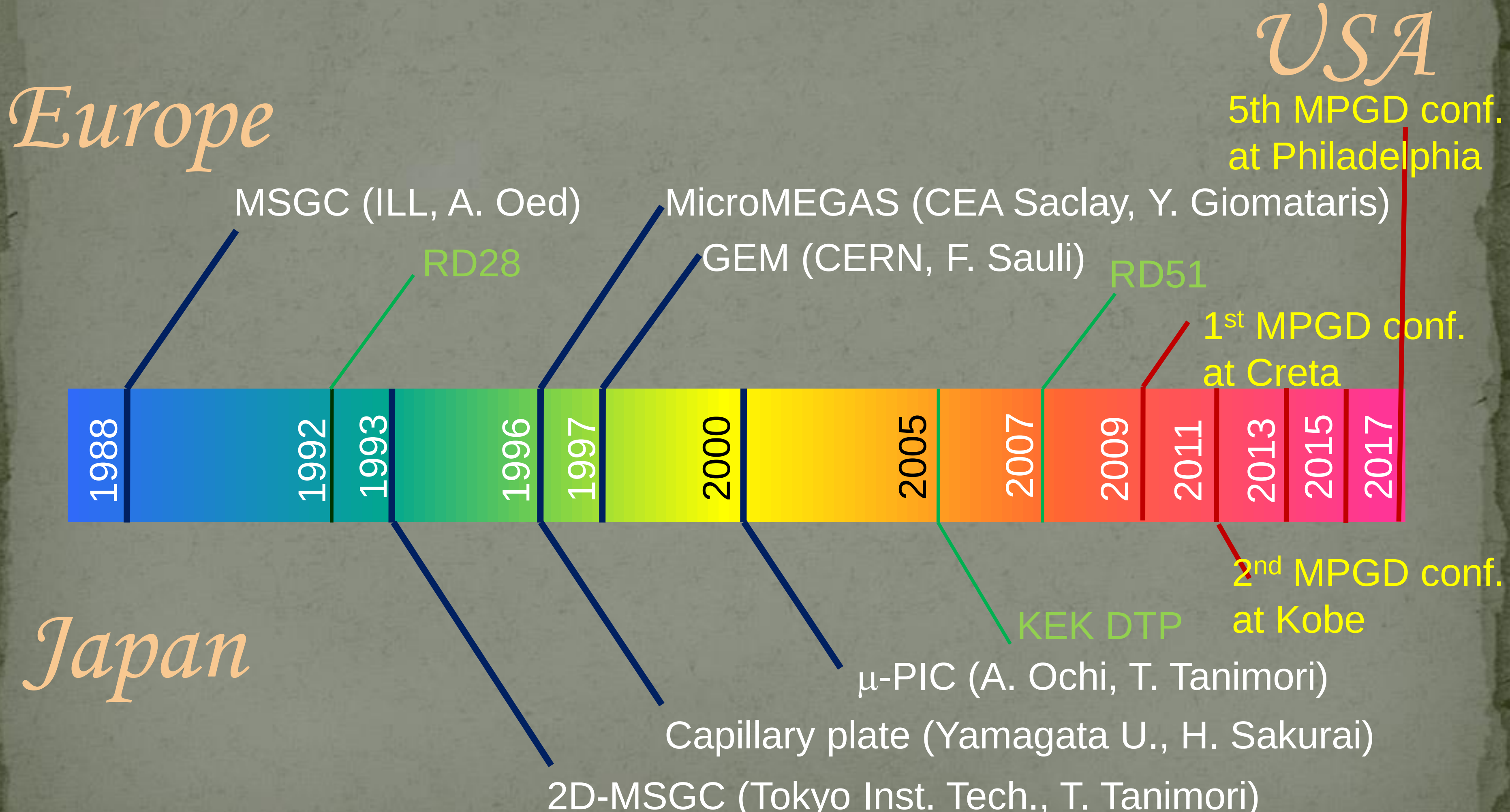
MPGD Applications and Development in JAPAN

Atsuhiko Ochi
Kobe University

5th MPGD Conference at Philadelphia, 24/05/2017

History of MPGD in Europe and JAPAN



MPGD Activities in JAPAN
(Not even a complete list)

- Structure studies
  - GEM (Gas electron multiplier)
    - @Many institutes … KEK, RIKEN, JAEA, U. Tokyo, Kyoto U., Saga U., TIT, Kinki U., TUAT ….
  - THGEM, Capillary plate,
    - Yamagata U., TMU, U.Tokyo, AIST
  - MicroMEGAS
    - Saga U., Kobe U., U. Tokyo
  - μ-PIC (Micro Pixel Chamber)
    - Kyoto U., Kobe U., ICRR, KEK, J-PARC
- Material studies (Substrate (conventional, polyimide))
  - LCP (Liquid crystal polymer)
    - KEK, RIKEN, U.Tokyo, (SiEnergy co.)
  - Glass
    - U.Tokyo, Yamagata U. AIST
  - PTFE, Ceramic
    - Tokyo IRI, RIKEN
- Resistive electrodes
  - Organic material
    - KEK
  - Sputtering carbon/metal
    - Kobe U.
  - Carbon loaded Epoxy
    - Kobe U., U. Tokyo
- Applications
  - Particle physics (Acc./ Non Acc.)
    - Kobe U. KEK, Kinki U. Saga U.
  - Neutron imaging
    - Kyoto U., KEK
  - Nuclear physics
    - TIT, U.Tokyo., JAEA, Tsukuba U., RIKEN
  - Astrophysics
    - Kyoto U., RIKEN
  - Gas Photomultiplier
    - Yamagata U, TMU, ICRR
  - X/gamma ray imaging
    - Kyoto U., KEK, AIST
  - Medical imaging
    - Kyoto U.

- I will introduce mainly recent material studies and applications of MPGD in JAPAN
- It is not all activities, and picked up by my sense
- Also, studies those have been (will be) presented in this conference are omitted.

Material studies for MPGD structure

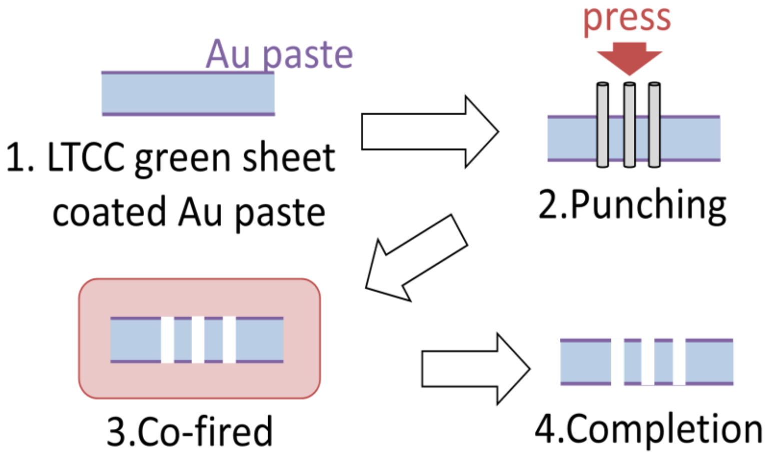
- MPGD Substrate
  - Not only polyimide, but also LCP, Glass, Ceramic…
  - Even in polyimide, Low BG material is studied
- Gas study
  - Special gas for negative ion drifts
- Resistive material
  - DLC sputtering with large (>1m^2) area

LTCC-GEM

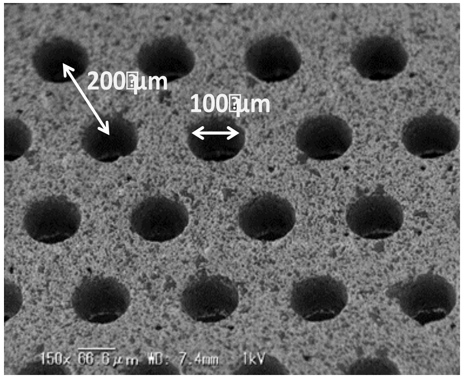
K. Komiya et al., Tokyo IRI

※LTCC : Low Temperature Co-fired Ceramics

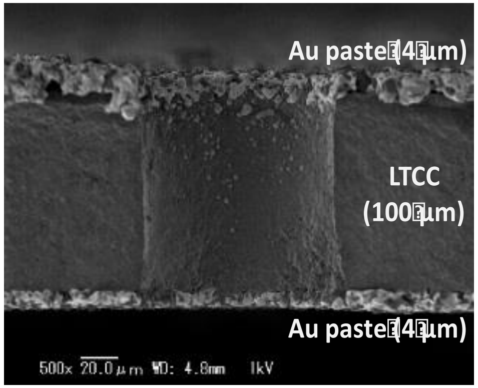
Manufactured by
Hirai Seimitsu Kogyo Co., Ltd. (Osaka, Japan)



Process of LTCC-GEM Easy process !!

