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Nuclear emulsion for directional dark matter search

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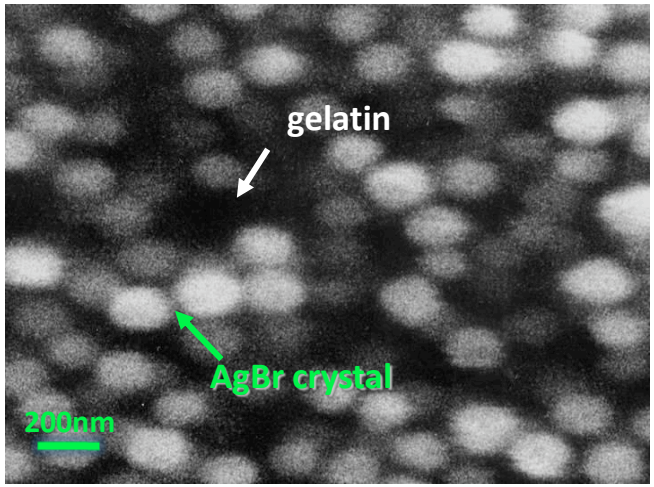
Nuclear Emulsion

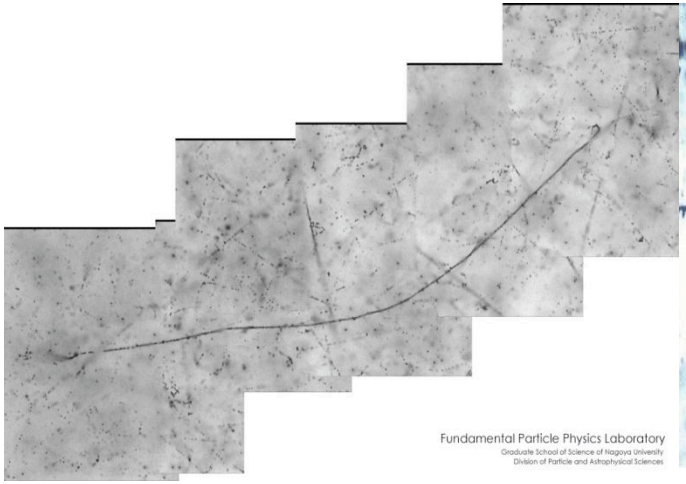
Nuclear Emulsion

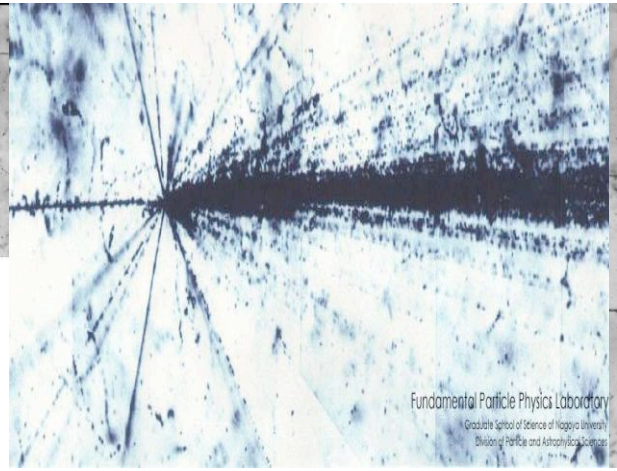
- a kind of photographic film
- high resolution 3D tracking detector
- component : AgBr crystal + gelatin

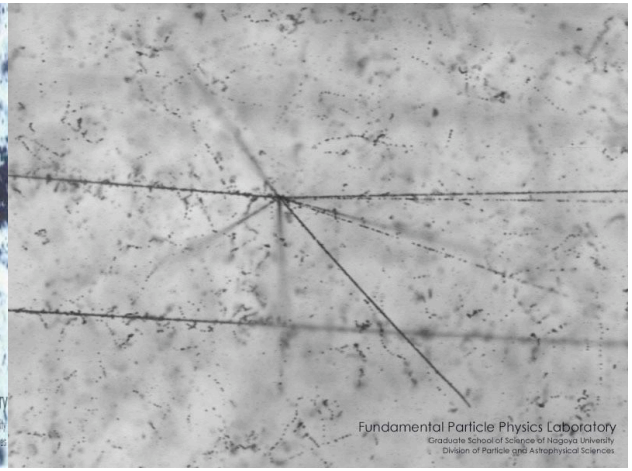
History
- discovery of π meson
- discovery of ντ (DONUT by us in 2000)
- discovery of charm (Cosmic-ray by us in 1971)
- discovery of double hyper nuclear (KEKE176 by us in 1988)

Electron microscope image
before development treatment

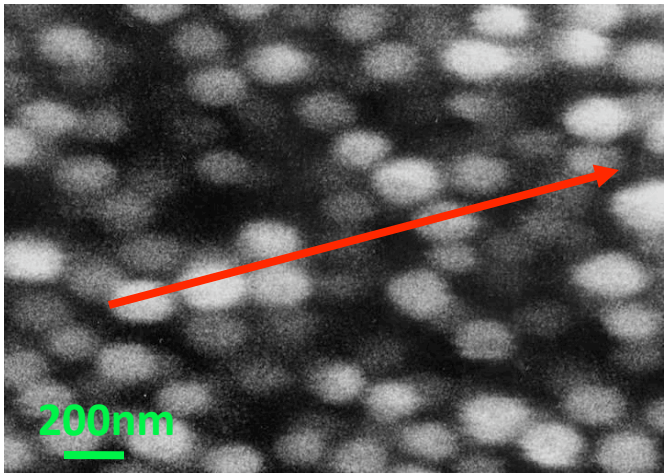


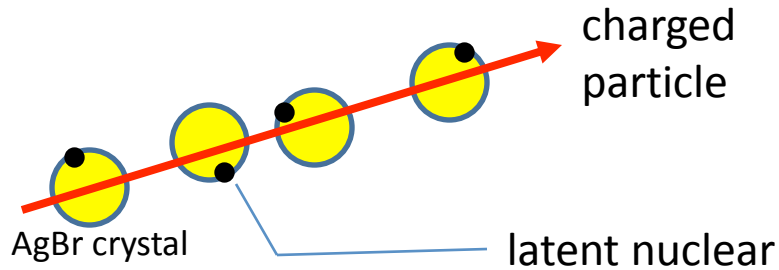






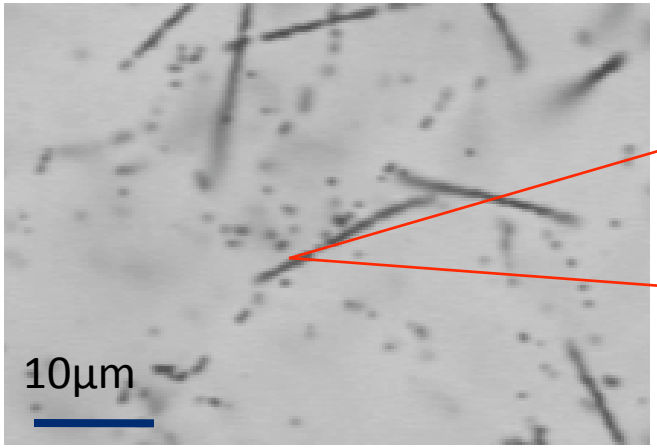
Principle of the Track detection in Nuclear Emulsion

