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Development of surface alpha ray detector with a low alpha-emitting μ-PIC

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Abstract: In a direct search for the dark matter, the detector is required to design with low radio purity materials. We have been developing a new detector of alpha-rays emitted from the material surface based on μ-TPC. It was upgraded with a low alpha-emitting μ-PIC and alpha emit point could be determined. The sensitivity as background level was improved by factor 10, to 10^{-2} alphas/cm^2/hr.

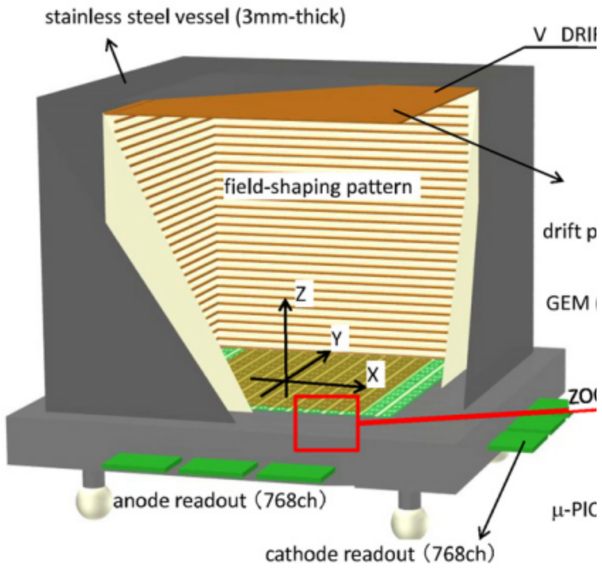
Introduction

In direct search for dark matter (DM), the detectors have located at underground and be covered with radiation shield in order to suppress background (BG) due to ordinary particles. Recently, a radioactivity impurities in detector material are focused as BG. Since the energy of nuclear recoil scattering with the weakly interacting massive particle (WIMP) as one of the candidates is an exponential function, the purify of the detector is important to gain more sensitivity at low energy region.

NEWAGE is a project of direct search for direction-sensitive WIMPs with gaseous μ-PIC [1]. The detector has a sensitivity of angular between nuclear recoil direction and the Cygnus constellation. The current best record for the upper limit of WIMP-proton cross section was marked to be 557 pb (90%CL) at a WIMP mass of 150 GeV/c^2 in 0.327 kg days of exposure [2].

In BG study, it was found that μ-PIC contains radioactive impurities of ^{238}U and ^{232}Th which emit α and γ rays. The impurities determined a limit of sensitivity in low energy region (~ 50 keV).

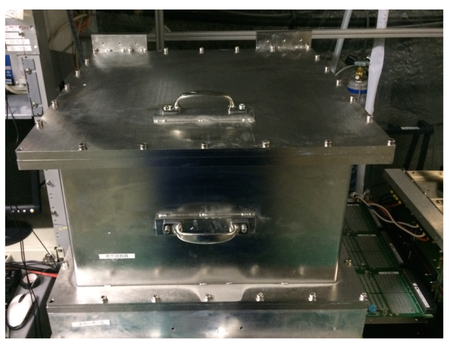
Surface alpha ray detector

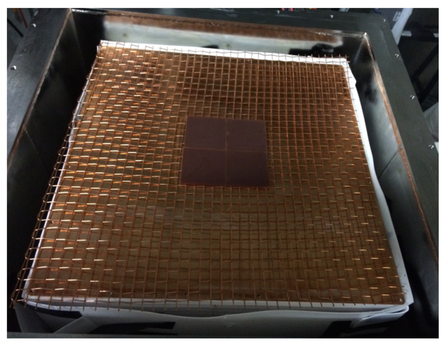


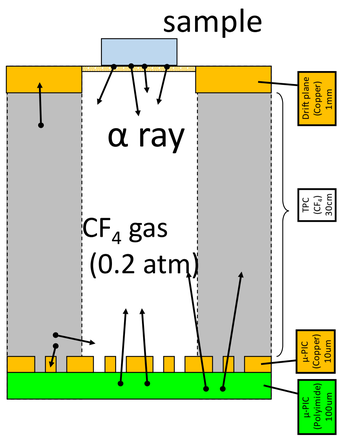
Purpose
- Selecting material with low radioactive impurities in the detector

