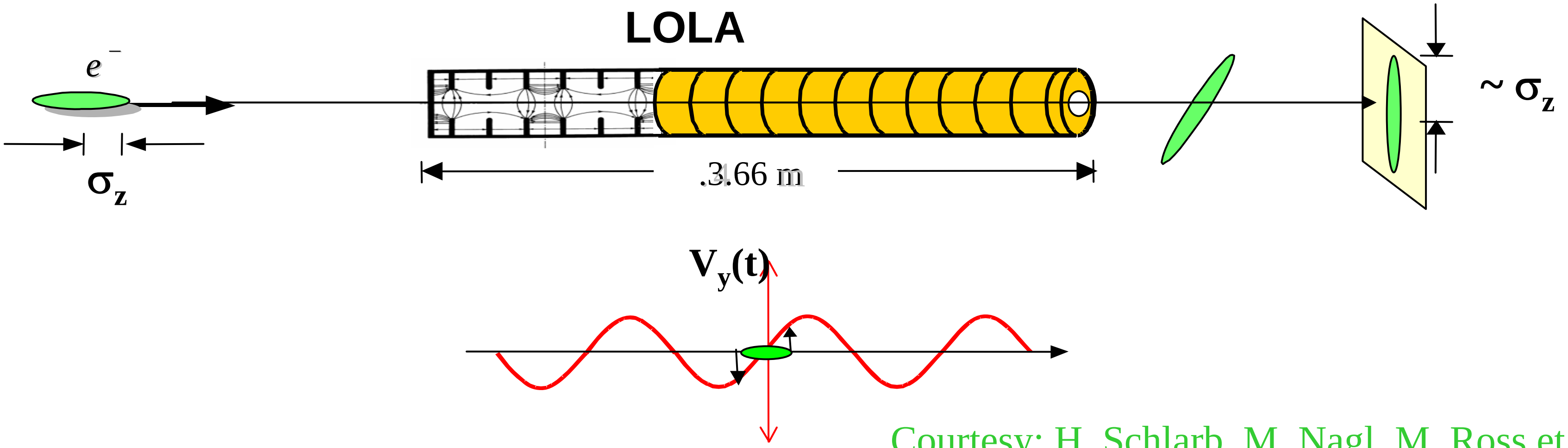
Time-resolved Measurements using the Transversely Deflecting RF-Structure LOLA at FLASH (DESY)

Michael Roehrs ,Holger Schlarb, Christopher Gerth, Andy Bolzmann, Markus Huening, Bolko Beutner

Outline

- Principle of measurements with LOLA
- LOLA and its integration into the FLASH-Linac
- Recent / possible measurements :
  - Longitudinal density profile
  - Slice emittance
  - Energy-time correlation
  - Horizontal slice centroid shifts
  - 3-dimensional spatial particle distribution

Introduction



Courtesy: H. Schlarb, M. Nagl, M. Ross et al.

- $\sigma_y^{streaked} >> \sigma_y$
- Maximum streak at 500 MeV: ~6mm/ps
- Streak depends on optics downstream of LOLA:

$$\Delta y \approx R_{34} \cdot y'$$

Some facts about LOLA

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

Courtesy: M. Nagl

LOLA installation at FLASH

Some important issues:

- Klystron
- Modulator
- Water Cooling
- Synchronization
- Kicker
- Diagnostic screen

The installation team:

Field of activity	Group	Contact
Coordination at SLAC		M. Ross D. McCormick T. Smith
Coordination at DESY	MIN	H. Weise M. Nagl K. Klose
Installation of LOLA and the vacuum components in the TTF2 Beamline.	MVP MPL	K. Zapfe H. Remde G. Weichert
Waveguide	MVA MVP MIN	D. Jagnow H. Remde J. Rothenburg
Modulator, Klystron 5045, RF Components	MIN	M. Rakutt J. Herrmann R. Jonas
Water-cooling Klystron + Cavity	MKK	F.-R. Ullrich O. Krebs
Synchronisation	MHF-P	S. Simrock M. Ross
BIS + Interlock	MVP	M. Staack
DOOCS	MVP	K. Rehlich
Trigger	MVP	K. Rehlich
Diagnostic Screens	MPY	K. Honkavaara D. Noelle

