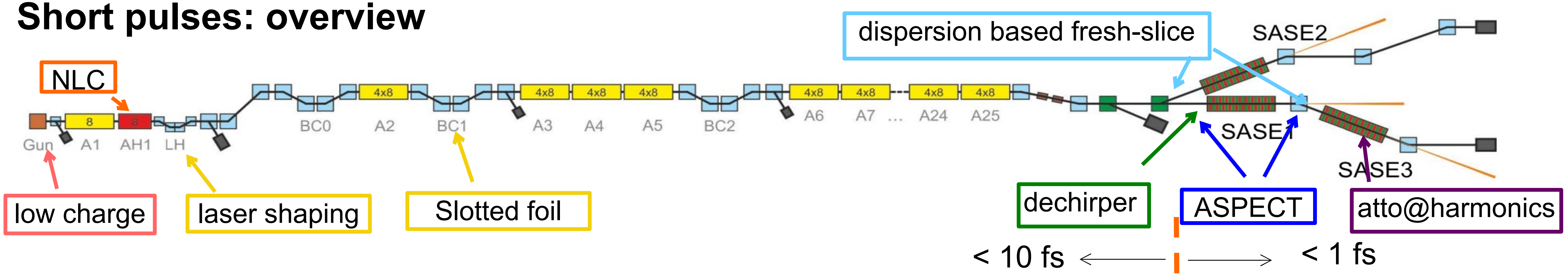
Project Overview for MDI
- ASPECT
- Beam shaping dechirper south
- Beam shaping dechirper north

Marc Guetg for FEL RD

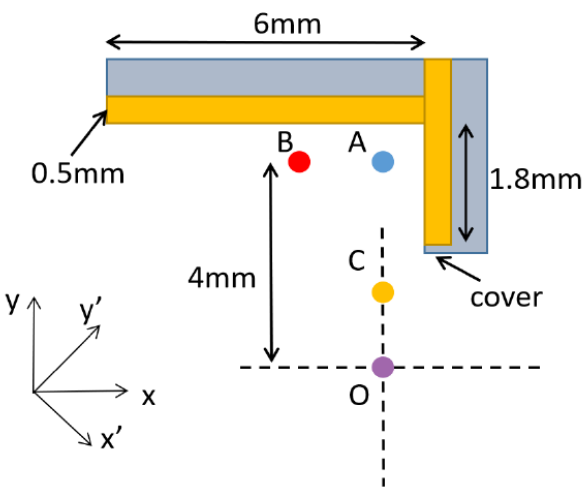
Short pulses: overview

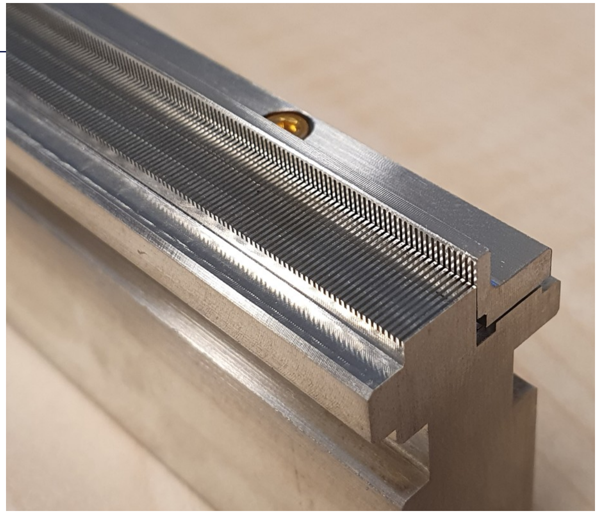


Technique	low charge	non-linear compression (NLC)	energy spread /emittance spoiler	wakefield based fresh-slice	dispersion based fresh-slice	ASPECT	atto@ harmonics
additional hardware	none	none	laser shaping / slotted foil	dechirper	none	laser + chicane +modulator	none
develop. stage	tested	delivered	under invest.	In develop.	delivered	in develop.	tested
operation influence	separate gun/ RF flattop	on separate RF flattop	affect all beamlines	for SA1/SA3	tested for SA2/3	for SA1/SA3	for SA3 only On separate RF flattop

Beam Shaping Dechirper

- Selective lasing suppression by creation of beam tilts (wakefield structure)
- Lasing window is selected by orbit within the undulator
- Kicker strength is defined by distance of the electrons to the yaw
- Structure is fully passive
- L-shape to
  - Kicks in both direction
  - Reduce higher order modes





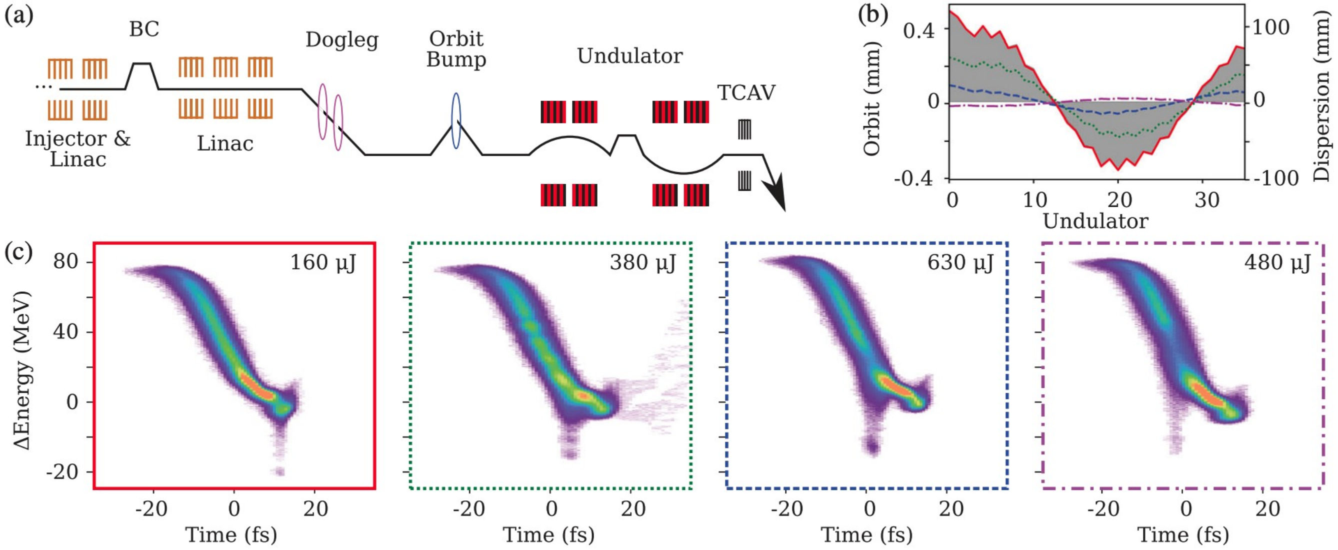
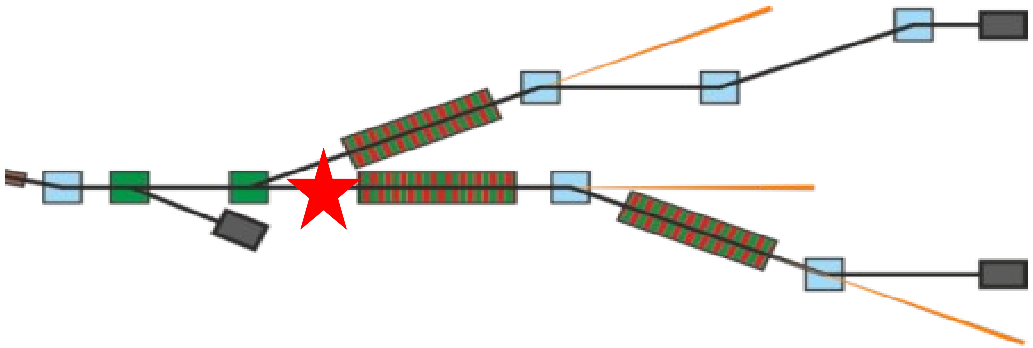


