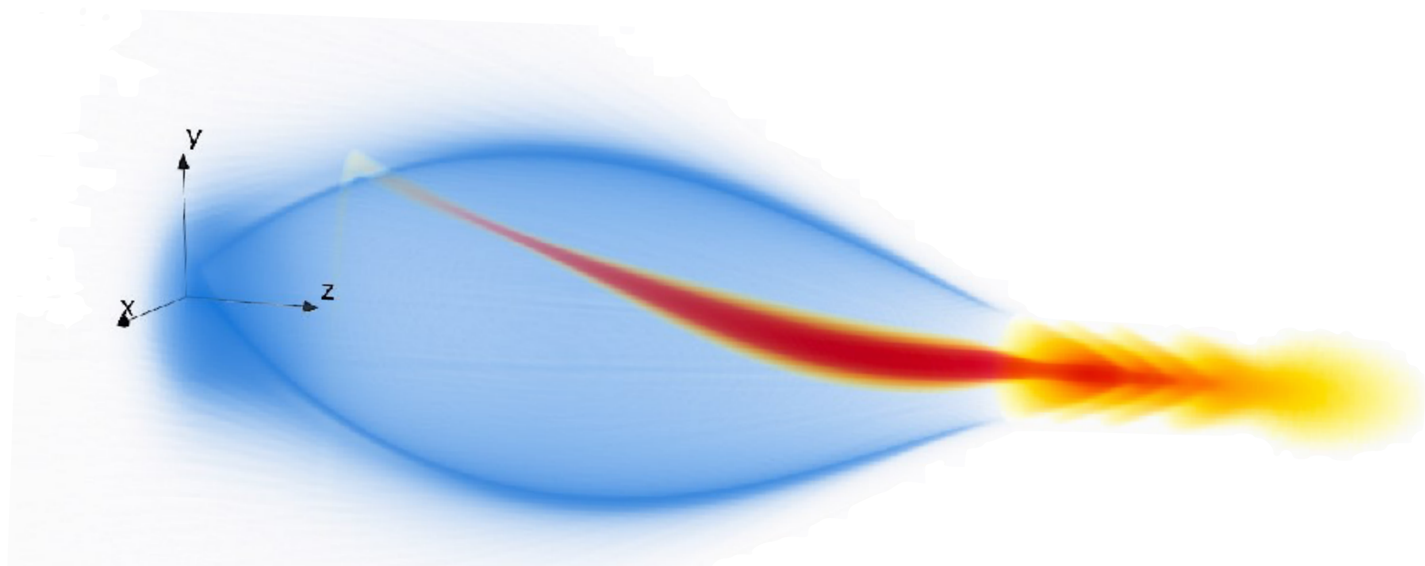
EAAC WG1 and WG8 joint session
Elba, Italy | September 27th, 2017



FLASHFORWARD

Future-Oriented Wakefield-Accelerator Research and Development at FLASH

Jens Osterhoff

Research Group for Plasma Wakefield Accelerators
Deutsches Elektronen-Synchrotron DESY, Particle Physics Division, Hamburg, Germany

Accelerator Research and Development, Matter and Technologies
Helmholtz Association of German Research Centres, Berlin, Germany

FLASHFORWARD contributors

> Core FLASHForward team

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Laboratori Nazionali di Frascati, Italy

University of California Los Angeles, US

Instituto Superior Técnico Lisboa, Portugal

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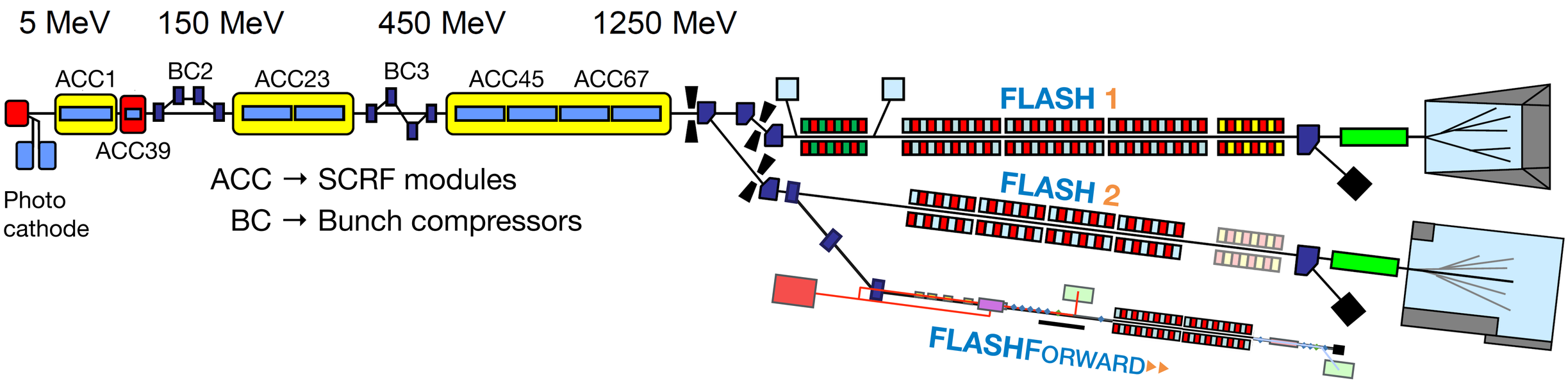
Bundesministerium für Bildung und Forschung
Verbundforschung

Friedrich-Schiller-Universität Jena, Germany

Heinrich-Heine-Universität Düsseldorf, Germany

FLASH drives free-electron laser and accelerator research

SUPERCONDUCTING SYSTEM FEEDS MULTIPLE BEAM LINES SIMULTANEOUSLY



> **FLASH** is an FEL user facility

> **FLASH**Forward▸▸ is a beam line for PWFA research

> Both share the same superconducting accelerator front-end. Typical electron beam parameters:

- ≲ 1.25 GeV energy with a few 100 pC at ~100 fs rms bunch duration
- ~2 μm trans. norm. emittance
- up to 800 bunches (≲ MHz spacing) at 10 Hz macro-pulse repetition rate, a few 10 kW average beam power

