Analysis of Beam Position Monitor

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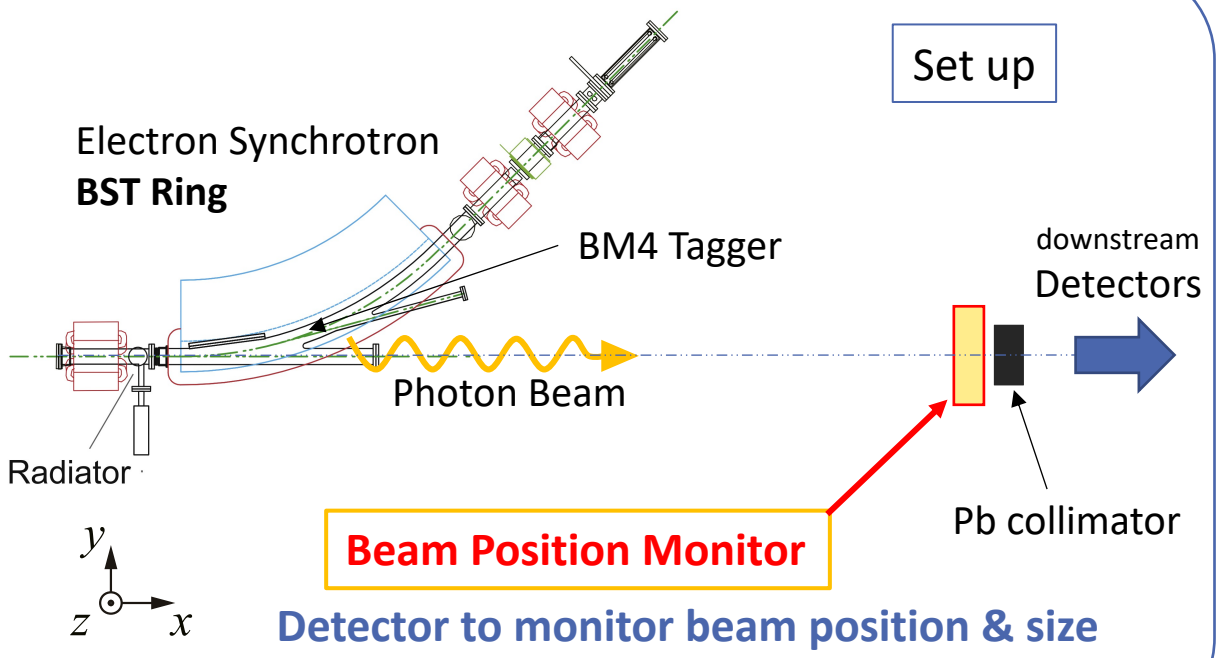
Beam Position Monitor

Hypernucleus experiment at ELPH

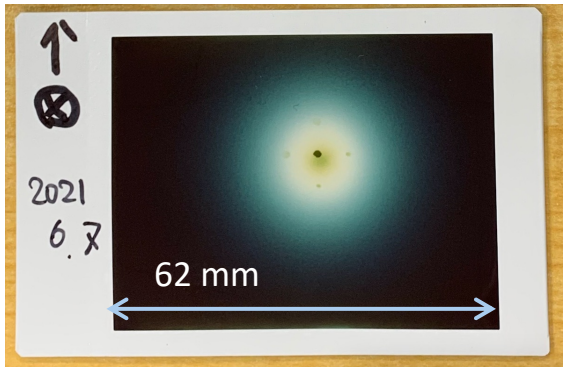


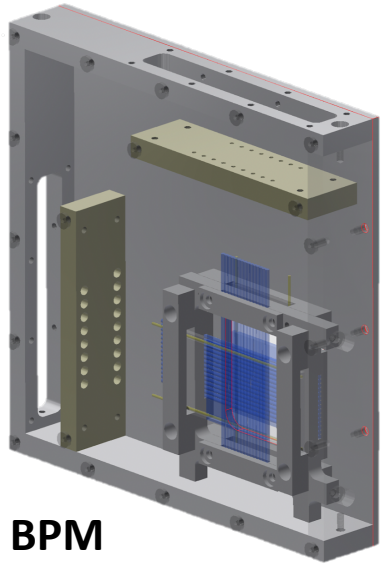
Detector to monitor beam position & size for use in spectrometer calibration

< Tagged Photon Beam >

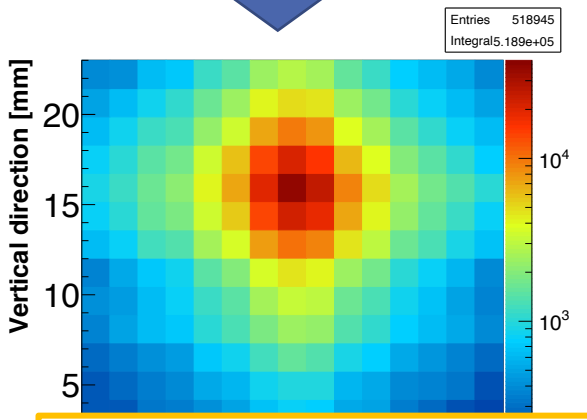
- size : ϕ~1 cm
- energy: 0.73 – 1.25 GeV
- rate : ~MHz

