NEWAGE
Direction-Sensitive Dark Matter Search

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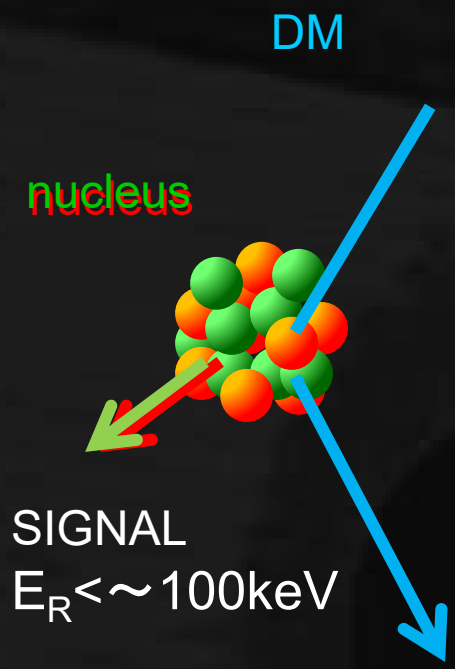
CAASTRO-CoEPP workshop

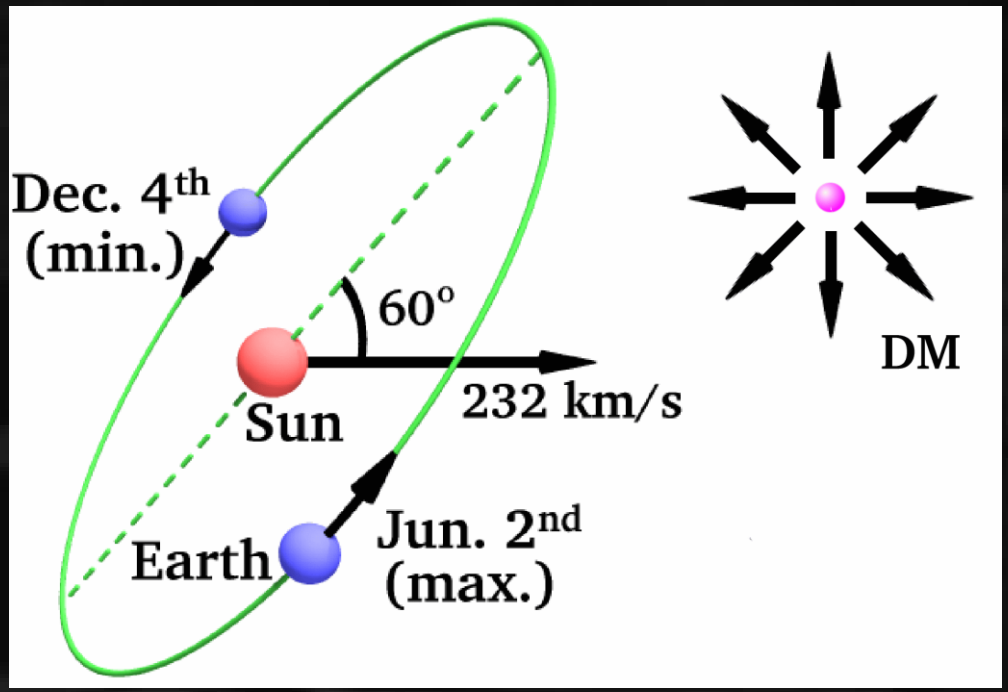
Contents

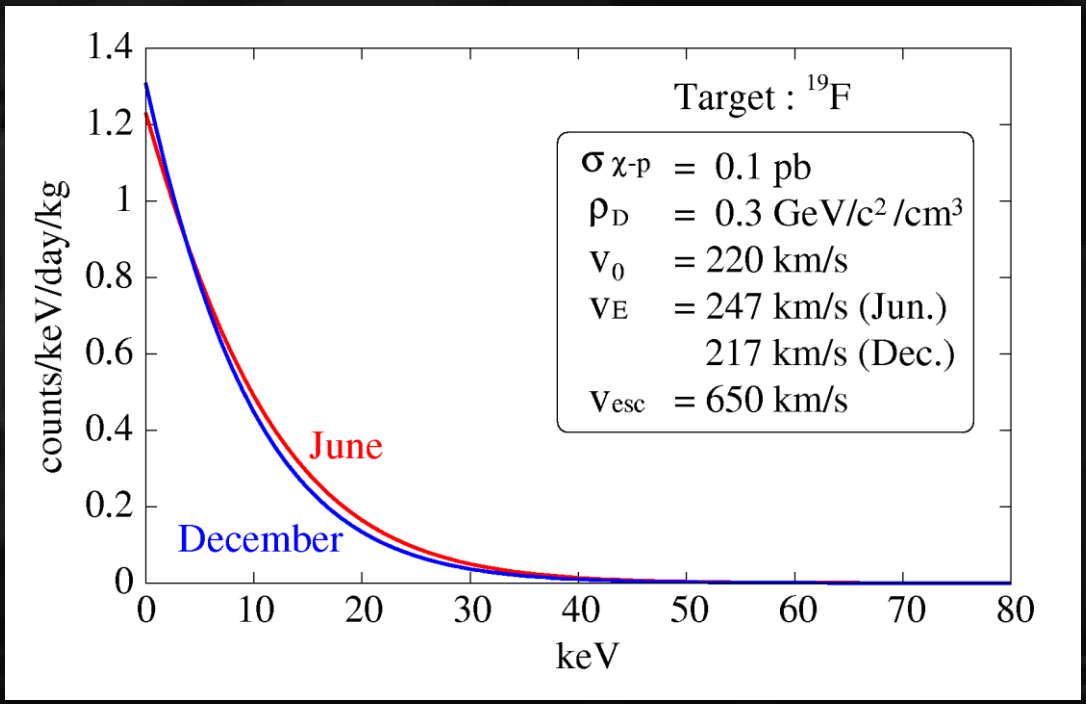
Physics
NEWAGE

科研費 KAKENHI

DM direct detection





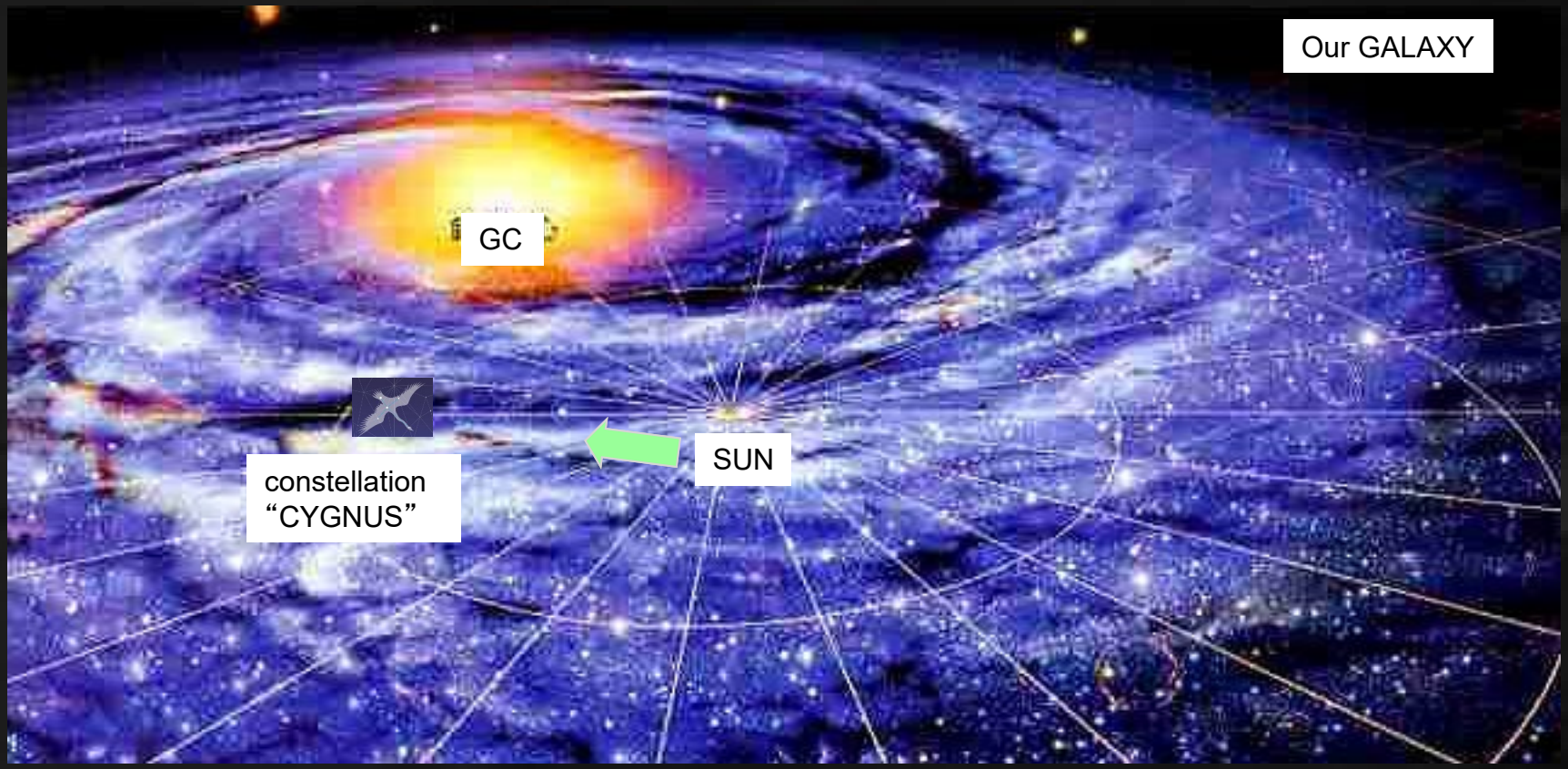


expected direct DM signals

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

Physics cases

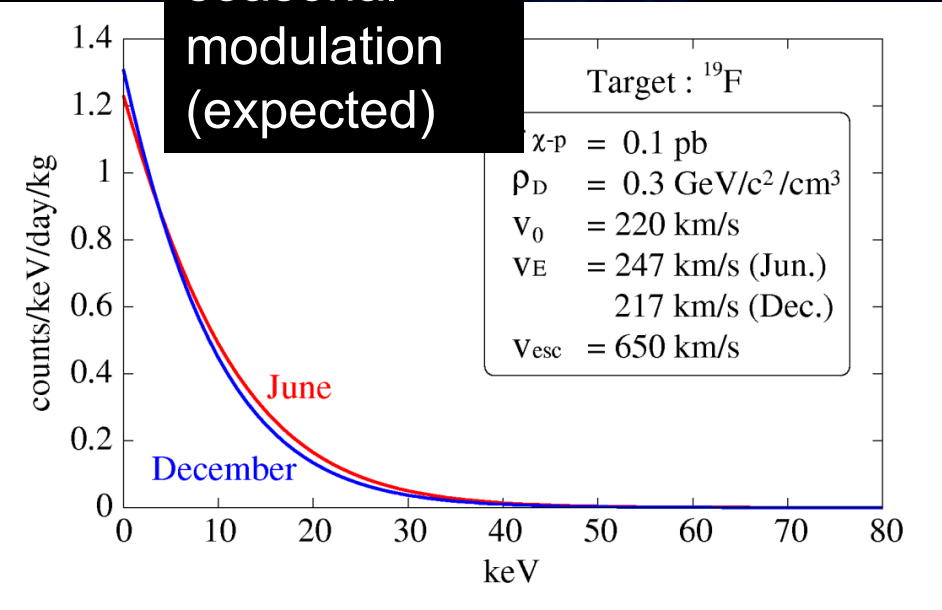
Direction-Sensitive Dark Matter Search concept “CYGNUS”



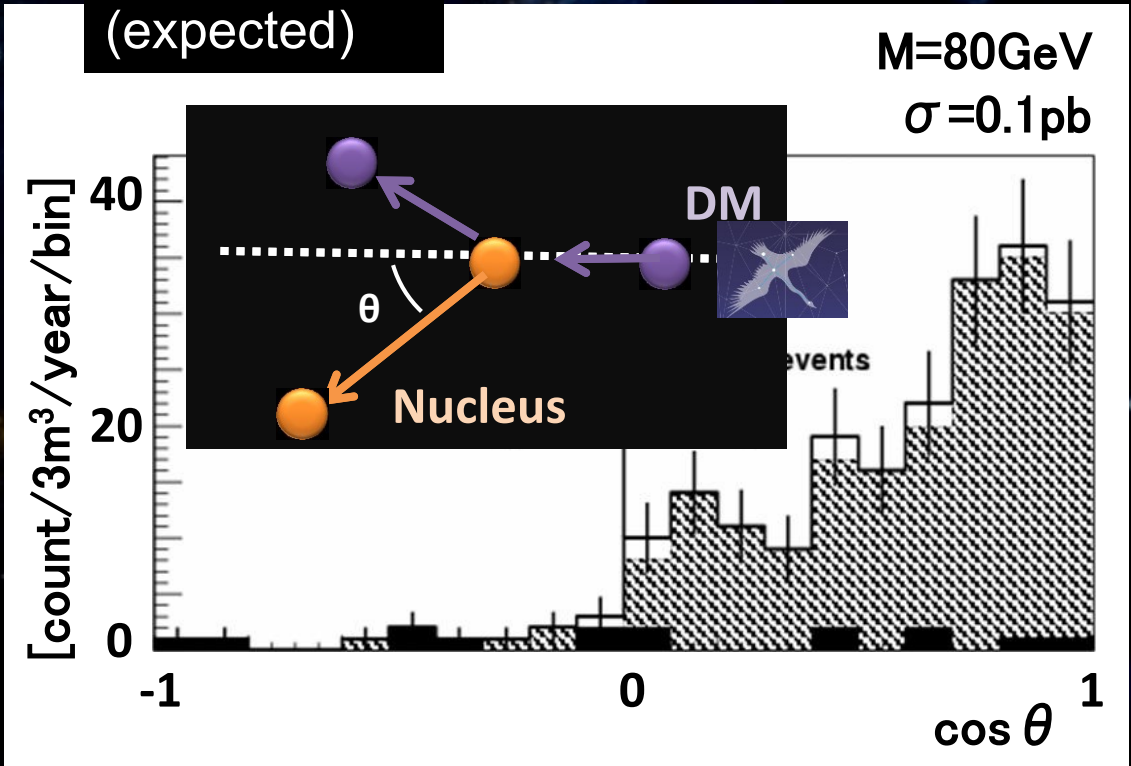
WIMP-WIND from “CYGNUS”

