Emulsion production and background rejection in the NEWSdm experiment

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On behalf of the NEWSdm Collaboration

CYGNUS 2019 / 12 Jul 2019 / La Sapienza in Roma (Italy)

NEWSdm COLLABORATION

75 physicists / 14 Institutes

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

ITALY
University and INFN Bari
LNGS, Gran Sasso
University and INFN Napoli
INFN Roma

JAPAN
Chiba, Nagoya, Toho

RUSSIA
LPI RAS Moscow
JINR Dubna
SINP MSU Moscow
INR Moscow
Yandex School of Data Analysis

SOUTH KOREA
Gyeongsang University

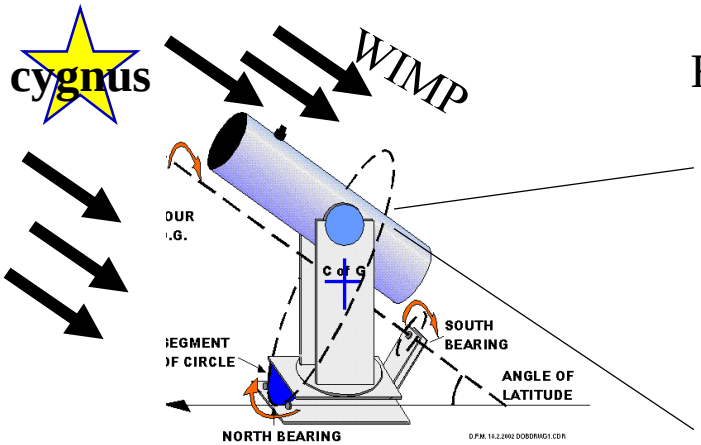
TURKEY
METU Ankara

Directional search with nuclear emulsion

- Good scalability
  - Solid state & good uniformity
  - Large scale production
    - Self production (~ 10 kg / month)
  - high scanning power
    - 46.5 g/year at current R&D, and ~kg scale in 2 years
- Good Angular resolution
  - ~ 20 deg (1 sigma) including scattering for Carbon
  - DM direction sensitivity with equatorial telescope

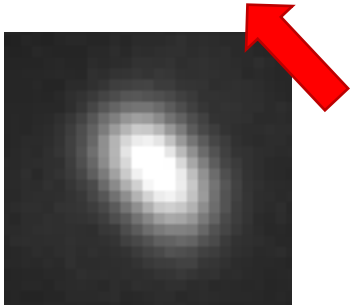
Light & heavy component

Element	Mass%	Atom%
Ag	44.5	10.5
Br	31.8	10.1
I	1.9	0.4
C	10.1	21.4
N	2.7	4.9
O	7.4	11.7
H	1.6	41.1

