PSI Center for Photon Science

SwissFEL -Photonics Technologies for Advanced Light Sources

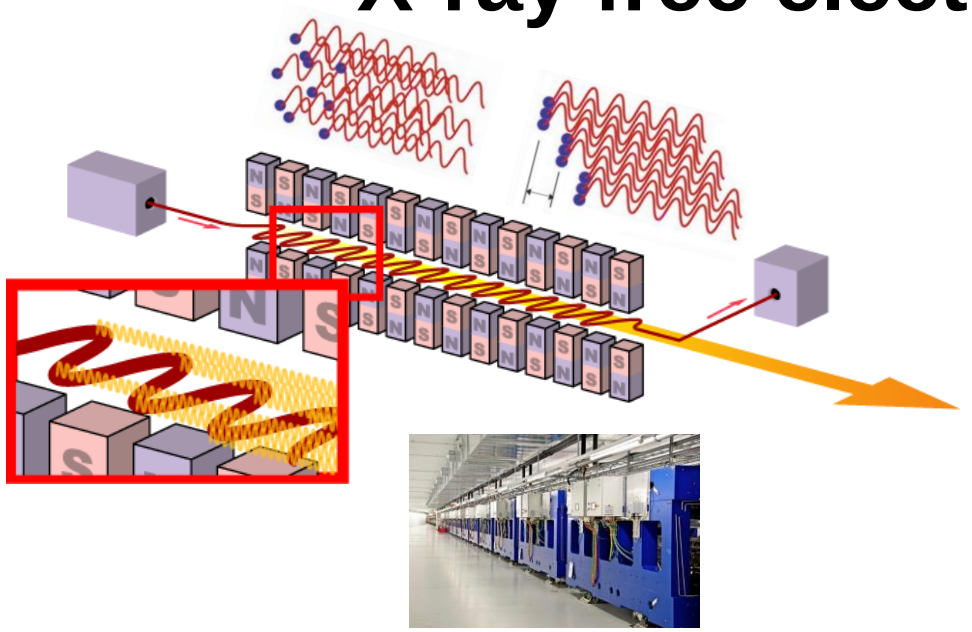
Christopher Arrell
28 October 2024

Outline

Christopher Arrell
Responsible for X-ray photon diagnostics at SwissFEL

- Very brief overview of SwissFEL and a small taster of photonic systems

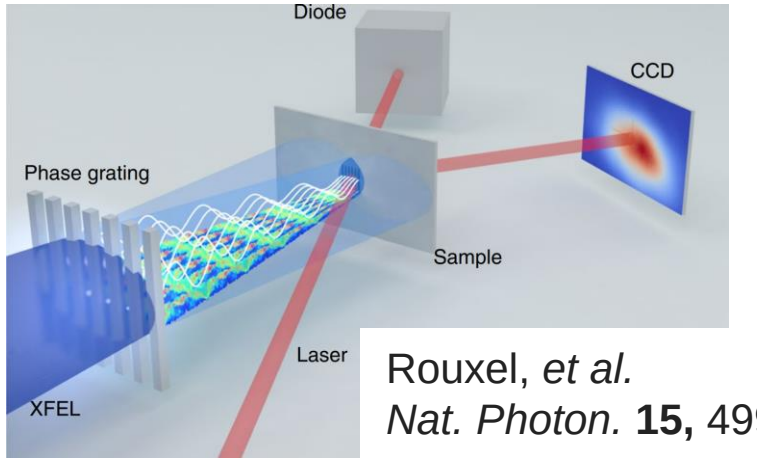
X-ray free electron lasers



Pulses unprecedented peak brilliance

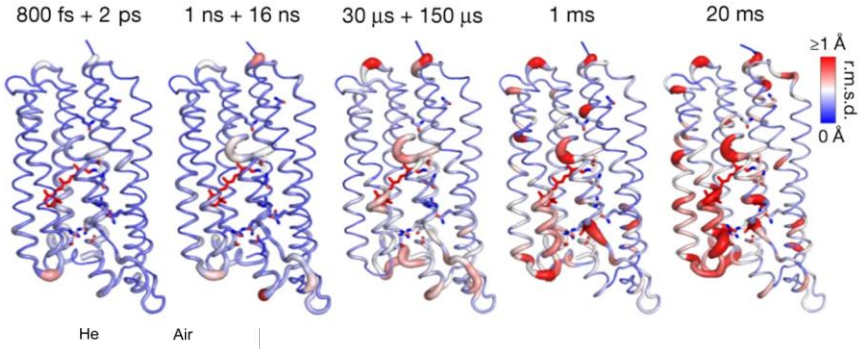
- Full transverse coherence
- Ultra short pulse
- Ultra high peak intensity

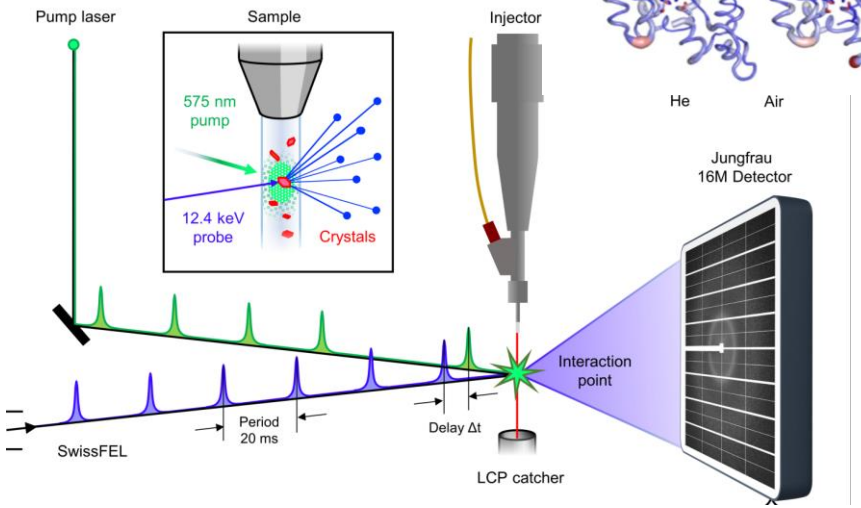
Advanced spectroscopic methods



Rouxel, *et al.*
Nat. Photon. **15,** 499–503 (2021)

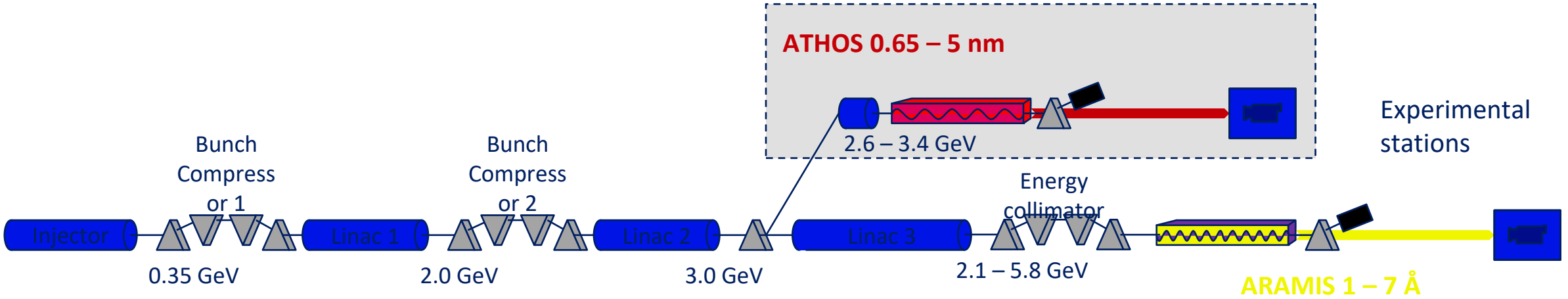
Structural and functional dynamics in biological systems





Skopintsev, P *et al.*
Nature **583,** 314–318 (2020)

SwissFEL machine



Main parameters

Wavelength:	**1 Å – 5 nm**
Photon energy:	**0.24 – 12.4 keV**
Pulse energy:	**1 mJ**
Pulse duration:	**1 – 100 fs**
e^- Energy 5.8 GeV	
e^- Bunch charge	10 – 200 pC
Repetition rate	**100 Hz**

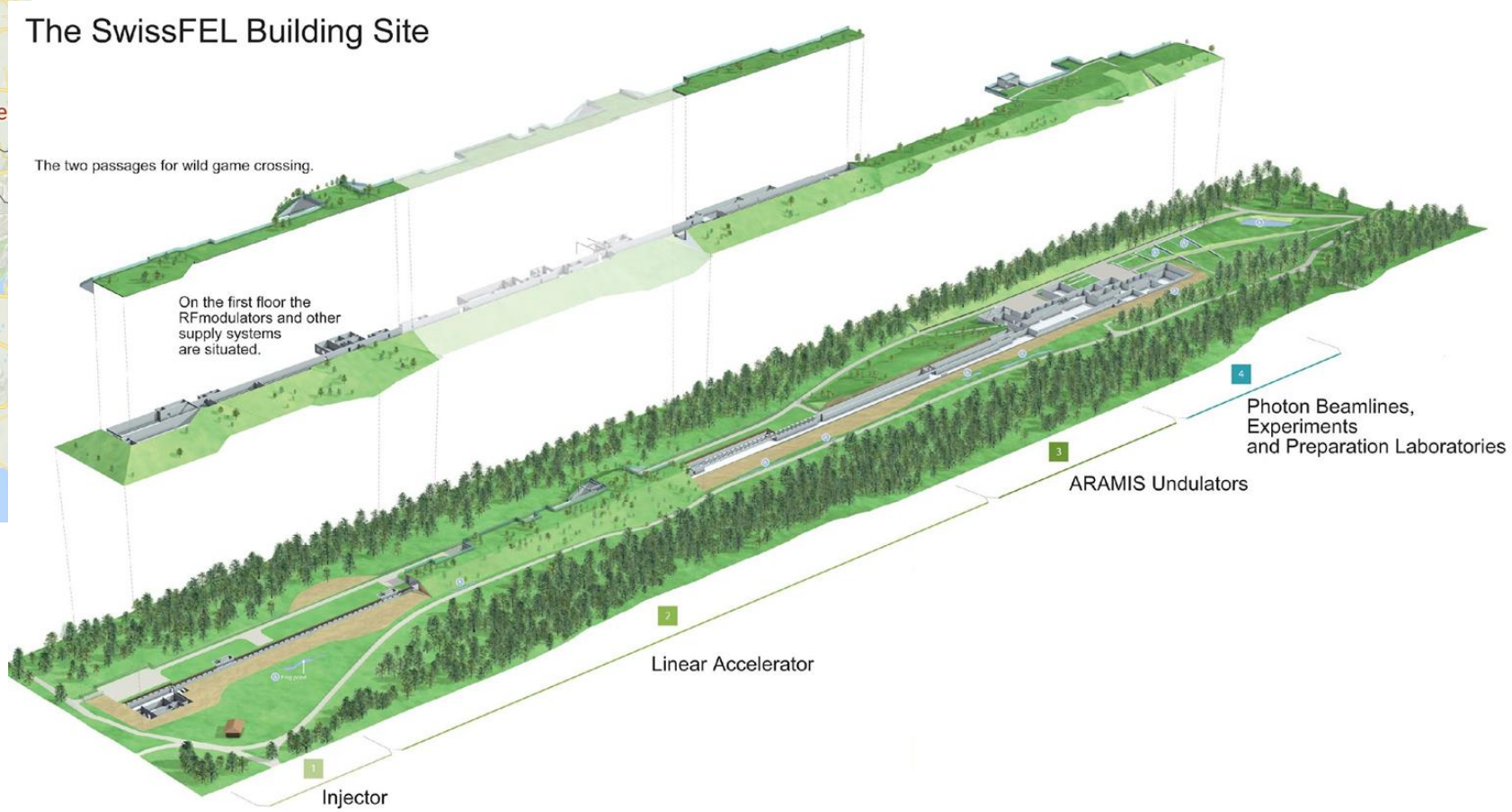
ARAMIS

- Hard x-ray FEL, **λ = 1 – 7 Å (1.8 – 12.4 keV)**
- Attosecond mode possible, 100 as FWHM (no pedestal), few ten uJ
- new two color tune (range -20 – 20 fs)
- Linear polarization, variable gap undulators
  - High k “hot” @ 4 – 8 keV

ATHOS

- Soft x-ray FEL, λ = 0.65 – 5 nm (240 – 1’930 eV)
- Variable polarization Apple X undulators
- Operation modes: SASE (CHIC)
  10x smaller BW
- Attosecond modes of operation

