



High-Field Physics on Dual-Beam Ultrafast High-Power Lasers at SJTU

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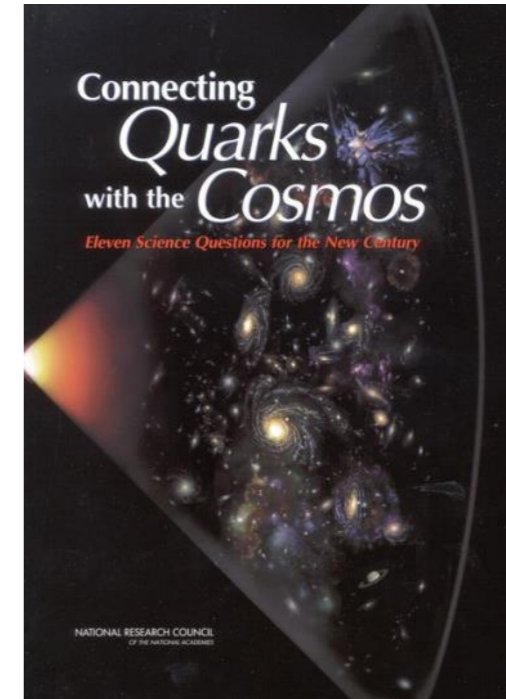
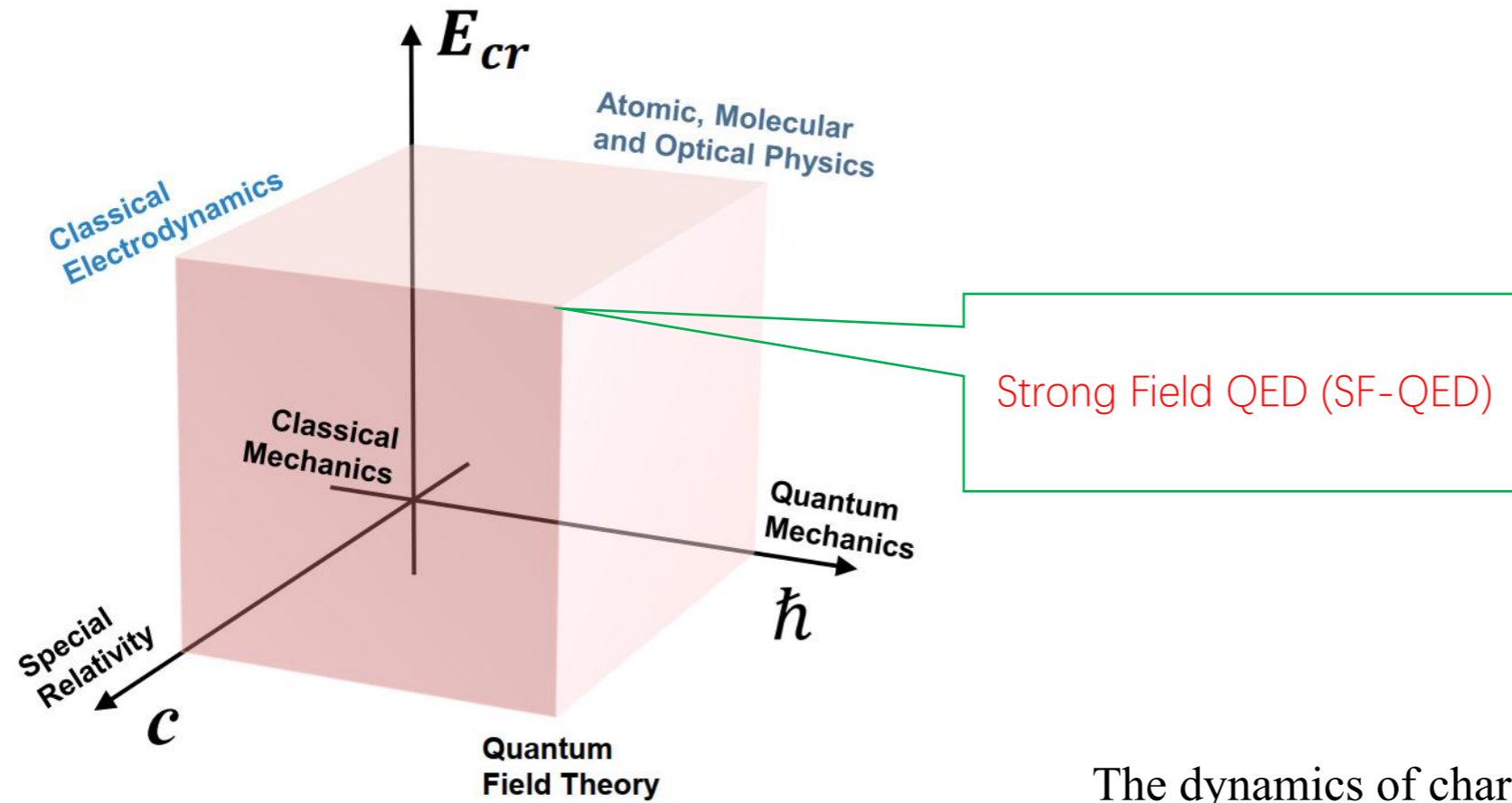
EAAC 2023, Elba, Italy

Outline

- ❑ **Motivation**
- ❑ **Ultrahigh field physics Experiments with dual pulse**
 - All-optical Thomson/Compton scattering experiment
 - Optical Injection
- ❑ **New facilities and future plans**



Motivation



The dynamics of charged particles in electromagnetic fields is an essential component of understanding the most extreme environments in our Universe.

Gonoskov *et al.*, Reviews of Modern Physics 94 (4), 2022

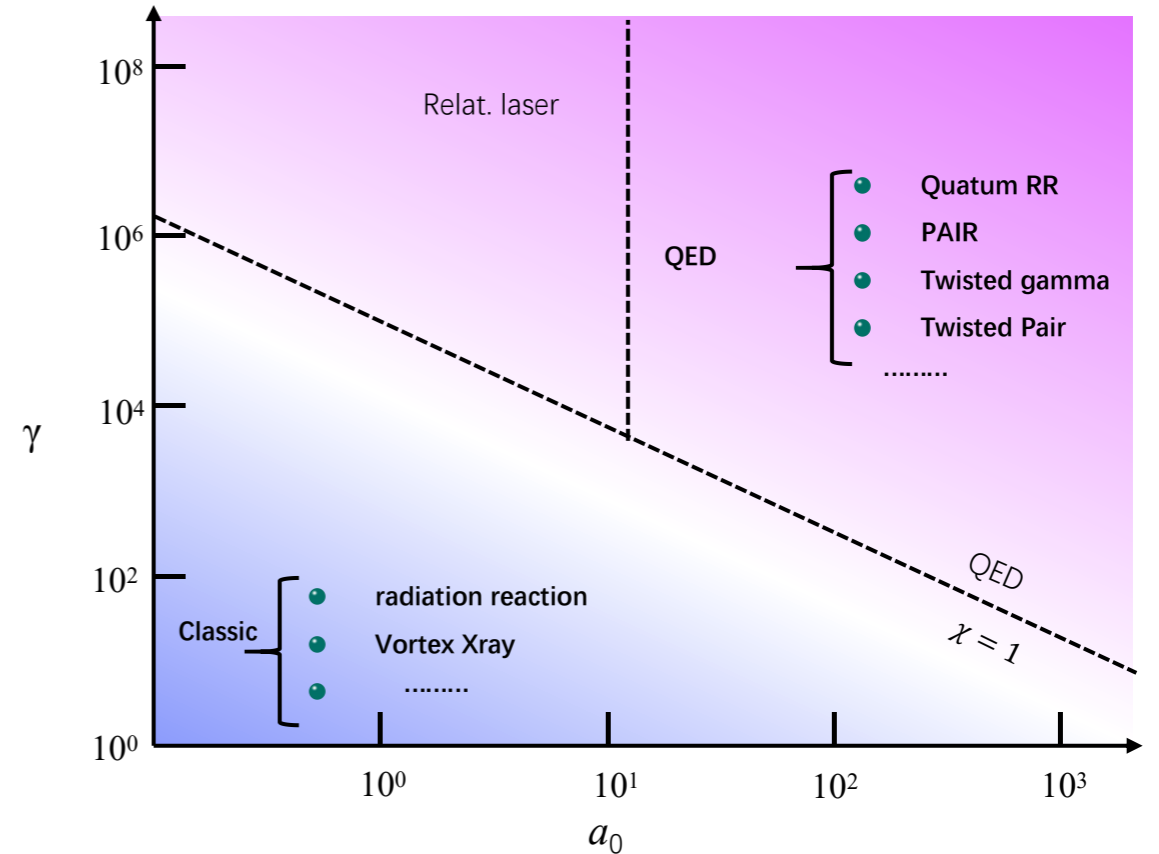
Electron as a messenger for SF-QED

QED
parameter

χ

$$\begin{aligned}\chi_e &= \frac{\sqrt{-(F_{\mu\nu}p^\nu)^2}}{mcE_{\text{cr}}} \\ &= \gamma \frac{\sqrt{(\mathbf{E} + \mathbf{v} \times \mathbf{B})^2 - (\mathbf{E} \cdot \mathbf{v}/c)^2}}{E_{\text{cr}}} \\ \chi_\gamma &= \frac{\hbar \sqrt{-(F_{\mu\nu}k^\nu)^2}}{mcE_{\text{cr}}} \\ &= \frac{\hbar\omega}{mc^2} \frac{\sqrt{(\mathbf{E} + (c^2\mathbf{k}/\omega) \times \mathbf{B})^2 - (\mathbf{E} \cdot (c\mathbf{k}/\omega))^2}}{E_{\text{cr}}}\end{aligned}$$

$$\chi_e \simeq 0.18 \mathcal{E}_0 [\text{GeV}] I_0^{1/2} [10^{21} \text{ Wcm}^{-2}] \propto a_0 \gamma$$



- Rest frame of e- $E' \approx 2\gamma E$
- The relativistic effect of e- reduce the laser intensity threshold of QED effect by several orders of magnitude
- electron-photon collision scheme

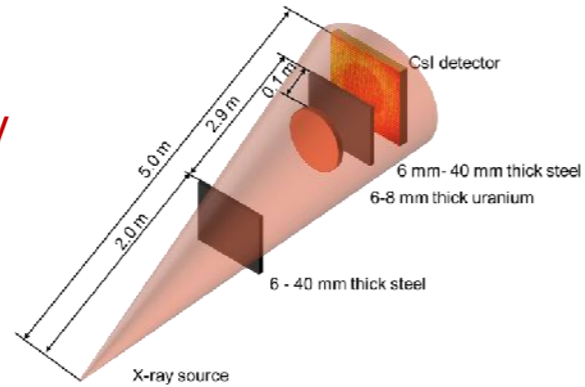
Motivation

more applications



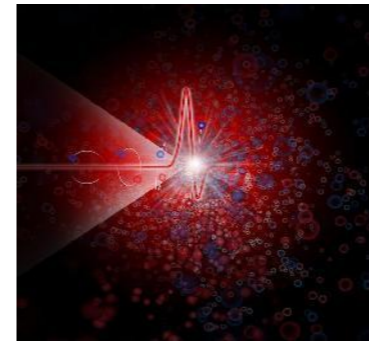
High-energy Light Source

- High brightness
- Multiple turnability
- Colimated



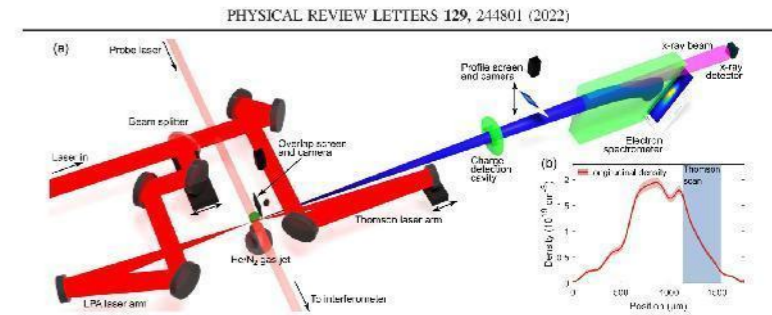
D. Umstadter *Contemporary Physics* 56 (4), 417-431

Diagnostics on Laser

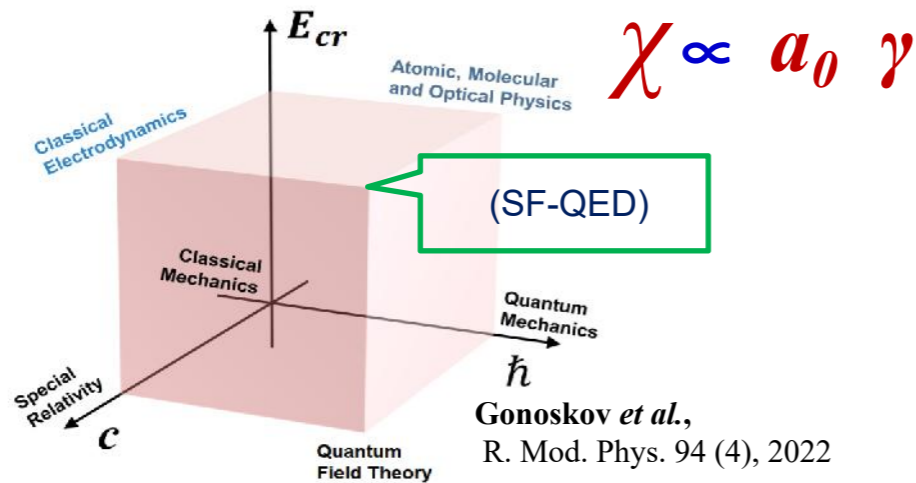


Yan et al, *Nature Photonics*, 11, 514. (2017)
Har-Shemesh, Di Piazza, *Opt. Lett.* 37, 1352 (2012).

