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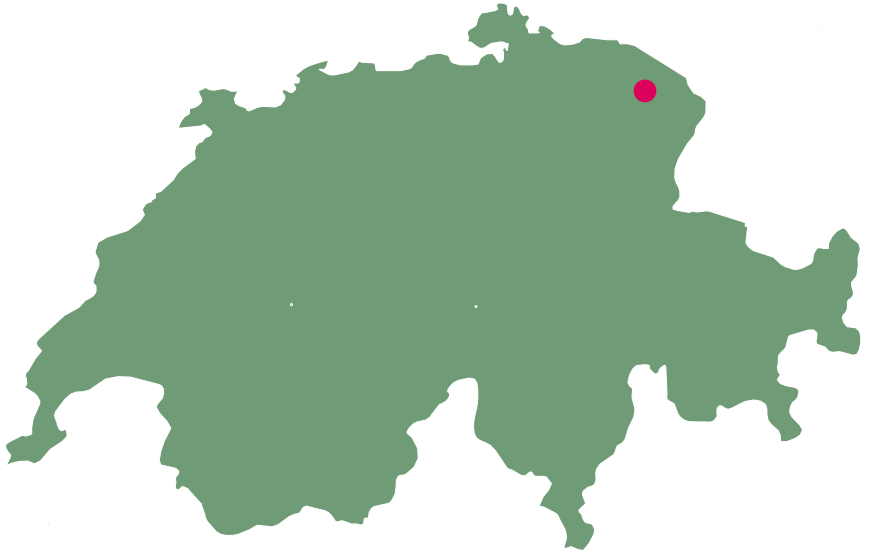


simplemaps.com/svg/country/ch#all

EPFL

EuPRAXIA Preparatory Phase

PSI

Rasmus Ischebeck

Diagnostics & Instrumentation

Paolo Craievich

Fabio Marcellini

Radio Frequency Systems

Sven Reiche

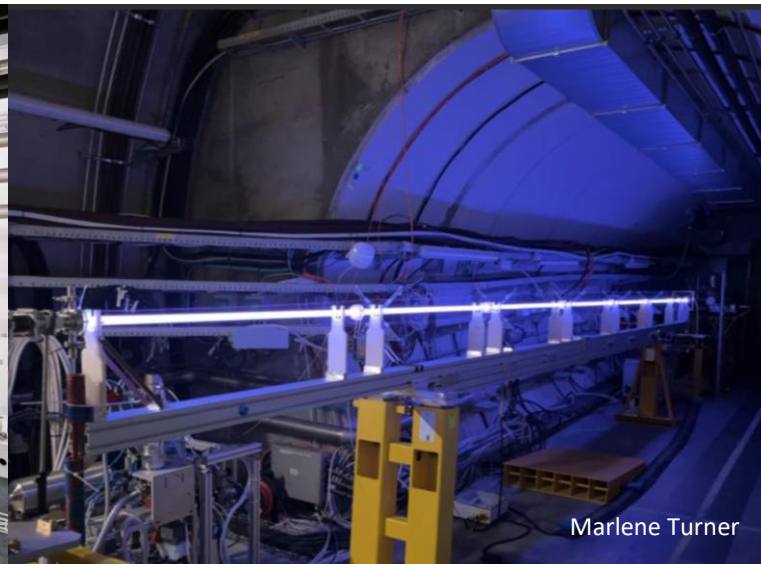
Eduard Prat

Beam Dynamics

Mike Seidel

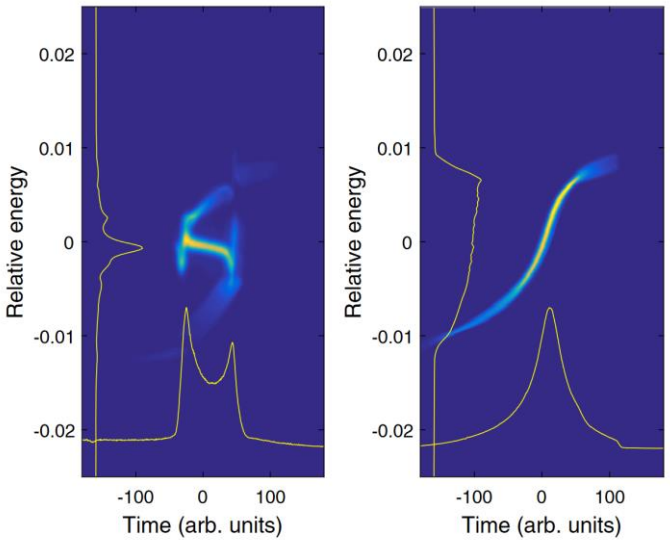
Large Research Facilities

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101079773

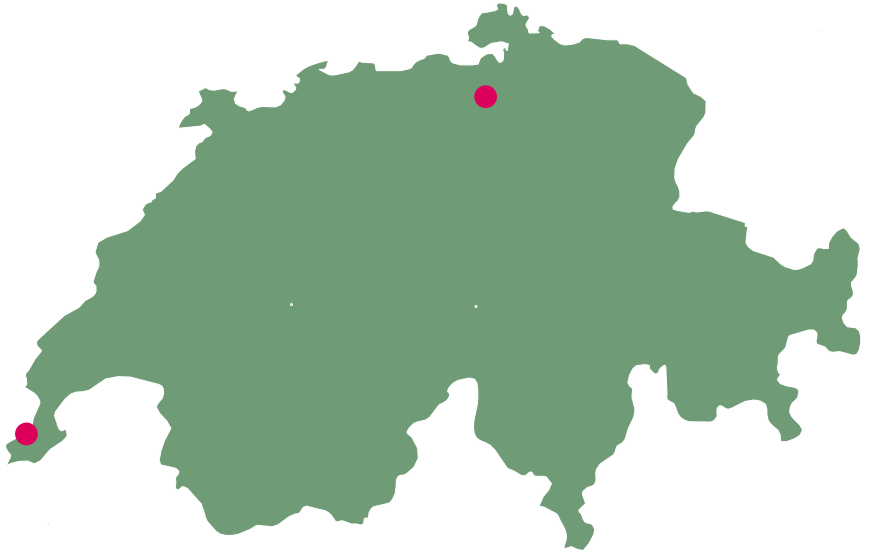


~ 30 MV/m

~ 1000 MV/m



Demonstration of Large Bandwidth Hard X-Ray Free-Electron Laser Pulses at SwissFEL, Prat, et al.



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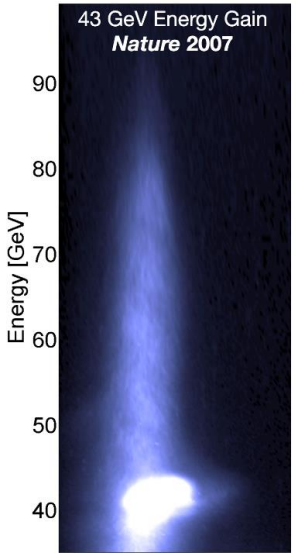
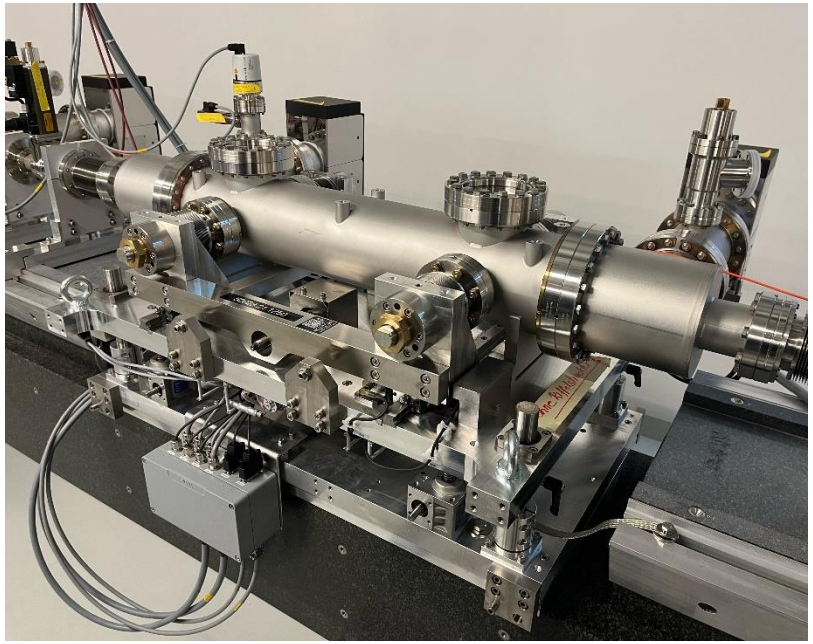
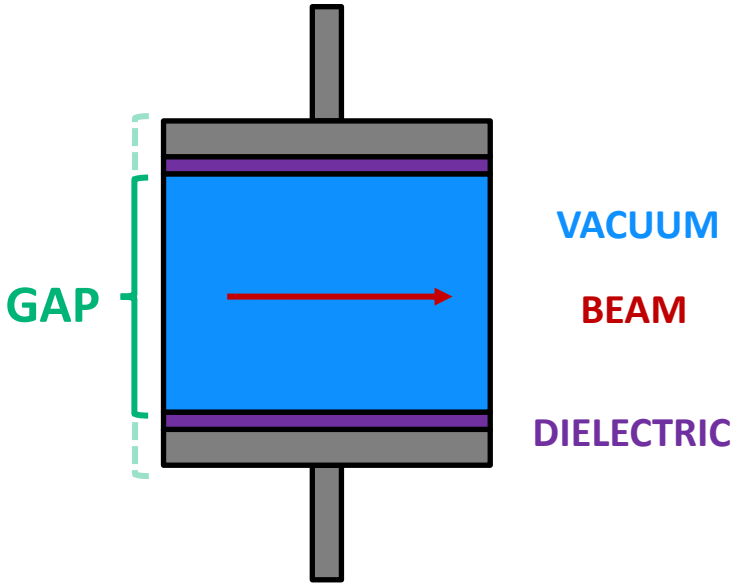
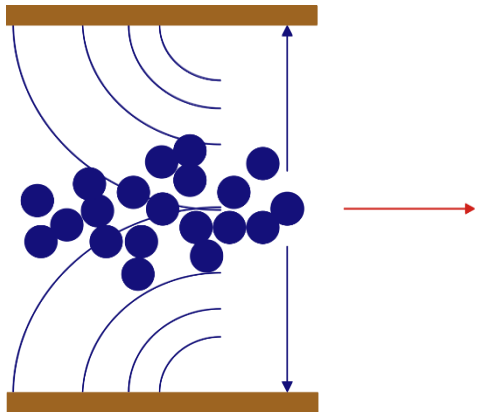


