

NEWAGE

Direction-Sensitive Dark Matter Search

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KOBE University

Jan 31st 2017

CAASTRO-CoEPP workshop

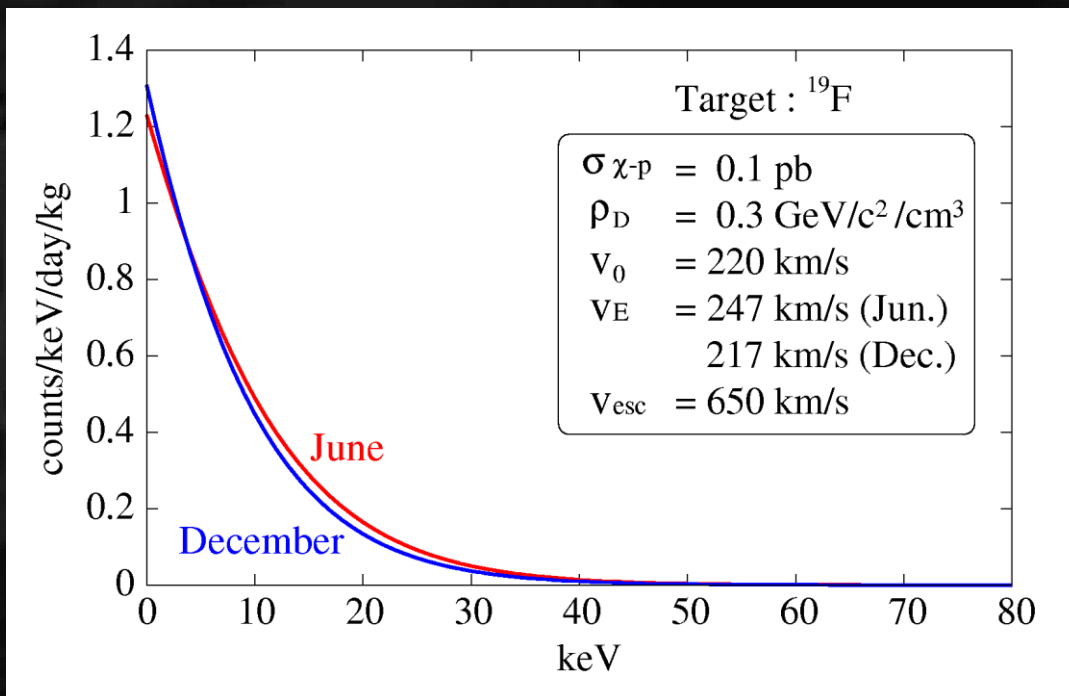
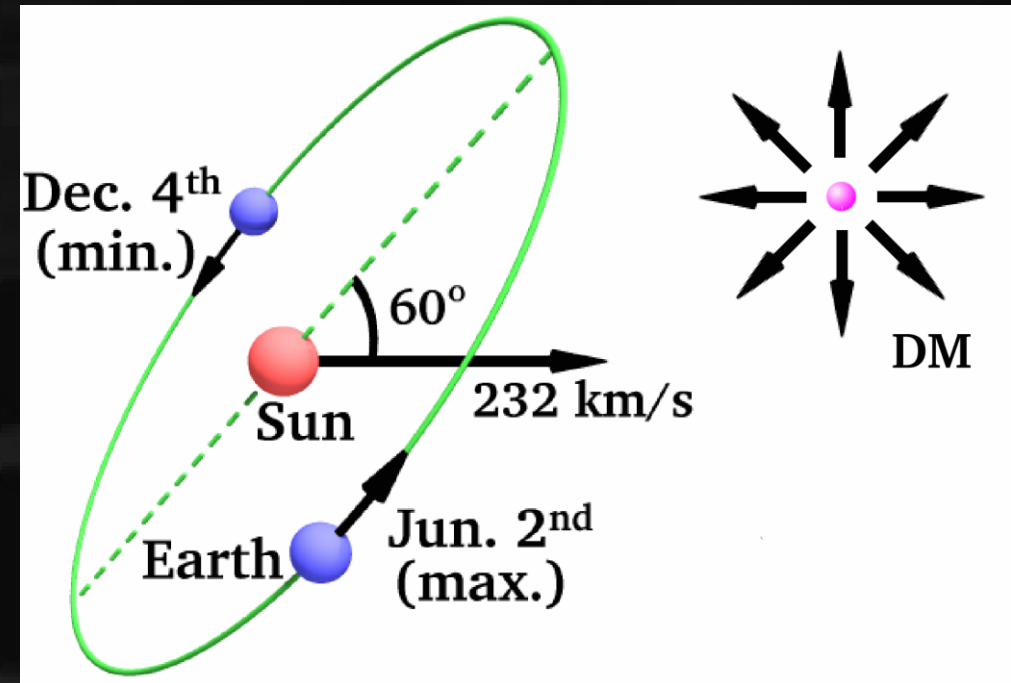
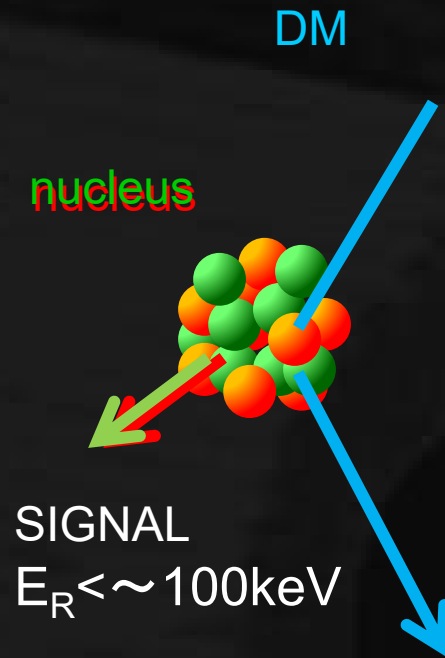
Contents

Physics

NEWAGE



DM direct detection



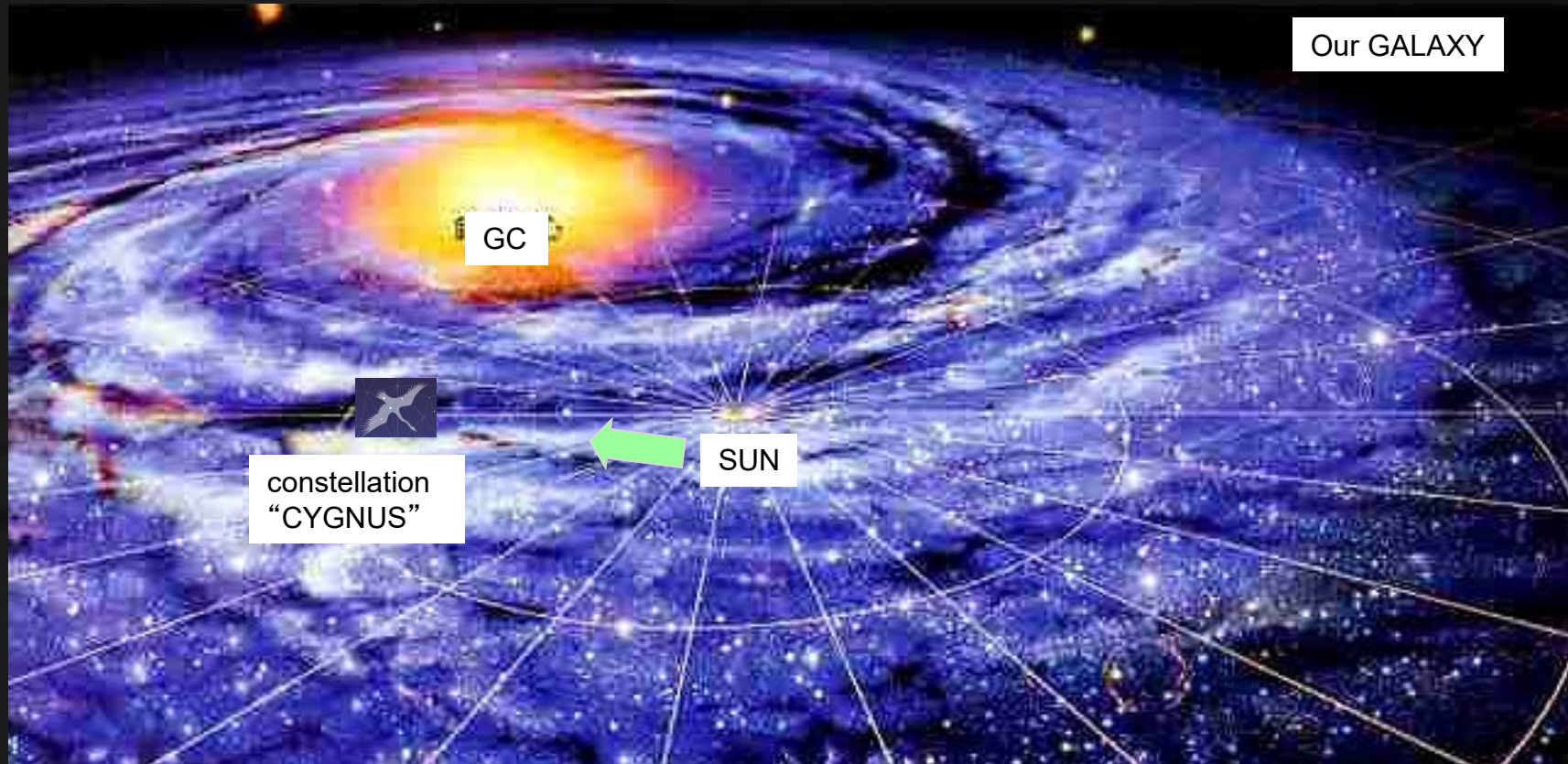
expected direct DM signals

- ① observed * events
- ② energy spectrum
- ③ seasonal modulation
- ④ material dependence
- ⑤ direction-sensitive

A dark, stylized illustration of a hand holding a pen, with the text "Physics cases" overlaid in white. The background is a dark, textured surface, possibly a book cover or a piece of paper, with a hand holding a pen in the center. The text is in a bold, sans-serif font.

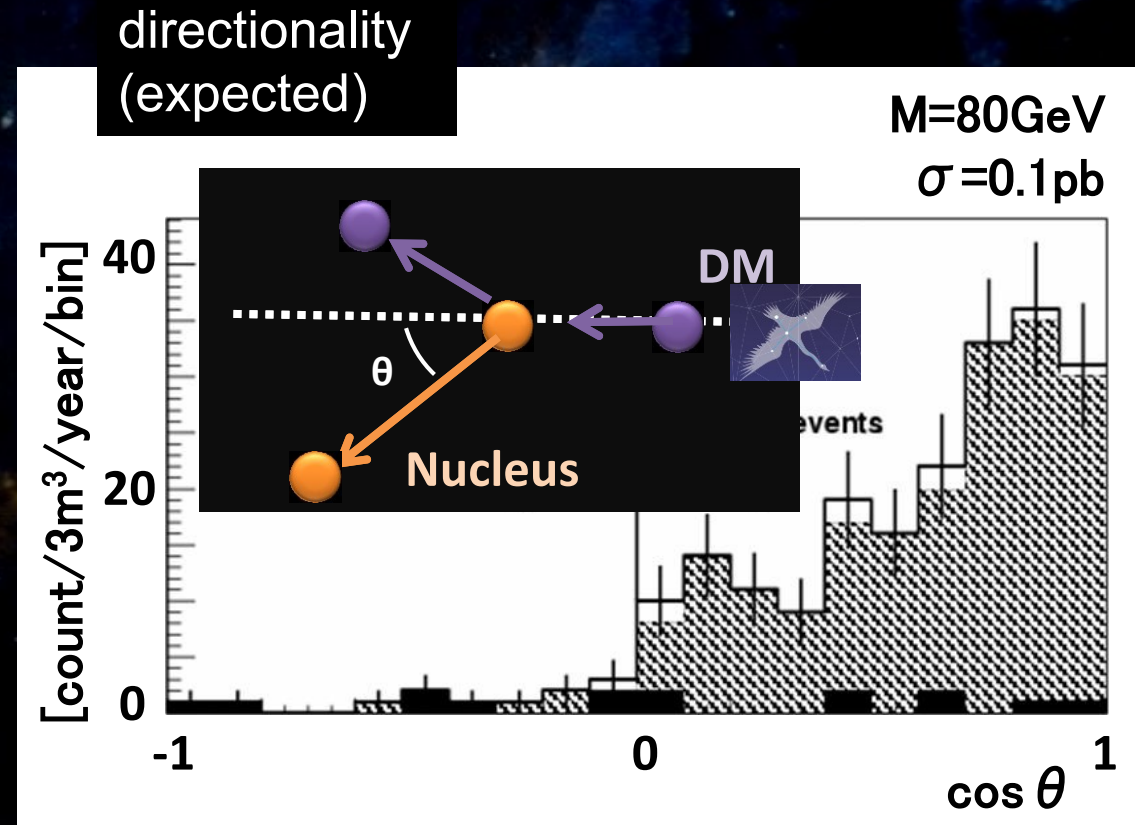
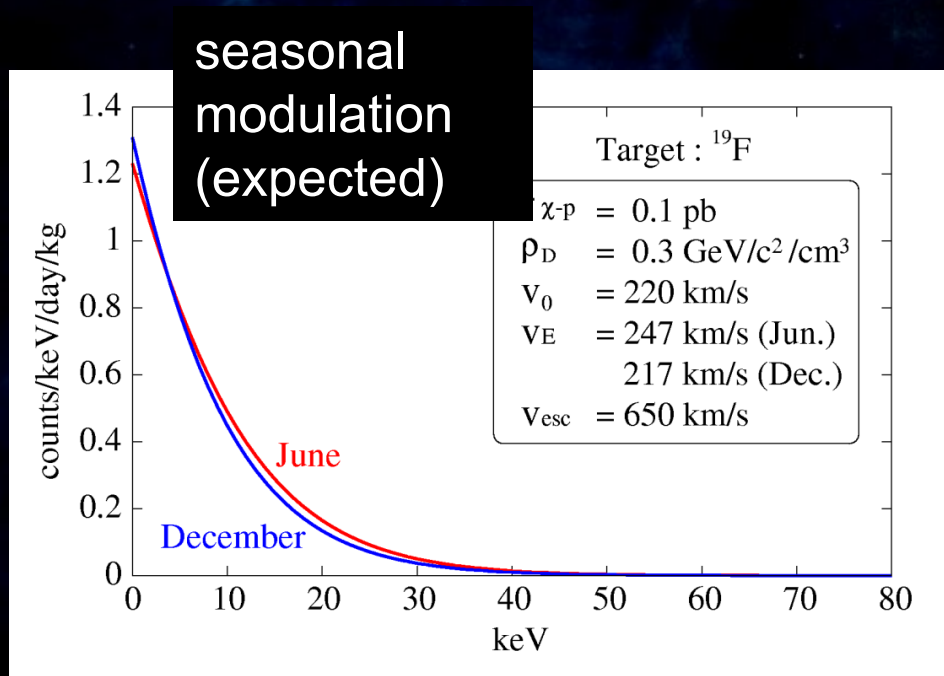
Physics cases

