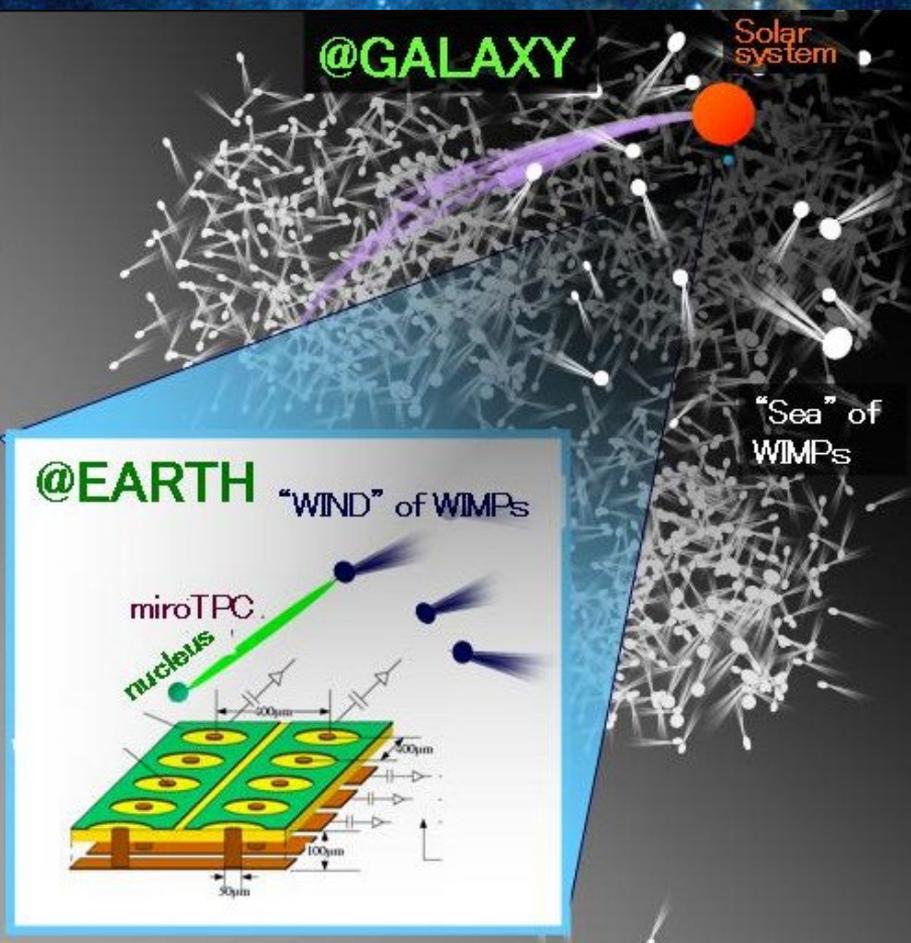


Direction-sensitive dark matter search with MPGD

Kiseki Nakamura (Kyoto university)

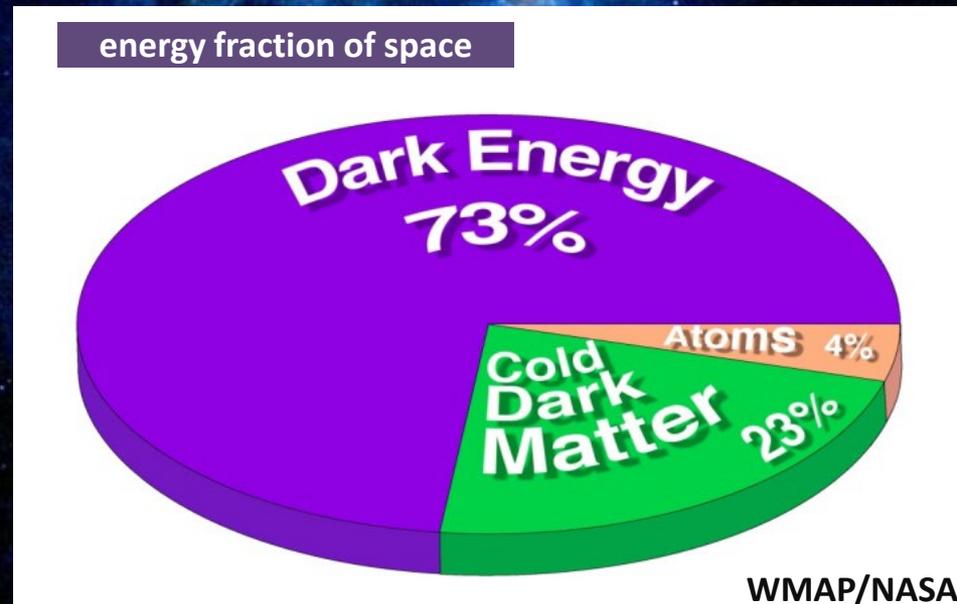
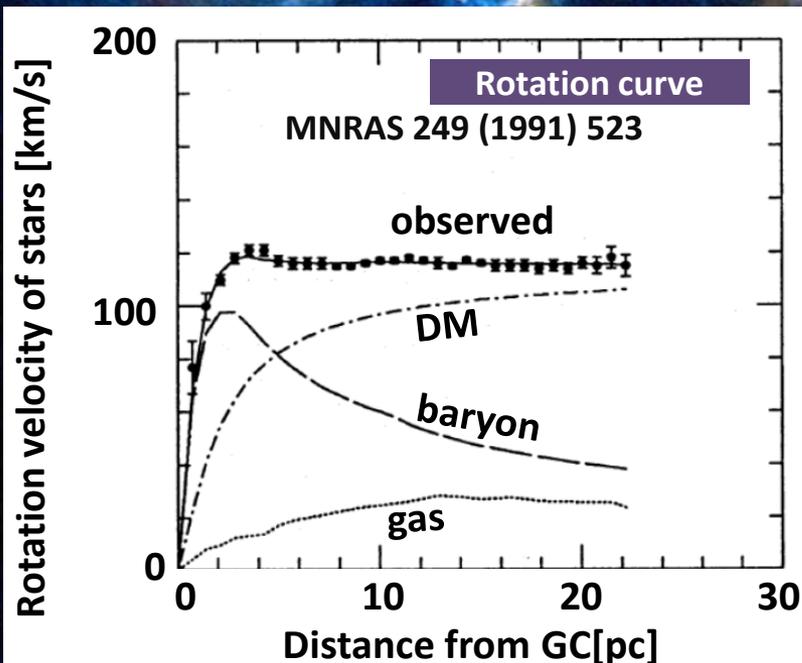
T.Tanimori, K.Kubo, K.Miuchi, T.Mizumoto,
J.Parker, A.Takada, H.Nishimura, S.Iwaki,
T.Sawano, Y.Matsuoka, S.Komura, Y.Sato



- Dark Matter
- Direction-sensitive search
- NEWAGE Detector " μ -TPC"
- Low pressure gas
- Summary

Dark Matter (DM)

- Rotation curve of stars in the galaxy does not dump even outer region
⇒ DM at galaxy
 - Observation of cosmological parameters
⇒ DM at cosmological scale
- ⇒ Unknown mass "Dark Matter" exist at various scale



DM candidate "WIMP" Weakly Interacting Massive Particle

DM candidates

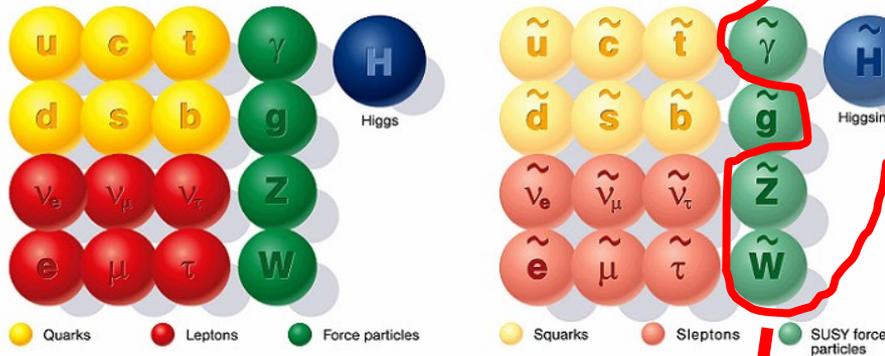
- **WIMP**
- axion
- sterile neutrino
- Q-ball
- ...etc

neutralino (χ)

Super Symmetry theory

- Lightest neutral **SUSY particle**
- It can be **WIMP**
- **Elastic scatter** with **nucleus**

