Direction-Sensitive Dark Matter Search
--NEWAGE--

(New generation WIMP search with an advanced gaseous tracker experiment)

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K. Miuchi June 13, 2012 4th NDM
OUTLINE

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Motivation
1. Motivation

“WIMP-wind” detection

@GALAXY

SOLAR SYSTEM
220 km/s

@EARTH

“WIND” of WIMPs

low pressure gas
forward recoils
short tracks

The WIMP-wind

K. Miuchi June 13,

PLB 578 (2004) 241

Motivation

“WIMP-wind” detection

PLB 578 (2004) 241

Motivation

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PLB 578 (2004) 241

Motivation

“WIMP-wind” detection

PLB 578 (2004) 241
WHY “Direction-sensitive”?

- Large mass for exclusion (and indication)
- BUT Annual modulation is not enough...
- Direction-sensitive for a concrete evidence and further study of halo dark matter
Expected Sensitivities

- **Goal:** Detect the WIMP-wind
  - low pressure (CF$_4$ 0.05 bar) • large volume ($1\text{m}^3 \times N$) • radio-pure materials

- **CURRENT:** pilot run
  - CF$_4$ 0.2 bar • (0.3m$^3$) • normal materials
Community: CYGNUS

- direction-sensitive DM search workshop
  - 2007 (UK)
  - 2009 (US)
  - 2011 (France)
  - 2013 (Japan)

@CYGNUS2009 (MIT)
Direction-sensitive DM search

**NEWAGE [Japan]**
- μ-PIC (400μm pitch)
- Only NEWAGE obtained direction-sensitive limit
- Underground

**DRIFT [UK]**
- MWPC (2mm pitch)
- First started direction-sensitive method
- Underground
- Low background
- Large size (1m³)

**DMTPC [USA]**
- MWPC (2mm pitch)
- First started direction-sensitive method
- Underground
- Large size (1m³)

**MIMAC [France]**
- Micromegas (~400μm pitch)
- Measured quenching factor in detail
- R&D at surface

**HAWAI**
- CCD
- 2D image
- Identification of head-tail
- Reading to underground

**NAGOYA**
- CCD
- 2D image
- Identification of head-tail
- Reading to underground

**Note:** The diagram shows the locations and key features of various DM search projects and detectors.
Methods
Methods (3D tracking device)

- **NEWAGE-0.3a**: $23 \times 28 \times 31\text{cm}^3$
3D tracking device: microTPC

2D imaging device:
μ-PIC (gas gain 5000)
- 400mm pitch
- 30 × 30cm²

Gas volume
- DRIFT length 31cm

Readout electronics
- Digital ”3D-HIT” (track) + charge (energy)

TPC system
- Gas volume
- 100MHz, pipeline

30cm μPIC (Toshiba)
TPC Performance

1. Nuclear Tracking

- $\text{CF}_4 + \text{C}_4\text{H}_10$ (9:1) 0.2 atm
- $n \rightarrow p$ forward scattering
  (emulation of WIMP $\rightarrow F$ scatterings)

Proton tracks

- $^{252}\text{Cf}$ run

Recoil direction image

- Zenith $^{252}\text{Cf}$ (NE45°, zenith 35°)

Direction Sensitive WIMP-search NEWAGE
TPC Performance

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

† gamma rejection efficiency = electron detection efficiency
1st underground result
=NEWAGE-0.3a Kamioka Run5

K. Miuchi+
PLB2010(686)11
NEWAGE @ Kamioka

• Kamioka mine
• 2700m w.e depth
  • DM measurement
  • Background Study
RUN5: Detector

- Target gas: CF4 0.2atm (0.0115kg)
- Exposure: 0.524 kg·days (Sep. 2008 - Dec. 2008)

- Energy resolution
  70%@100keV (FWHM)

- Position resolution
  800μm (rms)

- Angular resolution
  ~55° (RMS)
RUN5 results

- Energy spectrum 1/5 rate of the surface run

North sky by C and F nuclei (100-400keV)

(PLB 686 (2010) 11)
RUN5 results

- The sky map
  --> cosθ distribution
  --> upper limits

New limits 5400pb for 150GeV

North sky by C and F nuclei (100-400keV)

Cosθ distribution
(100-400keV)

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Recent activities

- Sensitivity improvement (underground updates)
- To go further (surface R&Ds)
Sensitivity improvement

- radon gas
- gamma rays
- $\alpha$ particles

$\Rightarrow$ low background

$\Rightarrow$ low threshold

Kamioka RUN-13

- RUN13-1: 2012 Jan. 23 – March 8
- RUN13-2: 2012 March 8 – May 24
- RUN13-3: 2012 May 28 – TODAY
Radon: charcoal

- gas circulation system
- monitor radon rate (~6MeV)
- radon rate ~1/10 after day 10

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 ~ 1 Bq/m³
gamma: precise gain map

gas gain is not uniform in $30 \times 30 \text{cm}^2$

old gain map

RUN5

new gain map

RUN13

137Cs run remaining events after gamma rejection

gamma rejection $8.1 \times 10^{-6}$

137Cs run remaining events after gamma rejection

gamma rejection $1.0 \times 10^{-6}$
radon, gamma, alpha: "clean" materials to <1/10 radon emanation level

glass-reinforced fluoro-plastic

PTFE + copper wire

U-chain (6.5MeV, 7.83MeV)
Results (preliminary)

- exposure 0.140kg · days
- spectrum threshold 100keV ⇒ 50keV
- rate: ~1/5 at 100keV
- direction-sensitive analysis: on-going

RUN5
RUN13

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

preliminary
RUN13
(E>100keV analysis)
To go further…
(R&D in surface labo.)

- NEWAGE-0.3b detection volume $31 \times 31 \times 50\text{cm}^3$
- Cold charcoal
- $0.2\text{atm} \Rightarrow 0.1\text{atm}$ CF4 gas for lower threshold

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SUMMARY

- NEWAGE: direction-sensitive DM exp.
- 1st underground run: updated direction-sensitive results
- underground and surface R&Ds are on-going