Energy doubling of 42 GeV electrons in a metre-scale plasma wakefield accelerator, Blumenfeld, at al.

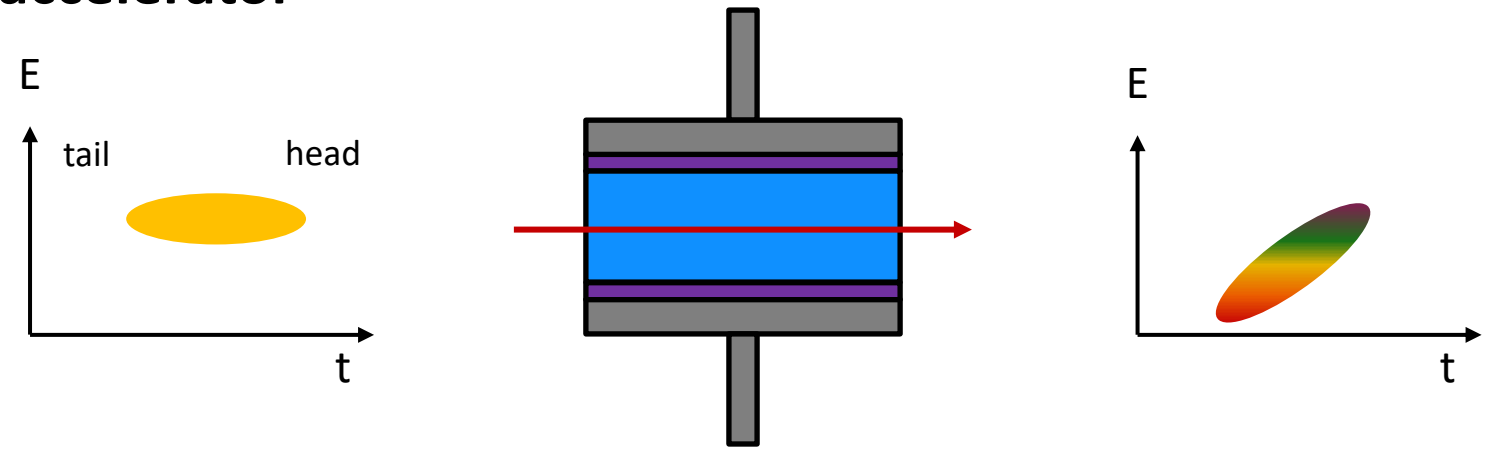



GAP
VACUUM
BEAM
DIELECTRIC

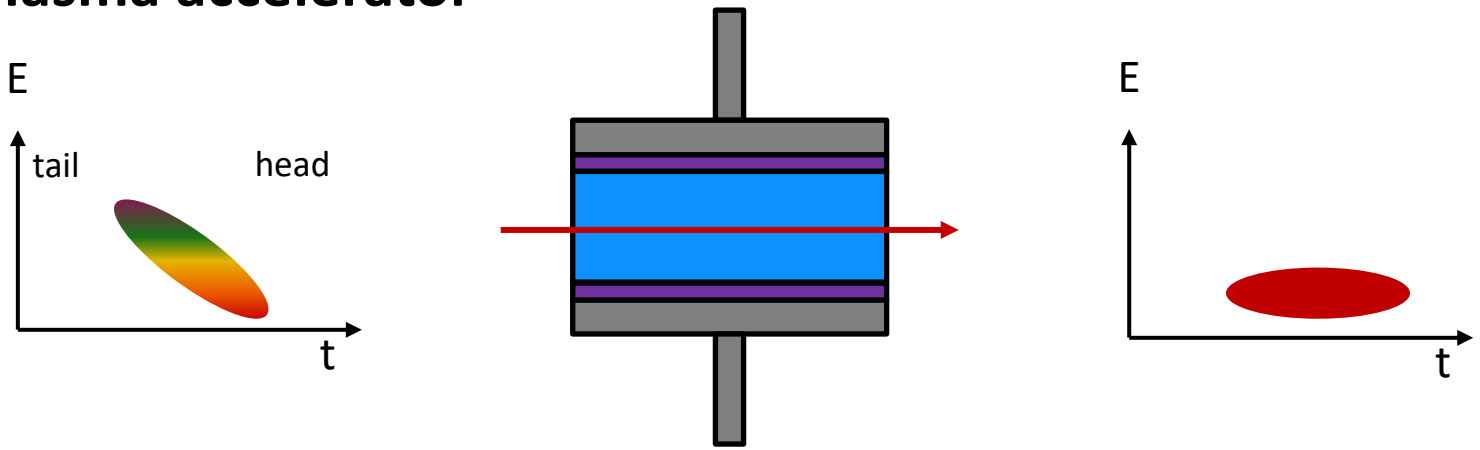


The effect of the wakefield structure depends on the input

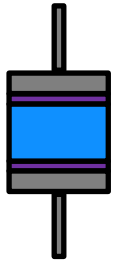
Chirping for RF accelerator

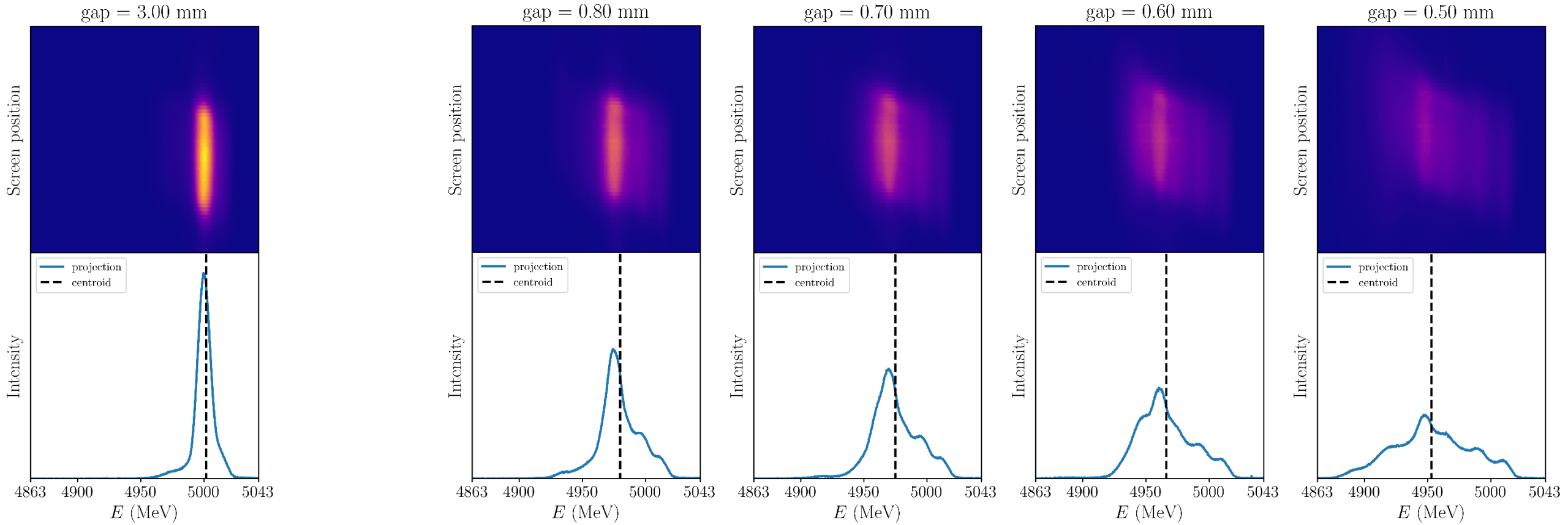


Dechirping for plasma accelerator

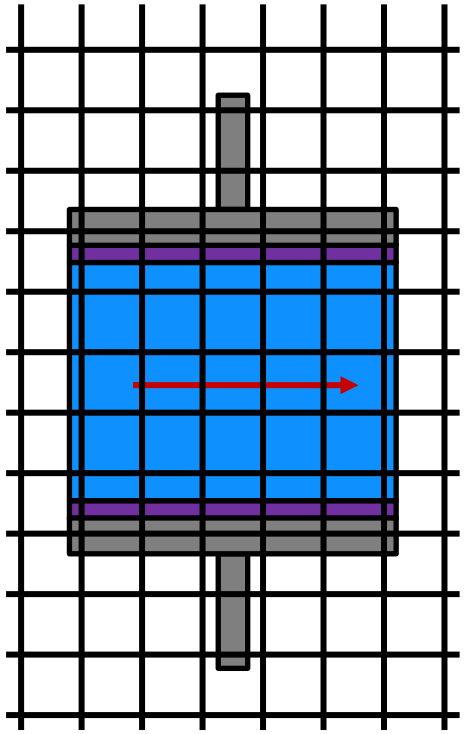


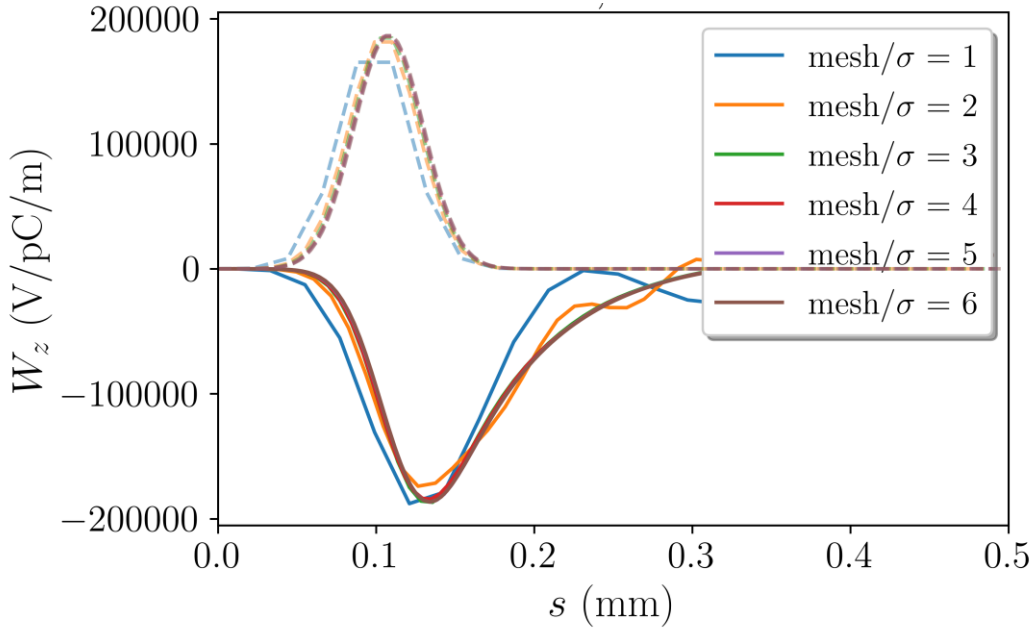
The wakefields change both the energy spread and centroid energy





