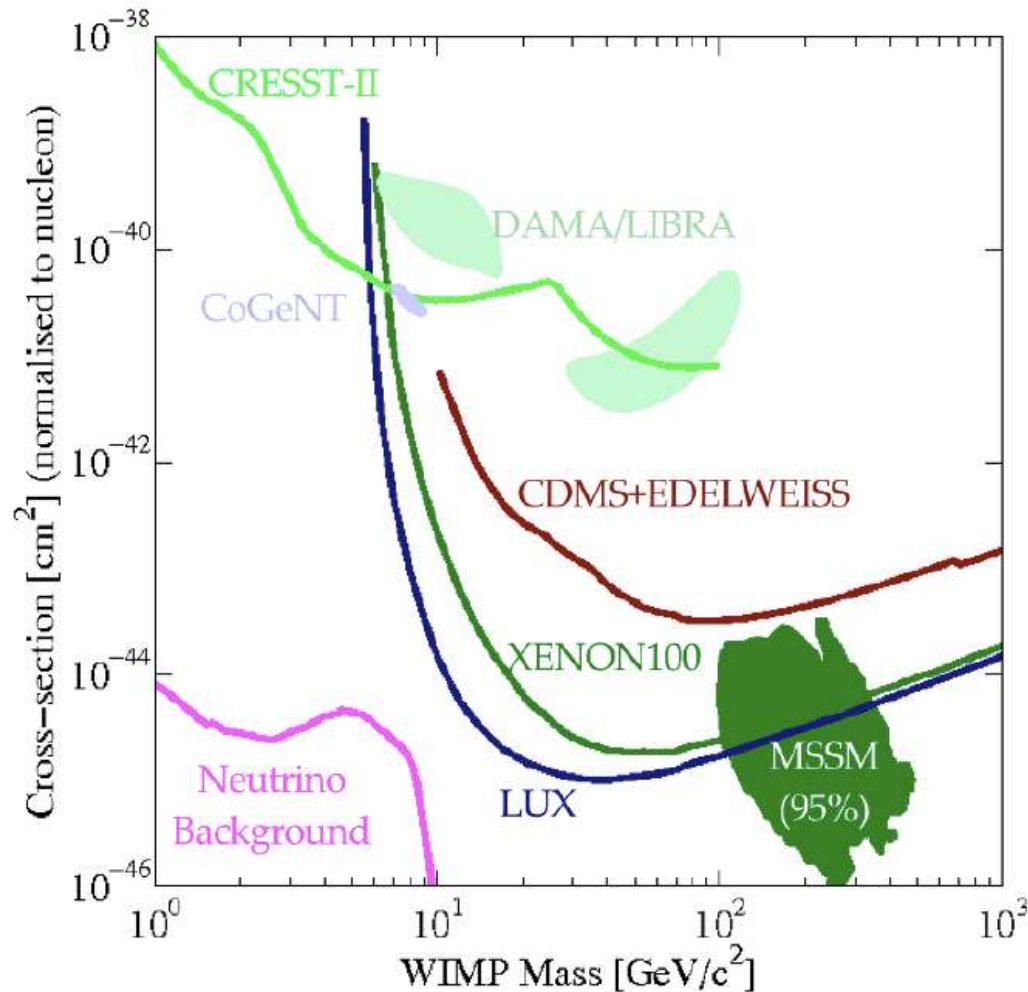


NEWS実験と開発課題

Masahiro Yoshimoto (Nagoya University)

and NEWS collaboration

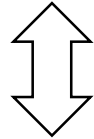
Dark matter search



Spin
independent

Directional DM search

- A annual modulation by Earth revolution.



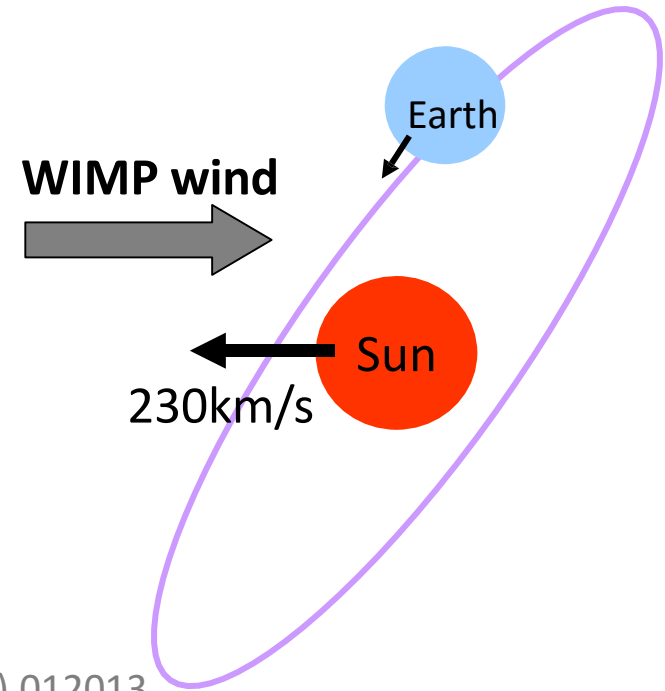
- A **directional** modulation by motion of Solar System.

- The direction of nuclear recoil is expected to have a **strong modulation**.

D. N. Spergel, Phys. Rev. D37 (1988)

- The directional search is a prove of **WIMP and halo properties**.

