CHiP 高能與強場物理研究中心 CENTER FOR HIGH ENERGY AND HIGH FIELD PHYSICS

Belle II related hardware Experiences

- CDC Front-end Electronics
- BEAST2 Background Monitor
- Neutron Detector
- LYSO Light Yield Determination
- Beam Position Monitor
- Future Prospects

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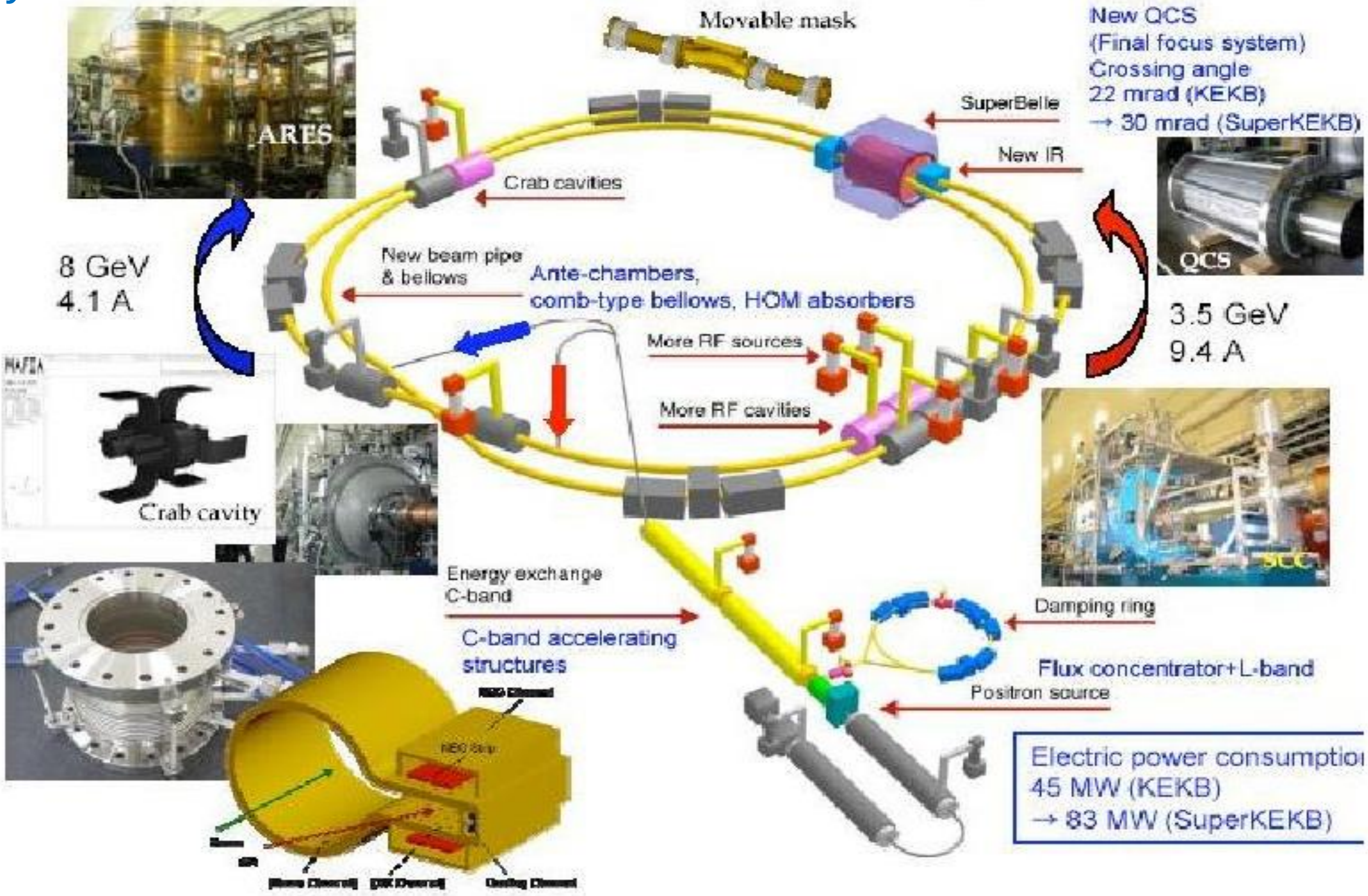
海峽兩岸尖端探測器與技術交流研討會議

The SuperKEKB collider overview

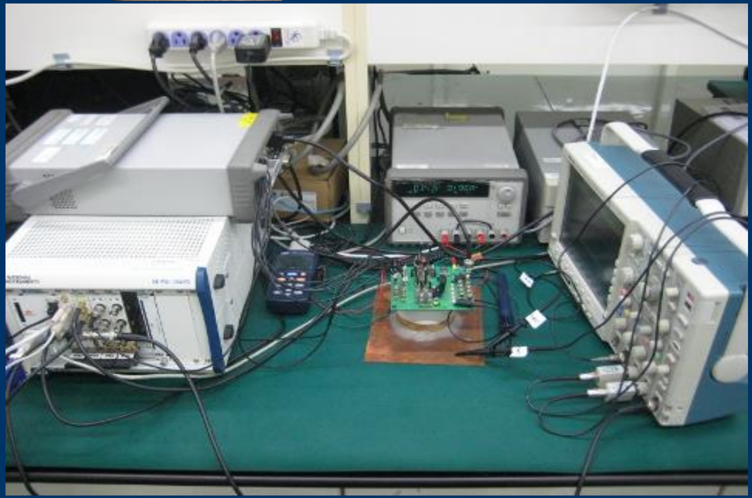
Very old information !!!

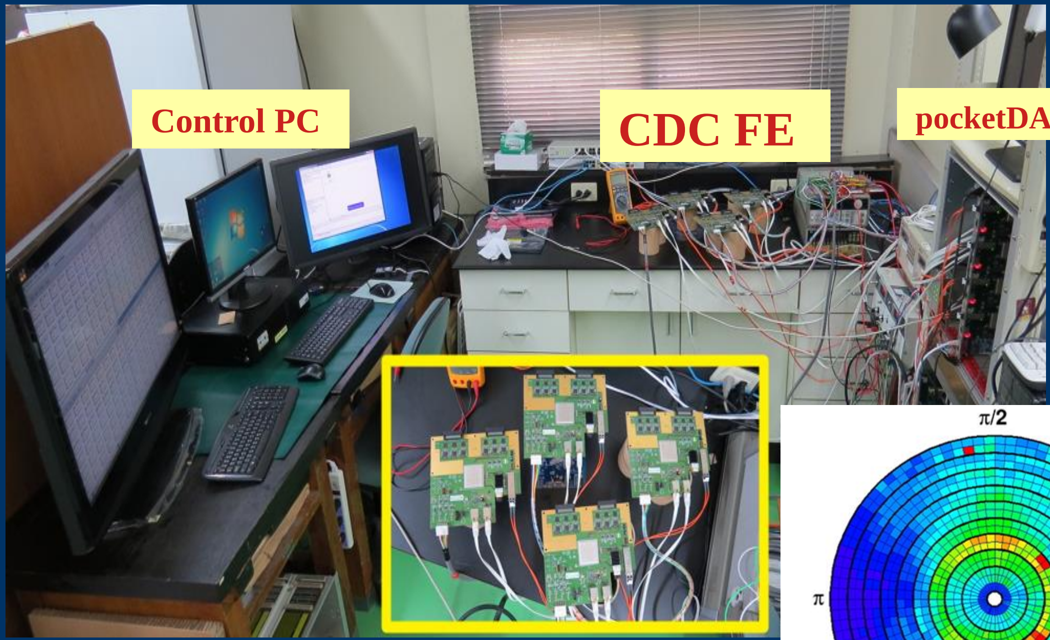
2018/4/26 First Collison!

