



Status of the NEWSdm experiment

T. Asada

On behalf of the NEWSdm Collaboration

NEWSdm collaboration

NEWSdm

Nuclear Emulsions for WIMP Search
with Directional Measurement



Website:

news-dm.lngs.infn.it

Letter of intent:

<https://arxiv.org/pdf/1604.04199.pdf>

CDR is submitted to LNGS committee in 2023



ITALY

University and INFN Bari
LNGS

University and INFN Napoli
INFN Roma



JAPAN

Chiba University
Nagoya University
Toho University
Kanagawa University



RUSSIA

LPI RAS Moscow
JINR Dubna
SINP MSU Moscow
INR Moscow

Yandex School of Data Analysis



SOUTH KOREA

Gyeongsang University

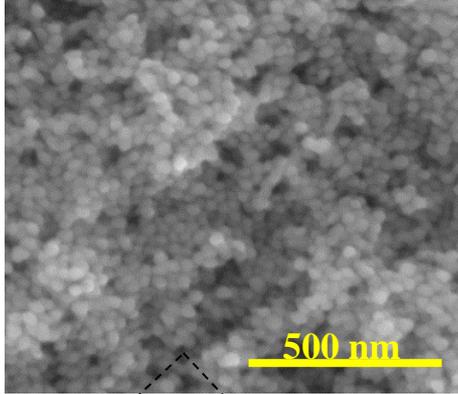


TURKEY

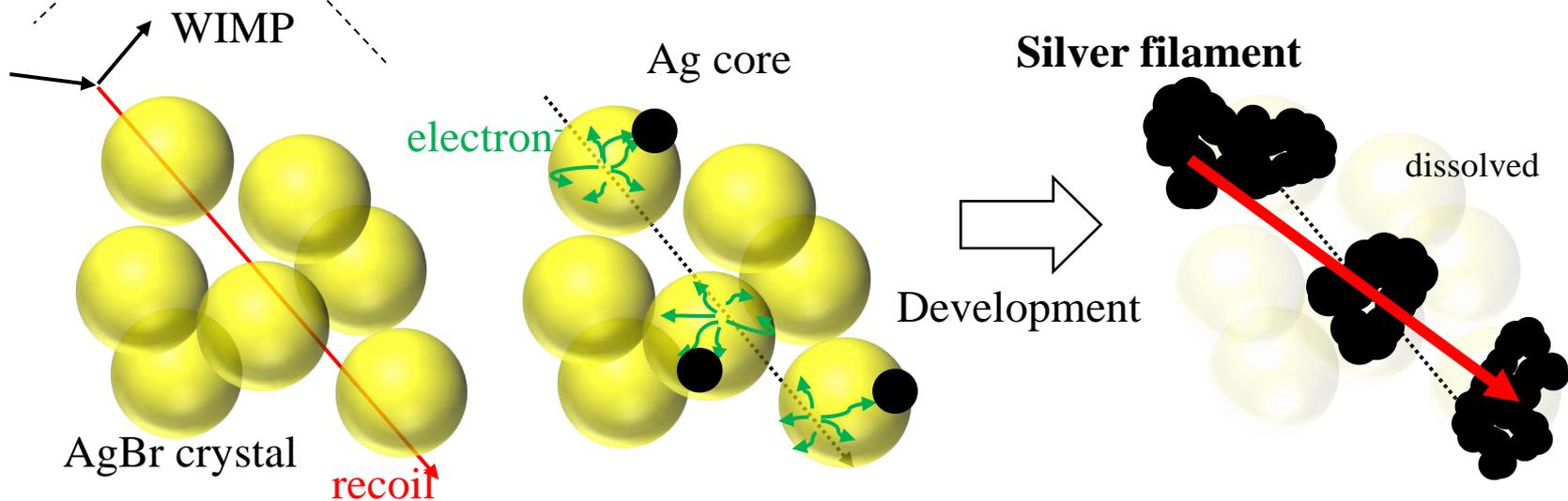
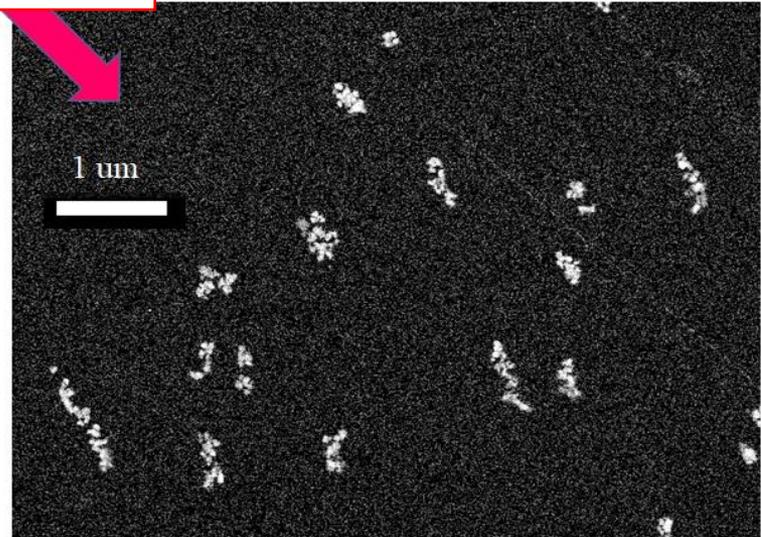
METU Ankara

Nuclear emulsion

AgBr(I) Crystals in SEM

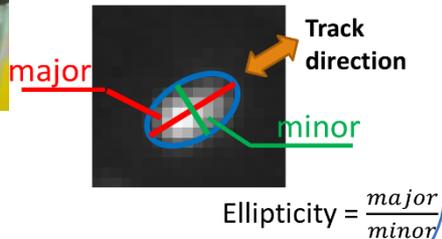


Carbon



Analysis method

TSL (Topological SeLection) method



Automatic readout

- PTS system (Japan)
- Elliptical selection + image data

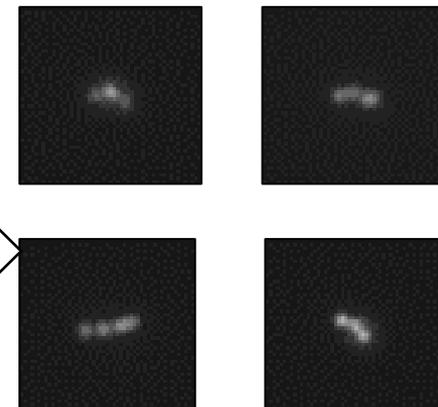
CNN
(machine learning)

- Convolution neural network
- Performance will depend on number and quality of training sample

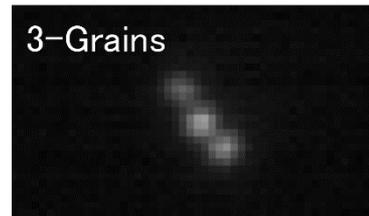
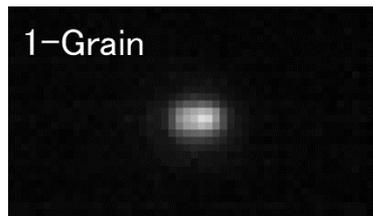
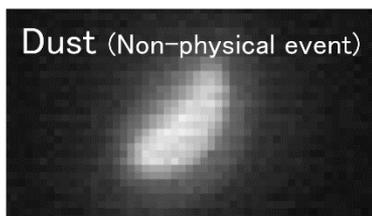
Manual selection

- Selection by eye check
- Currently selection the events recognized as with 3 or more grains

Manual check
(≥ 3 grains, straight track)



Training data : neutron recoil track (AIST Neutron 880keV, 1,2,3..grains track)
+ Dust (LNGS Run sample)

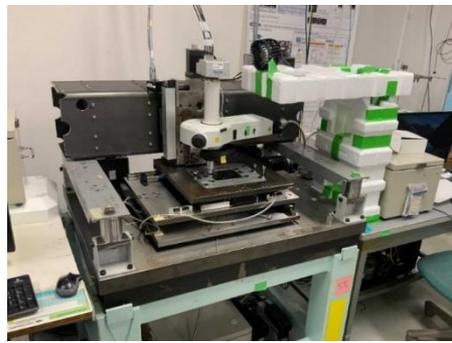


Scanning machine

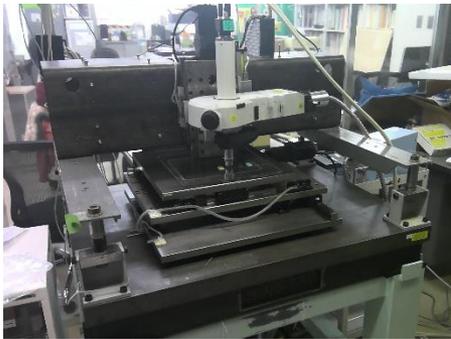
PTS-2 @ Kanagawa U.



