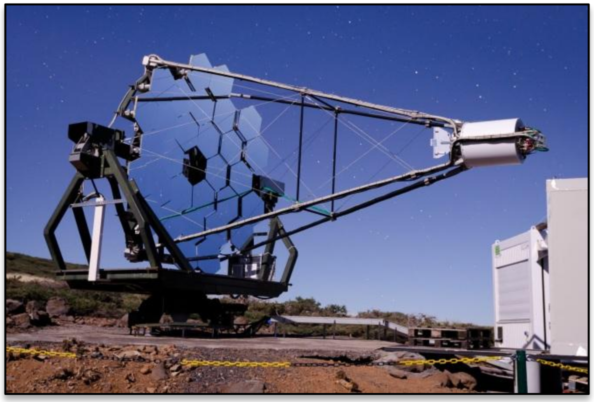
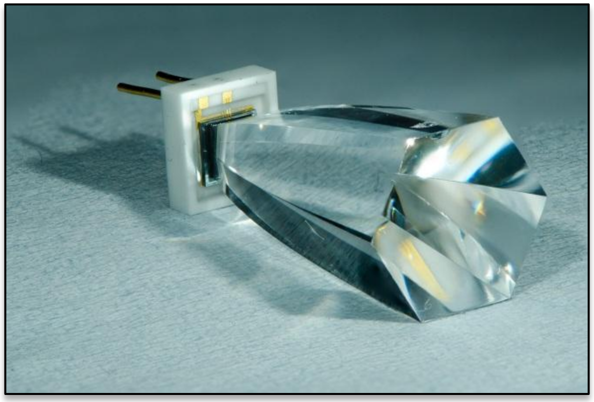
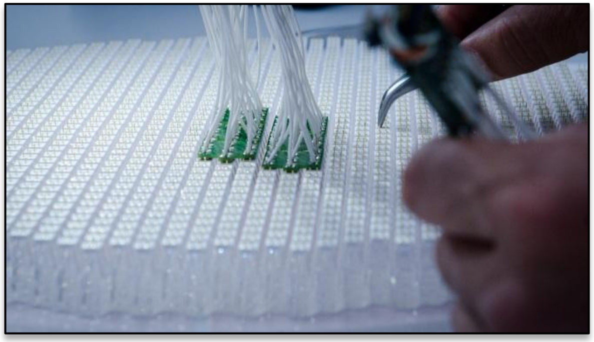
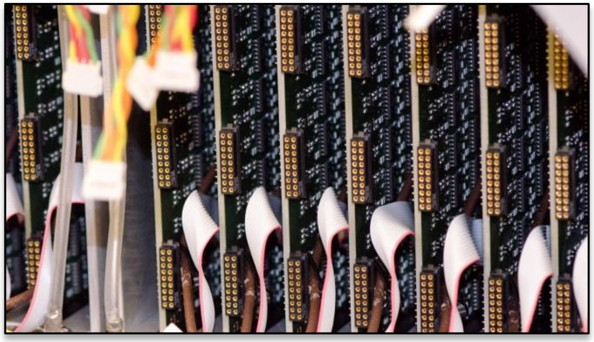
First experience with the FACT camera

FACT: First G-APD Cherenkov Telescope

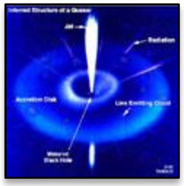
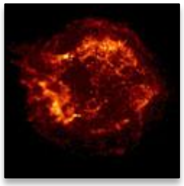
Th. Krähenbühl for the FACT collaboration

PhotoDet2012 - International Workshop on New Photon-detectors

Paris – France, June 13-15, 2012

Imaging Atmospheric Cherenkov Telescopes

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

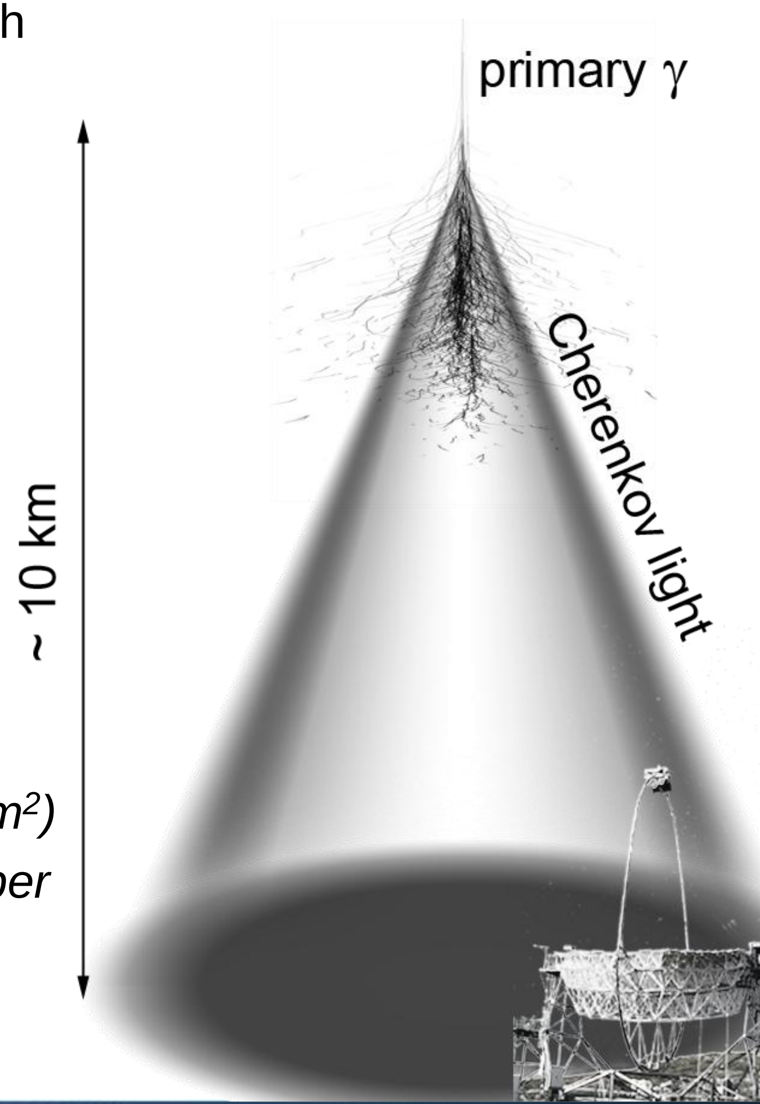



- When those photons hit the earth's atmosphere…
- …a shower of secondary particles is produced…
- …which emit Cherenkov light…
- …which is detected by IACTs on the ground.