FLASHFORWARD

FUTURE-ORIENTED WAKEFIELD ACCELERATOR RESEARCH AND DEVELOPMENT AT FLASH

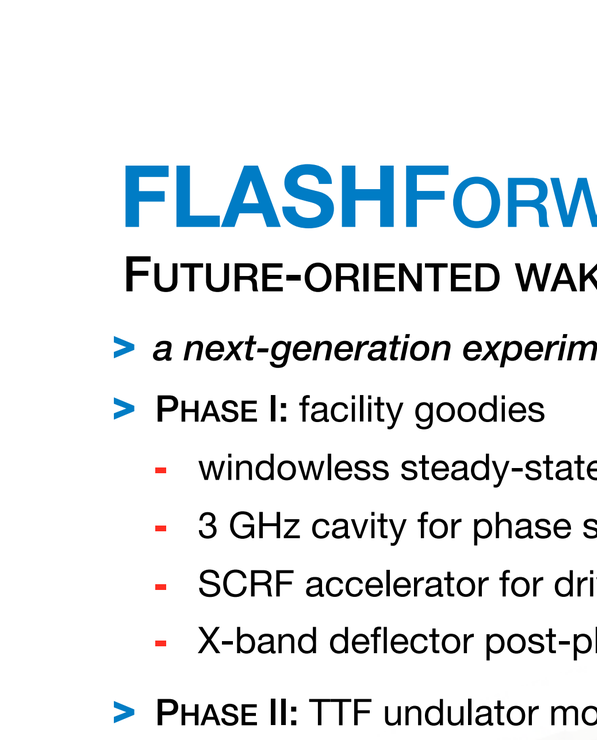
> *a next-generation experiment for beam-driven plasma wakefield accelerator research*

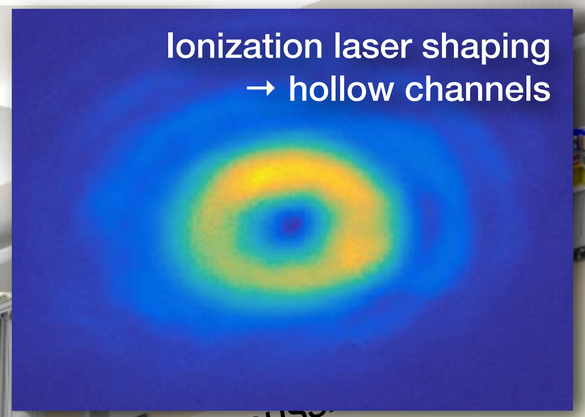
> **PHASE I:** facility goodies

- windowless steady-state-flow plasma target supporting H_2, N_2, and noble gases → **emittance conservation, driver depletion**
- 3 GHz cavity for phase space linearization → triangular current profiles → **transformer ratio + beam loading**
- SCRF accelerator for drive and witness beams with up to MHz repetition rate → **high repetition rate, high average power PWFA**
- X-band deflector post-plasma with ~1 fs resolution *(2019)* → **lon**

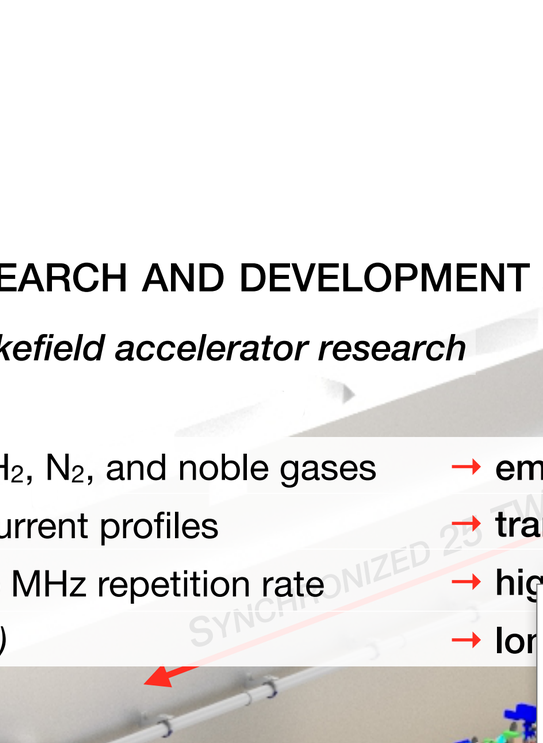
> **PHASE II:** TTF undulator modules *(2020+)*

