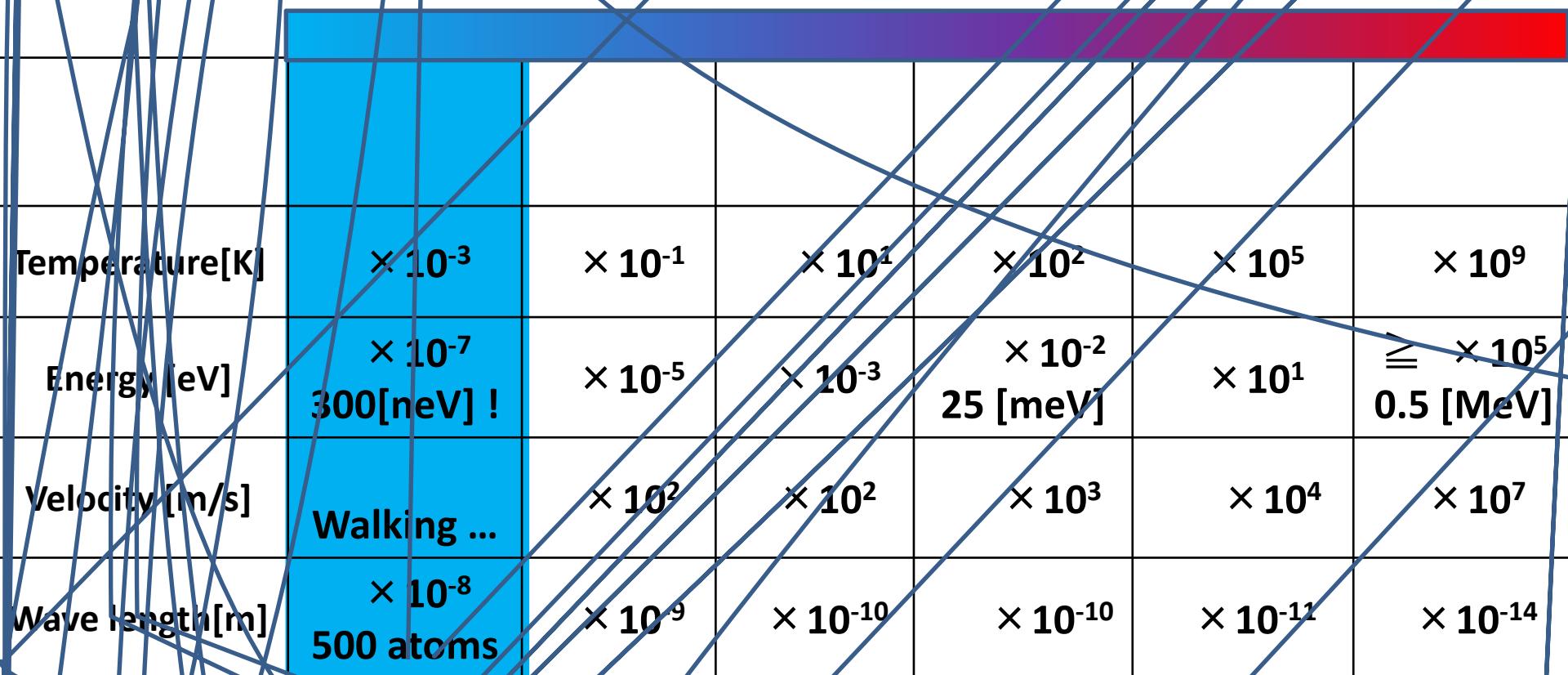


What is Ultra-Cold Neutron (U.C.N.) ...



Reflected on the surface of Ni etc.

Can be fully reflected by mirrors or contained in a bottle

No electric charge
Experiment in vacuum...
the one of neutron, EDM, interference...

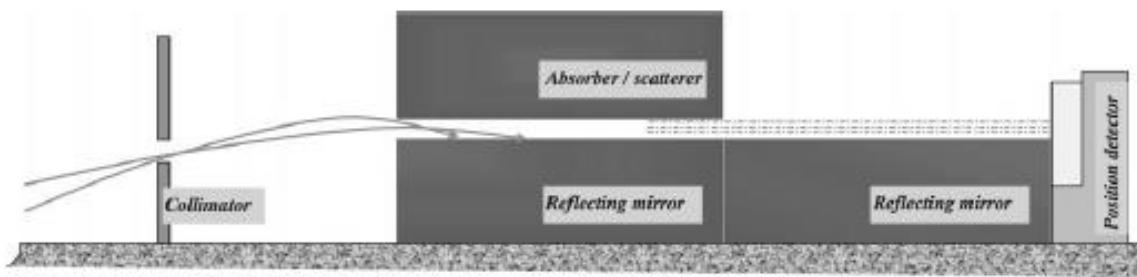


Fig. 3. General scheme of the experiment.

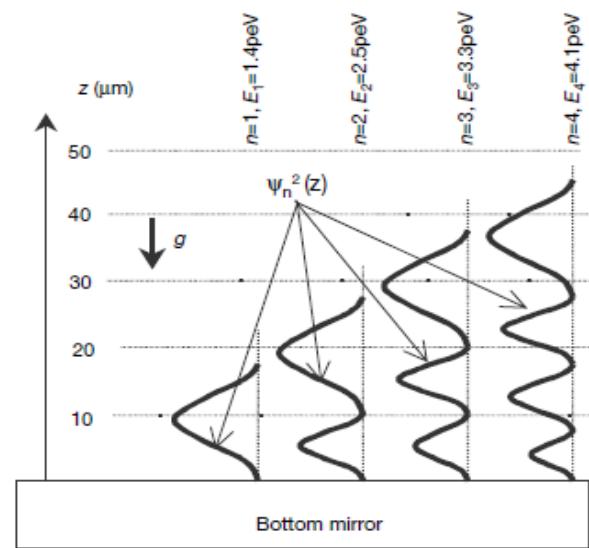
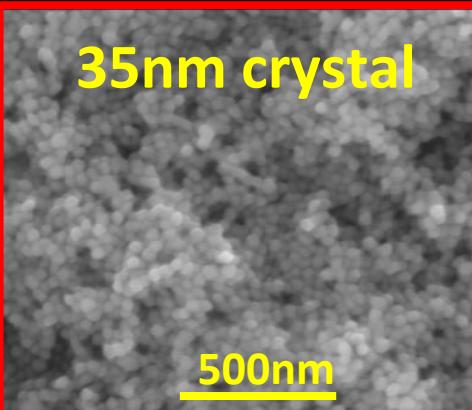
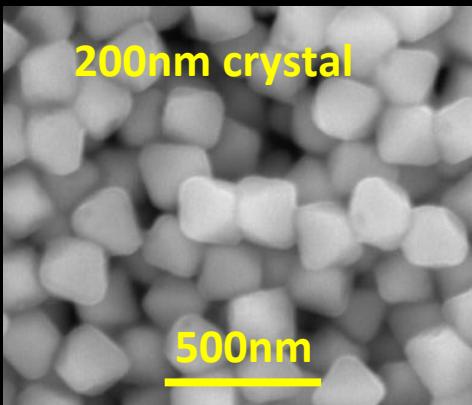


Figure 1 Wavefunctions of the quantum states of neutrons in the potential well formed by the Earth's gravitational field and the horizontal mirror. The probability of finding neutrons at height z , corresponding to the n th quantum state, is proportional to the square of the neutron wavefunction $\Psi_n^2(z)$. The vertical axis z provides the length scale for this phenomenon. E_n is the energy of the n th quantum state.