Diagnostics on plasma

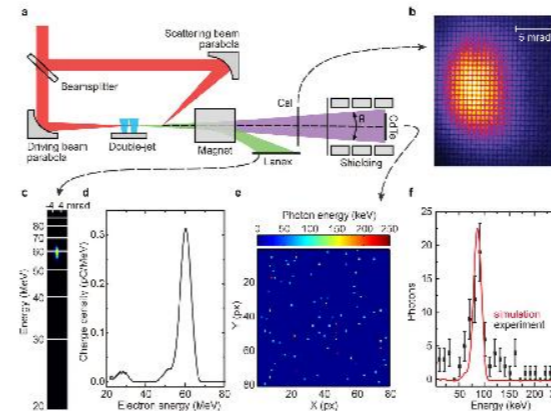


Extreme Strong field physic(QED)

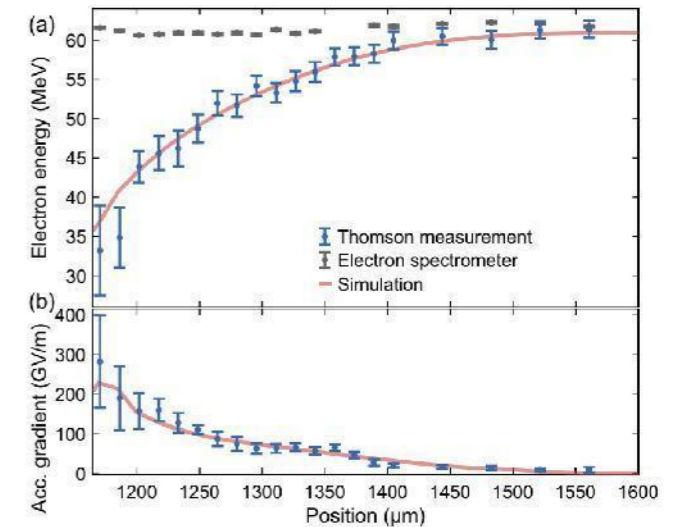


Gonoskov et al.,
R. Mod. Phys. 94 (4), 2022

Diagnostics on electron



G. Golovin et al *SciRep* 6, 24622 (2016)



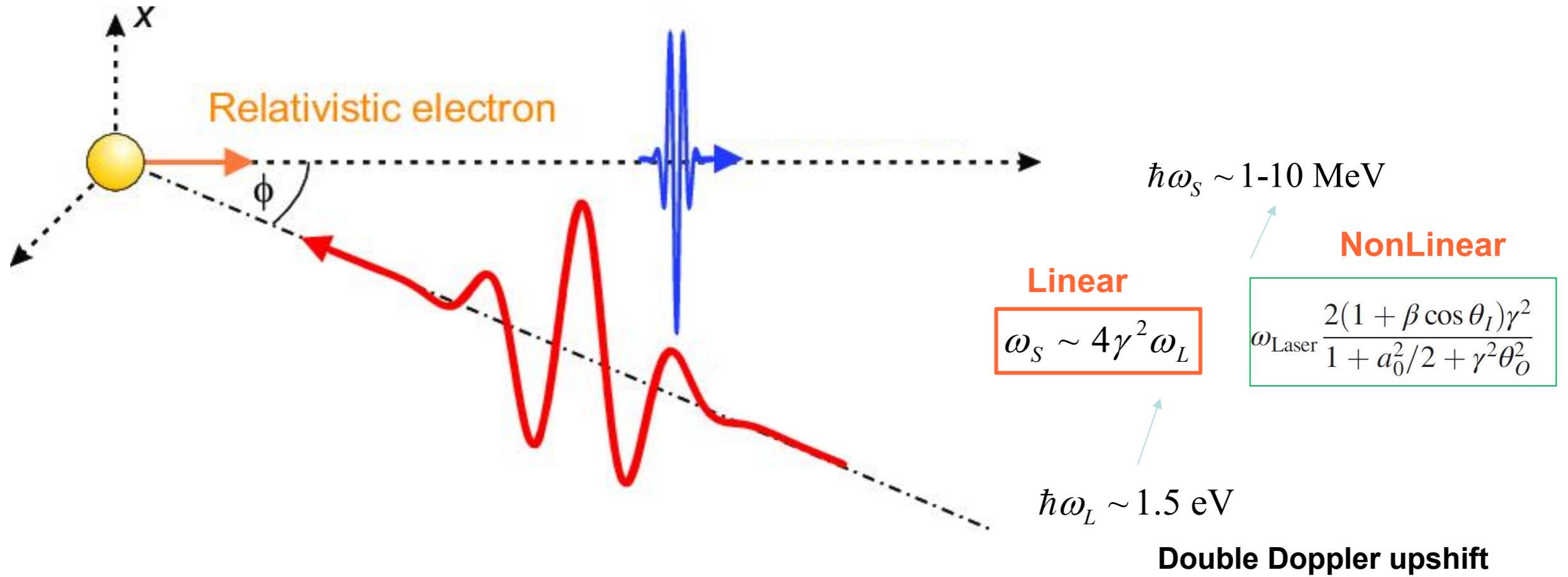
Bohlen et al. *PRL* 129, 244801 (2022)

Outline

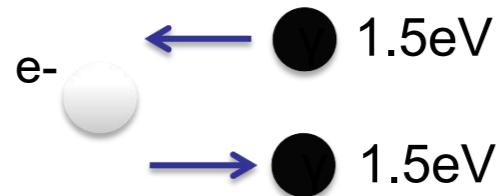
- ❑ Motivation
- ❑ **Ultrahigh field physics Experiments with dual pulse**
 - **All-optical Thomson/Compton scattering experiment**
 - **Opitcal Injection**
- ❑ New facilities and future plans



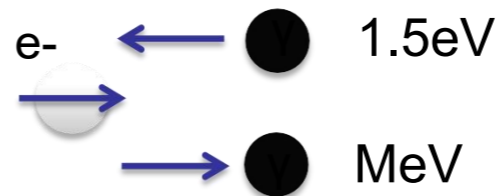
Thomson/Compton scattering



Ave. rest frame of e- : TS



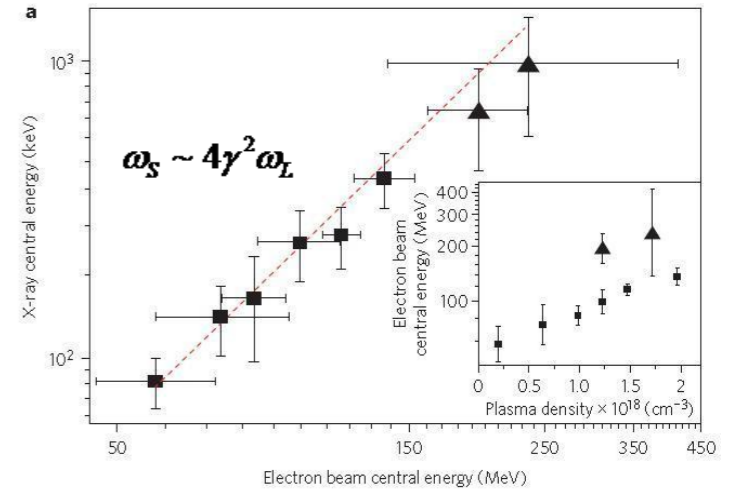
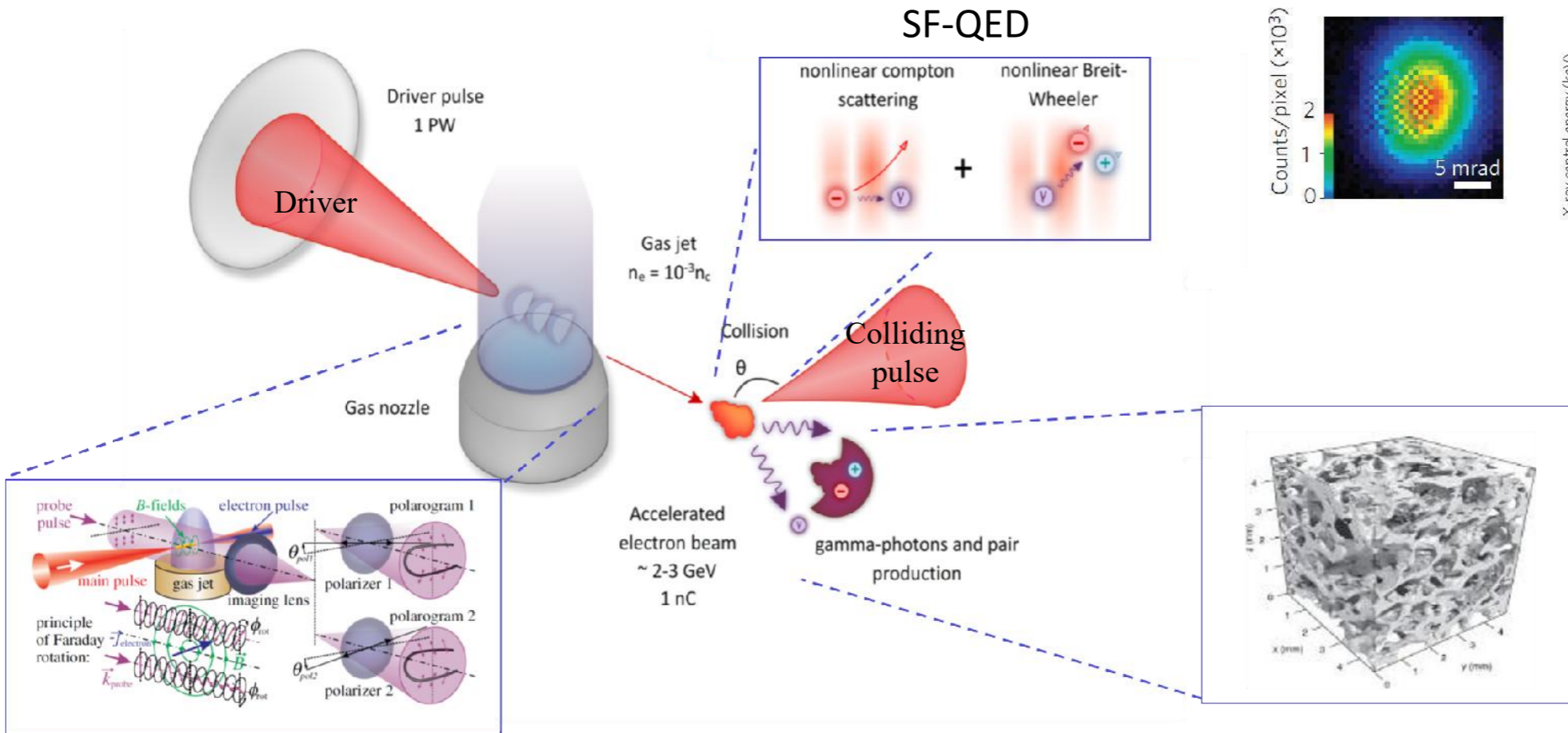
lab frame: ICS