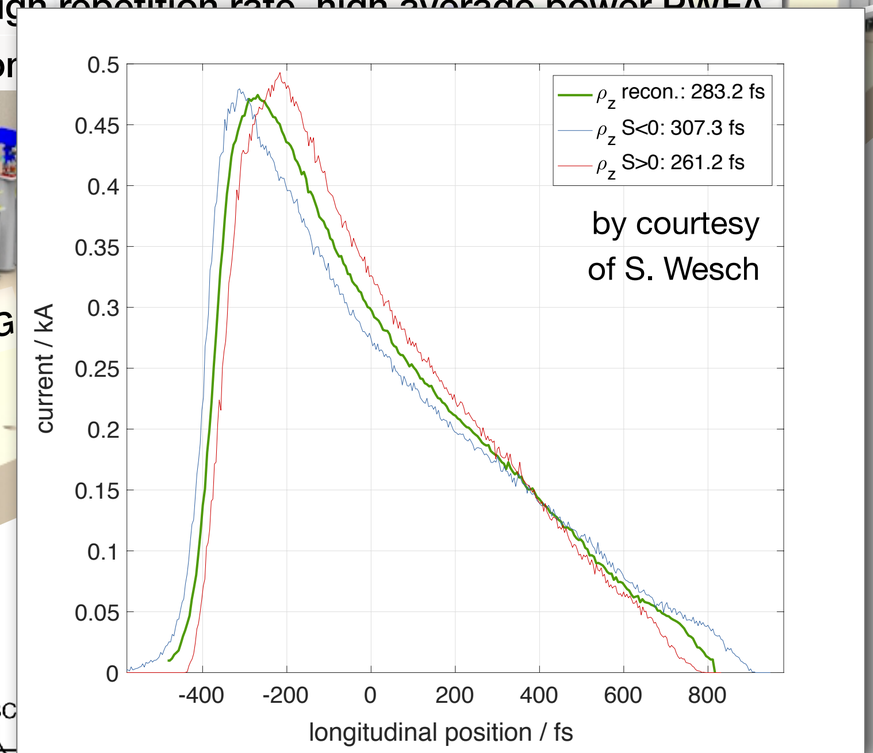
1.2 GEV BEAMS FROM FLASH

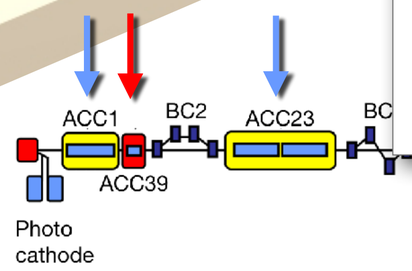


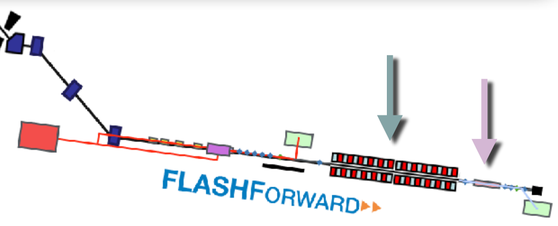


→ A. Aschikhin *et al.*, NIM A **806**, 175 (2016)





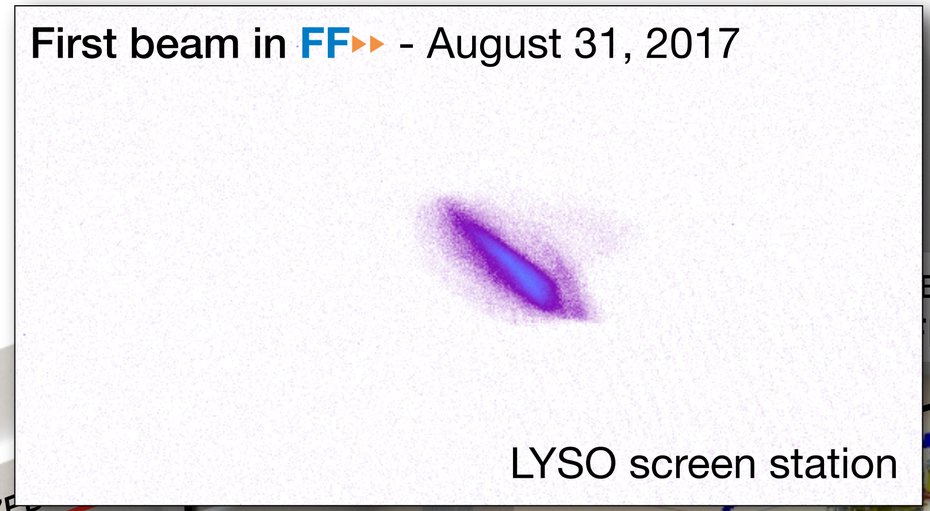




FLASHFORWARD▸▸ - current status

BEAM LINE COMMISSIONING STARTED ON AUGUST 30

> Planned beamline completion as depicted: *January 2018*



setup completed
up to here

SYNCHRONIZE

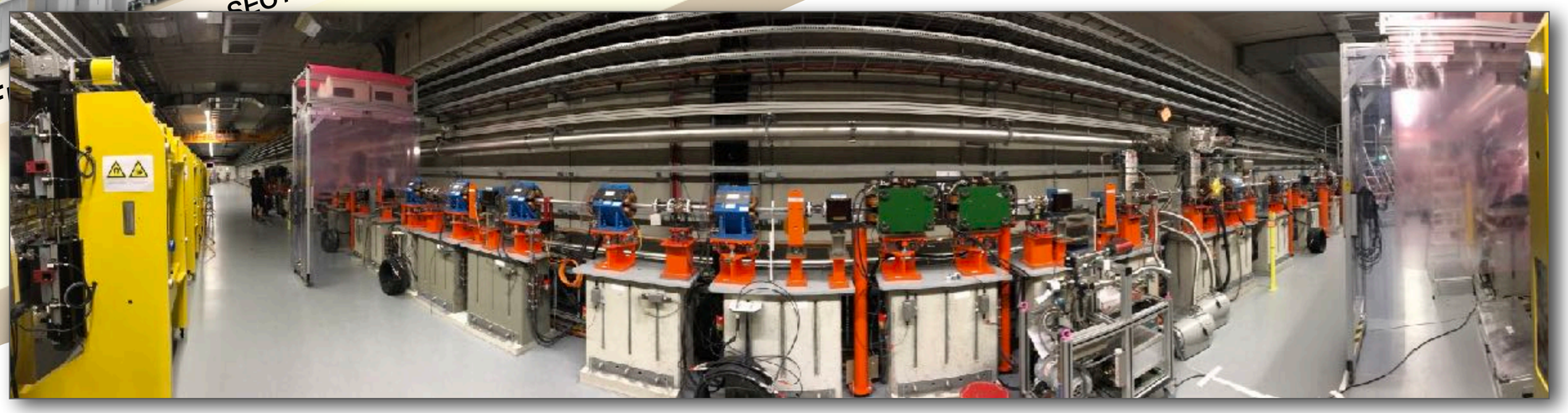
BEAMS
LASH

DISPERSIVE SECTION

DIFFERENTIAL PUMPING

SECTION

CENTRAL INTERACTION AREA



Experimental programme in preparation

Separated into core experimental studies and prototyping

Talk by A. Knetsch
WG 1, Mon. at 18:00

Poster by B. Sheeran
Mon. at 19:30

Talk by V. Libov
WG 1, Tue. at 18:3

Talk by A. Aschikhin
WG 6, Tue. at 16:40

Plenary by T. Mehrling
today at 12:00

ERIMENTS

X-10	Transf…er Ratio ↑ ▸ **PI:** V. Libov (U Ha…burg)
X-11	…SY)
X-12	MHz PWFA ▸ **PI:** R. D'Arcy (DESY)
X-13	Beam (De-)chirping ▸ **PI:** R. D'Arcy (DESY)
X-14	Ion Motion Studies ▸ **PI:** t.b.d.
X-100	FEL Gain ▸ **PI:** t.b.d.