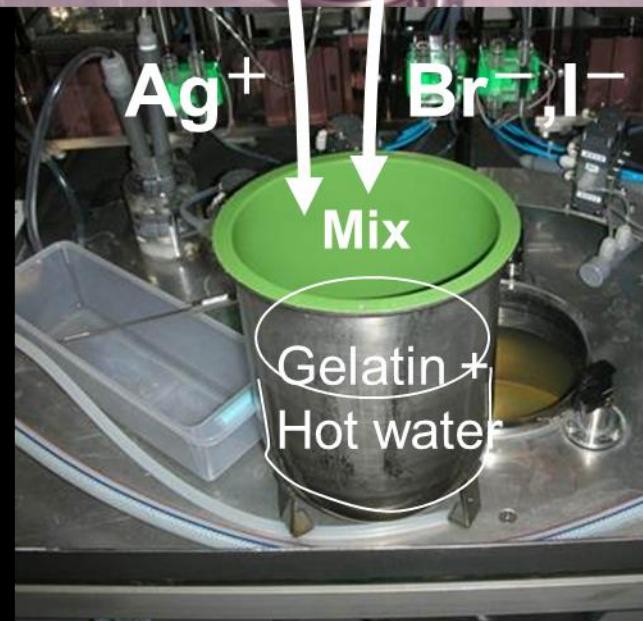
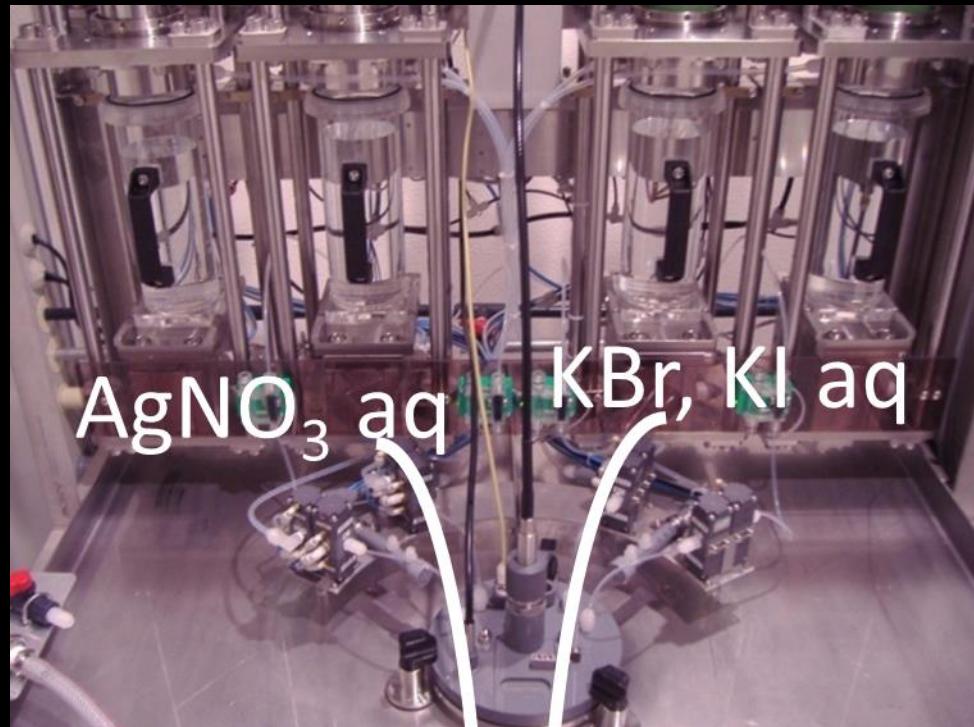
Nuclear emulsion

R&D @Nagoya since 2010

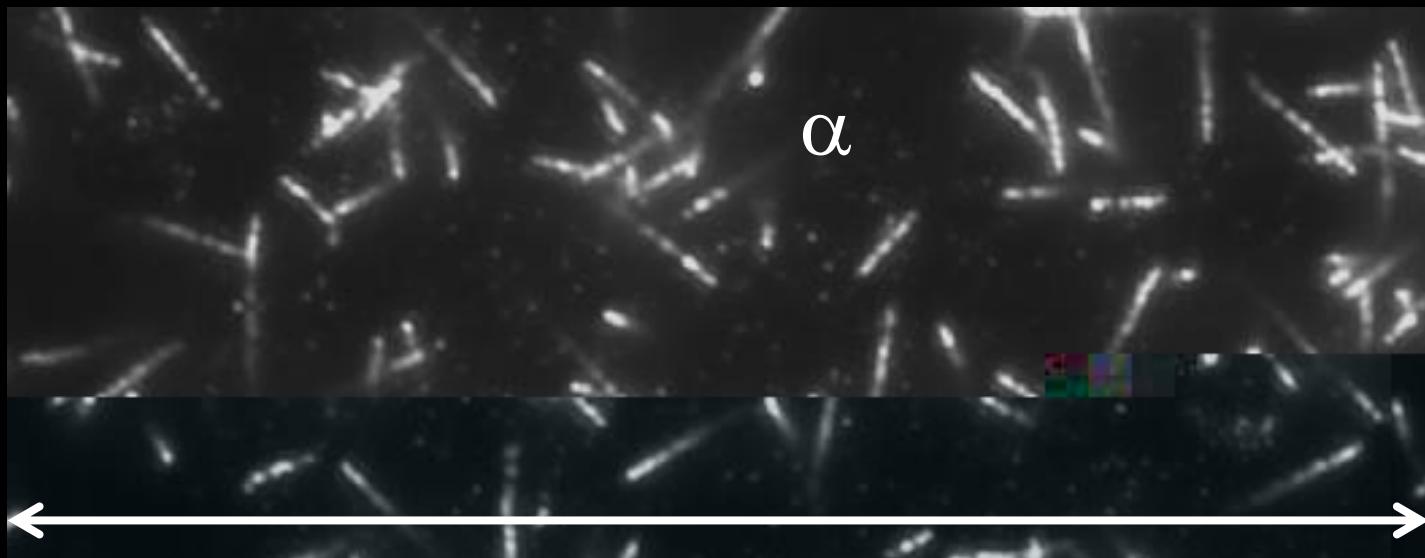
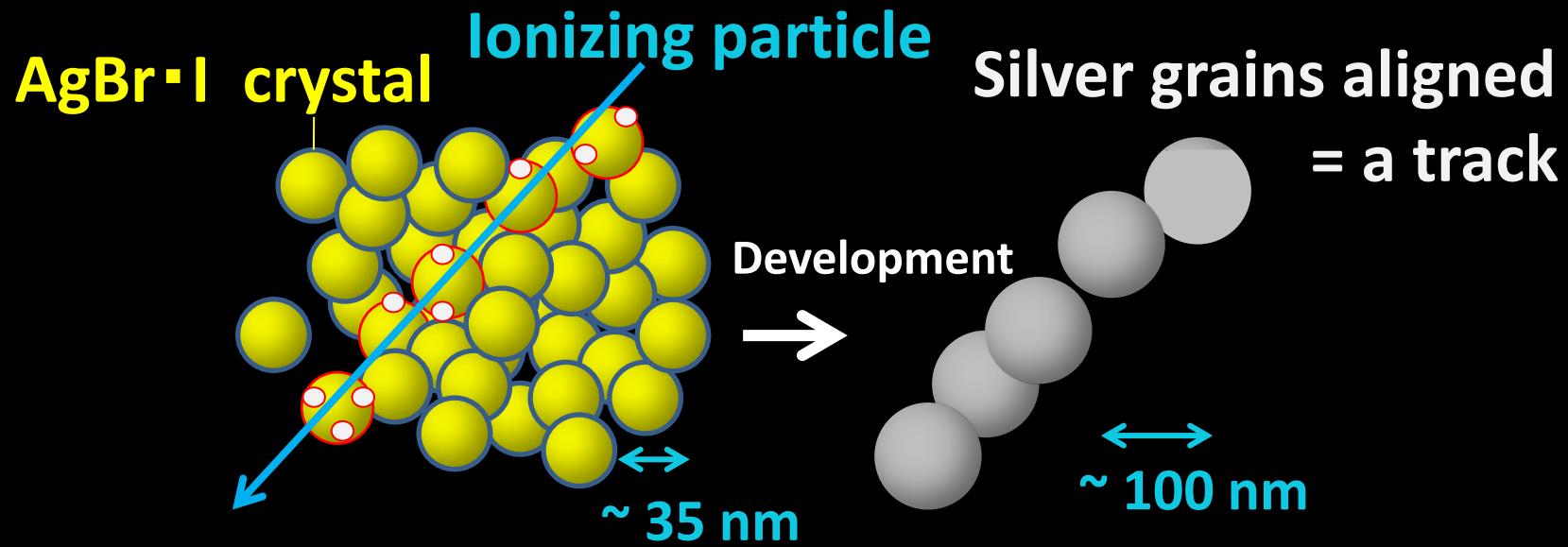
AgBr crystals grown and dispersed in gelatin.



