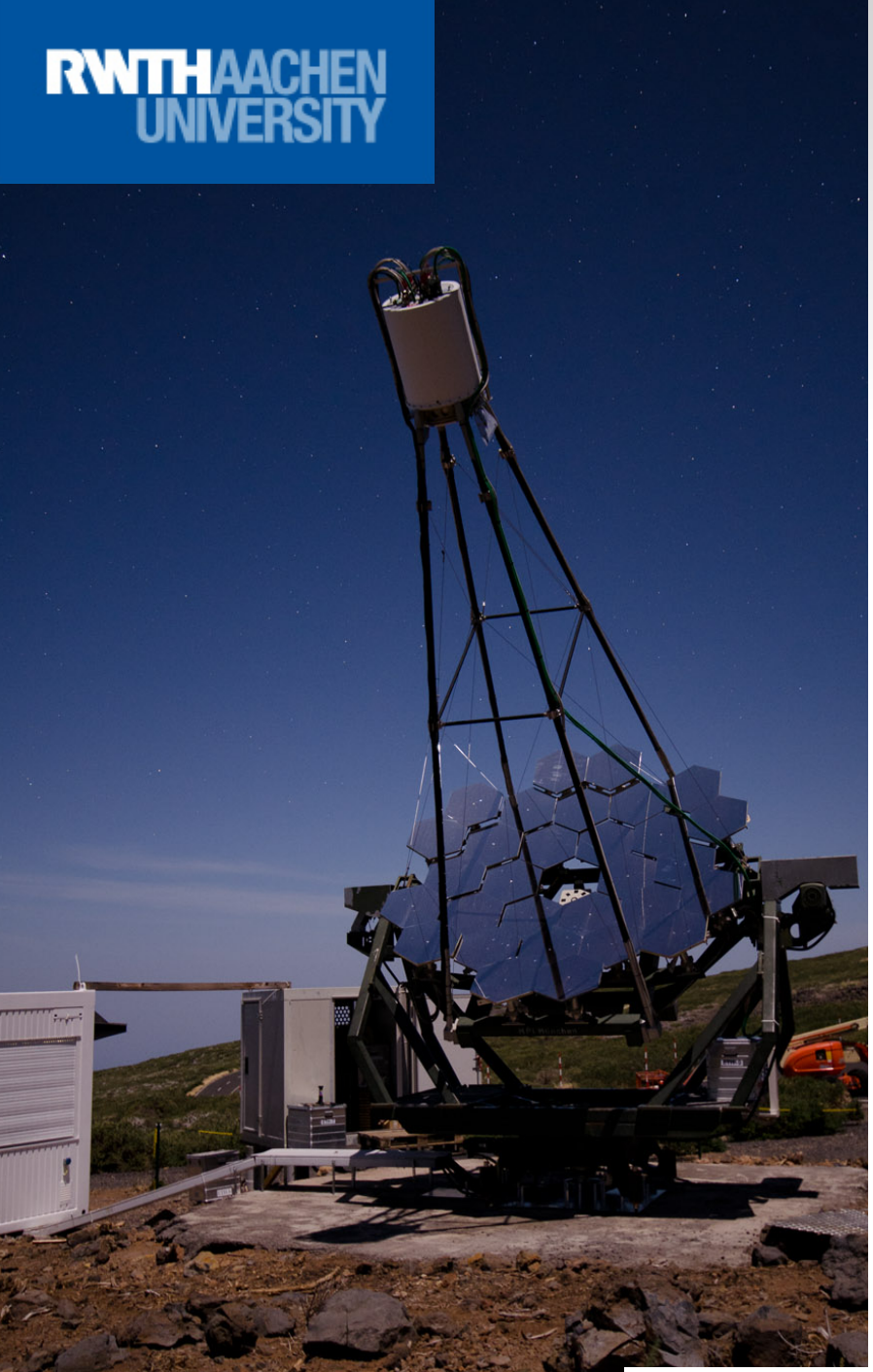
RWTH AACHEN UNIVERSITY



SiPMs in *Ground-based High Energy* Astroparticle Physics

from my perspective

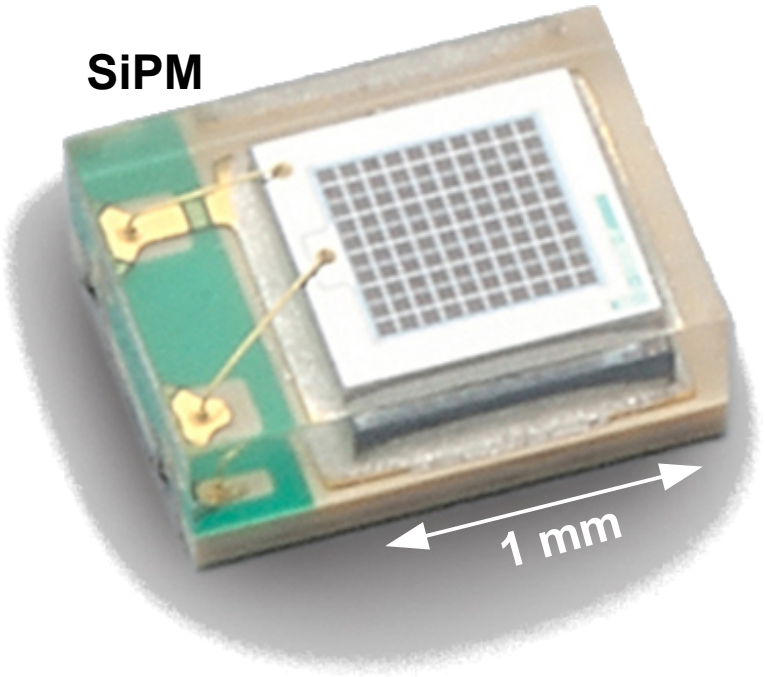
Thomas Bretz
(RWTH Aachen)

HELMHOLTZ GEMEINSCHAFT
Allianz für Astroteilchenphysik

Mass Product
→ high precision
→ low cost product

What is a SiPM?

Silicon based photo sensors



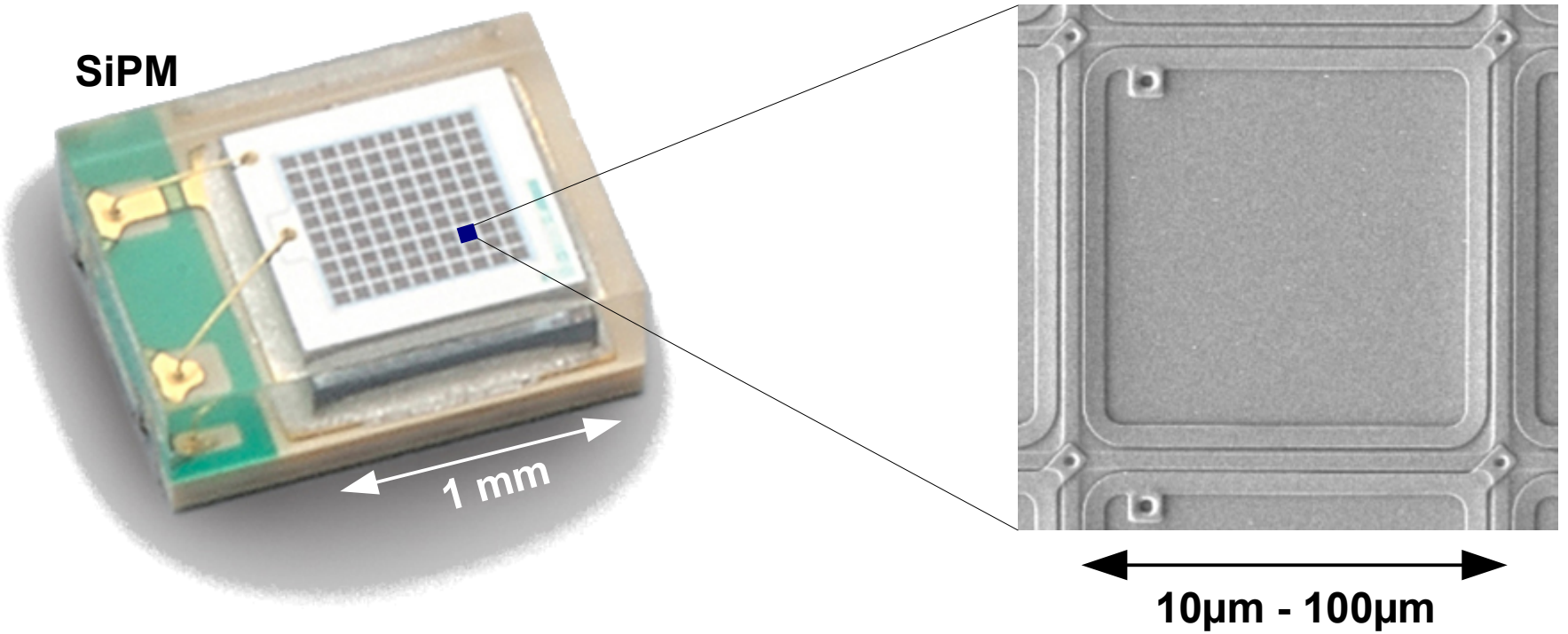
Example: Hamamatsu 1mm²

Credits: Hamamatsu

What is a G-APD?

Silicon based photo sensors

Geiger-mode
avalanche photo diode



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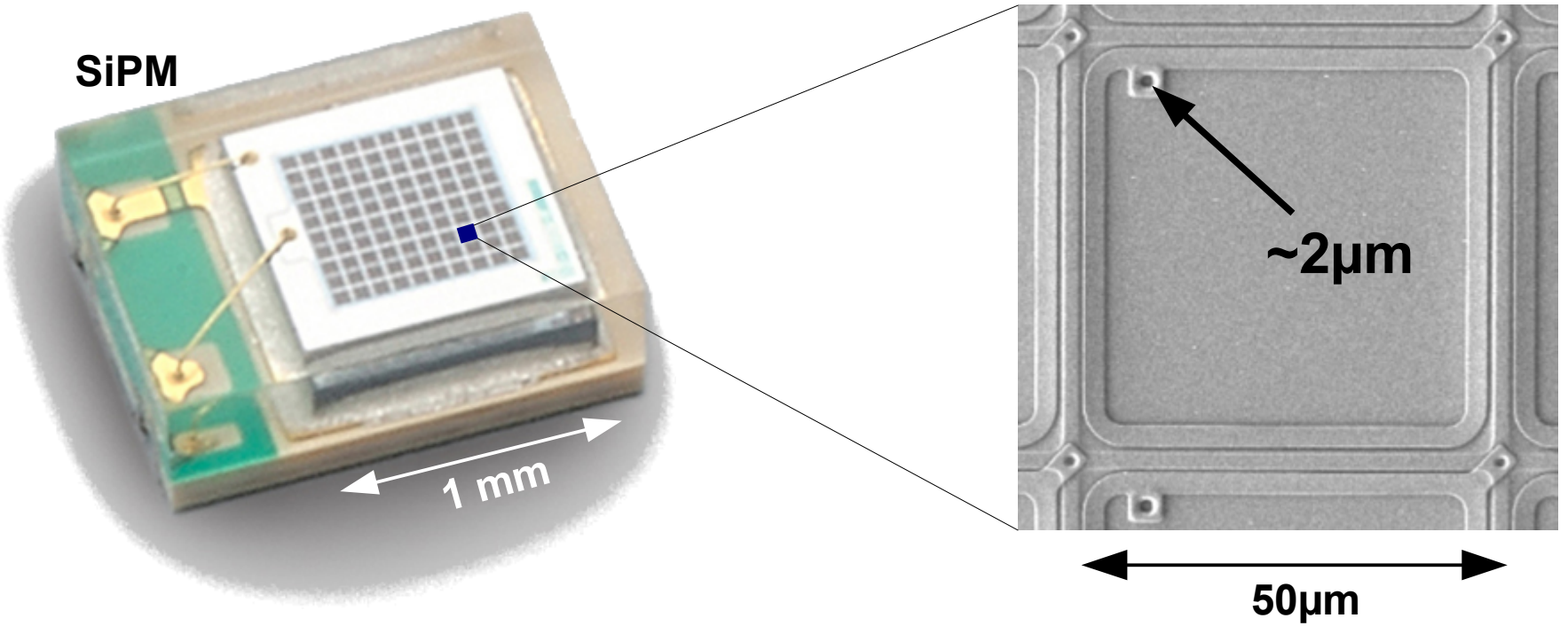