…lain FF▸▸ scientific goals

- **X-1 High-brightness beam generation in plasma ("plasma cathode"):** > 1 GeV energy gain, trans. norm. emittance ~100 nm, current ≳ 1 kA, ~fs bunch duration
- **X-2 Plasma booster module for FLASH:** > 1 GeV energy gain, conservation of energy spread and transverse emittance, depletion of drive beam energy, 10% conversion efficiency
- **X-100 Demonstration of FEL gain from plasma-accelerated beams** (≳ 2020)

Advanced diagnostics and prototypes

P-1	…Y)
P-2	…opy …(DESY)
P-3	β-tron Radiation Det. ▸ **PI:** S.P.D. Mangles (ICL)
P-4	⊥ Laser Probe ▸ **PI:** M. Kaluza (U Jena)
P-5	⊥ Beam Probe ▸ **PI:** P. Niknejadi (DESY)
P-6	Pulsed Dipole ▸ **PI:** S. Wesch (DE…)
P-7	…Y)
P-8	…s …n (DESY)
P-9	…SY)
P-10	Laser-Beam Timing ▸ **PI:** t.b.d.
P-11	ICS Radiation Det. ▸ **PI:** S. Bohlen (DE…)

Poster by P. Winkler
today at 19:30

Poster by L. Goldberg
today at 19:30

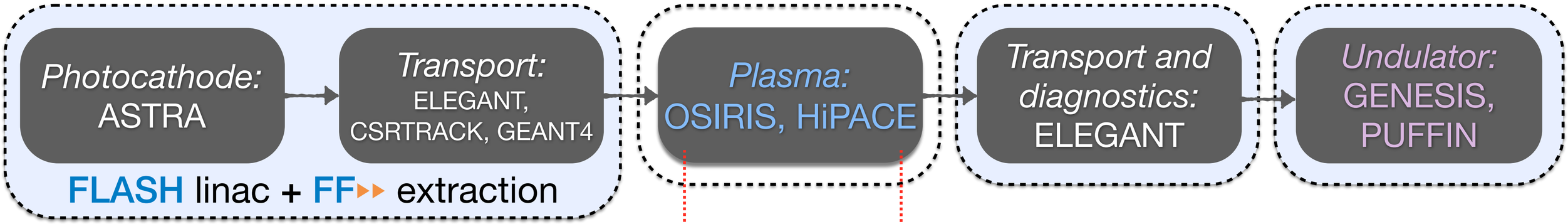
Poster by R. D'Arcy
today at 19:30

Talk by G. Tauscher
WG 1, Mon. at 16:36

Talk by J.-H. Röckemann
WG 5, Tue. at 18:00

Talk by S. Bohlen
WG 5, Tue. at 17:00

Full start-to-end simulations implemented including CSR, space charge, and wakefield effects



Osiris 3.0 by UCLA / TÉCNICO LISBOA

HiPACE - a highly efficient plasma accelerator emulation

- > **3D quasi-static, relativistic, fully electromagnetic PIC code**
- > **fully parallelized** and well scalable (tested up to 1024 cores)
- > dynamic time-step adjustment
- > **orders-of-magnitude speedup** vs. full PIC
- > **interfaces** seamlessly with OSIRIS and tracking codes

developed in collaboration between DESY and LBNL

> **T. Mehrling et al., PPCF 56, 084012 (2014)**

Full start-to-end simulations implemented including CSR, space charge, and wakefield effects

FF▸▸ HIGHLIGHTS

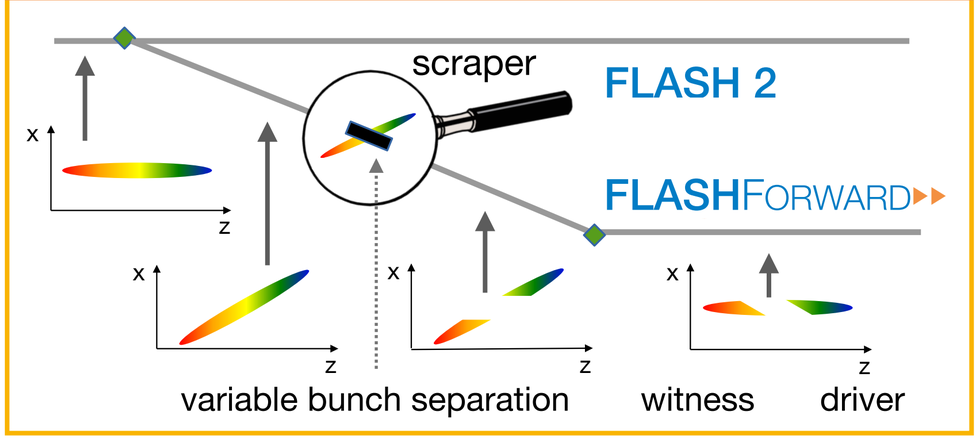
Photocathode: ASTRA

Transport: ELEGANT, CSRTRACK, GEANT4

FLASH linac + FF▸▸ extraction

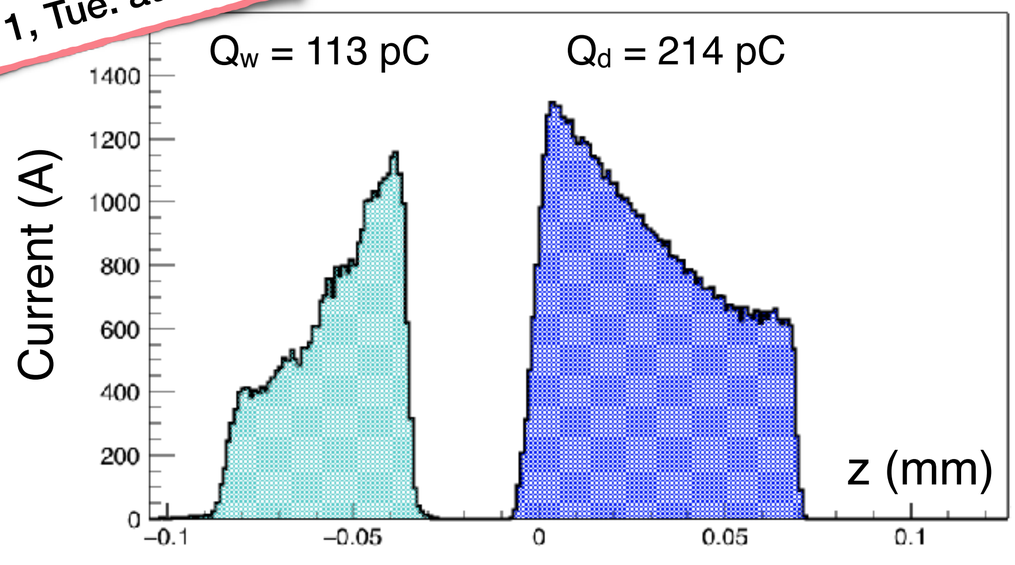
P. Muggli *et al.*, PRSTAB 13, 052803 (2010)

