Photon beams at SPring-8-II

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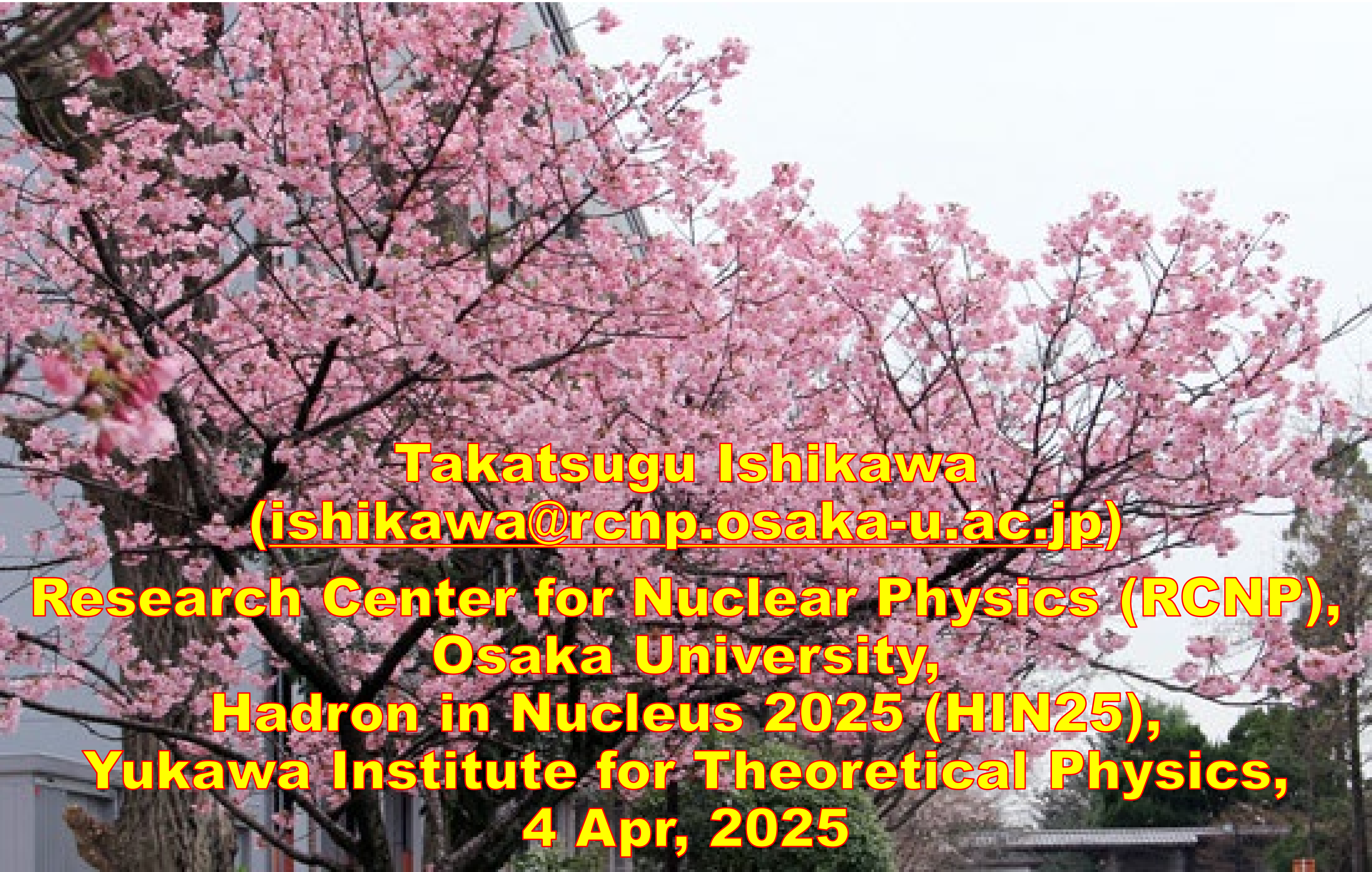

Takatsugu Ishikawa
(ishikawa@rcnp.osaka-u.ac.jp)
Research Center for Nuclear Physics (RCNP),
Osaka University,
Hadron in Nucleus 2025 (HIN25),
Yukawa Institute for Theoretical Physics,
4 Apr, 2025

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- Photon beams at SPring-8
- SPring-8-II upgrade
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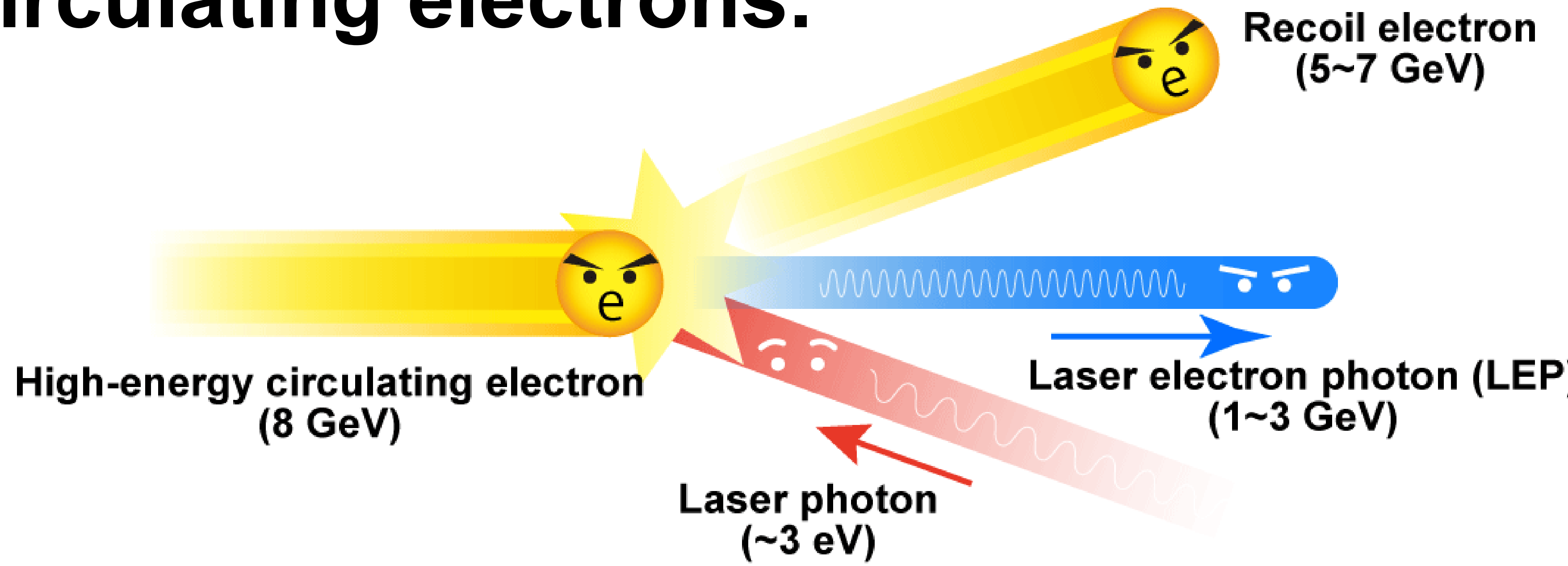
T. Ishikawa