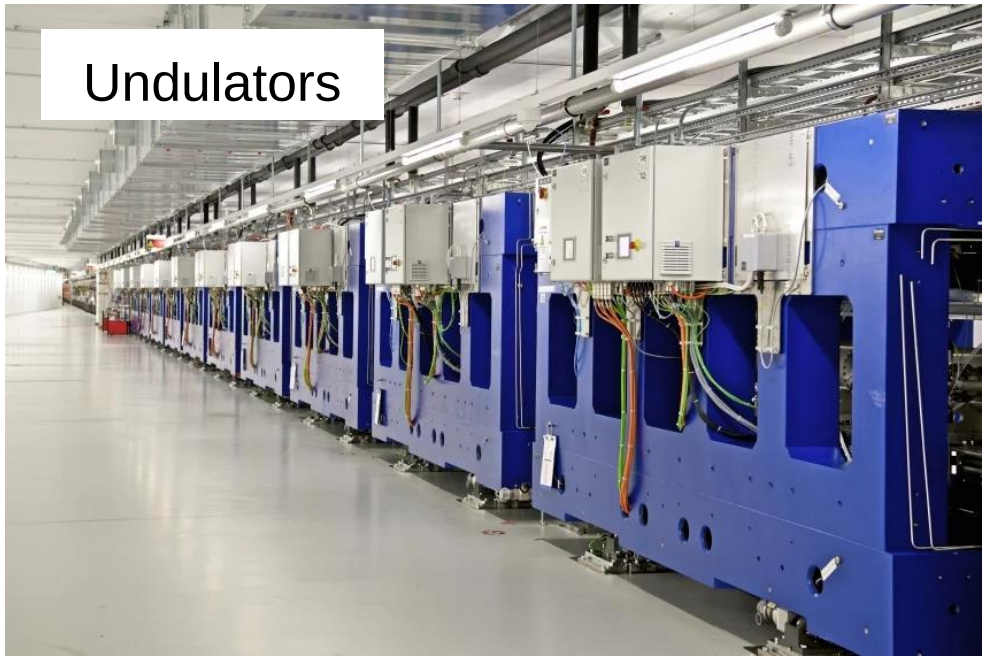
SwissFEL machine



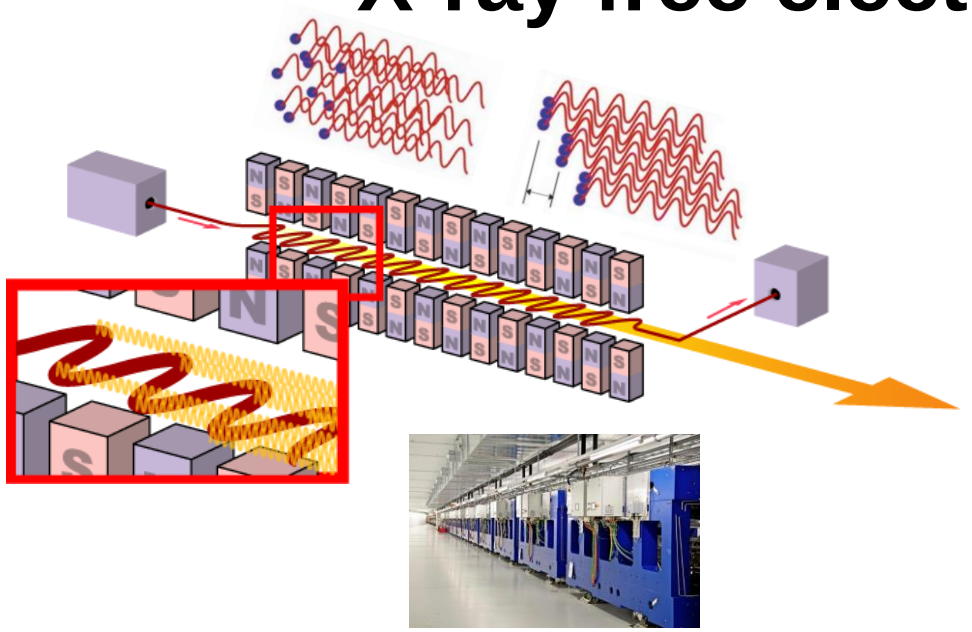
SwissFEL machine

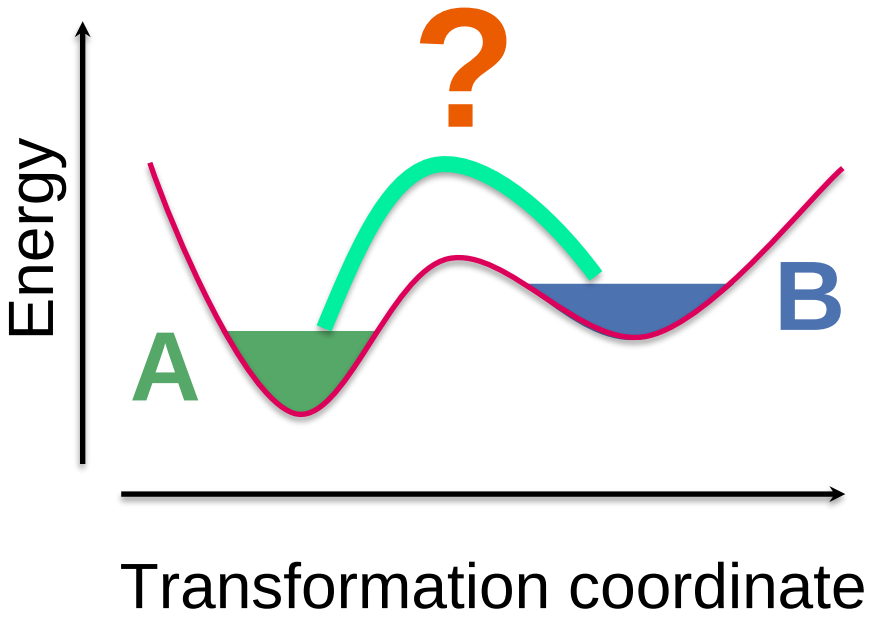
Accelerator

Undulators



X-ray free electron lasers





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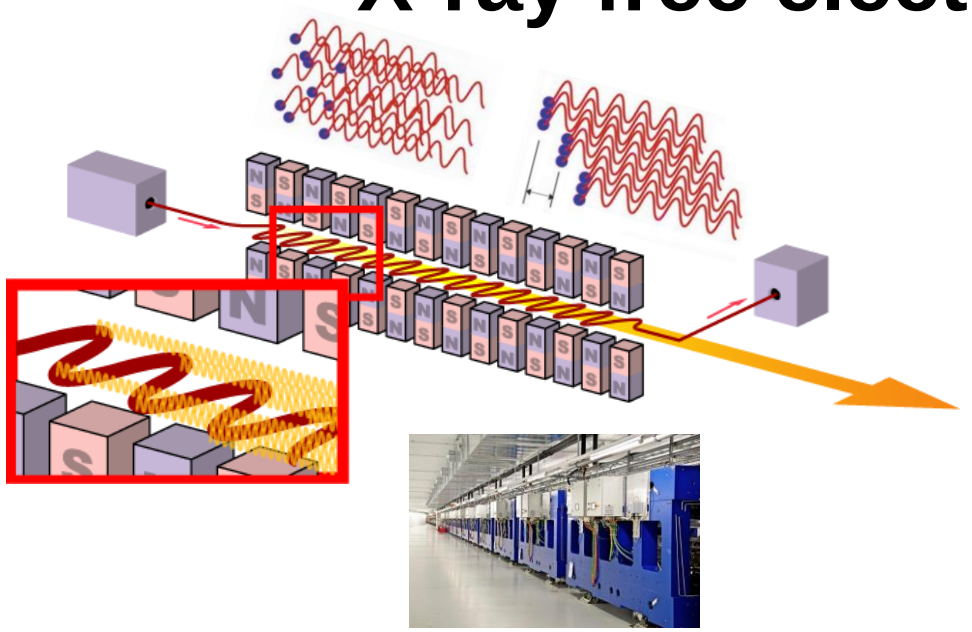

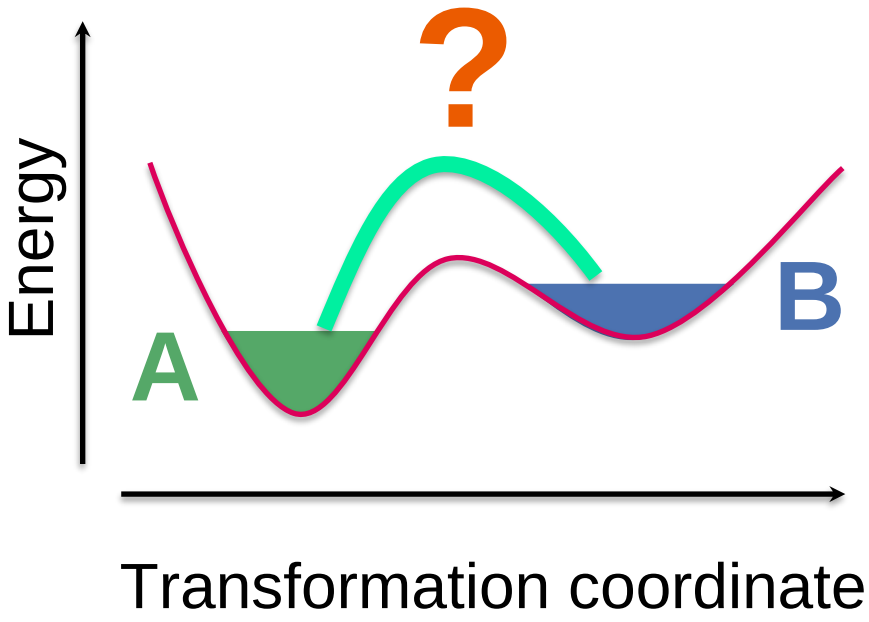

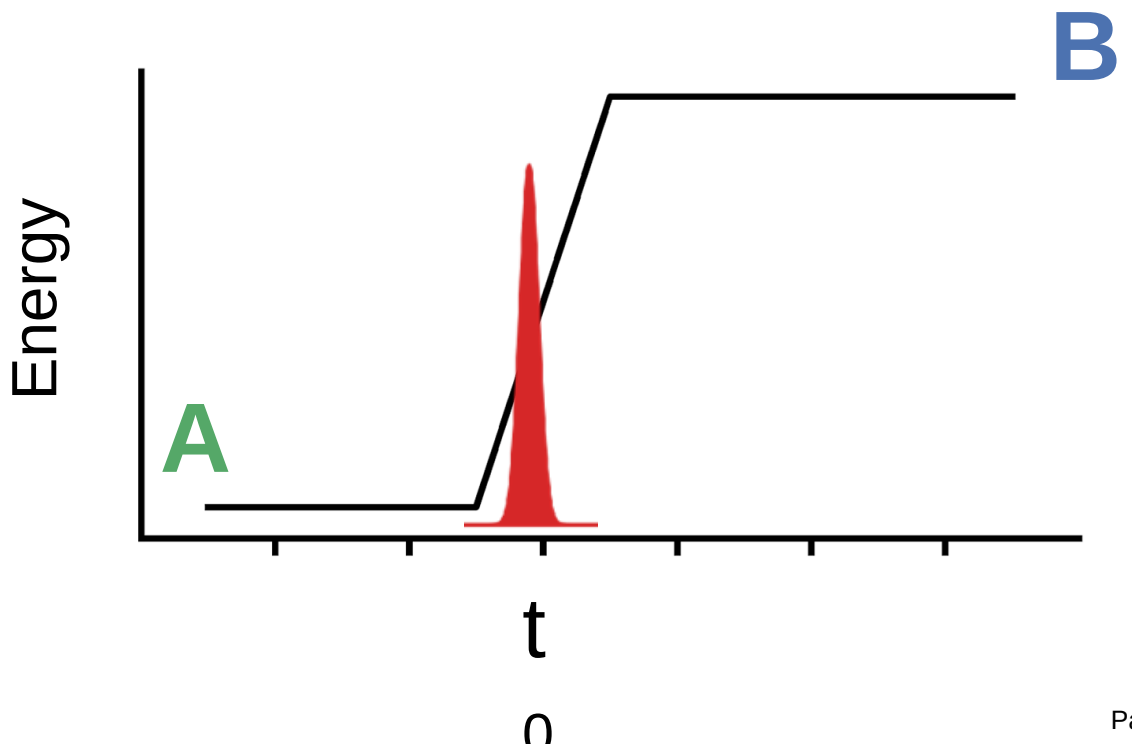

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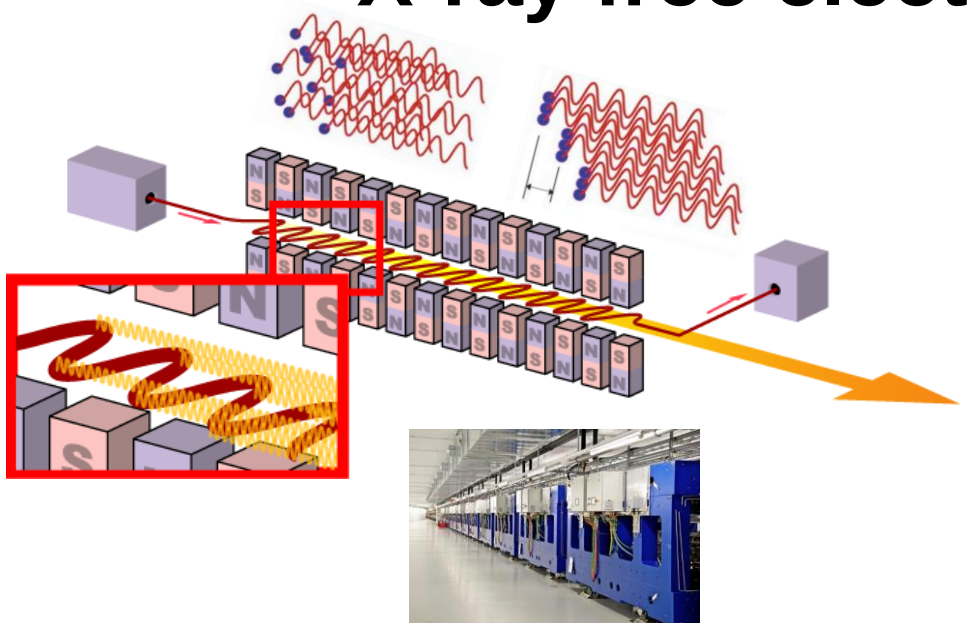

