Plasma Wakefield Acceleration Experiments at DESY – emphasis FLASH

E. Elsen & J. Osterhoff
for the DESY & Uni Hamburg group

Pre-meeting of the Virtual InstitutePlasma wakefield acceleration of highly relativistic electrons with FLASH, SLAC, Oct 8, 2012

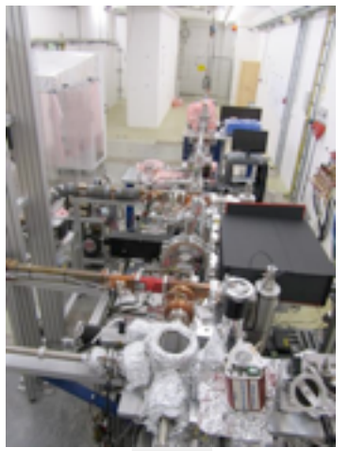
Plasma Wakefield Experiments and plans at DESY

2010

2015

2020

REGAE



5 MeV e⁻

laser

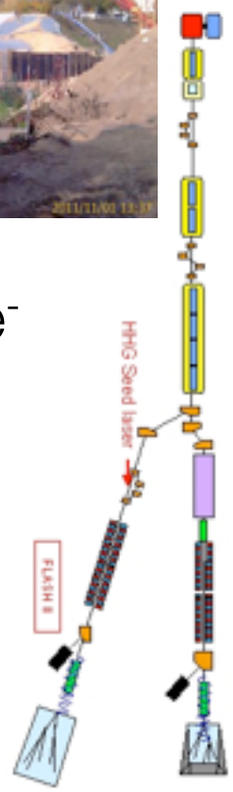
PITZ

14 MeV e⁻

beam

FLASH

1 GeV e⁻



laser & beam

Dedicated facility

laser & beam

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5 MeV e^-

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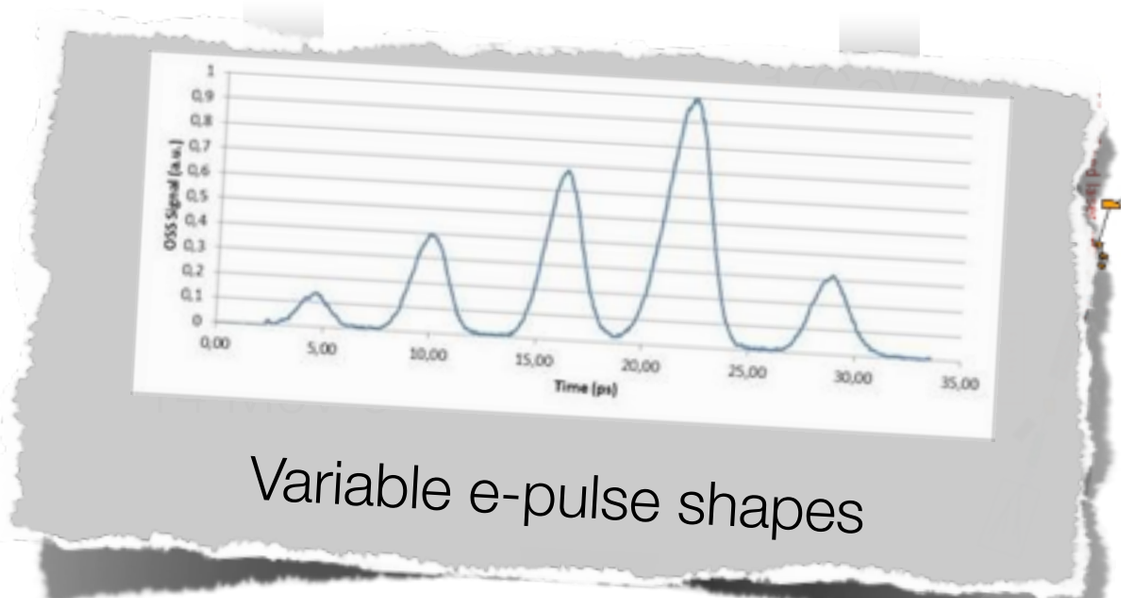


