PandaX-20T Photosensor System Design and Verification

Yiyu Pan (潘奕羽), SJTU

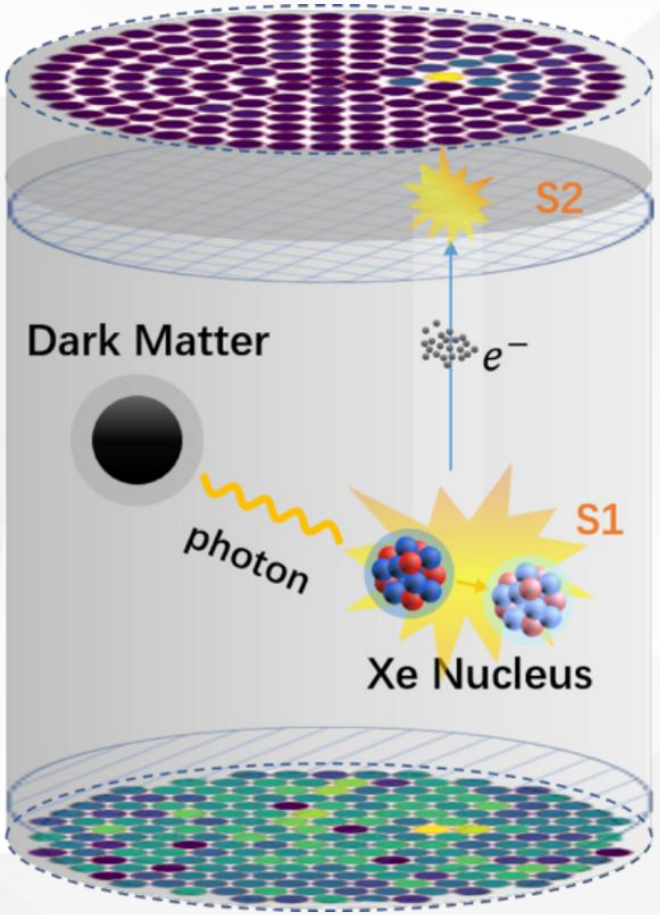
On Behalf of the PandaX Collaboration

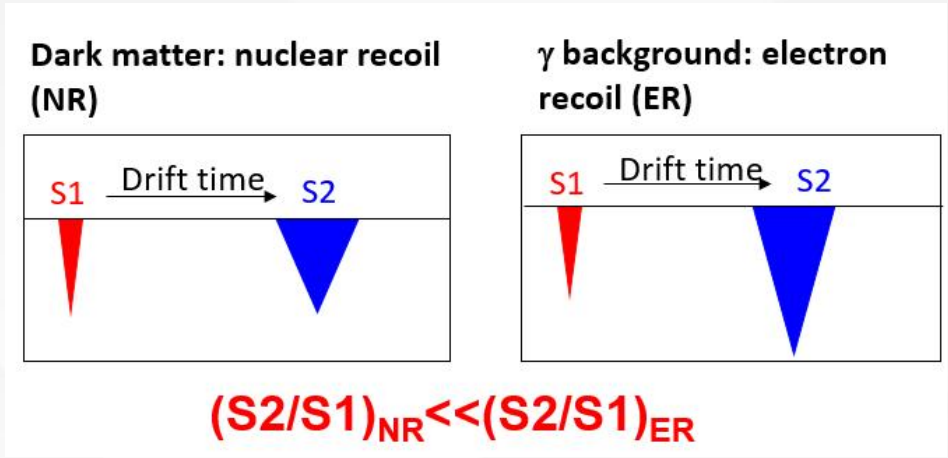
2026.7.16 @Guangzhou

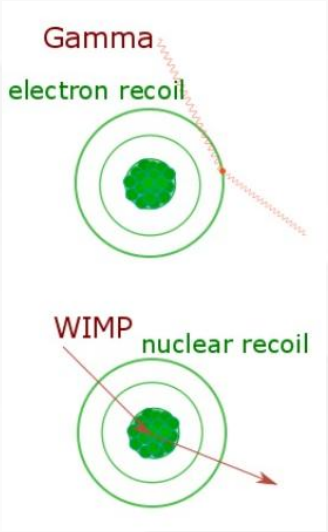
Outline

- PandaX-20T Photosensor System Overview
- Top & Bottom Array Design and Validation
- System Integration
- Summary and Outlook

PandaX: Particle AND Astrophysical Xenon Experiments







- Scintillation (S1) and Ionization (S2) Signals.
- Identify event types, and reconstruct the time, energy, and 3D position of each event.
- Physics goals: dark matter, neutrino physics (solar neutrinos, 0νββ).

I. PandaX Stages

- PandaX: Particle AND Astrophysical Xenon Experiments

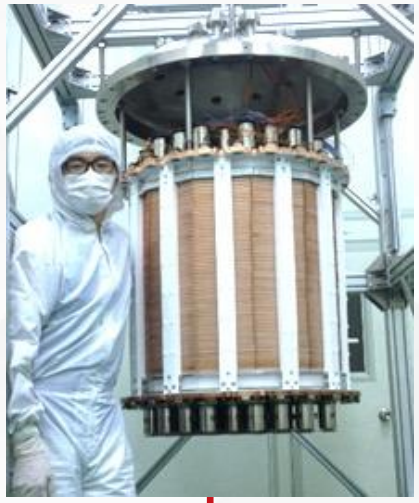
PandaX started

2009.3

PandaX-I
120 kg

2012.7-2014.10

PandaX-II
580 kg

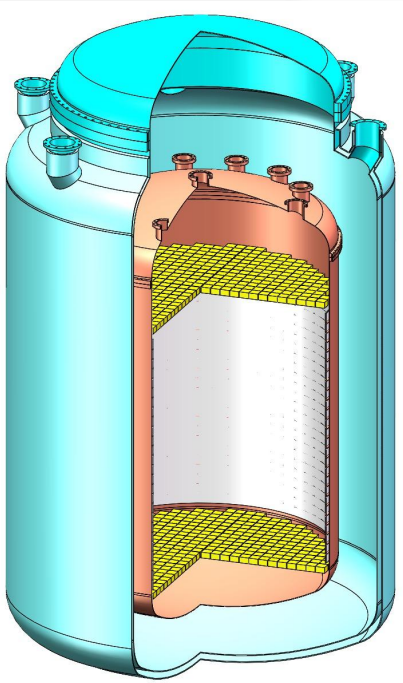


2016.7-2019.7

PandaX-4T
3.7 tonne

2019.8-2026.4

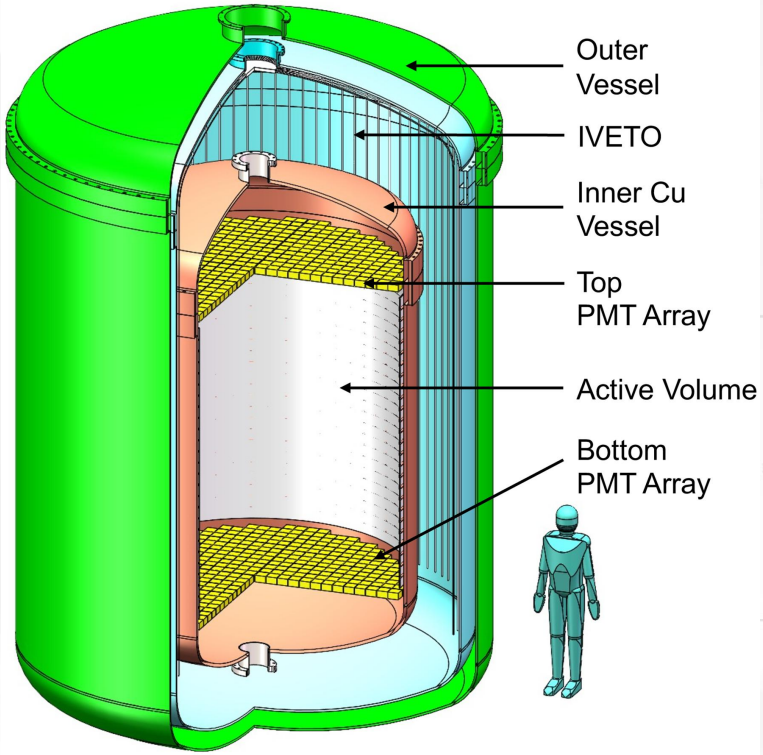
PandaX-20T/xT



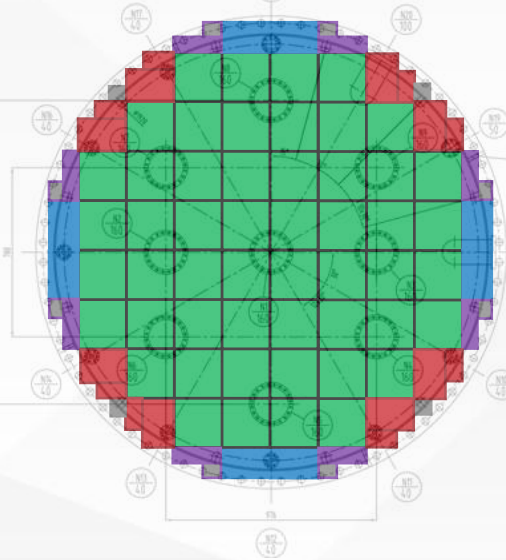
2027-

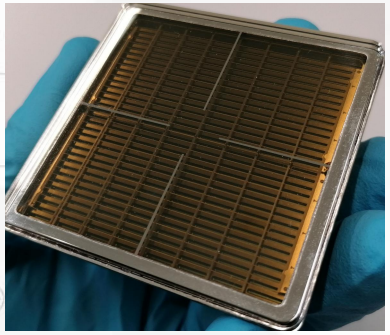
I. PandaX-20T Photosensor System Design

- **PandaX-20T photosensor system:** photocathode coverage ~10 m^2 for ~17T active volume (total LXe mass ~20T) *Sci. China Phys. Mech. Astron. 68 (2025) 2, 221011*



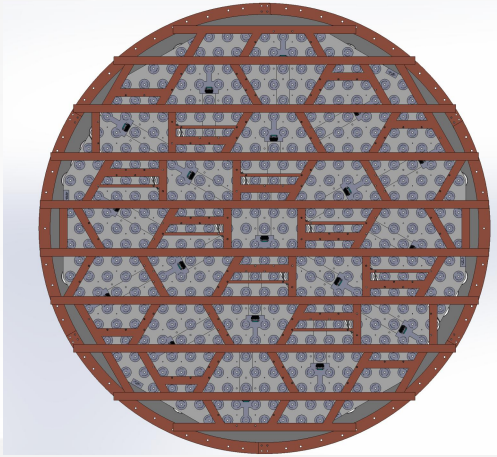
- **Top PMT Array: 616 R12699 PMTs (novel 2” square)**





