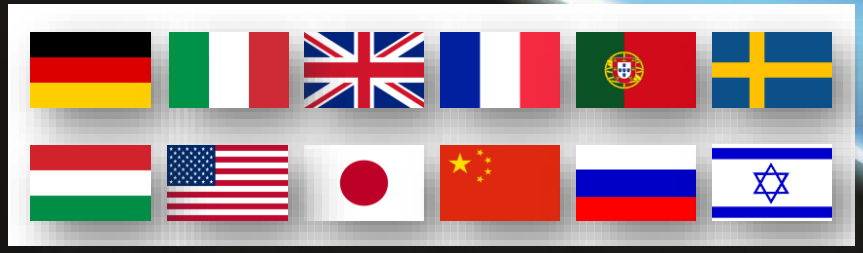
EUROPEAN
PLASMA RESEARCH
ACCELERATOR WITH
EXCELLENCE IN
APPLICATIONS

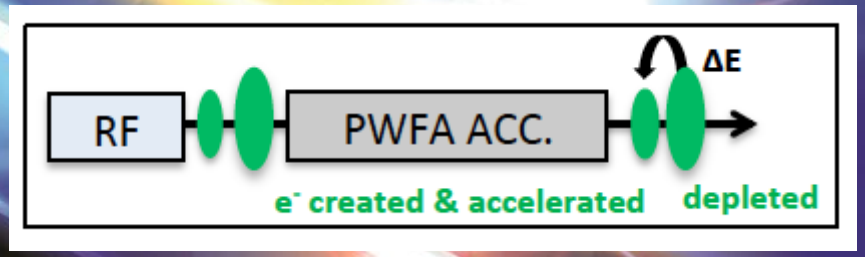
EuPRAXIA

WP9 - Beam Driven Plasma Acceleration Status Report

Massimo Ferrario (INFN) & Jens Osterhoff (DESY)

July 4, 2018, Liverpool





This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 653782.

WP9 Deliverables

- **Del 9.1**. Baseline design report including electron beam optics, plasma modules, plasma diagnostics and beam transport to applications [**May 2018**] (WP2+WP5).

- Del 9.2. Staging analysis [May 2019].

- Del 9.3. Tolerance analysis [May 2019].

- Del 9.4. Full design report EUPRAXIA, contribution from WP9 [October 2019].

Thanks to A. Marocchino

Project Number: 653782

Project Acronym: EuPRAXIA

Project title: European Plasma Research Accelerator with eXcellence In Applications

Milestone Report

Deliverable 9.1

Contents

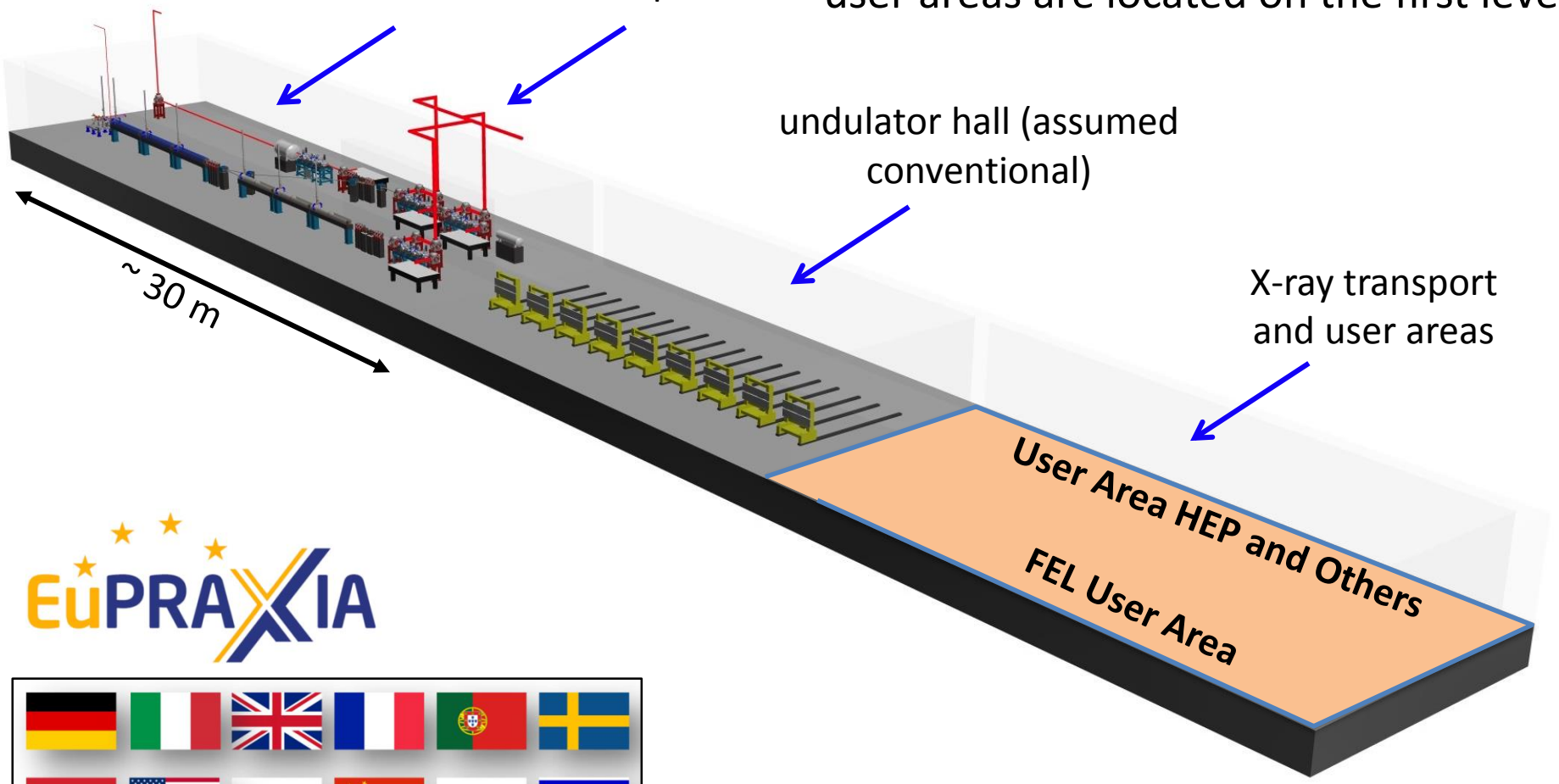
Conceptual Design Report Ready for the LNF site

