Investigation of the Longitudinal Electron Bunch Structure at FLASH with a Transverse Deflecting RF-Structure

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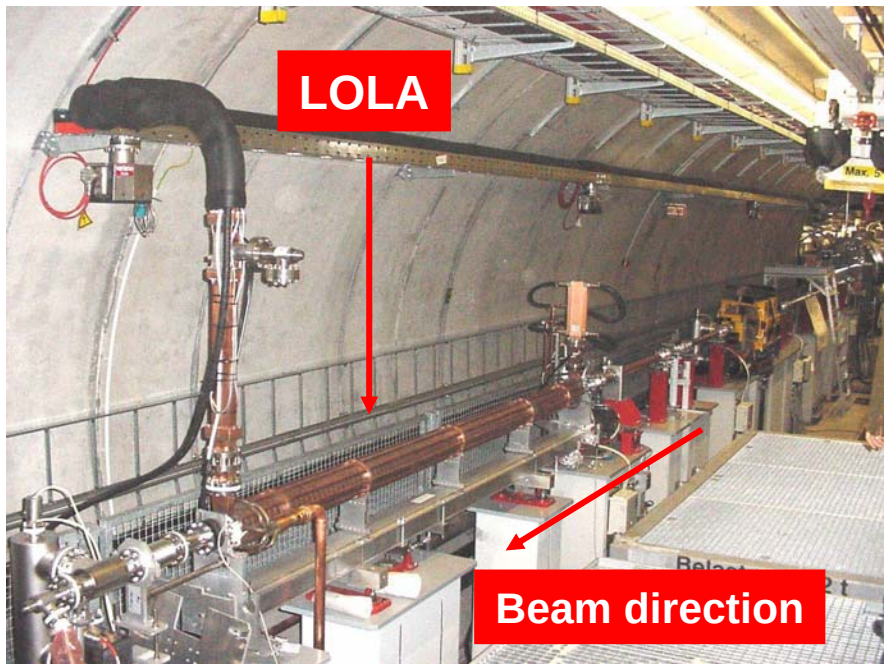
Outline

- Description of the transverse deflecting rf-structure LOLA at FLASH
- Results of measurements for two different accelerator settings:
  - without longitudinal compression (on-crest operation of all accelerating modules)
  - for SASE operation
- Conclusions

LOLA at FLASH

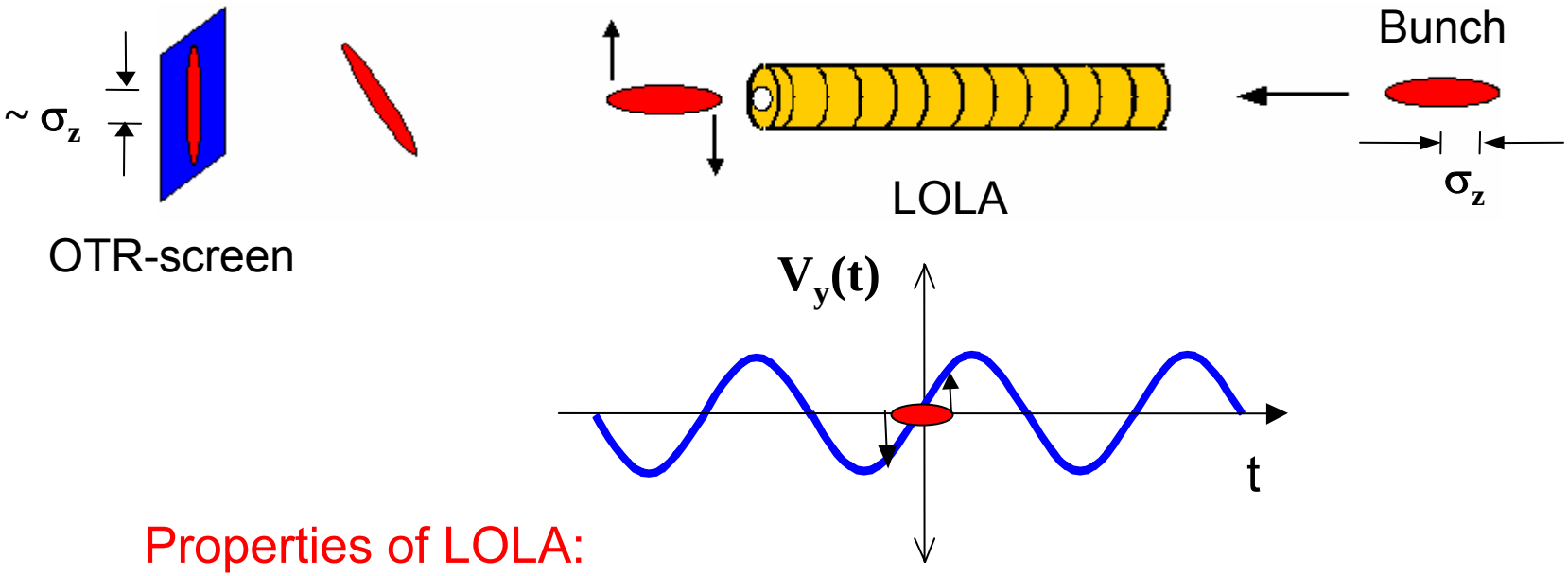
- Originally used as an rf separator for secondary particles (1968)
- Named after its designers G. LOew, R. Larsen, O. Altenmueller
- Already used for beam diagnostics at SLAC (SPPS)
- Installation at DESY in 2003 in cooperation with SLAC, in operation since 2005