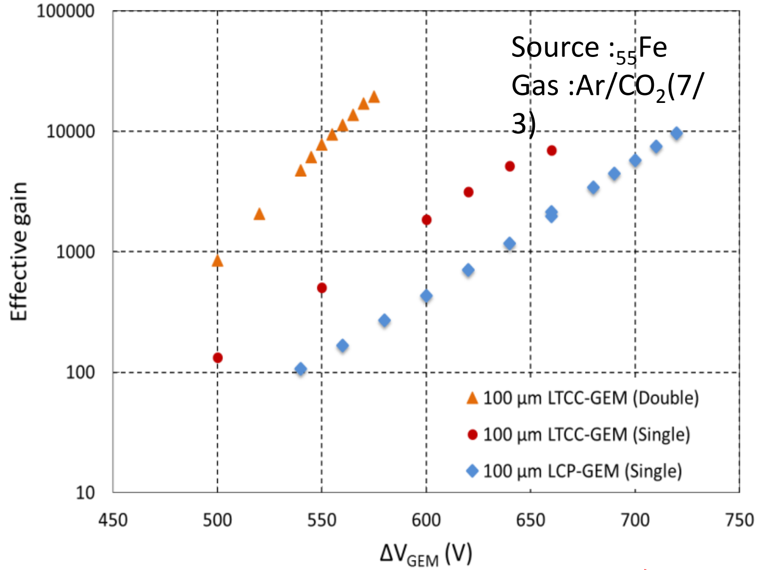


Enlarged view



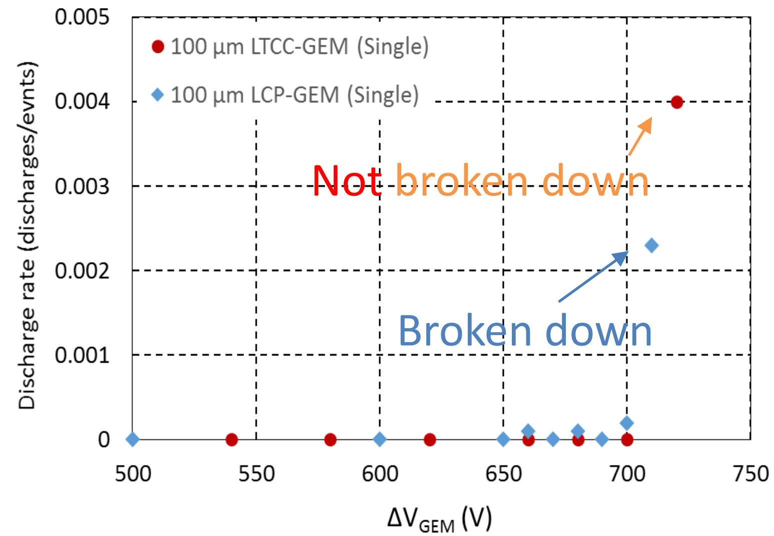
Cross-section view

Effective gain curve



Ceramic-GEM : Max. gain ≧ 20,000

Discharge rate

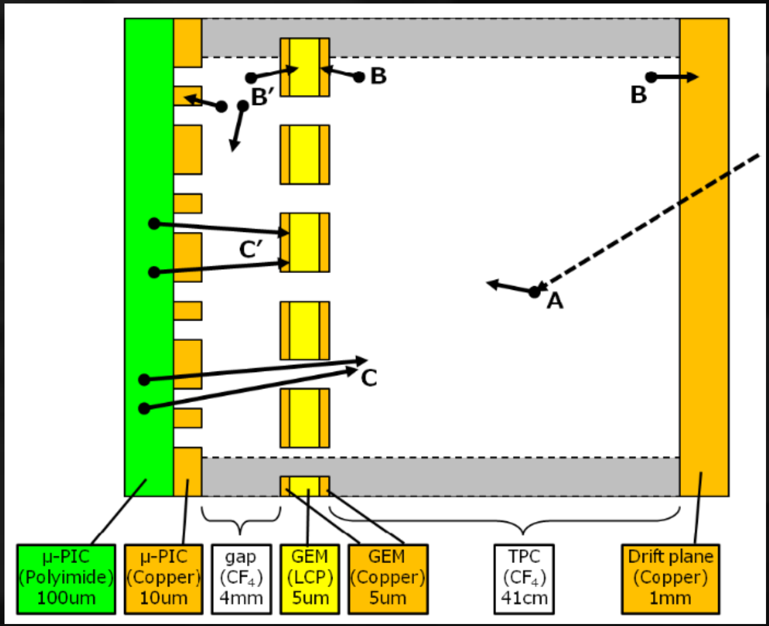


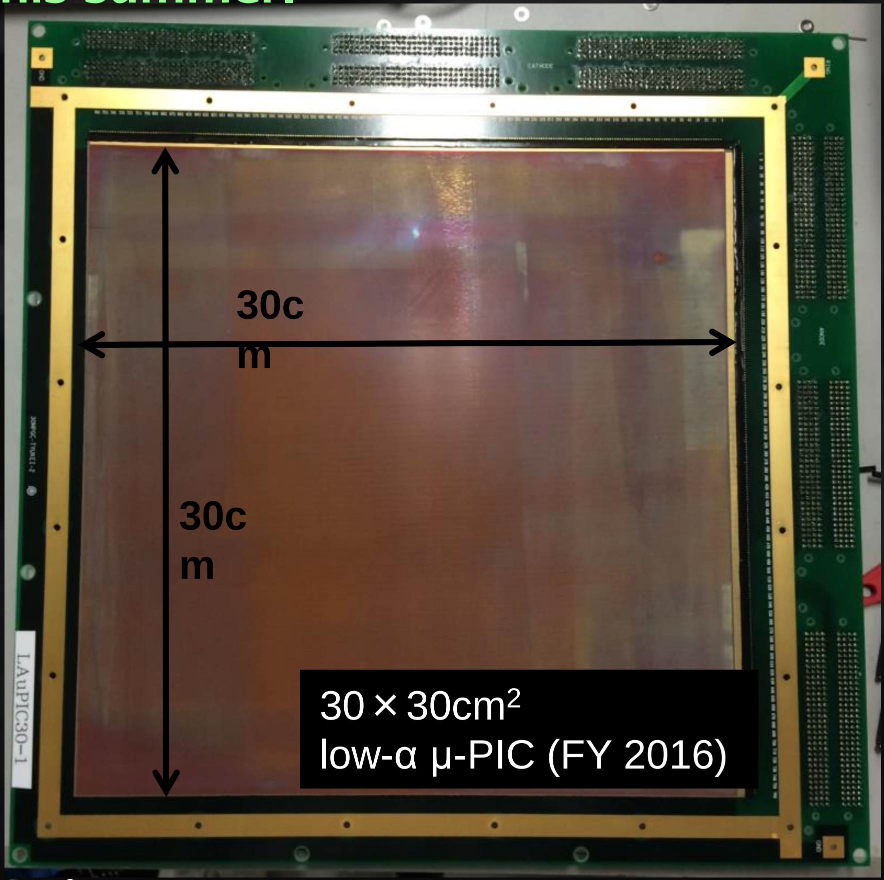
Ceramic-GEM is not broken down !!

K. Miuchi, Kobe U.

Recent NEWAGE① : Low α μ-PIC development

- Largest background: alpha-rays from μ-PIC surface (Cand C′ in the figure)
- Low alpha-emitting (<1/100) μ-PIC, made
  - first light confirmed
- Replace the underground my-PIC: this summer.

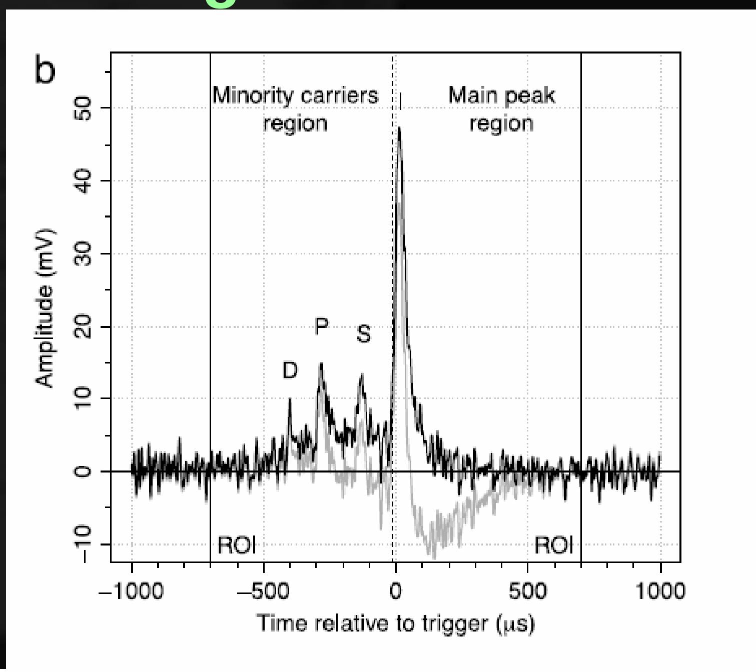




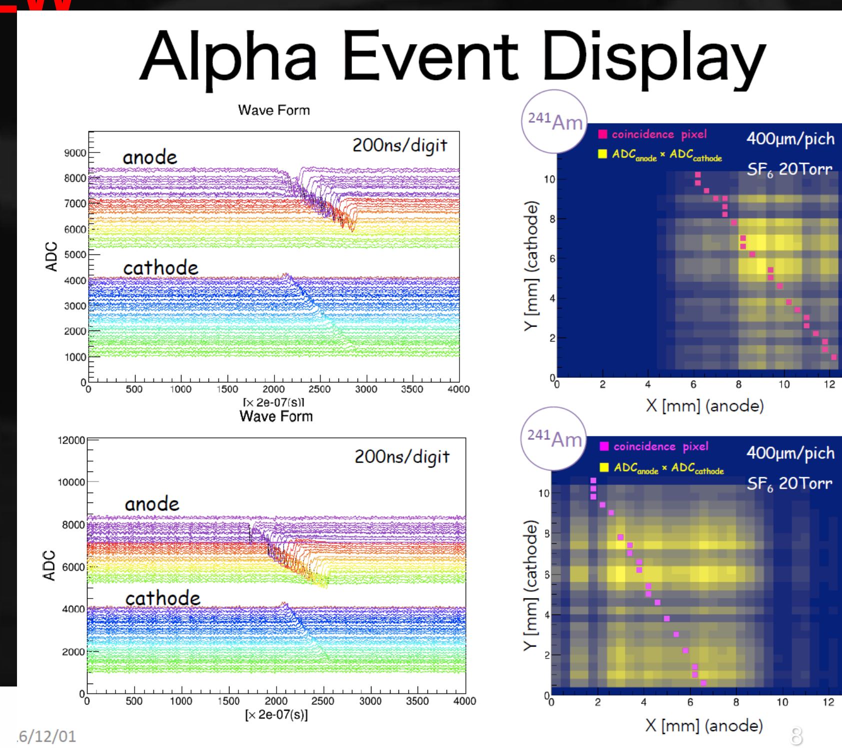
K. Miuchi, Kobe U.

