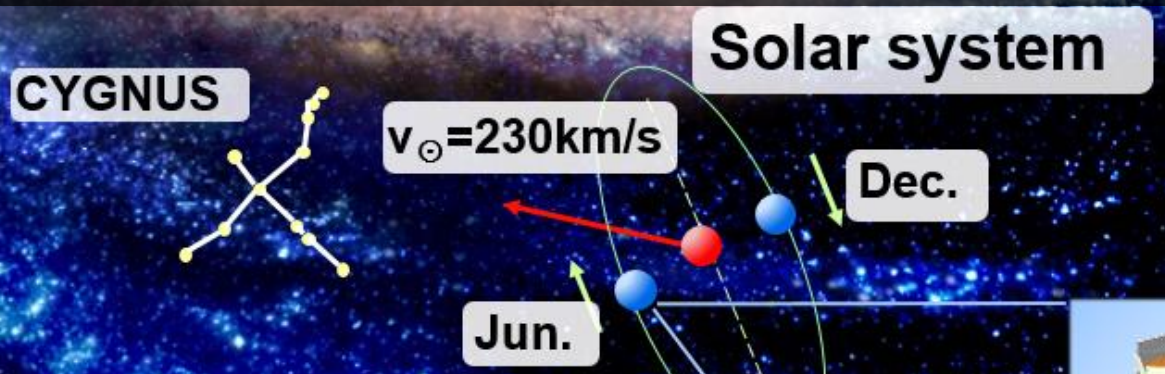
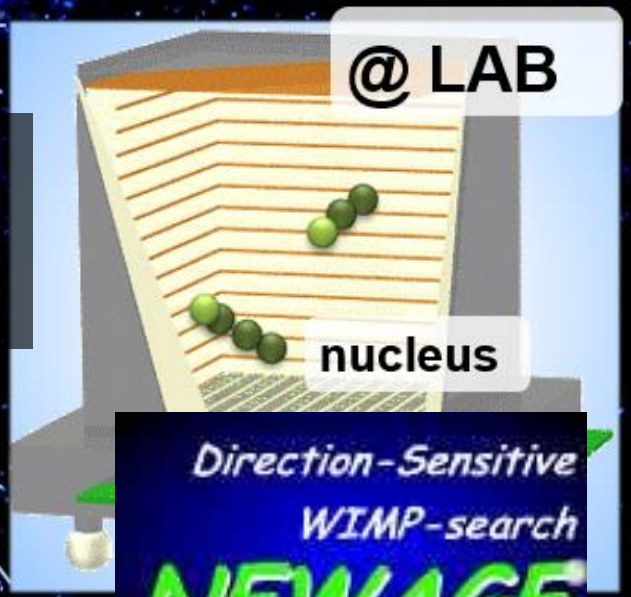
Status of NEWAGE/CYGNUS-KM

Kentaro Miuchi
KOBE University





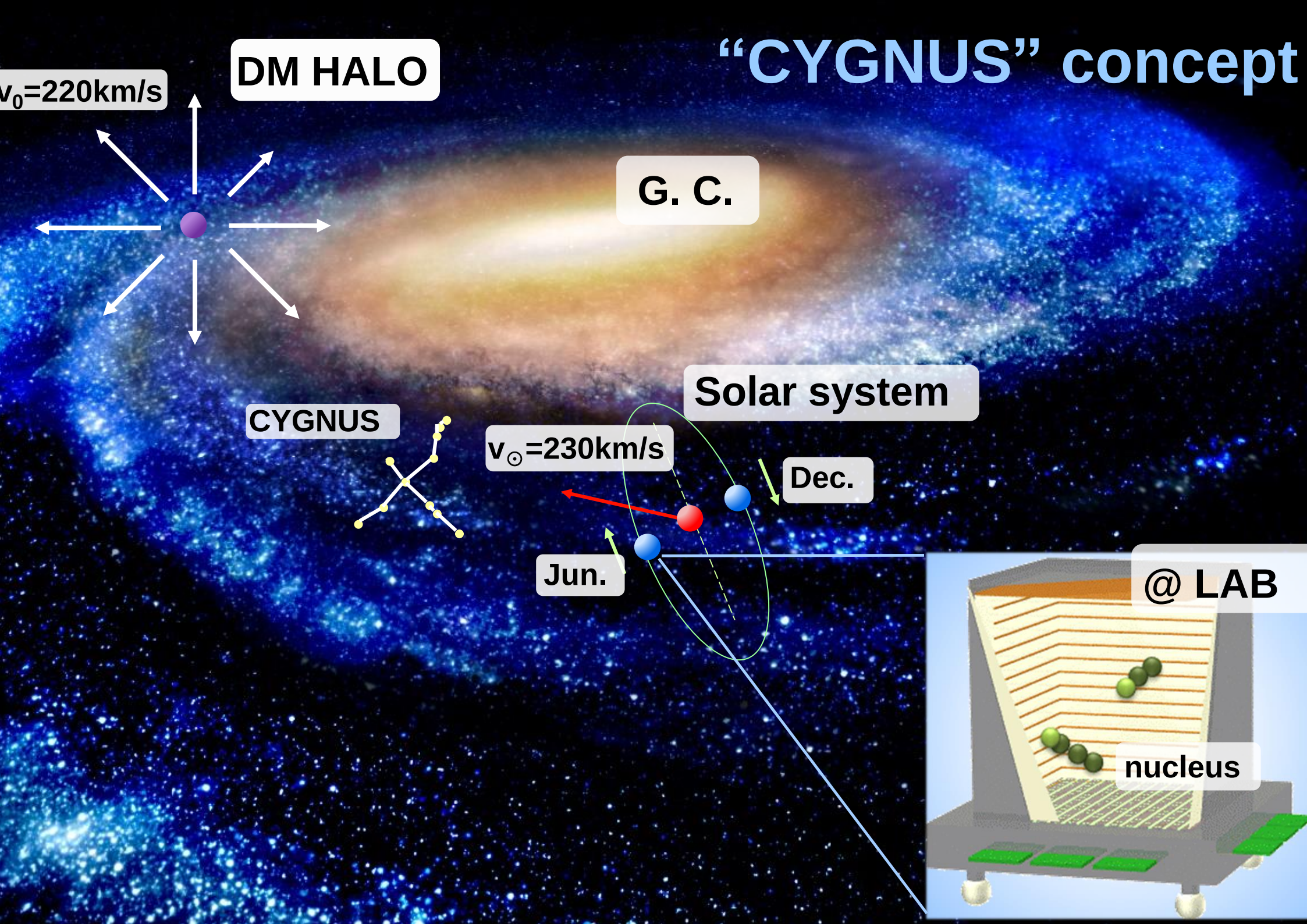
科研費 KAKENHI

JSPS 二国間事業
「ガス飛跡検出器を用いた暗黒物質探索実験」

NEWAGE

New general WIMP search with an Advanced Gaseous tracker Experiment

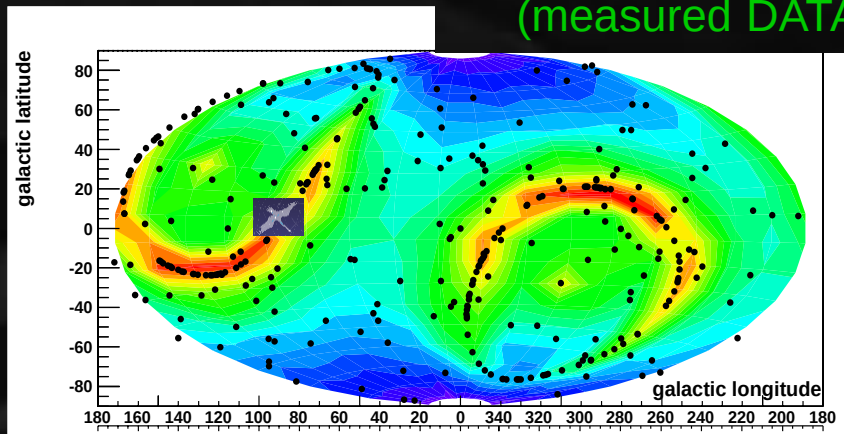
“CYGNUS” concept



NEWAGE history

- μ-PIC(MPGD) based TPC
  - 3-D tracks SKYMAP
- CF4 gas for SD search

SKYMAP
(measured DATA)

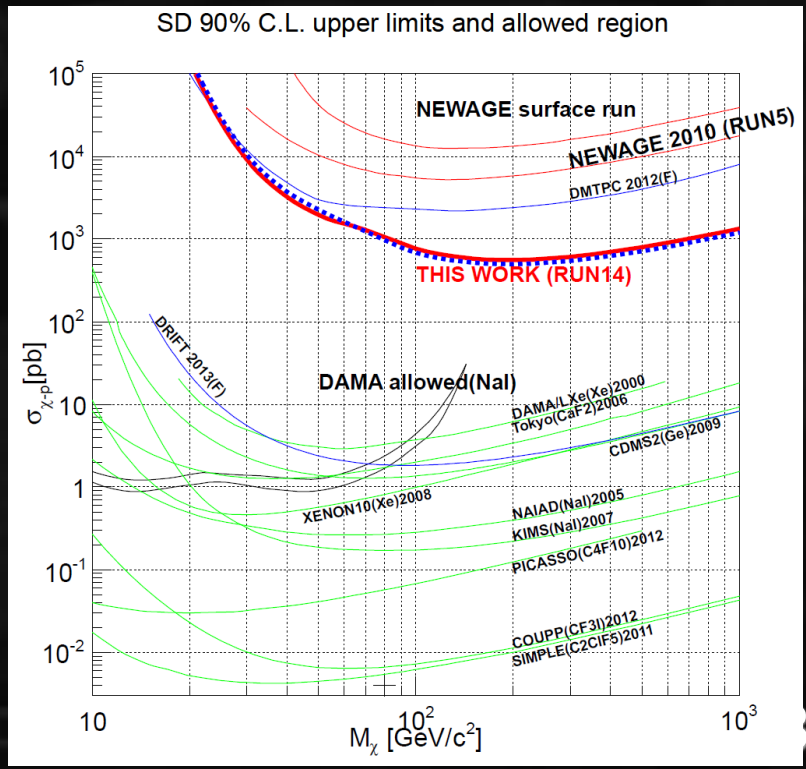


- Proposal PLB 578 (2004) 241
- First direction-sensitive limits

  PLB654 (2007) 58
- Underground results

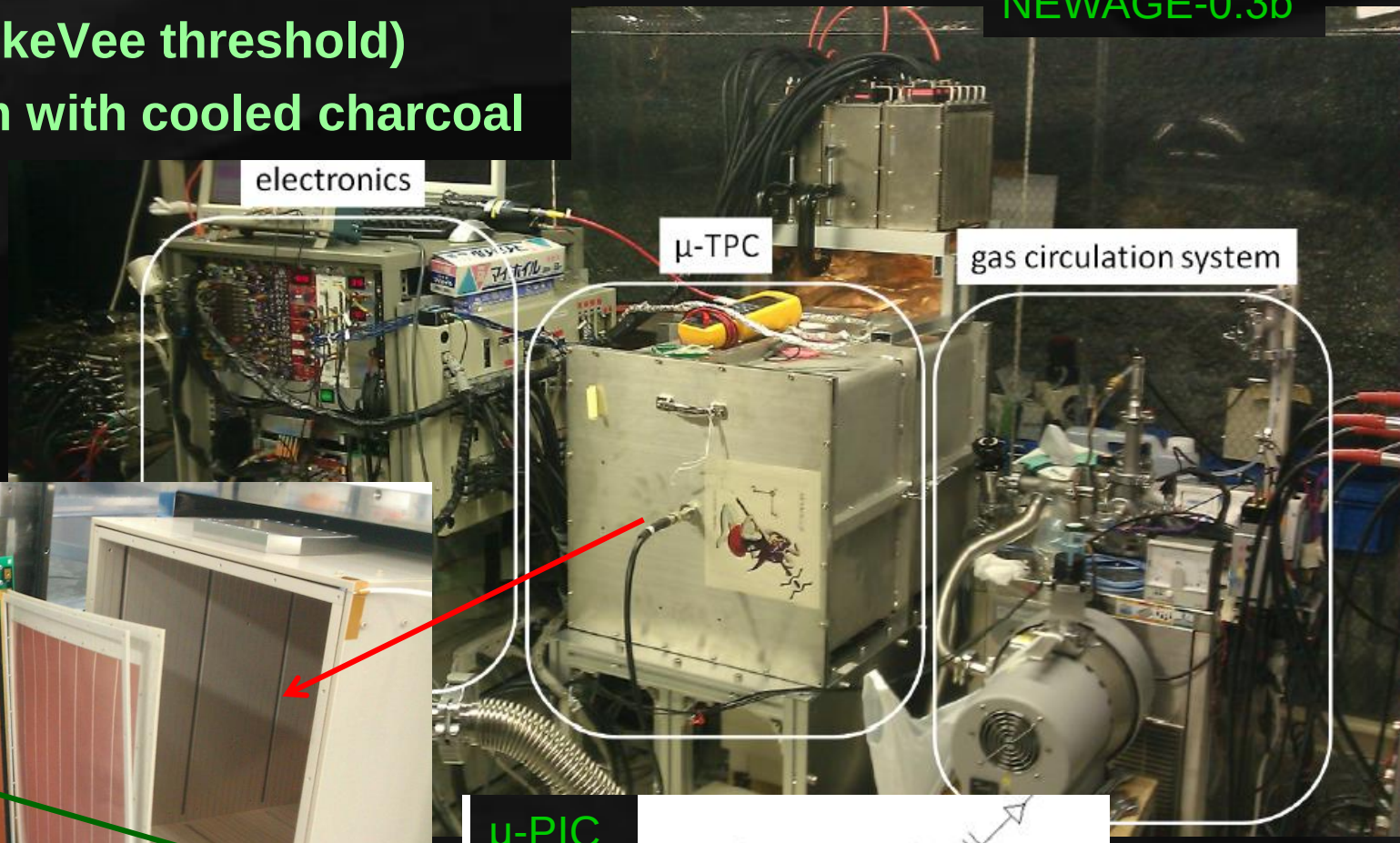
  PLB686 (2010) 11, PTEP (2015) 043F01s
- Phase for “low BG detector”

limits PTEP (2015) 043F01s

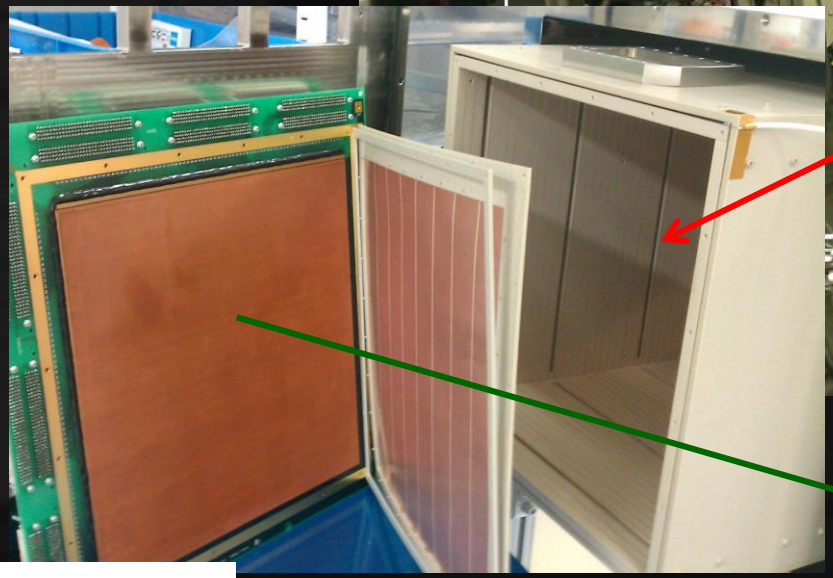


NEWAGE detector

- NEWAGE-0.3b'
- Detection Volume: 31×31×41cm^3
- Gas: CF4 at 0.1atm (50keVee threshold)
- Gas circulation system with cooled charcoal