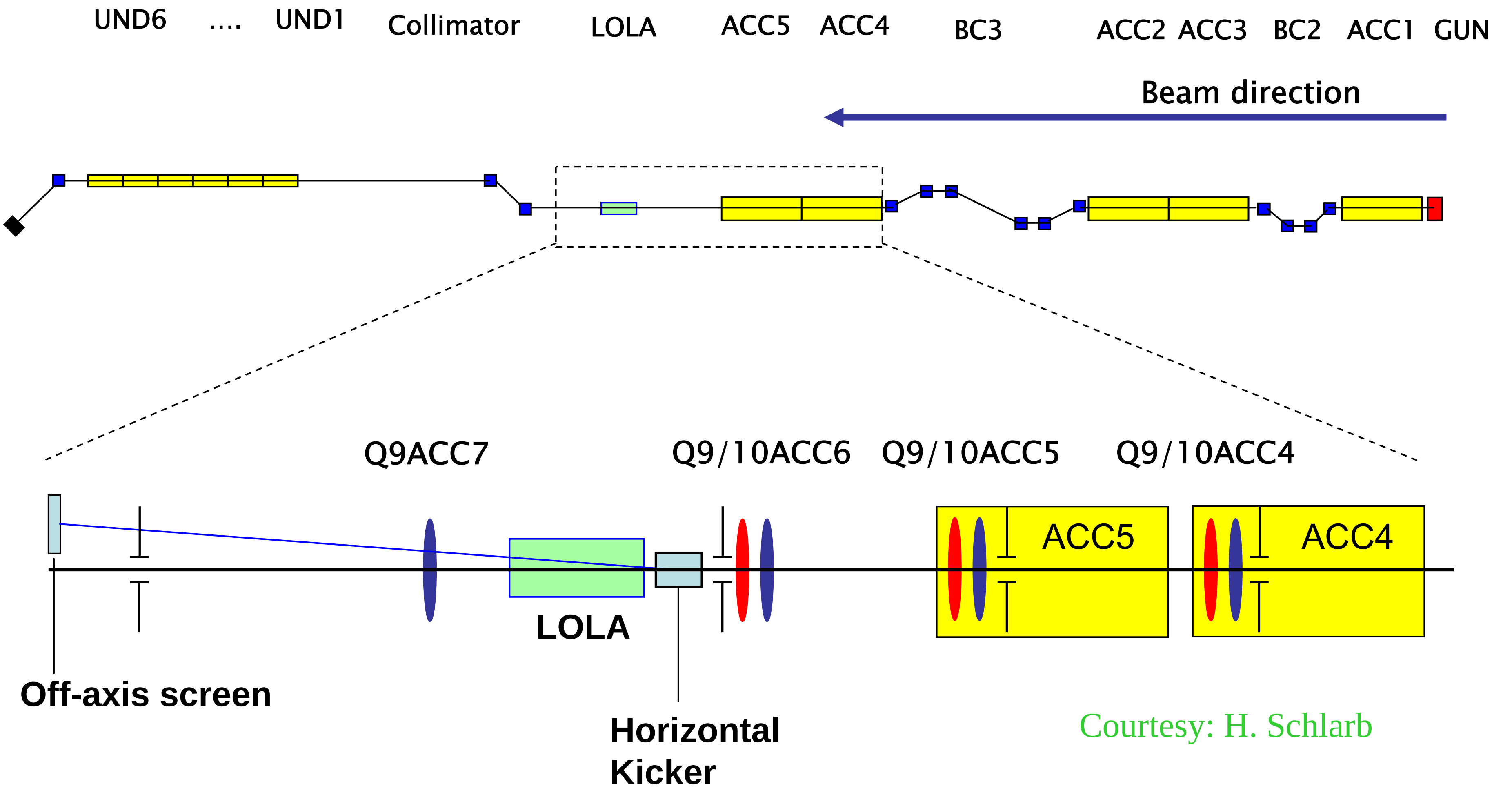
Courtesy: M. Nagl

Parameters of LOLA IV

Type of structure	Constant impedance structure
Mode type	TM 11 (Hybrid Mode)
Phase shift / cell	120° (2 Pi / 3)
Cell length	35 mm
Design wavelength	105 mm
Nominal operating frequency	2856 MHz
Nominal operating temperature	45 °C
Quality factor	12100
Relative group velocity	1.89 %
Filling time	0.645 µs
Attenuation	0.477 N = 4.14 dB
Transverse shunt impedance	16 MΩ / m
Deflecting voltage	$V_o = 1.6\ \mathrm{MV}\cdot L/m\cdot(P_o/\mathrm{MW})^{1/2}$
Nominal deflecting voltage	26 MV at 20 MW
Maximum operating power	25 MW
Length of structure	3640 mm (about 12 feet)
Disk thickness	5.84 mm
Iris aperture	44.88 mm
Cavity inner diameter	116.34 mm
Cavity outer diameter	137.59 mm