→ Short flashes *(few ns)*

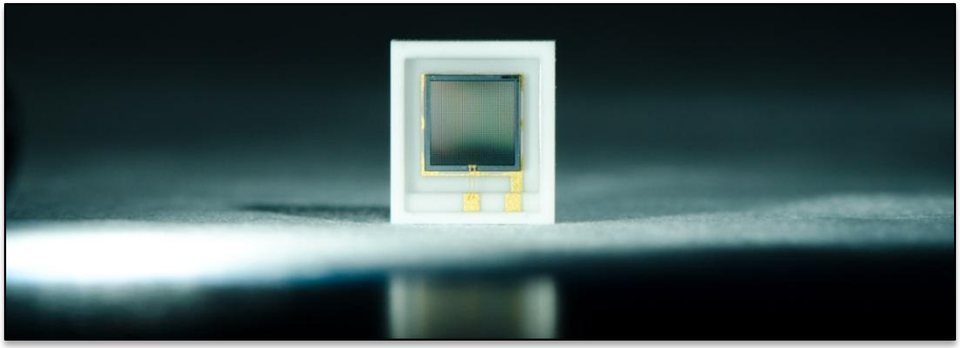
→ …with few photons *(typical shower: 100 photons/m^2)*

→ …in high background conditions *(50 MHz – GHz per pixel)*



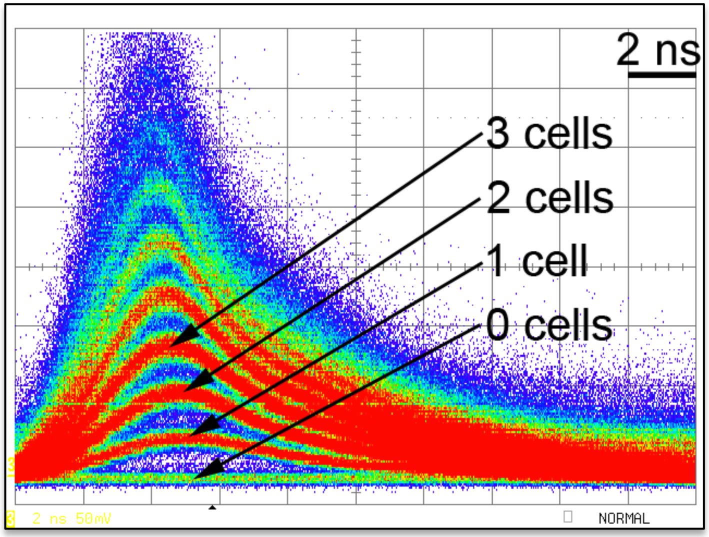
ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Design: why 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

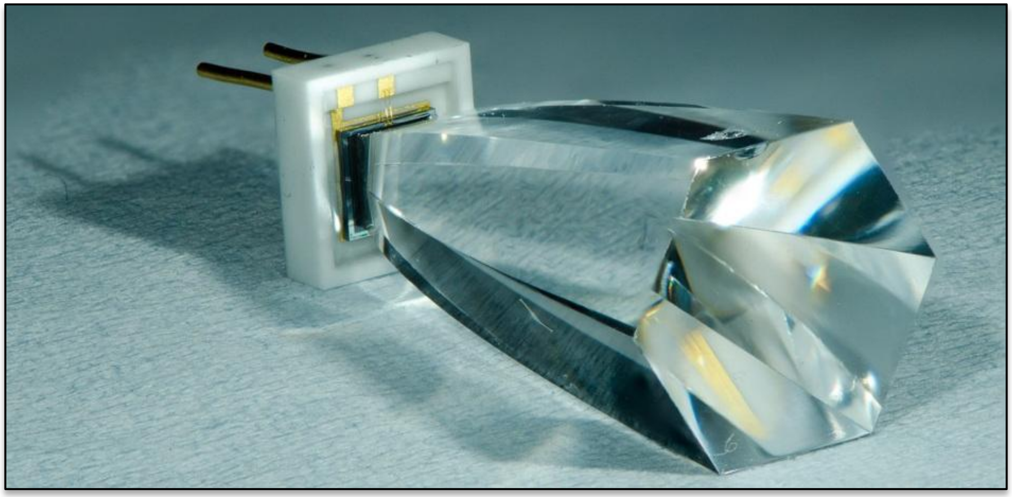


Hamamatsu MPPC S10362-33-050C

Design: light-collecting cones

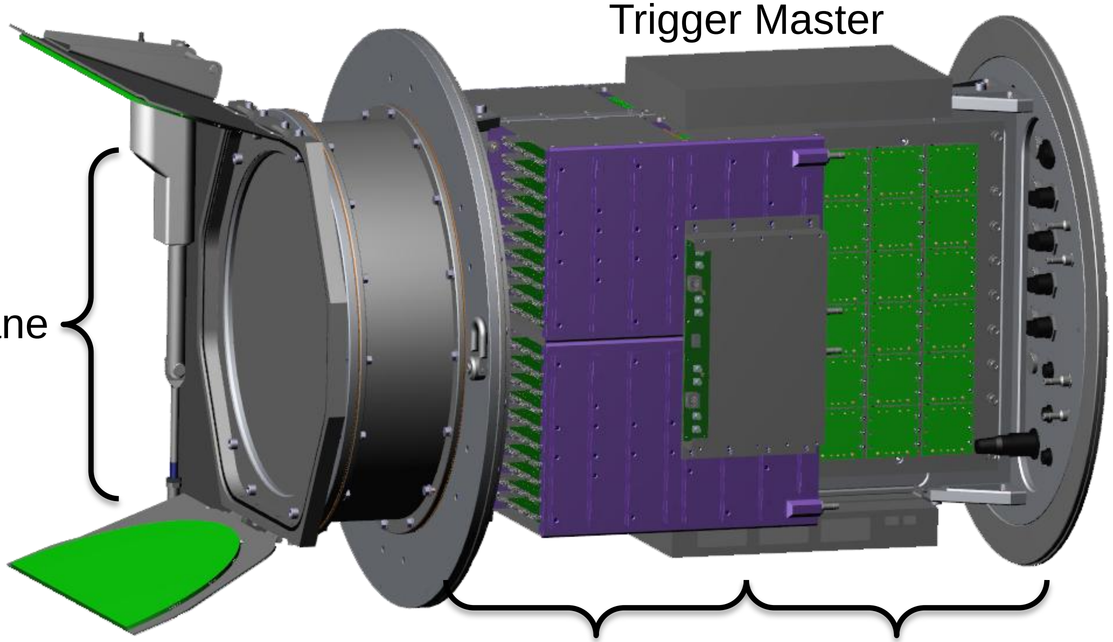
- Solid vs. open cones:
  - Higher concentration ratios A_in / A_out
  - Transmission losses vs. reflection losses
  - Additional design possibilities
- FACT cones:
  - Injection moulded PMMA
  - No surface treatment (e.g. polishing)
  - Hexagonal entry window, square exit
  - Area concentration (78 mm^2 to 7.8 mm^2)