http://www.lnf.infn.it/sis/preprint/pdf/getfile.php?filename=INFN-18-03-LNF.pdf

Overall layout status (ongoing)

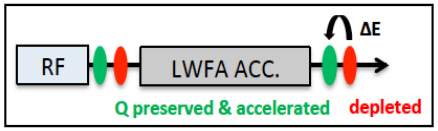
Horizon 2020

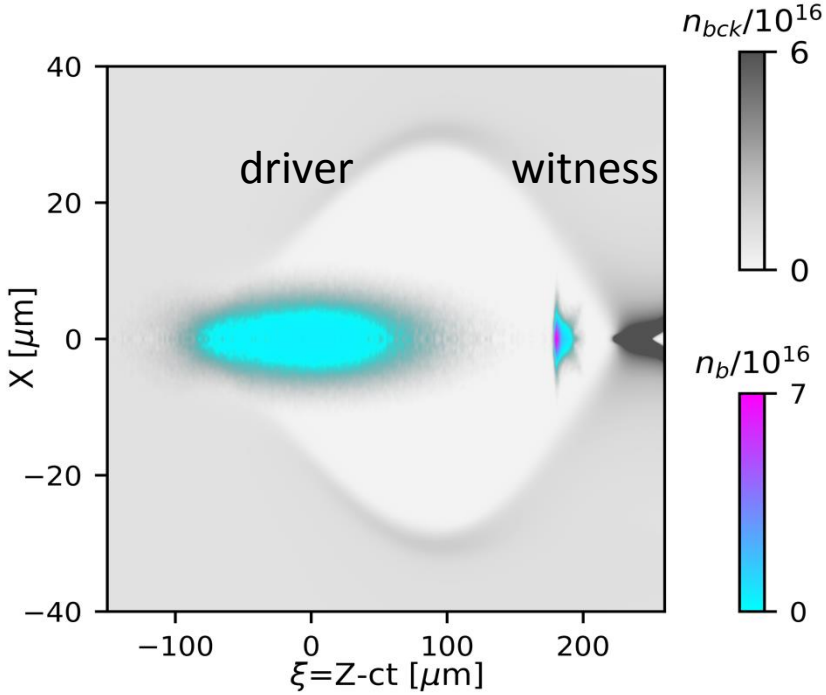
Accelerator research, undulators and user areas are located on the first level

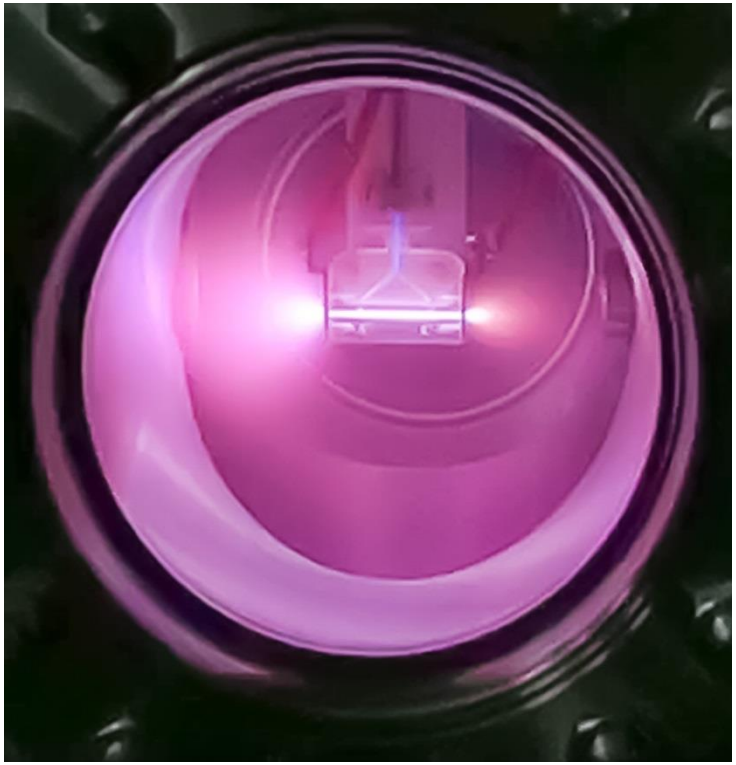


Design by A. Walker (DESY) and Dariusz Kocoń (ELI-Beams)

