DEMONSTRATION OF NRF-CT IMAGING BY LASER COMPTON BACKSCATTERING GAMMA-RAYS IN UVSOR

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Outline

1. Introduction
2. Demonstration Experiment in UVSOR
3. GEANT4 simulation
4. Conclusions

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ELI-NP : Gamma Beam Application

A. Industrial applications based on NRF

- **Nuclear safeguard and waste management (U, Pu, Cu, Pb)**
- Food contamination (Cd, Hg, As > 0.1 mg/kg)
- Medical applications (cancer screening with ^{39}K density, and Fe level count in a liver)
- Material inspection

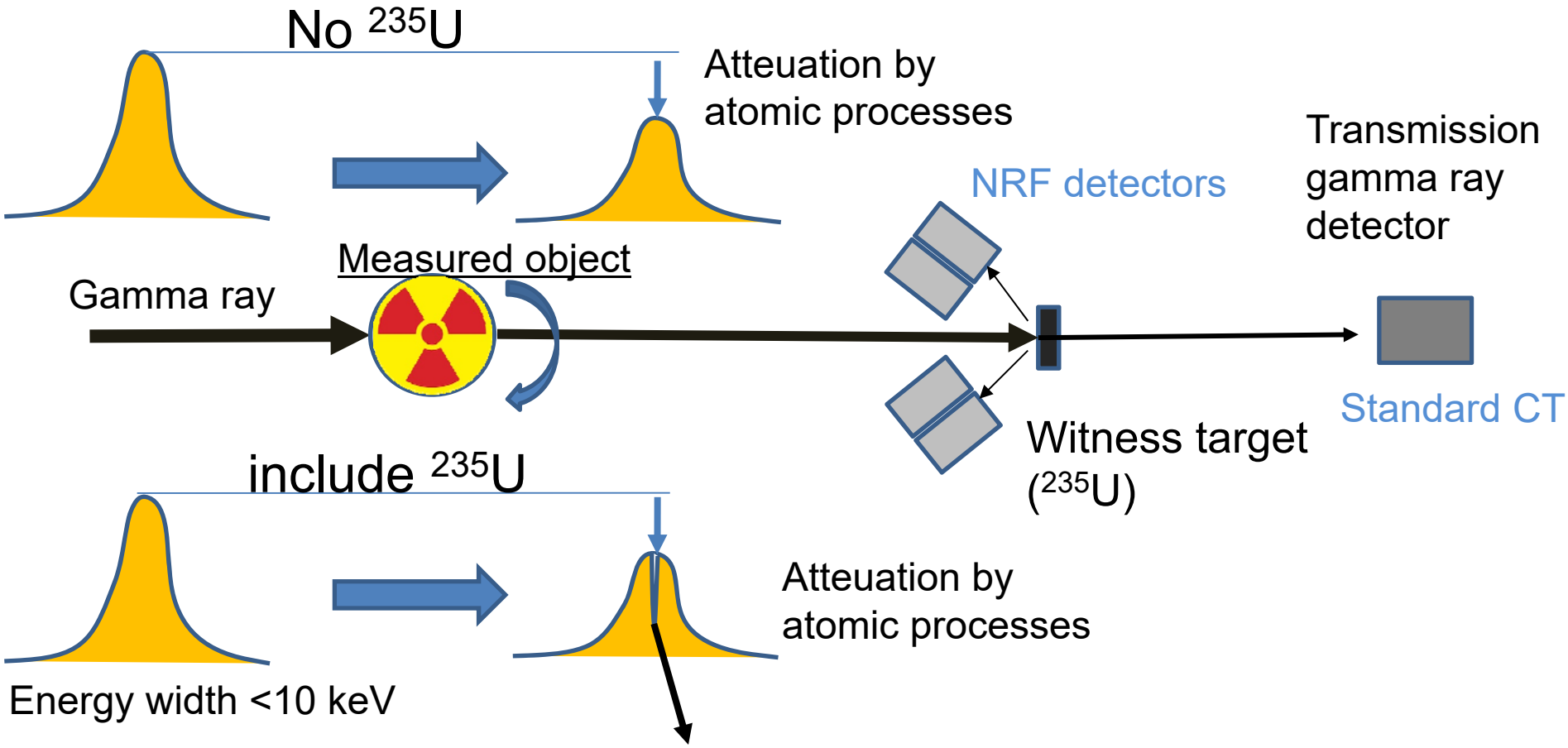
B. Industrial Radiography and Tomography

Transmission experiments (gamma ray attenuation)

