中国科学院上海高等研究院

"The workshop on photonuclear science in 2025"

Laser compton scattering gamma source at SARI

Hanghua Xu, Gongtao Fan, Longxiang Liu,

Yue Zhang, Zirui Hao, Hongwei Wang,

on behalf of the SLEGS Team

Aug.8-10/2025@Shanghai

Contents

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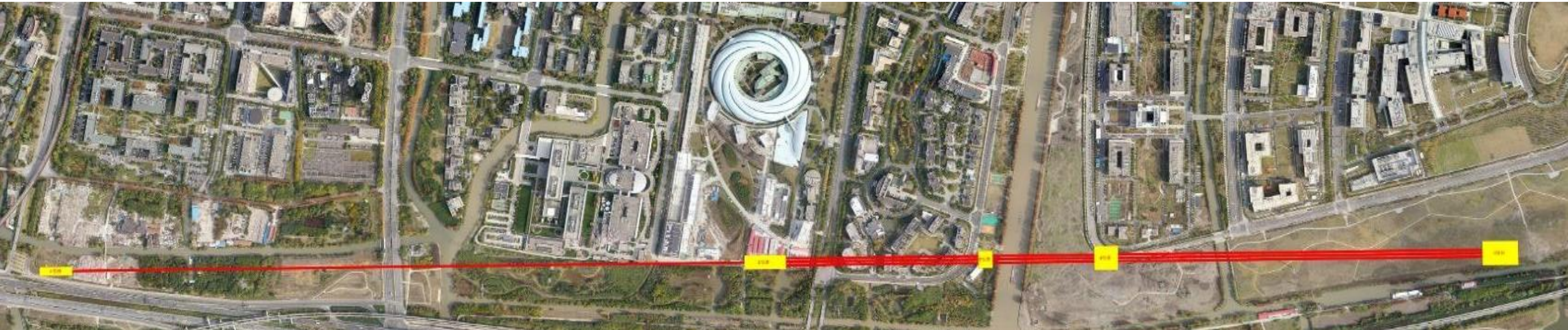
Energy	**3.5 GeV**
Beam Sizeσ_x	276.9 um
Beam Sizeσ_y	12.24 um
Pulse RMS	3 mm
Current	**200 mA**
Q_e	1.44 nC
Emittance$\varepsilon_x/\varepsilon_y$	2.59 / 2.59E-2 nmrad
Divergenceη_x/η_y	0.207 / 0 m
β_x/β_y	14.86 / 5.78 m
Energy spread	0.944E-3
Pulse Number	500



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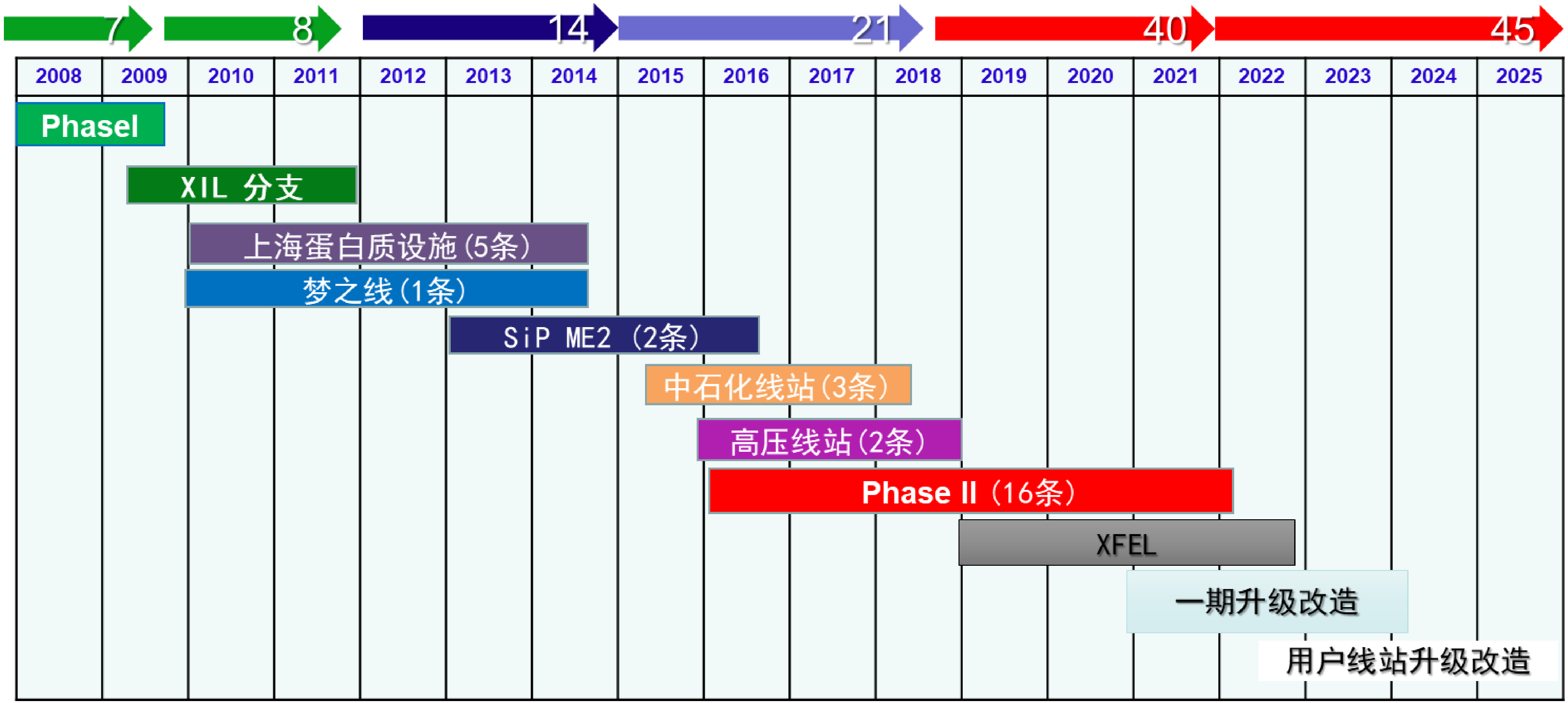
7
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2008
2009
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2020
2021
2022
2023
2024
2025
PhaseI
XIL 分支
上海蛋白质设施(5条)
梦之线(1条)
SiP ME2 (2条)
中石化线站(3条)
高压线站(2条)
Phase II (16条)
XFEL
一期升级改造
用户线站升级改造

1 SLEGS@SSRF

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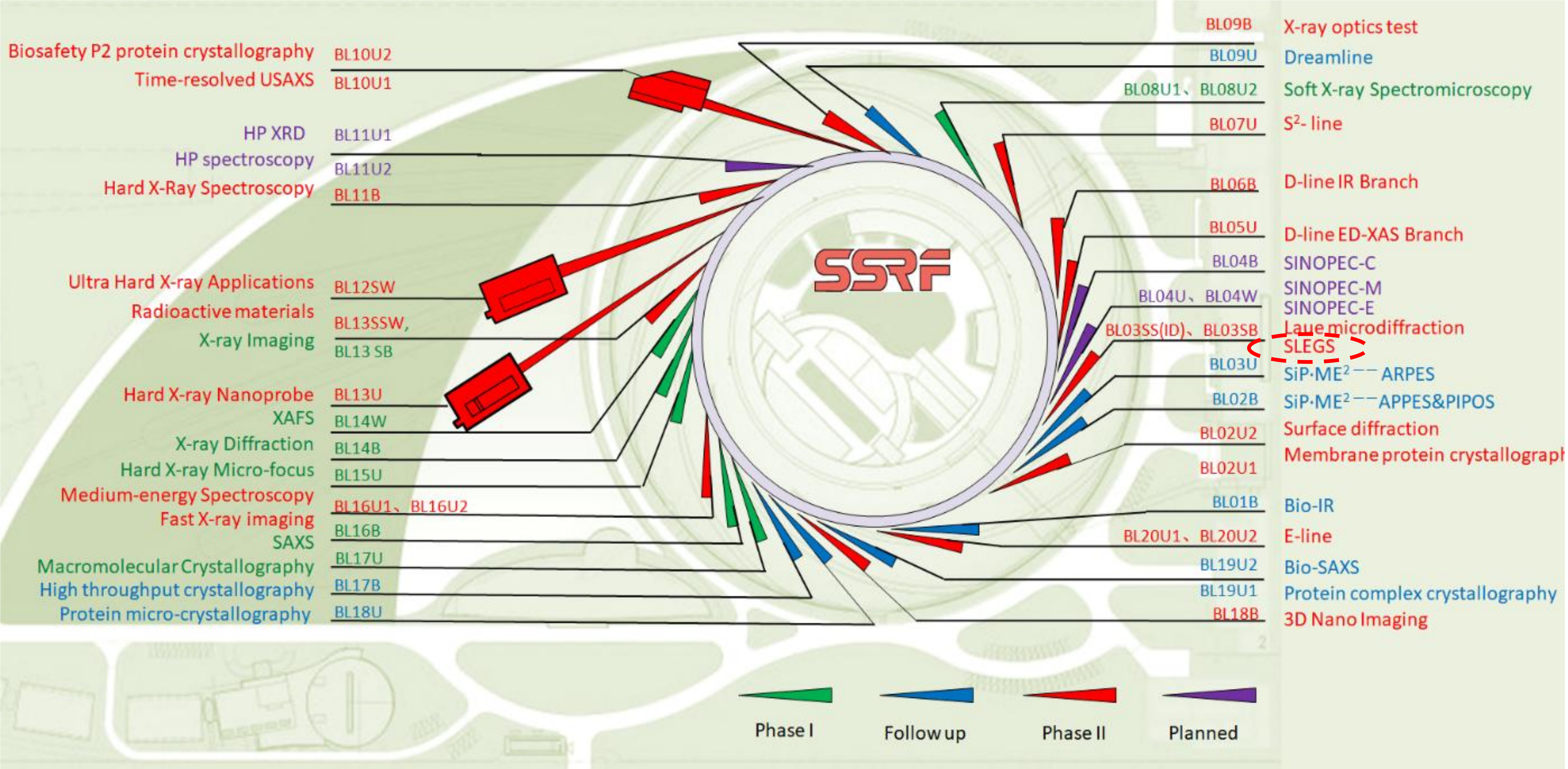
SSRF
Biosafety P2 protein crystallography BL10U2
Time-resolved USAXS BL10U1
HP XRD BL11U1
HP spectroscopy BL11U2
Hard X-Ray Spectroscopy BL11B
Ultra Hard X-ray Applications BL12SW
Radioactive materials BL13SSW,
X-ray Imaging BL13 SB
Hard X-ray Nanoprobe BL13U
XAFS BL14W
X-ray Diffraction BL14B
Hard X-ray Micro-focus BL15U
Medium-energy Spectroscopy BL16U1、BL16U2
Fast X-ray imaging BL16B
SAXS BL17U
Macromolecular Crystallography BL17B
High throughput crystallography BL18U
Protein micro-crystallography
BL09B X-ray optics test
BL09U Dreamline
BL08U1、BL08U2 Soft X-ray Spectromicroscopy
BL07U S²- line
BL06B D-line IR Branch
BL05U D-line ED-XAS Branch
BL04B SINOPEC-C
BL04U、BL04W SINOPEC-M
SINOPEC-E
BL03SS(ID)、BL03SB Laue microdiffraction
SLEGS
BL03U SiP·ME² —— ARPES
BL02B SiP·ME² —— APPES&PIPOS
BL02U2 Surface diffraction
BL02U1 Membrane protein crystallograph
BL01B Bio-IR
BL20U1、BL20U2 E-line
BL19U2 Bio-SAXS
BL19U1 Protein complex crystallography
BL18B 3D Nano Imaging
Phase I
Follow up
Phase II
Planned

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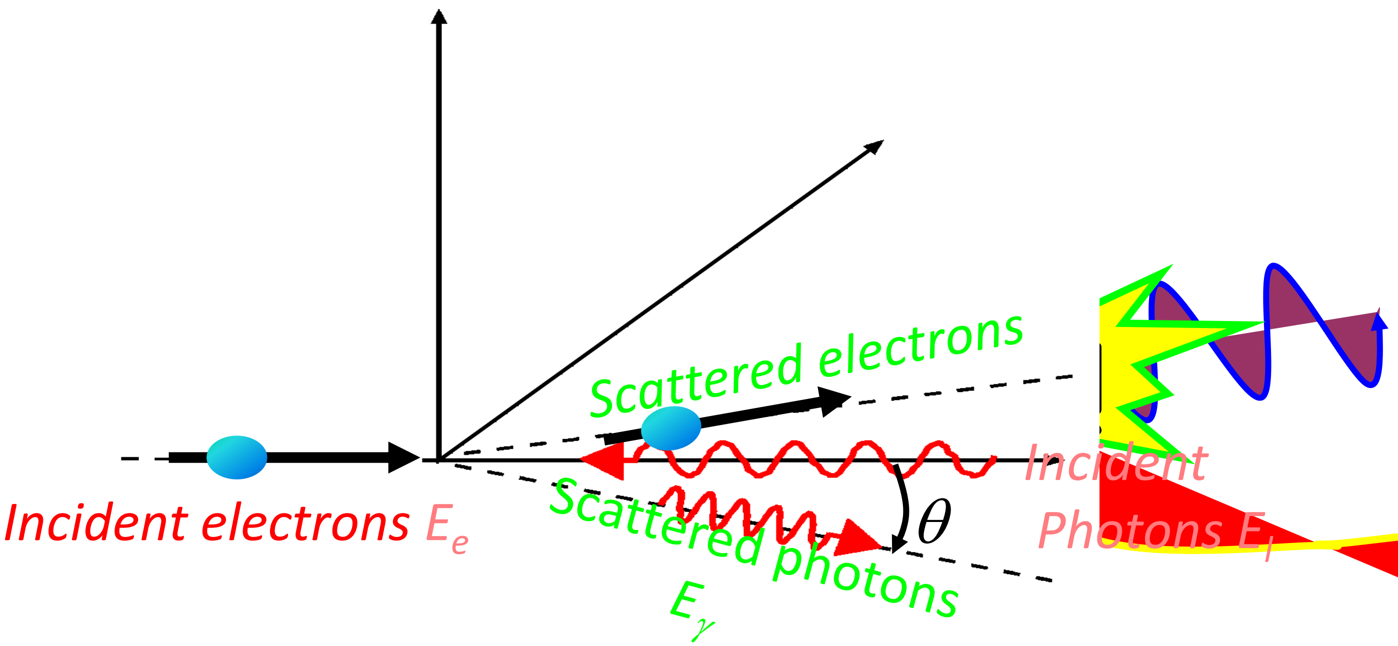
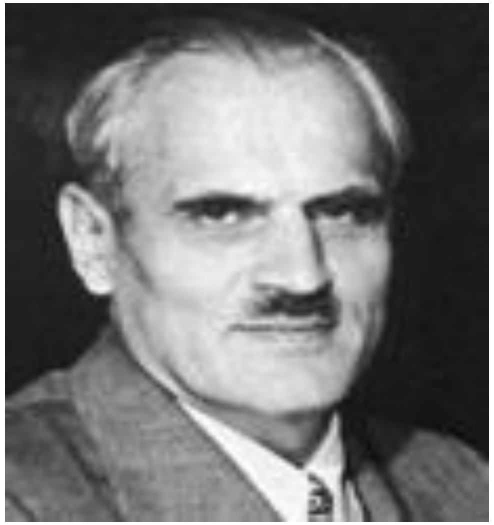
Laser-Compton scattering