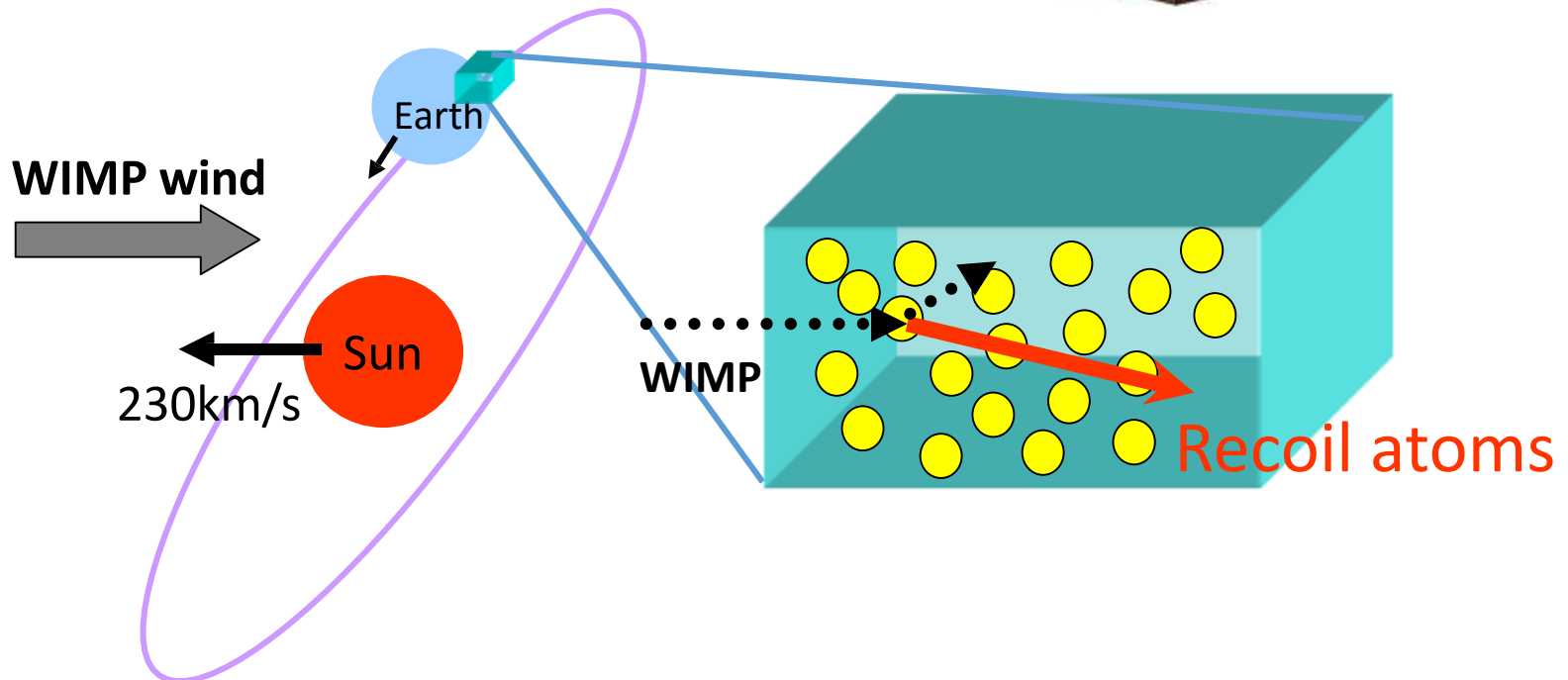
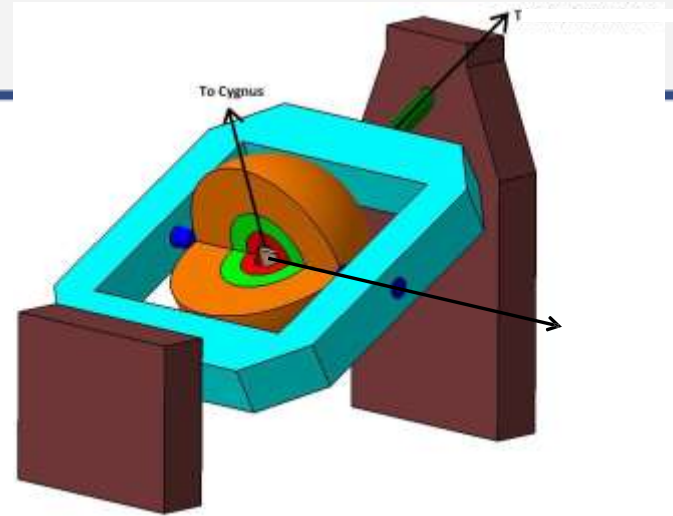
F. Mayet, J.Phys.Conf.Ser. 469 (2013) 012013



Concept of NEWS

- Nuclear Emulsion for **WIMP** Search
- Targets: Ag, Br, C (N,O)
- high density (solid), spin-independent