Imaging large and/or complex objects with high resolution

Proposed NRF based isotope-CT

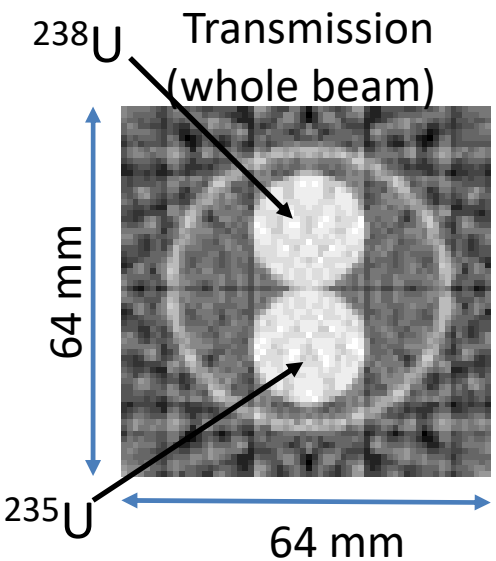
Proposed Method : Absorption NRF-CT



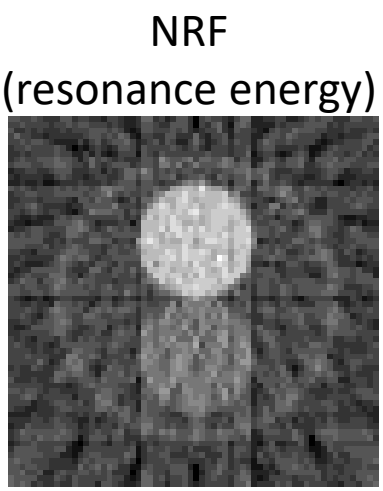
+ Absorption by ^{238}U nuclear resonance (δE ~ eV)

Image Reconstruction
(GEANT4 simulation)

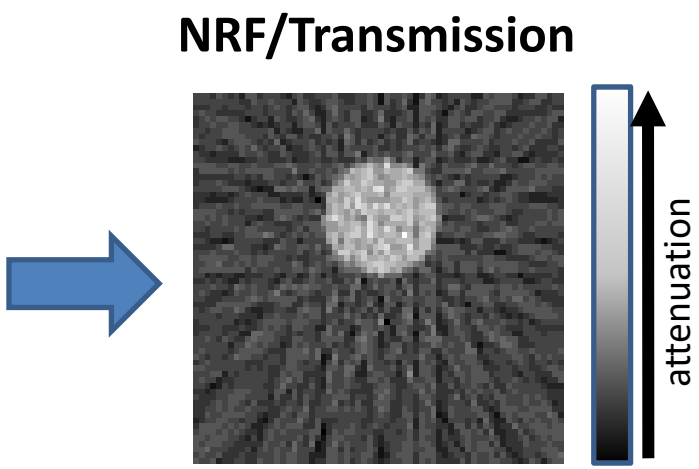
Pixel size 1 mm × 1 mm (= beam diameter)
12 Projection Angle (15 degree step)
about 21 hours measuring time@ELI-NP



Atomic process



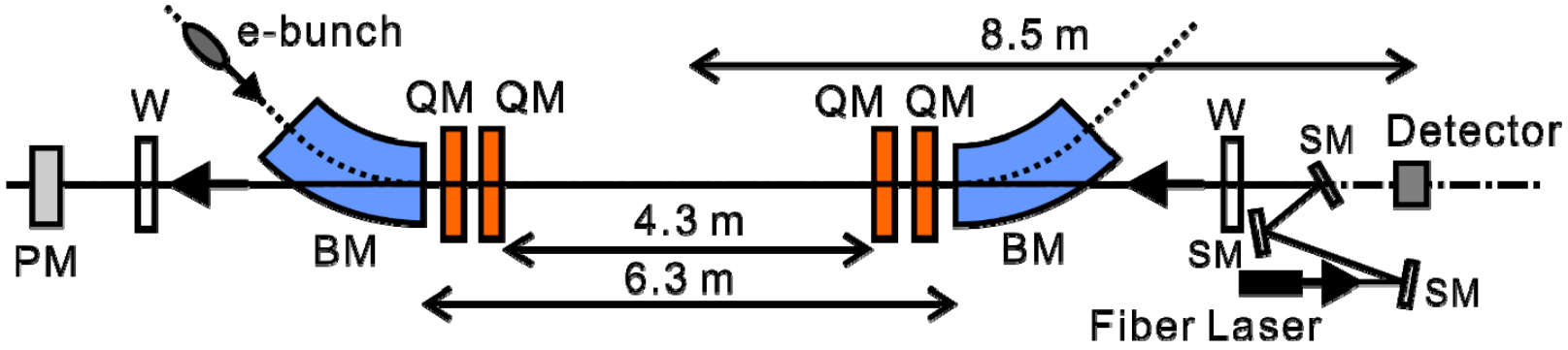
Atomic + NRF process



^{238}U isotope distribution

I. Daito et al., Energy Procedia 89 (2016), 389 – 394.

Demonstration Experiment in UVSOR



UVSOR-III Storage Ring

Beam Energy : 750 MeV
Normal Beam Current : 300 mA
Energy Spread : 5.26 x 10^{-4}
Natural Emittance : 17.5 nm-rad

