GAMMA RAY GENERATION FOR NUCLEAR TRANSMUTATION

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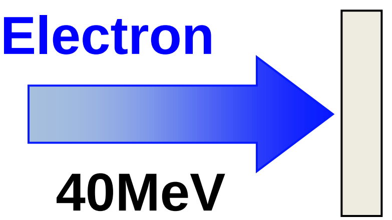
FP and TRU Nuclei for **Transmutation**

Nuclei	Half decay (year)	Neutron cross section (b)	Production (Ci／year)	Amount (kg／year)
FP				
85Kr	11	1.7	3.0×10^5	0.79
90Sr	29	0.014	25×10^6	17.8
93Zr	1.5×10^6	2.6	61	24.0
99Tc	2.1×10^5	20	433	25.5
107Pd	6.5×10^6	1.8	3.6	7.0
129I	1.6×10^7	27	1.0	5.8
135Cs	2.3×10^6	8.7	13.5	11.7
137Cs	30	0.25	3.5×10^6	39.5
151Sm	90	15000	1.1×10^4	0.4
TRU				
237Np	2.1×10^6	181	11	14.4
241Am	432	603	5.0×10^3	1.46
243Am	7380	79	601	3.03
243Cm	28.5	720	55	0.01
244Cm	18	15	5.8×10^4	0.72
245Cm	8500	2347	4.1×10^3	0.03

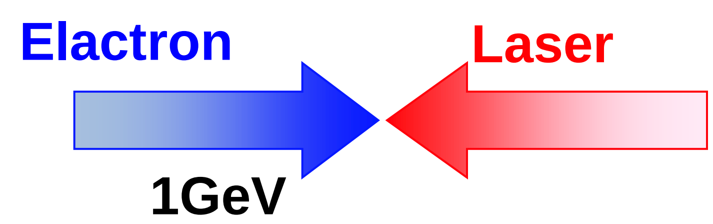
L- life FP and TRU are objects to transmutation as for 129I,99Tc and 237Np and so on.
There is long life nuclei of small neutron cross section so on.
They are the targets for gamma ray transmutation,