PTS-3 @ Nagoya



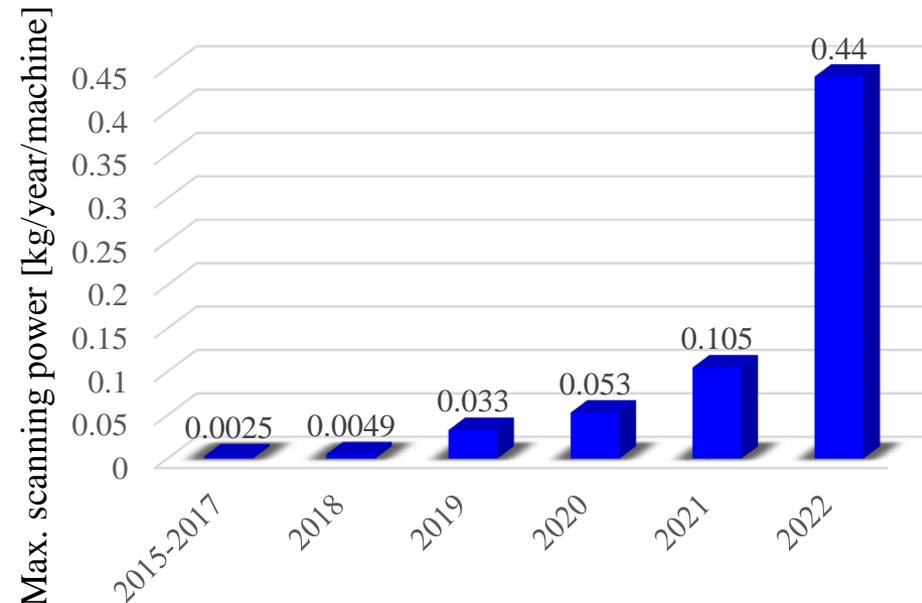
PTS-4 @ Toho



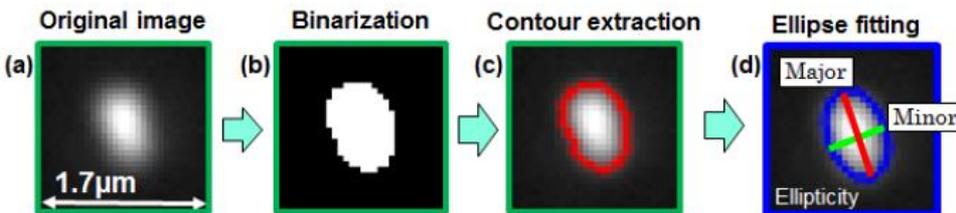
PTS-5 @ Toho



Scanning speed history (PTS3)

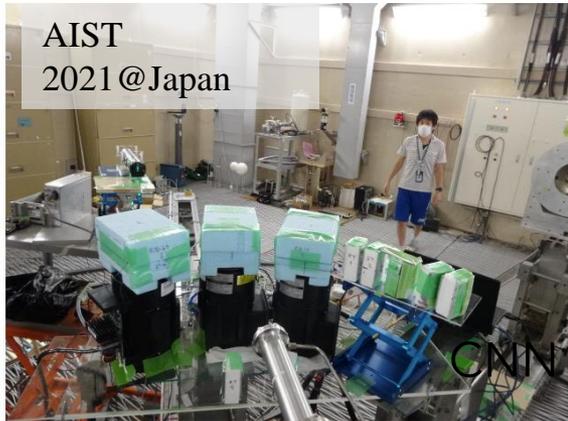


- We have two machines and other two are under commissioning
- Further upgrade is under study (5kg/year/machine is planned)

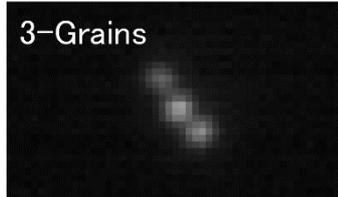
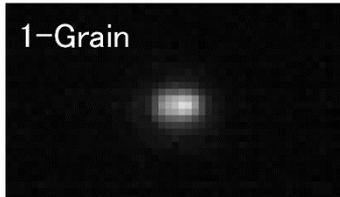
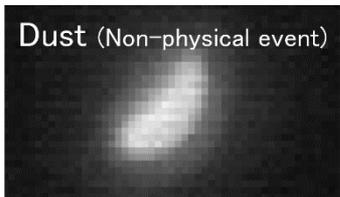
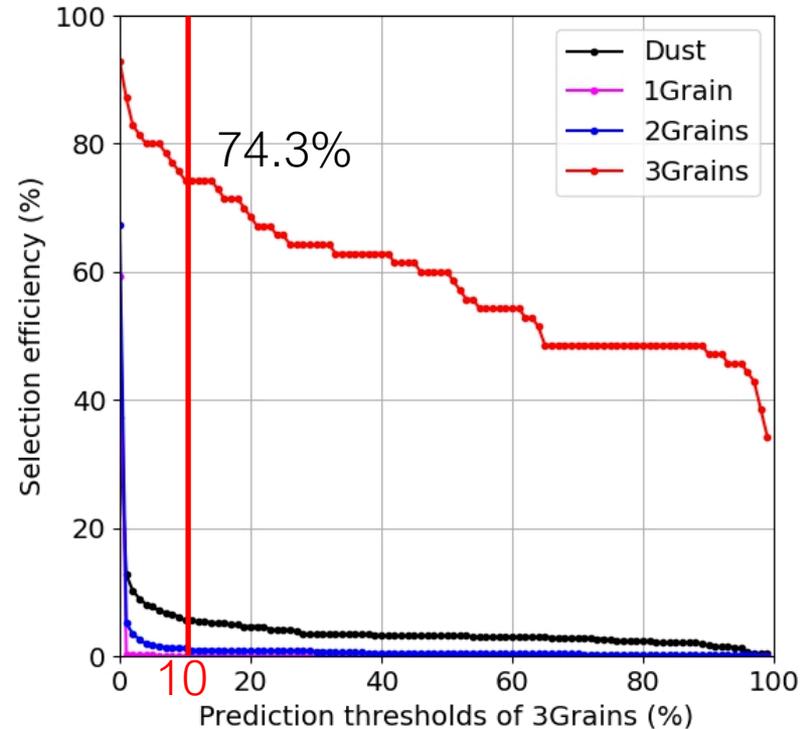


O(10 – 100) kg scale is realistic in near future!

Track like event selection (Topological SeLection;TSL)

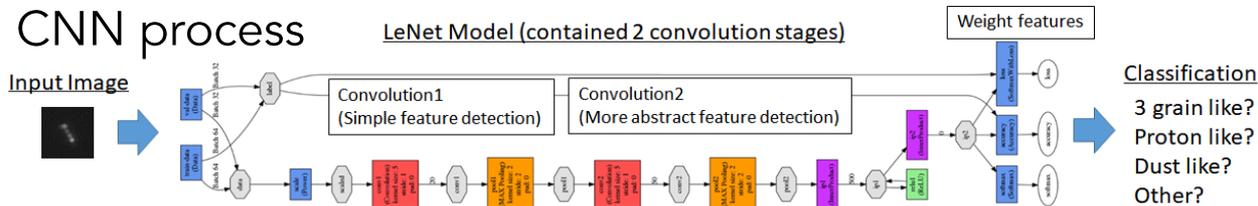


CNN process

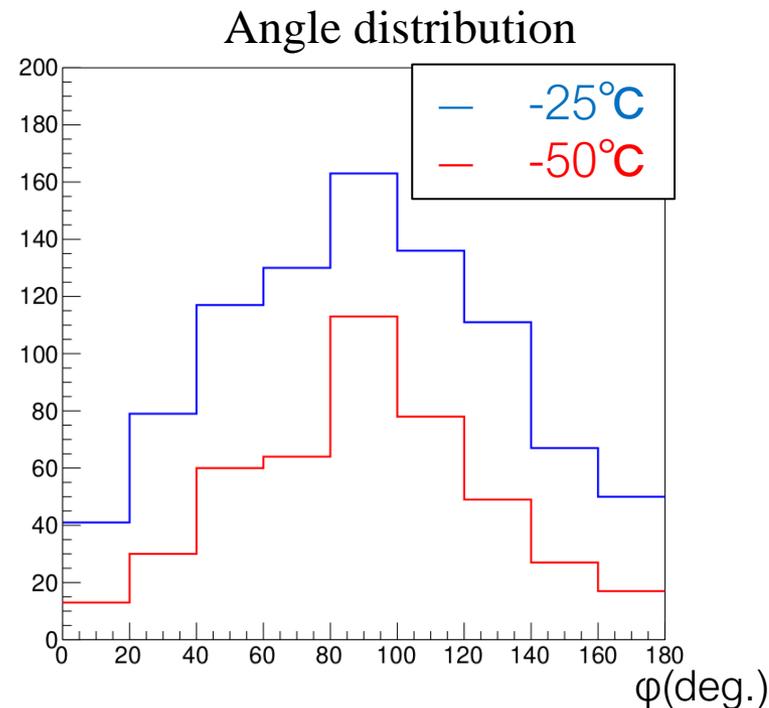
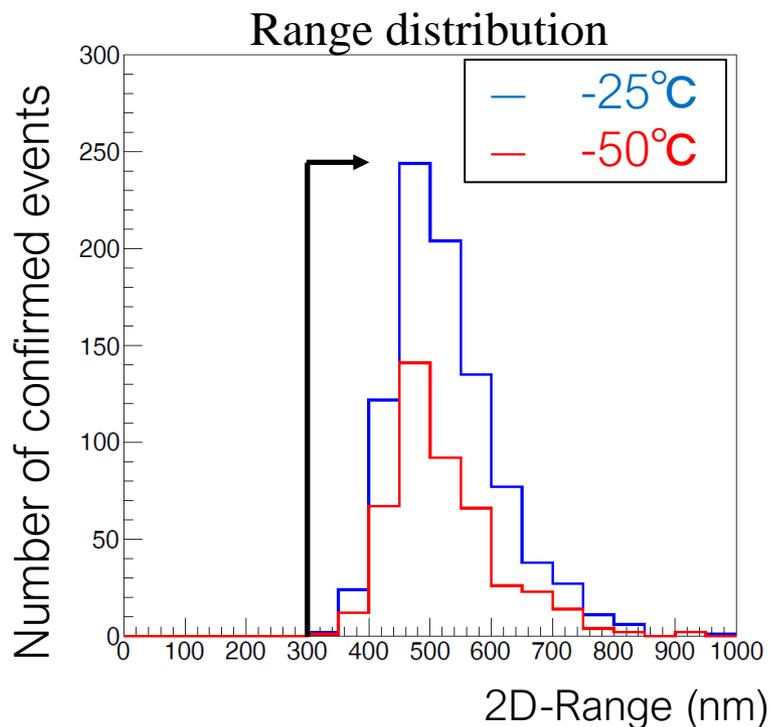


After elliptical screening of signals, manually classified data were collected

CNN process



TSL results with neutron source



Number of detected events(/100 mg)

