Neutron Detector with Ceramic GEM

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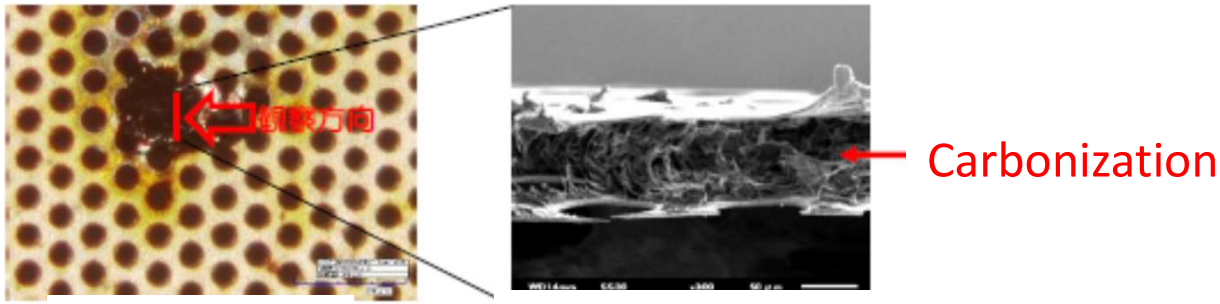
KEK50 年

New GEM

- One big issue is that serious damage occurs in GEM foils.
  - Large charge stores in large capacitance of GEM foil.
  - Small discharge (trigger)
    − > Large discharge − > Serious damage (Carbonization)

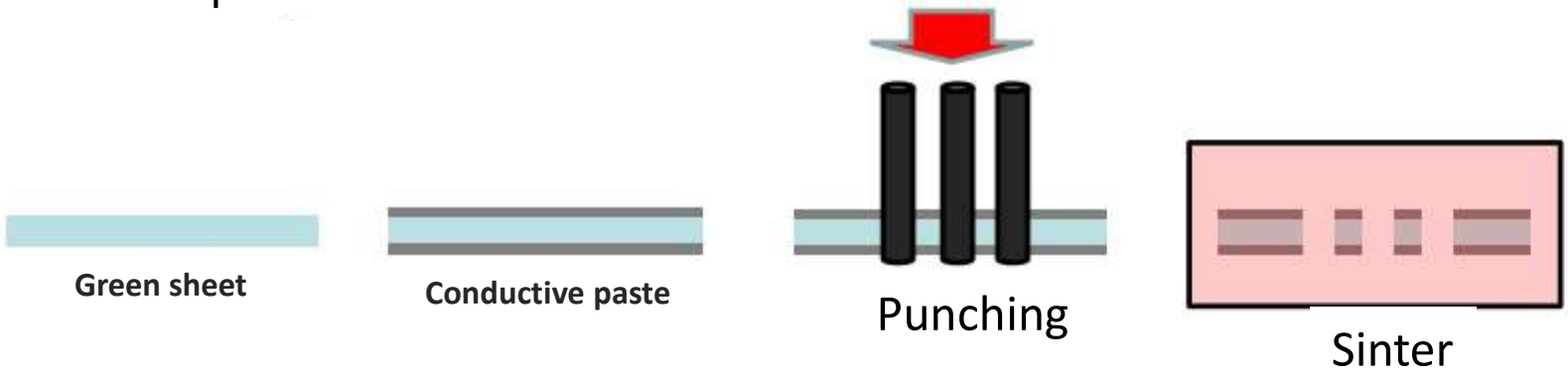


Broken GEM Image with SEM

- To avoid serious damage
  - Resistive GEM (RE-GEN)
    - Resistive electrode instead of Cu → Sacrifice rate capability
  - Teflon (PTFE, polytetrafluorethylene) GEM
    → Some difficulty in production
  - Ceramic GEM

2. Low Temperature Co-fired Ceramic (LTCC) GEM

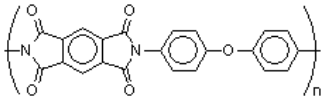
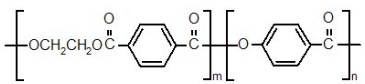
(1) Production process



