NEWAGE / CYGNUS strategy

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DarkOn 2017

Contents

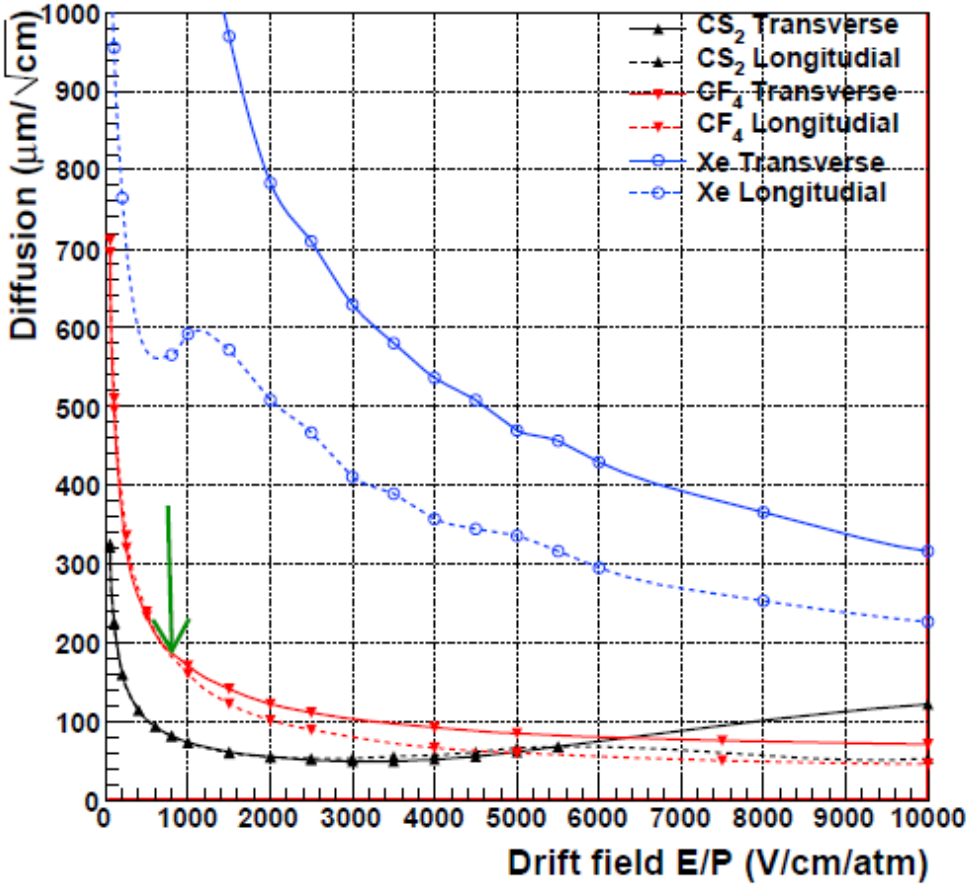
Dark Matter Direct detection

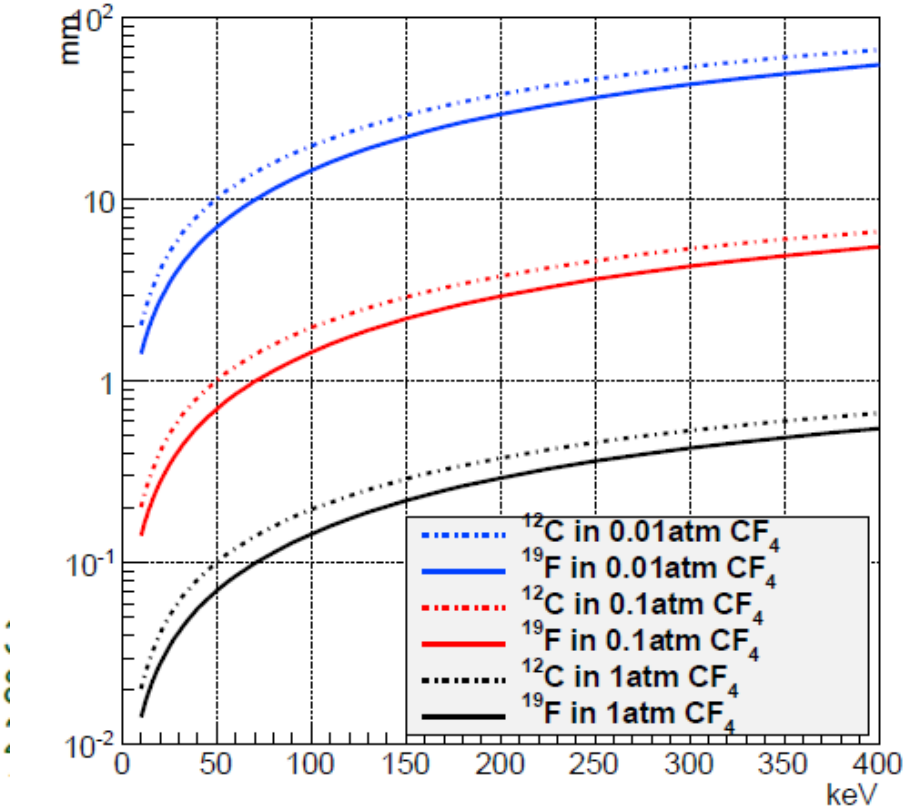
Physics

Experiments

科研費 KAKENHI

飛跡長と拡散

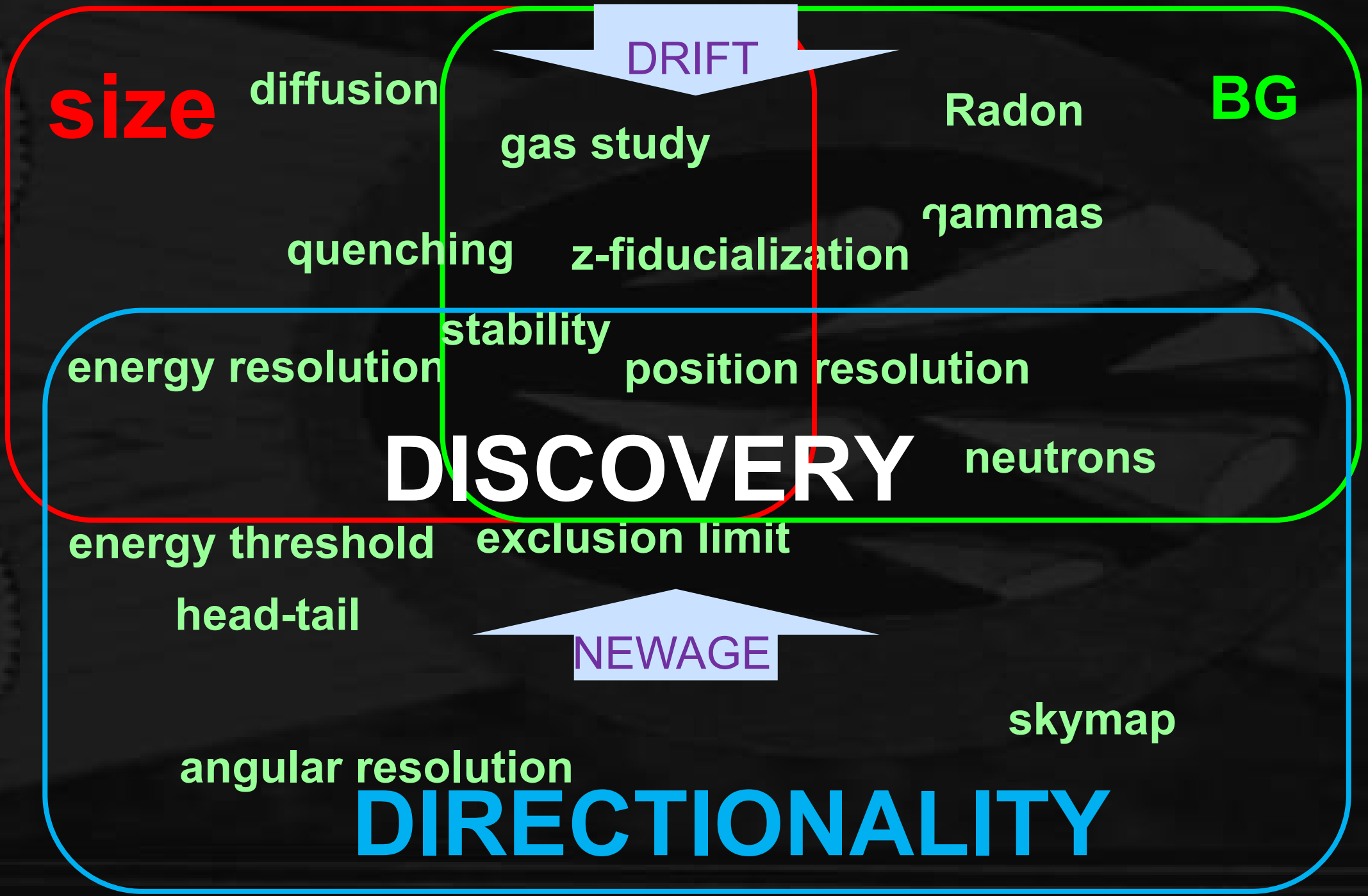




ength of recoil ^{12}C(dotted line) and ^{19}F(solid line) in CF_4 gas calculate
lue:0.01atm, red:0.1atm, black:1.0atm).

200um/sqrt(cm)
→1.2mm@40cm

NEWAGE strategy since its new ages

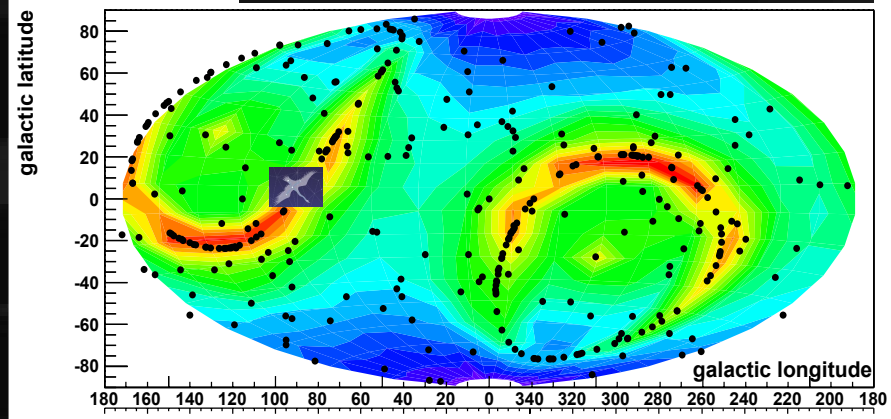


NEWAGE: always direction-sensitive

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

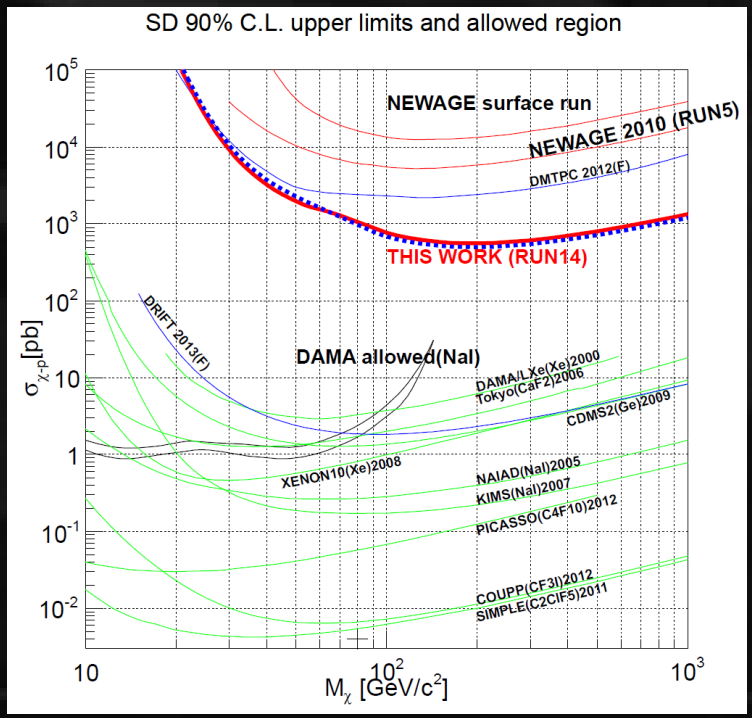
SKYMAP (measured DATA)



- 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”



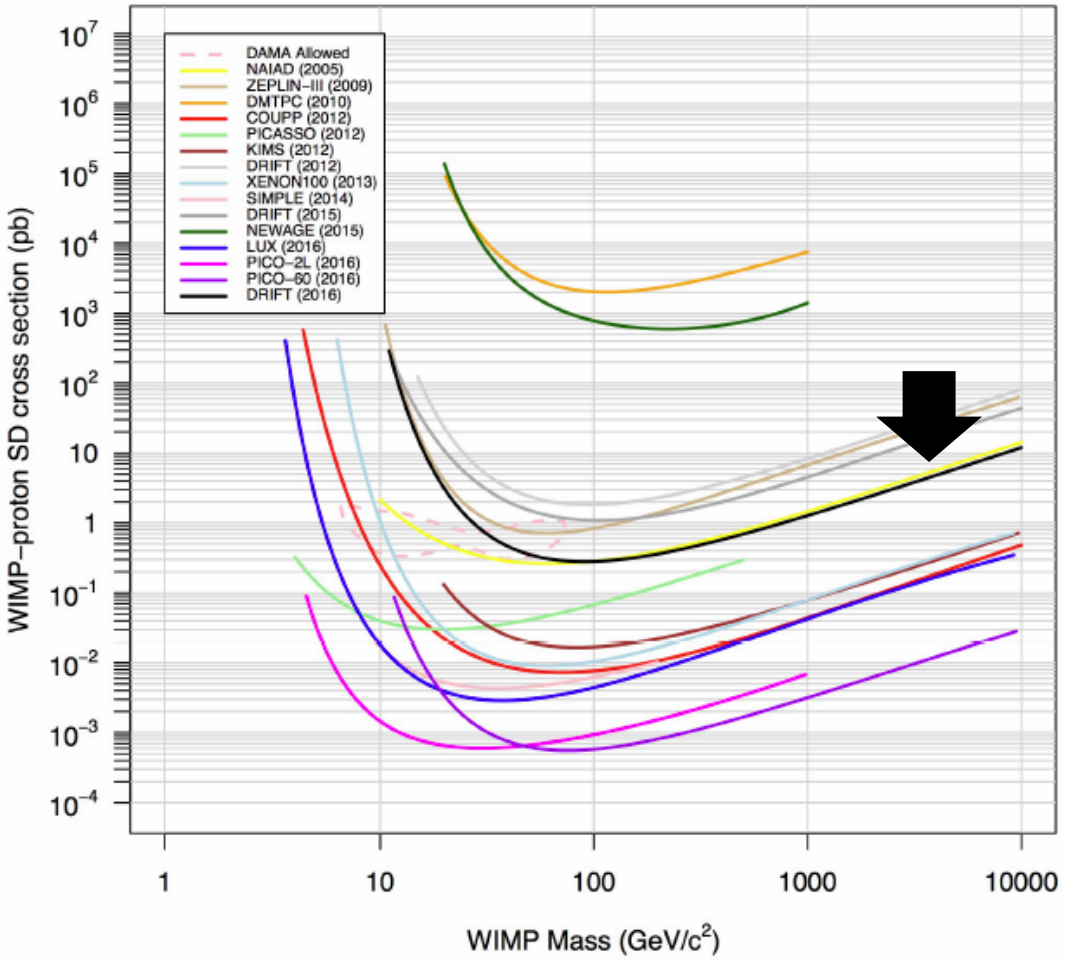
DRIFTはdirection sensitive?

- yes, but not direction-sensitive analysys

Low Threshold Results and Limits from the DRIFT Directional Dark Matter Detector

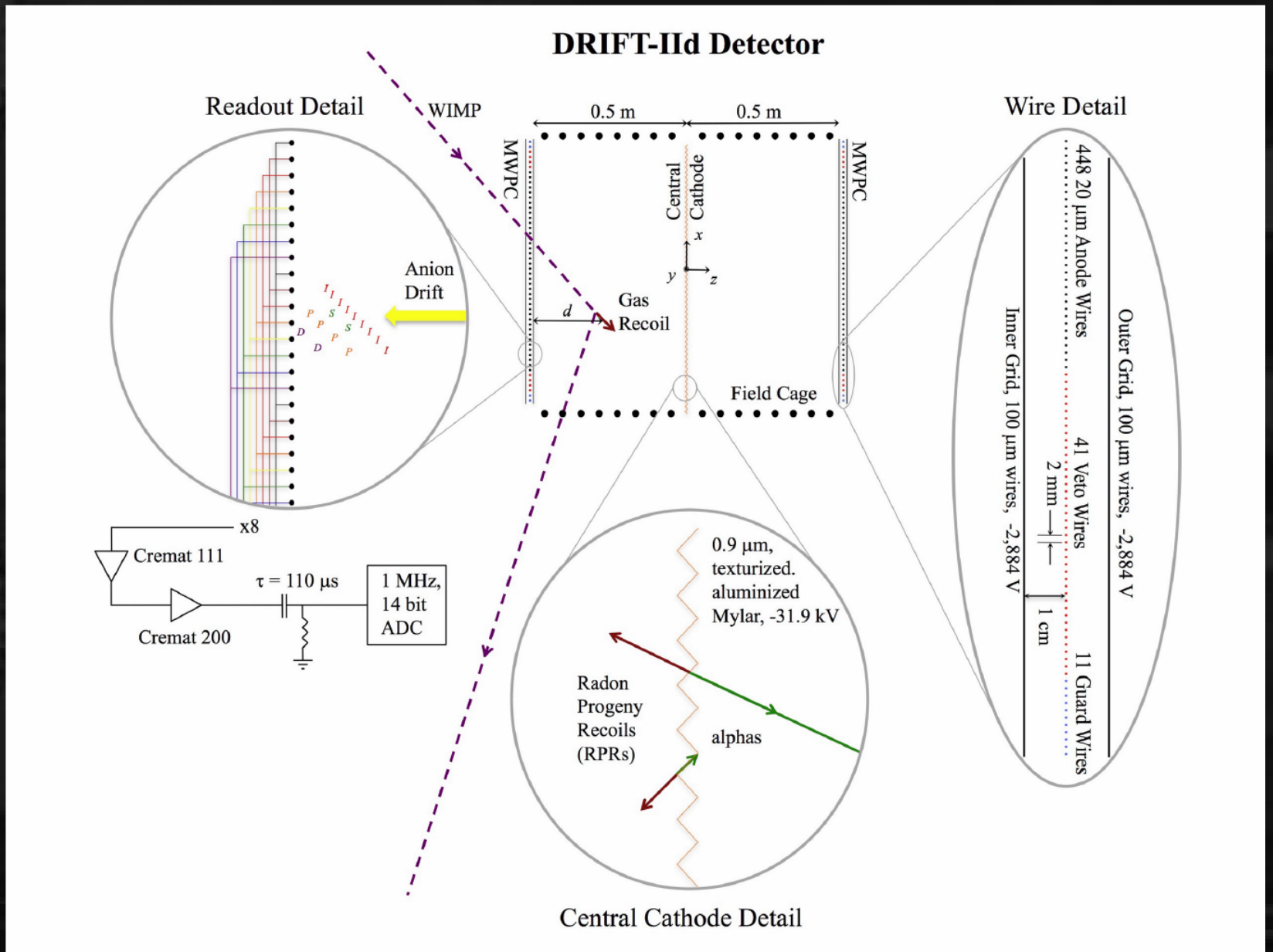
J.B.R. Battat,[1] A.C. Ezeribe,[2,6] J.-L. Gauvreau,[3] J. L. Harton,[4] R. Lafler,[5] E. Lee,[5] D. Loomba,[5] A. Lumnah,[3] E.H. Miller,[5] A. Monte,[3] F. Mouton,[2] S.M. Phan,[5] M. Robinson,[2] S.W. Sadler,[2] A. Scarff,[2] F.G. Schuckman II,[4] D.P. Sn N.J.C. Spooner,[2] and N. Waldram[3]

arXiV:1701.00171 (DRIFT collaboration)



DRIFTの”direction sensitive”は?

- x 2mm y 2mm <- VETO以外には使い物にならん
- z (drift方向)の時間発展のみ使用可能　だが解析では不使用



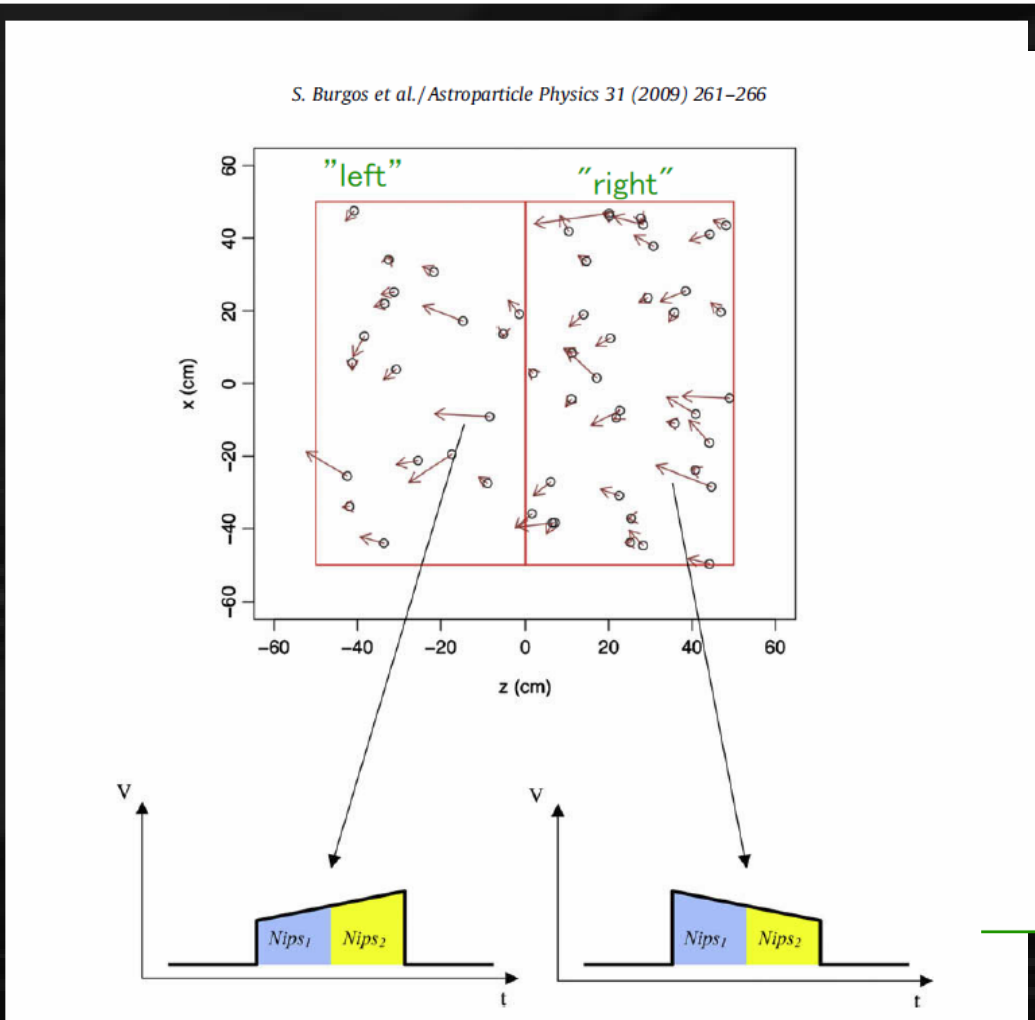
DRIFTの”direction sensitive”は?

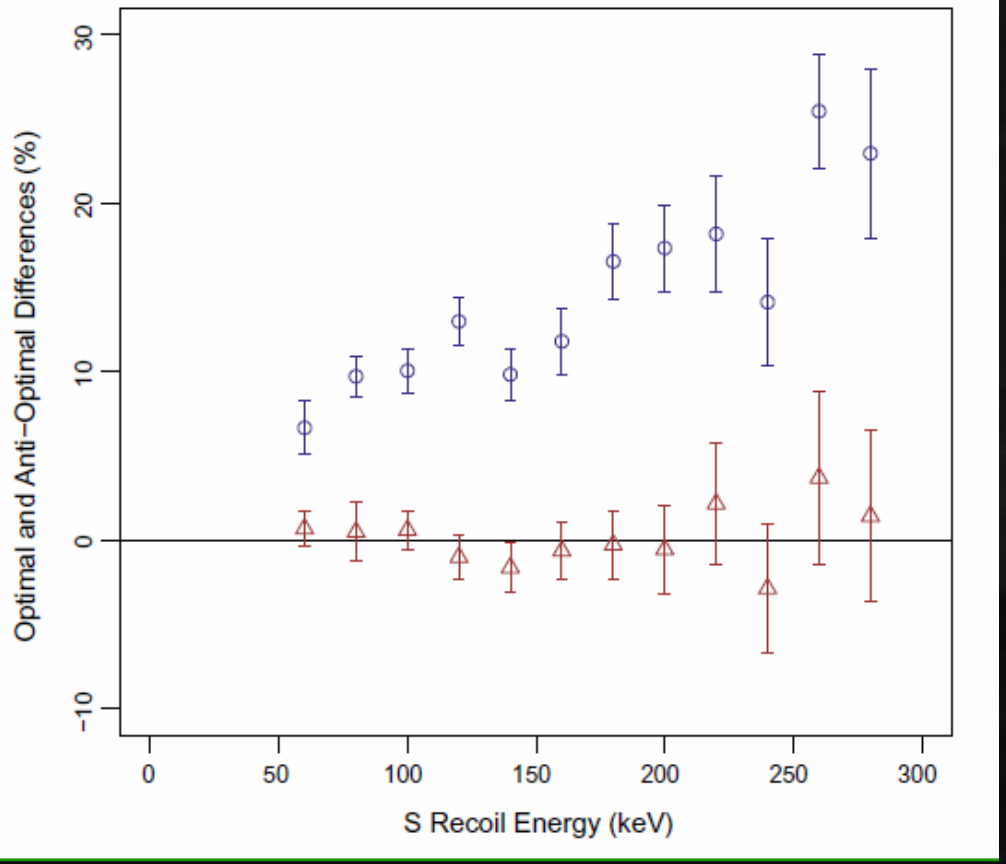
- z (drift方向)の時間発展のみ使用可能
- 右から来たか左から来たか　1000発あれば　統計的に識別可能

First measurement of the head–tail directional nuclear recoil signature at energies relevant to WIMP dark matter searches

Astroparticle Physics 31 (2009) 261–266

S. Burgos [a], E. Daw [b], J. Forbes [c], C. Ghag [d], M. Gold [d], C. Hagemann [d], V.A. Kudryavtsev [b], T.B. Lawson [b], D. Loomba [d], P. Majewski [b], D. Muna [b], A.StJ. Murphy [c], G.G. Nicklin [b], S.M. Paling [b], A. Petkov [a], S.J.S. Plank [c], M. Robinson [b], N. Sanghi [b], D.P. Snowden-Ifft [a,*], N.J.C. Spooner [b], J. Turk [d], E. Tziaferi [b]



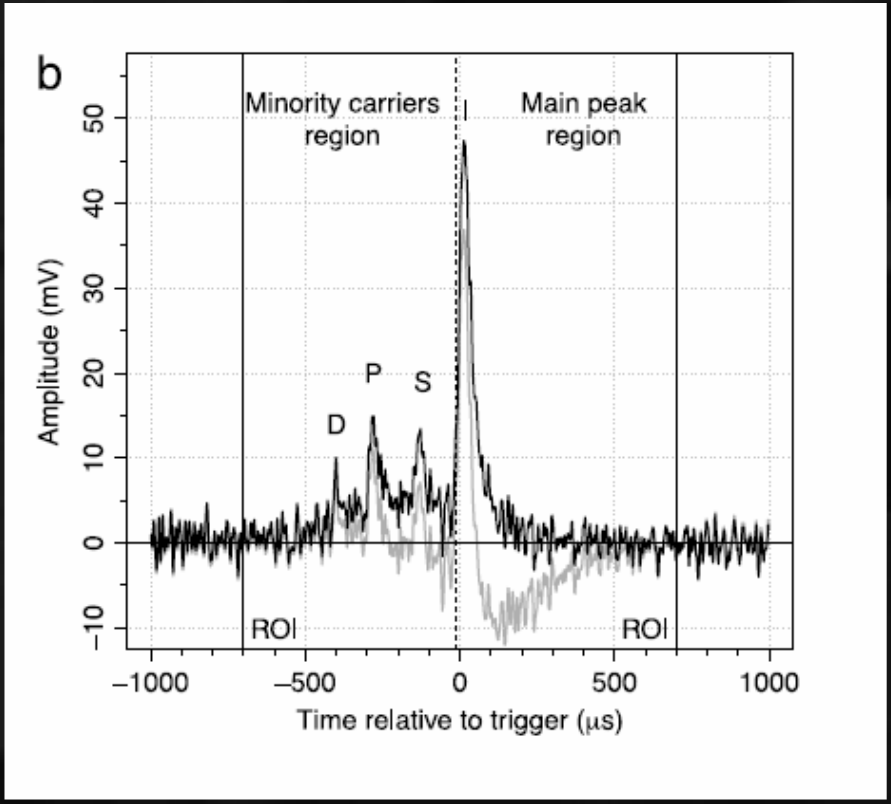


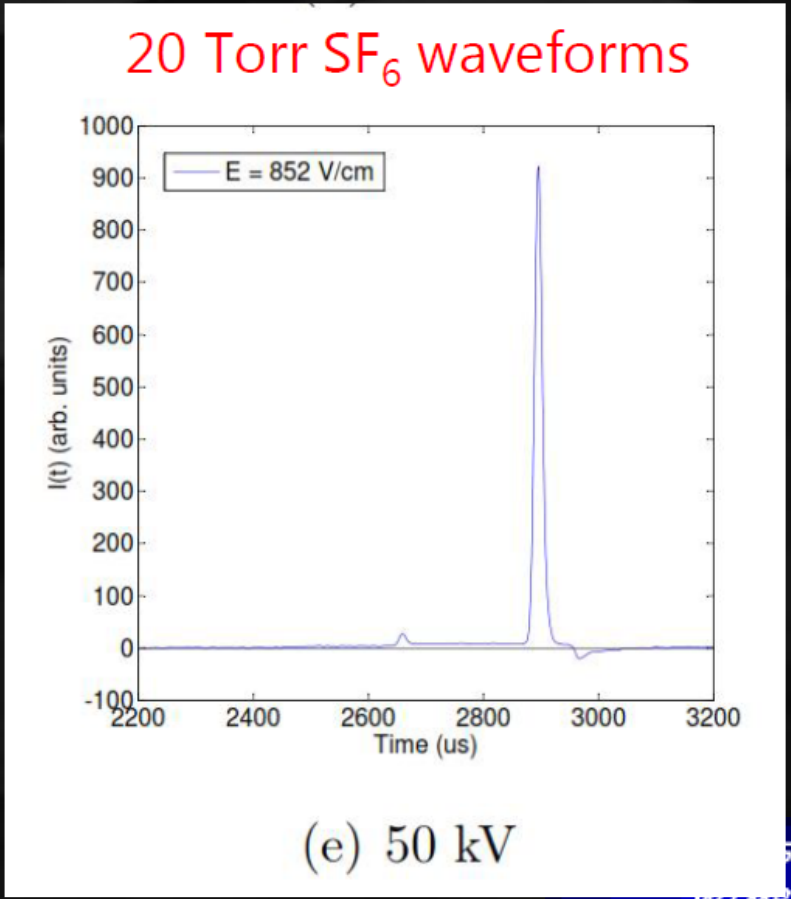
- **DRIFT**
  - best limit with directional detector
- **NEWAGE**
  - best limit with directional analisys

世界的なながれ：Z-fiducialization

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

minority peaks (DRIFT group)





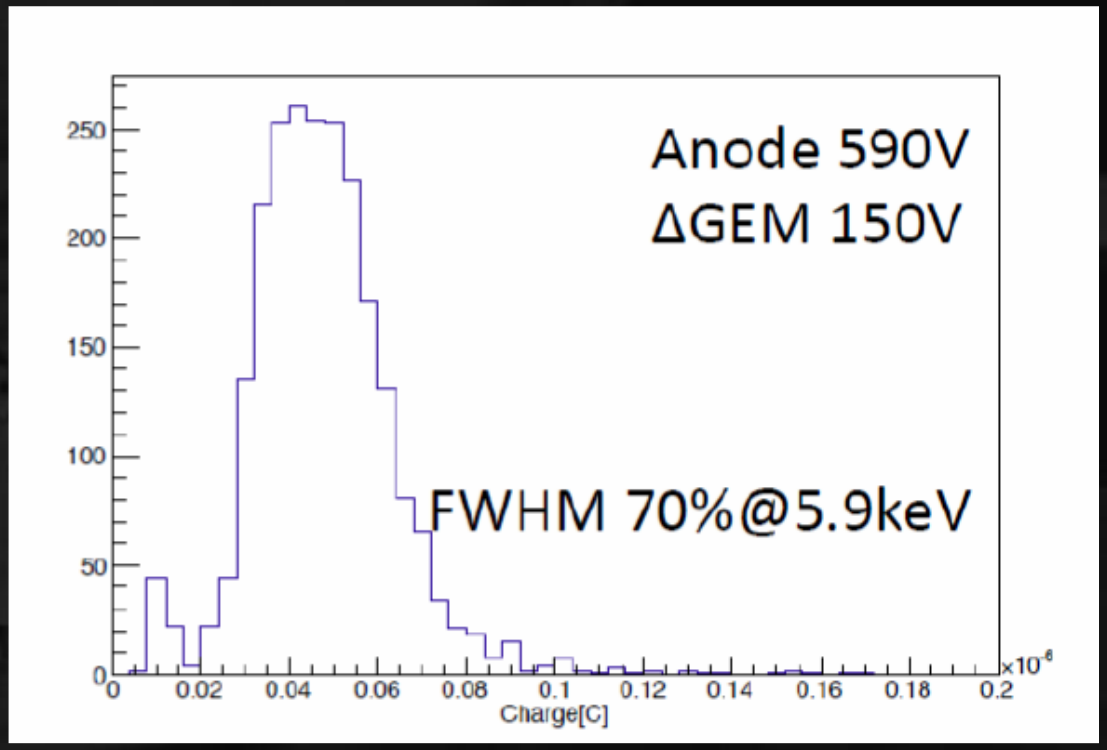
J.B.R. Battat et al. / Physics of the Dark Universe 9–10 (2015) 1–7