Direction-Sensitive Dark Matter Search concept “CYGNUS”



WIMP-WIND from “CYGNUS”

"CYGNUS" concept



Clear Discovery

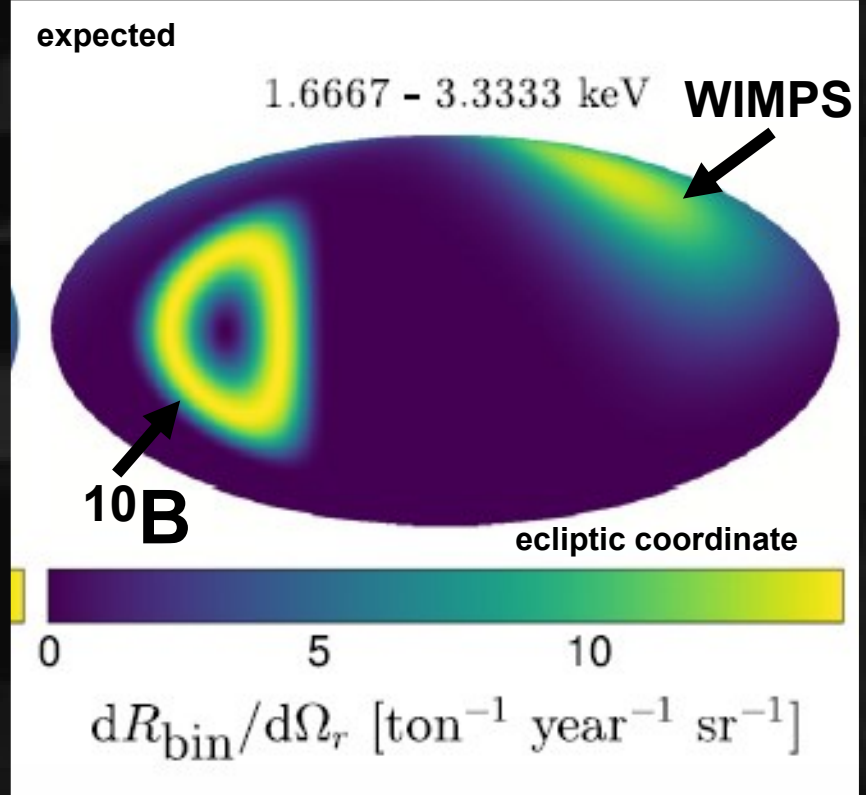
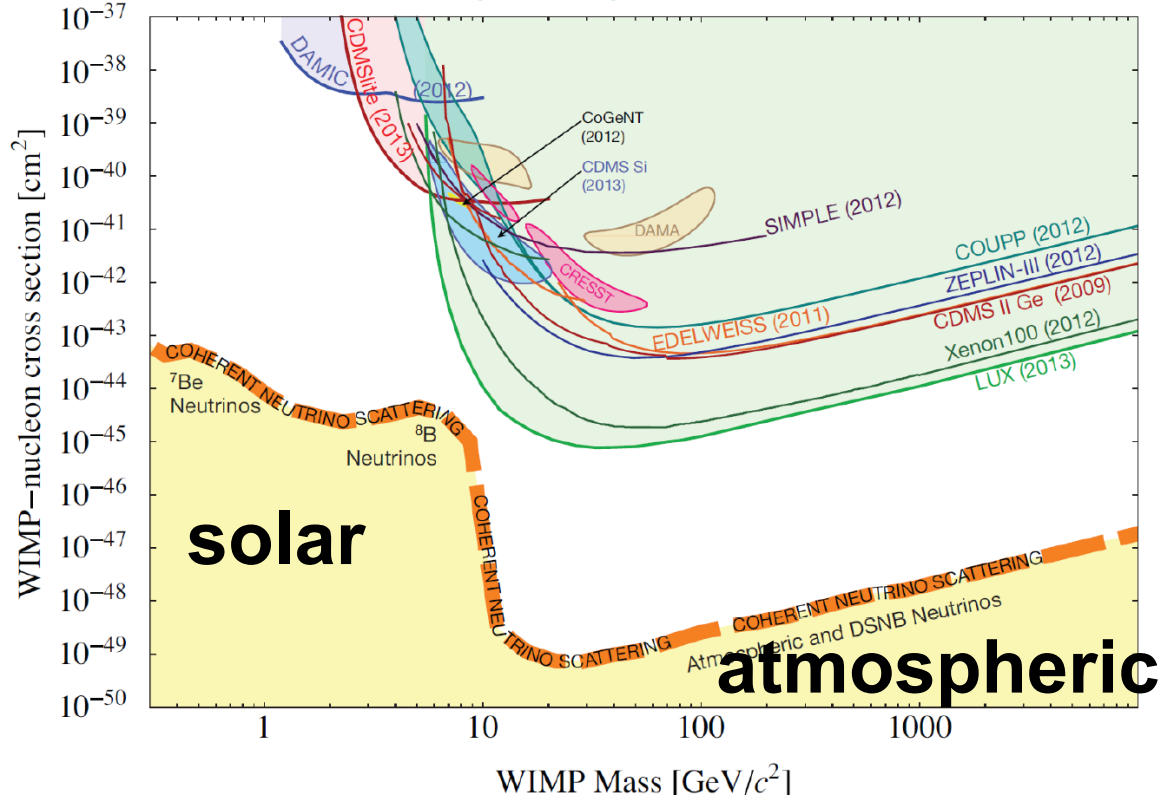
+ study the nature of DM after discovery

“CYGNUS” physics towards discovery

Potential to search beyond the “neutrino floor”†

F. Mayet et al. / Physics Reports 627 (2016) 1–49

J Billard, L Strigari, E Figueroa-Feliciano arXiv:1307.5458



clearly distinguishable

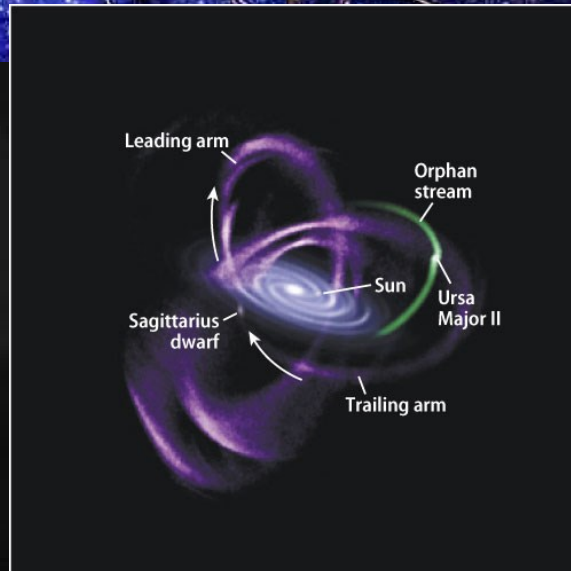
† neutrino-nucleus coherent scattering

“CYGNUS” physics after discovery

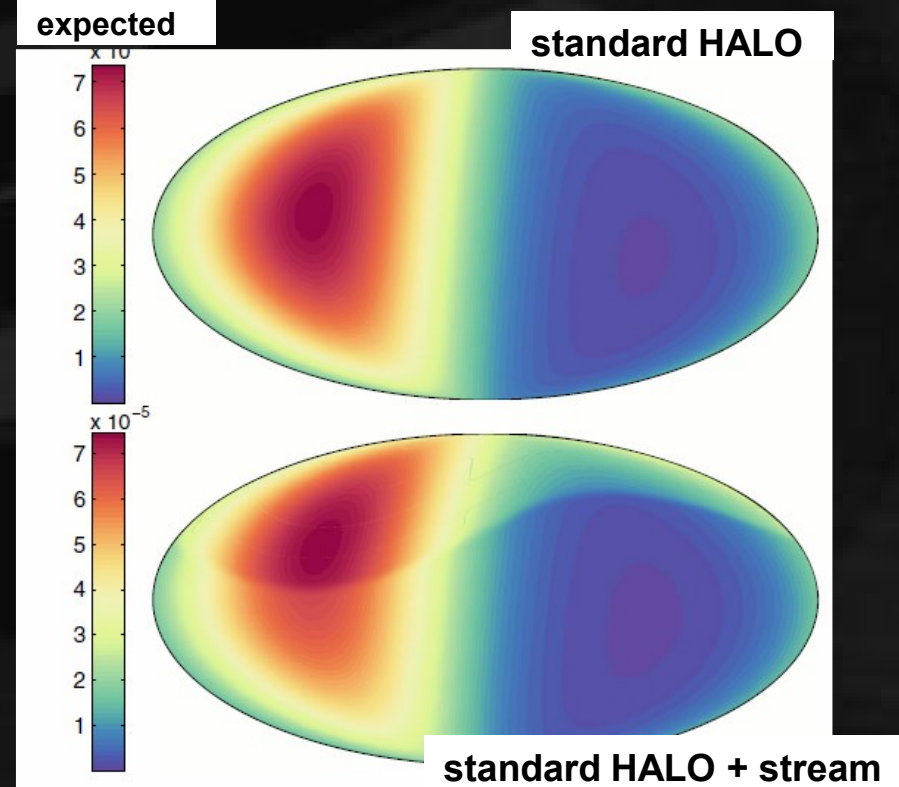
Test the DM motion

ex. Sagittarius stream

Our GALAXY



PHYSICAL REVIEW D 90, 123511 (2014)



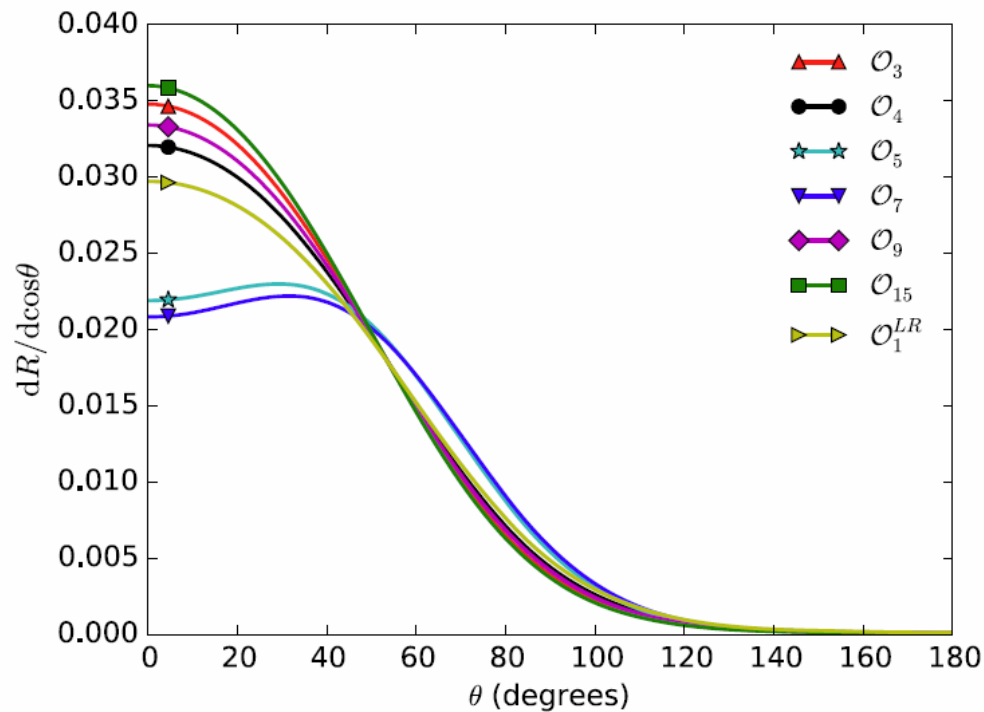
galactic coordinate

streams, halo model...