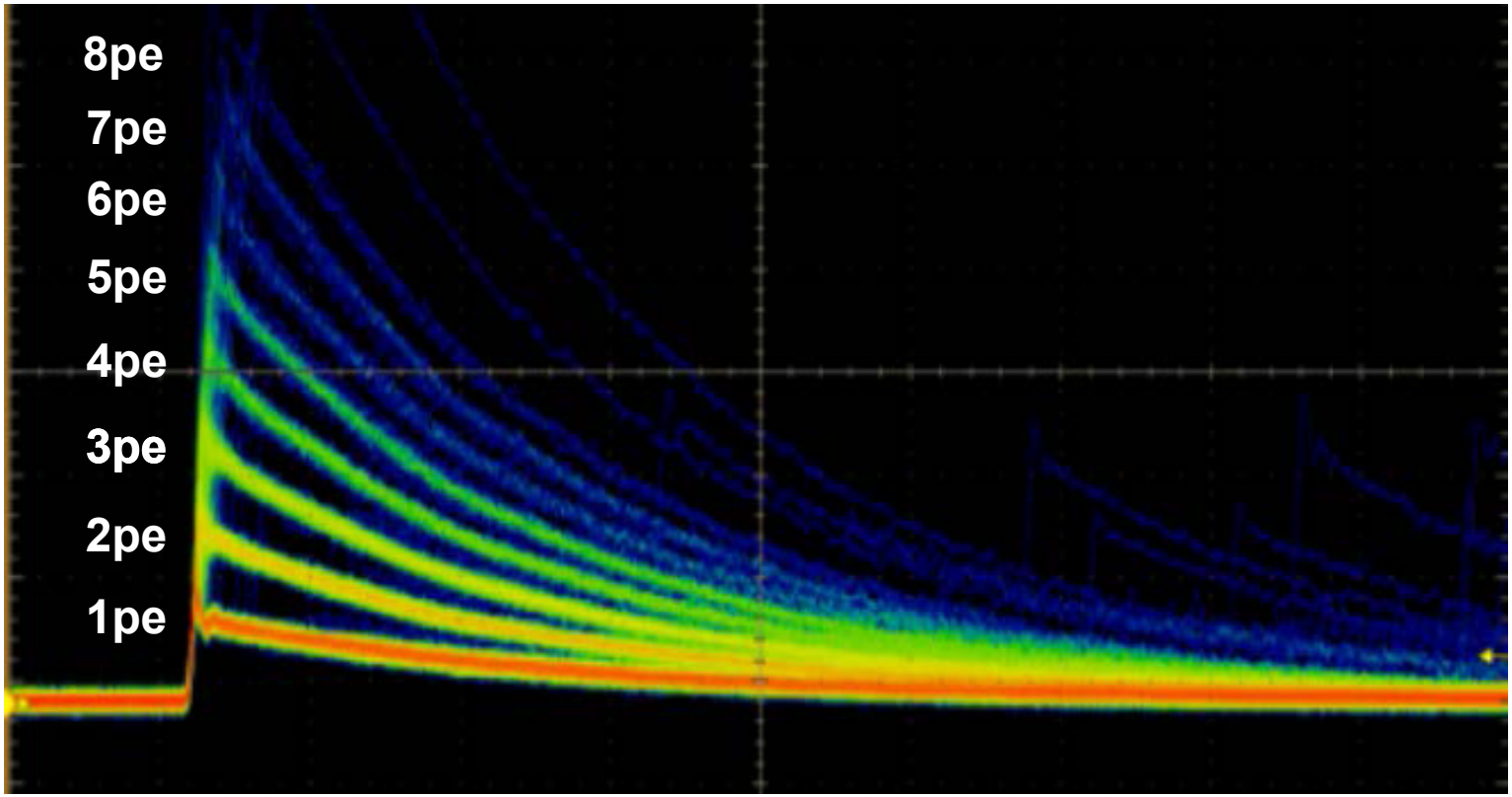
Example: Hamamatsu 1mm²

Transistor in 2015: ~20nm(!)

Credits: Hamamatsu

Photon counting

High precision → every avalanche (cell) releases similar charge

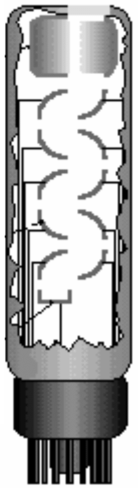


Credits: Hamamatsu

FACT

First G-**A**PD **C**herenkov **T**elescope

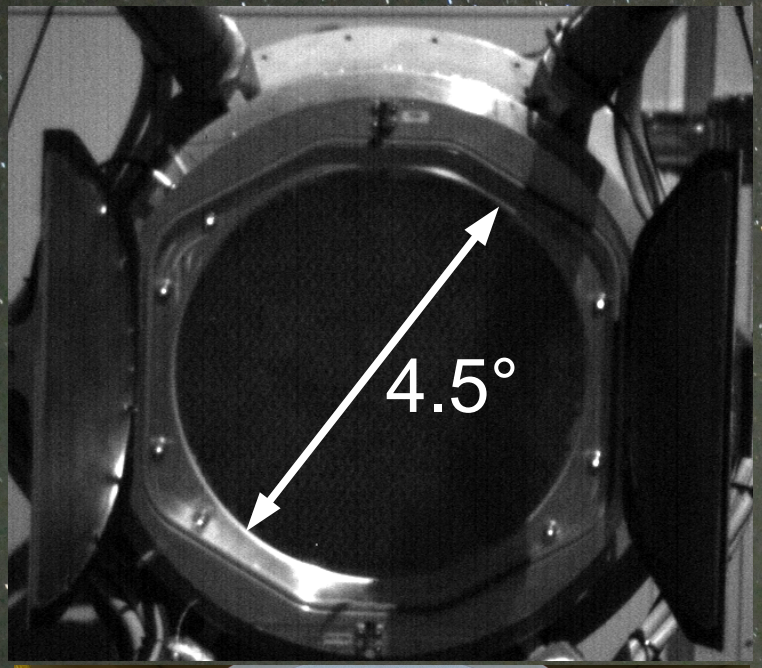
~1934



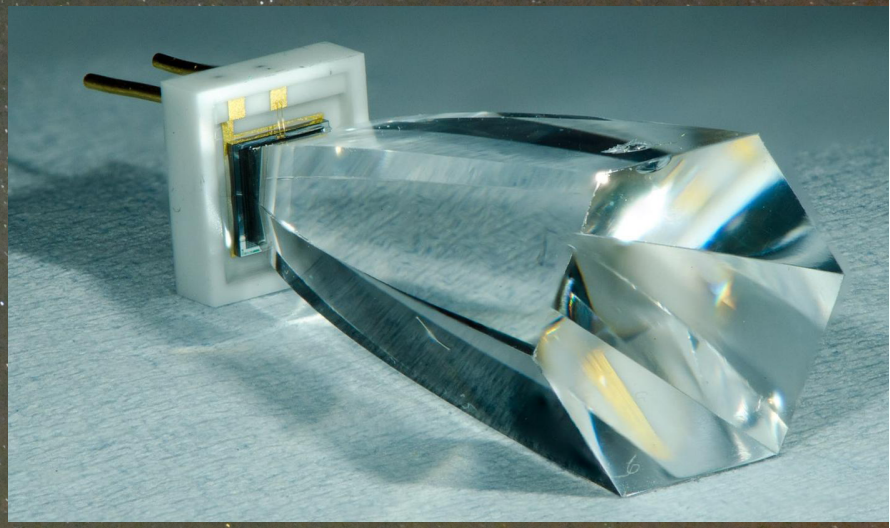
~ 2008

21st century

Dedicated monitoring telescope
with the possibility to observe during strong moon light



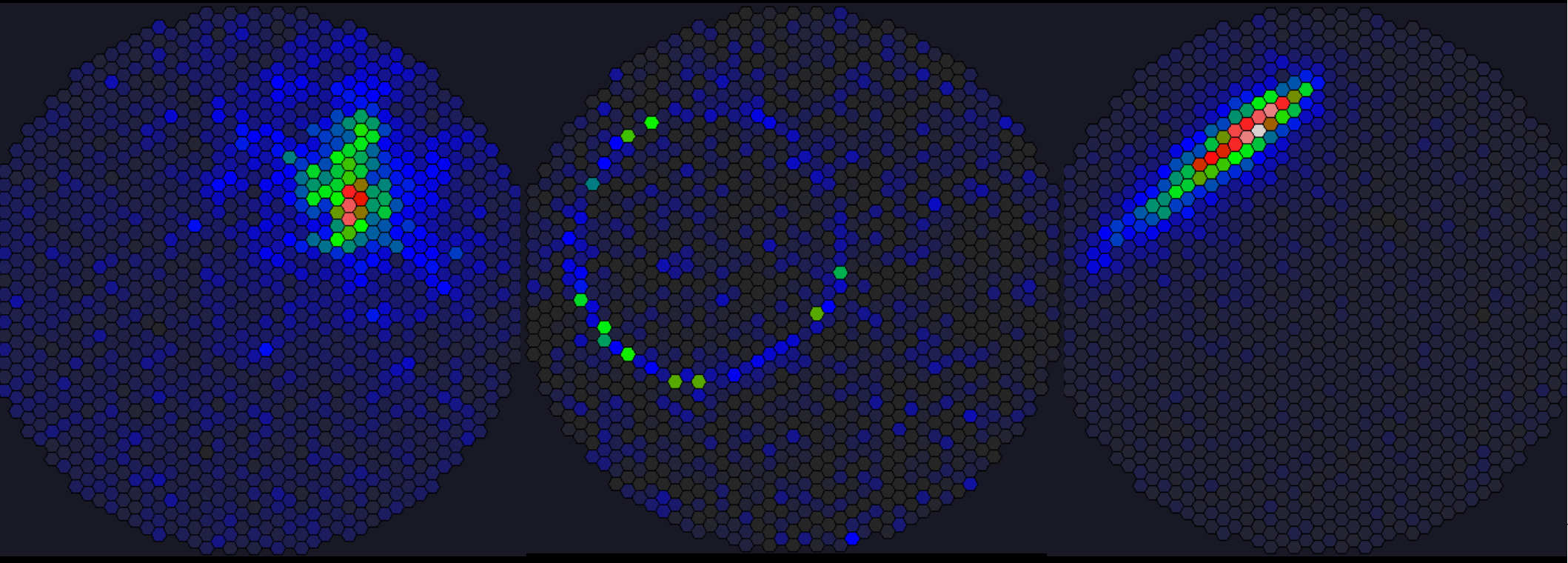
1440 channels à 0.11°



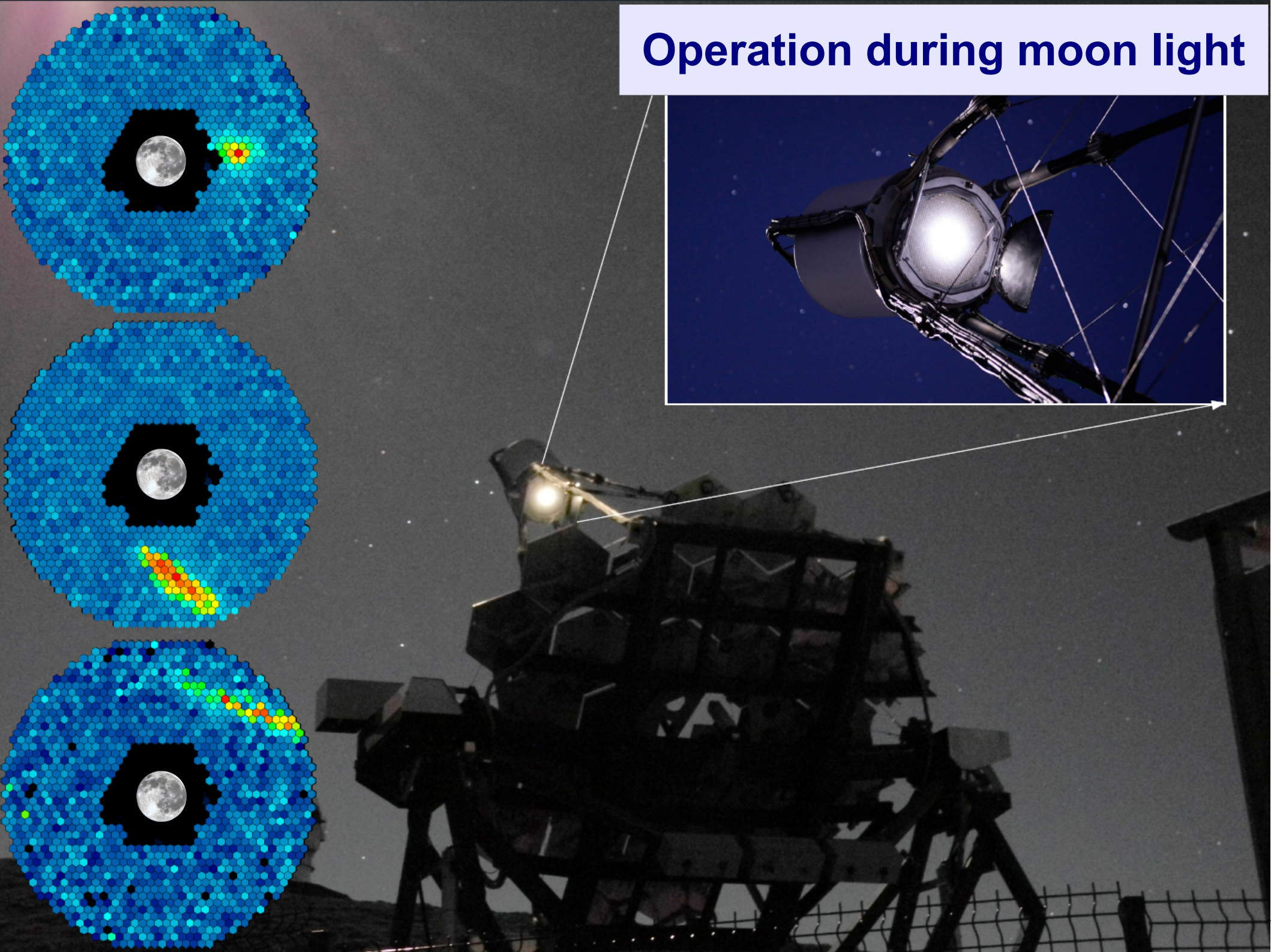
SiPM with solid cone

Construction 2009 – 2011

FACT – Selected events of the first nights of data-taking (11 Oct. 2011)