A. H. Compton
(1892-1962)

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

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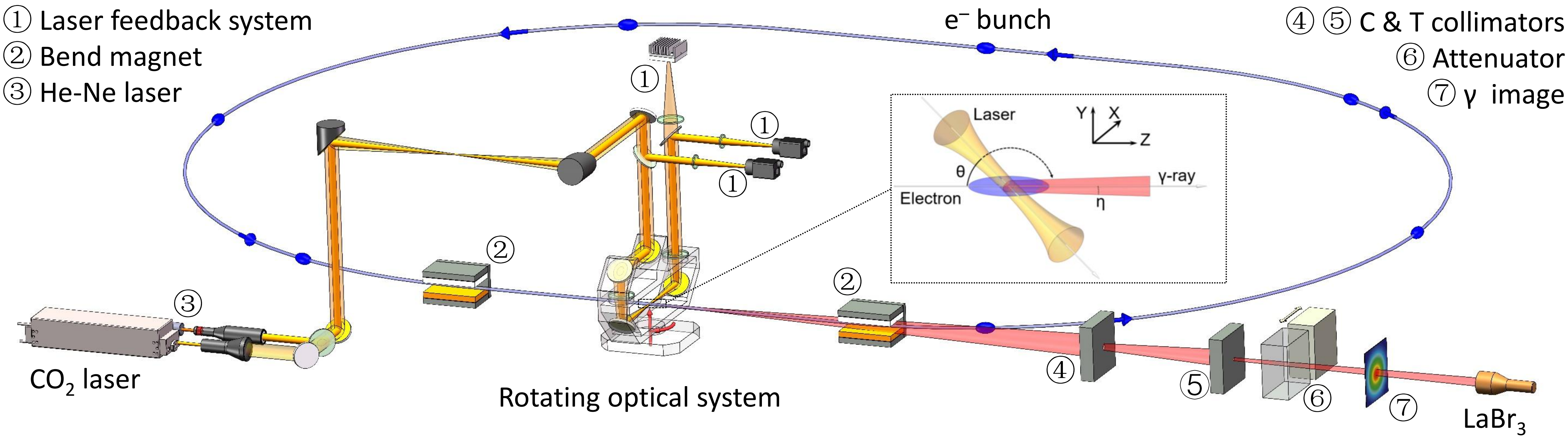
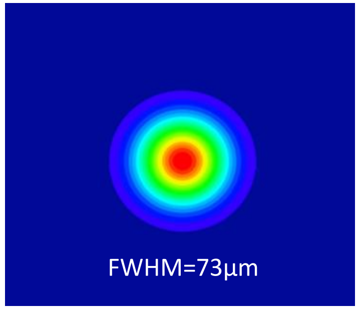
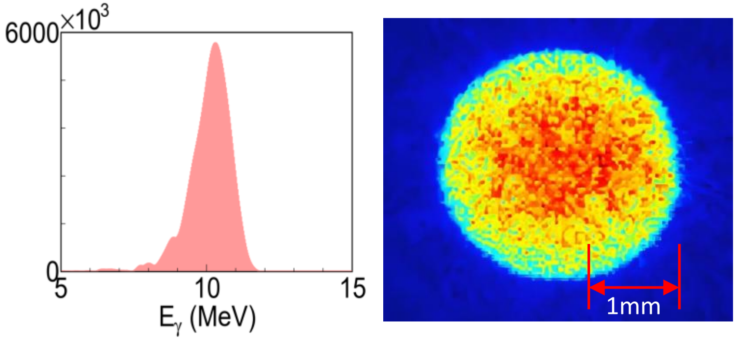
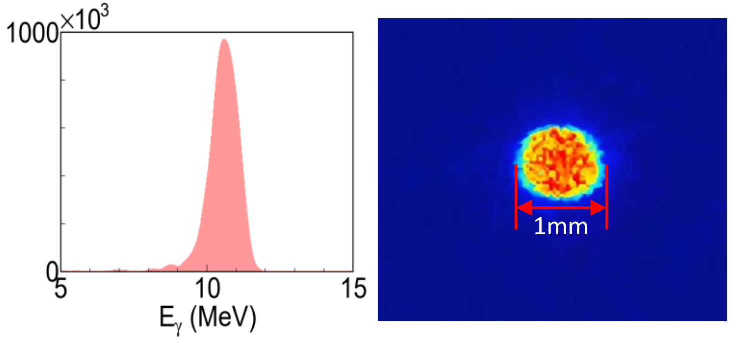




Laser focal spot



γ spot and spectrum @ C3



γ spot and spectrum @ C3T1

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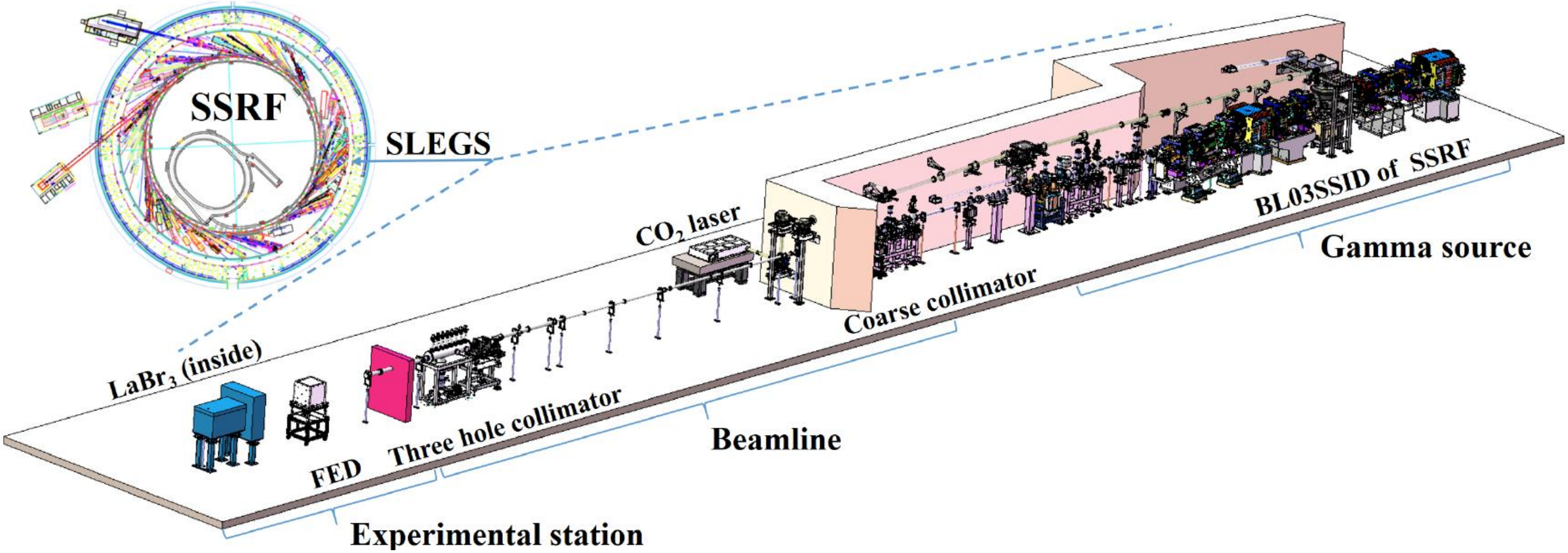
Layout



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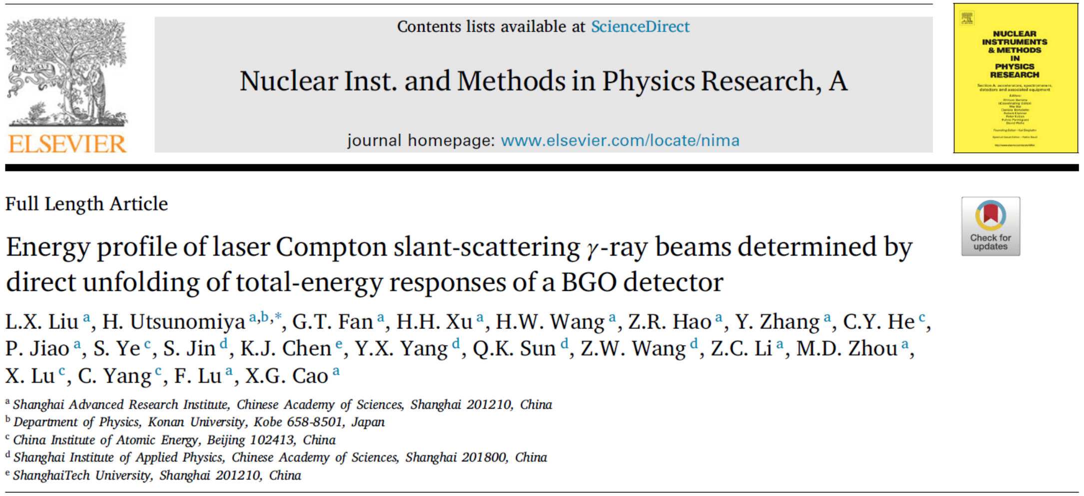
◻ Energy Spectra


Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima

Full Length Article

Energy profile of laser Compton slant-scattering γ-ray beams determined by direct unfolding of total-energy responses of a BGO detector

L.X. Liu [a], H. Utsunomiya [a,b,*], G.T. Fan [a], H.H. Xu [a], H.W. Wang [a], Z.R. Hao [a], Y. Zhang [a], C.Y. He [c], P. Jiao [a], S. Ye [c], S. Jin [d], K.J. Chen [e], Y.X. Yang [d], Q.K. Sun [d], Z.W. Wang [d], Z.C. Li [a], M.D. Zhou [a], X. Lu [c], C. Yang [c], F. Lu [a], X.G. Cao [a]

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[d] Shanghai Institute of Applied Physics, Chinese Academy of Sciences, Shanghai 201800, China
[e] ShanghaiTech University, Shanghai 201210, China

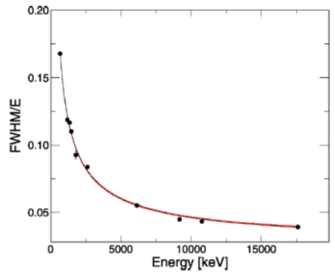


Fig. 4. Energy-resolution of the 76 mm × 200 mm BGO detector as a function of gamma ray energy. The 1-σ uncertainty is shown by the red band.

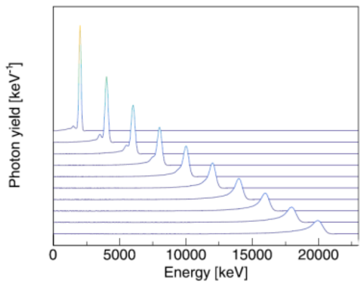
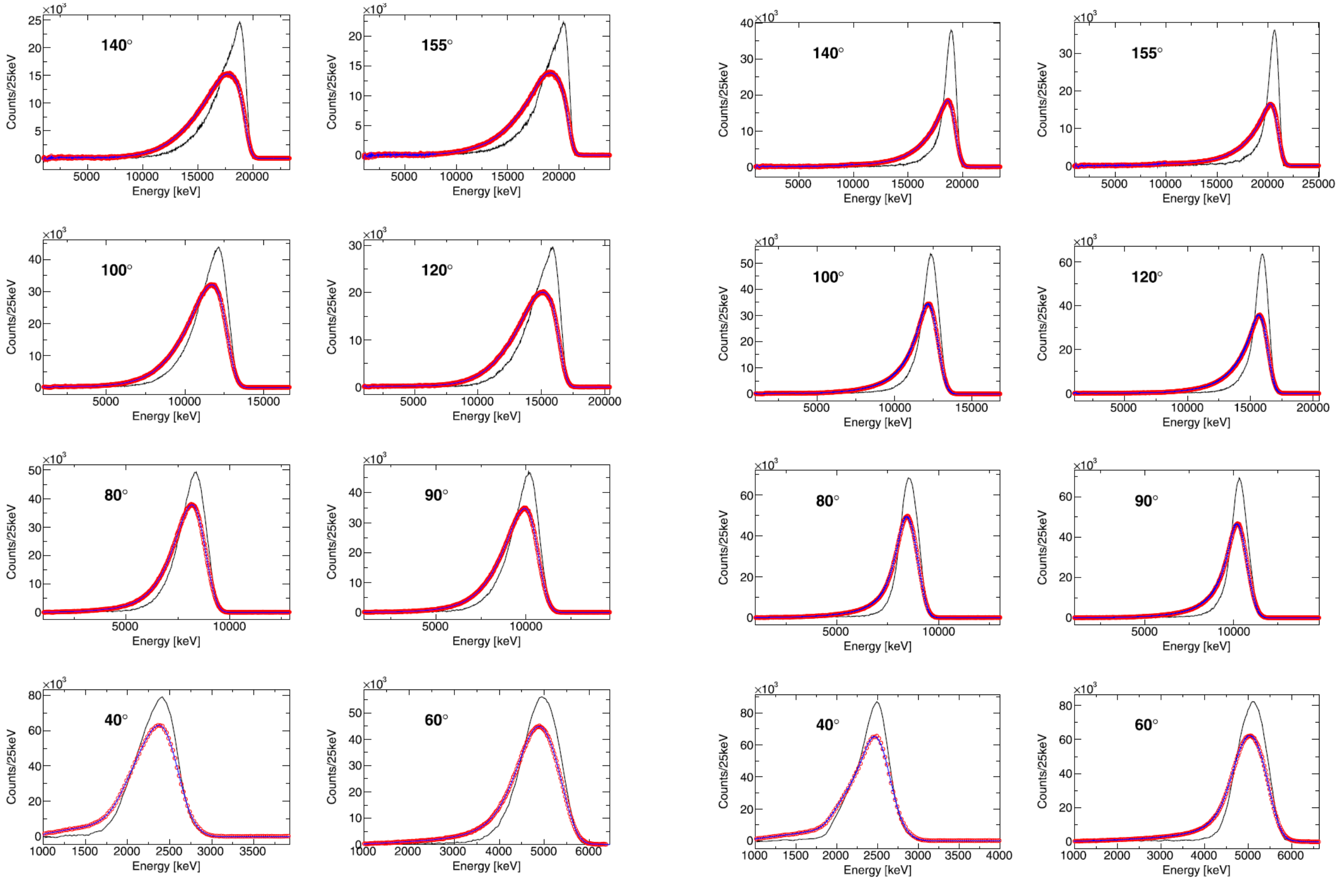


Fig. 6. Samples of the response functions of the BGO detector to monoenergetic γ rays at 10 energies from 2 to 20 MeV in 2 MeV increments.

C3: θ_{col}=83μrad

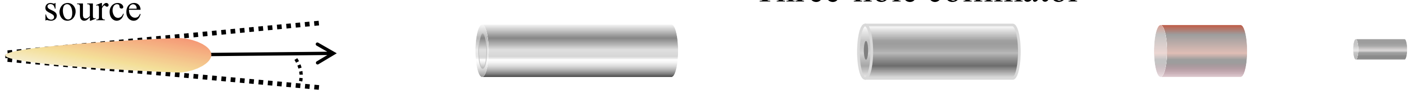
T2: θ_{col}=26μrad



SLEGS light source

Three-hole collimator

BGO Detector



θ_{col}

Coarse collimator

Attenuator

https://doi.org/10.1016/j.nima.2024.169314

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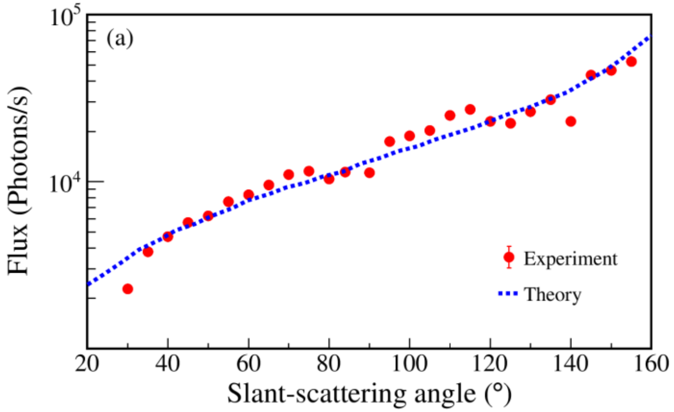
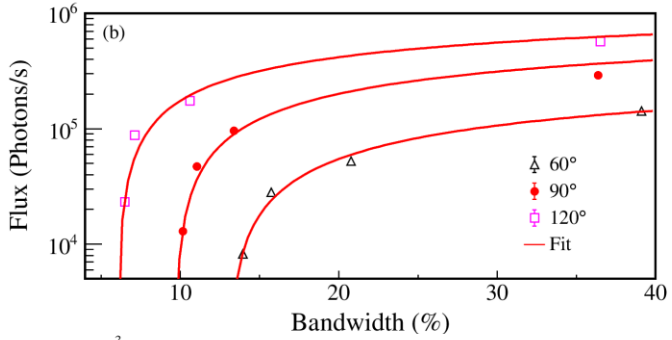
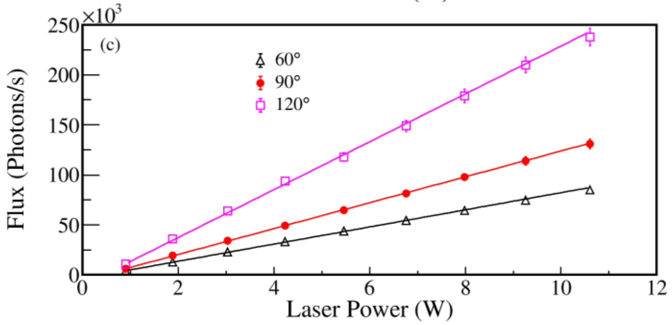
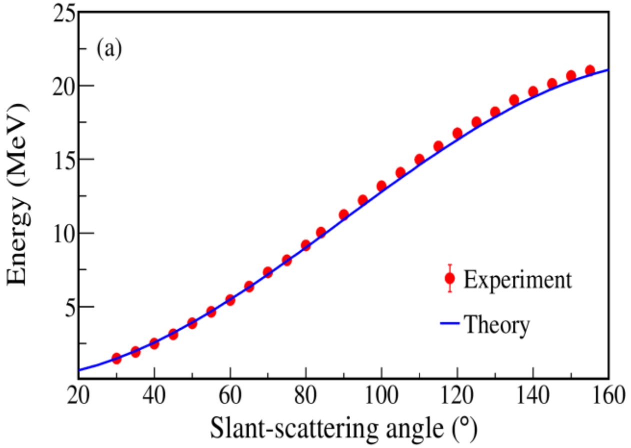
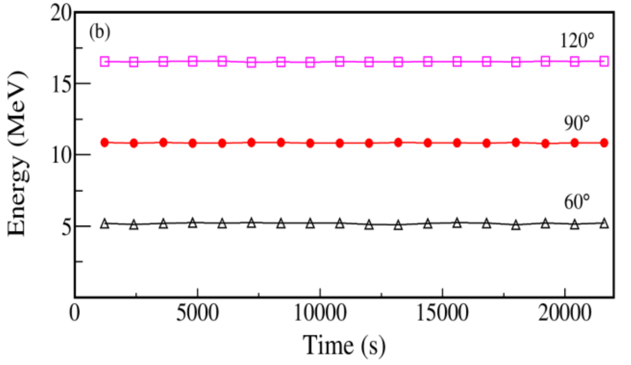
Flux, energy and bandwidth