- Crystals with 35nm of diameter.
- M.I.P.s and low E electrons are not detected. (neither γ)



High spatial resolution 3D tracking detector



Neutron absorption by nuclides

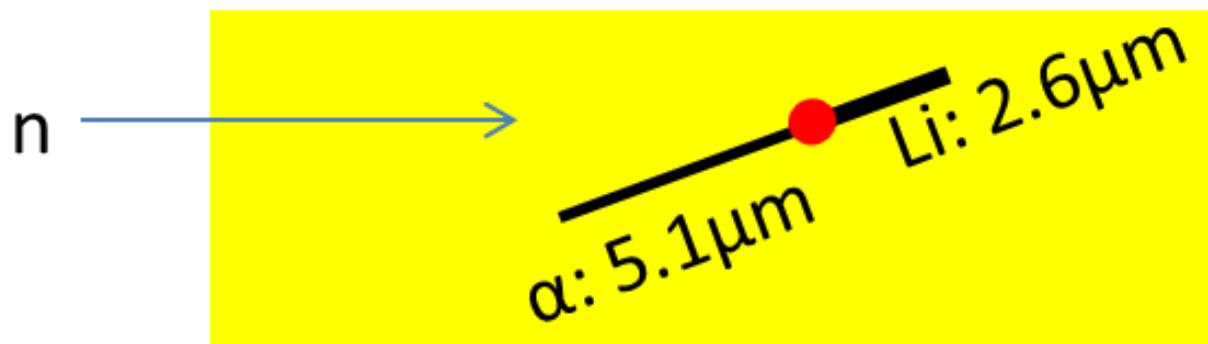
- large absorption cross section
- emission of charged particles with high dE/dx

