First evaluation of the prototype 19-modules camera for the Large Size Telescope of the CTA

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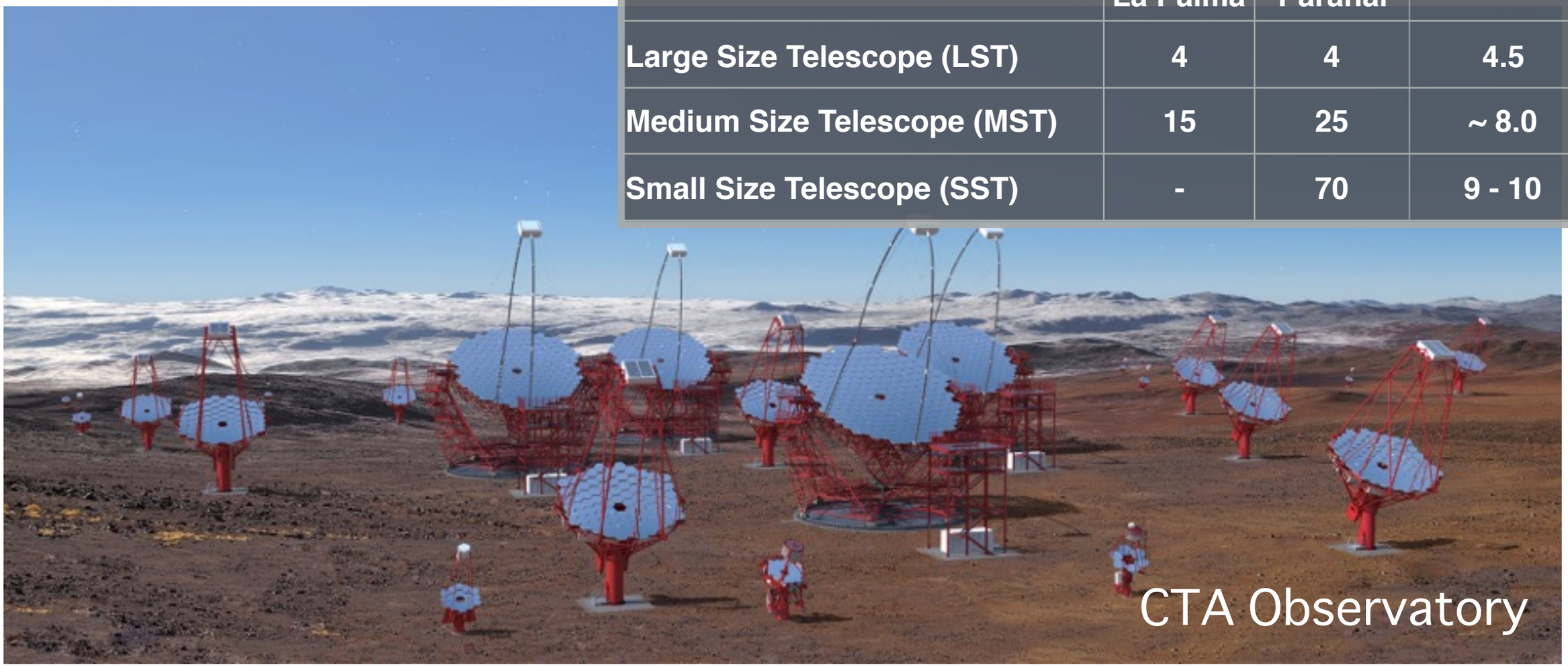
Cherenkov Telescope Array (CTA)

- Extend the accessible energy coverage from 20 GeV to 300 TeV
- Improve flux sensitivity up to factor of 10
- Survey capability through a wider field of view
- Two sites (North: La Palma (Spain), South: Paranal (Chile))

	North La Palma	South Paranal	FOV [deg]
Large Size Telescope (LST)	4	4	4.5
Medium Size Telescope (MST)	15	25	~ 8.0
Small Size Telescope (SST)	-	70	9 - 10



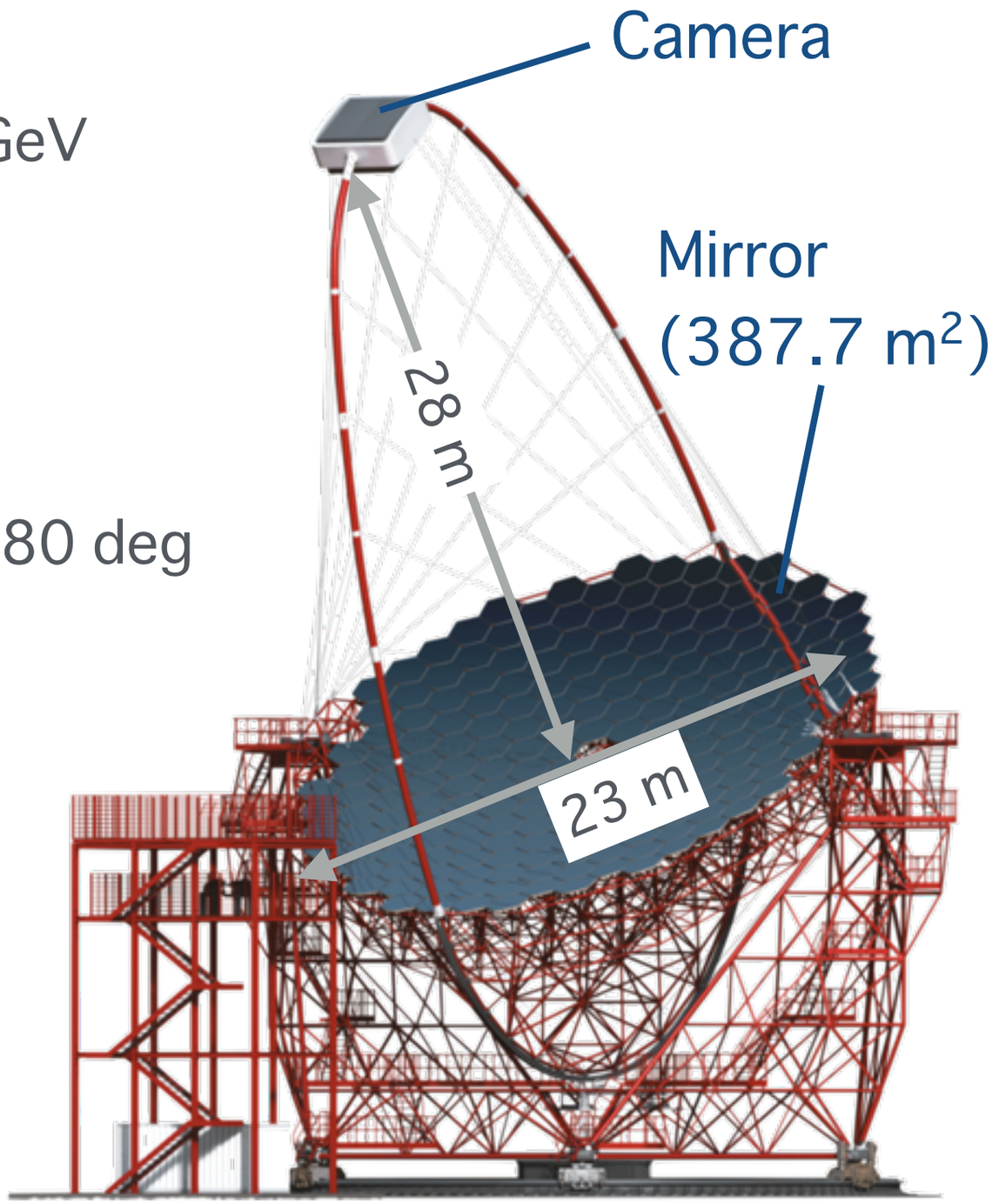
Large Sized Telescope (LST)

- Improving CTA sensitivity in 20 - 200 GeV

- The main requirements for LST
  - Low energy threshold : 20 GeV
  - Fast repositioning speed : < 20 sec/180 deg

- Large discovery potential
  - pulsars, distant AGNs, GRBs

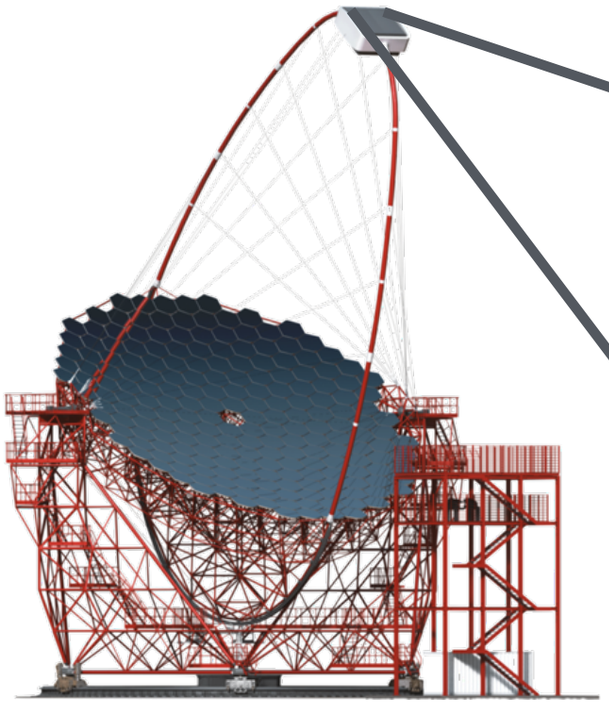
- LST-1 construction is ongoing(North)

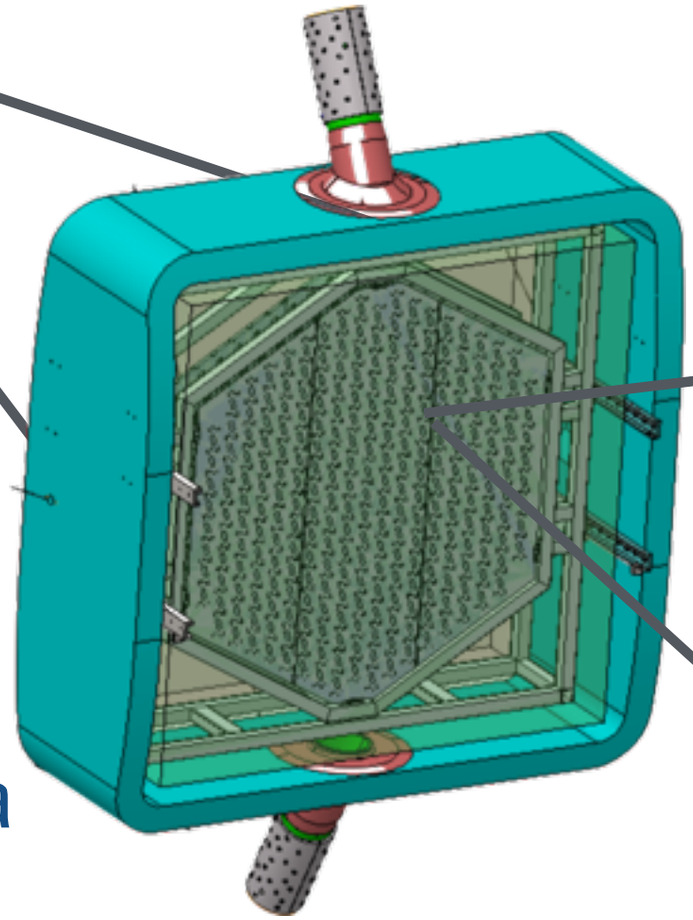


CTA Observatory

LST camera

- 1855 PMT pixels and 0.1 deg/pixel (50 mm)
- The minimum camera unit is the so-called “PMT module”





