

FLASHForward▶▶ status update

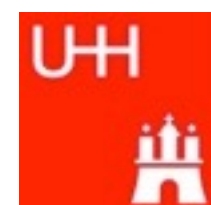
Future-oriented wakefield-accelerator research and development at FLASH

Jens Osterhoff

Project coordinator FLASHForward
Deutsches Elektronen-Synchrotron DESY

Team: *A. Aschikhin, C. Behrens, J. Dale, E. Elsen, C. Entrena, B. Foster, L. Goldberg, O. Kononenko, V. Libov, K. Ludwig, A. Martinez de la Ossa, T. Mehrling, H. T. Olgun, C. A. J. Palmer, J. Schaffran, L. Schaper, B. Schmidt, J.-P. Schwinkendorf, M. J. V. Streeter, V. Wacker, S. Wunderlich, J. Zemella.*

for the
LAOLA. collaboration



Mission and goals of the **FLASHForward**▶▶ project

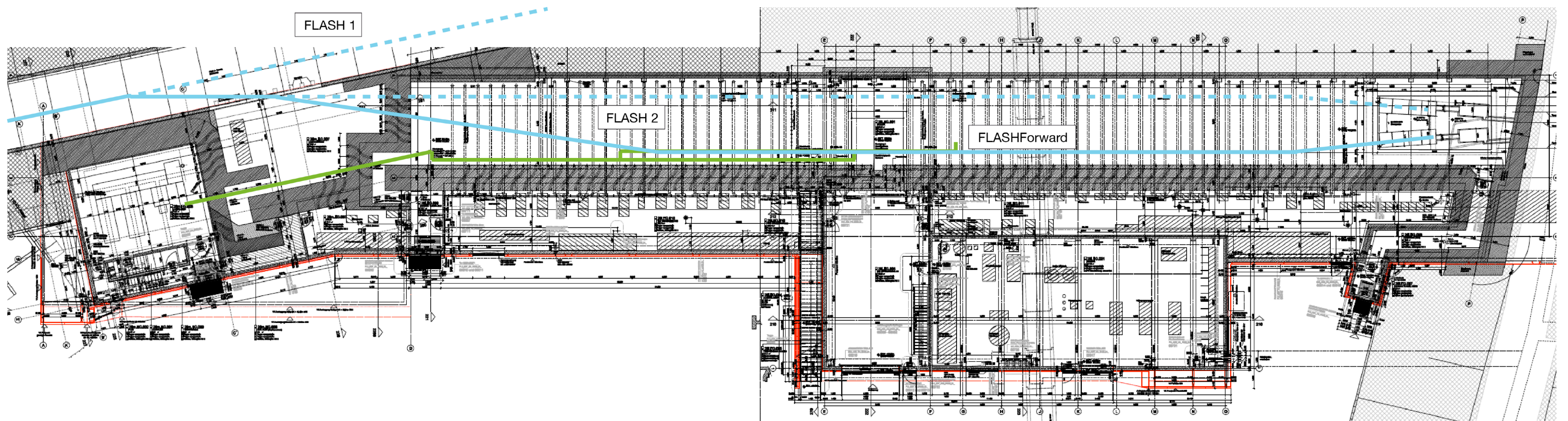
- FLASHForward is
- > an extension to the FLASH 1.2 GeV water-window FEL facility
 - > a new beamline for beam-driven plasma wakefield accelerator research

- Scientific goals
- > the characterization of **externally injected** electron beams and their controlled release from a wakefield accelerator with **energies > 1.6 GeV** (→ *phase I*)
 - > the exploration of novel **in-plasma beam-generation**¹ and acceleration techniques to provide **> 1.6 GeV energy, < 100 nm transverse normalized emittance, ~1 fs duration, and > 1 kA current** electron bunches (→ *phase I*)
 - > **to drive a free-electron laser** with these beams at wavelengths on the few-nanometer scale (→ *phase II*)

¹ A. Martinez de la Ossa *et al.*, “High-Quality Electron Beams from Beam-Driven Plasma Accelerators by Wakefield-Induced Ionization Injection”, *Physical Review Letters* **111**, 245003 (2013)
A. Martinez de la Ossa *et al.*, “High-Quality Electron Beams from Field-Induced Ionization Injection in the Strong Blow-Out Regime of Beam-Driven Plasma Accelerators”, *NIM A* **740**, 231 (2014)
J. Grebenyuk *et al.*, “Beam-Driven Plasma-Based Acceleration of Electrons with Density Down-Ramp Injection at FLASHForward”, *NIM A* **740**, 246 (2014)
B. Hidding *et al.*, “Ultracold Electron Bunch Generation via Plasma Photocathode Emission and Acceleration in a Beam-Driven Plasma Blowout”, *Physical Review Letters* **108**, 035001 (2012)

Beamline location and layout in the FLASH facility

*Conceptual and technical design in progress
Operation to start in ~2016, run for 4 years+*



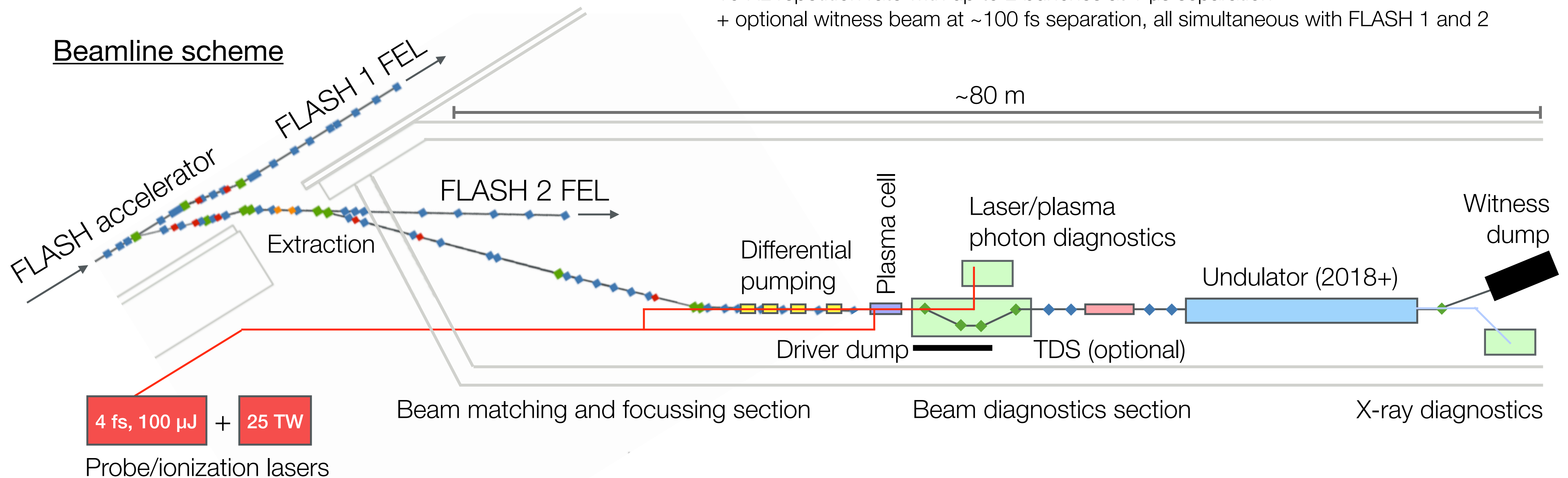
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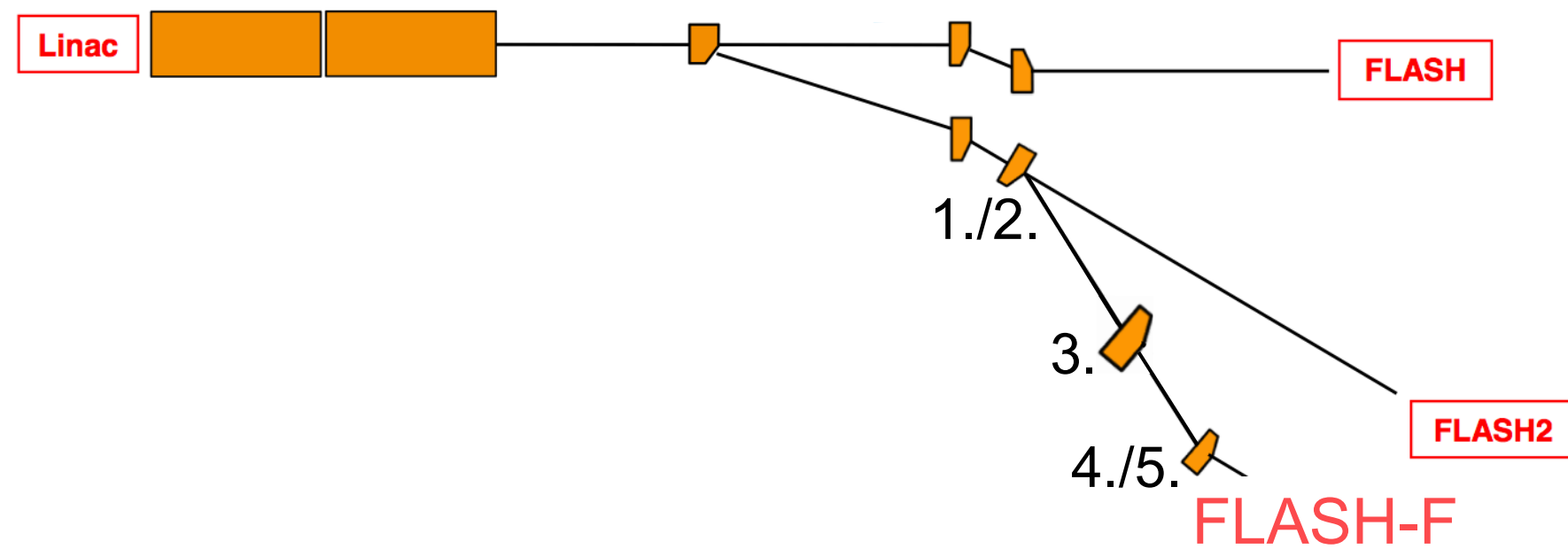
Expected driver beam capabilities

