TDR Status of the CEPC gamma synchrotron radiation

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Outline

- Parameters of the gamma source
- Applications of a high intensity γ-ray source
- Detection methods of high-intensity gamma-ray

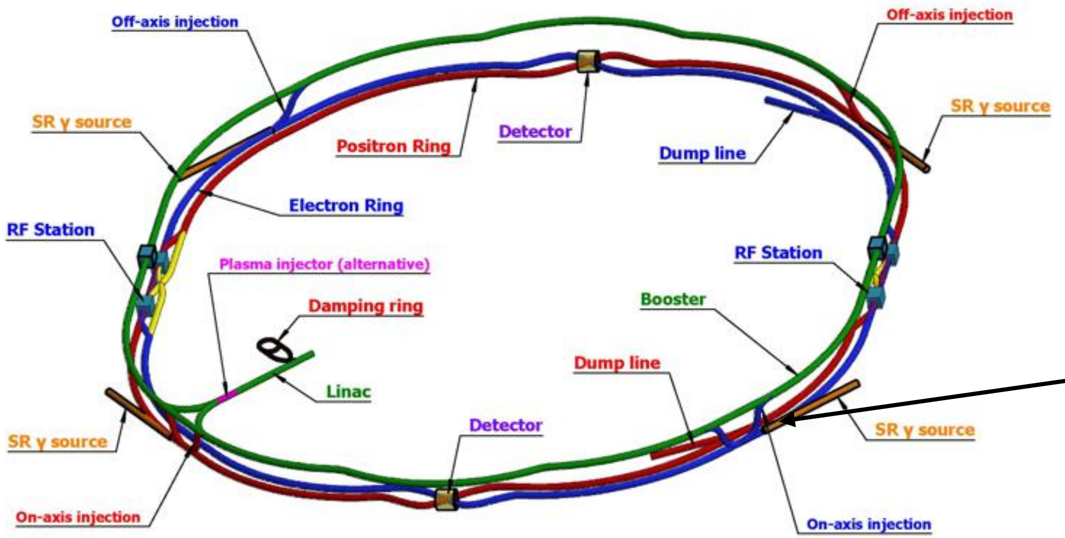
Parameters of the gamma source

Wiggler parameters	
B (T)	2
Total length (m)	0.32
Magnetic period Length (m)	0.32
Period number	1
K value	59.97
characteristic gamma energy (MeV)	19.2
Bending magnet parameters	
B (T)	0.04
Length (m)	20
Critical energy (keV)	383

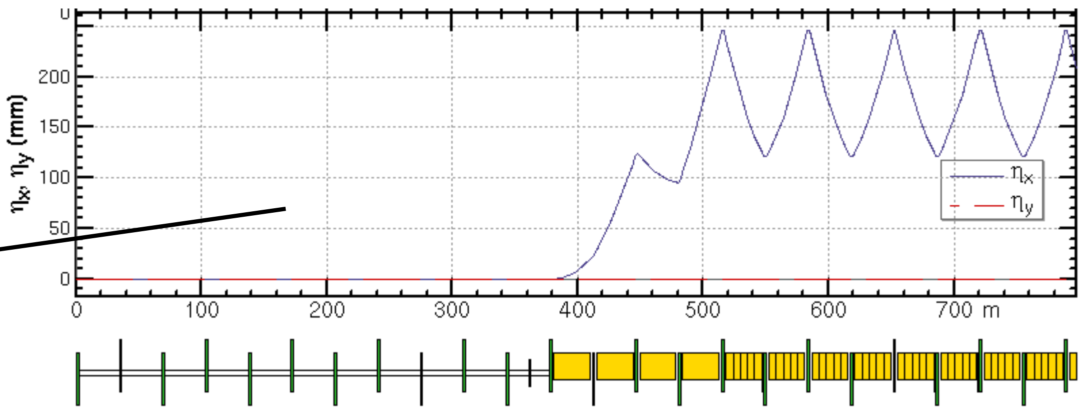
A short wiggler was installed in the lattice at the down stream of the on-axis injection region.

