

Driver / witness bunch PWFA experiments at FLASHForward>>

4th European Advanced Accelerator Concepts Workshop 2019

16.9. - 21.09.2019, La Biodola Bay, Isola d'Elba, Italy

Sarah Schröder | DESY |

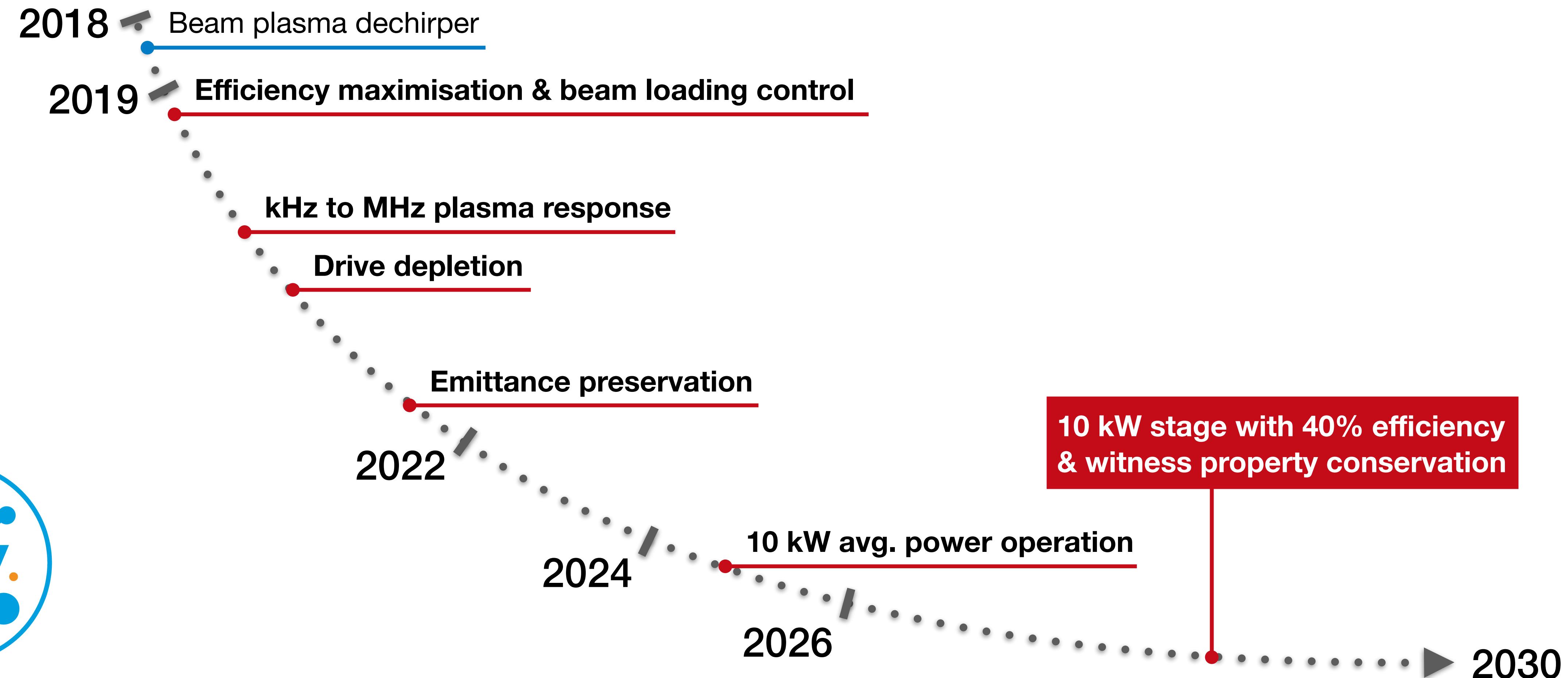
HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES



A. Aschikhin, S. Bohlen, G. Boyle, L. Boulton, R. D'Arcy, M. Dinter, T. Brümmmer, J. Chappell, S. Diederichs, B. Foster, M. J. Garland, L. Goldberg, P. Gonzalez, S. Karstensen, A. Knetsch, P. Kuang, V. Libov, C. A. Lindstrøm, K. Ludwig, A. Martinez de la Ossa, F. Marutzky, M. Meisel, T. J. Mehrling, P. Niknejadi, K. Pöder, A. Rahali, J.-H. Röckemann, J. Schaffran, L. Schaper, A. Schleiermacher, B. Schmidt, J.-P. Schwinkendorf, B. Sheeran, G. Tauscher, S. Thiele, S. Wesch, M. Zeng and J. Osterhoff