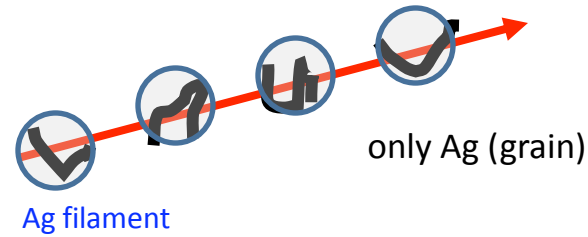




Normal emulsion ~2.3AgBr/μm

Development





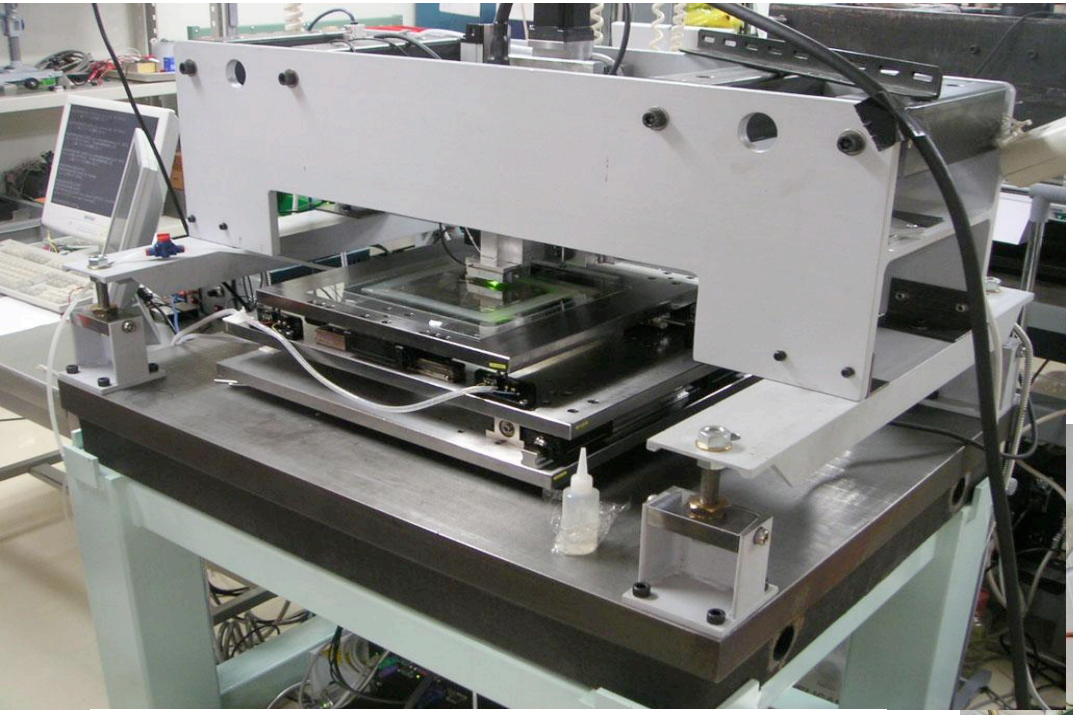
Developing probability depend on the dE/dx of the incident particle → Grain Density (G.D)

Ex) G.D αray > electron

Resolution(angle and position) depend on AgBr size,density and grain size after development.

Analysis of track

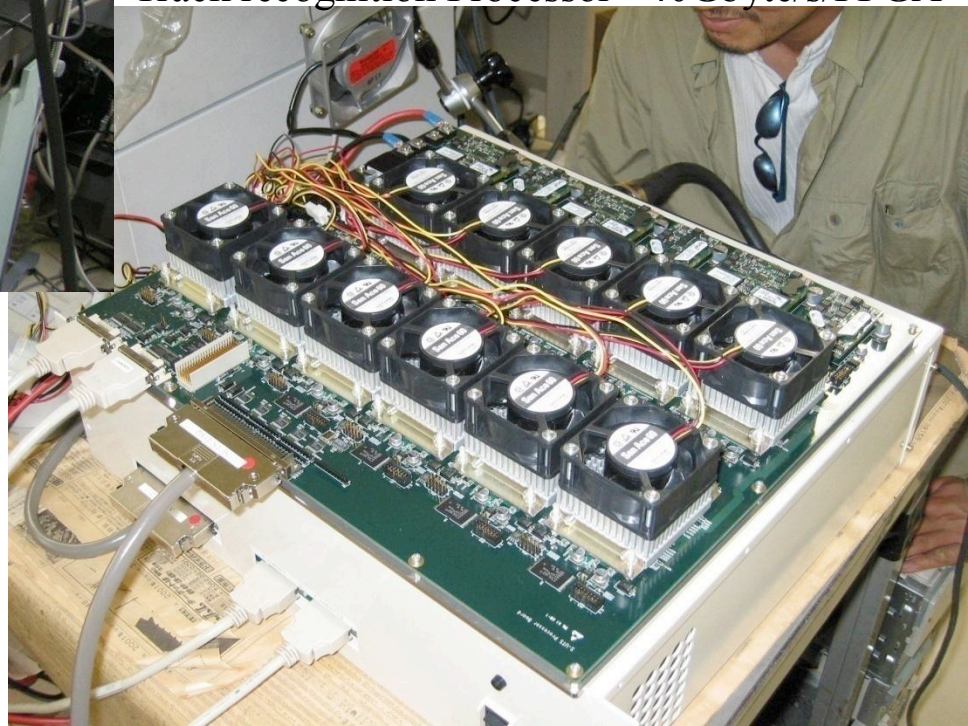
Nuclear emulsion is scanned by all automatic system



Automated Nuclear Emulsion read-out system:

SUTS ～1.2g/h by Nakano@Nagoya

Track recognition Processor ~40Gbyte/s/FPGA



Status nuclear emulsion experiment

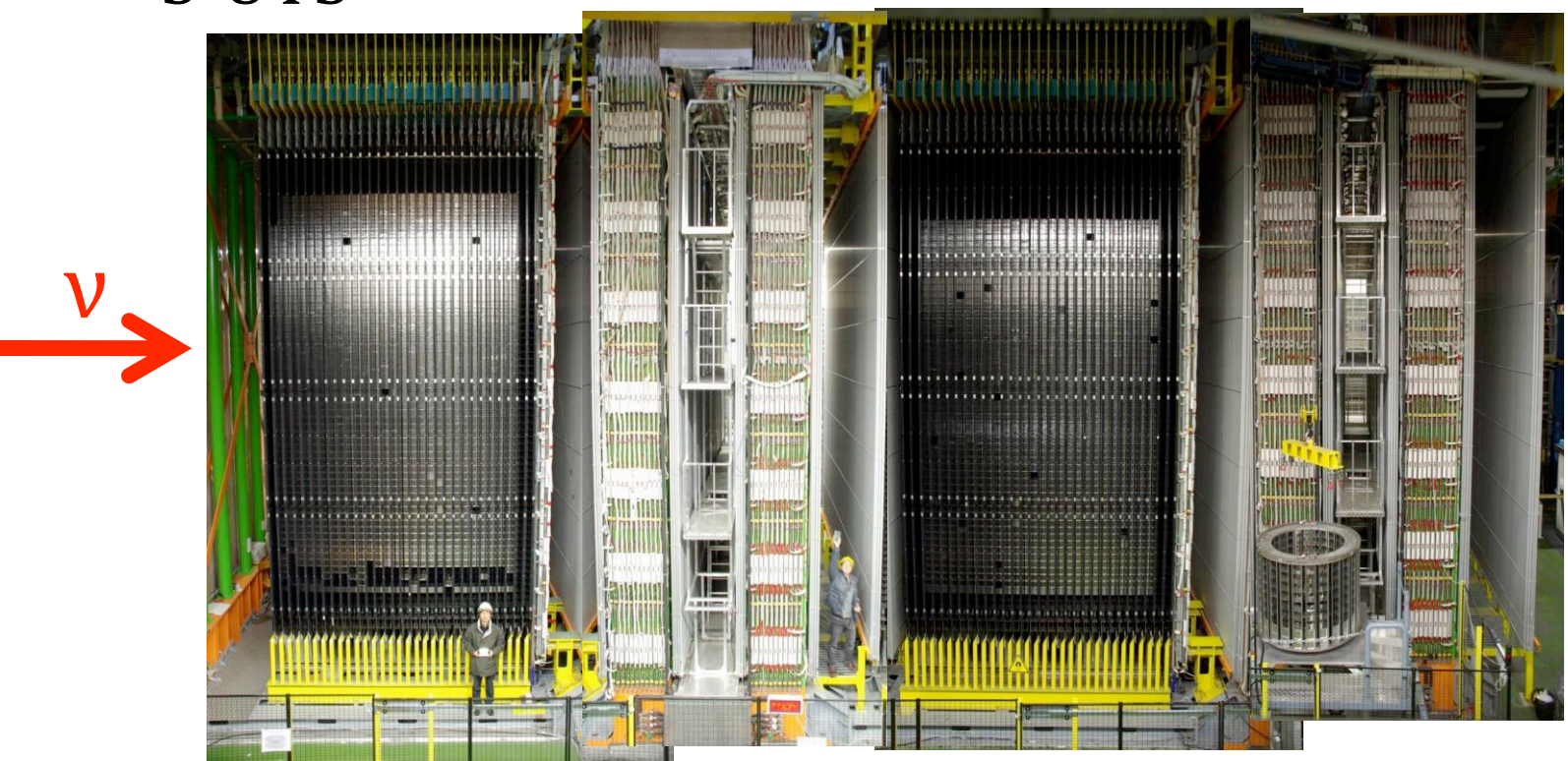
<u>Modern big experiment</u>

OPERA @Gran Sasso

→neutrino oscillation($\nu_\mu \rightarrow \nu_\tau$) appearance experiment

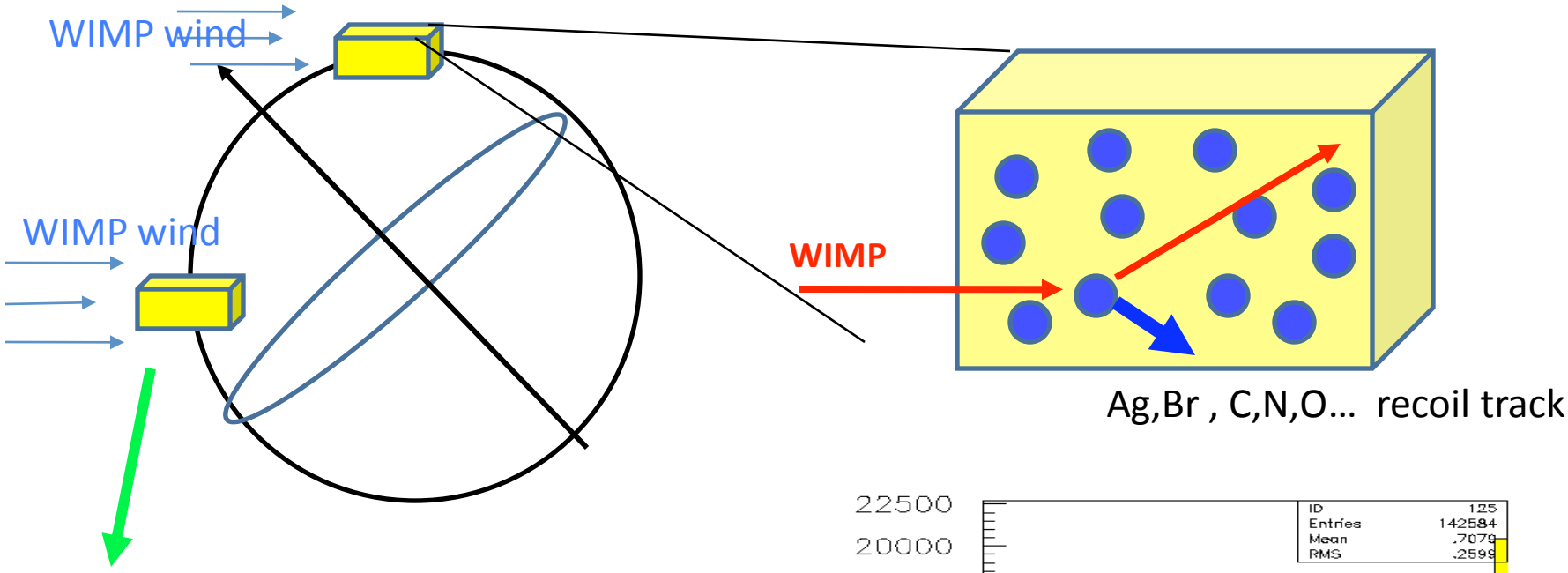
- total emulsion quantity : 30000 kg
- now, emulsion scanning is all automatic.

  →S-UTS



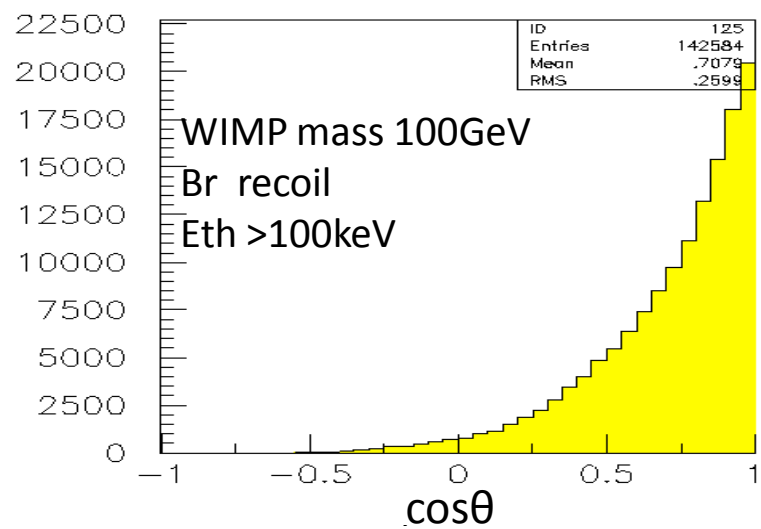
Concept of Directional detection by Nuclear Emulsion.

◎Nuclear Emulsion: density 3g/cm^3 ⇒Easy to realize large mass detector
◎Very high resolution tracking detector



