FLASHForward.

Stephan Wesch

On behalf of the FLASHForward Team

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

Contributors.

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Students
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> **… many DESY engineering & technical support groups**

Collaboration Partners.

Helmholtz

HZDR

HELMHOLTZ Helmholtz-Institut Jena

KIT Karlsruher Institut für Technologie

HMGU

Universities

UHH

JG|U

LMU

Friedrich-Schiller-Universität Jena · Seit 1558 ·

Universitas Osloensis · MDCCCXI ·

University of Oxford

UCL

National labs

Berkeley Lab

Brookhaven National Laboratory

SLAC

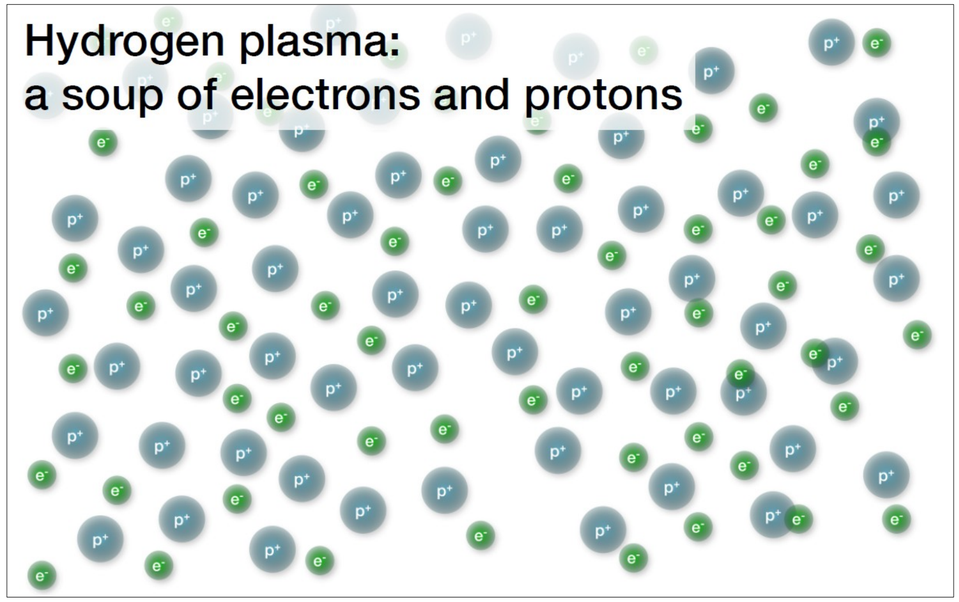
Paul Scherrer Institut PSI

CERN

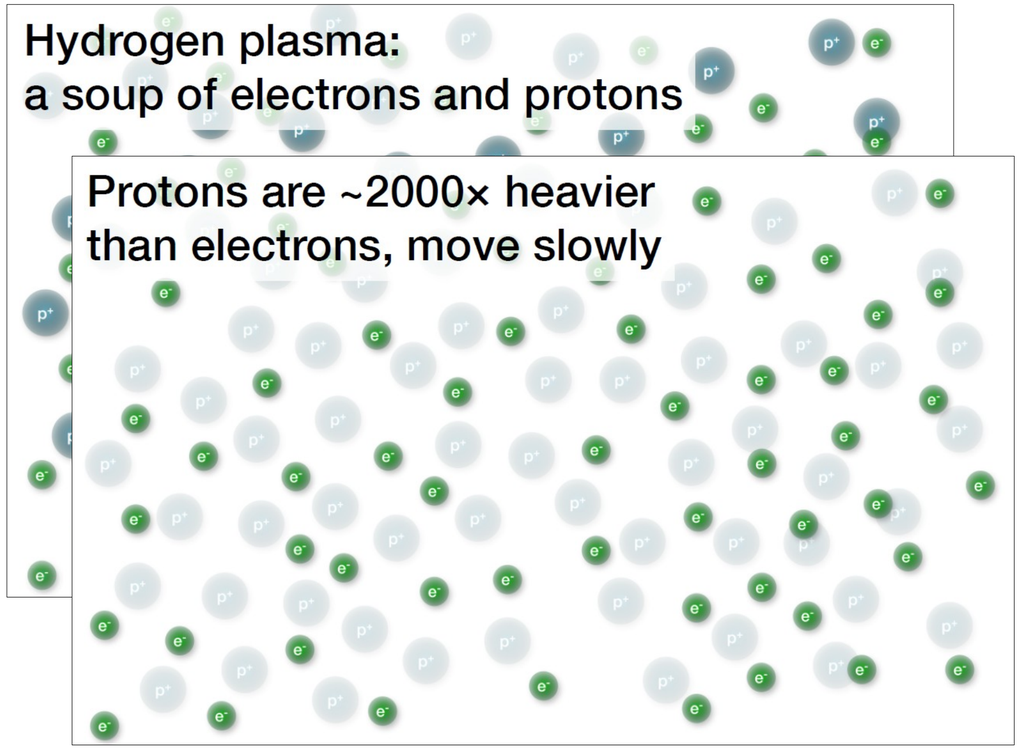
Science & Technology Facilities Council

eli beamlines

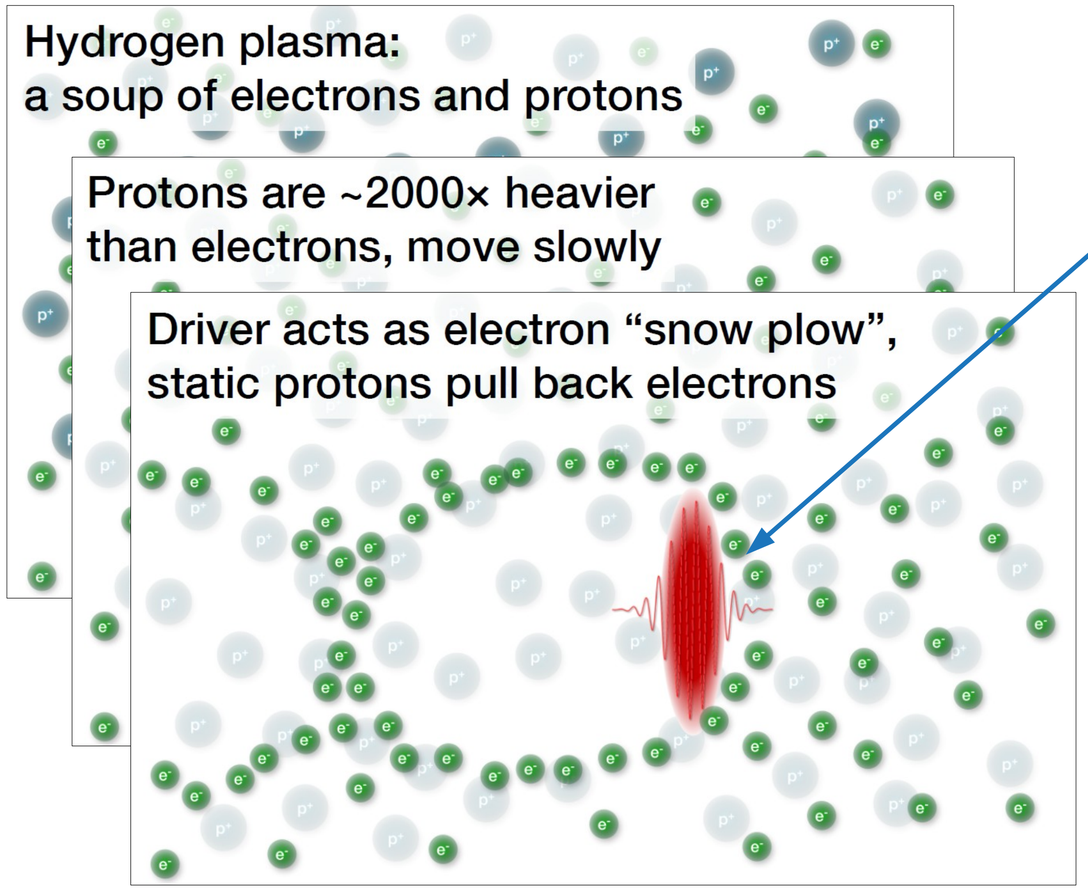
Plasma Wakefield Accelerator Cartoon.



Plasma Wakefield Accelerator Cartoon.



Plasma Wakefield Accelerator Cartoon.

