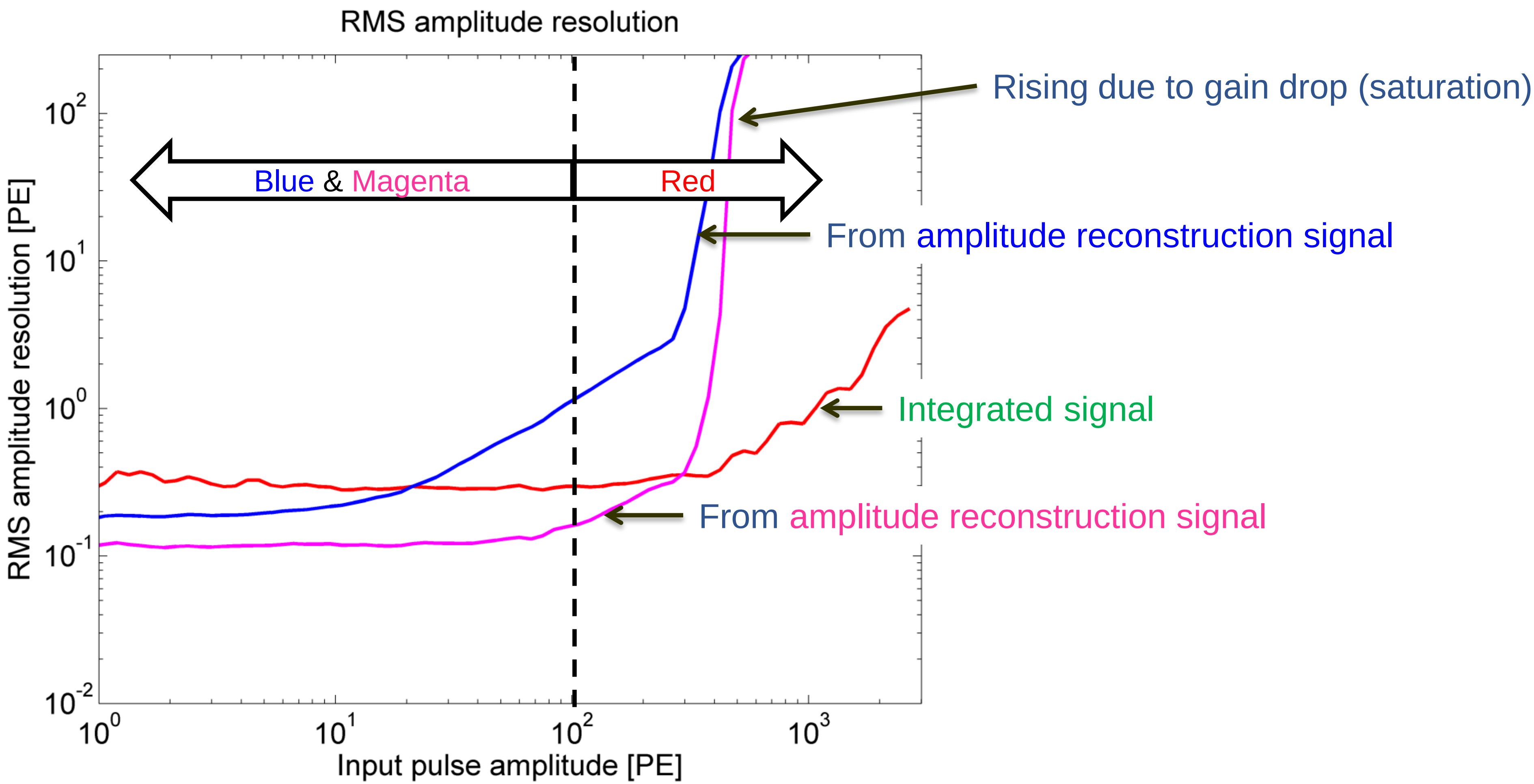
1000 PE equivalent input pulse



Readout window (60 ns)

