Micro-pixel chamber with photo readout

Atsuhiko Ochi
Kobe University

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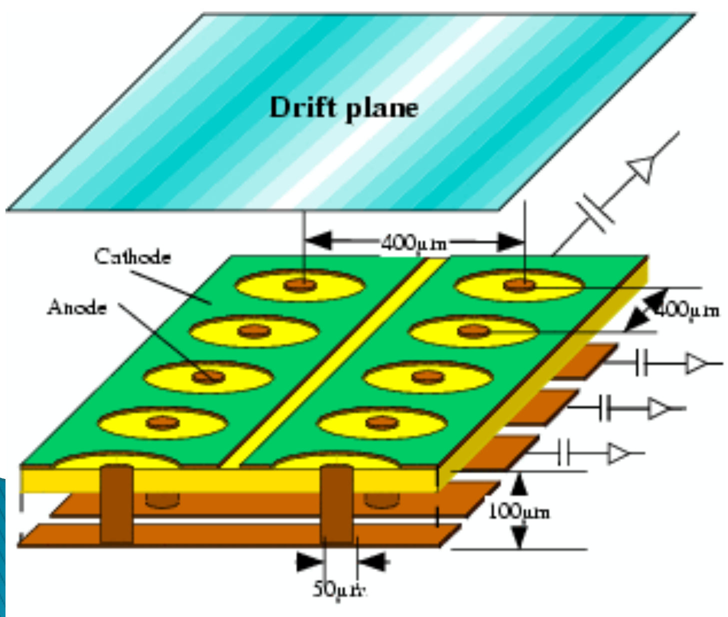
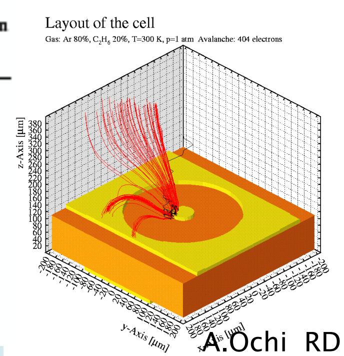
Introduction to μ−PIC

- μ-PIC：micro pixel gas chamber
- Large area with PCB tech.
- pitch :400μm
- high gas gain
- small discharge damage

	MSGC	μ-PIC
Maximum gain	1700(with capillary)	15000
Stable Gain	1000	7000
Long time		>30 days
Area	10×10cm²	30×30cm²
Pitch	200μm	400μm (300μm possible)
uniformity（σ）	~35%	4%

