NEWAGE

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(3) Kyoto university RISH

• What’s NEWAGE?
• New result by NEWAGE-0.3a’
• Commissioning of NEWAGE-0.3b’
• Head-tail R&D with NEWAGE-0.1a
• Summary
1. Annual modulation (conventional)
   Large mass -> Solid or liquid detector
   Require for $3\sigma$ : ~10000 events

2. Direction sensitivity (new)
   Nuclear track -> Gas detector (or emulsion)
   Require for $3\sigma$ : ~20 events

Expected energy spectrum

\[ \sigma_{SD} = 1 \text{pb} \]
M = 100 GeV

Target: F

Large difference in forward to back

Expected cos\(\theta\) distribution
NEWAGE

- 3D tracking : μ-TPC
  - 2D : μ-PIC (400μm pitch)
  - 1D : Drift timing (100MHz)

- gas: CF$_4$ 76~152torr

- Typical gas gain ~5000(Ar 1atm)
- 30x30cm size is available
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**1st talk**
- NEWAGE-0.3a’
- NEWAGE-0.1a

**2nd talk**
- NEWAGE-0.3b’

**3rd talk**
- 40cm
- 15cm
### Detector Name

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New result
(NEWAGE-0.3a’)

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NEWAGE-0.3a’

- X readout (768ch)
- Y readout (768ch)
- TPC
- FAGA position encoder (1536ch)

- 23 x 28 x 31 cm³
- 152 torr CF₄ = 11.48g
NEWAGE-0.3a’ updates

• Sensitivity Improvement
  • $\alpha$ particle
  • radon gas
  • gamma rays
  • DAQ upgrade

\{ \rightarrow \text{Low BG aiming 1/10} \\
\rightarrow \text{Low threshold} \}
• radon, gamma, alpha: "clean" materials

• to <1/10 radon emanation level

NEWAGE-0.3a

glass-reinforced fluoro-plastic

NEWAGE-0.3a’

PTFE + copper wire

Time dependence of Rn rate measured by Rn detector

5.4 (+ 0.0) cdp
• Radon: charcoal

  • gas circulation system
  • monitor radon rate (~6MeV)
  • radon rate ~1/10 after days

charcoal filter ~100g (TSURUMICOAL 2GS))
getter pump (SAES GETTER C400-2DSK)
circulation (Teflon bellows pump)

NEWAGE0.3a 152 torr CF4 gas

without charcoal
with charcoal

cf: 1e5 counts/kg/days ~ 1Bq/m³
**Gamma: ① length-cut**

- energy vs length cut
- gamma rejection efficiency*: $8.1 \times 10^{-6}$

* gamma rejection efficiency = electron detection efficiency
• Gamma: ② precise gain-map

• gas gain is not uniform in 30 x 30 cm²

old gain map

RUN5

new gain map

RUN13

137Cs run
remaining events after gamma rejection (100-120keV)

gamma rejection
8.1e-6

137Cs run
remaining events after gamma rejection (100-120keV)

gamma rejection
1.0e-6>
NEWAGE-0.3a’ underground run

- Underground run in 2012 (RUN13)

- Target gas: CF₄ 152torr
- Fiducial volume: 14 x 13 x 31 cm³
- Target mass: 0.00424kg

- Date: Jan. 23, 2012 - Jan. 24, 2013
- Live time: 179.12 days
- Exposure: 0.760 kg days
RUN13 result

- exposure: 0.760 kg days
- spectrum threshold: 100keV $\Rightarrow$ 50keV
- rate: $\sim 1/5$ at 100keV
- $\cos \theta$ distribution: flat

**Measured energy spectrum**

**Measured $\cos \theta_{\text{cygnus}}$ distribution**

100-300keV combined detection efficiency applied
How to get direction sensitive limit

detector response measured by 252Cf

simulation “DM wind”

expected cosθ distribution (DM)

Input Parameters:
- energy resolution
- angular resolution
- WIMP mass
- energy range

scanning

Comparison

Scanning $\sigma_{\text{DM}}$, we set direction sensitive limit.
Direction sensitive limits

- 3100pb @ 150GeV

SD 90% C.L. upper limits and allowed region

- NEWAGE surface run
- NEWAGE 2010
- RUN5
- NEWAGE 2012
- PRELIMINARY

Threshold=100keV
E resolution=30%
Ang. resolution 55°
## NEWAGE-0.3b’ Commissioning

K. Nakamura et al 2012 *JINST* 7 C02023

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NEWAGE-0.3b’

• Developments at Kyoto (surface lab)
  • Larger GEM
  • Longer drift length
  • PEEK drift cage
  • Cooled charcoal
  • Low pressure gas
  • DAQ upgrade

• Large size ~ x2
• Low BG ~ 1/10
• Low threshold ~ 1/2
**NEWAGE-0.3b’ : Geometry**

- Detection volume: 2 x NEWAGE-0.3a’
- PEEK for low BG

**NEWAGE-0.3b’**
PEEK + copper wire

**NEWAGE-0.3b**
glass-reinforced fluoro-plastic

**GEM**
23x28 -> 31x31 cm²

**Drift Cage**
31 -> 41 cm
PEEK

Significance estimation

- drift length: 10cm
- drift length: 20cm
- drift length: 30cm
- drift length: 40cm
- drift length: 50cm

3 month measurement
- no-BG
- 2-bin method

\[
\sigma_{p,DM(SD)} = 268 \text{pb} \\
M_{DM} = 100 \text{GeV}
\]