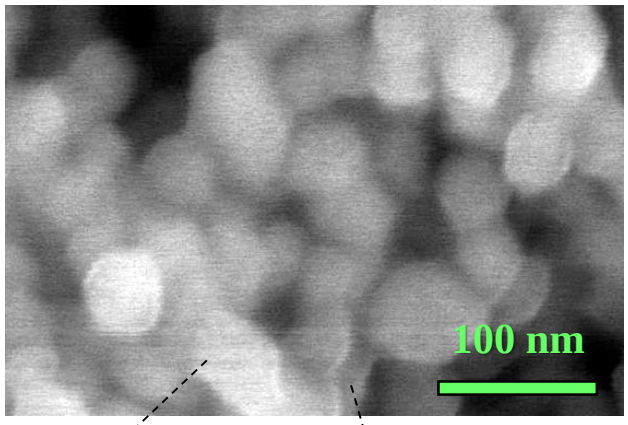


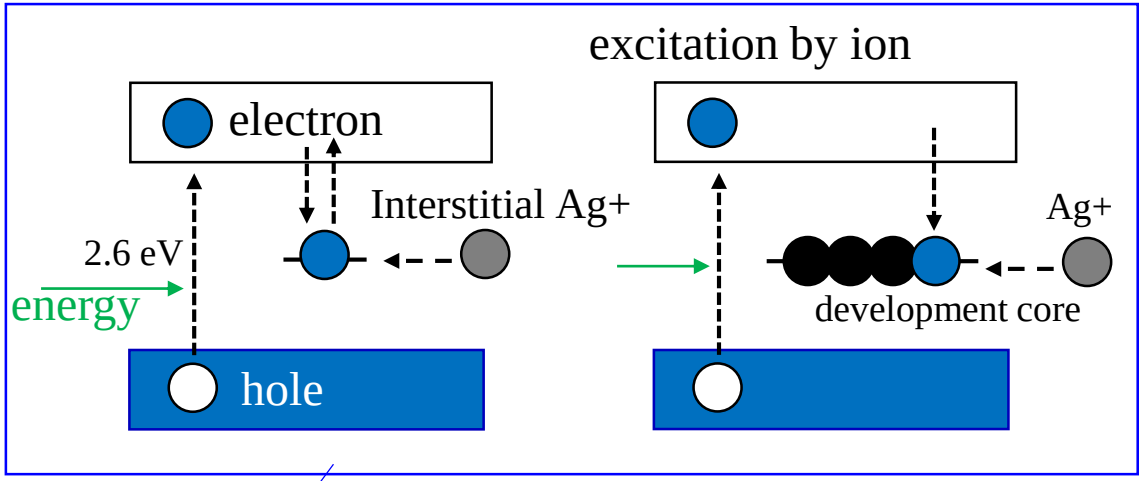
Fine crystal nuclear emulsion
NIT

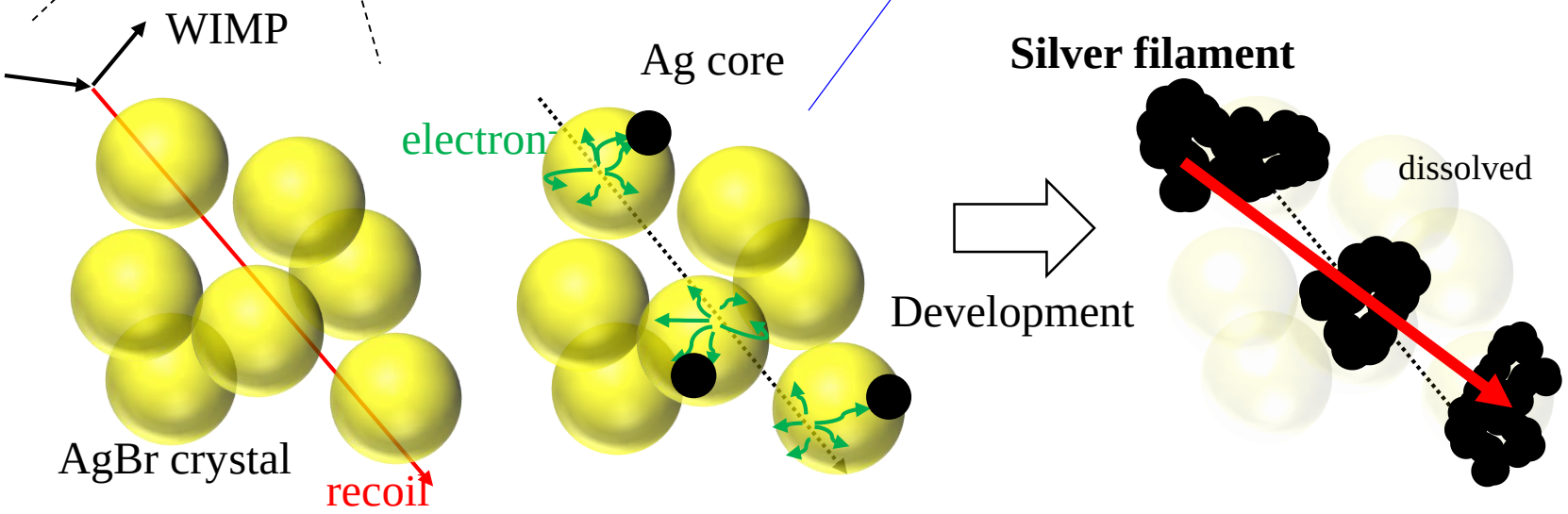
Direction recognizing



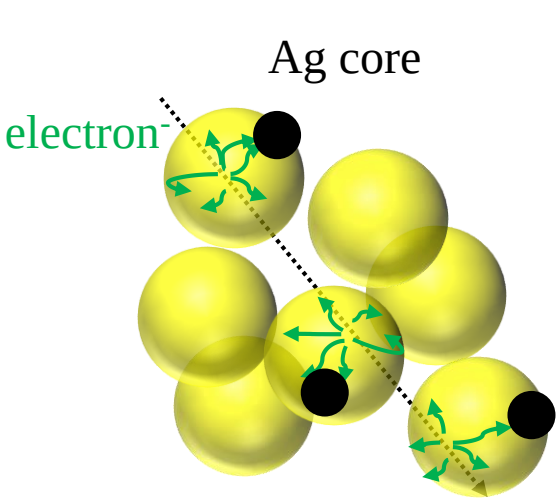
Nuclear emulsion

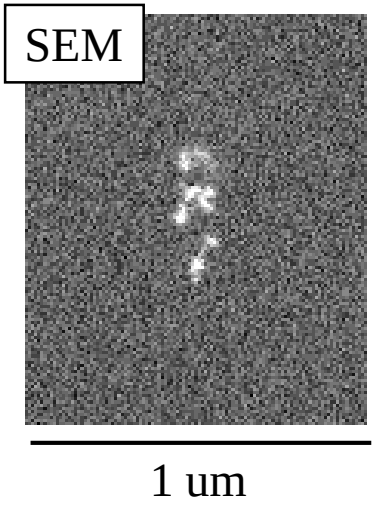


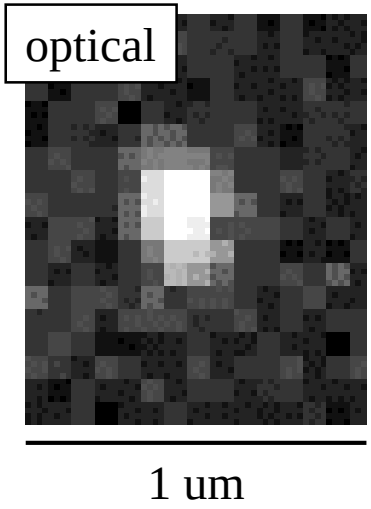




Characteristics of Nuclear Emulsion



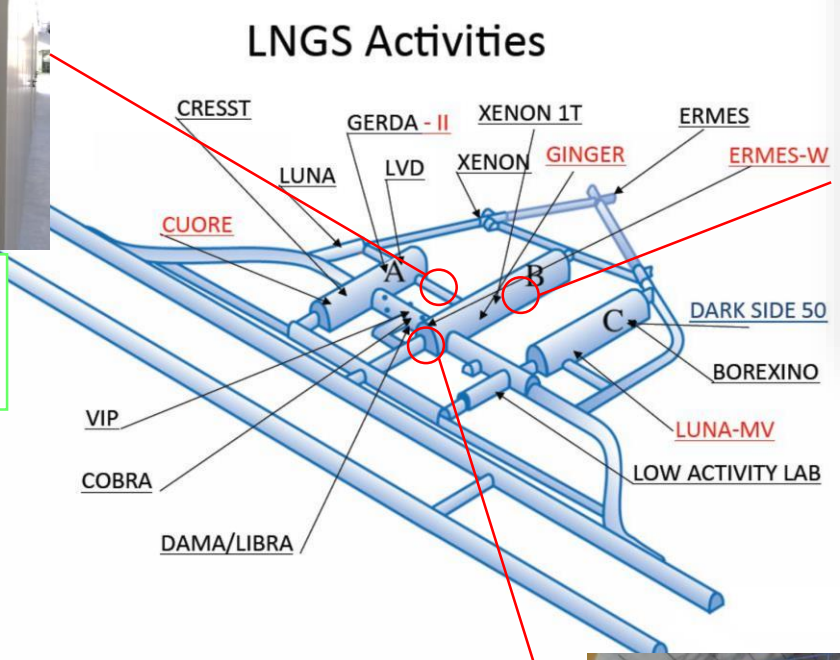




- Electron diffusion is limited to crystal scale → Good angular resolution
- Sensitivity of 1 crystal for ions (≥ C) is almost 100% against the recombination.
- Main parameter is flight length. Energy deposit is our future plan (e.g. color analysis reported in 1st and 2nd day)
- Readout of nuclear emulsion is challenging
- Dust reduction is important (not using clean room yet)

NEWSdm new experimental site at LNGS

New NEWSdm facility
(production machine, development room)

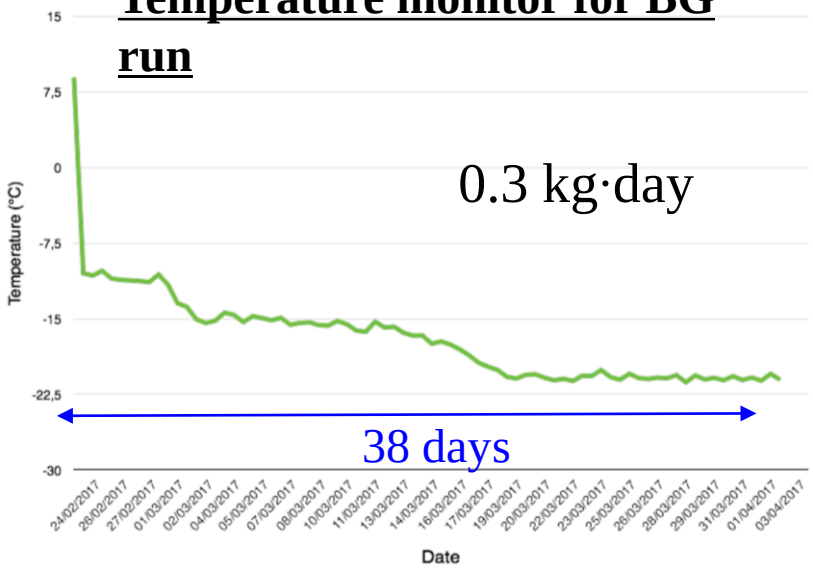


NEWSdm shield

Old facility
(development room, Test climatic chamber)

Technical test (2017)

Temperature monitor for BG run



	Event rate [/kg/d] w/o shield	Event rate [/kg/d] w/ shield	
Environment γ-rays	1 x 10^7	5 x 10^3	Geant4
Environment neutron	~1-2 /kg/day	< 0.1 /kg/day	Geant4
Cosmogenic neutron	< 1 x 10^{-3} /kg/day	2 x 10^{-3} /kg/day	Geant4

^{14}C decay rate : 24 Bq/kg ➡ 2.1×10^6 /kg/day

Physical background is dominated by ^{14}C beta with shield

2017 BG Run Schedule :

2017/2/22-23 : Film production (old lab)

