Recent Development of Glass GEM

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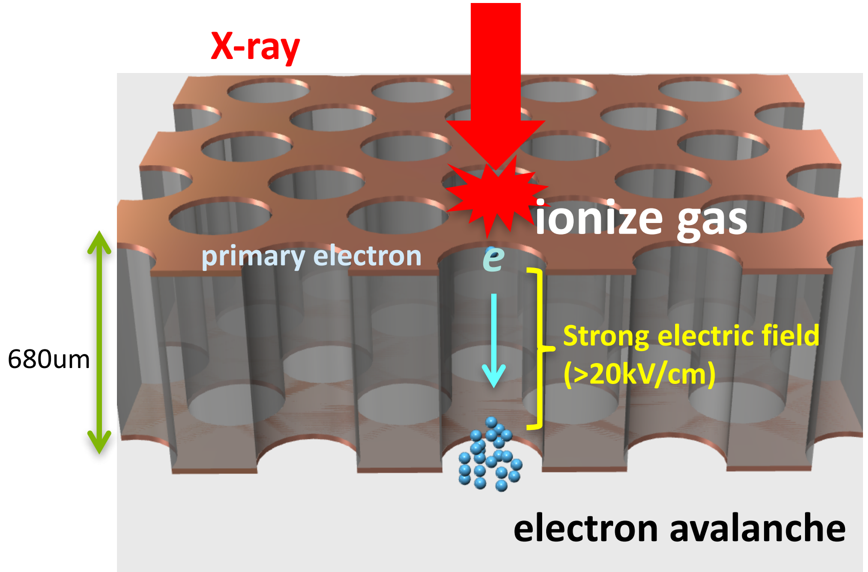
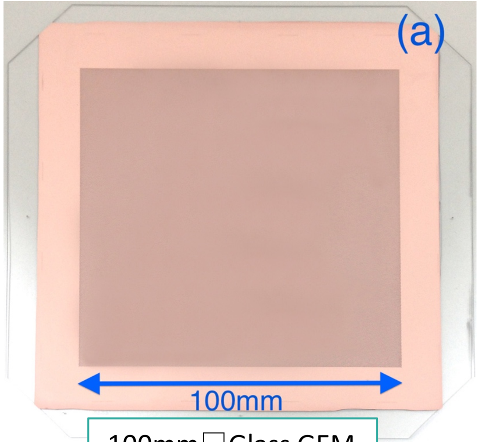
Outline

1. Updates in Glass GEM fabrication
2. Hadron Therapy
3. Neutron Bragg-Edge Imaging
4. Summary

1. Background & Motivation - X-ray imaging with Glass GEM





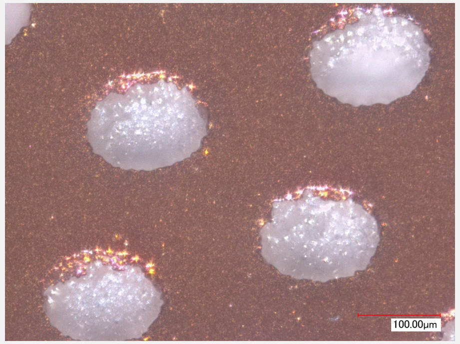
100mm□Glass GEM

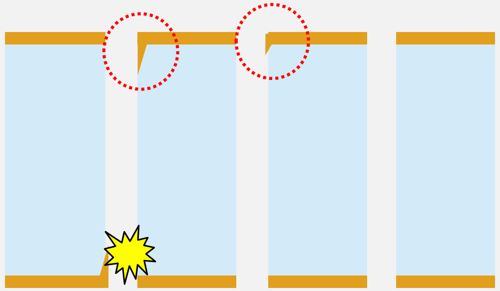
- In MPGD2011 we first introduced GEM made with glass substrate[1, 2]
- Why Glass GEM?
  - **Robust – tolerant against discharges**
  - **Rigid – self-supporting structure, easy to handle**
  - **High gas gain – up to 90,000 with single Glass GEM[3]**
  - **High spatial resolution – minimize charge spread**

[1] T. Fujiwara, et al., MPGD2011
[2] H. Takahashi, et al., NIM A, vol. 724, pp. 1–4, (2013)
[3] T. Fujiwara, et al., JINST, vol. 9, pp. 11007 - 11007, (2014)

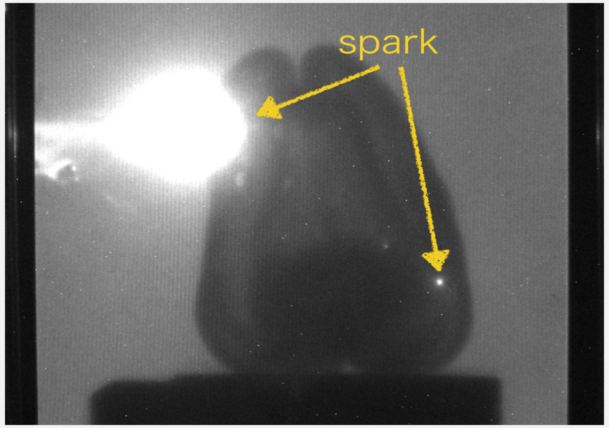
An issue...

Metals inside via causes sparks





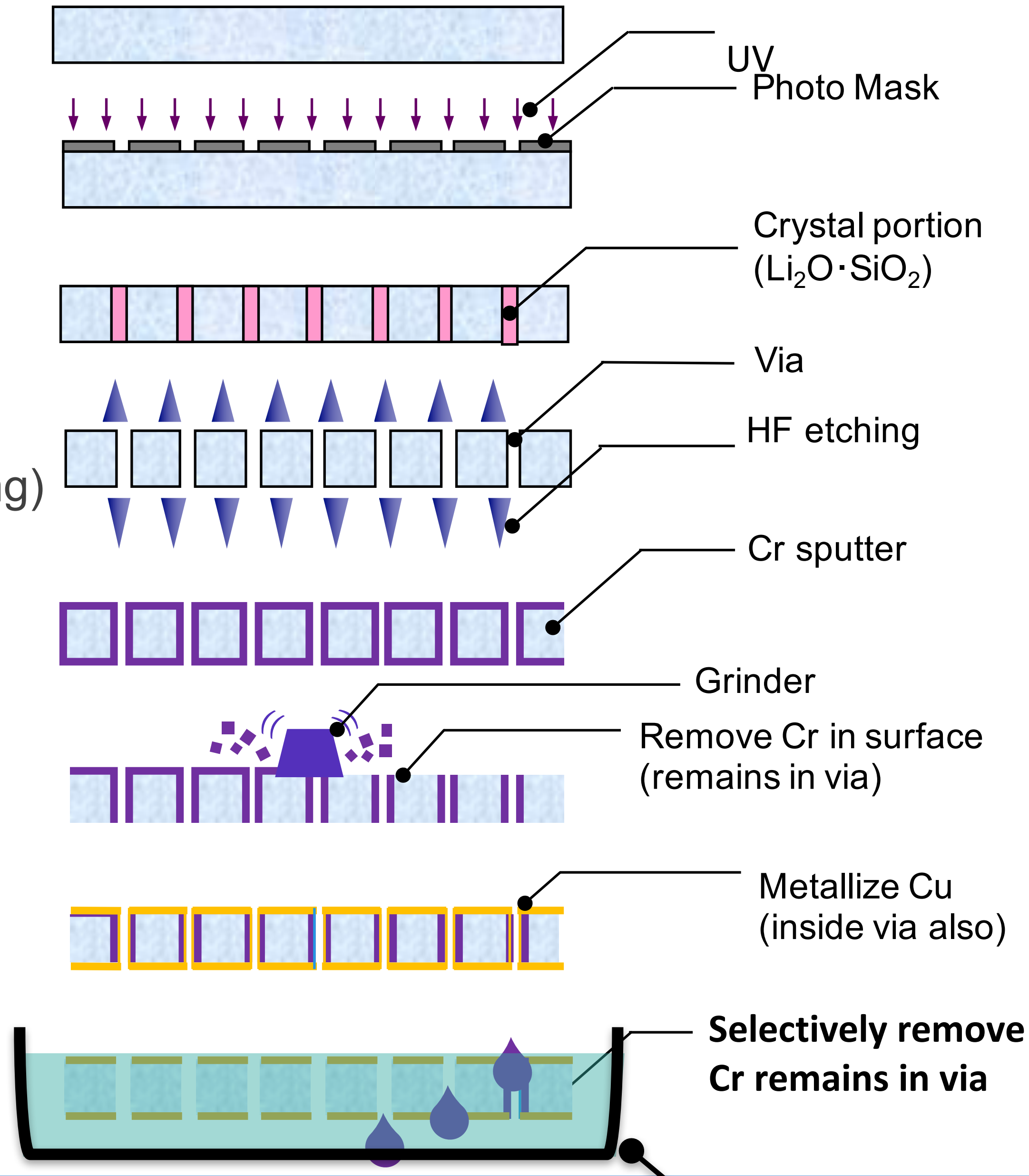
Micrograph of Glass GEM in early days



Discharges ruins the electrodes

2. The new Glass GEM fabrication process at AIST

1. Glass Substrate
2. UV exposure (1st_exp)
3. Crystal formation (heat treatment)
4. Via etching (Hydrogen Fluoride wet etching)
5. Poison Metallization
6. Remove metal except in via
7. Metallization process II (Cu)
8. Selectively etch metal in via