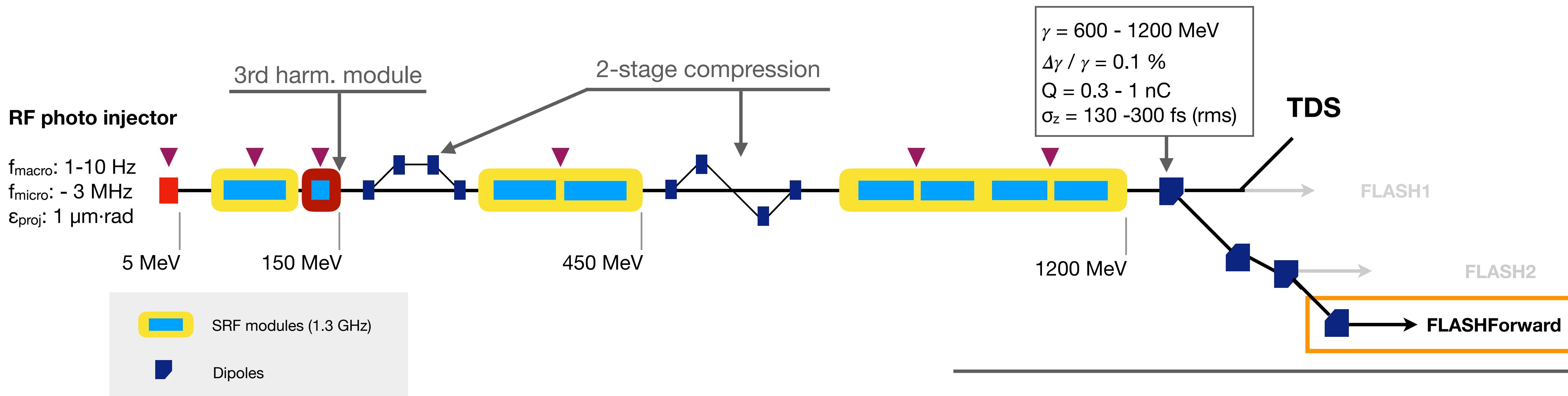
The FLASHForward► project

Beam-driven plasma-based accelerator research



FLASH as PWFA injector

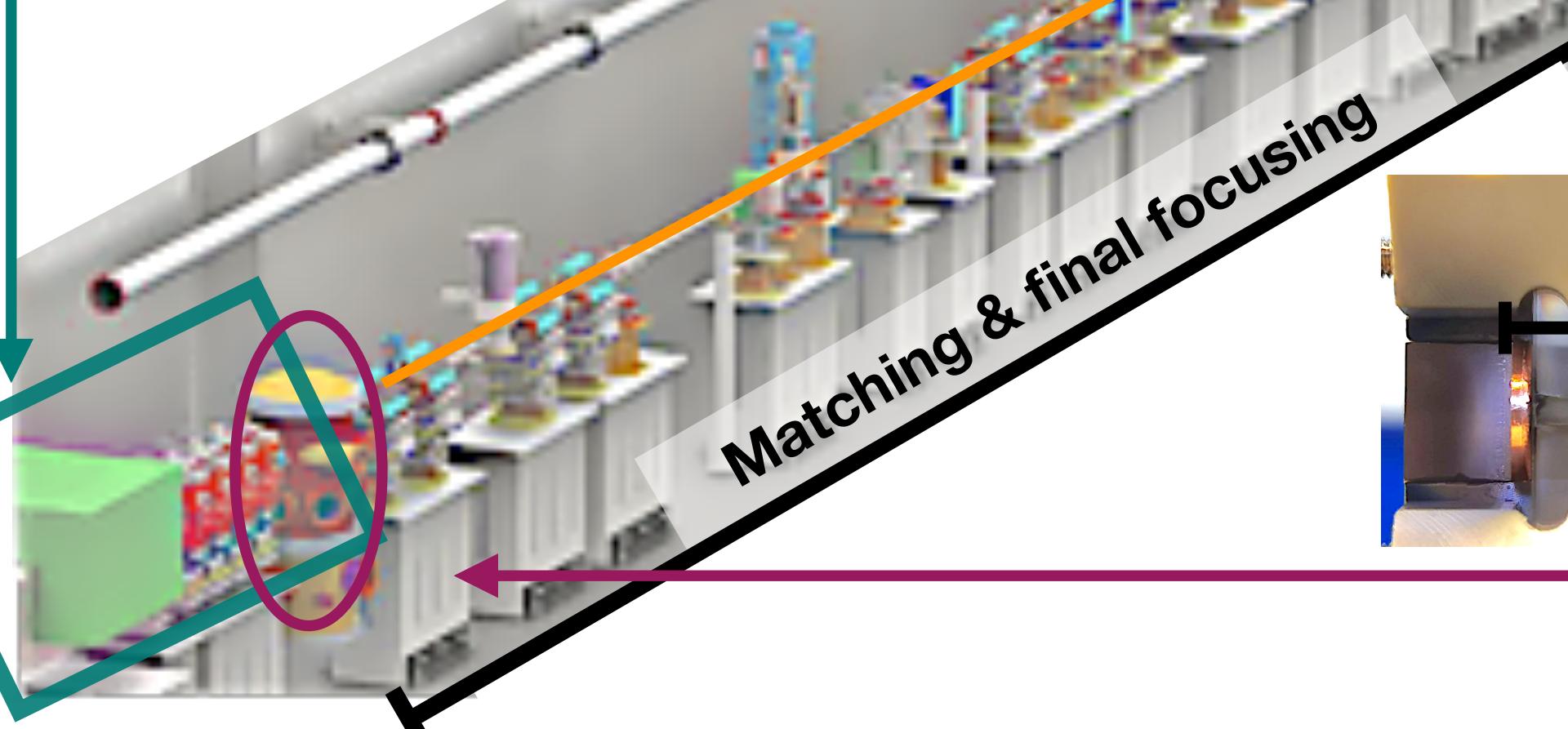
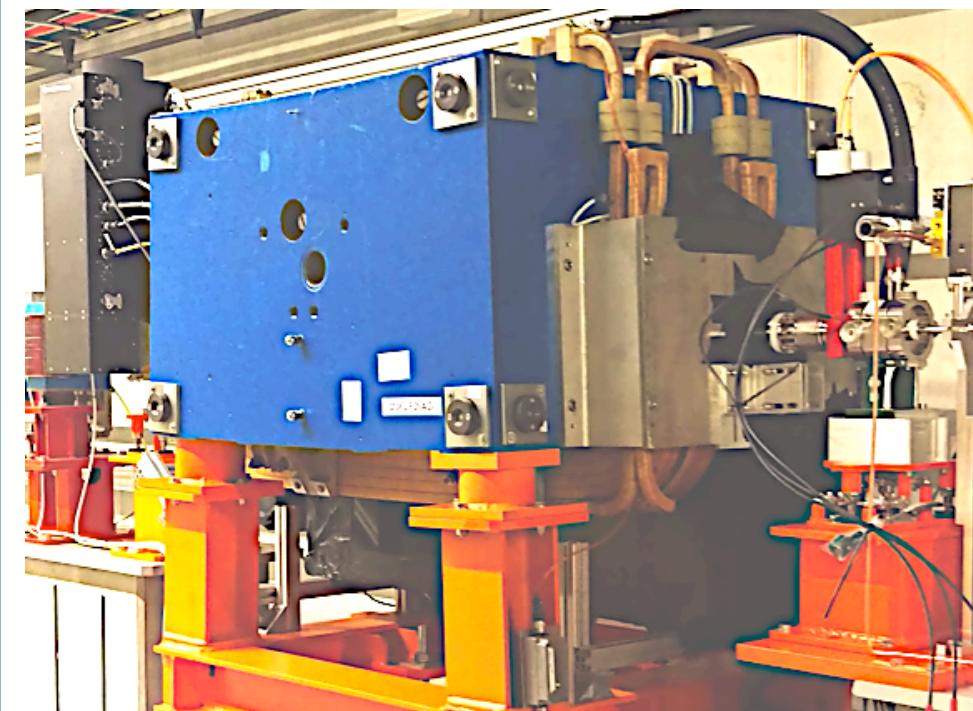
- ▶ FLASH (Free-Electron Laser Hamburg) as electron injector for PWFA
- ▶ Longitudinal phase space (LPS) shaping with 3rd harmonic module
- ▶ LPS measurement: Transverse deflecting cavity in parallel photon beamline



FLASHForward beamline status

Post plasma diagnostics

- ✓ Large energy range electron spectrometer
- ✓ X-band TDS
- High res. spectrometer



Beam - plasma interaction chamber

Adjustable via hexapod
Diagnostics (OTR / YAG)

Plasma channel:

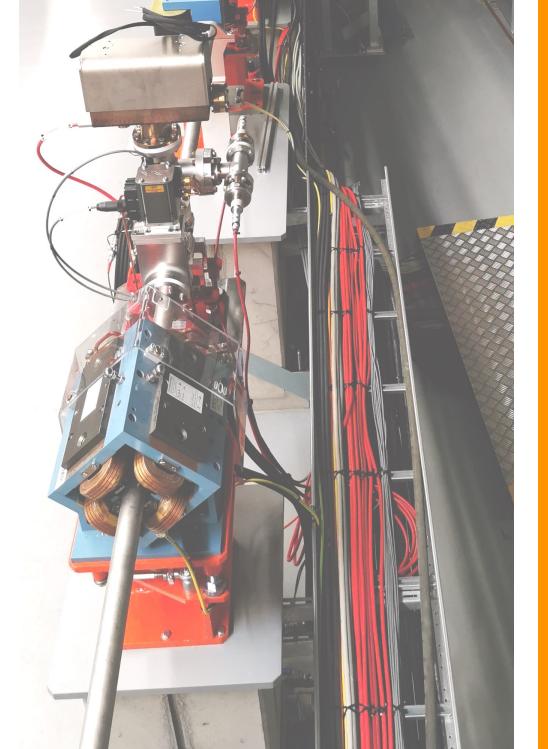
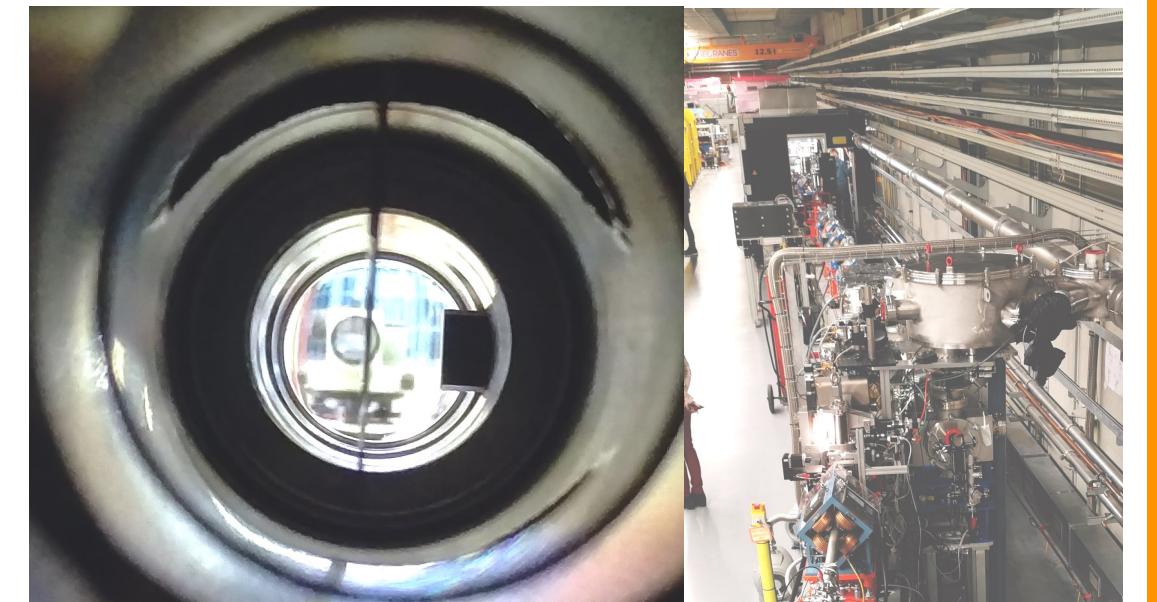
Argon
Discharge triggered
 $n_p \sim 1-3 \times 10^{16} \text{ cm}^{-3}$



