Evaluation of γ-ray background from neutron beams for the detection of the Migdal effect

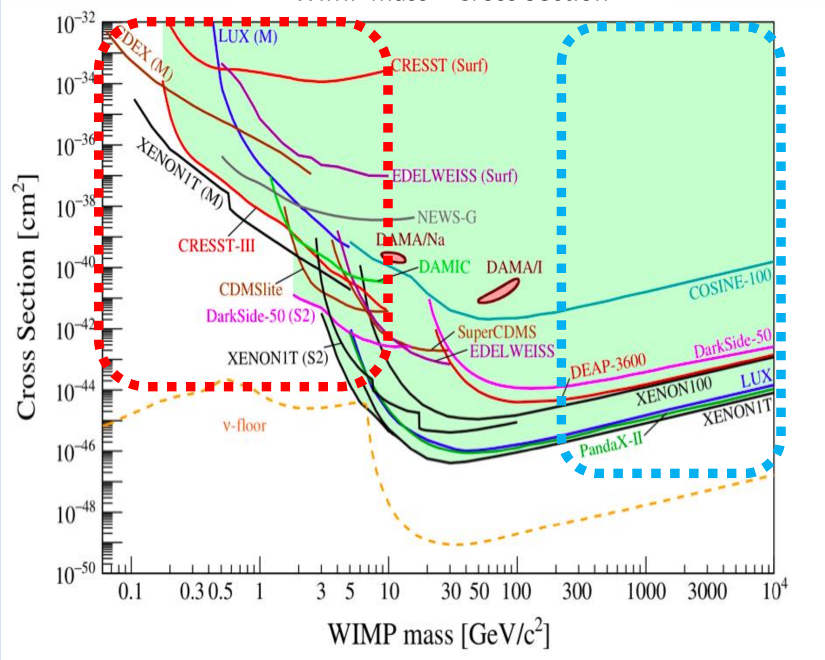
Mizuno Ofuji, Kobe university
on behalf of the MIRACLUE Collaboration

1. Introduction

WIMP: Leading Candidate for Dark Matter
→Search for high-mass region has been progressing
…but no results yet
→want to search for low-mass regions

But low-mass region is difficult to see due to low recoil energy…
→Use the Migdal effect
→The effect itself has not been observed yet.
Therefor we search for the effect via nuclear recoil.