Variable e-pulse shapes

beam

laser & beam

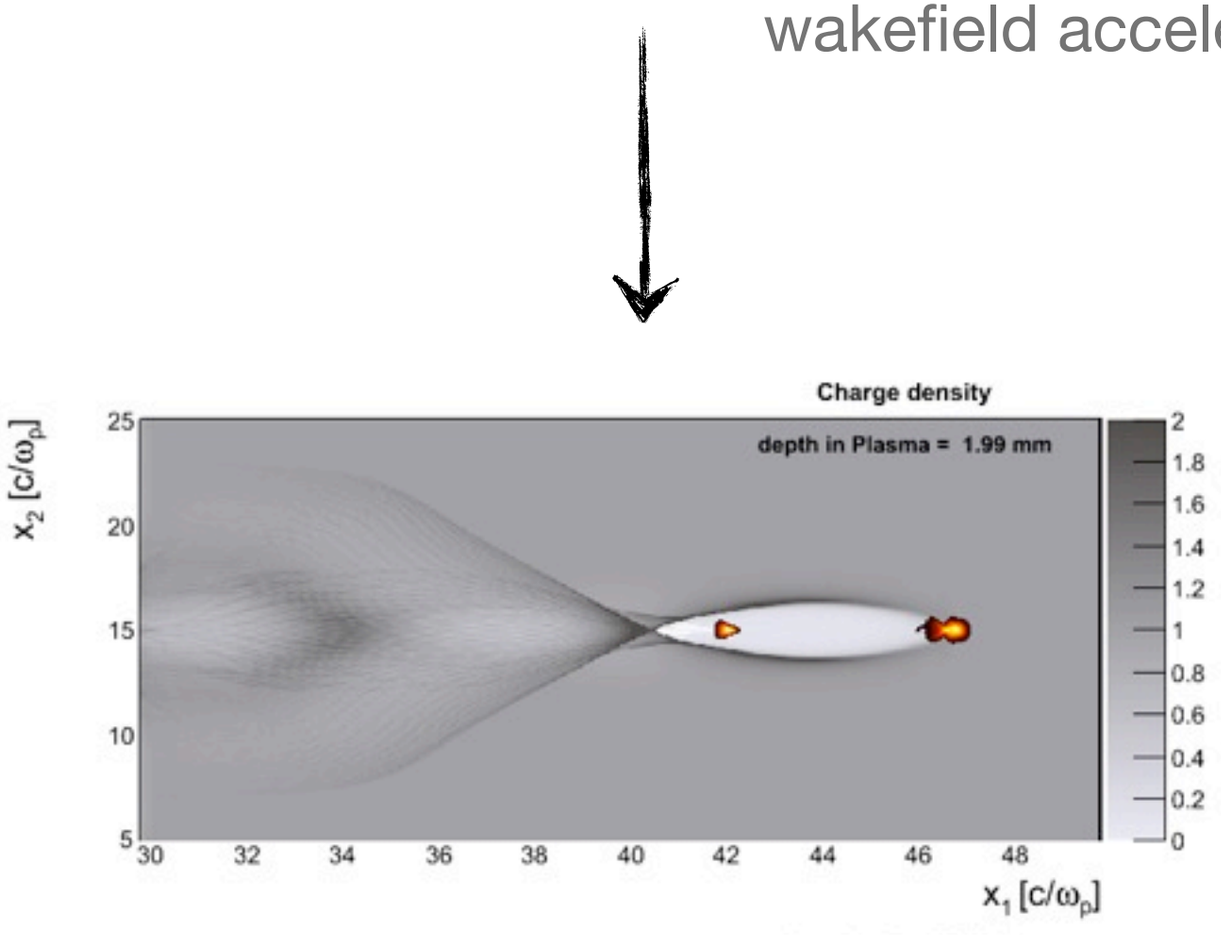
Dedicated facility

laser & beam

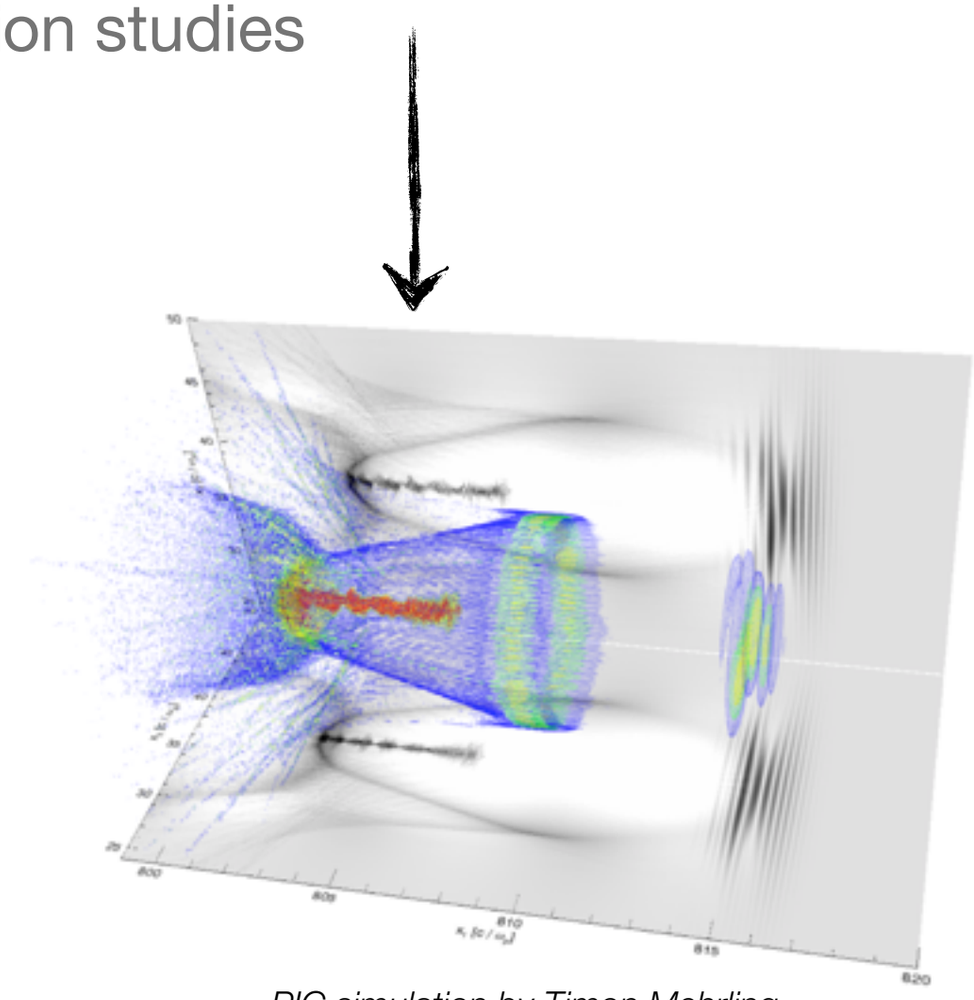
The goal

Beam-driven **Laser-driven**

wakefield acceleration studies



PIC simulation by Alberto Martinez de la Ossa



PIC simulation by Timon Mehrling

Why at FLASH? – Scientific interest…

- FLASH offers unique electron-bunch shaping capabilities
  - triangular beams
  - tailored bunch trains (e.g. with the addition of a PITZ-like gun-laser system)
- GeV beam energy
  - stiff beams (compared to e.g. PITZ and REGAE)
    - probe longitudinal and transverse field of plasma
  - $\gamma_{beam} \geqq \gamma_{wake}$ for LPA

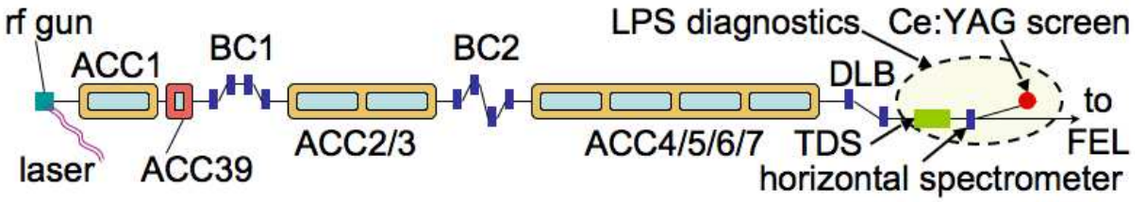
DESY TESLA-FEL 11-02 and FERMILAB-PUB 11-339-APC

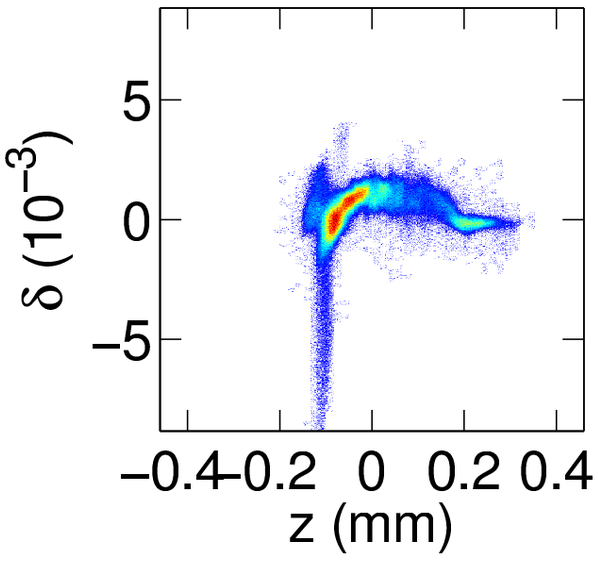
Generation and Characterization of Electron Bunches with Ramped Current Profiles in a Dual-Frequency Superconducting Linear Accelerator

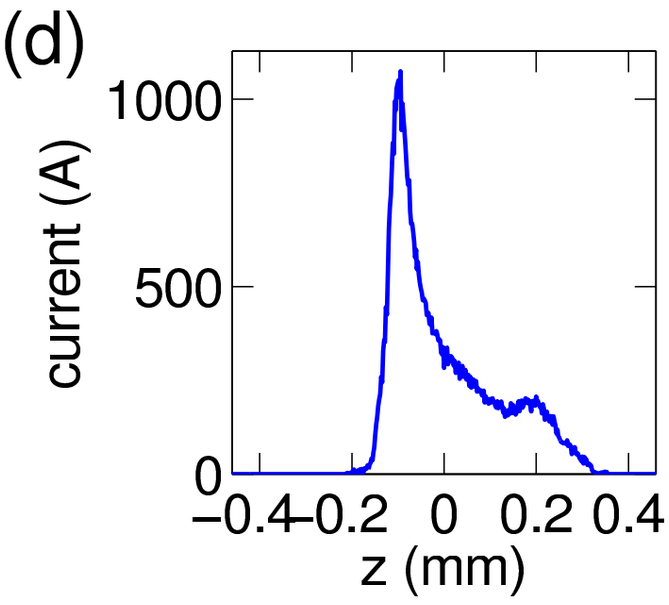
P. Piot,[1,2] C. Behrens,[3] C. Gerth,[3] M. Dohlus,[3] F. Lemery,[1] D. Mihalcea,[1] P. Stoltz,[4] and M. Vogt[3]