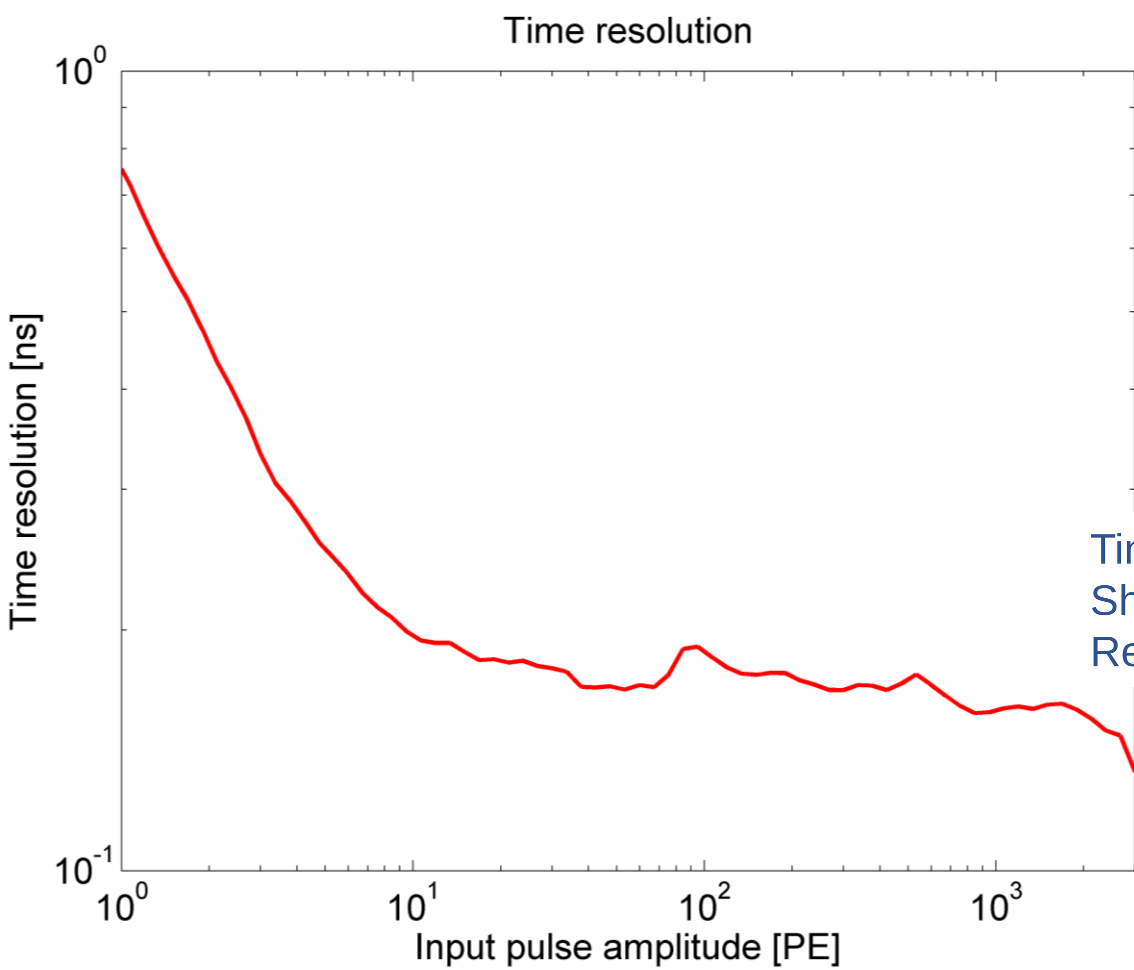
Preamplifier / Amplitude resolution

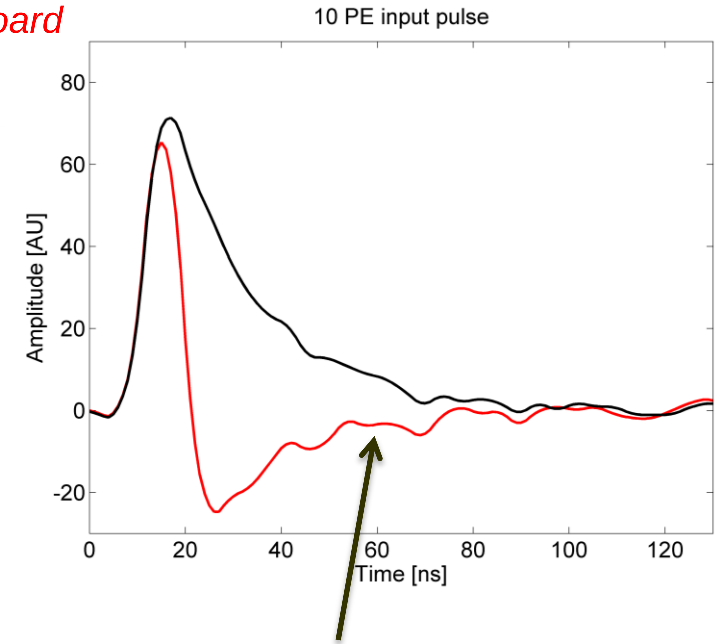
Measured with FlashCam demo board



Preamplifier / Time resolution

Measured with FlashCam demo board