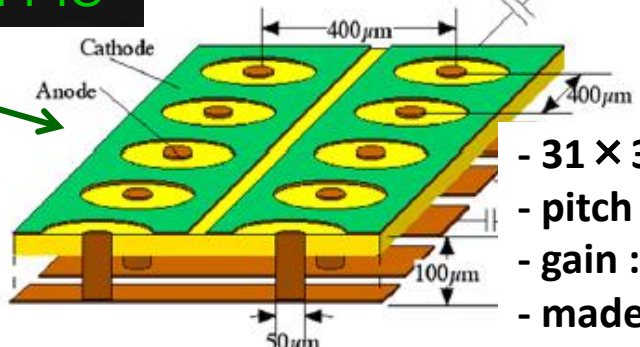


μ-TPC



Drift length: 41cm
PEEK + copper wires

μ-PIC



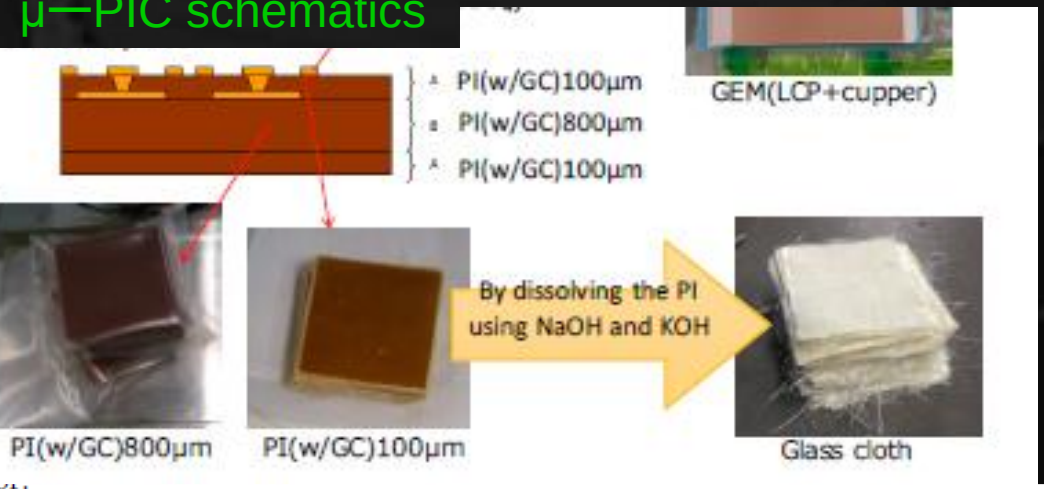
- 31×31cm^2
- pitch : 400μm
- gain : ~1000
- made by DNP, Japan

BG study

K. Nakamura
T. Hashimoto

BG source: alpha particle from μ-PIC

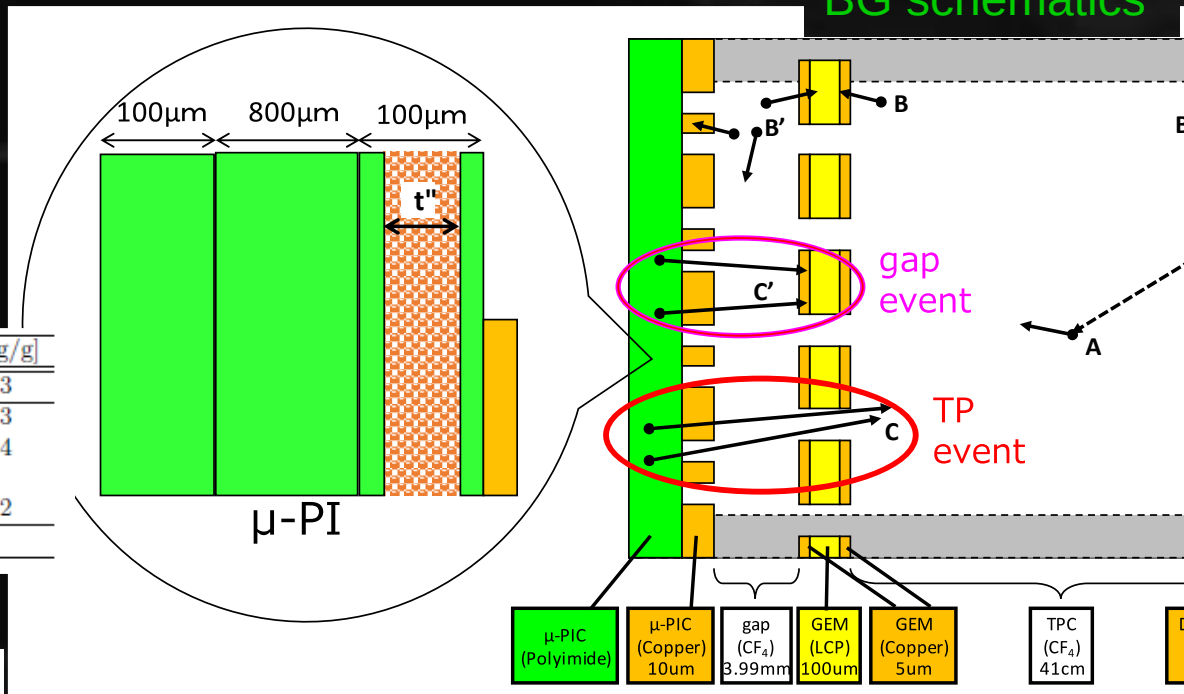
μ—PIC schematics



Glass cloth in PI had O(ppm) U/Th

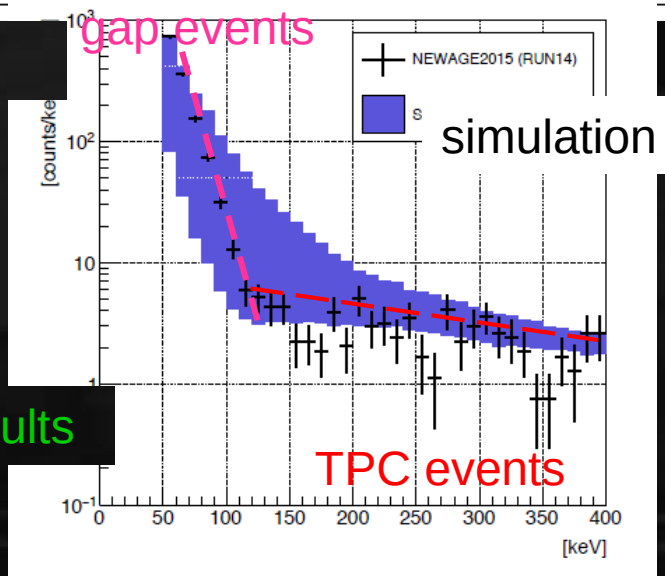
Sample	^{238}U middle stream [10^{-6} g/g]	^{238}U upper stream [10^{-6} g/g]	^{232}Th [10^{-6} g/g]
μ-PIC	1.17 ± 0.01	1.14 ± 0.01	5.84 ± 0.03
PI(w/GC)800 μmpart	0.78 ± 0.01	0.76 ± 0.01	3.42 ± 0.03
PI(w/GC)100 μmpart	0.39 ± 0.01	0.38 ± 0.01	1.81 ± 0.04
Plating solution[1]	< 0.01	< 0.13	< 0.06
Glass cloth	0.84 ± 0.03	0.91 ± 0.02	3.48 ± 0.12
GEM	< 0.02	< 0.17	< 0.12

BG schematics



HPGe results

MC results



TARGET:
low-α emitting μ-PIC development

Low-α μ-PIC

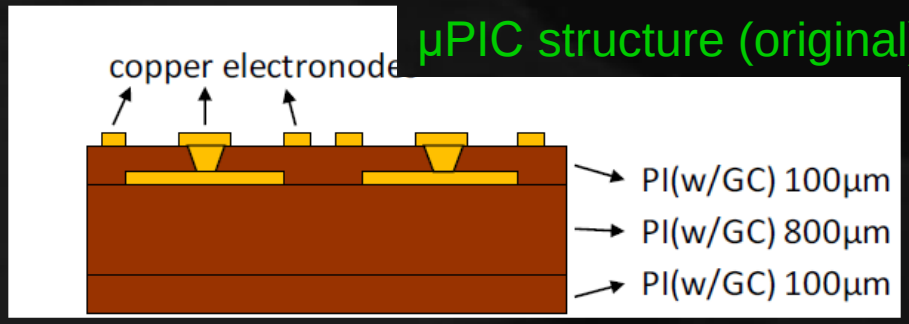
T. Hashimoto
helped by K. Ichimura, K.Abe (XMASS)

- **2014 material selection**
  - **new material :PI + epoxy**
  - **BG level: < 1/100**

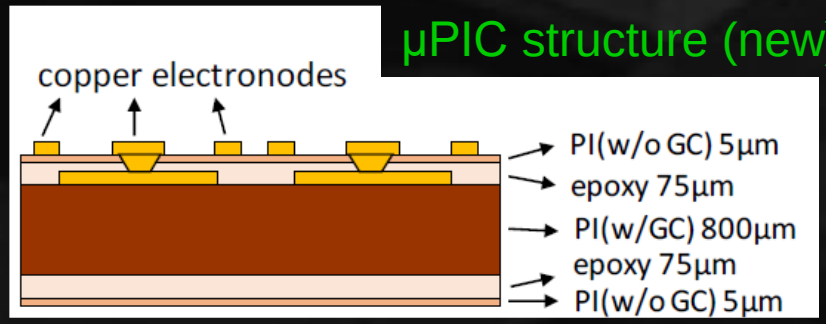
material selection results

	^{238}U[ppm]	^{232}Th[ppm]	
PI including glass cloth	0.39±0.01	1.81±0.04	
PI+epoxy	$< 2.98\times10^{-3}$	$< 6.77\times10^{-3}$	← New material

μPIC structure (original)



μPIC structure (new)



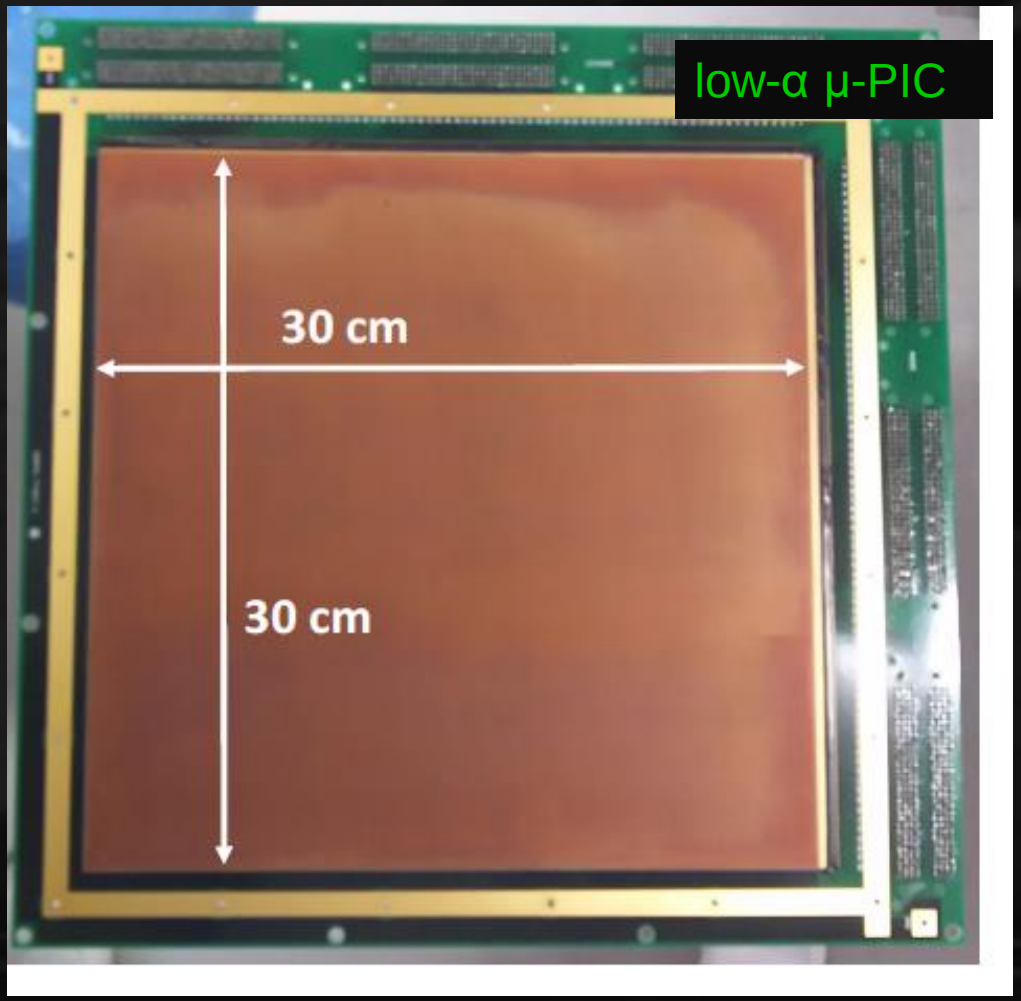
Direction Sensitive WIMP-search NEWAGE

Low-α μ-PIC：development

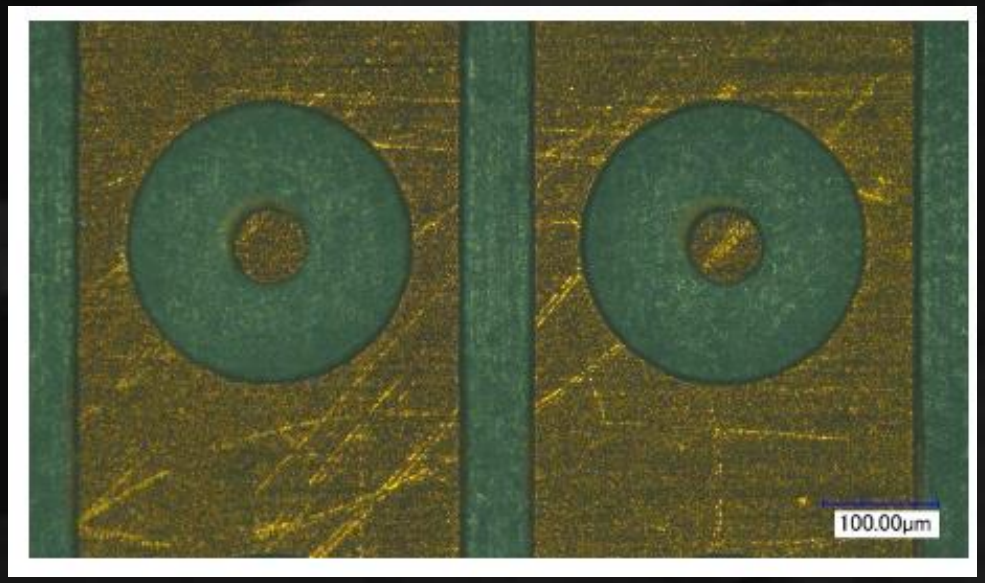
T. Hashimoto

& DNP Co.