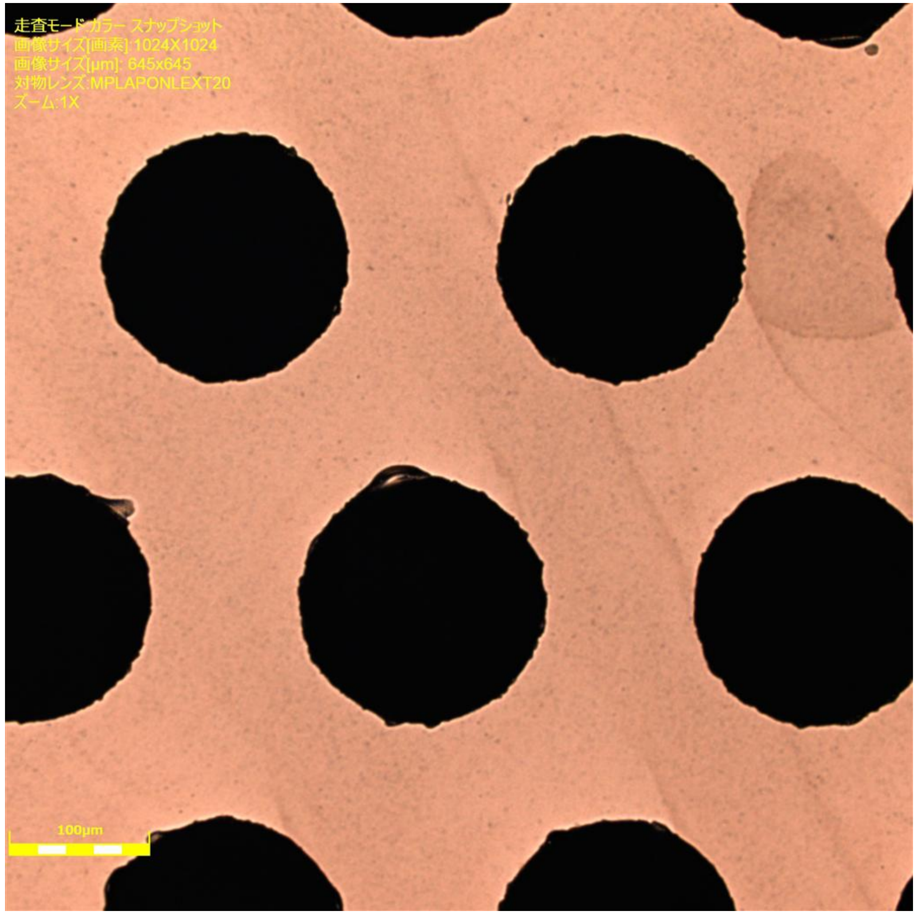
Optimizing the time and temperature

9. Ultrasonic bath

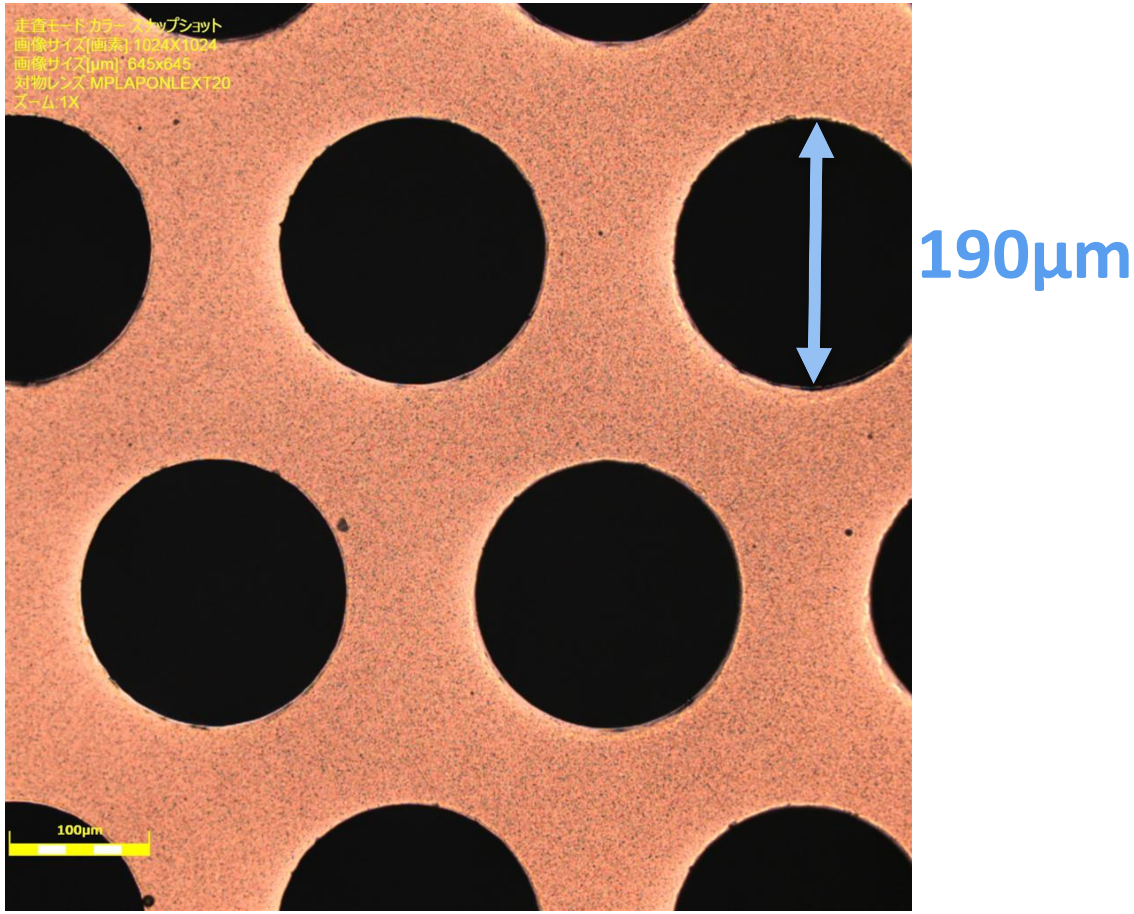
[4] T. Fujiwara, et al., NIM A, 878 (2018)