LST camera

FoV: 4.5 deg

1855 pixels

256 PMT modules

Power consumption: 7 kW

PMT module

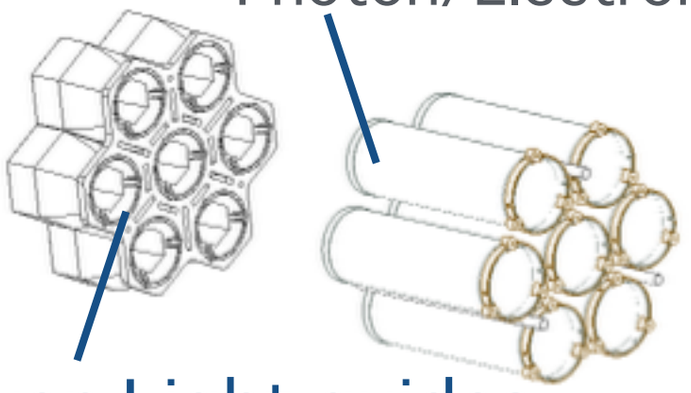
Seven PMTs

Power consumption: 3 W/ch

PMT module

Seven PMTs

Photon/Electron conversion



Seven Light guides

Reducing dead space

Readout board

A/D conversion

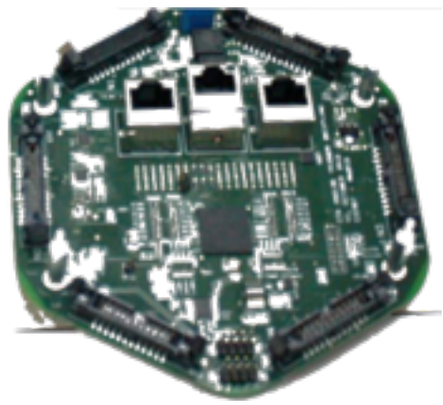
Slow control board

Controlling and monitoring PMTs

Backplane board

Ethernet and power connector

+



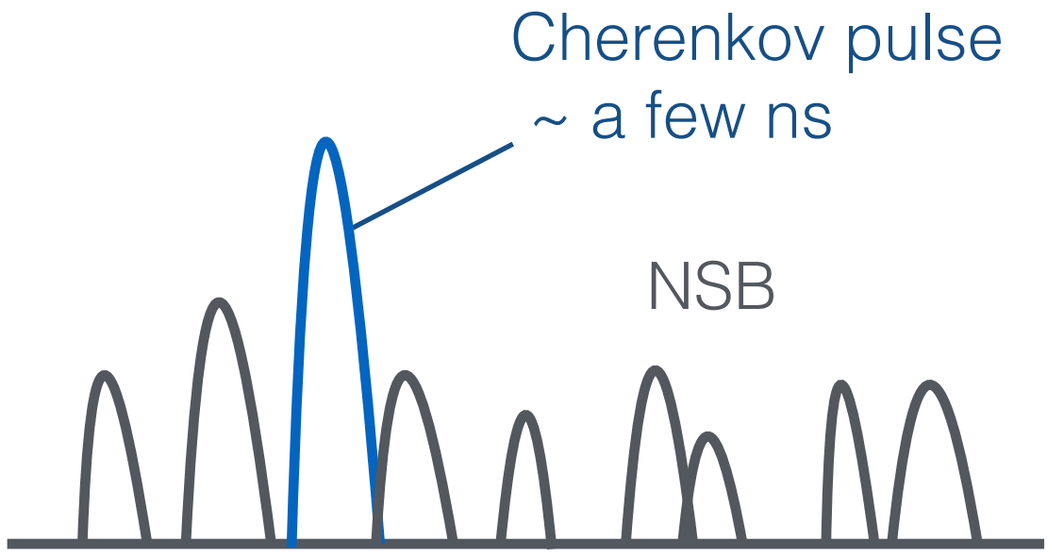
The issues of low energy observations

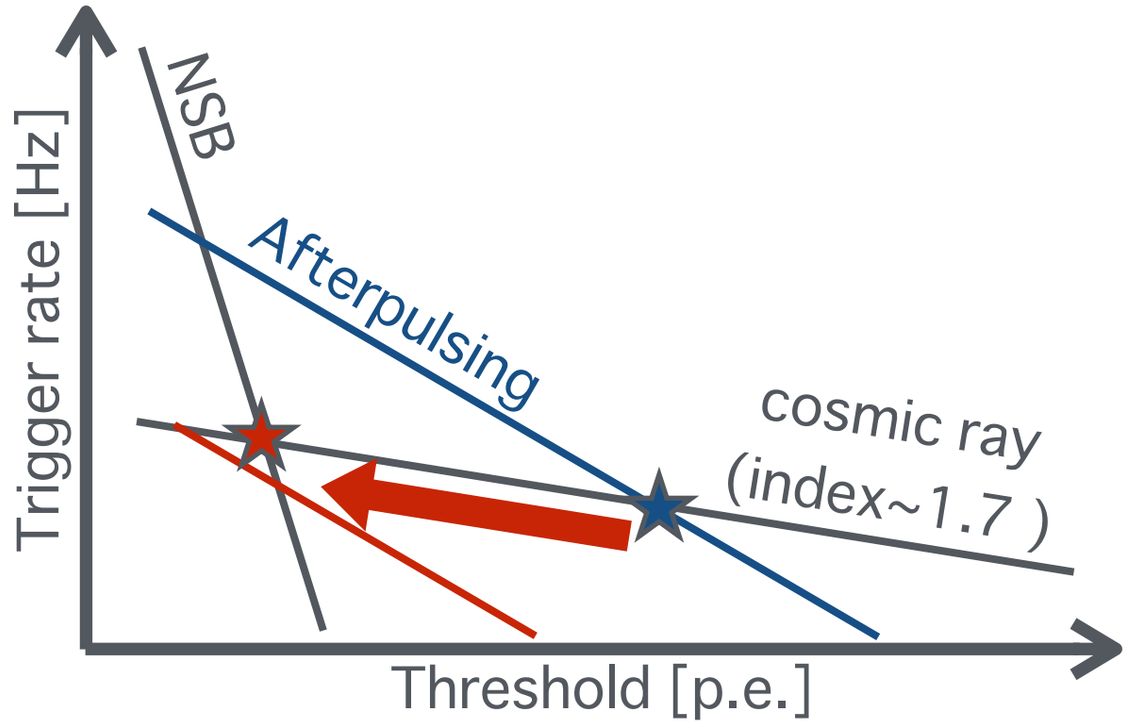
- Dim Cherenkov emission
  - High QE PMTs