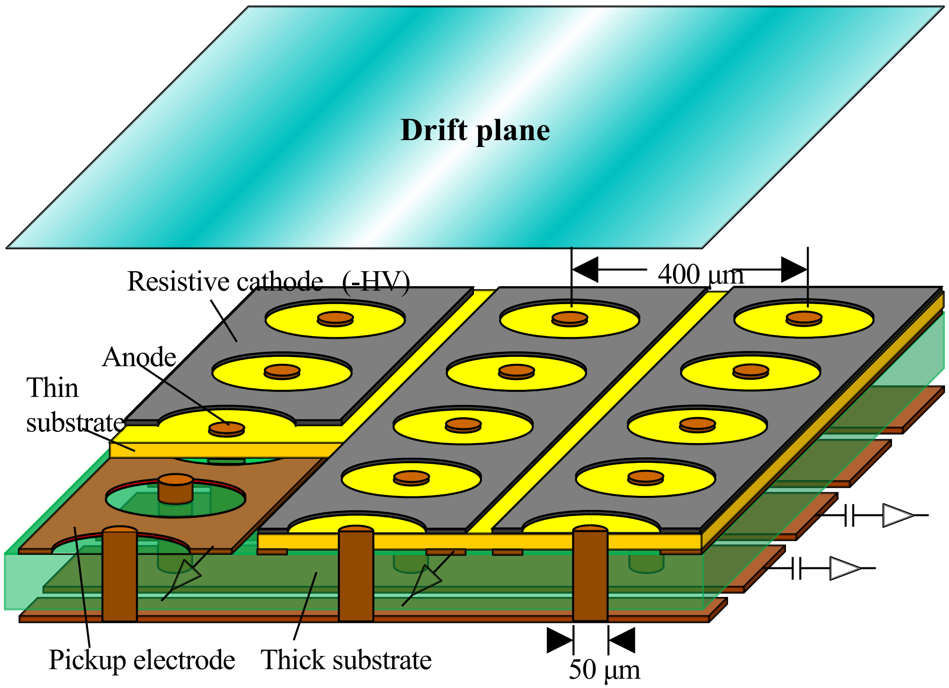


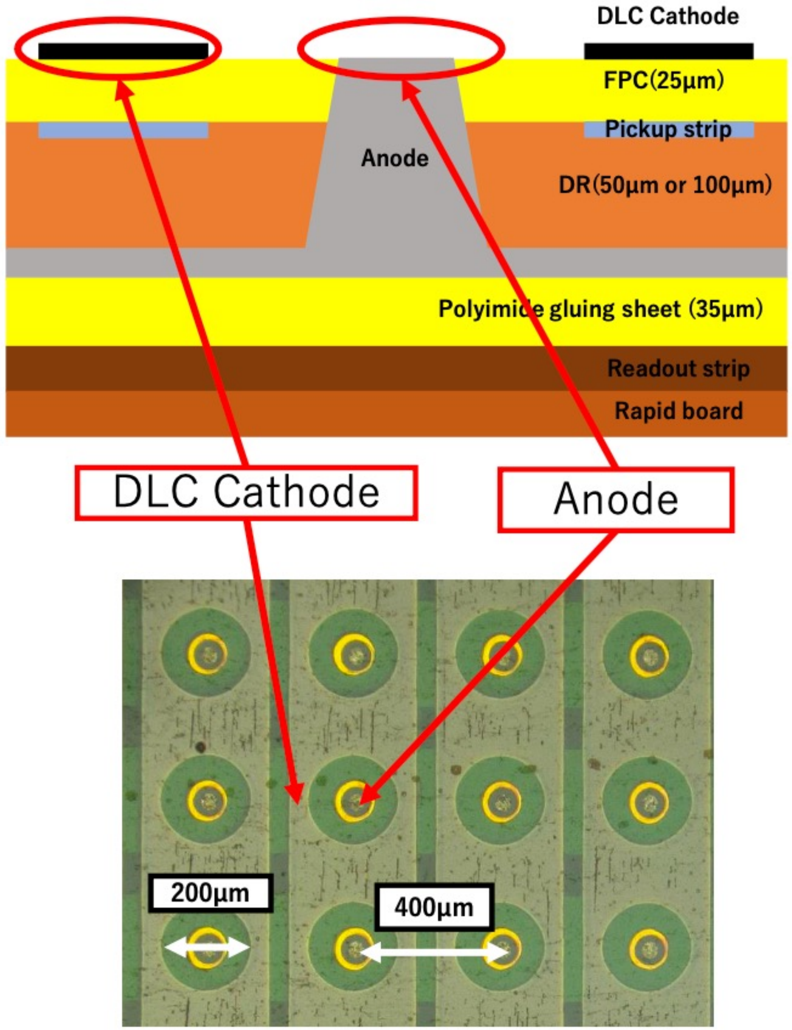


Invented by A.Ochi and T.Tanimori
(NIMA 471 (2001) 264)
Application: X-ray imaging, Gamma camera, Medical RI tracing, etc.

DLC u-PIC

- Fine patterning … μ-PIC with resistive cathode

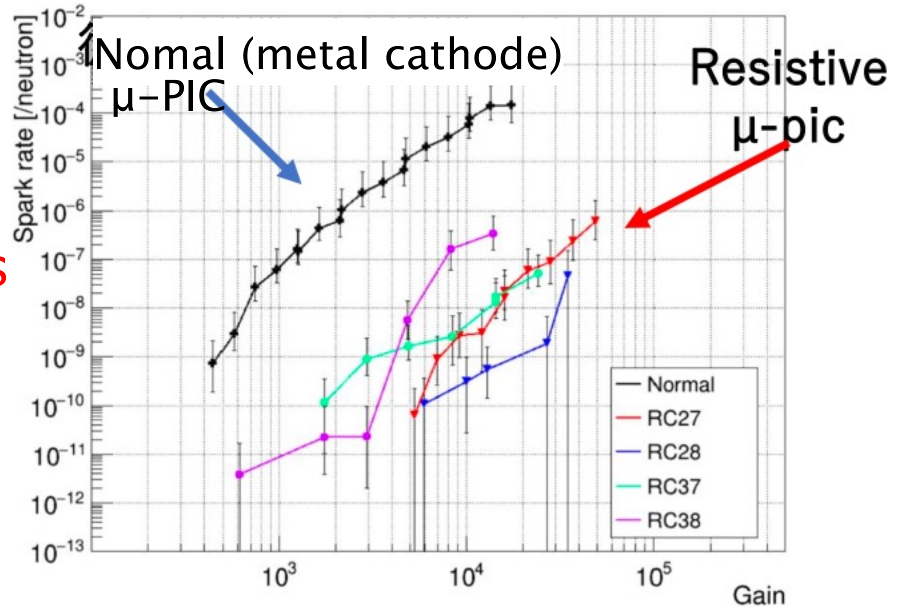




Spark reduction with resistive electrodes

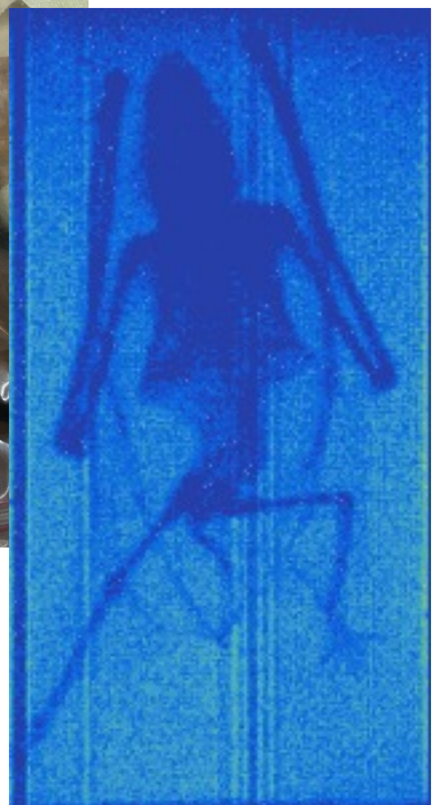
- Strong spark reduction was shown at high gain(>10000) operation under irradiation of the fast neutron(a few MeV)
  - Spark rate was 10^4 times less than normal μ-PIC
    - Spark rate = Spark counts / Number of neutron