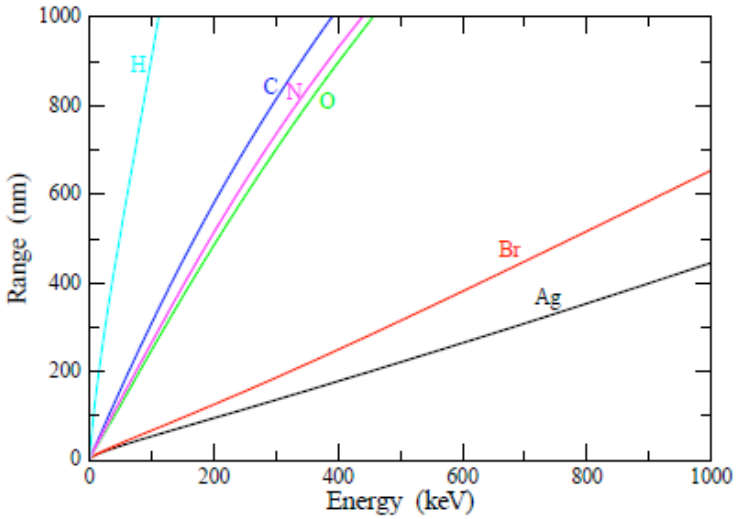
Mount on Equatorial telescope

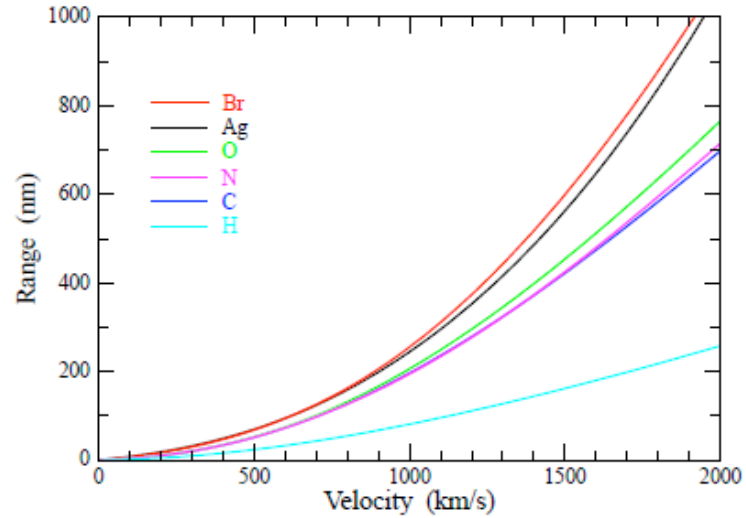
⇒keep the detector direction to the WIMP wind.



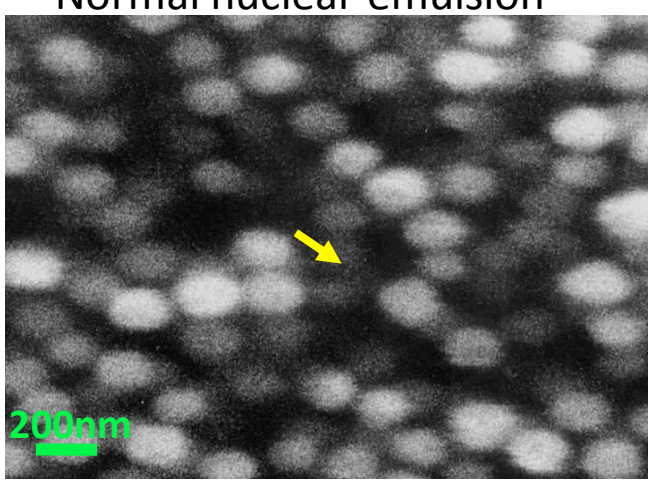
Nuclear Emulsion for dark matter search

- <u>Track length of target nuclei recoil</u>





Normal nuclear emulsion

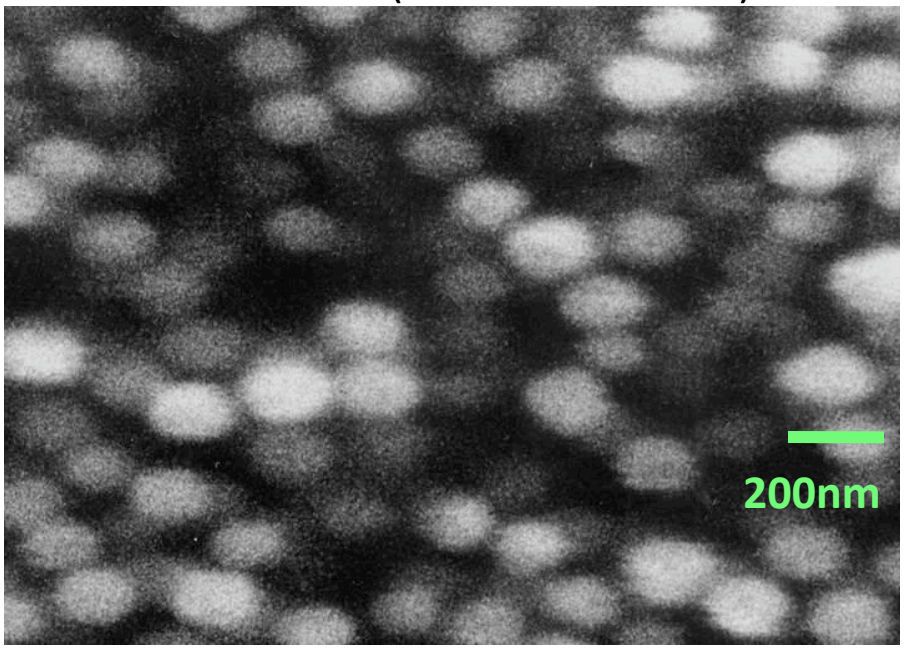


Resolution of normal emulsion
-> 2.3grains/μm is penetrated in maximum.

Higher resolution emulsion is needed.

High resolution emulsion
(Nano Imaging Tracker:NIT)

normal emulsion(OPERA emulsion)