LOLA at FLASH:



Courtesy: M. Nagl

Transverse deflecting structures



Properties of LOLA:

Length: 3.64 m ; Nominal operating frequency: 2856 MHz

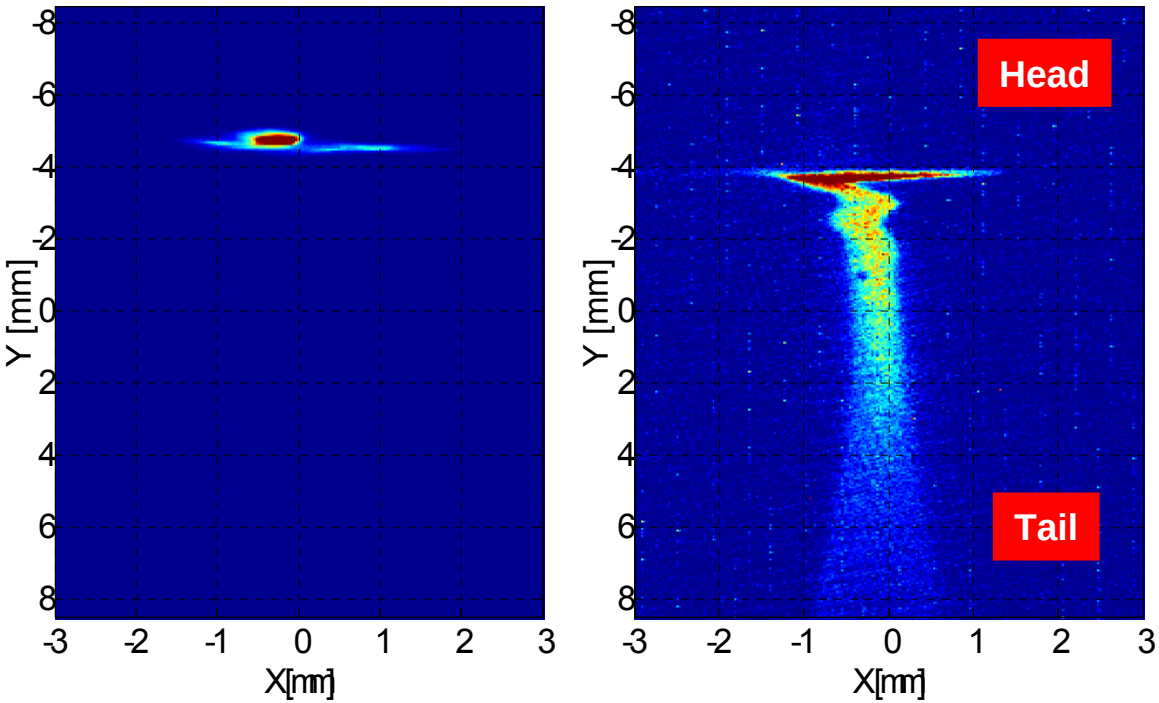
Filling time: 0.645 μs ; Nominal deflecting voltage: 26 MV

Mode type: TM 11 (Hybrid Mode)