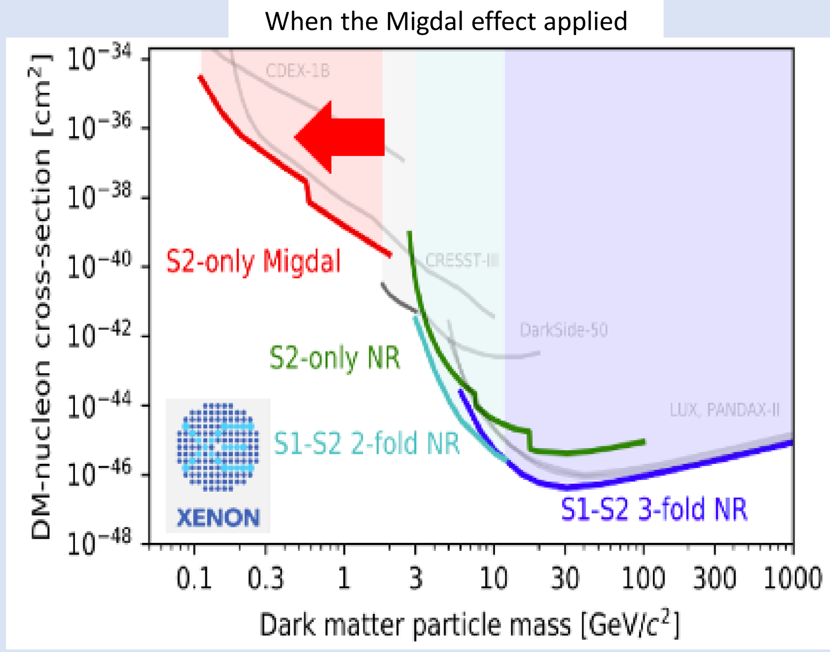
WIMP mass – Cross Section



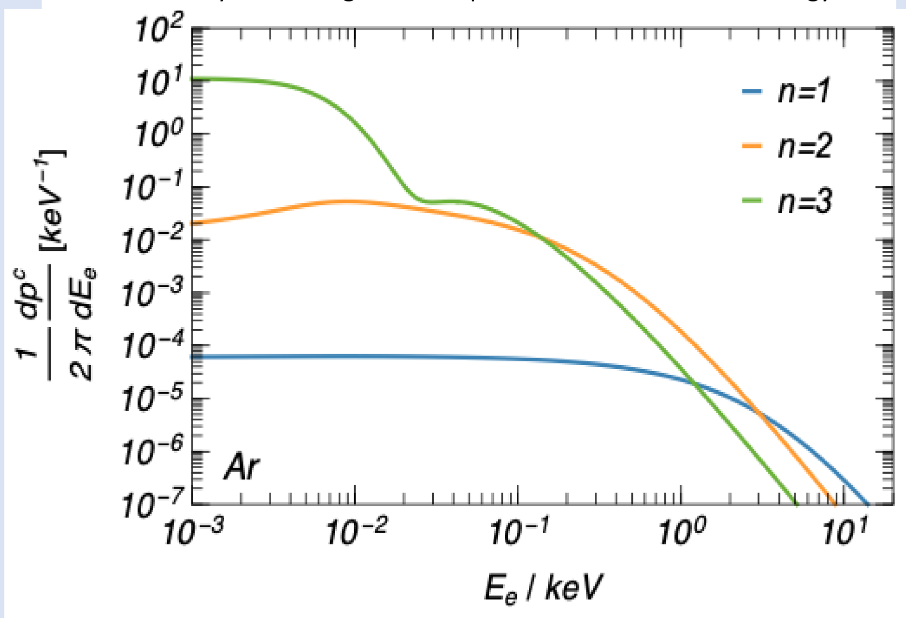
Migdal effect

・ The phenomenon of excitation and ionization of electrons caused by the sudden movement of the nucleus.
・We focus on the Migdal effect of K-shell ionization of nuclear in this study

When the Migdal effect applied



Probability of the Migdal effect per shell and detectable energy

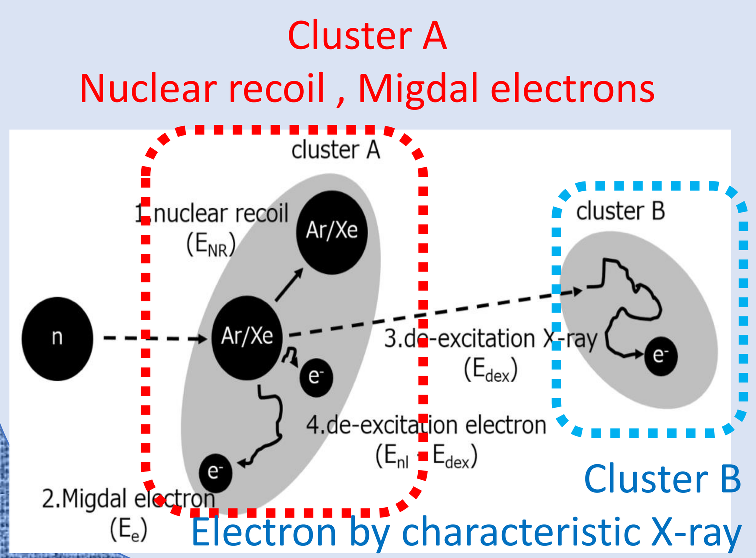


2.MIRACLUE

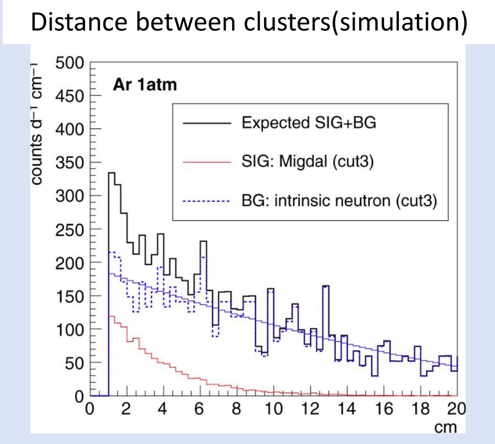
- Migdal effect Investigation as RAre event CLUEs

・Search for Migdal effect via nuclear recoil using neutron beam
・2 clusters detection
→Characteristic X-rays from k-shell ionization of nuclei are the second cluster
→Determined by the absorption length, etc.