^{10}B

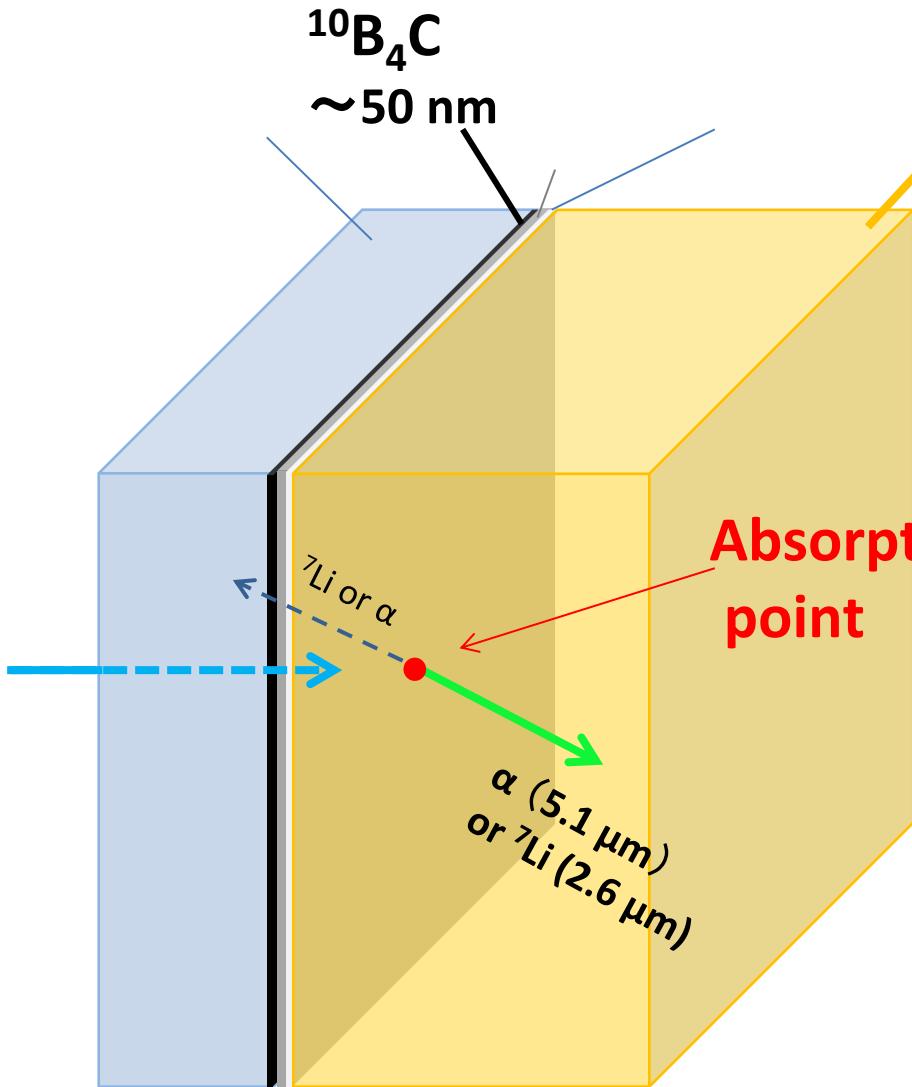
$^{10}\text{B}(\text{n},\alpha)$

×

α
 α



Structure of the detector



Sputtered by M.Hino at KURRI

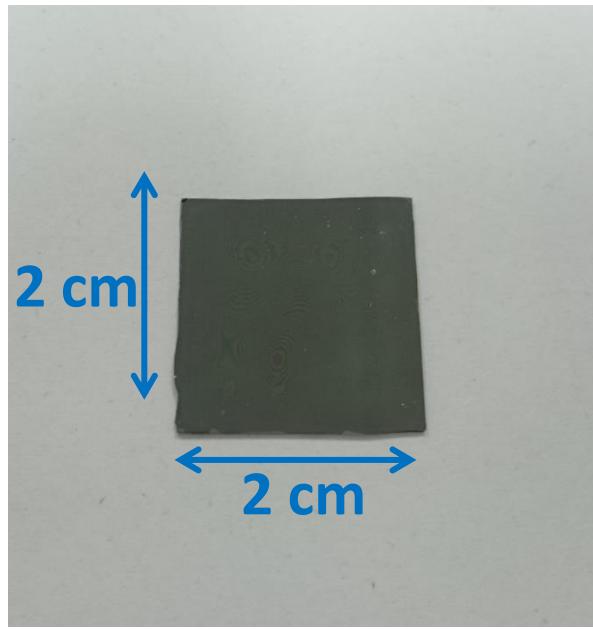
Fine-grained emulsion
 $10 \mu\text{m}$

Expected
position resolution $< 100\text{nm}$

- stable $\text{B}_4\text{C}-\text{NiC-C}$ layer sputtered on Si
- $^{10}\text{B}_4\text{C}$ (^{10}B enriched $\sim 96\%$)

Absorption eff. By ^{10}B
(from n transmittance
measurement by cold neutrons) :

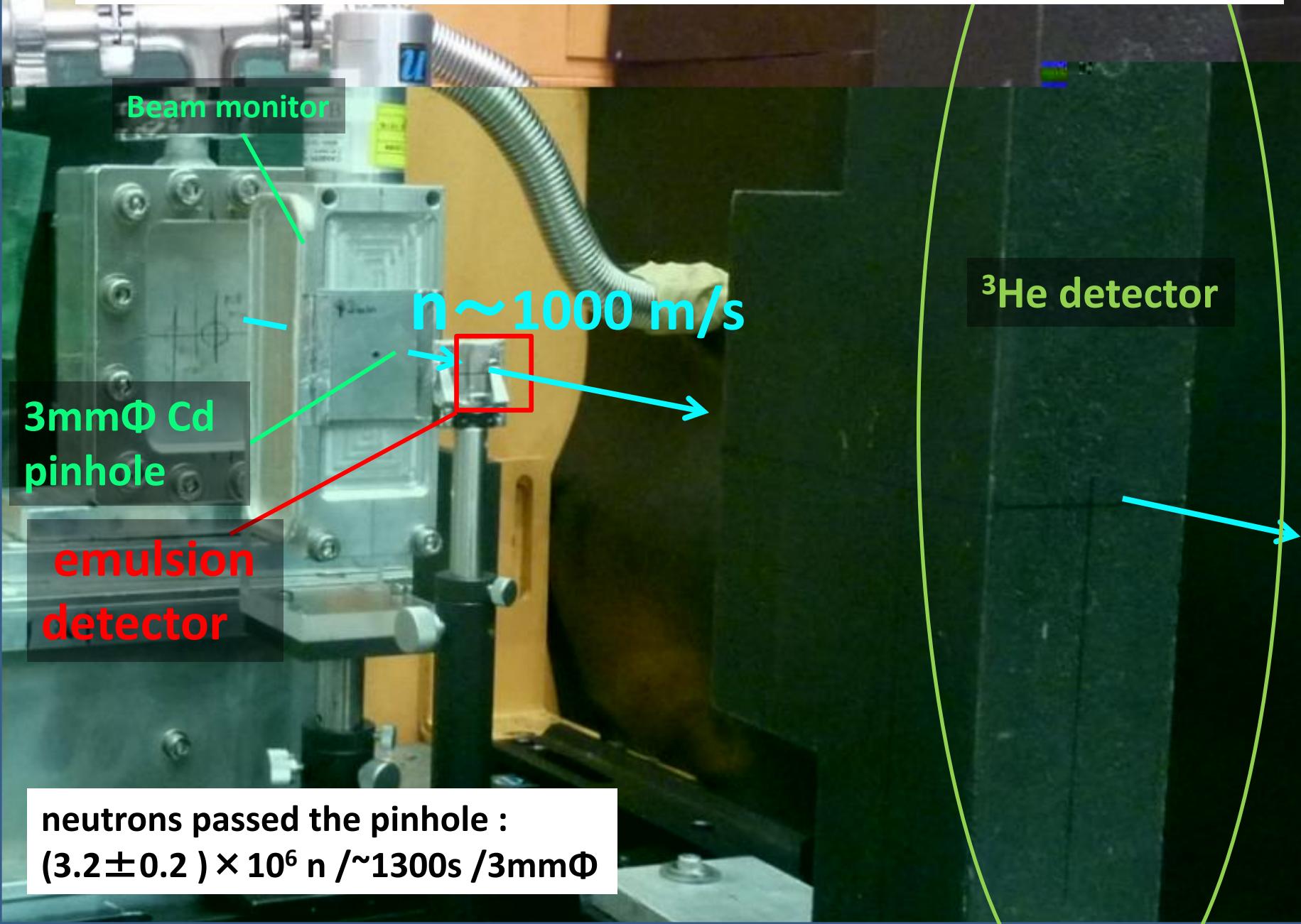
$(0.14 \pm 0.04)\% @ 1000\text{m/s}$
 $(13 \pm 3) \text{ \% @ } 10\text{m/s}$