The electron-photon interaction--All-optical Thomson/Compton Scattering Exp

variable controllable parameters : laser & **electron**

variable controllable parameters :
 ➤ **Electron**: energy



N. Powers et al, Nat. Photon. **8**, 28 (2014)
 G. Golovin, W. Yan, et al NIMA, **830** 375(2016)

Optical Injection

Application

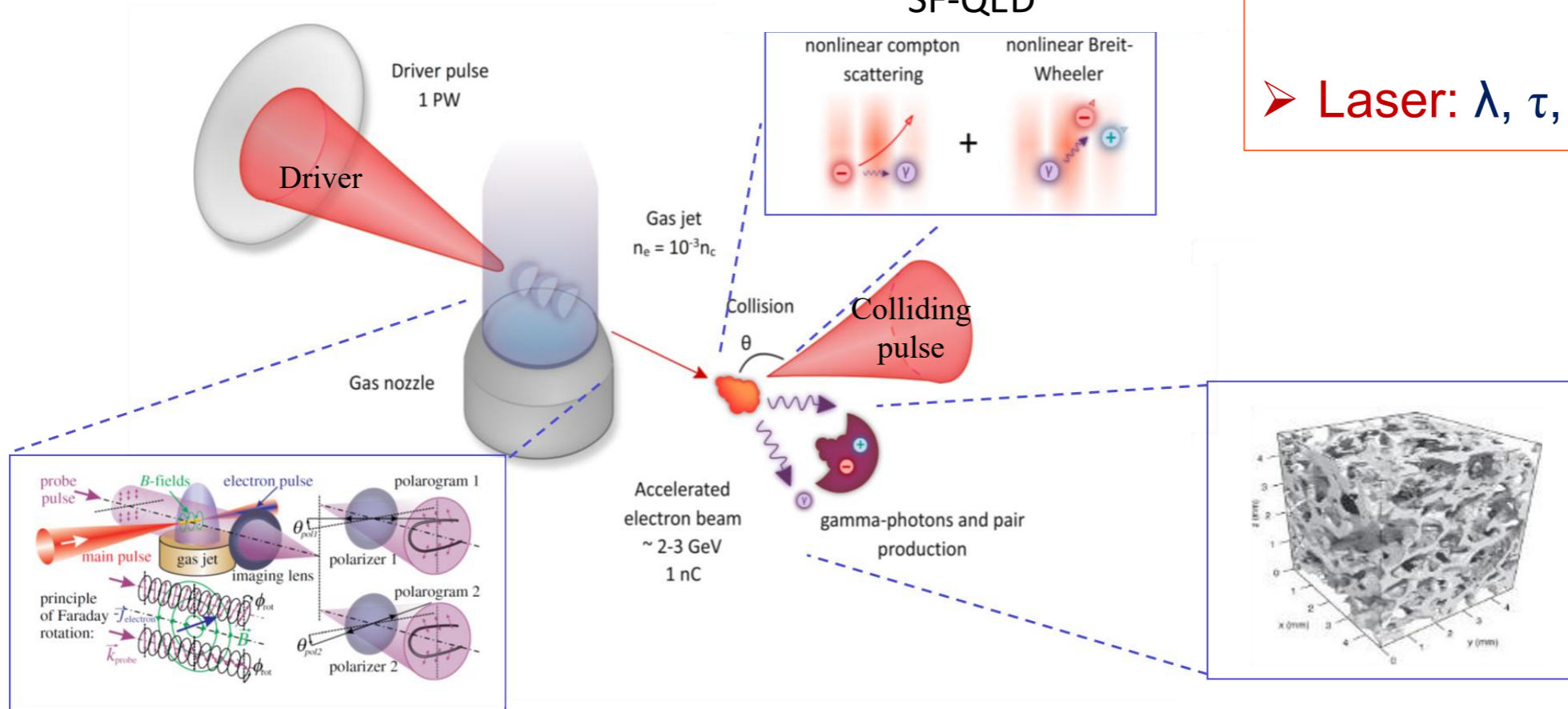
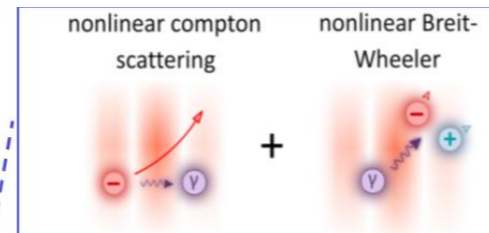
The electron-photon interaction--All-optical Thomson/Compton Scattering Exp

variable controllable parameters : **laser** & electron

variable controllable parameters :

➤ **Laser:** λ , τ , pol, a_0 , OAM...

SF-QED



Optical Injection

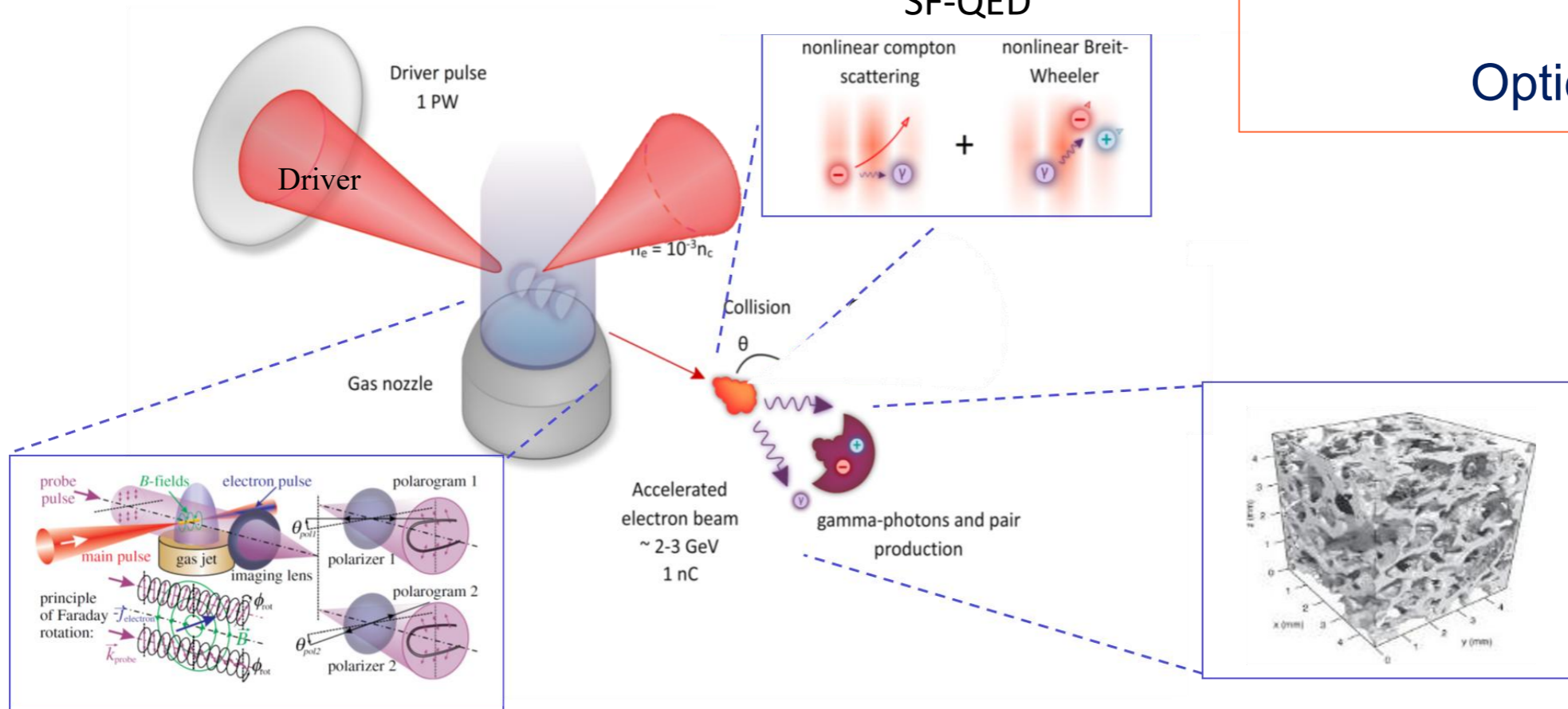
Application

The electron-photon interaction--All-optical Thomson/Compton Scattering Exp

variable controllable parameters : **laser** & electron

SF-QED

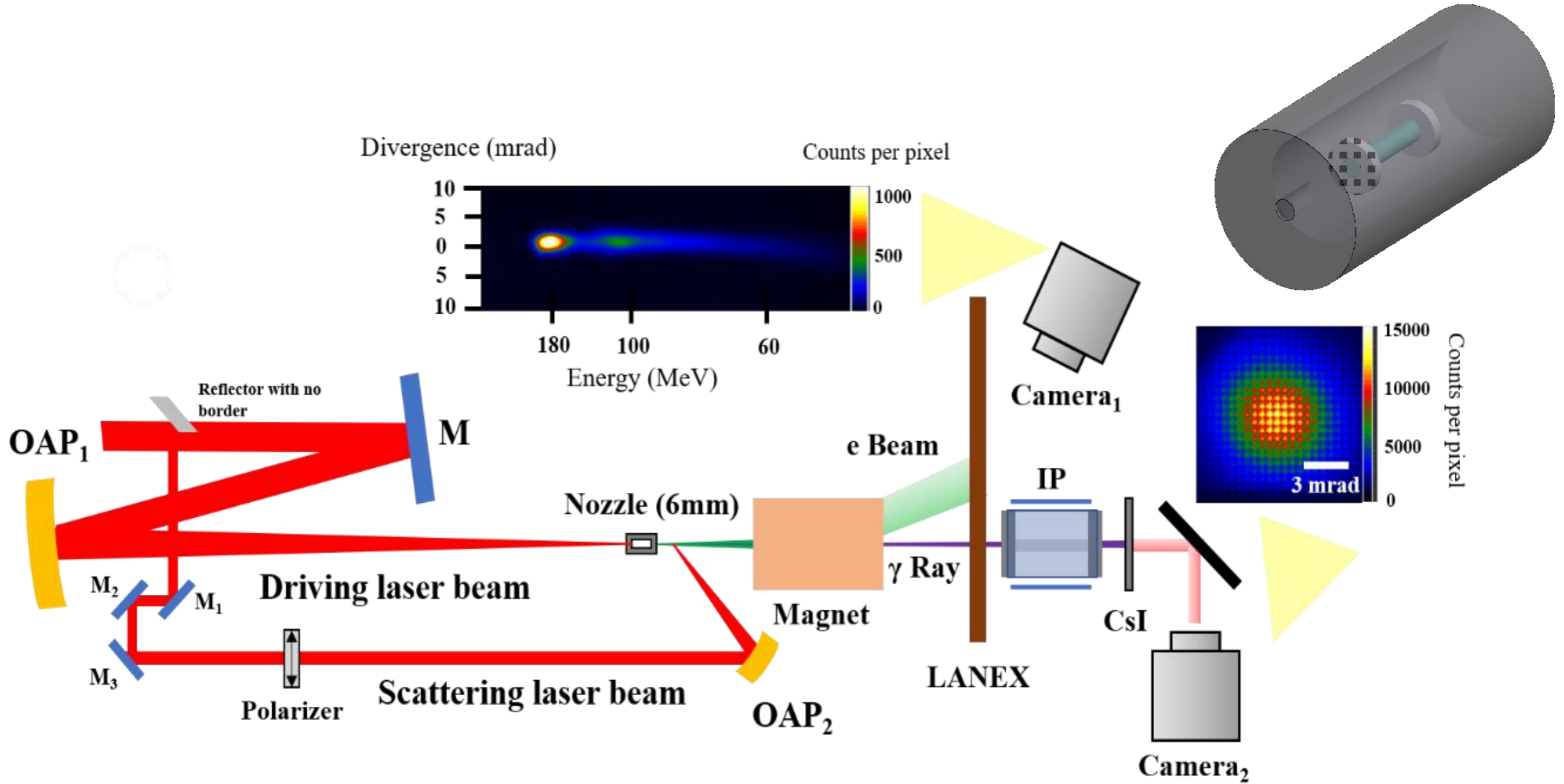
Optical Injection



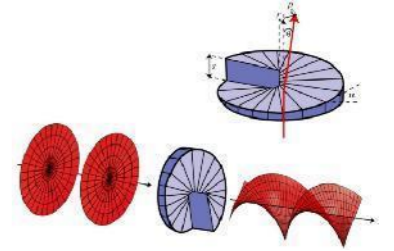
Optical Injection

Application

2、 Polarization control of TS X-rays



3、OAM control of TS X-rays

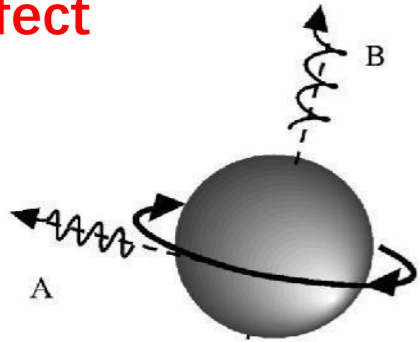


- Matter manipulation (Motions & Quantum state)
- Quantum communications (information encryption)
- Molecule diagnostic (phase contrast image)
- Nuclear physics (nucleon excitation)
- Astrophysics (Observation and Astrophysics experiments)