- ~ 300 MHz Night Sky Background (NSB)
  - GHz sampling speed

- Trigger threshold
  - Low afterpulsing probability PMTs

LST requires
- high QE and low afterpulsing PMTs
- GHz sampling readout boards

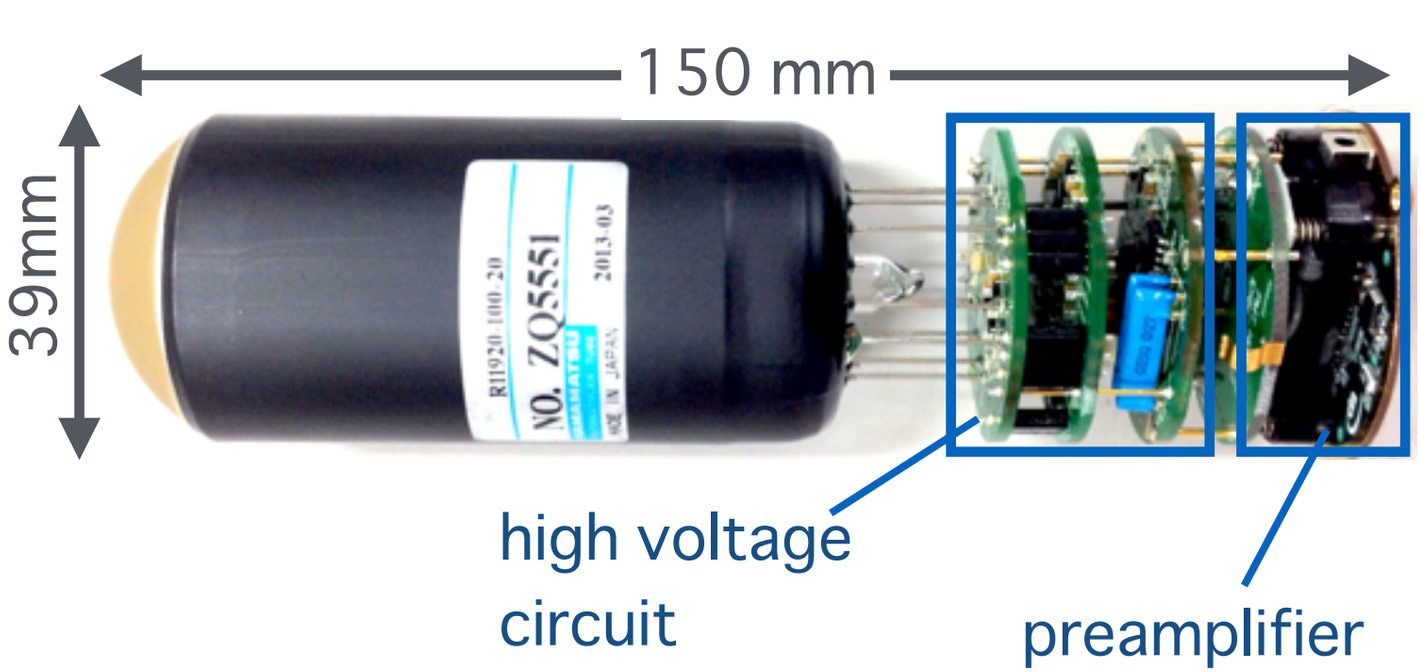


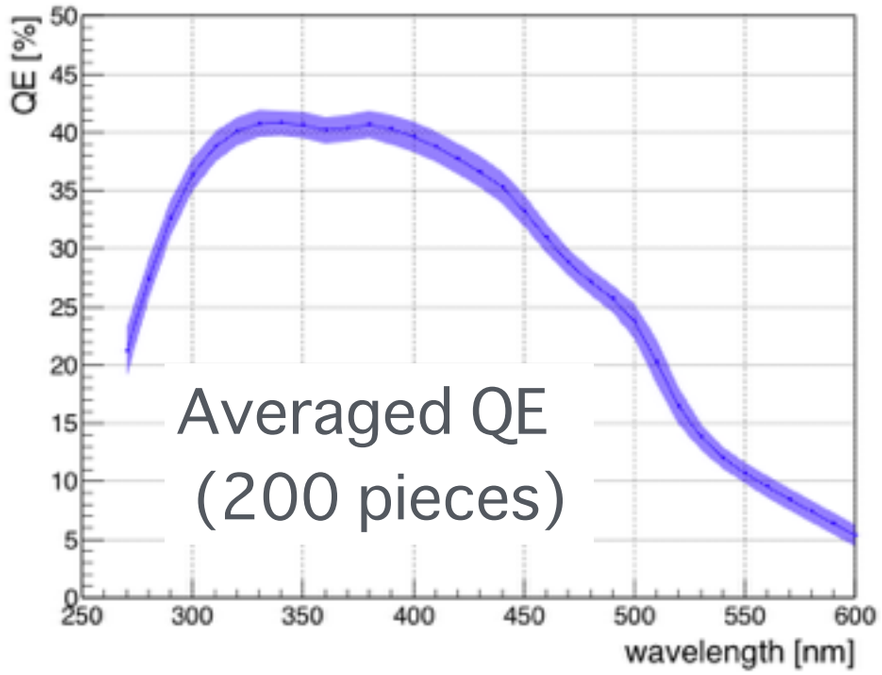


Afterpulse : dummy pulse generated in PMT

PMT unit

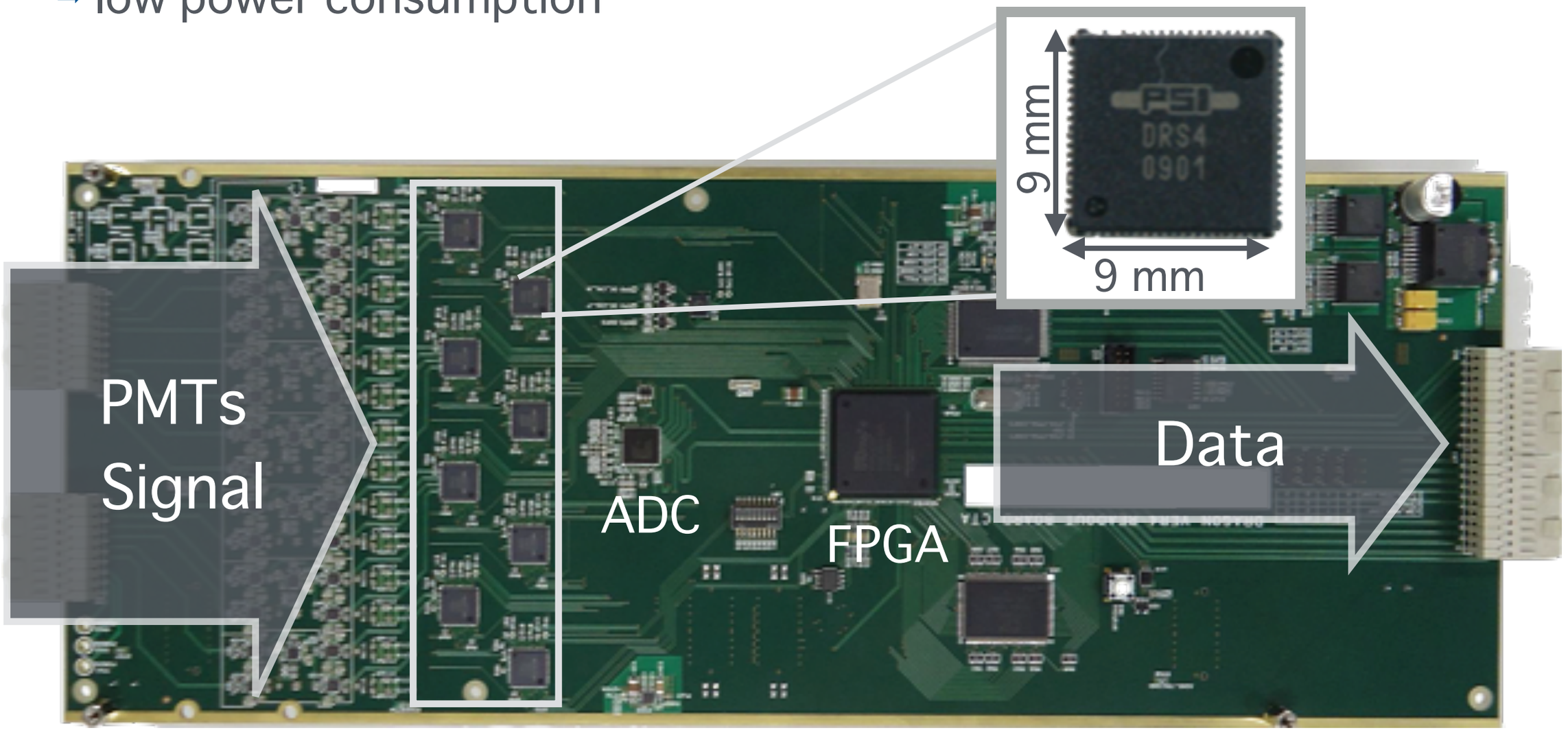
- The PMTs for the first LST have been developed by HAMAMATSU Photonics
- Superbialkali surface ~ 40 % QE
- Quality control was done at ICRR (Japan)
  - nominal voltage distribution (gain : $4 \cdot 10^4$) is narrower than 20 %
  - average pulse width : 2.7 ns
  - average afterpulsing probability : 0.003 %
  - 1988 PMTs work well and meet the requirements (total 2015 PMTs)





Readout board

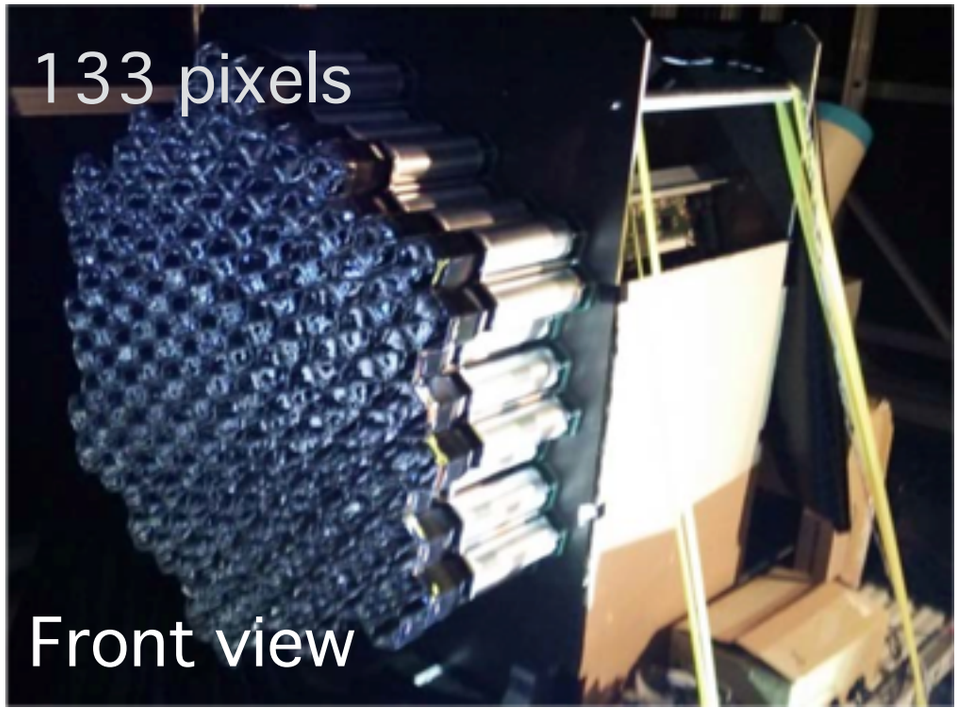
- LST adopted the analog memory ASIC “DRS4”
  - Sampling signal with GHz speed and digitising with MHz speed
    - ➡ GHz sampling speed
    - ➡ low power consumption

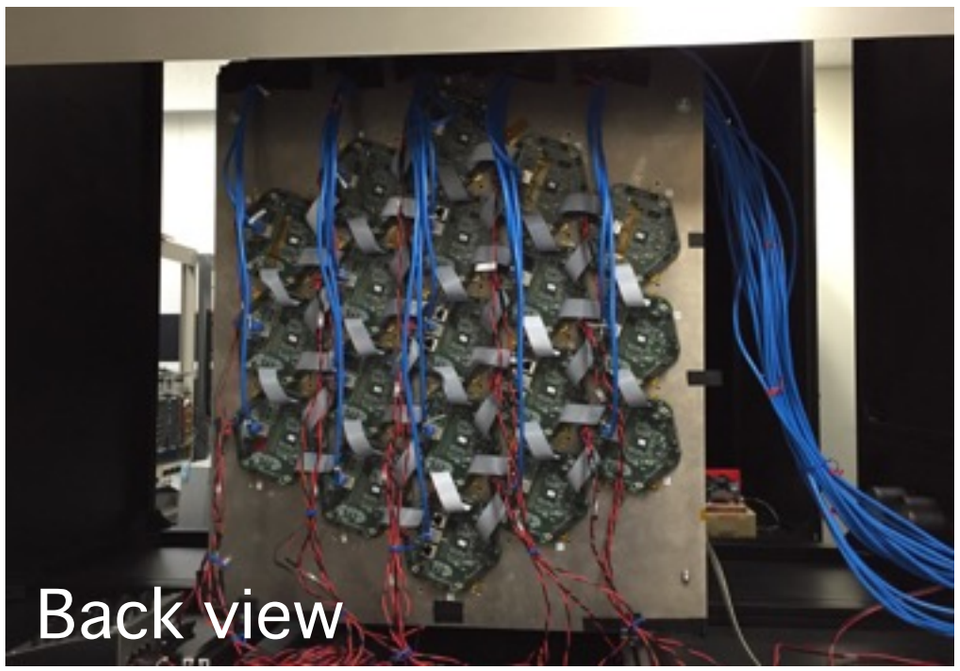


Integration test using Mini Camera

- The Mini Camera system consists of 19 PMT modules (1/14 scale copy of the final LST camera)

