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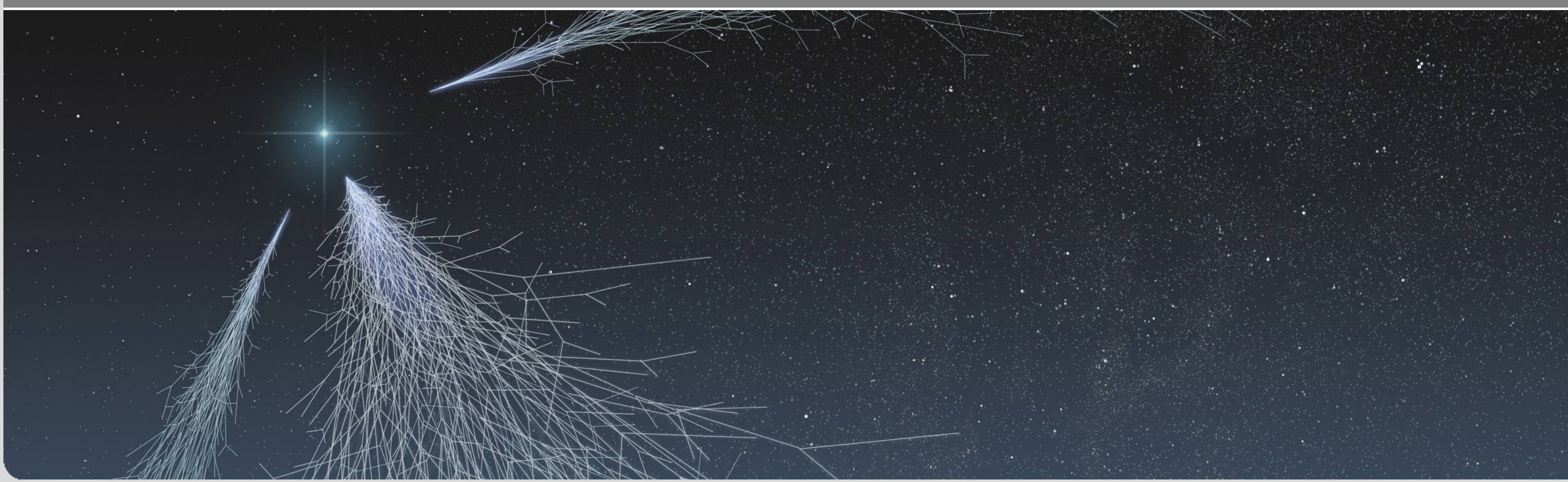
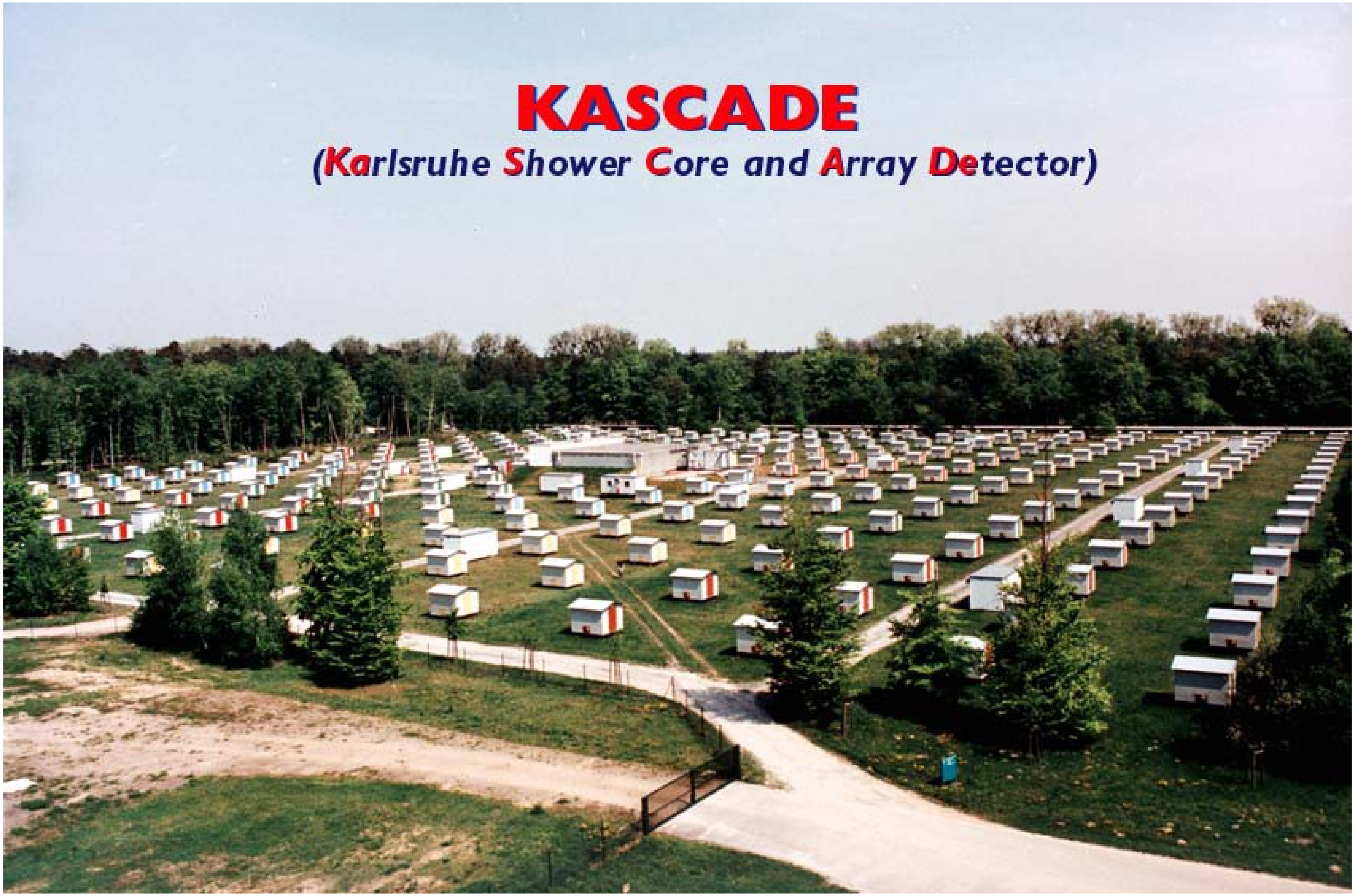
Mini-KASCADE – electronics miniaturization

Christian Tesch | Karlsruhe Institute of Technology | Institute of Experimental Nuclear Physics (IEKP) | Cosmic Ray Group



