The conference of AYSS

Mass Characterization of SiPM Tiles for the TAO Experiment at JUNO.

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JUNO

(The Jiangmen Underground Neutrino Observatory)

Goals:

- Neutrino mass hierarchy measurements
- Oscillation parameters measurements
- Astrophysics and rare processes

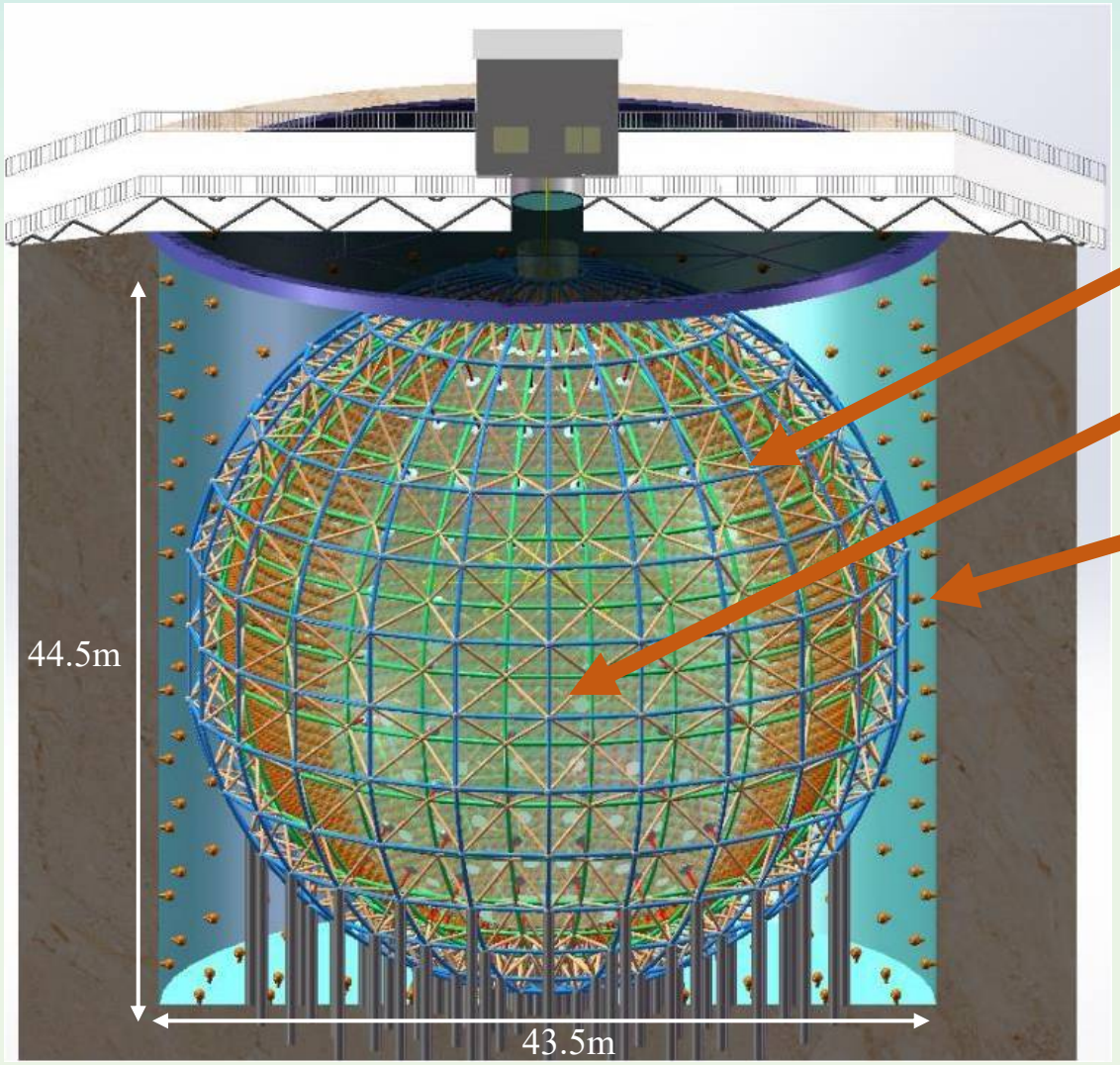
Location:

Powerful source:

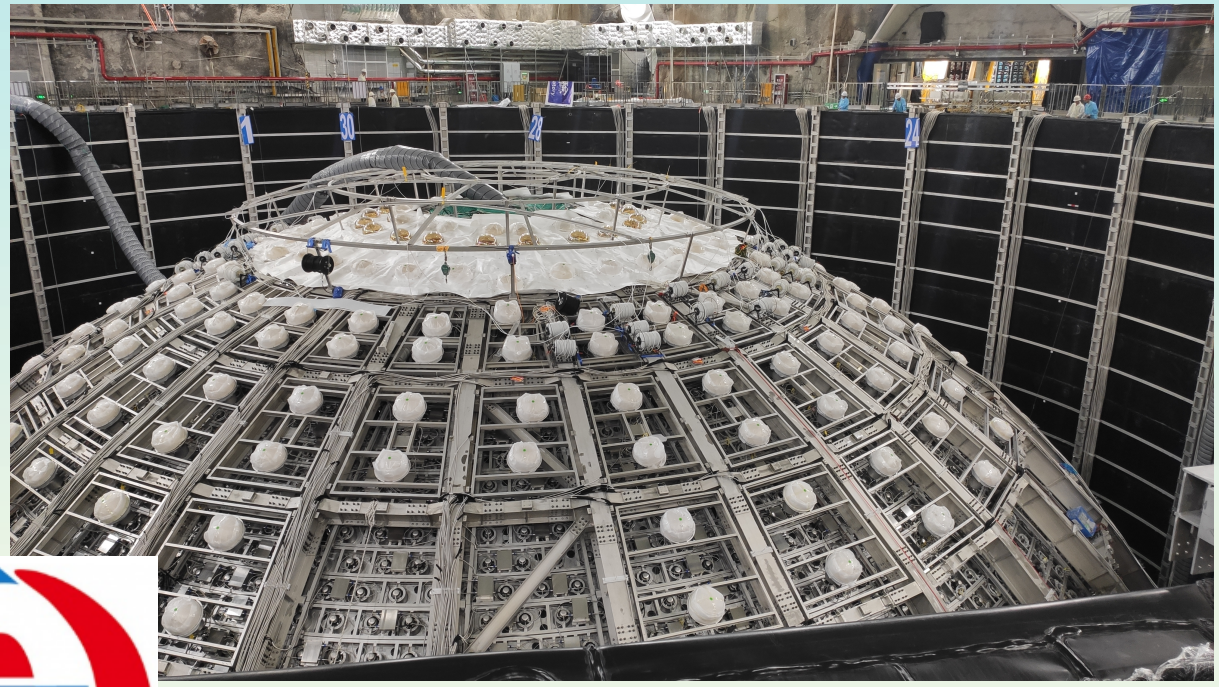
Yangjiang and Taishan power plants
26.6 GWth in 2020, later 35.7 GWth

Ideal baseline:

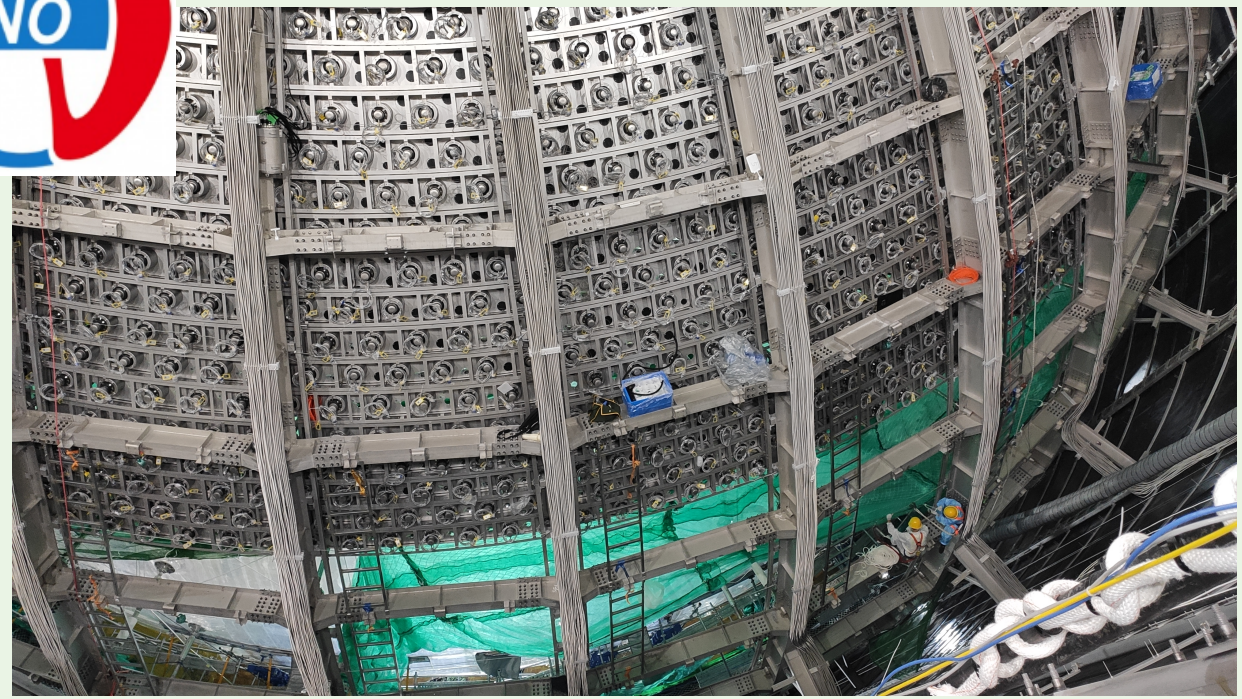
52.5 km



- Acrylic Sphere 35.4m diameter
- 20 kton liquid scintillator
- Water Cherenkov Veto 20kt ultrapure water and 2000 20" PMTs
- About 20,000 large 20"photomultiplier tubes (PMTs)
- 25000 3" small PMTs
- 700 m underground



JUNO



TAO

The Taishan Antineutrino Observatory (satellite experiment)

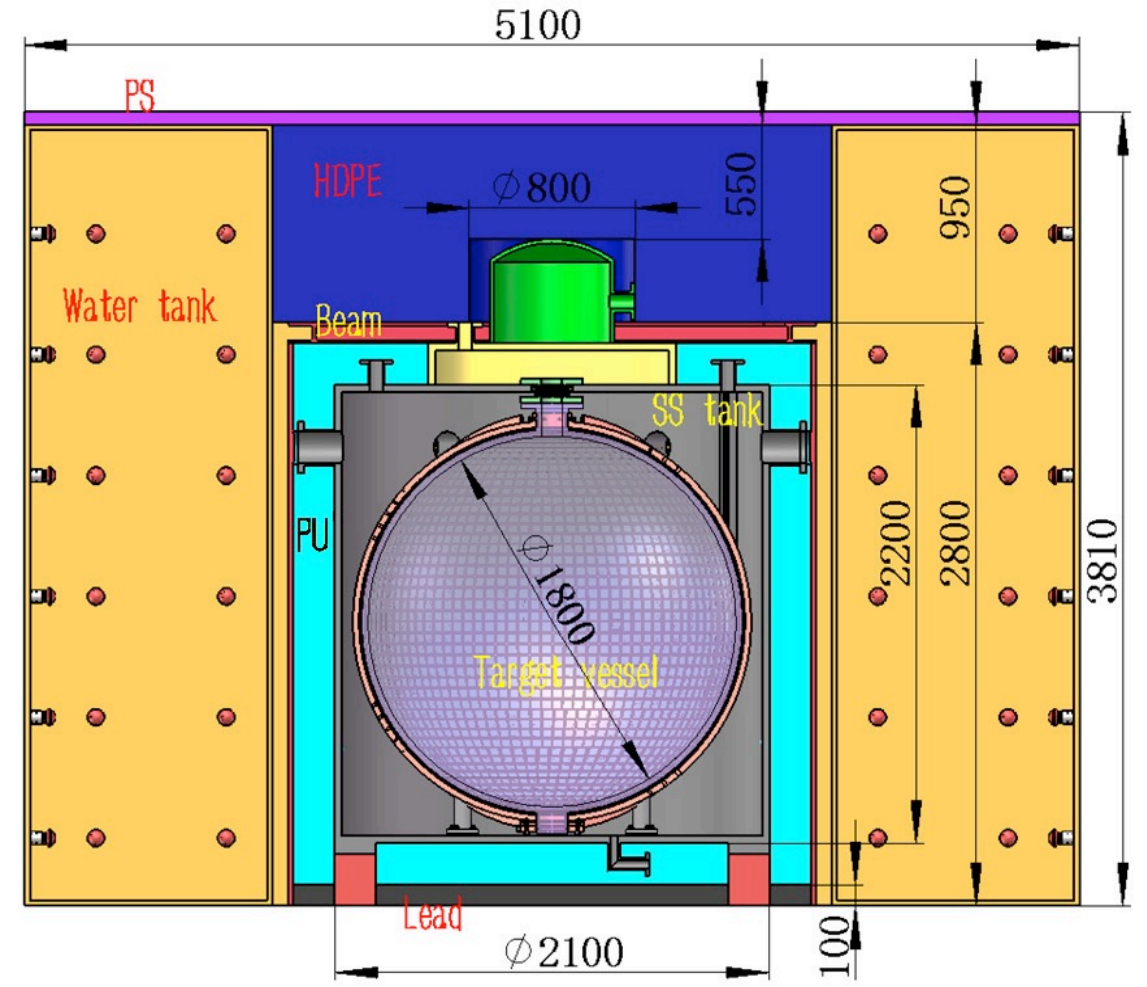
The main TAO's goals are:

1) to measure primary spectrum for JUNO

2) A new benchmark for investigation of the nuclear database

3) Reactor monitoring: status/fuel

4) New physics: sterile neutrino



Schematic view of the TAO detector.

- A spherical acrylic vessel will be contain ~ 2.8 ton liquid scintillator.

- TAO will be placed at 44.15 m from a core of the Taishan Nuclear Power Plant.