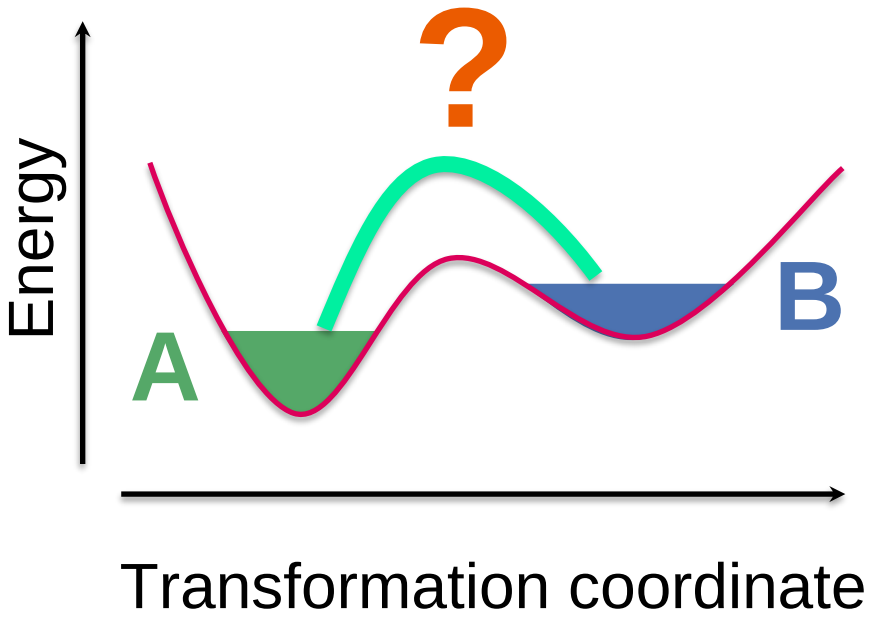

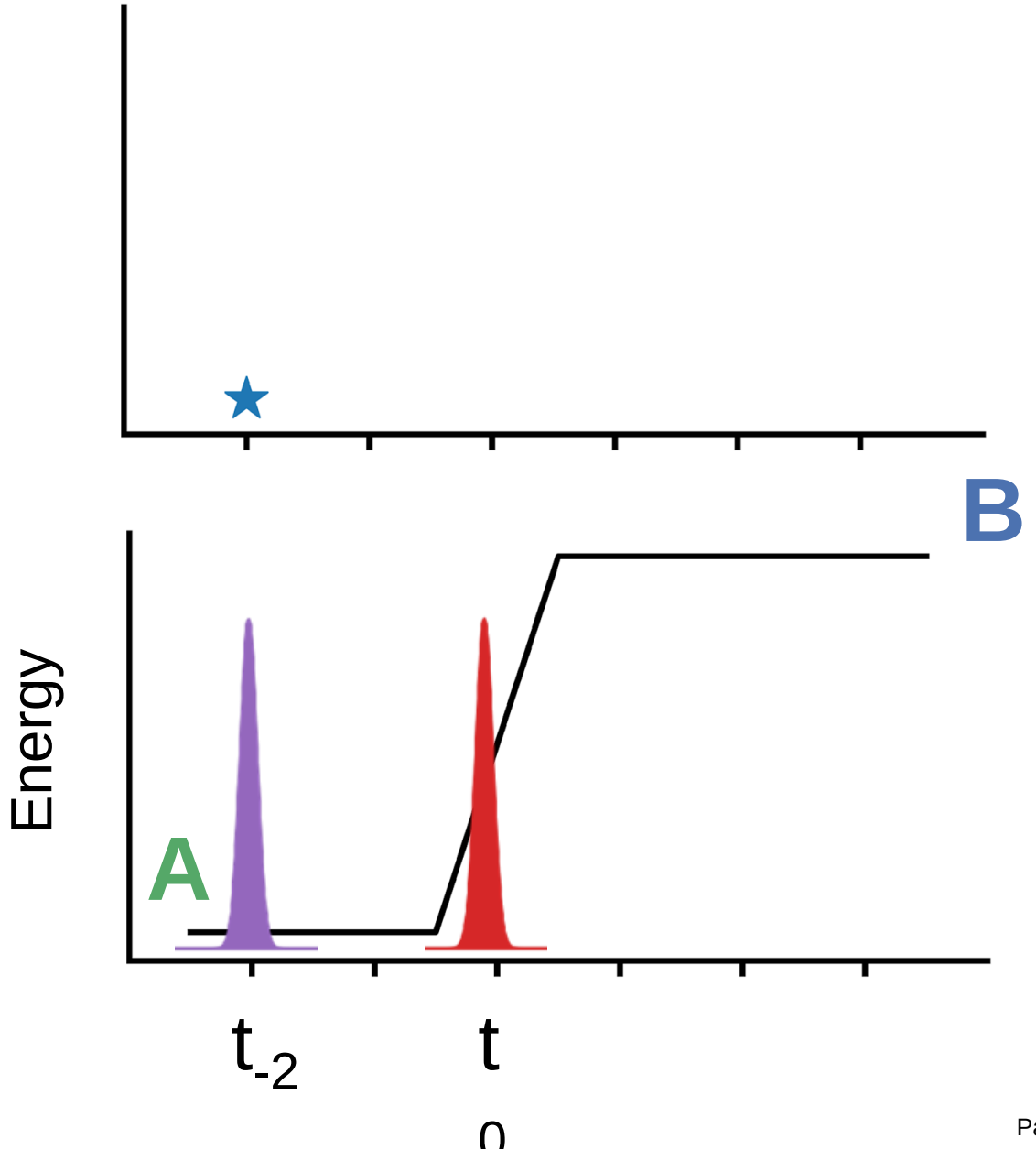

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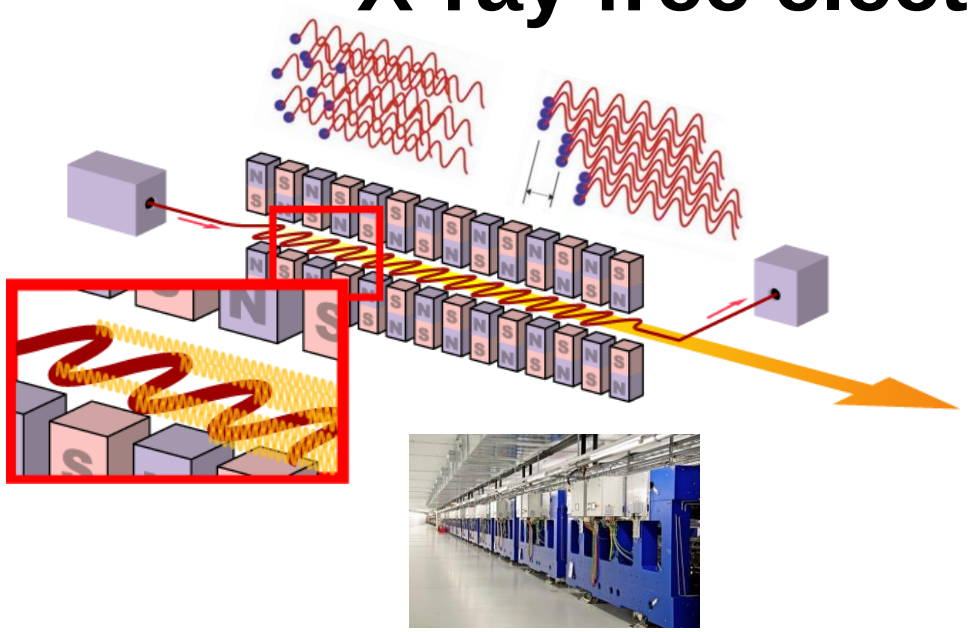

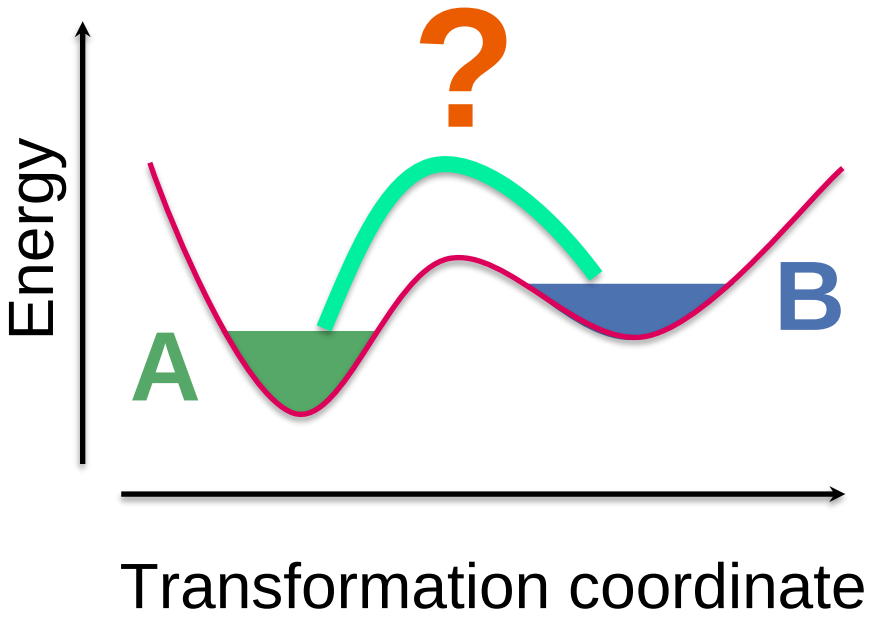

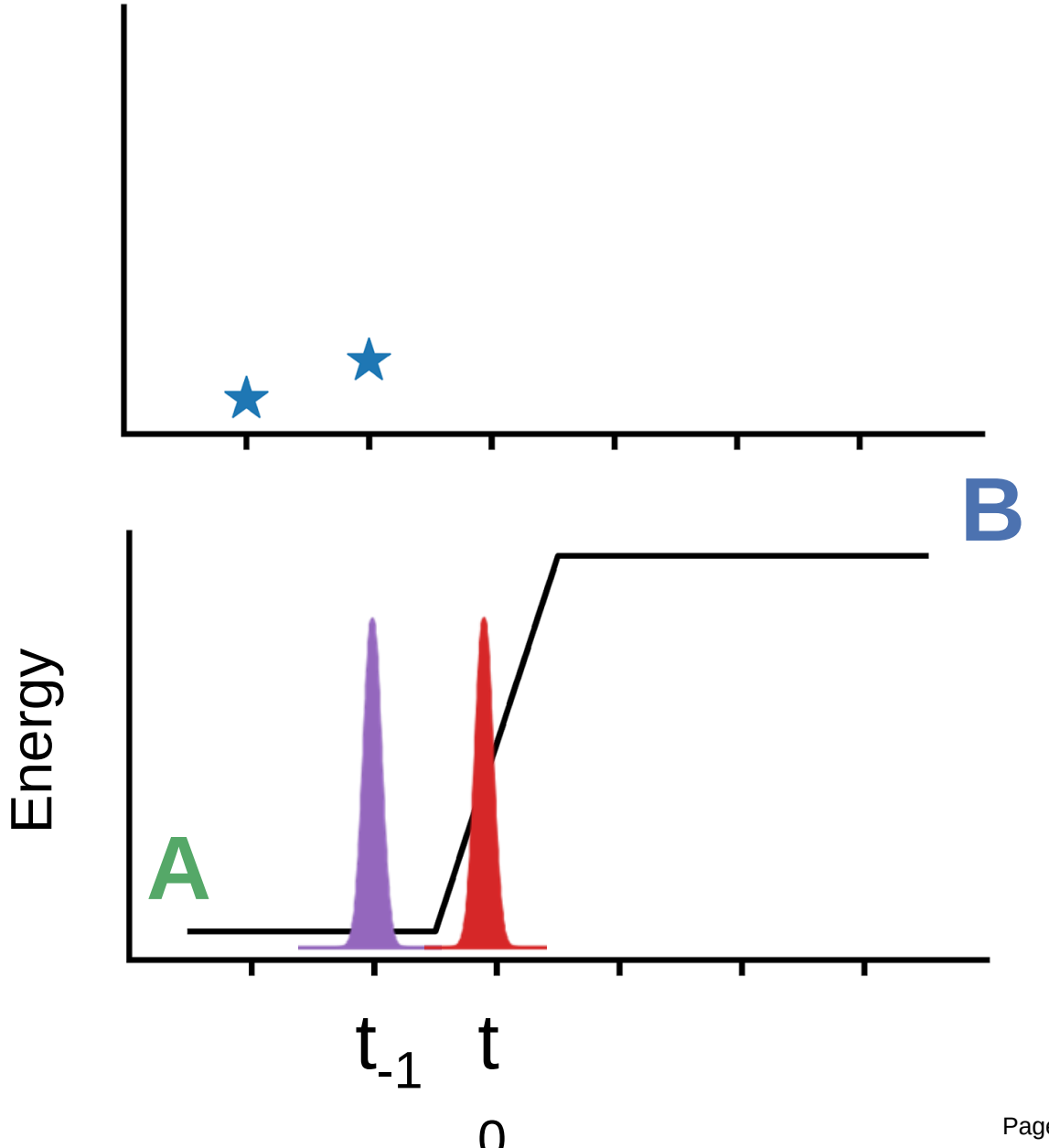

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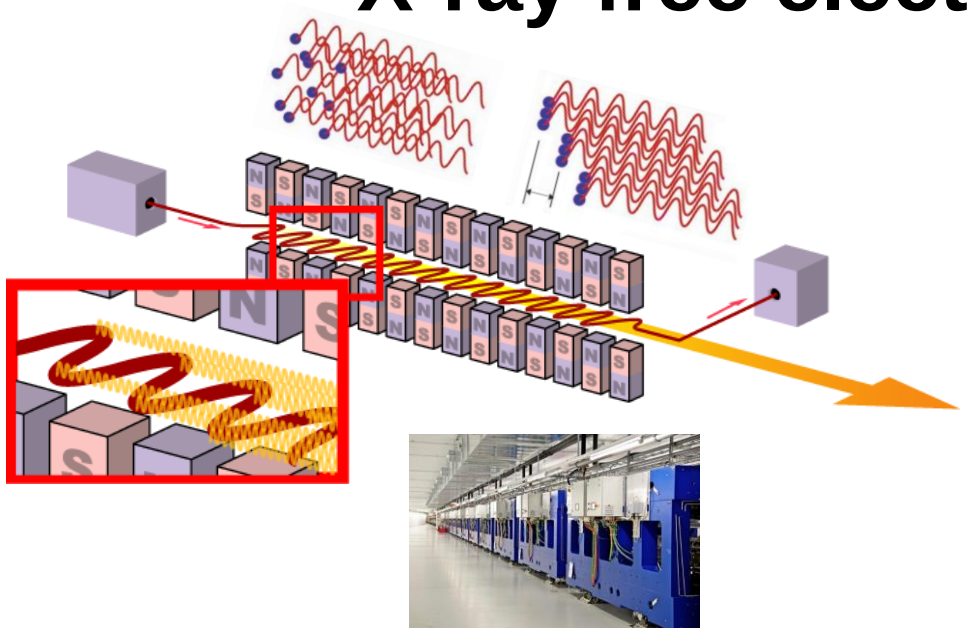

