Time-Resolved Phase Space Tomography at FLASH Using a Transverse Deflecting RF-Structure

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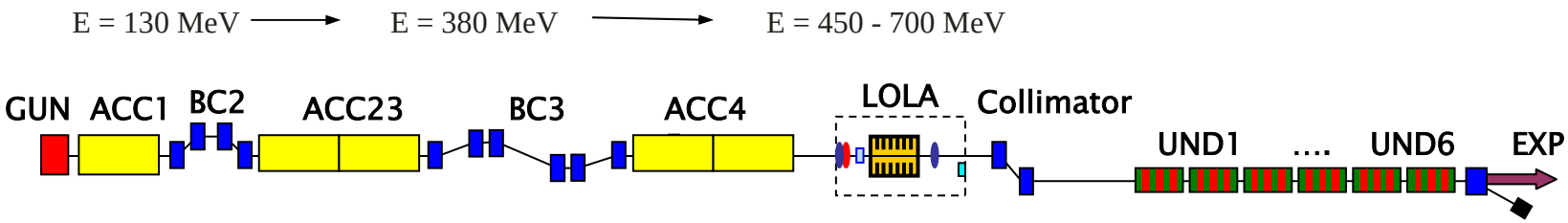
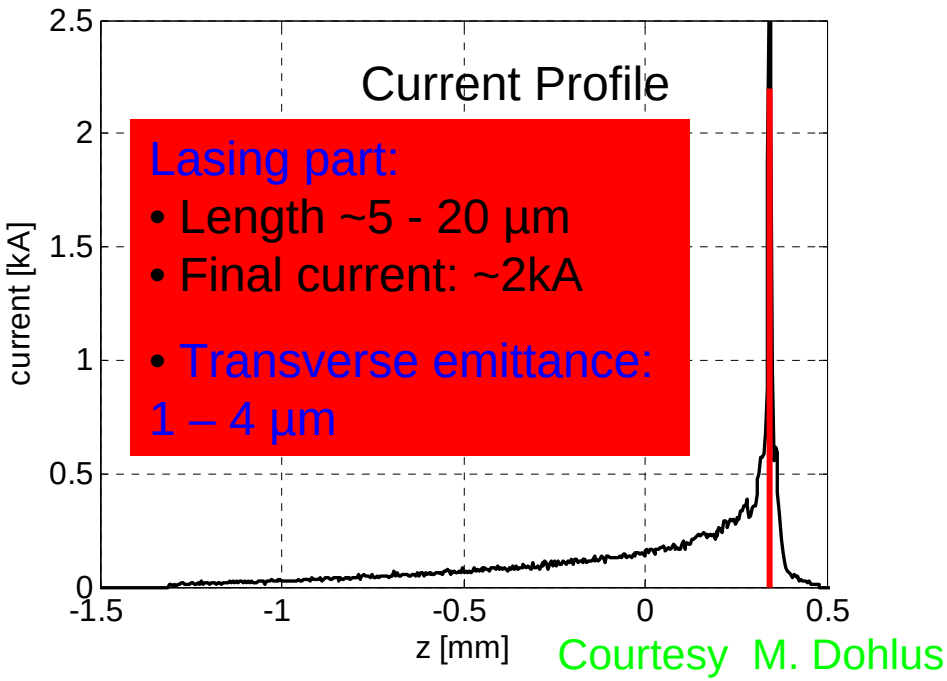
The Free-electron LASer at Hamburg (FLASH)



Important Parameters:

- Final energy 450 - 700 MeV
- Lasing tunable from 47 - 13 nm (fundamental wavelength)
- Pulse length ~ 10 – 50 fs
- Energy per pulse ~100 µJ

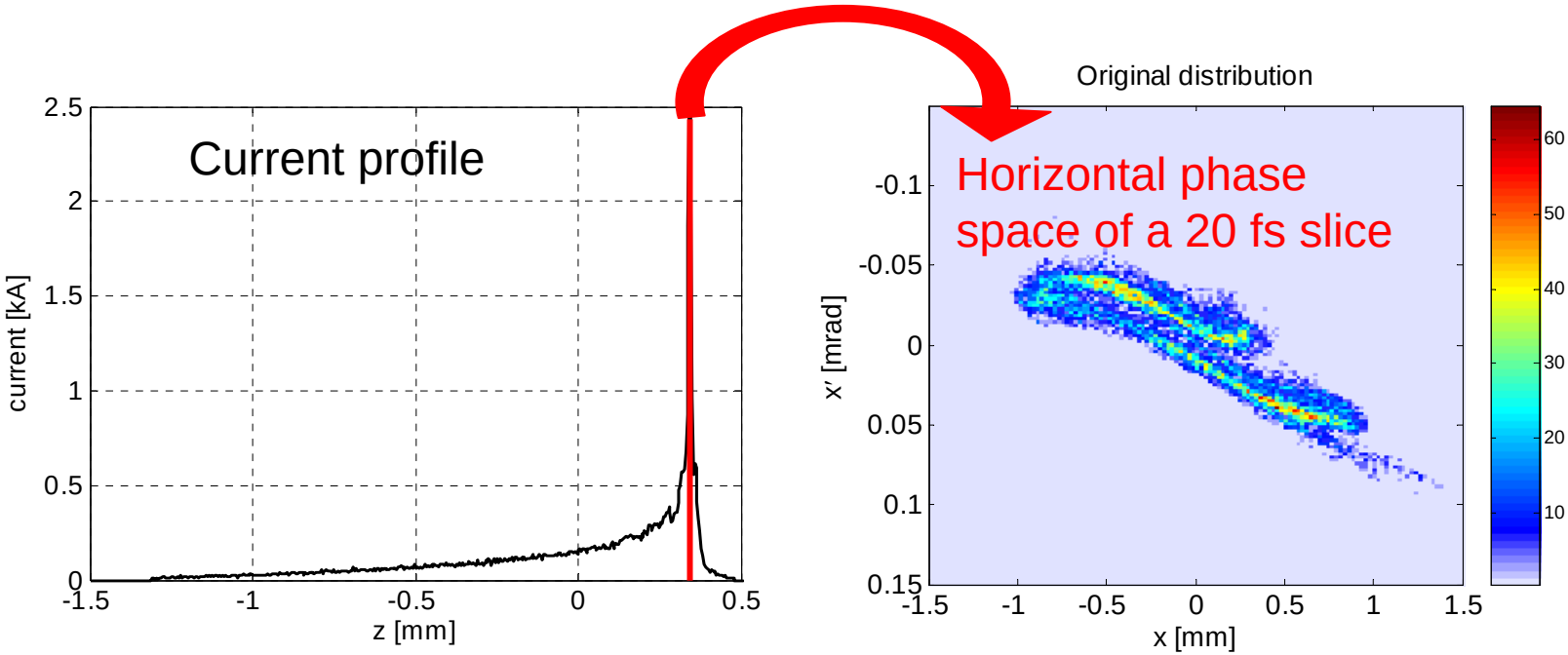


Courtesy M. Dohlus

How to measure the emittance of the lasing bunch fraction?