Compton Gamma: More efficient coupling for E1 G— R than Bremsstrahlung

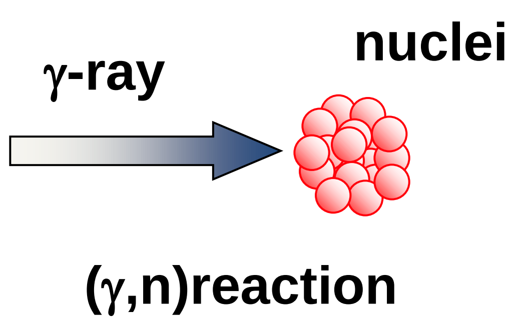
Bremsstrahlung

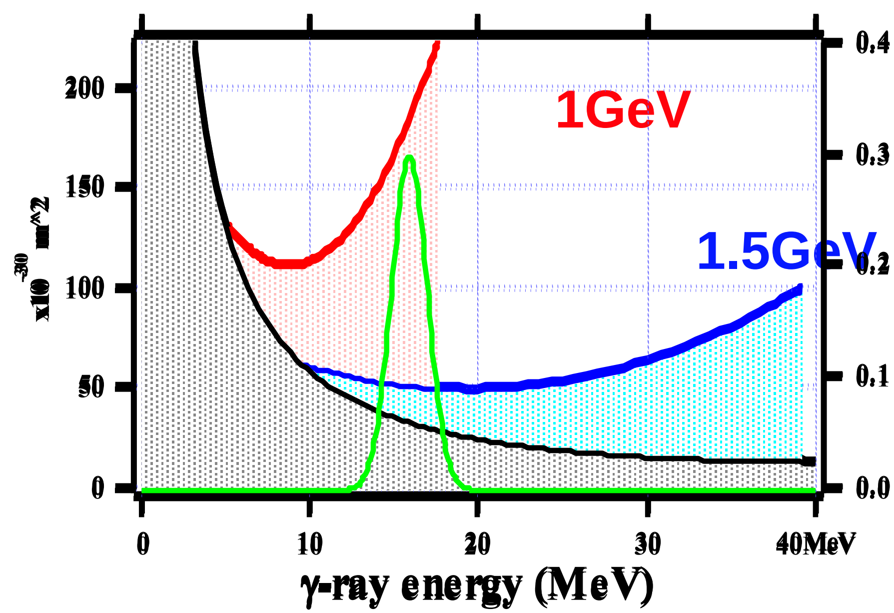


Compton Scattering Gamma Ray

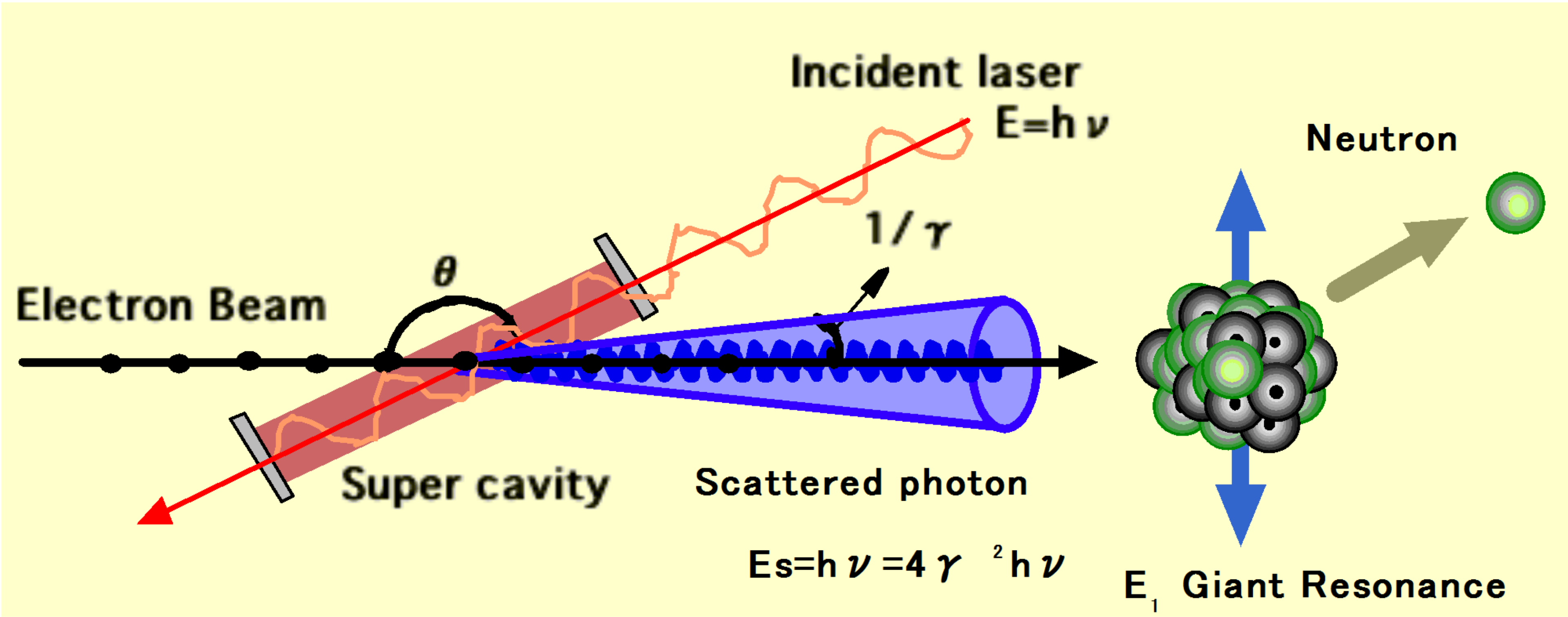


Giant resonance

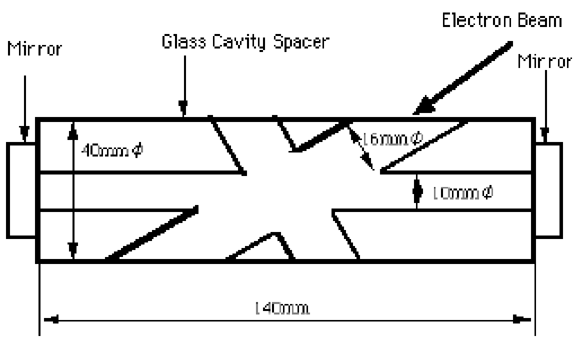


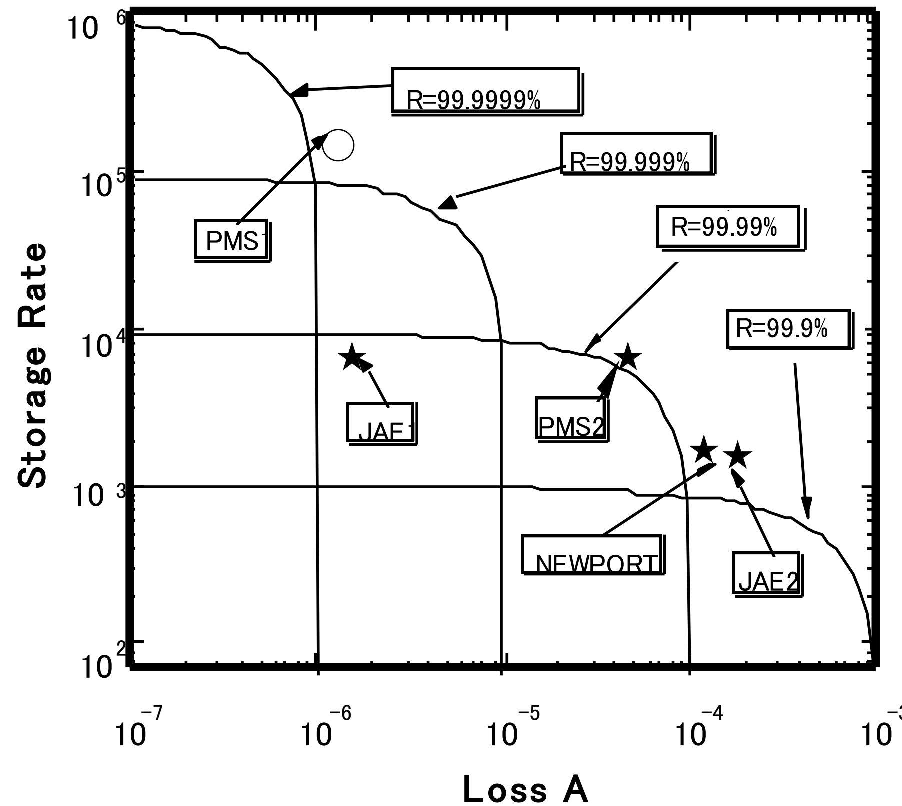


TRANSMUTATION
byγray in a super-cavity



Storage Cavity and Rate





Principals of this scheme are simple and well proofed

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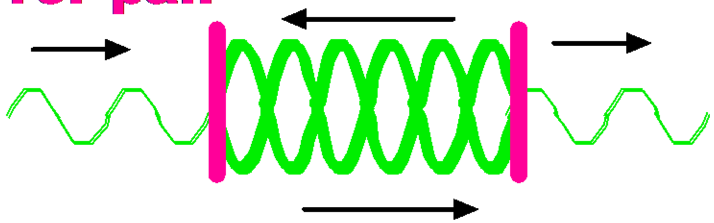
Cavity with high reflective mirror pair



Laser light accumulation: 10000

Compton Scattering of accumulated laser and storage electron in the cavity.

Electron

γ^2

Gamma-ray of $4h\nu\gamma^2$

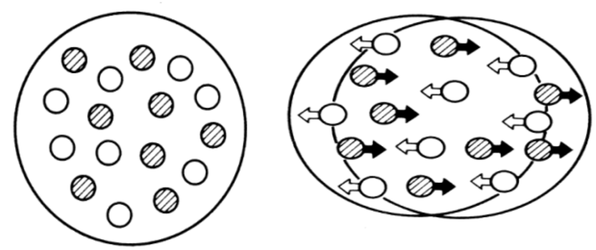
with $1/\gamma$ solid angle

Giant resonance is well known reaction as (γ,n).

Cross section and scaling are investigated.

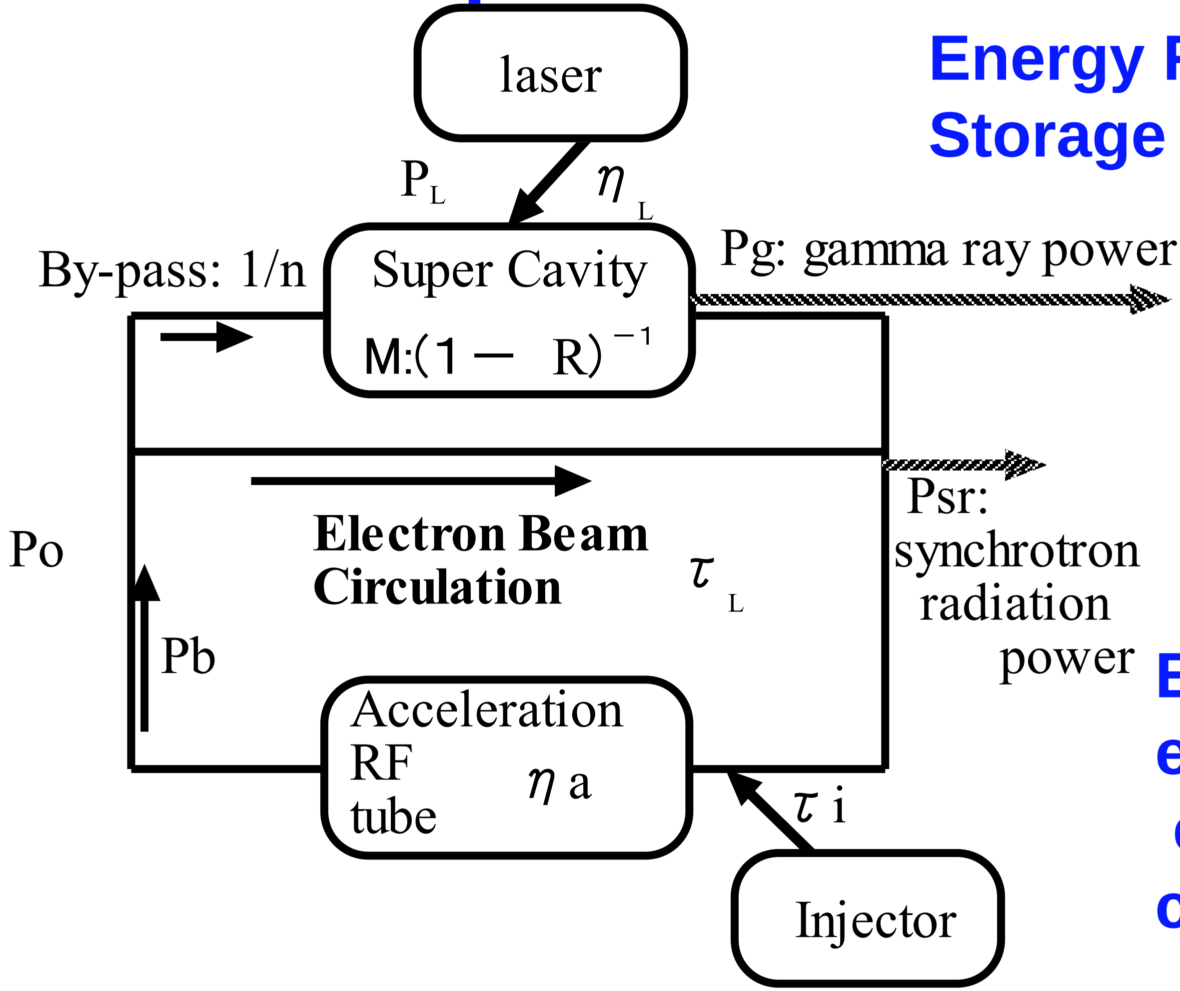
We will apply the gamma ray to this reaction.

The required energy range is about 17MeV.