“CYGNUS” concept

seasonal modulation (expected)



directionality (expected)

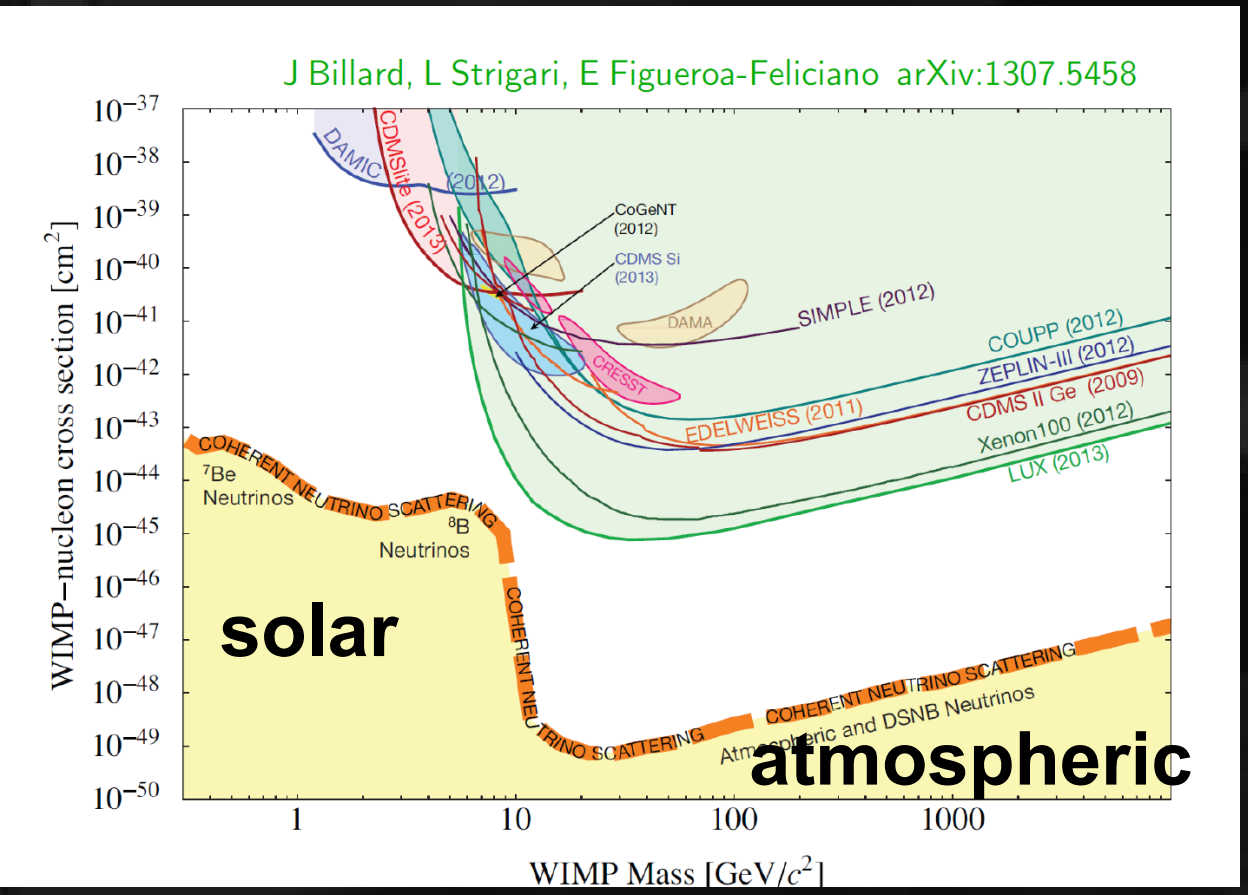


Clear Discovery

+ study the nature of DM after discovery

“CYGNUS” physics towards discovery

- **Potential to search beyond the “neutrino floor”†**



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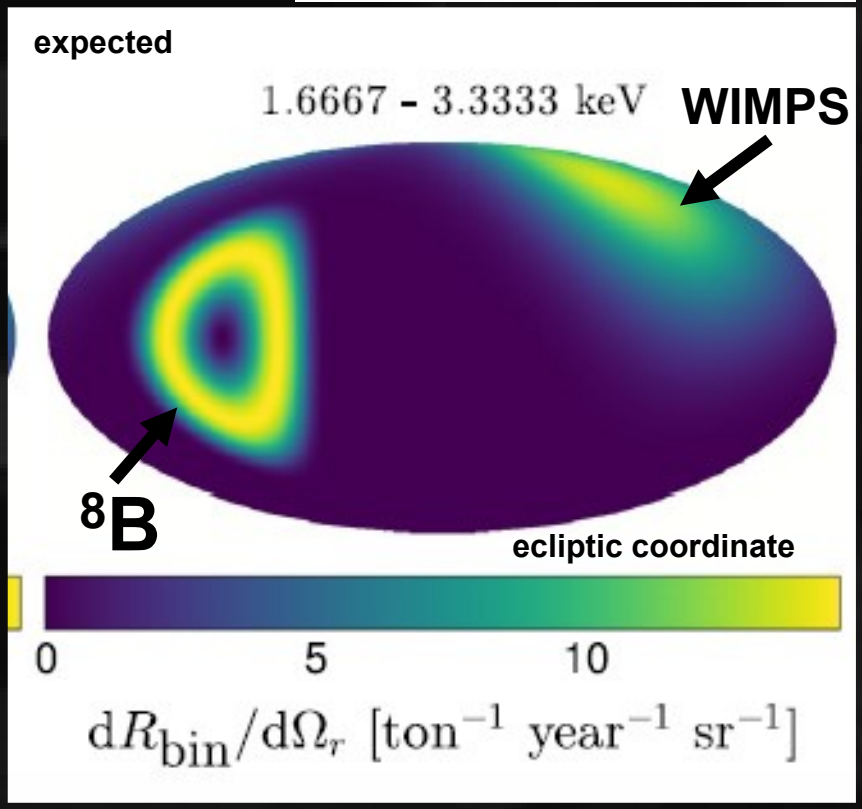
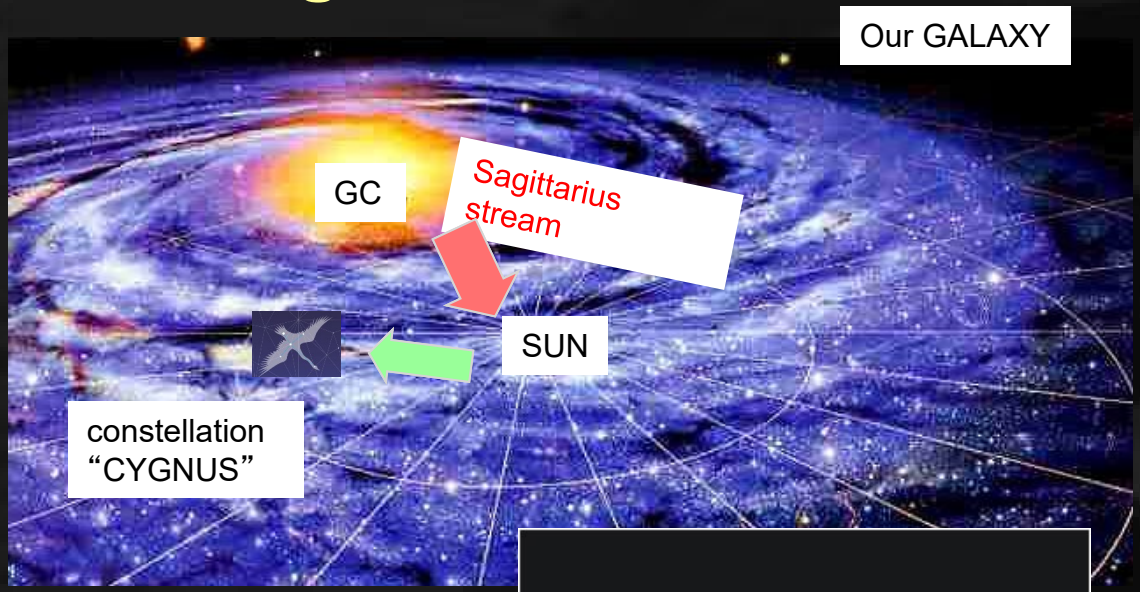


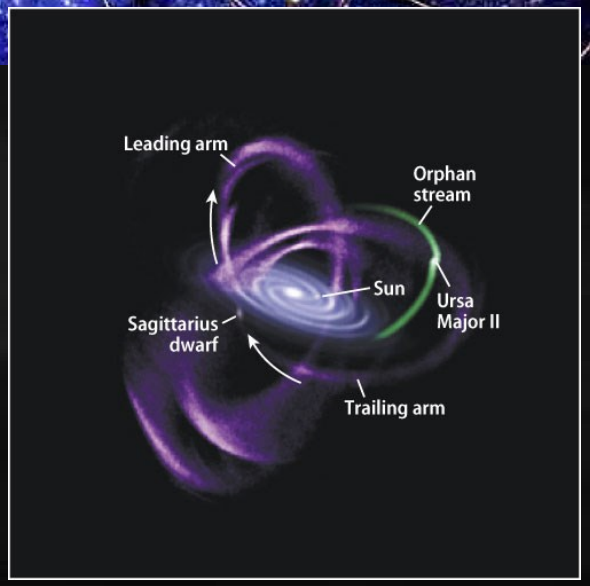
- **clearly distinguishable**

† neutrino-nucleus coherent scattering

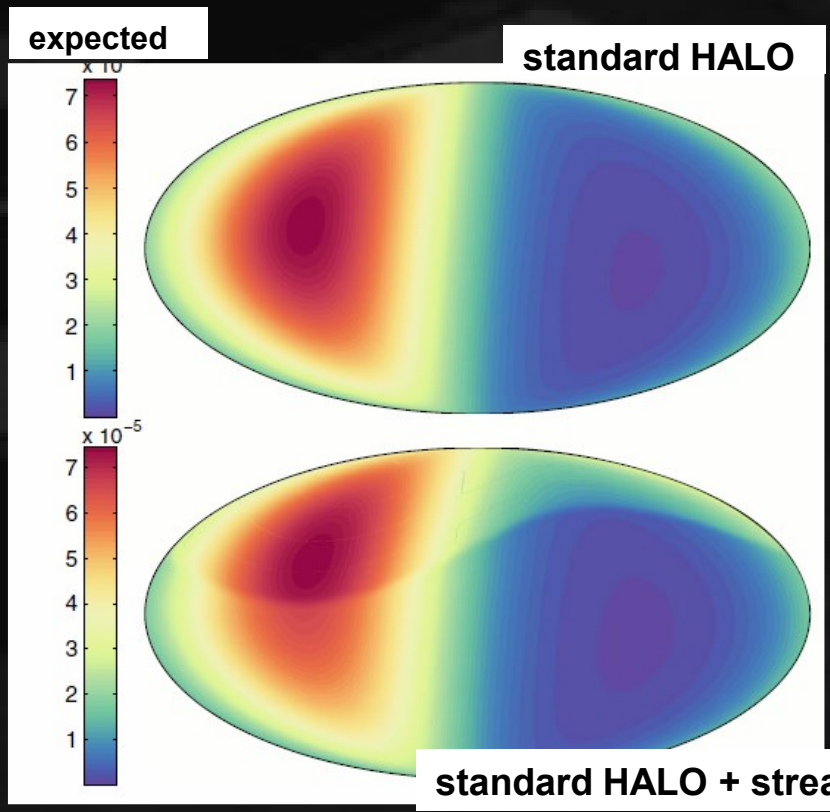
“CYGNUS” physics after discovery

- **Test the DM motion**
  - **ex. Sagittarius stream**





PHYSICAL REVIEW D **90,** 123511 (2014)