- Simulations: slice emittance may strongly vary along the bunch

  Time-resolved methods are needed , resolution ~< 10 fs

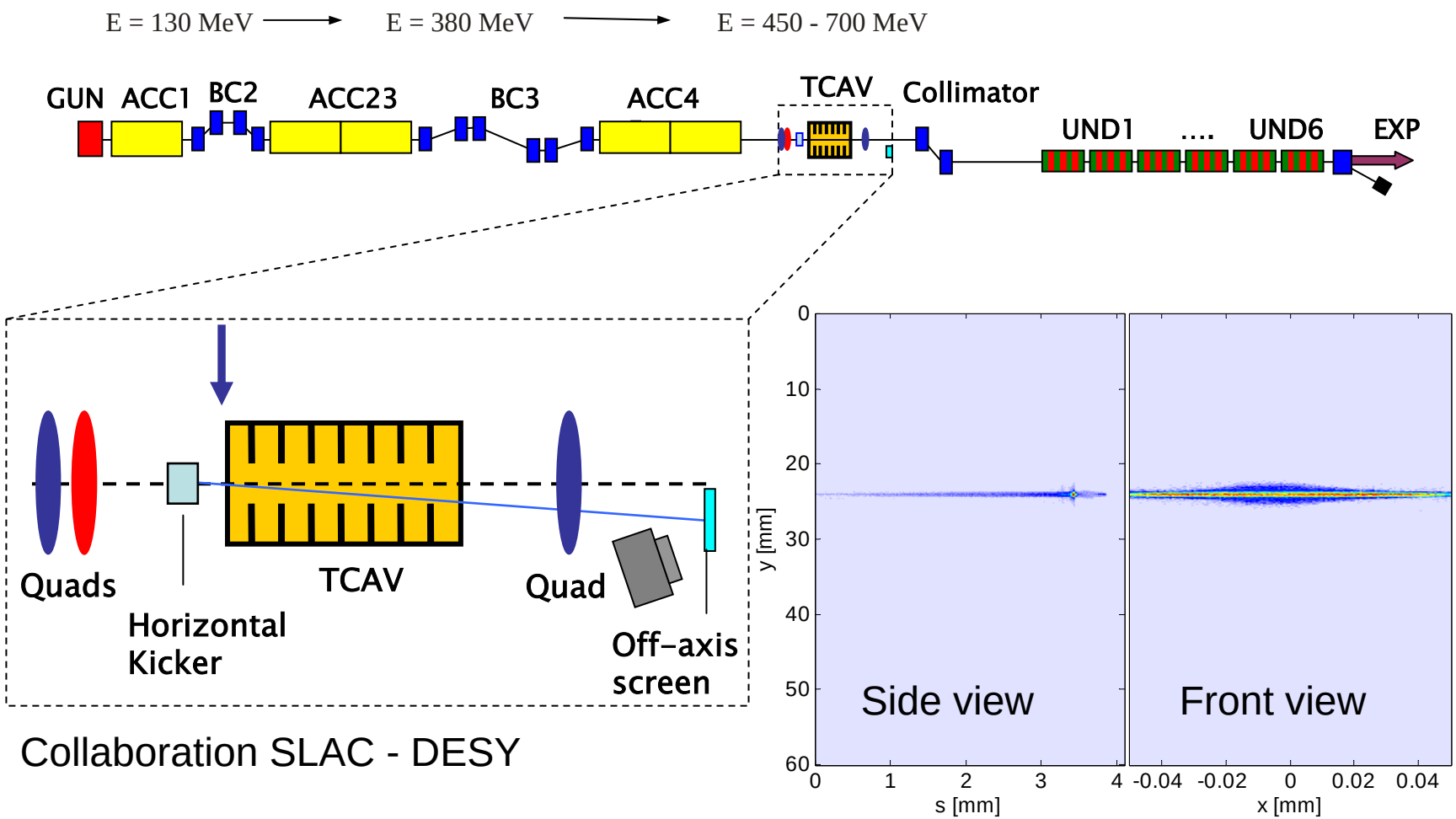


Desirable: transverse phase space distribution of longitudinal slices

Outline

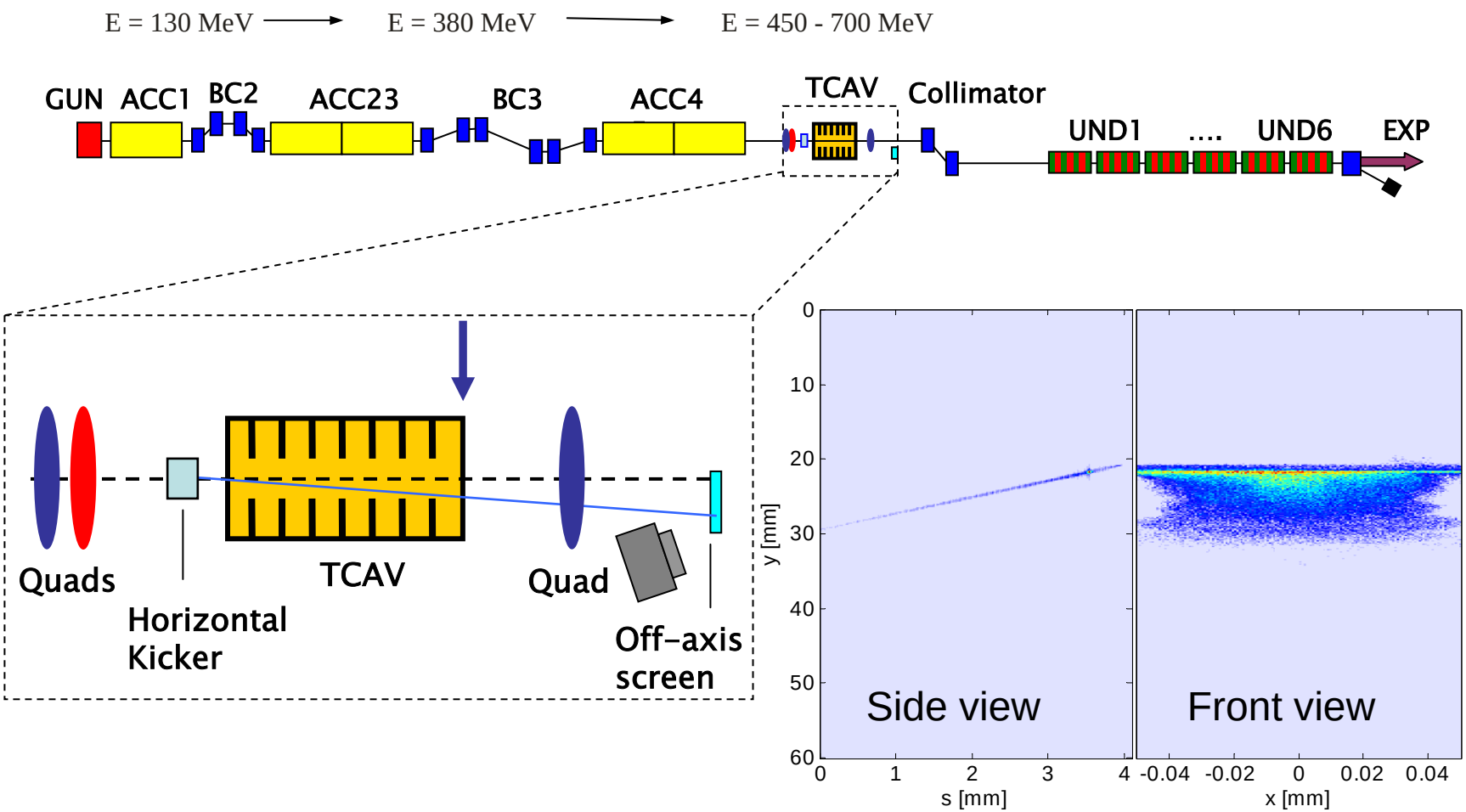
- Experimental setup
- Experimental results under lasing conditions
- Comparison with start-to-end simulations