5 mesh elements per σ produces accurate wake potentials

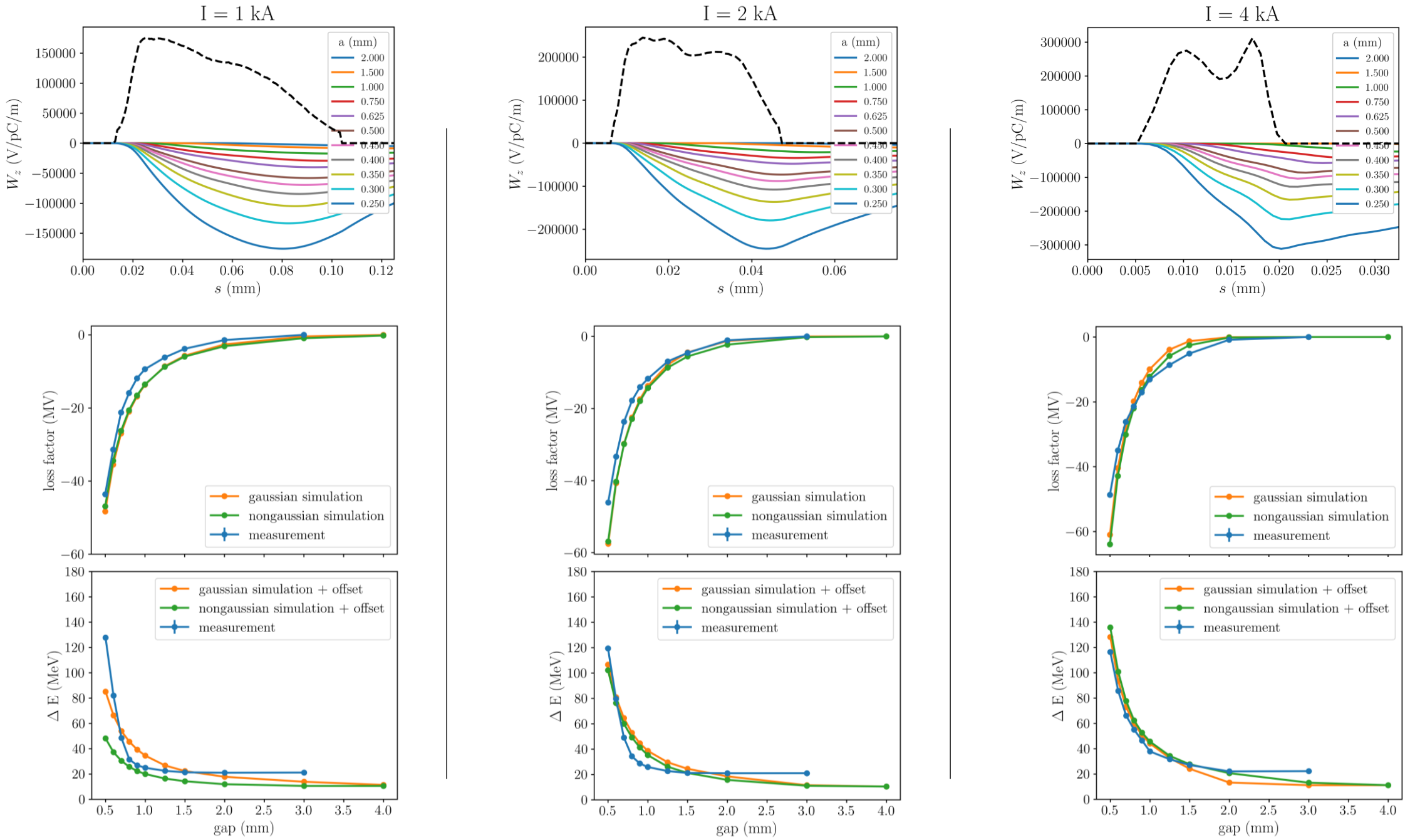




Mesh setting determines how accurately the

1. Source
2. Boundaries
3. Electromagnetic fields

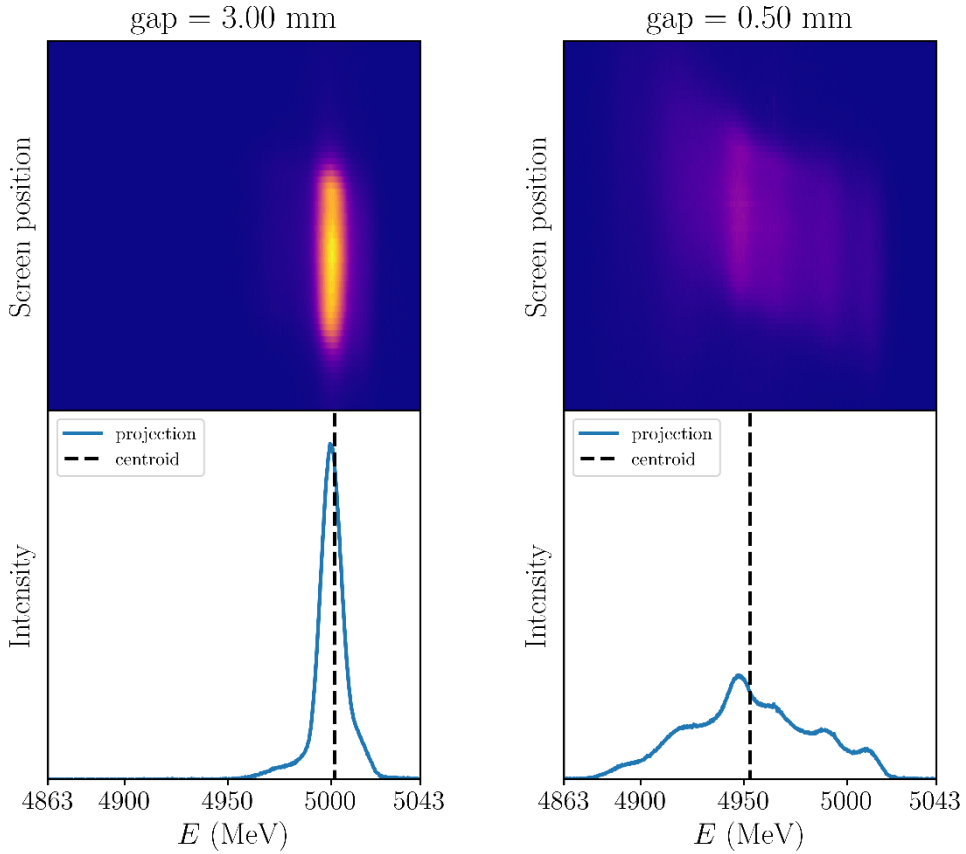
are represented in the simulation

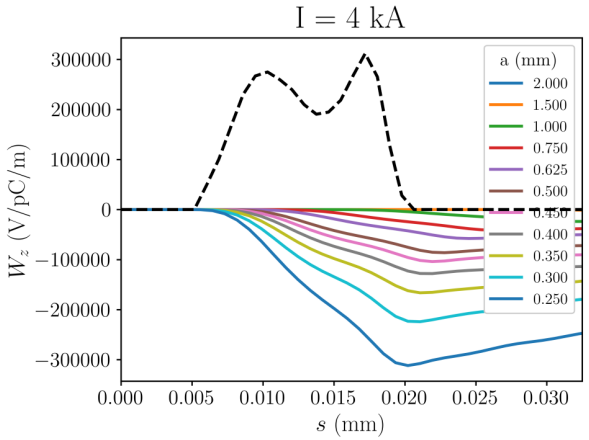

I = 1 kA
I = 2 kA
I = 4 kA
a (mm)
2.000
1.500
1.000
0.750
0.625
0.500
0.450
0.400
0.350
0.300
0.250
W_z (V/pC/m)
s (mm)
loss factor (MV)
gaussian simulation
nongaussian simulation
measurement
Δ E (MeV)
gaussian simulation + offset
nongaussian simulation + offset