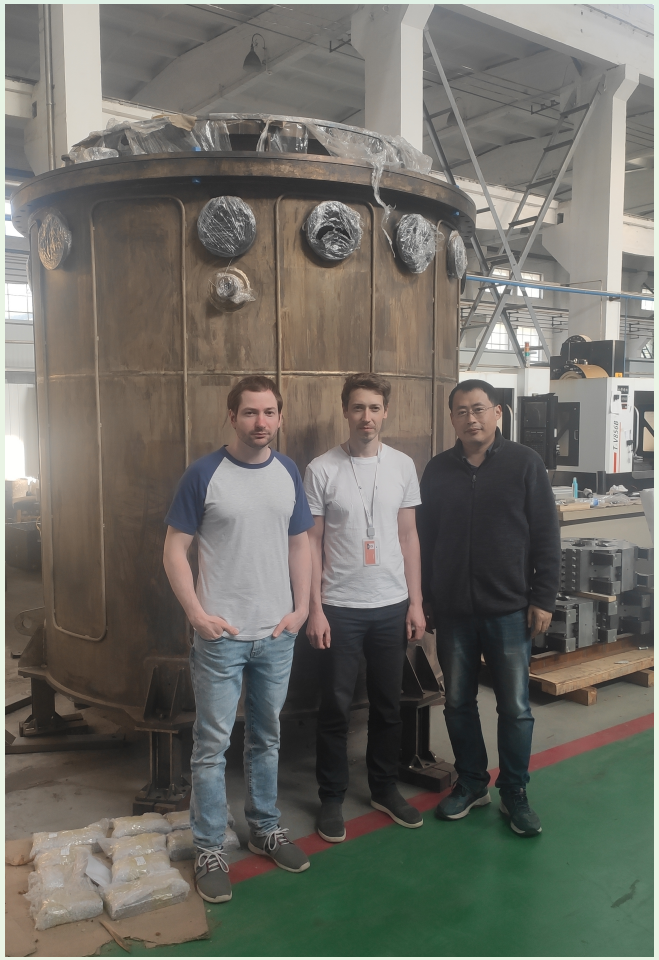
- Sphere will be covered by ~10 m2 Silicon Photomultipliers (SiPMs)

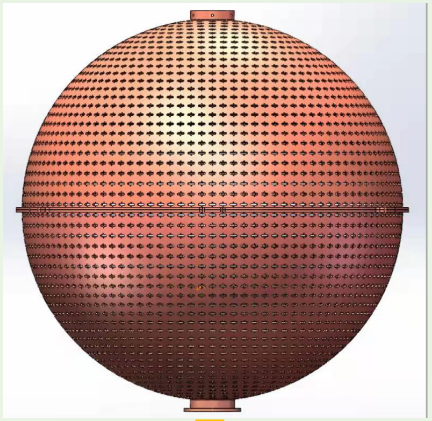
- TAO will be operates at -50℃

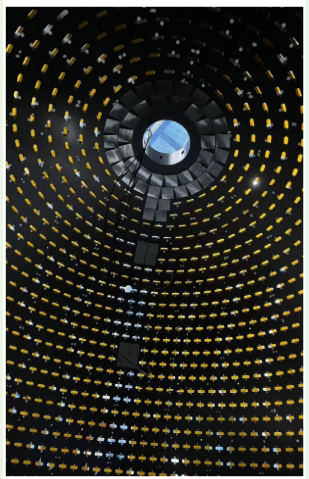
- SiPMs are grouped in tiles ~ 4100 pcs

- all tiles need to be comprehensively characterized

IHEP

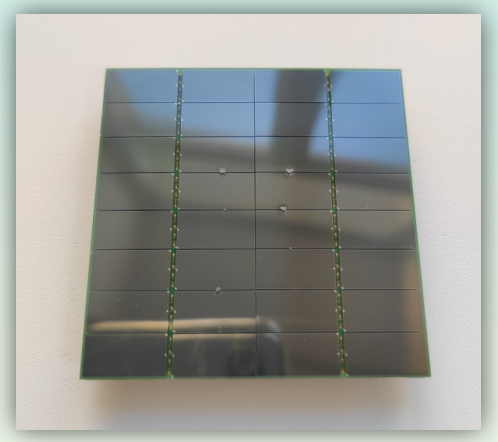


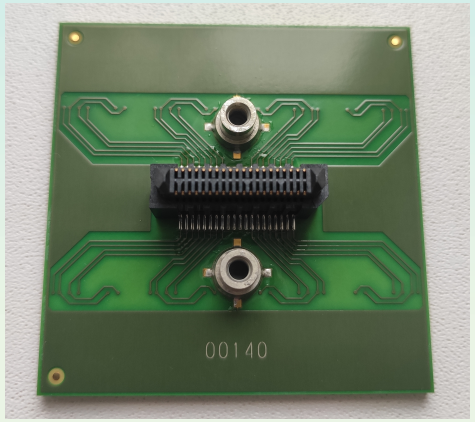




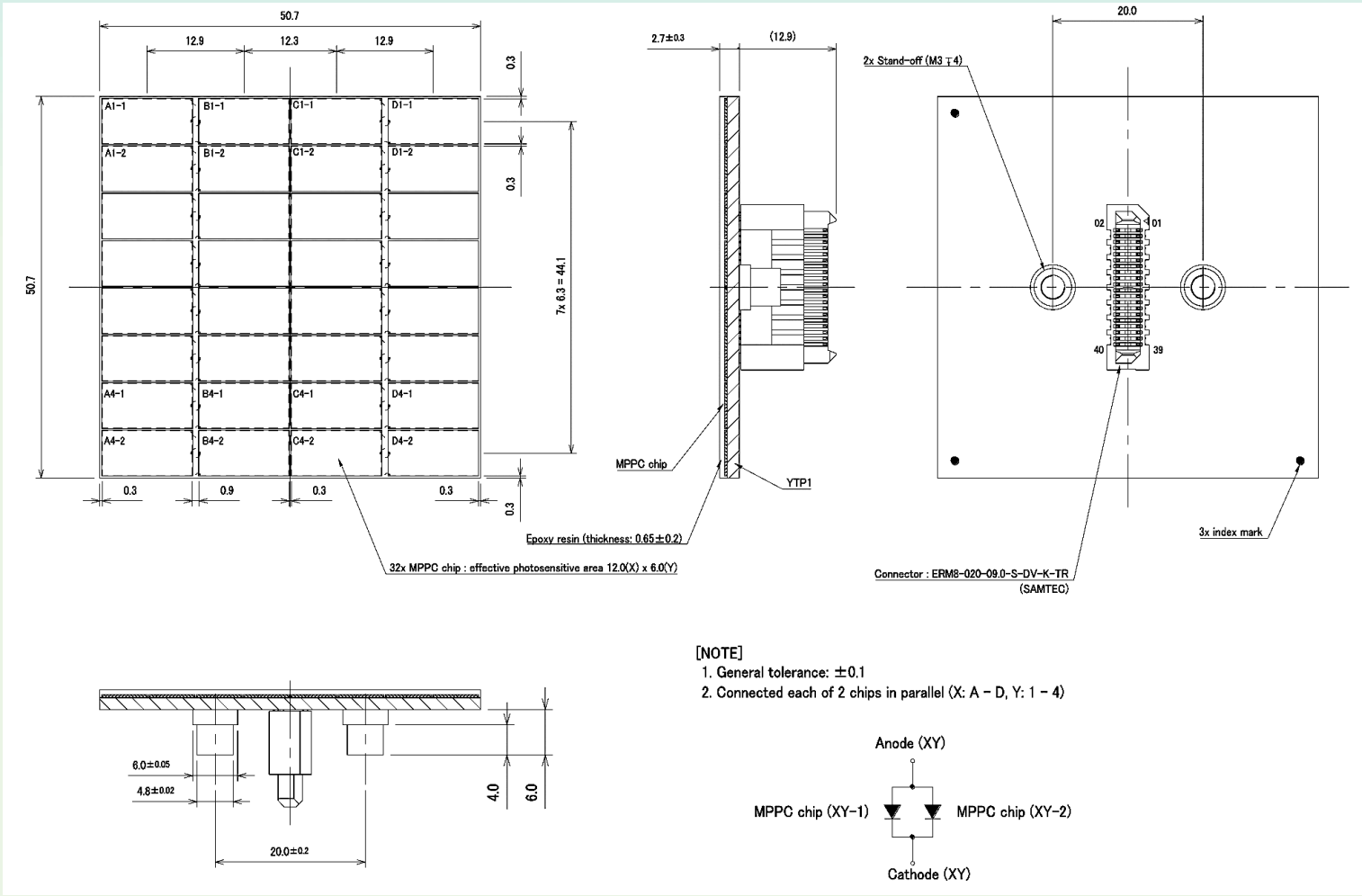
TAO SiPM Tiles

Hamamatsu S16088





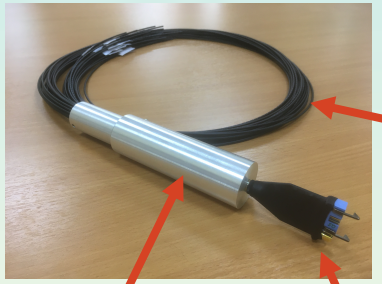
Parameters	Value	Units
Number of channels	16 (Connected 2 chips in parallel)	
Effective photosensitive area	12.0(X) × 12.0(Y)	mm^2/ch.
Pixel Pitch	75	μm
PDE at 420 nm	Typ. 47	%
Breakdown voltage	53 +/-5	V
Gain	4.0×10^6	
Dark count rate at -50°C	Typ. 2000 / Max. 6000 (Typ. 13.9 / Max. 41.7)	cps/ch. cps/mm^2
Crosstalk probability	Typ. 12 / Max. 15	%