Extraction & Compression

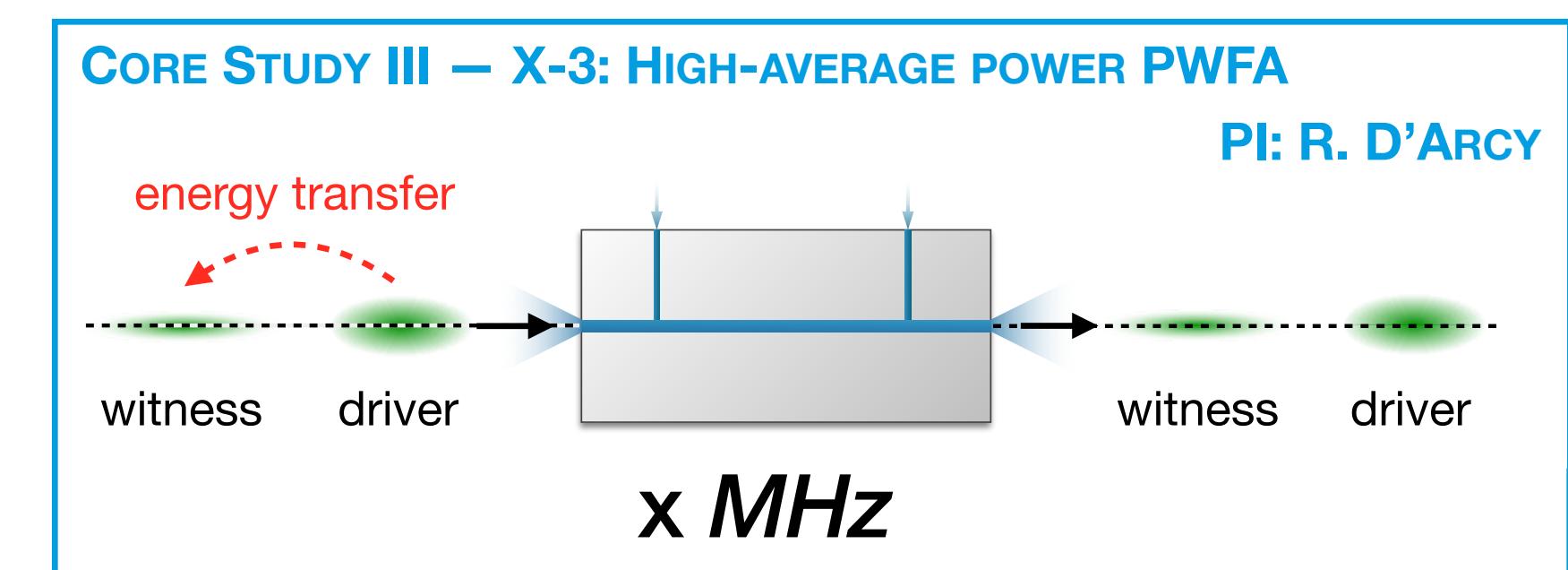
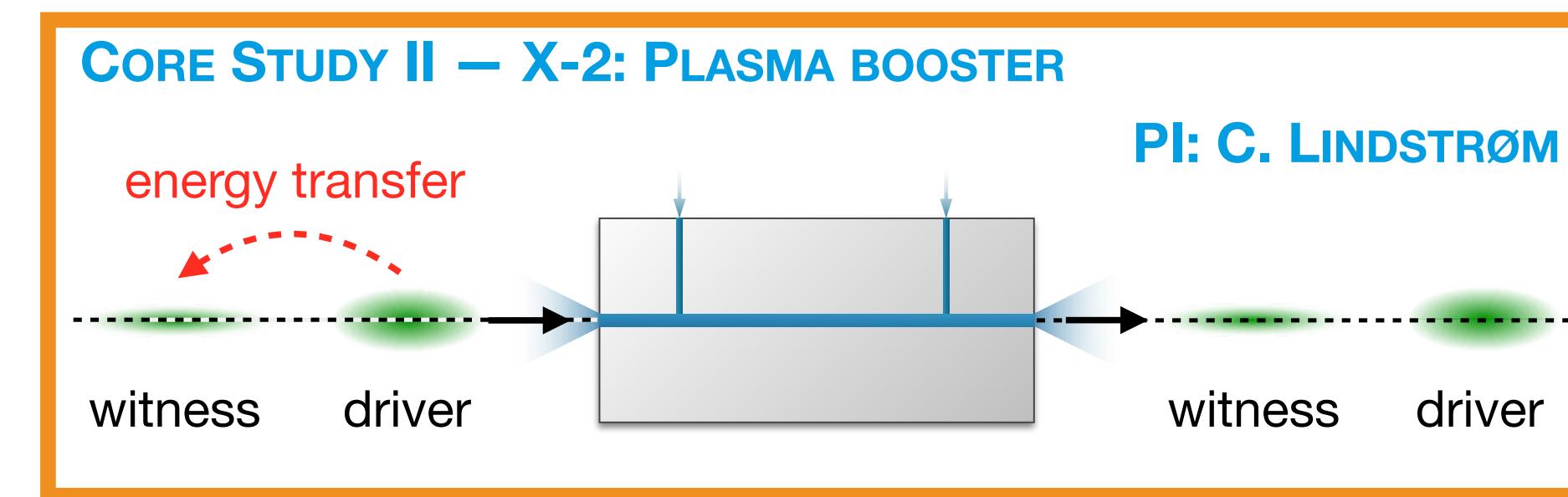
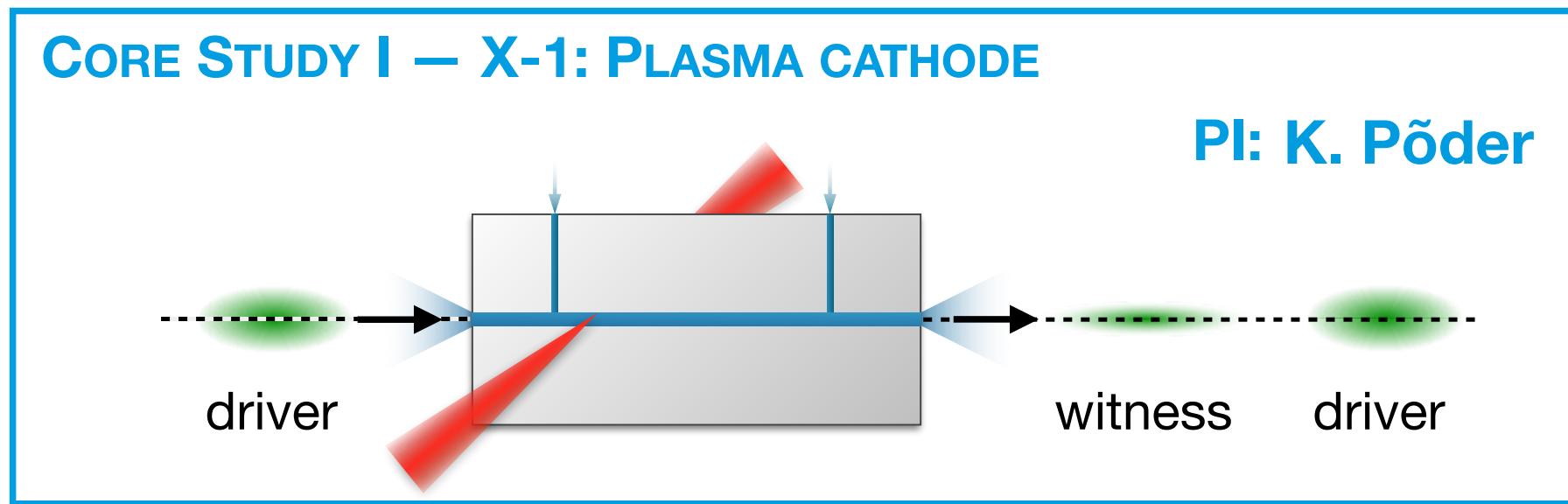
Electron beam line

- ✓ Collimator apparatus in dispersive section
- ✓ Two sets of quadrupoles: matching & final focussing
- ✓ Beam capture after plasma