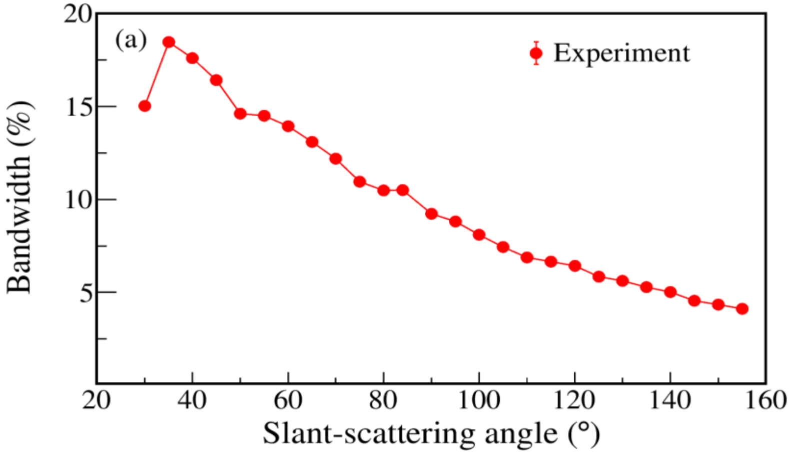


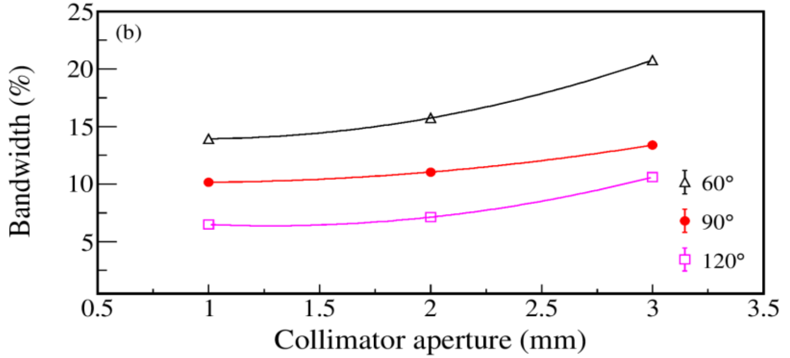


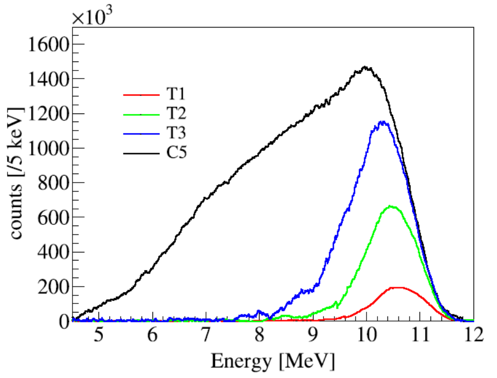


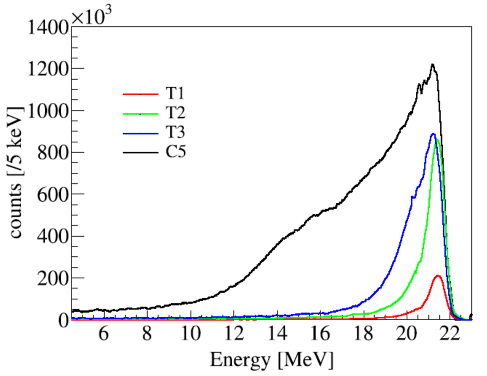












1 SLEGS@SSRF

Properties of Gamma-ray beam

	HIGS		SLEGS	
E_γ [MeV]	Low energy range	High energy range	Slant scattering	Back scattering
	1-20	21-60	0.4-21.1	21.7
E_e [GeV]	0.4-0.7	0.7-1	3.5	3.5
λ_L [nm]	450-1064	190-450	10640	10640
Flux [ph/s]	10^{8-9}	10^8	10^{5-7}	10^7
Bandwidth [%]	?		4-18	
E_γ scanning accuracy [keV]	40		14	
Emission angle [mrad](θ=1/γ)	1.27-0.73		0.15	
γ density at sample [ph/s/mm²]	0.7×10^4-0.4×10^6 (60 m from IP)		1.2×10^4-1.2×10^6 (38 m from IP)	
Stability of flux [%]	>20		<3	
Mode/speed of energy regulation	E_e /min		θ/s	

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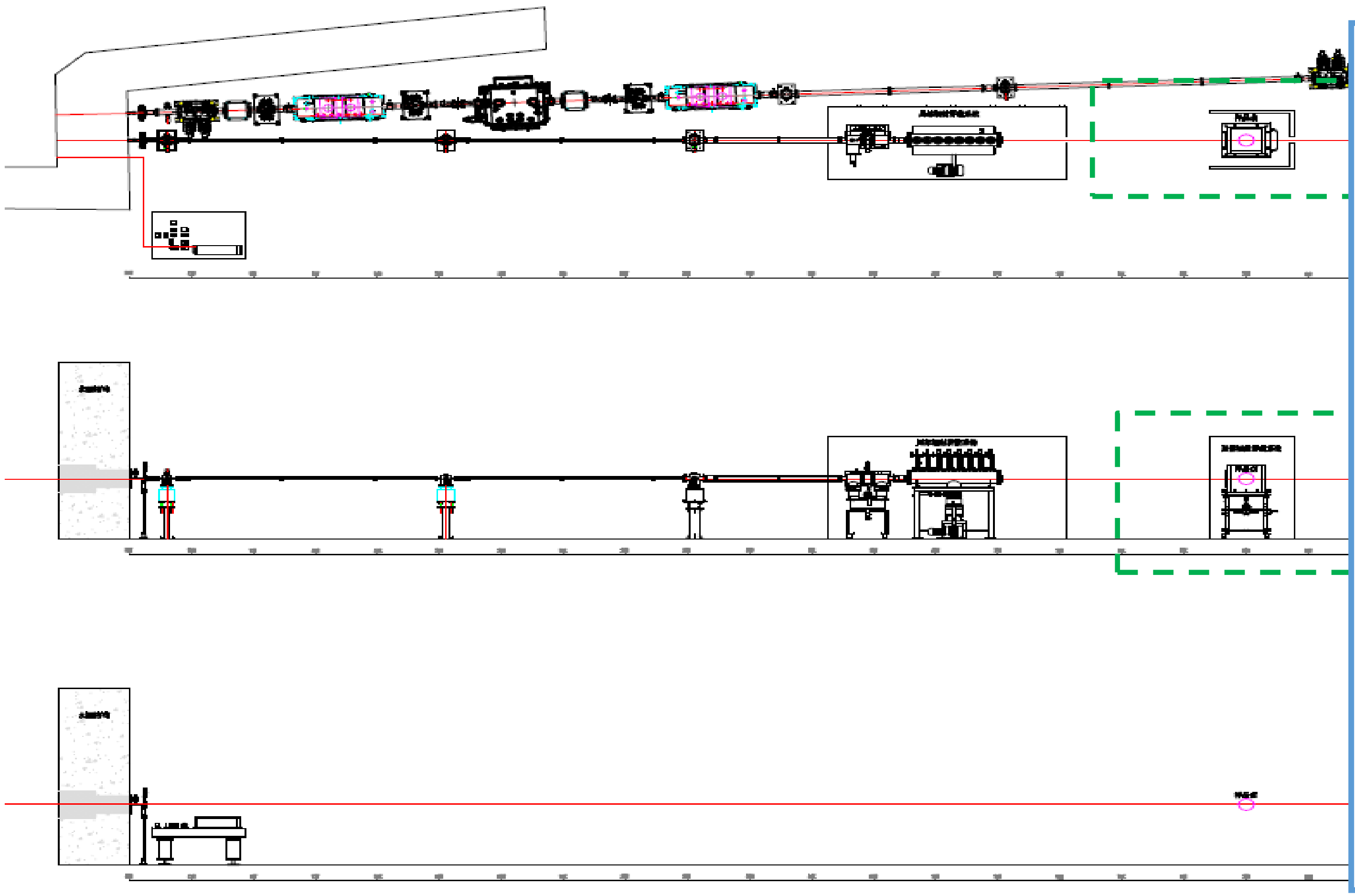
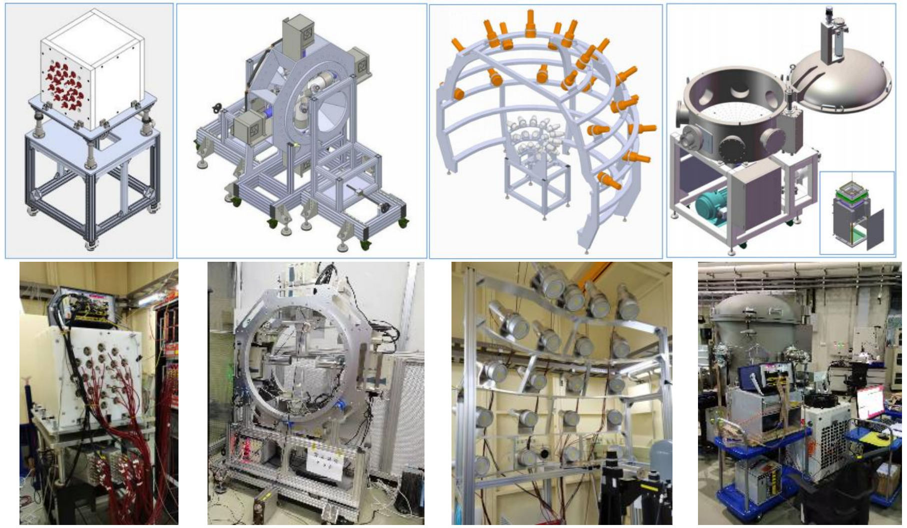
End station



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

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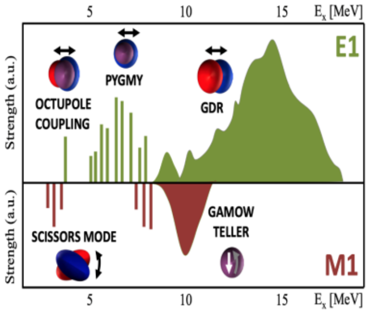
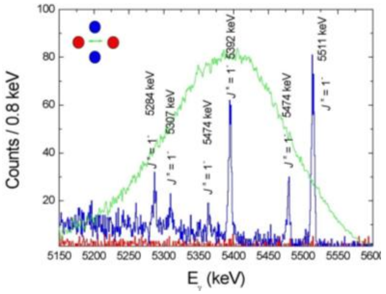
Research area

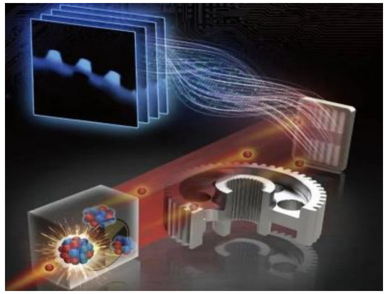
(γ,n) measurement and nuclear data



Anti-γ radiation properties of aerospace device

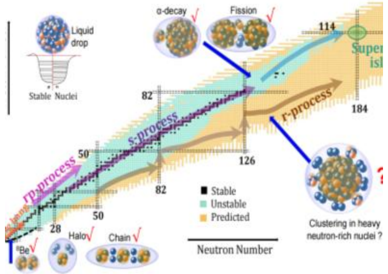
(γ, γ) measurement and nuclear excitation