[1] *Northern Illinois Center for Accelerator & Detector Development and Department of Physics, Northern Illinois University, DeKalb IL 60115, USA*
[2] *Accelerator Physics Center, Fermi National Accelerator Laboratory, Batavia, IL 60510, USA*
[3] *Deutsches Elektronen-Synchrotron DESY, Notkestraße 85 D-22607 Hamburg, Germany*
[4] *Tech-X Corporation, Boulder, CO 80303, USA*

(Dated: September 8, 2011)



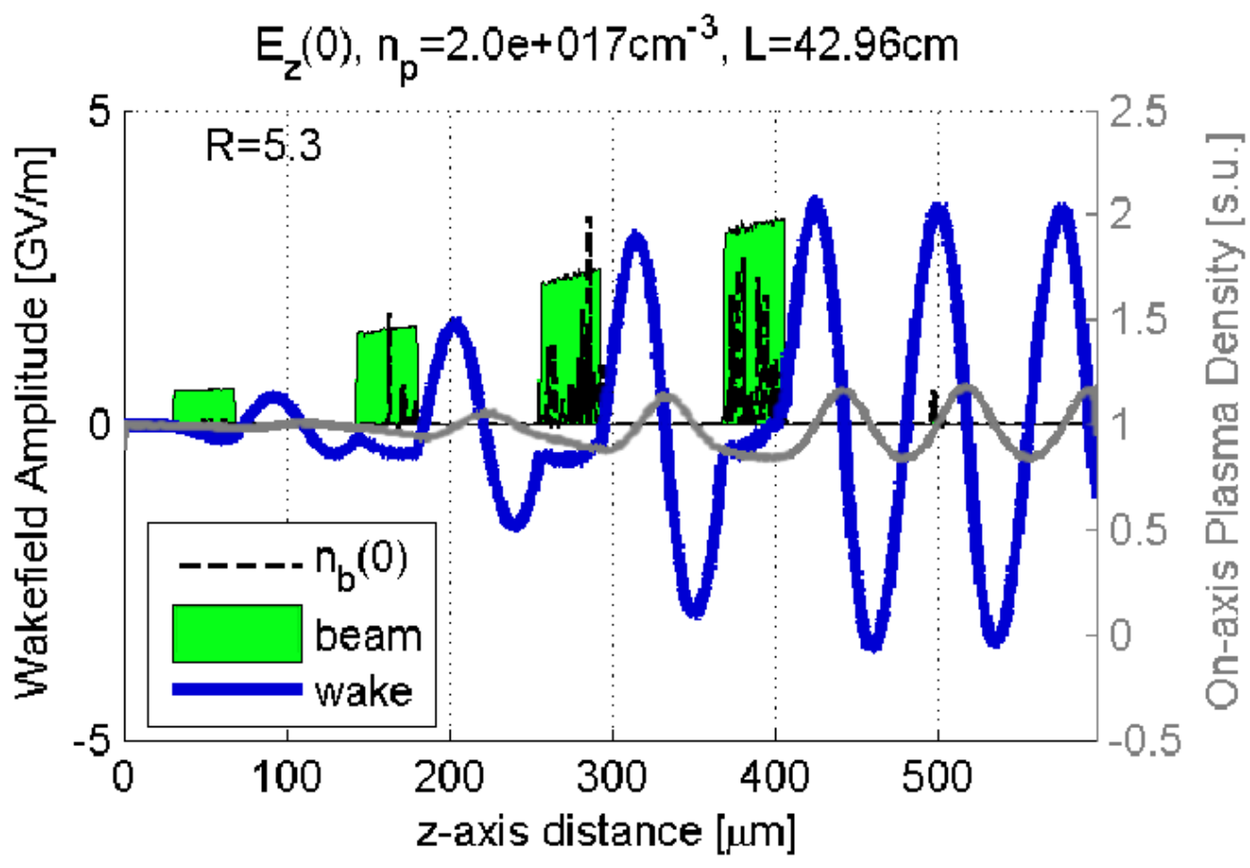




Electron beam	Laser pulse	Scientific purpose
Single beam driver (various longitudinal shapes, durations)	–	*Beam etching, stopping experiments*
Single beam driver + short witness bunch (various longitudinal shapes, durations)	–	*Witness acceleration experiments:* Driver shape → transformer ratio study Witness shape → (slice) emittance, energy spread preservation study, beam loading Phase-space mapping Energy doubling+ (from 1 to 2+ GeV)
Multi-bunch driver + short witness bunch (longitudinally tailored)	–	*Witness acceleration experiments:* Bunch-train shape → transformer ratio study, beam loading Phase-space mapping Energy doubling+++ (from 1 to multiple GeV)
Short witness bunch (longitudinally tailored)	Wake driver	*External bunch-injection experiments:* Plasma beam dump Mapping of wake phase space Off-axis injection for tailored radiation source Witness shape → emittance, energy spread preservation study, beam loading Energy doubling++ (with 200 TW laser) Staging testbed FEL with undulator
Various schemes (also dielectrics!)	Probe pulse	*Develop novel high-temporal resolution diagnostics:* Optical transverse deflection cavity, …

Multi bunch excitation – simulation

- Charge density increases linearly to cancel field under each bunch and excite the wake resonantly



Simulations of a High-Transformer-Ratio Plasma Wakefield Accelerator Using Multiple Electron Bunches

Efthymios Kallos[a], Patric Muggli[a], Thomas Katsouleas[a], Vitaly Yakimenko[b] and Jangho Park[b]

[a]University of Southern California, Los Angeles, CA 90089
[b]Brookhaven National Lab, Upton, NY 11973