NGUYEN PHAN, ERIC LEE
UNIVERSITY OF NEW MEXICO

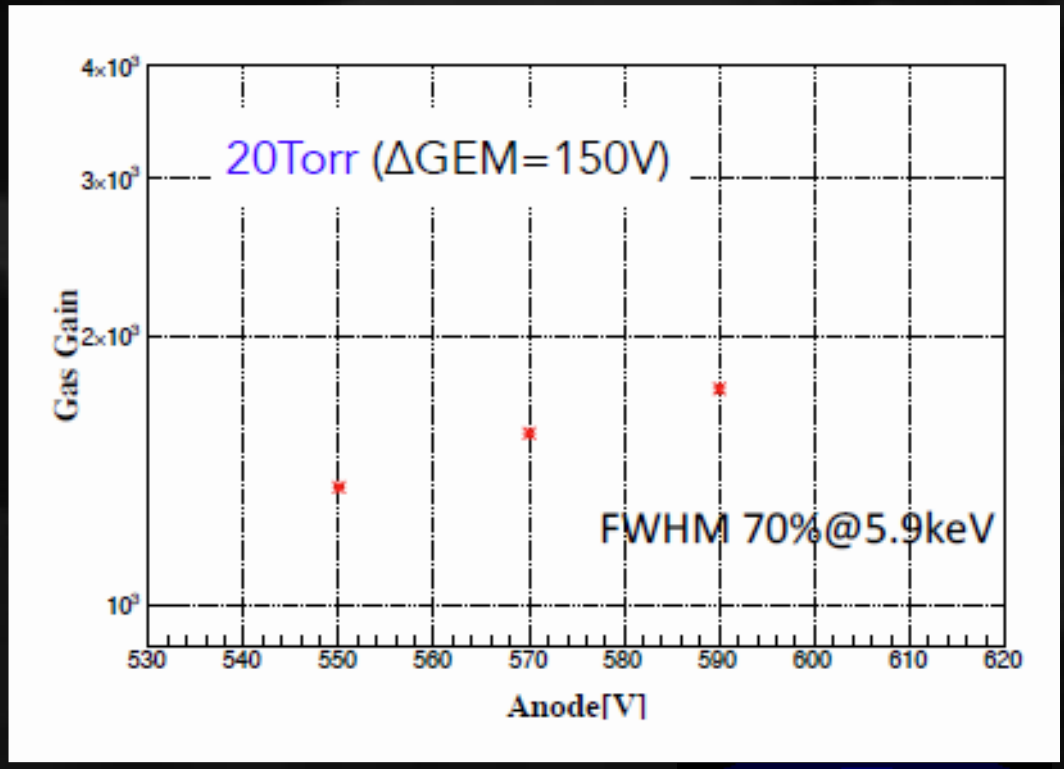
NEWAGE SF_6 study (池田)

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

SF6 study (NEWAGE)



SF6 study (NEWAGE)

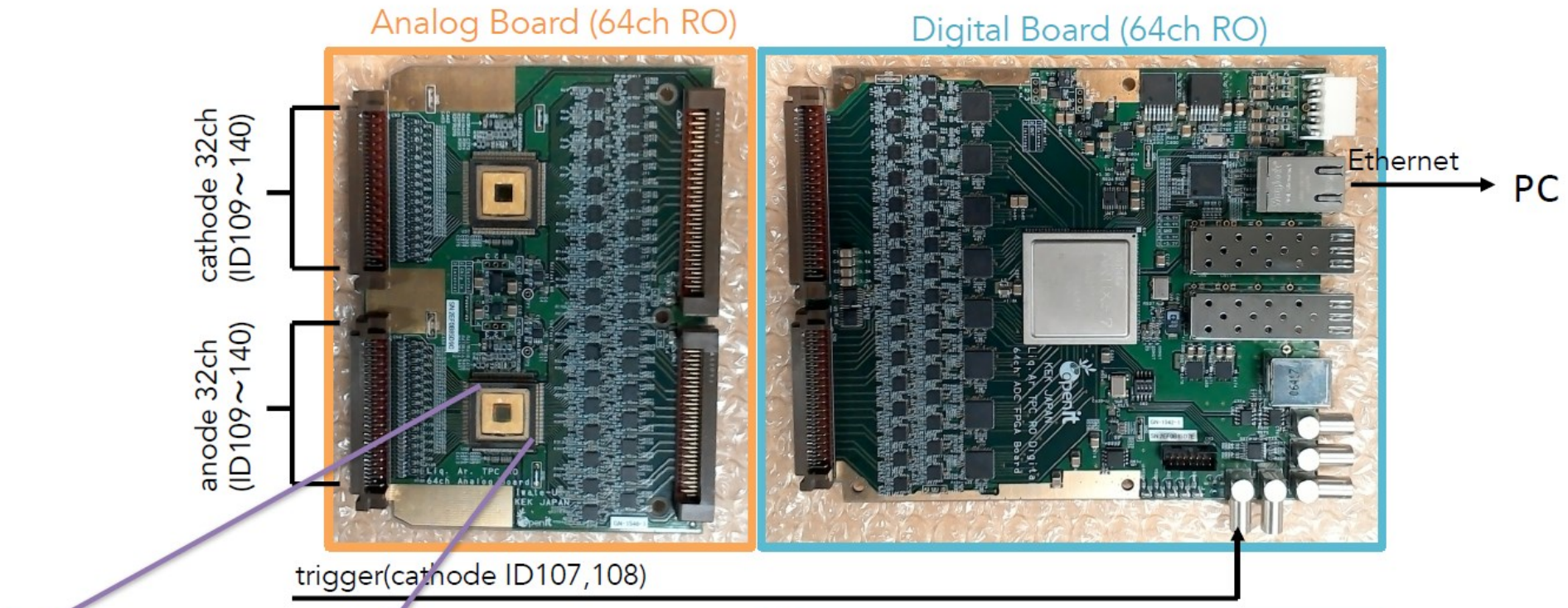


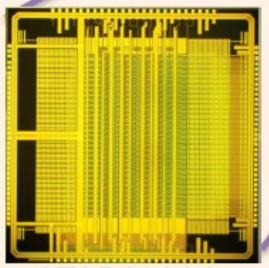
ここまでは後追い

Direction Sensitive WIMP-search NEWAGE

Erectronics

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

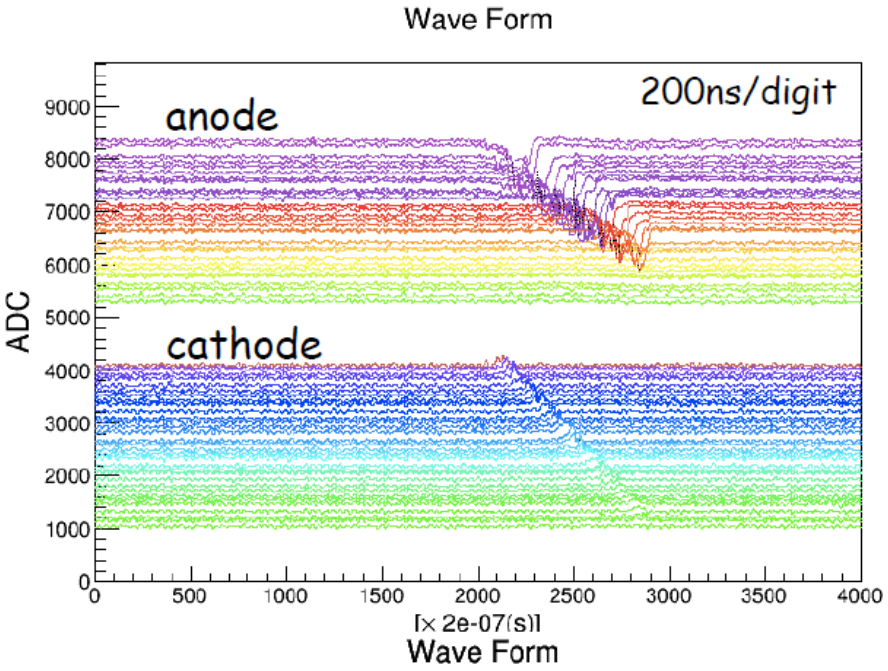


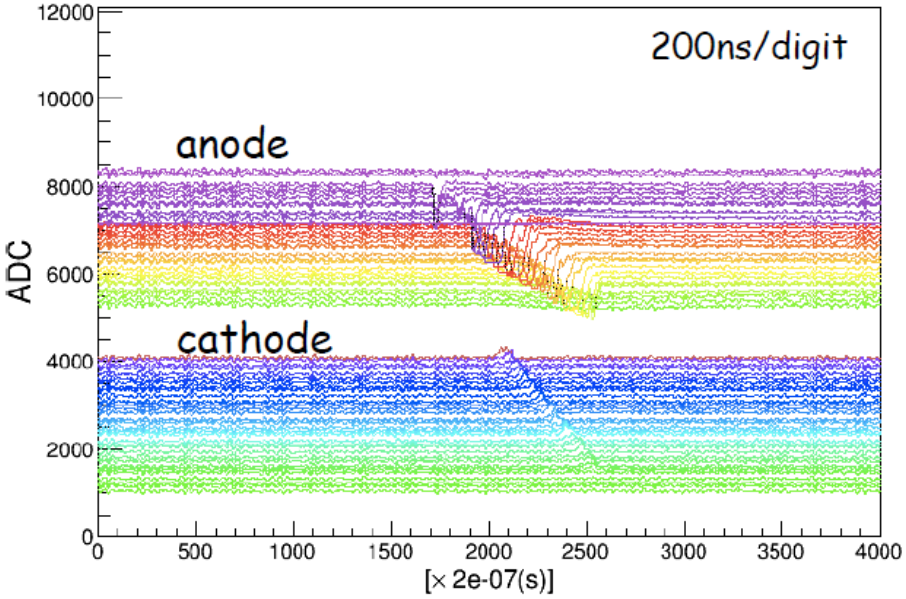

LTARS2014

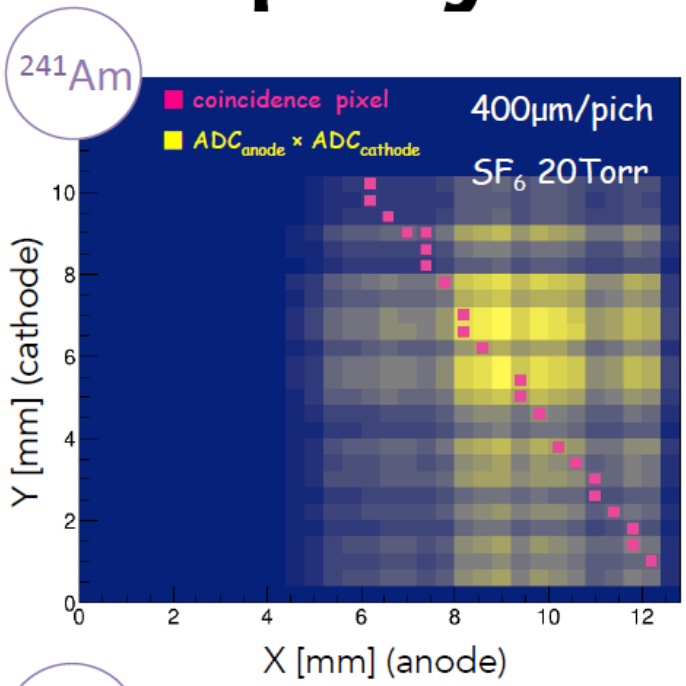
Conversion gain : ～9.0mV/fC
Max input charge : 60~100fC
ENC : below 2000@300pF
Shaping time : 1us

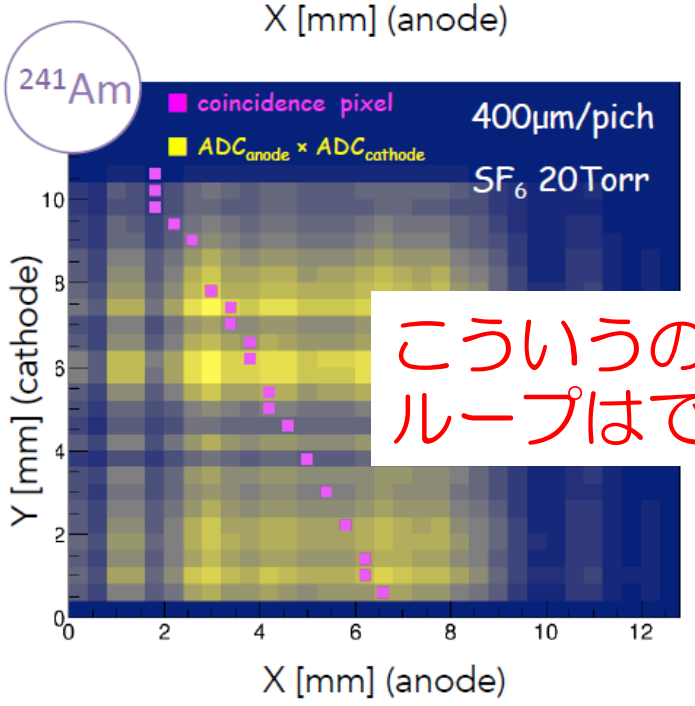
32ch differential inputs(2Vpp)
12bits FADC
4000 sampling
Sampling frequency <20MHz

Alpha Event Display









こういうのが他グループはできない。

irection Sensitive WIMP-search EWAGE

NEWAGEのつよみ

方向感度に注力しながら全部やってきた。

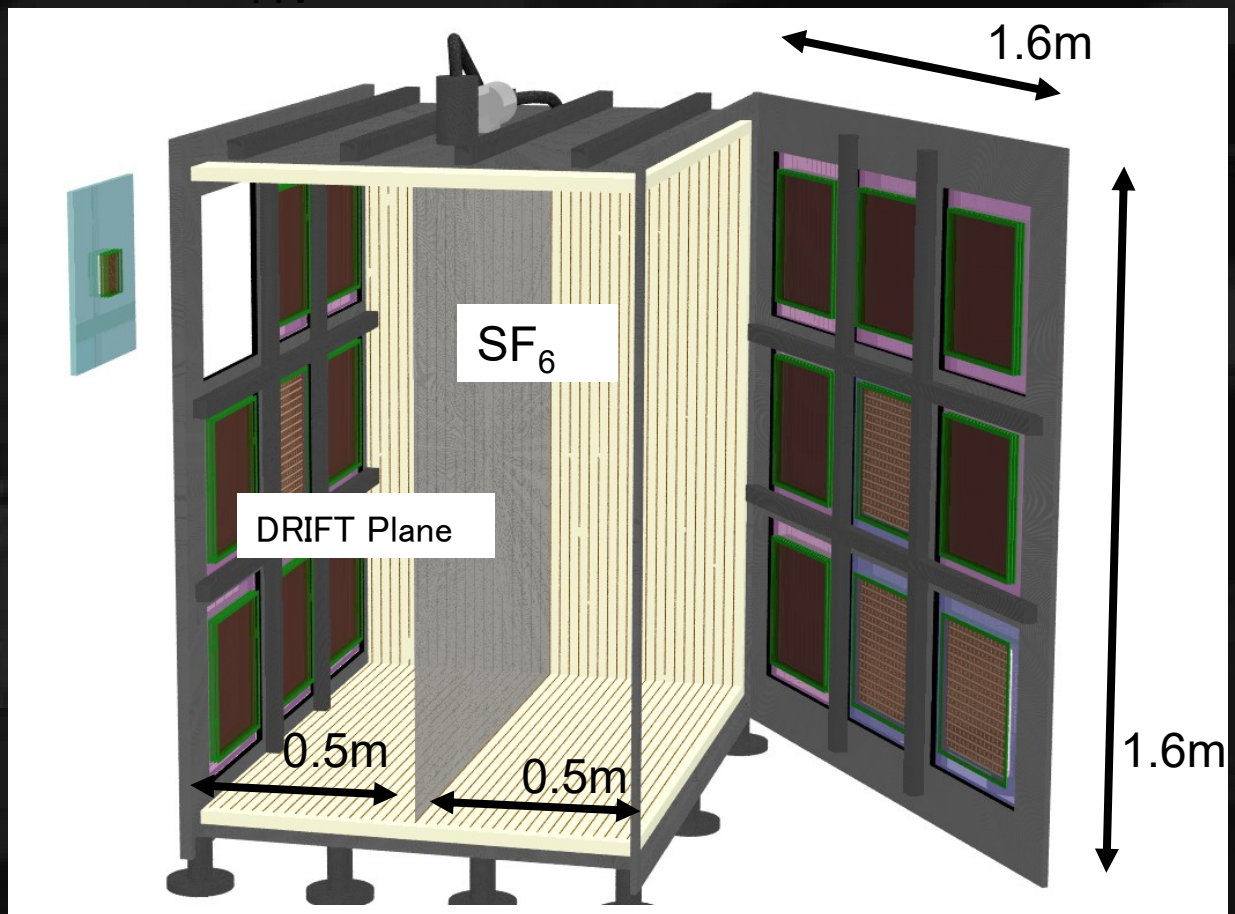
　　自前のエレキがあるのが強み。

　　増幅できても飛跡が取れない人が多い。

lowBGはこれからだが、必要なものは全部持っている。

大型化・低BG・方向感度　のバランスを取りながら、進めてゆく。

- **Neil Spooner:** すぐにでもみんなで協力してでかいもの=24m^3　を作ろう
- **Miuchi (NEWAGE):** お友達はOK。国際協力はそれぞれがもっと強くなってから



CYGNUS/NEWAGE vessel
「連れ込みチェンバー」 20torr ～100g/m^3

戦略：CYGNUSとNEWAGEの並走

MPGDのR&Dを個別に行っている CYGNUS(DRIFT)メンバーを連れ込むためのチェンバーを製作中。

「40cm角のモジュールをはめることができますよ」。

一部はμ-PIC（NEWAGE）を優先的に配置。
→　NEWAGEの名前、アクティビティーはキープ

既成事実からの協力を期す

SKは50000m^3　→　5t くらいのガスになる

まとめ

- 方向に感度をもった発見、暗黒物質の銀河内での運動、反応　を目指す。
- 必要に応じて国際協力も

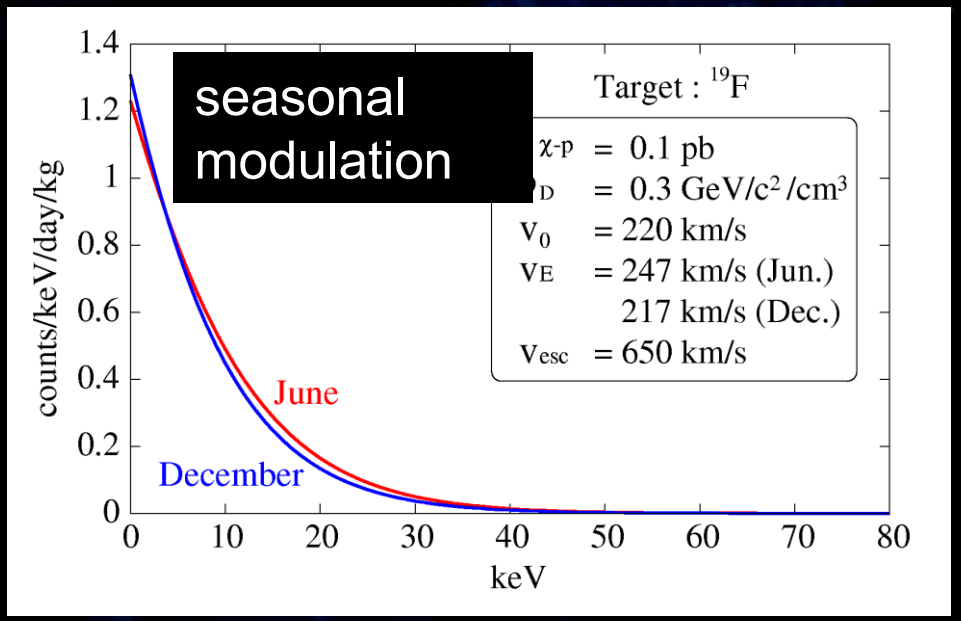
“CYGNUS” concept

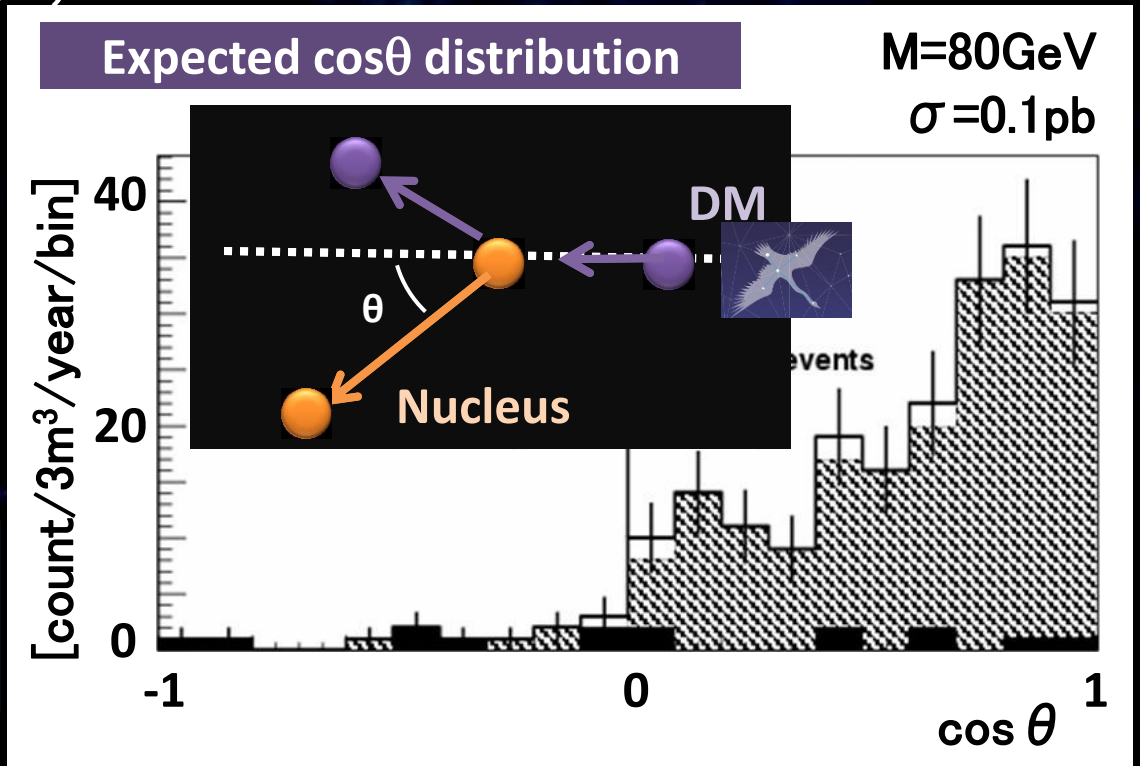
Direction-sensitive dark matter search
even below the “neutrino floor”

Clear detection of dark matter

DM precise study after detection
DM kinematics in the galaxy,
DM-nucleon interaction operators…

Difficulty: short track (a few mm >)





Gas TPC

DRIFT

NEWAGE MIMAC

DM-TPC

D3 NITEC

Solid/Liquid

NEWS DCaNT

ZnWO4 RED

DAMA

- NaI 250kg
- 14サイクルの「季節変動」
- 新しい結果は来年出す。

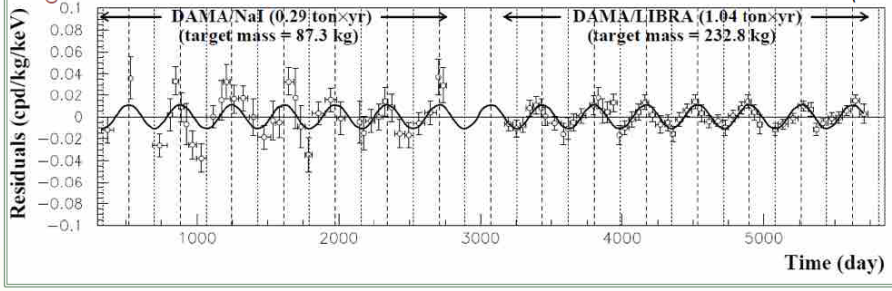
初めての季節変動　PLB450(1999)448
14サイクルの季節変動EPJC73(2013)2648
DAMAにまつわるエトセトラ PRL114(2015)151301

Model Independent Annual Modulation Result

DAMA/NaI + DAMA/LIBRA-phase1 Total exposure: 487526 kg×day = **1.33 ton×yr**

Single-hit residuals rate of scintillation events *vs* time in 2-6 keV

EPJC 56(2008)333, EPJC 67(2010)39, EPJC 73(2013)2648

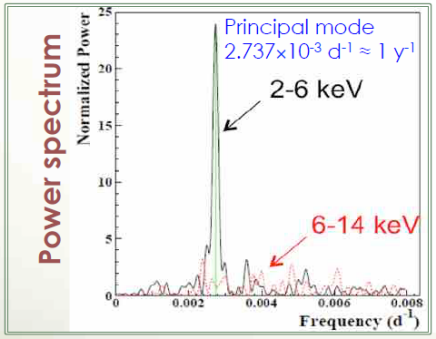


continuous line: t_0 = 152.5 d, T =1.0 y

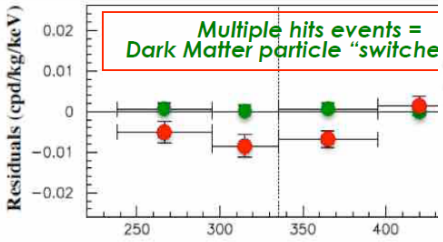
A=(0.0110±0.0012) cpd/kg/keV
χ^2/dof = 70.4/86　9.2 σ C.L.

Absence of modulation? No
χ^2/dof=154/87 P(A=0) = 1.3×10^{-5}

Fit with all the parameters free:
A = (0.0110 ± 0.0012) cpd/kg/keV
t_0



Comparison between **single hit residuc**
hit residual rate (green points); Clear m
No modulation in the residual rate of th
A=-(0.0005±0.0004) cpd/kg/keV

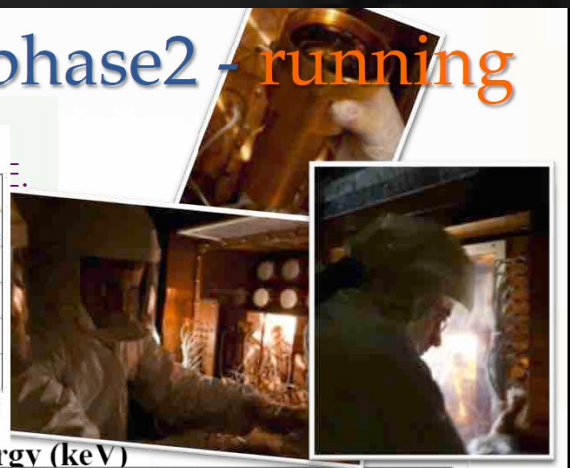


This result offers an additional strong support fo
galactic halo further excluding any side effect
procedures or from background

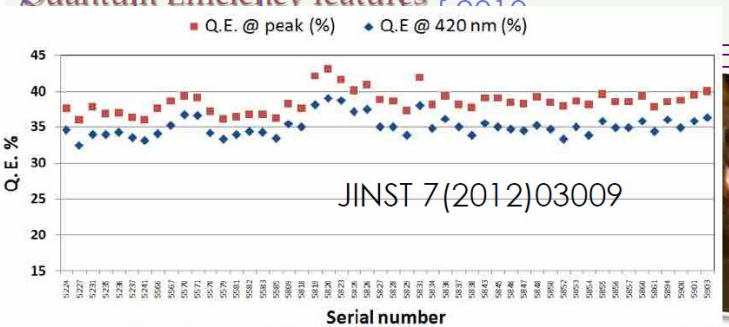
No systematics or side reaction able to account for the measured modulation amplitude and to satisfy all the peculiarities of the signature

The data favor the presence of a modulated behaviour v
features for DM particles in the galactic halo at abc

DAMA/LIBRA phase2 - running



Quantum Efficiency features

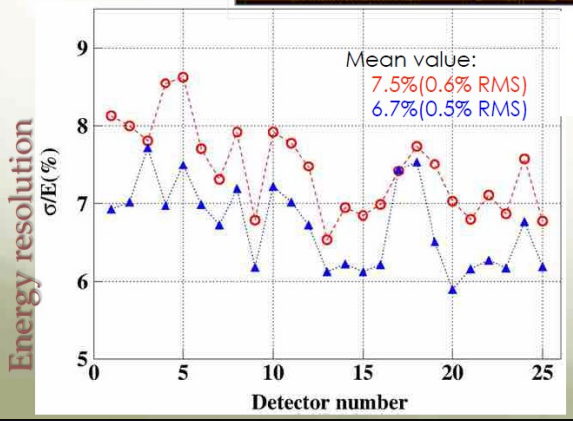


Residual Contamination

The limits are at 90% C.L.

PMT	Time (s)	Mass (kg)	^{226}Ra (Bq/kg)	^{234m}Pa (Bq/kg)	^{238}U (mBq/kg)	^{228}Ra (Bq/kg)	^{228}Th (mBq/kg)	^{40}K (Bq/kg)	^{137}Cs (mBq/kg)	^{60}Co (mBq/kg)
Average			0.43	-	47	0.12	83	0.54	-	-
Standard deviation			0.06	-	18	0.02	17	0.16	-	-

Energy (keV)



σ/E @ 59.5 keV for each detector with new PMTs with higher quantum efficiency (blu points) and with previous PMT EMI-Electron Tube (red points).