“CYGNUS” physics after discovery

Test the interaction by scattering angle

PHYSICAL REVIEW D 92, 023513 (2015)

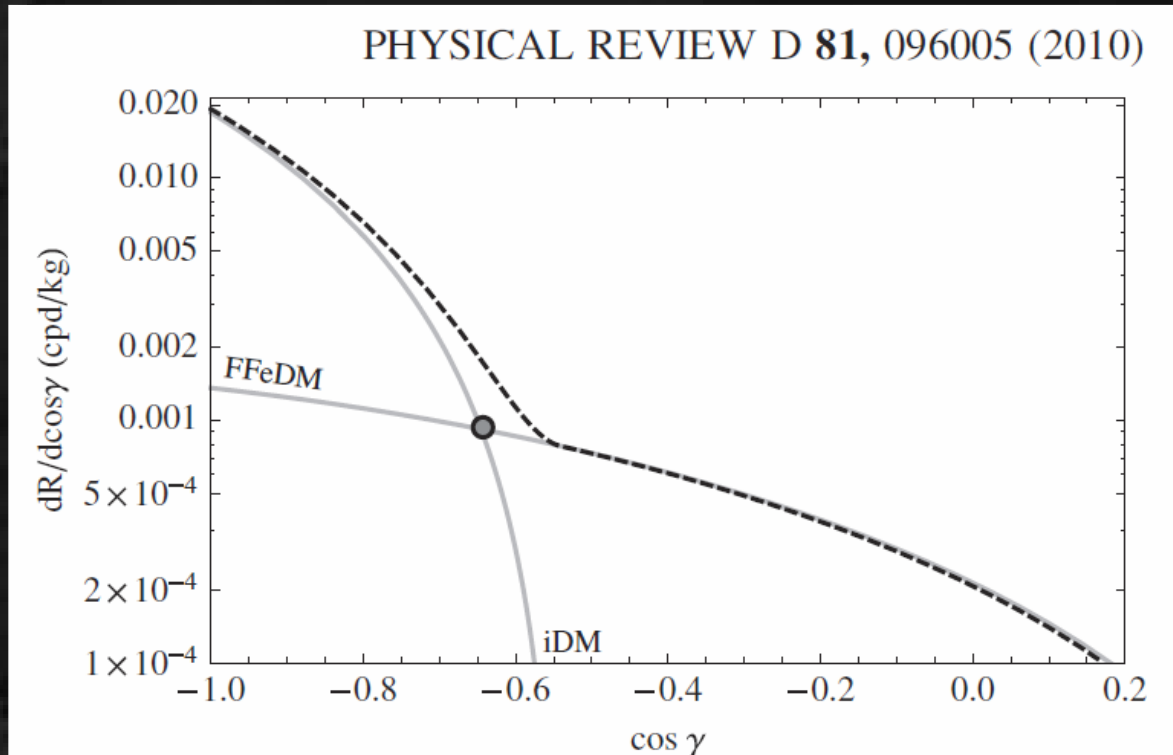


	SI	SD
Proportional to	1	: $\mathcal{O}_1, \mathcal{O}_4,$
	v_{\perp}^2	: $\mathcal{O}_7, \mathcal{O}_8,$
	q^2	: $\mathcal{O}_9, \mathcal{O}_{10}, \mathcal{O}_{11}, \mathcal{O}_{12},$
	$v_{\perp}^2 q^2$: $\mathcal{O}_5, \mathcal{O}_{13}, \mathcal{O}_{14},$
	q^4	: $\mathcal{O}_3, \mathcal{O}_6,$
	$q^4(q^2 + v_{\perp}^2)$: $\mathcal{O}_{15},$
	q^{-4}	: $\mathcal{O}_1^{LR}.$

some operators are distinguishable

“CYGNUS” physics after discovery

Test the interaction by scattering angle ②



- **iDM (inelastic scatterings dark matter) and normal darkmatter (FFeDM (form factor elastic dark matter)) show different angular DISTRIBUTION**

The background is a dark, monochromatic image of a hand holding a pen, rendered in a sketch-like or low-poly style. The hand is positioned as if writing, with the pen held between the fingers. The lighting is dramatic, highlighting the contours of the hand and the pen. The overall tone is professional and focused.

Experimental Status

Experimental concept

Recoil nuclear track detection $< 100\text{keV}$

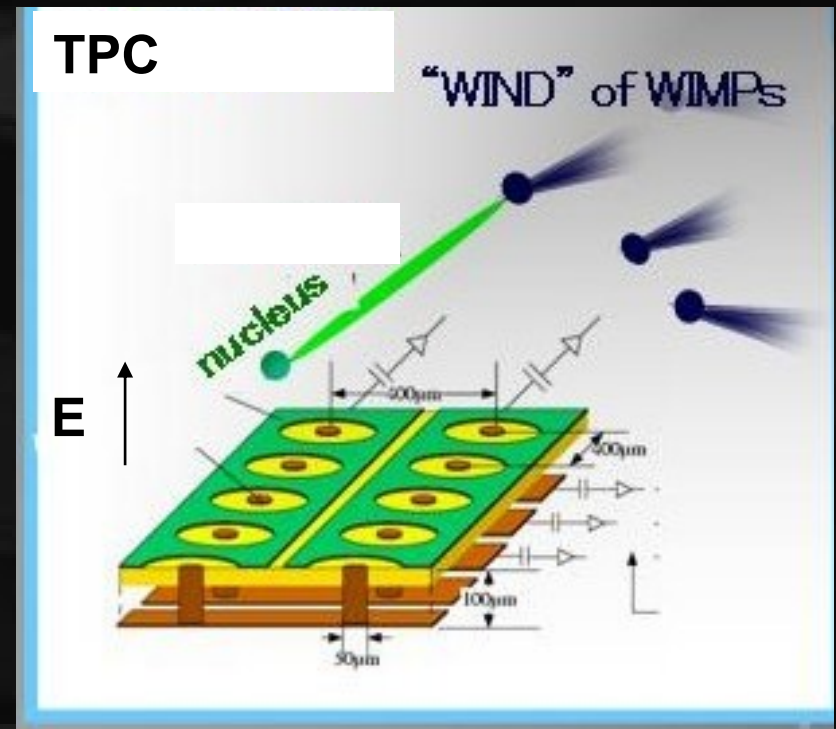
challenge: short track

a few mm in low pressure gas

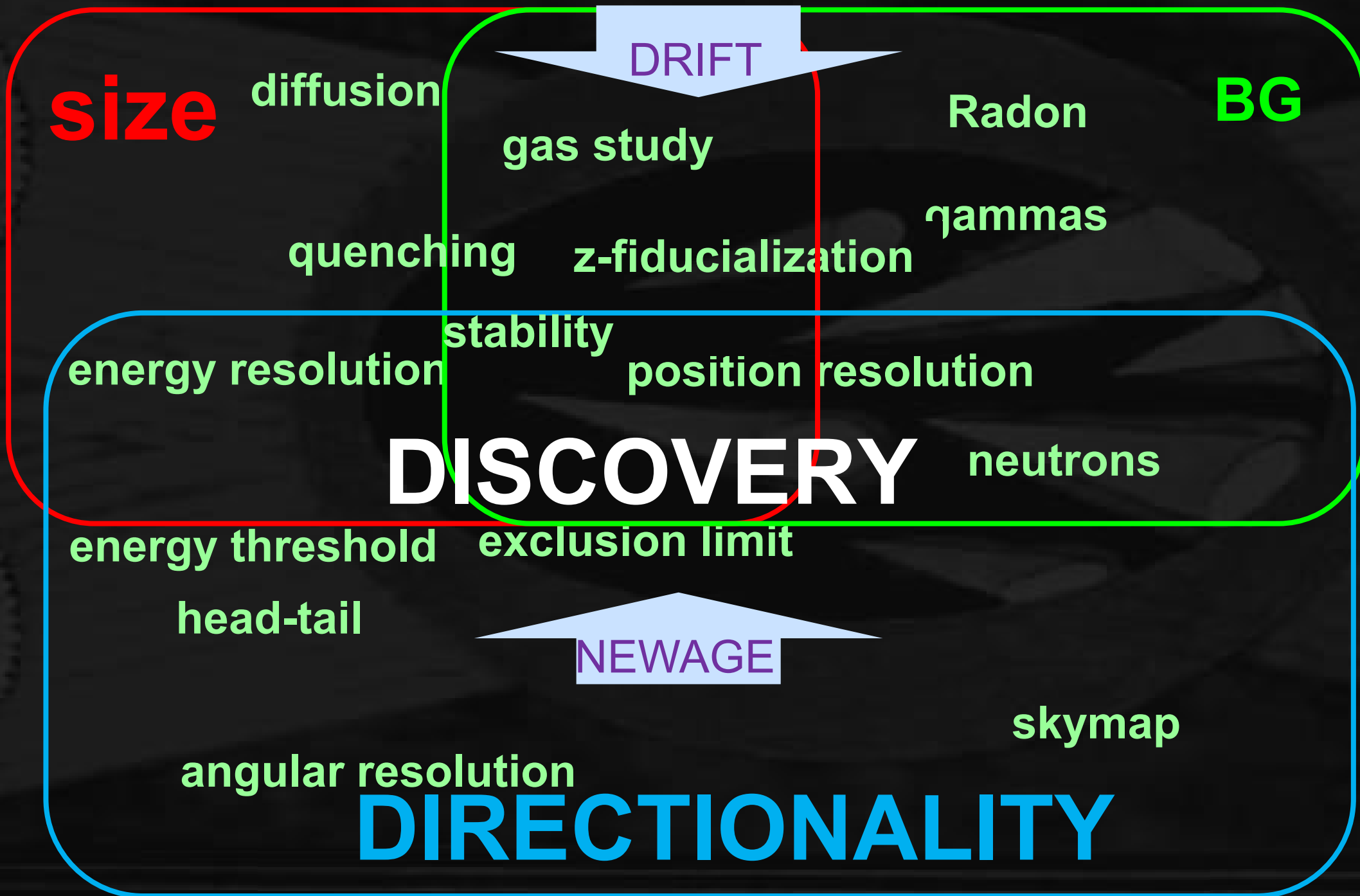
a few 100 nm in solid

Most typical “CYNGUS”:
low pressure gas TPC

2D readout + timing
→ 3D tracking



NEWAGE strategy since its new ages



NEWAGE: always direction-sensitive

New general WIMP search with an Advanced Gaseous tracker Experiment

▣ μ -PIC(MPGD) based TPC

▣ 3-D tracks SKYMAP

▣ CF_4 gas for SD search

▣ Proposal PLB 578 (2004) 241

▣ First direction-sensitive limits

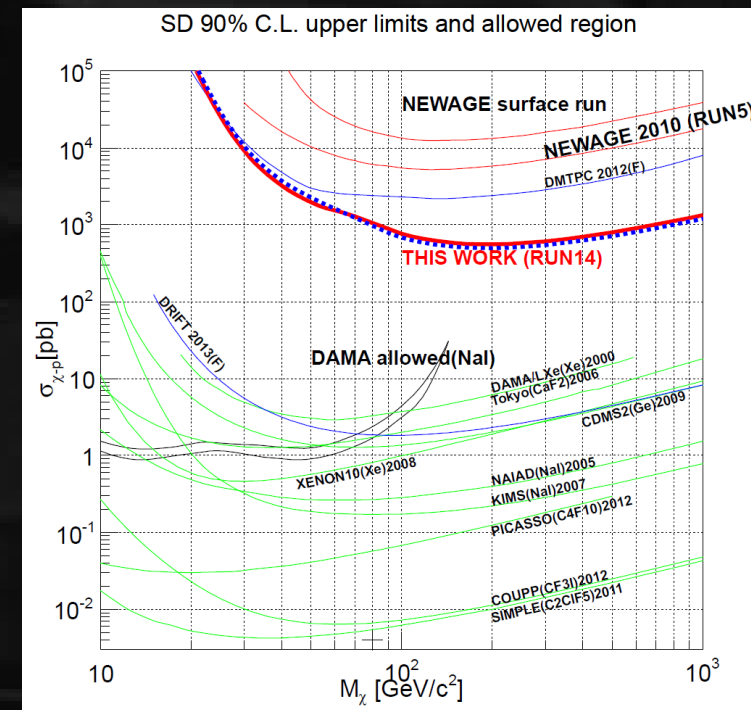
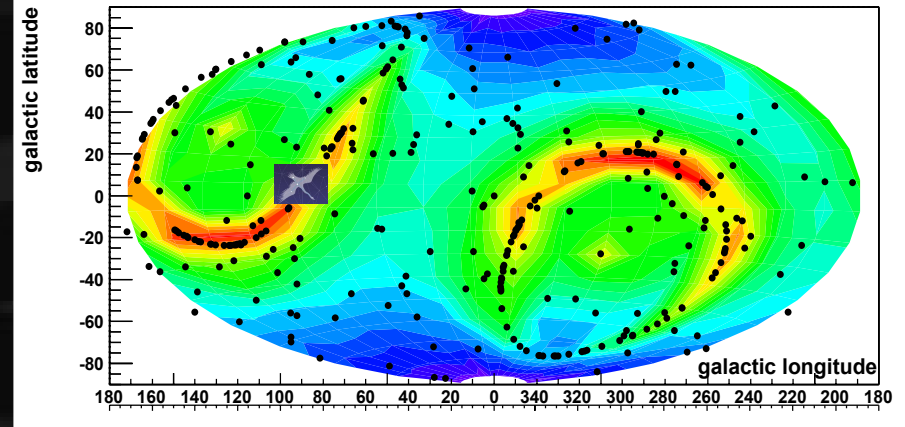
PLB654 (2007) 58