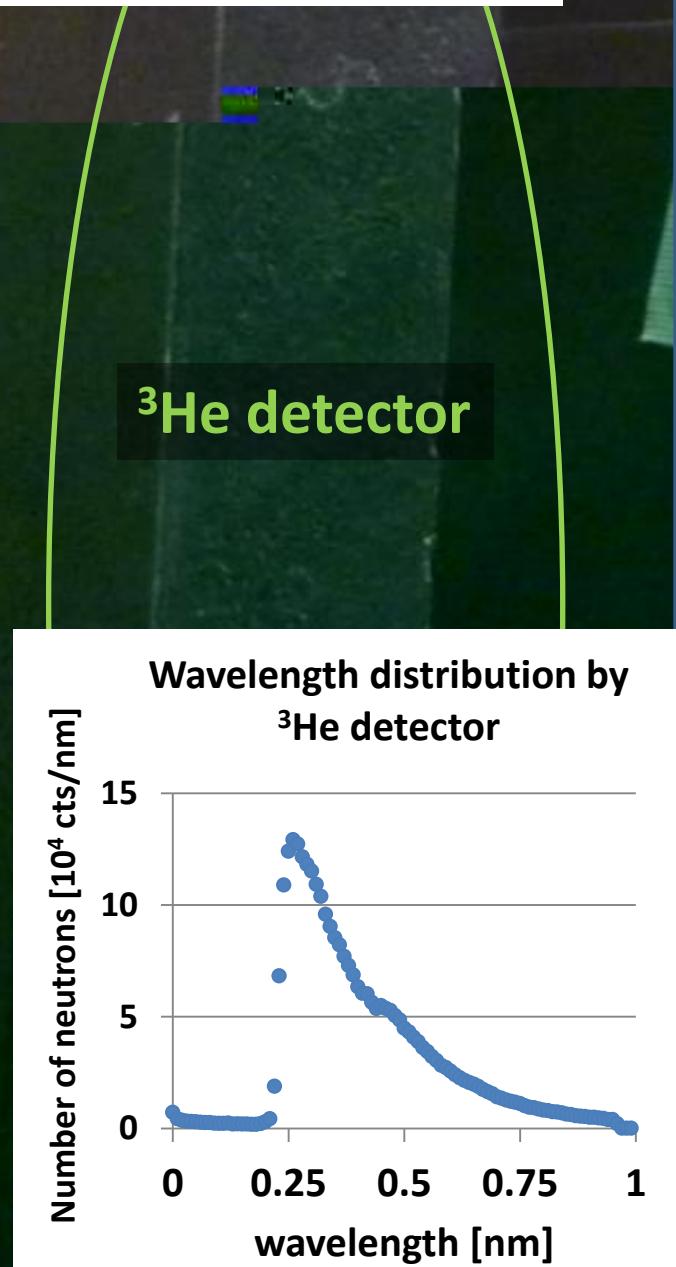
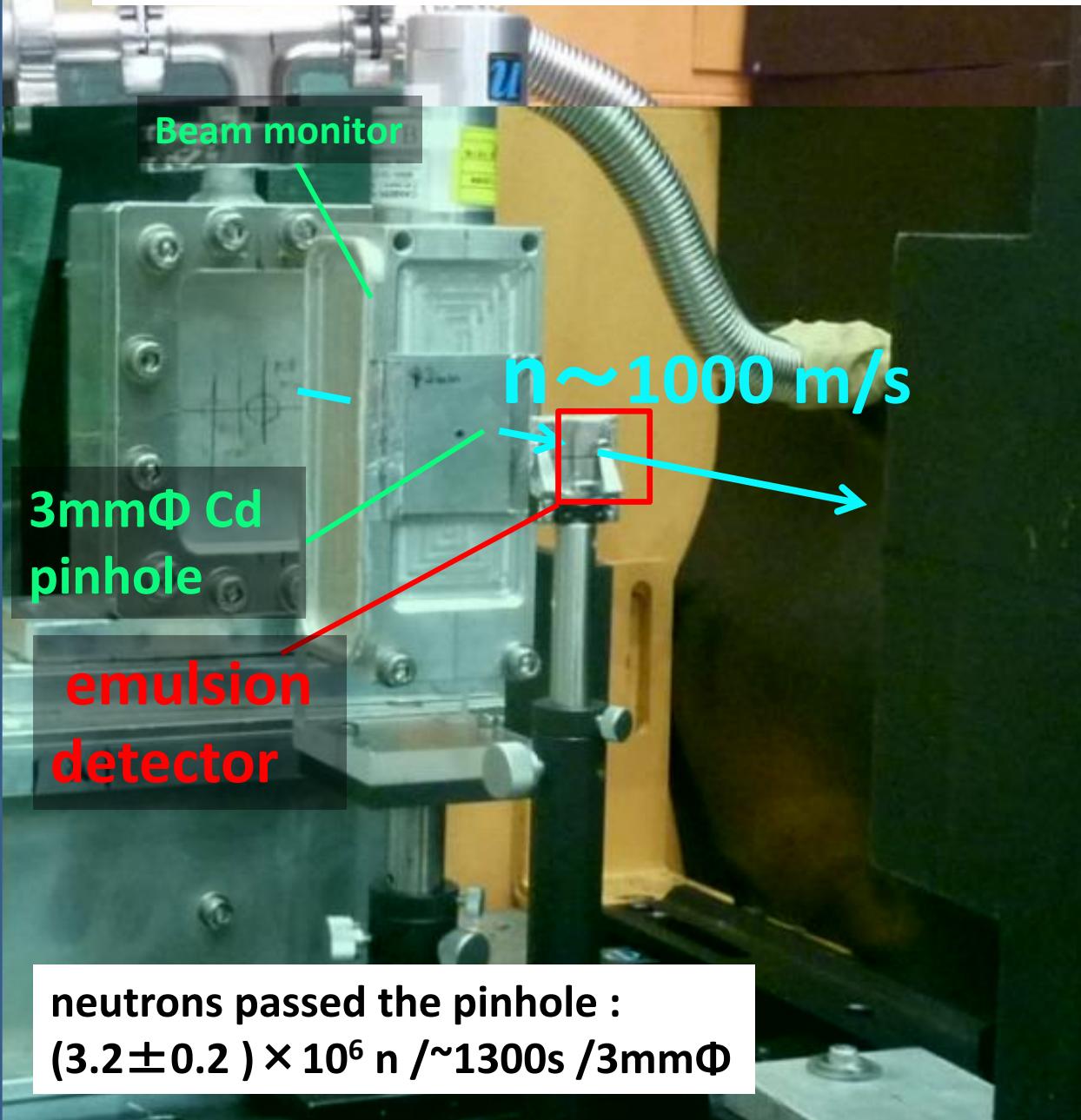
μ