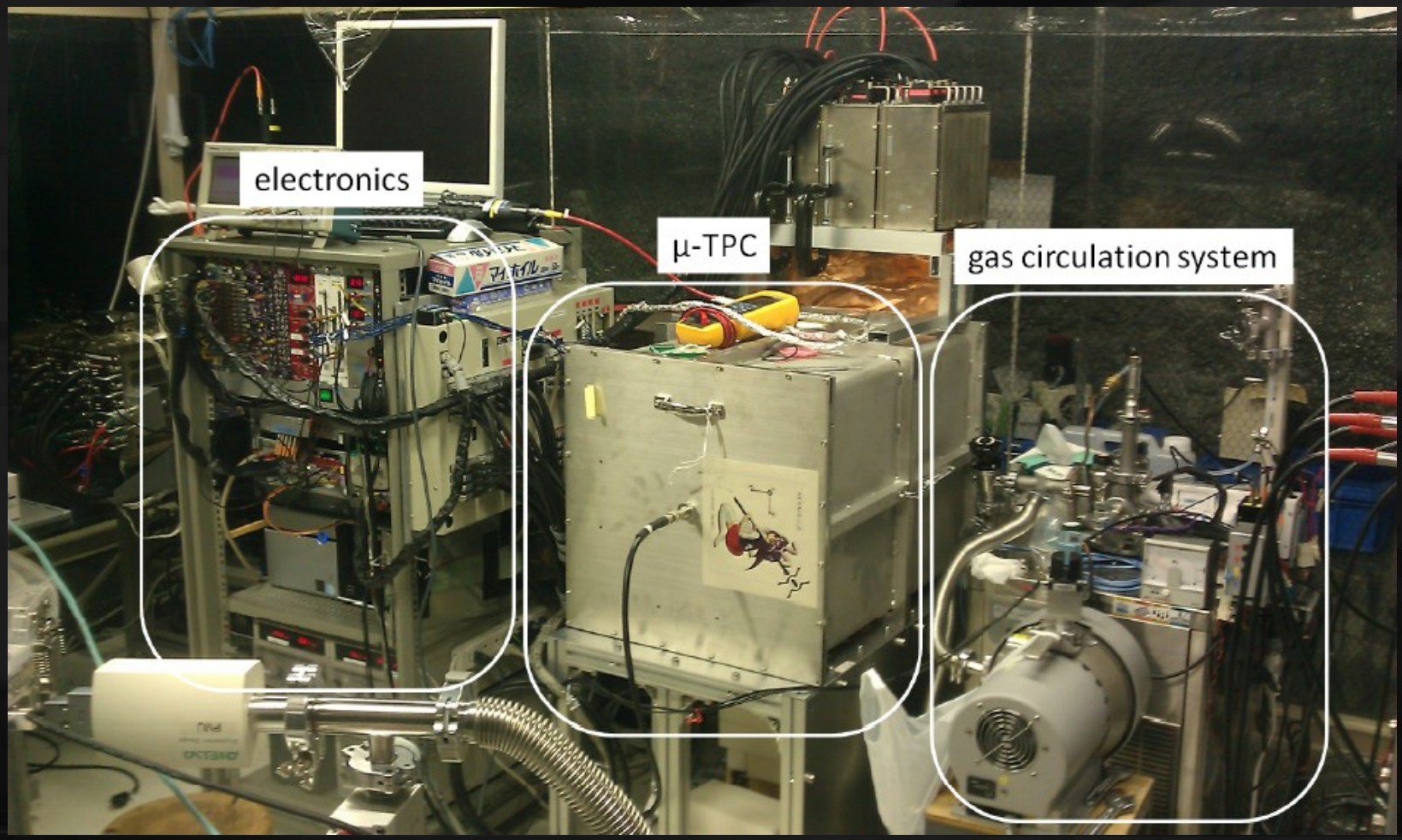
The light responses

Previous PMTs:	5.5-7.5 ph.e./keV
New PMTs:	up to 10 ph.e./keV

- To study the nature of the particles and features of related astrophysical, nuclear and particle physics aspects, and to investigate second order effects
- Special data taking for *other rare processes*

NEWAGE detector

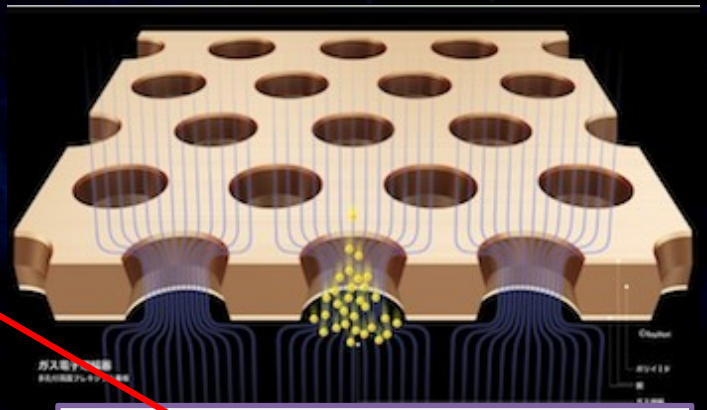
- NEWAGE-0.3b'
- Detection Volume: 31×31×41cm^3
- Gas: CF4 at 0.1atm (50keVee threshold)
- Gas circulation system with cooled charcoal

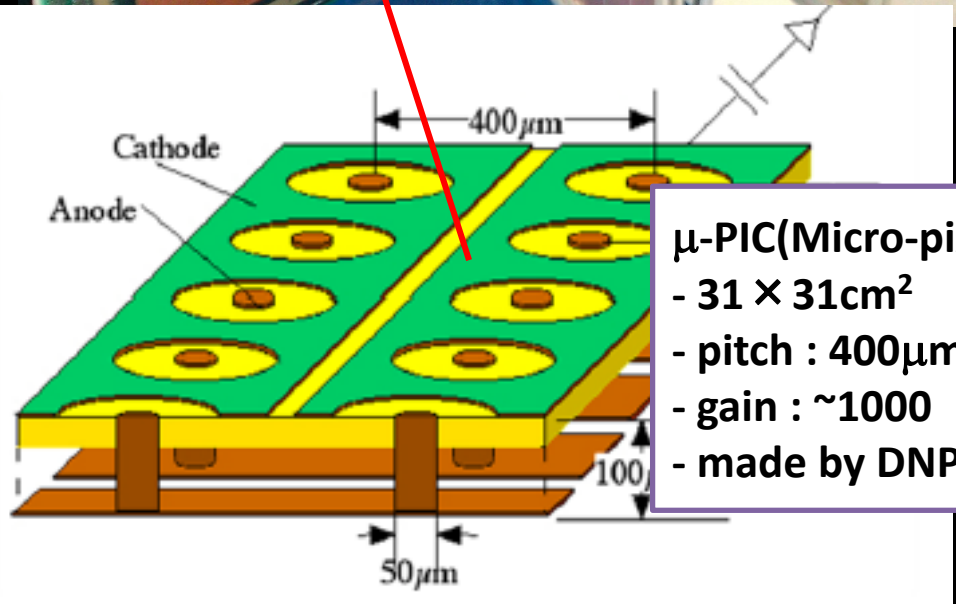


NEWAGE-0.3b' inside view

Detection Volume: 30×30×41cm^3

Field cage
Drift length: 41cm
PEEK + copper wires



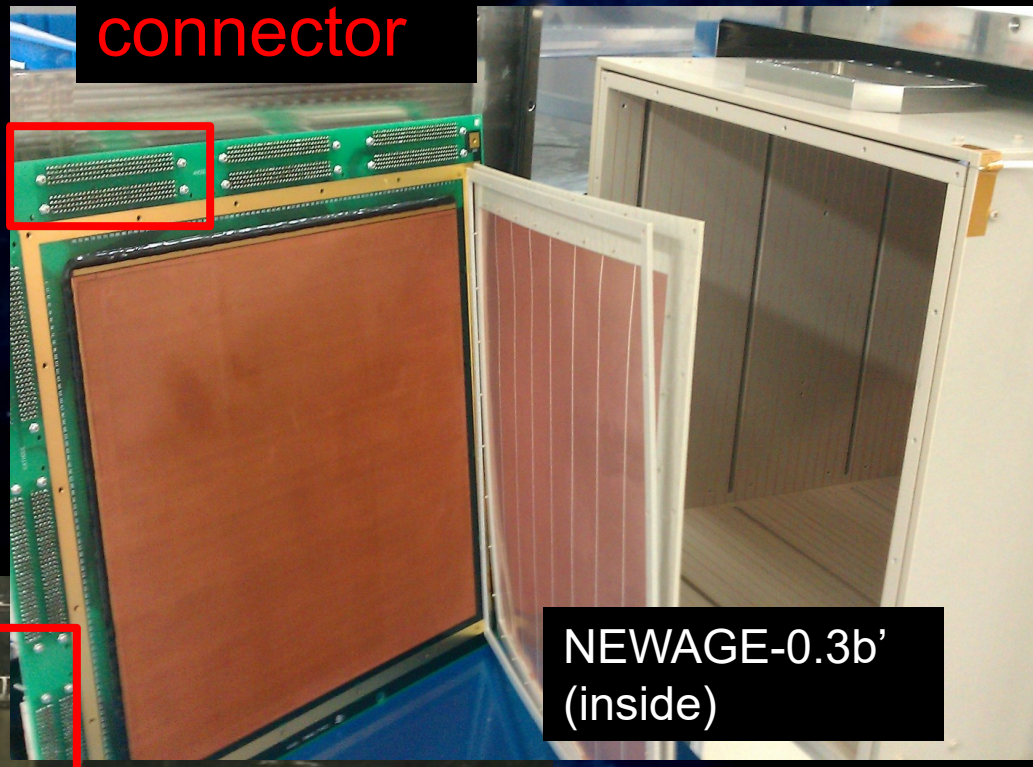


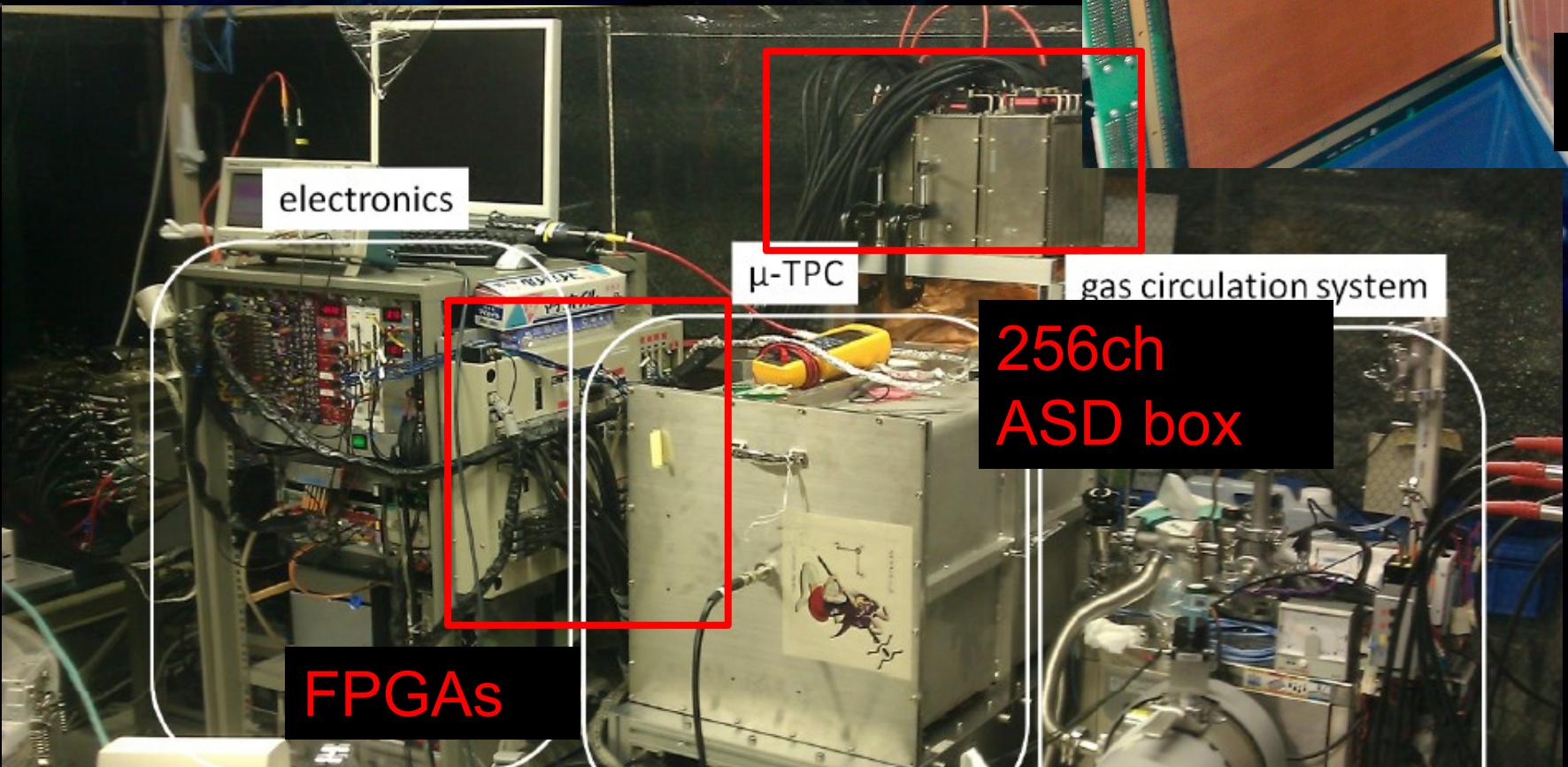
μ-PIC(Micro-pixel chamber)
- 31×31cm^2
- pitch : 400μm
- gain : ~1000
- made by DNP, Japan

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' data

- TOT of every strip by FPGA (clock 100MHz)

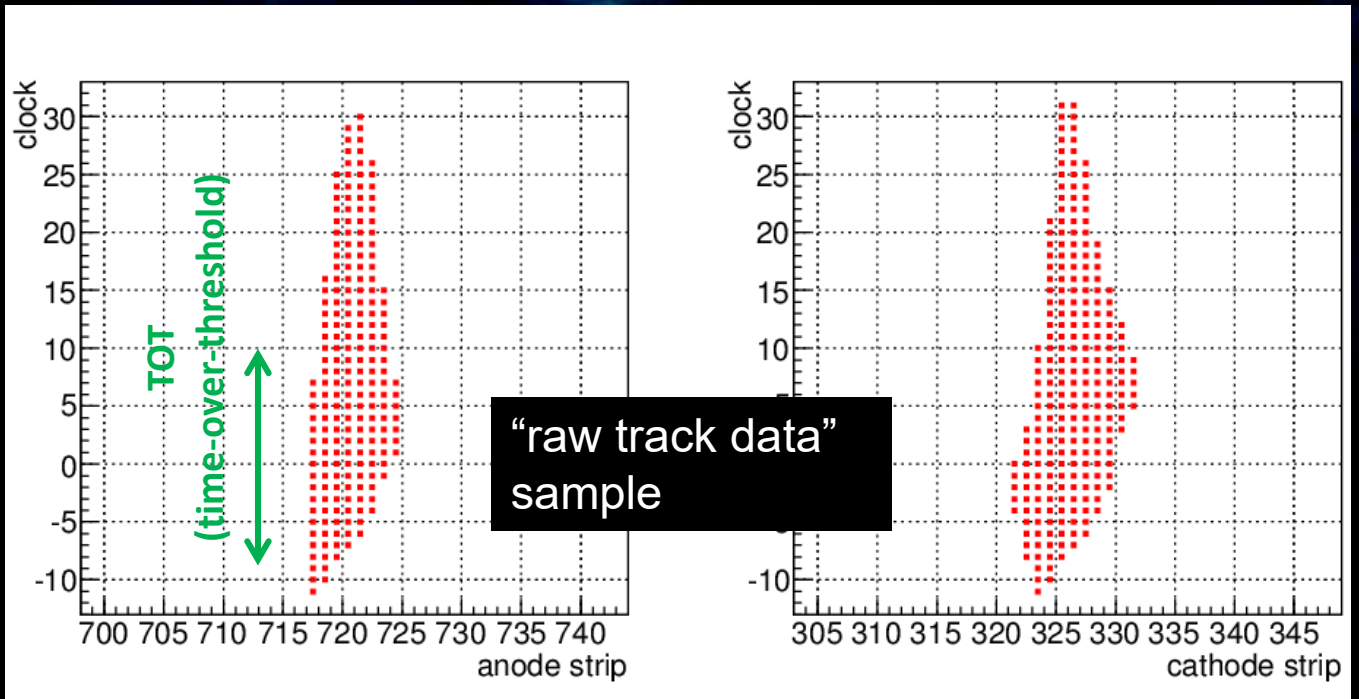
  ⇒3D tracks, headtails in X,Y

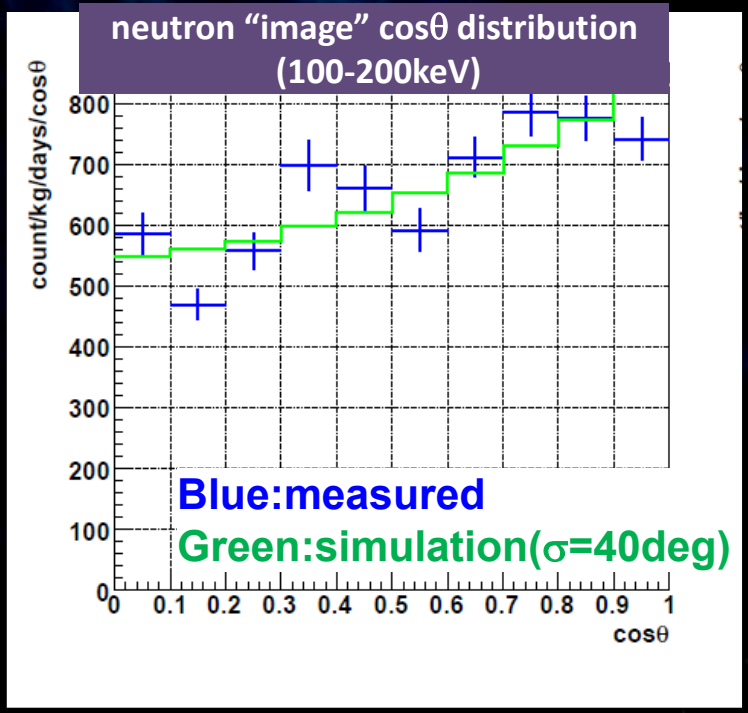
  +

- Summed waveforms by FADC (100MHz)

  ⇒energy, headtails in Z

combined ⇒ PID, absolute z



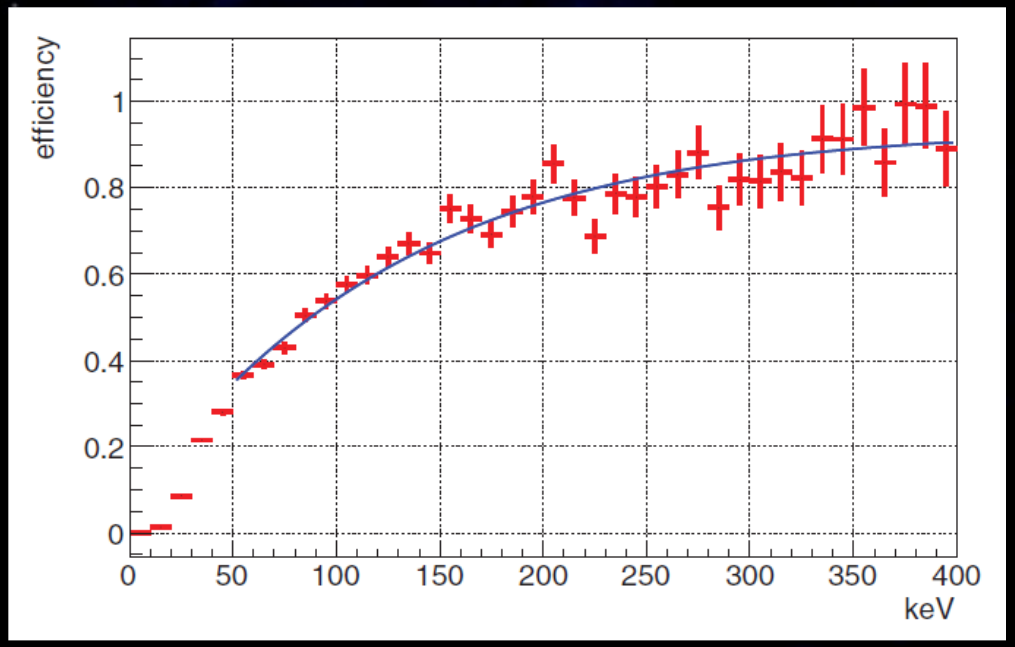


NEWAGE-0.3b' performance

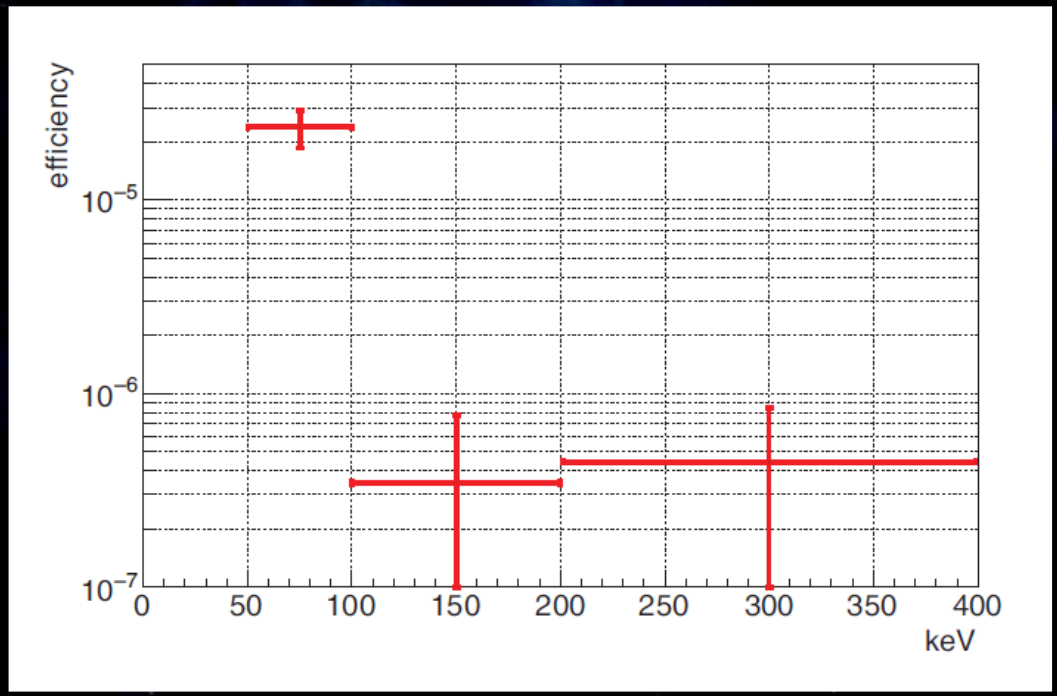
PTEP (2015) 043F01s

- 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



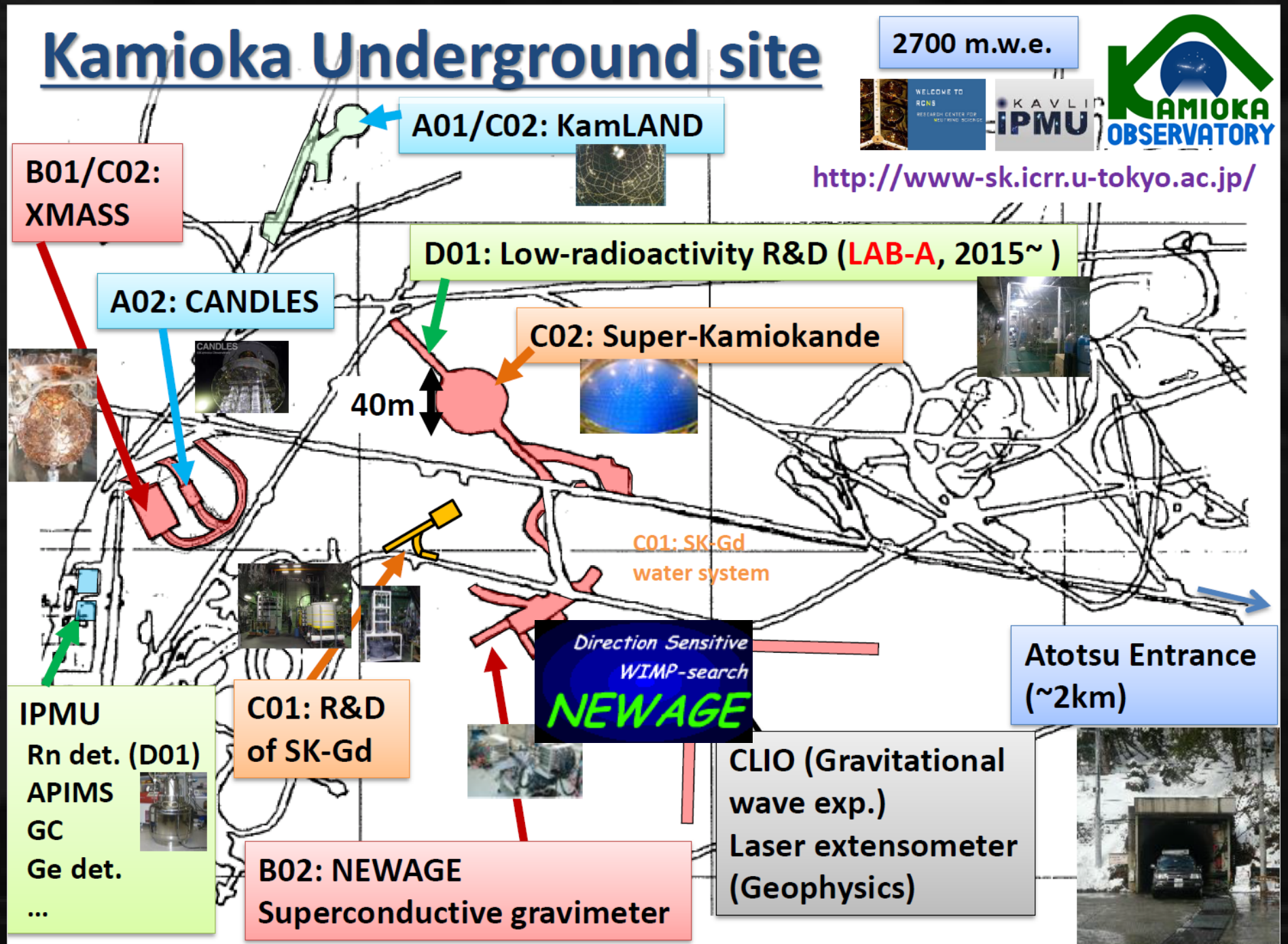
electron track detection efficiency
(gamma rejection factor)



NEWAGE
Kamioka run

KAMIOKA in Japan

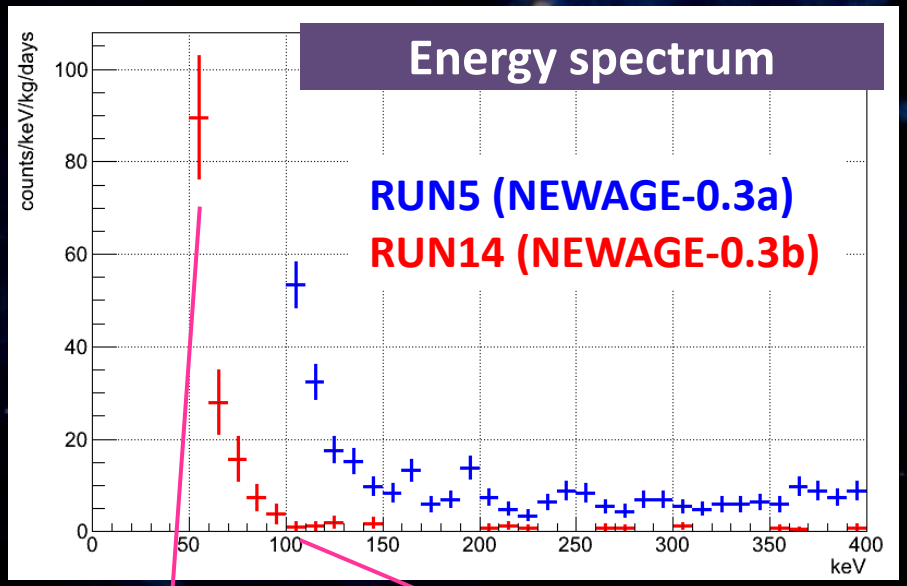
NEWAGE in KAMIOKA



NEWAGE underground run

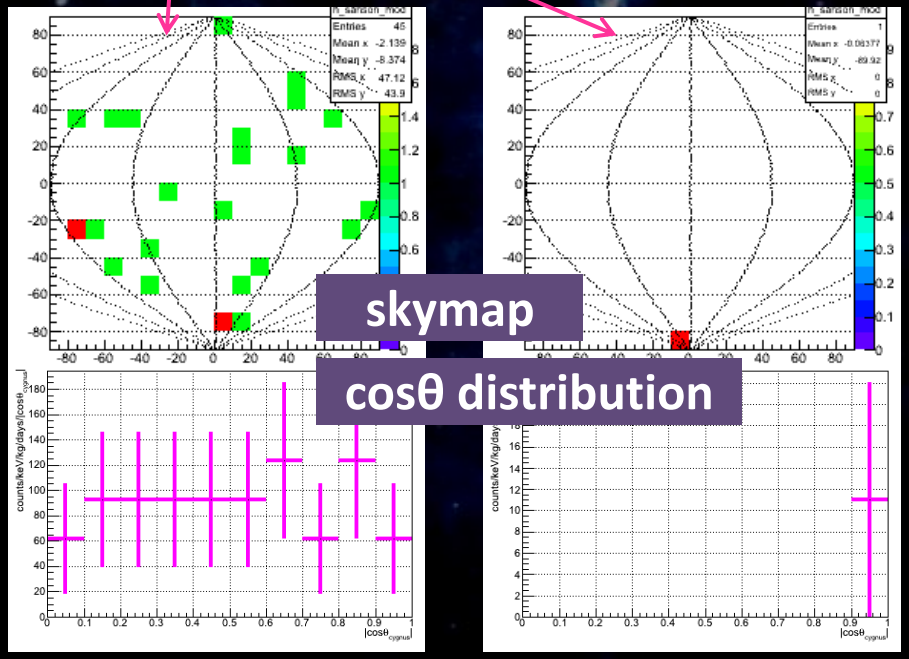
RUN14

- 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

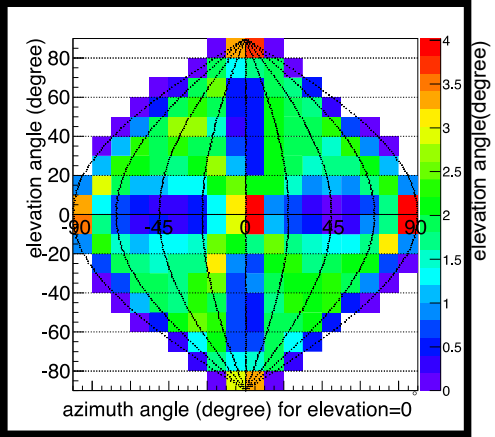
- *Skymap, cosθ distribution*
  - Set limit by significant difference in 2-binned measured cosθ and DM-wind simulated cosθ