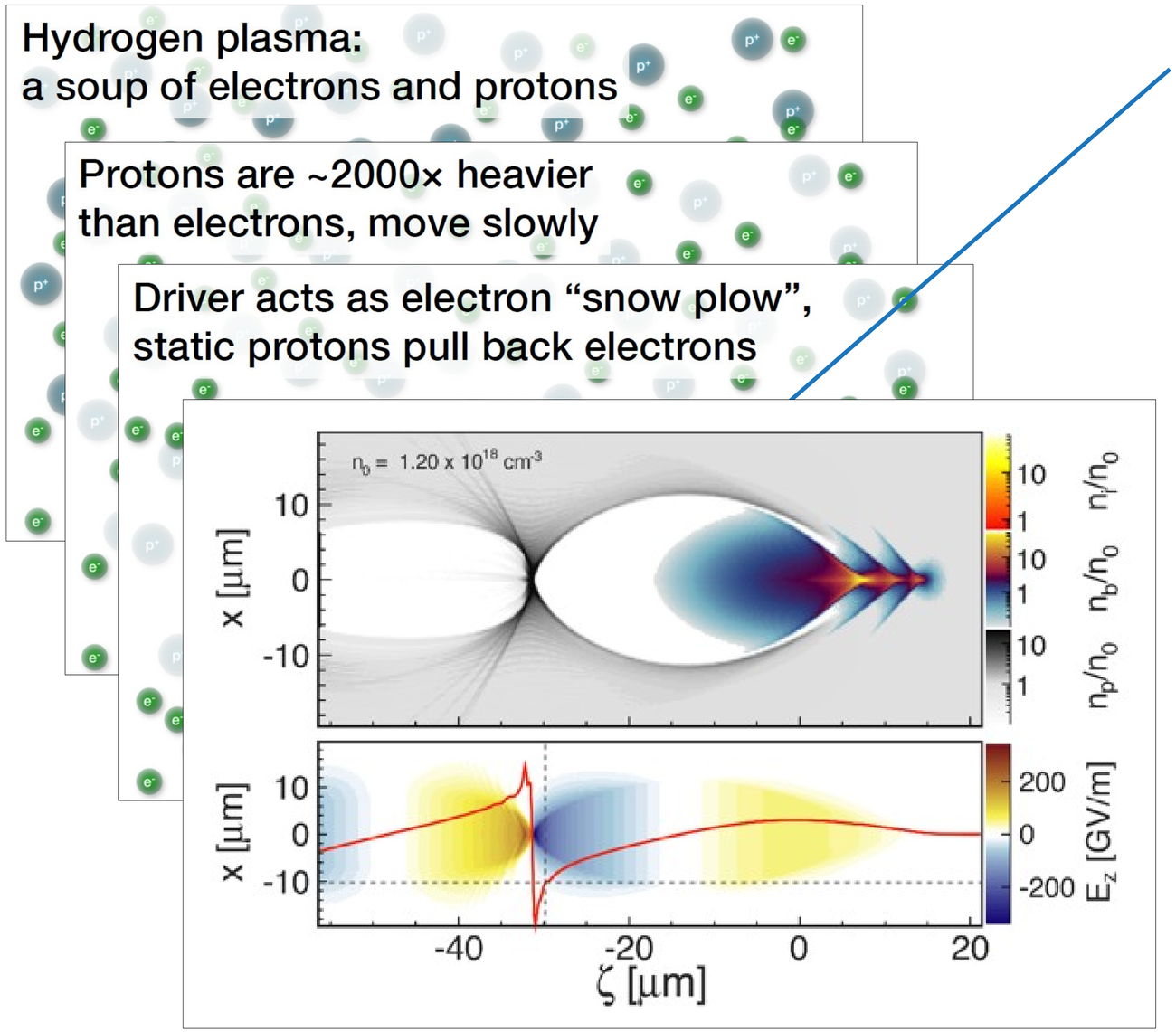


Driver == electron bunch → „PWFA“

Blow-out condition:

$n_b > n_p$

Plasma Wakefield Accelerator Cartoon.



Driver == electron bunch → „PWFA“

Blow-out condition:

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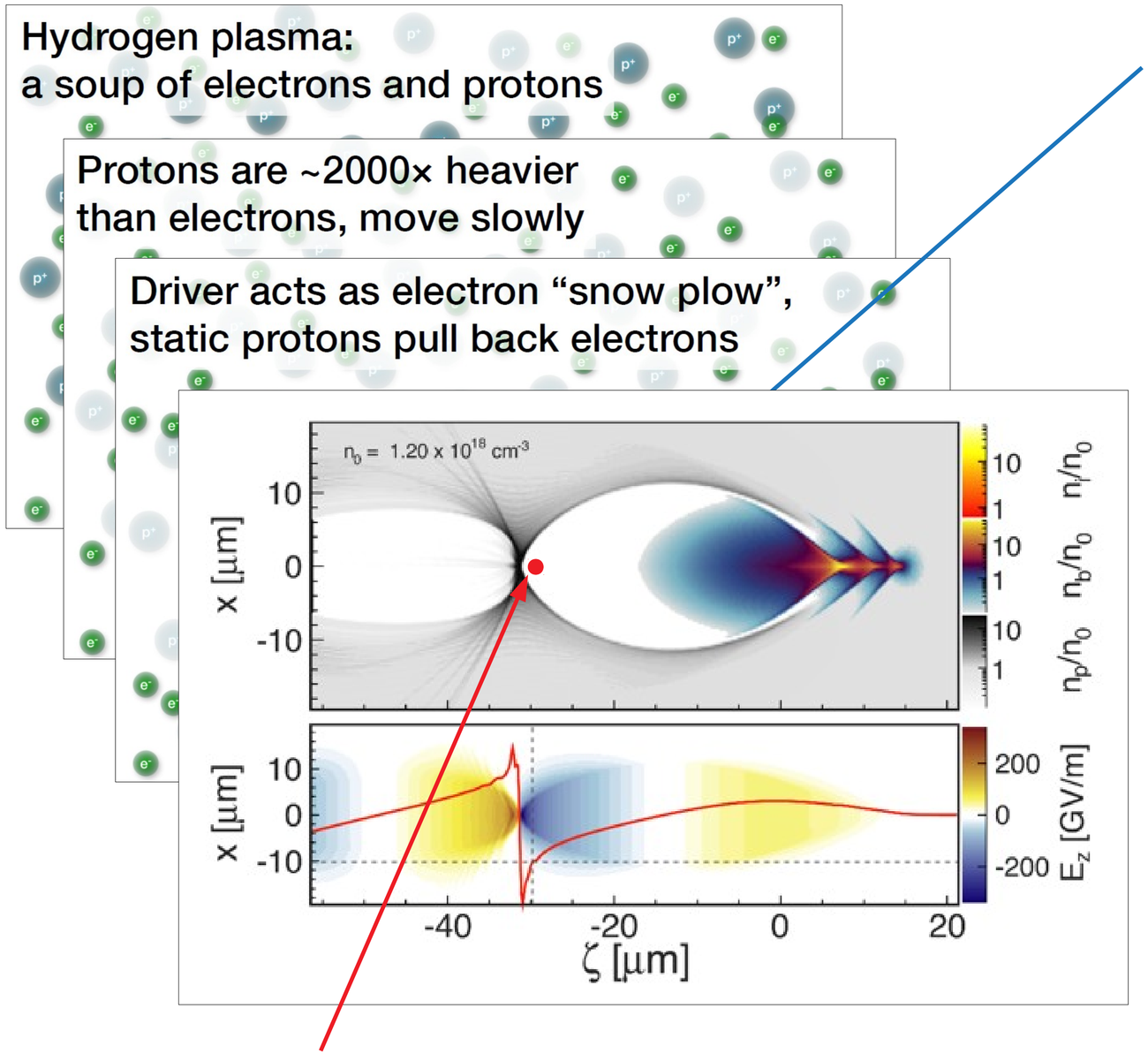
Gradient of few 10 GV/m

Plasma Wakefield Accelerator Cartoon.



Driver == electron bunch → „PWFA“

Blow-out condition:

$n_b > n_p$

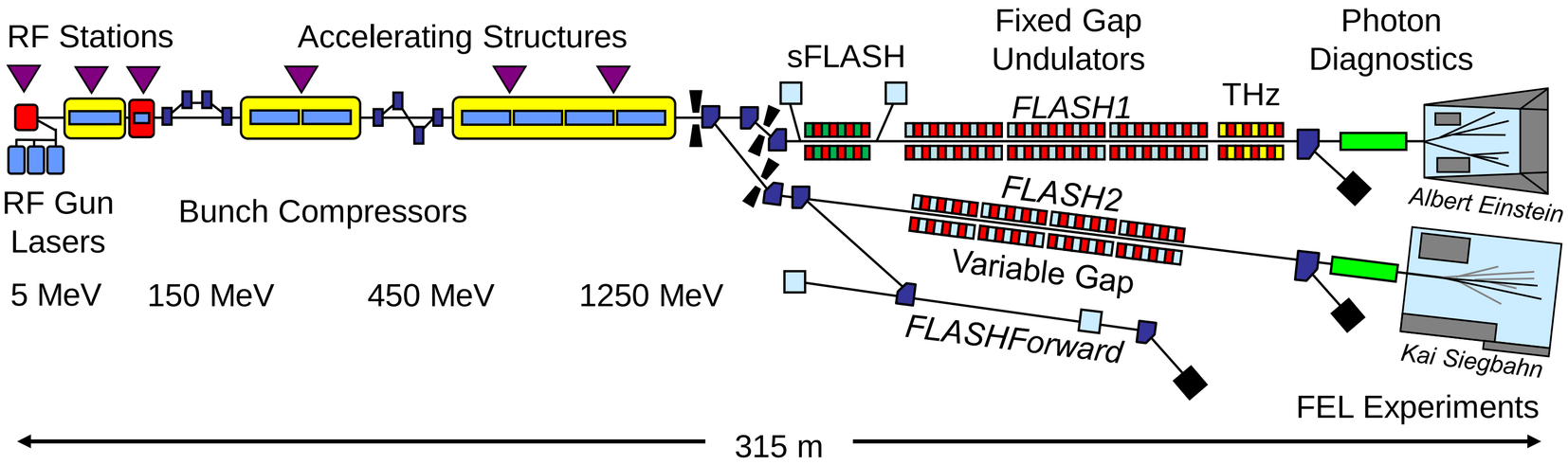
Gradient of few 10 GV/m

Witness bunch → positioning is crucial!