measurement
gap (mm)

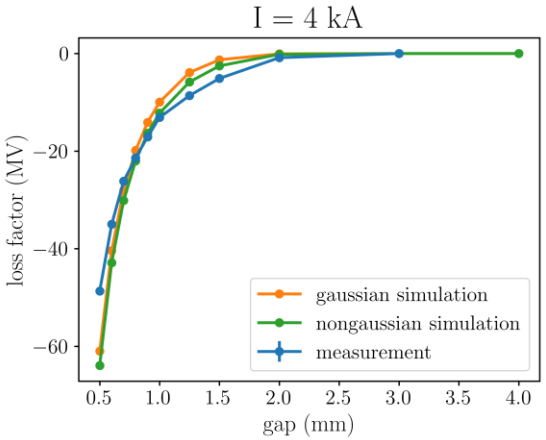
Conclusion

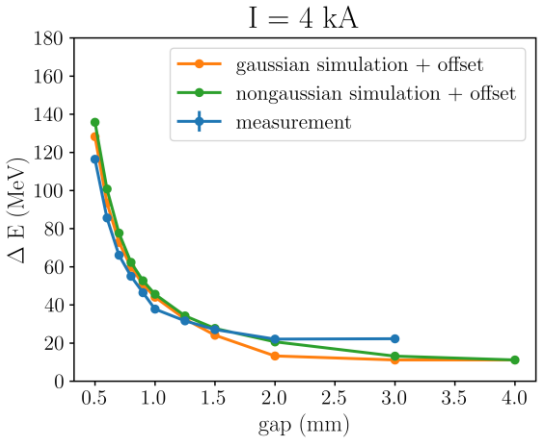
We have demonstrated the manipulation of the longitudinal phase space of beams from a conventional accelerators using a wakefield structure

I think we should use wakefield structures to control the energy spread of future particle accelerators







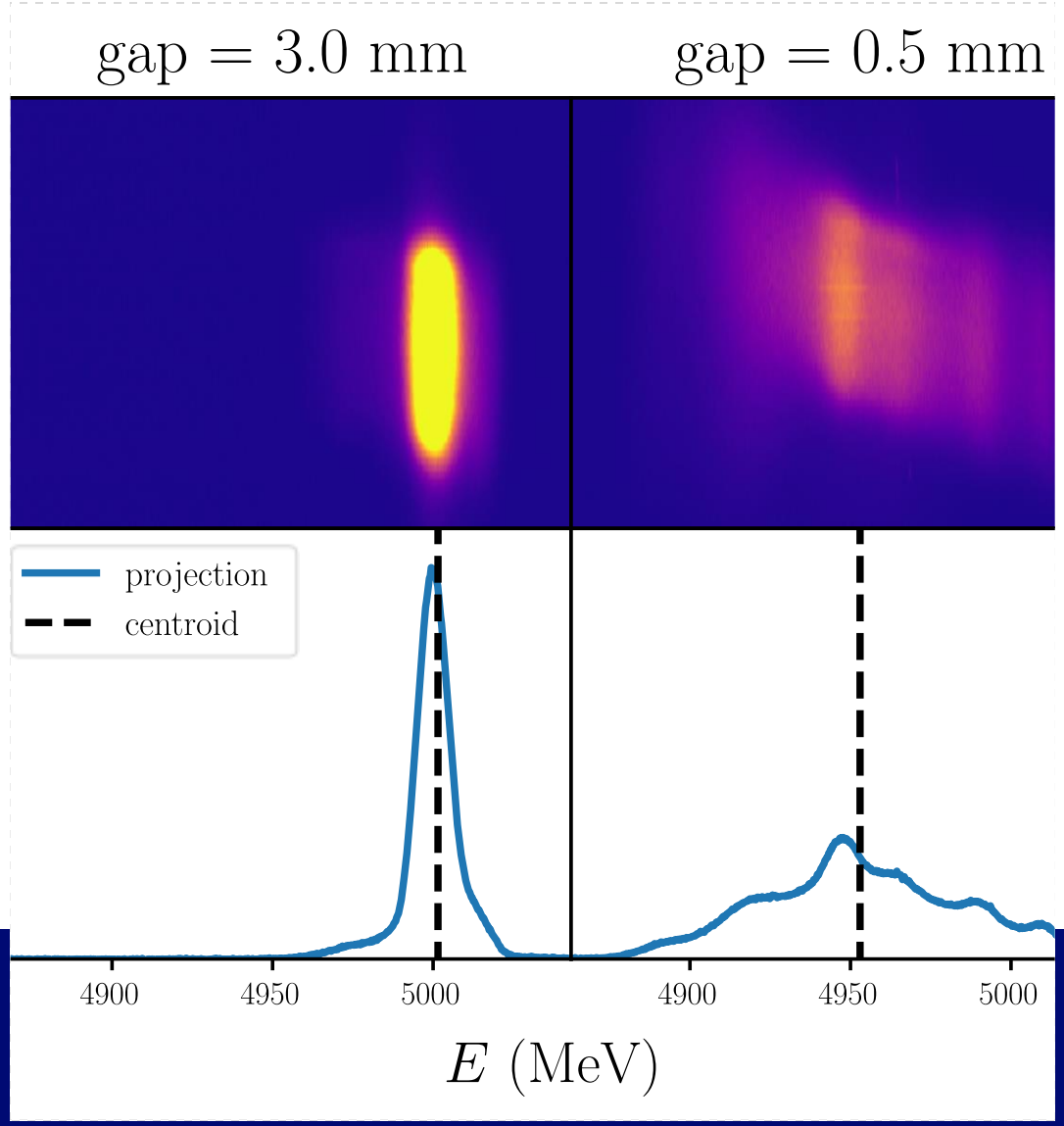


Extra slides

PSI Center for Accelerator Science and Engineering

EPFL

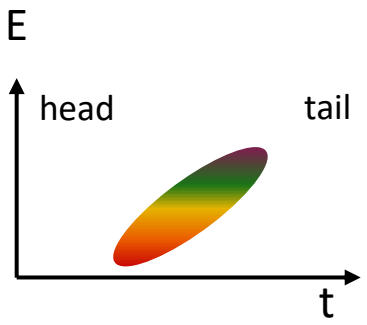
Controlling the electron beam energy at SwissFEL