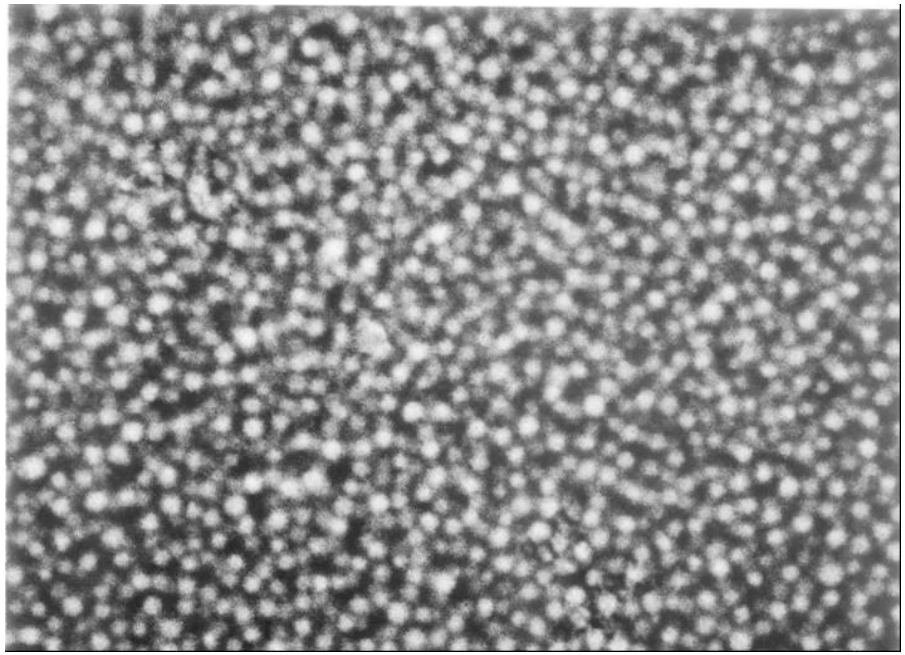
size 200±16 nm

density 2.8g/cc →V_{AgBr} : V_{gel} = 3 : 7

↓

2.3 grains/μm

NIT



size 40±9 nm

density 2.8g/cc →V_{AgBr} : V_{gel} = 3 : 7

↓

11 grains/μm

5times high resolution

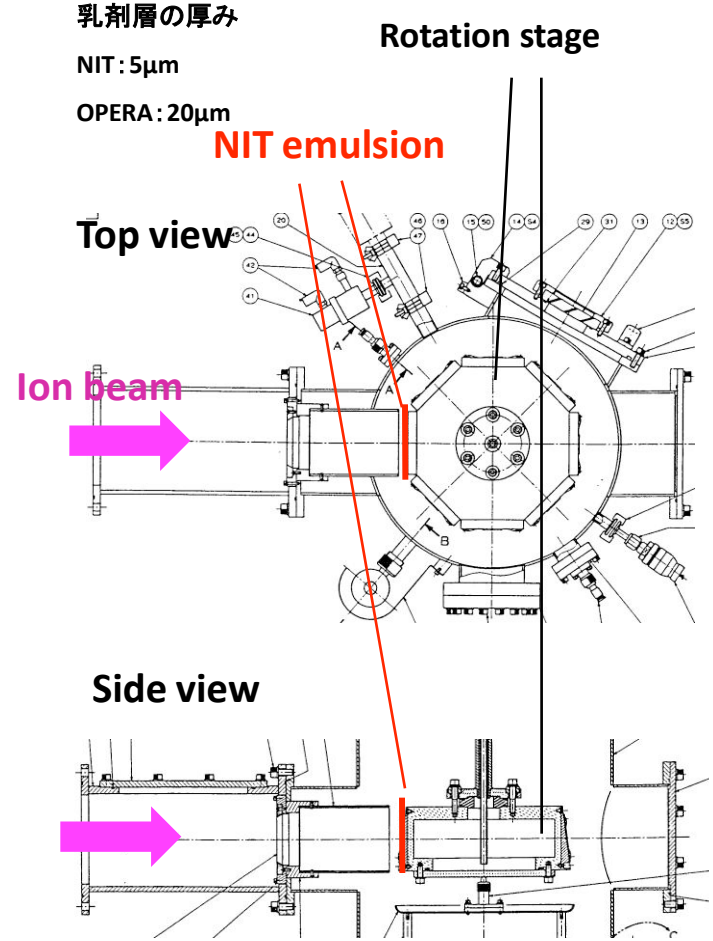
Check of the sensitivity of nuclear emulsion to the low velocity Kr ion.