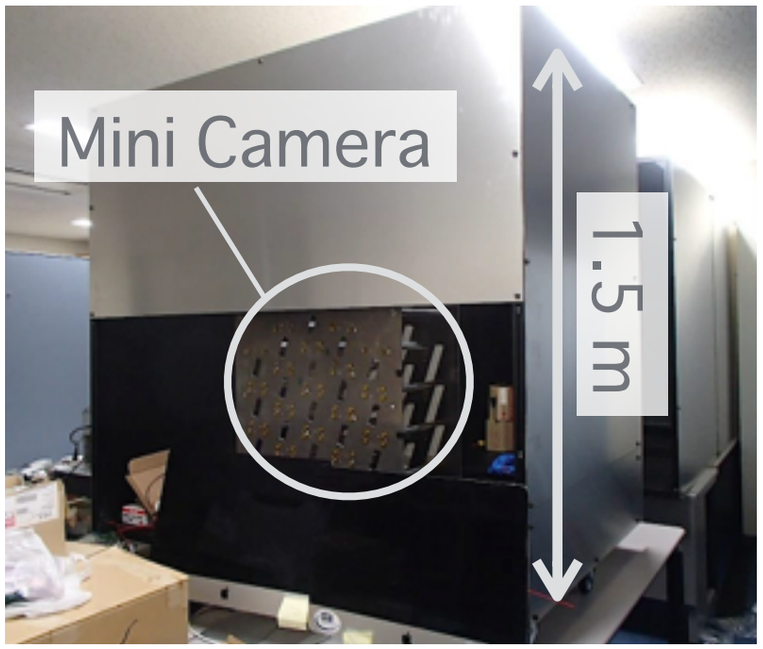
- Aims of Mini Camera test :
  - Test mechanics
  - Construct camera control system
    - ➡ Module control
    - ➡ Trigger propagation system
  - Evaluate total noise level



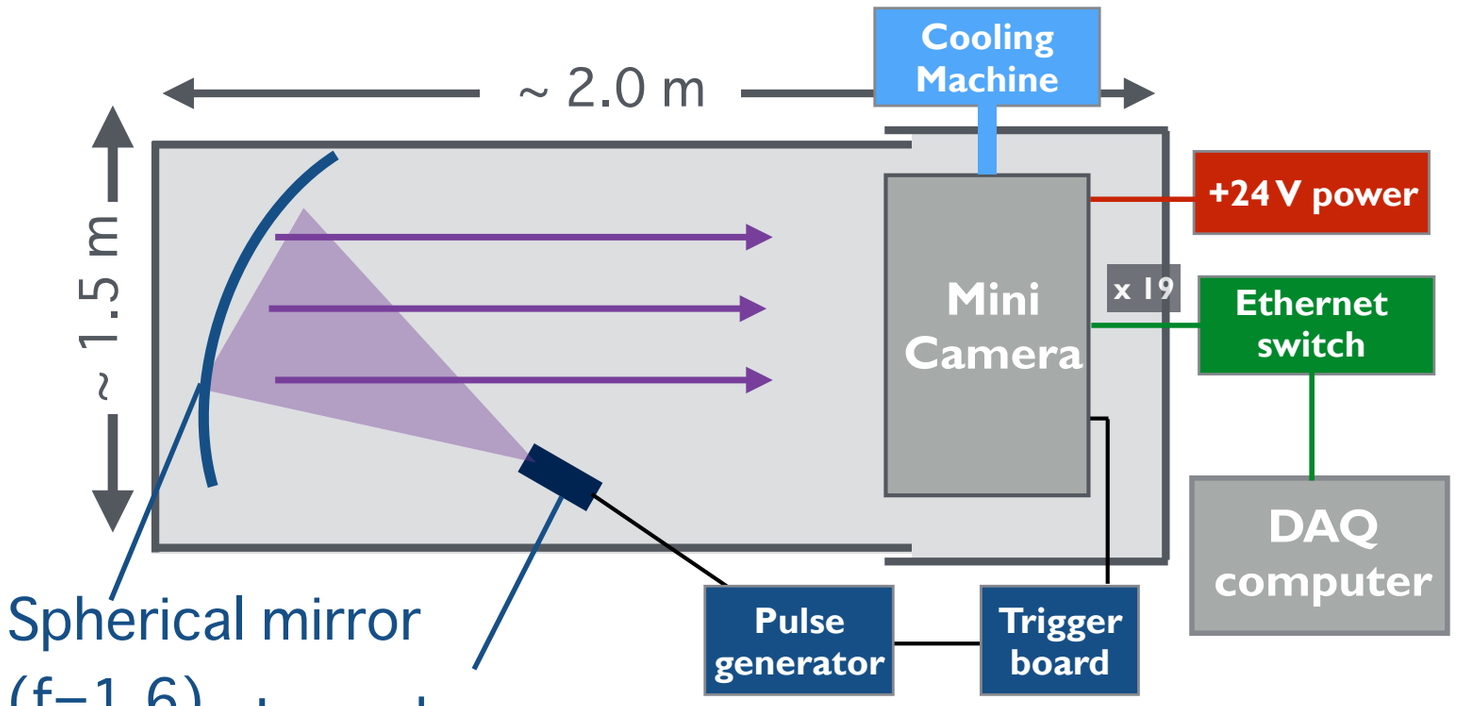


Mini Camera setup

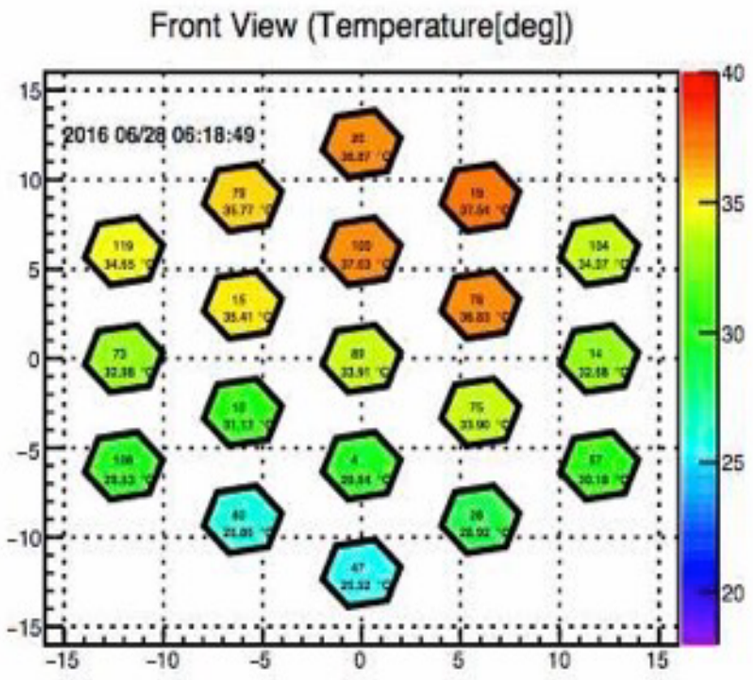
- First mini camera setup was constructed at ICRR (Japan)
- 1.5 m x 2.0 m x 1.5 m dark box
- A spherical mirror and a diffuser are used to make the light intensity homogeneous (±15%)
- Data is sent via Ethernet
- A module control program was developed

