中国科学院上海高等研究院

International Symposium on Stored Ions for Precision Measurements

Shanghai Laser Electron Gamma Source and its Photonuclear Reaction Research

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SSRF Science Center

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Outline

1. A brief introduction to Shanghai Light Source (SSRF)

2. Shanghai Laser Electron Gamma Source (SLEGS) Bramline

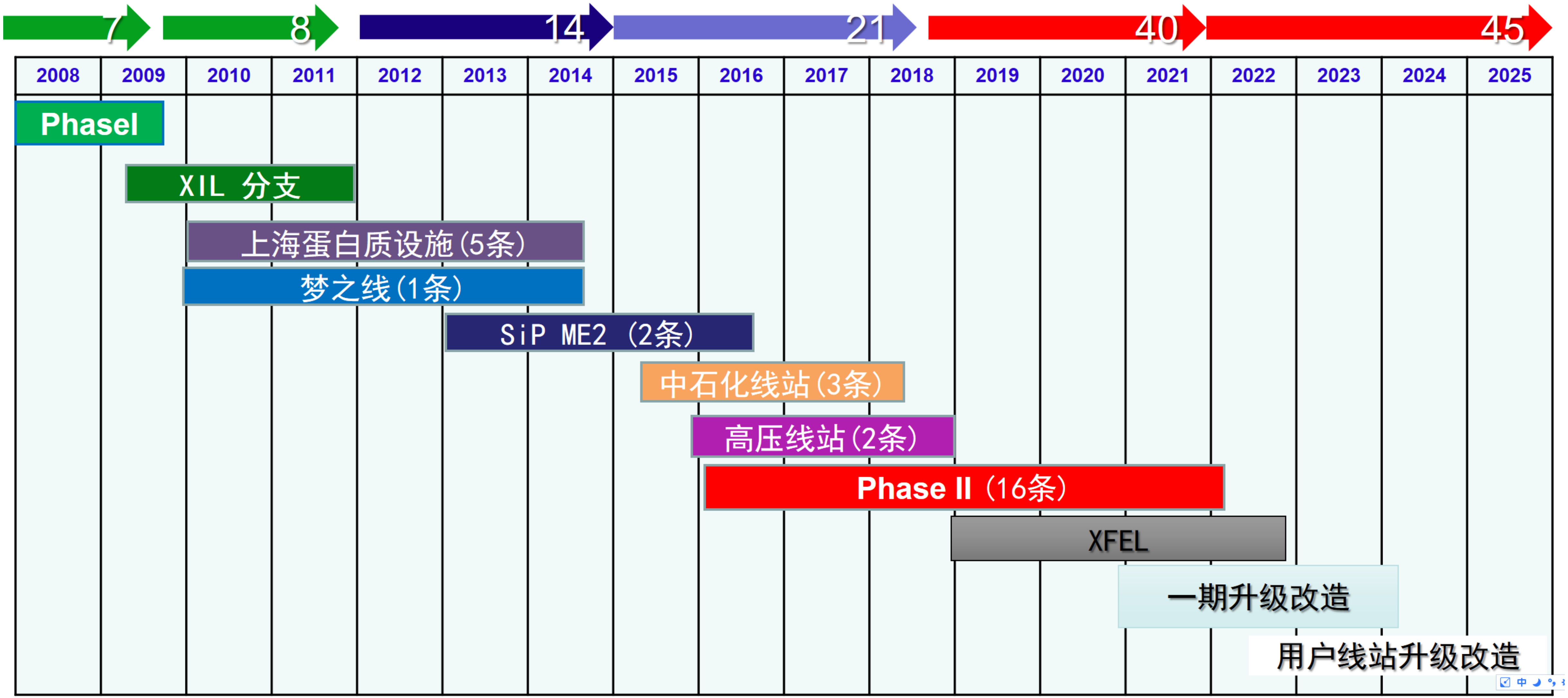
3. Photonuclear Reaction Research at SLEGS

4. Summary

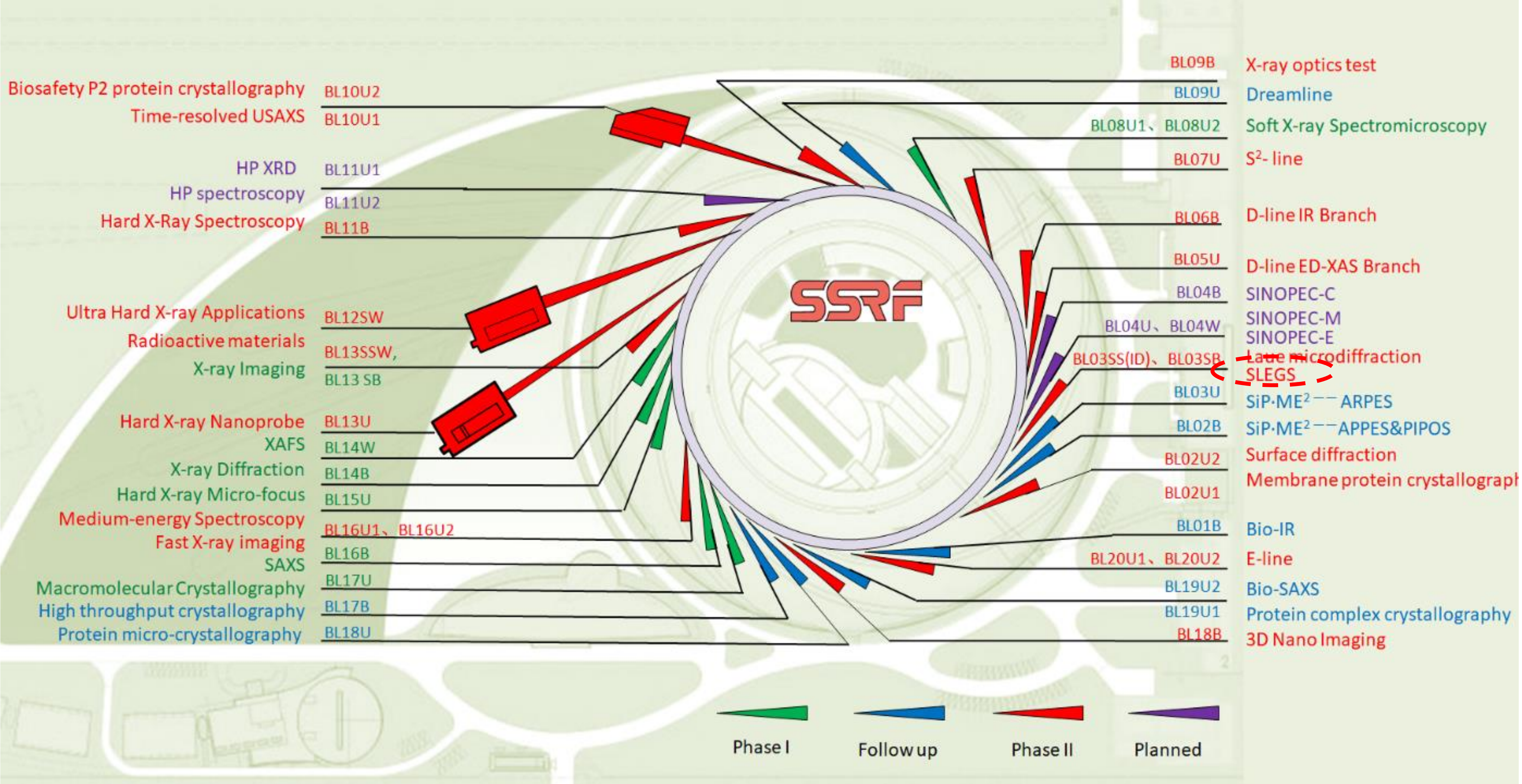
1. A brief introduction to SSRF

Energy	**3.5 GeV**
Beam Sizeσ_x	276.9 um
Beam Sizeσ_y	12.24 um
Pulse RMS	3 mm
Current	**300 mA**
Q_e	1.44 nC
Emittance$\varepsilon_x/\varepsilon_y$	2.59 / 2.59E-2 nmrad
Divergenceη_x/η_y	0.207 / 0 m
β_x/β_y	14.86 / 5.78 m
Energy spread	0.944E-3
Pulse Number	500

1. A brief introduction to SSRF



1. A brief introduction to SSRF



1. A brief introduction to SSRF

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已运行

X射线成像及医学应用
X射线小角散射
生物大分子晶体学
XAFS
XRD
硬X射线微聚焦
软X射线谱学显微

已建设

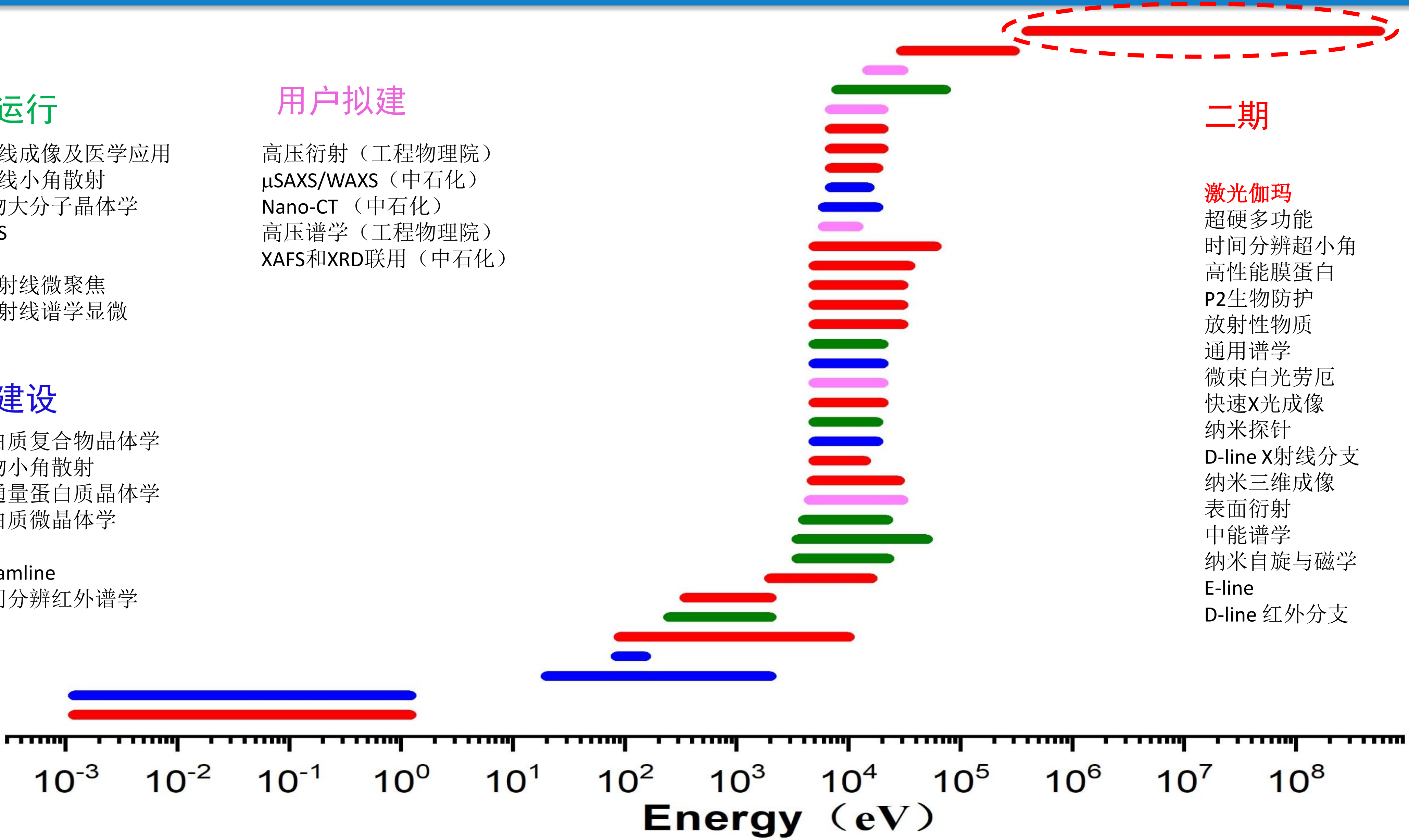
蛋白质复合物晶体学
生物小角散射
高通量蛋白质晶体学
蛋白质微晶体学
XIL
Dreamline
时间分辨红外谱学

用户拟建

高压衍射（工程物理院）
μSAXS/WAXS（中石化）
Nano-CT （中石化）
高压谱学（工程物理院）
XAFS和XRD联用（中石化）

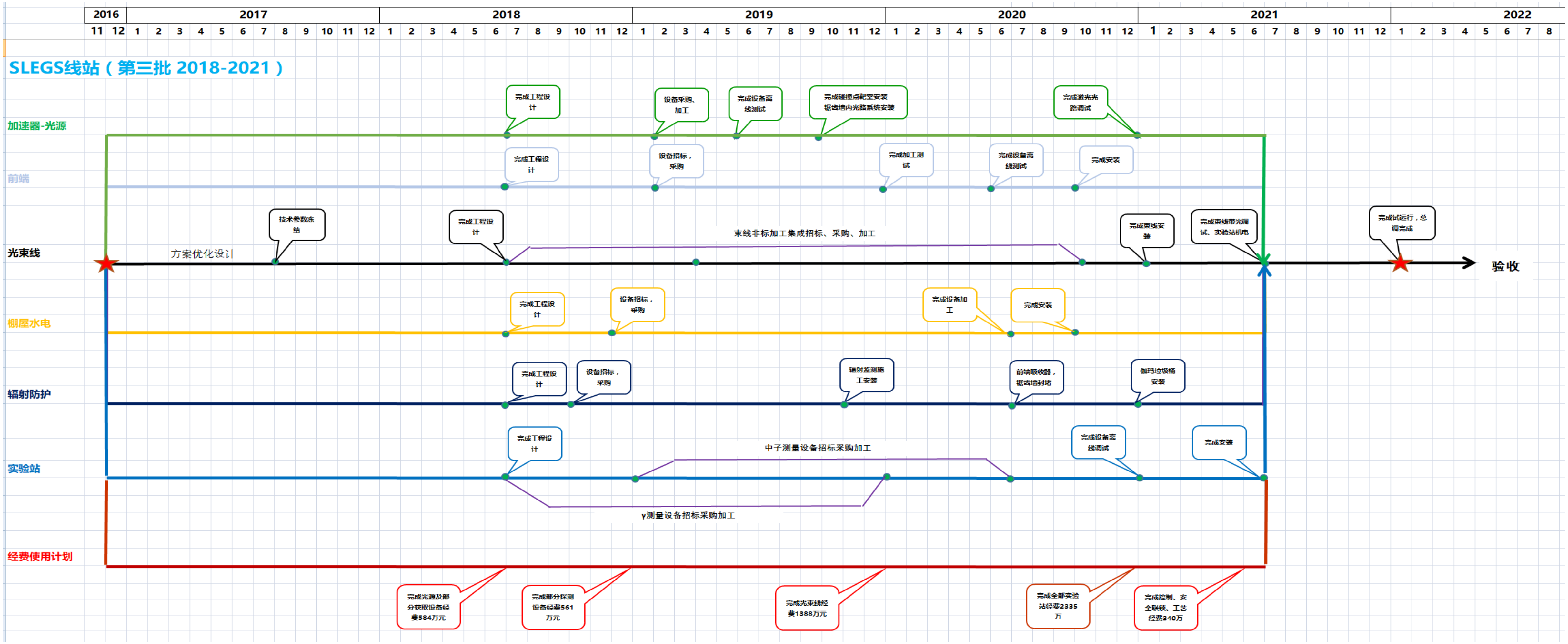
二期

激光伽玛
超硬多功能
时间分辨超小角
高性能膜蛋白
P2生物防护
放射性物质
通用谱学
微束白光劳厄
快速X光成像
纳米探针
D-line X射线分支
纳米三维成像
表面衍射
中能谱学
纳米自旋与磁学
E-line
D-line 红外分支