Requirements on SiPMs specifications

Parameters	Specification
Uniformity of breakdown voltage (within Tile)	within 0.19V range
Dark Count Rate in each channel [@-50℃]	< 41.7 Hz/mm2
Gain in each channel	$>1\times10^{6}$
Photon Detection Efficiency (PDE)	≥ 44%
Crosstalks	<15%

Scanning station design

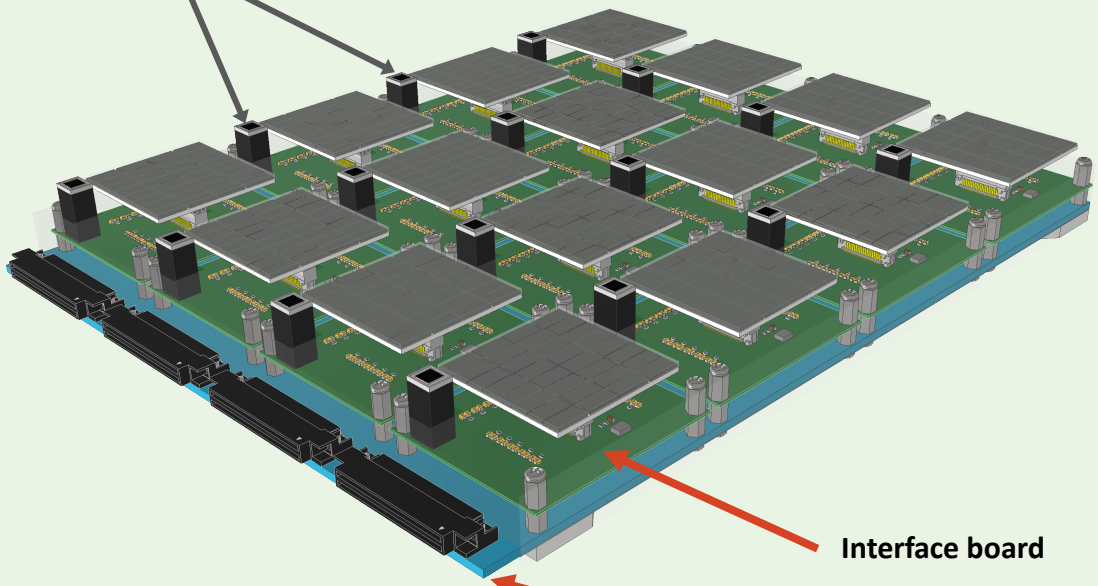


Optical fibers

Light splitter

LED

Reference SiPMs

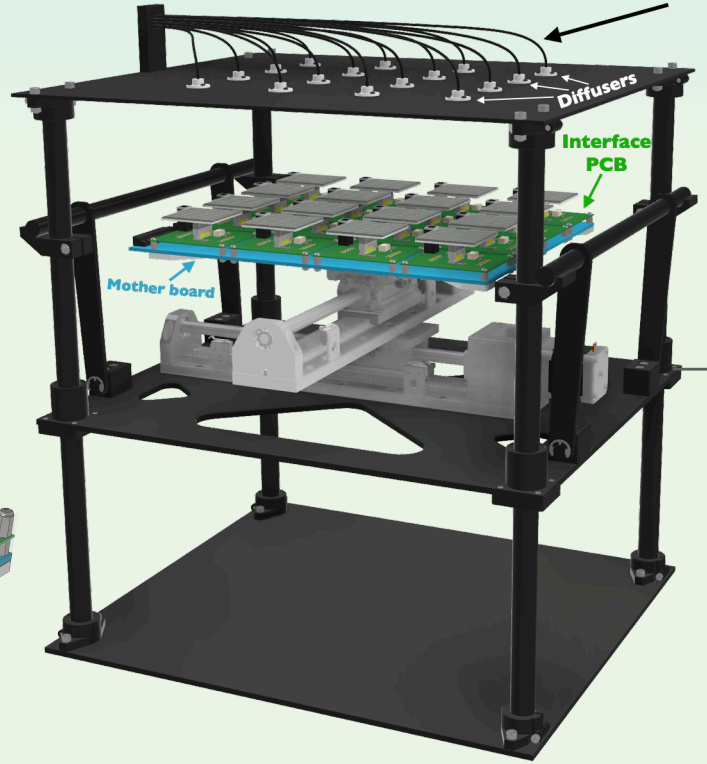


