
Hardware camp for fast and low-light detection

Son Cao (IFIRSE, ICISE)



MAR. 4TH 2024

**This camp served as an
invitation to particle
physics research!**

**also to illustrate the interplay
btw. particle and nuclear
physics and technology**

Interplay between science and technology

- **Transistor** was not invented by people who wanted to build computers but by physicists who dealing with counting the nuclear particles
- **Nuclear power** was not developed by one who seek for new power but Curies, Rutherford, and Fermi
- **Electron discovery** (credited for by J.J. Thomson) was not for electronic industry but to understand the basics of atoms.
- **Induction coils** in motor cars and other vast application, not invented by who want to make motor transport but the principle of induction was discovered by M. Faraday
- **Communication with electromagnetic waves**, founded by H. Hertz who wanted to emphasized the beauty of physics
- **Global positioning system (GPS)** can't function well if not including the General Relativity
- **Development of new materials and molecules** benefits from precise mathematical techniques used in particle physics
- **Word Wide Web** was first invented by particle physicists to share information quickly and effectively around the world.
- **Cancer therapy, drug development** thanks to the **particle accelerators**
- **Behind of almost all photodetectors is photoelectric effect, which is discovered by Hertz in 1887 and modeled by Einstein in 1905**
- **Photodetectors developed and improved for particle physics** drive industrial application such as x-ray, medical scanning
- **Help for national security**, eg. cargo scanning, looking insides of the nuclear reactor
- ...

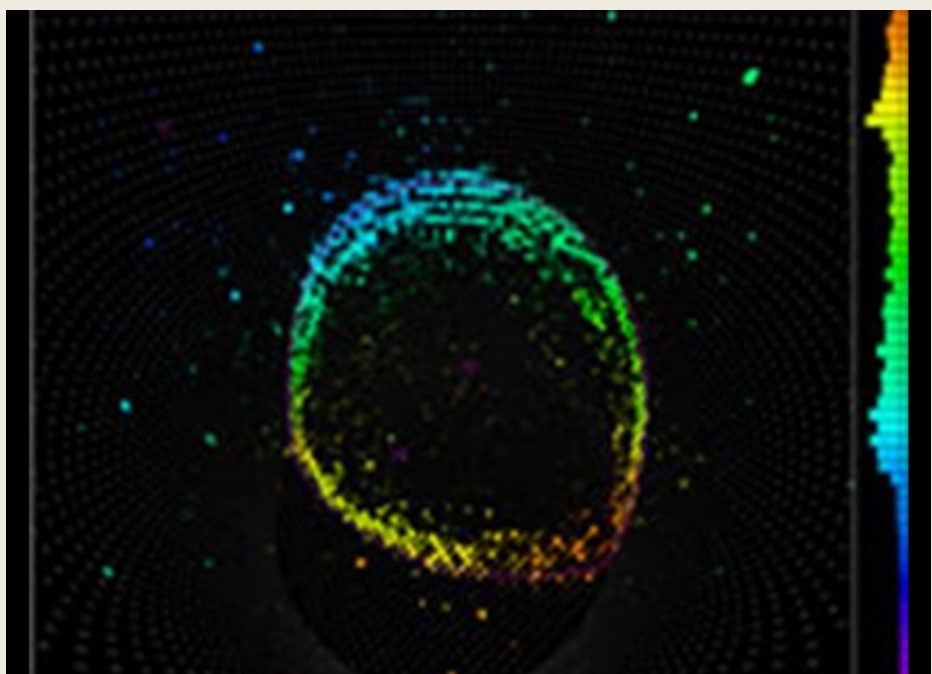
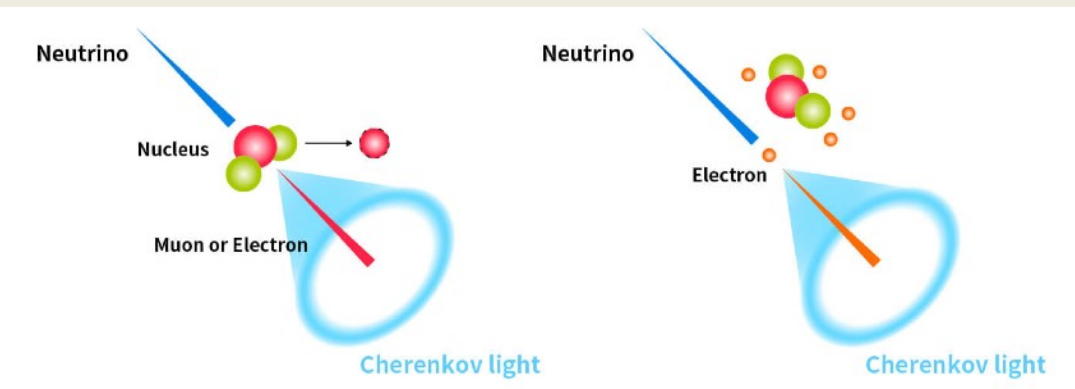
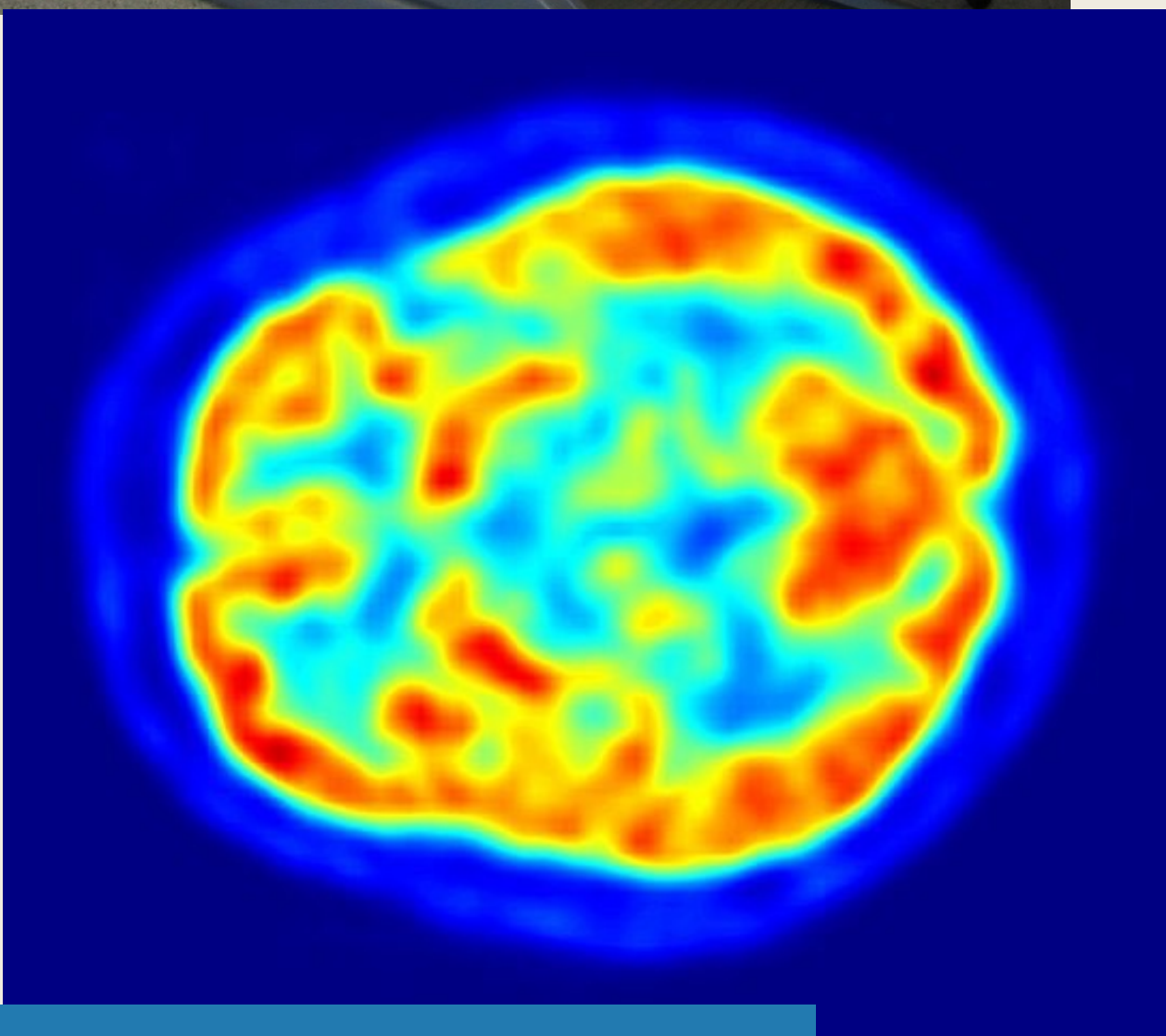
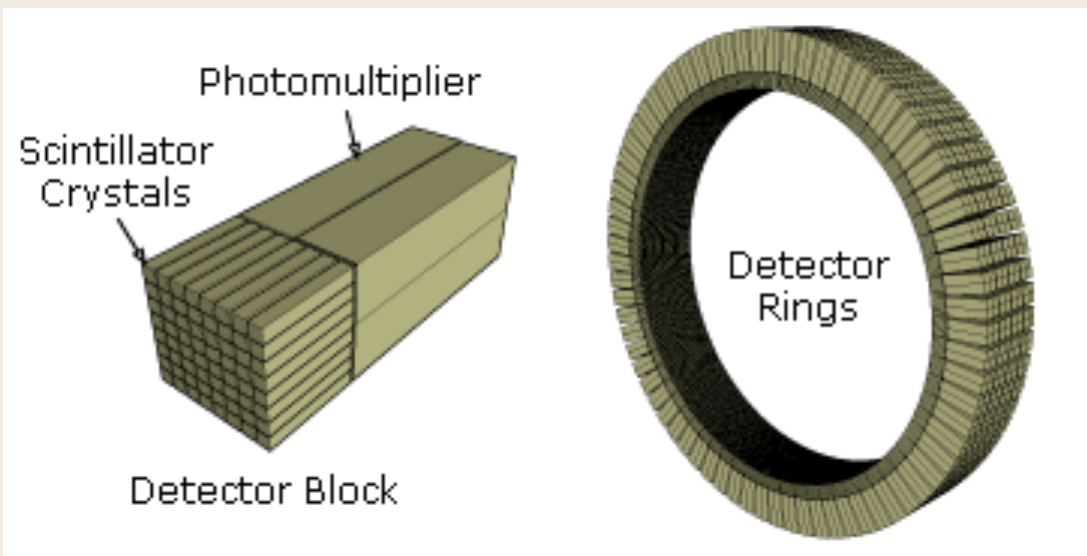
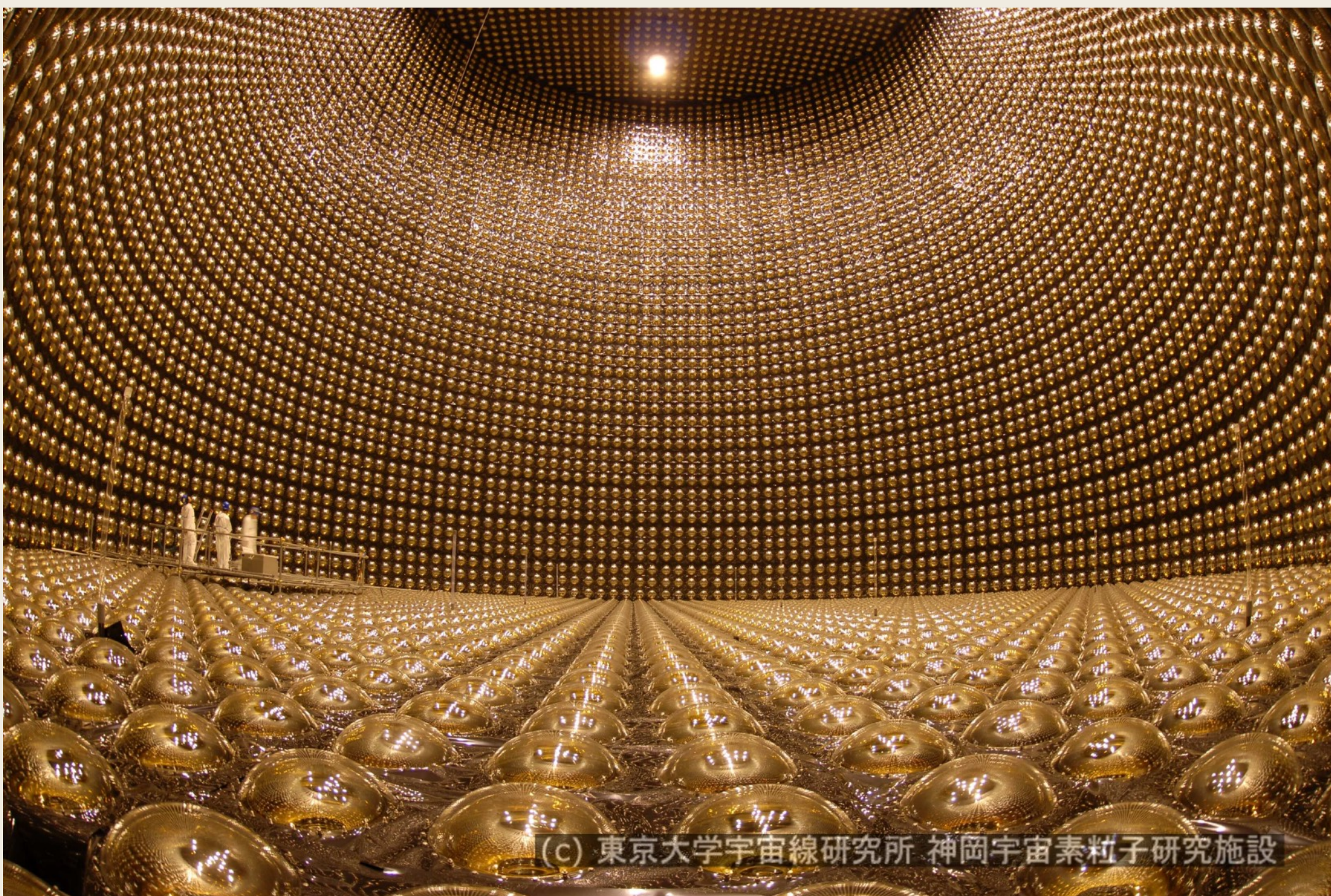
IN RESPONSE, ADVANCEMENTS IN TECHNOLOGY ARE CRITICAL FOR BASIC RESEARCH.

