方向に感度を持った暗黒物質探索実験NEWAGE

2017.10.17

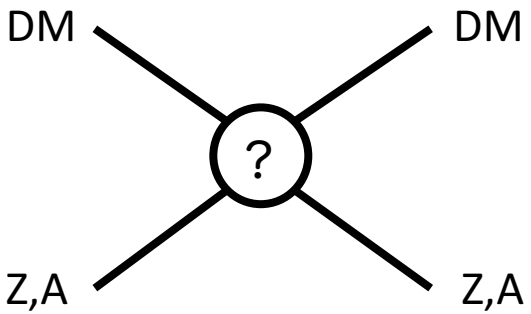
第2回宇宙素粒子若手の会秋の研究会

@東京大学宇宙線研究所柏キャンパス

神戸大学　池田智法

WIMPの直接探索

- 暗黒物質と原子核の散乱を観測する



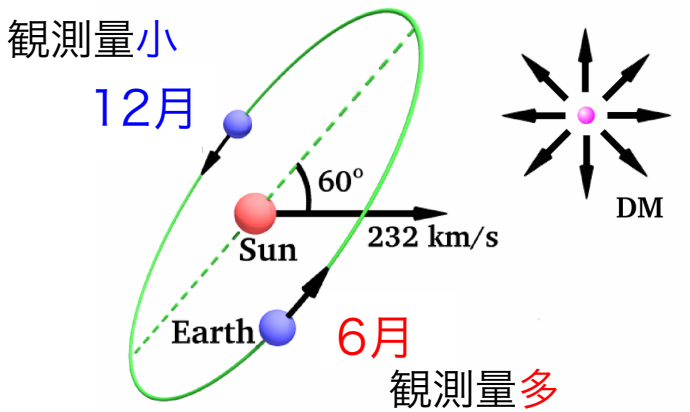
Spin Independent Interaction

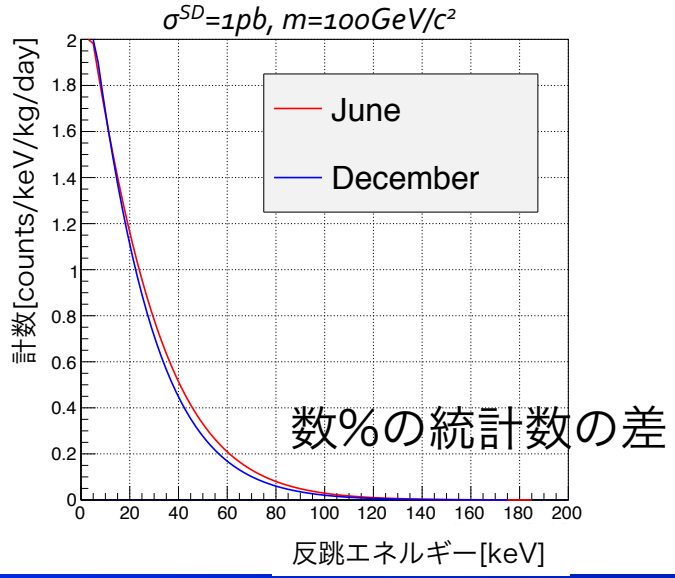
$$\sigma_A = \frac{\mu_A^2}{\mu_n} A^2 F_A(q)^2 \sigma_n$$