KASCADE



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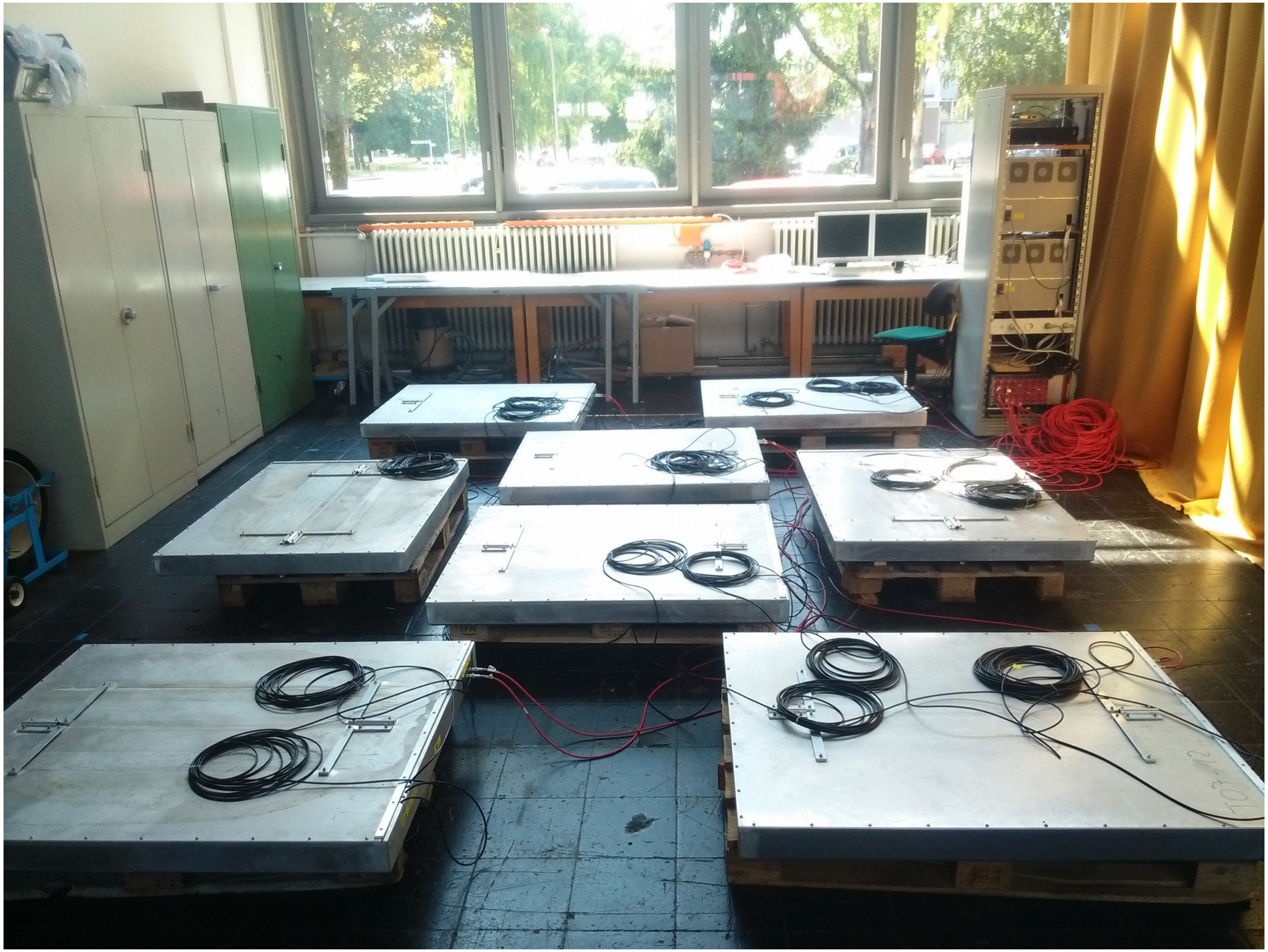
current Mini-KASCADE – test setup



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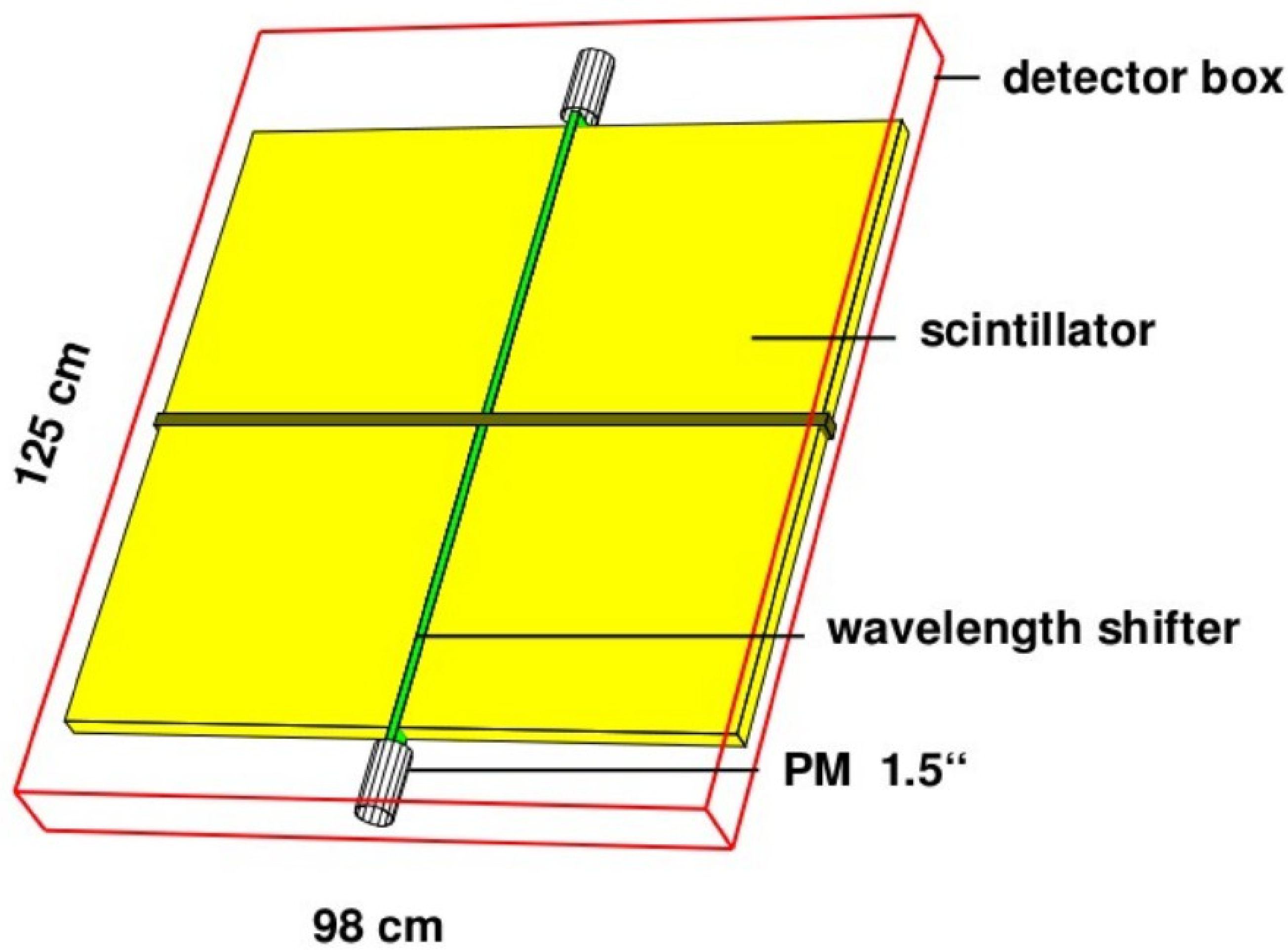
Mini-KASCADE scintillators