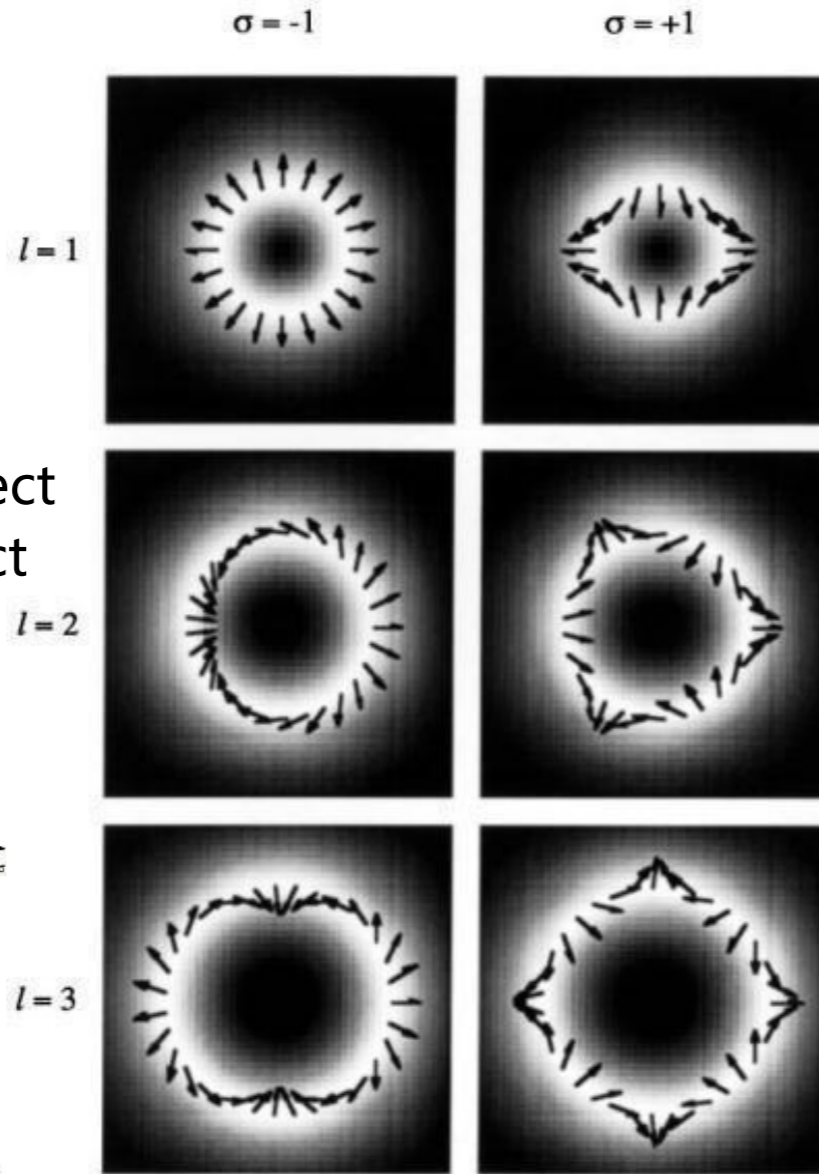
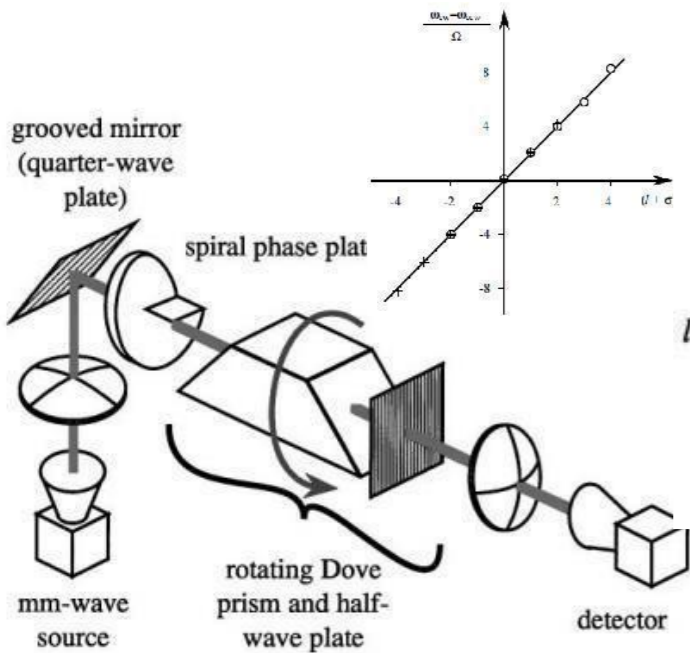
Development of vortex beams

4, SAM & OAM control of TS X-rays

Rotational Doppler effect

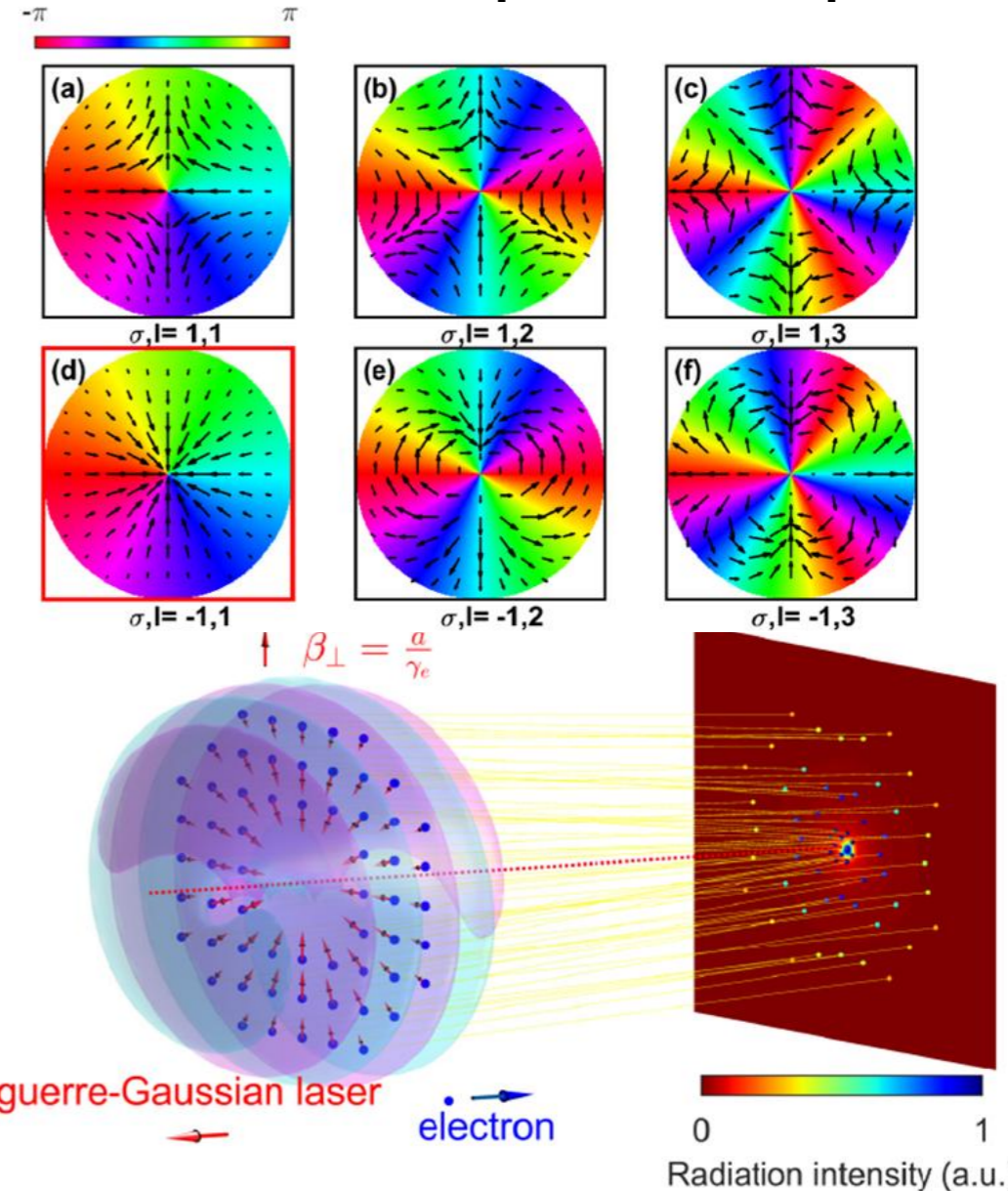


A: translation Doppler effect
B: rotational Doppler effect

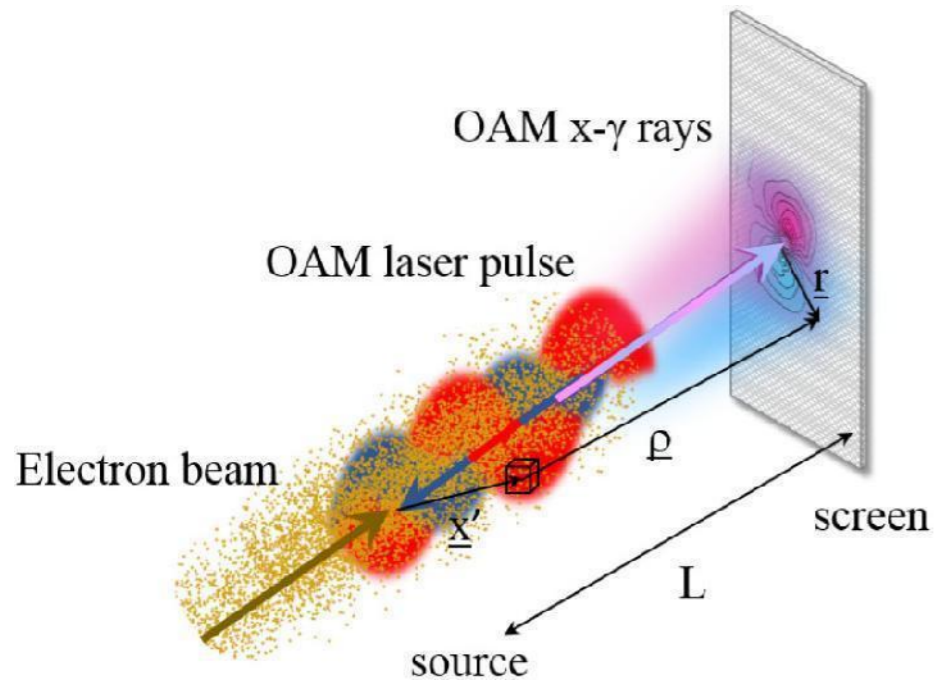


J. Courtial et al., PRL, 81.4828. (1998)

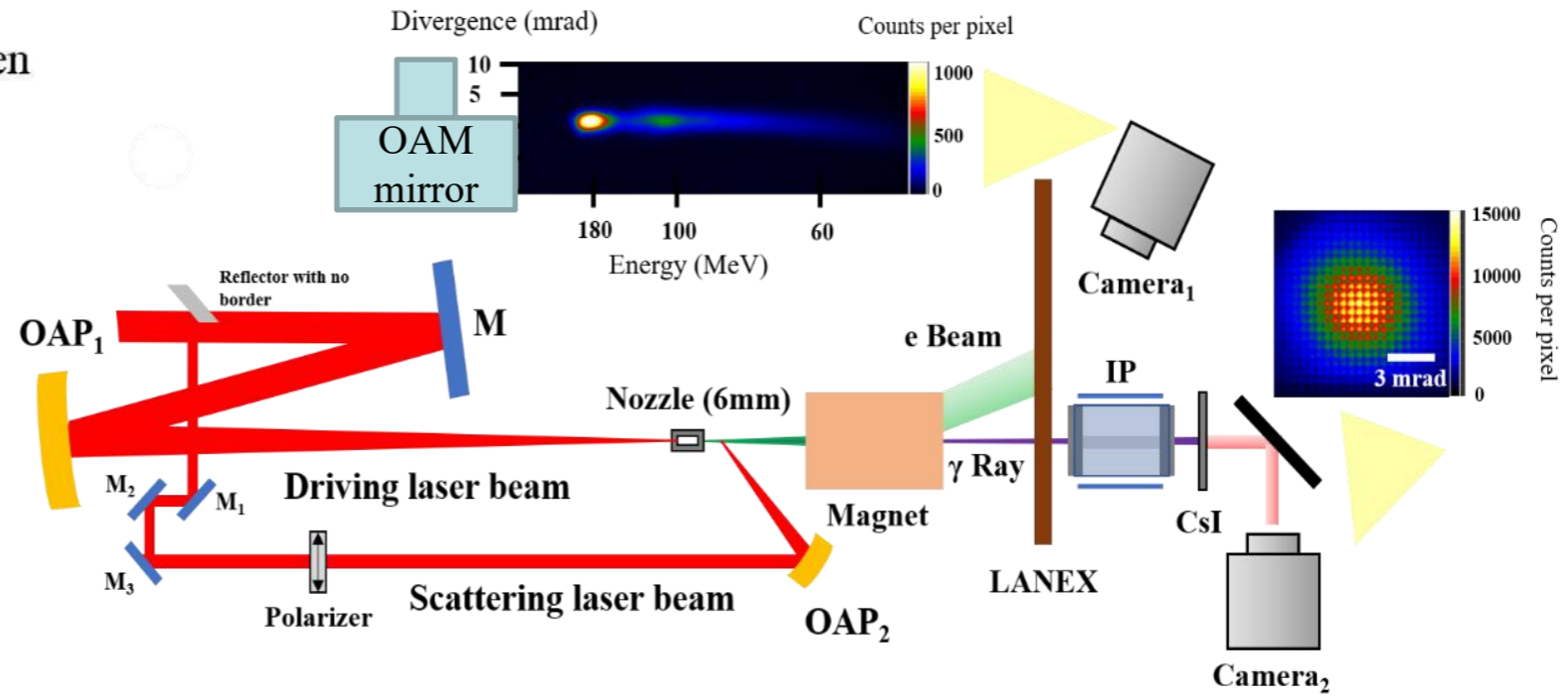
Transverse distributions of laser vector potential and phase