	-25°C	-50°C
1st trigger	49,759	40,605
CNN	1,998	1,152
Confirmed	785	451

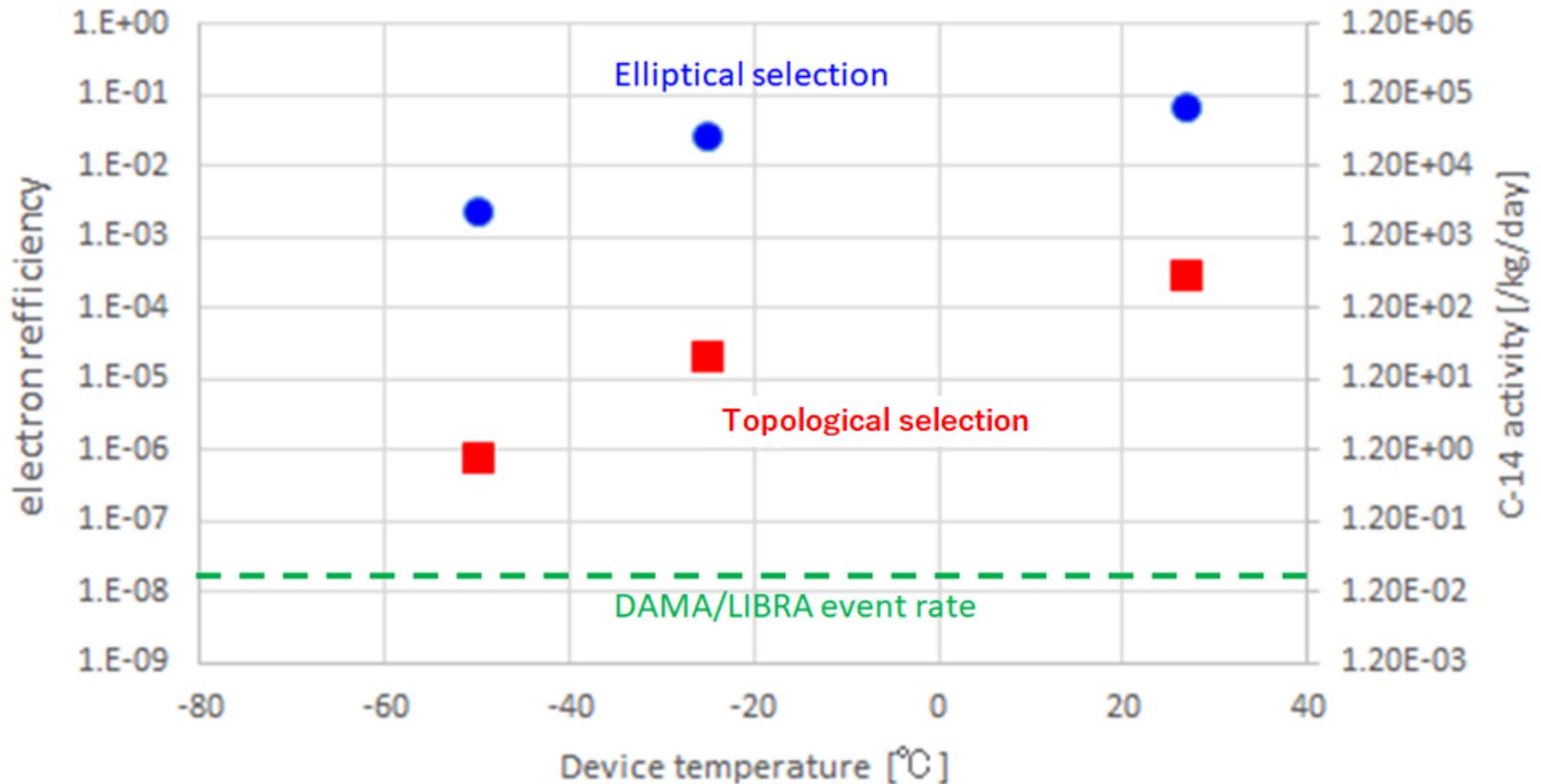
300–1000 nm range

H: 10-150 keV

CNO: 50-250 keV

>1000 nm → neutron measurement method

Gamma-electron BG with TSL



TSL detection ratio of neutron recoil for -50°C/-25°C: ~0.5

TSL detection ratio of gamma for -50°C/-25°C:

~0.5

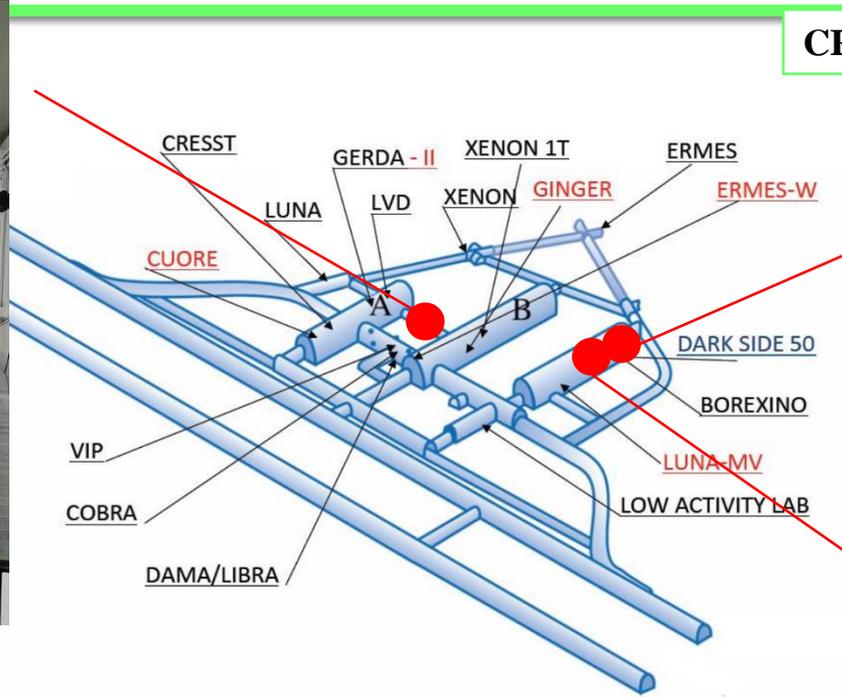
~ 0.05 → better S/N!

NEWSdm activity at LNGS

NEWSdm cleanroom



CR1 Radon free clean room



NEWSdm shield



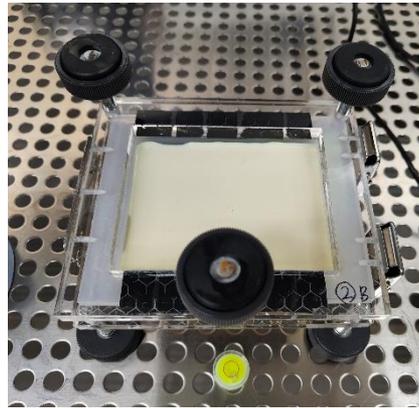
Surface level exposing site



LNGS underground Run for BG understanding



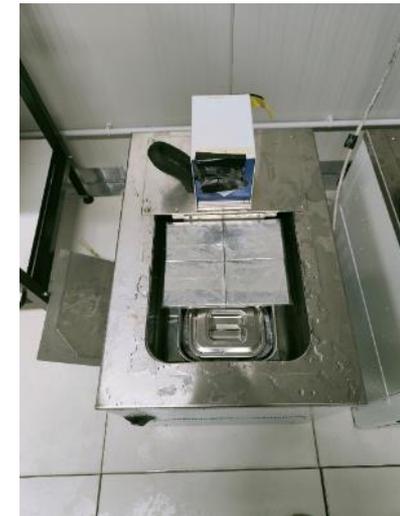
- emulsion production
- desalting



- Film pouring
- Packing @wet



- drying @shielded
- Exposure w/ cooler



development

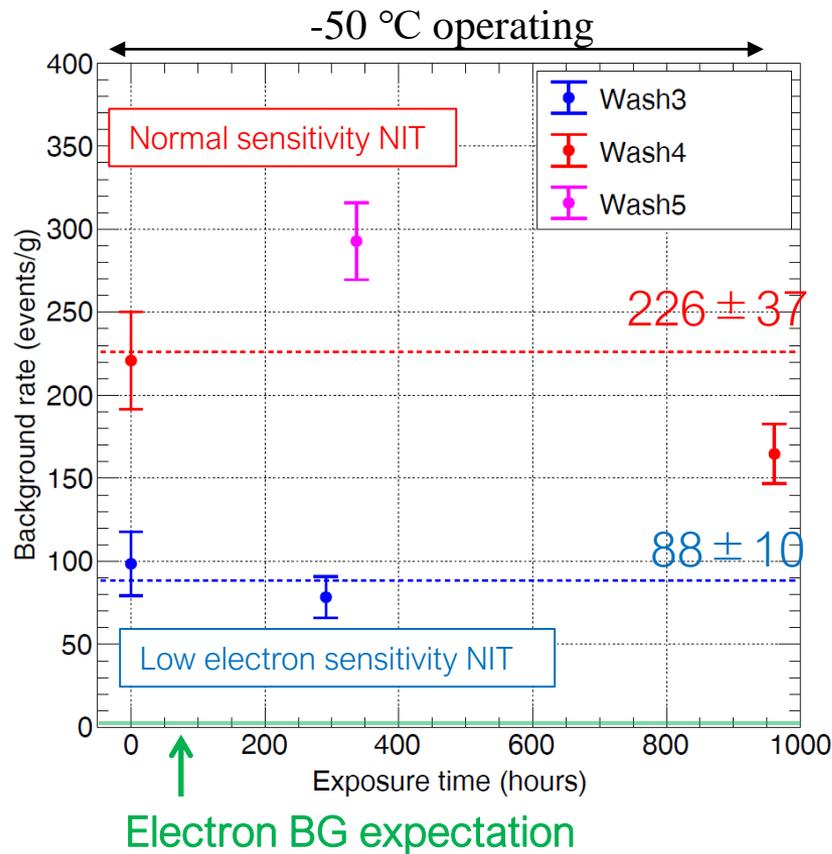
Mainly aiming reduce / evaluate gamma effect