Experimental setup

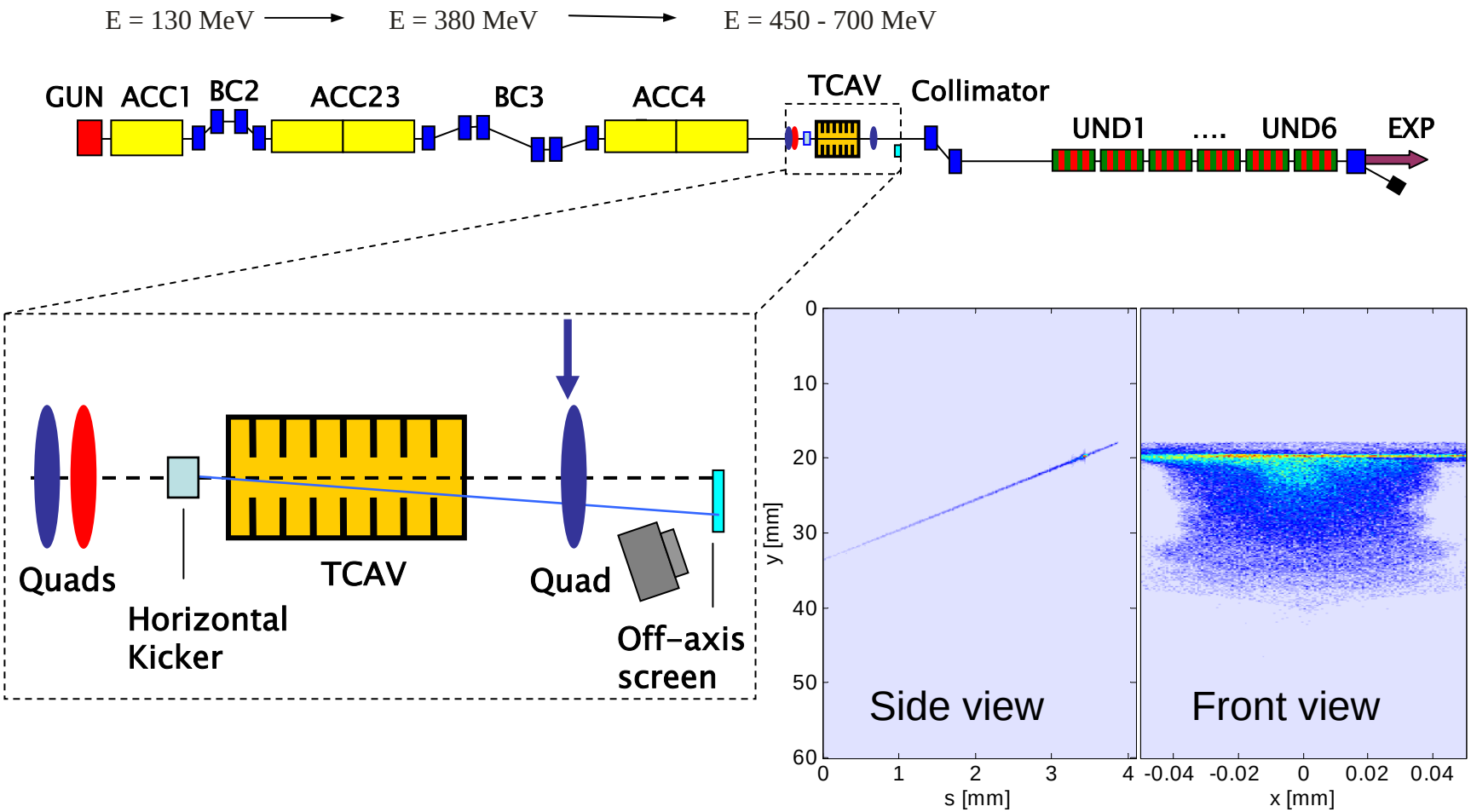


Collaboration SLAC - DESY

Experimental setup



Experimental setup



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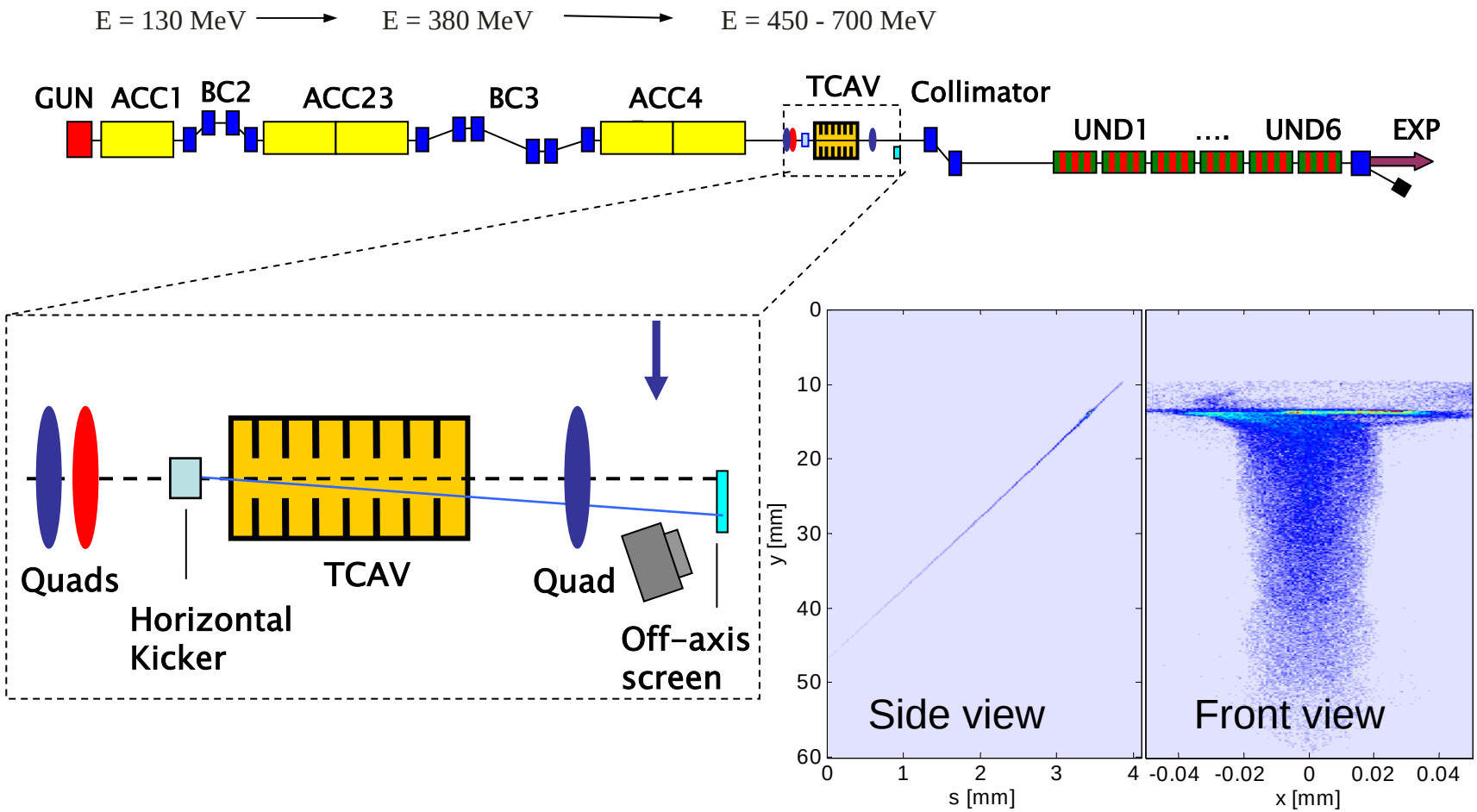