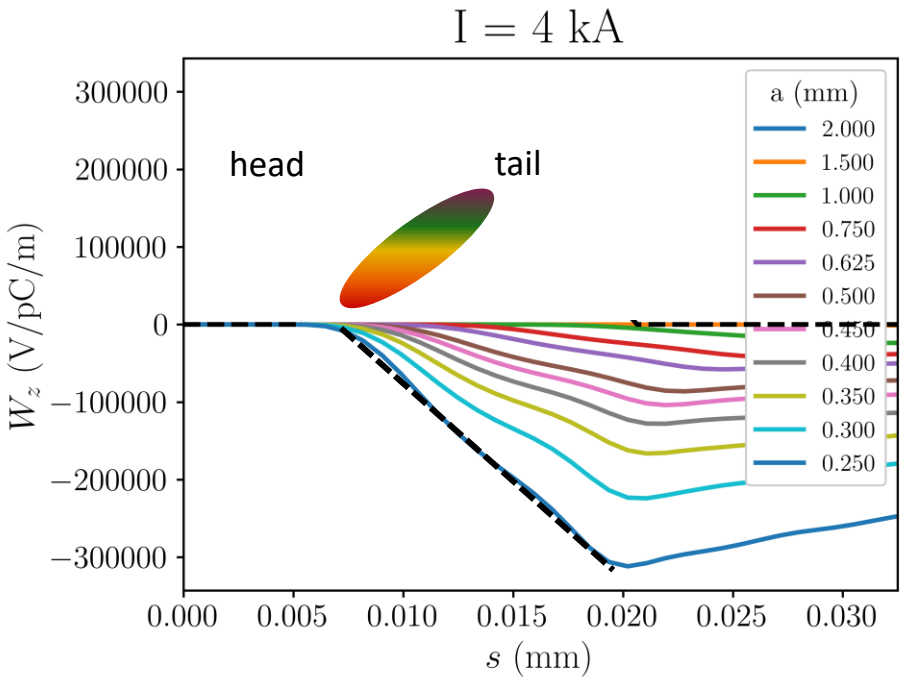


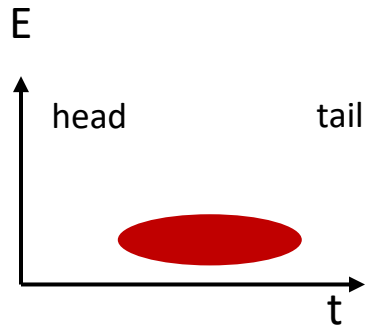
Evan Ericson, Rasmus Ischebeck, Paolo Craievich,
Fabio Marcellini, Eduard Prat, Sven Reiche, Mike Seidel

Swiss Physical Society Annual Meeting 2024, September 13, 2024

Dechirping strength

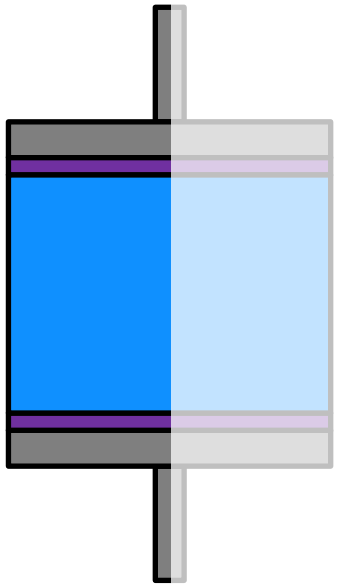


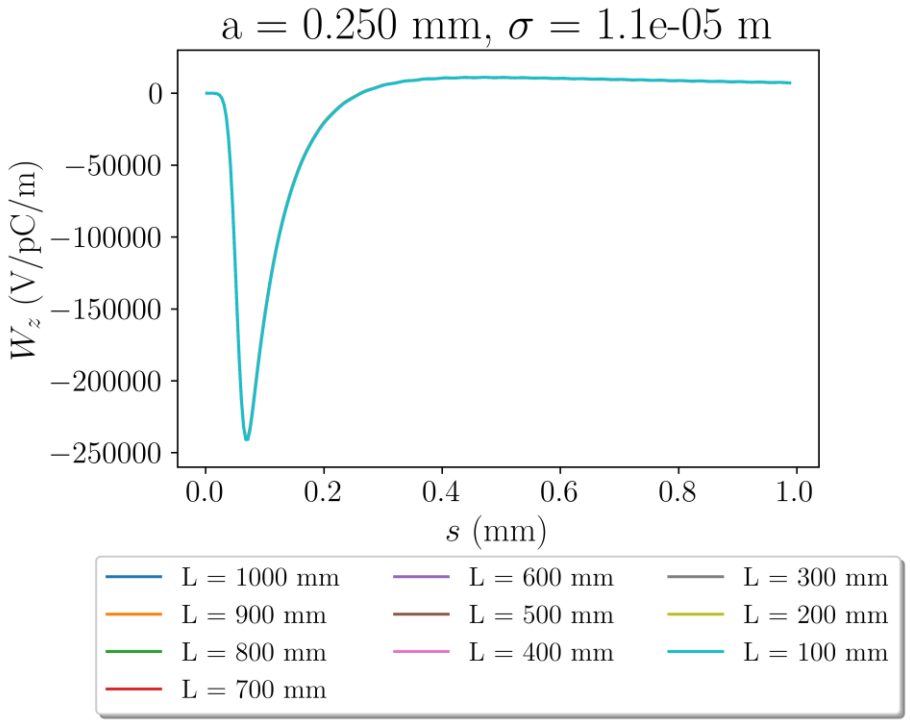


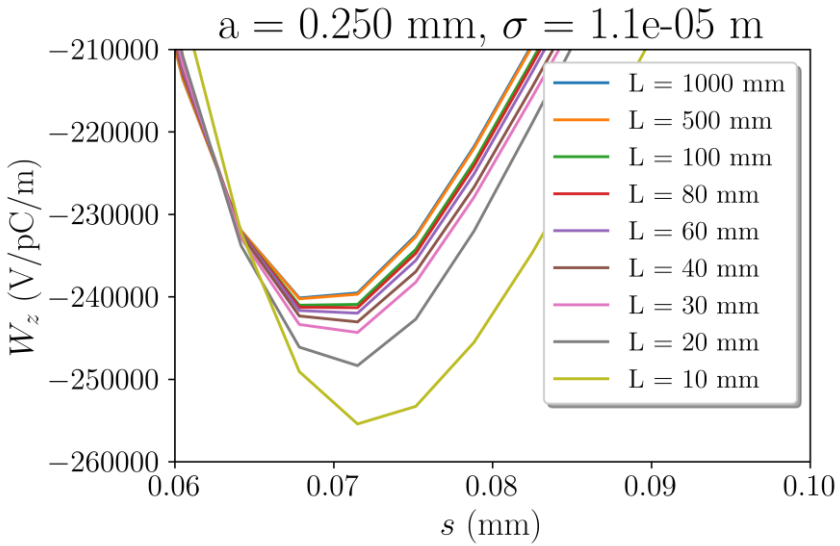


For gap = 0.5 mm, structure produces wake with slope of -26 MV/pC/m/mm
For 2*1 m structure, 200 pC bunch:
Bunches with -10.4 MV/um chirp can be dechirped

Less than a tenth of the structure needs to be simulated to obtain accurate wake potentials