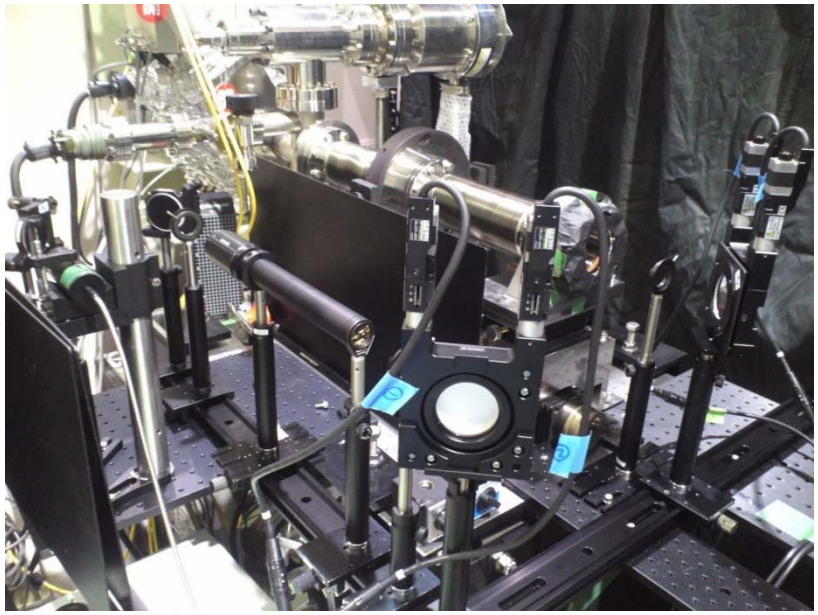
Fiber Laser

Wavelength : 1.94 μm
Maximum Power : 5 W (CW)
Beam Quality, M^2 : < 1.1
Output Polarization : Linear