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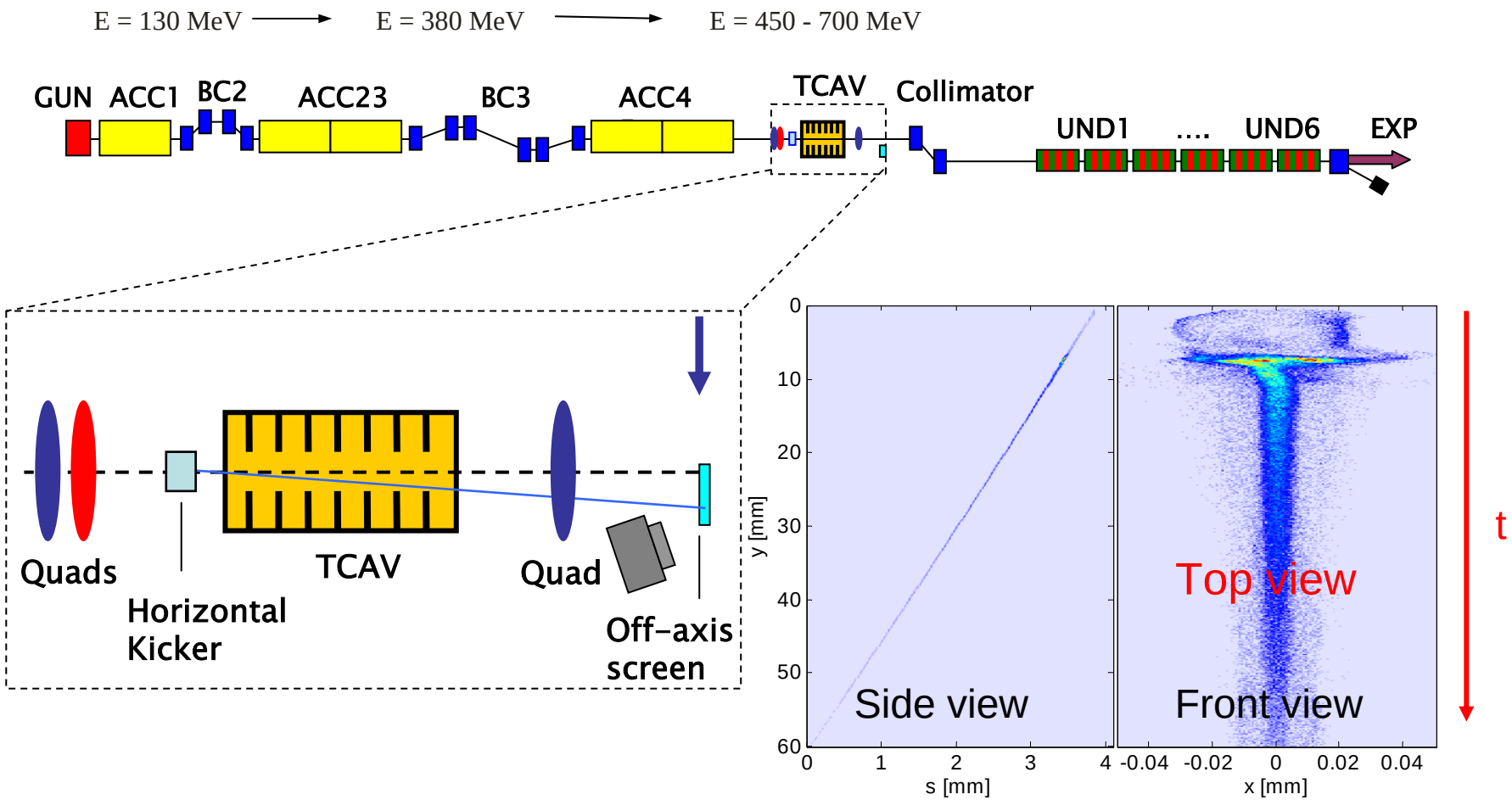


Investigations of transverse phase space

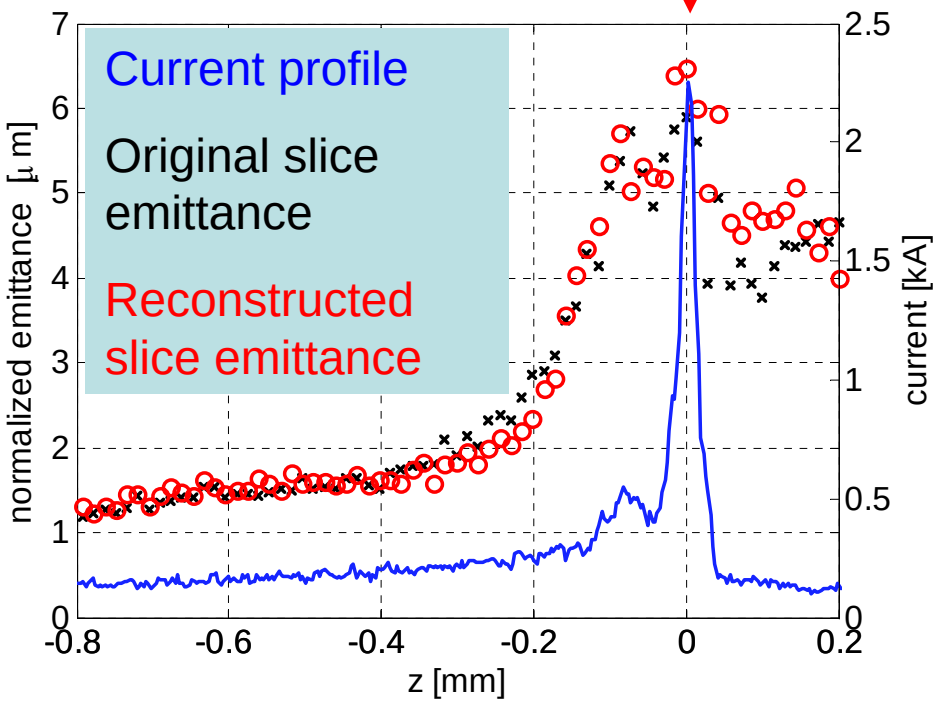
1. Measurement of the second moments of spatial projections + calculation of the emittance (RMS method)
2. Measurement of the spatial profiles + tomographic reconstruction of the phase space distribution