Interface board

Motherboard

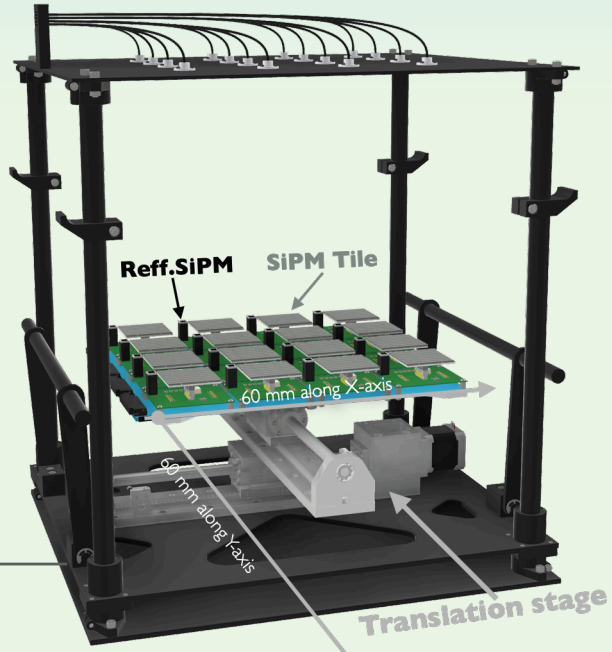
Working position

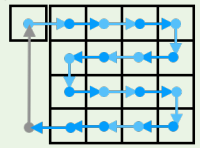
Fibers



can be lifted up

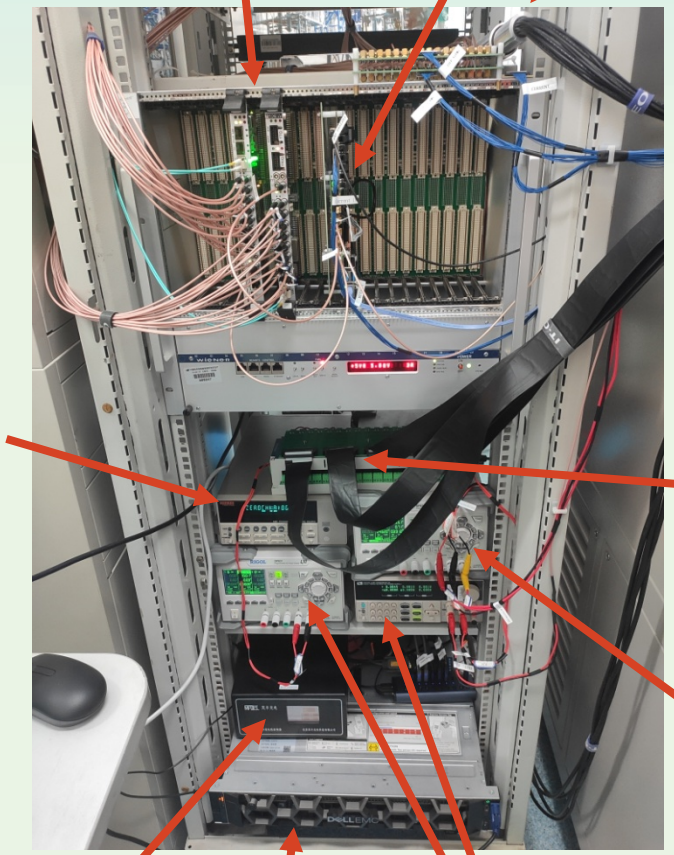
Service position

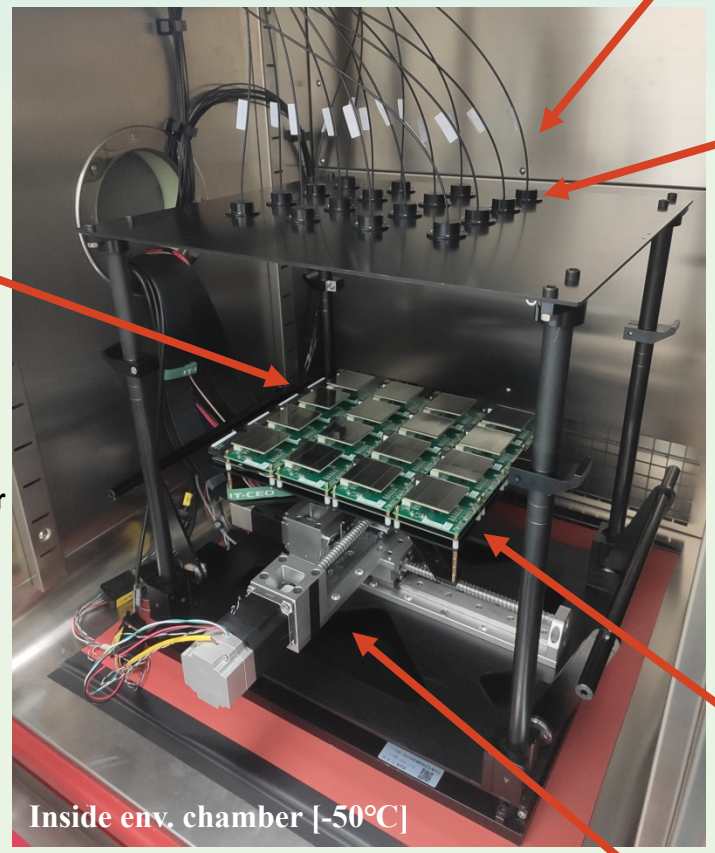




Free movement on two axes

Mass-testing setup

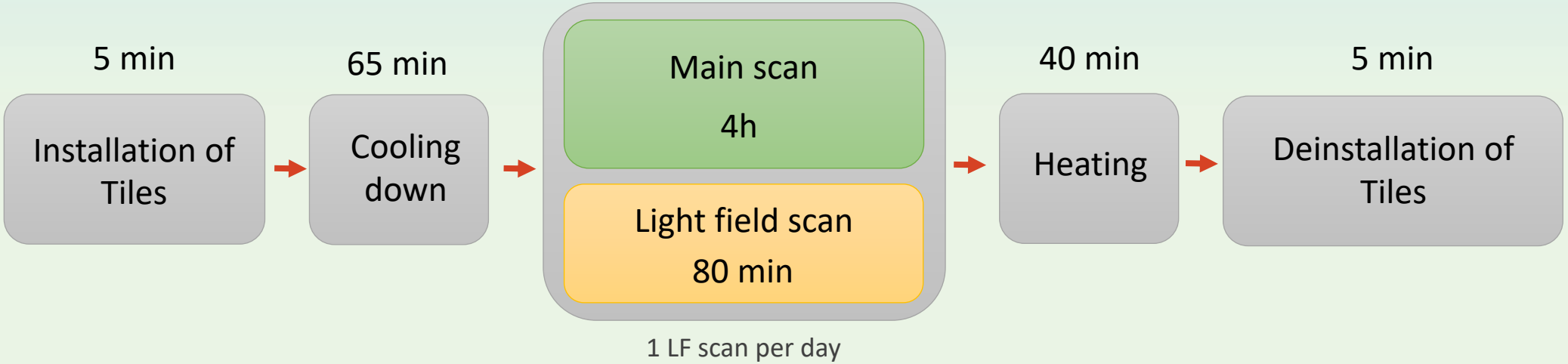




Environmental chamber

IHEP

Overview of testing procedures