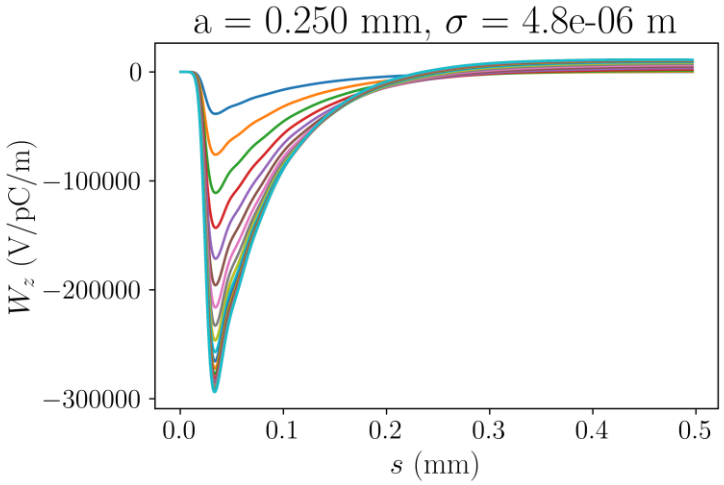


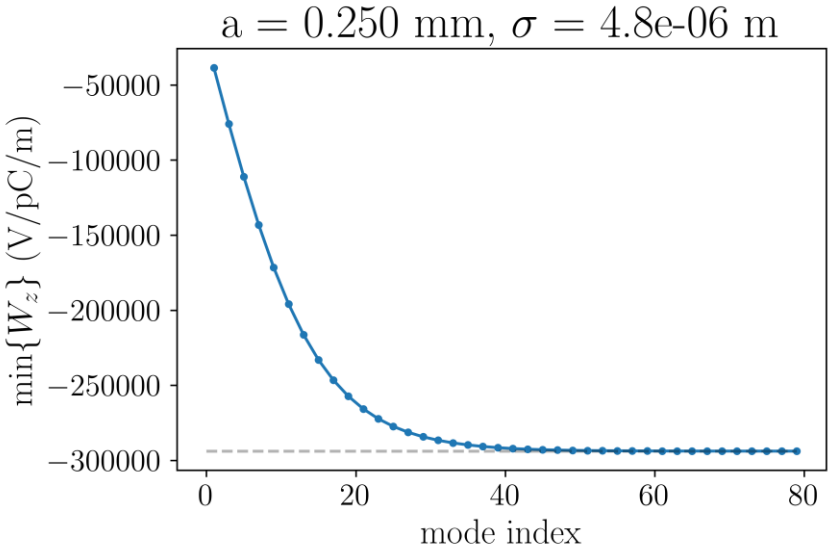


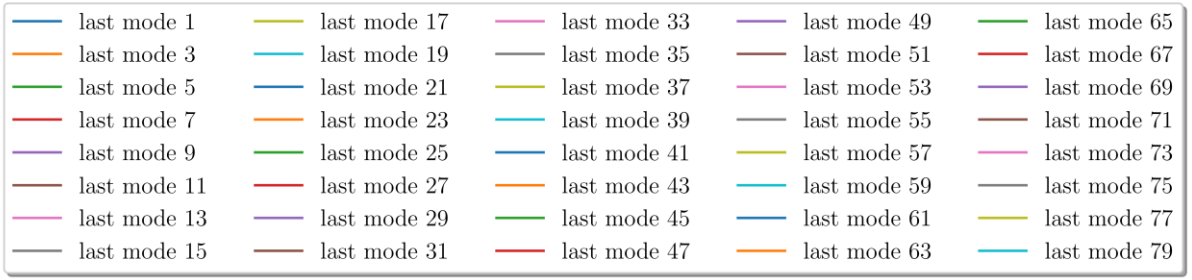


Wake potential does not change when including terms above index 45

$$W = \sum_{i=1}^{?} w_{m,i}$$

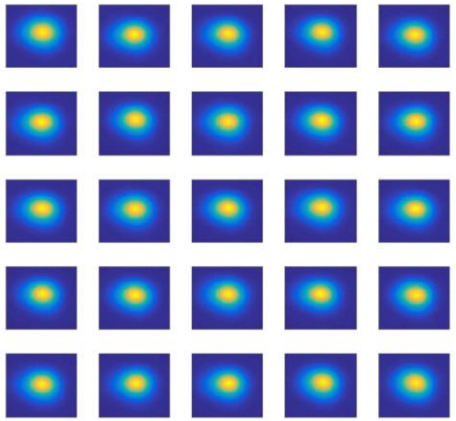




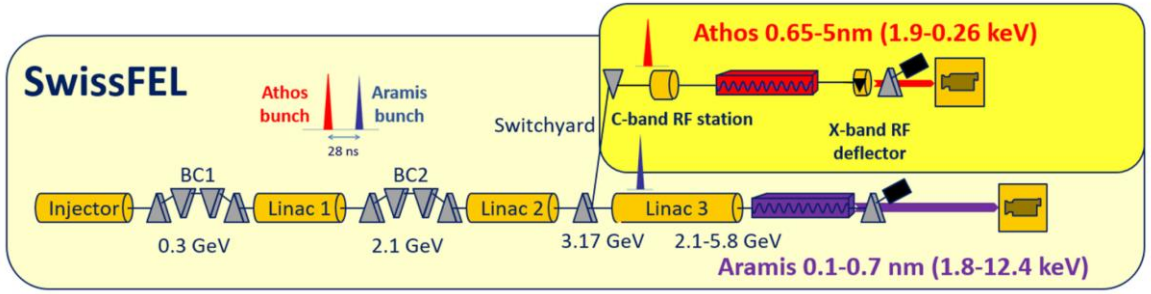


SwissFEL

Parameter	Value
Length	740 m
LINAC frequency	5.7 GHz (C-band)
Repetition rate	100 Hz
Energy	up to 6.1 GeV
Bunch charge	10 – 200 pC
Trajectory jitter	< 10% of beam size
Relative energy jitter	~ 10^{-4}
Arrival time jitter	< 10 fs
Slice emittance	200 nm (for 200 pC)
Bunch length	< 1 fs – 50 fs

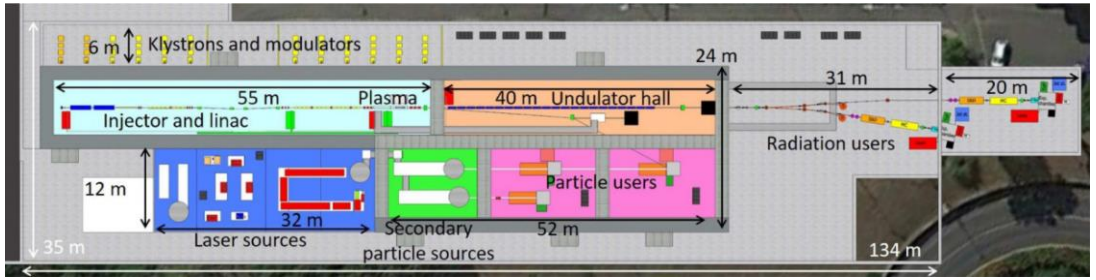


Courtesy: Eduard Prat

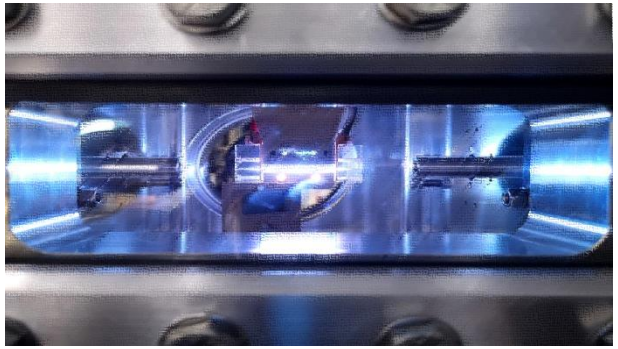


EuPRAXIA

Parameter	SwissFEL	EuPRAXIA [*]
Length	740 m	150 m
LINAC frequency	5.7 GHz (C-band)	11.9942 GHz (X-band)
Repetition rate	100 Hz	~ 50 Hz
Energy	up to 6.1 GeV	1 – 1.2 GeV
Bunch charge	10 – 200 pC	30 – 50 pC
Trajectory jitter	< 10% of beam size	–
Relative energy jitter	~ 10^{-4}	–
Arrival time jitter	< 10 fs	–
Slice emittance	200 nm (for 200 pC)	500 nm
Bunch length	< 1 fs – 50 fs	10 fs



EuPRAXIA Conceptual Design Report, Assmann, et al.

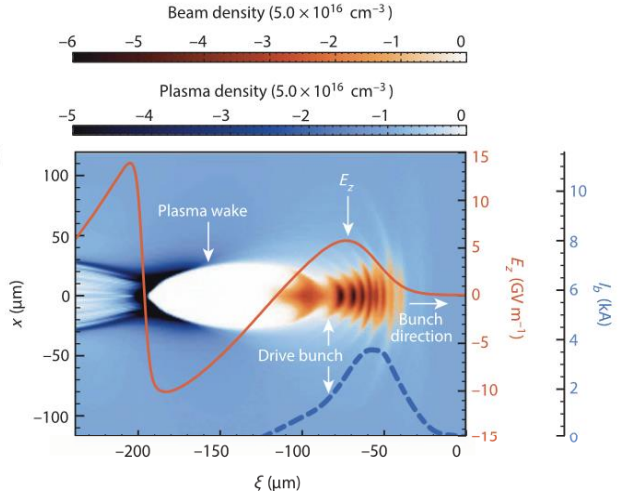


Presented by A Biagioni at EuPRAXIA-DN School April 2024

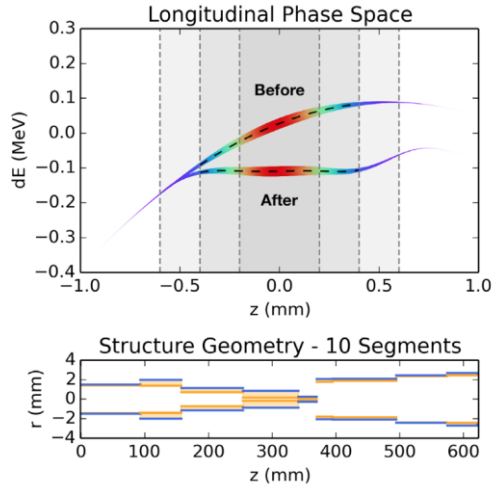
[*] Presented by C Welch at EuPRAXIA-DN School April 2024

EuPRAXIA

- Smaller accelerator may be less expensive and more sustainable
- Challenge: produce beams with low energy spread
- Small wavelength of plasma wake leads to large difference in acceleration of particles within a bunch with a finite length
- The beam's energy spread determines the bandwidth of the FEL
- One possible solution is wakefield structures



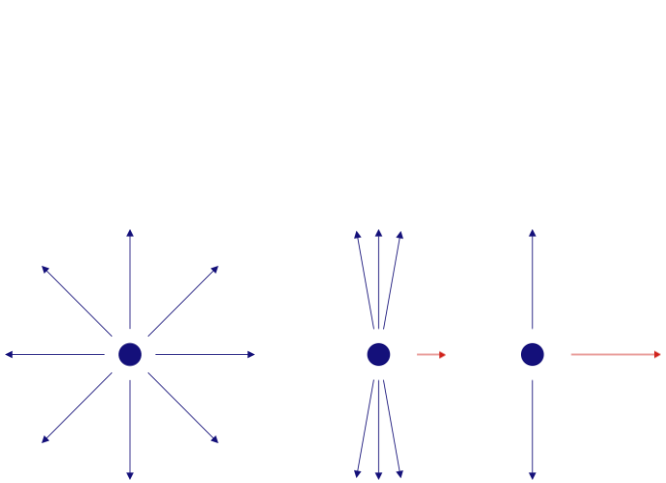
Positron acceleration in plasma wakefields, Cao, et al.