▣ Underground results

PLB686 (2010) 11, PTEP (2015) 043F01s

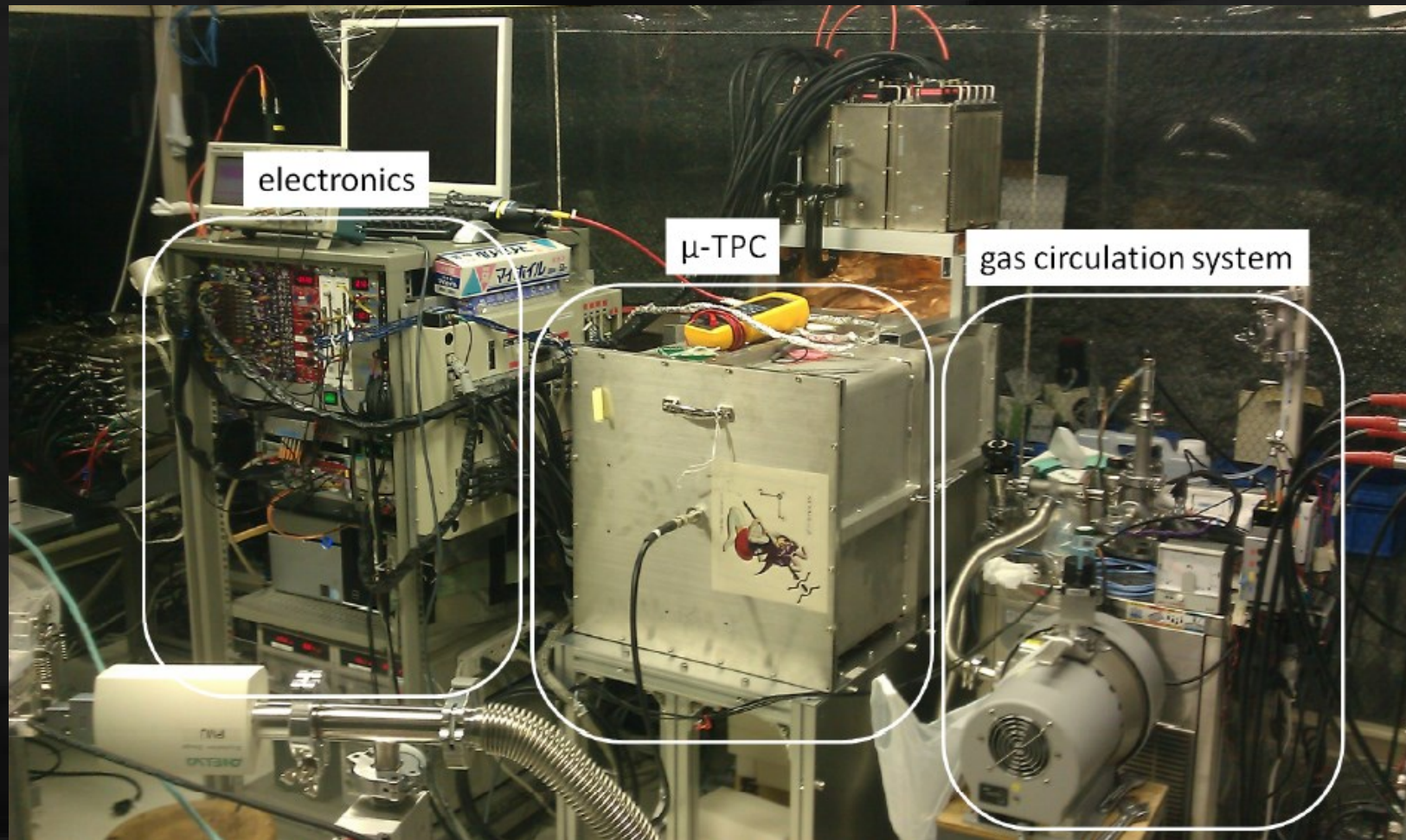
▣ Phase for “low BG detector”

SKYMAP (measured DATA)



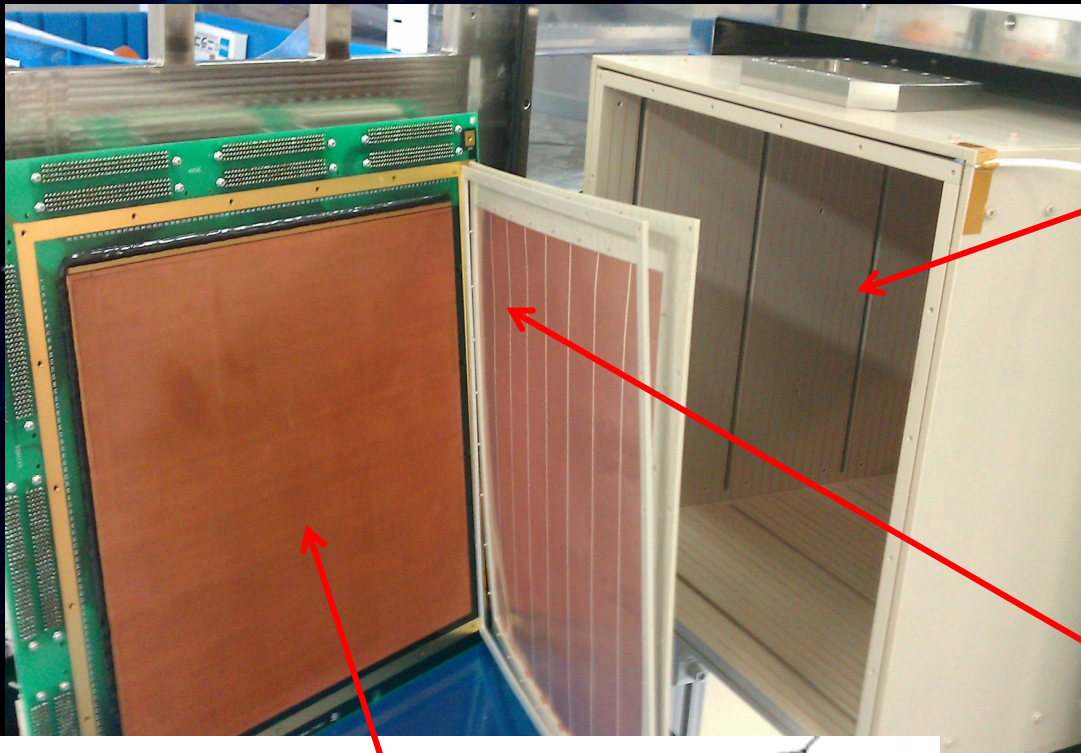
NEWAGE detector

- **NEWAGE-0.3b'**
- **Detection Volume: $31 \times 31 \times 41 \text{cm}^3$**
- **Gas: CF₄ at 0.1atm (50keVee threshold)**
- **Gas circulation system with cooled charcoal**

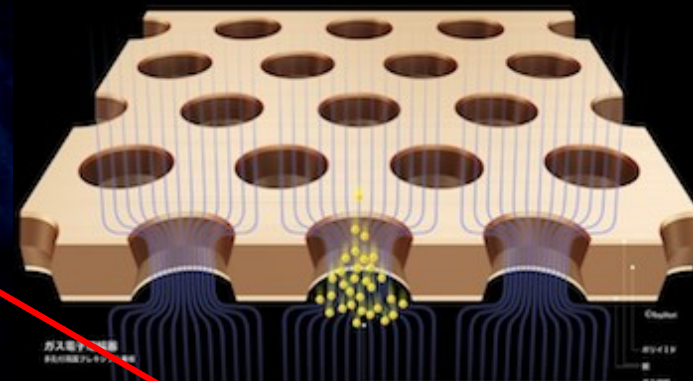


NEWAGE-0.3b' inside view

Detection Volume: $30 \times 30 \times 41 \text{cm}^3$

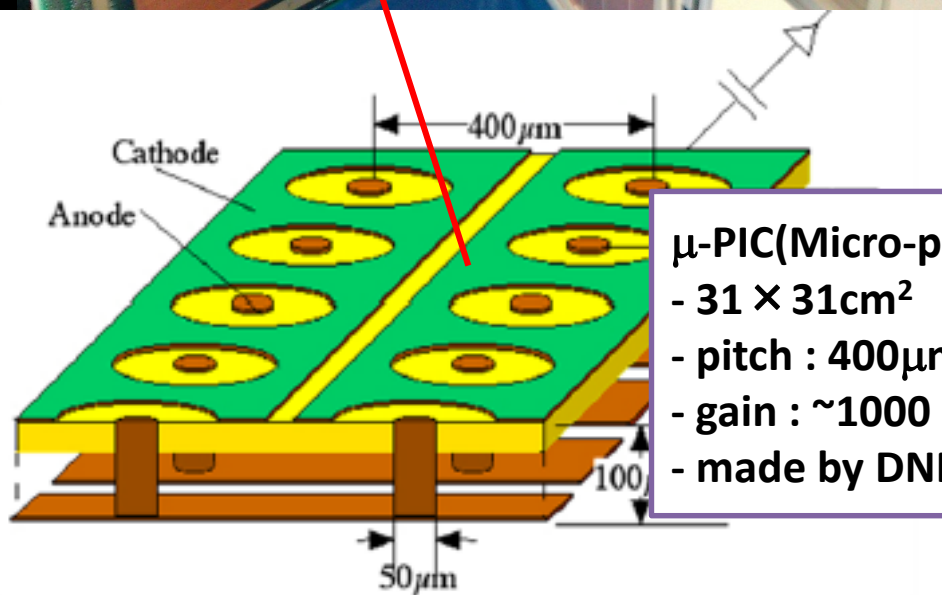


Field cage
Drift length: 41cm
PEEK + copper wires



GEM

- $31 \times 32 \text{cm}^2$
- 8-segmented
- hole pitch : $140 \mu\text{m}$
- hole diameter: $70 \mu\text{m}$
- insulator : LCP $100 \mu\text{m}$
- gain : ~ 5
- made by Scienergy, Japan



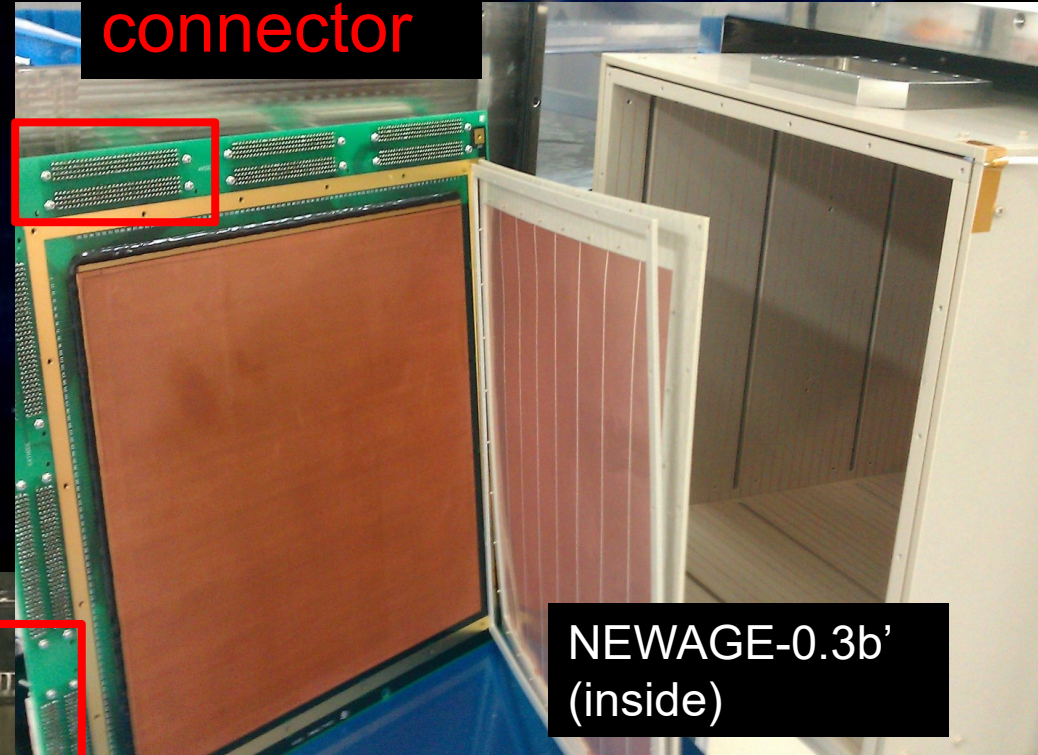
μ-PIC (Micro-pixel chamber)

- $31 \times 31 \text{cm}^2$
- pitch : $400 \mu\text{m}$
- gain : ~ 1000
- made by DNP, Japan