Complex system gamma imaging

(γ, p, α) measurement and nuclear structure



Gamma ray detector calibration

2 Operation & Opening

30
User groups

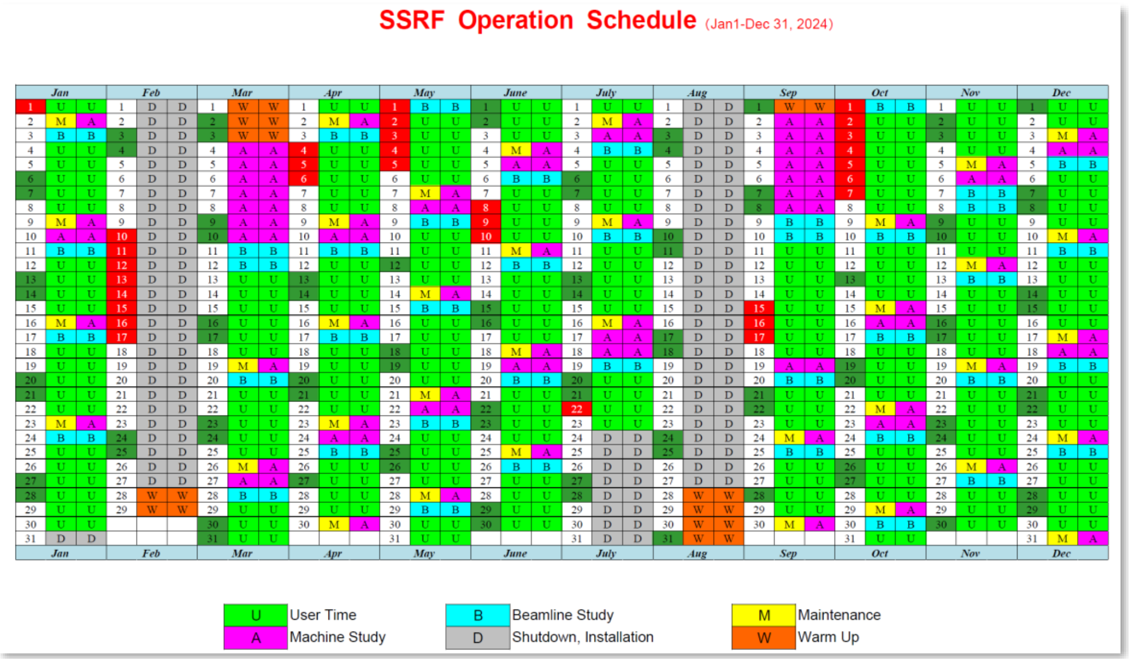
80
Proposals

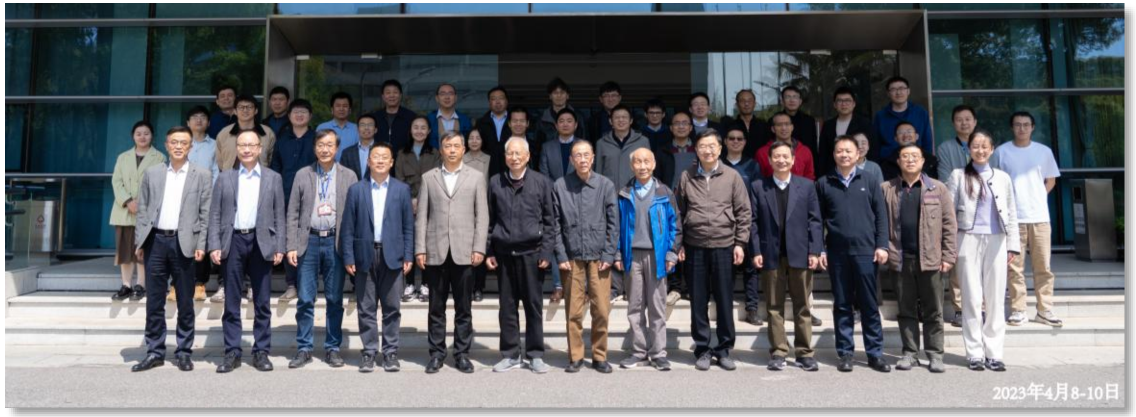
19
Affiliations

150
Number of Users

6
International User Group

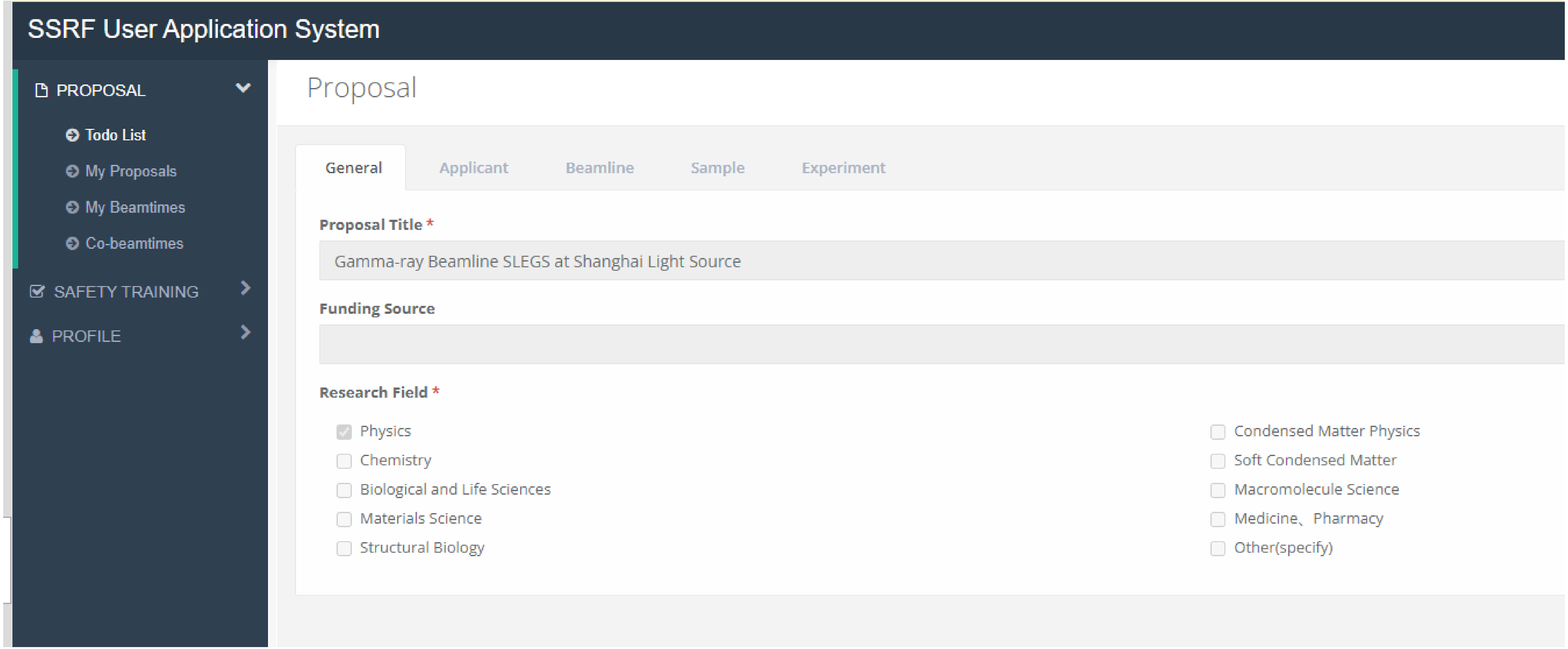
>40
Publications





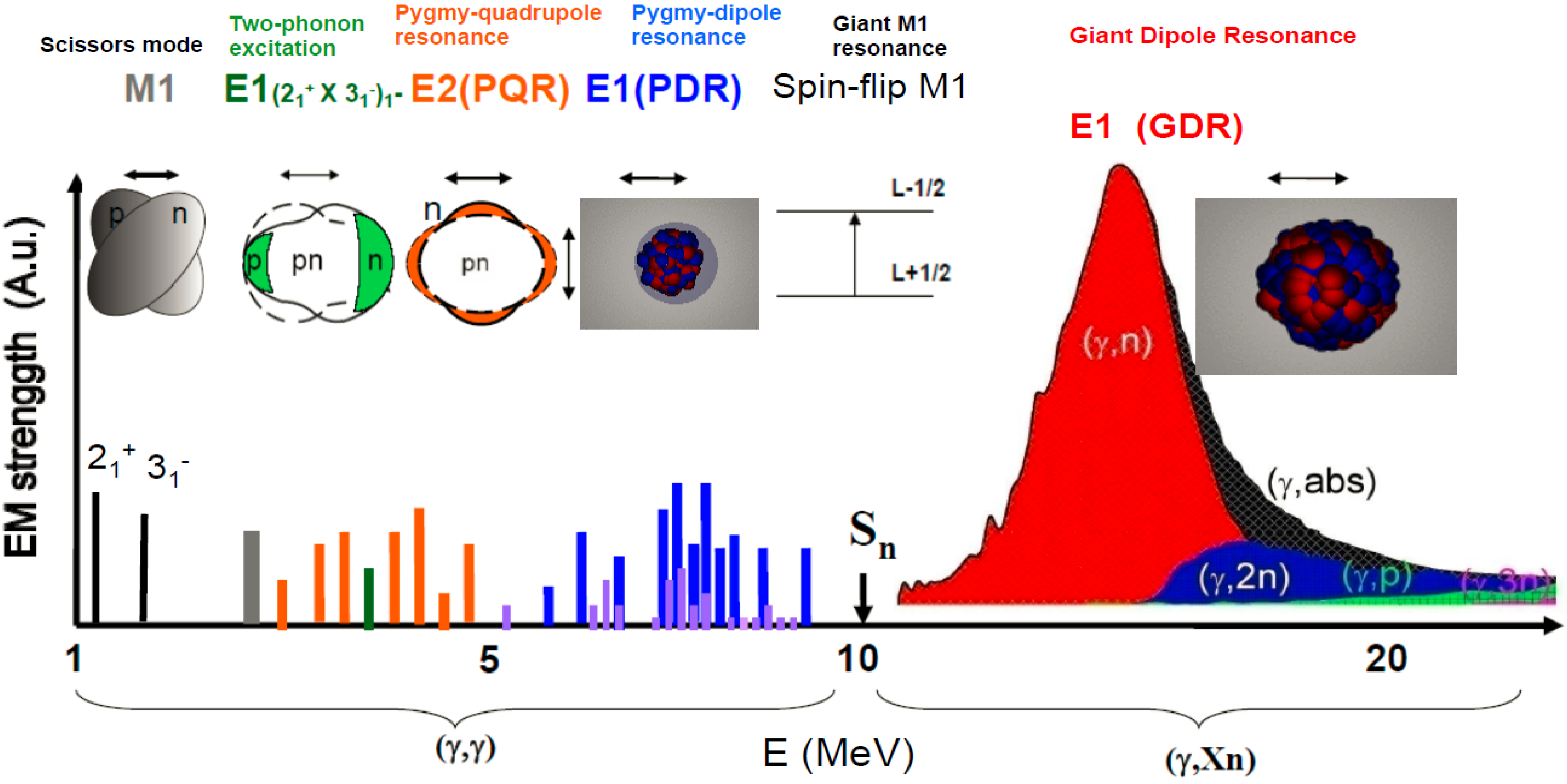
2 Operation & Opening

☐ For fundamental research



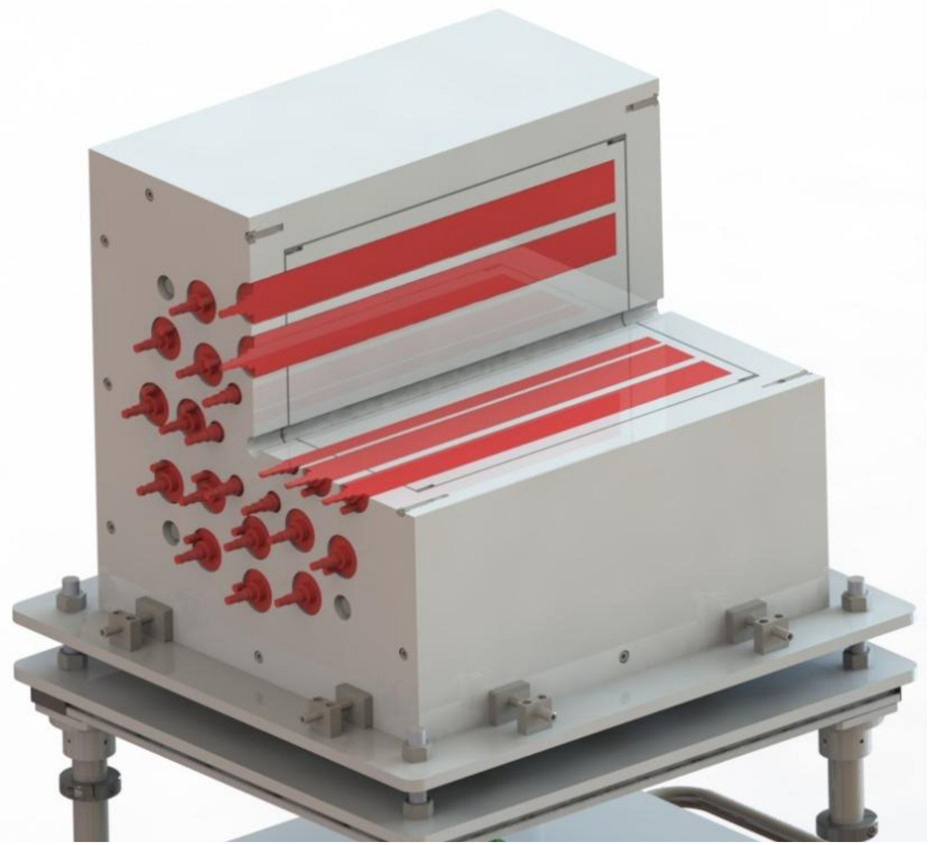
https://ssrfwx.ssrf.ac.cn/proposals/en/a/login

3 Typical experiments



3 Typical experiments

I. ^{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 Typical experiments

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

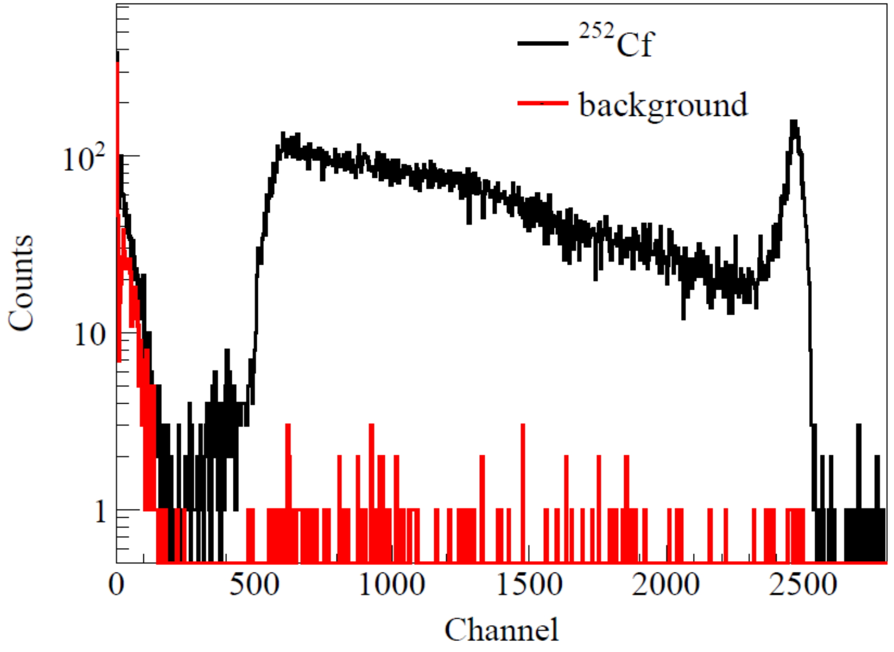
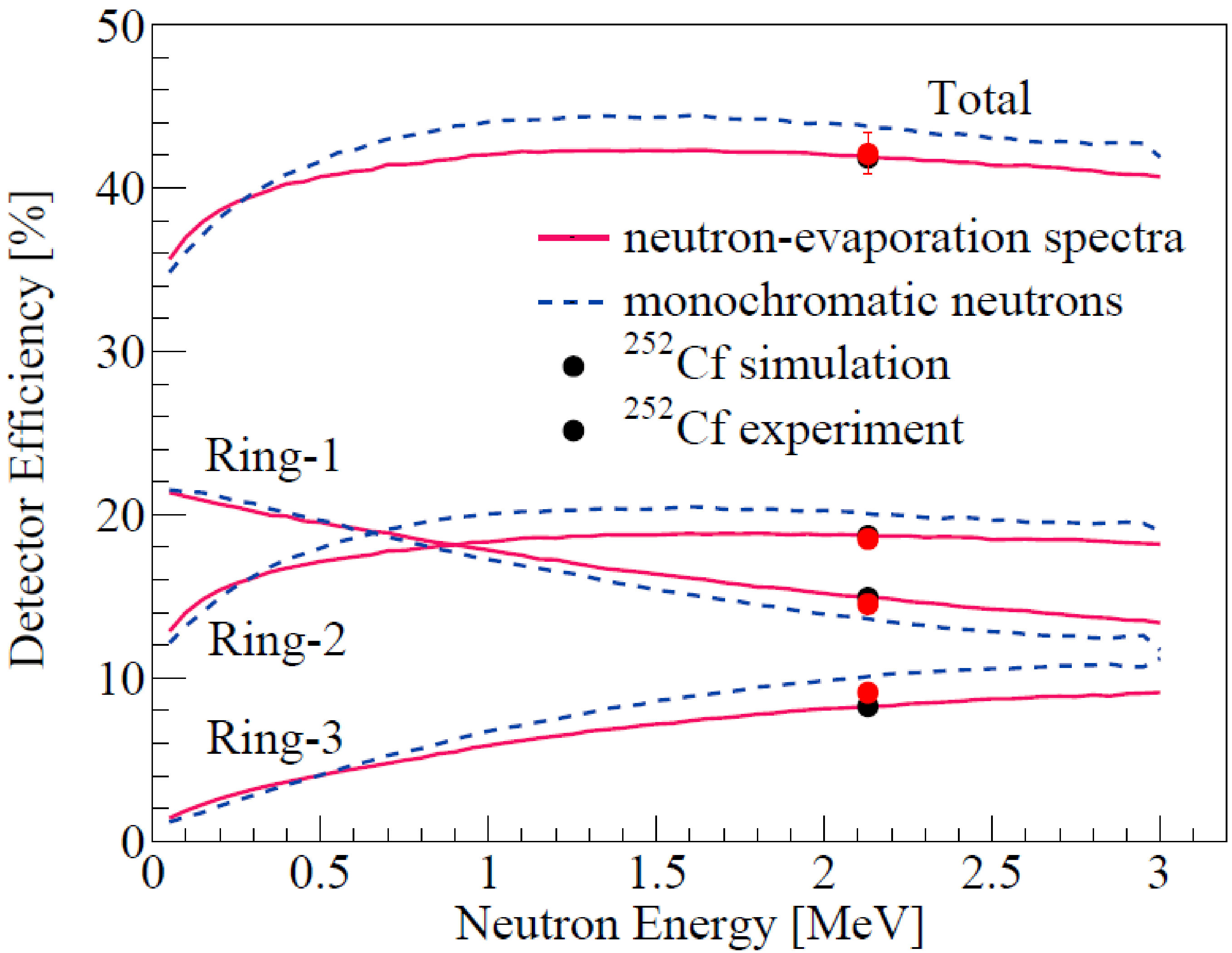


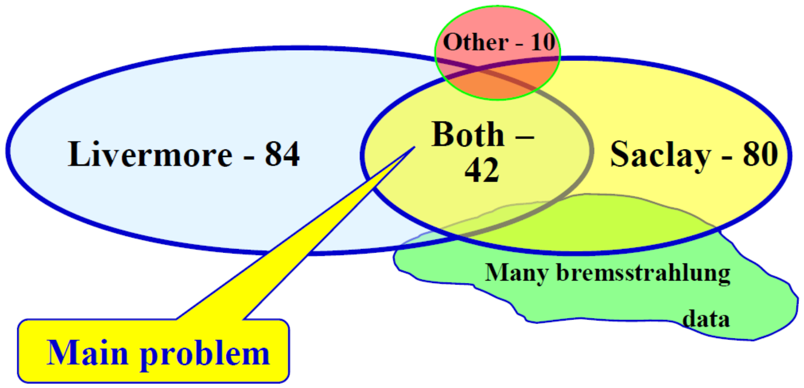
Table 1
Adjustment of the setting parameters and the resultant detector efficiencies.