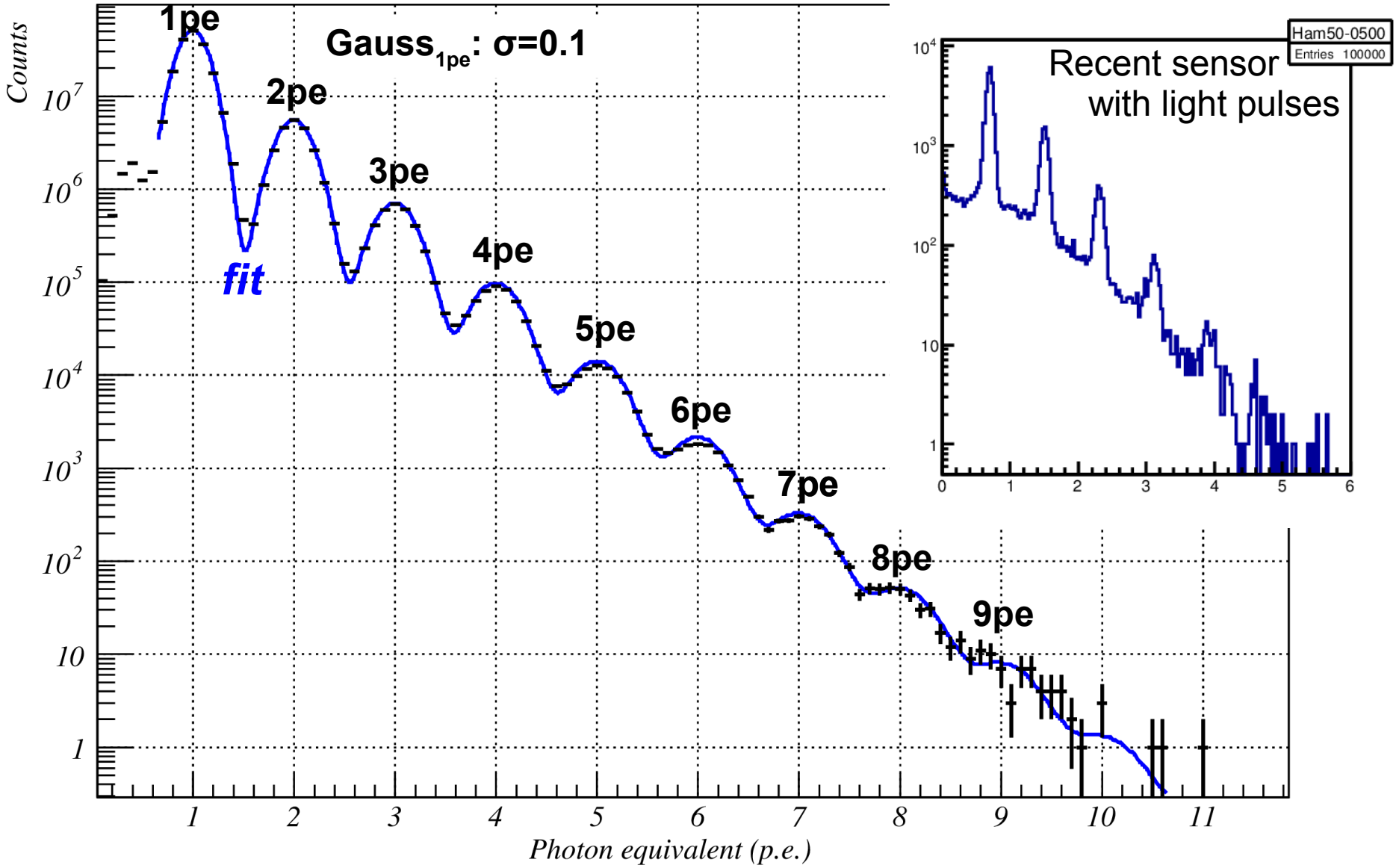


Operation during moon light



Self calibrating / Stability

all pixels; **one year**; temp: ~0°C – 25°C



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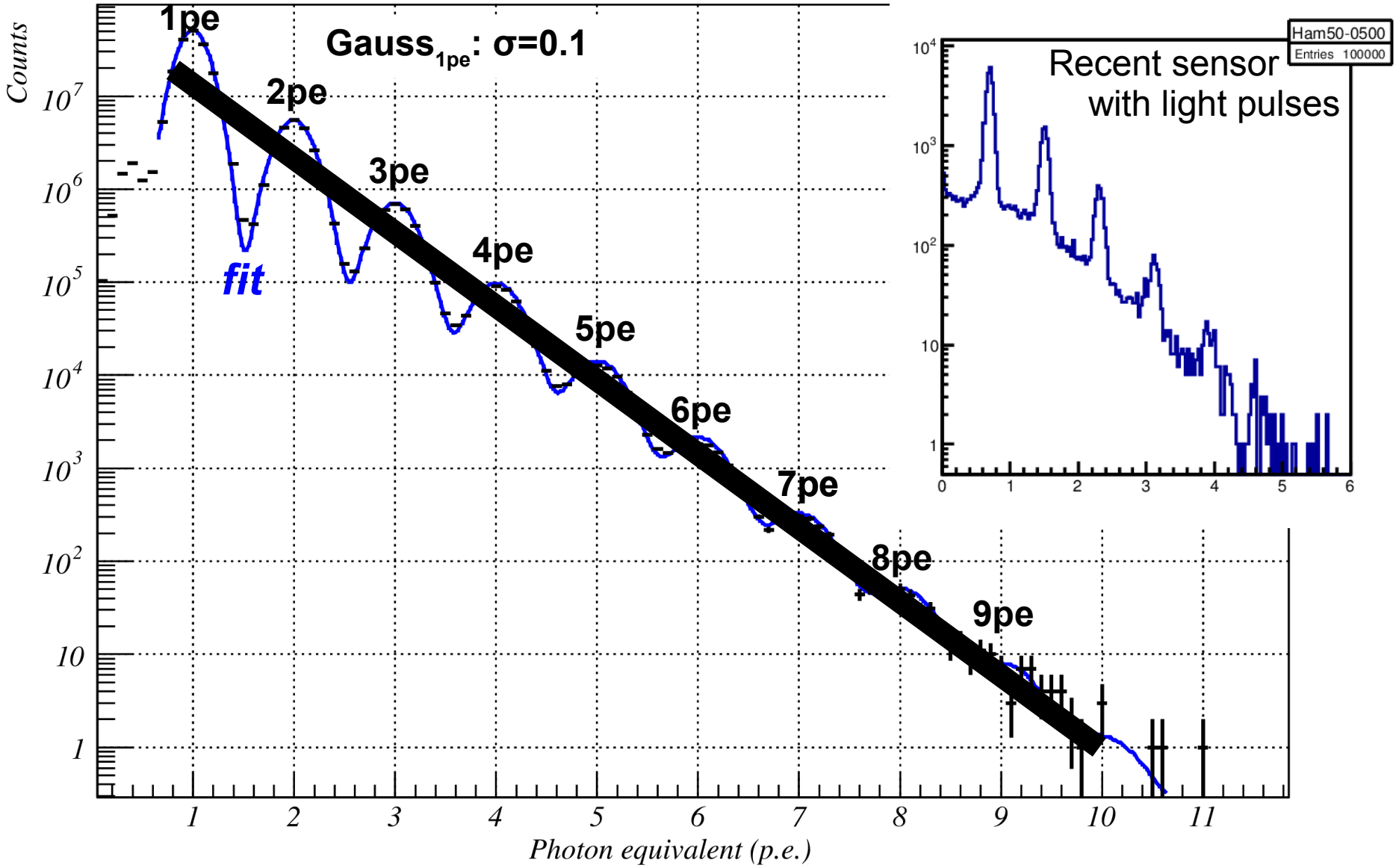

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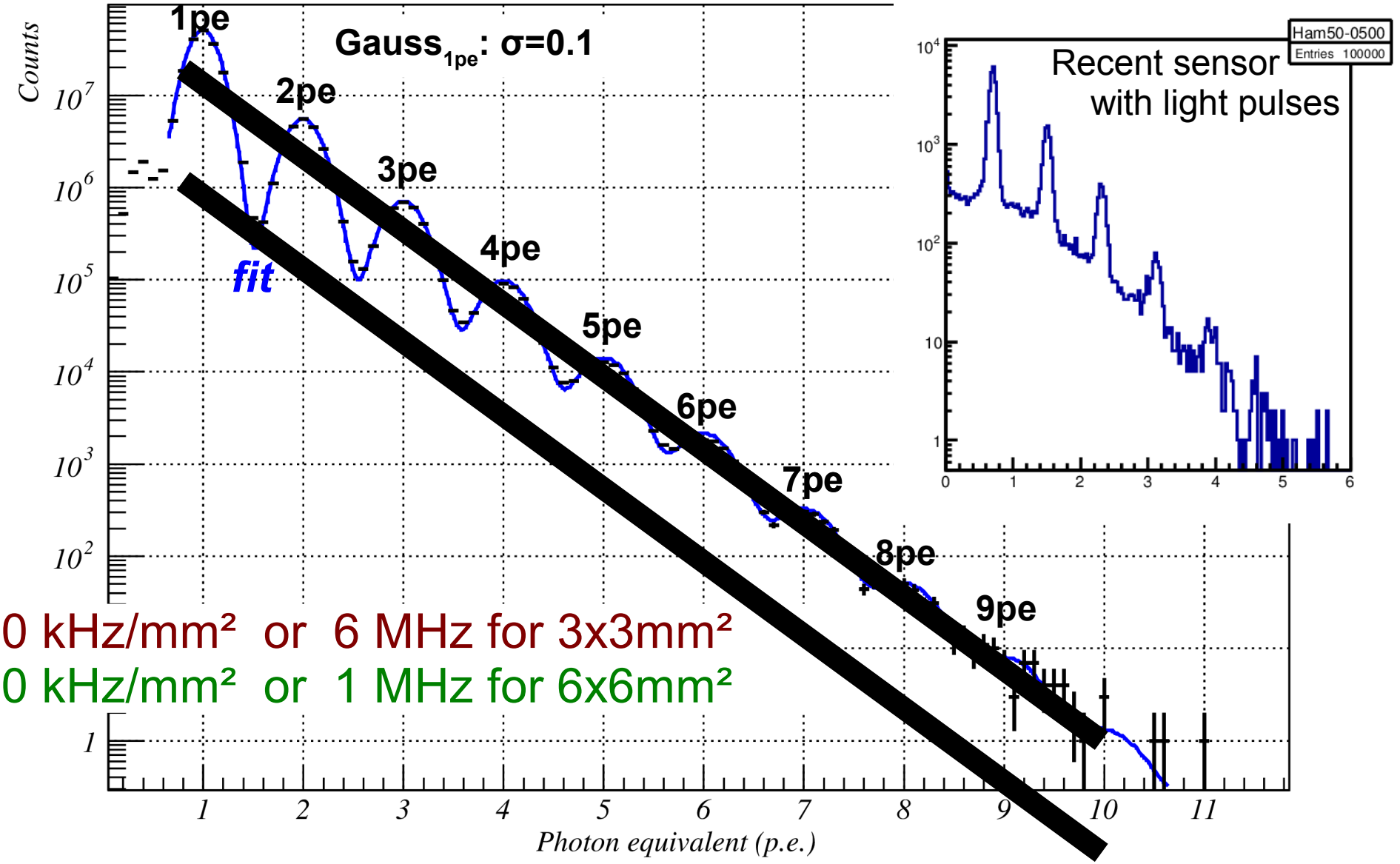
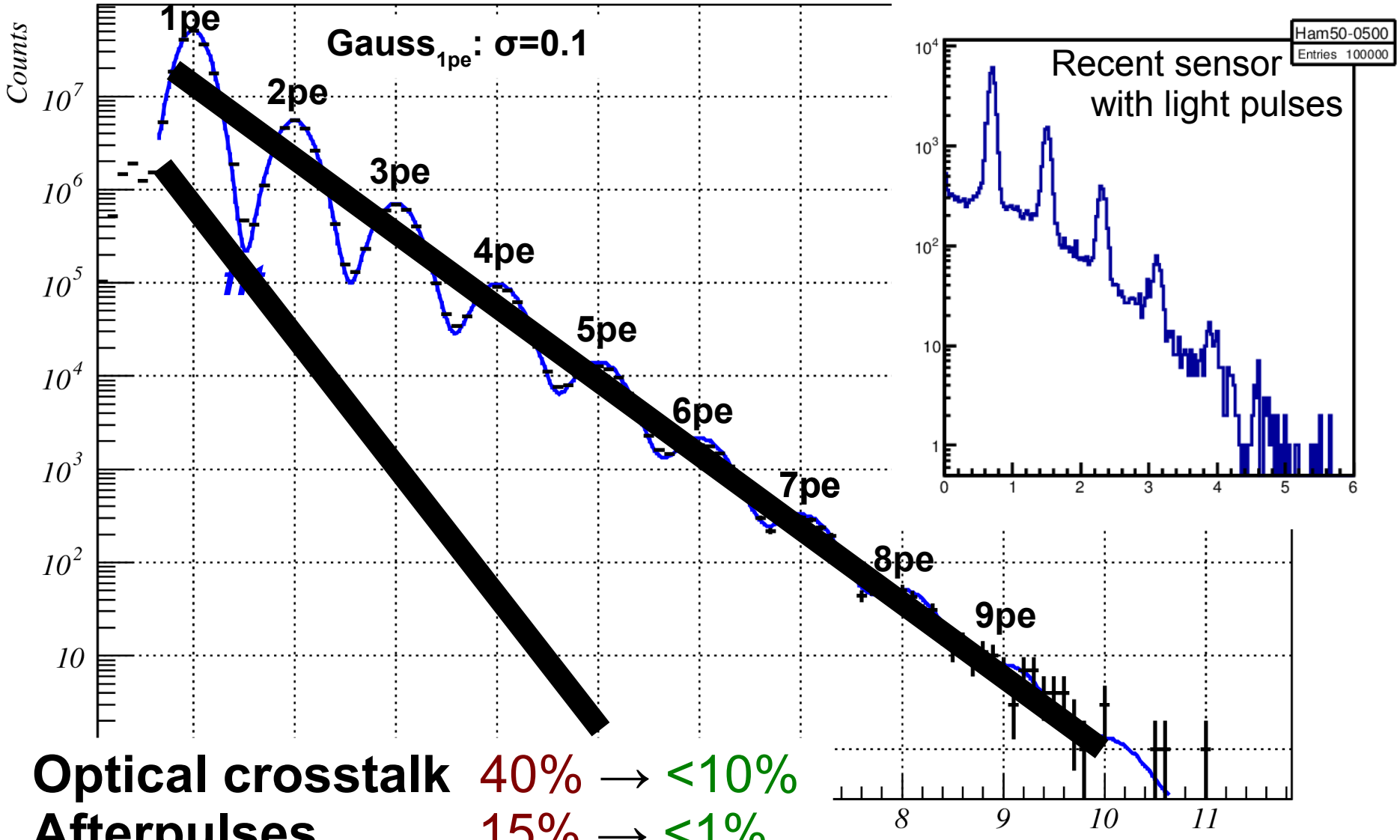