$(2” \times 2”)$

- **Bottom PMT Array: 433 R11410 PMTs (3”, from PandaX-4T)**

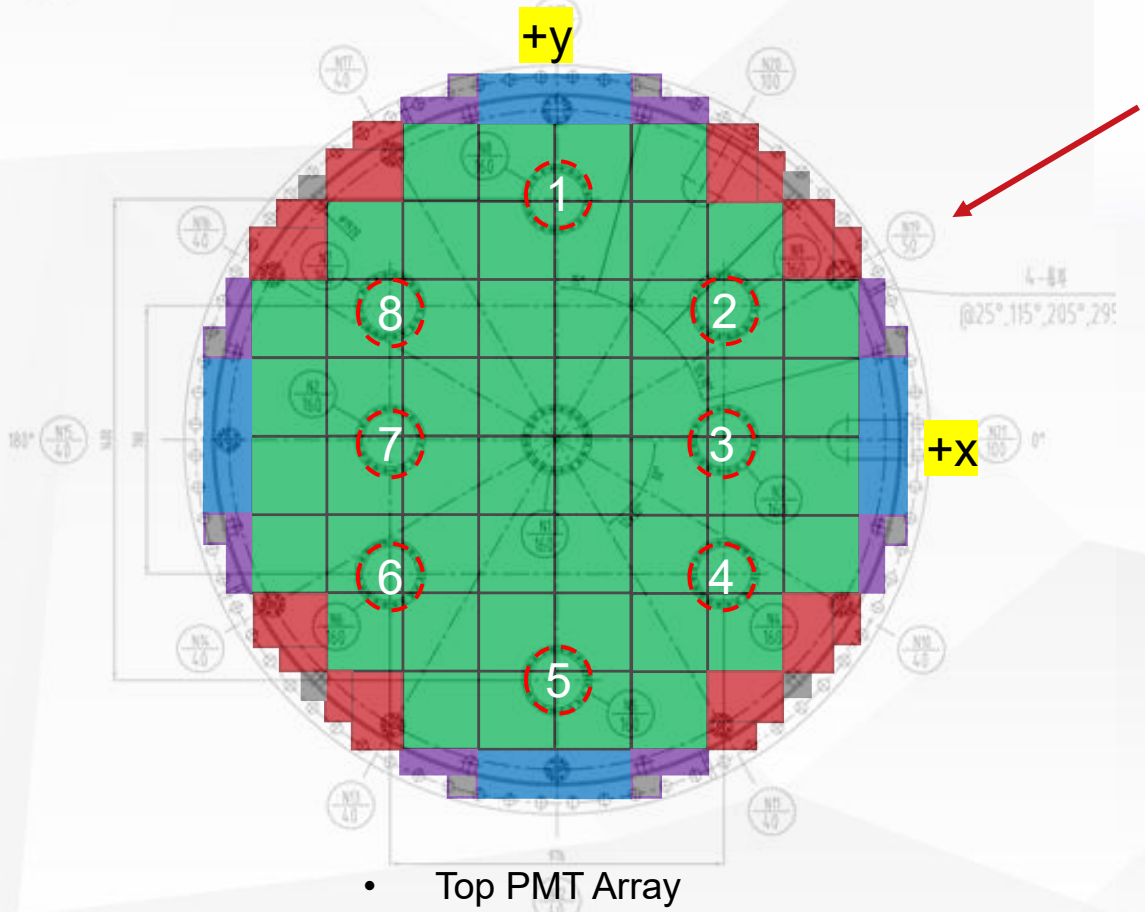


$(R = 3”)$

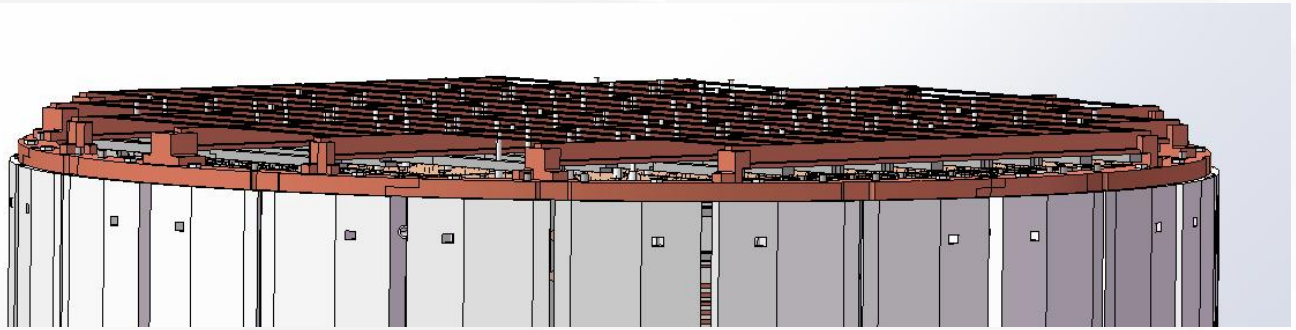
➢ **A next-generation xenon detector requires a large-area, low-background photosensor system.**

II. Top Array Design

Top PMT array design:



- Top PMT Array



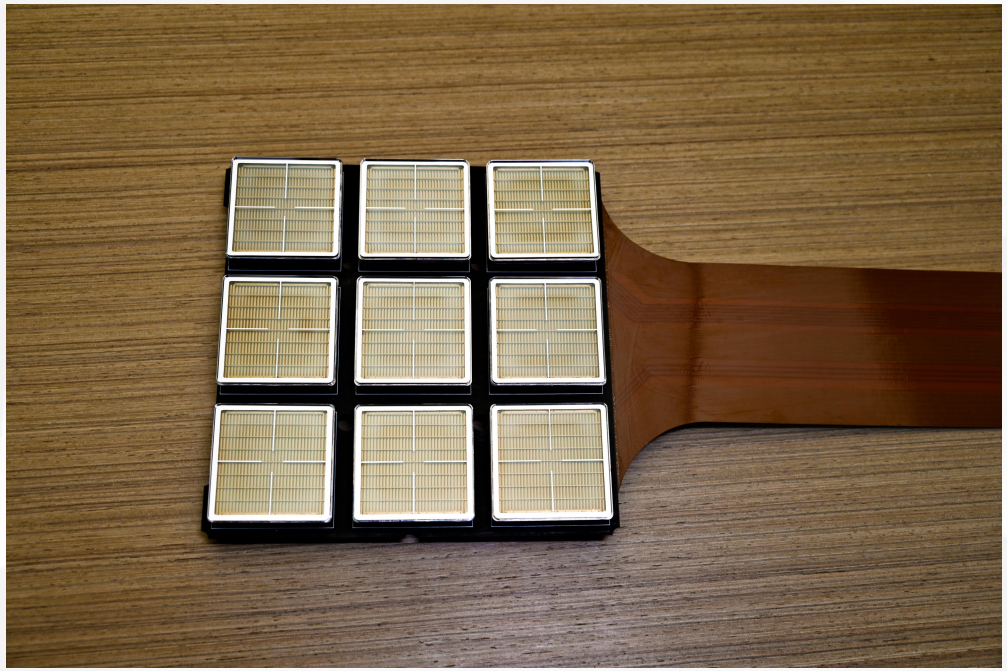
	Number	Gap between FRPs	Distance between PMTs	Total PMTs
FRP	76	2 mm	65 mm	616
Single base	12			

➢ **Flex-rigid PCB enables compact routing and simplified integration.**

II. Top Array FRP

☐ Top array FRP (Flex-Rigid PCB) design:

Rigid base　　Flexible cable



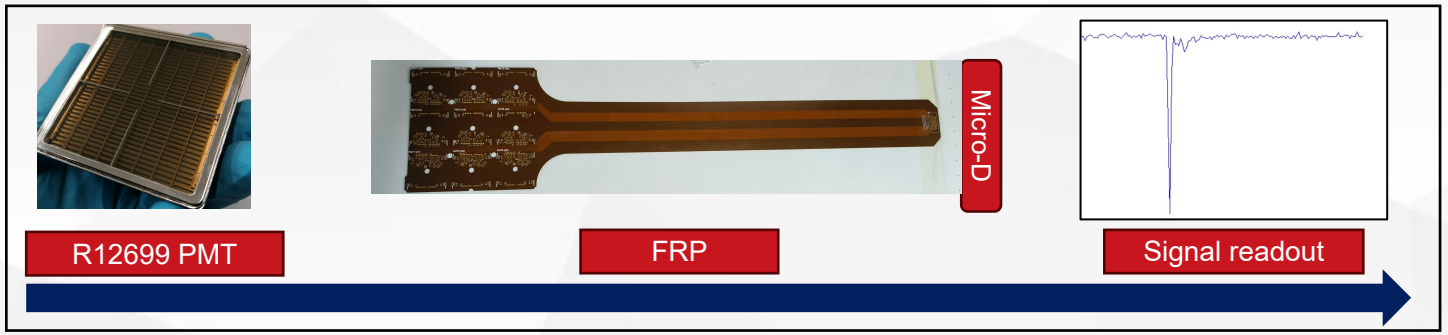
- FRP with 9 PMT

A single FRP board is made of laminated PI foils:

- Rigid base: 19.5 cm×19.5 cm×1.5 mm
- Flexible cable: 0.5 mm thick (L=70~110 cm)
  →to replace cables (reduce bkg, simplify integ.)

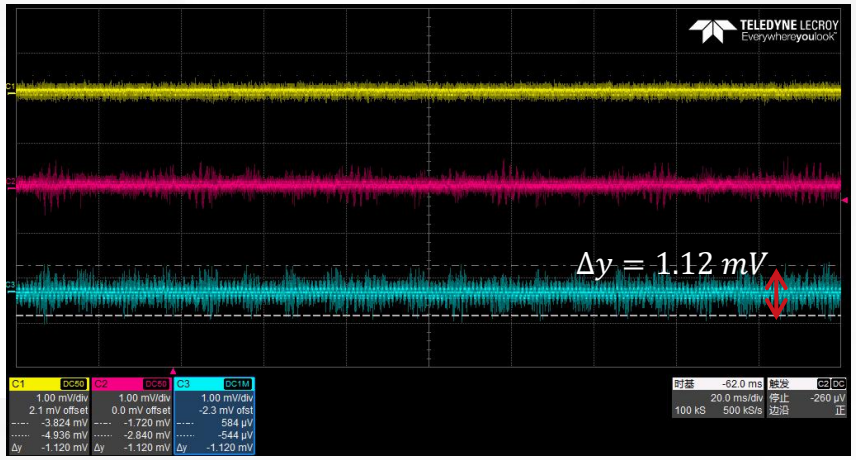
Modularization FRP and PMTs:

- 9 R12699 PMTs.
- 9 HV (negative) channels.
- 36 signal channels (four channels per PMT).