Advantage for μ-TPC
- Position sensitive
- Measurable with powder or non-conductor sample

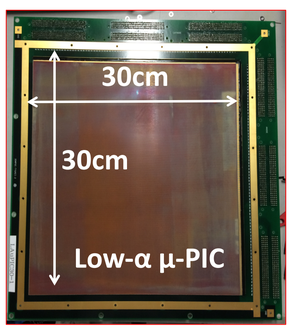
Development status
- Upgrade with NEWAGE-0.3a
- Installed Low-alpha μ-PIC
- Previous BG level: 1.32 x 10^{-1} αs/cm^2/hr (Goal: Ultralo-1800 10^{-4} αs/cm^2/hr [3])
- α emit point determination by Bragg peak



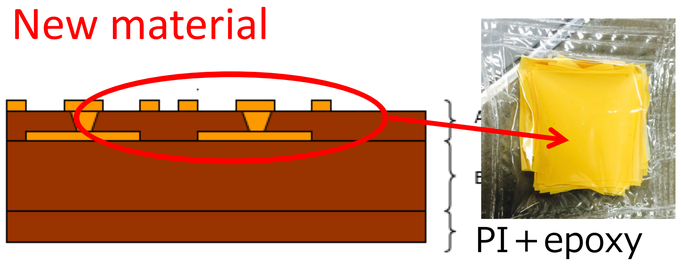




Low-alpha-emitting μ-PIC

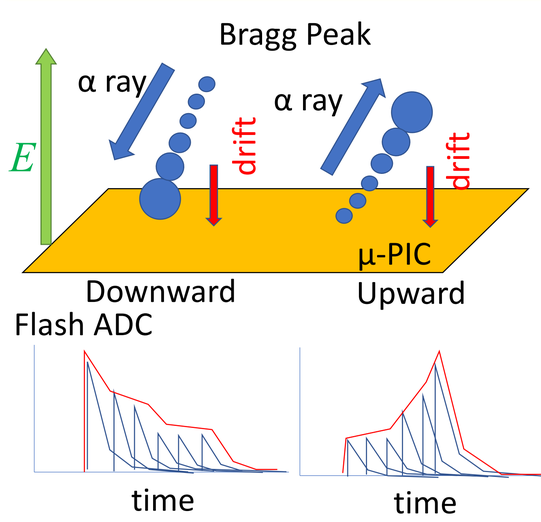


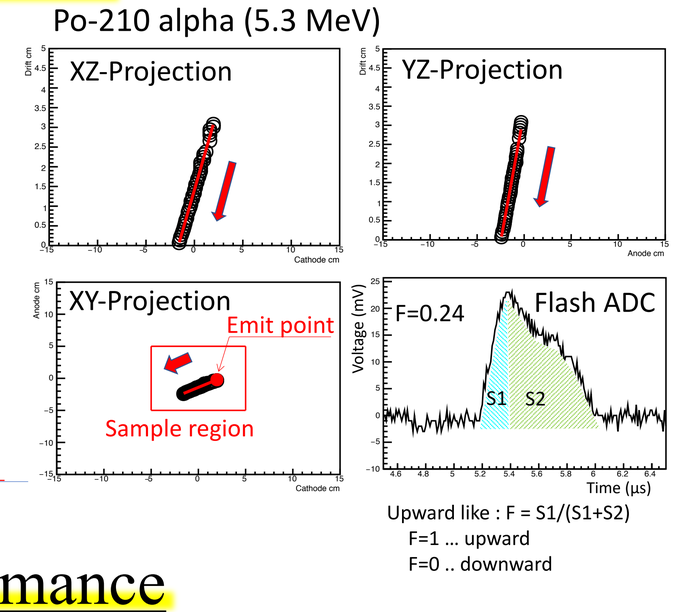
New material



Sample	^{238}U [ppm]	^{232}Th [ppm]
PI100μm (Conventional μ-PIC material)	0.39±0.01	1.81±0.04
PI + epoxy (New material) [4]	**< 2.98×10^{-3}**	**< 6.77×10^{-3}**