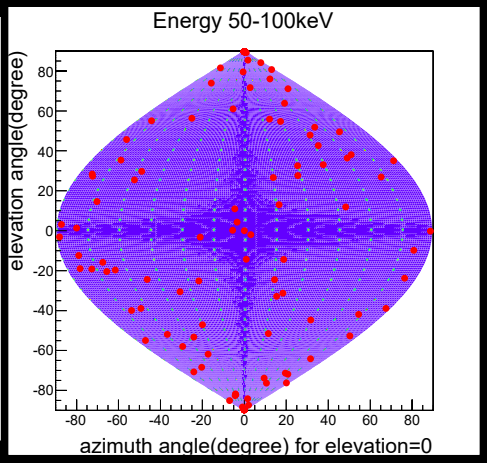


Galactic-plane sky-map

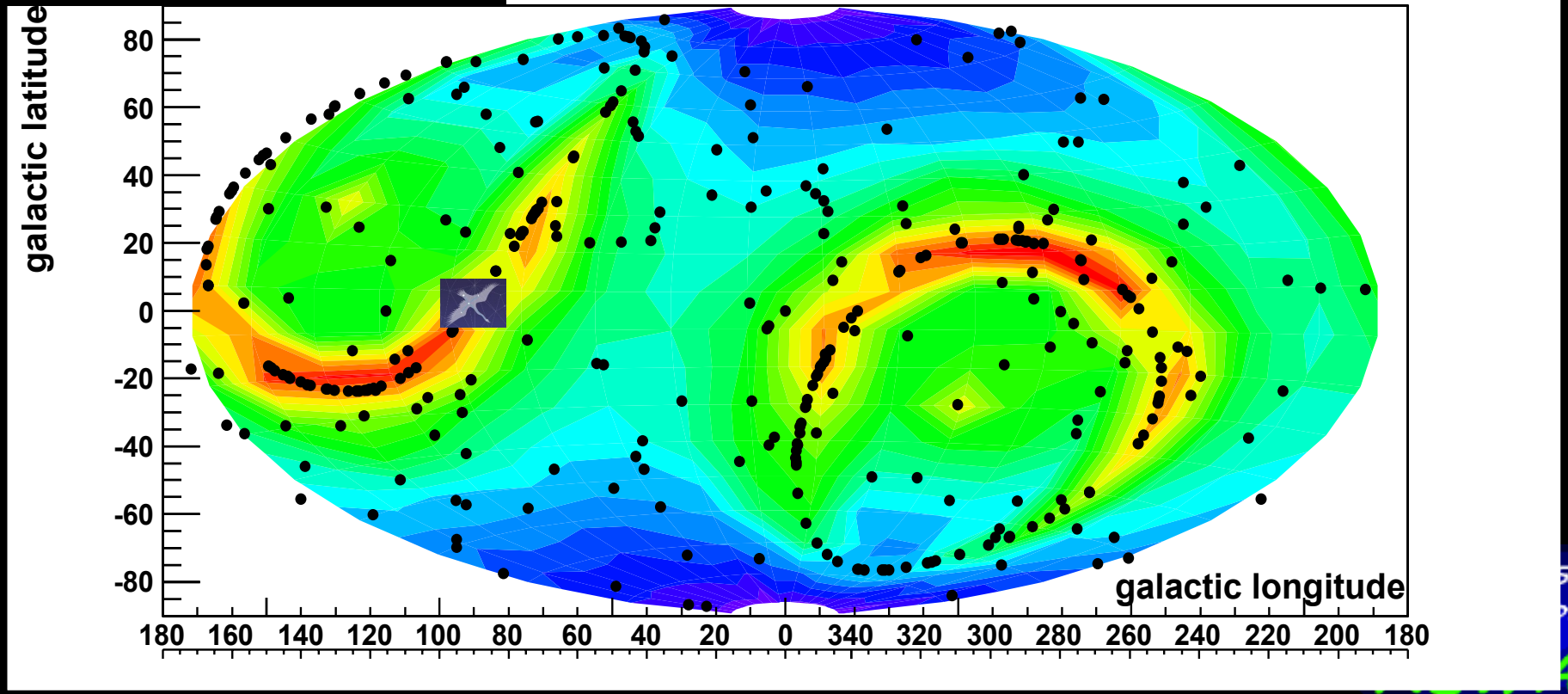
lab-coordinate

- correlation with efficiency = consistent with isotropic

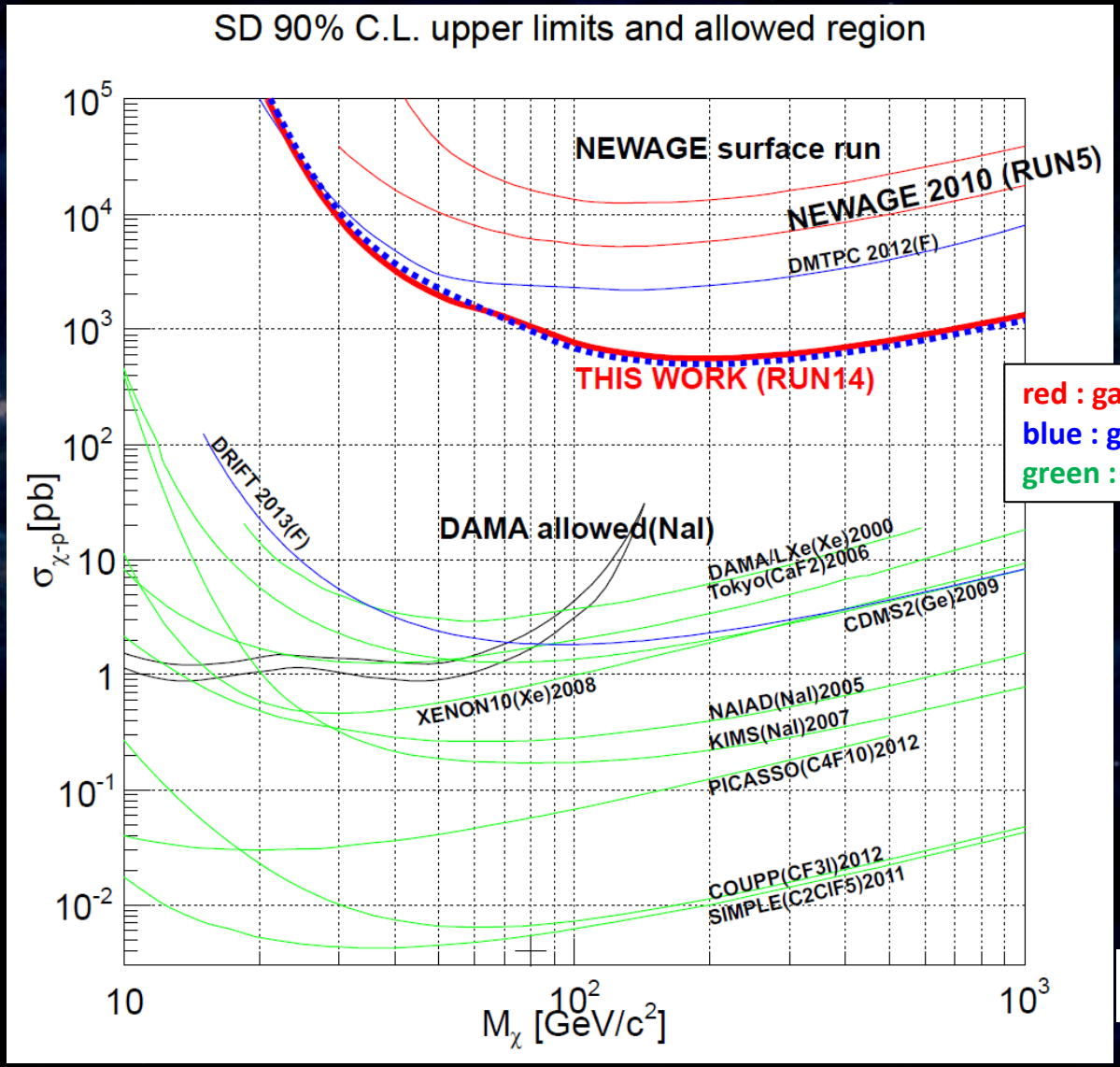




galactic coordinate



Direction-sensitive limit



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

PTEP (2015) 043F01s

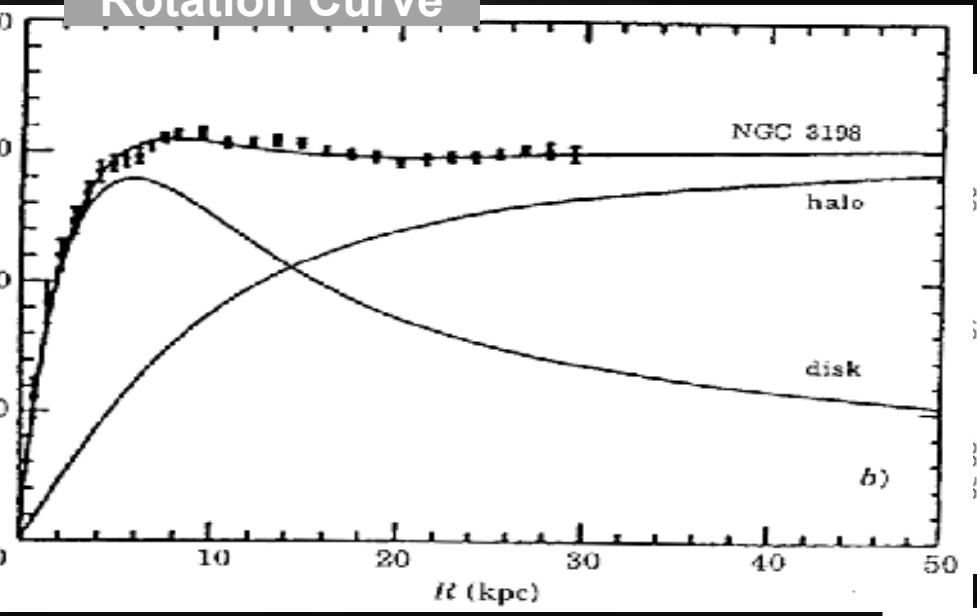
- Obtained limit : 557pb @200GeV
  (Best direction-sensitive limit)
- Improved one order of magnitude from previous RUN5

Recent R&Ds

Dark Matter
exists in many scales of the universe.

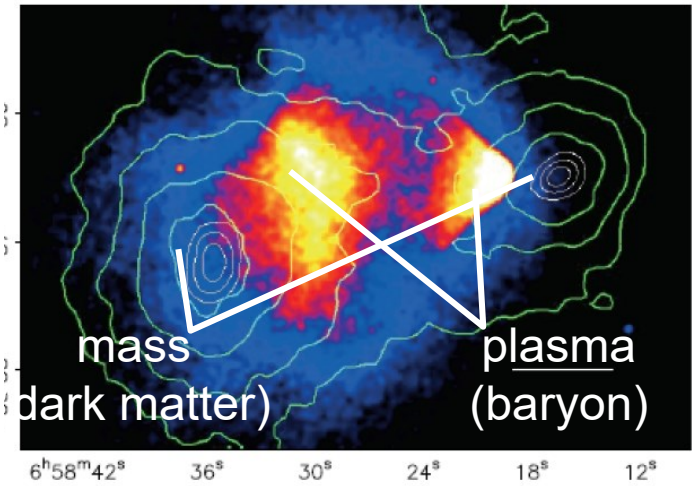
- @ Galaxy: Rotation Curves（1970～）
- @ Clusters of Galaxies:
  clusters of galaxies's collision (2007~)
- @ Universe:
  CMB and other obsevations (2002~)

Rotation Curve



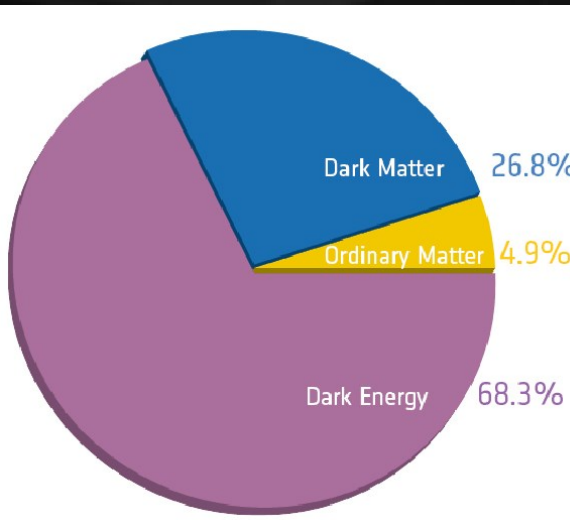
Annu. Rev. Astron. Astrophys. 29(1991)409

clusters of galaxies' collision



THE ASTROPHYSICAL JOURNAL, 648:L109–L113, 2006 September 10

PIE chart of universe



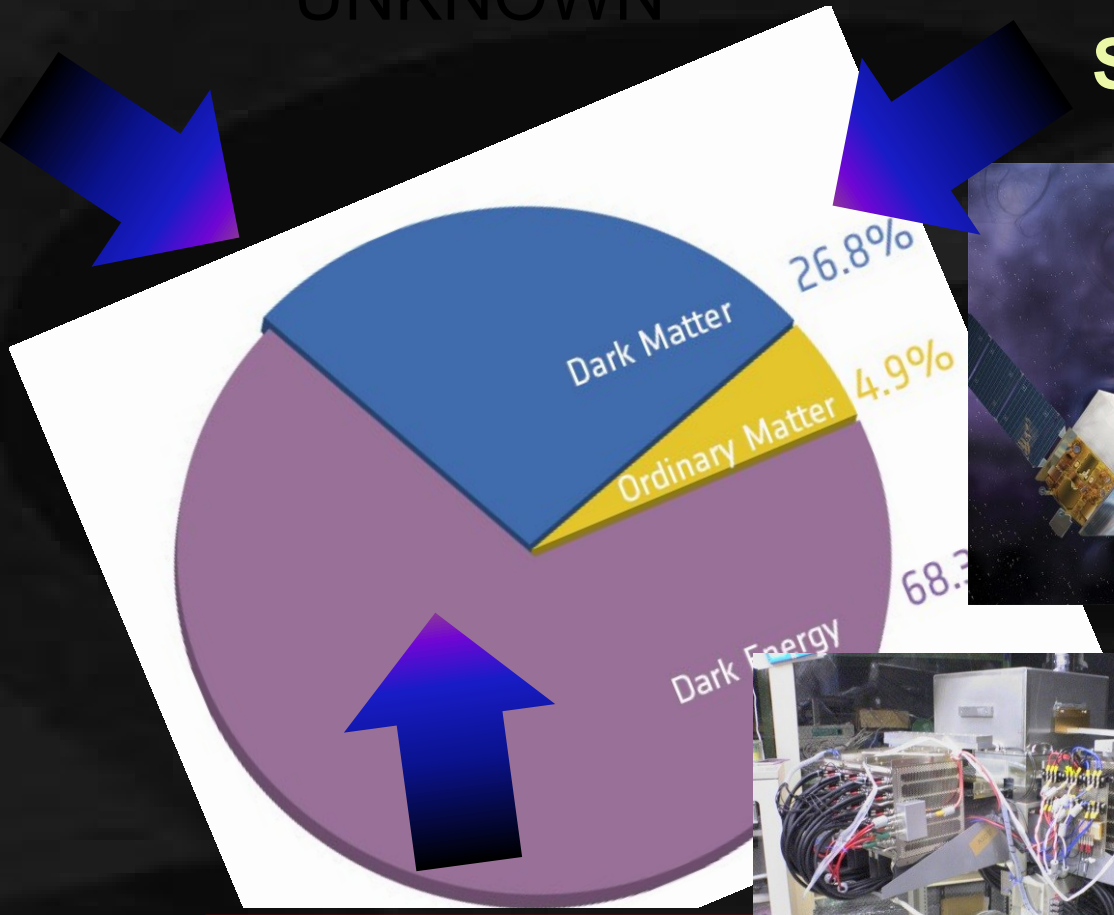
Plank team

Attack the Dark Matter

Accelerator experiment

MAKE it !

THE UNKNOWN



Indirect Search

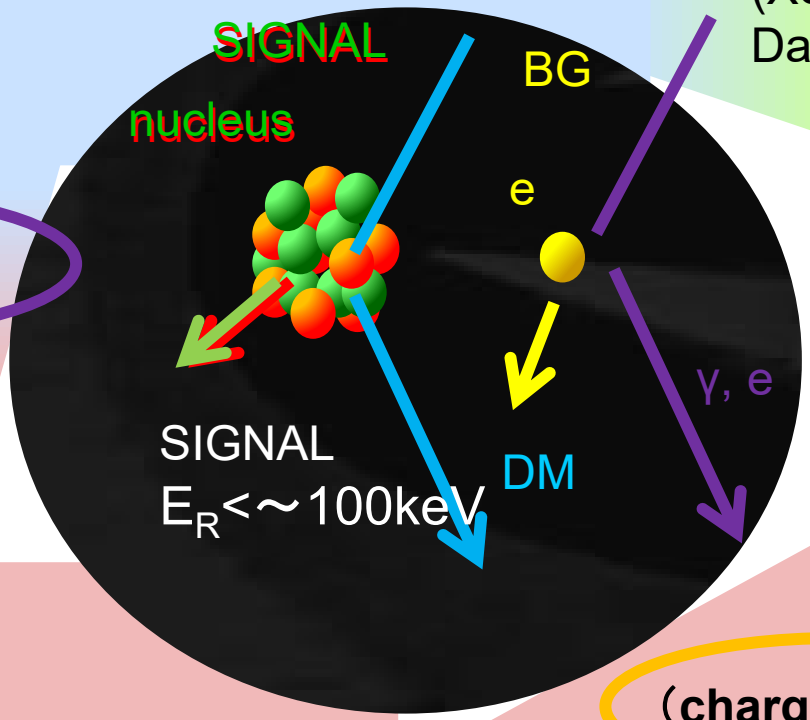
SEE it !

Direct Search

WAIT for it !

Direction Sensitive WIMP-search NEWAGE

Dark Matter Direct Searches (2016)



E_R(photon)

DAMA, DM-ICE
COSINE, SABRE, ANAIS(NaI)
KIMS(CsI,NaI)
DEAP
XMASS(Xe)

(photon + charge)

XENON, LUX, PANDA-X,LZ
(Xe)
DarkSide (Ar)

(photon + heat)

CRESST
(CaWO4)

E_R(charge)

CoGent
DAMIC (Ge)
NEWS-SNO (Ne)

E_R(heat)

PI-COUPP,SIMPLE(CxFx)

(charge + heat)

CDMS(Ge/Si)
EDELWEISS(Ge)

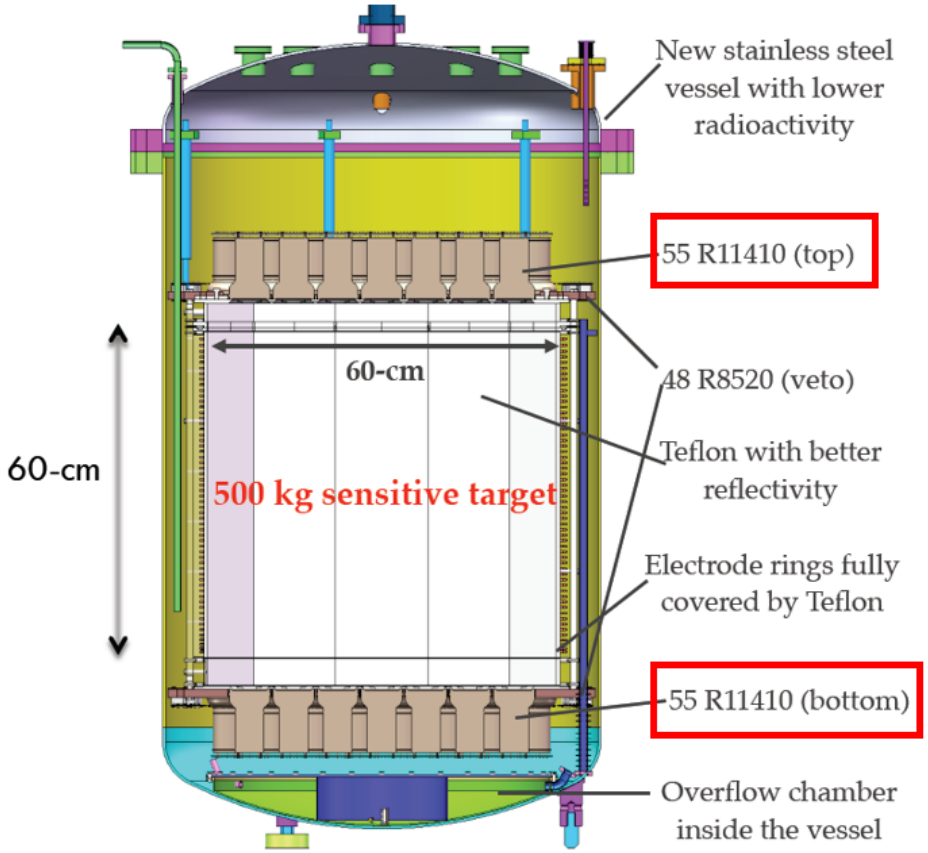
E_R+DIRECTION

DRIFT, NEWAGE,
DMTPC, MIMAC,
NEWS(elustion)

2-phase Xenon detectors

- 2-phase Xenon XENON (161kg total) LUX(250kg active) PandaX-II (500kg sensitive)
- good gamma rejection

PandaX-II

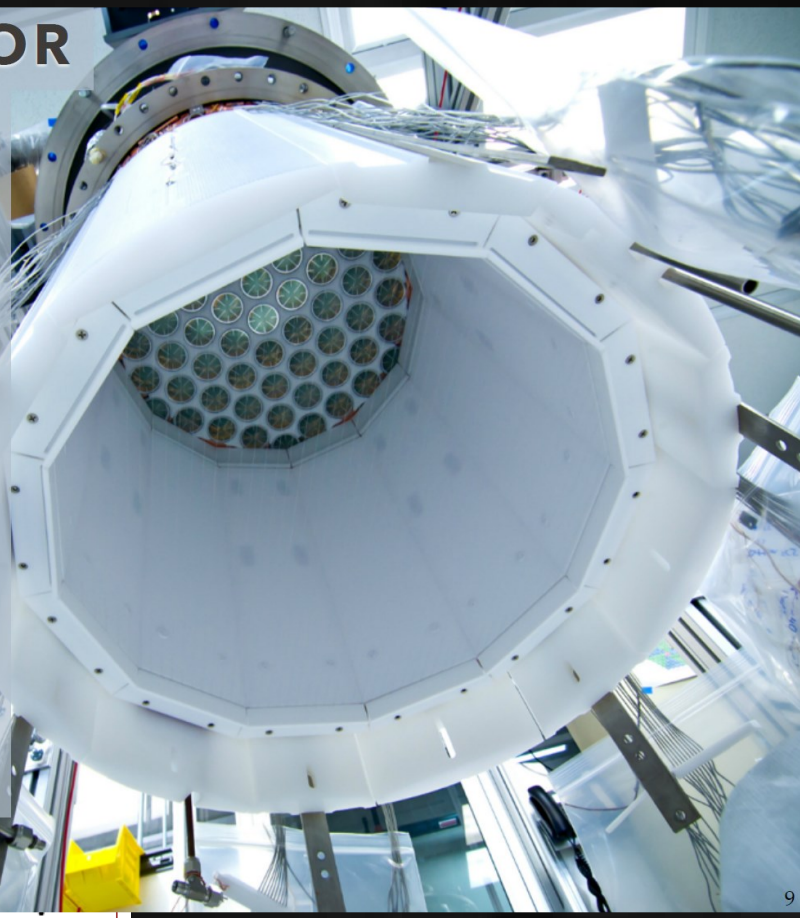


improved base design

- New separate skin veto region

LUX DETECTOR

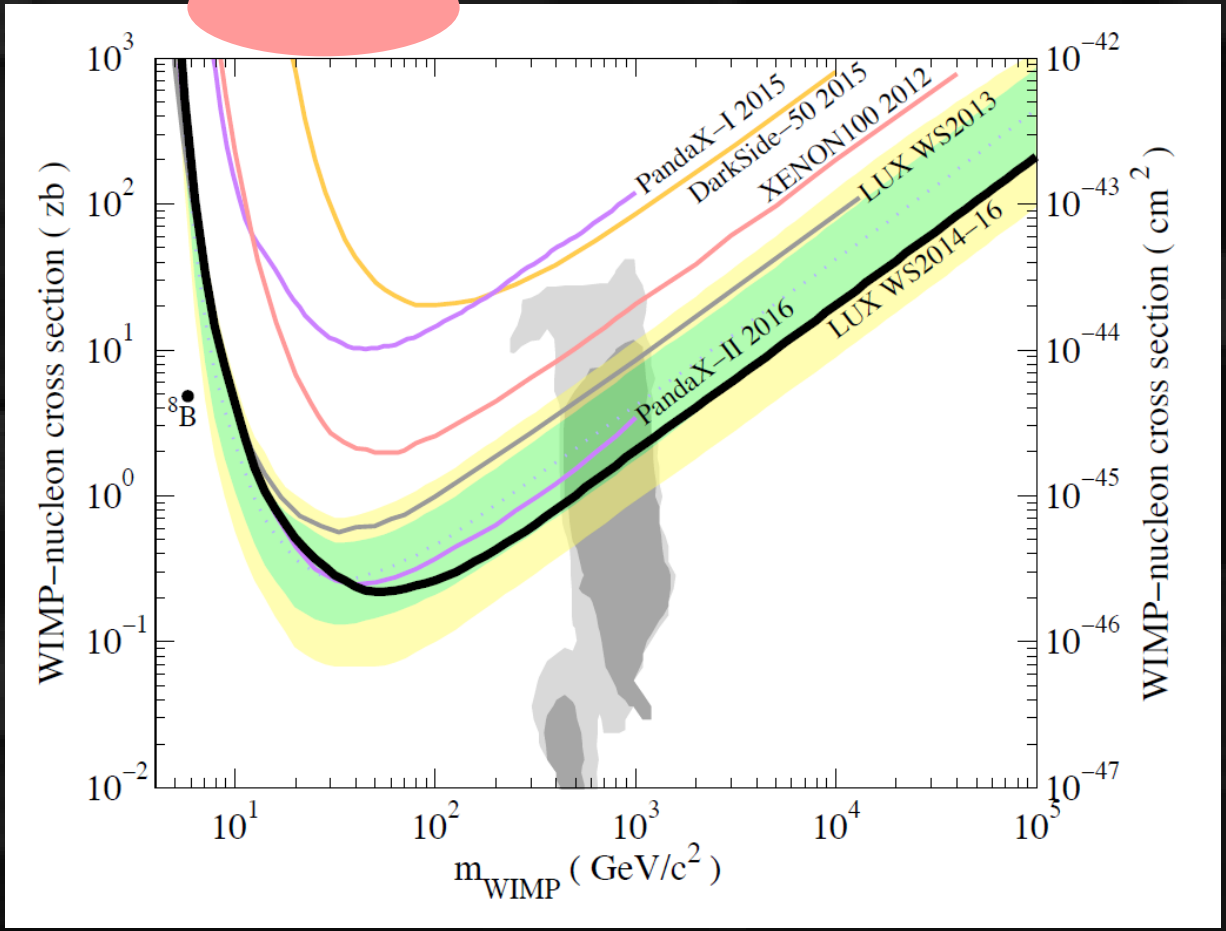
- 48cm diameter by 48 cm height dodecagonal "cylinder".
- 250.9 kg LXe in active region
- 61 PMTs on top, 61 on bottom, specially produced for low radiogenic BGs and VUV sensitivity.
- Xenon was pre-purified via chromatographic separation, reducing residual krypton.
- Liquid is continuously recirculated (¼ tonne per day) to maintain chemical purity.
- Ultra-low BG titanium cryostat.



LUX arXiv 1608.07648
PandaX-II arXiv 1607.074003

- **DAMA and others… in tension**

- **any other clear evidence ?**



- **directionality!**

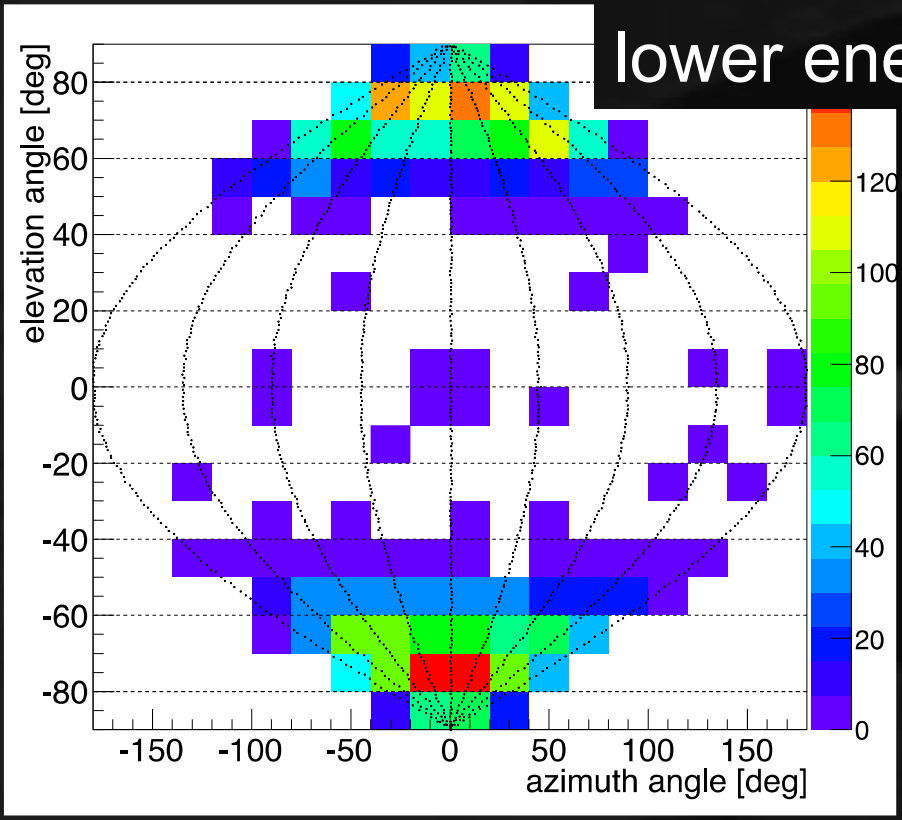
BG study

- **Directionality helps!**

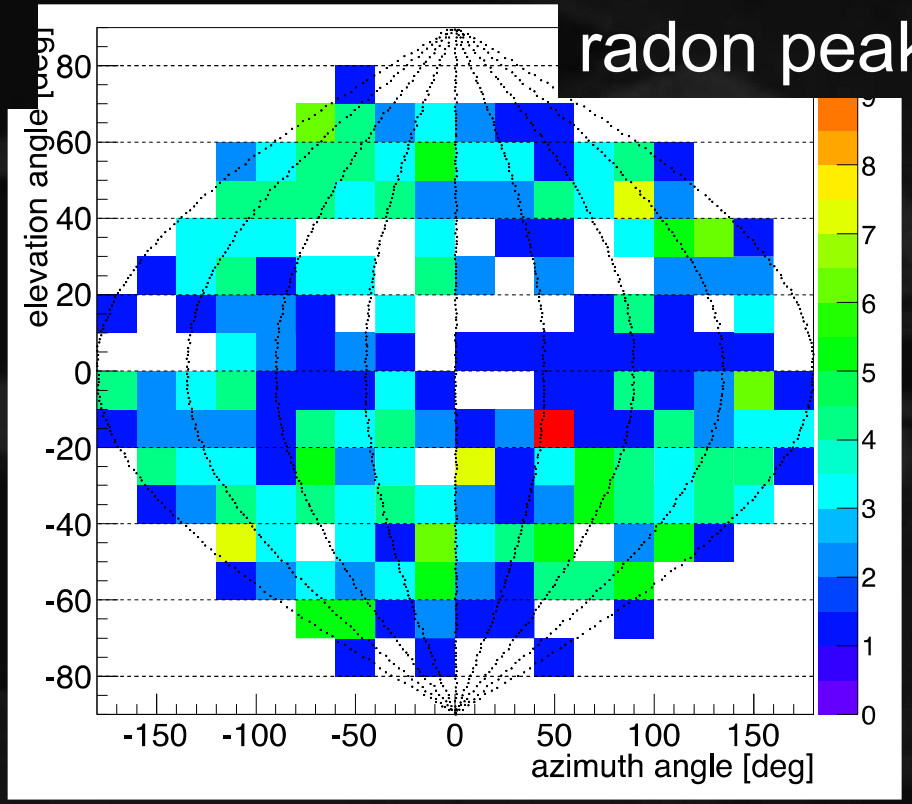
SKYMAP @ detector coordinate

color: number of events

lower energy



radon peak

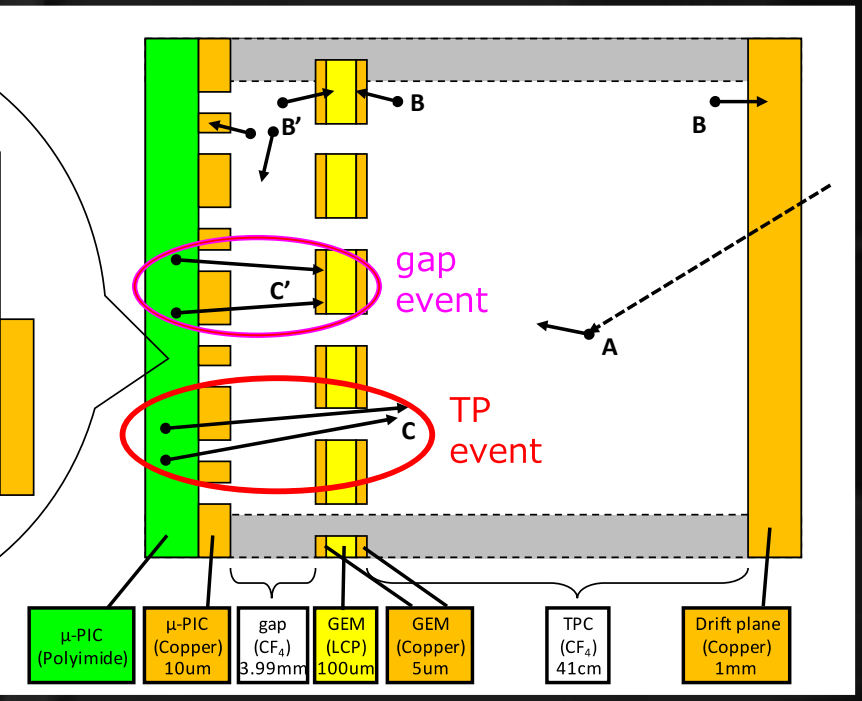


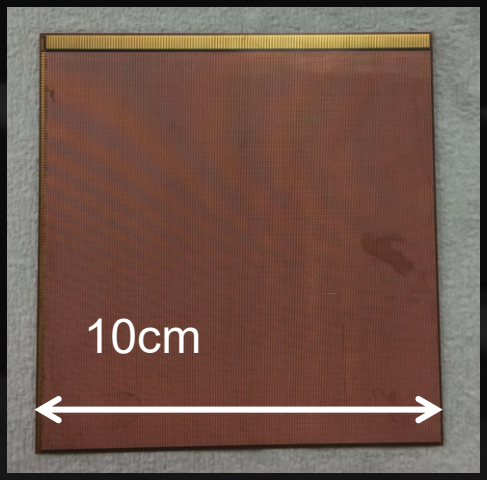
- **BG identified: upgoing events**

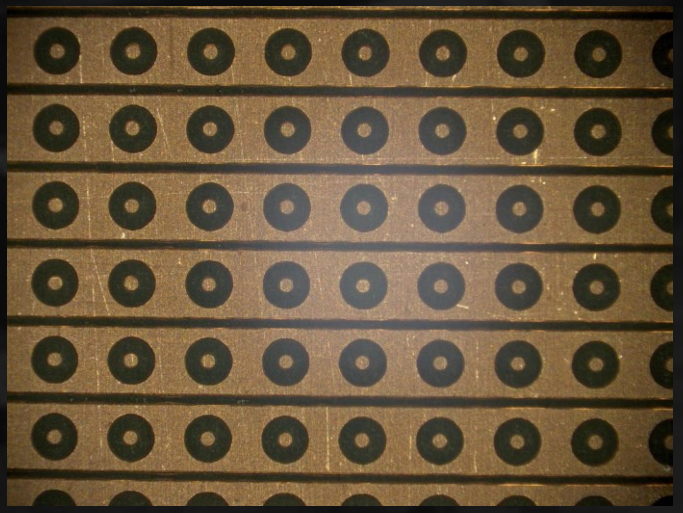
NEWAGE

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

MICROMEGAS and Multi GEM

- μ-PIC(+GEM)
  - Anode diameter : 50um
  - Cathode hole diameter : 250um
  - made by DNP in Japan

- Multi GEM
  - Width : 100um
  - Material: liquid crystal polymer
  - Made by Scienergy in Japan

From now,

  - μ-PIC+GEM system , we don't know only GEM gain.
  - How gain can we get ?