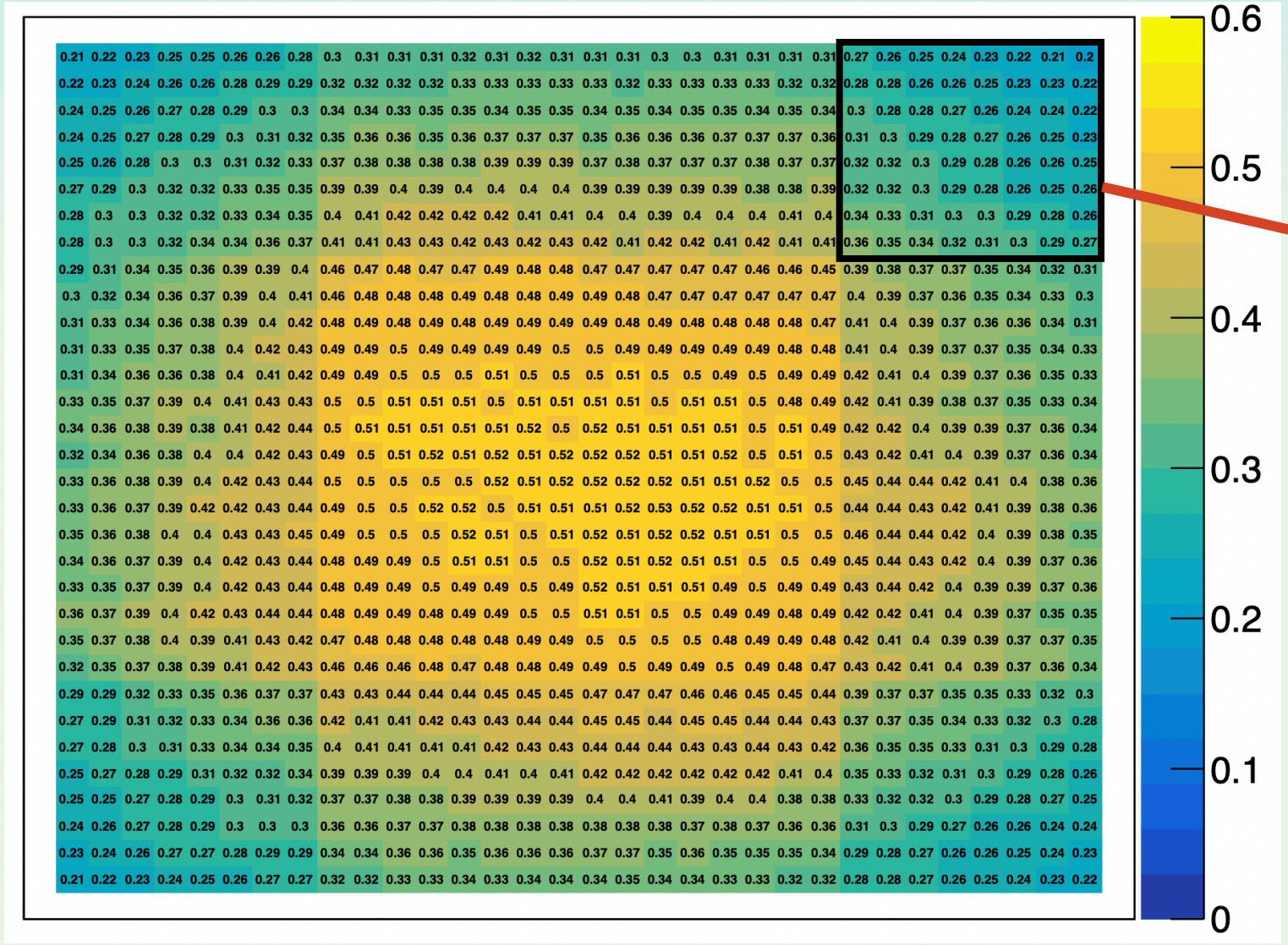


Total procedure time ≈ 6h

~3 scans/day (48 tiles)

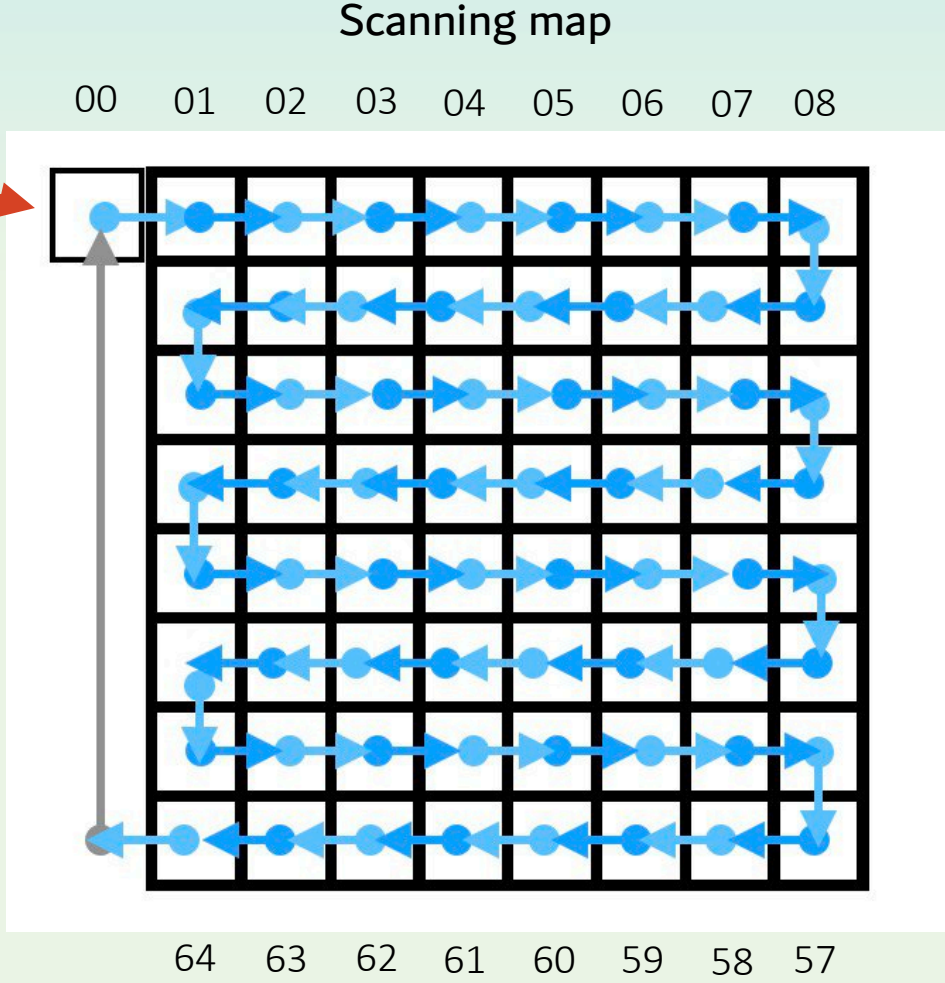
Total estimated mass testing time ≈ 90 days

Calibration of the light field

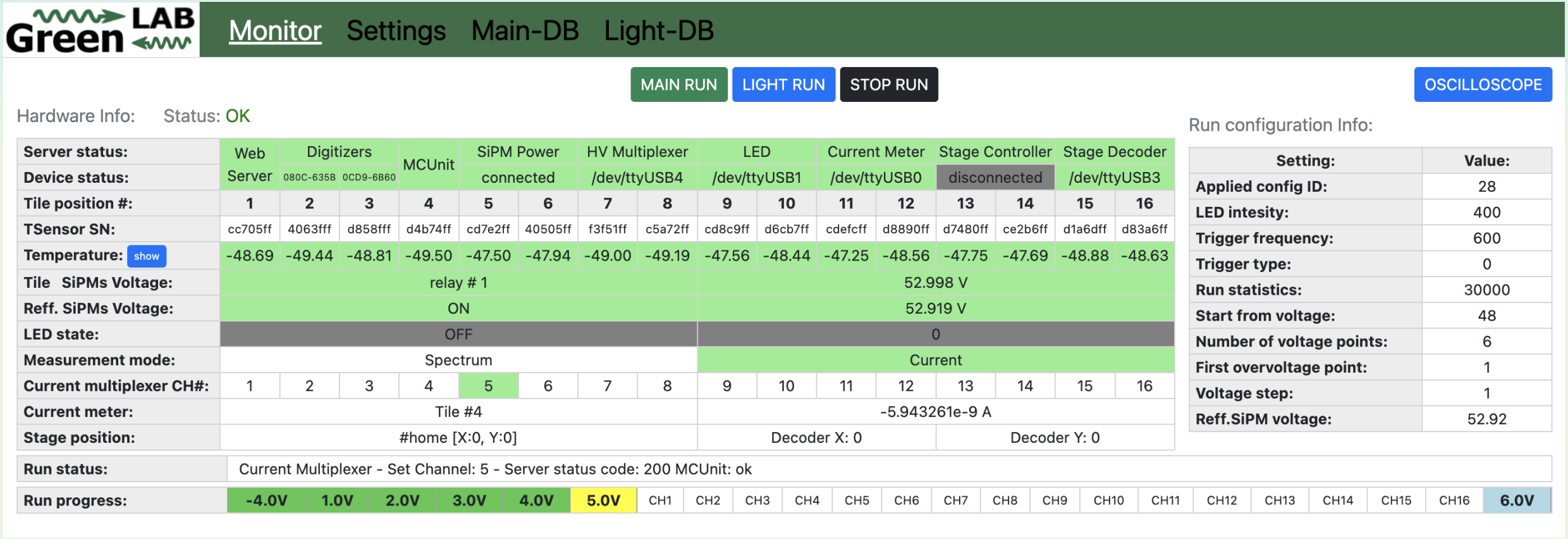


The light field map

Scanning map



Monitoring system



Monitoring system of the mass-testing setup

Analysis

1. Gain

$$G_{pix} = \frac{Q_1}{K_{amp} \cdot q_e}.$$

Q_1 - (peak 1 – pedestal)