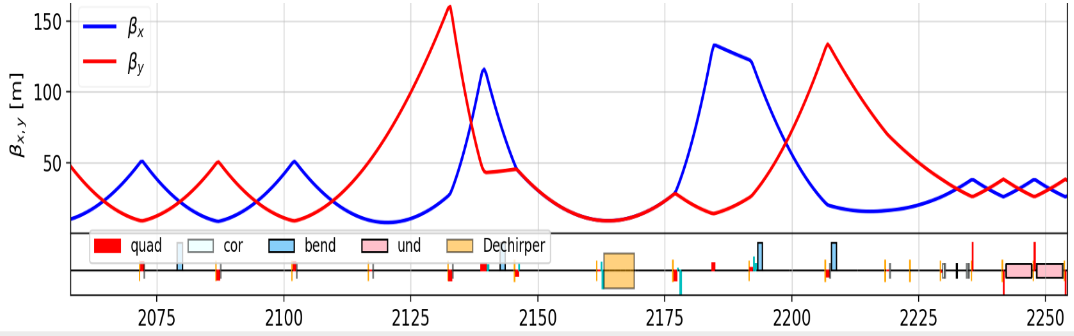
FIG. 1. (a) Schematic experimental setup for the LCLS. The electrons coming from the linac (left) are overcompressed in the last bunch compressor, followed by the last linac section adding both energy and chirp, which is followed by the dogleg, containing two tweaker quadrupole magnets (magenta) to control dispersion, followed by an orbit bump (blue) and the undulators (red and black). A transverse deflector following spectrometer allows direct longitudinal phase space measurements. (b) Dispersion (filled, gray) within the undulator with four different selected orbits leading to selective lasing within the electron beams shown in (c). Electron beam energy: 10.1 GeV, charge: 185 pC.

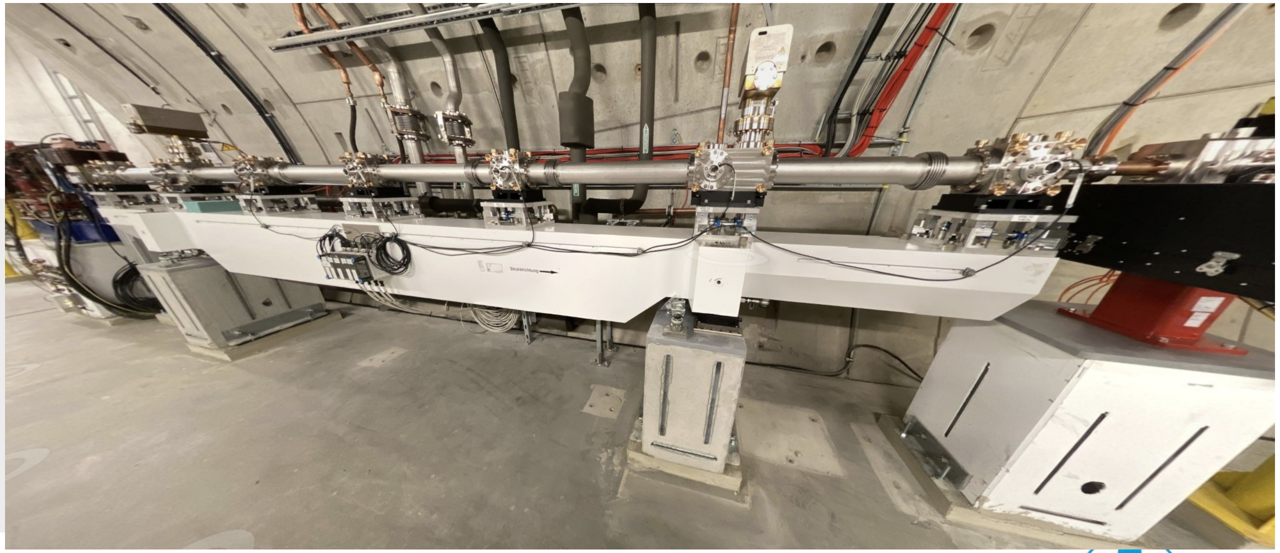
M. Guetg et al, Dispersion-Based Fresh-Slice Scheme for Free-Electron Lasers, 10.1103/PhysRevLett.120.264802

Lattice Layout

- The hardware was installed this winter
  - Currently in commissioning
- Requires special optics
  - Not detrimental to lasing performance
  - We are considering to switch to this as the new normal optics
- Requires orbit control
- Operation in one or both planes
  - Quad wakes can be switched on/off