Recent Activity in LNGS

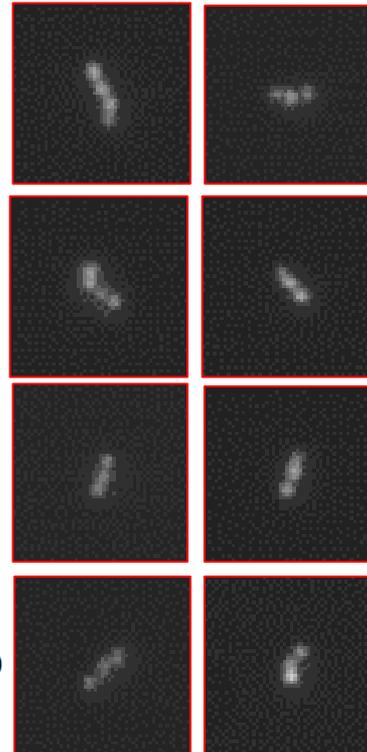
Run	starting date	pouring	purpose	scale
Run1	25-Apr-2021	hall F	First shield run with film insertion in wet conditions	4g:0day
Run2	28-Apr-2021	hall F	sequential Shield Run; 0-day exposure, optimization of operation	4g:0day
Run3	3-May-2021	hall F	sequential Shield Run; 2 weeks exposure	4g:12days
Run4	18-May-2021	hall F	sequential Shield Run; 0-day exposure, batch quality check	4g:0day
Run5	27-May-2021	hall F	sequential Shield Run; 40 days exposure	4g:40days
Run6	10-Aug-2021	hall F	sequential Shield Run; 2 weeks exposure	4g:13days
Run7	24-Nov-2021	hall F	sequential Shield Run with same batch; 0-day exposure	4g:0day
Run8	29-Nov-2021	hall F	sequential Shield Run with same batch; 2 weeks exposure	4g:13days
Run9	21-Dec-2021	hall F	sequential Shield Run with same batch; 5 weeks exposure	4g:35days
Run10	14-Feb-2022	hall F	check of drying step with shield	4g:5days
Run11	22-Feb-2022	hall F	check of development step with shield	4g:0day
Run12	25-May-2022	hall F	shortest drying test	2g:0day
Run13	16-Jun-2022	hall F	shortest drying test + N2 purging	4g:0day
Run14	18-Oct-2022	hall F	non-sensitized emulsion; BG investigation	4g:0day
Run15	16-Nov-2022	CR1	dry test at radon free room	8g:0day
Run16	13-Dec-2022	CR1	shielded dry test in radon free room	6g:0day
Run17	4-Apr-2023	CR1	shielded dry + sequential shield Run; 0day exposure	6g:0day
Run18	19-Apr-2023	CR1	shielded dry + sequential shield Run; 3 weeks exposure	6g:19days
Run19	15-May-2023	CR1	shielded dry + sequential shield Run; 1 week exposure	6g:7days
EMRun1	27-Jul-2023	hallF	Equatorial mount Run (CR1 was under maintenance)	8g:0-2months
CRDMRun1	21-Nov-2023	CR1	surface+equatorial mount with low sensitivity emulsion	3g:0-2weeks
n-Run1	22-Nov-2021	hall F	first neutron measurement test at the external laboratory	20g:0-1months
n-Run2	23-May-2022	hall F	neutron measurement in the external laboratory with less Radon treatment	20g:0-2months
n-Run3	12-Oct-2022	hall F	neutron measurement in the underground laboratory with less Radon treatment	30g:0-4months
n-Run4	22-Nov-2023	CR1	neutron measurement in the underground laboratory in Radon Free condition	25g:0-4months

Many activity in LNGS after COVID!

First BG Run result (Run3-6)

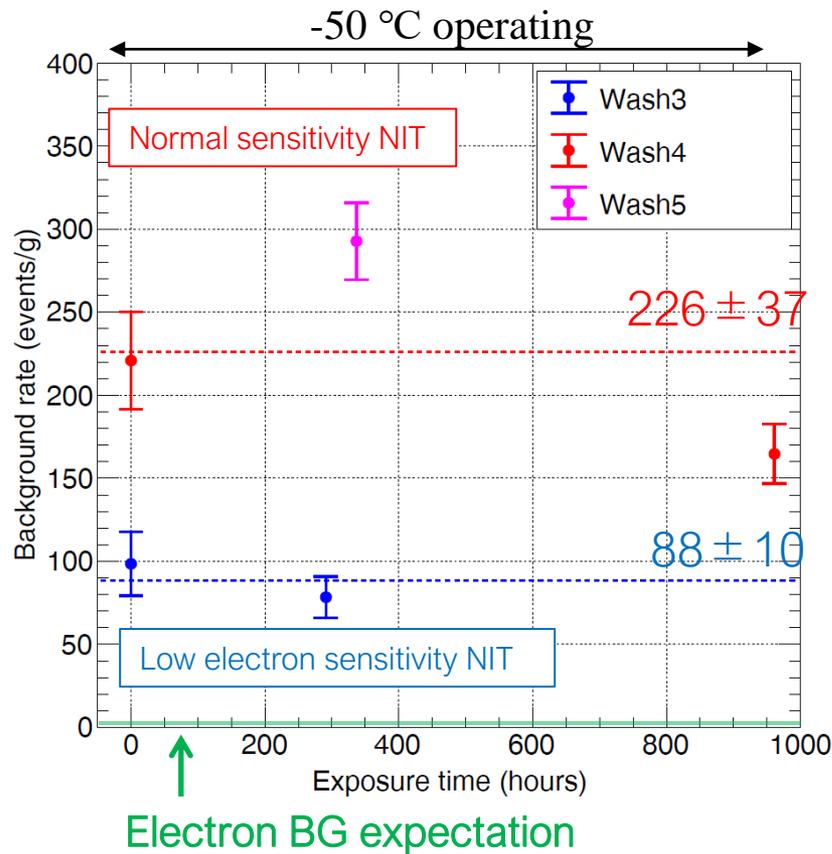


Found candidates

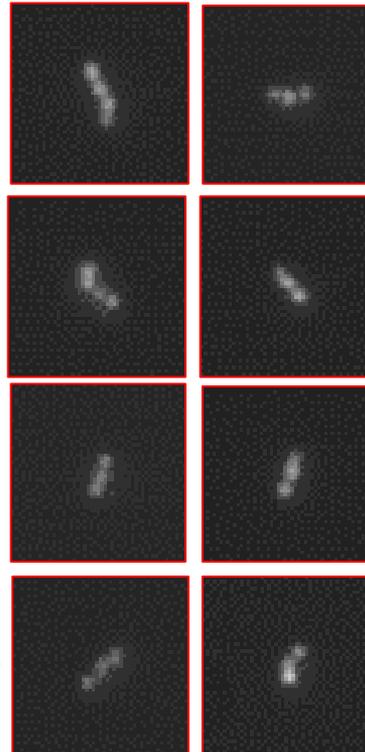


too much BG events (100-200/g) against expectation
 Long exposure is flat as expected, problem is offset part

First BG Run result (Run3-6)



Found candidates

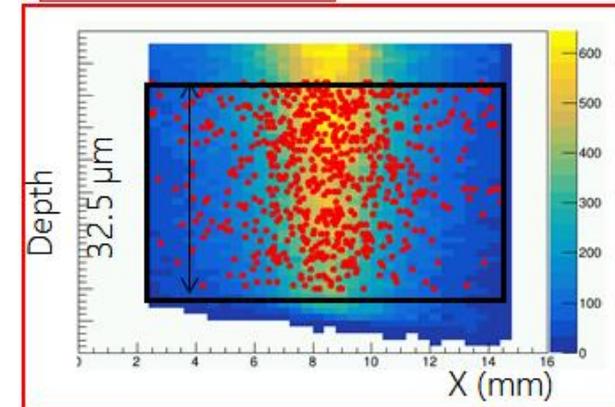


× 2.6 times difference for BG

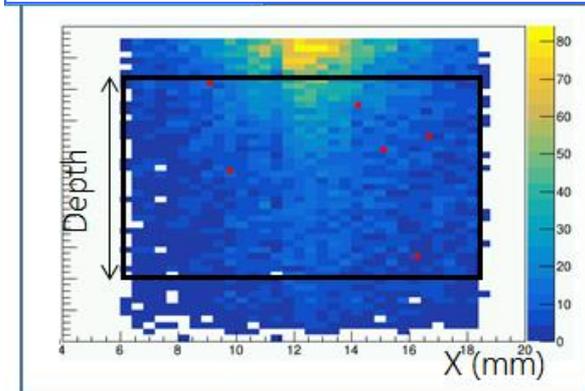
→ Not electron like

Am-γ test

Standard emulsion

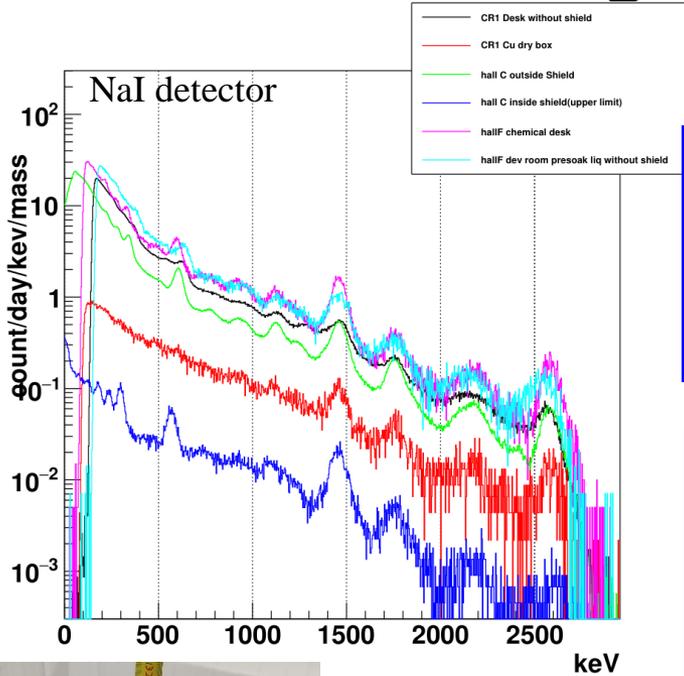


Low sensitivity emulsion



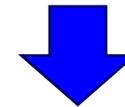
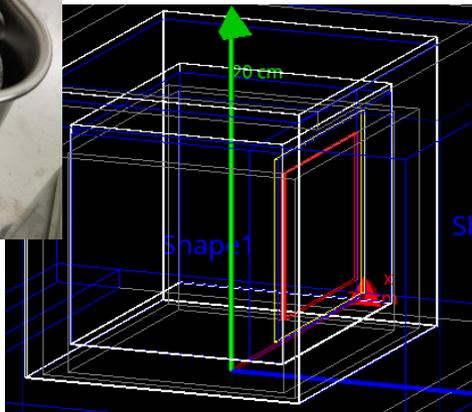
× 130 times difference
for gamma