Recent NEWAGE②: Negative-ion TPC (SF_6)

- Potential for absolute z measurement with "minority peaks" (first realized by DRIFT group)
- SF_6 study for GEM+μPIC system (reported in MPGD2015)
- Wide dynamic-range ASIC development ⇐ NEW
- Tracking with MPGDs ⇐ NEW



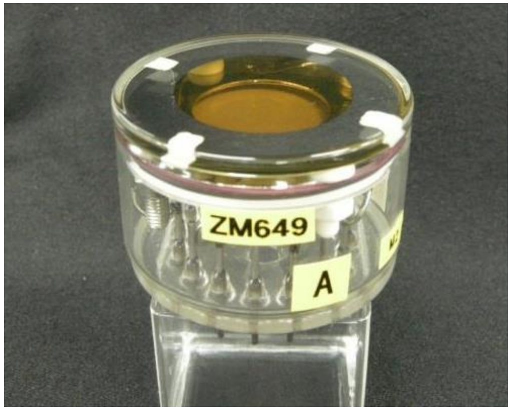
J.B.R. Battat et al. / Physics of the Dark Universe 9–10 (2015) 1–7



Application for Gas PMT and neutron detector

Gaseous PMT with MPGD

F. Tokanai et al.,
Yamagata U., HAMAMATSU, TMU



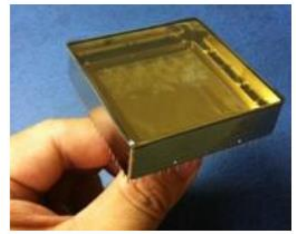
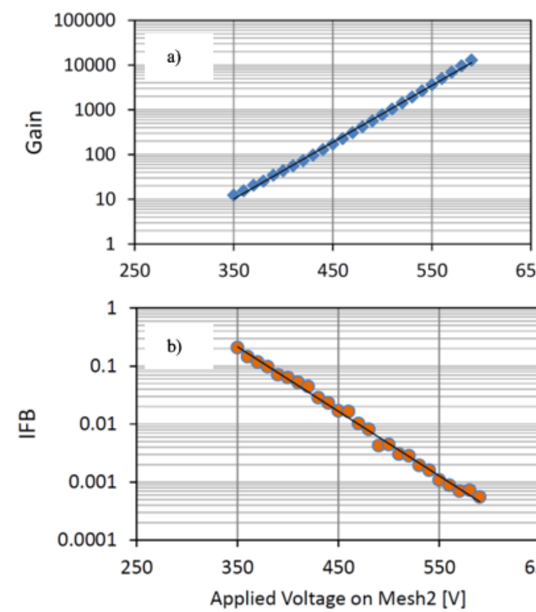
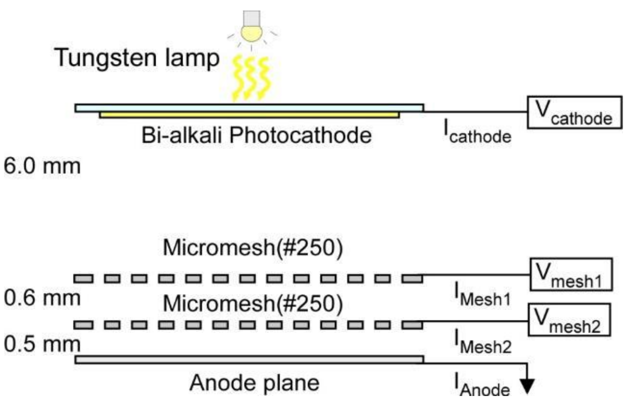
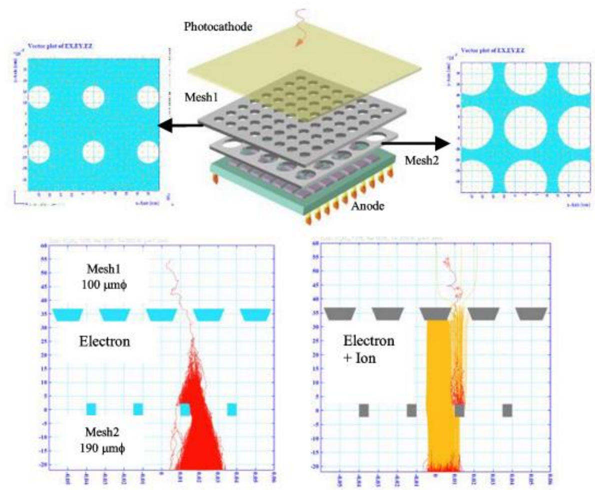
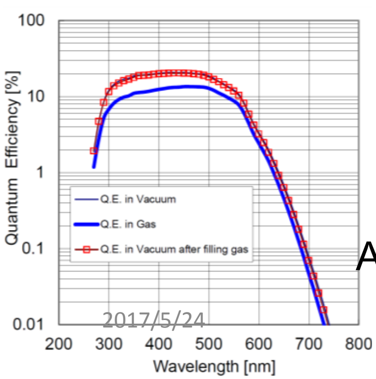


Fig. 15 Photograph of flat-type gaseous PMTs with bialkali photocathode and double Micromegas detector.









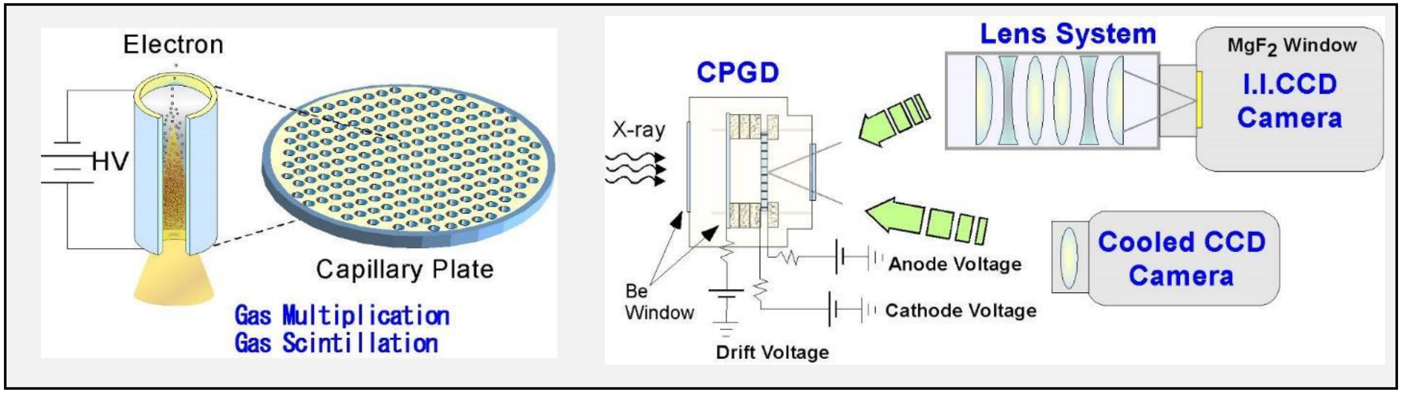
QE in vacuum **20%**

QE in the gas **12%**

After evacuation QE recovered to 20%.

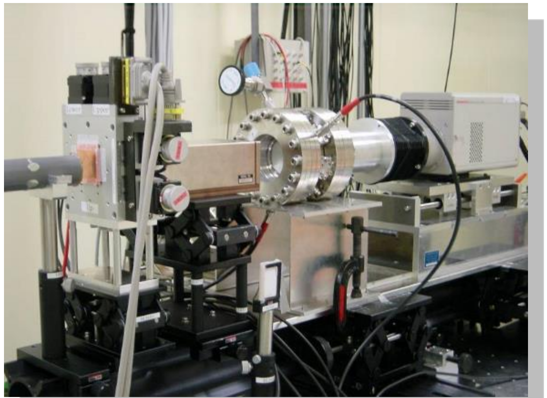
Optical Imaging CP Gas Detector

F. Tokanai et al.,
Yamagata U., HAMAMATSU, TMU



It is possible to provide pixelized imaging capability with a high position resolution.