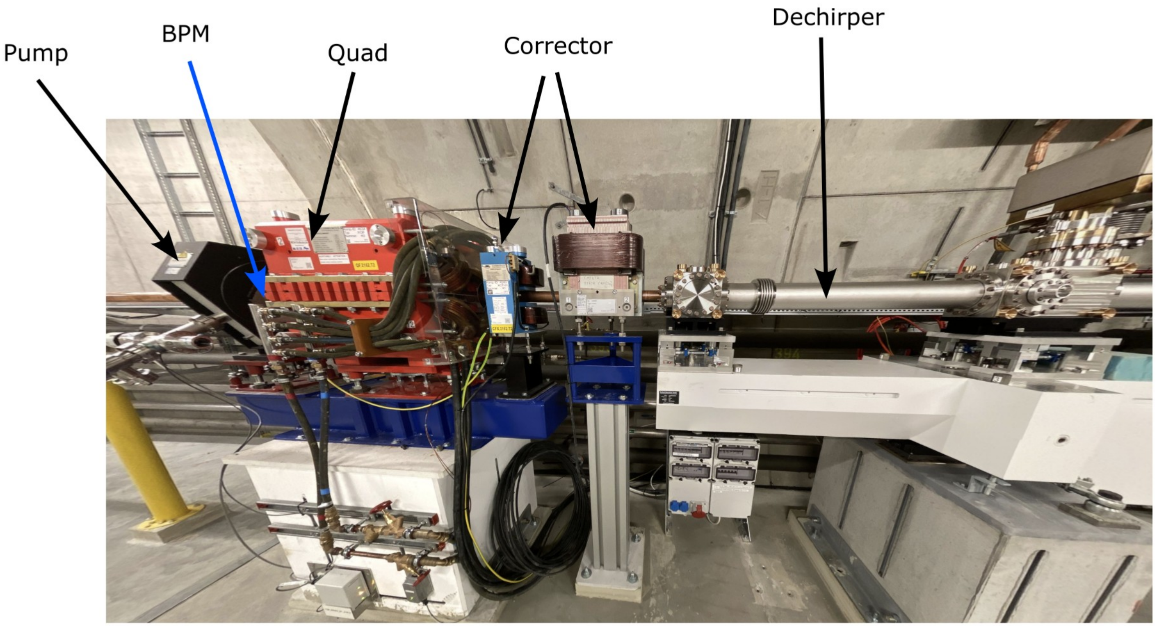


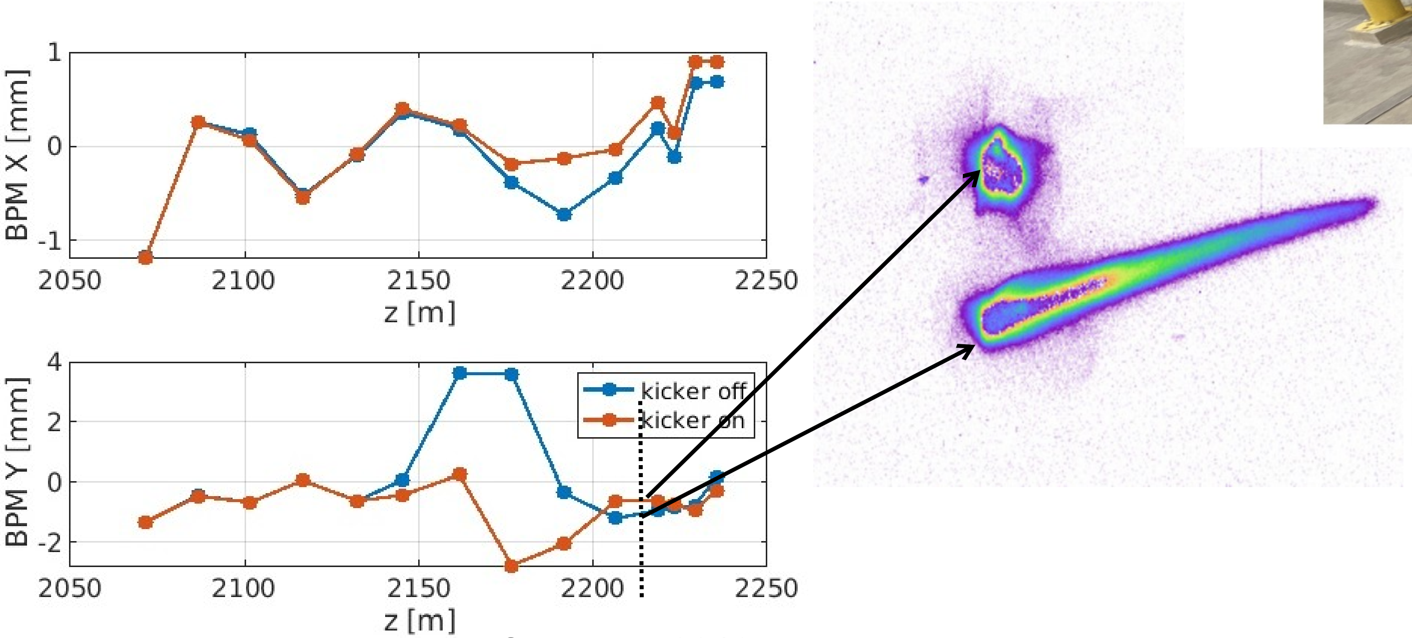




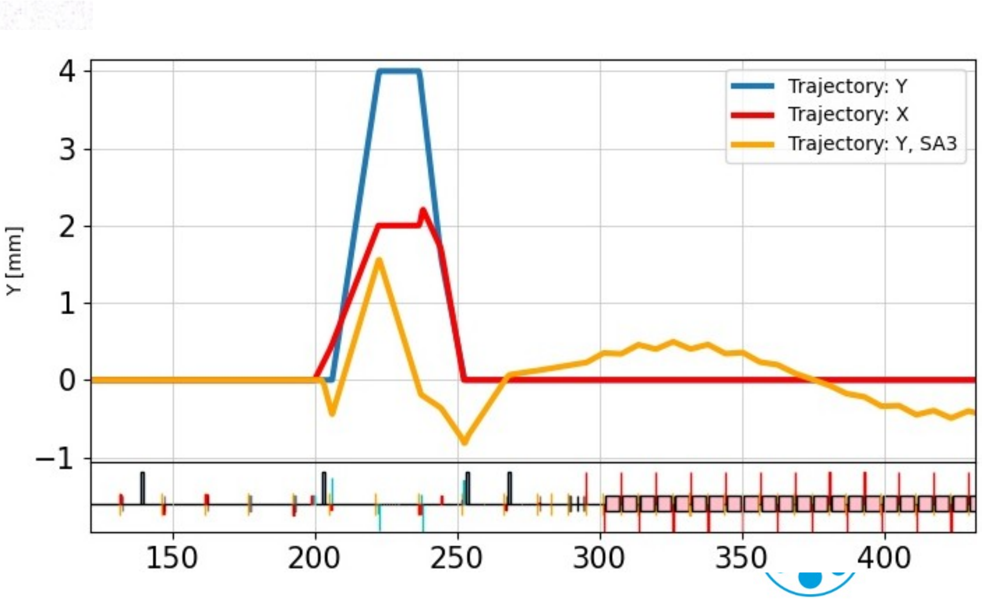
Orbit control

- Location allows pulses for both hard and soft X-rays
- Kicker system allows parallel operation of streaked and unstreaked pulses in the same pulse train