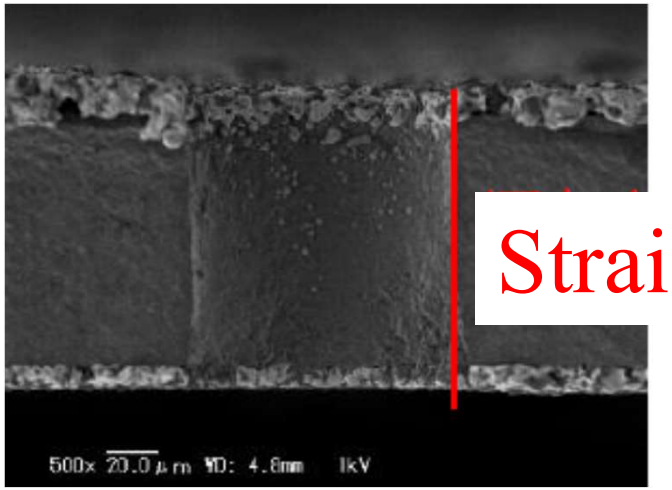
- Simple
- Mask-less

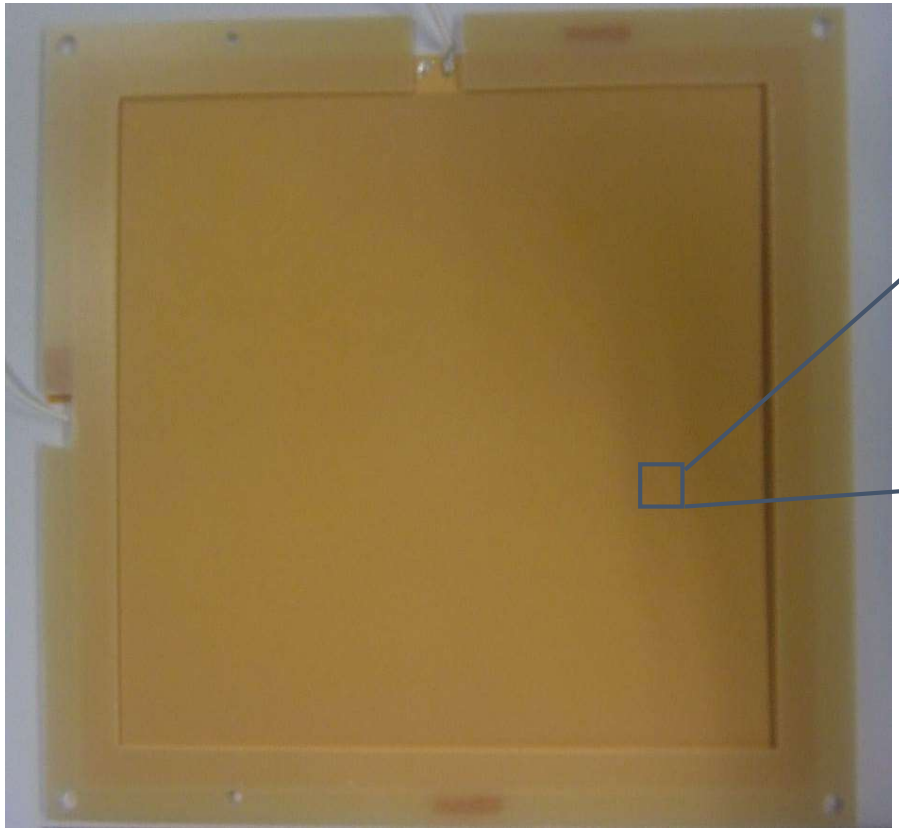
No carbon and no hydrogen in ceramic.
It is better for the neutron detector.

(2) Strong against discharge

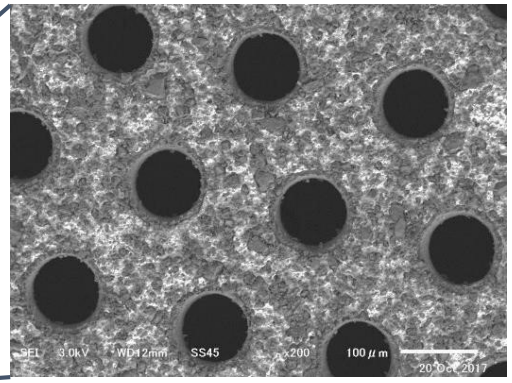
		Past		New
		Foil GEM		Ceramic GEM
		polyimide	LCP	LTCC
Material				CaO $Si_2 + Al_2O$ B_2O_3
Voltage registance	$kV \cdot mm^{-1}$	22	26-40	> 15
Ark discharge	Sec	135	186	> 300
Melting point	℃	< 800	< 450	> 800

LTCC-GEM





LTCC-GEM



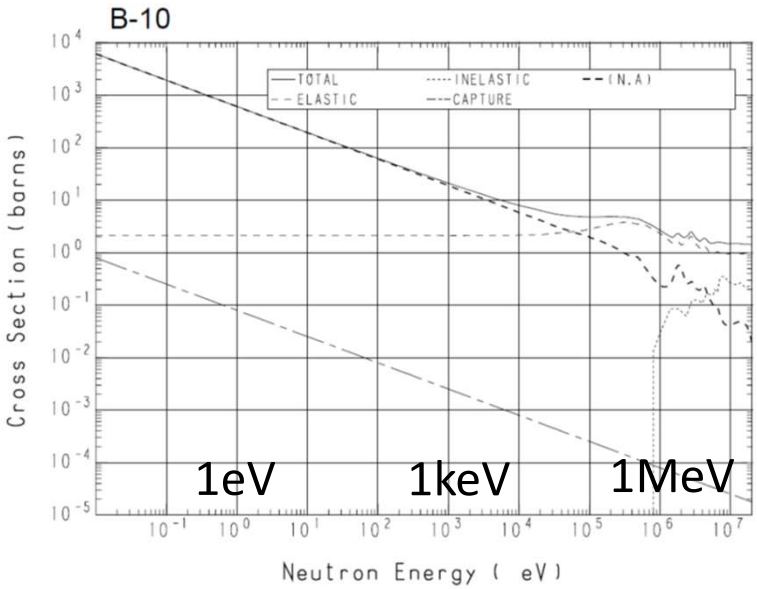
LTCC GEM (normal GEM)

- Size : 100 mm×100 mm
- Hole diameter : 100 μm (70 μm)
- Hole pitch : 200 μm (140 μm)
- Thickness : 100 μm (50 μm)
- Material of Electrode : Au (Cu)