Photon beams at SPring-8

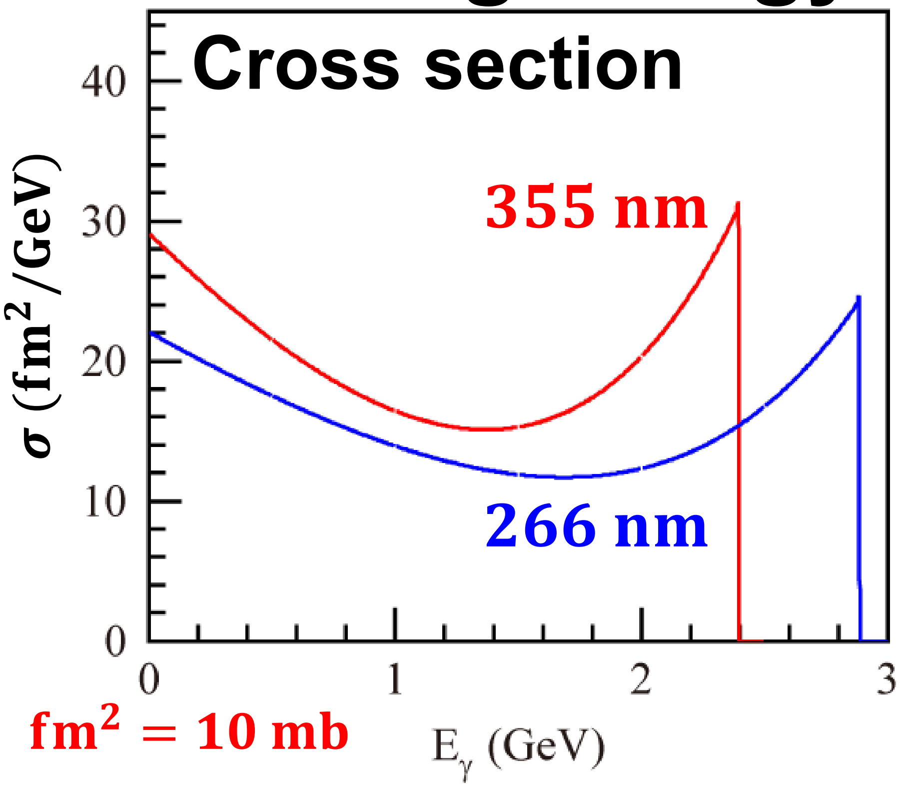
Photon beams at SPring-8

We use **the laser electron photon (LEP) beam**, which is generated by Compton scattering from laser photons and 8-GeV circulating electrons.

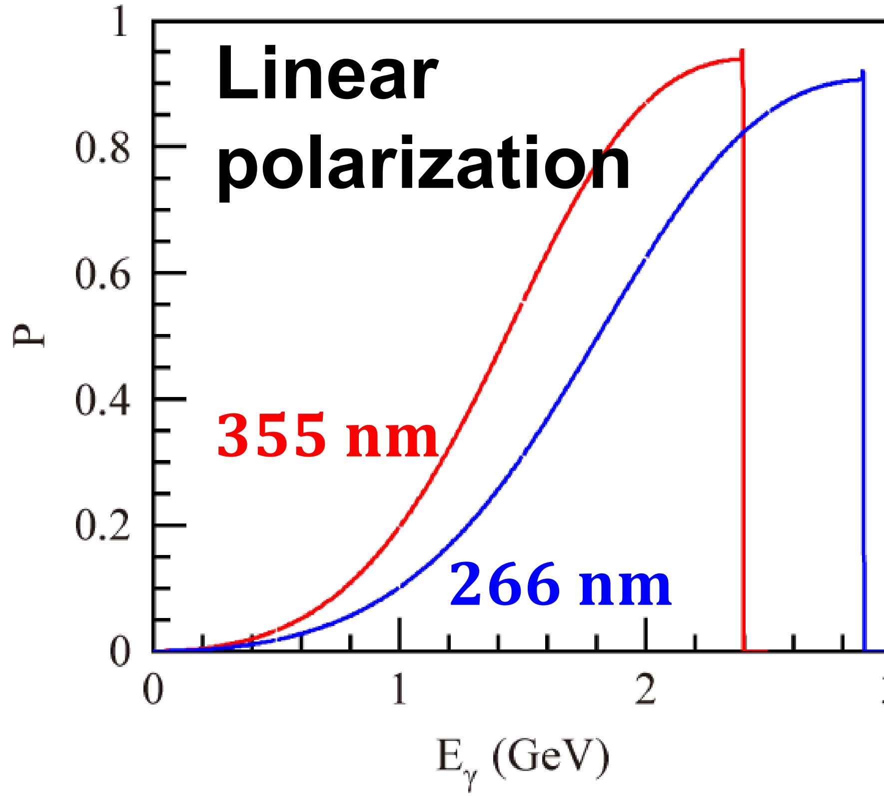


Photon beams at SPring-8

Circulating energy 7.96 GeV



$\text{fm}^2 = 10\ \text{mb}$



Maximum

2.40 GeV, 94% for 355 nm

2.88 GeV, 91% for 266 nm

Photon beams at SPring-8

Continuous wave (CW) lasers
→Pulse lasers
Laser emission is synchronized to the electron bunch structure (508. 58 MHz)

Photon beams at SPring-8

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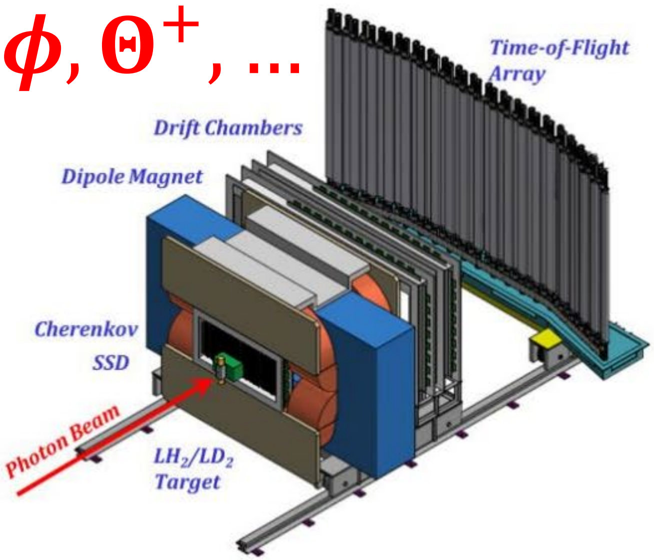
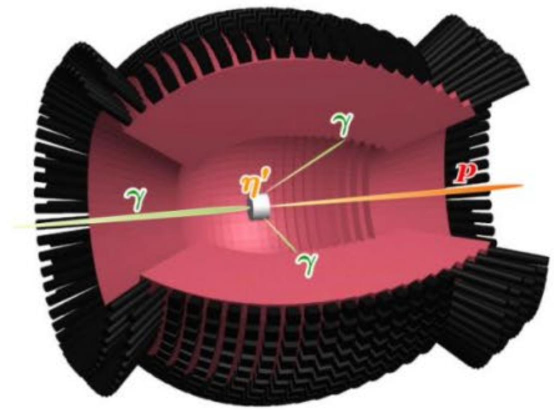
$\phi, \Theta^+, \ldots$