Increasement of the power lost due to the wiggler magnets: 1%, accepted

B [T]	Np	Length [m]	ΔU0/U0
2	1	0.32	1.3%



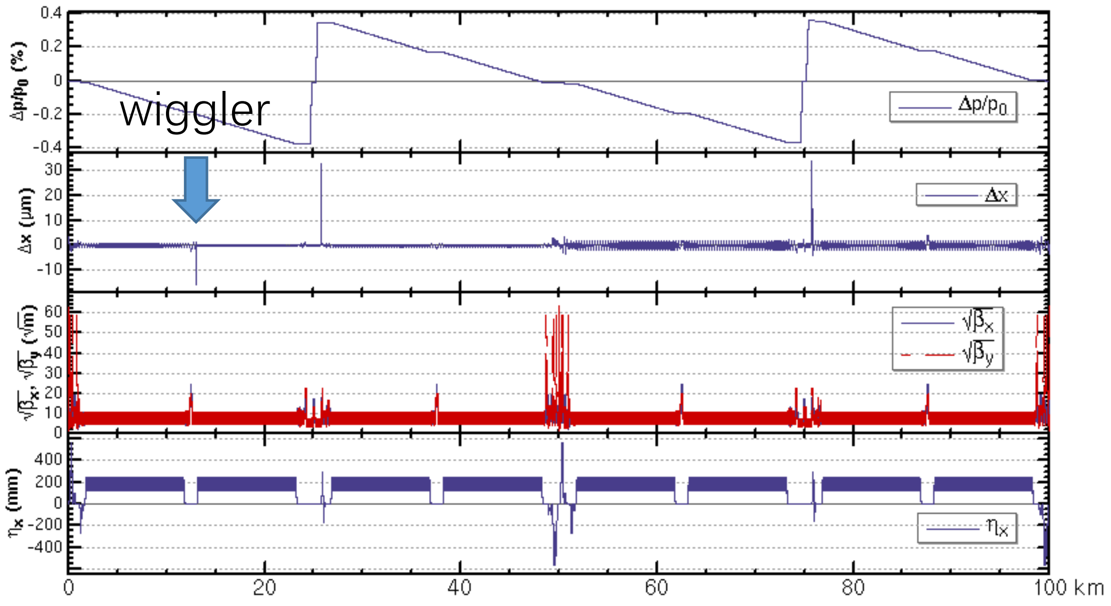
- Two BM lines+Two wiggler lines：

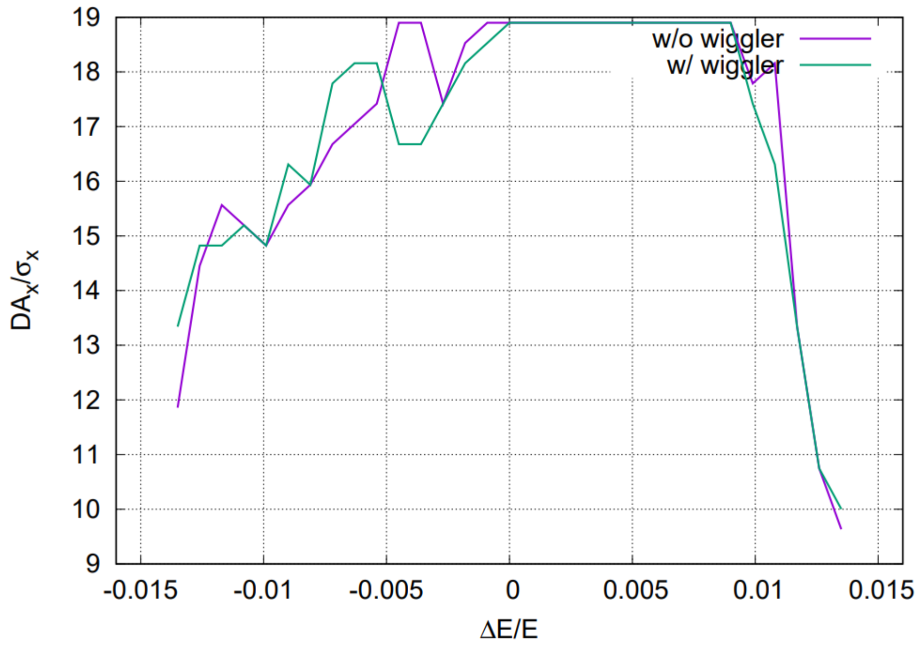


From Yiwei Wang

SR effects of the wiggler on beam dynamics

- The SR effect can be cured by **tapering the magnet strength** to take into account the beam energy at each magnet.
  - The closed orbit becomes 1um after such tapering and only 15um at wiggler.
  - The dynamic aperture w/ and w/o wiggler are almost the same.





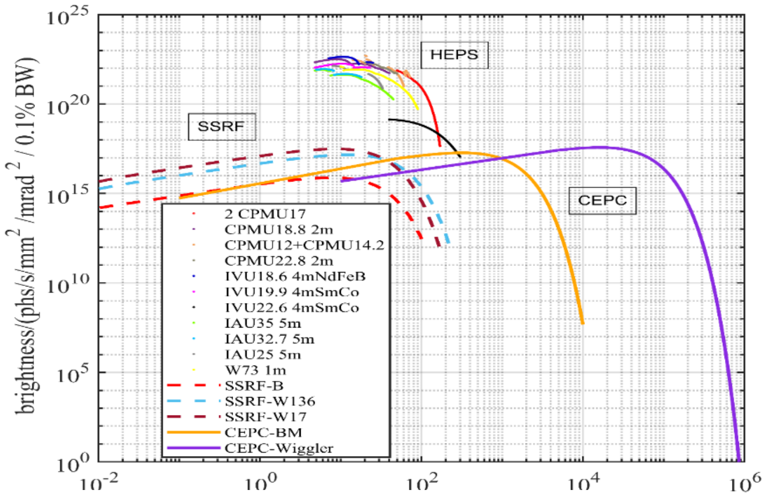
High energy, high brightness synchrotron radiation

Compared with the energy of the exist SR source, the energy of γSR is three orders of magnitude higher.

$$\left.\frac{d^2F_{bm}}{d\theta d\psi}\right|_{\psi=0} = 1.327\times10^{13}E^2[GeV]I(A)H_2(y)$$

F_{bm},flux; I, the curent of the ring, $\mathrm{H_2(y) = y^2K^2_{\frac{2}{3}}(y/2)}$, K, the second Bessel function $\mathrm{y} = \epsilon/\epsilon_c$, ϵ,the photon energy, $\epsilon_c = 0.665E^2[GeV]B[T] = 358.2keV$.Divergence angle: 4.17urad

Beam size: 20um*0.068um-----→6mm at the end of the beamline of



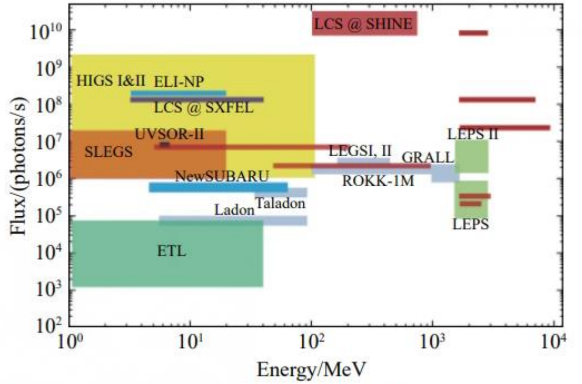
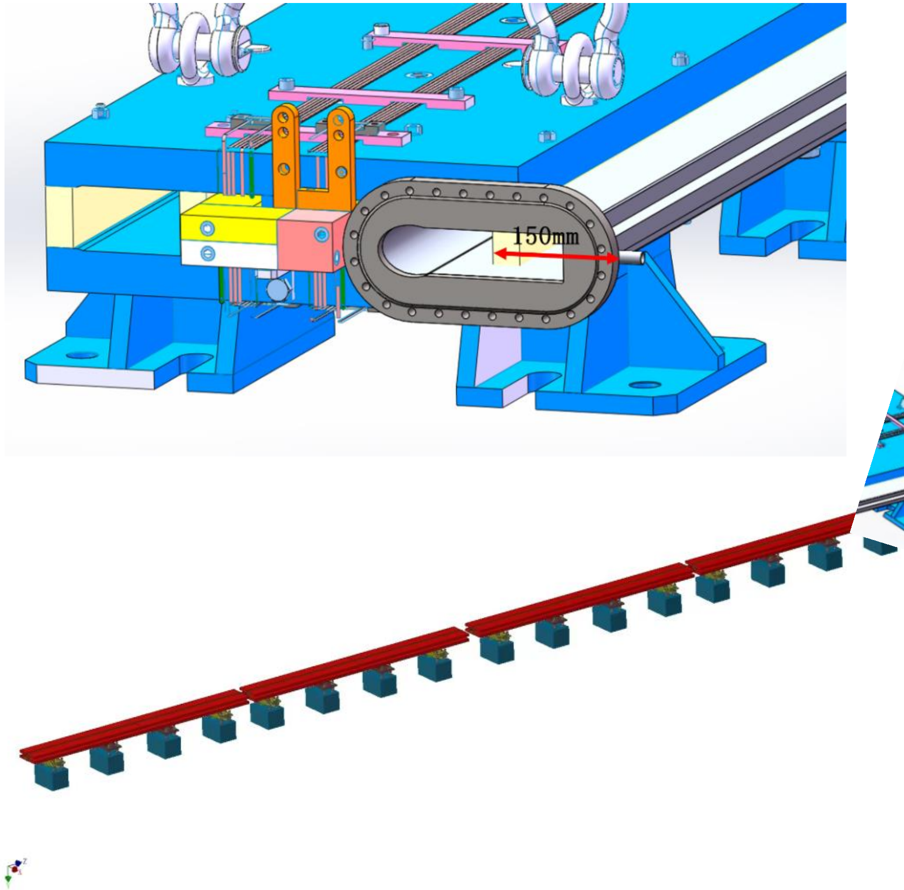