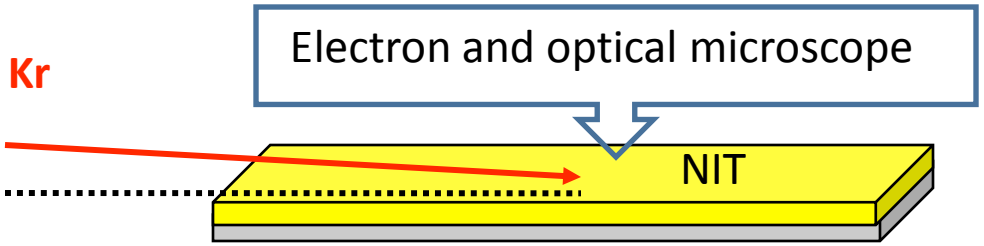
サイズ　7cm×3cm

乳剤層の厚み

NIT : 5μm

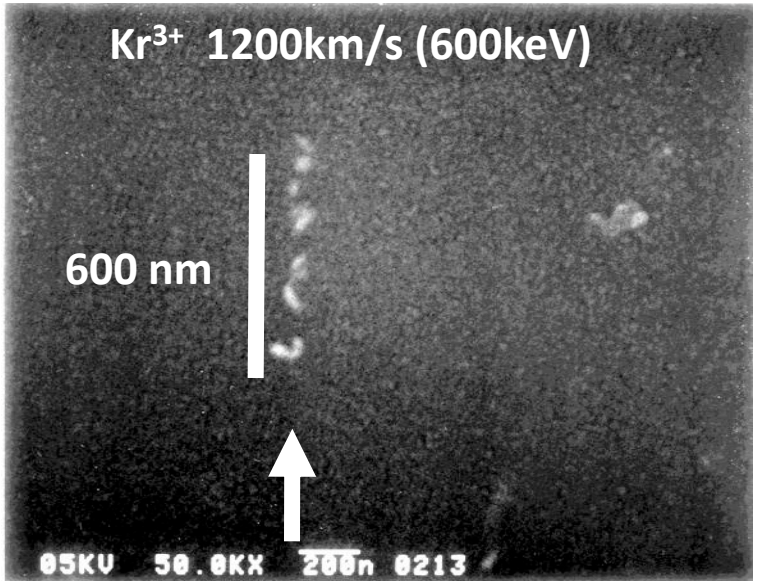
OPERA : 20μm

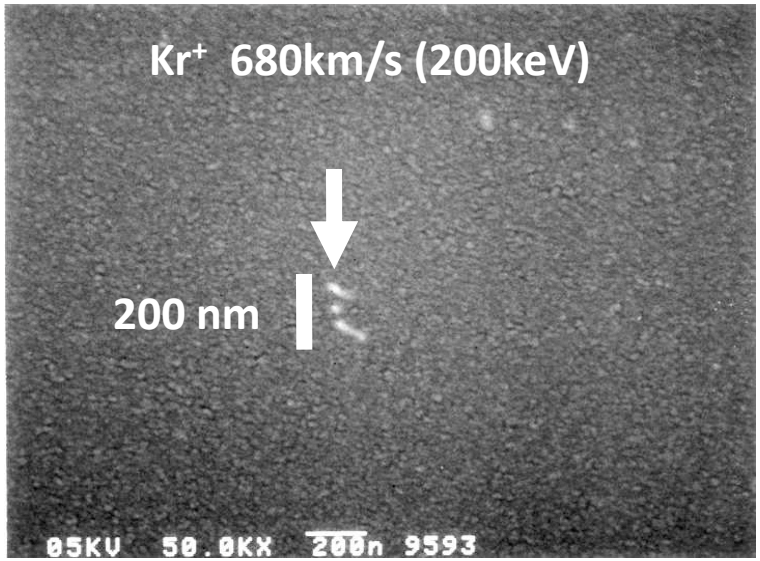


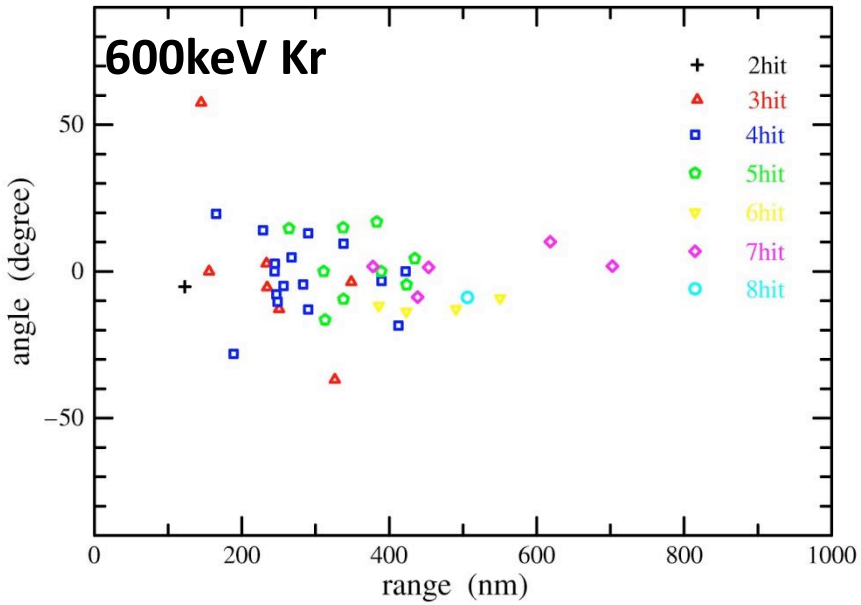


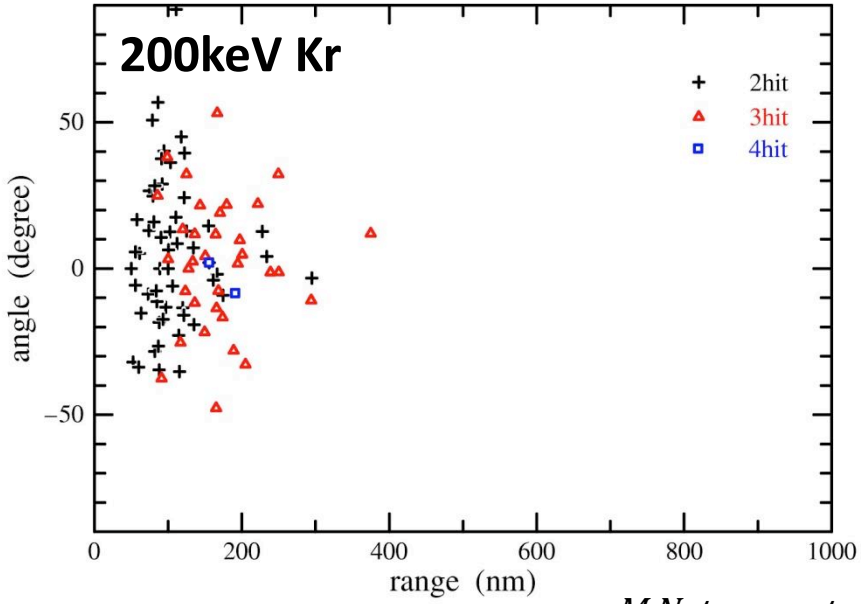
SEM image

Track data





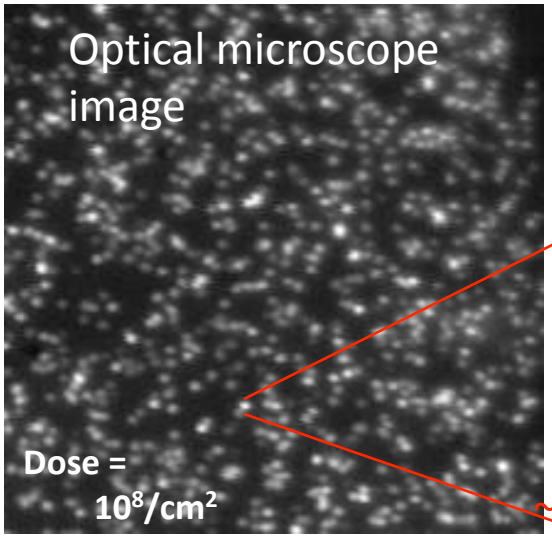




NIT can detect tracks recoiled by WIMPs!

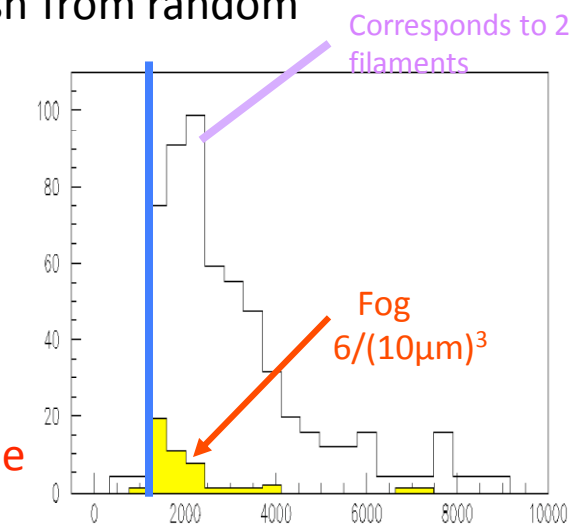
M.Natsume et al. NIM A 575(2007) 439

Recognition of recoil track by optical microscope



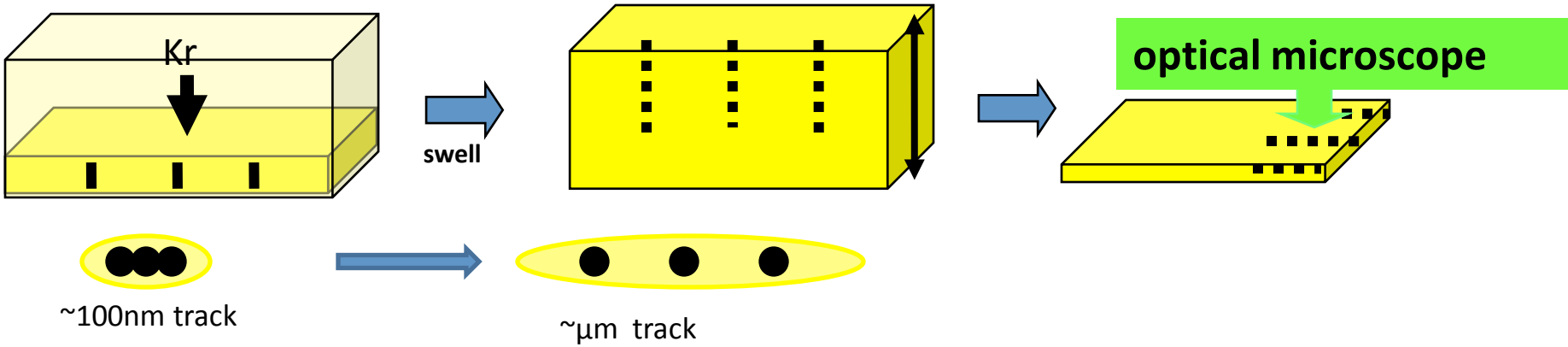
Recoil tracks don't distinguish from random fog(noise).

~100nm tracks are like just one point signal.



