Detection gamma-ray from laser plasma using nuclear emulsion

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1.Abstract

・Achievable focusing intensity of laser is increasing

→ The energy emitted from the laser plasma is also increasing

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Nuclear reaction are within experimental reach

・Clarify the occurrence of nuclear reactions

→Measurement of gamma-rays emitted from laser plasma to clarify the generation mechanism

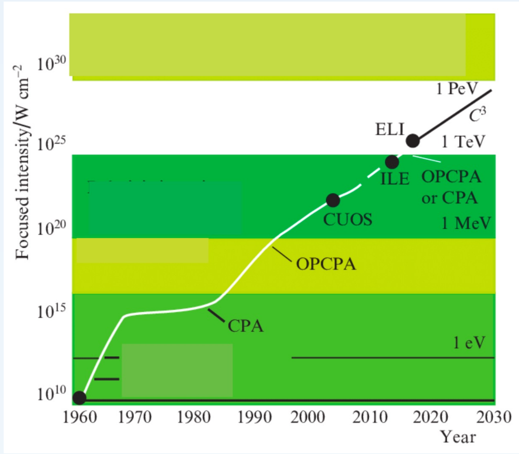
・Challenging to measure γ-ray with detectors such as scintillator

→Requires a different detector

→Nuclear Emulsion

(gamma-ray determined from the electron and positron tracks of pair production)

→More resistant to pile-up than detectors such as scintillators



2.What is the Emulsion?

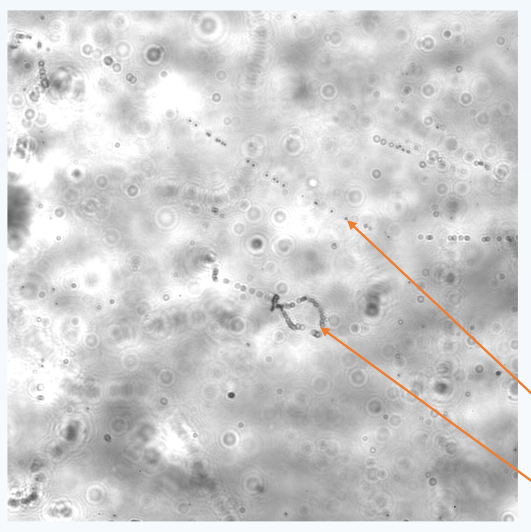
Nuclear Emulsion

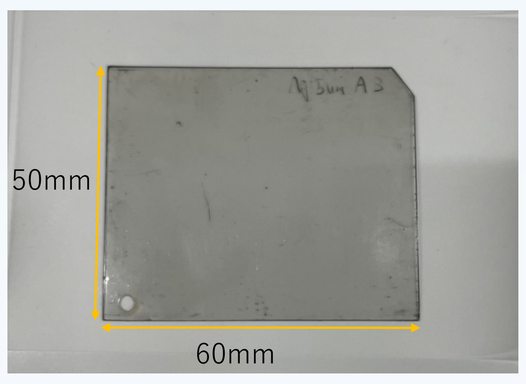
→ A type of photographic film, a detector that has long been used in particle experiments

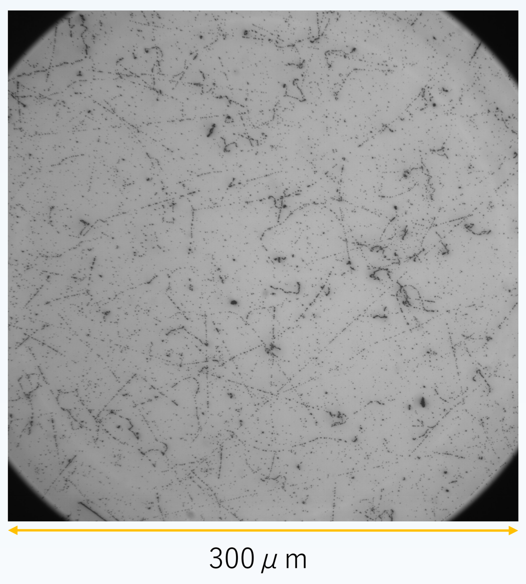
Feature

・High spatial resolution

（The size of the silver halide crystals determines this resolution）(200nm)