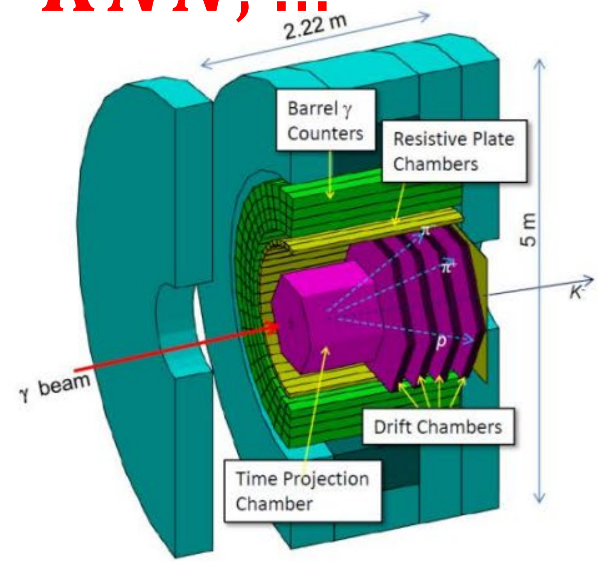
LEPS spectrometer

$\eta', f_0(980), \ldots$



BGOegg calorimeter

$\bar{K}NN, \ldots$



Solenoid spectrometer

LEPS from 2000 to 2020

- **Forward dipole spectrometer**

LEPS2 from 2014

- **BGOegg calorimeter**
- **Solenoid spectrometer**

SPring-8-II upgrade

SPring-8-II upgrade

From SPring-8 to SPring-8-II

More than 25 years have passed since SPring-8 was put into service in 1997.

SPring-8-II will be constructed as the world's most advanced synchrotron facility, having 100 times the brightness of the synchrotron radiation at SPring-8.

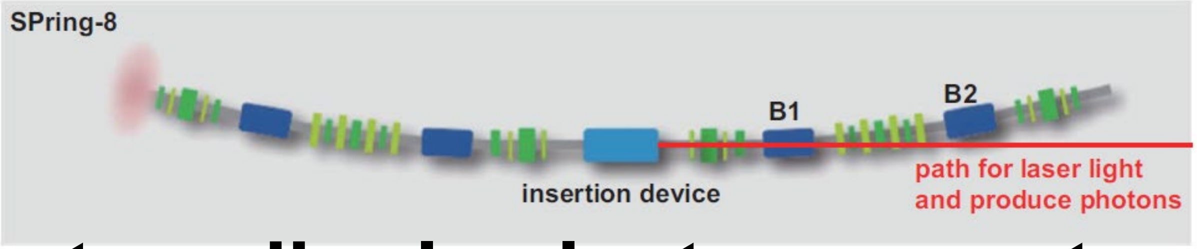
Construction works with a long shutdown period are expected to start from the middle of 2027.