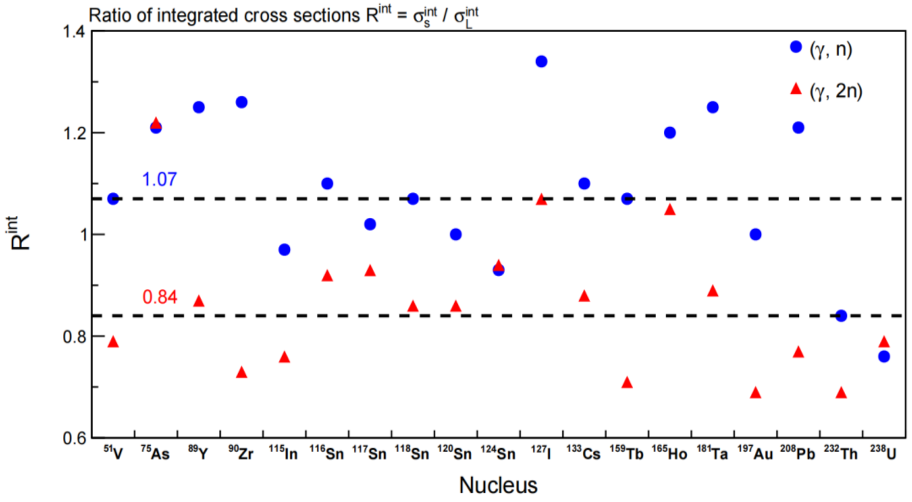
Settings	Offset	Efficiency
Threshold	+10	42.16%
Pz	+1 μs	42.13%
Pz	-1 μs	42.11%
Shaping time	- 11 μs	42.11%
Gain	× 2	41.94%

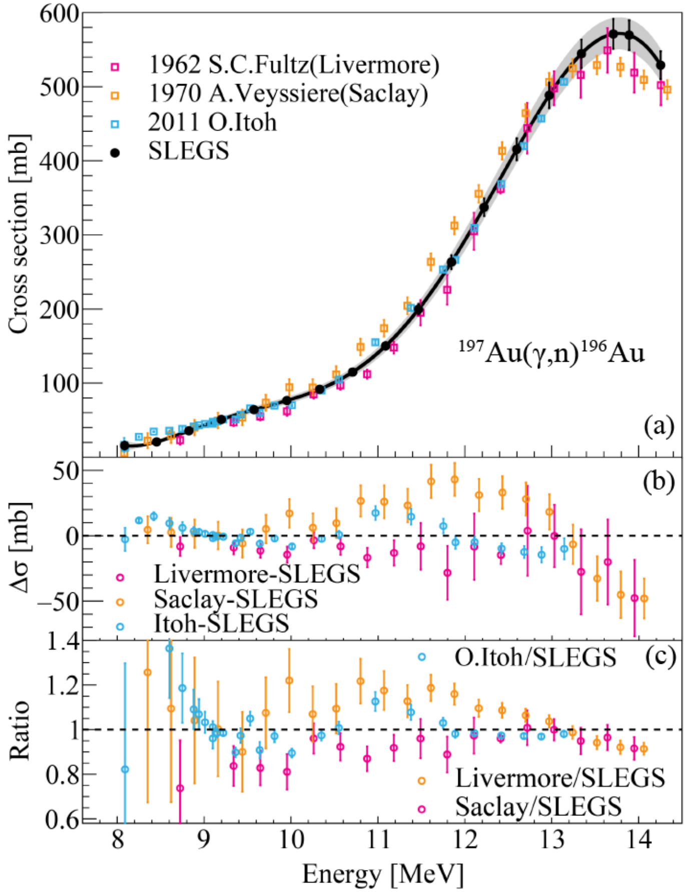


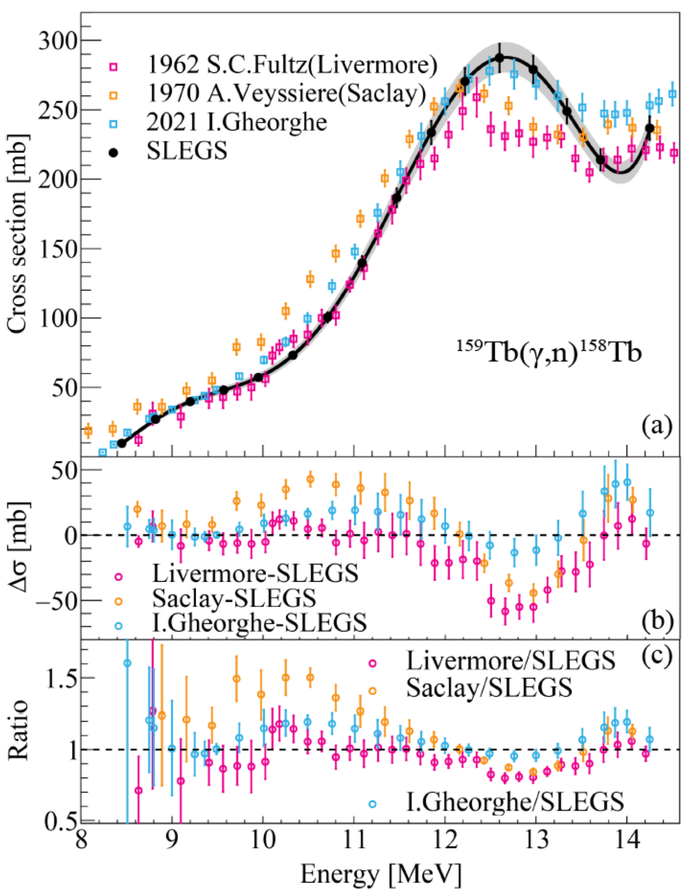
3 Typical experiments

I. 1) Day-one experiment with FED





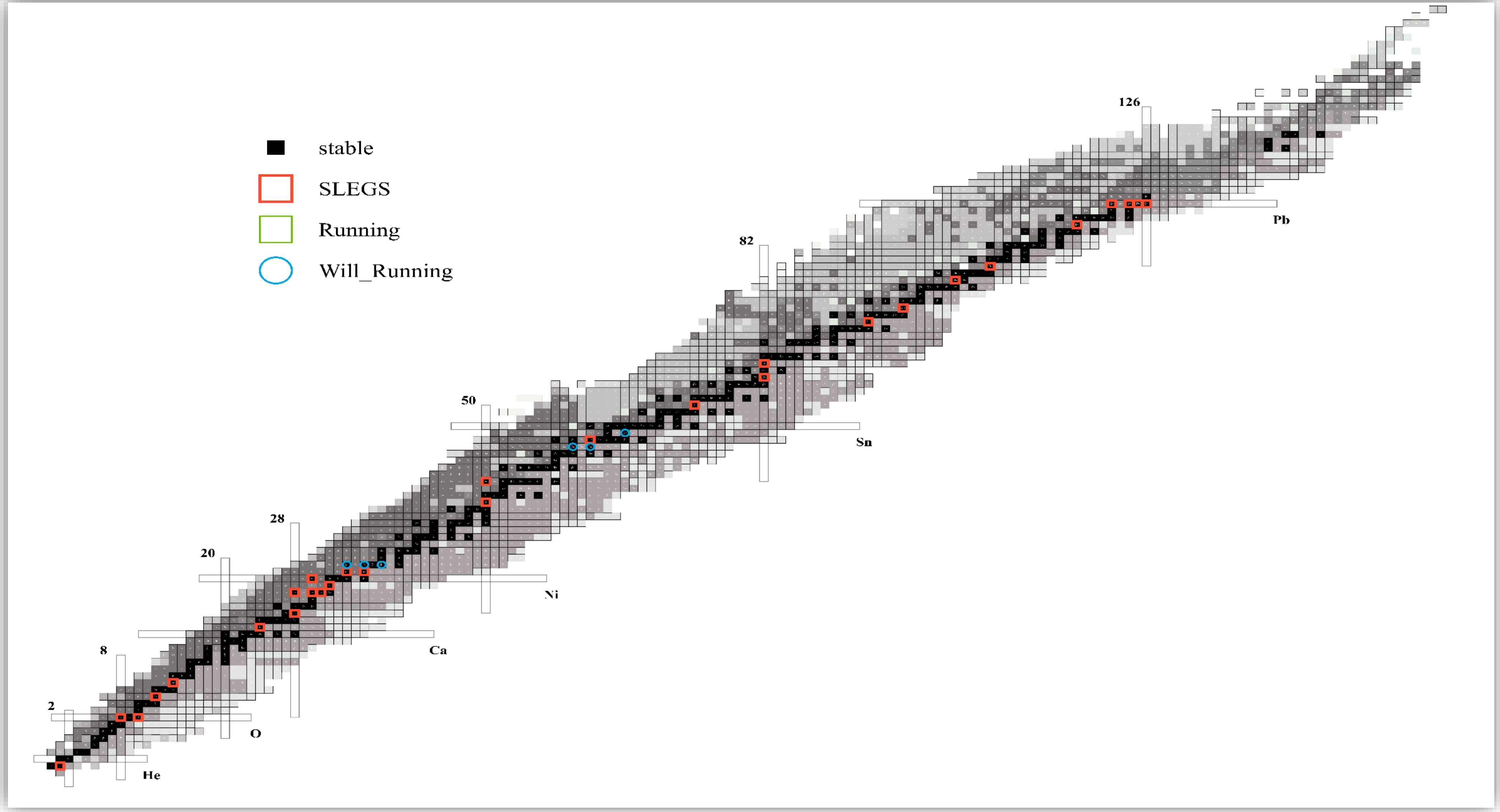




Science Bulletin(2025) https://doi.org/10.1016/j.scib.2025.05.037

See Zirui Hao’s talk for more details

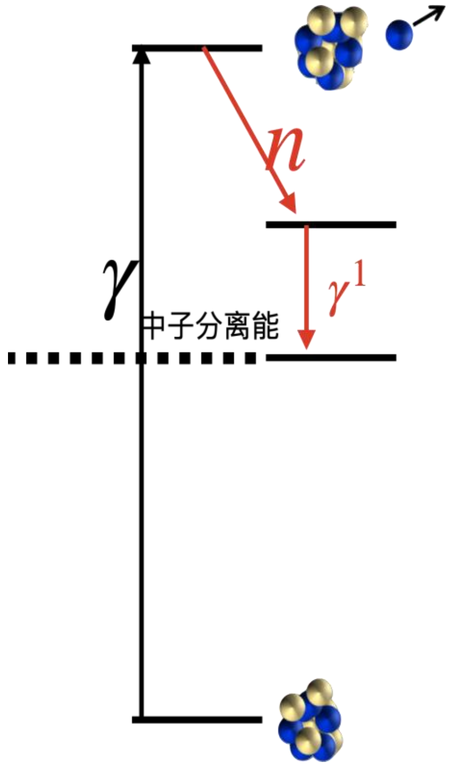
SLEGS@SSRF

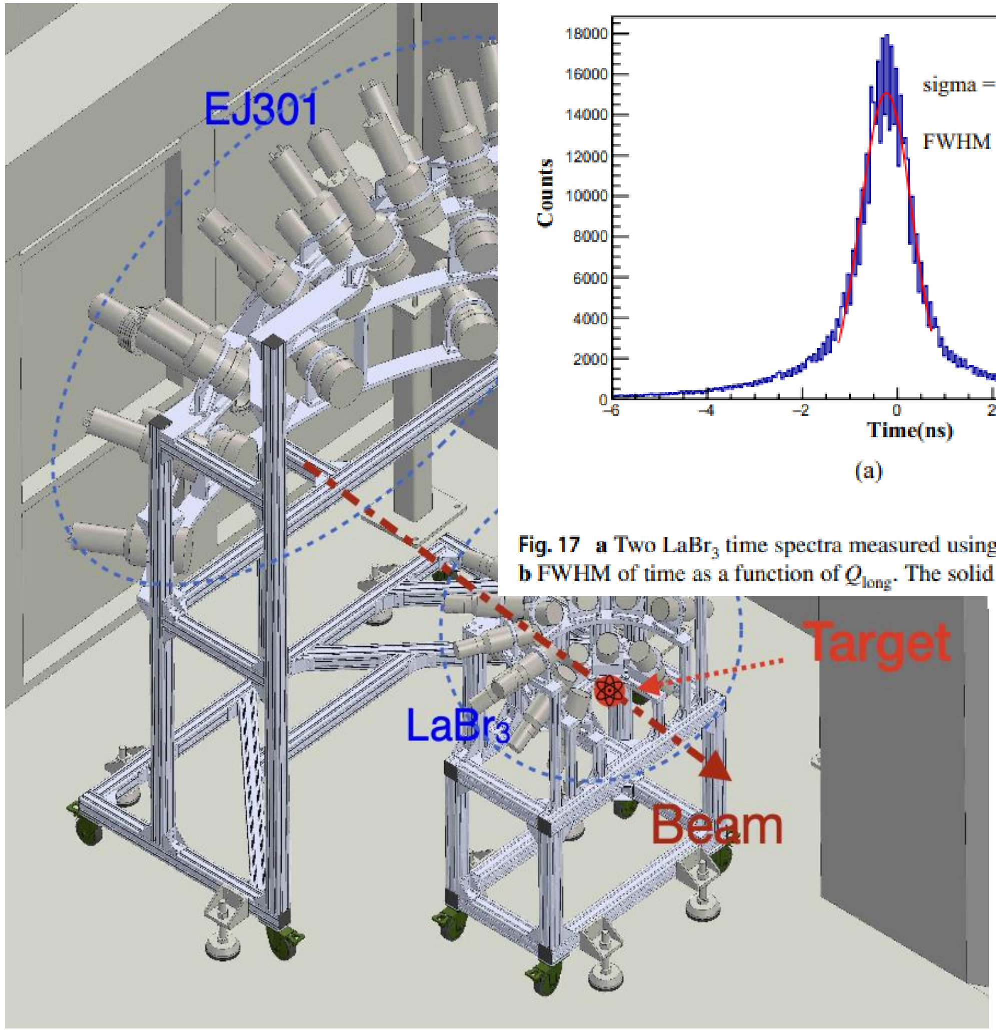


stable
SLEGS
Running
Will_Running
126
82
50
28
20
8
2
Pb
Sn
Ni
Ca
O
He

3 Typical experiments

II. n-TOF detector for (γ, n)





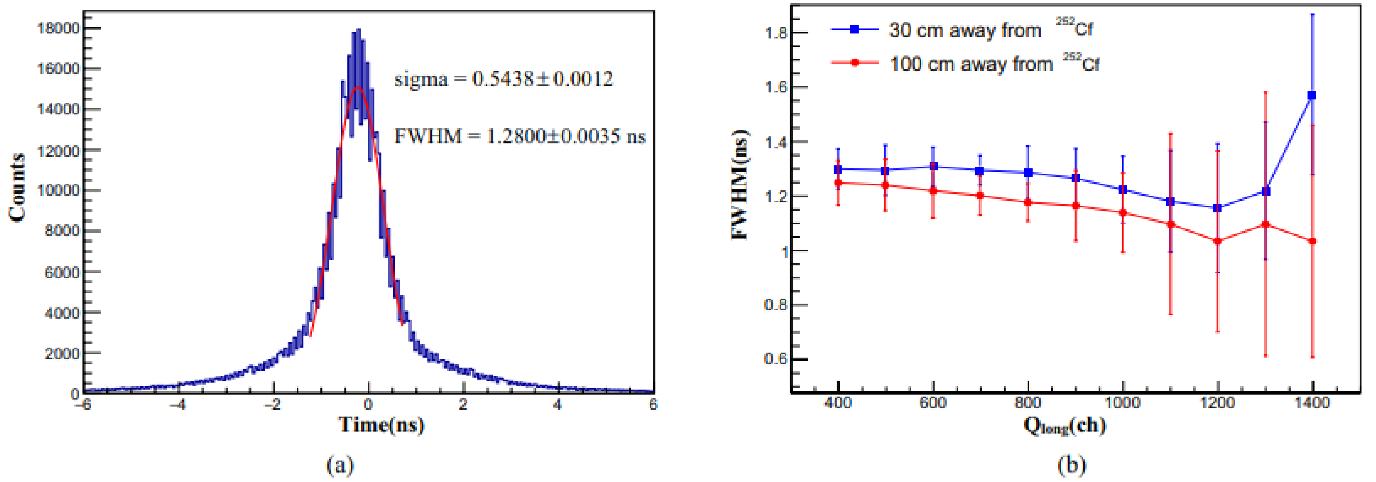


Fig. 17 **a** Two $LaBr_3$ time spectra measured using γ-rays from ^{252}Cf. Similar time spectra were accomplished for $LaBr_3$ and an EJ301 detectors. **b** FWHM of time as a function of Q_{long}. The solid lines connecting the experimental data are used to guide the eyes

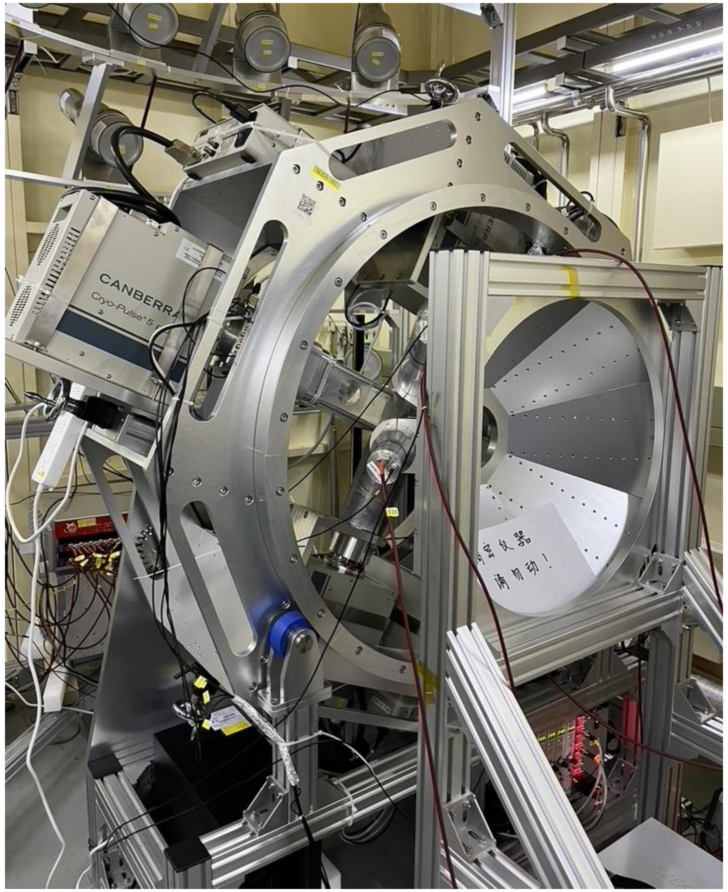
- angular distribution
- cross section
- branching ratio
- Giant multiple resonances

https://doi.org/10.1007/s41365-023-01194-3

3 Typical experiments

III. NRF detector

The SLEGS-NRF spectrometer is a special experimental spectrometer specially used for nuclear resonance fluorescence experiments.