2017/2/24 : device mount on the system

38 days ~8 g

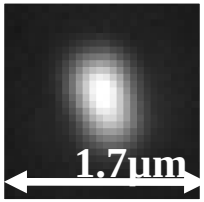
2017/4/3 : extraction of device

⇒development treatment

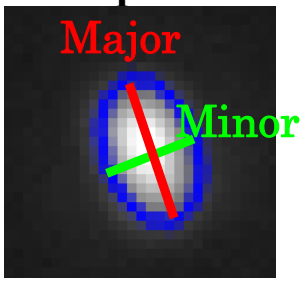
Selection Applied to the data

1st selection

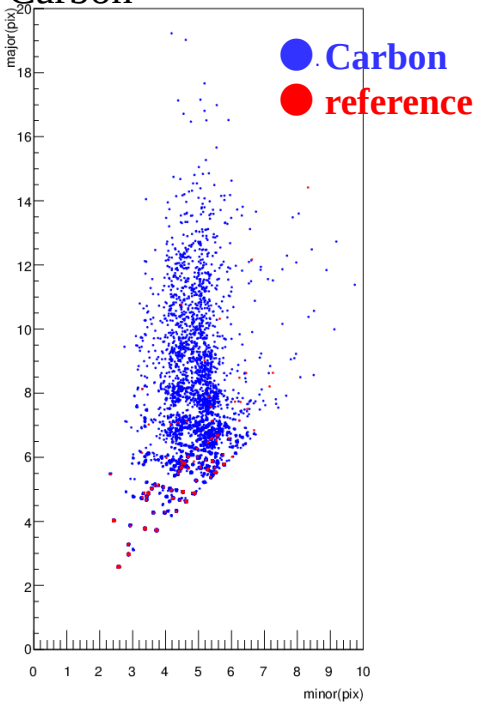
Original image



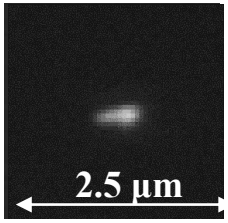
Ellipse fit



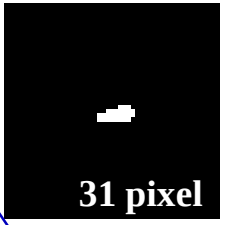
Major and minor distribution of 150 keV Carbon



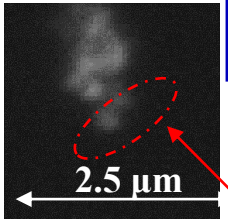
2nd selection



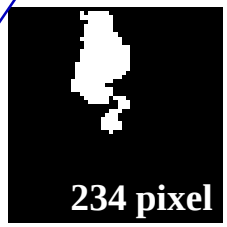
minor = 5.0 pixel
ellipticity = 2.48



Binarization with the threshold by each average brightness

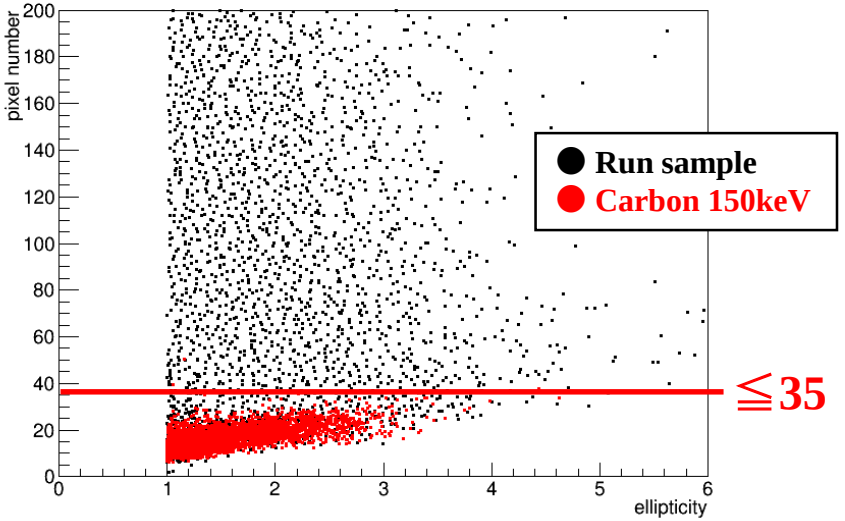


minor = 4.5 pixel
ellipticity = 2.45



Dust misidentification

Binarized pixel number and ellipticity

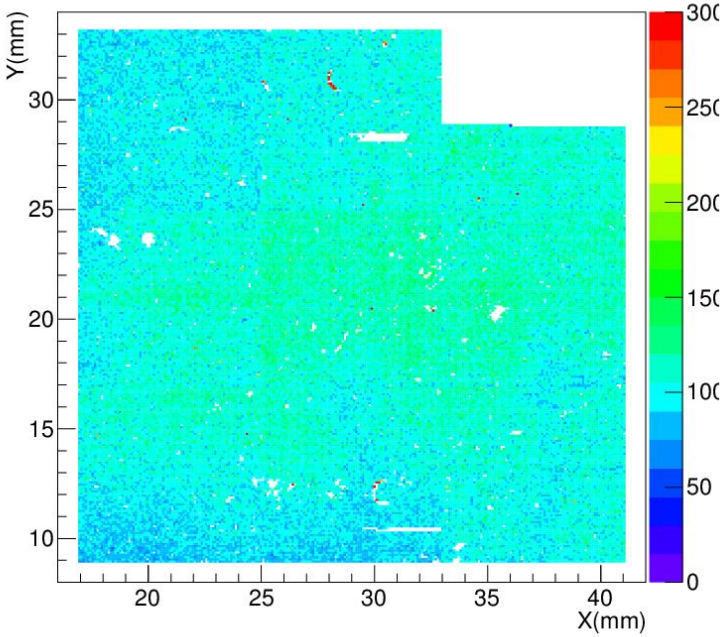


Confirmed techniques were applied
Other techniques are updating!