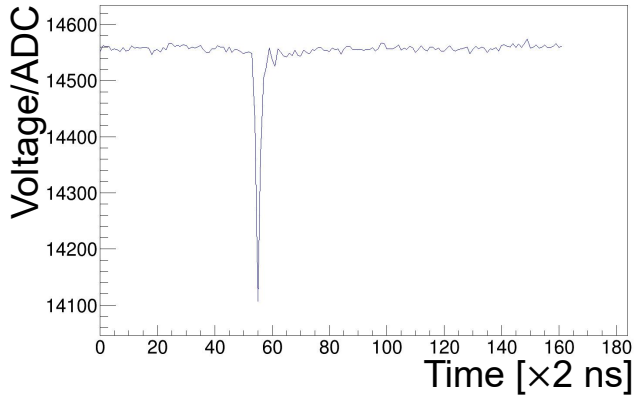


II. Flex-Rigid PCB Validation: Waveform Quality

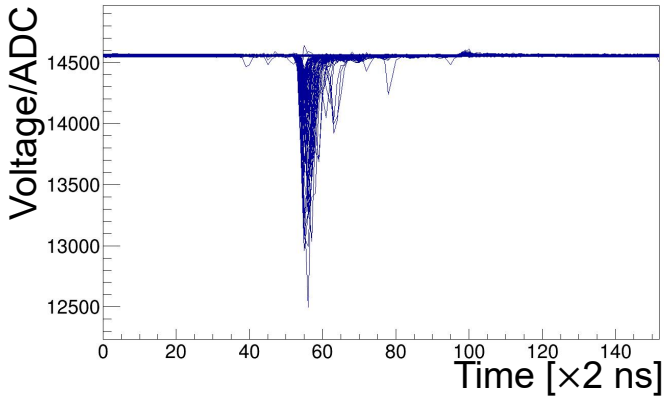
☐ FRP performance (L=110 cm): good signal quality, noise level ~1 mVpp.



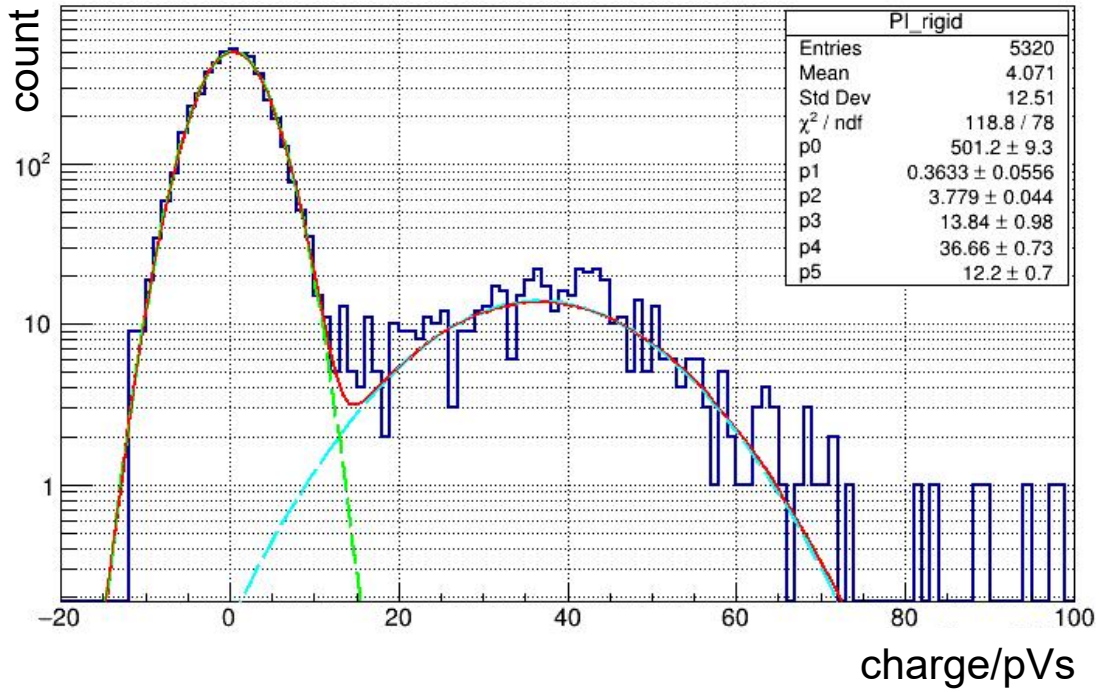
- Noise level



- One waveform from FRP



- 100 waveforms overlaid

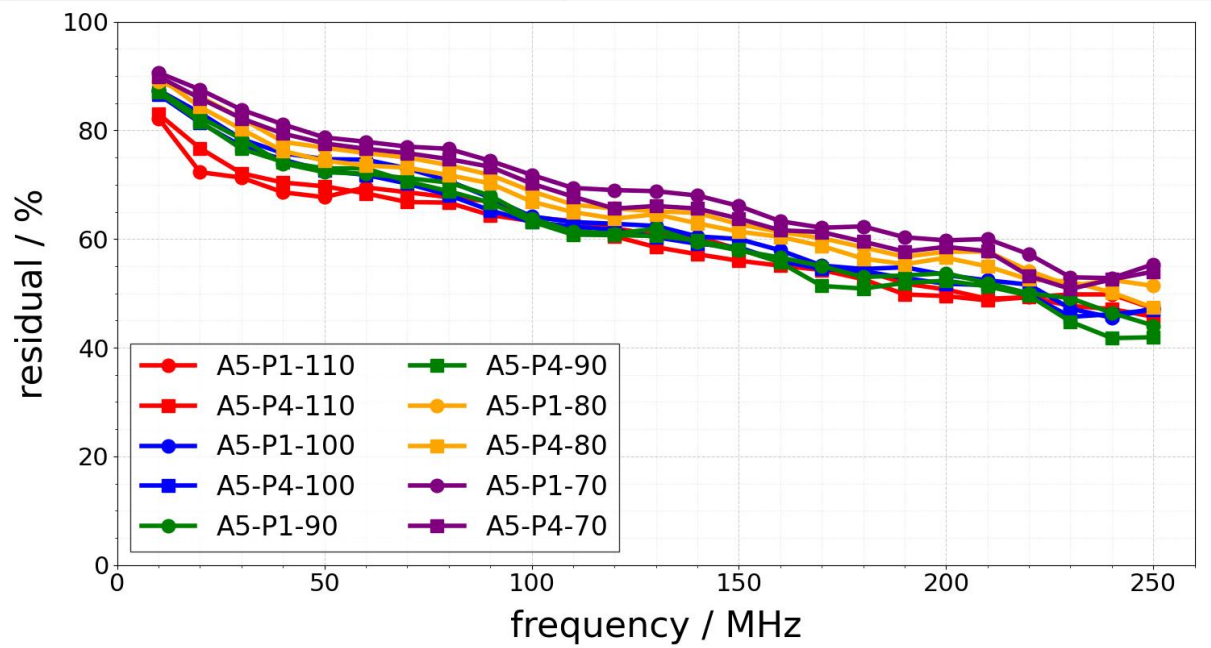


- Typical SPE spectrum

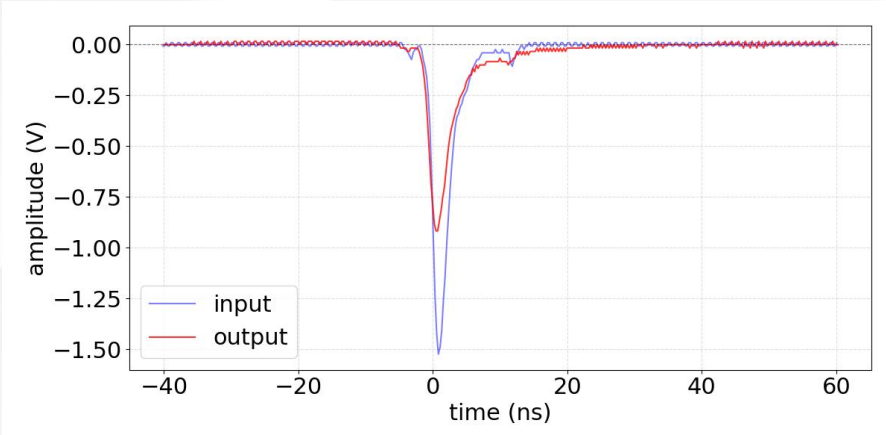
II. Flex-Rigid PCB Validation: Attenuation

☐ FRP performance (L=110 cm):

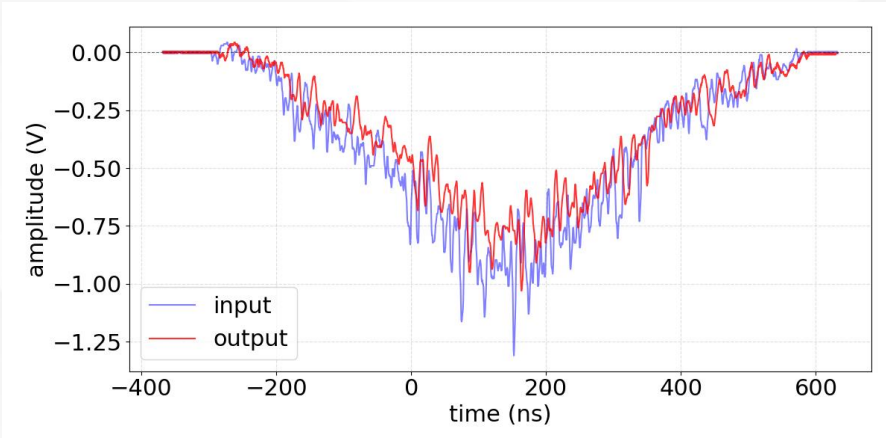
- Amplitude attenuation: ~40% for S1, ~20% for S2.
- Area attenuation: <10% for S1 and S2.