SPring-8-II upgrade

Major changes

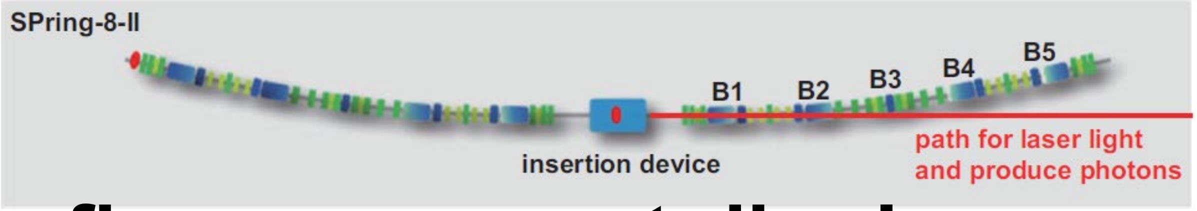
1) Circulating energies from 8 to 6 GeV

2) Replacement of bending magnets



Weaker bending power

two dipole electromagnets



five permanent dipole magnets

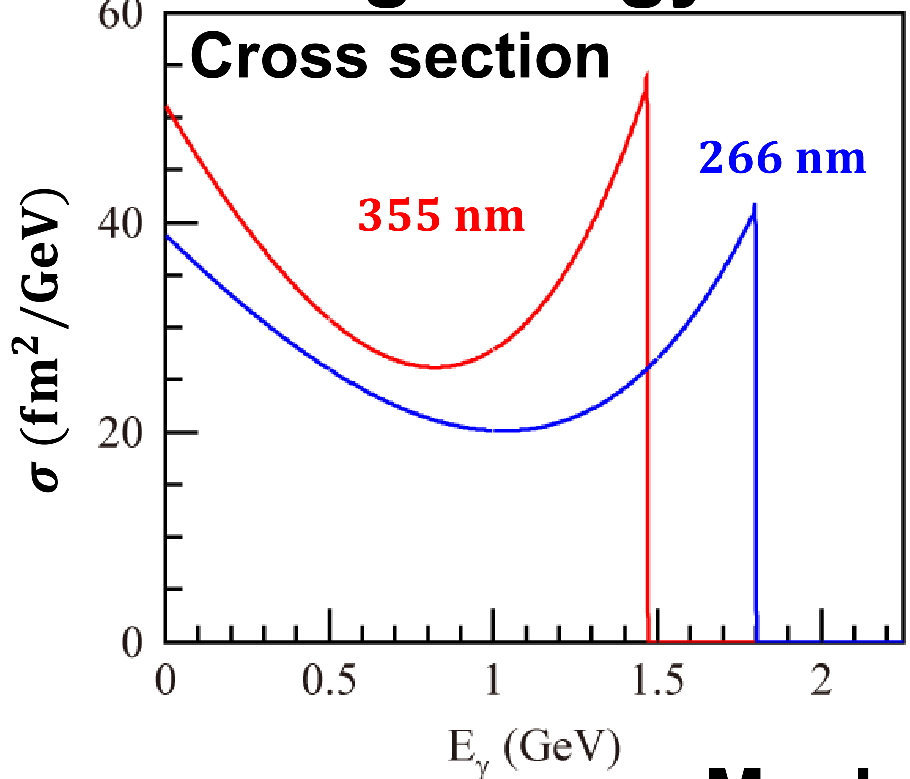
3) Introduction of a dumping wiggler

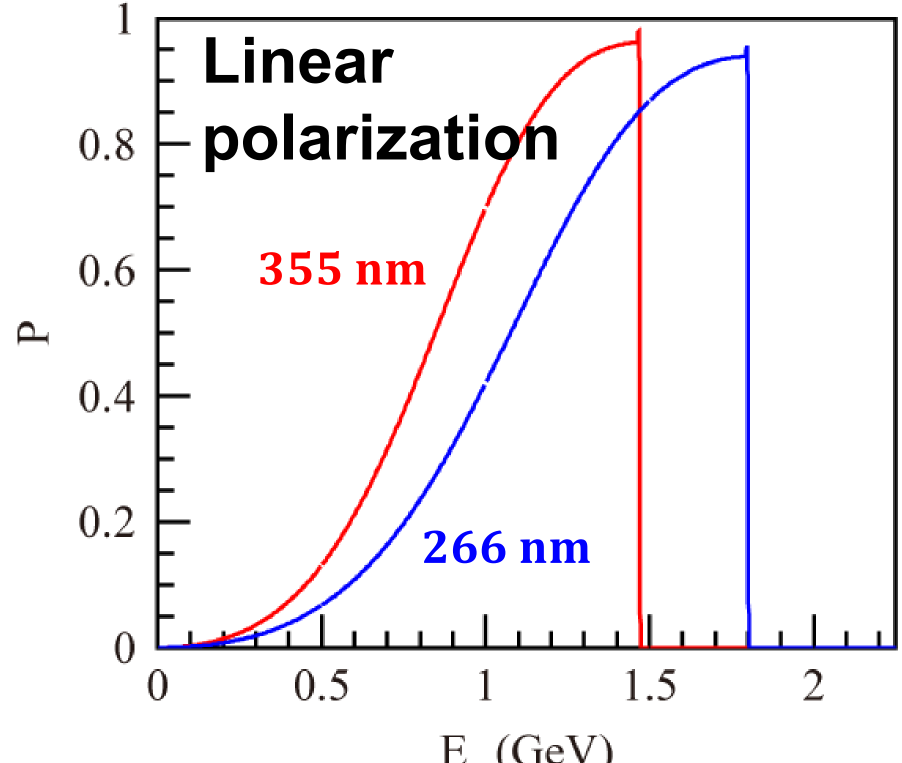
Much shorter straight section

Expected photon beams

Photon beams at SPring-8-II

Circulating energy 6.00 GeV





Much higher polarization can be obtained than bremsstrahlung

Maximum

1.47 GeV, 96% for 355 nm

1.80 GeV, 94% for 266 nm

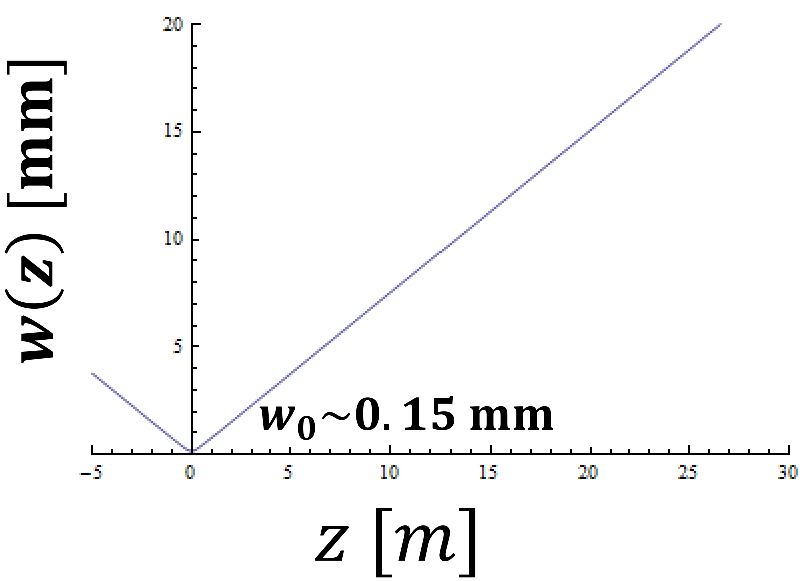
Intensity @ SPring-8-II

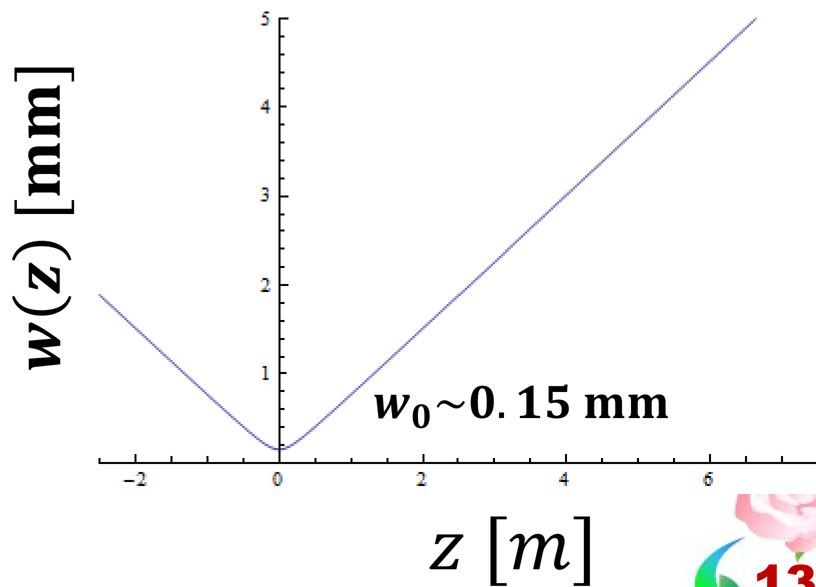
Laser focus

Distance of the collision point from a laser: 31.5 m

$$w(z) = w_0 \left\{ 1 + \left(\frac{\lambda z}{\pi w_0^2} \right)^2 \right\}^{1/2}$$

SPring-8





Laser focus

Distance of the collision point from a laser: 31.5 m

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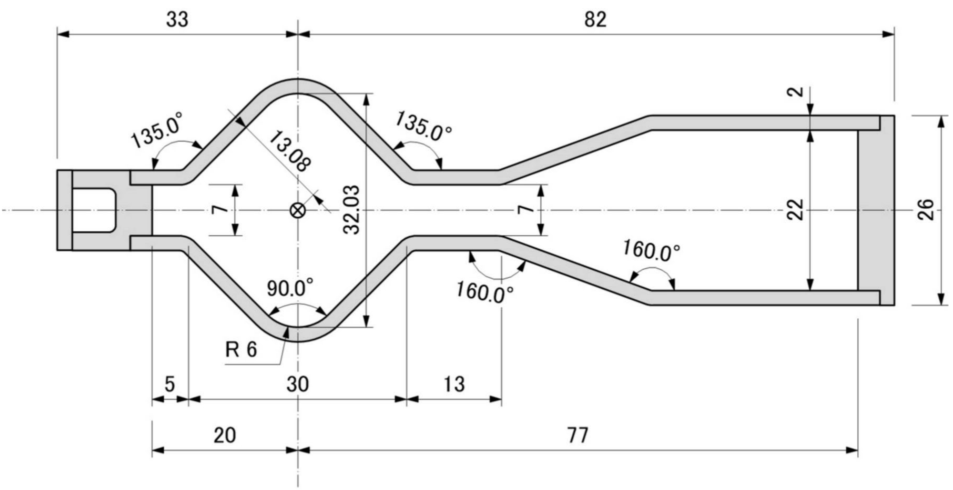
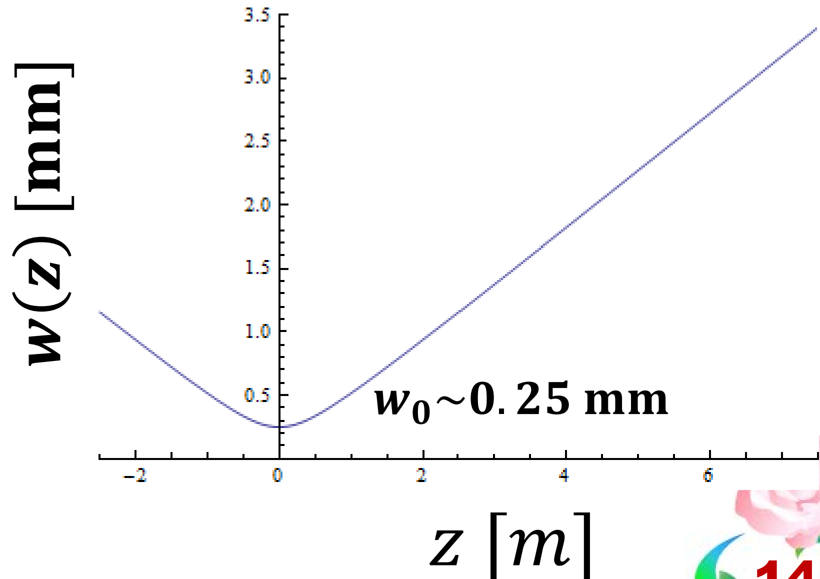
SPring-8-II