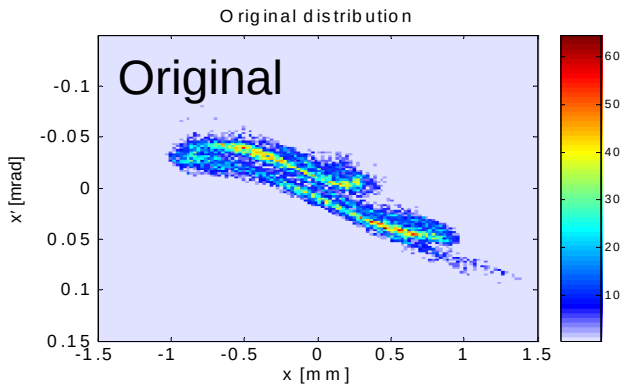
Algorithm: Maximum ENTropy (MENT)

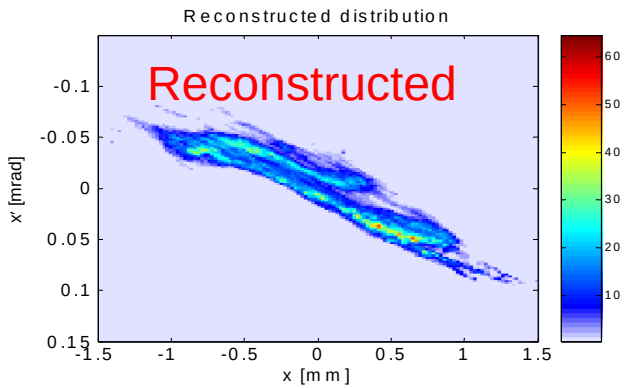
(Implementation: J. Scheins, 2004)

Simulation of a phase space reconstruction

Horizontal phase space of one slice:

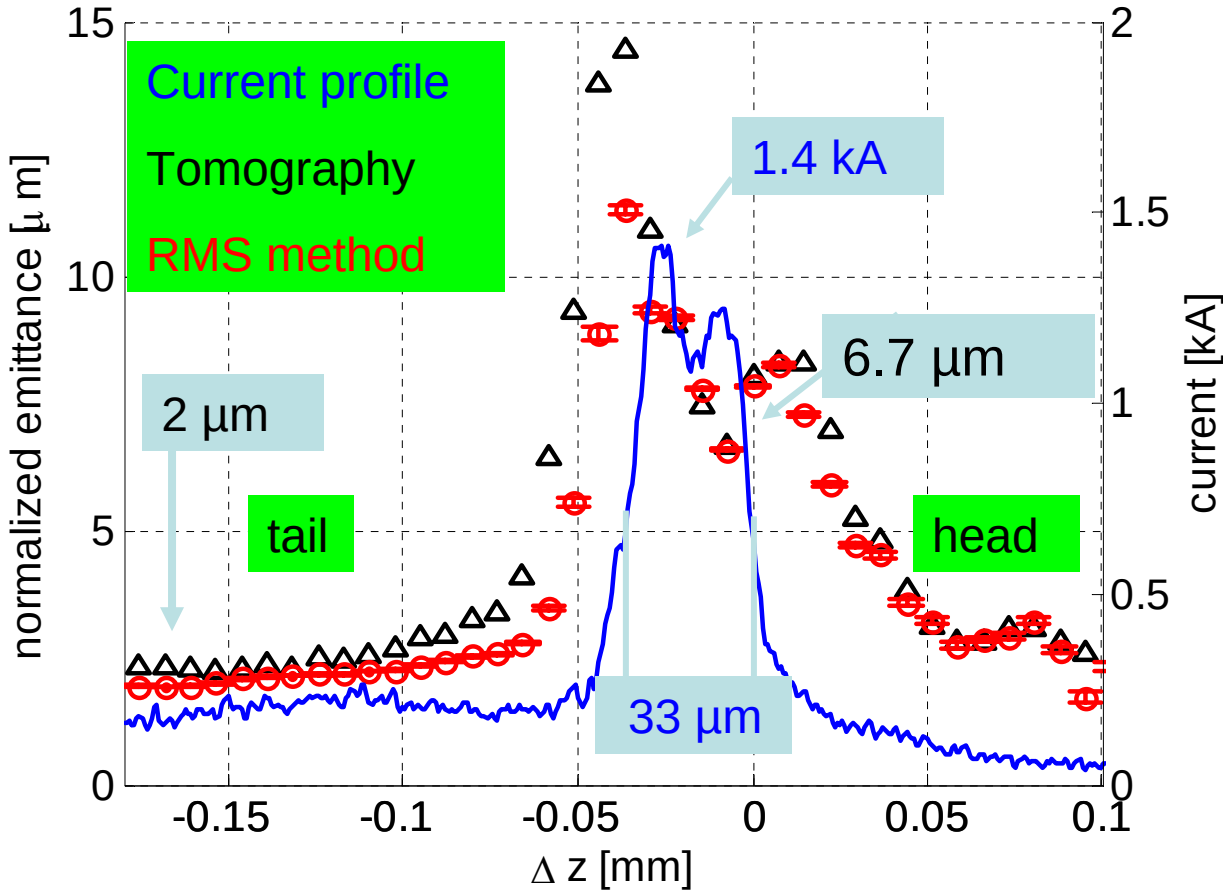






Slice width: vertical RMS bunch width times calibration factor (~10 μm)