Spin Dependent Interaction

$$\sigma_A = \frac{\mu_A^2}{\mu_n} \frac{J_A + 1}{J_A} S_n^{A\,2} \sigma_n$$

- 季節変動





直接探索実験の紹介

Direction Sensitive WIMP-search NEWAGE

液体シンチ

XMASS
XENON1T
LUX
Darwin
LZ
PANDAX
DEAP3600
ANKOK

泡箱

PICO

結晶シンチ

SABRE
PICOLON
DAMA
COSINE-100
CRESST-3

半導体

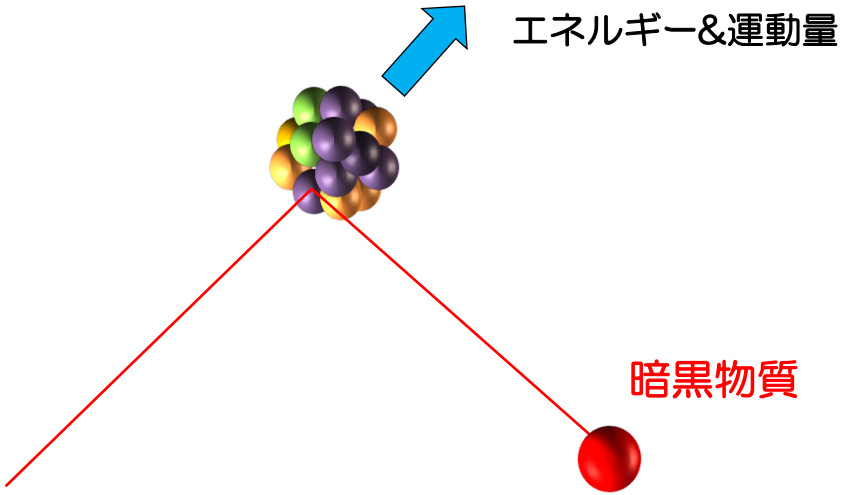
SuperCDMS
EDELWEISS-3
DAMIC
CDEX

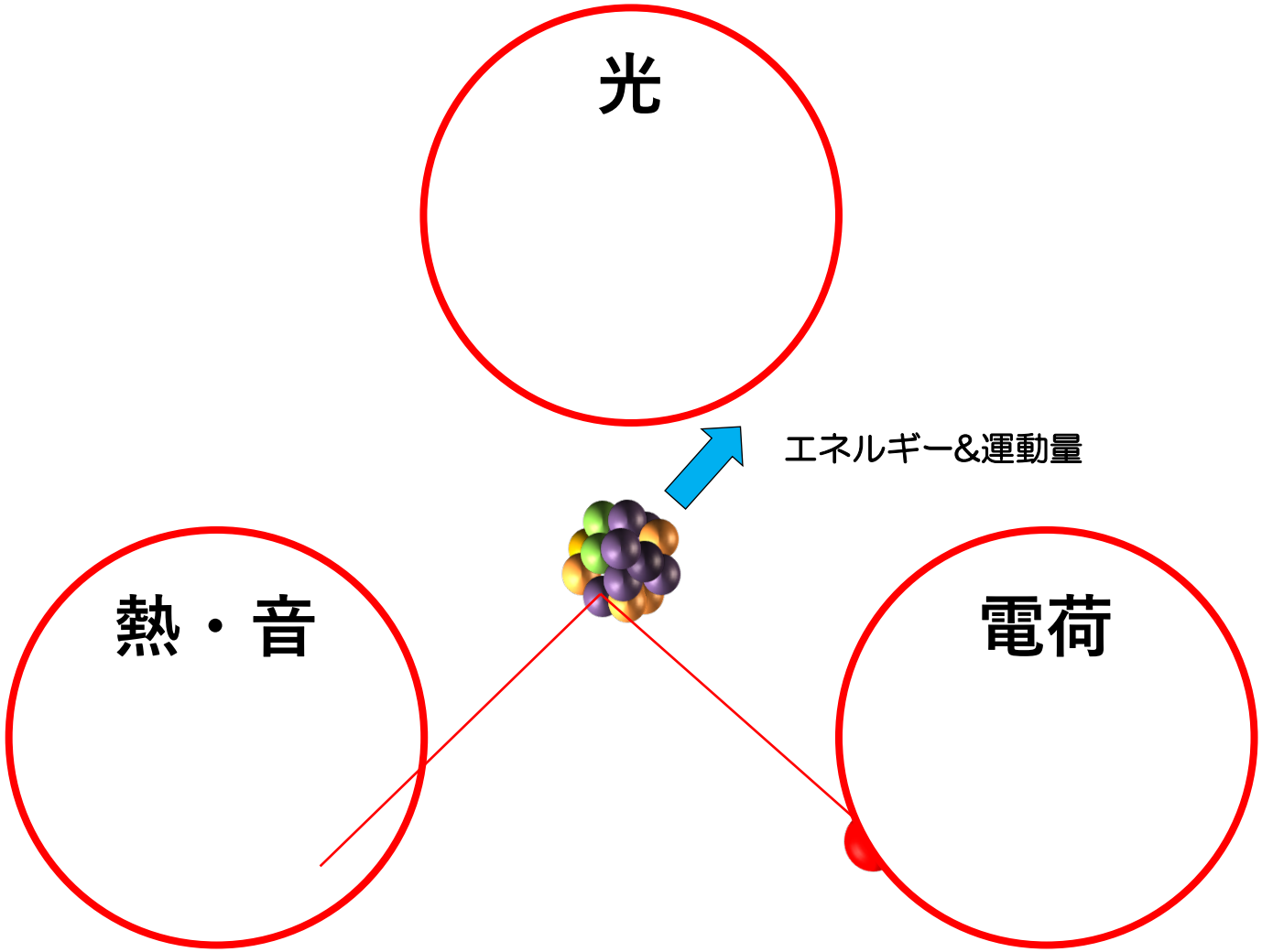
気体

NEWAGE
DRIFT
MIMAC
DM-TPC
NEWS-G

原子核乾板

NEWS-DM


エネルギー&運動量
暗黒物質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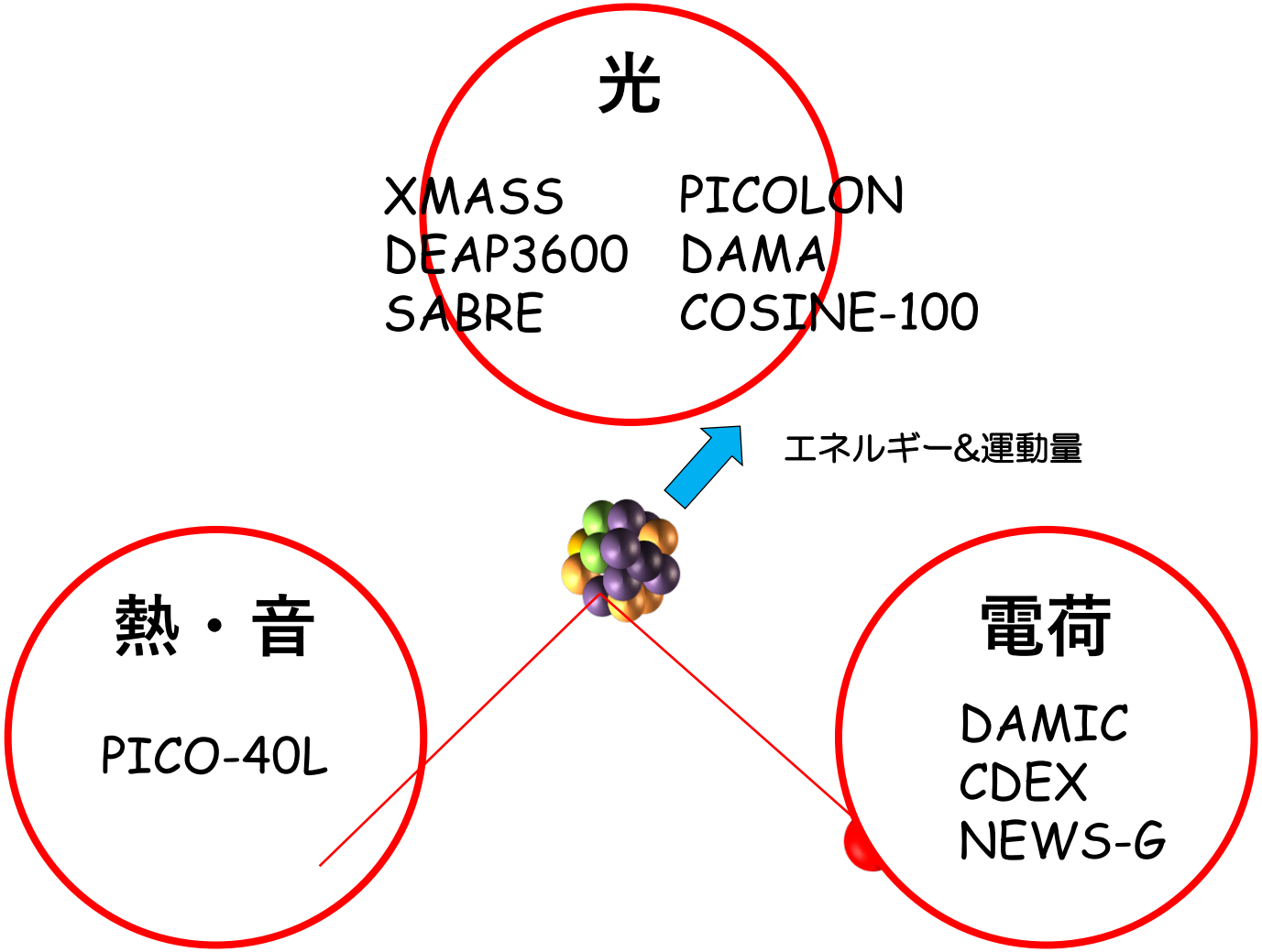
エネルギー&運動量
熱・音
電荷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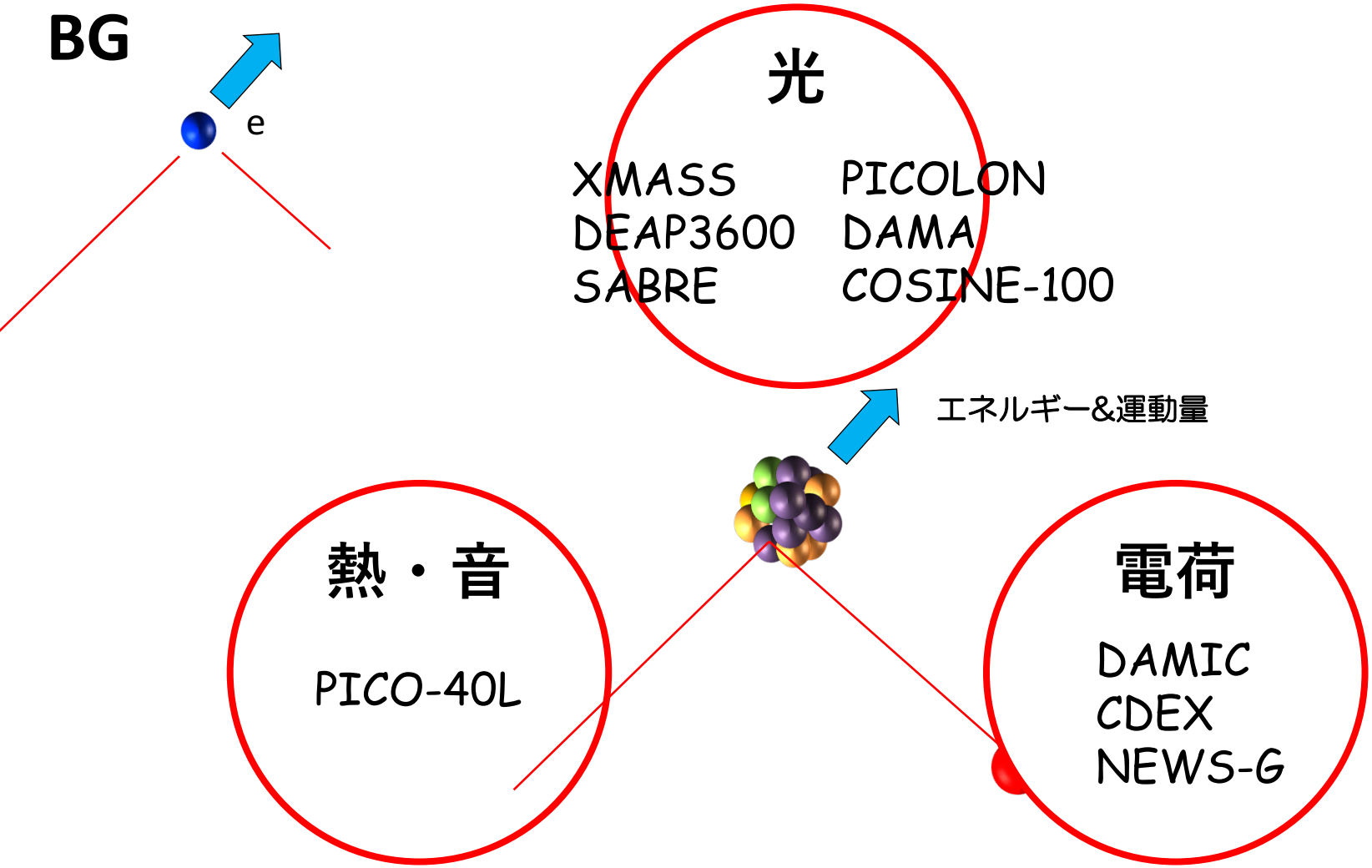
DEAP3600
SABRE
PICOLON
DAMA
COSINE-100
エネルギー&運動量
熱・音
PICO-40L
電荷
DAMIC
CDEX
NEWS-G

BG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COSINE-100
エネルギー&運動量
熱・音
PICO-40L
電荷
DAMIC
CDEX
NEWS-G

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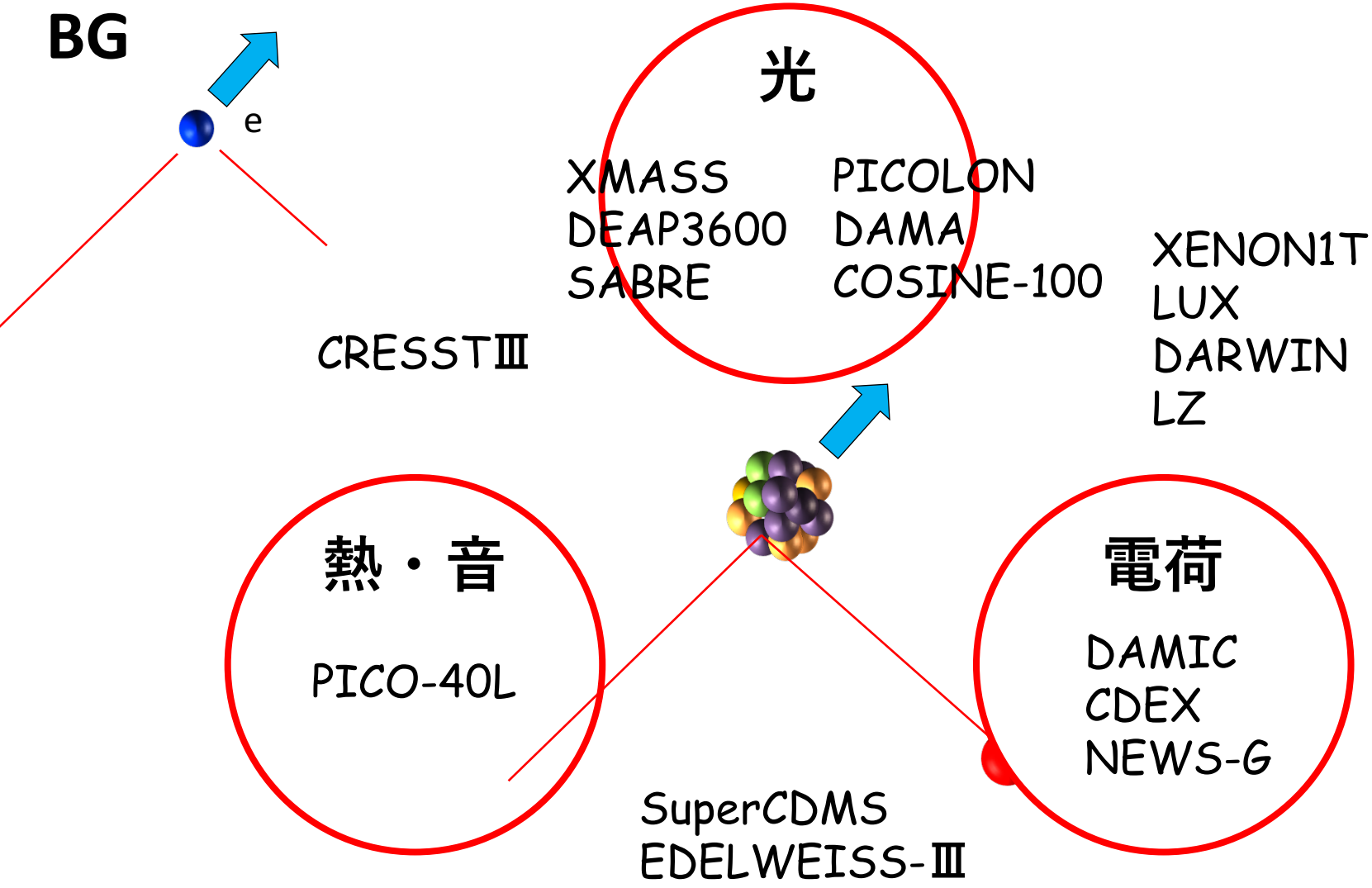
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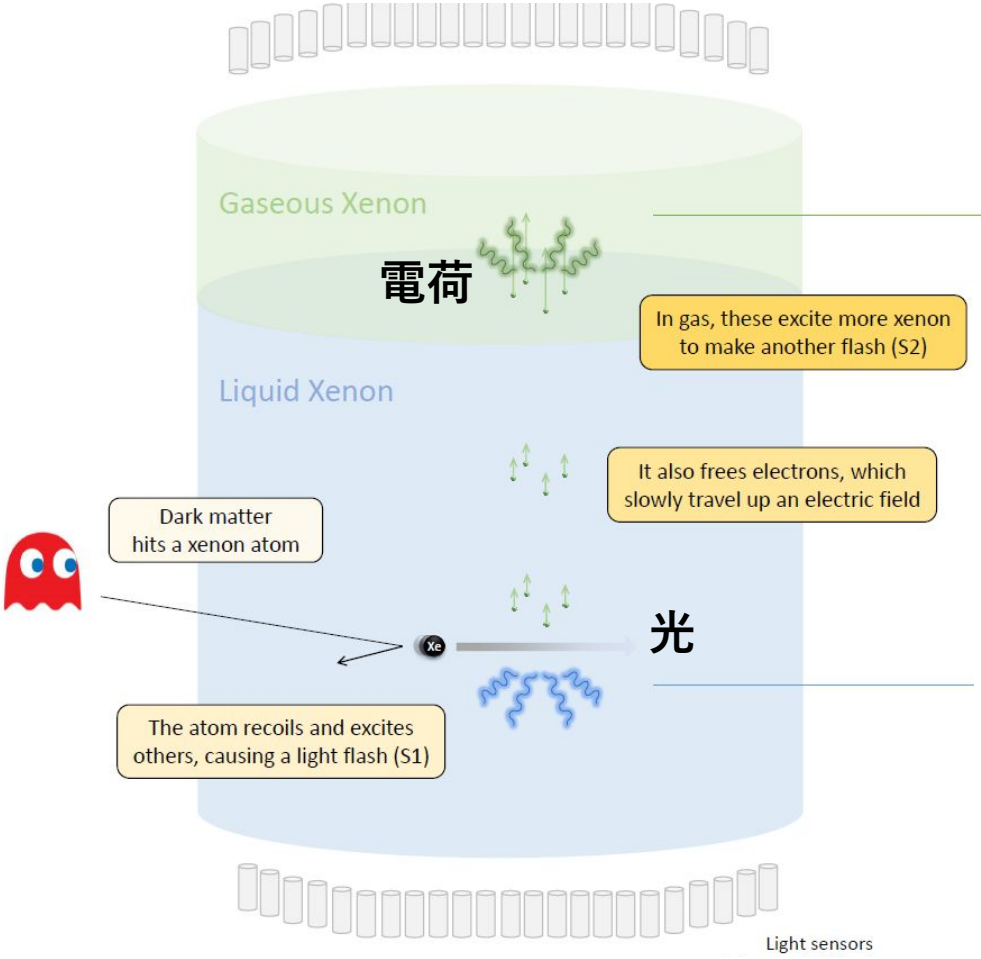
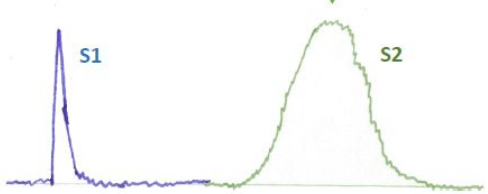
LUX
DARWIN
LZ
CRESSTⅢ
熱・音
PICO-40L
電荷
DAMIC
CDEX
NEWS-G
SuperCDMS
EDELWEISS-Ⅲ