Prototype cones (reflective foil)



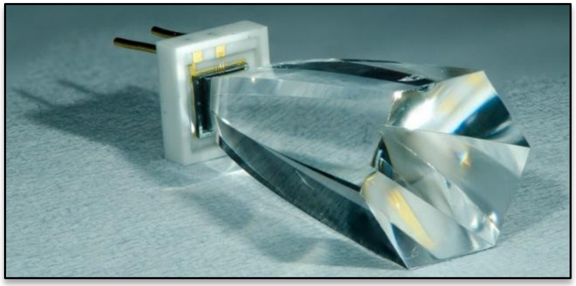
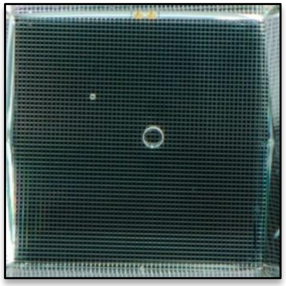
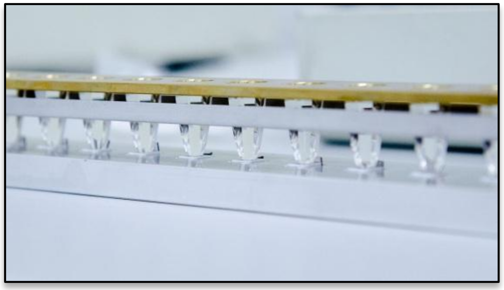
FACT cones: UV-transparent PMMA

Design: the FACT camera

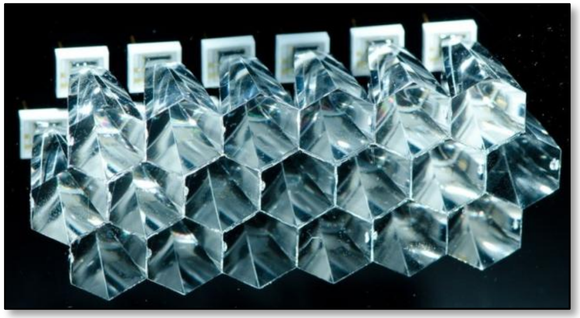
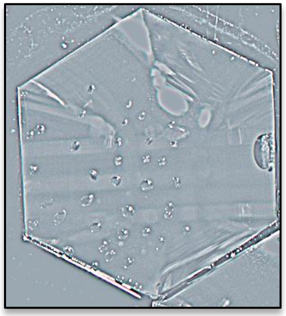
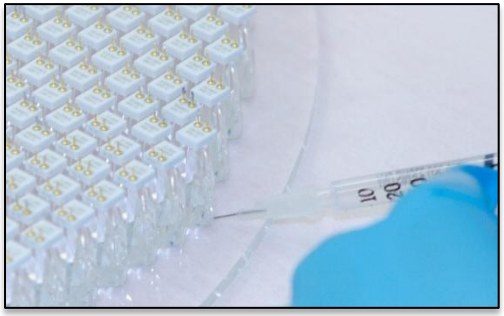


- 1440 G-APDs with light-collecting cones
- Integrated electronics: trigger, pre-amplification and digitisation
  - Trigger logic: threshold on analog sums of 9 pixels
  - Digitisation: using the DRS4 chip

Construction: two gluing joints per pixel

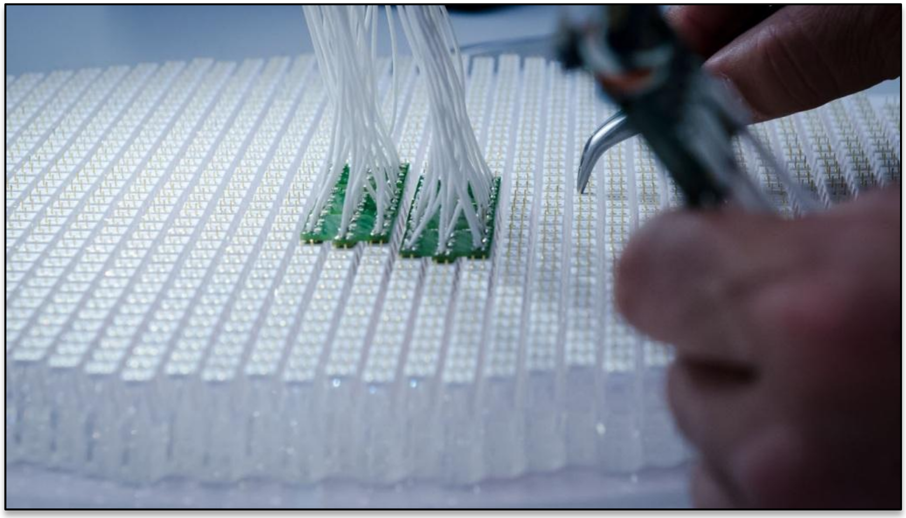
Cone to G-APD: EPO-TEK 301 (Epoxy Technology)

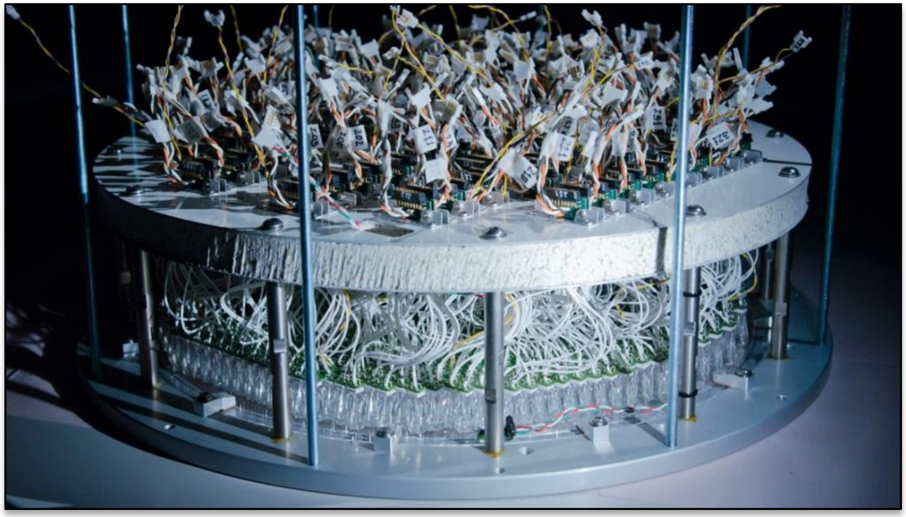
Pixel to front window: Acrifix 1R 9019 Solar (Evonik)

- Avoiding bubbles: very careful cleaning & viscosity-optimized glue
- …but they have anyway little effect on the light transmission...