Neutron detection

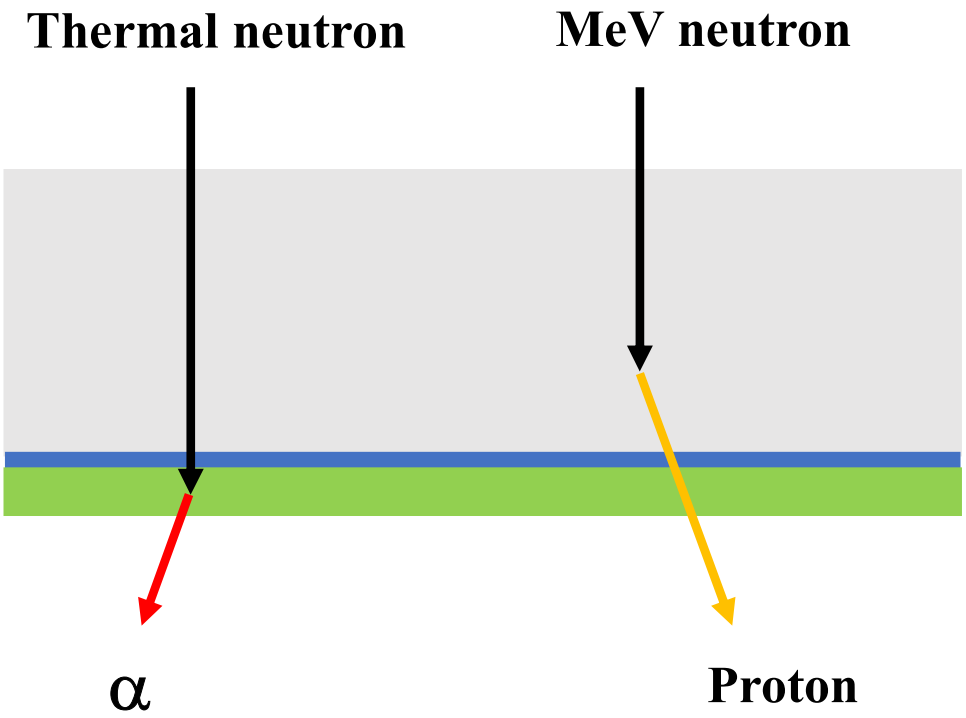
- Thermal (or cold) neutron : Boron
  - $n + {}^{10}B \rightarrow Li + \alpha$ $\sigma = 3840$ b for 25 meV neutron
    - Large cross section
    - Large ionization loss in gas volume for α (Li nuclei)

- High energy neutron (MeV) : Hydrogen
  - Cross section for Boron becomes small. $\sigma \sim 1/\sqrt{E}$
  - Hydrogen is good target.
    - Proton comes out.
      - Still, larger ionization loss than electron from gamma.
    - Plastic contents large amount of Hydrogen.
    - PET : Polyethylene terephthalate

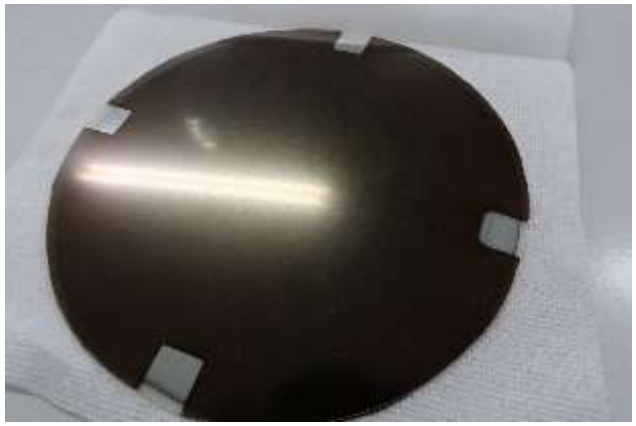


Hybrid cathode

- One hybrid cathode
  - to detect both thermal neutron and MeV neutron



PET 0.5mm



Aluminum 0.4 μm
Boron 1.0 μm

90ϕ mm

Single GEM setup

- Single LTCC GEM + Hybrid cathode
  - 100 × 100 mm aluminum frame with 90ϕ mm hole

- Register chain is used to provide each voltage for each part with single HV supply.

Cathode		0.5mm PET + Al + B (1μm)
	Drift region 1 mm gap, 1.5 kV/cm	
LTCC GEM		$\Delta V_{GEM} = 510V$
	Induction region 1 mm gap, 4.7 kV/cm	
Anode		XY strips (0.8mm pitch)

Note : Voltage and field strength are correspond to 100% HV setting.

Neutron detector

HV cables

All cables and pipes can be connected from one side.