Synchrotron JSR JOURNAL OF SYNCHROTRON RADIATION
Tanaka *et al.*
Volume 31 | Part 6 | Novemeber 2024 | Pages 1420–1437 | 10.11107/S1600577524008348

Intensity @ SPring-8-II

Luminosity of laser-electron collisions

Electron beam   Laser

	σ_E (mm)	σ_L (mm)	$\mathcal{L}$
SPring-8	~0.34, ~0.01	~0.15	2.849
SPring-8-II	~0.027, ~0.006	~0.25	2.531

Beam size at ID, SPring-8-II Conceptual Design Report, 2014

1) Similar luminosity can be obtained,
2) Cross sections of Compton scattering increases by a factor of ~1.6

Tagging @ SPring-8-II

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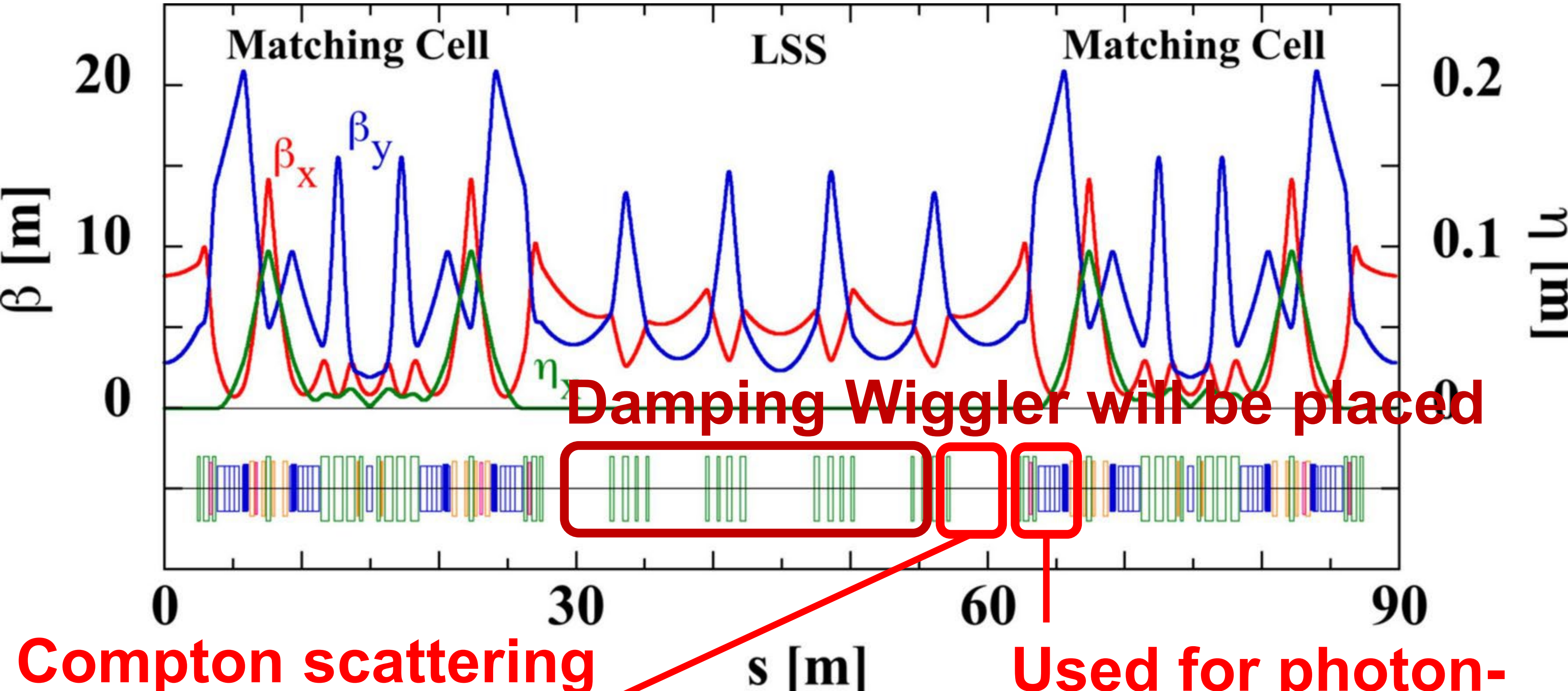
Current optics @ the long straight section



Damping Wiggler will be placed

Compton scattering region (controlled by pulse lasers with an interval of 10 mm)

Used for photon-tagging system

H. Tanaka, *et al.*, J. Of Sync. Rad., 31, 1420 (2024).

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Tagging @ SPring-8-II

Displacement of the scattered electron orbit

E_γ [GeV]	**@ tagger** (mm)
1.5	22.7
2.4	42.4
3.0	59.5

Decrease of the bending power

~40 MeV / mm (SPring-8)

E_γ [GeV]	**@ BM exit** (mm)	**@ 1.5 m** (mm)
0.5	3.3	7.0
1.0	7.1	15.3
2.0	17.8	38.1

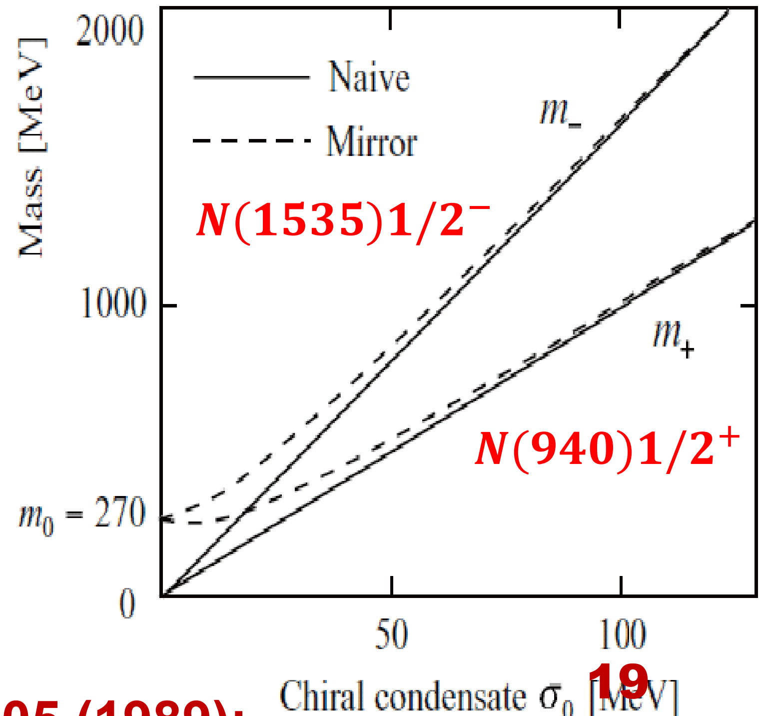
~100 MeV / mm (SPring-8-II)

Possible experiments

Chiral partner

The **chiral partner** of a hadron exists with the same mass and same quantum numbers except for the parity if chiral symmetry is not breaking or $\bar{q}q$ condensate is absent.