- MICROMEGAS
  - Pillar length : 125um
  - Strip pich : 400um
  - made by Raytech in Japan

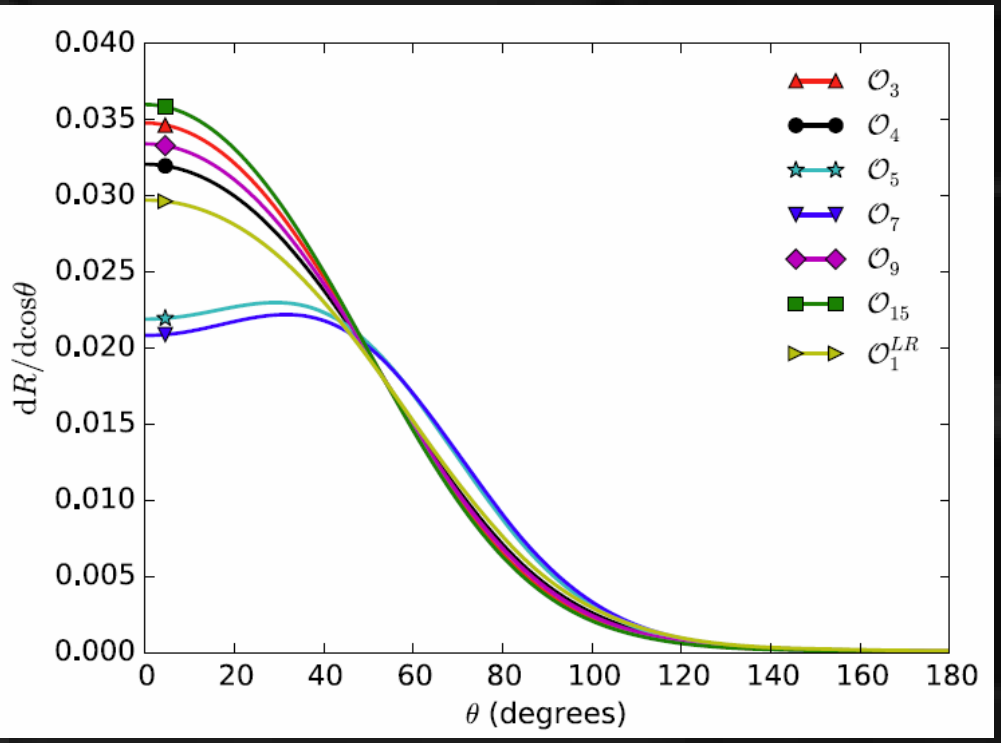
From now,

  - Can we use Micro Megas in SF_6 gas?

“CYGNUS” physics after discovery

- **Test the interaction by scattering angle**

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



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

$$\mathcal{O}_1 = 1 \quad \leftarrow \text{SI}$$

$$\mathcal{O}_3 = i\vec{S}_n \cdot \left(\frac{\vec{q}}{m_n} \times \vec{v}^\perp \right)$$

$$\mathcal{O}_4 = \vec{S}_\chi \cdot \vec{S}_n \quad \leftarrow \text{SD}$$

$$\mathcal{O}_5 = i\vec{S}_\chi \cdot \left(\frac{\vec{q}}{m_n} \times \vec{v}^\perp \right)$$

$$\mathcal{O}_6 = (\vec{S}_\chi \cdot \vec{q})(\vec{S}_n \cdot \vec{q})$$

$$\mathcal{O}_7 = \vec{S}_n \cdot \vec{v}^\perp$$

$$\mathcal{O}_8 = \vec{S}_\chi \cdot \vec{v}^\perp$$

$$\mathcal{O}_9 = i\vec{S}_\chi \cdot (\vec{S}_n \times \vec{q})$$

$$\mathcal{O}_{10} = i\vec{S}_n \cdot \vec{q}$$

$$\mathcal{O}_{11} = i\vec{S}_\chi \cdot \vec{q}$$

$$\mathcal{O}_{12} = \vec{S}_\chi \cdot (\vec{S}_n \times \vec{v}^\perp)$$

$$\mathcal{O}_{13} = i(\vec{S}_\chi \cdot \vec{v}^\perp) \left(\vec{S}_n \cdot \frac{\vec{q}}{m_n} \right)$$

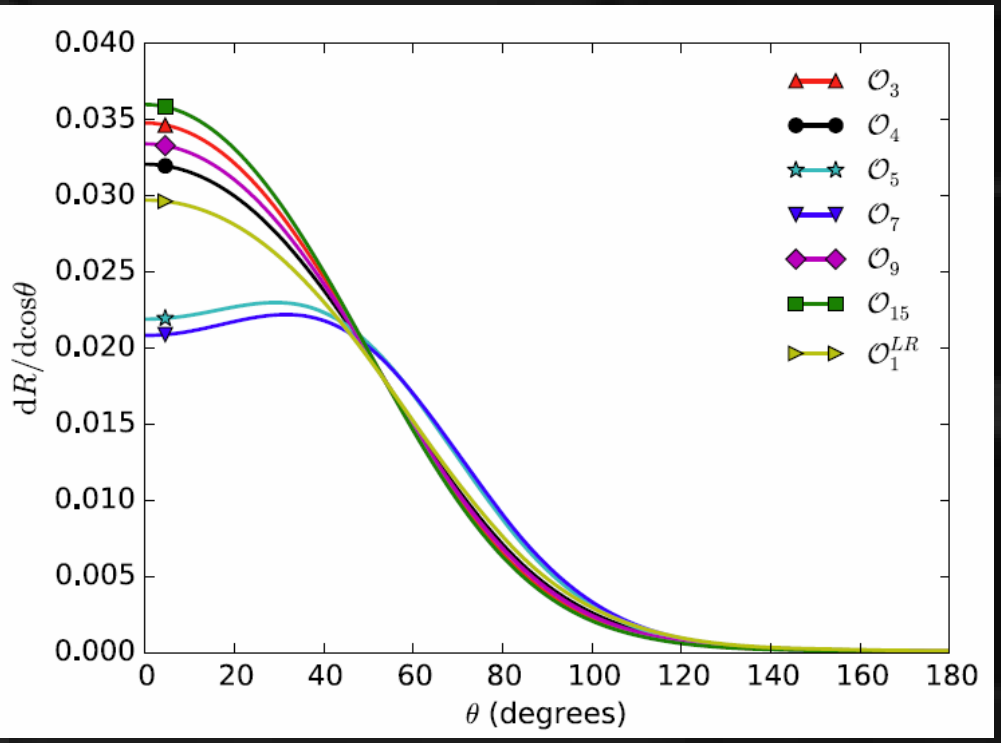
$$\mathcal{O}_{14} = i \left(\vec{S}_\chi \cdot \frac{\vec{q}}{m_n} \right) (\vec{S}_n \cdot \vec{v}^\perp)$$

$$\mathcal{O}_{15} = -\left(\vec{S}_\chi \cdot \frac{\vec{q}}{m_n} \right) \left((\vec{S}_n \times \vec{v}^\perp) \cdot \frac{\vec{q}}{m_n} \right). \qquad \text{(A2)}$$

“CYGNUS” physics after discovery

- **Test the interaction by scattering angle**

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



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

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$$\mathcal{O}_3 = i\vec{S}_n \cdot \left(\frac{\vec{q}}{m_n} \times \vec{v}^\perp \right)$$

$$\mathcal{O}_4 = \vec{S}_\chi \cdot \vec{S}_n \quad \leftarrow \text{SD}$$

$$\mathcal{O}_5 = i\vec{S}_\chi \cdot \left(\frac{\vec{q}}{m_n} \times \vec{v}^\perp \right)$$

$$\mathcal{O}_6 = (\vec{S}_\chi \cdot \vec{q})(\vec{S}_n \cdot \vec{q})$$

$$\mathcal{O}_7 = \vec{S}_n \cdot \vec{v}^\perp$$

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$$\mathcal{O}_9 = i\vec{S}_\chi \cdot (\vec{S}_n \times \vec{q})$$

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$$\mathcal{O}_{12} = \vec{S}_\chi \cdot (\vec{S}_n \times \vec{v}^\perp)$$

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$$\mathcal{O}_{15} = -\left(\vec{S}_\chi \cdot \frac{\vec{q}}{m_n} \right) \left((\vec{S}_n \times \vec{v}^\perp) \cdot \frac{\vec{q}}{m_n} \right). \qquad \text{(A2)}$$

Summary

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

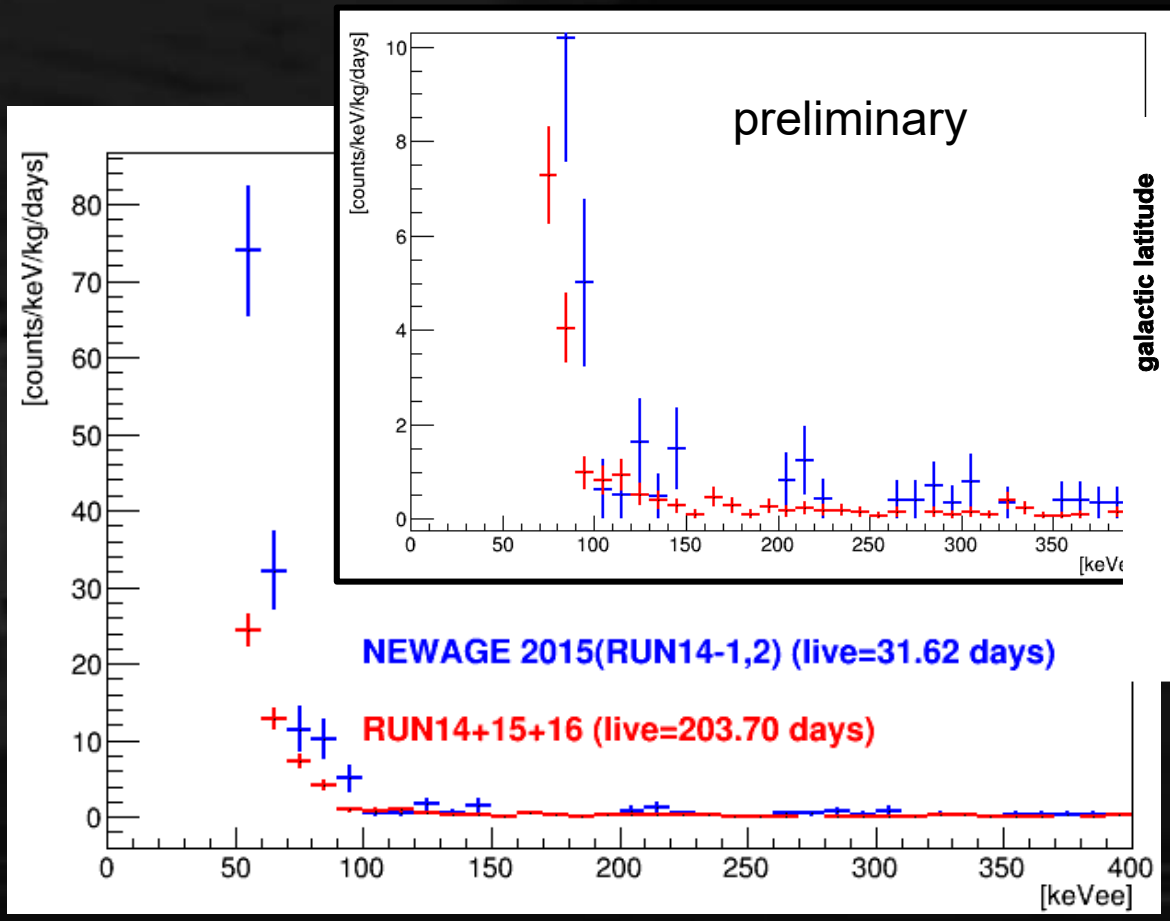
Direction Sensitive
WIMP-search
NEWAGE

backup

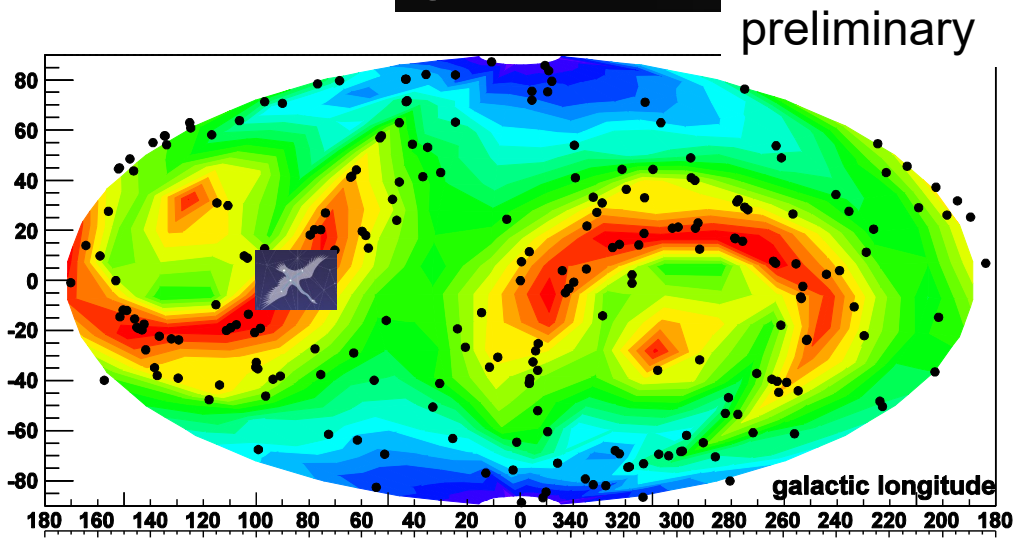
Direction Sensitive
WIMP-search
NEWAGE

Latest underground data

- RUN14 (31.6days) + 172.08days
  - gamma-ray cut improvements
  - increased statistics



galactic coordinate

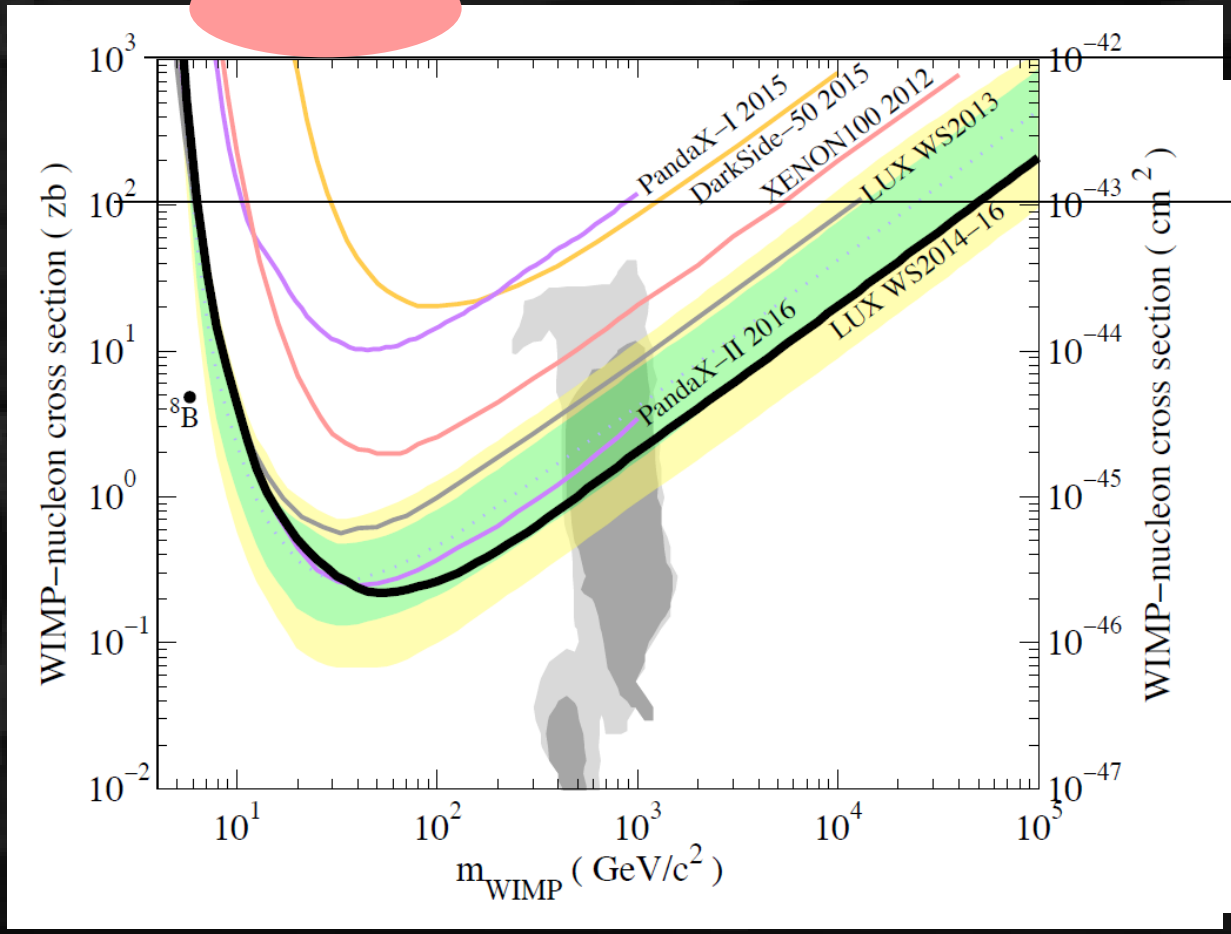


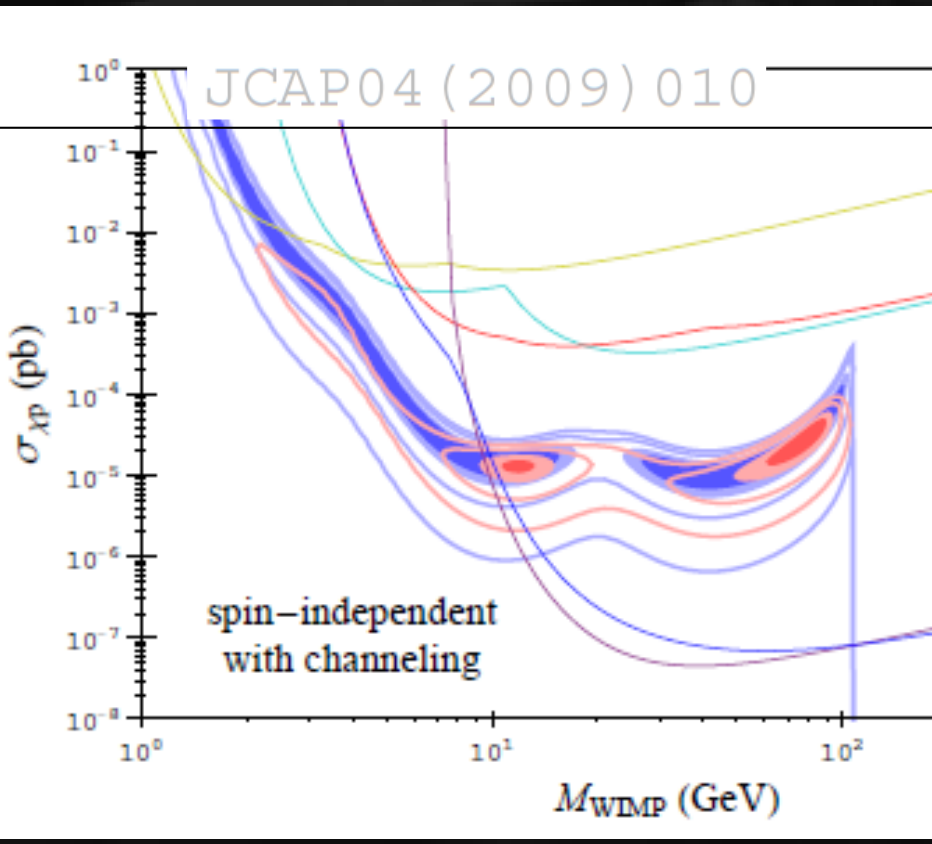
color: efficiency
dots: recoil events

- **DAMA and others… in tension**

- **any other clear evidence ?**

LUX arXiv 1608.07648
PandaX-II arXiv 1607.074003

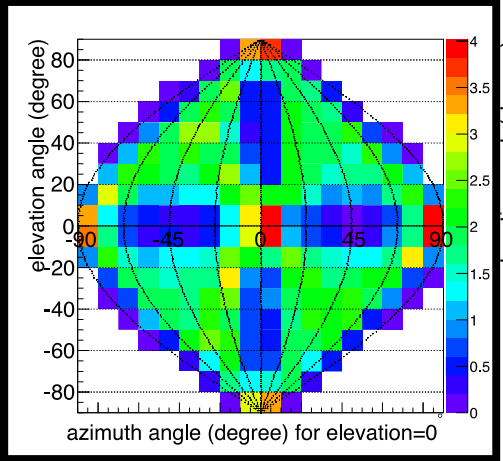


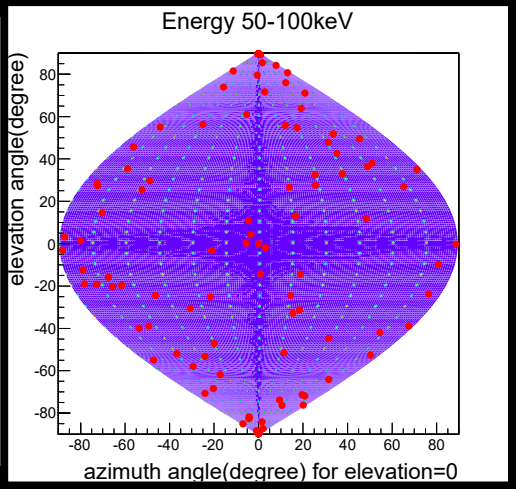


Galactic-plane sky-map

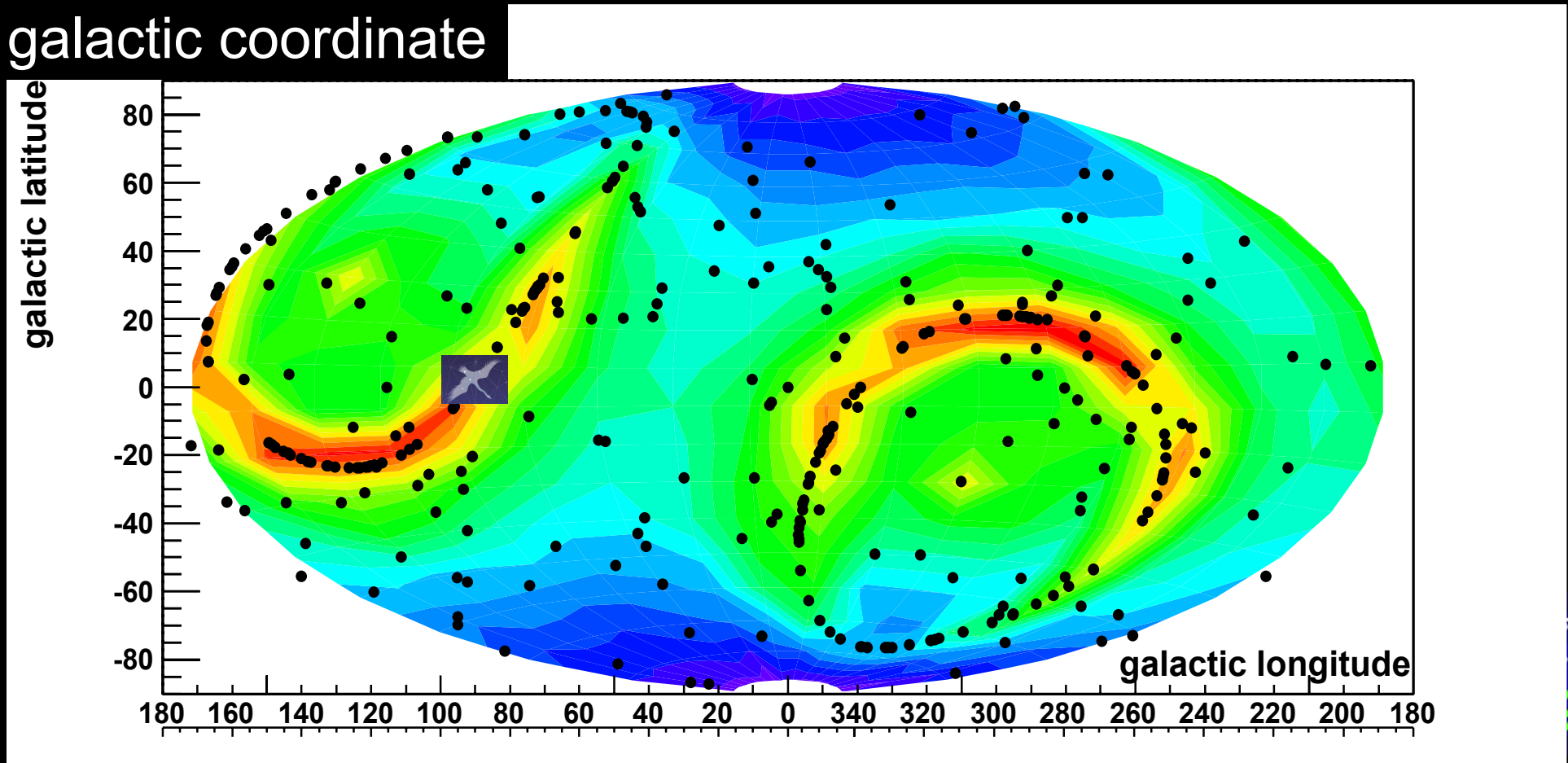
lab-coordinate

- correlation with efficiency = consistent with isotropic

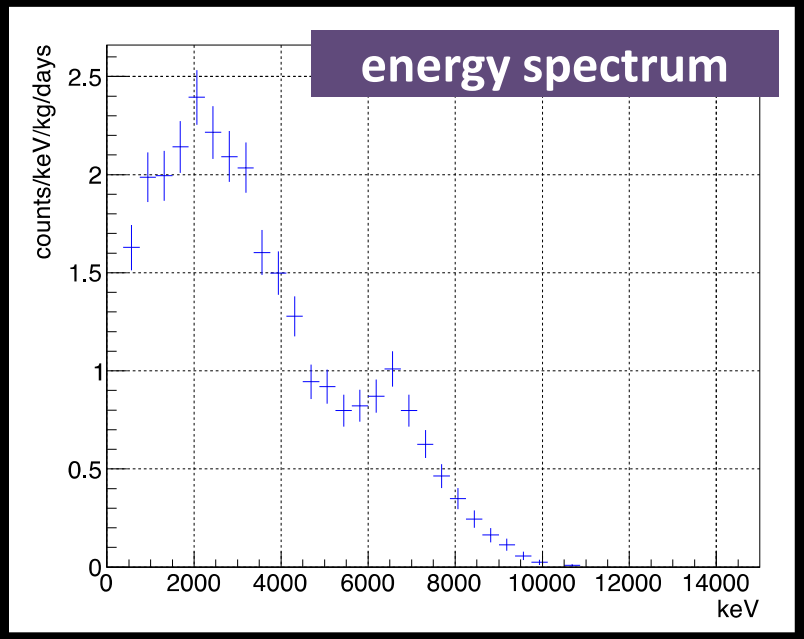




galactic coordinate

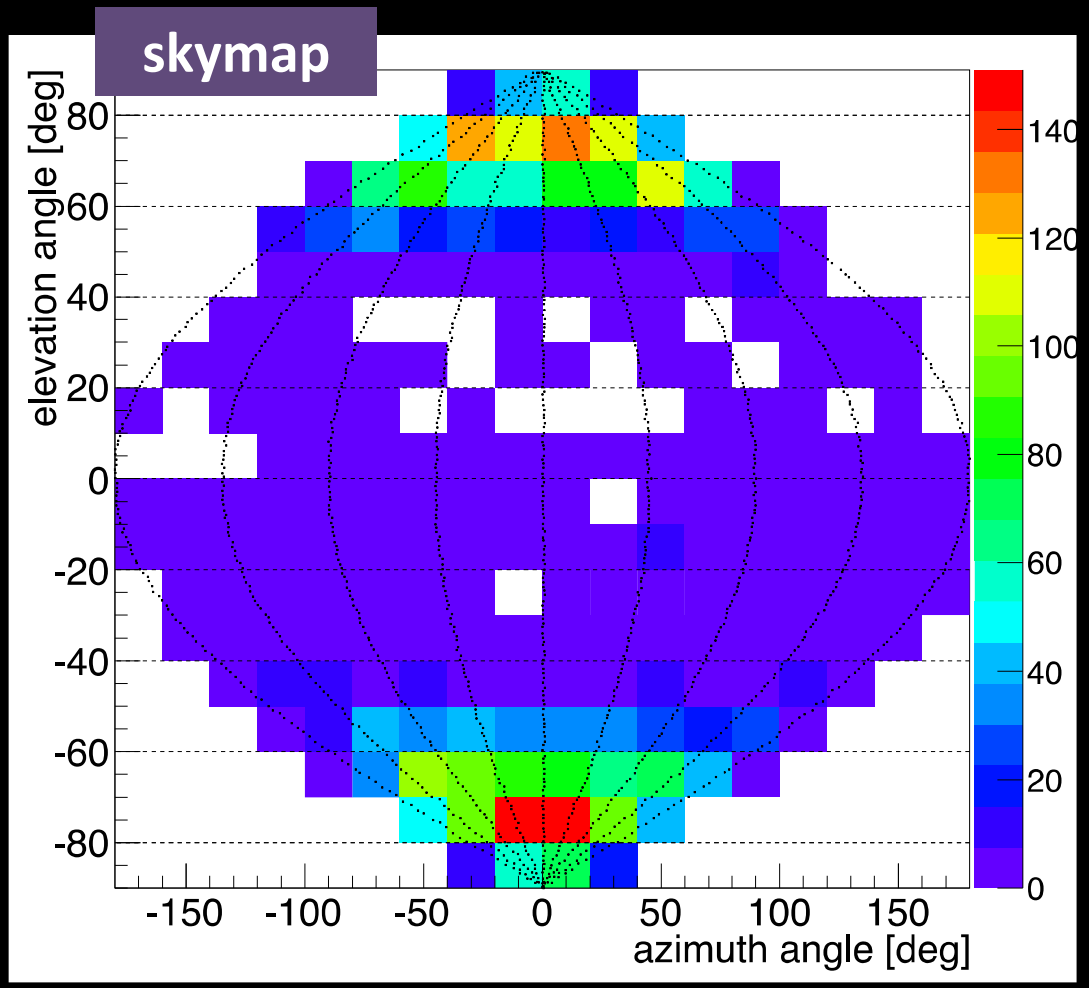


3. Direction sensitive background study

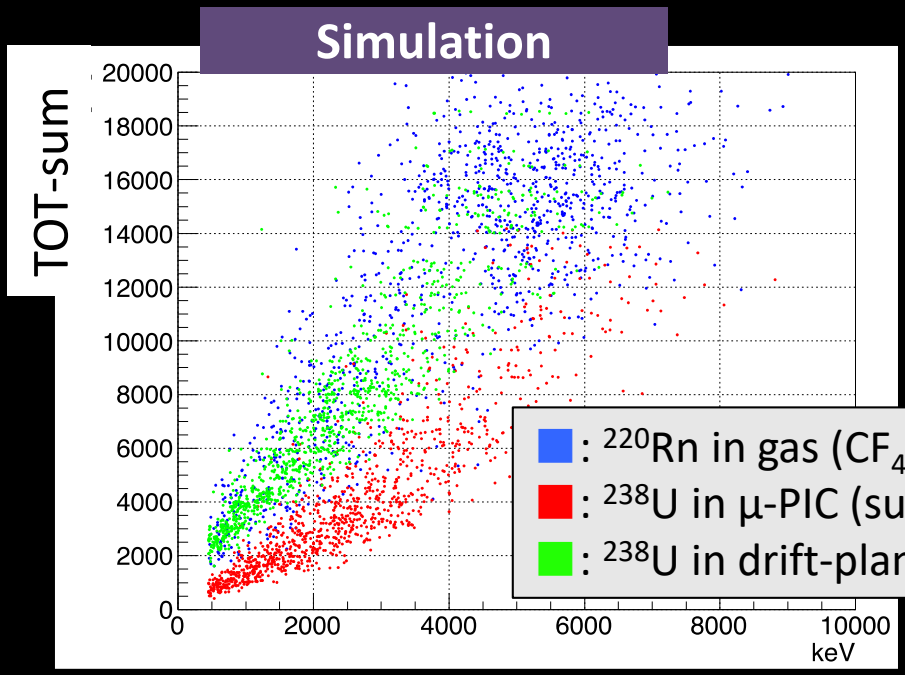


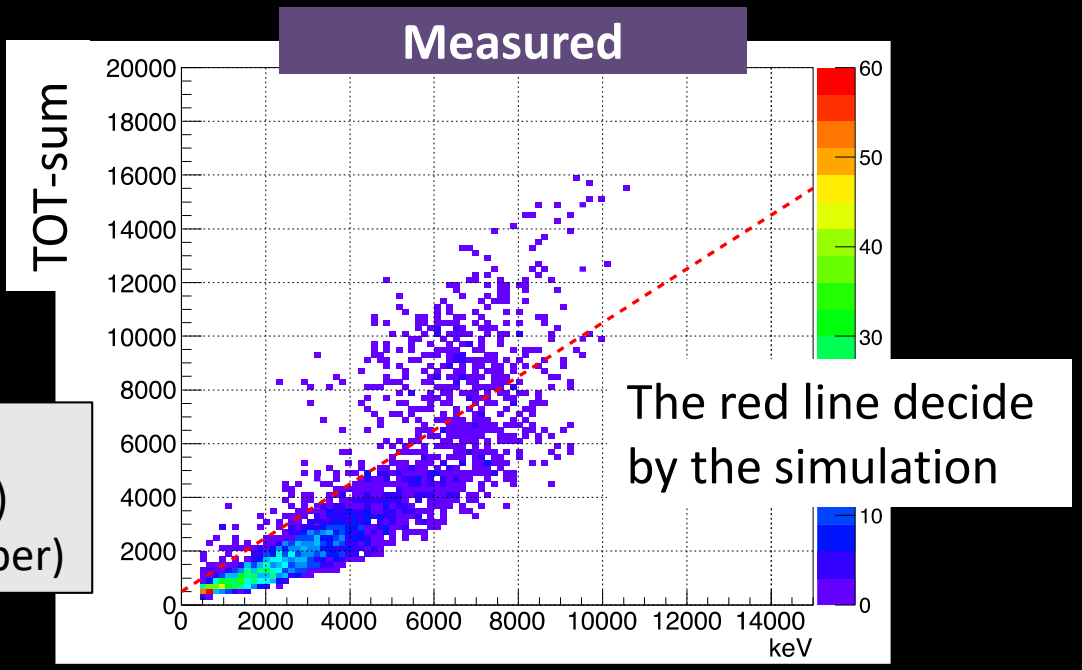
RUN14 Measurement

- Fiducial-cut only and high energy events (500~15000 keV)
- The directional distribution is not isotropic
- Mary vertical events