Examples for bunch images

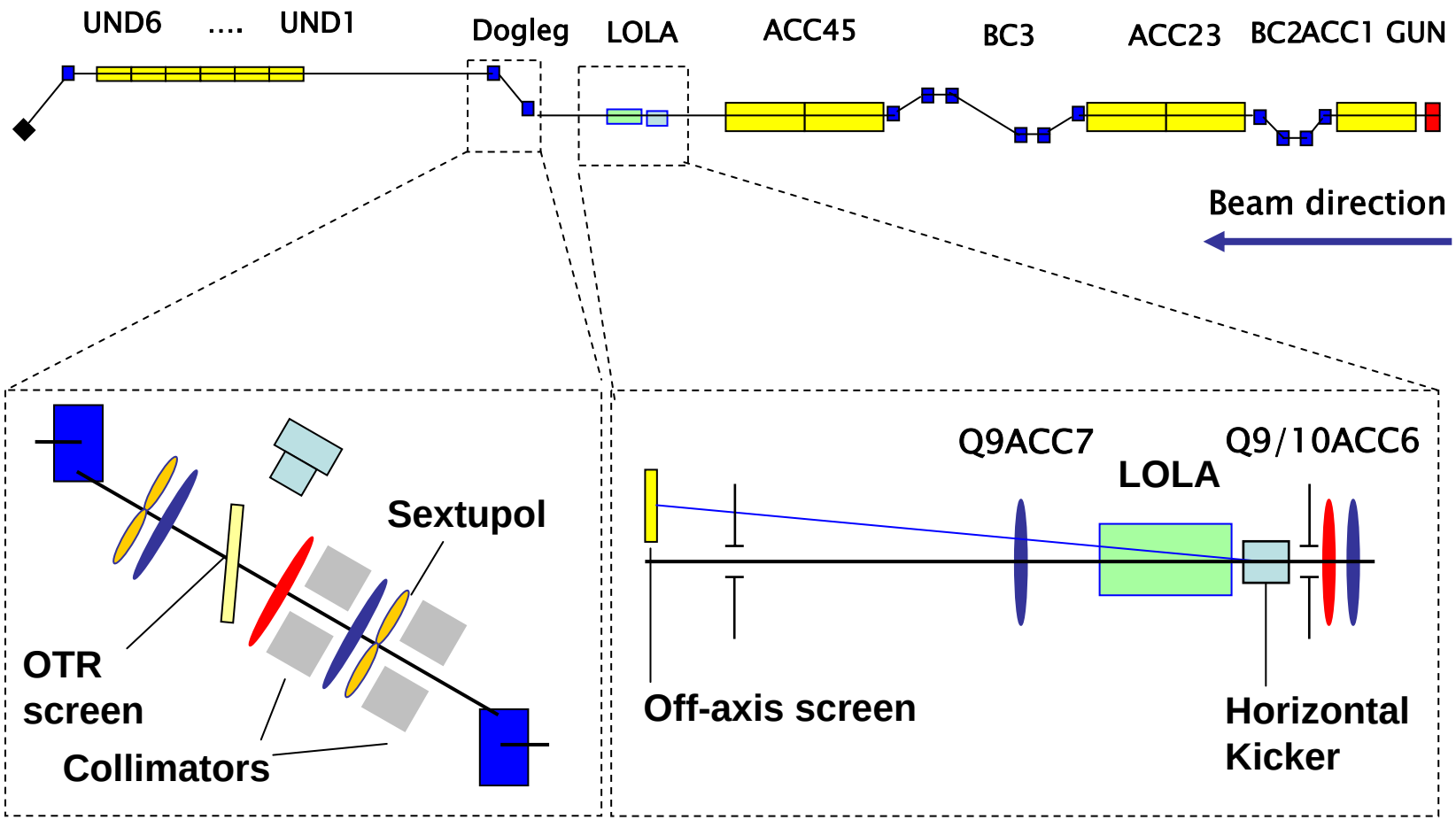
LOLA off:

LOLA on:

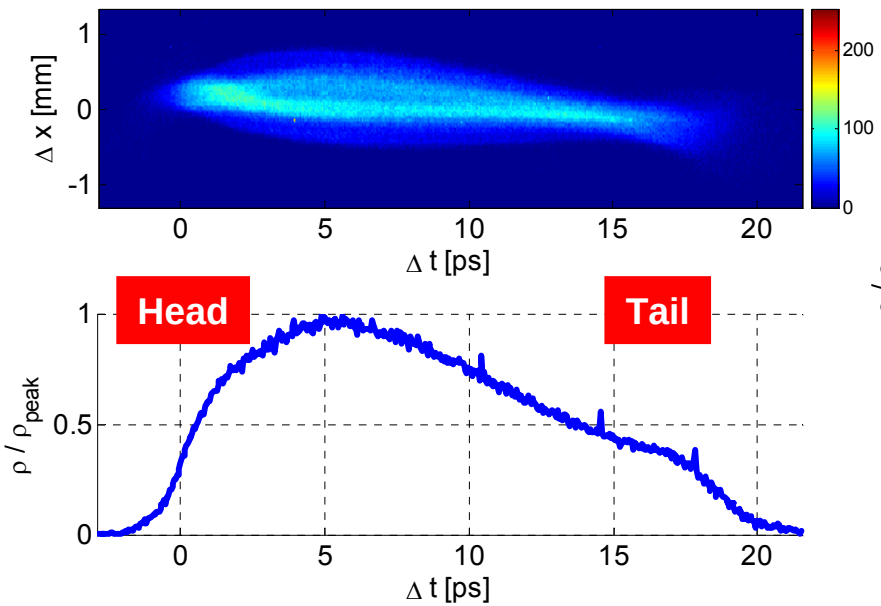


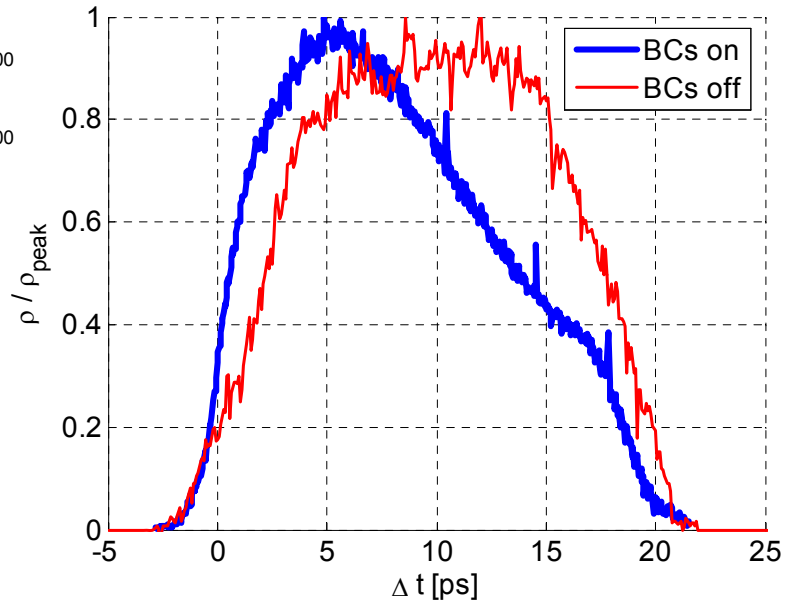
- Typical streak strength: 3.5 mm / ps
- Time resolution: vertical rms beam size (LOLA off) / streak