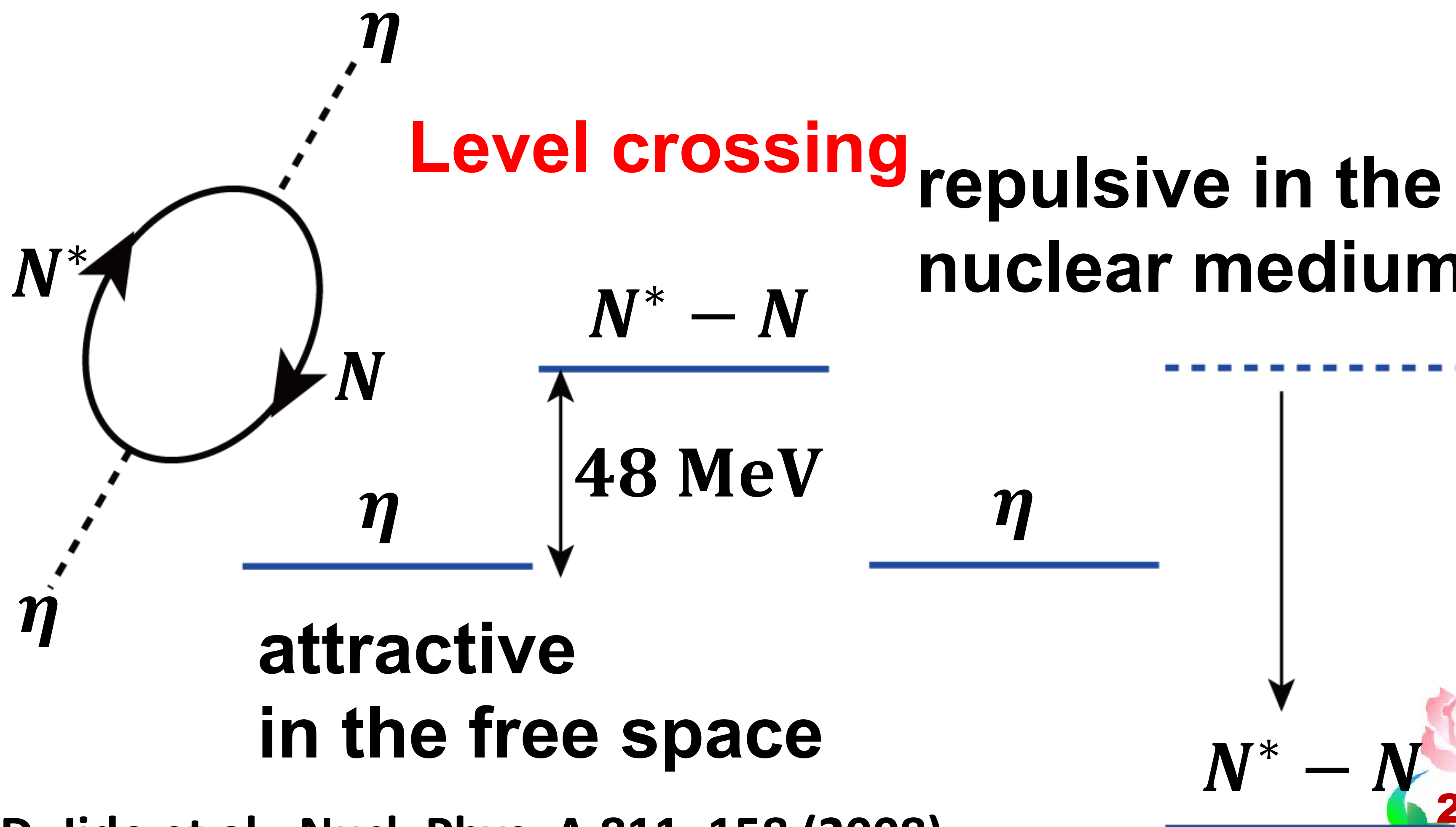
$N(1535)1/2^{-}$ is speculated to be the chiral partner of the nucleon



C. DeTar and T. Kunihiro, Phys. Rev. D 39, 2805 (1989);
T. Hatsuda and M. Prakash, Phys. Lett. B 224, 11 (1989);

η-mesic nucleus

$N^* \equiv N(1535)1/2^-$ strongly couples to ηN



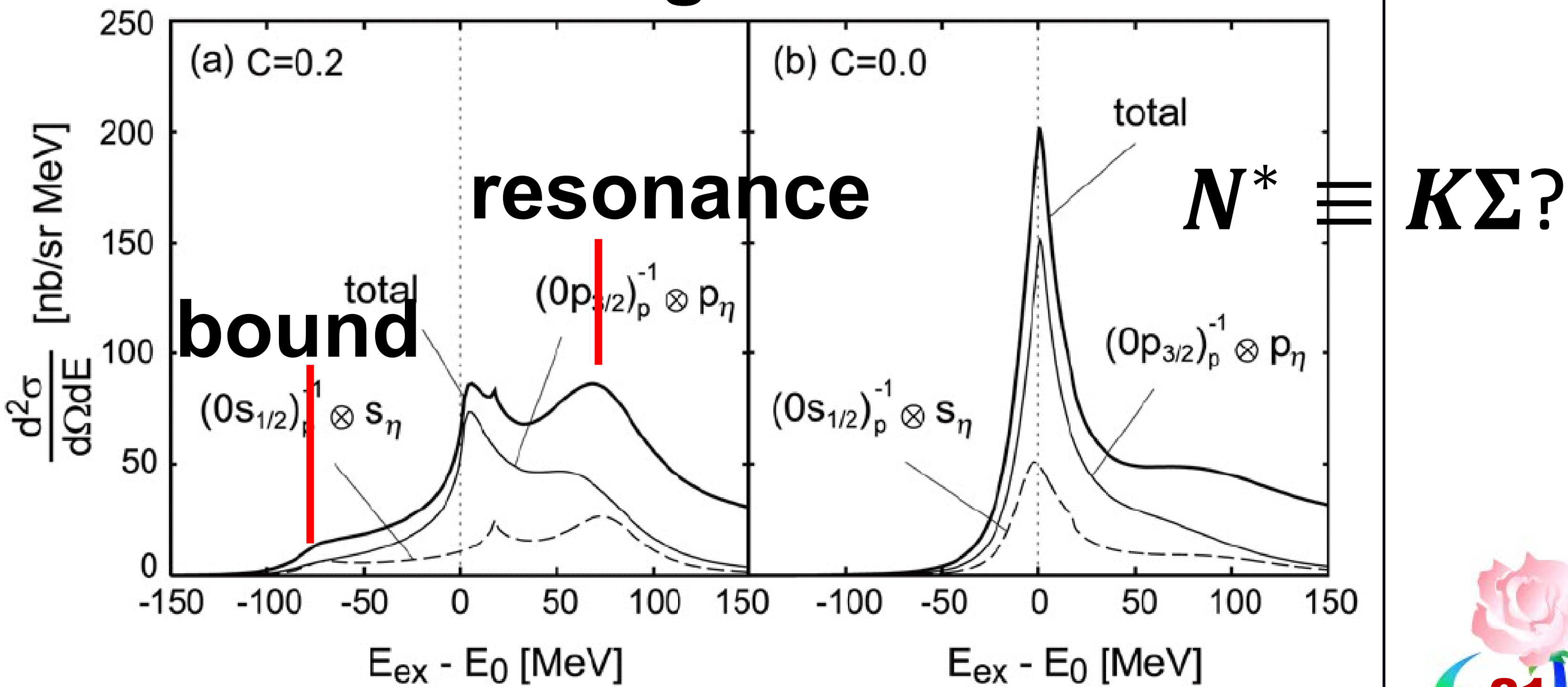
D. Jido et al., Nucl. Phys. A 811, 158 (2008);
H. Nagahiro et al., Phys. Rev. C 80, 025205 (2009).