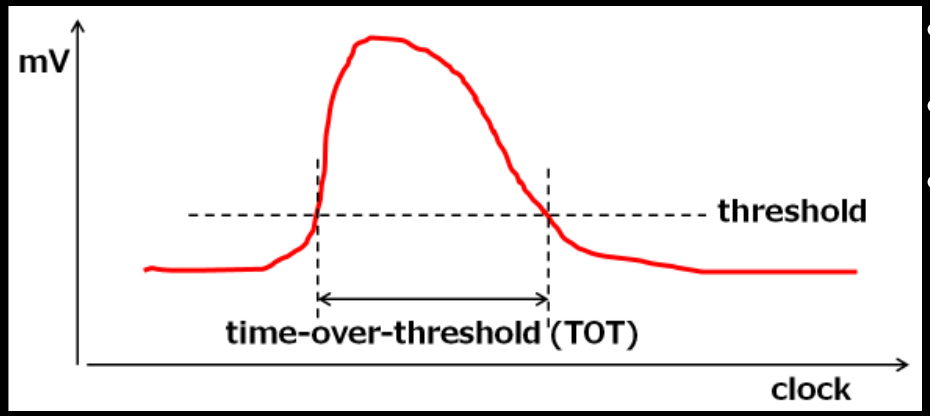


TOT-sum vs. Energy



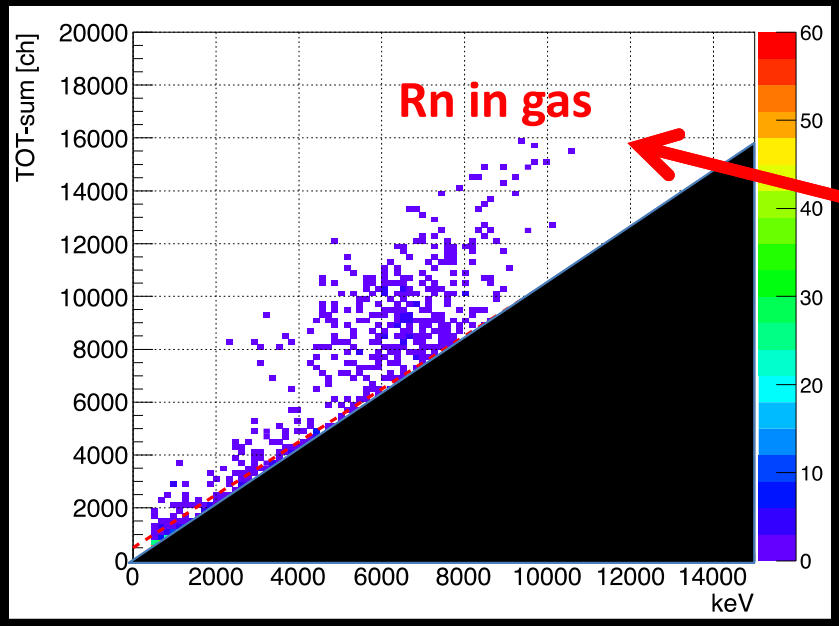


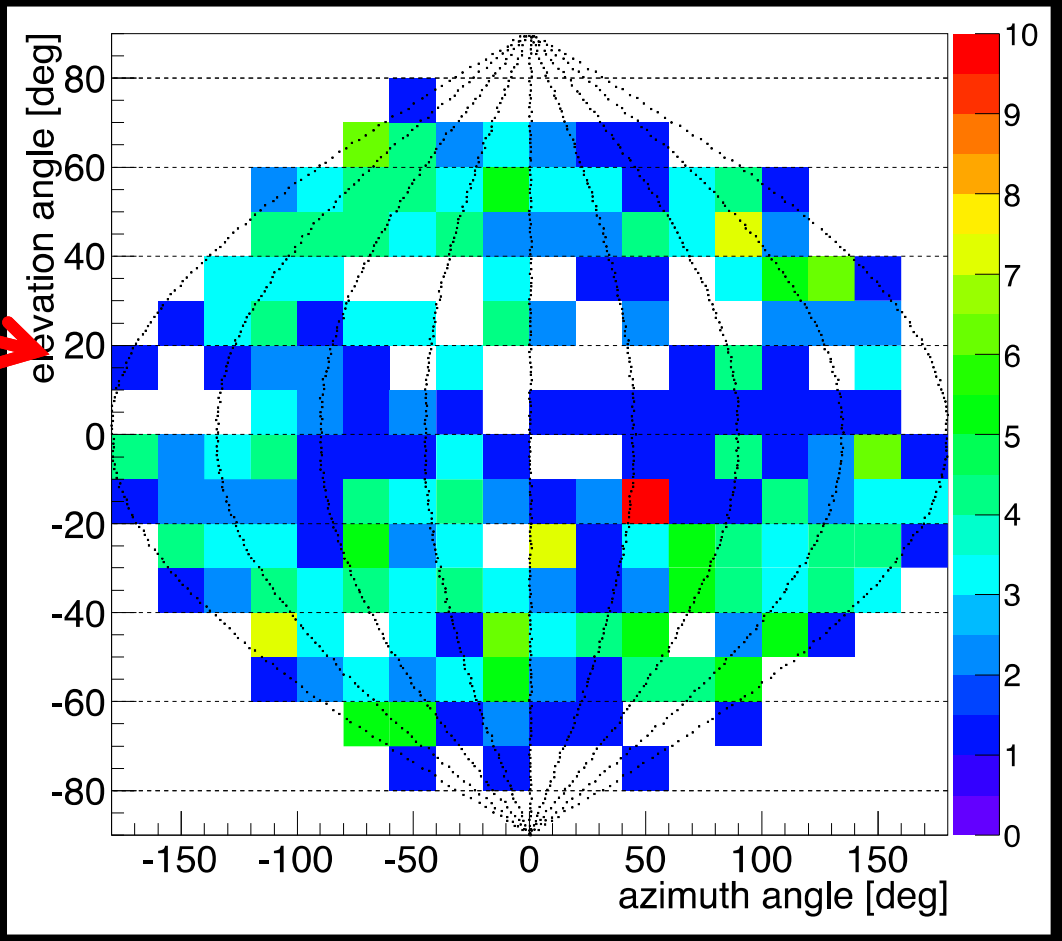
- Simulated and measured TOT-sum are alike
- Background events are considered to be due to α-particles
- We can divide into two regions by the red line

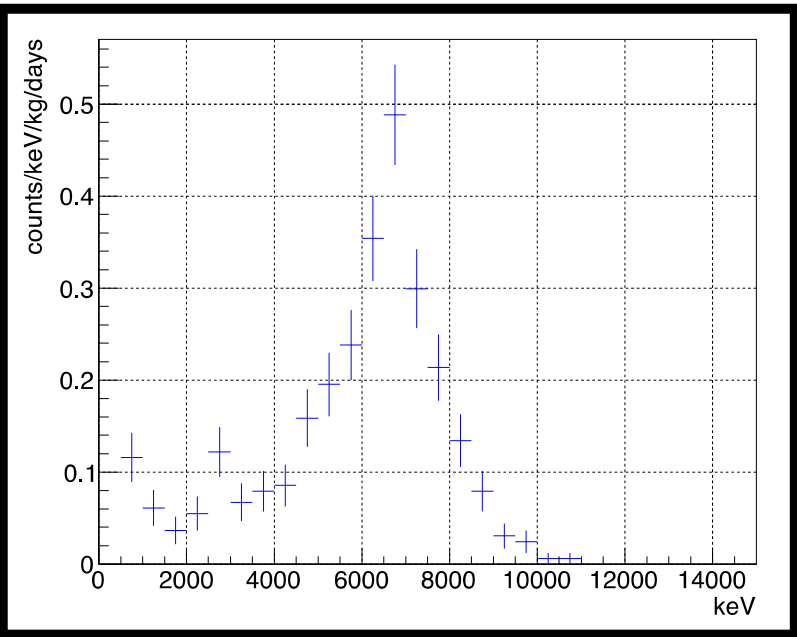


- We records Time-Over-Threshold(TOT)
- TOT is the time duration of waveform
- TOT-sum is a sum of the TOT of all strip

Peak component







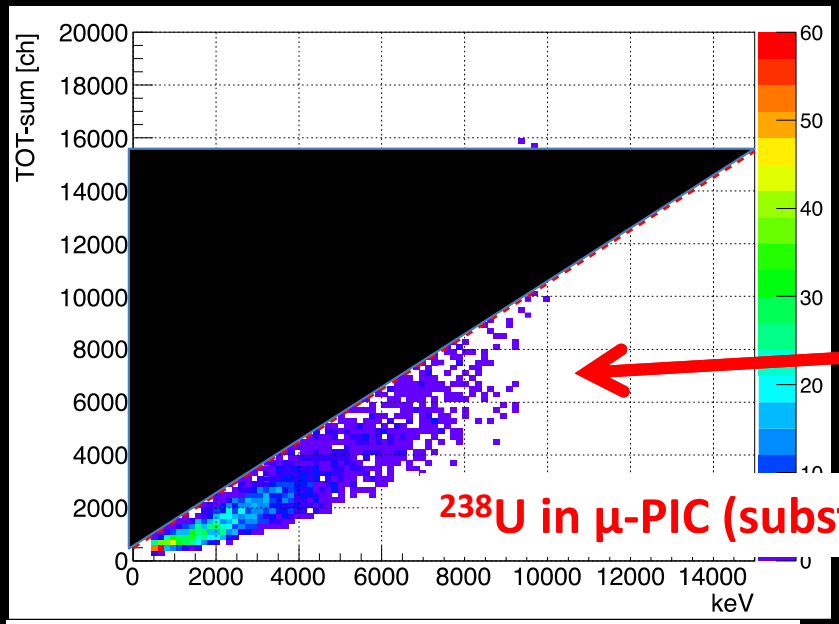
Rn

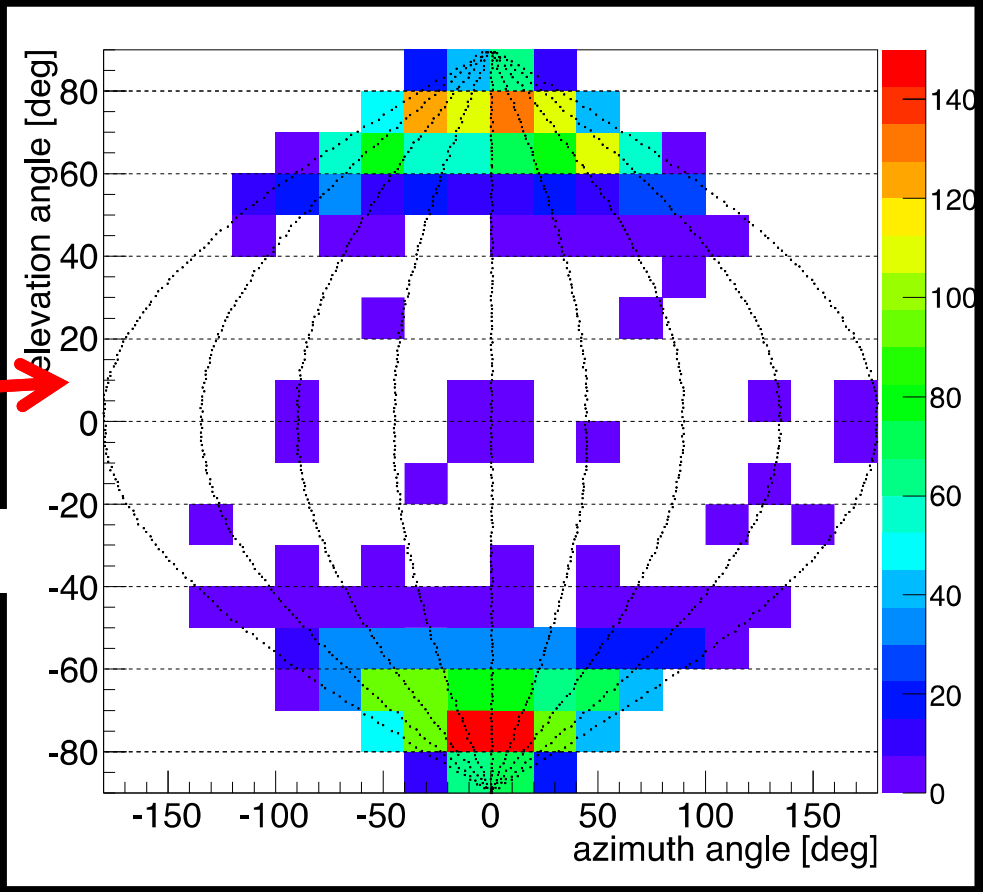
<u>In the upper region</u>

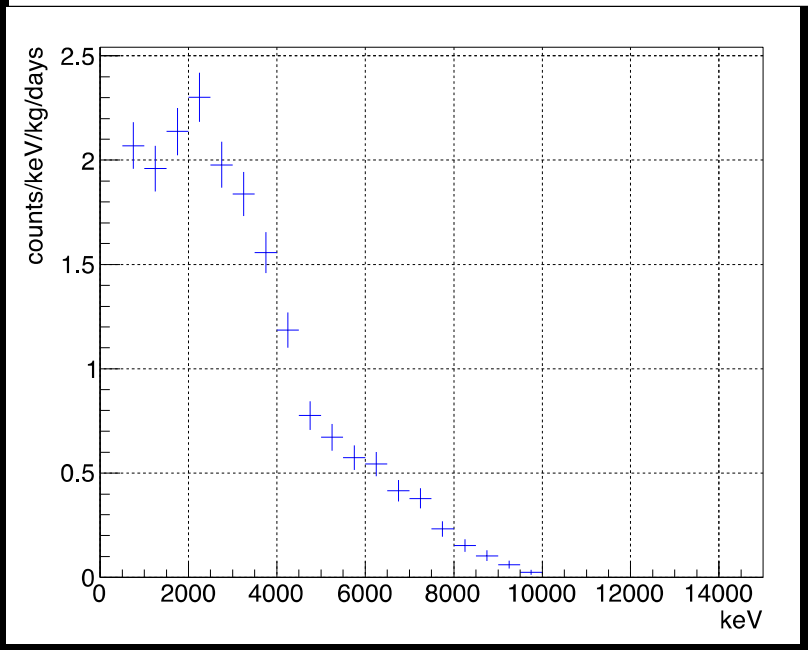
- Isotropic distribution
- Peak component

the measurement is Consistent with the simulation

Continuous component







<u>In the bottom region</u>

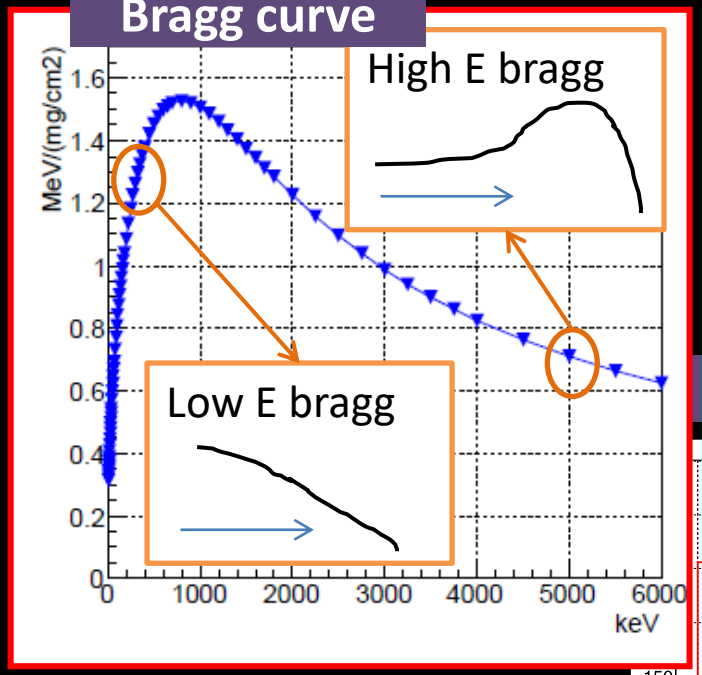
- Mary vertical events
- Continuous component

Next page

Direction of vertical events

α energy > 500keV

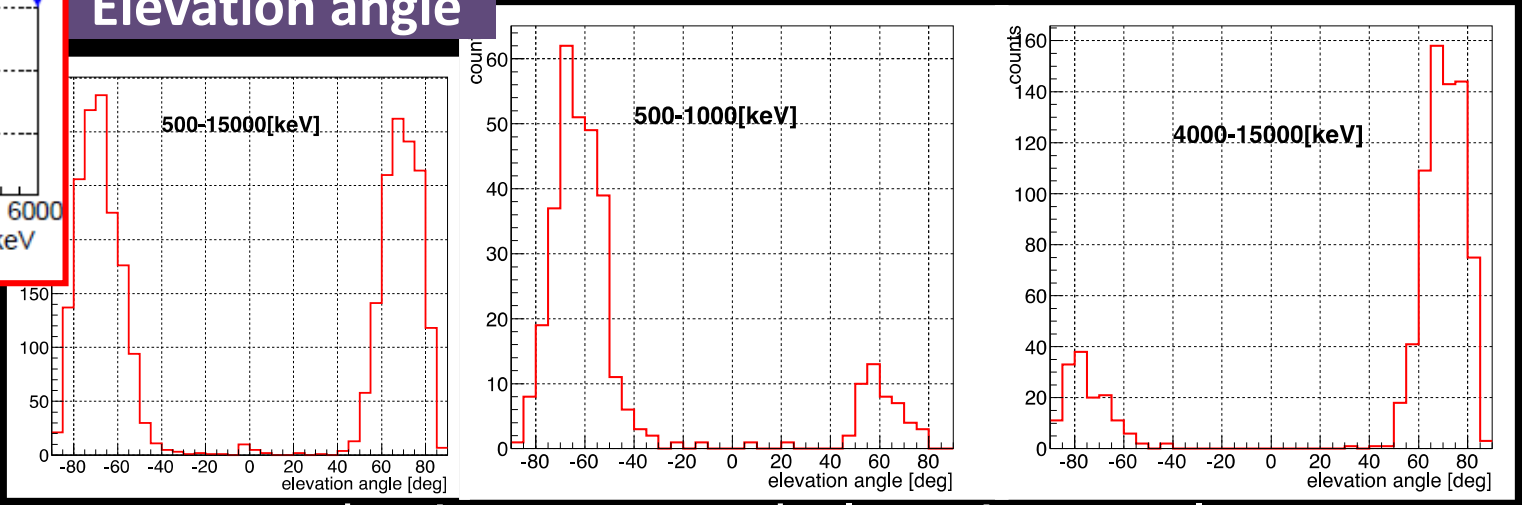
Bragg curve

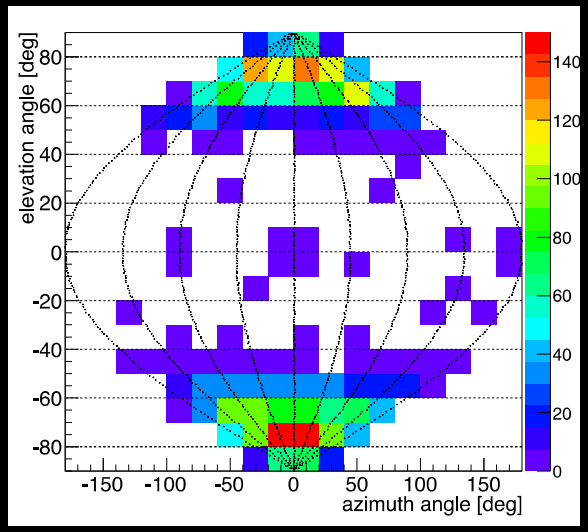


We consider the energy deposition of α particles a function.This function has a peak around 1MeV

- α energy > ~4MeV : “Normal Bragg curve”
- α energy < ~1MeV : “Inversed Bragg curve”

Elevation angle





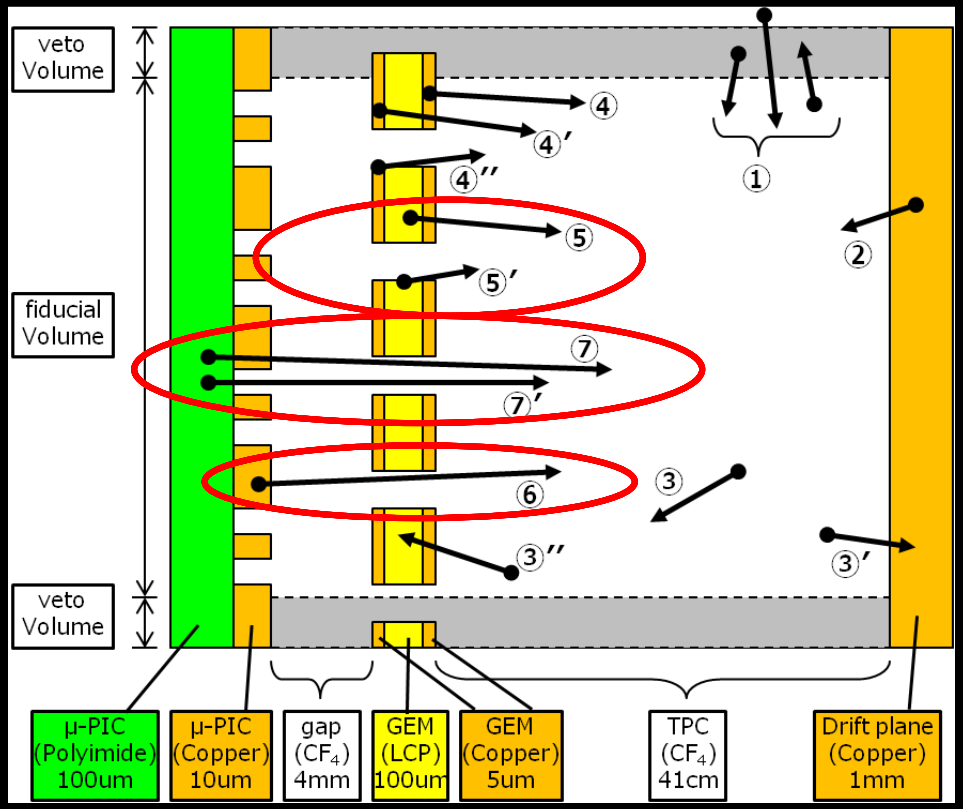
- We can obtain measured elevation angle distribution as “normal Bragg-curve” regardless of α energy

α-particles with an energy

- > ~4MeV : ±Z → ±Z
- < ~1MeV : ±Z → ∓Z

α-particles are **+Z direction**

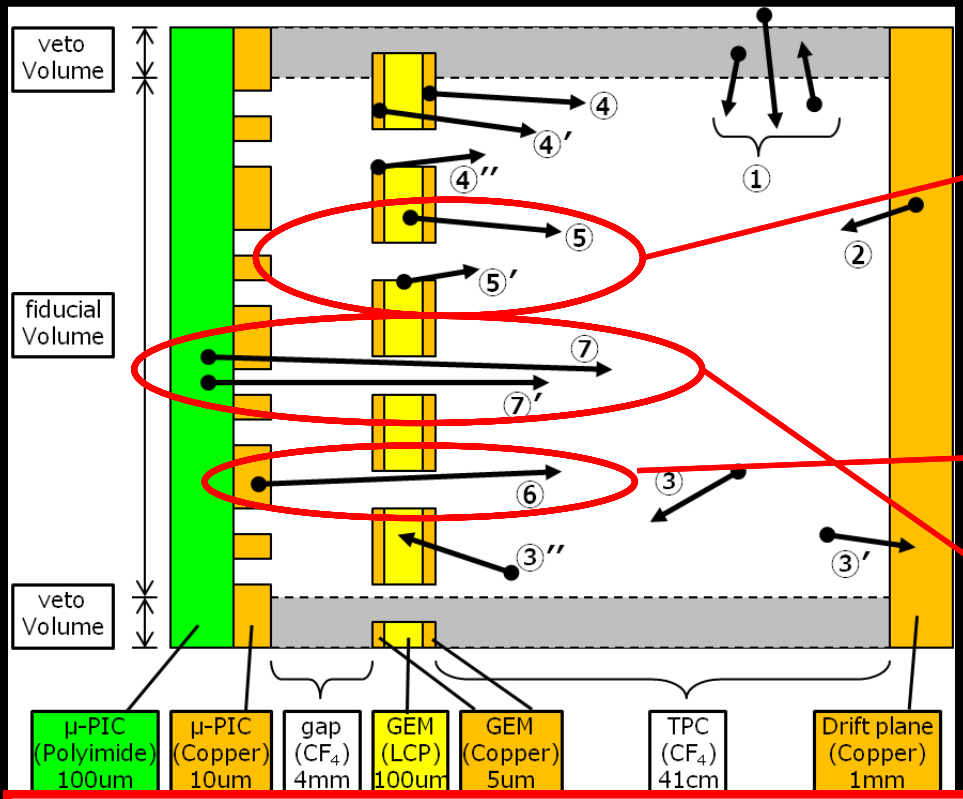
Origin of +Z direction

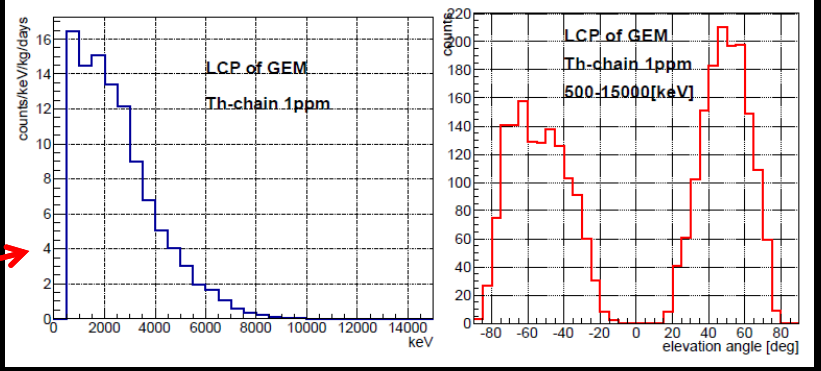


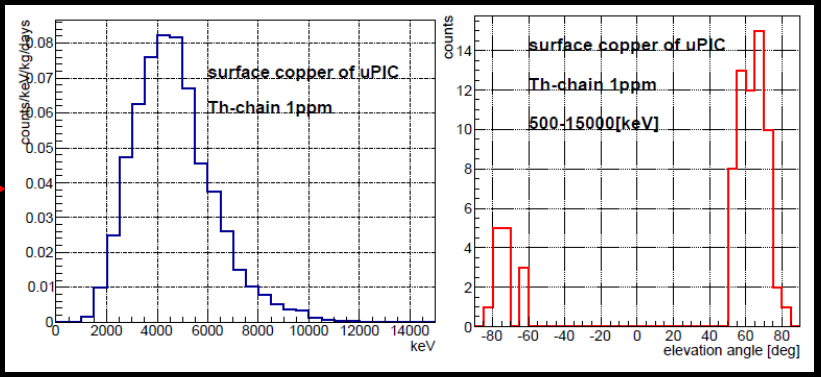
α-particles are +Z direction

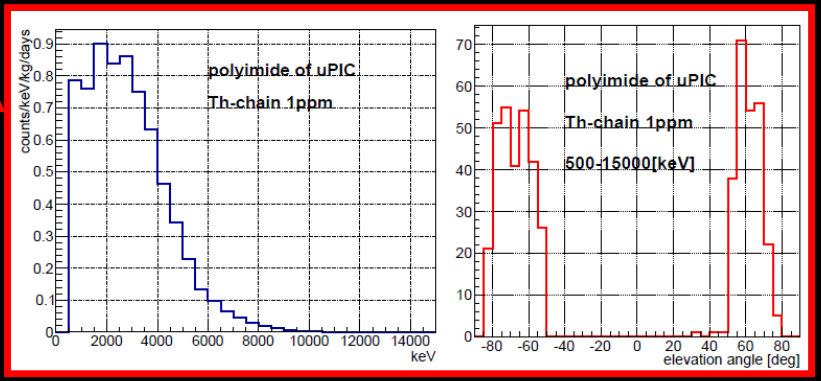
- The α background source should be located in μ-PIC or GEM(5,5’,6,6’,7,7’)
- We simulated the α particles emission from Th-chain in each parts

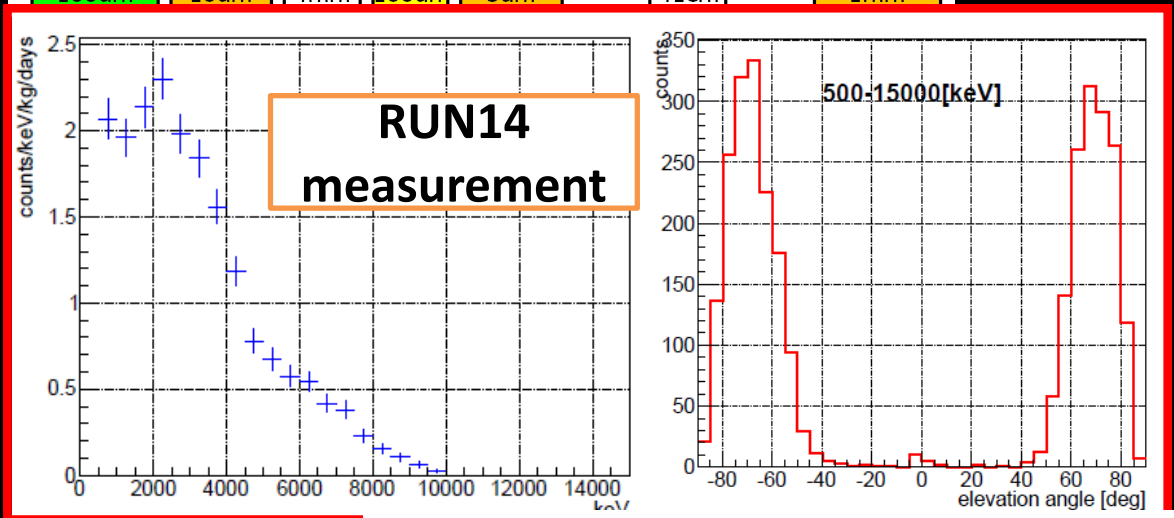
Origin of +Z direction











- α particles emission from Th-chain in μ-PIC reproduce RUN14 measurement

The result is **consistent with HPGe + simulation study**

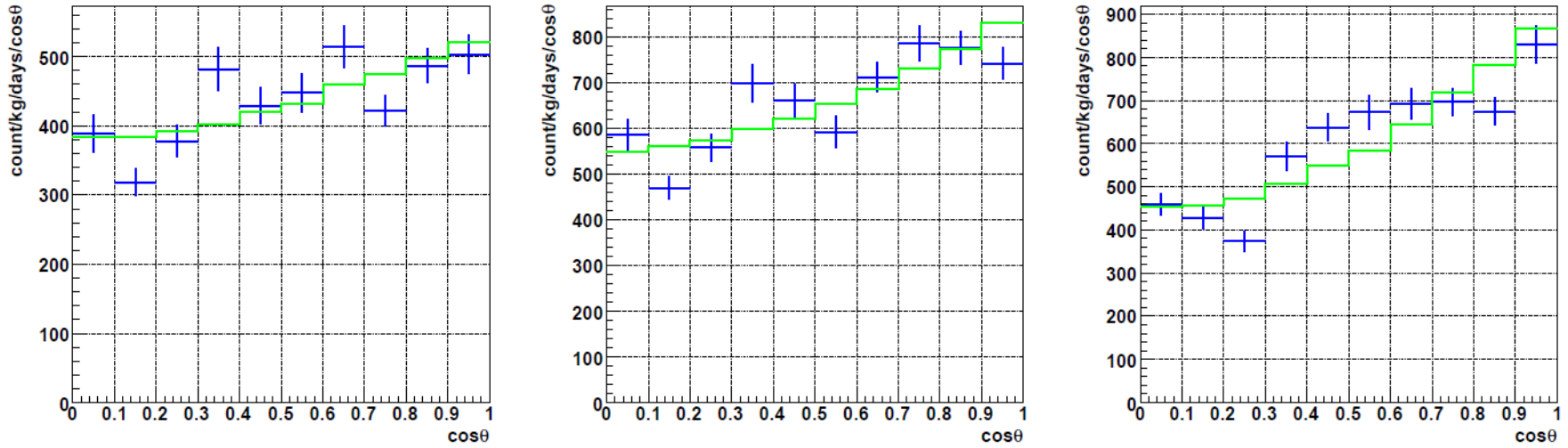


Figure 4.4.18: $|\cos\theta|$ distribution of the scattering angle in nuclear recoil events that occur by irradiation with neutrons from ^{252}Cf. The energy range of left, center, and right figures are $50-100\,\mathrm{keV}$, $100-200\,\mathrm{keV}$, and $200-400\,\mathrm{keV}$, respectively. Measured and simulated distributions are shown by blue and green histograms respectively.