Integration into the FLASH Linac



On-crest operation: Longitudinal density profile

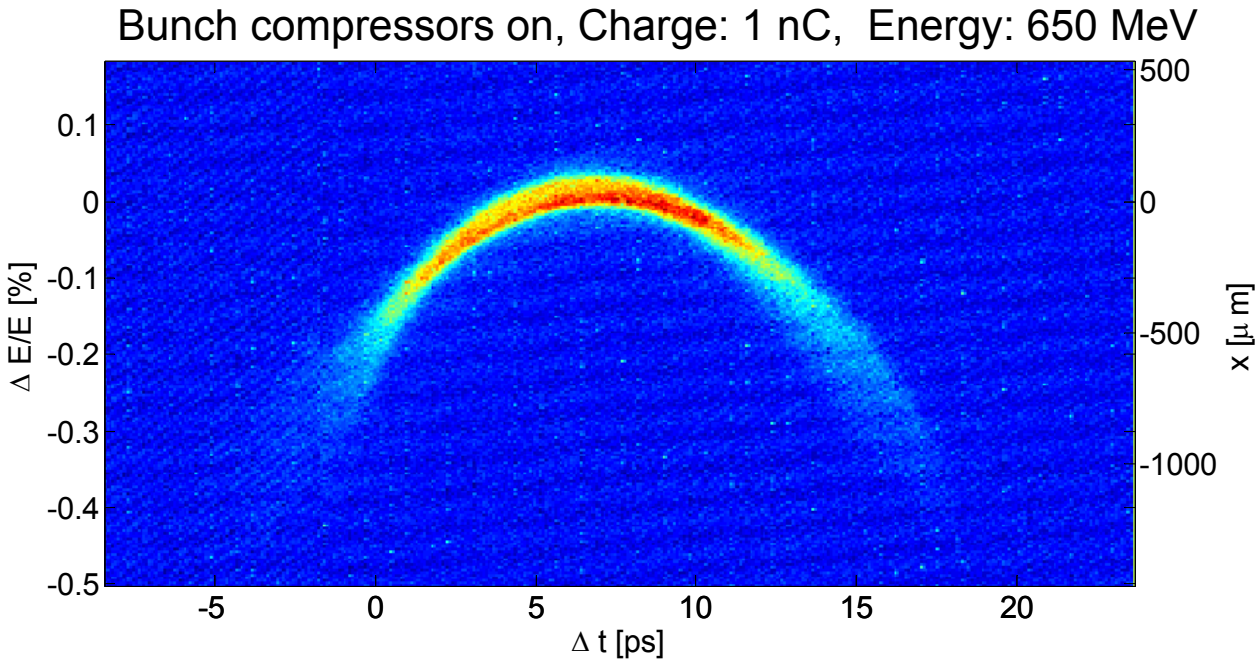




rms-lengths: 3.8 ps (BCs on) 4.8 ps (BCs off)