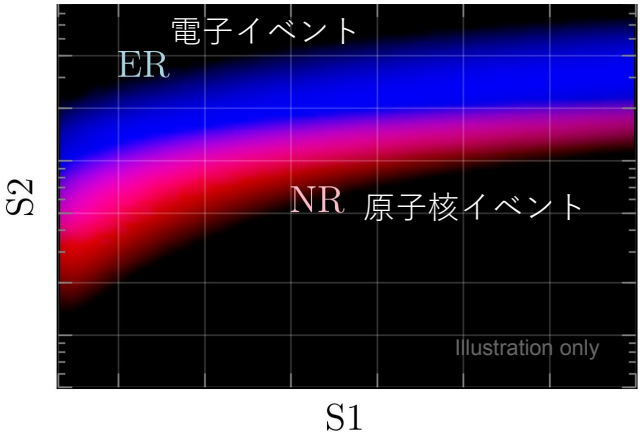
XNONE 1T

Direction Sensitive WIMP-search NEWAGE

LXe TPC principle



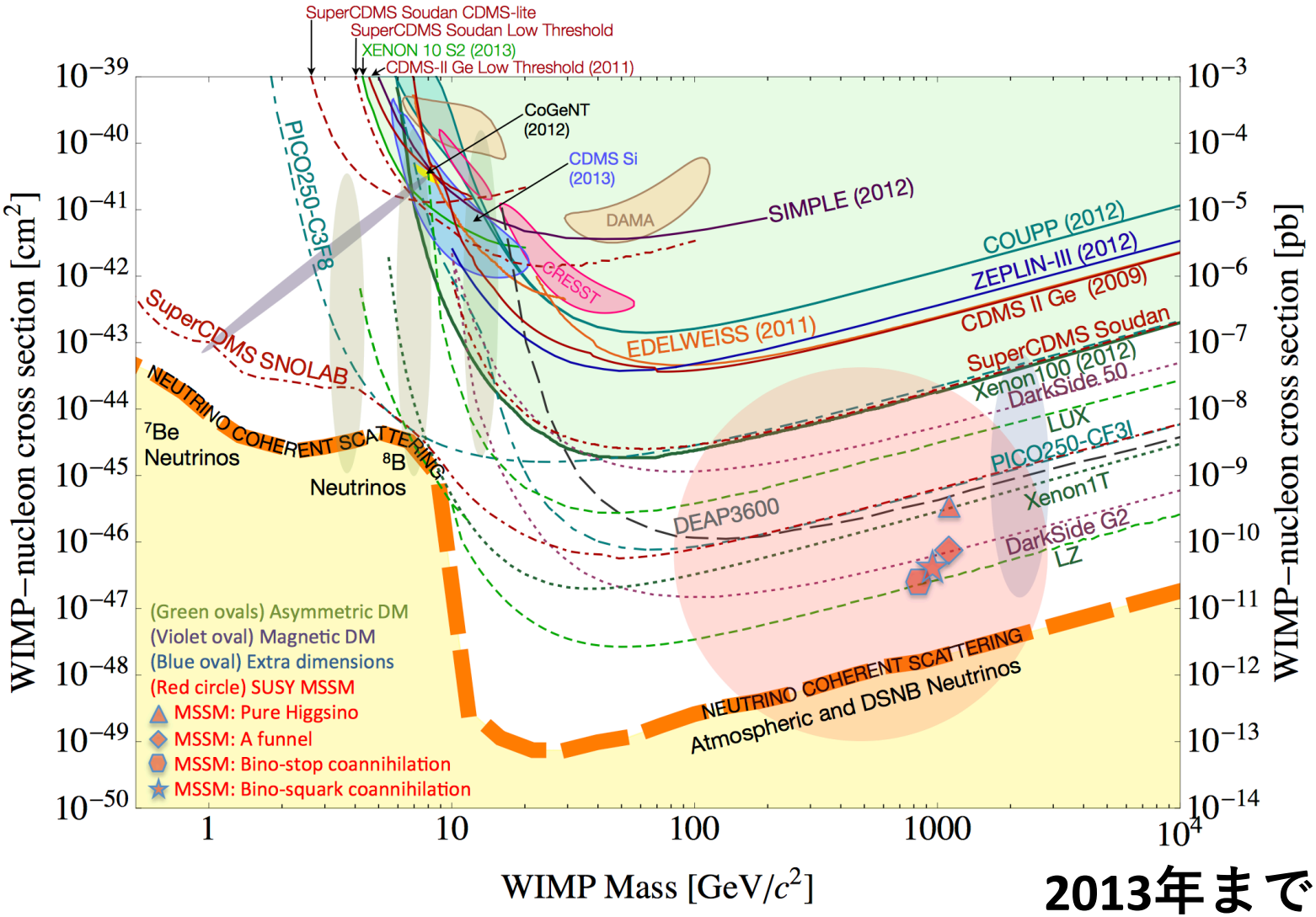




Jelle Aalbers @TAUP2017のスライドから

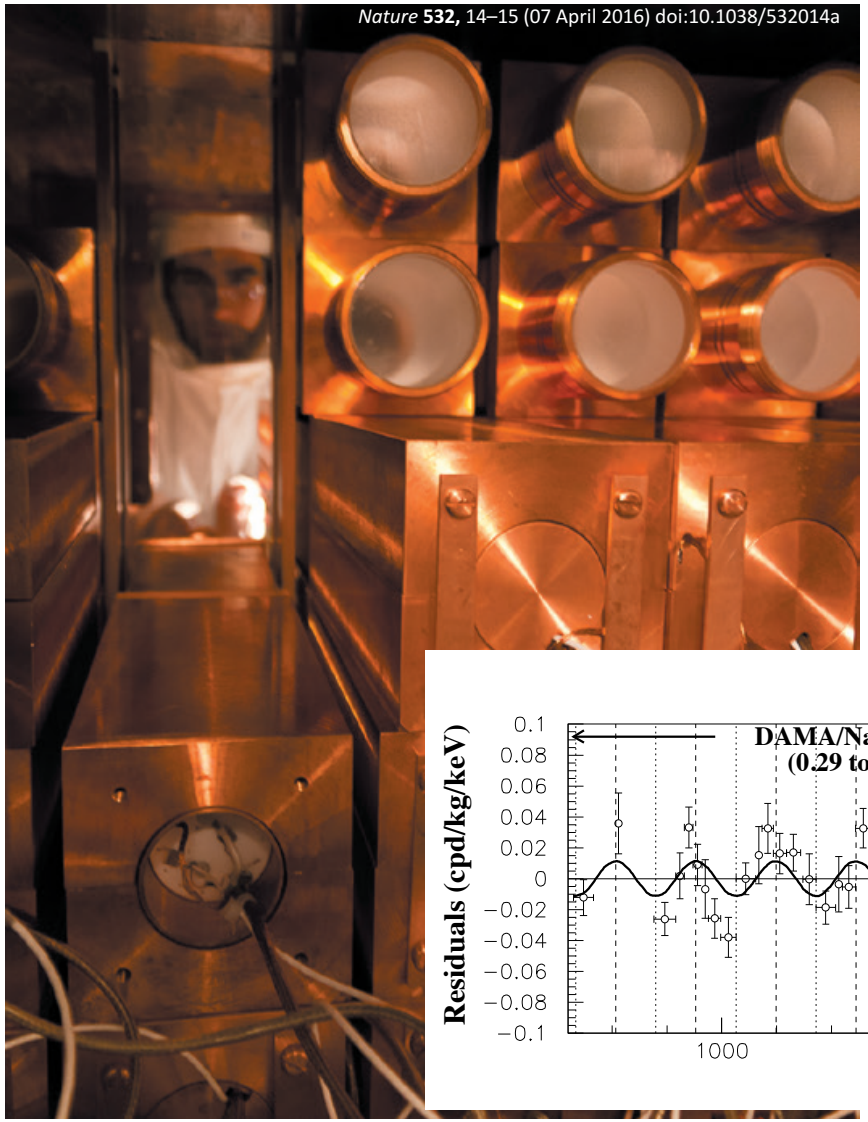
S1/S2 discrimination

直接探索現状(2013まで)