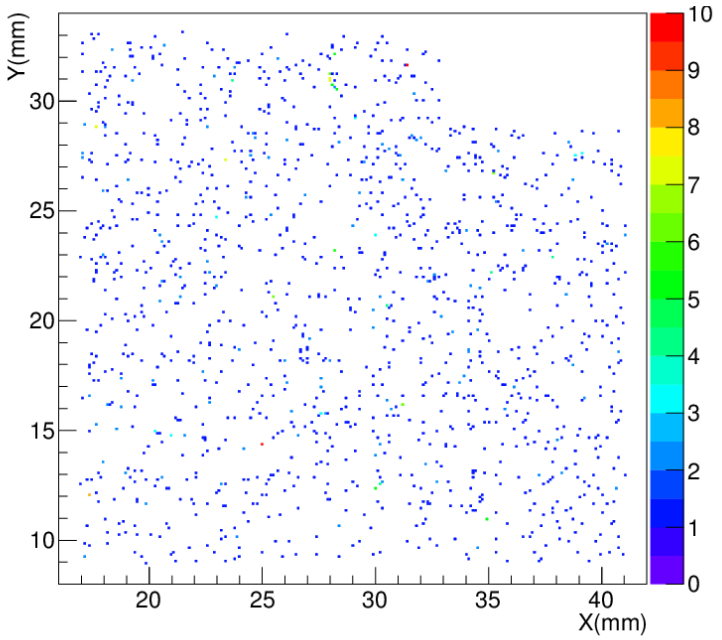
Analysis of technical test

A part of film is analyzed
0.035 g / 8 g

Event map w/o any selection



Event map after 1st and 2nd selection

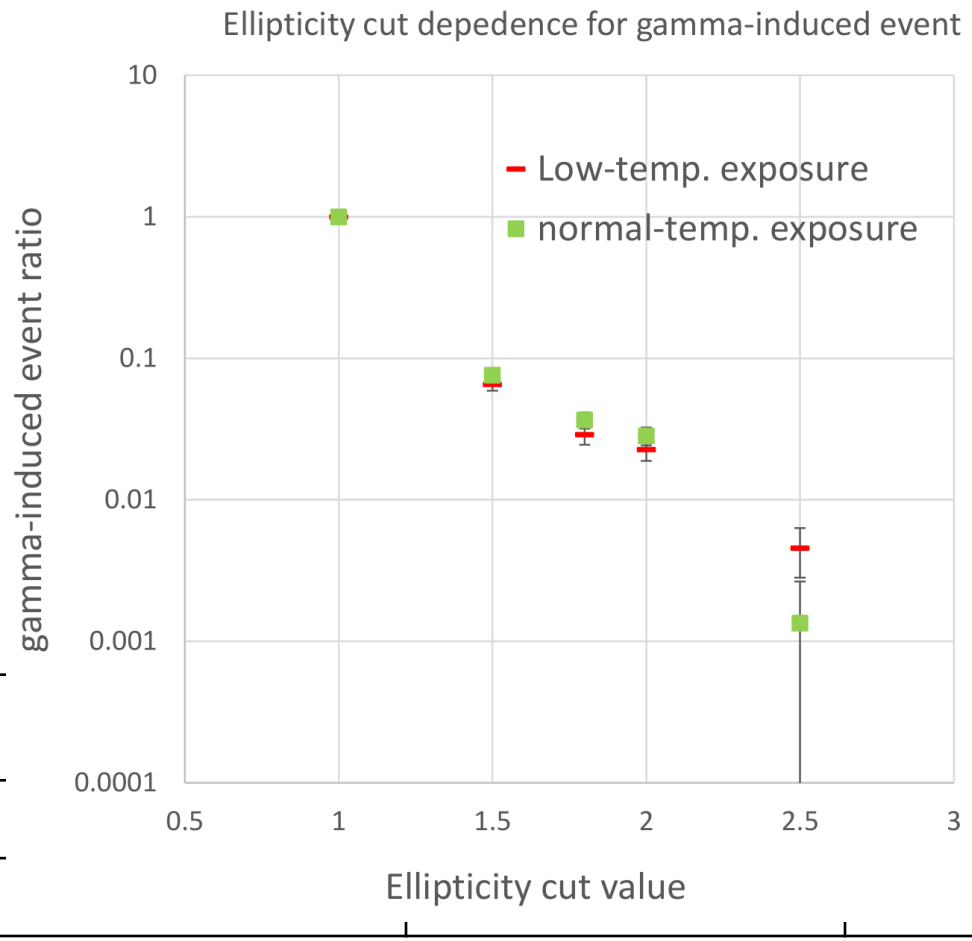


	all event	**1st selection (ellipticity ≧ 2)**	**2nd selection Pixel cut ≦ 35**
38 days・0.035 g	(6.45 ± 0.35) x 10^6	(2.62 ± 0.22)x 10^4	(1.30 ± 0.05) x 10^4
0 days・0.035 g *	(4.03 ± 0.23) x 10^6	(2.55 ± 0.21)x 10^4	(1.17 ± 0.10) x 10^4

*Scanning mass is normalized
19mg→ 35 mg

No dependency on the exposure time

Background characterization with technical test



^{14}C decay: ~ 2.1×10^6 /kg/day

Ellipticity Cut > 2.0
~ 60 events/38days/0.035g

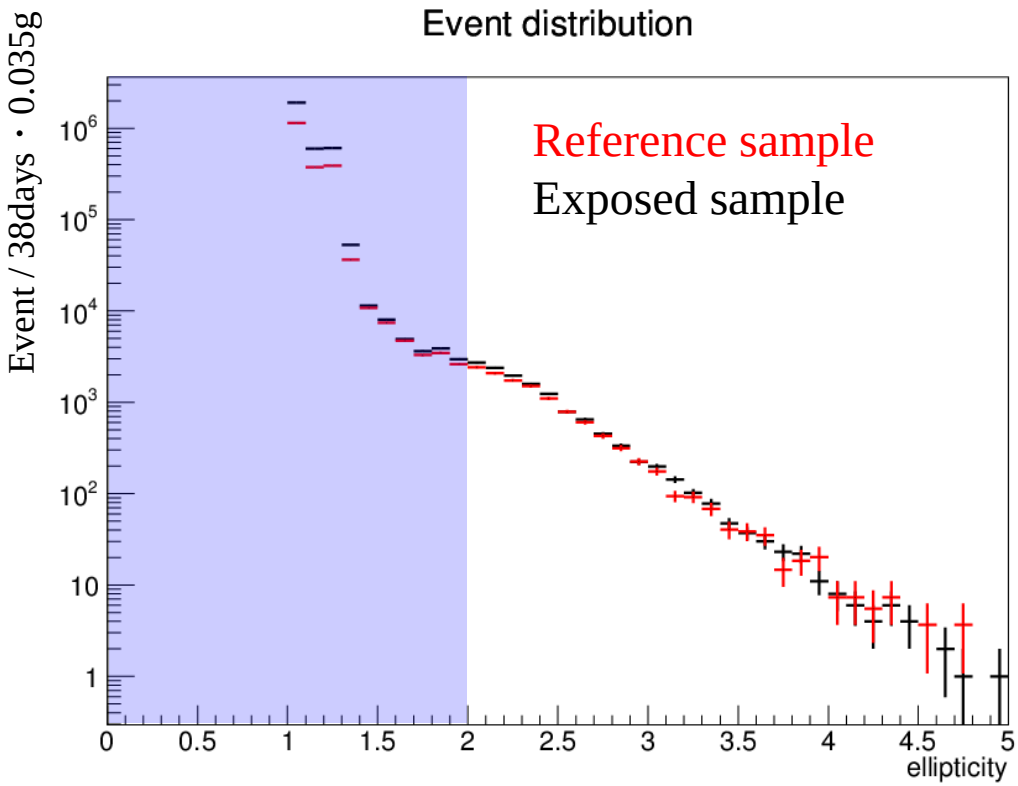
Non physical BG is dominant

	st selection lipticity≧2)	**2nd selection Pixel cut≦35**
	2 ±0.22)x 10^4	(1.30 ± 0.05) x 10^4
	5 ±0.21)x 10^4	(1.17 ± 0.10) x 10^4

*Scanning mass is normalized
19mg→ 35 mg

No dependency on the DM exposure time

Shape Distribution of BG



Two components

- Dominant and spherical
  → development fog
- Elliptical shape
  → dust

We believe it is "dust" contamination

We have to produce emulsion film in clean conditions

Production and study of nuclear emulsion for dark matter search

-2010 Company (Fuji Film in Japan)

- Proto type of fine-grained nuclear emulsion

2010- Nagoya University (Japan)

- First direct study of nuclear emulsion by physicist
- Fine-grained nuclear emulsion (NIT/UNIT)
- R&D and fine tuning of production recipe
- Study of material purification

Asada et al. PTEP 063H01 (2017)

2019- LNGS (Italy)

- Direct production at the udergound experimental sites
- Production in a Clean room

Recent activity at LNGS underground

Feb-Apr 2017

- 10 g technical test

Sep 2018

- New facility available to start activity
- transportation of production machine

Nov-Dec 2018

- Installation of Emulsion Production machine

Jun-Feb 2019

- First emulsion production test (Not clean room)

May- 2019

- Activity started with 2 air filters (not really clean room)
- Test production with gelatin filtering