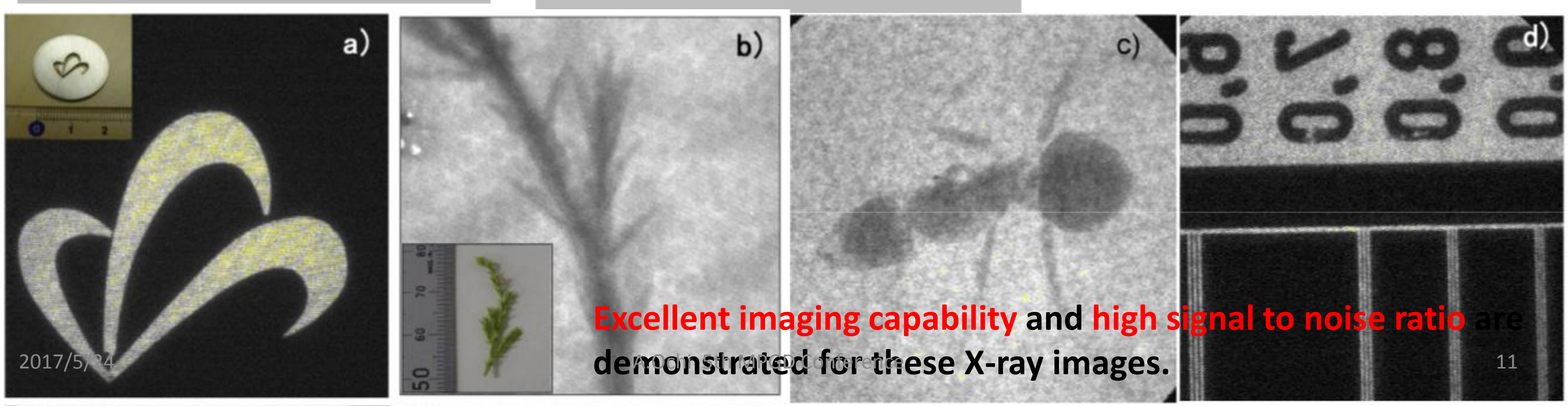
F. Tokanai et al.
NIM A 567 376-380 2006
F. Tokanai et al.
accepted IEEE TNS 2007



Ar(90%)+CF_4(10%) at 1 atm.

Micro-foucs X-ray Generator

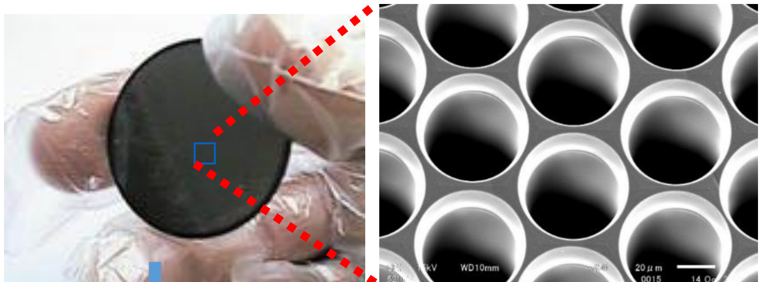
- **Anode Voltage: 15 kV**
- **Current : 15 μA**

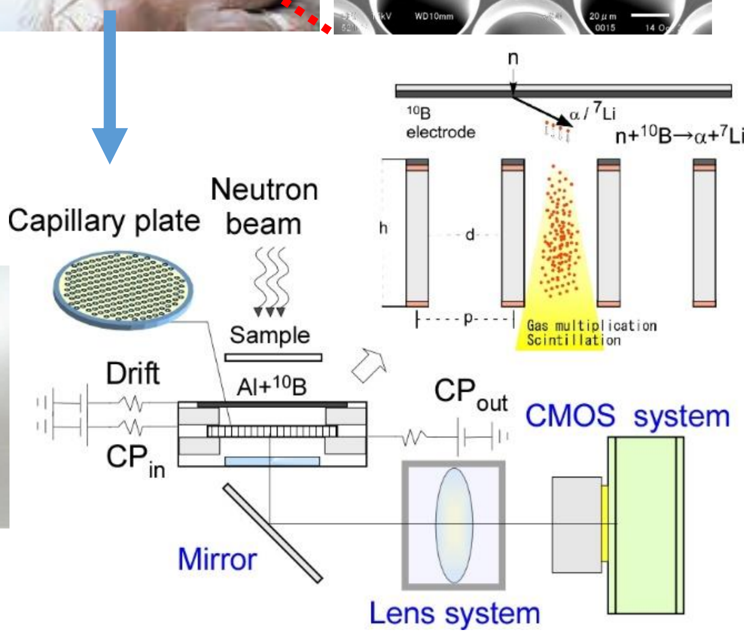


Excellent imaging capability and high signal to noise ratio are demonstrated for these X-ray images.

F. Tokanai et al.,
Yamagata U., HAMAMATSU, TMU

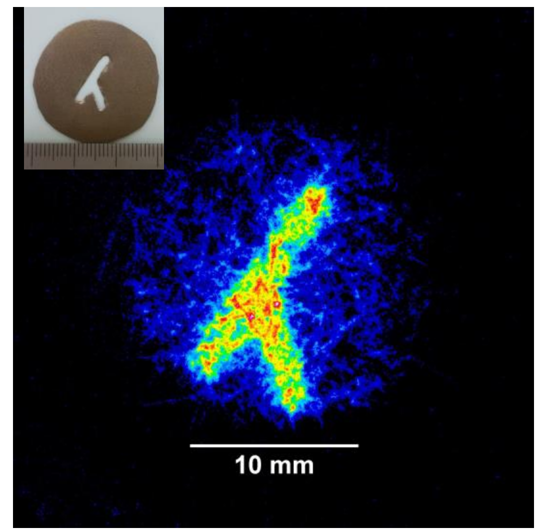
Gas Scintillation Imager for Neutron (n-GSI)





"Sealed" Tube

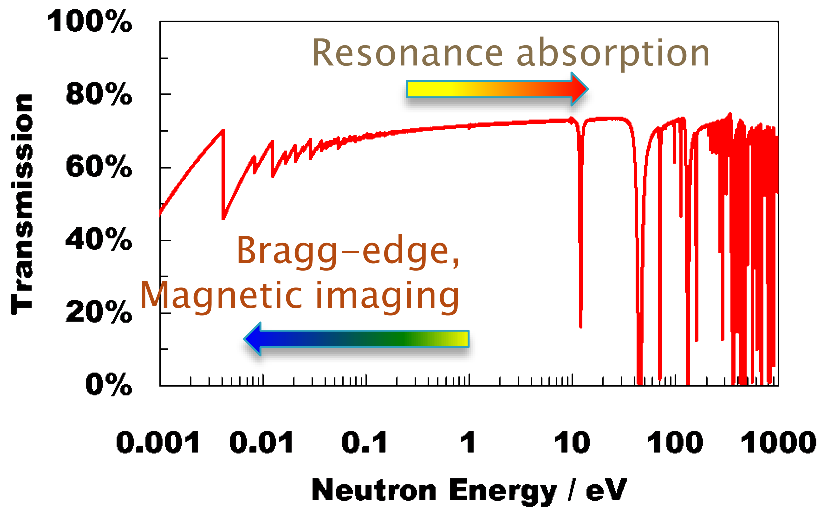
Neutron source:
Kyoto University Accelerator-driven Neutron Source (KUANS)
thermal neutron flux: 450n/cm^2/s at detector



山形大学 YAMAGATA UNIVERSITY
HAMAMATSU PHOTON IS OUR BUSINESS
TOKYO METROPOLITAN UNIVERSITY 首都大学東京

J. Parker et al., CROSS-Tokai

μPIC-based detector for energy-resolved neutron imaging at J-PARC

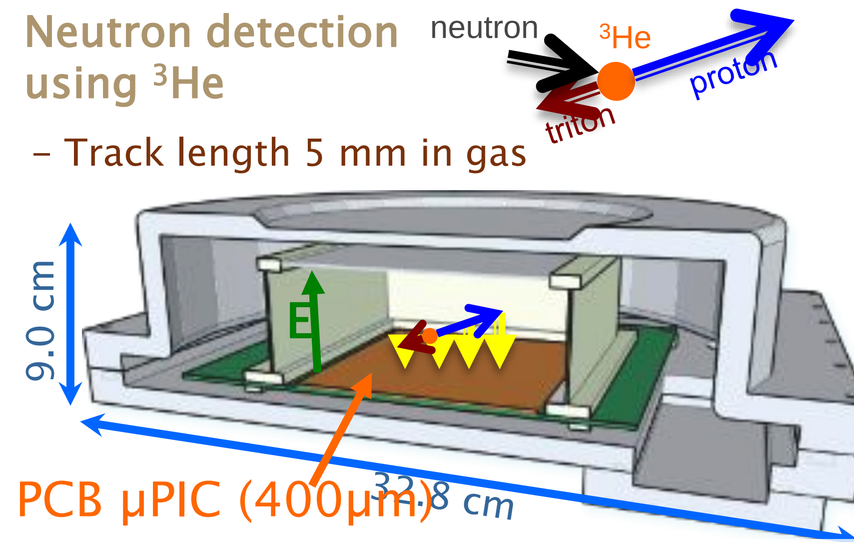


- Energy-dependent transmission spectra with pulsed neutron beam
  - Utilize energy measurement by time-of-flight method
  - Used to determine macroscopic distribution of microscopic quantities
- Requires detector with good time and spatial resolution, high count rate, and good background rejection

μPIC-based Neutron Imaging Detector (μNID)