Courtesy: M. Nagl

LOLA in the FLASH beamline



Courtesy: H. Schlarb

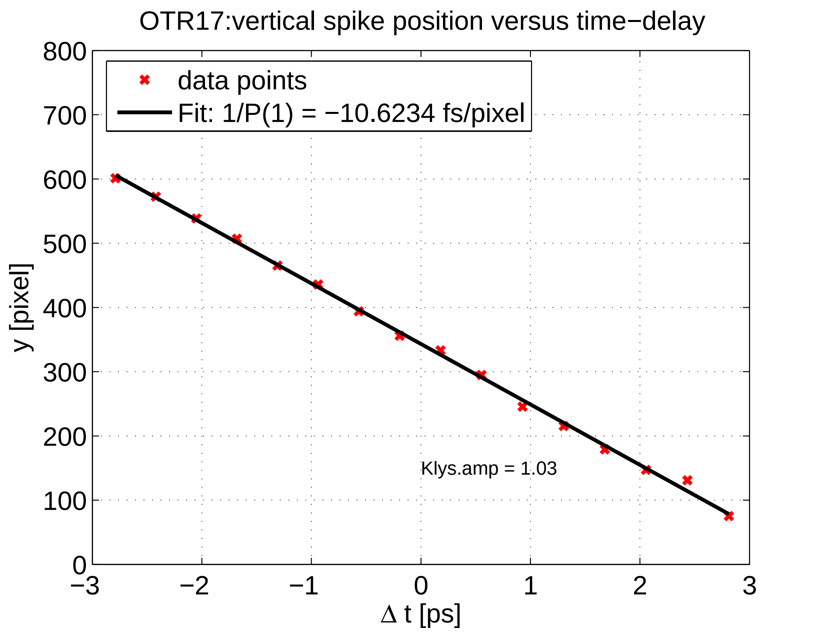
Screen Calibration

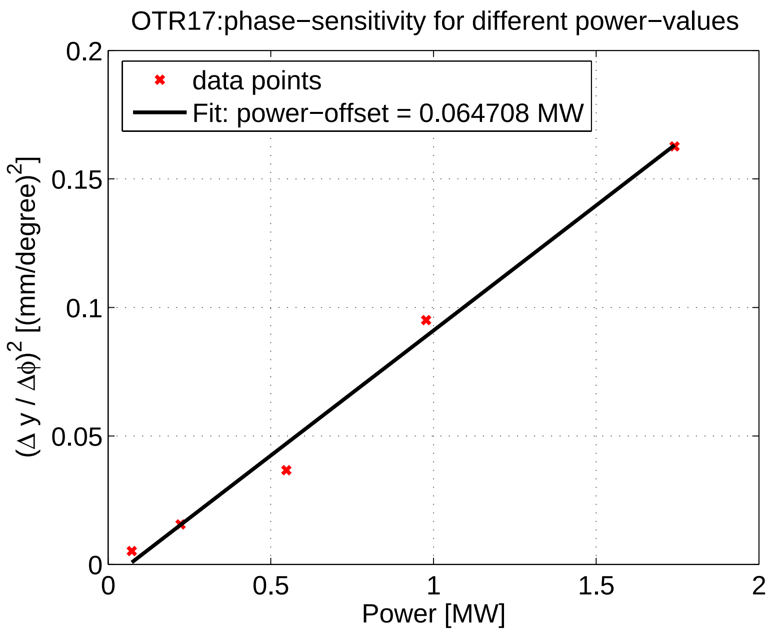
- For fixed power: measurement of the vertical beam position for different phases ϕ

$$\Delta y \approx const \cdot \phi, \quad \phi = \omega_{LOLA} \cdot \Delta t$$

- For arbitrary power:

$$\frac{\Delta y}{\Delta t} = const \cdot \sqrt{P_0}$$





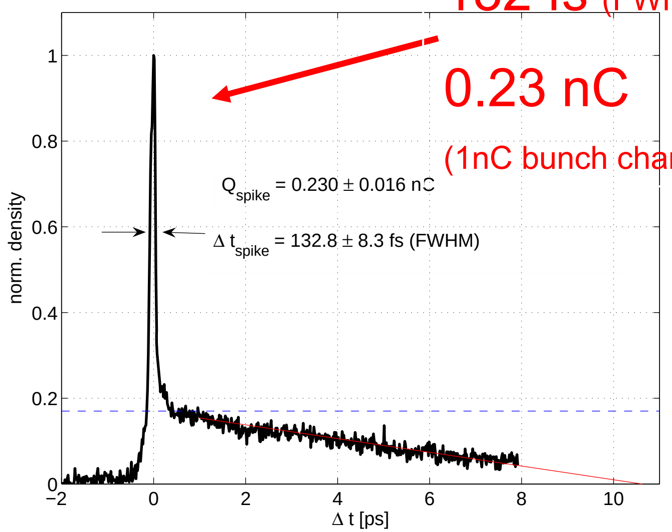
Measurements with LOLA:

Longitudinal density profile

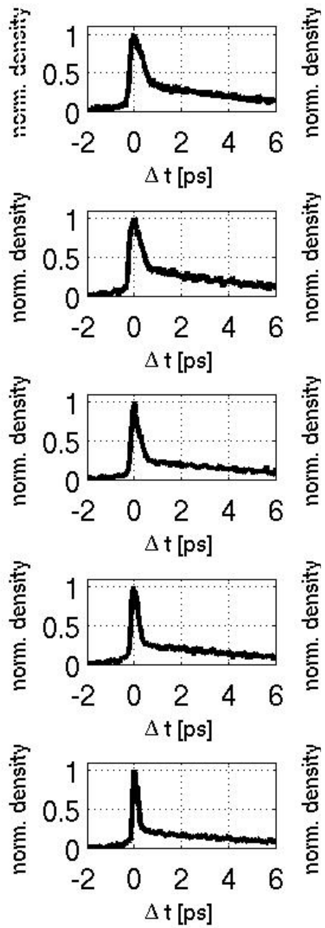
132 fs (FWHM);

0.23 nC

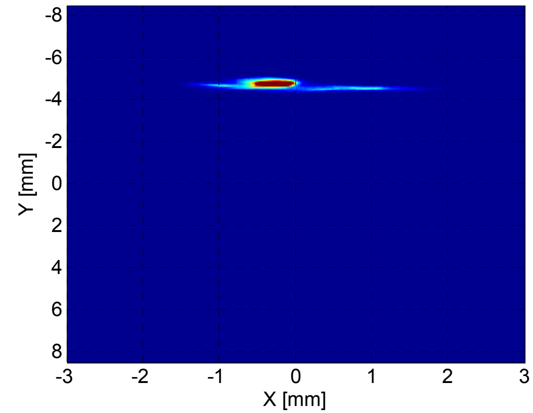
(1nC bunch charge)



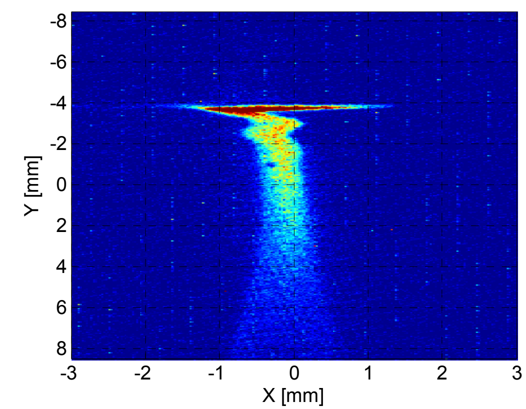
→ Resolution depends on the vertical beam size at the screen



LOLA off:

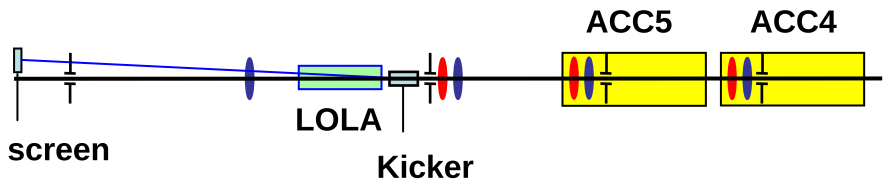


LOLA on:



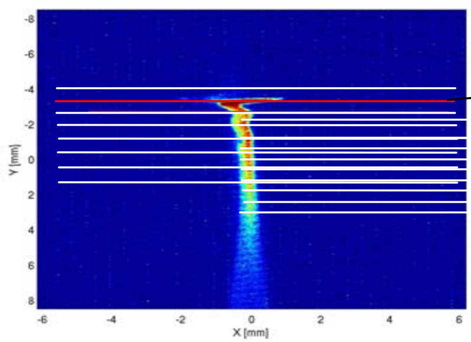
Measurements with LOLA:

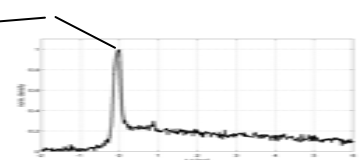
Horizontal slice emittance



- → scan of quadrupole(s) upstream of LOLA
- → measurement of horizontal slice widths
- → both BCs on, 4.5 deg from maximum compression

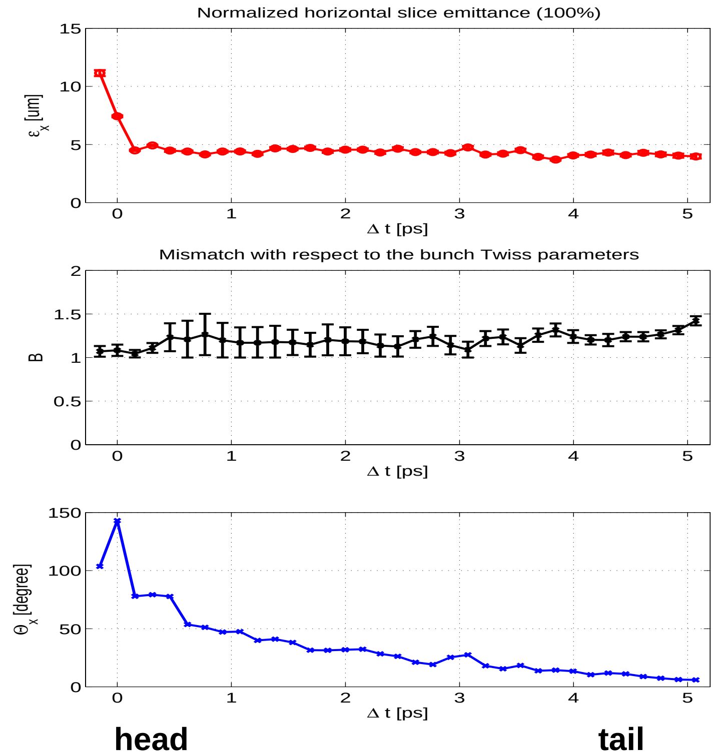
Subdivsion into slices:





Slice width: 0.4 mm (y) , 0.24 ps (z)

Results:

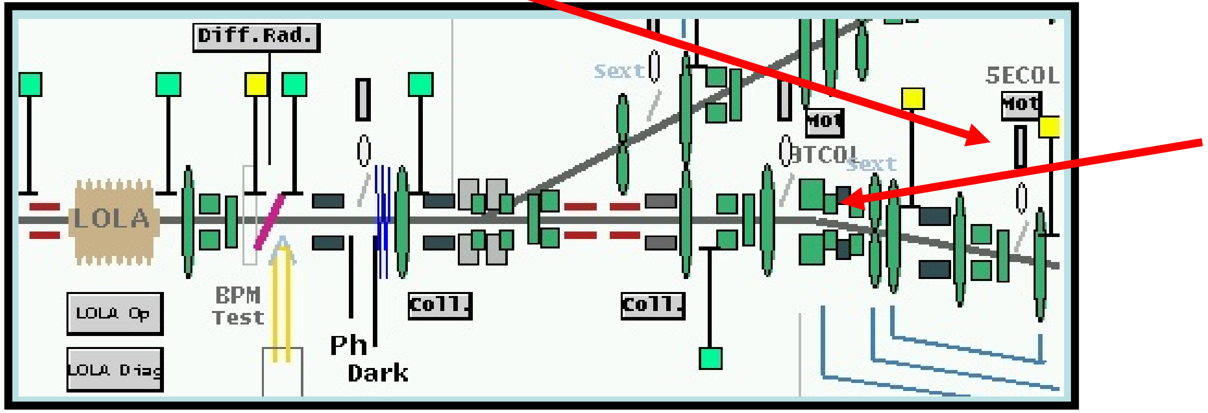


- → emittance blow up in the head
- → gradually changing twiss parameters along the bunch