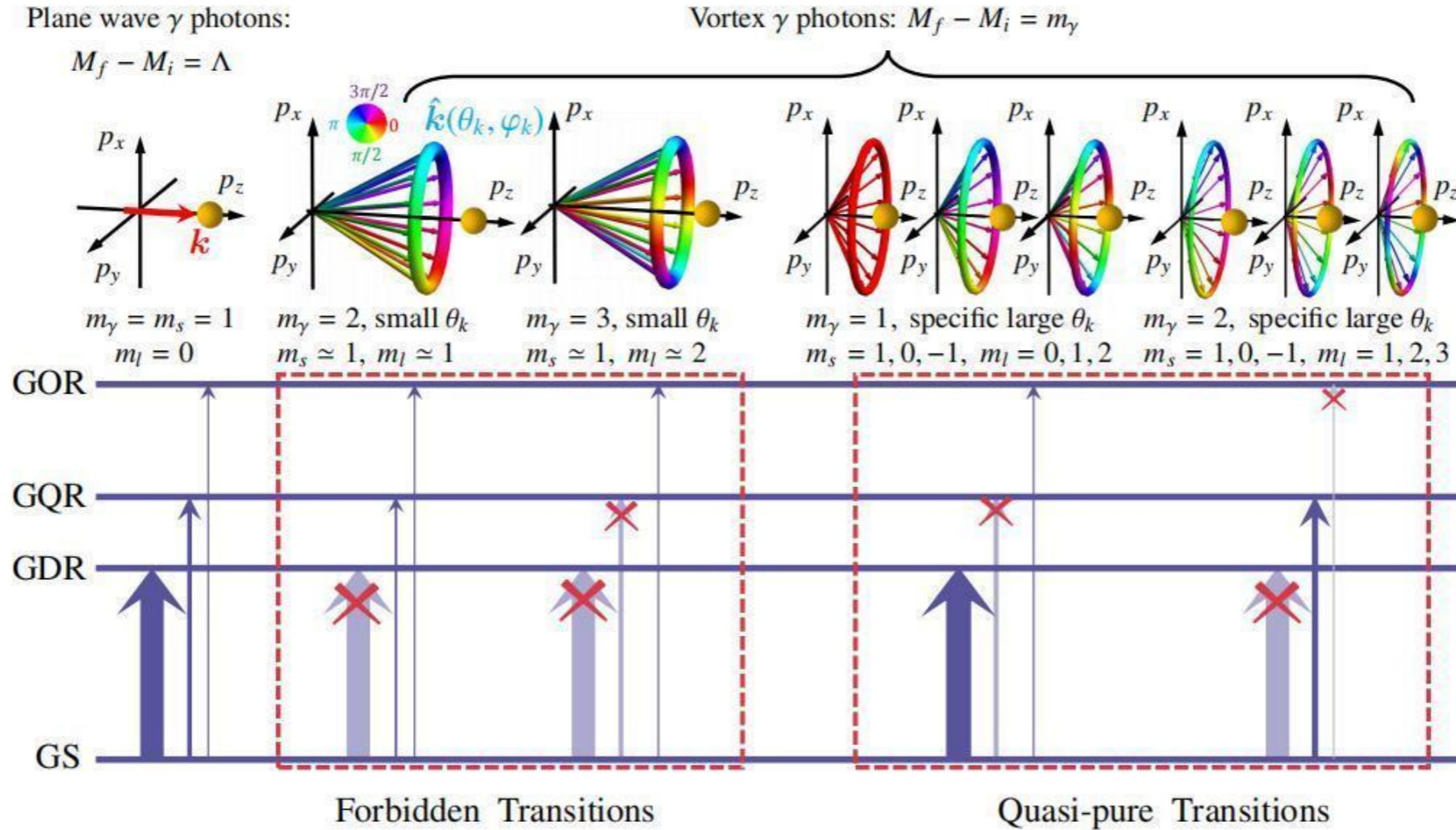


5、 Experiments of OAM TS X-rays



V. Petrillo et.al., PRL, 117, 123903. (2016)

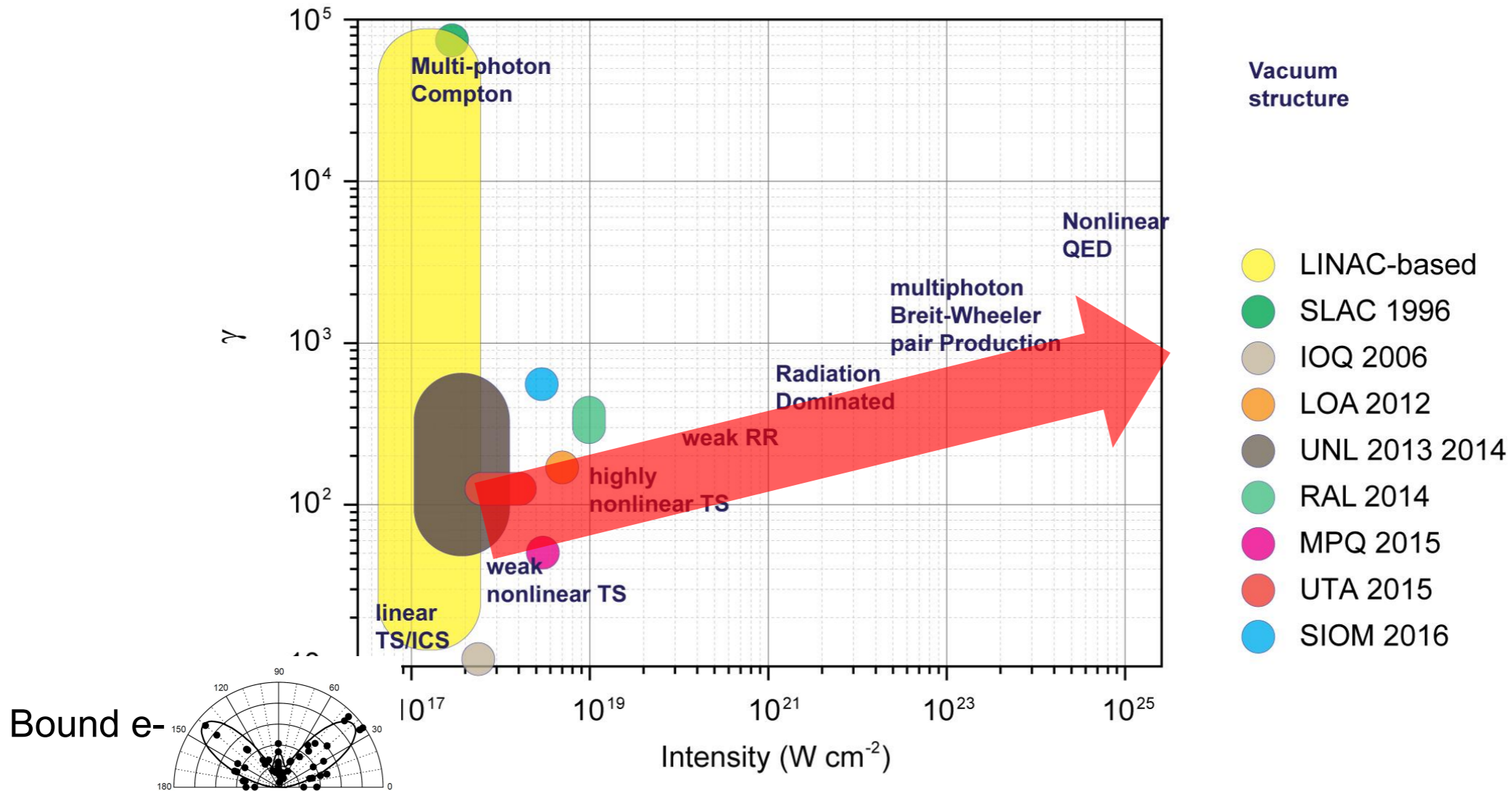




Towards strong field QED

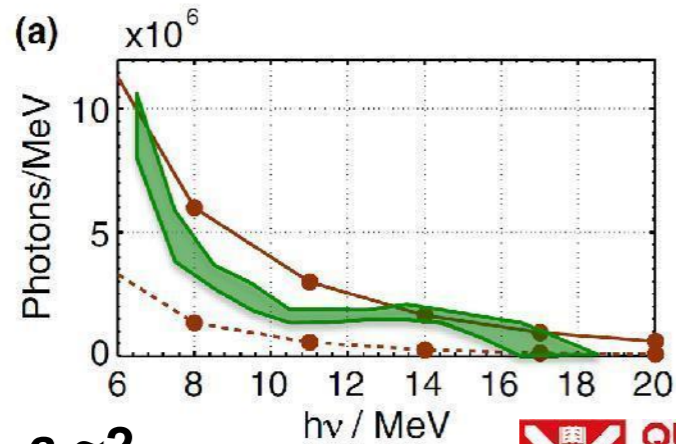
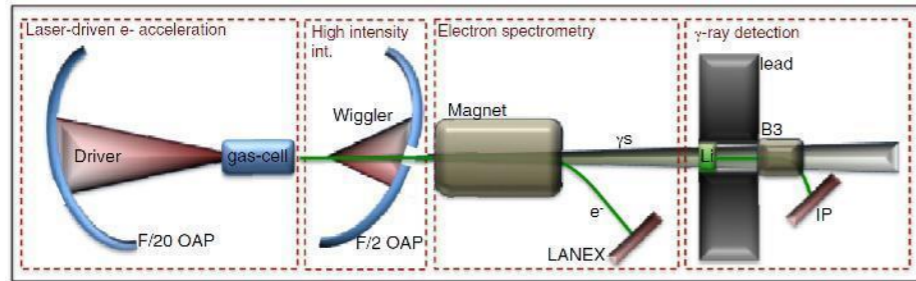
Electron-photon interaction

Controlling laser intensity a_0



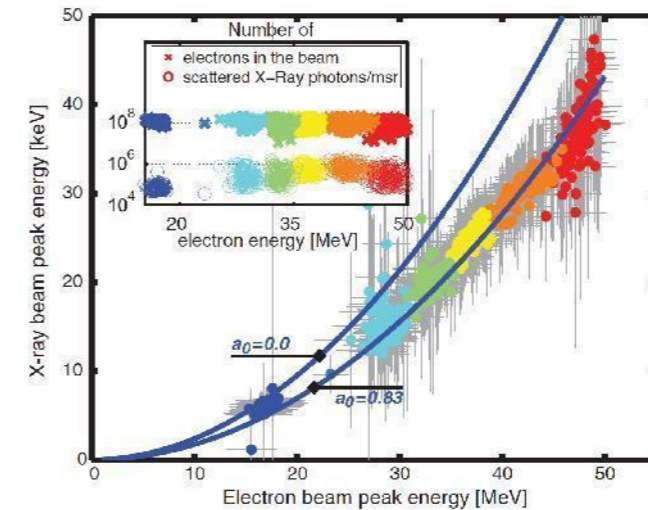
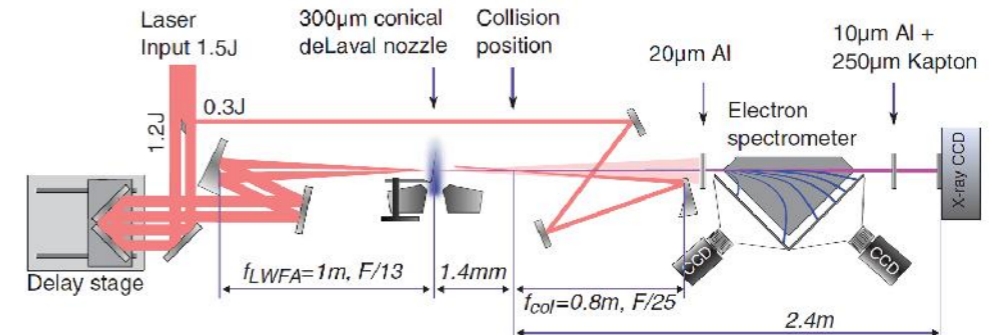
Towards strong field QED