Screen at 2212m



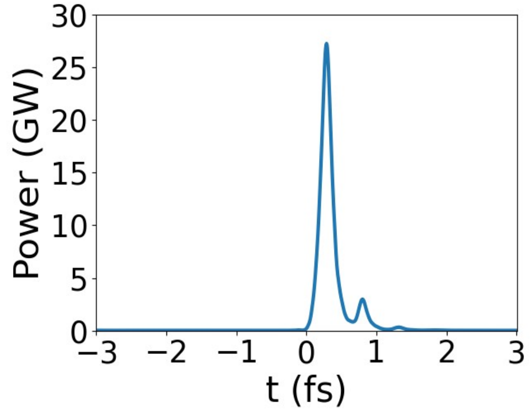
Beam Shaping Dechirper (South)

- Beam shaping dechirper (North) is installed and we are commissioning it
- A follow up dechirper is likely to be installed in the following years (not a project yet)
- We plan to learn from our experiences and apply them towards the new dechirper, a few things which we are likely to change:
  - Movable support of the structure
  - No kicker system
  - BPM placement
- Furthermore, we are considering more diagnostic dechirpers
  - Not a project yet and still in the design phase

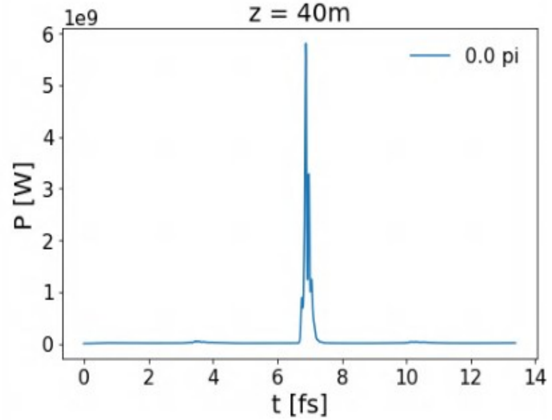
Atto-Second Pulses with eSASE and Chirp/Taper (ASPECT)

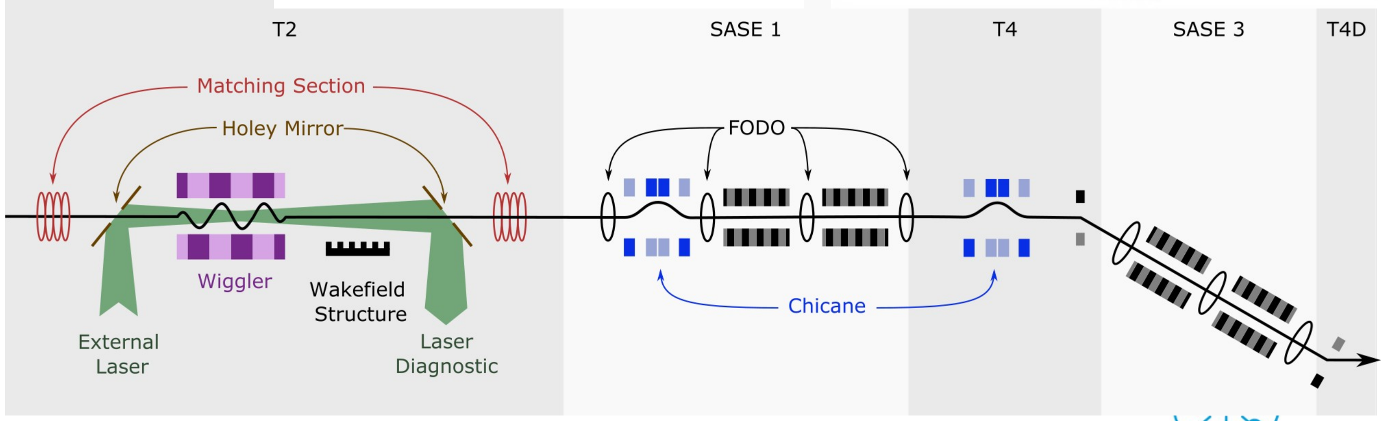
- Variety of science cases
  - Charge migration in molecules after core ionization
  - X-ray diffraction at population inversion
- Offers various operation modes for both HXR and SXR
  - Isolated atto-second spikes
  - Upon minor upgrade: two color production with variable delay, incl. zero crossing
- Laser system could potentially be used for
  - External seeding
  - Enhanced self-seeding
  - Similar capability for SASE2
- Investigation of laser less options
  - Compression based
  - Cathode shaping