Particle physics, a key driver for innovation

“The complex and sophisticated tools of particle physics are rich sources of new concepts, innovation and groundbreaking technologies, which benefit various applied research disciplines and eventually find their way into many applications that have a significant impact on the economy and society.”

<https://cds.cern.ch/record/1431474/files/ParticlePhysicsEurope-New.pdf>

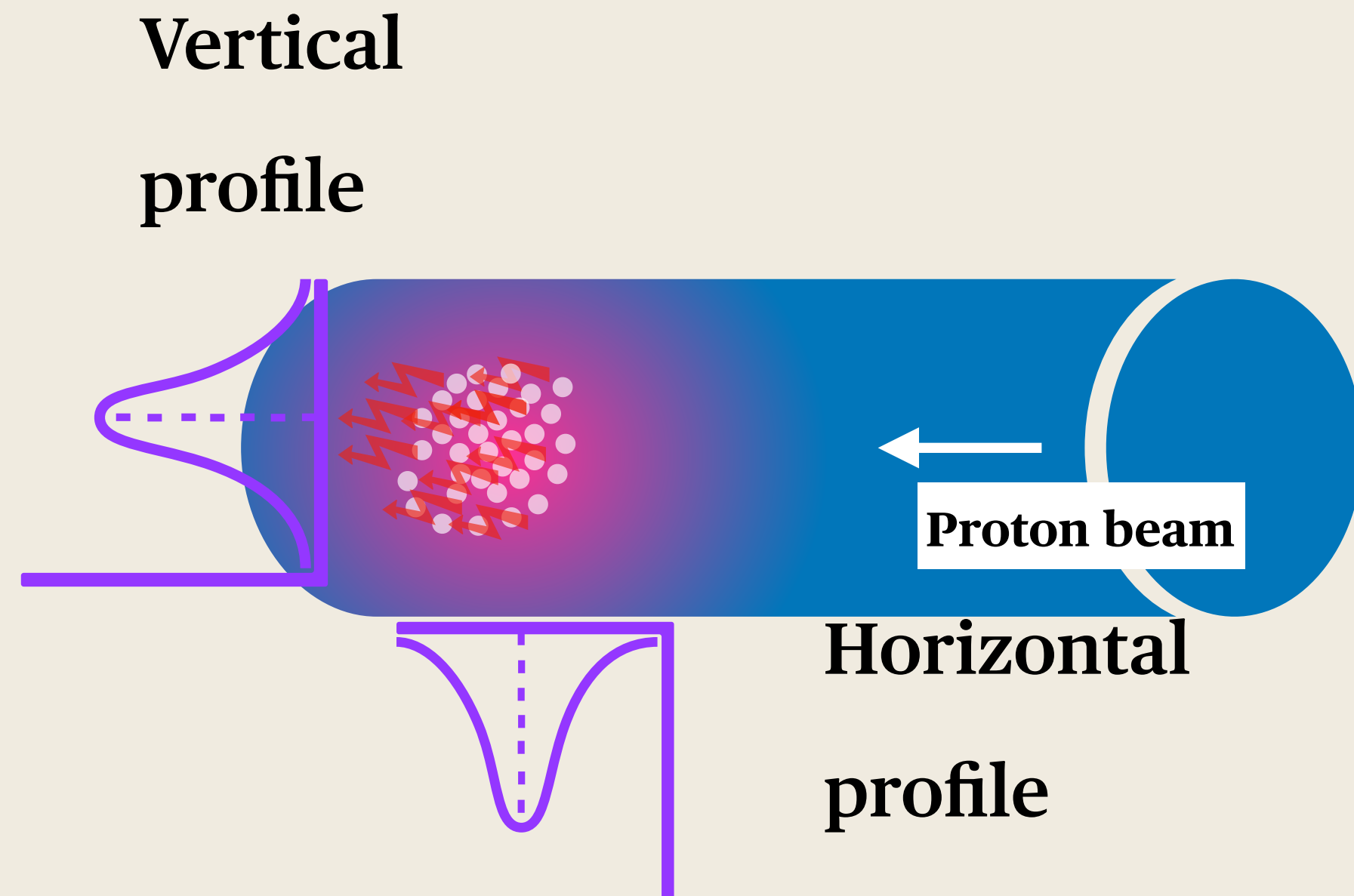
Interplay btw. physics and technology



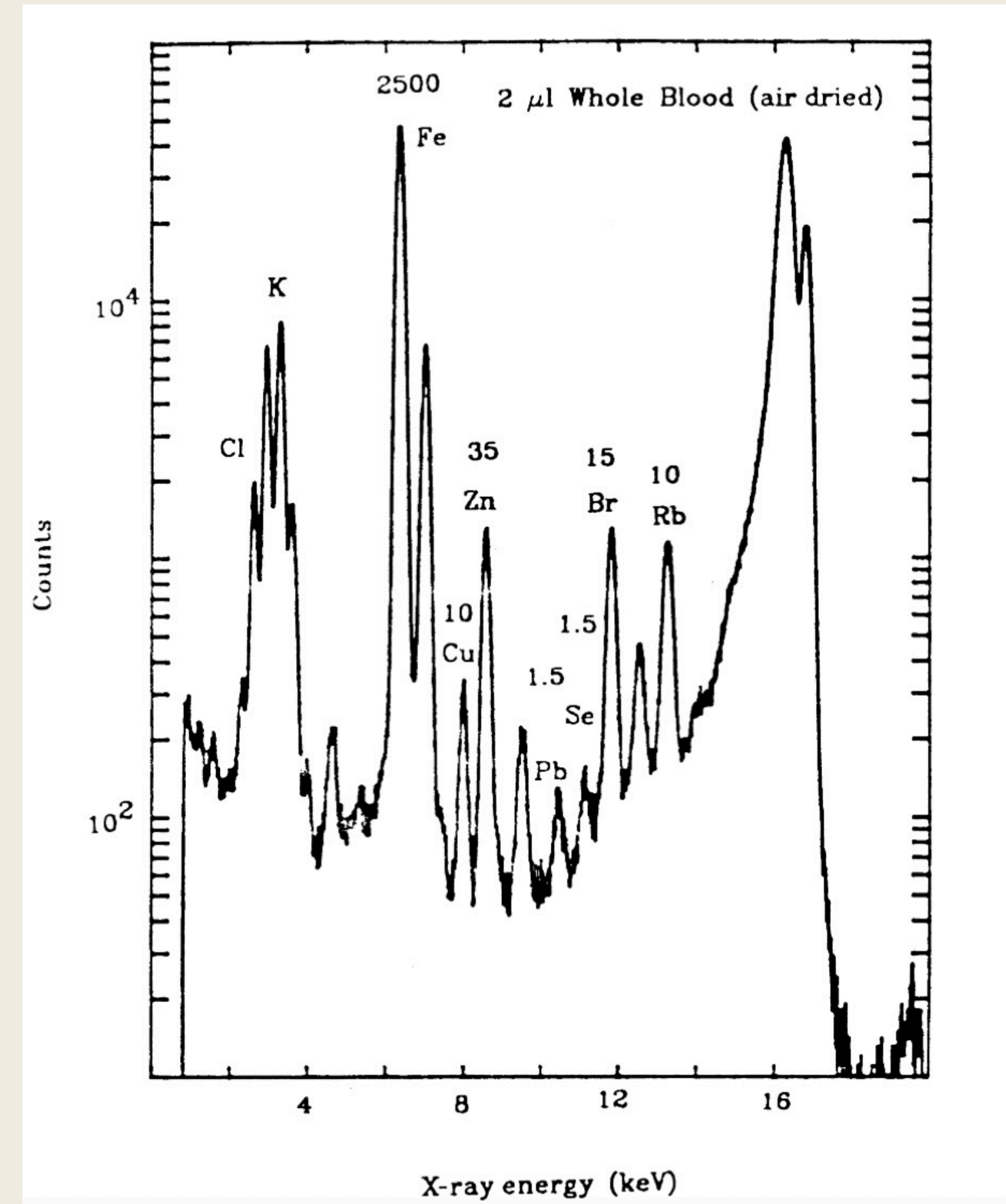
SUPER-KAMIOKANDE

POSITRON EMISSION TOMOGRAPHY

Interplay btw. physics and technology