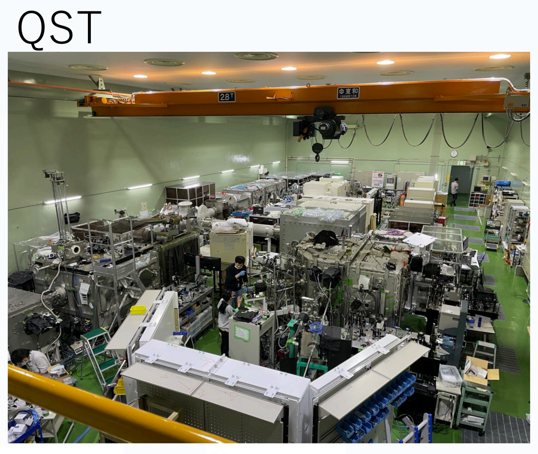


3.Experimental Setup

・Facility

J-KAREN-P of the Kansai Photon Science Institute, QST

(The achievable focusing intensity in QST is about $10^{21-22} W/cm^2$)



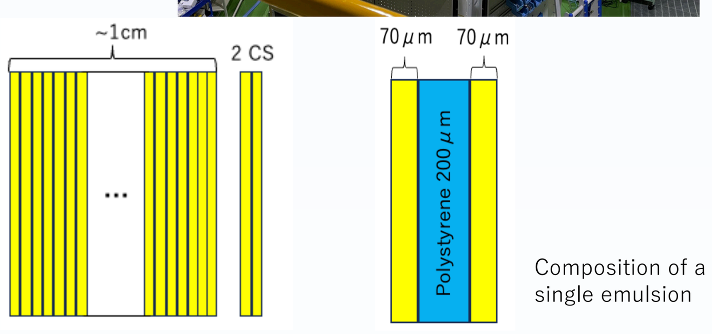
・Performance of the laser

30 fs at a focusing intensity of $10^{21} W/cm^2$ on 5 μm Ag target

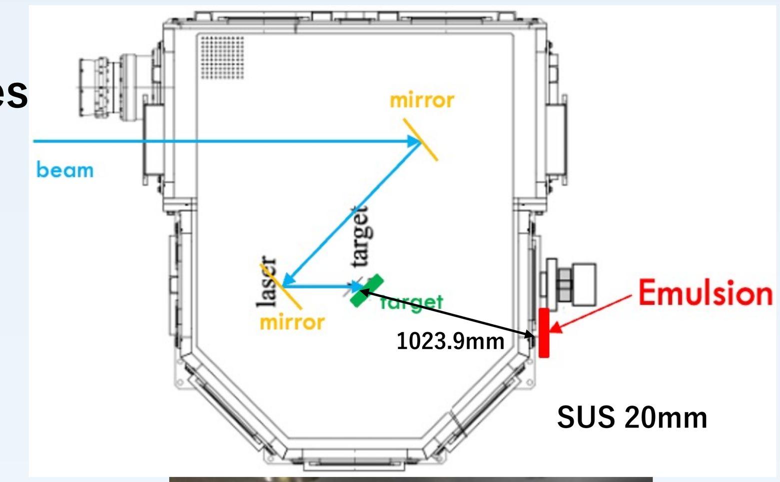
・Location of Emulsion

Emulsion is attached to the wall of the vacuum chamber

→One set of 30 emulsions + 2 CSs were installed at two locations



4.Measurement



・Necessary to adjust the amount of incident particles

→many incident charged particles analysis difficult.

・Adjustment of the distance from the target

・Material of the object between the target and the emulsion

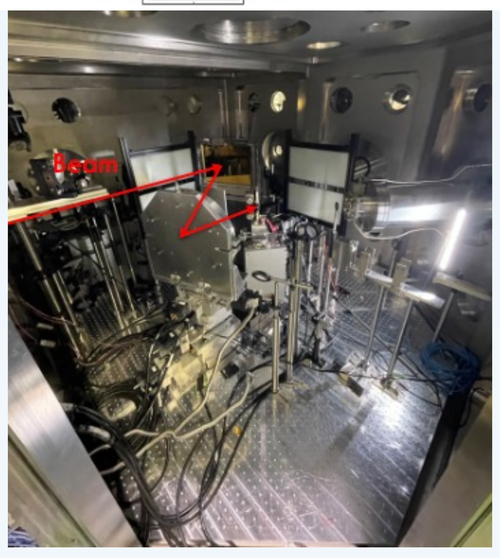
・Adjustment of the number of laser shots