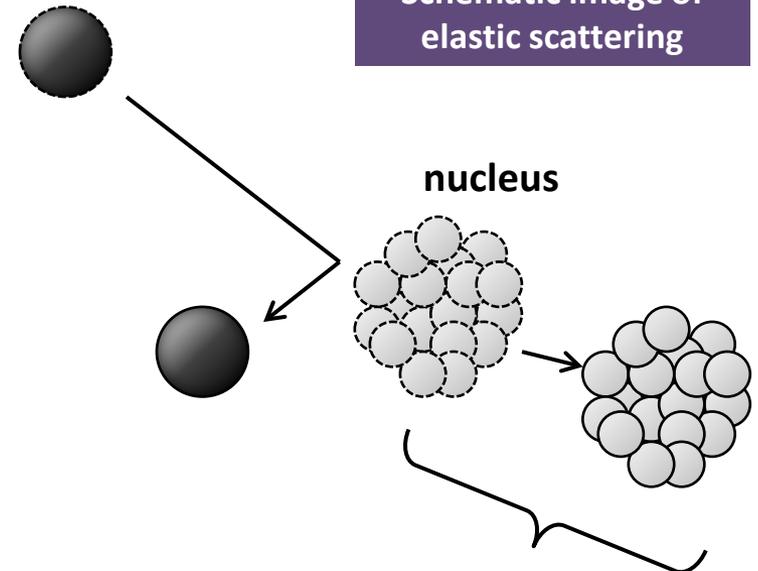
Standard model particles and SUSY particles



neutralino consists of these particles

DM

Schematic image of elastic scattering



We observe recoil nucleus

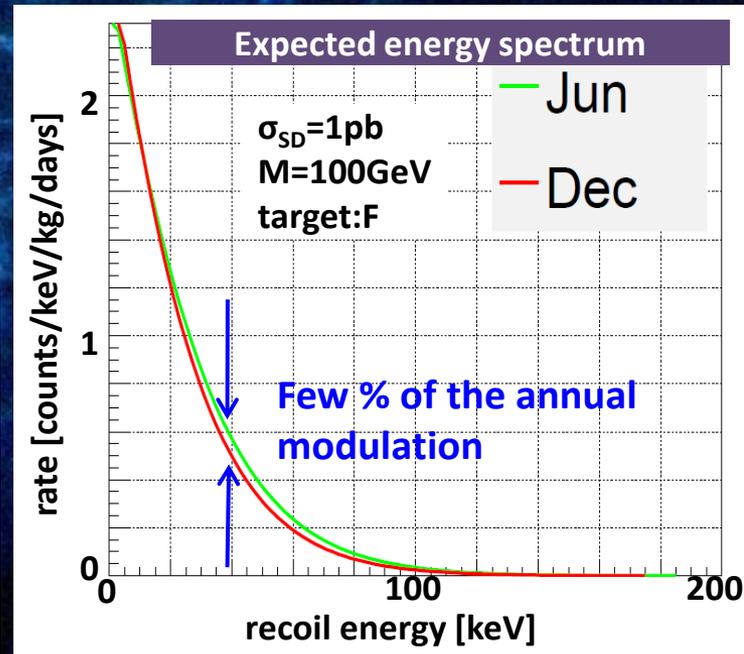
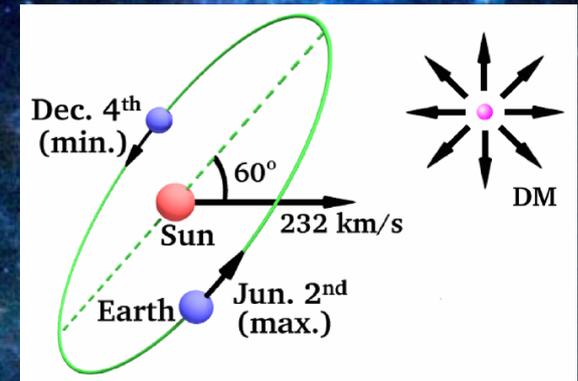
DM detection method 1

1. Annual modulation (conventional)

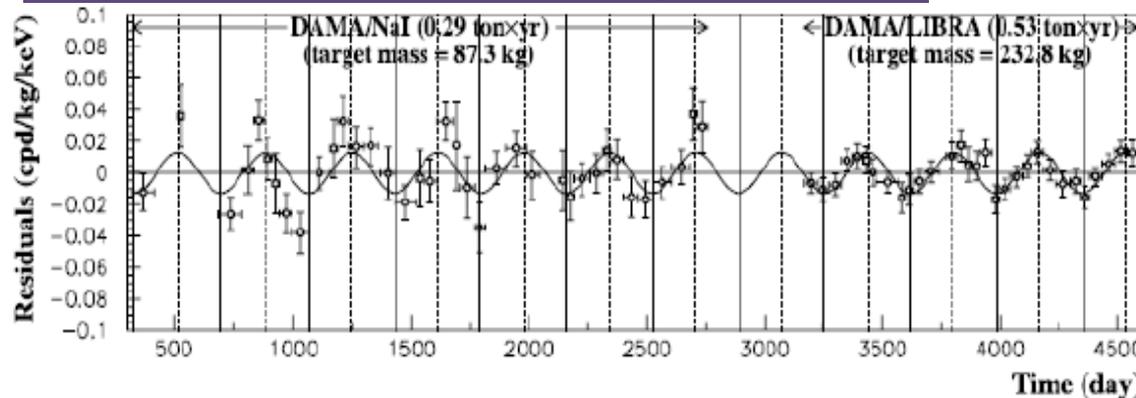
Large mass \rightarrow Solid or liquid detector
Require for 3σ : ~ 10000 events

2. Incoming direction of DM (new)

Nuclear track \rightarrow Gas detector
Require for 3σ : ~ 20 events



Annual modulation observed by DAMA



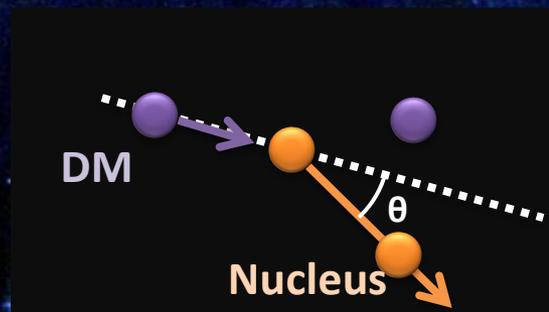
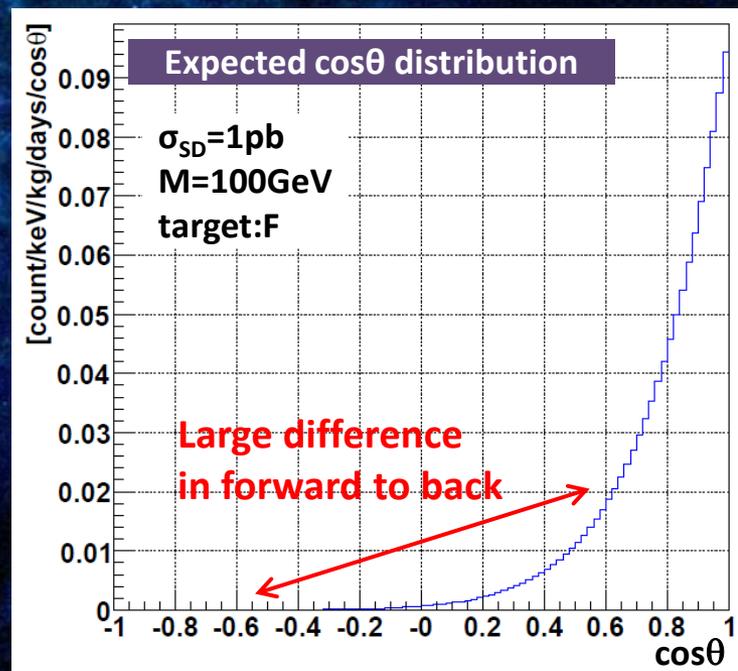
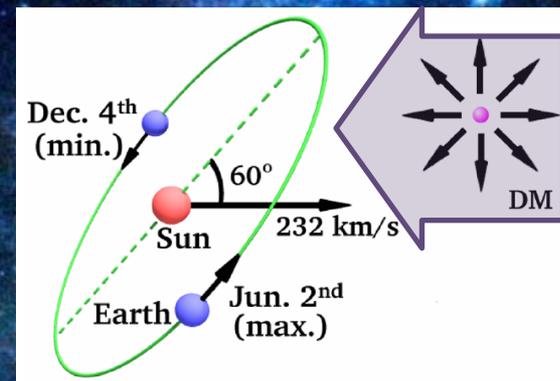
DM detection method 2