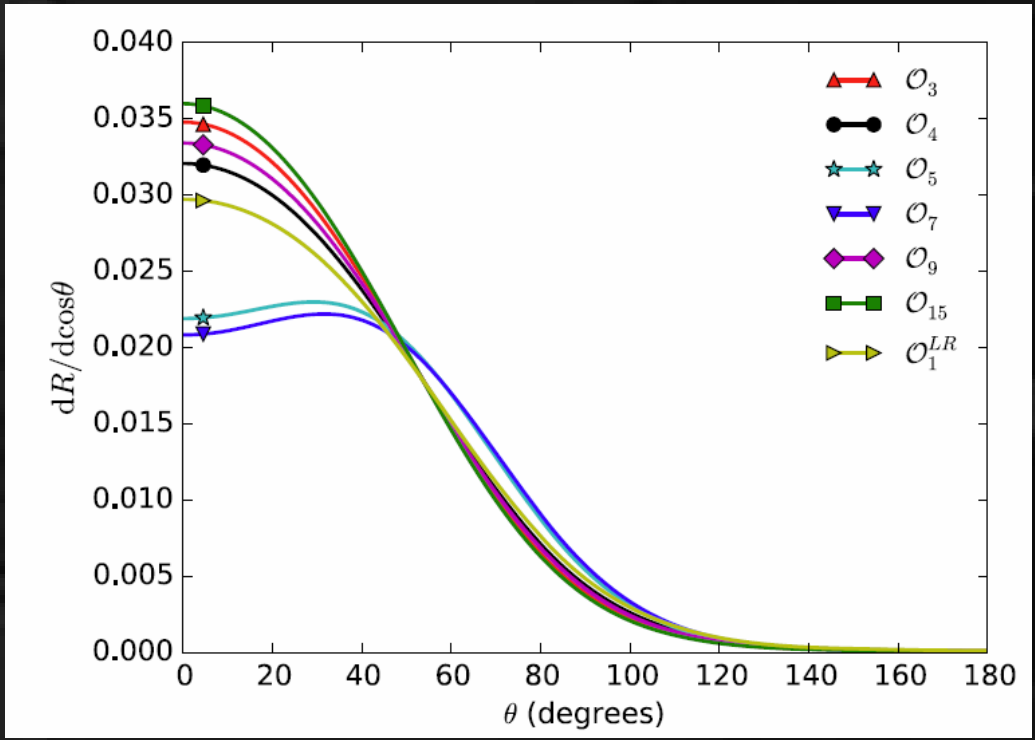
galactic coordinate

- **streams, halo model…**

“CYGNUS” physics after discovery

- **Test the interaction by scattering angle**

PHYSICAL REVIEW D **92,** 023513 (2015)



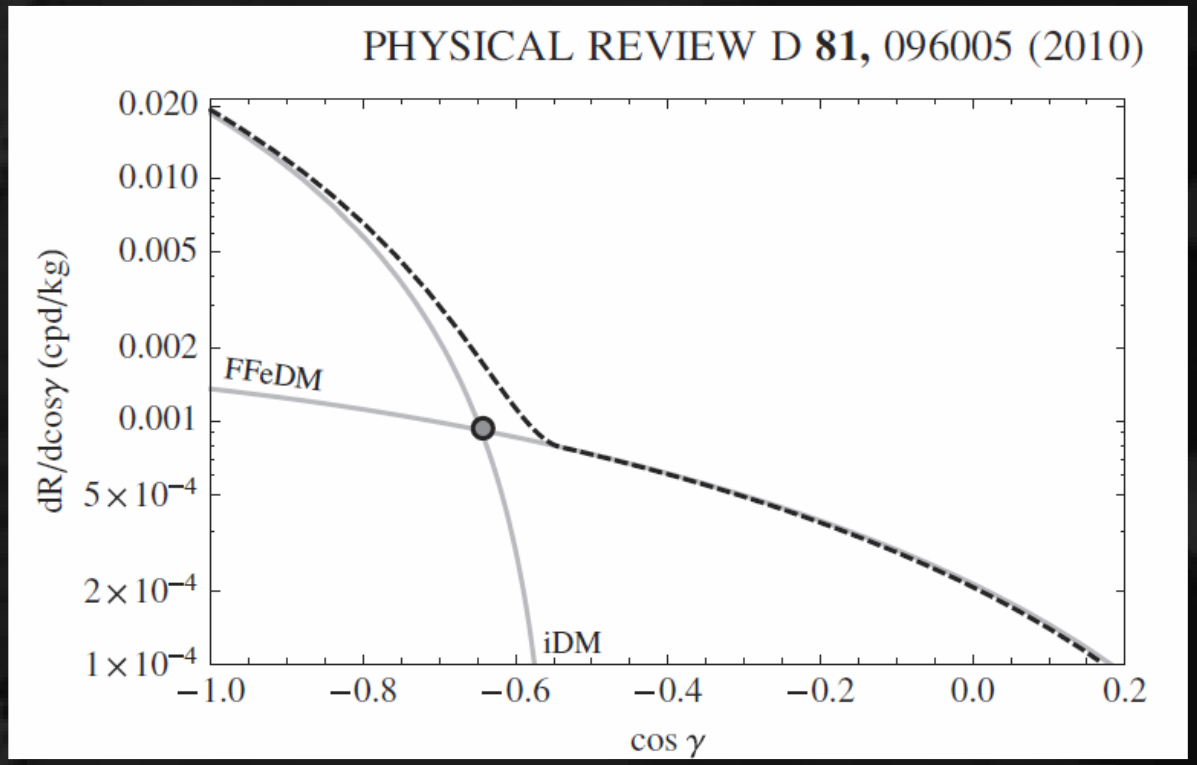
SI SD

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

- **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**

Experimental Status

Experimental concept

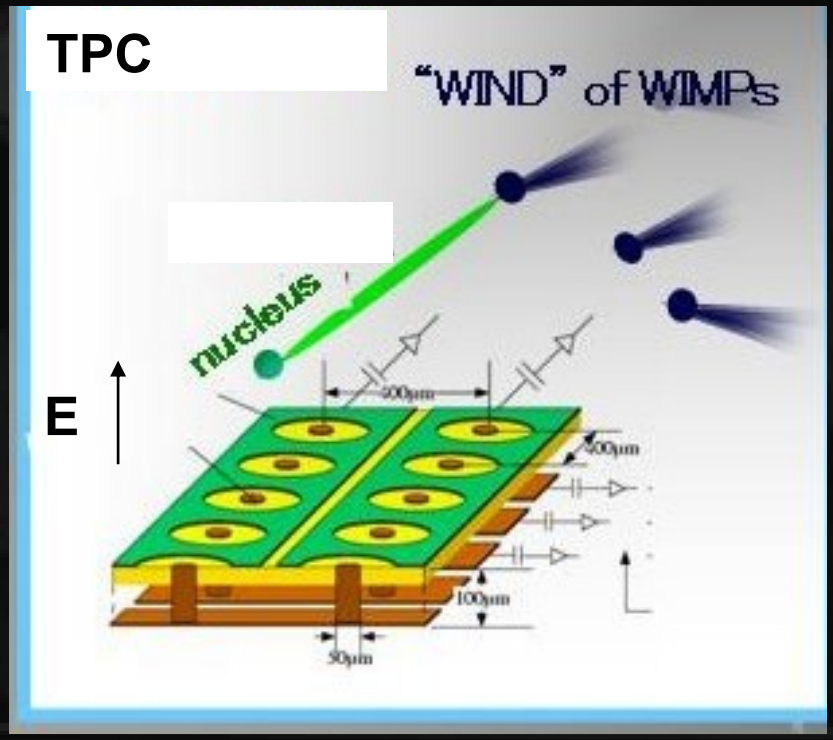
Recoil nuclear track detection < 100keV

challenge: short track

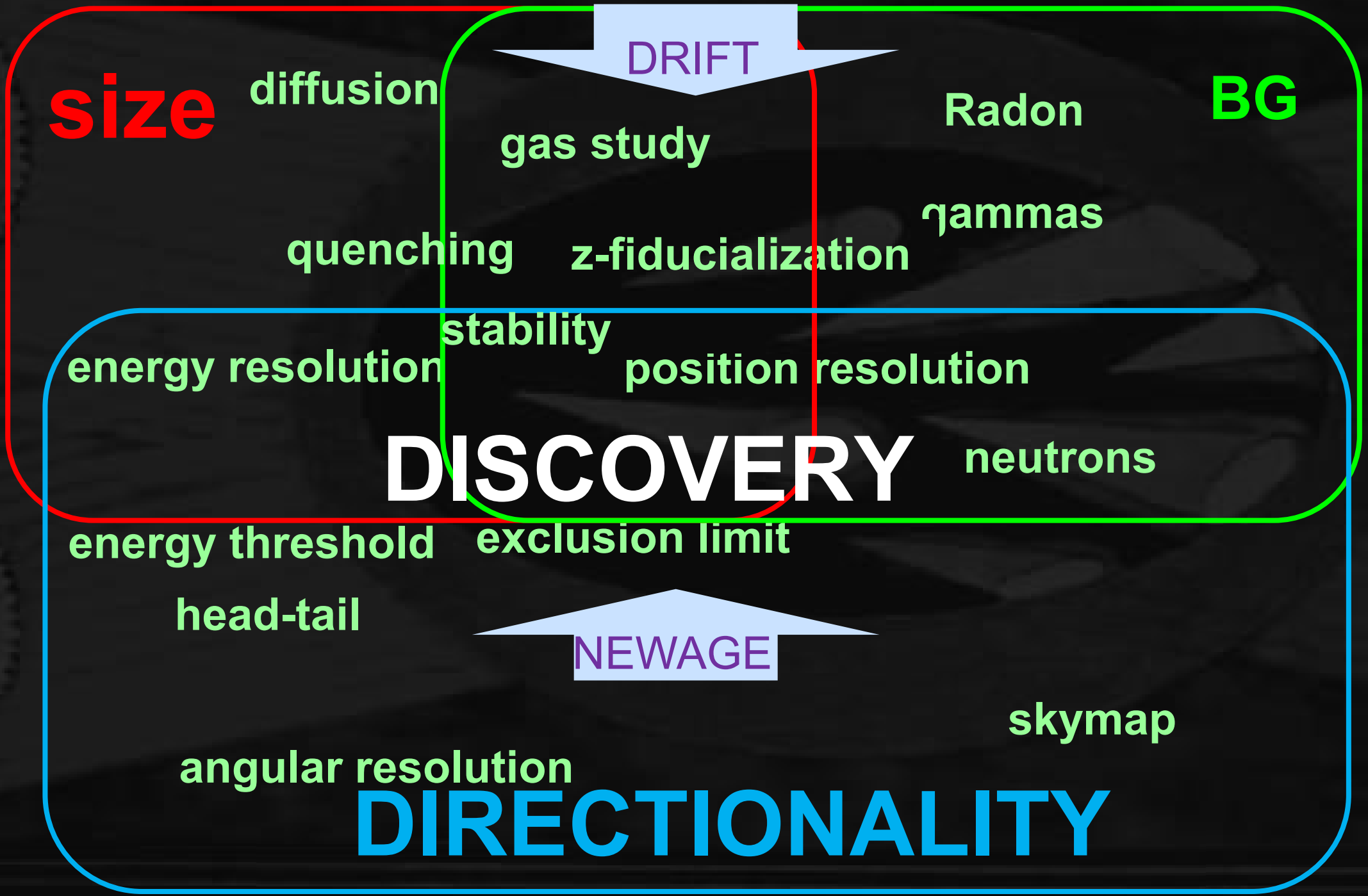
a few mm in low pressure gas
a few 100 nm in solid

Most typical “CYNGUS”: low pressure gas TPC

2D readout + timing
→ 3D tracking



NEWAGE strategy since its new ages

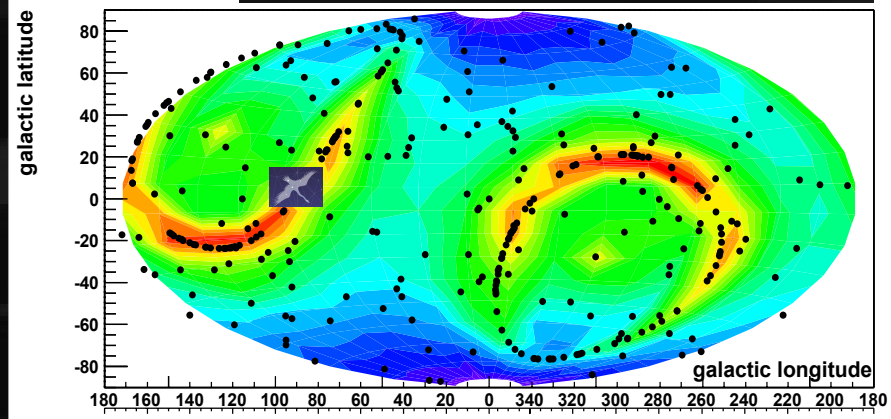


NEWAGE: always direction-sensitive

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

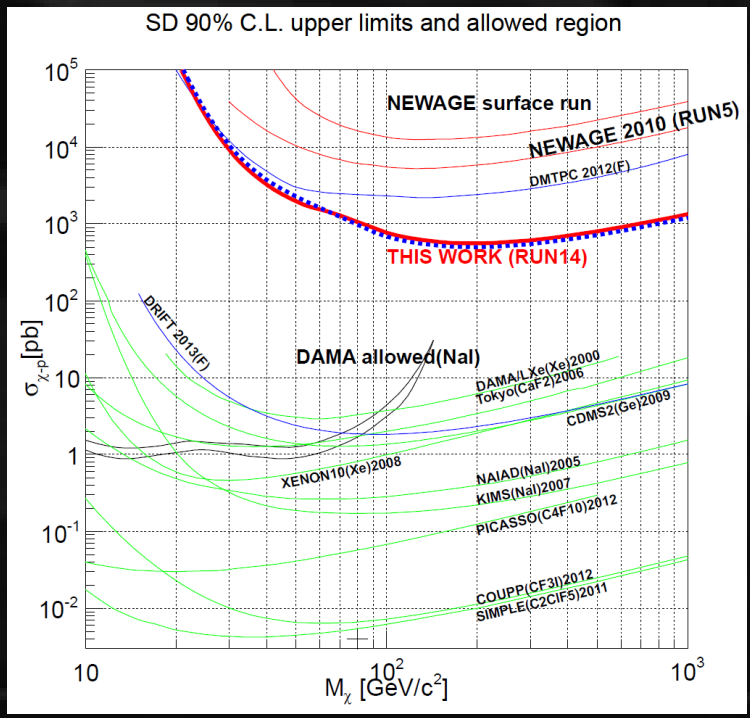
SKYMAP (measured DATA)