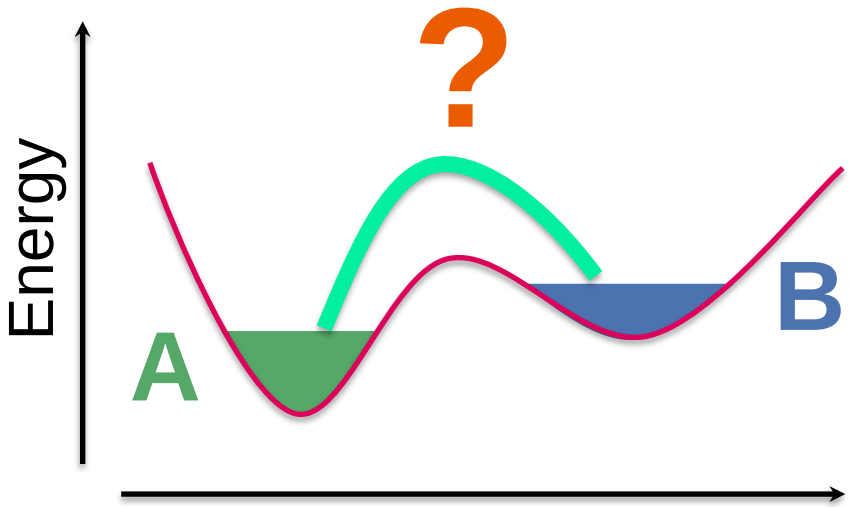

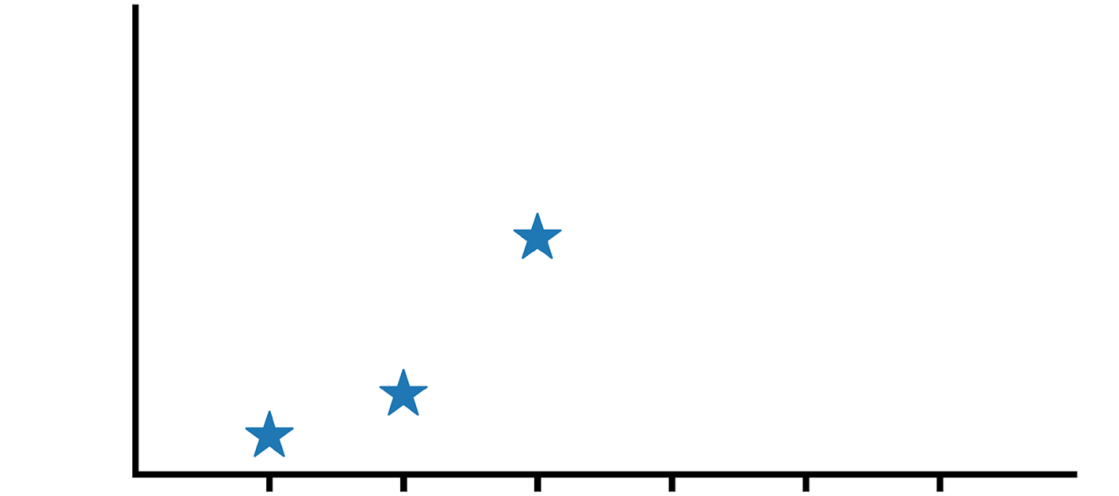

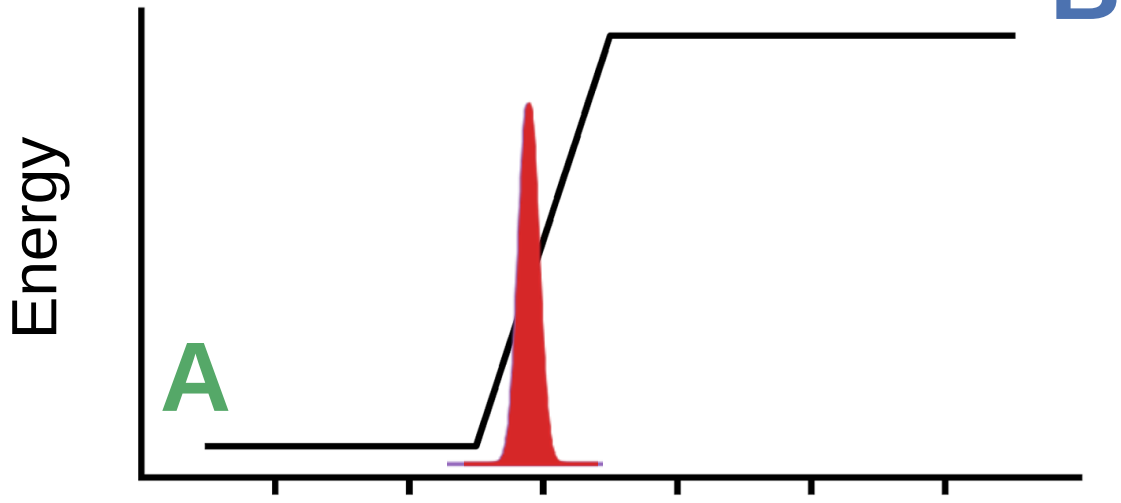

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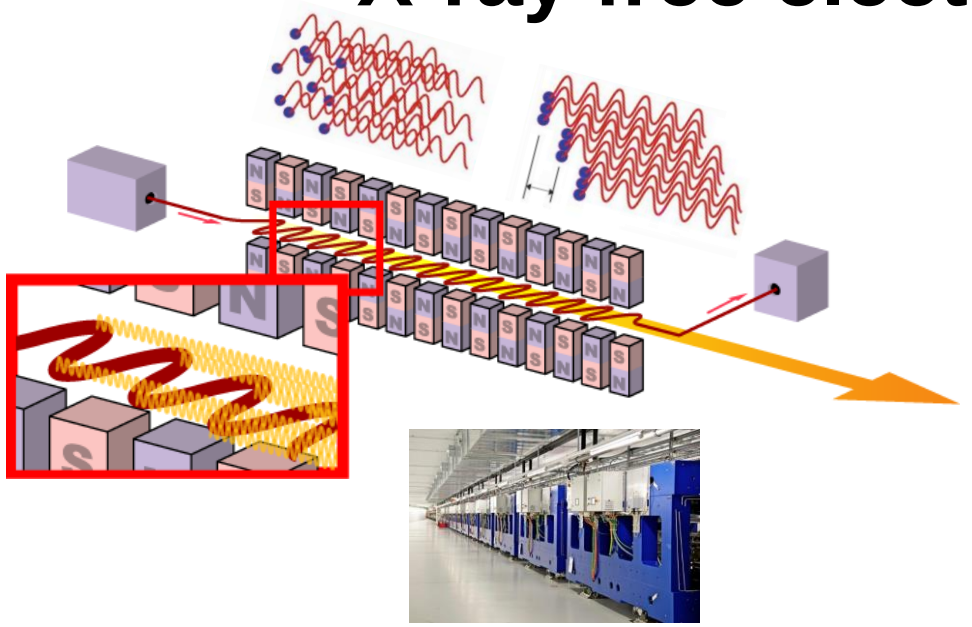
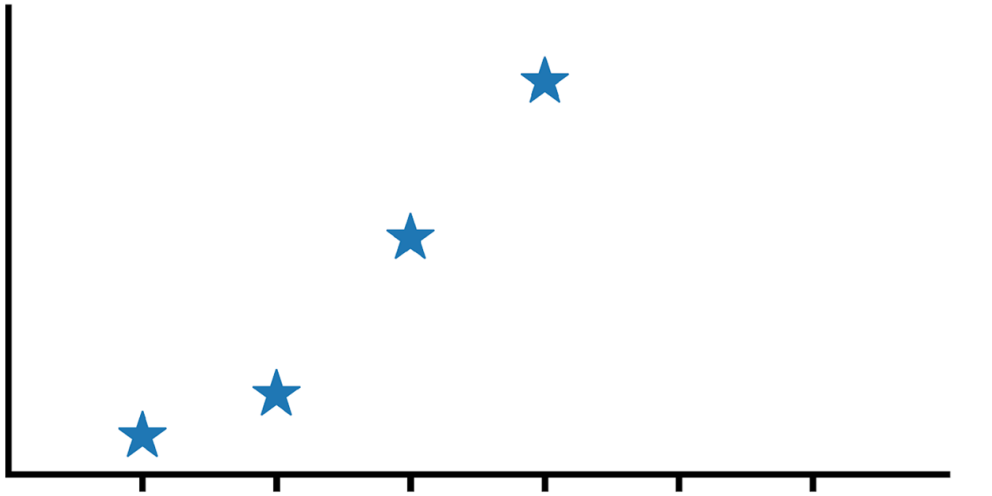
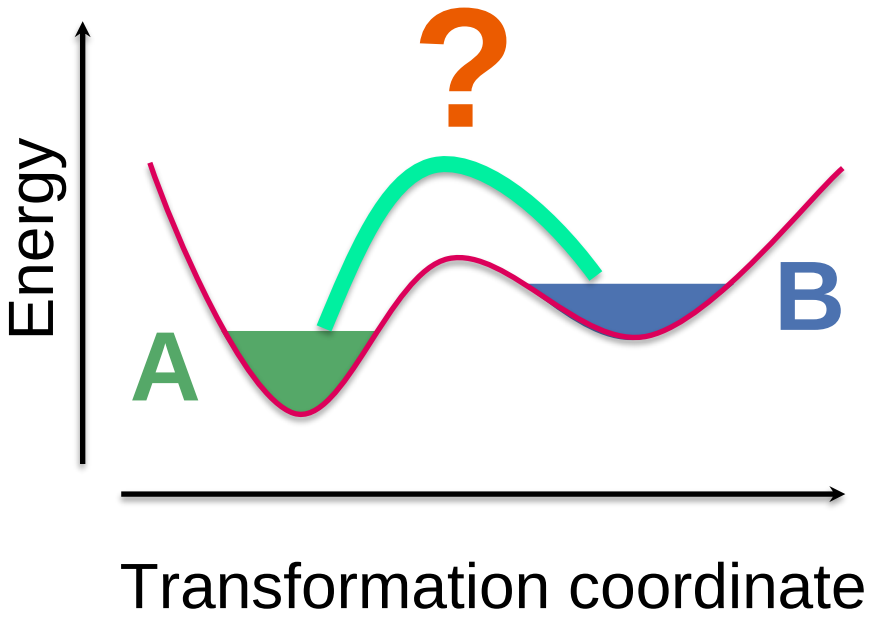
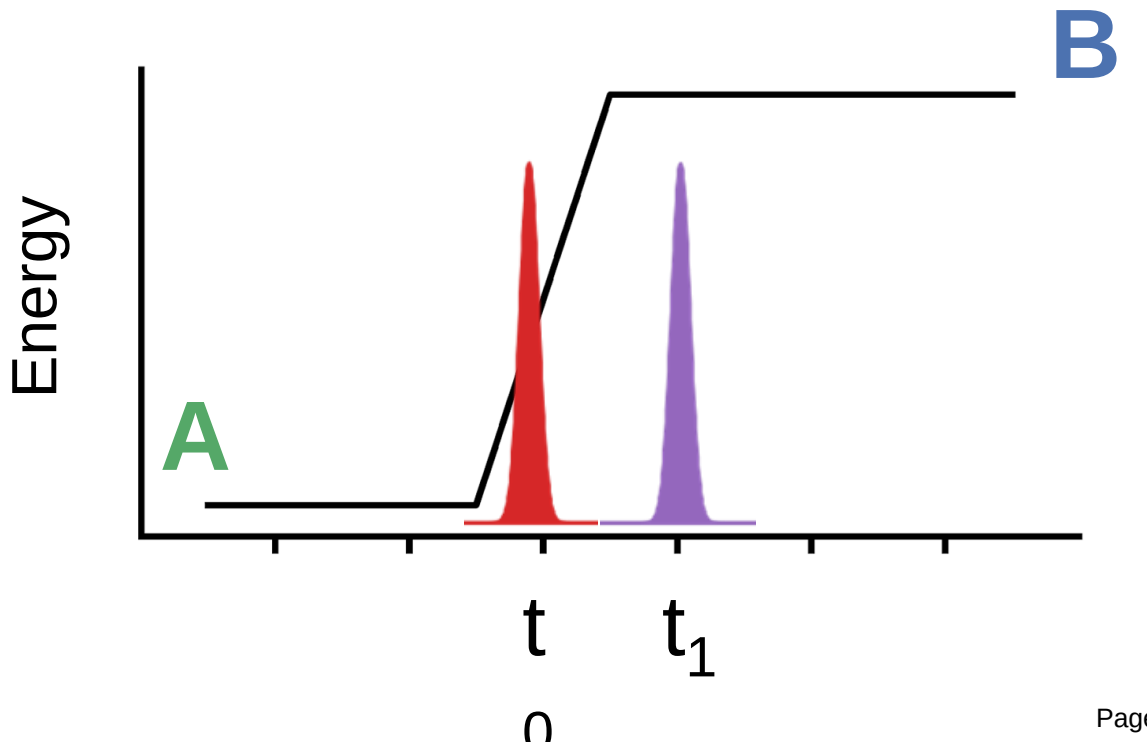
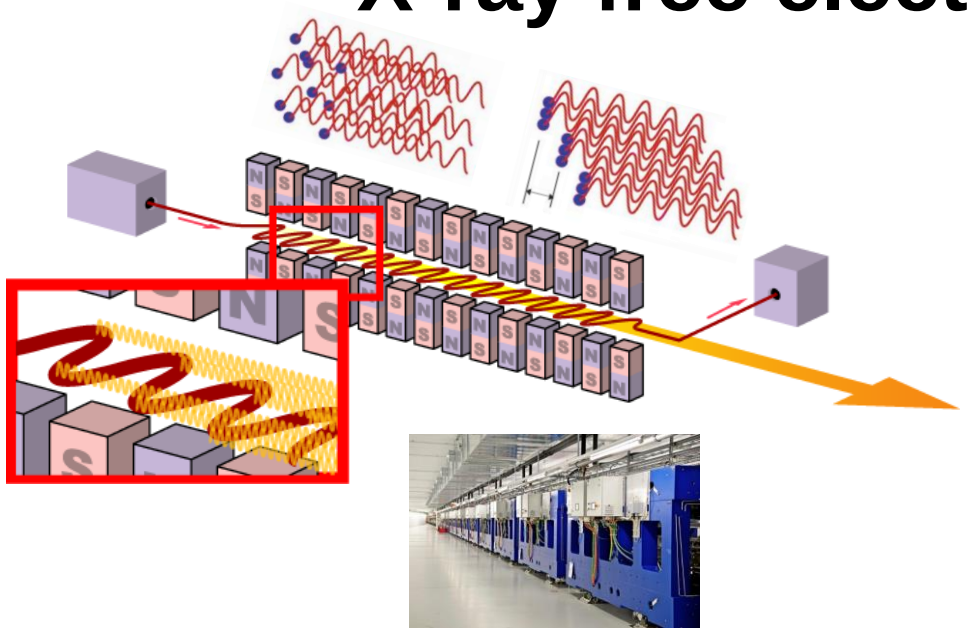