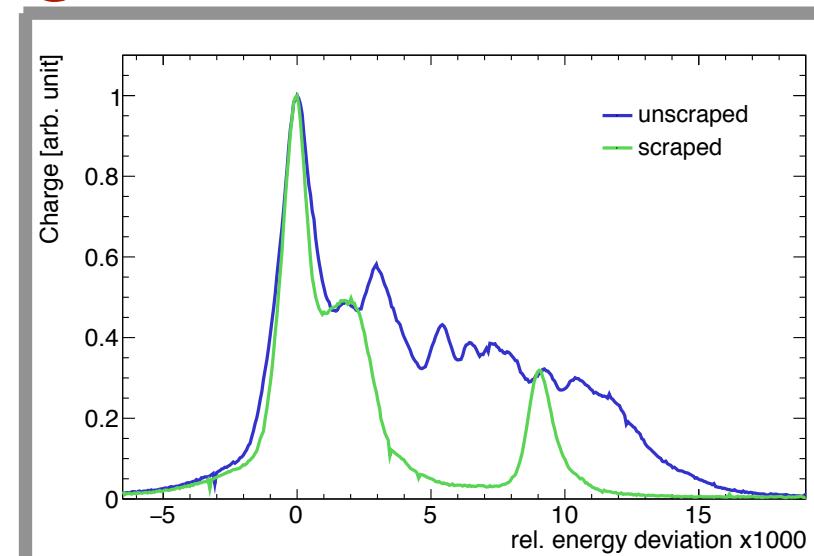


Core experiments at FLASHForward



X-2: External injected PWFA at FLASHForward ►►

Driver / witness generation

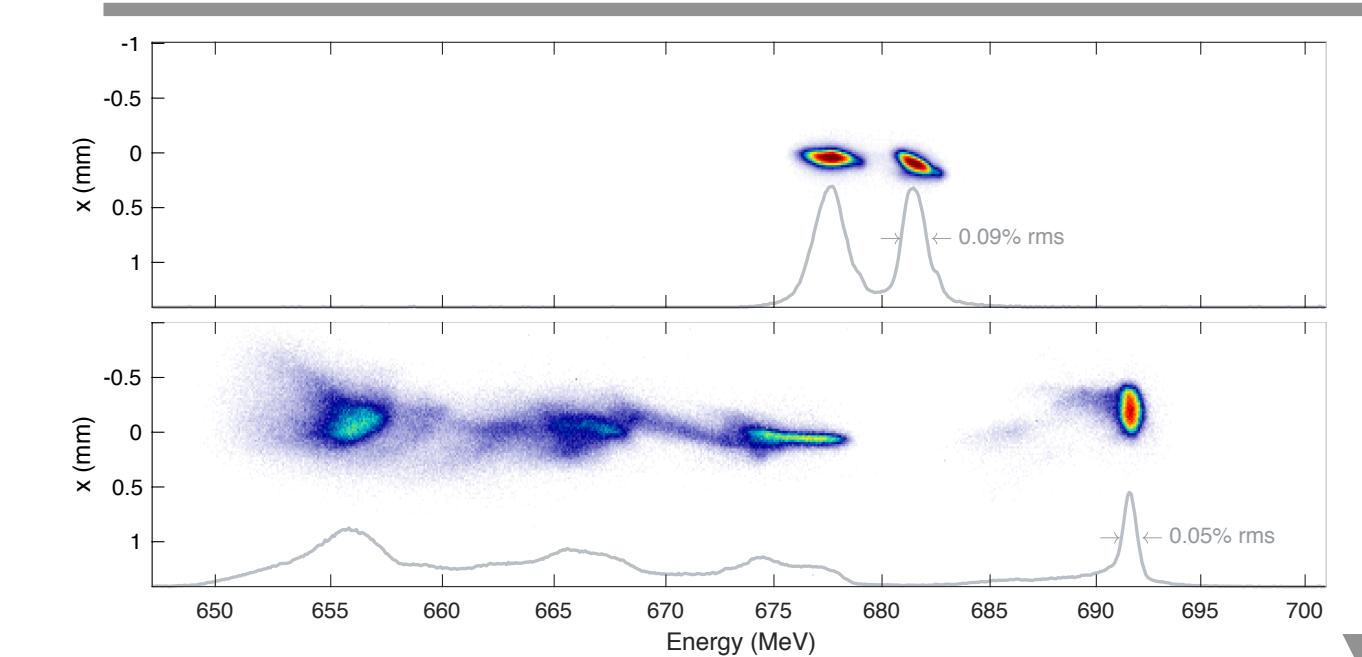


June

First decelerating wakefields 12 GV/m



Preserved 0.1% energy spread

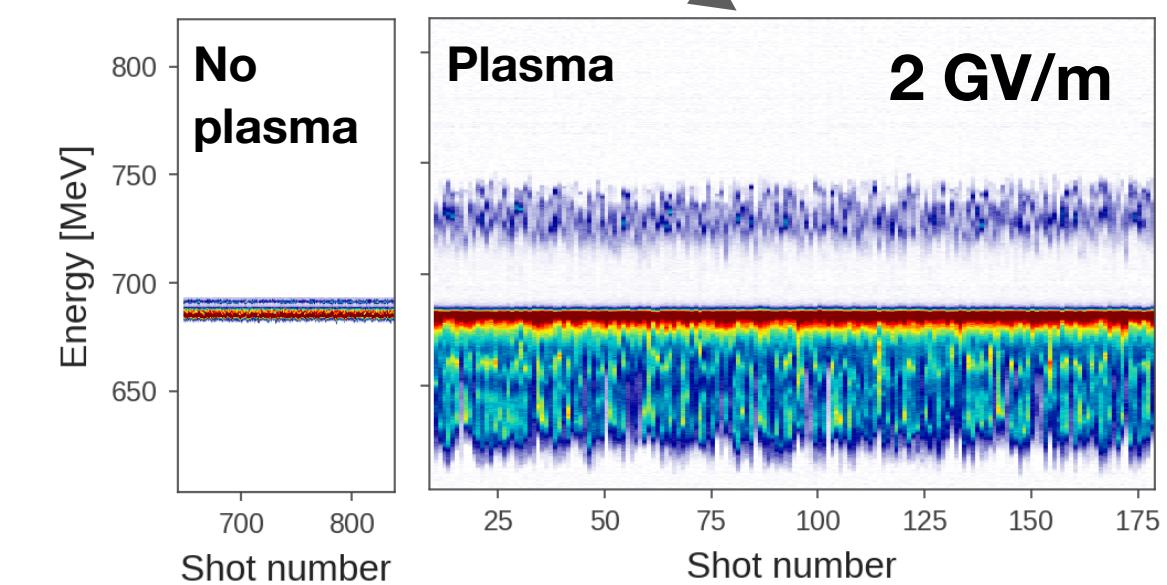


2019

250 MV/m

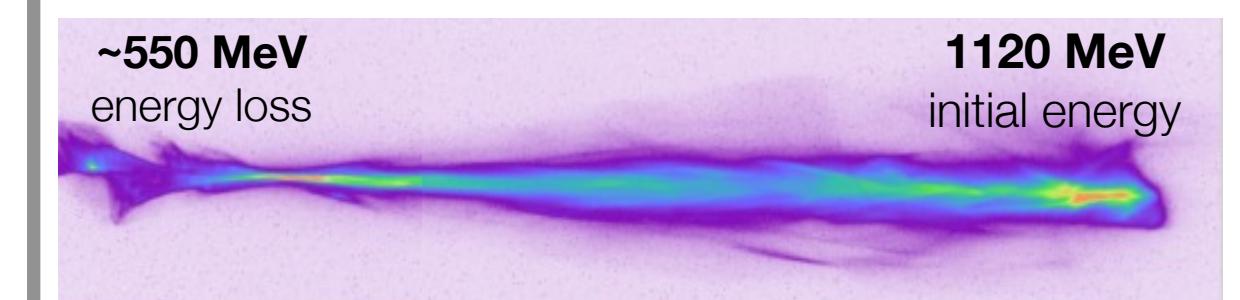
500 MV/m

1 GV/m



Stable witness acceleration

Transport through 195 mm plasma



Talk: K. Poder

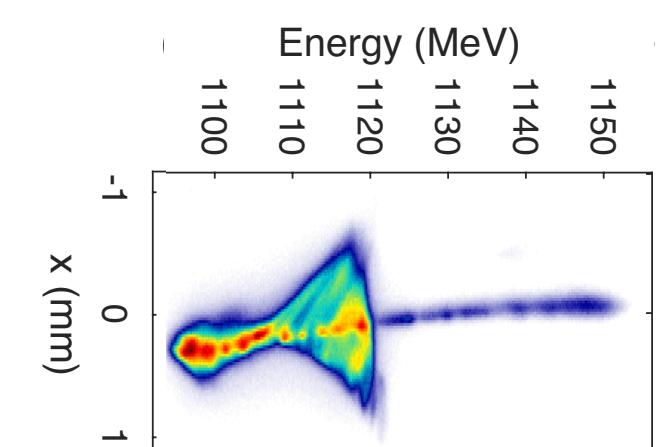
June

TDS commissioning

Talk: P. Gonzalez

Goals

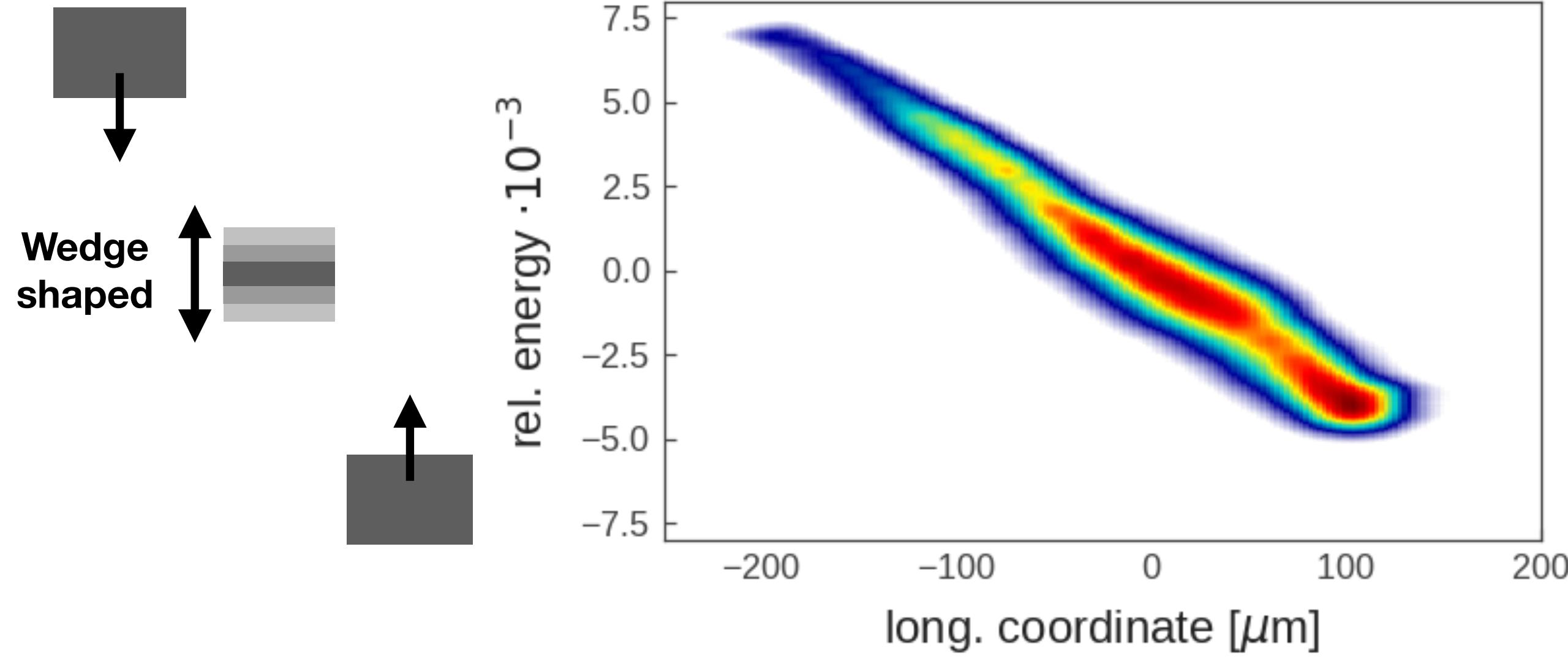
- Emittance preservation
- High overall efficiency
 - Beamloading
 - Depletion