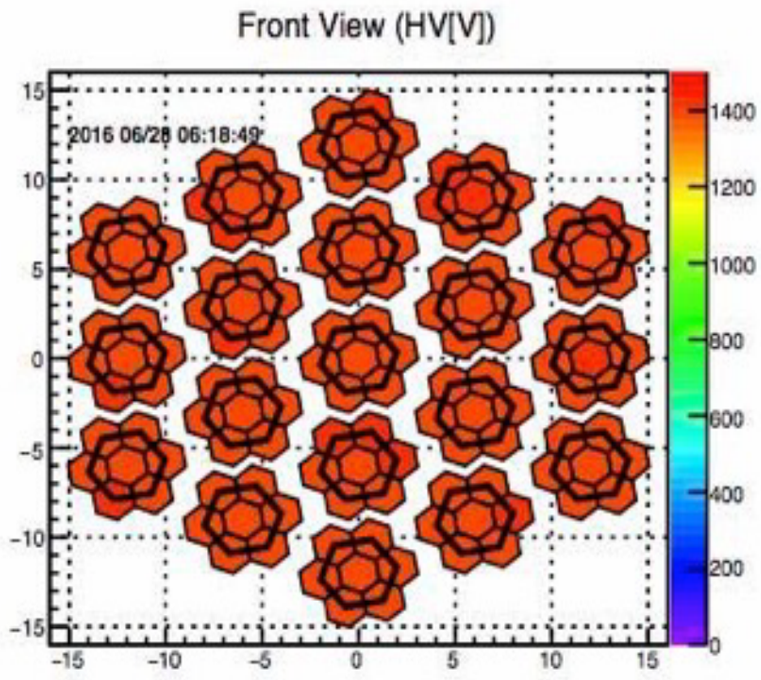


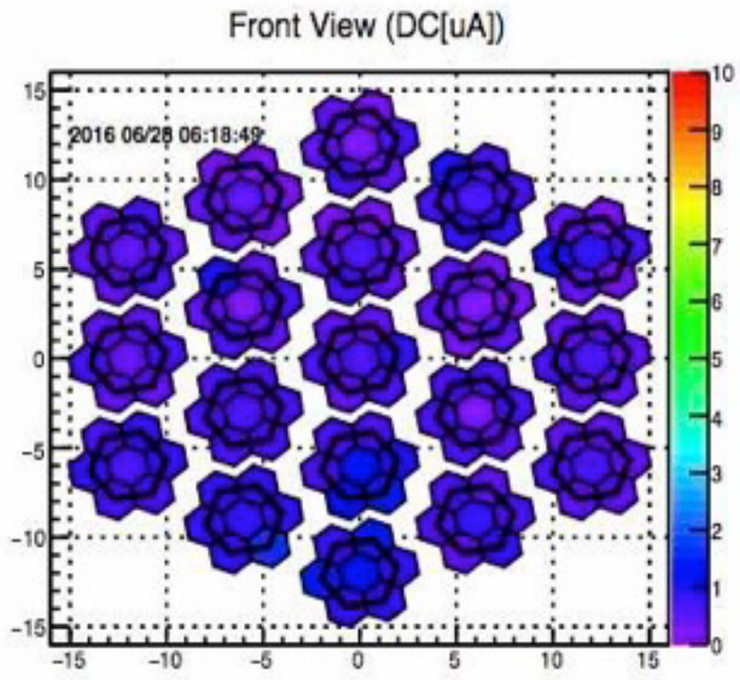
Setup @ ICRR

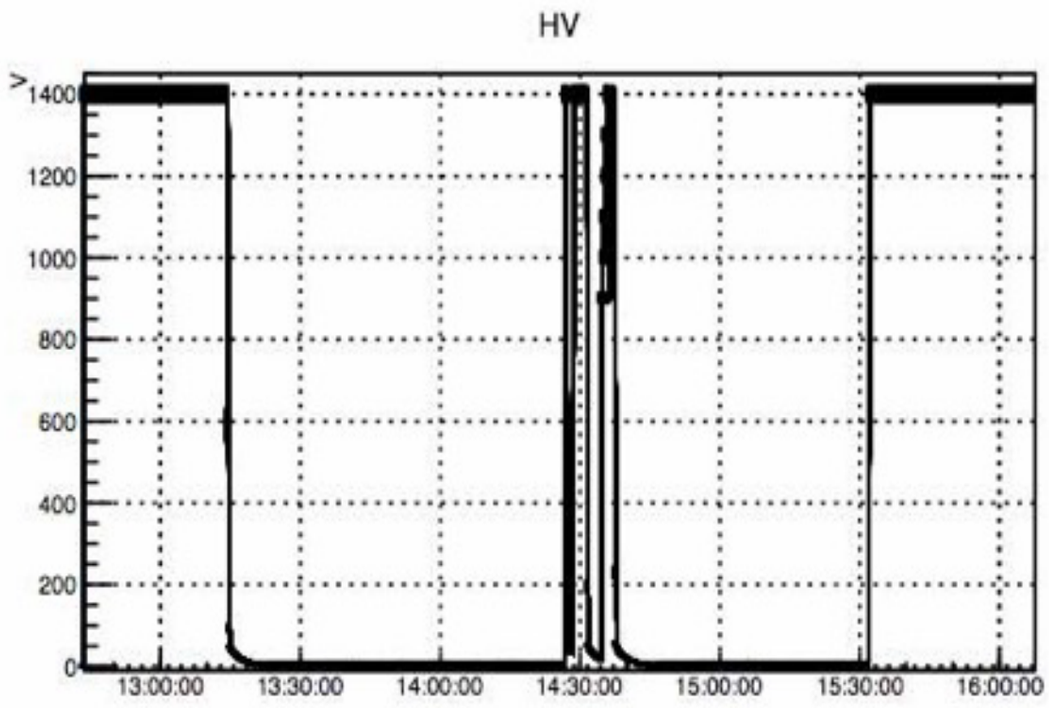


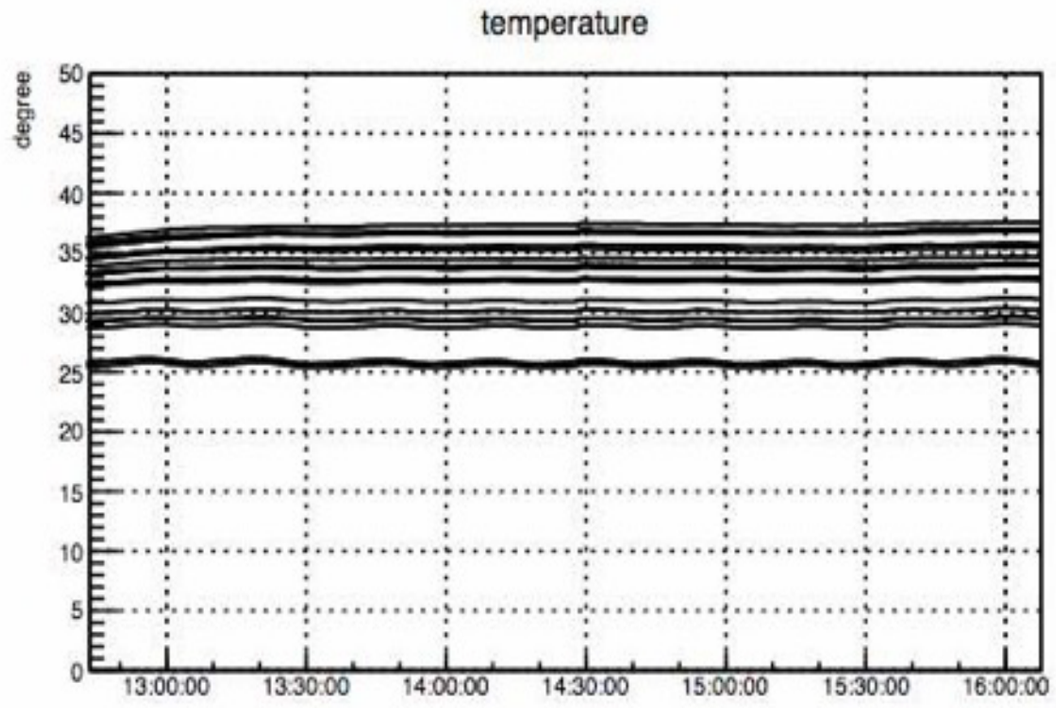
Monitoring display





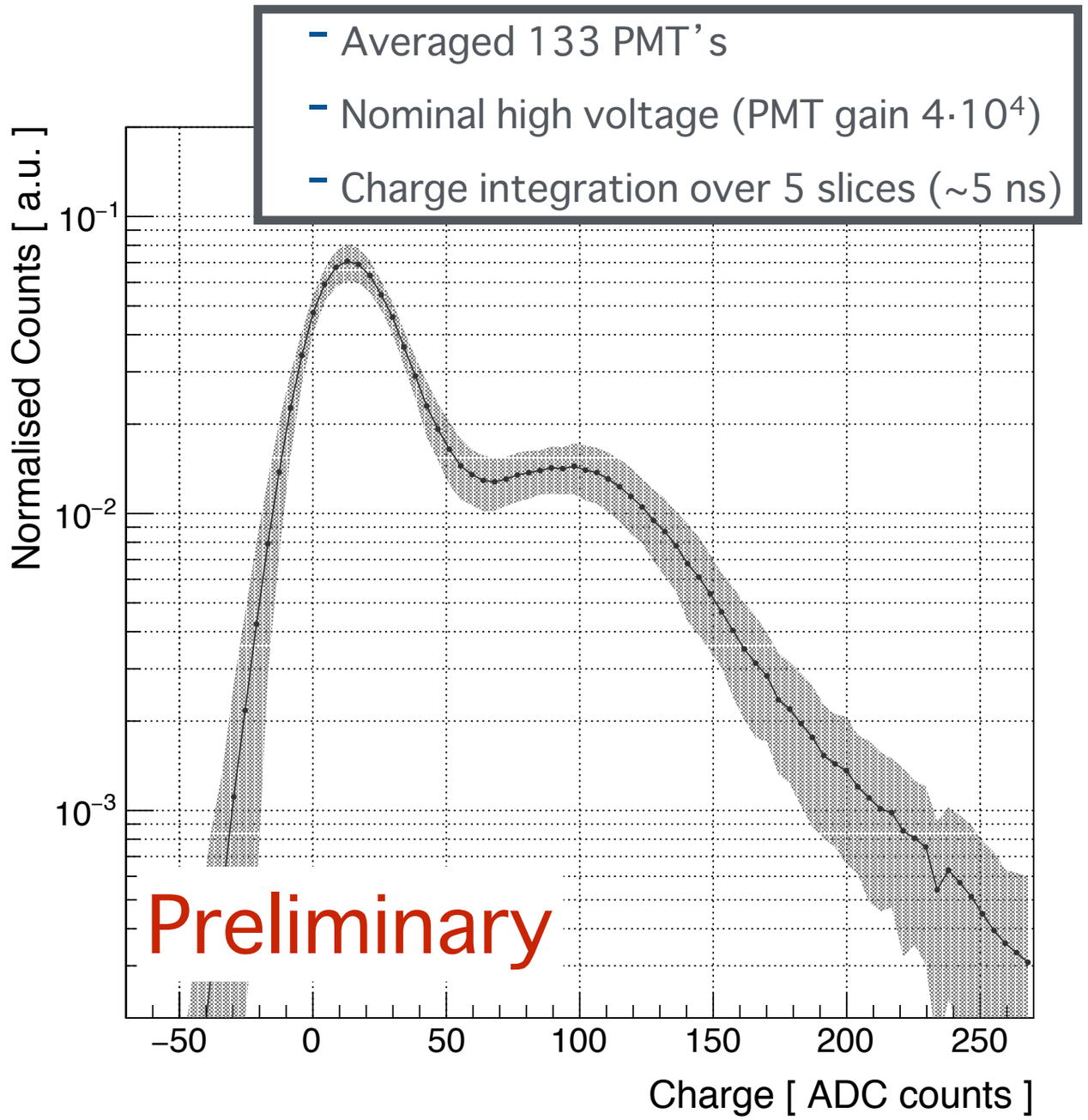




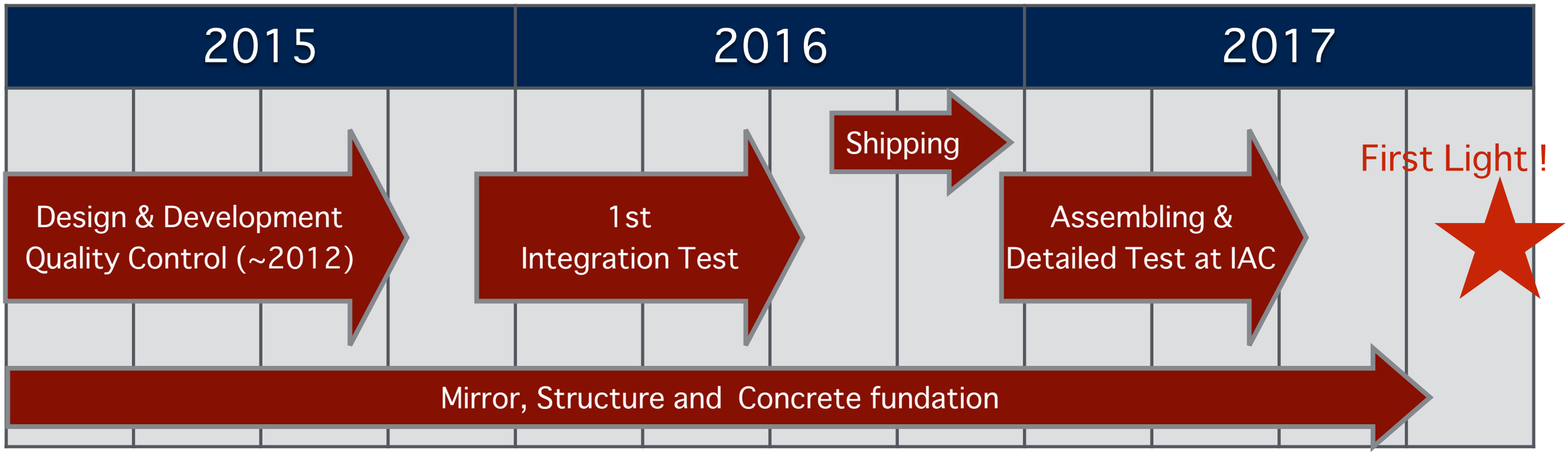


Single phe response of PMT modules

- Measured with low light intensity
- Single phe peak clearly visible
  - Single phe :
    68.78 ± 0.03 [ADC counts]
  - Noise level (total):
    15.15 ± 0.16 [ADC counts]
- S/N = 4.59 ± 0.05



Status and Plan



- All camera elements were shipped to Tenerife, located next to La Palma
- The PMT module assembly and the final integration test using the Mini Camera system are ongoing at Tenerife
- Camera installation will be performed on September 2017
- First Light of LST-1 on November 2017 !