One Ethernet cable for digital data transfer

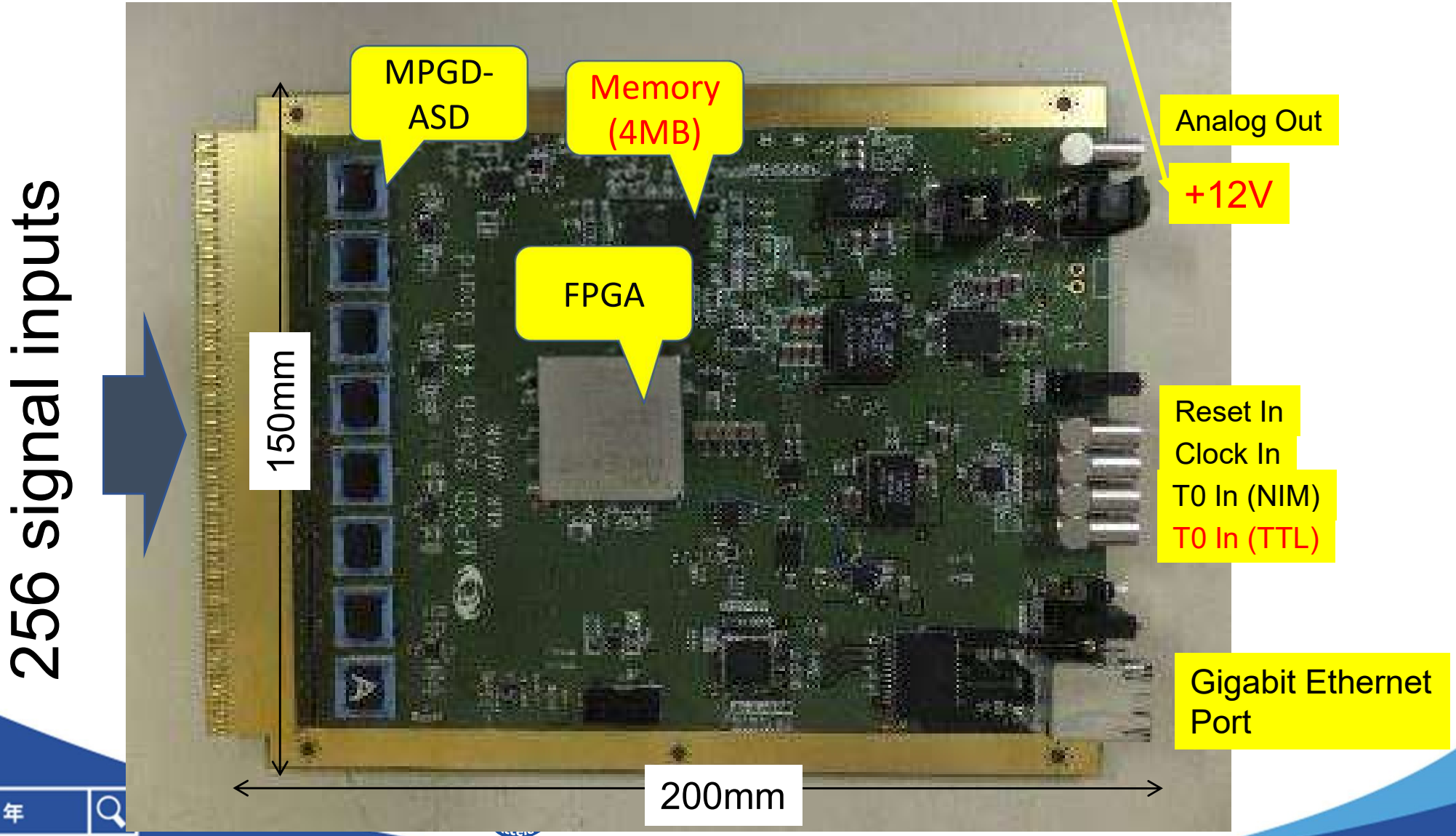
Two gas pipes for inlet and outlet

Active aria

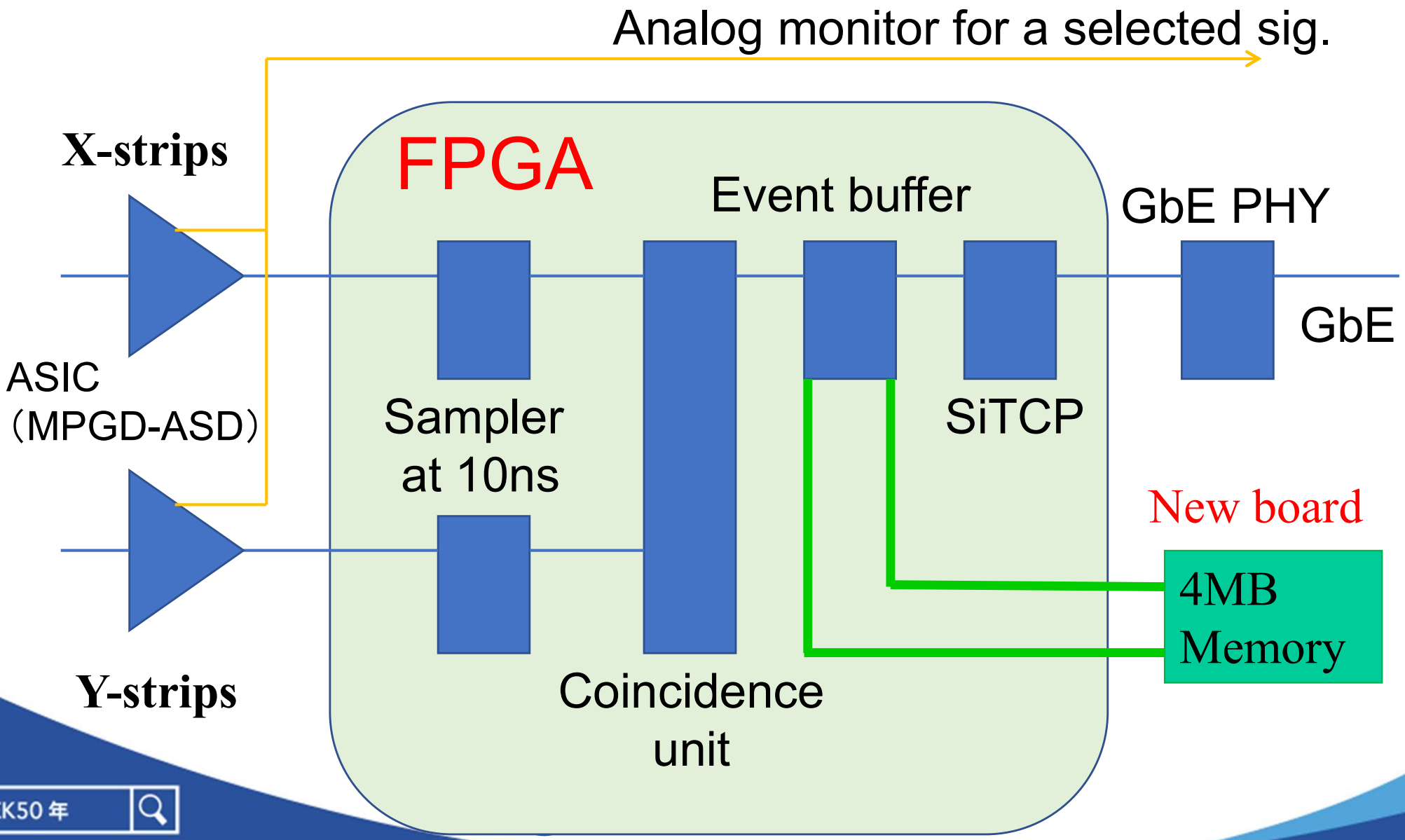
Electronics aria

Electronics board

ASD 32ch/chip with analog monitor