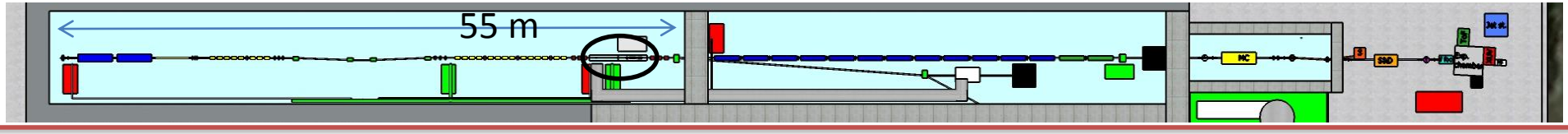
Plasma WakeField Acceleration – External Injection







Capillary discharge at SPARC_LAB



Driver S2E

Bunch parameters				
bunch	Q [pC]	σ_x [µm]	σ_z [µm]	ε_x [mm mrad]
Driver	200	4	75	3
Witness	25–30	1.5	6	1

Plasma parameters		
n_0 [cm^{-3}]	λ_p [µm]	k_p [µm $^{-1}$]
10^{16}	334	0.02

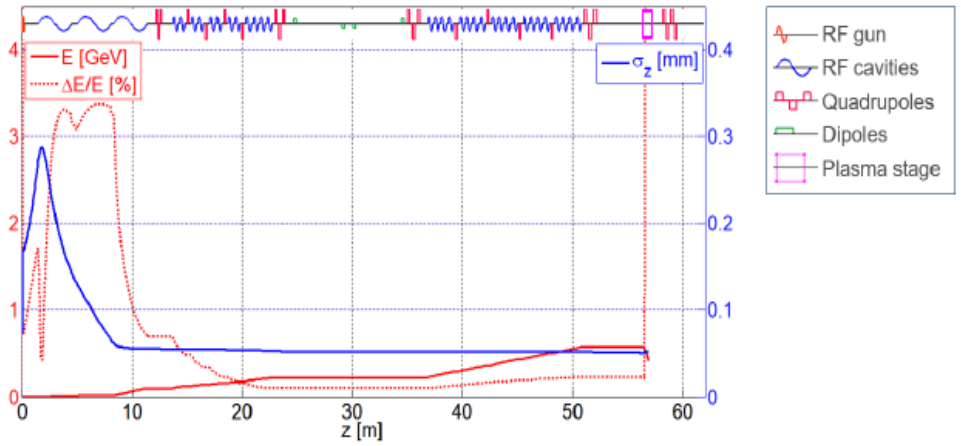
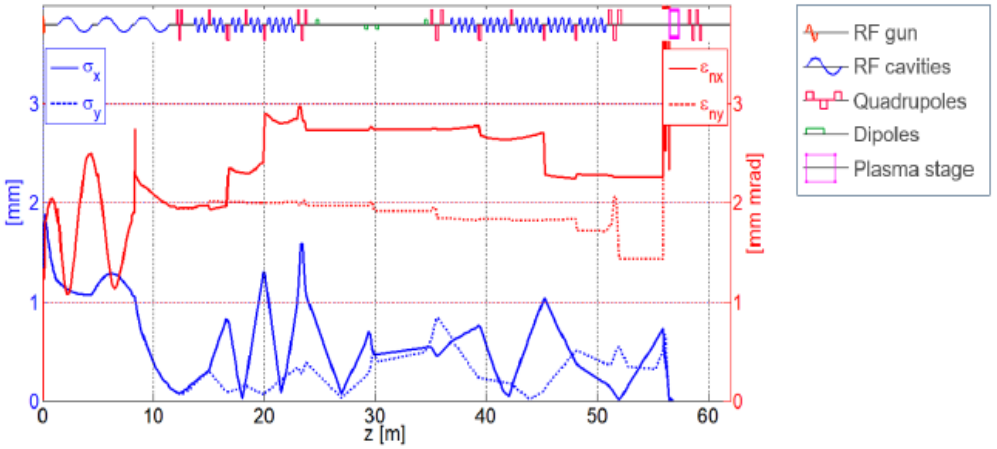


Figure 4.7: Start to end simulation results for the driver bunch for the PWFA case: evolution along the injector of the energy (E red line) and energy spread ($\Delta E/E$ red dotted-line) and longitudinal bunch length (σ_z blue line).