Simulation of gamma-electron background



	Hall F Film making	Hall F Development	Hall C transportation	Hall C shielding	CR1 Drying shielding
Electron produced in emulsion (/d/plate(2g))					
From Lead	-	3150	-	2400	<100
From environmental gamma	456360	60310	257140 (Hall C) 422650 (CR1)	13	10540

	Drying shielding (100% dry case)	Drying shielding (50% dry case)	Drying shielding (0% dry case)
Counts (/d/plate(2g))			
Electrons produced in emulsion	10540	53800	106900
Gamma-rays entering emulsion	136500	138050	140100

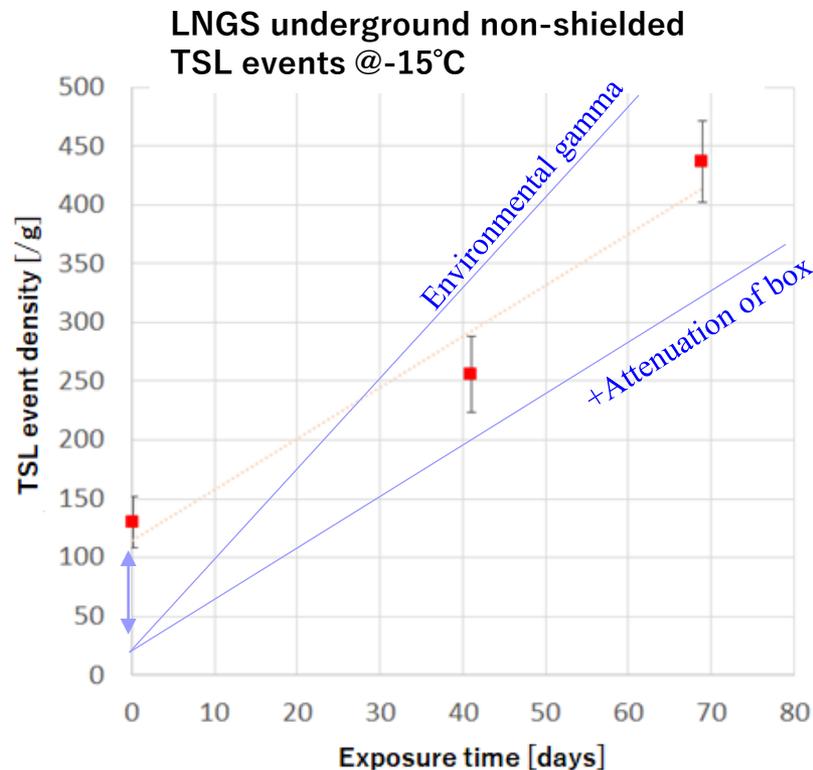


Run5

situation	time (h)	selection efficiency	Electron (/g/day)	wet factor	gamma TSL (/g)	¹⁴ C TSL (/g)
set	1.5	1.7 × 10 ⁻⁴	2313745	0.003	0.072	5.7 × 10 ⁻⁵
pre-dry	21.2	1.7 × 10 ⁻⁴	1163718	0.010	1.745	2.7 × 10 ⁻³
dry	19.38	1.7 × 10 ⁻⁴	1207	1 (-0.01)	<0.166	<2.5 × 10 ⁻¹
exposure	961.12	5.7 × 10 ⁻⁷	1207	1	0.027	4.1 × 10 ⁻²
extraction	0.3	5.7 × 10 ⁻⁷	128570	1	0.001	1.4 × 10 ⁻⁵
develop	0.20	1.7 × 10 ⁻⁴	228180	1	0.323	2.6 × 10 ⁻³
total events					< 2.17	< 0.30

Crosscheck of TSL method

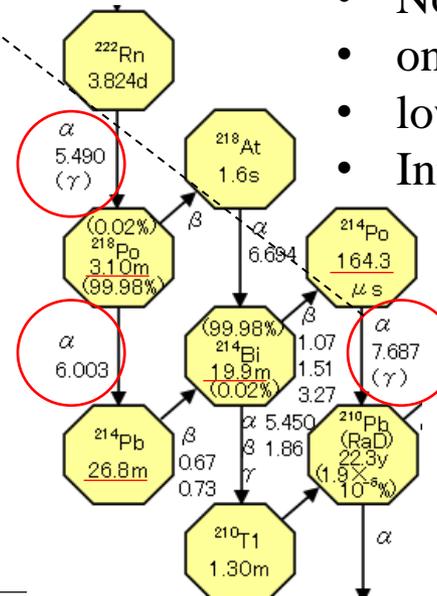
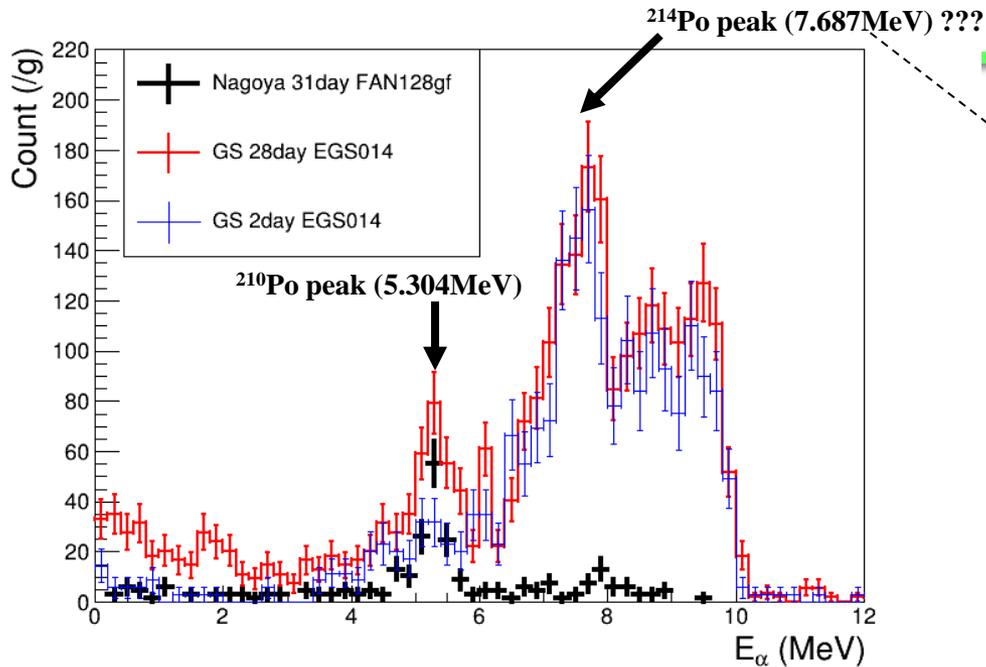
Non-shielded exposure



- Without shielding, time dependent signals appeared
- $\sim 4.5/\text{g}/\text{day}$
- Expectation of Simulation $\sim 8/\text{g}/\text{day}$
- Attenuation of freezer $\sim \times 0.6$
- \rightarrow mostly consistent

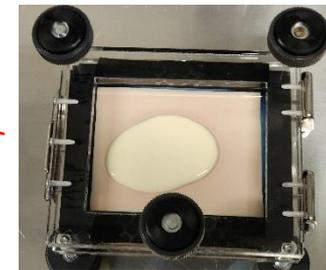
Estimation of offset ~ 20 events
 \rightarrow unknown source?

Radon (daughter) contamination at film production?