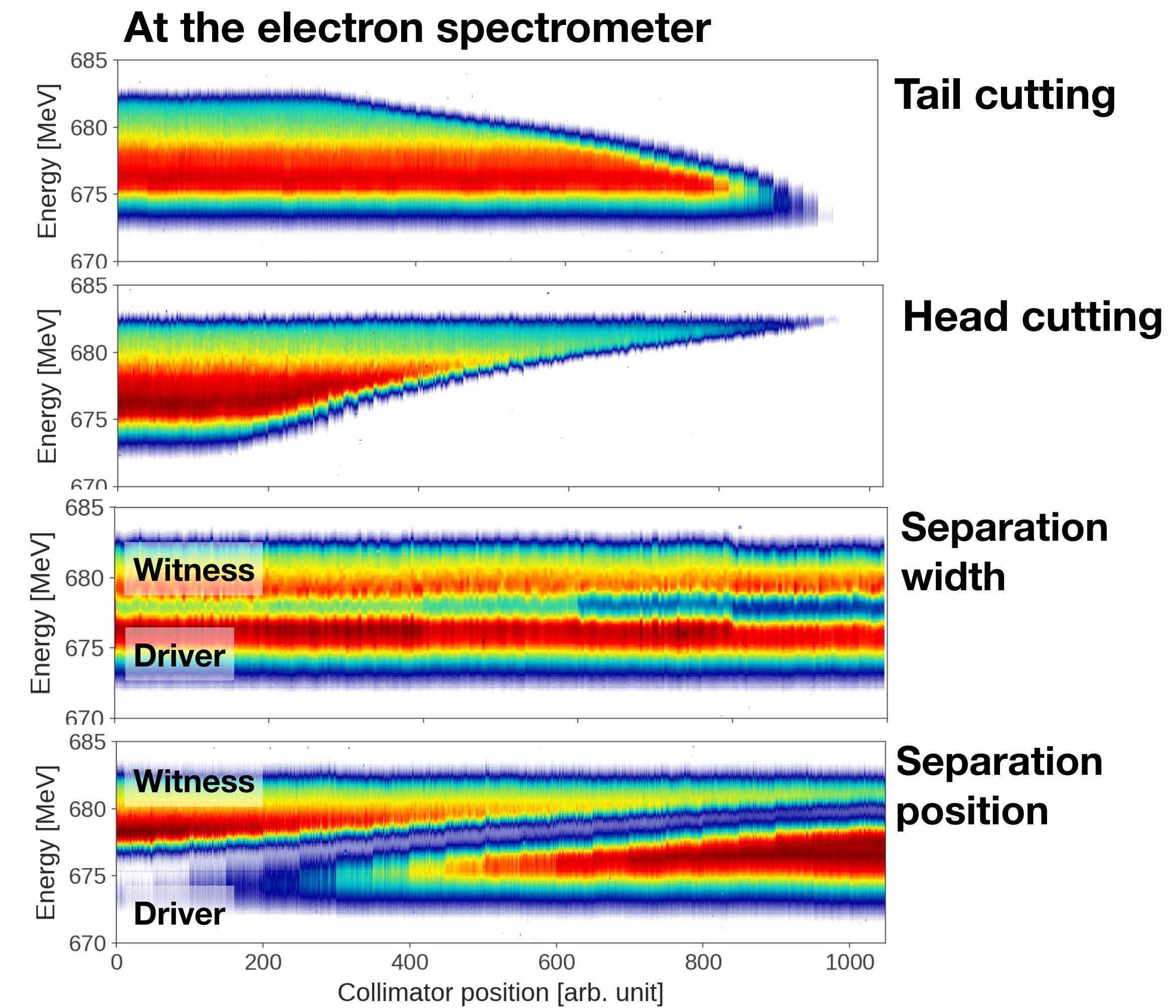
Wakefield measurement

Near-'matched' beams

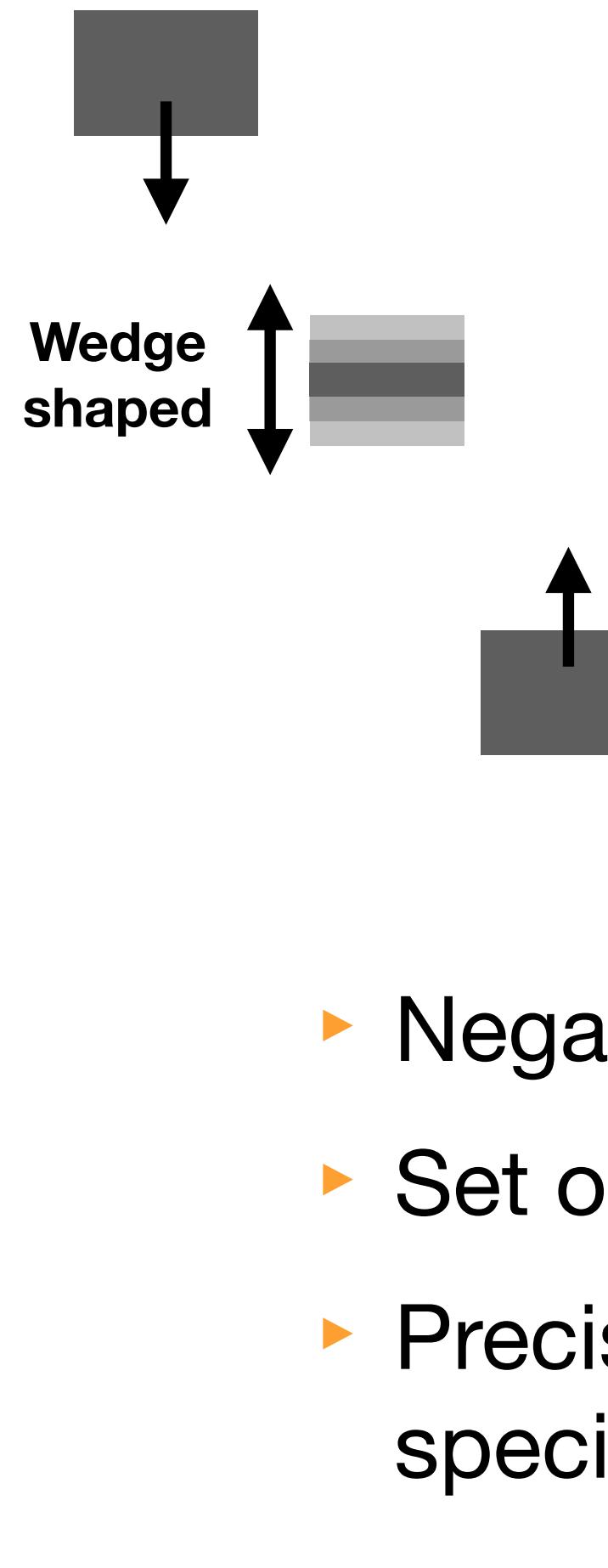
Precision driver / witness bunch pair generation



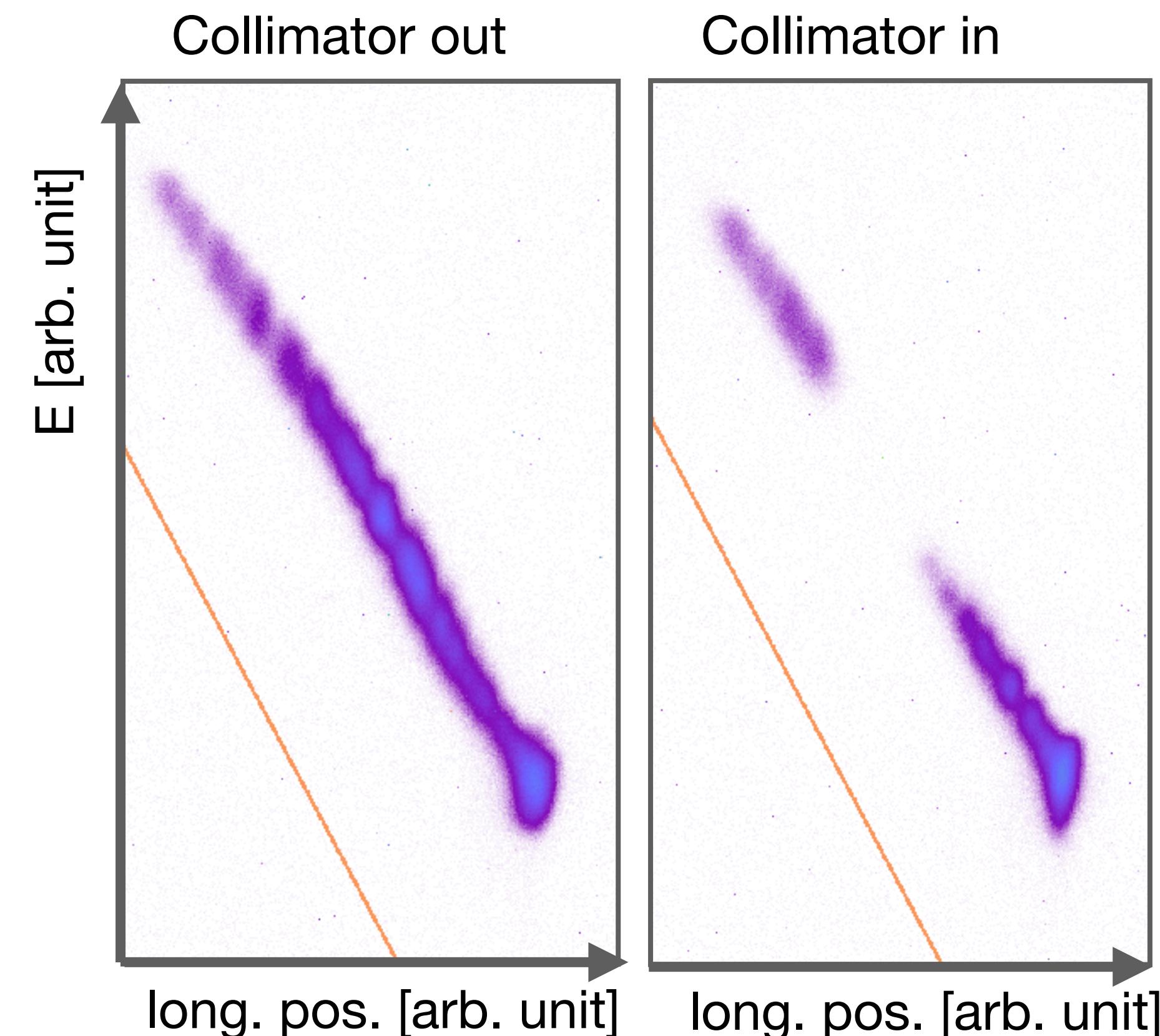
- ▶ Negatively chirped bunch: E-t correlation
- ▶ Set of collimators in dispersive section
- ▶ Precise tunability of driver / witness specifications (depending on incoming bunch)