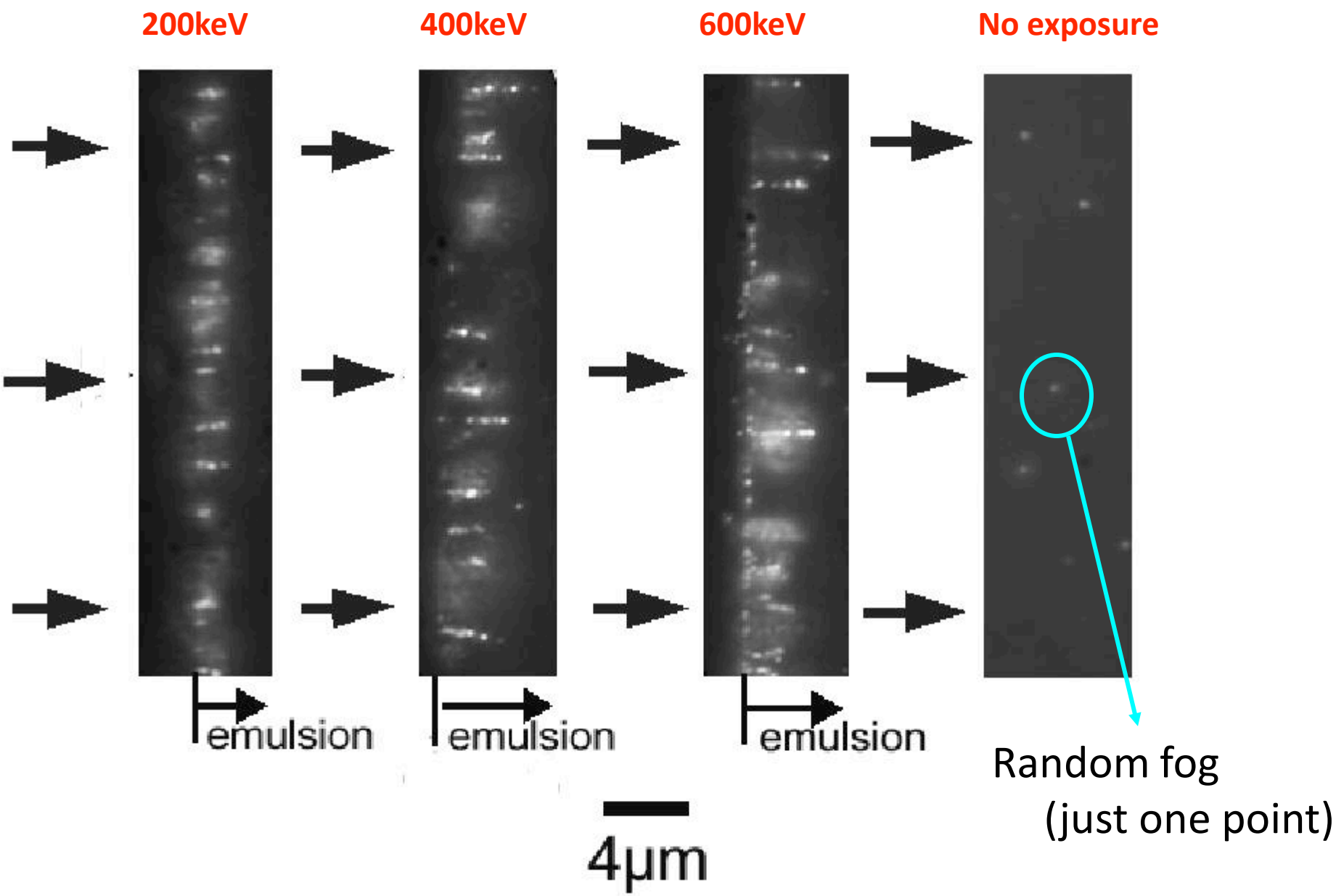
Idea

Expansion of track



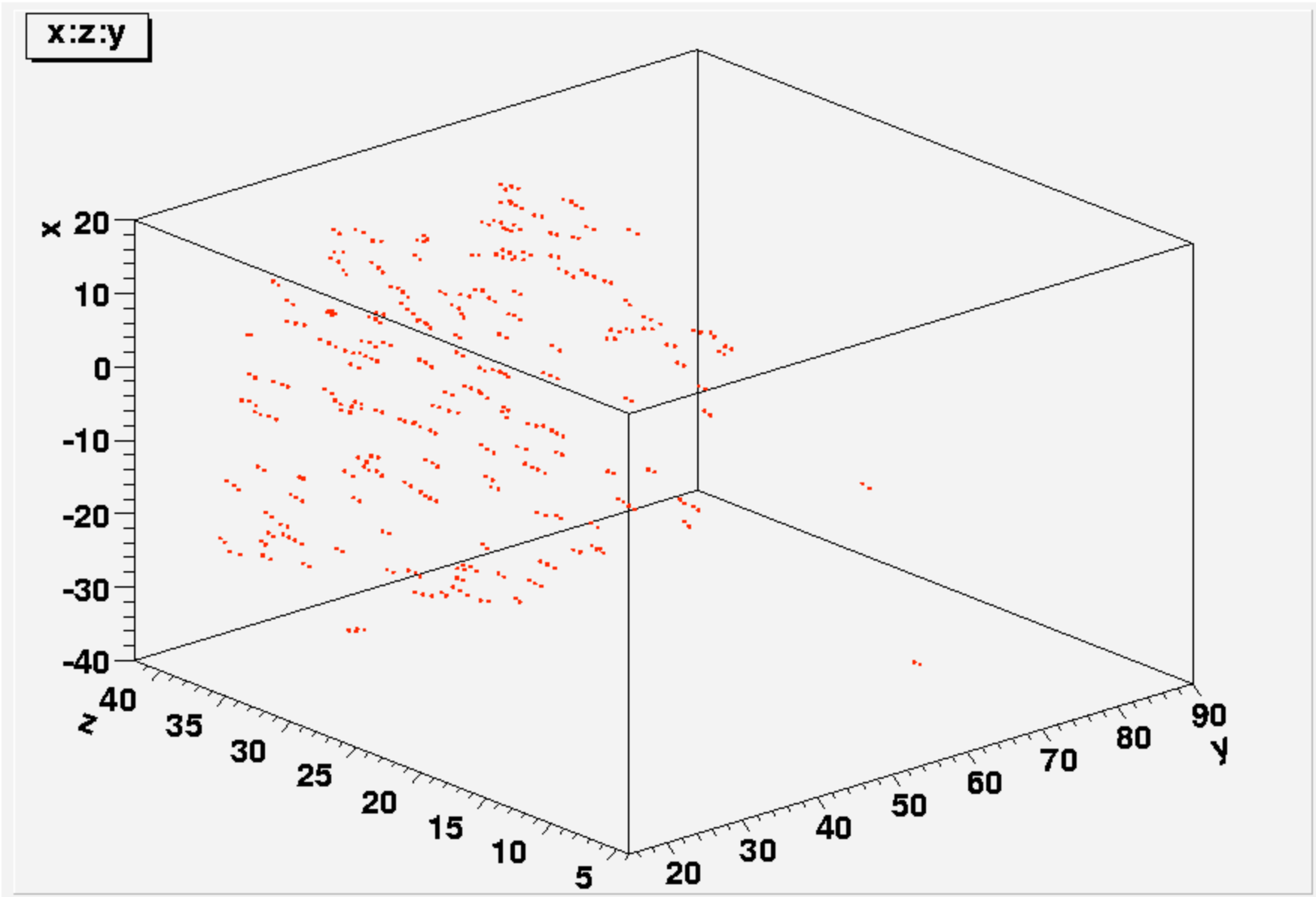
If grains of ~100nm track make separated and track length become ~µm track, optical microscope can recognize nuclear recoil as track.

Readout track by optical microscope



T.Naka et al. Nucl. Inst. Meth. A 581(2007) 761

600keV Kr 3D image of optical microscope



Background rejection concept

For γray, electron

Sensitivity of emulsion is corresponded to generated rate of latent image. ⇒ depend on dE/dx of incoming particle.