1. Annual modulation (conventional)

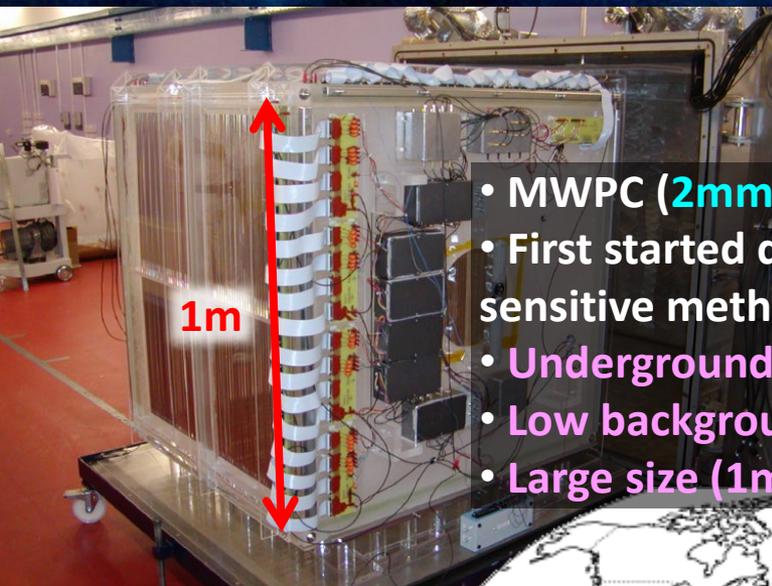
Large mass \rightarrow Solid or liquid detector
Require for 3σ : ~ 10000 events

2. Incoming direction of DM (new)

Nuclear track \rightarrow Gas detector
Require for 3σ : ~ 20 events



Direction-sensitive DM search

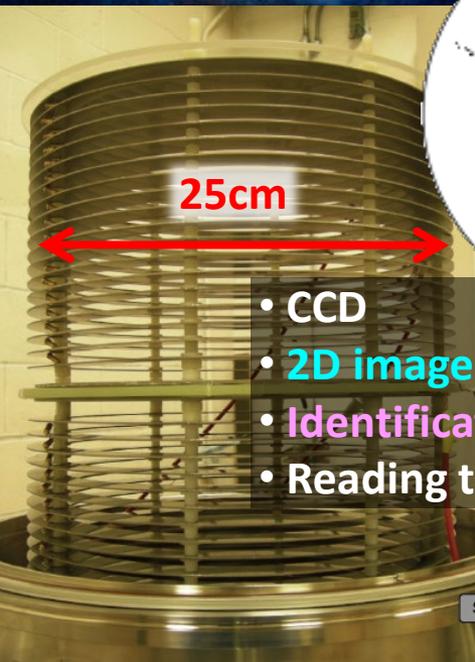
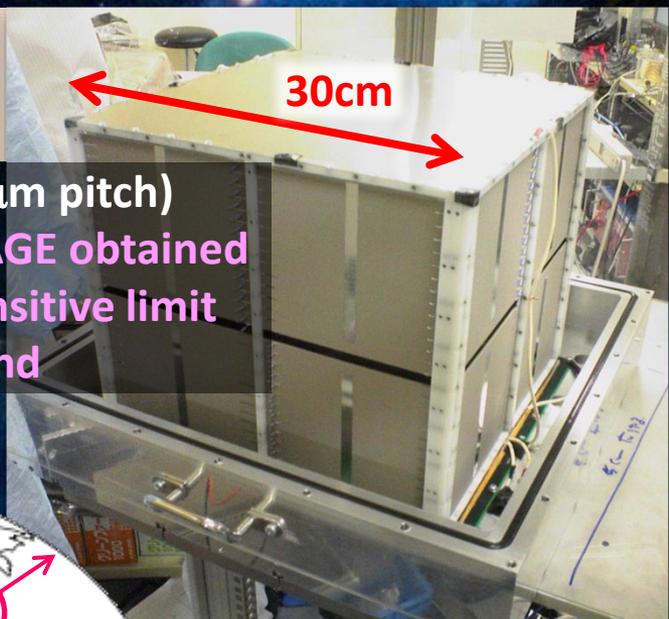


DRIFT
[UK]

- MWPC (2mm pitch)
- First started direction-sensitive method
- Underground
- Low background
- Large size (1m³)

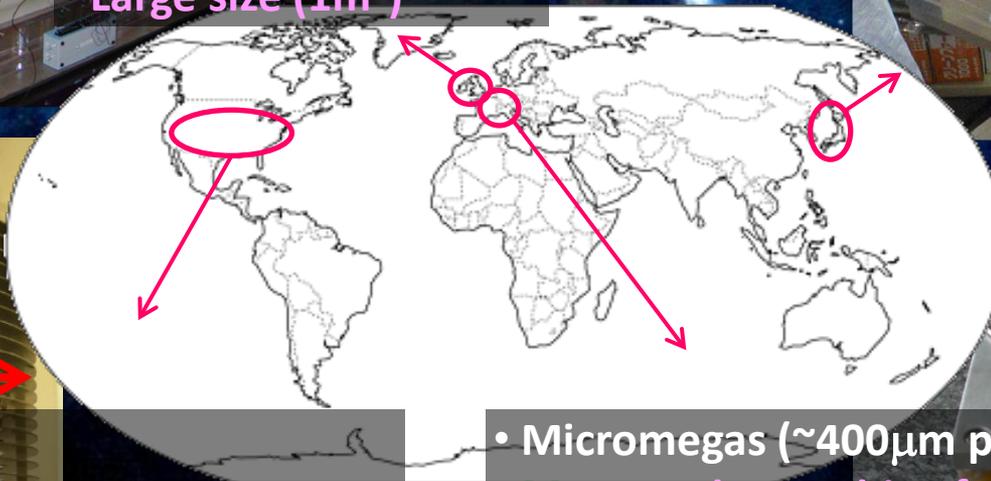
NEWAGE
[Japan]

- μ -PIC (400 μ m pitch)
- Only NEWAGE obtained direction-sensitive limit
- Underground



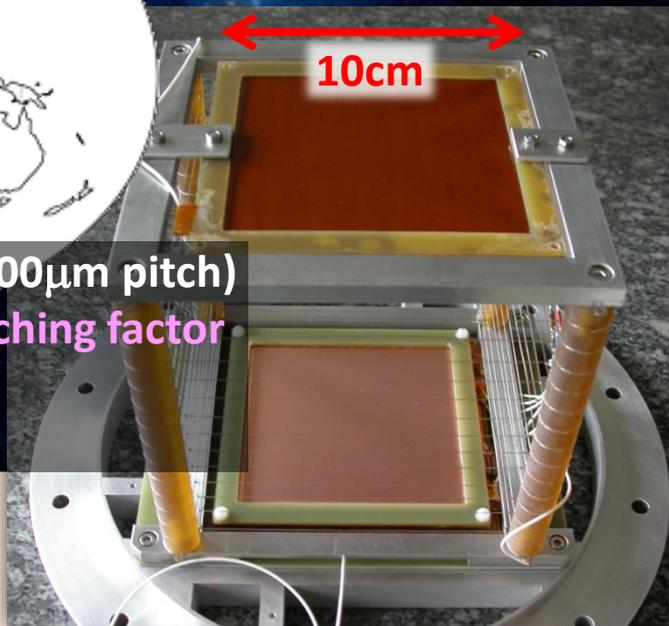
DMTPC
[USA]

- CCD
- 2D image
- Identification of head-tail
- Reading to underground



- Micromegas (\sim 400 μ m pitch)
- Measured quenching factor in detail
- R&D at surface

MIMAC
[France]