Precision driver / witness bunch pair generation

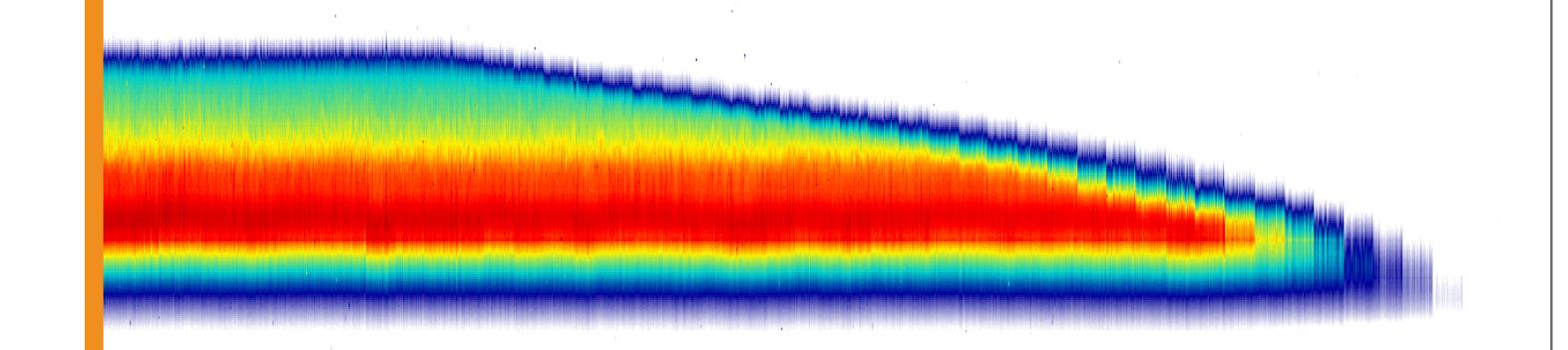


Driver / Witness observed in XTDS

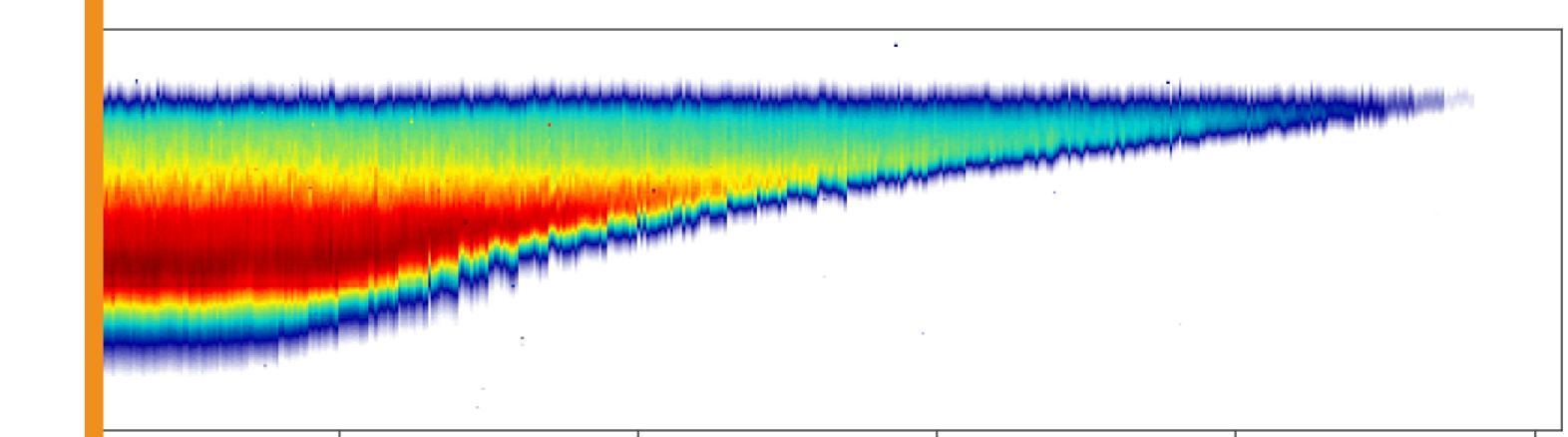


- ▶ Negative energy
- ▶ Set out of phase
- ▶ Precise separation

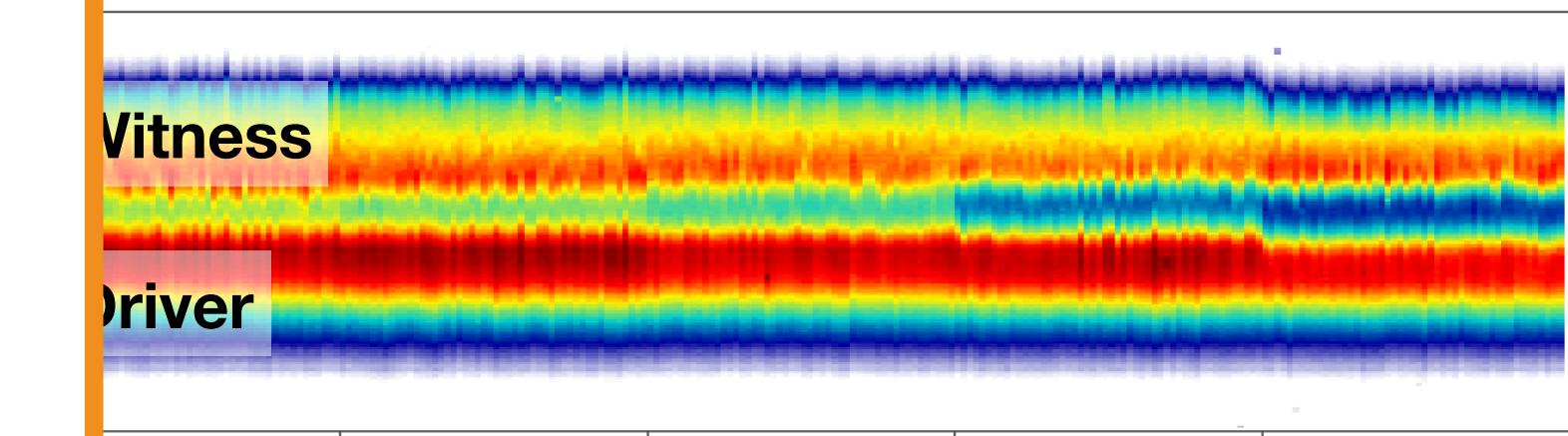