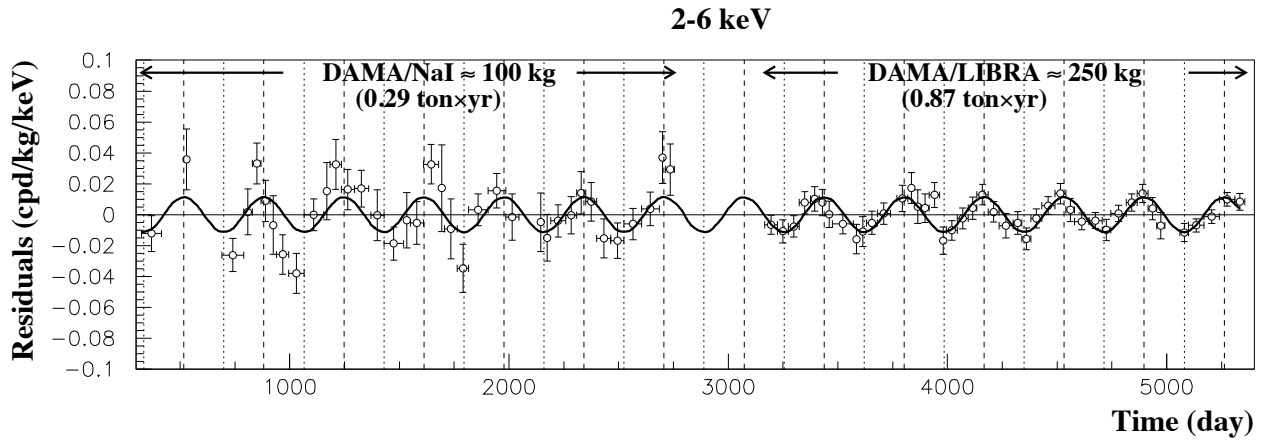


2013年まで

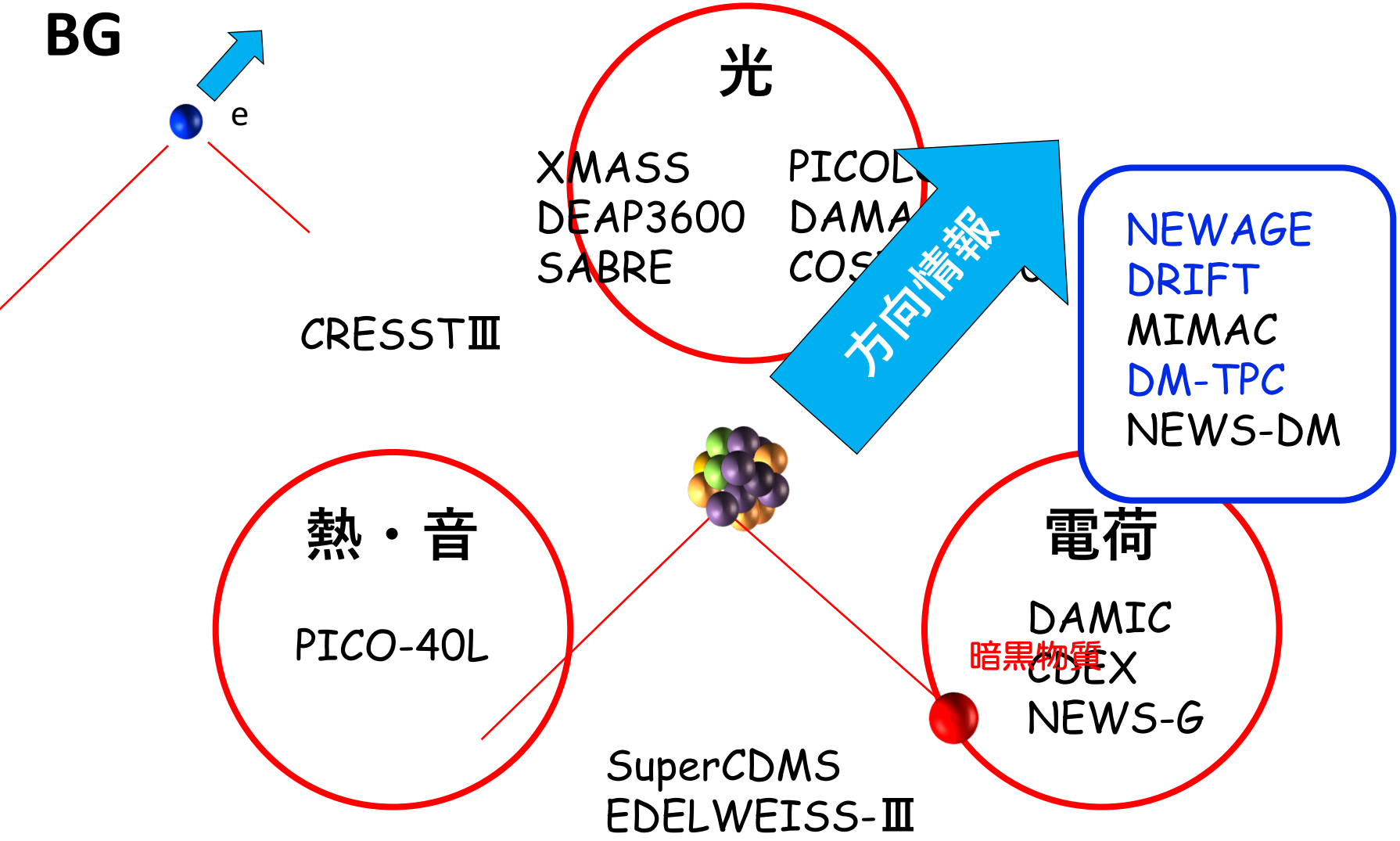
DAMA



- NaIを用いた直接探索実験
- 季節変動の観測を唯一主張
- 2-6keVで9.3σの観測



方向情報


BG
e
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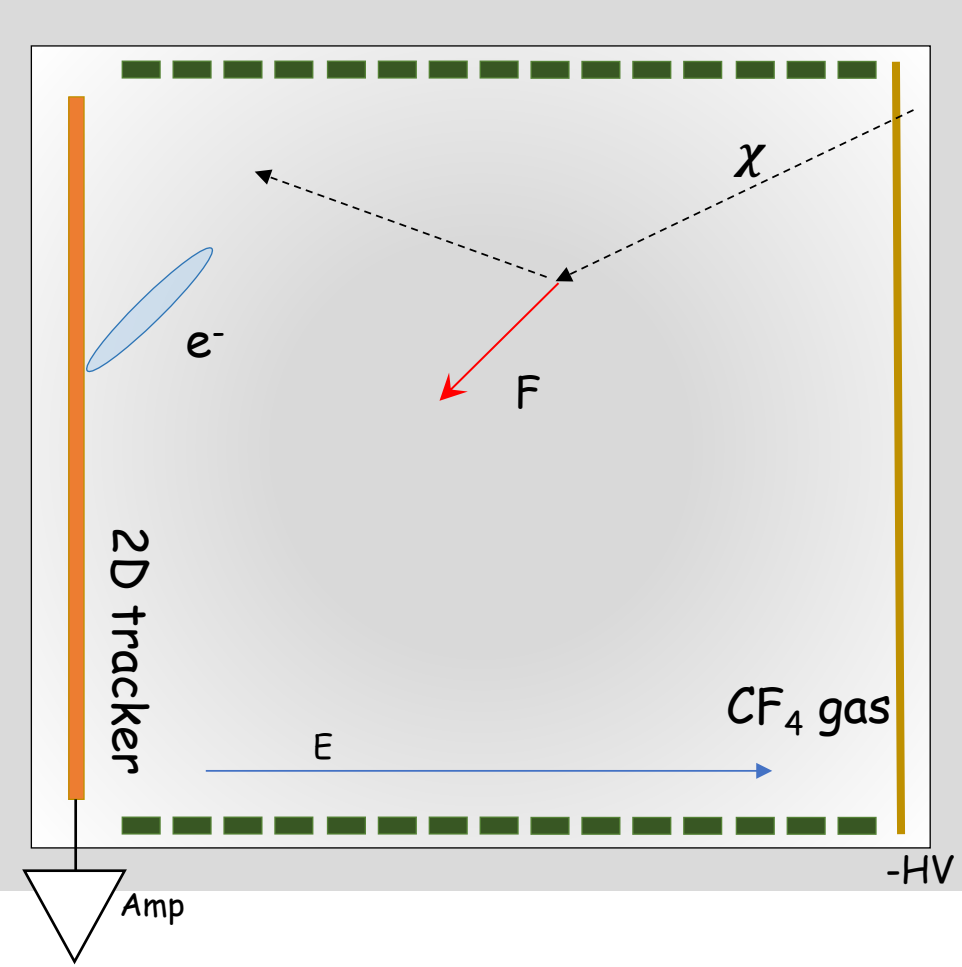
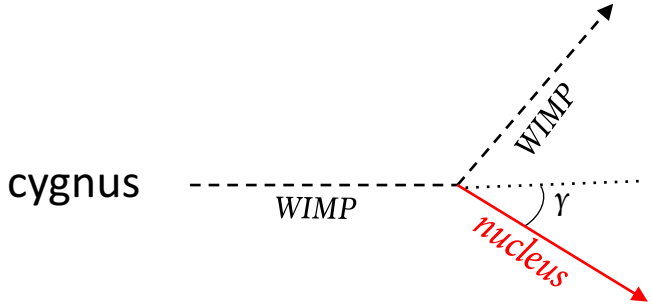
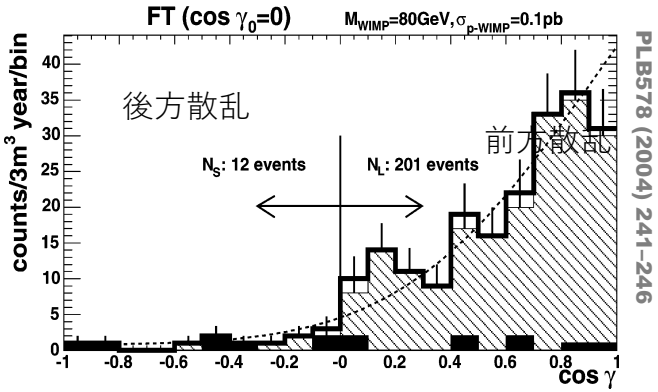
XMASS
DEAP3600
SABRE
PICOL
DAMA
COS
CRESSTⅢ
方向情報
NEWAGE
DRIFT
MIMAC
DM-TPC
NEWS-DM
熱・音
PICO-40L
電荷
DAMIC
暗黒物質
CDEX
NEWS-G
SuperCDMS
EDELWEISS-Ⅲ

NEWAGE : Detector Concept



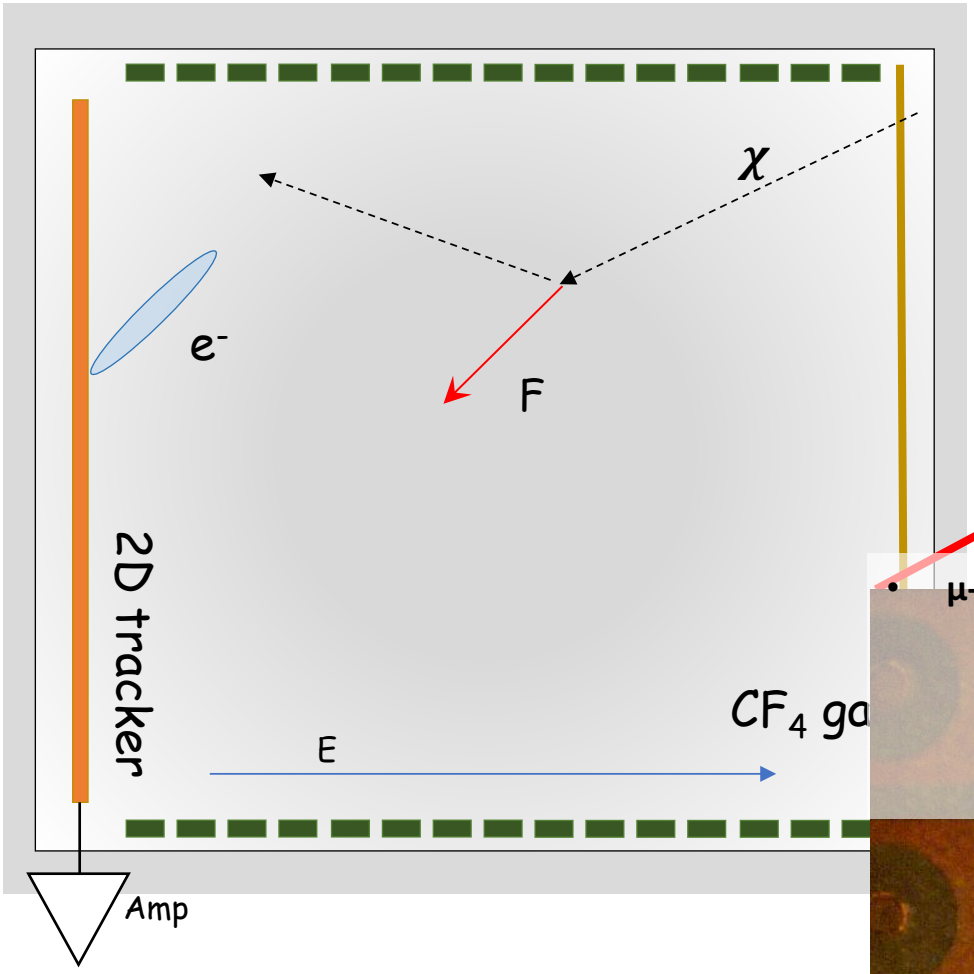


方向情報を用いた手法

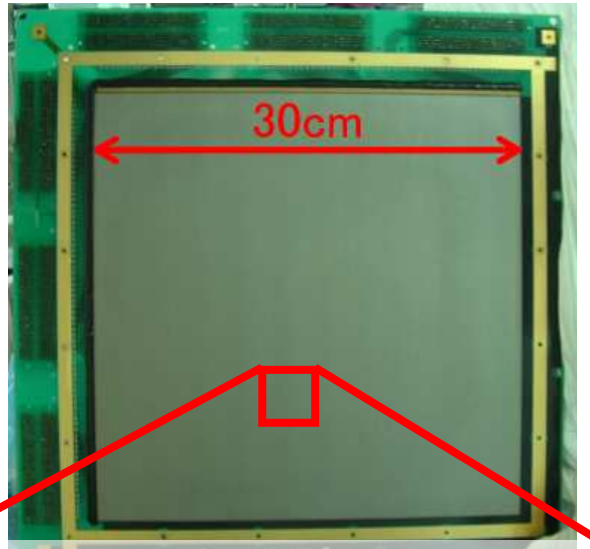


最大10倍の前後非対称性

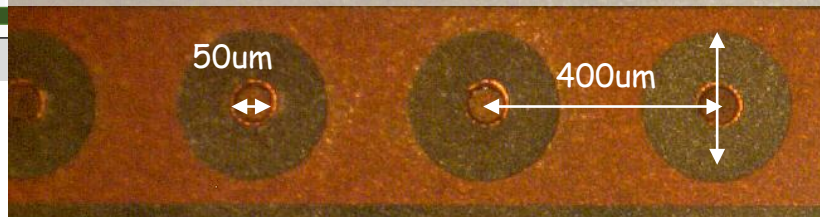
NEWAGE : Detector Concept



μ-PIC (30cm × 30cm)



