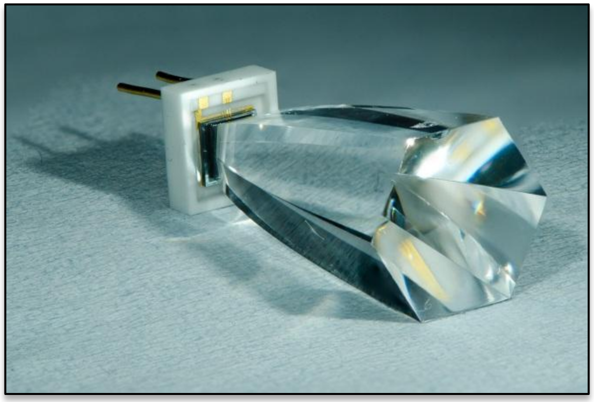
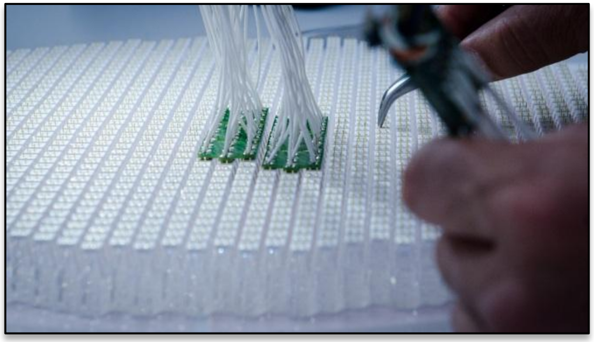
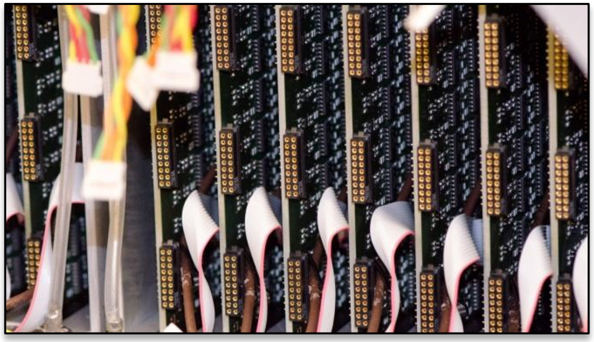
G-APDs in Cherenkov astronomy: the FACT camera

Th. Krähenbühl for the FACT collaboration

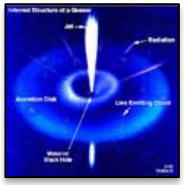
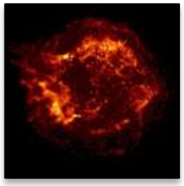
6th International Conference on New Developments in Photodetection

Lyon – France, July 4–8, 2011

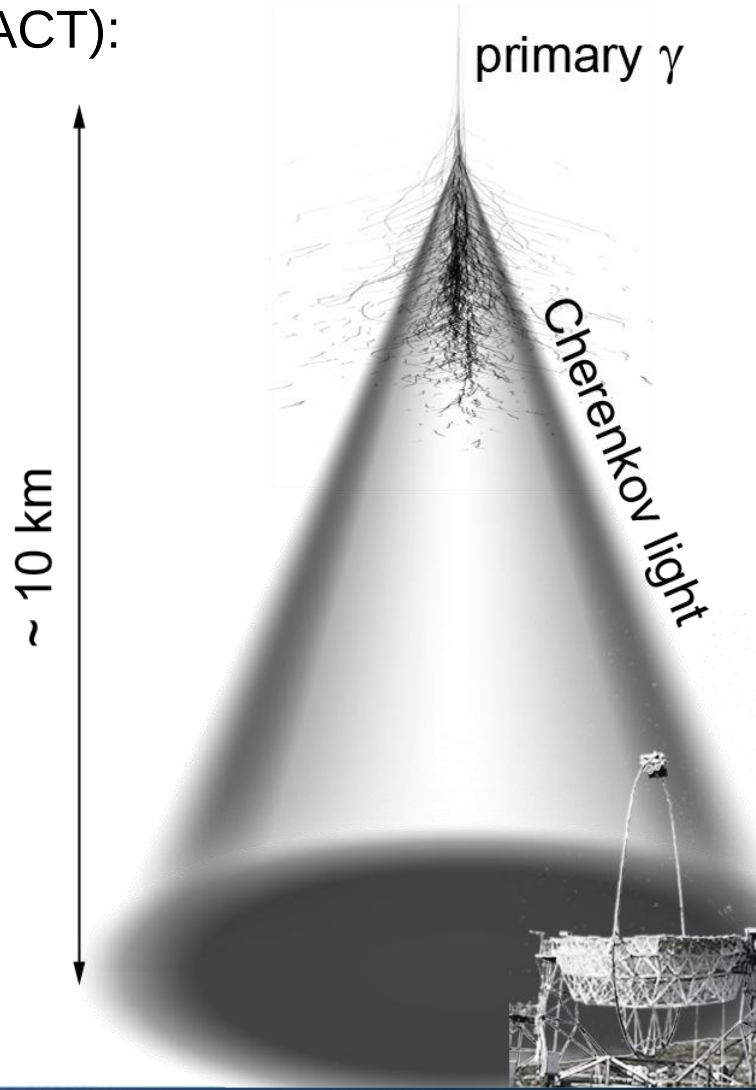
What is the camera for?