↓ Beam profile by the instant camera that has been adopted in the past





new BPM

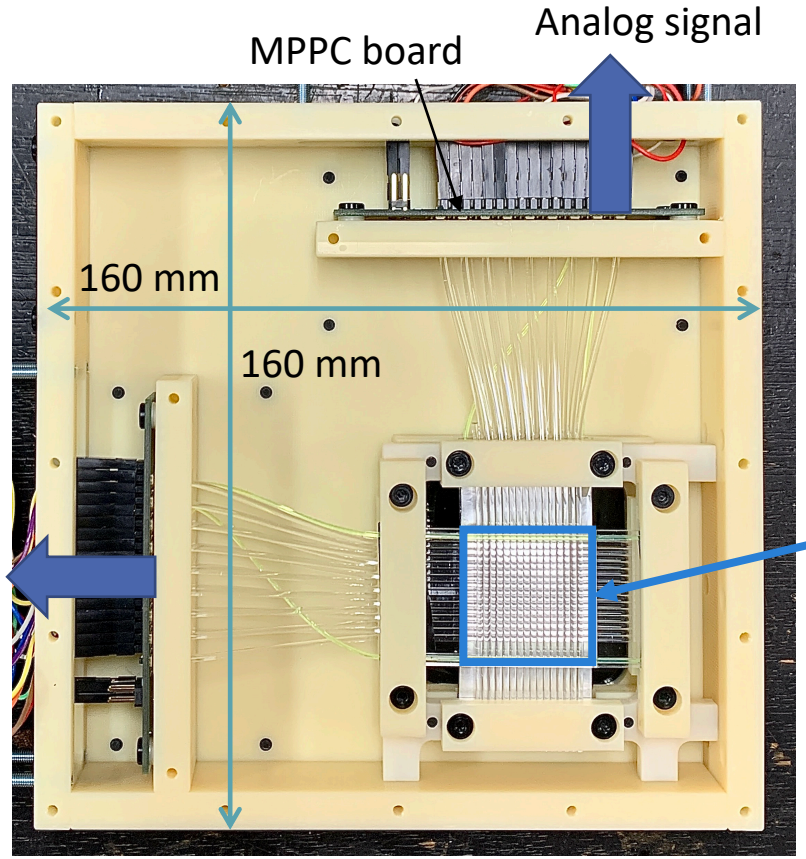


Beam profiling is possible in real time and quantitatively!

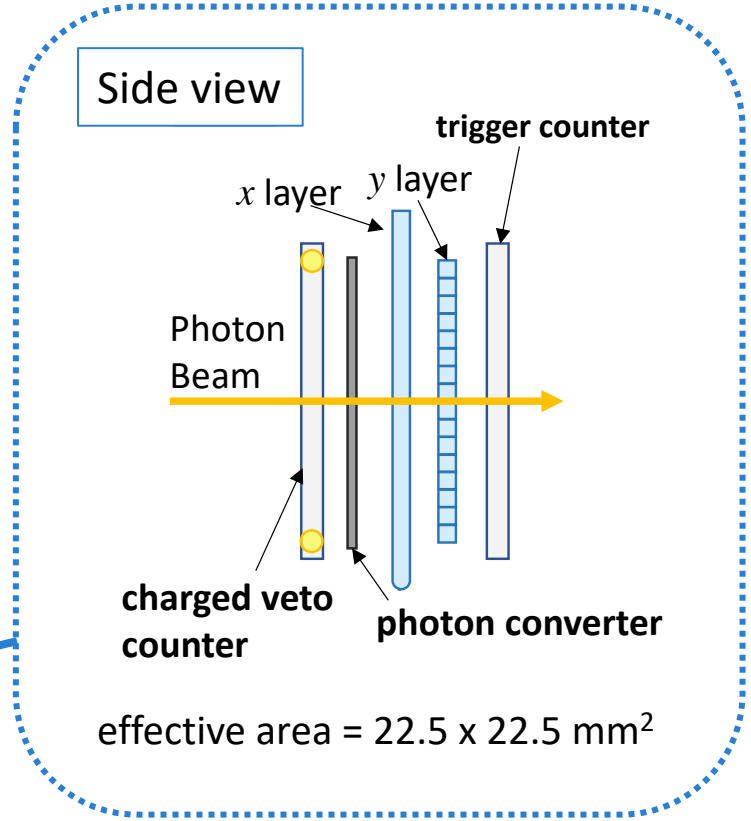
Basic Design of BPM

Basic Structure

- Scintillation Fibers (ϕ1.5 mm)
  SCSF-78 (Kuraray)
- SiPM
  MPPC S13360-1350PE
  (Hamamatsu Photonics K.K.)
- DAQ: streaming type TDC
  (Hadron Universal Logic)



Beam Position Monitor

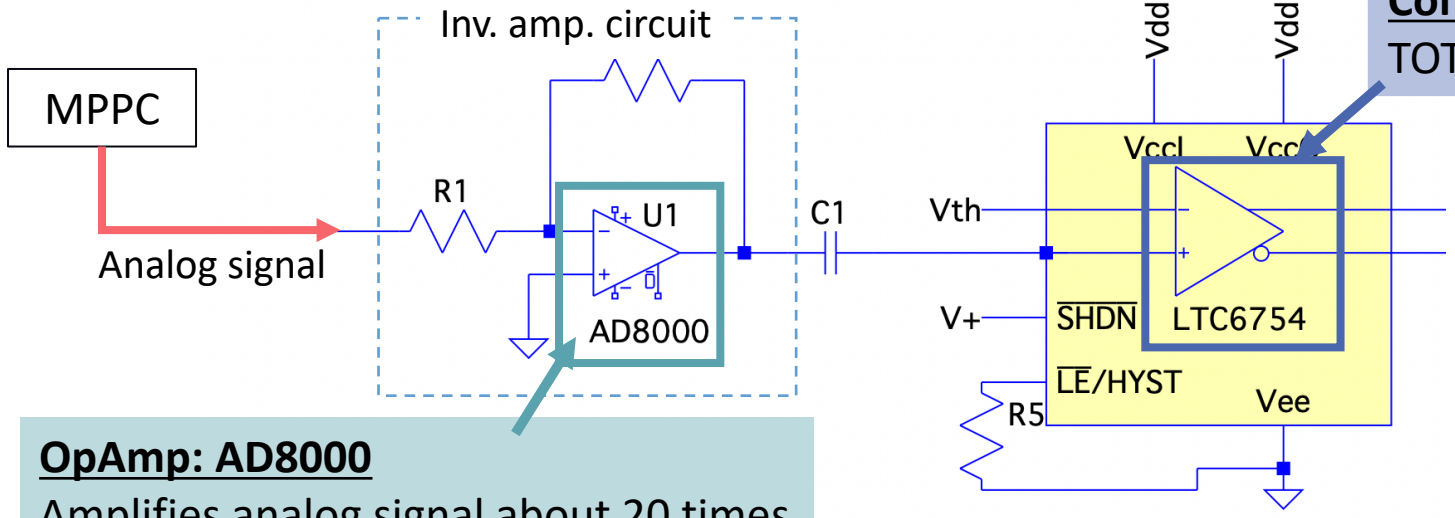


event ID:

$[\ \overline{\text{veto}}\ ] \otimes [\ \text{x layer}\ ] \otimes [\ \text{y layer}\ ] \otimes [\ \text{trig.}\ ]$

→ **Only photon events can be extracted!**

Readout Circuit

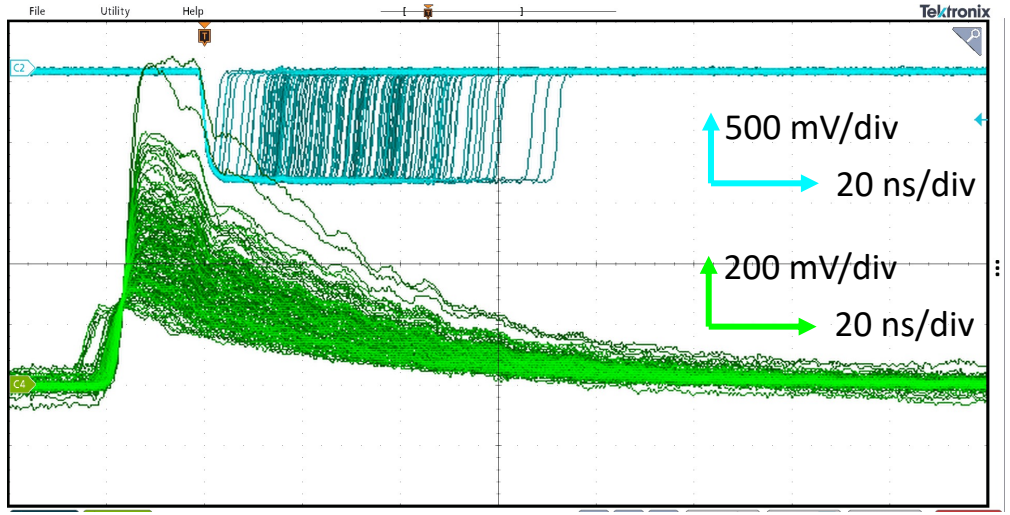


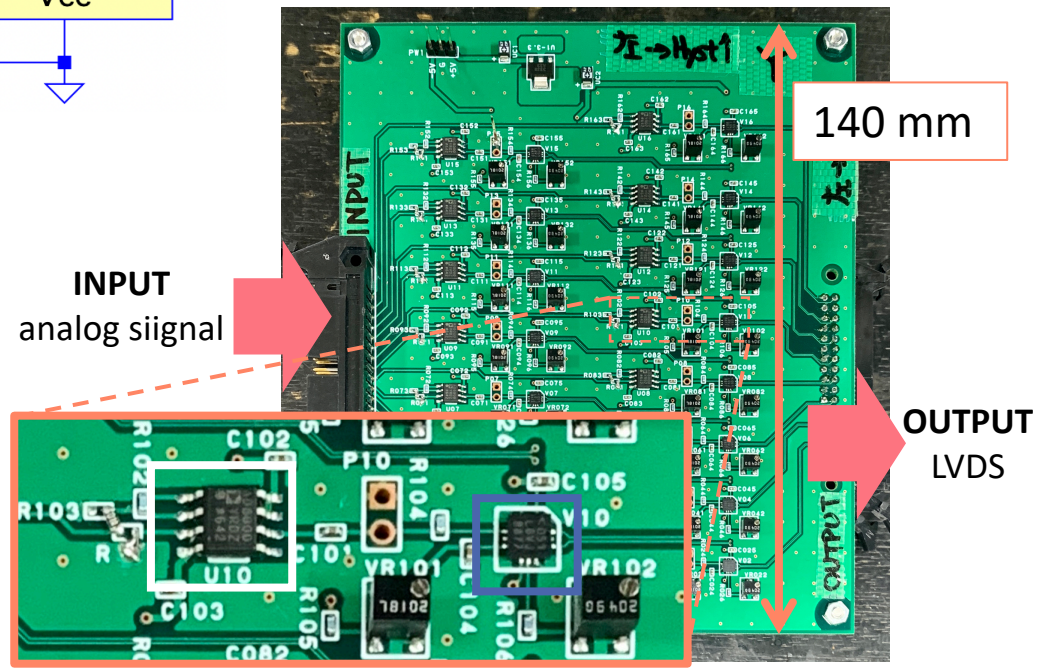
Comparator: LTC6754
TOT circuit: Output as LVDS signal