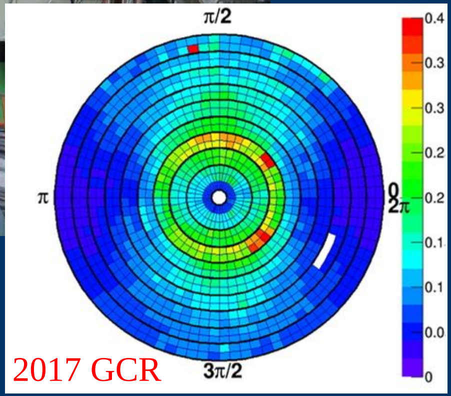


Quality assurance of CDC ASIC and FE

8 analog outputs (Q)
8 digital outpus (time)







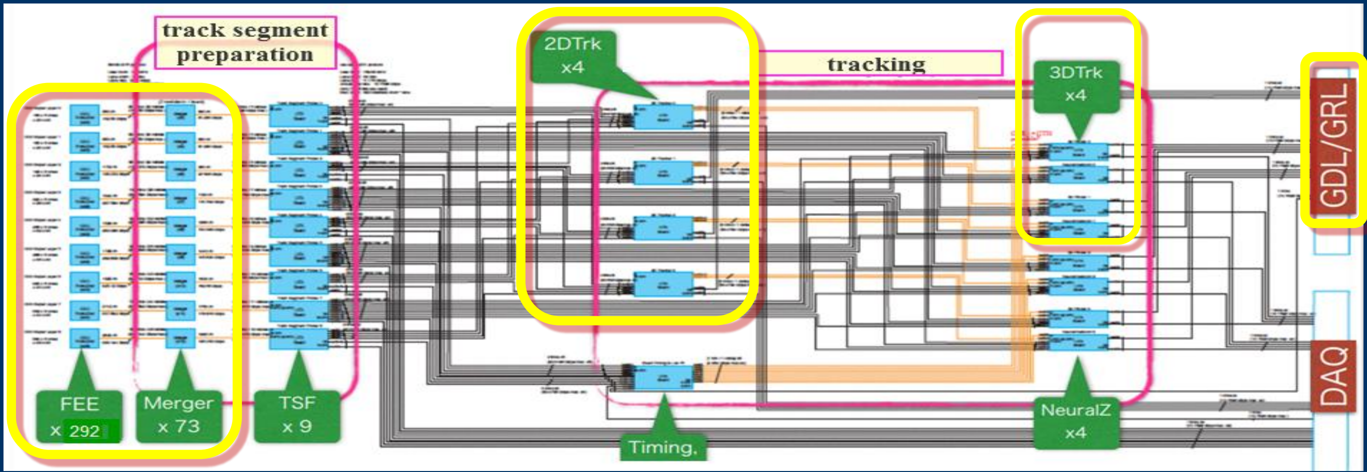
CDC ASIC

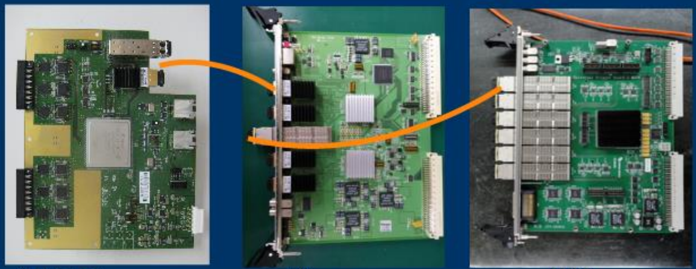
- ✓ total 3147 chips tested
- ✓ 2833 pass online QC selection (90%)
- ✓ 2131 selected for production

CDC FE

- ✓designed by KEK, assembled in Taiwan
- ✓48 channels (6 ASIC)/FE.
- ✓330 board produced and tested. (299 FE needed for commissioning)
- ✓QC completed in early 2015, installation done in Jan. 2016

CDC trigger system and GDL





CDC FE (KEK/NTU) | Merger (NUU/NTU) | UT3 (KEK)

292 x FE: hit information from detector (KEK/NTU)
73 x merger: collection of hits from FE (NUU/NTU)
9 x TSF: track segment composition
4 x 2D: 2D track finder (FJU/NTU/KIT)
4 x 3D: 3D track finder using TS matching algorithm (KU/NTU)
4 x NN: 3D track finder using neuro-network algorithm
1 x ETF: event time finder

GRL: global rec. Logic (NTU, new in Belle II)
GDL: global decision logic (NTU)

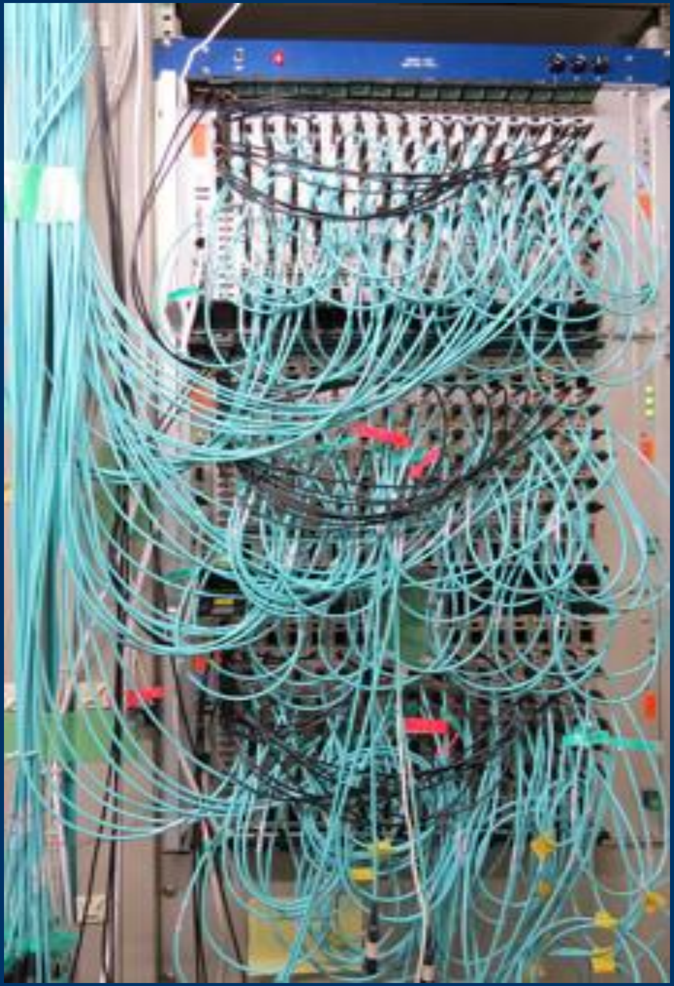
data trasmission (NTU, FE → GDL < 4.4 μs)
Belle II link to DAQ for monitoring (NTU)

A home-made protocal made to satisfy the latency constraint.

Protocol	Line rate	userclk	Hardware link	Latency (# of userclk)	Latency (ns)
Aurora 8B/10B	5.08 Gbps	254 MHz	GTX – GTX	47 ~ 48	185 ~ 190
Raw-level 8B/10B	5.08 Gbps	254 MHz	GTX → GTX	33 ~ 34	133 ~ 134
	5.08 Gbps	254 MHz	GTH → GTX	33 ~ 34	133 ~ 134
	5.08 Gbps	254 MHz	GTH → GTH	23 ~ 24	91 ~ 95
	5.08 Gbps	254 MHz	GTX → GTH	23 ~ 24	91 ~ 95
Aurora 64B/66B	10.16 Gbps	158.75 MHz	GTH – GTH	47 ~ 48	296 ~ 302
Raw-level 64B/66B	11.176 Gbps	169.33 MHz	GTH – GTH	18 ~ 19	106 ~ 112

[4]