Giant resonance

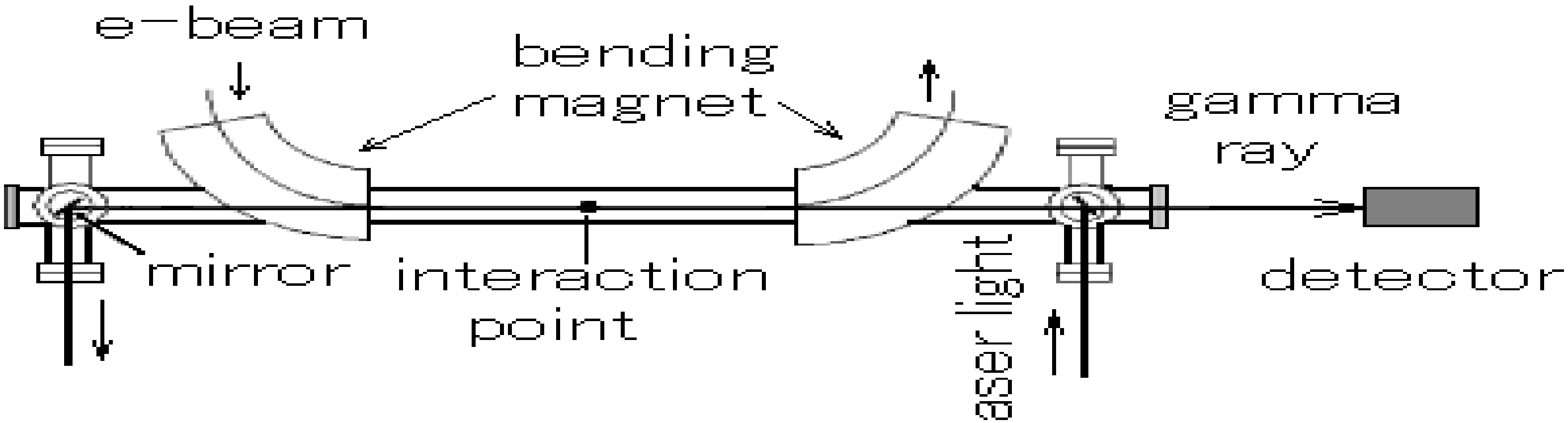
Principal of Total System　1



Energy Recovered Linac/ Storage Ring with by-pass

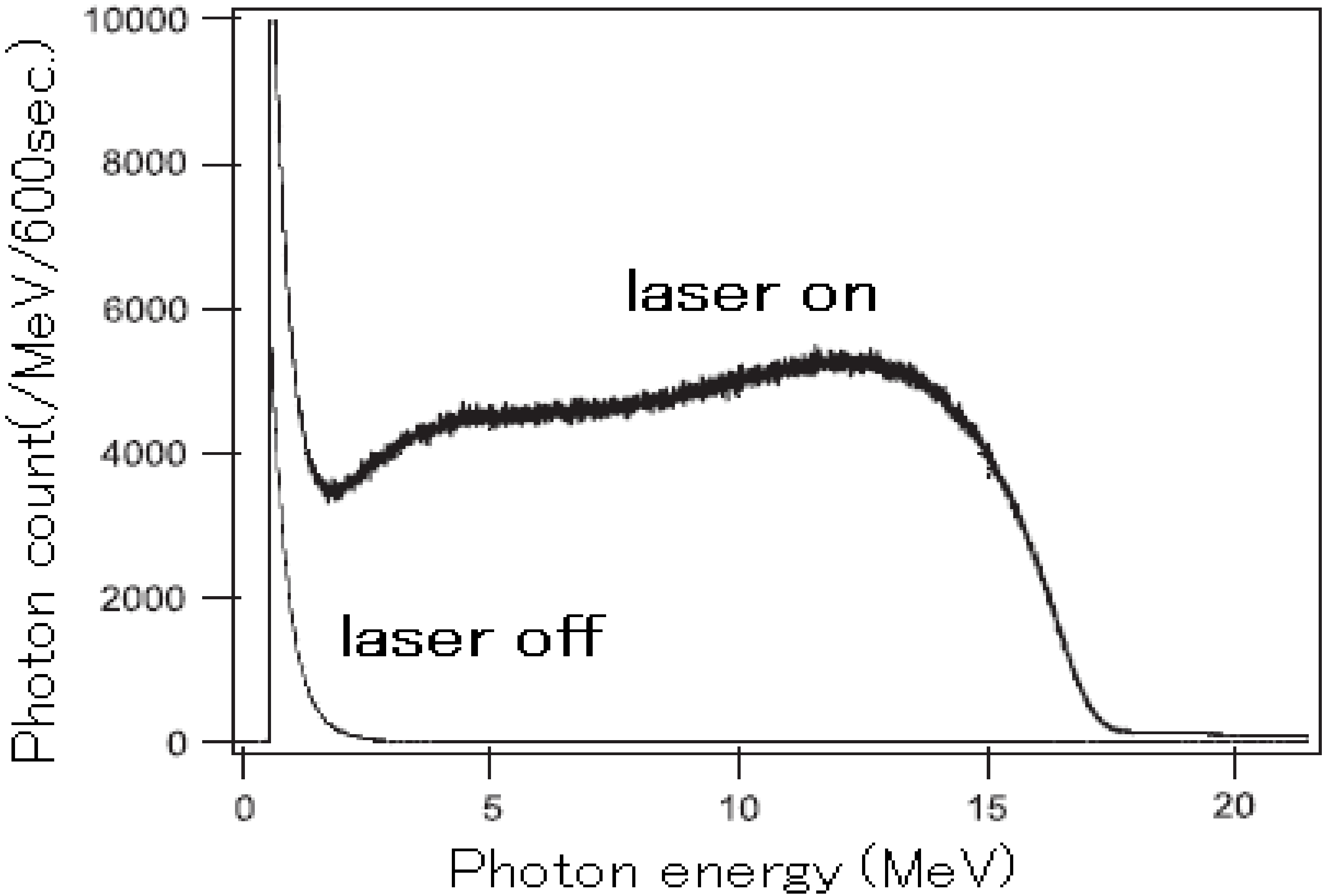
Efficient Conversion is expected when the electron beam is circulated.

γ ray is irradiated from 15m distant point



The laser is installed at the outside of the shielding wall and is injected into the vacuum duct using six mirrors deliberately arranged and a convex lens with focal length of 5 m in a well-designed position, 7.5 m away from the laser and 15 m away from the center point of the straight section. This results in a focused spot of light with radius of 0.82 mm. The electron beam size is determined by the function and emittance. For the NewSUBARU storage ring, at the center point of the straight section, these parameters are characterized as m, m, nm, and nm, resulting in the electron beam size of 0.30 mm for the horizontal direction and 0.19 mm for the vertical direction. Consequently, the size of electron beam is smaller than that of the laser beam at the interaction point.

Laser on/off of the γ-ray waveform



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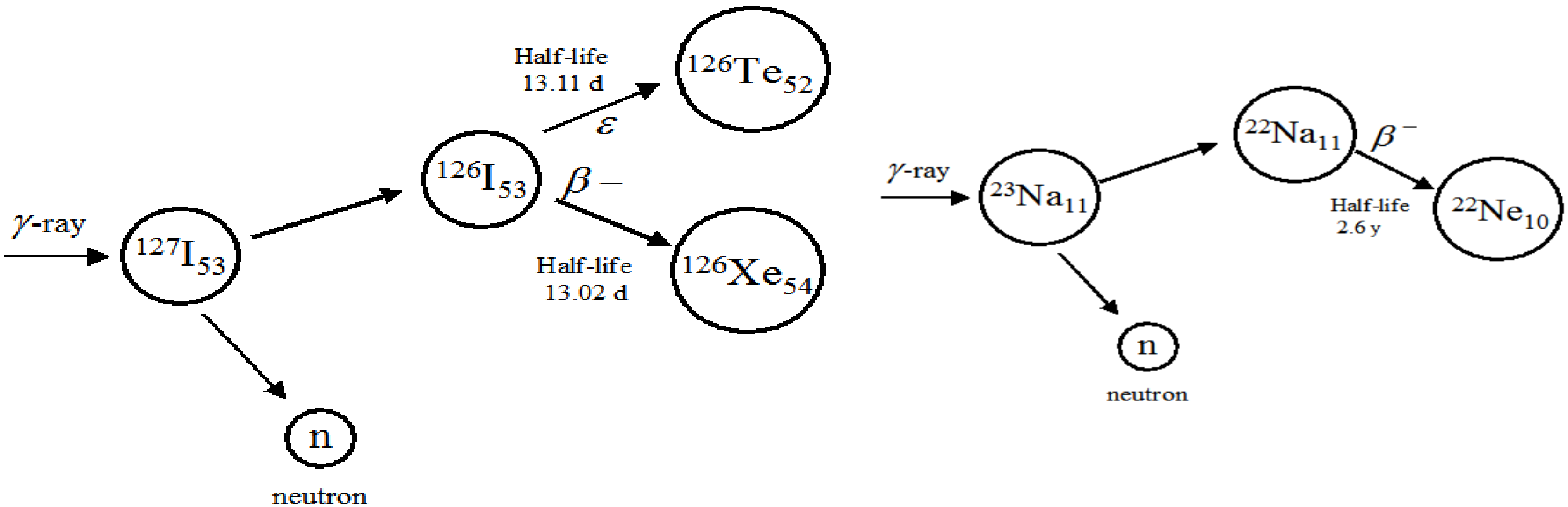
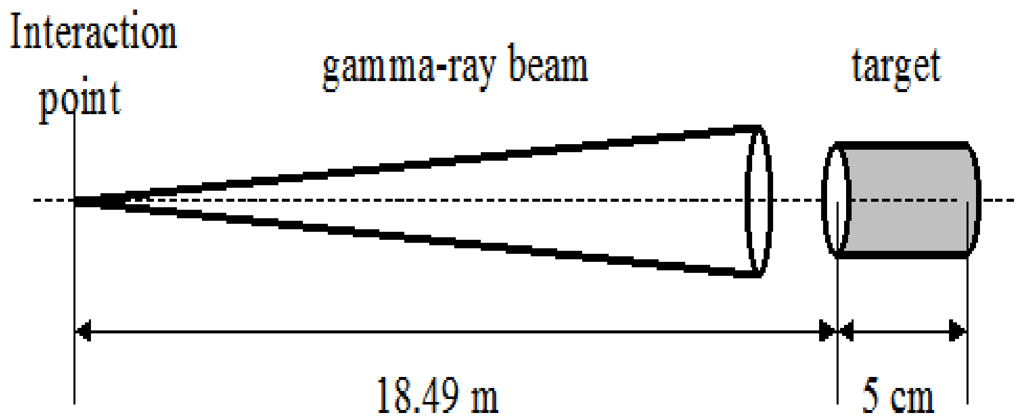
Iodine target with Na(NaI)