700 eV FWHM <200as



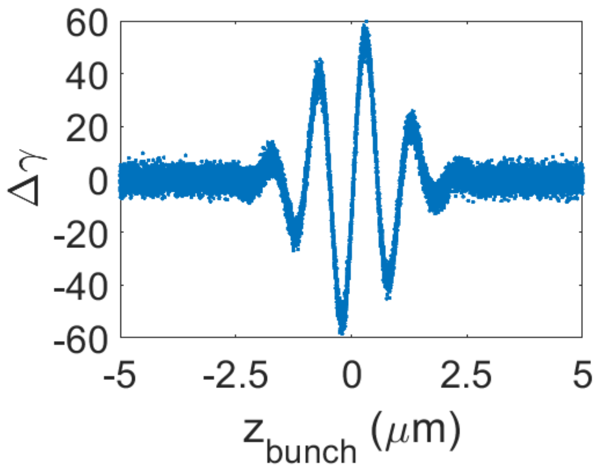
6 keV FWHM <100as



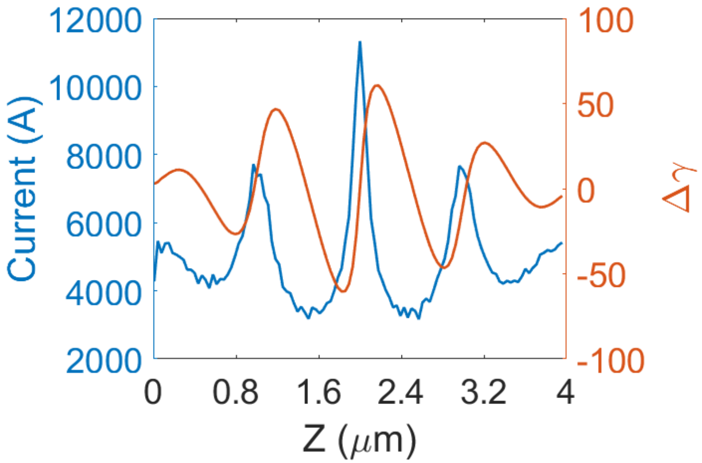


Chirp/taper and eSASE

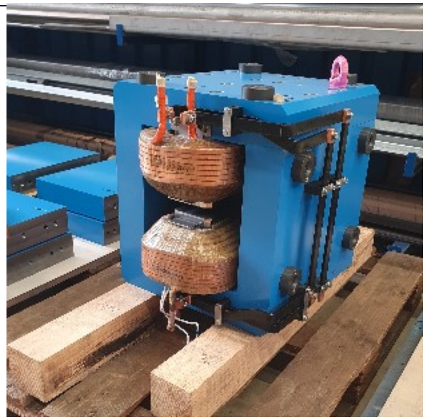
- Chirp/taper
  - Modulate the electron beam
  - Follow the chirp with the taper of the undulator
    - ► lasing is suppressed at other places along the pulse



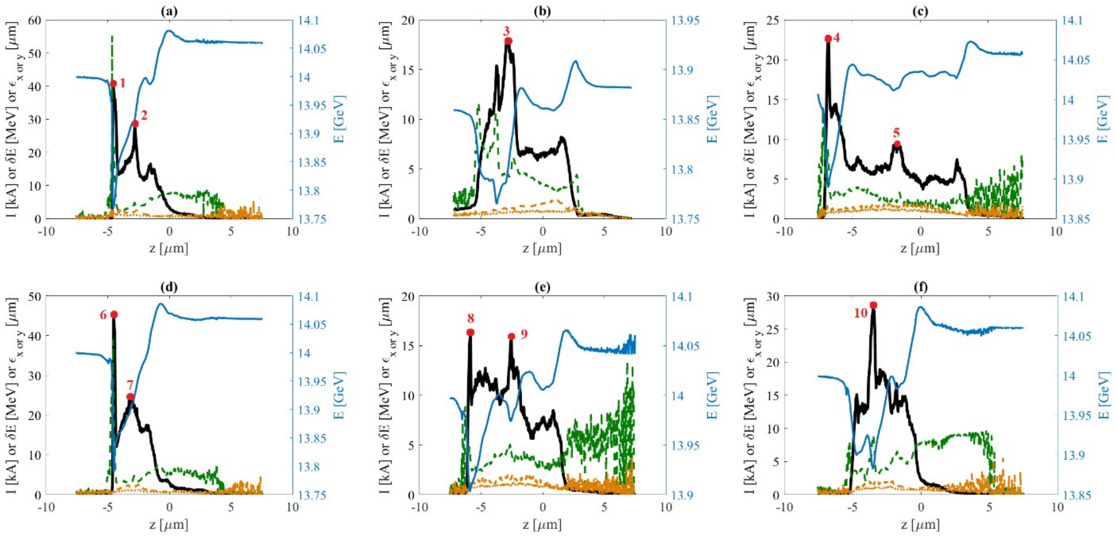
- eSASE
  - Compress the beam for strong current spike
  - Enhances lasing process
  - Further increase the chirp (Longitudinal space charge)



Laserless options

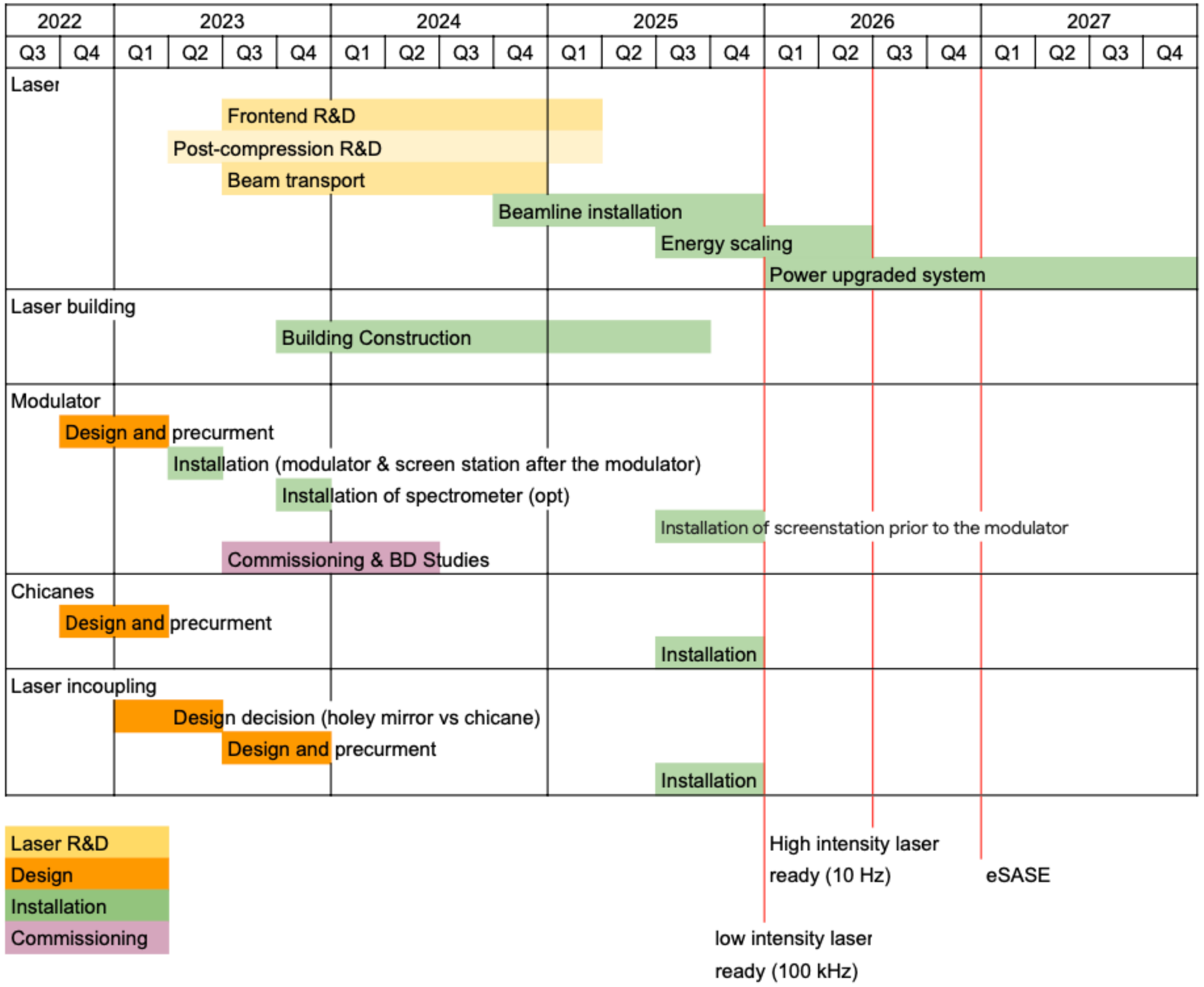


- The laser system
  - Drives the cost of the project
  - Responsible for the majority of the risk
- Self-compression and self-modulation methods
  - The modulation comes from the beam itself
- Early installation of modulator this summer
  - Perform BD test on laserless options
  - Not directly for short pulse production