FLASHForward.

Future-**OR**iented **W**akefield **A**ccelerator **R**esearch and **D**evelopment at FLASH

Project start: summer 2014 – Start commissioning Oct 2017 – Experiments since Juli 2018

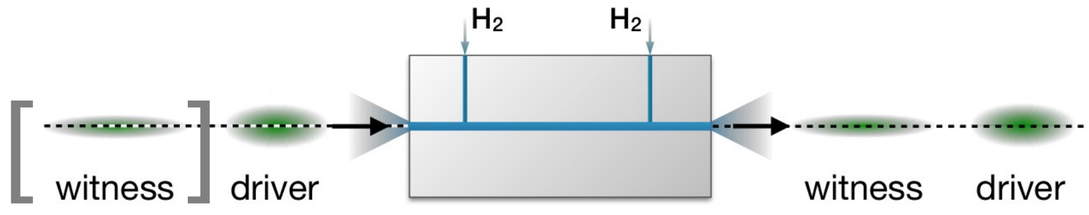


> Main goal

Accelerate external injected bunches in a PWFA up to >1.5 GeV

Preservation of high quality bunch properties

Test beams for FEL gain capability



> Others

Investigation of different injection techniques

Explore parameters for high repetition rate, high average power

Development of suitable diagnostics for plasma and electron bunches

FLASHForward.

FF

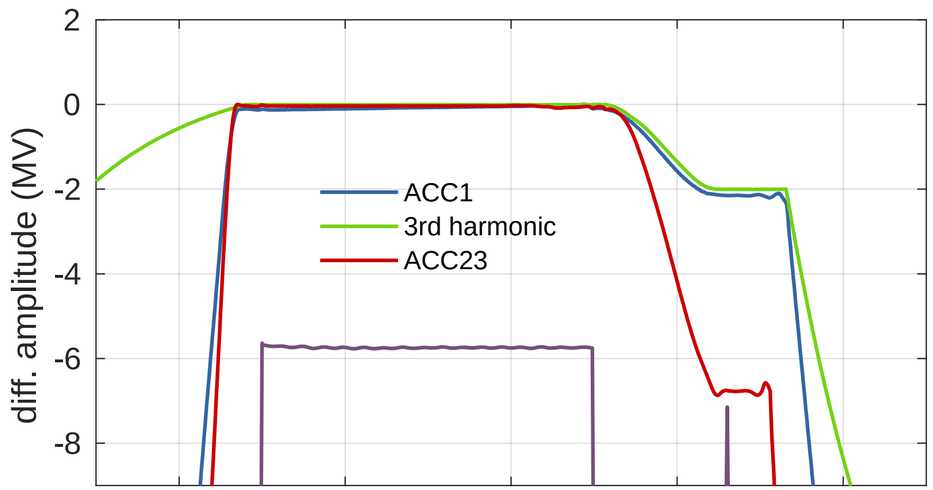
> **Usual beam parameters**
- Energy: 550 – 1000 MeV
- Charge: ~ 300 pC
- Bunch length: ~200 fs rms

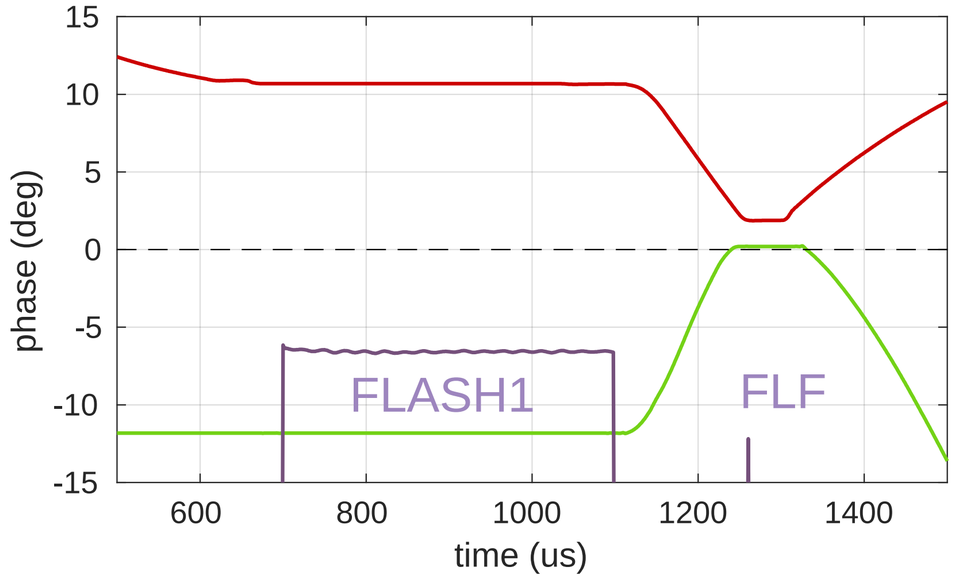
> **Standard tools available**
- Magnet middle layer server
- Slow RF and charge feedback
- Orbit displays
- …

> **Parallel operation with RF steps**
- FLASH1 / sFLASH

> **Beam time after commissioning**

year	dedicated	parallel	total
2018	292 h	954 h	1246 h
2019	128 h	184 h	312 h





Beamline in Feb 2019.

FLASH2 Tunnel

FLASH extraction

> **Laser beamline**

> **FLFEXTR (extraction)**

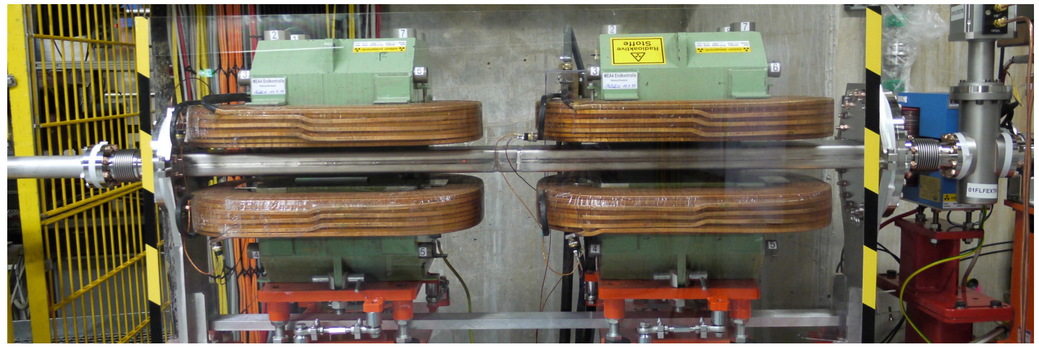
> **FLFCOMP (final compression with variable R56)**