- **Proposal** PLB 578 (2004) 241
- **First direction-sensitive limits**

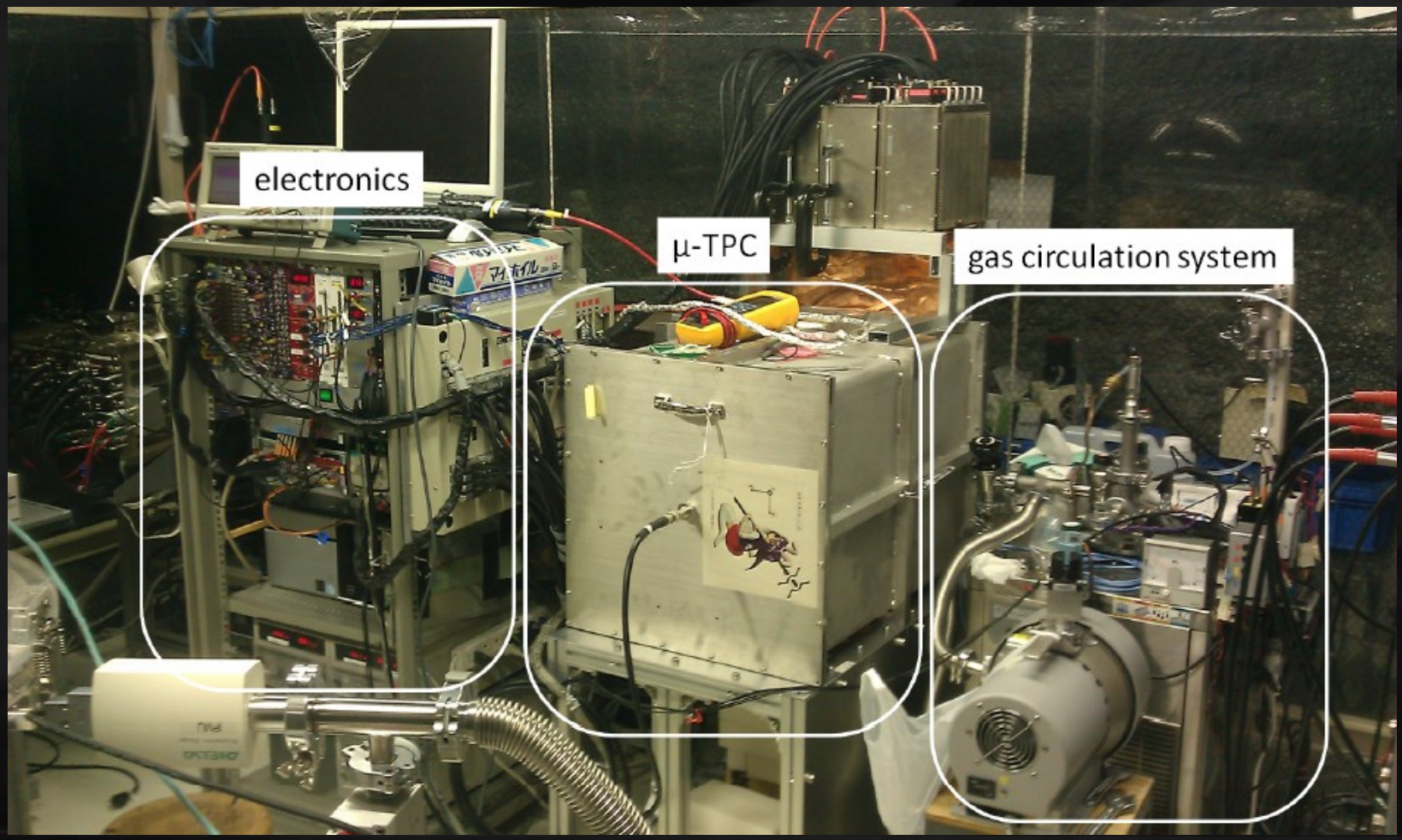
  PLB654 (2007) 58
- **Underground results**

  PLB686 (2010) 11, PTEP (2015) 043F01s
- **Phase for "low BG detector"**



NEWAGE detector

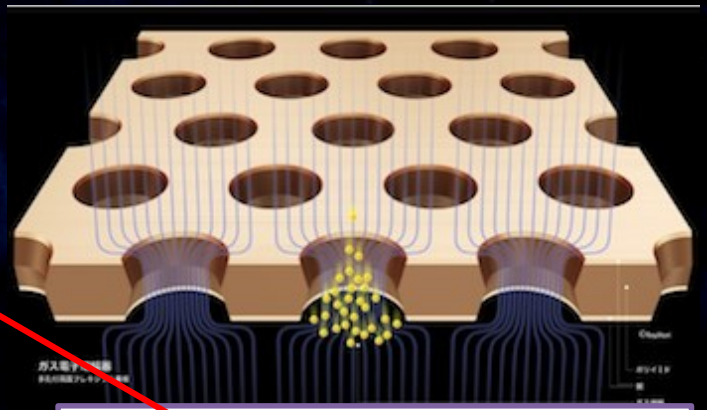
- NEWAGE-0.3b'
- Detection Volume: 31×31×41cm^3
- Gas: CF4 at 0.1atm (50keVee threshold)
- Gas circulation system with cooled charcoal

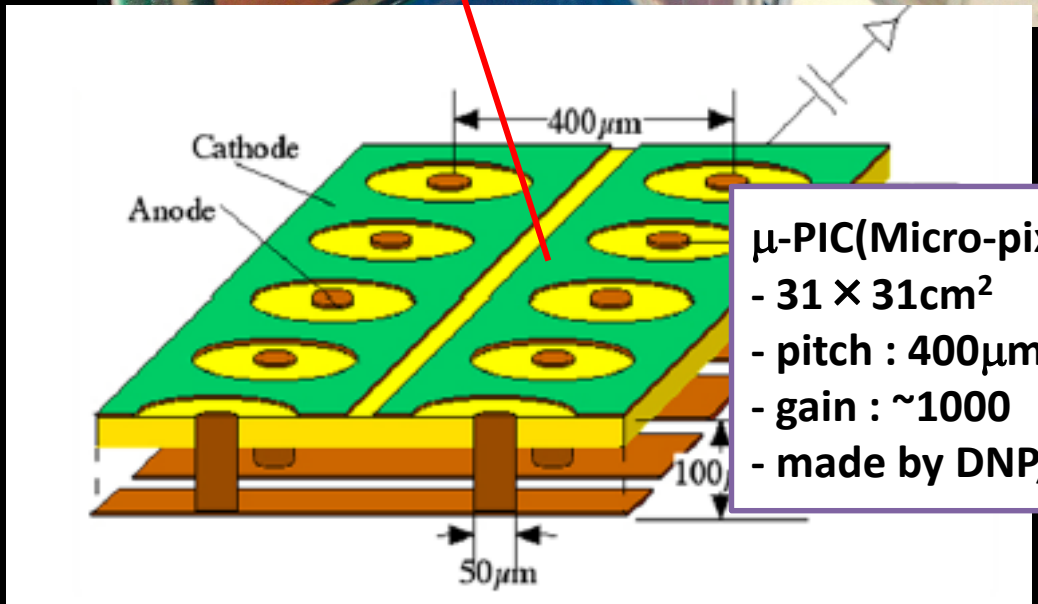


NEWAGE-0.3b' inside view

Detection Volume: 30×30×41cm^3

Field cage
Drift length: 41cm
PEEK + copper wires



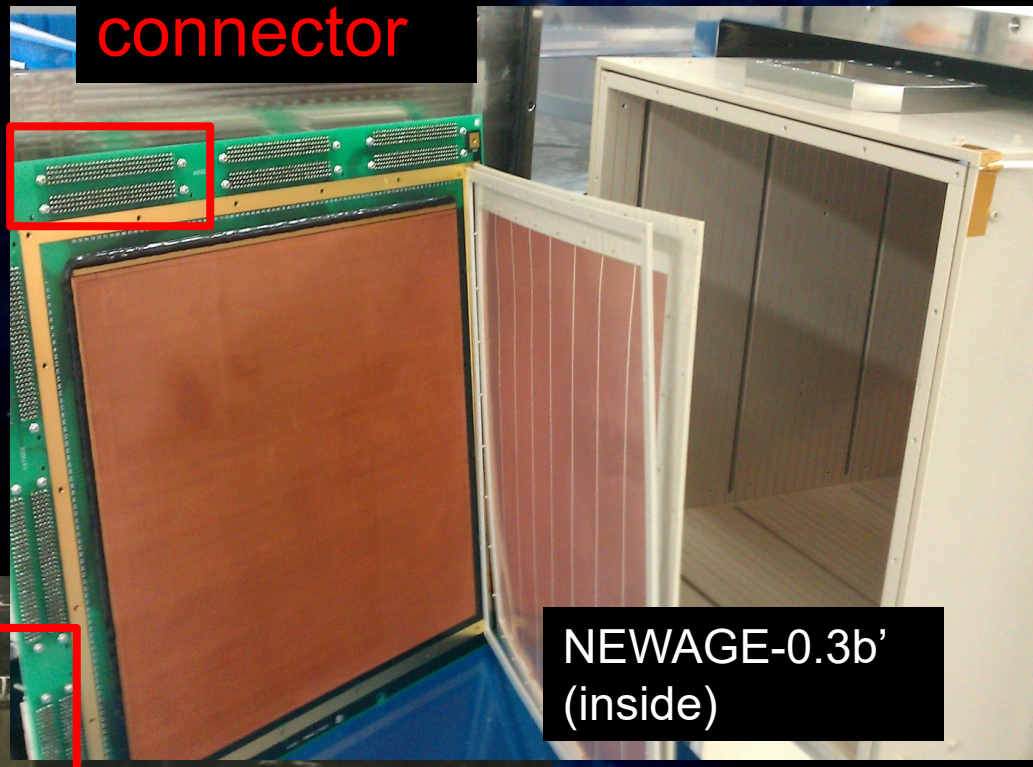


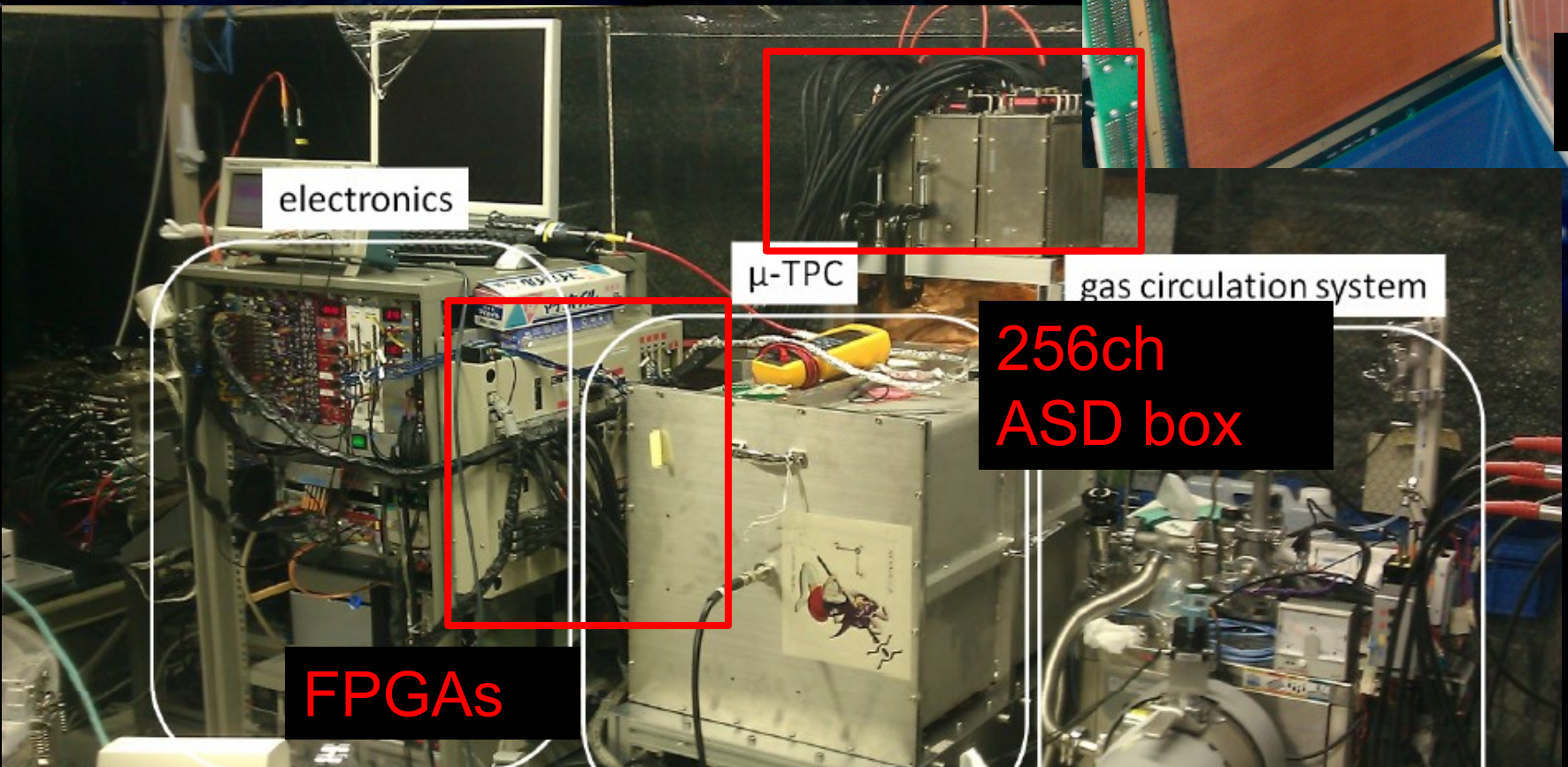
μ-PIC(Micro-pixel chamber)
- 31×31cm^2
- pitch : 400μm
- gain : ~1000
- made by DNP, Japan