Witness S2E

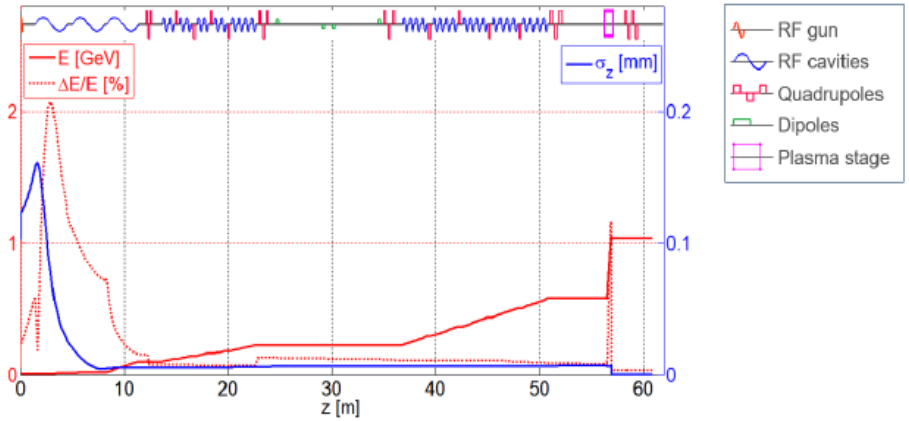
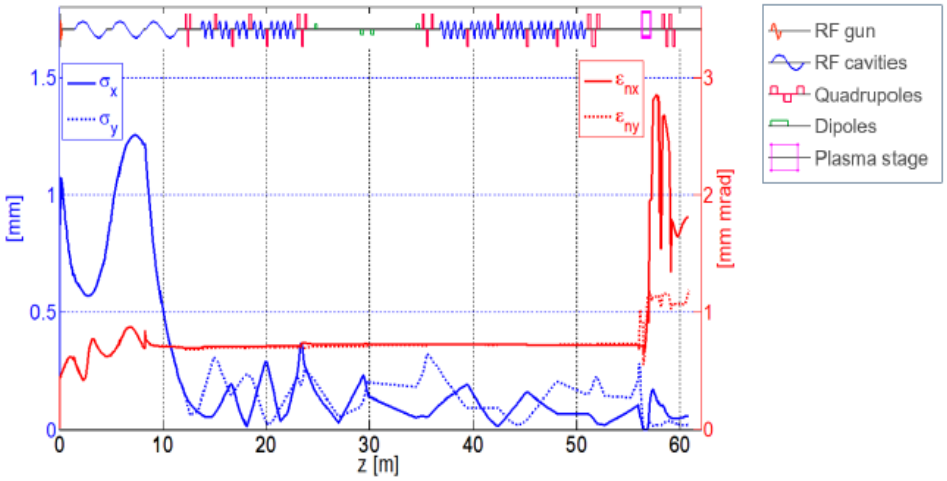
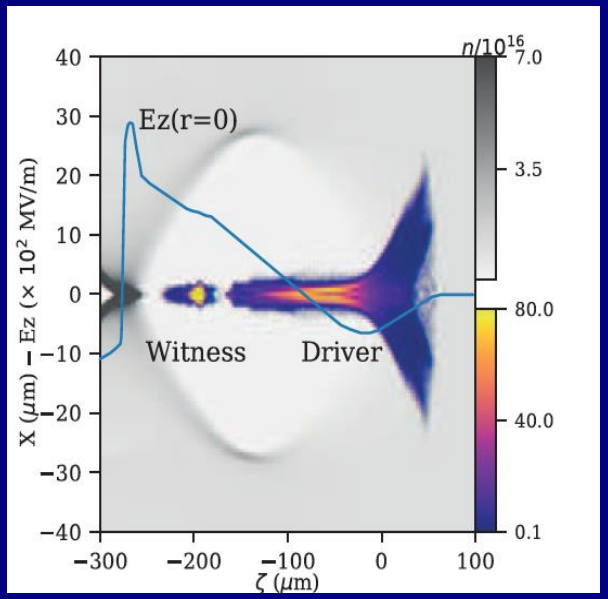
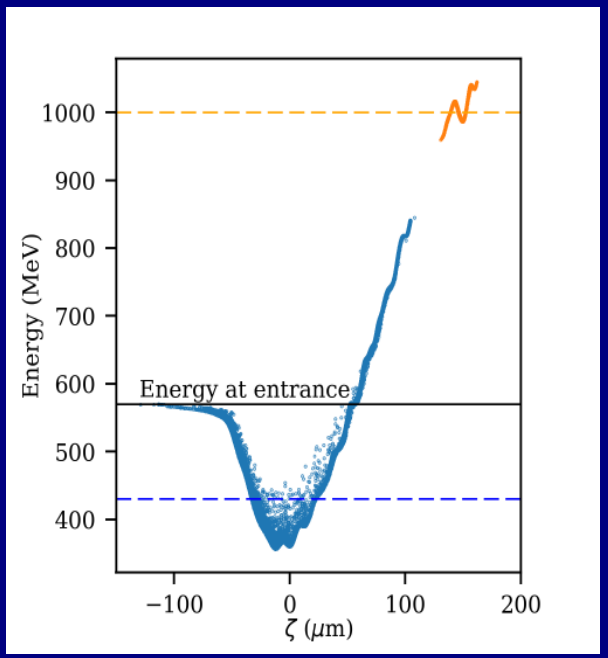


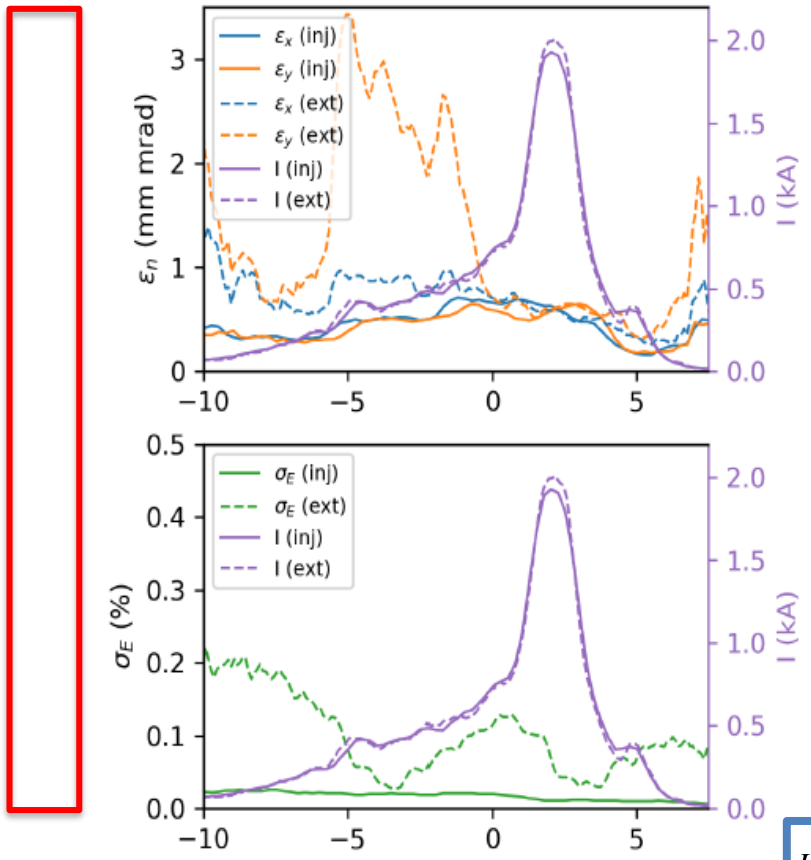
Figure 4.5: Start to end simulation results for the trailing bunch for the PWFA case: evolution along the injector of the energy (E red line) and energy spread ($\Delta E/E$ red dotted-line) and longitudinal bunch length (σ_z blue line).







