Transition Radiator

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OUTLINE

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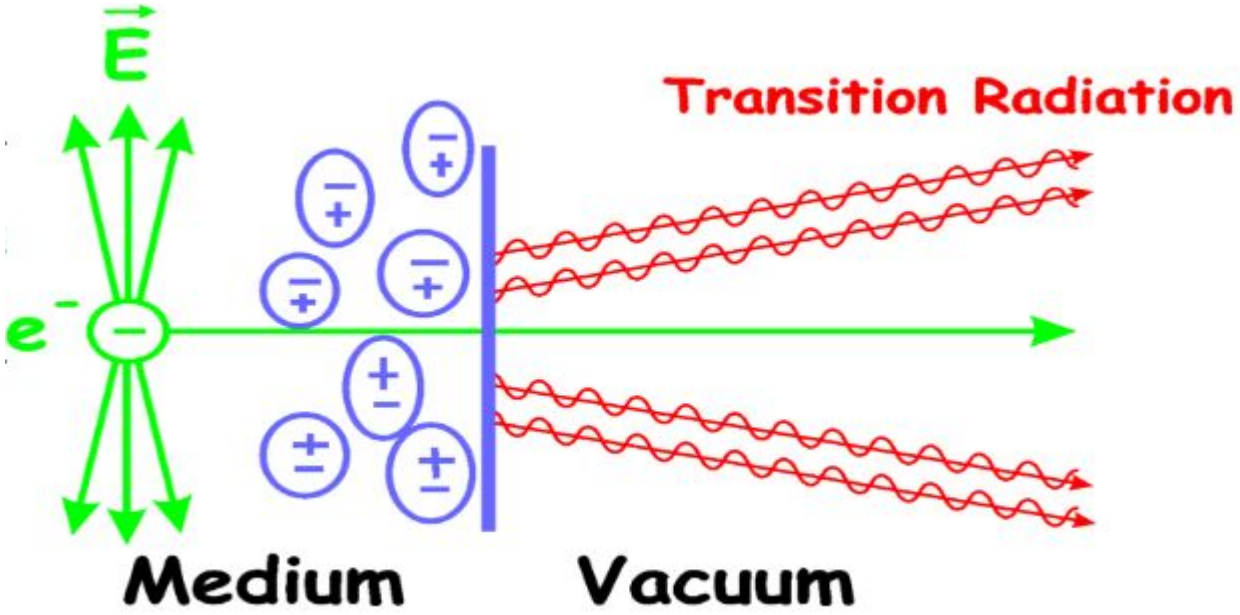
Transition Radiation

- *Transition radiation is the electromagnetic radiation that is emitted when a charged particle traverses the boundary between two media of different dielectric.*



- *When a charged particle passes the boundary between two media of different dielectric, radiation is emitted because the Coulomb field of the particle has to readjust itself.*

Transition Radiation

Characteristics of transition radiation

- Radiation energy is proportional to the energy of the incident particles:

$$W \propto \gamma$$

- The angle of radiation is inversely proportional to the energy of the incident particles: $\theta \propto 1/\gamma$

- Radiation generation and saturation : $\gamma_{\text{threshold}} \sim 10^3,\ \gamma_{\text{saturation}} \sim 10^4$

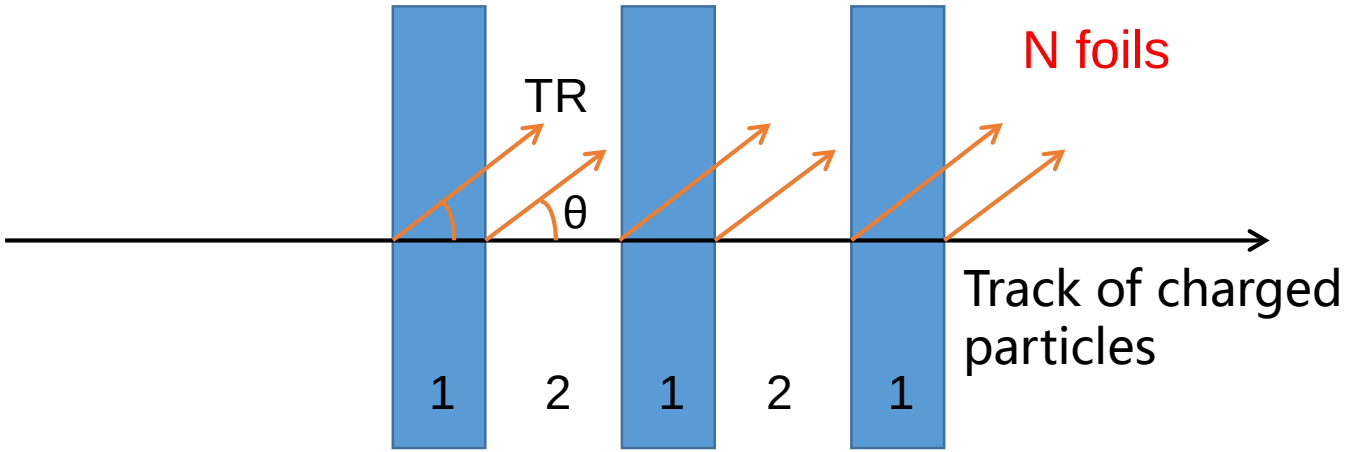
- The radiation intensity is very weak, and usually only multi-interface overlapping structures can effectively observe this effect.

- The energy spectrum is continuum, and the radiation is mainly concentrated in the X-ray energy region.