- **Development of low-α emitting μ-PIC**
  - **2015: 10×10 cm² μ-PIC**
  - **2016: 30×30 cm² μ-PIC**



low-α μ-PIC electrodes



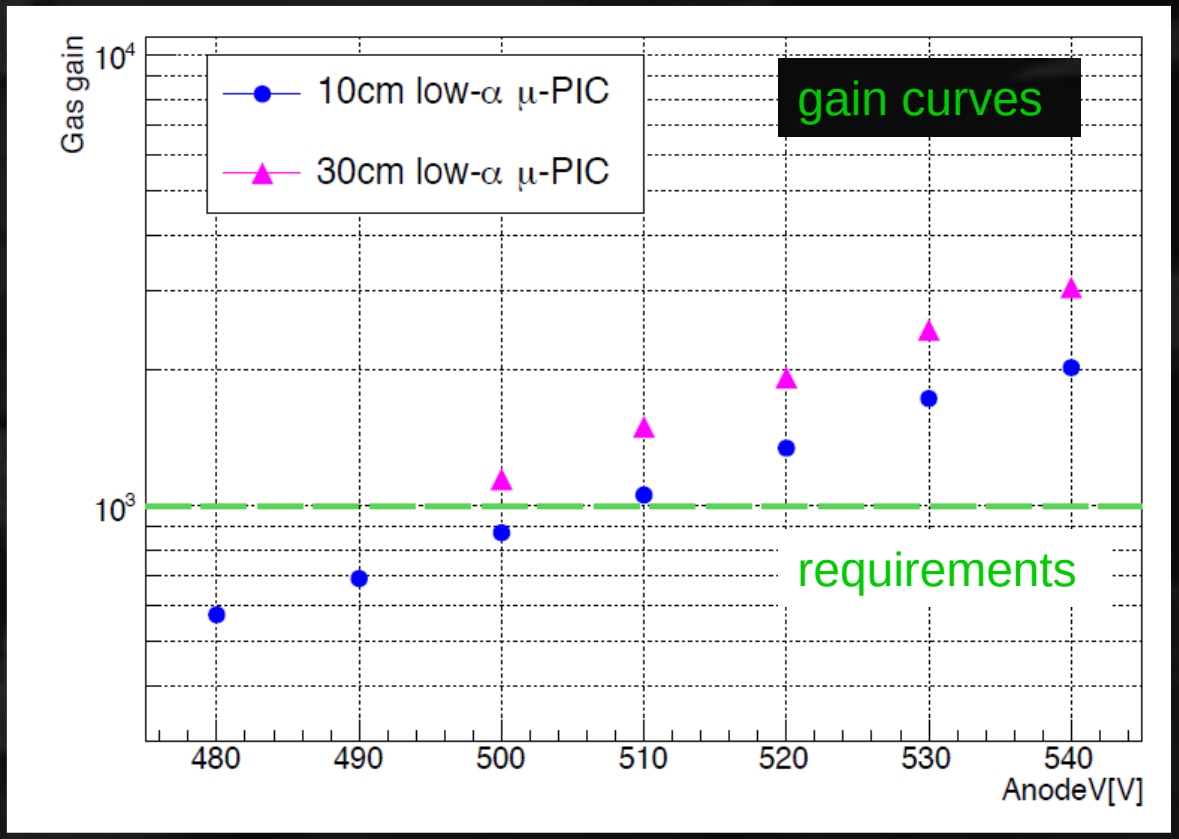
perfectly produced !

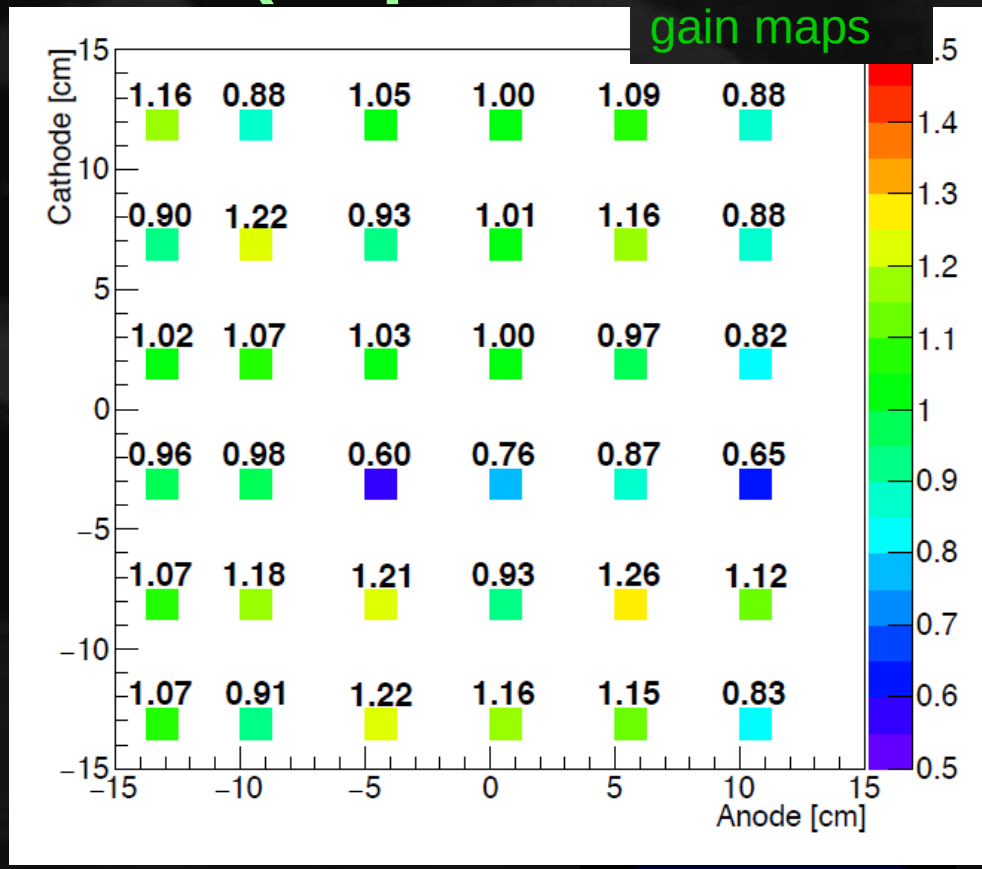
in spite of the material change

Low-α μ-PIC：performance

T. Hashimoto
NIMA submitted

- 2017: performance of low-α emitting μ-PIC
  - gas gain >1000　(requirements)
  - gain non-uniformity RMS < 20% (requirements)



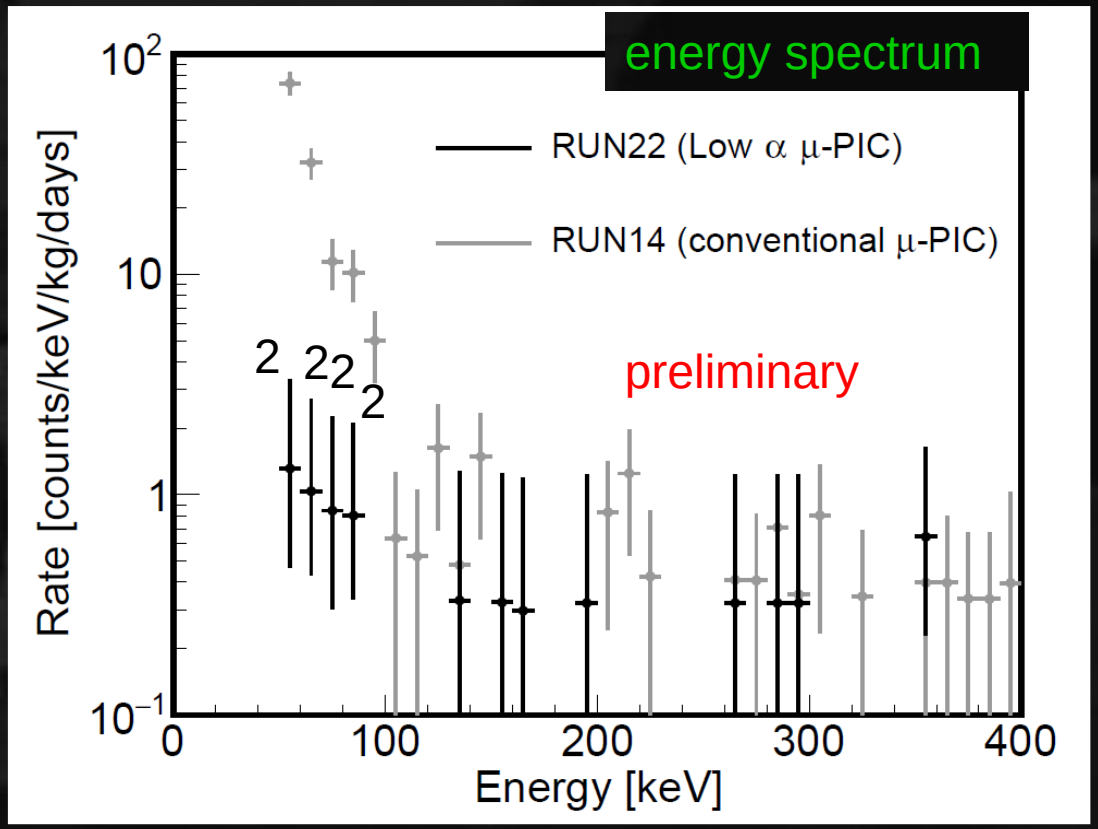


Direction Sensitive

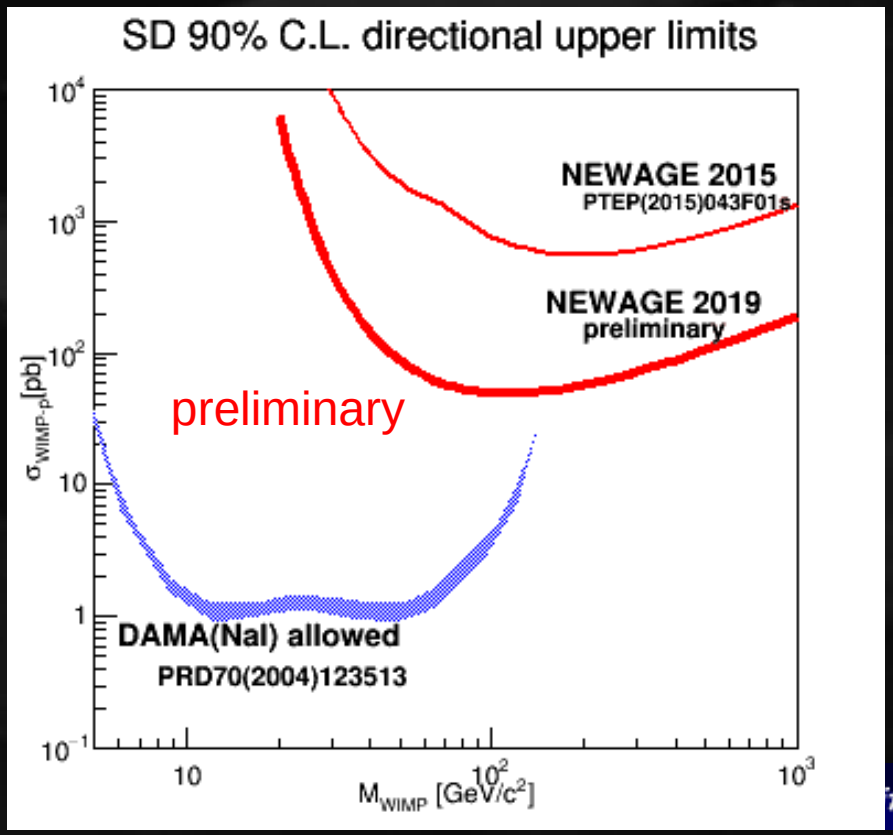
requirements satisfied !

Low-α μ-PIC：DM run

- **Installation: Dec. 2017**
- **DM run: 2018-**
  - **RUN22-1 2018/6/6~2018/8/24 (47days)**
  - **RUN22-2 2018/9/20~2018/12/3 (61days)**



directional limits



～×10 improvements

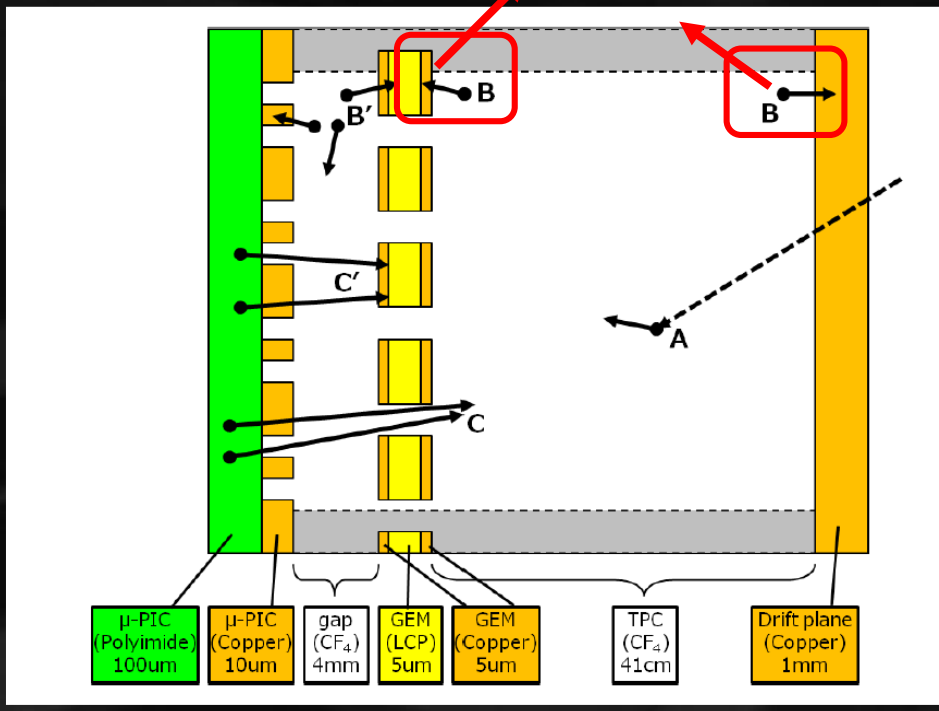
NEWAGE
and beyond

NEWAGE：next

- **new main BG:**
  - **μ-PIC: surface BG**
  - **radons**

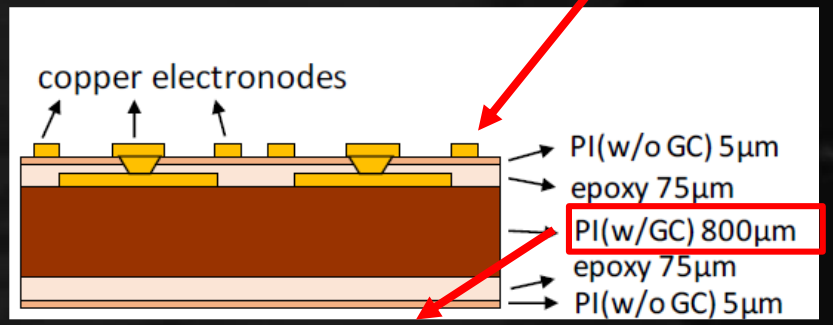
BG schematics

Radon BG



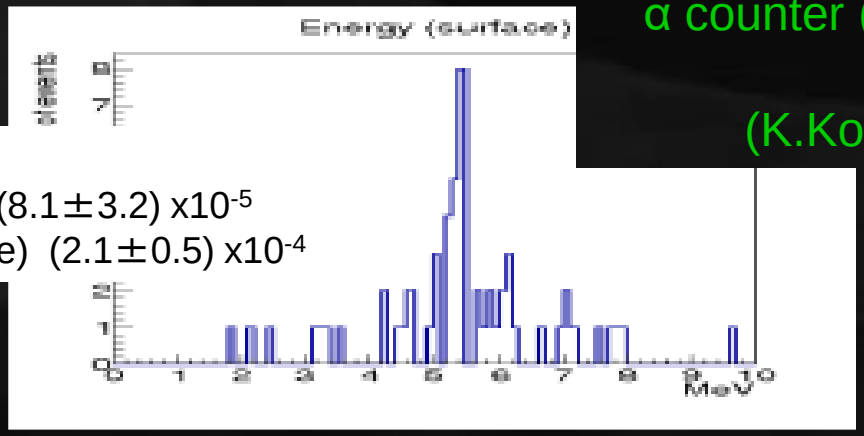
μPIC structure (now)

surface BG was observed



β-rays from the 800 μm "core substrate" (near future BG)