- **μ-PIC (Micro-pixel chamber)**
  - X-Y readout
  - Detection area : 10 × 10cm^2
  - Strip pich: 400μm
  - Made by DNP, Japan

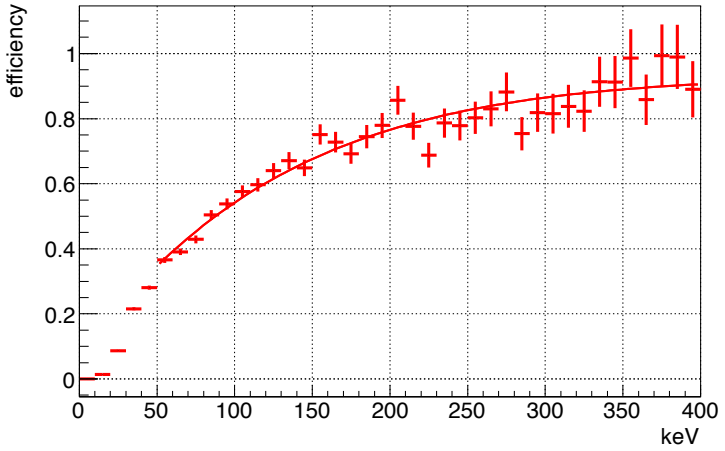


Detector Performance

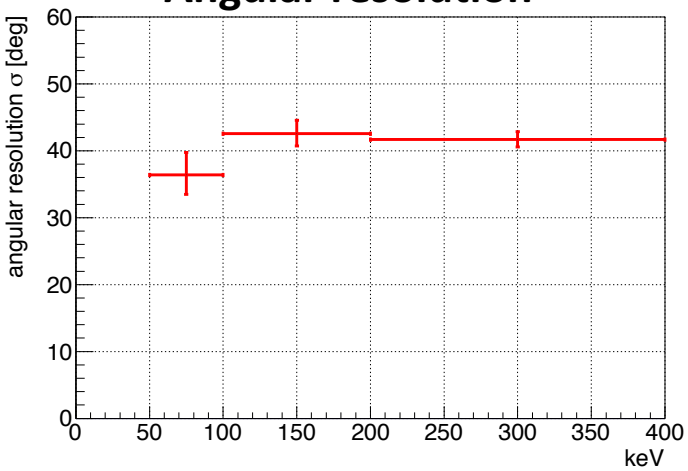
K.Nakamura et.al, PTEP(2015)043F01s

- Nuclear track detection efficiency : ~40% @ 50keVee
- Gamma rejection : 2.5e-5 @ 50keVee
- Energy resolution : 7.8keV(σ) @ 50keVee
- Angular resolution : 40° (σ) @50keVee

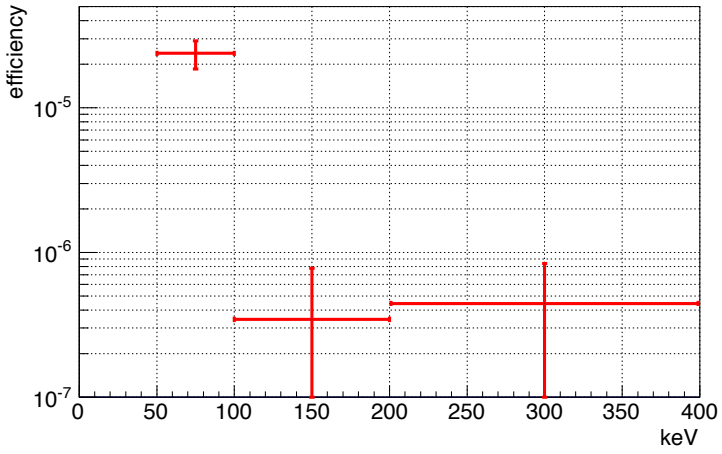
Nuclear track detection efficiency



Angular resolution

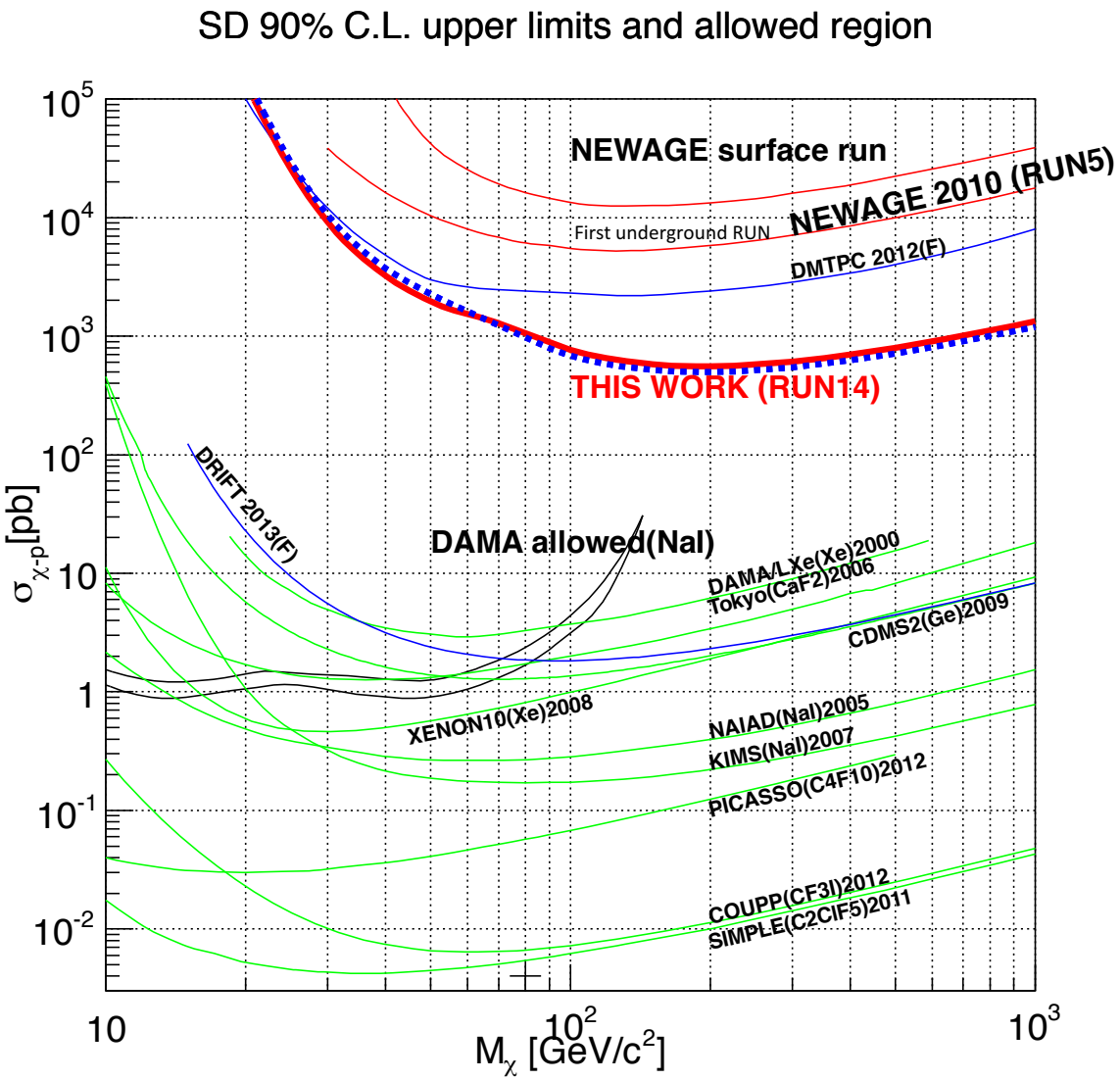


Gamma rejection Efficiency



Direction-sensitive limit

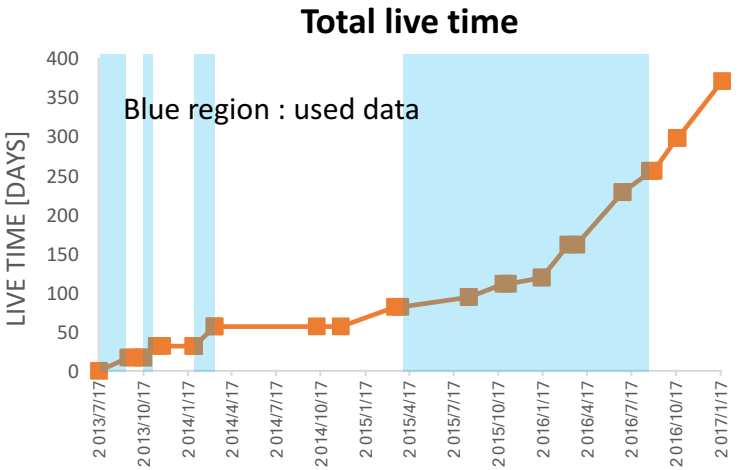
K.Nakamura et.al, PTEP(2015)043F01s



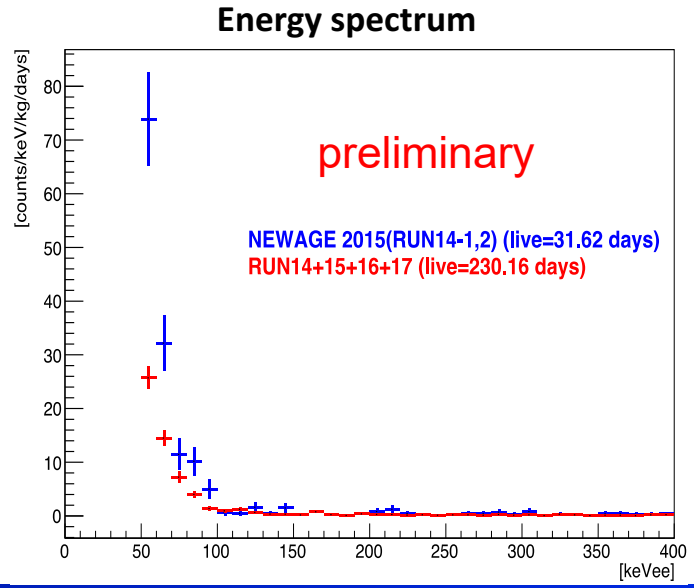
Red : directional analysis
Blue : spectrum analysis