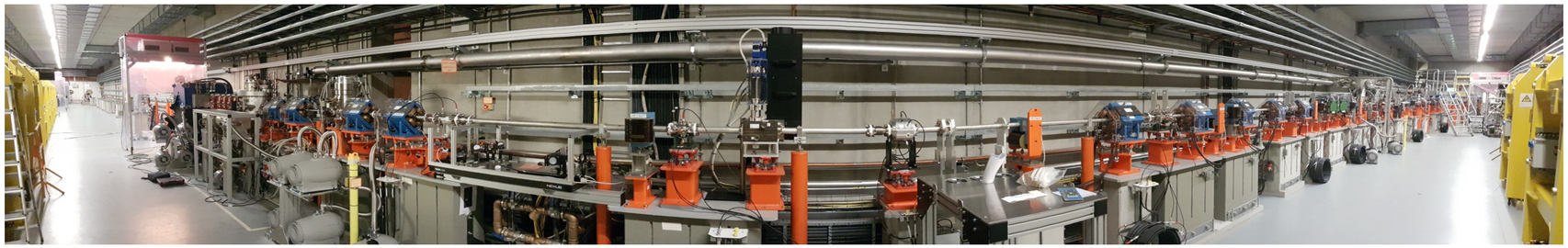
> **FLFMAFF (matching & final focus)**

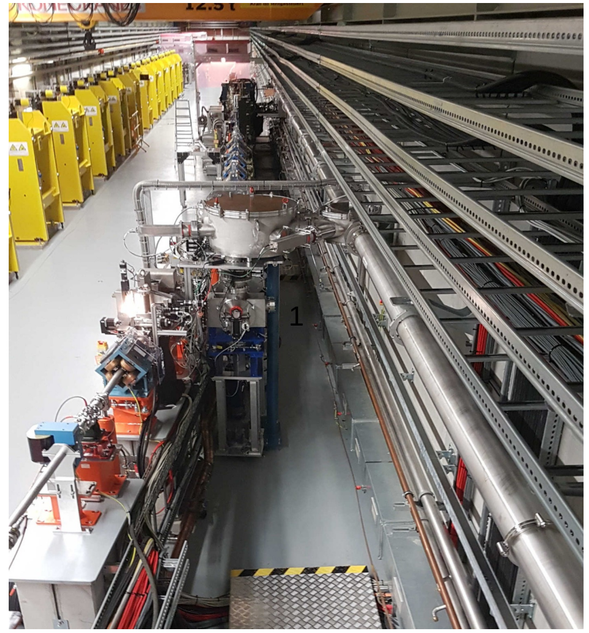
> **Target Chamber**

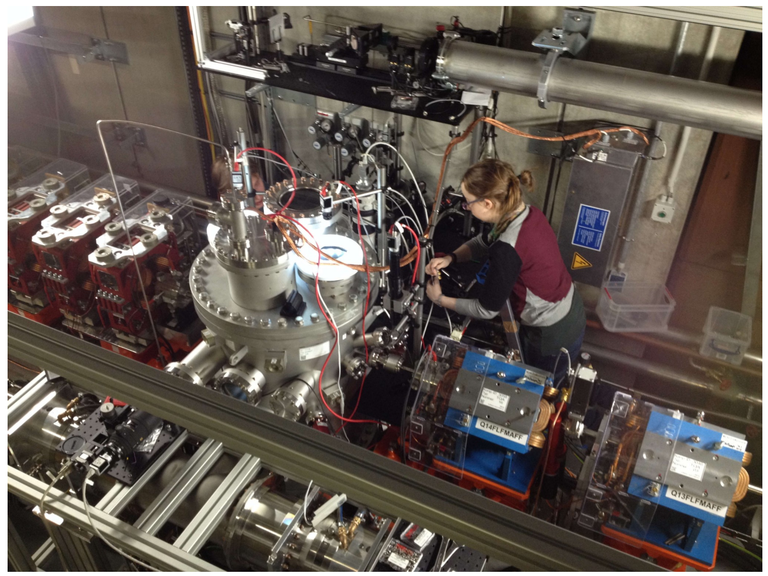
> **FLFDIAG (refocus & spectrometer)**

Beamline in Feb 2019.







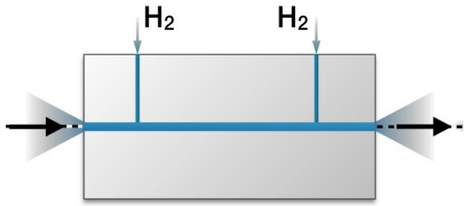


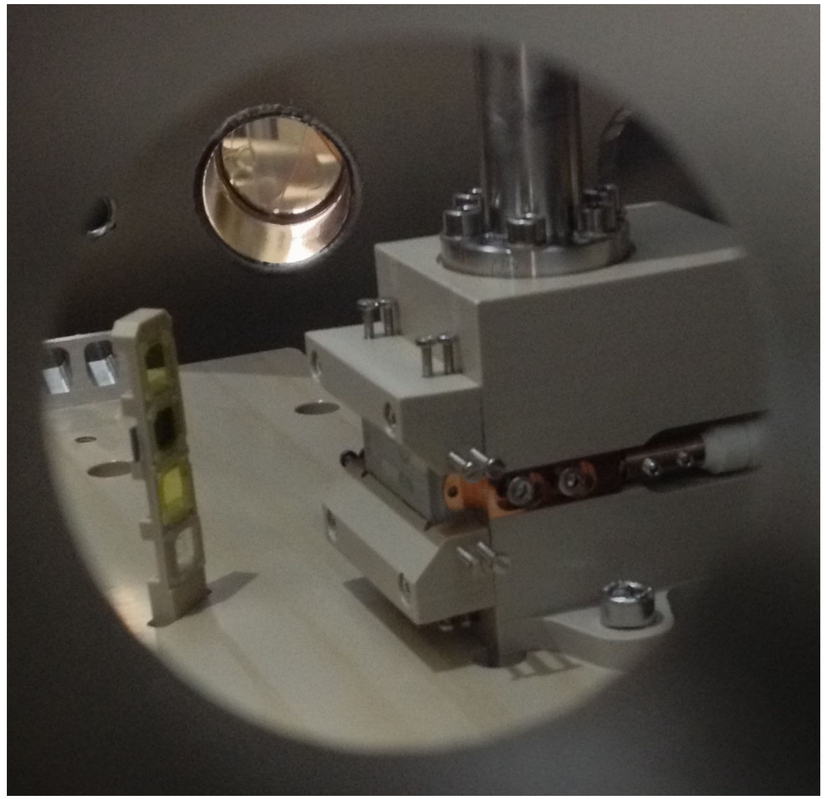
Plasma Target.

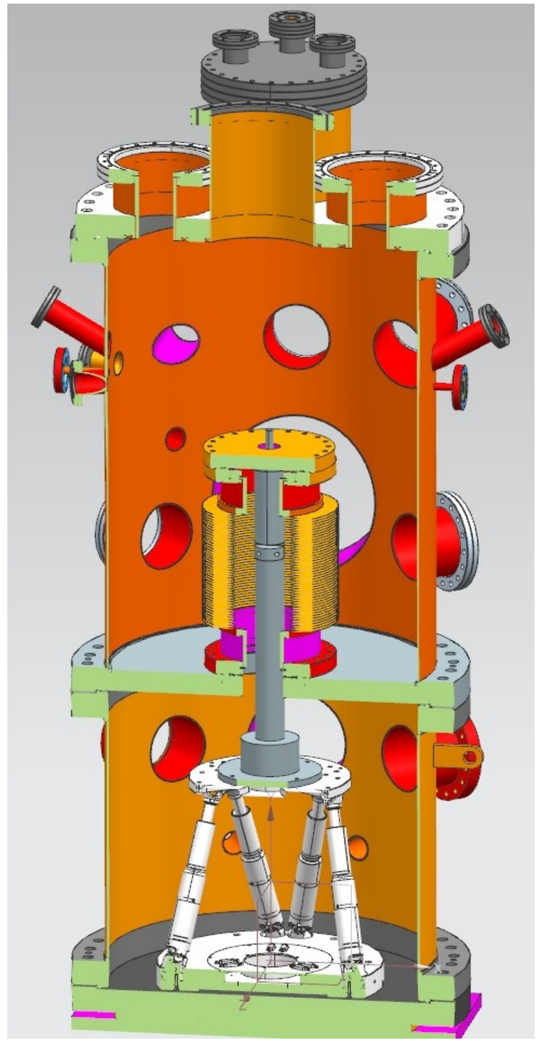
> Target
- Windowless sapphire capillary
- Length 33 mm / diameter 1.5 mm
- Copper electrodes / PEEK holder

> Diagnostics
- 3 screen holders
- Different scintillators
- OTR screens

> Target plate
- Adjustable in 6 axis by Hexapod
- Spatial accuracy: 1 um
- Angular accuracy: 5 urad



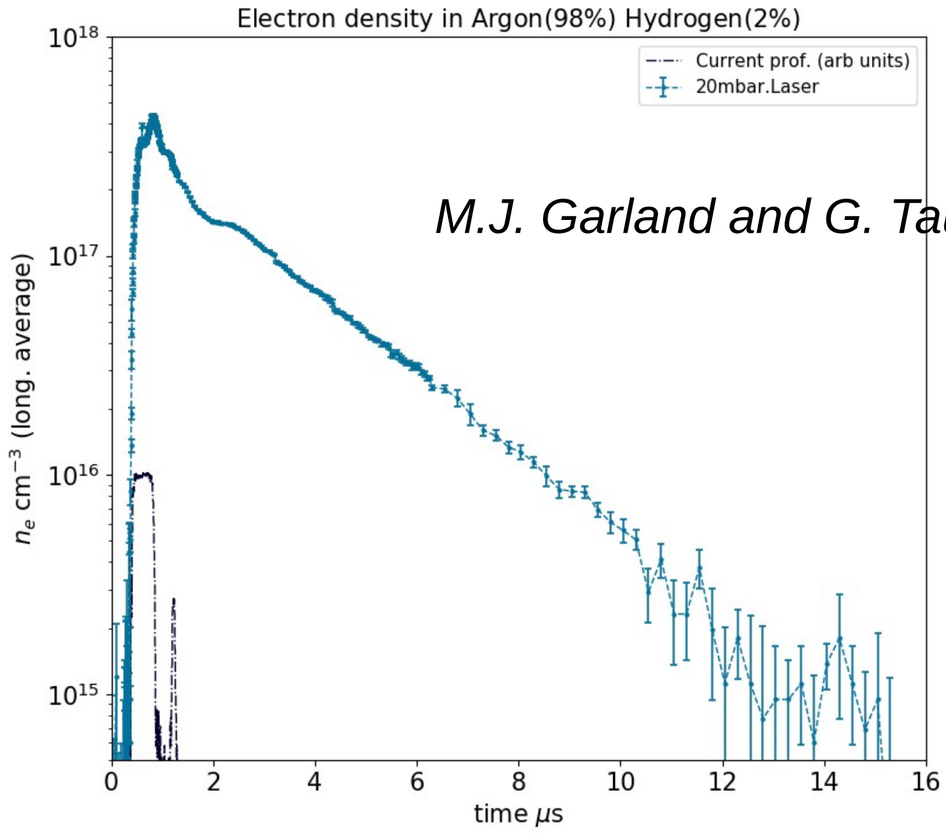




Discharge Plasma.