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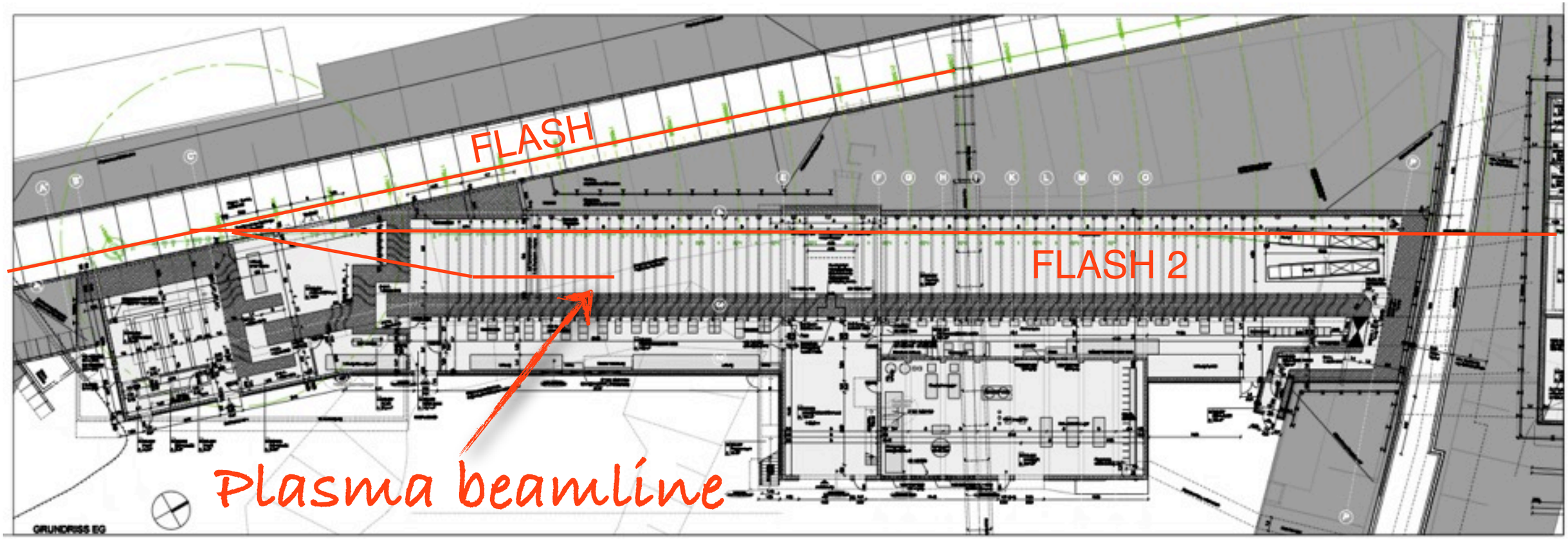
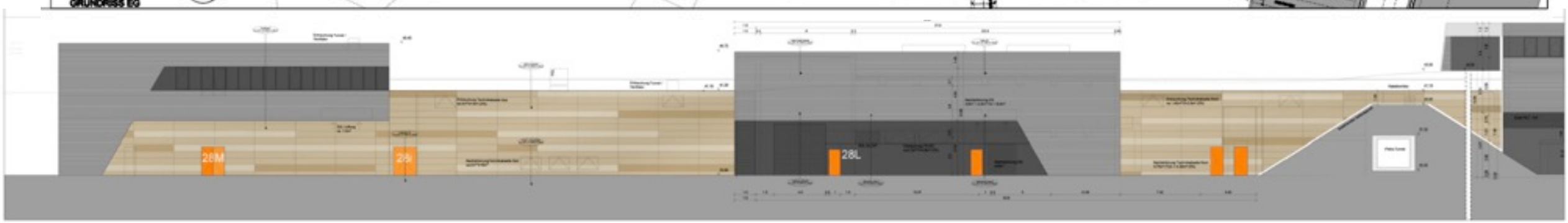
Construction