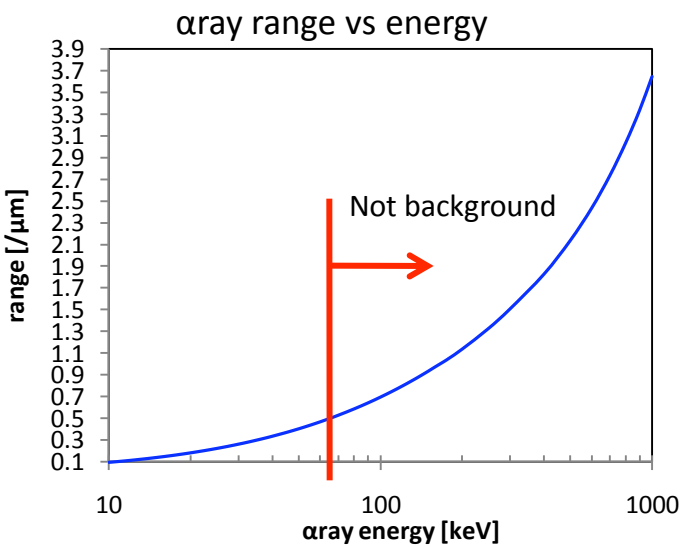
⇒Sensitivity control

- nuclear emulsion itself
- development control → tomorrow talk

For αray

- range discrimination
- development control
- fiduecial cut

alpha from Th,U chain and Rn is not background



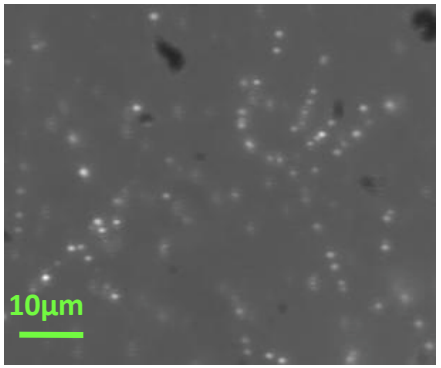
For neutron

- development control
- directional

Sensitivity control for NIT itself ―γ,e rejection―

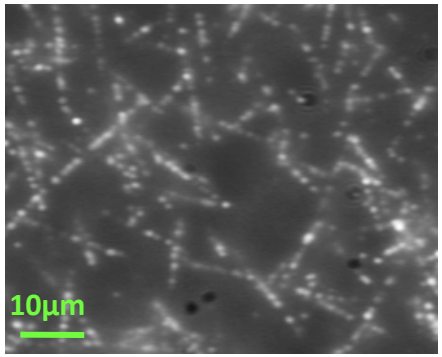
Alpha ray

No sensitized NIT



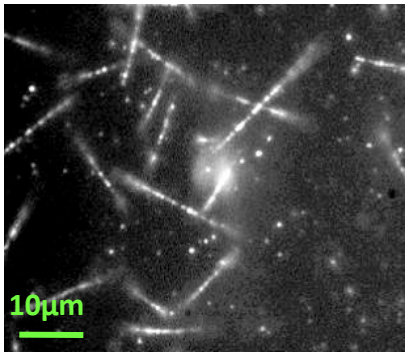
1.1grains/μm

HA sensitized NIT



2.0grains/μm

normal NIT(high sensitivity)



6.0grains/μm

2 times

1/3 times

	No sensitized NIT	HA sensitized NIT	normal NIT(high sensitivity)
Nuclear recoil	× (Eff. ~20%)	○ (Eff.>80%)	◎(Eff. ~100%)
Electron rejection	◎(Eff. < 10E-7)	○(Eff.< 10E-5)	× (Eff. ～10E-2)

Good sensitized treatment

WIMP sensitivity with NIT

WIMPs event rate 1 counts/（1000kg year）limit

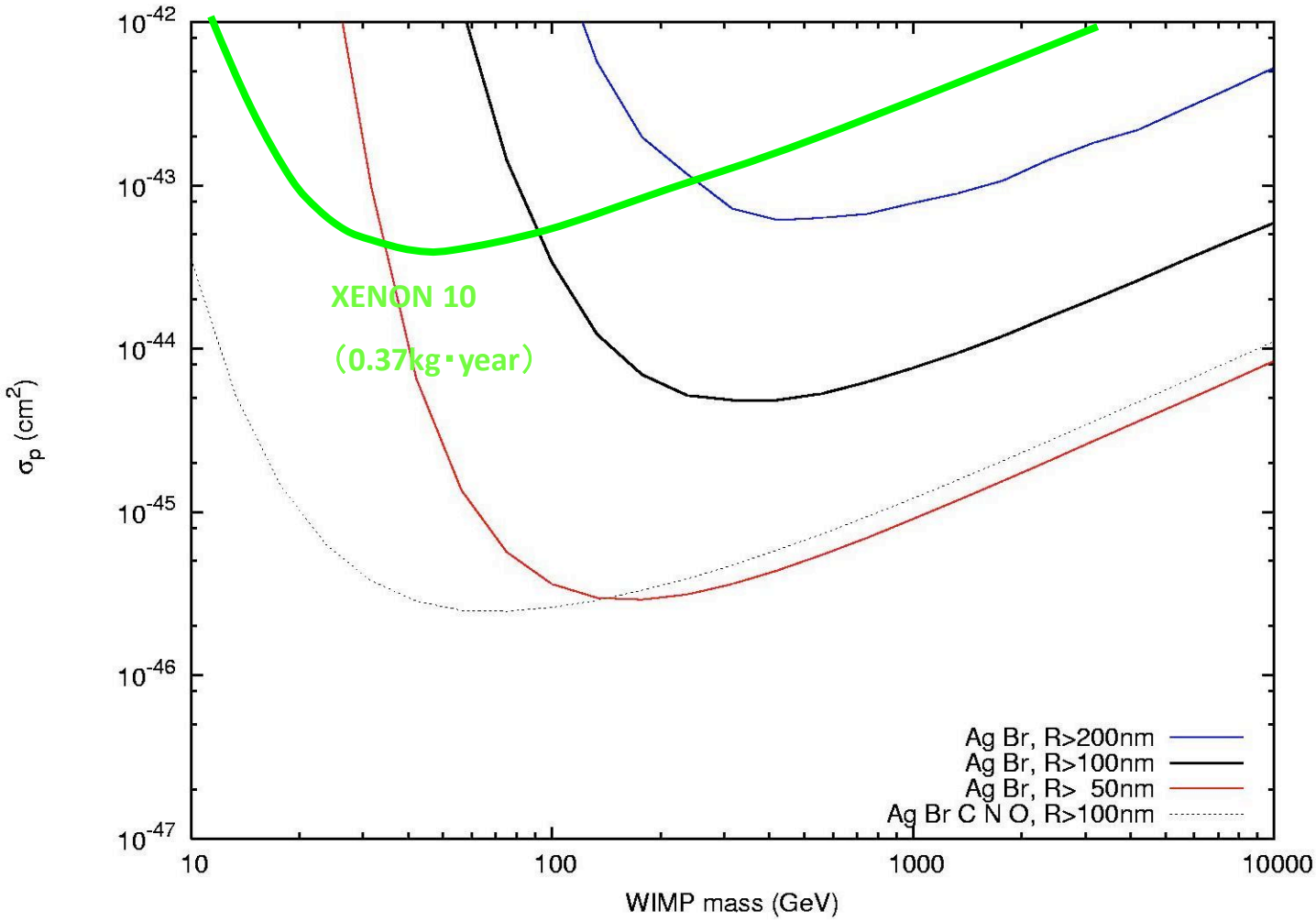
Range threshold

200nm

100nm

50nm

Finer grain NIT
(AgBr size~20nm)



Near future plan

2009

- construction of readout system
- background rejection by development treatment
- construction of emulsion production system
  - emulsion production for first experiment
  - R&D of low background and higher resolution NIT

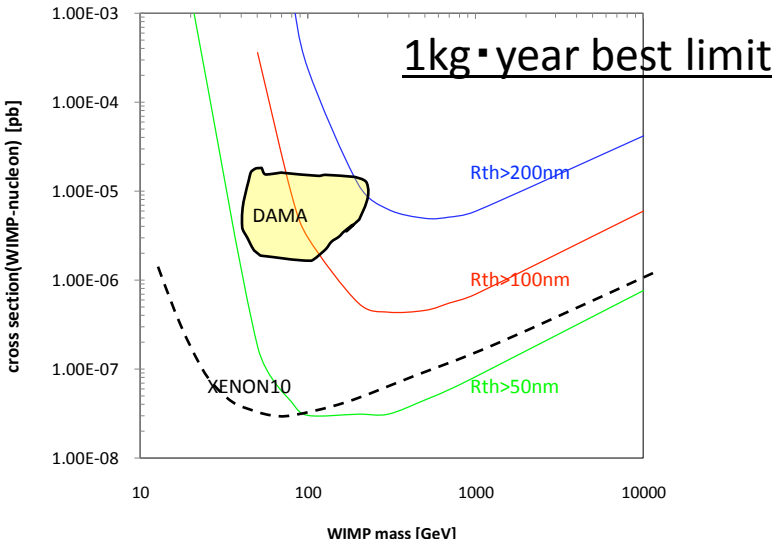
⇒ detail will be talked tomorrow session,

⇒**progressing now**

2010

- put readout system and produced emulsion to practical use
- extensive study of background
- 1kg prototype detector

⇒cover the DAMA region



conclusion

- High resolution nuclear emulsion(NIT) was developed
- NIT can detect the nuclear recoil track
- By expansion technique, optical microscope can distinguish the nuclear recoil track from random fog.
- By control of sensitivity of NIT, electron rejection is better than 10E-5
- Just doing R&D for first running of 1kg detector