PM/PMT = Photomultiplier tube

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electronics upgrade – main goals, use cases

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Main goals:

- a modular, scalable, easy to set up detector array:
  - minimize size of data acquisition (DAQ) electronics
  - minimize data per event → use single-board computer (like a Raspberry Pi)
  - minimize size of high voltage supply
  - avoid cables where possible

Use cases:

- mini detector array for outreach projects (currently used in Stuttgart)
- trigger stage
- veto detector for neutrino experiments
- calibration of other detector arrays (AugerPrime, Gen2 IceTop, …)

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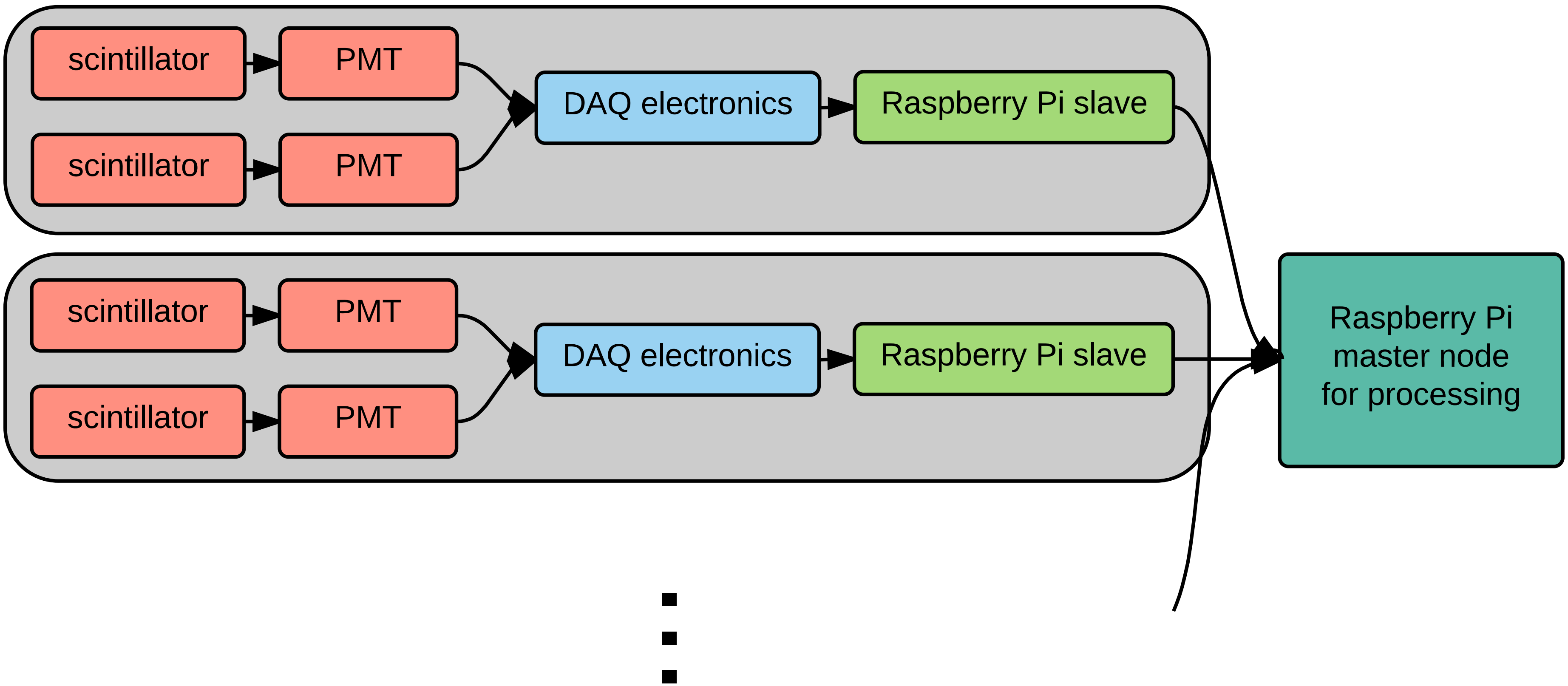
basic setup for electronics upgrade



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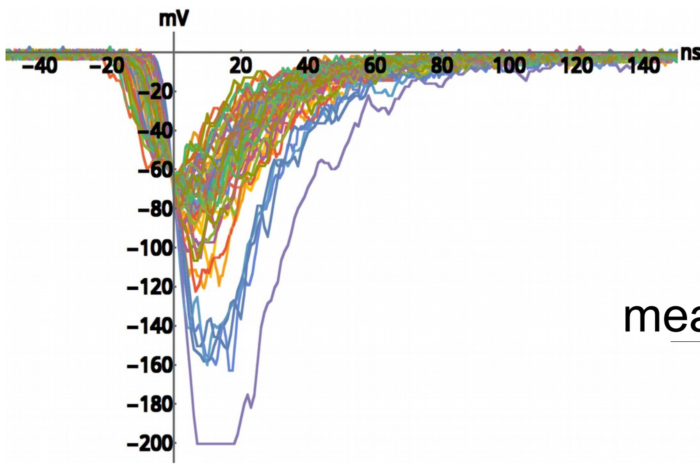
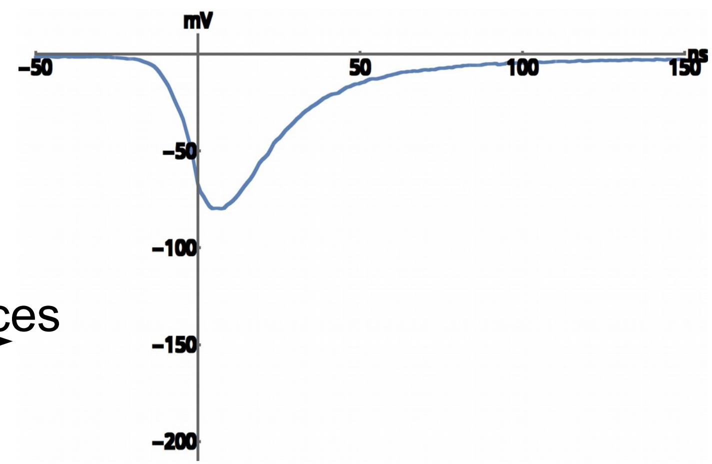
DAQ - measurement requirements – example dataset



mean of 50 traces



Overall requirements:

$$t_{rise} \approx 10 - 40\, ns$$

$$t_{width} \approx 50 - 100\, ns$$

$$f_{max} \approx 30\, kHz$$

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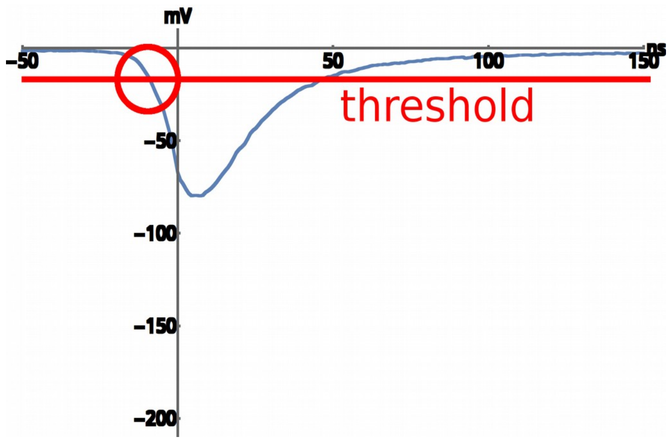
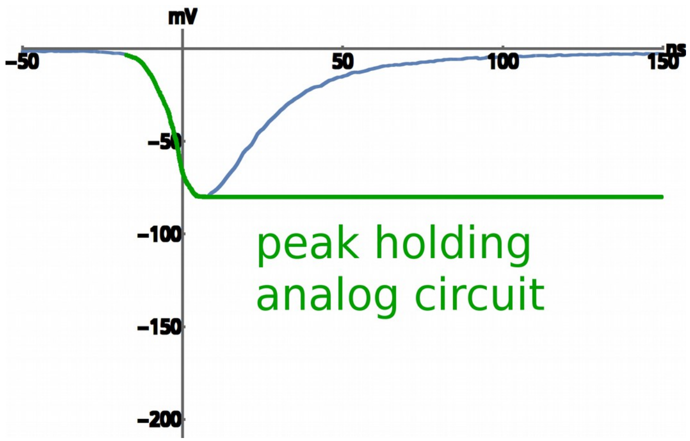
DAQ - data reduction

basic idea:
pulse shape nearly identical for all measured pulses
→ reduce pulse data to one **timestamp** + **peak amplitude**

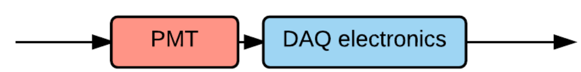


external clock + TDC → **timestamp**



peak ADC → **peak amplitude**
(no need for fast ADC)

ADC = analog to digital converter
TDC = time to digital converter



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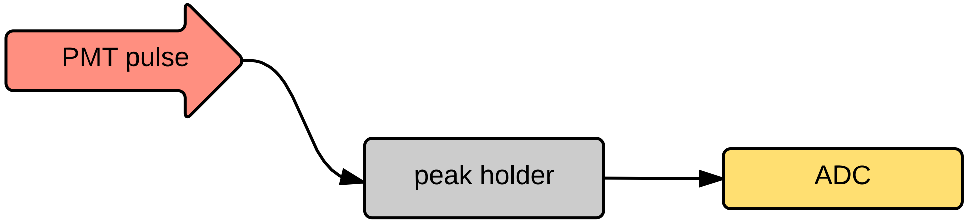
DAQ - data acquisition - concept



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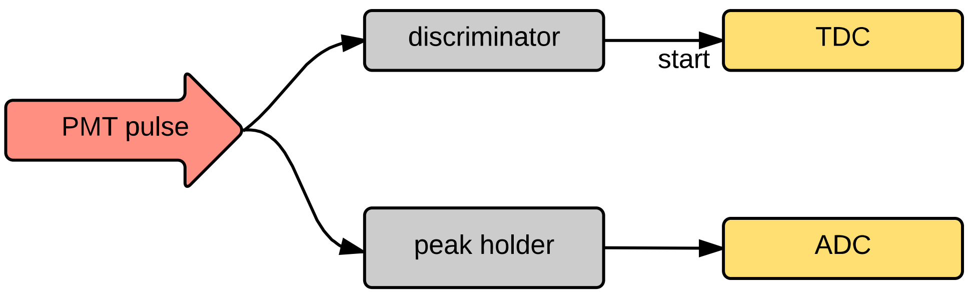

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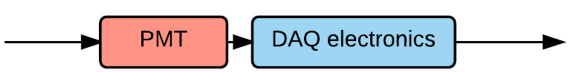

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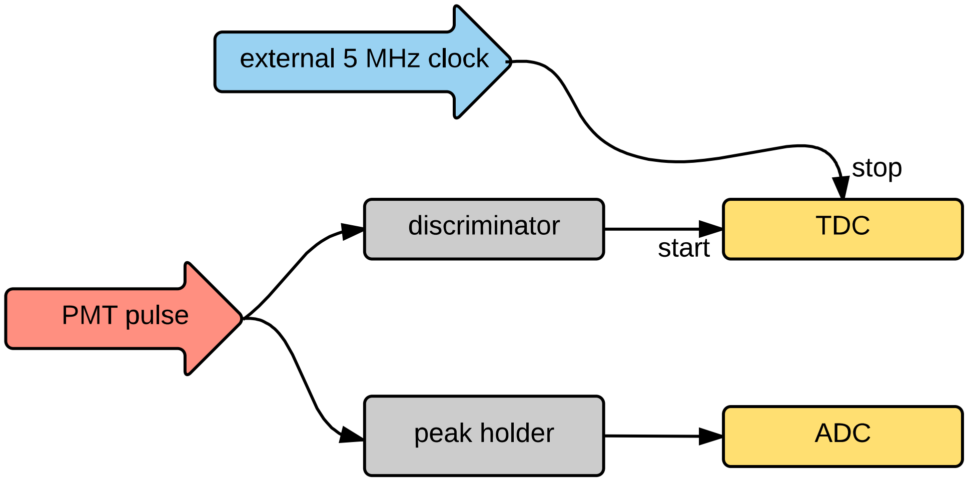

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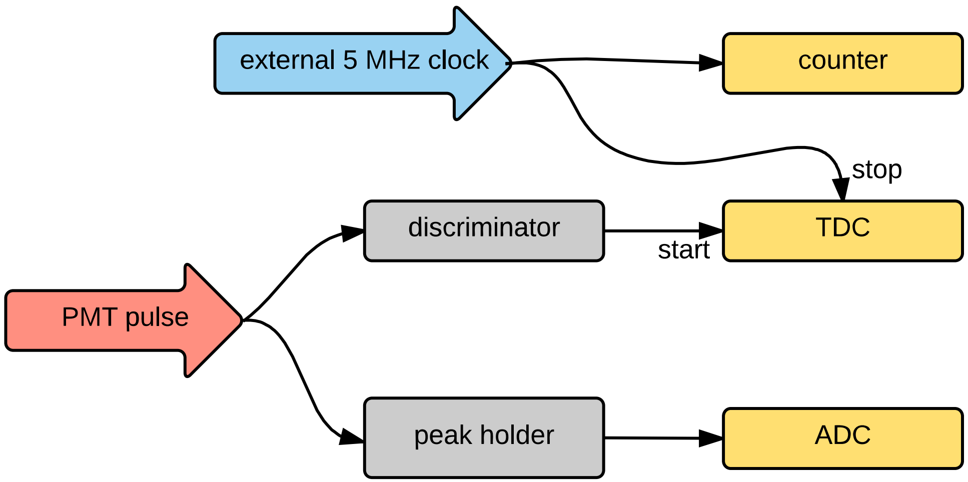