2. Shanghai Laser Electron Gamma Source

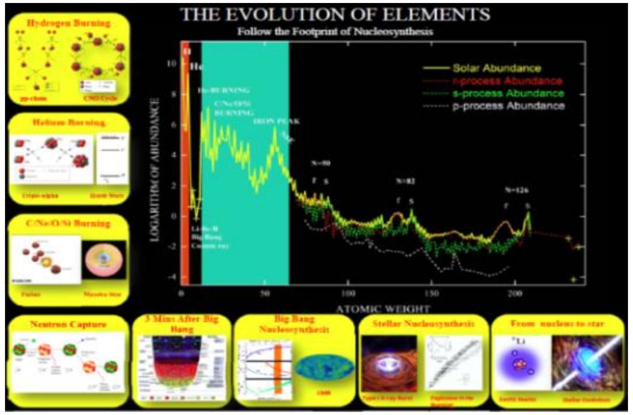
Timing Plan



2. Shanghai Laser Electron Gamma Source

Scientific goals

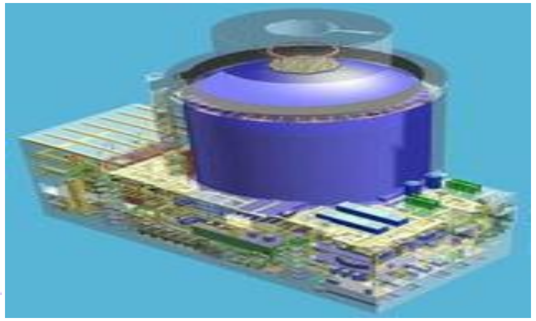
- ➢Photo-nuclear physics:
  - ✓ Nuclear Astrophysics： nuclear reactions which have a critical impact on stellar evolution and nucleosynthesis of elements
  - ✓ Nuclear structure GDR and NRF, etc.
- ➢Research on the anti-γ radiation properties of aerospace device and calibration for the X/γ detector equipped on aerospace device
- ➢Nuclear waste transmutation research and nuclear safety,
- ➢Gamma-ray imaging techniques (in particular: isotope imaging technology), etc.



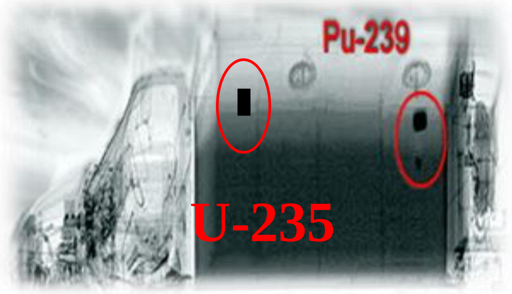
Space (radiation hardened)

Nuclear technology and data

Gamma image

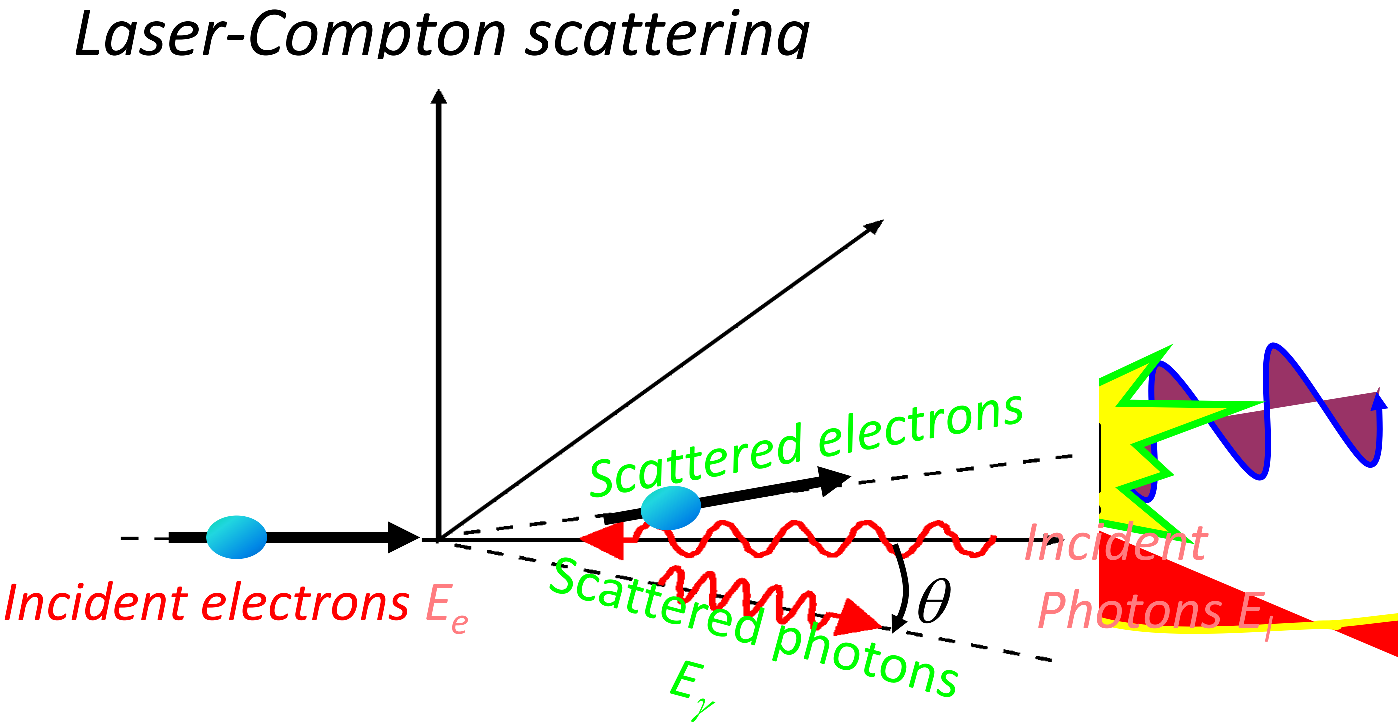


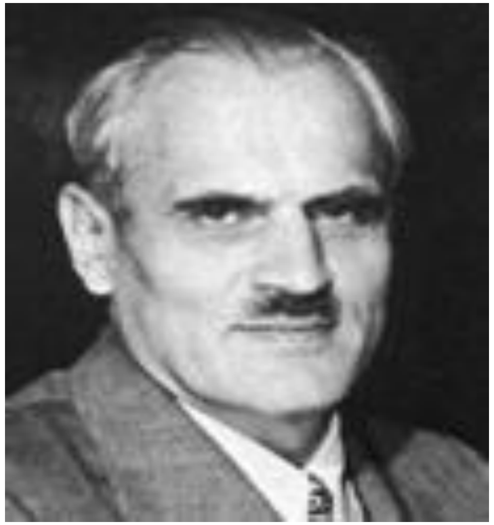
Nuclear reactor



Isotope Detection

2. Shanghai Laser Electron Gamma Source



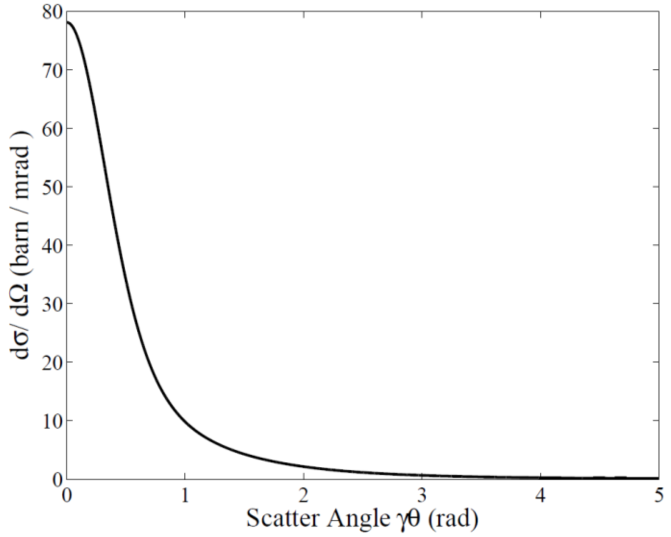


A. H. Compton
(1892-1962)

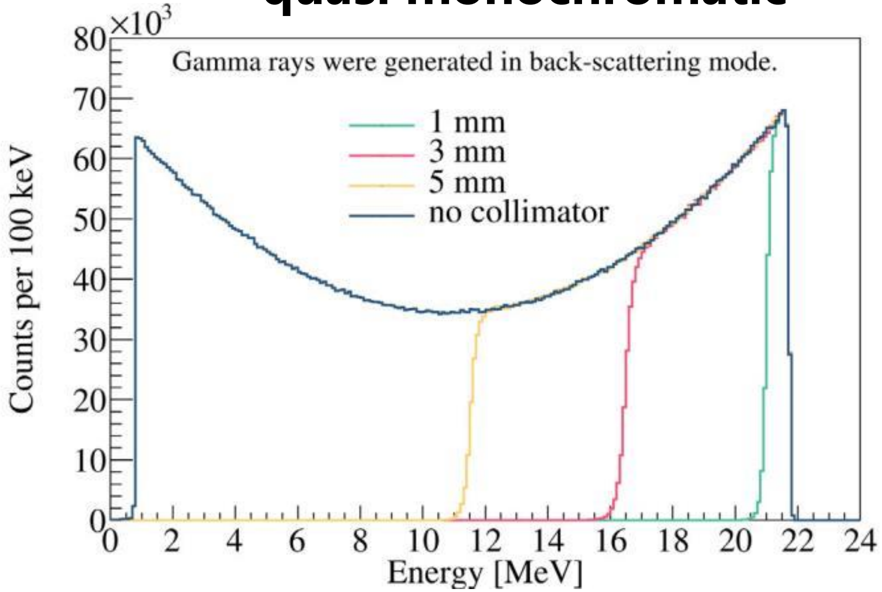
$$E_\gamma = \frac{E_l\left(1-\beta\cos\theta_L\right)}{1-\beta\cos\theta + \dfrac{E_l\left\{1-\cos\left(\theta_L-\theta\right)\right\}}{E_e}}$$

2. Shanghai Laser Electron Gamma Source

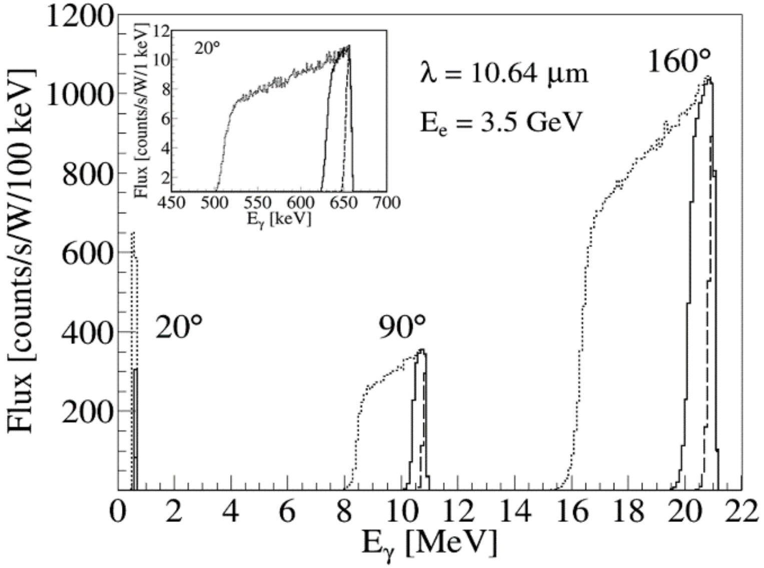
small divergence

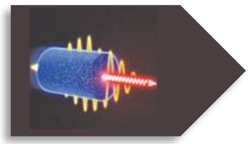


quasi monochromatic

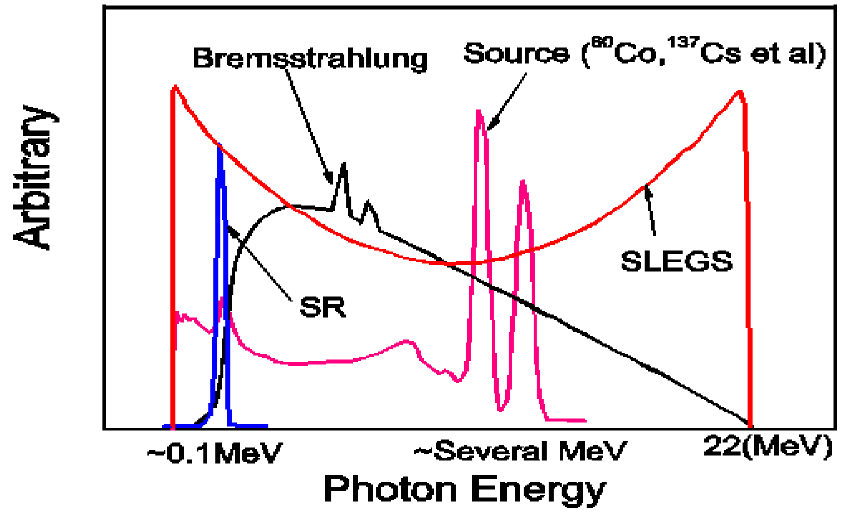


adjustable energy





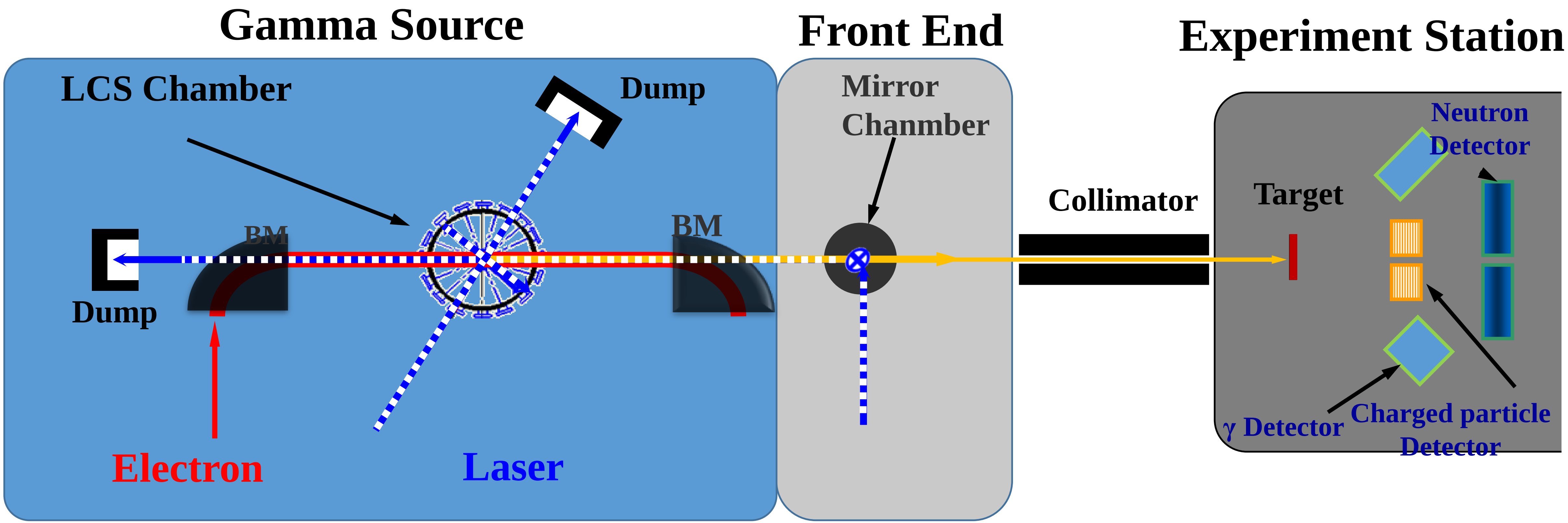
small divergence, high brightness, adjustable energy, quasi monochromatic, short pulse



With the breakthrough progress made in several important principle experiments of LCS light sources, the laser Compton light source was recognized by Science as one of the four most promising new light sources in the field of ultra short pulses in 1996, and began to attract widespread attention from the international scientific community. In 2010, at the 48th ICFA Advanced Beam Dynamics Workshop on Future Light Sources held at SLAC in the US, it was once again recognized as one of the most promising future light sources (with FEL, ERL, and synchrotron radiation light sources).