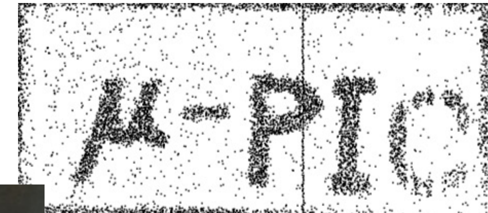
Spark rate using fast (~2MeV) neutrons

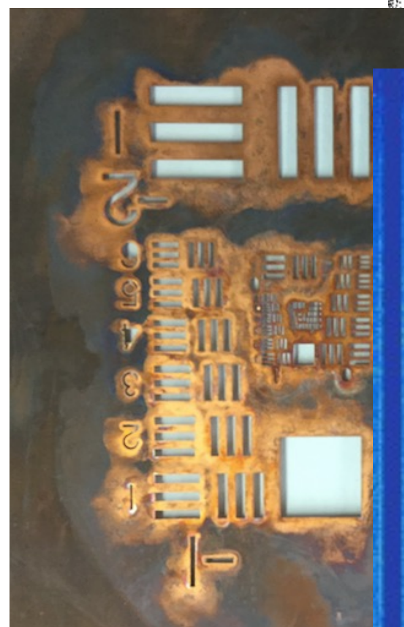


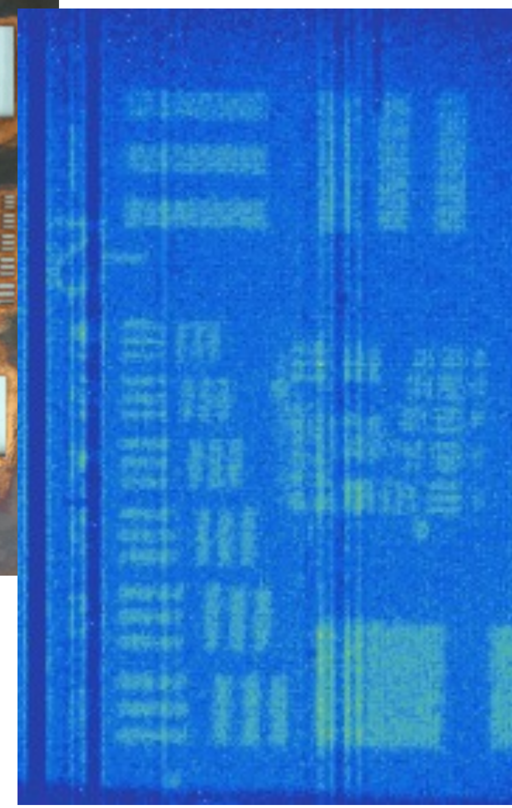
: Fumiya Yamane, et al, NIM, A 951 (2020) 162938

Imaging with SRS readout









Motivation of photo readout

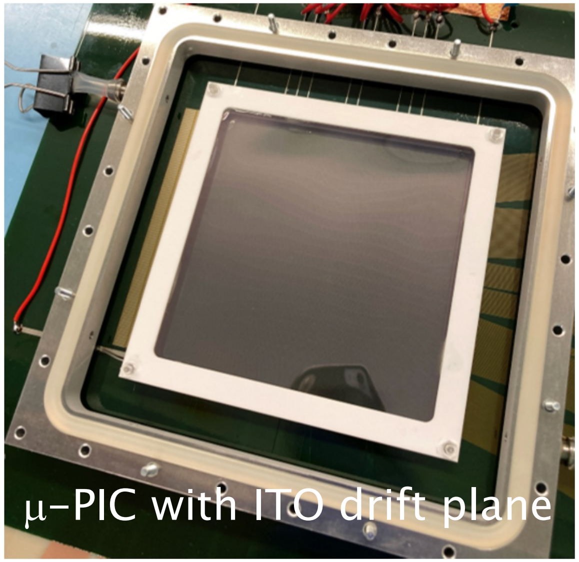
- Imaging readout with very simple electronics
- Gas multiplication process can be seen directly
  - Where avalanche process works in the detector?
    →Fine area (less than pixel pitch) can be seen.
  - Quick check for the uniformity

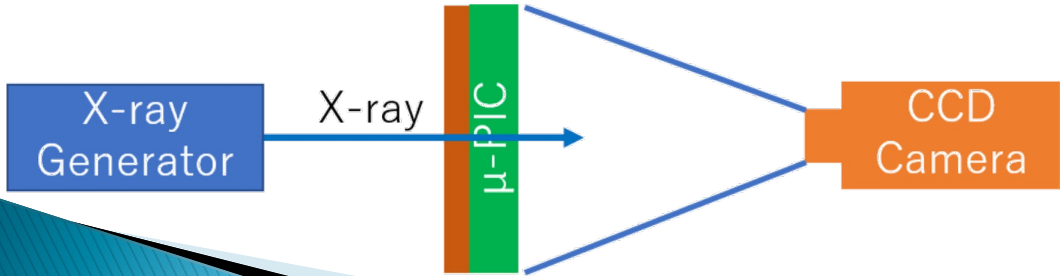
6MPixel CCD (Qimaging Retiga R6)

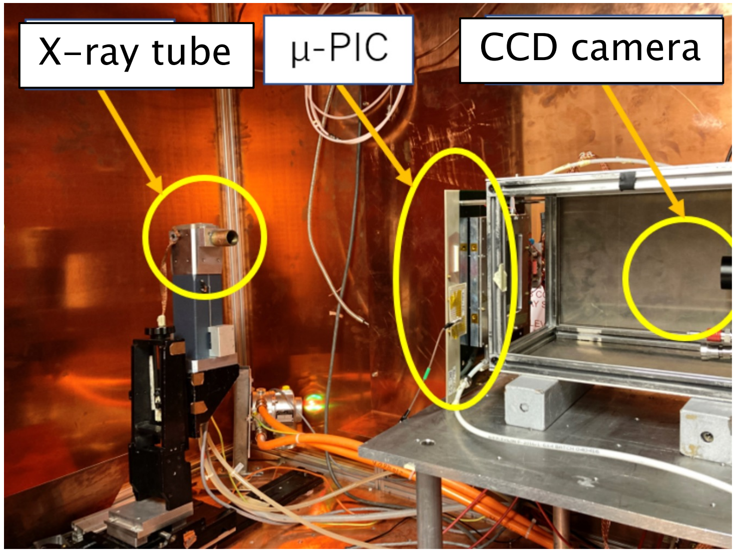
- These photo readout tests are performed at CERN GDD labo from 25th Nov. to 10th Dec. 2022
  - As a theme of master thesis by Tsubasa Yamashita
  - We have great thanks to Florian and GDD labo member
- This is a first trial for photo readout using μ−PIC

Setup for photo readout

- DLC μ–PICs with 10cm x 10cm are used
  - Two μ–PIC prototypes with different electrode structures are tested.
- A Drift electrode is replaced to ITO film
- Gas: Ar(80%)+CF4(20%)
- X–ray tube: Cu target