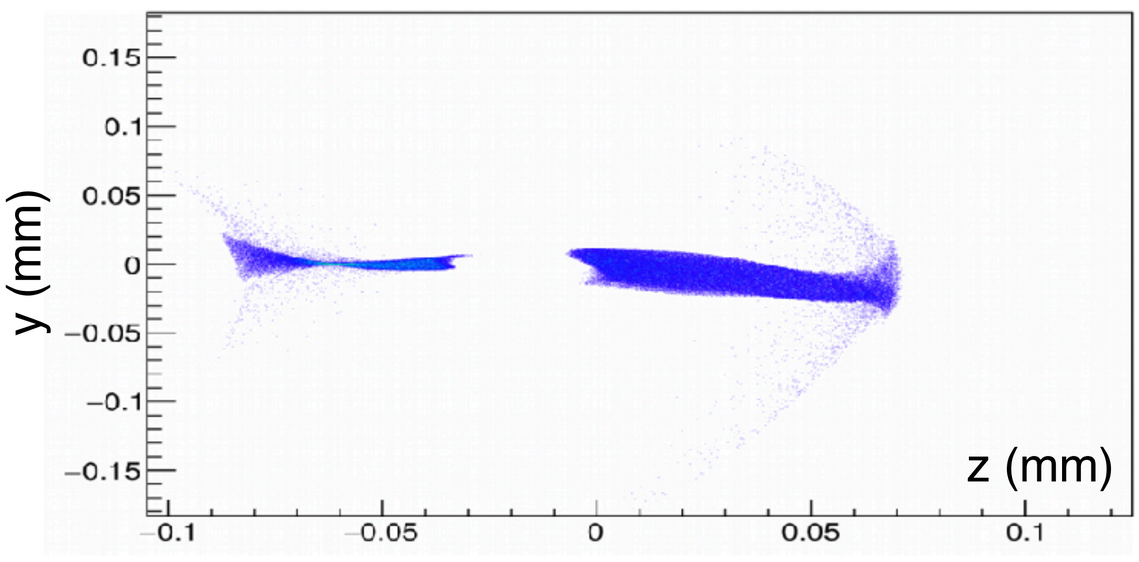
BEAM SCRAPER



Talk by V. Libov
WG 1, Tue. at 18:36

DRIVER/WITNESS PAIR CREATION IN DISPERSIVE SECTION BY VARIABLE MASK





X-2 Plasma Booster

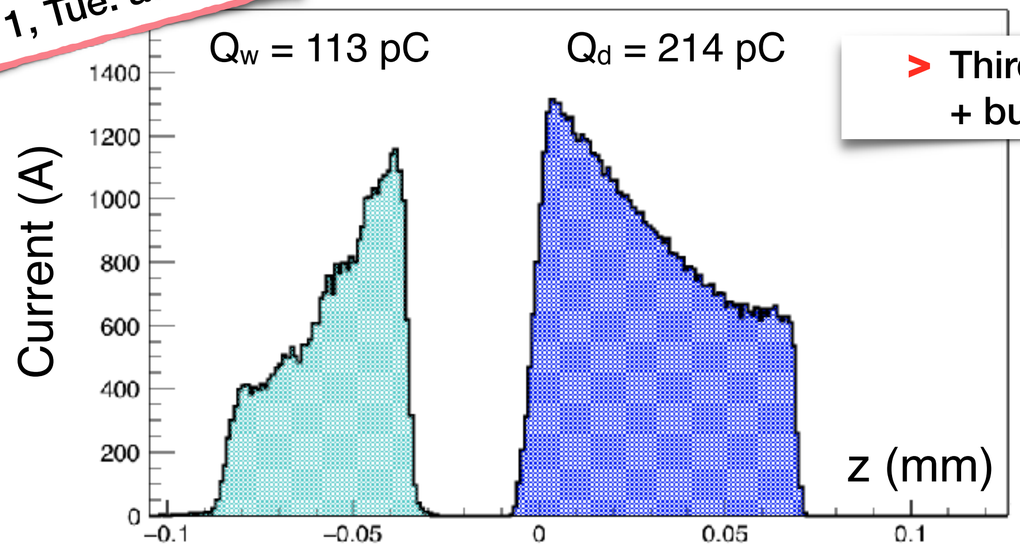
- **PI:** V. Libov (U Hamburg)

Full start-to-end simulations implemented including CSR, space charge, and wakefield effects

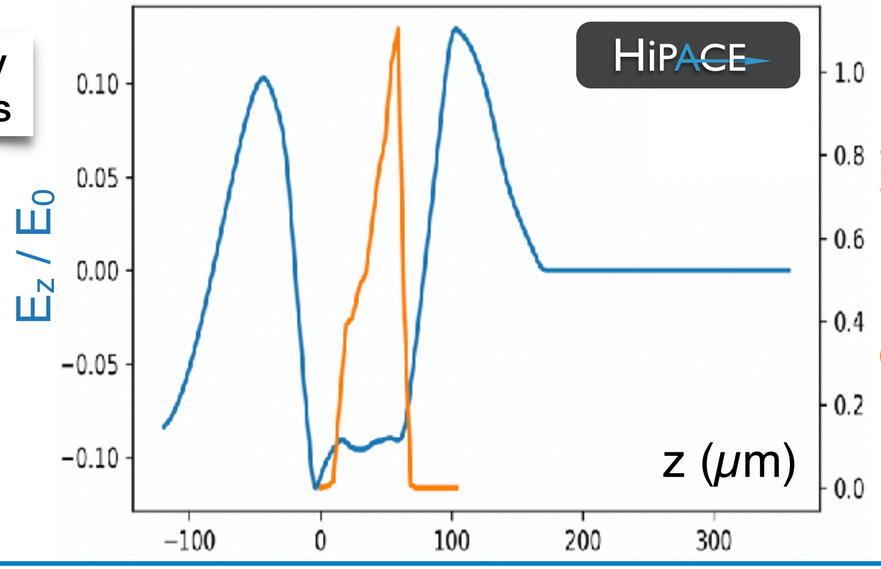
FF▸▸ HIGHLIGHTS

Talk by V. Libov
WG 1, Tue. at 18:36

WITNESS SHAPING FOR BEAM LOADING CONTROL



> Third harmonic cavity + bunch compressors



X-2 Plasma Booster

- **PI:** V. Libov (U Hamburg)