SLEGS-NRF

High detection efficiency
High energy resolution.

SLEGS-NRF parameters

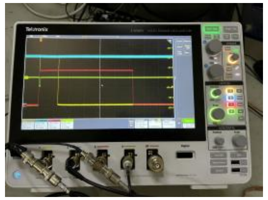
- 2 Φ80 mm×70 mm HPGe (RE= 105%)
- 2 Clover HPGe detectors (RE = 22.5%/crystal)
  8 3*4 in. $LaBr_3$ detector
- DAQ: CEAN V1730S
- Near-spherical layout
- Rotation angle from 0 to 360°

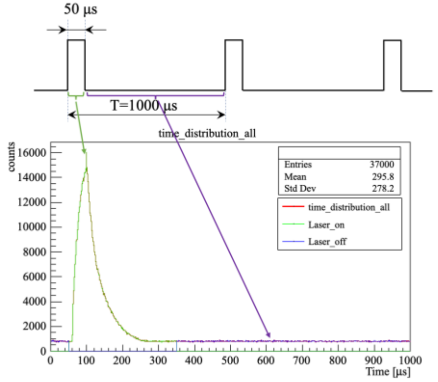
RE: relative to a 3 in. × 3 in. NaI

Experimental method

laser signal → Signal Generator → TTL signal

SLEGS-NRF signal





3 Typical experiments

Gamma Imaging

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima

Full Length Article

Gamma Spot Monitor at SLEGS beamline

Z.R. Hao [a], H.H. Xu [a,*], G.T. Fan [a,b,c], L.X. Liu [a], Y. Zhang [a], H.W. Wang [a,b,c], W.X. Wen [d], C.Y. Zu [d], Y.X. Yang [b,e], K.J. Chen [b,f], S. Jin [b,c], Q.K. Sun [b,c], Z.W. Wang [b,c]

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[b] Shanghai Institute of Applied Physics, Chinese Academy of Sciences, Shanghai, 201800, China
[c] University of Chinese Academy of Science, Beijing, 100080, China
[d] Soochow University, Suzhou, 215006, China
[e] School of Physics and Microelectronics, Zhengzhou University, Zhengzhou, 450052, China
[f] School of Physical Science and Technology, Shanghai, 201210, China

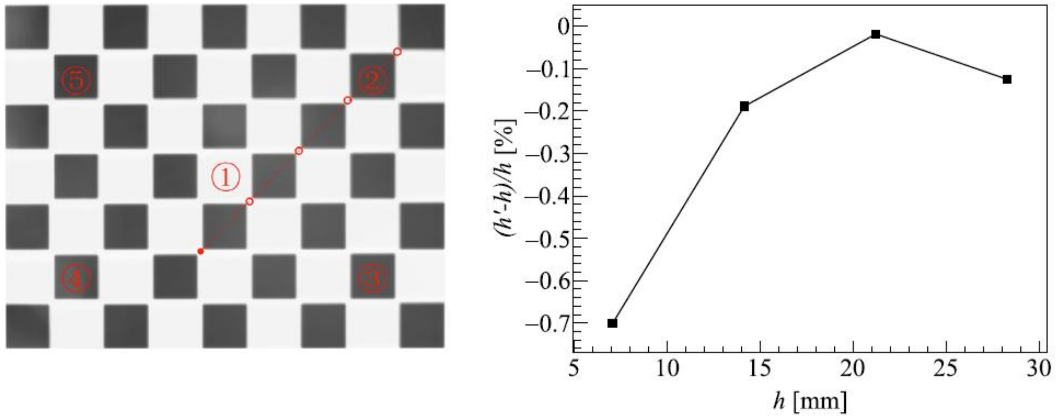
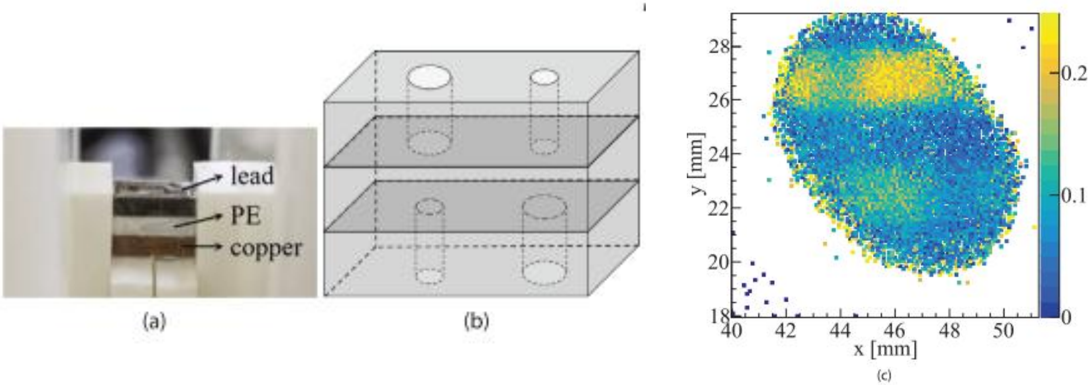
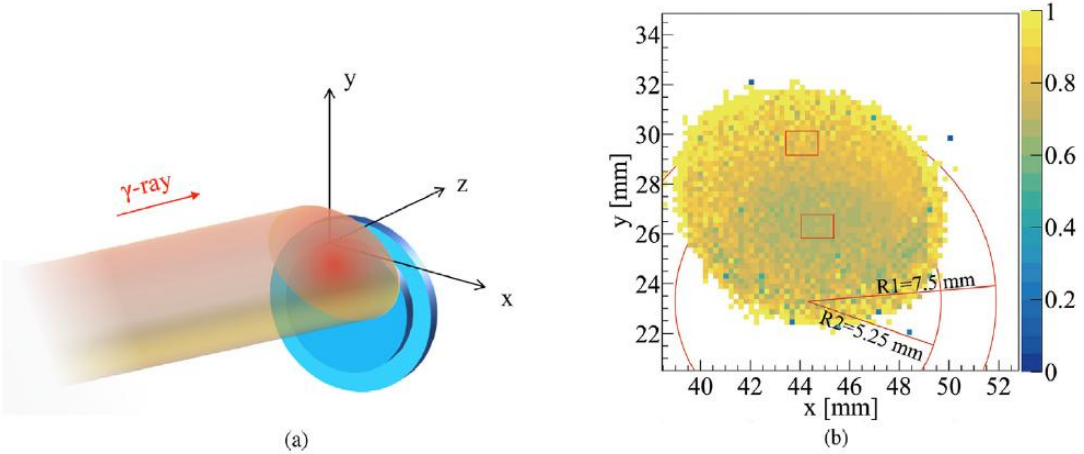


Fig. 2. (a) Image of the black-white chessboard glass plate. (b) Relative distortion curve of the GSM.

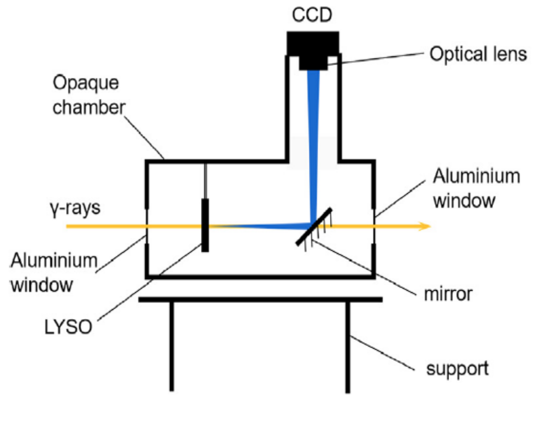




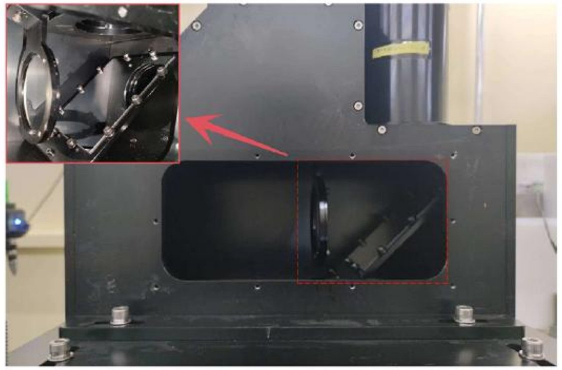
https://doi.org/10.1016/j.nima.2024.169748

3 Typical experiments

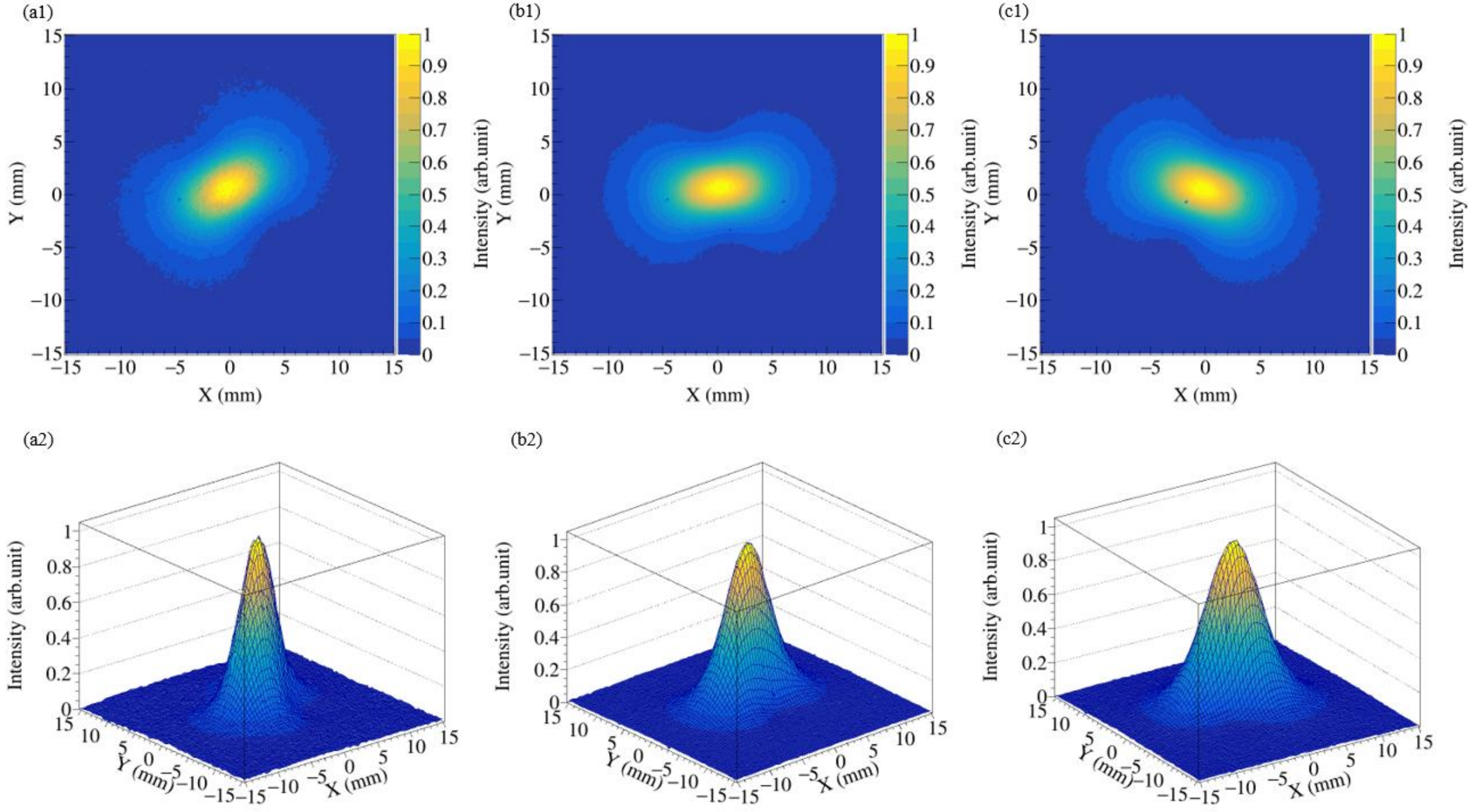
Polarization measurement



(a)



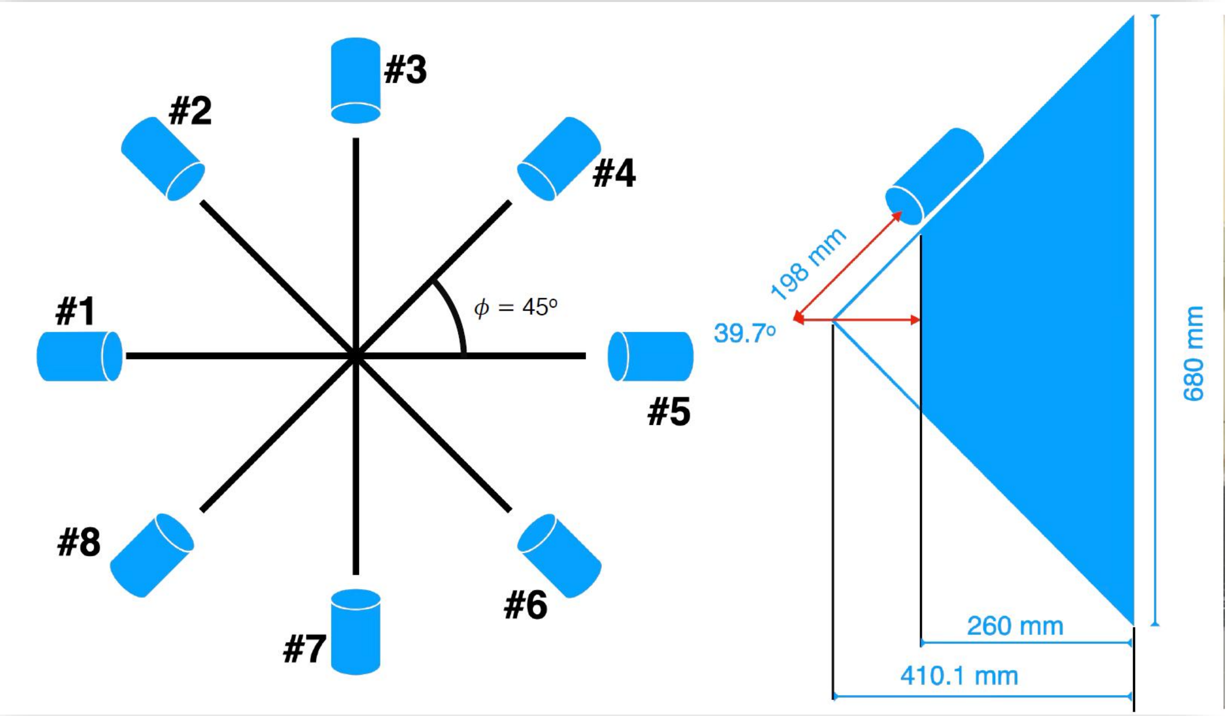
(b)



See Xiangfei Wang's talk for more details

3 Typical experiments

Polarization measurement



Doi: 10.48550/arXiv.2506.00767

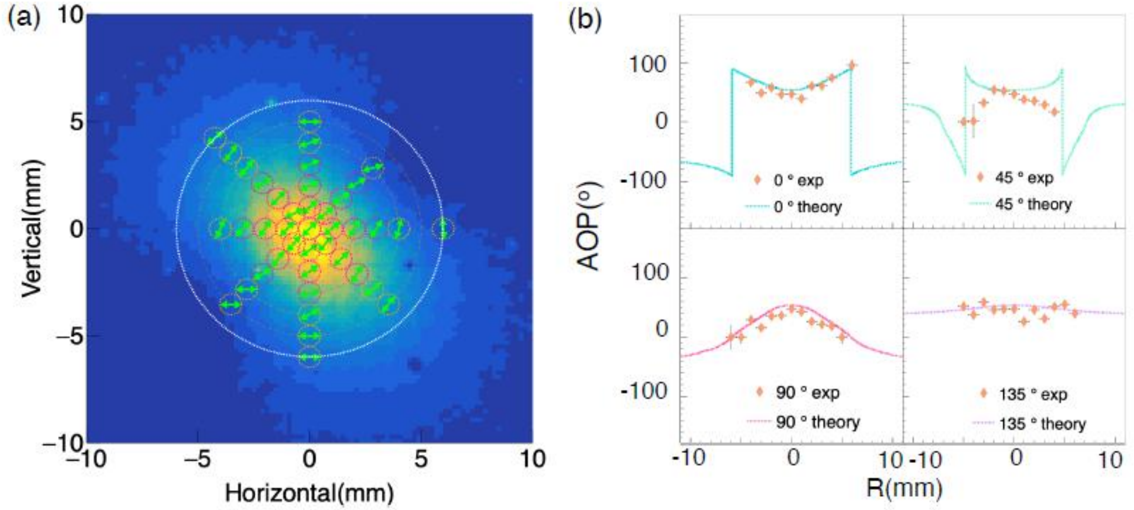


FIG. 4: (a) the polarization direction (AOP) for each measurement point, where the circle with pink represents the $1/\gamma$. A comparison between the experimental and calculation based on QED [52] is presented in (b).