Plasma Exit: Rolling Slice analysis



$$L_s = \frac{\lambda_r}{2\sqrt{3}\rho} \approx 1\ \mu\text{m}$$

Figure 7.12: Rolling slice analysis for the witness bunch at plasma input, dashed line, and at plasma exits, solid line. The top panel report the emittance in both transverse plane and the current. The bottom panel plots the energy spread together with the current. The corresponding current axis is the left y axis.

Beam	units	Driver-IN	Driver-OUT	Witness-IN	Witness-OUT
Charge	pC	200	200	30	30
σ_x	µm	8	6.4	1.47	1.42
σ_y	µm	3.1	10	3.17	1.4
σ_z	µm	52	50	3.85	3.8
ε_x	mm mrad	2.56	4.1	0.6	0.96
ε_y	mm mrad	4.8	11.4	0.55	1.2
σ_E	%	0.2	20	0.07	1.1
E	MeV	567	420	575	1030
Best Slice					
current	kA			2	2.0
ε_x	mm mrad			0.59	0.57
ε_y	mm mrad			0.58	0.62
σ_E	%			0.011	0.034

Table 7.3: PWFA bunch parameters at plasma entrance and at plasma exit. The best slice value is also reported.

FEL Simulations (Genesis)

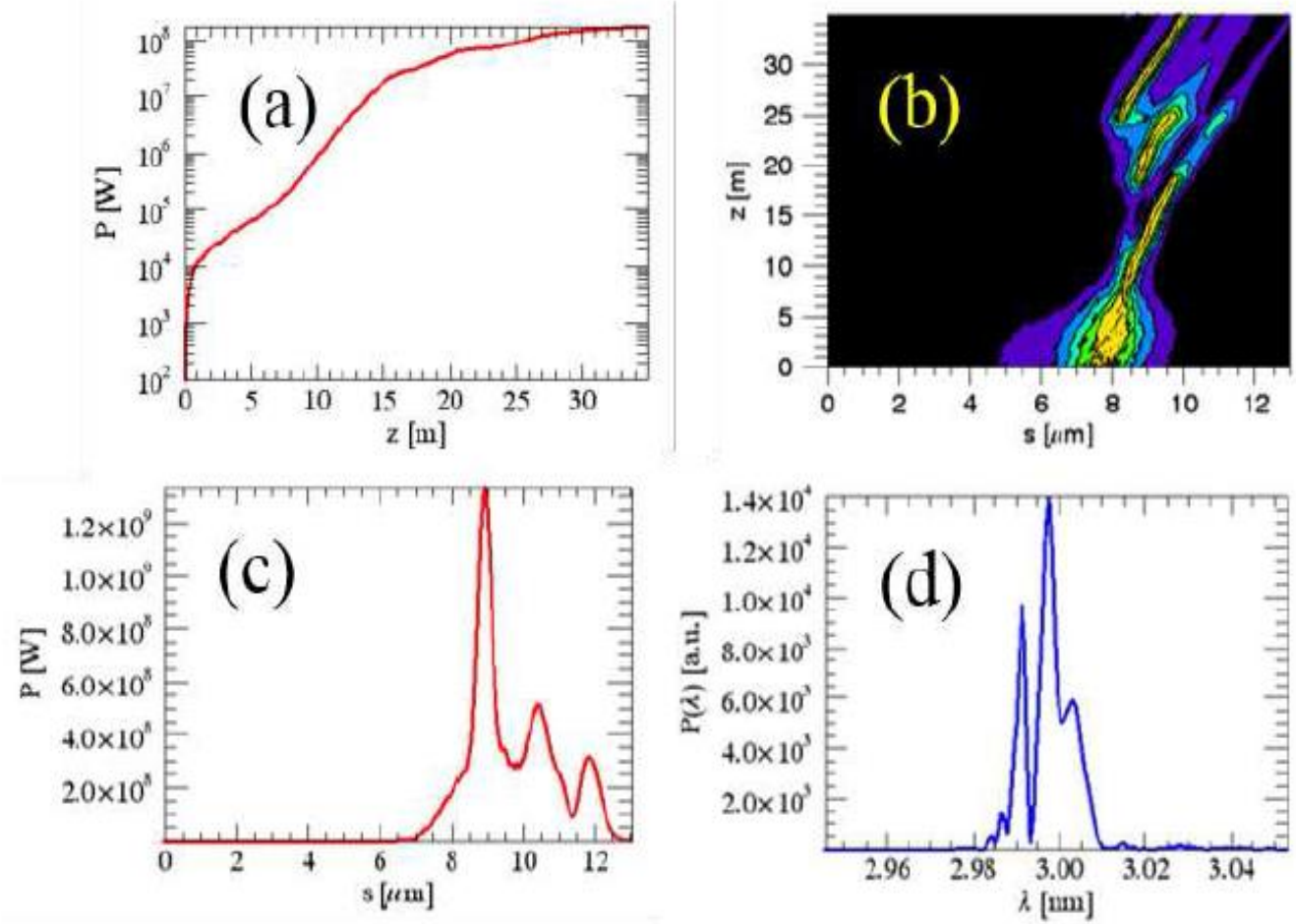


Figure 7.18: Particle driven acceleration: (a) Radiation growth along the undulator coordinate z(m). (b): Contour plot of the power P in the plane (s, z). (c) Power and (d) spectrum of the radiation at 30 m.