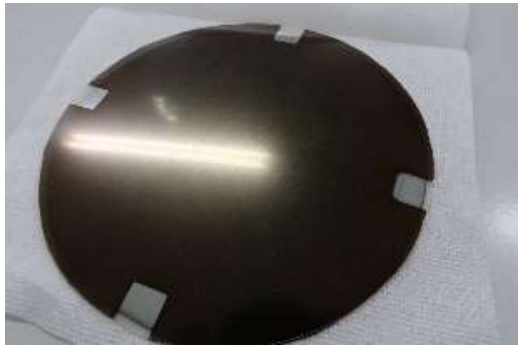


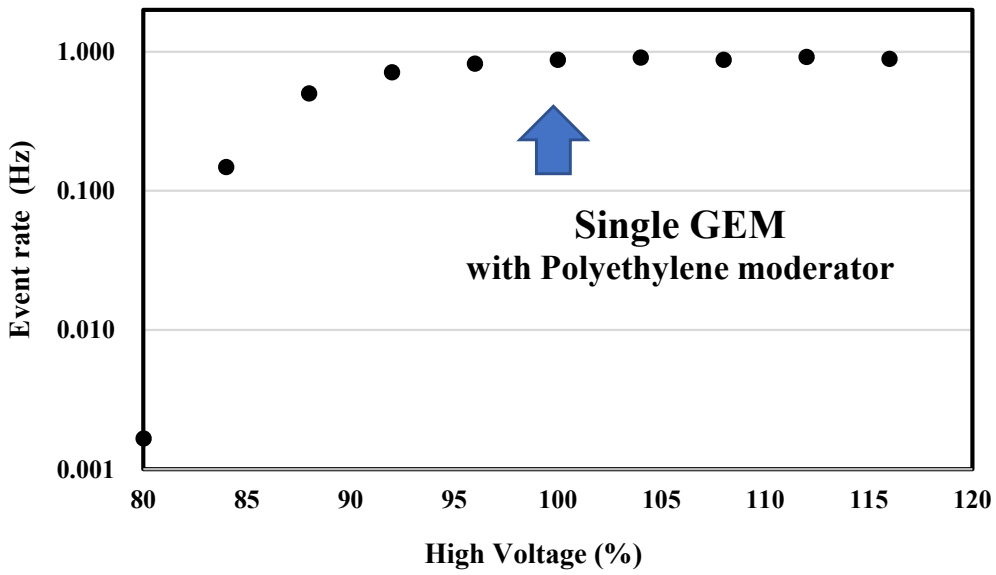
Block diagram

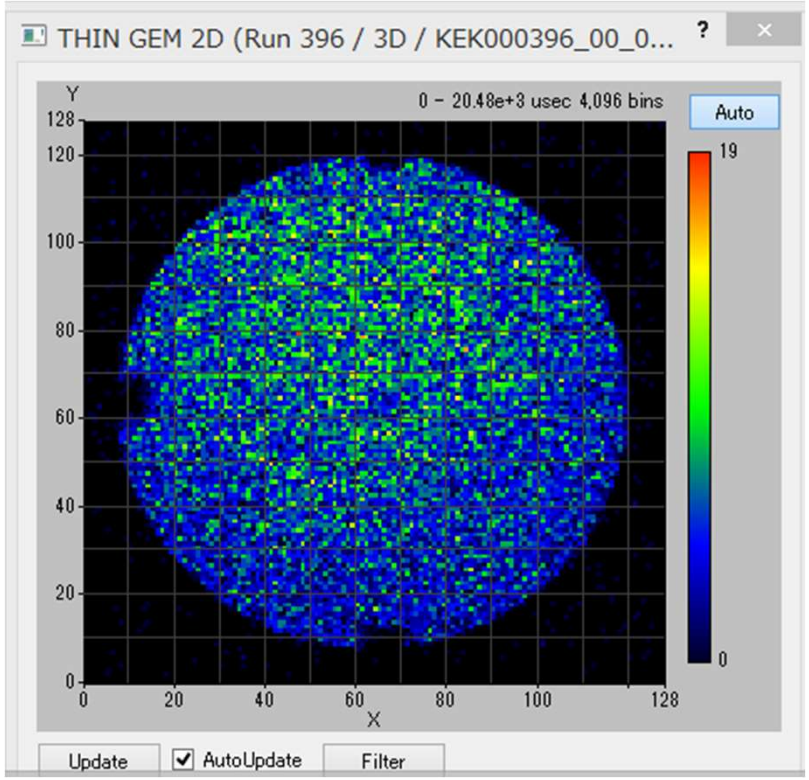


Thermal Neutron

- With Polyethylene moderator
  using 252 Cf radioactive source
- Nice HV curve
- Clear image
  - Fine structure can be seen.