MPGD advantages for DM search

- Direction sensitivity

Detect **short track**

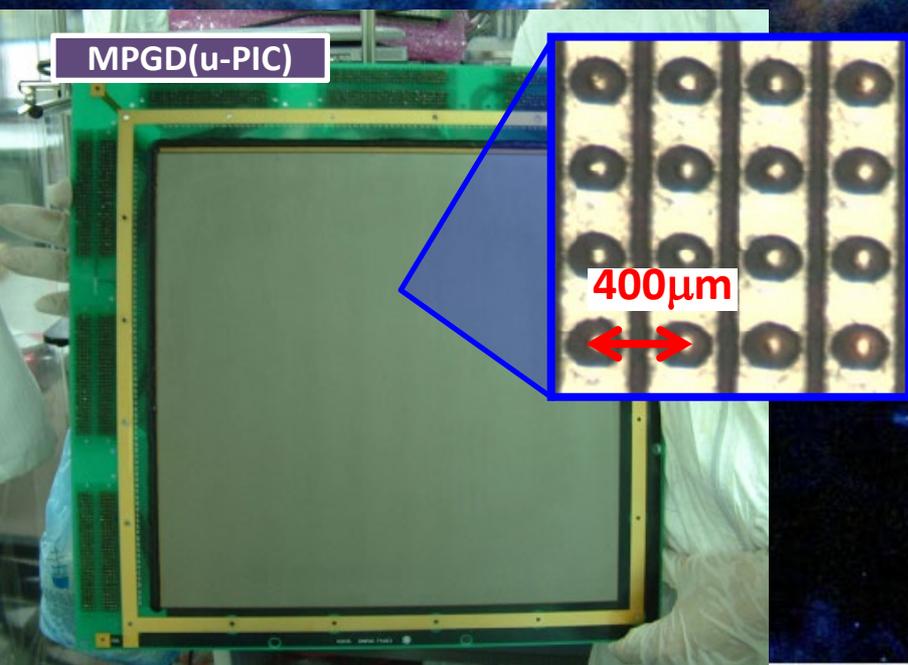
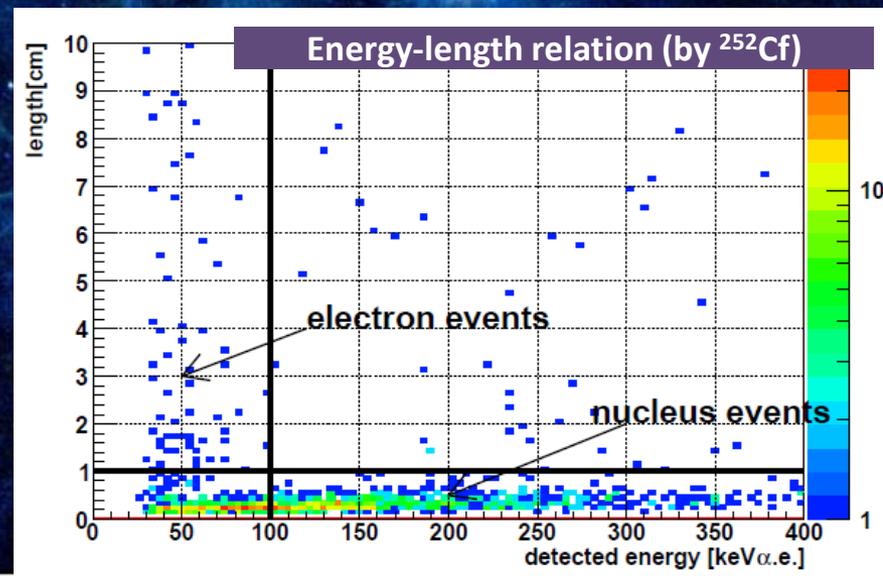
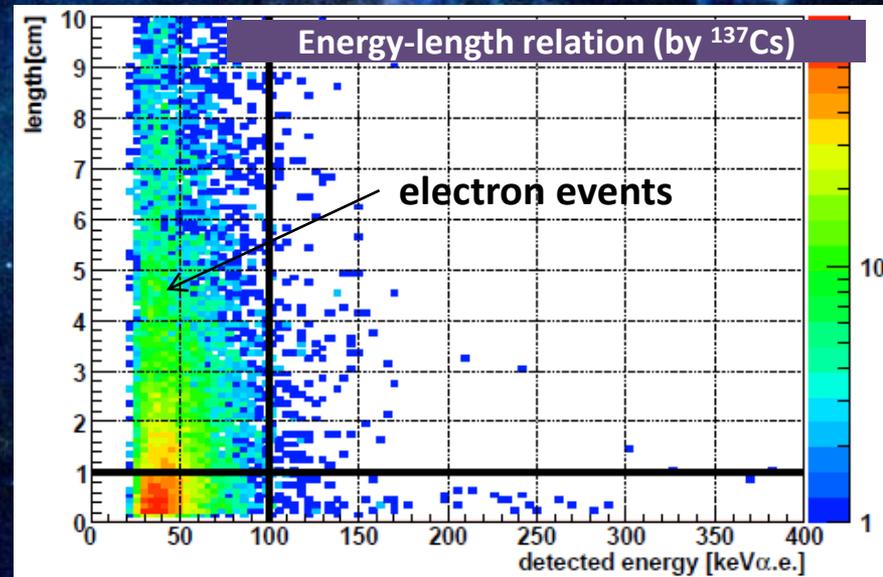
(Typically **2mm**@100keV(F in 0.1atm CF₄)

- Background decrease

Discriminate electron tracks (BG)

from nuclear tracks by track length

(rejection : 10⁻⁶)



NEWAGE



NEWAGE Detector " μ -TPC"

New general WIMP search with an Advanced Gaseous tracker Experiment

μ -TPC

- gas : CF_4
- pressure : 0.1-0.2atm

0.5cm

30cm or 50cm

GEM (8-segmented)

- size : 28x23cm
- thickness : 50 μm
- hole : 70 μm
- pitch : 140 μm

μ -PIC

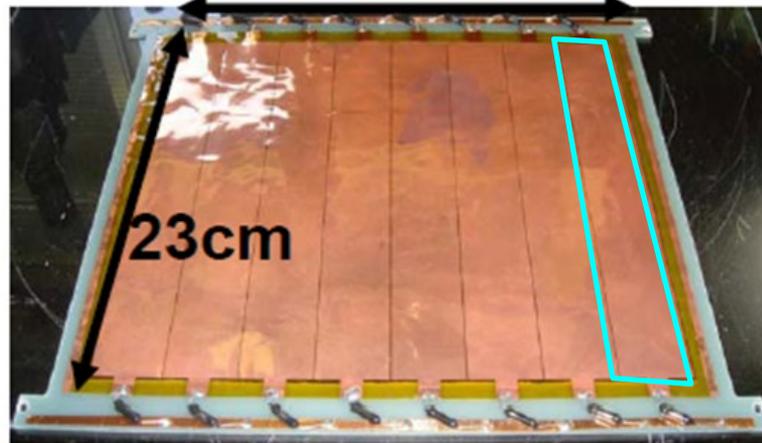
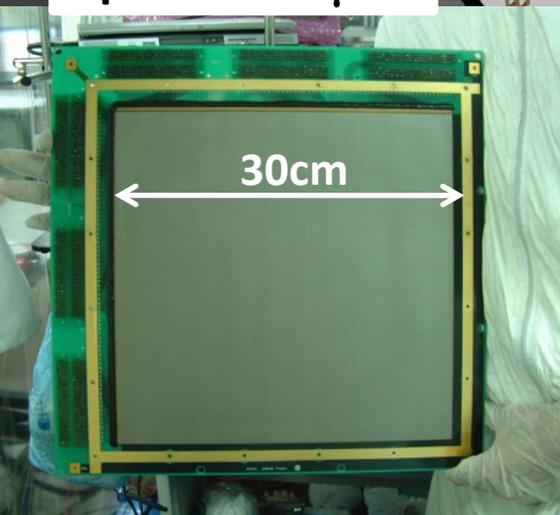
- size : 30x30cm
- pitch : 400 μm