Imaging Atmospheric Cherenkov Telescopes (IACT):

- Some cosmic sources emit photons up to very high energies (50 GeV – 50 TeV)

- When those photons hit the earth’s atmosphere…
- …a shower of secondary particles is produced…
- …which emit Cherenkov light…
- …which is detected by IACTs on the ground.



The First G-APD Cherenkov Telescope (FACT) Camera

G-APD & Winston Cones

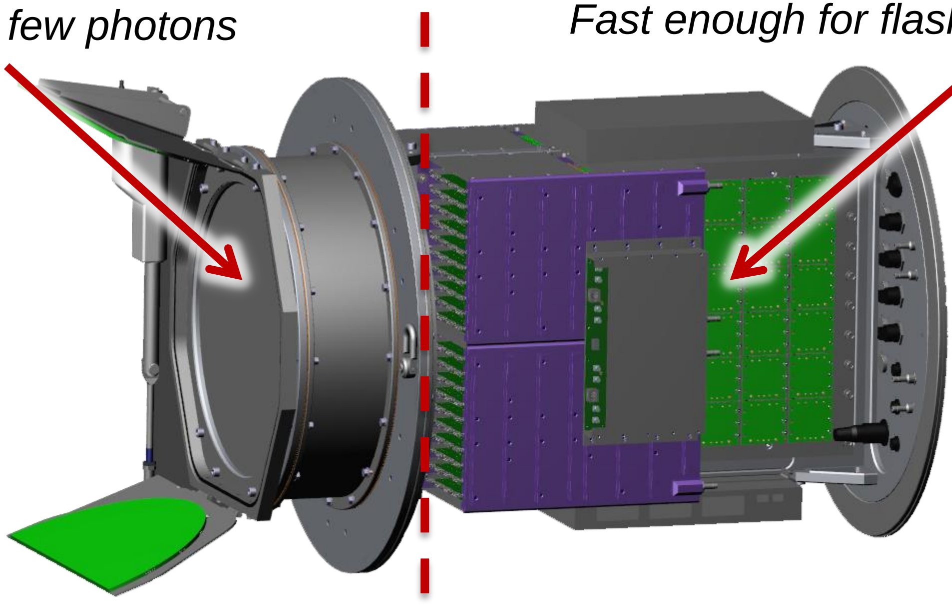
→ Sensor compartment

Sensitive to few photons

Integrated digitisation based on the DRS4 chip

→ Readout electronics

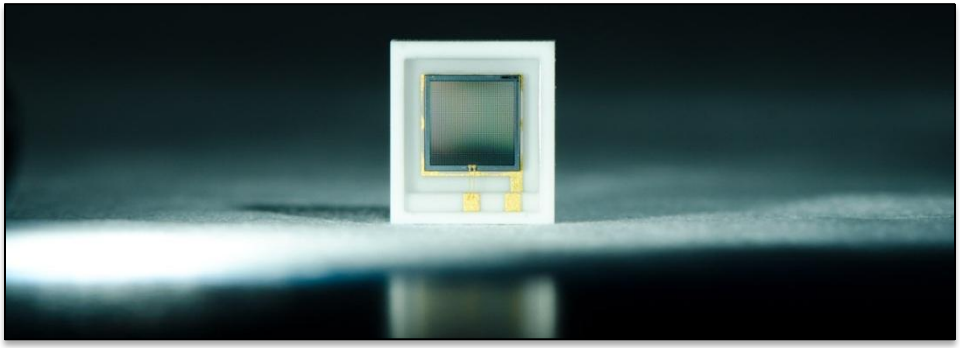
Fast enough for flashes of few nanoseconds