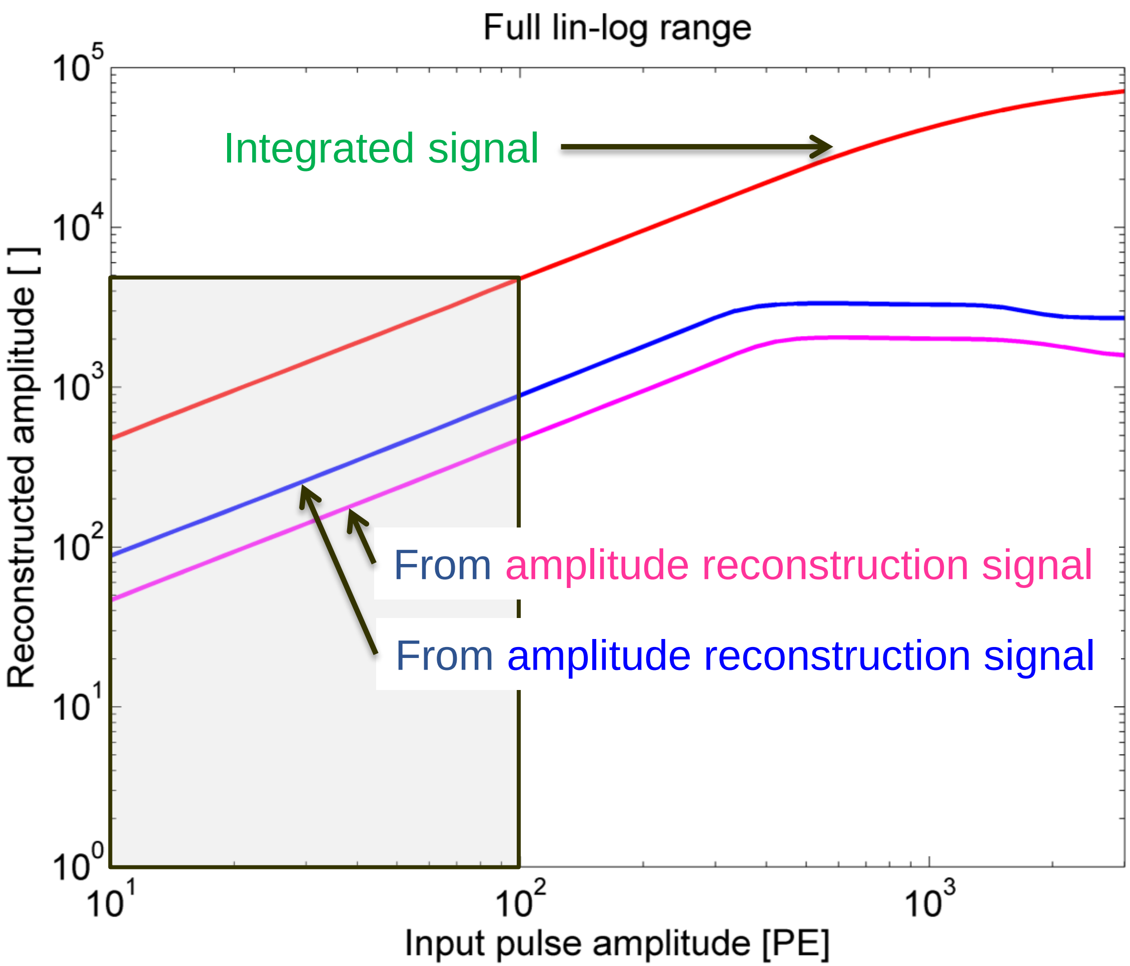




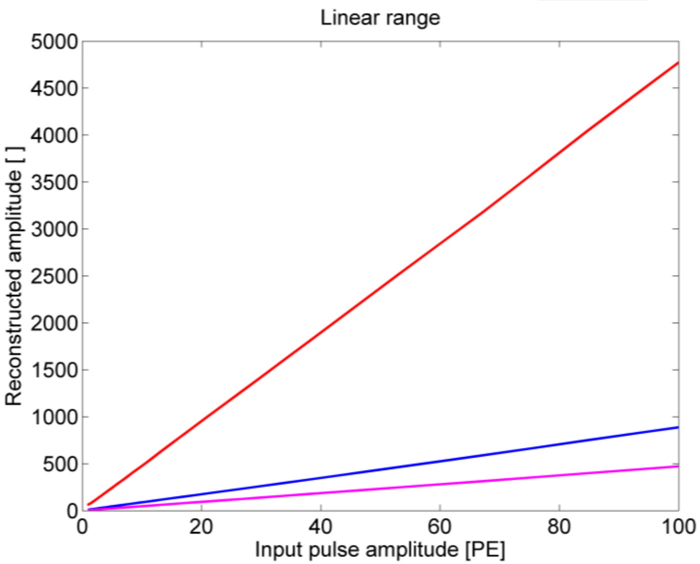
Time reconstructed from timing signal
Shown is comparison to reference signal
Reference signal has ~ 100 ps resolution