Jun-Jul 2019

- Test run with the emulsion of LNGS product

8-9 Jul 2019

- extraction from shield + development of films

Production machine

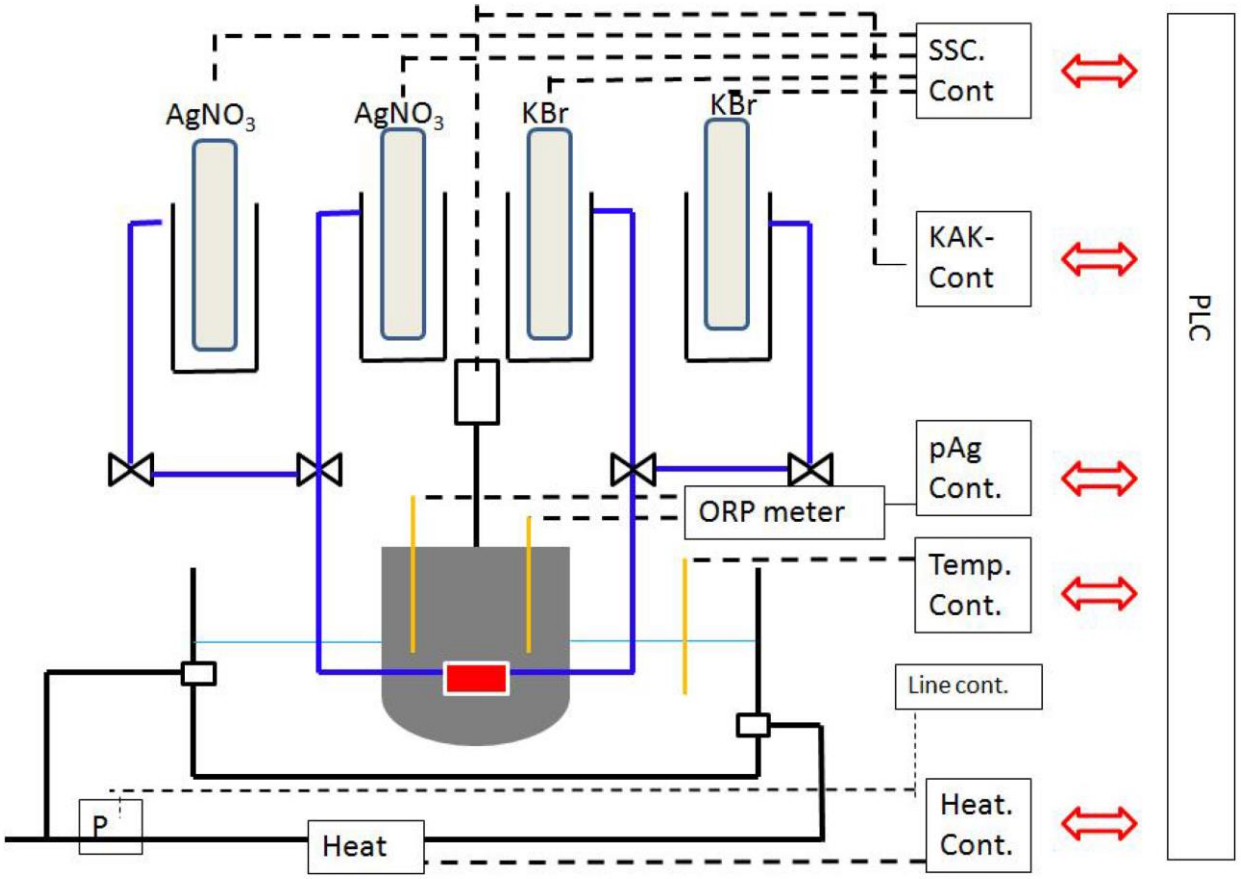
Installed on Dec 2018

The machine produces main component gel of nuclear emulsion film.

Production capacity:
100-200g/day
→~kg scale is possible!

Same system as Nagoya production machine (validated system)

Scheme of emulsion production machine



feeding speed control

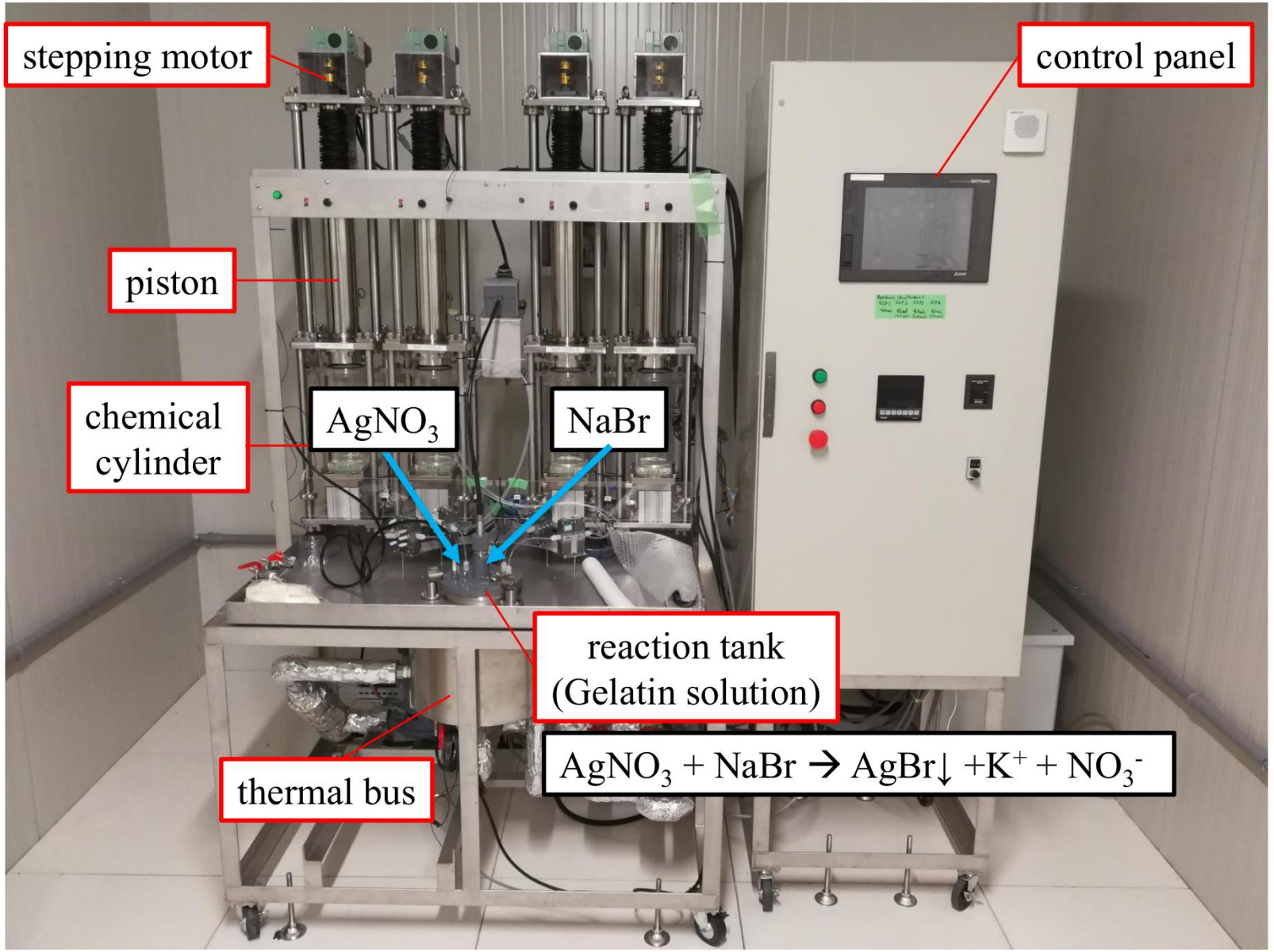
mixing speed control

pAg feedback

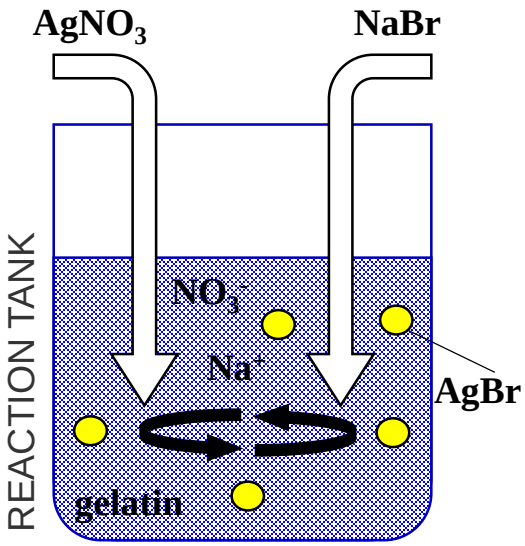
temperature feedback

temperature control

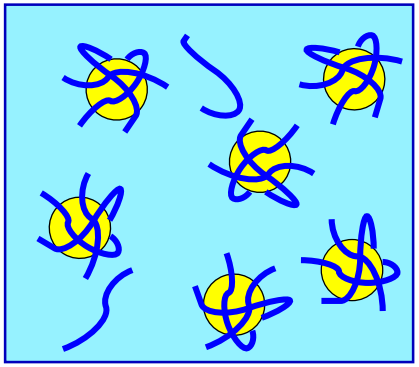
production machine



How to produce nuclear emulsion film



crystal formation



Gelatin protects the crystal and keep small size (protecting colloidal action)