- > FLASH FEL-quality (~1.25 GeV, ~0.1% energy spread, ~2 μm transverse norm. emittance)
- > variable longitudinal beam shape (e.g. triangular) with tunable peak current up to 10 kA
- > Sub 30 fs laser-to-beam synchronization for diagnostics/laser-triggered injection schemes
- > 10 Hz repetition rate with up to 2 bunches at 1 μs separation
 + optional witness beam at ~100 fs separation, all simultaneous with FLASH 1 and 2

Beamline scheme

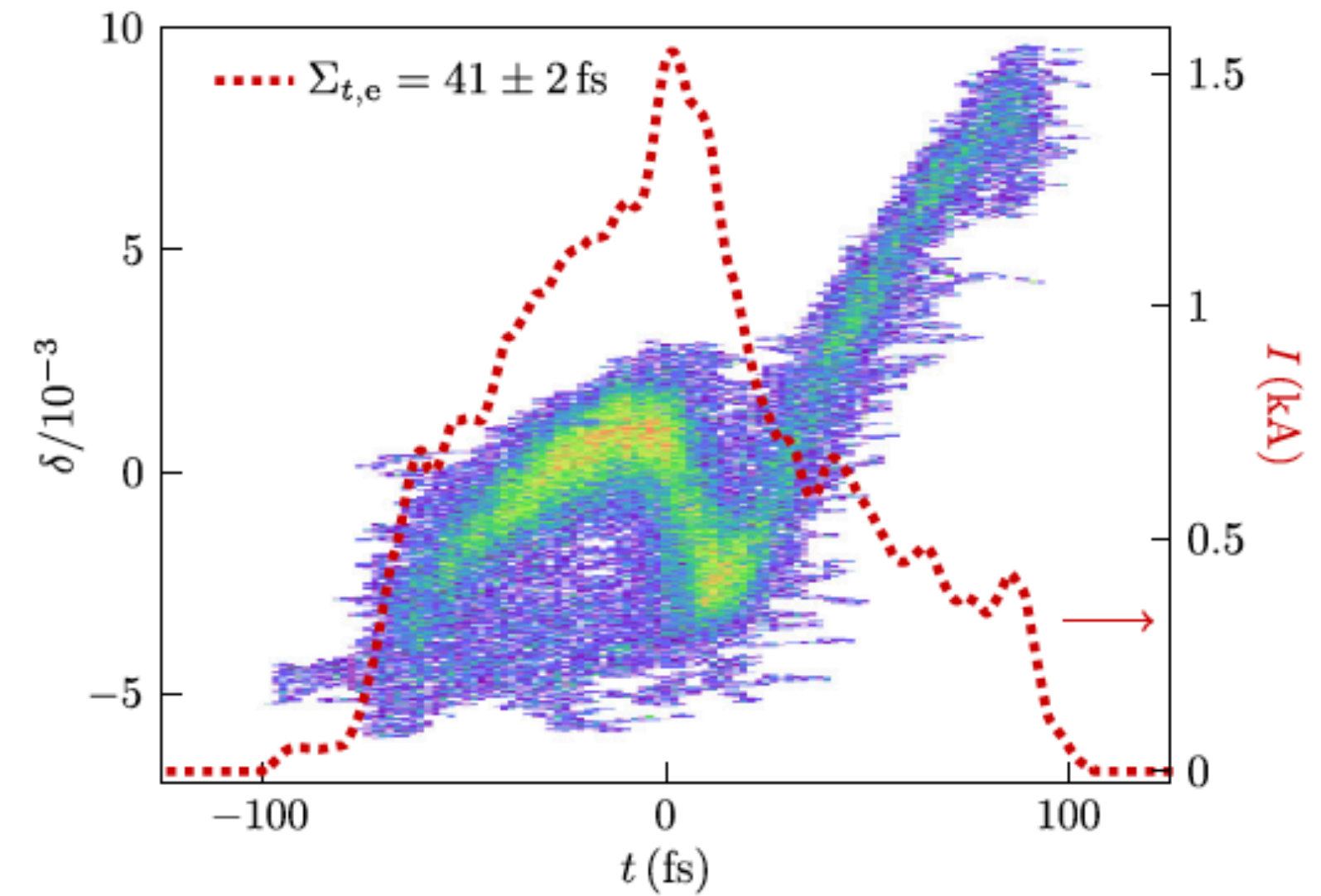


FLASHForward feature: tunable R_{56} in extraction dogleg for optimized peak current

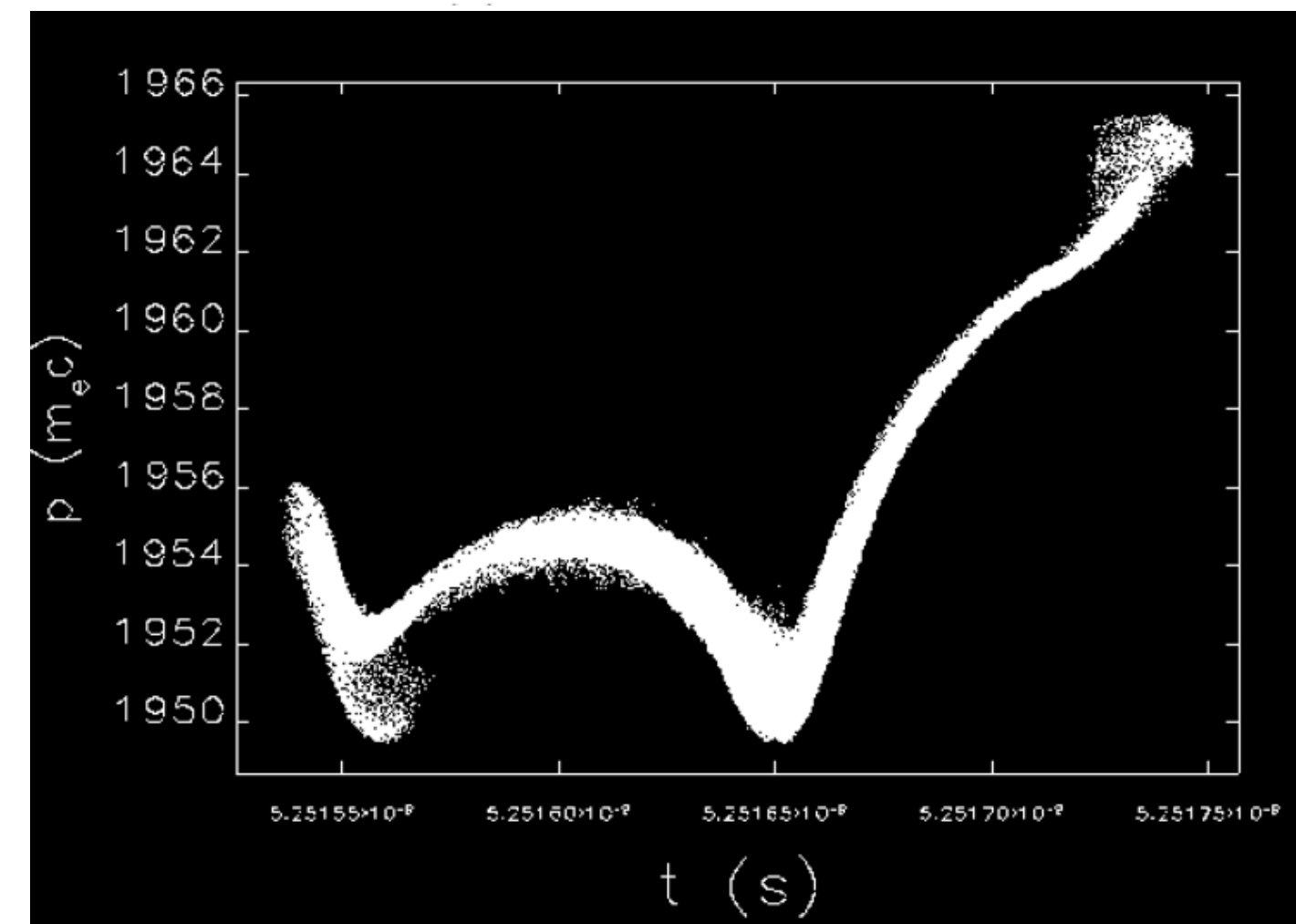


- > FLASH beams are
 - close to maximum compression
 - strongly affected by longitudinal space charge
 - chirp of the core has different sign