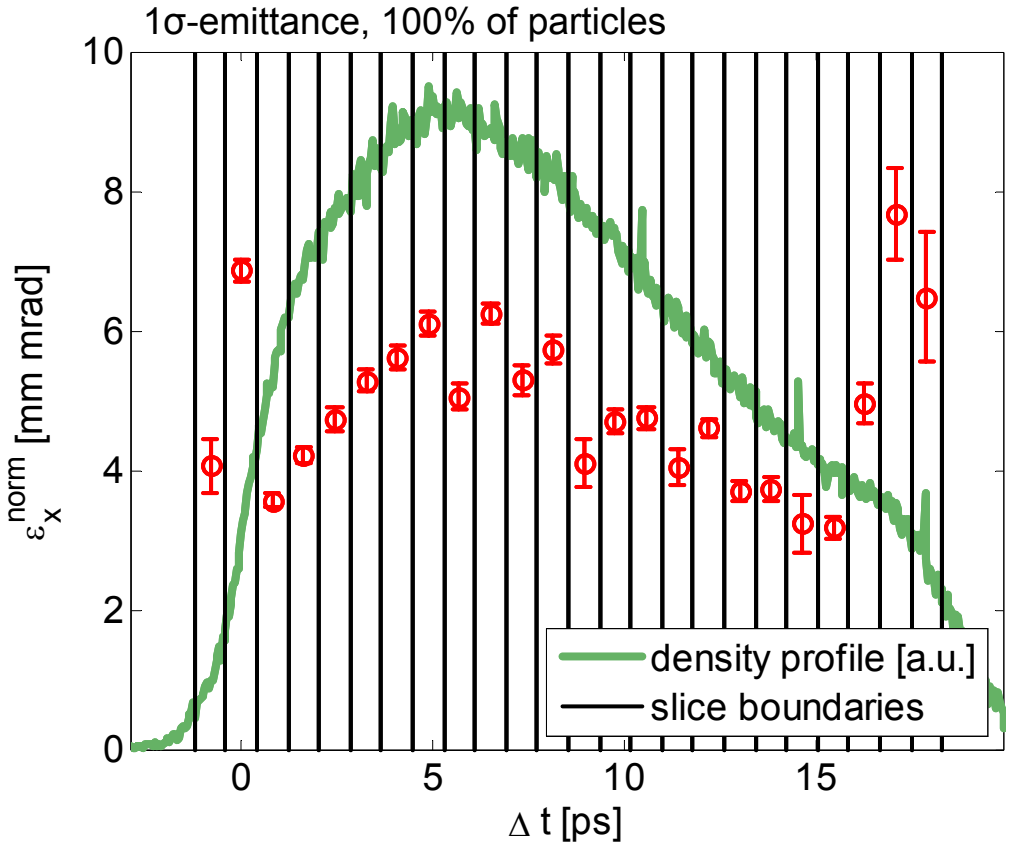
Charge: 1 nC, Energy: 650 MeV

On-crest operation: Longitudinal phase space



- Dispersion at the screen: 290 mm
- Total rms energy spread: 0.09% (585 keV)
- rms slice spread < 0.02% (130 keV)

On-crest operation: Slice emittance

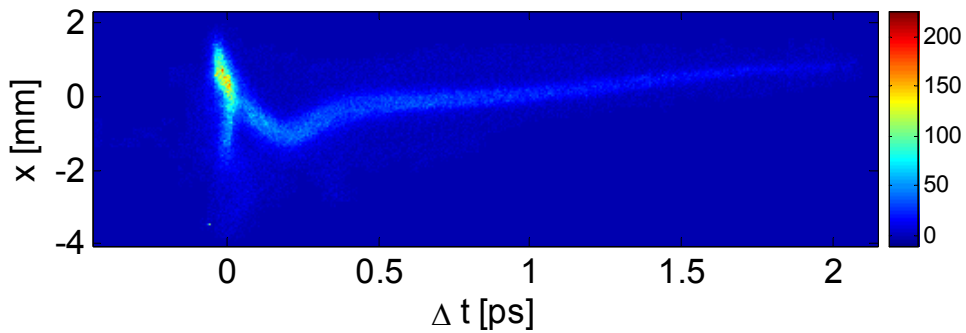


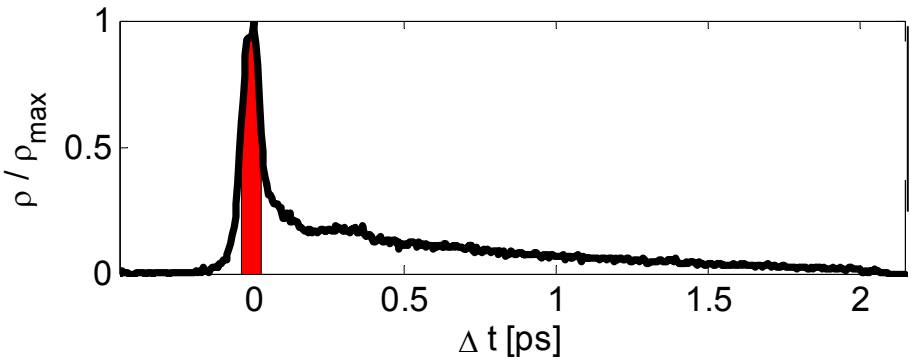
- Systematic rms error of absolute values ~ 30% due to quadrupole gradient end energy errors.
  But: ratios not affected!

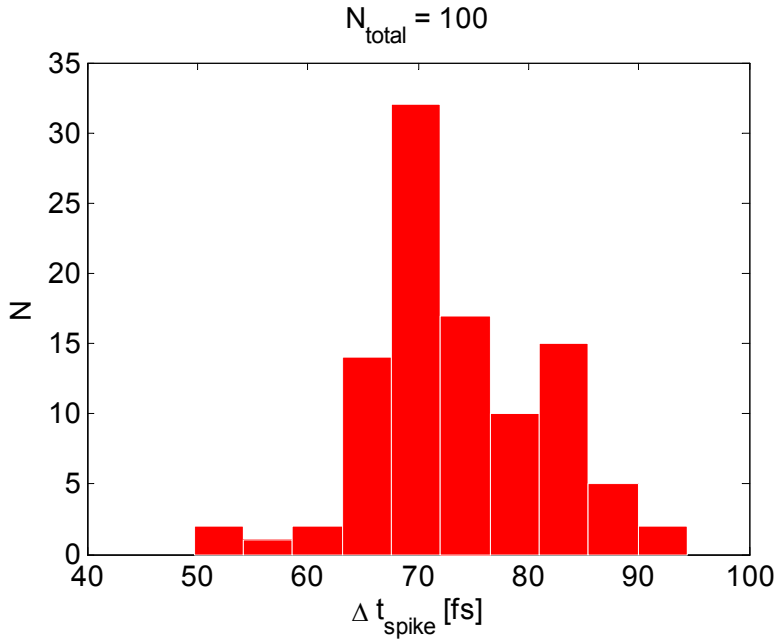
- Projected emittance upstream of BC3:
  4.3 mm mrad