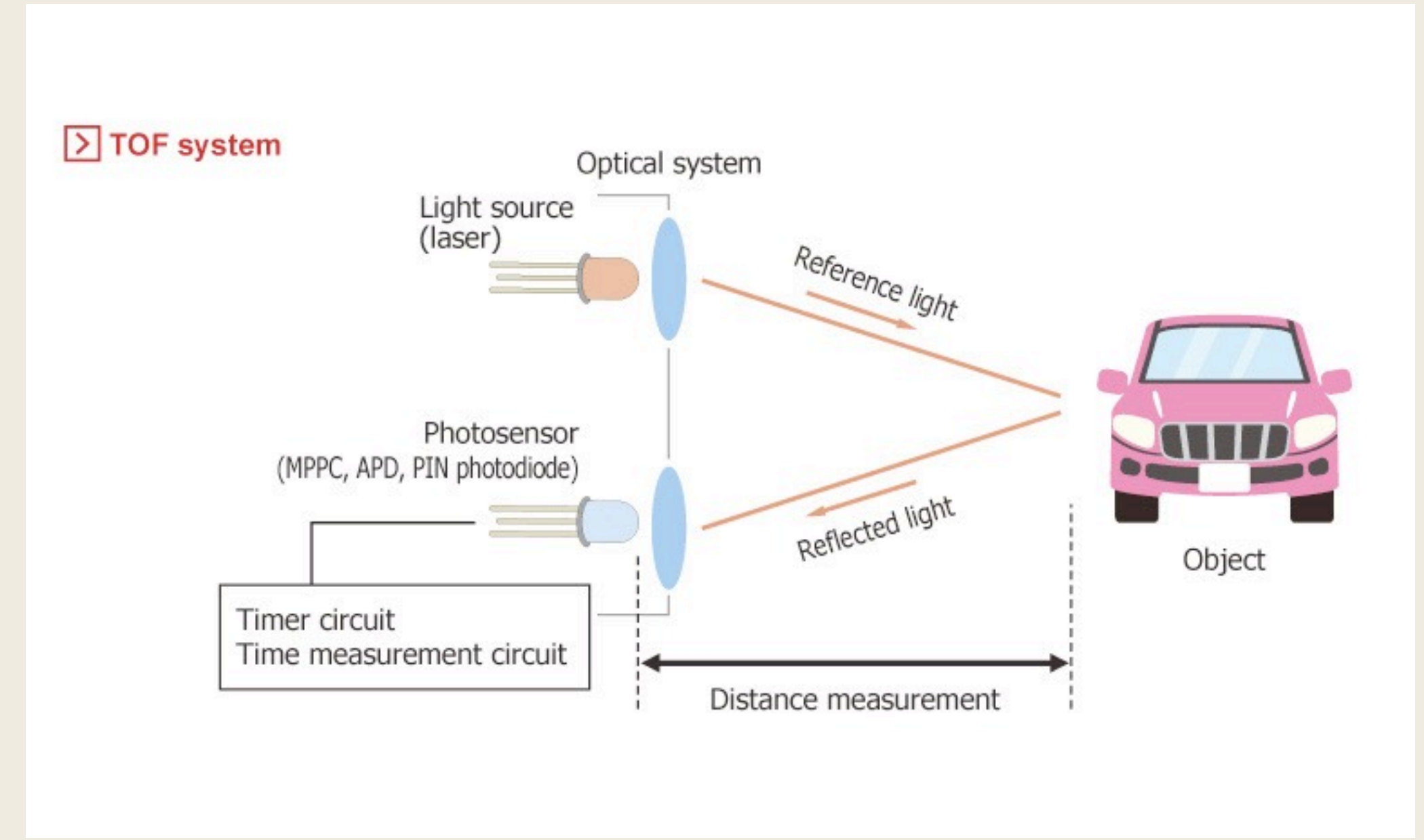
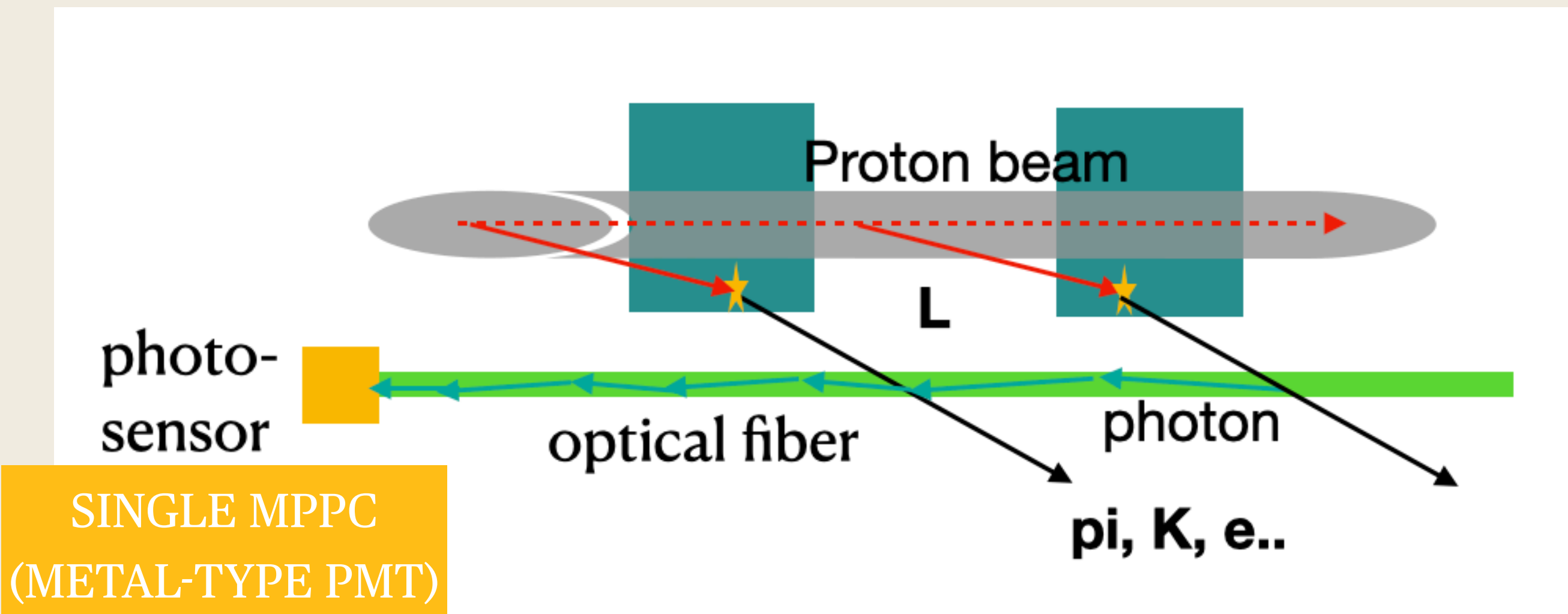


NON-DESTRUCTIVE BEAM-INDUCED FLUORESENCE MONITOR
UNDER-DEVELOPING AT J-PARC NEUTRINO BEAMLIN



X-RAY FLUORESENCE OF HUMAN BLOOD

Interplay btw. physics and technology



OPTICAL-FIBER BASED BEAM LOSS MONITOR
UNDER-DEVELOPING AT J-PARC NEUTRINO BEAMLIN

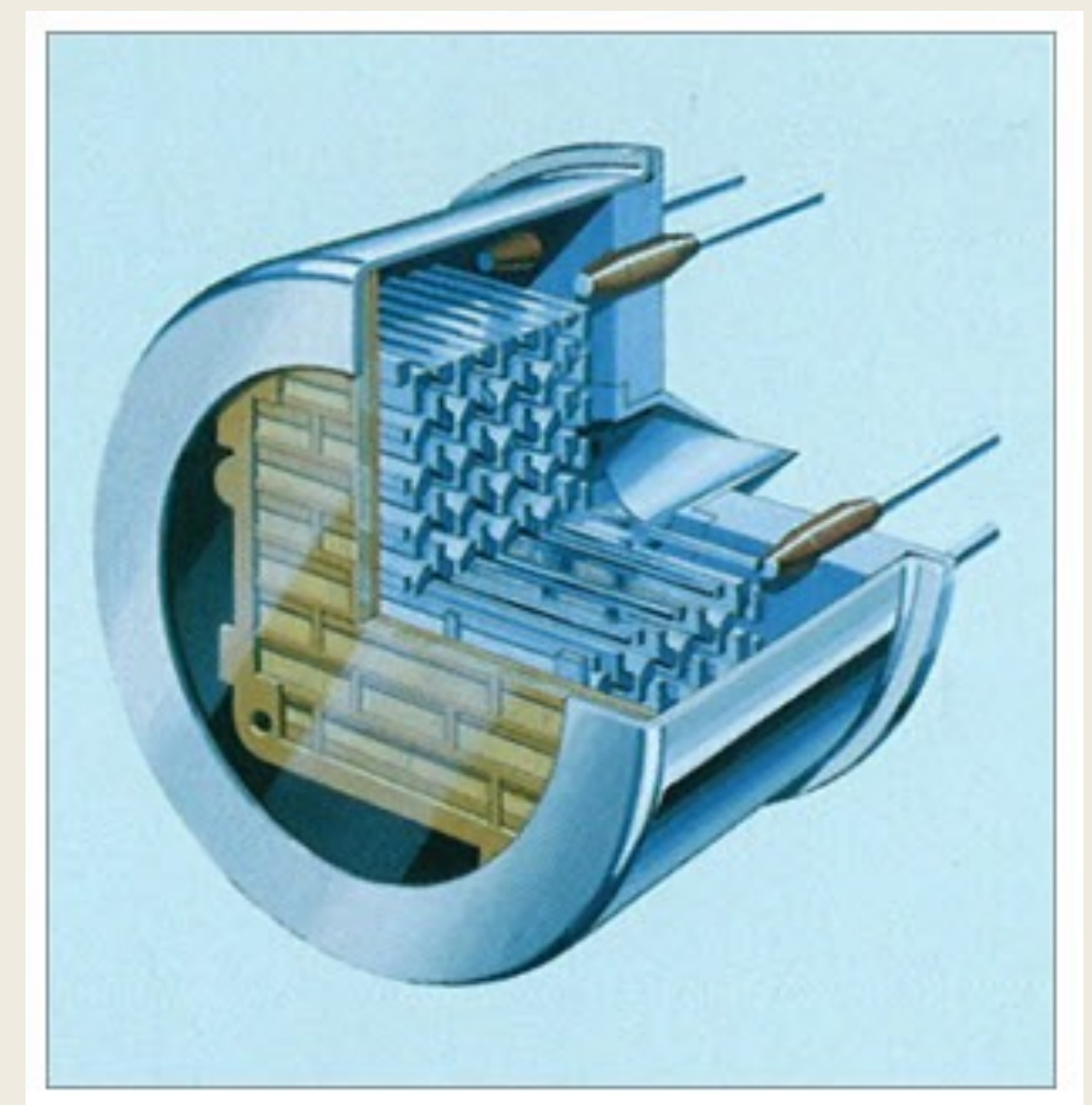
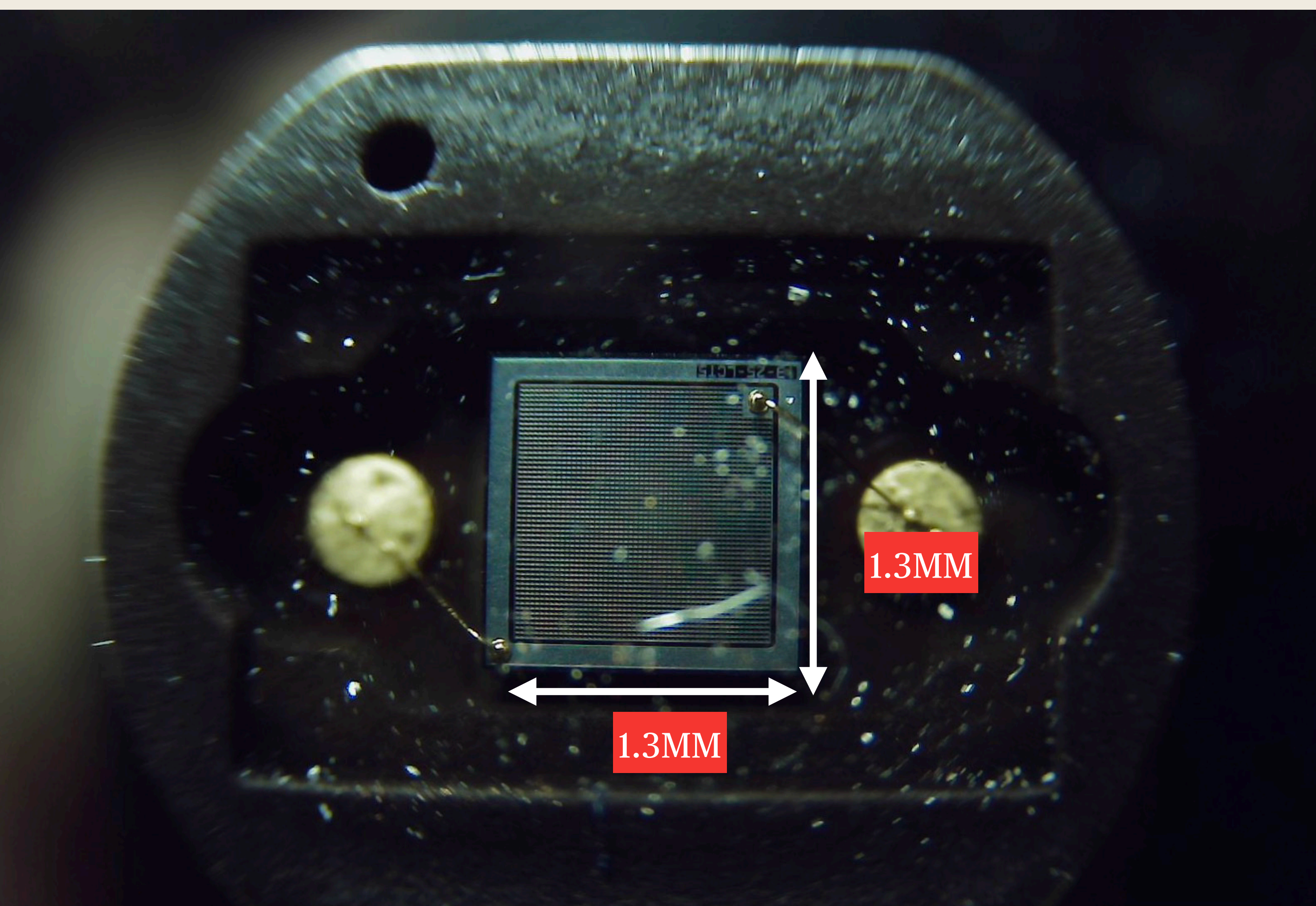
CONCEPT OF LIGHT DETECTION AND RANGING (LIDAR)
WITH TIME-OF-FLIGHT MEASUREMENT BTW REFERENCE LIGHT
AND REFLECTED LIGHT -- HAMAMATSU PHOTONICS K.K

Why fast and low-light detection?