Boards installed and ran smoothly

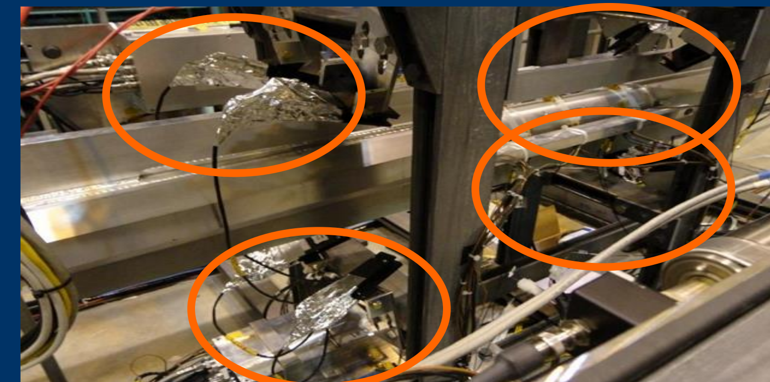


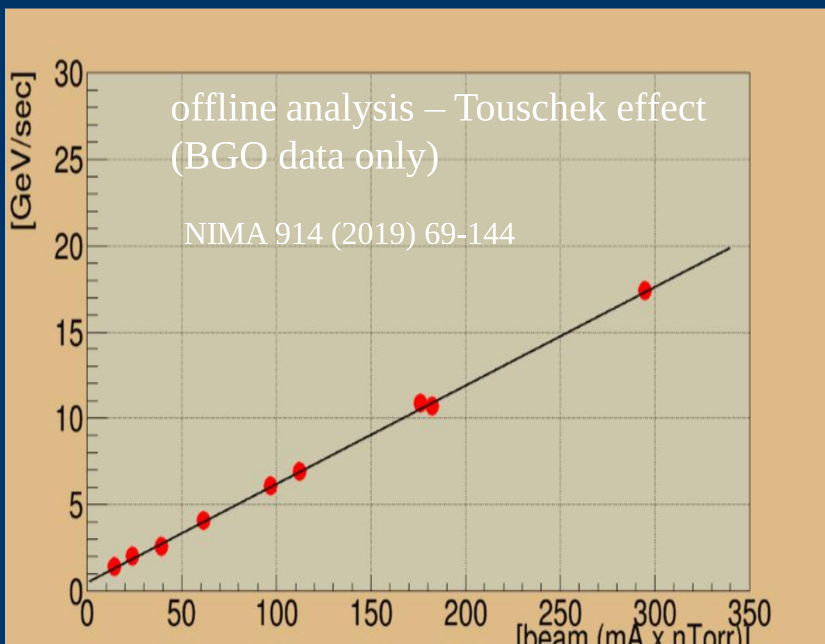
BEAST2: background monitoring system

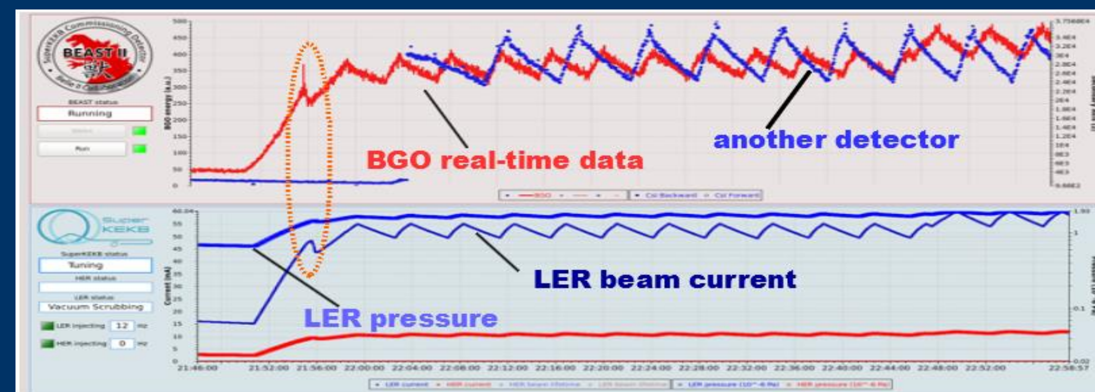
fibers

8 x BGO scintillators
from Belle EFC

MAPMT and DAQ







BGO system online monitoring vs. SKEKB monitoring

KEK on-site LED + source calibration
for Phase 1 operation

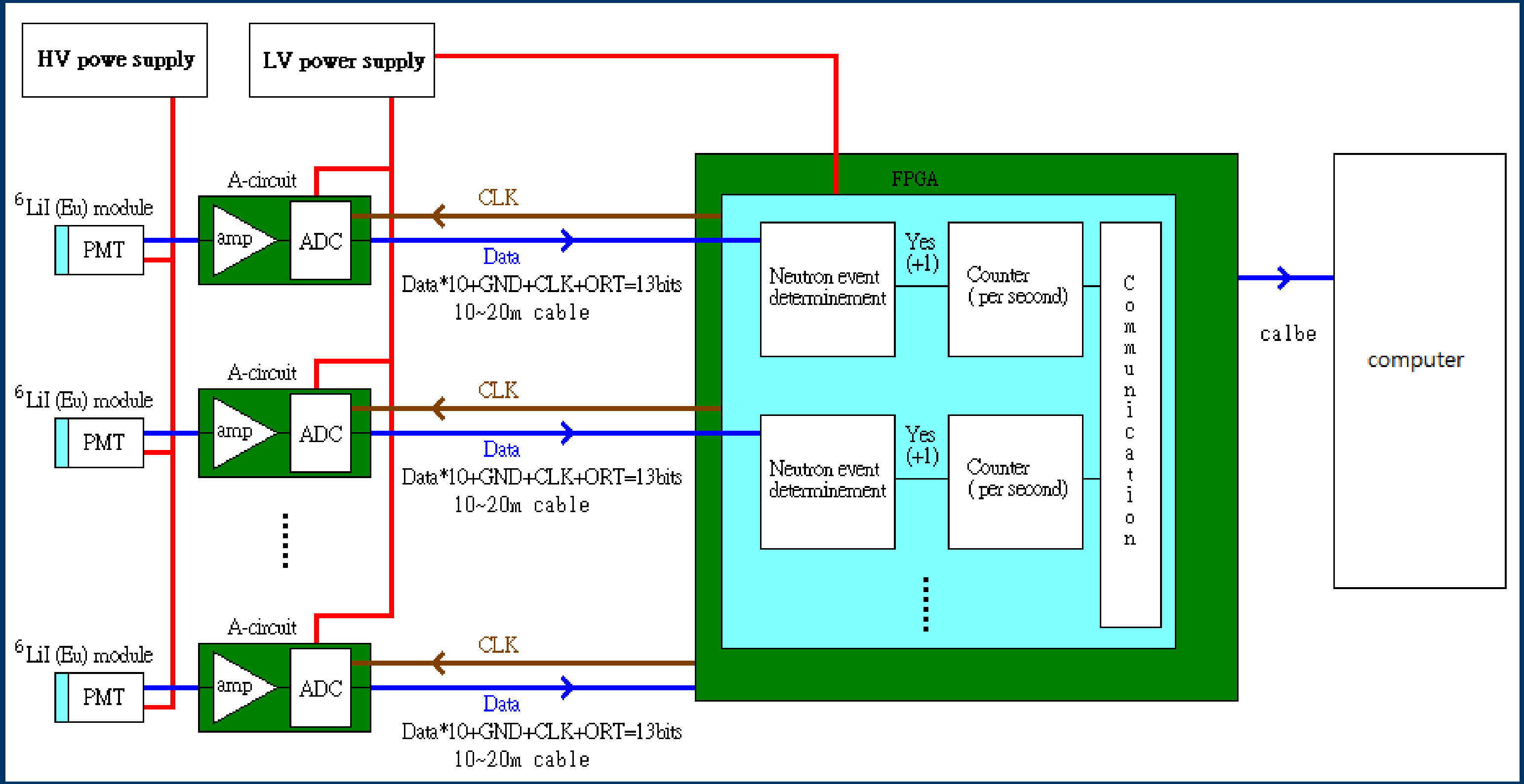
Home-made LED pulsing module

Firmware for luminosity and background monitoring

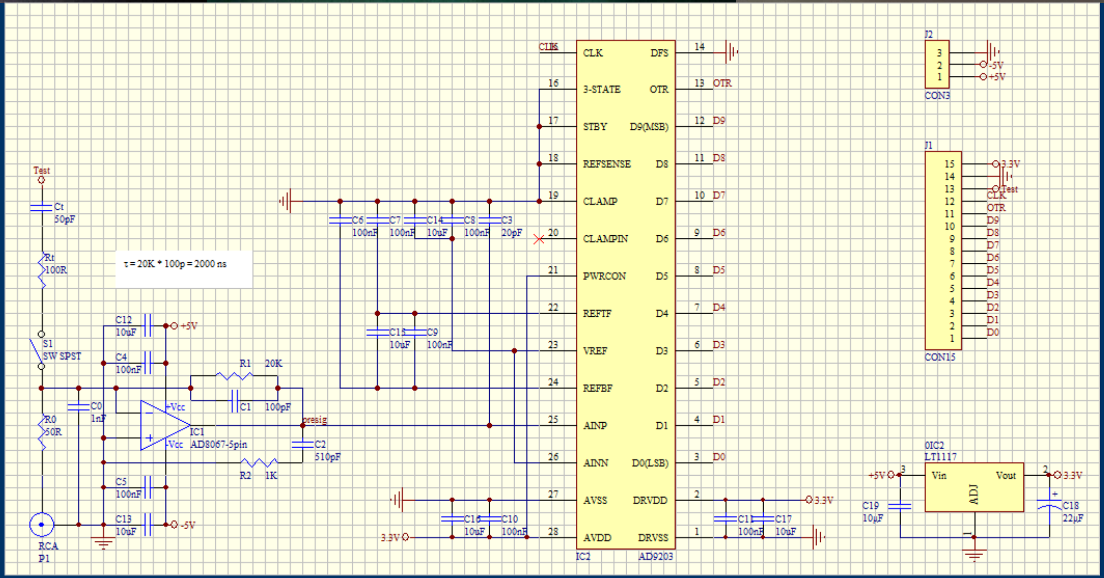
1 μ Ci ^{90}Sr

Accumulated charges w.o./with ^{90}Sr source