GEM
- 31×32 cm^2
- 8-segmented
- hole pitch : 140μm
- hole diameter: 70μm
- insulator : LCP 100μm
- gain : ~5
- made by Scienergy, Japan

NEWAGE-0.3b' readouts

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



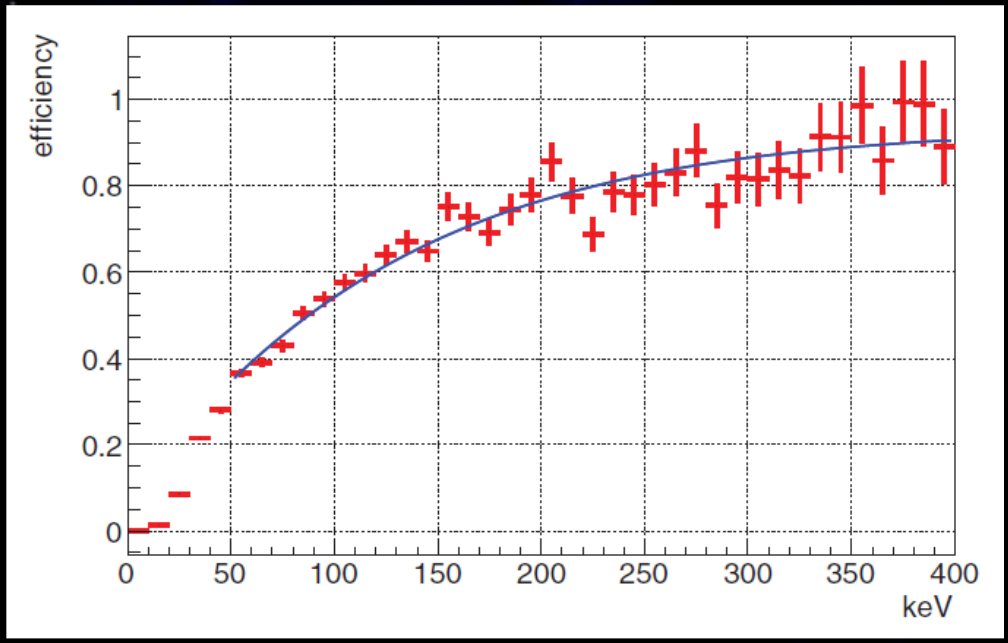


NEWAGE-0.3b' performance

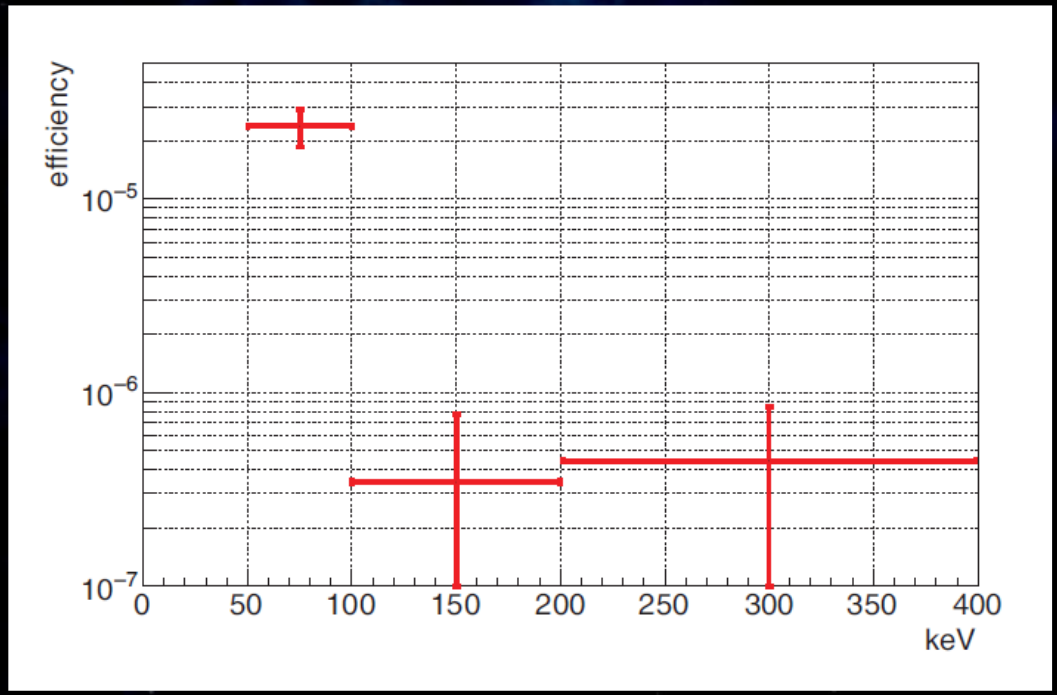
PTEP (2015) 043F01s

- nuclear tarck 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



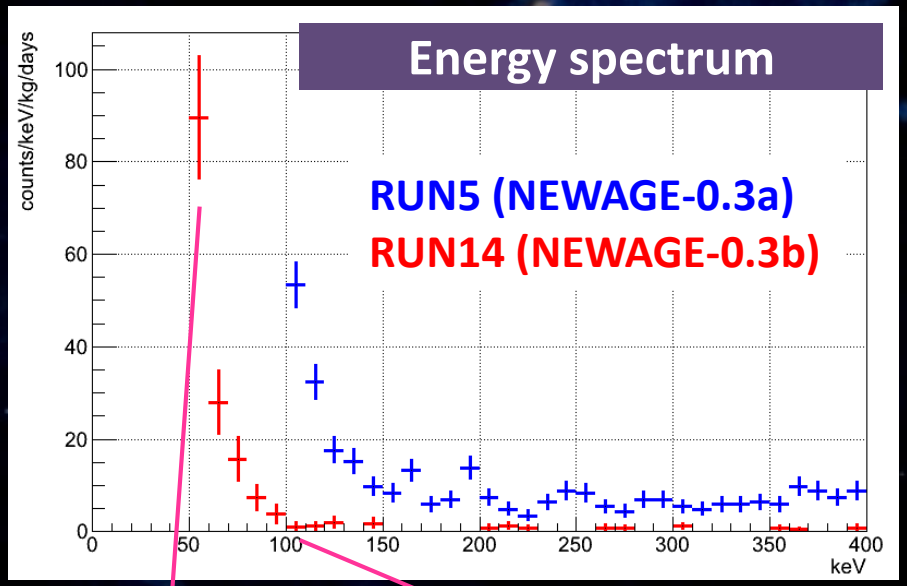
electron track detection efficiency
(gamma rejection factor)



NEWAGE
Kamioka run

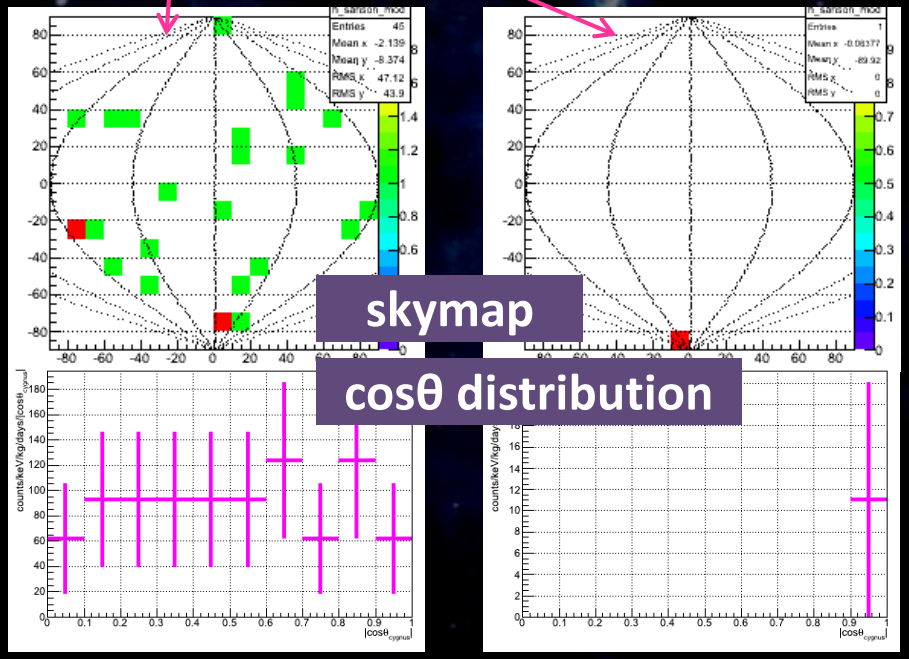
NEWAGE underground run

RUN14
- period : 2013/7/20-8/11, 10/19-11/12
- live time : 31.6 days
- fiducial volume : 28x24x41cm^3
- mass : 10.36g
- exposure : 0.327 kg･days



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

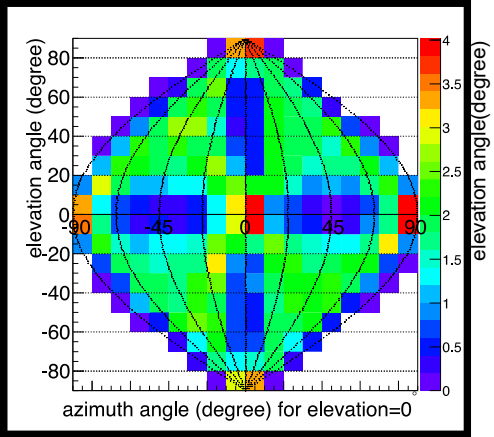
- *Skymap, cosθ distribution*
  - Set limit by significant difference in 2-binned measured cosθ and DM-wind simulated cosθ