~700 kHz/mm² or 6 MHz for 3x3mm²

~30 kHz/mm² or 1 MHz for 6x6mm²

Self calibrating / Stability

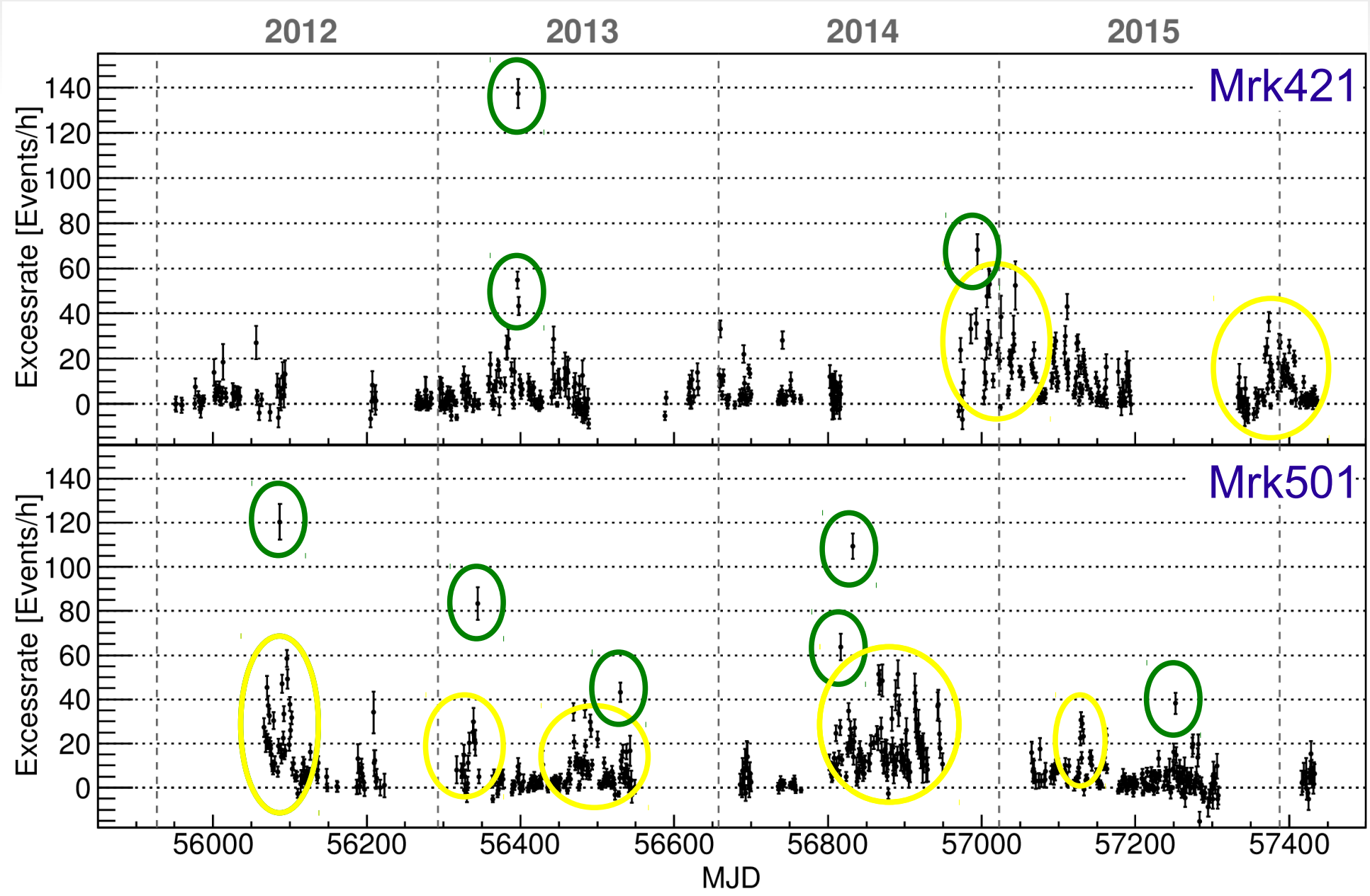
all pixels; **one year**; temp: ~0°C – 25°C



Optical crosstalk 40% → <10%

Afterpulses 15% → <1%

~5 Years of Monitoring



MOTE

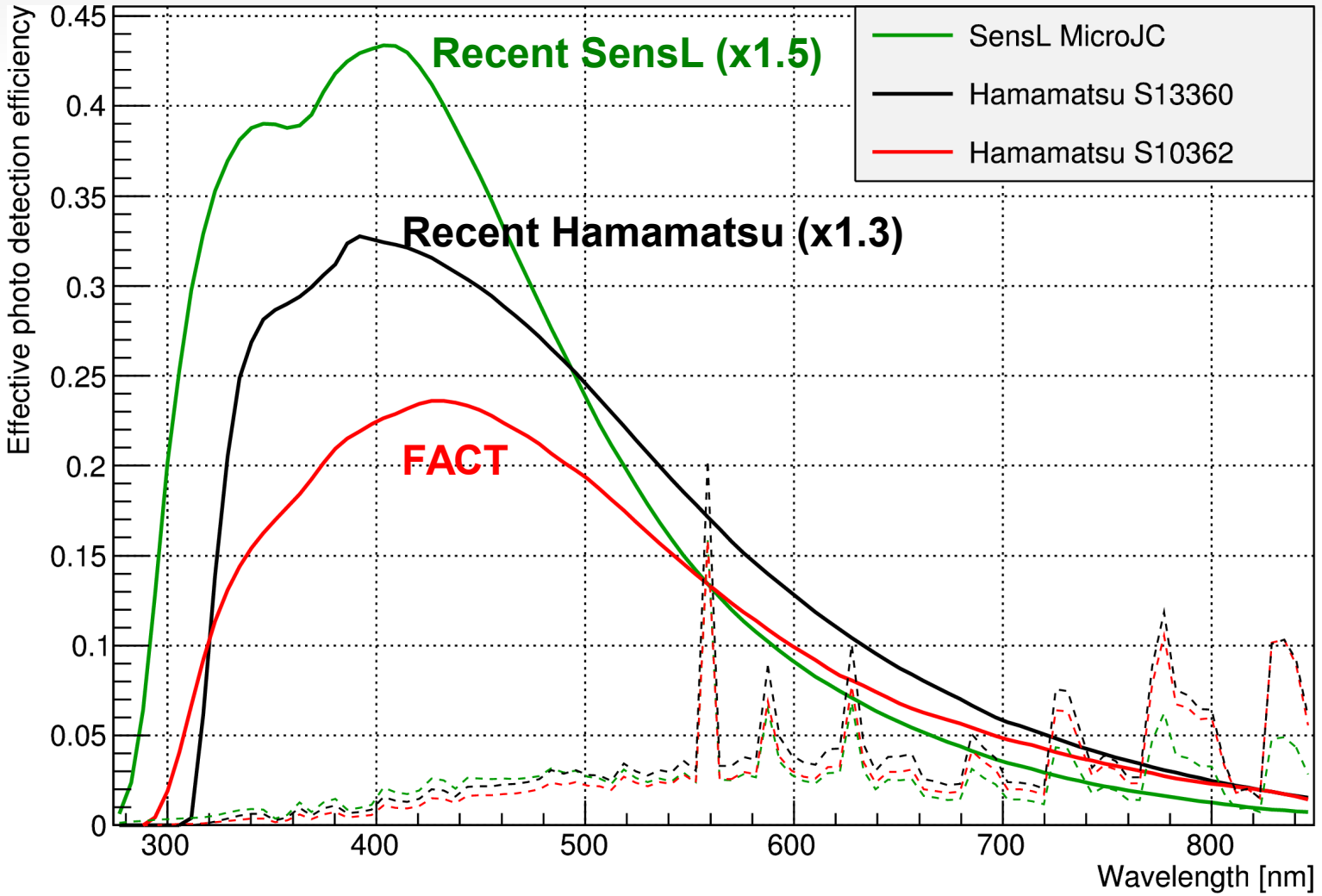
Monitoring @ TeV Energies

HAWC site, Mexico

Two HEGRA mounts in Mexico

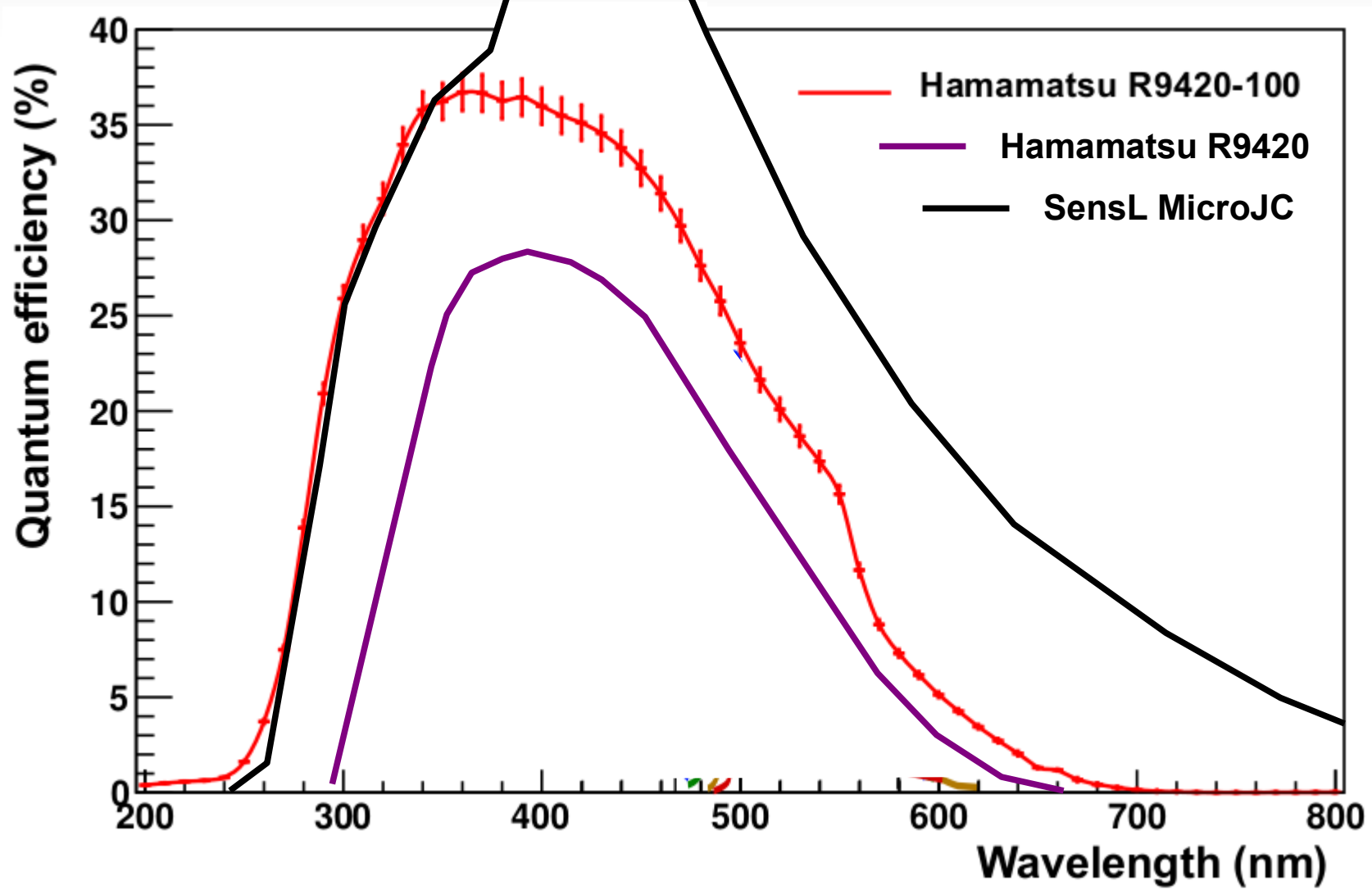
COMING SOON!