> **Current parameters**
- Argon gas, 40 mbar
- Ignited by 400 ns long, 20 kV discharge
- Repetition rate 2 Hz

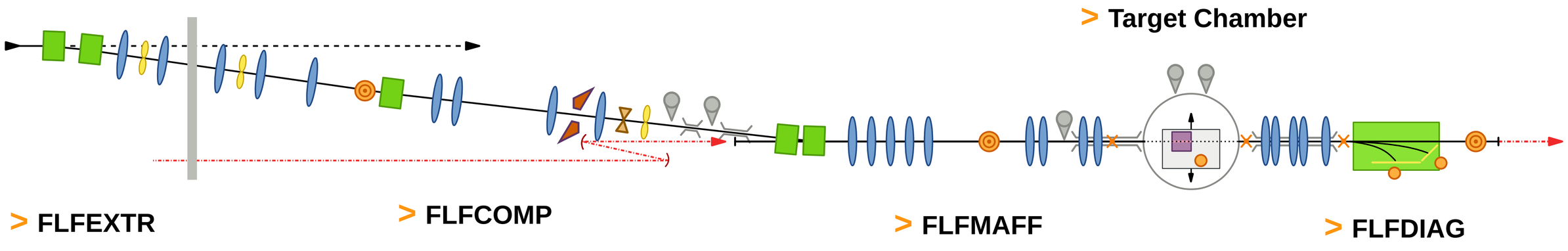
- Characterization in LWFA laboratory 28m



M.J. Garland and G. Tauscher

> **Plasma density control by time delay between discharge and bunch**

Beam Preparation.



I Linac set-up
- Measure on-crest phases
- Injector match
- Set to minimum energy spread bunch

II FLASH1 compression set-up
- Tune long. phase space with LOLA-TDS
- Go back to minimum energy spread

in dedicated shifts

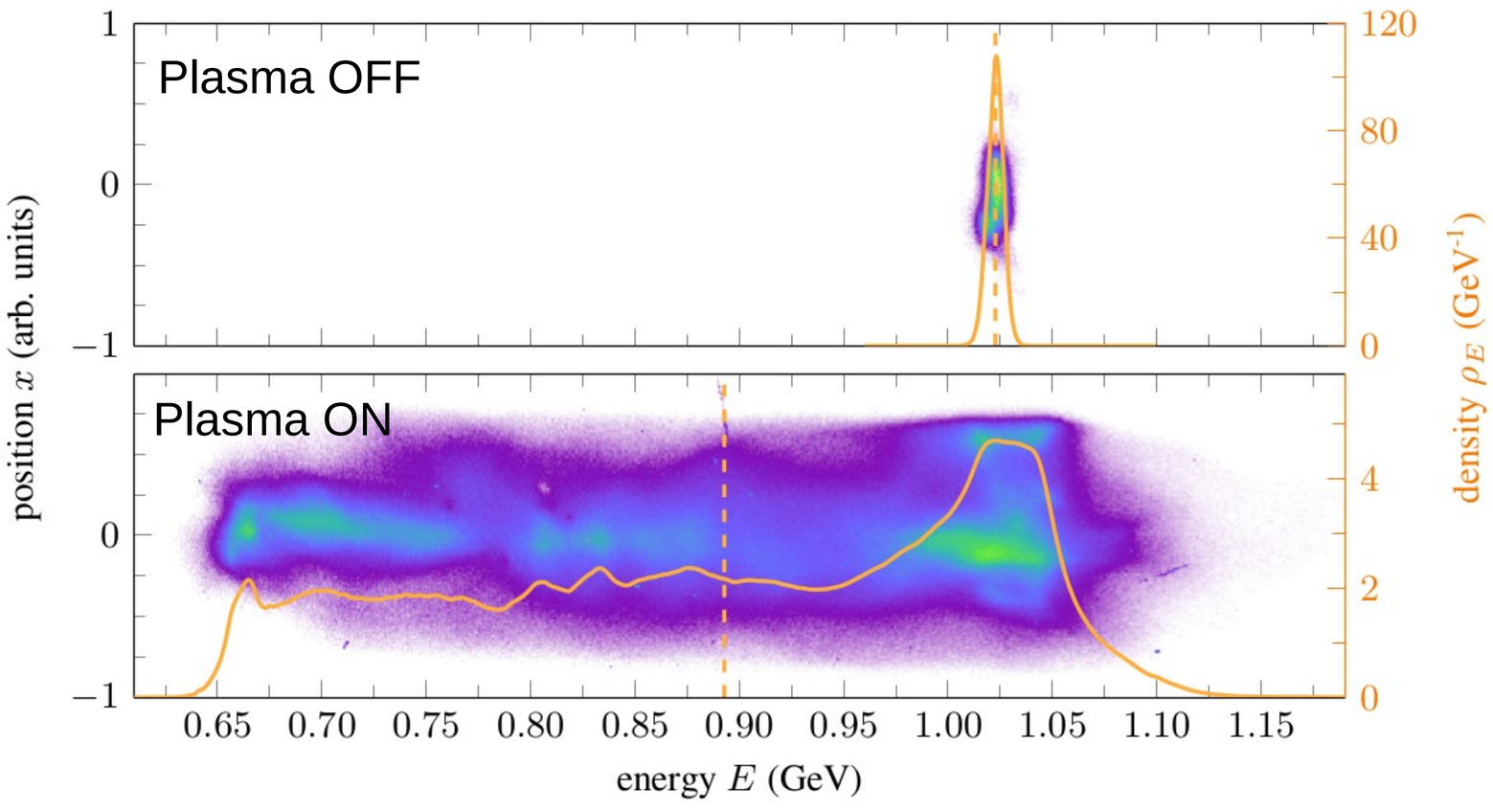
III FLASH2
- Close dispersion in extraction line

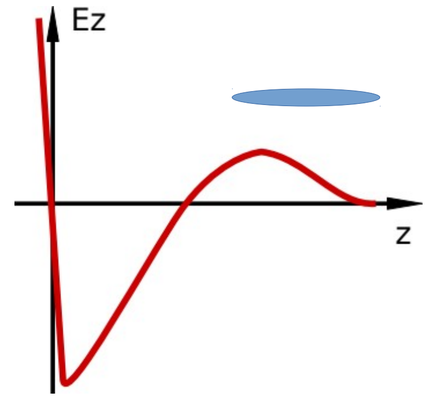
IV FLASH3
- Close dispersion
- Measure optics by multi quadrupole scan*
- Set to focus optics
- Verify focus
- Set compression
- Tuning

First Wakefield in 19th June 2018.

FF

> Injection of a SASE-like compressed bunch
after focus and plasma density tuning



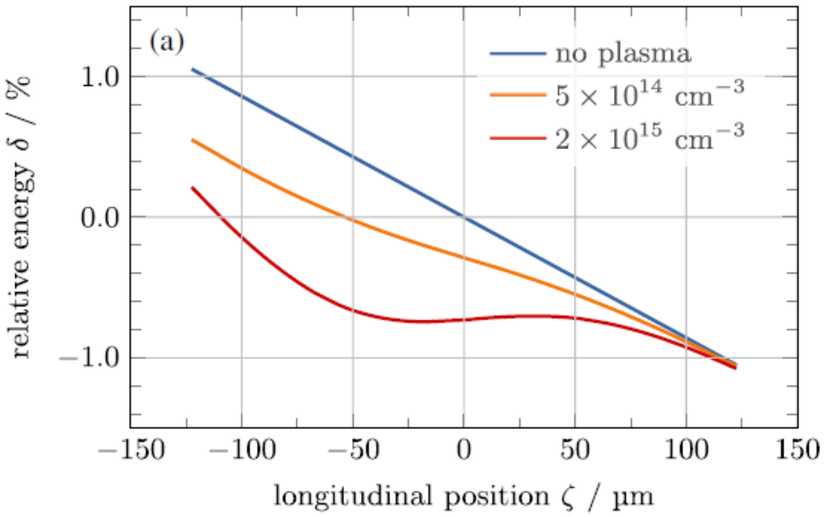


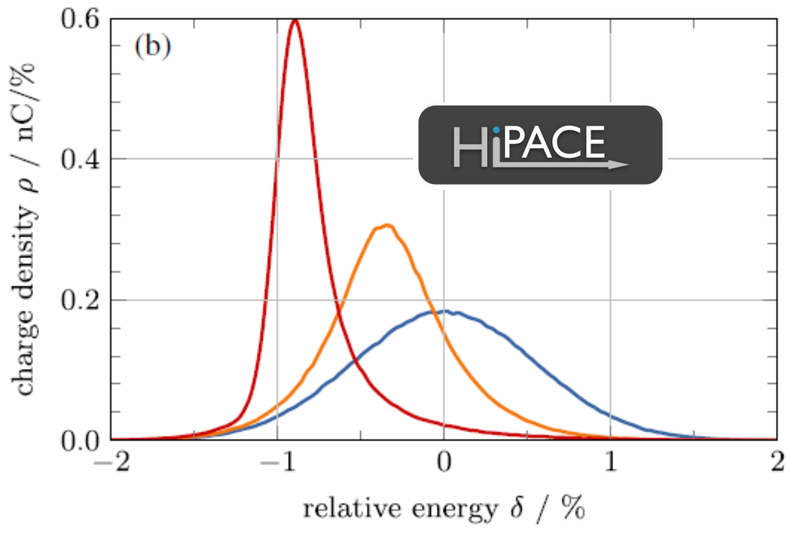
10 % depletion

average wakefield up to 12 GV/m

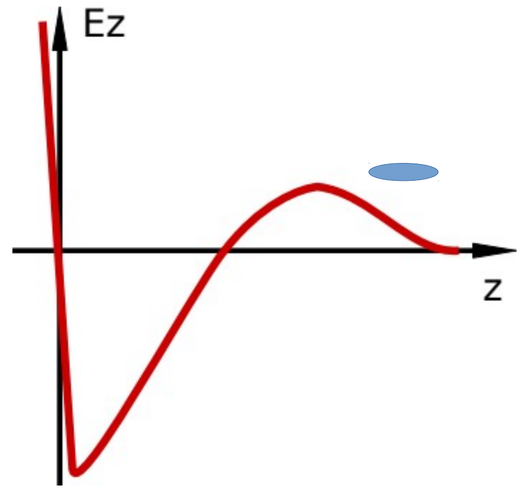
Experiment: Plasma Dechirper.