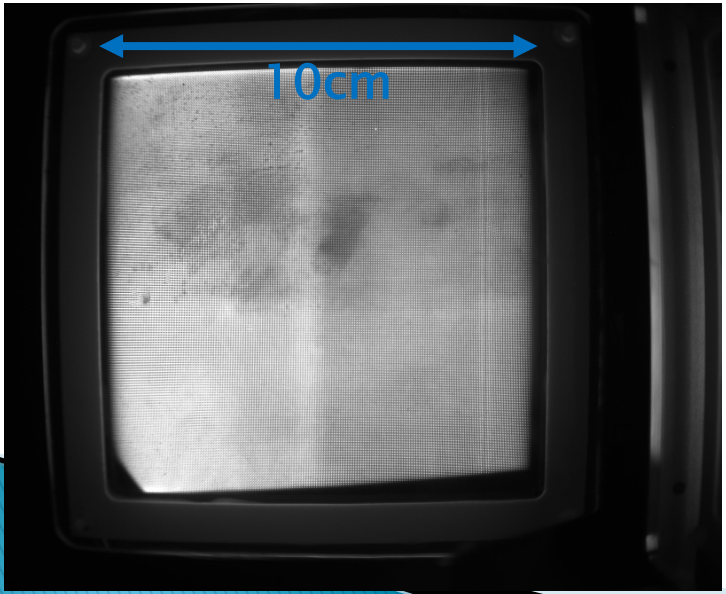




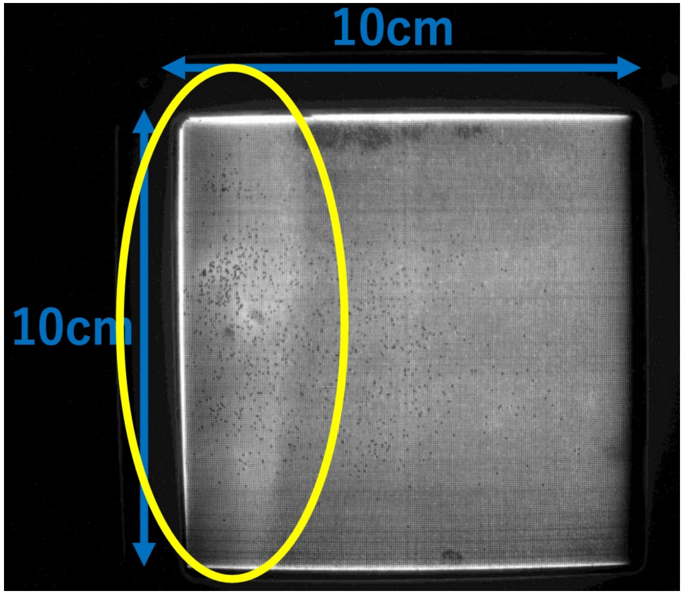
X-ray image of whole area

- Two prototypes works well.
  - RC51 has 75 μm, and RC52 has 125 μm height of anode electrodes.
- We found non uniformities and pixel defects
  - For example, inside the yellow circle is brighter than other area.
  - There are many defects in RC52 prototype
  - Edge of the area is brighter than inside.

Prototype – 1 (RC51)

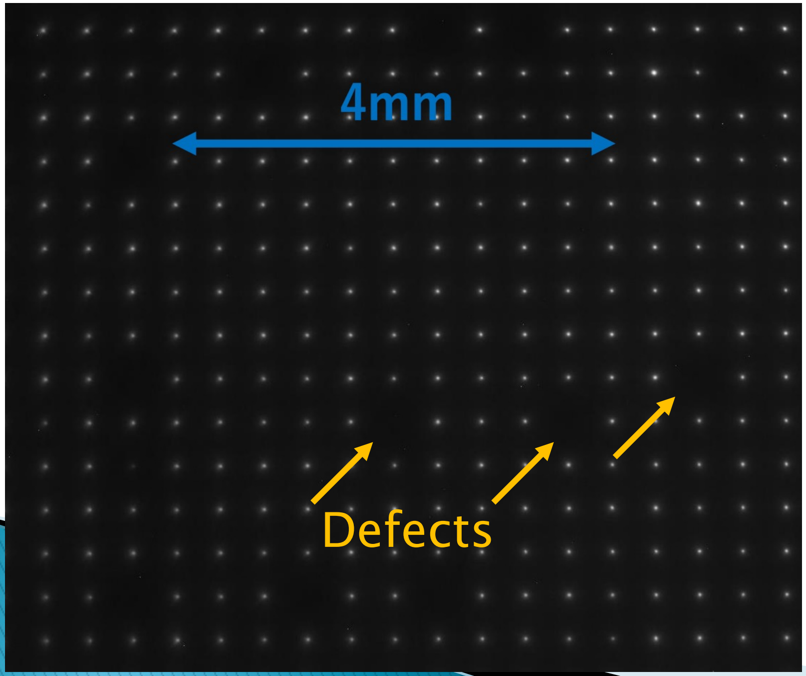


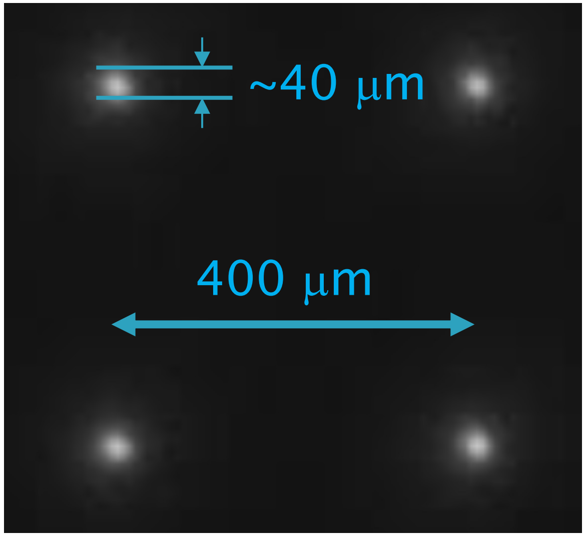
Prototype – 2 (RC52)



Magnified image shows detailed information

- We can see avalanche multiplication on each pixels using magnified lens.
  - The size of bright dot is very small
  - Size of bright spots of each pixel (~40 μm) is less than anode pixel radius (~60 μm).
  - Some pixels don't work (No bright spot)
    It was very difficult to find using electric readout.