- Light is a *omnipotent* tools to *perceive* almost everything from the world of sub-atomic particles to the Cosmos
- Light is also a *sustainable and effective* solution for various sectors of modern life (*food, communication, entertainment, energy, environment, medicine...*)
- Modern life demands *high-speed* on almost everything → Nothing (*physical object*) is faster than light (*in vaccum*). To harness power of light-speed, one may need help from fast-response (*ns-level*) photosensor.
 - *Do you know how fast can our eyes perceive?*
- When come to ns-level, you may not have an intense light (*photons*) reaching to your photosensor. You need technique to detect the faint light.



THE CAMP OBJECTIVE IS TO DEAL WITH FAST AND LOW-LIGHT DETECTION.
IT'S FUNDAMENTAL IN PARTICLE AND NUCLEAR PHYSICS, BUT CAN BE ADOPTED FOR MANY
SECTORS IN OUR DAILY LIFE



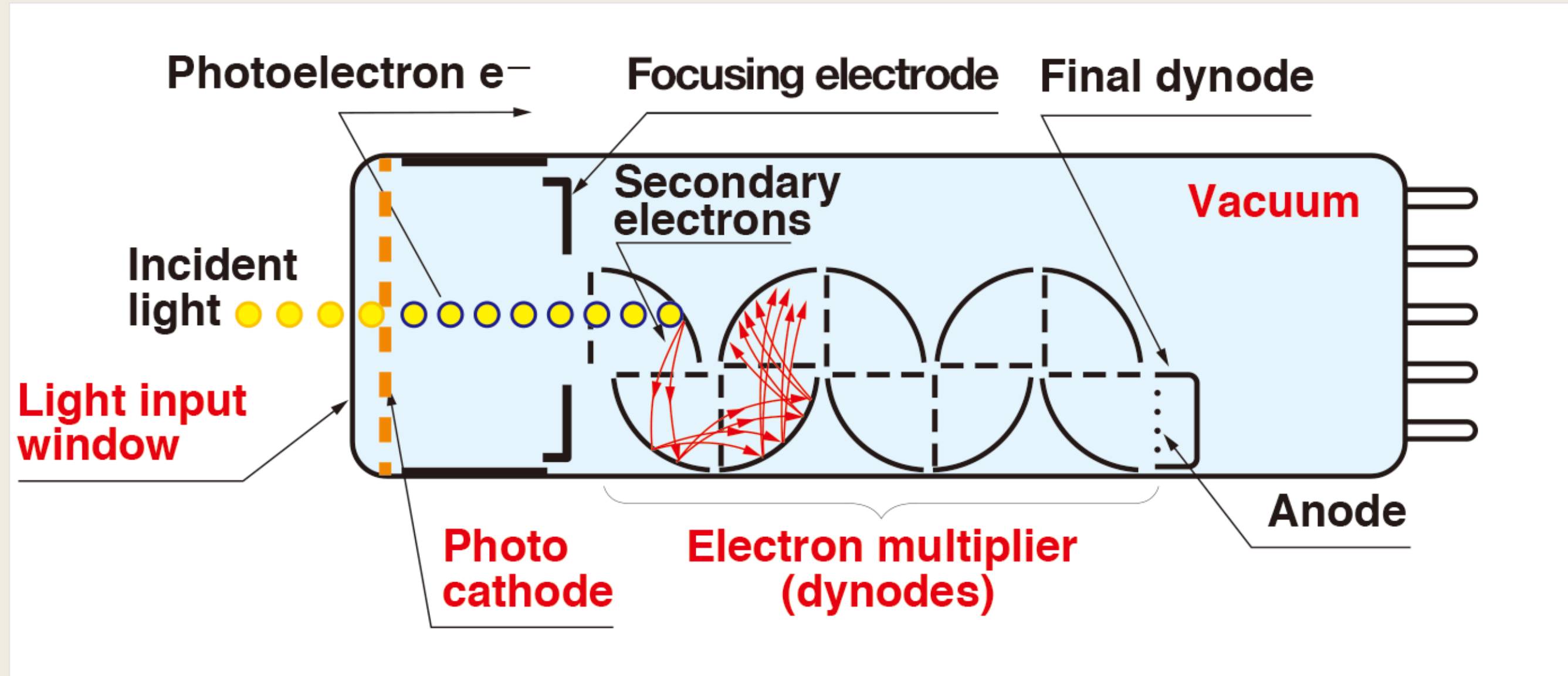
METAL PACKAGE PMT

A SI-BASED PHOTOMULTIPLIER, CALLED MPPC

These photosensor, we believe, are *capable and have a wide range of applications.*

We have experience to work with this device and would like to share w/ you!

A glance at PMT



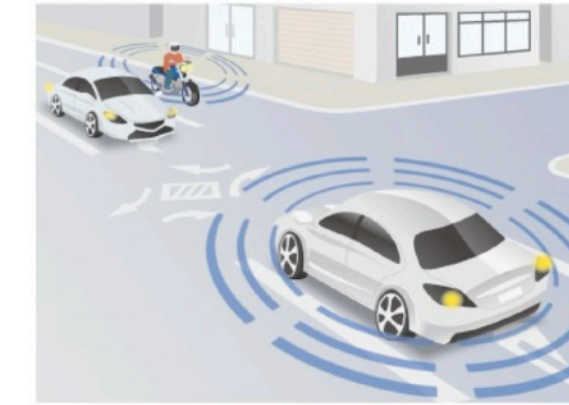
20-inch diameter PMT for research by Hamamatsu

	Kamiokande (From 1983 to 1996)	SuperKamiokande (From 1996 to present)	HyperKamiokande (In planning stage)
Facility name	Kamiokande (From 1983 to 1996)	SuperKamiokande (From 1996 to present)	HyperKamiokande (In planning stage)
Type No.	R1449	R3600	R12860
Collection efficiency	40 % to 50 %	70 %	90 %
Electron transit time spread	4.4 ns	2.2 ns	1.0 ns

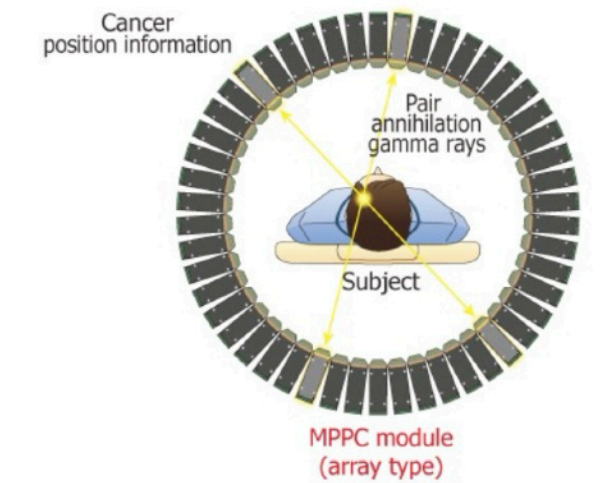
Key features of MPPC and application

- High electrical gain: 10^5 to 10^6
- Single photon-resolving capability with relatively high dynamic range (*few p.e. to ~10k p.e*)
- Excellent time resolution and quantum detection efficiency
- Compact and portability
- Immune to the magnetic field (*vs. PMT usually need magnetic shield*)
- Low operation voltage (*~50-70V DC vs. 1000V of PMT*); simple readout circuit, high integrated capability
- Relatively cost-effective

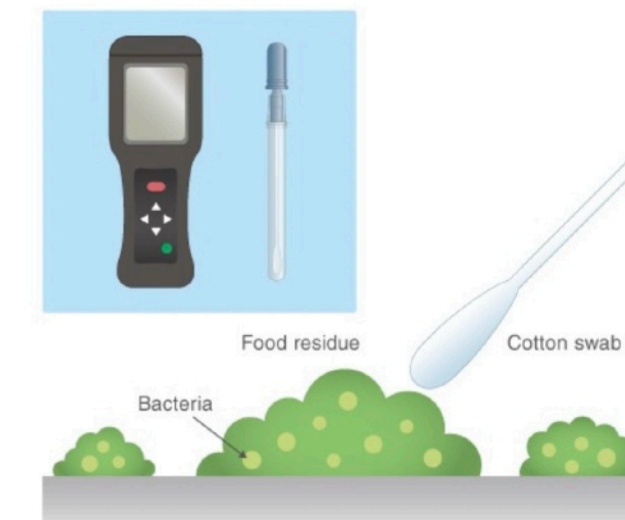
Distance Measurement (LiDAR)



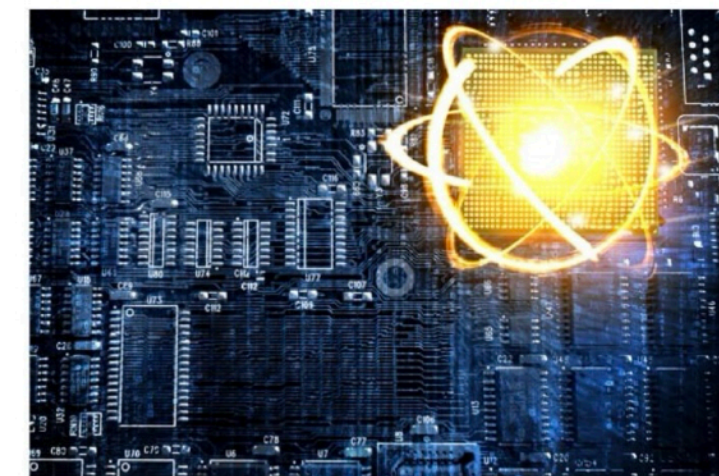
PET (Positron Emission Tomography)