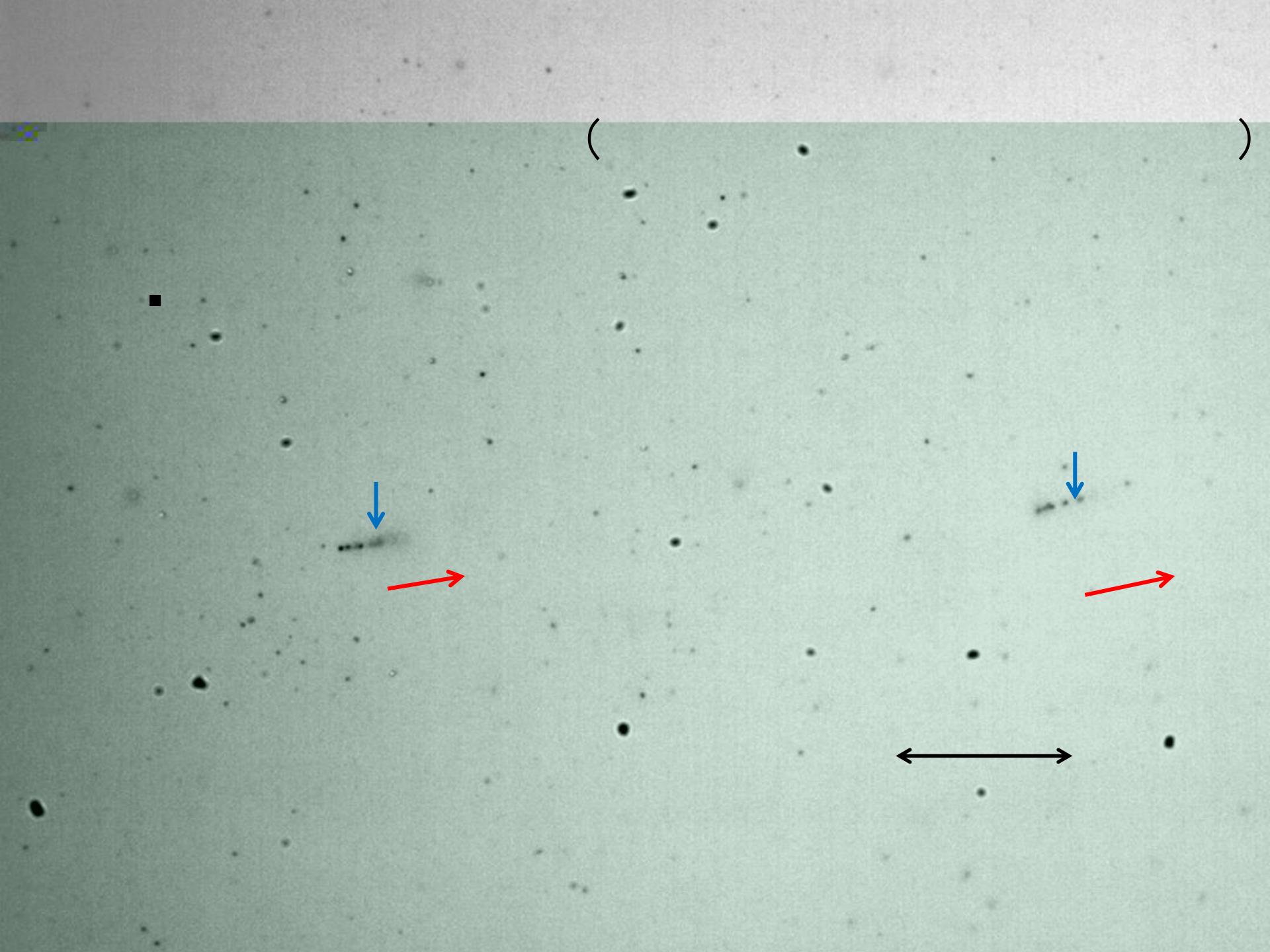
\times

Cold neutron exposure @J-PARC MLF BL05



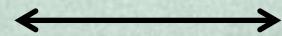
Cold neutron exposure @J-PARC MLF BL05





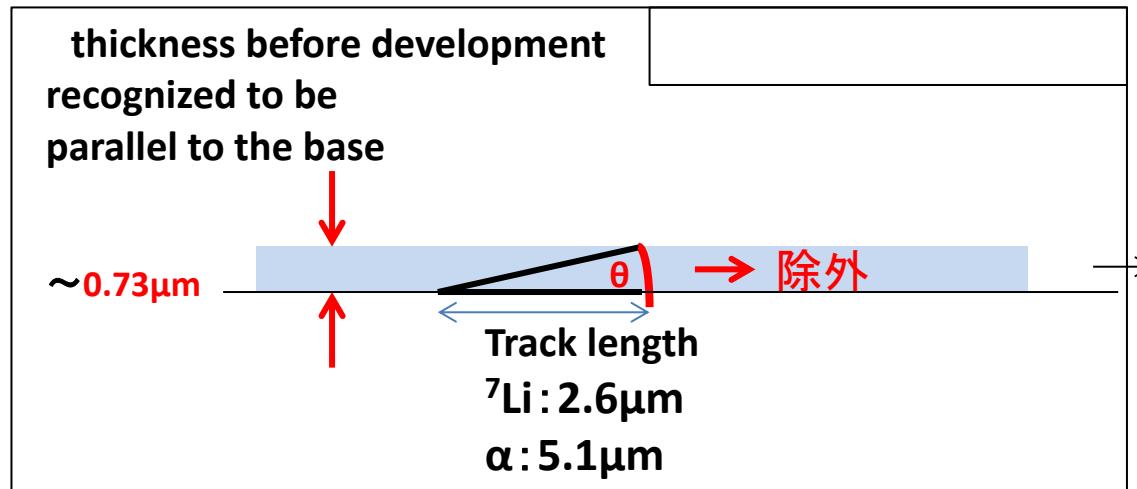
()