→1 laser shot per measurement

・Maximize the detection efficiency of emulsions

→Perform angular alignment of target and emulsion

・Accuracy of about $\tan\theta \leq 0.2$



・How to install emulsions

→ Good to have a high degree of freedom (self-made)

・How to store emulsions

→Keep perpendicular to the ground.

5.Scan and Analysis

HTS (Hyper-track selector nuclear emulsion readout system)

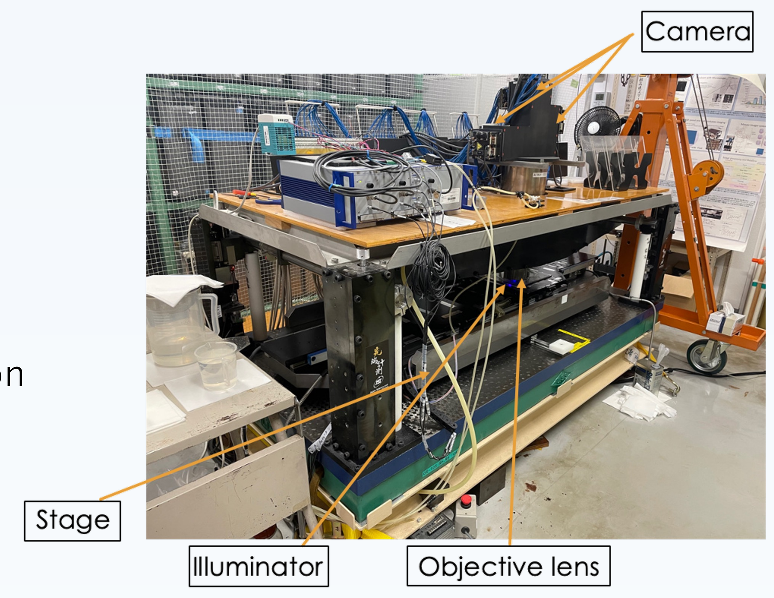
Procedure

Measurement(KPSI,QST)

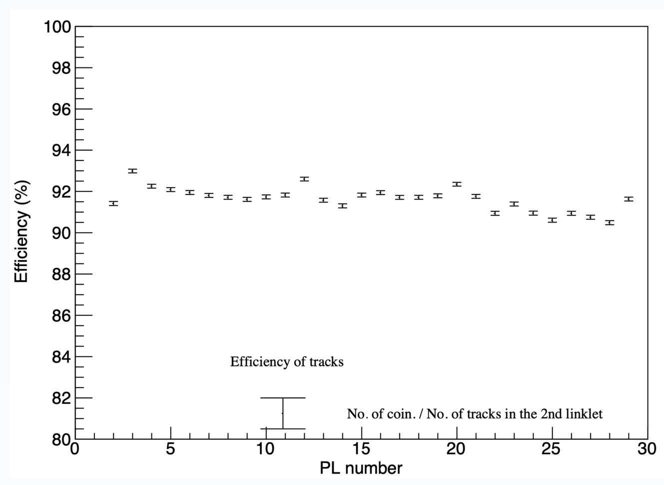
→**Development**(Gifu University)

→**Swelling**(Nagoya University)

→**scanning**(Nagoya University)



Calculate the detection efficiency in a single film of emulsion



6.Search for gamma-ray pair production

Search for charged particle trails that are generated along the way in the emulsion stack.

Procedure

All track→penetrating track

→After veto track→Pair topology

Final checks are made by the human eye.

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4 γ-ray pair production events were identified.