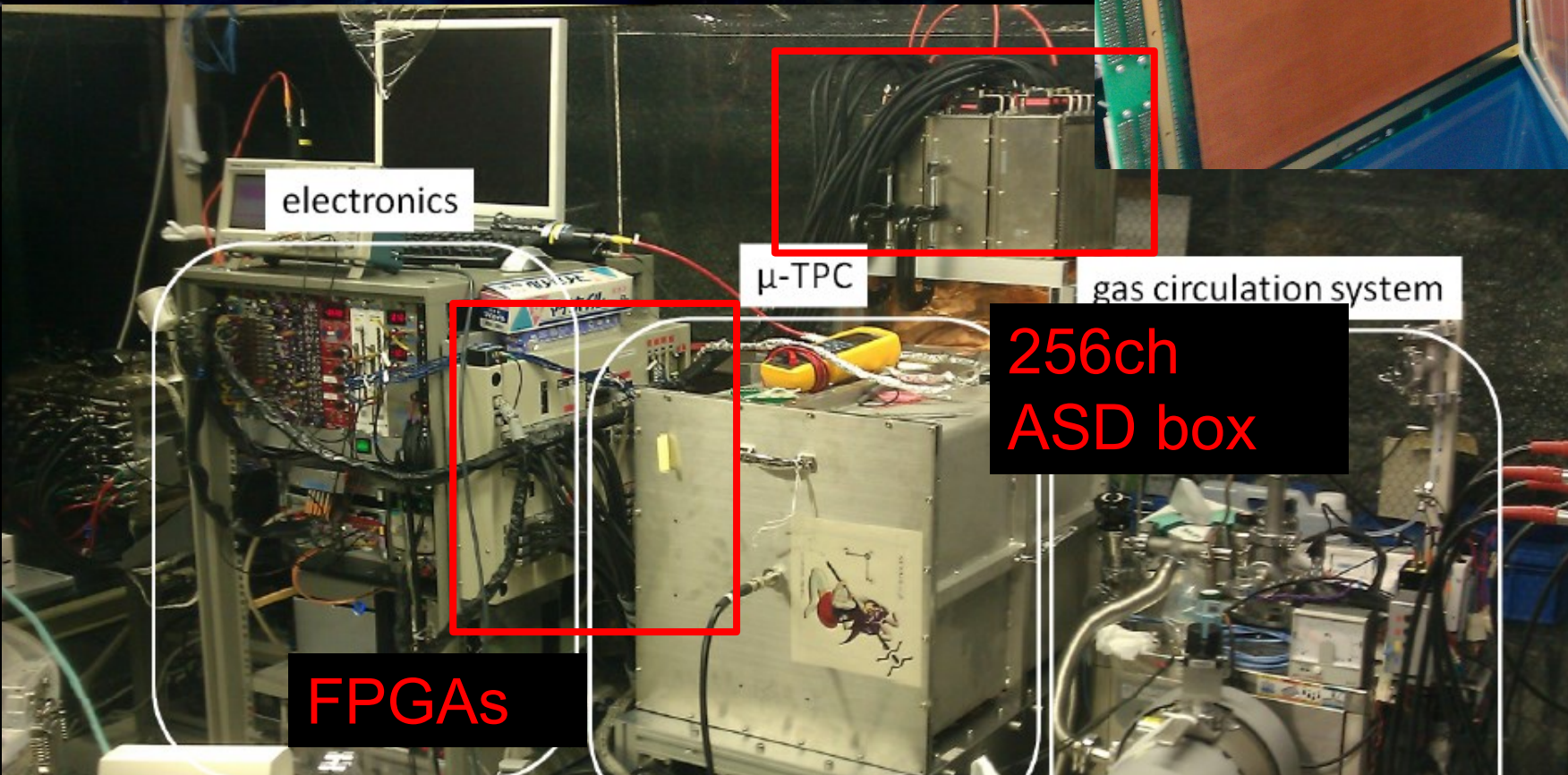
NEWAGE-0.3b' readouts

- μ -PIC is X-Y readout
- ALTAS TGC ADS chips
- General purpose FPGA-based electronics since early 2000's

256ch
connector



NEWAGE-0.3b'
(inside)



electronics

μ -TPC

gas circulation system

256ch
ASD box

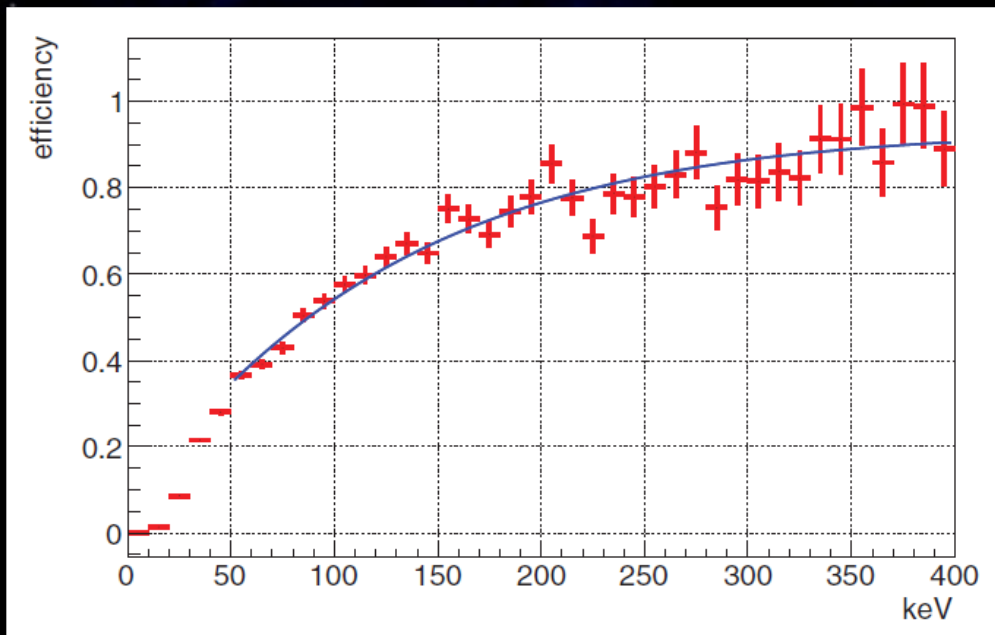
FPGAs

NEWAGE-0.3b' performance

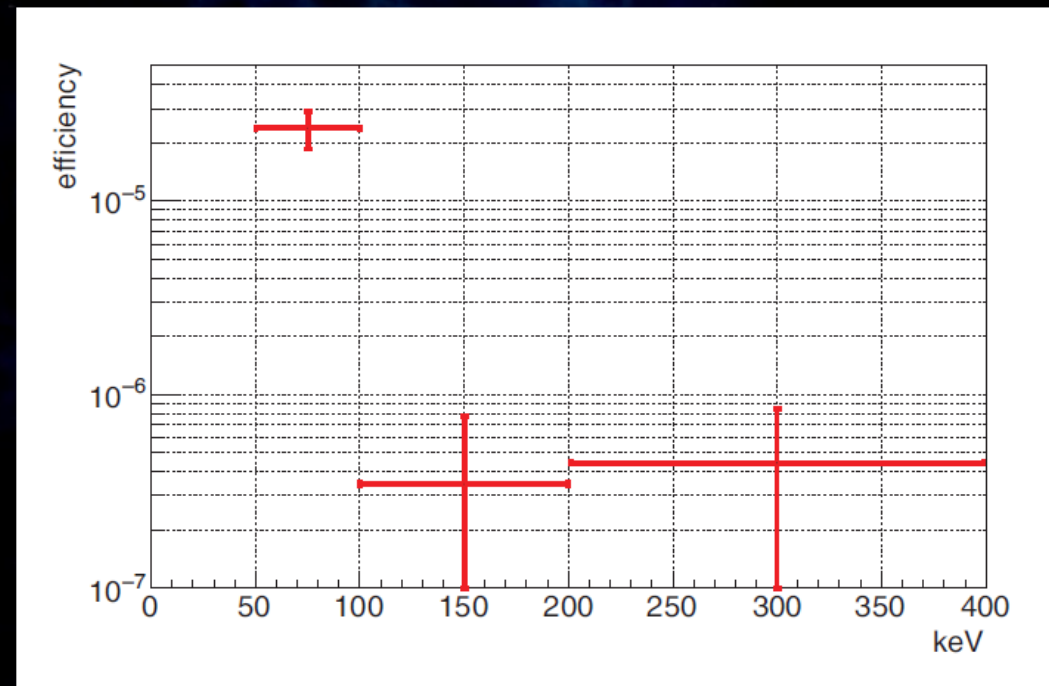
PTEP (2015) 043F01s

- nuclear track detection efficiency: 40% @50 keVee
- gamma rejection: $2.5e-5$ @ 50keVee
- energy resolution: 7.8keV σ @50keVee
- angular resolution: 40° σ @ 50keVee

nuclear track detection efficiency



electron track detection efficiency
(gamma rejection factor)



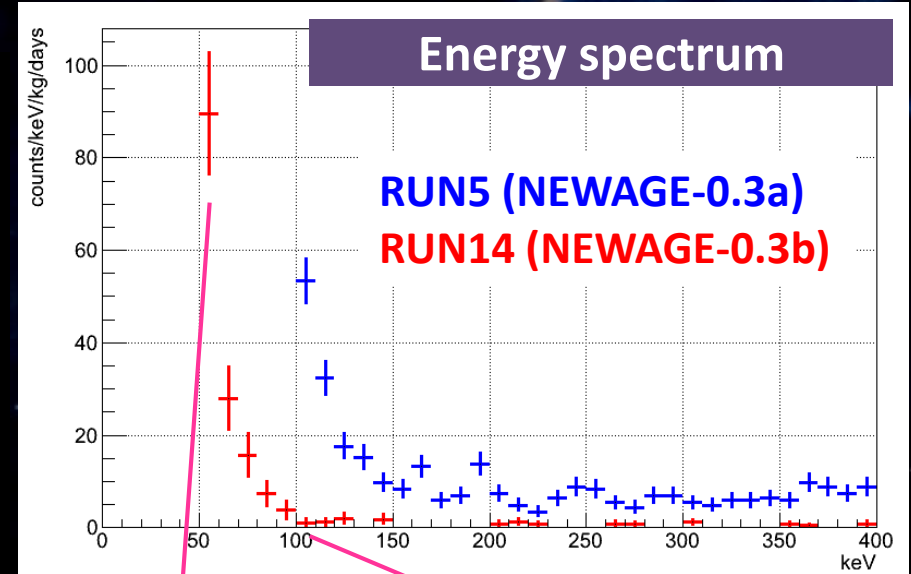


NEWAGE
Kamioka run

NEWAGE underground run

RUN14

- period : 2013/7/20-8/11, 10/19-11/12
- live time : 31.6 days
- fiducial volume : 28x24x41cm³
- mass : 10.36g
- exposure : 0.327 kg·days

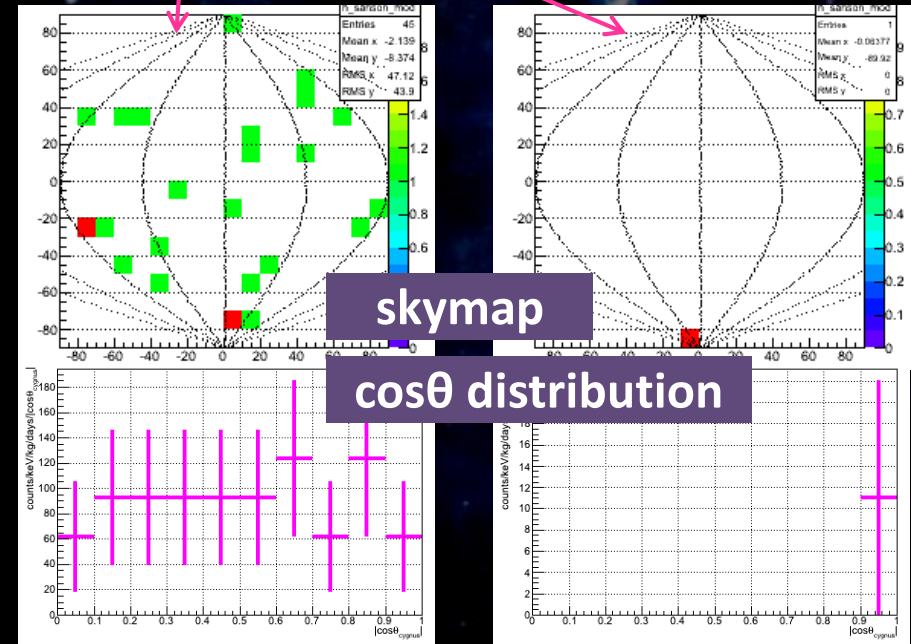


Energy spectrum

- Threshold : 100 => **50keV**
- BG rate : **1/10**@100keV

Skymap, cosθ distribution

- Set limit by significant difference in 2-binned measured cosθ and DM-wind simulated cosθ



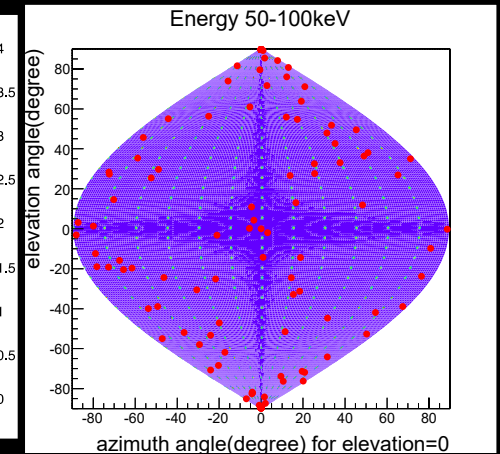
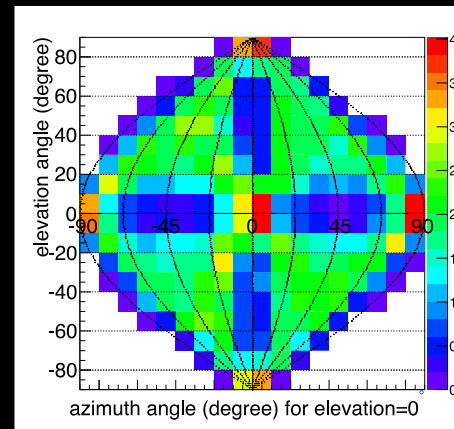
50-60keV