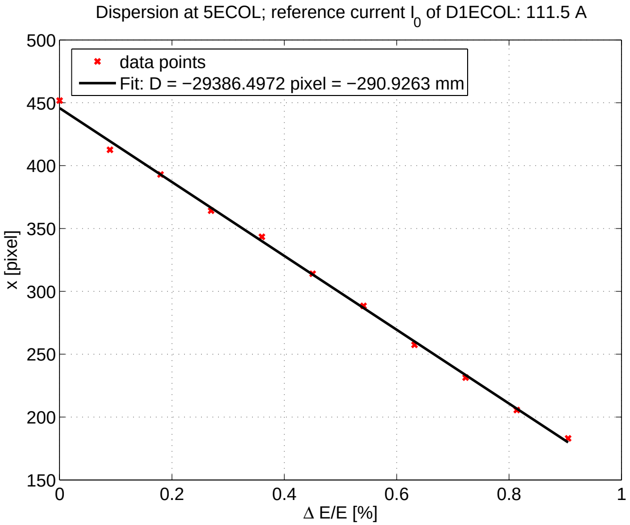
Measurements with LOLA:

Energy – time correlation

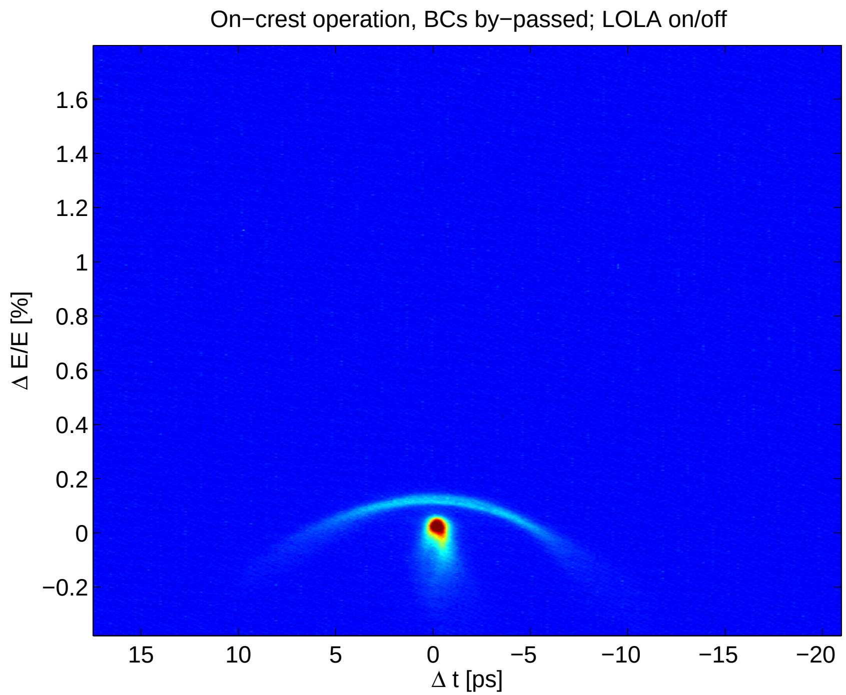
- Measurement on screen 5ECOL in a dispersive section

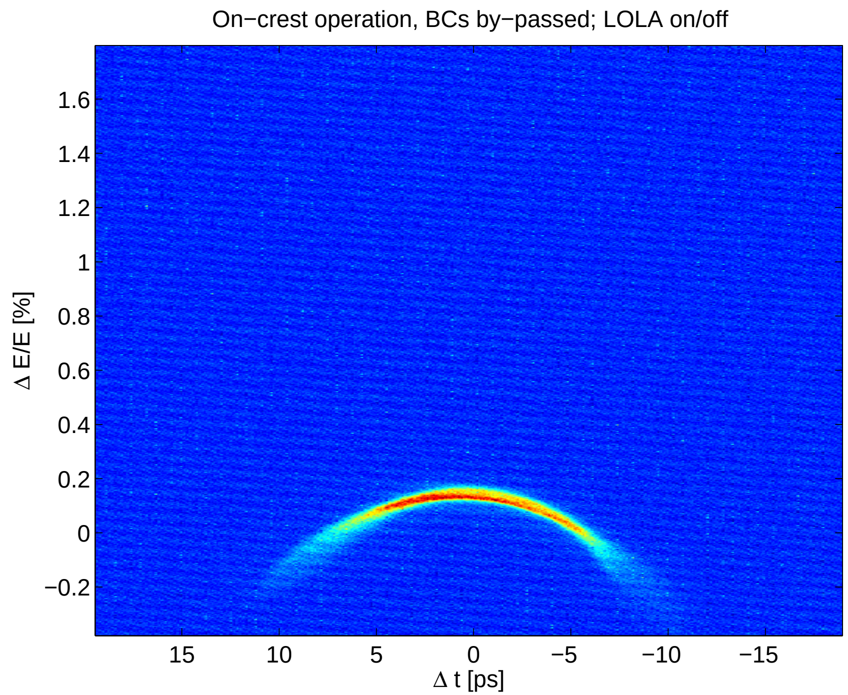


- Calibration of screen, measurement of horizontal dispersion
  → establish $\frac{\Delta E}{E}$ on x-axis and time on y-axis of the screen