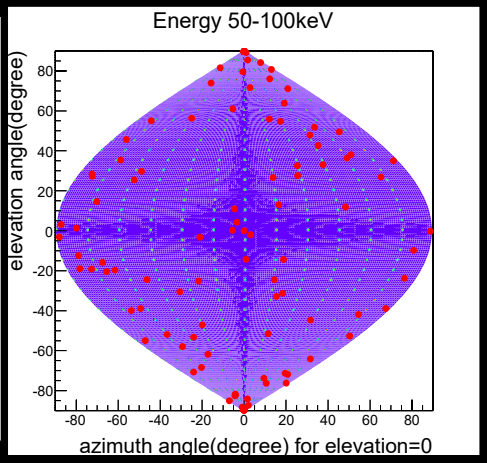


Galactic-plane sky-map

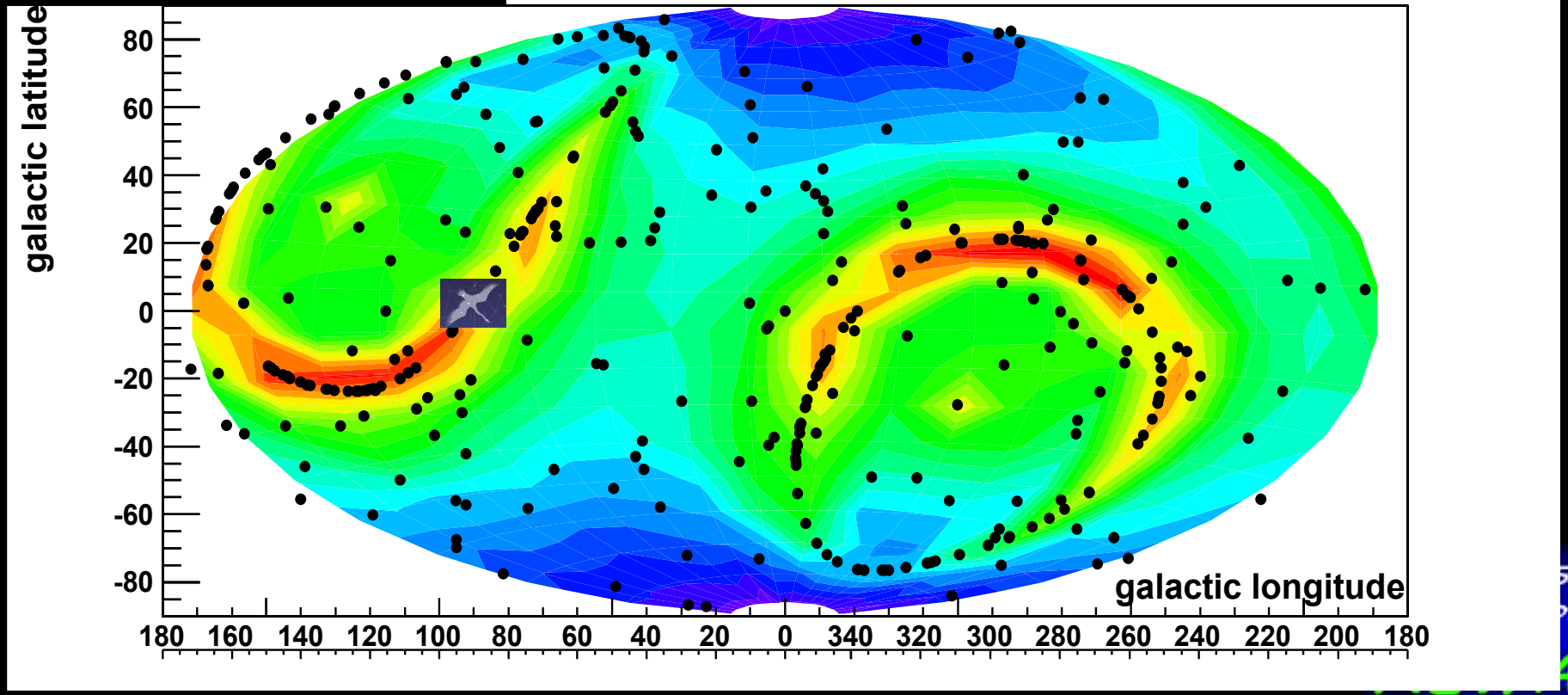
lab-coordinate

- correlation with efficiency = consistent with isotropic

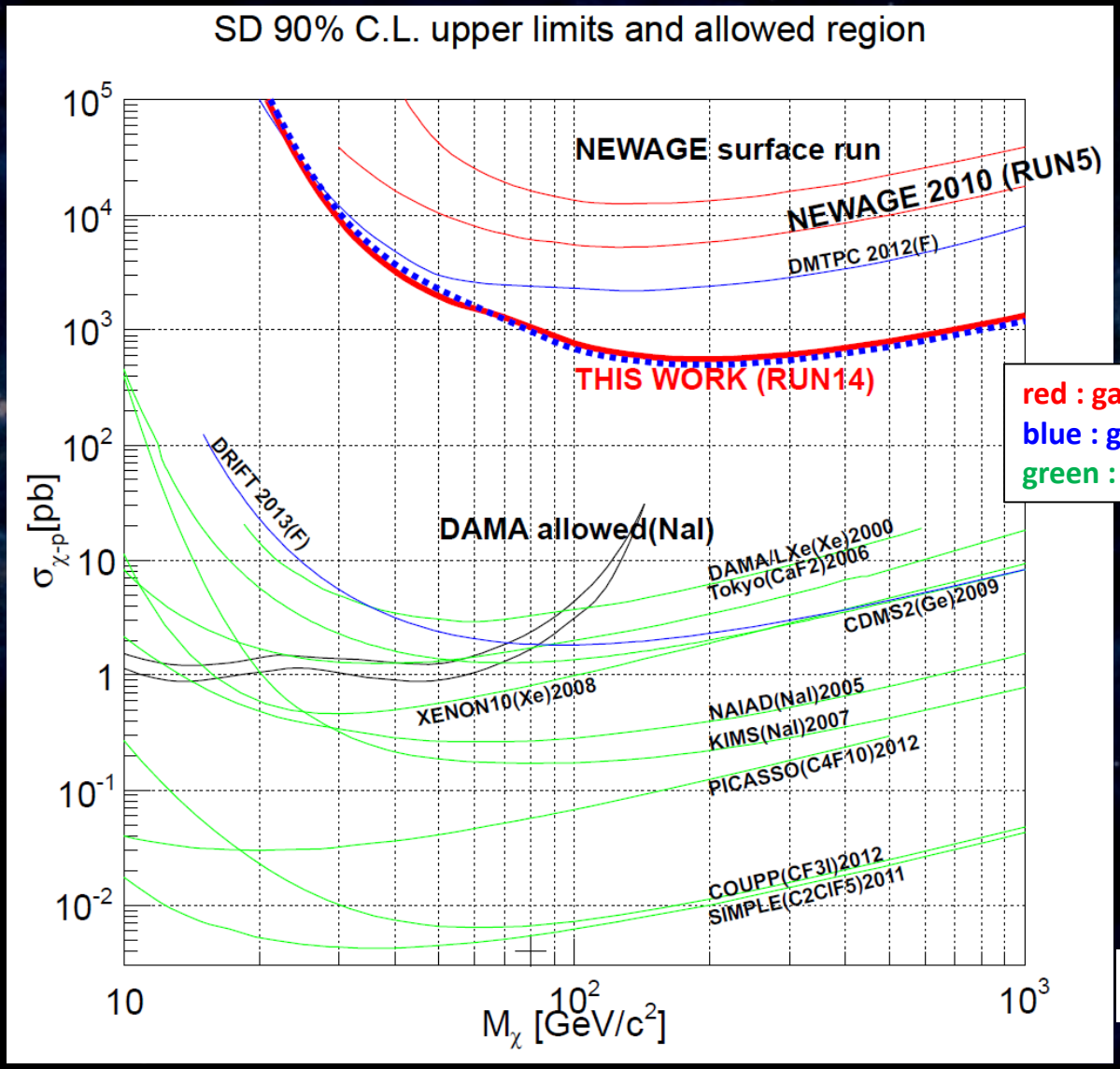




galactic coordinate



Direction-sensitive limit



red : gas, with directional analysis
blue : gas, without directional analysis
green : solid, liquid detector

PTEP (2015) 043F01s

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

Recent R&Ds

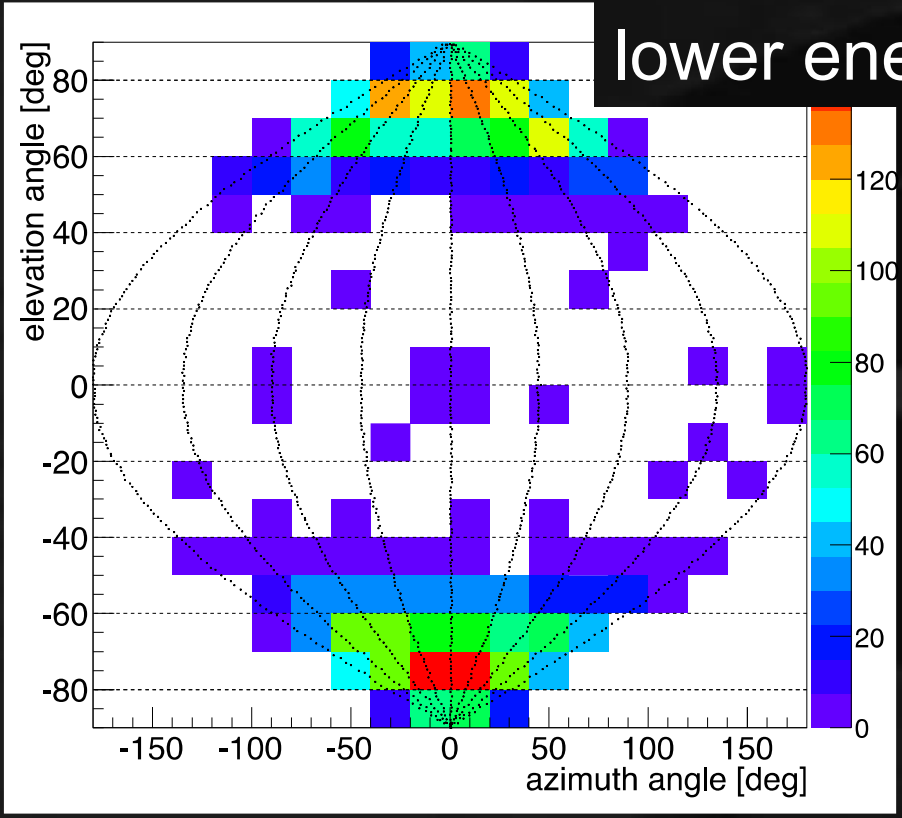
BG study

Directionality helps!

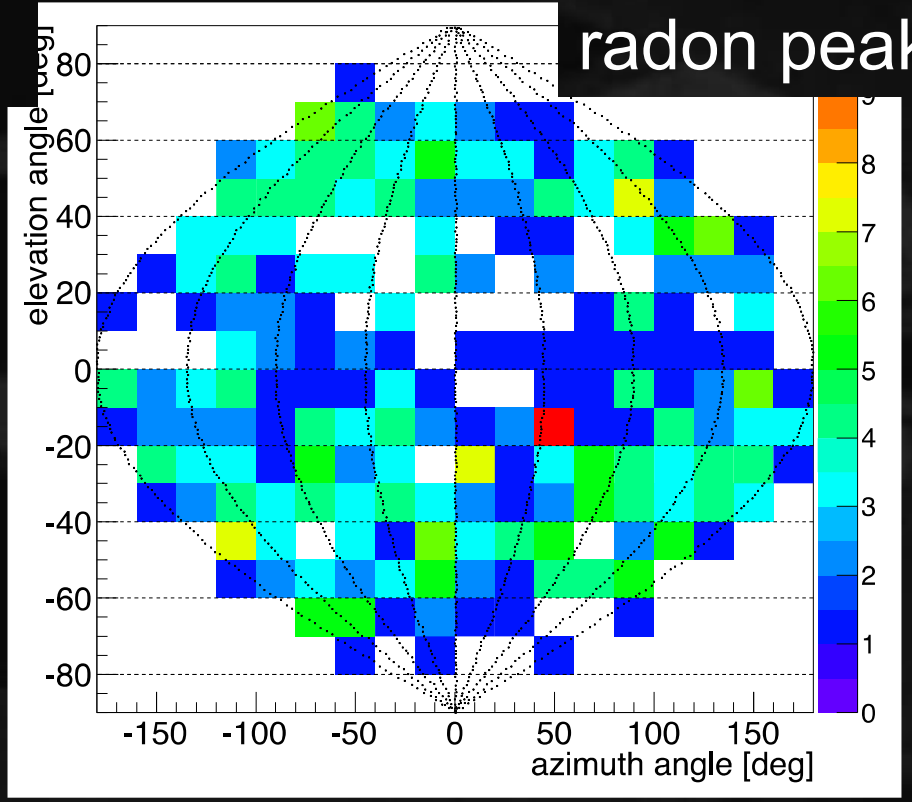
SKYMAP @ detector coordinate

color: number of events

lower energy



radon peak

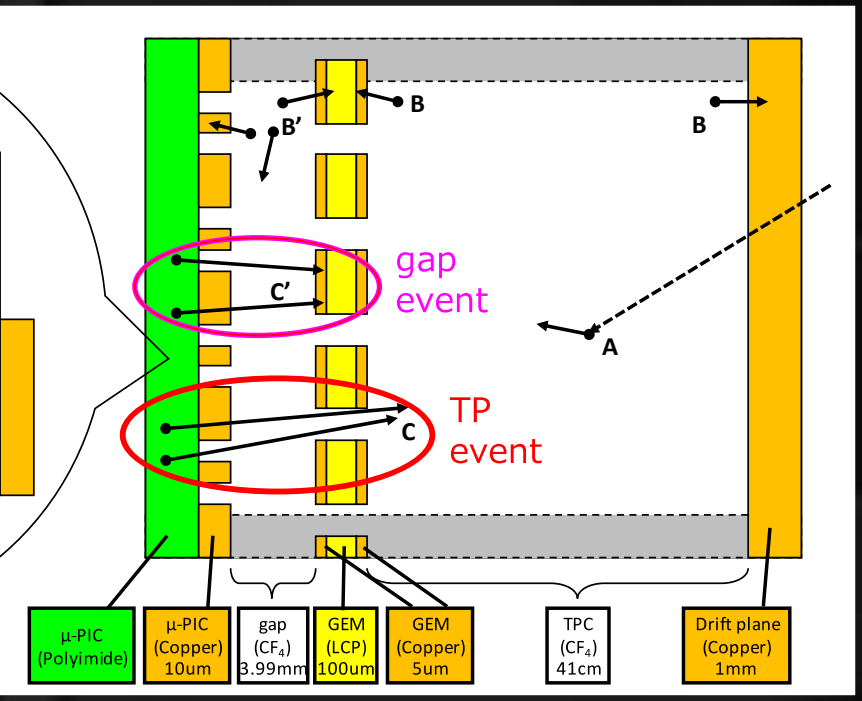


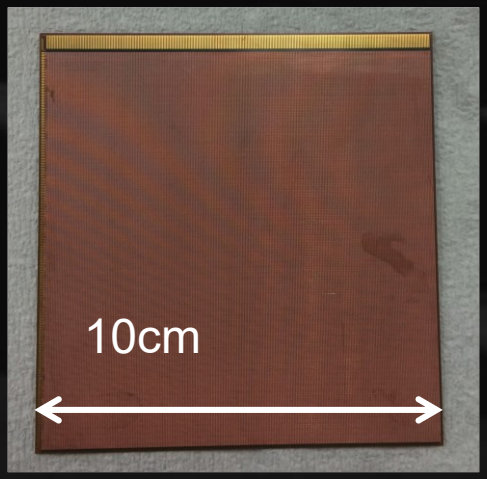
BG identified: upgoing events

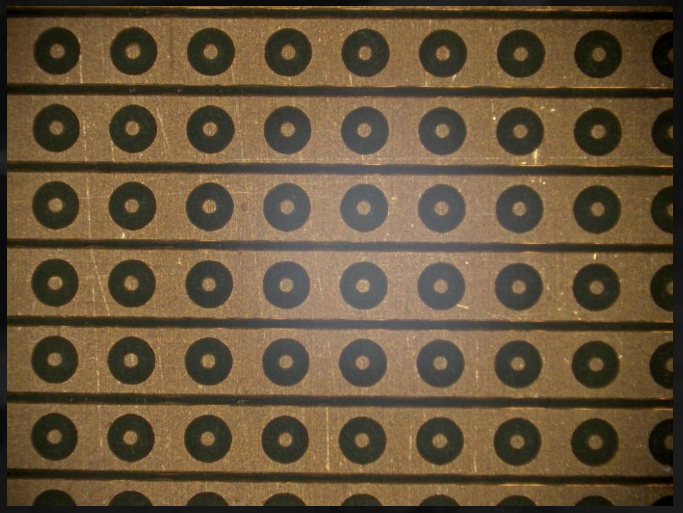
NEWAGE

Low BG R&Ds

- Largest BG source: alpha particle from μ-PIC
- Development of radio-pure(BG×1/100) μ-PIC: 10×10cm^2 μ-PIC was made and tested