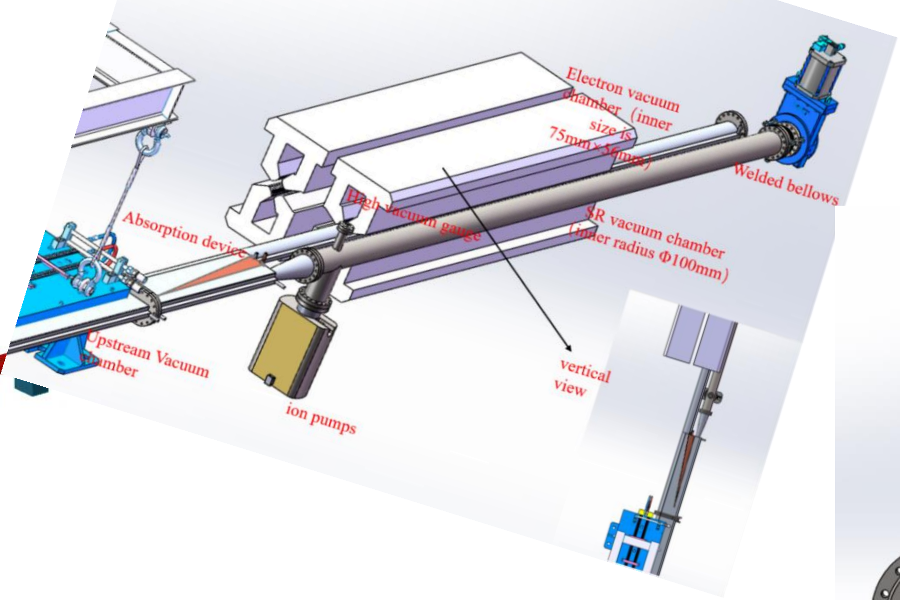
图 10　未来高能康普顿散射伽马光源的通量和能区分布的比较

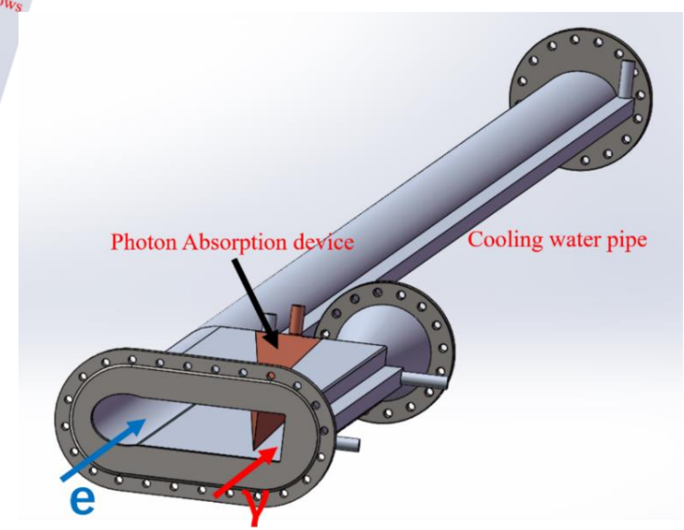
Source	CEPC BM	CEPC Wiggler	SSRF (China)	TUNL-HIGS (USA)	TERAS (Japan)	ALBL (Spain)
Gamma energy range(MeV)	0.1~5	0.1~100	0.4-20 330-550	2-100	1-40	0.5-16 16-110 250-530
Energy resolution (ΔE/E)	continuous	continuous	5%	0.8~10%		
Flux	$>10^{12}$@0.1%	$>10^{14}$@0.1%	10^6	10^8	10^4~10^5	10^5~10^7

The design of the beamlines

- Photon absorption device：800W radiation power
- 700m long of the line
- Need to do：
- The mechanical design of the total beamline



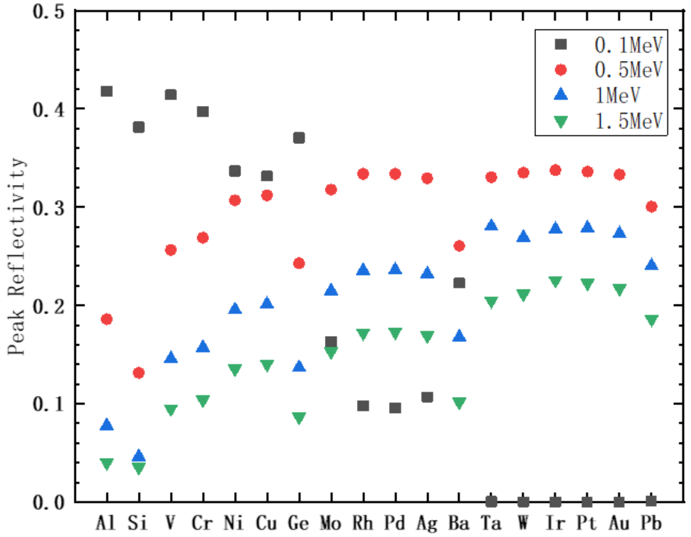


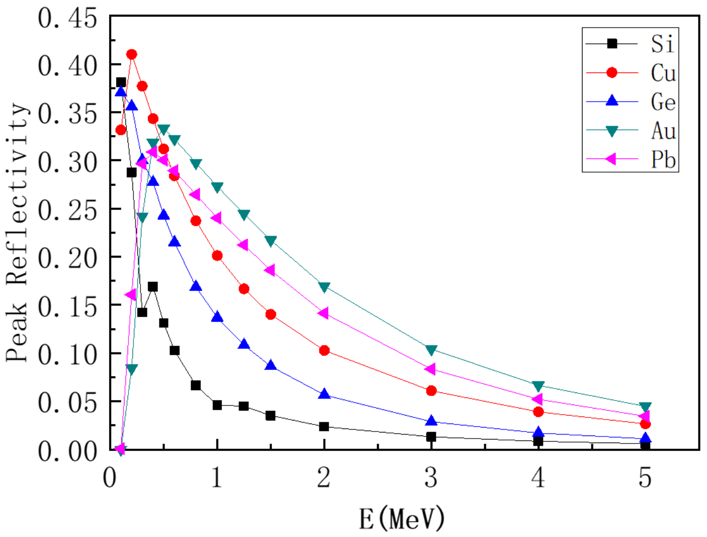


The vacuum design of the synchrotron radiation beamline needs to consider:

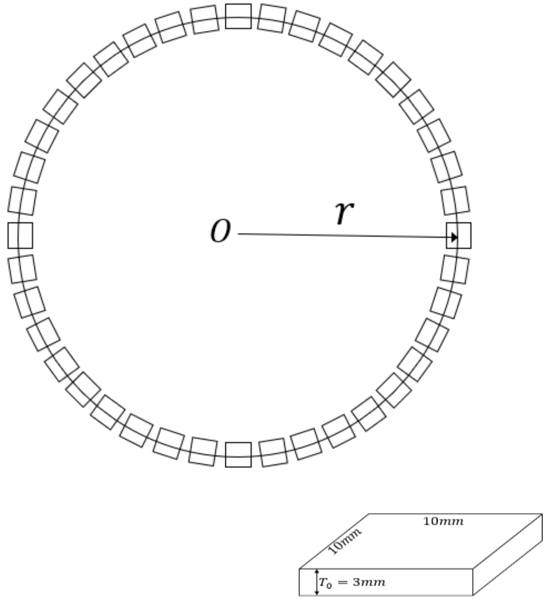
- (i) the vacuum system: getter films (NEG films) + ion pump.
- (ii) 8 sections, each section is separated by all-metal ultra-high vacuum valves (9 valves). Each section has a separate rough suction port and gas filling port, and in each section 5-10 ion pumps are uniformly distributed (used to pump out gases that are not easy to pump out of getter films such as CH_4), and the inner walls of all vacuum boxes are plated with NEG films.
- (iii) 304 stainless steel (the inner diameter is 100 mm, the thickness of wall is 3 mm).
- (iv) Vacuum measurement adopts 2 measurement points in each section, and a cold cathode vacuum gauge is used for measurement.
- (v) arrange temperature measurement points to monitor the temperature changes of the outer wall of the vacuum box.