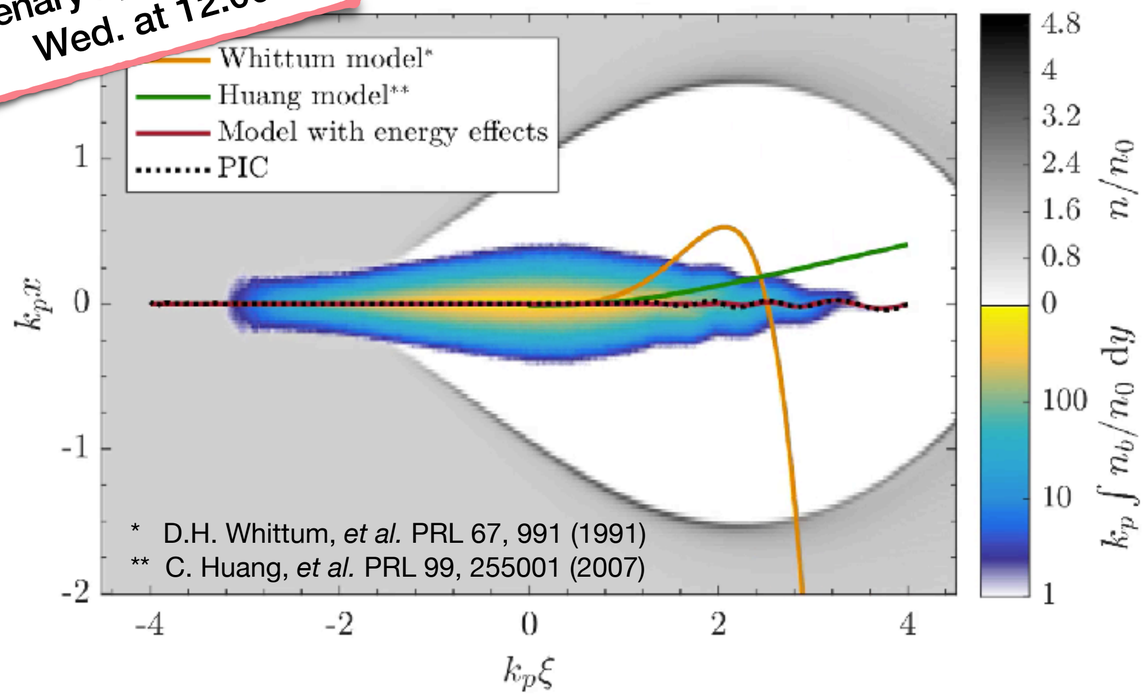
Hosing instability growth-rate and mitigation studies

FF▸▸ HIGHLIGHTS

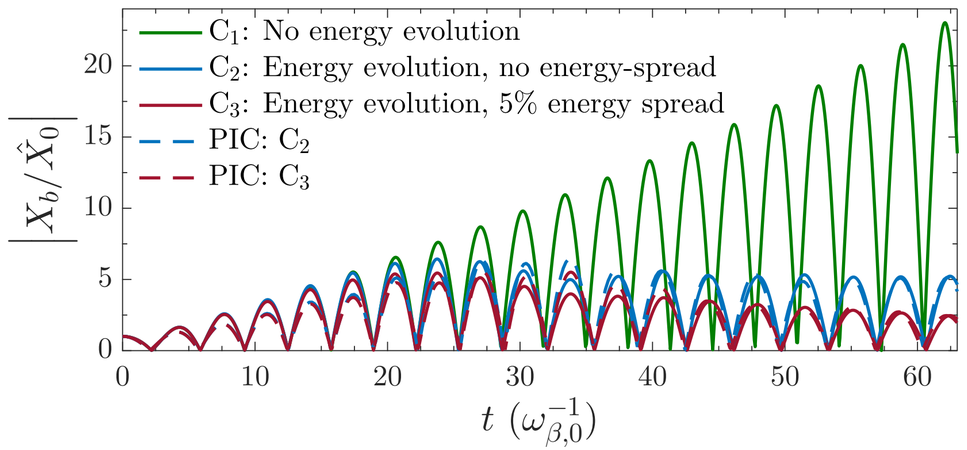
Extension of hosing theory → T. J. Mehrling et al., Phys. Rev. Lett. 118,174801 (2017)

collaboration with
U Hamburg and IST Lisbon

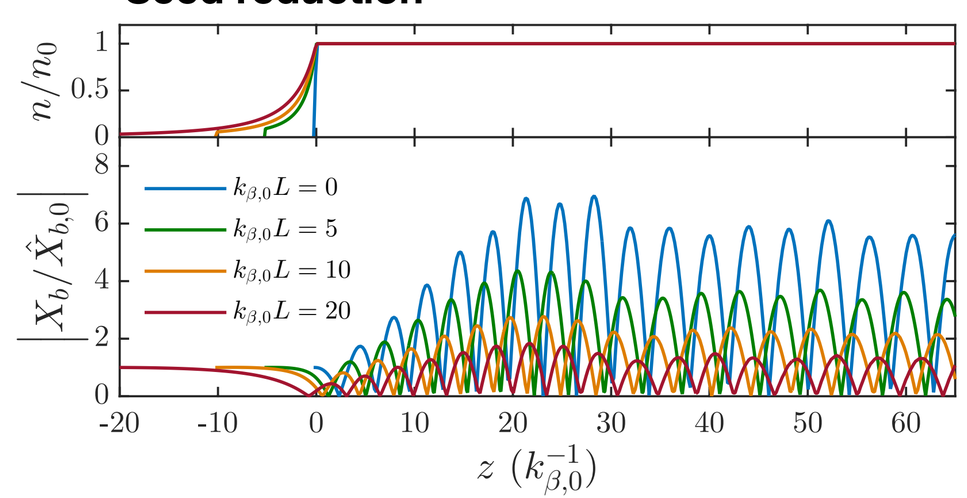
- Energy spread in driver reduces hosing (i.e. BNS damping)
- Plasma taper can reduce hosing seed strength