- Amplitude attenuation vs. Frequency



- S1 signal before & after FRP



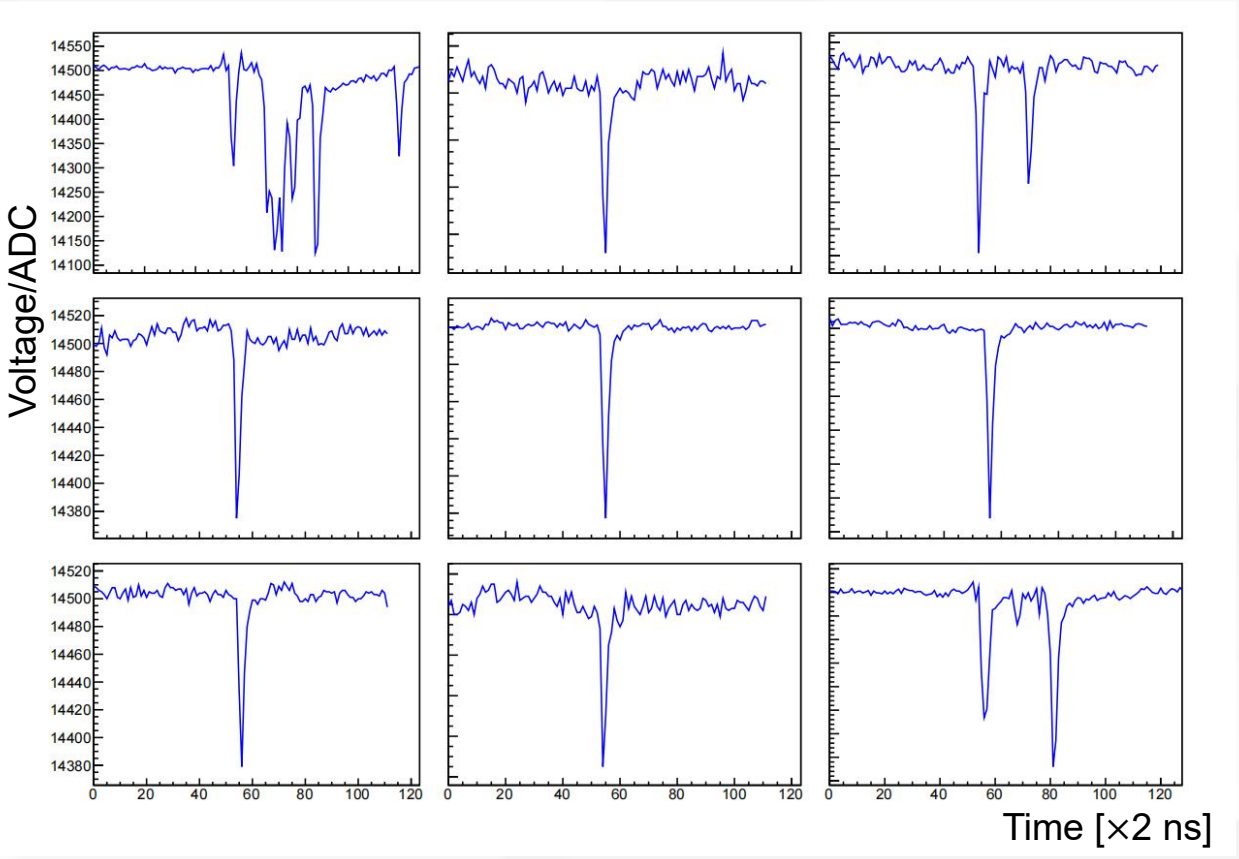
- S2 signal before & after FRP

➢ **Note: above results include unavoidable cabling + connectors during test.**

II. Flex-Rigid PCB Validation: In LXe

☐ FRP in LXe run of PandaX-20T prototype at TDLI:

- FRP in top array installed TDLI platform

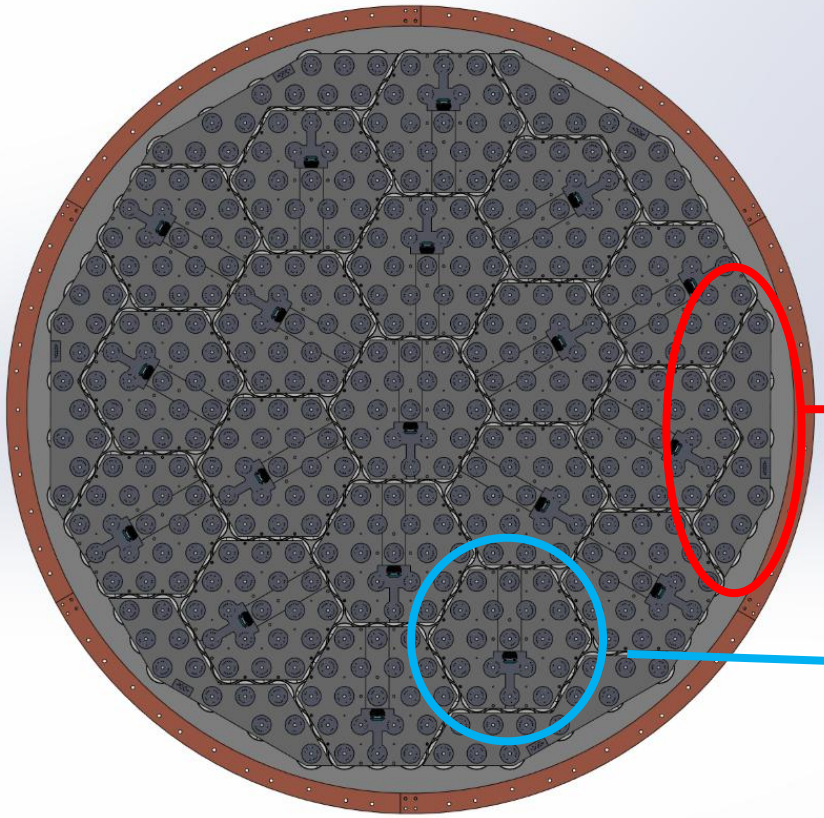


- Waveforms from FRP in LXe

➢ The FRPs satisfies the requirements for PandaX-20T.

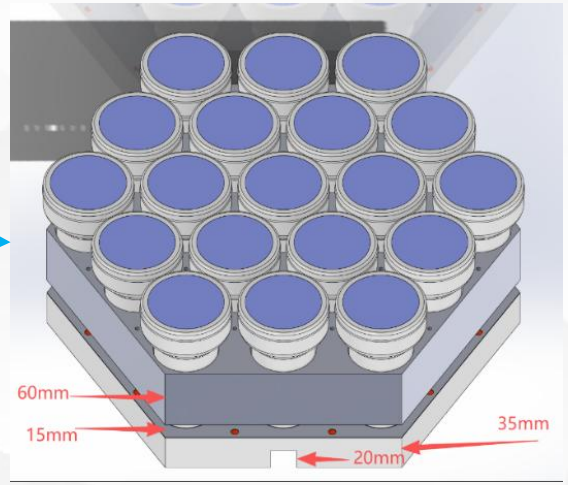
II. Bottom Array Design

Bottom PMT array design:

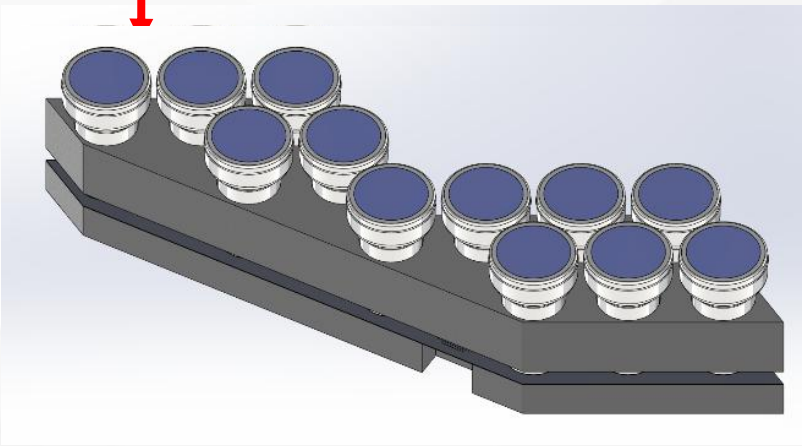


- Bottom PMT Array

PCB Shape	No. of PMTs	No. of PCBs	PMT separation	Total PMTs
Hexagonal module	19	19	81.5 mm	433
Irregular module	12	6		



- Hexagonal module

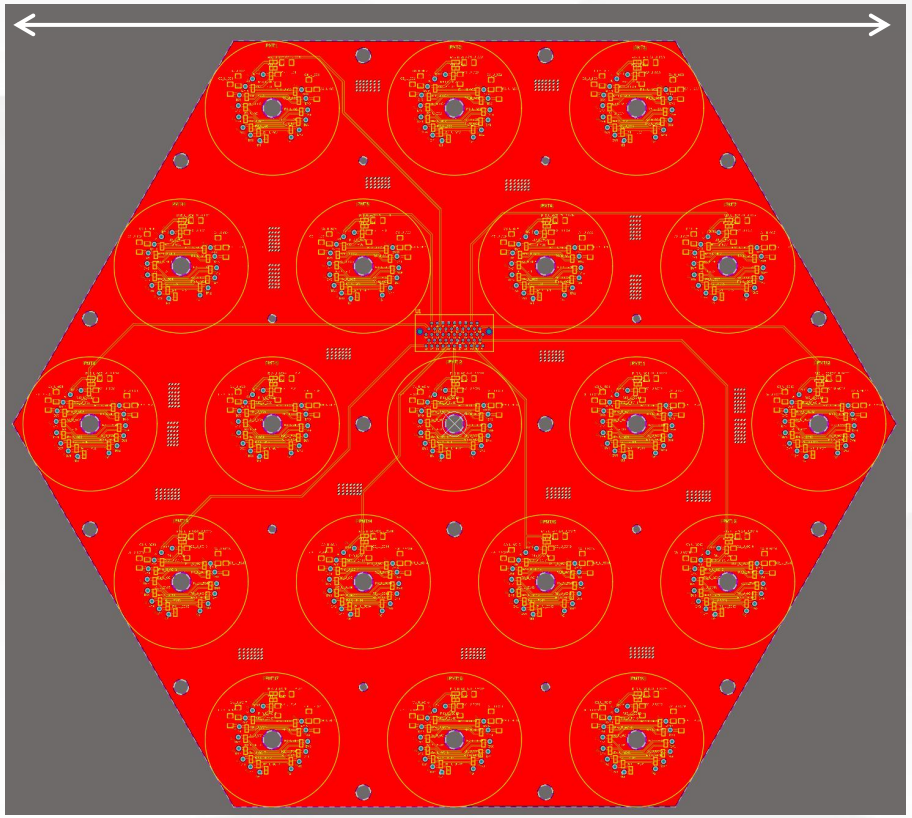


- Irregular module

II. Bottom Array Design

Bottom array PCB design:

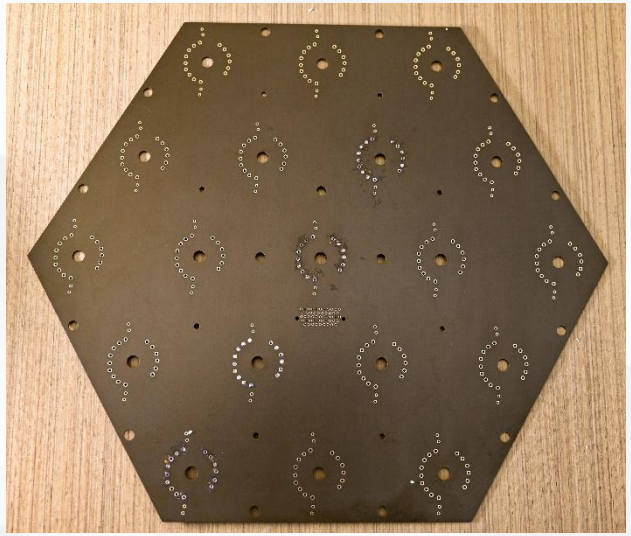
$\Delta x = 395\ mm$



- PCB of Bottom PMT Array

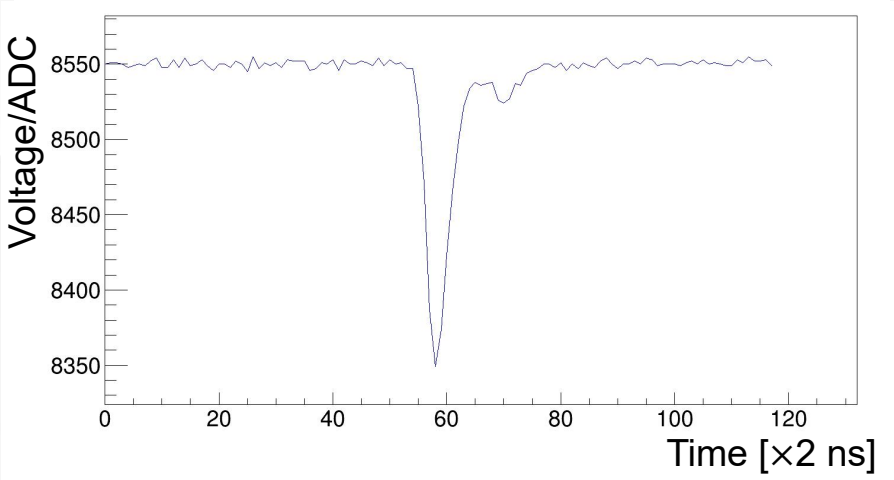
Modularization PCB and PMTs:

- 19 R11410 PMT
- 19 positive HV channels (coupled with signals)
- 8 shared negative HV channels

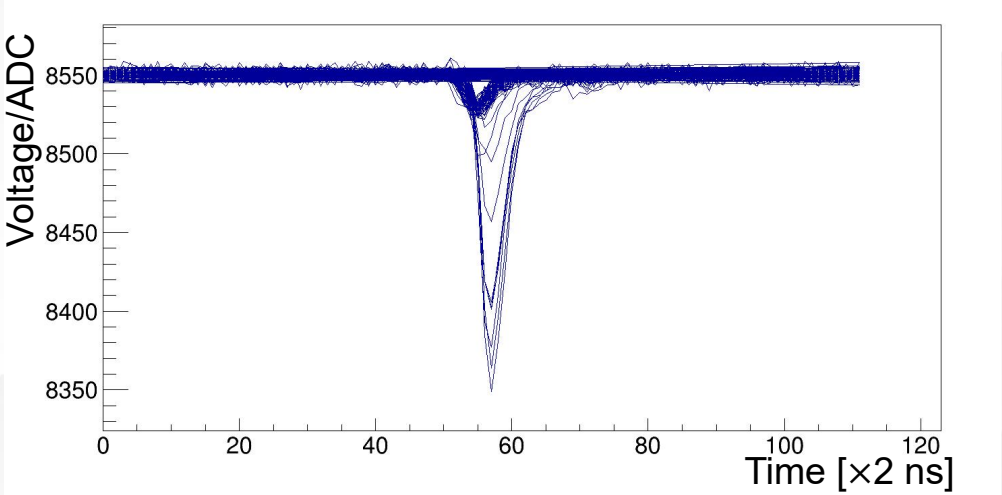


II. Bottom Array PCB Validation: Waveform Quality

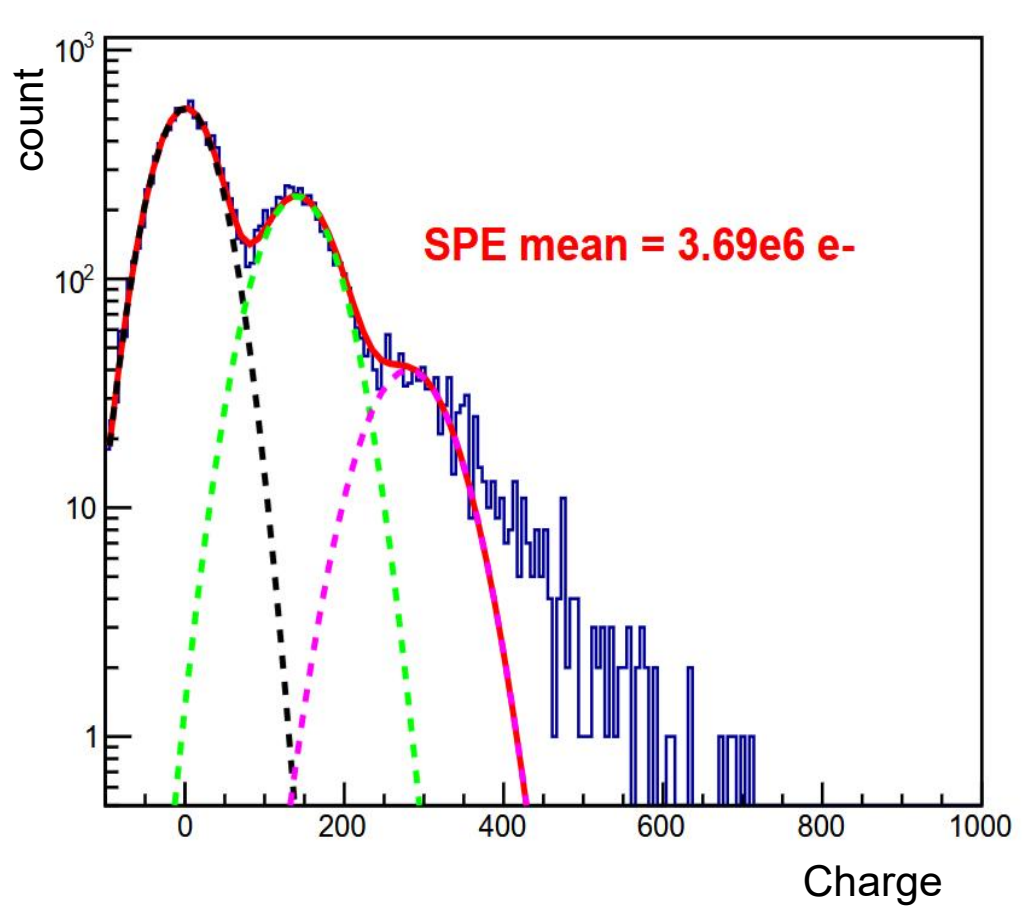
☐ PCB performance: good signal quality.