TU Dortmund ISDC Genève EPFL Lausanne

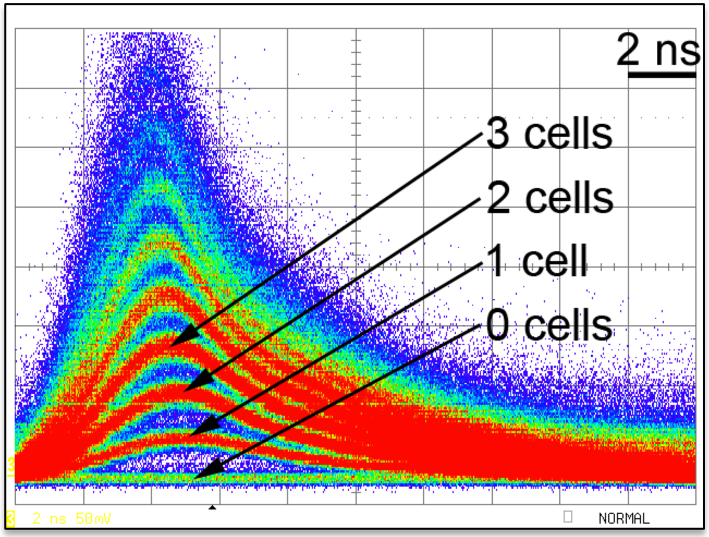
University of Würzburg ETH Zurich

Sensor compartment: G-APDs



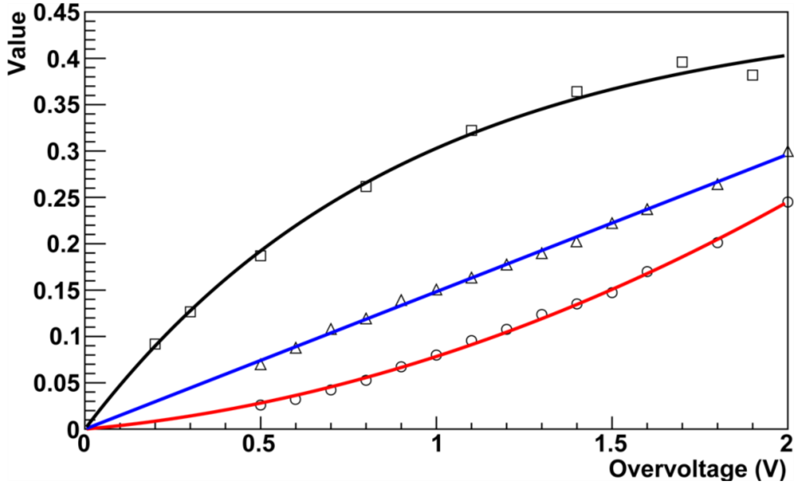
All current IACTs use Photomultiplier Tubes. G-APDs offer:

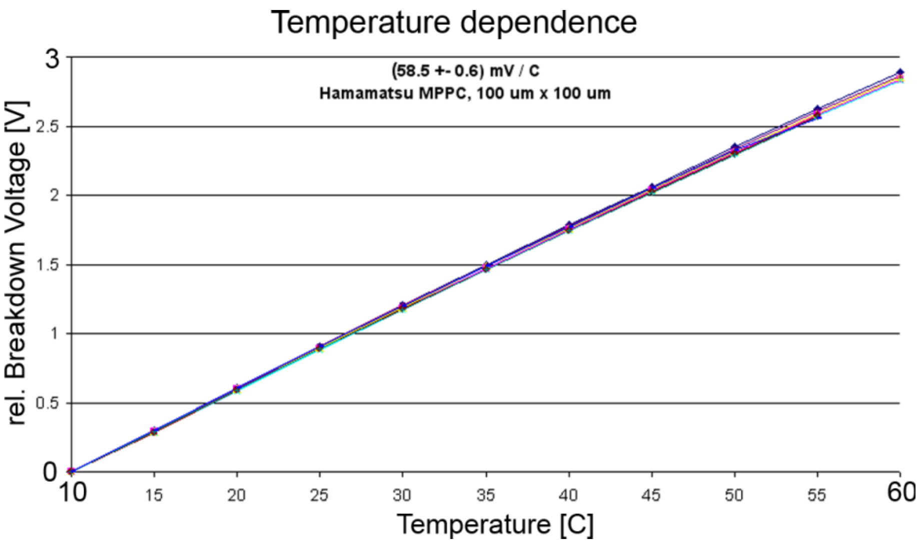
- Advantages in data analysis:
  - Single photon resolution
  - High Photon Detection Efficiency
  - No known ageing
  - Insensitive to magnetic fields
- Advantages for the construction:
  - No need for high voltages (~70 V vs. kV)
  - More robust to light exposure
  - Mechanically more robust



Hamamatsu S10362-33-050C

Sensor Compartment: G-APDs (2)





- Many parameters of G-APDs depend strongly on the applied bias voltage: Photon detection efficiency – Gain – Crosstalk probability
- Overvoltage = Bias voltage – breakdown voltage
- The breakdown voltage shows a strong temperature dependence.
- Background light variation: change of the applied bias voltage due to a serial resistor in the readout electronics.