Spectral response

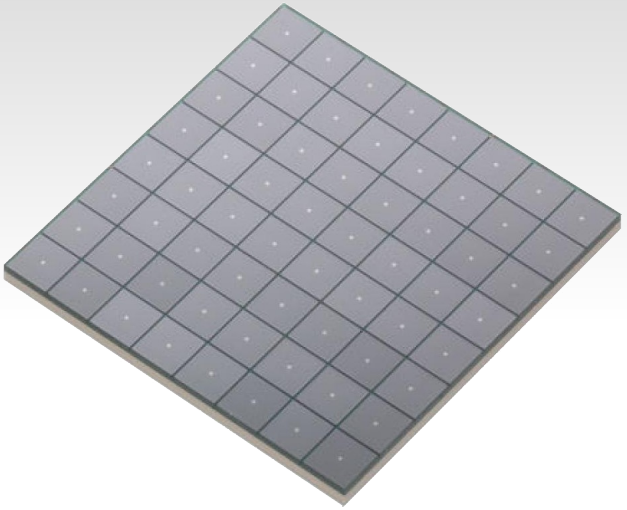


(x ~1)

SensL @ 5V (MicroJC)



Properties



- Small **effective area** (≤ 36mm²)
  Max. 3x3mm² → 6x6mm² TSV techn. (borderless, tillable)

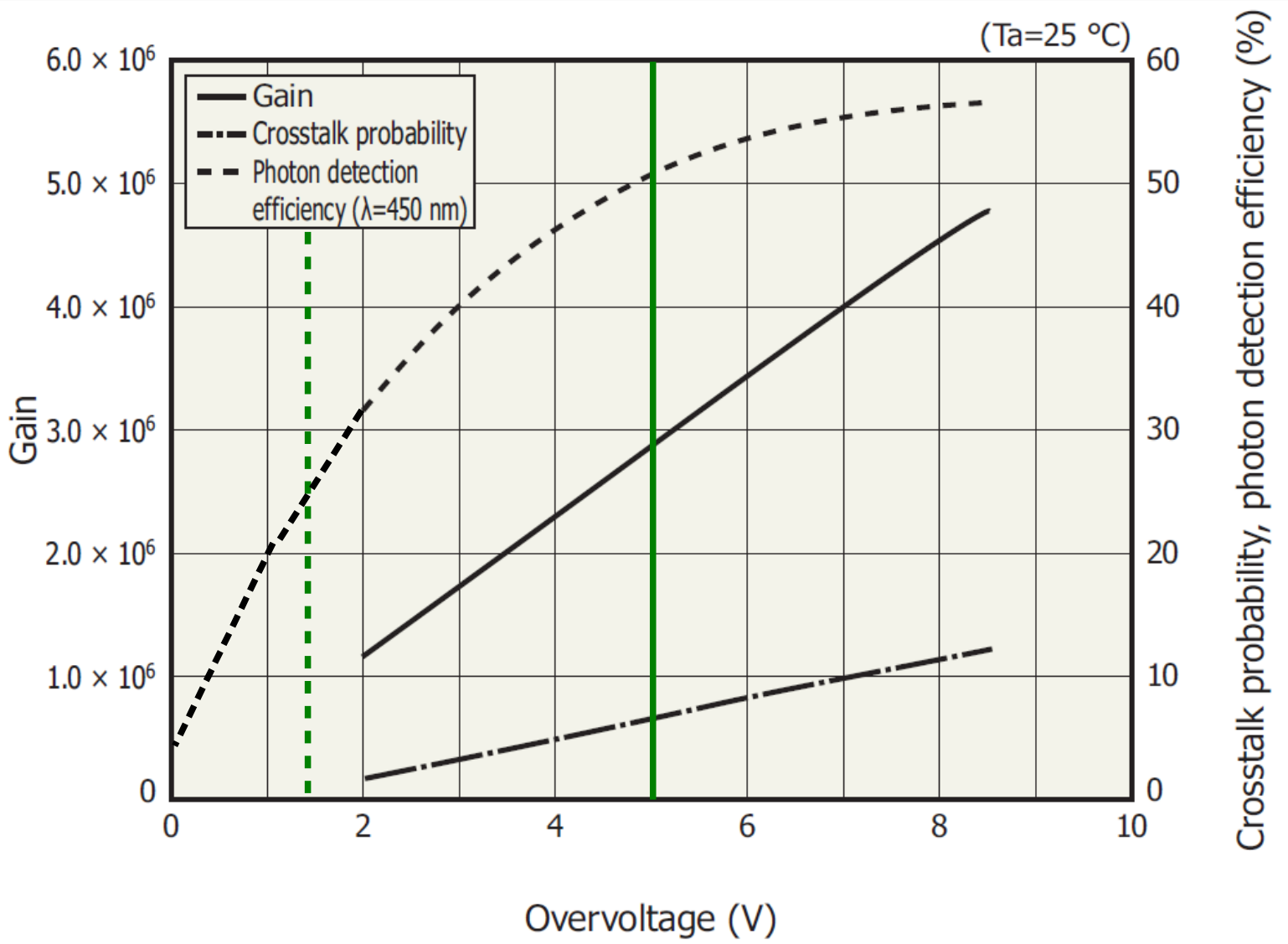
- Very good **time resolution** O(50ps) due to low time jitter

  Reach **dynamic range** comparable to PMTs (~5·N_{cells})
  → e.g. > 200,000 pe (6x6mm², 25µm), but not linear

- **Price**
  20 €/mm² → 0.5 €/mm² (20€ – 30€ / sensor)

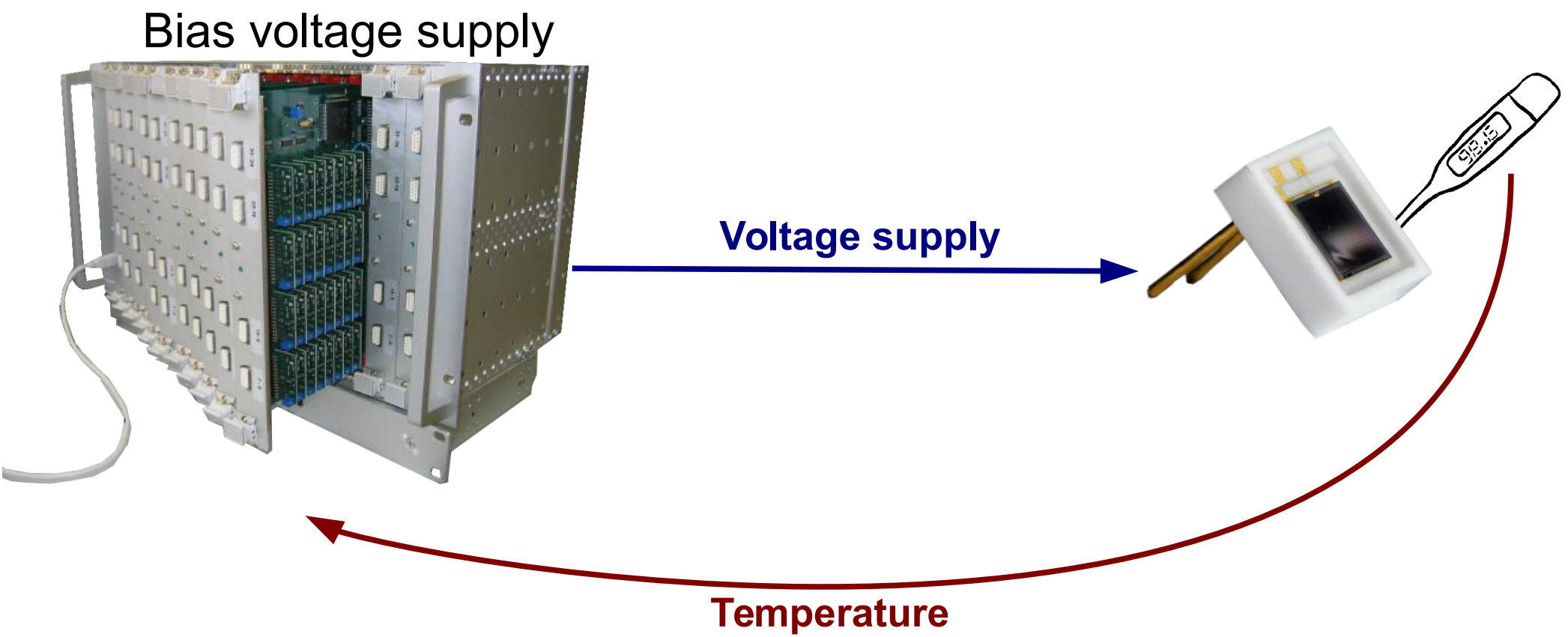
Temperature dependence

- O(few % / K)