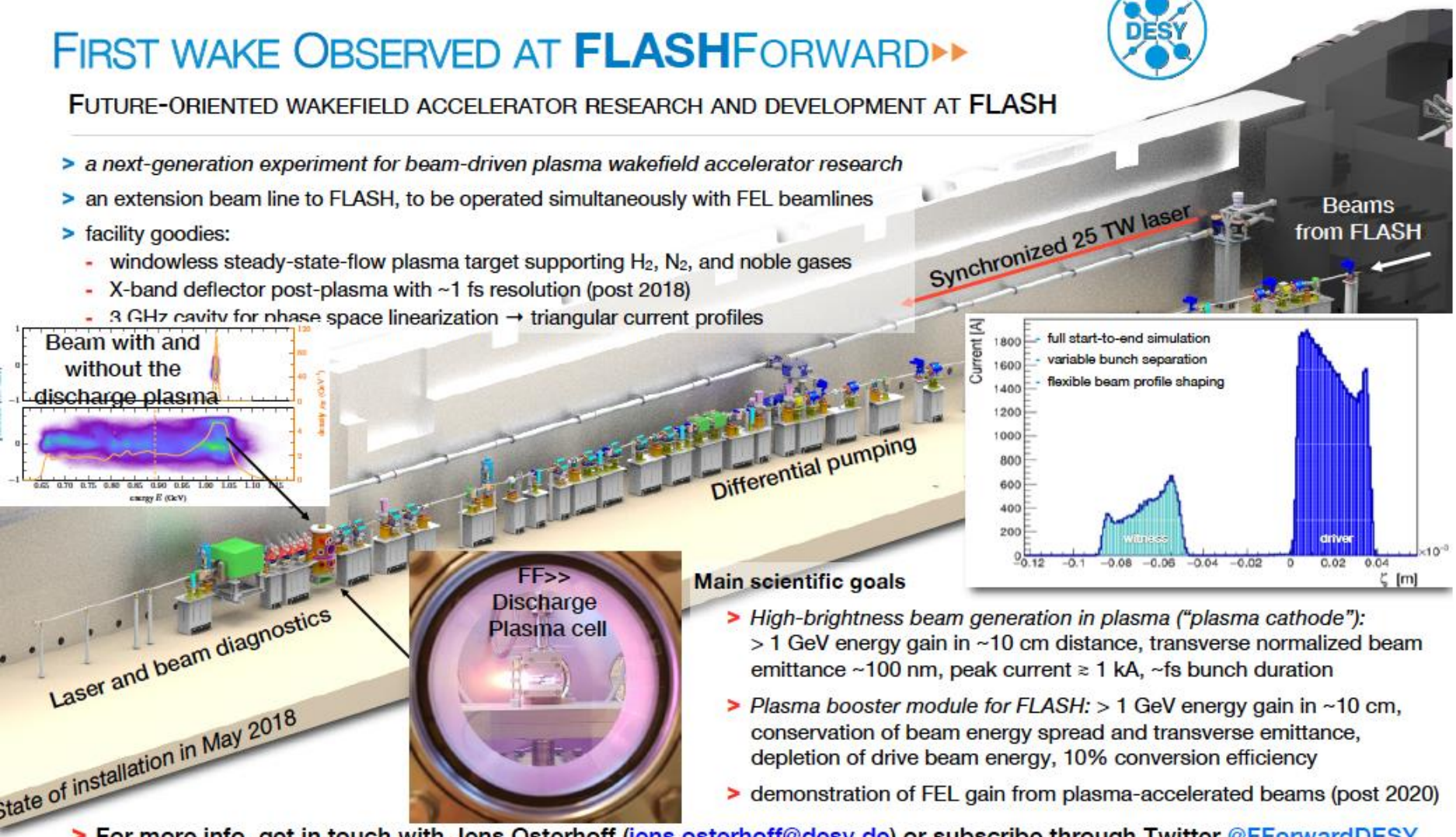
	Units	Full RF case	LWFA case	PWFA case
Electron Energy	GeV	1	1	1
RMS Energy Spread	%	0.05	2.3	1.1
Peak Current	kA	1.79	2.26	2.0
Bunch Charge	pC	200	30	30
RMS Bunch Length	µm (fs)	16.7 (55.6)	2.14 (7.1)	3.82 (12.7)
RMS normalized Emittance	mm mrad	0.5	0.47	1.1
Slice Length	µm	1.66	0.5	1.2
Slice Charge	pC	6.67	18.7	8
Slice Energy Spread	%	0.02	0.03	0.034
Slice normalized Emittance (x/y)	mm mrad	0.35/0.24	0.45/0.465	0.57/0.615
Undulator Period	mm	15	15	15
Undulator Strength $K(a_w)$		0.978 (0.7)	1.13 (0.8)	1.13 (0.8)
Undulator Length	m	30	30	30
Pierce parameter ρ (1D/3D)	$\times 10^{-3}$	1.55/1.38	2/1.68	2.5/1.8
Radiation Wavelength	nm (keV)	2.87 (0.43)	2.8 (0.44)	2.98 (0.42)
Photon Energy	µJ	177	40	6.5
Photon per pulse	$\times 10^{10}$	255	43	10
Photon Bandwidth	%	0.46	0.4	0.9
Photon RMS Transverse Size	µm	200	145	10
Photon Brilliance per shot	(s mm^2 mrad^2 bw(0.1%))$^{-1}$	1.4×10^{27}	1.7×10^{27}	0.8×10^{27}