100-110keV

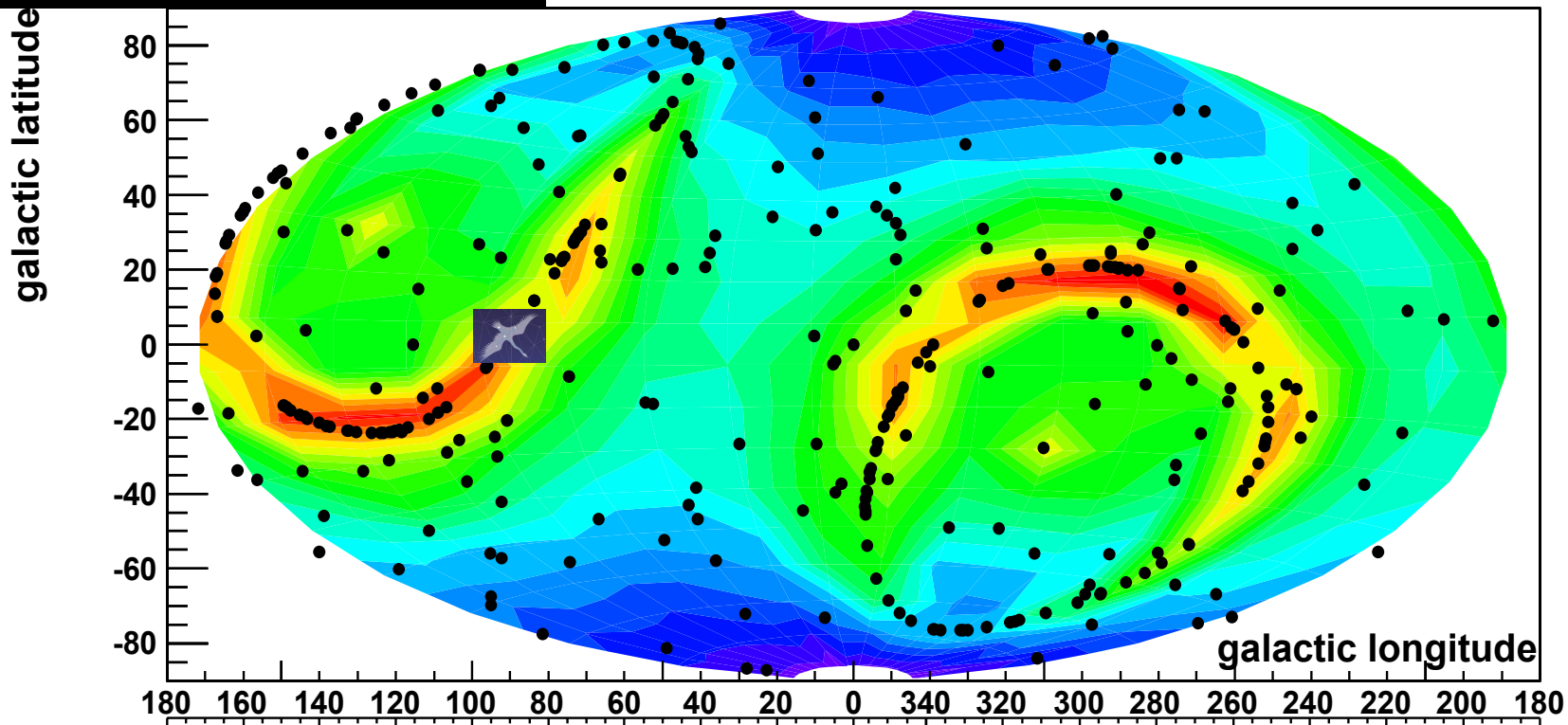
Galactic-plane sky-map

lab-coordinate

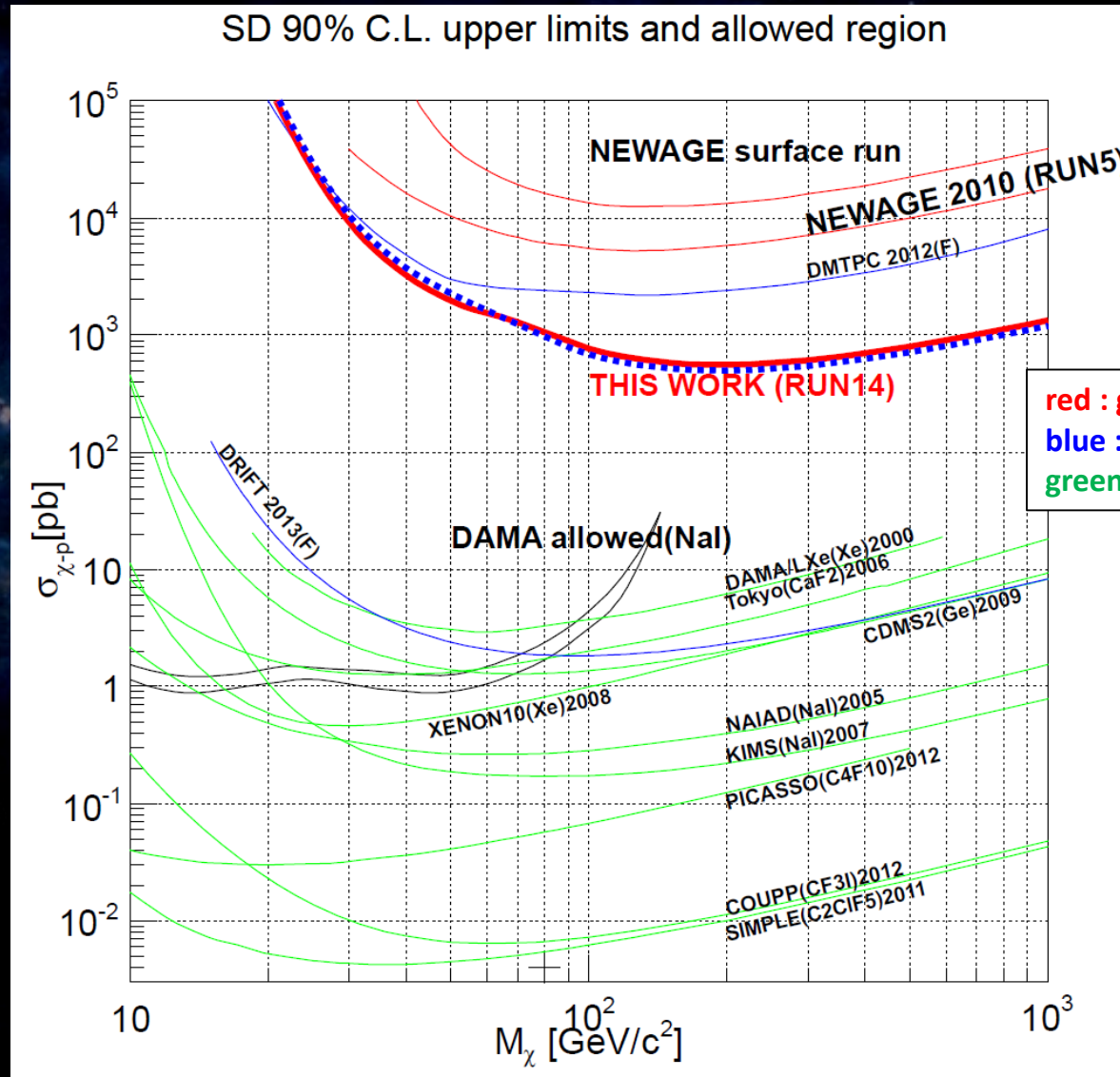
correlation with efficiency = consistent with isotropic



galactic coordinate



Direction-sensitive limit



PTEP (2015) 043F01s

- Obtained limit : **557pb @200GeV**
(Best direction-sensitive limit)
- Improved one order of magnitude from previous RUN5



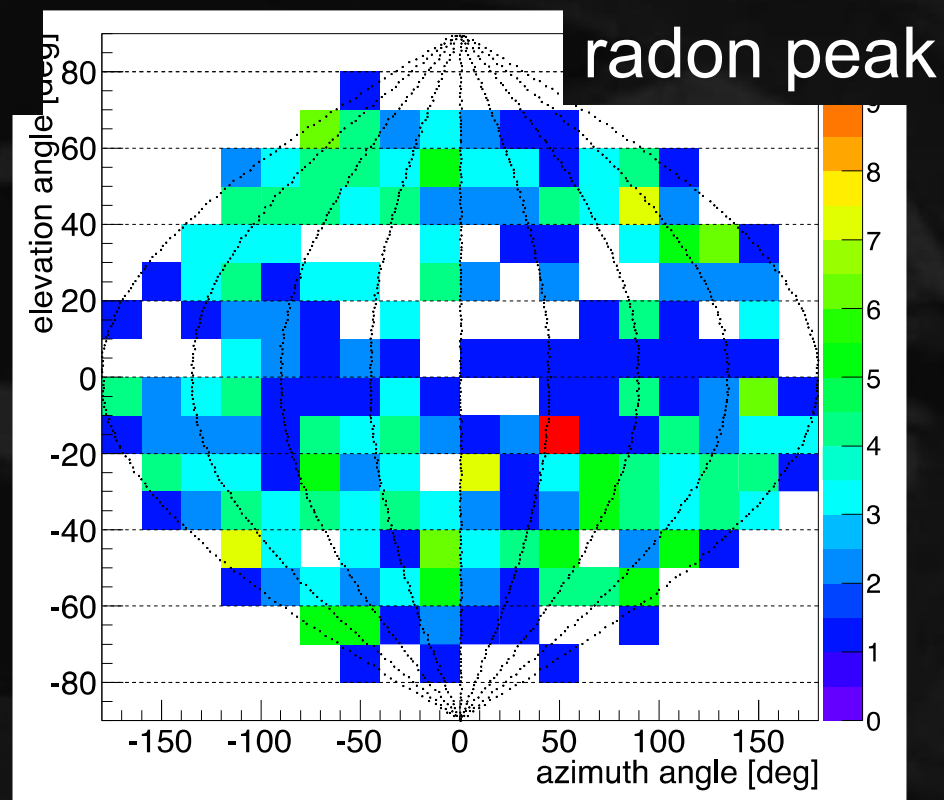
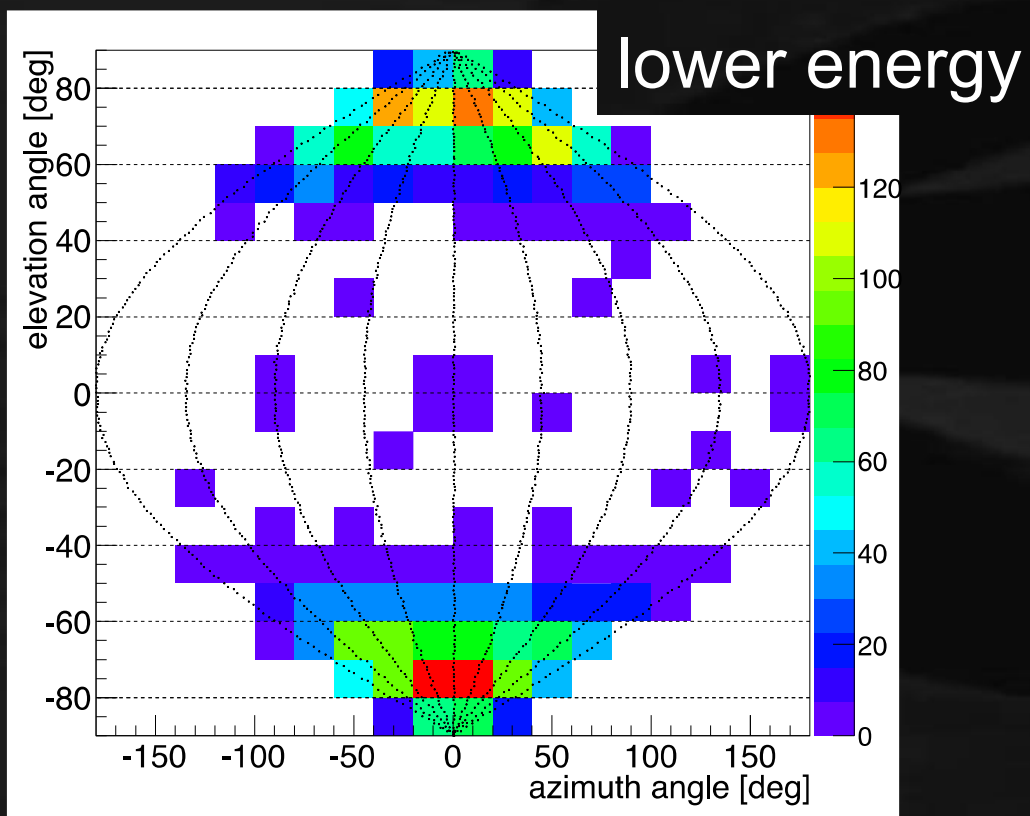
Recent R&Ds

BG study

Directionality helps!