veto	1 ch
trigger	1 ch
SciFi.	30 ch

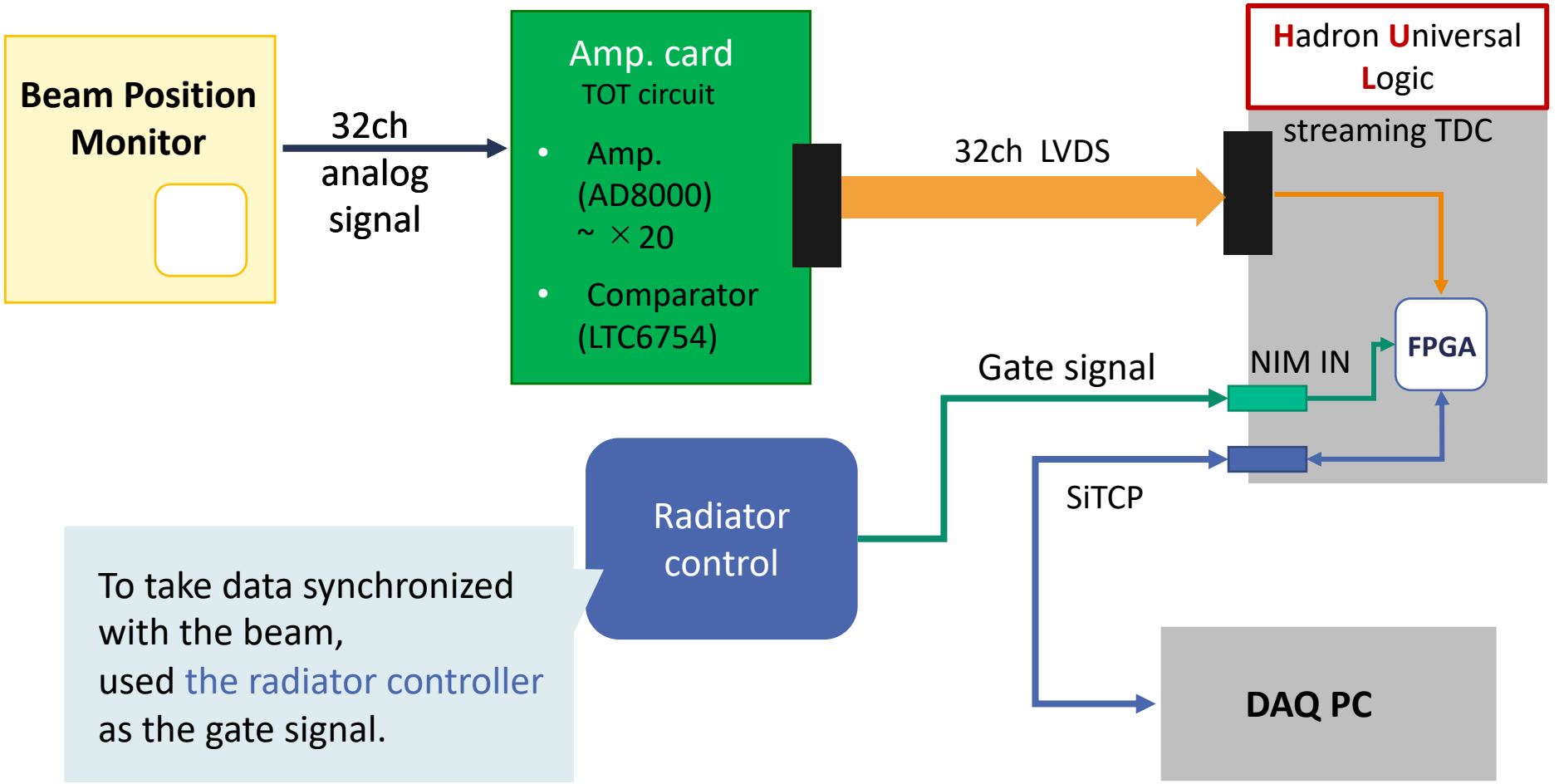
→ Read a total of 32 channels

OpAmp: AD8000
Amplifies analog signal about 20 times





DAQ System



To take data synchronized with the beam,
used the radiator controller as the gate signal.