Sensor Compartment: G-APDs (3)

Stabilised light pulser

Bias voltage adjustment

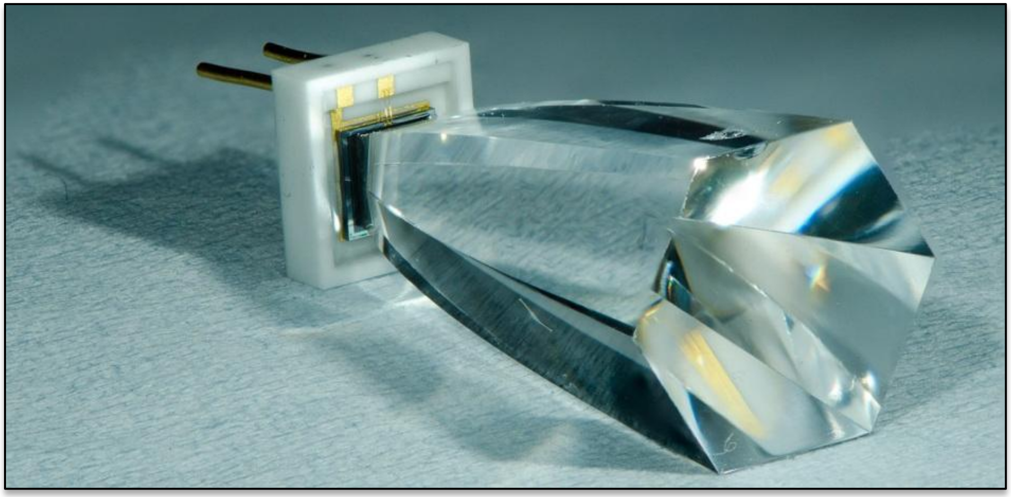
G-APD detects the pulses

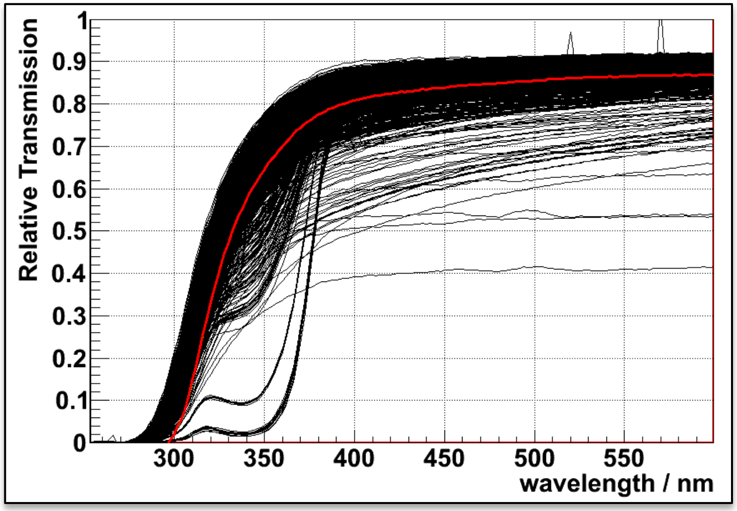
Online analysis of the pulses
(PC-based)

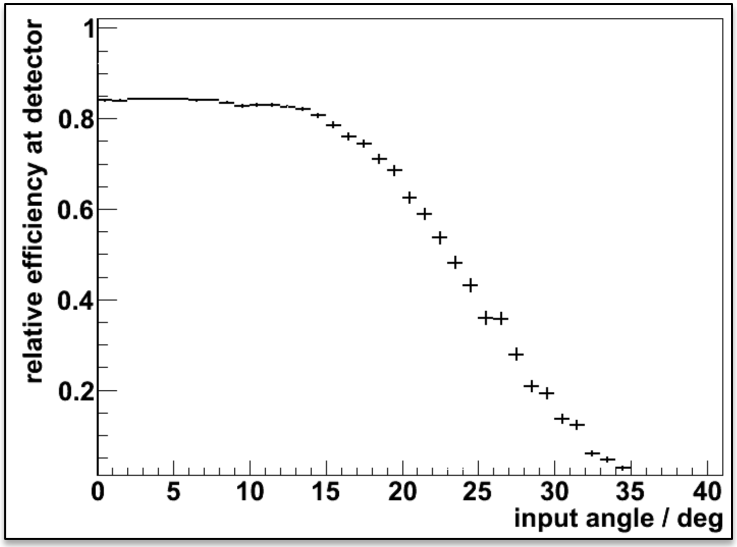
Light pulser stabilisation (ie. the calibration of the calibration system):

- PIN-diode (temperature-independent) in the light pulser box
- Long-term stability: dark night runs with single photon resolution