Preamplifier / Linearity

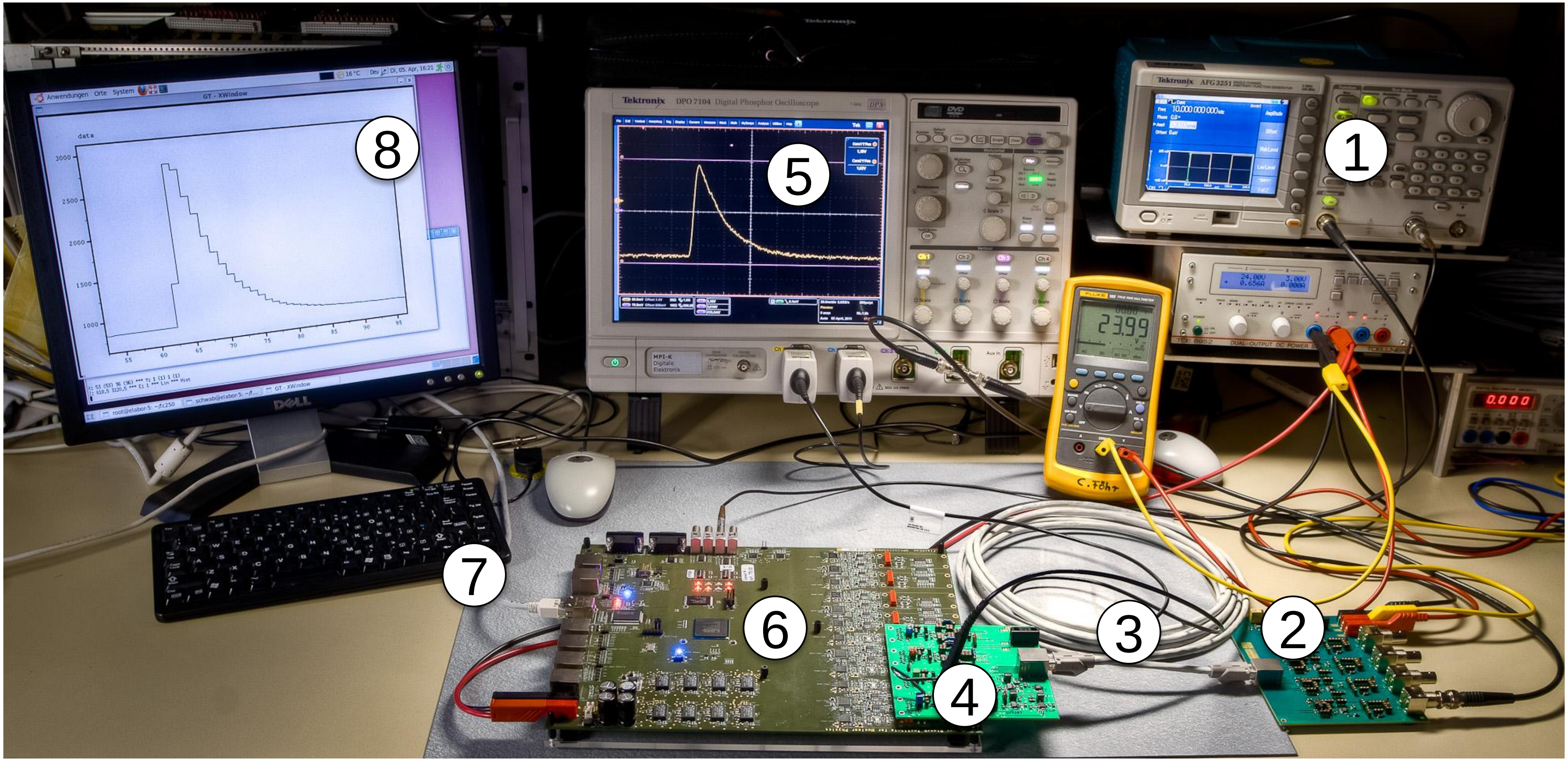
Measured with FlashCam demo board



Zoom in of linear range



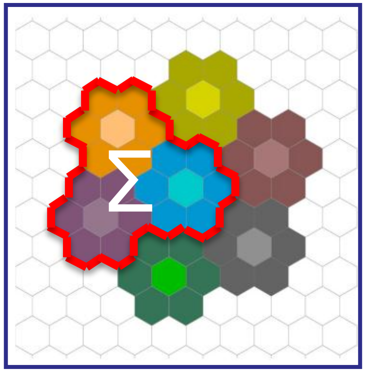
The FlashCam demo board setup

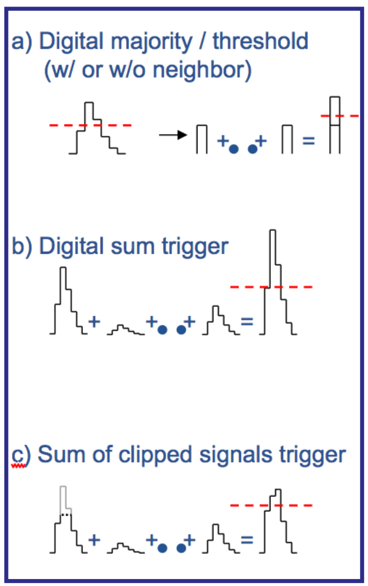