Good light-tightness for low background level

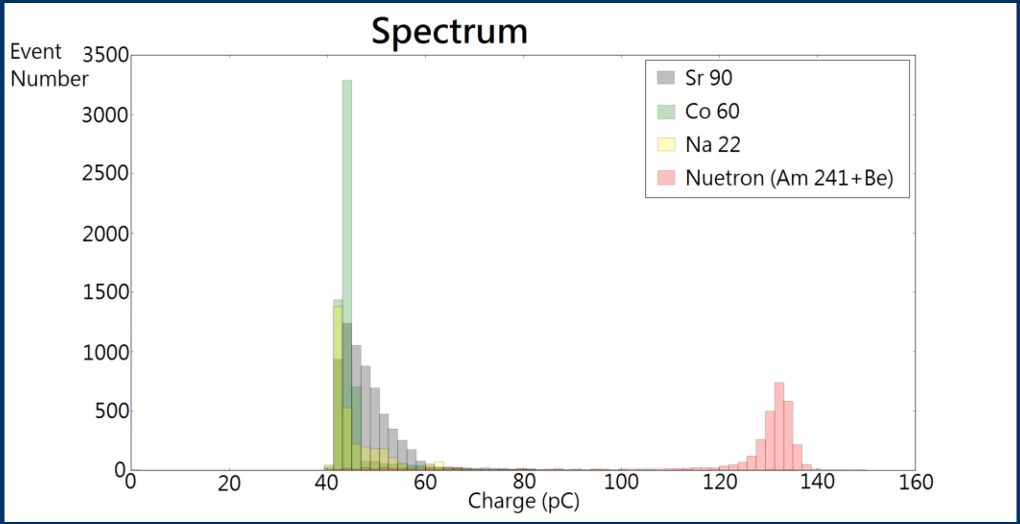
Neutron flux monitoring for the proton-therapy environment

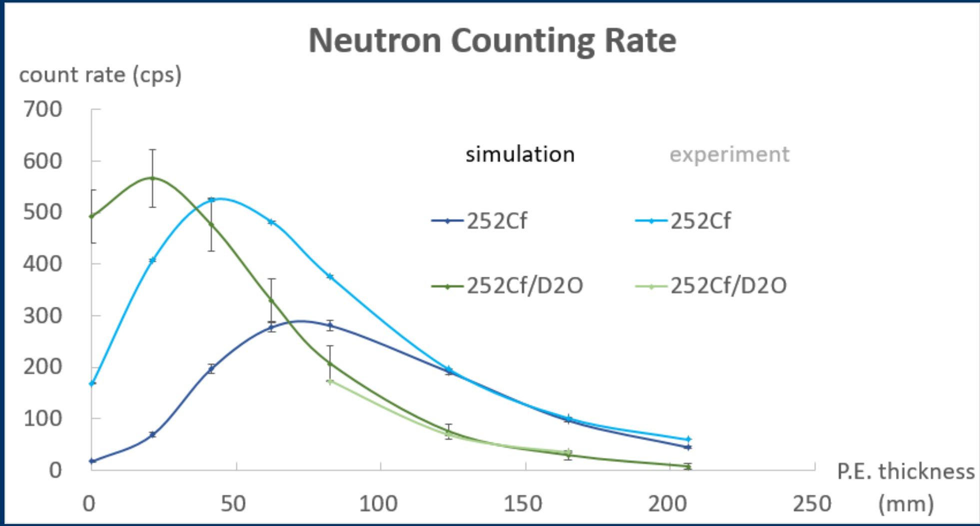


Neutron detector protype sensor ^{6}LiI(Eu)



Calibration by different radioactive sources and PE shielding





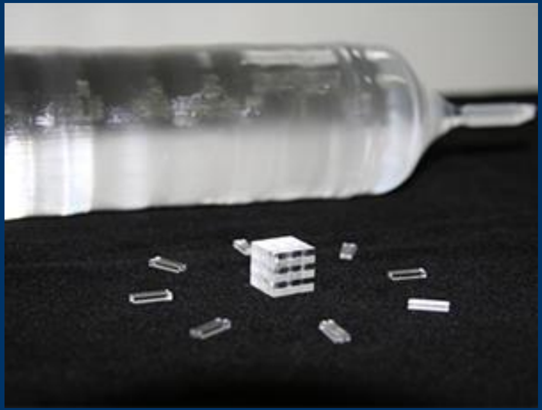
Tested with strong source at INER

LYSO tests collaborated with Taiwan Applied Crystal

LYSO characteristics:

decay times	~40 ns
small response time jitter	O(2) ps
light yield	~28 photons/keV

- Light yield measurement
- Time jitter measurement (R.S. Lu's student)