Feedback system

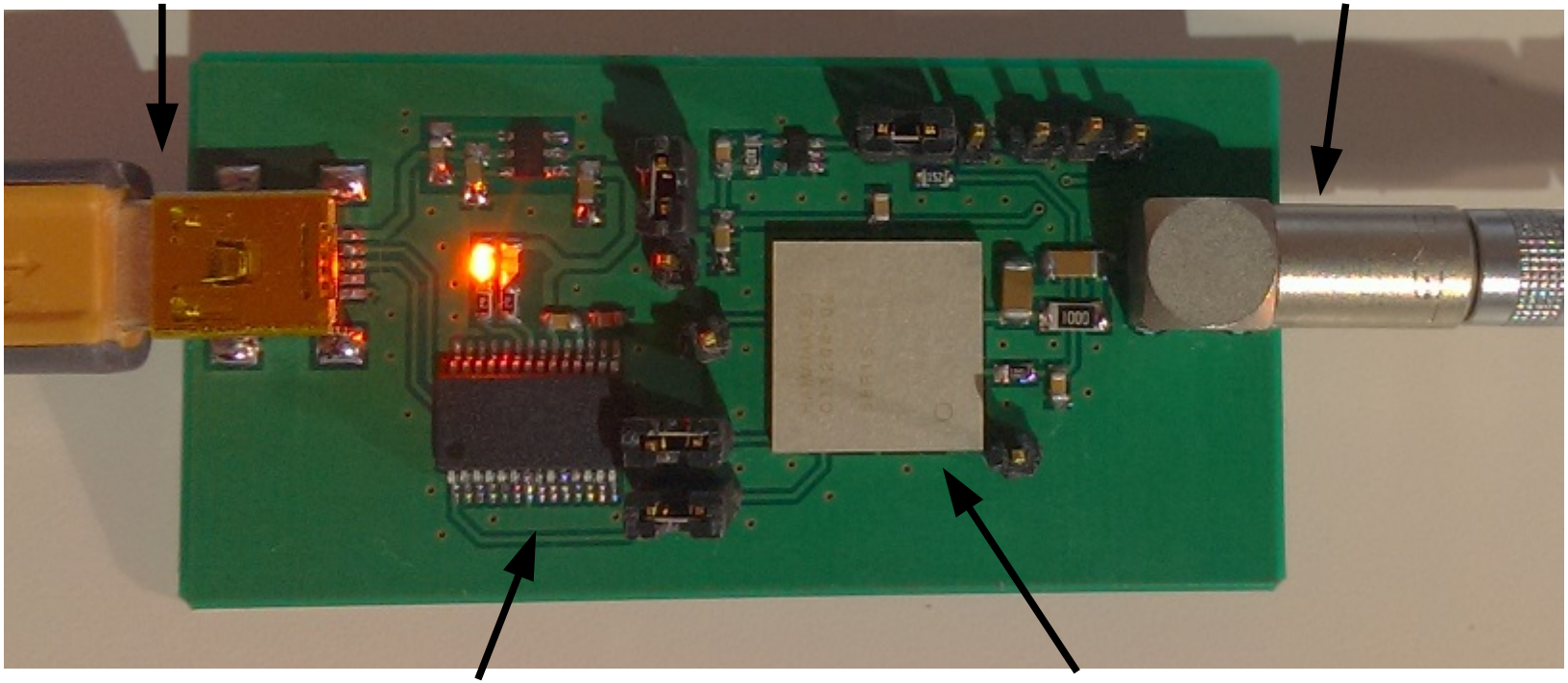
simplified sketch



Integrated circuits

IN:
USB for Communication and power

OUT:
Temp. compensated SiPM voltage

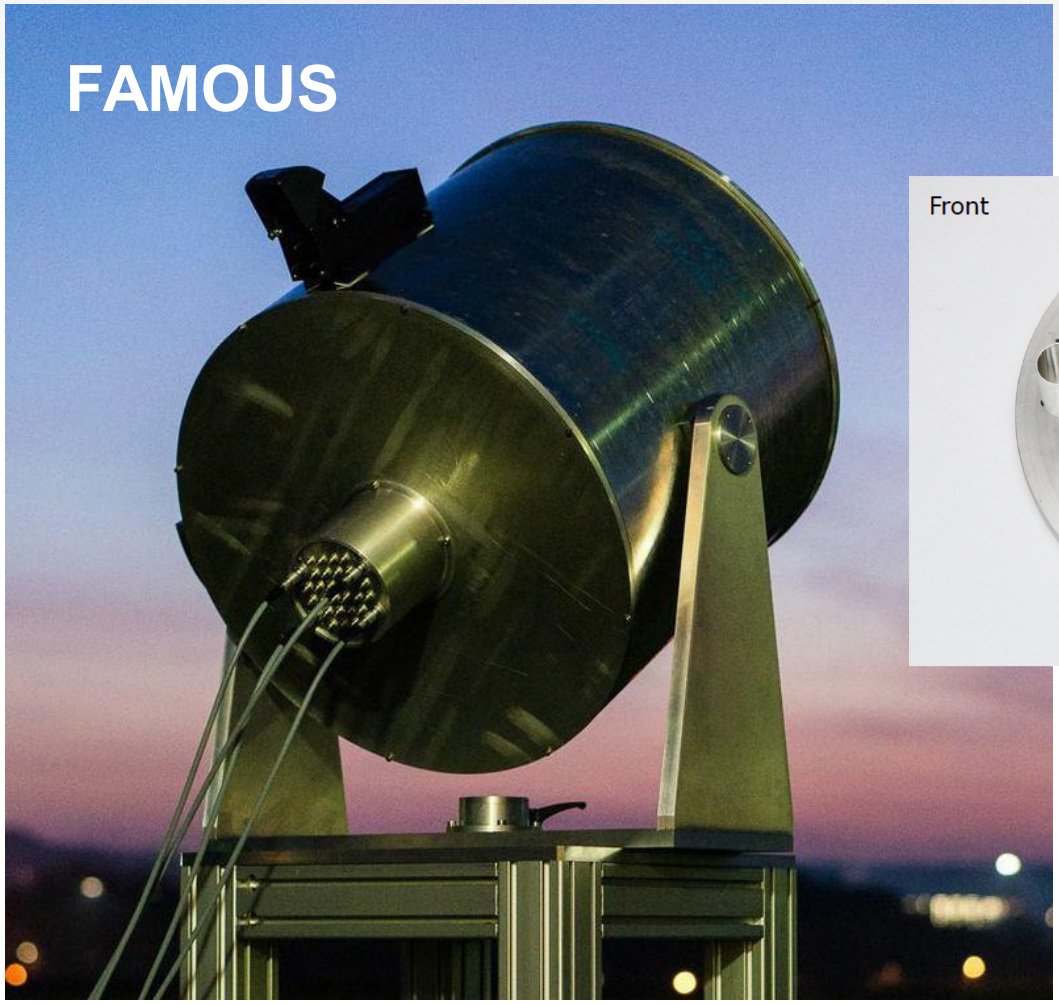


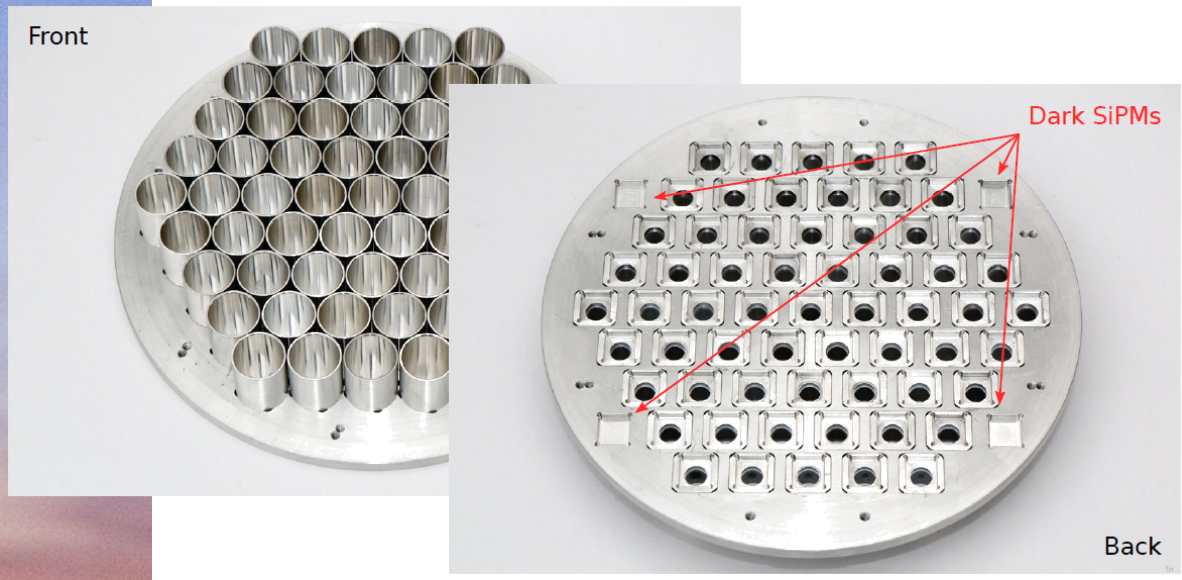
FTDI (USB driver)

Hamamatsu C11204-02

→ More example applications

Fluorescence telescopes

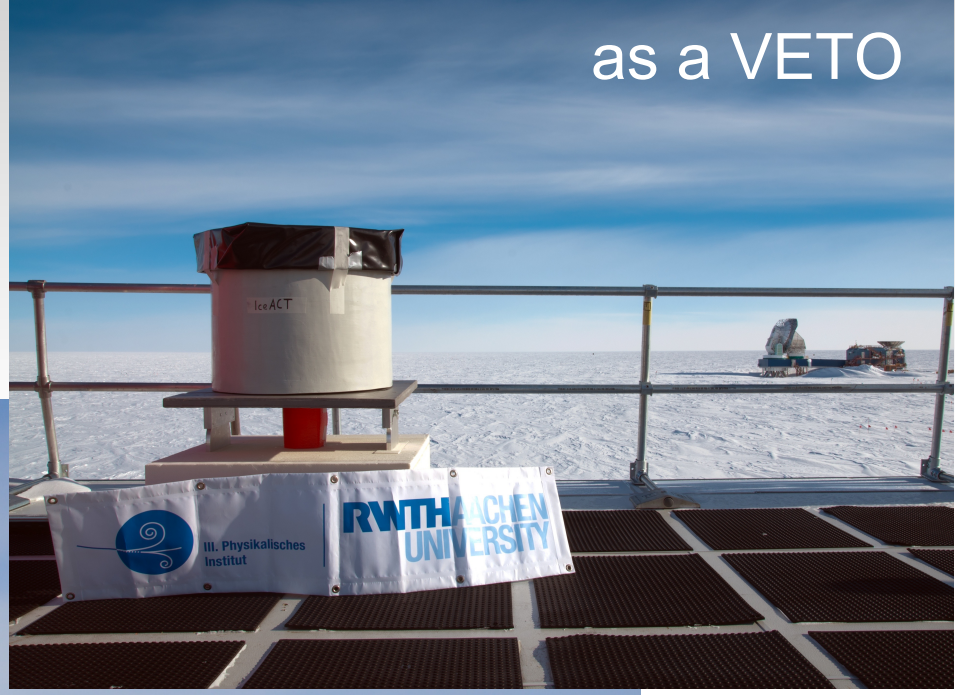


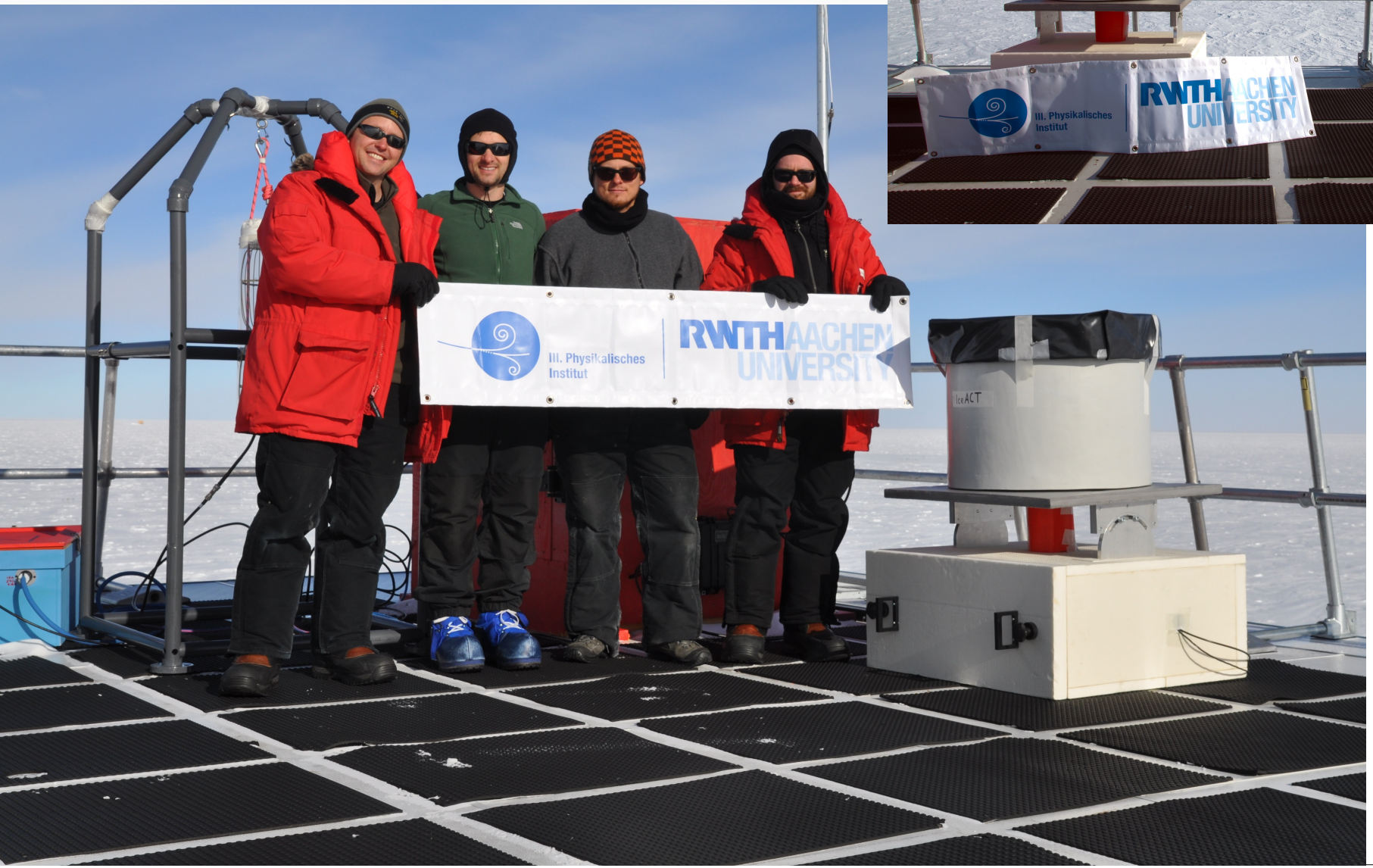


prototype → goal: installation at Auger site

FAMOUS / IceAct

First SiPMs at South Pole!

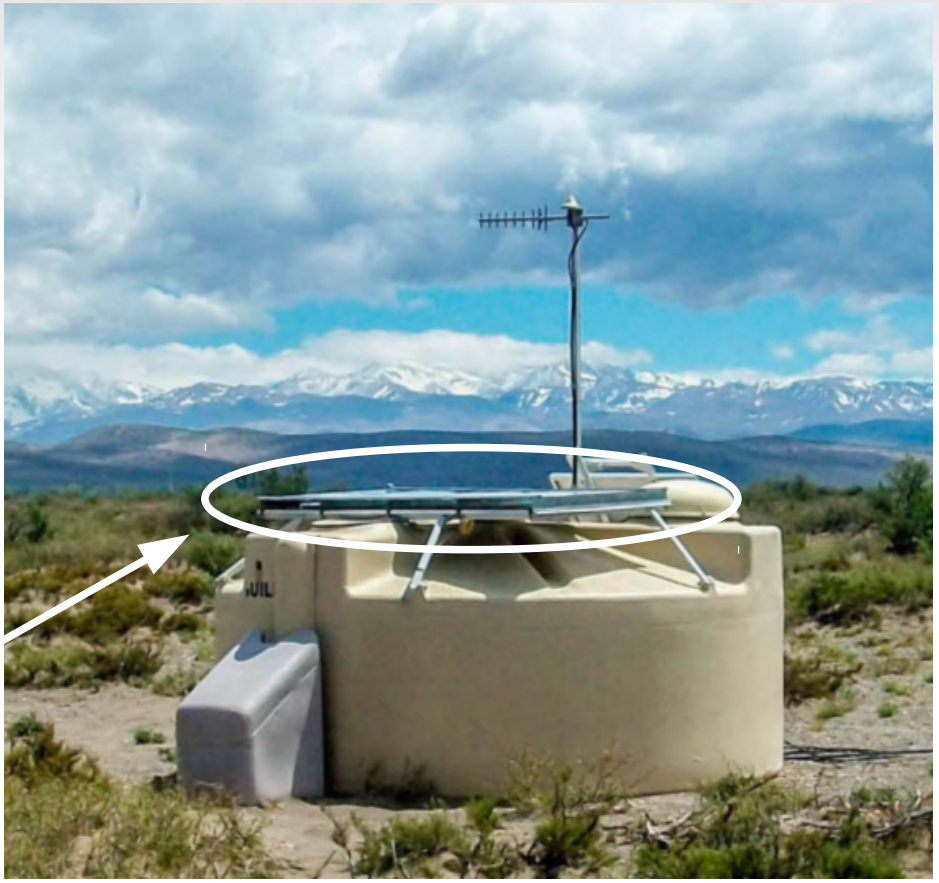


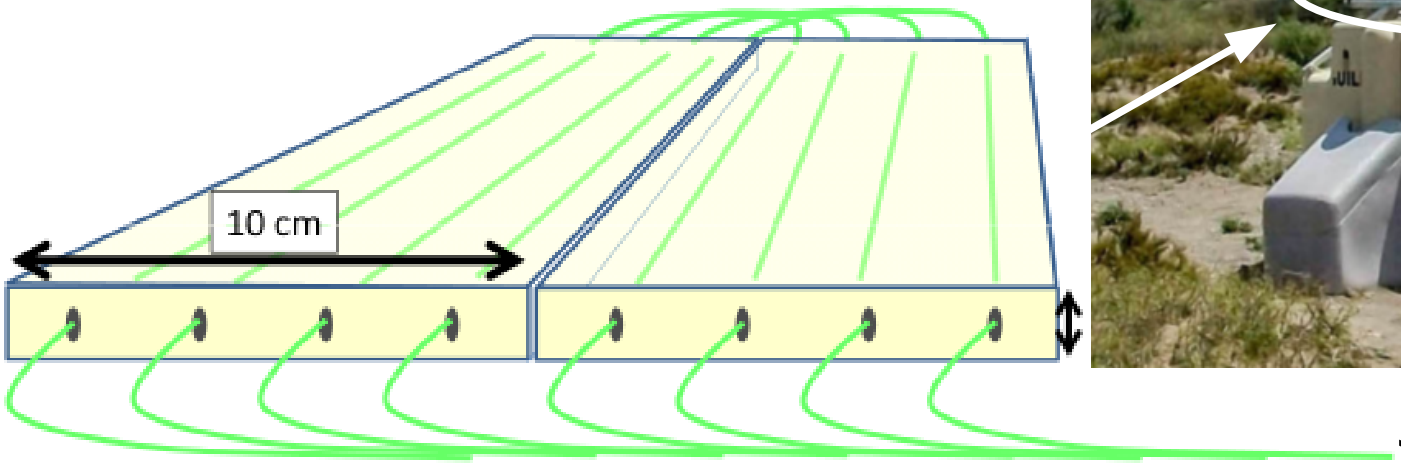



Pampa Amarilla, Argentina
?