Current Spike Nr.	I [kA]	ΔE [MeV]	Δs [μm]	ΔE/Δs [MeV/μm]	δE [MeV]
1	41	50	0.6	83	14
2	27	30	0.4	75	4.6
3	18	90	1.0	90	4.9
4	22	30	0.3	100	7.0
5	9	10	1.1	9	2.2
6	45	70	0.4	175	15
7	22	100	1.7	59	3.3
8	16	10	0.3	33	3.6
9	16	10	0.5	20	4.2
10	29	40	0.7	57	9.0

Timeplan

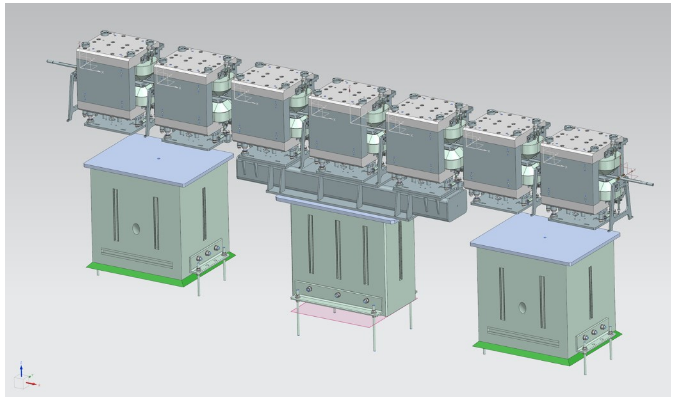

2022
2023
2024
2025
2026
2027
Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4
Laser
Frontend R&D
Post-compression R&D
Beam transport
Beamline installation
Energy scaling
Power upgraded system
Laser building
Building Construction
Modulator
Design and precurment
Installation (modulator & screen station after the modulator)
Installation of spectrometer (opt)
Installation of screenstation prior to the modulator
Commissioning & BD Studies
Chicanes
Design and precurment
Installation
Laser incoupling
Design decision (holey mirror vs chicane)
Design and precurment
Installation
Laser R&D
Design
Installation
Commissioning
High intensity laser
ready (10 Hz)
eSASE
low intensity laser
ready (100 kHz)

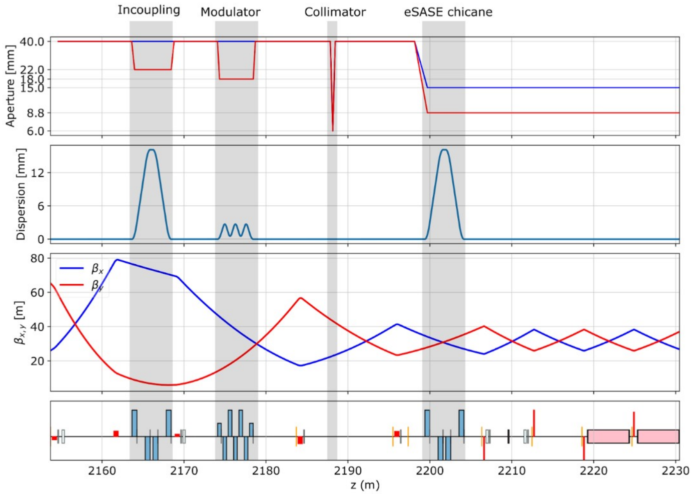
Hardware requirements (not including diagnostics)

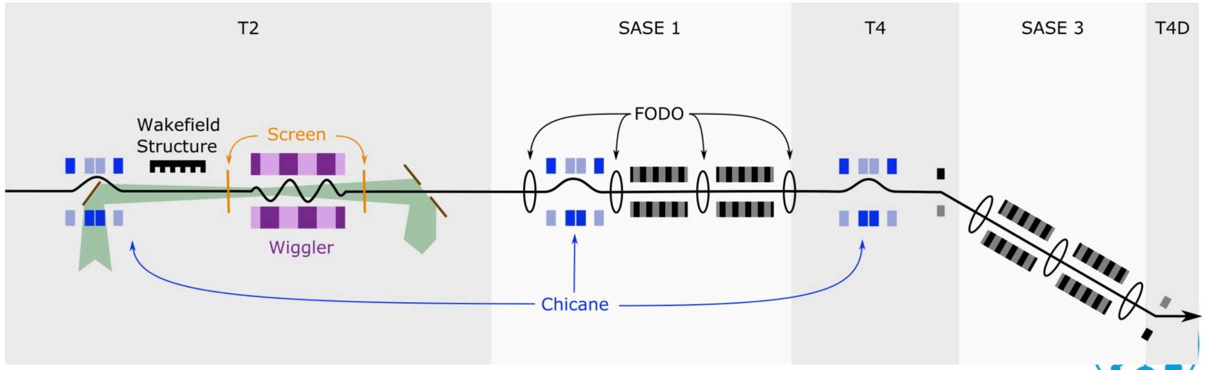
- Modulator
  - Installation hopefully this summer
  - Electromagnetic modulator
  - Investigation self-modulation
  - At later stage, also cathode shaping (Nepal)

- Laser transport
  - Laser room above ground
  - Either incoupling chicane or holey mirror
  - Laser dumping on a fixed gap collimator (+ reflected beam outcoupling)

- Chicanes
  - eSASE and compensation chicane
  - Already existing design







Required Diagnostic

- IR Spectrometer in the range from 1100 - 2200 nm (MDI, ASAP)
  - After the modulator (specific location needs to be evaluated)

- Two YAG screen for laser/electron alignment surrounding the wiggler (MDI, 2025)
  - 1030 nm laser beam & electron beam (roughly 40 um)
  - Priority to the downstream screen

- Outcoupling of the spent laser beam (MVS, FS-LA, 2025)