Neutron detection using ^3He

- Track length 5 mm in gas



- 3-dimensional tracking of decay pattern with energy via time-over-threshold (TOT)
- Spatial resolution: < 0.2 mm
- Time resolution: 0.25 μs
- Count rate capacity: up to 8 Mcps
- Effective gamma sensitivity: $< 10^{-12}$

J. Parker et al., CROSS-Tokai

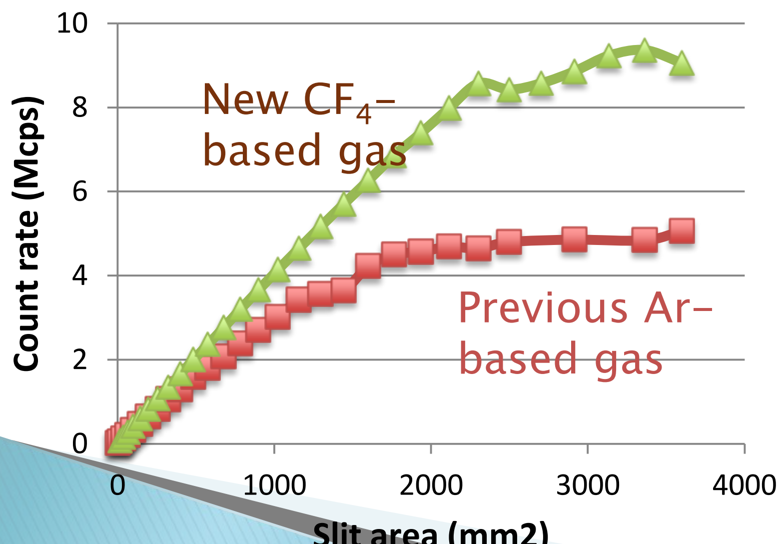
Recent μNID development

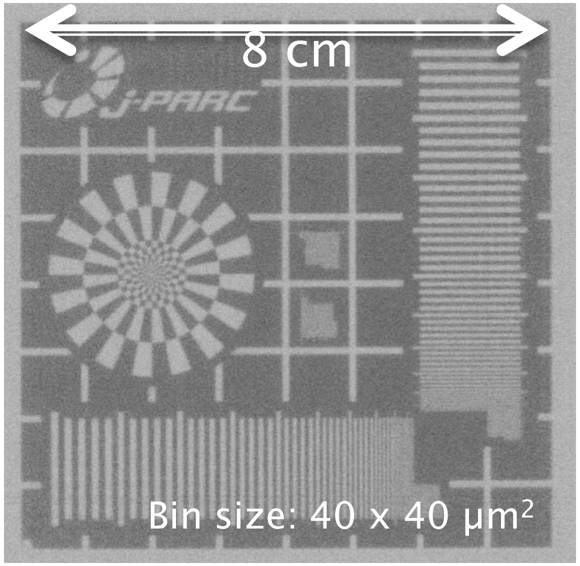
Standard μNID

- Implementation of new data encoders with GbE data transfer
- New gas mixture for improved count rate and spatial resolution

→ Increased rate capacity from **0.6 Mcps** (100Mbps Ethernet) to **8 Mcps** (GbE and new gas)

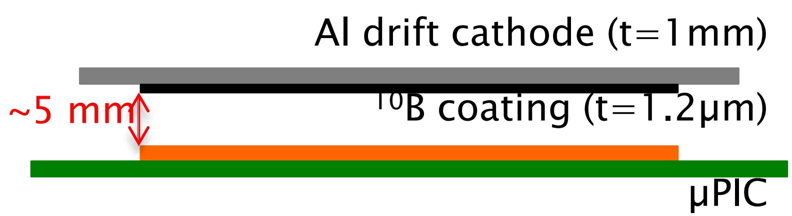
Neutron rate with GbE encoders





Neutron radiograph of Gd test pattern showing better than 0.2 mm spatial resolution

New μNID with boron converter



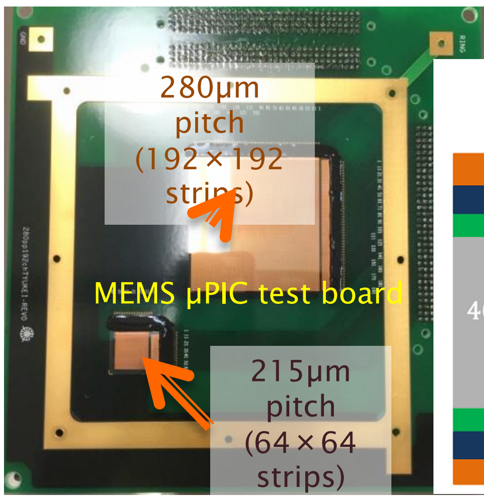
- Measure alpha instead of proton-triton → reduced event size for 3 times increased rate capacity
- Recently tested at J-PARC

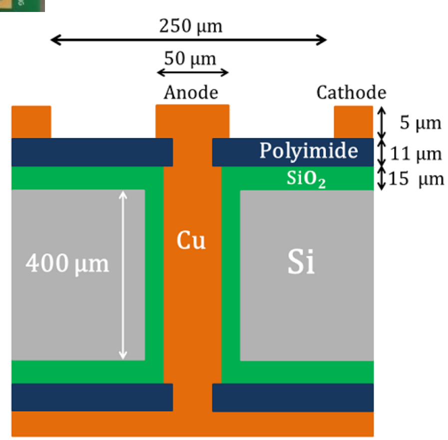
J. Parker et al., CROSS-Tokai

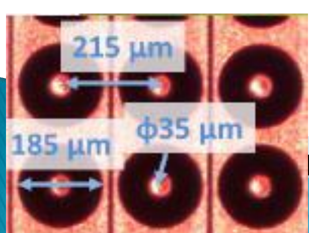
Ongoing μNID development

New μPIC detection elements

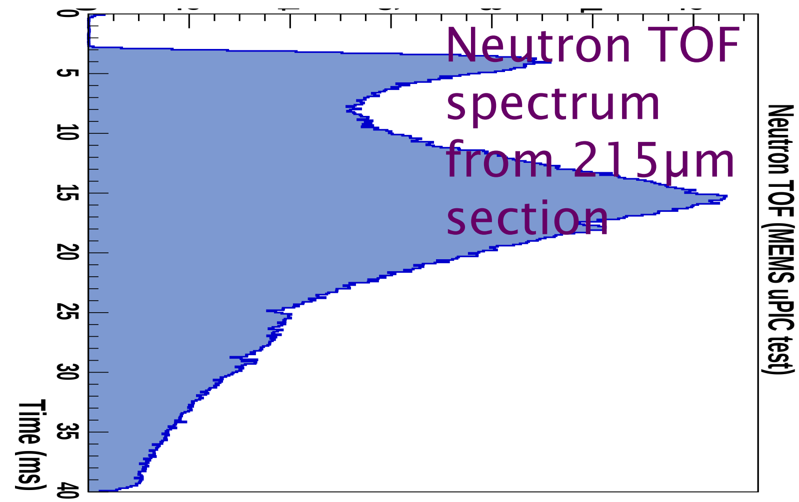
- **MEMS μPIC** with 215μm pitch for two times better spatial resolution
- **3-axis μPIC** for improved event separation at high rate







First MEMS test at J-PARC



- Signal confirmed on 215μm section
- Poor gain stability observed (dependent on neutron intensity)

First 3-axis test at J-PARC

- Signal observed on third axis but signal strength was too low to be used

T. Taniguchi et al., Kyoto U.

MPGD in space station

PS-TEPC (μ-PIC based detector) was launched at Dec.9, 2016 to ISS (International Space Station)

Y. Kishimoto, KEK

Concept and Design of PS-TEPC

Comparison of typical dose rate

In Space : 0.1 ～ 1 mSv/day (without in SPE)

On the ground : 2 ～ 3 mSv/year (from natural radiation)

※In SPE (Solar Particle Emission) : >100 mSv/day

Contributions of radiations to dose in space

In Space vehicles: charged particle (80%), neutron (20%)*1

On lunar surface: charged particle (93%), neutron (7%)*2

*1: Measured (STS-89), *2:Calculated (Spa. Rad 2006)

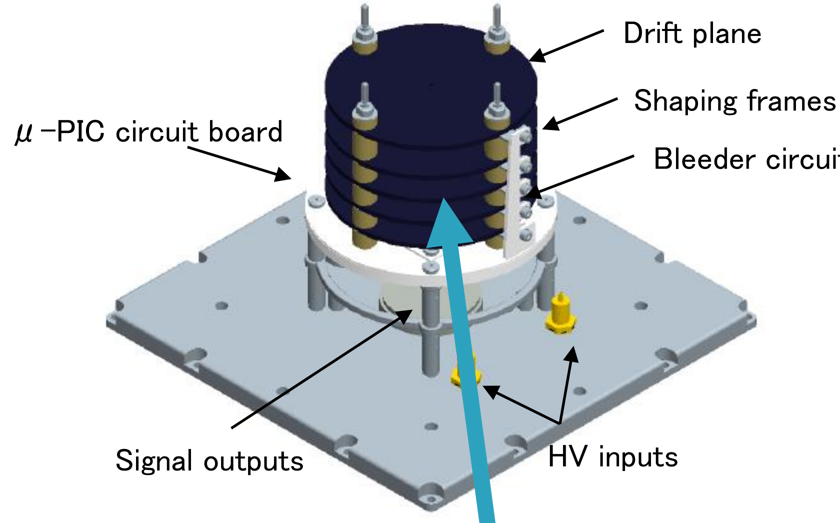
H [Sv] = Quality factor(LET) x Absorbed dose [Gy]

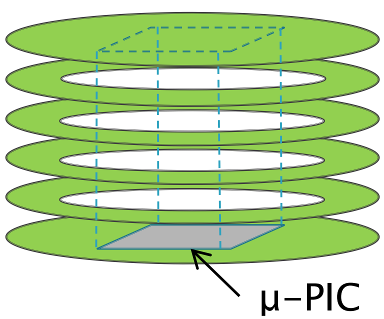
LET = Energy deposition / Path length

We need to measure LET: deposit energy and track length of radiation simultaneously.