α counter (Ultra-lo) results (K.Kobayashi)



[α/cm^2/hr]
2.5<E<4.8MeV(bulk) (8.1±3.2) x10^{-5}
4.8<E<5.8MeV(surface) (2.1±0.5) x10^{-4}

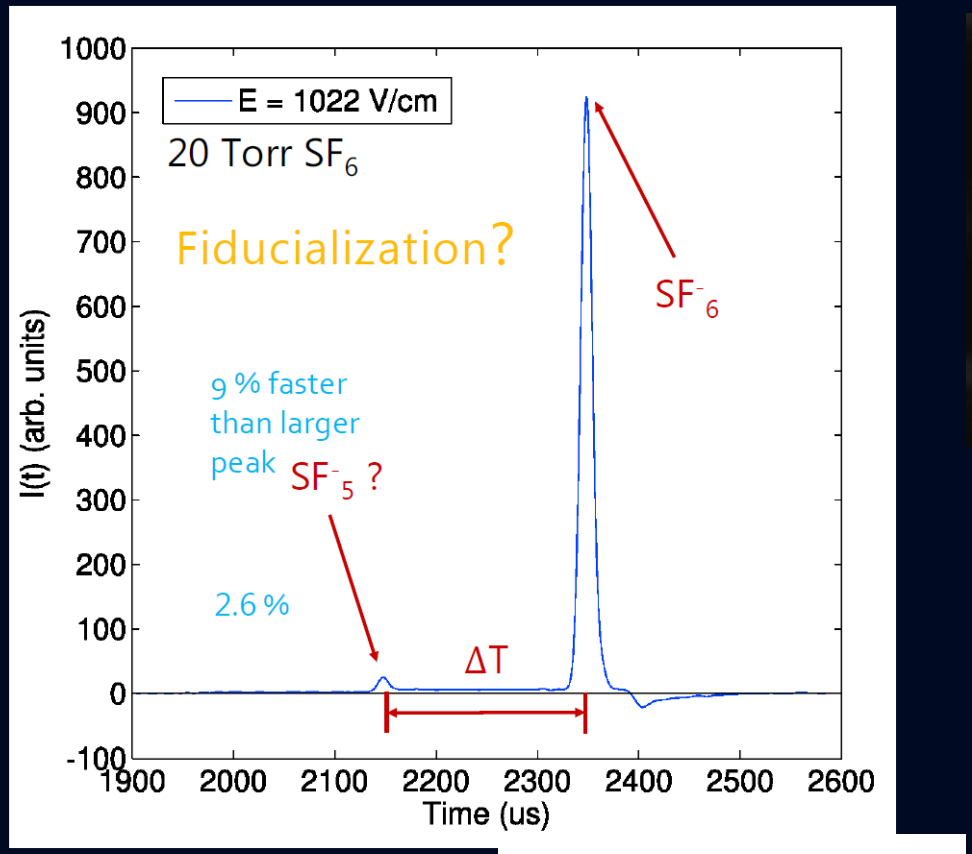
Direction Sensitive

more than ×10 improvements in next 5 years

- **Negative ion TPC**
  - **minority peaks “discovery”** （DRIFT group）
  - **O_2 addition to CS_2+CF_4 gas**
  - **SF_6 gas** several species of ions with different velocities

$$z = (t_a - t_b)\frac{v_a v_b}{(v_b - v_a)}$$

SF_6 results



averaged waveform

Detection of absolute z-position

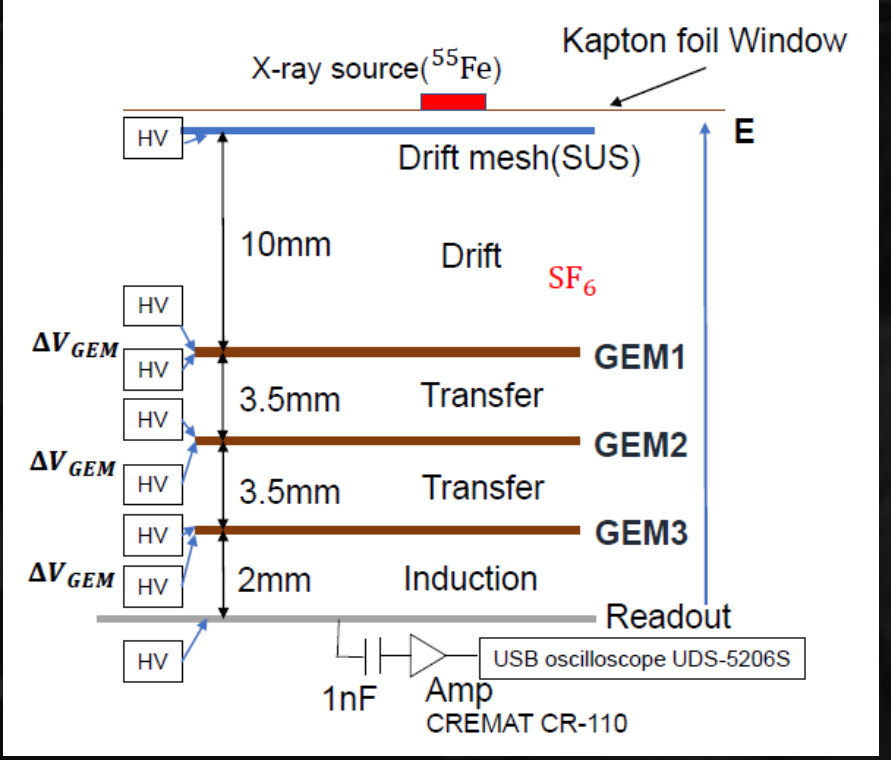
⇒ BG reduction

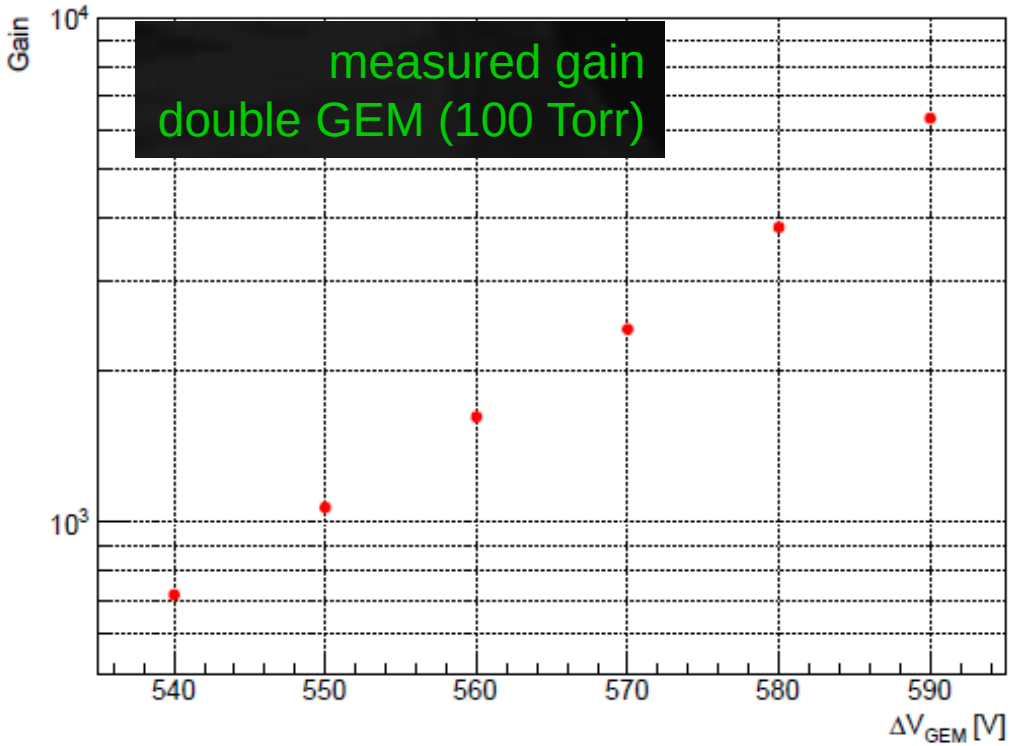
Direction Sensitive WIMP-search NEWAGE

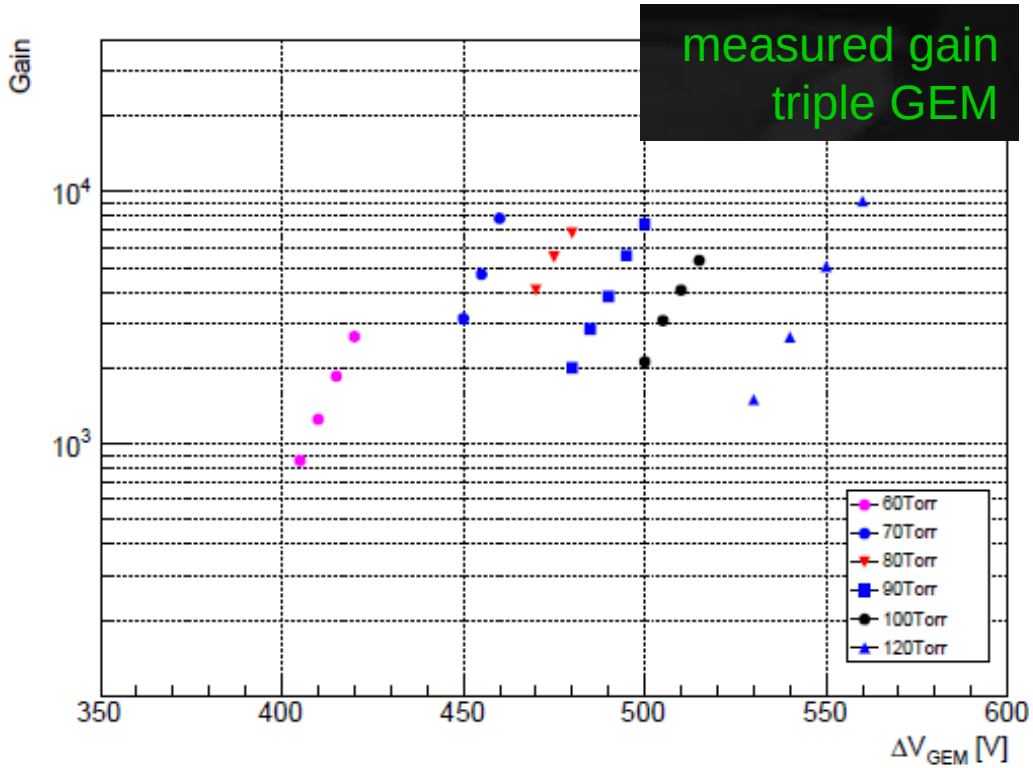
SF6 gain study

- 2 (or3)×GEM (LCP, 100μm Scienergy)