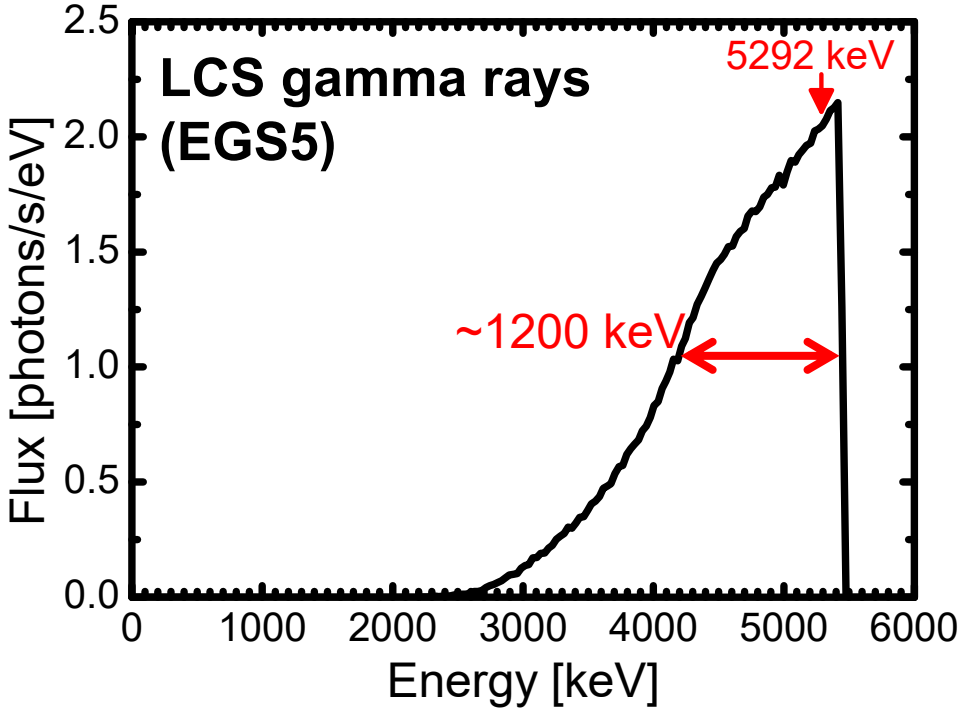
Gamma-ray parameter

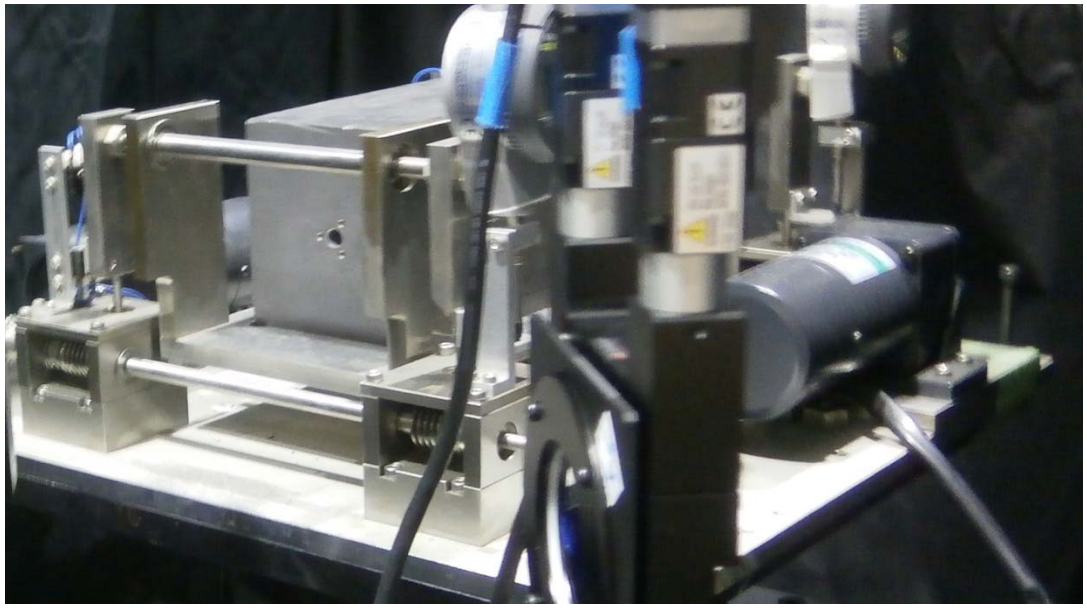
- Maximum γ-ray energy : 5403 keV (e-Beam Energy : 746 MeV)
- Evaluated total flux : ~1 x 10^7 ph/s (wo collimator)