2. Shanghai Laser Electron Gamma Source

Operating mode



LCS Mode 1
Slanting Scattering

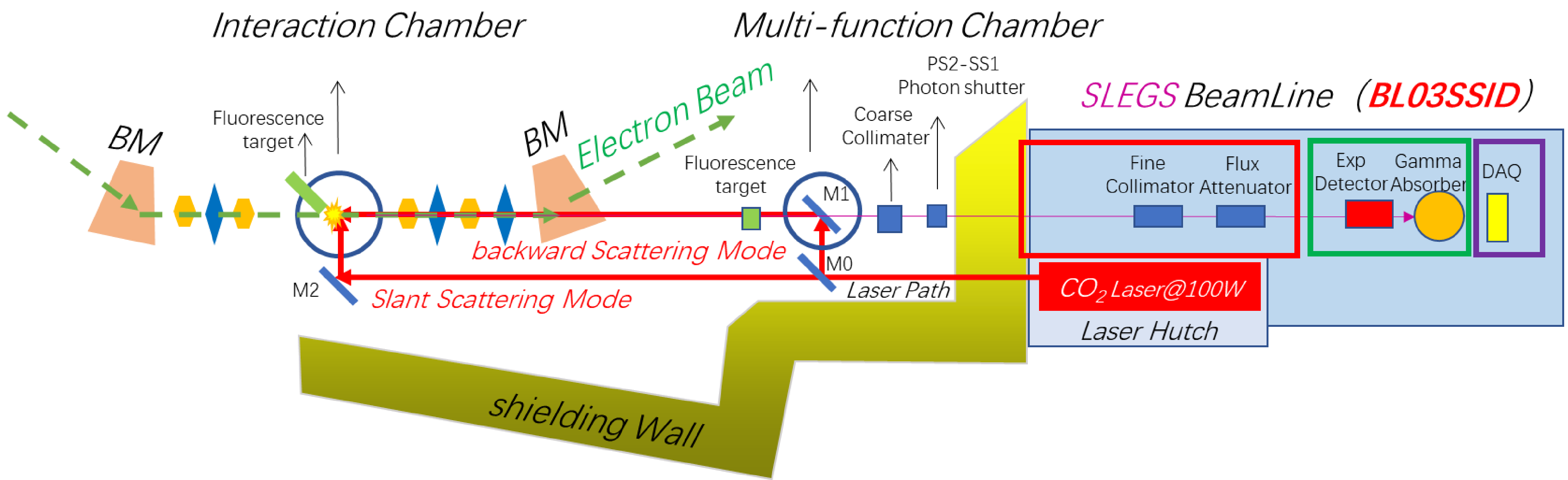
LCS Mode 2
Backward Scattering

Alternative mode

Reset

2. Shanghai Laser Electron Gamma Source

Layout



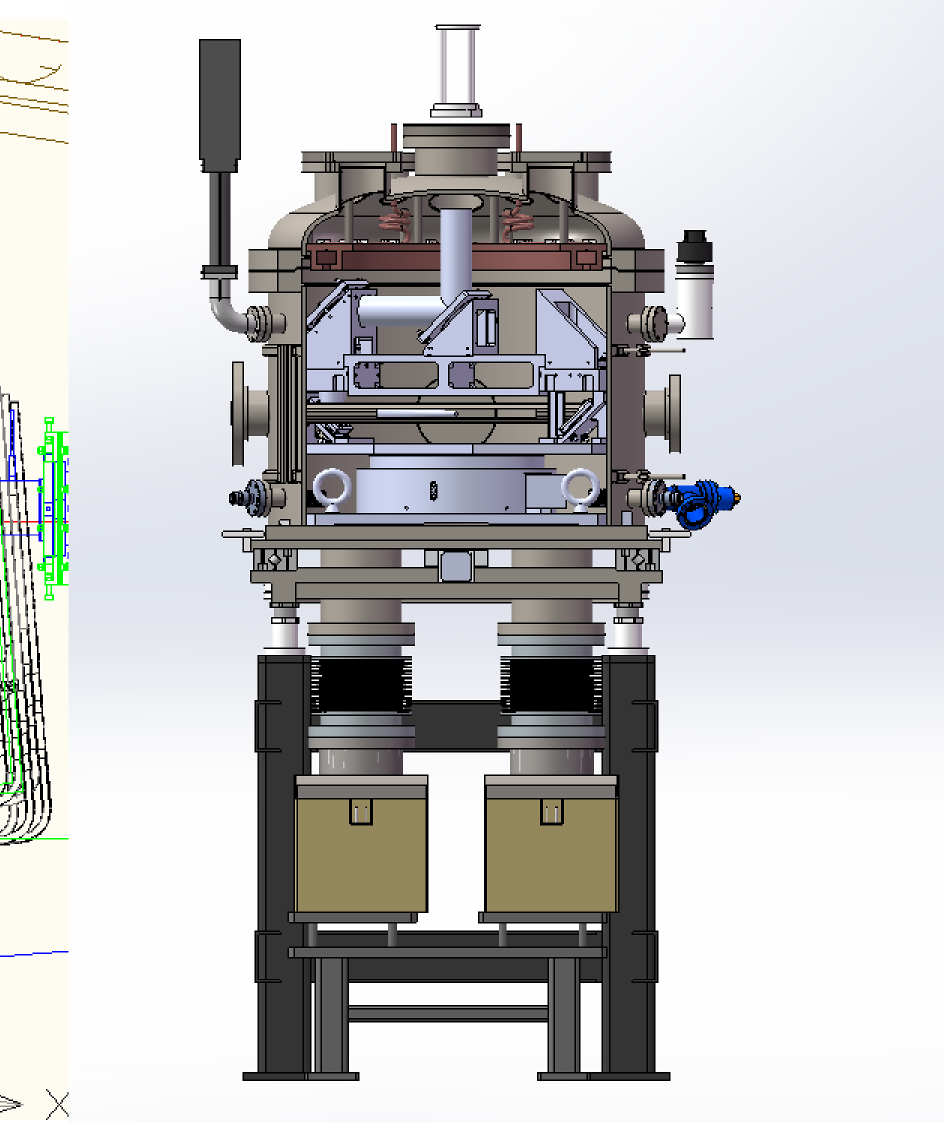
(1) Gamma source: electron, laser, LCS chamber(slanting mode), mirror chamber(back scattering).

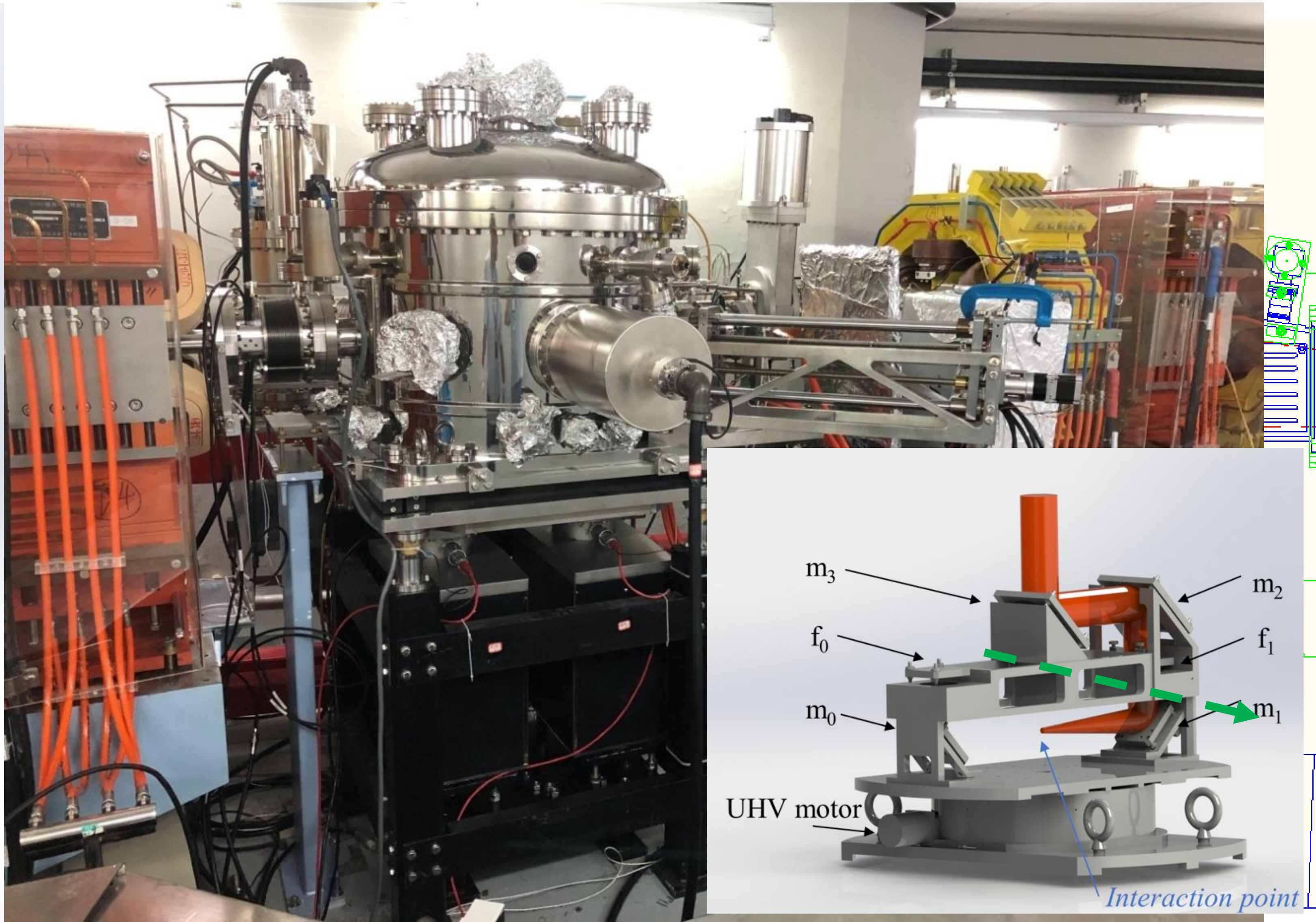
(2) Beamline: Collimators, attenuator, energy detector, position detector, flux detector and absorber.

(3) End station: (γ,n) Neutron detector， (γ,p/α) Charged particle detector， (γ,γ) Gamma detector