Optimization of transition radiator parameters

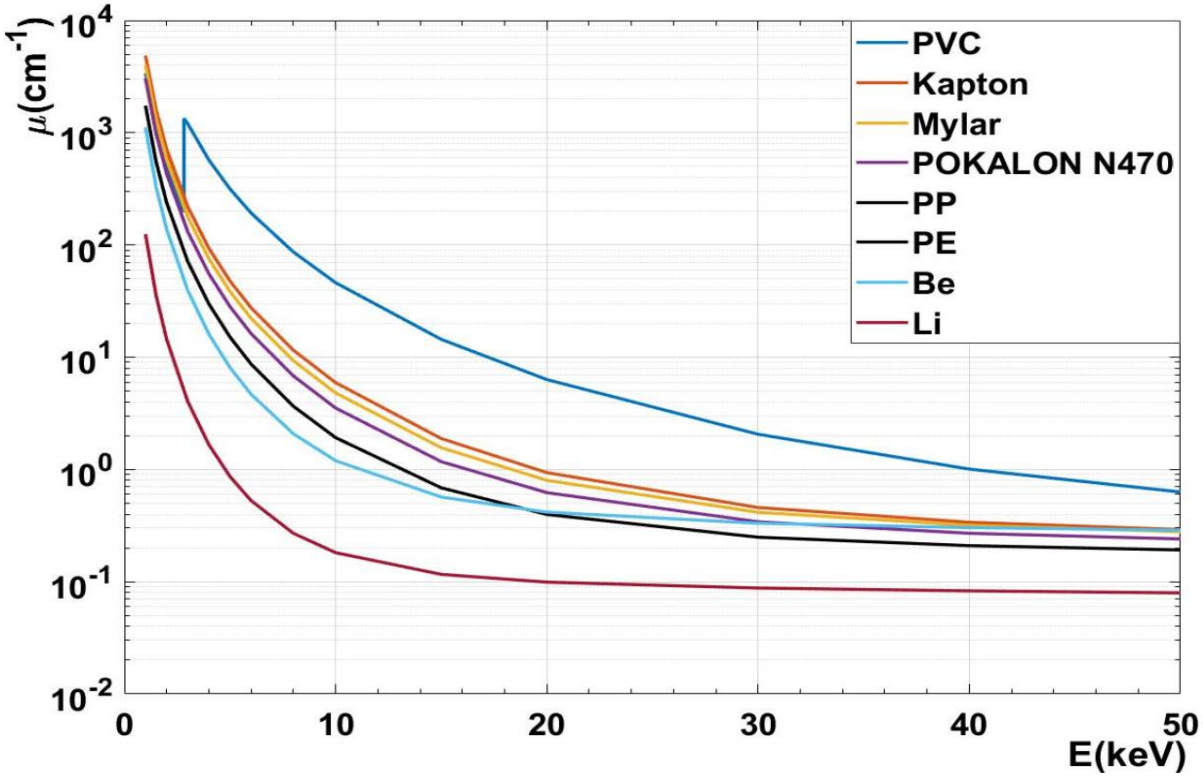
In order to get enough TR photons, Making the TR signal distinct. It can be optimized from the following aspects:

1、 foil material
2 、 gap material
3 、 foil thickness
4 、 gap thickness
5 、 number of layers



Foil material

Foil material	atomic number	atomic mass	density (g/cm³)	plasma frequency (eV)
Polyethylene terephthalate	4.55	8.73	1.393	24.54
polyethylene	2.67	4.68	0.900	20.64
Polypropylene	2.67	4.68	0.900	20.64
Polyvinyl chloride	5.33	10.42	1.300	23.49
Kapton	5.03	9.80	1.430	24.67
Li	3.00	6.94	0.534	13.84
Be	4.00	9.01	1.848	26.09
N470	4.06	7.71	1.150	22.42



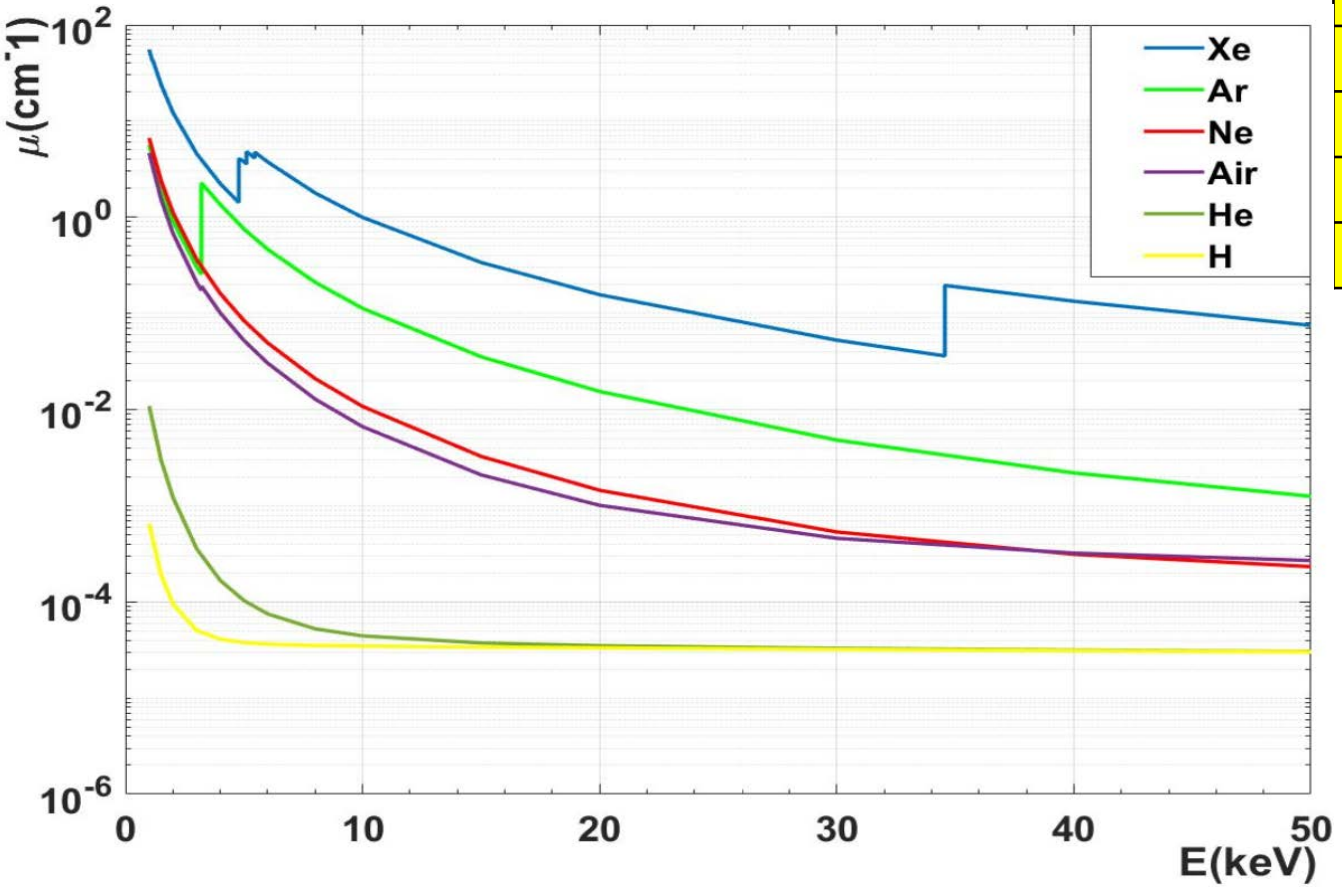
The relationship between the mass attenuation coefficient of the material and the radiation photon energy.