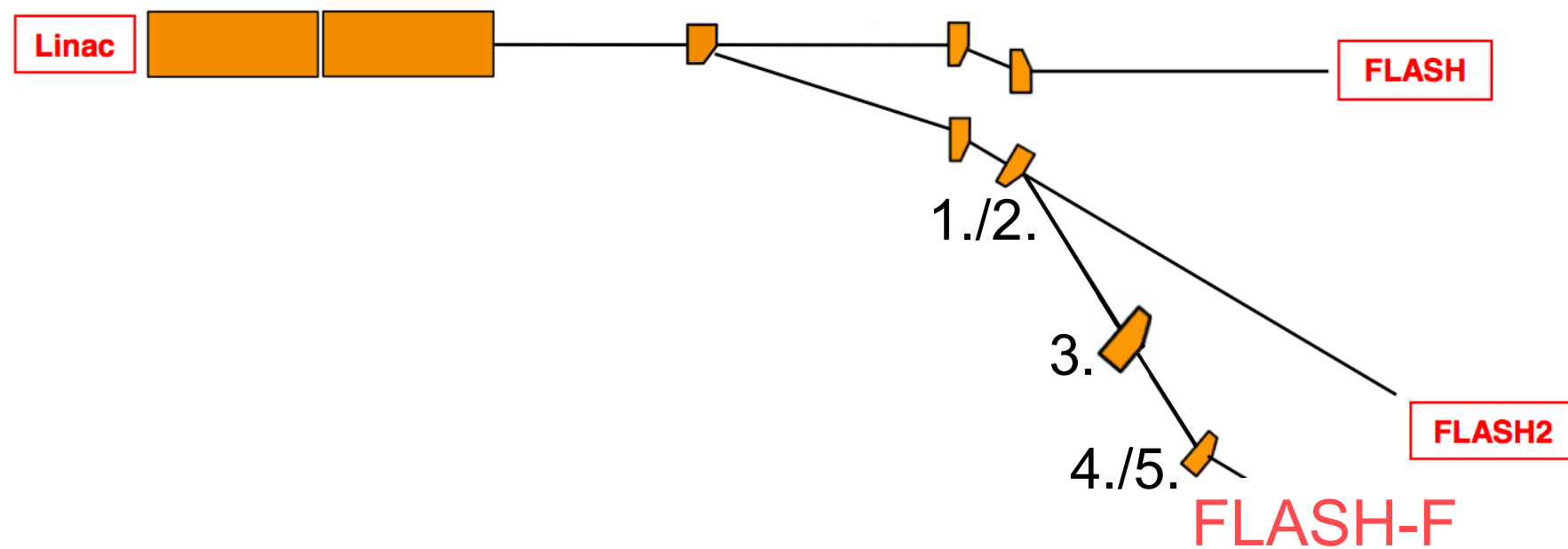
Experiment



Simulation

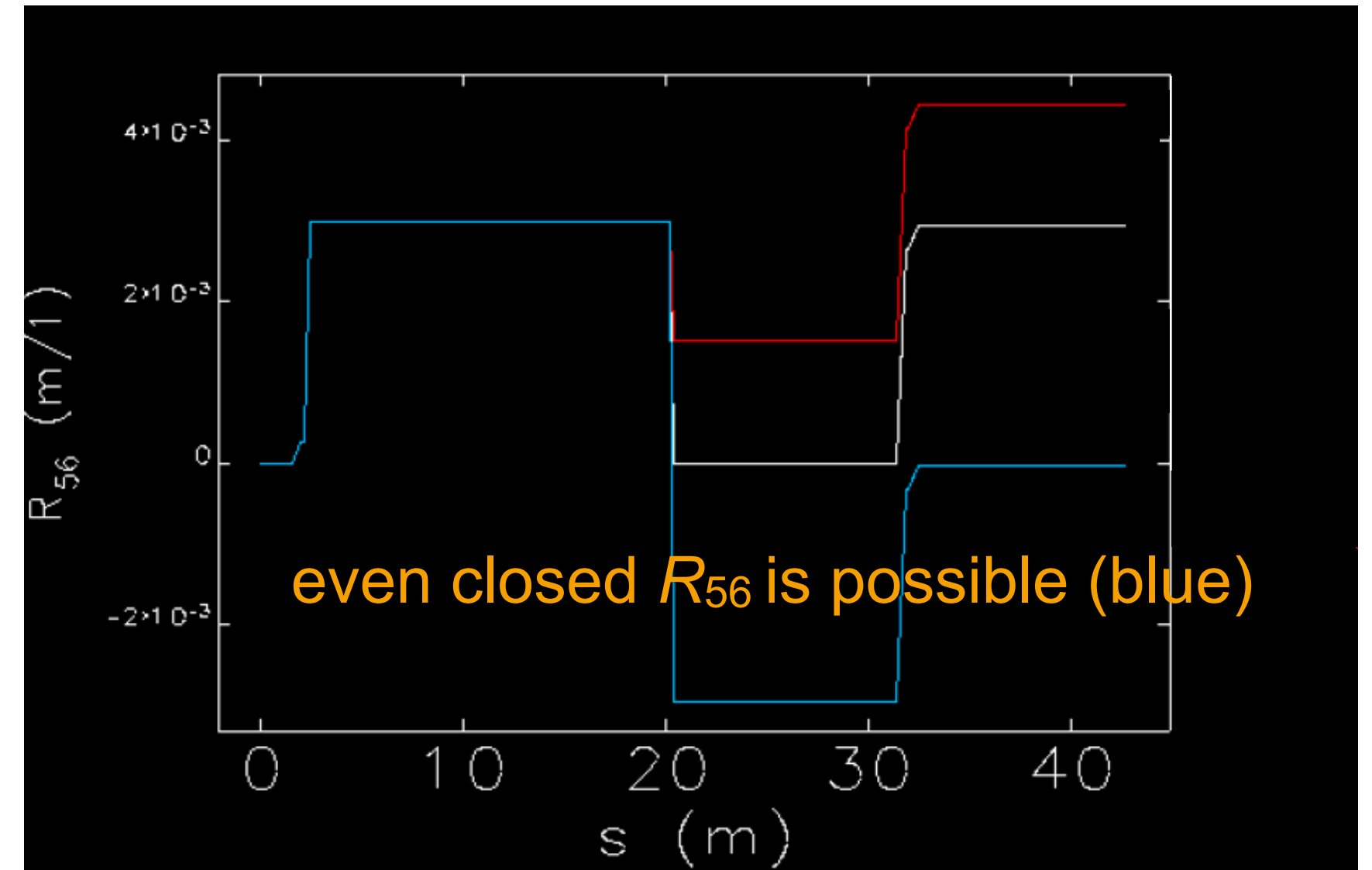


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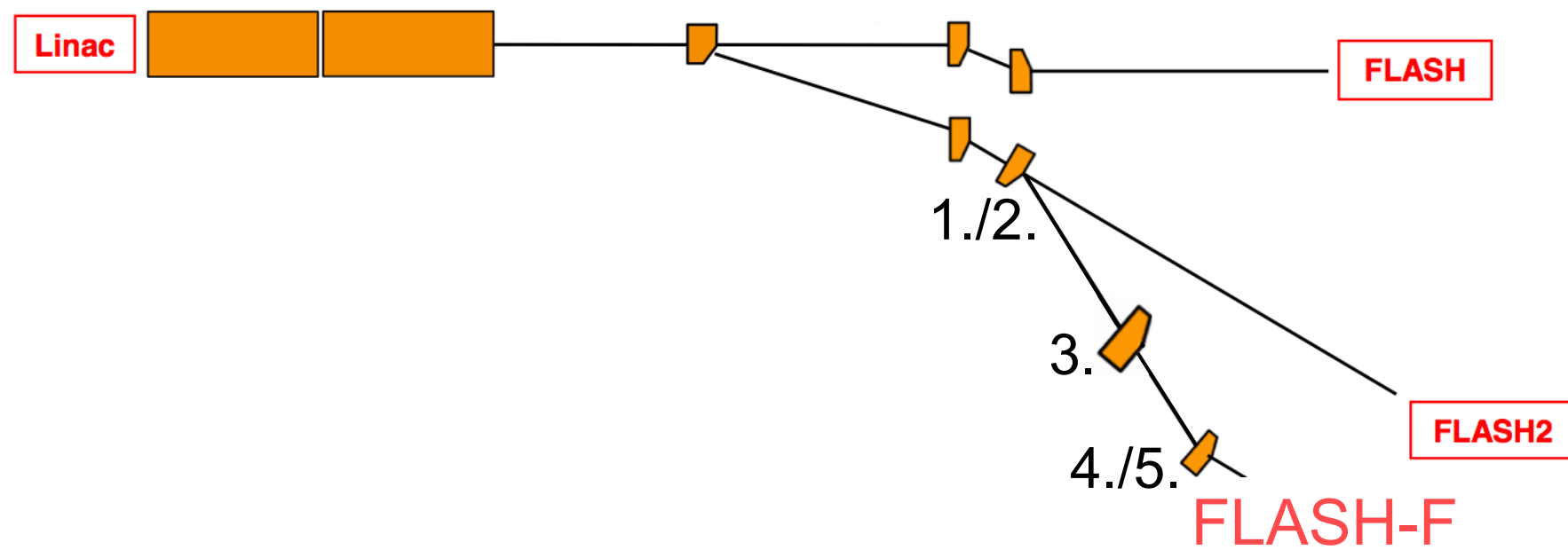


- > FLASH beams are
 - close to maximum compression
 - strongly affected by longitudinal space charge
 - chirp of the core has different sign
- > Our strategy:
 - decompress the whole beam, but compress the core for high peak current
 - keep $R_{56} \geq 0$ along the extraction beamline
 - tunability in the RF settings
- > Status:
 - optimization of emittance growth for high current mode ongoing
 - emittance growth for $R_{56} = 0$ small