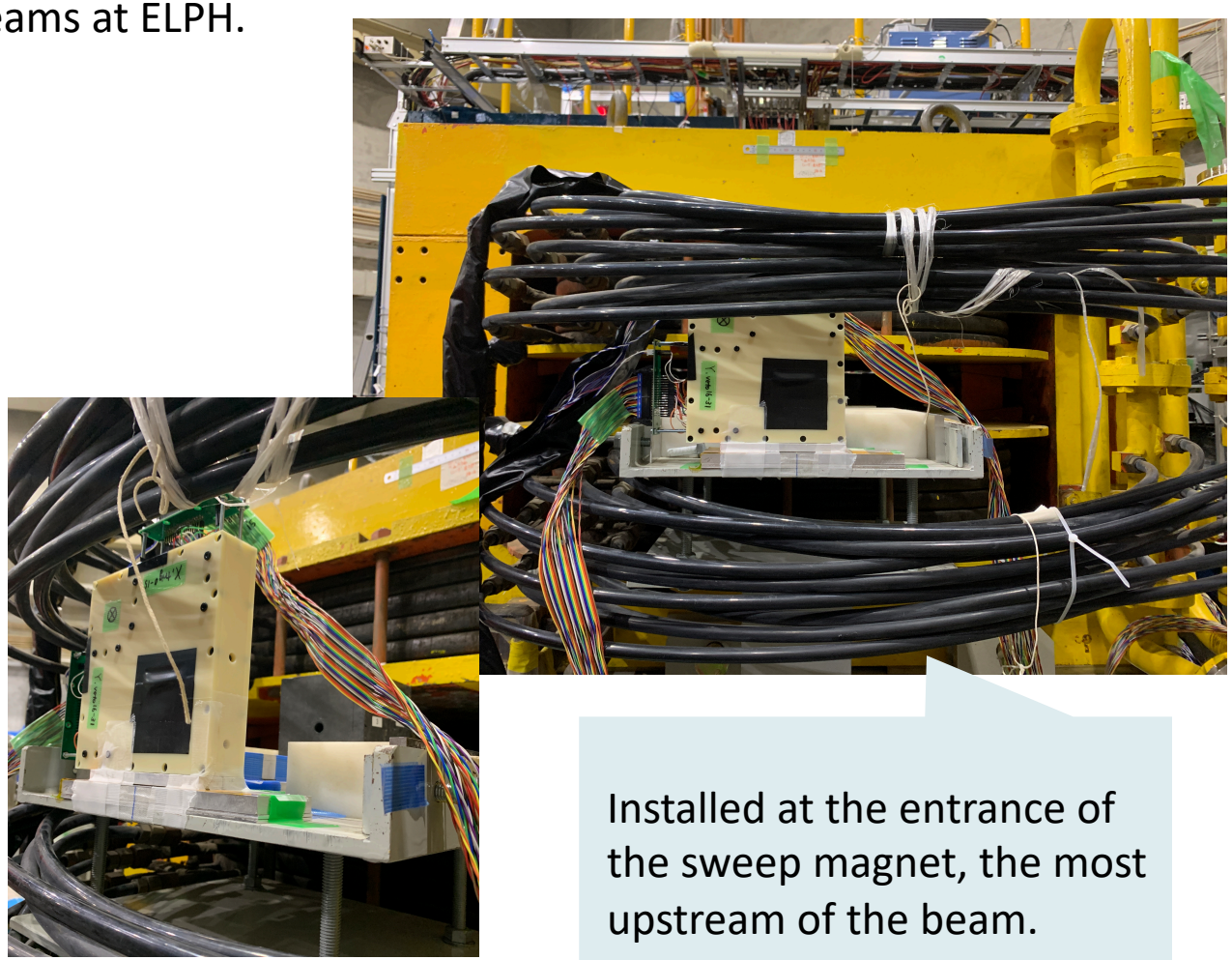
Beam Test in July 2021

Conducted BPM first operation using tagged photon beams at ELPH.

It was confirmed that these are possible.

- Stable operation in a magnetic field (~ 0.3T)
- Separation of actual photon and background
- Beam fluctuation monitoring

- Sampling rate: Can be monitored in 1ms
- Total count rate: ~ MHz

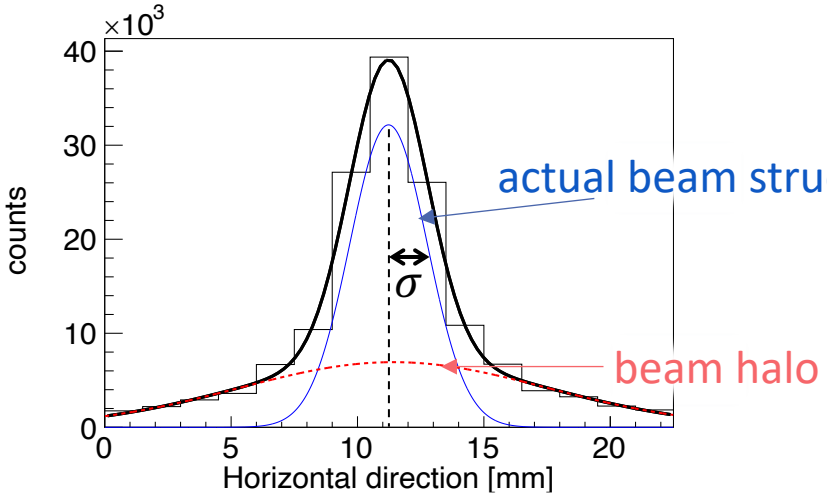


Installed at the entrance of the sweep magnet, the most upstream of the beam.

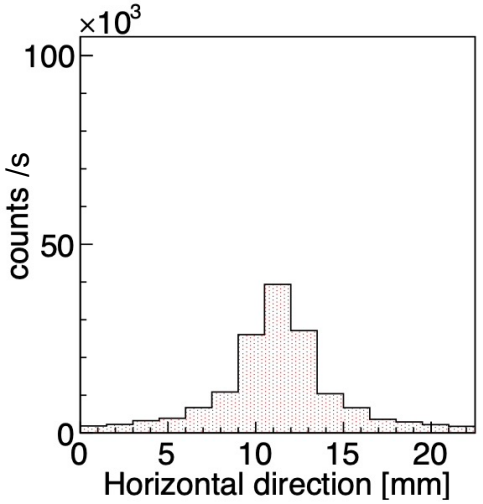
Beam Position and Size

Check the time dependence of
beam center position (μ) and size (σ).

The hit distribution(/s) is plotted on the histograms in the horizontal and vertical directions, and determined by fitting.
Function: gaussian + gaussian

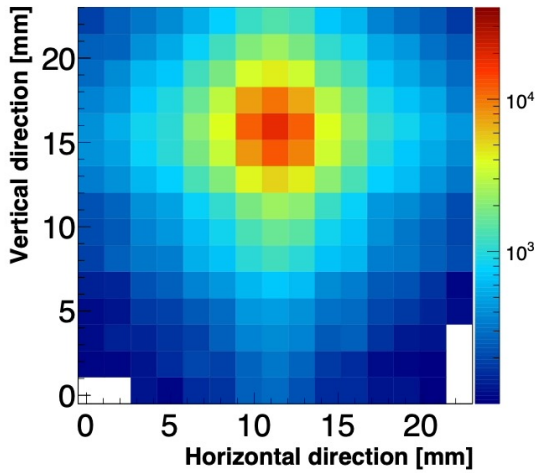


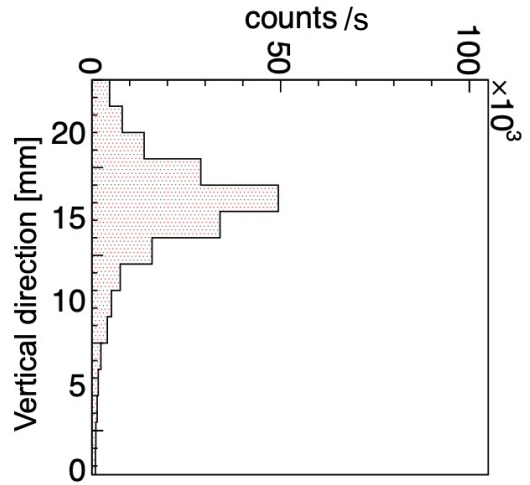
→ **Achieved accuracy $\Delta\mu$, $\Delta\sigma \leq$ 10 µm**