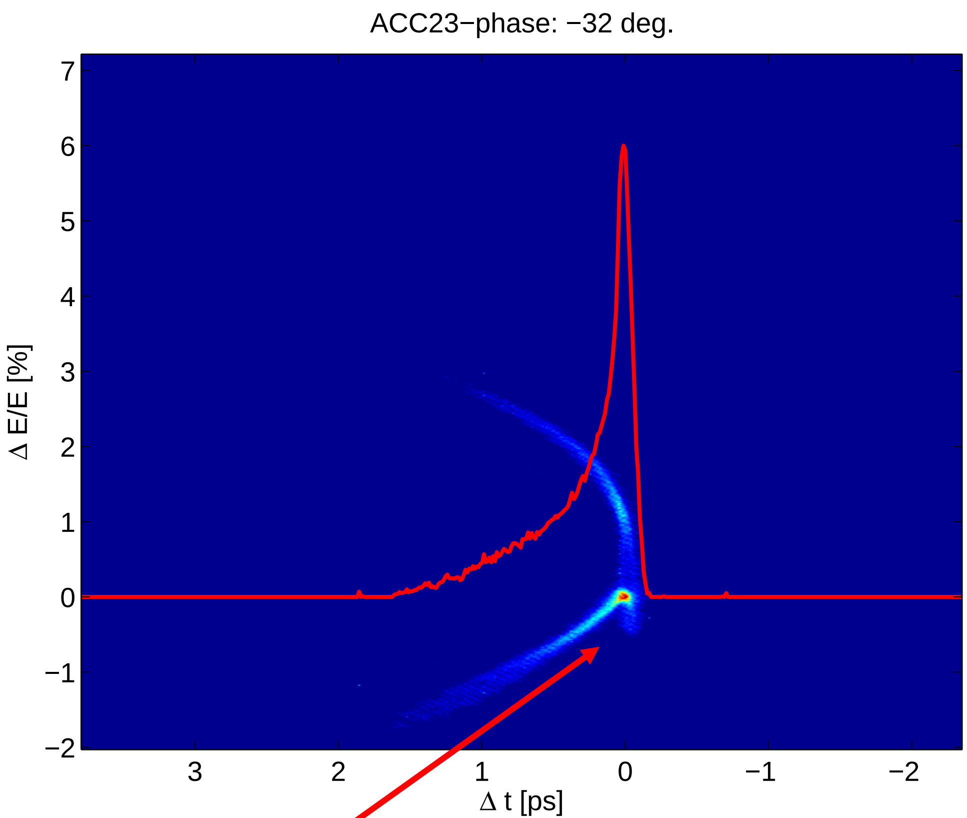
Energy-time correlation: Both BCs by-passed





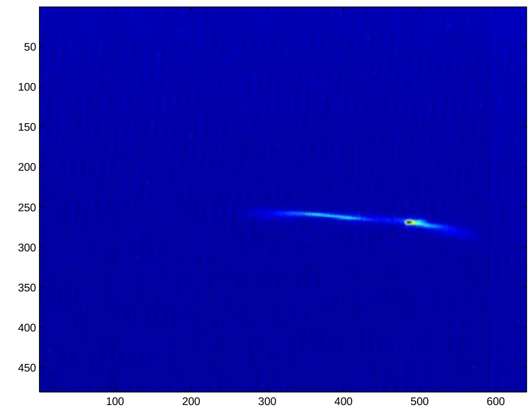
Dispersion: D = 290 mm

Energy-time correlation: BC3 on, ACC23 off-crest



CSR/ longitudinal space charge forces

LOLA off:

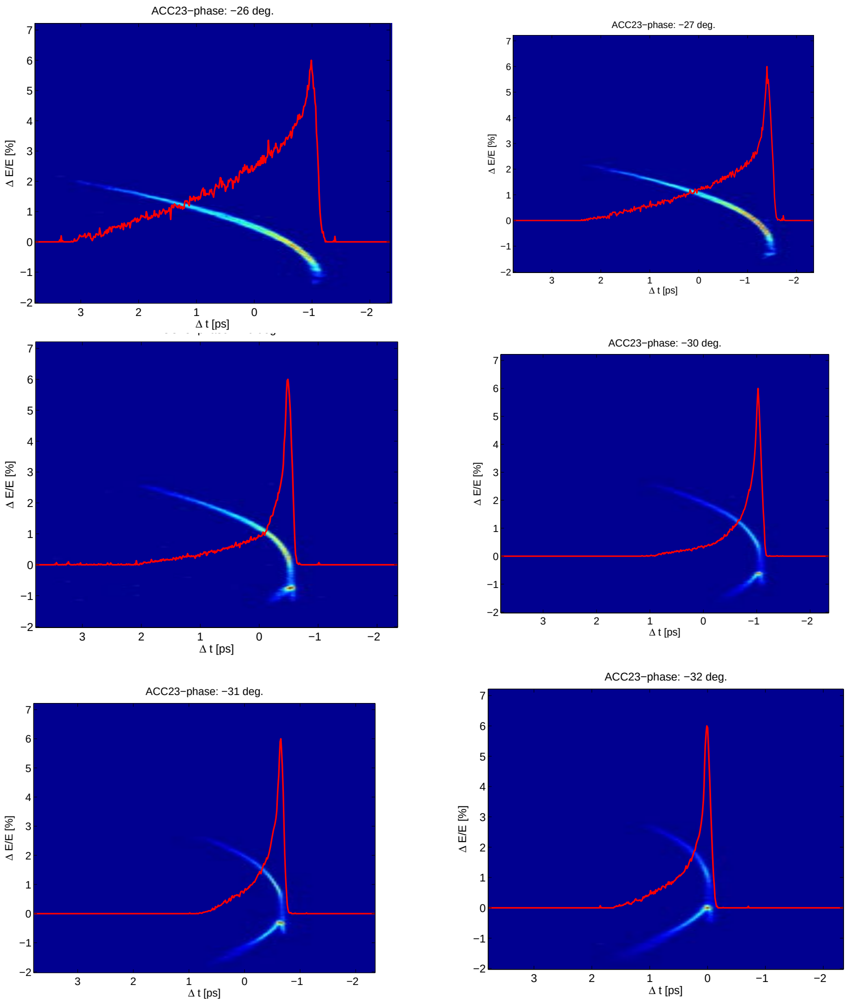


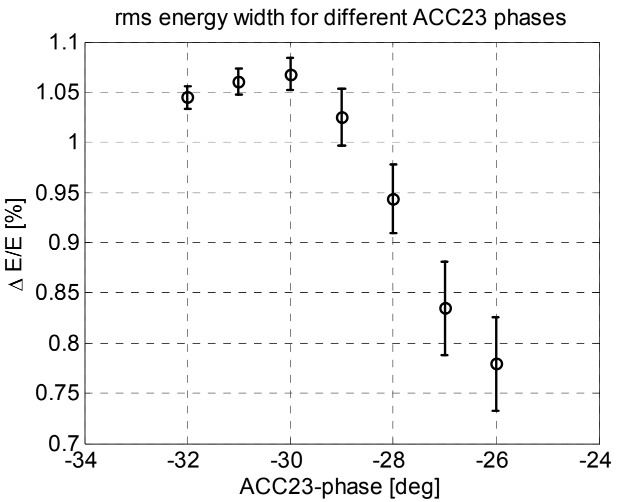
→ slice energy width

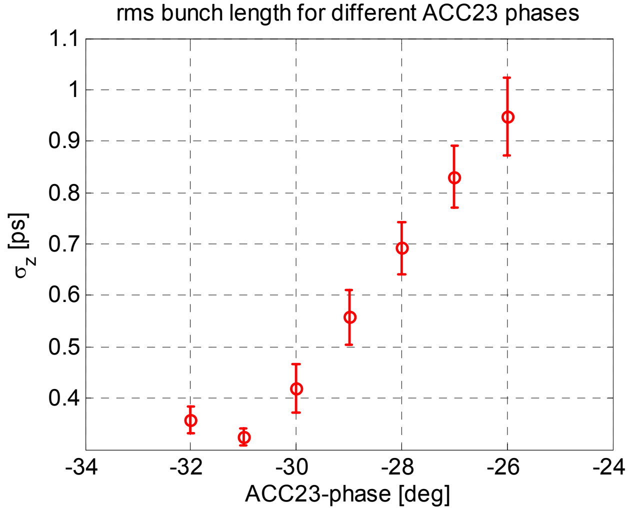
→ Calculation of the peak current?