Gamma beam



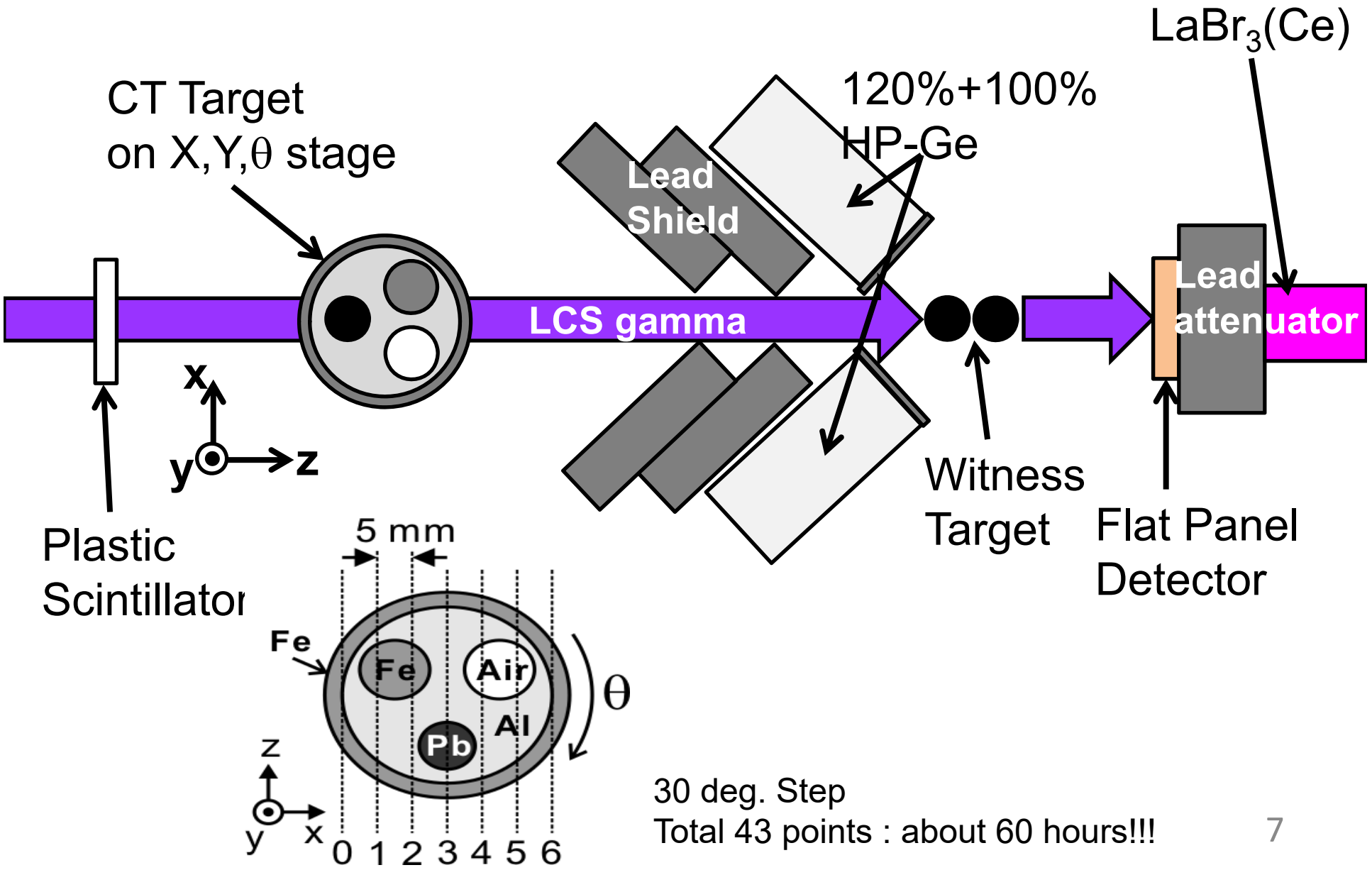
↑**Laser optics**





Collimator (8mm)→

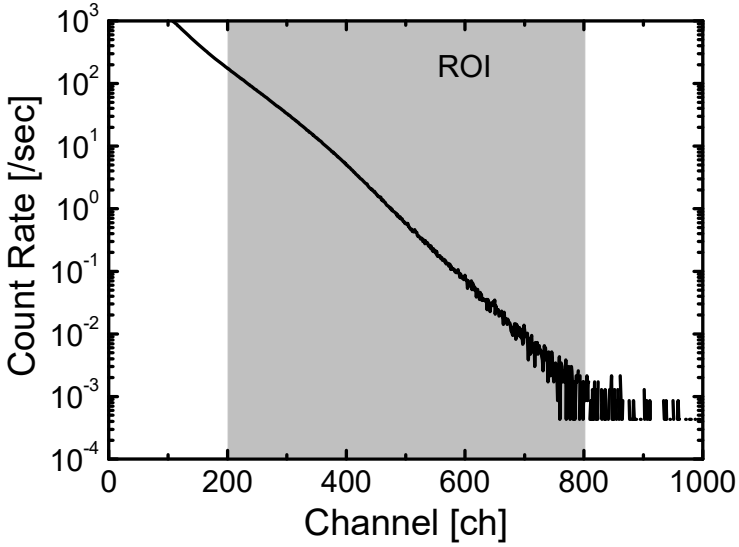
Setup



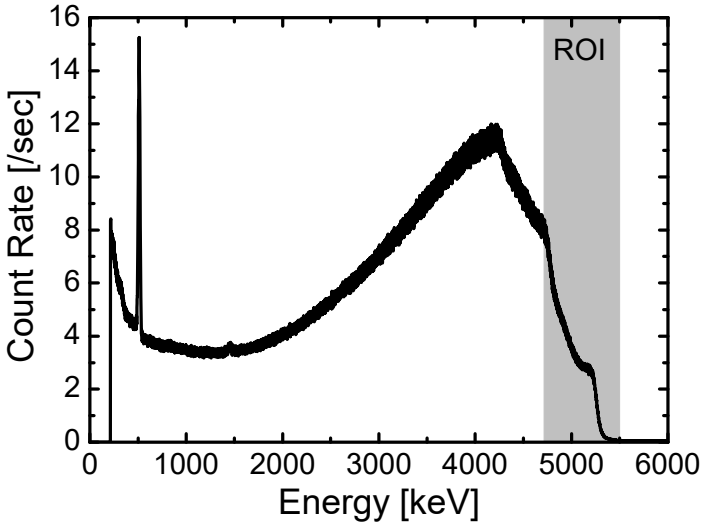
30 deg. Step
Total 43 points : about 60 hours!!!