Light yield measurement

- Method: calibration with single photon signal

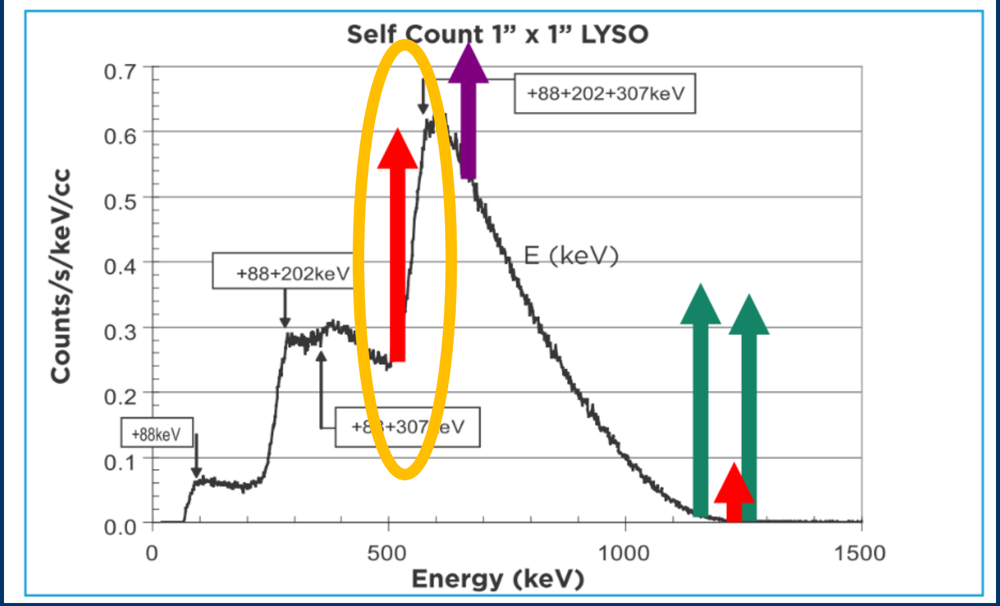
  due to the sensitivity and dynamic range, the measurements are done at two HV levels.
  - measure the single photoelectron signal at HV_h, ADC_{single} (LED source)
  - measure the LYSO photoelectron signal, with Na-22 (511KeV) source , at HV_ℓ, ADC_{LYSO}
  - measure the gain difference between HV_h and HV_ℓ, G_{HV}
  - estimate the PMT QE from its datasheet, QE ~ 20%
  - assuming the emission light collection efficiency ~100%

The light output of LYSO:

$$LO_{LYSO}(photon/keV) = \frac{ADC_{LYSO}}{ADC_{single}} * \frac{G_{HV}}{QE * 511}$$

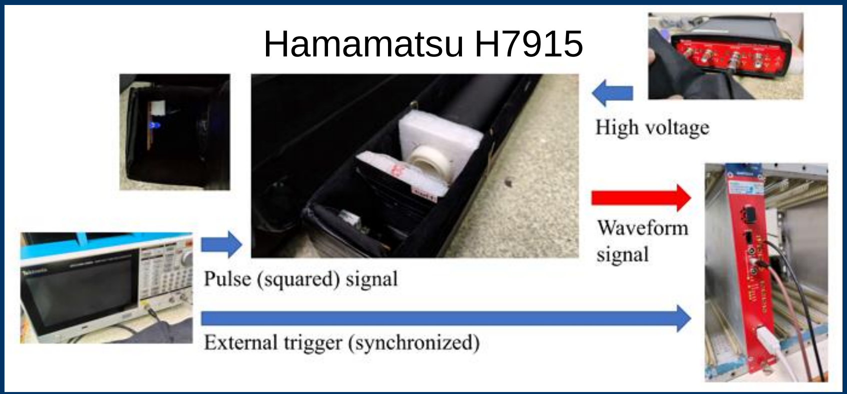
HV_h = 2500V; HV_ℓ = 1500V

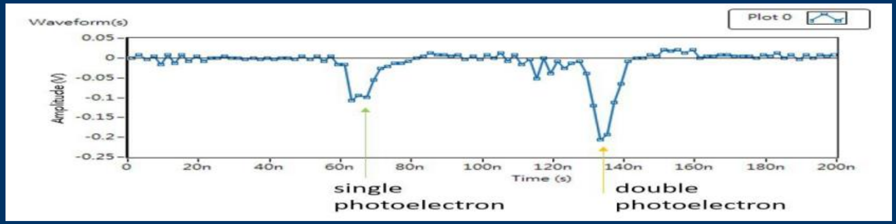
G_{HV} = Gain(HV_h)/Gain(HV_ℓ)



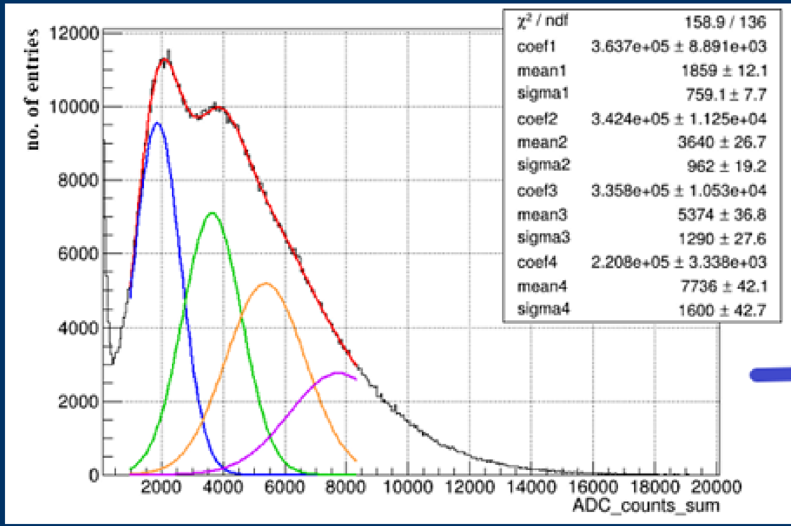
Light yield measurement

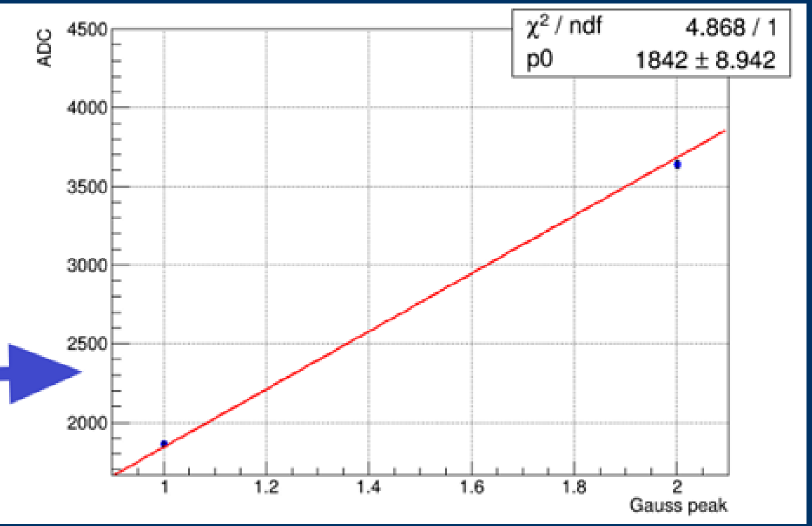
- ADC_{single} at HV_h (2500V):
  first tuning the FGen to get the single photoelectron signal from blue light LED.





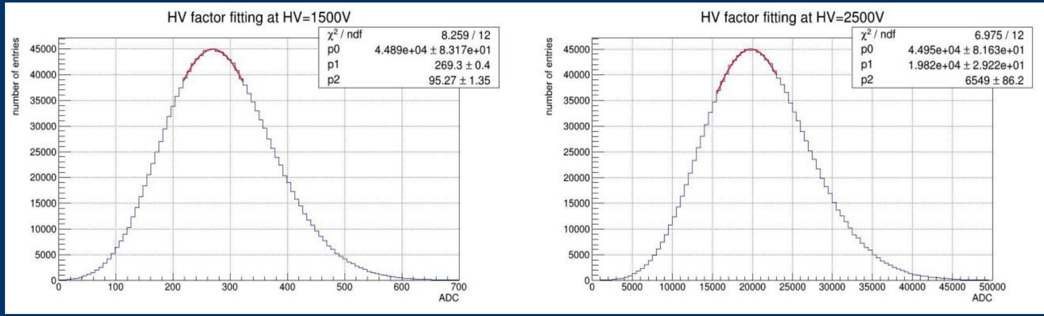
ADC_{single} = 1839±40





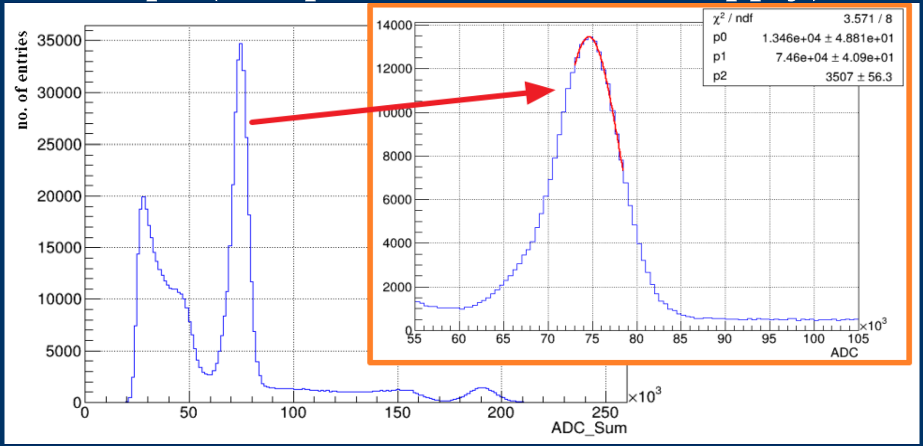
Light yield measurement

- G_{HV} = Gain(HV_h)/Gain(HV_ℓ) (determined by a moderate LED light ~ 10 photoelectron)
  - fit the spectrum peaks at HV_h and HV_ℓ by Gaussian