Pampa Amarilla, Argentina

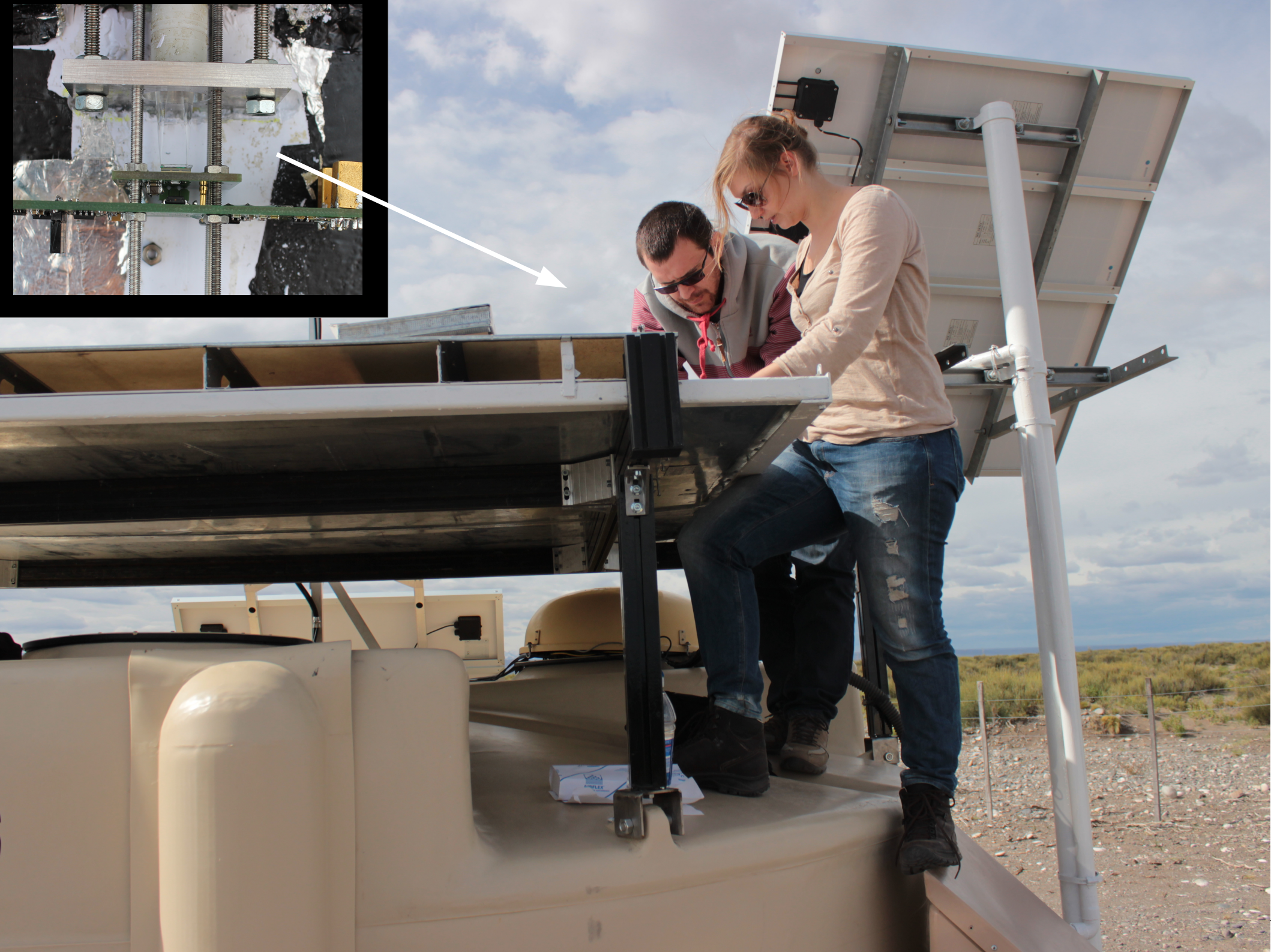
The Upgrade – AugerPrime



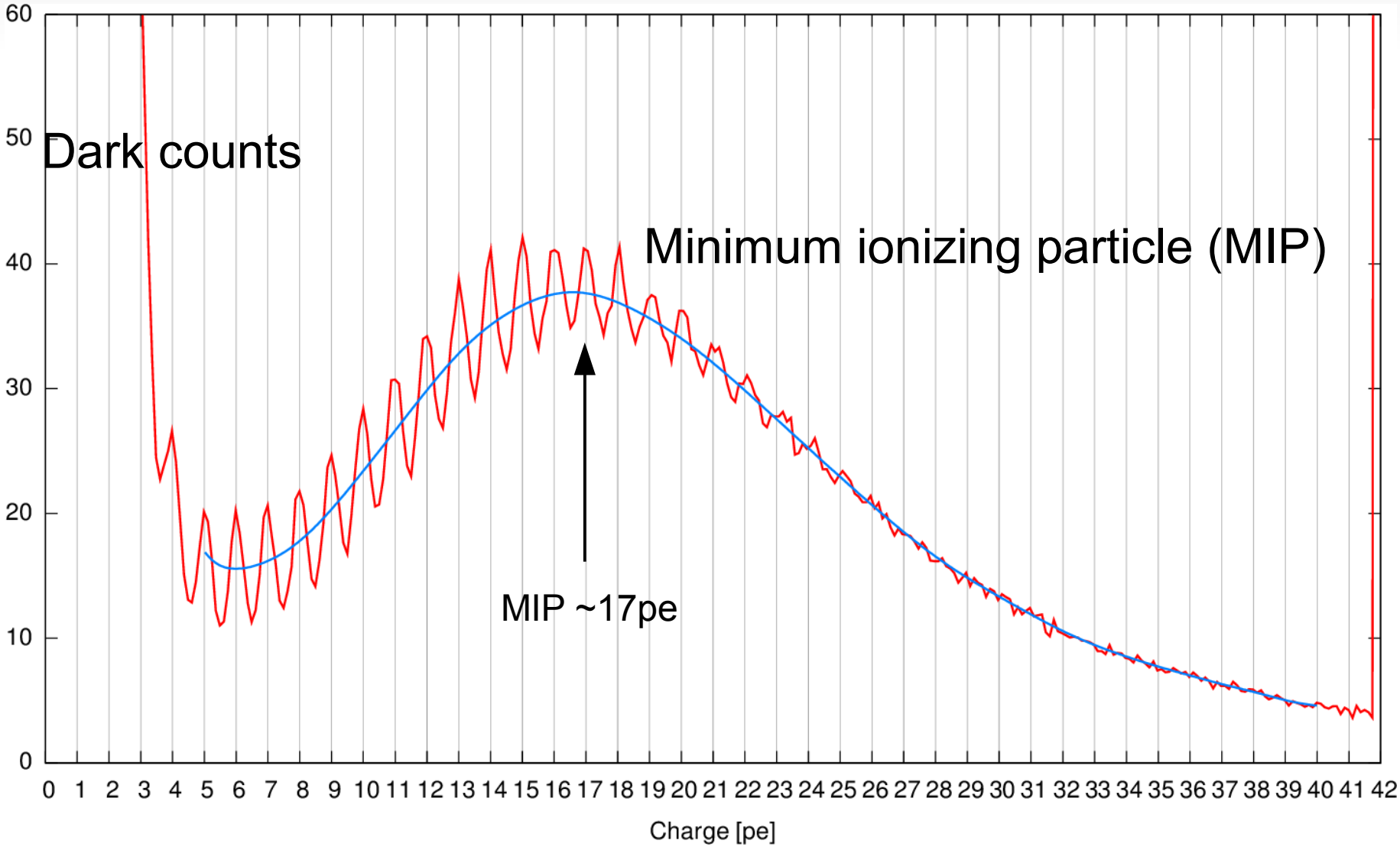


>=1 SiPM

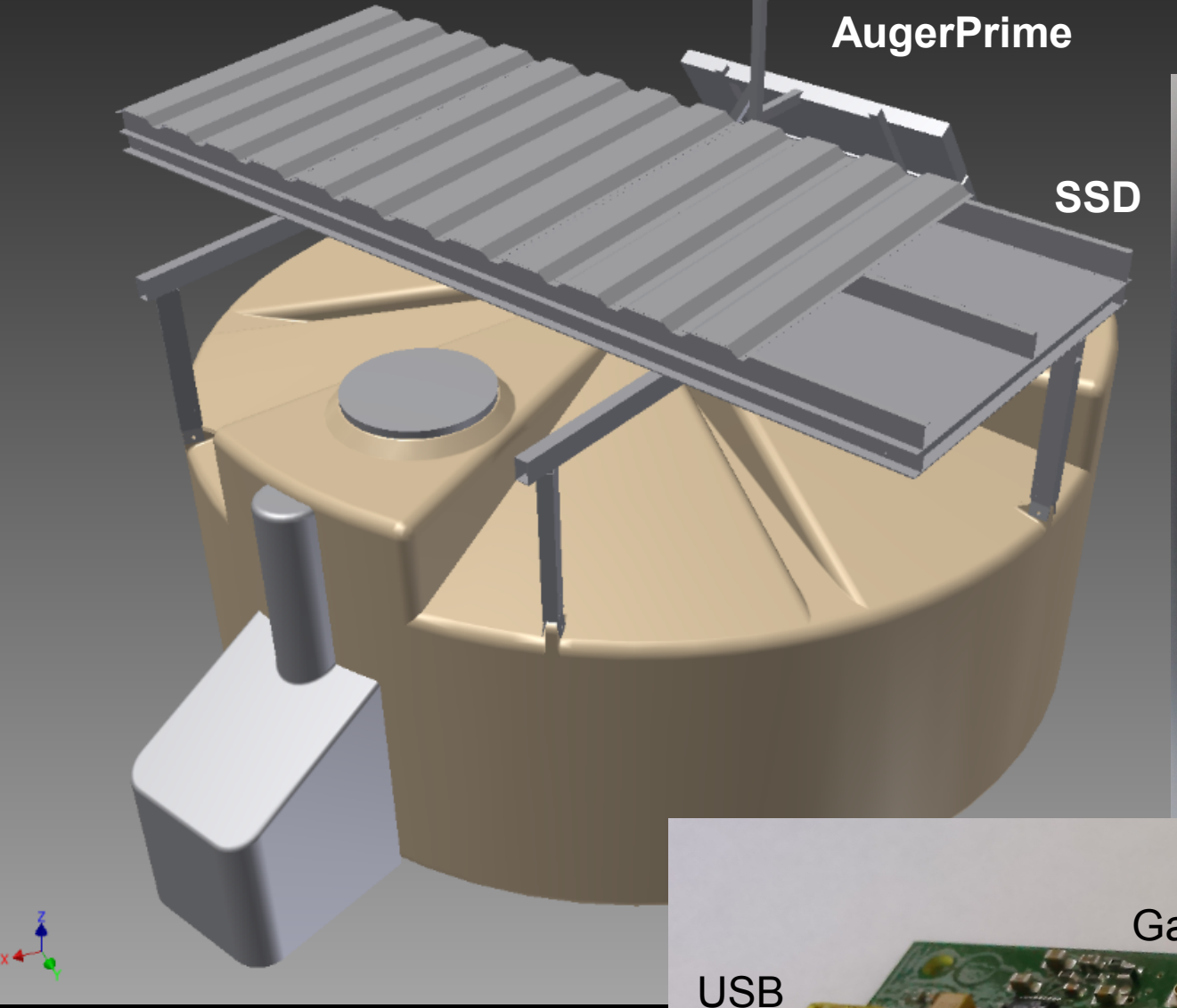
→ Replace PMT with SiPM

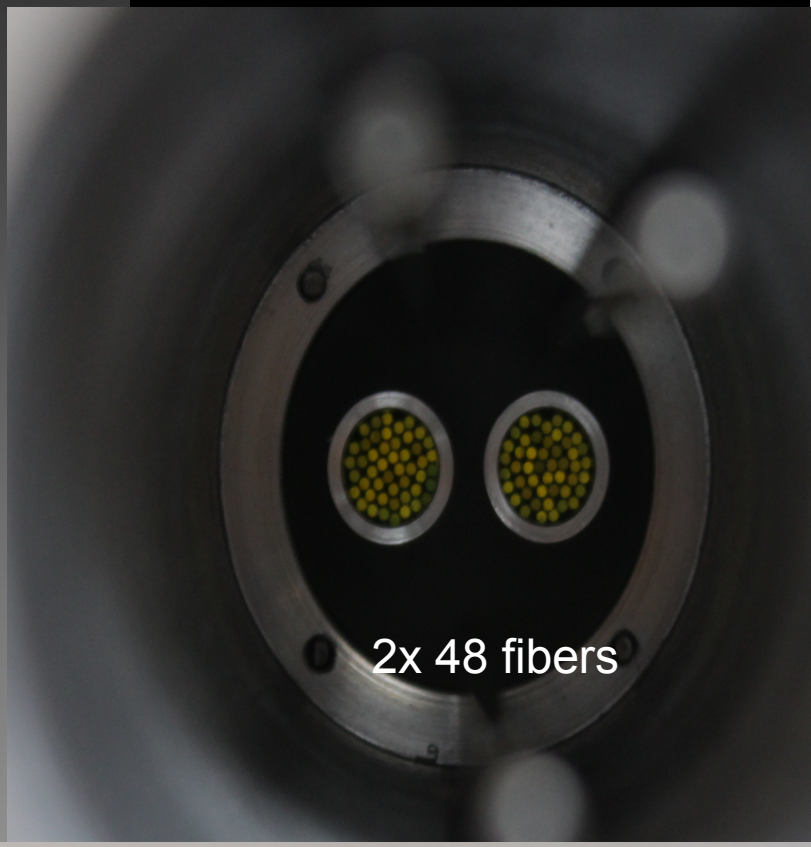


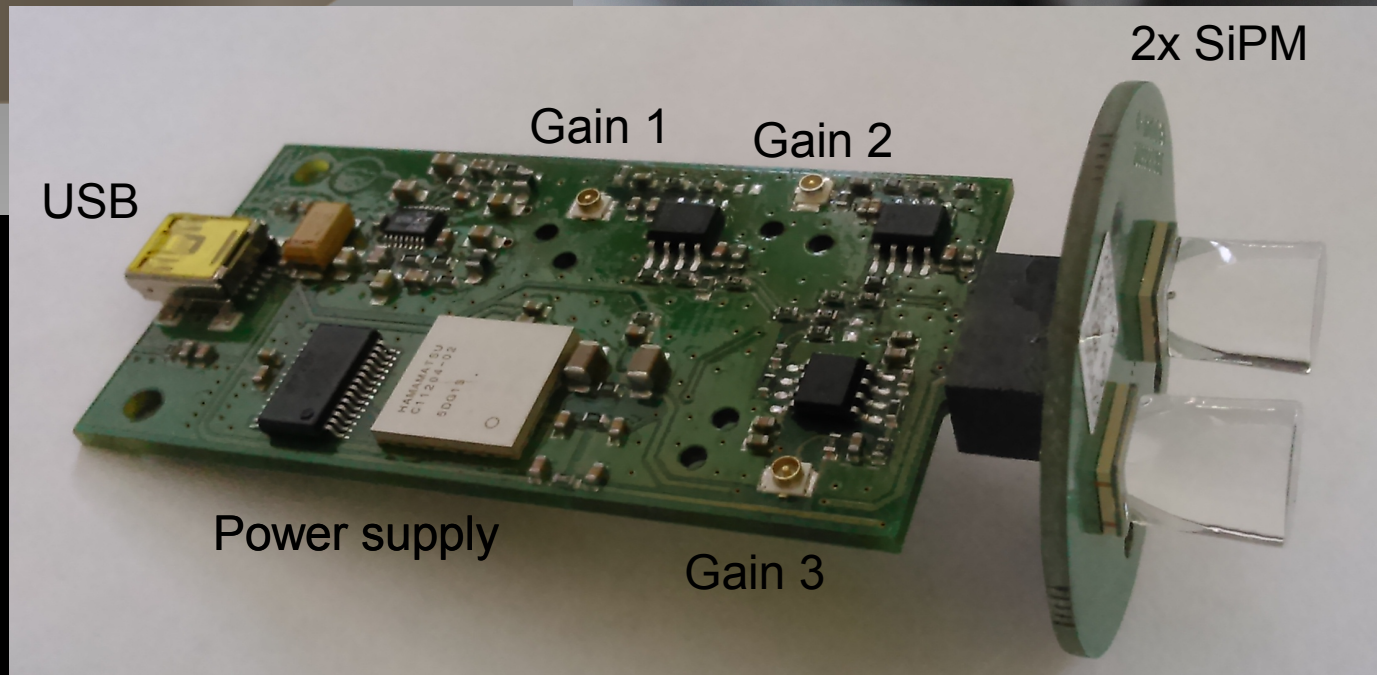
Charge spectrum (calibrated)



AugerPrime







Installation
→ this week

Technology outlook

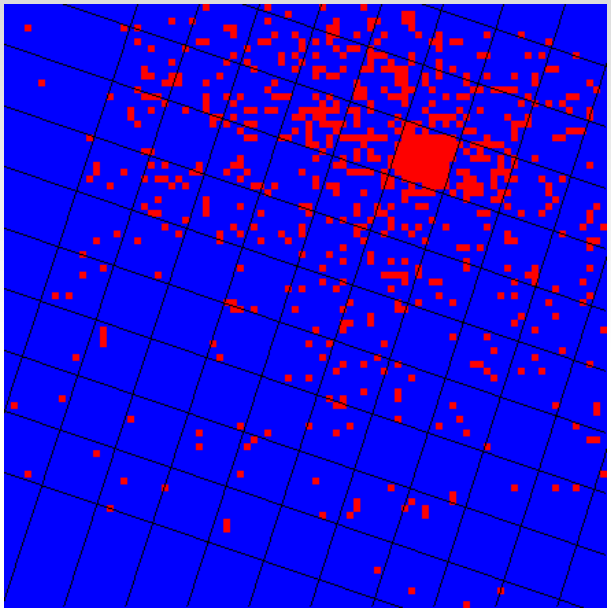
- No significant further improvement expected in the near future
  (but some are still in the queue)