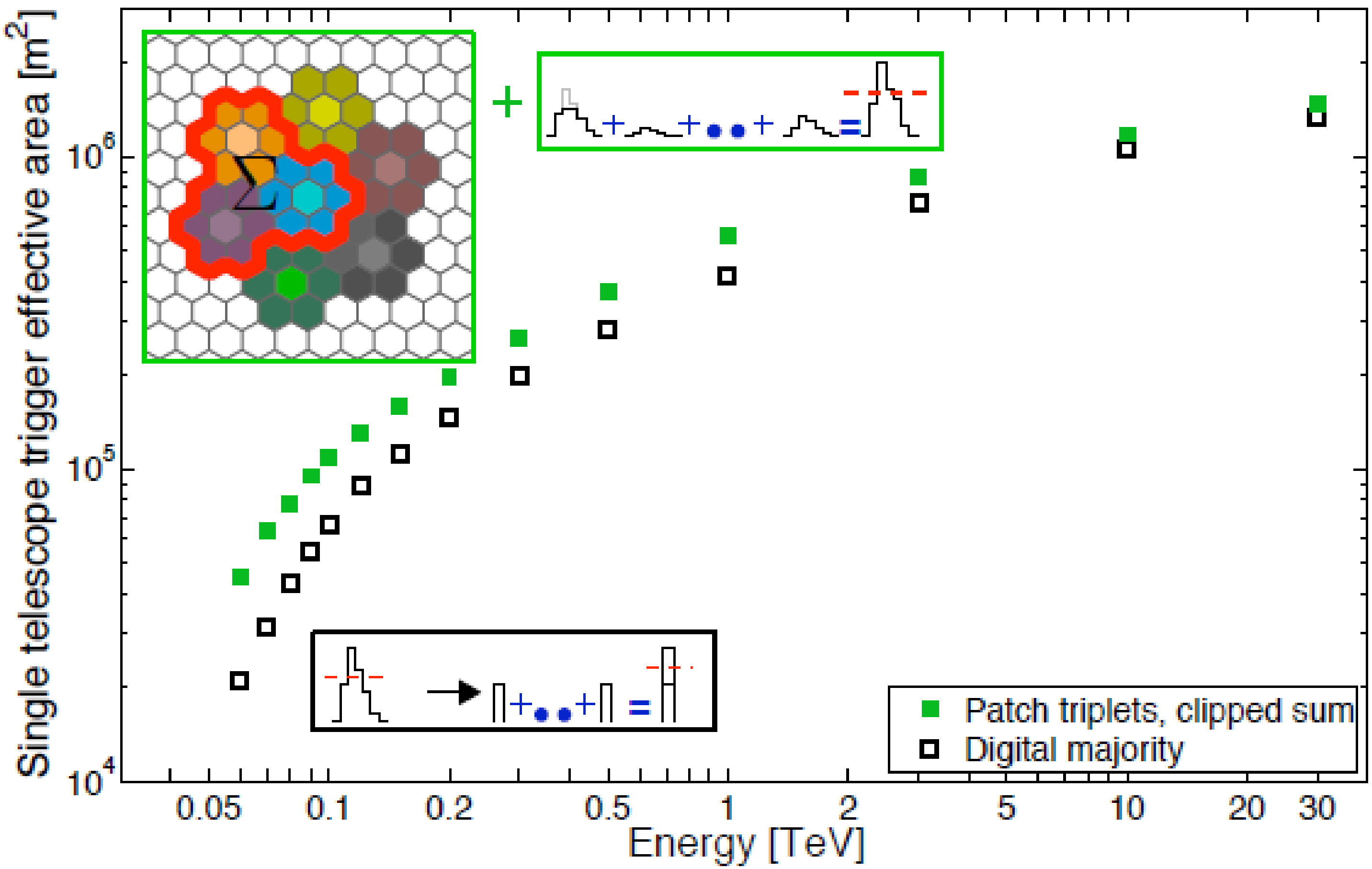
1 PMT pulse generator
2 Preamplifier board
3 Analogue signal transmission (CAT5)
4 ADC driver board
5 Analogue pulse before ADC
6 Demo board with 8 parallel FADCs and FPGA
7 Event transmission via LAN
8 Digitized pulse (4 ns / step)