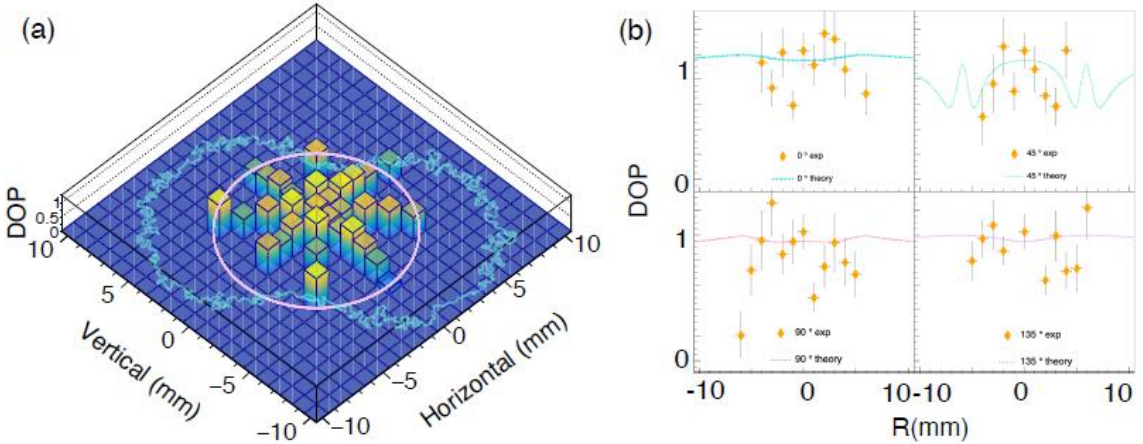


FIG. 5: The experimental DOP distribution is shown in (a), where the blue line in the shape of peanut indicates γ-rays spot and the circle with pink represents the $1/\gamma$. A comparison between the experimental and calculation based on QED [52] is presented in (b).

3 Typical experiments

Electron beam size diagnostics

$$\sigma_m = \left[\sigma_0^2 + \left(\frac{M^2\lambda(z-z_0)^2}{\pi\sigma_0}\right) + \sigma_{ey}^2 + \sigma_{jitter}^2\right]^{1/2}$$

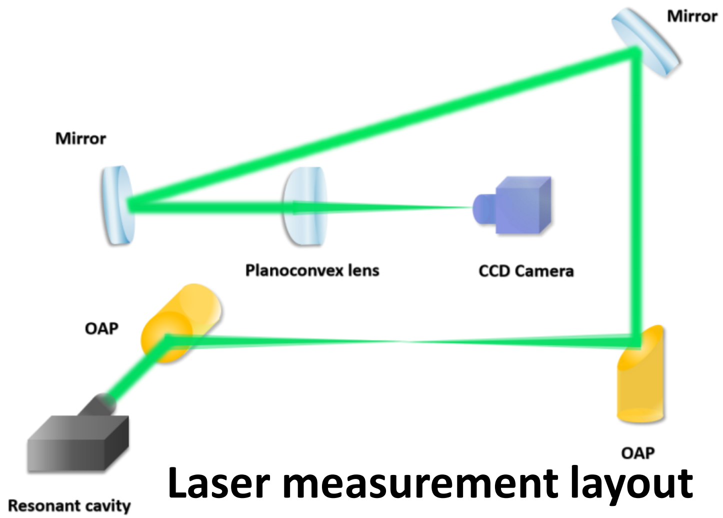
σ_m: spatial convolution size of laser and electron beam

σ_0: 1/2size of laser waist

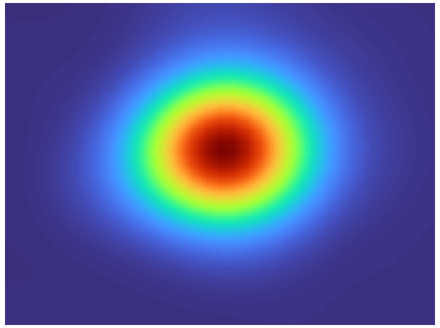
σ_{jitter}: jittering of laser focal point

Size of electron bunch in vertical axis:

$\sigma_{ey} = 8.07 \pm 10.45\mu m$

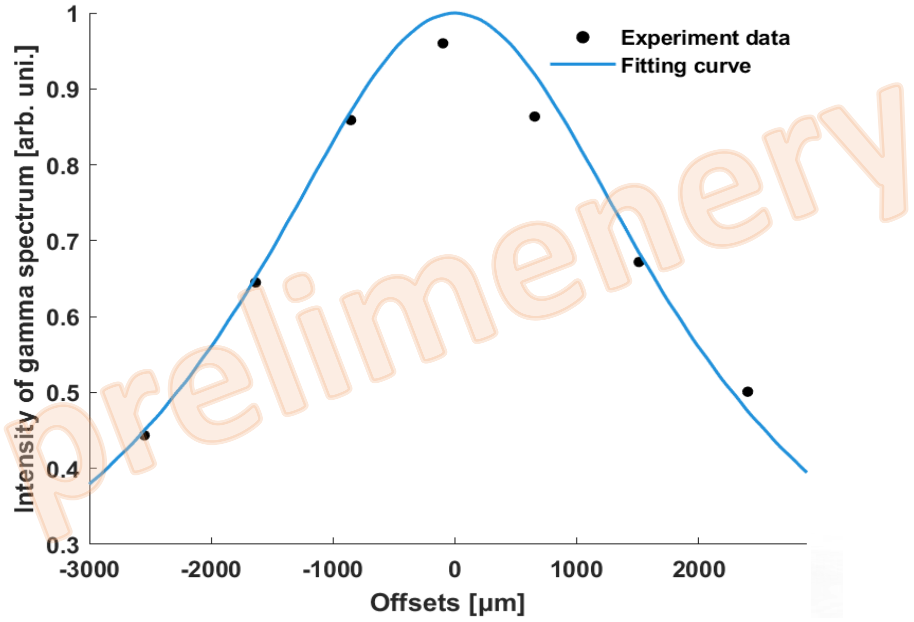


Laser measurement layout



$\sigma_0 = 31.00 \pm 2.67\mu m$

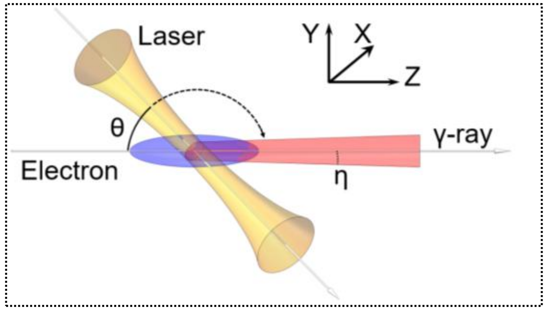
$\sigma_{jitter} = 3.08\mu m$



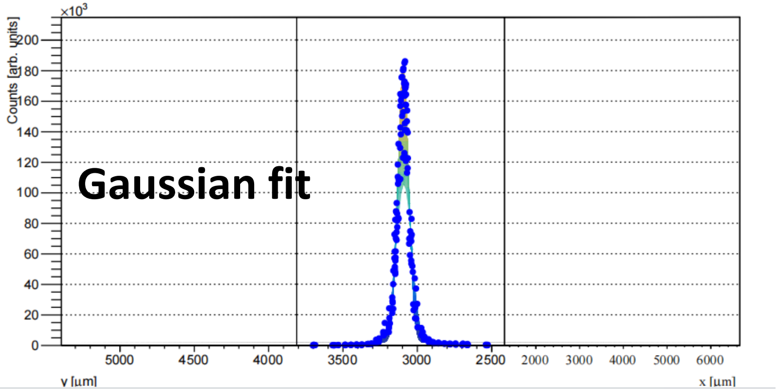
$$\mathcal{L}_{sc}(u,v) = \int \rho_e(x,y,z)\rho_l(x',y',z',t,u,0,v)dVdt$$

Size of electron bunch in horizontal axis:

$\sigma_{ex} = 277 \pm 4\mu m$



Online laser wirescan layout



$\sigma_m = 33.68 \pm 0.57\mu m$

4 Upgrades & New LCS

Facility/Project: SLEGS
Photon energy: 0.6 – 21.7MeV
Total flux : 10^5 ~ 10^7ph/s
Resolution: 4~15% (FWHM)
Research: Nuclear structure

SSRF

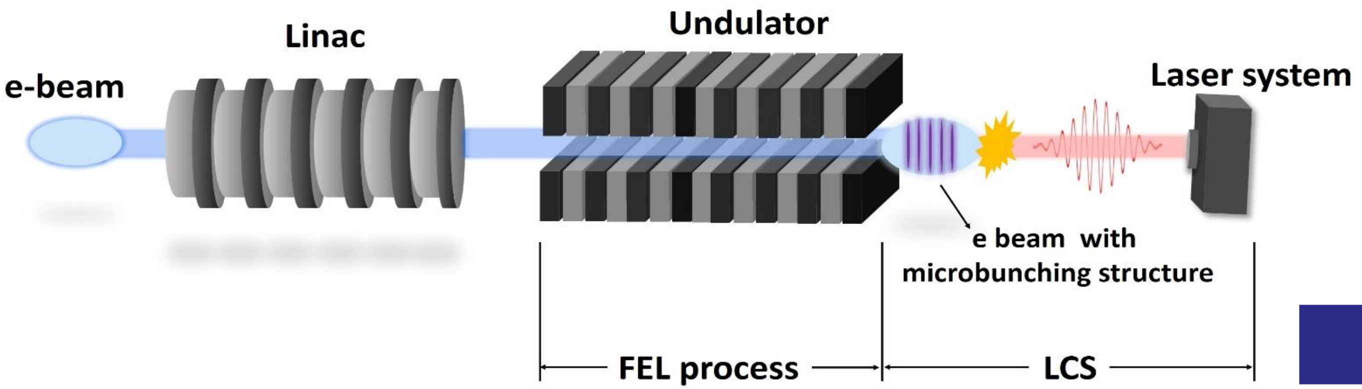
Facility/Project: SLEGSII
Photon energy: ~ 100MeV
Total flux : ~ 10^8ph/s
Research: Nuclear structure

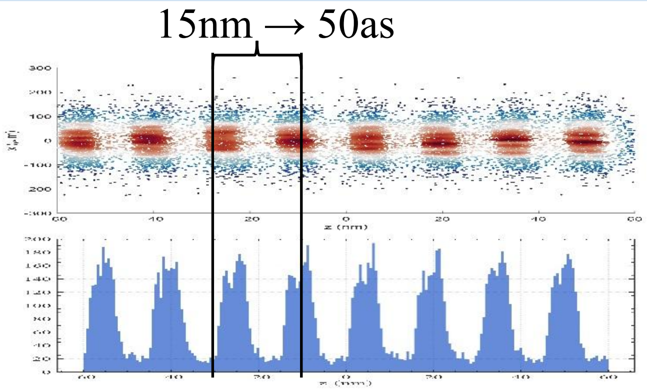
SXFEL

Facility/Project: SLEGSIII
Photon energy: ~ GeV
Total flux : 10^6 ~ 10^{10}ph/s
Research: Particle

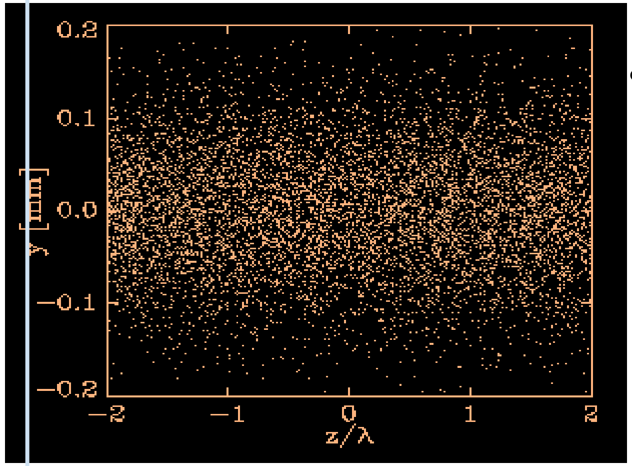
SHINE

LCS@SXFEL





Microbunch generated during the FEL process



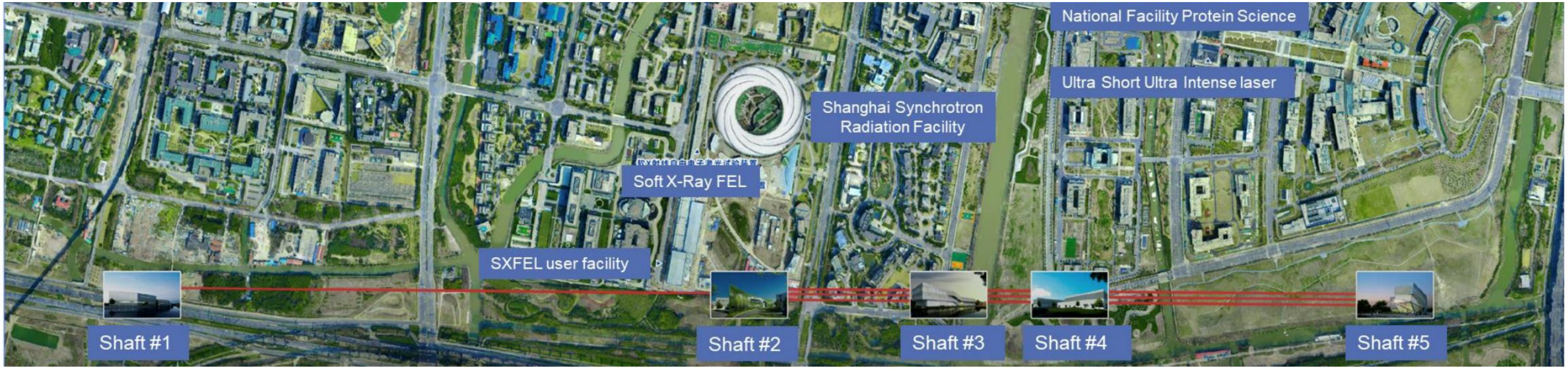
- Electron beams with micro bunch structures and laser pulses undergo Compton scattering in the interaction cavity, producing ultrafast gamma-ray pulse trains.