Hit distribution /1.0 sec

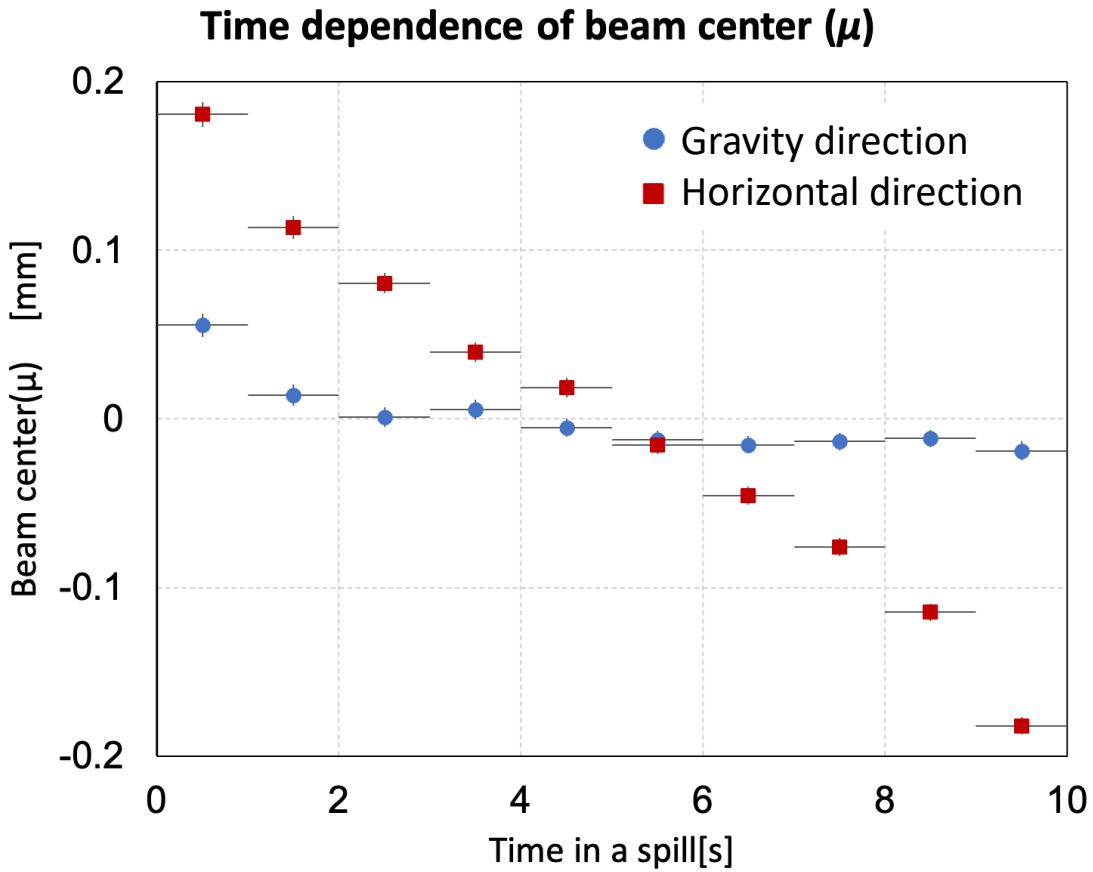
beam current: 0.5 [mA]
bias voltage: 55 [V]
converter: 300 [µm]





Time dependence: Beam position

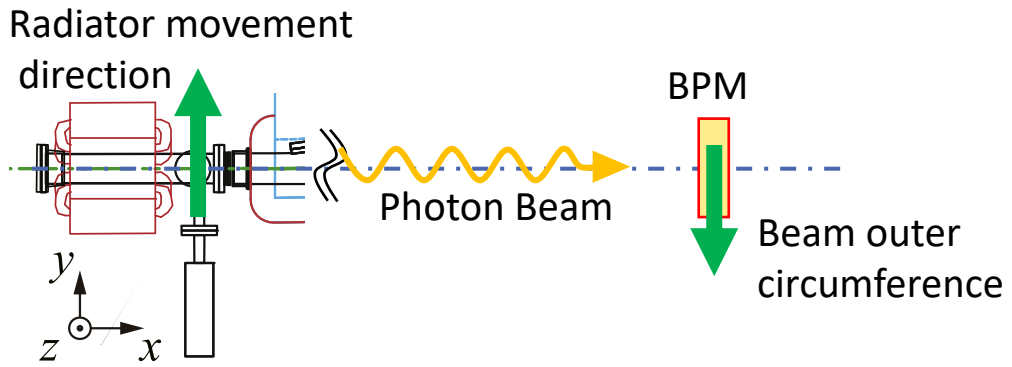
#11 1st spill



Gravity direction: No major fluctuation.

Horizontal direction: Moves about 0.4 mm toward the outer circumference of the beam.