2. The new Glass GEM fabrication process at AIST

Old process

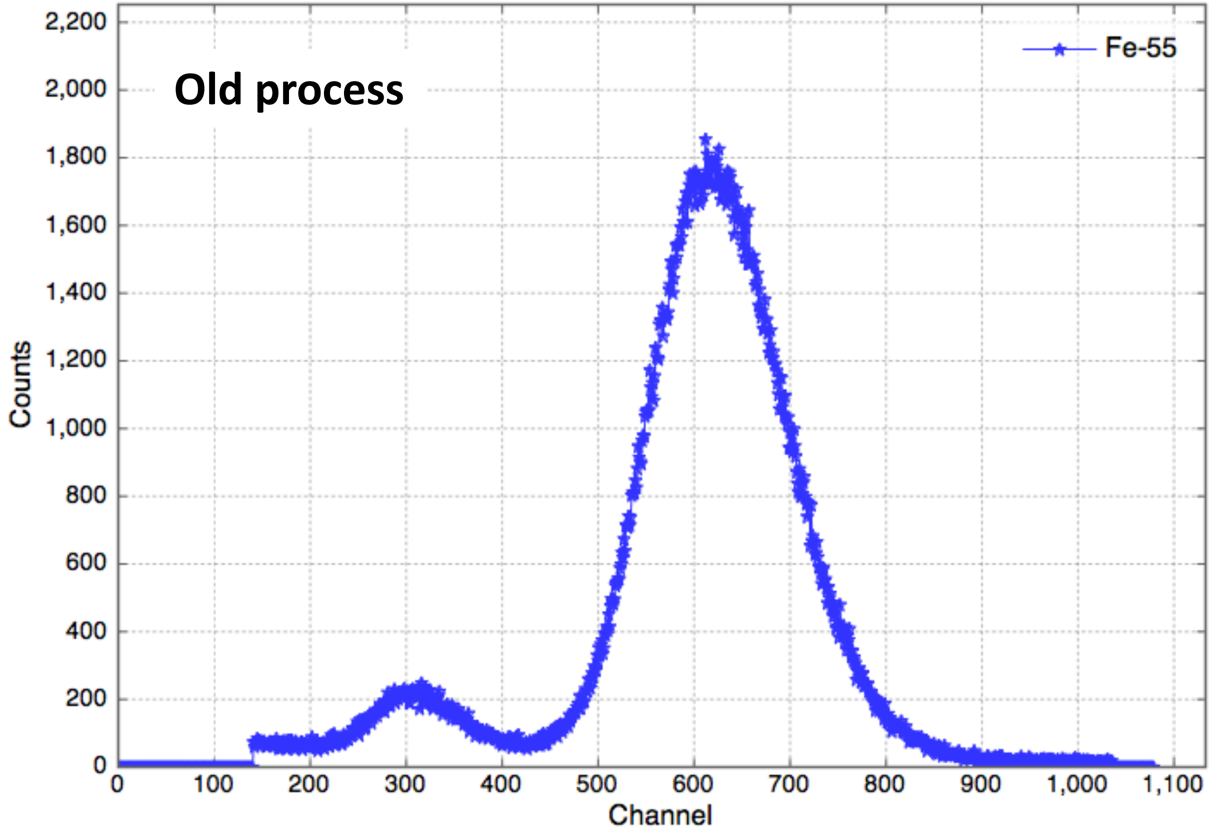


The New process

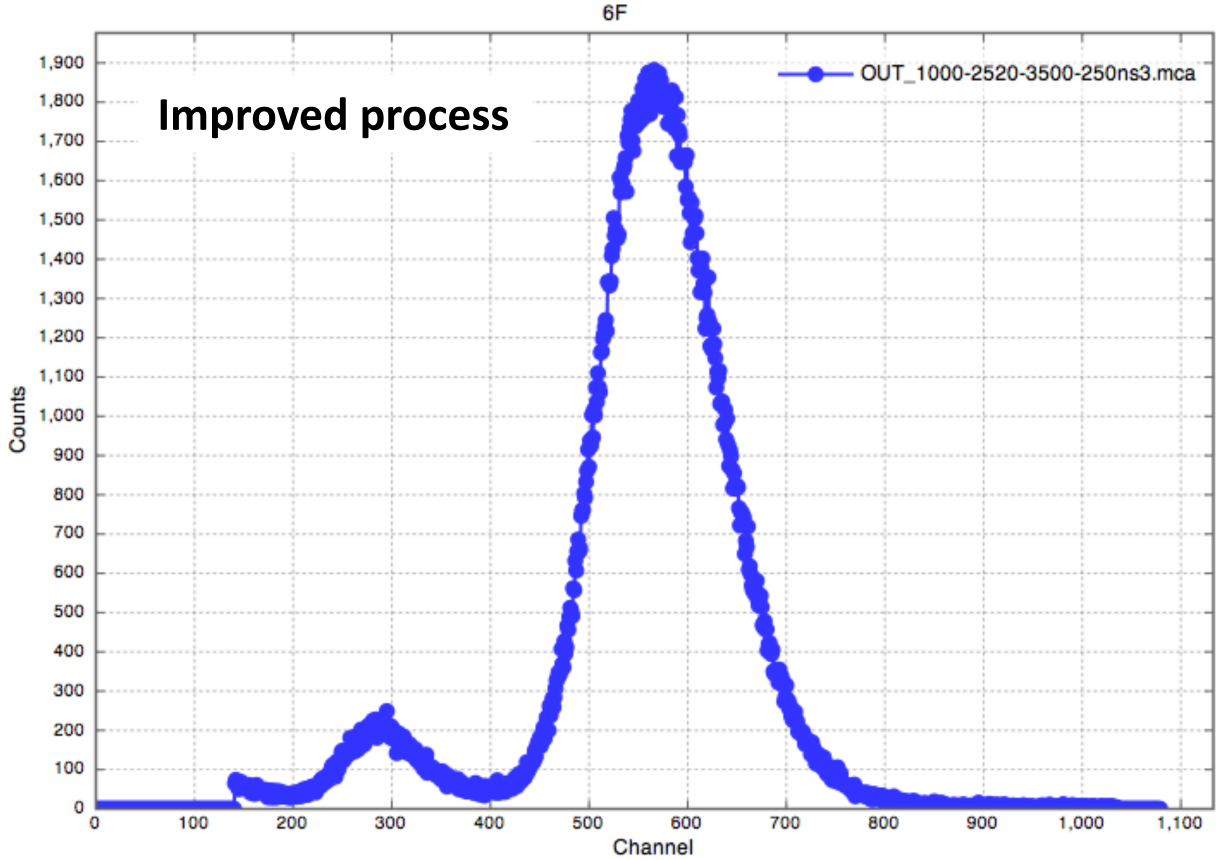


Smooth electrode: Uniformity of the electric field improves, and the GEM’s stability improves

2. The new Glass GEM fabrication process at AIST



Pulse height spectra of 5.9 keV
Energy resolution 26%, gas gain ≒3,000



Pulse height spectra of 5.9 keV
Energy resolution 22%, gas gain ≒3,000

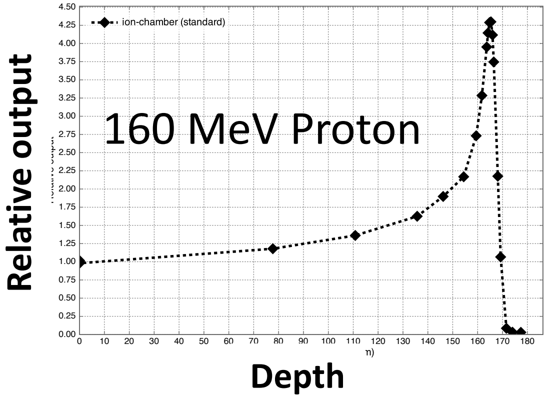
Discharge rate < 1/hour

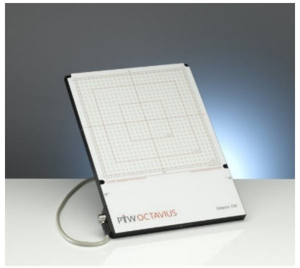
DOSE IMAGER FOR HADRON THERAPY

1. Background and motivation – what is the issue for dosimetry?

Conventional detector 1: Ion chamber

- Standard in clinical use
- Sharp Bragg peak is achievable
- Peak-to-Plateau ratio up to 4~5.
- **Spatial resolution is not enough (5mm)**
- **Takes time for each measurement**





Ion Chamber array

(5mm pixel)

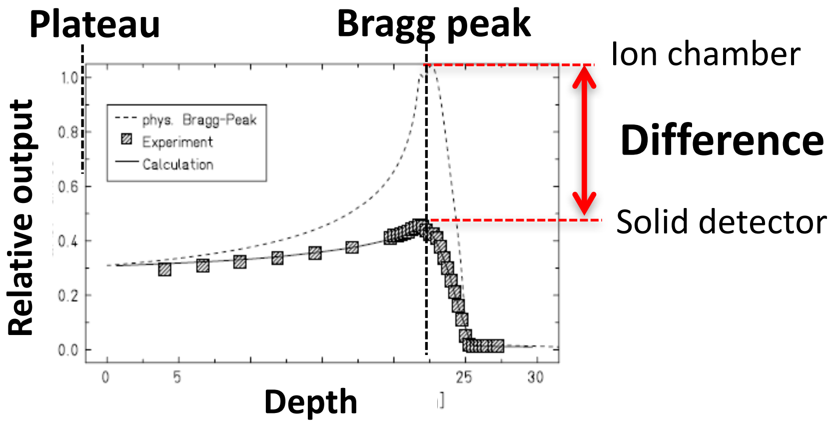
Peak-to-Plateau ratio

4.2 ~ 5.0

Proton/Carbon beam

Conventional detector 2: Solid detectors

- Great spatial resolution (films, imaging plates, scintillator screens, semi-conductors)
- Radiation hardness would be an issue
- **Saturated in Bragg Peak**



Peak-to-Plateau ratio

1.3 ~ 3.2

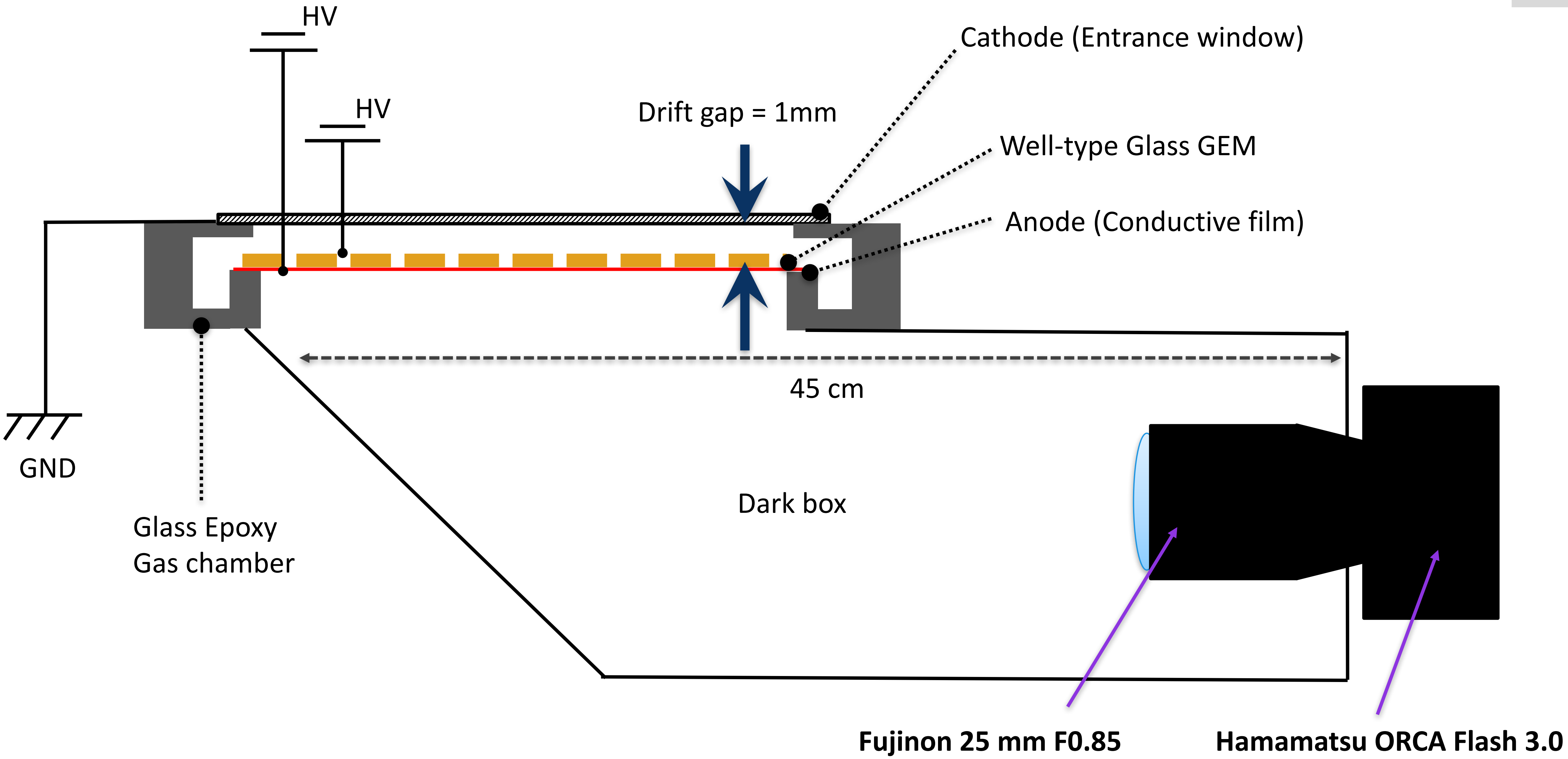
Proton/Carbon beam

Solid detectors has a quenching effect in high-LET radiation.

- Energy deposition density at Bragg Peak is larger than the density of luminescense center.

MPGDs have very little quenching effect and high spatial resolution

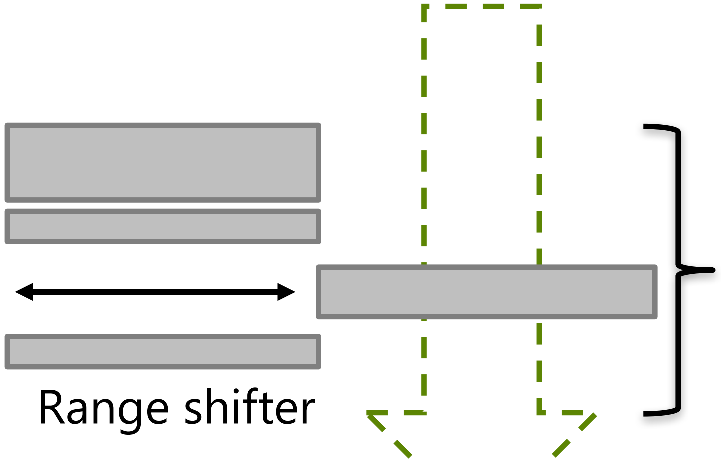
Detector construction (side view)



Updated to Brighter lens, high sensitive camera and shorter camera mount.