H. Ishiura @MPGD 2019
proceeding in preparation



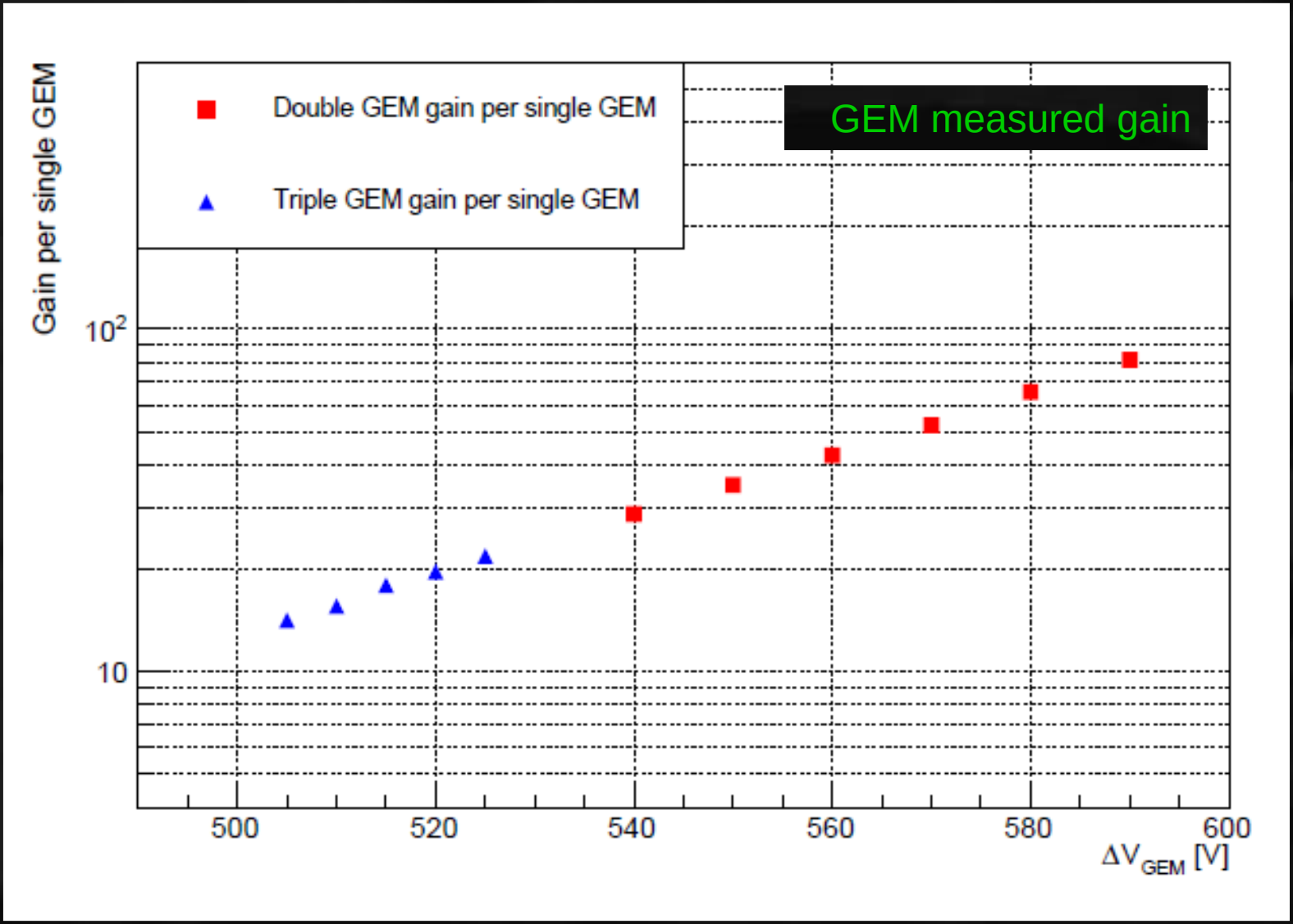




Measurement results

- normalized to single GEM gain

H. Ishiura @MPGD 2019
proceeding in preparation

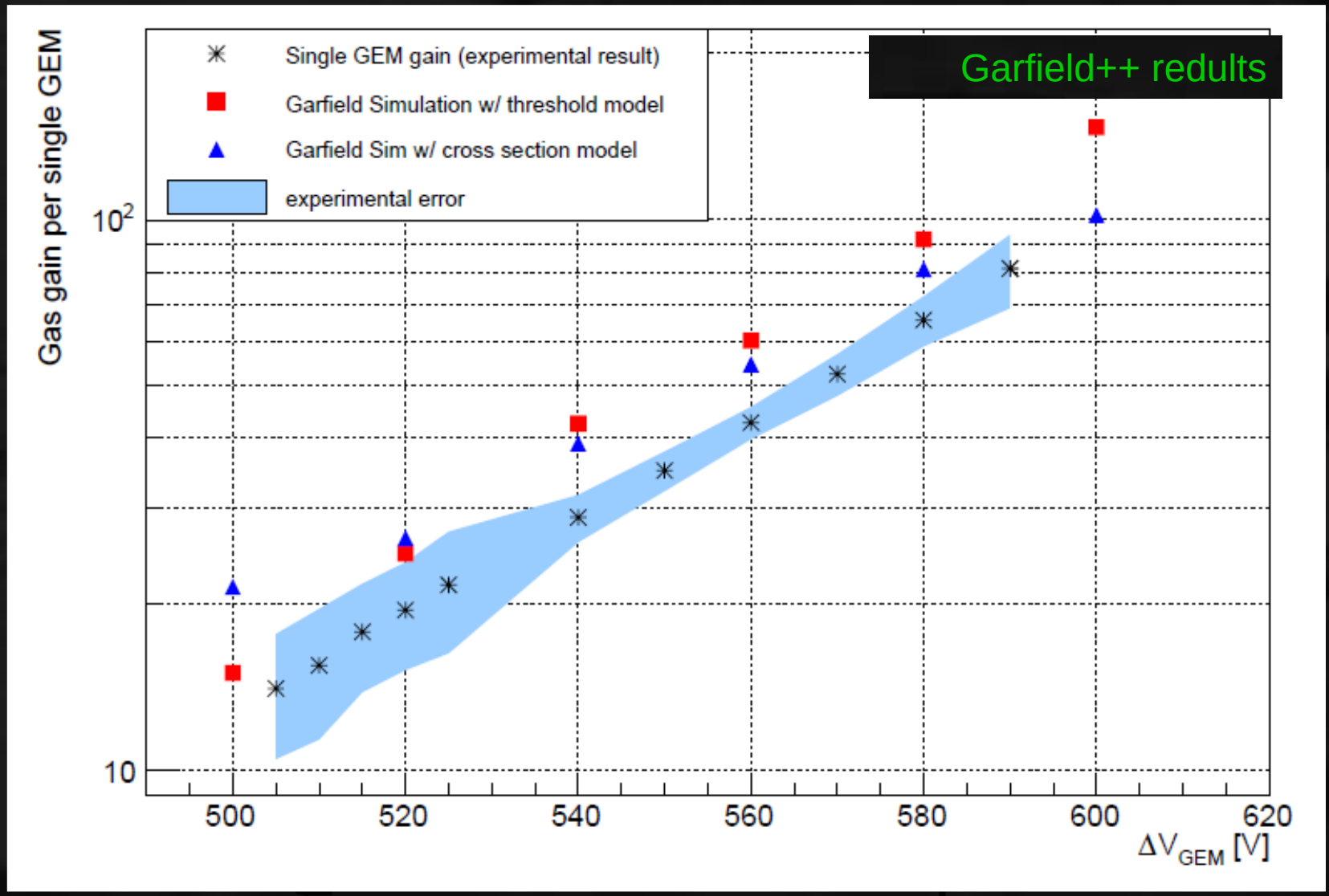


- plotted on one line ⇒no (significant) charge loss

Garfield for negative ion

H. Ishiura @MPGD 2019
proceeding in preparation

- (details in tomorrow's Miuchi's talk)

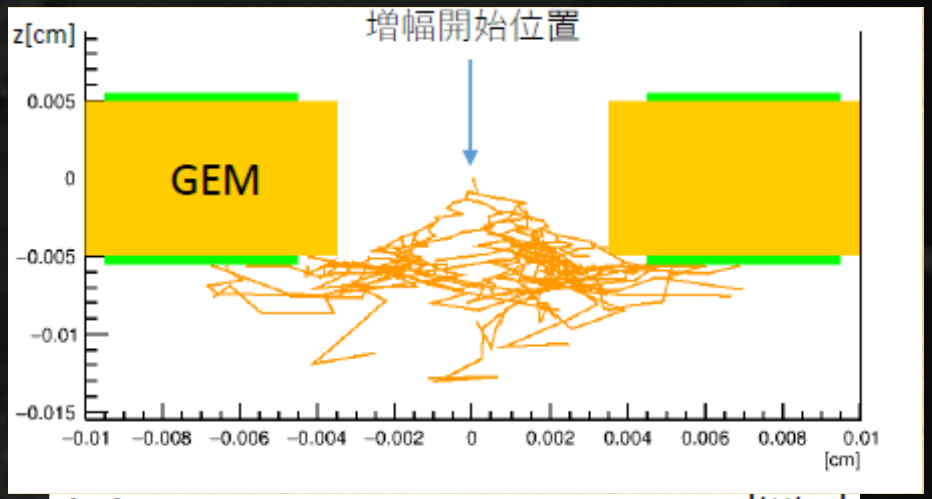


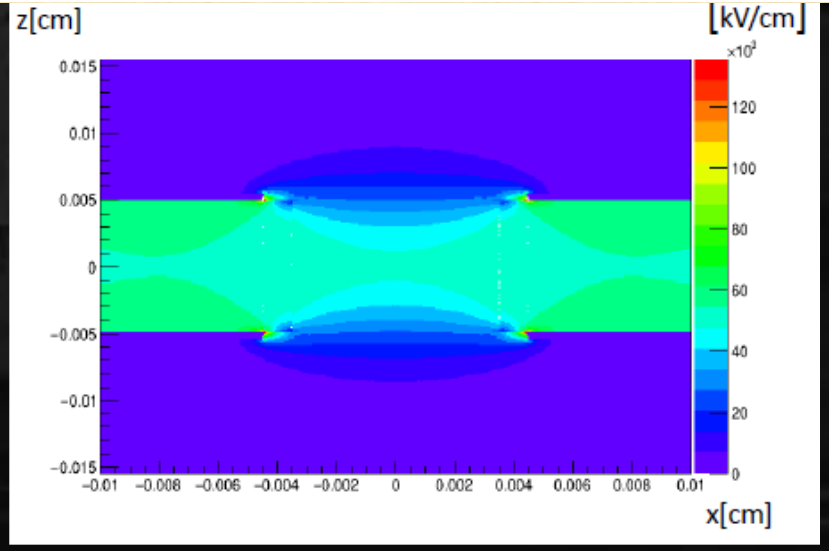
- gain curve reproduced (without any CORRECTION !)

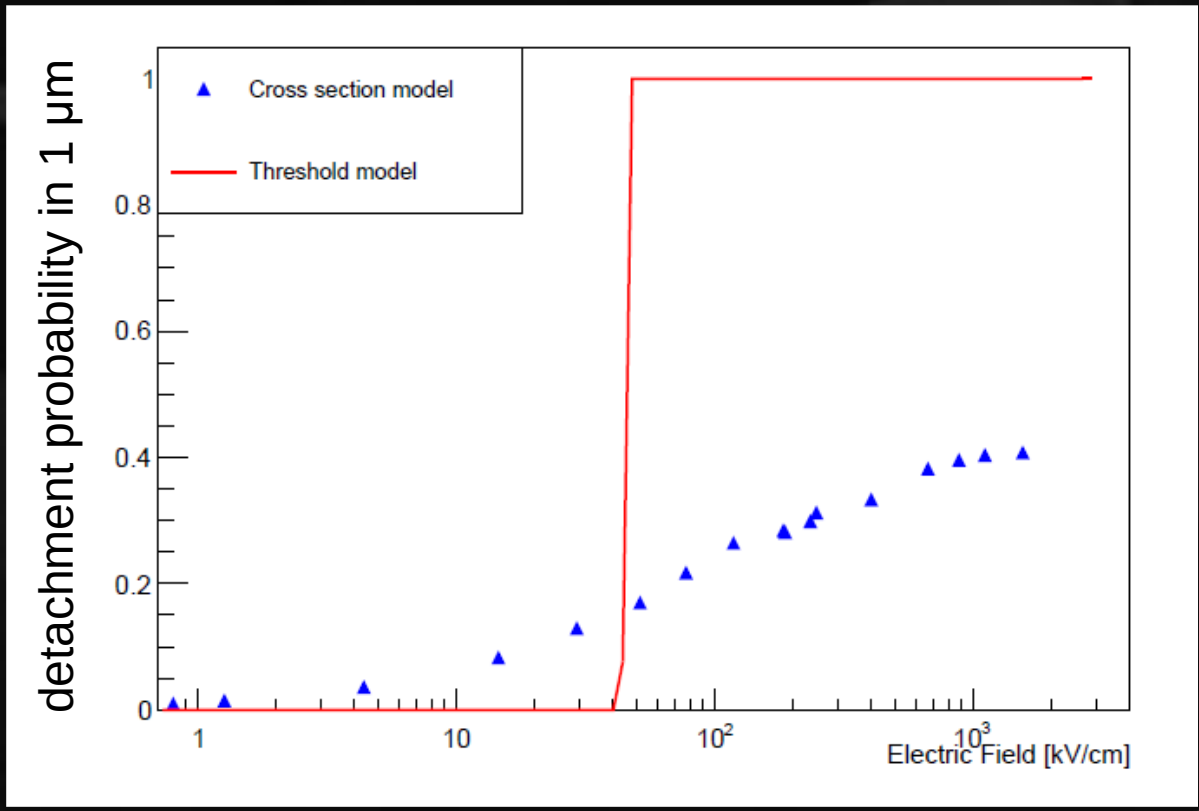
Garfield++ for negative ion

H. Ishiura @MPGD 2019
proceeding in preparation

- most of the process are already in Garfield++
- detachment process needs to be implemented
- Two detachment models were made



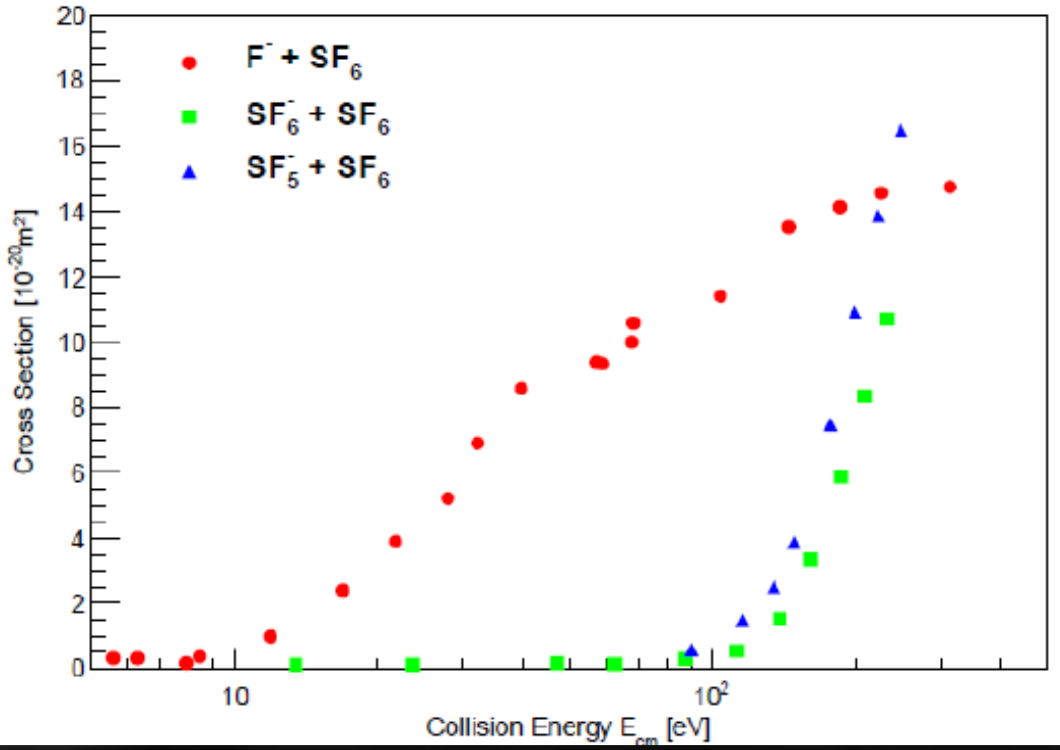


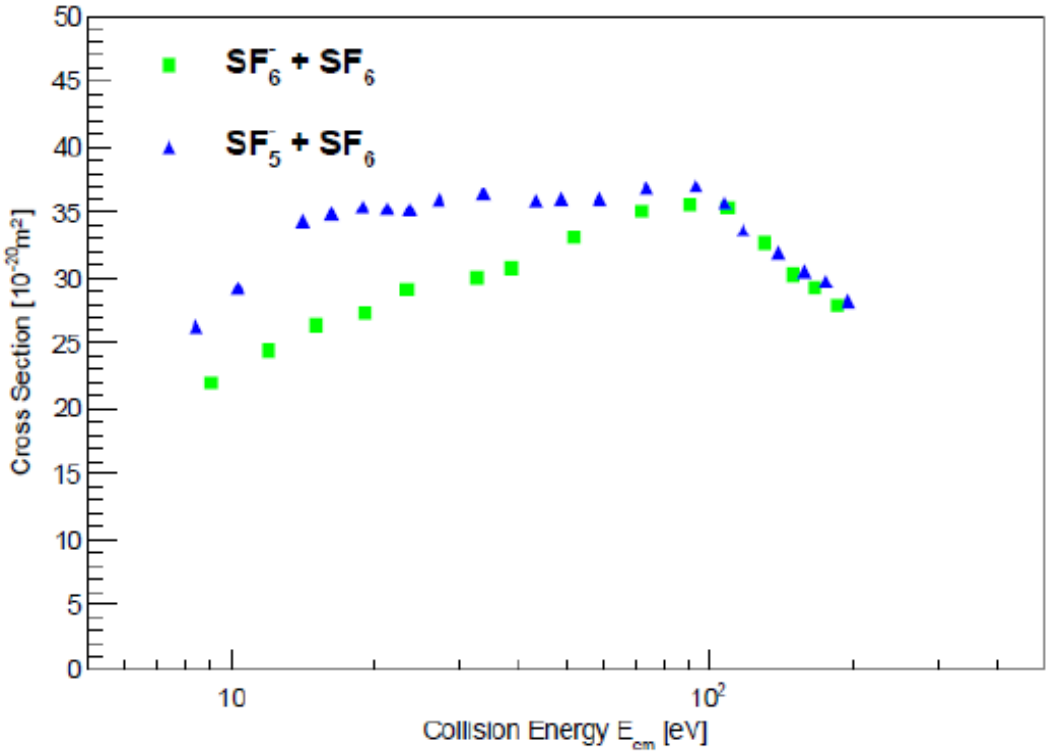


$$SF_6^- + SF_6 \rightarrow e^- + SF_6 + SF_6 \quad (1)$$
$$SF_5^- + SF_6 \rightarrow e^- + SF_5 + SF_6 \quad (2)$$

$$SF_6^- + SF_6 \rightarrow F^- + SF_5 + SF_6 \quad (3)$$

$$SF_5^- + SF_6 \rightarrow F^- + SF_4 + SF_6 \quad (4)$$
$$F^- + SF_6 \rightarrow e^- + F + SF_6 \quad (5)$$





The Journal of Chemical Physics 91 (1989) 2254

ASIC development for negative ion readout

- Liq Ar electronics “LTARS2014”
- slow shaaping time (∼several μs)
- Wide dynamic range(1.6pC)
- Large Cdet (300pF)
- need SPECS for nuclear track detection

⇒ LTARS 2016

2019 J. Inst. 14 T01008

Table 1. Specification and requirements of the ASIC.