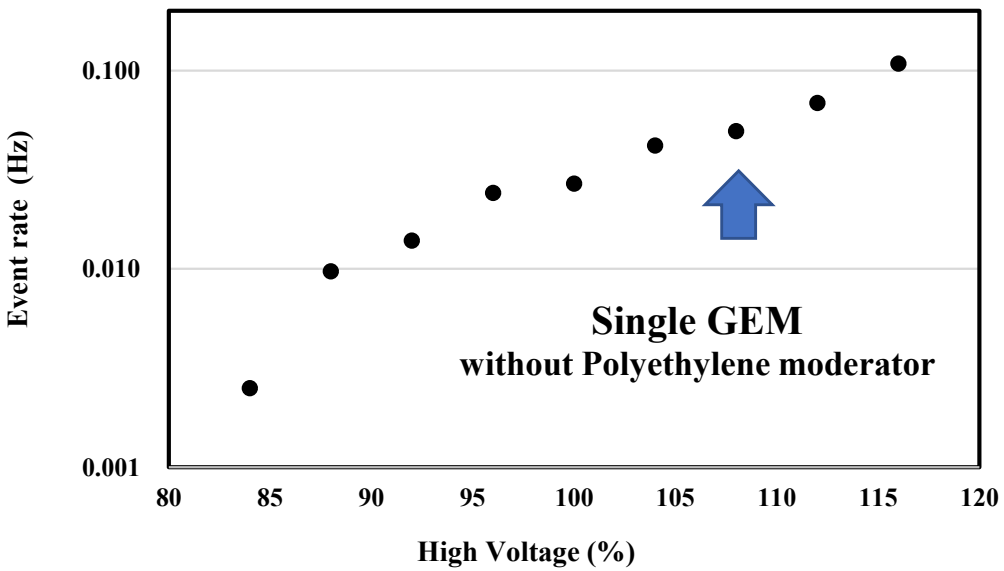
HV =100%, ~15 h data taking

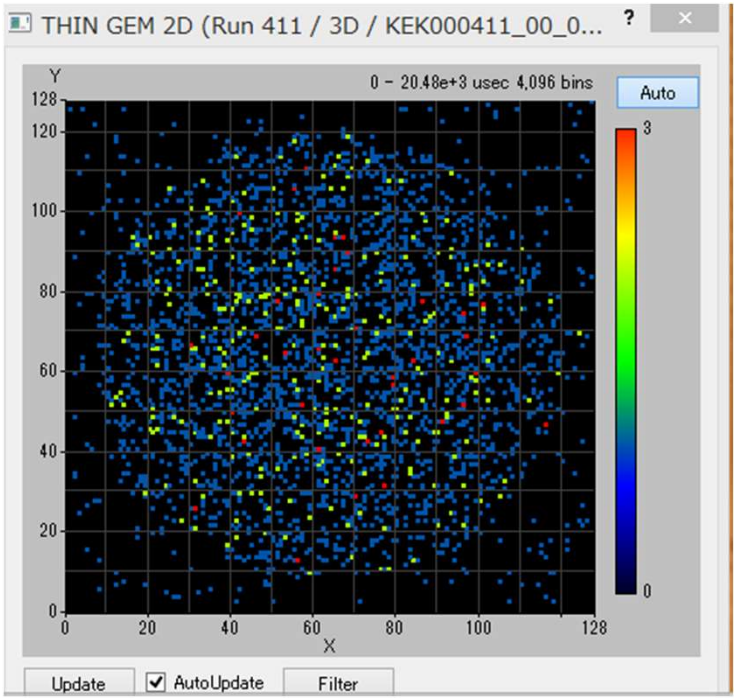
MeV Neutron detection

- Without Polyethylene moderator

  using ^{252}Cf radioactive source

- Not so good HV curve
  - MeV Neutron may react in Boron also.