- Since material has self-absorption for TR photons, a material having a small Z value is selected as the material of radiator

- Lithium is also a good material of radiator, but it is chemically active and needs to be stored in an inert gas.

PP(Polypropylene) is used here as the radiator material.

Gap material



The relationship between mass attenuation coefficient of materials and radiation photon energy

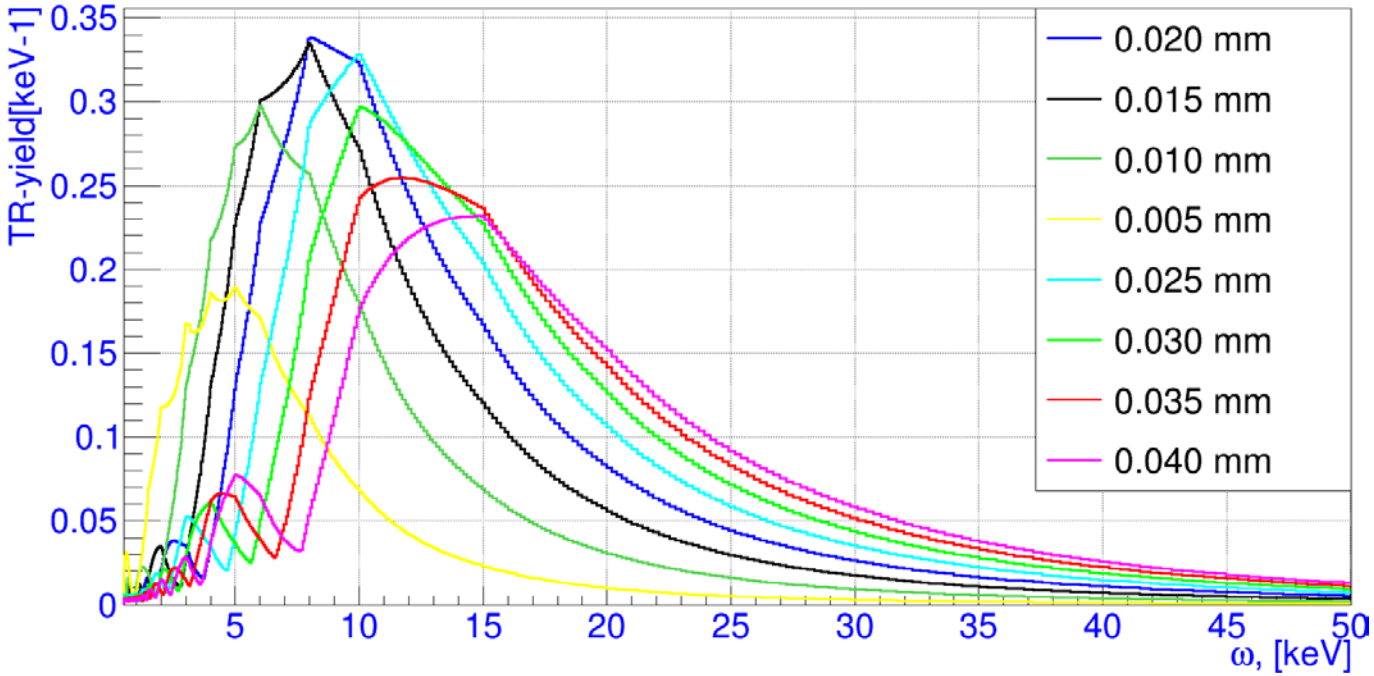
gap material	atomic number	atomic mass	density (g/cm^3)	plasma frequency (eV)
H	1.00	1.01	8.38e-05	0.26
He	2.00	4.00	1.70e-04	0.27
Ne	10.00	20.18	8.40e-04	0.59
Ar	18.39	39.95	1.66e-03	0.80
Xe	54.00	131.30	5.46e-03	1.36
Air	14.49	29.02	1.20e-03	0.70

- Air absorption is low, manufacturing cost is low and easy.