Emit point determination

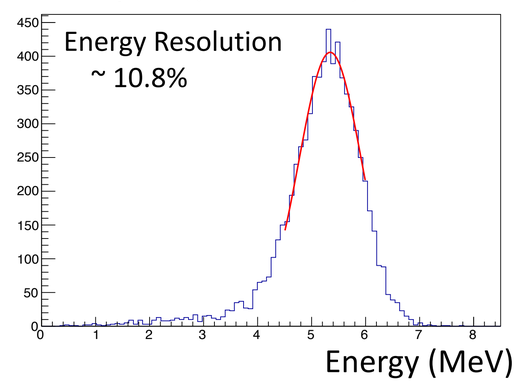


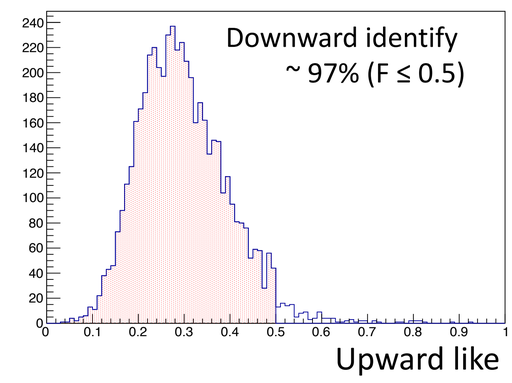


Upward like : F = S1/(S1+S2)
F=1 … upward
F=0 .. downward

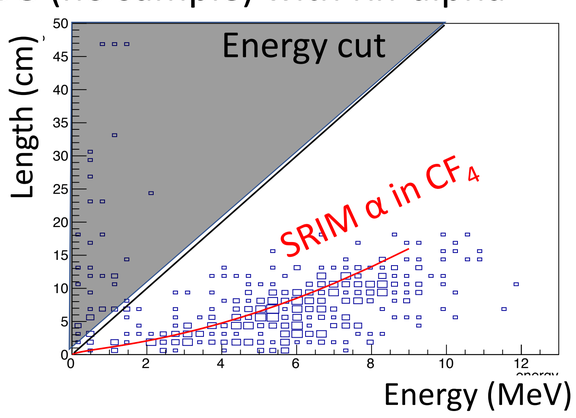
Calibration & Performance

Po-210 alpha (5.3 MeV)





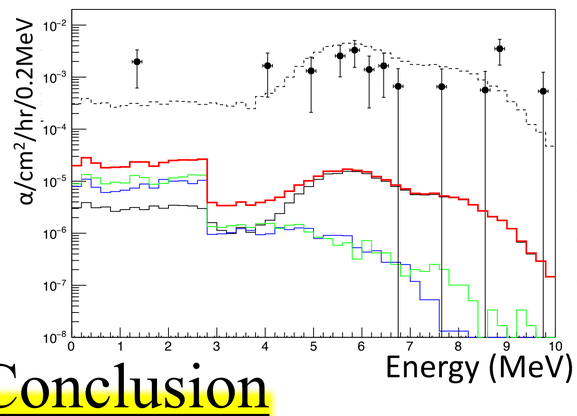
BG (no sample) with Rn-alpha



Result:
Detection efficiency (contain cut eff.)
: ~95% @5.3 MeV
α ray rate=0.0031 ± 0.0070 α/cm^2/hr
BG level = 1.3×10^{-2} α/cm^2/hr (90%CL)

By cut of upward tracks (over 3MeV):
BG level ~ 8×10^{-3} α/cm^2/hr (90%CL)

Plan for improvement to 10^{-4} α/cm^2/hr



Conclusion

For a selection material of DM search detector, a surface α ray detector using low-alpha-emitting μ-PIC can select a material with low impurities. In this work, a performance was checked using Po-210 α ray (5.3 MeV) source, α emit point was determined, and BG level was improved by factor 10. We plan to improve to more factor 100 by suppressing radon.

Acknowledgements

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Reference

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[3] B. D. McNally, et al., Nucl. Instr. Meth. A 750 (2014) 96.
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