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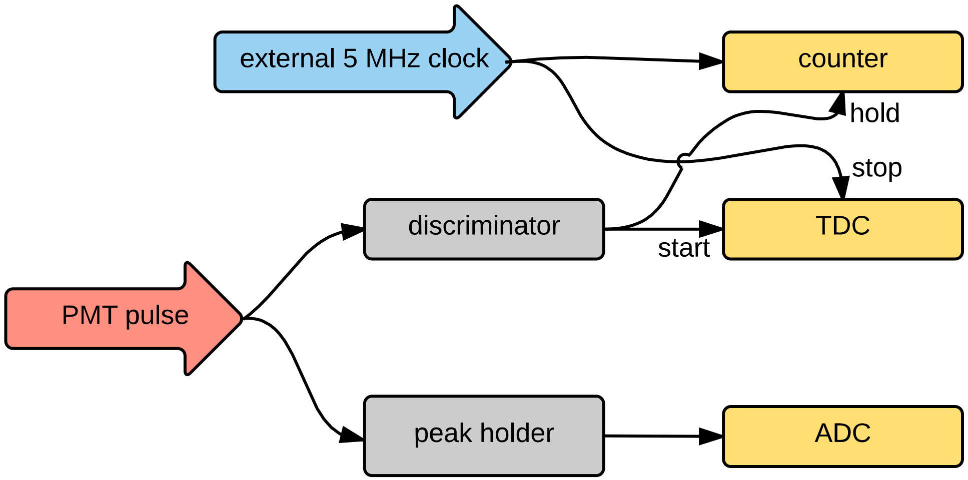

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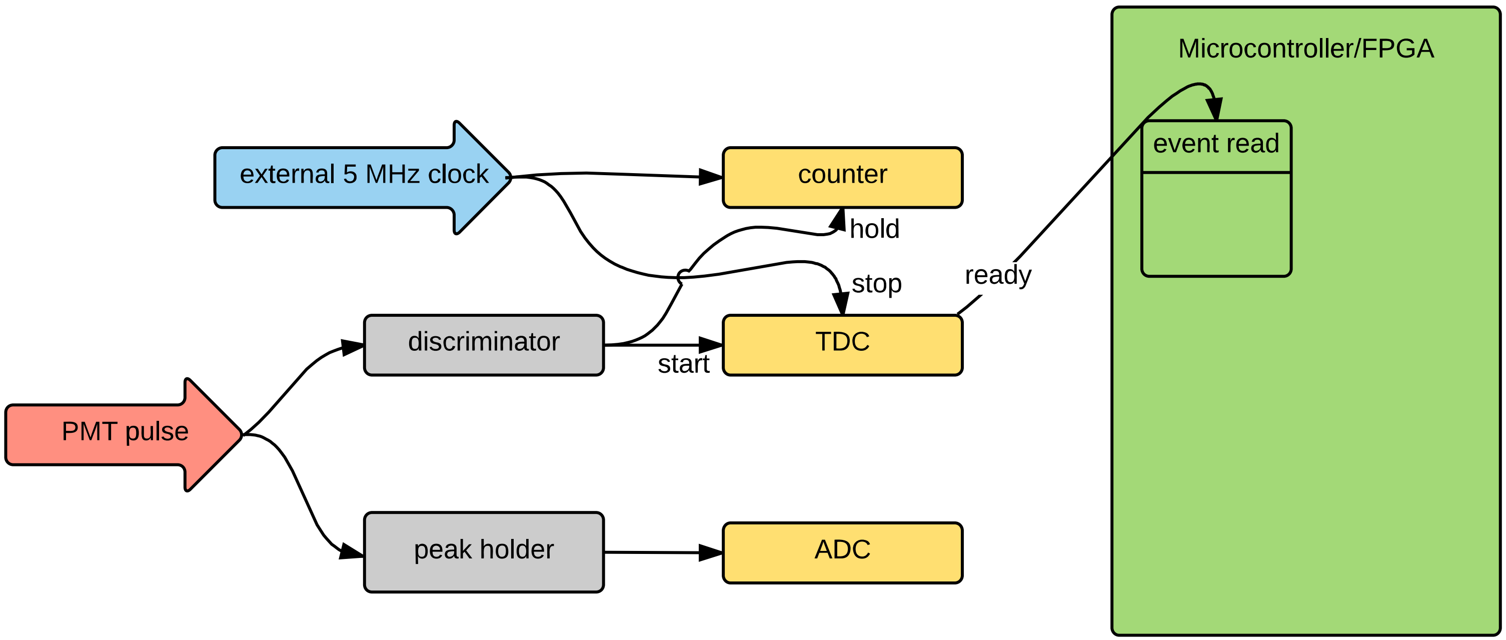

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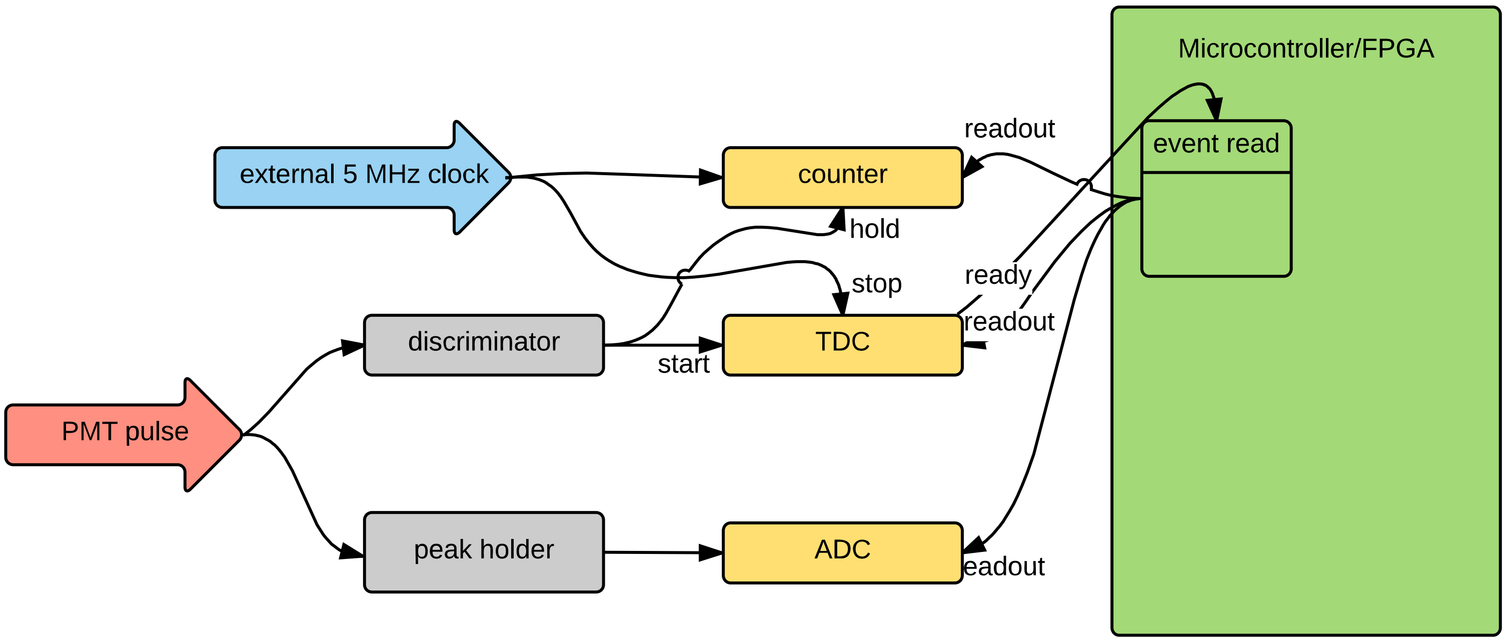