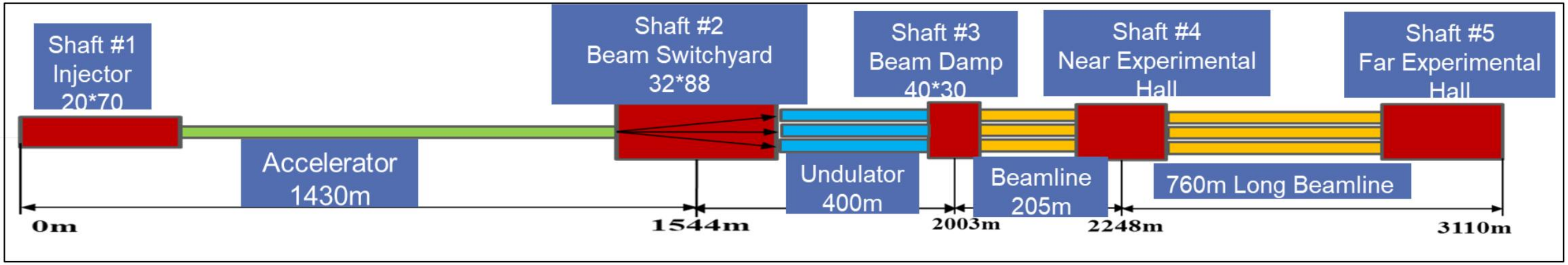
Doi: 10.48550/arXiv.2503.00899

laser Parameter	Values
Wave length(nm)	800
Peak Power(TW)	20
waist size w_0(μm)	30
wave length spread（rms）	<0.3%
Pulse length (rms-ps）	0.03~10
Frequency(Hz)	5
Pulse energy	0.7J

e Parameter	Values
Electron Energy(GeV)	1.0
charge per pulse(pC)	500
Normalized emittance(mm·mrad)	1
Transverse size σ_e(rms-um)	65
Slice energy spread（rms）	<0.1%
Pulse length (FWHM), (ps）	1→0.5
Frequency(Hz)	10
Undulator period (cm)	3.0
Radiation wavelength (nm)	15

LCS@SHINE



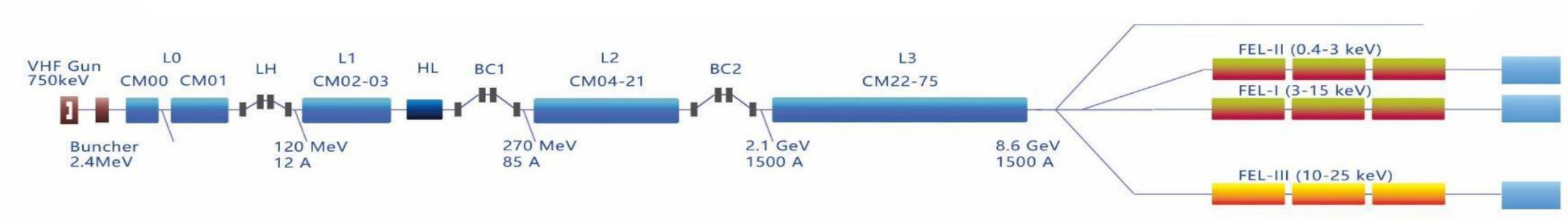


An **8 GeV** SCRF linac, 3 undulator lines to deliver photons from **0.4-25 keV**, up to **1 MHz** pulse train with pulse duration of 1-100fs

- 3 X-ray beamlines and 10 End-stations
- 100 PW super-intense laser facility
- Total length 3110 m; 29.0 m underground

LCS@SHINE

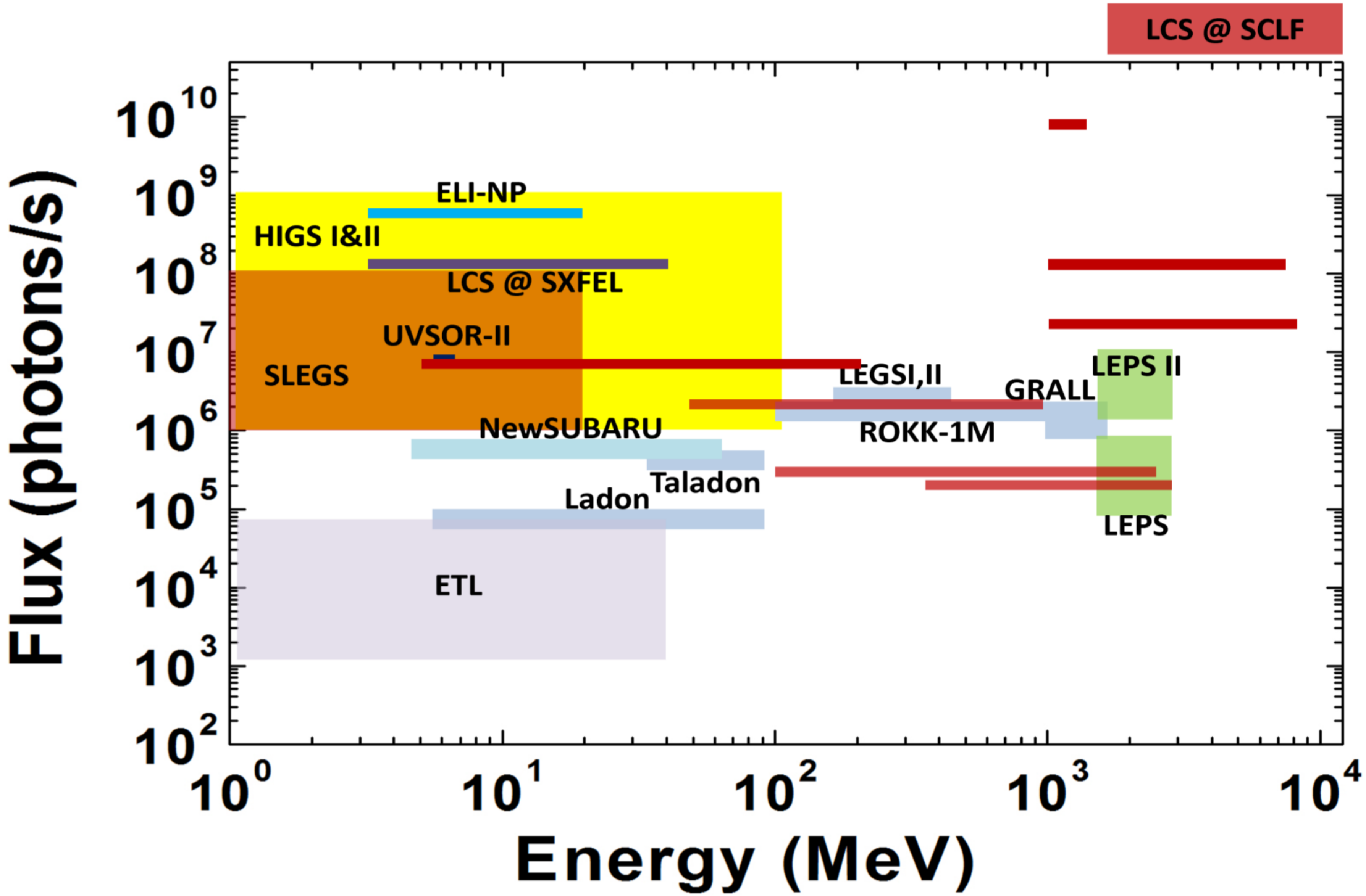
SHINE Accelerator and FEL Lines



	Nominal	Range
Beam energy/GeV	8.0	4-8.6
Bunch charge/pC	100	10-300
Max rep-rate/MHz	1	up to 1
Beam power/MW	0.8	0 - 2.4
Photon energy/keV	0.4-25	0.4-25
Pulse length/fs	20-50	5-200
Peak brightness	5×10^{32}	1×10^{31}-1×10^{33}
Average brightness	5×10^{25}	1×10^{23}-1×10^{26}
Total facility length/km	3.1	3.1
Tunnel diameter/m	5.9	5.9
2K Cryogenic power/kW	12	12
RF Power/MW	2.28	3.6

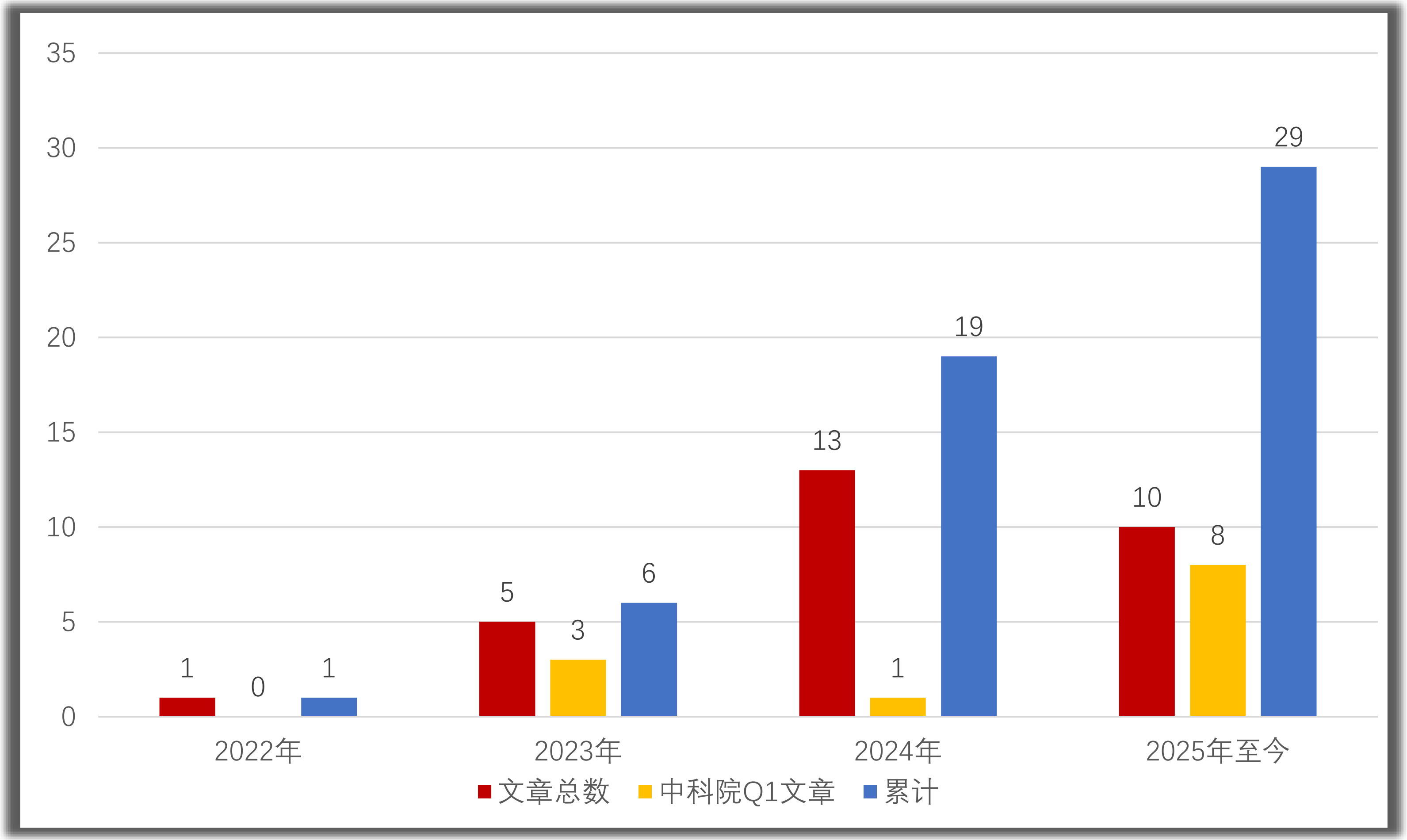
FEL Line	Nominal	Objective
FEL-I		
Photon energy/keV	3-15	3-15
Photon number per pulse @12.4keV	$>10^{10}$	$>10^{11}$
Max pulse repetition rate/MHz	0.66	1
FEL-II		
Photon energy/keV	0.4-3	0.4-3
Photon number per pulse @1.24keV	$>10^{12}$	$>10^{13}$
Max pulse repetition rate/MHz	0.66	1
FEL-III		
Photon energy/keV	10-25	10-25
Photon number per pulse @15keV	$>10^{9}$	$>10^{10}$
Max pulse repetition rate/MHz	0.66	1

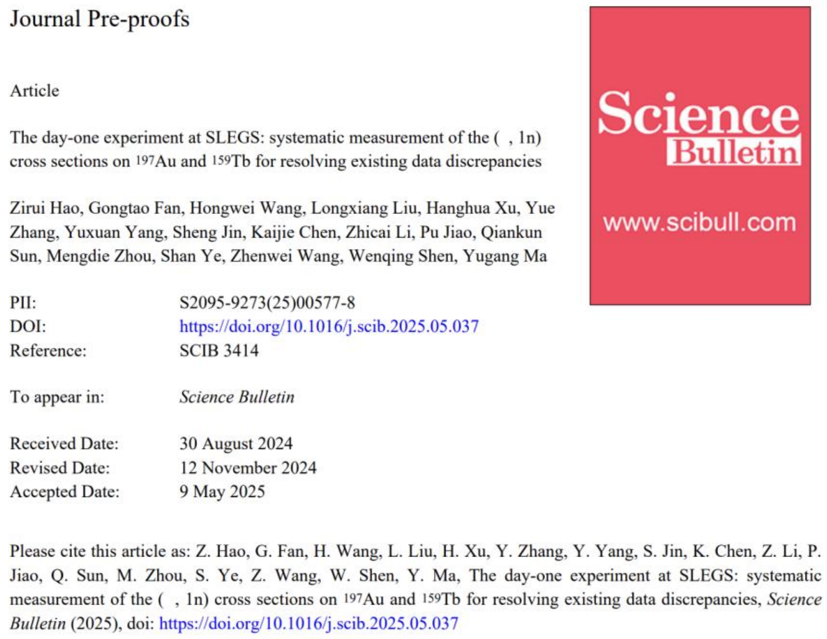
4 Upgrades & New LCS



5 Summary & Outlook

Publications from operation





Journal Pre-proofs

Article

The day-one experiment at SLEGS: systematic measurement of the (, 1n) cross sections on ^{197}Au and ^{159}Tb for resolving existing data discrepancies

Zirui Hao, Gongtao Fan, Hongwei Wang, Longxiang Liu, Hanghua Xu, Yue Zhang, Yuxuan Yang, Sheng Jin, Kaijie Chen, Zhicai Li, Pu Jiao, Qiankun Sun, Mengdie Zhou, Shan Ye, Zhenwei Wang, Wenqing Shen, Yugang Ma

Science Bulletin

www.scibull.com

PII: S2095-9273(25)00577-8
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Reference: SCIB 3414

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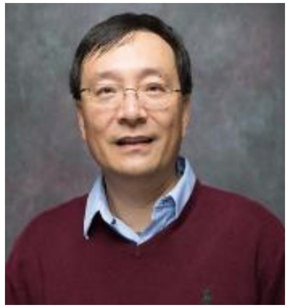
Since its opening in 2022, a total of 29 articles have been published

5 Summary & Outlook

Cooperation



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5 Summary & Outlook

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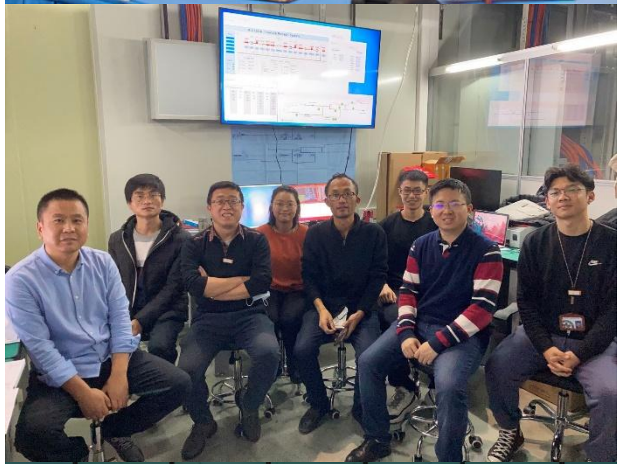

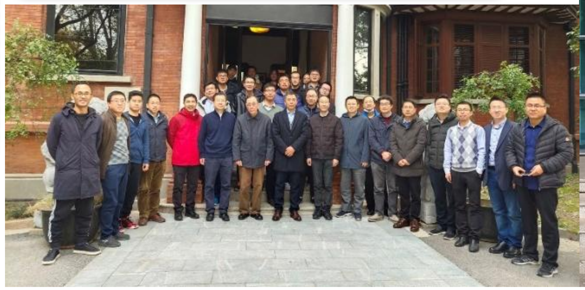

Summary

- SLEGS, an energy-variable gamma-ray source developed based on the laser Compton slant scattering of 10.6 μm photons from a 100 W CO_2 laser on 3.5 GeV electrons from the Shanghai Light Source. It produces gamma-rays in the energy range of 0.66–21.7 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 spectrum in basic research to while that in the application research.
- The SLEGS is already open to international users. Nuclear physicists from all over the world are welcome to do experiments at SLEGS.

https://ssrfwx.ssrf.ac.cn/proposals/en/a/login

Thanks for your attention !