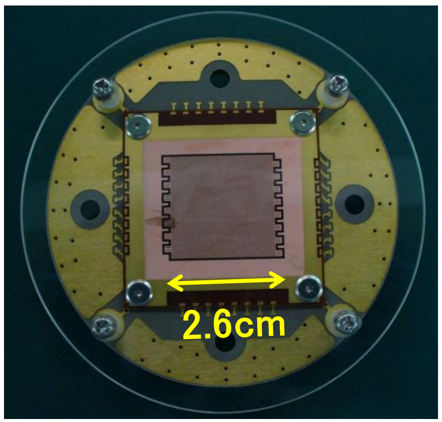
Position Sensitive Tissue-Equivalent Proportional Chamber(PS-TEPC) as a small time projection chamber using μ-PIC

KEK, JAXA, Kobe Univ., Keio Univ., Kyoto Univ., NIRS





Detection volume
$2.6 \times 2.6 \times 5.0 cm^3$



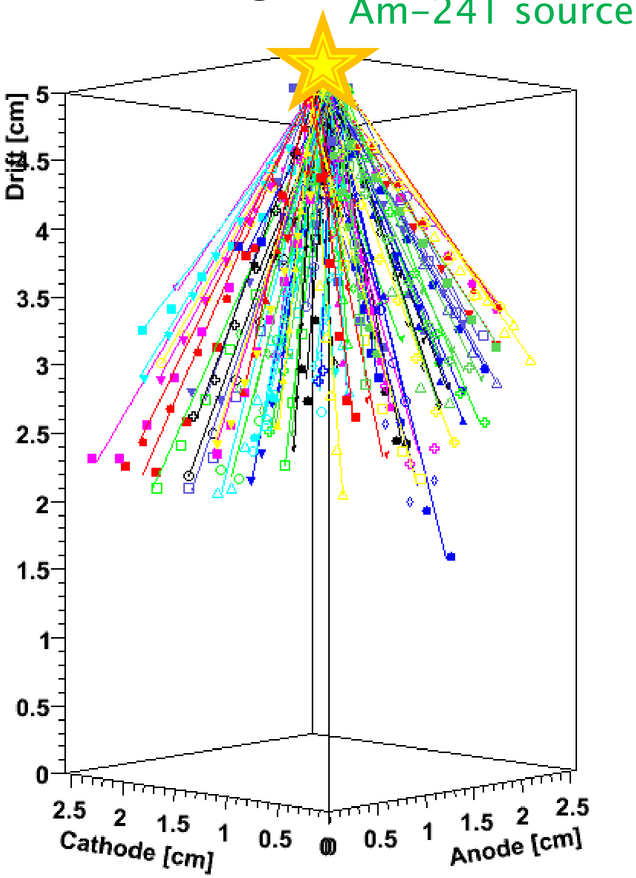
μ-PIC circuit board

Y. Kishimoto, KEK

Demonstration of measurement principle

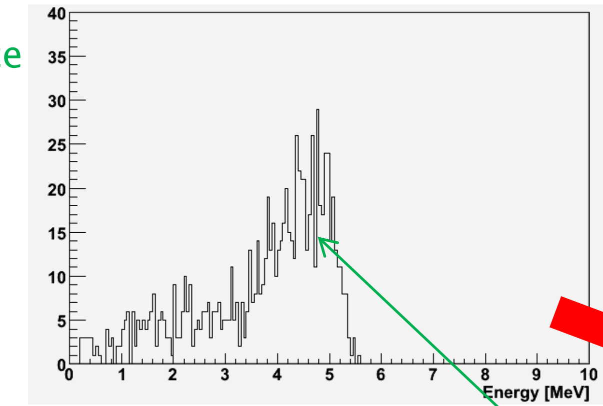
Track image

Am-241 source



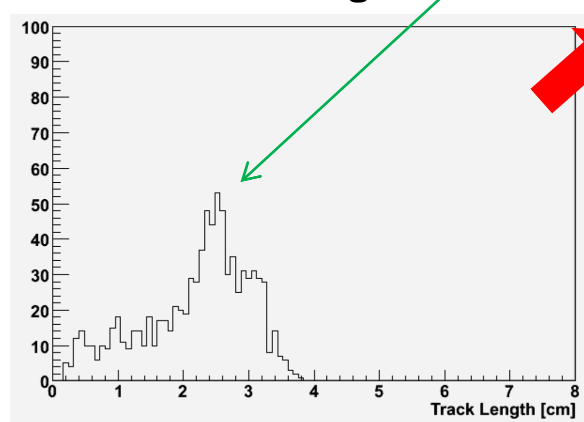
3D tracks can be reconstructed by the event

Energy deposition

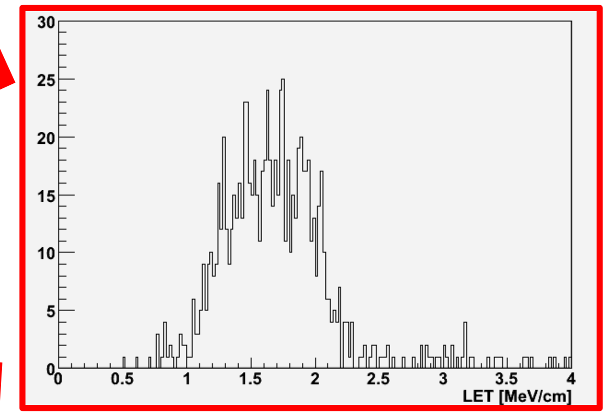


α-particles which stop completely in detection volume

Track length



LET



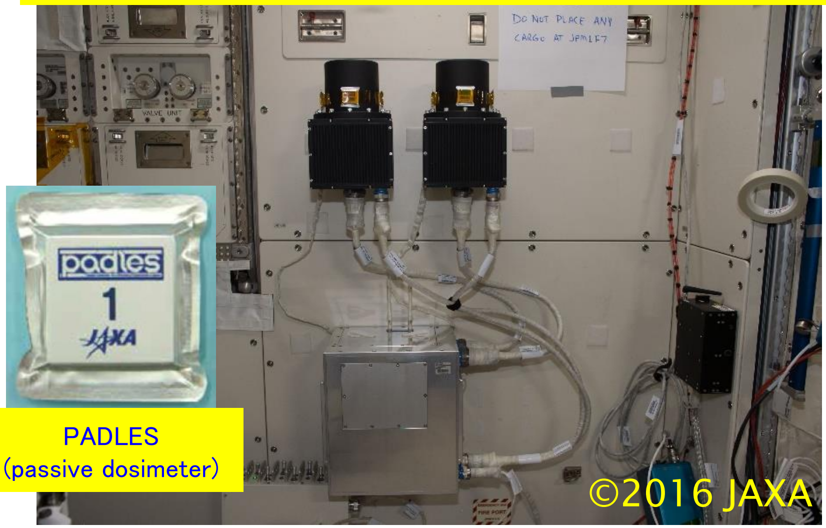
LET can be obtained by dividing energy by track length

Y. Kishimoto, KEK

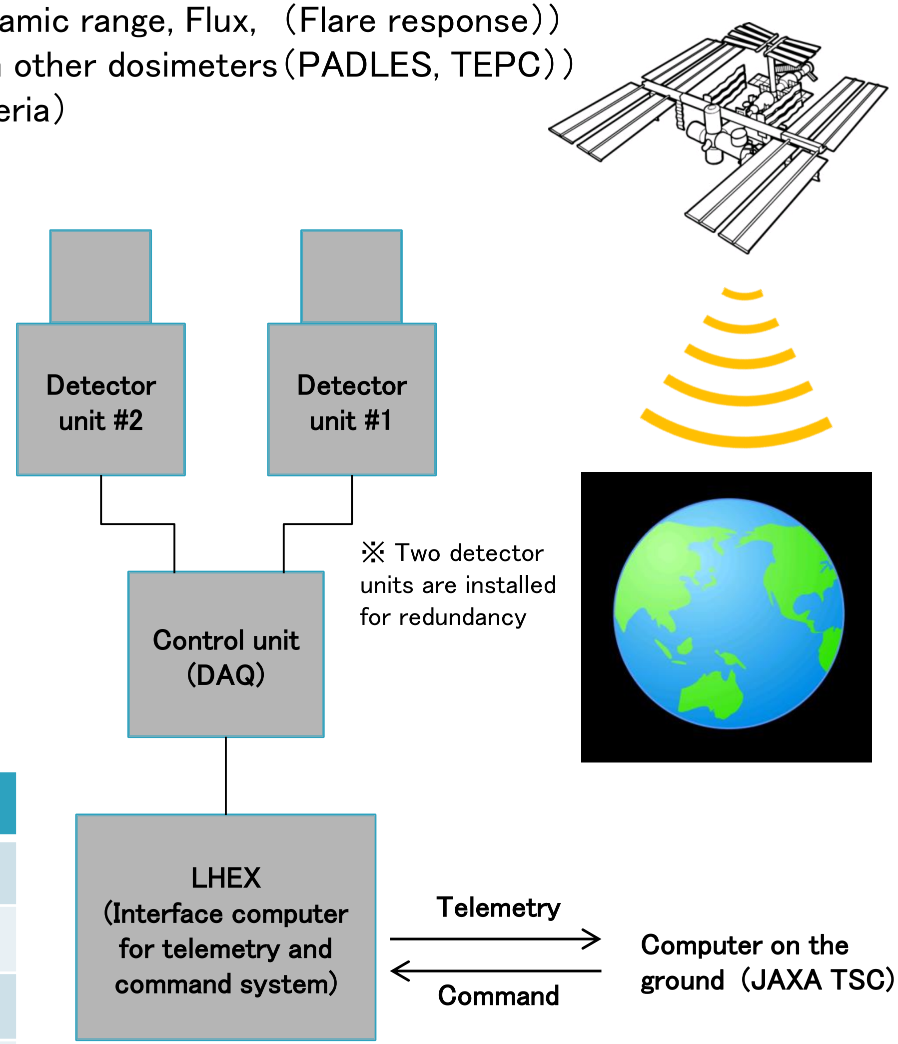
Experiments in the International Space Station