Betatron decoherence



Seed reduction



X-11 Hosing Studies
▸ **PI:** S. Wesch (DESY)

Osiris 3.0

HiPACE

Hosing instability growth-rate and mitigation studies

FF▸▸ HIGHLIGHTS

Extension of hosing theory → T. J. Mehrling et al., Phys. Rev. Lett. 118,174801 (2017)

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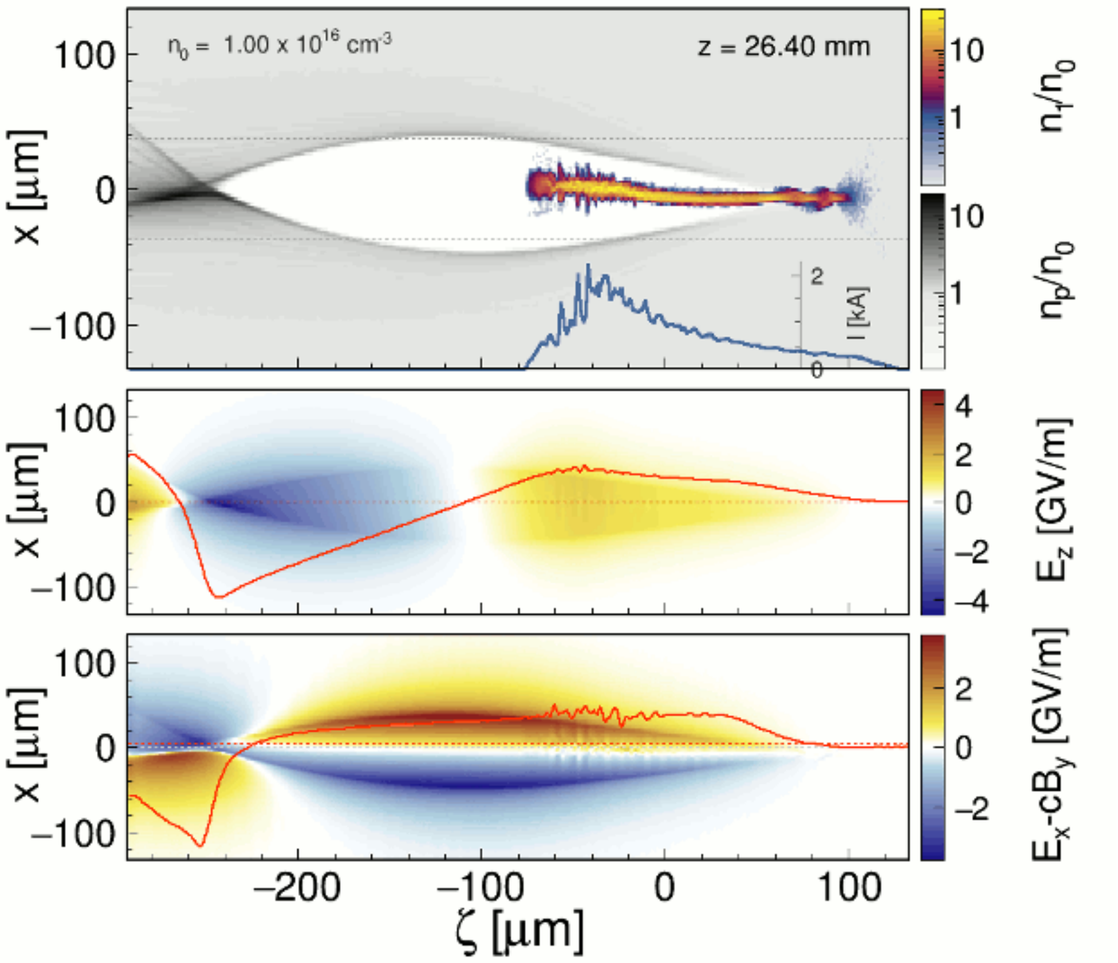
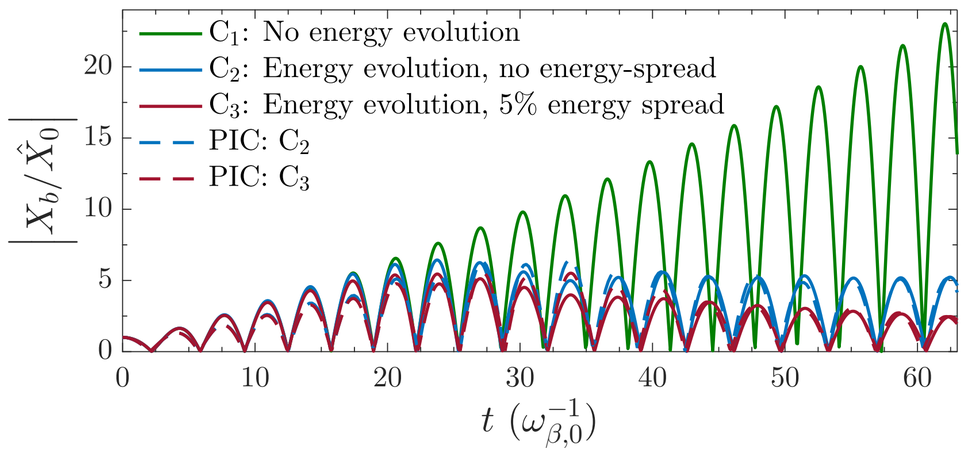


Betatron decoherence



- Full start-to-end simulations confirm hosing modes can be excited
- Measurement of growth rates & hosing saturation vs. beam parameters

X-11 Hosing Studies
- **PI:** S. Wesch (DESY)