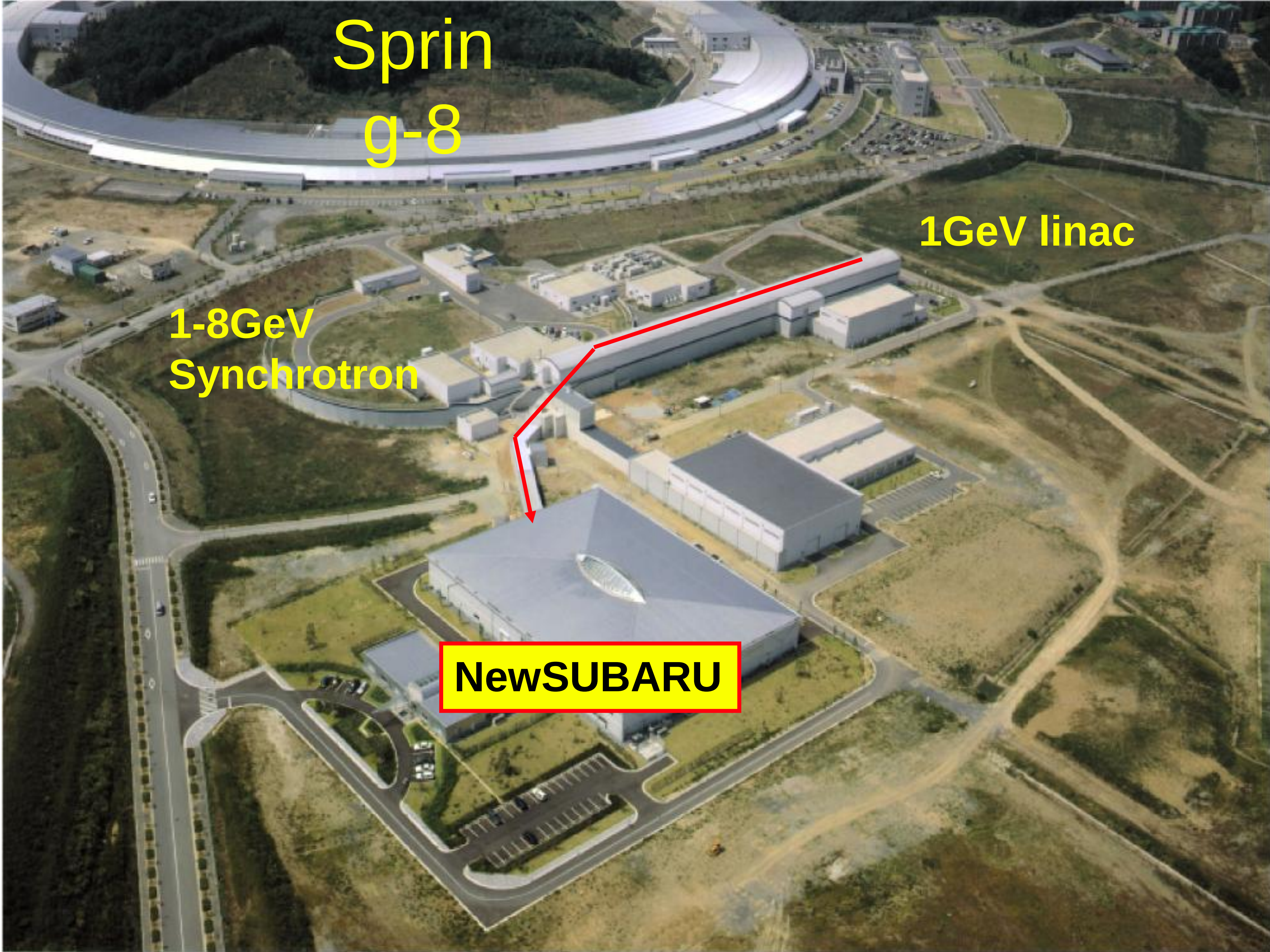
Actually, it is hard to use the target of ^{129}I directly because of its hazard. Instead, we consider ^{127}I for the transmutation experiment since its photonuclear cross section is very near to that of ^{129}I. Usually, the pure ^{127}I is unavailable, and its compound, sodium iodide $^{23}Na^{127}I$, is available to make a practical target.

The transmutation processes for ^{23}Na and ^{127}I are given in Fig.3.with absorbing a gamma photon, the ^{127}I nucleus possibly

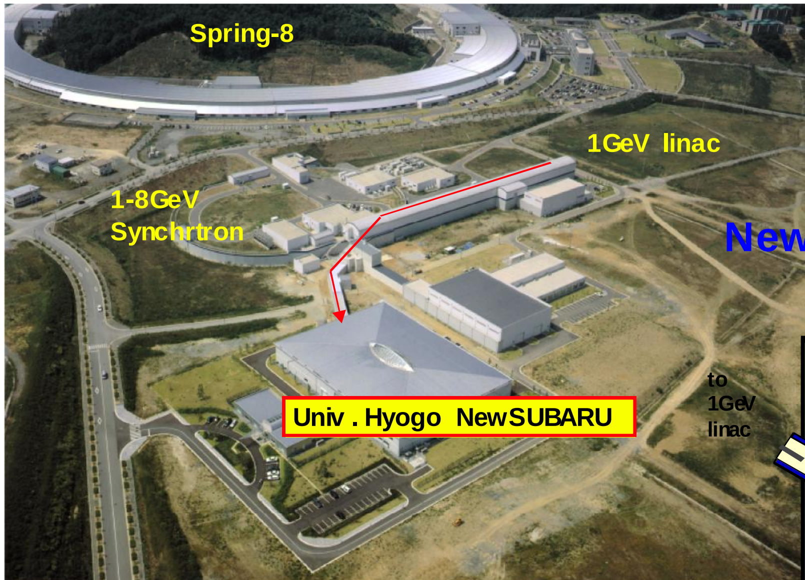
Beam and the target

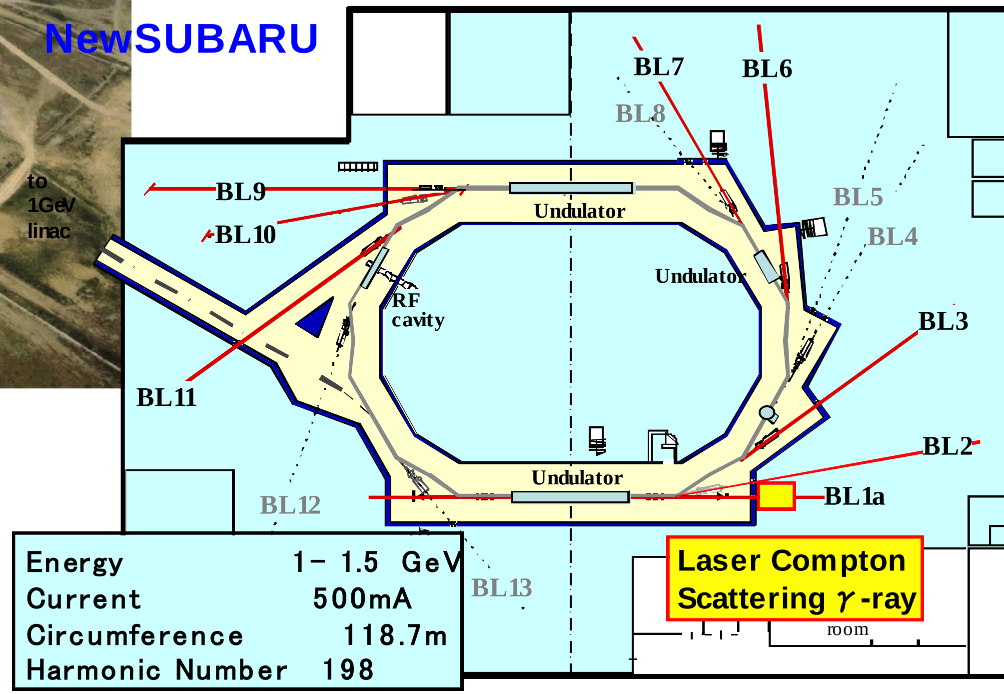


Based on the setup of NewSUBARU LCS gamma-ray, the simulation model is described. A cylindrical target is located at the center of the gamma-ray beam and 18.49 m away from the interaction point of the electron beam and laser light.
The target is taken 5 cm in length, so that most of the gamma-ray photons are absorbed in the target.
According to the definition mentioned above, the reaction rate depends on the target radius.