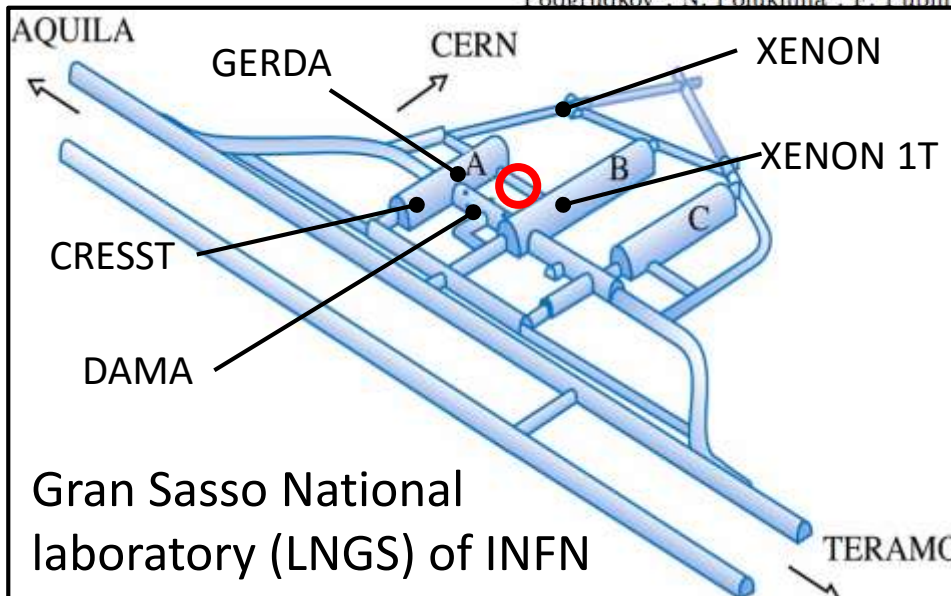
equatorial telescope



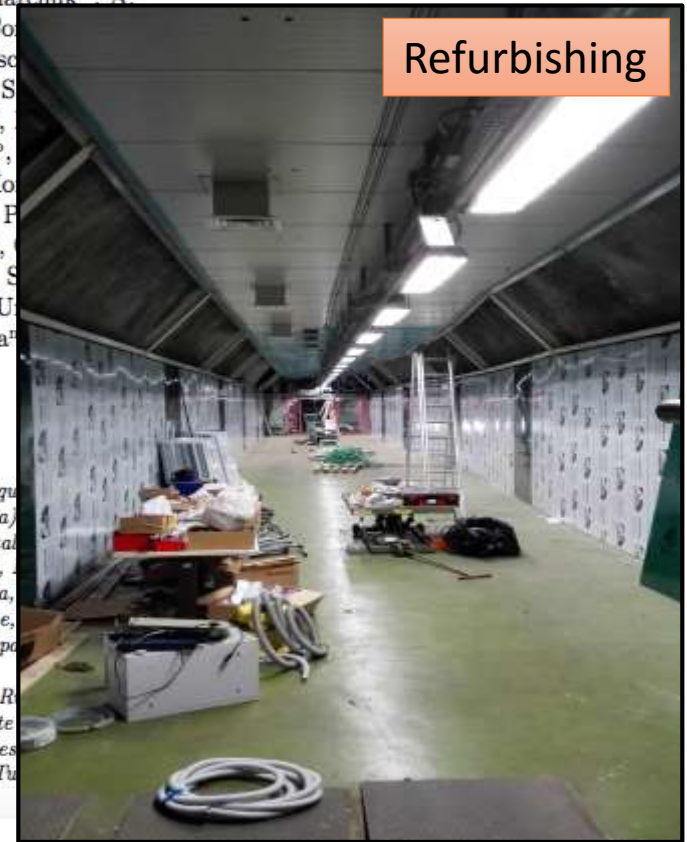
LOI submitted to LNGS science committee

NEWS: Nuclear Emulsions for WIMP Search Letter of Intent (NEWS Collaboration)

A. Aleksandrov^{b,h}, A. Anokhinaⁿ, T. Asada^k, I. Bodnarchuk^m, A. Buonauro^{b,h}, M. Chernyavskii^o, A. Chukanov^m, L. Cozzani^g, D'Ambrosio^e, G. De Lellis^{b,h}, M. De Serio^{a,s}, A. Di Crescenzo^h, Marco^e, S. Dmitrievskii^m, T. Dzhatdoevⁿ, R.A. Fimi^{a,s}, S. Galati^{b,h}, V. Gentile^{b,h}, S. Gorbunov^o, Y. Gornushkin^m, Ichiki^k, T. Katsuragawa^k, M. Kimura^k, N. Konovalova^o, Lauria^{b,h}, P. Loverre^{d,j}, S. Machii^k, A. Managadzeⁿ, P. Montesi^{b,h}, T. Naka^k, M. Nakamura^k, T. Nakano^k, A. Podgrudkovⁿ, N. Polukhina^o, E. Pupilli^f, T. Roganovaⁿ, S. Sirignano^{c,i}, A. Suvorov^h, Tioukov^{b,h}, A. Usov^h, V. V. Zhurav^h, S. Zemskova^h



Gran Sasso National
laboratory (LNGS) of INFN



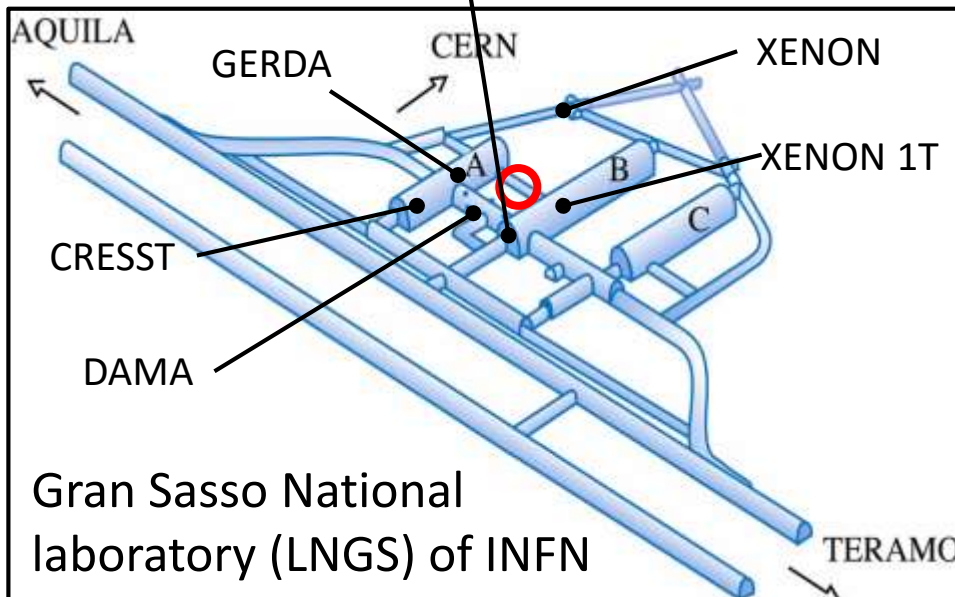
arXiv:1604.04199



現在のラボ



ラボの屋上からの写真(2014年7月)