Moderate Nonlinear regime



G. Sarri et al, PRL **113**, 224801 (2014)

Controlling laser intensity a_0



$a_0 \sim 0.83$

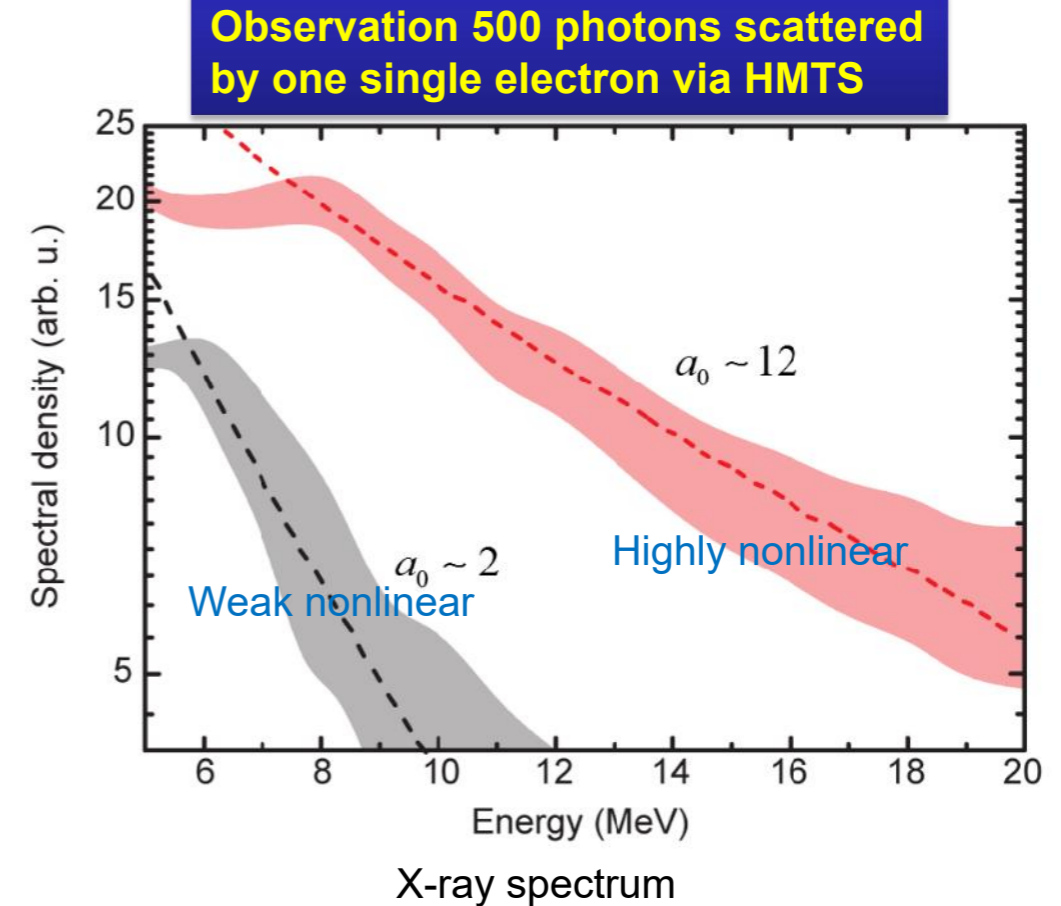
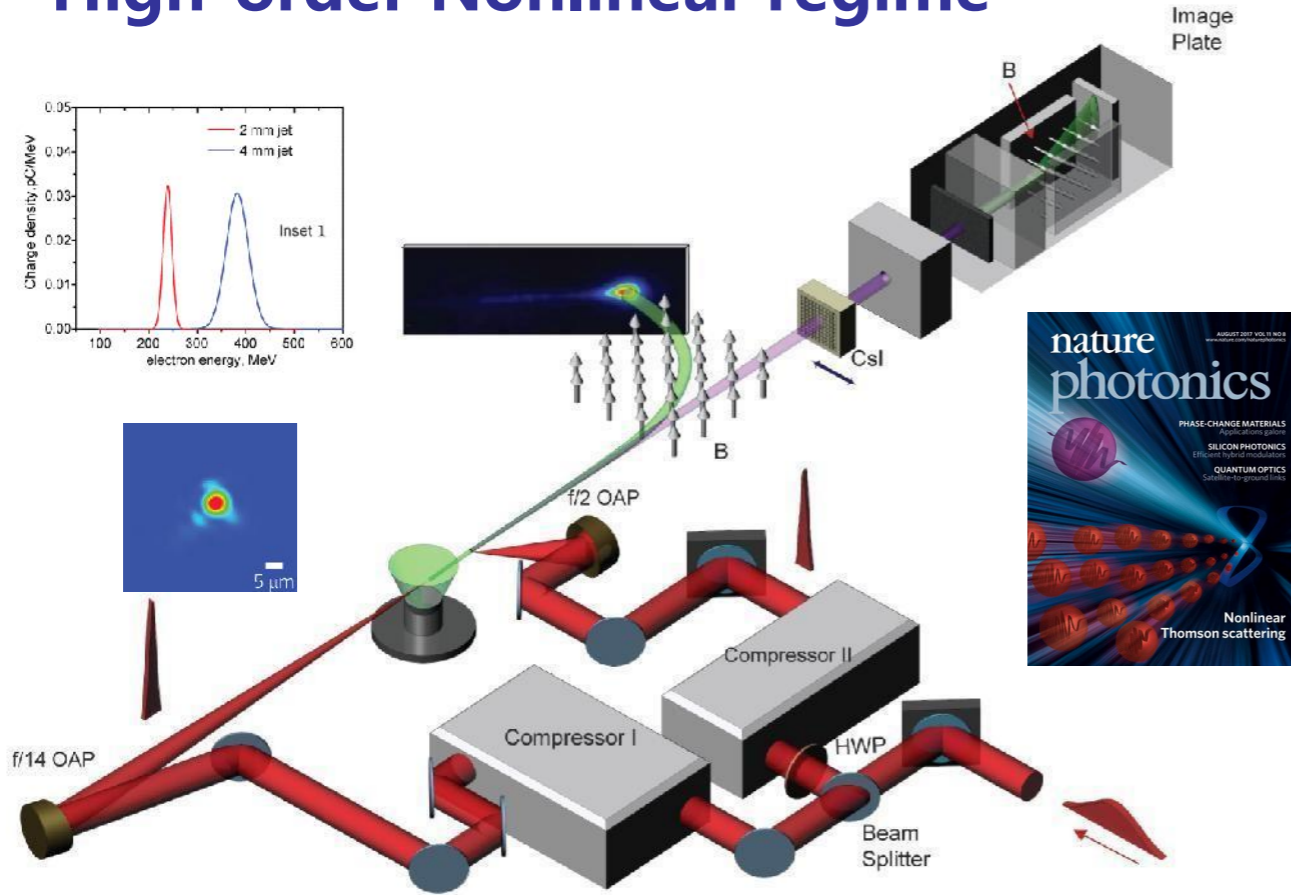


K. Khrennikov, et al, PRL **114**, 195003 (2015)

Controlling laser intensity a_0



High-order Nonlinear regime



Experimental parameters

Electron	200 MeV e^-
Scater	$a_0 : 1.5 \sim 12$

W. Yan et al, *Nature Photonics*, **11**, 514. (2017)
 S. Banerjee, et al, PRAB, (2012)
 G. Golovin, W. Yan, et al NIMA, 830 375-380 (2016)

- Electron oscillation in the P plane getting larger with increase a_0 .
- **Confirmed $a_0 \sim 12$**

Controlling laser intensity a0

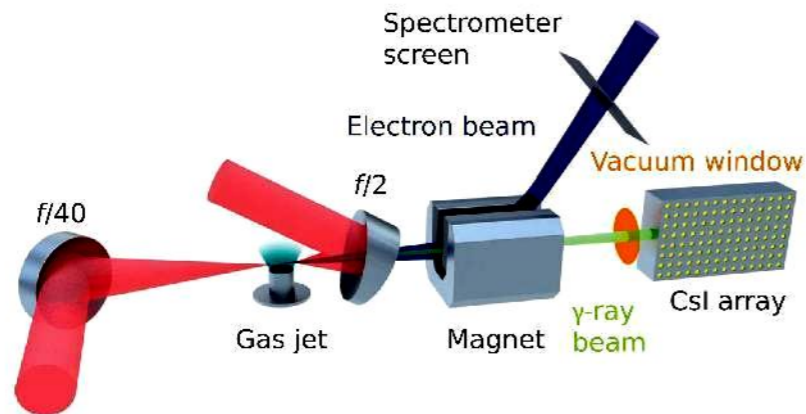
Radiation Reaction experiment

PHYSICAL REVIEW X **8**, 011020 (2018)

Featured in Physics

Experimental Evidence of Radiation Reaction in the Collision of a High-Intensity Laser Pulse with a Laser-Wakefield Accelerated Electron Beam

J. M. Cole,^{1,*} K. T. Behm,² E. Gerstmayr,¹ T. G. Blackburn,³ J. C. Wood,¹ C. D. Baird,⁴ M. J. Duff,⁵ C. Harvey,³ A. Ilderton,^{3,6} A. S. Joglekar,^{2,7} K. Krushelnick,² S. Kuschel,⁸ M. Marklund,³ P. McKenna,⁵ C. D. Murphy,⁴ K. Poder,¹ C. P. Ridgers,⁴ G. M. Samarin,⁹ G. Sarri,⁹ D. R. Symes,¹⁰ A. G. R. Thomas,^{2,11} J. Warwick,⁹ M. Zepf,^{8,9,12} Z. Najmudin,¹ and S. P. D. Mangles^{1,†}

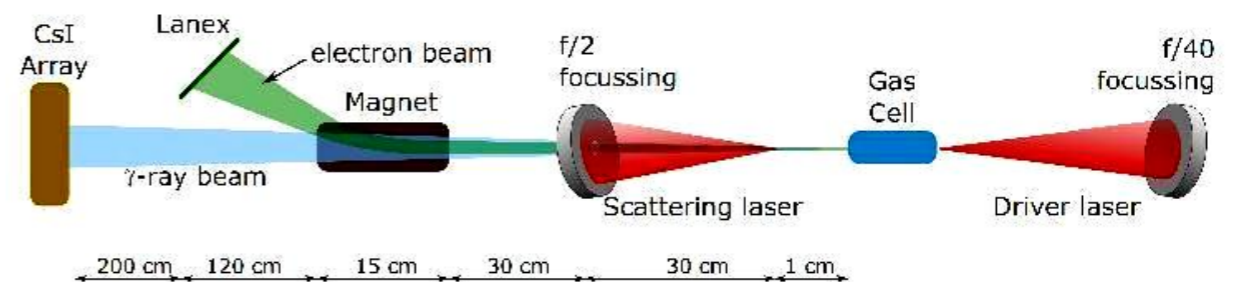


PHYSICAL REVIEW X **8**, 031004 (2018)

Experimental Signatures of the Quantum Nature of Radiation Reaction in the Field of an Ultraintense Laser