at the electron spectrometer



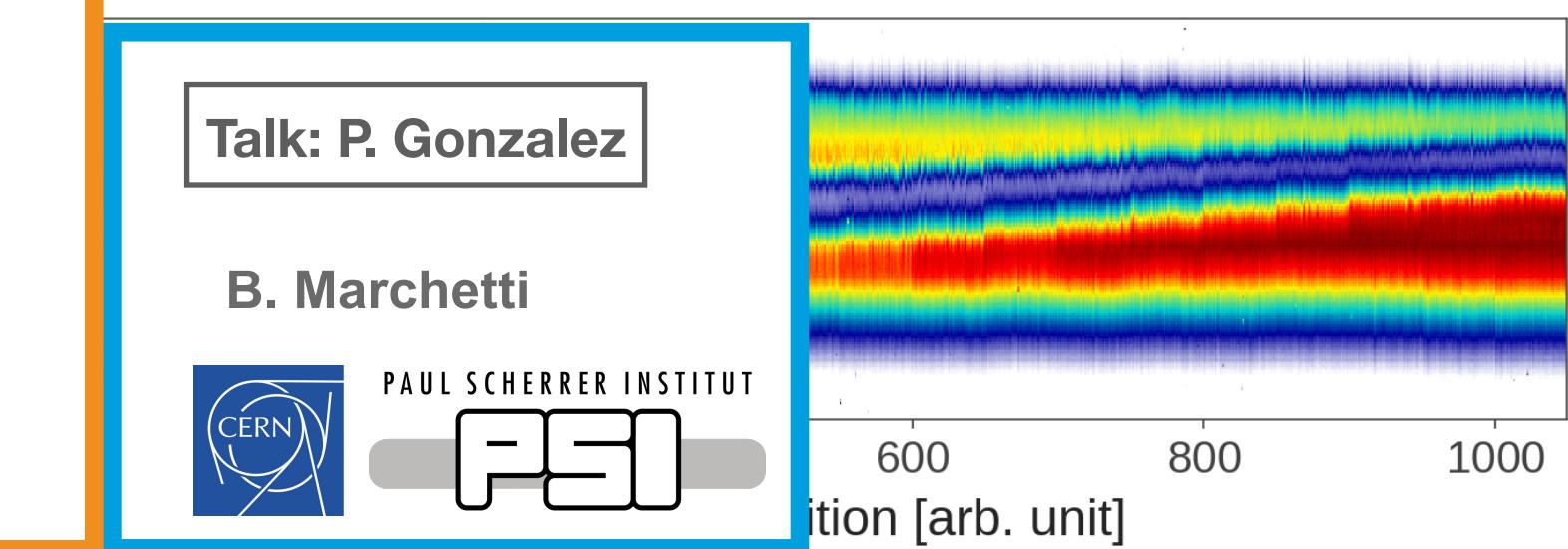
Tail cutting



Head cutting



Separation width



Separation position

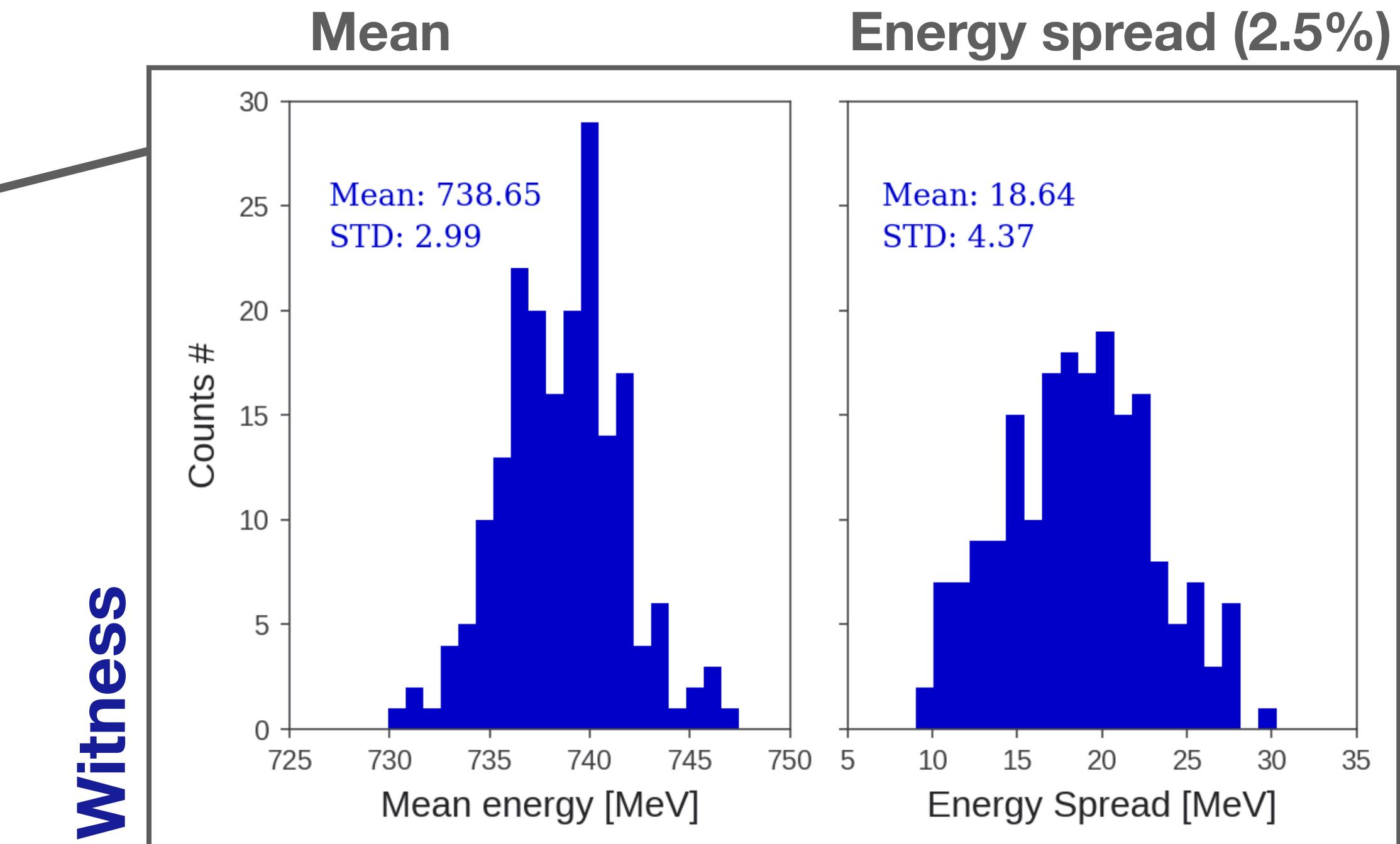
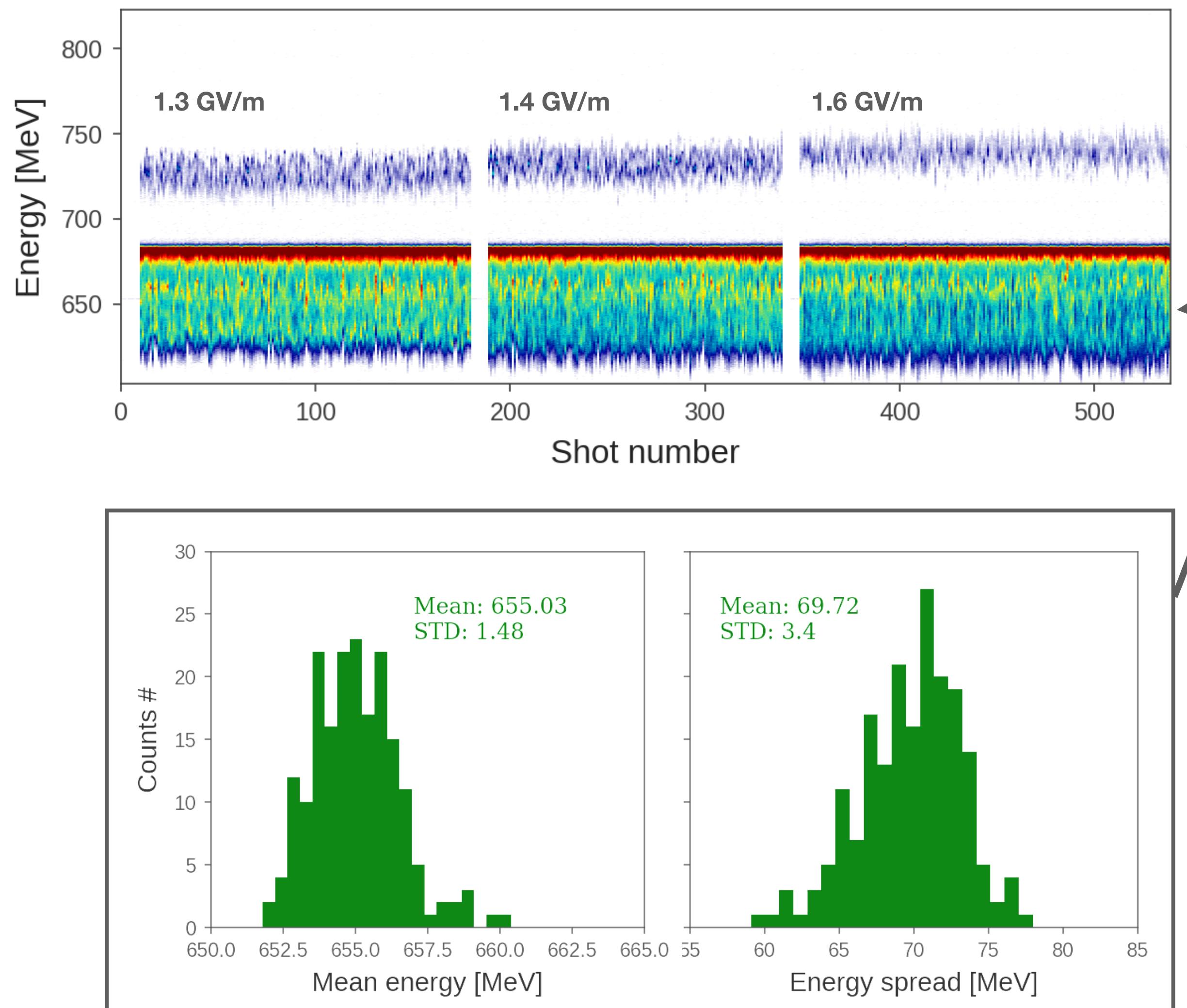
Talk: P. Gonzalez

B. Marchetti



position [arb. unit]