The NEWS Collaboration



Japan
Chiba,
Nagoya



Italy
Bari,
LNGS,
Naples,
Padova,
Rome



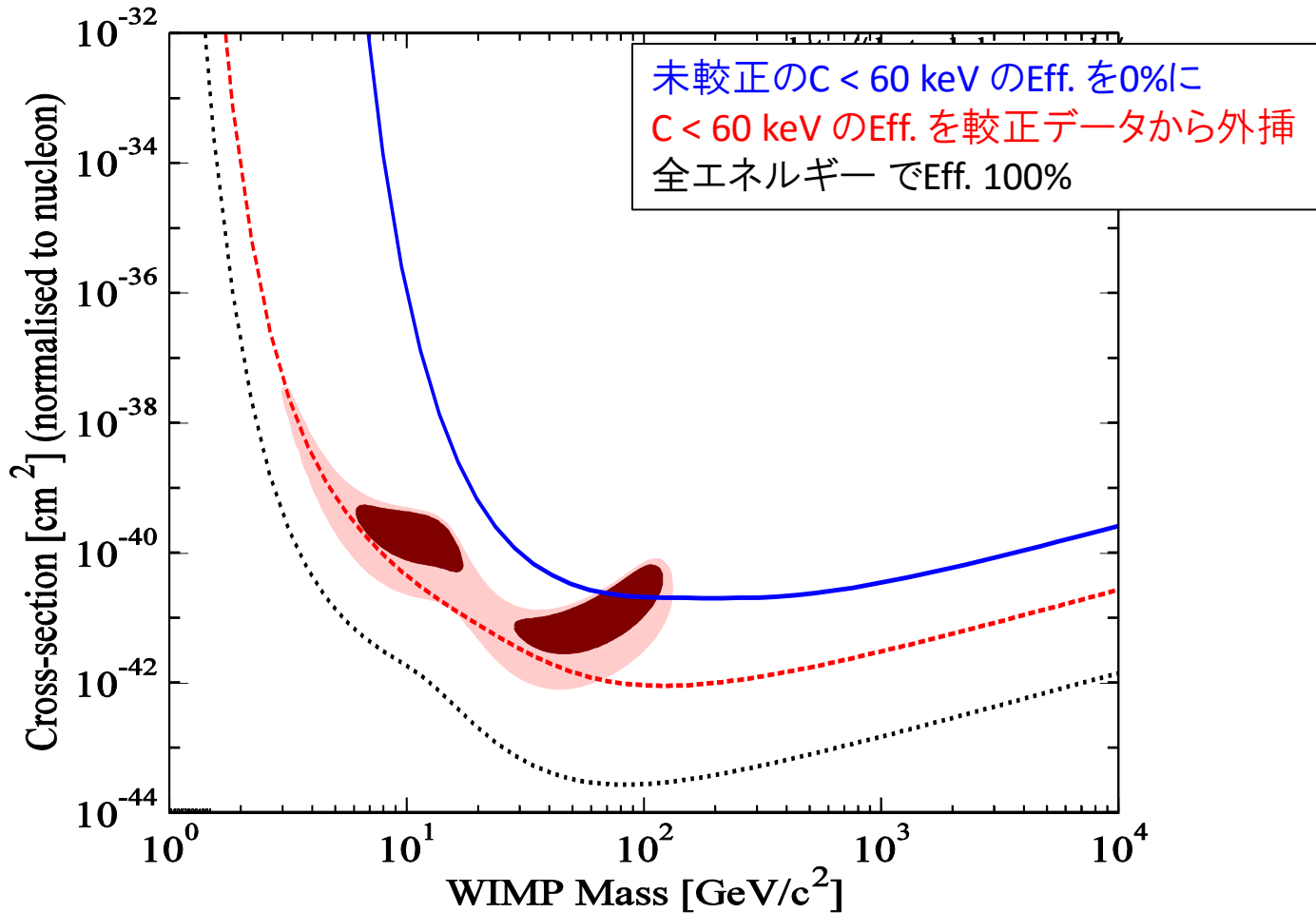
Russia
LPI RAS
Moscow,
JINR Dubna,
SINP MSU
Moscow



Turkey
METU Ankara

~60 physicists

Physics aims



条件： 10 kg·year 90% C.L., zero BG, NIT40 w/ PPD development, ellipticity cut > 1.4

Nuclear spallation taken with a microscope



A black and white micrograph showing several dark, linear tracks of nuclear spallation. The tracks are most prominent in the center, where they appear to originate from a single point and radiate outwards. Some tracks are solid lines, while others are dashed. The background is a light gray, grainy texture with scattered dark spots. Two black arrows point from the left towards the central tracks. A white box with a black border contains the text 'Carbon ion ~100 MeV/n'. In the bottom left corner, there is a scale bar consisting of a horizontal line with the text '10 um' above it. In the bottom right corner, there is text identifying the laboratory and university.

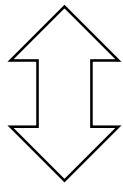
Carbon ion
 $\sim 100 \text{ MeV/n}$

10 μm

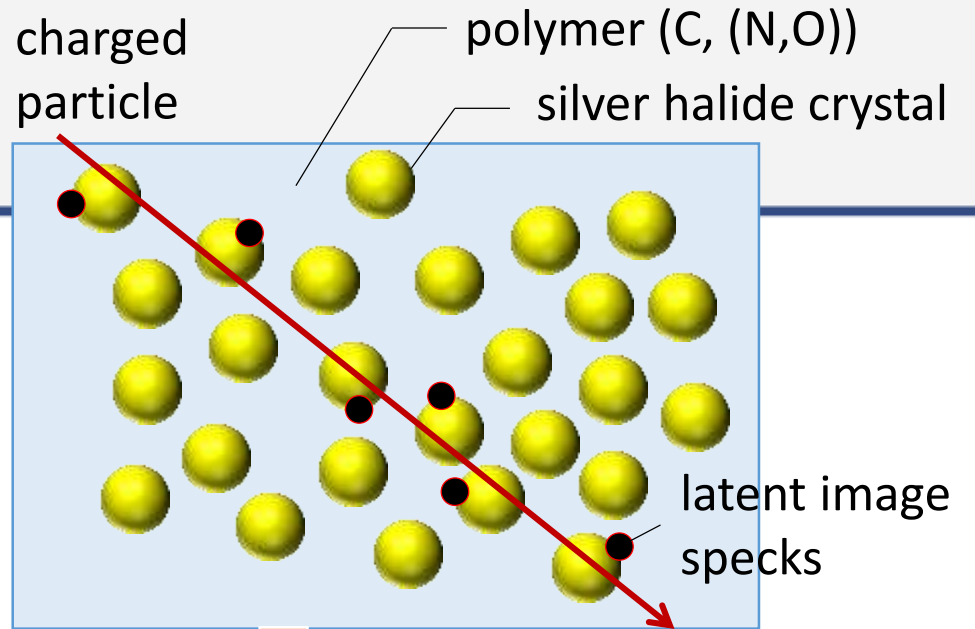
Nuclear emulsion

- 3D tracking detector
- easy to enlarge a detector mass
- low cost (1k€ / 1Kg)
- no time resolution