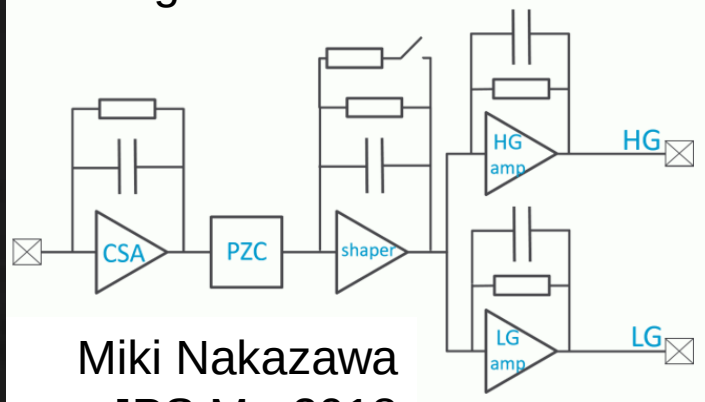
Technology	Silterra 180 nm CMOS	
Chip size	5×5 mm^2, 16 total channels	
Supply power	1.8 V core/IO, ±0.9 V operation, max. 2.4 mW/ch	
Fabrication options	6 metals, deep N-well, high-value poly res., MIM cap.	
Minimum signal charge	3 fC (minority species)	100 fC (main species)
ENC	2000 e^- (S/N=10) 4000 e^- (S/N=5, see Section 5)	$< 6.4 \times 10^4$ e^-
Dynamic range	±80 fC (narrow range)	±1600 fC (wide range)
Voltage gain	10 mV/fC	0.5 mV/fC
Shaping time	4–7 μs for NI μTPC / 1–4 μs for LAr-TPC	

LTARS 2016

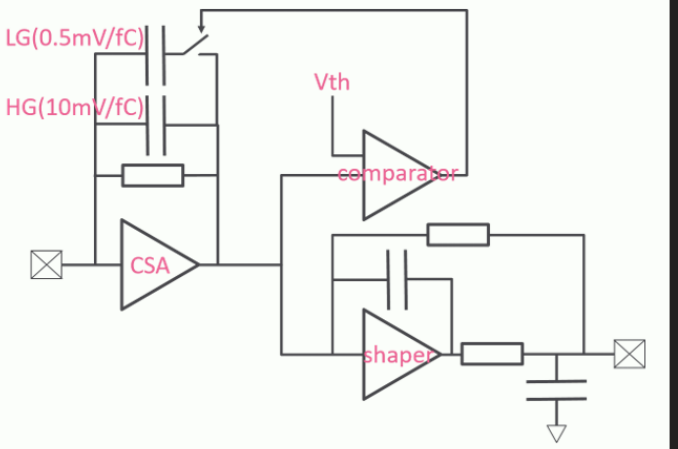
2019 J. Inst. 14 T01008

- two types of architectures

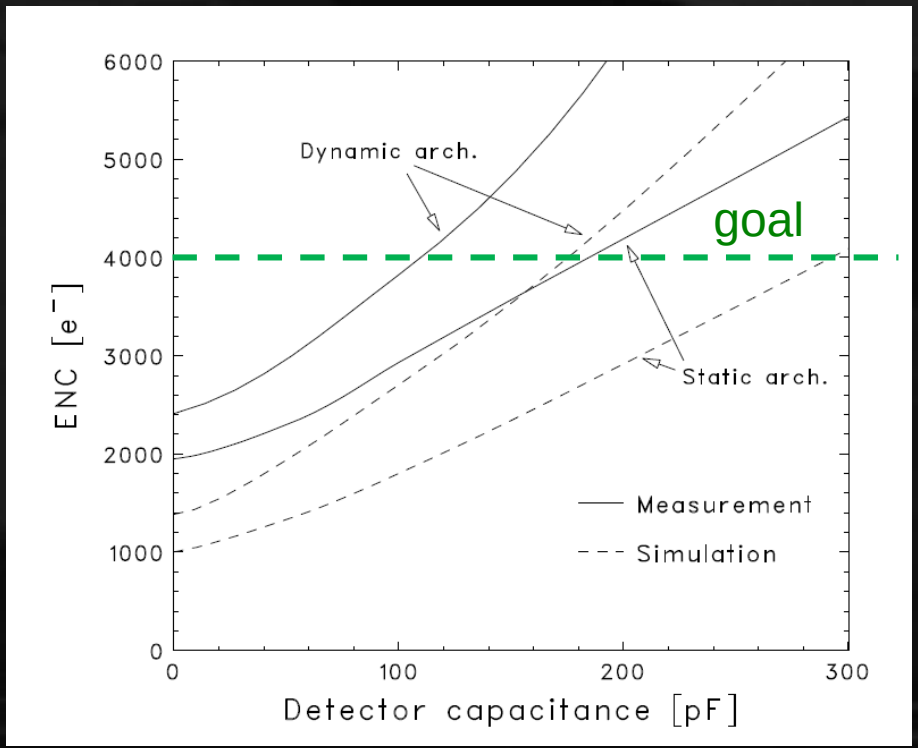
static-gain



dynamic-gain



Miki Nakazawa
JPS Mar2018

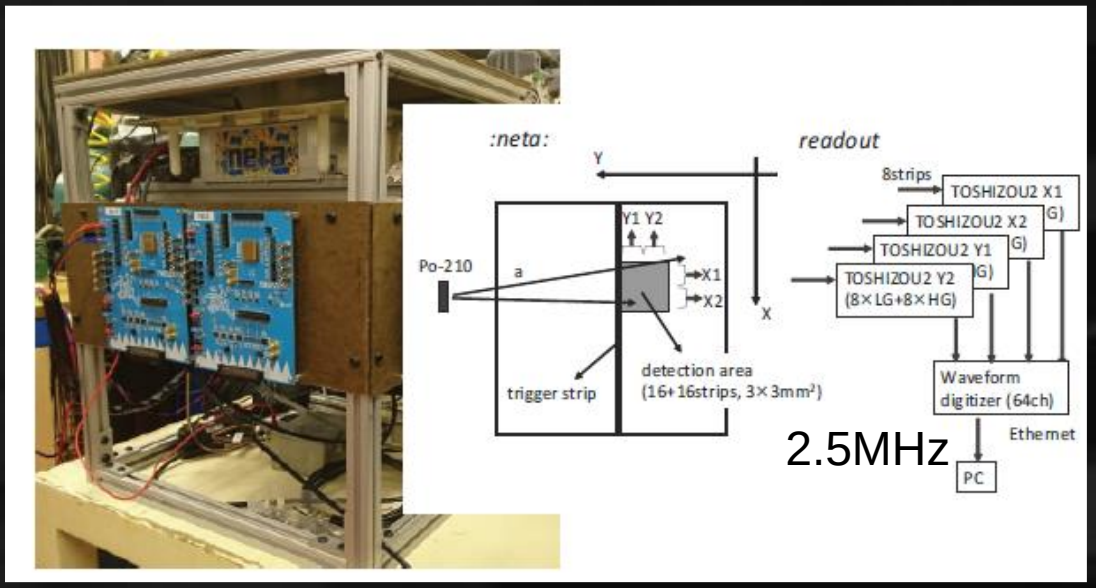


noise was larger than designed
→ modified for LTARS 2018

LTARS 2018:
sharing full-wafer run with other groups. several k channels were made. Chip test starts soon.

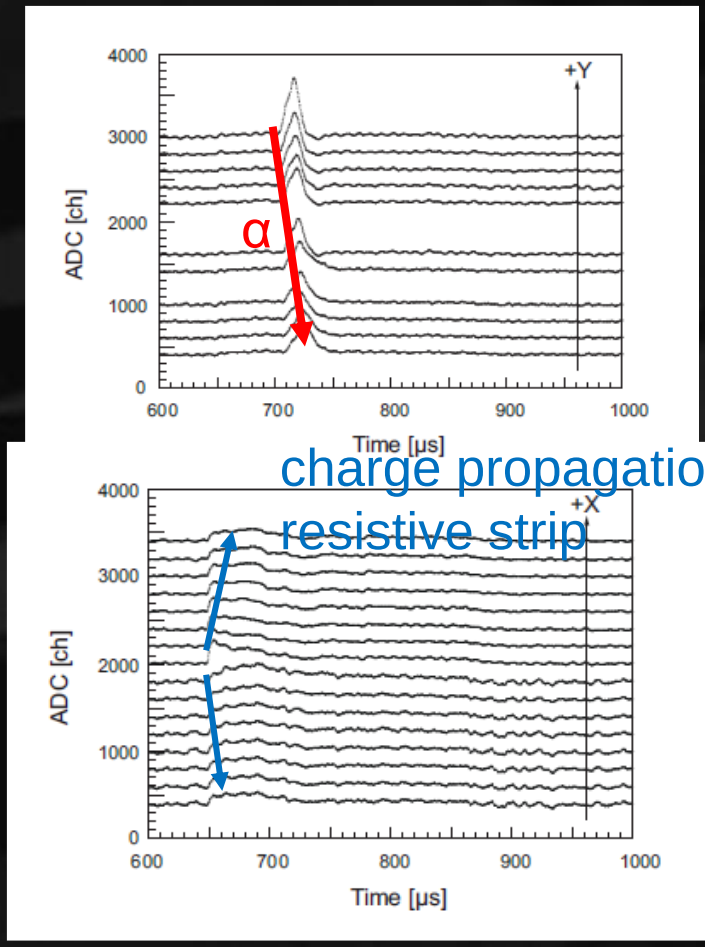
LTARS2016 TEST with detectors

- @Wellesley (Oct 2017) c/w 256μm micromegas
- 16ch+16ch active area



2019 J. Inst. 14 T01008

2D tracking of α was confirmed

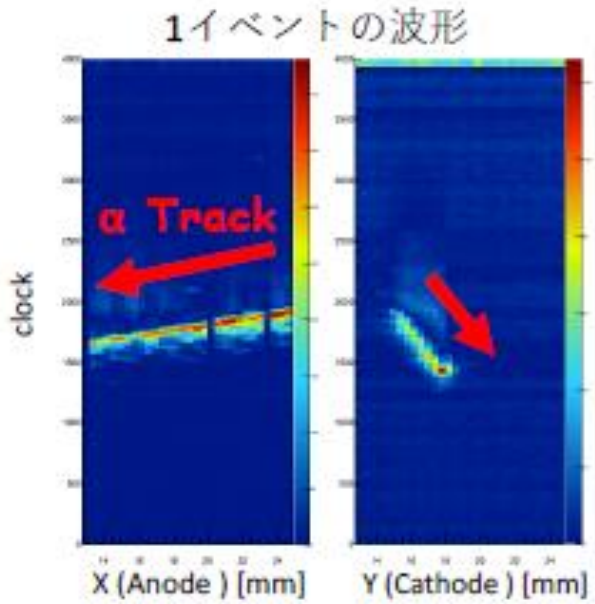


- with Sheffield group micromegas, wires

20

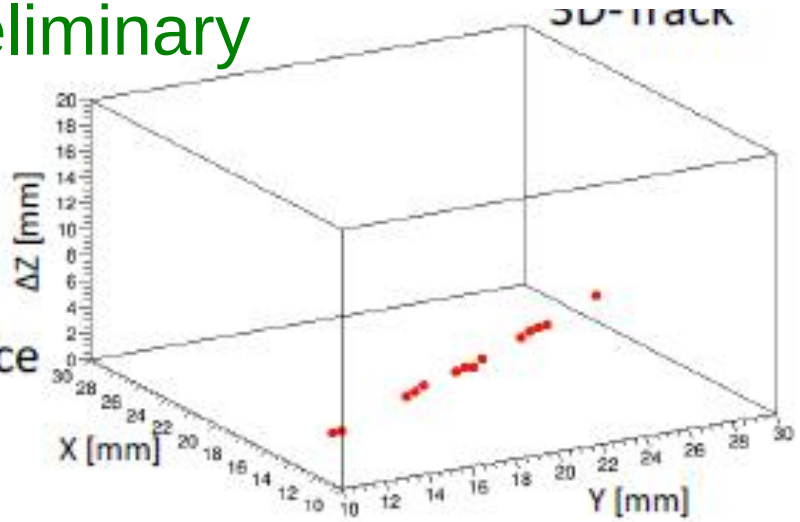
3D tracking + z-fiducialization (first!)

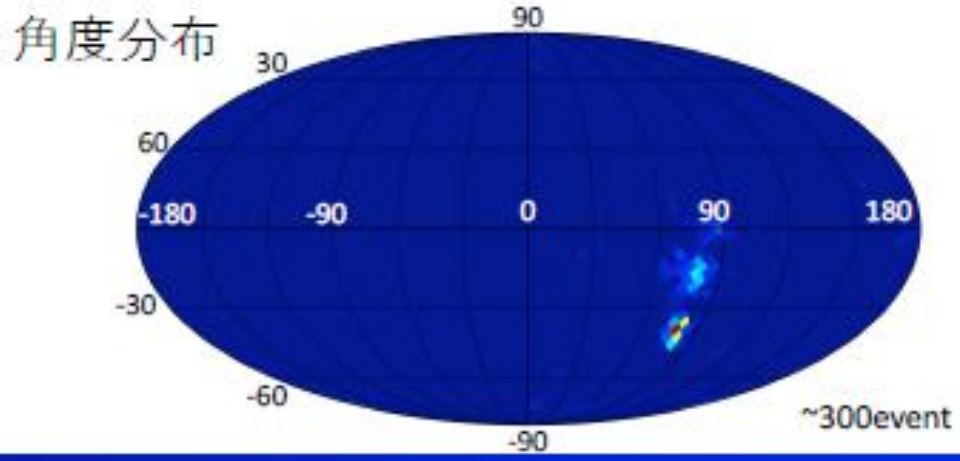
Tomonori Ikeda JPS
Mar2018
paper in preparation



coincidence

preliminary





Dark Matter Search

WIMP-search
NEWAGE

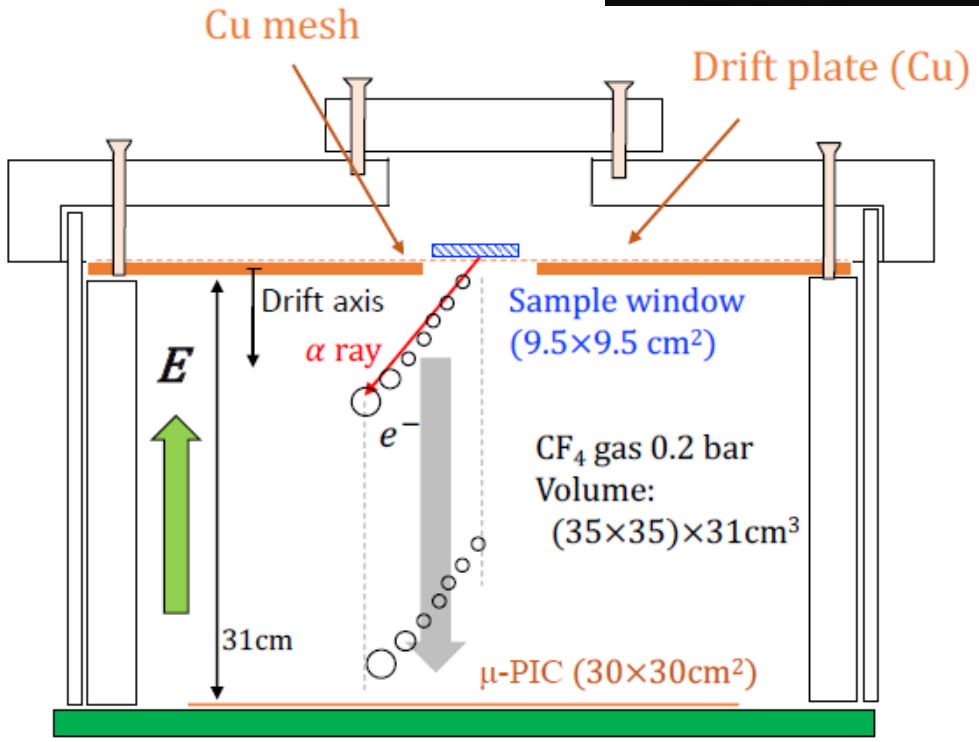
NEWAGE
and low BG activities

α-ray imaging chamber (AI-cham)