- Temporal electron and photon diagnostic
  - Partly available (X-ray spectrometer, wakefield structure)
  - Partly under investigation (X-ray streak, additional wakefield structures)

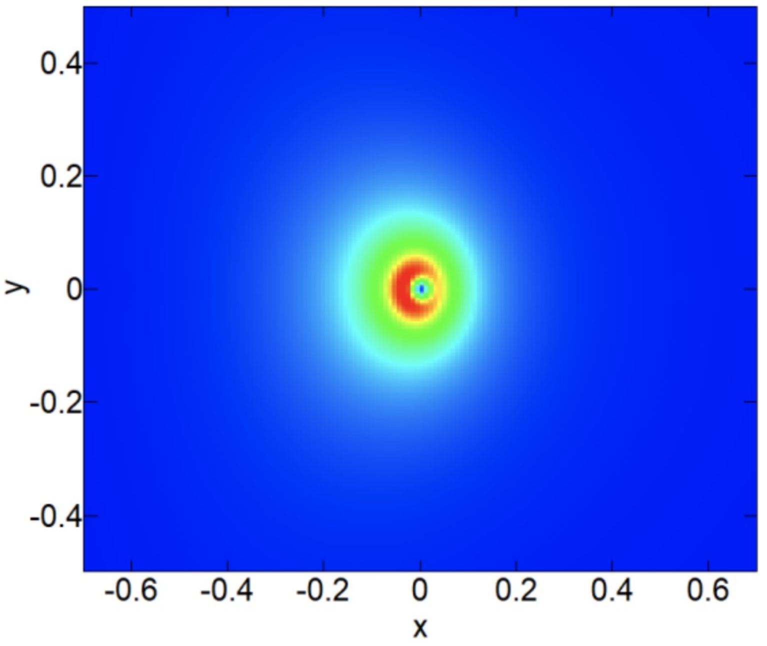
Spectrometer

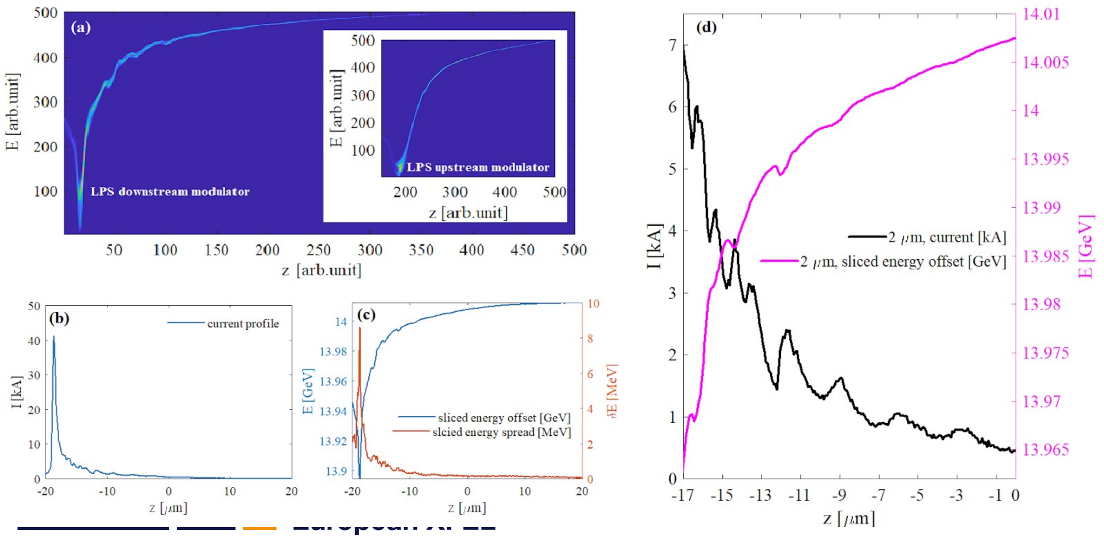
- Wavelength range of modulator
  - We can reach a maximum wavelength of about 1700 nm at 16.3 GeV (longer at lower energies)

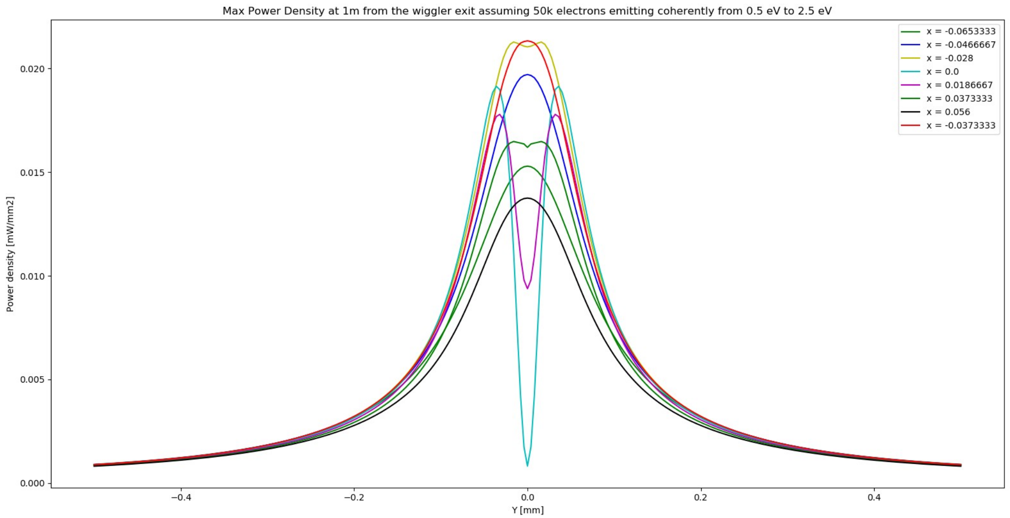
- We have slight preference to the right one (NIR-II)

Parameter		TG-cooled NIR-I C9913GC	TG-cooled NIR-II C9914GB	Unit
Spectral response range		900 to 1700	1100 to 2200	nm
Spectral resolution (FWHM)*2	Typ.	5	6	nm
	Max.	7	8	nm
Wavelength reproducibility*3		-0.2 to +0.2	-0.4 to +0.4	nm
Wavelength temperature dependence		-0.02 to +0.02	-0.04 to +0.04	nm/°C
Spectral stray light*2 *4		-35 max.	-35 max.	dB