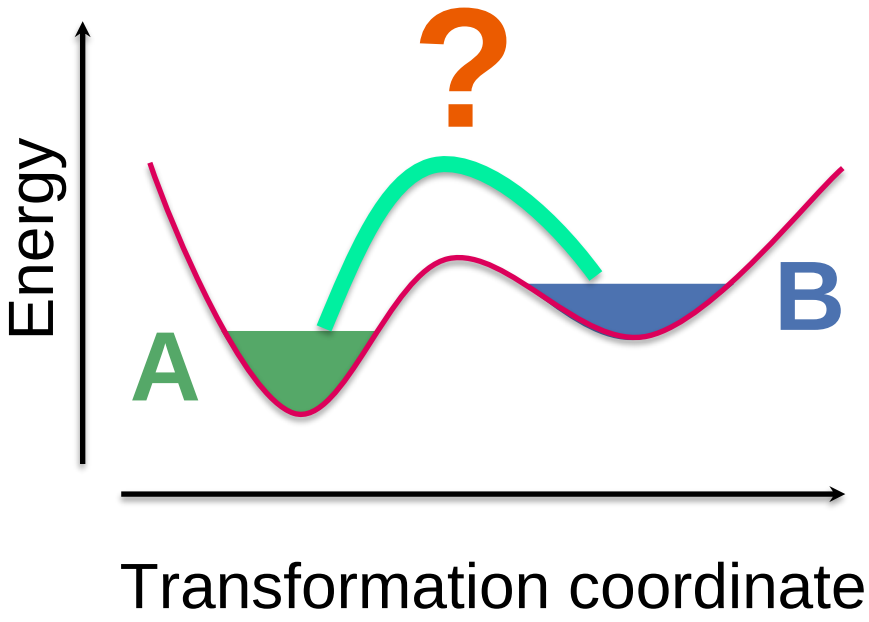


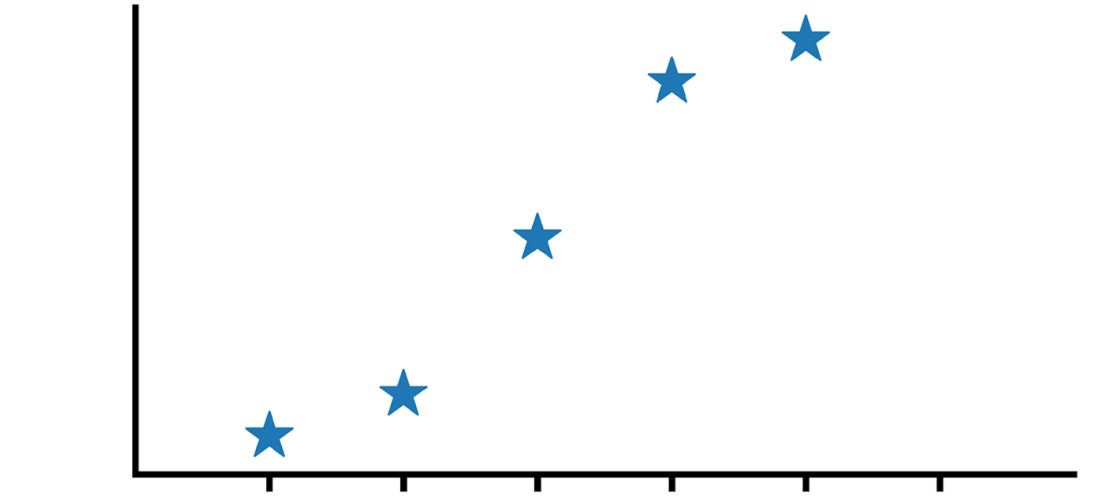


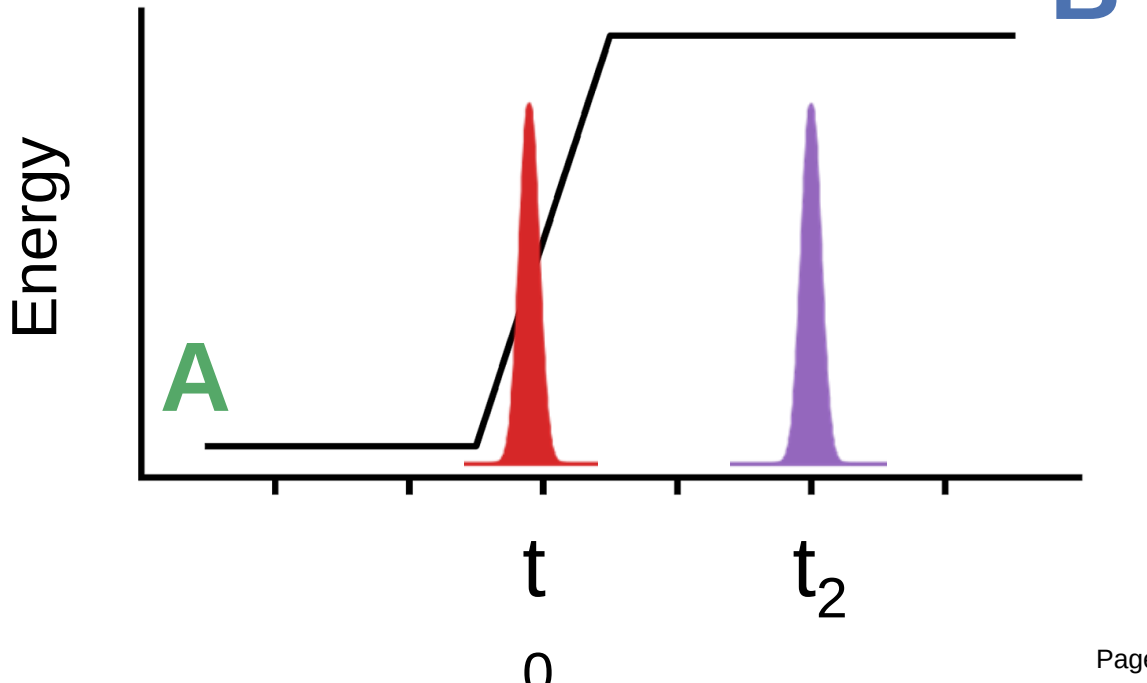


X-ray free electron lasers









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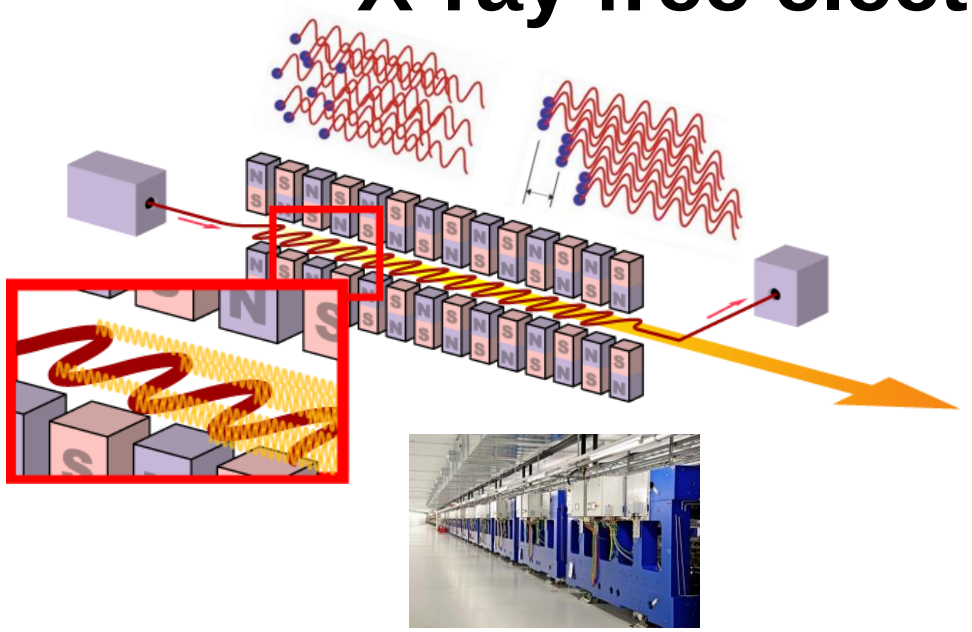