- current angular resolution
- 10deg improved
- 20deg improved

**angular resolution σ [deg]**

**Significance**

```text

<table>
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<th>Drift length</th>
</tr>
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<tr>
<td>12</td>
<td>10cm</td>
</tr>
<tr>
<td>11</td>
<td>20cm</td>
</tr>
<tr>
<td>10</td>
<td>30cm</td>
</tr>
<tr>
<td>9</td>
<td>40cm</td>
</tr>
<tr>
<td>8</td>
<td>50cm</td>
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**angular resolution σ [deg]**
NEWAGE-0.3b: Circulation

- Circulation with cooled charcoal
- Radon rate: <1/10
NEWAGE-0.3b: angular resolution

- Gas pressure: 152->76 torr (NEWAGE-0.3a’->NEWAGE-0.3b’)
- Comparing $\cos \theta$ distribution measured to simulation

$^{252}$Cf neutron nuclear

F nucleus tracks

$^{252}$Cf

$\chi^2$ minimum is 49°

$\chi^2$-values for each angular resolution

Simulated vs measured $\cos \theta$ distributions

(measured with DAQ-mode1)
NEWAGE-0.3b : threshold

- Gas pressure: 152->76 torr (NEWAGE-0.3a’->NEWAGE-0.3b’)
  - Angular resolution: 40deg @50-100keV
  - Detection efficiency: 60% @50keV

- Energy threshold with angular resolution: 100->50keV (by 152->76torr)

(measured with DAQ-mode1)
### NEWAGE-0.3b’ : DAQ upgrade

<table>
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<td>(“energy” of each strip)</td>
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<td>mode3 all</td>
<td>Rise timing</td>
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<td>mode1 x-y coincidence max, min only</td>
<td>Rise timing</td>
<td>NEWAGE-0.3b</td>
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- **Mode 5**: All strips, Rise & Fall timing ("energy" of each strip), Detector: NEWAGE-0.3b’ and NEWAGE-0.1a
- **Mode 3**: All strips, Rise timing, Detector: NEWAGE-0.3a’
- **Mode 1**: X-Y coincidence, max, min only, Rise timing, Detector: NEWAGE-0.3b

![Graph showing strip information for each mode](image)

- We confirmed DAQ-mode5 works with no bug.
Transfer
From Kyoto to Kamioka
(Mar. 2013)

We're visiting here at "Kamioka tour"
drift velocity

- Measure clock of drift
  - $4.7 \mu s$ for $41\text{cm} \rightarrow v=8.7\text{cm/}\mu\text{s}$
- Consistent to surface measurement

- Electric Field: $0.095\text{kV/cm}$
- gas: CF$_4$ 76torr

Clock (=10ns)
calibration

- Calibration with $^{10}\text{B}$
  - $^{10}\text{B}(n,\alpha)^7\text{Li}$ reaction
  - $(Q=2.70\text{MeV} \sim 1.5\text{MeV}\ \alpha)$
BG radon

- Drift cage Material: glass -> PEEK
- radon rate: <1/3
- Further 1/10 with cooled charcoal

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NEWAGE-0.3b’ summary

- Commissioning almost done (analysis tuning now)
- DM run started (RUN15-)
# Head-tail R&D

(NEWAGE-0.1a)

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Head-tail introduction

- Head-tail recognition of nuclear track
  -> Sensitivity improvement: 3 ~ 10 times

Expected sensitivity

solid (with head-tail recognition)  
dotted (without)

NEWAGE-0.1a detector

- \( \mu \text{TPC}: \ 10 \times 10 \times 10\text{cm}^3 \)
- readout: 400\( \mu \)m pitch
- GEM: polyimide, 100\( \mu \)mth
- gas: CF4, 152torr
### DAQ-mode5 (again)

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**Diagram:**
- **mode5**
- **mode3**
- **mode1**

**Axes:**
- x strip: clock
discrth
- y strip: clock
Event display

- observed “Bragg Curve”

20110512/per167
file 92 event 2

252Cf (0, -30.5)[cm]
length = 0.95 cm
FADCsum = 494.1

X hitsum = 40
mean = -2.815
skewness = -0.125

Y hitsum = 54
mean = -2.546
skewness = -0.437

130keV  F track

neutron
Symmetry parameter: skewness

\[ \gamma_{x_i} = \frac{\langle (q(x_i) \cdot (x_i - \langle x_i \rangle)^3) \rangle}{\langle (q(x_i) \cdot (x_i - \langle x_i \rangle)^2)^{3/2} \rangle} \]

- If symmetric, \( \gamma = 0 \)

- difference was observed
Head-tail recognition

(252Cf@30cm)

± X run

± Y run

X skewness

Y skewness

parallel

orthogonal
Combined results

• Energy dependence of parallel and orthogonal skewness
• statistically significant ( >70keV )

- To do for next
  • the skewness definition improvement
  • 3-dimensional track
Latest limit by NEWAGE-0.3a’
• Direction sensitive limit updated:
  450pb @150GeV

Commissioning of NEWAGE-0.3b’
• Commissioning almost done &
  Started DM run

Head-tail R&D using NEWAGE-0.1a
• 2-dim Head-tail can be
  statistically seen for >70keV
Summary

**Latest limit by NEWAGE-0.3a’**
- Direction sensitive limit updated: 450pb @150GeV

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Thank you for your attention!