Summary

- LST will archive 20 GeV energy threshold and improve the sensitivity of CTA between 20 and 200 GeV

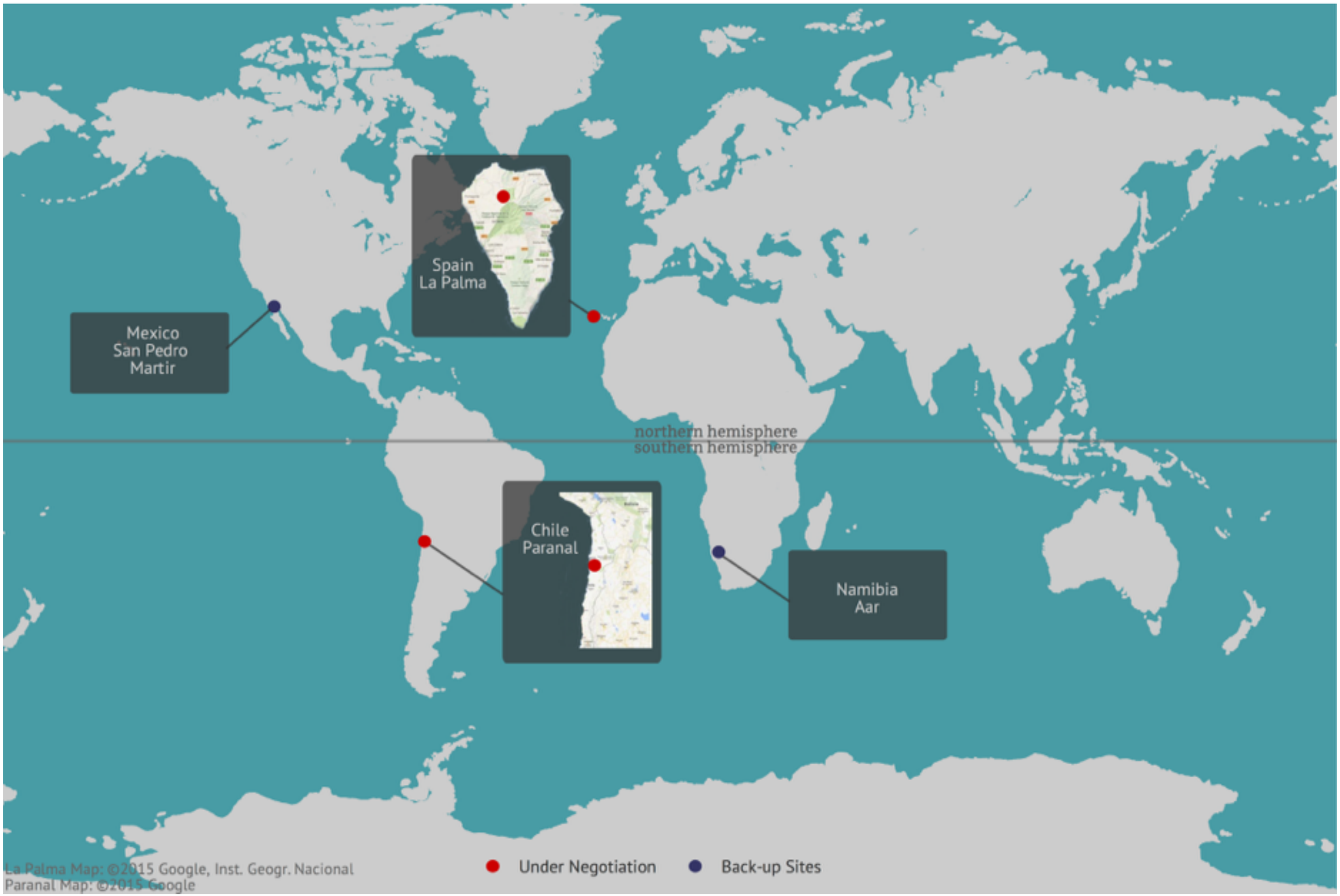
- LST camera has been designed for the lowest energies:
  - PMTs have high QE and low afterpulsing probability
  - Readout board has a low power consumption and GHz sampling speed

- The QCs of each part of the PMT module have been carried out

- We performed the integration test using the Mini Camera system
  - The module control program was developed
  - The trigger system was confirmed to work
  - S/N > 4

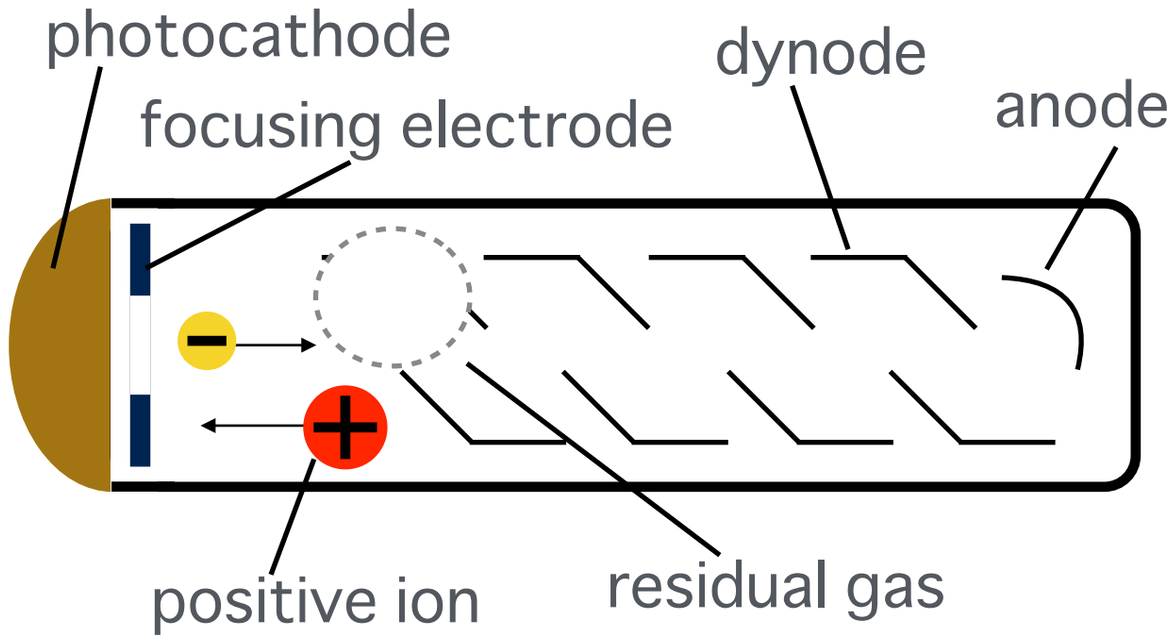
- Now we are focusing on the first light of LST-1 on Nov 2017 !

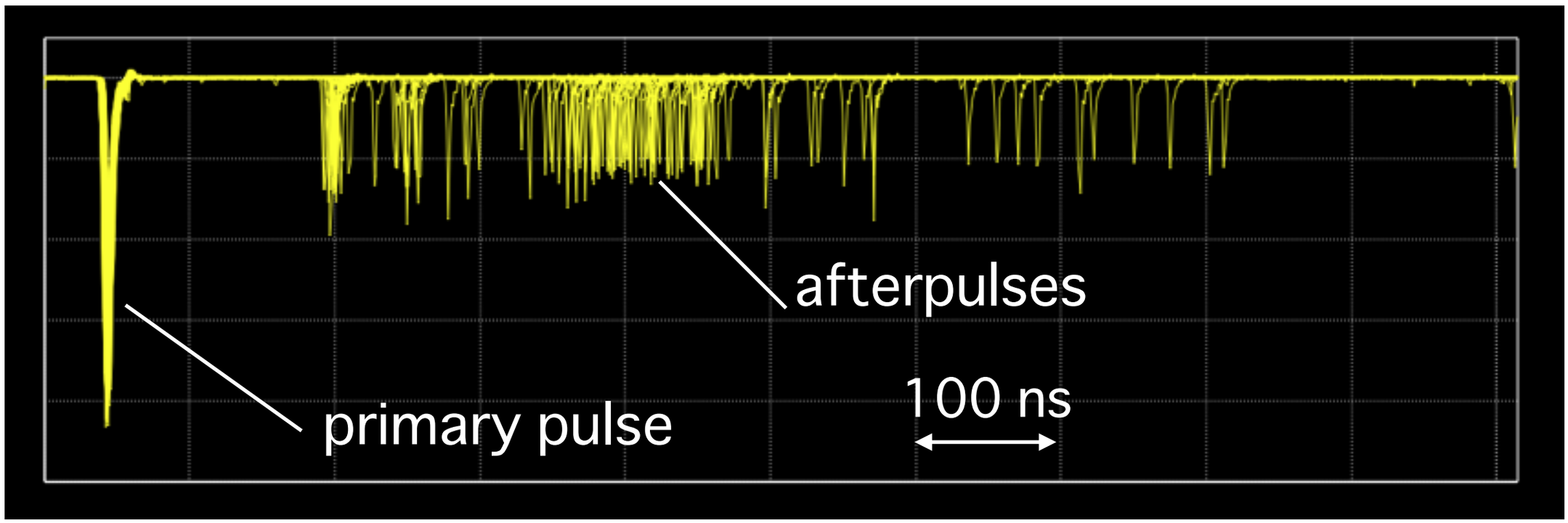
Back up


Spain
La Palma
Mexico
San Pedro
Martir
northern hemisphere
southern hemisphere
Chile
Paranal
Namibia
Aar
Under Negotiation
Back-up Sites
La Palma Map: ©2015 Google, Inst. Geogr. Nacional
Paranal Map: ©2015 Google