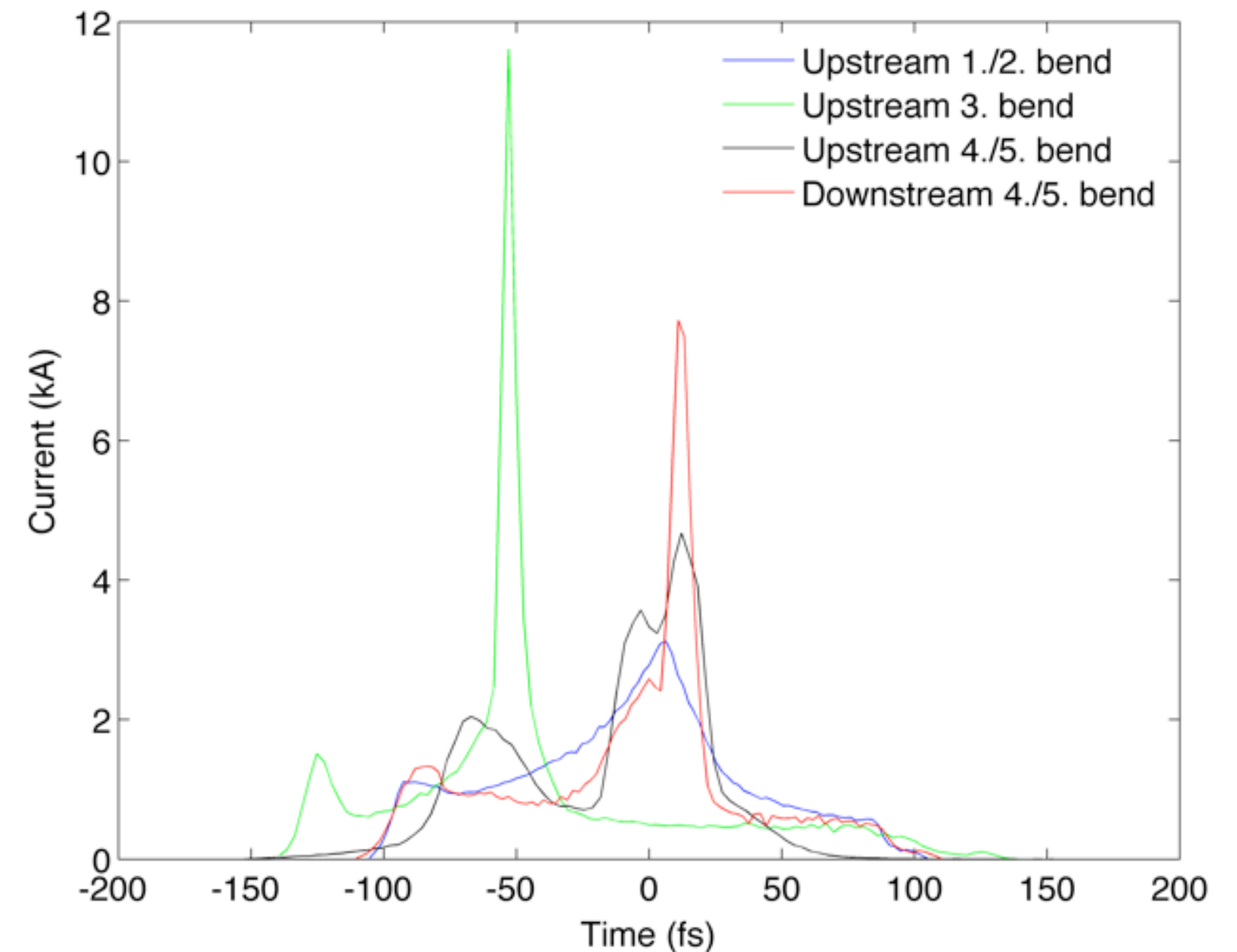
> R_{56} tunable from 0 to 4mm



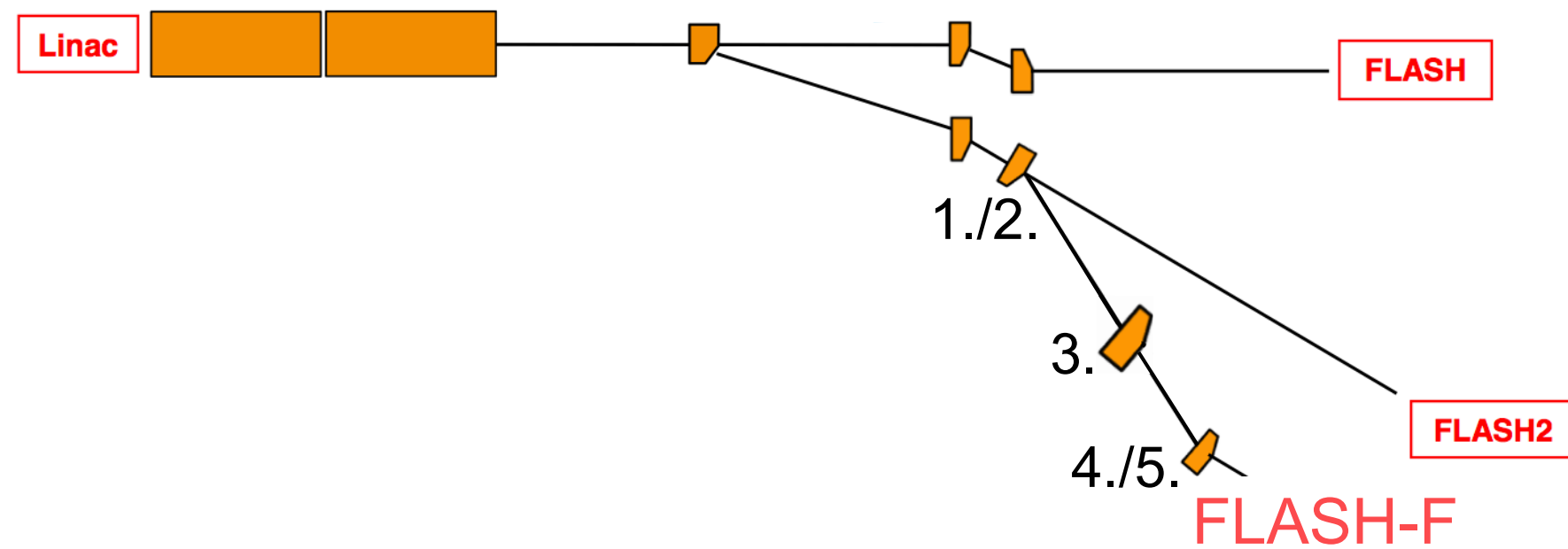
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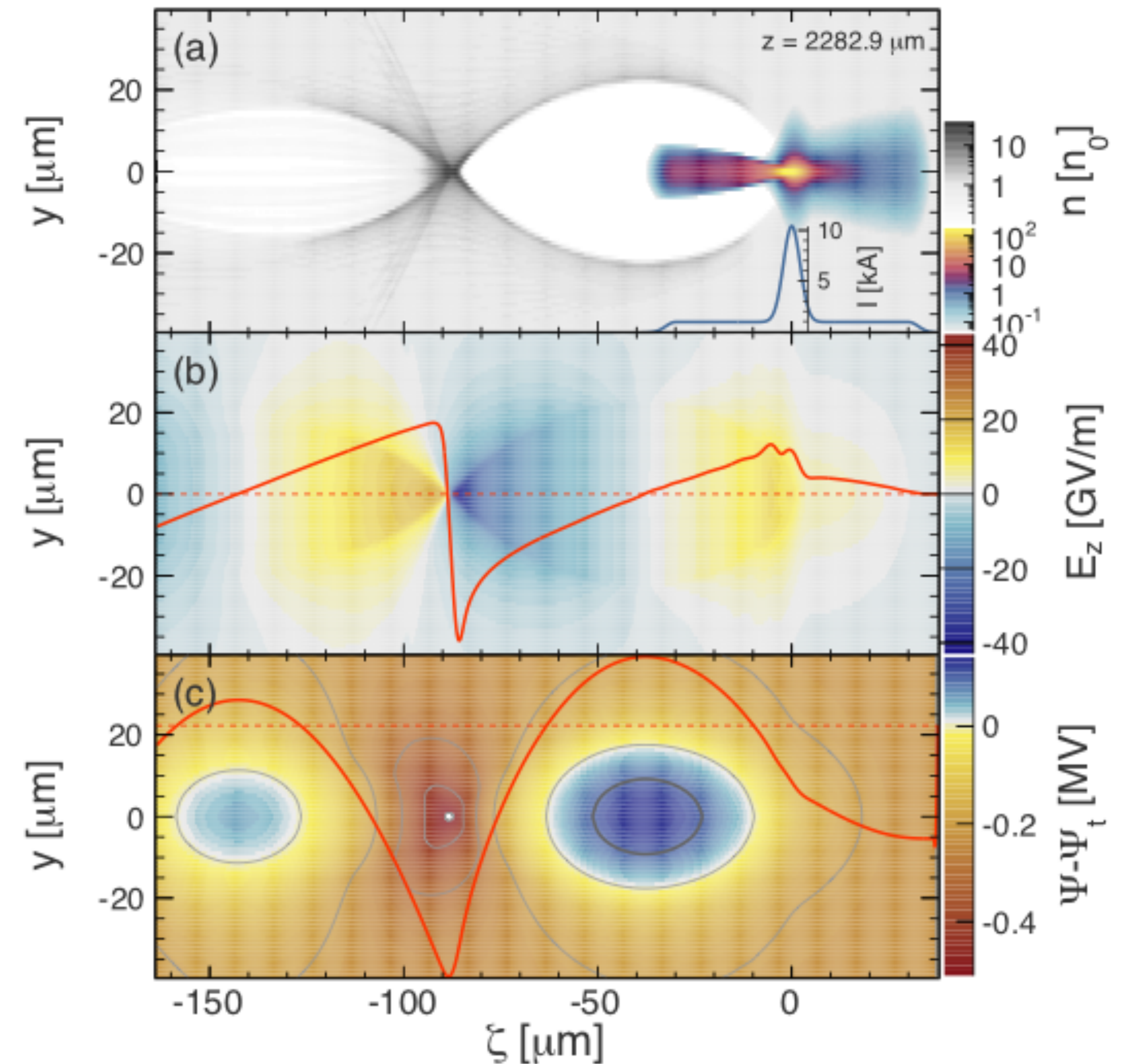
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FLASHForward feature: tunable R_{56} in extraction dogleg for optimized peak current