→ Comparison with simulations

Scan of ACC23-phase

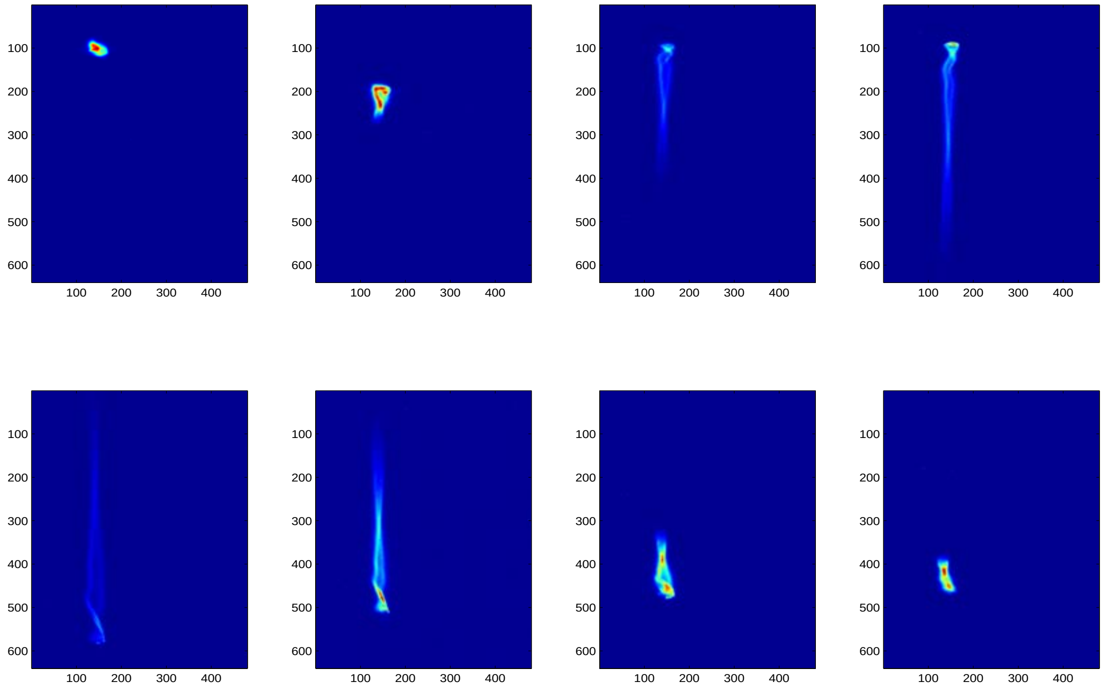






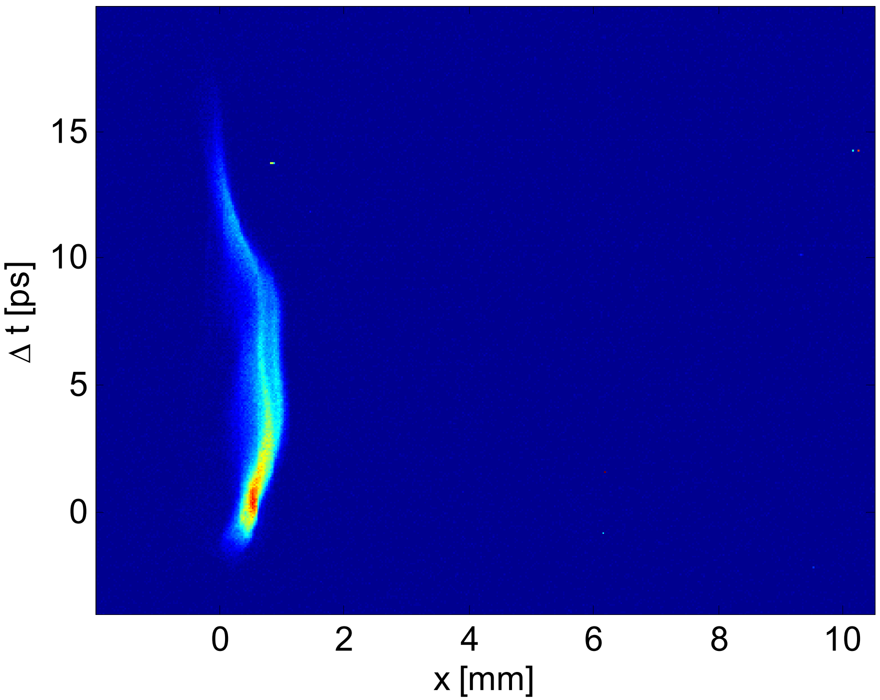
Measurements with LOLA:
Tomography

- Scanning the LOLA power allows to reconstruct the 3-dimensional spatial particle distribution
  → reconstruction of the vertical slice emittance?
  → combination with phase space tomography?



Measurements with LOLA:
Slice centroid shifts

Over-cpmressed beam with slice centroid shifts



BC2 off, BC3 on, overcompression

- Energy-loss due to coherent synchrotron radiation in the dipoles of the bunch compressors lead to horizontal slice centroid shifts
- Comparison with simulations (Bolko Beutner)

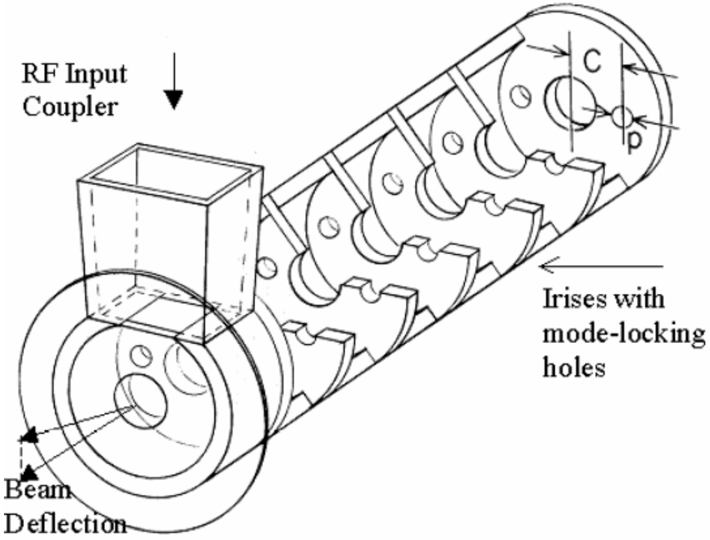
Summary and Outlook

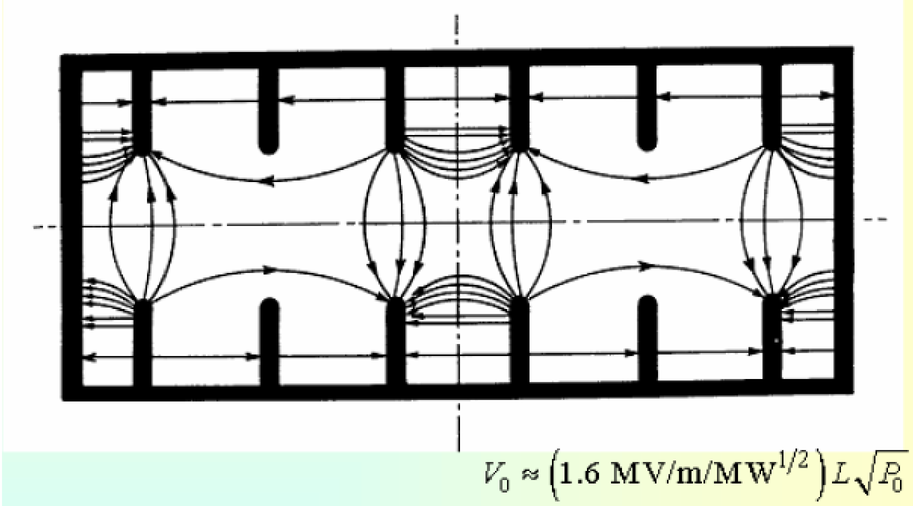
LOLA is a very powerful device especially well-suited for measurements of bunch length and the spatial particle distribution, slice emittance, energy-time correlations and for studies of CSR- and space charge effects

Future plans:

- Measurement of slice-emittance and energy-time correlation under SASE- conditions (planned for August 2006)
- Comparison with simulations
- Study of slice-centroid shifts (Bolko Beutner)
- Reconstruction of the complete spatial particle distribution by tomography

Cavity geometry and history





•LOLA IV transverse deflecting structure fabricated in 1968 for use in the End Station C secondary beam as an RF separator.

•It was called LOLA after its designers, Greg <u>LO</u>ew, Rudy <u>L</u>arsen and Otto <u>A</u>ltenmuller.

•The use of transverse RF for secondary beam separation, where secondary particles of different species are naturally phase shifted by their time of flight, was first proposed in the 1950's.

•Twenty MW in the LOLA structure delivers a peak integrated deflecting field of 33 MV.

Courtesy: M. Ross