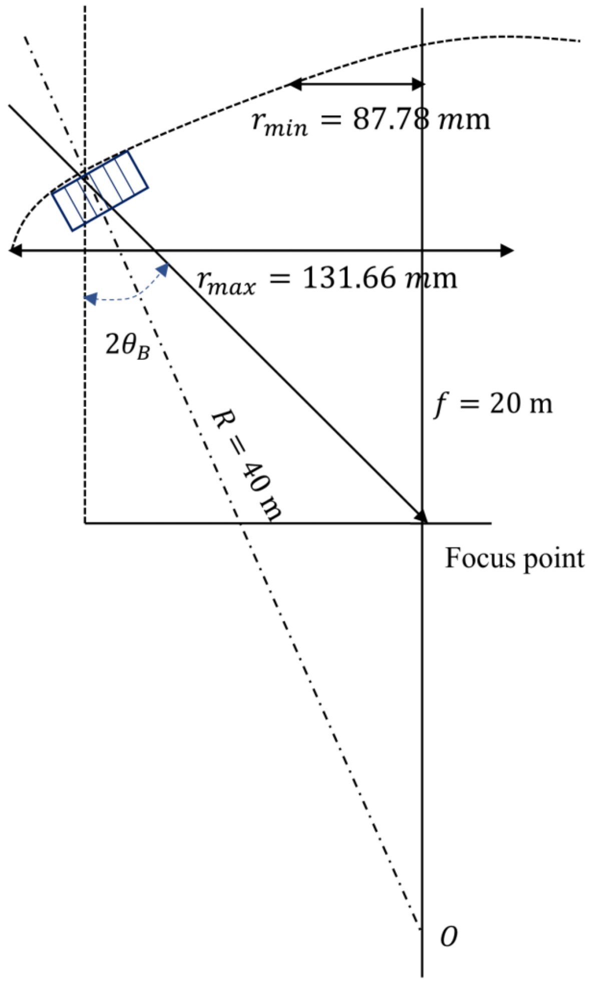
The focalization of gamma-ray





- **focusing of the synchrotron radiation beam: Laue lenses, Bragg diffraction, Au or Pb**





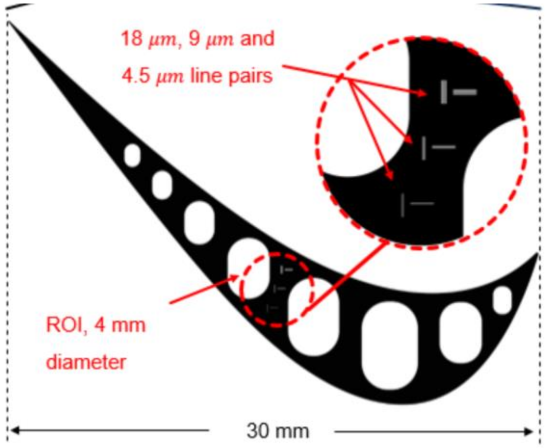
Outline

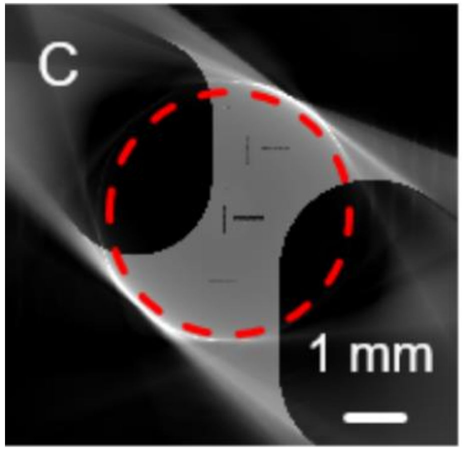
- Parameters of the gamma source
- Applications of a high intensity γ-ray source
- Detection methods of high-intensity gamma-ray

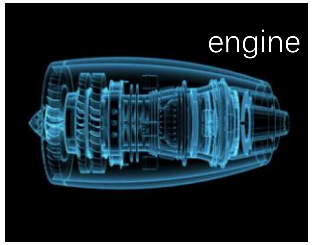
The applications on material:

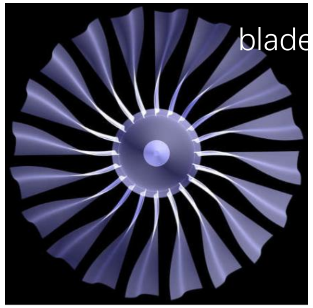
the Integration of Material Technology-Structure-Performance

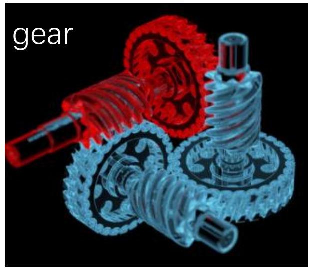
- Processing of **heavy metal materials** in an in-situ environment
- **Non-destructive** characterization of the **internal structure** of the workpiece under **casting, forging and service** conditions
- **Internal welding problems, defect evolution, grain arrangement and failure analysis of materials**

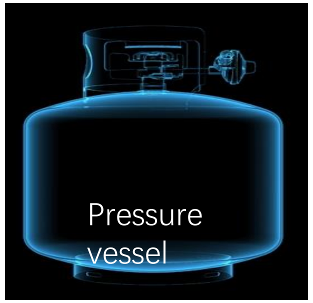












Dynamical diagnosis >1kHz+ large penetration depth+ clear imagination

$>10^{12}$photon/s

10^{9}photon----enough for a clear imagination

>1000Hz can satisfy:

Dynamical diagnosis of defect evolution/metal phase change process-droplet solidification/seawater corrosion mechanism

The applications on nucleon:
γ assistant transmutation

- The shortage of ADS idea is the transmutation by using neutrons in the sub-critical system, but meanwhile it produces actinides and long- lived fission products (LLFPs).