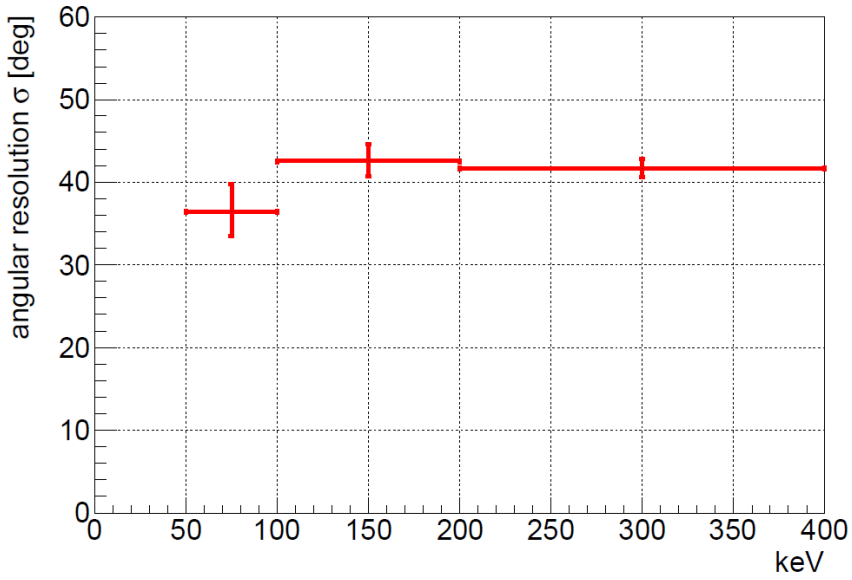
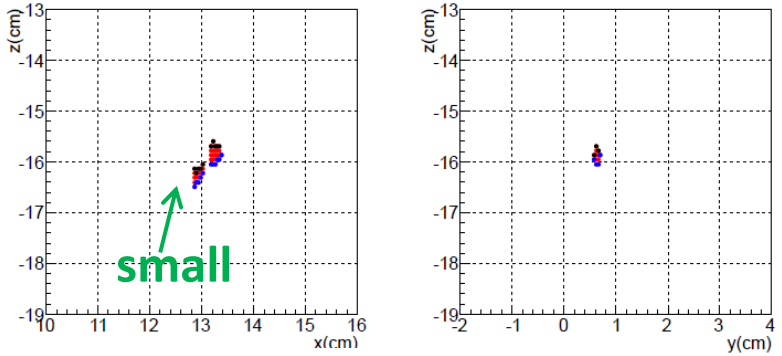


Figure 4.4.21: Obtained angular resolution for each energy.

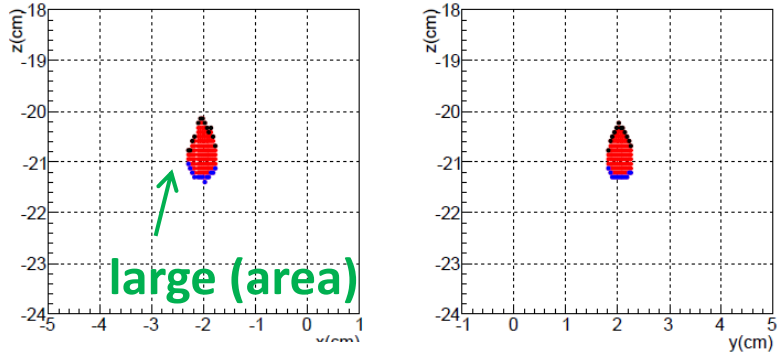
Cut improvement

TOT(Time Over Threshold)-sum-cut (gamma-ray cut)

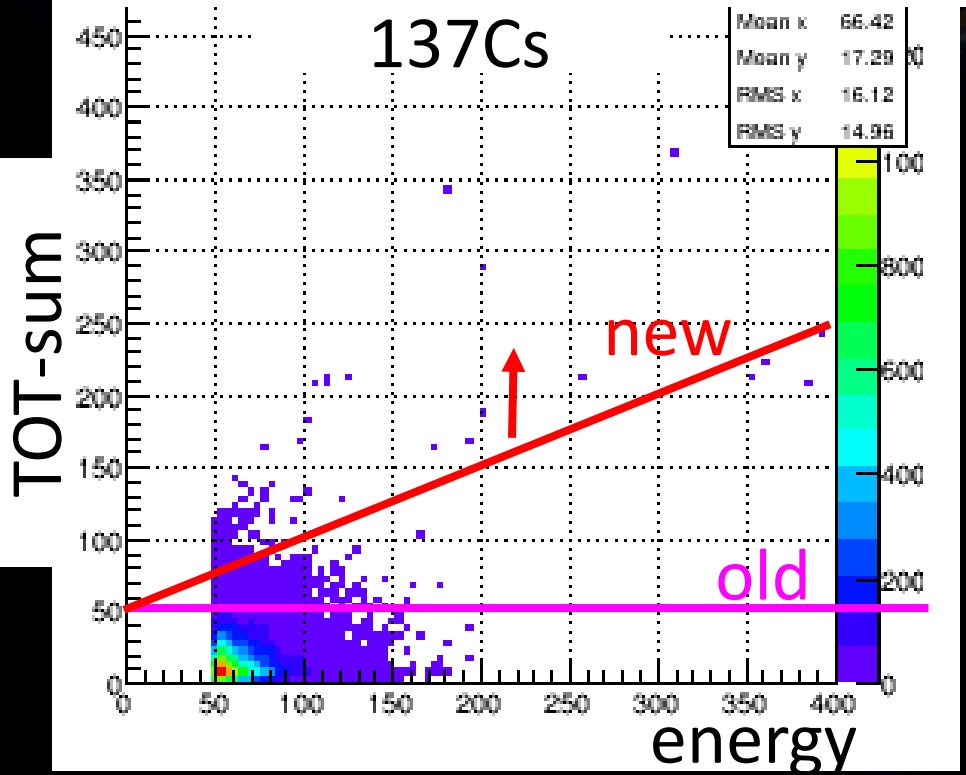
- Nuclear (^{252}Cf) : TOT-sum is proportional to energy
- Electron (^{137}Cs) : scratched track (small dE/dx)

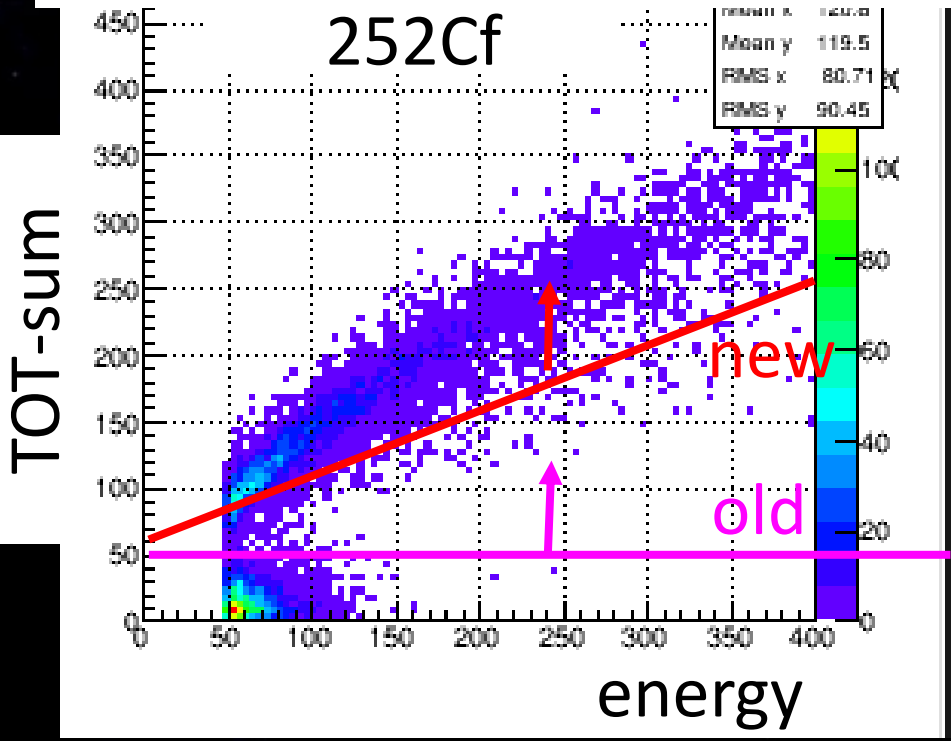


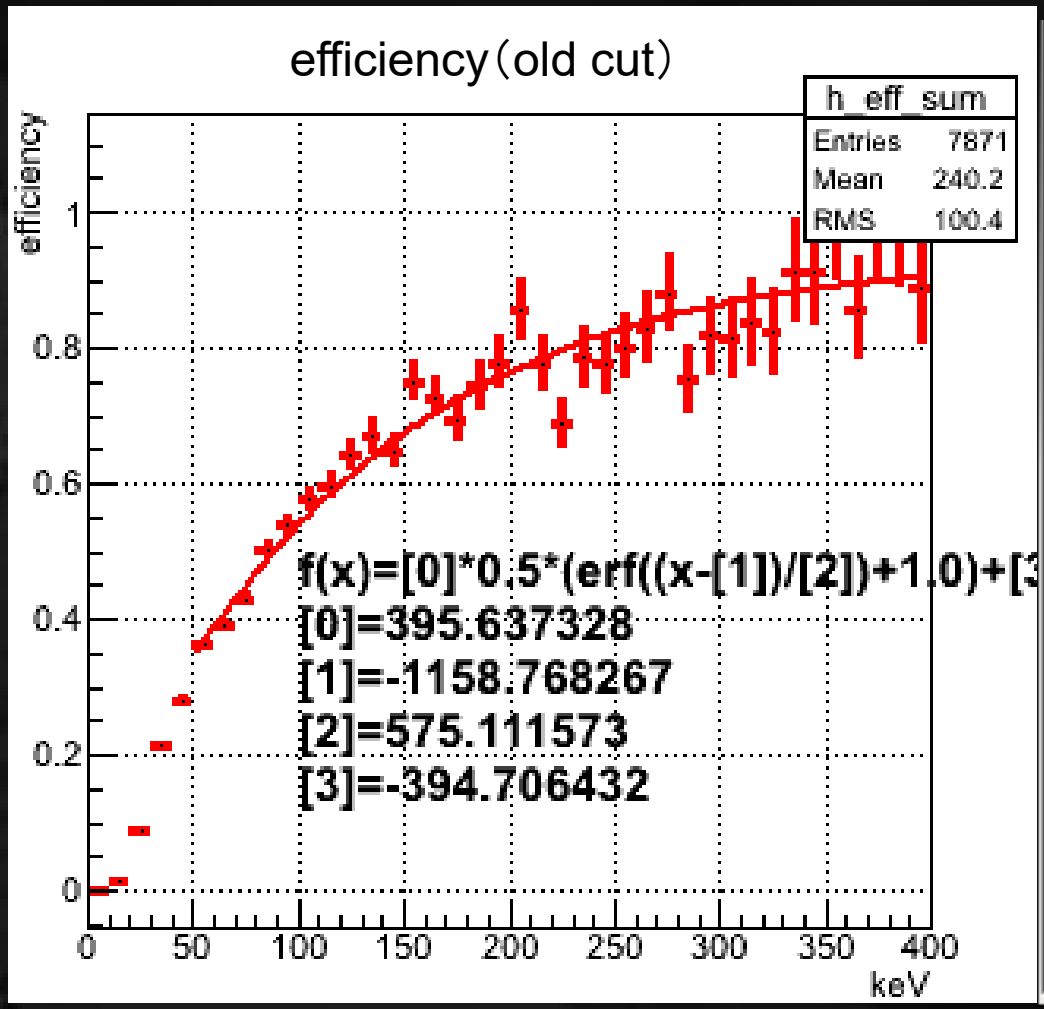
^{137}Cs RUN
ene_low=100.0545(
length=0.814168 [c
TOT-sum=55
roundness=0.0211

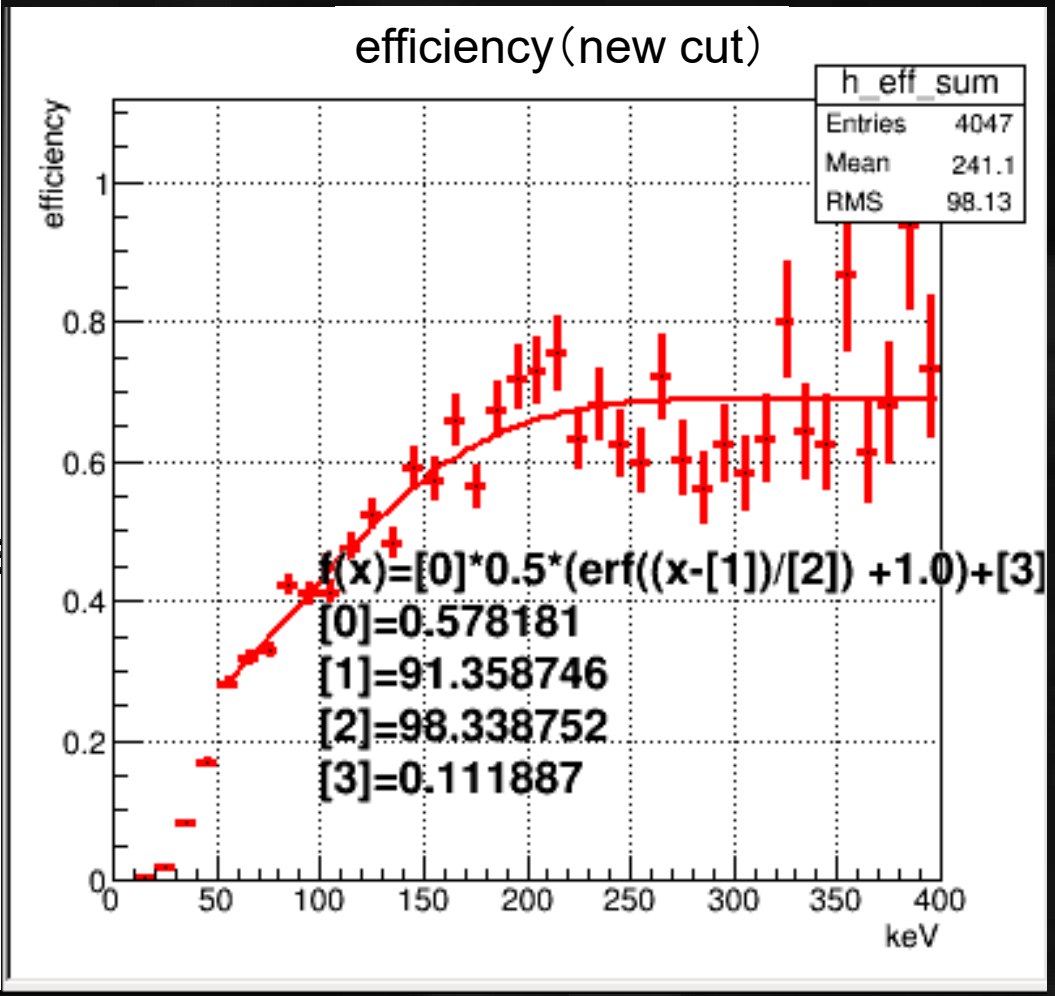


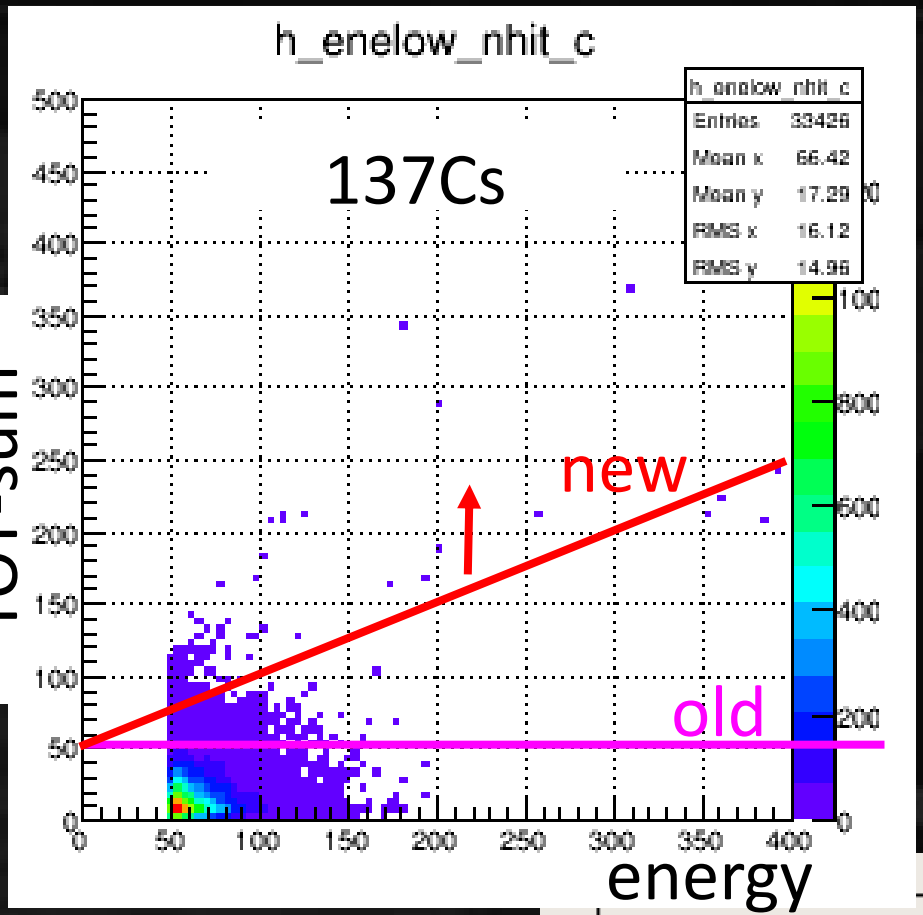
^{252}Cf RUN
ene_low=100.783500 [keV]
length=0.689406 [cm]
TOT-sum=250
roundness=0.055549

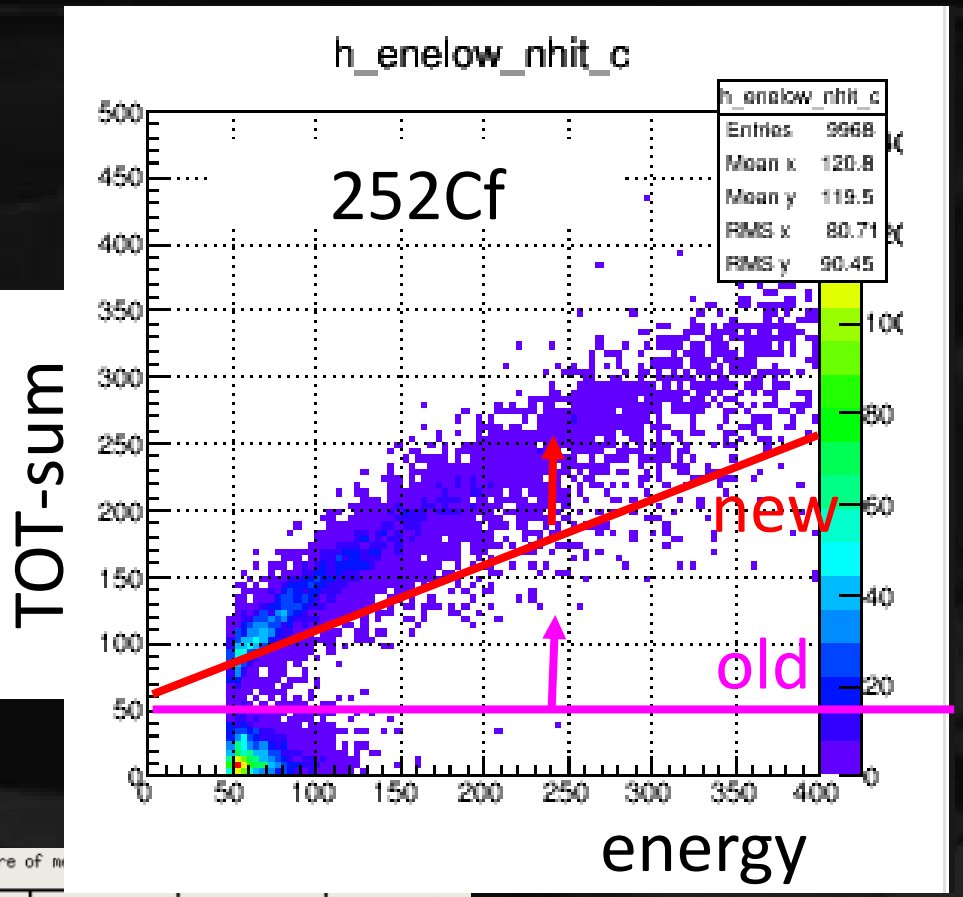




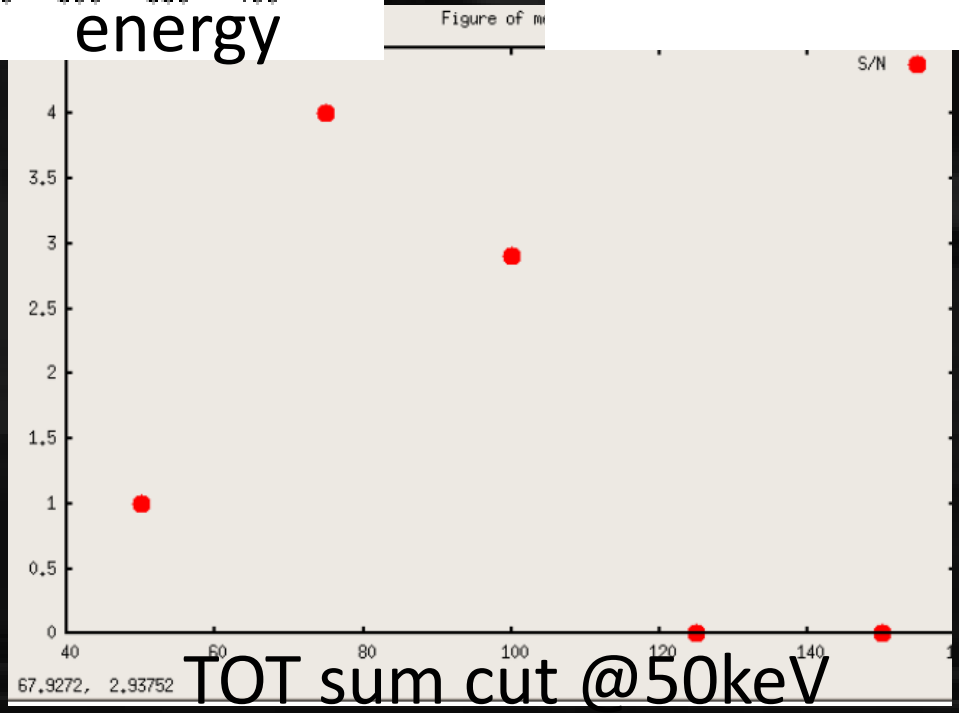

efficiency（old cut）
h_eff_sum
Entries 7871
Mean 240.2
RMS 100.4
efficiency
f(x)=[0]*0.5*(erf((x-[1])/[2])+1.0)+[3
[0]=395.637328
[1]=-1158.768267
[2]=575.111573
[3]=-394.706432
keV


efficiency（new cut）
h_eff_sum
Entries 4047
Mean 241.1
RMS 98.13
efficiency
f(x)=[0]*0.5*(erf((x-[1])/[2]) +1.0)+[3]
[0]=0.578181
[1]=91.358746
[2]=98.338752
[3]=0.111887
keV





FOM



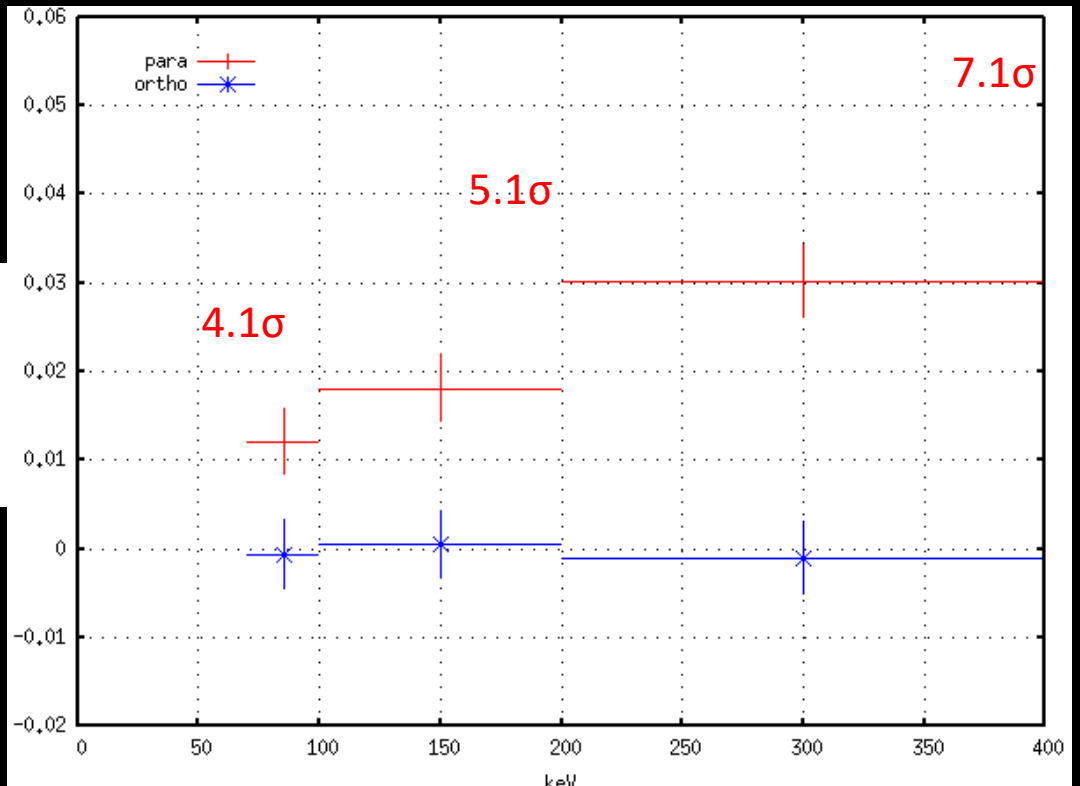
TOT sum cut @50keV

Head/tail study

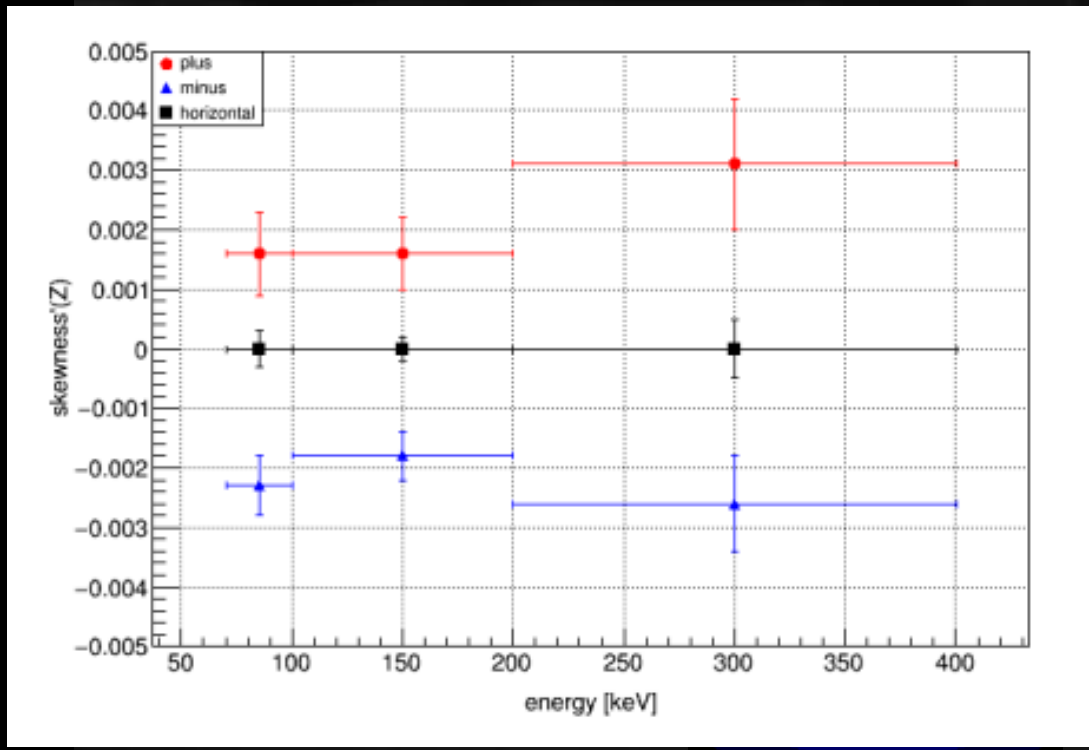
Poster by YAKABE

- Head tail in X-Y plane, Z-axis
- Proof of concept, DONE.
- Improvement for practical use: being studied

X-Y plane

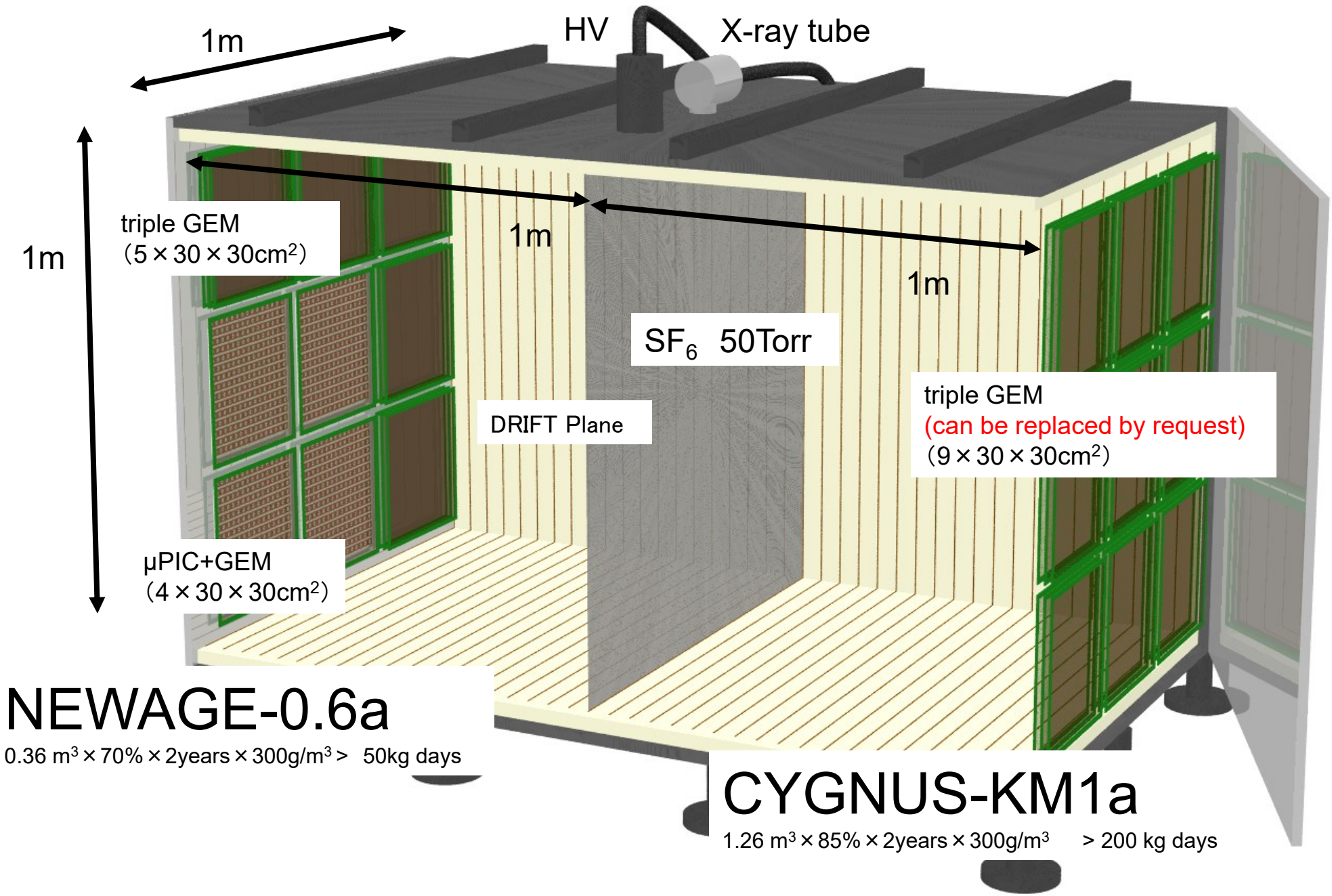


Z axis



NEWAGE and CYGNUS

half-NEWAGE half-CYGNUS “observatory”