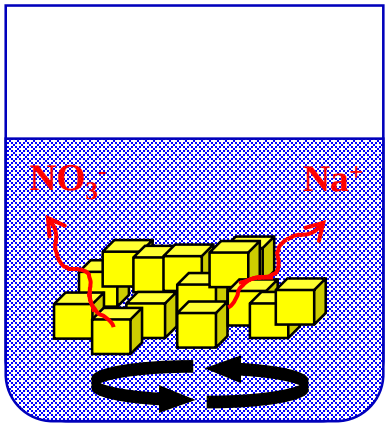
Liquid gel is produced

Frost the liquid by freezer

$$AgNO_3 + NaX \rightarrow AgX \downarrow + Na^+ + NO_3^-$$

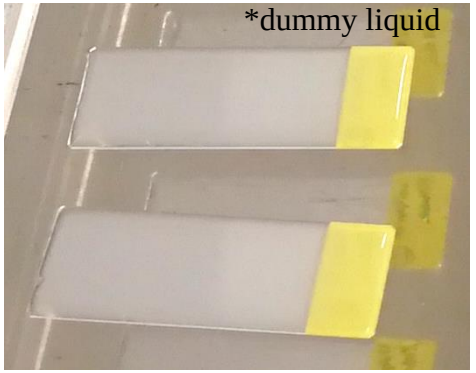
(x: halide)

How to produce nuclear emulsion

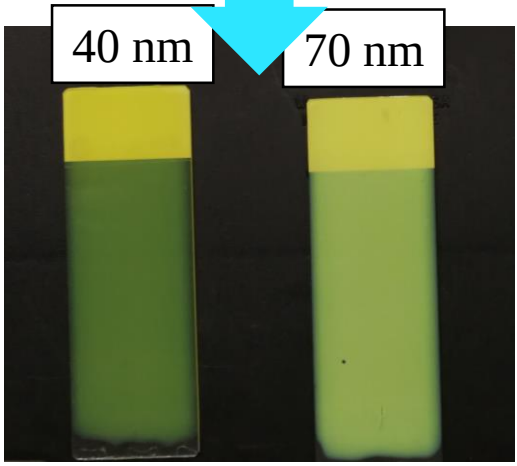


Washing (deionization)

Melting
& pouring



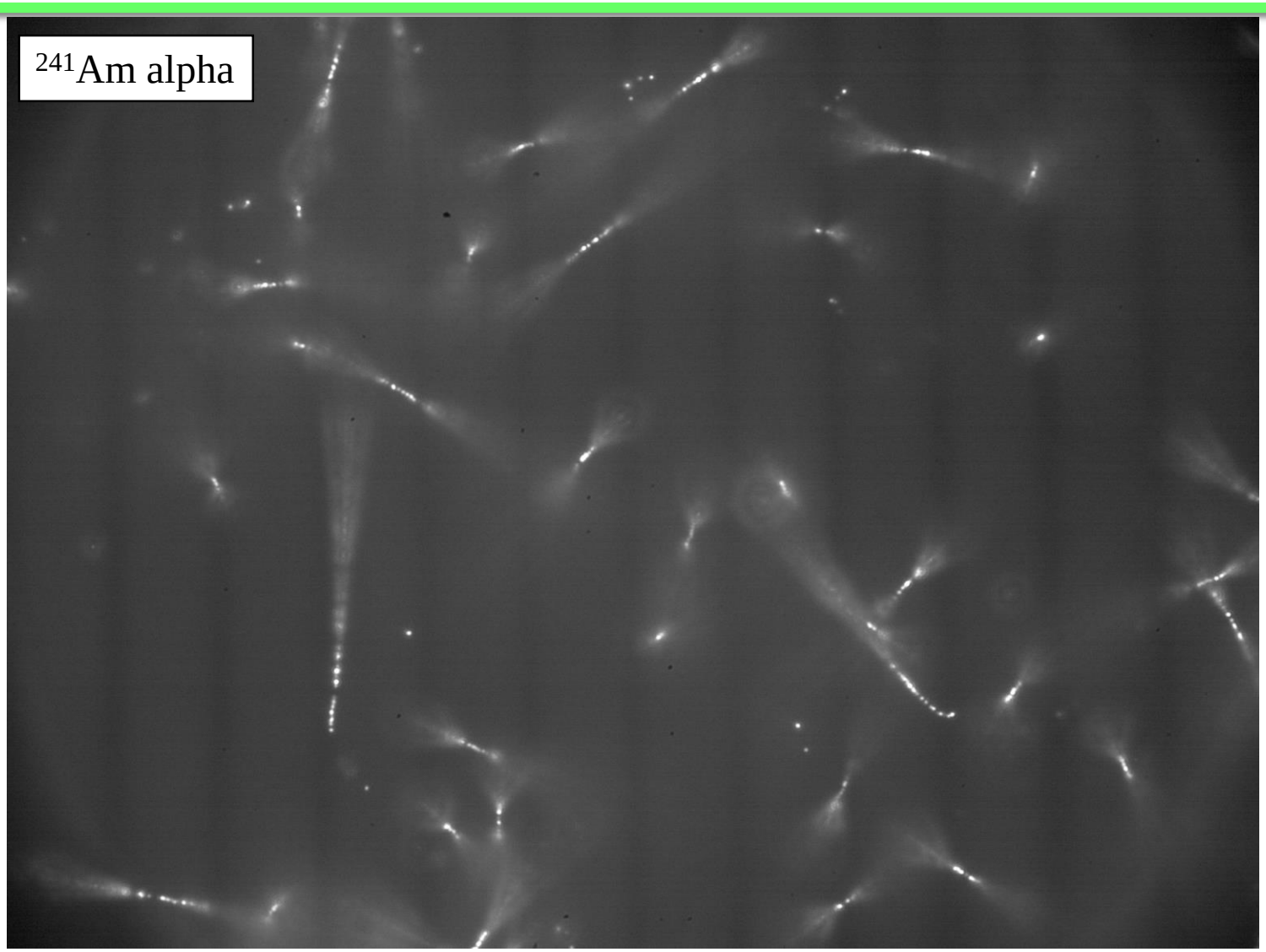
Volume ~1/20 by drying



$$AgX \downarrow + Na^+ + NO_3^-$$

All process can be done in the underground now!