G_{HV} = 73±1

- ADC_{LYSO} at HV_ℓ (1500V)
  - LYSO sample 3.0 mm x 20.0 mm x 3.0 mm (Ca), illuminated with Na-22
  - wrapped with 4 layers of PTFE pipe sealant tape (acceptable and easiest to apply)

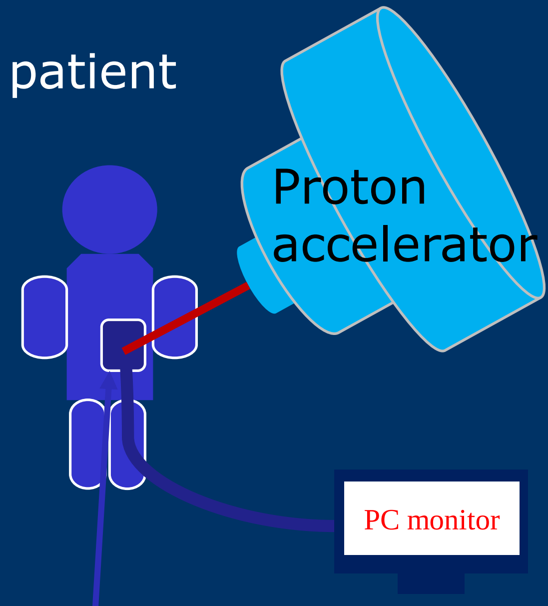


ADC_{LYSO} = 74500±2119

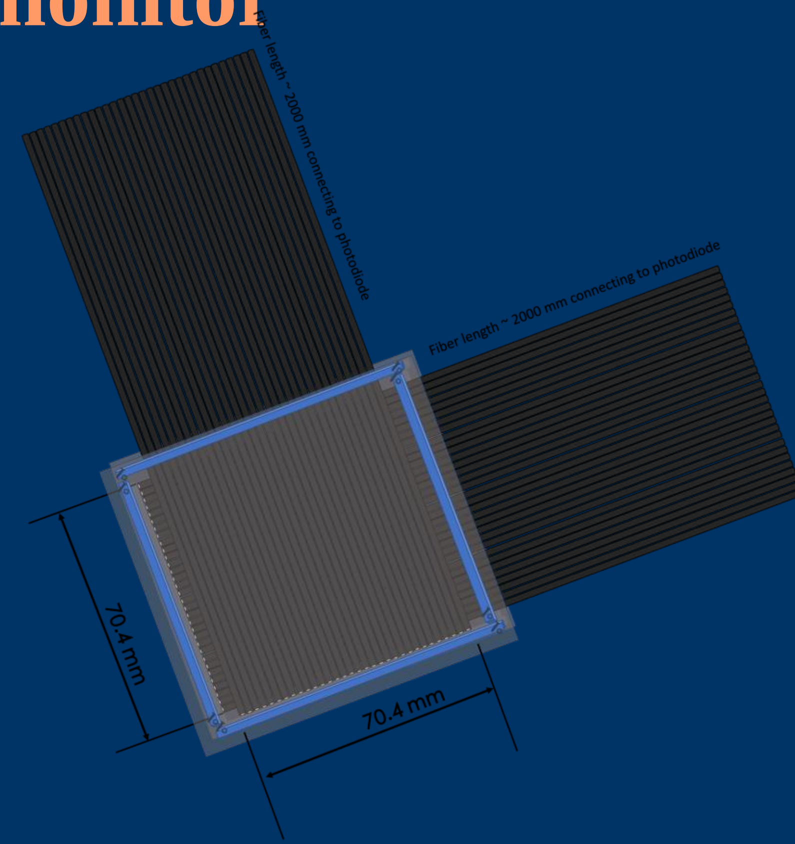
→ LO_{LYSO} = 29 ± 1 photon/keV

* LYSO sample with other dimentionals and doppings are also tested preliminarily.