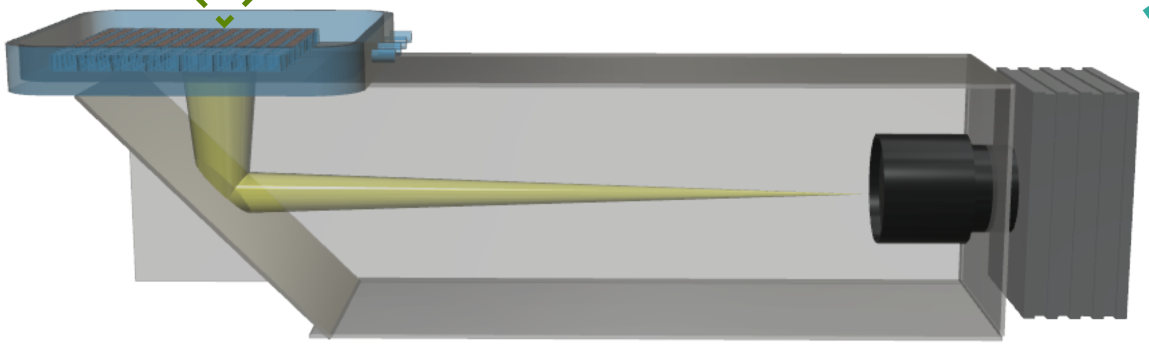
Experiment

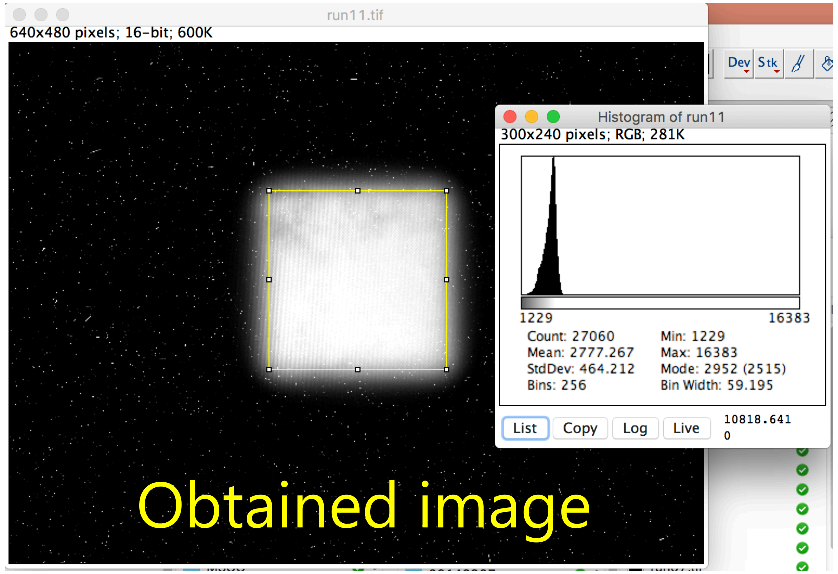
Hadron beam

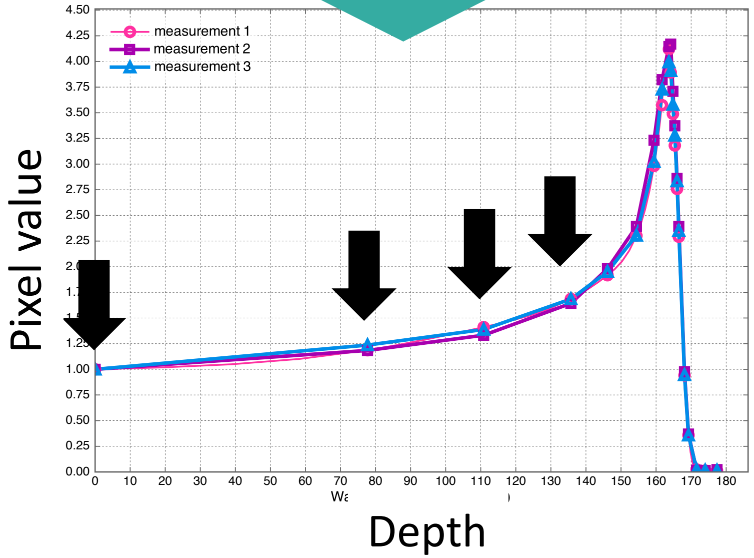


At HIMAC (Clinical Beam)
Intensity: $1.8*10^9$ particles/sec

Control depth of the measurement (water equivalent)

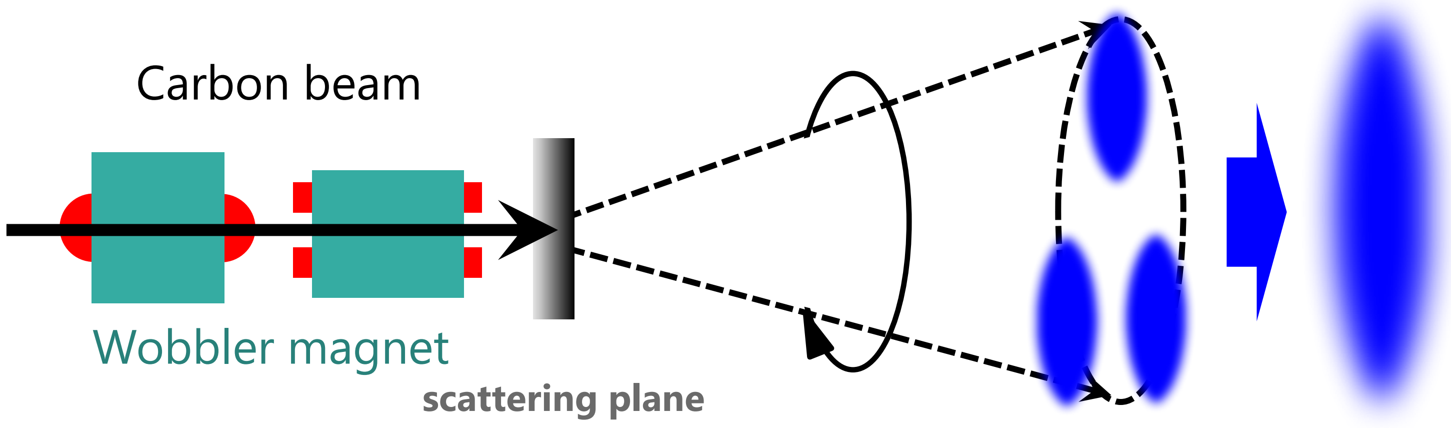


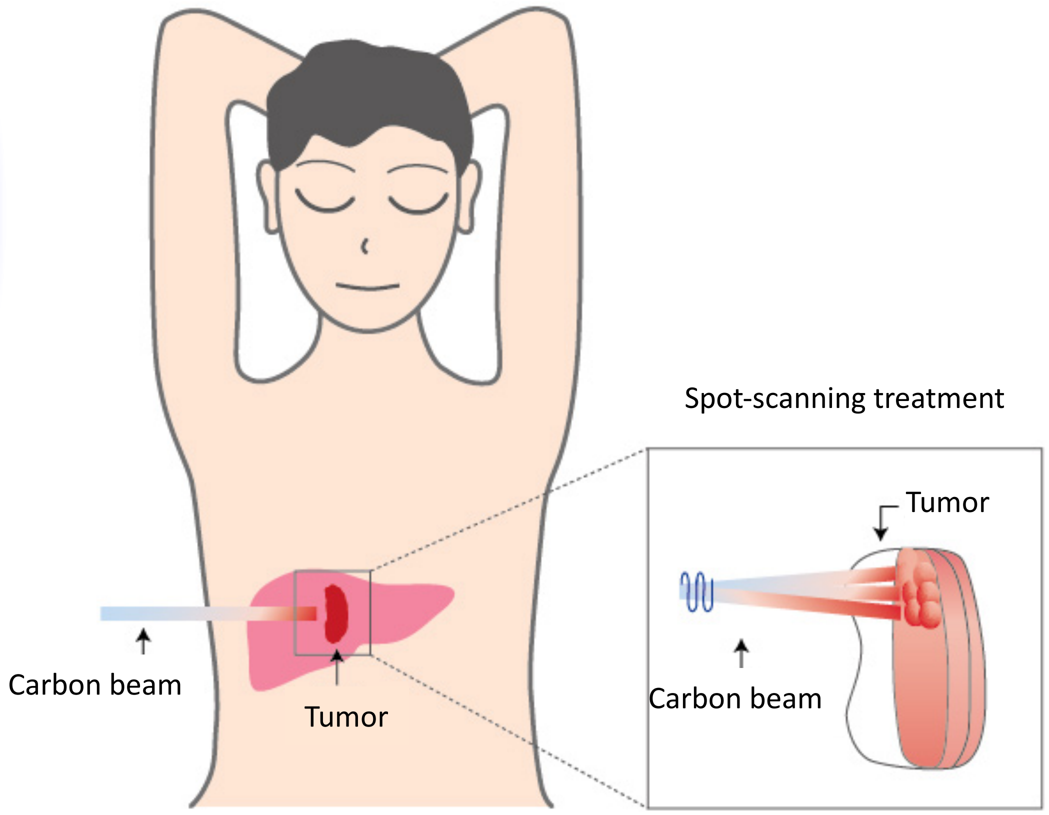




The pixel value of obtained image from CCD camera is plotted for each depth.