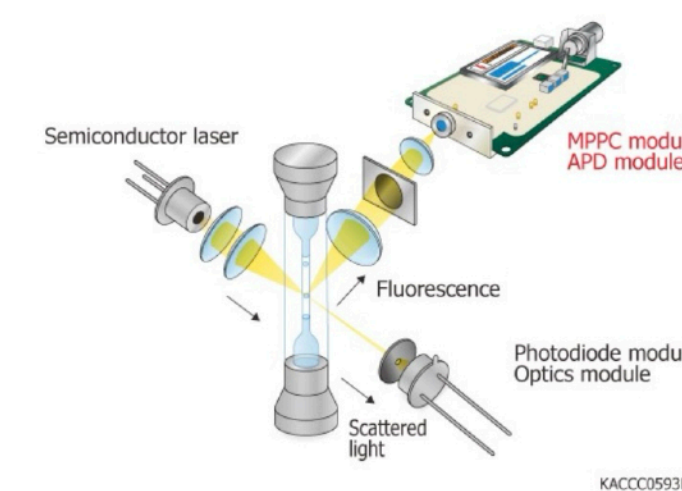
Hygiene Monitor



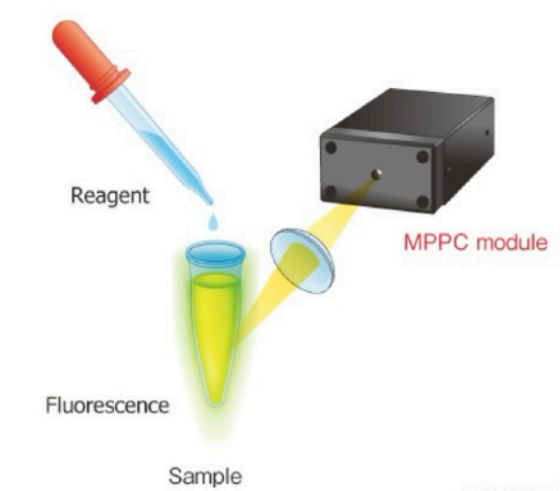
Quantum Computing & Cryptography



Flow cytometry

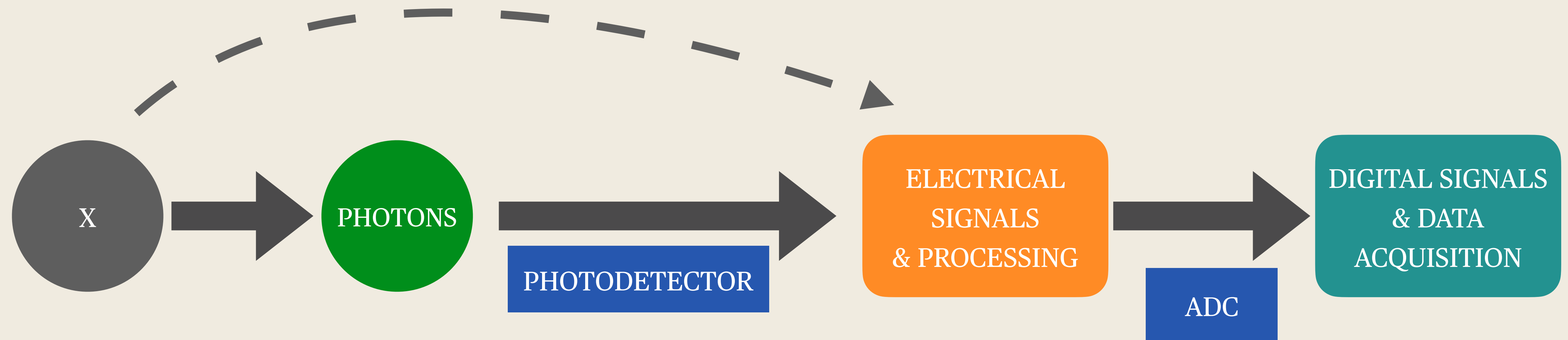


Fluorescence & chemiluminescence measurement



Role of photodetectors

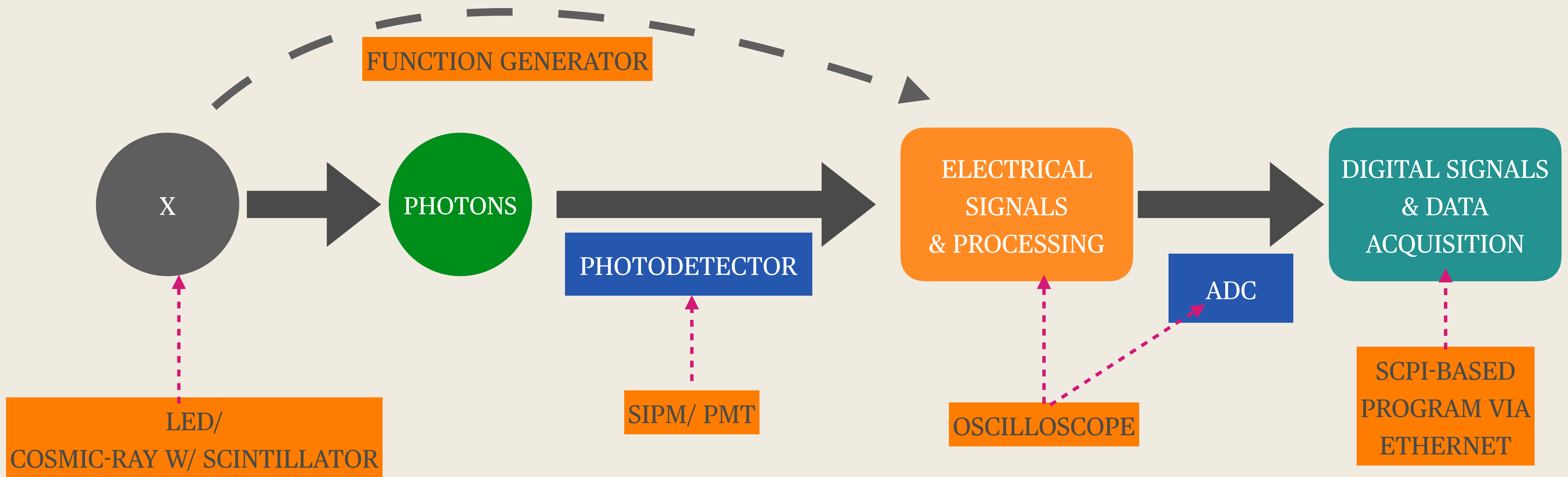
Typically, we sense/measure the things (*elementary particles, chemical elements...*) by converting into the **optical** signals, which can be detected by the photodetectors



Signal processing and data acquisition are needed to obtain information from photosensor

Role of photodetectors

Typically, we sense/measure the things (*elementary particles, chemical elements...*) by converting into the **optical** signals, which can be detected by the photodetectors



Most of Vietnamese students are lacking in hardware

(PARTICULARLY TRUE IN PARTICLE AND NUCLEAR PHYSICS)

- Did you use multimeter before?
- Did you use oscilloscope before?
- Did you use function generator before?
- Did you use DC power supply before?
- Did you use NIM modules before?
- ...

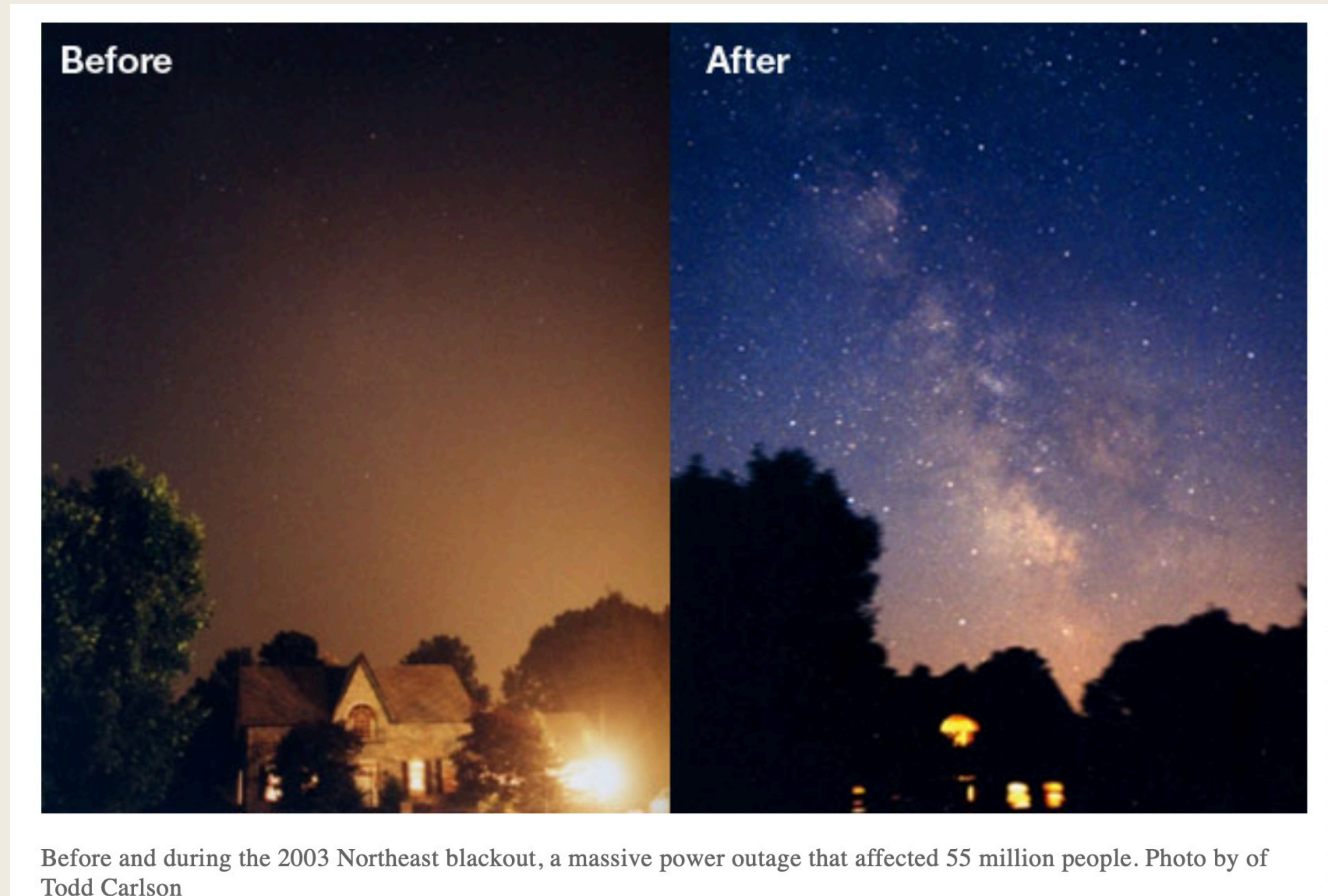


THE CAMP IS ALSO TO PROVIDE SOME SKILLS WITH THESE PARTICULAR HARDWARES

Most challenging for fast and low-light detection?

- Make use of the fast-response photosensors
- Suppress the noise, light lightening/shielding
- Utilize the fast signal processing
-

WE WILL GO (PARTIALLY)
THROUGH THESE CHALLENGING



Mon, 4	Tue, 5	Wed, 6	Thu, 7	Fri, 8	Sat, 9
7:30am ↻ Bus from hotel to ICISE	7:30am ↻ Bus from hotel to ICISE	7:30am ↻ Bus from hotel to ICISE	7:30am ↻ Bus from hotel to ICISE	7:30am ↻ Bus from hotel to ICISE	7:30am ↻ Bus from hotel to ICISE
8am Welcome address - ICISE vice- 8:15am Welcome lecture (Prof. Yuichi Oyama, KEK, JP)	8am Introduction to Electronics (Dr. Thanh Dong, Duy Tan Univ., VN)	8am DAQ with J-PARC neutrino beamline (remote) (Dr. Ken Sakashita, KEK, JP)	8am Firmware and machine learning (remote) (Dr. Nhan Tran, Fermilab, US)	8am Triggering system (Super-K and Hyper-K) (remote) (Dr. Guillaume Pronost, ILANCE, CNRS-The Univ. of Tokyo)	8am PET as MPPC application (remote) (Dr. Cesar John, The Univ. of Texas at Austin, US)
8:45am Introduction to the camp/logistics/safety (Dr. Son cao,	9am Short-break	9am Short-break		9am Short-break	9am ☑ Student prepare for final presentation
9:15am Short-break	9:15am Hands-on Act#2	9:15am GEANT4 simulation (remote) (Dr. Nam Tran, Boston Univ., US)		9:15am Hands-on Act #7	
9:30am ☑ Students' self-introduction (all-students)					
11am Photo-detectors in Particle physics (remote) (Prof. Tsuyoshi Nakaya, Kyoto Univ., JP)	10:45am Introduce to Cosmic ray (Prof. Atsumu Suzuki, Kobe Univ., JP)	11:15am ☑ Lab Q&A and setup	11am Short-break 11:15am ☑ Lab Q&A and setup		11:45am Lunch break
12pm ↻ Lunch break	11:45am Cosmic ray muon and muon radiography (Prof. Yuichi Oyama, KEK,	12pm ↻ Lunch break	12pm ↻ Lunch break	12pm ↻ Lunch break	
	12:15pm Lunch break				1pm ☑ Final presentation/report
1:30pm Introduction to Elementary Particles and Photons (remote) (Prof. Van Nguyen, IOP, VAST, VN)	1:30pm Electronics for cosmic ray muon detector (Prof. Yuichi Oyama, KEK, JP)	1:30pm Tracking and calorimetry detectors (Dr. Son Cao (IFIRSE, ICISE, VN))	1:30pm Hands-on Act #5	1:30pm ☑ CHIPS setup demonstration (Alex Snell, UCL, UK)	
2:30pm Short-break	2:30pm Short-break	2:30pm Short-break	3:15pm Short-break	2:30pm Short-break	2:30pm Conclusion and ending by 3pm (local time)
2:45pm Hands-on Act#1	2:45pm Hands-on Act#3	2:45pm Hands-on Act #4	3:30pm Guidance for presentation (Prof.	2:45pm Hands-on Act#8	
	4:30pm A short introduction to MPPC and its application (Dr. Son Cao, IFIRSE, ICISE, VN)		3:45pm Hands-on Act #6		
5:30pm ↻ Beak time at ICISE	5:30pm ↻ Beak time at ICISE	5:30pm ↻ Beak time at ICISE	5:30pm ↻ Beak time at ICISE	5:30pm ↻ Beak time at ICISE	
6pm ↻ Dinner	6pm ↻ Dinner	6pm ↻ Dinner	6pm ↻ Dinner	6pm ↻ Dinner	

THE CAMP PROGRAM IS DESIGNED TO PROVIDE HANDS-ON ACTIVITIES WHILE ALSO PROVIDING BACKGROUND, RELEVANT KNOWLEDGE FROM SHORT LECTURERS.