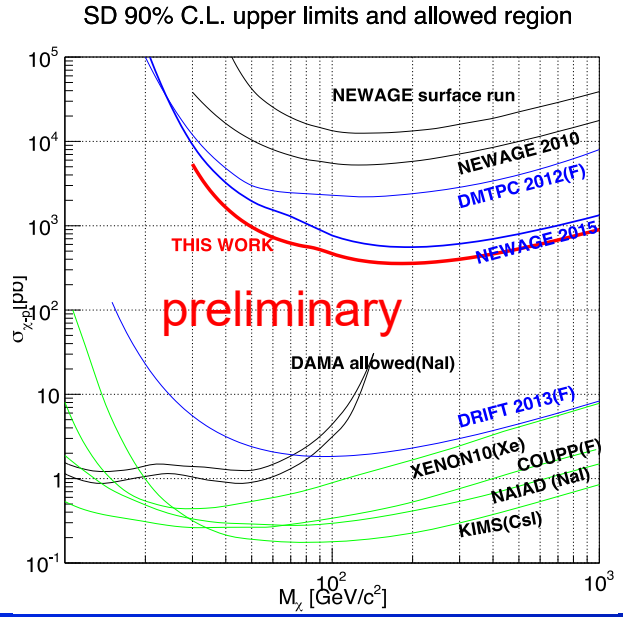
- Obtained limit: 557pb@200GeV
- Improved one order of magnitude from first underground RUN

After RUN14



- Continued underground RUN
  - Period : 2013/7/20 - 2016/8/24
  - Live time : 230.2days (RUN14-17)
- Optimized cut parameters
  - 50keV-100keV region : improved gamma/α rejection efficiency





Background Study

By Takashi Hashimoto

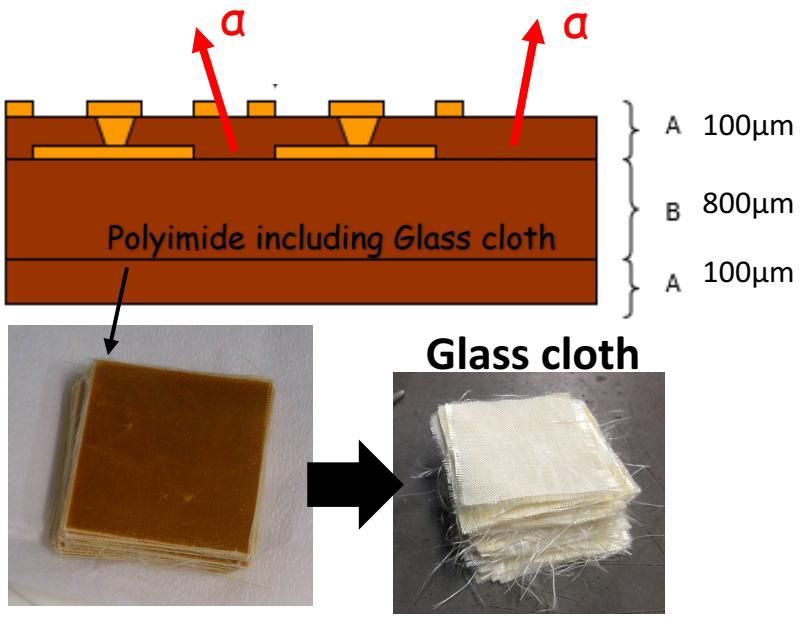
- Main BG is alpha particle from μ-PIC
  - Measured by high pure Ge detector

U/Th contamination

	^{238}U [μBq/cm^2] middle stream†	^{232}Th [μBq/cm^2]
PI 100μm	68.5 ± 1.5	102.1 ± 2.3
Glass cloth	64.5 ± 0.1	86.8 ± 1.1
(PI)-(Glass cloth)	4.0 ± 1.5	15.3 ± 2.6

- U/Th in the Polyimide 100um can be explained by U/Th of glass cloth

Cross-section view of μ-PIC

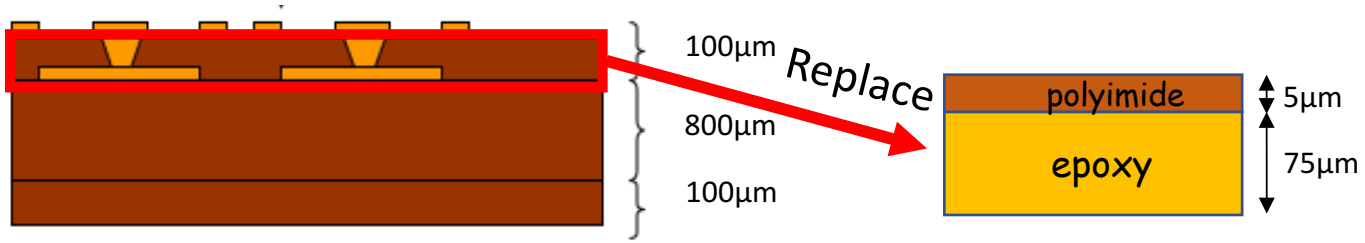


➢ Two approach for reduction of BGs
  - Low α μ-PIC
  - Full-fiducialization analysis using Negative Ion

Development of Low α μ-PIC

By Takashi Hashimoto

- Production of μ-PIC with low radioactive materials
  - Glass cloth was used as reinforced material
  - Epoxy can be replacement



PI + epoxy

U/Th contamination

	^{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

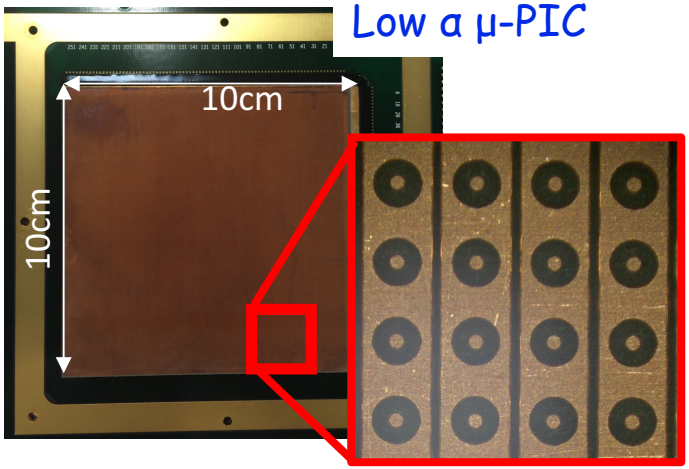
- Polyimide+epoxy has 1/100 radioactivity

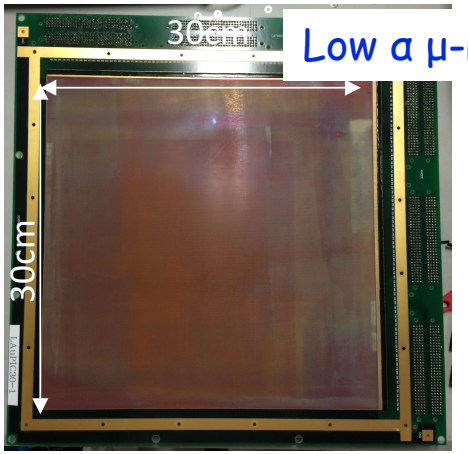
Performance of Low α μ-PIC

Direction Sensitive WIMP-search NEWAGE

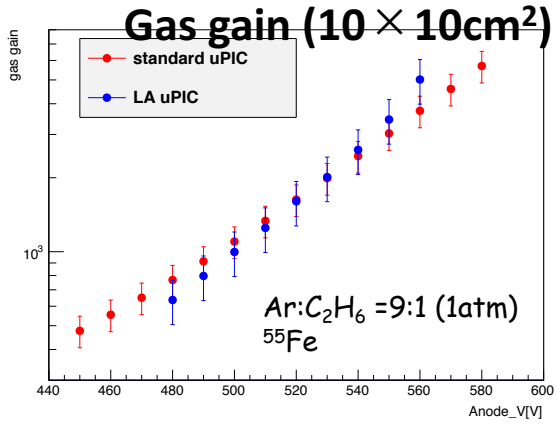
By Takashi Hashimoto

- The Low α μ-PIC was successfully created
  - Detection area : 10 × 10cm^2 and 30 × 30cm^2
  - Alignment is good





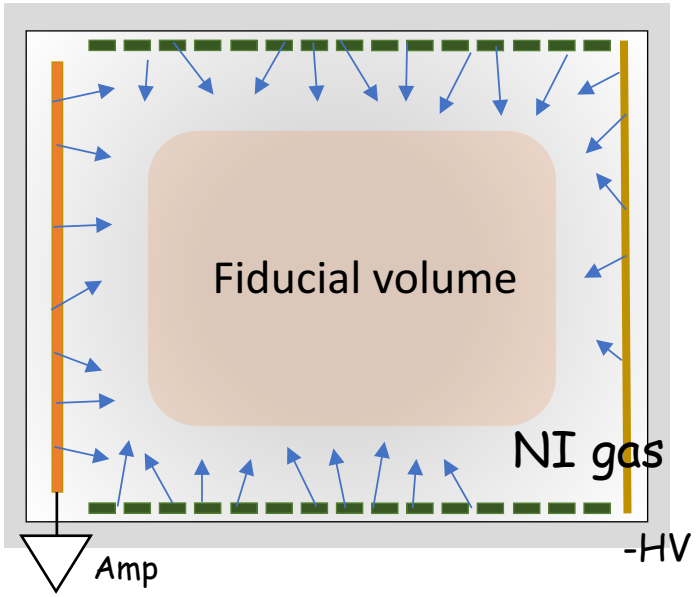
- Gas gain is almost the same as standerd μ-PIC
  - Max gas gain is about 5000
- The Low α μ-PIC with large size will be installed in July 2017



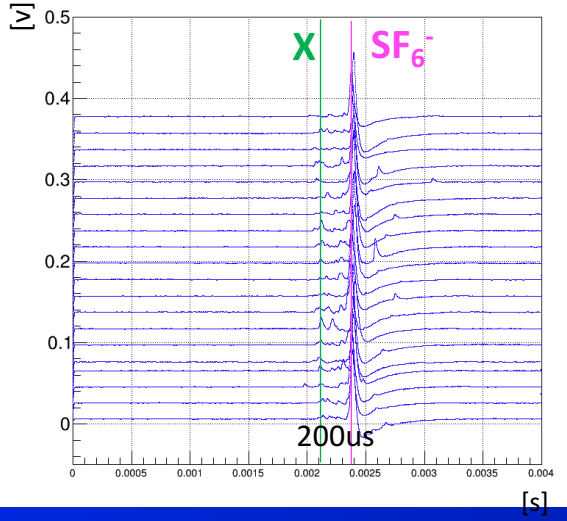
陰イオンガス検出器の開発

- 陰イオンガスを用いたZの位置決定
  - DRIFTグループ(英・米)が陰イオンガスCS_2を用いてMWPC-TPCでZの絶対位置決定に成功
  - ガス検出器でも有効体積カットが可能に