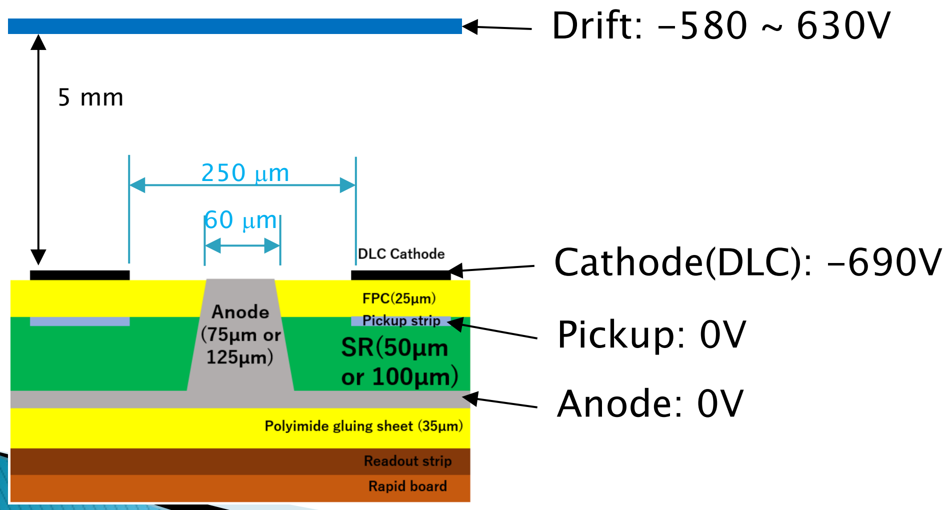




Operation in low drift field

- We have experiences when we operate the MPGDs with very low drift field, we found unstable properties. Sometimes, probability of breakdown is rising up.
- We have operate the μ-PIC with low drift field with photo readout.

- Setup



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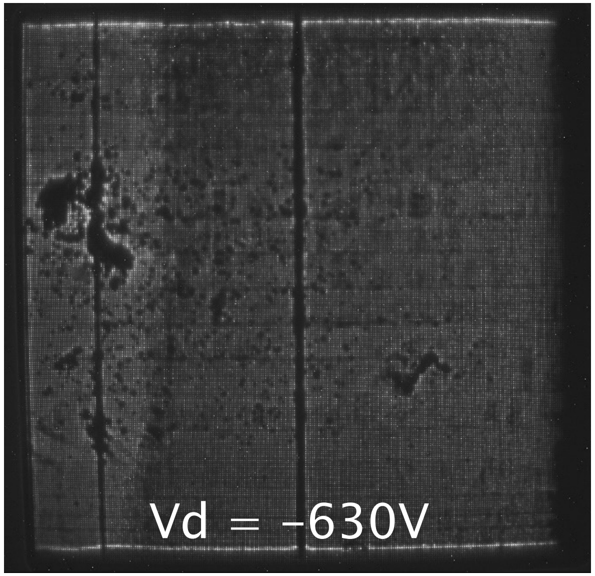

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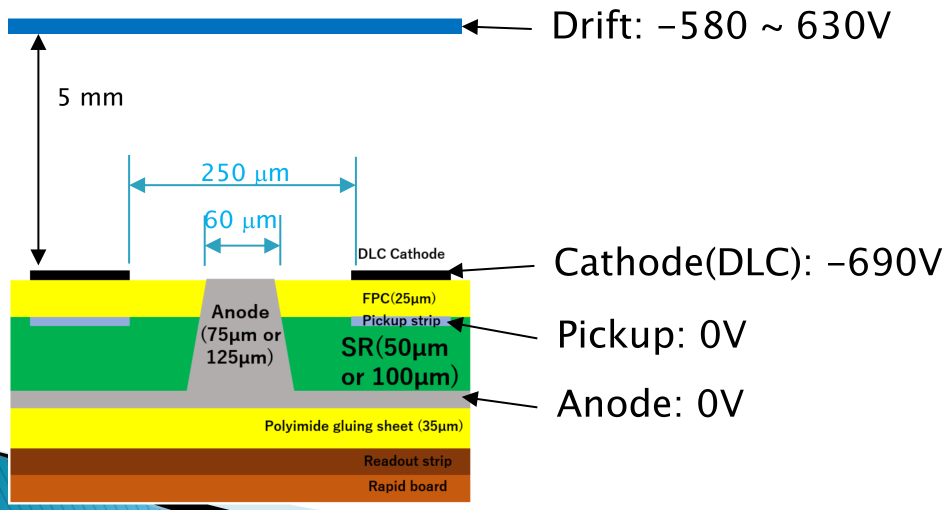

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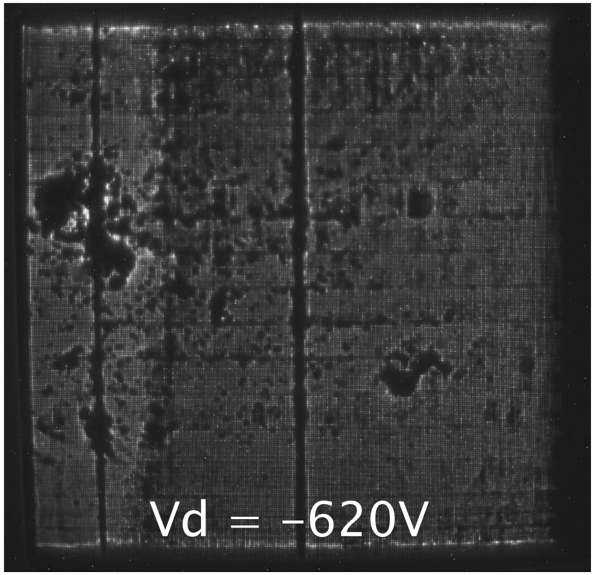