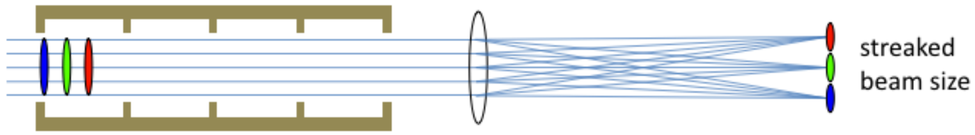
Osiris 3.0

HiPACE

X-band transverse deflector for femtosecond phase-space characterization

DESY coordinator: B. Marchetti

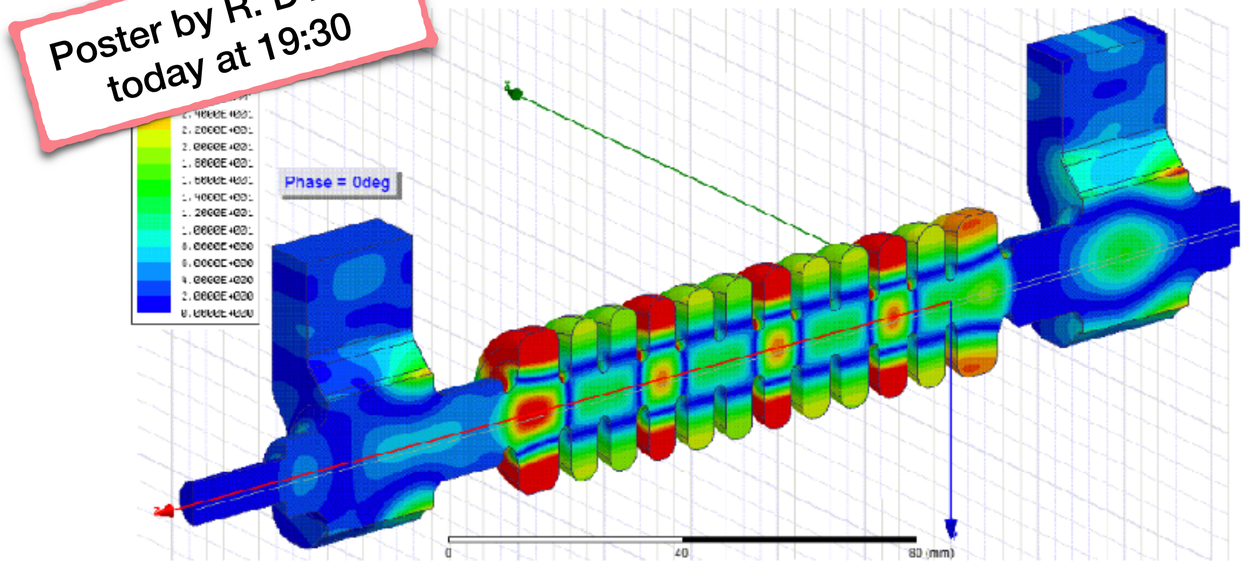
FF▸▸ HIGHLIGHTS



> A collaboration between DESY, CERN, and PSI to share expertise and develop X-band technology

> A novel dual-polarisation RF deflecting cavity has been developed for prototyping on FLASHForward
→ tomographic reconstruction of phase space

Poster by R. D'Arcy today at 19:30



Courtesy of Alexej Grudiev, CERN

> Resolutions witness* and driver** beam working points:

$$R_z = \frac{\sigma_y}{S} = \sqrt{\frac{\varepsilon_y(s)}{\beta_y(s_0)}} \frac{1}{|\sin \mu_y|} \frac{E}{eVk}$$

$$R_\delta = \frac{\sigma_x}{|D_x|} = \sqrt{\varepsilon_x} \frac{\sqrt{\beta_x}}{|D_x|}$$

$R_t > 0.9$ fs (witness)
$R_t > 1.5$ fs (driver)

$R_\delta > 2\text{x}10^{-4}$ (witness)
$R_\delta > 1\text{x}10^{-4}$ (driver)

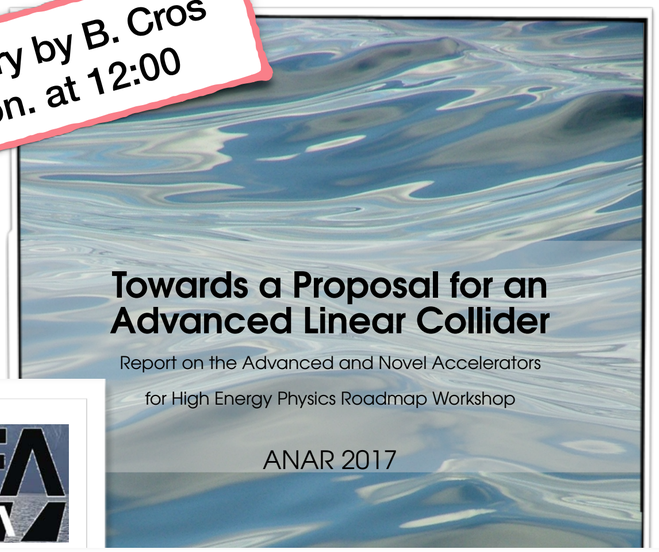
*E = 1.5 GeV, ε = 0.5 μm

**E = 1.0 GeV, ε = 2.0 μm

P-9 X-Deflector
▸ **PI:** R. D'Arcy (DESY)

How FLASHForward wants to help…

Plenary by B. Cros
Mon. at 12:00



Main challenges towards an ALC

- e- >< e+
- injector + accel modules

- ✓ Beam acceleration with s
- ✓ Preservation of small e-be
- Concepts for **positron acc** brightness
- ✓ **High efficiency** of acceler
- **Staging** required to reach
- ✓ **Repetition rates** averagin
- ✓ Beam **stability and reproc**

3rd EAAC workshop, 25th Se

Challenges related to novel accelerator compor

- ✓ **Injectors**: e-/e+ high 6 bubble, nanotips)
- ✓ Accelerating **structu** sustaining high rep rate
- ✓ **Diagnostics**: for micr
- **Staging:** in- out-coupl management, alignmer
- ✓ **Stability, reproducib** and control system,dec

3rd EAAC workshop, 25th S

Challenges related to beam dynamics at high energy

- ✓ Narrow **energy spread**
- ✓ **Efficiency** and beam loading
- ✓ **Emittance** preservation
- Scattering (plasma)
- ✓ Beam break-up and hosing instabilities
- Spin polarization preservation
- ✓ Ion motion (plasma)
- Structure charging and radiation damage
- **Numerical simulation**

3rd EAAC workshop, 25th September 2017, Isola d'Elba, Italy 11

Jens O

Summary

> **FLASHForward**▸▸ is a next-generation experiment for beam-driven plasma accelerator research

> Beamline commissioning has started in August 2017 → first plasma experiments in early 2018

> Work focusses on key challenges toward photon science and particle physics applications