NEWAGE-0.6a

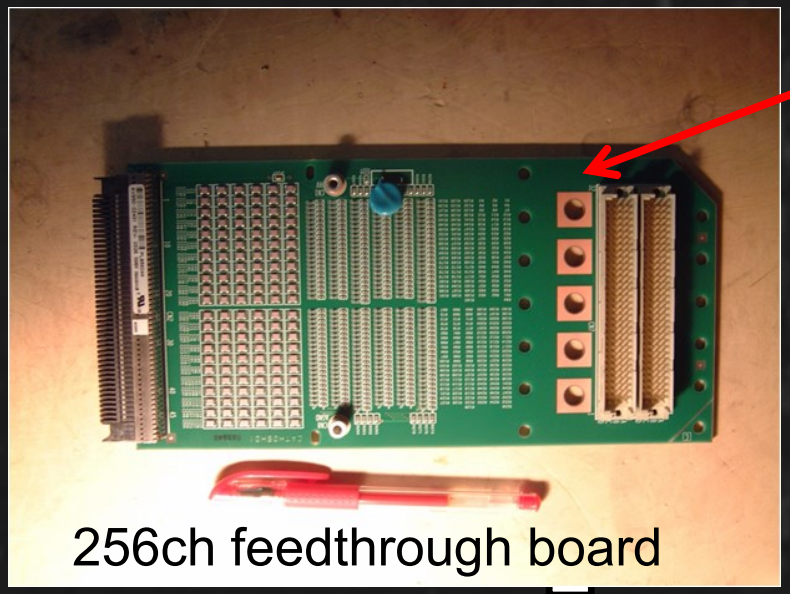
0.36 m^3 × 70% × 2years × 300g/m^3 > 50kg days

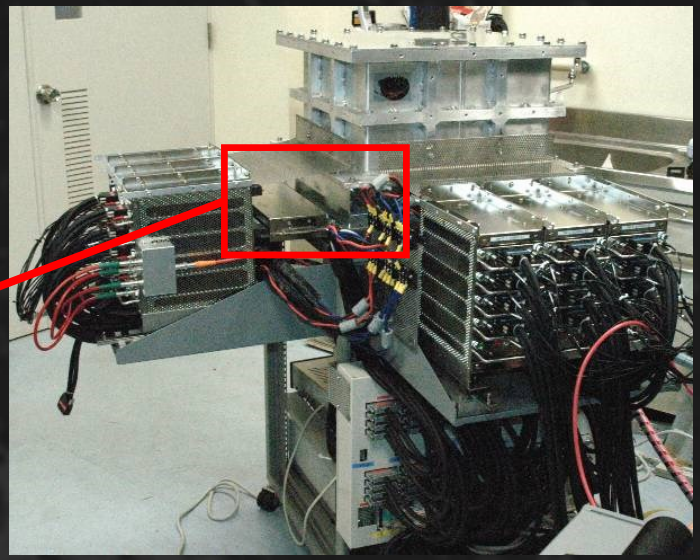
CYGNUS-KM1a

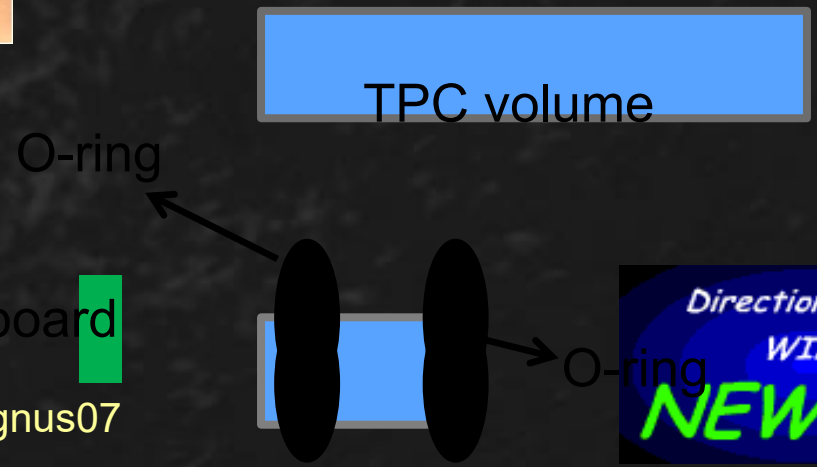
1.26 m^3 × 85% × 2years × 300g/m^3 > 200 kg days

1500ch feedthrough

- feedthrough board
- everything is out of the vessel
- easy to maintain
- keep the gas purity





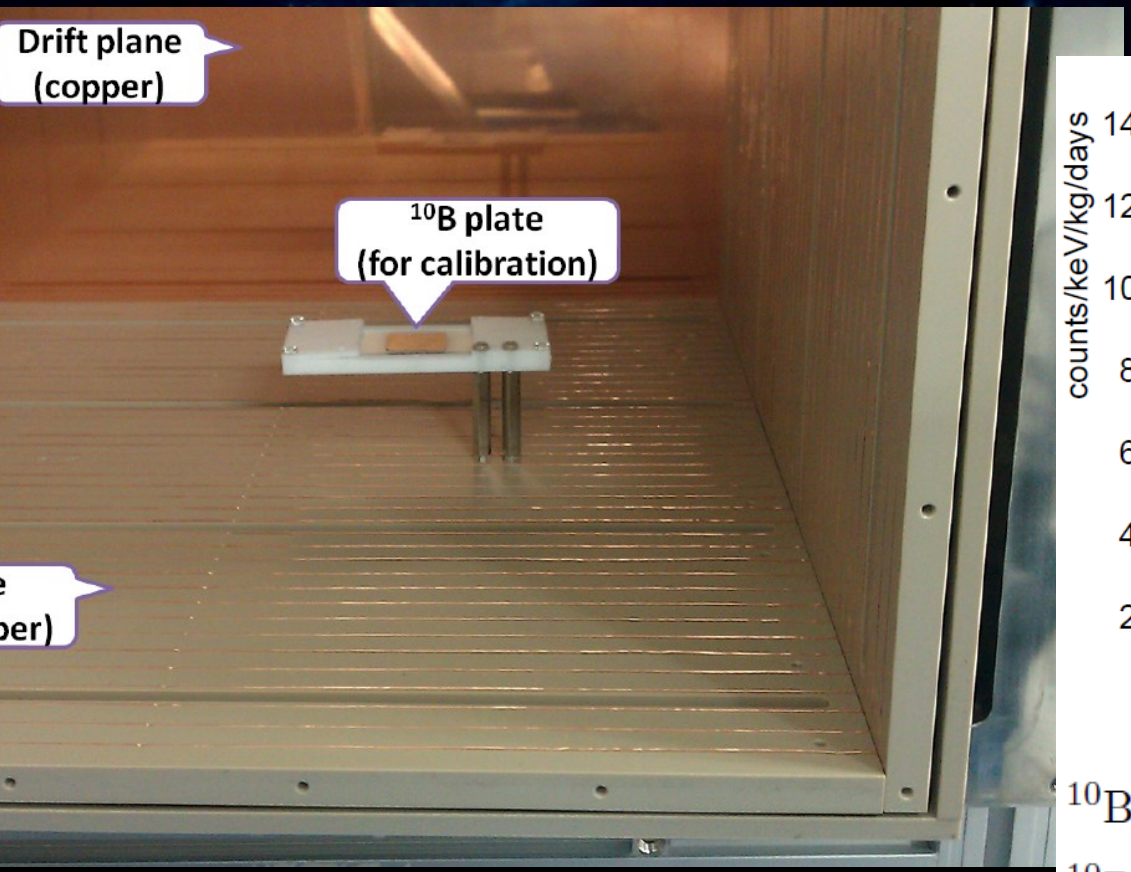


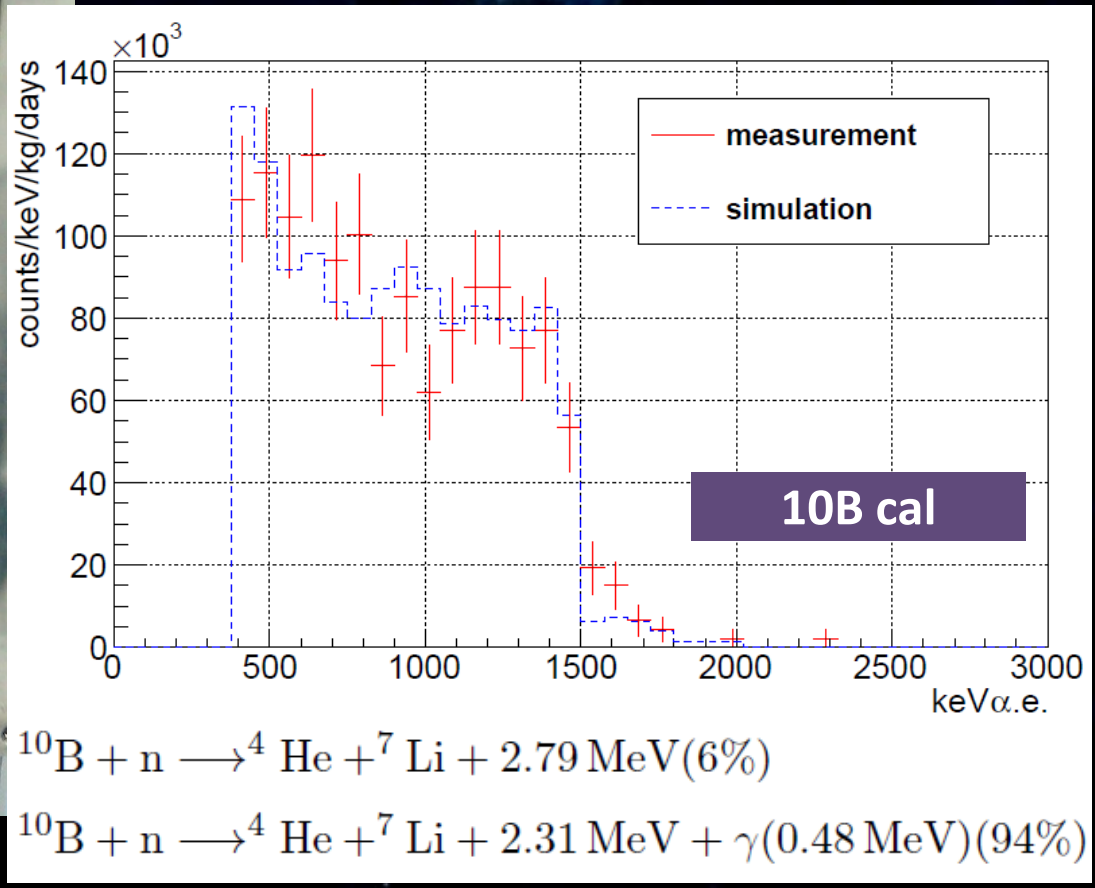
Direction Sensitive WIMP-search NEWAGE

- **NEWAGE-0.3b' performance**
  - Energy threshold: 50keV
  - Energy resolution:
    20% (dominated by gain non-uniformity)
  - Nuclear track detection efficiency: 40% @50keVee
  - Gamma rejection 2.5E-5@50keVee
  - angular resolution 40°　@50keVee

NEWAGE-0.3b' : calibration

- α'sfrom $^{10}B(n,\alpha)^{7}Li$ reaction
- 10B plate stays in the TCP
- irradiated with thermalized neutrons



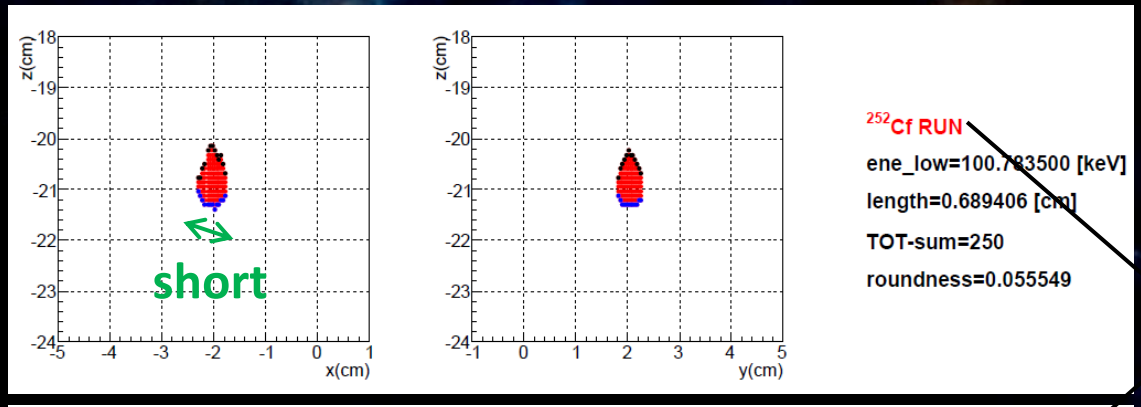


- linearity check: 1.5MeV+ 5.9keV, 6MeV

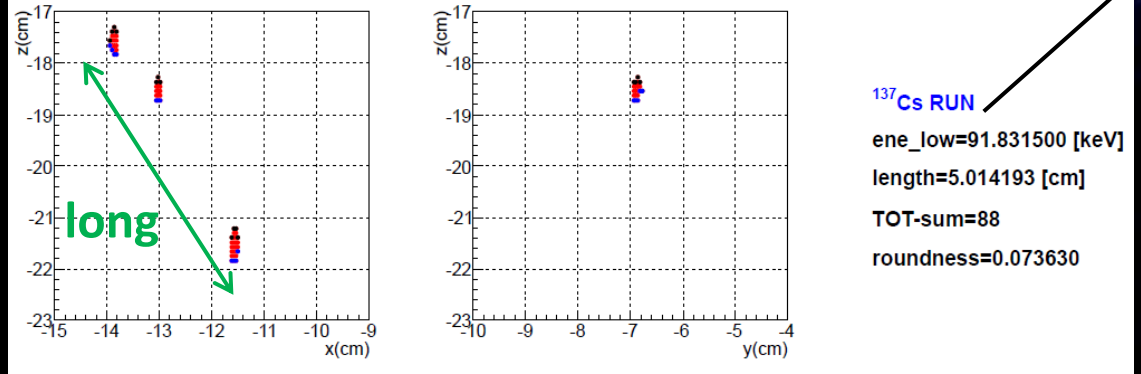
Event selection 1

length-cut (conventional gamma-ray cut)

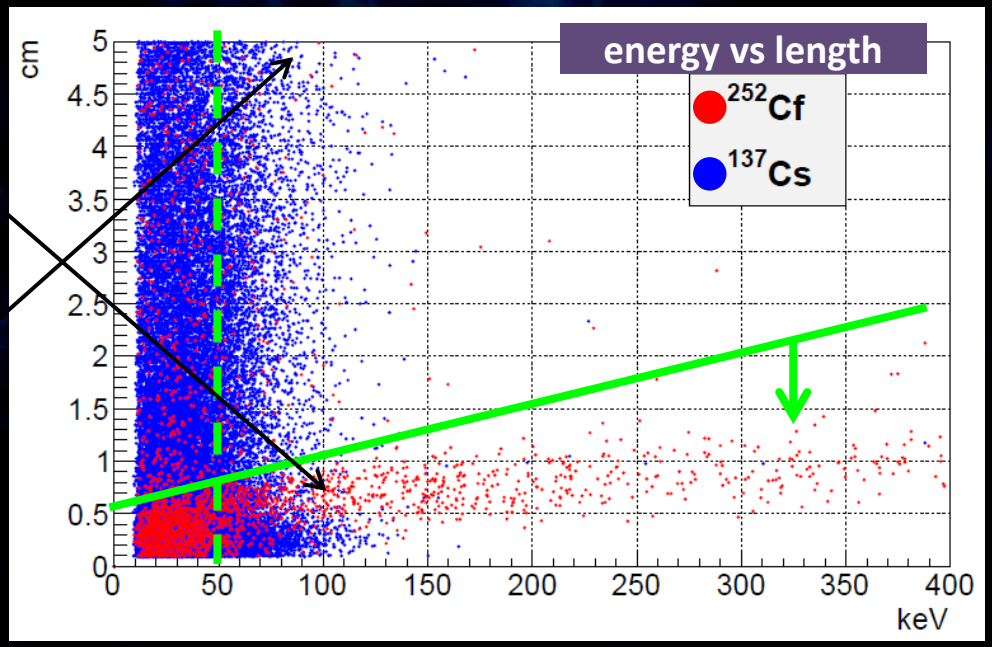
dE/dx : nuclear (^{252}Cf) > electron (^{137}Cs)
track length : electron > nuclear



^{252}Cf RUN
ene_low=100.783500 [keV]
length=0.689406 [cm]
TOT-sum=250
roundness=0.055549



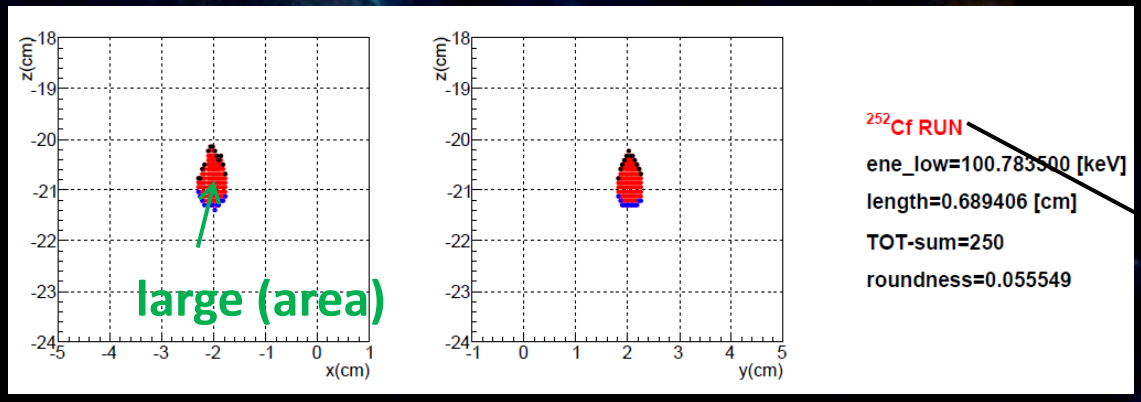
^{137}Cs RUN
ene_low=91.831500 [keV]
length=5.014193 [cm]
TOT-sum=88
roundness=0.073630



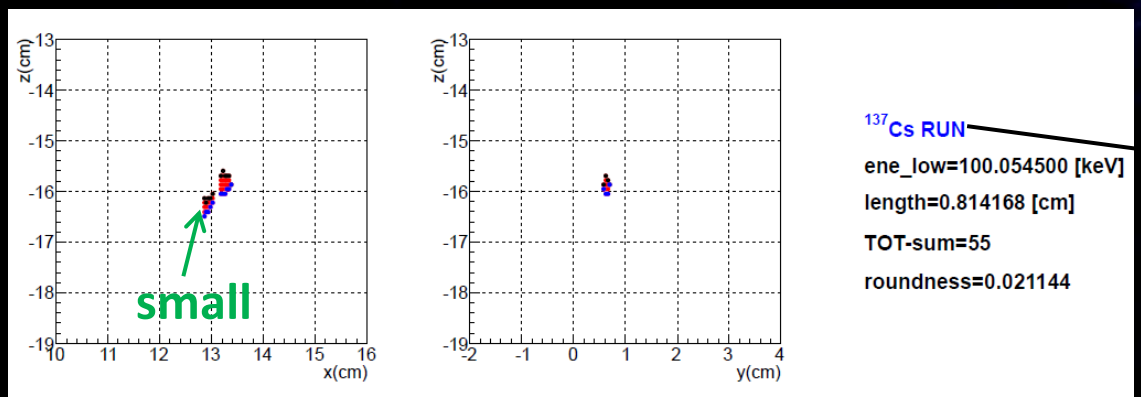
Event selection 2

TOT-sum-cut (new gamma-ray cut)

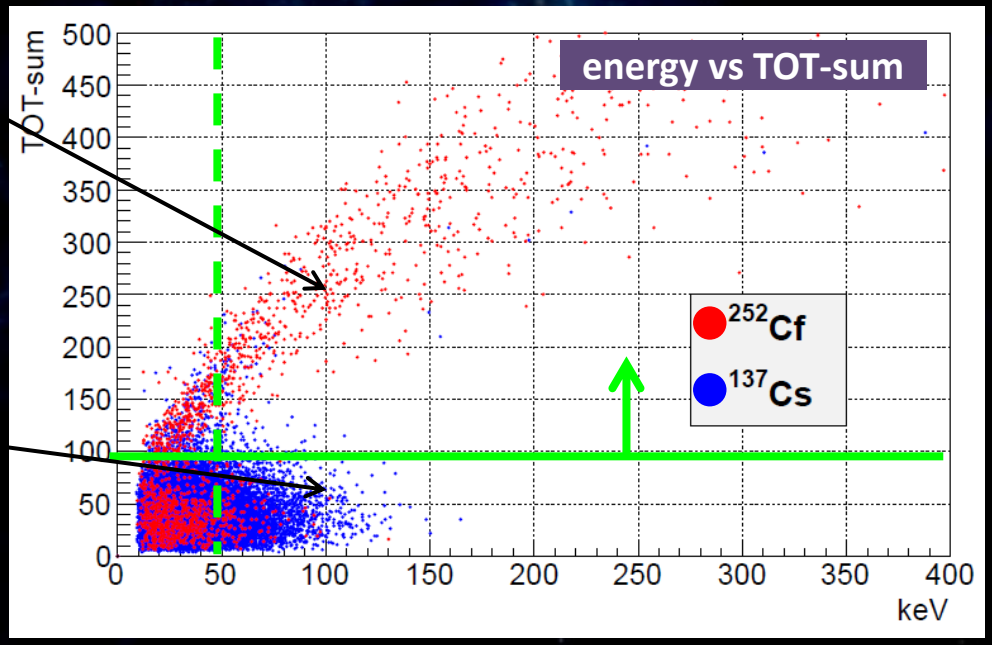
- Nuclear (^{252}Cf) : TOT-sum is proportional to energy
- Electron (^{137}Cs) : scratched track (small dE/dx)



^{252}Cf RUN
ene_low=100.783500 [keV]
length=0.689406 [cm]
TOT-sum=250
roundness=0.055549



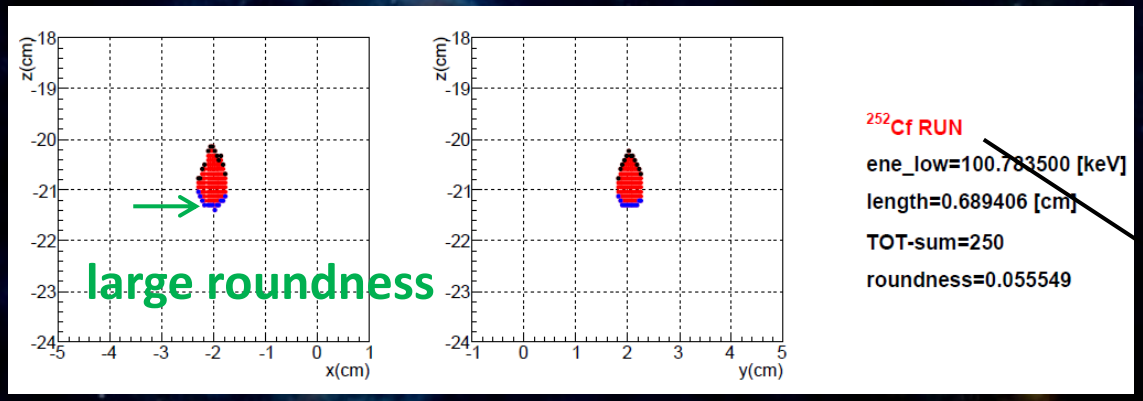
^{137}Cs RUN
ene_low=100.054500 [keV]
length=0.814168 [cm]
TOT-sum=55
roundness=0.021144



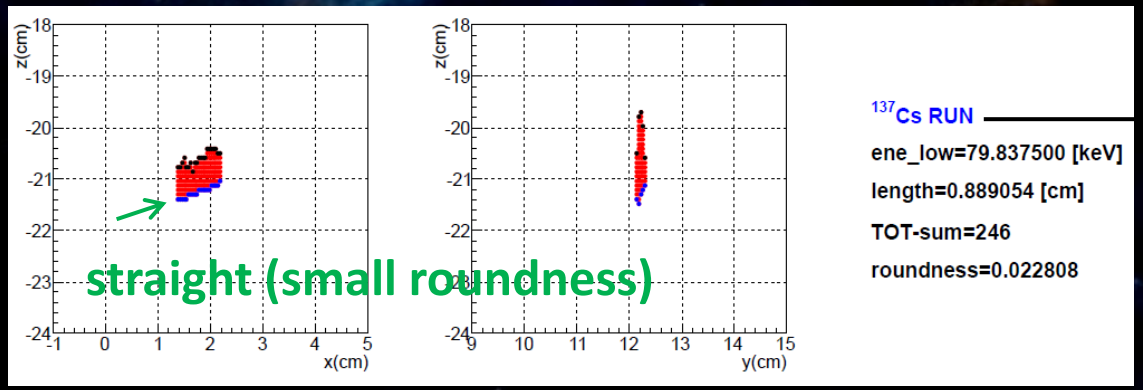
Event selection 3

roundness-cut (third cut)

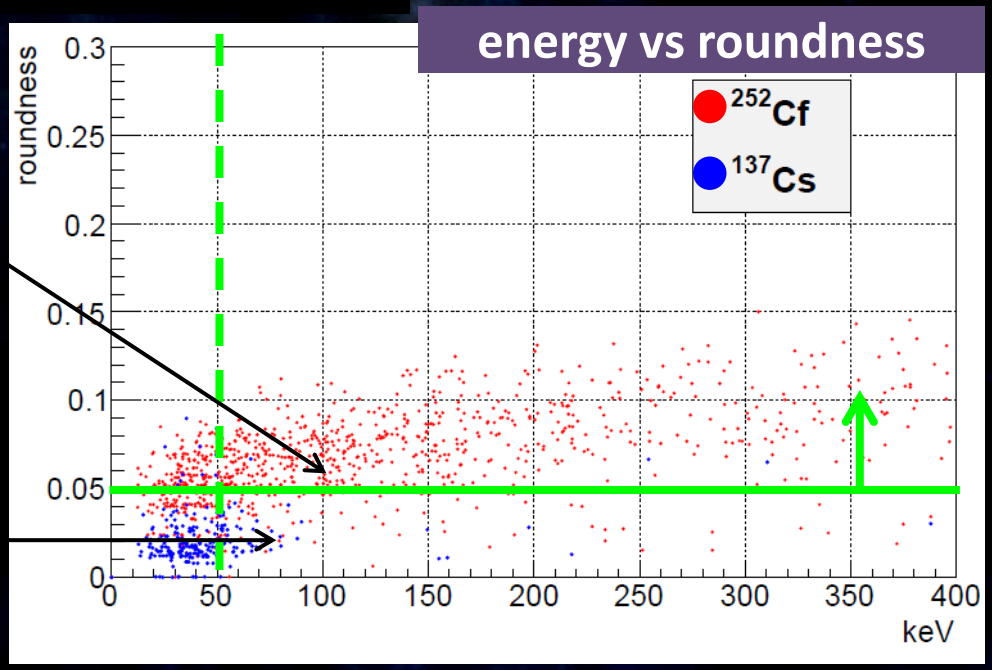
Remained ^{137}Cs events : straight track shape

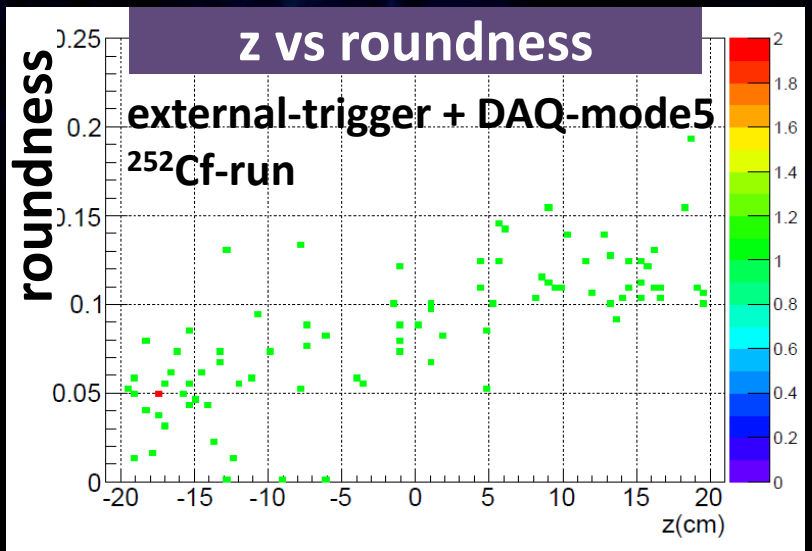


^{252}Cf RUN
ene_low=100.783500 [keV]
length=0.689406 [cm]
TOT-sum=250
roundness=0.055549



^{137}Cs RUN
ene_low=79.837500 [keV]
length=0.889054 [cm]
TOT-sum=246
roundness=0.022808





Diffusion (drift distance) affects roundness !

(Almost all electron events are cut)

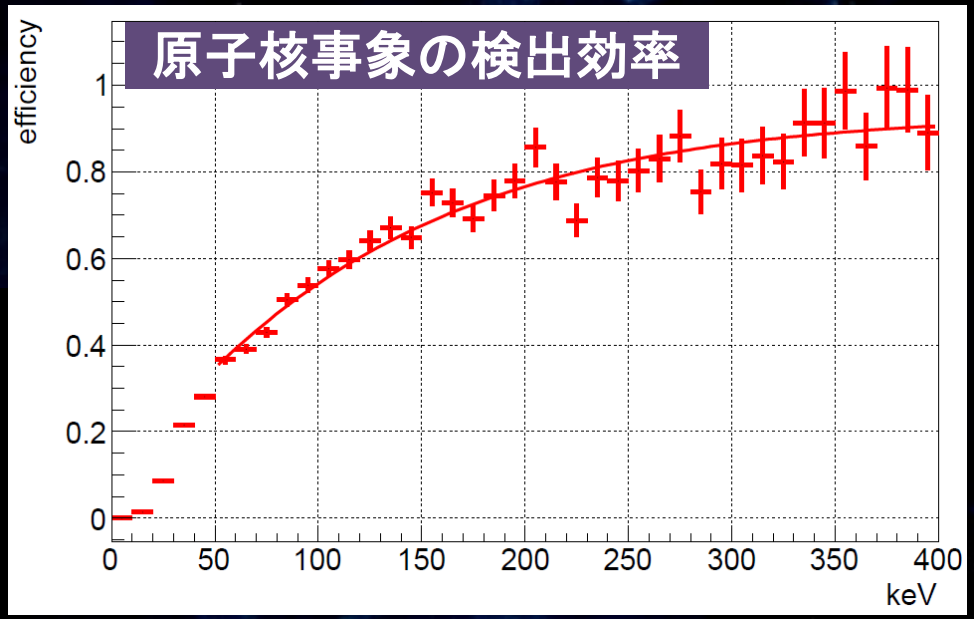
(Remained events are BG α from μ-PIC)

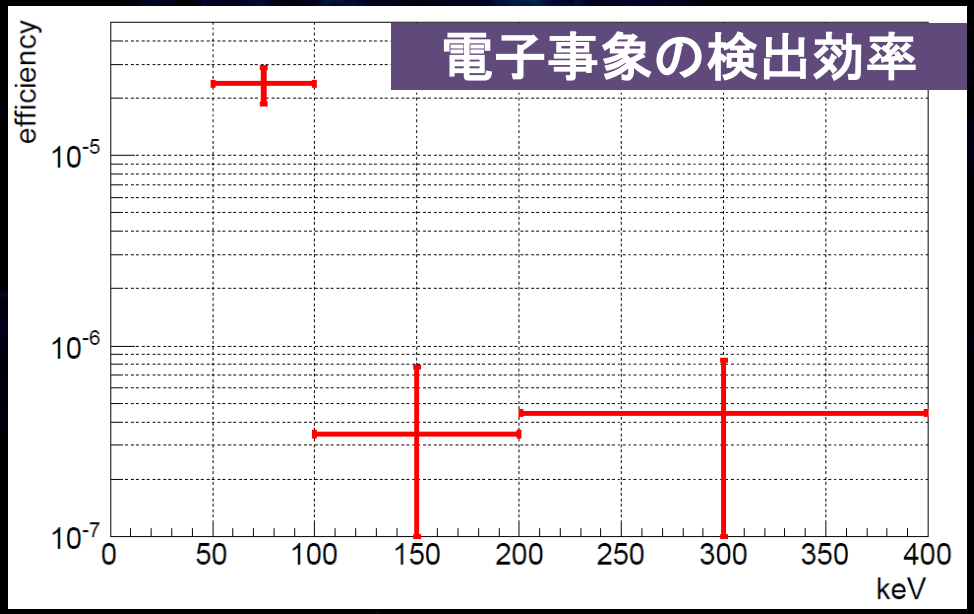
Roundness-cut works as "z-fiducial-cut"

Efficiency

After all cut, compare to Geant4

- Nuclear (^{252}Cf neutron source)
  Efficiency : 40%@50keV
- Electron (^{137}Cs γ source)
  Rejection : 2.5×10^{-5}@50-100keV





Galactic-plane sky-map

Demonstration for direction sensitivity