Construction: sensor compartment

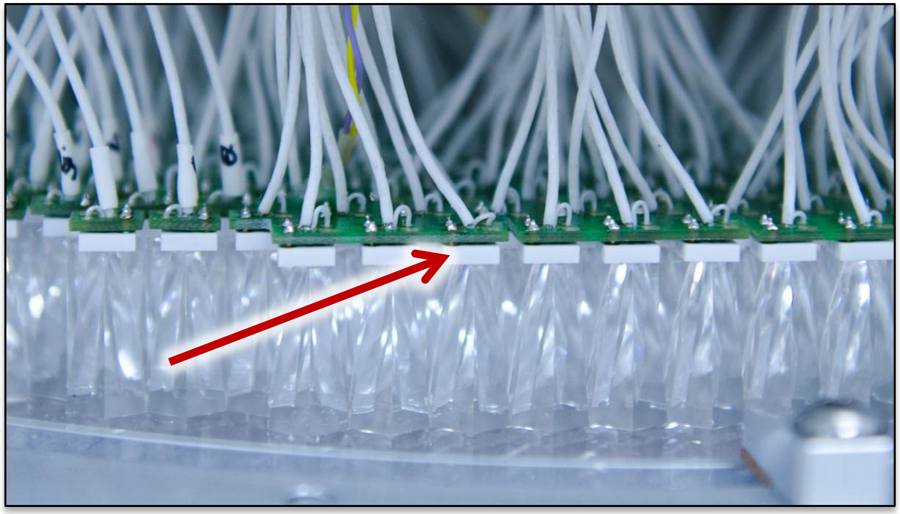


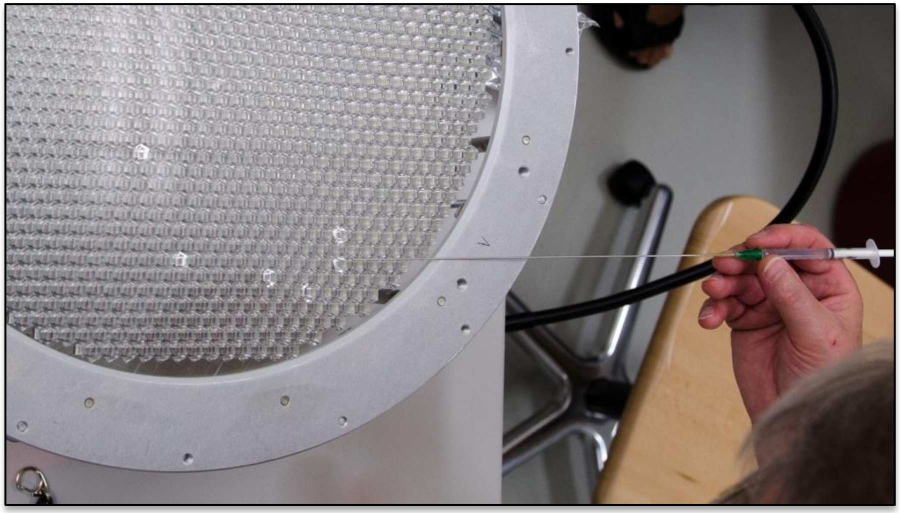
- 1440 pixels were glued onto the front window
- Electronic contacts soldered (groups of 9 pixels)
- Temperature isolation from the electronics installed