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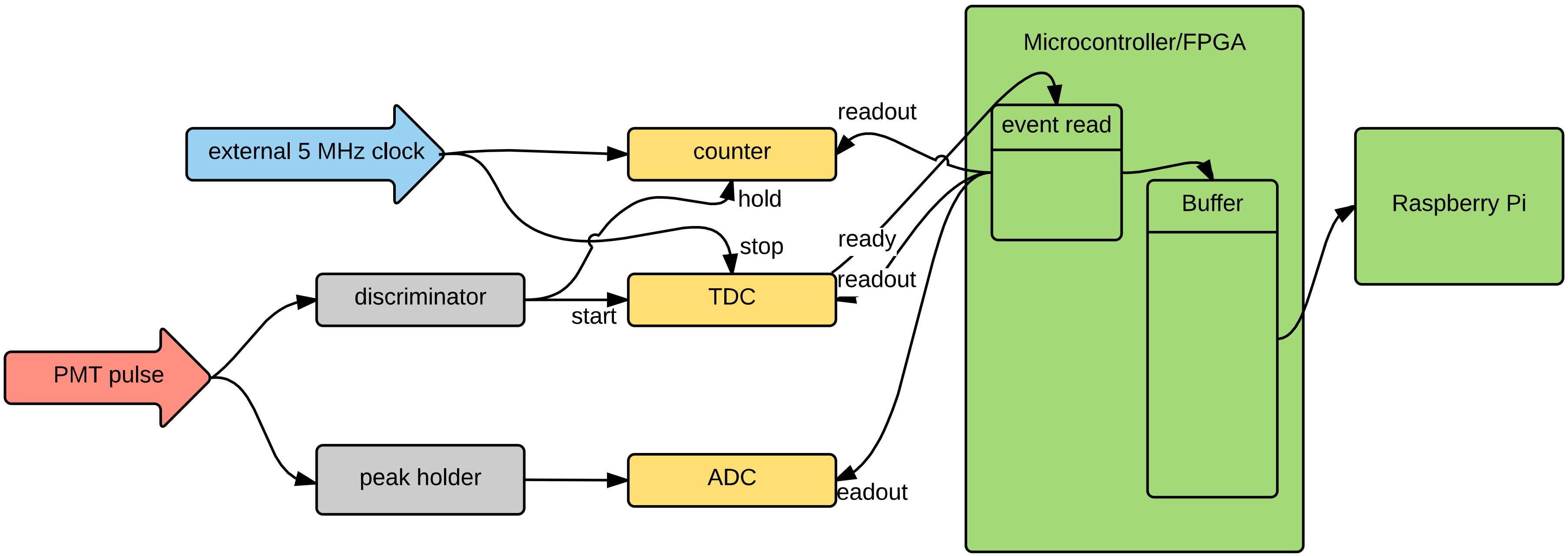

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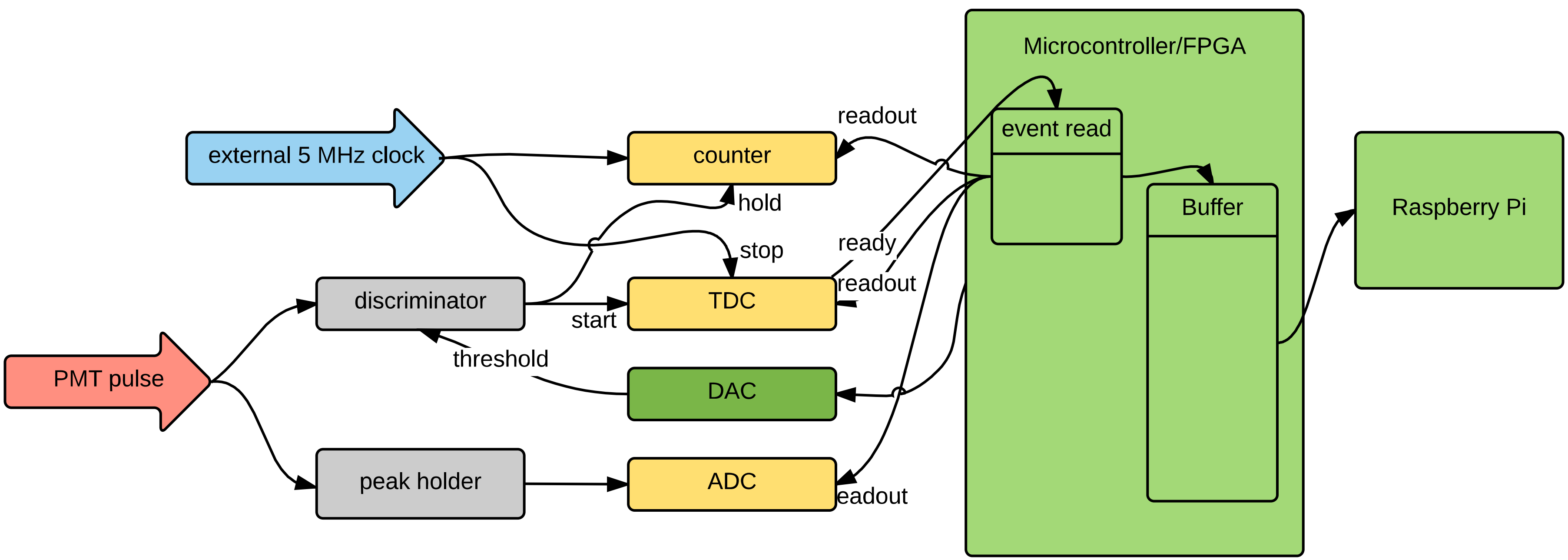
DAQ - data acquisition – concept – one channel



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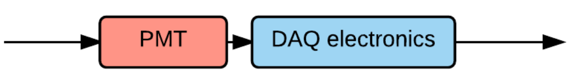

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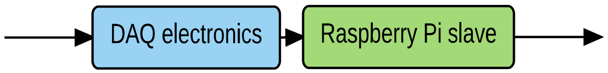
DAQ - data communication

(rough) event size estimation:
16 Bit TDC + 32 Bit clock counter + 16 Bit ADC = **8 Bytes per event**

max. data rate estimations:
2 * 30 kHz * 8 Bytes = **480 kBps** **(+ overhead)**

available communication methods to Raspberry Pi:
- **I2C:** max speed **~50kBps**
- **SPI:** max speed: **~2MBps**
- **USB** (FTDI: SPI->USB)**:** max speed: **~1,5MBps**

→ **USB preferred:**
slower and more complex on the electronics side,
but easier to port to different setups
(e.g. exchange Pi for PC/Smartphone/...)