Bunch compressors on, Charge: 1 nC, Energy: 650 MeV

SASE at 13.7 nm (5µJ): Longitudinal profile







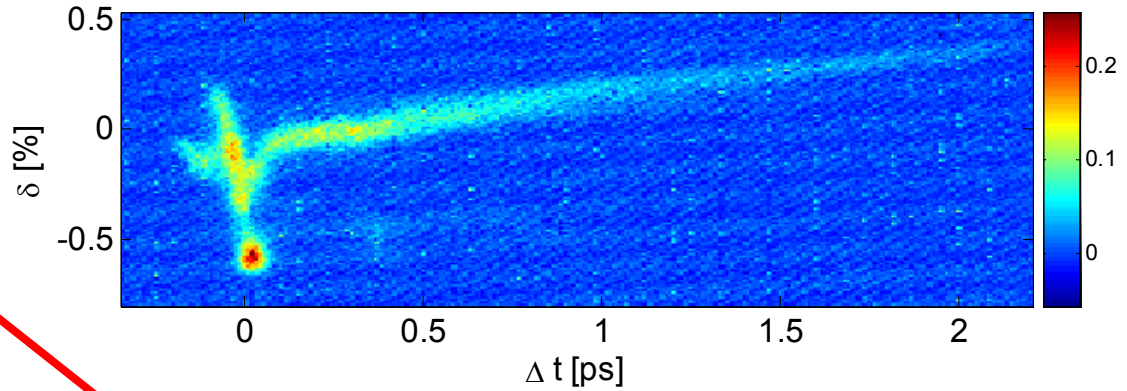
Spike width: ~70 fs (FWHM)
Resolution: ~20 fs
Charge in spike: ~0.12 nC (23%)
Peak current: ~1.7 kA

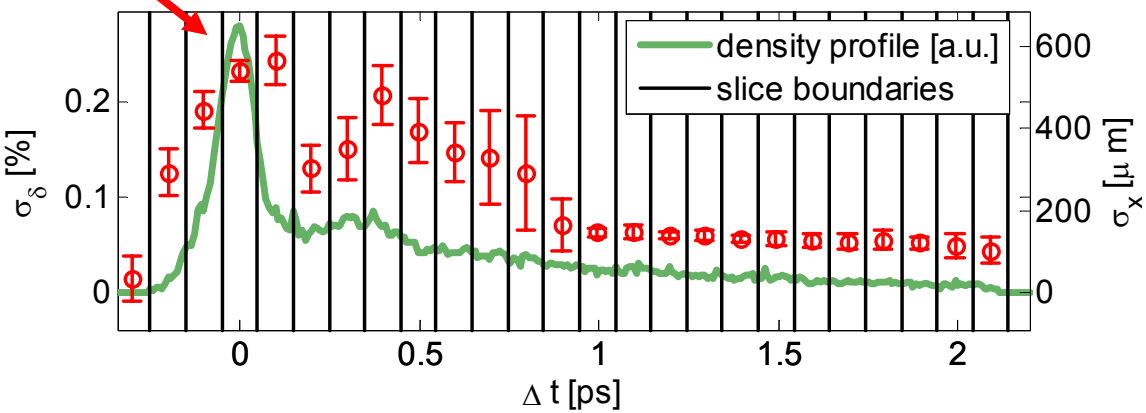
Parameter:
Charge: 0.5 nC
Energy: 677 MeV
ACC1-phase: -9˚
ACC23-phase: -25˚
ACC45-phase: 0˚

SASE at 13.7 nm: Longitudinal phase space

- Energy spread in the spike: ~0.23% (1.6 MeV)