2. Shanghai Laser Electron Gamma Source

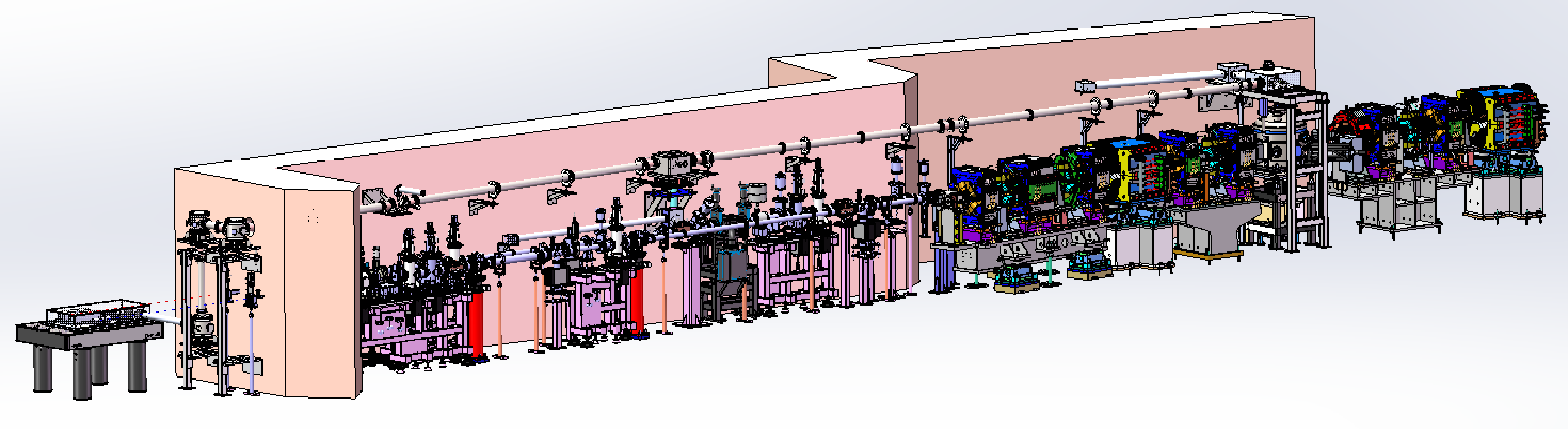
Construction-Gamma source





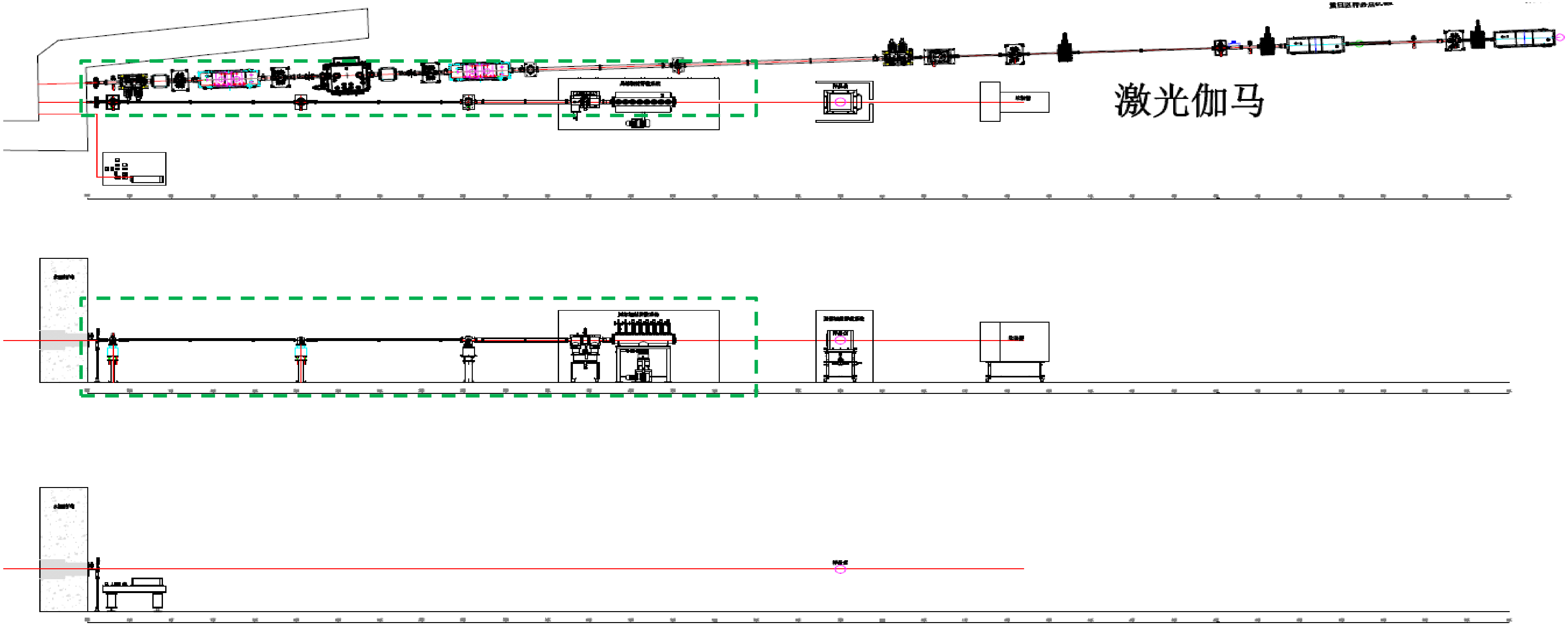
2. Shanghai Laser Electron Gamma Source

Construction-Gamma source



2. Shanghai Laser Electron Gamma Source

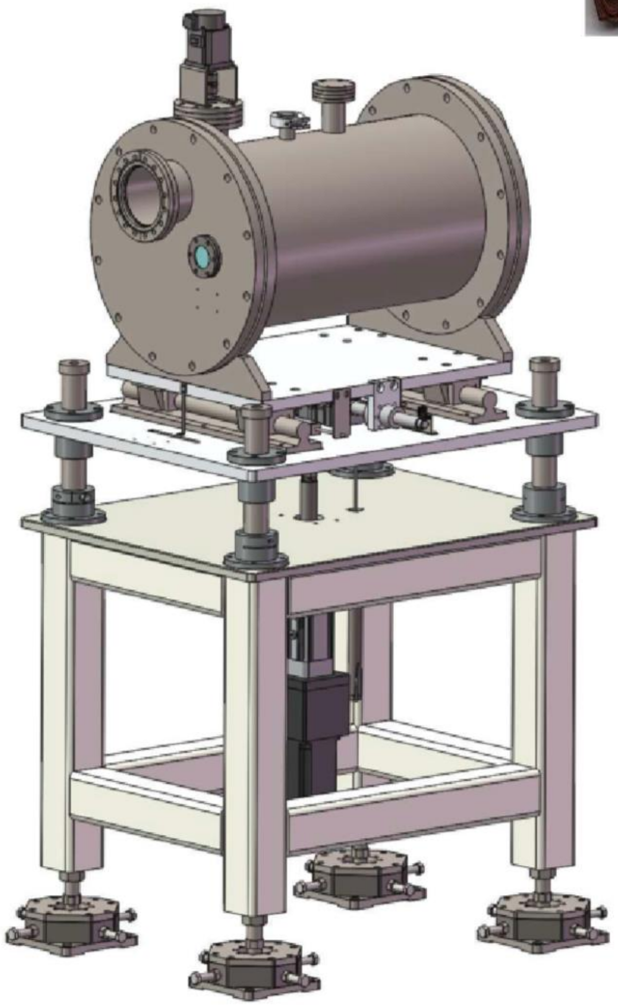
Construction-Beamline

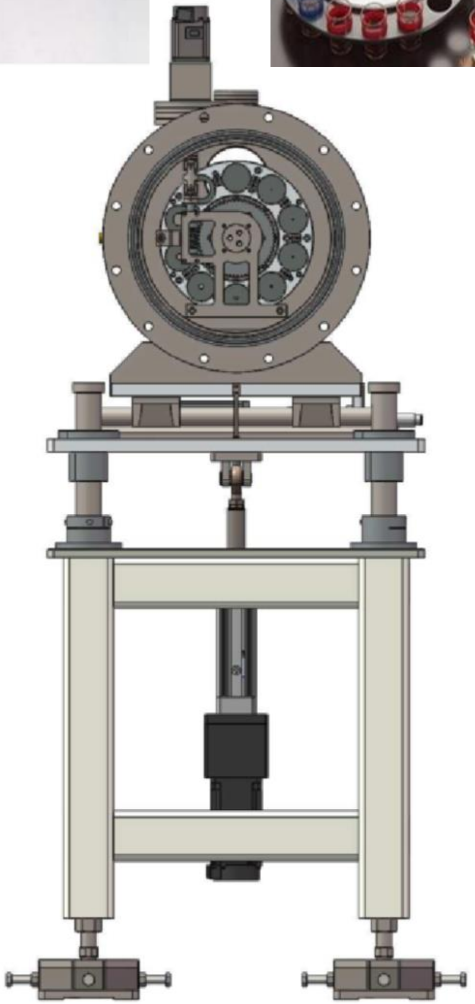


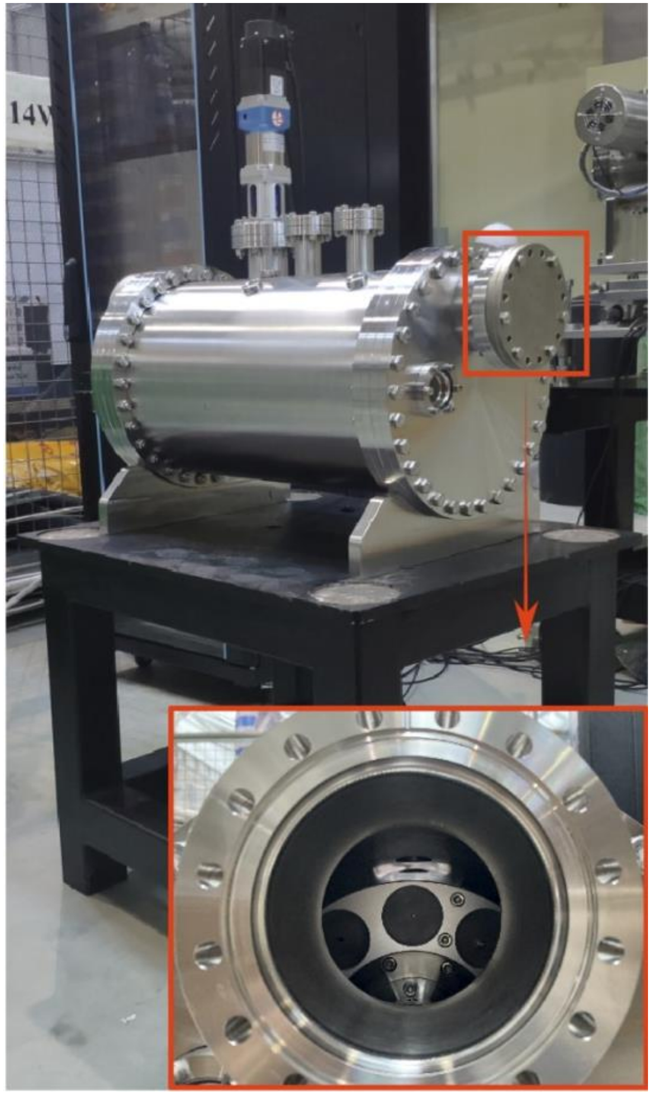
Collimators, attenuator, energy detector, position detector, flux detector and gamma absorber