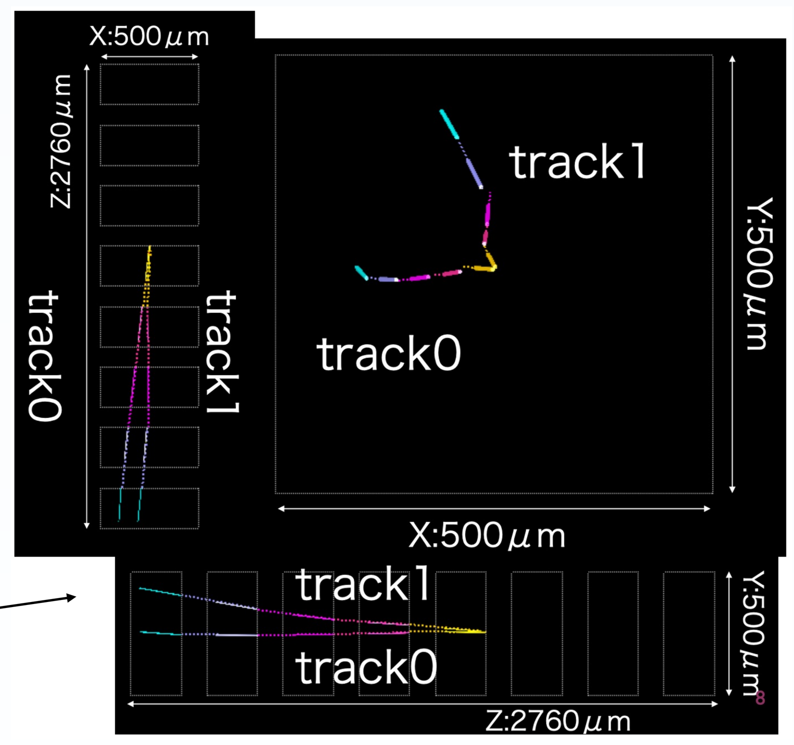


Figure of one of the four pair-generating events found

7.Momentum calculation

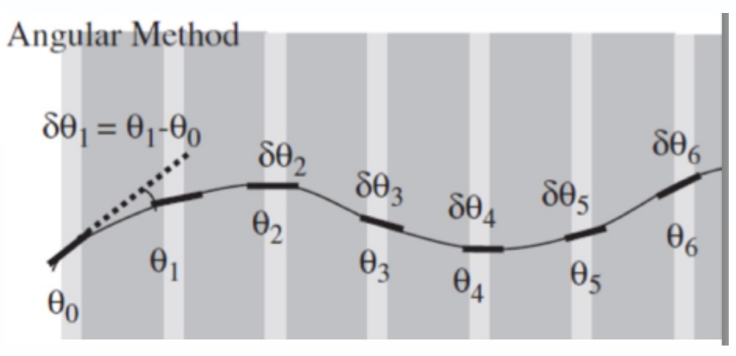
・Calculation Method

multiple electromagnetic scattering methods

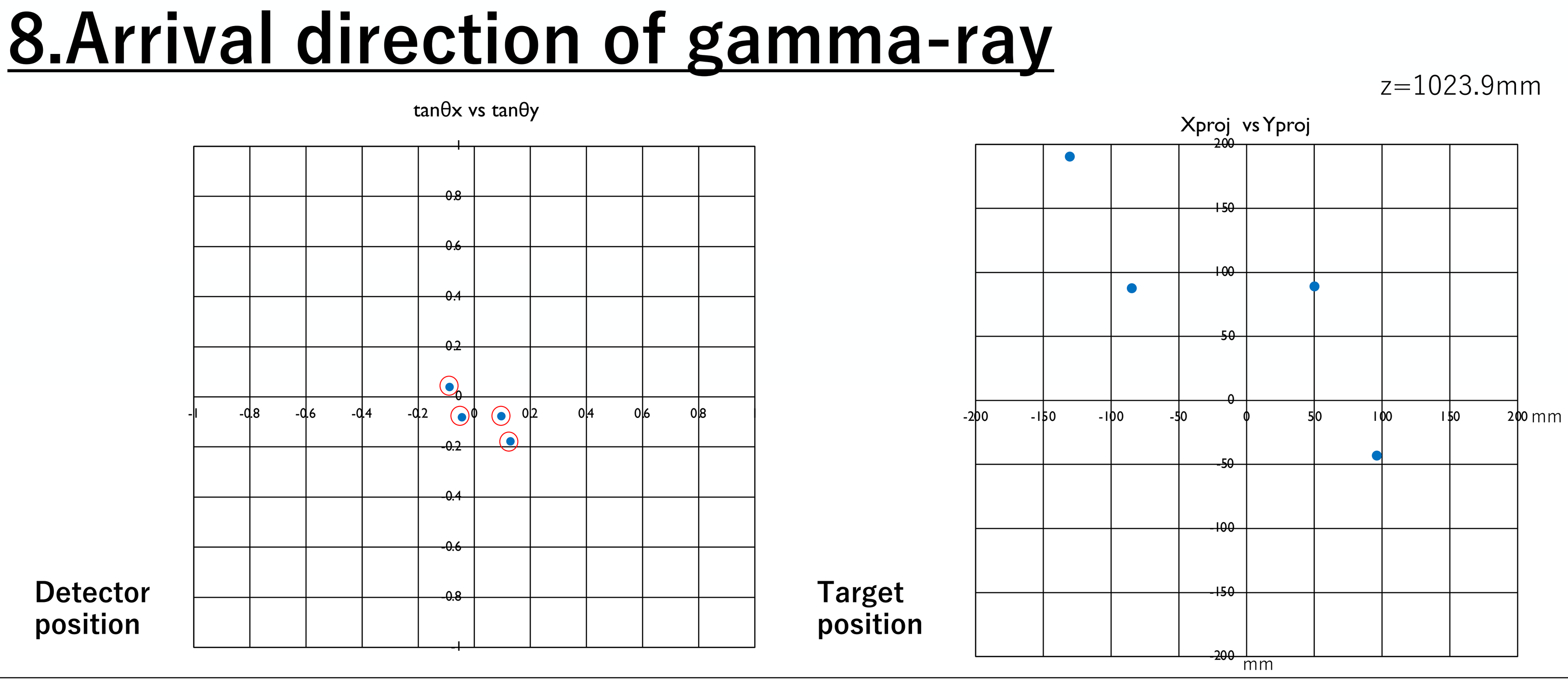
$$(\delta\theta)_{RMS} = \frac{13.6MeV}{\beta cp}\sqrt{x/Xo}\,[1 + 0.038\ln(x/Xo)]$$

δθ: measured value, x = 0.005Xo

Momentum	error
Ev27840	44 ±12
Ev29565	75 ±20
Ev40964	46 ±12
Ev73020	39 ±10 (MeV)



8.Arrival direction of gamma-ray



9.Conclusion, Future prospect

・4 γ-ray pair production events identified in this experiment (40~70MeV)

Calculate the Flux of γ-ray

→$7.1\times10^2 (/cm^2/shot)$ (Approximate distance between target and emulsion is 1 m)

→**Emulsion can detect γ-ray in this flux**

・Arrival direction indicates

→Electron-positron pair event comes from the vacuum chamber

→Thought to be γ-rays from the laser shot

・Approximate target position

→4 event are not from target

→ Secondary bremsstrahlung released from the walls of the vacuum chamber

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Really want to see is bremsstrahlung coming directly from the target

・In this experiment, we succeeded in confirming the pair production of γ-rays using emulsions (4event in $7.1\times10^2 (/cm^2/shot)$)

⇩

It could be an effective detector for detecting γ-rays from laser plasma

・The emulsion was placed outside the vacuum chamber

→ γ-rays coming directly from the target could not be detected

→Bremsstrahlung from the wall of the vacuum chamber was detected this time

⇩

1. **Allowing emulsions to be installed in the vacuum chamber**
2. **Changing the flange of the vacuum chamber so that the amount of material between the target and the emulsion is smaller**

→**Currently in the process of experimentation！！**

・The track-finding efficiency in the low-energy band of emulsions has not yet been studied in detail

→Probably very poor

→At weak energies, the track shakes a lot and the efficiency falls off

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Track-finding efficiency in the low-energy band of emulsions should also be investigated

Reference

Hyper-track selector nuclear emulsion readout system aimed at scanning an area of one thousand square meters

- Masahiro Yoshimoto, Toshiyuki Nakano, Ryosuke Komatani, and Hiroaki Kawahara etc...