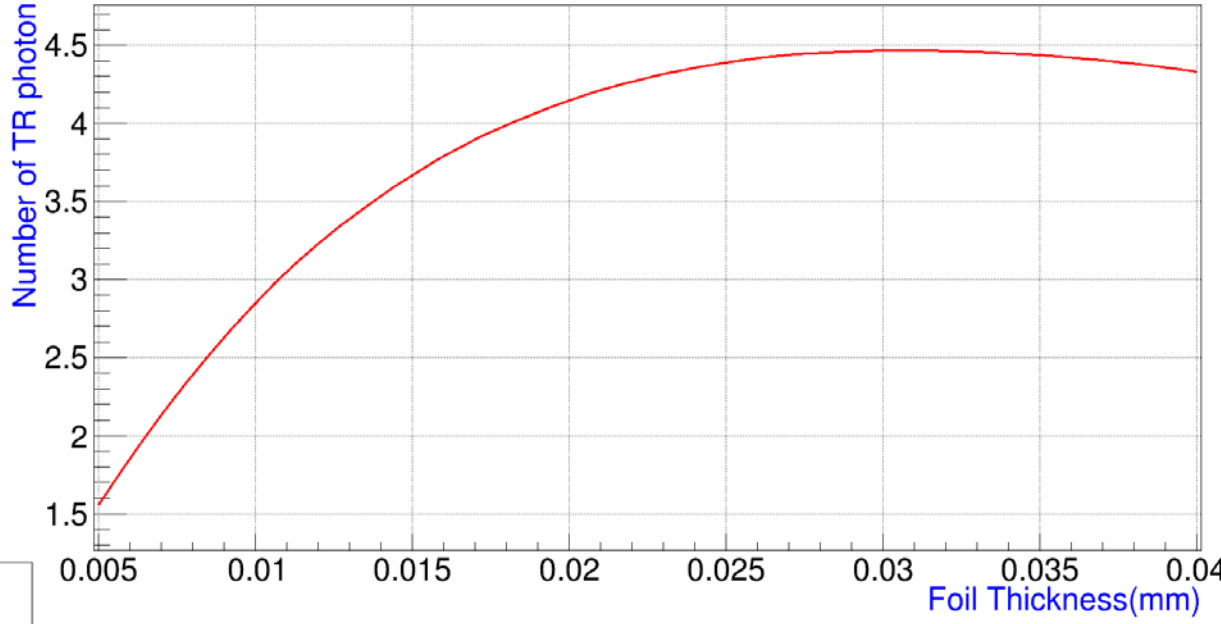
Air is selected as the radiator gap material.

Foil thickness

foil material : PP
gap material : Air
gap thickness : 0.5mm
layers : 300



TR radiation spectrum as a function of foil thickness

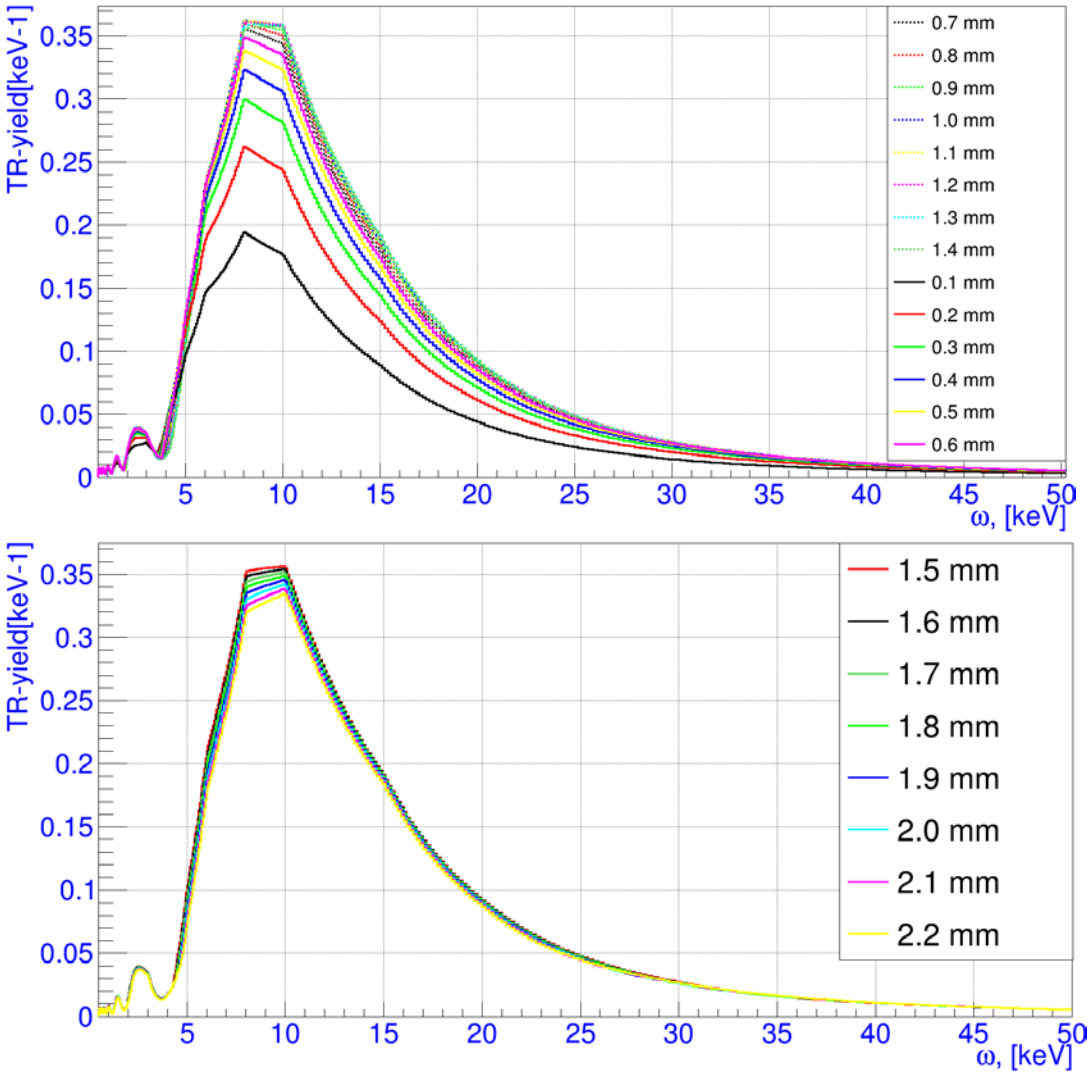


The total number of photons as a function of foil thickness

As the thickness of the PP foil increases, the peak of the TR spectral distribution shifts to the right, and the number of photons increases first and then decreases.

The foil thickness was chosen to be 0.02 mm.