We called “camp” for some reasons

- We’re learning and exploring together. There are somethings we don’t know yet.
- Our main approach: students learn from his/her hands-on experiences
- The camp is for students to learn, not for us to teach. So try to get most of it. Don’t be shy. If you don’t ask, we can’t know if you understand or not.

THE CAMP LIKES AN “INFORMAL” FORUM

Three main study objectives

1. Explore the properties of photodetectors (dark count rate, electric gain or size of a single photoelectron, rising/falling time...)
2. Measure the time-of-light of photon in the optical fibers (group-A); light profile (group-B); and light spectrum (group-C)
3. Muon counter, the rate (angular dependence); observing muon decays if having time

DETAILS WILL BE EXPLAINED DURING THE HANDS-ON ACTIVITIES

- We will have final presentation for each group on Saturday
- We ask for final science report for each group by Mar. 23rd (2 weeks after the camp) ← take note carefully during the camp

SAFETY FIRST!!!

- ✦ Lab safety rules are posted on the door. Please take a look.
- ✦ Electric equipments: (AC 220V vs. 110V; AC vs. DC power). Think at least twice before plug in/out; turn on/off.
- ✦ Do not take out or put in any item without permission
- ✦ *Swimming/ Not good season yet*

Many things in the lab and the best approach to manage is to

(1) *put at right place*

(2) *clean and return after use*

Please,
NO FOOD inside,
DRINK at designated areas,
CLEAN after using,
MINDFUL of the others.
DON'T turn off any PC in lab

Indoor Slipper only
NO  **BARE foot**

WE TRIED OUR BEST TO MAKE PROPER GROUNDING. BUT PLEASE USE SLIPPER TO AVOID THE ELECTROSTATIC SHOCK

Room map for hardware camp 3/3-9/3



room-A

room-B

SET-B

PC for group-B

UCL CHIPS SETUP

SCINTILLATOR, WLS

SET-A

PC for group-A

ELECTRONIC MODULES, CABLE, CONNECTOR...

BOOKS

SMALL C R OBSERVER

SOLDERING

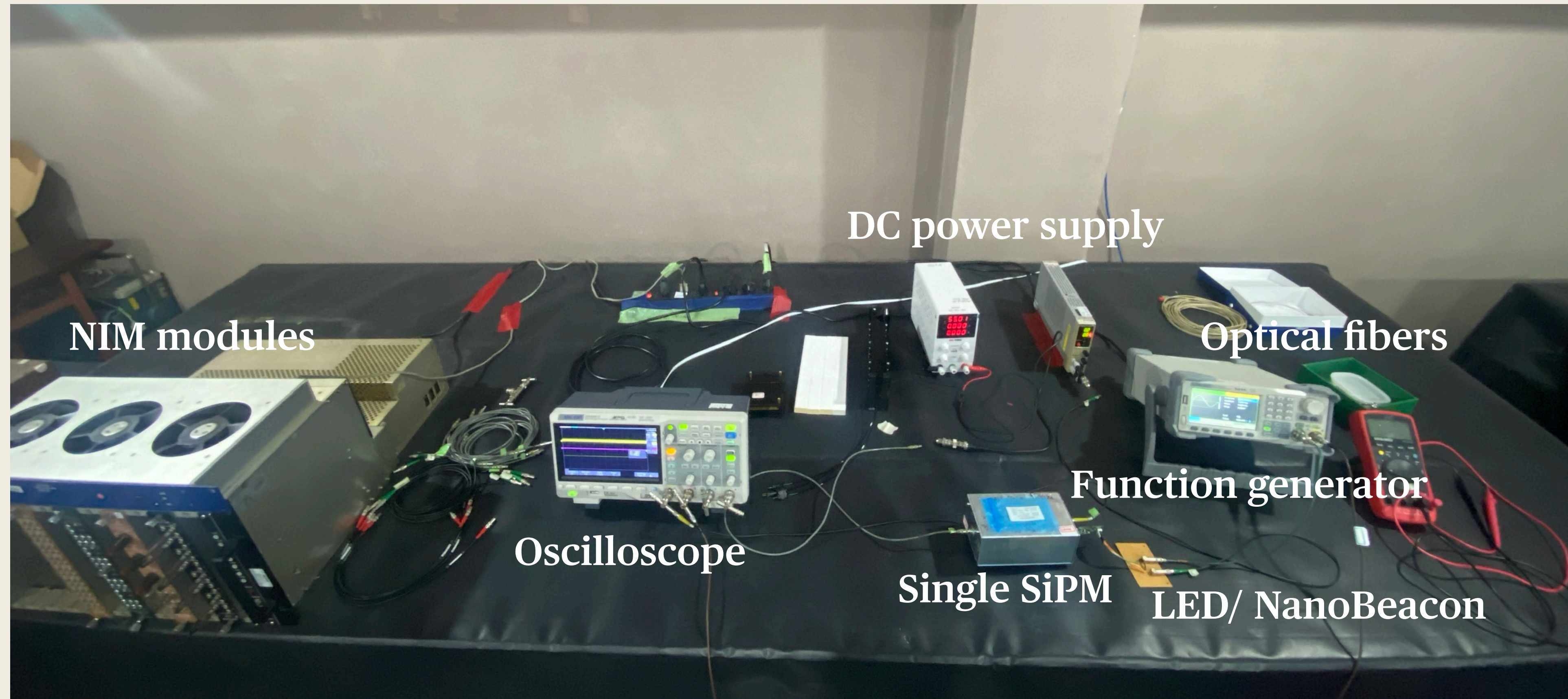
PC for group-C

SET-C

TABLE, SEAT FOR LECTURE OR GROUP DISCUSSION

PROJECTOR FOR LECTURE

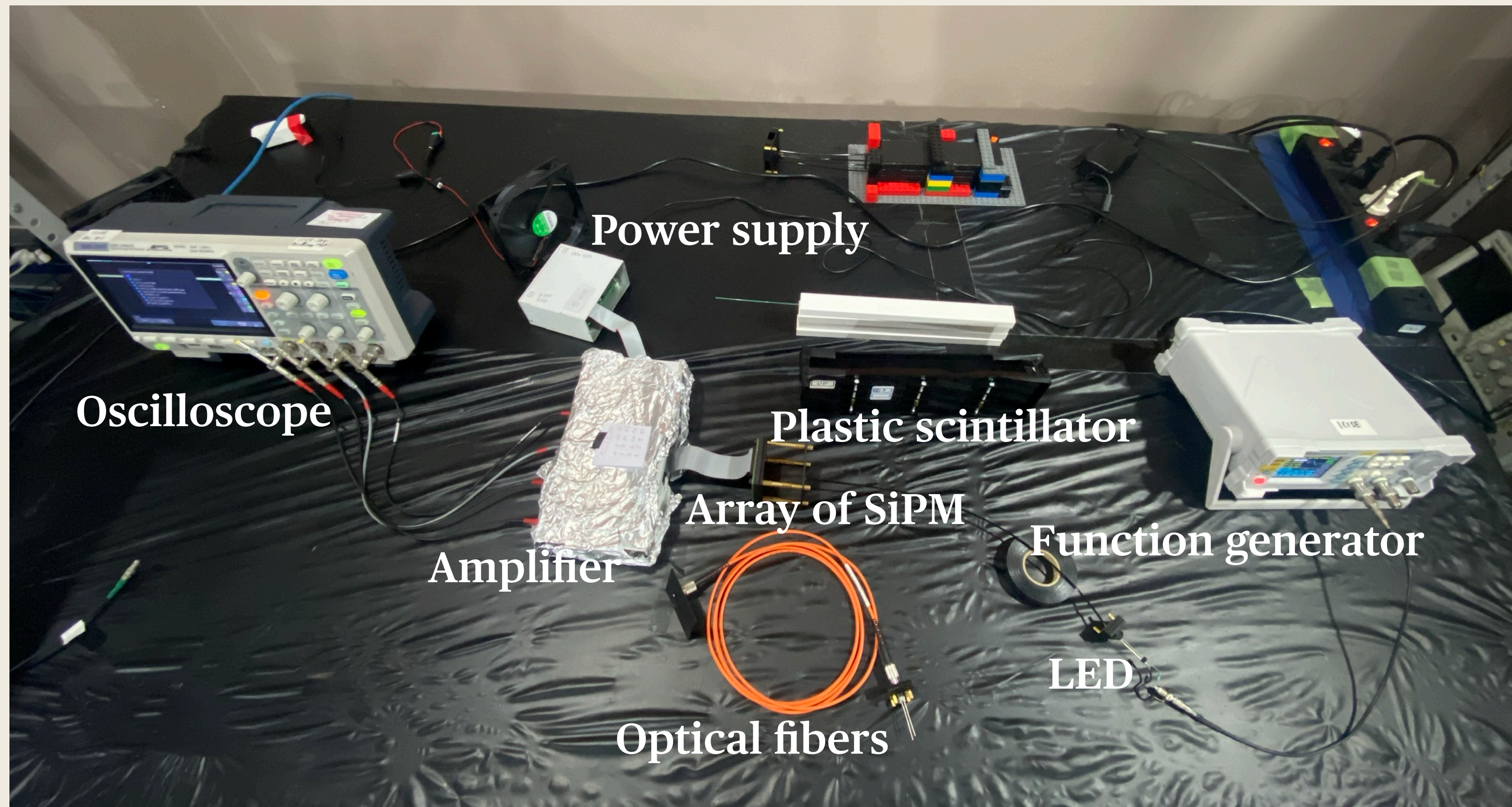
For Team-A



DETAILS WILL BE EXPLAINED DURING THE HANDS-ON ACTIVITIES

- Members: TBD
- Mentors: Dr. Dong V. Thanh, M.Sc. Thanh Nguyen, M. Sc. Shouvik Mondal

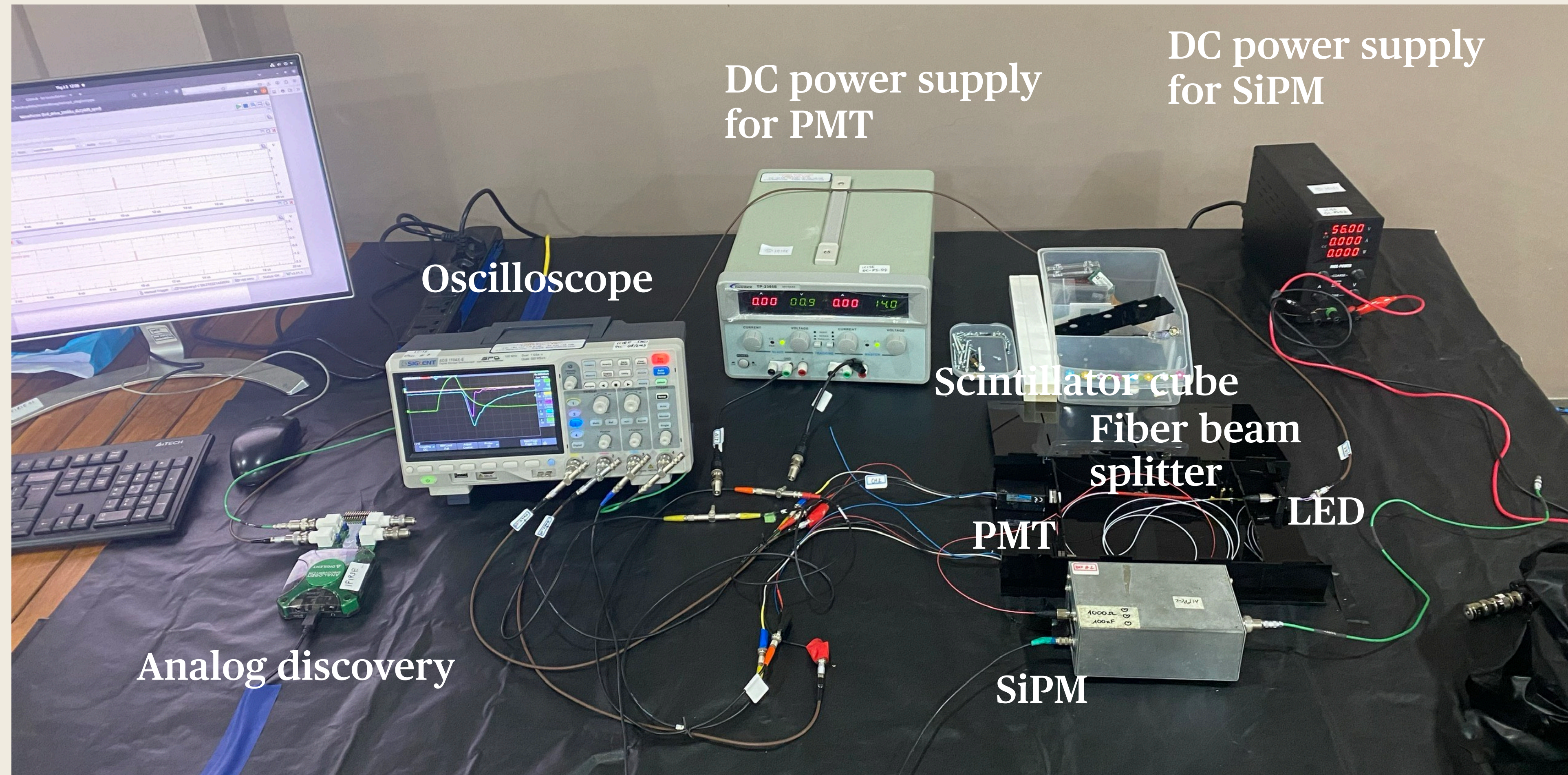
For Team-B



DETAILS WILL BE EXPLAINED DURING THE HANDS-ON ACTIVITIES

- Members: TBD
- Mentors: M.Sc. Sang Nguyen, M.Sc. Quyen Phan

For Team-C



DETAILS WILL BE EXPLAINED DURING THE HANDS-ON ACTIVITIES

- Members: TBD
- Mentor: Dr. Son Cao

Soldering station

Use protective glass!