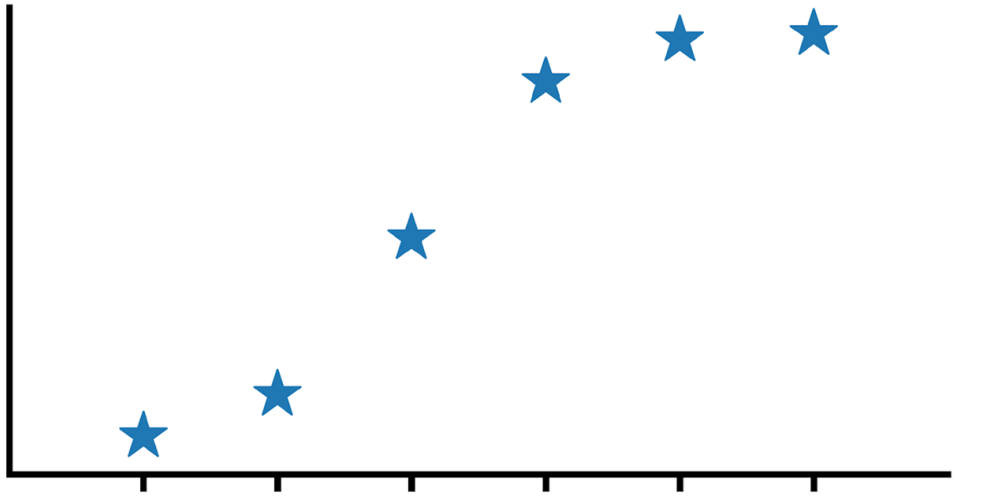

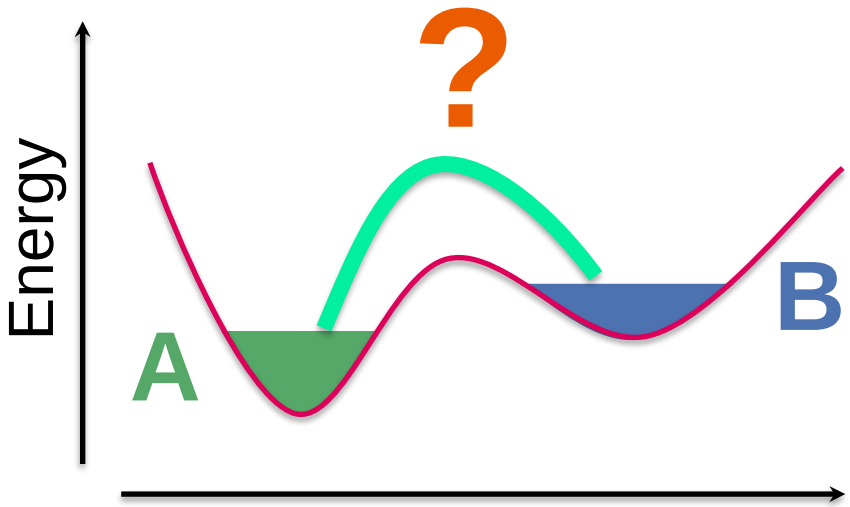

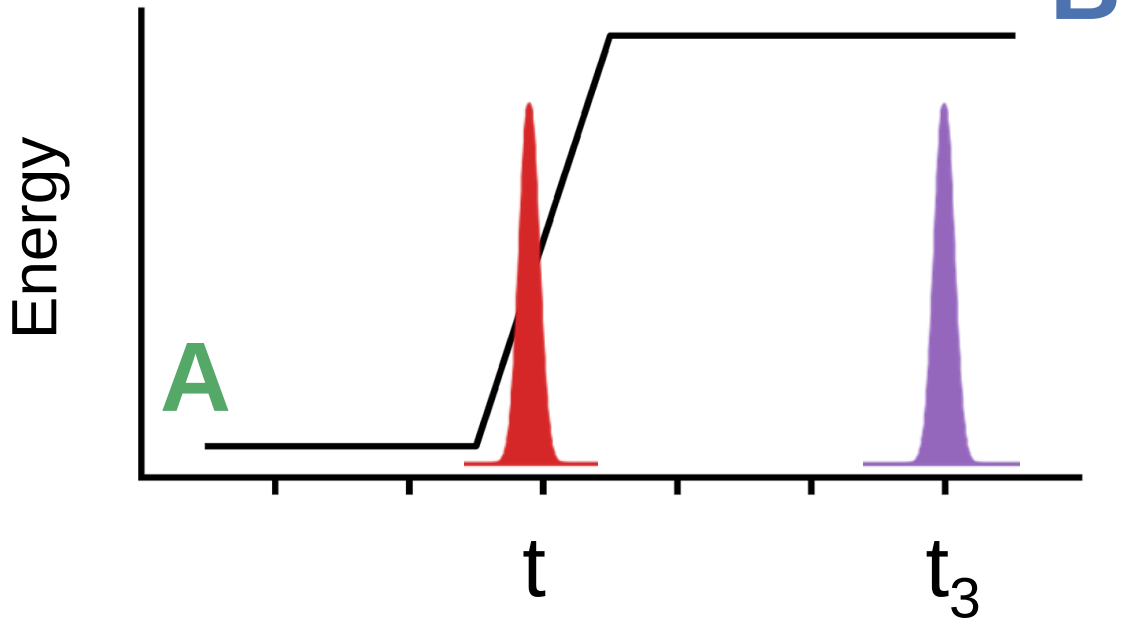

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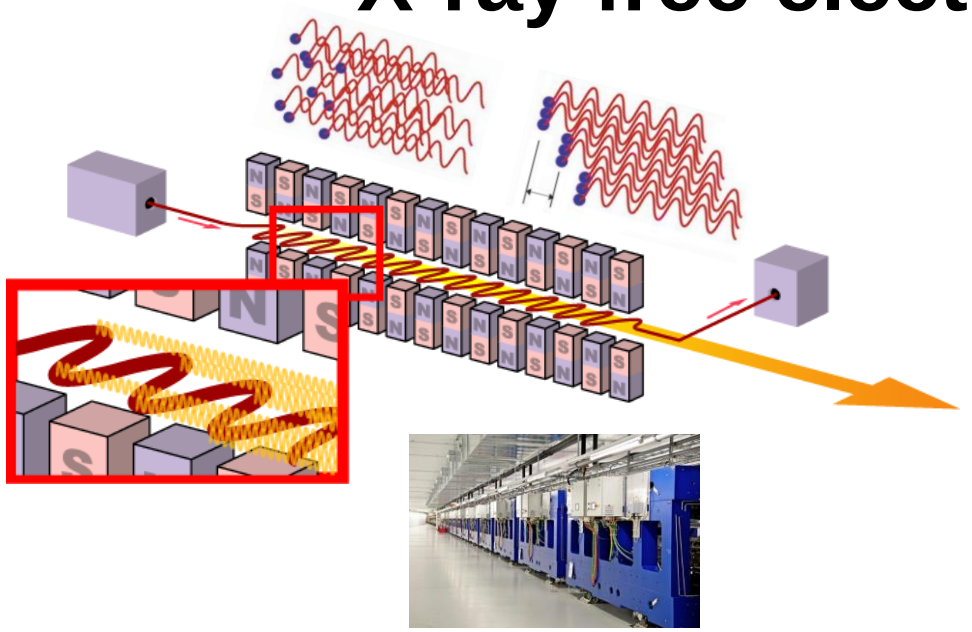
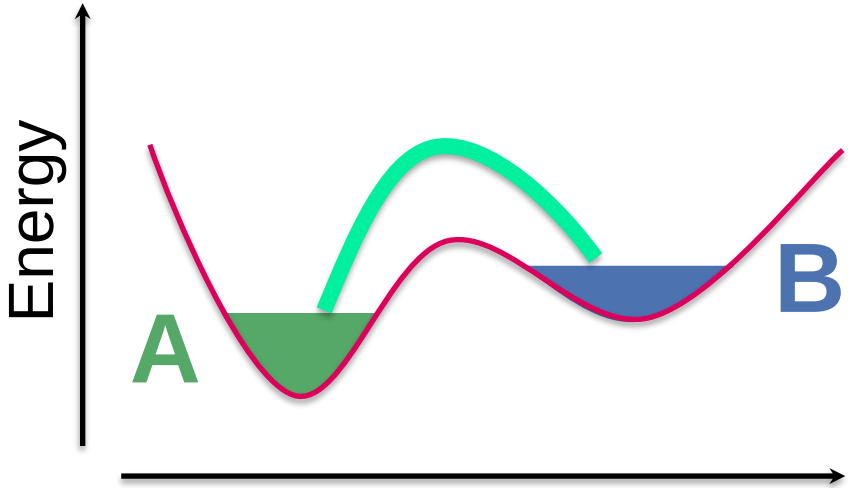
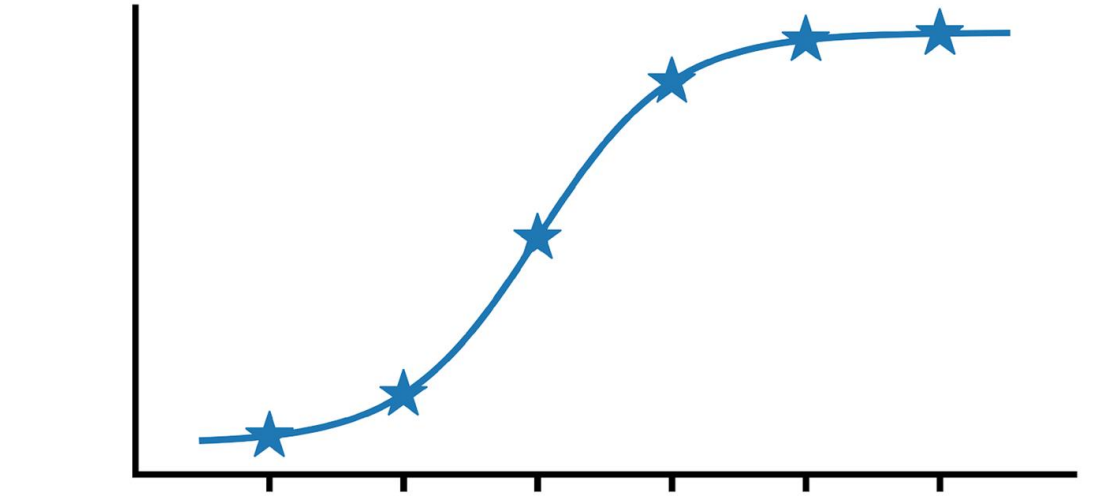
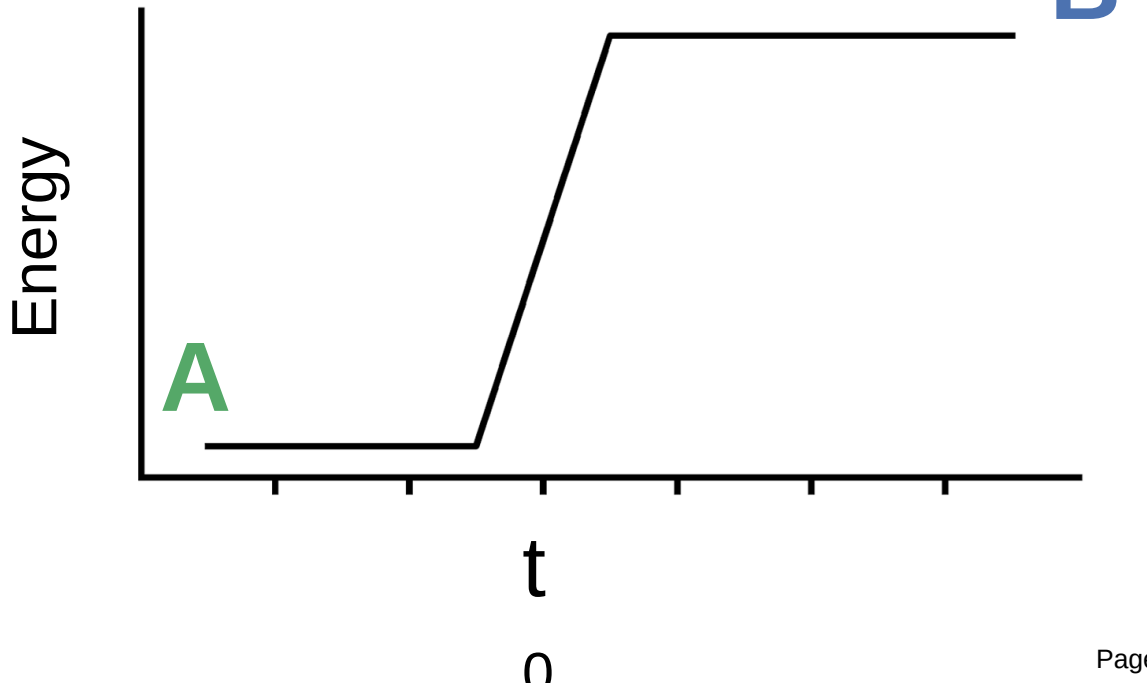
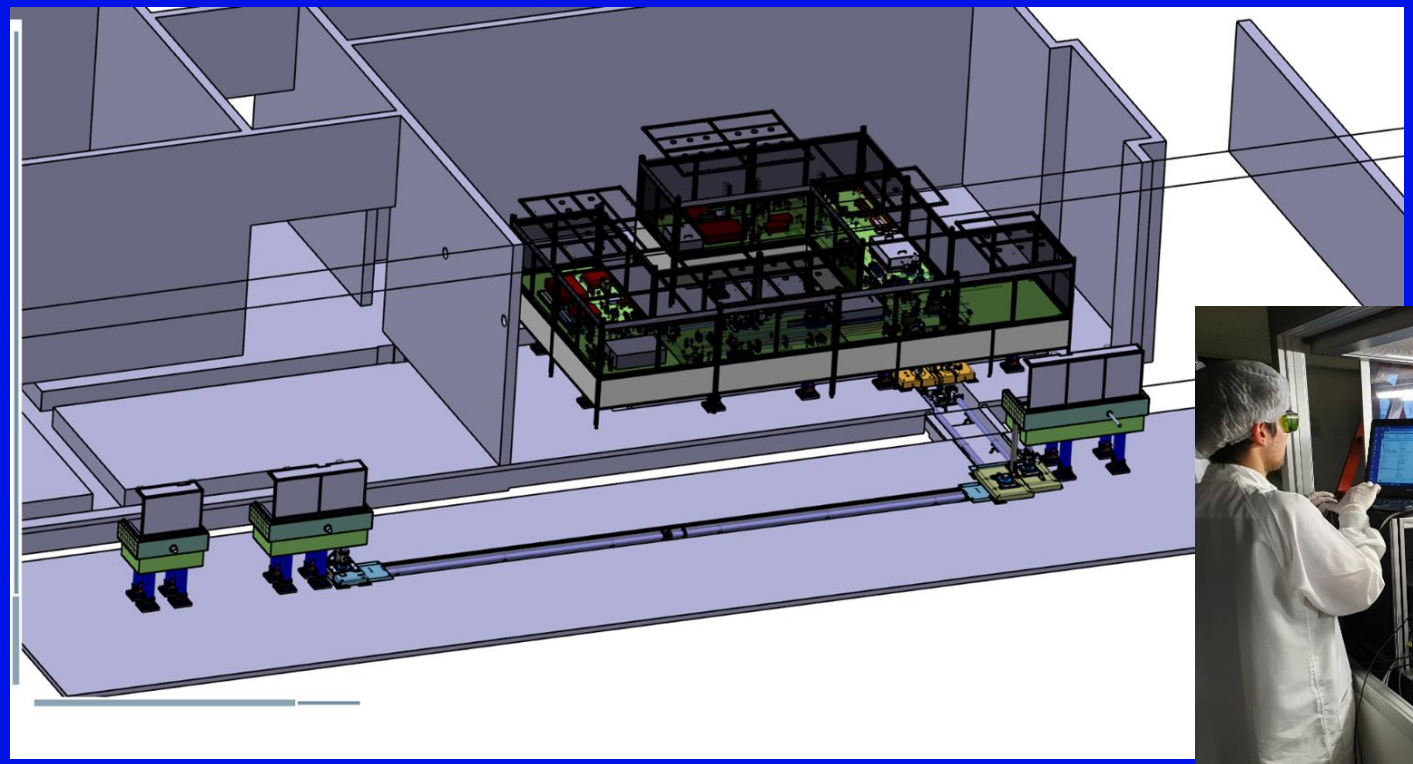