290 MeV/u Carbon spot scanning treatment



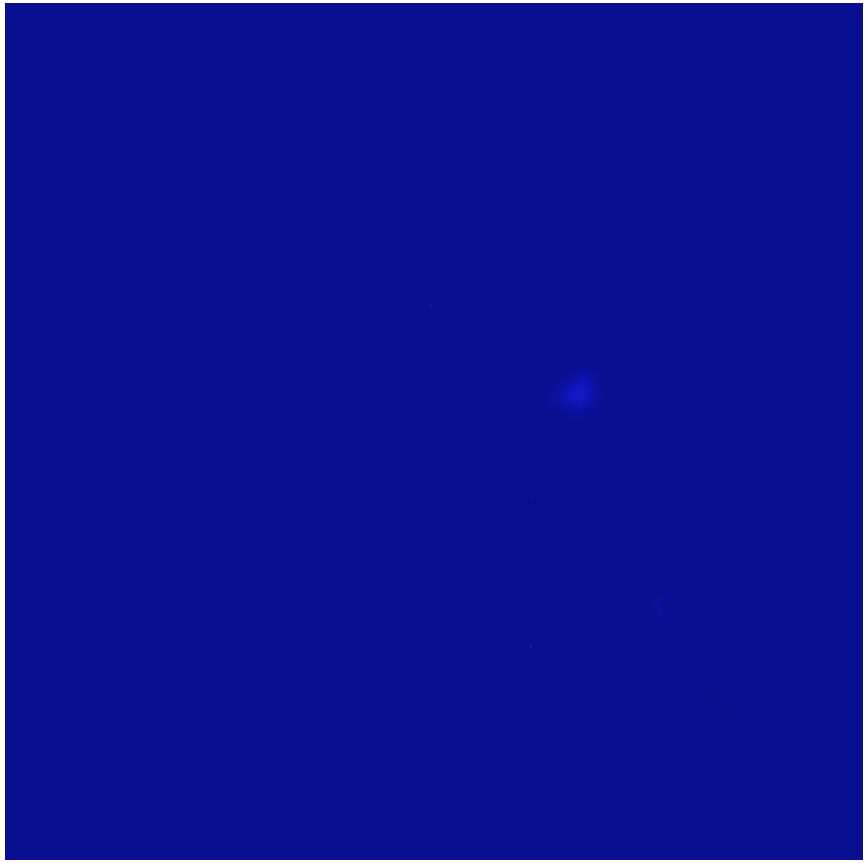


High speed dose imaging demonstration

- Real-time imaging of 290 MeV/u Carbon beam
- 3Hz Scanning beam with Wobbler magnet.

The high dose spots are scanned one after the other over the whole tumor volume

First real-time dose imaging of spot-scanning technique

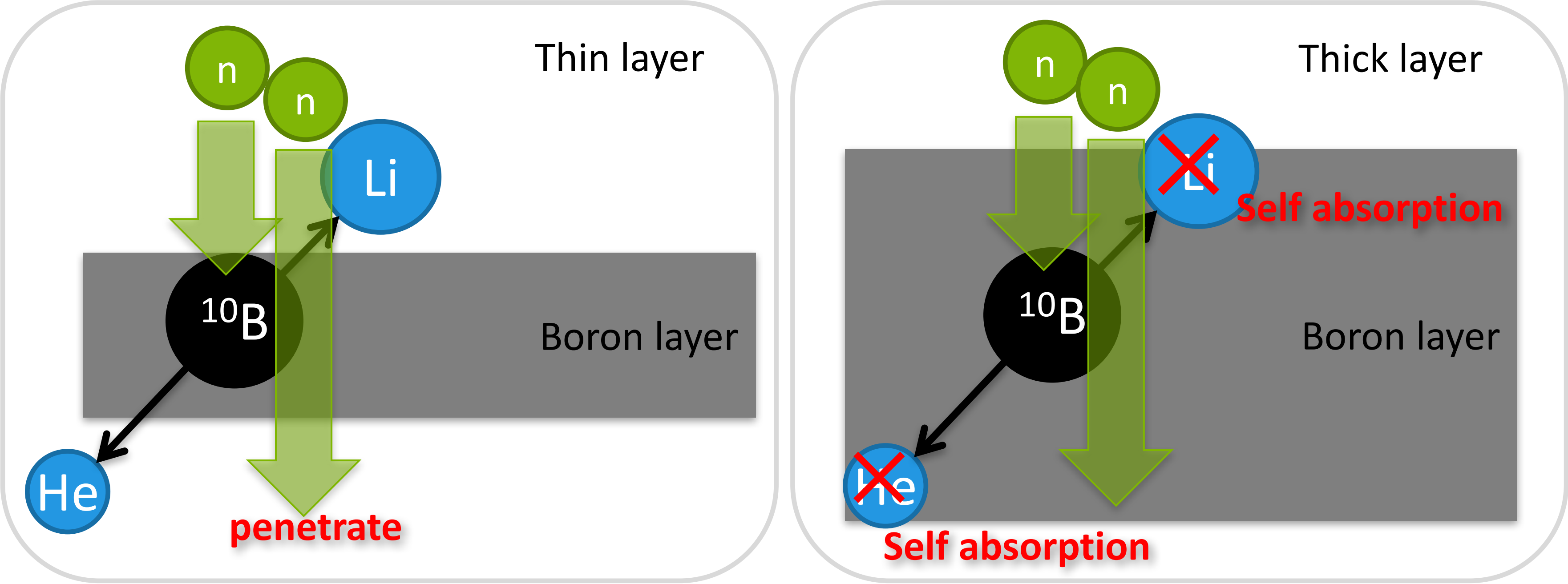


A treatment example of prostate cancer

Succeed in taking real-time dose imaging of active hadron therapy (50ms/frame)

Bragg-Edge Neutron Imaging Detector

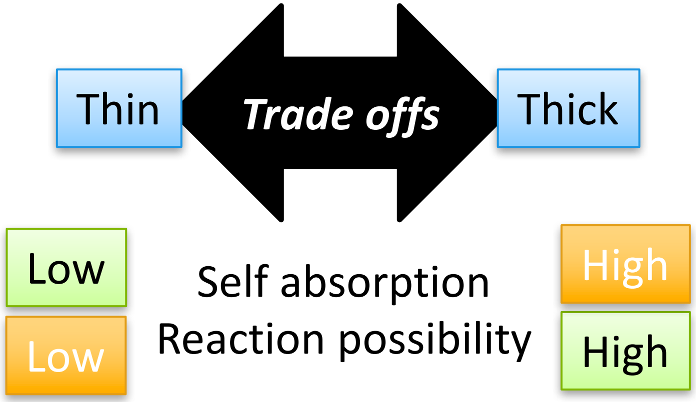
Micro-structured Boron detector



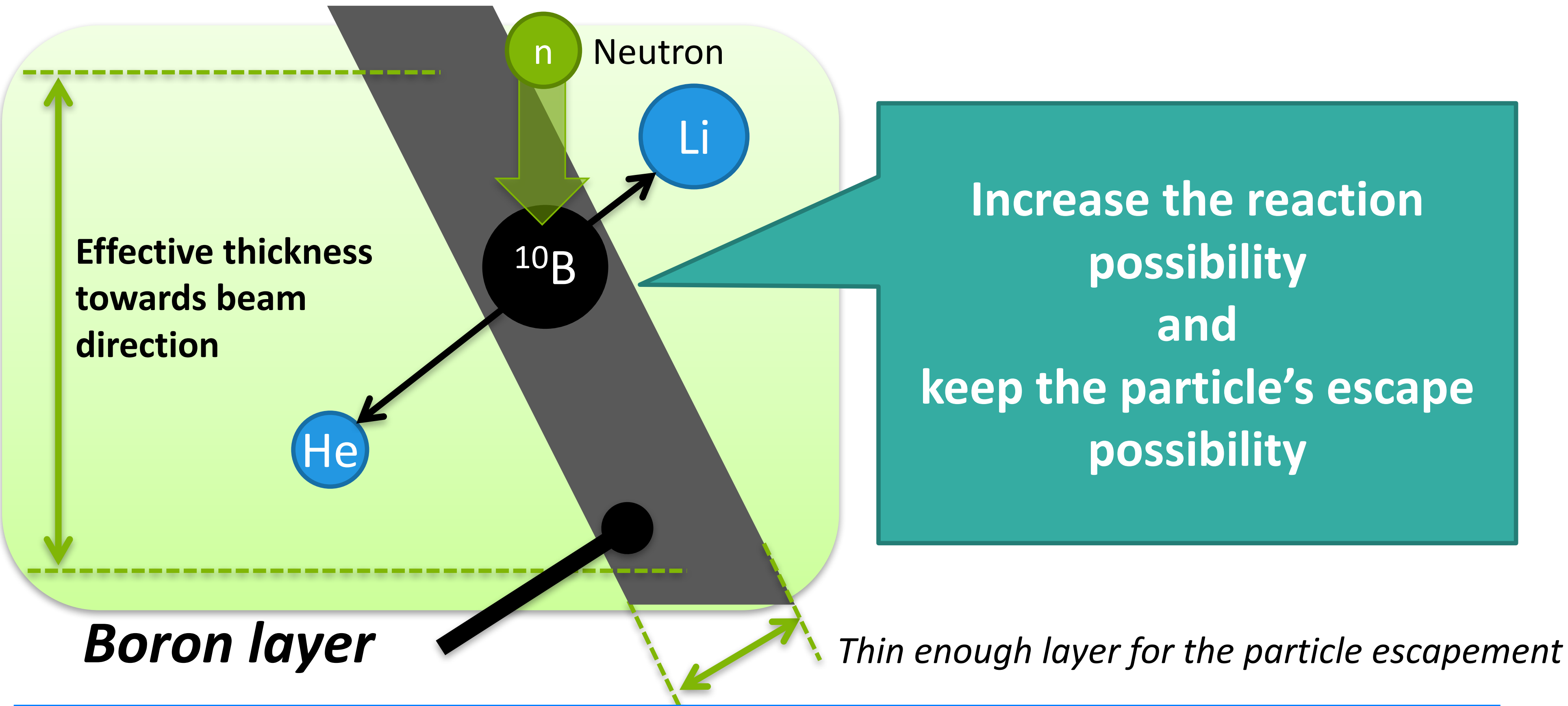
Reaction possibility -> Low
Self absorption -> Low

Reaction possibility -> High
Self absorption -> High

- B-10 are low price neutron converter
- Detect the charge from ionized α/Li particle
- Self absorption of the particle is an issue
- Charged particle cannot escape to counting gas