- Construction of FLASH II ongoing
  - dedicted lab foreseen





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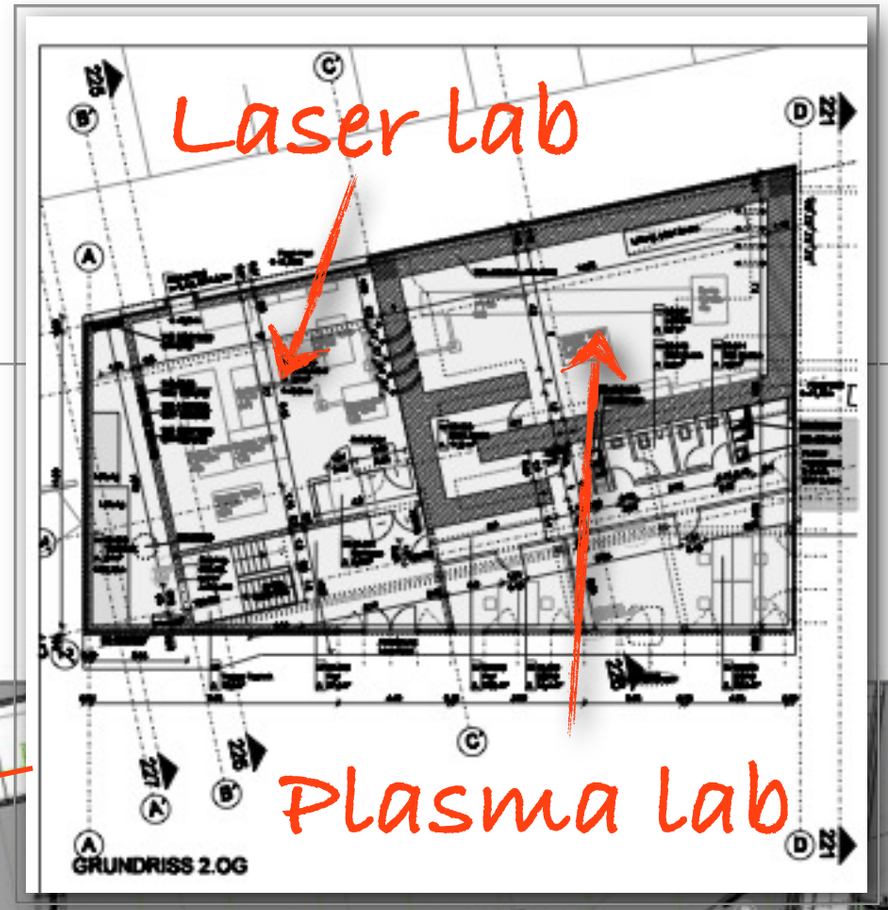
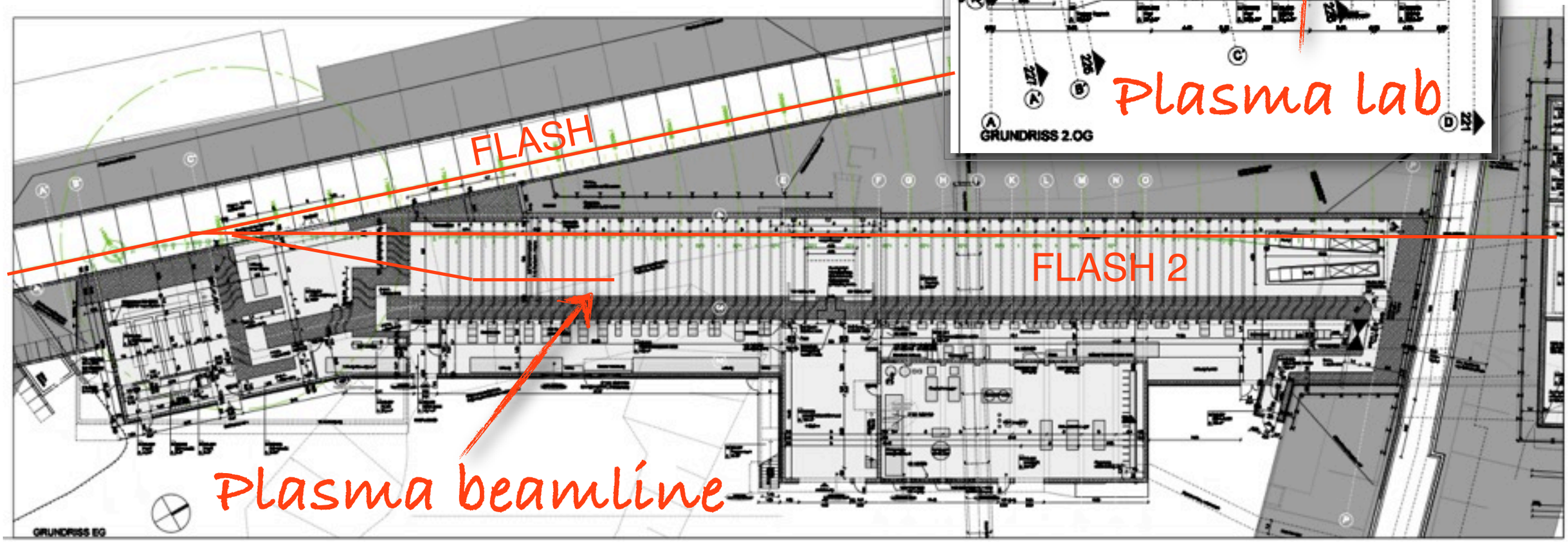
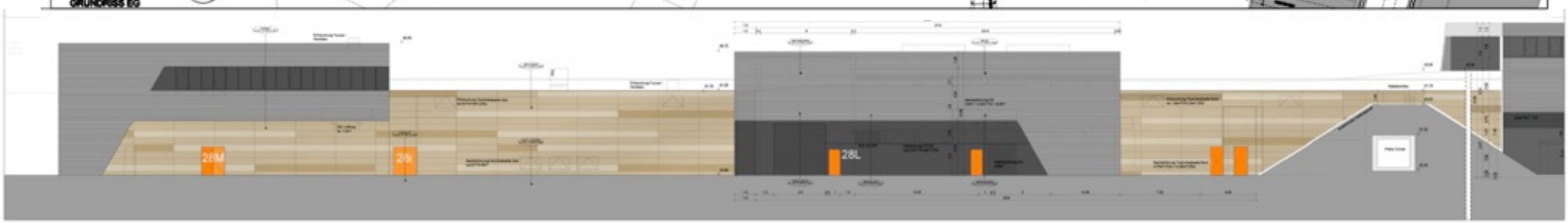
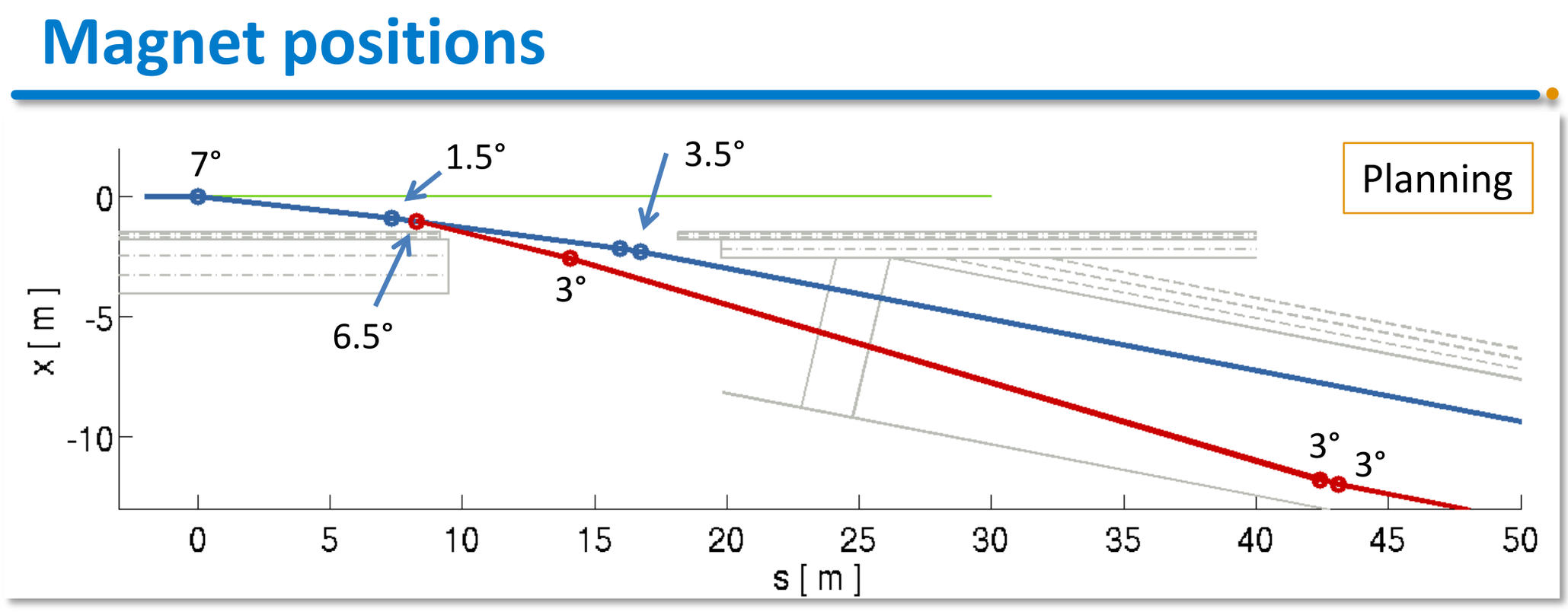