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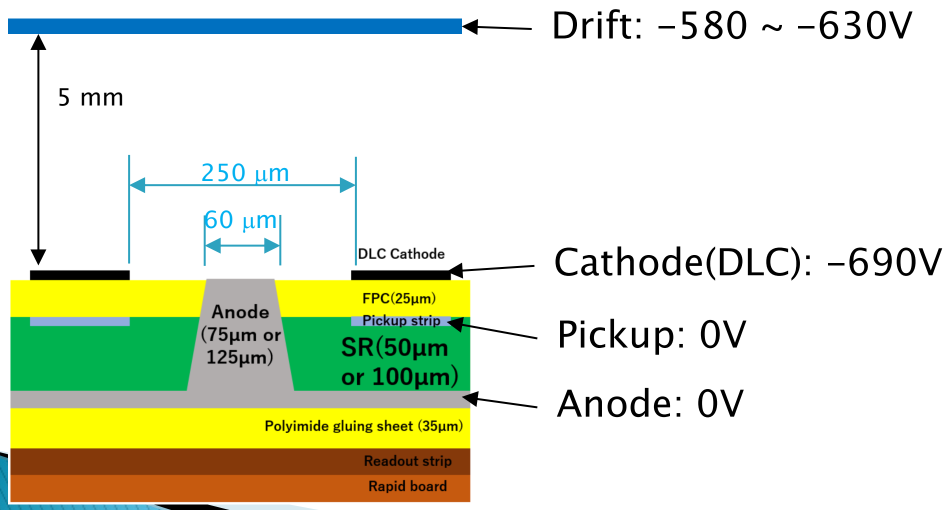

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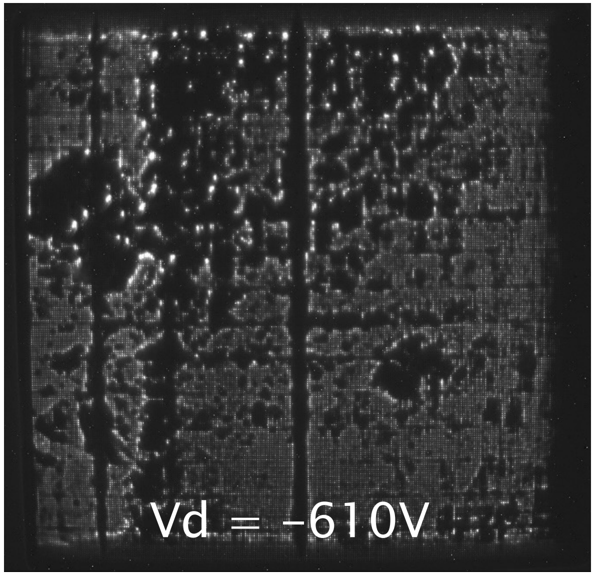

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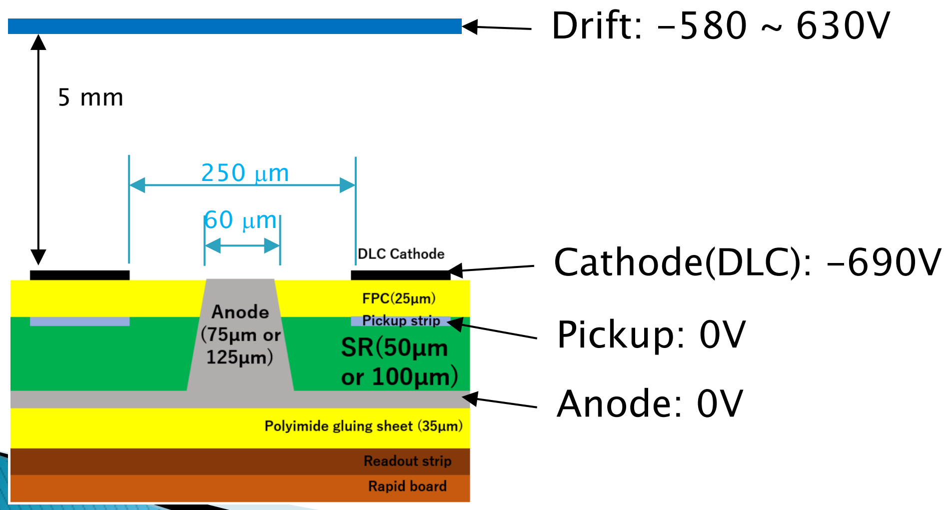

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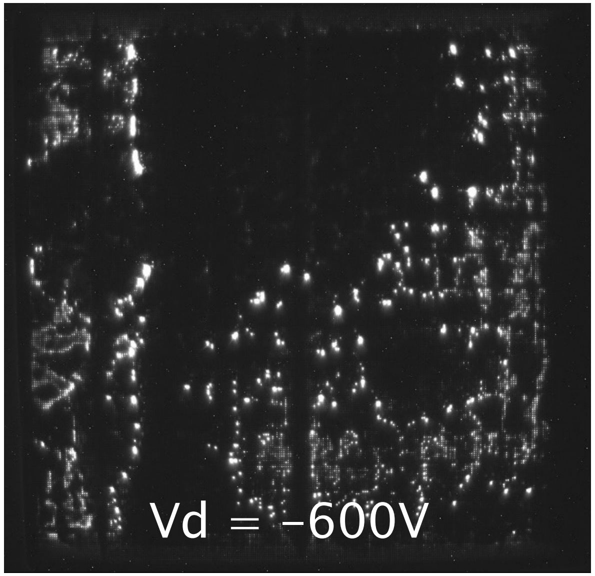