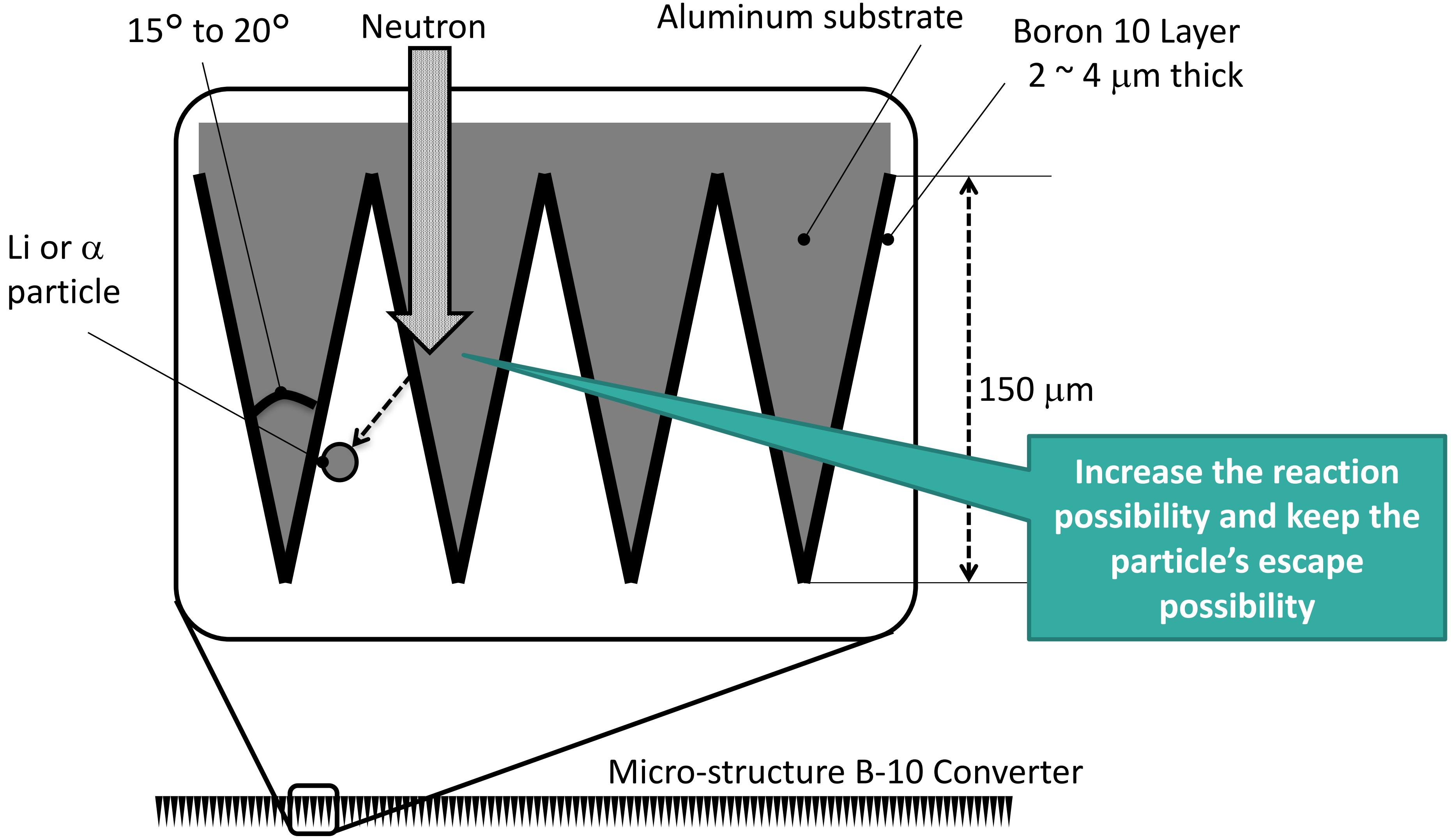


Micro-structured Boron detector

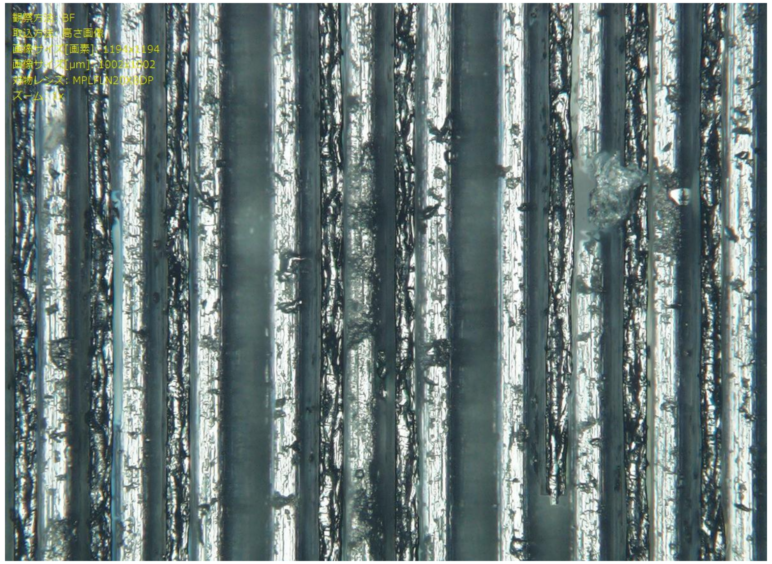


- Slanting the absorber layer towards the incoming beam
- Grazing incident angle allows a larger proportion of neutrons to be absorbed in the first few microns of the layer
- It results secondary particles have a higher probability of escaping into the counting gas.
- This leads to increase neutron detection efficiency.