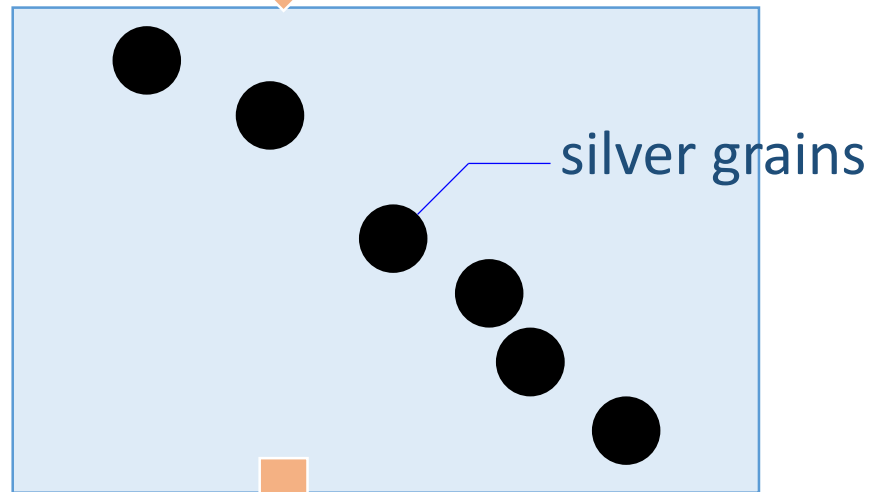
Crystal size : 200 nm



WIMP-induced recoils are $\mathcal{O}(10 - 100 \text{ nm})$ track length.



chemical development



readout with microscope

Fine grained nuclear emulsion

- R&D emulsion specialized in DM search by ourselves from 2010.