Single Electron emission

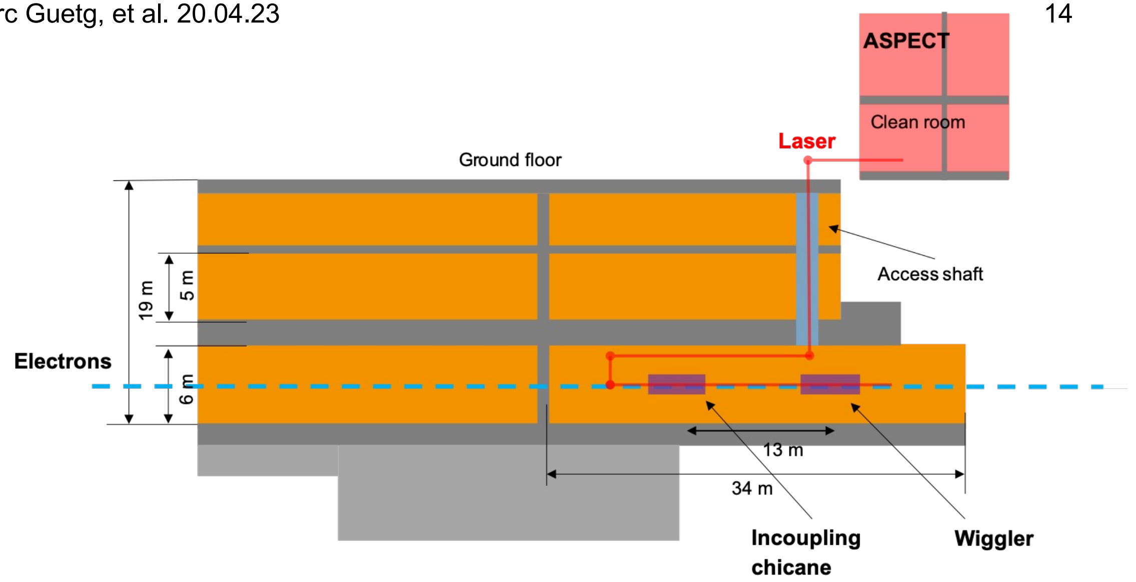


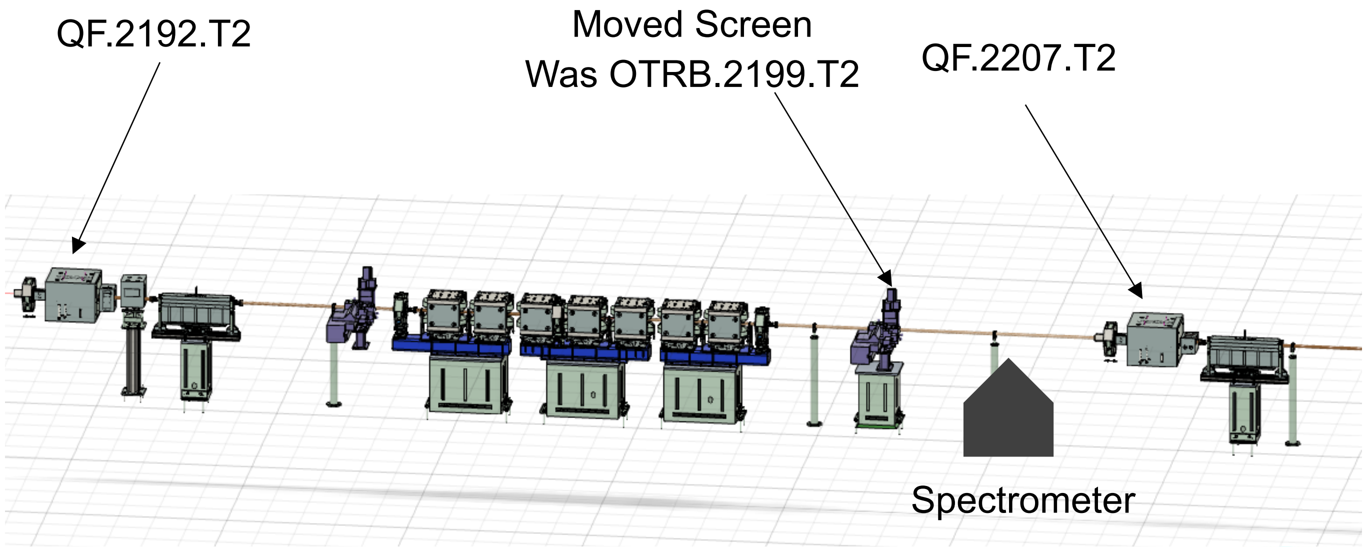




Layout (in the tunnel)

T2	XTD2_001	QF.2192.T2	QF.4.T2	0,5321	2169,19	342,99024
T2	XTD2_001	CFX.2192.T2	CFX.5.T2	0,1	2169,66	343,46024
T2	XTD2_001	CMY.2192.T2	CMY.2.T2	0,3	2170,01	343,814188
T2	XTD2_001	KL.2193.T2	KL.2193.T2	0,93	2170,88	344,683138
T2	XTD2_001	OTRB.2195.T2	OTRB.T2	0	2172,61	346,41324
T2	XTD2_001	XBP.2196I.T2	XBP.1.T2	0,44	2173,43	347,23324
T2	XTD2_001	XBP.2196II.T2	XBP.2.T2	0,44	2174,08	347,88324
T2	XTD2_001	XBP.2197.T2	XBP.3.T2	0,44	2174,73	348,53324
T2	XTD2_001	XBP.2198I.T2	XBP.2.T2	0,44	2175,38	349,18324
T2	XTD2_001	XBP.2198II.T2	XBP.3.T2	0,44	2176,03	349,83324
T2	XTD2_001	XBP.2199.T2	XBP.2.T2	0,44	2176,68	350,48324
T2	XTD2_001	XBP.2200.T2	XBP.1.T2	0,44	2177,33	351,13324
T2	XTD2_001	OTRB.2202.T2	OTRB.T2	0	2179,45	353,25324
T2	XTD2_001	BPMA.2206.T2	BPMA.T2	0	2183,71	357,51524
T2	XTD2_001	QF.2207.T2	QF.5.T2	0,5321	2184,19	357,99024





Summary

- Beam shaping dechirper north
  - Is in the commissioning phase
  - Currently all diagnostic requirements are met

- Beam shaping dechirper south
  - Design is not matured yet
  - There is the idea to install it in a few years (likely during the ‘25 shutdown)
  - There might be more diagnostic dechirpers installed in the same timeframe

- ASPECT
  - Modulator will (likely) be installed this summer
    - ► Would strongly benefit from spectrometer
  - The rest of the electron hardware will be installed in the ‘25 shutdown
    - ► Installation of the YAGs and the laser outcoupling
  - Actual laser incoupling might come at a later date