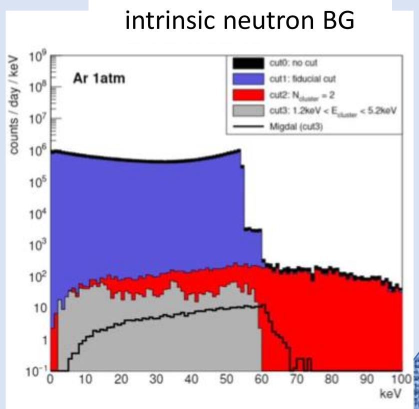
Detector : **Ar TPC (Kobe.U)** & Xe TPC (Tohoku.U)
Difficulty : Low probability phenomenon, important to reduce BG properly



Distance between clusters(simulation)

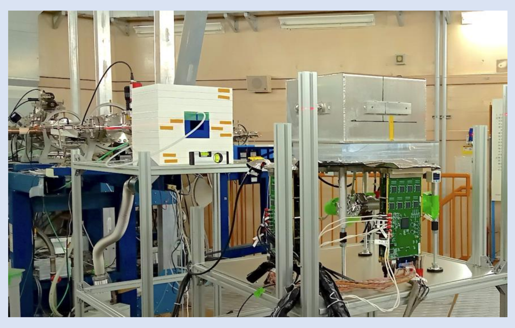


intrinsic neutron BG

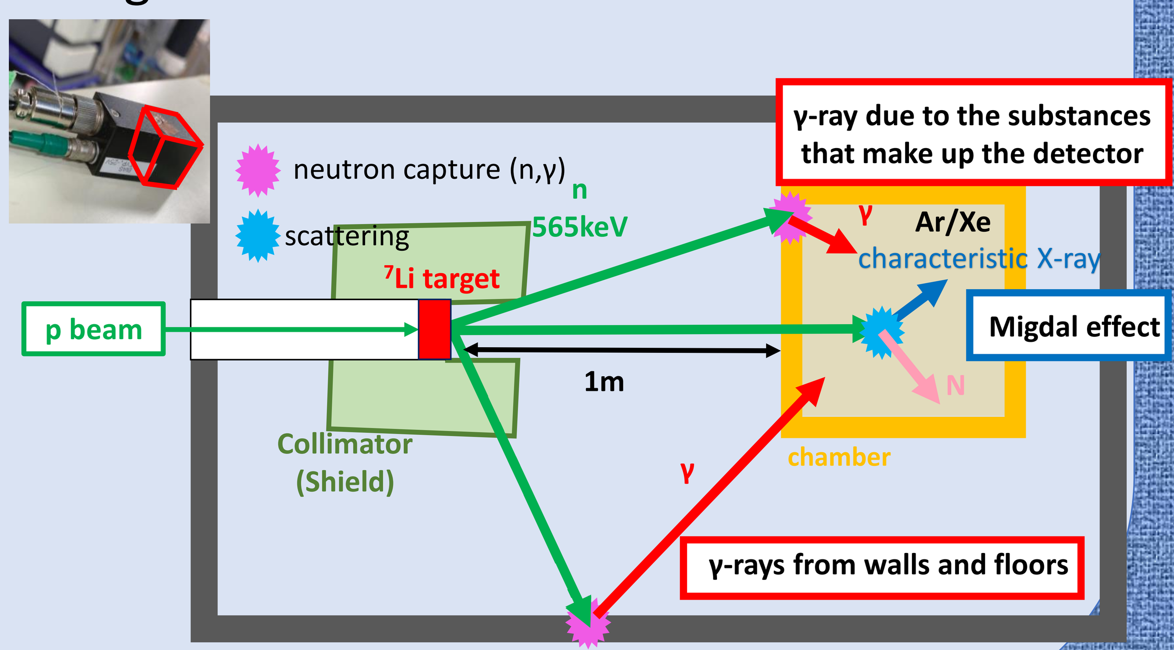


3.BG measurement

Pilot run for MIRACLUE experiment for BG estimation using neutron beam (565 keV, DC)
Location:
National Institute of Advanced Industrial Science and Technology,Tsukuba, Ibaraki, Japan