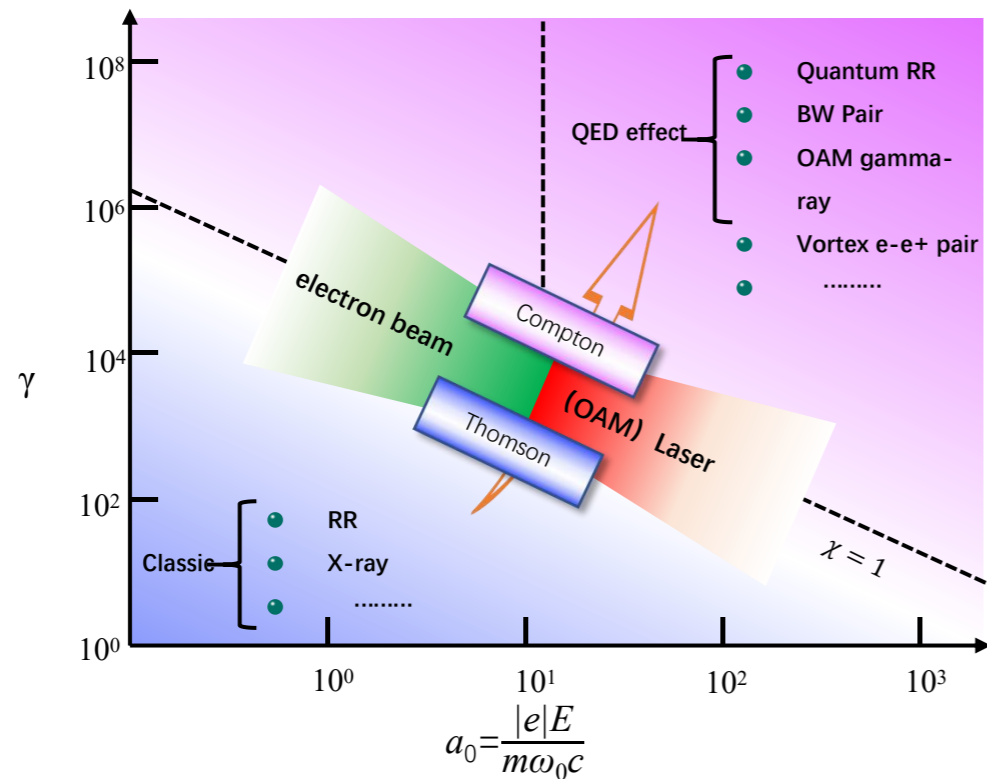
K. Poder,^{1,‡} M. Tamburini,² G. Sarri,^{3,*} A. Di Piazza,² S. Kuschel,^{4,5} C. D. Baird,⁶ K. Behm,⁷ S. Böhlen,⁸ J. M. Cole,¹ D. J. Corvan,³ M. Duff,⁹ E. Gerstmayr,¹ C. H. Keitel,² K. Krushelnick,⁷ S. P. D. Mangles,¹ P. McKenna,⁹ C. D. Murphy,⁶ Z. Najmudin,¹ C. P. Ridgers,⁶ G. M. Samarin,³ D. R. Symes,¹⁰ A. G. R. Thomas,^{7,11} J. Warwick,³ and M. Zepf³⁻⁵

¹The John Adams Institute for Accelerator Science, Blackett Laboratory, Imperial College London, London SW7 2AZ, United Kingdom
²Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg, Germany
³School of Mathematics and Physics, Queen's University Belfast, University Road, Belfast BT7 1NN, United Kingdom



QED exploration: from all-optical Thomson scattering to Compton scattering

National Key R&D Program of China Funded by MOST, China



0.5 PW SJTU



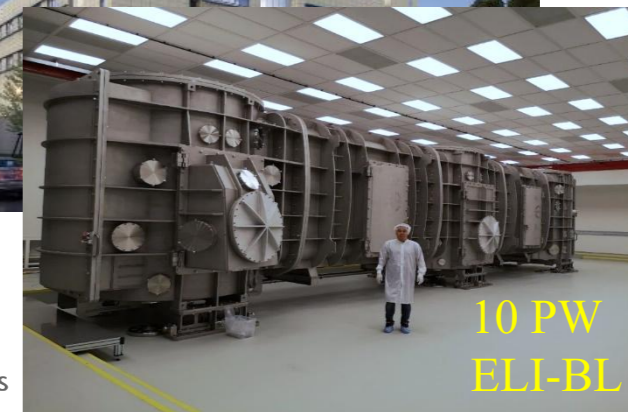
1 PW Beijing



2.5 PW
SJTU&TDLI



10 PW SULF



10 PW
ELI-BL



Aim at different a_0 & γ SF-QED regime



Wenchao Yan (PI)
Experiments



Y. Chen
Theory&Simu.



L. Yi
Theory&Simu.



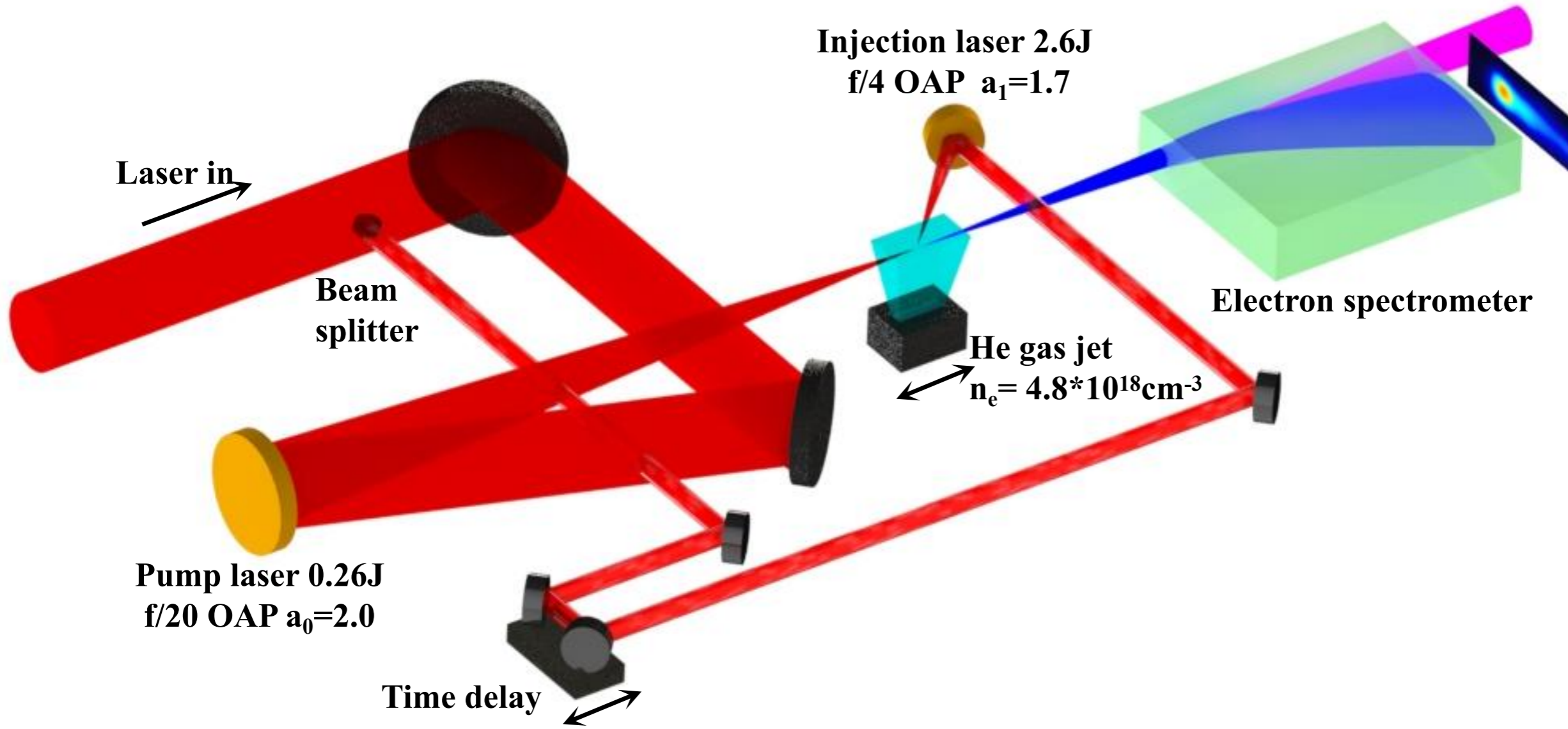
G. Liao
Diagnostics

Outline

- ❑ Motivation
- ❑ Ultrahigh field physics Experiments with dual pulse
 - All-optical Thomson/Compton scattering experiment
 - **Opitcal Injection**
- ❑ New facilities and future plans



Dark-current-free low energy spread



Outline

- ❑ Motivation
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 - Optical Injection
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LLP @SJTU



SIOM
(Fusion study & High field)



SULF 10PW
SEL 100PW



TDLI
2.5PW
Laboratory
Astrophysics

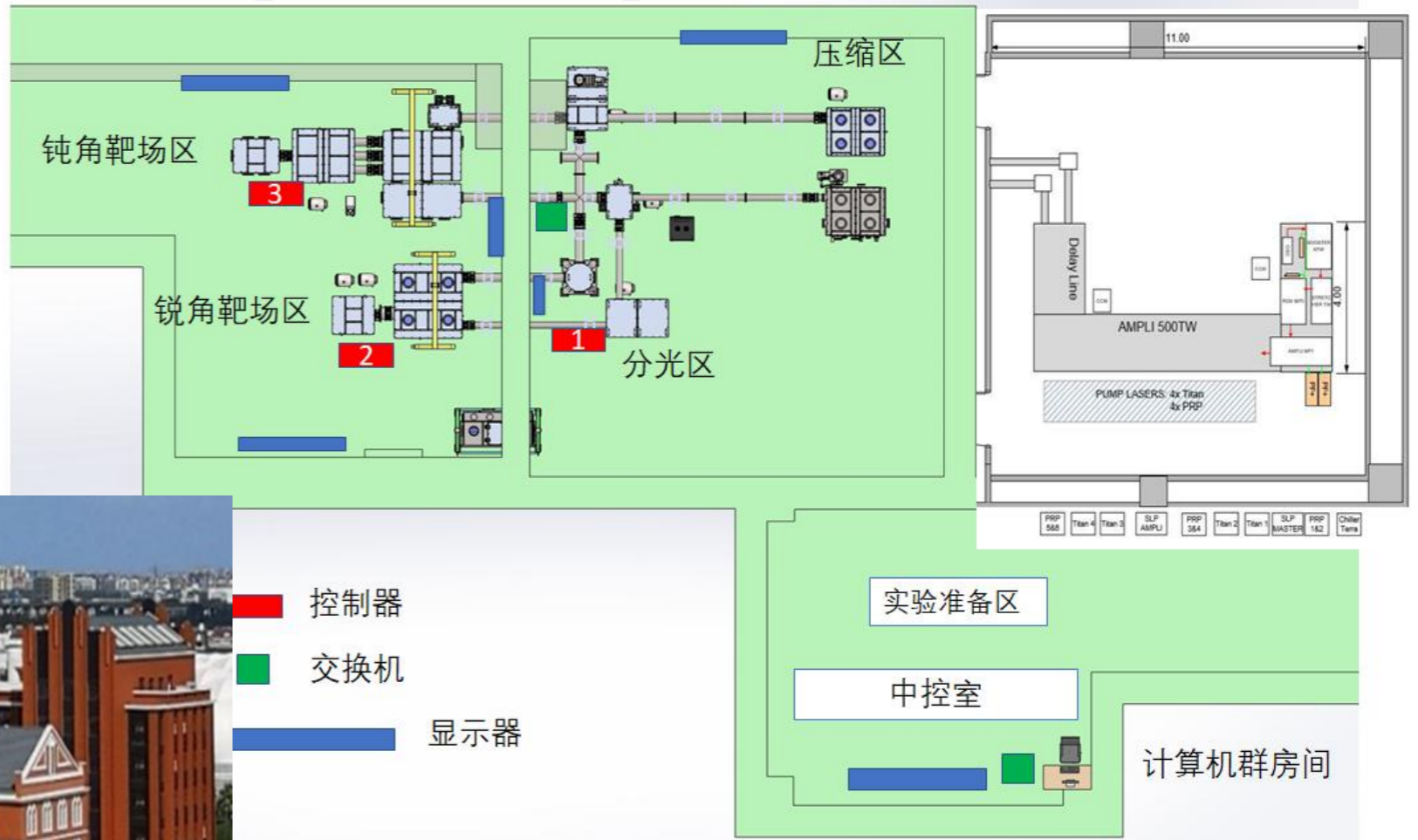
SJTU
(200TW+300TW)
acceleration & radiation
Laser technology



东校浜

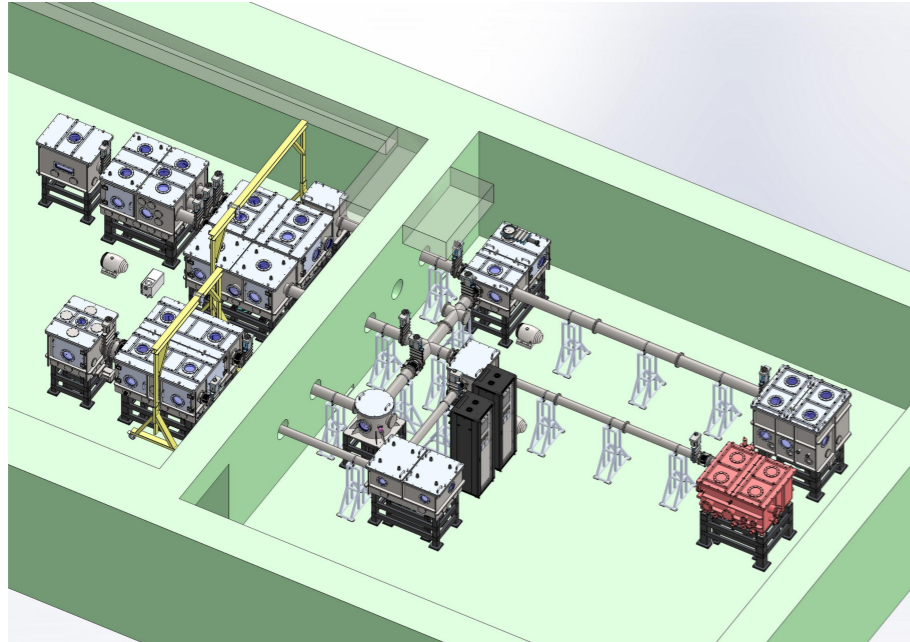
Facility (I) @SJTU Campus

New 200+300 TW experimental platform



Facility (I) @SJTU Campus

New 200+300 TW experimental platform



This platform will be commissioned around this November!