- Tests of operation in space environment (Oscillation, Discharge)
- Demonstration of performance for cosmic rays (Dynamic range, Flux, (Flare response))
- Measurement of dose rate actually (comparison with other dosimeters(PADLES, TEPC))
- Duration of experiments: 3 months (Full success criteria)

PS-TEPC installed in the Japanese Experiment Module(JEM)



PADLES
(passive dosimeter)



Date	Event
2016/12/9	PS-TEPC was launched by HTV-6
2016/12/14	PS-TEPC was installed in JEM
	Initial check and configuration were done
2016/12/28	Experiments were started

PS-TEPC has been operated well without fatal trouble until now.

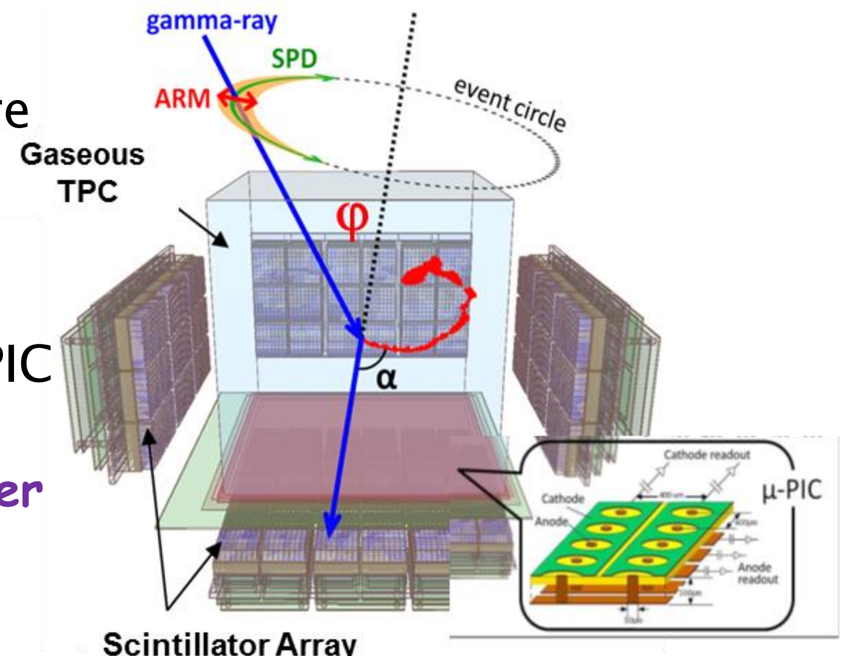
Venture Business

- ETCC based gamma-ray camera using MPGD

T. Tanimori, Kyoto-u

ETCC with μ-PIC

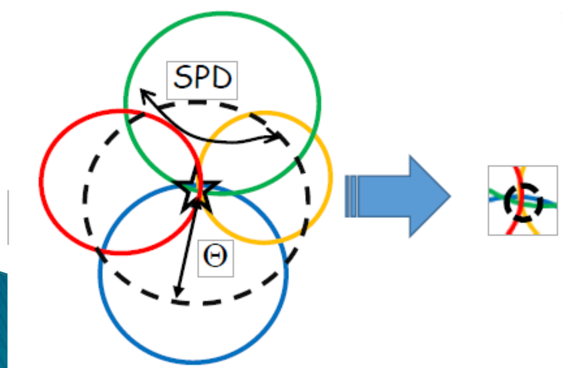
- Kyoto university launched the venture business: "Kyoto Space Gamma" for radiation vidualization system (founded in 1st March 2017)
- Base technology is ETCC (Electron Tracking Compton Camera) with μ-PIC

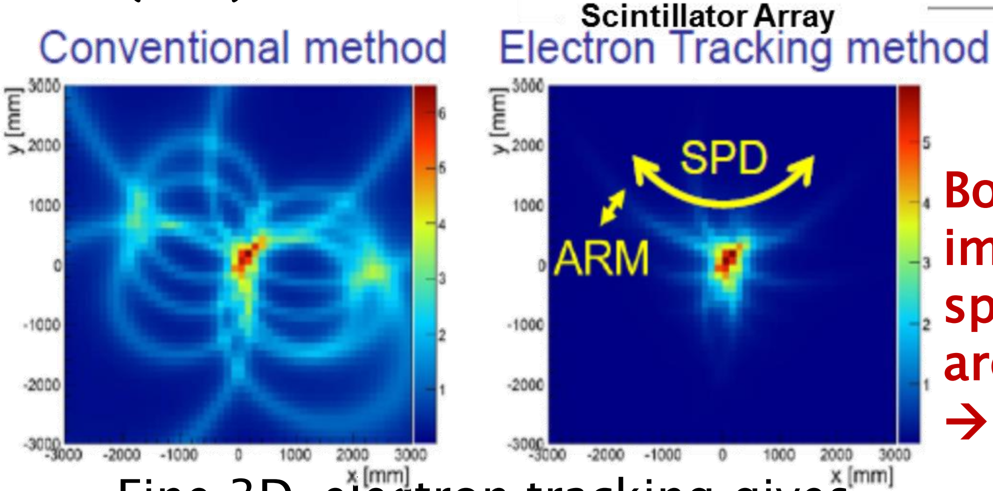


30cm-cubic Gaseous Time Projection Chamber

--- tracking of recoil electron ---

SPD ->a Point Spread Function(PSF)





Both γ-ray imaging and spectroscopy are available → Color image

Fine 3D-electron tracking gives φ, and well-defined PSF (1-2°)

T. Tanimori, Kyoto-u

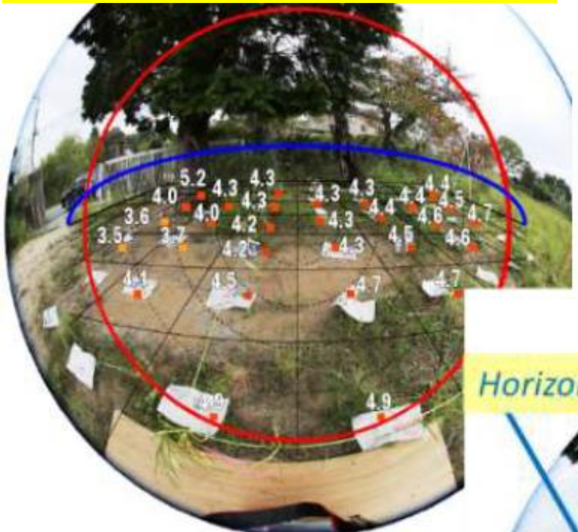
Contents of business of KSG

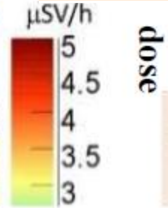
- Medical equipment
  - Development and Pruduction of cancer diagnostic system with combination of BNCT (Boron Neutron Capture Therapy) and ETCC technique
  - Low dose Gamma camera
- Radiation monitoring equipment
  - Providing "Radiation Visualization Equipment".
  - Enviromental monitoring system for FUKUSHIMA nuclear disaster
  - Radiation monitoring system for decommissioning of reactor
- Non-destructive inspection equipment
  - With gamma-ray