2. Shanghai Laser Electron Gamma Source

Construction-Beamline

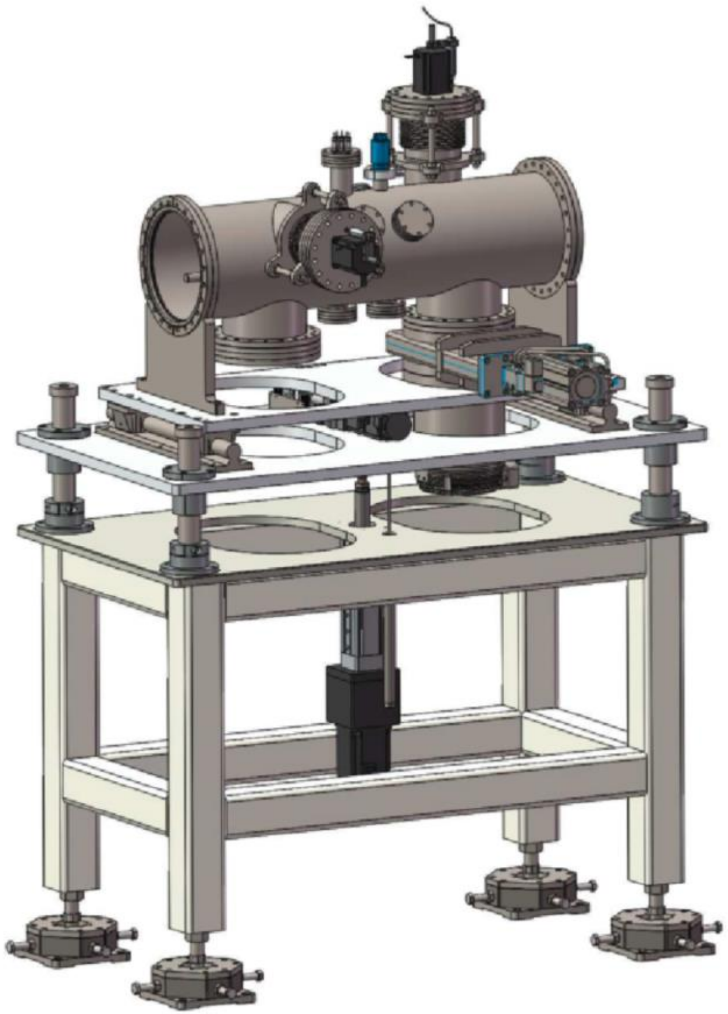


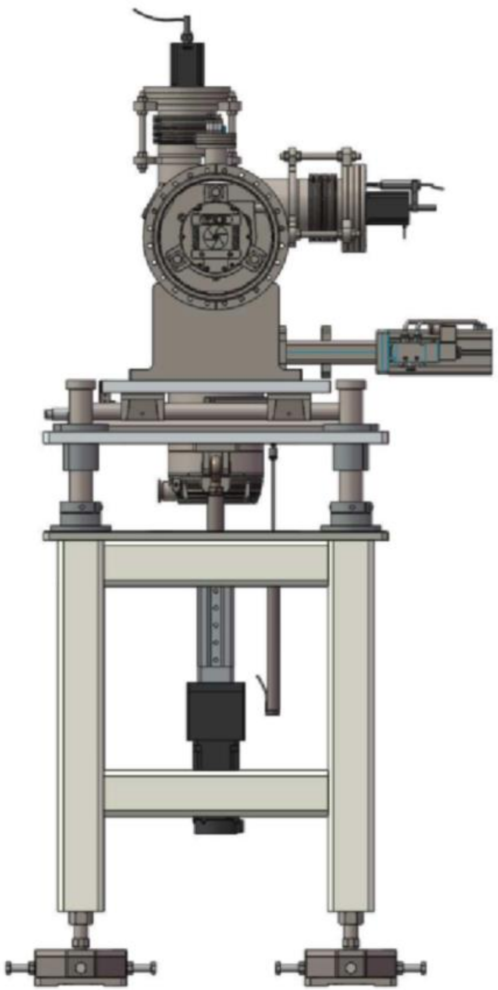


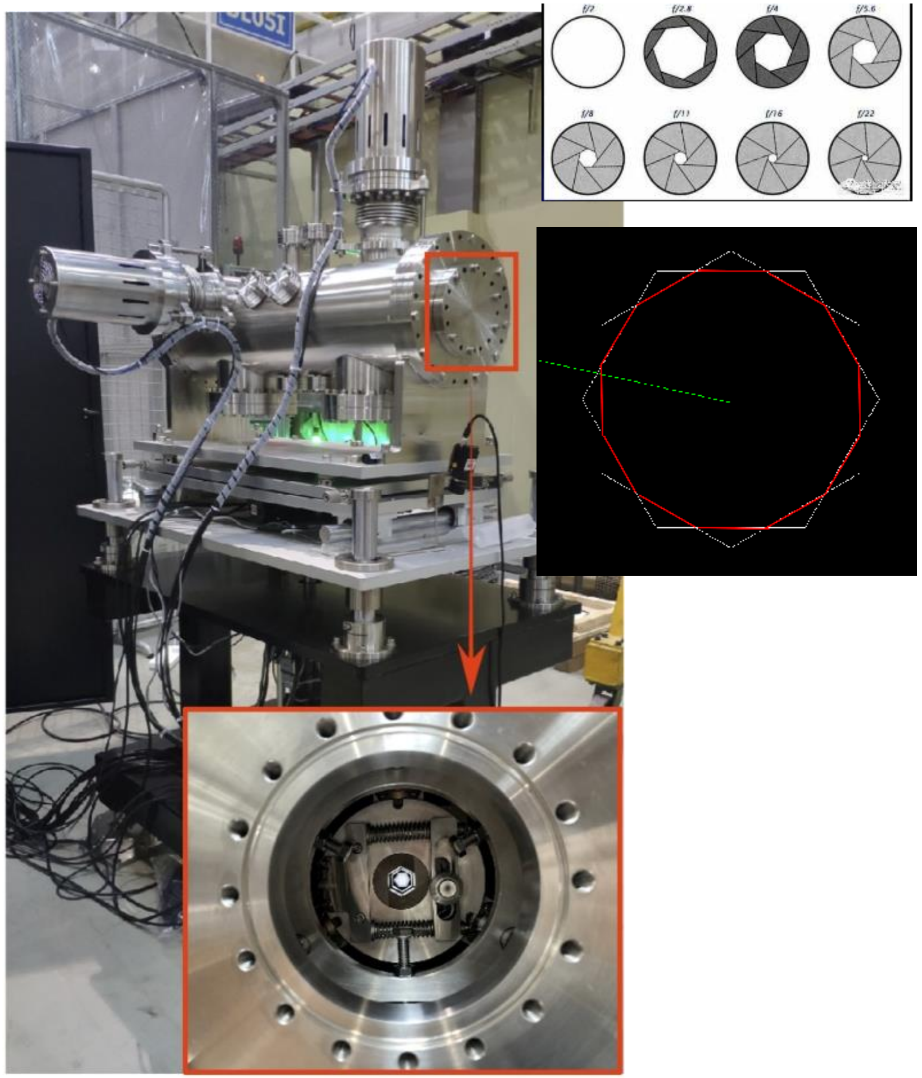


2. Shanghai Laser Electron Gamma Source

Construction-Beamline

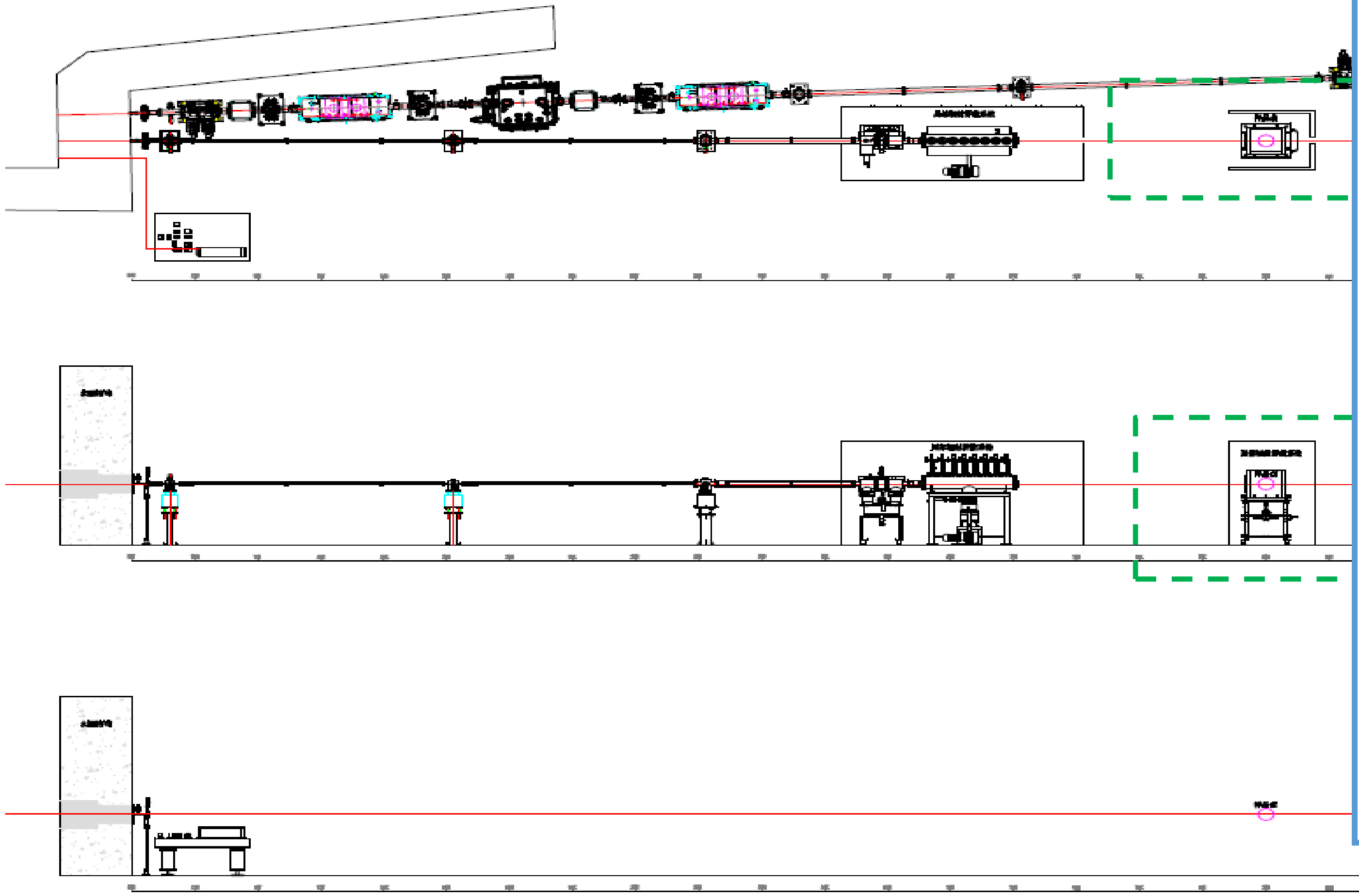






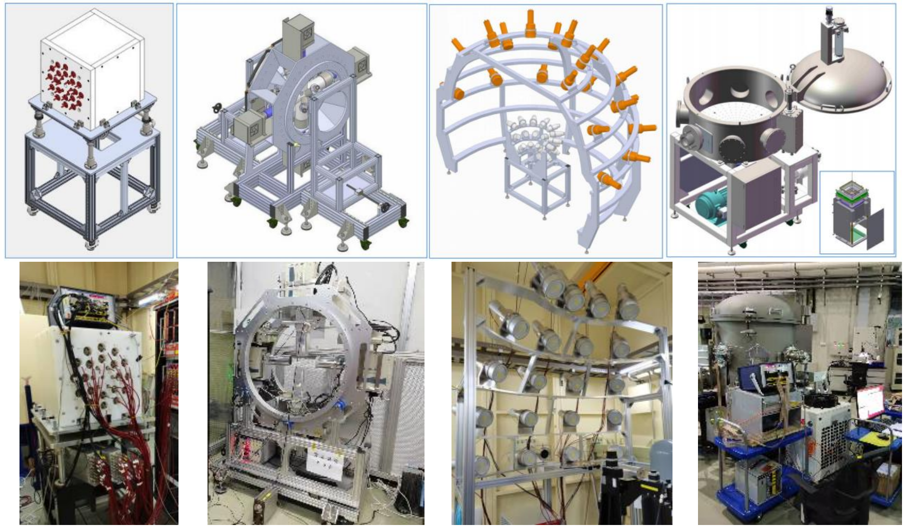
2. Shanghai Laser Electron Gamma Source

Construction-End station



Key Detectors

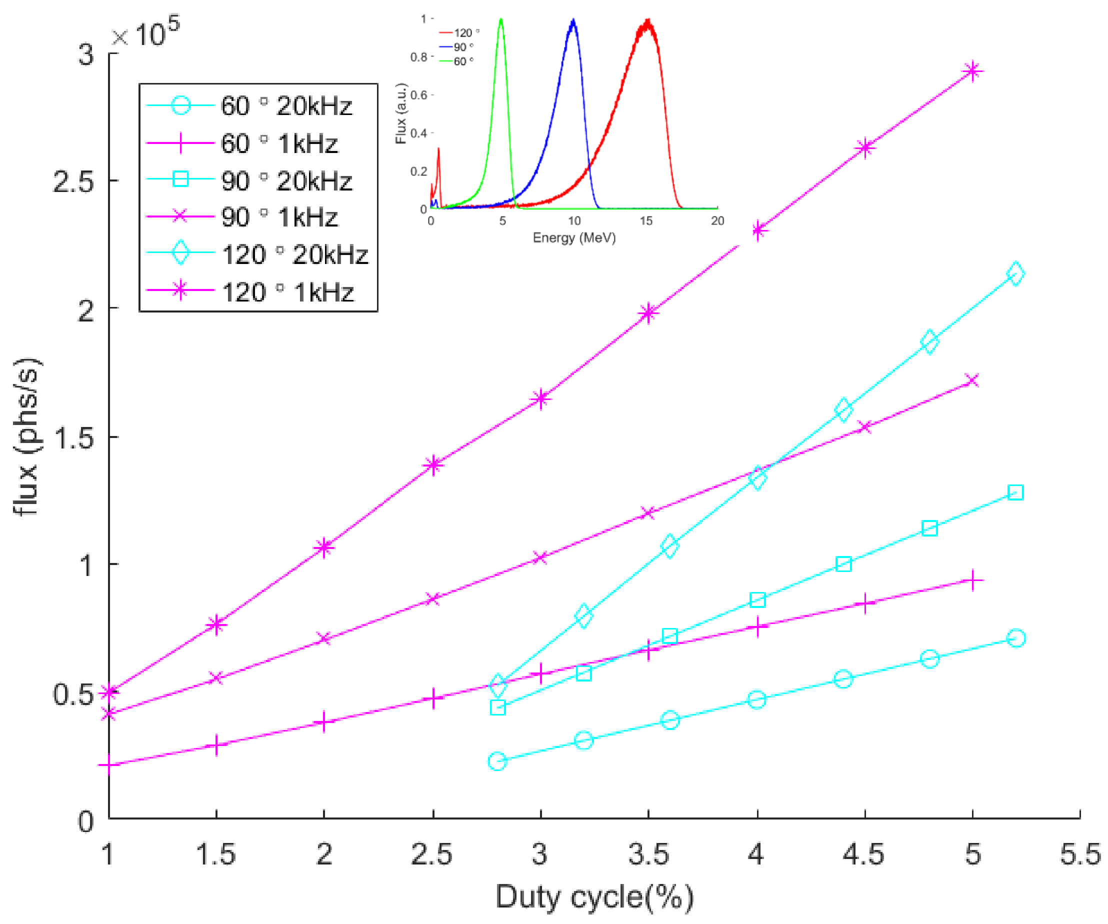
Neutron flattening efficiency spectrometer	Nuclear resonance fluorescence spectrometer	Photoneutron time-of-flight spectrometer	Charged particle spectrometer