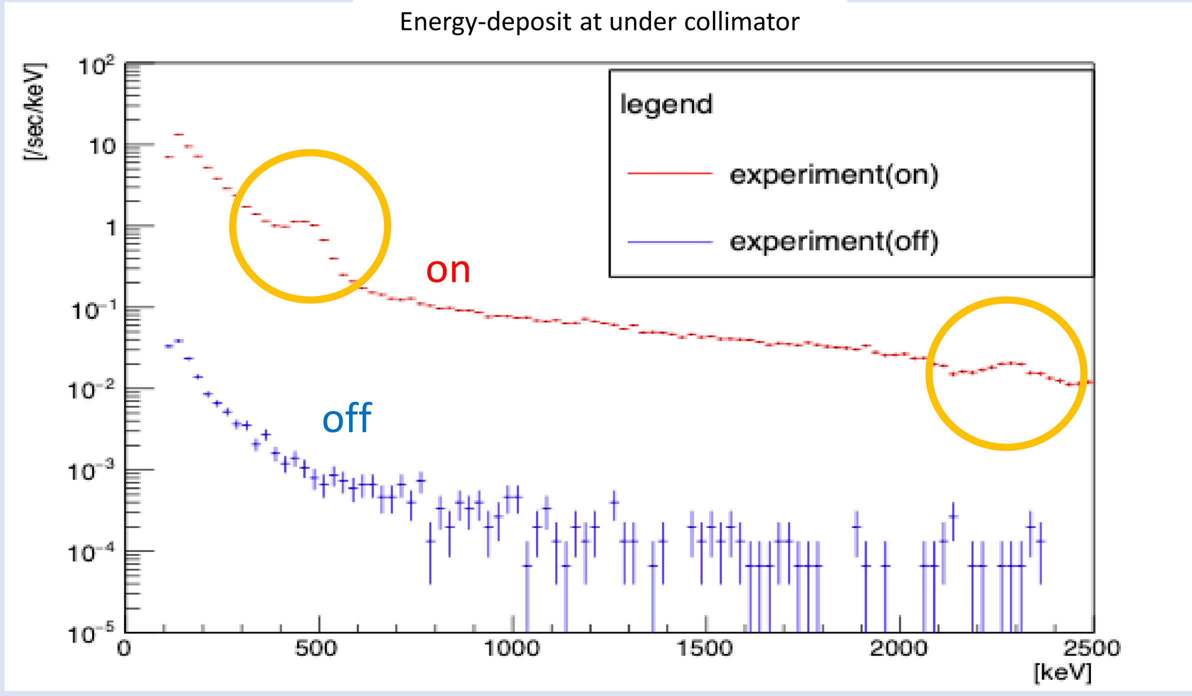
Measure the γ-rays BG from laboratory via (n,γ) reactions
☆Collimator is placed around the Li target
Date : 2022/4/11~14
Tool : CsI scintillator($1 \times 1 \times 1 cm^3$)
What : γ-ray energy spectrum
How :
Set scintillator under collimater
Calibration :
^{22}Na,^{137}Cs



4.Result

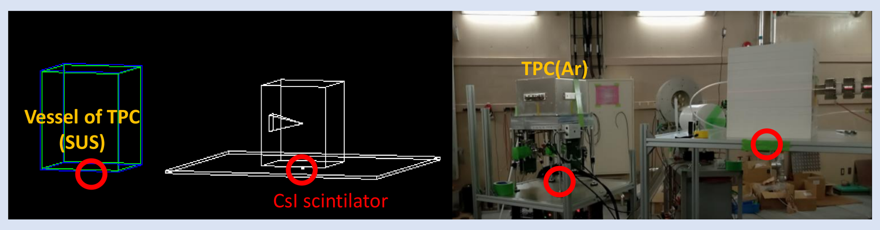
Comparison of neutron beam "on" and "off":
・Peak at 478 keV
→^{7}Li(p,γ) is also happening by Li
・Peak at ~2.2 MeV
→ Reaction is the H(n,γ) of collimator (made from polyethylene)