Sensor compartment: Solid (Winston) Cones



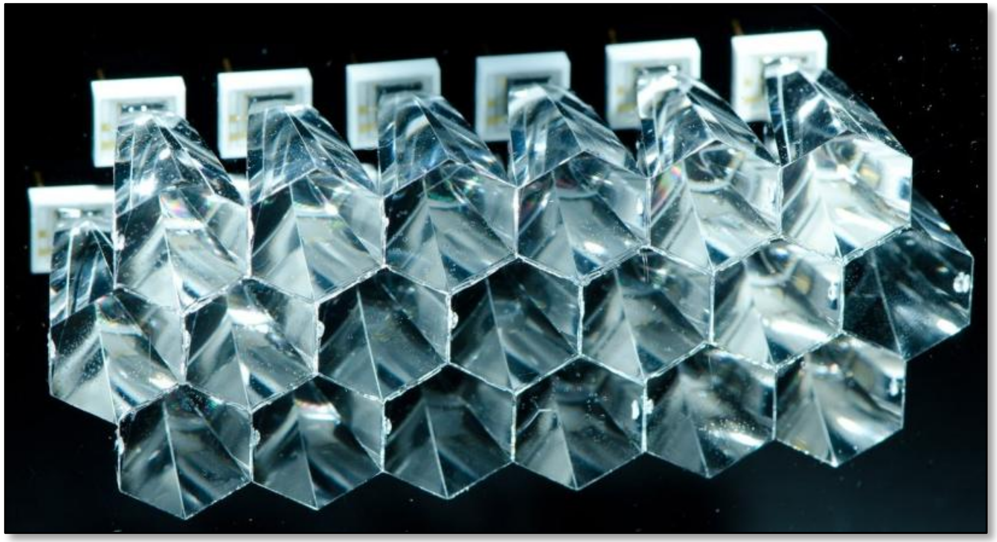


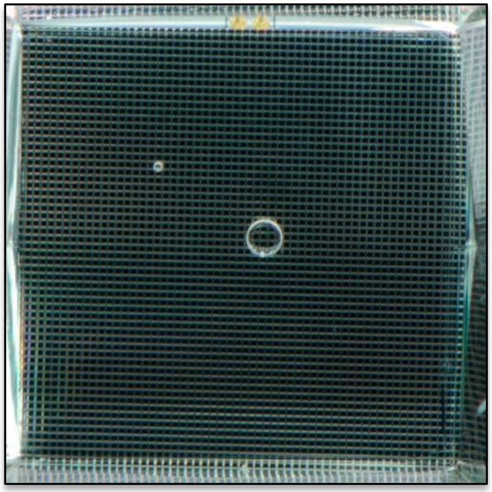


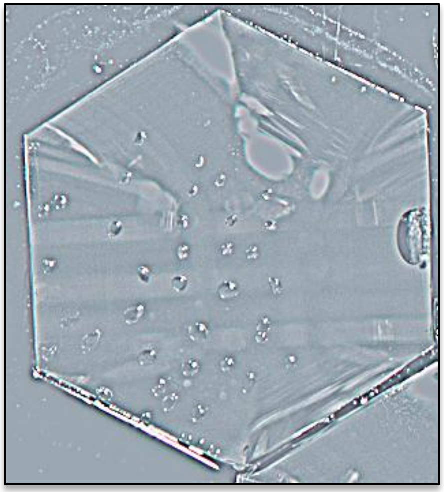
- Solid vs. open cones:
  - Higher concentration ratios A_in / A_out
  - Transmission losses vs. reflexion losses
- Our cones:
  - UV-transparent PMMA, injection moulded
  - Hexagonal entry window, square exit
  - Area concentration (78 mm^2 to 7.8 mm^2)
  - Cutoff angle: approx. 20°

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Sensor compartment: Glueing experience





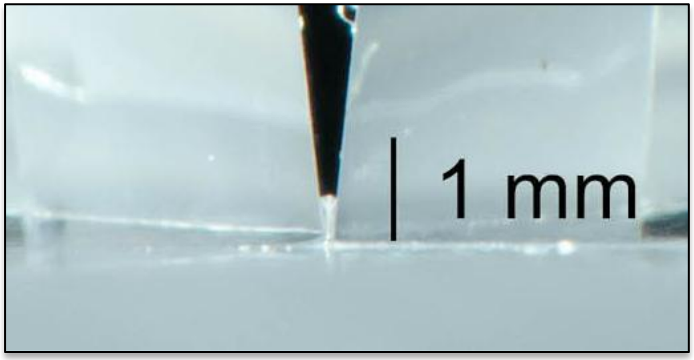


Two glueings:

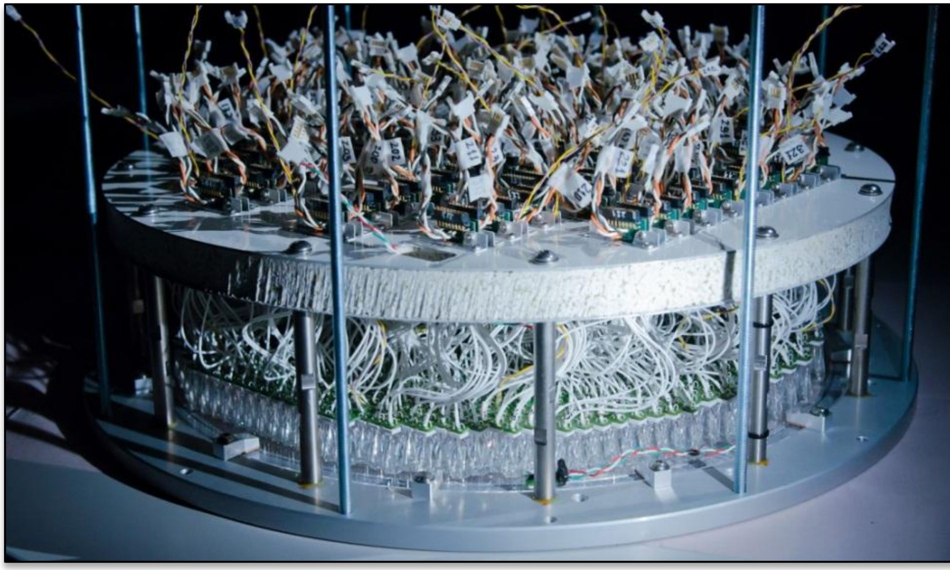
G-APD – Cone – Window

Studied & resolved issues:

- Bubbles
  - Very careful cleaning necessary
  - Glue viscosity crucial
- Capillary force
- Mechanical stability

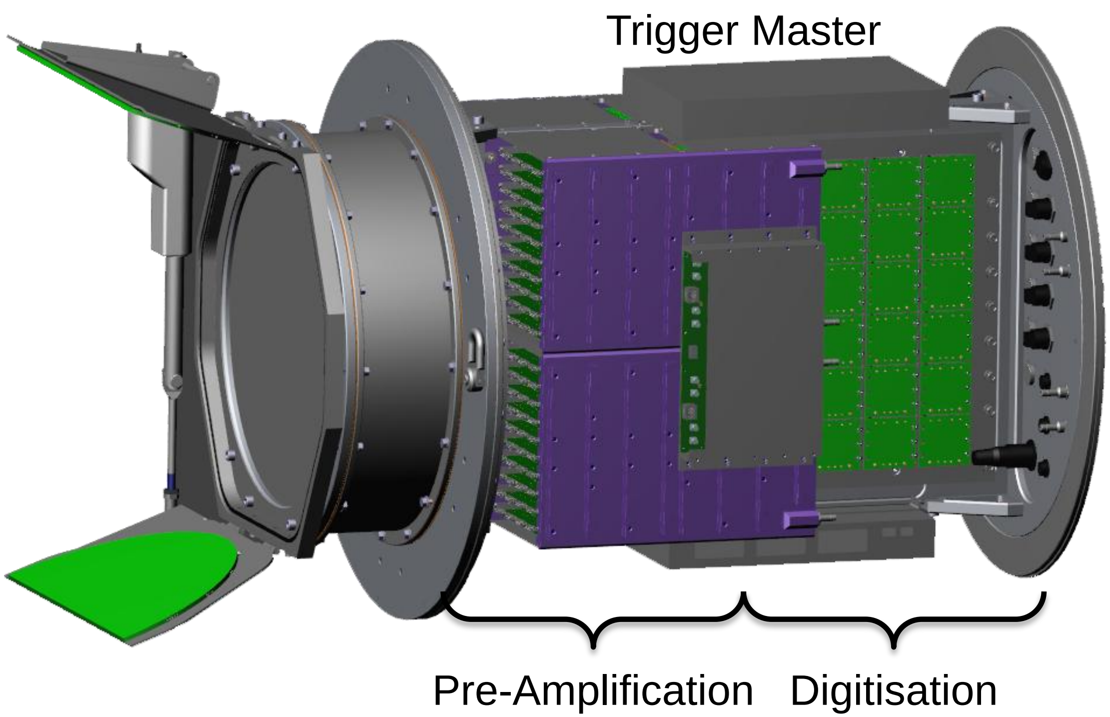


Sensor compartment: Status



- All 1440 cones equipped with a G-APD and glued to the front window
- Electronic contacts soldered
- Mechanical integration finished

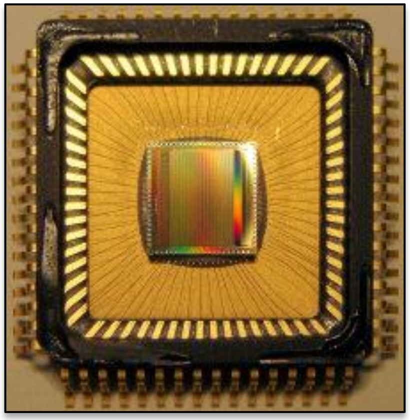
Electronics: Design



- The complete electronics is integrated: compact and power-saving design
- Trigger uses a threshold on analog sums of 9 pixels
- Digitisation of all 1440 channels with 2 Gigasamples per second
- Readout via Ethernet