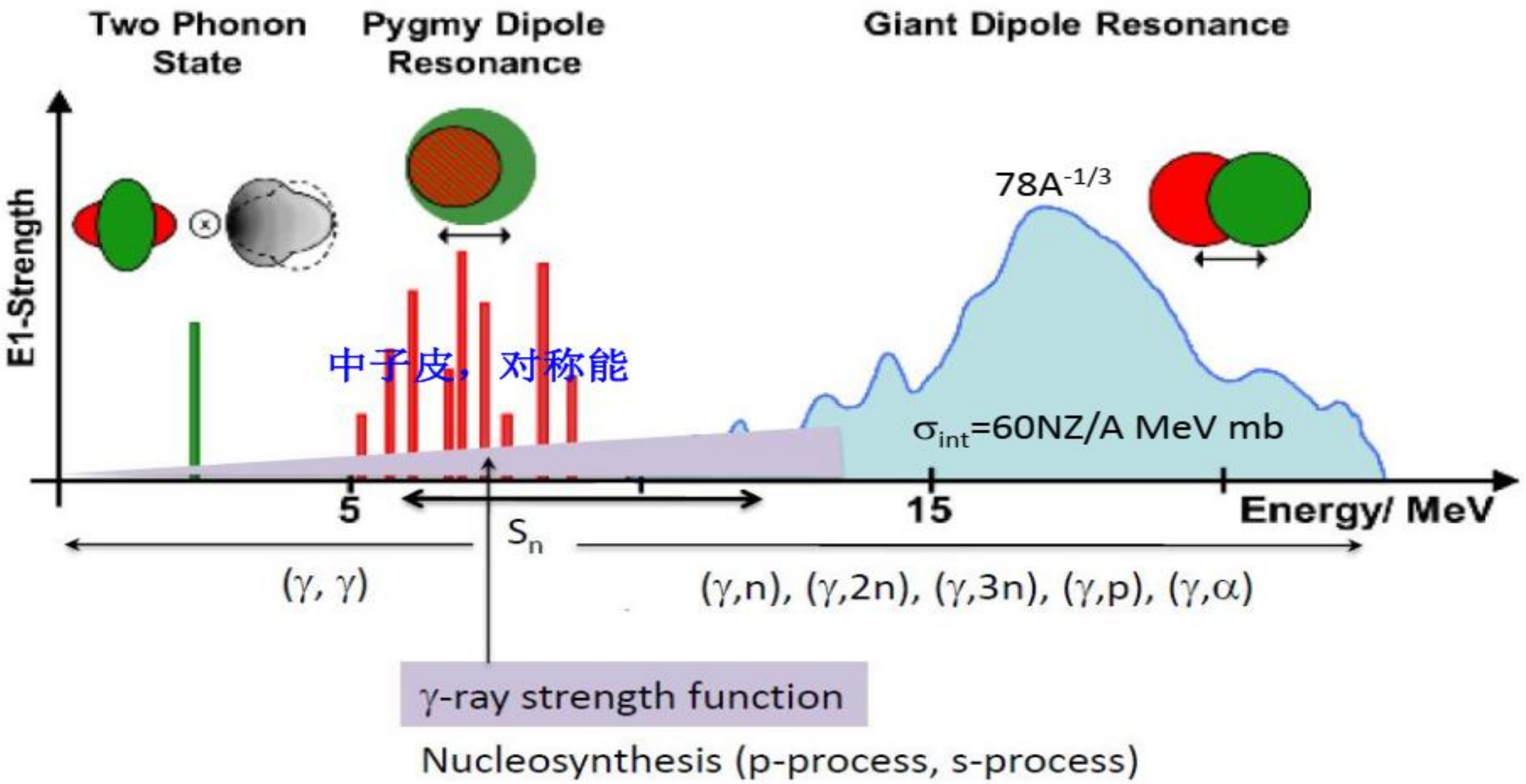
n+133Cs →	134Cs →	135Cs →	136Cs
stable	2.06 y	2.3 My	13.16 d

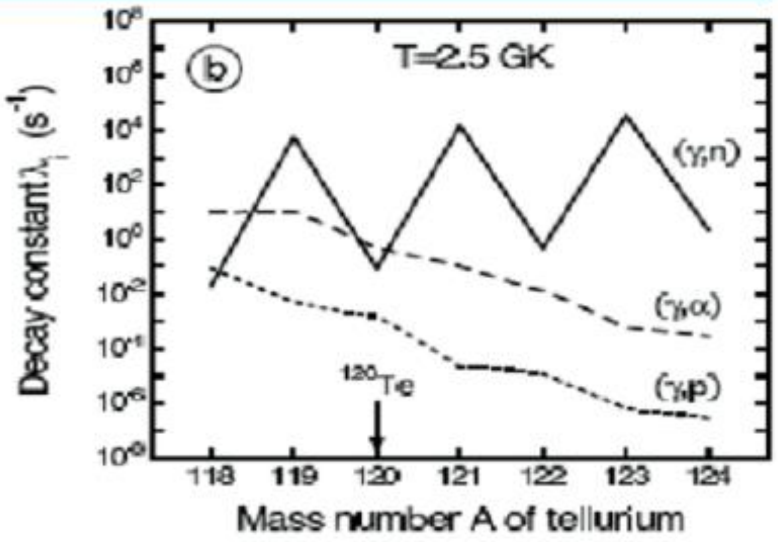
- **γ assistant transmutation is quite-valuable, and is an important supplement to neutron transmutation.**
- **(γ,n), (γ,2n), Can increase the average number of fission neutrons!**
- γ+135Cs → 134Cs、 133Cs; γ+ 133Cs → 132Cs、131Cs

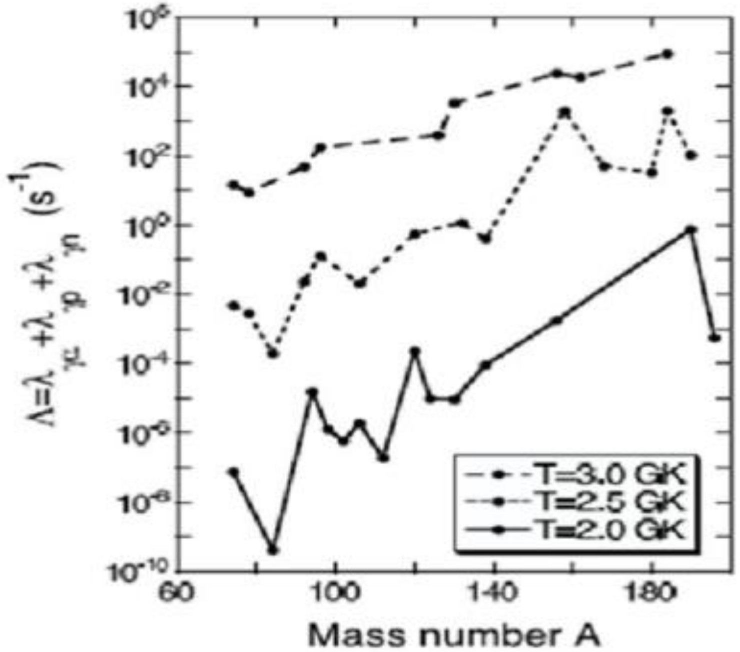
The applications on nucleon:

photon-nuclear reactions

- **(γ, n), (γ, p), (γ, α) are the main photonuclear reaction exit channels**
- **Temperature dependence**



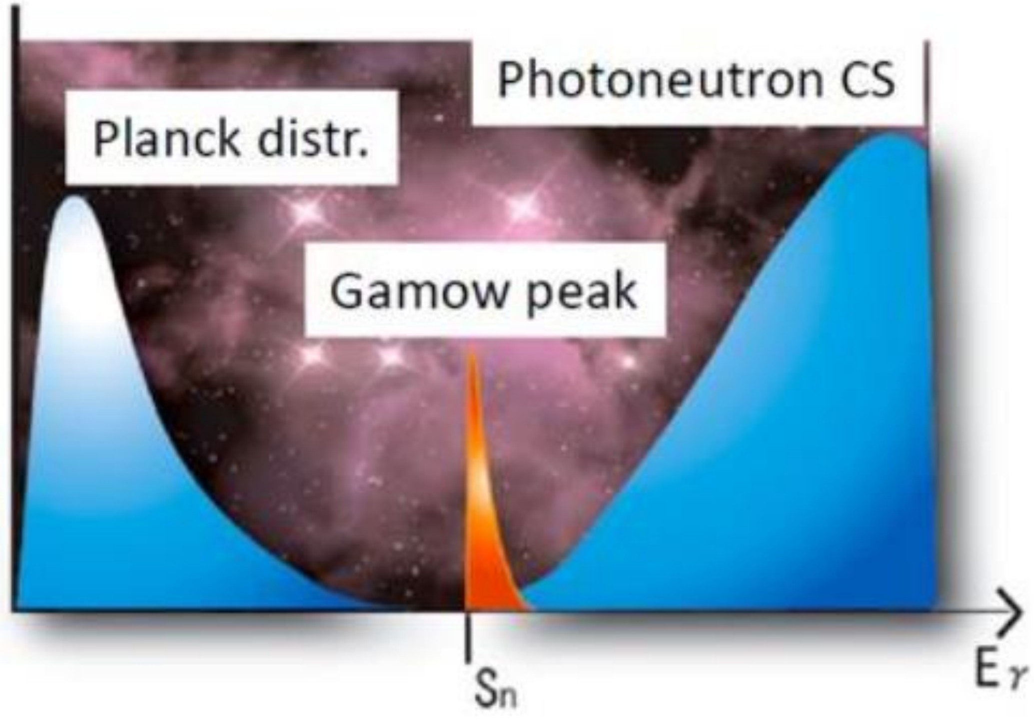




The applications on nucleon and astrophysics:

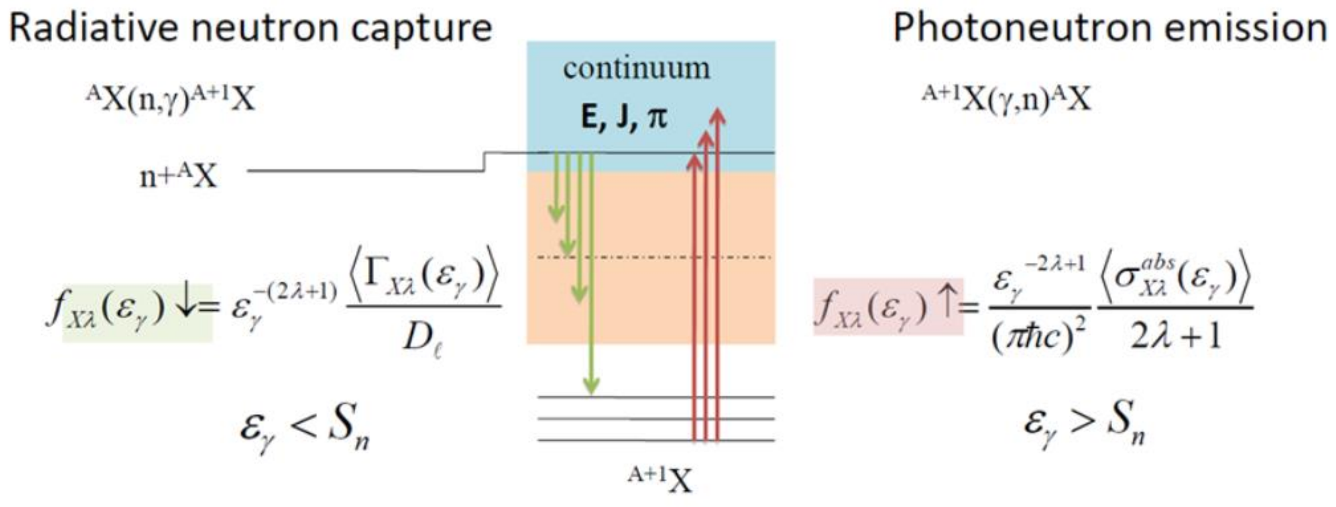
photon-nuclear reactions

- The interesting energy range of **photon-nuclear reactions:**
- Gamow peak, Gamow window: $(E_0-\Delta/2, E_0+\Delta/2)$



$$E_0 = 1.22(Z_1^2 Z_2^2 \mu T_6^2)^{1/3}$$

$$\Delta = 0.749(Z_1^2 Z_2^2 \mu T_6^5)^{1/6}$$



Brink Hypothesis $\boxed{f_{X\lambda}(\varepsilon_\gamma)\uparrow \cong f_{X\lambda}(\varepsilon_\gamma)\downarrow}$

The applications on nucleon and astrophysics: photon-nuclear reactions

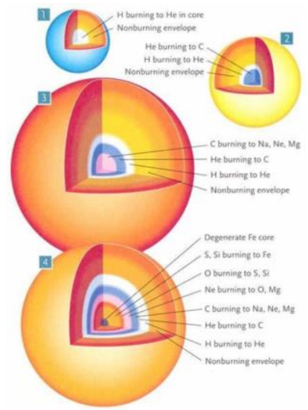
Tick the time of the evolution of the universe

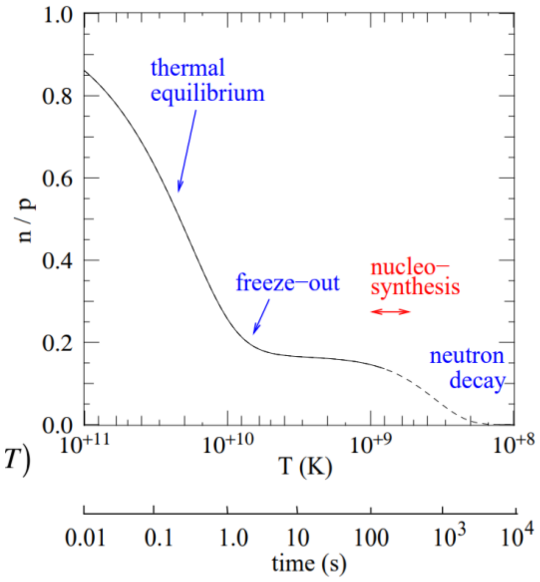
Control the sequence of nuclear combustion

Determines the waiting point of the nuclear process

Participate in important nuclear processes (e-process, r-process, p-process)

2H(γ,n)1H determines the time window of the big bang nucleosynthesis





1. Carbon ~ 5×10^8 K

$^{12}C+^{12}C \rightarrow {}^{23}Na+p$
$\rightarrow {}^{20}Ne+\alpha$

$^{23}Na(p,\alpha)^{20}Ne$;
$^{20}Ne, ^{23}Na + p,\alpha \rightarrow ^{24-26}Mg$; ^{27}Al;....

2. Neon ~ 10^9 K

$^{20}Ne+\gamma \rightarrow {}^{16}O+\alpha$
$^{20}Ne+\alpha \rightarrow {}^{24}Mg$

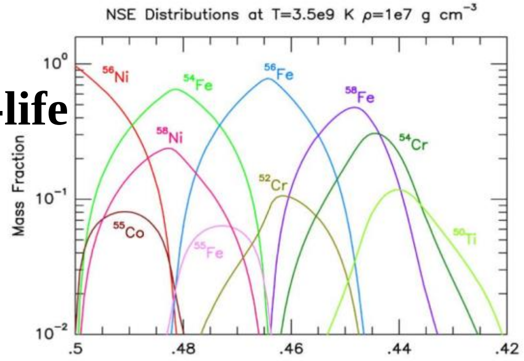
$^{24}Mg(\alpha,\gamma)^{28}Si$; $^{25}Mg(\alpha,n)^{28}Si$;
$^{26}Mg(\alpha,n)^{29}Si$; $^{26}Mg(\alpha,\gamma)^{30}Si$; $^{27}Al(\alpha,p)^{30}Si$;
$^{30}Si(p,\gamma)^{31}P$

3. Oxygen ~ 2×10^9 K

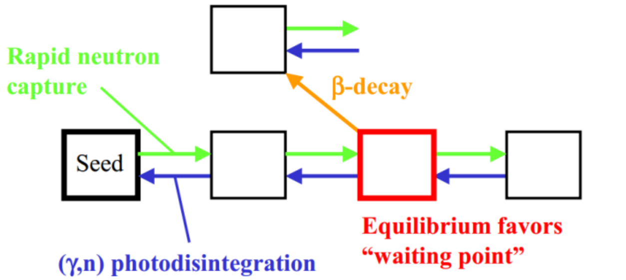
$^{16}O+^{16}O \rightarrow {}^{28}Si+\alpha$
$\rightarrow {}^{31}P+p$
$\rightarrow {}^{31}S+n$