T. Tanimori, Kyoto-u

Inspection of radiation in FUKUSHIMA with ETCC

Kyoto Space Gamma

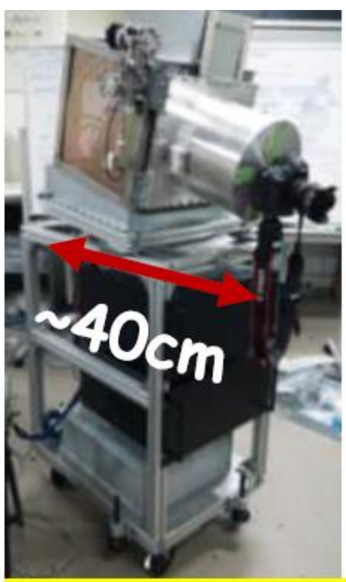




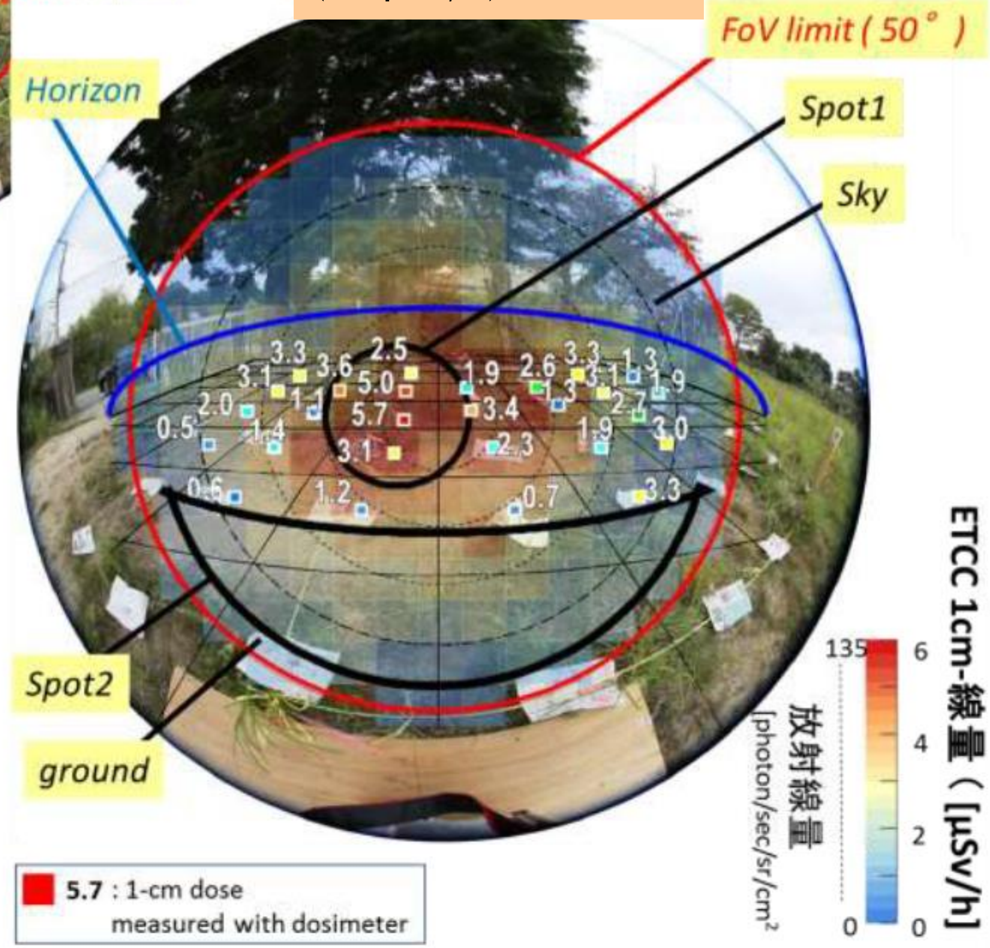
Tomono et al., (2017), Scientific Reports

Contaminaton area
(~ 5µSv/h)

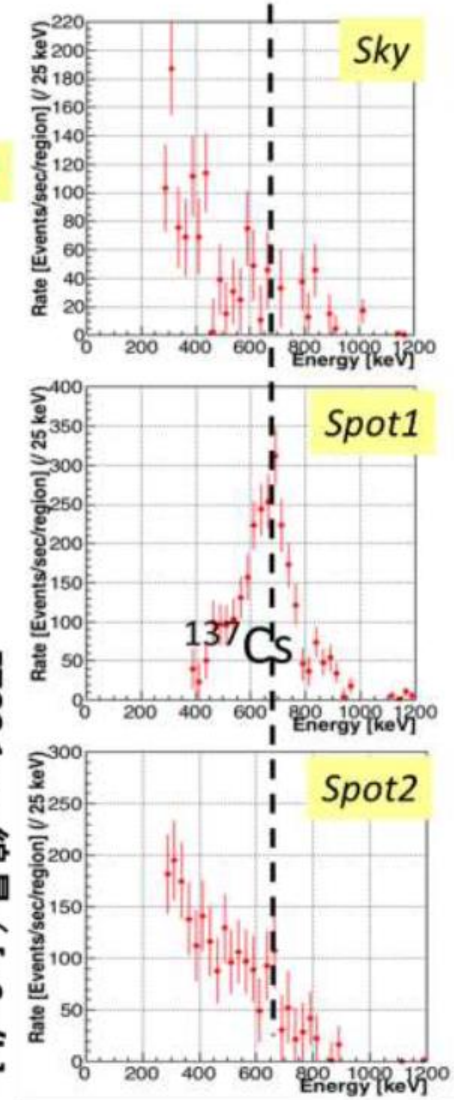
Portable ETCC



検出面積　数mm²
PSF ~15°



5.7 : 1-cm dose measured with dosimeter



Low dose medicine diagnosis

T. Tanimori, Kyoto-u

Kyoto Space Gamma

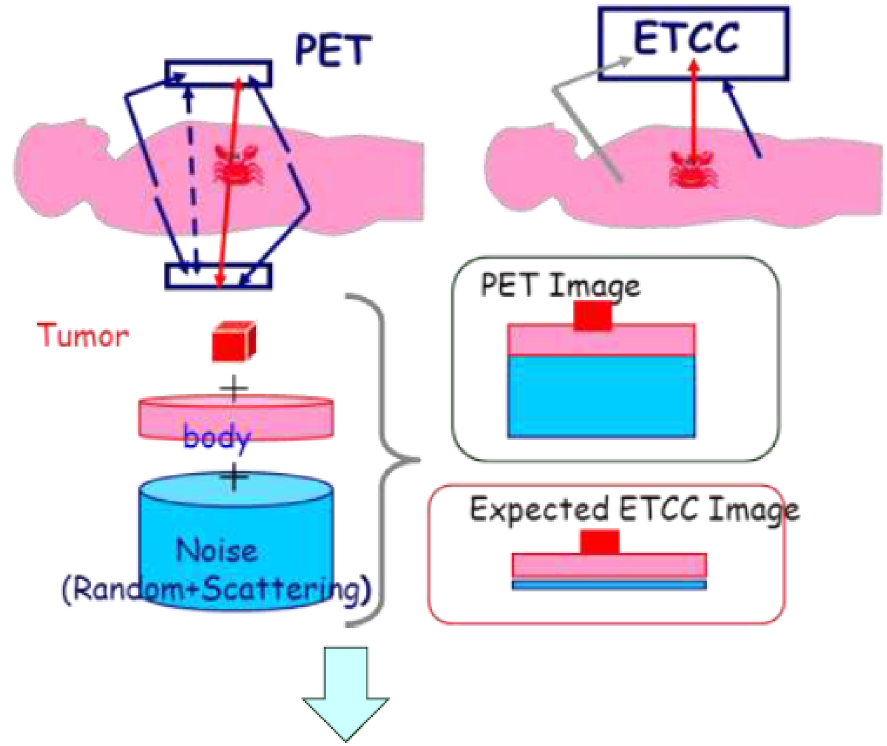
- Administration dose calculation for PET

ETCC well-defined PSF 2-3degree
→ Using only 5mm radius of scattered gamma

- NECR 5×10^4cps@10kBq/ml (600MBq/60kg)

Total trigger ~1.6×10^6cps

- Random ~10^6cps
- Scattering ~3×10^5cps
- True(body) ~3×10^5cps
- Only 10% of dose are contributed for image. Other 90% is noise.
- Imaging quality is reduced to 10% due to noise. Statistically, noiseless image is same as 60MBq dose
- PET can diagnose 1cm of tumor
- For 5mm tumor diagonosis, more than 10 times dose are needed



ETCC: for 1cm tumor → 100sec. diagnosis for 5σ
Condition: 30% coverage, Efficieincy = 0.1%
Administration dose -20MBq
In future, efficiency will be improved to a few %
→ a few Bq

MPGD Community in JAPAN

- There is no strong community (e.g. RD51) in JAPAN for MPGD R&D.
- However, we have shared information through annual workshop (2004~) and some collaborative works
- Beginning of international conference and RD51 make us accelerate to internationalization
- 2nd MPGD conference was held in Kobe JAPAN.

MPGD annual workshop in JAPAN (2004~)

- Many institutes started the MPGD studies in this century
- December 2004, First MPGD workshop held in Kyoto
- The workshop held once every year now
  - More than 70 participants have joined for each workshop.

13th MPGD workshop (JAPAN) in Kobe
(9–10 December, 2016)

KEK Detector Technology Project (2005~)

- Organizing detector development group across the fields of studies
- 8 group progressing now
  - MPGD, PPD, SCD, LiquidTPC, SOI, ASIC, FSCI, CO2cooling
- MPGD project is one of main projects in KEK DTP
  - Member institutes:
    - KEK, Tokyo U. of Science, Osaka City U., Saga U., U. Tokyo
    - The fields of high energy, neutron, material science, medical diagnostics are joined

Summary

- High activities and variety of MPGD developments in JAPAN
  - Both application developments and basic detector studies are very active.
  - Especially, material studies are very active
- Several projects are going to practical application
  - MPGD is launched to space for active dose meter
  - New venture business is founded for gamma-ray imaging

- **We should bring our experiences to a successful conclusion by sharing our knowledge, experience and know-how**

Thank You