200 fs rms Gaussian bunch with linear chirp



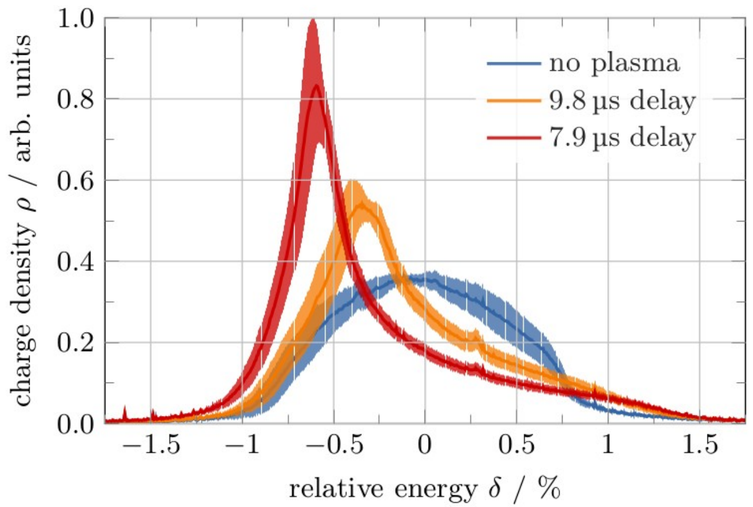


> Wake imprints large positive chirp on driver beam
→ to dechirp a negative chirped bunch

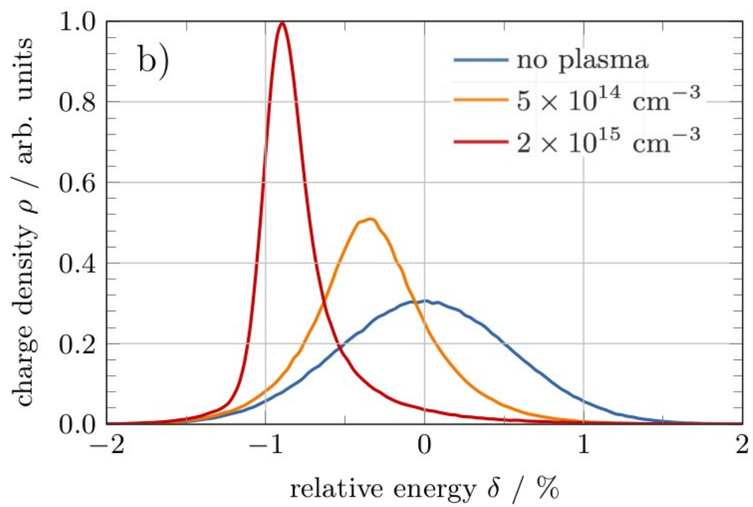


Experiment: Plasma Dechirper.

Data

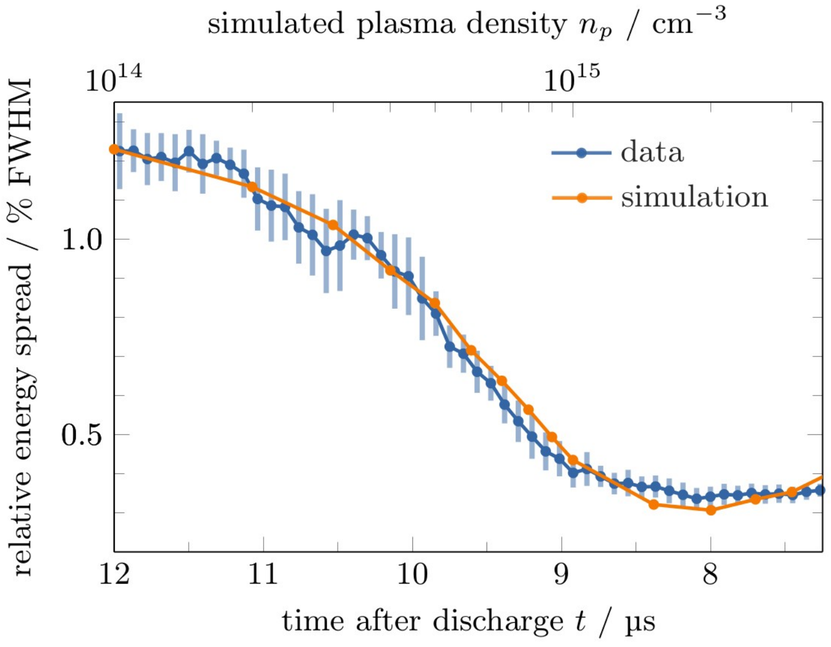


HiPACE simulation

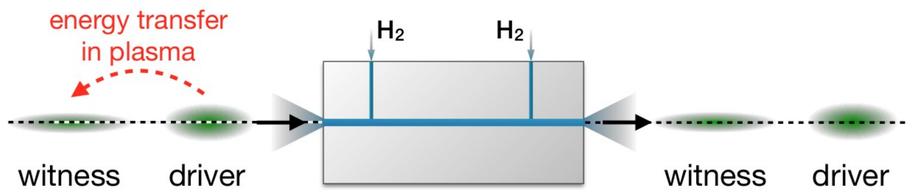


+ Reduction of energy spread by factor of **4**
+ Maximum dechirping strength of **1.8 GeV/mm/m**
+ No additional jitter on stability measureable
+ Easily tunable by varying plasma density

R. D'Arcy et al., Phys. Rev. Lett. 122, 034801 (2019)

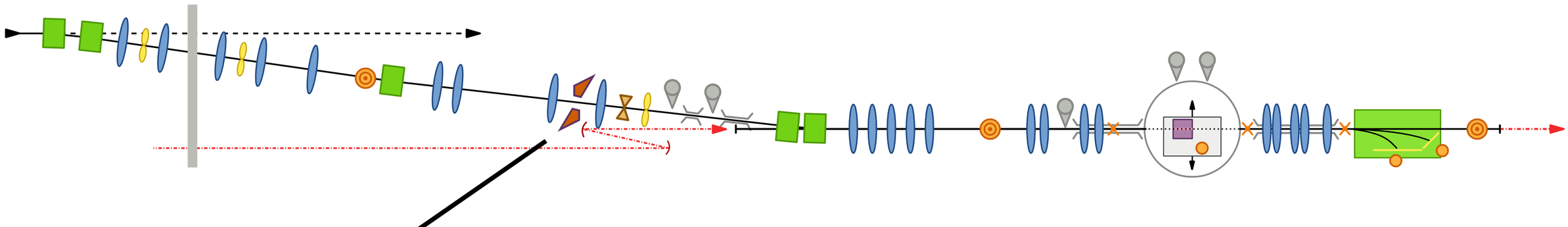


Experiment: External Injection.

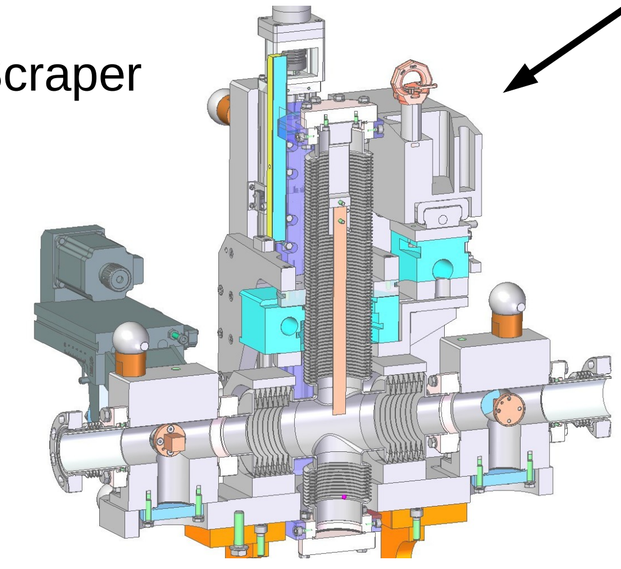


> **High gradients >1 GV/m**

> **Preserving beam quality**

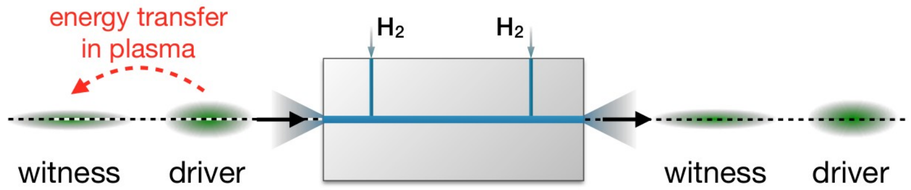


Scraper



Beam block in dispersive section

Experiment: External Injection.