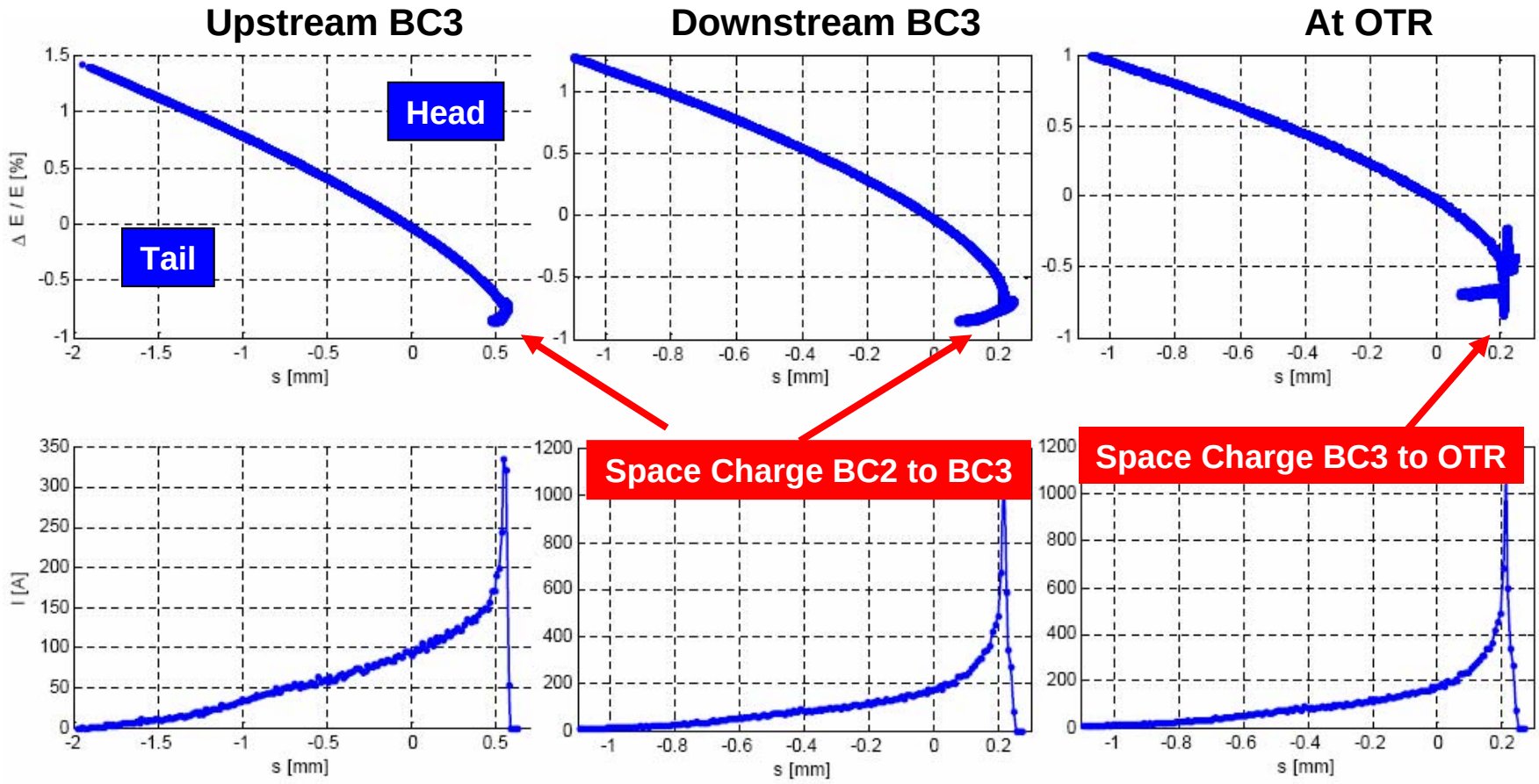
- Result for SASE operation at 31.4 nm (450 MeV): 0.4% peak energy spread, similar shape of energy-time correlation





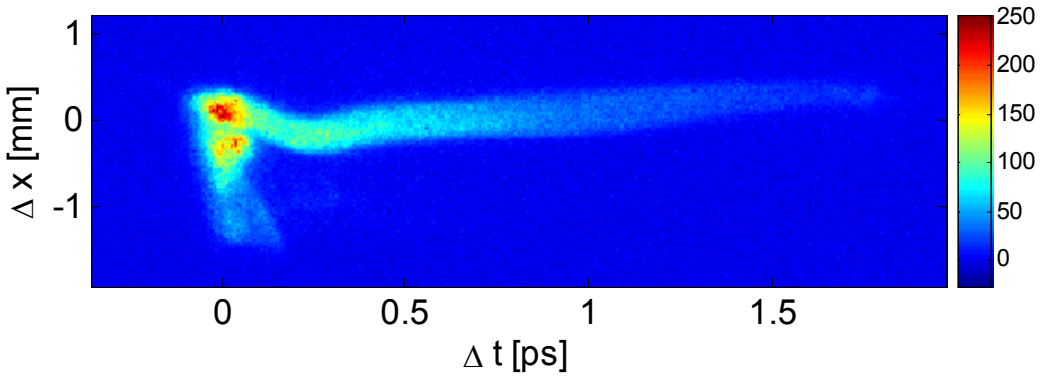
Dispersion: 233 mm; Time resolution: ~ 50 fs; Energy spread resolution: ~ 0.06% (380 keV)

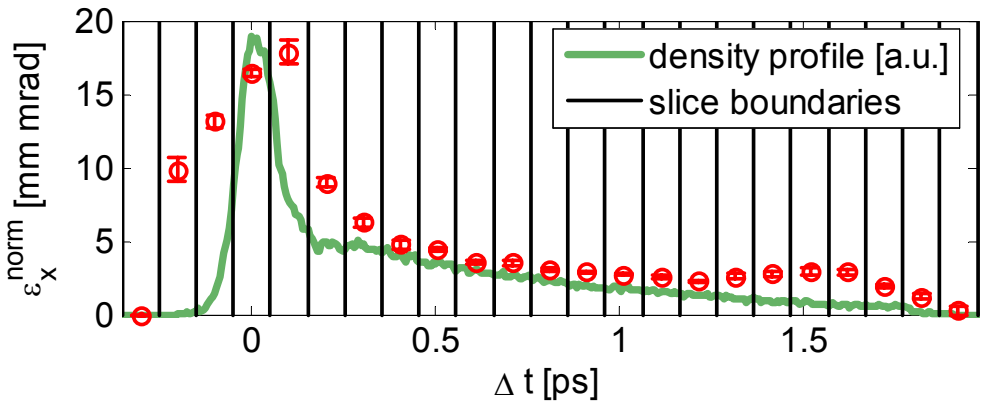
ASTRA-simulation: SASE at 31.4 nm (4µJ)