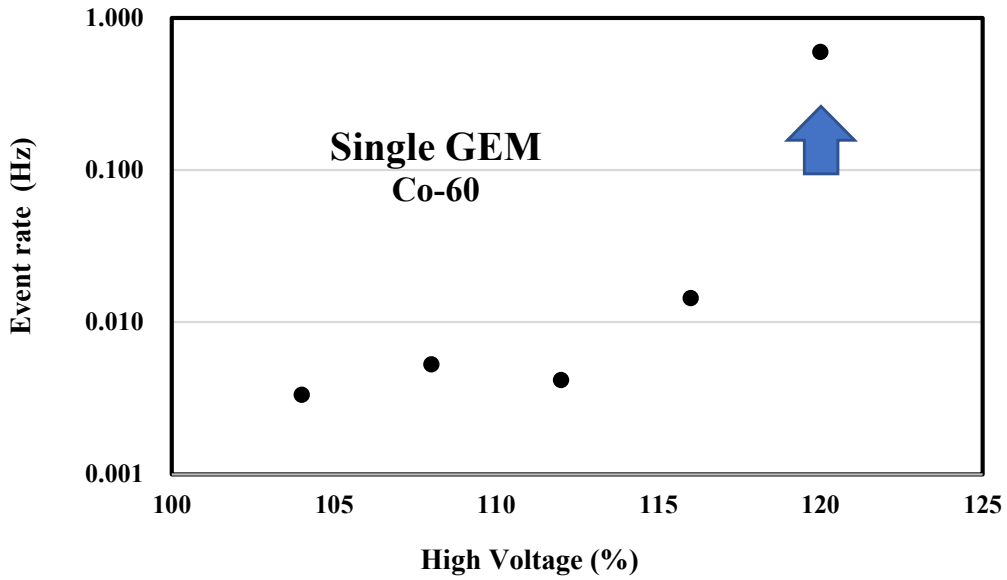


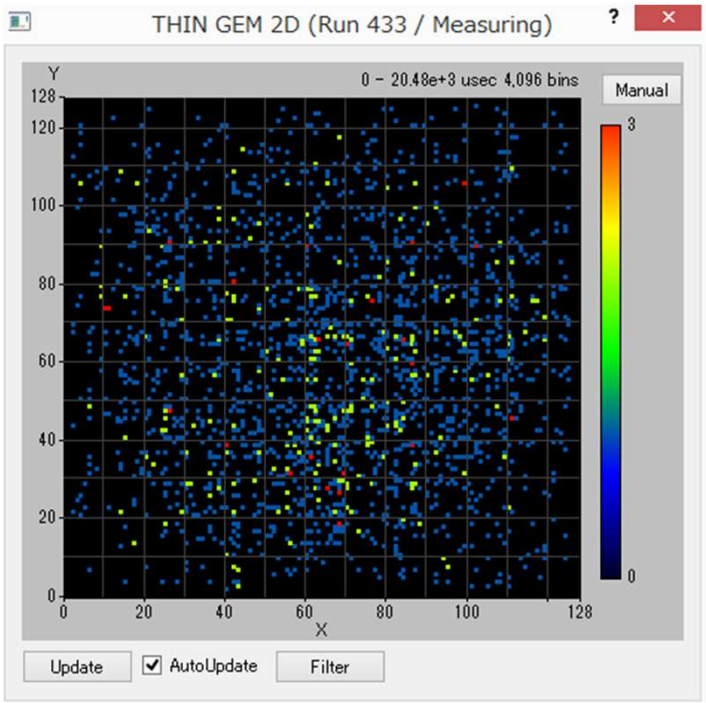


HV =108%, ~16 h data taking

Gamma detection

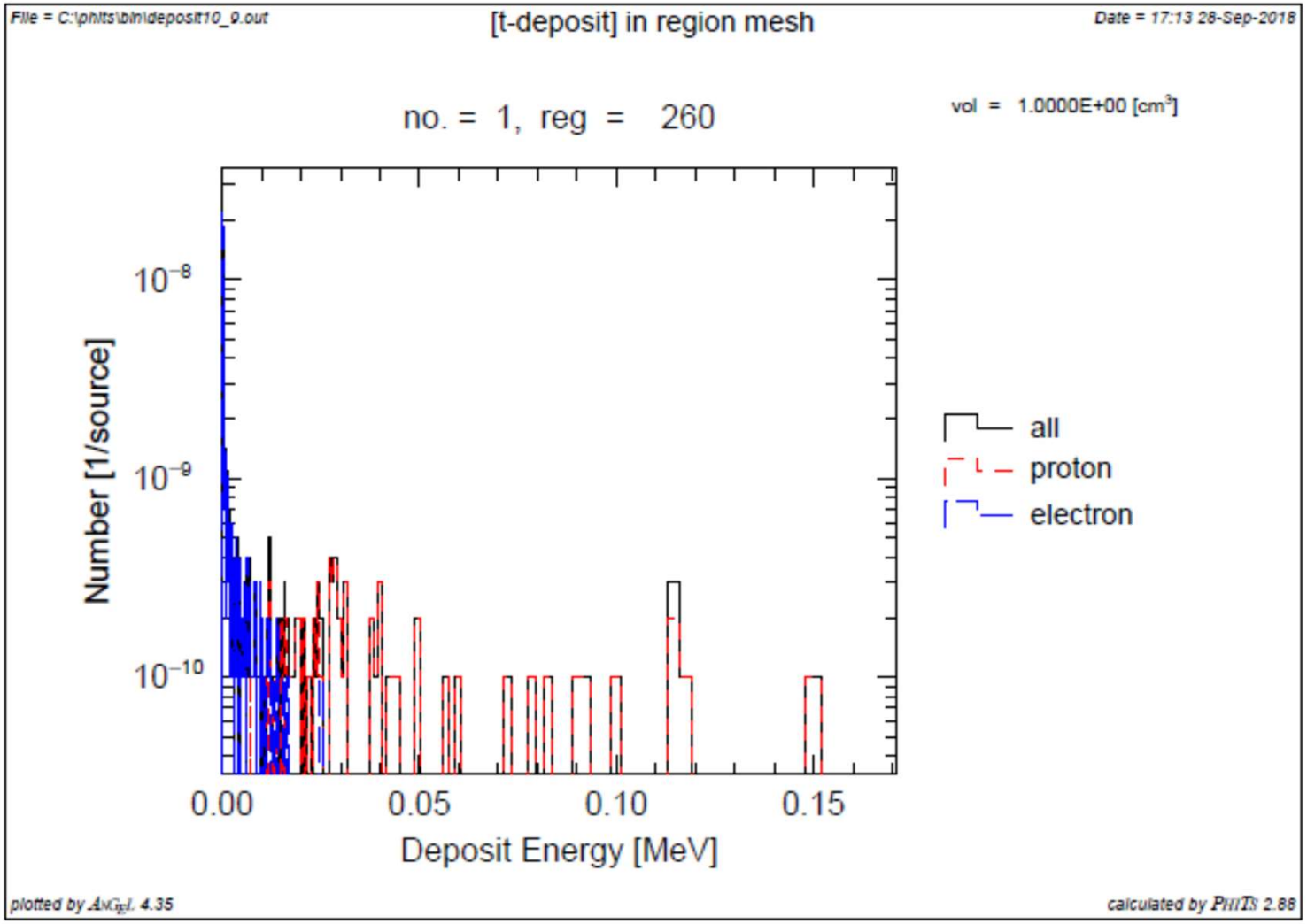
- Co-60 radioactive source
- Quick increasing after 116%
- No clear circle image.