Gap thickness



TR radiation spectrum as a function of gap thickness

foil material : PP
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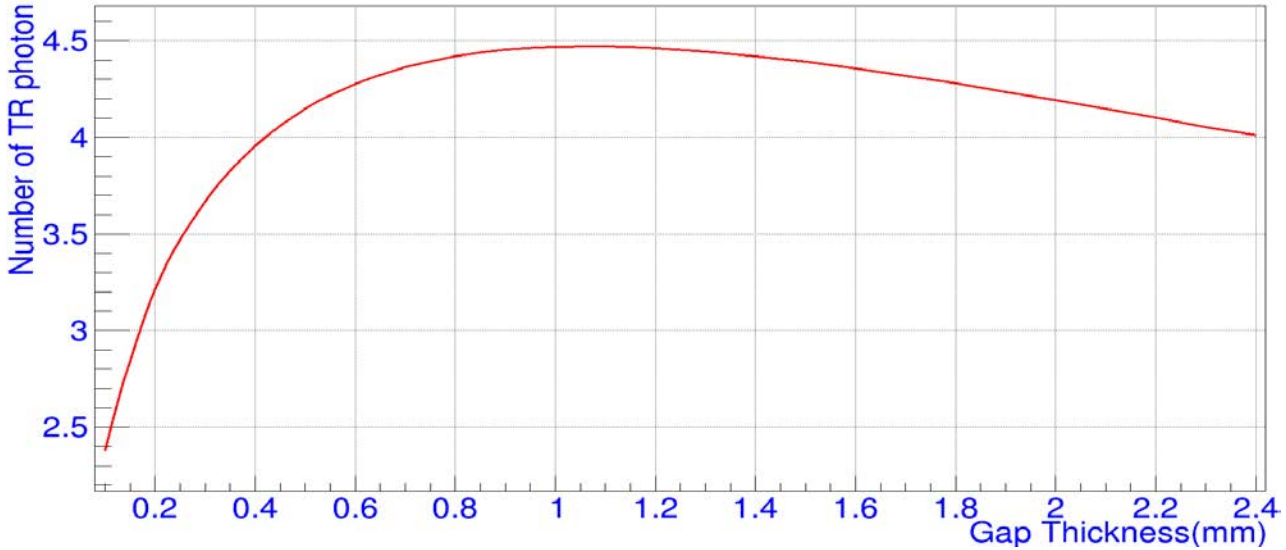


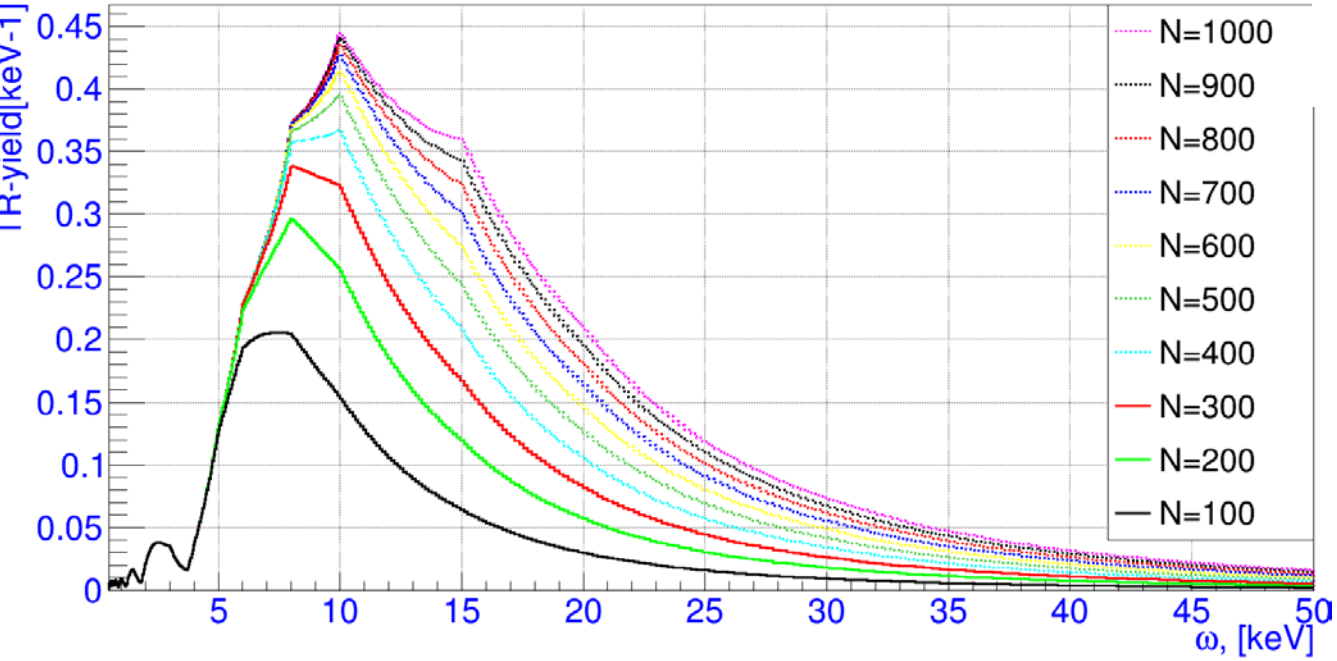
The total number of photons as a function of gap thickness

As the thickness of the gap increases, the number of TR photons increases, and the maximum value of the TR spectrum increases, and moves slightly toward the higher energy region.