- One waveform from PCB



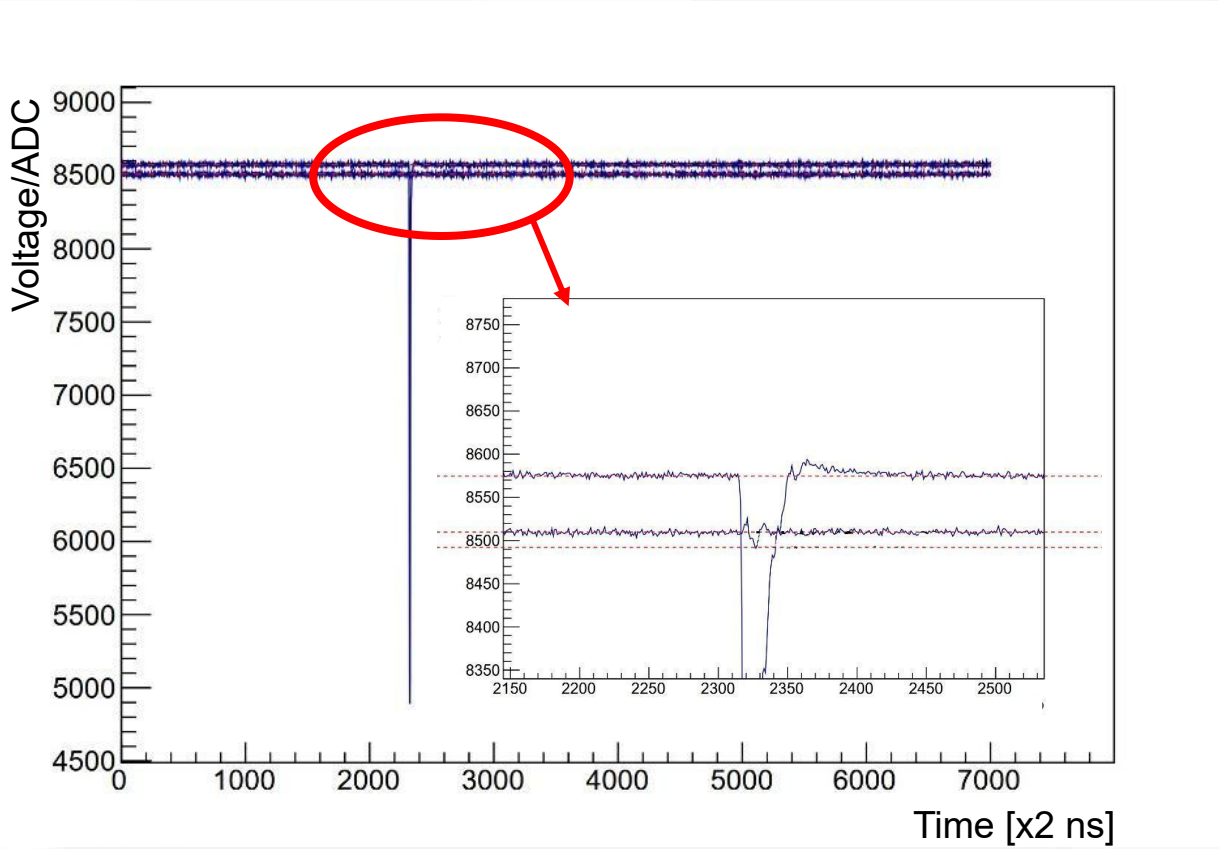
- 100 waveforms overlay



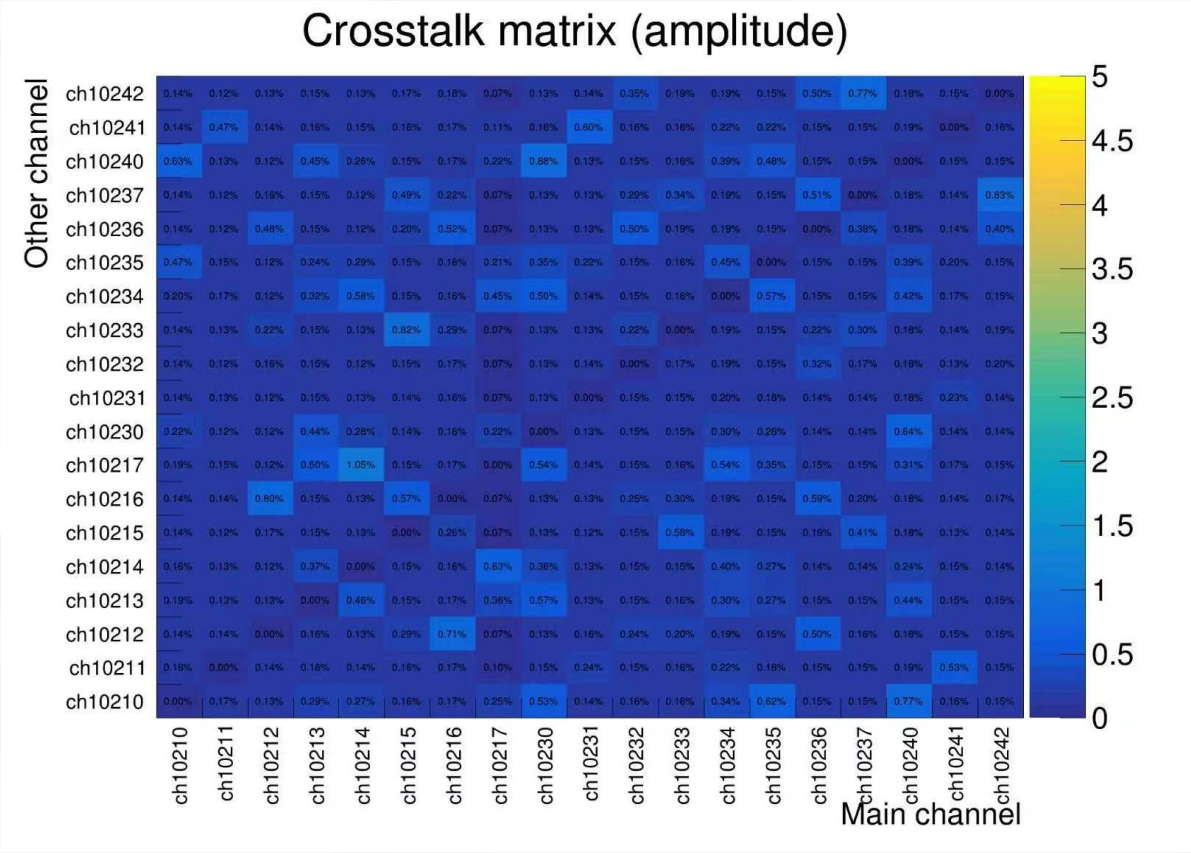
- Typical SPE spectrum

II. Bottom Array PCB Validation: Crosstalk

☐ PCB performance: low crosstalk in amplitude (<1%)