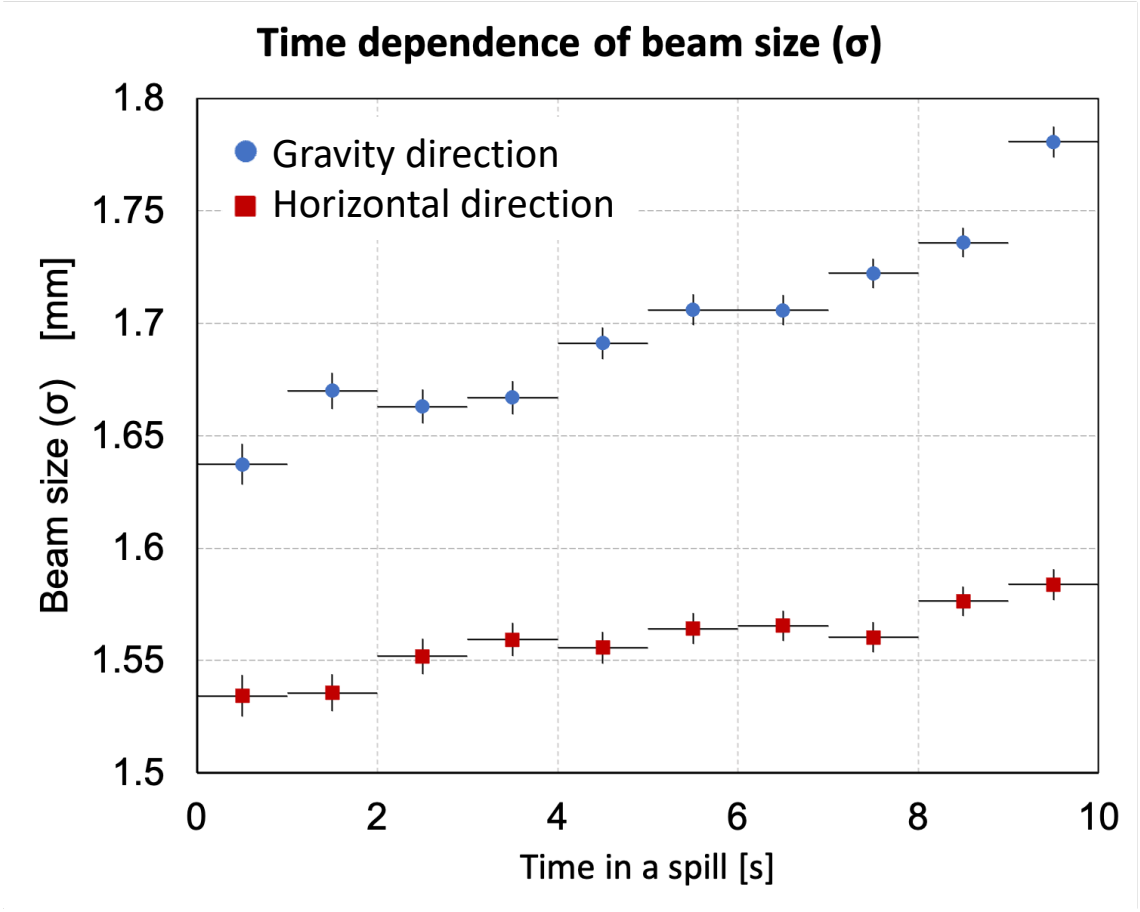
It has been reported that the center position of the photon beam moves in the direction opposite to the movement of the Radiator [1] [2].



[1]T. Ishikawa, et al., Nucl. Instr. and Meth. A 811 (2016) 124–132
[2] F. Hinode, et al., in: Proc. of 2005 PAC 2458;

Time dependence: Beam Size

#11 3rd spill



Beam size (ave.):

Gravity direction σ = 1.70 mm

Horizontal direction σ = 1.56 mm

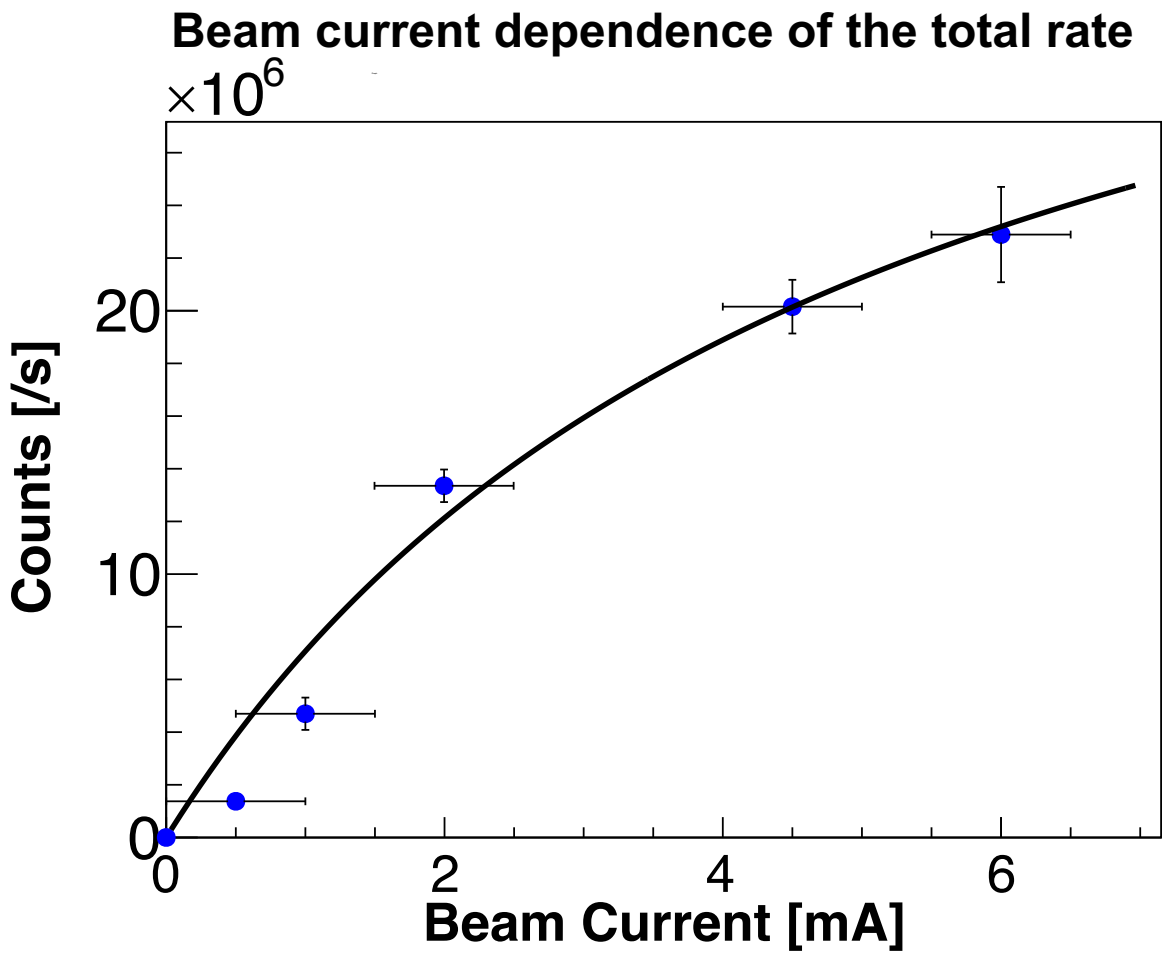
→ Consistent with the theoretical beam size [3] predicted.

Beam size increases significantly within a spill.