Drift plane

28 cm

23cm

30cm



Data taking

Track

1. ASD^(*) (Amp Shaper Discriminator)

See which strip hit

2. Position Encoder (100MHz)

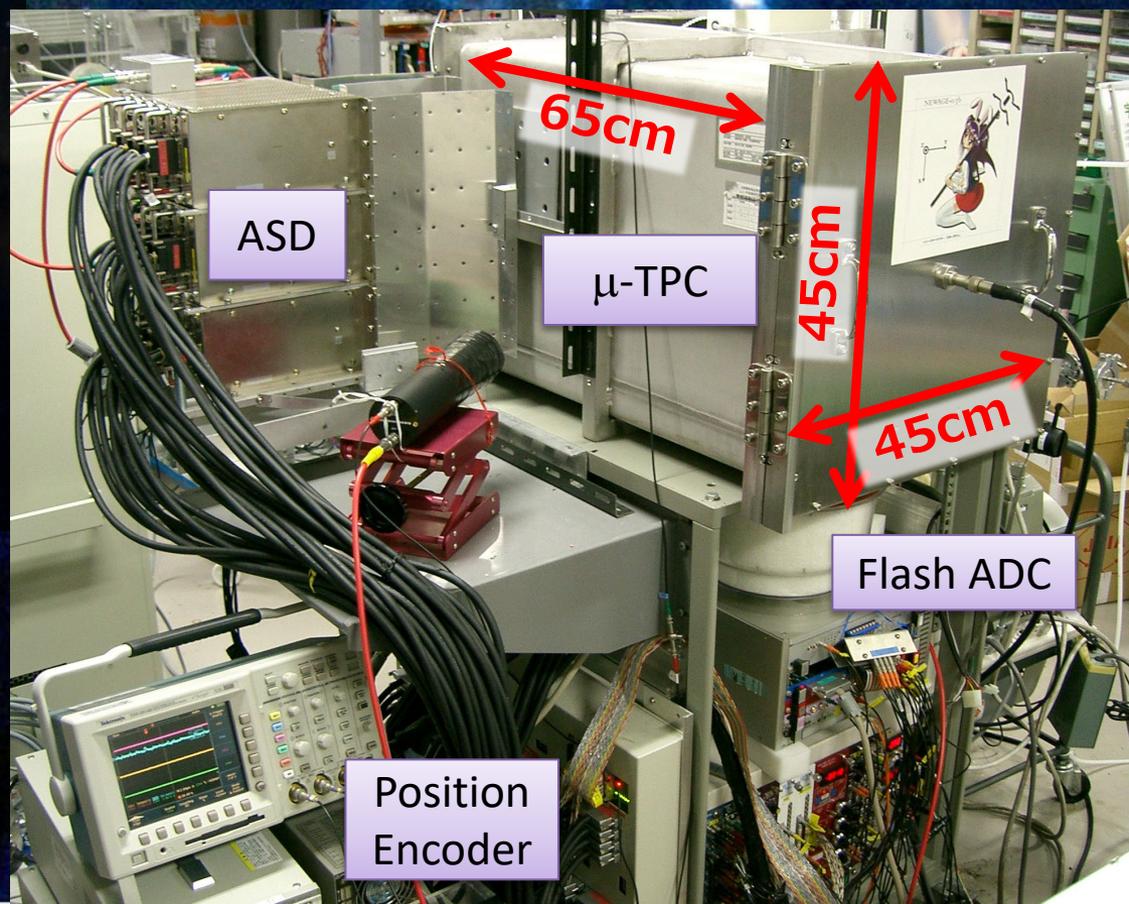
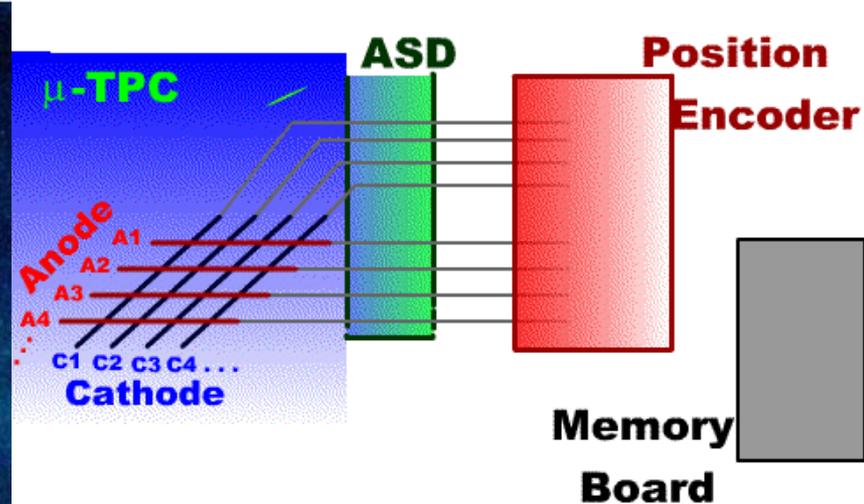
Take coincidence

(drift field : 625 V/cm/atm)

(drift velocity : 8.5 cm/ μ s)

Energy

Flash ADC (100MHz)

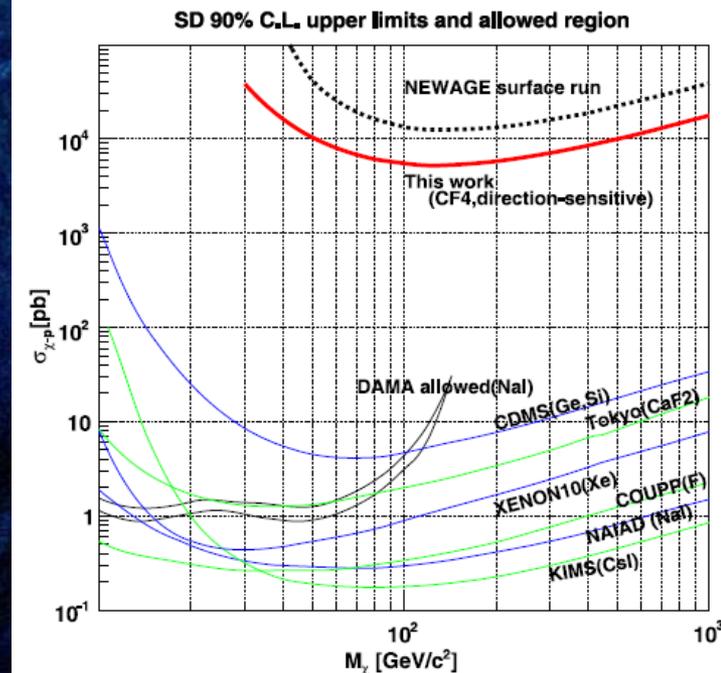
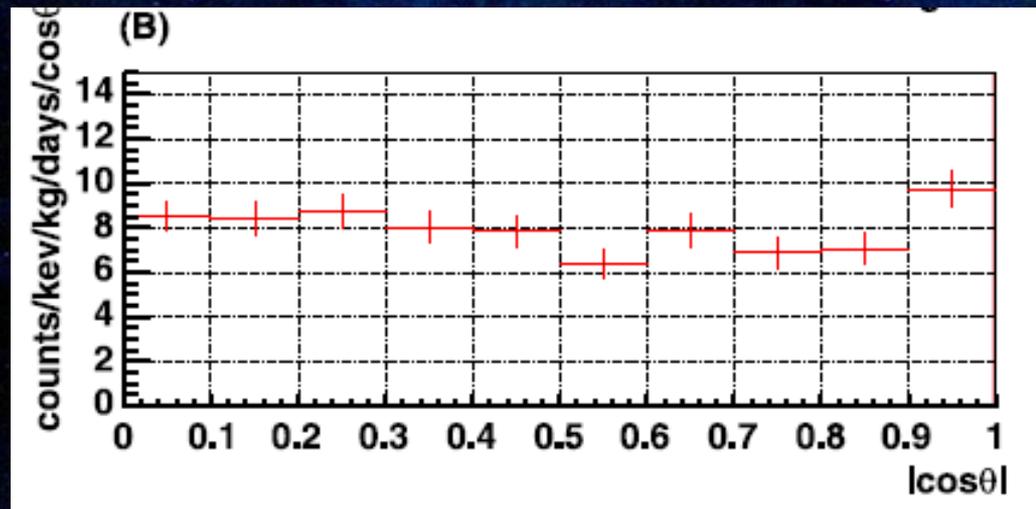
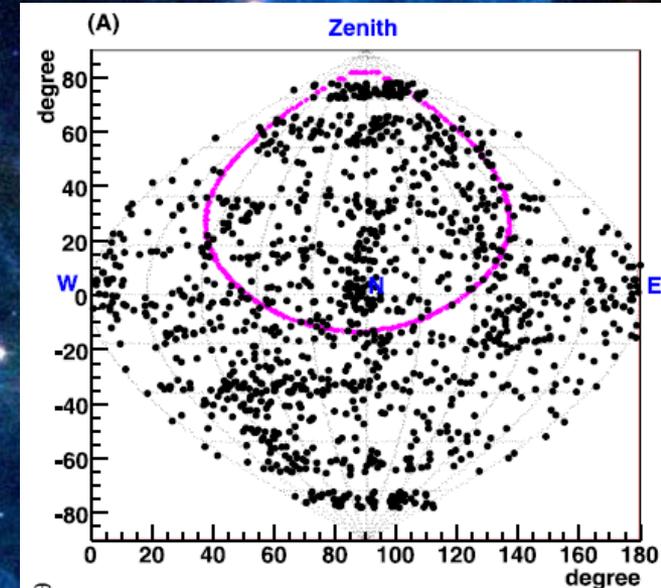


(*) IEEE Tra. Nuc. Sci. 51, 4, 1, Aug. 2004, 1337-1342

NEWAGE up to 2010

PLB 686 (2010) 11

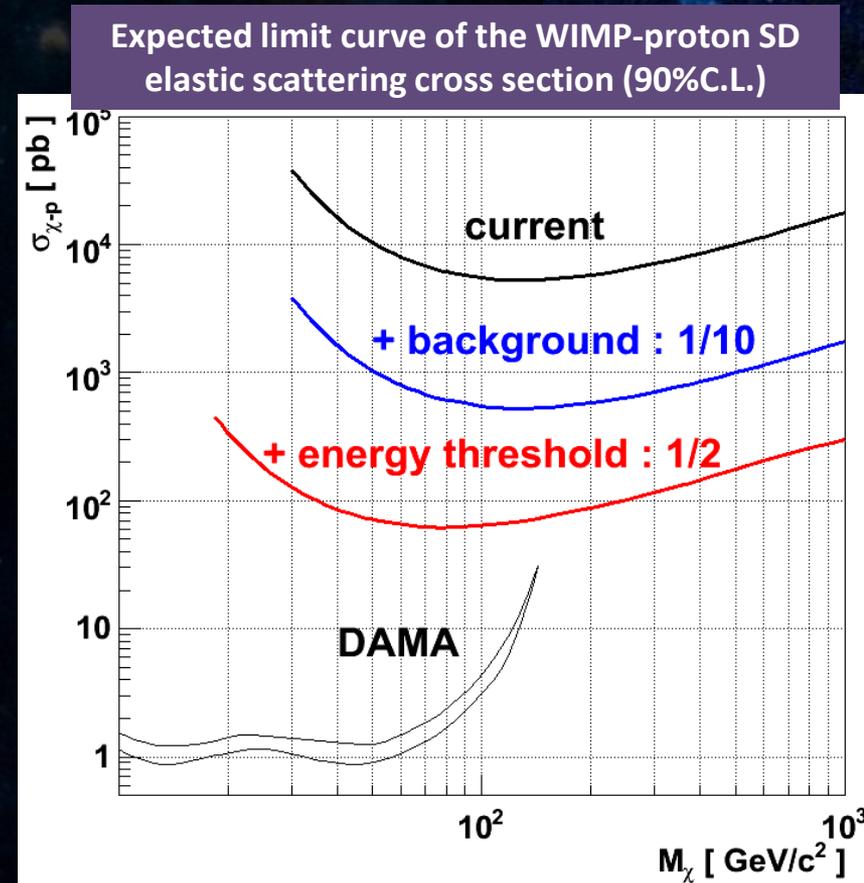
- Place : **Kamioka** (depth : 2700m.w.e)
- Exposure : 0.524 [kg days]
- Pressure : 0.2atm
- $\cos\theta$ distribution : **Flat**
- Limit : **5600pb** for 150GeV