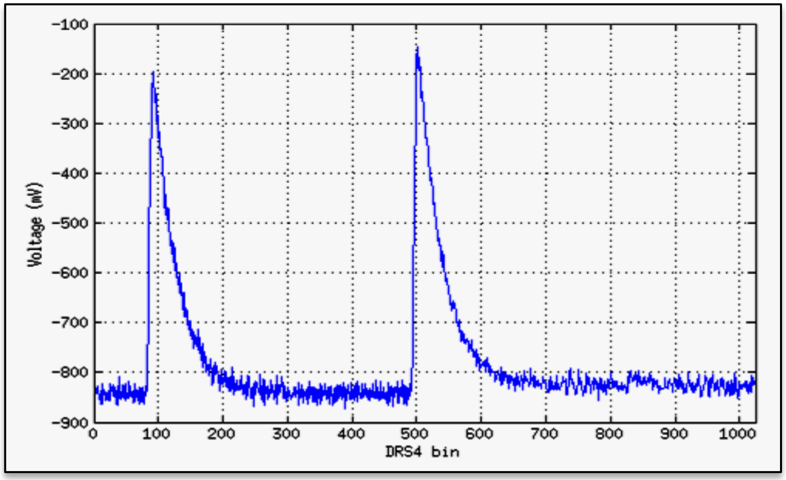
Electronics: DAQ system

- Based on the DRS4 chip
  - Switched capacitor array developed at PSI (CH)
  - 9 channels per chip, 1024 samples each
  - 11.5 bit resolution
  - 700 MSPS – 5 GSPS
  - Region Of Interest adjustable to reduce readout time and data volume



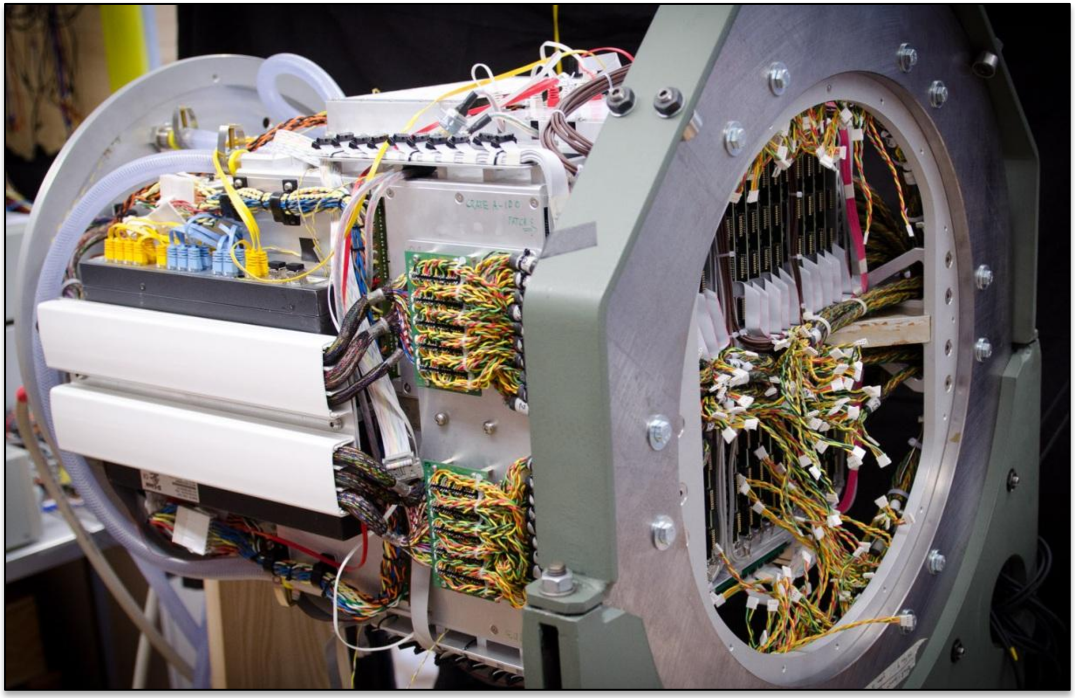
drs.web.psi.ch

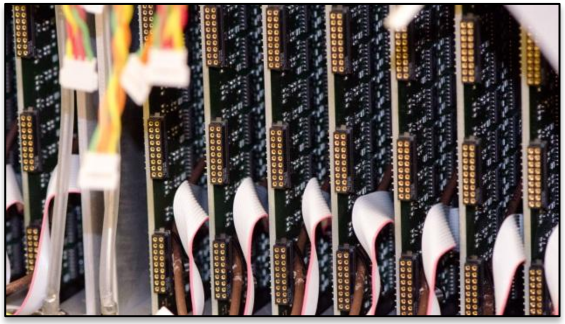
- Dynamic Range ~250 photons / pixel
  (< Dyn. range of the G-APD with 3600 cells)
- Amplitude Resolution < 0.5 photons
  (for small pulses)
- Timing resolution < 500 ps