First observation of tracks with new nuclear emulsion films produced at LNGS

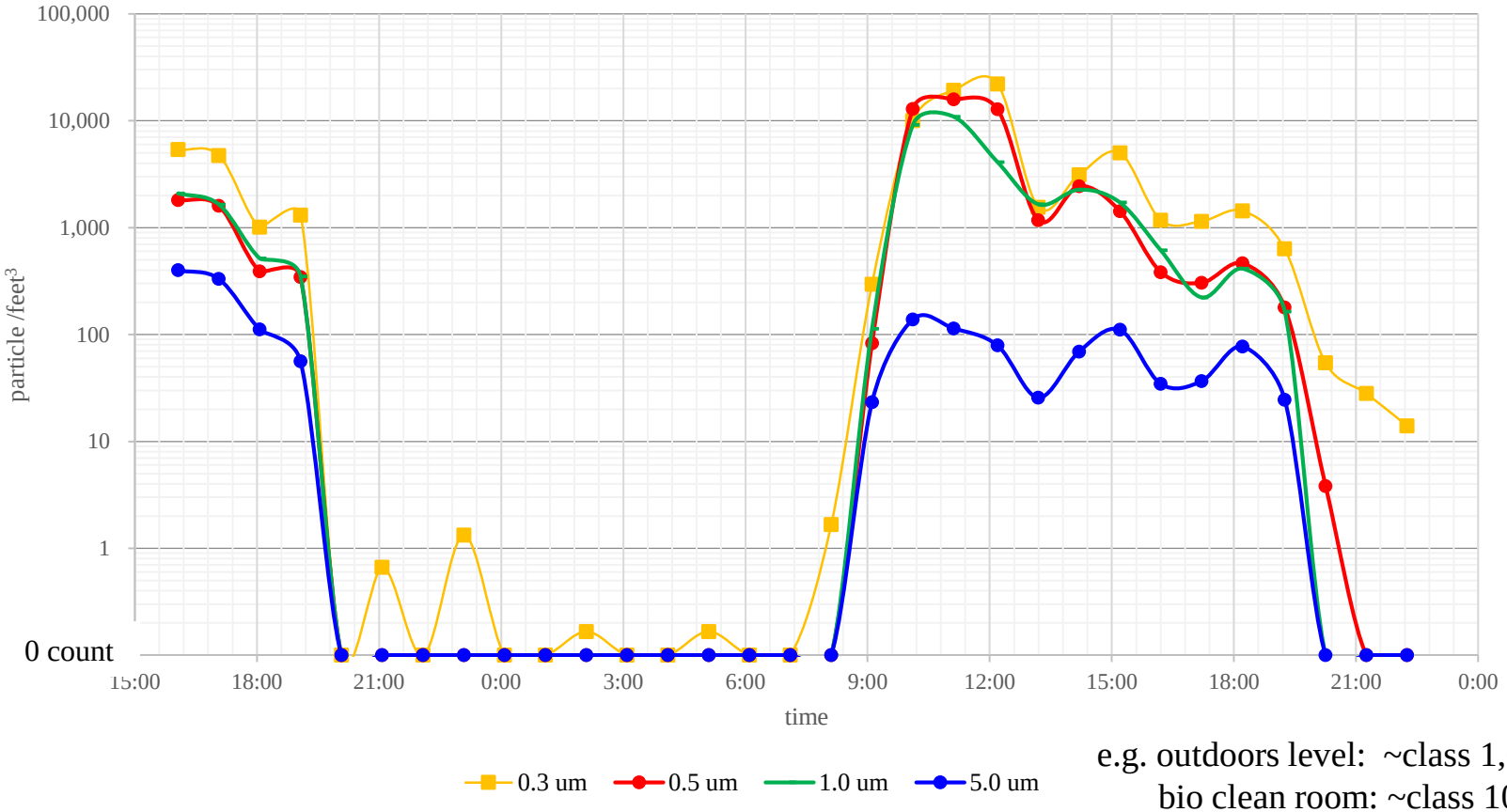


Gelatin filtering

PTFE sheet
Pore size = 0.1 um

First trial of gelatin filtering underground, but the pump produced $7 \times 10^6/(\text{feet})^3$ particles
(dirty → outdoor..)
→ Urgent construction to put pump outside

Measured particle level in the emulsion lab

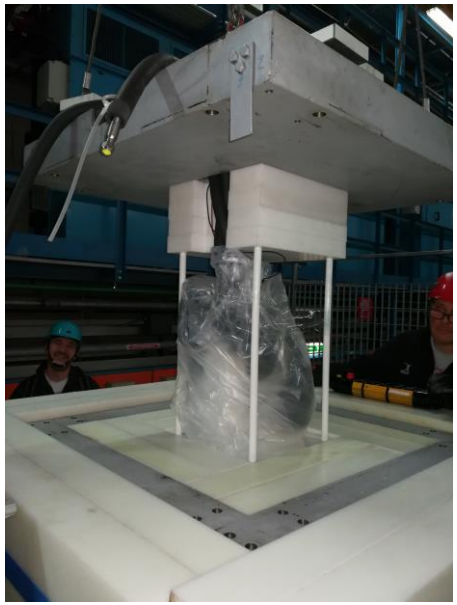


e.g. outdoors level: ~class 1,000,000
bio clean room: ~class 100
super clean room: < class 1

Value of 0.5 um particle / $(feet)^3$ represents Class (USA Fed.Std.209E)
Still Class is 1,000-10,000 from our activity. It needs to be updated

New 11 g Test Run for Understanding of BG

11.6 g of emulsion is exposed



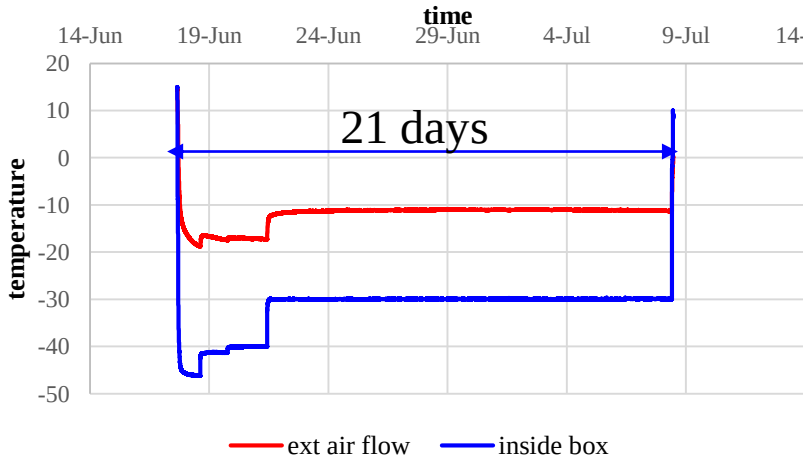
Cooling system is updated and very stable!

Same Shielding as 8 g technical test, but with new nuclear emulsion produced at LNGS

expected to apply updated analysis method

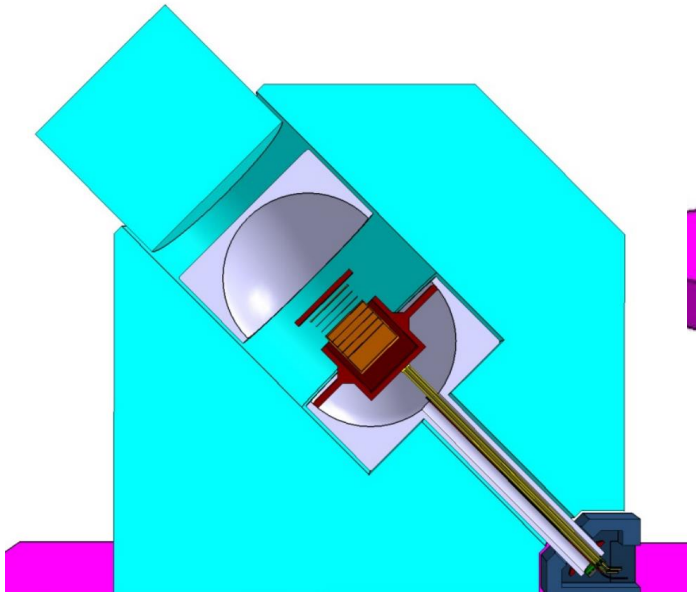
Installation completed at 17 Jun 2019
Extraction completed 8 Jul 2019 (This Monday!)
Analysis will start soon…