Trigger methods

Patch triplets, clipped sum

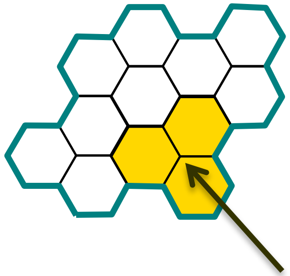






E.g. 100 GeV shower: ~1.6 higher effective area for clipped sum

Focal plane with PMTs

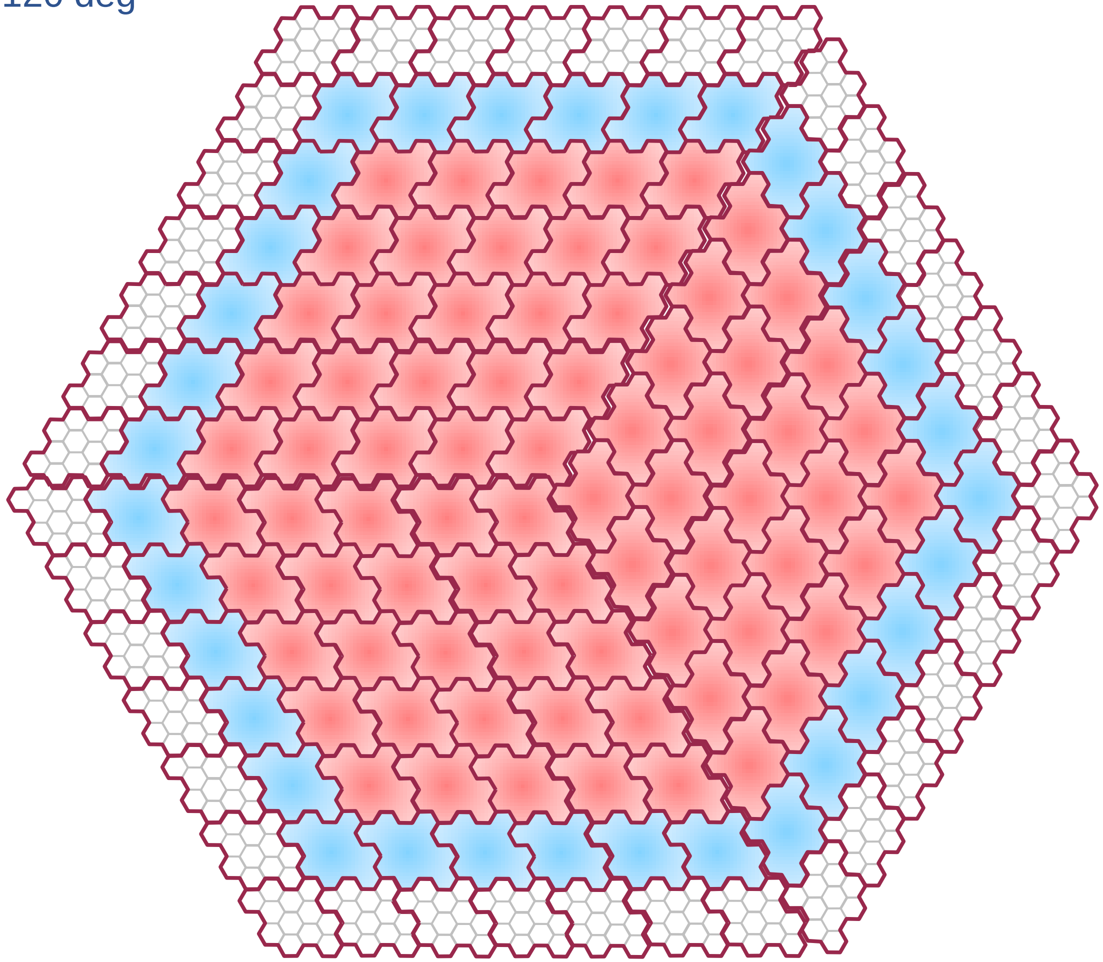


Mechanical group of 12 PMT pixels

3 sectors, rotated by 120 deg

Hexagonal structure

Perfect edges



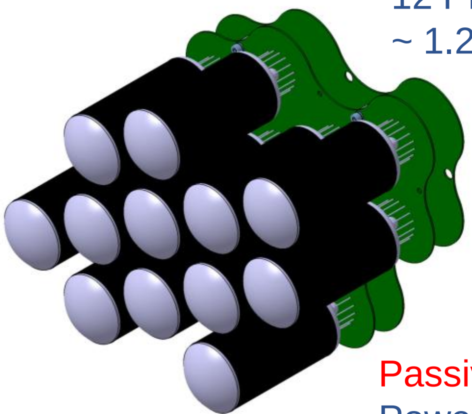
Possible sizes

Fully populated 12 pixel modules

5 x 5 x 12 x 3 =	900	SST
6 x 6 x 12 x 3 =	1296	SST
7 x 7 x 12 x 3 =	1764	MST
8 x 8 x 12 x 3 =	2304	LST
9 x 9 x 12 x 3 =	2916	