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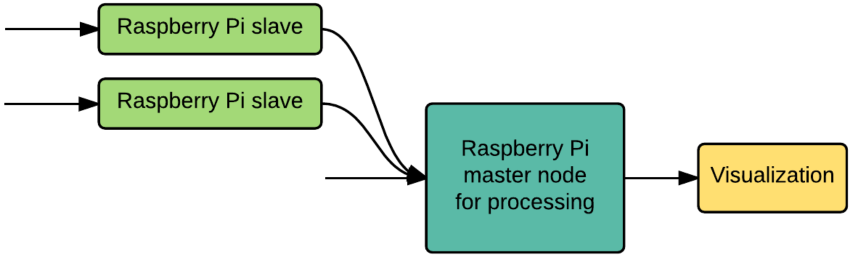
master node

- collection of slave data
- data analysis: e.g. calculation of shower direction, etc.
- synchronization of slave clocks, counters
  - auto-calibration of cable lengths
- maybe visualization of data



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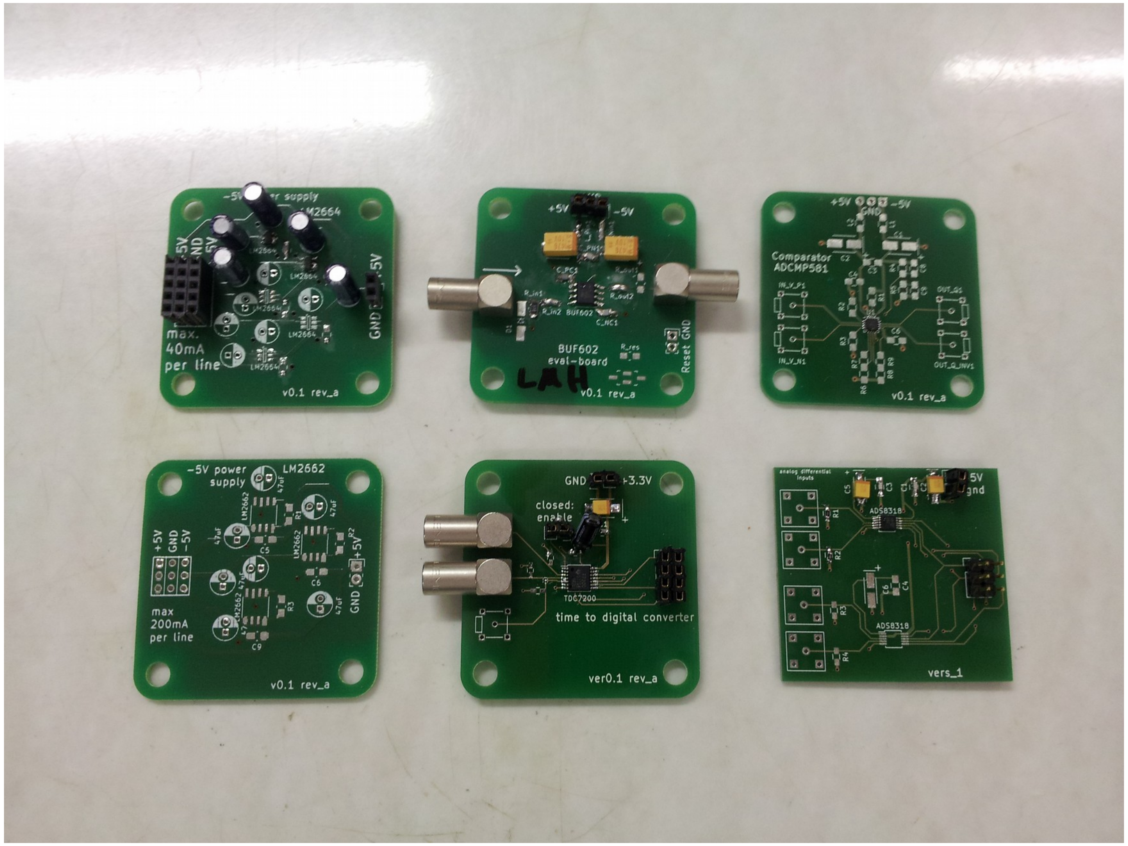
development plan

- first: separate PCBs for every stage of the DAQ board
- later: combine everything on one PCB