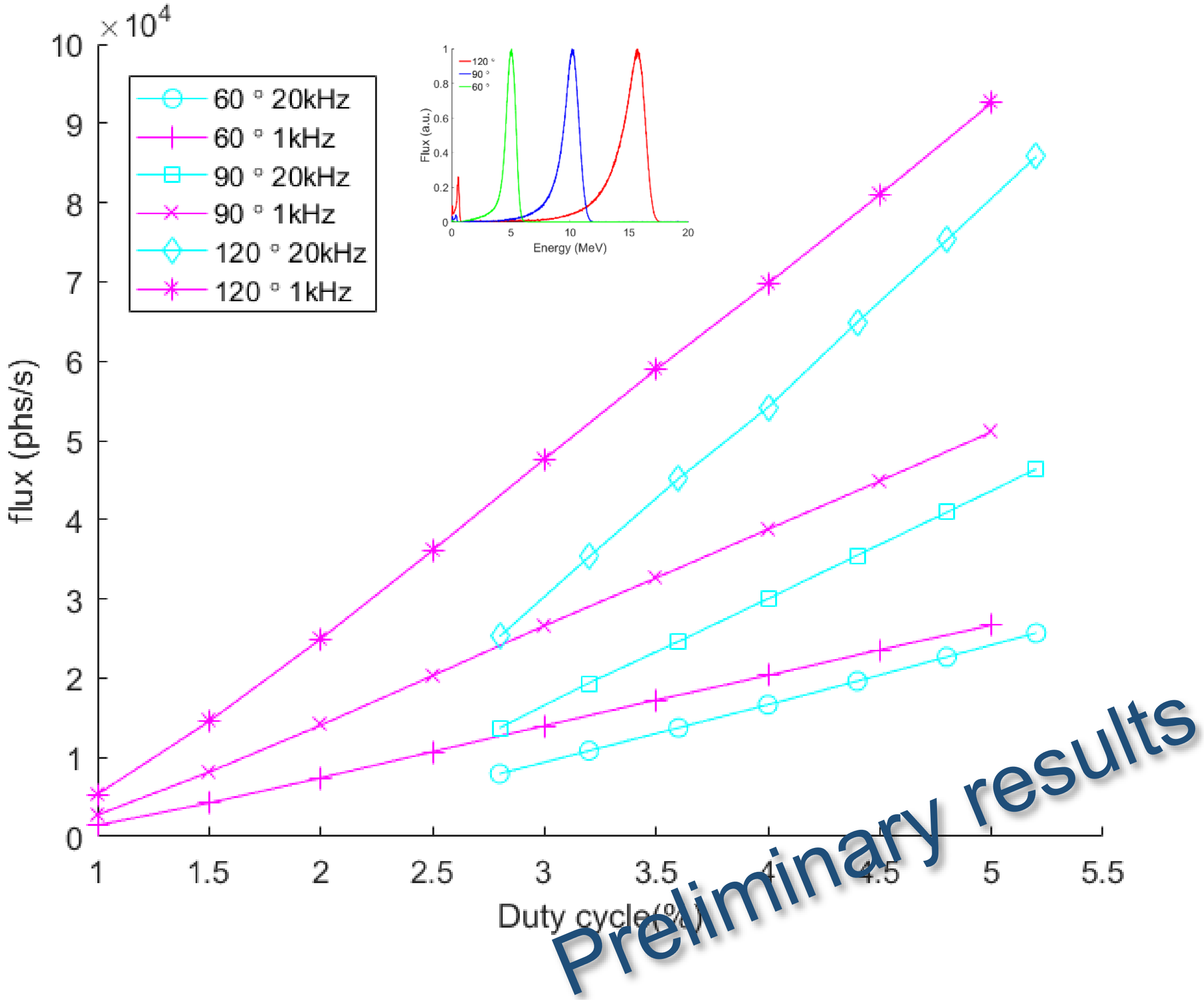


(γ,n） Neutron detector， (γ,p/α） Charged particle detector，
(γ,γ） Gamma detector

2. Shanghai Laser Electron Gamma Source

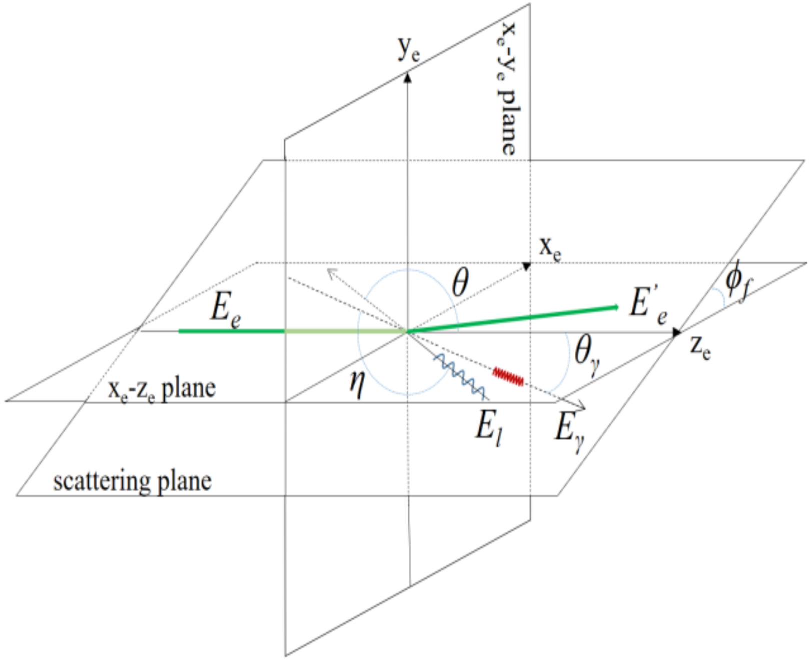
Gamma properties – flux

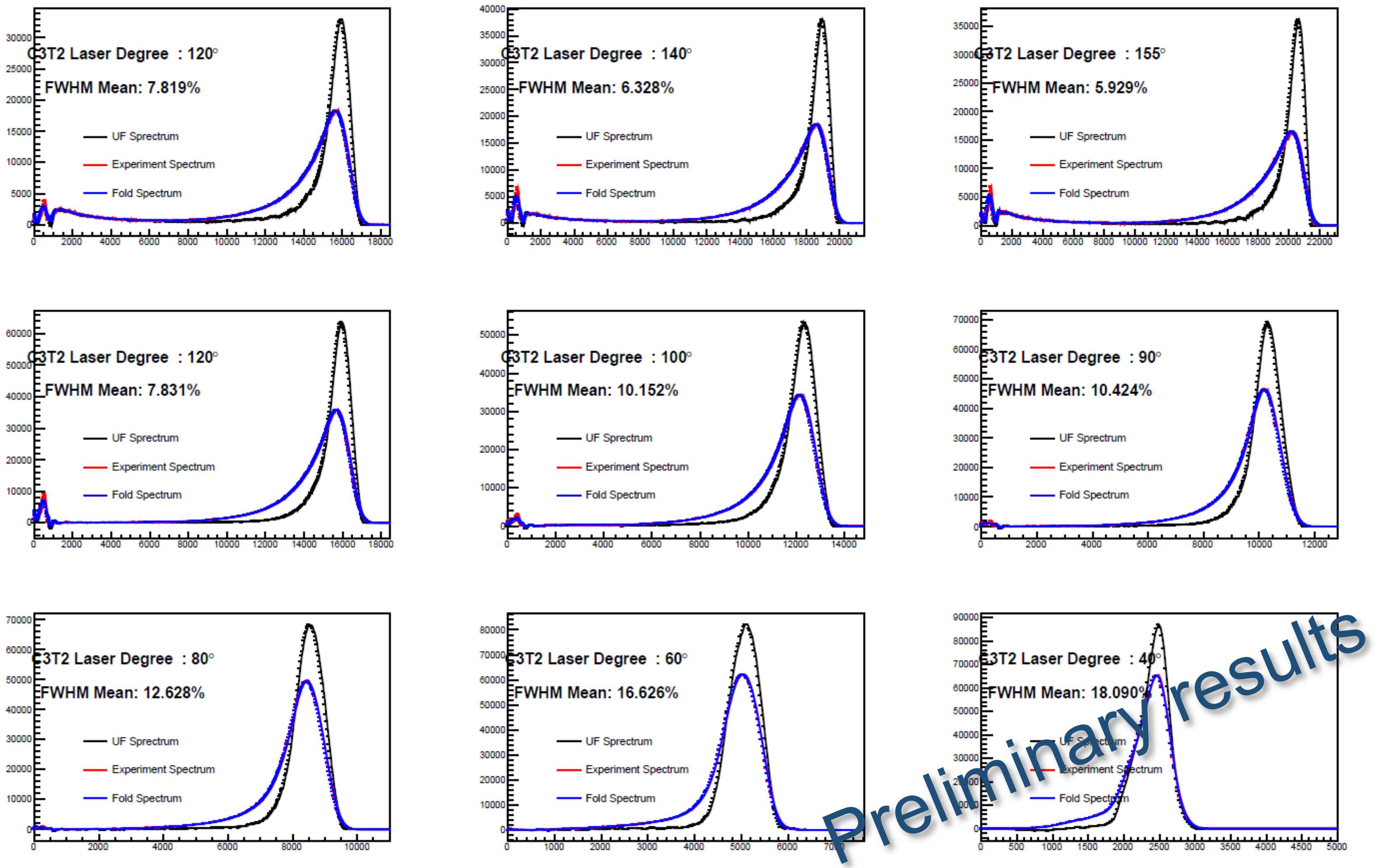




2. Shanghai Laser Electron Gamma Source

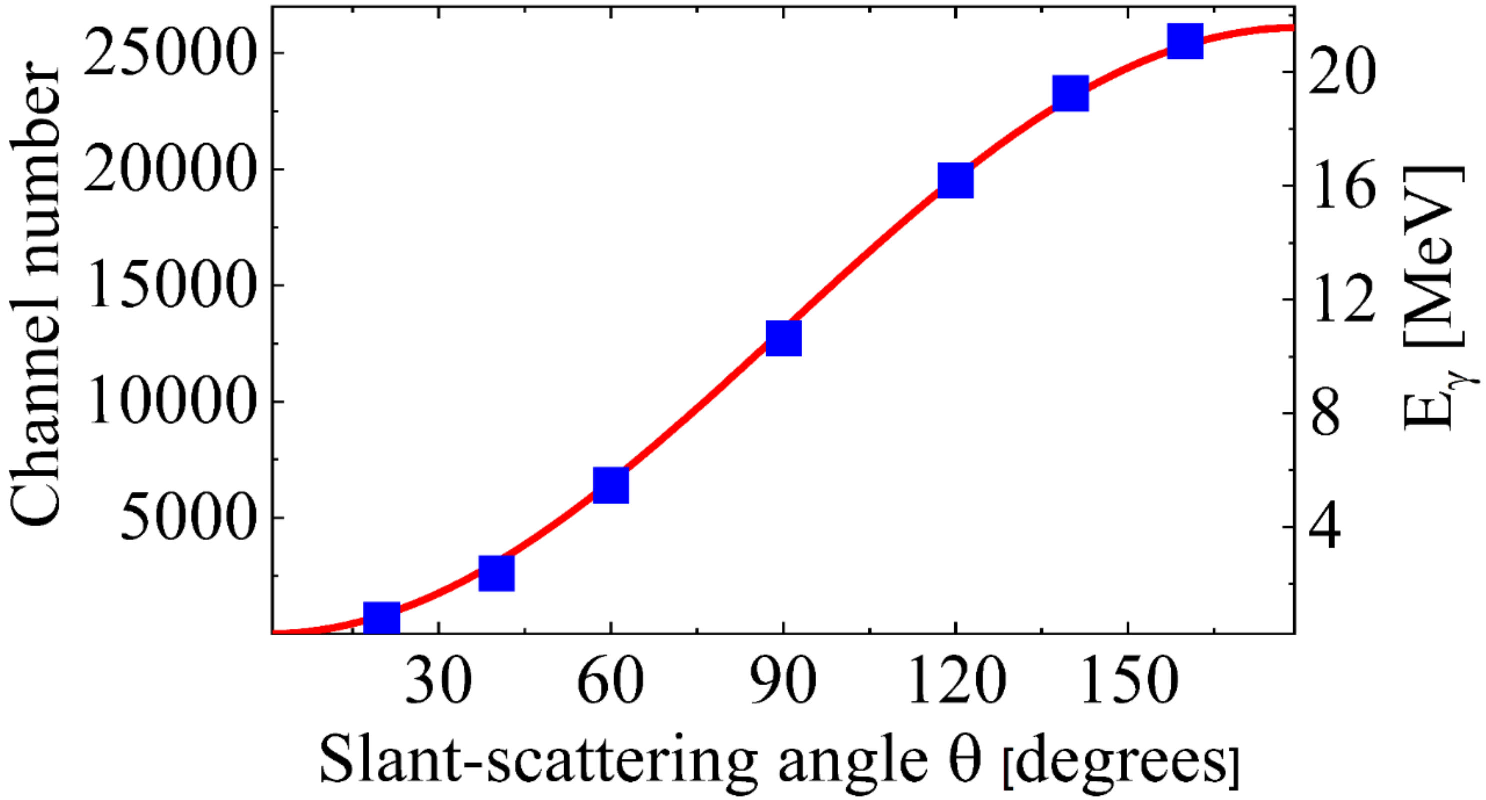
Gamma properties – energy & scattering angle





2. Shanghai Laser Electron Gamma Source

Gamma properties – energy & scattering angle

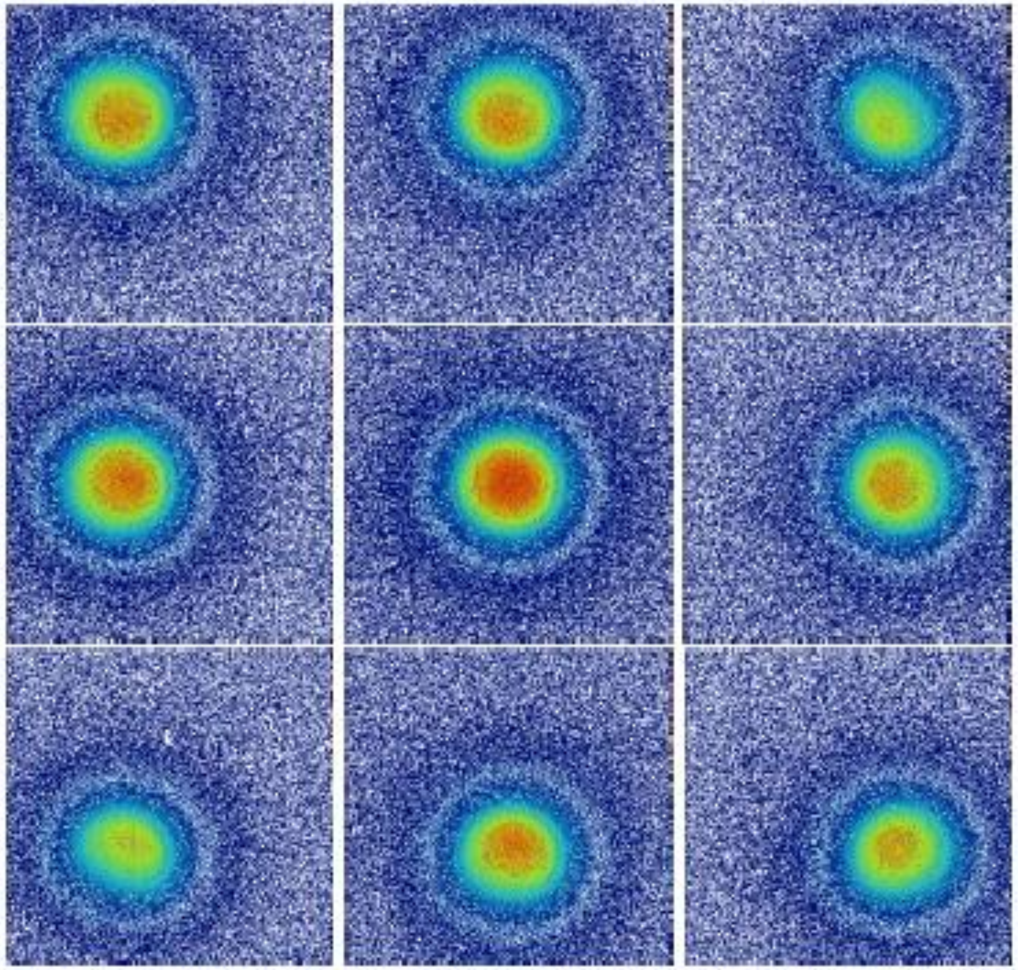


E_γ	**0.6-21.7 MeV**	**Integrated gamma flux**	**2×10^4phs/s@20°-2×10^6phs/s@180°**
E_γ resolution (FWHM)	**~5-15 % (determined by incident angle and collimator)**	**γ-ray divergence**	<0.4 mrad

Preliminary results

2. Shanghai Laser Electron Gamma Source

Gamma properties – spots



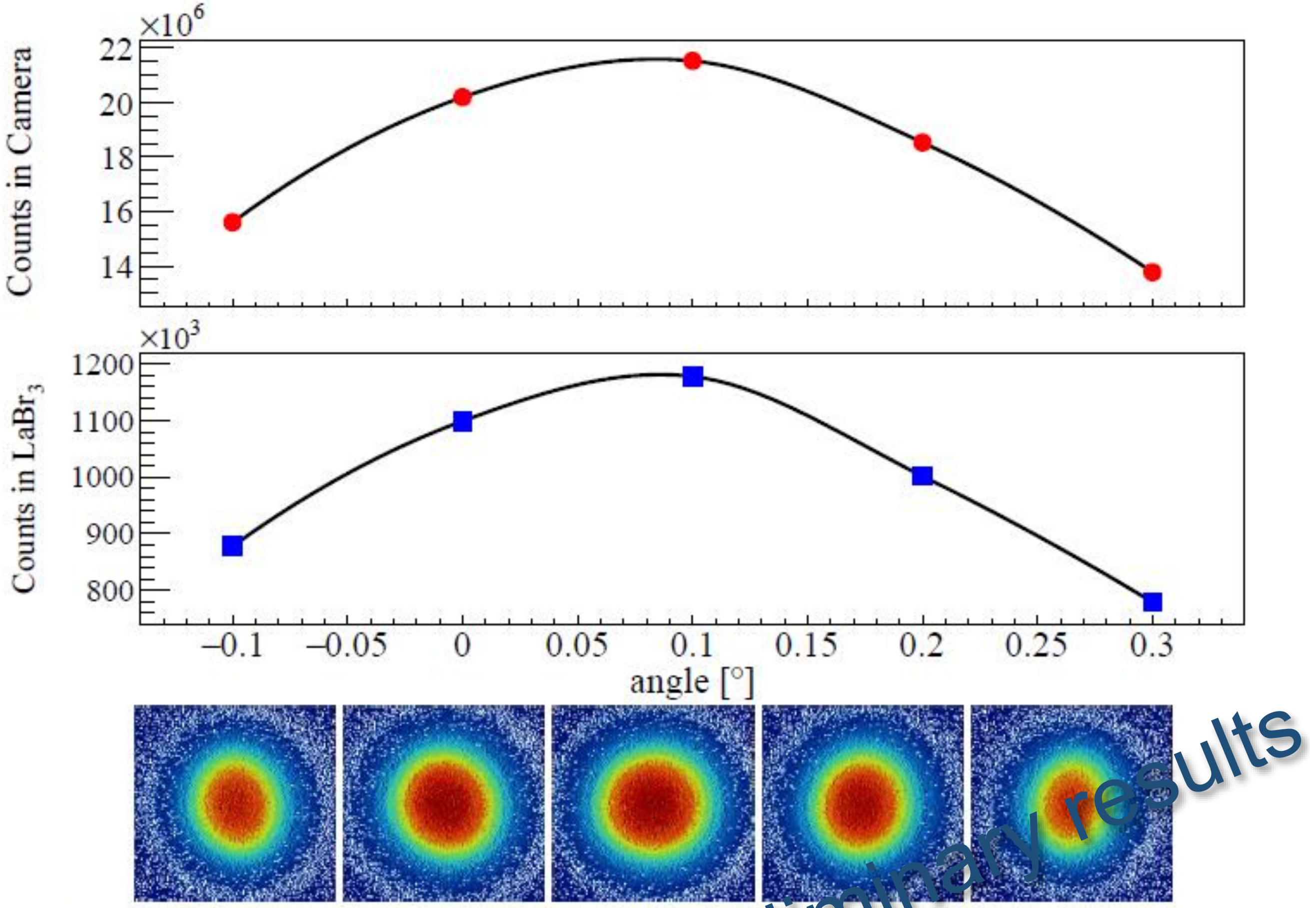
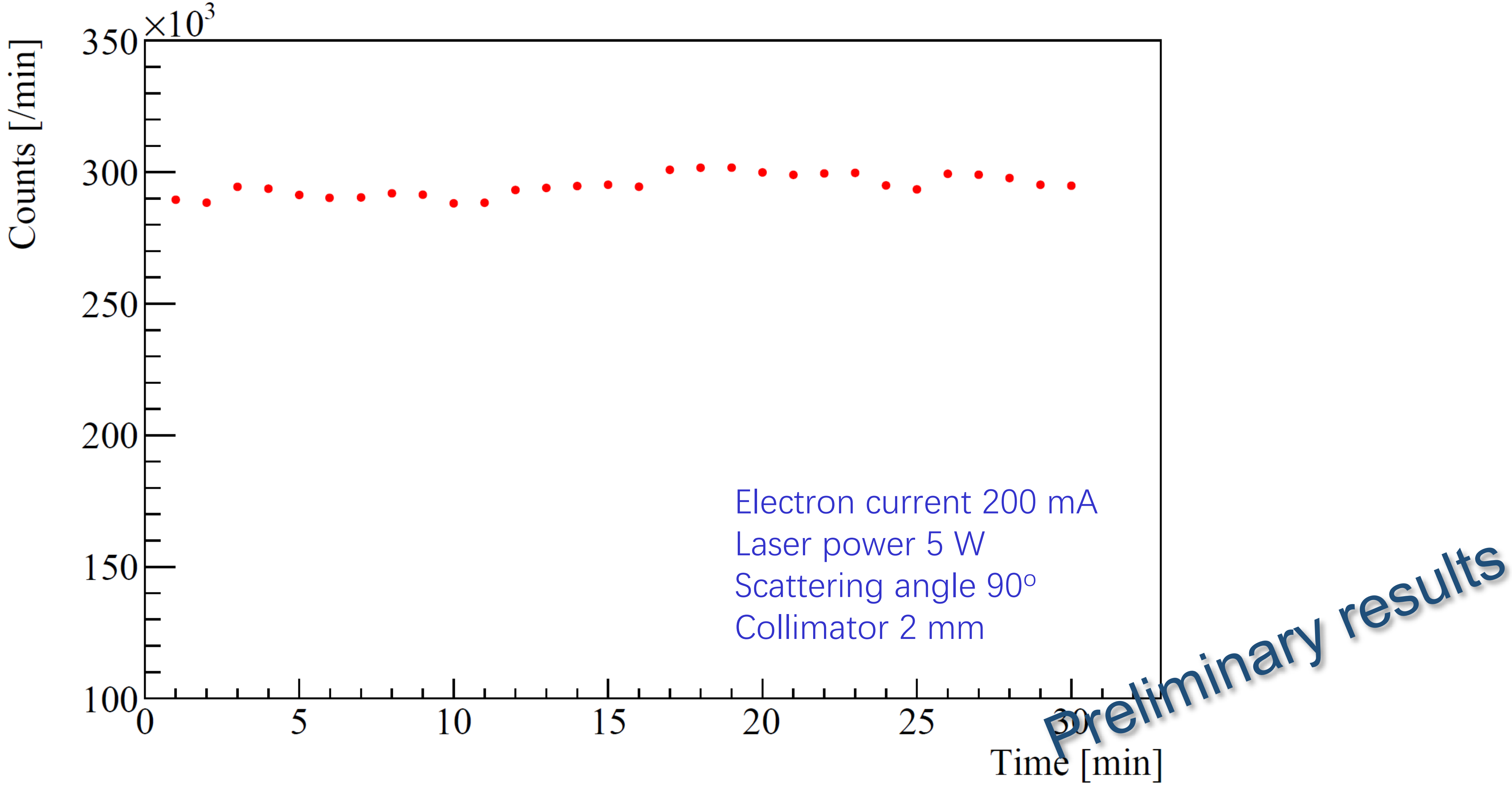