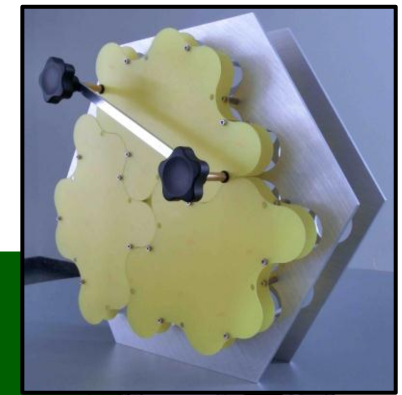
Current mechanics for up to 2304 pixels

Focal plane: The PMT solution

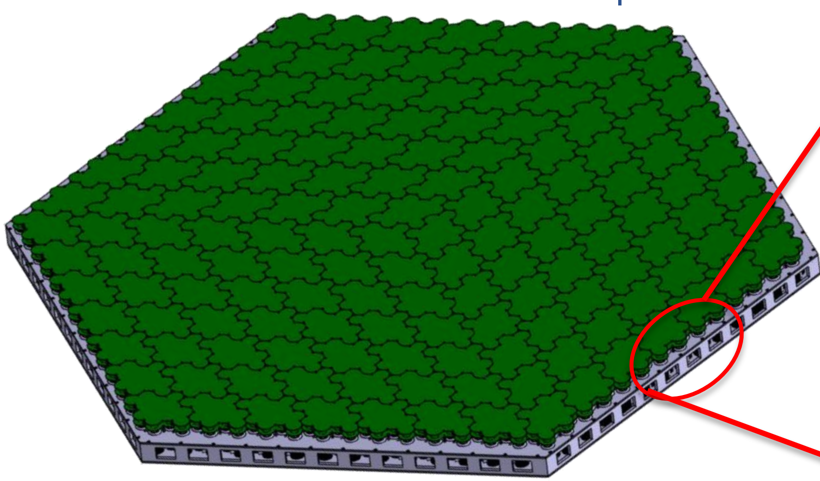


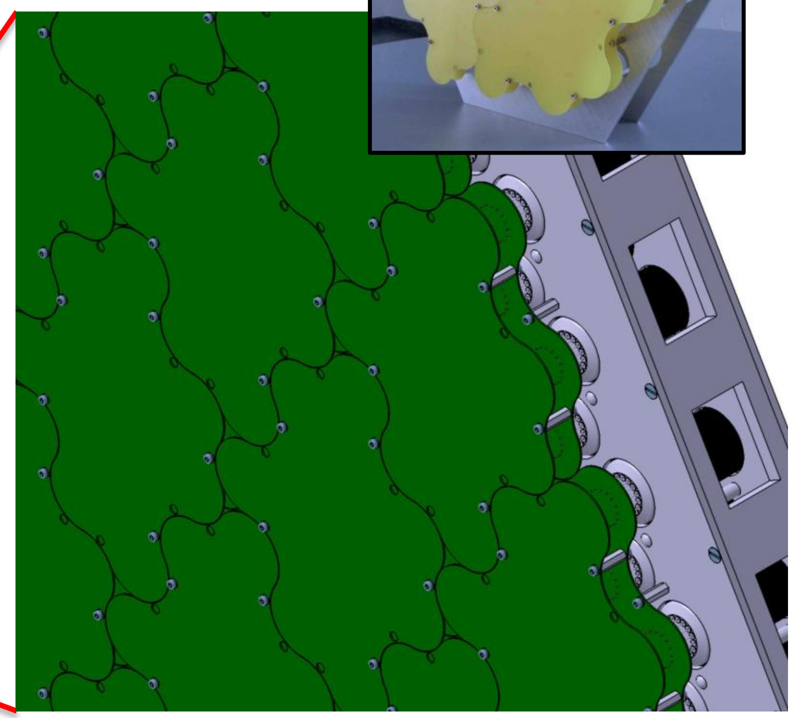
12 PMTs module, preamp and HV incl.
~ 1.2 kg / module

36 pixel prototype



Passive cooling of PDP
Power for 1764 pixels < 300 W





Structure weight: 81 kg
Flat to flat: 2170 mm
FEM calculation: 180 kg load at 90° → 0.68 mm sagging

147 modules, 1764 PMTs
~ 180 kg (incl. electronics)

The (possible) needs of an SST camera

High energy shower physics

- Handling of high energy showers with long time spread over whole camera (< 100 ns)

Using (G)APDs or multi-anode PMTs instead of PMTs

- Change of high voltage supply and stabilization
- Long signal tail, larger dark count, high NSB gives large DC component with (G)APDs
- Smaller pixel-pixel distance

Separation of front-end electronics from 'readout' electronics for a lightweight camera

- Separation of detector and digitization
- Transmission of analogue signals over long distances (> 10 m)

Number of pixels

- Much smaller or much larger pixel number as MST or LST

The FlashCam as an SST camera

High energy shower physics

- Handling of high energy showers with long time spread over whole camera (< 100 ns)
  - FlashCam can send all pixel information of a 4 μs window with pre- and post-trigger
  - No introduction of dead time