η-mesic nucleus

Excitation spectra for $\gamma^{12}\mathrm{C} \to pX$

$$E_{\mathrm{ex}} = M_X - M_\eta - M_{^{11}\mathrm{B}}$$

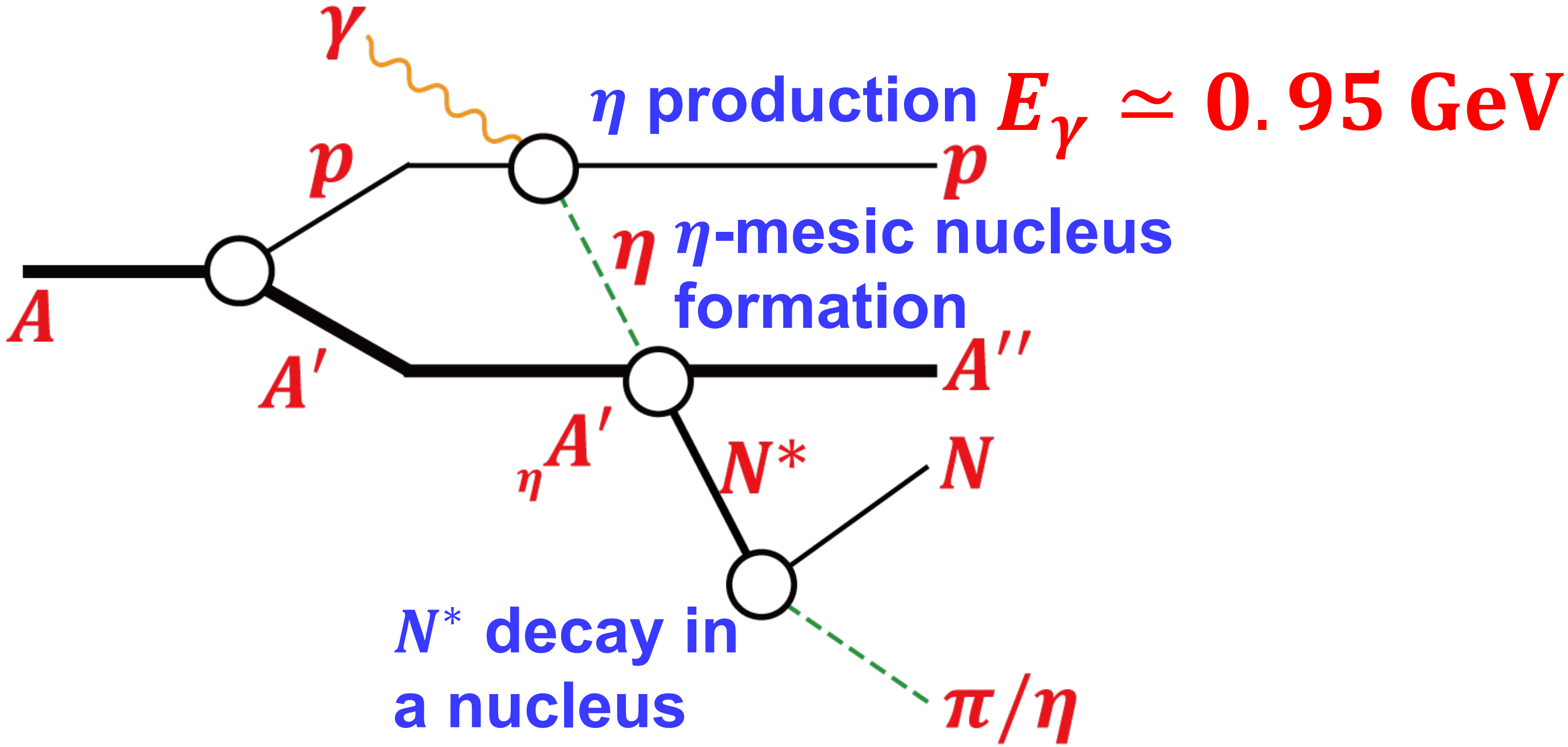
with level crossing **without level crossing**



H. Nagahiro et al., Nucl. Phys. A 761, 92 (2005);
D. Jido et al., Nucl. Phys. A 811, 158 (2008).

η-mesic nucleus

Elementary process for producing η-mesic nucleus: $\gamma p \rightarrow p\eta$



No experiment has been conducted with simultaneous identification of production and decay processes

Summary

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Summary

SPring-8 has been upgraded to SPring-8-II

Expected photon beams as SPring-8-II:

↓ maximum energies

↑ intensities

Distinct experiments can be conducted at the new photon beamline in SPring-8-II

Backup

SPring-8-II upgrade

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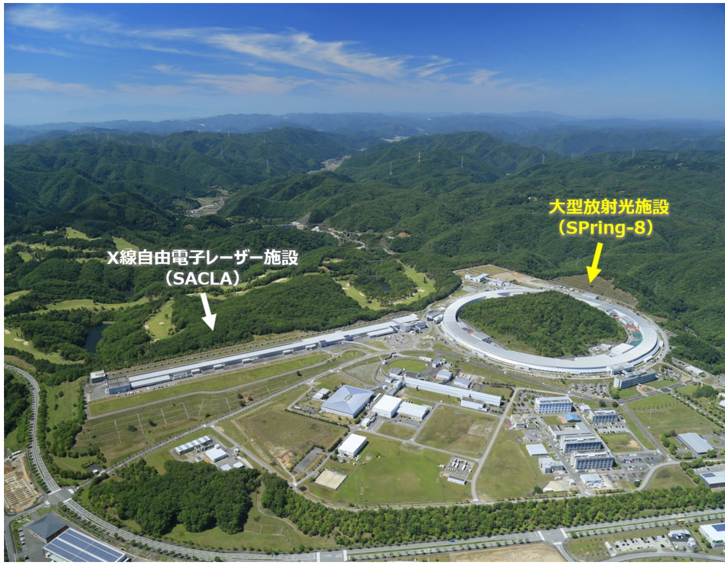
Major modification



Injector from a combined system of the 1-GeV linac and 8-GeV booster ring to an 8 GeV linac in the XFEL facility, SACLA **[already performed]**

Cell structure in the storage ring for **reducing the power consumption** to 60% of the current level, and **decreasing the emittance of the electron beam**