Sprin
g-8
1GeV linac
1-8GeV
Synchrotron
NewSUBARU

Gamma ray beam
Sharp shooting and tunability





On New Subaru BL1, we obtained 10^{15}/Y photon with 2W CW YAG laser.

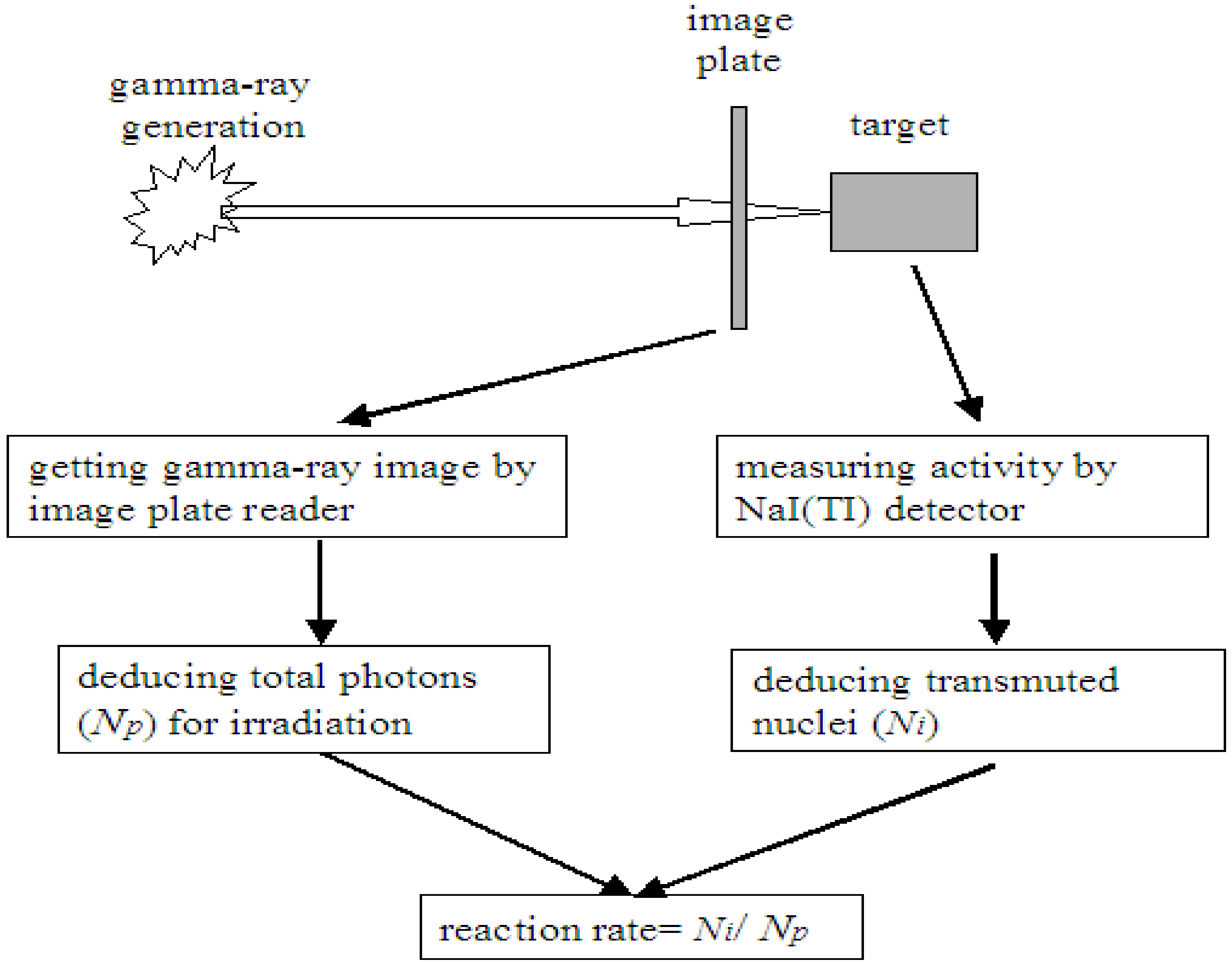


image plate
gamma-ray generation
target
getting gamma-ray image by image plate reader
measuring activity by NaI(TI) detector
deducing total photons (Np) for irradiation
deducing transmuted nuclei (Ni)
reaction rate= $Ni/\ Np$

The gamma-ray is introduced to the hatch from the tunnel to irradiate the target. An image plate is placed before the target. The image plate can record the transited photons, therefore, the total photons enter the target can be deduced.

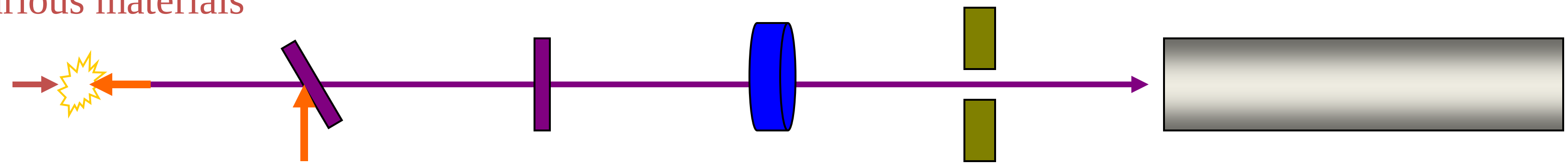
Through the measurement of radioactivity of irradiated target, the number of transmuted nucleus at the terminus of irradiation can be deduced according to the decay law

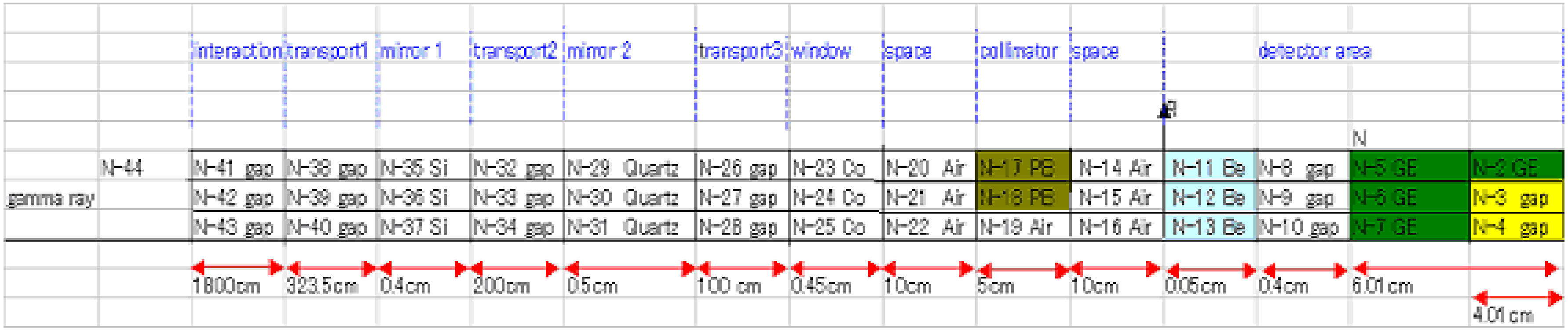
$$N_i = \frac{\Delta N e^{\lambda t}}{1 - e^{-\lambda \Delta t}} \qquad (1)$$

where N_i is the number undecayed nuclei, ΔN is the number of decays in the duration of Δt, λ is the decay constant, and t is the time interval from the end of irradiation to the beginning of activity measurement. The way to get the reaction rate is sketched .