SKYMAP @ detector coordinate

color: number of events



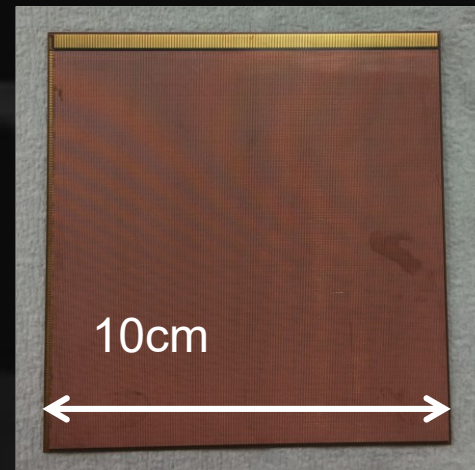
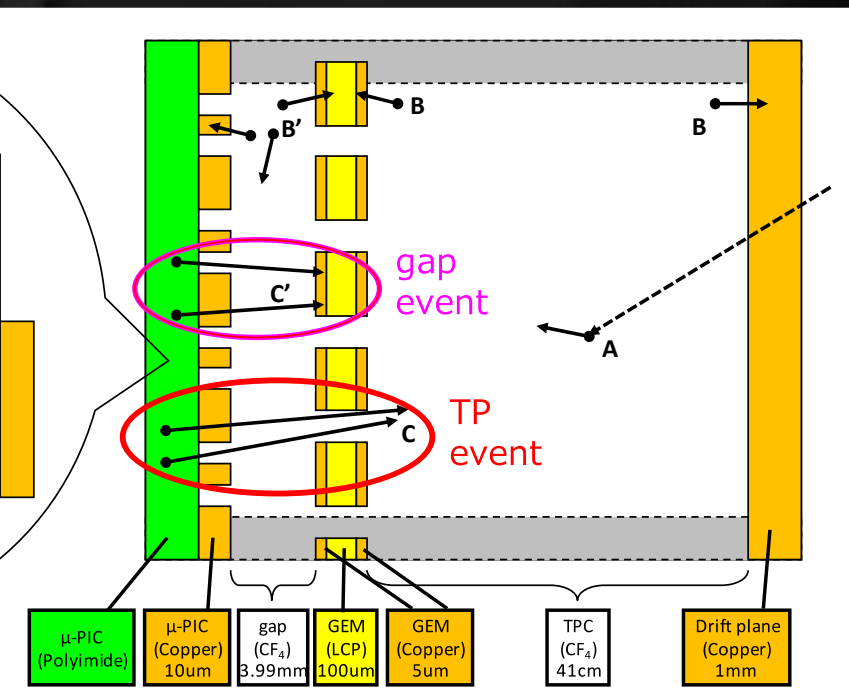
BG identified: upgoing events

Positive
Search

NEWAGE

Low BG R&Ds

- Largest BG source: alpha particle from μ -PIC
- Development of radio-pure(BG $\times 1/100$) μ -PIC:
10 \times 10 cm² μ -PIC was made and tested

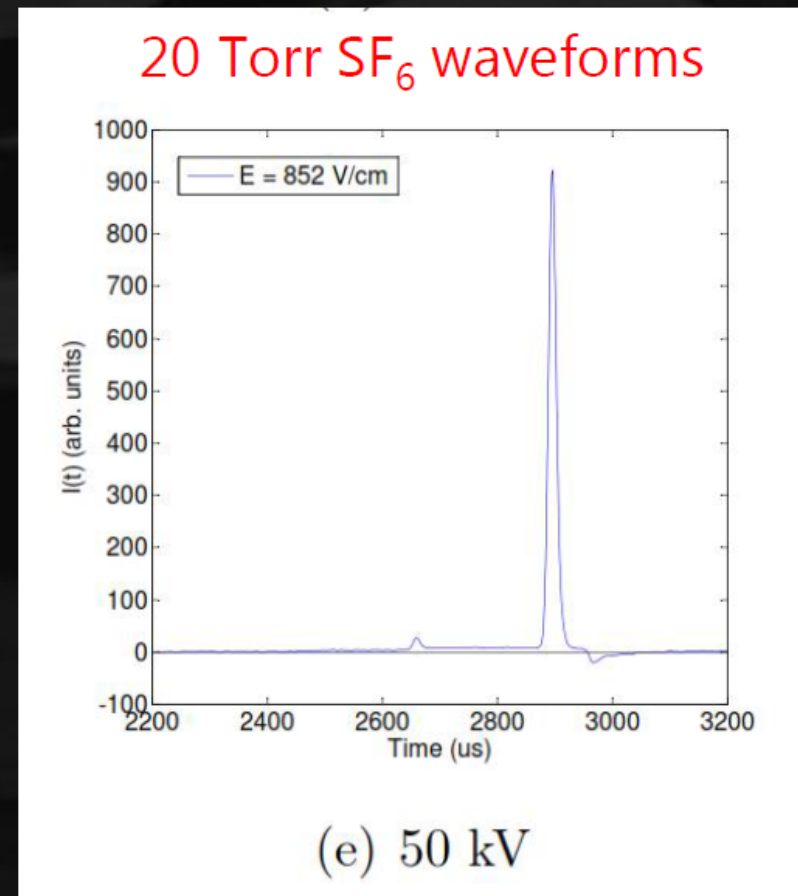
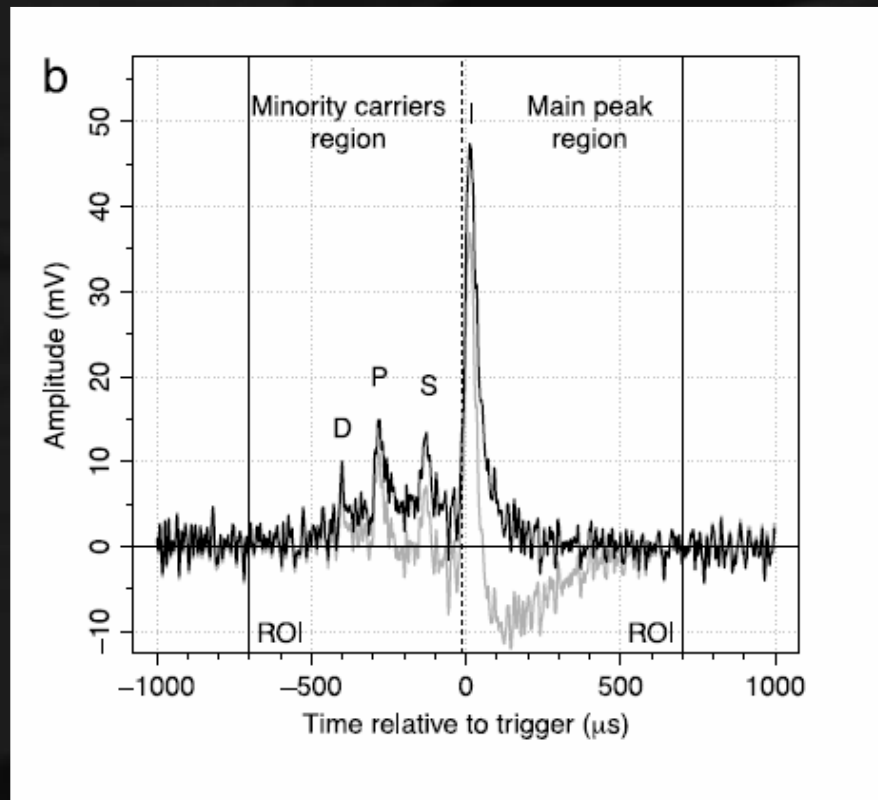


- FY2016: development of 30 \times 30 cm² μ -PIC
- FY2017~: underground run

Z-fiducialization

- minority peaks “discovery” by DRIFT group
- First with CS_2 , then with SF_6

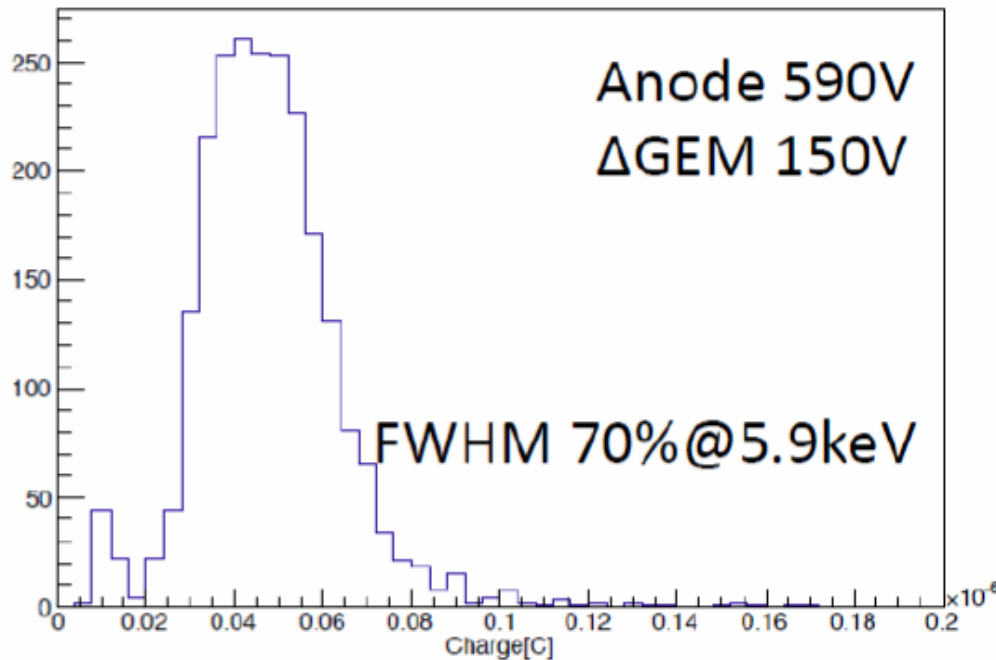
minority peaks (DRIFT group)



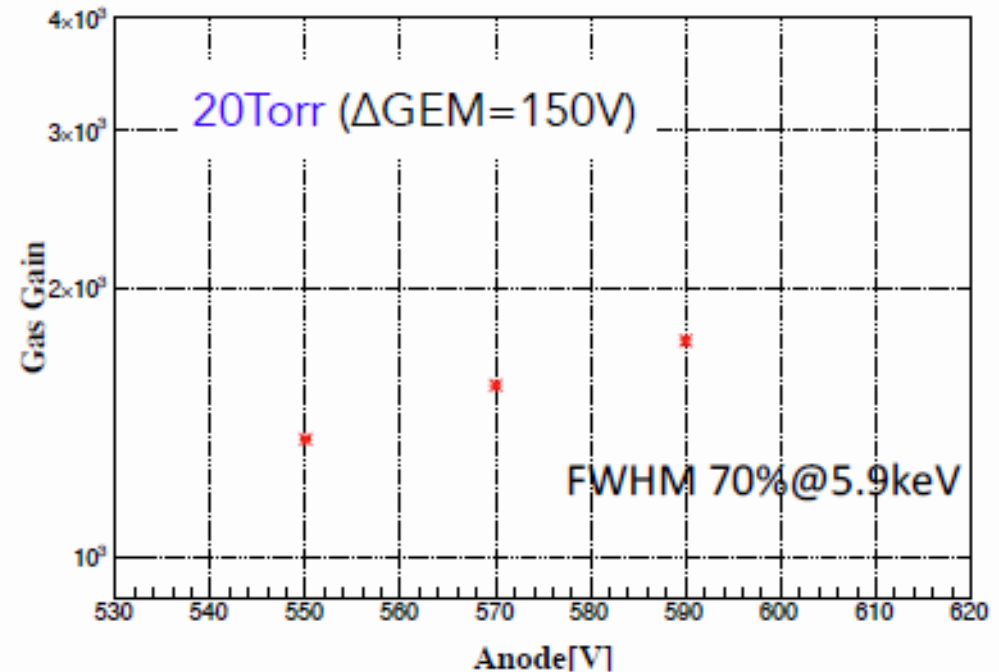
NEWAGE SF₆ study (by Tomonori Ikeda)

- SF₆ study for GEM+ μ PIC system
- Wide dynamic-range ASIC development

SF6 study (NEWAGE)



SF6 study (NEWAGE)



Erelectronics

- Using analog and digital board made by KEK for Liquid Argon detector

Analog Board (64ch RO)

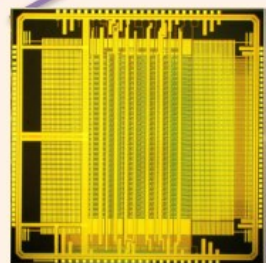
Digital Board (64ch RO)

cathode 32ch
(ID109~140)

anode 32ch
(ID109~140)

trigger(cathode ID107,108)