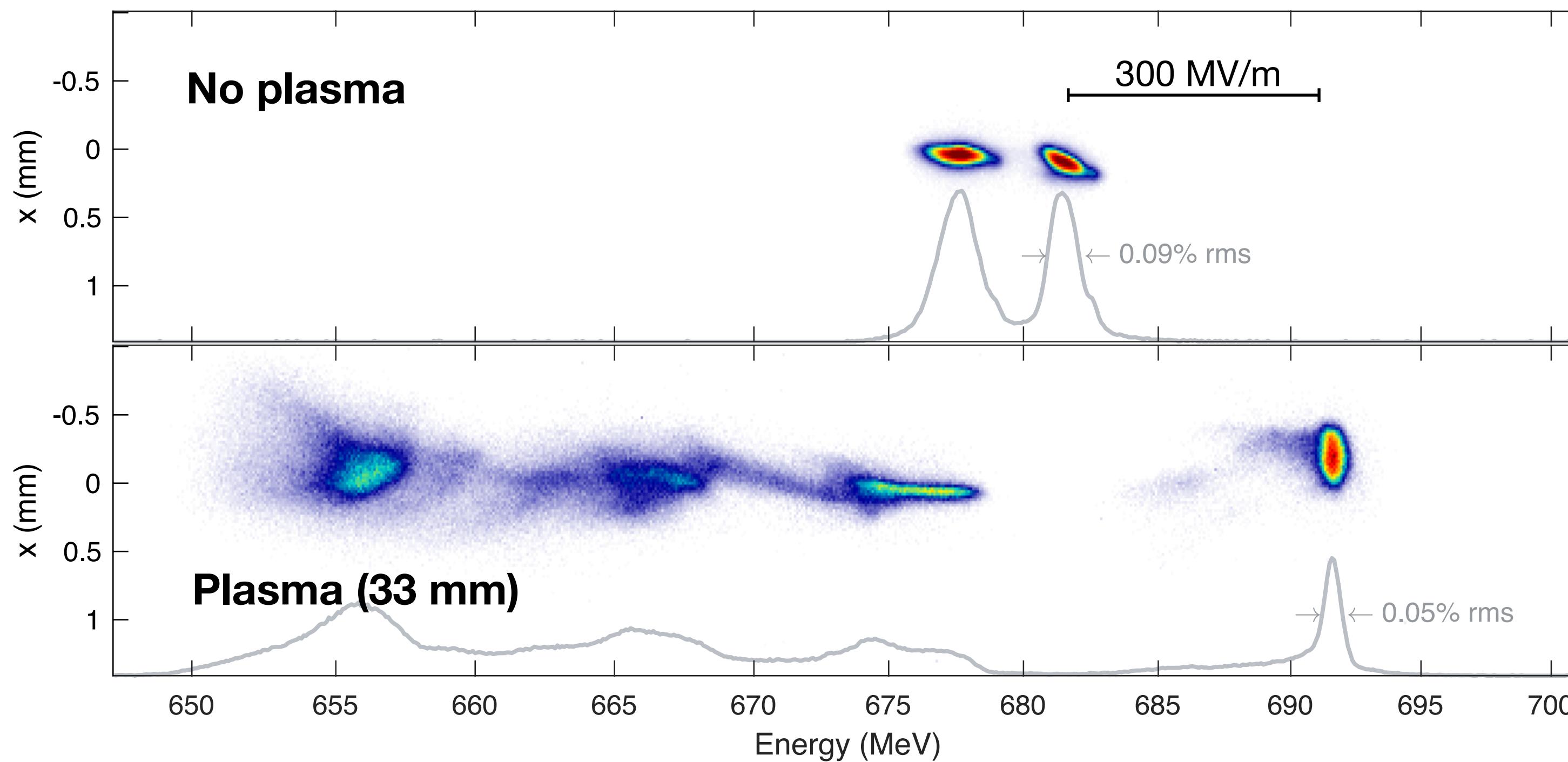
Stable high gradient acceleration



- High shot-to-shot stability demonstrated at 1.6 GV/m

Optimised beamloading - tunability is key

- ▶ Fine multi-dimensional parameter scan:
 - ▶ Plasma density
 - ▶ Driver / Witness separation position



1. Precision tunability of driver - witness bunch pair
2. High beam and plasma stability



Energy spread preservation

Wakefield measurements so far

Available techniques

- ▶ Spectral interferometry
- ▶ Shadowgraphy

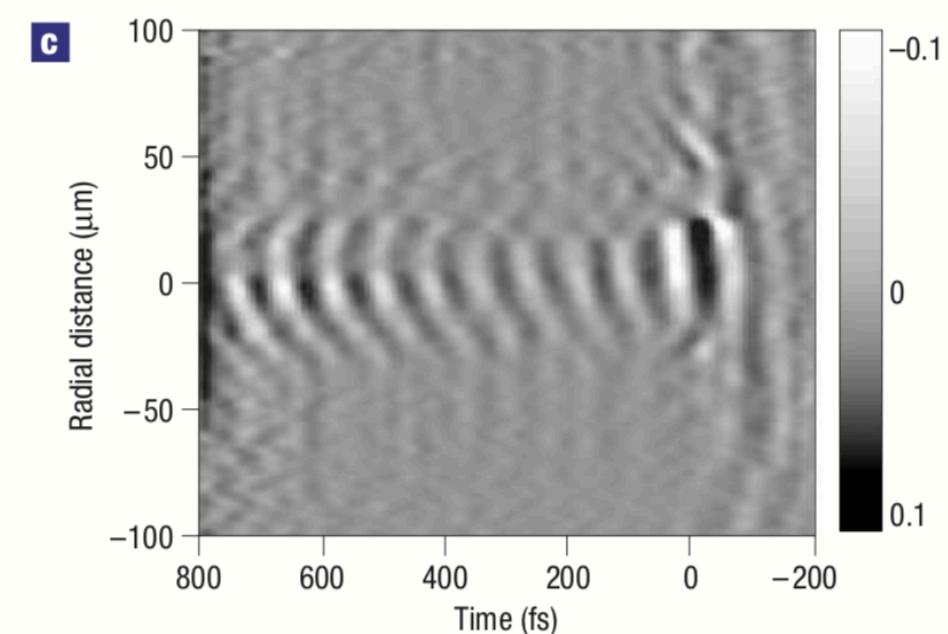


Wakefield measurements

Wake visualisation

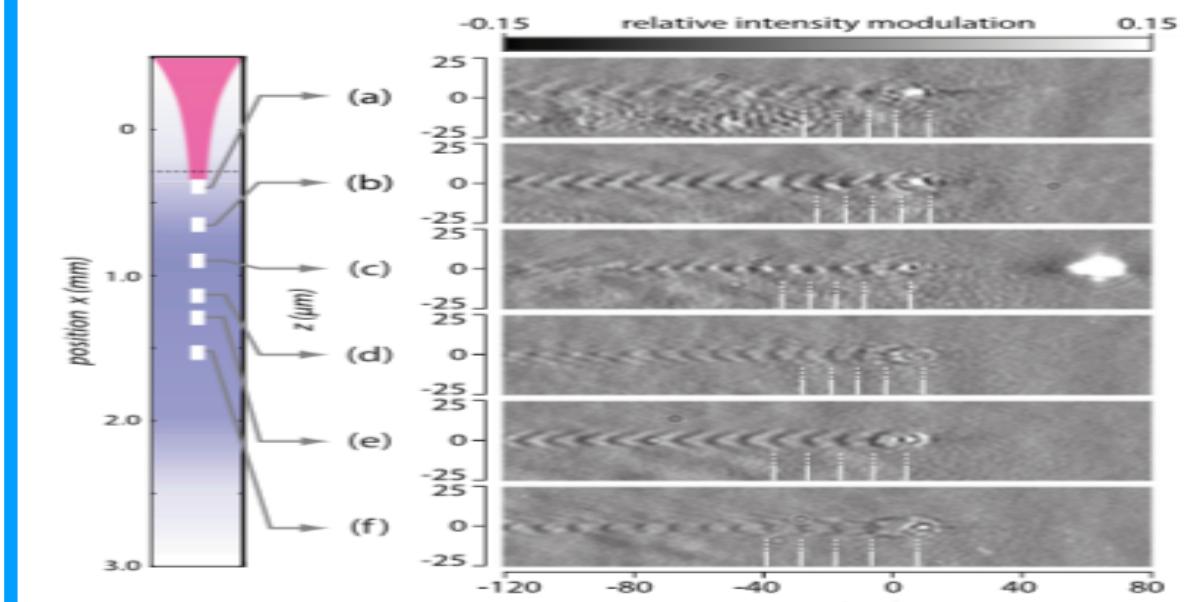
N. H. Matlis et al., Nat. Phys., 2006.

(LWFA, $n_p = 10^{19} \text{ cm}^{-3}$)



A. Sävert et al., PRL, 2015.

(LWFA, $n_p = 10^{19} \text{ cm}^{-3}$)



- ▶ Self-mapping
- ▶ Transverse electron probe

Wakefield measurements

C. J. Zhang et al., PRL, 2017.

(LWFA, $n_p > 10^{17} \text{ cm}^{-3}$)

P. Muggli et al., PRL, 2004.

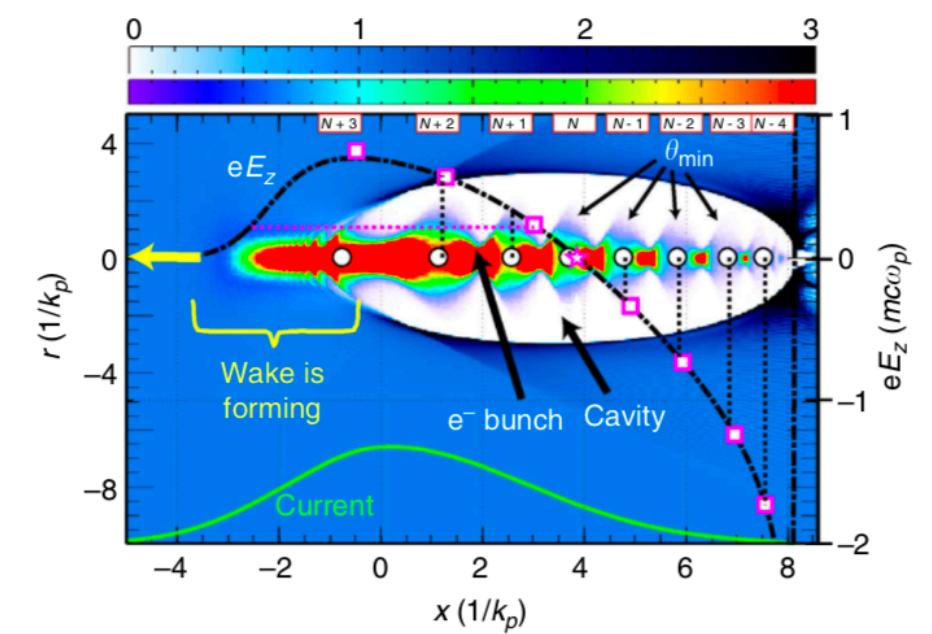
(PWFA, $n_p = 10^{14} \text{ cm}^{-3}$)

M. Gross, PRL, 2018.

(PWFA, $n_p = 10^{14} \text{ cm}^{-3}$)

C.E. Clayton et al., Nat. Comm., 2016.

(PWFA, $n_p = 10^{17} \text{ cm}^{-3}$)



Contributing a direct wakefield measurement

The following slides, which showed our concept of the wakefield measurement and the results, unfortunately had to be removed.



Summary / Outlook



- ▶ FLASHForward: stable PWFA
- ▶ Generation of driver-witness pair
 - ▶ High flexibility / tunability
 - ▶ Enables acceleration optimisation
- ▶ Direct and precise PWFA wakefield measurement
- ▶ Benchmarking of PIC simulations in GV/m regime

- ▶ Beamline modifications
 - ▶ XTDs installed
 - ▶ Emittance measurement diagnostics
 - ▶ Longer plasma cell
 - ▶ Now: 50 mm / 195 mm
- ▶ Emittance preservation
 - ▶ High overall efficiency
 - ▶ Beamloading
 - ▶ Depletion

Thank you for your attention ...

... and your support



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DESY technical support (M-Division)
FLASH management & operators