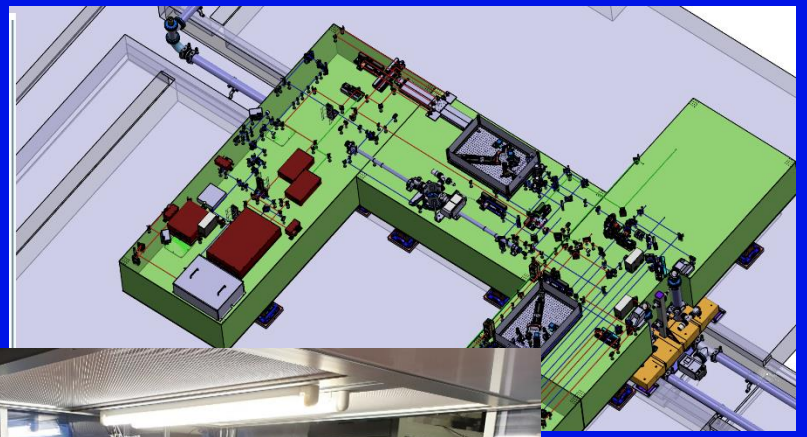


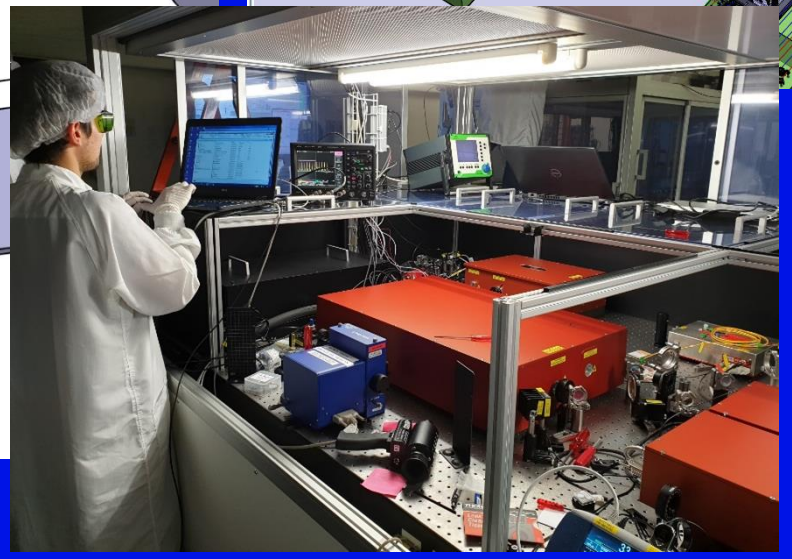




Photonics as the source - The Photo Cathode Laser Facility

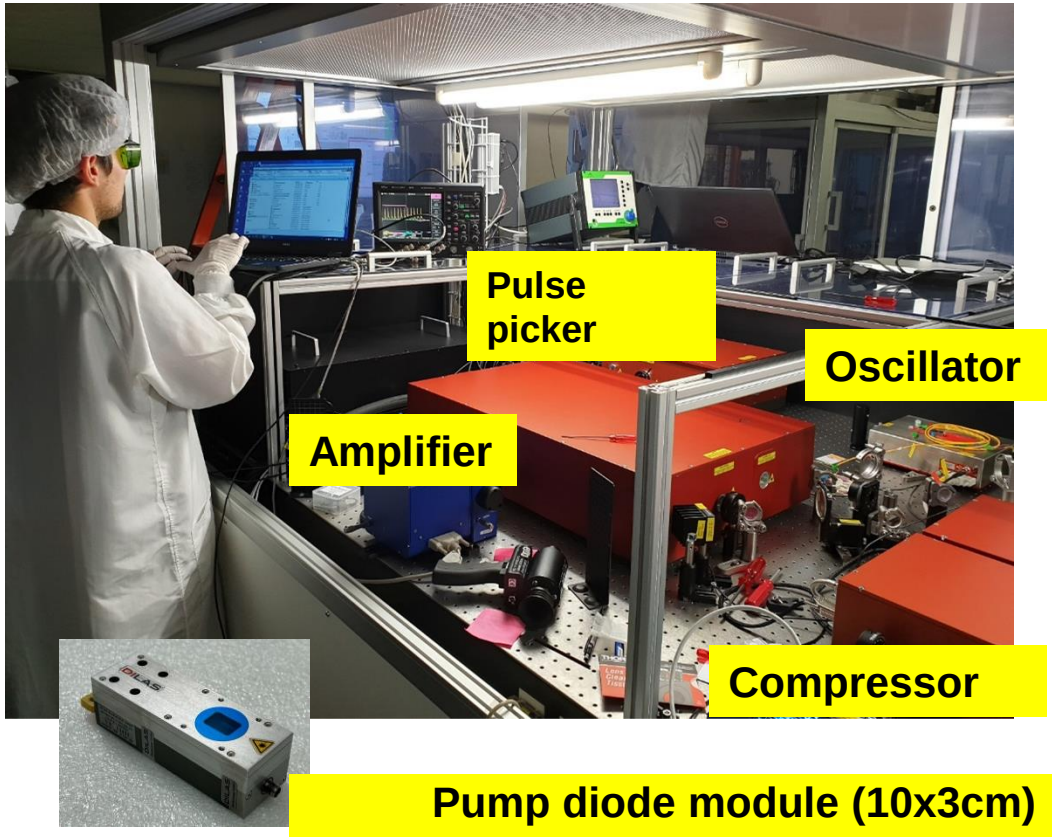






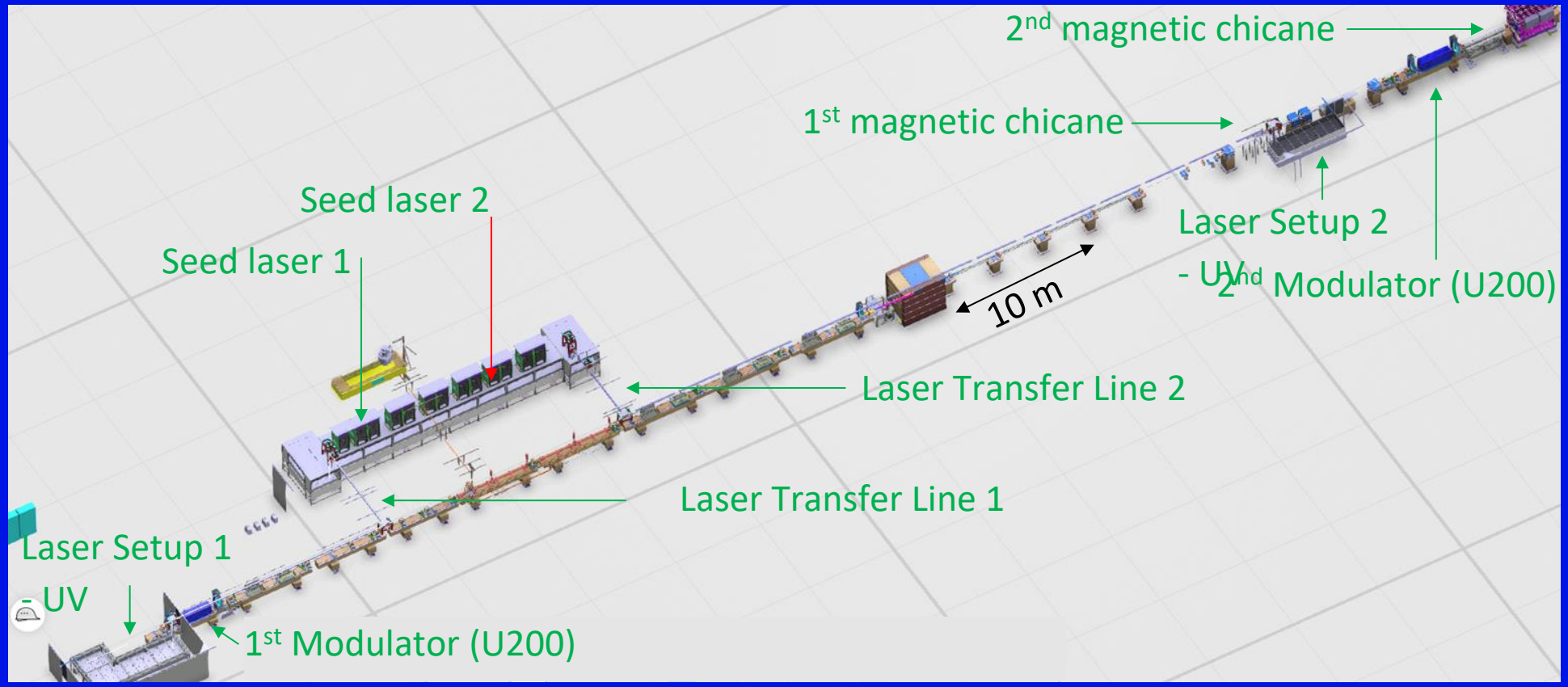
Photonics as the source - The Photo Cathode Laser Facility

Ytterbium Calcium Fluoride ($Yb:CaF_2$): 450 fs / 3 mJ / 1040 nm / 100 Hz



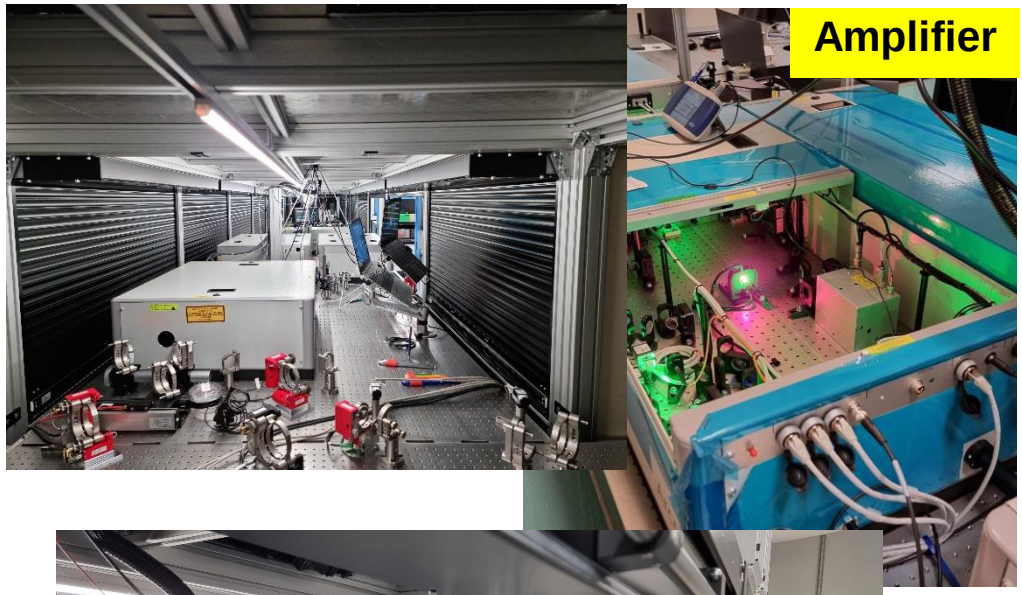
- Innovative and performant technology
- Multi-mJ pulse energy
- Uneven energy stability ~0.005% rms
- Compact = more passive stability
- Directly diode pumped
- Low maintenance cost (years of diode life time)
- Pulse duration >450 fs and RR<500 Hz

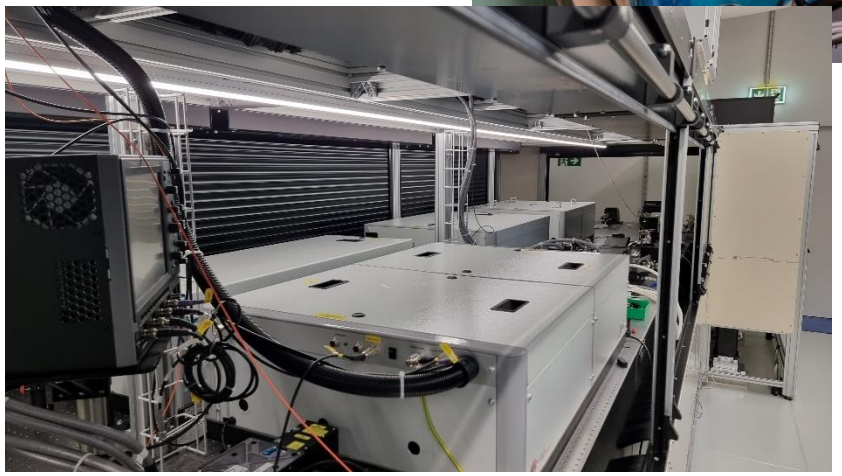
Photonics as the modulator -The Seed Laser Facility



Photonics as the modulator -The Seed Laser Facility

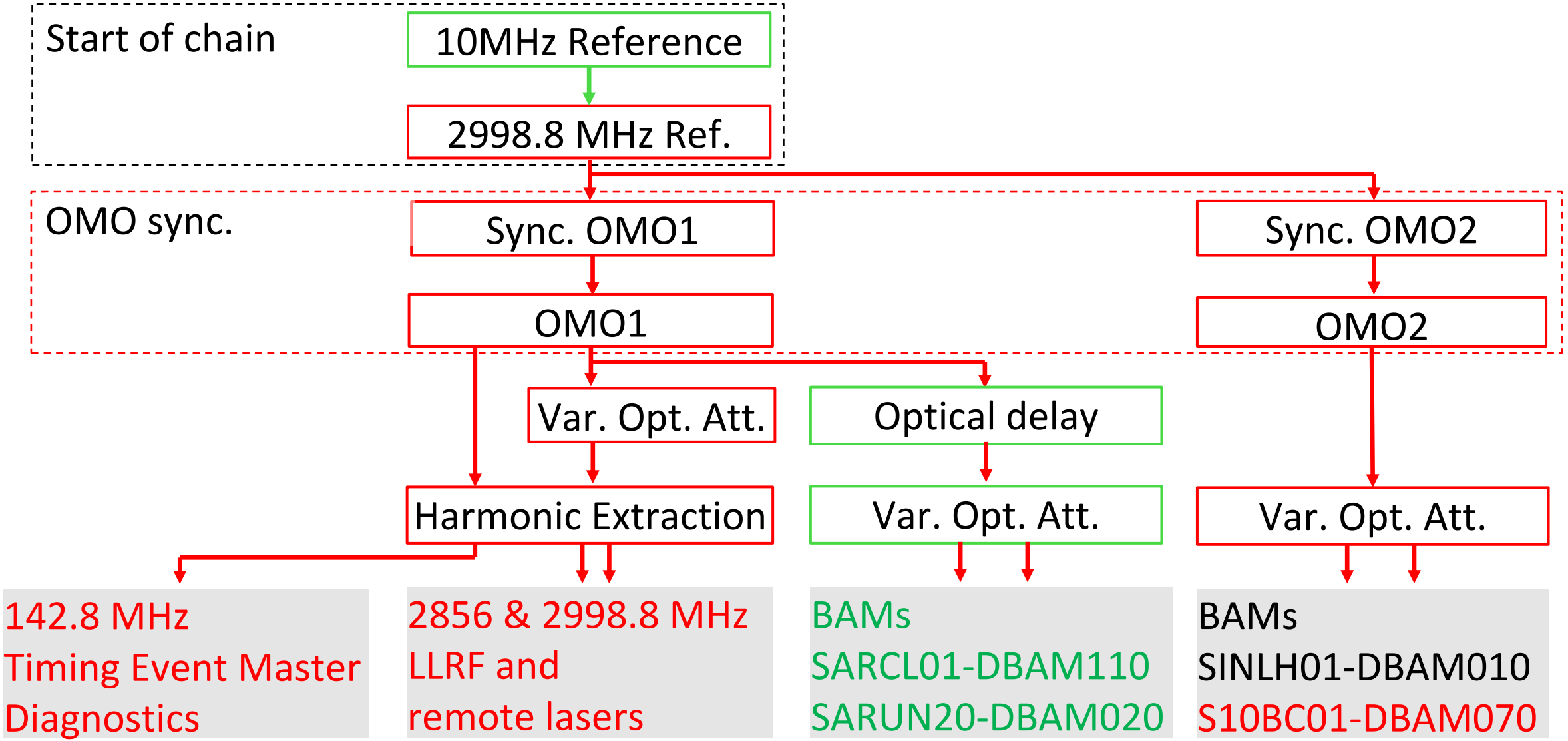
Titanium Sapphire (Ti:Sa): 40 fs / 15 mJ / 800 nm / 100Hz





- Mature and performant technology
- Used in many accelerator facilities
- Can generate <50 fs FWHM laser pulse duration
- Multi-mJ pulse energy and >1kHz RR
- Not compact = less passive stability
- Limited energy stability (~0.8% rms)
- Complex and expensive system
- Prohibitive Pump lasers (DPSS) costs

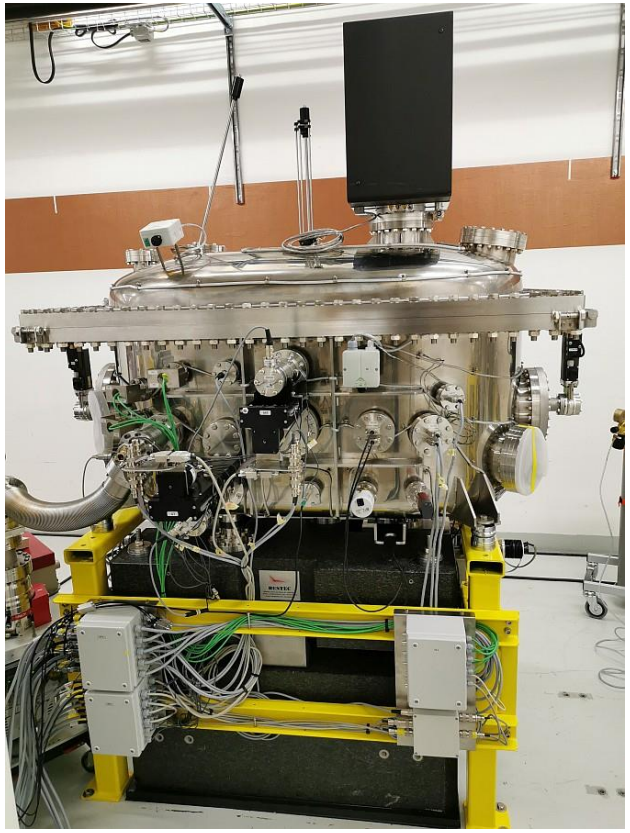
Photonics as the clock -Timing and synchronization