Ethernet → PC



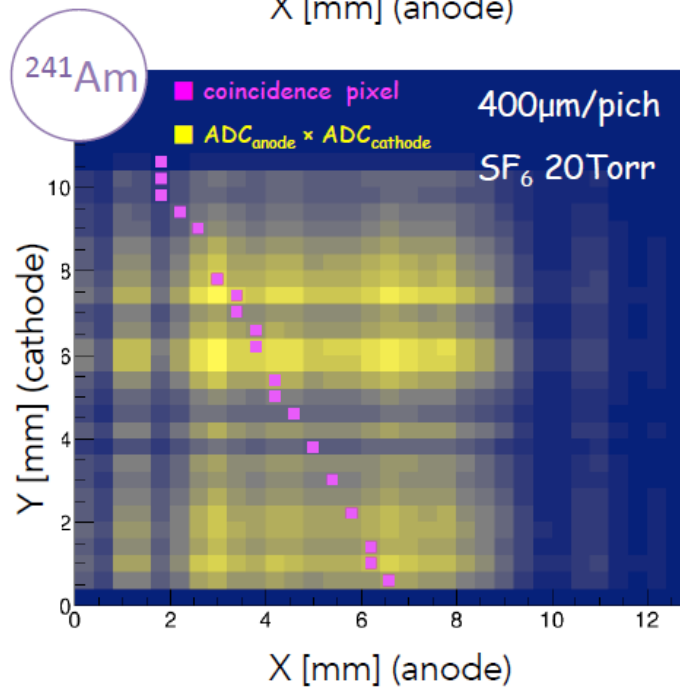
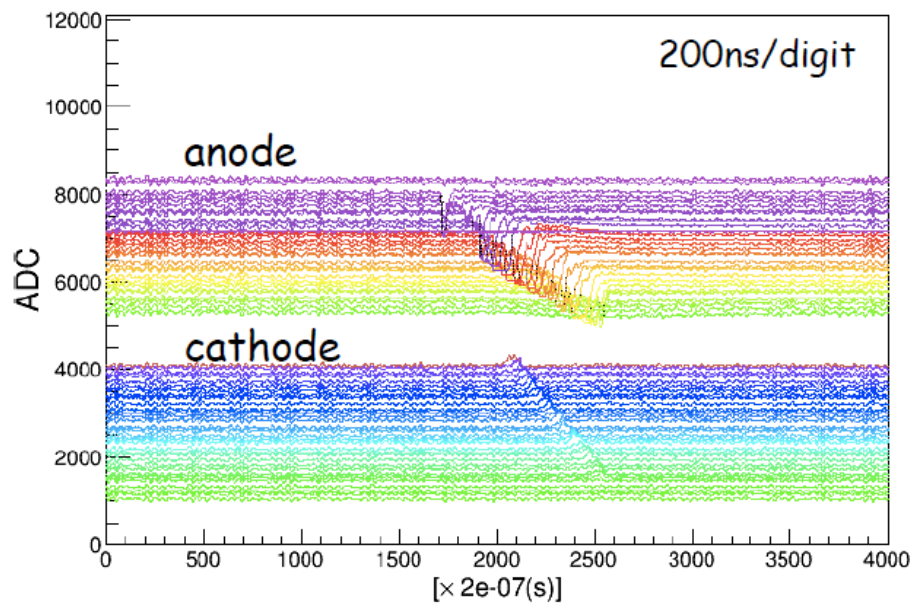
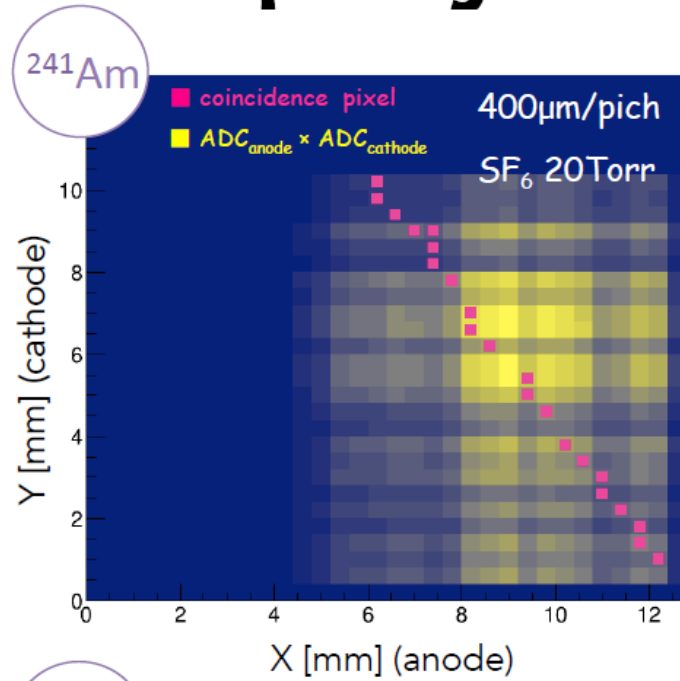
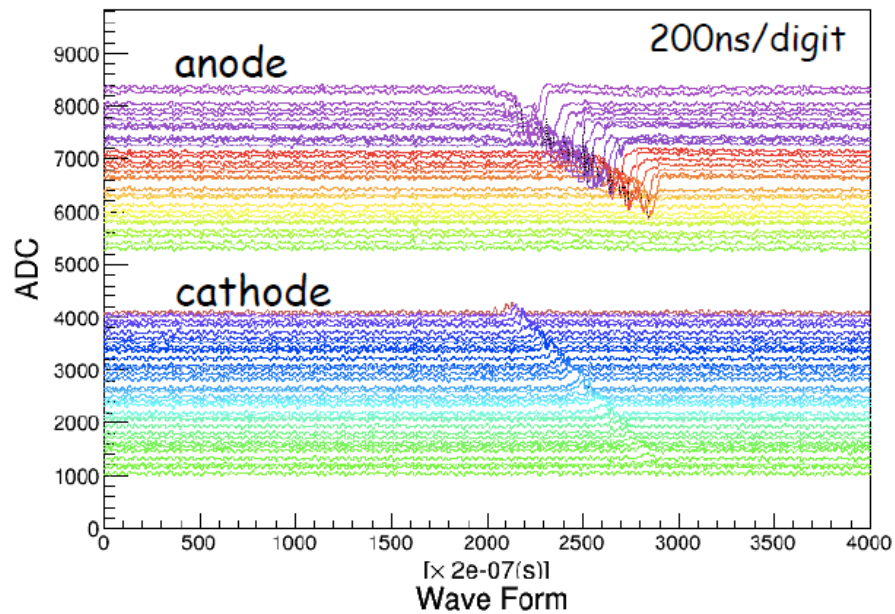
LTARS2014

Conversion gain : $\sim 9.0\text{mV/fC}$
Max input charge : $60\sim 100\text{fC}$
ENC : below 2000@300pF
Shaping time : 1us

32ch differential inputs(2Vpp)
12bits FADC
4000 sampling
Sampling frequency $< 20\text{MHz}$

Alpha Event Display

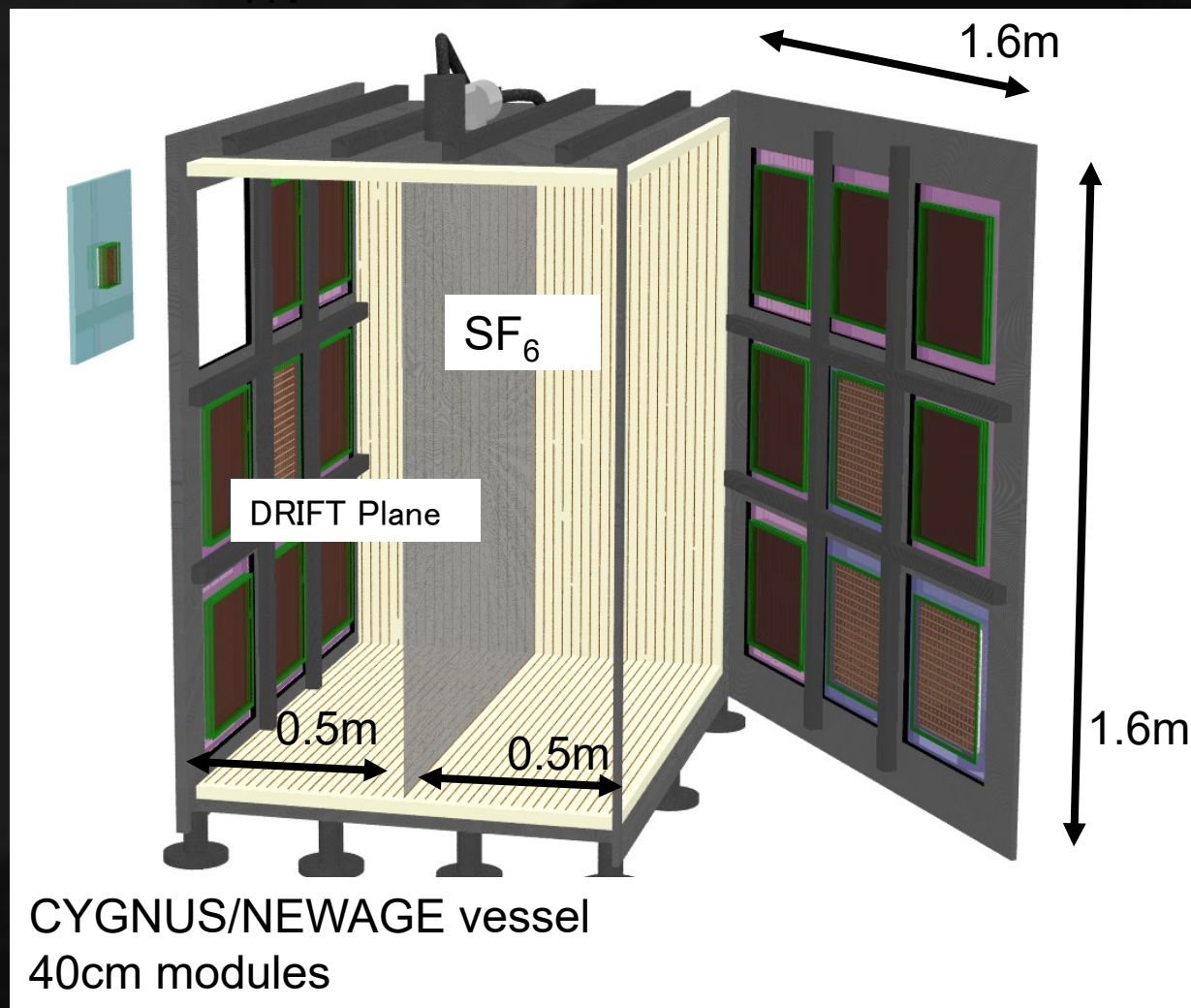
Wave Form



scaling-up: modulated chamber

will be ready by Apr 2017

μ -PIC, GEMs, micromegas, pixels, MWPCs...



Summary

- **NEWAGE :**
 - direction sensitive with 3D track detection.
- **Sensitivity improvements are on-going.**

DRIFT: pioneer of “CYGNUS” concept

■ early 2000s ~

■ large TPC

■ low BG study

ELSEVIER Nuclear Instruments and Methods in Physics Research A 463 (2001) 142–148
RESEARCH Section A
www.elsevier.nl/locate/nima

Measurement of carbon disulfide anion diffusion in a TPC

Tohru Ohnuki^{a,*}, Daniel P. Snowden-Ifft^a, C. Jeff Martoff^b

^aDepartment of Physics, Occidental College, 1600 Campus Road, Los Angeles, CA 90041-3314, USA

^bDepartment of Physics, Temple University, 1900 N. 13th Street, Philadelphia, PA 19122-6082, USA

Received 15 May 2000; received in revised form 13 November 2000; accepted 14 November 2000

RESEARCH Section A Nuclear Instruments and Methods in Physics Research A 498 (2003) 155–164
www.elsevier.com/lo

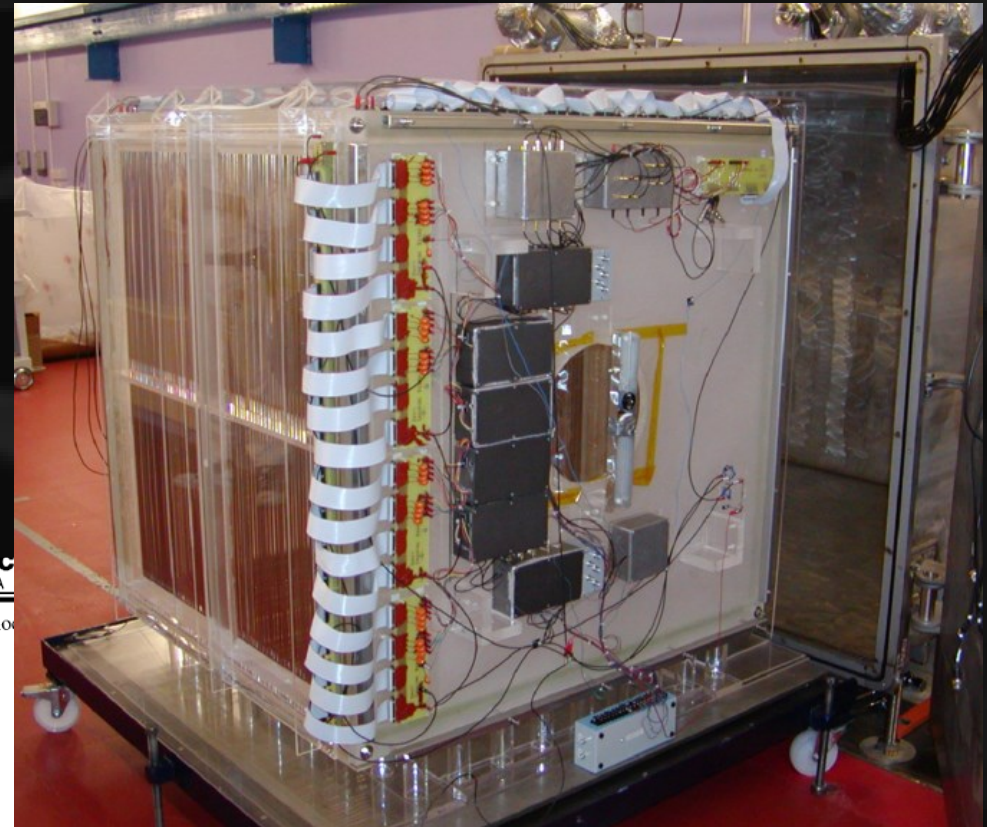
Neutron recoils in the DRIFT detector

D.P. Snowden-Ifft^{a,b,*}, T. Ohnuki^{a,b}, E.S. Rykoff^{a,b}, C.J. Martoff^{a,b}

^aPhysics Department, Occidental College, 1600 Campus Road, Los Angeles, CA 90041, USA

^bBarton Hall, Temple University, 1900 N. 13th St., Philadelphia, PA 19122-6082, USA

Received 5 July 2002; received in revised form 11 October 2002; accepted 27 November 2002



- 2mm pitch multi-wire proportional chamber
- not very direction-sensitive

NEWAGE-0.3b' data

TOT of every strip by FPGA (clock 100MHz)

⇒ 3D tracks, headtails in X,Y

+

Summed waveforms by FADC (100MHz)

⇒ energy, headtails in Z

combined ⇒ PID, absolute z