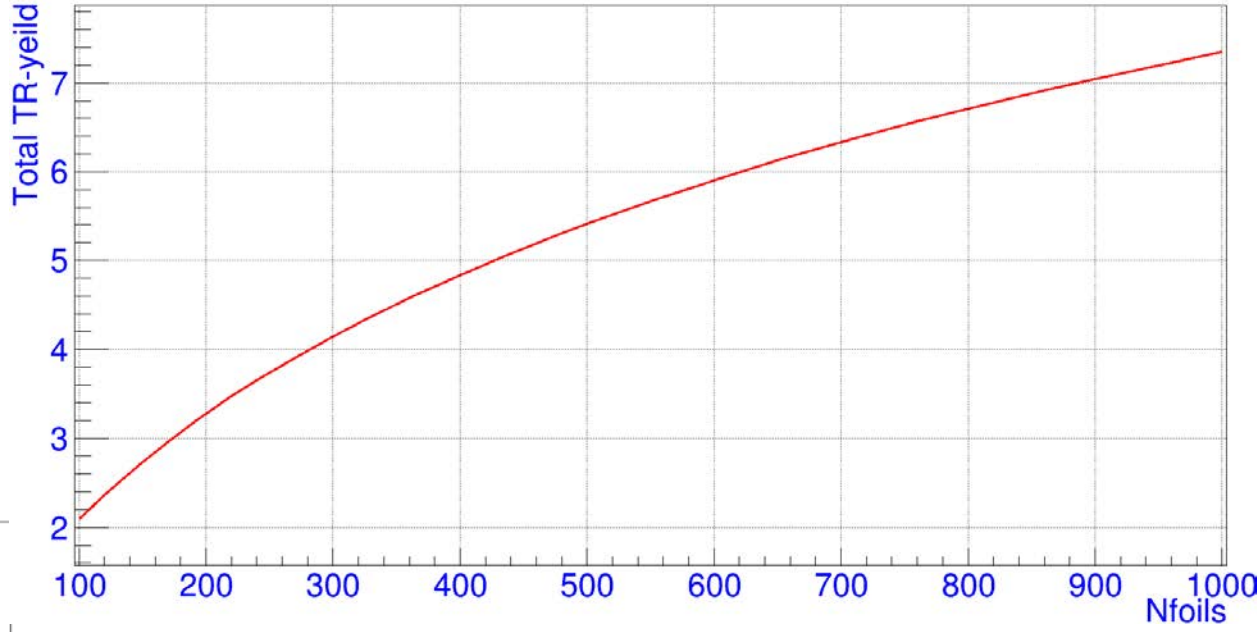
The thickness of the gap was chosen to be 0.5 mm and 0.8 mm.

Number of layers

foil material : PP
gap material : Air
foil thickness : 0.02mm
gap thickness : 0.5mm



TR radiation spectrum as a function of layer number



The total number of photons as a function of layer number

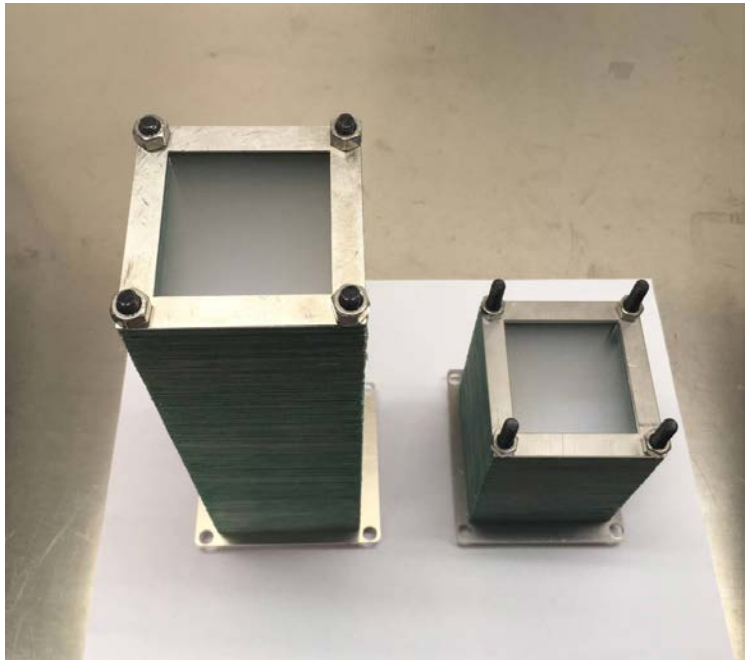
As the number of layers increases, the number of TR photons increases, and the maximum value of the TR spectrum increases and moves slightly toward the high energy region.
The increase in the number of layers makes the mass and volume of the radiator larger.

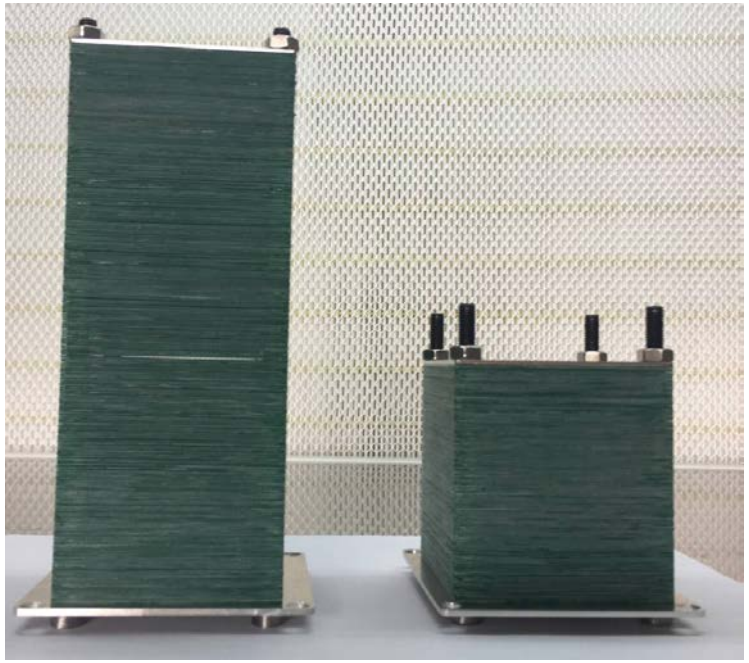
Select 300 and 225 layers

Optimization results

- According to the above optimization results, the parameters are selected as shown in the following table.