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current status

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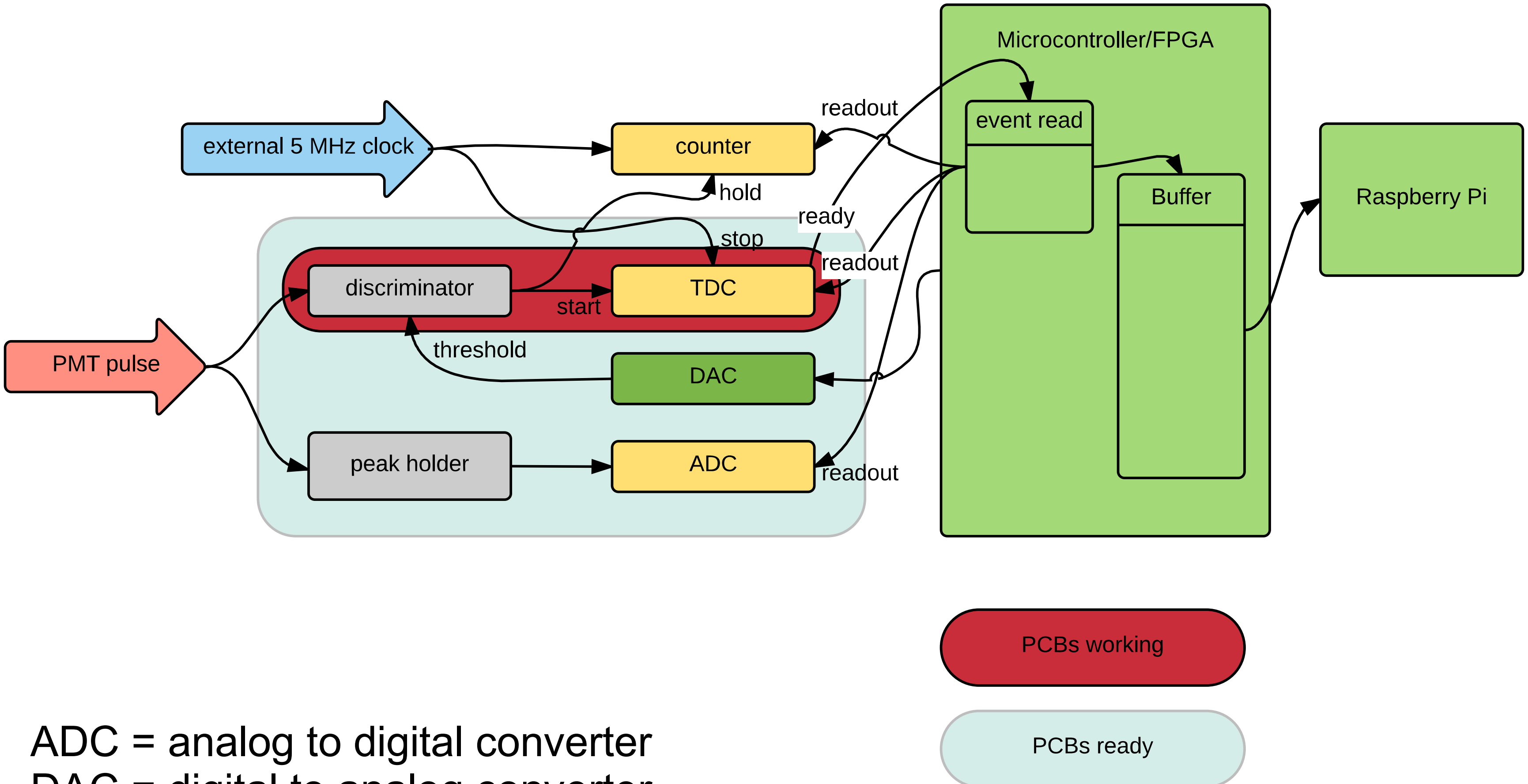

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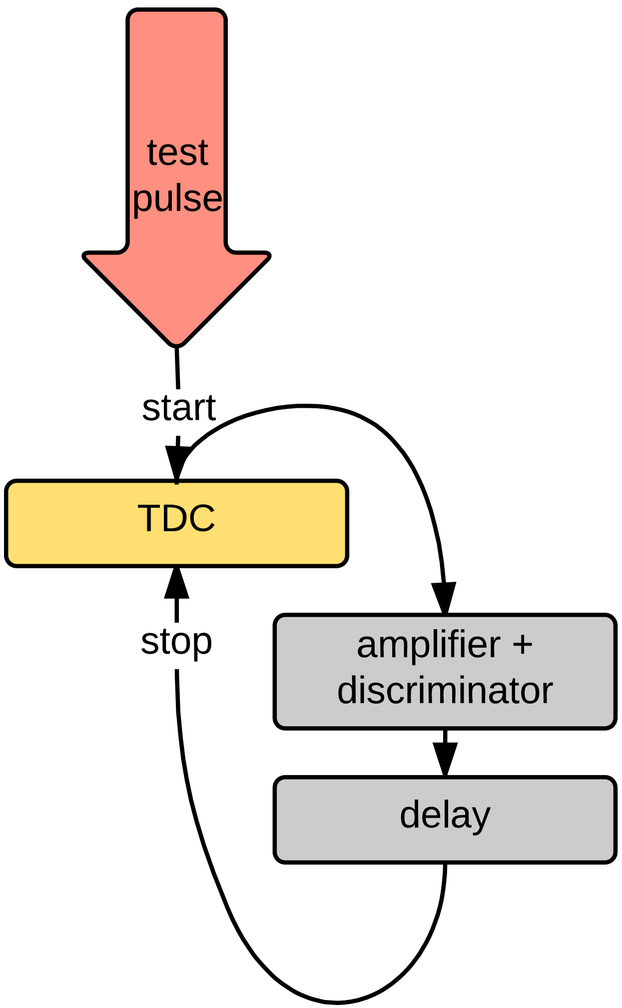
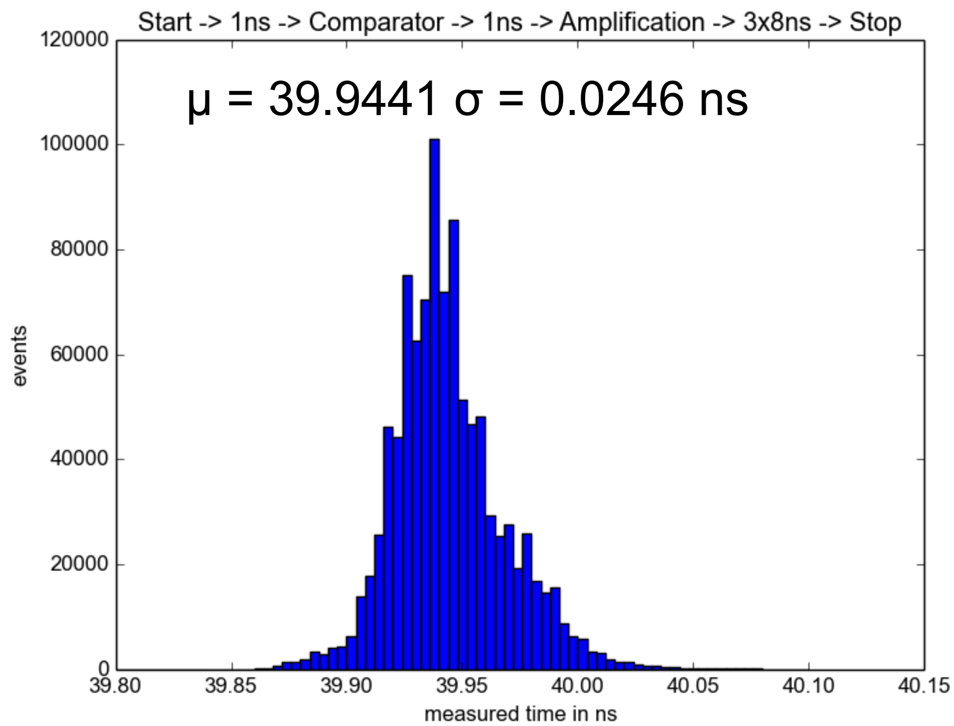
current status: TDC – precision testing





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open questions

- clock generation/distribution
  - GPS clock (accuracy insufficient)
  - clock distribution by cables
    - separate clock line via coaxial cables
    - white rabbit project (synchronous Ethernet used by CERN)
    - using additional pairs in Ethernet cables (100Mbit uses only 2 of 4 pairs)
- MCU/buffer layer between ADC/TDC/Counter and USB connection
  - microcontroller (pros: cheap, easy development - cons: maybe too slow)
  - FPGA (pros: fast DAQ possible – cons: expensive, more complex in development)

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Thank you!
Any Questions?

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