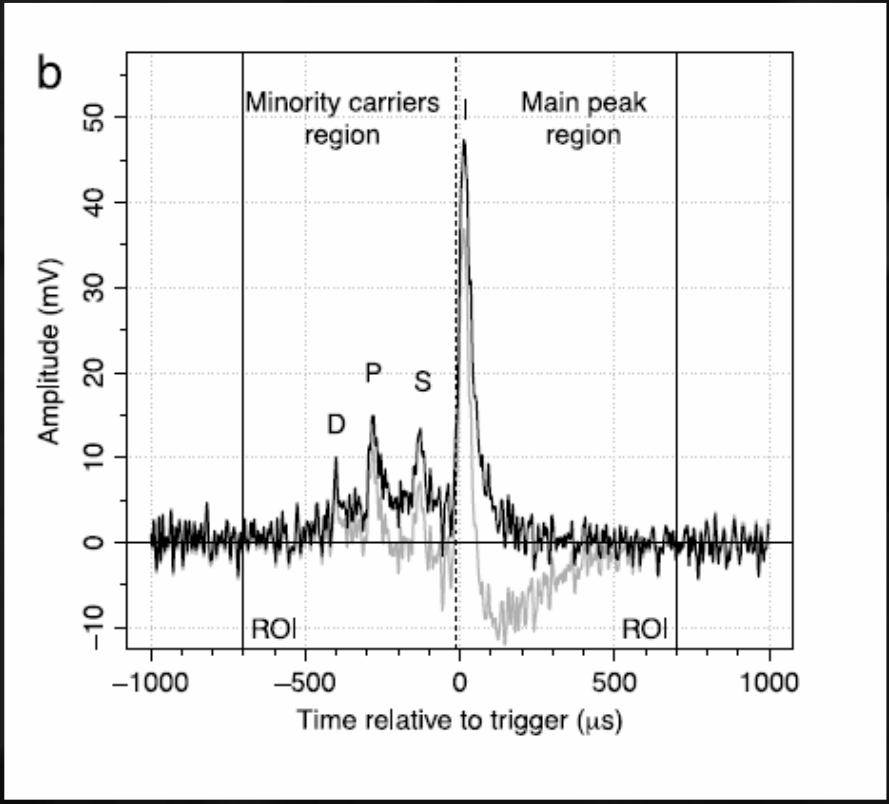
- FY2016: development of 30×30cm^2 μ-PIC
- FY2017~: underground run

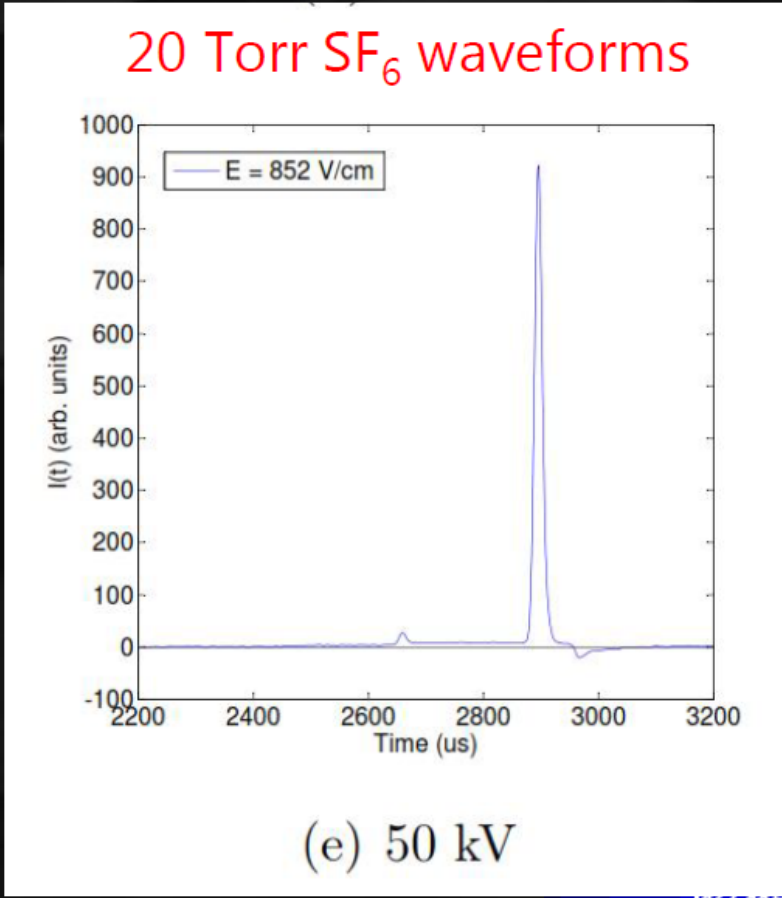
Direction Sensitive WIMP-search NEWAGE

Z-fiducialization

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

minority peaks (DRIFT group)





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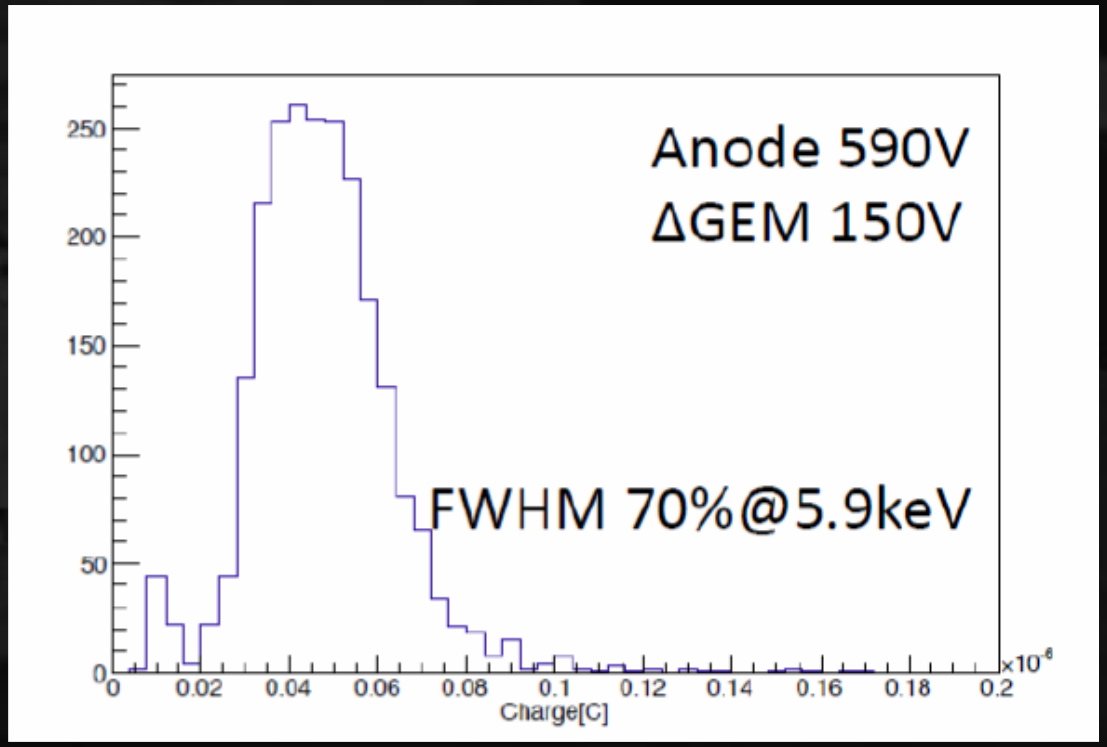
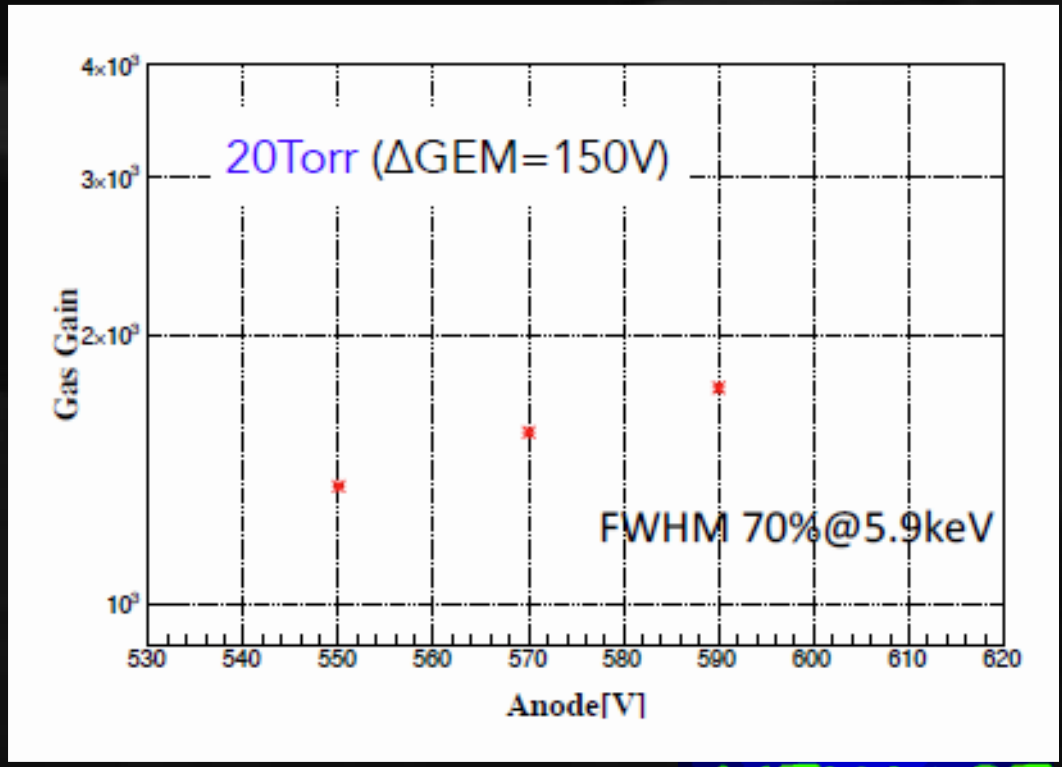
NEWAGE SF_6 study (by Tomonori Ikeda)

- SF_6 study for GEM+μPIC system
- Wide dynamic-range ASIC development

SF6 study (NEWAGE)



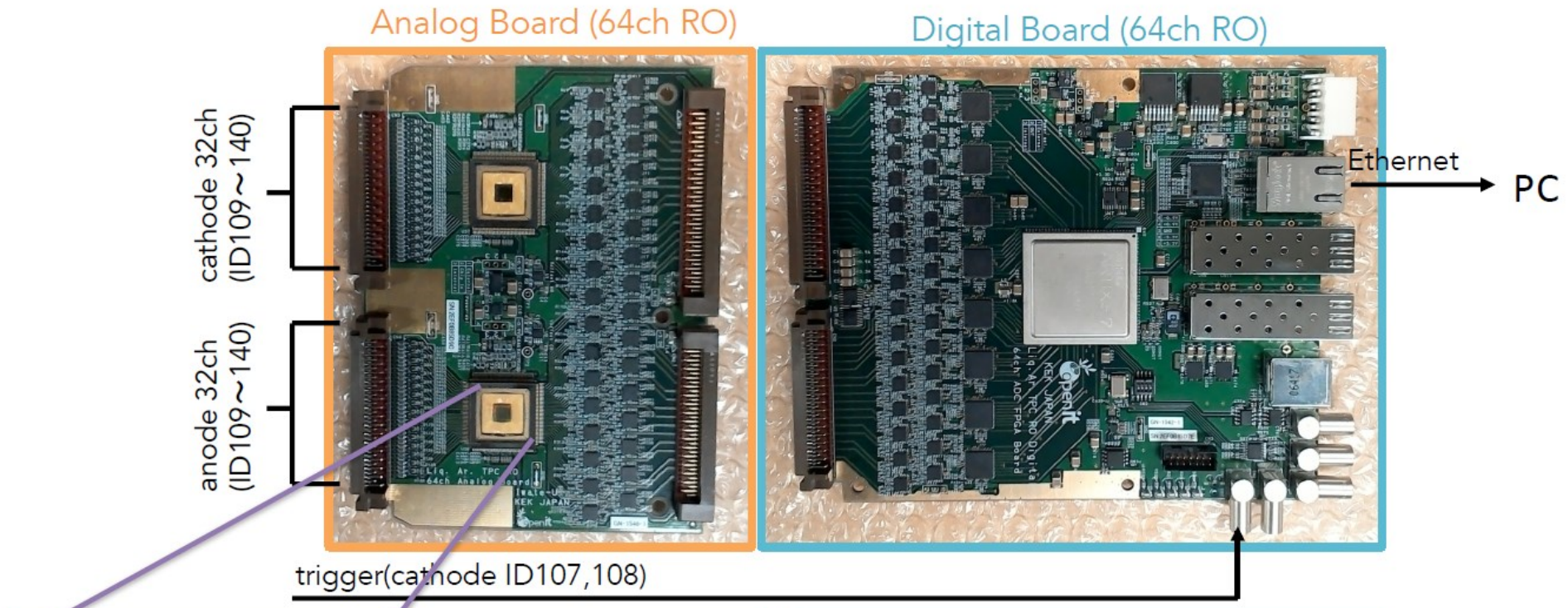
SF6 study (NEWAGE)