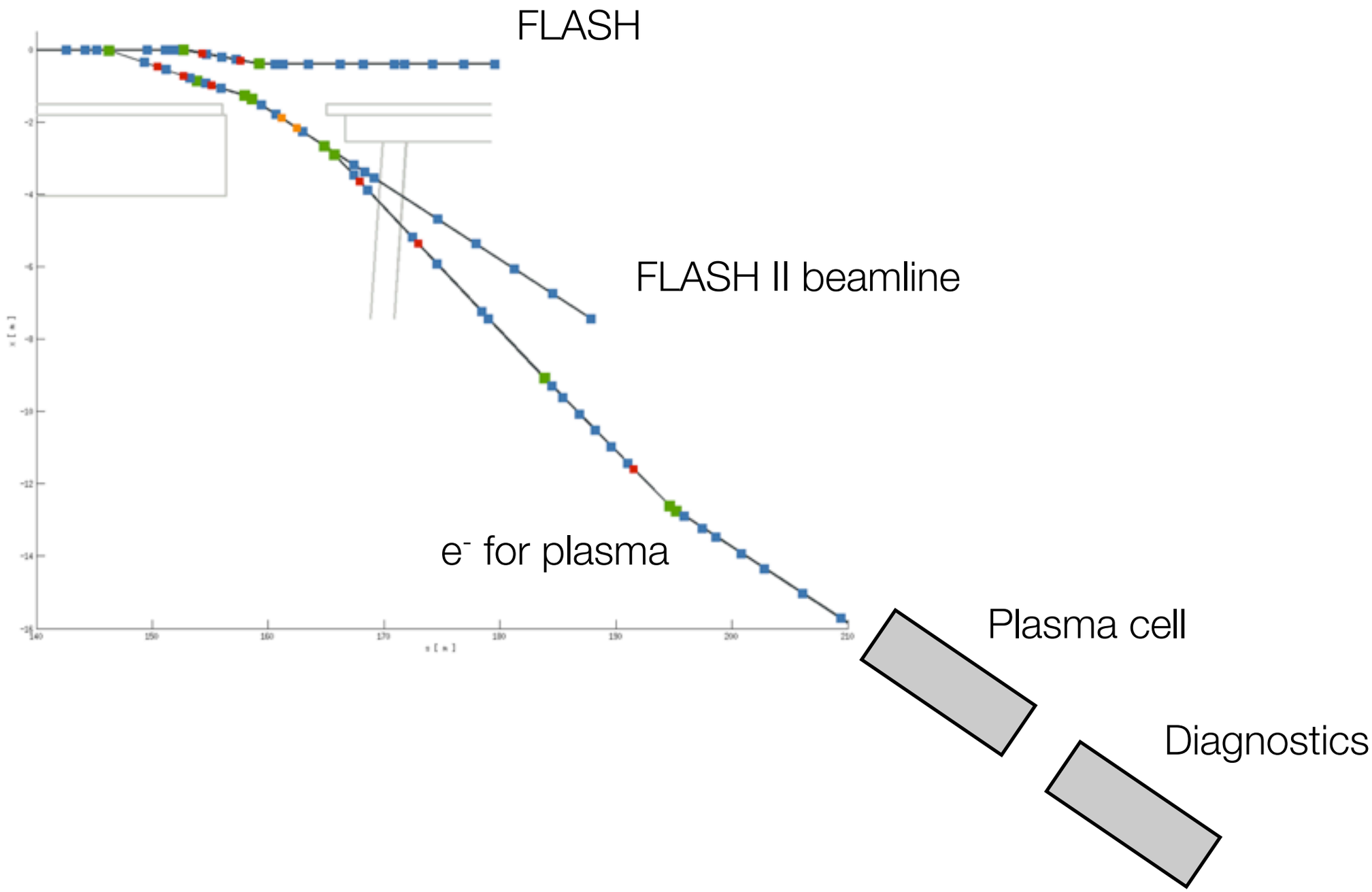


Beam transport scheme

- FLASH bunch extraction for plasma beamline is being worked on (with strong contributions of M. Scholz and W. Decking)



Beam extraction @ FLASH



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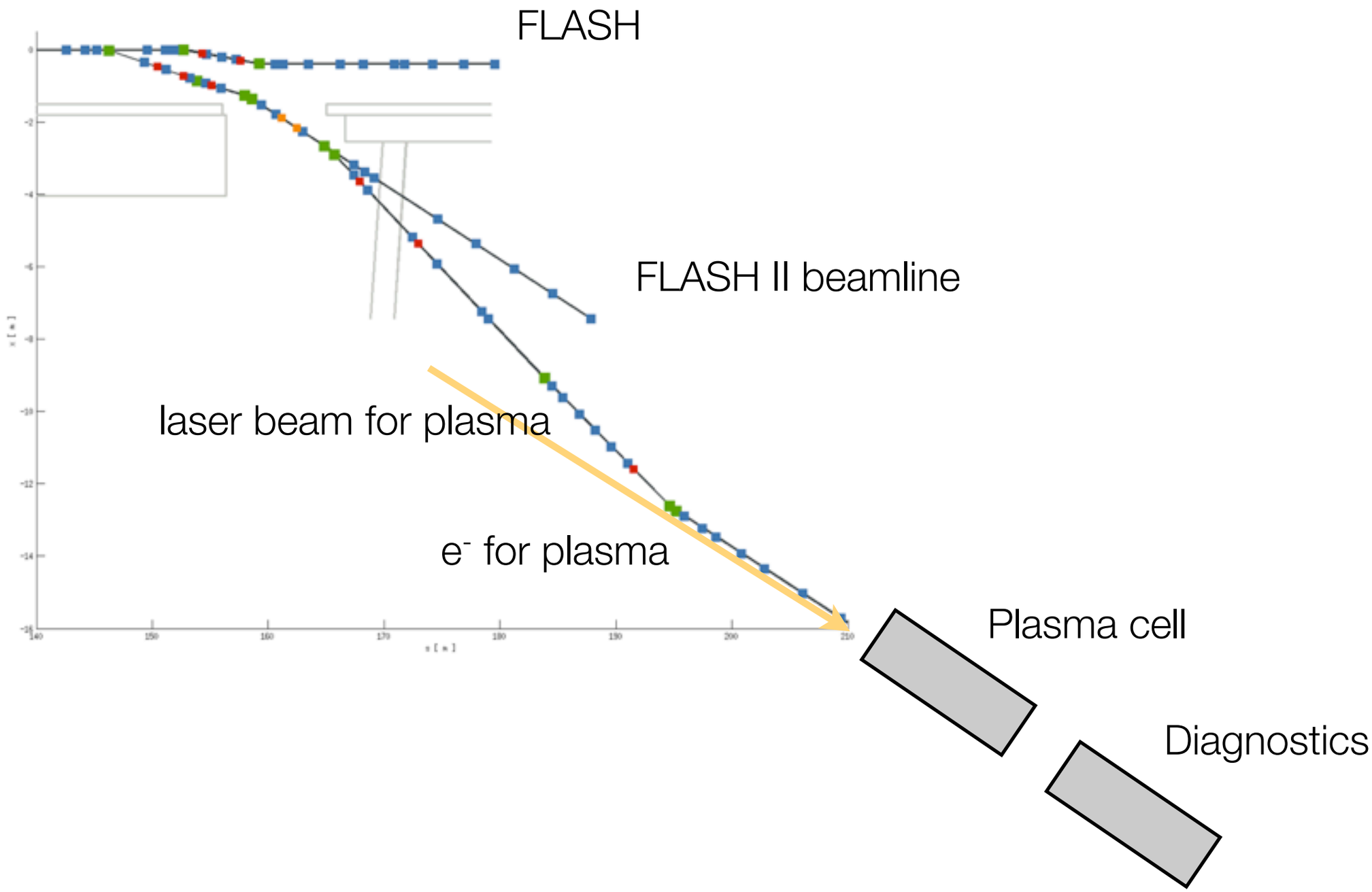
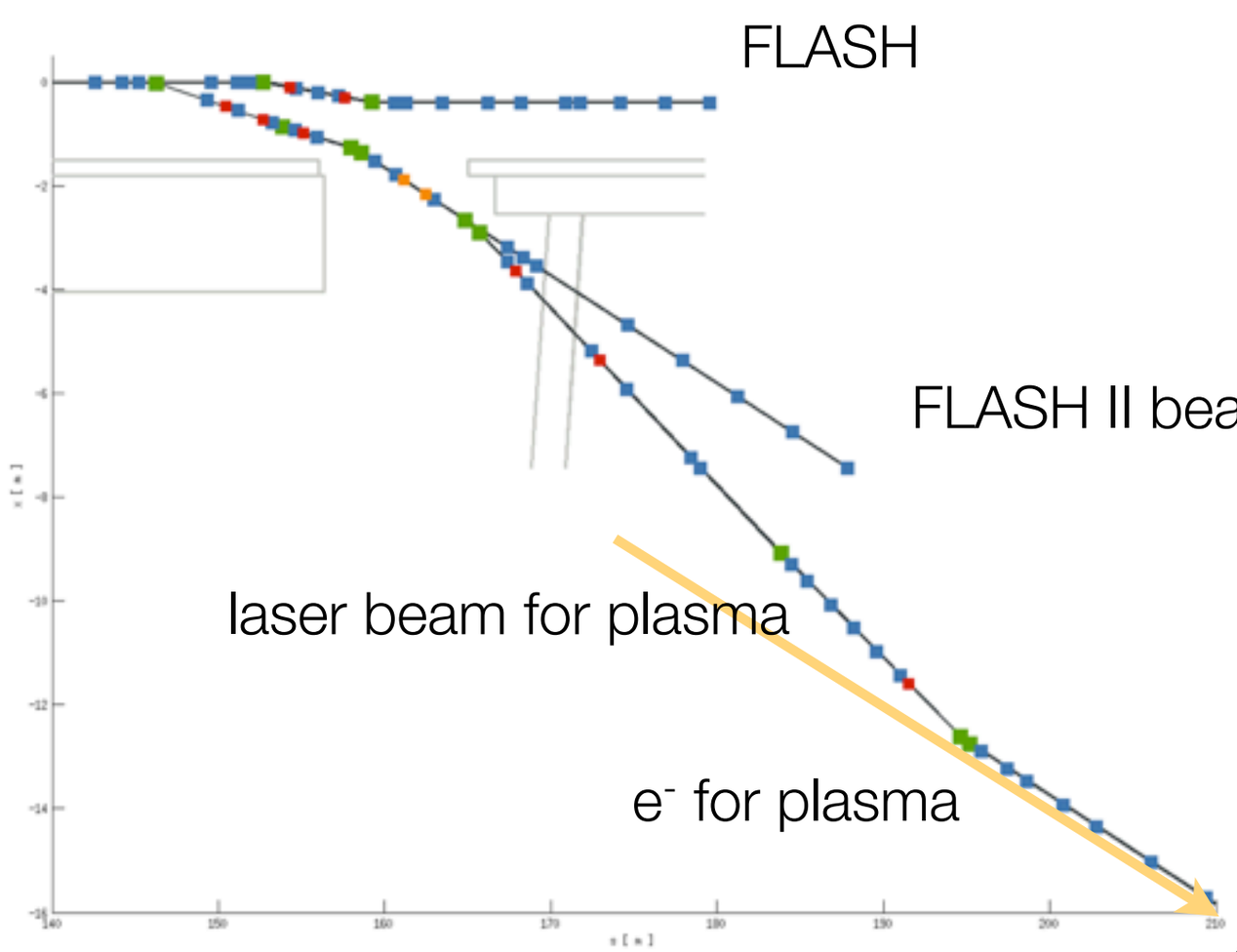