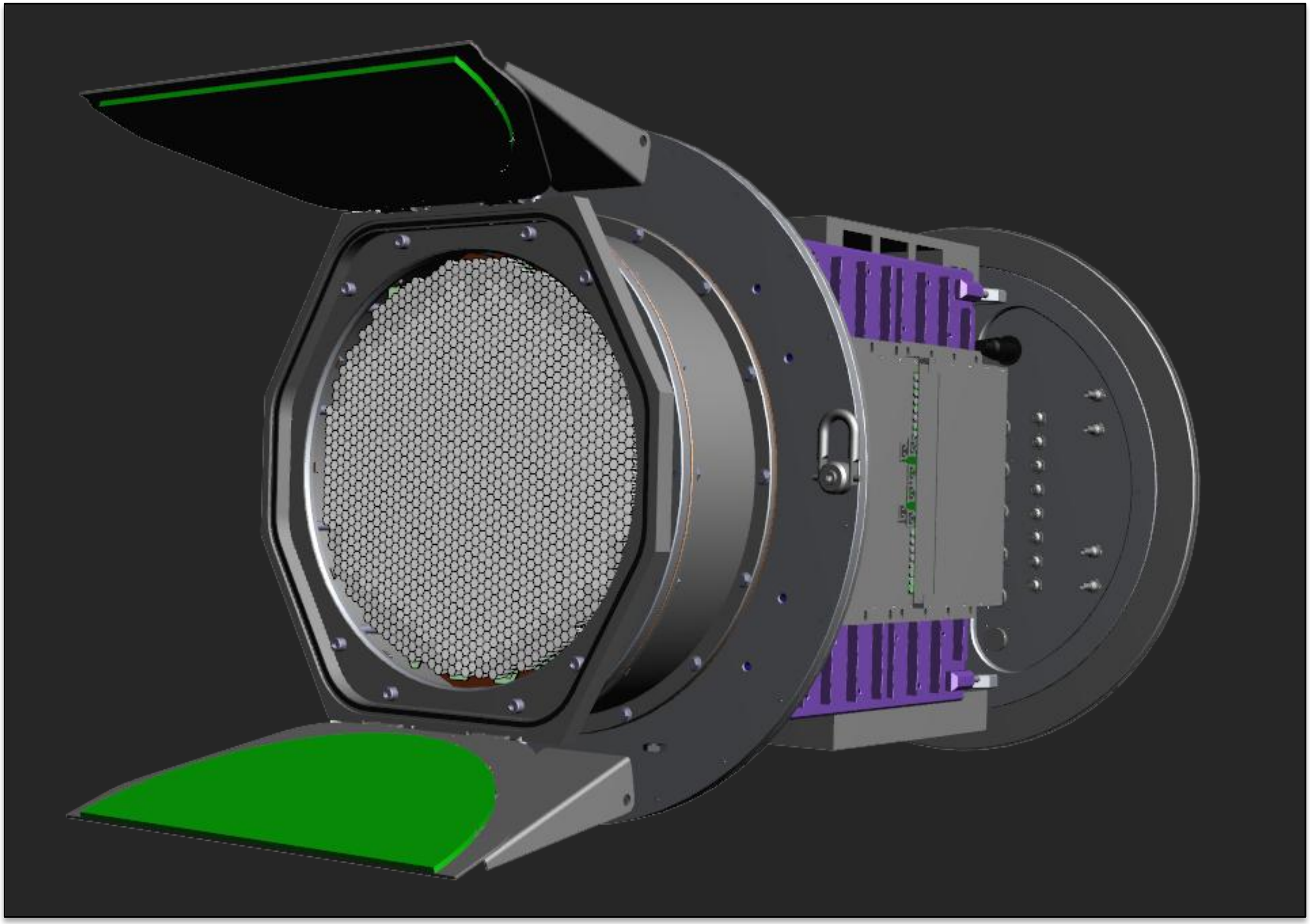
Sensor compartment: gluing repairs

- For seven of the inner pixels, the mechanical stress during the construction was too large
- Difficult access: syringe with 25 cm long needle…

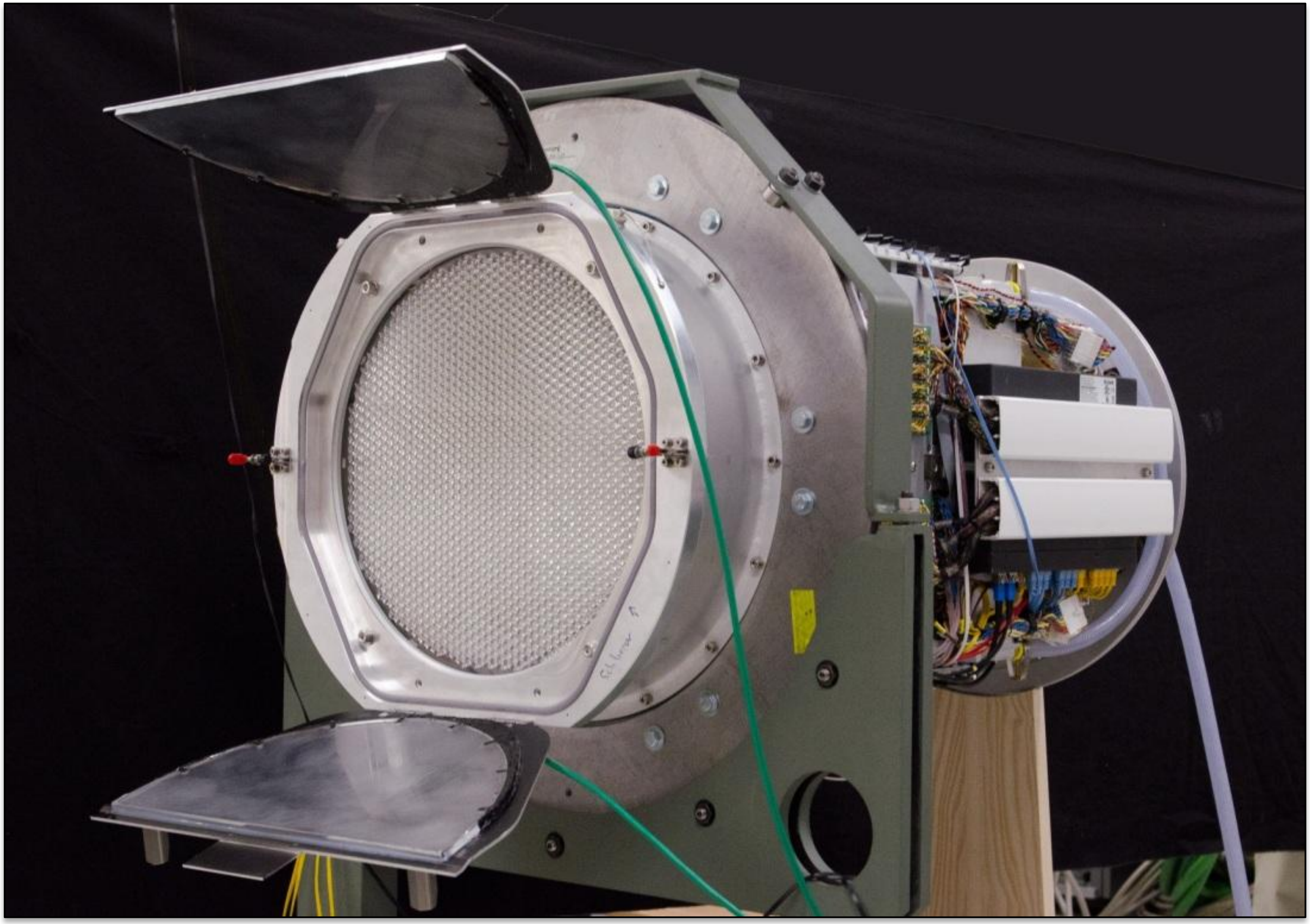




Installation: a CAD drawing…



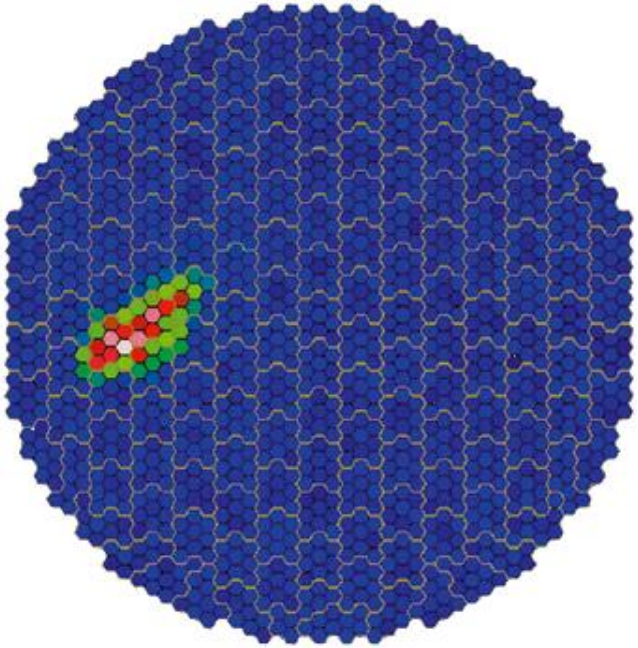
Installation: …becomes a finished camera…