Next

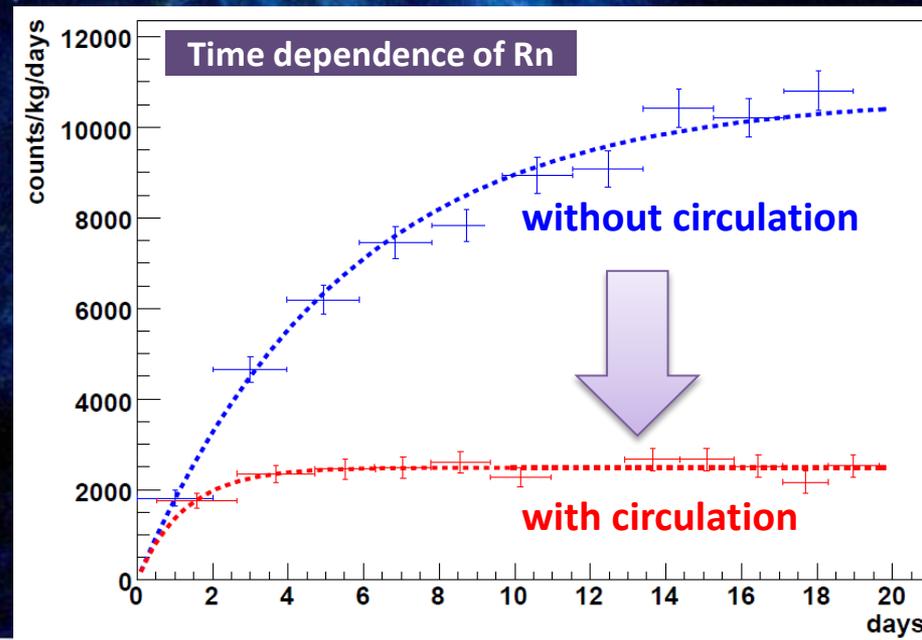
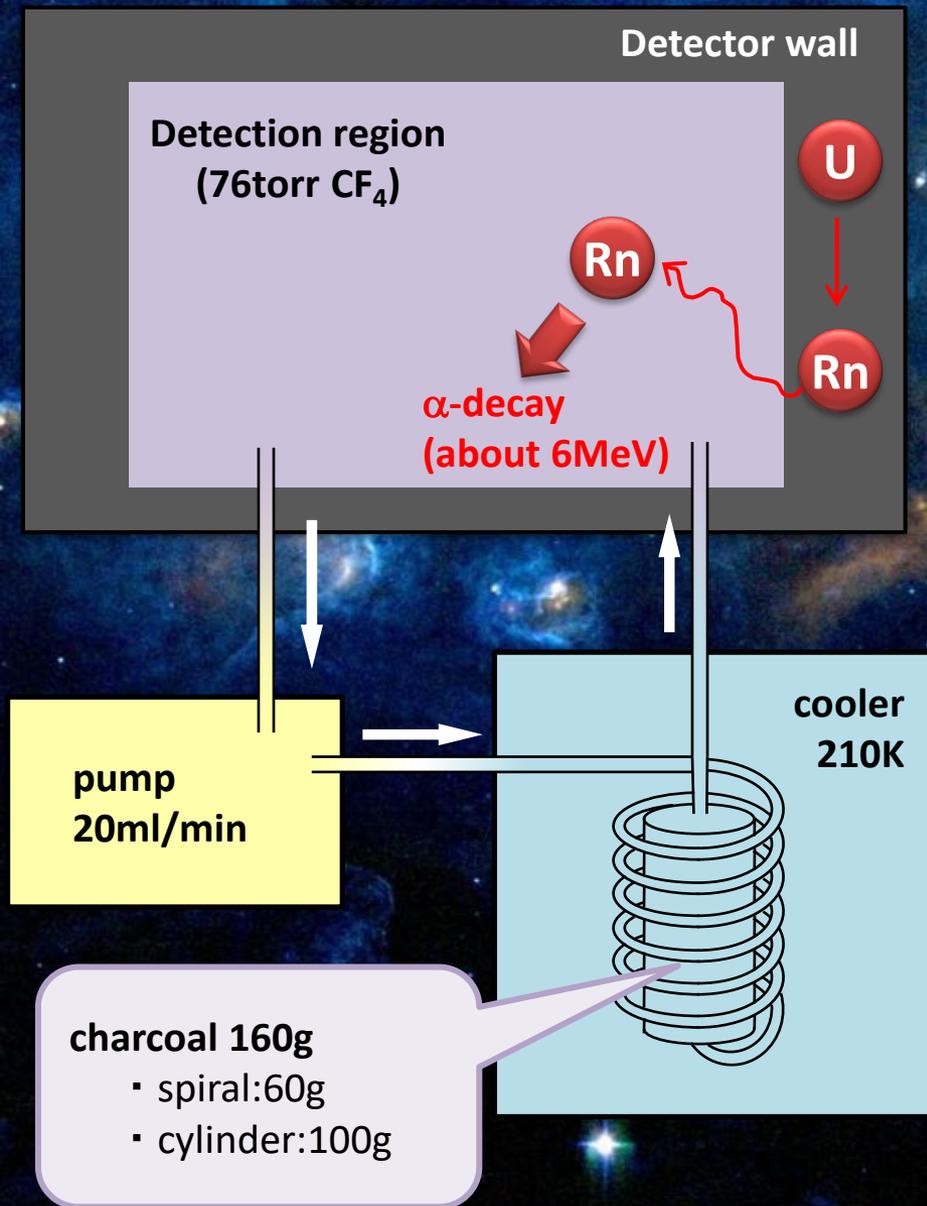
We aim to search DAMA-region (sensitivity x1000)

- Background : 1/10 (x10)
 - > **Radon elimination (sub talk)**
Material selection
- Energy threshold : 1/2 (x10)
 - > **low pressure gas (main talk)**
- Large size (x10)
 - > Several 1m³ size detectors
(current : (30cm)³)
- Head-tail identification (x3)
 - > New DAQ (time-over-threshold)



Gas circulation system

- Circulation with cooled charcoal
- Radon rate : $1/4$ (prototype pump)
- Further reduction is expected with full spec (600ml/min) pump