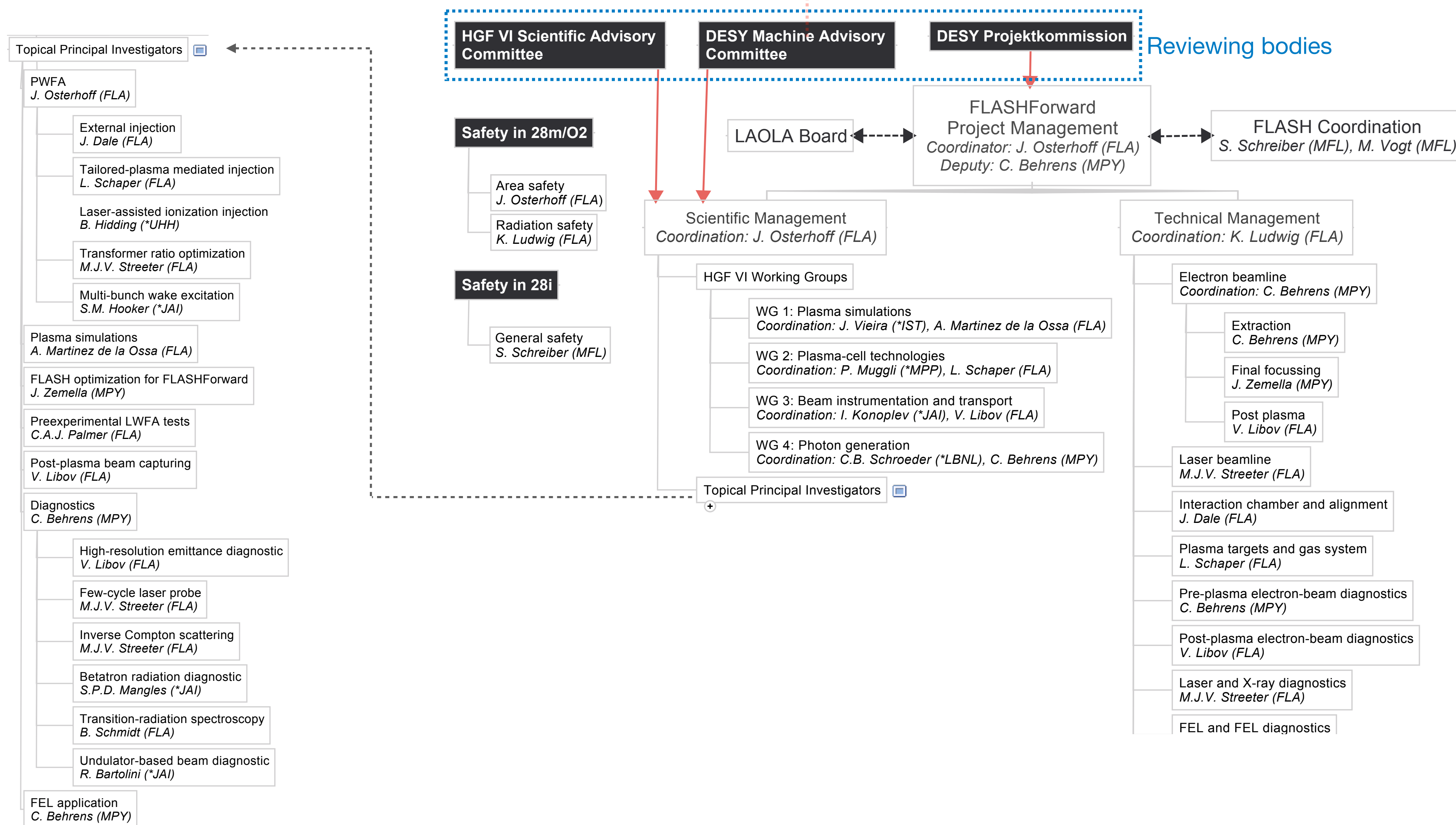
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Project organization

“The interest in PWFA experiments worldwide and DESY's strength in accelerator and FEL expertise make this proposal [i.e. FLASHForward] very competitive and timely. The MAC strongly endorses this project to move forward in the ARD framework.”

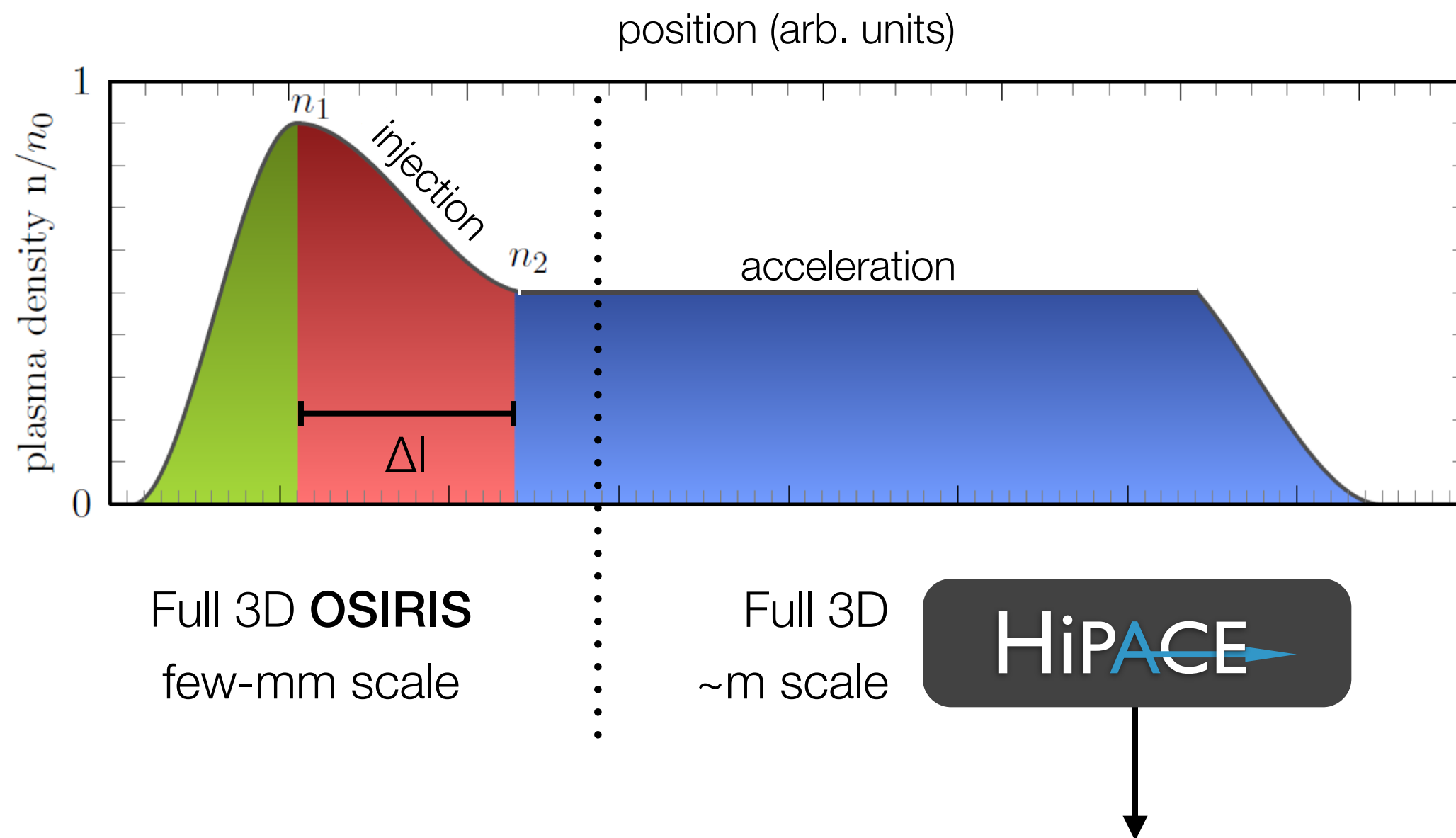
MAC minutes from May 7th and 8th, 2013



HGF VI Working Groups to develop and advance FLASHForward science program and tools

- > Working groups:
 - > WG 1 “Plasma simulations”, coordinators: Jorge Vieira (IST), Alberto Martinez de la Ossa (DESY)
 - > WG 2 “Plasma-cell technologies”, coordinators: Patric Muggli (MPP), Lucas Schaper (DESY)
 - > WG 3 “Beam instrumentation and transport”, coordinators: Ivan Konoplev (JAI), Slava Libov (DESY)
 - > WG 4 “Photon generation”, coordinators: Carl Schroeder (LBNL), Christopher Behrens (DESY)
- > Goals of these working group:
 - a) to **develop** and **advance** the FLASHForward science case by simulations and theory
 - b) to **propose** and **conduct** experiments at FLASHForward
- > The WGs are essential for the development of FLASHForward and are foreseen to play a major role in defining its experimental programme
- > FLASHForward is no user facility (e.g. such as FACET). Experimental proposals will be discussed and implemented through the collaboration, i.e. this VI and its WGs.
- > FLASHForward will be a unique facility with its capabilities, VI a great opportunity to gain access
- > WGs are open, please contact coordinators, if interested in participation