LED pulses with FACT DAQ (500 ns)

Electronics: Status

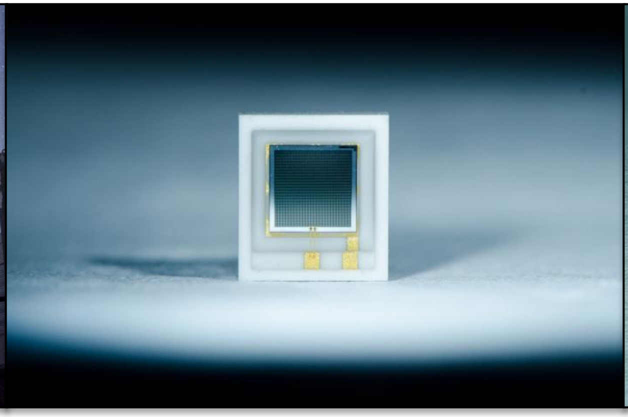


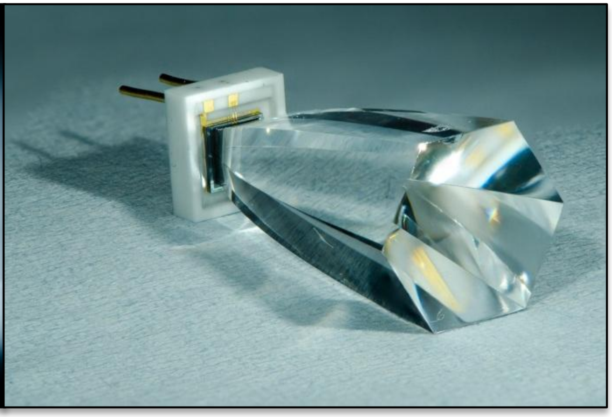


- All boards tested and integrated in the camera
- Full system tests & debugging ongoing
- Readout rate of ~300 MB/s achieved
  (eg. 500 Hz for 1440 pixel, ROI of 200 slices)

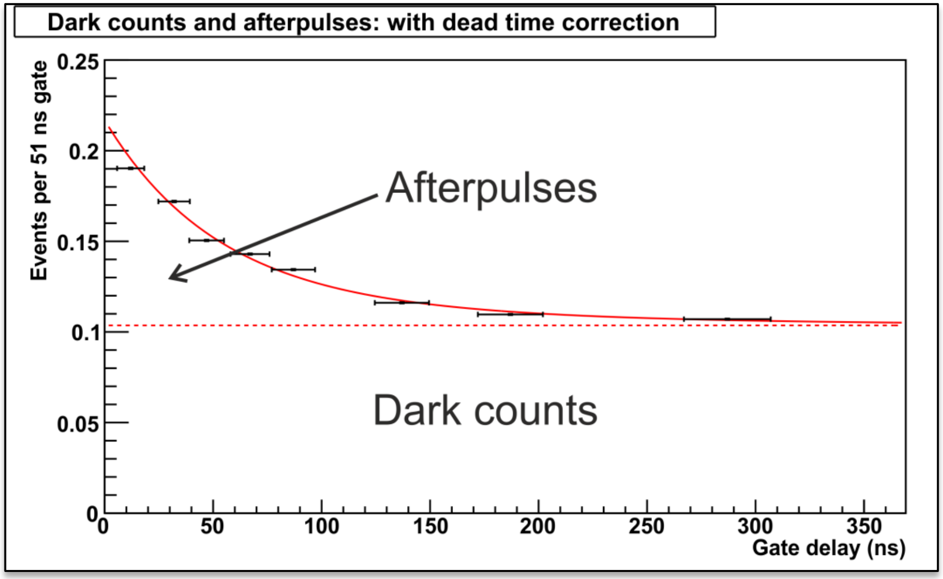
Conclusions

- Design goals achieved
- Final electronics tests ongoing
- Final assembly in July
- Followed by full system tests and the transfer of the camera to the telescope on the Roque de los Muchachos (2200 m a.s.l.), La Palma
- Regular physics observations by the end of the year





Backup: Afterpulses and dark counts



- Afterpulses:
  - Timing: exponentially decreasing probability after initial pulse.
- Dark counts:
  - 5-8 MHz per G-APD
  - Night sky background (NSB) photon rate between 40 MHz and 1 GHz

Backup: Cherenkov Spectrum