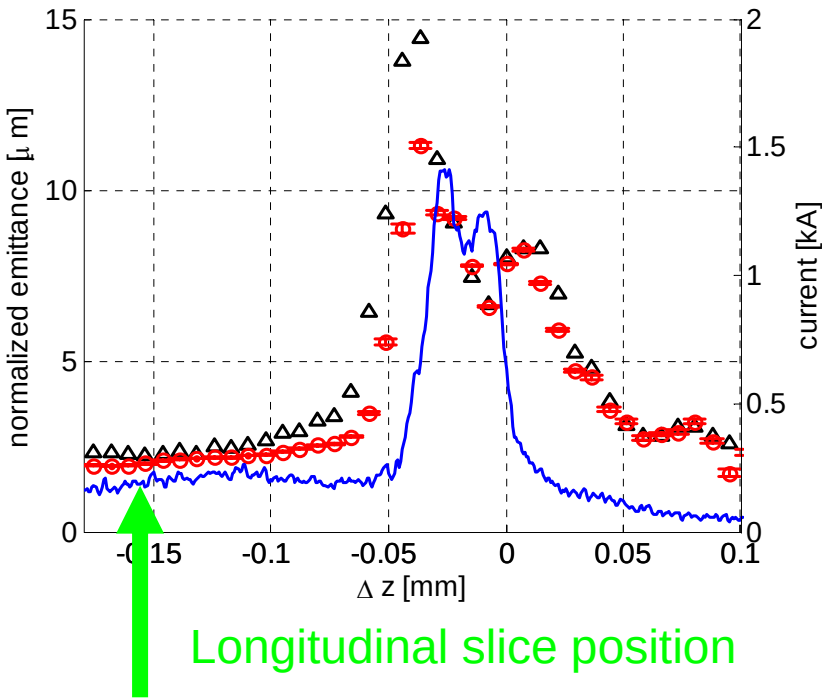
Experimental results



- E = 493 MeV, Q = 0.72 nC, λ = 30 nm, radiation energy per bunch: 5µJ
  Longitudinal resolution: 8 µm (24 fs)

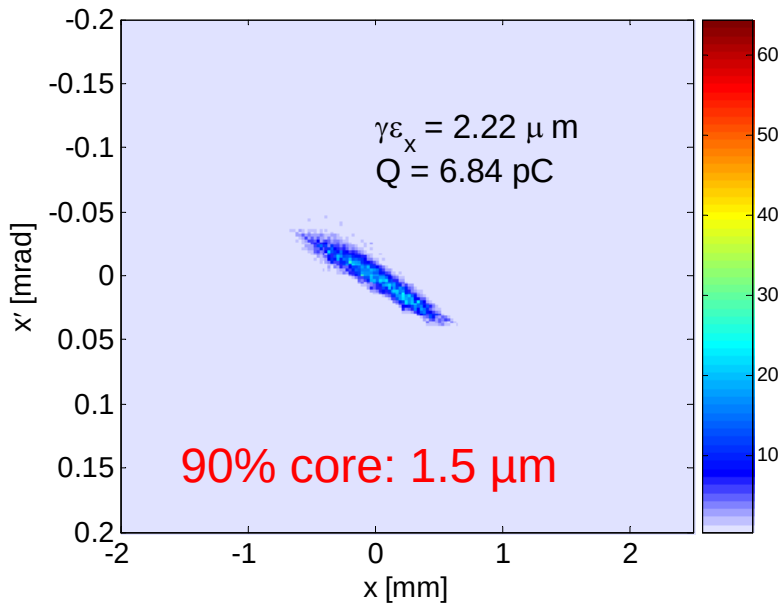
Measured distributions of time slices in horizontal phase space

Slice emittance and current:



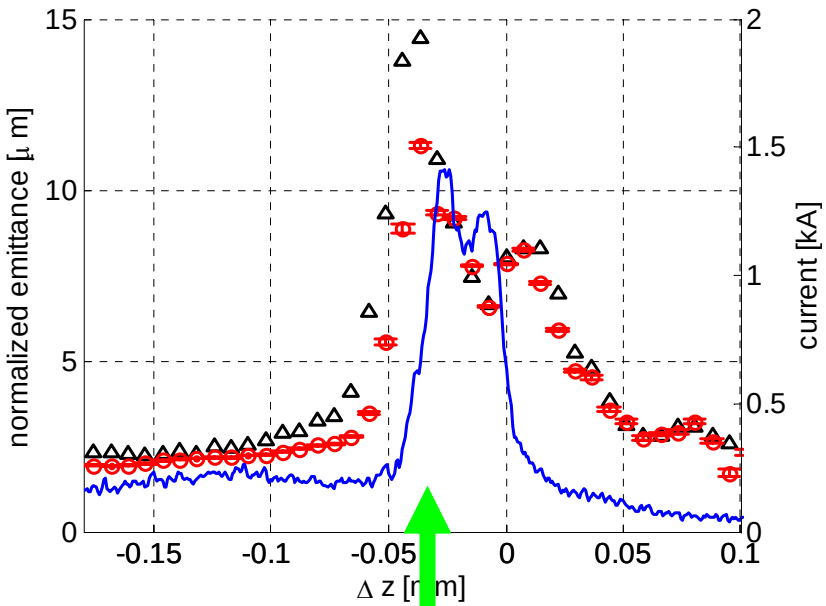
Longitudinal slice position

Horizontal phase space (selected slice) :



Measured distributions of time slices in horizontal phase space

Slice emittance and current:



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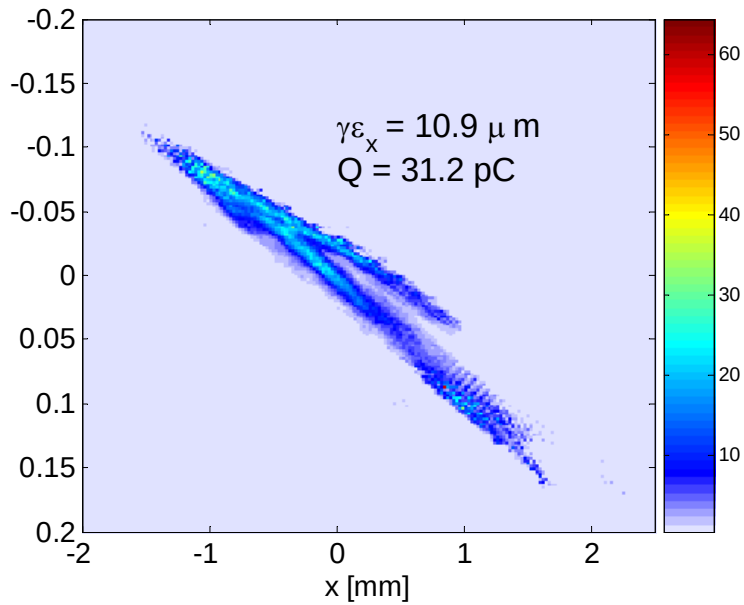