Afterpulsing

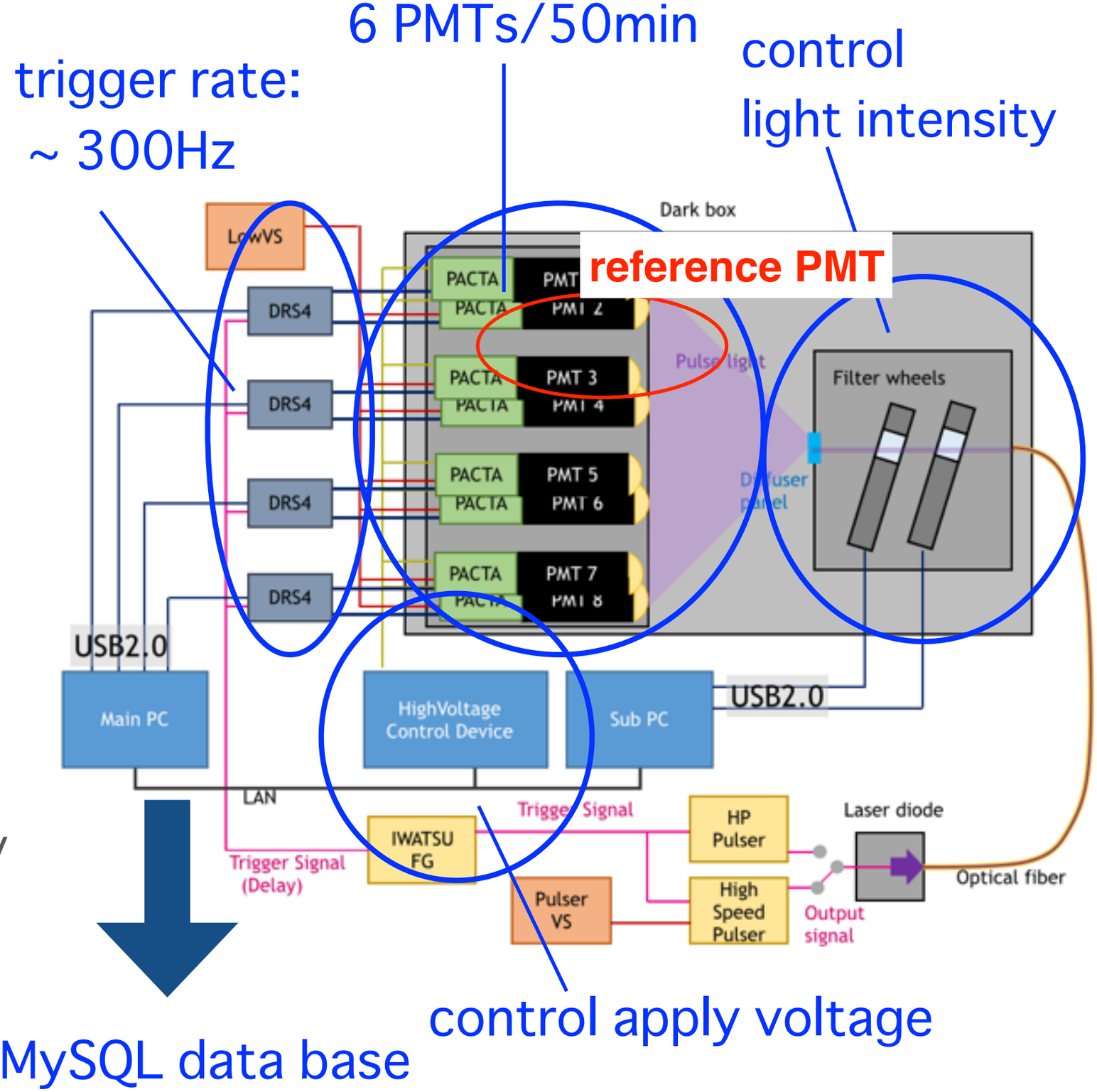
- Generated by the positive ions which are generated by the ionisation of residual gas (ion feedback)
- The delay time is a few hundred ns to a few us
- Peak amplitude is 4 - 5 phe





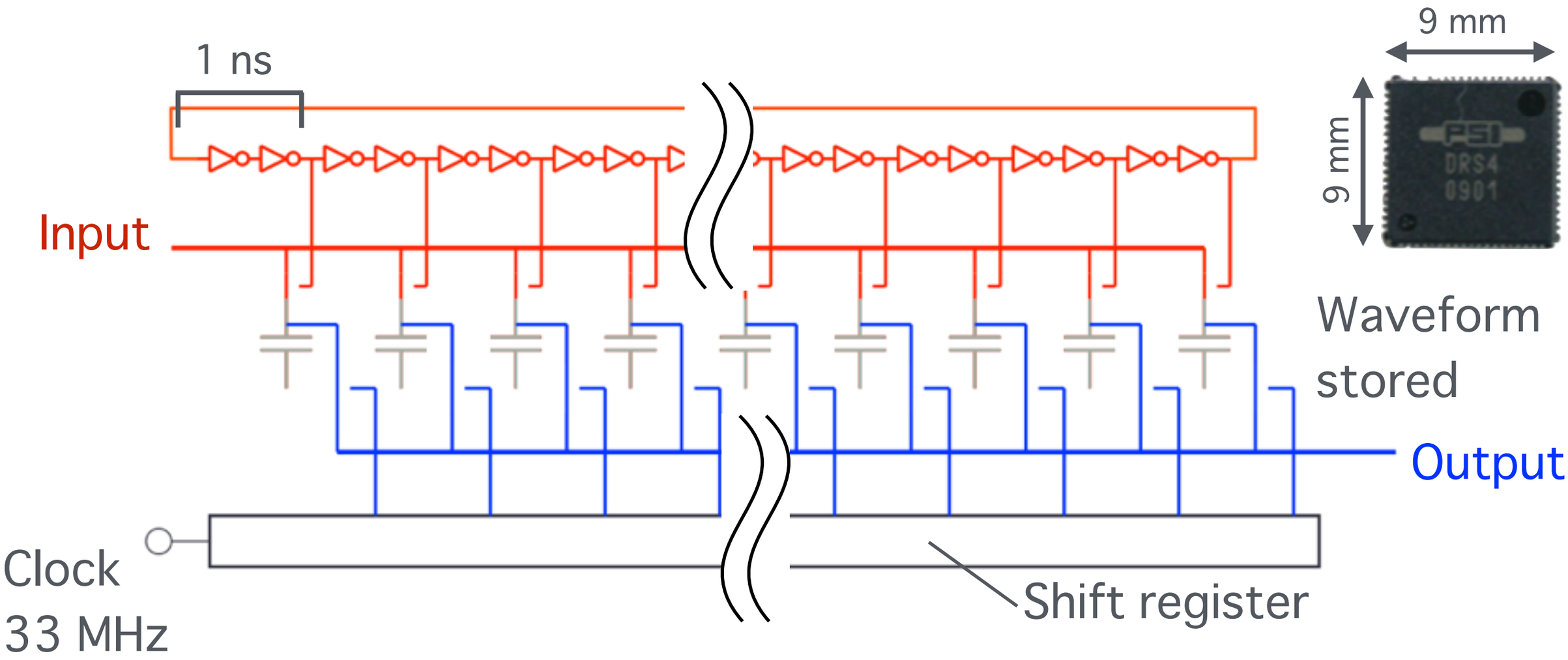
Setup of PMT QC

- Automatic operation
  - control light intensity
  - control HV
  - DAQ
  - Analysis
  - Access to MySQL
- Measured items
  - Operation HV
  - Pulse width
  - Afterpulsing probability



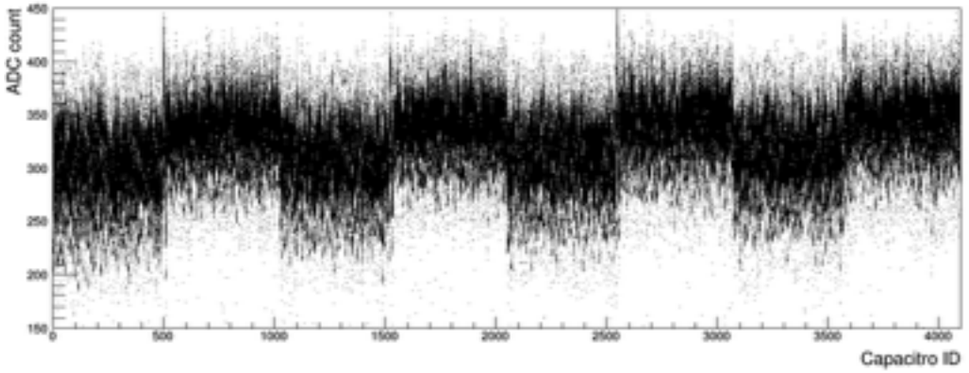
DRS4 chip

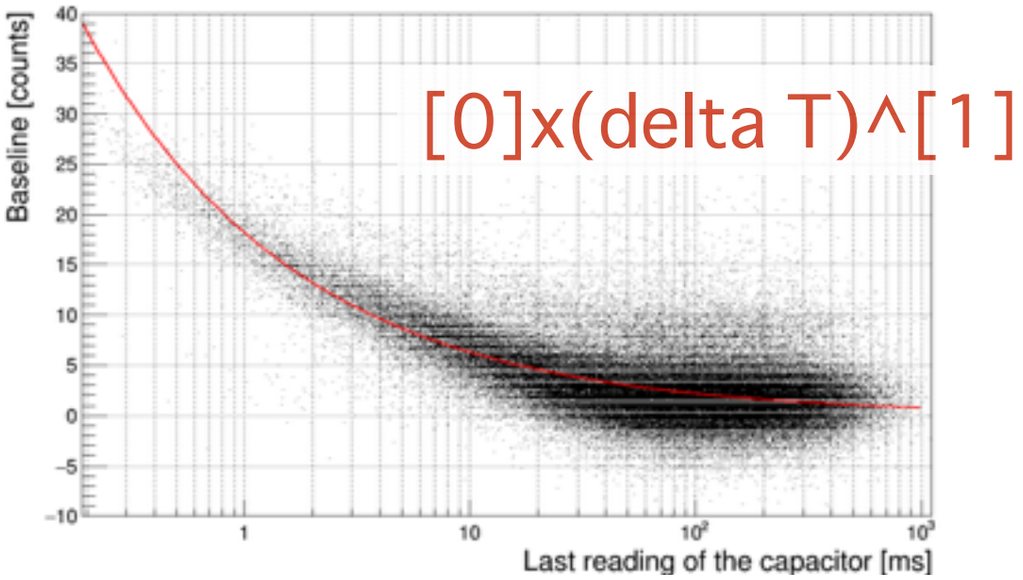
- The DRS4 readout system is based on an array of 1024 capacitors for each channel
- Sampling signal with GHz speed and digitising with MHz speed
- The memory depth is enhanced to 4096 capacitors by cascading four channels, and total memory depth archive ~ 4 us (1GHz sampling speed)