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4 Apr. 2025

Photon beams at SPring-8-II

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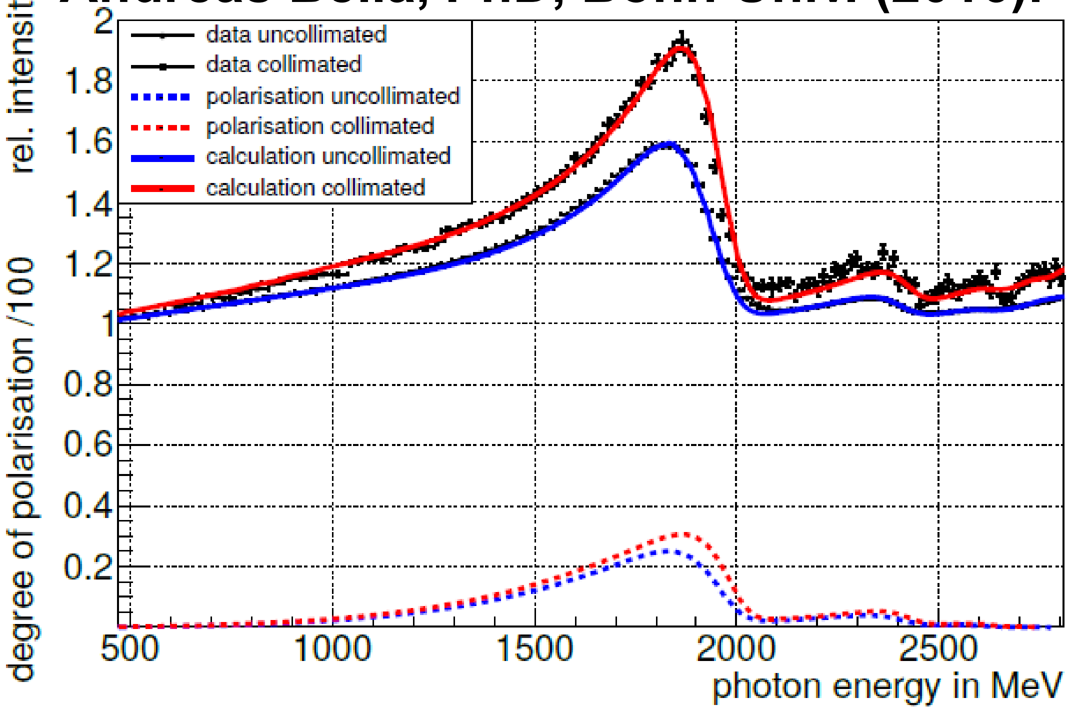
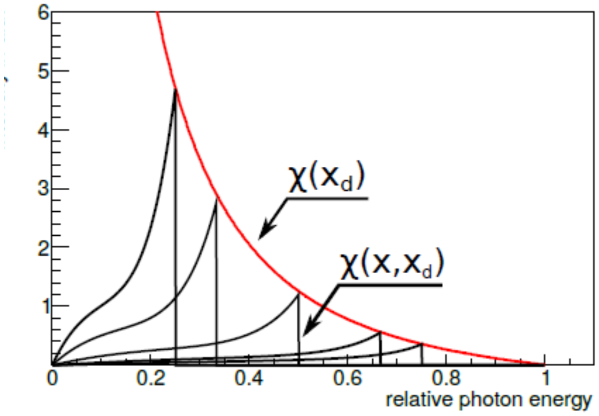
Usage of 355-nm lasers
Photon energy 1.47 GeV (max)
Linear polarization 96% (max)

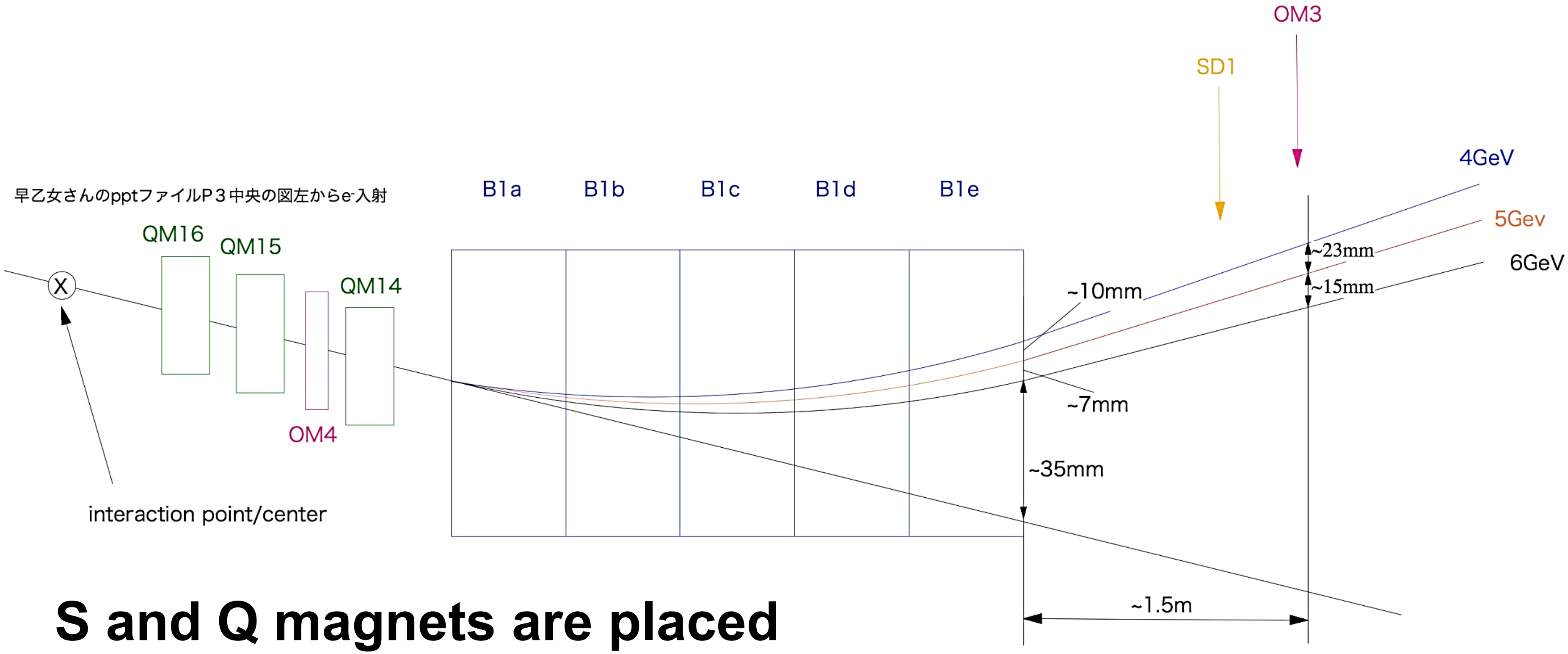
Andreas Bella, PhD, Bonn Univ. (2016).



Coverage of photon-energies overlaps with that at ELSA/Bonn



Decrease of the bending power



S and Q magnets are placed between B magnets

K. Soutome, private comm.

Distinct experiments

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Many nucleon target experiments with measurement of polarization observables have been conducted so far.

Photon beams provided at SPring-8-II have unique features:

- **high linear (circular) polarization**
- **high directionality**

Distinct experiments to be conducted:

- **high linear (circular) polarization**
- **measurement of final-state protons**
- **identification of final-state nuclei**

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Distinct experiments at SPring-8-II

Photoproduction of vector mesons on the nucleon

Two spin-parity states: $1/2^-$ and $3/2^-$

For separation

1. circular polarization photon + polarized nucleon target
   development of the HD target [terminated]
2. circular polarization photon + measurement of polarization of the final-state nucleon
   necessary to develop a double scattering method

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η-mesic nuclei