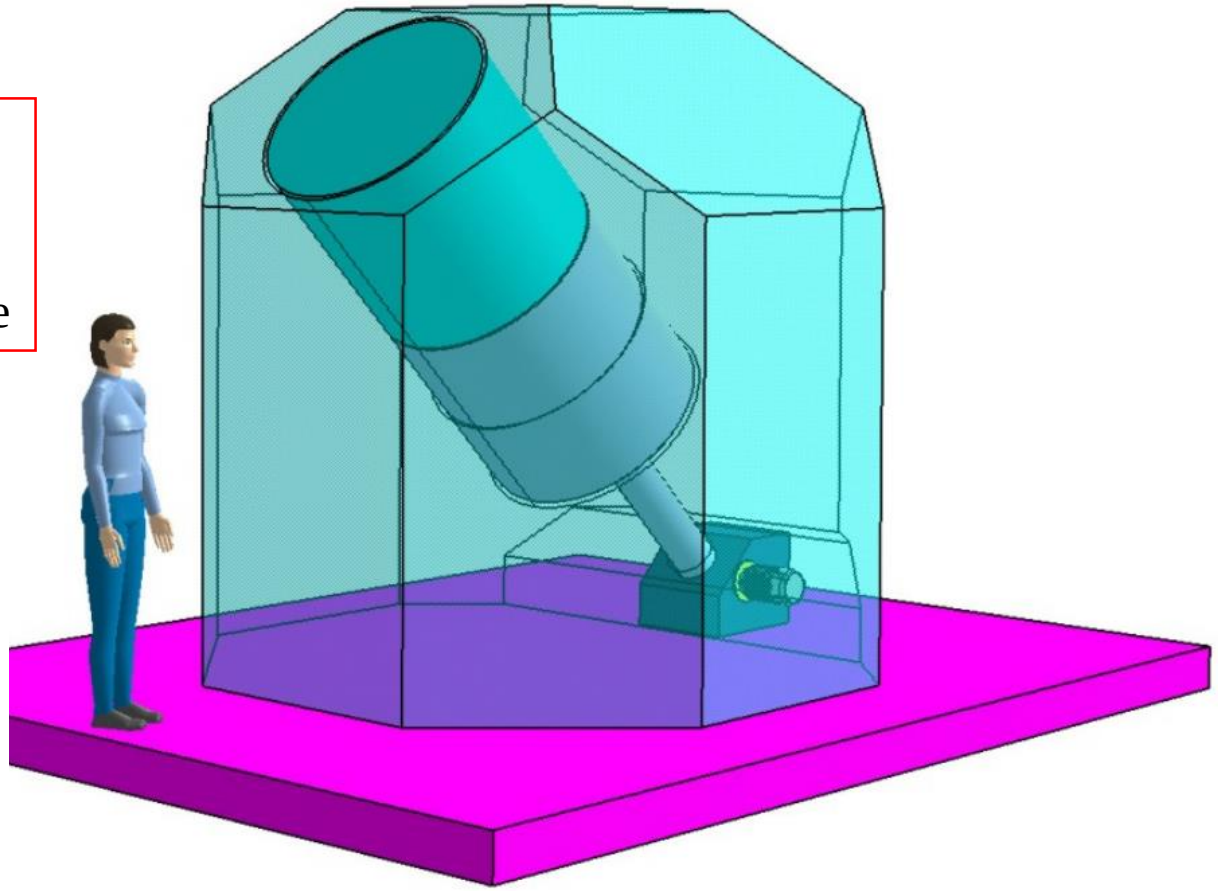
Temperature of the Shield



Toward physics run with equatorial telescope

New shield project is going on
- 1 m PE shield
- Cooling system
- Built in Equatorial telescope

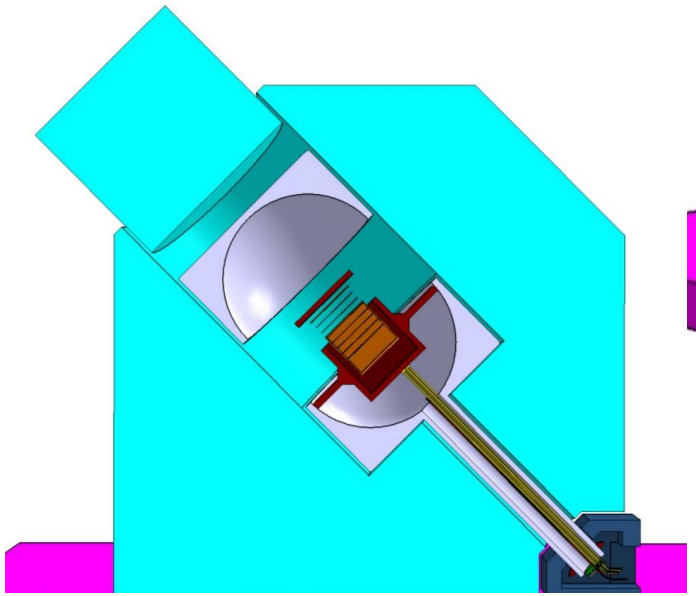


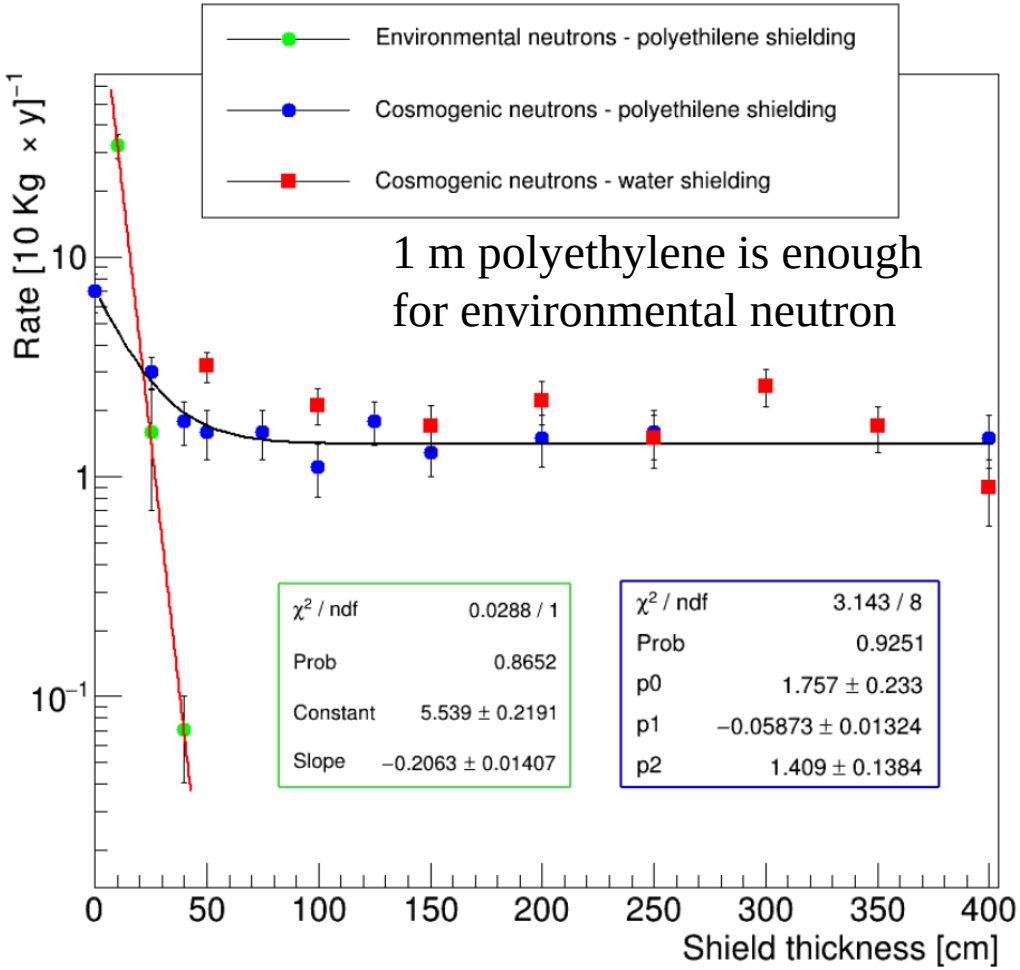


3 m x 3 m

Toward physics run with equatorial telescope

New shield project is going on
- 1 m PE shield
- Cooling system
- Built in Equatorial telescope





Summary

- 8 g technical test on 2017 implied current dominant background is “dust”
- We start to produce emulsion film in clean conditions
  - Emulsion production machine is installed at LNGS underground facility and full production is available in underground
  - New facility provides filtered air, and is updating to be clean room
- New test run with nuclear emulsion produced in LNGS underground is performed and analysis starts soon
- We are planning upgrade of shield toward physics run