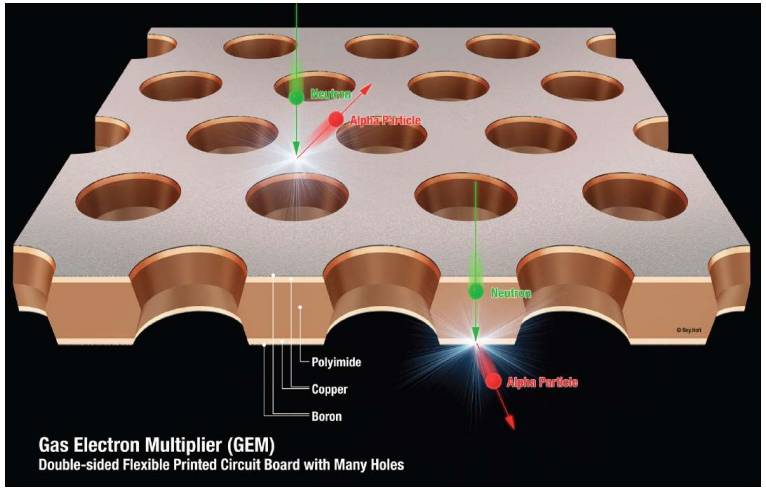


HV =120%, 1 h data taking

Energy spectrum on simulation



Higher efficiency for thermal neutron



Expensive ^{3}He Gas is not necessary.

No pressure vessel

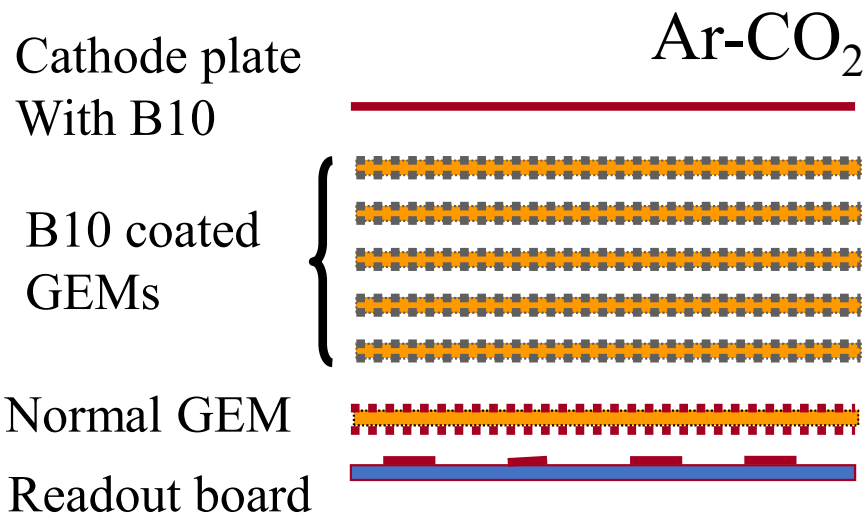
Free readout pattern

High resolution

Position and **Time**

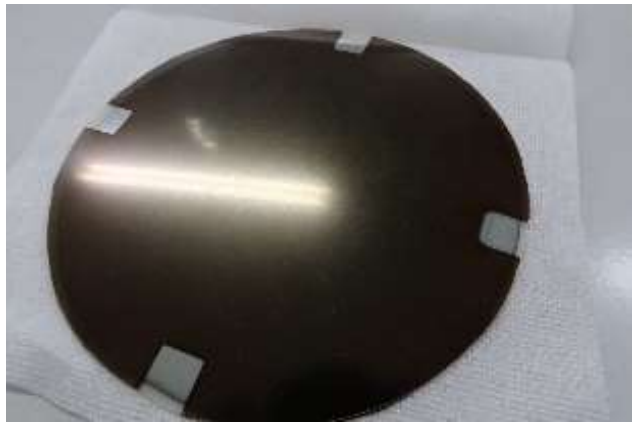
Insensitive against γ-ray

Capability against high counting rate

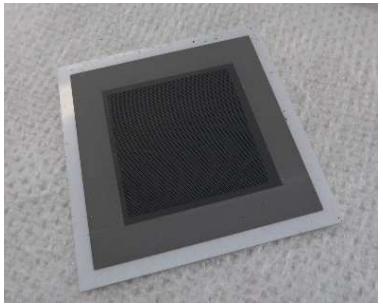


Boron GEM

90ϕ mm



- Now, we are sputtering the boron on the various plates by ourself.
  - Many parameters can be optimized.
- Test production of boron GEM just started.
- Unfortunately, the sputtering machine has a trouble, now.
  - We can not make GEM with normal size (100 × 100 mm^2).
  - After the repairing, the test production will start again.



Boron GEM with smaller size

Summary

- Ceramic GEM is working fine without serious damage.
- Our detector system is compact and simple.
- Hybrid cathode is working fine to detect both thermal neutron and MeV neutron.
- Boron GEM comes soon.