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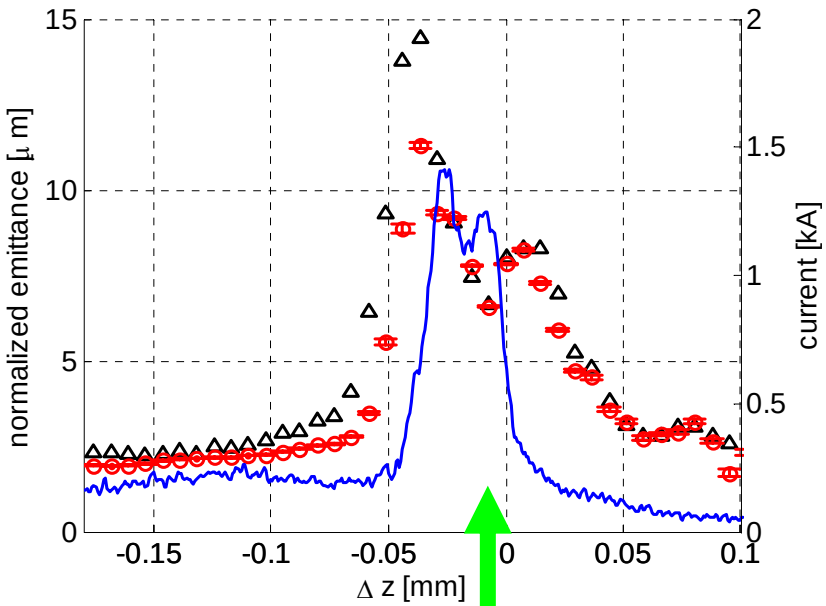
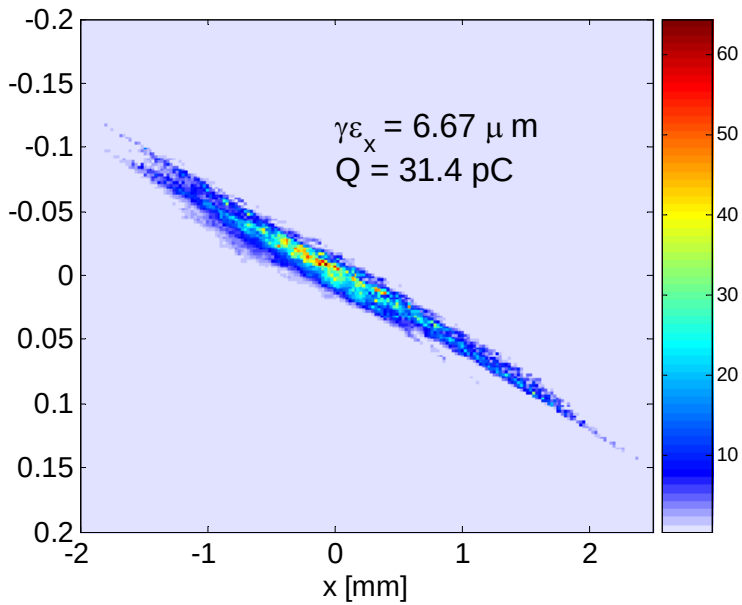
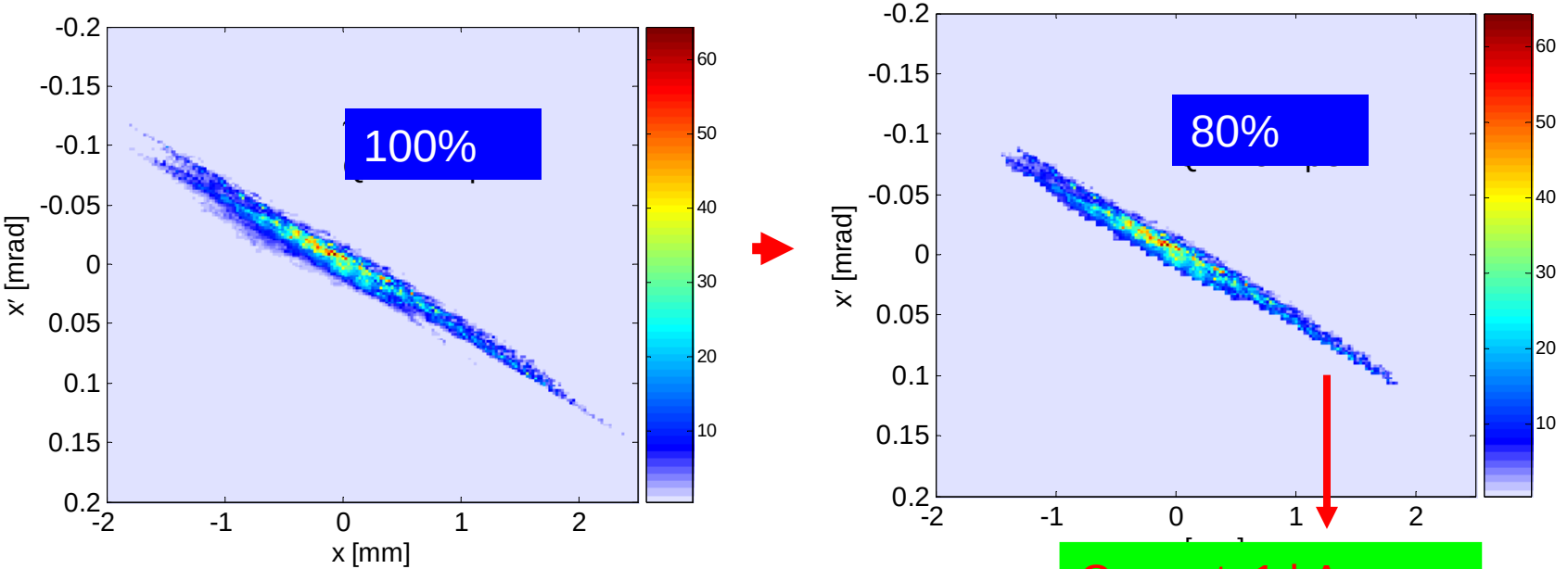


Horizontal phase space (selected slice) :



Longitudinal slice position

Emittance of the high density core



Beam fraction [%]	100	90	80	70	60
Current [kA]	1.3	1.2	1.0	0.9	0.8
Normalized emittance [µm]	6.7	4.1	3.3	2.5	2.0