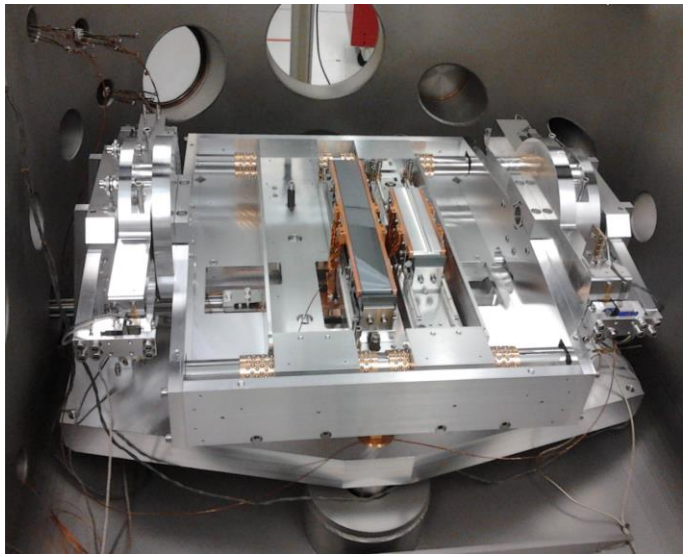


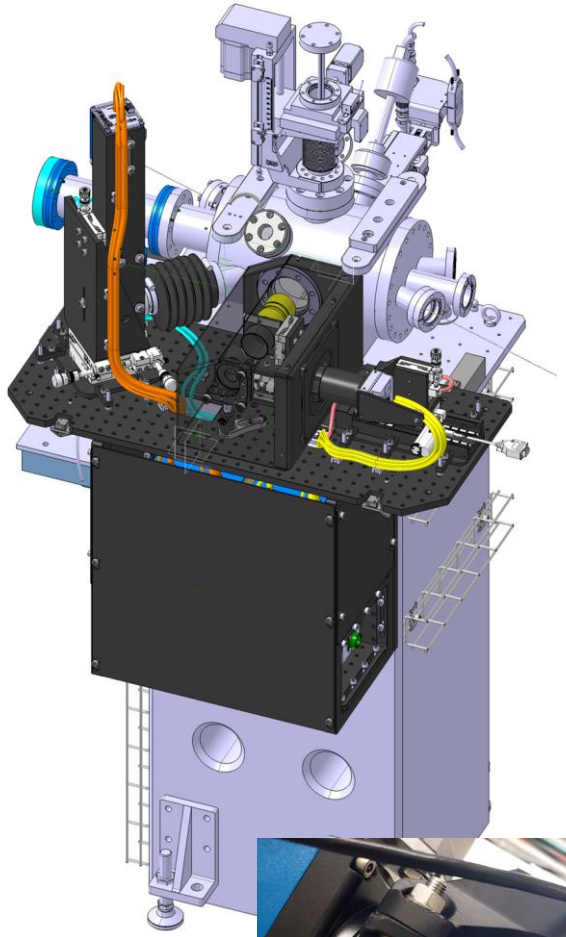
Photonics for diagnostics

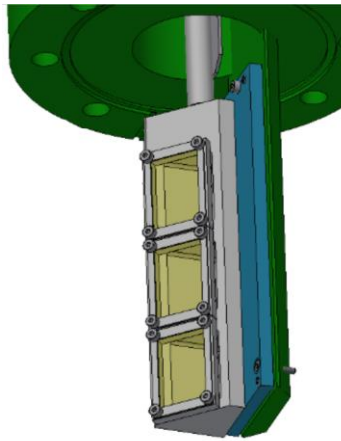
PSI

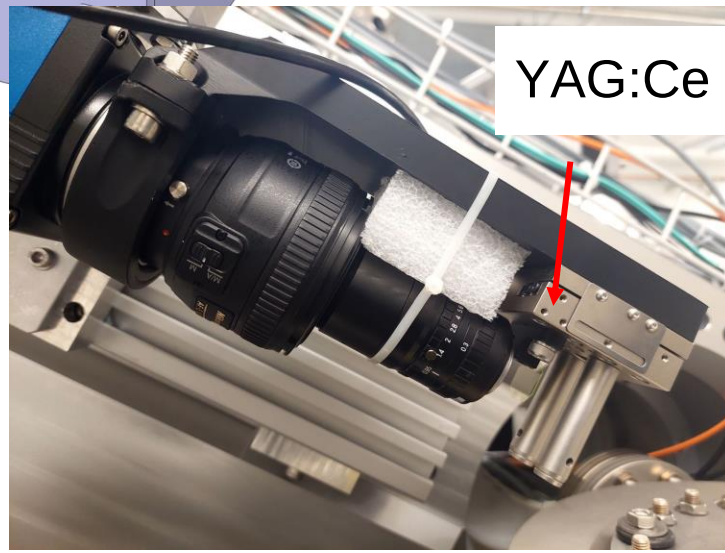
Soft X-ray spectrometer

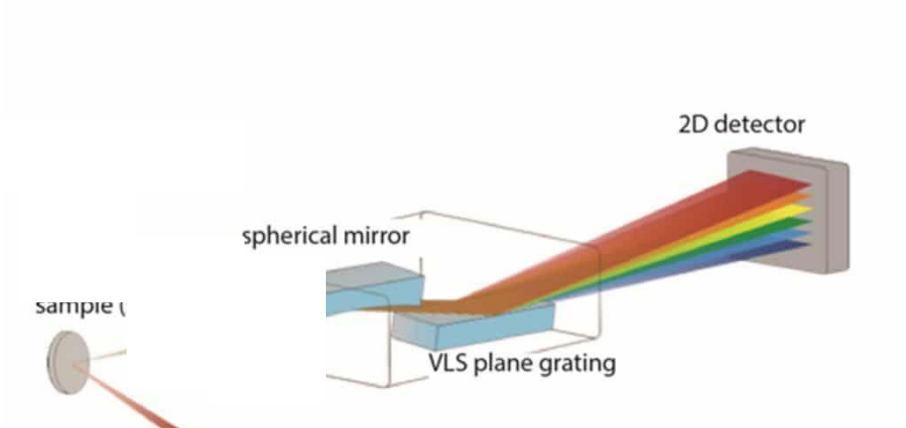




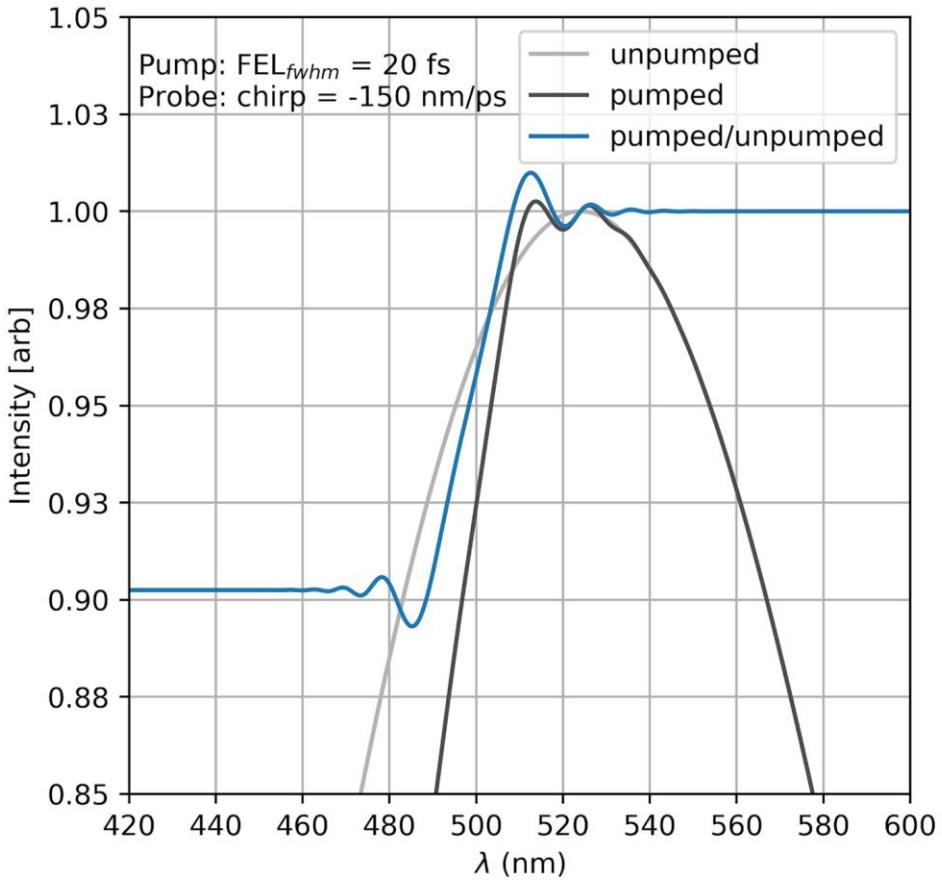


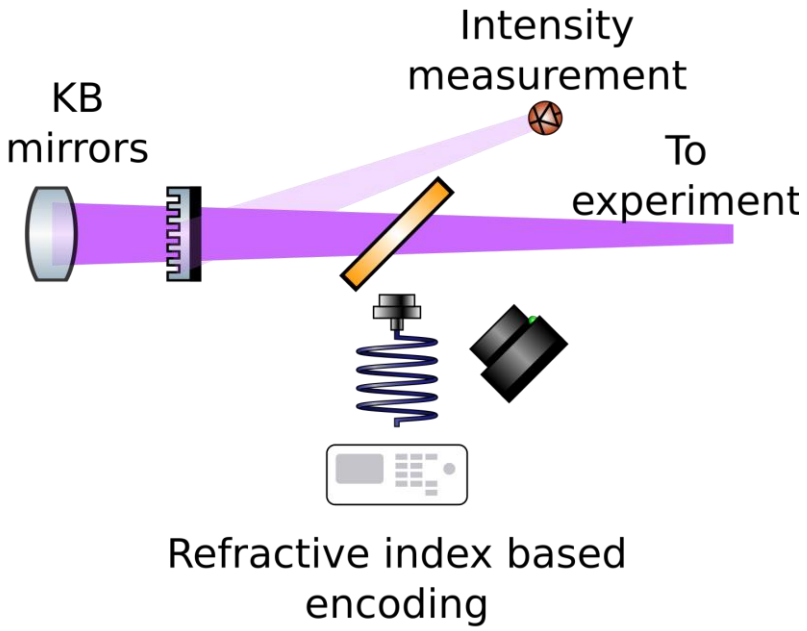






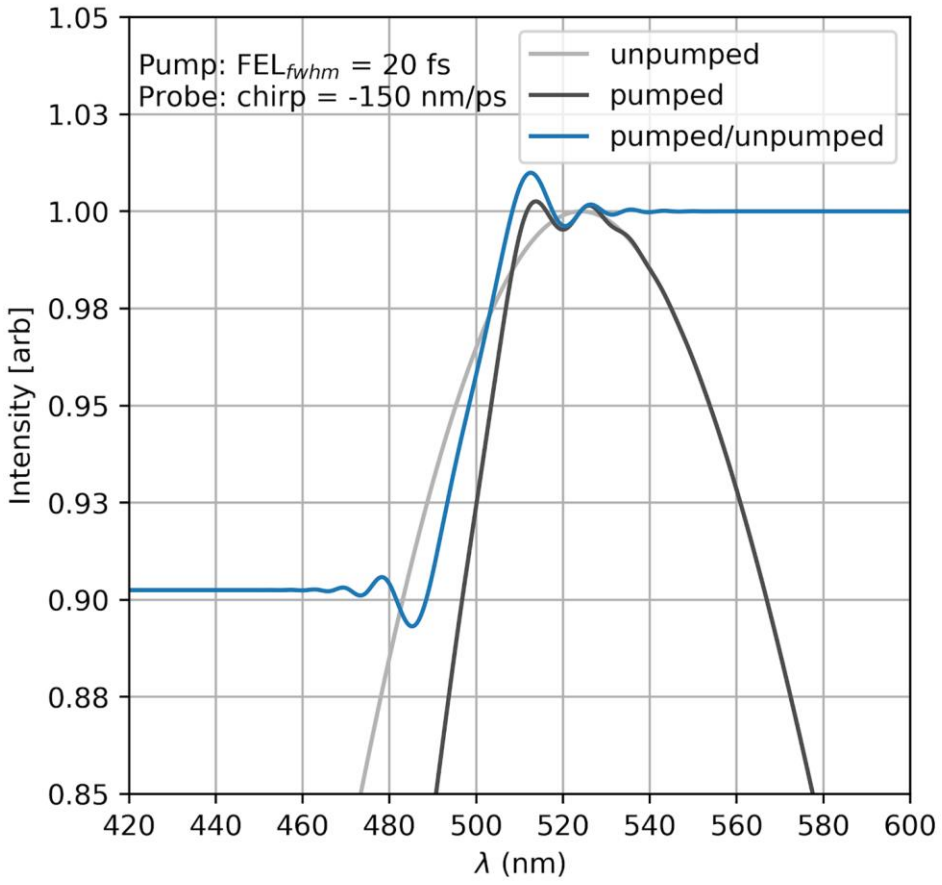
Photonics for diagnostics

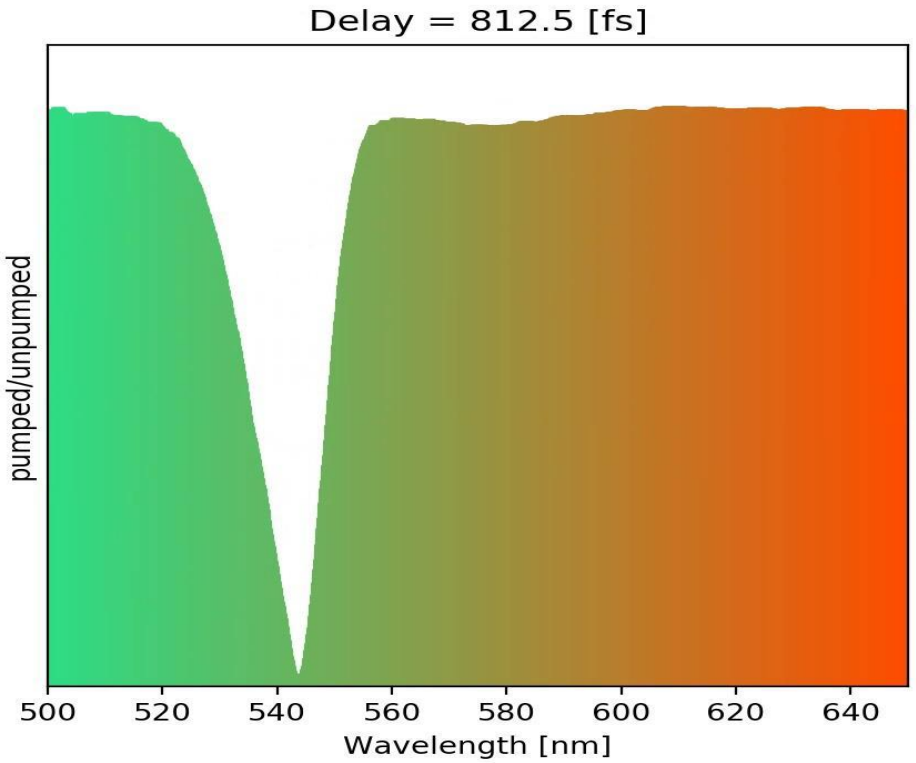




Endstation: Alvra **Device:** Spectral encoding **Groups:** Photon Diagnostics, Alvra, Bernina, Exp Laser, Scientific IT, Controls

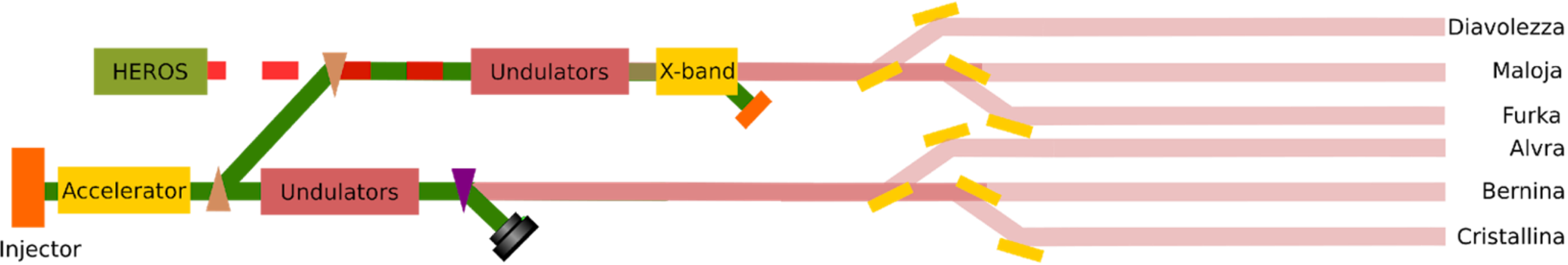
Photonics for diagnostics





Endstation: Alvra **Device:** Spectral encoding **Groups:** Photon Diagnostics, Alvra, Bernina, Exp Laser, Scientific IT, Controls

Horizon 2030+



Horizon 2030+

- The energy range of Porthos will bring new challenges:
  - Statistical and physical limit for high resolution online diagnostics
- 3 electron bunches more cross talk between beamlines
  - Standardized online diagnostic analysis critical
  - Large data flows need to be managed to avoid operator overload