Do not adjust the soldering temperature without discussion.

Do not hold metal part which contacts with the soldering tip.

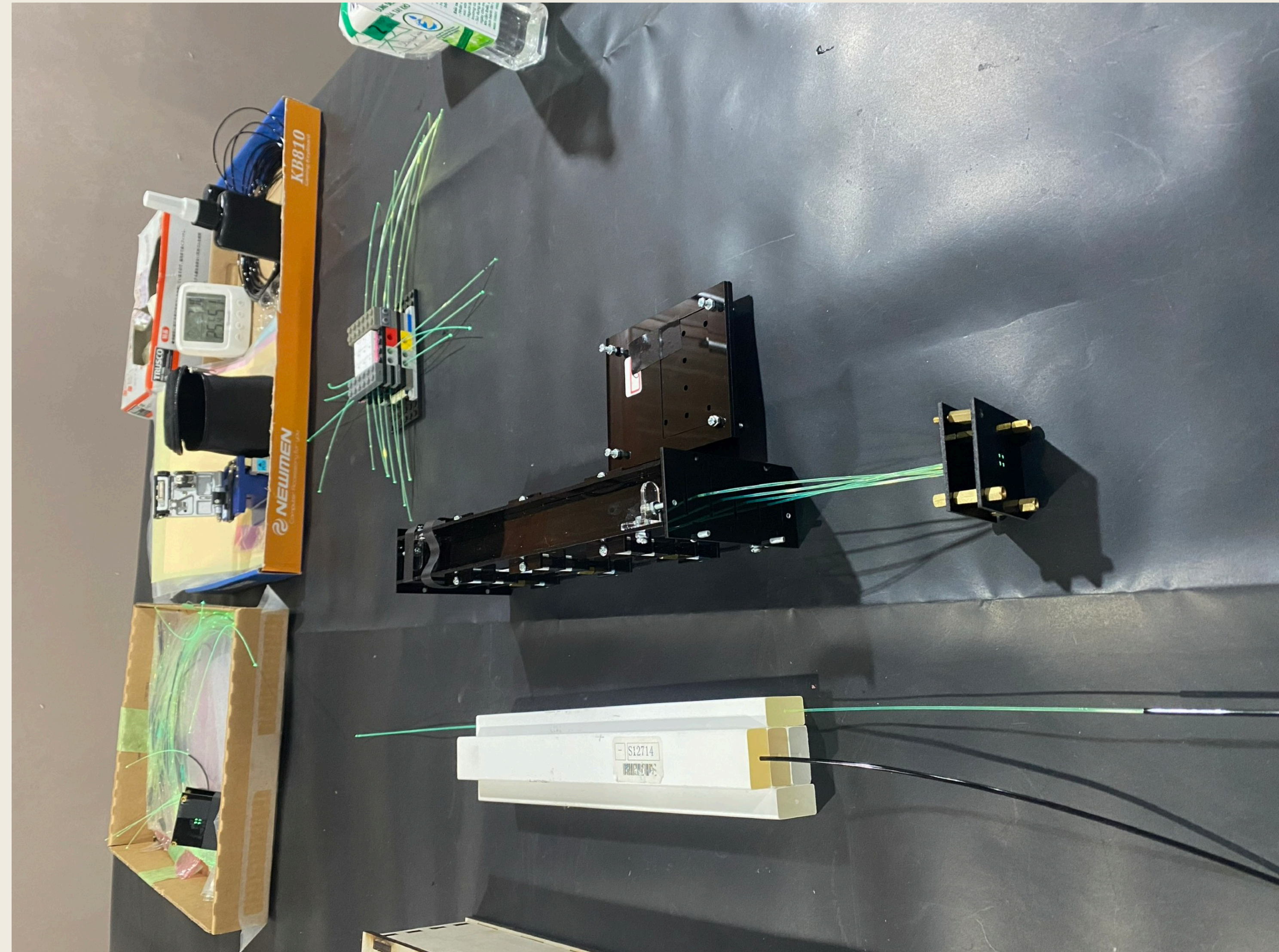


Scintillators, wavelength shifting fibers for student to fabricate and assembly

Be gentle!

Do not bend
the fiber too
much.

Do not shine
UV light
directly on
your skin,
your eyes



Books and some technical note

If you
want to
take out,
please put
your name
and
remember
to return





KEK



**We greatly thank
for your donation**

WITHOUT THEIR GENEROSITY, THIS INITIATIVE IS IMPOSSIBLE.



[HTTP://IFIRSE.ICISE.VN/NUGROUP/](http://ifirse.icise.vn/nugroup/)



A science and education urban area is emerging



Neutrino group formed 2017

Core group members of Japan side

- **T.Nakaya (Kyoto Univ.): scientific group leader**
- Atsumu Suzuki (Kobe Univ.)
- Yuichi Oyama (KEK)
- Makoto Miura (Kamioka, ICRR, Tokyo)

International Advisory Committee

- M. Nakahata (Kamioka, ICRR, Tokyo, JP)
- T. Kobayashi (KEK, JP)
- Karol Lang (The Univ. of Texas at Austin, USA)
- Jacques Dumarchez (LPNHE- Univ. of Paris, FR)
- Boris Kayser (Fermilab, USA)



MOU signing ceremony in July 2017

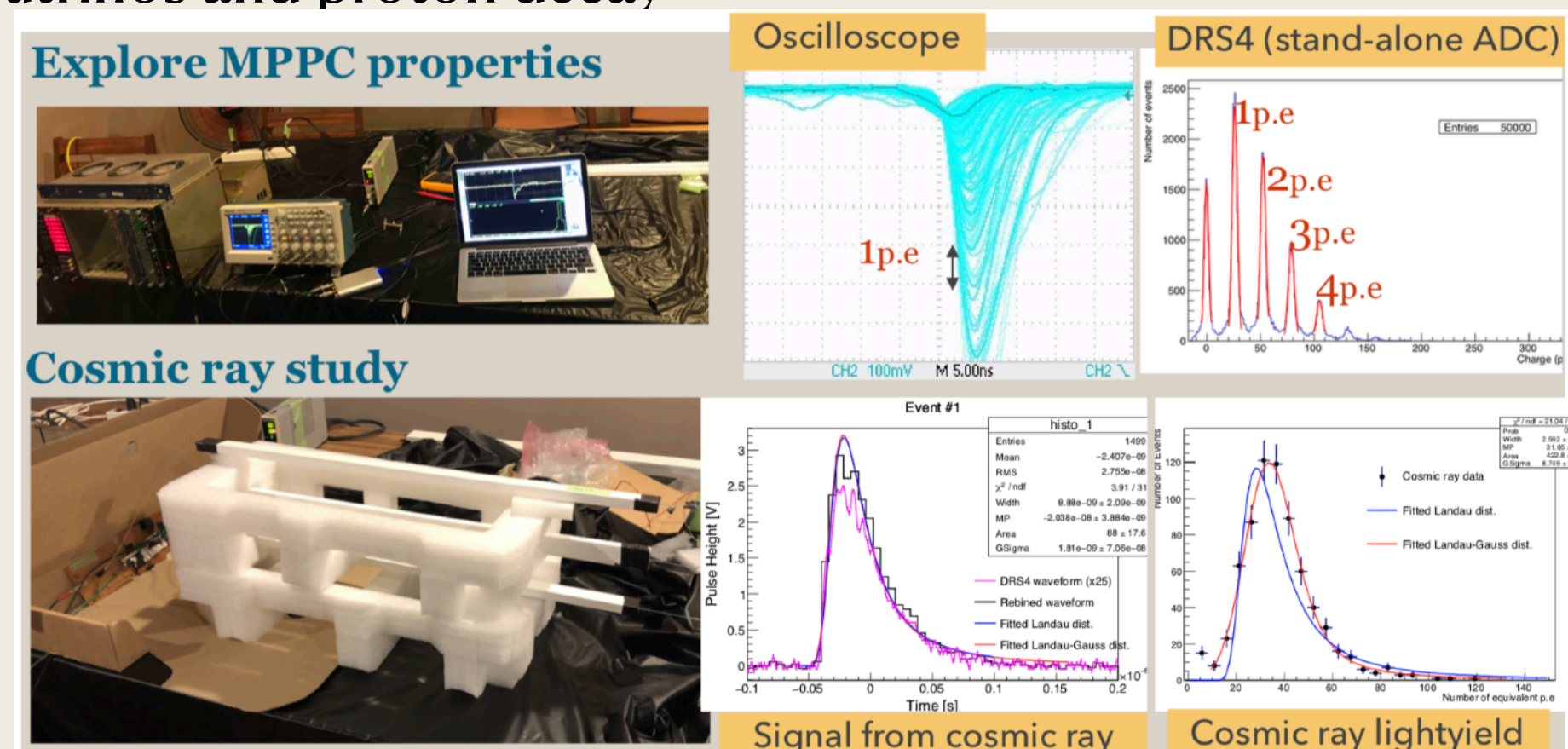
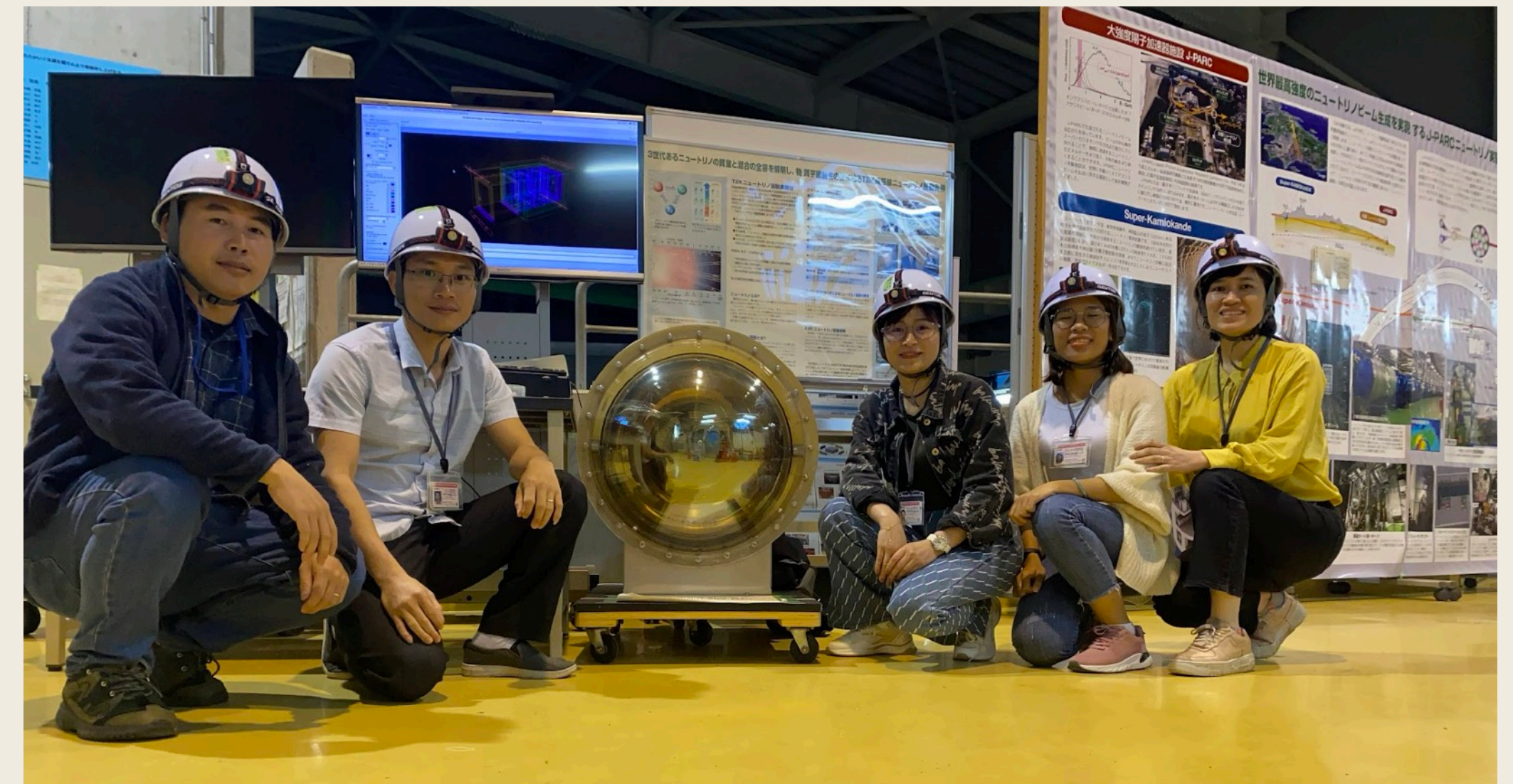
NEUTRINO is our 

**If you are interested in Neutrino, come and
talk with us during the break times.**

What are we doing?