Low Pressure Experiments



How to make threshold lower

Energy threshold : 100keV -> 50keV
-> Sensitivity to DM : x10

Low pressure gas (152torr -> 76torr)
-> Track length : x2

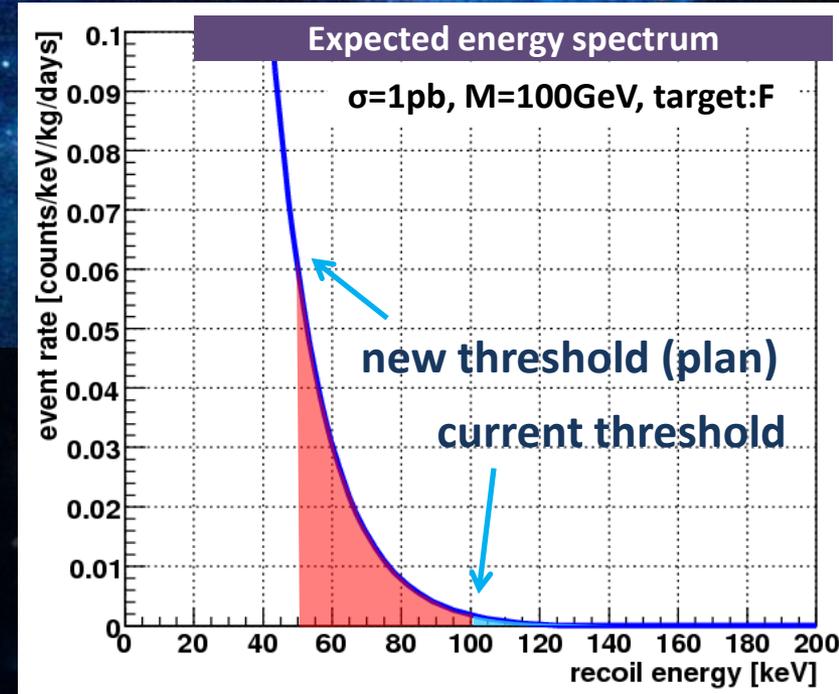


Advantage

- Sensitive to low energy (short) tracks
- Improve angular resolution

Difficulty

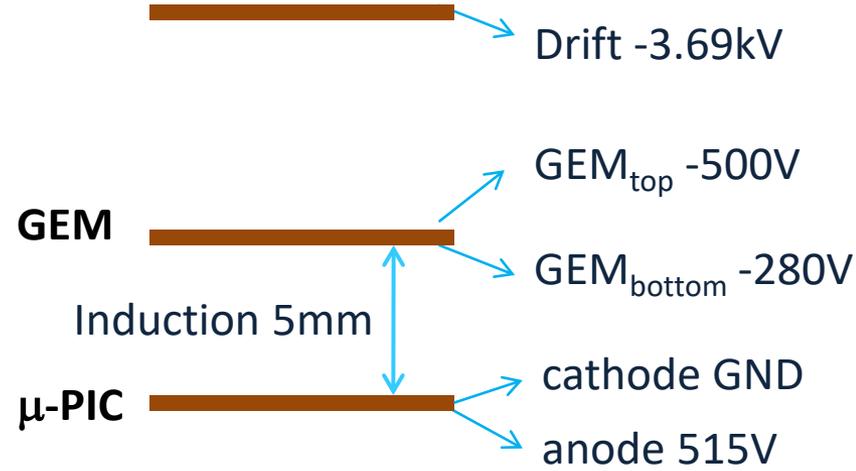
- Electrons density : half
-> Necessary gas gain : x2 (=1500)



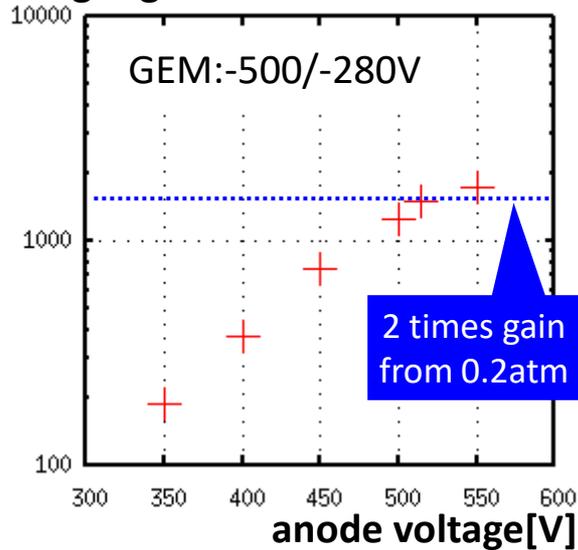
Gain curves

- μ -TPC works at 0.1atm gas
- Gain curve
 - anode (μ -PIC amplification)
 - Δ GEM (GEM amplification)
 - induction (passing rate)

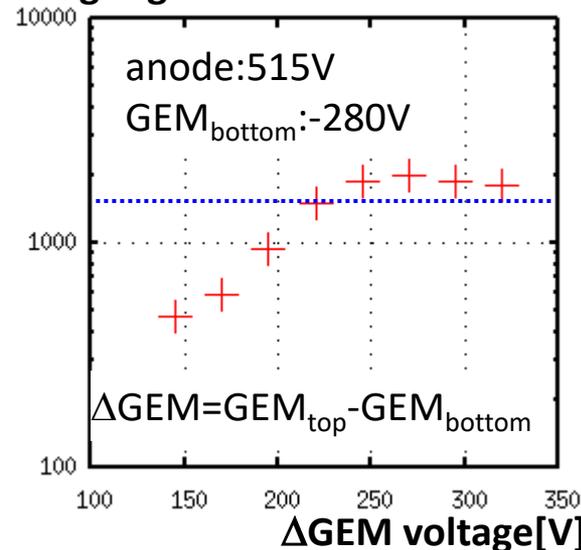
Drift Plane



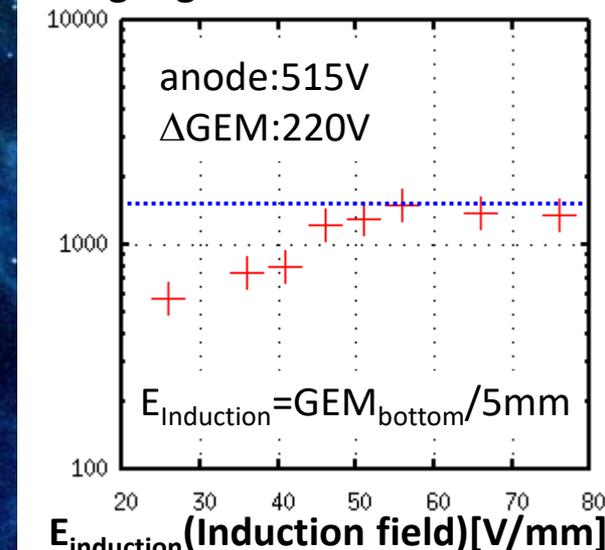
gas gain



gas gain



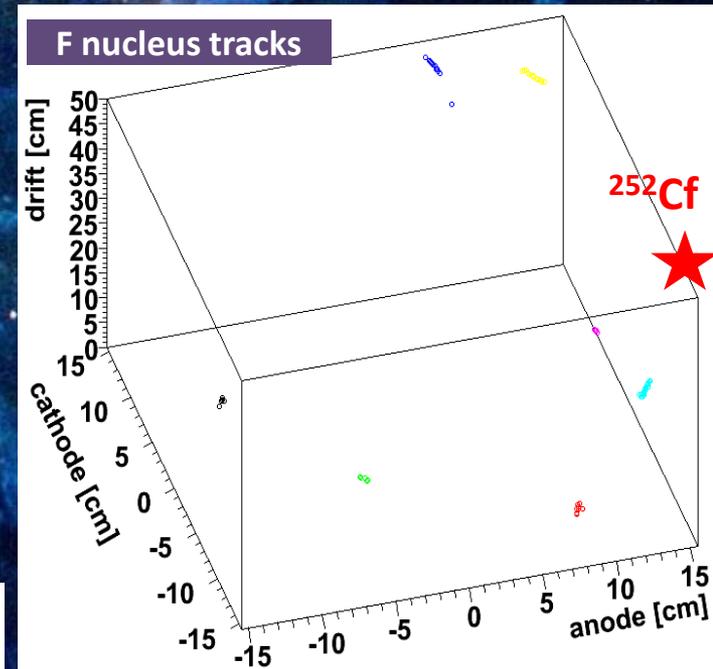
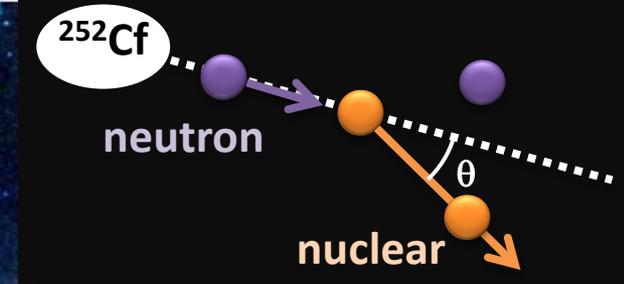
gas gain



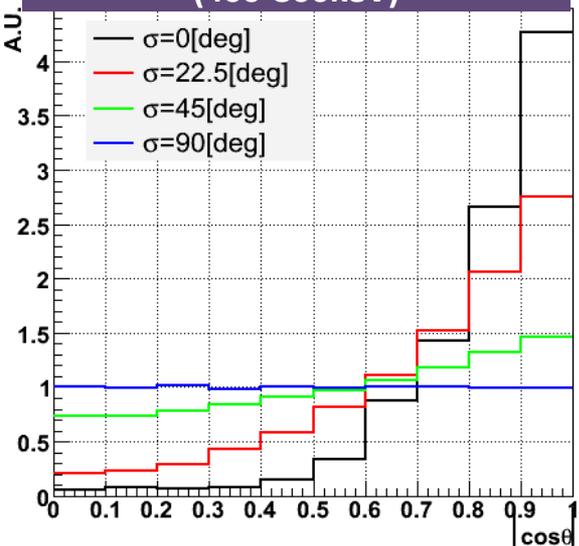
- Gain curves **saturated** (mean free path of e^- : several μm)
- Reach the **sufficient gain** derived from 0.2atm operation