Charge: 0.9 nC, Energy: 450 MeV, ACC1: -7.5˚, ACC23: -20˚, ACC45: 0˚

SASE at 13.7 nm: Slice emittance





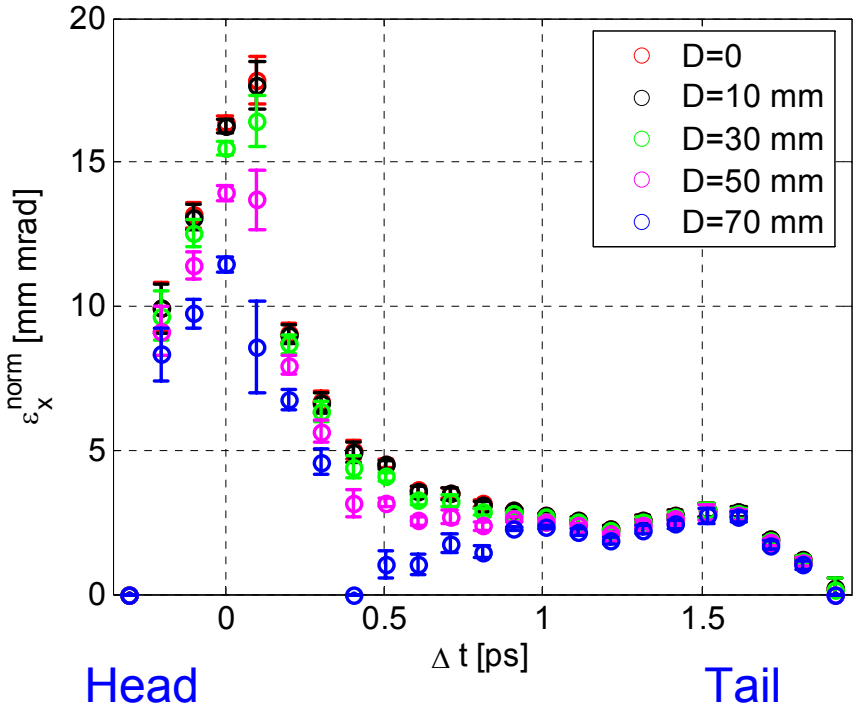
- Vertical rms width during the scan: < 220 µm (60 fs resolution)

- Projected emittance: 13.5 mm mrad

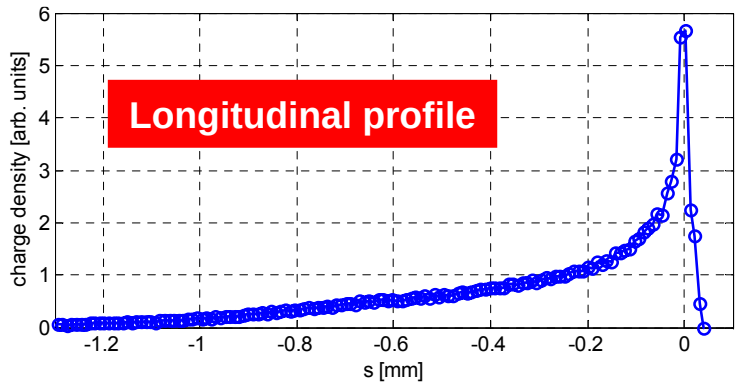
- Similar result for SASE operation at 31.4nm

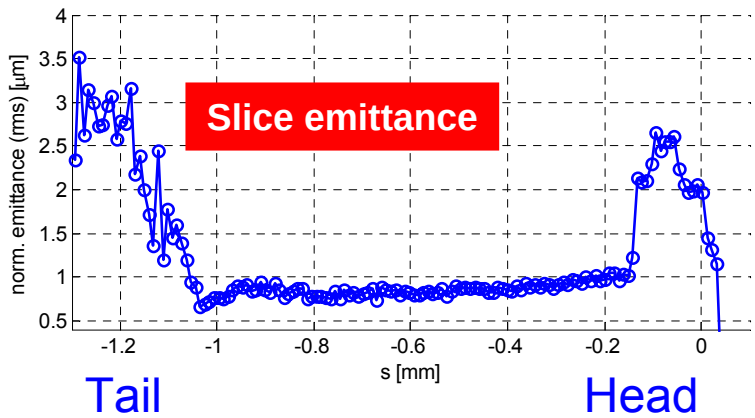
Causes for increase in slice emittance

Dispersion and energy spread due to longitudinal space charge forces:



Transverse space charge forces (ASTRA-simulation, SASE@31.4nm)





Conclusions

- LOLA provides the possibility to measure longitudinal density profile, slice emittance and energy-time correlation with high accuracy
- The main cause for emittance and energy spread degradation seem to be space charge forces
- There is a clear discrepancy in absolute slice emittance values between measurement and simulation

Thank you very much!