Table 4.1: Beam parameters from start-to-end simulations for full RF and for plasma wakefield acceleration cases with electron (PWFA) or laser (LWFA) driver beam

FIRST WAKE OBSERVED AT **FLASH**FORWARD

FUTURE-ORIENTED WAKEFIELD ACCELERATOR RESEARCH AND DEVELOPMENT AT **FLASH**

- *a next-generation experiment for beam-driven plasma wakefield accelerator research*
- an extension beam line to FLASH, to be operated simultaneously with FEL beamlines
- facility goodies:
  - windowless steady-state-flow plasma target supporting H_2, N_2, and noble gases
  - X-band deflector post-plasma with ~1 fs resolution (post 2018)
  - 3 GHz cavity for phase space linearization → triangular current profiles



Main scientific goals

- *High-brightness beam generation in plasma ("plasma cathode"):* > 1 GeV energy gain in ~10 cm distance, transverse normalized beam emittance ~100 nm, peak current ≈ 1 kA, ~fs bunch duration
- *Plasma booster module for FLASH:* > 1 GeV energy gain in ~10 cm, conservation of beam energy spread and transverse emittance, depletion of drive beam energy, 10% conversion efficiency
- demonstration of FEL gain from plasma-accelerated beams (post 2020)

For more info, get in touch with Jens Osterhoff (jens.osterhoff@desy.de) or subscribe through Twitter @FForwardDESY

FLASHFORWARD

FUTURE-ORIENTED WAKEFIELD ACCELERATOR RESEARCH AND DEVELOPMENT AT FLASH

Latest Milestones:

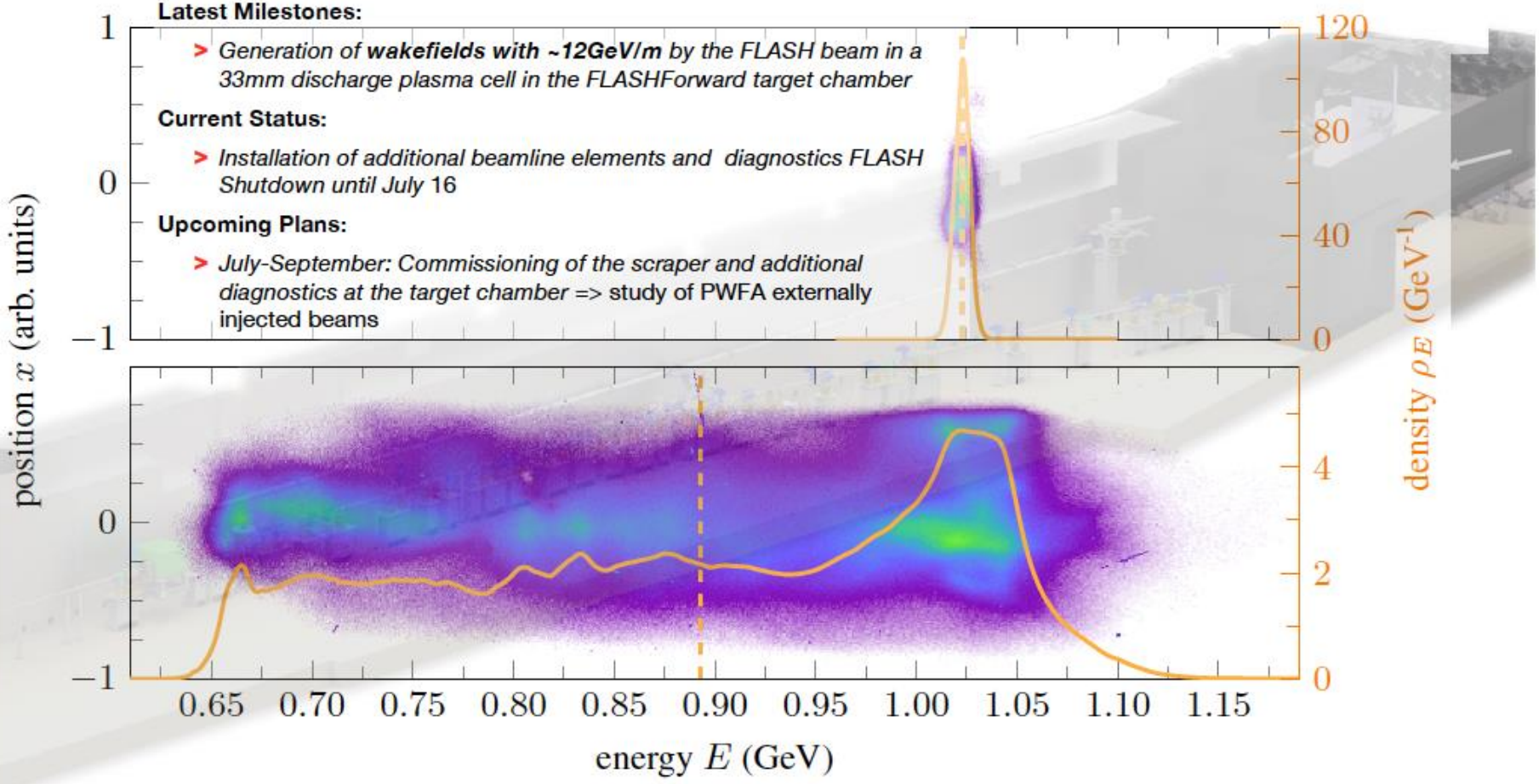
> *Generation of **wakefields with ~12GeV/m** by the FLASH beam in a 33mm discharge plasma cell in the FLASHForward target chamber*