Challenges for 20 cm-scale down-ramp injection simulations



Computational challenge

- > 20 cm-scale acceleration with ~ 100 nm spatial resolution
- > capture physics of trapping \rightarrow full PIC required
- > cost: $\sim M$ core hours with full PIC

> T. Mehrling *et al.*, accepted for publication in PPCF (2014)

HiPACE - a highly efficient plasma accelerator emulation

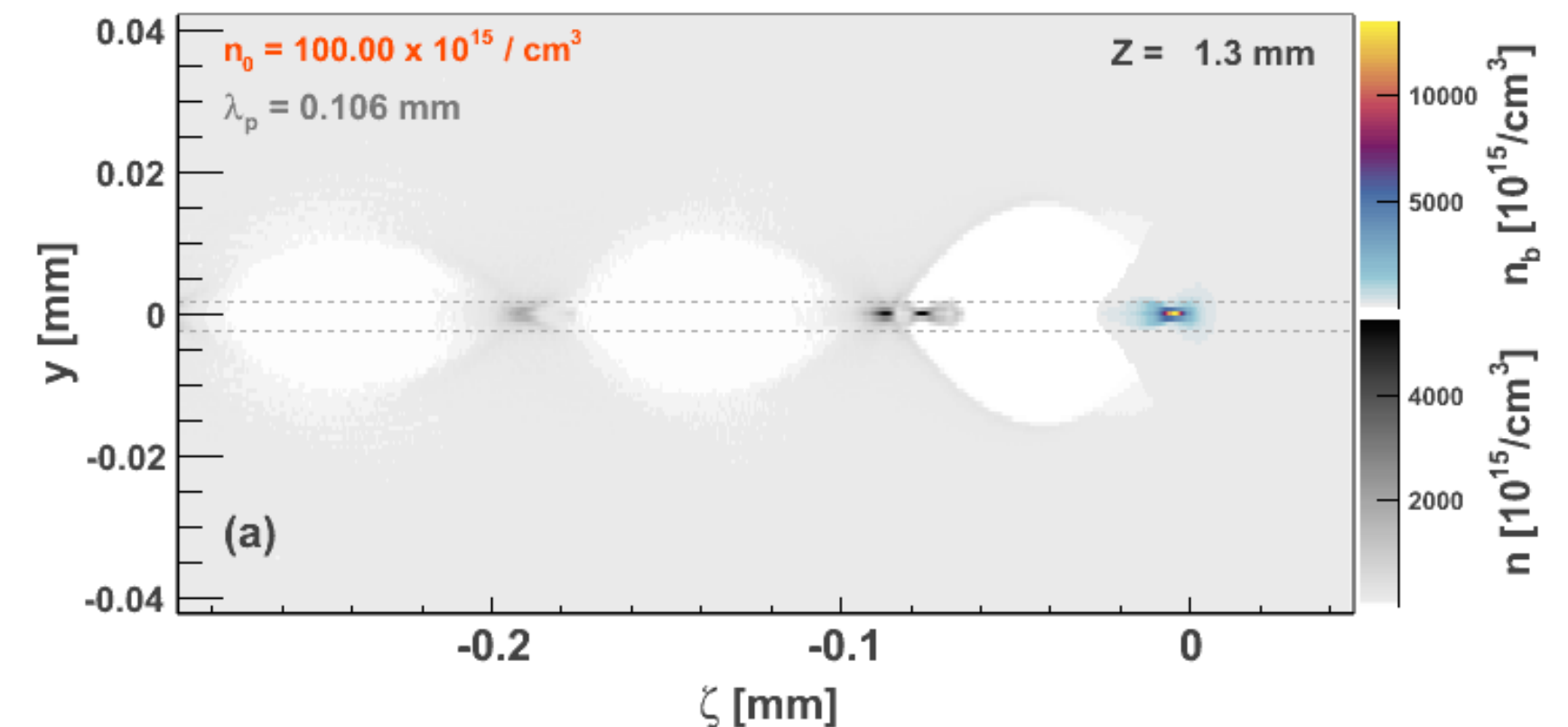
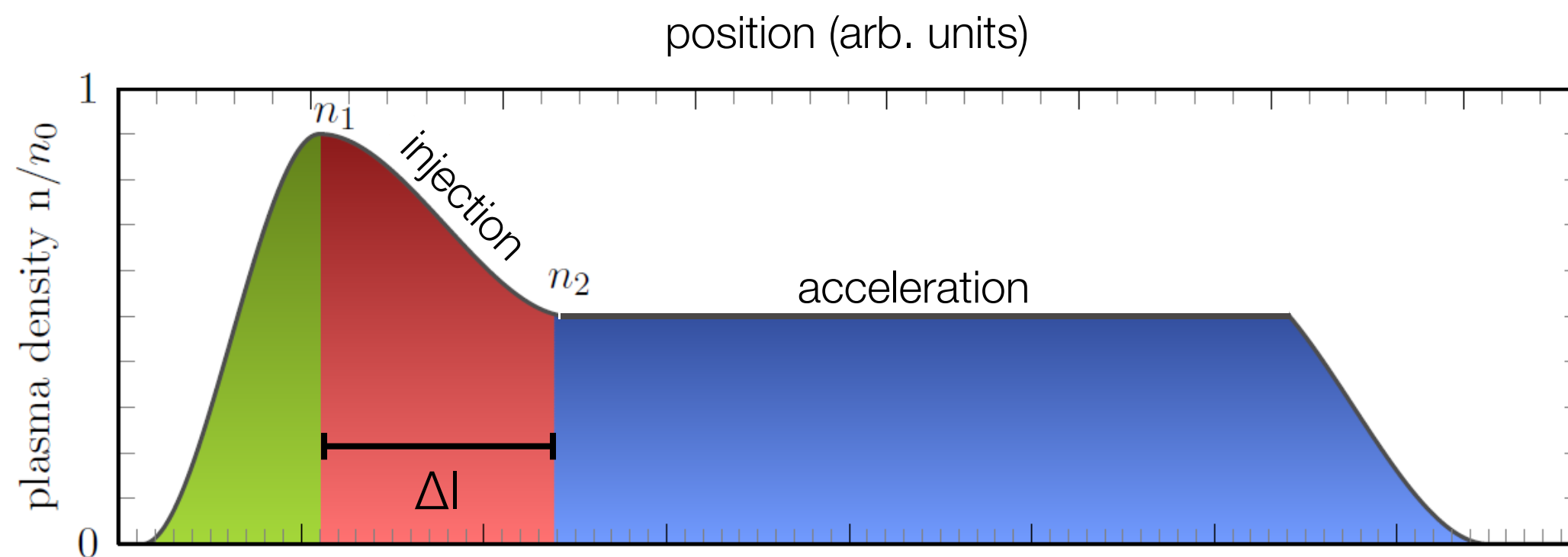


developed in collaboration
between DESY and LBNL

- > 3D quasi-static particle-in-cell code
- > fully parallelized and well scalable
- > dynamic time-step adjustment
- > allows **orders-of-magnitude speedup** for FLASHForward-type simulations vs. full PIC
- > interfaces seamlessly with OSIRIS

Density down-ramp injection produces low-transverse-emittance witness beams

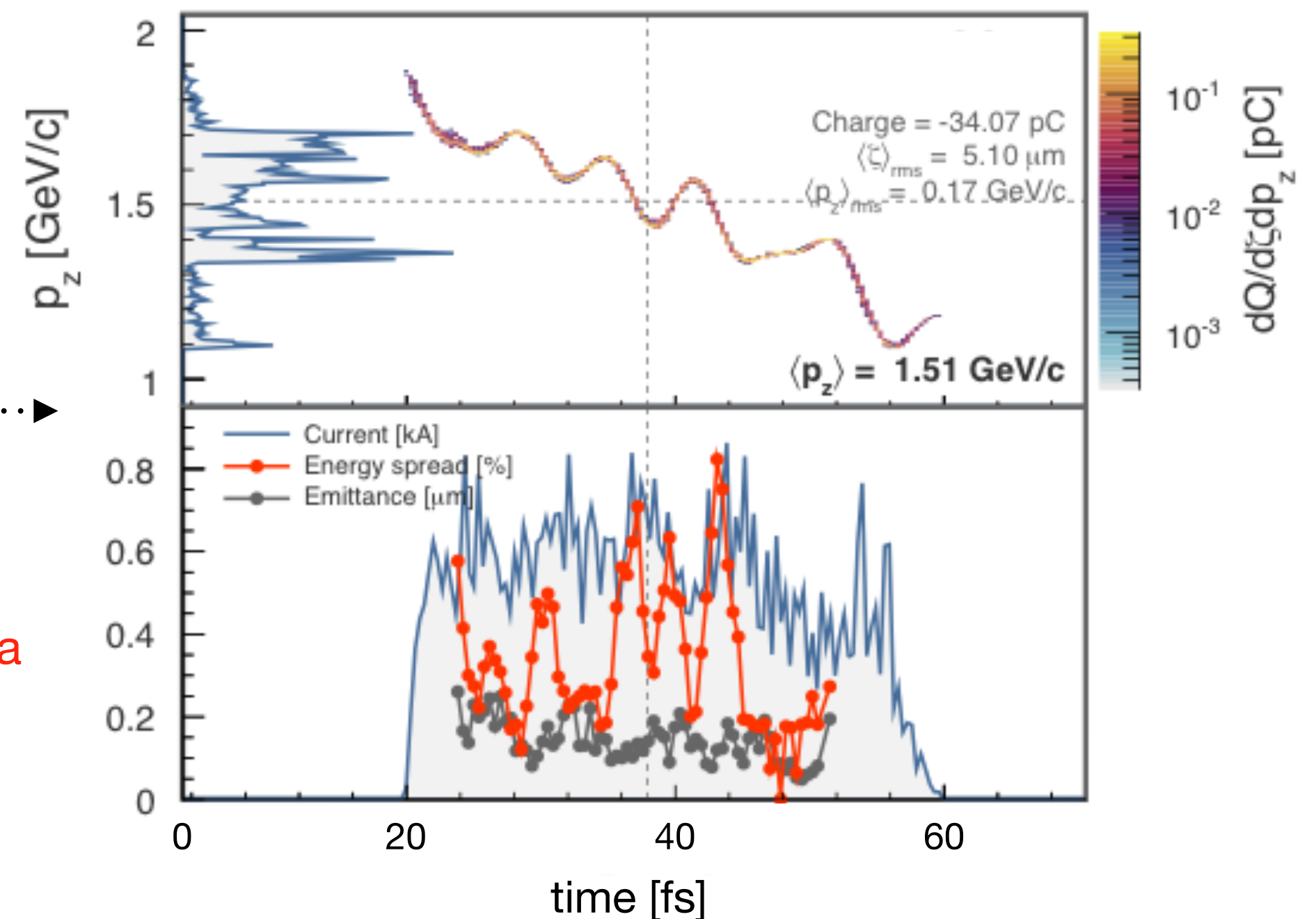
→ J. Grebenyuk et al., NIM A 740, 246 (2014)