Gamma-ray—ESG4

EGS4 code is employed to simulate the whole interaction process of gamma photons and various materials





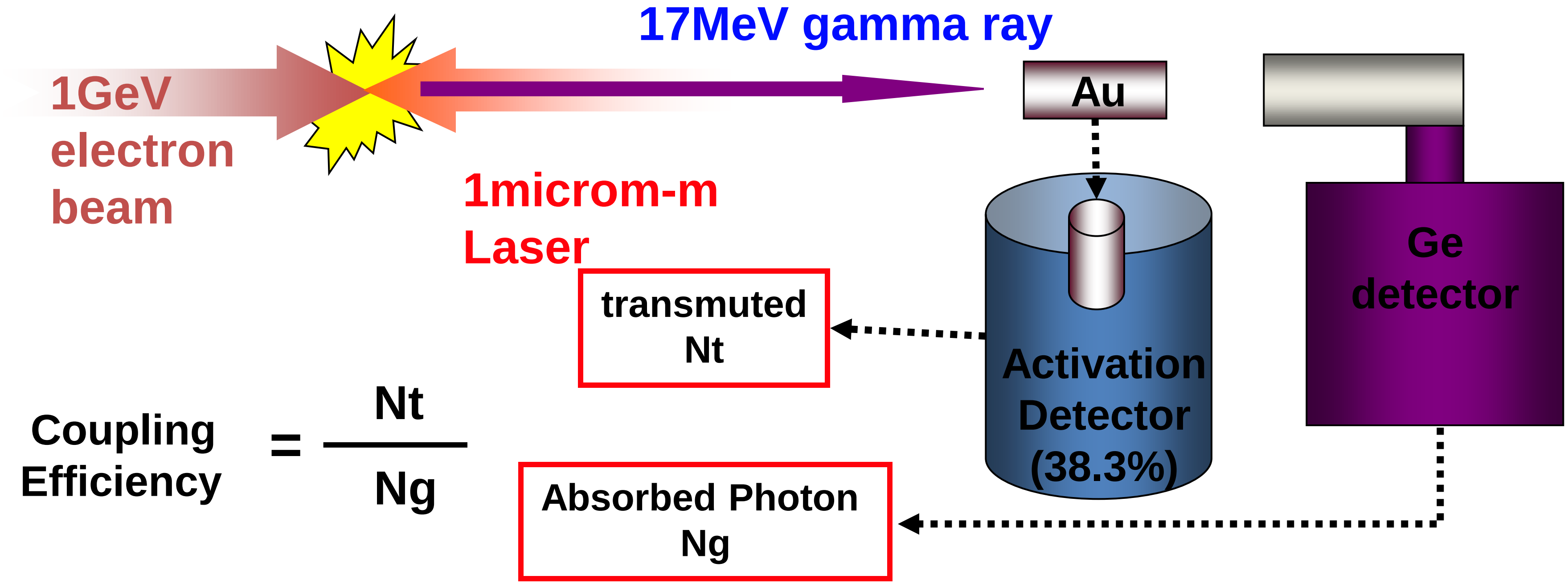
Simulation structure for EGS4 code

Au target to obtain the transmutation rate

target

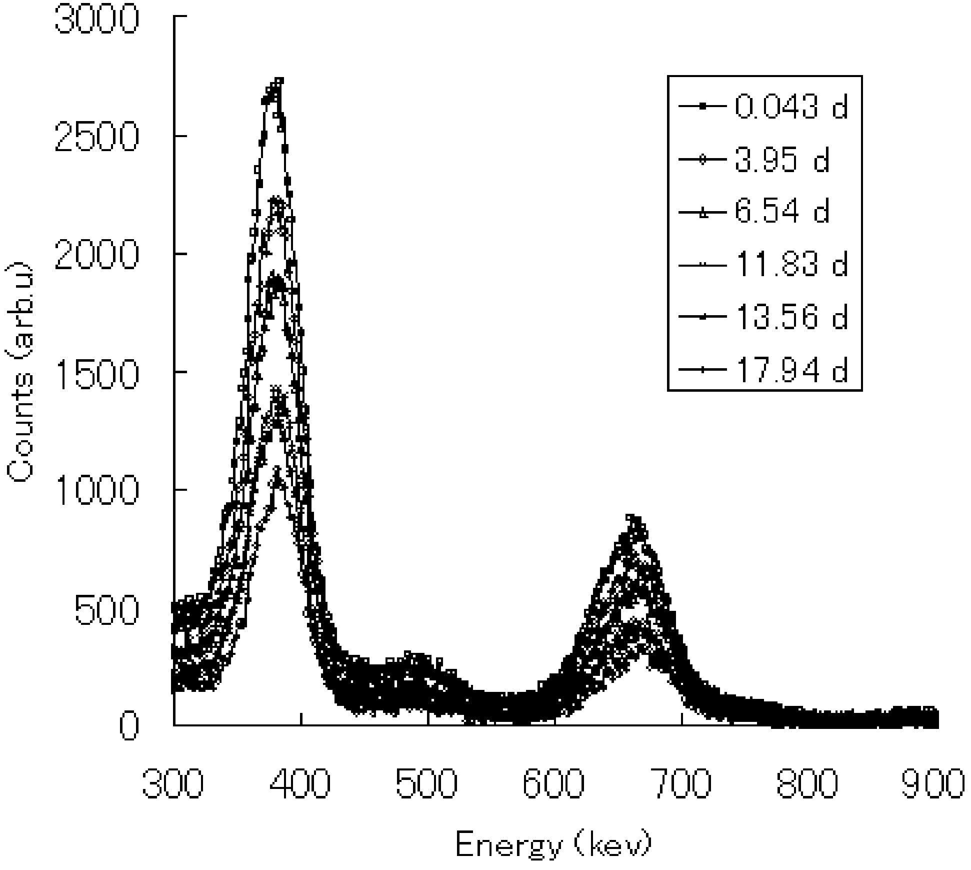
$^{197}Au\ (\gamma,n)\ ^{196}Au$ → EC ⇨ ^{196}Pt (92.5%)

^{196}Au → β^- ⇨ ^{196}Hg (7.5%)