- Not time dependency
- one prong
- lower sensitivity
- Inner film events

place	Radon Bq/m ³	temperature °C	humidity %
hallF prod.room	72.5	20.7	44.8
hallF dev.room desk	87	17.2	53.5
hallF corridor air	73.8	17.1	46
hallC	46.9	14.5	45.3
hallC compressed air (drying in shield)	163.1	15.1	11
hallC N2 (exposure in shield)	2.3	15.1	7.8
hallB air (source of room air)	18.6	14.5	46
CR1 (druing Run19)	3.7	17.1	11.5



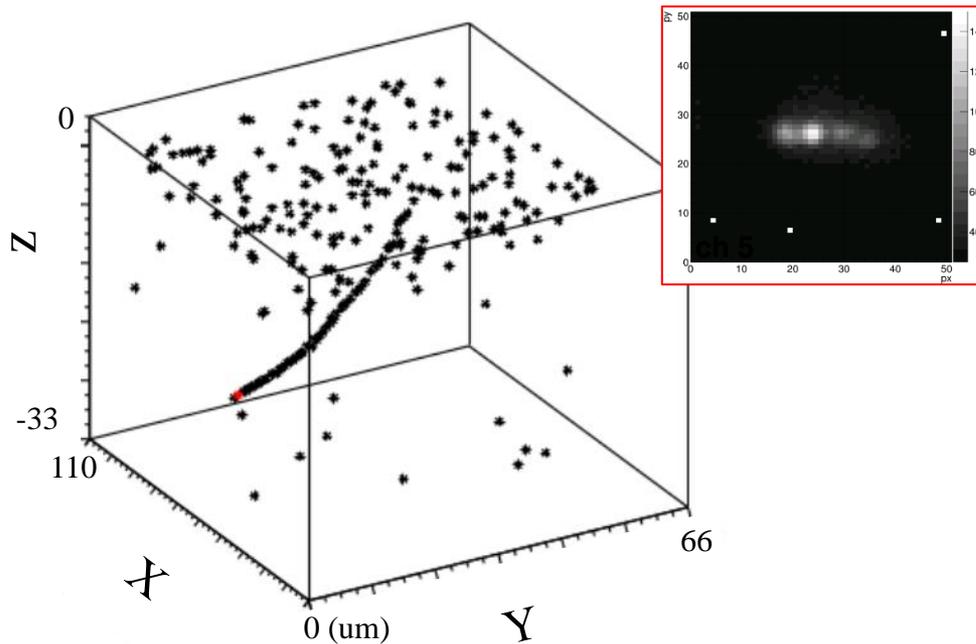
dry



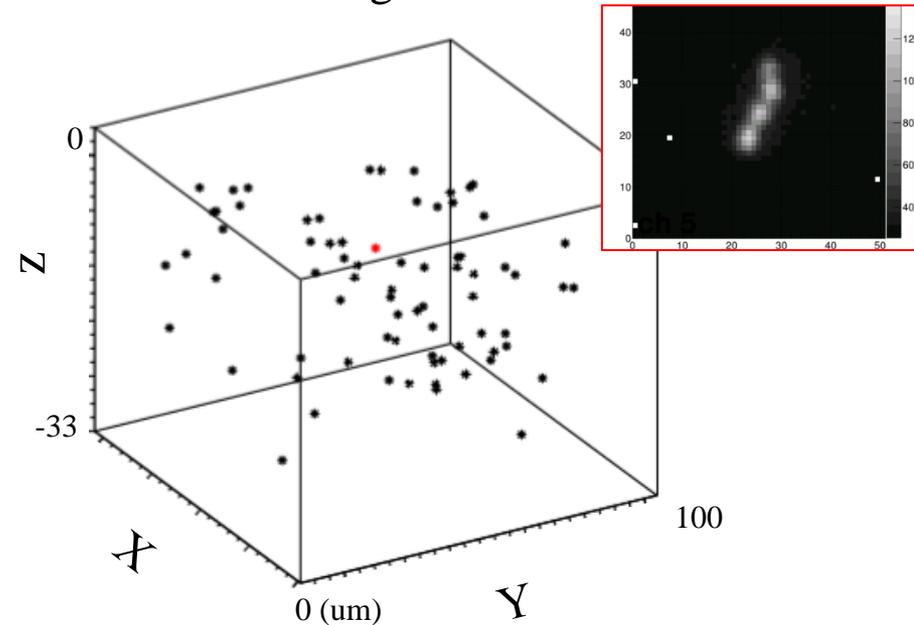
Radon rich environment...

TSL candidates and radon identification

Normal Radon event



Found event in
LNGS underground Run



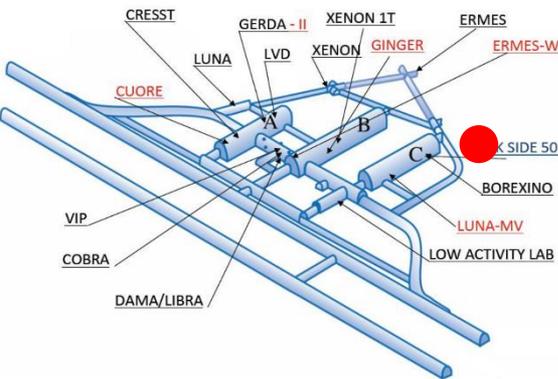
If they are also Radon, it is not from outside, not at dried state

Radon daughter may be dynamically contaminated in film making process
at non-negligible level

Move to Radon Free room



LNGS Activities



CR1 Dark-Side radon free clean room

Use:

- DS-50 TPC components cleaning and packing + TPB deposition on TPC inside surface
 - SABRE crystal assembling
- + NEWS emulsions preparation (Nov 2022-)
 → Radon Free clean **Dark** room

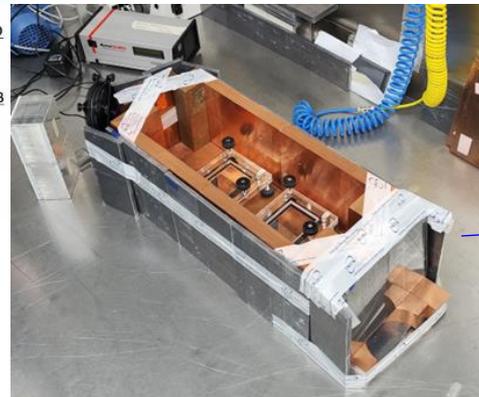
Rn abatement system: Ateko 220 m³/h

Rn level

outlet of Rn abatement ~ 1 mBq/m³

outlet of CR1 ~ 400 mBq/m³

NEWSdm Run: <10 Bq/m³ at portable detector



Emulsion production

Emulsion desalting

Film making

Film packing

Exposure

Development

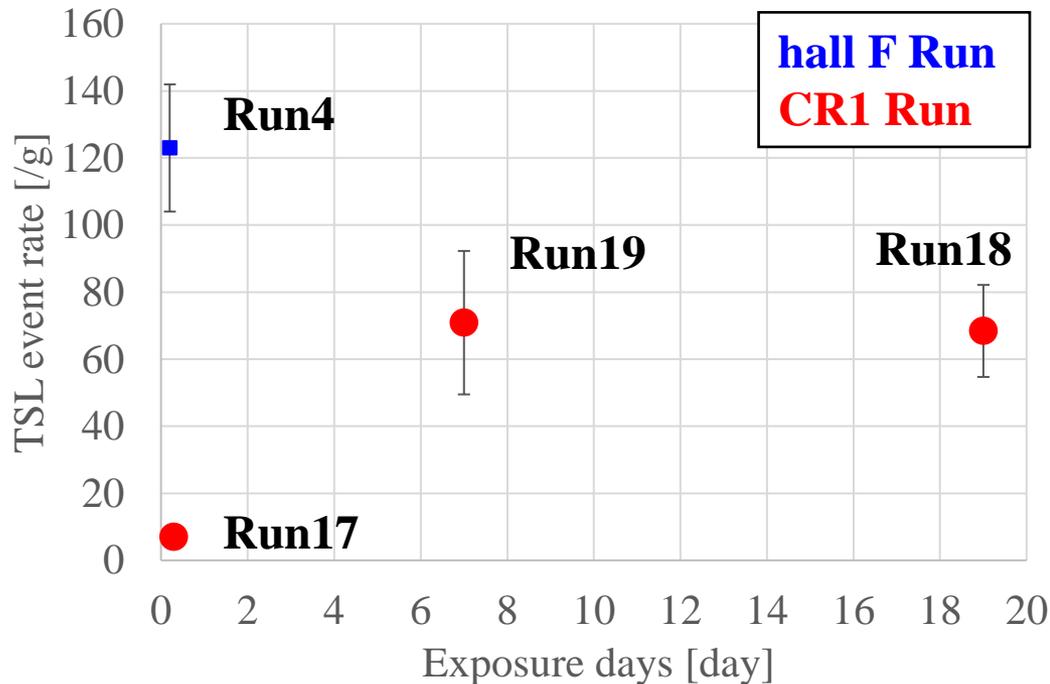
hall F

CR1

hall C shield

hall F

Latest situation of BG study



0 day (non-exposed) events was greatly suppressed
 However, exposed events has some constant jump
 → Unexpected source in shield?

Still 0 day has O(1-10) events while gamma estimation is O(0.1)

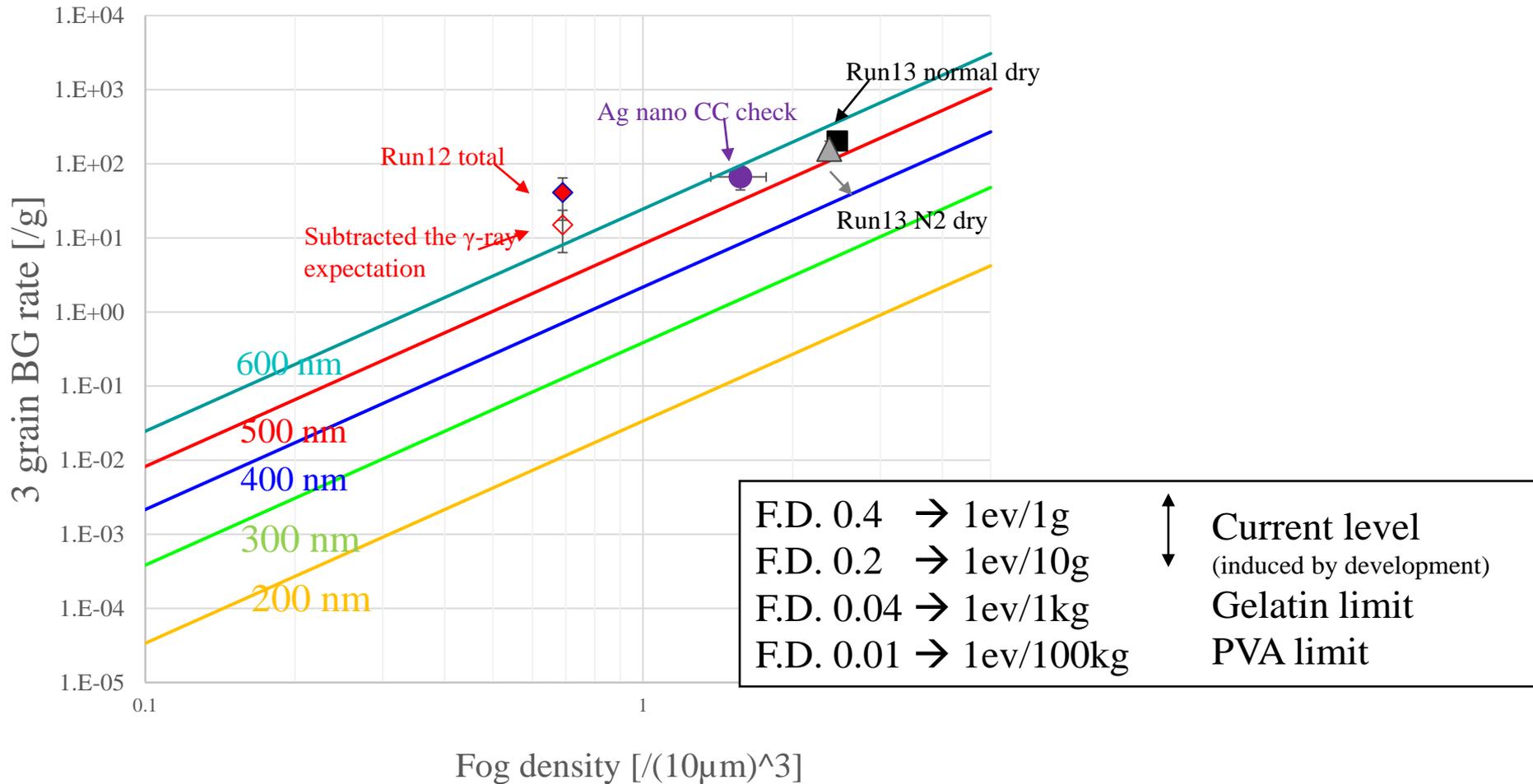
chance coincidence of single grain may be problem...