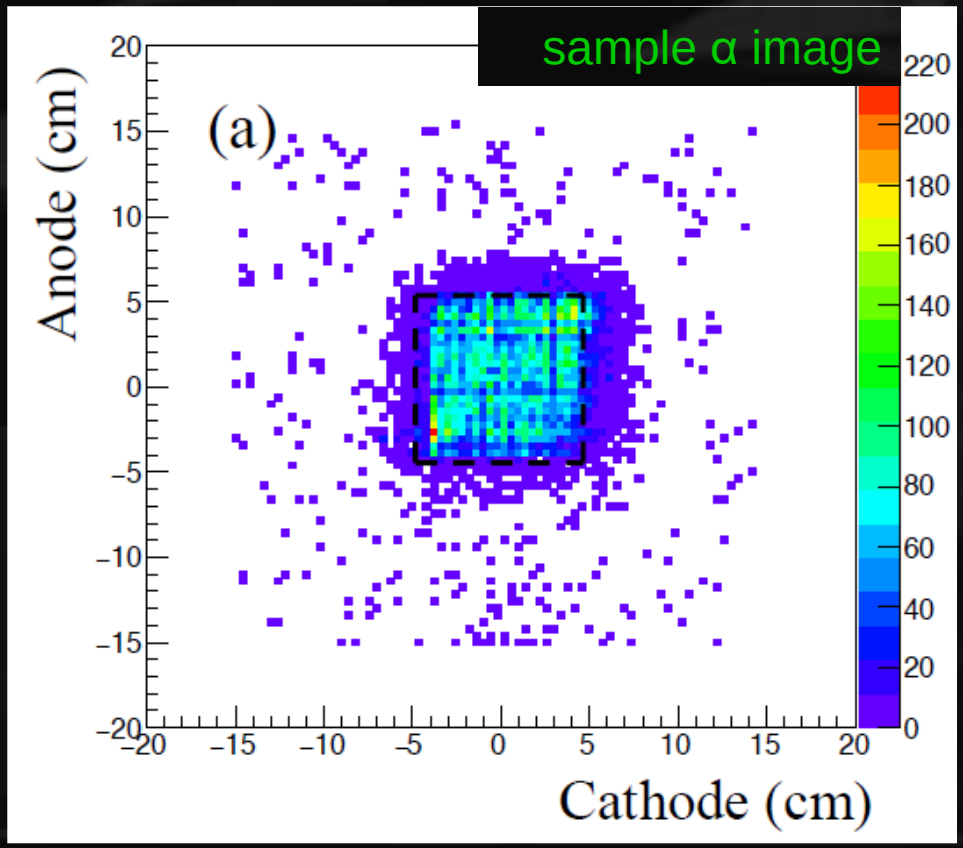
- application of low-α μ-PIC
- α-ray imaging (pos. res. = 0.7cm)
- BG level = 1.58×10^{-2} α/h/cm^2 (subtraction possible)

H. Ito. (NIMA submitted, 1903.01090)

AIcham profile



sample α image

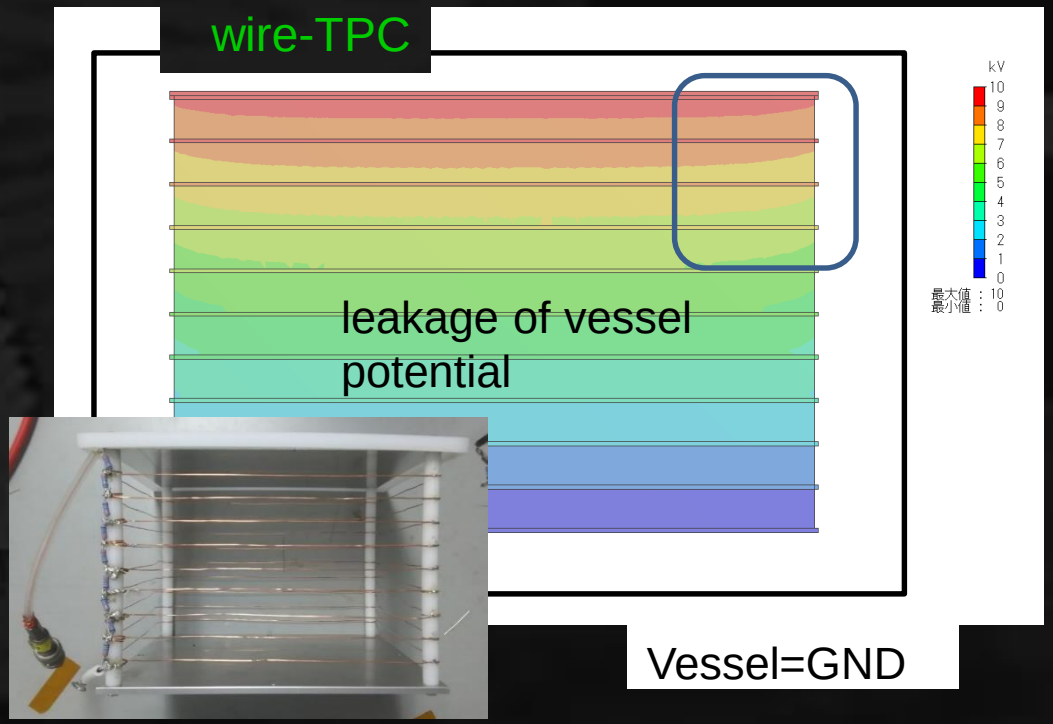


New concept TPC with sheet resistor

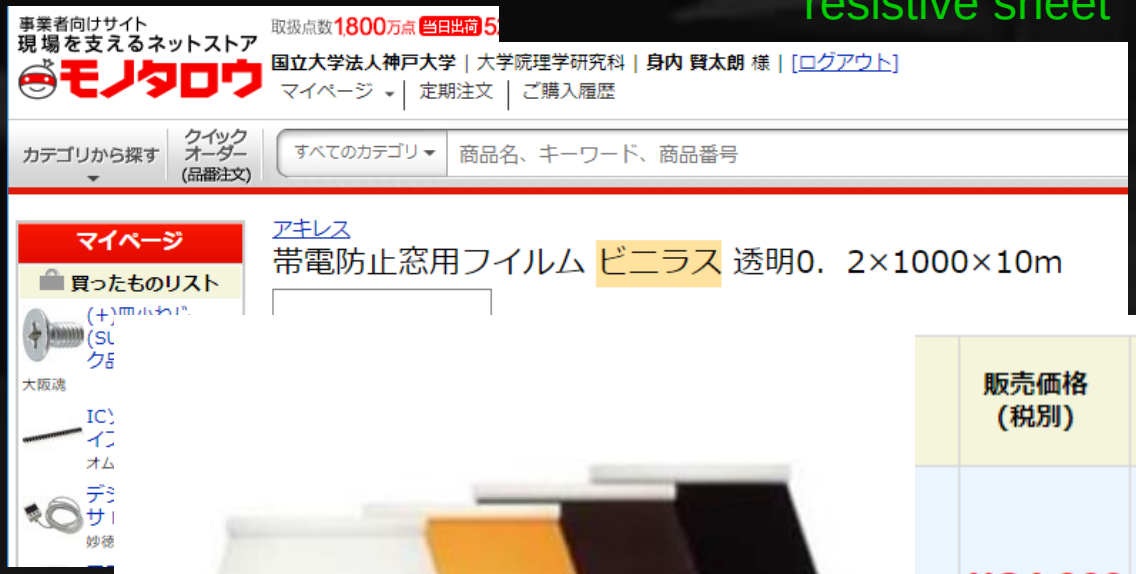
- to overcome potential problem of existing TPCs:
  - distortion of field cage or complicated design
  - radioactive background

K. Miuchi (PTEP 2019 (2019)063H01 **)**

E filed of wire-TPC



Commercially available resistive sheet



(～10GΩ/□)

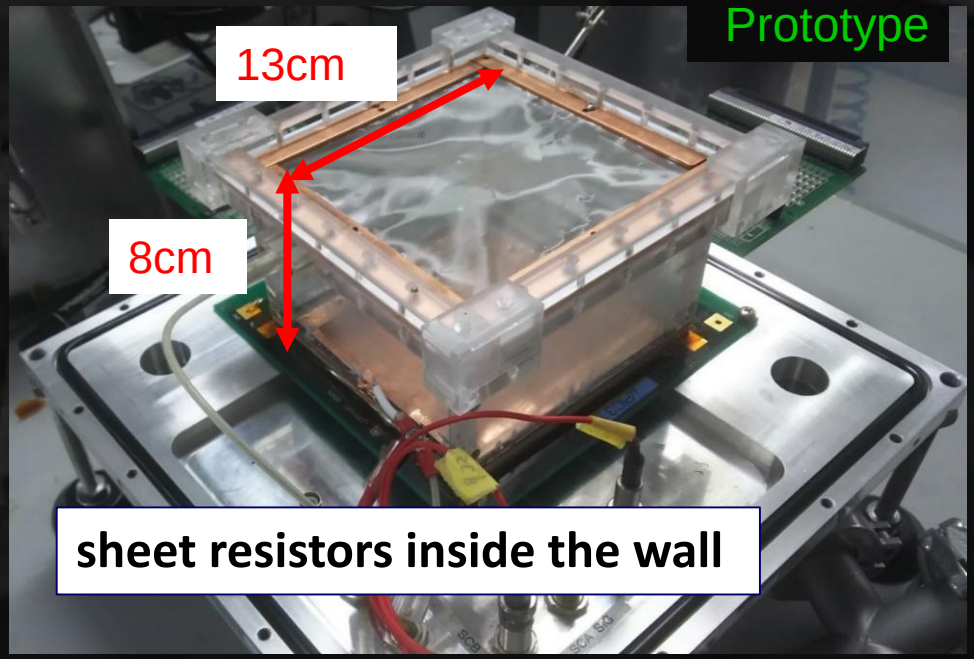
prototype of SR μ-TPC

K. Miuchi (PTEP 2019 (2019)063H01)

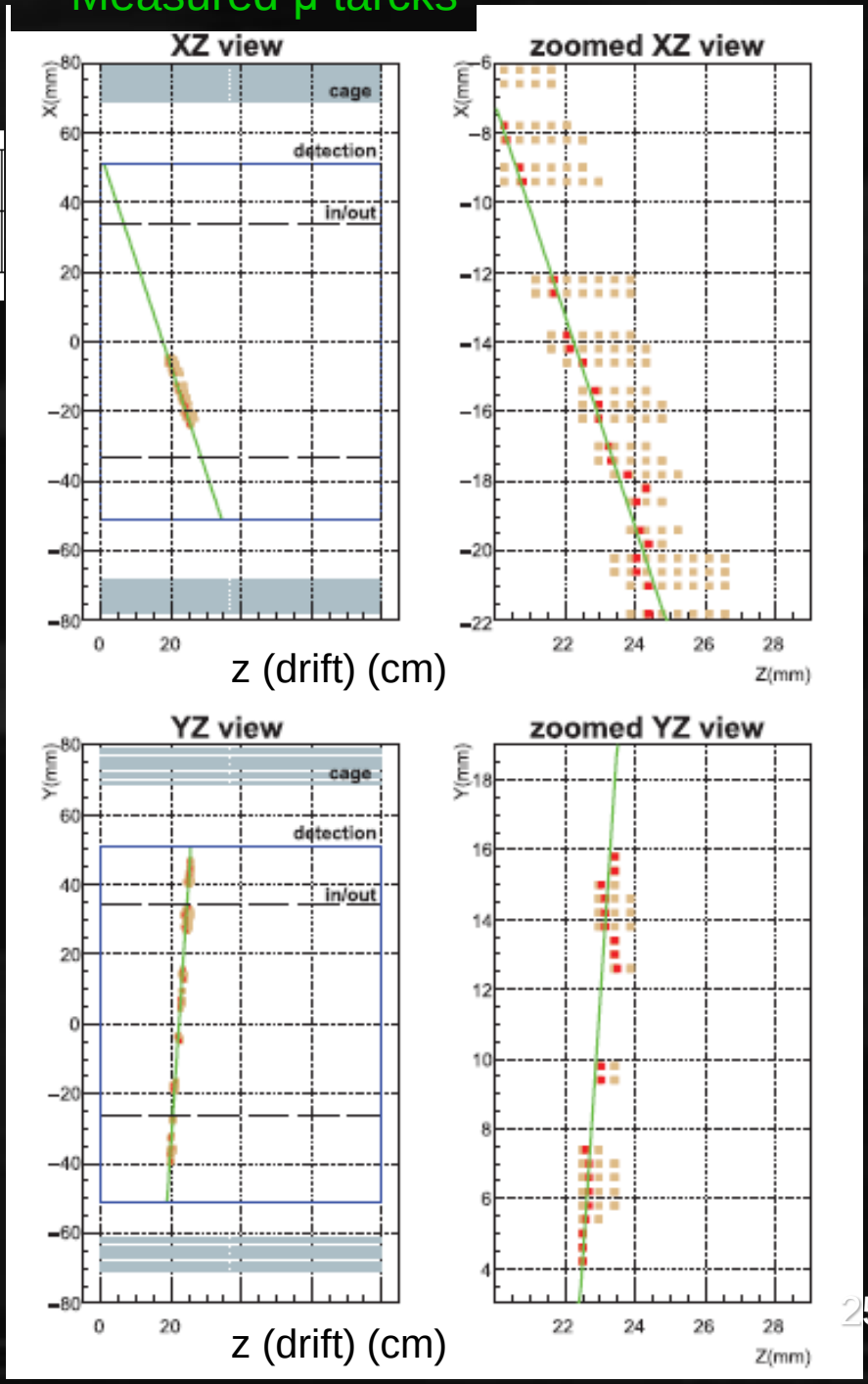
RI measurement (mBq/kg)

Upper U-chain	Middle U-Chain	^{210}Pb	^{232}Th	^{40}K
< 59.6	< 18.4	< 134	< 7.77	< 112