[3]T. Muto, PASJ2015 WEP003

Rate Study

The fitting of the non-paralyzed counting correction function was performed in consideration of the dead time.



MPPC bias voltage：56 V

Fit function：$y = \frac{p_0 x}{1 - p_0 p_1 x}$

Fit parameter： $p_0 = (8.5 \pm 3.0) \times 10^6$

$p_1 = (2.4 \pm 0.9) \times 10^{-8}$

(χ^2/NDF = 0.48)

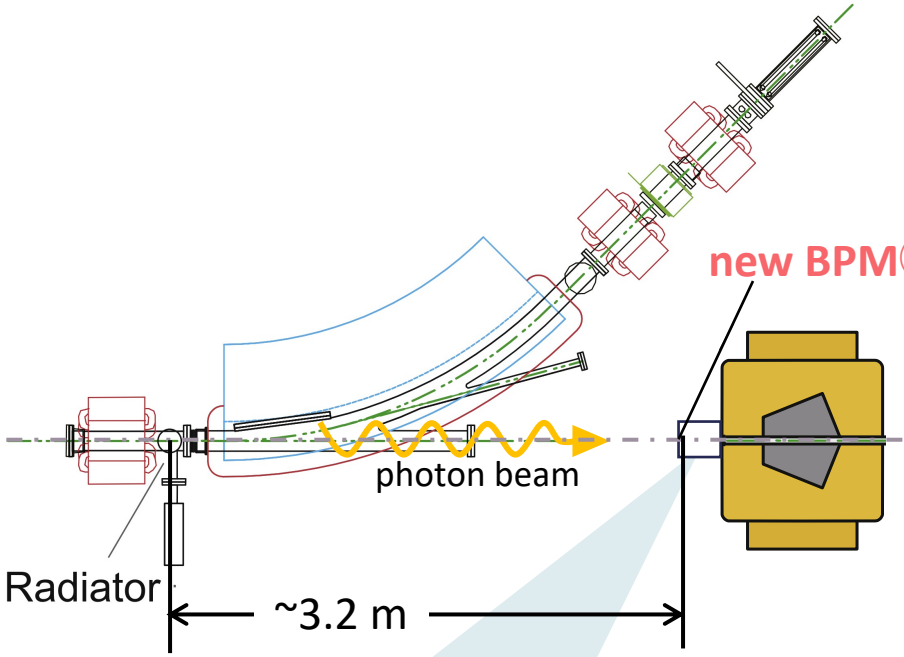
（※MPPC operation voltage = 54.4 V）

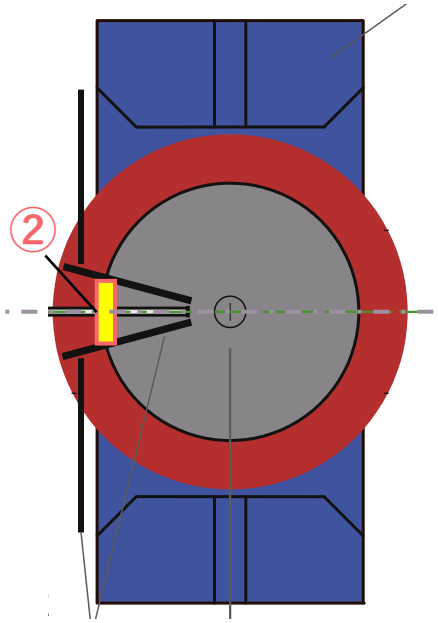
- Rate at beam current 6 mA: ~ 23 MHz
- Saturation is visible in the beam current region above 4 mA, however, beam profiling is possible.

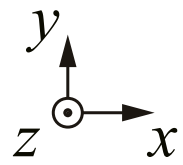
Now, designing the new BPM…

→ Plan to reduce the material thickness and reduce the rate

The next experiment

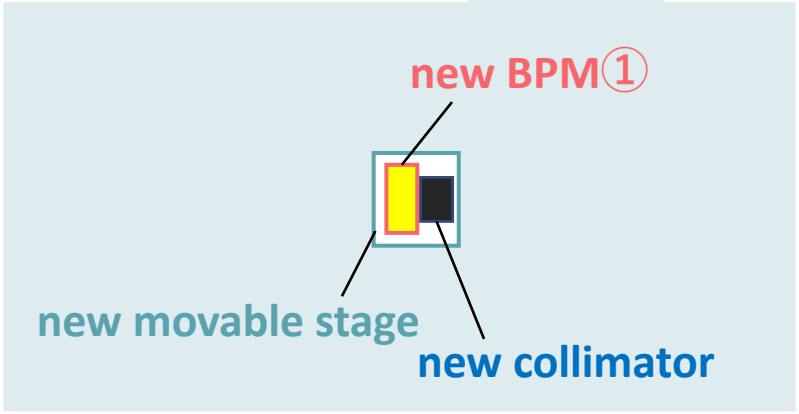






Replace the current BPM with a type using MPPC

Scheduled to be held on November 22 - 23



- Based on the results of the previous experiment, we will make an actual machine that can measure with higher accuracy.
- The beamline is adjusted by measuring at three points.

Summary

- Developed photon Beam Position Monitor (BPM) for hypernucleus photogeneration experiment at ELPH.

- **Photon Beam Position Monitor (BPM)**

- Basic design: Plastic scintillation fiber (kuraray SCSF-78)
  Hamamatsu Photonics SiPM (MPPC S13360-1350PE)
  By combining with an aluminum photon converter, it is possible to detect a photon beam.
- Readout: TOT circuit based on operation amplifier (AD8000) and comparator (LTC6754)
- DAQ: Streaming TDC (FPGA module (HUL)) can monitor beam position and size in a spill time

- Test experiment using tagged photon beam at ELPH, July 2021
- Beam profiling can be done with accuracy $\Delta\mu \leq 10$ µm, $\Delta\sigma \leq 10$ µm
- Data can be collected from beam current to 6 mA
- Under design of an improved version of the actual machine with a smaller material thickness

- The next experiment will take place in November 2021.