Proton beam position monitor

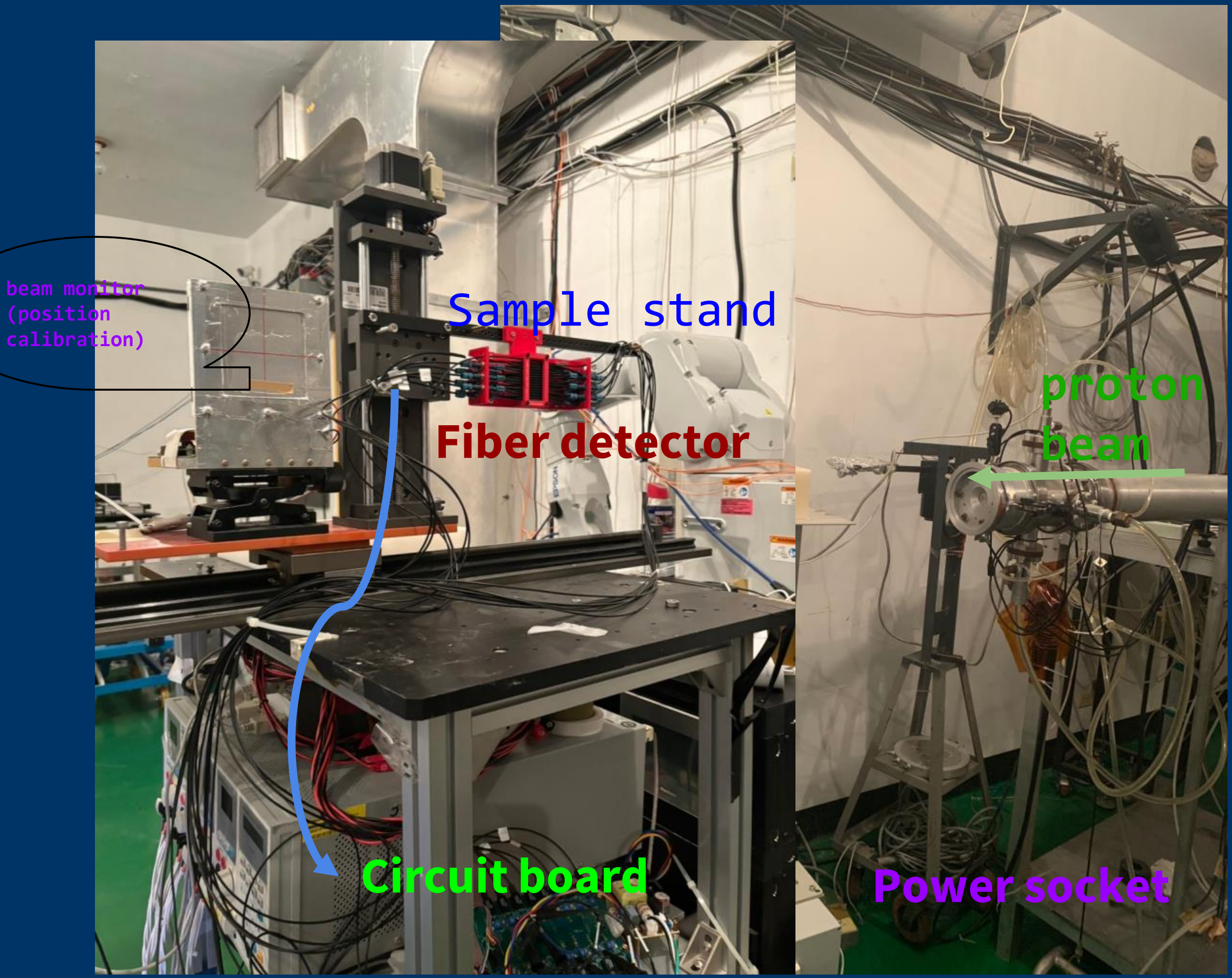


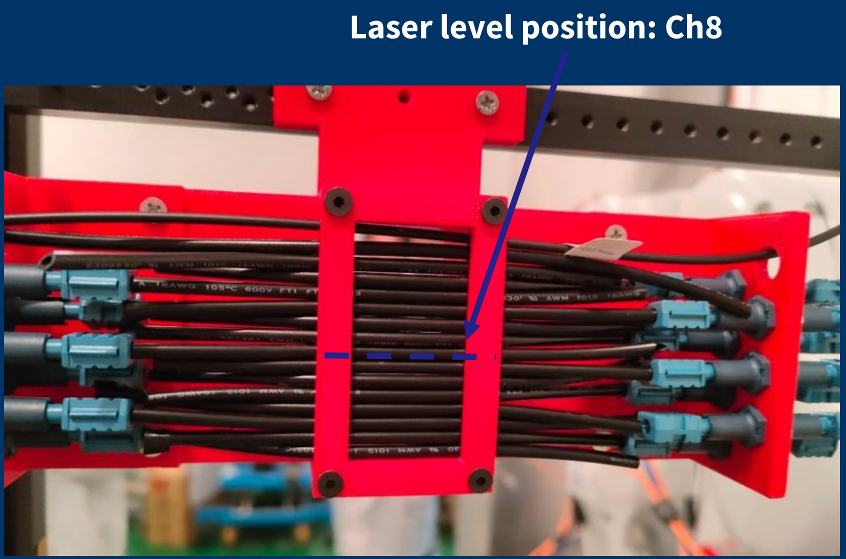
Proton beam monitor on the skin above cancer tumor



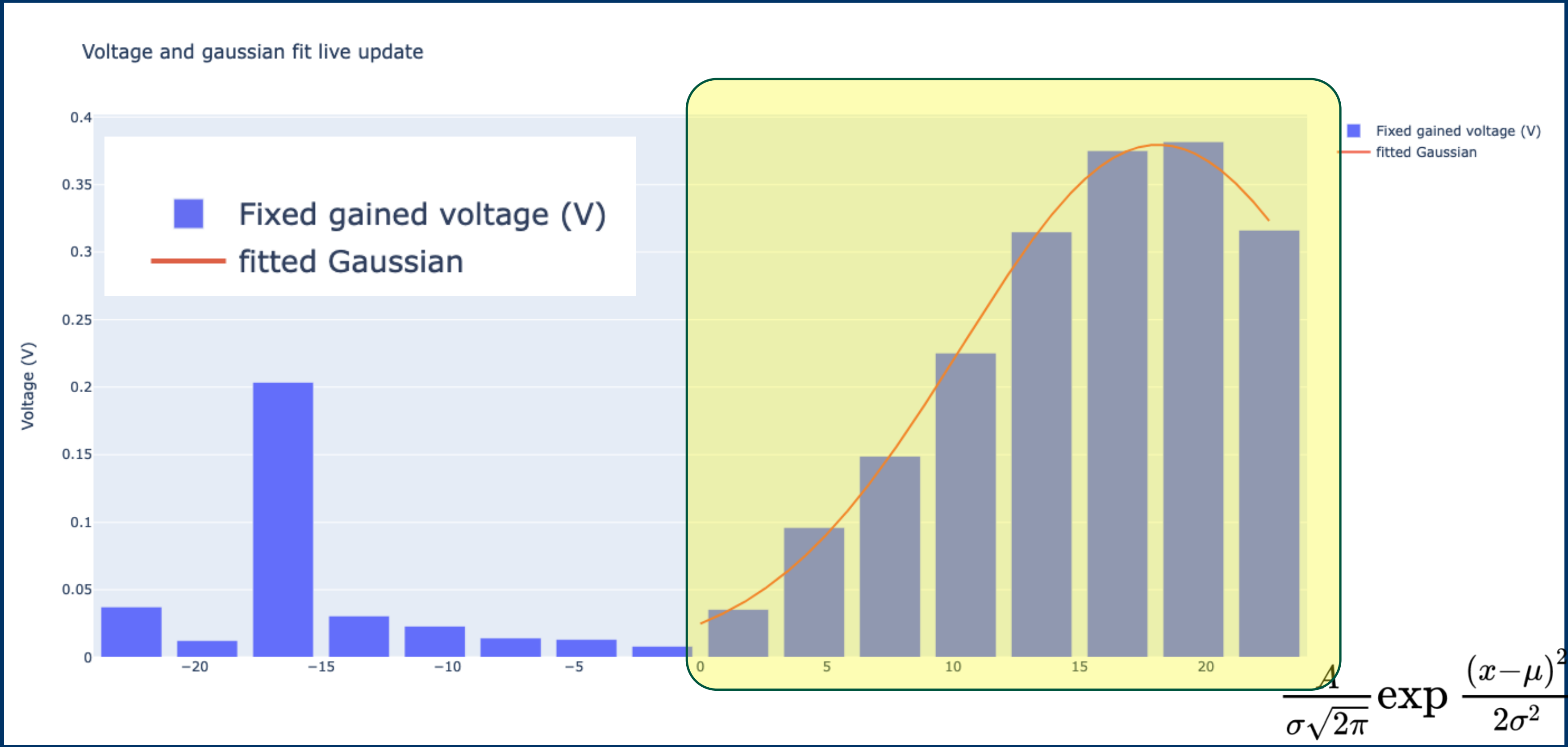
Sensitive area:
32+32 2D array of scintillation fibers
Fiber ϕ 1.0 mm, outer jacket ϕ 2.2 mm
Cover region: 70.4mm X 70.4 mm