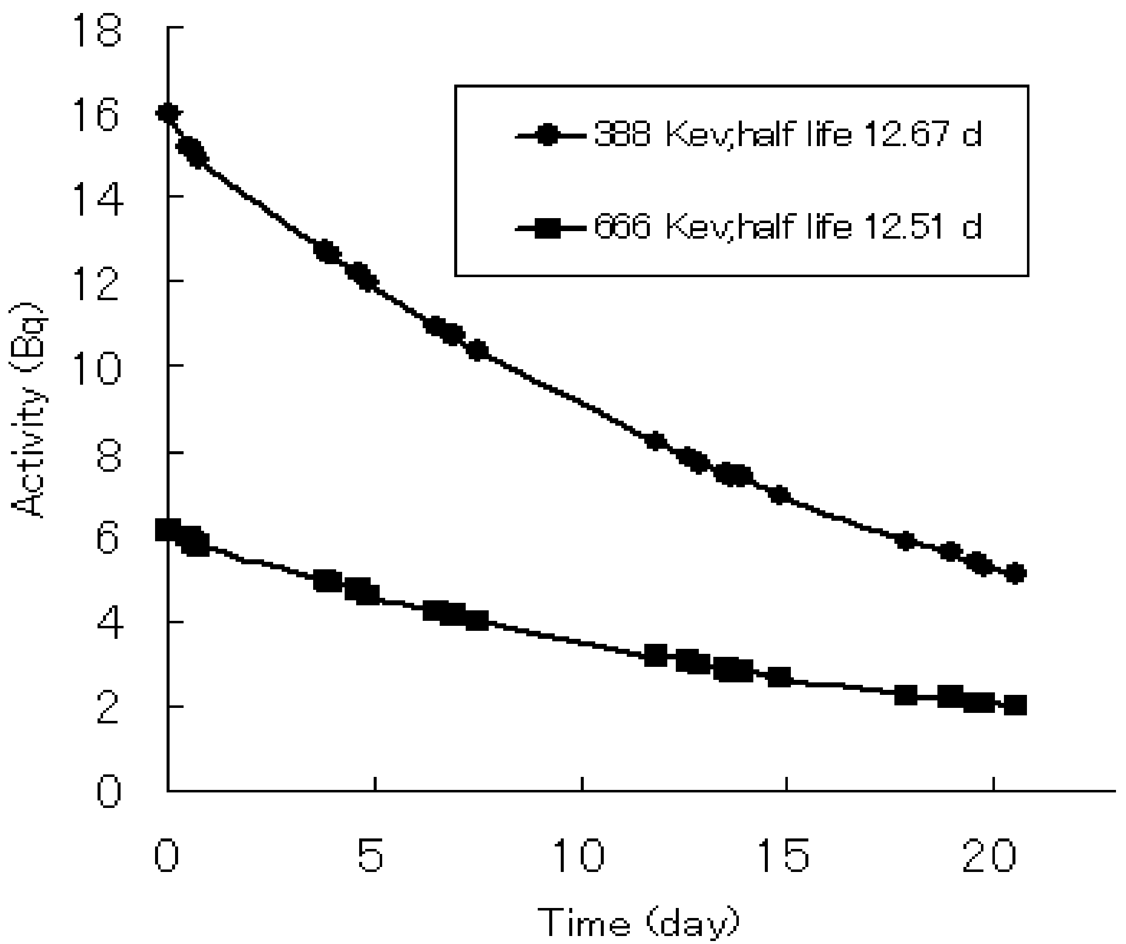


$$\text{Coupling Efficiency} = \frac{Nt}{Ng}$$

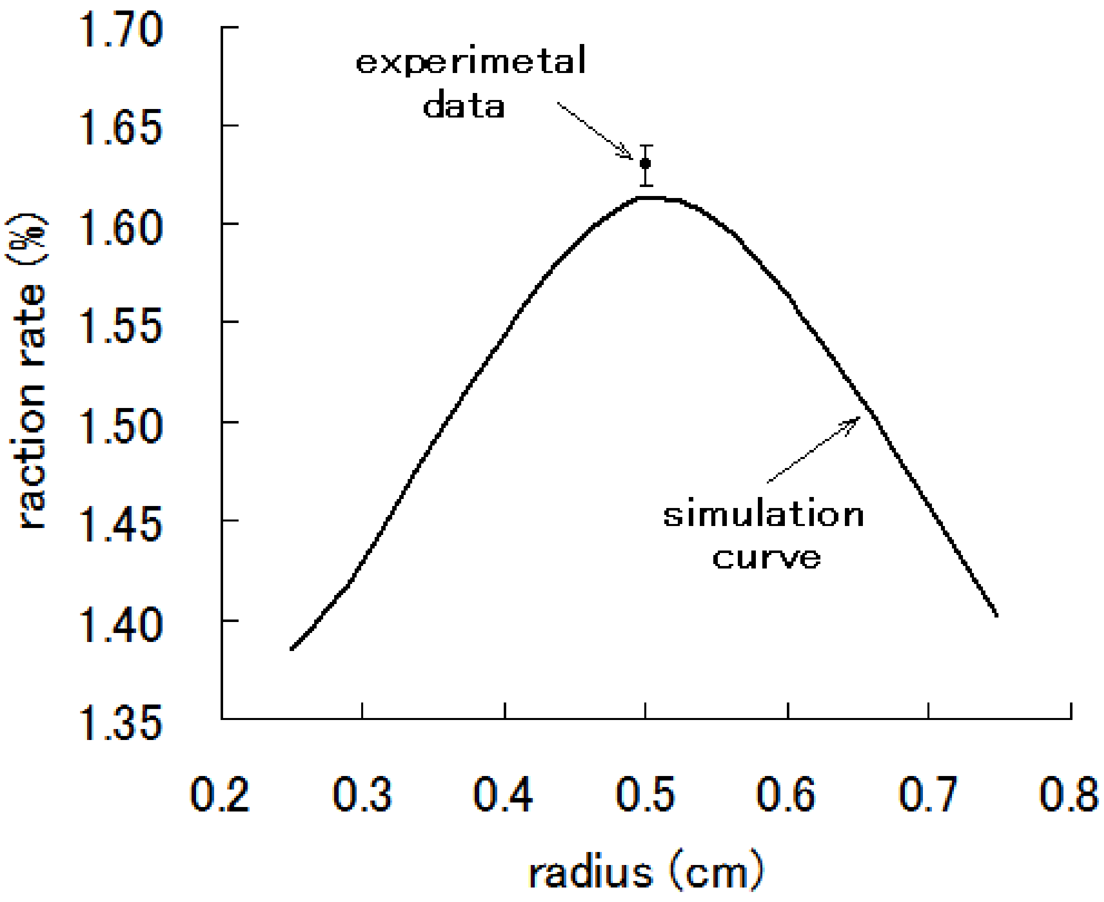
The cylindrical $^{23}Na^{127}I$ target, 5 cm long and 0.5 cm in radius,was irradiated for 8 hours, and the emission spectrum is given.



According to Fig. 6, the decay curve can be worked out as shown. the half-life deduced from our experiment The loss of the radioactivity inside the target was estimated by the MCNP5 code and after data processing



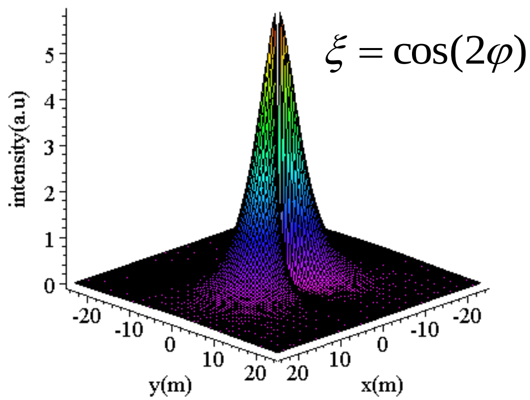
The simulation curve is also plotted for comparison.



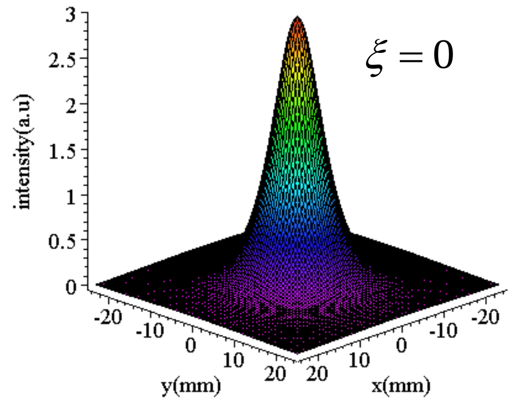
Polarized Effect

$$d\sigma = \frac{8r_e^2}{\varsigma^2}\left\{\frac{1}{4}\left(\frac{\varsigma}{\zeta}+\frac{\zeta}{\varsigma}\right)+(1-\xi)\left[\left(\frac{1}{\varsigma}-\frac{1}{\zeta}\right)^2+\left(\frac{1}{\varsigma}-\frac{1}{\zeta}\right)\right]\right\}\cdot\left(\frac{\hbar\omega'}{mc^2}\right)d\Omega$$

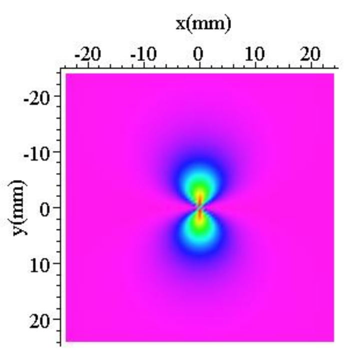
$$\varsigma = 2\gamma(1+\beta)\cdot\frac{\hbar\omega}{mc^2} \qquad \zeta = 2\gamma(1-\beta\cos\theta)\cdot\frac{\hbar\omega'}{mc^2}$$