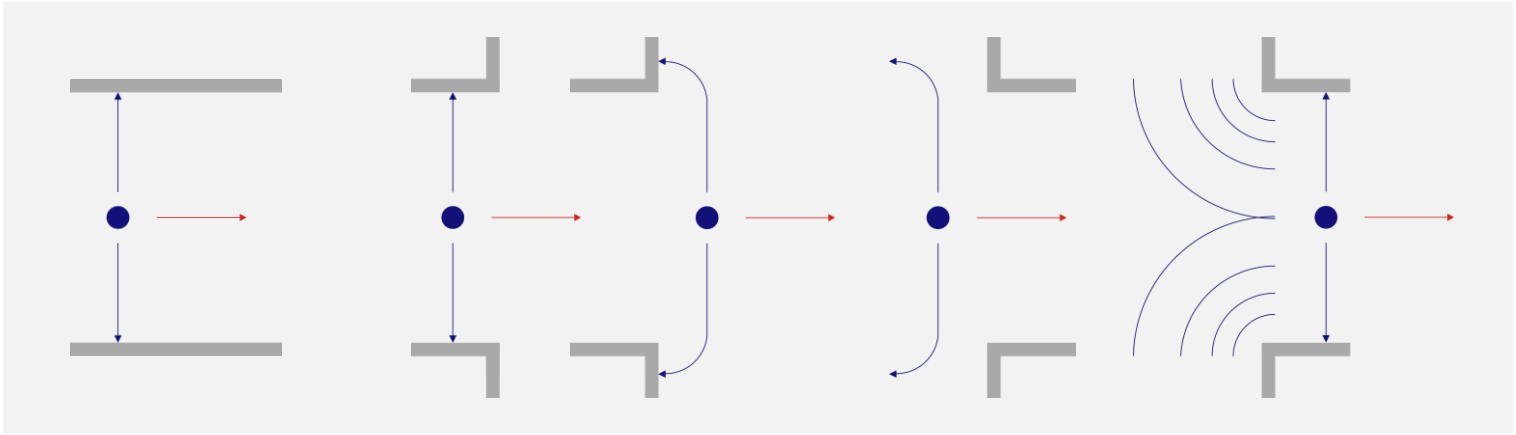


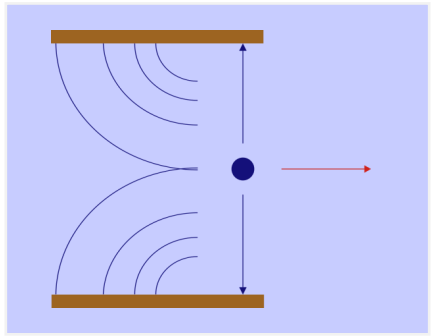
Longitudinal phase space synthesis with tailored 3D-printable dielectric-lined waveguides, Mayet, et al.

Wakefield structures

1. Geometric discontinuities of accelerator components produce wakefields
2. Finite conductivities of accelerator components produce wakefields

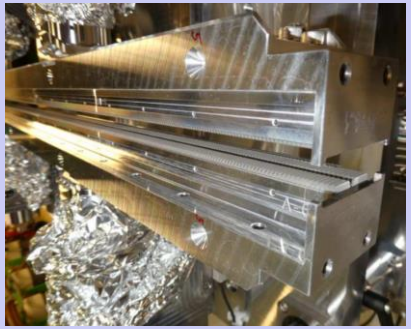
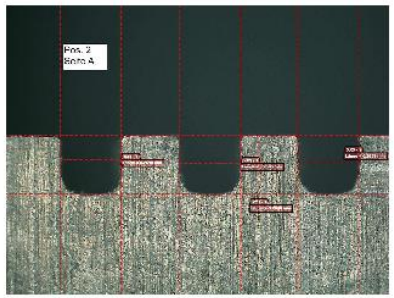
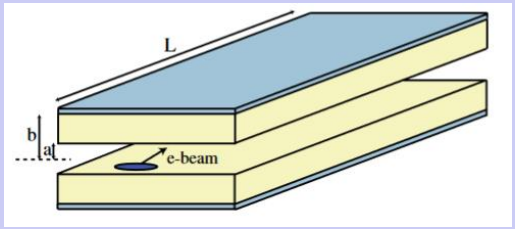
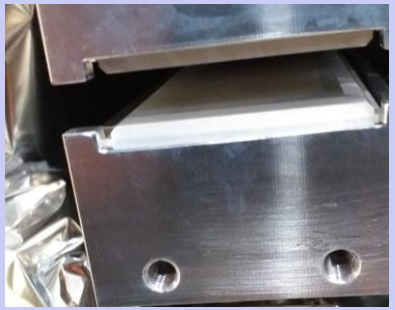
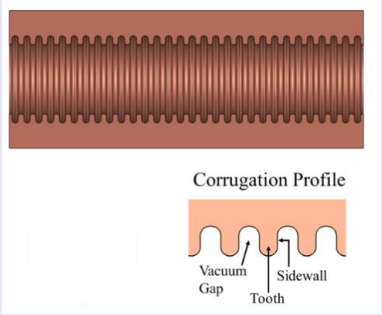




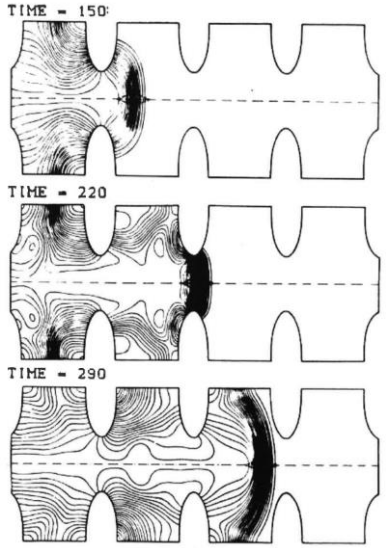


- Fields are synchronized with the beam
- No external power source required

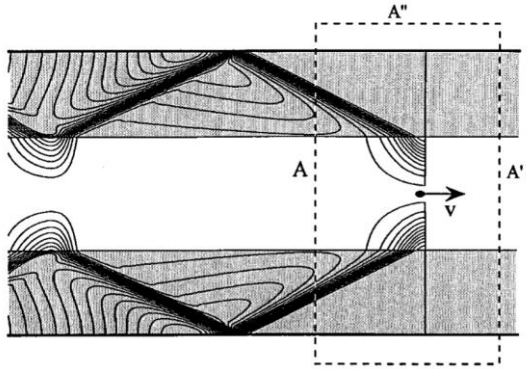
Wakefield structures

	Metallic	Dielectric
Flat	  Temporal profile measurements of relativistic electron bunch based on wakefield generation, Bettoni, et al.	  Dielectric Wakefield Acceleration of a Relativistic Electron Beam in a Slab-Symmetric Dielectric Lined Waveguide, Andonian, et al.
Round	 Design of a cylindrical corrugated waveguide for a collinear wakefield accelerator, Siy, et al.	 Temporal profile measurements of relativistic electron bunch based on wakefield generation, Bettoni, et al.