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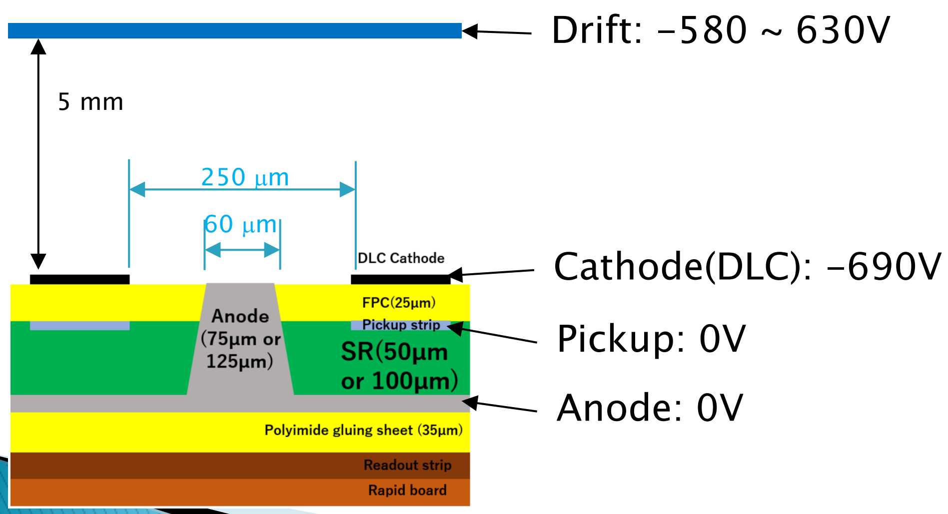

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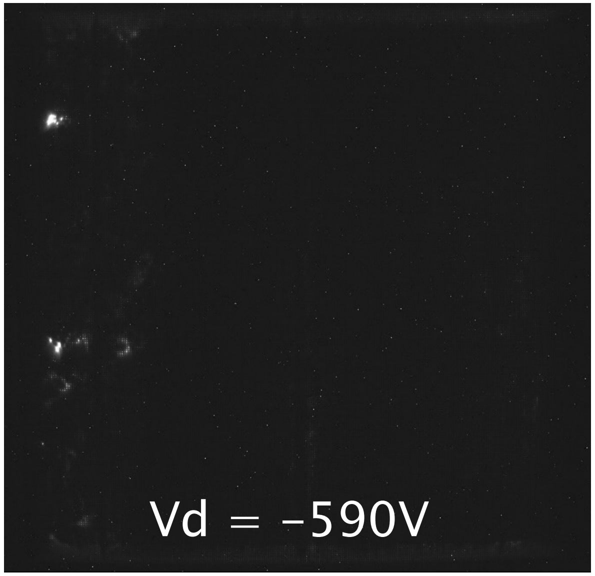
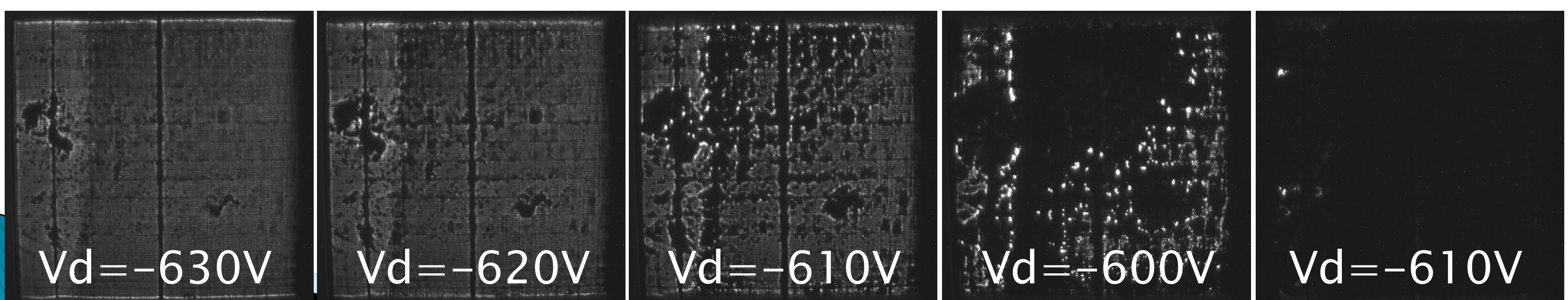


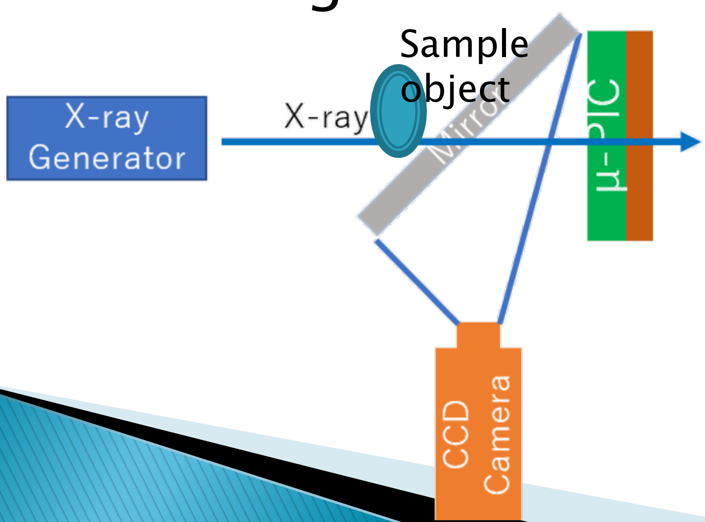
Operation in low drift field

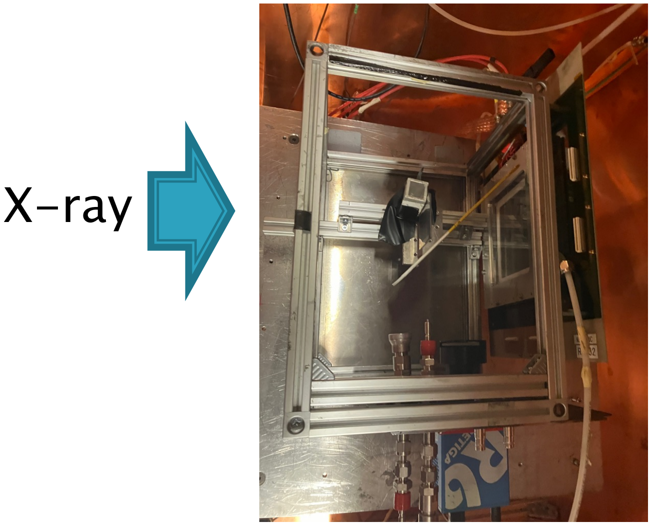
- These results shows, around the transition field for disappearing the image, there are many bright spots on the detector.
- Those unexpected bright spots might be sometimes grown over the Raeser limit, and makes breakdown.
- This phenomenon suggests, we should take care of drift voltage while ramp up/down.