Physics of the Dark Universe 9-10(2015)1-7

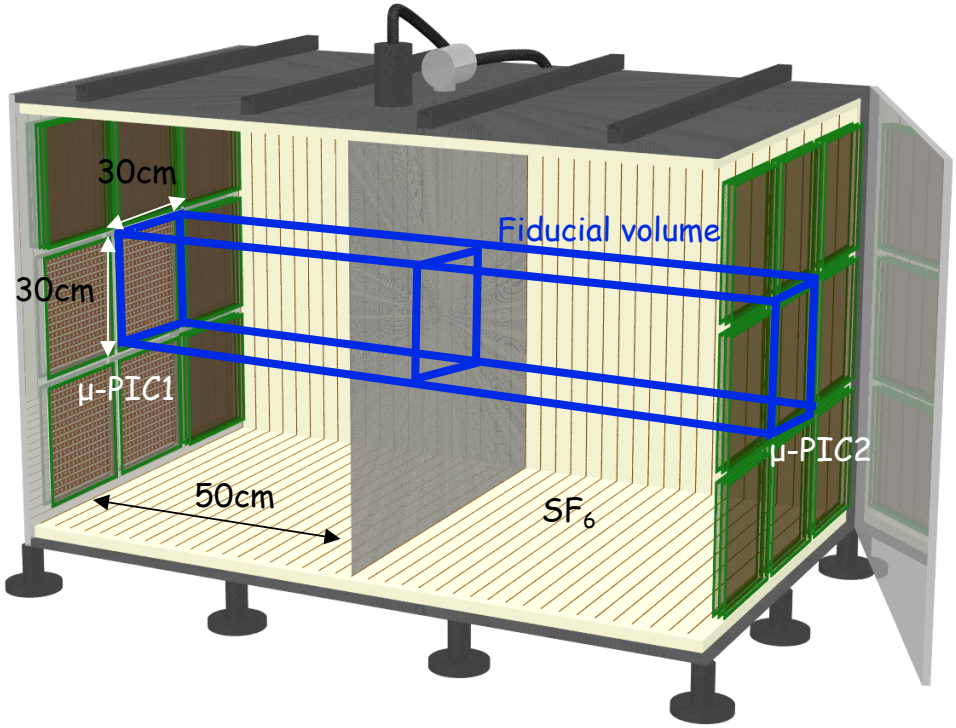


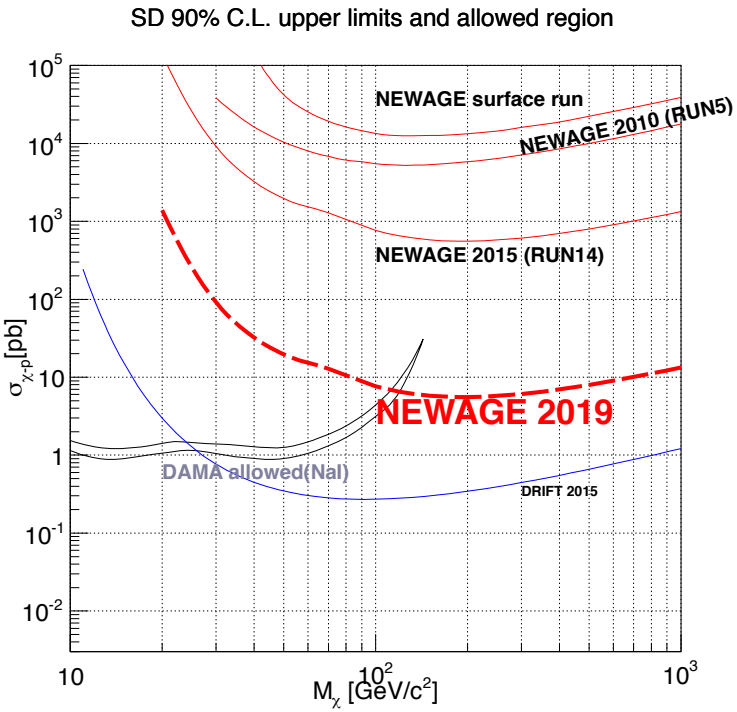
- NEWAGEグループでも2015年から陰イオン検出器の開発
  - SF_6+CF_4ガス
  - Zの位置分解能2.5cm(RMS)
  - 飛跡の2D位置分解能130um



Future Prospect

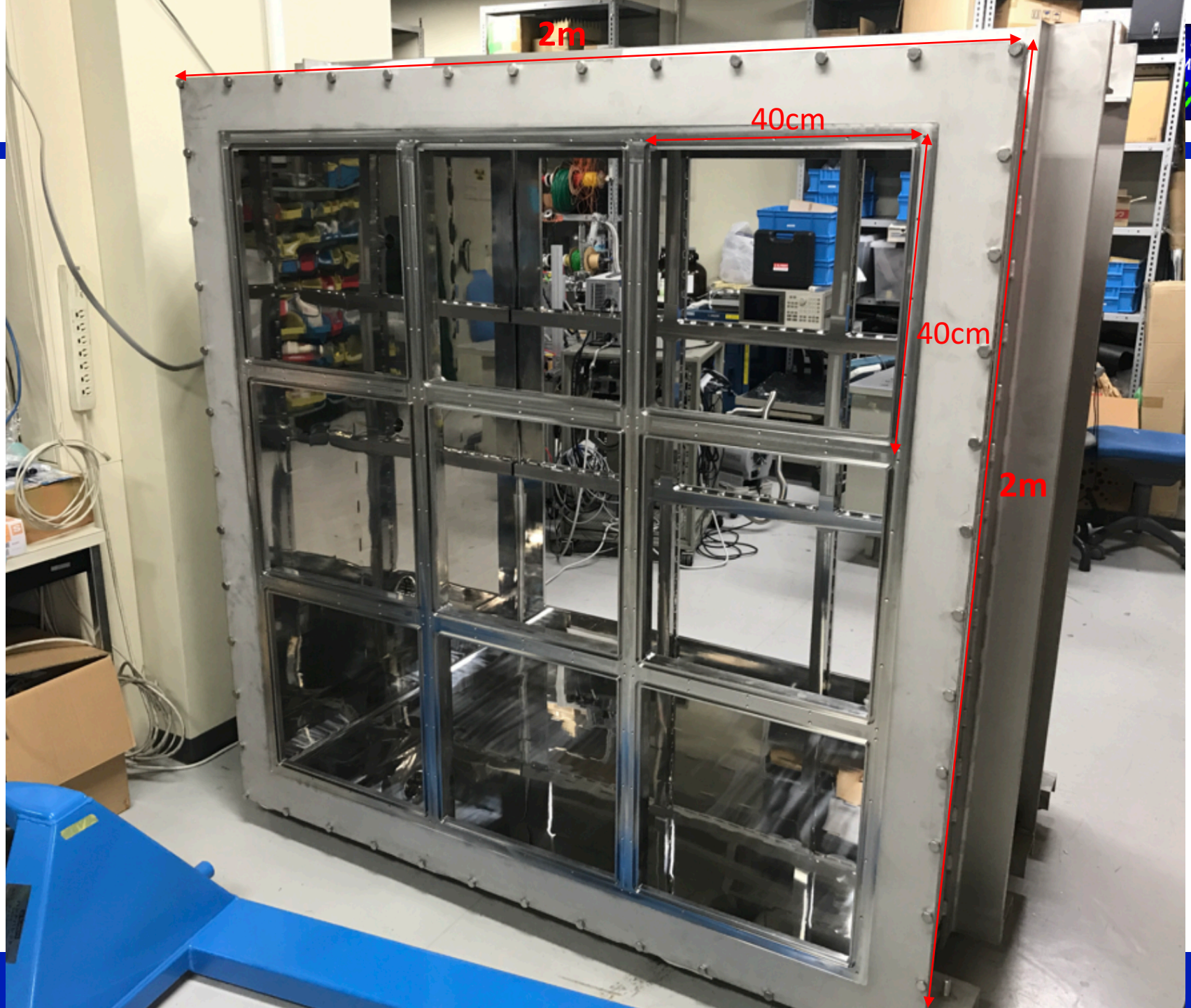
CYGNUS/NEWAGE vessel





- Two NI-μTPCs with 30 × 30 × 50cm^3 in cygnus vessel
- Will be ready by April 2018
- Expect two order improvement

搬入@神戸


2m
40cm
40cm
2m

まとめ

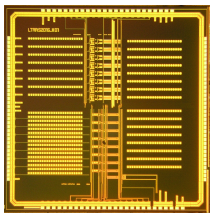
- NEWAGEは方向に感度を持った暗黒物質探索実験
- 方向情報を用いた解析で557pb@200GeV
- R&Dとして、低BGμ-PIC、陰イオンガス検出器の開発を行っている
- 将来1m^{3}級の検出器を用いて世界初の方向感度でDAMA領域の探索を行う

Next stage

Summary

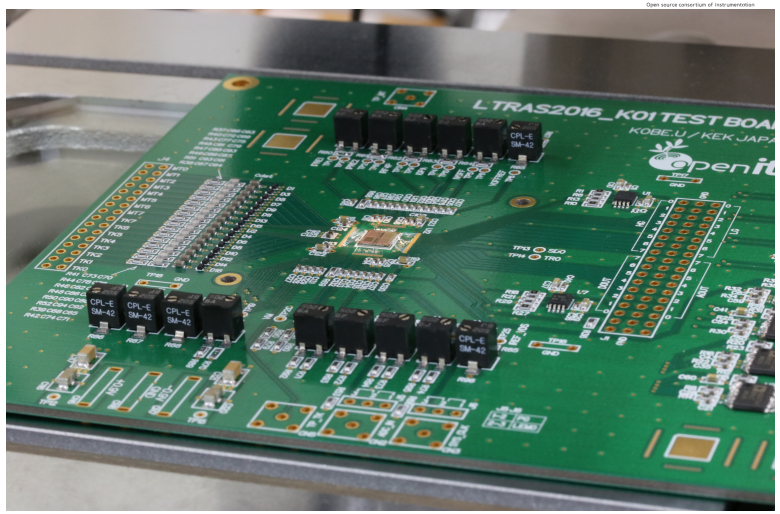
μ-PIC + GEM + SF_6		
Gas gain	2000	
Z resolution	6.8cm	Need more study
XY resolution	130um	

- Development of ASIC for NI-μTPC
  - Wide dynamic range : -10pC ～ 10pC
  - High gain : 10mV/fC
  - Slow shaper : 4us