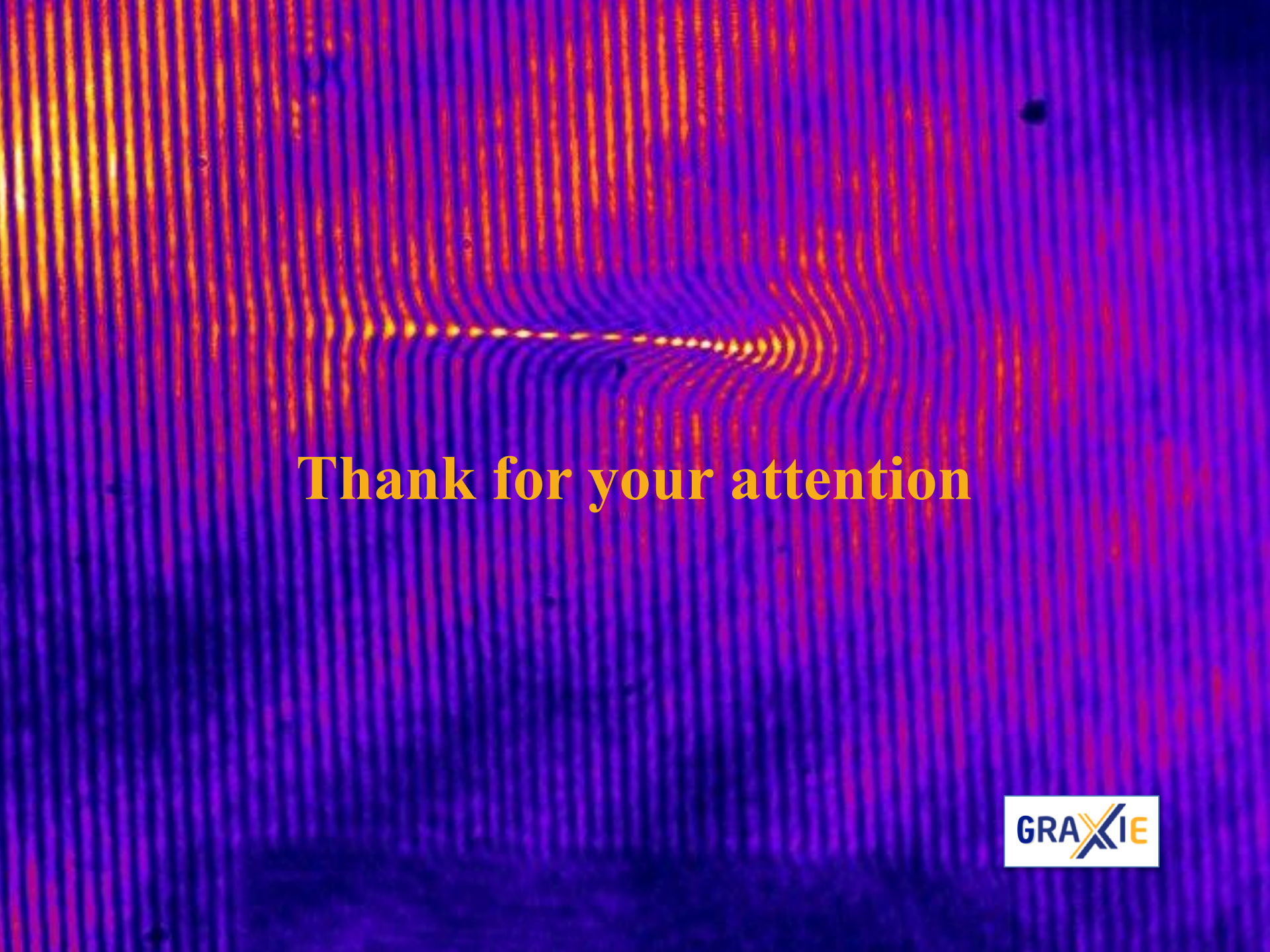
Current Status:

> *Installation of additional beamline elements and diagnostics FLASH Shutdown until July* 16

Upcoming Plans:

> *July-September: Commissioning of the scraper and additional diagnostics at the target chamber* => study of PWFA externally injected beams




Thank for your attention
GRAXIE