Run18

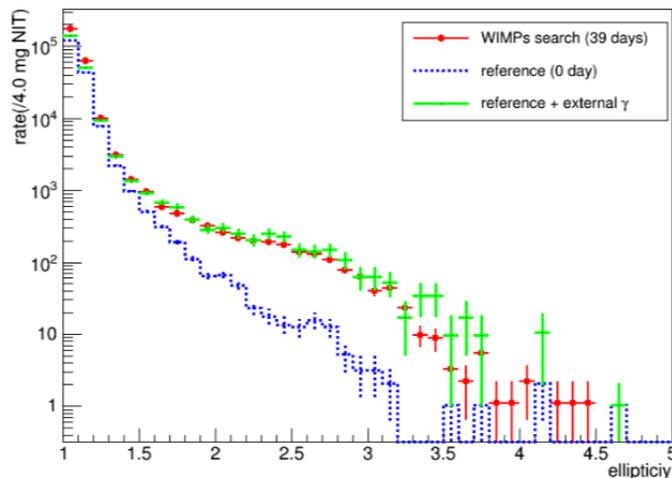
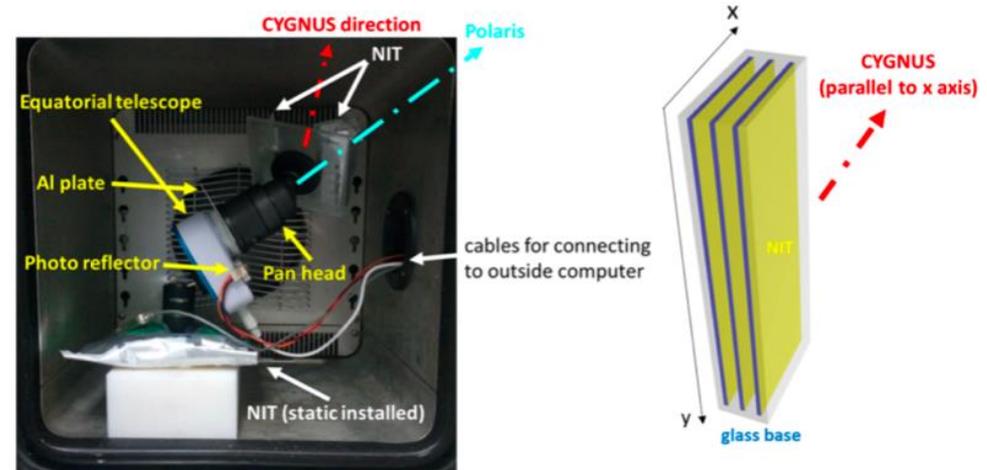
situation	time (h)	selection efficiency	Electron (/g/day)	wet factor	gamma TSL (/g)	¹⁴ C TSL (/g)
Set	0.5	1.0E-05	<2142836	0.003	<0.0014	1.2E-06
Dry	21.6	1.0E-05	5270	1 (-0.01)	<0.0473	0.0163
Exposure	454.0	3.3E-08	1207	1	0.0008	0.0011
Extraction	0.42	3.3E-08	128570	1	0.0001	1.0E-06
Develop	0.4	1.0E-05	31730	1	0.0056	3.2E-04
no shield	0.6	1.0E-05	128570	1	0.0296	4.2E-04
total events					<0.085	0.018

Total non-shielded time in operation is suppressed to ~30min!

rough estimation of Fog Chance Coincidence



First direction sensitive Run with equatorial mount

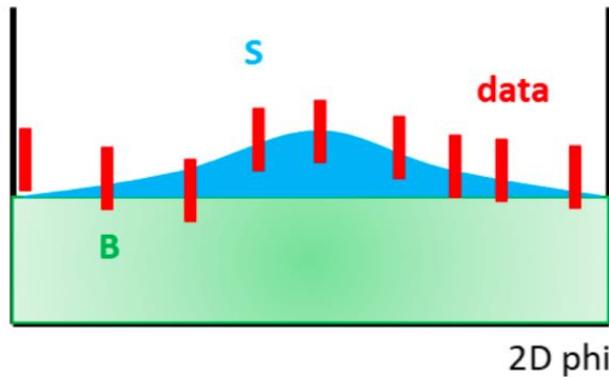
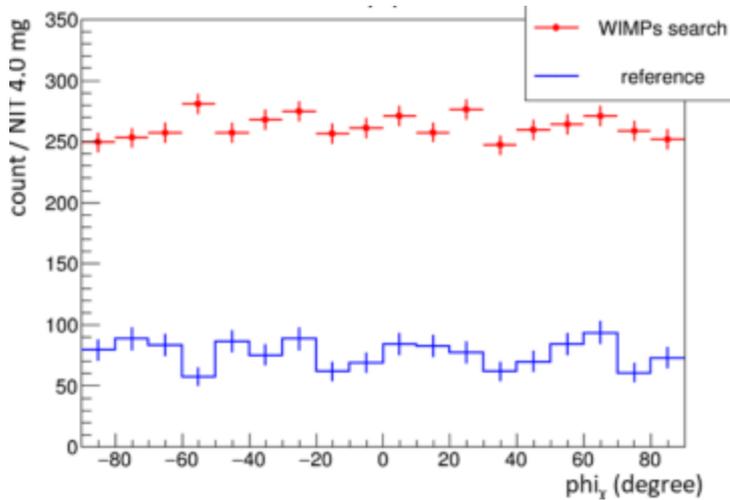


Small scale Run with equatorial mount @ Japan, 2019

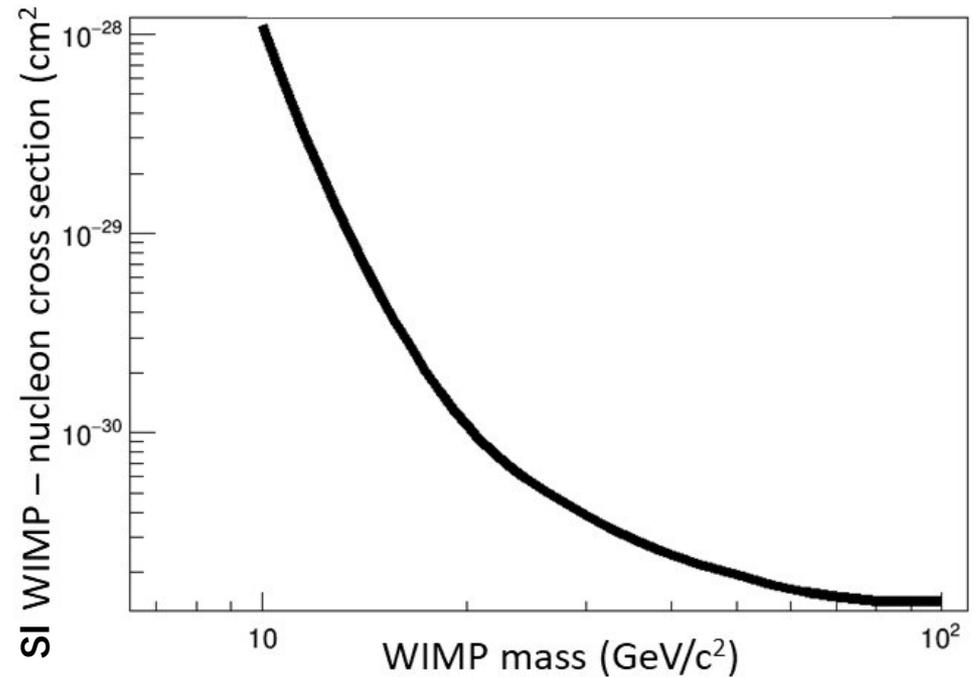
- 0.59 g·days (15.1 mg \times 39 days)
- No shielded \rightarrow dominated by environmental gamma
- Analyzed by elliptical shape (not TSL)