Witness-beam parameters after 140 mm of propagation

- standard FLASH driver beam at 2.5 kA
- witness beam at 1.5 GeV with 1.0 GeV driver
- further acceleration to ~2.5 GeV possible
- projected normalized transverse emittance < 0.5 μm
- strong longitudinal correlation

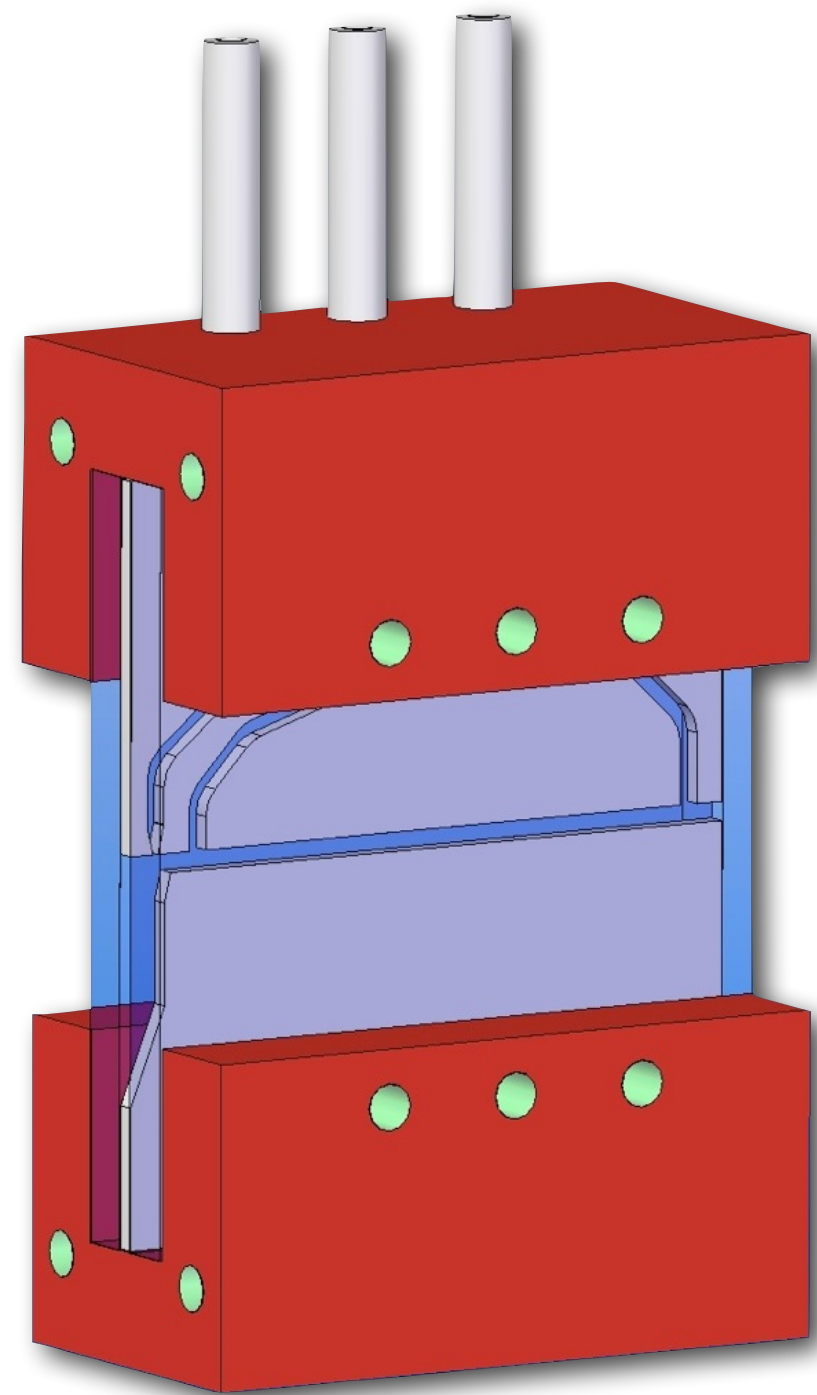
→ WG 1 talk by A. Martinez de la Ossa



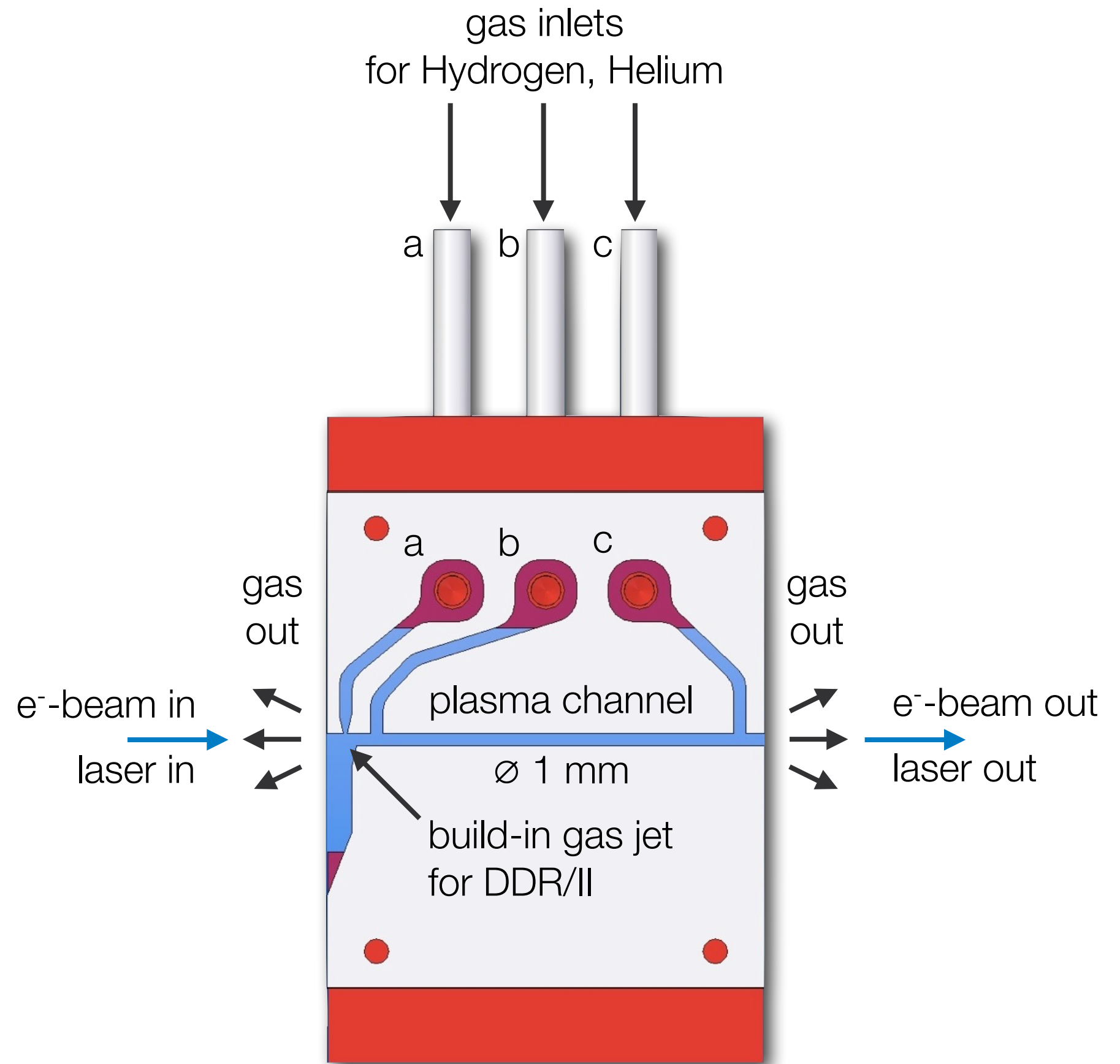
Can such beams drive an FEL?