Setup of beam test@ experimental hall at INER





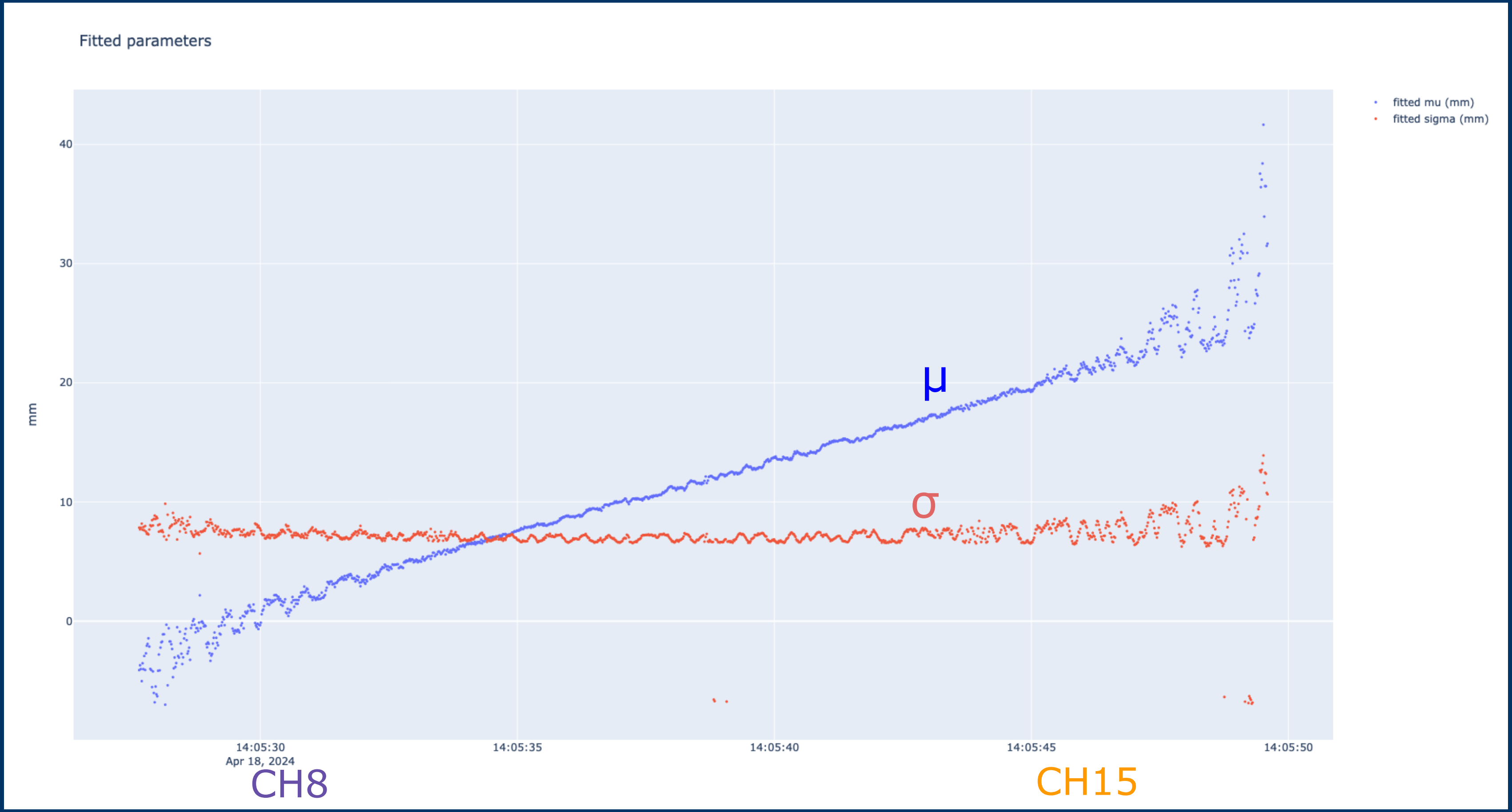
Gain caliobration and measured beam profile



$$\frac{A}{\sigma\sqrt{2\pi}}\exp\frac{(x-\mu)^2}{2\sigma^2}$$

8-channels with the same setup of
scintillator fiber with transmission fiber

Fitted parameter (μ,σ) at scan from bottom to top

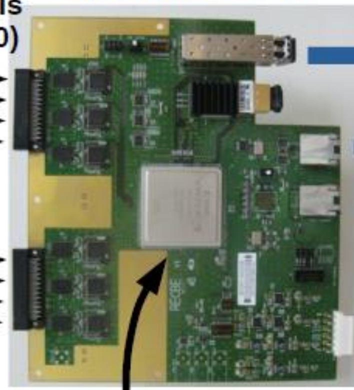


Prospects

Detectors
7

Analog Channels O(10000)

Front-End Electronics O(1000) boards



- User-designed ASIC: For ADC purpose.
- FPGA: data collection, zero suppression.

Optical link

Optical link

L1 Trigger signal: Y/N

DAQ system

Data readout / collector O(10) boards

PCIe / GbE

- Data collection.
- Data formatting.
- (Pre-)event building.

HLT / storage

- Real-time data processing with CPU.
- Also GPU, FPGA.

L1 Trigger, O(100) boards

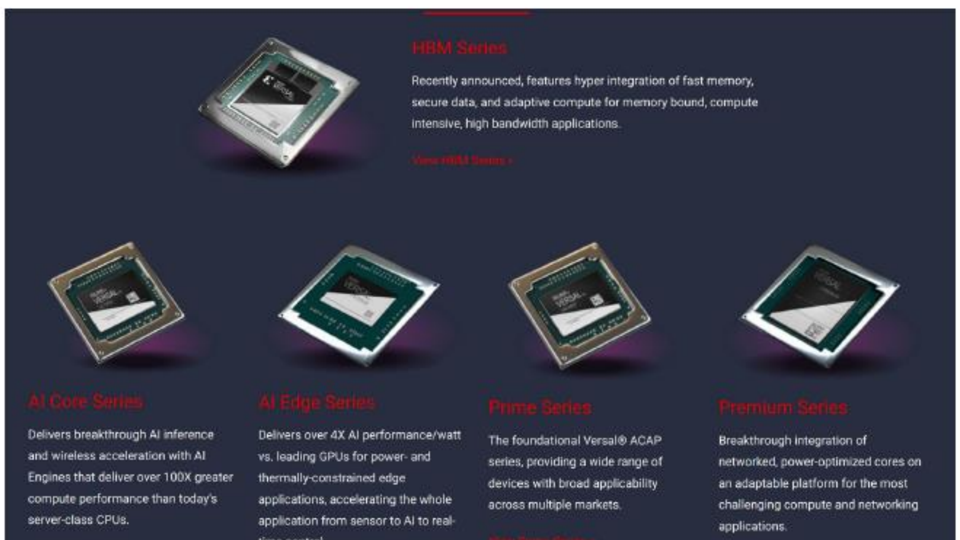
- Real-time complicated trigger algorithm for tracking / clustering / decision.
- Decide to take an event or not.
- Limited latency: ~5 μs.

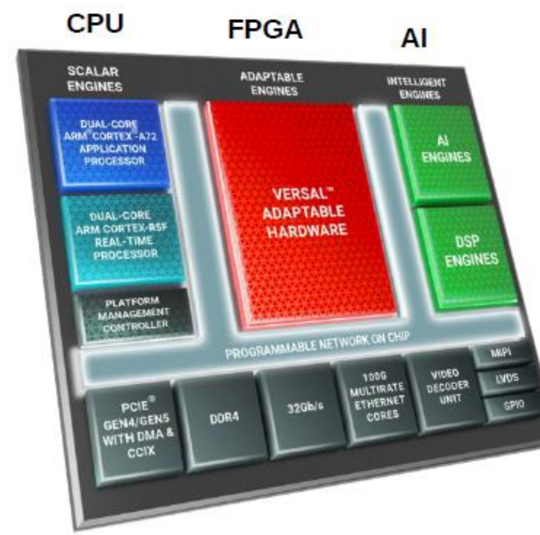
Versal project

Prospects

- KEK together with Japanese HEP community purchased a few evaluation kits of the Xilinx Versal series ACAP.
  - Plan: Common and general studies on the new technologies for future electronics device's R&D. Now we plan to use Versal for L1 TRG, DAQ or HLT purpose.

- The features of different Versal series ACAP:
  - AI engine: convenient interface to implement ML core into firmware.
  - High Bandwidth Memory (HBM).
  - Larger number of cells + High transmission bandwidth.





source: Xilinx website

Introduction

- LYSO: Lutetium-Yttrium oxyorthosilicate, $Lu_{2(1-x)}Y_{2x}SiO_5$:Ce:[M]

  Its properties strongly depend on the composition and manufacture process.

density	~7.1 g/cm^3	
refractive index	~1.8	
decay times	~40 ns	
small response time jitter	O(2) ps	
light yield	~28 photons/keV	(4xBGO; 75% of NaI(Tl))
peak wavelength emission	420 nm	
radiation length (511keV)	1.2 cm	
energy resolution	~10 %	
$R_{Moliere}$	2.07 cm	
hygroscopic	No	
radiation hardness	1x10$^{6\sim8}$ rad	[**Shalom EO** and **SA Materials**]
price	~ \$100 /cm^3	

- intrinsic radiation activity due to ^{176}Lu (about 2.6% in natural Lutetium).
- non-linear γ absorption (self-detection)