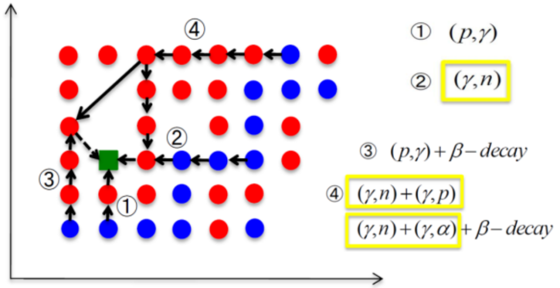
$\rightarrow {}^{28}Si$; ^{32}S

Even A nuclei, magic number nuclei, and short half-life nuclei are candidate waiting point nuclei



10-100 g/cm³ neutrons →neutron capture timescale: ~ 0.2 μs



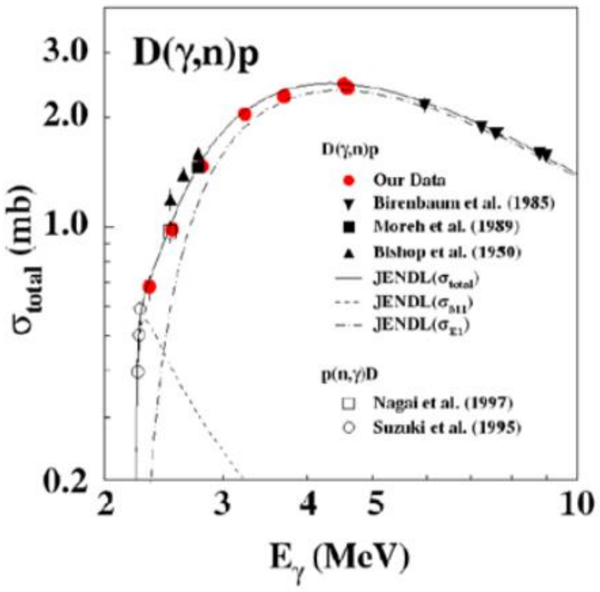


Location of path: $S_n = T_9/5.04 \times (34.08 + 1.5 \log T_9 - 1.5 \log n_n) = 2\text{-}4$ MeV

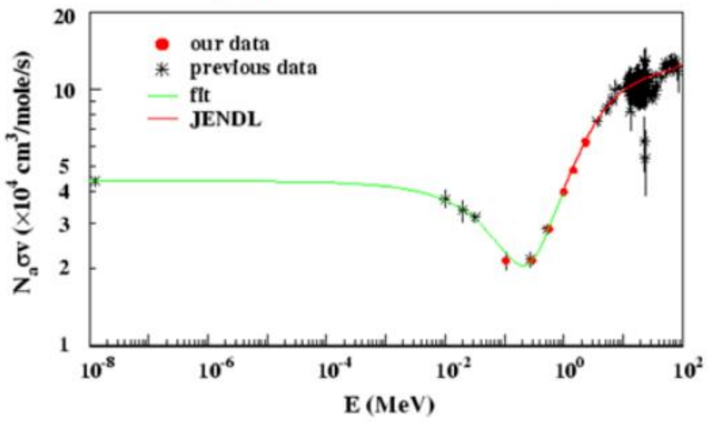
The applications on nucleon and astrophysics:

photon-nuclear reactions

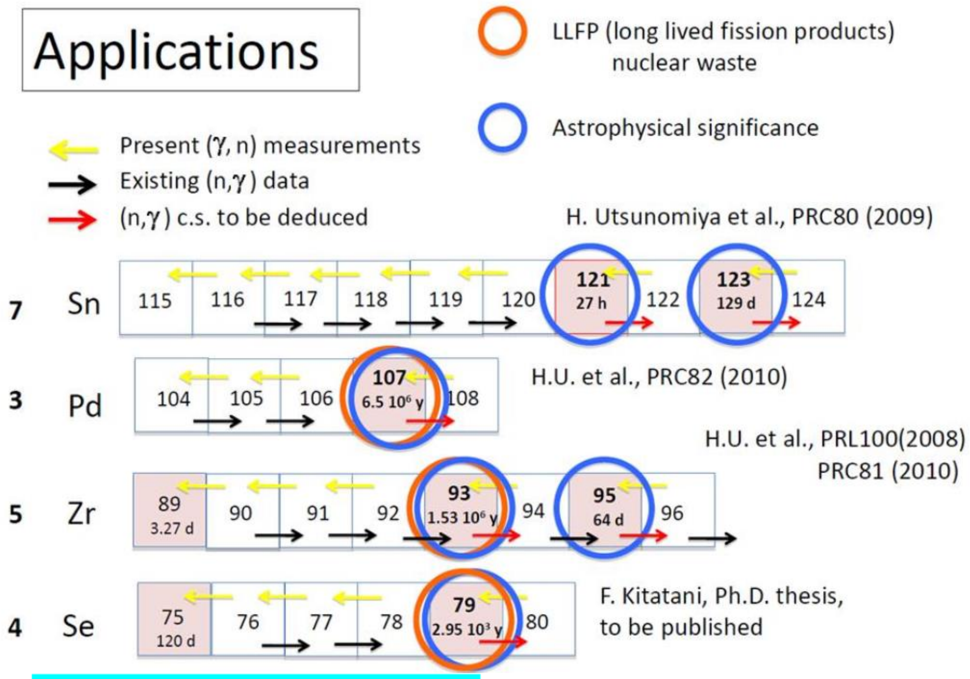
- **D(γ,n)p reactions related to the Big Bang**



(n,γ)天体物理反应率

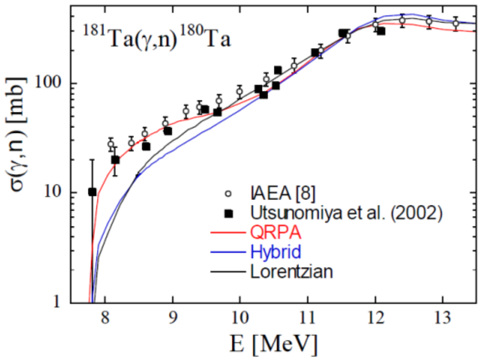


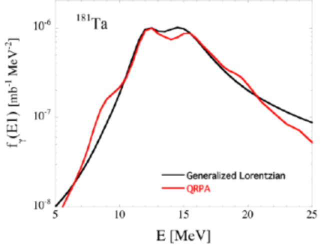
K. Y. Hara et al. PRD 68 (2003) 072001



Extra E1 γ-ray strength near Sn

Pygmy Dipole Resonance
N. Paar, D. Vretenar, E. Khan, G. Colò
Rep. Prog. Phys. ***70 691*** (2007)





The applications on medical:

Radioisotope preparation for SPECT/CT & Flash RT

- $10^{14} p/s$ flux can produce: 10000Ci/y Mo99 compared with a linac 1mA per year

SPECT/CT is the first choice for early diagnosis of bone metastases from malignant tumors.

The judgment of the function of thyroid nodules and the differentiation of benign and malignant are of high diagnostic value.