detection efficiency measurement



1. Starting from base.

2. Not parallel to the base (rejection of scratch marks on the base)

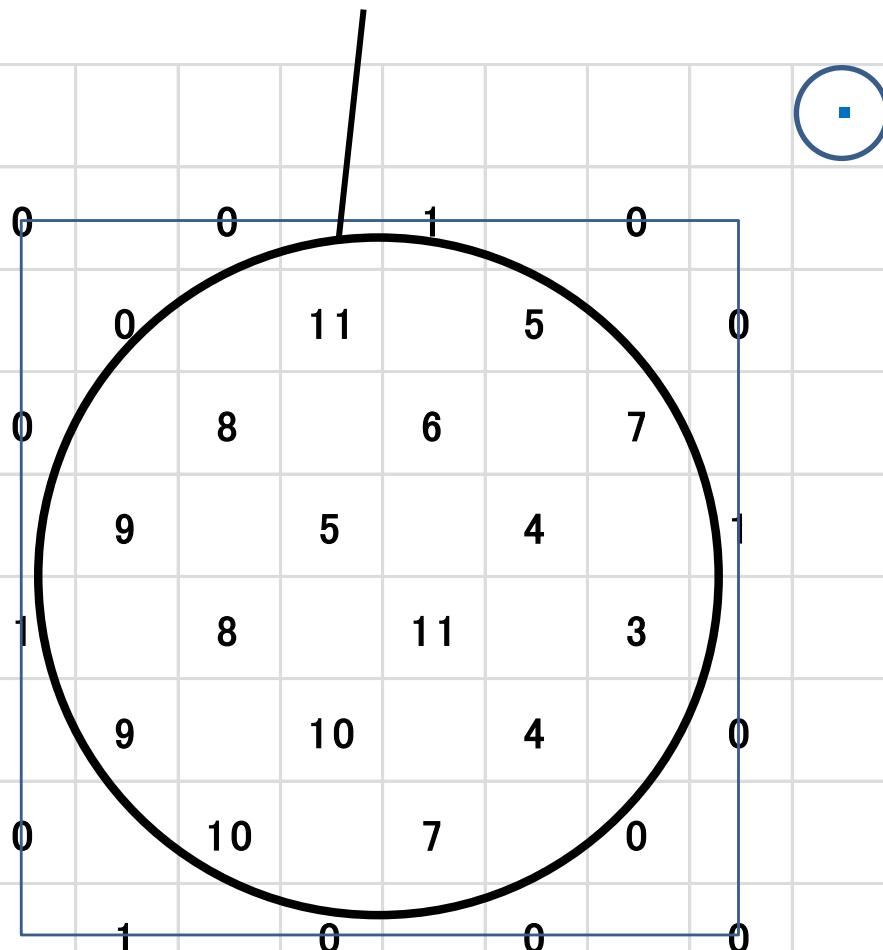


: :
angle
acceptance: 82%

3. Not penetrating the emulsion layer ($10 \mu\text{m}$)
(rejection of natural radiation)

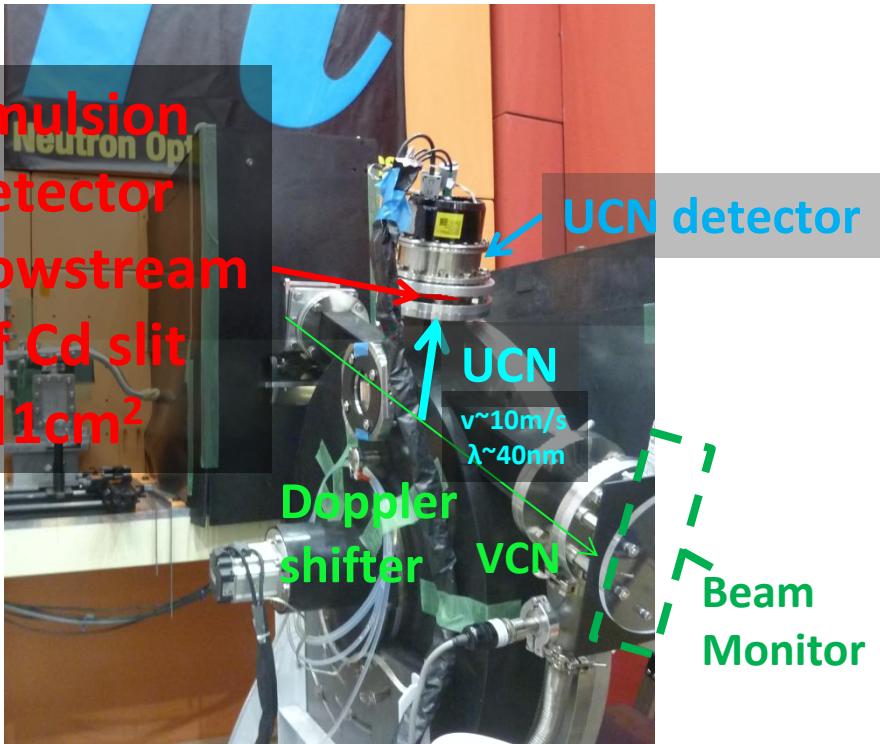
4. Grain Density > 1 grain/micron

μ

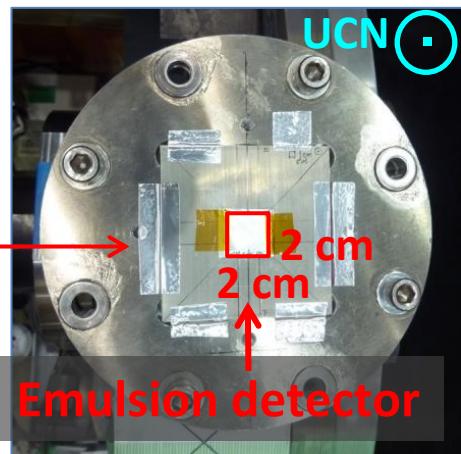
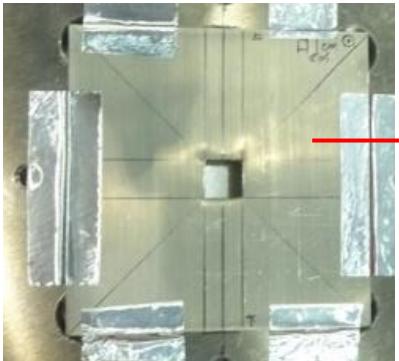


→detection eff. : $(0.16 \pm 0.02) \%$
($: (0.11 \pm 0.03) \%$)

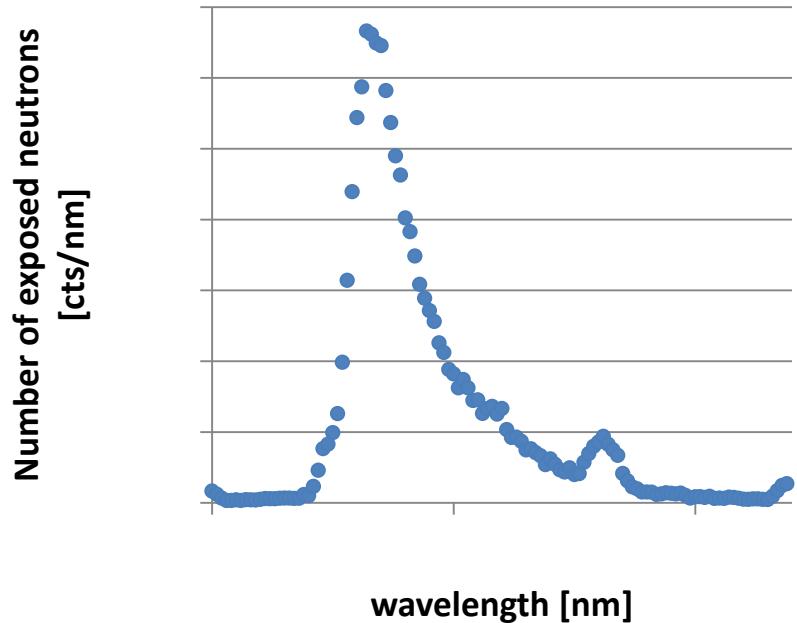
Emulsion
detector
downstream
Of Cd slit
 $\square 1\text{cm}^2$