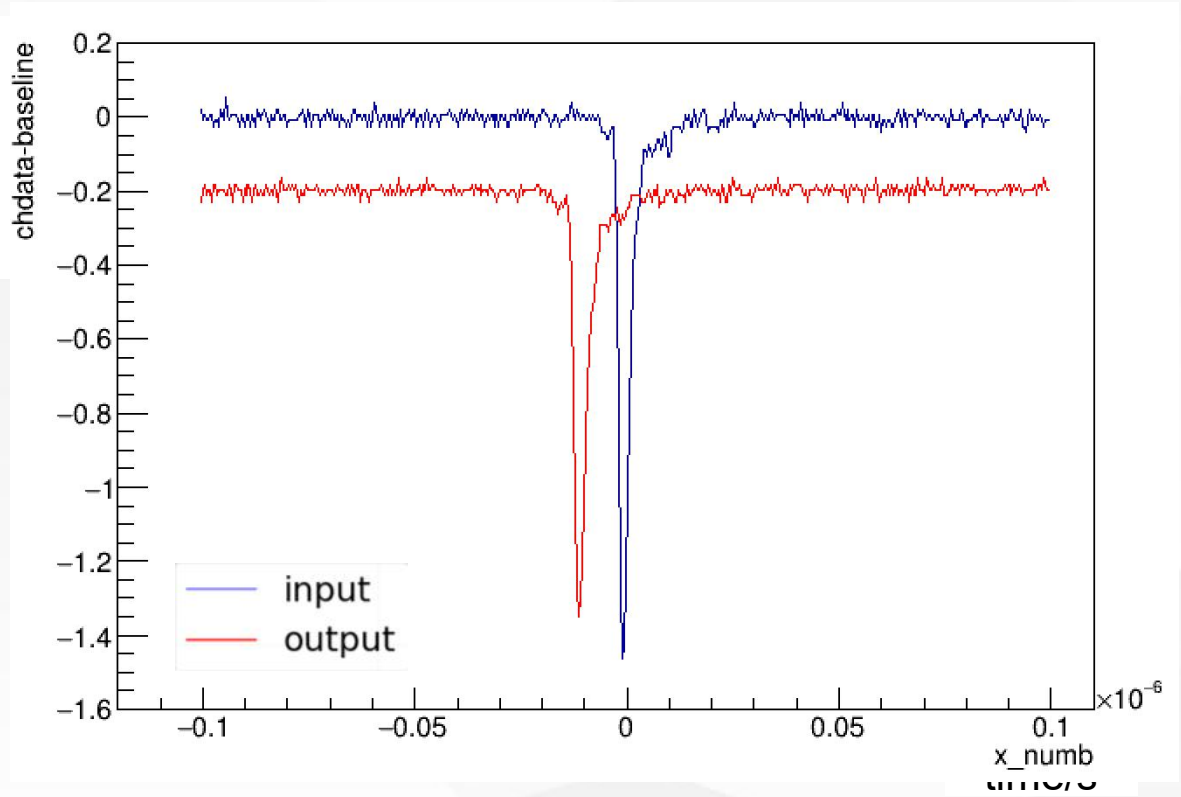
- Reference signal & crosstalk



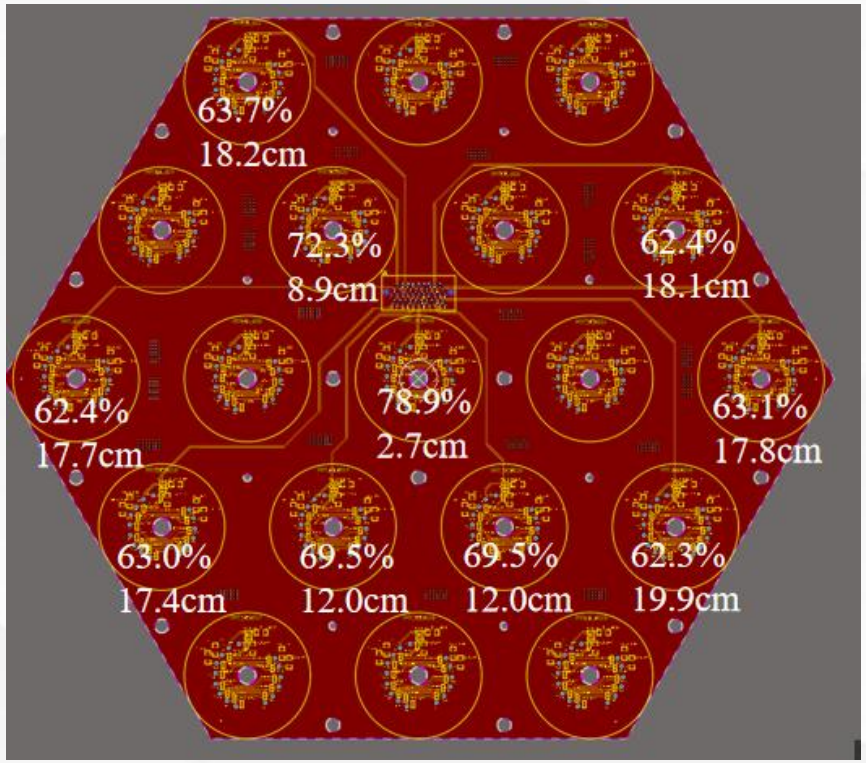
- Amplitude crosstalk distribution

II. Bottom Array PCB Validation: Attenuation

- **PCB performance: attenuation of S1 <40% (amplitude), <10% (area).**



- Waveform before & after PCB

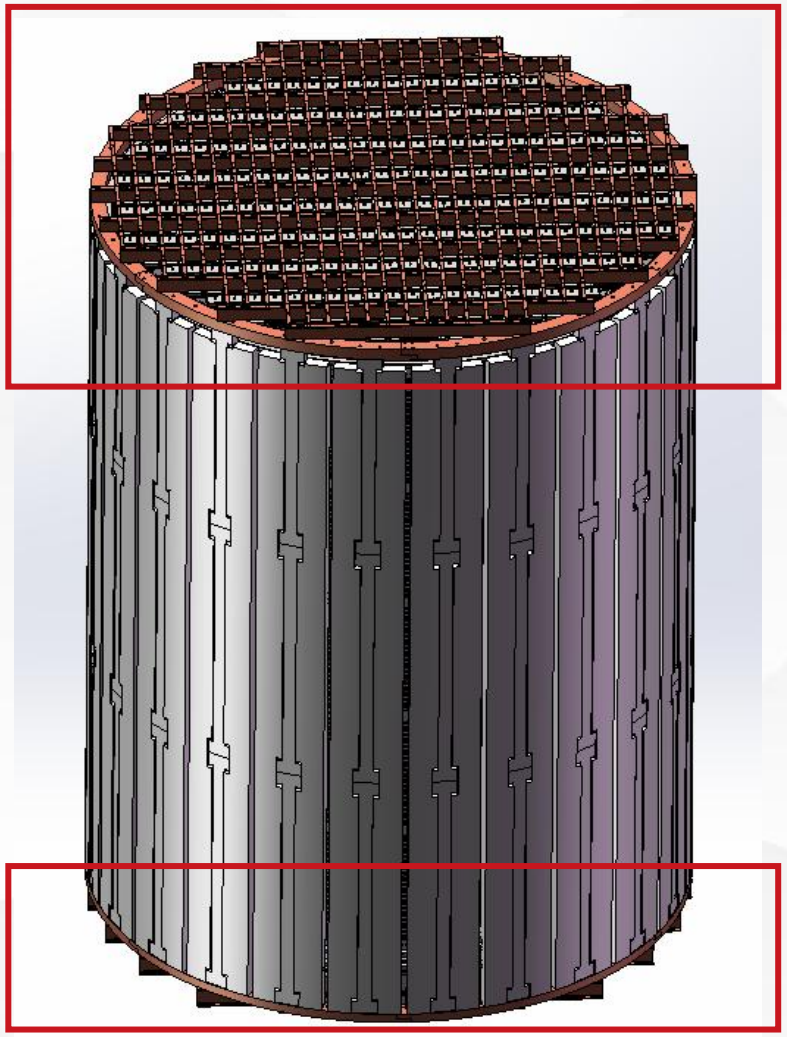


- Attenuation vs. circuit trace length

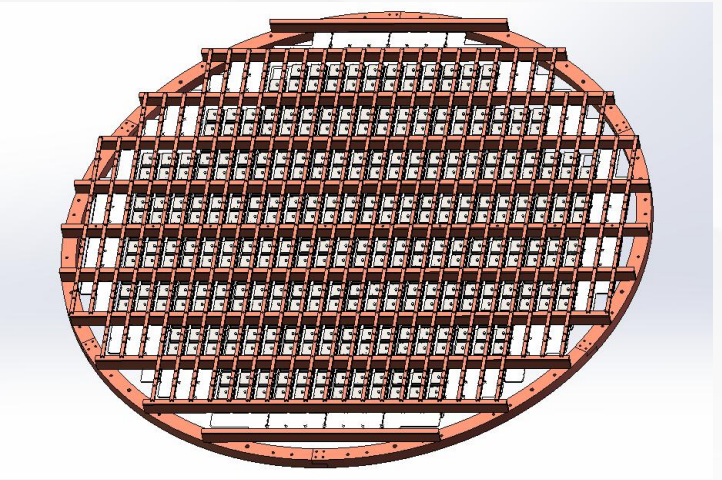
- **The attenuation of bottom PCB is acceptable.**

III. PMT Array Assembly

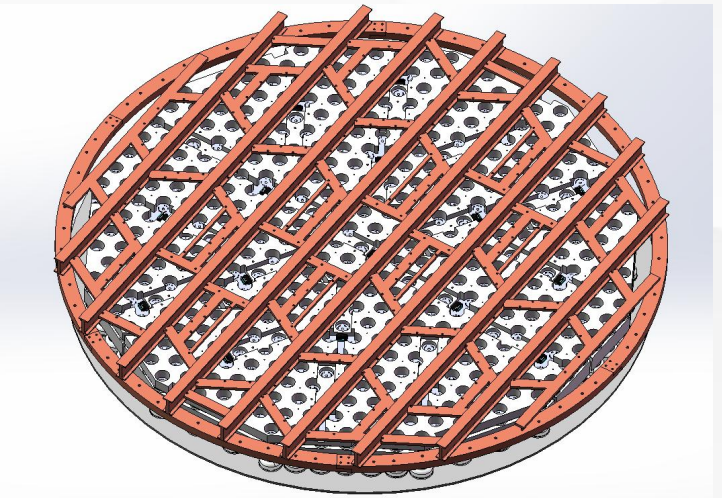
PMT array assembly design:



Top PMT array:
FRPs couple with TPC

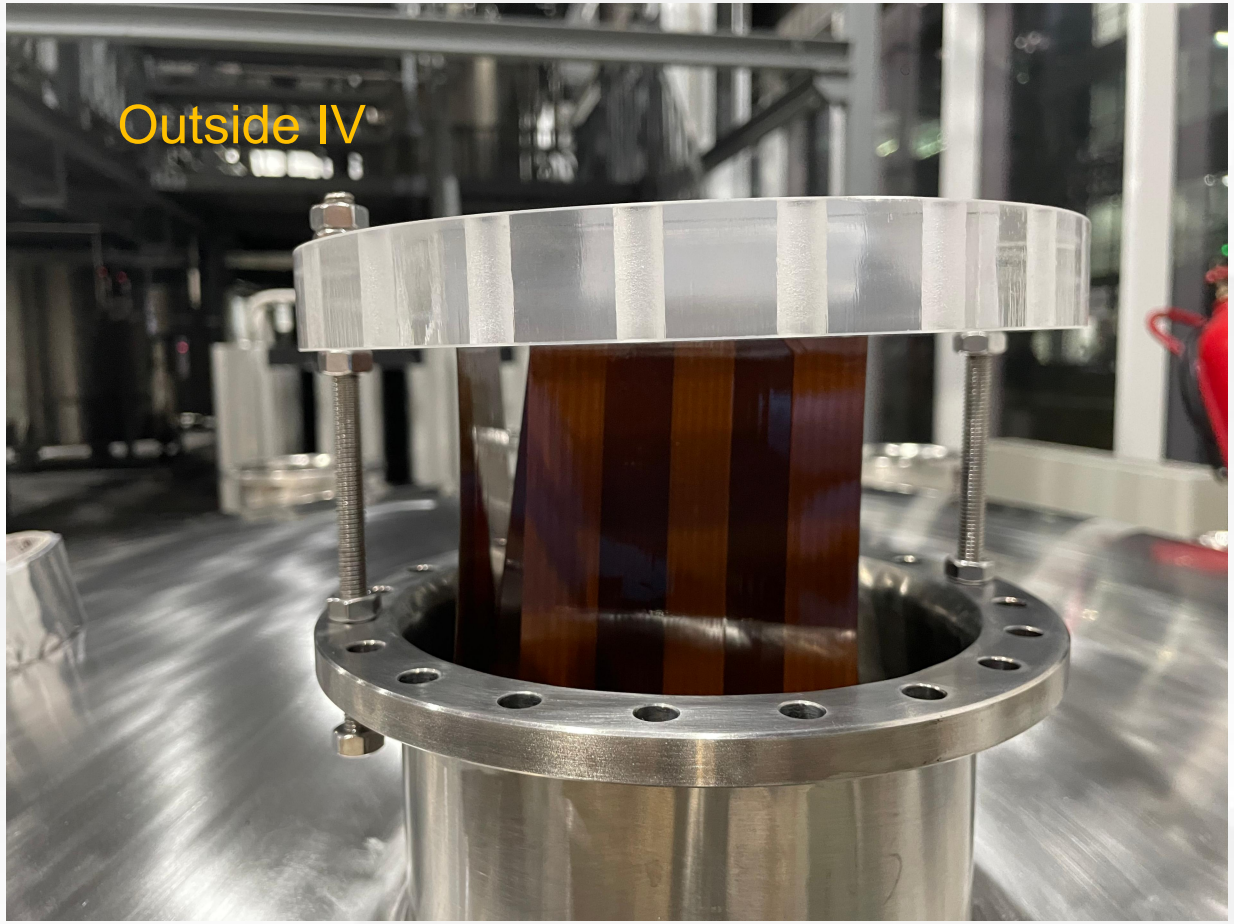


Bottom PMT array:
PCBs couple with TPC



III. PMT Array Assembly

☐ Top PMT array assembly practice:

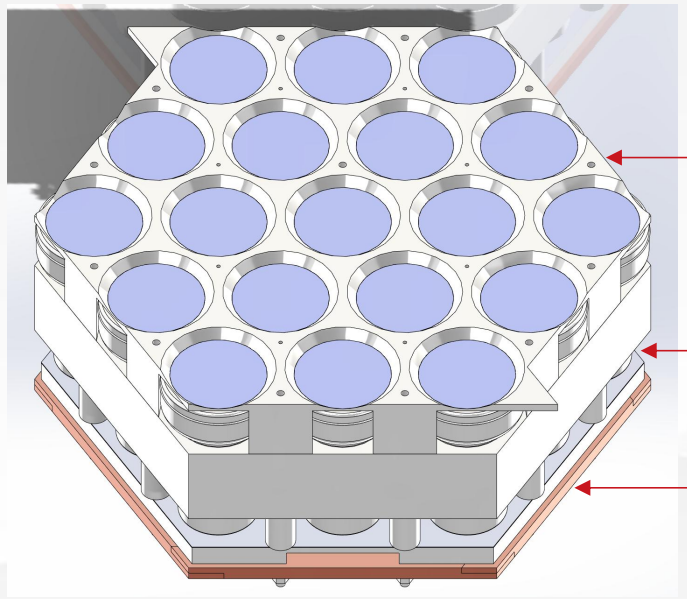


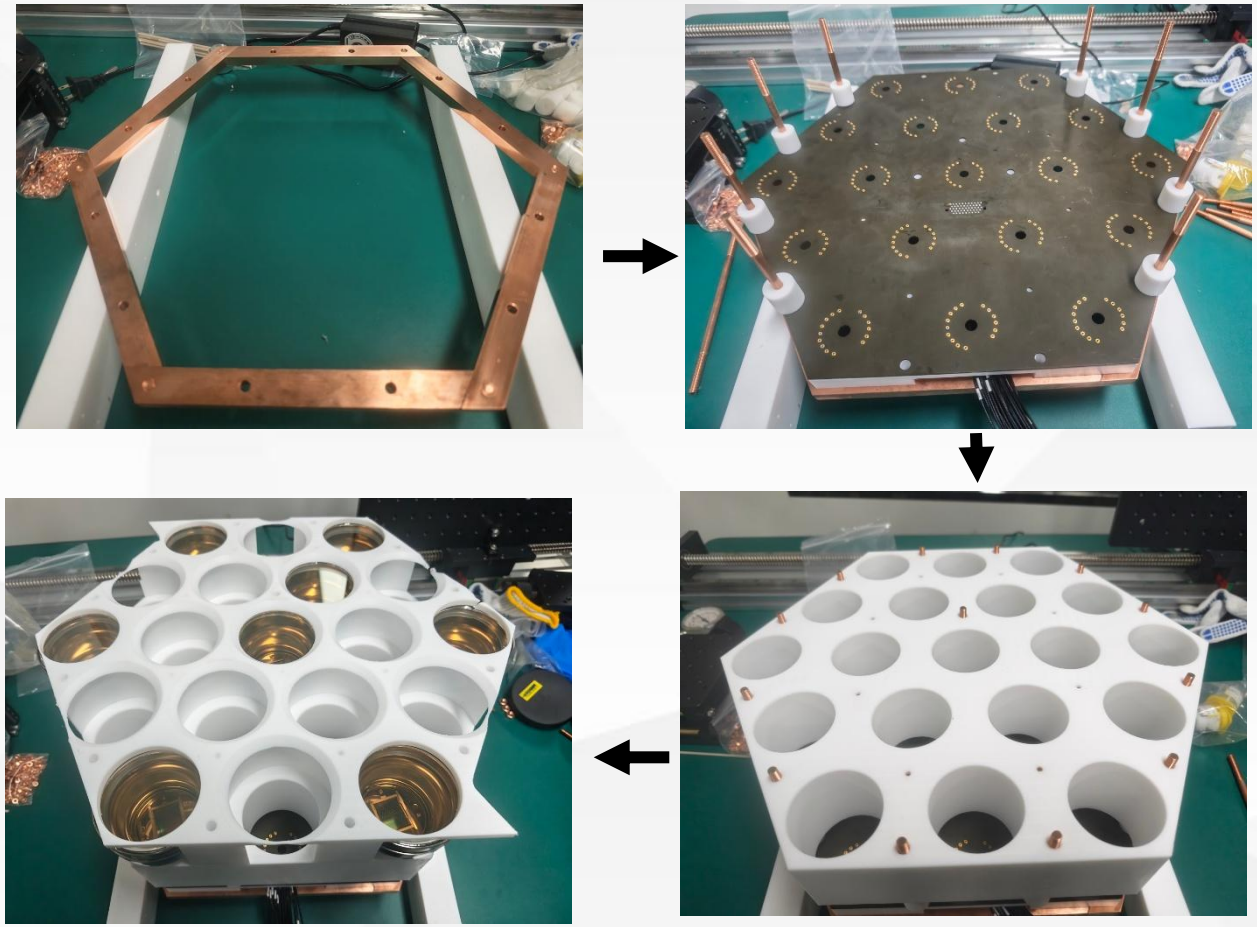
➢ **The assembly of top FRPs went well for all the areas.**