Installation: … which is installed…

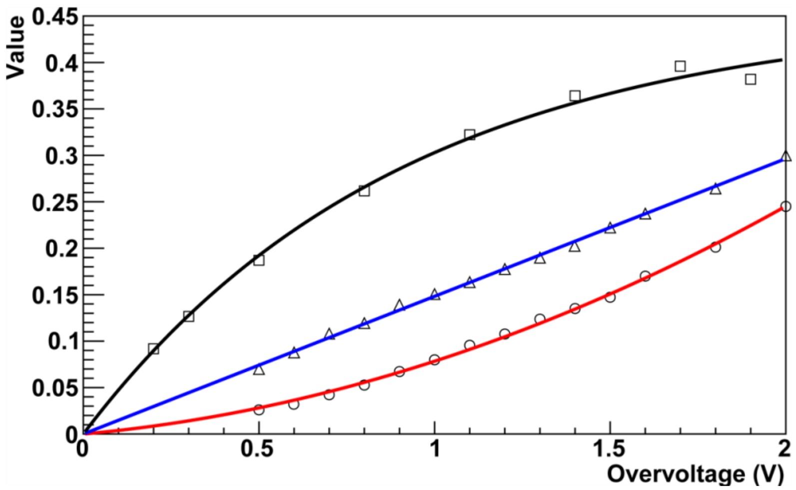
Installation: …and operated…

Installation: …even during full moon.



- First operation on the night of October 11, 2011 (full moon)
- Usually no operation of IACTs in full moon nights

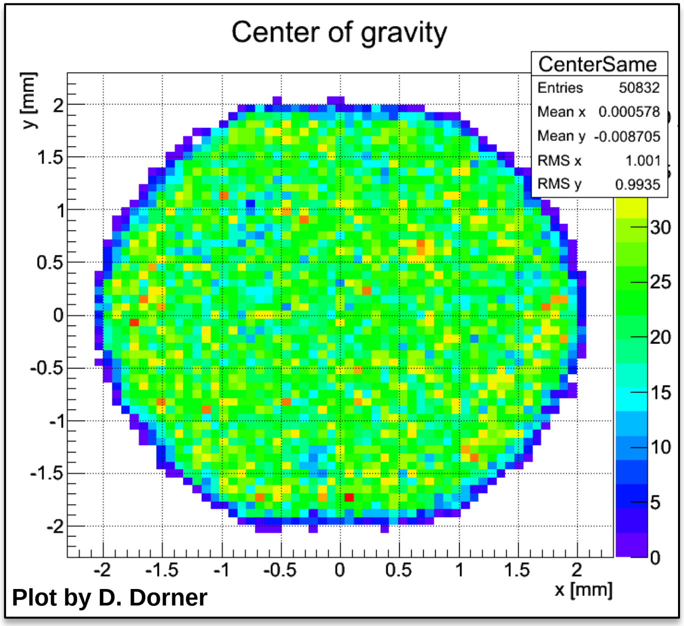
Operation: overvoltage stabilisation

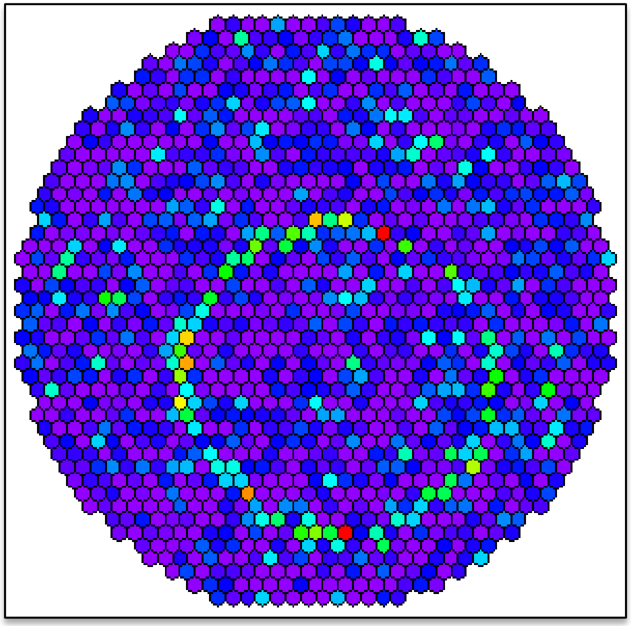


- Many parameters of G-APDs depend strongly on the overvoltage:
  - Photon detection efficiency – Gain – Crosstalk probability
- Correct temperature and background light changes
  55 mV per ºC – 20 mV per 10 uA

- Planned: monitor pulses from an external light pulser
- Implemented: calculate correction based on current readings and temperature sensors
  - Faster reaction to changing conditions
  - Independence of saturation if background light level is very high
  - External light pulser can be used as a cross-check

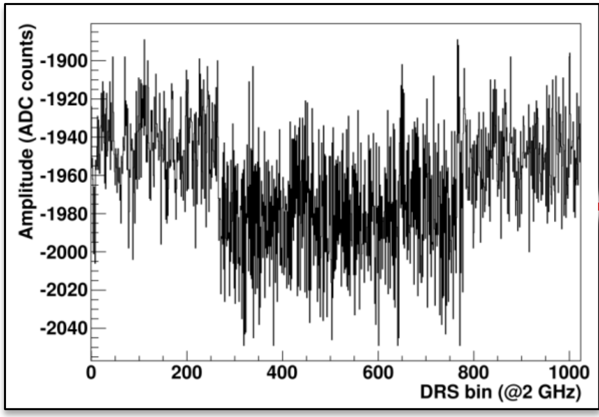
Performance: event properties



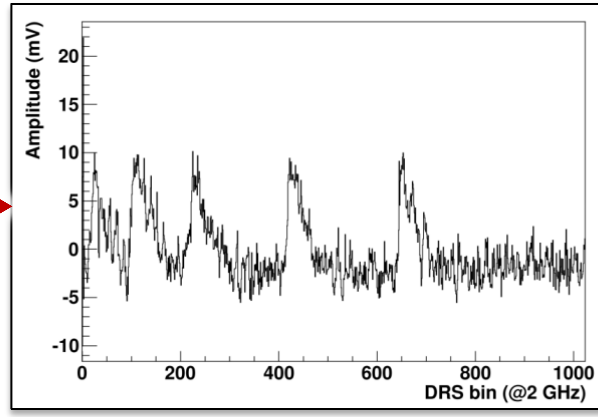


- Plot the center of gravity of the observed showers
- Analyse timing properties of muon events: timing resolution ~ 600 ps (previous lab measurement: < 500 ps)