production machine in Japan

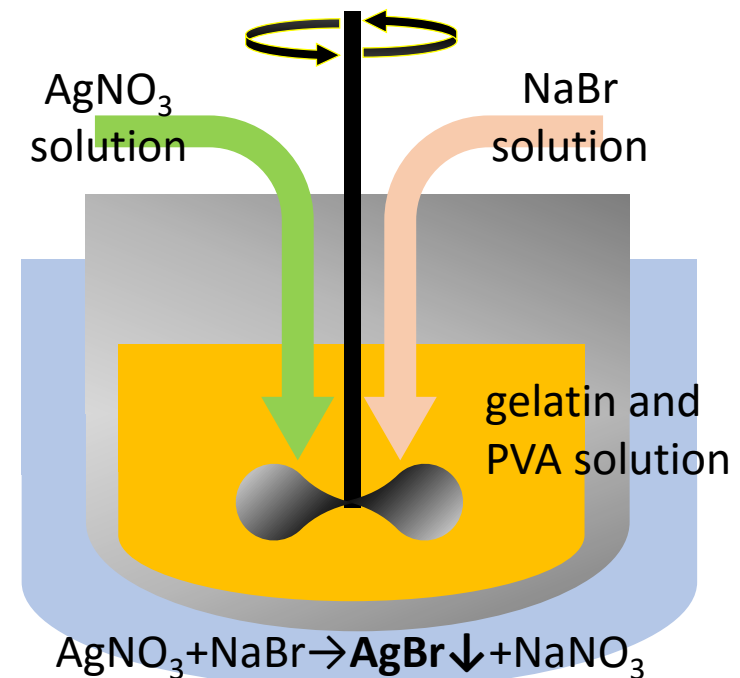
gel stage



pour on a support plate
& dry

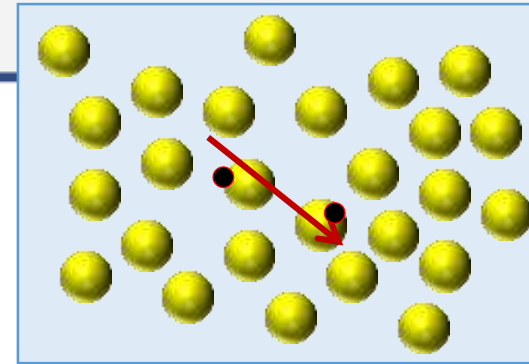


solid state

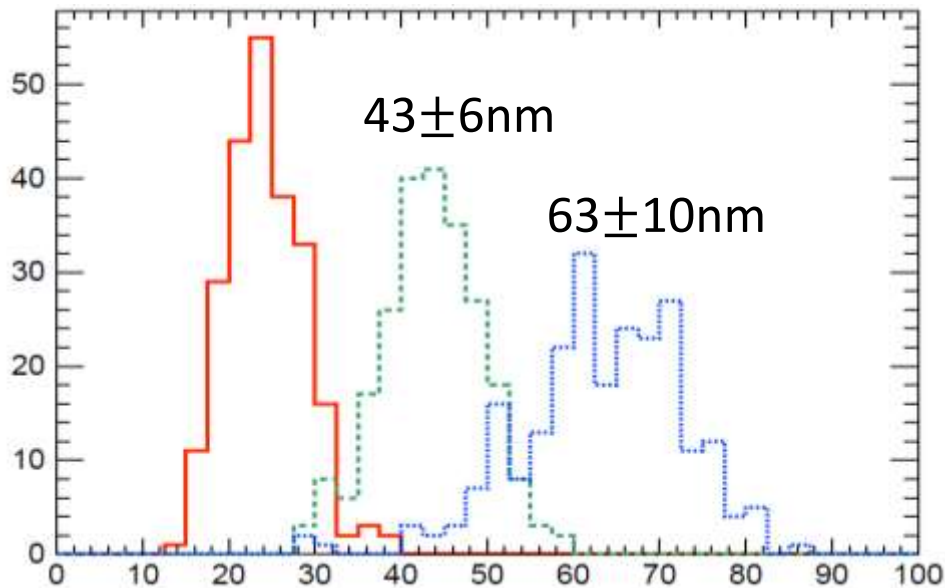


Fine grained nuclear emulsion

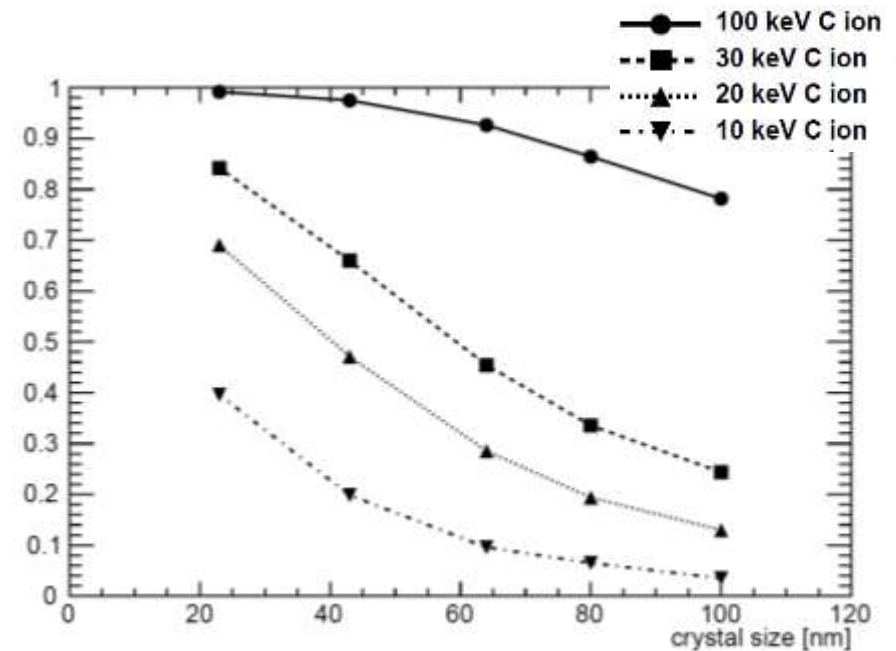
- Silver halide crystal size has been controllable
 - 20 – 60 nm (NIT type)
 - not sensitive to MIP



24 ± 4 nm crystal size



probability of penetrating two grains



Readout system