Using (G)APDs or multi-anode PMTs instead of PMTs

- Change of high voltage supply and stabilization
  - Front-end electronics is interchangeable and very flexible (HV generation on front-end module)
- Long signal tail, larger dark count, high NSB gives large DC component with (G)APDs
  - FlashCam's electronic is DC coupled and thus can measure NSB and dark count
  - Too large DC levels will reduce useable dynamic range of ADC → change to AC coupling
- Smaller pixel-pixel distance
  - Is limited only by the preamp, HV generation and slow control concept (staggering of PCBs possible)

Separation of front-end electronics from 'readout' electronics for a lightweight camera

- Separation of detector and digitization
  - This separation is already implemented in the FlashCam concept with front-end modules containing amplification and HV generation and back-end racks with the digitization and ethernet components
- Transmission of analogue signals over long distances (> 10 m)
  - Tests with up to 32 m CAT5 cables (1.5 – 2 % crosstalk) were already successfully performed. Longer cables will only introduce larger crosstalk.

Number of pixels

- Much smaller or much larger pixel number as MST or LST
  - FlashCam is sizeable with 900 up to 2304 (3600) pixels with the current mechanics using PMTs

Summary

- FlashCam's concept includes a separation of the FPI (modules) and the digitization electronics (racks).

- This modularity allows to exchange default photon detectors (PMTs) with other photon-detector types such as SiPMT (APD) or MaPMT with associated power supply and amplifiers.

- The front-end module architecture allows different number of pixels and pixel-pixel pitches while the back-end electronics can be adapted to the number of pixels by 'only' adding or removing ADC cards from the racks.

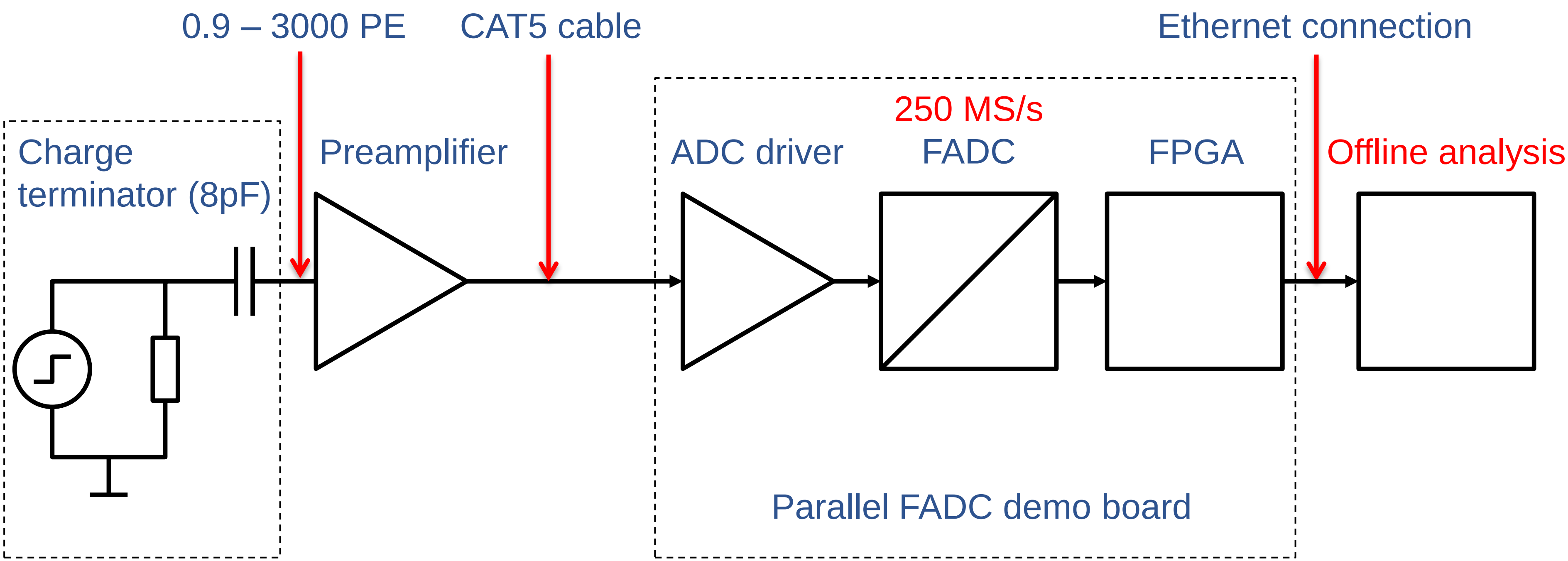
- The moderate sampling rate of 250 MS/s might well be ideally suited to the sampling and data storage needs especially of an SST.

- Dead time free data taking of long traces (≤ 4 µs buffer) for all pixels. Event trigger can be positioned anywhere within the readout window (pre-, post triggering).

Backup slides

Measurement chain

Taking measurements with the Demo Board chain:



MPIK