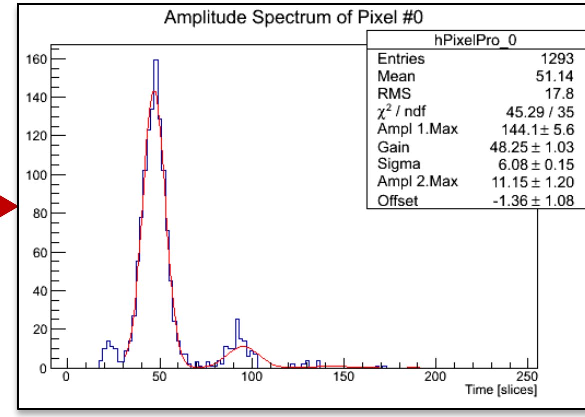
Performance: camera homogeneity with dark counts



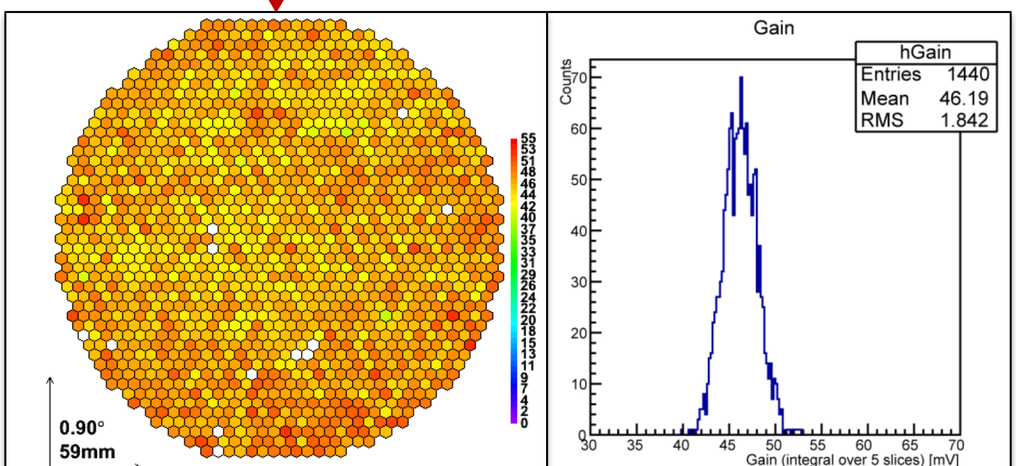
Pedestal data without DRS calibration



Single cell signal extraction



Spectrum with Gaussian fits



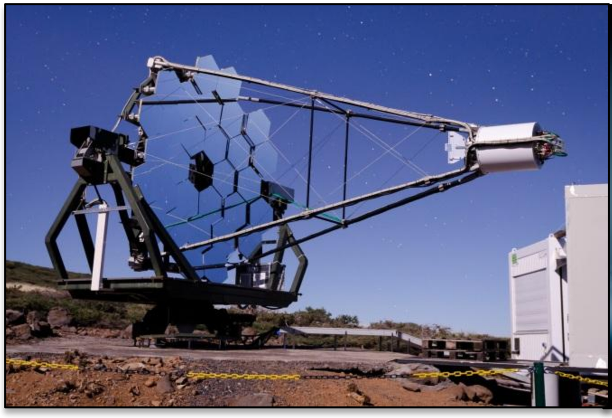
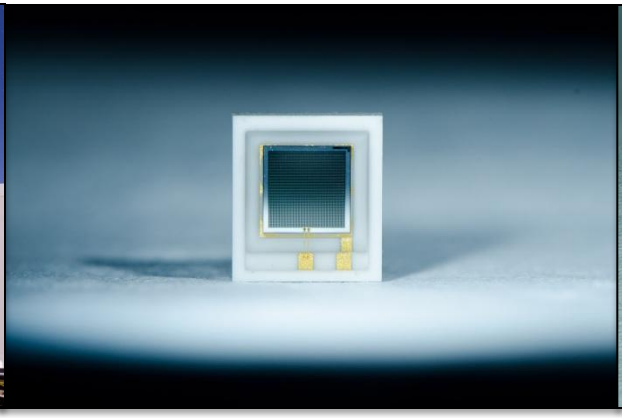
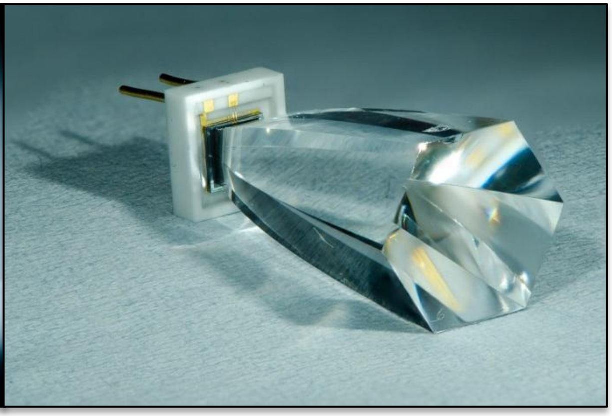
Gain for each pixel: RMS < 5%

Variations:

- Fit precision (~3%)
- Bias voltage supply in groups of four/five pixels, adjustable to 0.02 V (~2%)
- Temperature differences inside the camera

Conclusions

- Camera installed and operational, commissioning ongoing
- Very reliable and stable operation under varying conditions
- First astrophysical results will be presented at the Gamma2012 conference (Heidelberg, July 9-13)