Angular resolution

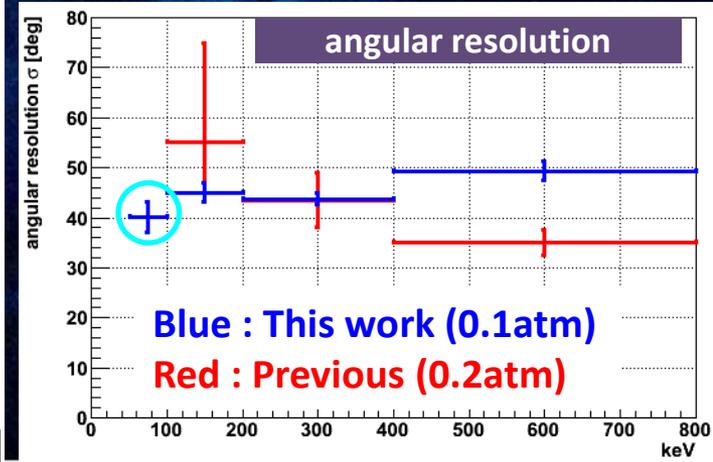
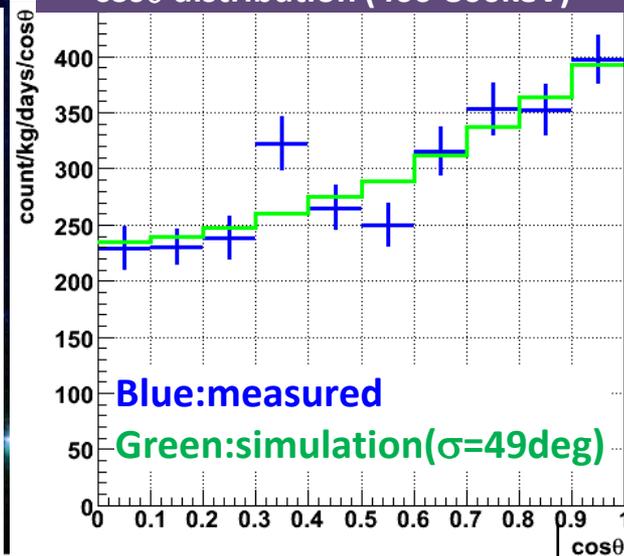
- Compare the $\cos\theta$ distribution between measured to simulation (simulate each angular resolution)
- We checked 50-100keV range : 40[deg] (Can't be seen at 0.2atm)



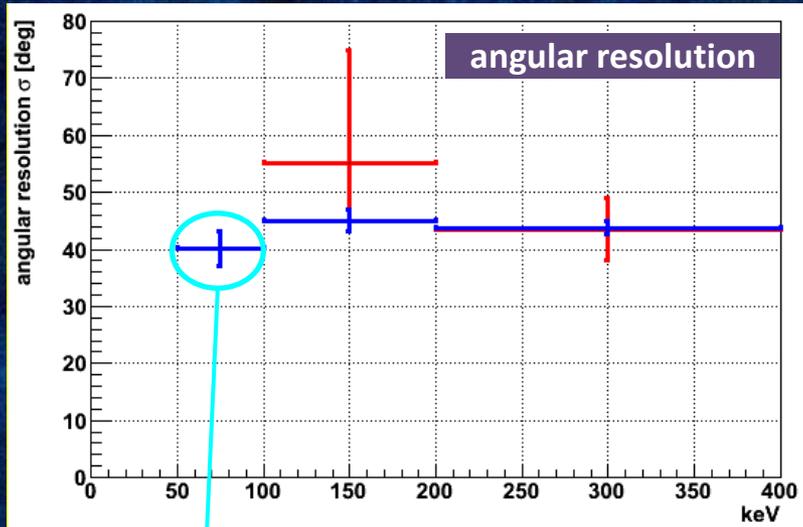
Simulated $\cos\theta$ distribution (400-800keV)



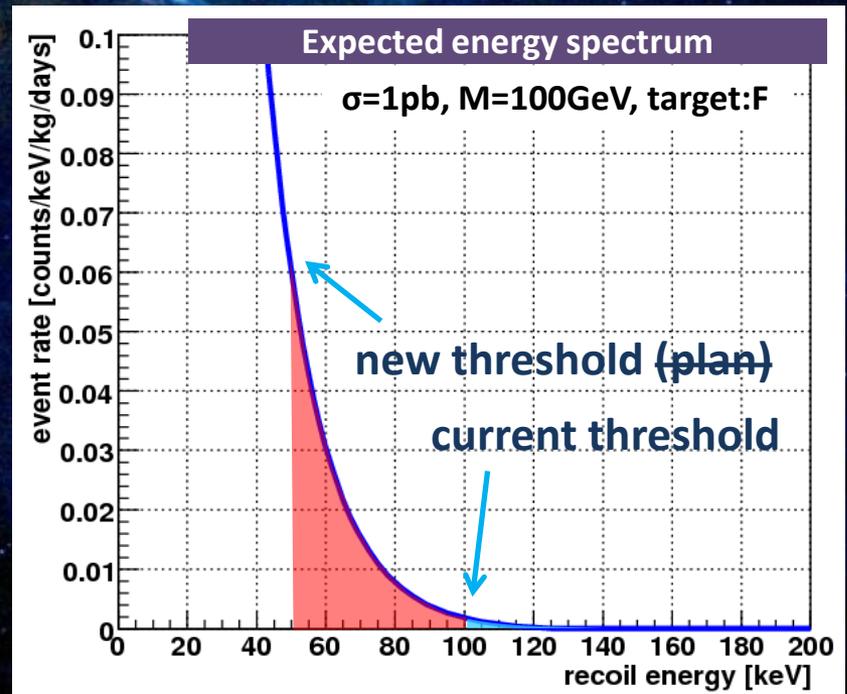
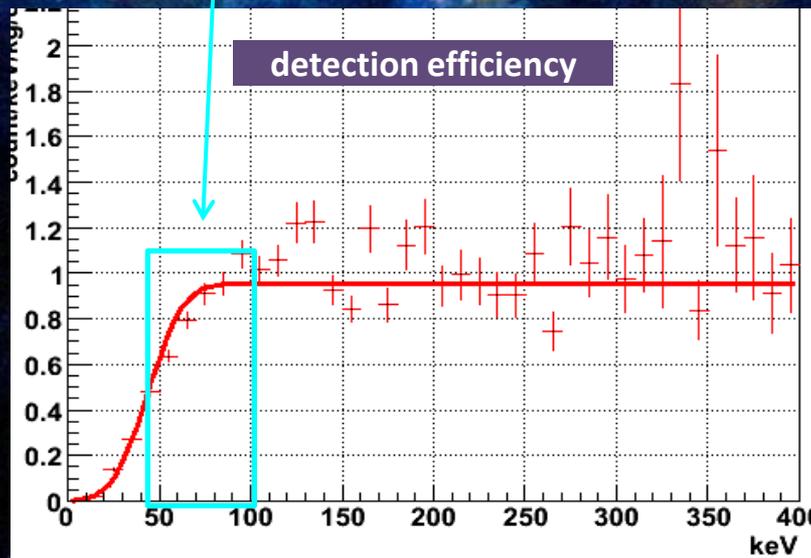
$\cos\theta$ distribution (400-800keV)



Detection efficiency



- Detection efficiency : **0.6@50keV**
(ratio of measured to simulation)
- Energy threshold : **100 -> 50keV**



Summary

NEWAGE

- Dark Matter search with MPDG "u-TPC"
- u-TPC can detect Incoming direction of DM

Low pressure (152torr \Rightarrow 76torr)

- Operation test
u-PIC work at 76torr with sufficient gain
- Angular resolution
 $40^{+3.1}_{-2.9}@50-100\text{keV}$
- Detection efficiency
0.6@50keV
Energy threshold : 100 \rightarrow 50keV

Next to search DAMA

- Update gas circulation system for radon elimination
- Use new DAQ for head-tail identification
- Simulation for constructing the large size detector

Summary

NEWAGE

- Dark Matter search with MPDG "u-TPC"
- u-TPC can detect Incoming direction of DM

Low pressure (152torr \Rightarrow 76torr)

- Operation test
u-PIC work at 76torr with sufficient gain
- Angular resolution
 $40^{\circ+3.1}_{-2.9}$ @50-100keV
- Detection efficiency
0.6@50keV
Energy threshold : 100 \rightarrow 50keV

Next to search DAMA

- Update gas circulation system for radon elimination
- Use new DAQ for head-tail identification
- Simulation for constructing the large size detector

Thank you for
your attention!



Mascot of NEWAGE
"Daakumatan"

まだだ、まだ終わらんよ