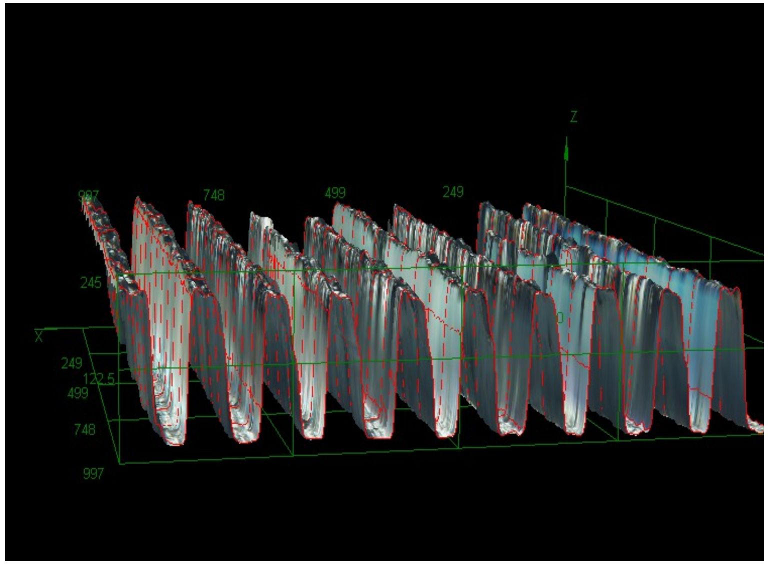
Micro-structured Boron detector



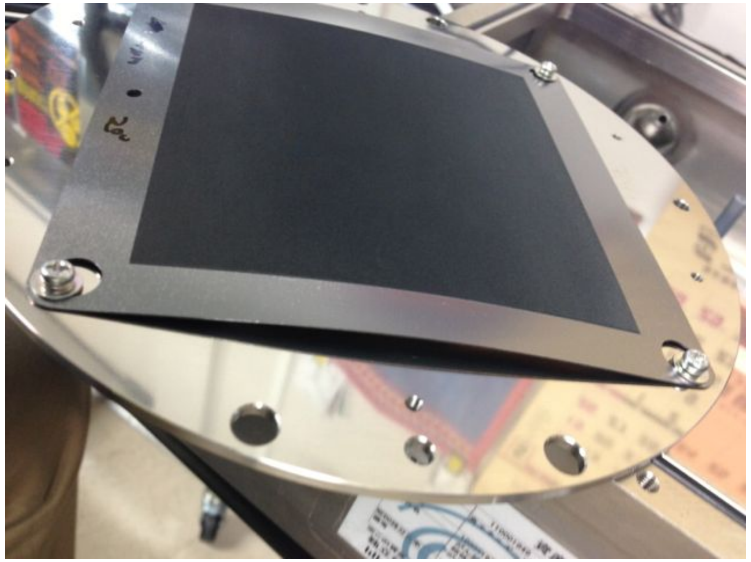
Micro-structured Boron detector



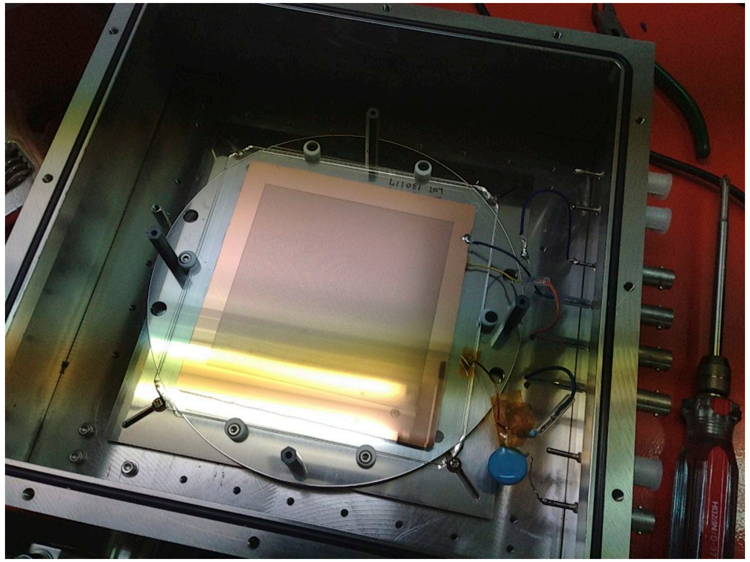
Micrograph of converter



3-D image

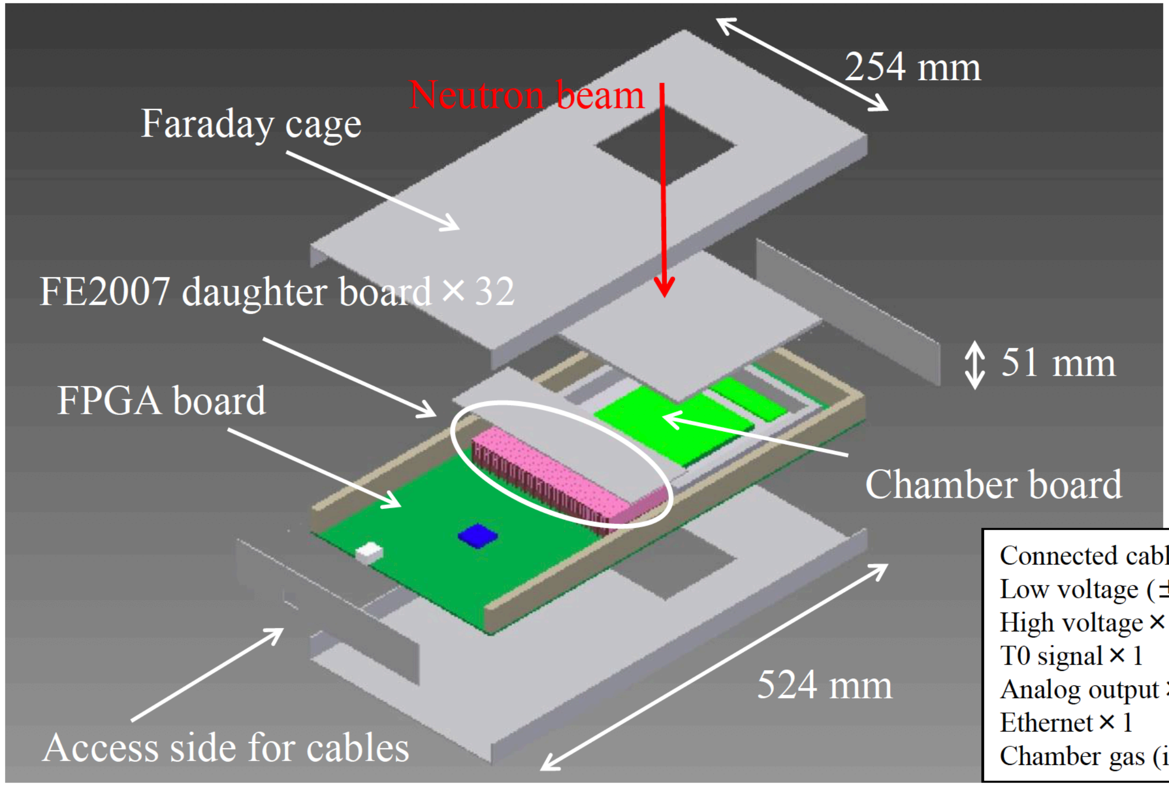


Picture of the micro-structure converter

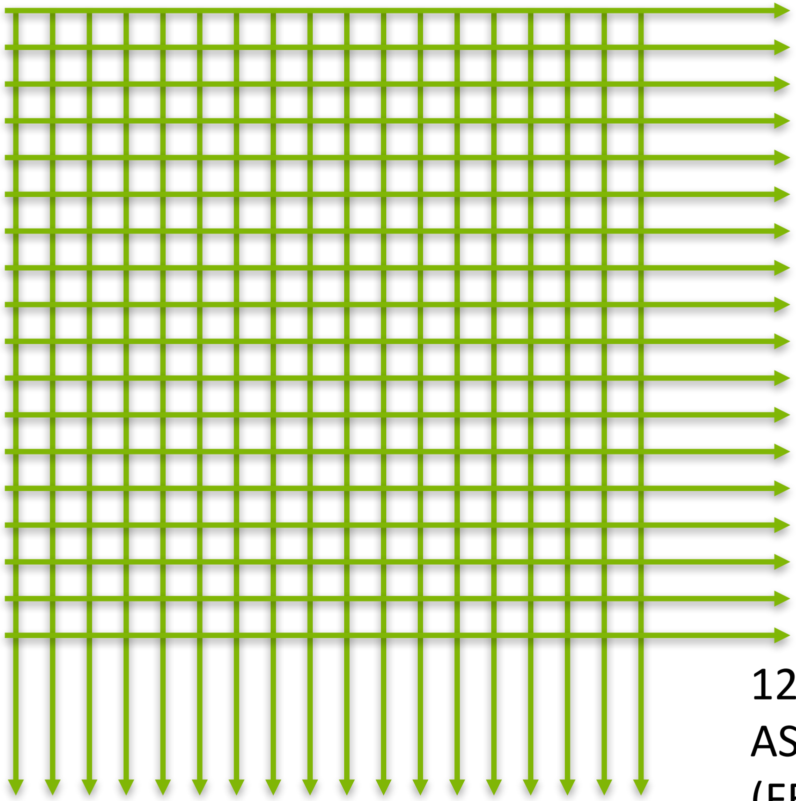


Glass GEM

Readout design



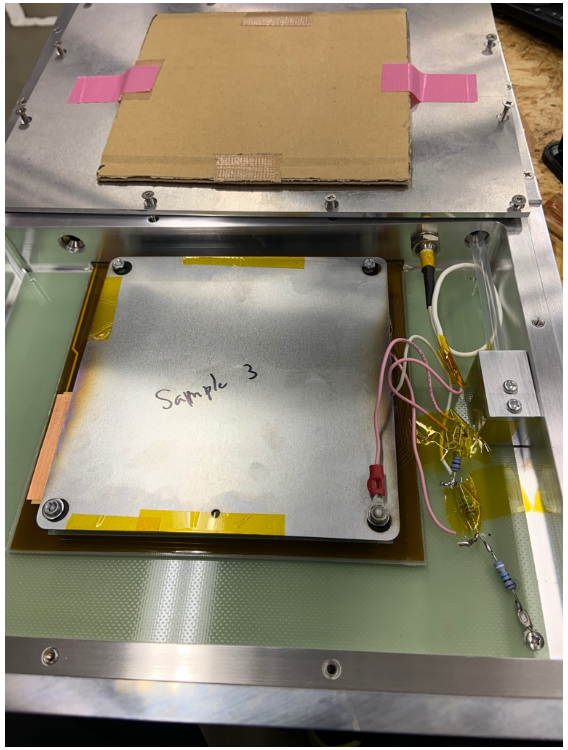
Connected cables and tubes are:
Low voltage (±5 V) × 1
High voltage × 1
T0 signal × 1
Analog output × 1
Ethernet × 1
Chamber gas (input and output) × 2

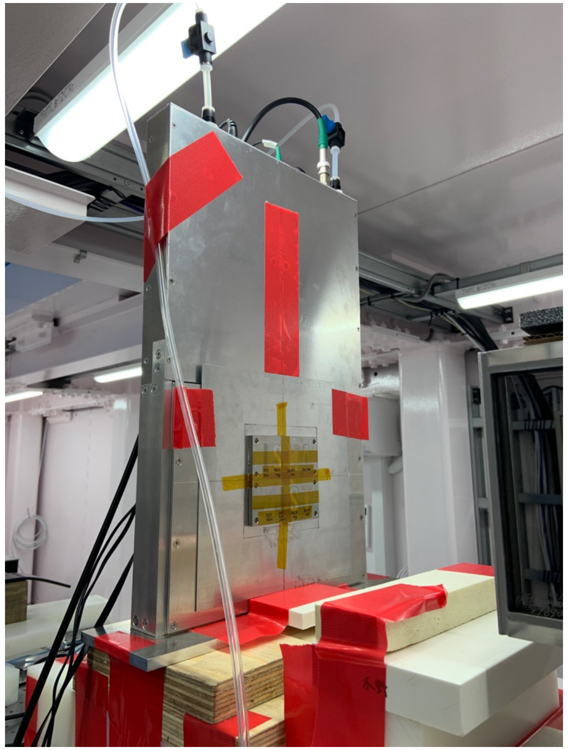


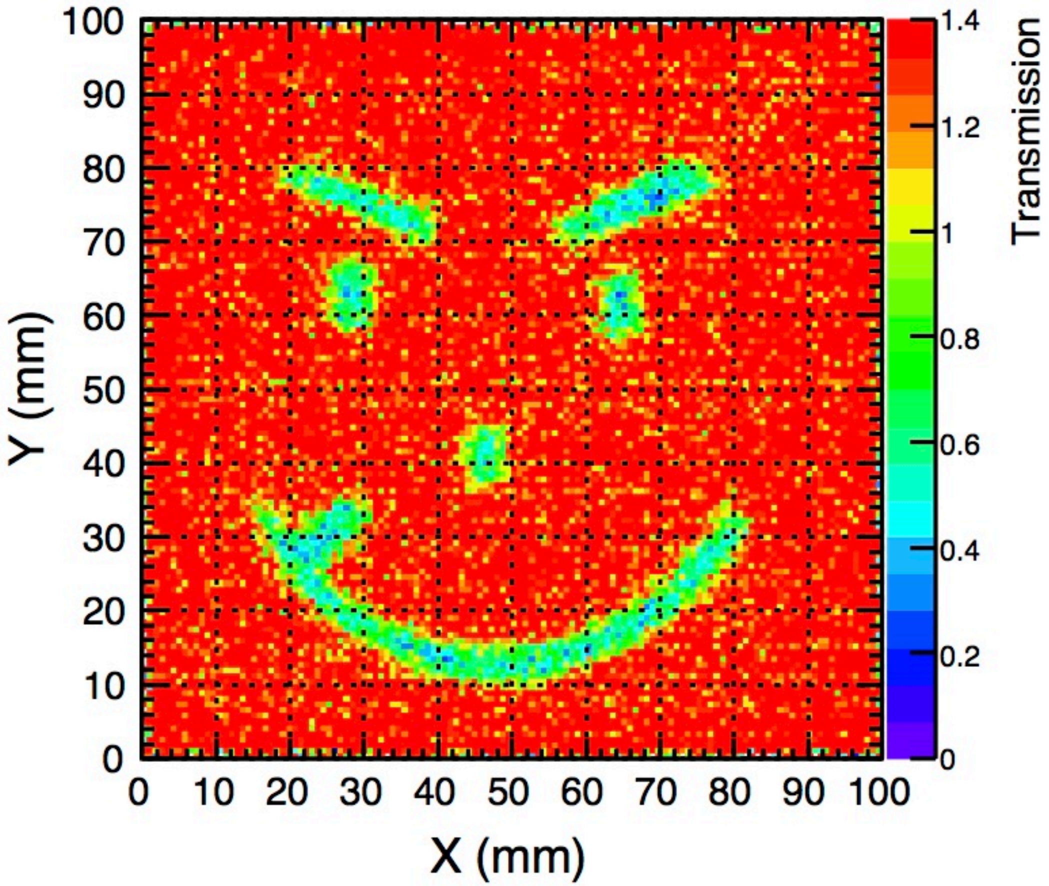
128ch
ASIC
(FE2009)