> **High gradients >1 GV/m**

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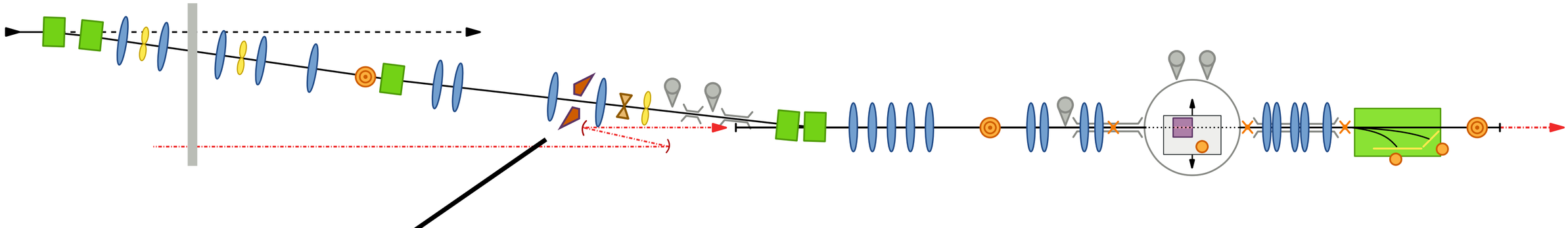
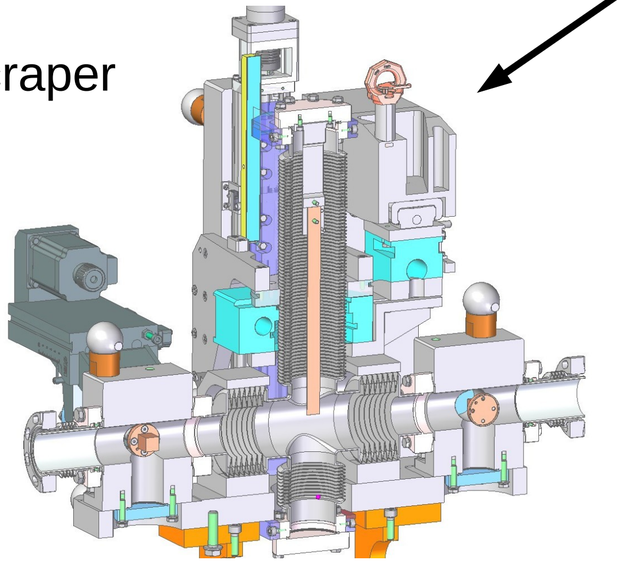
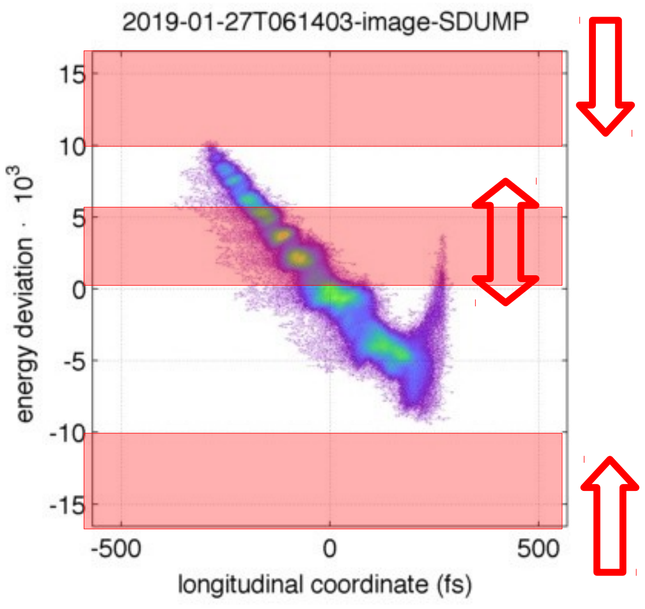


Scraper

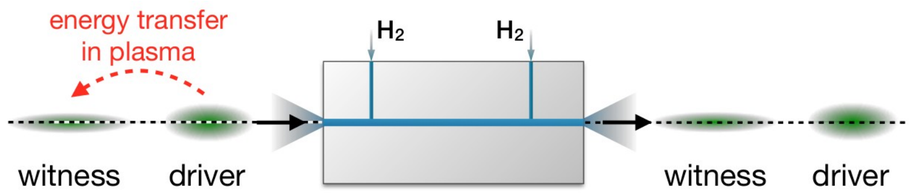




Beam block in dispersive section

Linear energy gradient

Experiment: External Injection.



> **High gradients >1 GV/m**

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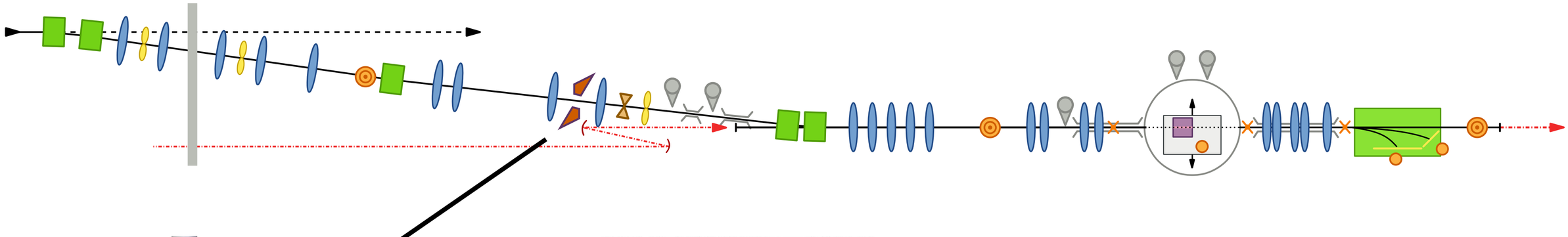
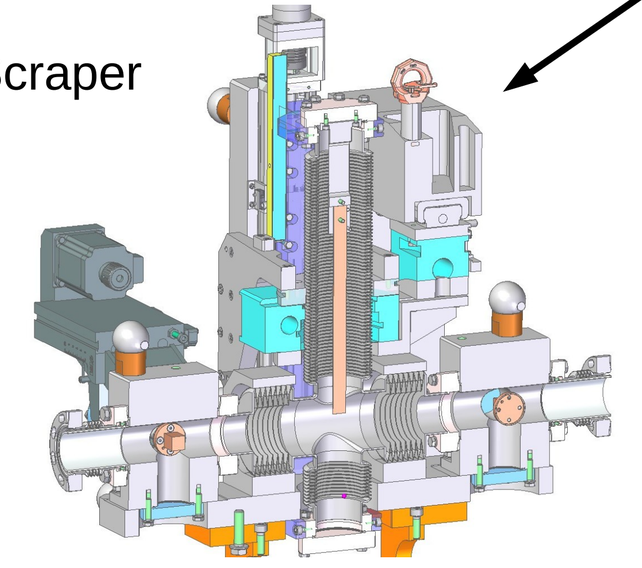
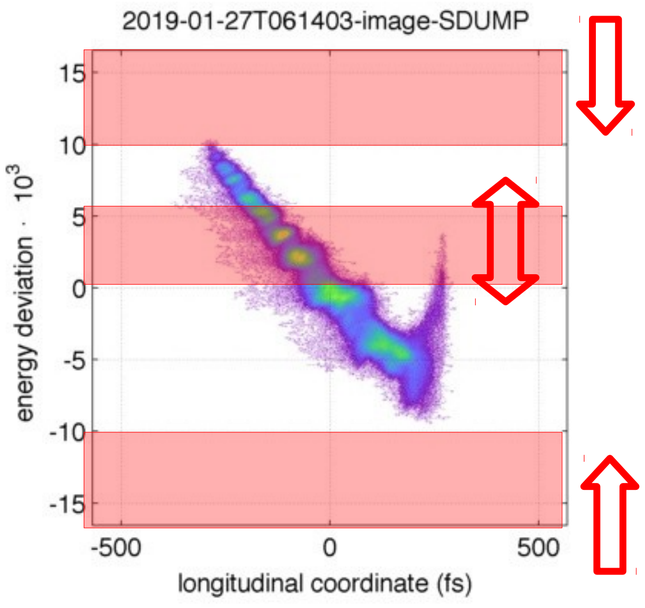