→ WG 4 talk by C. Behrens

New plasma-cells support novel PWFA-injection schemes



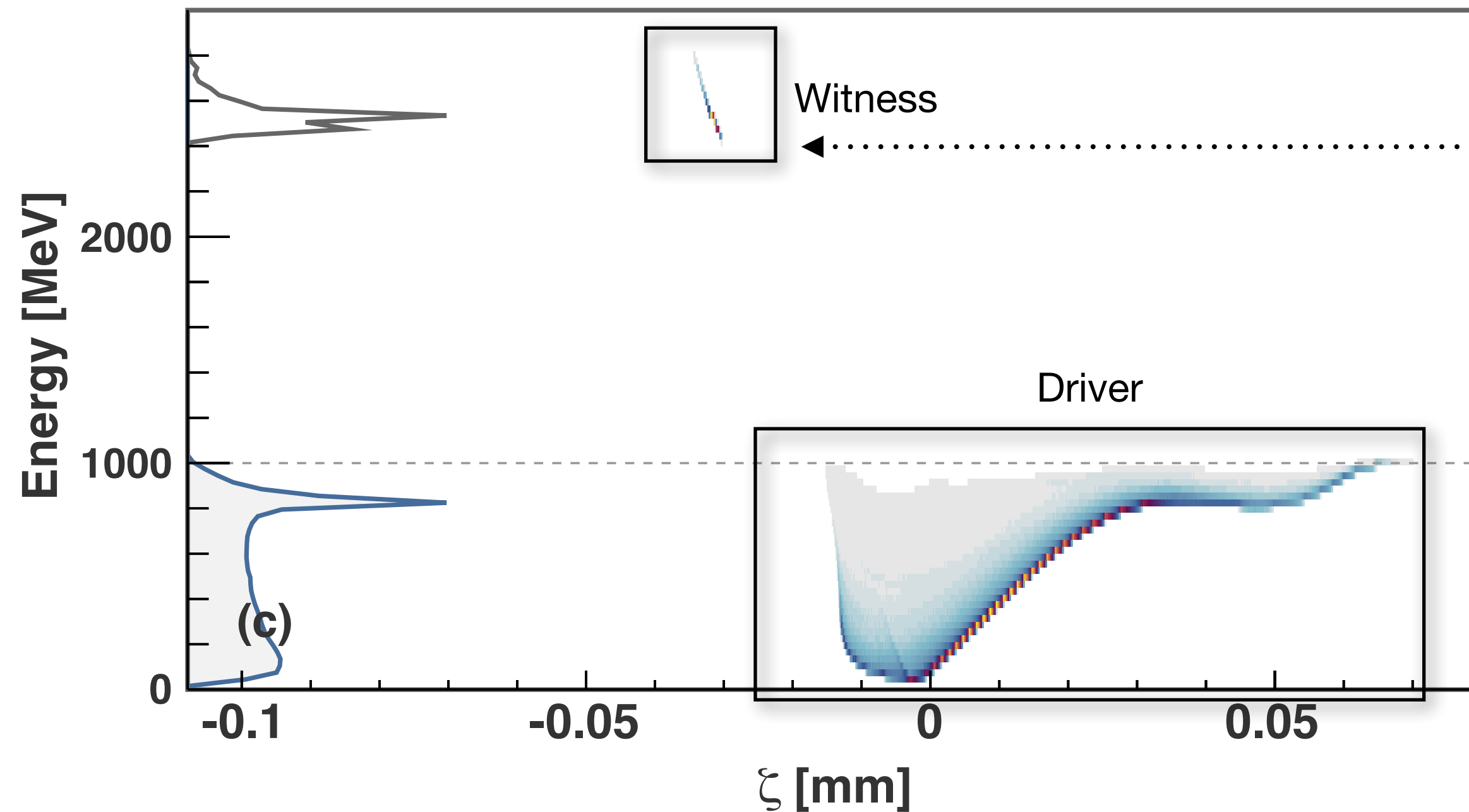
by L. Schaper (DESY),
N. Delbos, A. Maier (U Hamburg)



→ WG 2 talk by L. Schaper

Diagnositics and beam transport must fit PWFA requirements

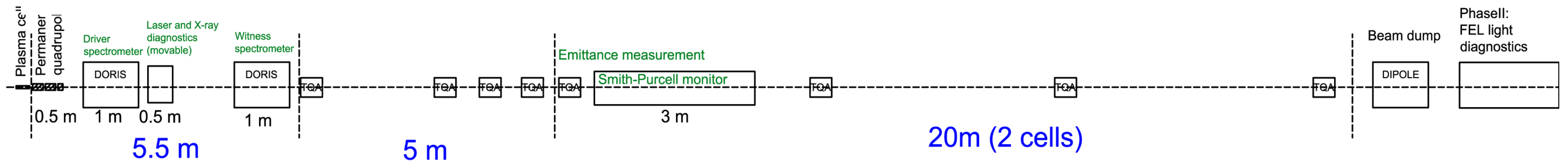
Example: longitudinal phase-space after plasma interaction at FLASHForward
(from a PIC simulation)



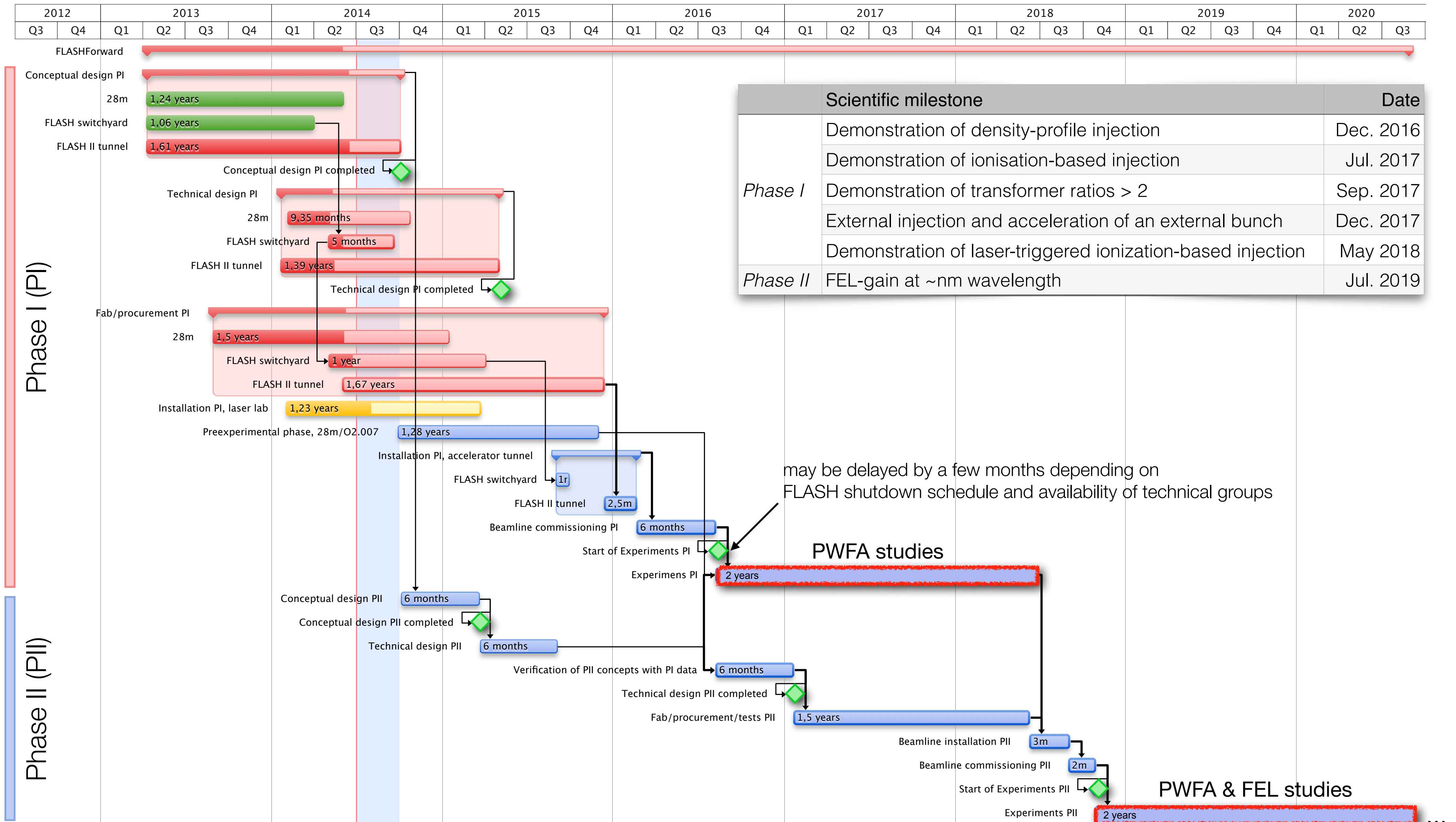
Common features

- > strong longitudinal correlation
- > projected energy spread in the few % range
- > uncorrelated energy spread in the ‰ range
- > < 1 to 20 fs rms duration
- > projected norm. emittances of $\ll 1 \mu\text{m}$

Longitudinal phase-space properties largely uncharacterized
challenge: temporal resolution



Experiments to start in 2016, run for 4 years



Summary

- > FLASHForward is a beamline for novel accelerator research and development, going into operation in 2016
- > Great chance to use a unique accelerator, FLASH, for significant scientific contributions towards the field of PWFA
 - > *external injection and in-plasma beam-generation* and acceleration techniques to provide high-energy (1.5 to 4+ GeV), low transverse emittance (~ 100 nm), ultrashort (\sim fs), and high current (> 1 kA) electron bunches
 - > the application of such beams to assess their potential for *free-electron laser gain* at photon energies inside and beyond the water window
- > Opportunities within this VI exist to do a lot of interesting accelerator R&D and physics over the next years