K_{amp}- coeff. of the amplifier

q_e- elementary charge

2. PDE

$$PDE_{tile\ SiPM} = \frac{\mu_{tile\ SiPM}}{\mu_{ref\ SiPM}} \times PDE_{ref\ SiPM}$$

$$\mu = -\ln\left(\frac{N_0}{D_0}\right).$$

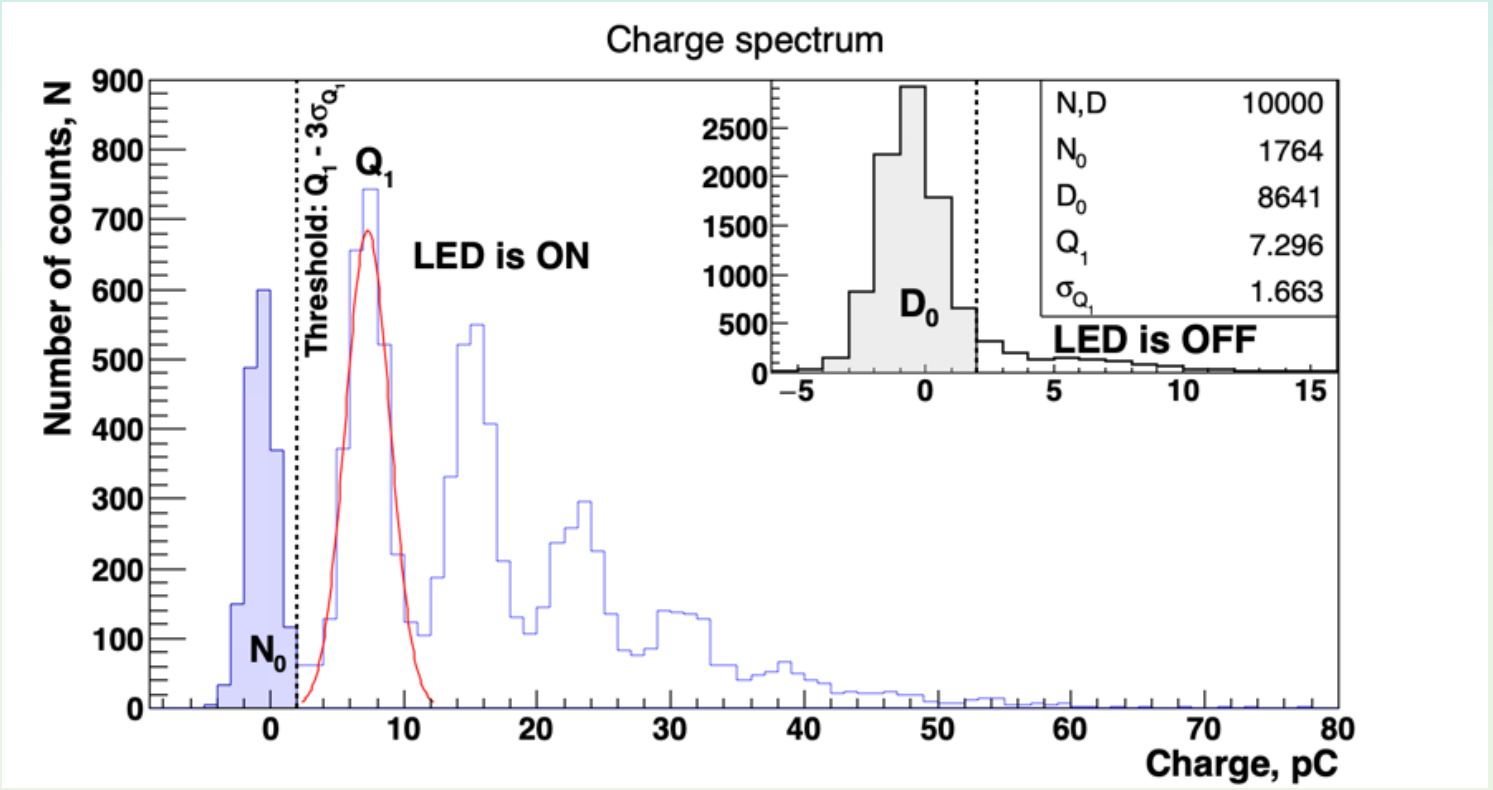
μ - average number of photoelectrons

3. Crosstalks

$$P_{crosstalk} = 1 - \exp(-\lambda)$$

$$\lambda = 1 - \frac{\mu Q_1}{S}$$

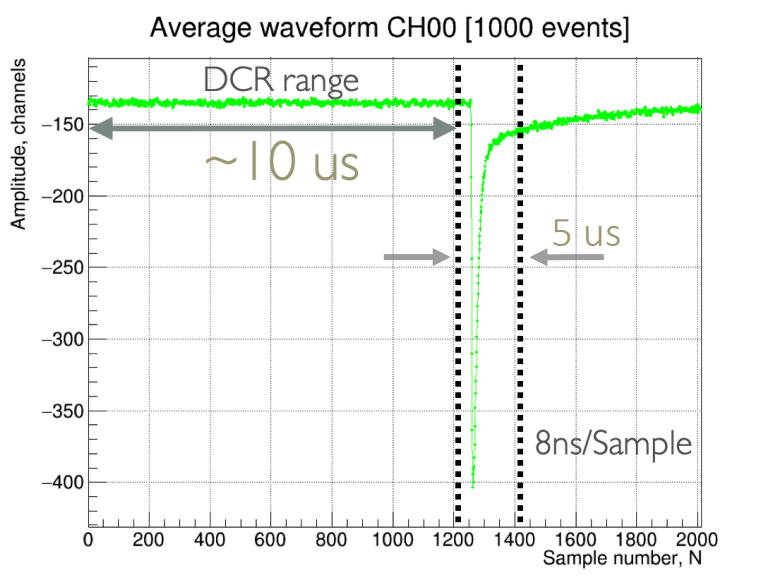
λ - number of fired pixels in the first generation