Prototype



Measured μ tarcks



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SR μ-TPC performance

K. Miuchi (PTEP 2019 (2019)063H01)

z-dependence of residuals

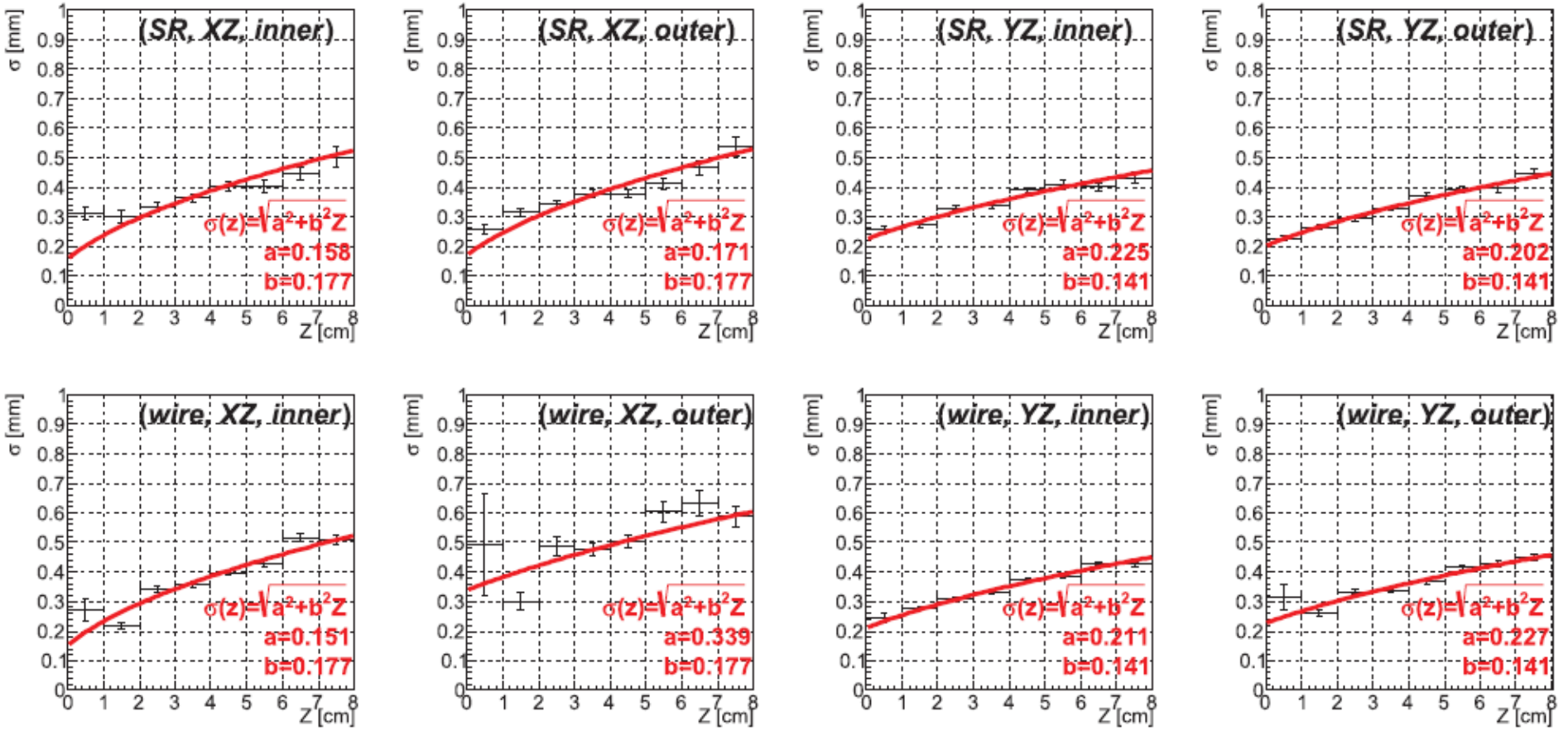


Fig. 5. σ dependence on Z for eight data-sets.

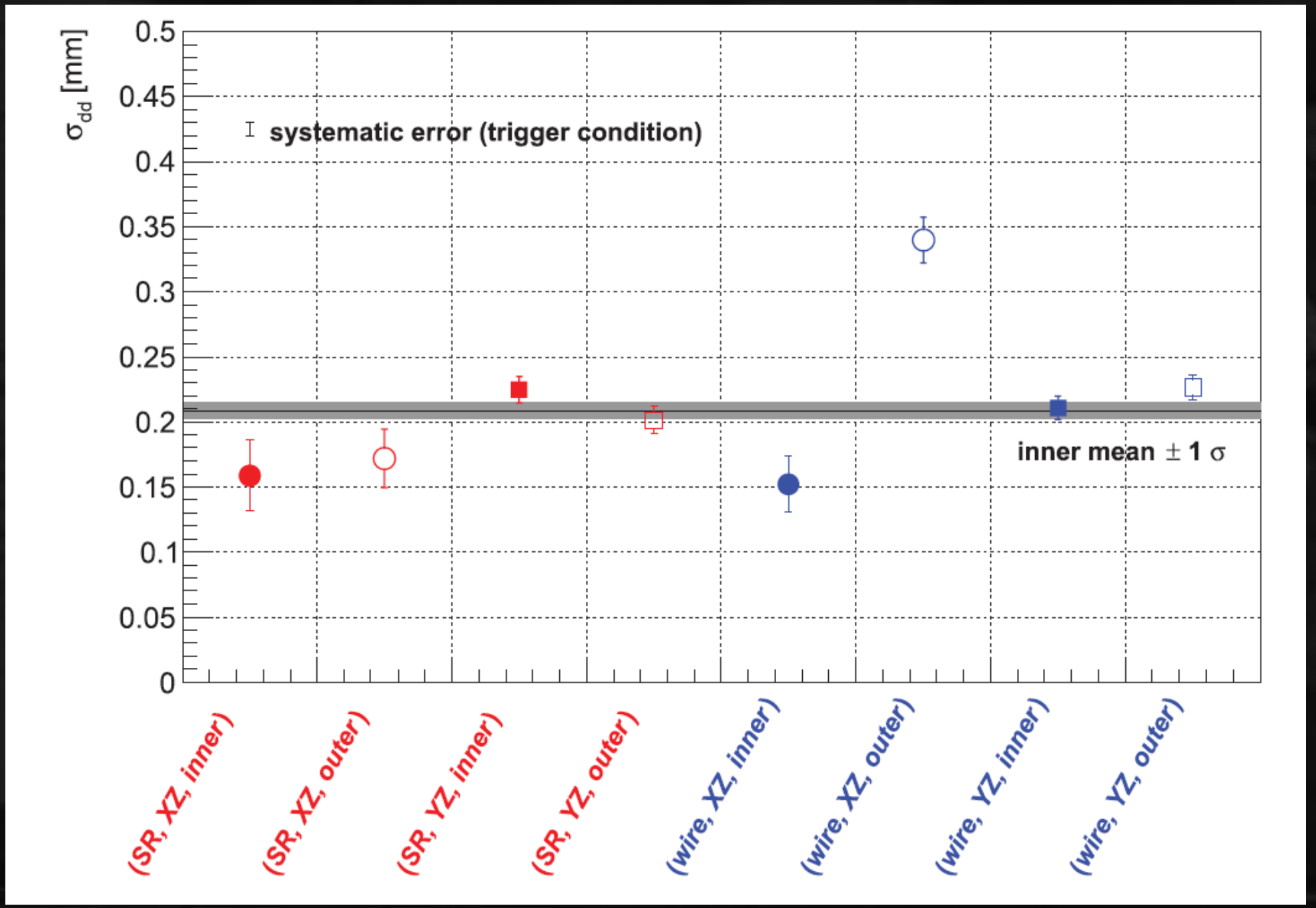
$$\{\sigma_{i,j,k}(Z)\}^2 = \{\sigma_{\mathrm{dd},(i,j,k)}\}^2 + \{\sigma_{\mathrm{diff},(i,j,k)}(Z)\}^2.$$

$$\sigma_{\mathrm{diff},(i,j,k)}(Z) = d'_j\sqrt{Z},$$

SR μ-TPC performance

K. Miuchi (PTEP 2019 (2019)063H01)

results TPC-dependent term



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Columnar recombination

K. D. Nakamura (JINST 13(2018)P7015)
With AXEL

- SI (Xe), high pressure

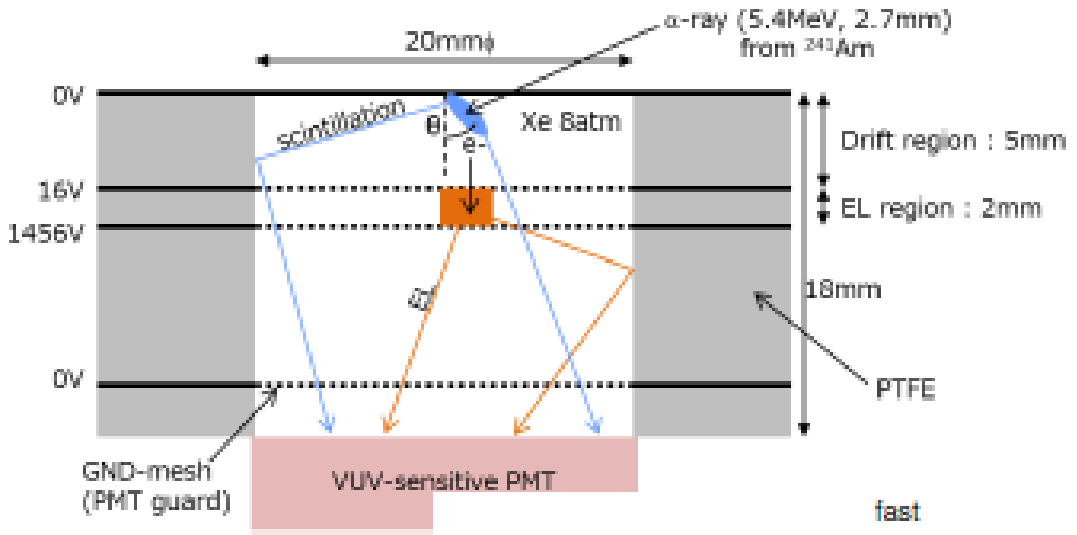
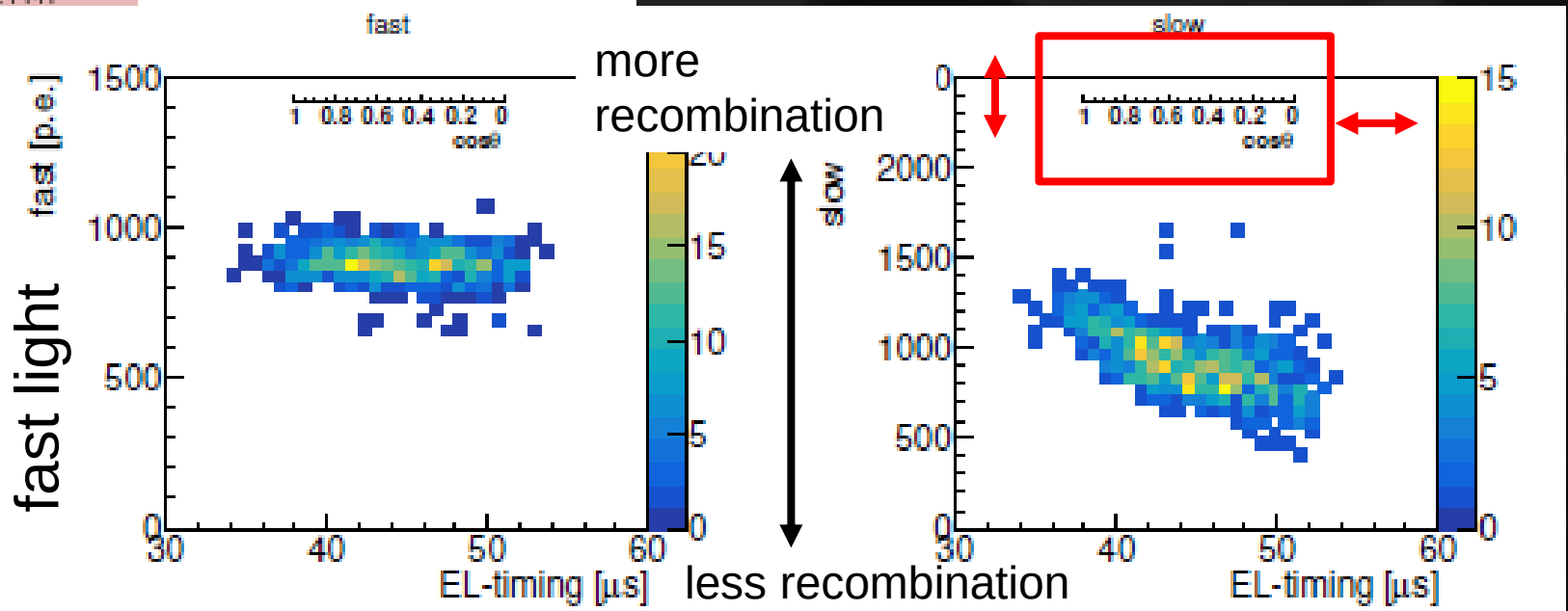


Figure 1.

See K. Nakamura's talk

- proof of concept
  (for high energy α's)

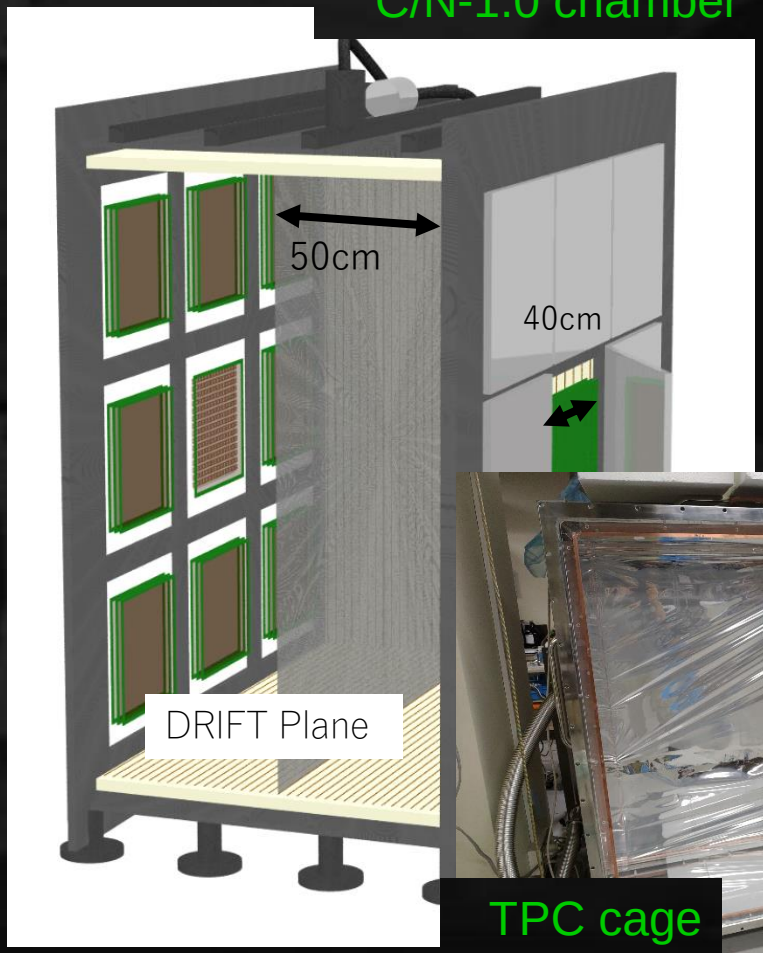


Japan (CYGNUS/NEWAGE)

- **C/N-1.0 chamber (18 × 30×30 cm² detectors)**
  - chamber ready
  - TPC cage (w/ resistive sheet), feedthrough being commissioned

should be ready in 3 month !

C/N-1.0 chamber



TPC cage

- **ASICs for negative ion strip readout**
  - > 5k channels made
  - chip test will test soon

⇒ system design and development

- **collaboration**
  - w/ US groups: KEK-DOE funding (2017)
  - w/ Sheffield: JSPS-RS funding (2018-2019)
  - w/ MMAC: TYL-FJPPL funding (2019)

⇒ welcoming more !

Summary

- NEWAGE ： low-α μ-PIC development
  ⇒ DM sensitivity ×10 improvement

- Further low BG μ-PICs
- ASIC development (LTARS 2018)

- α-imaging chamber (AI-cham)
- low BG TPC with sheet resistor (SRμ-TPC)