Current: 1 kA

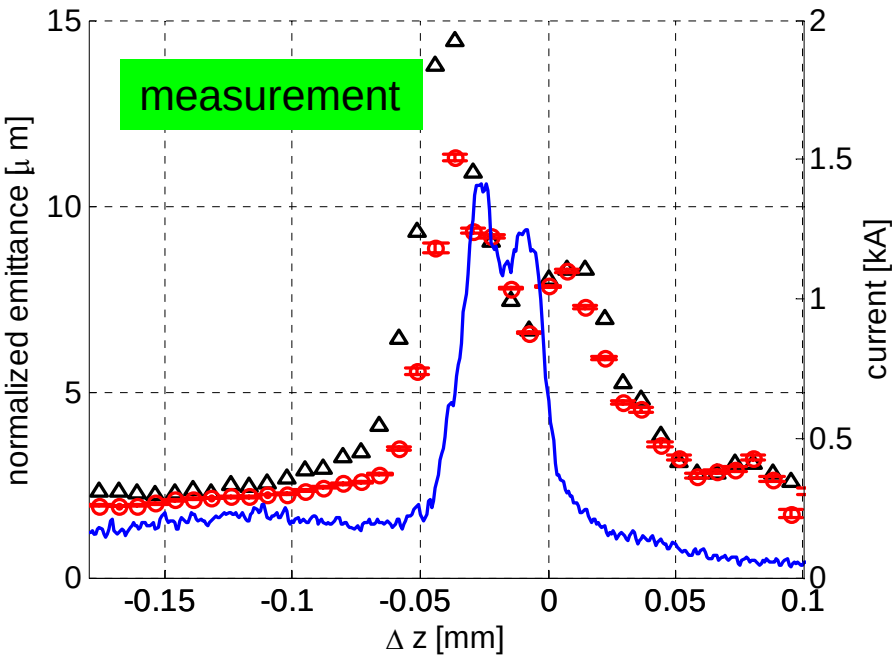
Emittance: 3.3 µm

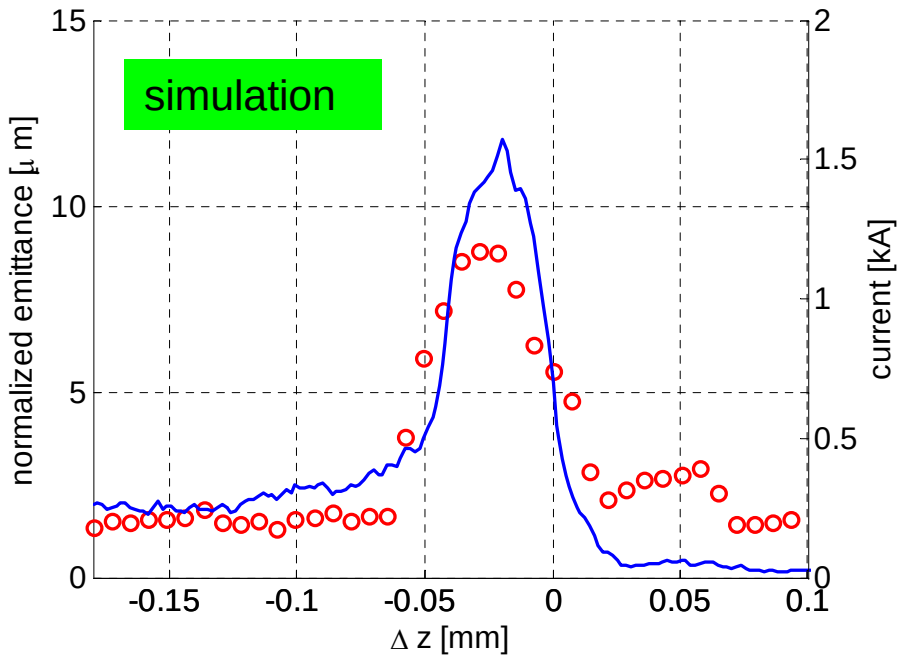
Expectation at this position:

Current: 1 - 1.5 kA
Emittance: 1 – 4 µm

Comparison with start-to-end simulations

- Phases in accelerating modules measured only up to ~1˚ (desirable: ~0.1˚)
- Comparison of simulated and measured current profile allows to fix the phases within ~0.2˚





Codes : ASTRA (K. Flöttmann) + CSR-track (M. Dohlus)

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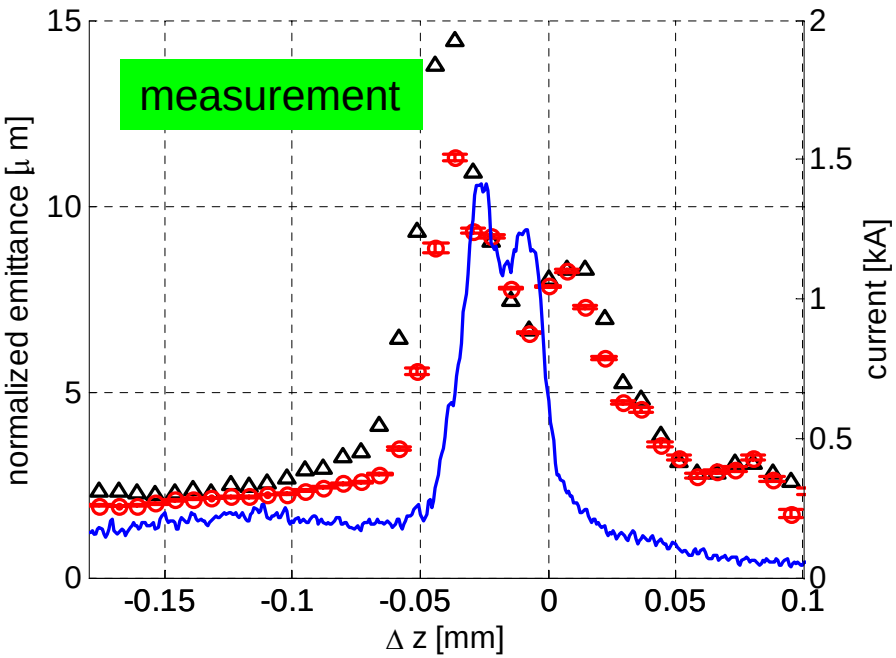

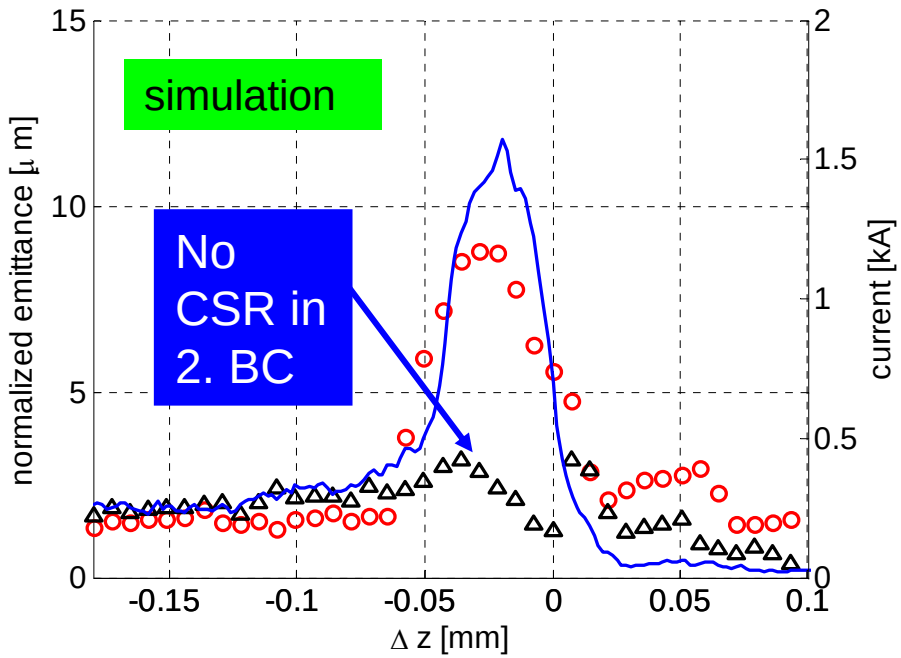

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Conclusions

- Measured parameters of a bunch fraction under lasing conditions at 500 MeV: ~1kA current and ~3 µm horizontal emittance
- A tomographic reconstruction appears to be necessary to analyse the beam under lasing conditions
- The results can partly be reproduced in simulations

Thanks to

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