III. PMT Array Assembly

☐ Bottom PMT array modular practice:

- Spacer: replace LXe to fill PMT gaps.
- Bottom plate: fix PCB and PMT
- Hexagonal copper ring: coupled with TPC.





➢ **The assembly of bottom PCBs went well.**

Summary & Outlook

- We designed a highly-integrated photosensor system for the PandaX-20T
  - Innovatively designed and fabricated the FRP for top PMT array;
  - Modularized the individual PMT base for the bottom array.
- The design and performance of both the top and bottom arrays have been well validated and meet the requirements of the PandaX-20T experiment.
- The PandaX-20T experiment is expected to be commissioning in 2027, ***stay tuned!!***

上海交通大學

SHANGHAI JIAO TONG UNIVERSITY

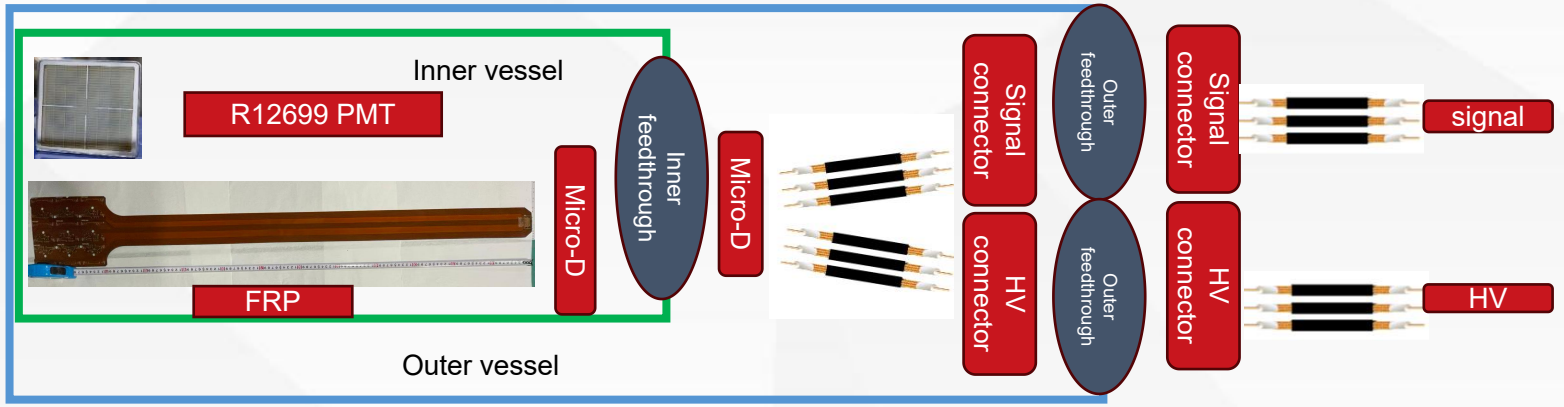
Thank You

饮 水 思 源　爱 国 荣 校

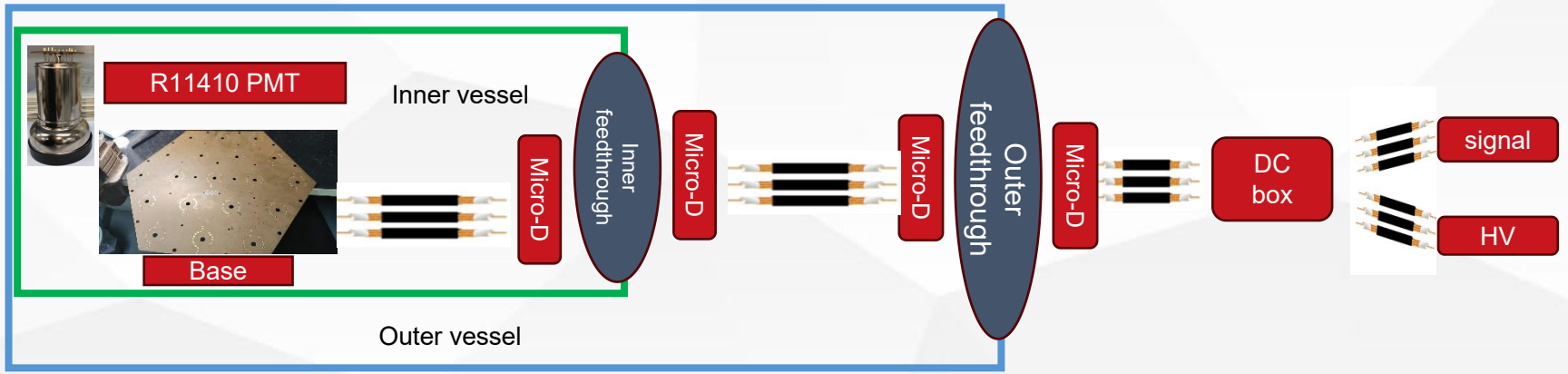
PandaX-20T Photosensor System Design

☐ PMT Array Readout Architecture:

Top Array Full Chain Schematic



Bottom Array Full Chain Schematic



➢ This talk focuses on the frontend integration and verification of the two PMT arrays.

Flex-Rigid PCB test

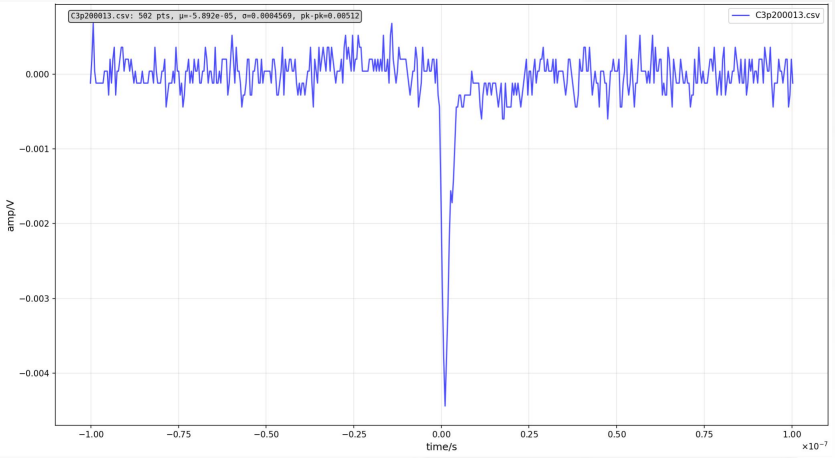
☐ FRP Performance (110 cm):

- **Thermal Properties:**

  Good performance at low temperature (-100 ℃).

  No obvious change in performance after thermal cycles.

- FRP for low tempurature test

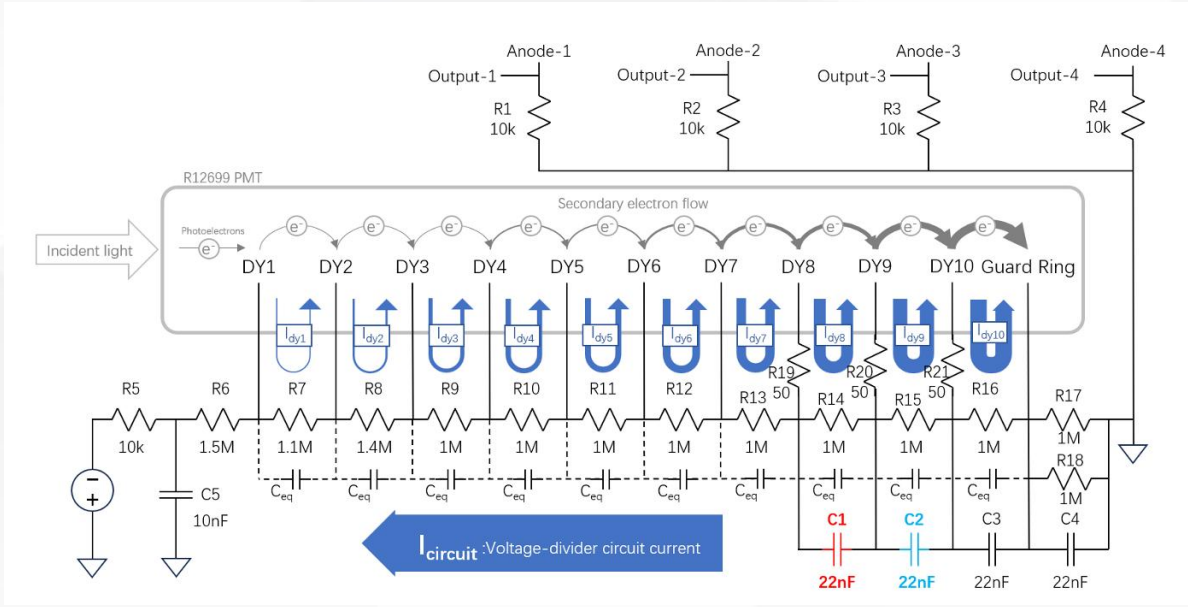


- Single photon signal at low temperature

- FRP for thermal cycles

Top/Bottom PMT base scheme

- Top PMT base scheme



- Bottom PMT base scheme