128ch
ASIC
(FE2009)

First neutron beam test at AIST







Spatial resolution =0.8mm (FWHM)

Summary

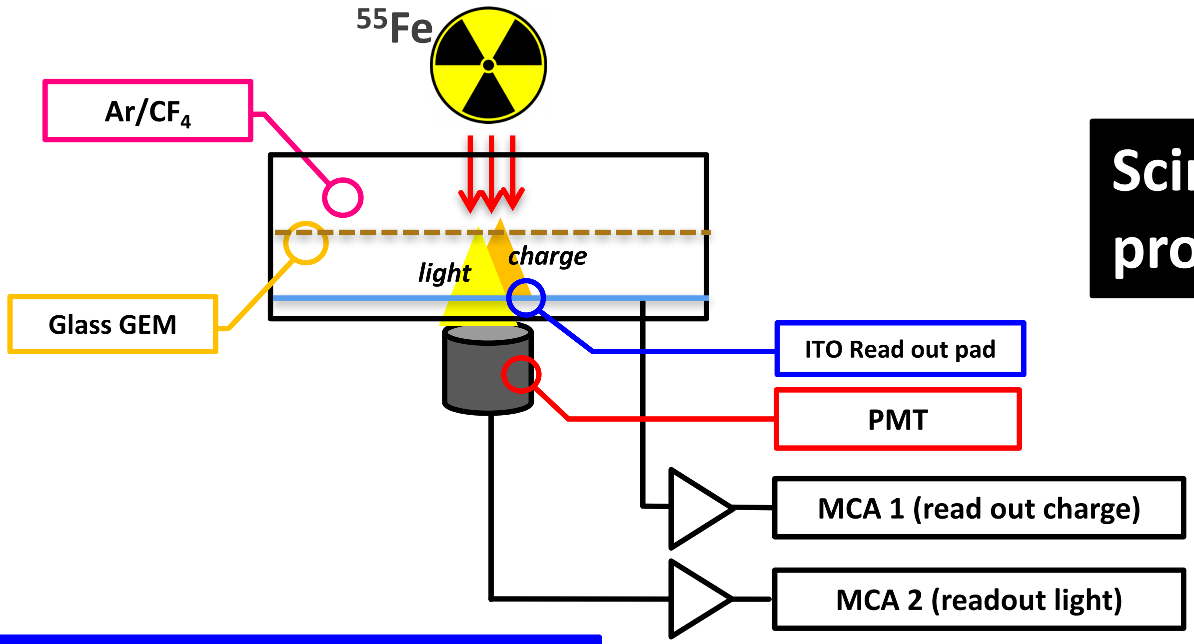
- Introduced the new fabrication process of Glass GEM
- **Proposed a new application of gaseous detector**
    - Dose imaging detector for hadron therapy
    - Neutron Bragg-edge imaging detector

- Glass GEM is now open to everyone, and collaborators are always welcome

Thank you for your kind attention.

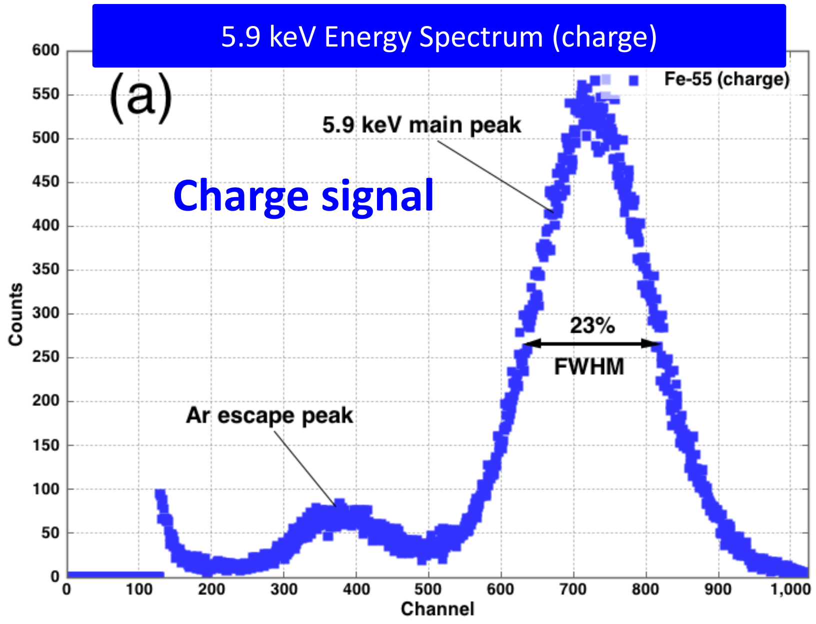
BACKUP SLIDES

3. Initial experiment：55Fe (5.9keV X-rays) & PMT [7]

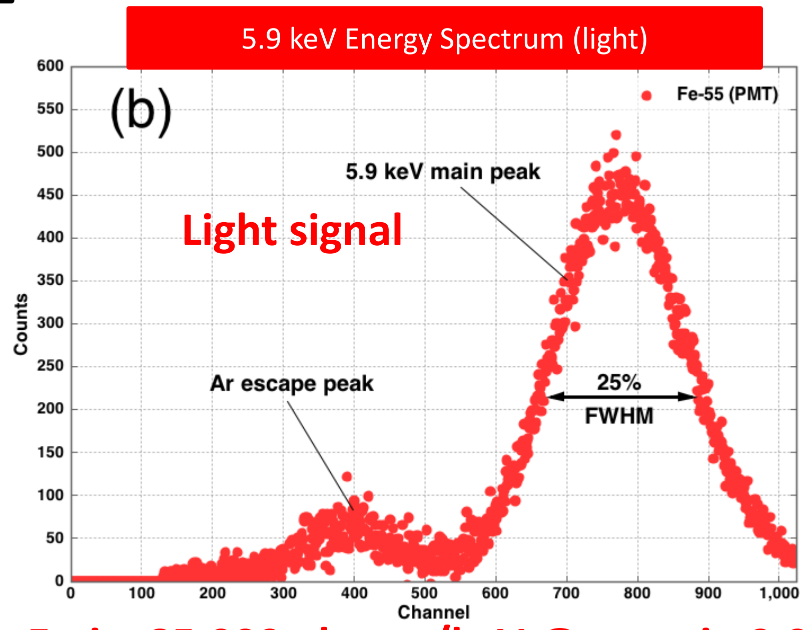


Scintillation light from Glass GEM is proportional to charge

Charge and light measured at same time



Good match



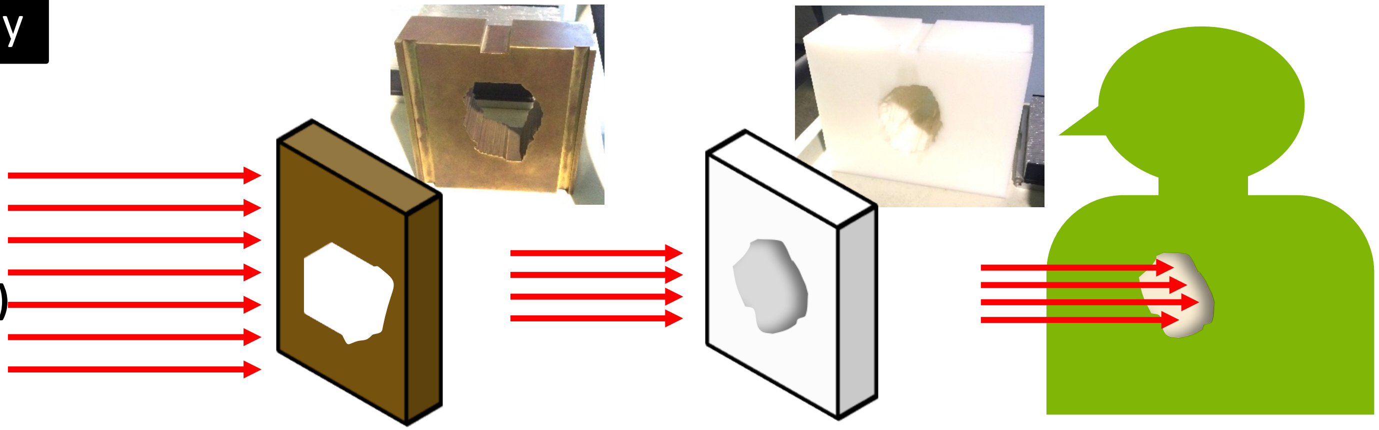
Emits 85,000 phtons/keV @gas gain 9,000

[7] T. Fujiwara, et al.,Jpn. J. Appl. Phys., vol. 55, no. 10 (2016)

1. Background and motivation – what is done in hadron therapy?

Hadron therapy

Hadron beam
(Proton/Carbon)



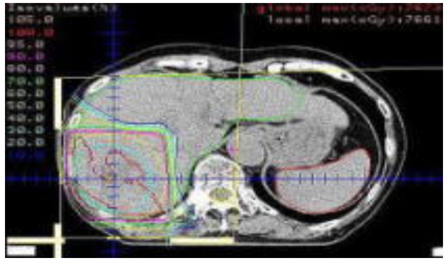
Collimator **Bolus (moderator)**

Personalized 3D dose formation is made with Collimator and Bolus for each patient.

Quality assurance

(1) X-ray CT

(2) Treatment plan



(3) Evaluation with dosimetry

(4) Treatment

Before the treatment, **quality assurance of treatment** is done with **precise dose measurement.**

Personalized dose is measured and <u>must be confirmed</u> that has good enough agreement with the treatment plan.