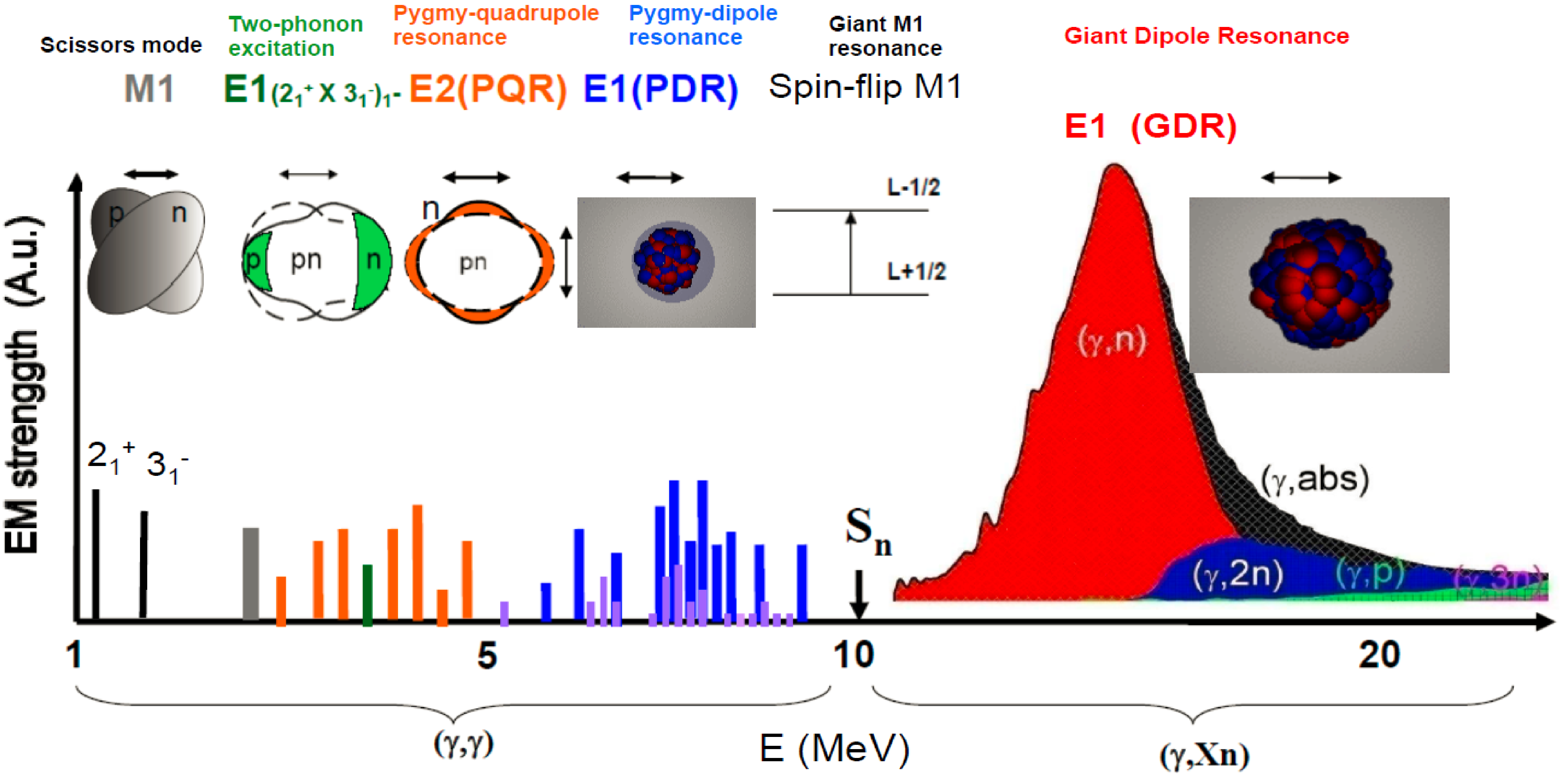
Figure 5: Images at different rotations of the external collimator and the corresponding counts in the $LaBr_3$ detector. The counts in the images are also shown in the top panel.

2. Shanghai Laser Electron Gamma Source

Gamma properties – flux stability

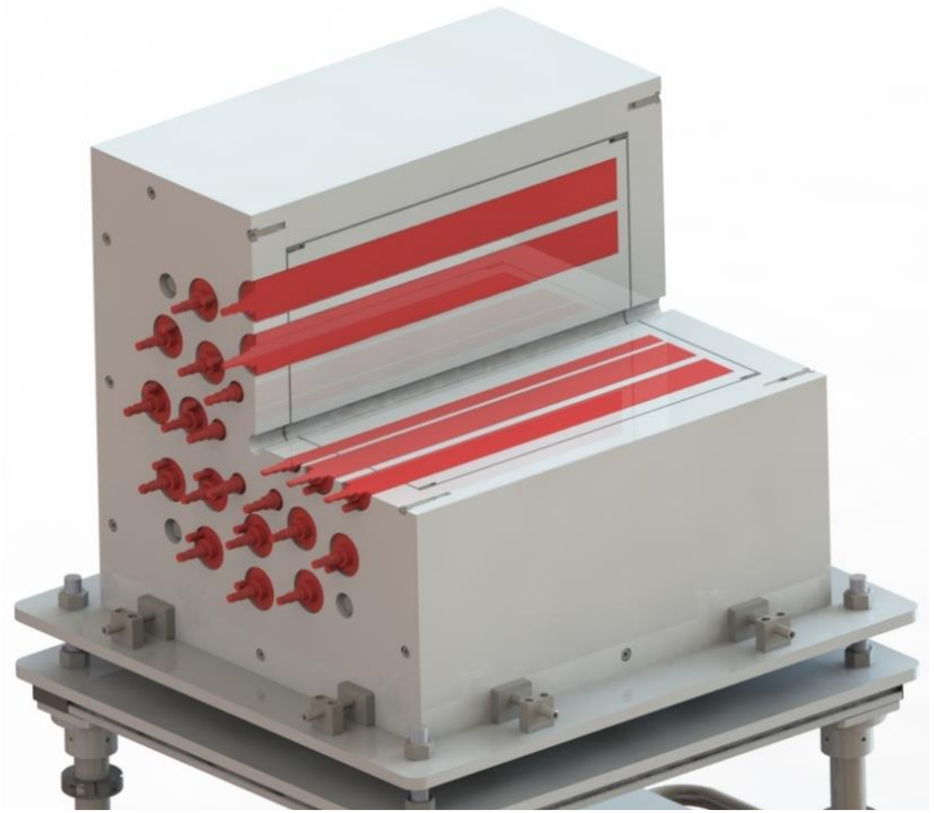


3. Photonuclear Reaction Research at SLEGS



3. Photonuclear Reaction Research at SLEGS

^{3}He 4π neutron detector-FED for (γ, n)



Detail parameters of the ^{3}He propotional Counter.

Name	^{3}He	Distance to center [mm]	Diameter [mm]	Effect length [mm]	Gas presure [atm]
Ring-1	6	65	25.4	500	2
Ring-2	8	110	50.8	500	2
Ring-3	12	175	50.8	500	2

3. Photonuclear Reaction Research at SLEGS

^3He 4π neutron detector-FED for (γ, n)

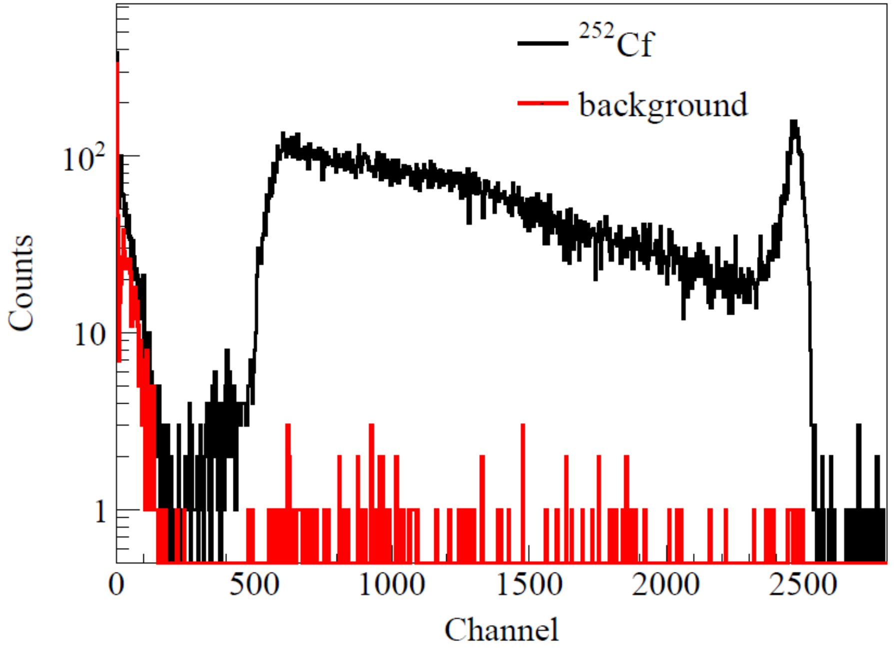
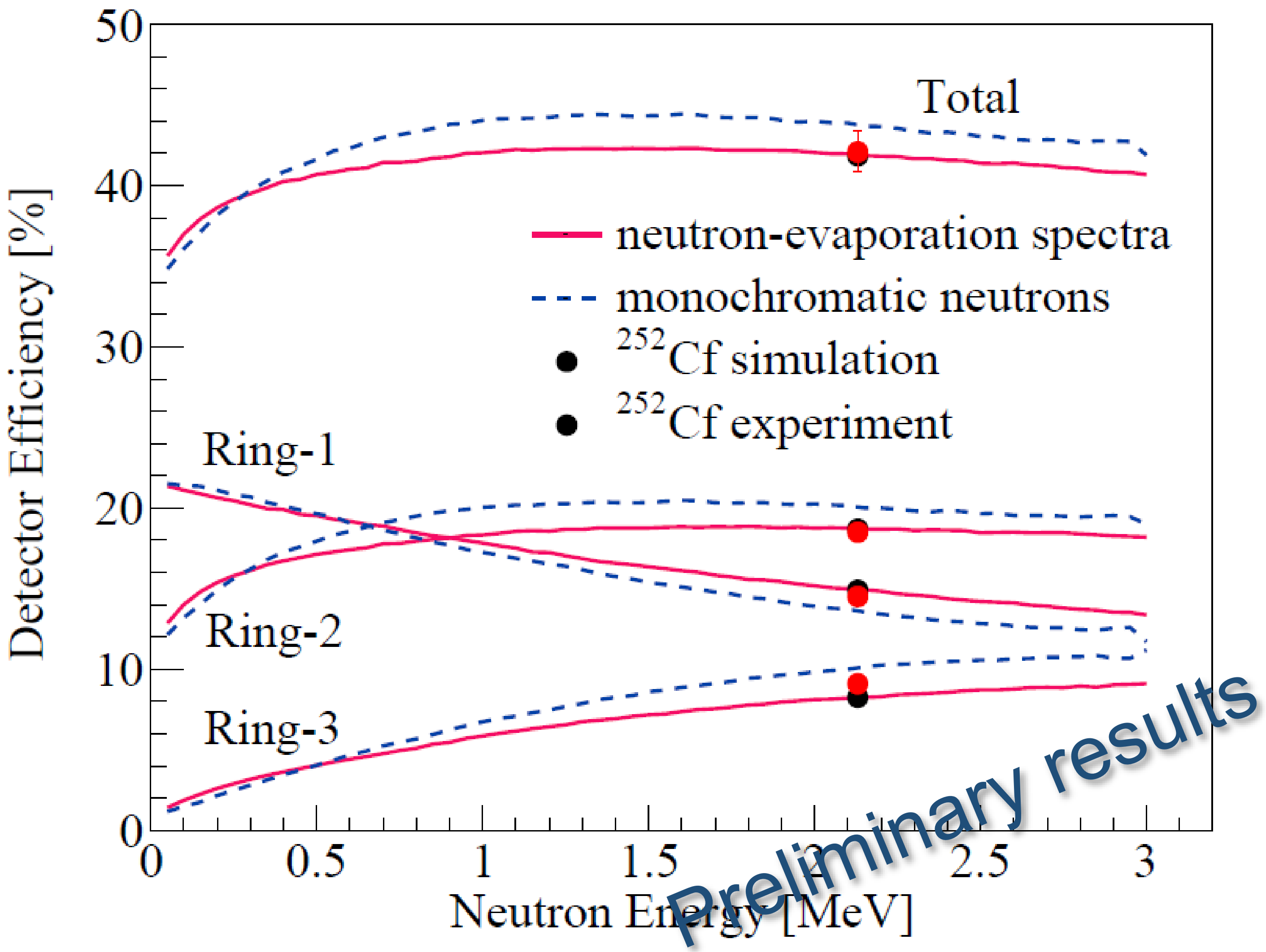


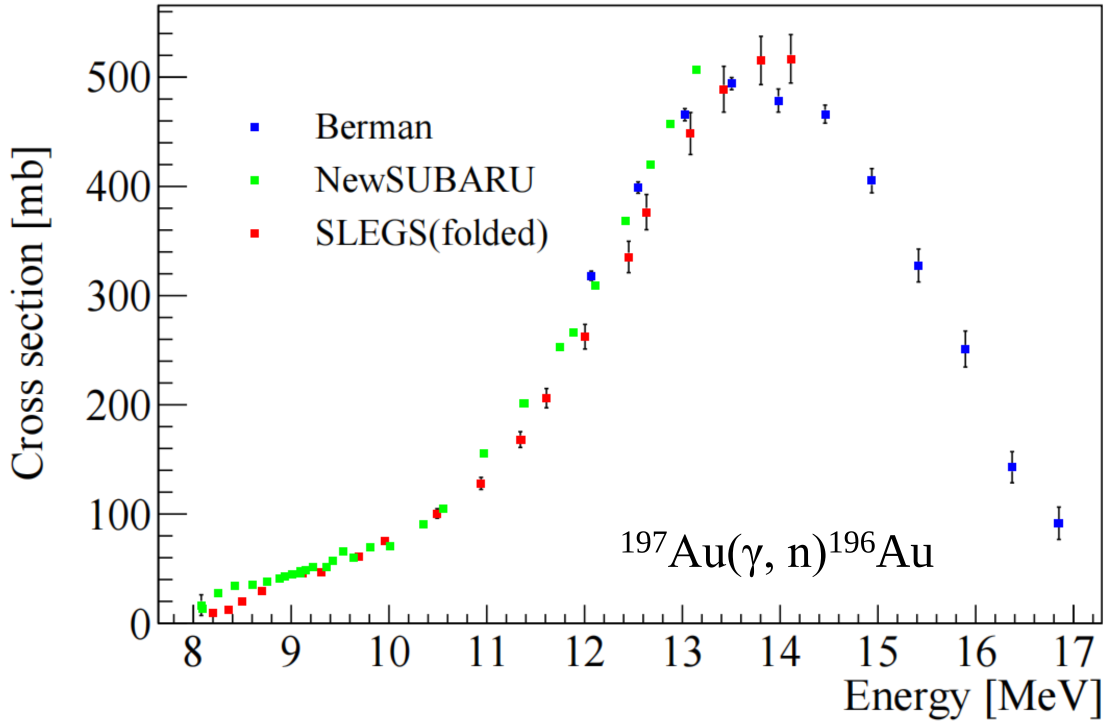
Table 1
Adjustment of the setting parameters and the resultant detector efficiencies.