Spectrum

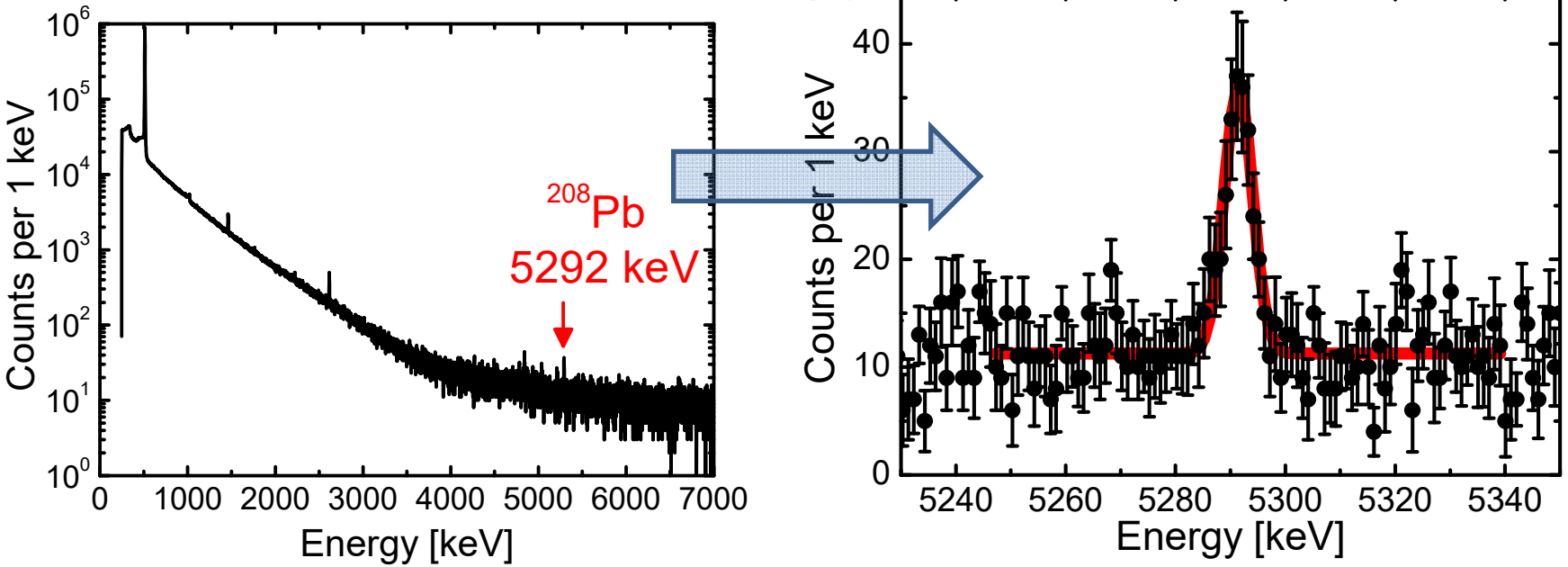
Plastic Scintillator



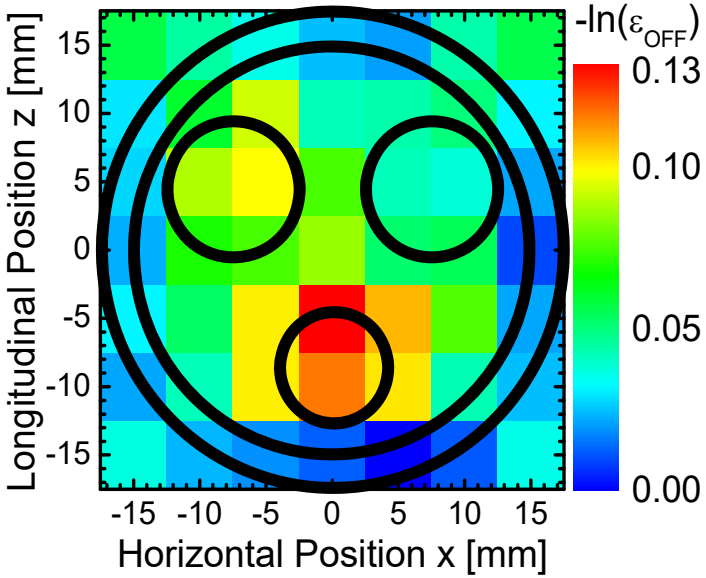
$LaBr_3(Ce)$

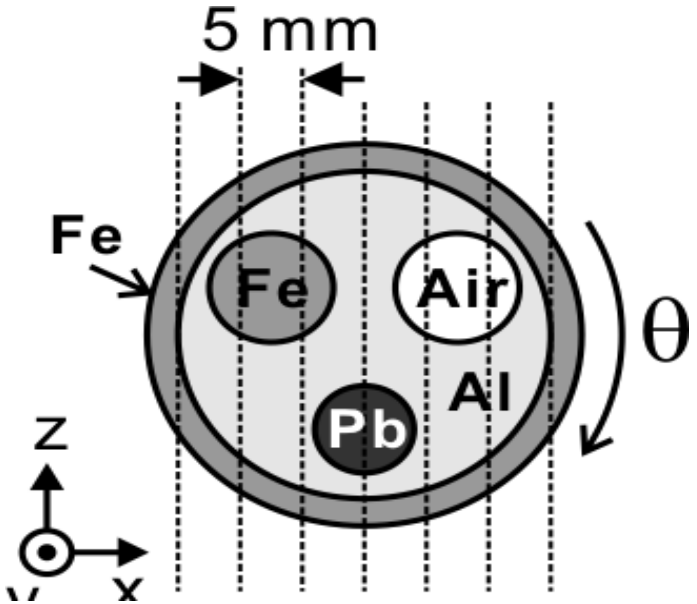


HP Ge

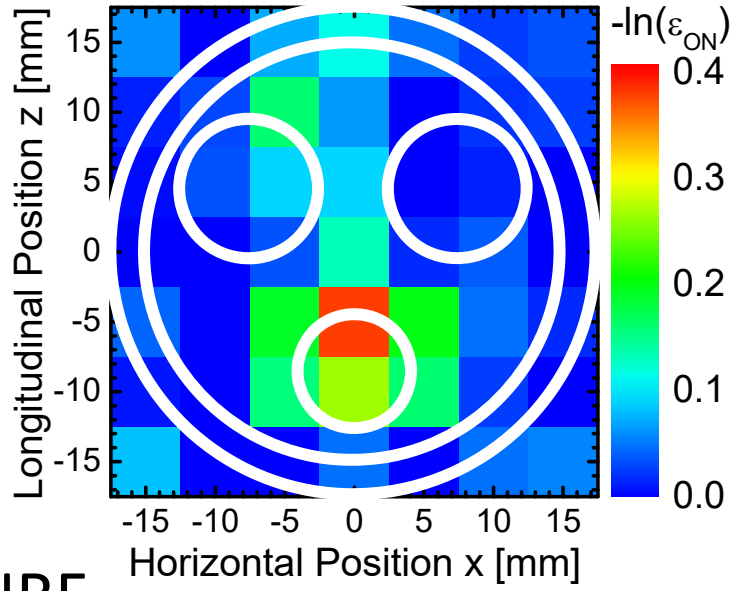


Transmission (atomic)