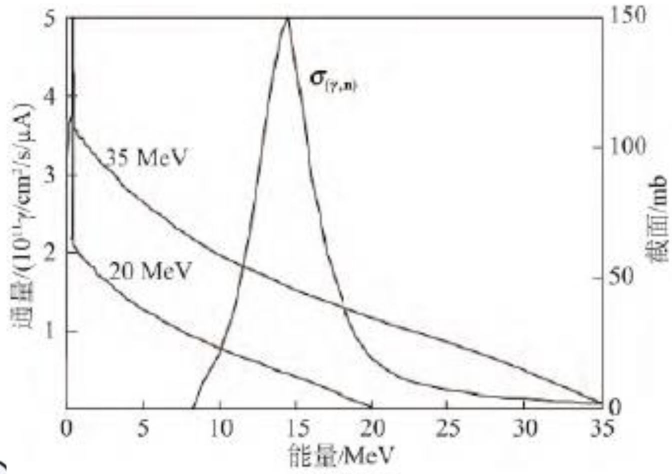
Diagnosis of myocardial ischemia.

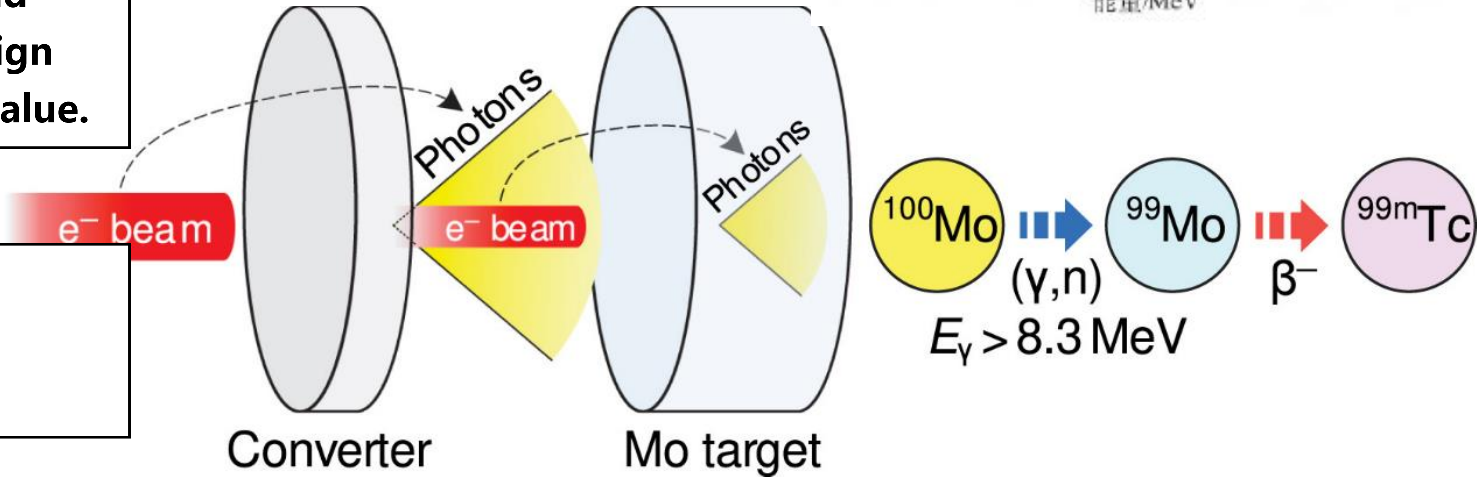
(1) $^{100}Mo+\gamma \rightarrow {}^{99}Mo+n$;

(2) $^{100}Mo+\gamma \rightarrow {}^{99m}Nb+p$, ^{99m}Nb $(T_{1/2}=15s) \rightarrow {}^{99}Mo+\beta$;

(3) $^{100}Mo+\gamma \rightarrow {}^{99m}Nb+p$, ^{99m}Nb $(T_{1/2}=12.6m) \rightarrow {}^{99}Mo+\beta$;

(4) $^{100}Mo+n \rightarrow {}^{99}Mo+2n$





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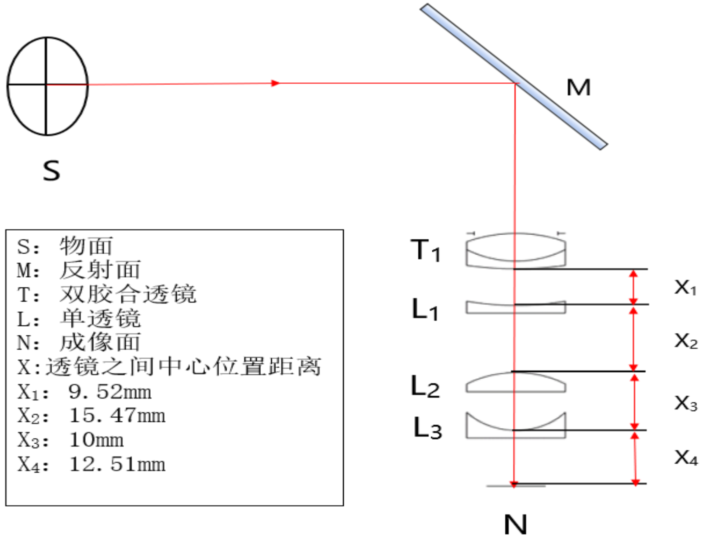
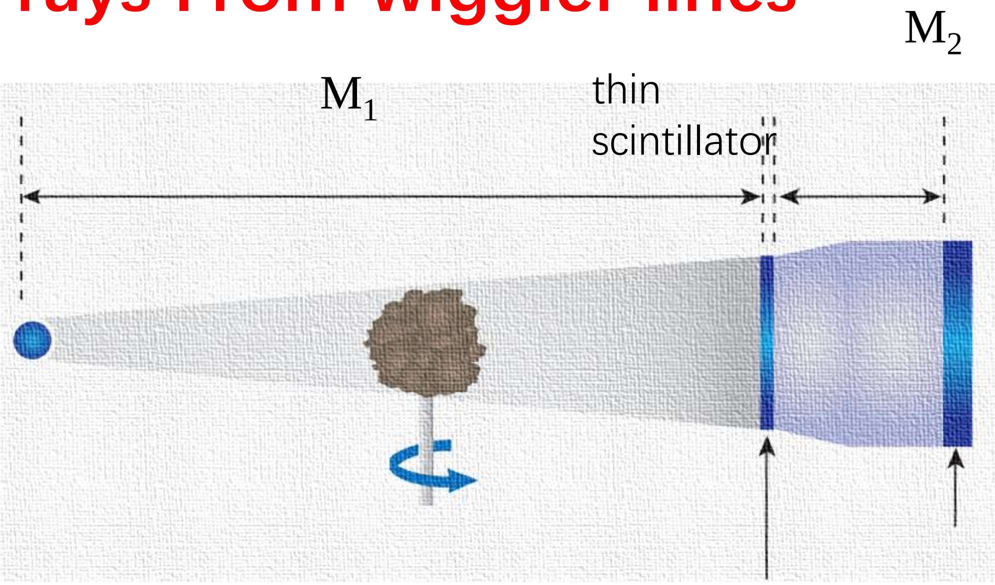
Gamma-ray camera: thin scintillator +focusing system+SPad

- The incident γ light passes through a thin scintillator and turns into visible light, which is imaged after lens focusing
- The focal plane uses a small-pixel SPAD （integrated SiPM)

X ray energy range: keV~MeV
Position resolution: 10 microns
Detector area: ~40mm

- Need to do：
- Flux and energy distribution of the gamma-rays From wiggler lines





Conclusion

- Parameters of the gamma source
- 1） The mechanical design of the total beamline
- 2） The vacuum design needs to consider
- 3） The focalization of gamma-ray
- Applications of a high intensity γ-ray source
- Detection methods of high-intensity gamma-ray

1） Flux and energy distribution of the gamma-rays From wiggler lines