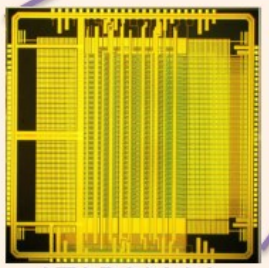


NEWAGE

Erectronics

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

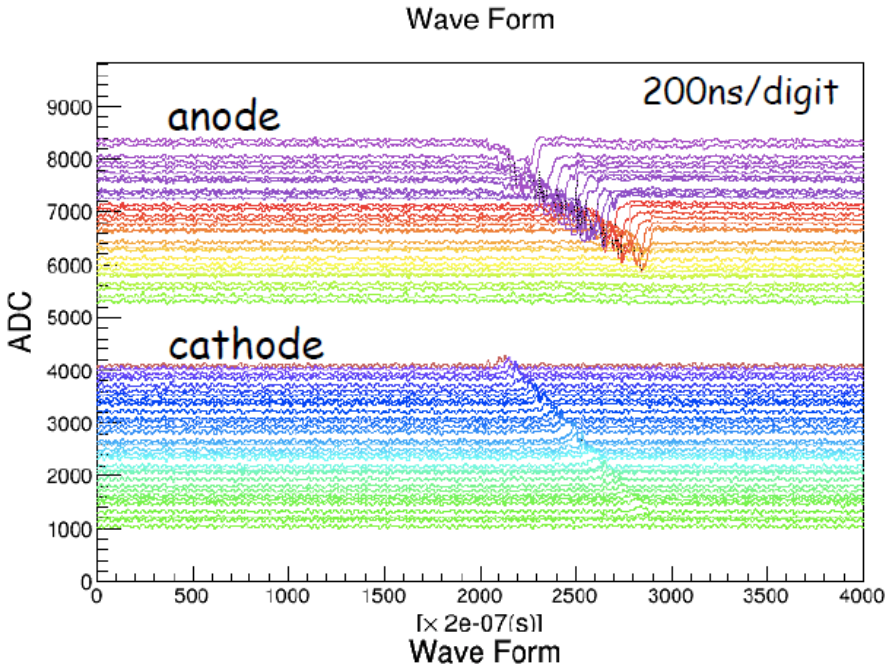


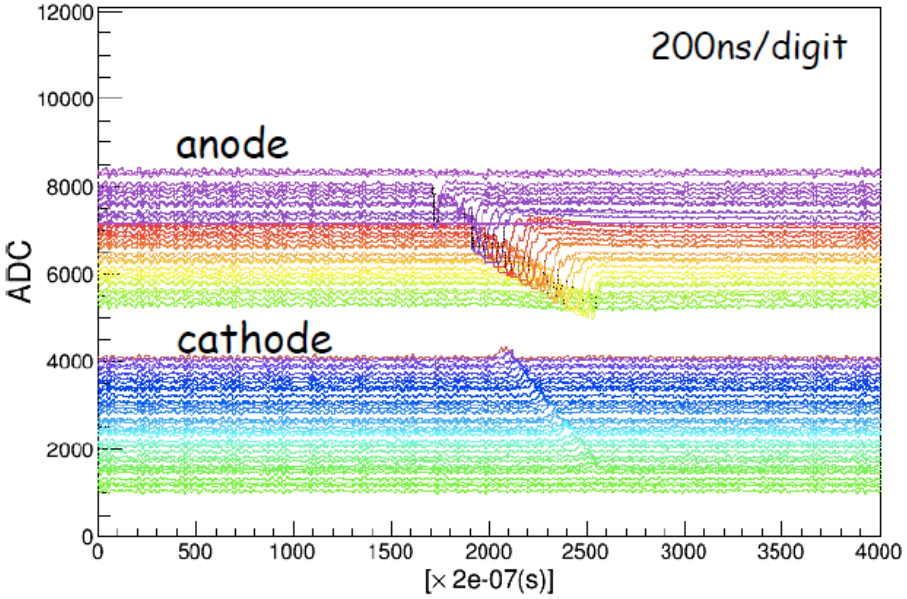

LTARS2014

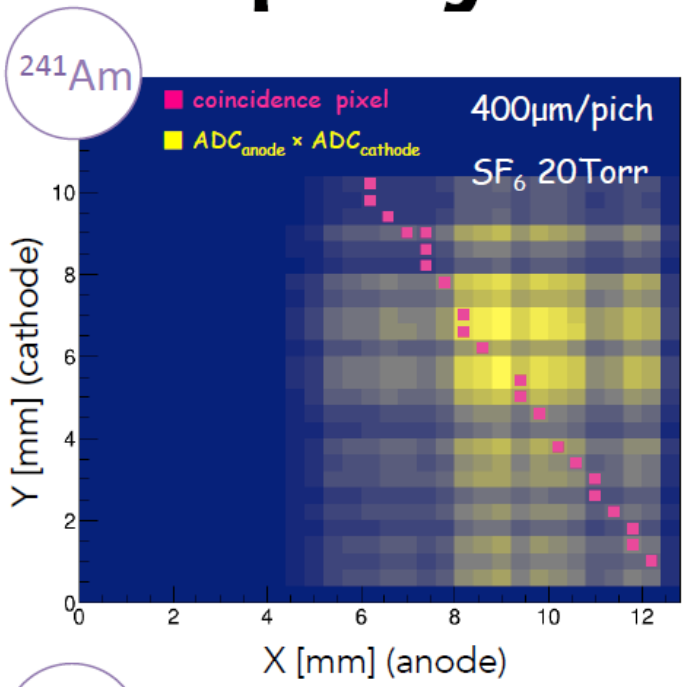
Conversion gain : ～9.0mV/fC
Max input charge : 60~100fC
ENC : below 2000@300pF
Shaping time : 1us

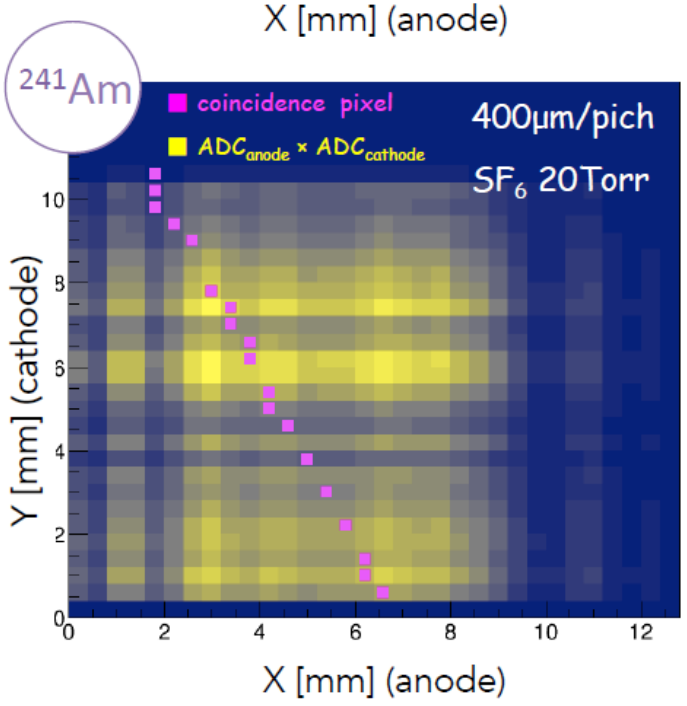
32ch differential inputs(2Vpp)
12bits FADC
4000 sampling
Sampling frequency <20MHz

Alpha Event Display





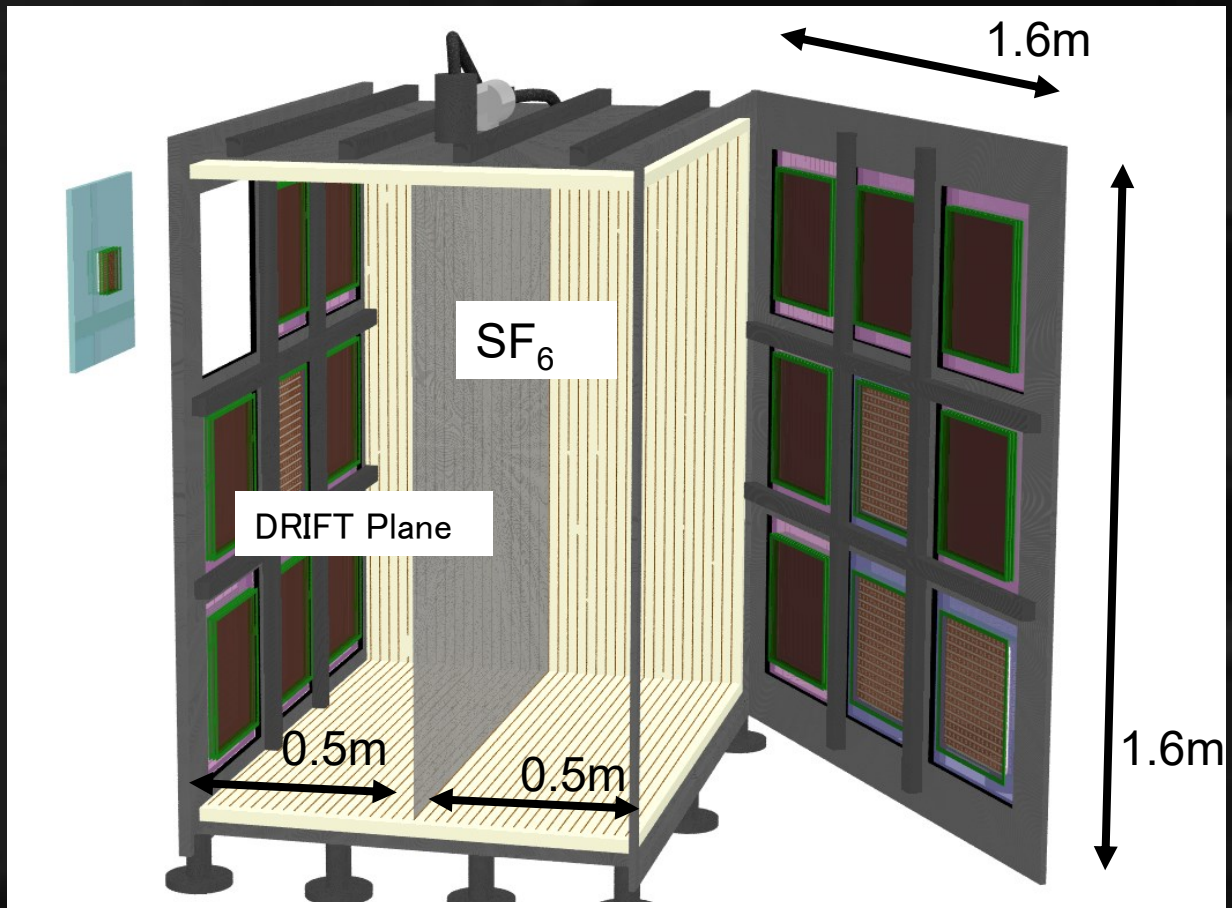




irection Sensitive
WIMP-search
EWAGE

scaling-up: modulated chamber

- will be ready by Apr 2017
- μ-PIC, GEMs, micromegas, pixels, MWPCs…



CYGNUS/NEWAGE vessel
40cm modules

Direction Sensitive WIMP-search NEWAGE

Summary

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

Direction Sensitive
WIMP-search
NEWAGE

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]

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[b] *Department of Physics, Temple University, 1900 N. 13th Street, Philadelphia, PA 19122-6082, USA*

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Neutron recoils in the DRIFT detector

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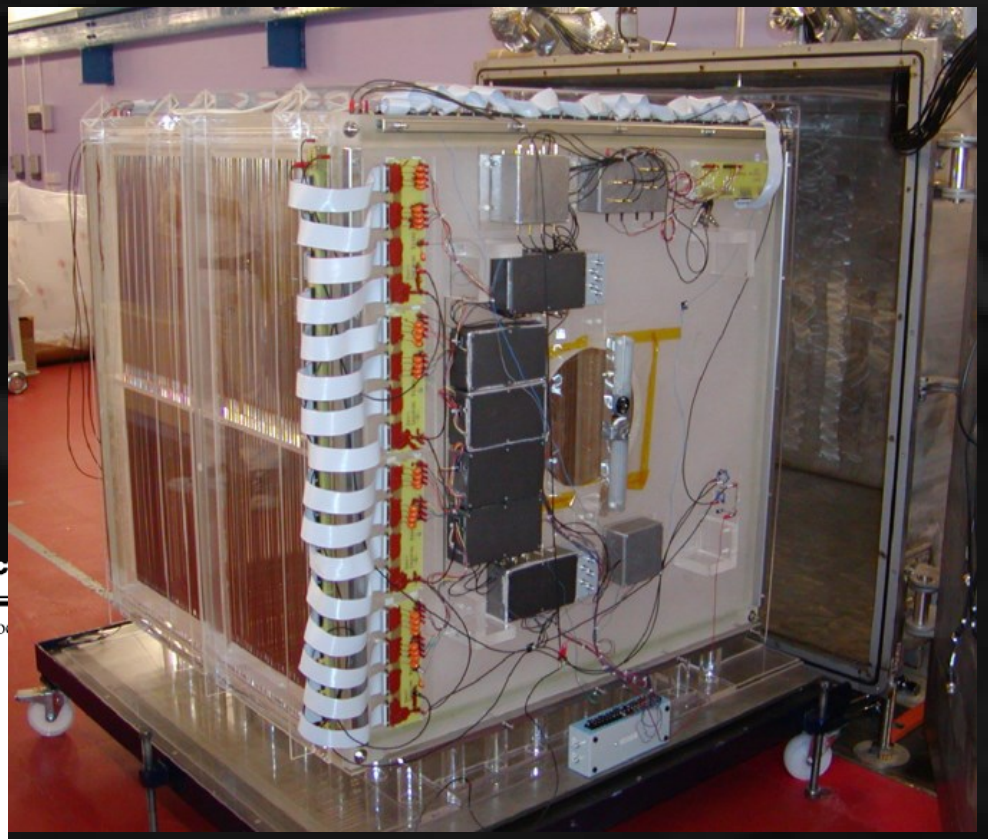

- 2mm pitch multi-wire proportional chamber
- not very direction-sensitive

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