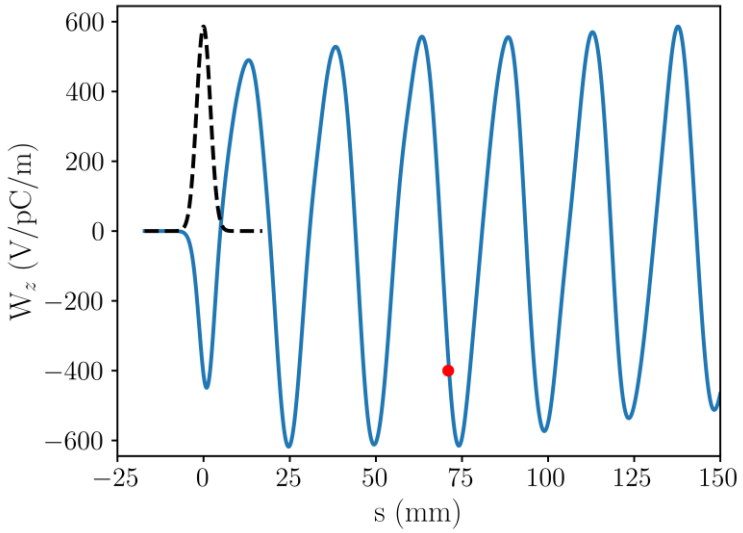
Wakefield structures



BNS damping, Novokhatski



Theory of wakefields in a dielectric-lined waveguide, Park & Hirshfield

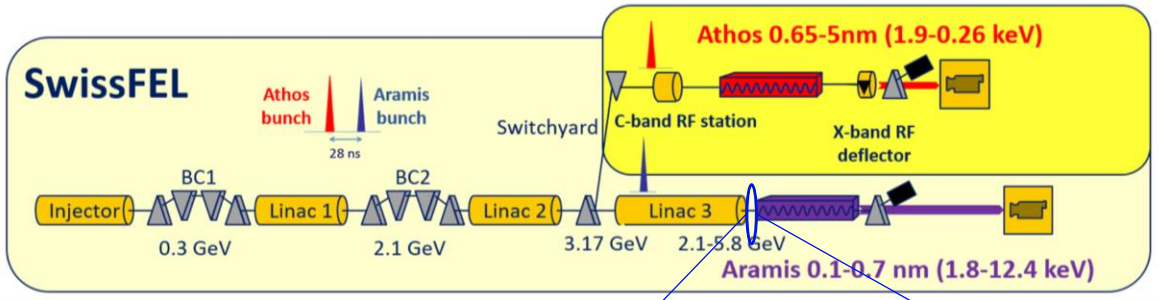


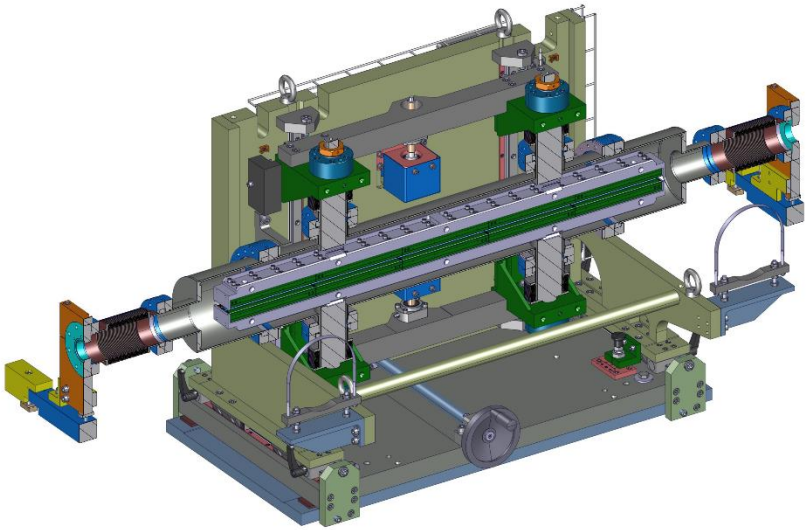
Wake function: $$w_z = -\frac{1}{q}\int_{z_1}^{z_2} dz\, E_z$$

Wake potential: $$W_z = \int_0^{\infty} ds'\, \lambda(s-s')w_z(s')$$

- Red witness particle experiences -400 V per pC in the drive beam per meter of structure

Wakefield structures

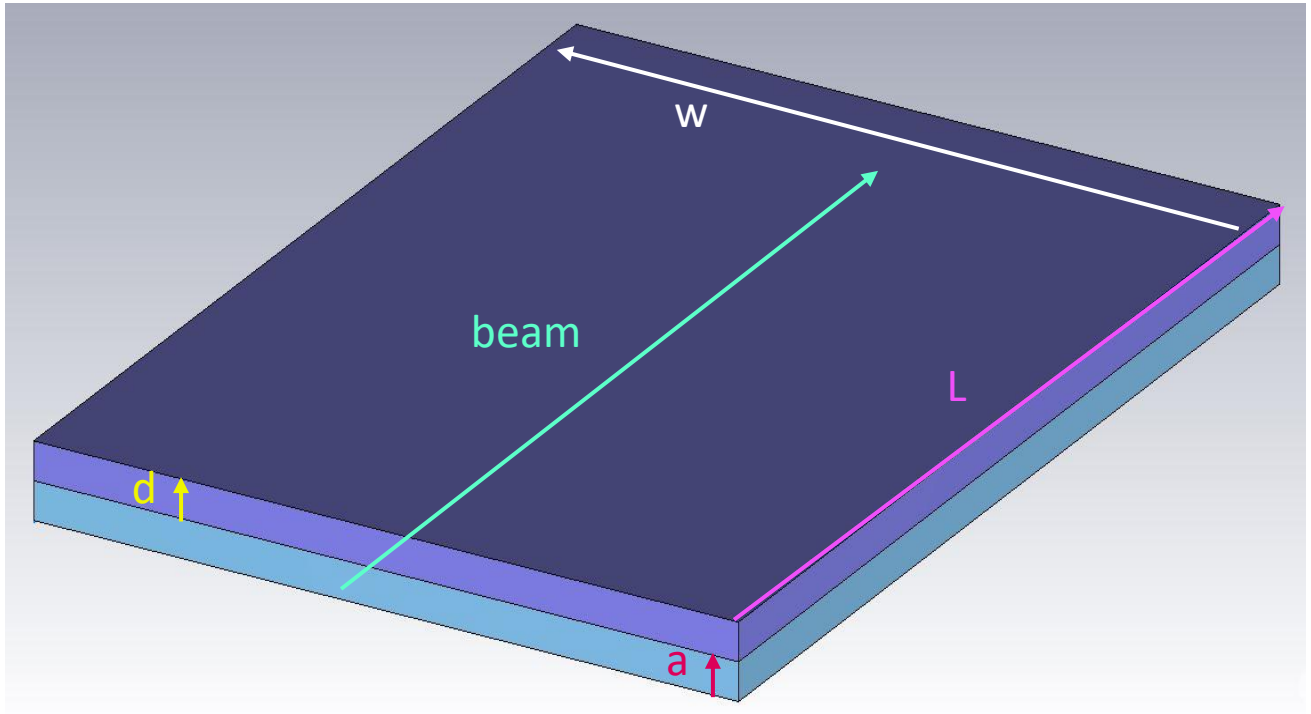




Peter Heimgartner

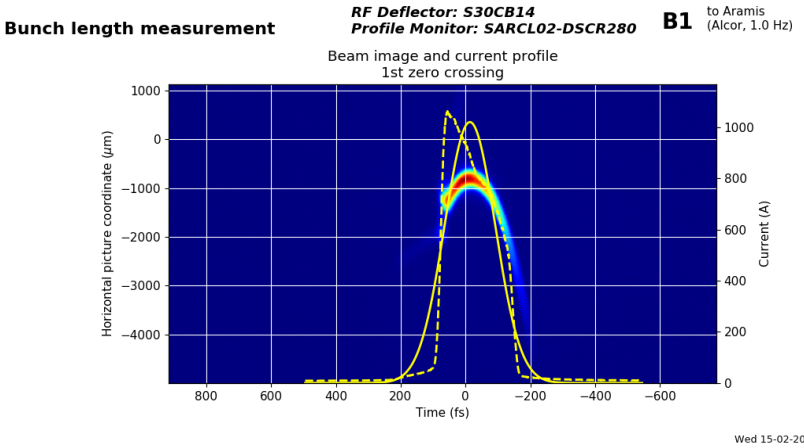
- Flat slab dielectric passive structure with adjustable gap
- Routinely used to make ultrashort pulses, adjust FEL bandwidth

Parameter	Value
half-gap, a	0.25 mm – 1.5 mm
Length, L	1 m
Width, w	15 mm
Dielectric thickness, d	0.4 mm
Alumina Permittivity, ε_r	~ 10

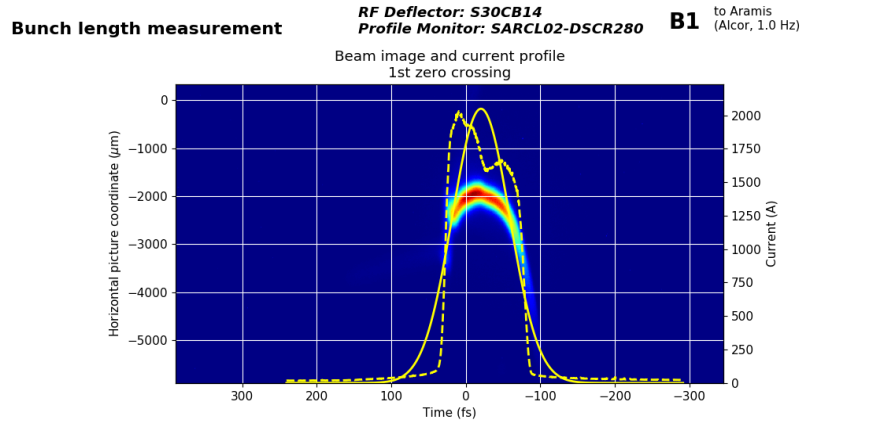


Sing bunch experiment

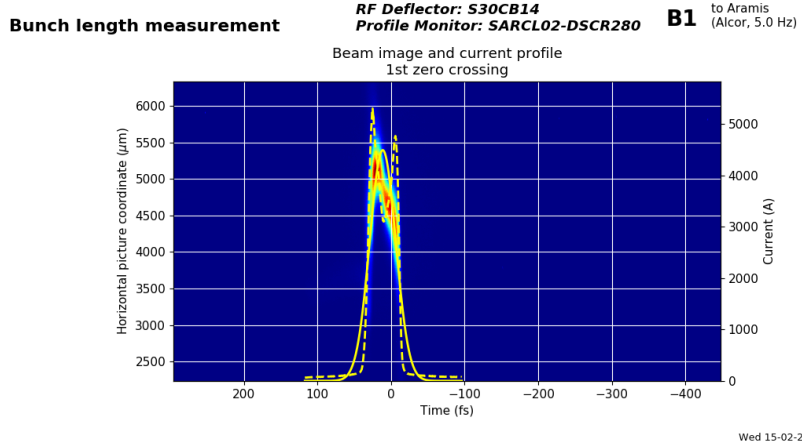
1 kA



2 kA



4 kA



Experiments that benefit from an increased FEL bandwidth

- X-ray crystallography
- X-ray emission spectroscopy
- X-ray absorption spectroscopy
- Stimulated Raman spectroscopy
- Multiple wavelength anomalous diffraction
- X-ray absorption near edge structure
  - 7050 eV – 7250 eV