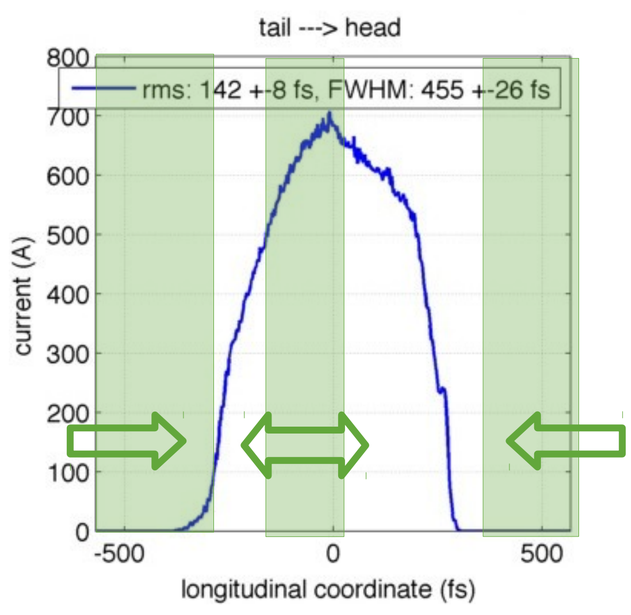
Scraper



Beam block in dispersive section

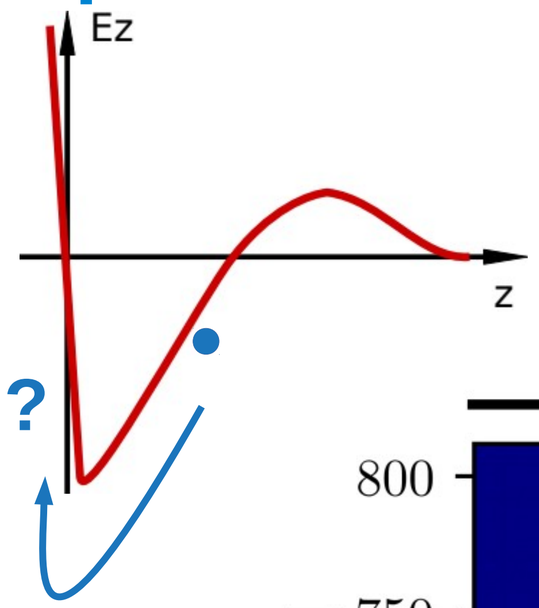


Linear energy gradient

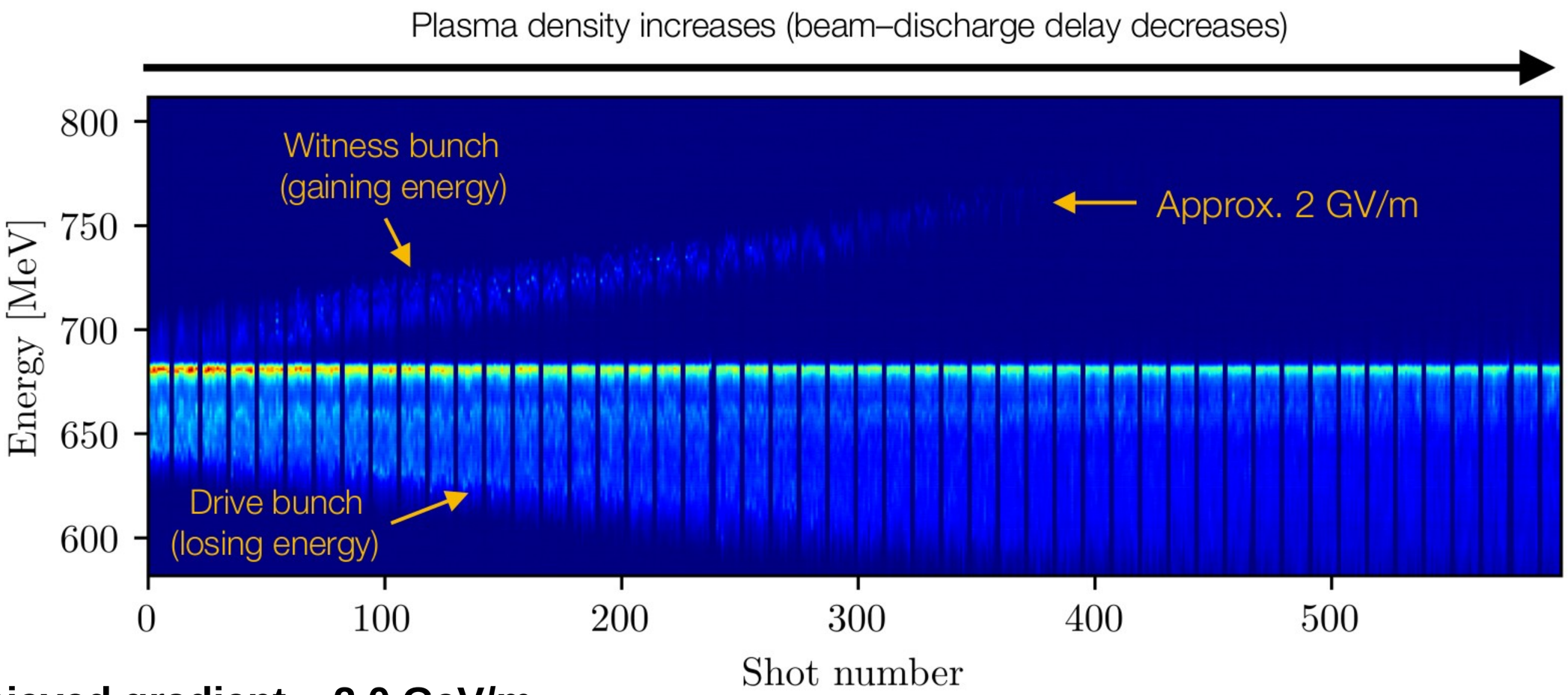


Bunch separation: Driver + Witness

Experiment: External Injection.



Fixed injected bunch parameters



> **Max. achieved gradient ~ 2.0 GeV/m**

> **Excellent shot-to-shot stability**

V. Libov (PI), S. Schröder, C.A. Lindstrøm

Upgrade: Long Shutdown in June/July 2019.

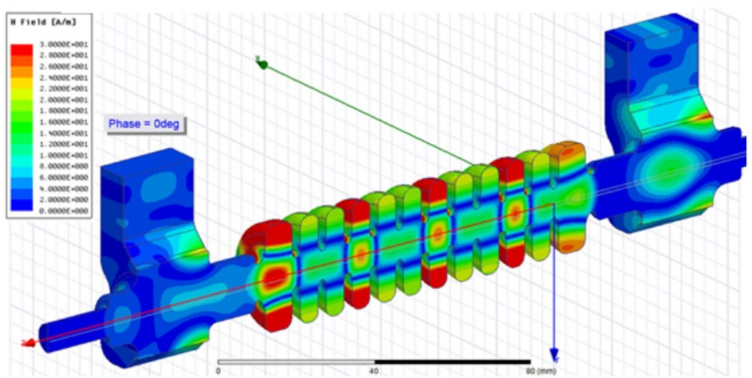
> New plasma cell
- Length: 33 mm to ~200 mm → higher energy
- Enable other injection techniques

> Improvement of focus diagnostics

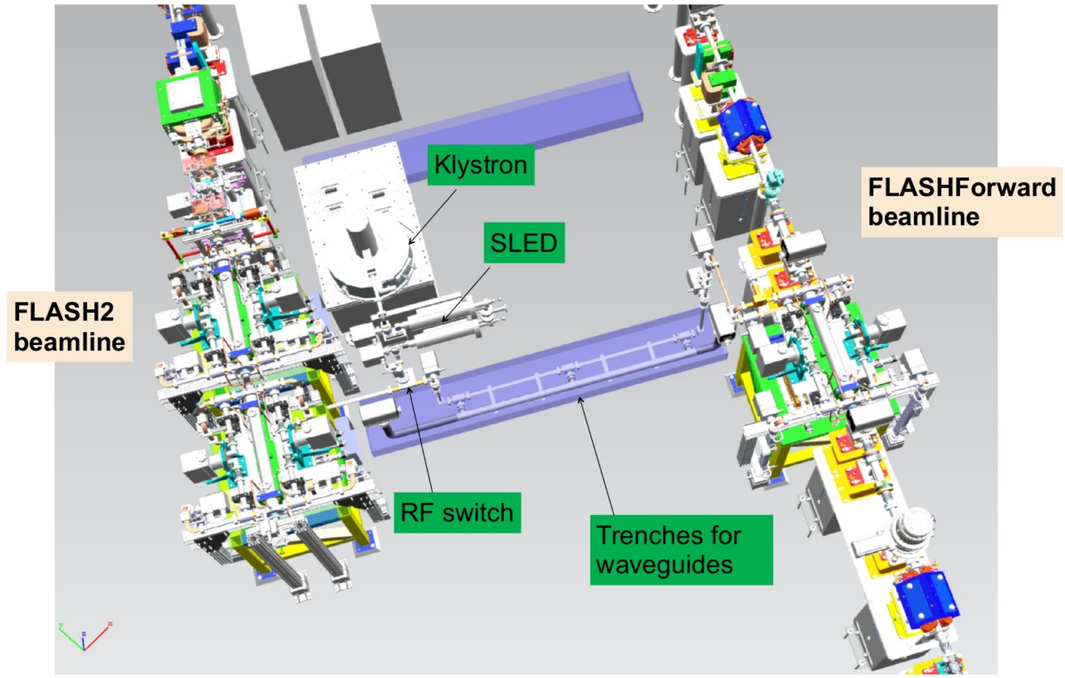
> Installation of hydrogen gas system

> Beamline extension for **PolariX-TDS**
- Slice emittance
- Long. phase space measurements
- X-band: ≥1 fs rms resolution

FLASHForward PI: R. D'Arcy
DESY project lead B. Marchetti



Courtesy A. Grudiev



Courtesy R. Jonas and M. Foese

Summary.

> FLASHForward is a beam-driven plasma-wakefield experiment at FLASH

> Goals
- Accelerate electron bunches >1.5 GeV while **preserving high-brightness properties**
- Test beams for FEL gain capability
- Investigation of injection techniques, diagnostics, high repetition rate, ...

> Operation of experiments since June 2018
- **Parallel** operation with FLASH1 (user-run, sFLASH)
- Up to now **1550 h** of beam time

> First results
- Plasma dechirper: strength of **1.8 GeV/mm/m**
- External injection: gradient of **~2 GeV/m**

> Extension in summer 2019
- Longer plasma targets: **higher energies + internal injection**
- Improved focus diagnostics and hydrogen gas system
- PolariX TDS for **≥1 fs** time resolution: longitudinal diagnostics for **driver + witness** bunch

Thank you for your attention!

http://forward.desy.de/