Beam extraction @ FLASH



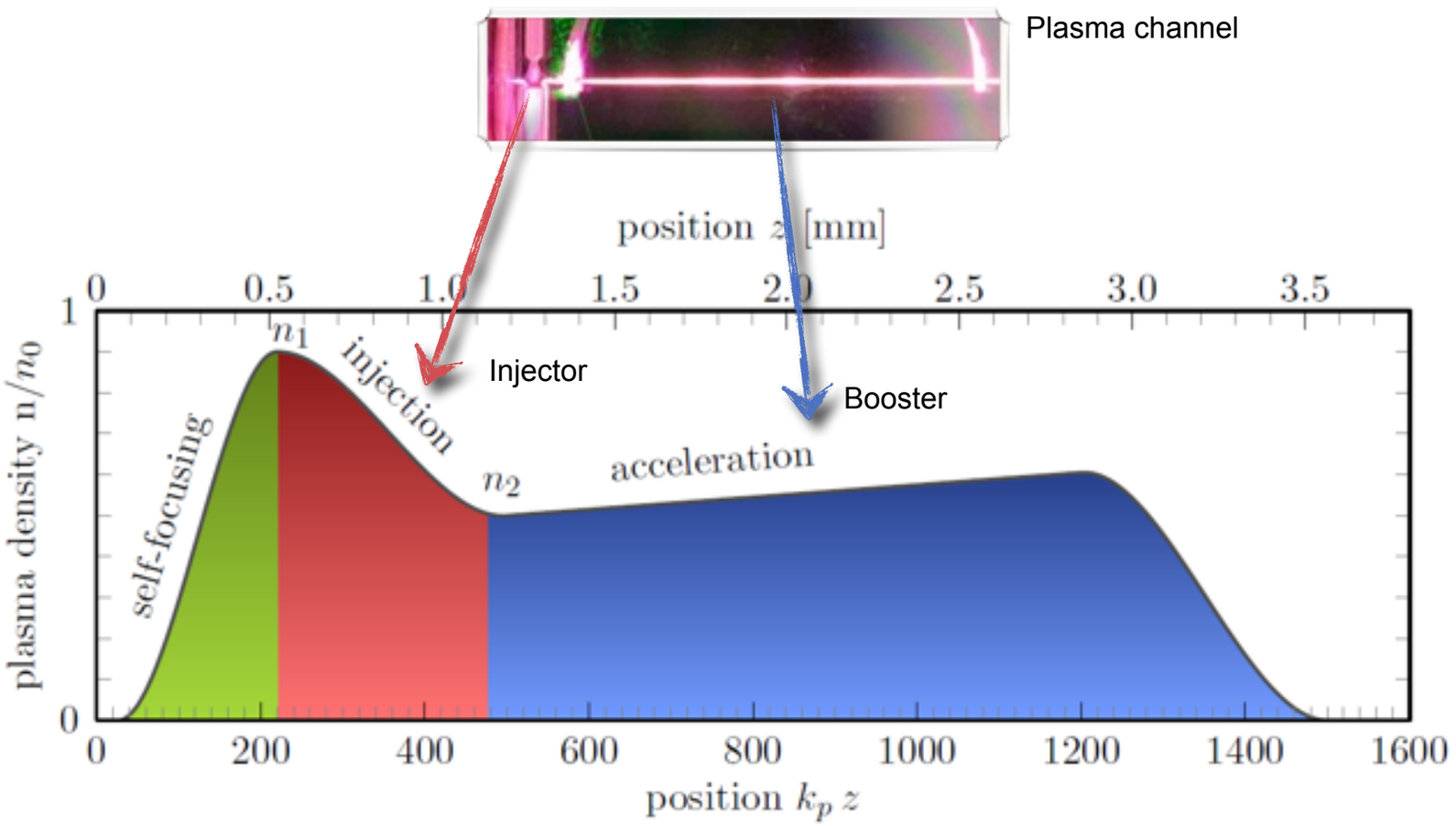
FLASH II is a user facility

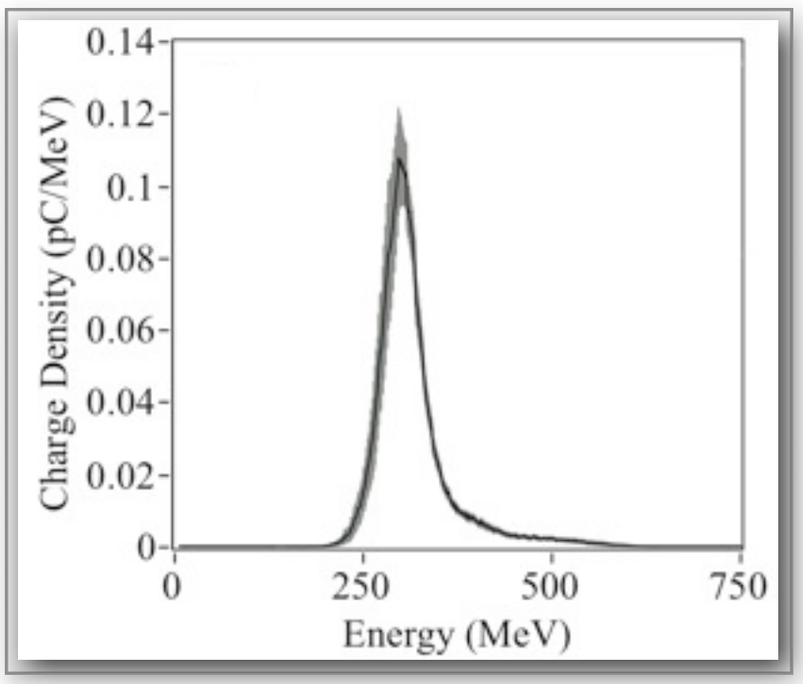
- remote alignment
- remote operation of experiments
- remote synchronisation
- remote laser/beam alignment