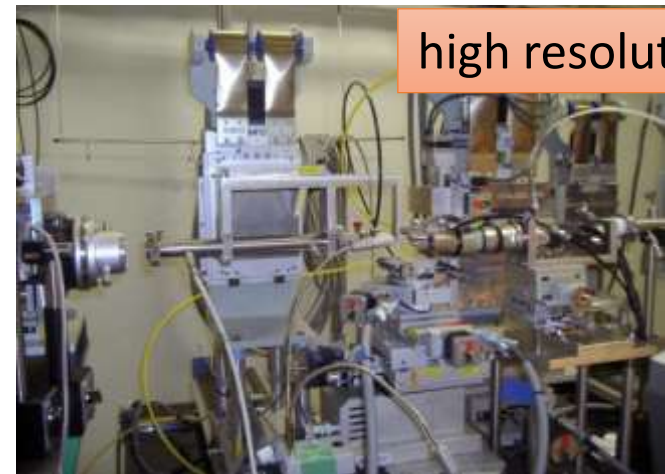
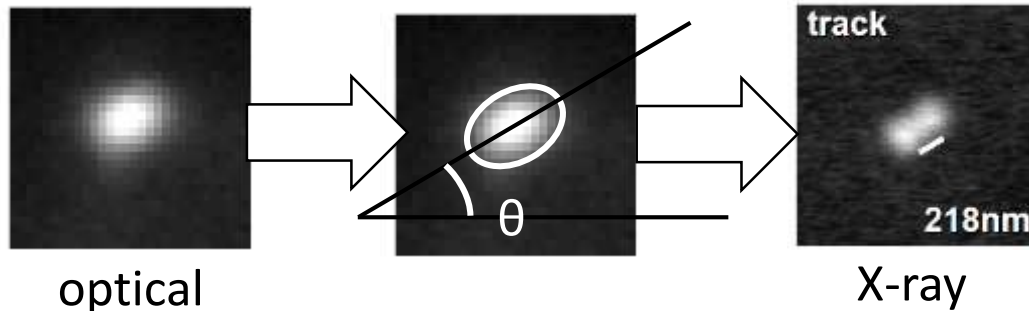
- total volume scanning
 - optical microscope
- event by event scanning with higher resolution optics
 - X-ray microscope
 - plasmon resonance



automated scanning stage
resolution ~ 200 nm

@ NIT-40

Fitting an ellipse



X-ray microscope
resolution 70 nm

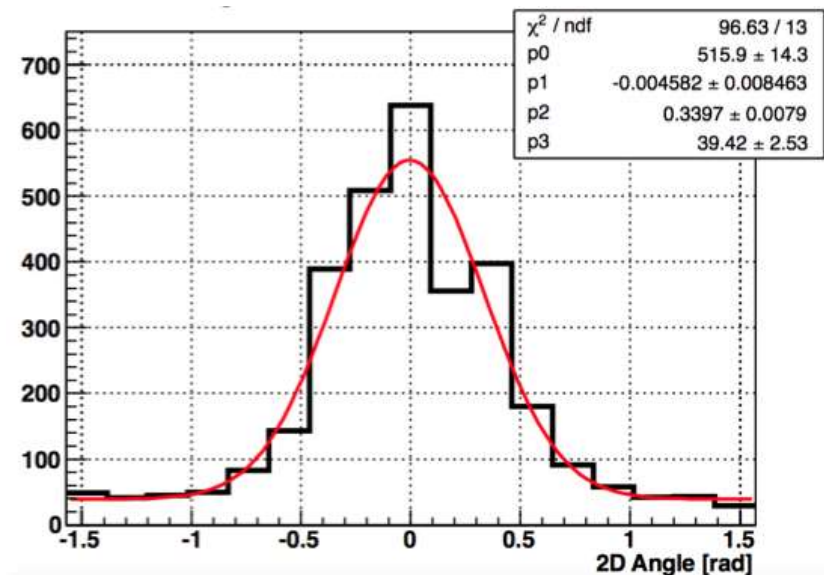
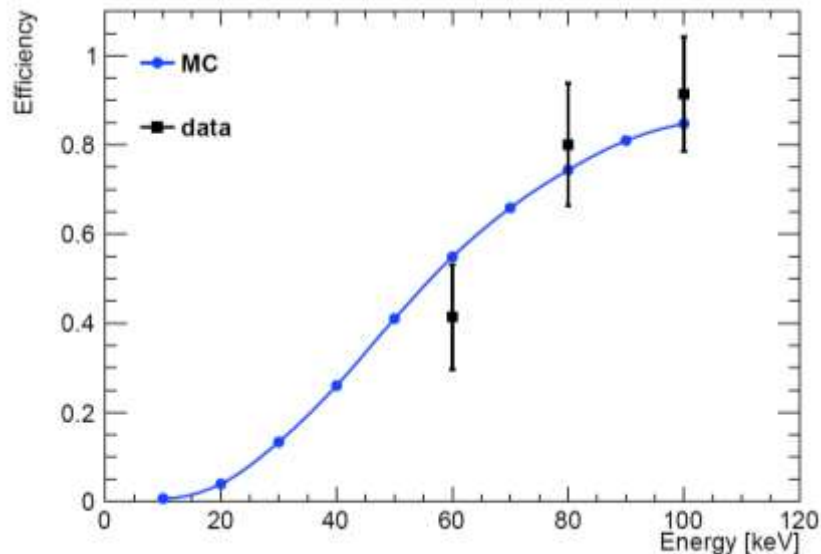
T. Naka, et al. Rev.Sci.Instrum. **86** (2015) 073701