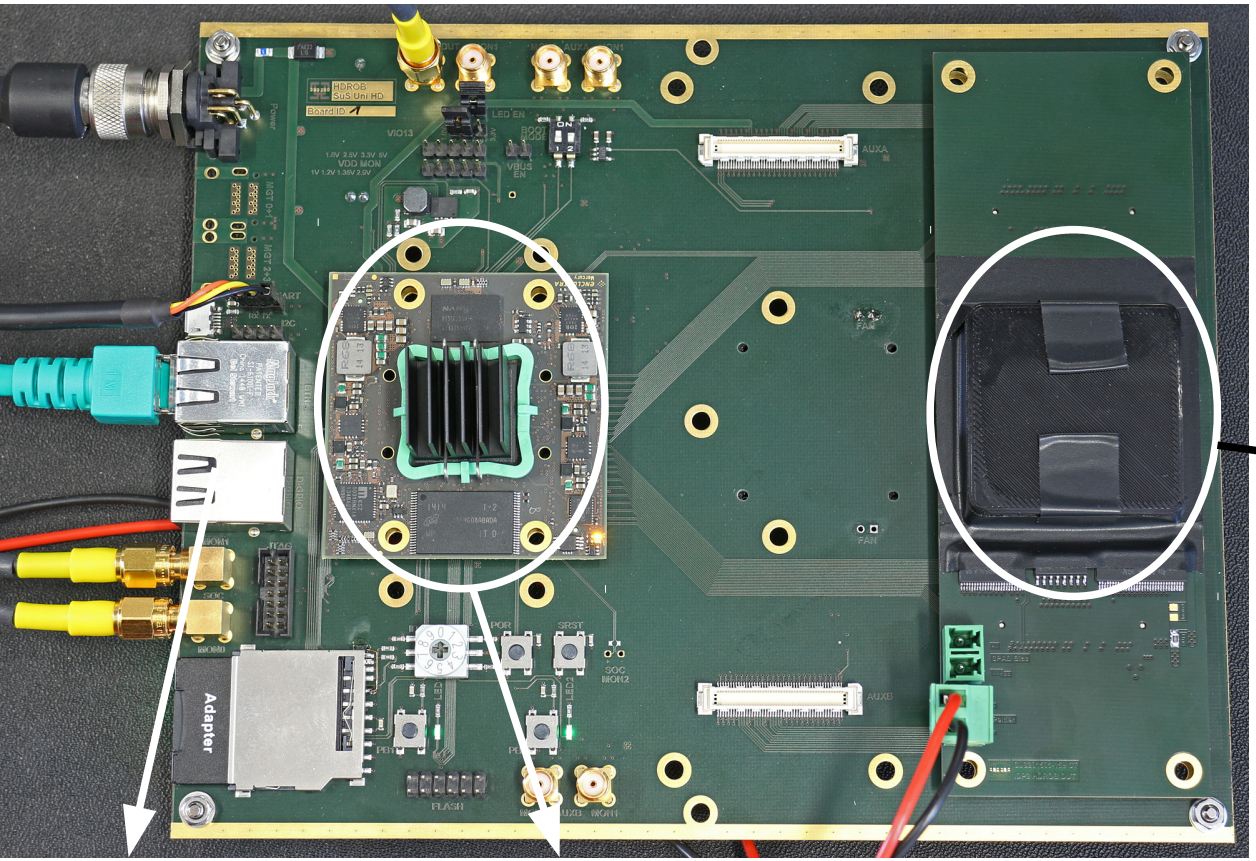
- Dedicated integrated (low cost) circuits
  (power supply, daq)

- SiPM integrated data acquisition
  (*digital SiPM*)

Digital SiPM…

Hit pattern on the SiPM

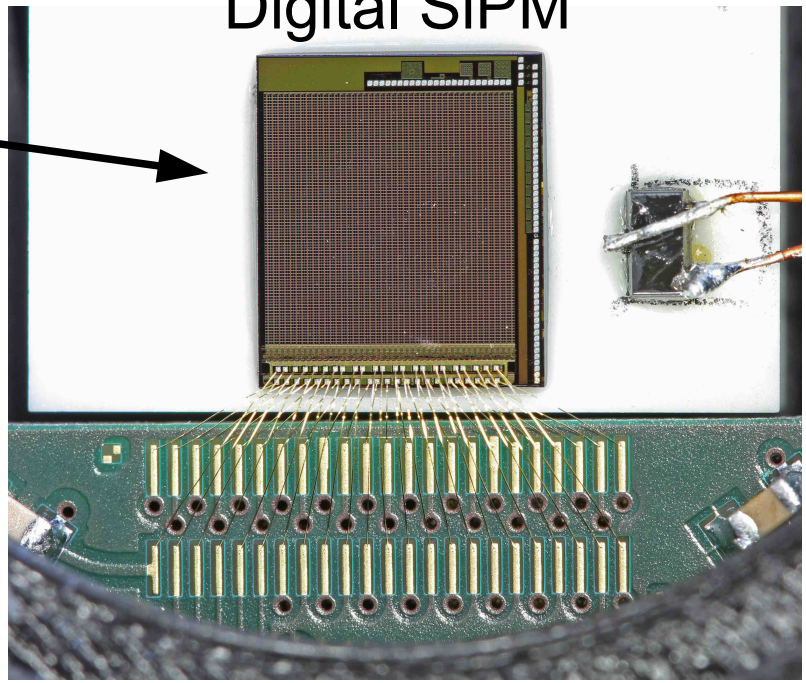




Ethernet

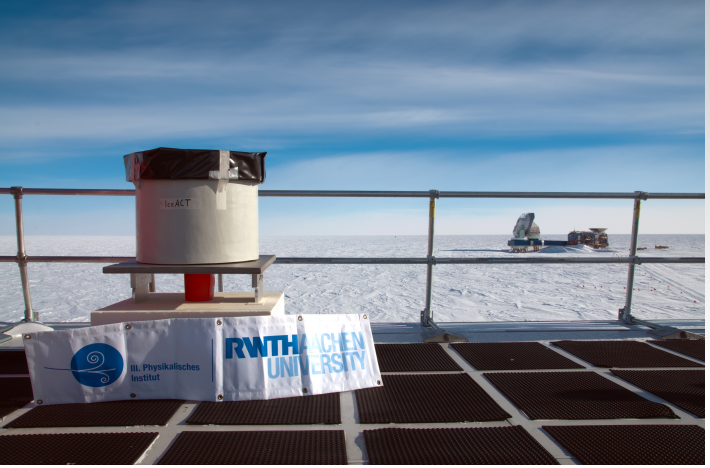
FPG for readout

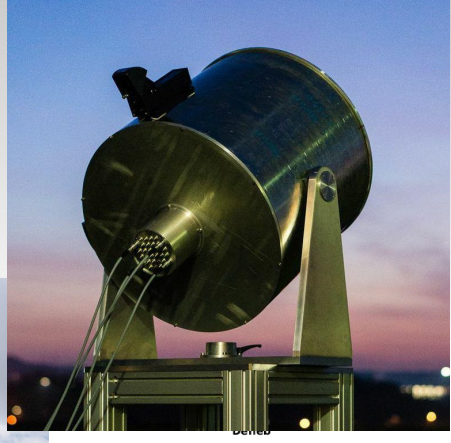
Digital SiPM

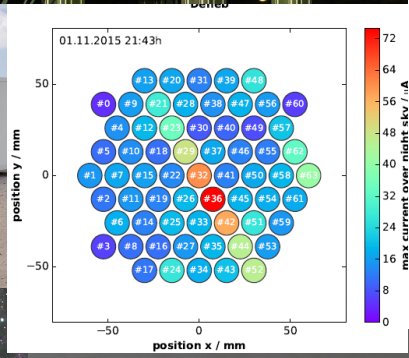


Peter Fischer, Heidelberg University

Conclusion







- SiPM will play a major role in Astroparticle physics

- Interesting new technology in the queue