Plasma targets

- Starting up tailored plasma cell development and characterisation at DESY

> Tailored plasma-density profiles



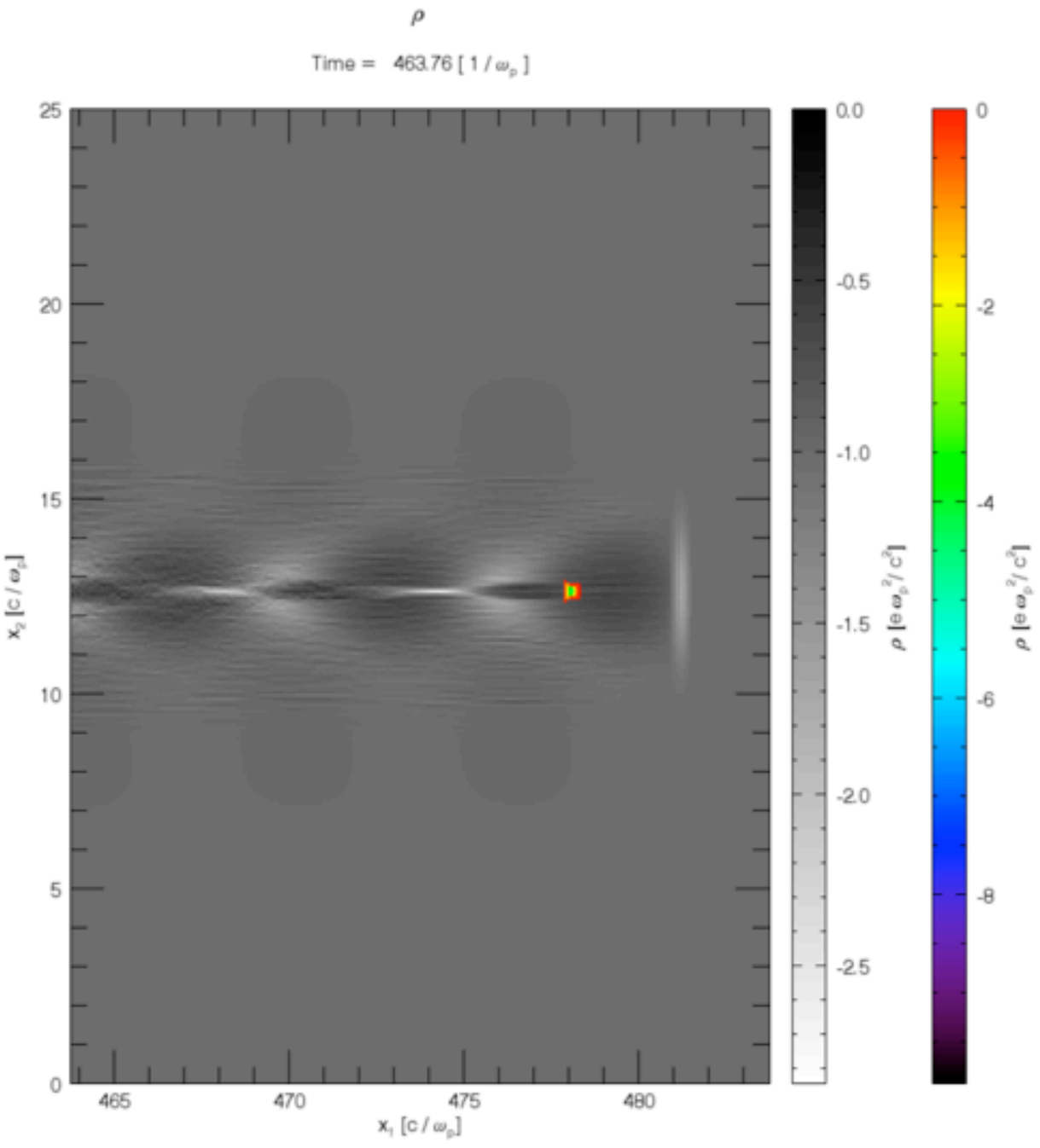


confer A.J.Gonsalves *et al.,* Nature Physics AOP (2011)

Progress so far - simulations

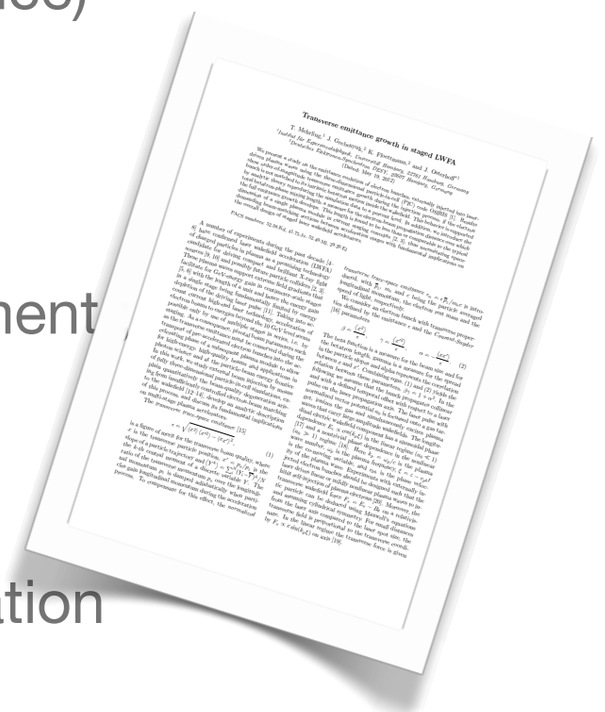
3D particle-in-cell (PIC) simulation

- Plasma-simulation infrastructure is set up and running in Zeuthen and Hamburg (focused on REGAE and PITZ, right now)
- Developing interface for ASTRA/ELEGANT to OSIRIS
- Preparing to employ full-scale 3D simulations with requirements of > 1 M core hours (~114 years of desktop PC with 100 GB RAM, Terabytes of data)
- Collaboration with UCLA initiated for access to code QuickPIC (reduced model for beam-driven studies, but way faster)
- Early simulations confirm feasibility of this project



Challenges of PWA studies at FLASH

- Generate
  - short bunches → FLASH fs-bunch operation
  - charge ramps → experimental studies (P. Piot, C. Behrens)
  - bunch trains → requires work on gun laser-system
- Transport bunch into FLASH II tunnel
  - maintain beam properties (pulse duration, beam shape, emittance)
  - synchronise with laser to within few 10 fs rms
- Diagnostics
  - longitudinal and transverse characterisation of bunch development recent paper by T.Mehrling et al.
- Framework for experiments
  - get sufficient beam time, possibly symbiotic (or parasitic) operation
  - implement remote operation of plasma experiments



Conclusions

- FLASH provides ample opportunities and could become a unique facility for plasma-wakefield experiments
  - Multi-bunch patterns
  - Superb diagnostics
  - Controlled bunch charge distribution
  - Synchronised to multi-hundred TW system