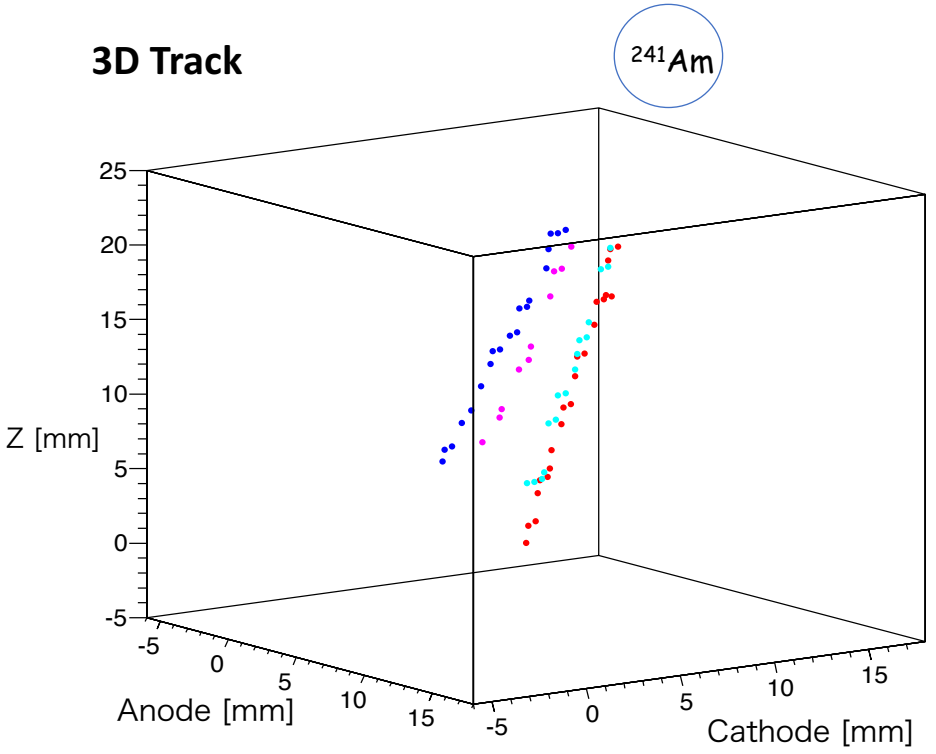
← LTARS2016_K01 TEG chip

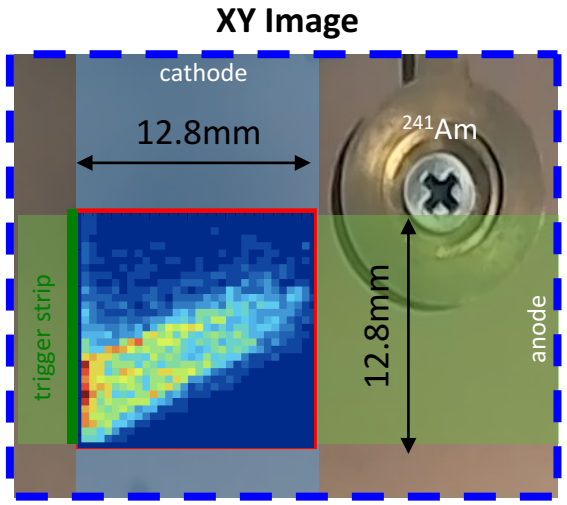
ASIC test board→

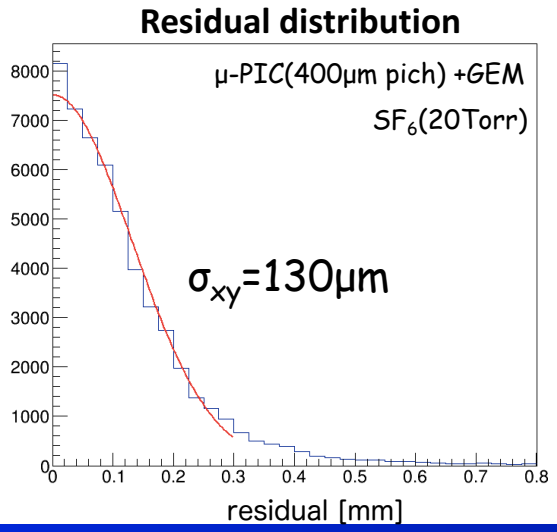


- Tracking with detection of minority carrier

3D Track

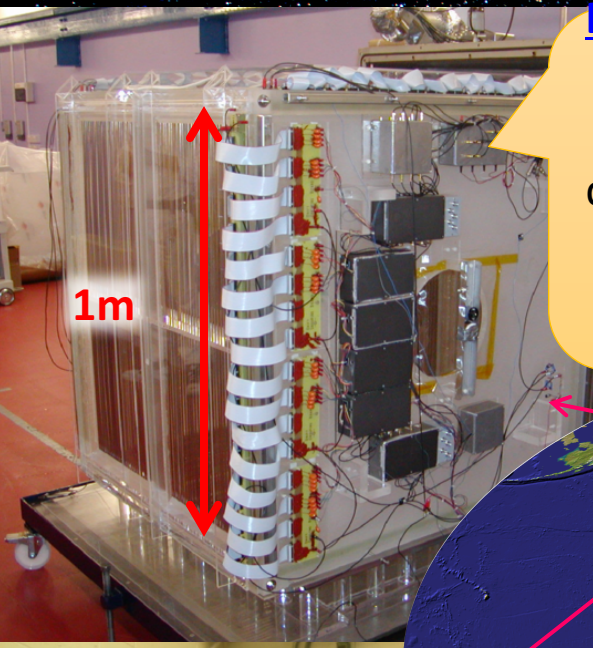






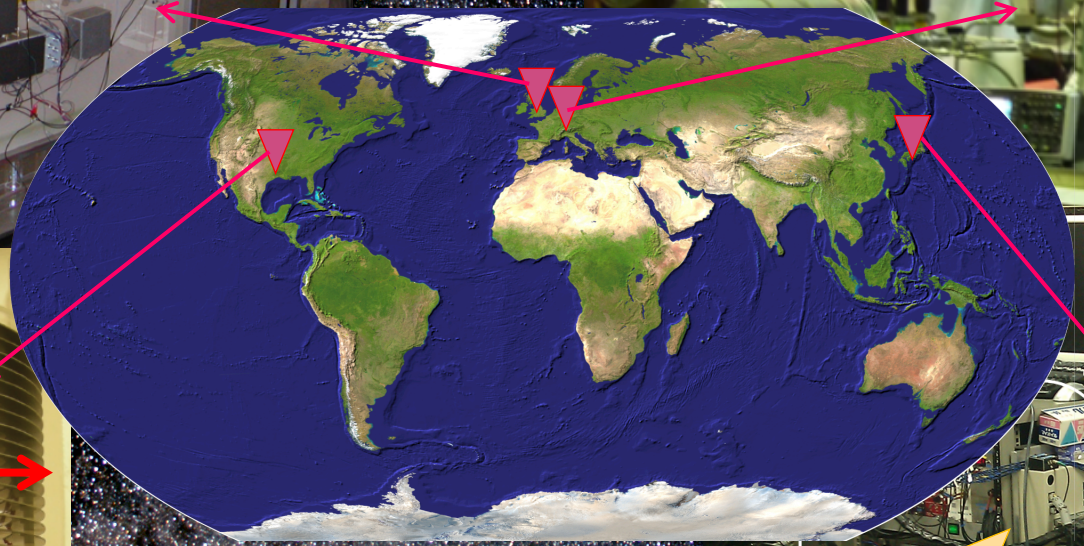
- Tracking was succeed
- 2D position resolution : 130μm(RMS)

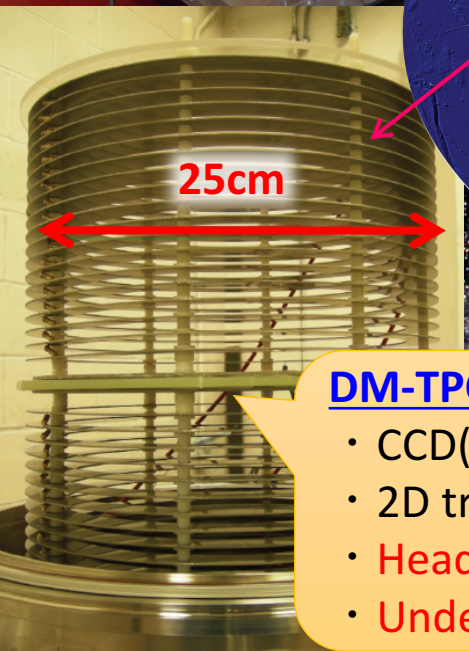
ガス検出器と暗黒物質実験の世界情勢



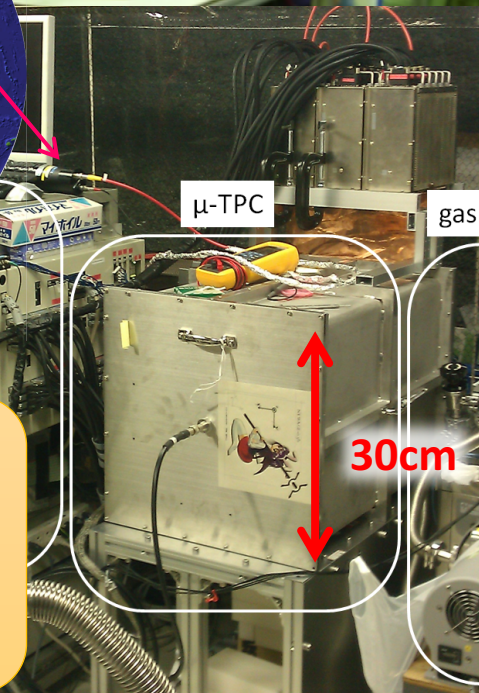
DRIFT
- MWPC(2mm pitch)
- First started gas detector
- Underground
- Low background
- Large size(~1m^3)

MIMAC
- MicroMegas(~424um pitch)
- Underground
- 10×10×25 cm^3



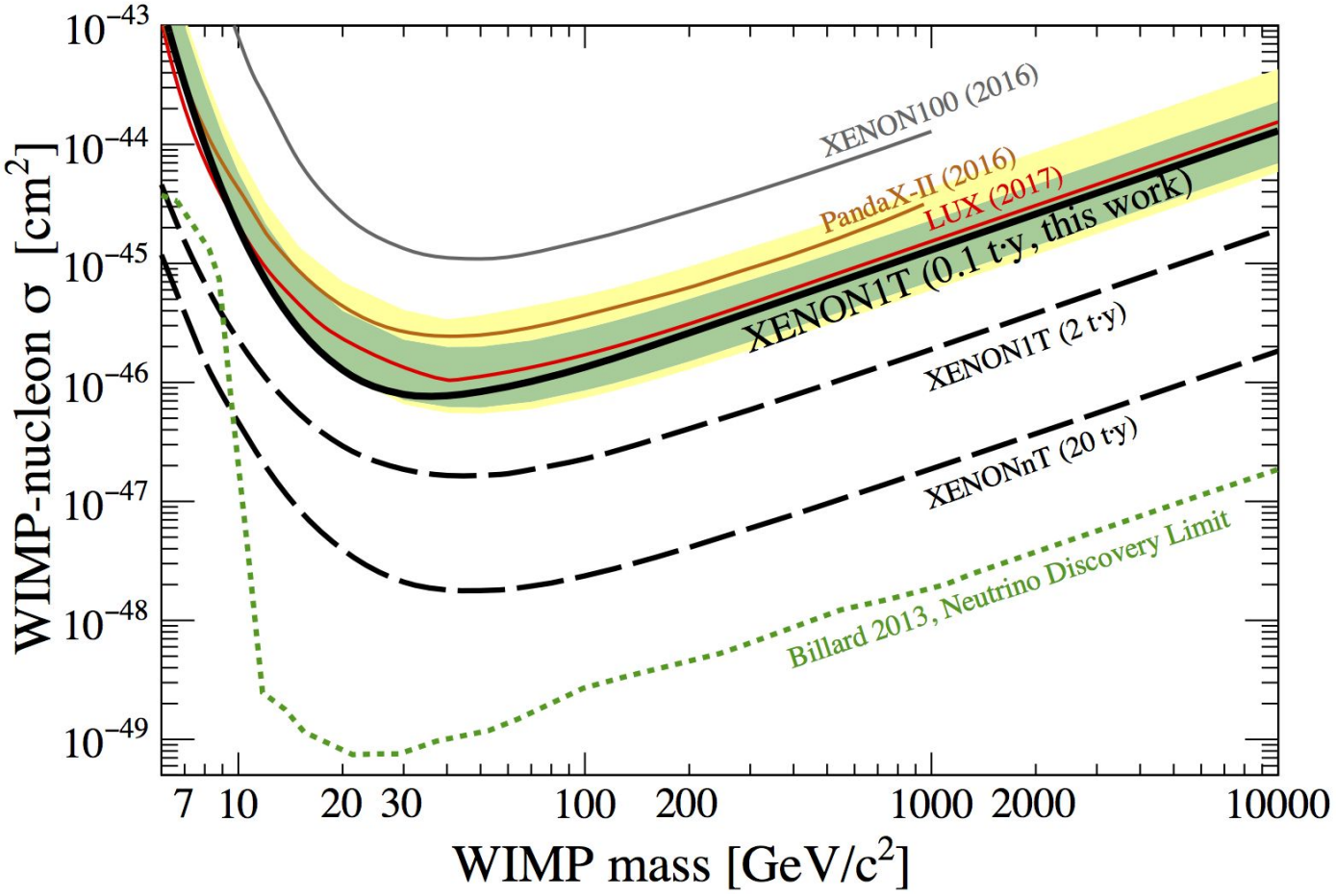


DM-TPC
- CCD(256um pitch)
- 2D track
- Head/tail recognition
- Underground



NEWAGE
- μ-PIC(4[illegible] pitch)
- 3D track
- Direction-sensitive limit
- Underground

XENON1T最新



[arxiv:1705.06655]

Underground RUN14

K.Nakamura et.al, PTEP(2015)043F01s

- **RUN14**
  - Period : 2013/7/20-8/11, 10/19-11/12
  - Live time : 31.6 days
  - Fiducial volume : 28 × 24 × 41cm^3
  - Mass : 10.36g
  - Exposure : 0.327kg・days

- **Energy spectrum**
  - Threshold : 100keV → 50keV
  - BG rate : 1/10 @100keV

- **Skymap, cosθ distribution**
  - Set limit by significant difference in 2-binned measured cosθ and DM-wind simulated cosθ