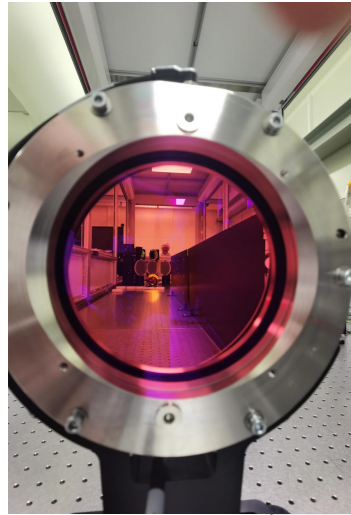
Facility (II) TDLI institute& SJTU

Lab-Astrophysics platform: QED, nuclear astrophysics etc

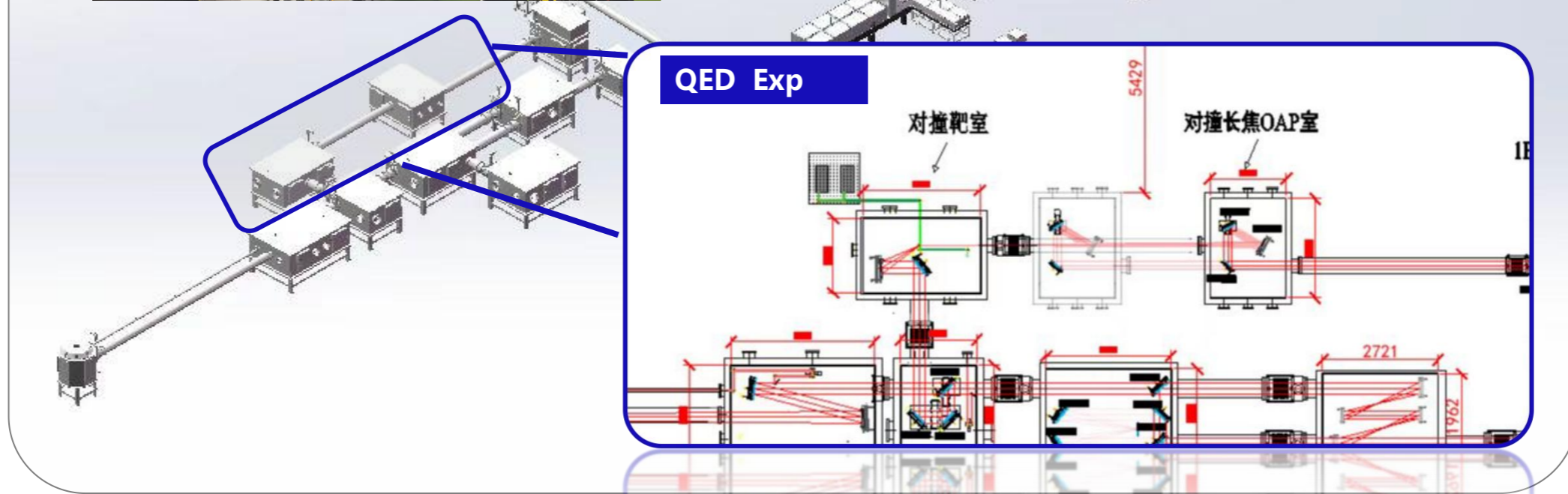
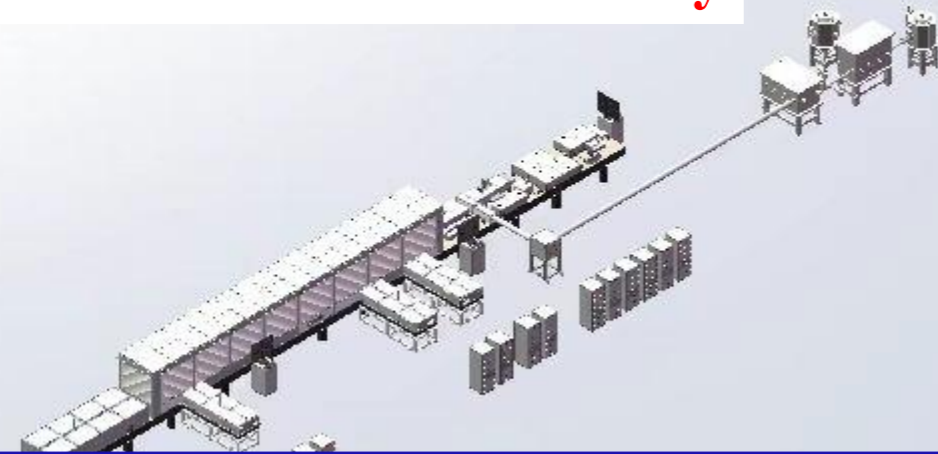


Facility (II) TDLI institute& SJTU

Lab-Astrophysics platform: QED, nuclear astrophysics etc



FAT was finished in this July

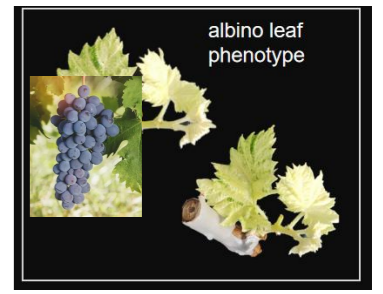
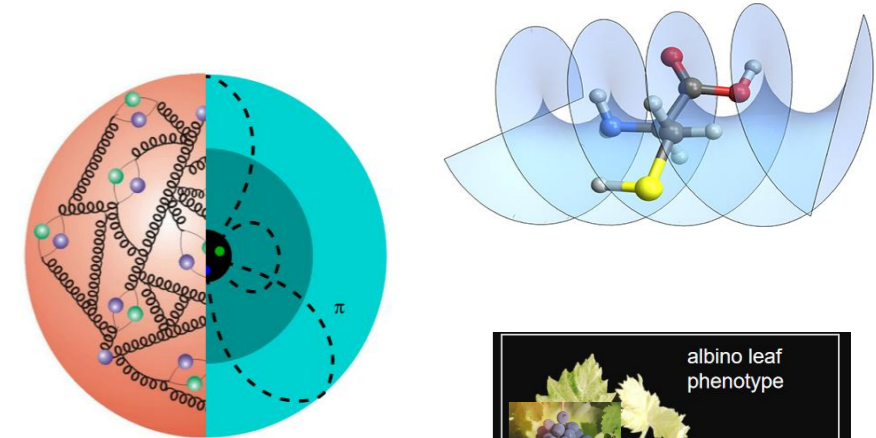


Summary



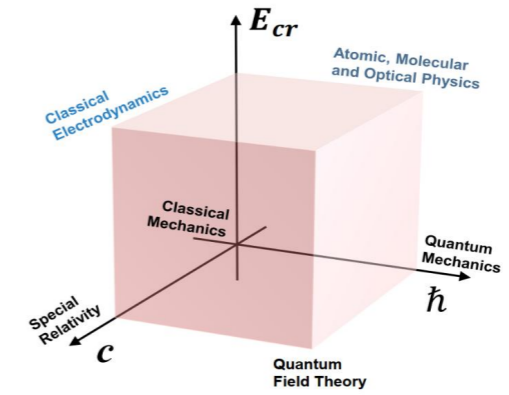
High-Energy Light Source

- **High brightness:** 10^{23}
- **Energy control:** e- energy, interact angle, wavelength λ
- **Conversion Efficiency improvement:** undulating period(pulse duration)
- **Angular momentum control:** spin(polarization) and orbital (Vortex)
- **Applications:** NDT, Nuclear physics, AMO, Medical, Agriculture
- **Coherence**



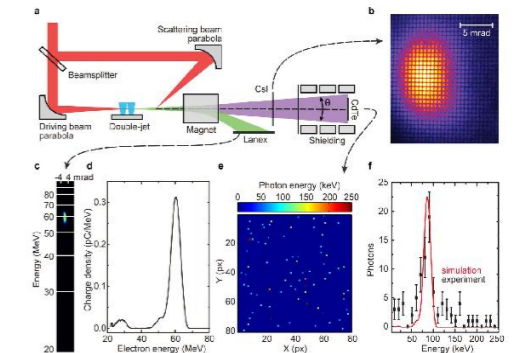
Extreme Strong field physic (QED)

- High-order Multi-Photon Thomson Scattering
- SF-QED effect: Radiation Reaction: HMP-TS(Classic)/CS(quantum)
- B-W Pair generation



Diagnosis on laser intensity LPI

- Laser parameter: intensity, S/OAM, Pol
- Electron: intrinsic property
- Laser-plasma intercation



**HIGH POWER
LASER** SCIENCE AND
ENGINEERING



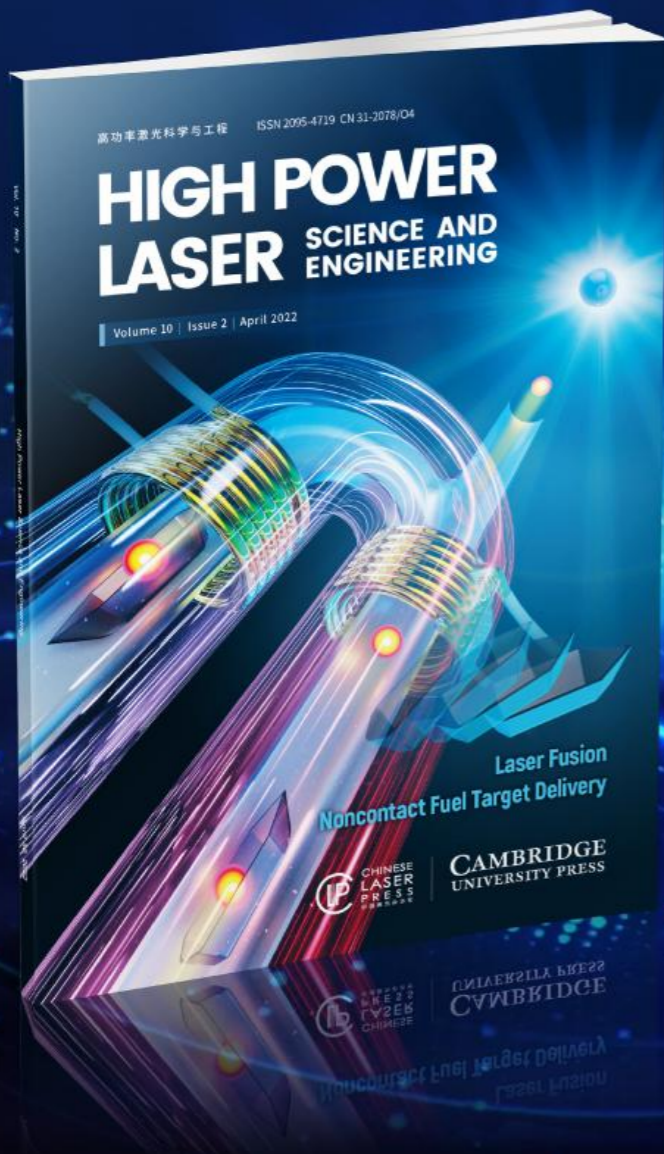
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LATEST IF

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JCR Q1

21/100 in Optics

First tier in CAS Journal Ranking

TOPICS

Laser technology | Laser facility |

Laser interactions | Secondary source generation



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Postdoc Positions Opening:
LWFA&Rad, QED, Laser-driven nuclear
Physics.

上海交通大学

Prof. Wenchao Yan
Shanghai Jiao Tong University
E-mail: wenchaoyan@sjtu.edu.cn