Energy-deposit at under collimator

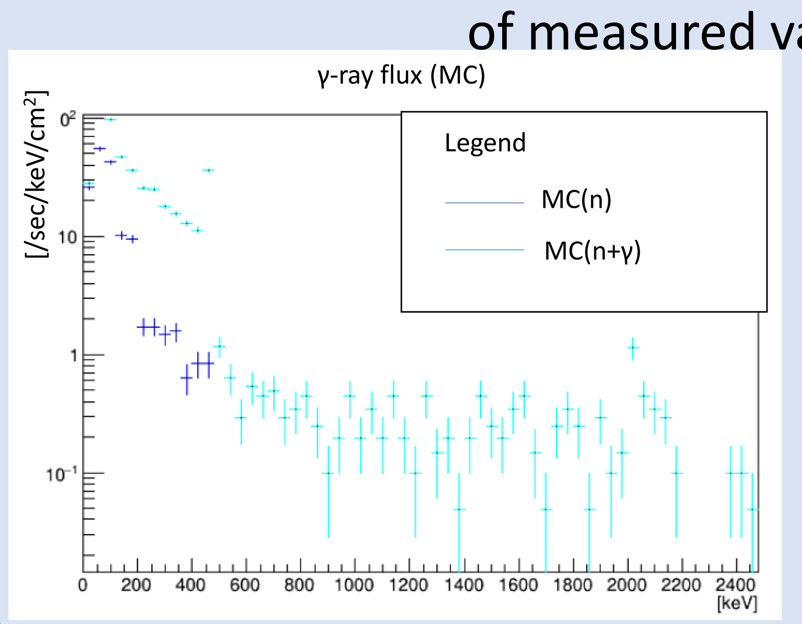


5.Comparison with simulation

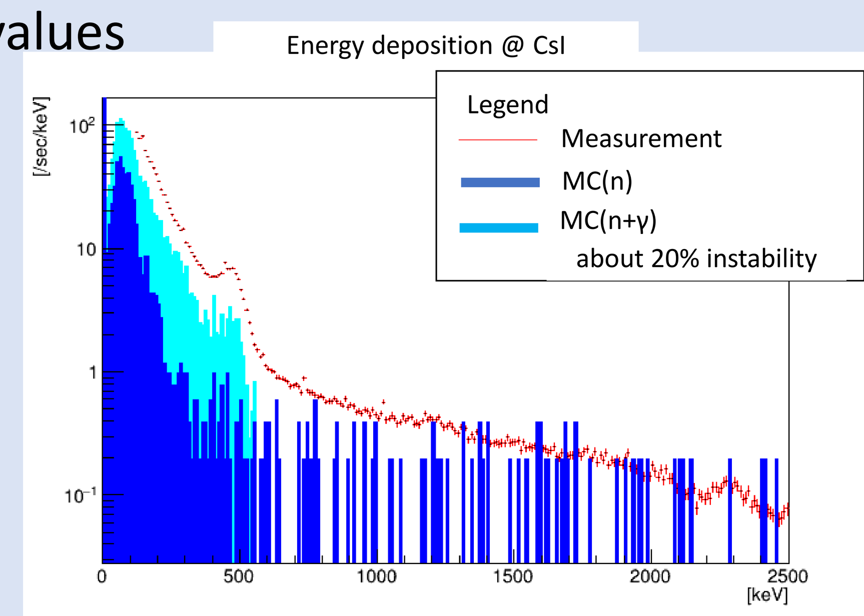
Geant4 Simulation
・neutron (565keV)
・γ-ray (478keV)
→ Another reaction during neutron beam creation ; ^{7}Li(p,γ)
*Scale by considering Branching ratio
・Left :flux of γ-rays, Right : energy-deposit in CsI scintillator
・Low energy region : simulation are about 1/2 to 1/3 of the measured values
・High energy region : simulations don't reproduce the continuous distribution of measured values



γ-ray flux (MC)



Energy deposition @ CsI



6.Improvements, hereafter

・Simulation does not reproduce experimental result
→Lack of geometry
→Other RI activities that haven't been considered yet

・Reproduce experimental sectup correctly in simulations
・Simulate reactions at TPC to estimate BG for Migdal observations

Summary

・Migdal effect is considered for low-mass dark matter search
・Aiming to observe the Migdal effect
・Preliminary experiment was carried out with CsI scintillator to understand BG
・Simulated date is produced to understand measured date and it turned out that 478 keV γ-rays from the (p,γ) reaction of the Li target are a major factor in the BG
・It is necessary to think about response at TPC and think about actual BG

Reference

・Direct Detection of Dark Matter -- APPEC Committee Report APPEC report arXiv:2104.07634v1
・Detection capability of Migdal effect for argon and xenon nuclei with position sensitive gaseous detectors arXiv:2009.05939
・Migdal effect in dark matter direct detection experiments 2018, Article number: 194 (2018)