Name	Material	l_1 (μm)	l_2 (μm)	N_f
GXU0.5×300	PP+Air	20	500	300
GXU0.5×225	PP+Air	20	500	225
GXU0.8×225	PP+Air	20	800	225





Radiators manufacture

The manufacturing process of the radiator is as follows

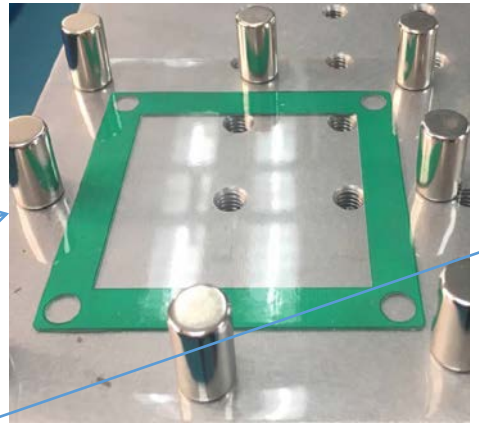
Stretched PP foil

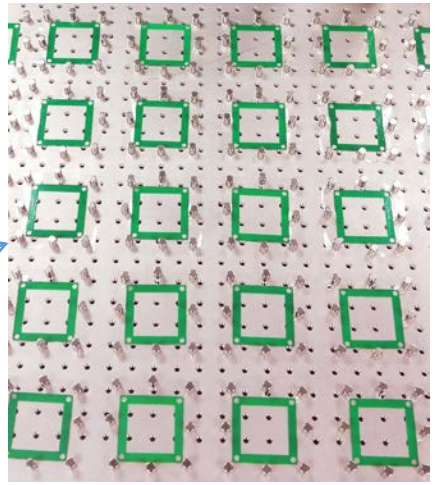
Paste to PCB board

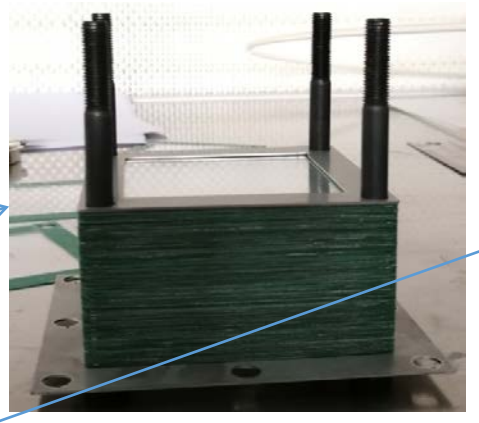
Superimposed

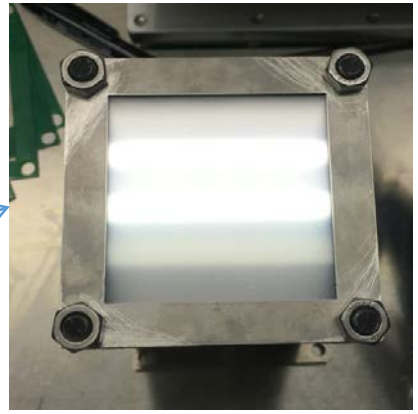
Press tight

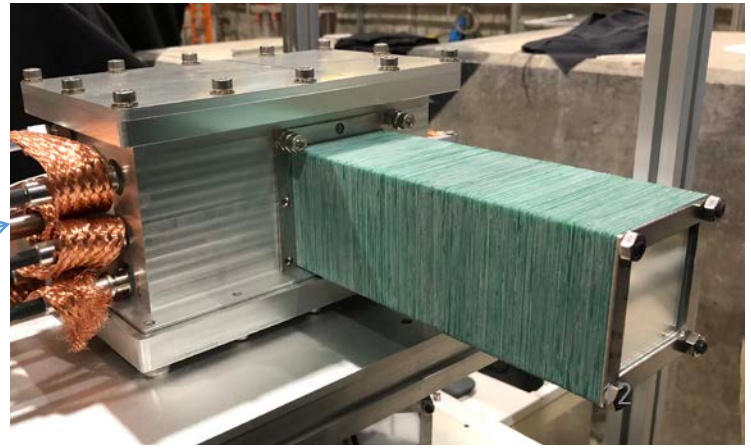
Fixed









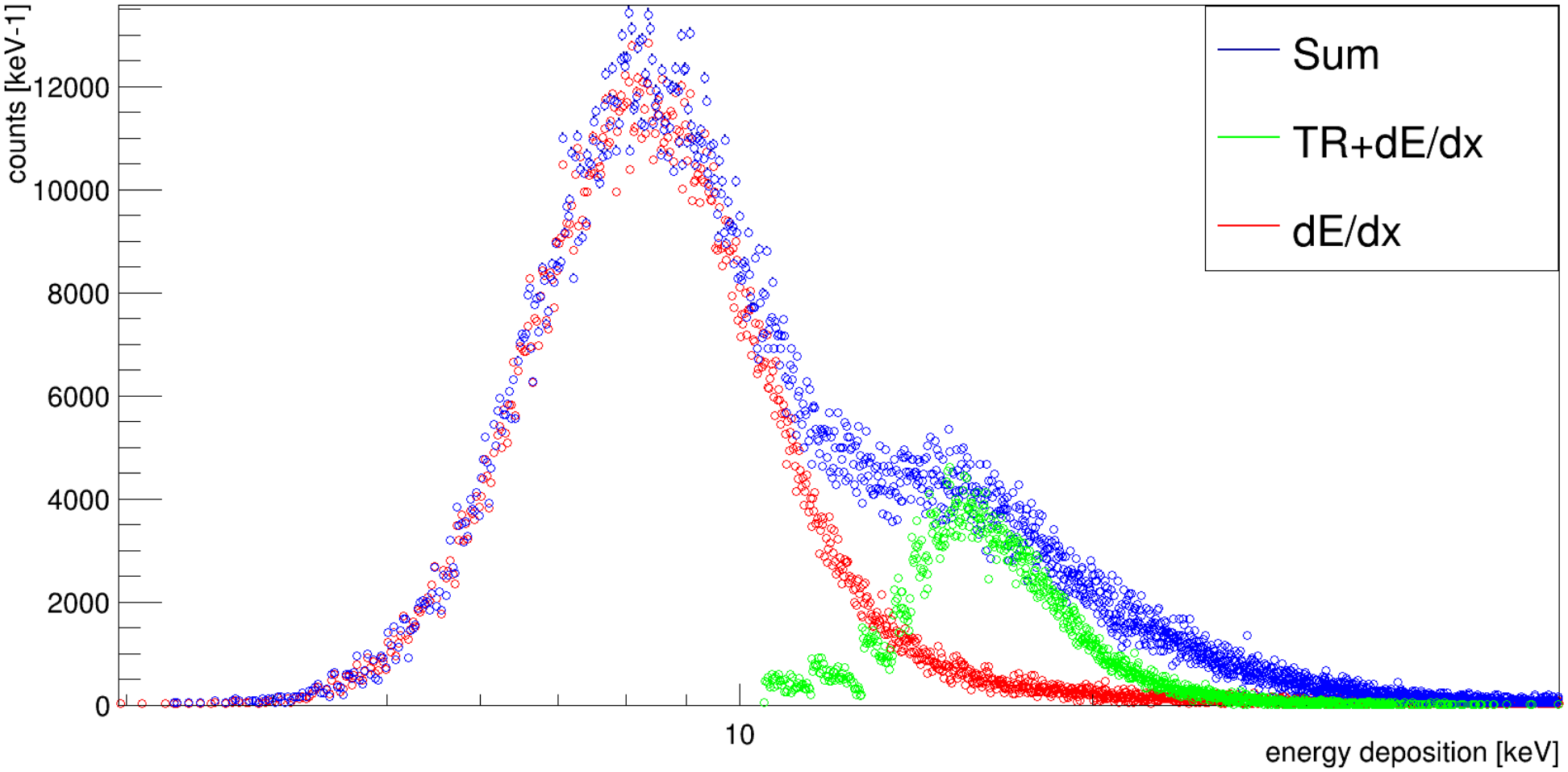


Simulation results

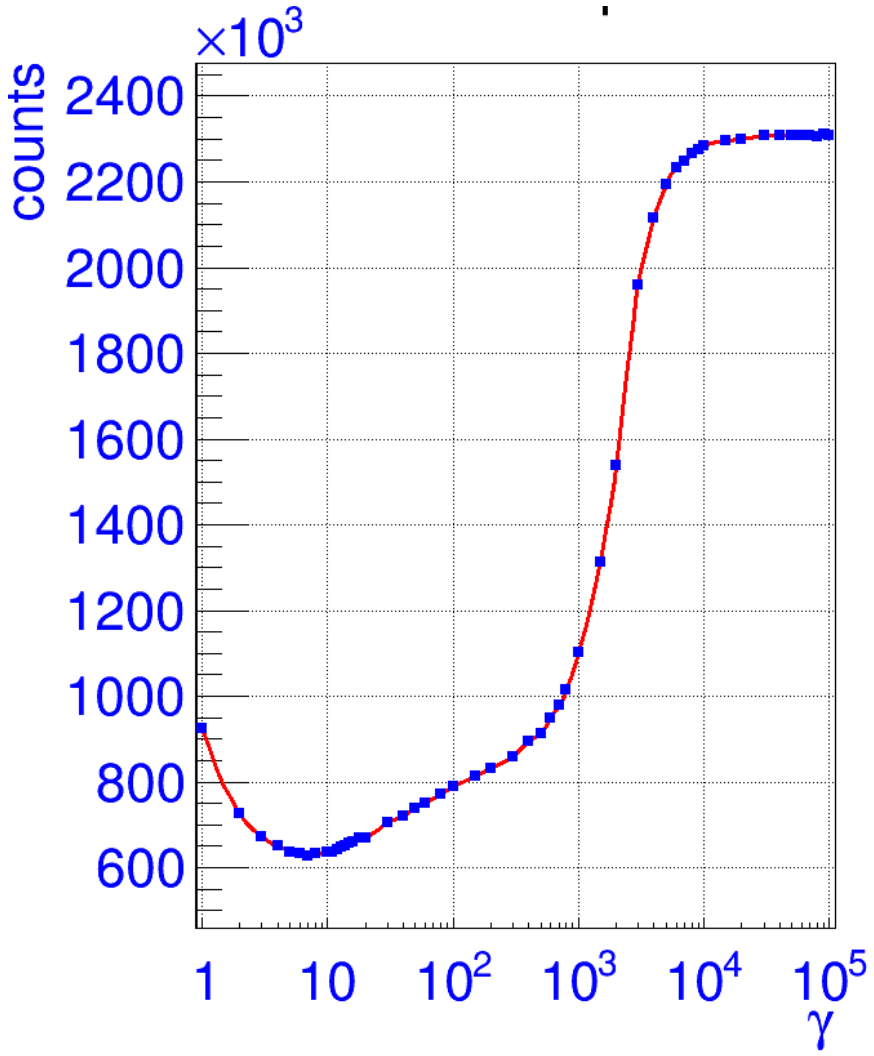
Incident particle: electron
Quantity: 100,000
Energy: 2.5GeV

Radiator
Foil: PP (20 μm)
Gap: Air (500 μm)
Number of floors: 300

THGEM gas detector
Working gas: Ne (90%) + CO_2 (10%)
Gas thickness: 5 cm
Detection efficiency: 7.82%



TRD simulation of energy detection



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Summary

- For extreme relativistic particles ($\gamma > 10^3$), the energy of the particles can be determined by measuring the energy of transition radiation.
- By optimizing the parameters of the radiator, suitable parameters are obtained.
- The manufacture of radiators is simple, reliable and economical.
- The experiment and simulation results are consistent.(Experimental results in Hongbang Liu's report)

The simulation program comes from this website :http://radiator.hepforge.org/

Thank you