Work as an international collaboration

- **T2K** (Oc. 2017~) an international accelerator-based long-baseline neutrino experiment in Japan (~500 collaborators from 65 institutes of 12 countries)
 - Neutrino Event Generator, Neutrino Oscillation Analysis
- **WAGASCI** (now part of T2K) (Feb. 2018~) a neutrino-nuclei interaction-focused experiment in Japan,
 - **Detector construction (our students are working directly with Japanese and other colleague)**
- **Super-Kamiokande** (Jun. 2021~) to search for the diffuse supernova neutrinos and proton decay



Build the lab at ICISE:

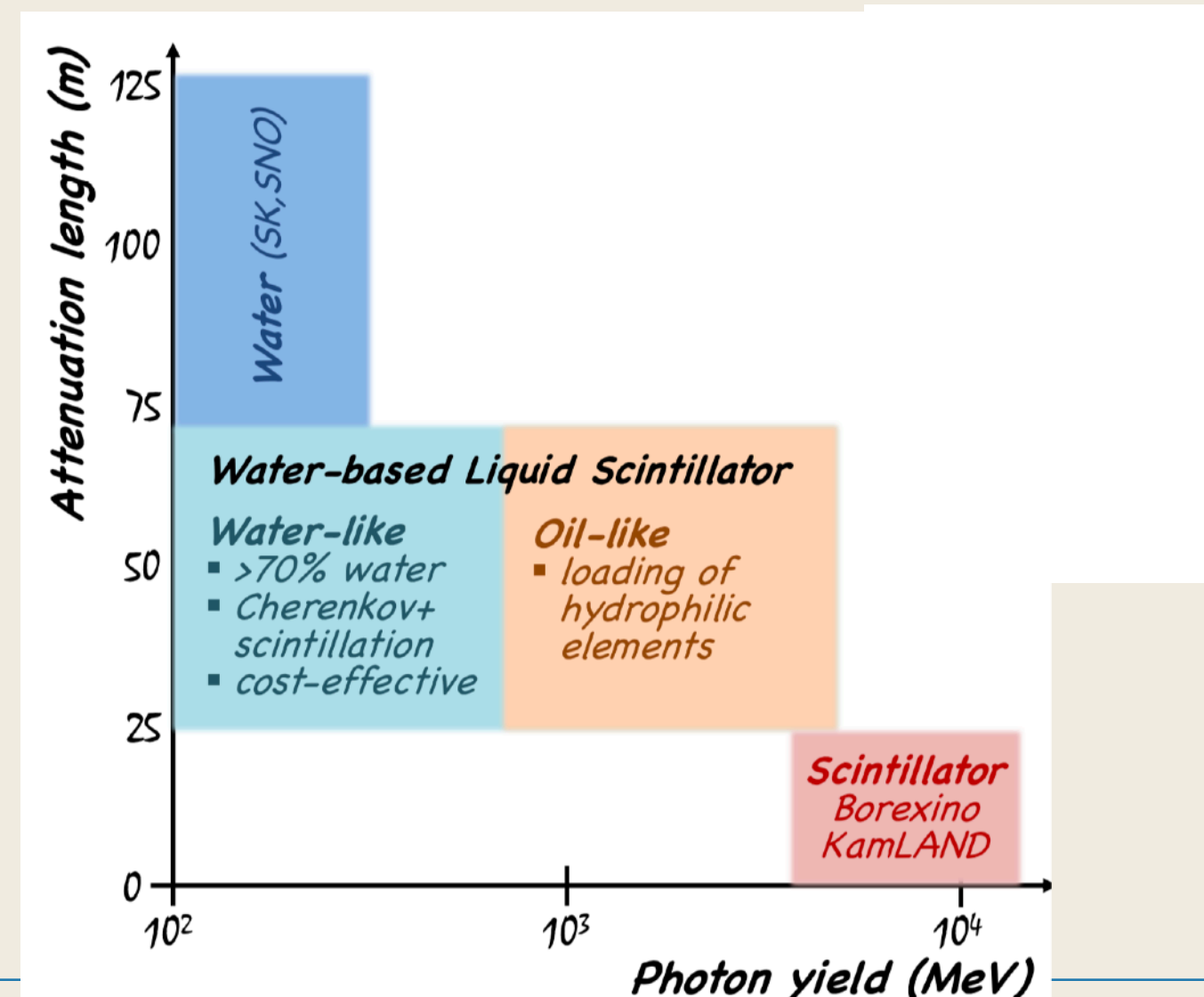
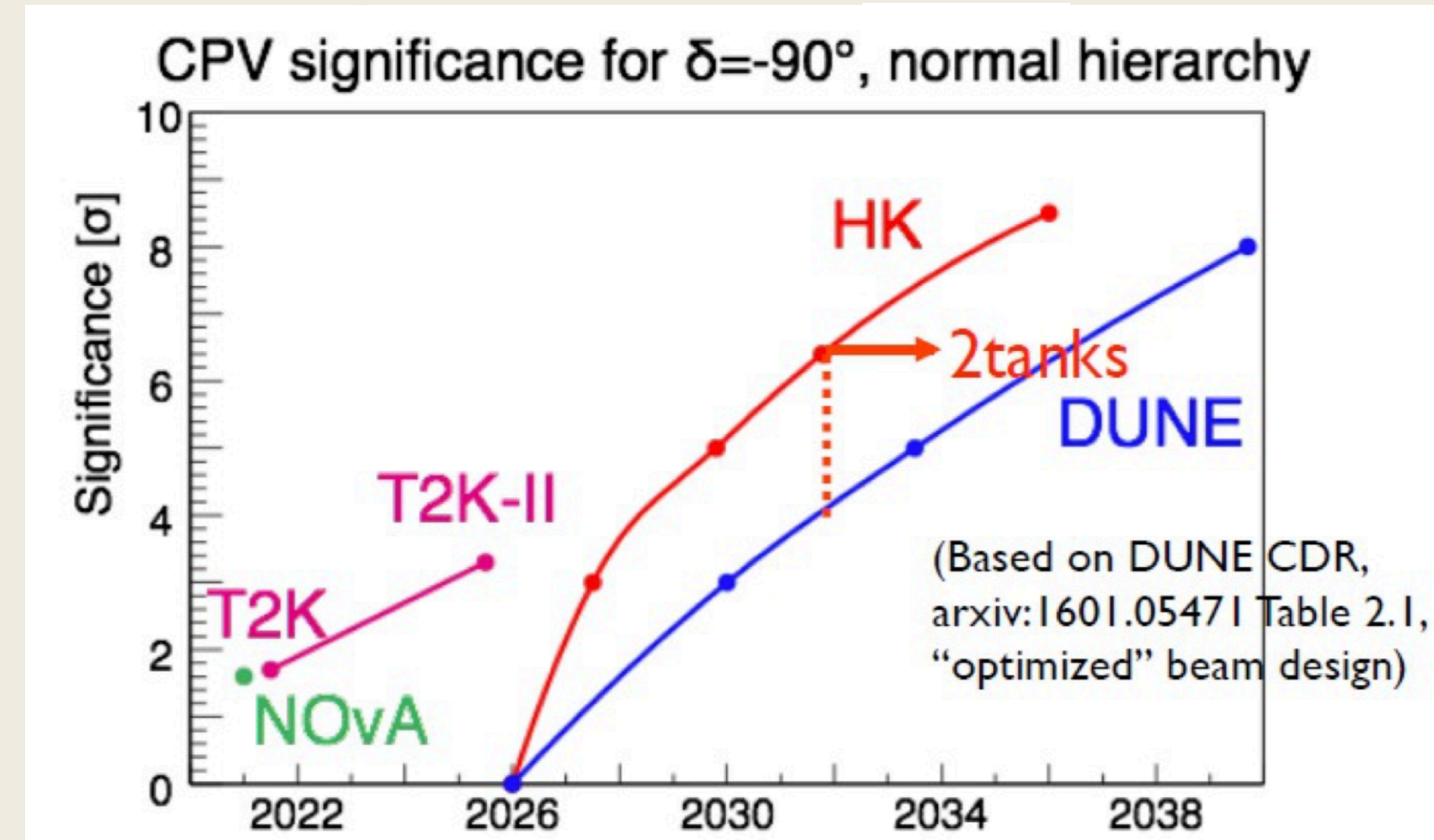
- Advance the single-photon sensitive sensor with the the plastic scintillators
- Detector prototypes for the cosmic ray measurements and other applications

- Organize annually *Vietnam School on Neutrinos (2024 will be the 8th in the series) and Hardware camp (2024 will be 3rd in the series)* to **train and encourage students and young researchers working on neutrino physics**
- Host the *International Symposium on Neutrino Frontiers (2018)*
- Host *Neutrino Workshop at IFIRSE (2023)*

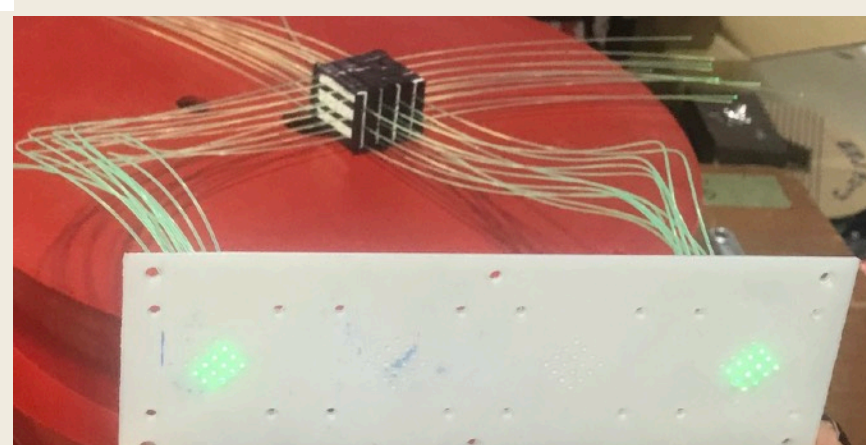
The path forward

International collaboration work

- **Keep working with T2K and Super-K experiment**
 - CP violation, neutrino mass ordering, and other unknown via the neutrino oscillation measurements
 - Search for diffuse supernova neutrinos and proton decay
- **Aim to join Hyper-Kamiokande experiment in the near future**
 - Effectively 8 times larger than Super-Kamiokande, will start operation from 2027
 - Along with data analysis, we may want to work on PMT



Portraits of MPPCs (taken from Hamamatsu)



Lab development

- Photosensor, eg. Multi-pixel Photon Counter, (micro)PMT
- Scintillator materials, eg. Water-based Liquid scintillator
- Lab test bench, detector prototype

ICISE internship



Enjoy the
camp!

Let try this after hard-work!!!