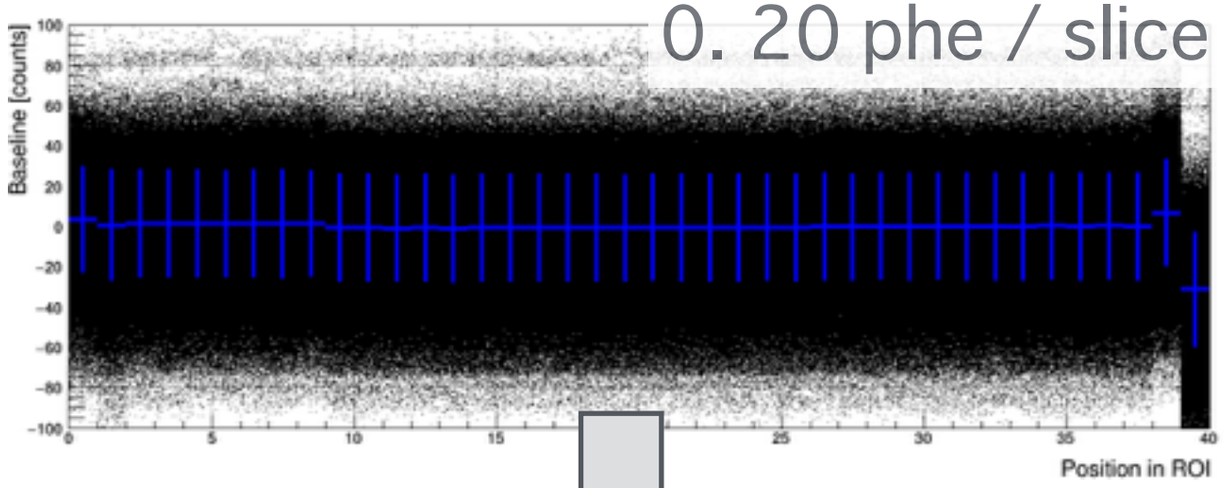
Baseline correction

- Each capacitor of each DRS4 channel has its own offset value
- The dependency of the baseline on the time lapse to the last reading of capacitor (capacitor needs time to release charge).
- After correction, the standard deviation is ~ 0.03 phe /slice



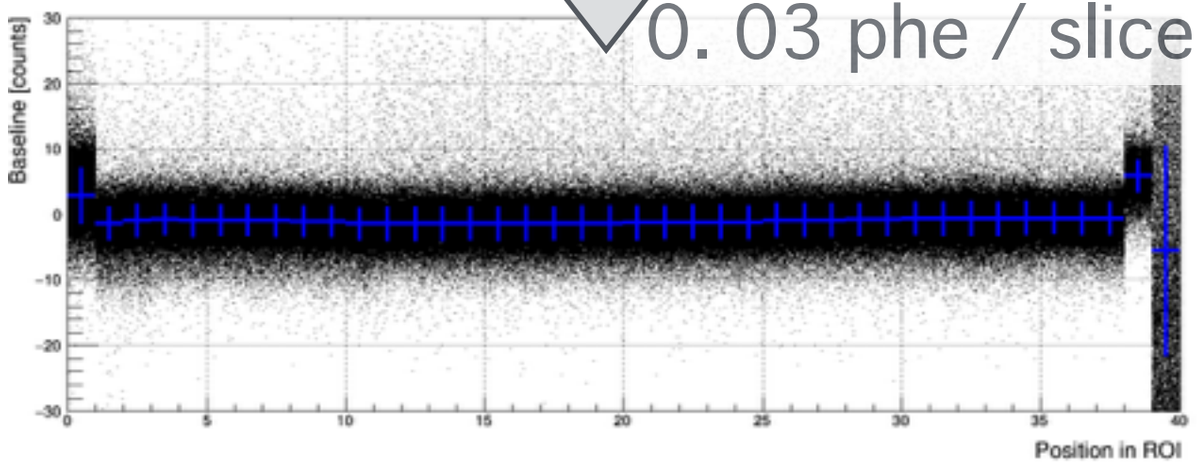


[0]x(delta T)^[1]

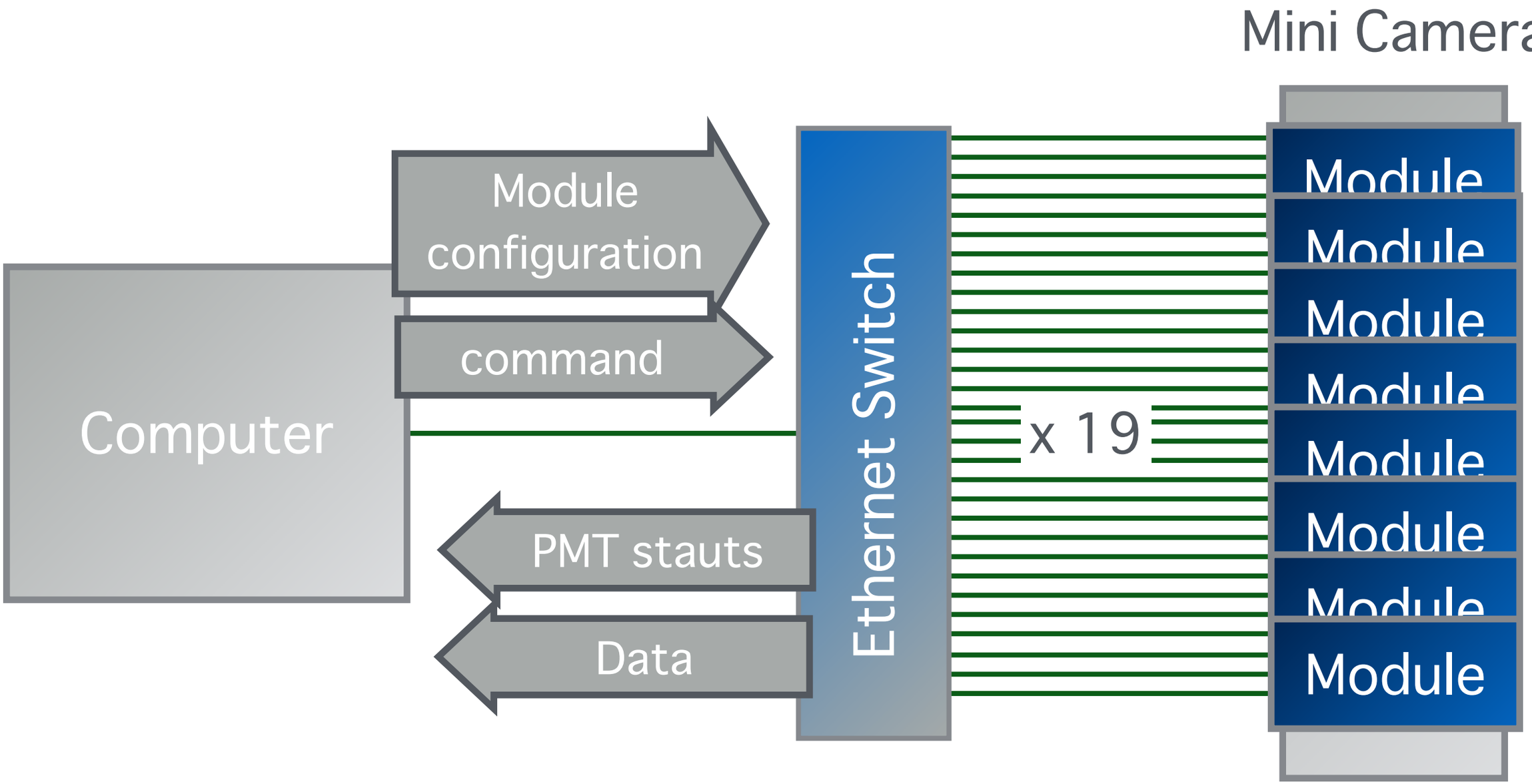


0. 20 phe / slice

0. 03 phe / slice

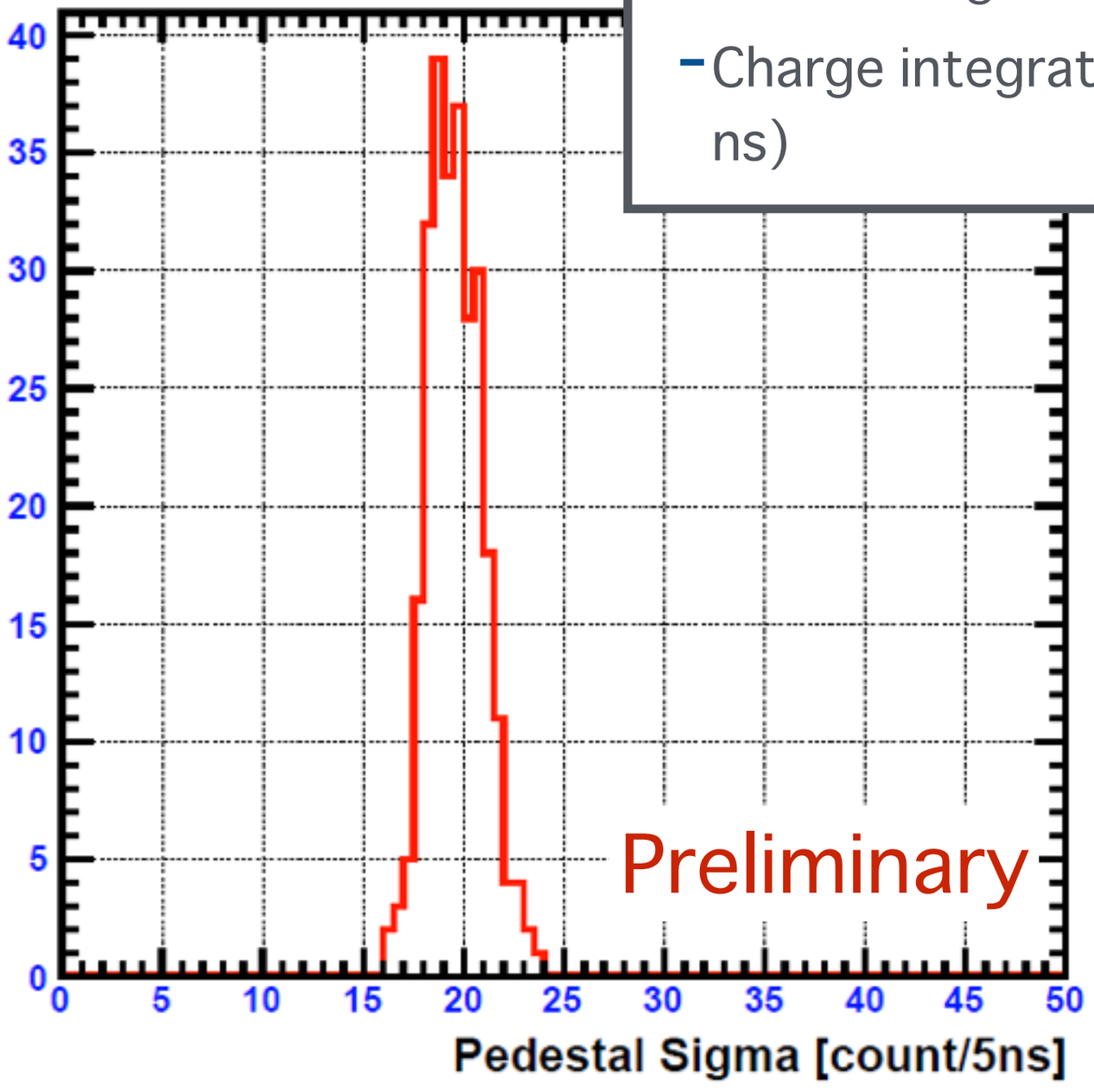


Communication with camera



Noise level of Mini Camera

- Nominal high voltage (PMT gain ~ 4e4)
- Charge integration over 5 slices (~5 ns)



Charge resolution