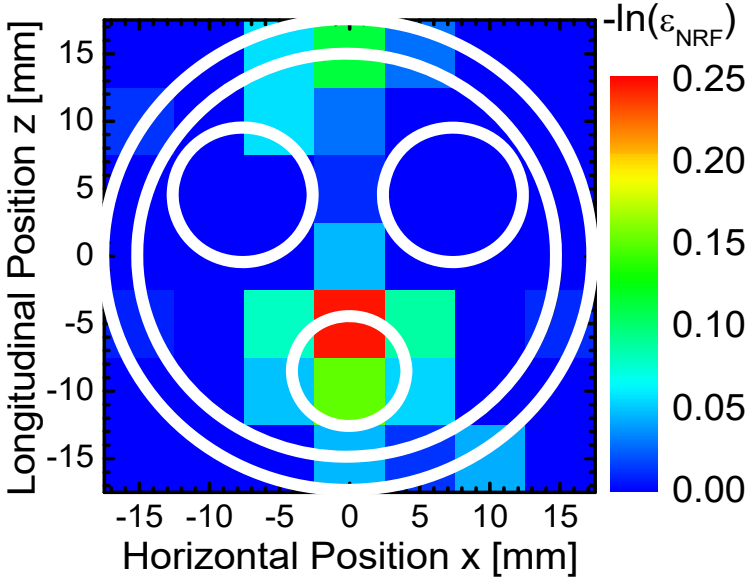




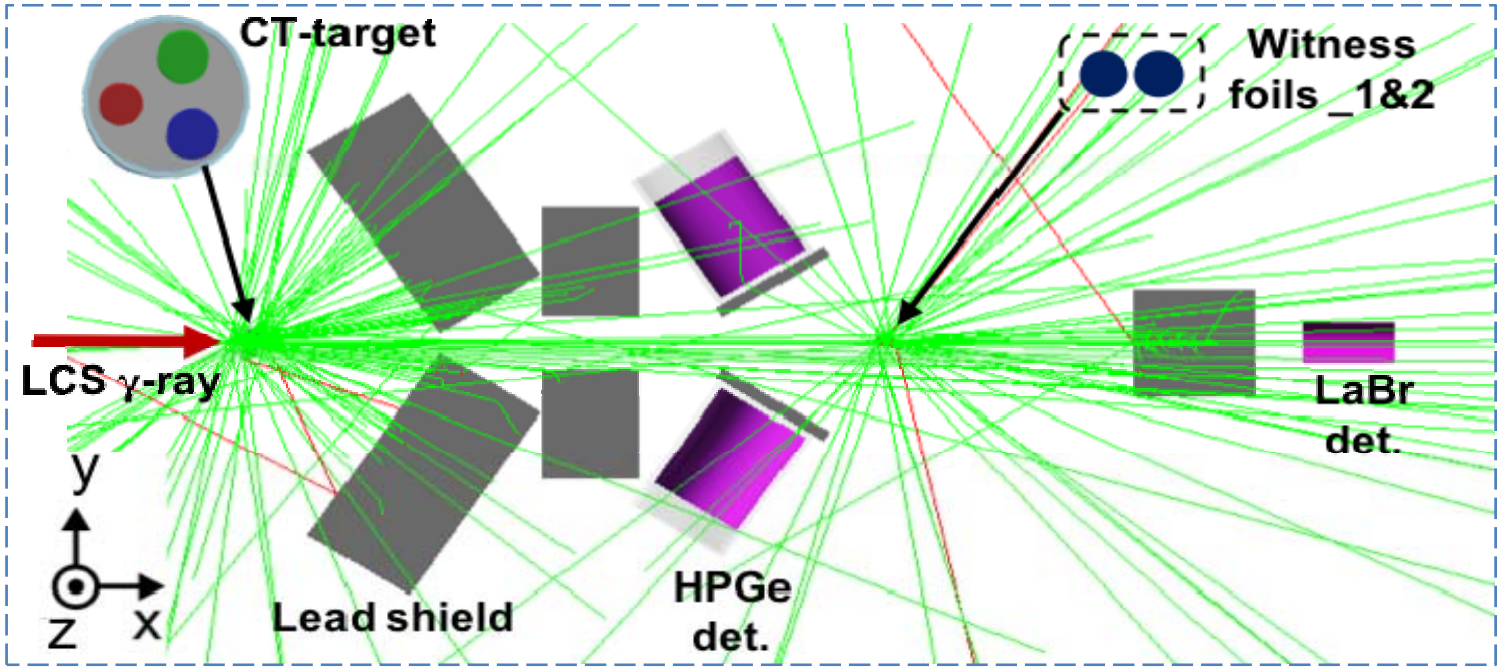
NRF + atomic



NRF



GEANT4 simulation



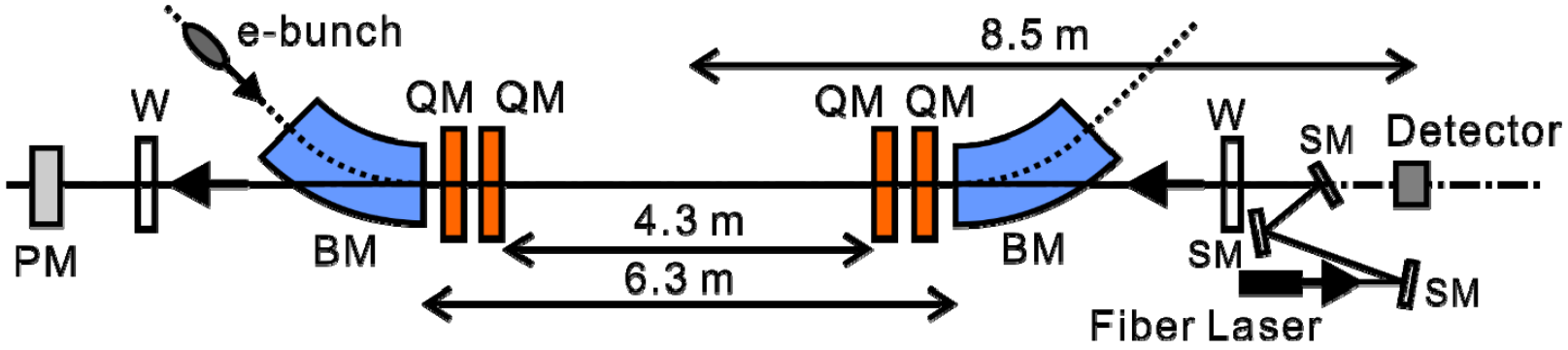
Benchmark test of the NRF part

⇒ Optimization of experimental setup

⇒ Estimation of measurement time

⇒ Estimation of image resolution and accuracy (detection limit)

LCS Gamma-rays in UVSOR : 2018 plan



Fiber Laser 2018

Wavelength : 1.896 μm
Maximum Power : 50 W (CW)
Beam Quality, M^2 : < 1.1
Output Polarization : random

Gamma-ray parameter

- Maximum γ-ray energy : **5528 keV** (^{208}Pb 5512 keV level)
- Evaluated total flux : >~1 x 10^7 ph/s (wo collimator)

Conclusions

- LCS-NRF based isotope-CT

  -demonstration experiment in UVSOR

  Lead (^{208}Pb 5.29 MeV level), Iron, Al

  NRF = (NRF + Atomic) / Transmission

  improve image : 2D interpolation,
  fine step

  -GEANT4 simulation in Kyoto

  Upgrade exp. in UVSOR: laser, ^{206,208}Pb

collaborators

- T. Kii, H. Zen, (I. Daito), H. Negm : Kyoto University
- H. Toyokawa, Y. Taira : National Institute of Advanced Industrial Science
- T. Hayakawa, T. Shizuma : National Institutes for Quantum and Radiological Science and Technology
- M. Katoh, J. Yamazaki : Institute for Molecular Science

In cooperation with ELI-NP : GB Industrial application team (V. Iancu, G. Suliman, M. Iovea and Calin)

We are waiting for ELI-NP operation!!