First direction sensitive Run with equatorial mount

Phi angle distribution of events

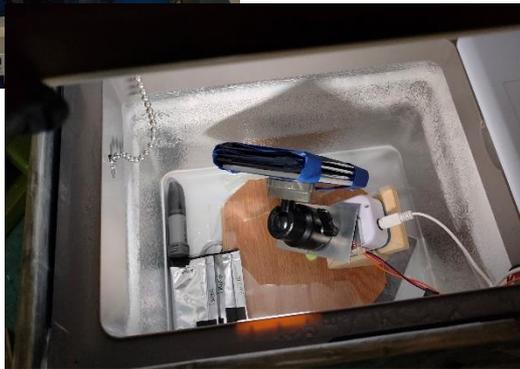


95% C.L. upper limits

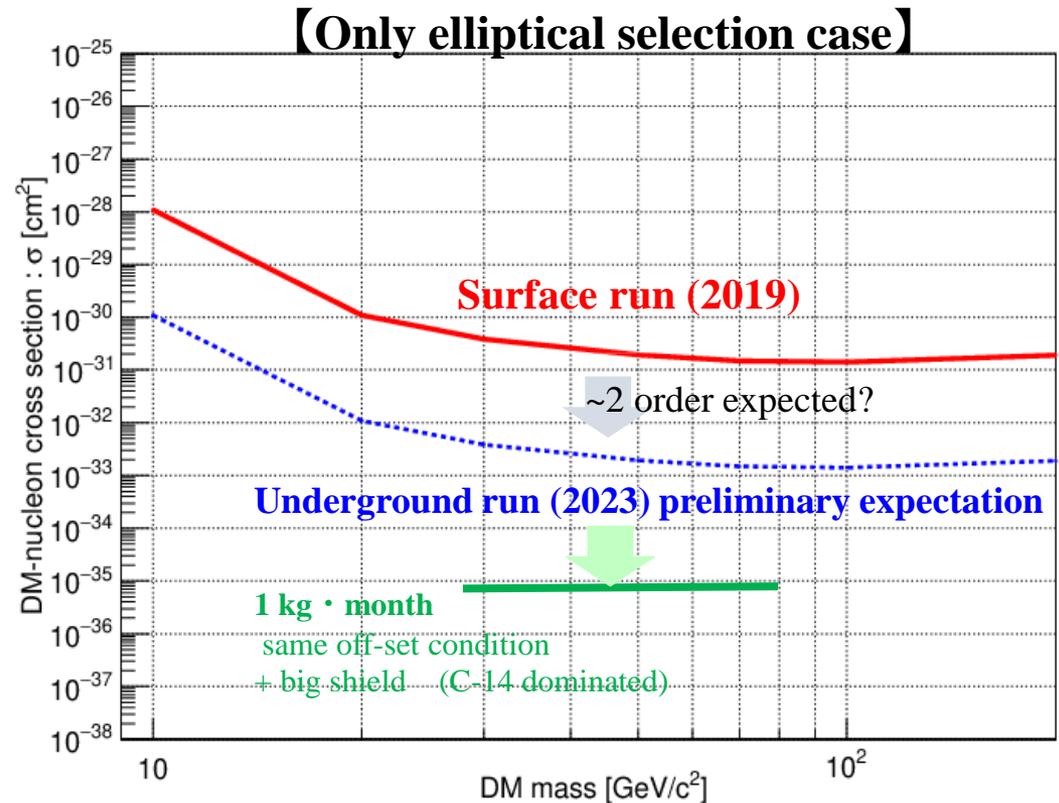


Under review
arXive:[2310.06265](https://arxiv.org/abs/2310.06265)

Equatorial Mount Run in LNGS underground (2023)

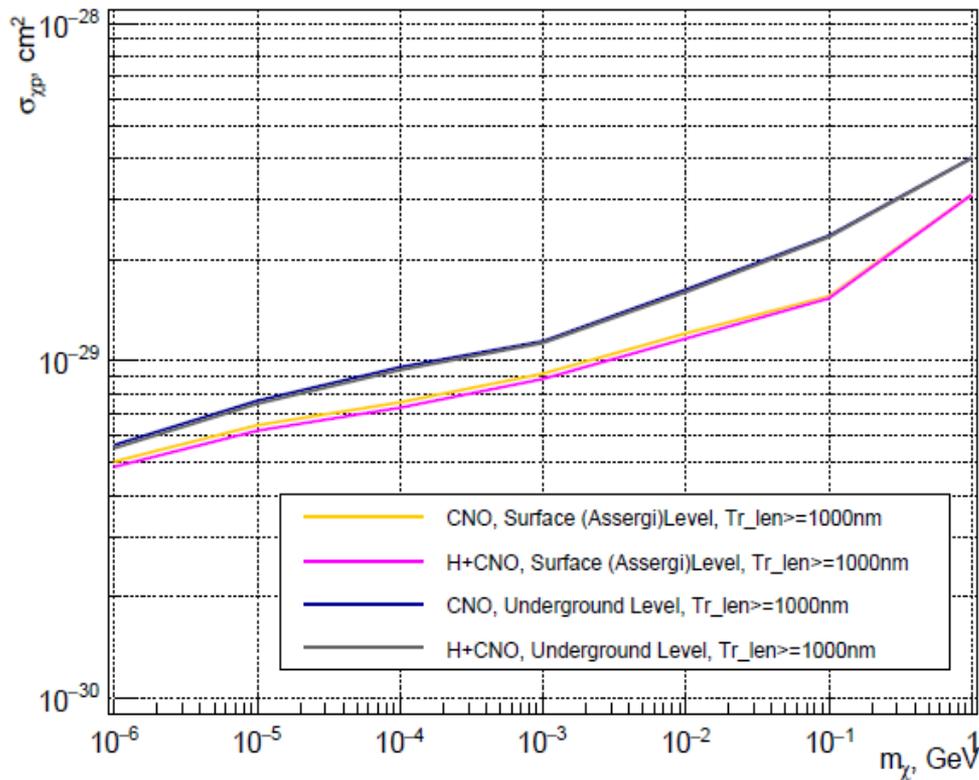


- LNGS underground (hall F)
- 1cm Pb shielding / -15°C at portable freezer
- ~2 g × 4 films (0, 0.2, 1, 2 months)
- Under analysis now



Cosmic-Ray Boosted DM search

10kg · 1 year case



- Higher cross section region is also important in CRDM
- Scattering in the rock can disturb directional search
- Surface exposure has higher background, especially cosmic-ray induced background such as neutron, proton and muon.
- In emulsion case, targeting only long CNO recoil may be a good strategy for CRDM
 - $>1\mu\text{m}$ CNO: 400keV/ μm or more
 - alpha Bragg peak: $<300\text{keV}/\mu\text{m}$
 - proton Bragg peak: $<100\text{keV}/\mu\text{m}$
 - Alpha insensitive emulsion is already verified

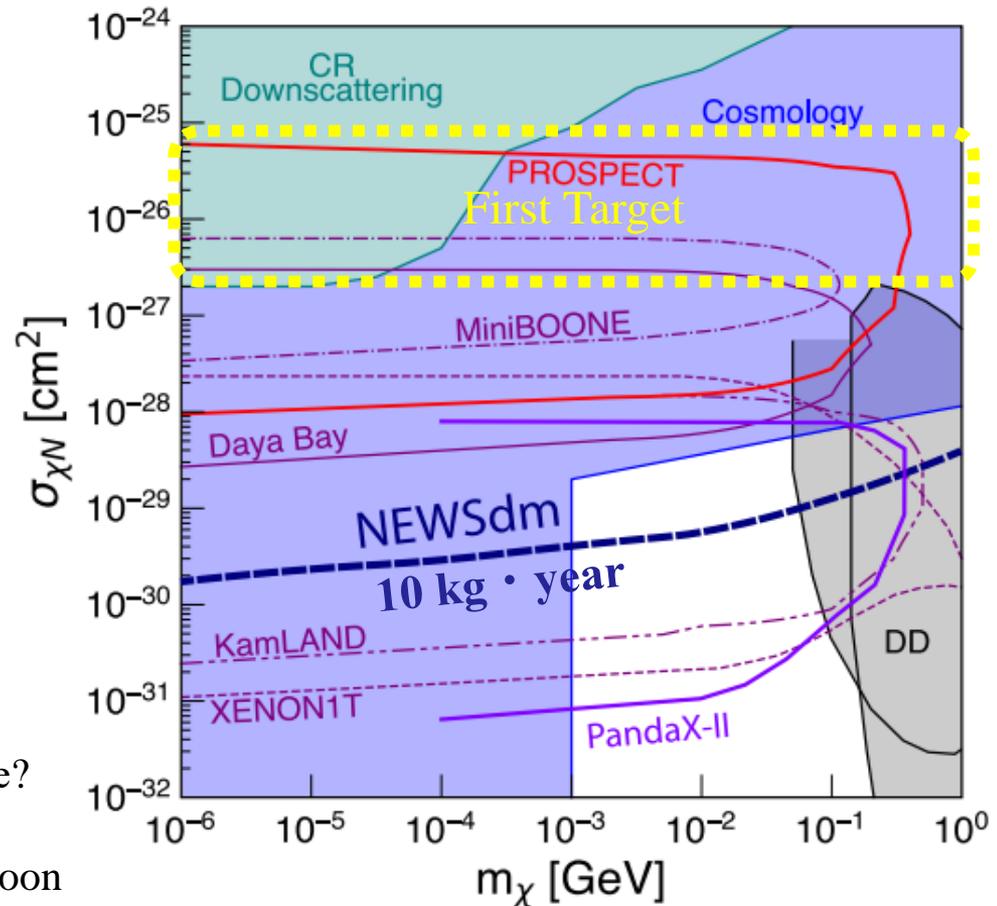
First Run targeting CRDM search



Same site as surface neutron measurement



- Nov-Dec 2023
- First trial of CRDM search
- very low sensitivity emulsion \rightarrow p, α free?
- Equatorial mount
- Analysis will start soon



summary

- NEWSdm started cleanroom operation in LNGS
- Radon problem was found, and we got help further clean environment
- Gamma BG is correctly measured and suppressed with new analysis method TSL
- Unknown BG effect is reminded correlated with shield insertion. Radon is still suspect
- Next barrier to reach larger scale is chance coincidence of chemically induced noises
- First DM search with equatorial mount was performed at surface, and we are repeating updated Run in LNGS underground
- Another type of Run targeting CRDM is also operated