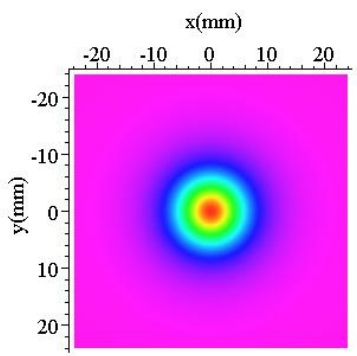
Linearly polarized



Circularly or unpolarized

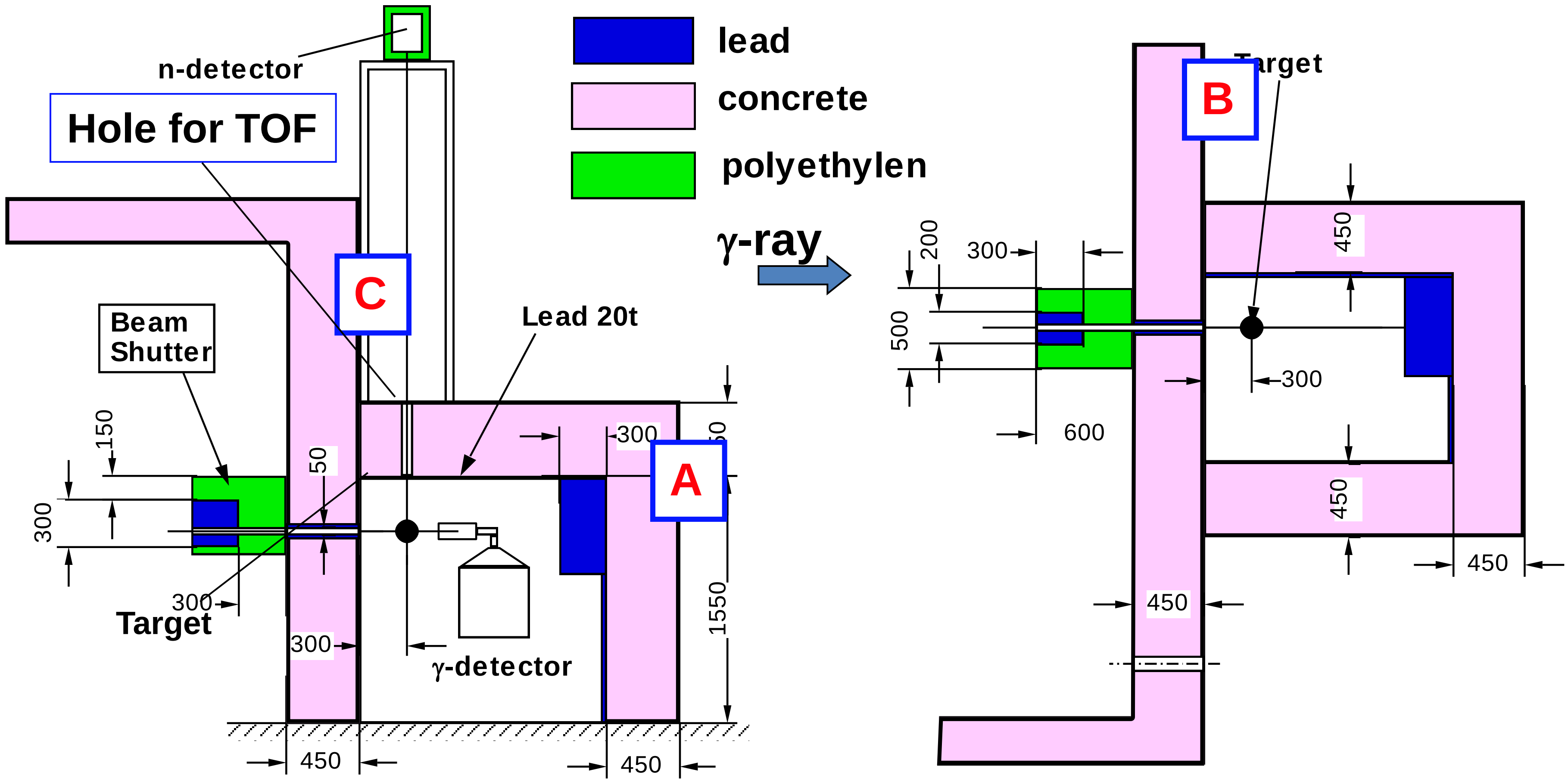


x-y plane hued image



x-y plane hued image

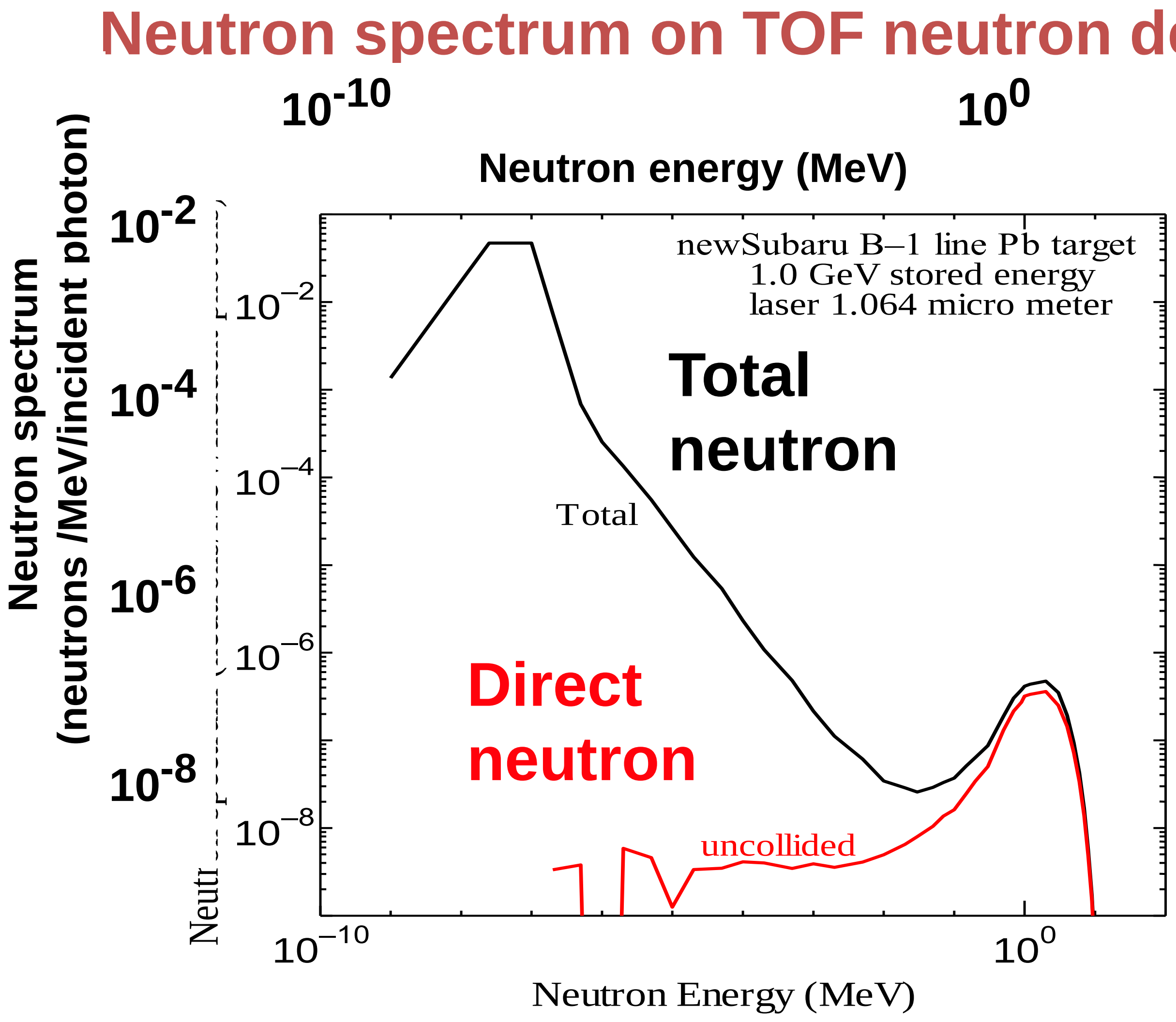
Neutron measurement box for TOF



ELEVATION

PLAN

Neutron spectrum is estimated by TOF for energy balance.



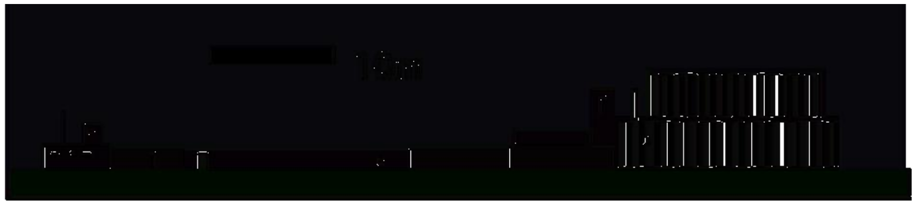
Target(lead)
2cm cubic

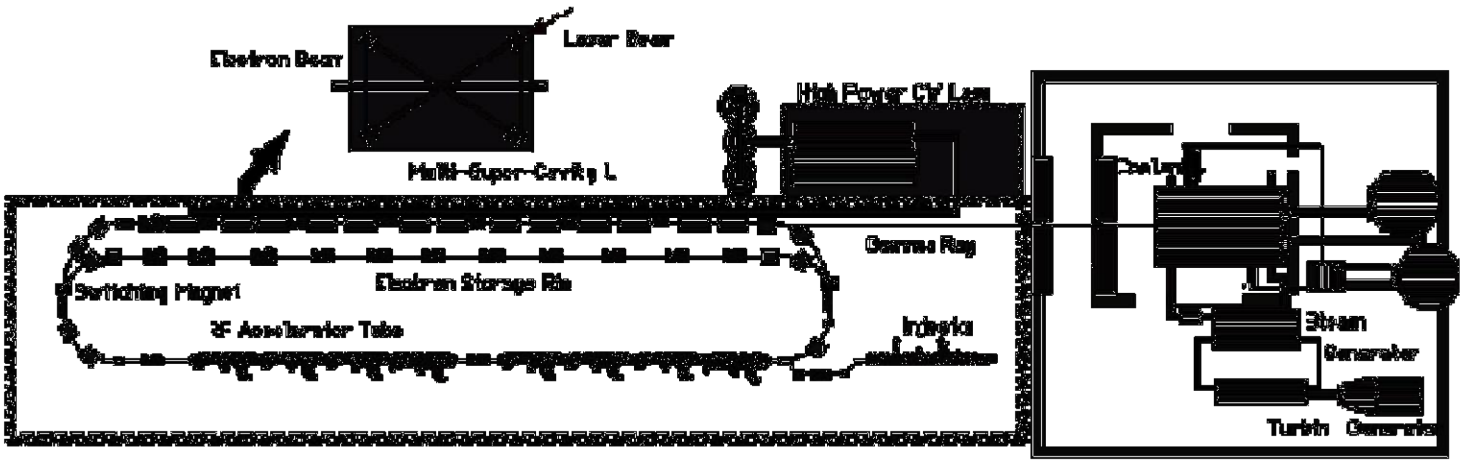
Distance from the target to detector
3.2 m

Stored electron energy
1 GeV

Laser wave length
1.064 μm

γ ray transmutation system





Total efficiency for γ ray generation is close to accelerator efficiency.

Multi-Compton-scattered tail of electron is one of serious issues of the system.

Conclusion

- A scheme of LCS gamma-ray induced transmutation is introduced. The reaction rate of the transmutation plays an important role
- The LCS gamma-ray facility has been built on NewSUBARU storage ring to perform these experiments
- In order to realize a good energy balance, a complex targets set is proposed to utilize the byproduct particles, and related research is going on.
- With the promotion of our detecting system, more precise measurement will be reached in the future.
- (Most of lf-nuclei are transmutationed.)