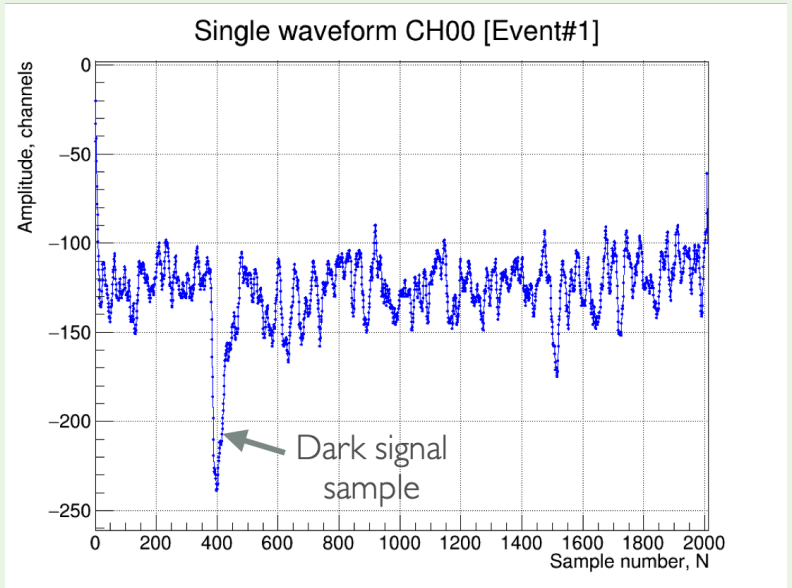


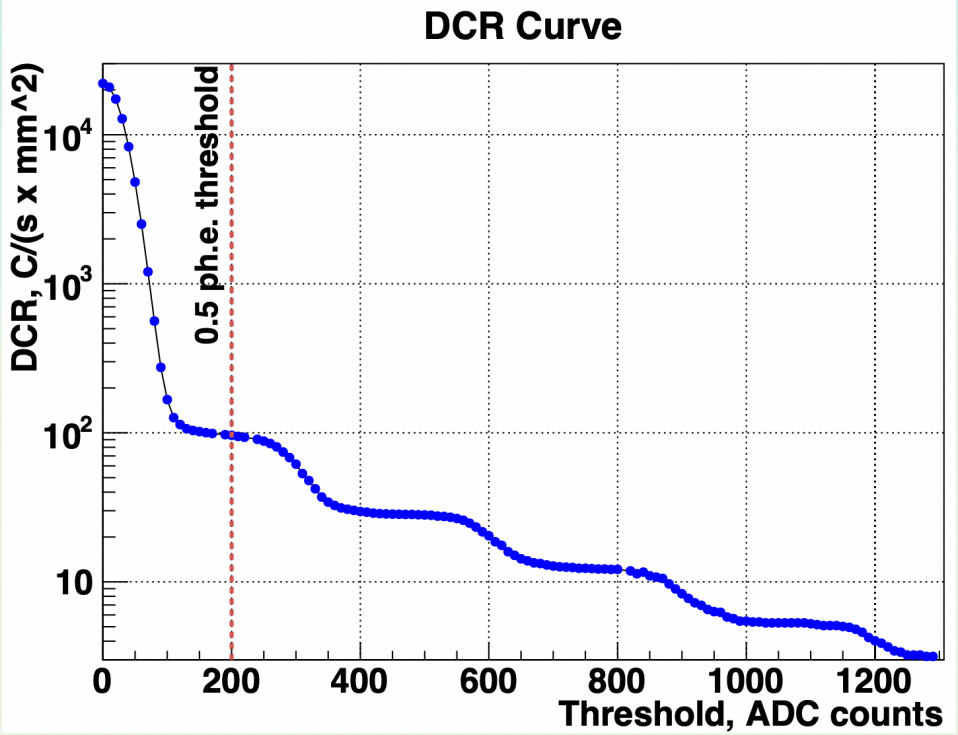
Typical charge spectrum of SiPMs. Charge spectrum illustrates the pedestal method for evaluation of an average number of photoelectrons.
Shaded area and N_0 - pedestal events on signal spectrum,
shaded area and D_0 - pedestal events on dark spectrum (incorporated picture)

S. Vinogradov, *Analytical models of probability distribution and excess noise factor of solid state photomultiplier signals with crosstalk*, *Nuclear Instruments and Methods in Physics Research Section A Accelerators Spectrometers Detectors and Associated Equipment* **695** (2011) .

Dark count rate





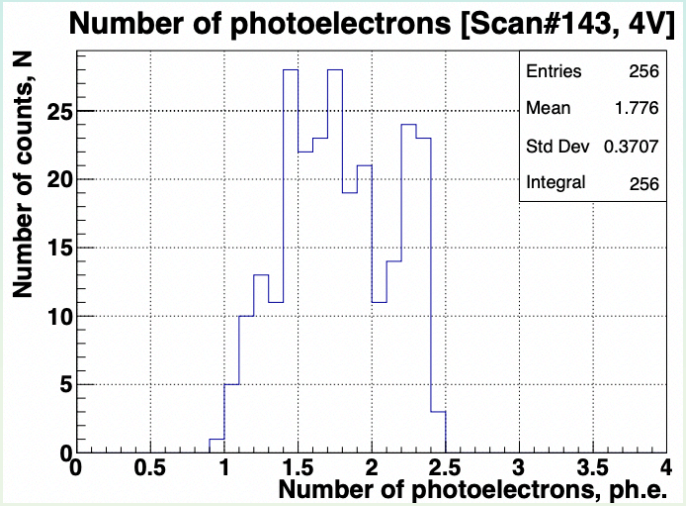


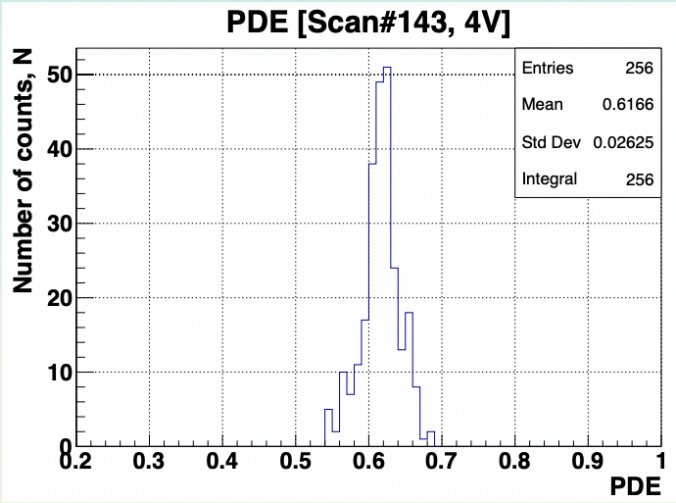
Run parameters

Parameters	Value	Units
Time window	10	us/oscillogram
Number of oscillograms	30k	-
Total acquisition time	0.3	second
SiPM area	144	mm^2

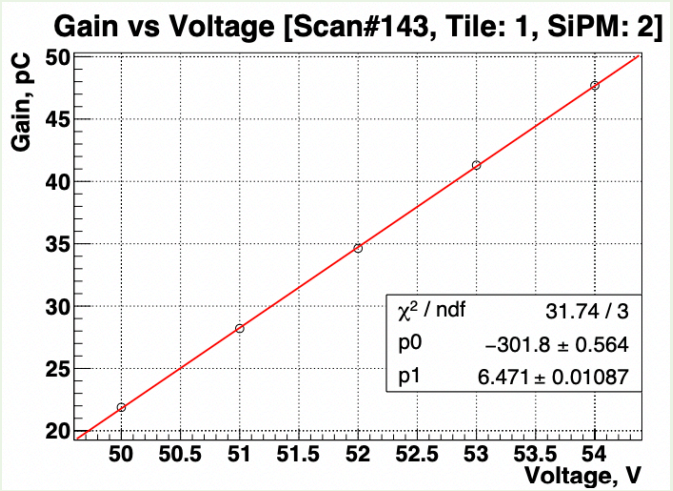
[max: 41.7 Hz/mm^2 / typical: 13.9 Hz/mm^2]

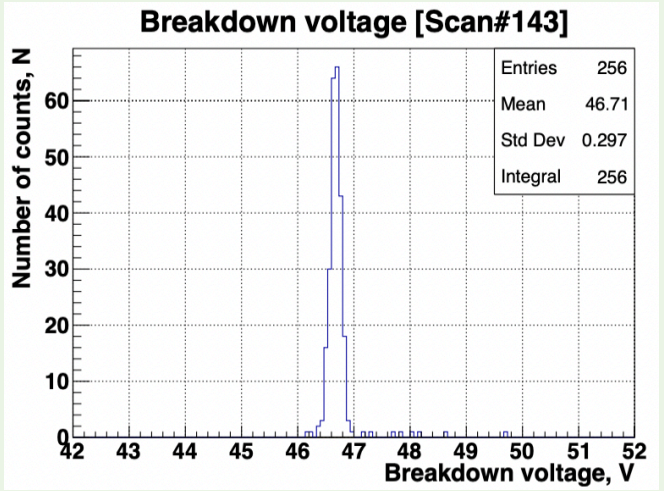
Results examples





An example of the distribution of values for 4 V overvoltage:
(a) - number of photoelectrones, (b) - photon detection efficiency





(a) - Gain voltage dependence, (b) - breakdown voltage distribution overall
SiPMs in a single run

Summary

- the setup design has been developed
- the testing procedures and methods have been developed
- the testing setup has been produced and putted into operation in China (summer 2023)
- > 2000 tiles have already been tested
- the data analysis is in progress
- the TAO detector assembling plans – 2024 year

Thank you for attention!

Questions?