Efficiency and angular resolution

@ NIT-40 emulsion
@ optical microscope

- Low energy **60 – 100 keV carbon** exposure test
- Ellipticity cut > 1.25
- 80% tracking efficiency @80 keV
- 340 mrad (**20 degree**) angular resolution@ 80 keV

$$Eff. = \frac{\# \text{ of selected events}}{\# \text{ of irradiated events}}$$



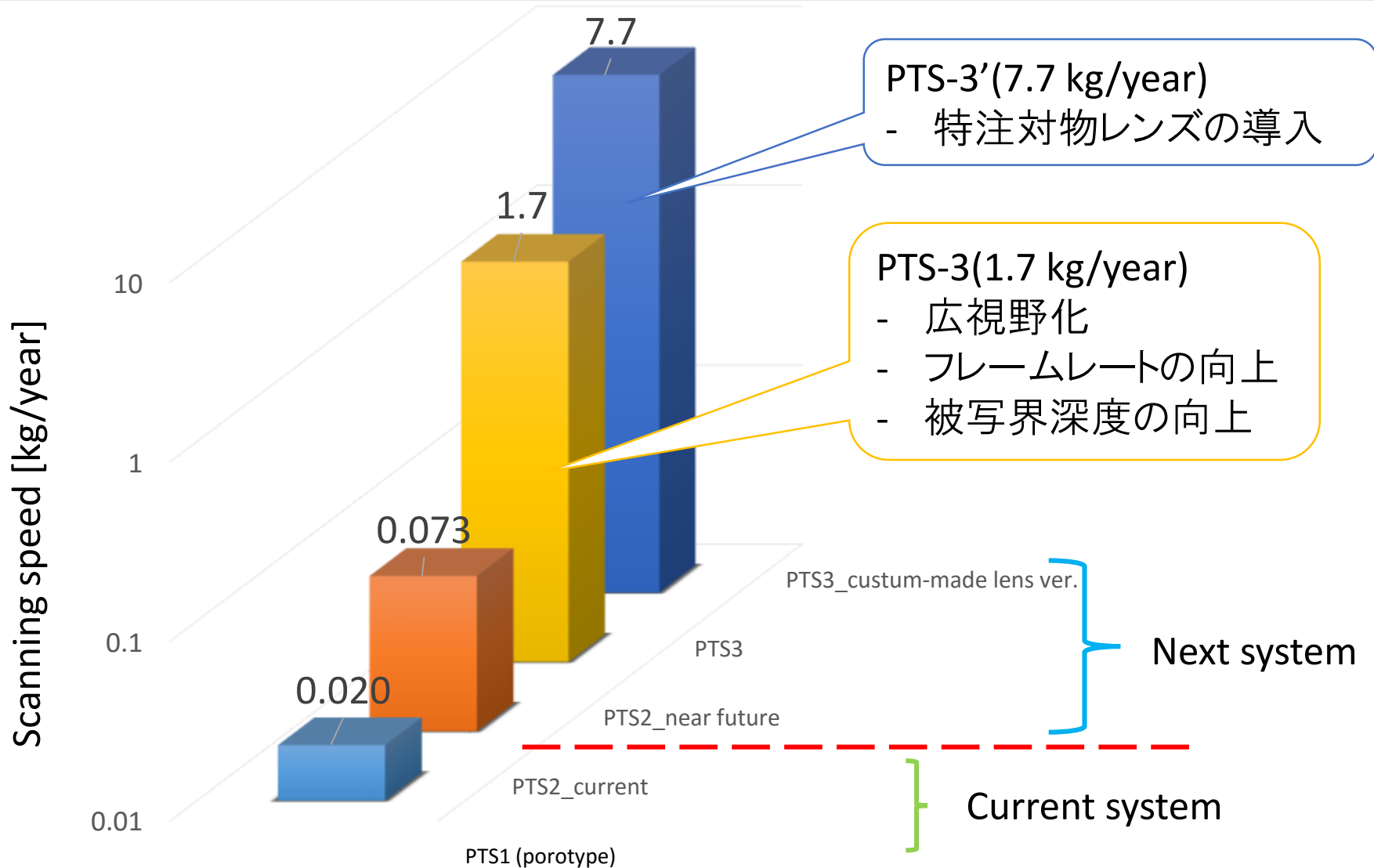
Background study

- NIT emulsion radioactivity

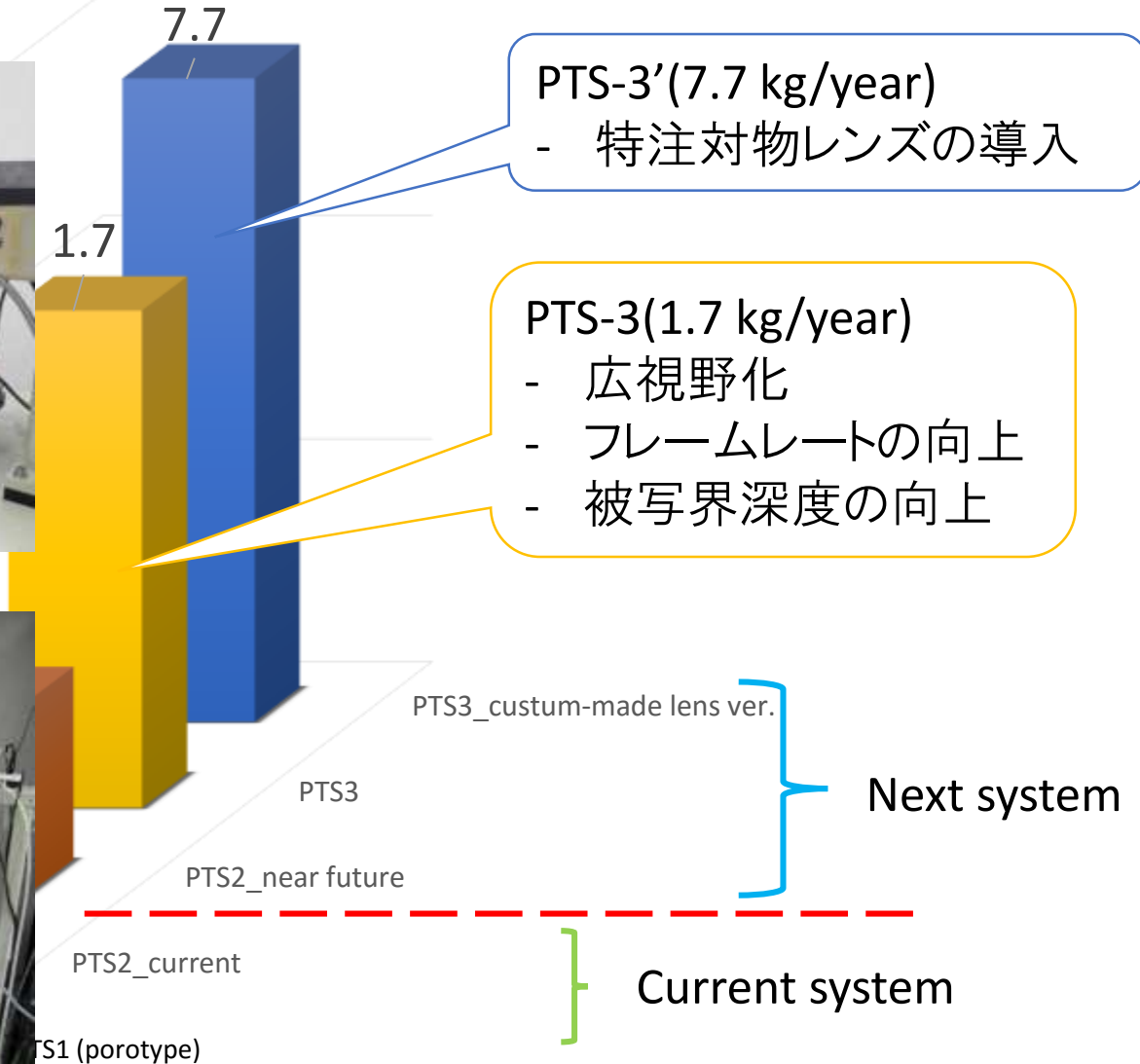
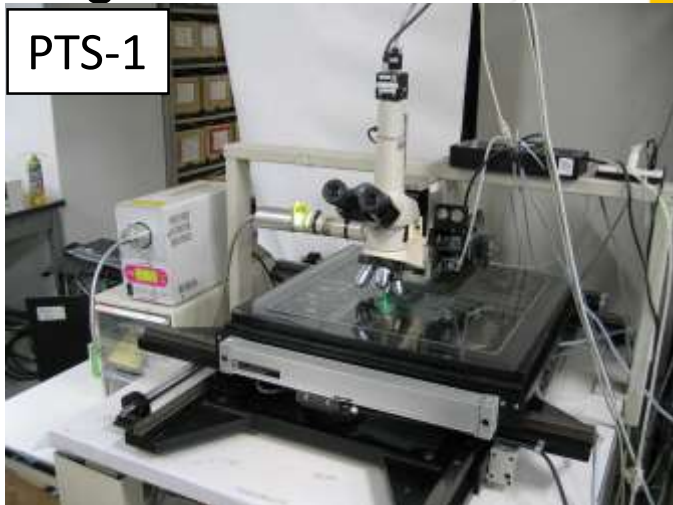
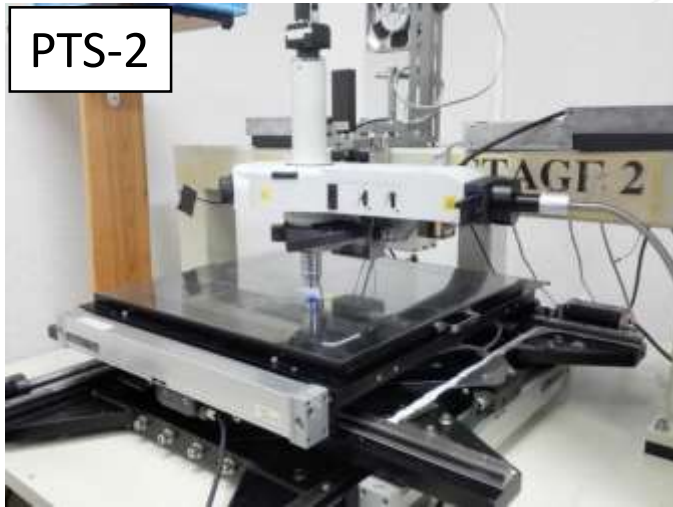
	U-238	Th-232	K-40	C-14
activity [mBq/kg]	27	6	35	24000
process	α decays (alpha, n) reaction		β, γ decays	β decays

- alpha-ray: rejection by track length difference
- (α, n) reaction: 0.11 neutron-induced recoils /kg /year A. Alexandrov *et al*,
Astropart.Phys. **80** (2016) 16-21.
- beta-ray: $R_\beta < 10^{-8}$ electron rejection power is required
 - NIT emulsion has $R_\beta < 10^{-6}$
 - a desensitization by cryogenic approach
 - a change in gelatin source (cattle bone -> petroleum-derived)
- Fake signal from raw materials or production process

Scanning speed improvement



Scanning speed improvement



Conclusion

- NEWS experiment
 - > A novel approach for directional dark matter searches
- Concept
 - > A solid detector would allow to explore spin-independent 10 – 1000 GeV/c² WIMP mass region.
- NIT emulsion
 - > 20 – 60 nm crystal size emulsion is available.
- Sensitivity to low energy ions
 - > 80% tracking efficiency and 20 degree angular resolution have been confirmed @ 80 keV carbon ions.
- Preliminary schedule
 - > **Pilot Experiment in 2018 with 1 Kg target mass.**