Cd slit $\square 1\text{cm} \times 1\text{cm}$



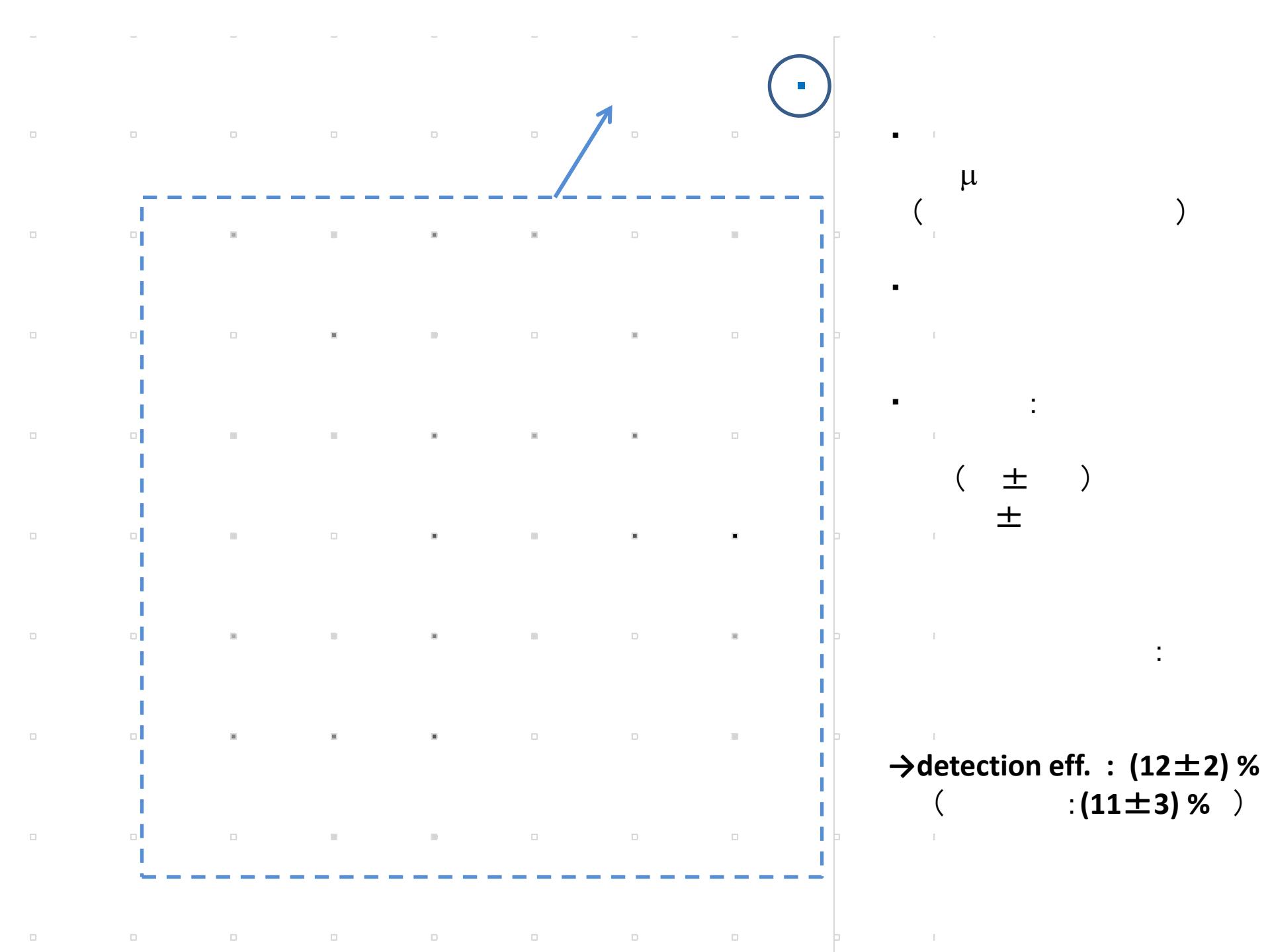
Wavelength measured by UCN detector



: ±

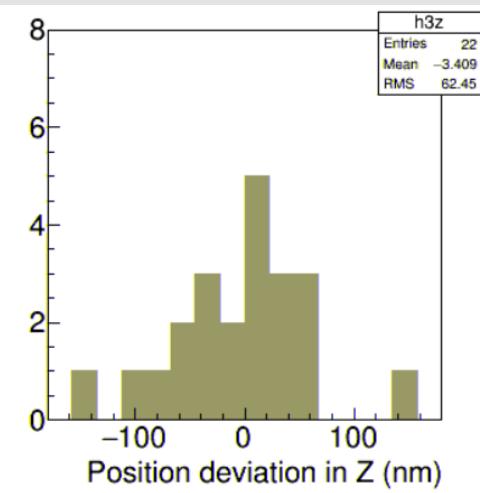
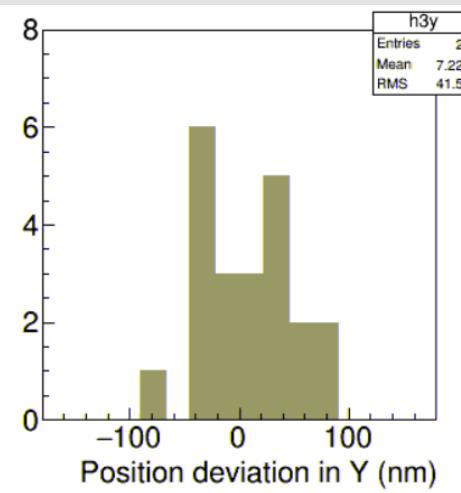
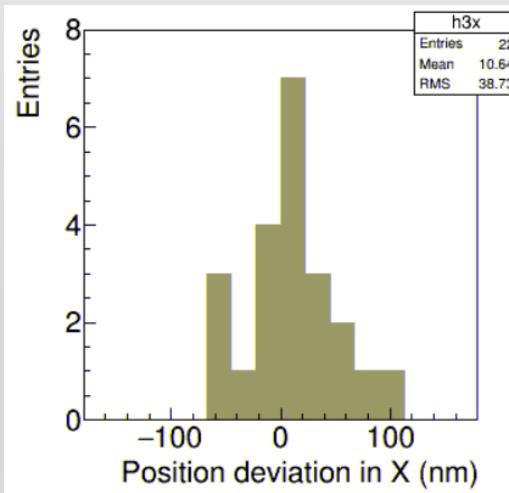
×

×

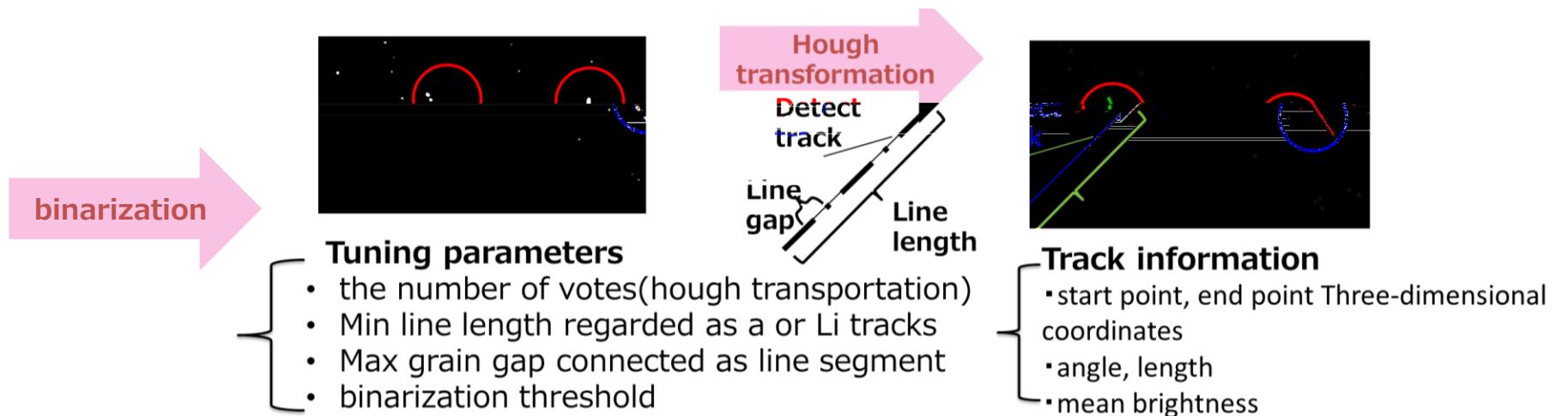


Estimation of resolution using real tracks is going on.

Deviation of grain positions from a line connecting first grain(x_0, y_0, z_0) and the last grain(x_1, y_1, z_1)



Developing algorithm for track recognition



Conclusion

- We have been developing a high spatial resolution cold/ultra-cold neutron detector by using fine-grained nuclear emulsion and an isotope with large absorption cross section emitting charged particles with high dE/dx .
- The detector with stable layers, $^{10}\text{B}_4\text{C}$ (~50nm)-NiC-C-Emulsion, is successfully developed. Spatial resolution of <100 nm is expected.
- Cold neutron (~ 1000 m/s)
Detection efficiency : $(0.16 \pm 0.02) \%$ (expected: $(0.11 \pm 0.03) \%$)
- UCN (~10m/s)
Detection efficiency : $(12 \pm 2) \%$ (expected: $(11 \pm 3) \%$)
- Development of automatic tracking algorithm is going on.