Imaging test

- Setup for X-ray imaging
  - We cannot use Cu Kα (8 keV) X-rays using backward irradiation, due to X-ray absorption in PCB.
    - Penetrate probability of 8keV X-ray is around 0.05%.
    - Photo image are generated by higher energy X-rays, which smear the position information.
  - For using Cu Kα X-rays, the setup is changed as followings.



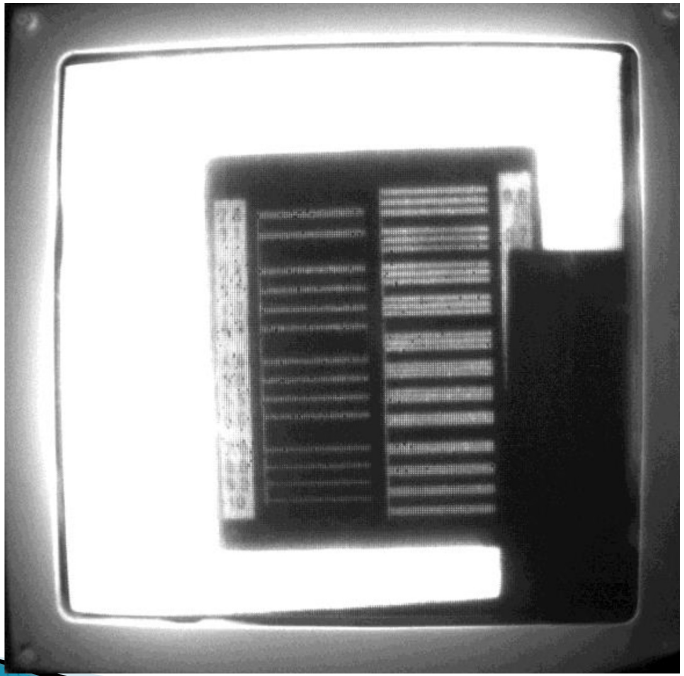


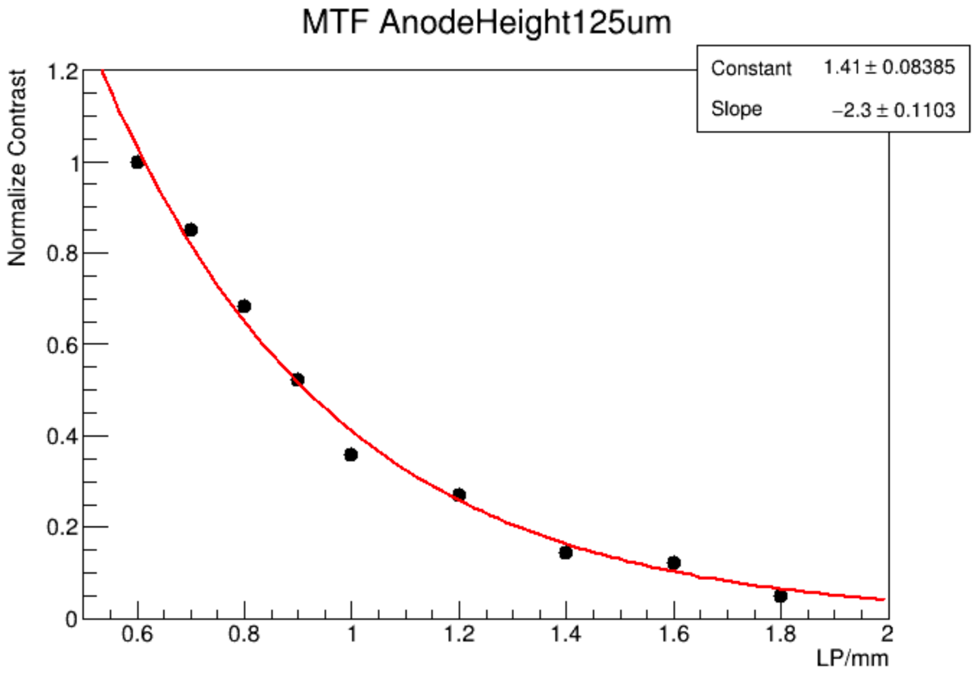
X-ray imaging using photo readout

- X-ray imaging of famous “Bat” and test pattern

Spatial resolution

- About 620 mm of spatial resolution using test pattern with MTF method (MTF=10%)





Summary

- X-ray Image using DLC μ-PIC with photo readout is taken firstly.
- Photo readout is powerful tools for investigating detector operation.
- Fine structure of gas amplification for each electrodes are seen.
- Study for unstable electrical field are performed. There is some dangerous condition in low drift field.
- X-ray imaging property is also good. Spatial resolution is consistent with affect of photo-electron running by X-ray.

Inputs to DRD1

- Kobe University is contributing to gaseous detector developments.
  - MPGD development for high rate particles and low background experiments (μ–PIC)
    - DLC μ–PIC development is ongoing
    - GEM + μ–PIC system is developing for DM search
  - Developments of resistive material for MPGD readouts (DLC, screen printing etc.)
    - We have firstly developed DLC electrodes for MPGDs.
    - Resistive electrodes for ATLAS NSW MM are produced by our group using screen printing.
  - Developments of very low material badget detector (DLC–RPC)
    - Developments for MEG II is ongoing