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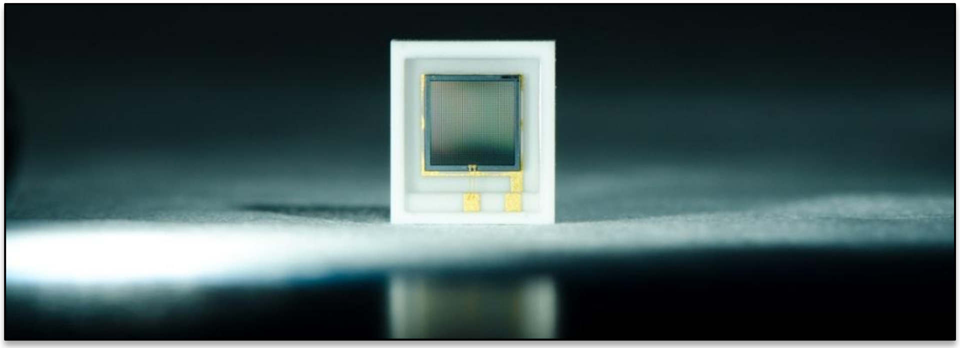
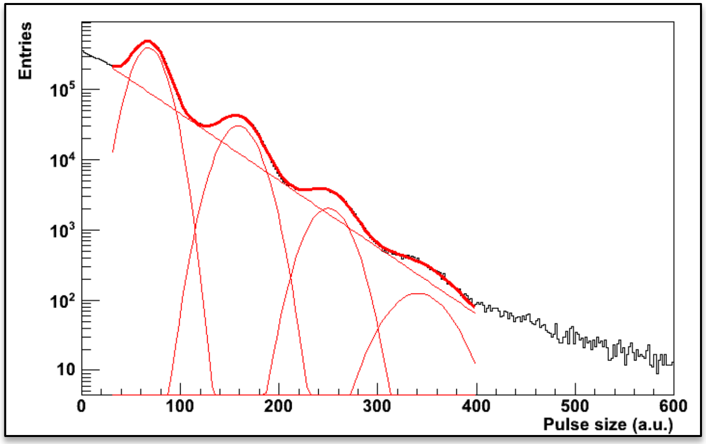
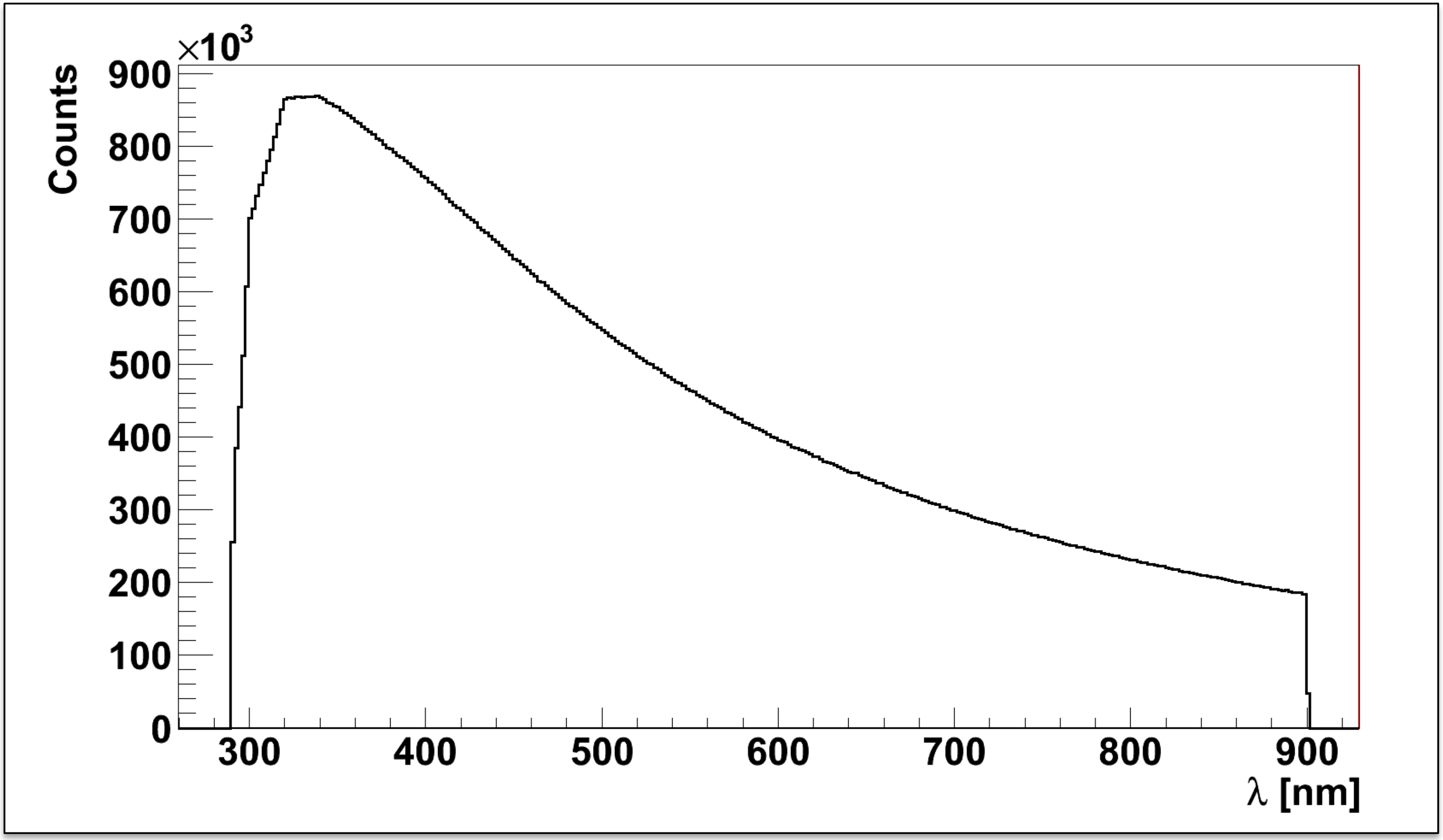
First impression of G-APDs in IACTs (personal opinion)



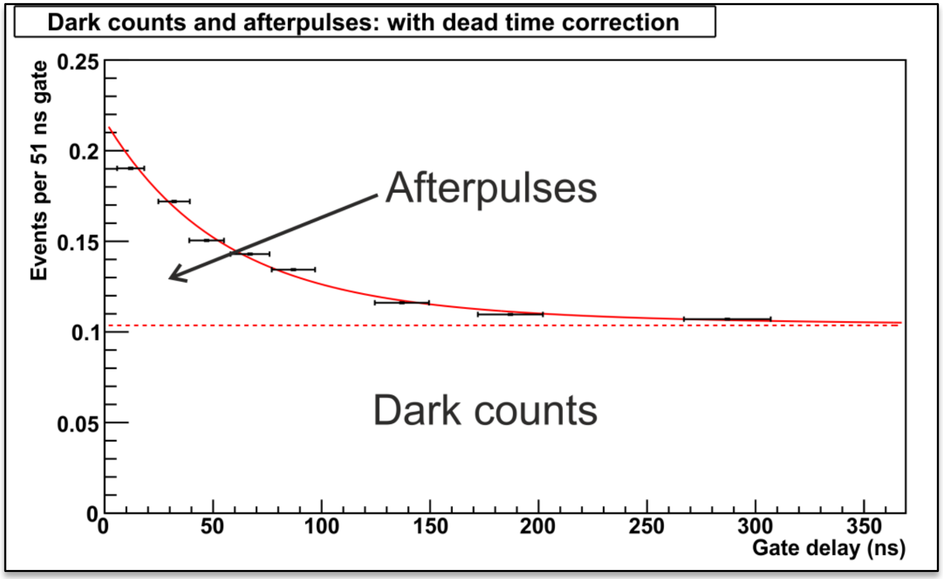
- – Precise voltage necessary
- – Crosstalk dominates energy threshold
- – High PDE in red (background) wavelengths
- + Very stable and homogeneous devices
- + Temperature dependence easy to correct
- + Robust (no lost pixel since installation)



Backup: Cherenkov Spectrum



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

Planned feedback system

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