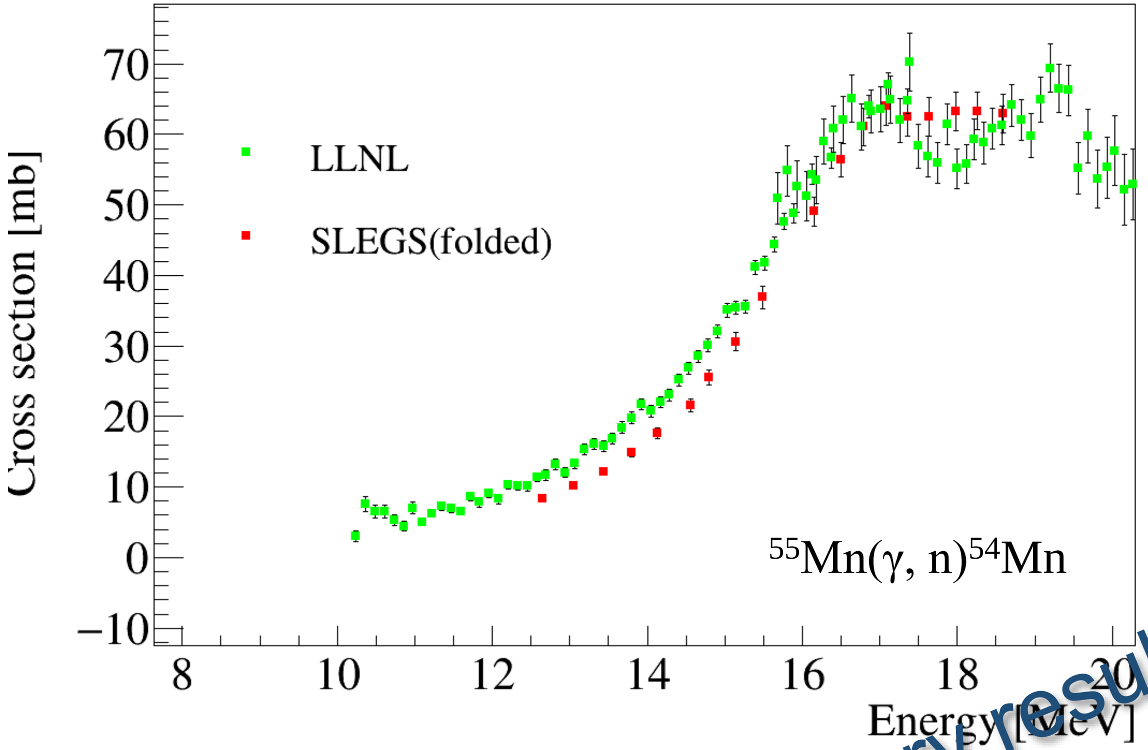
Settings	Offset	Efficiency
Threshold	+10	42.16%
Pz	+1 μs	42.13%
Pz	-1 μs	42.11%
Shaping time	- 11 μs	42.11%
Gain	× 2	41.94%



3. Photonuclear Reaction Research at SLEGS

^{3}He 4π neutron detector-FED for (γ, n)

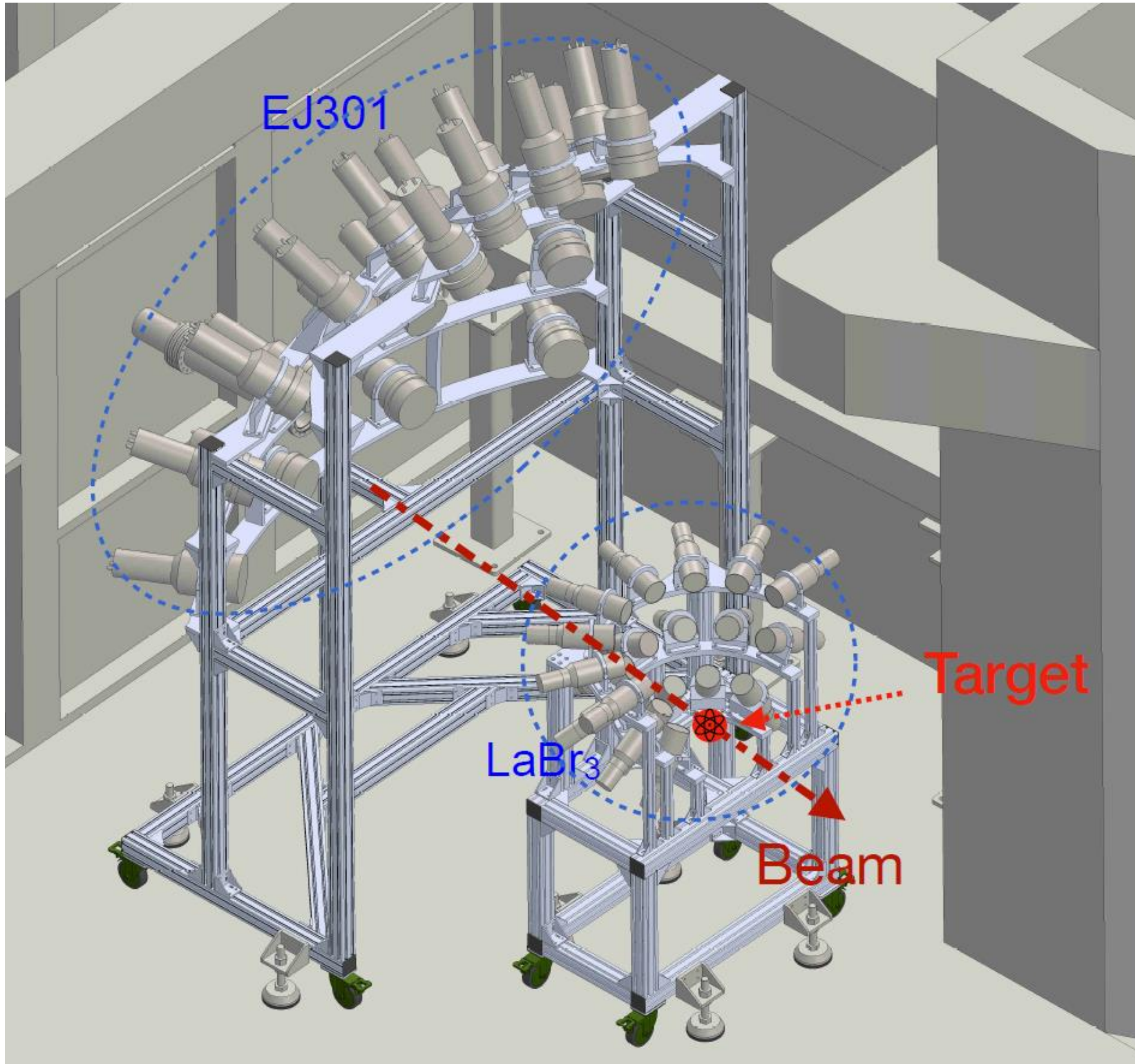




Preliminary results

3. Photonuclear Reaction Research at SLEGS

Status - End station: TOF for (γ, n)



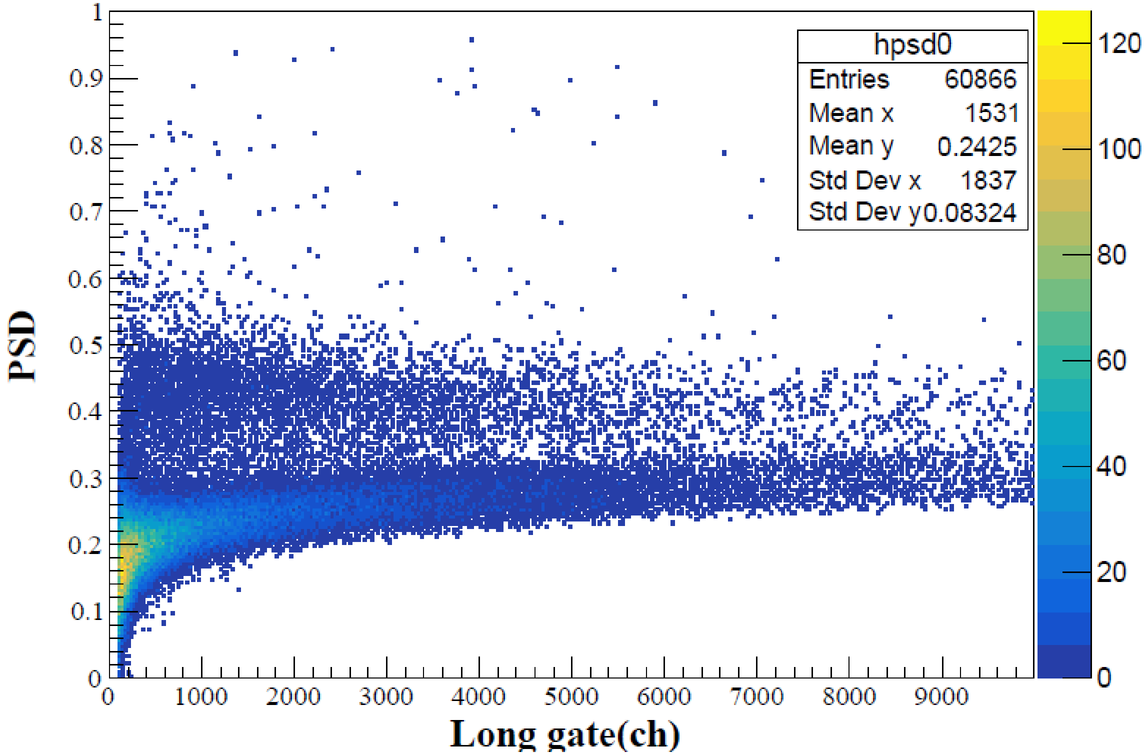


TABLE 1. The related parameters of the SLEGS TOF spectrometer.

Detector	Number	Material	Density	Distance	Diameter	Thickness
$LaBr_3$	8-20	$LaBr_3$	$5.10\,g/cm^3$	30 cm	3 inches	4 inches
EJ301	20	xylene	$0.86\,g/cm^3$	150 cm	5 inches	2 inches

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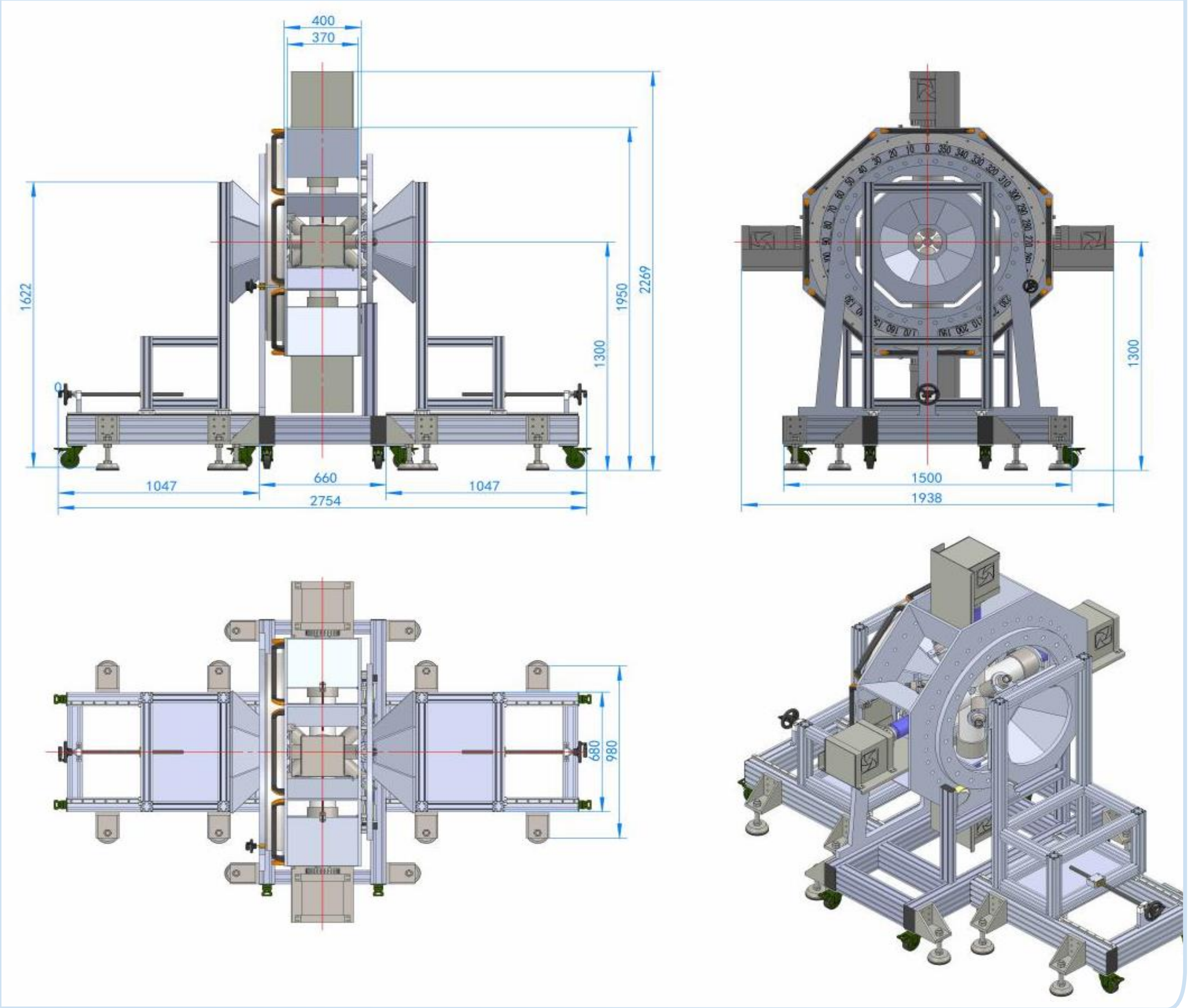
3. Photonuclear Reaction Research at SLEGS

Status - End station: HPGe and $LaBr_3$ for NRF



Summary

- SLEGS, an energy-variable gamma-ray source developed based on the inverse Compton scattering of 10640 nm photons from a 100 W CO2 laser on 3.5 GeV electrons from the Shanghai Light Source. It produces gamma-rays in the energy range of 0.4–21.7 MeV with a flux of 10^5–10^7photons/s.
- The SLEGS serves as a multi-functional experimental platform for research in nuclear science and technology. The research in basic research, on the one hand, ranges from collective excitation of nuclei, nuclear equation of state, while that in the application research, on the other hand, ranges from nuclear transmutation, gamma imaging, to national security.

Thanks for your attention !