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Commissioning of the TTF Linac Injector at the DESY VUV-FEL

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- Injector Layout
- RF Gun and Laser System
- Measurement of Beam Parameters
- Summary and Outlook

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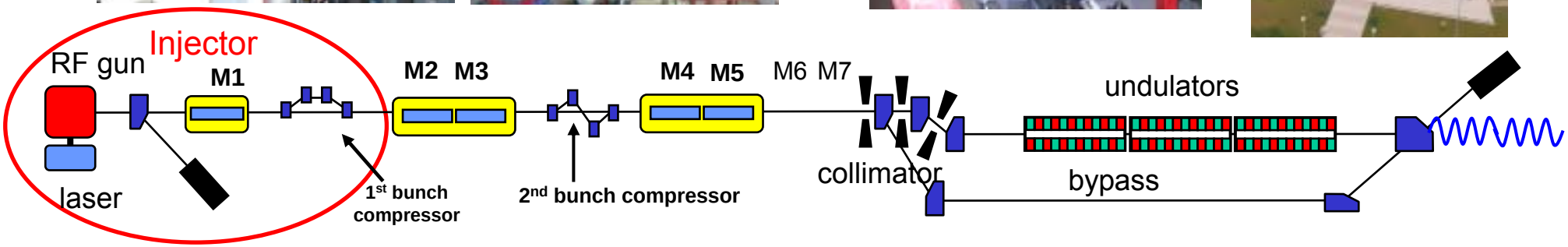
VUV–FEL at DESY

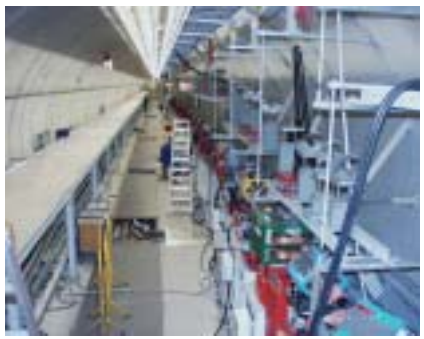
- Upgrade of TTF (phase 1) FEL
- SASE FEL user facility in the wavelength range from VUV down to 6 nm
- Superconducting linac based on TESLA technology, energy up to 1 GeV
  - Present stage of upgrade up to 800 MeV
- Up to 7200 bunches per bunch train with 110 ns spacing (9 MHz), repetition rate of 10 Hz
- Design electron beam parameters
  - Charge 1 nC / bunch
  - Normalized emittance 2 mm mrad
  - Peak current 2.5 kA
  - Energy spread 0.1 %
  - Bunch length after 2 compression stages 50 μm

TTF Linac



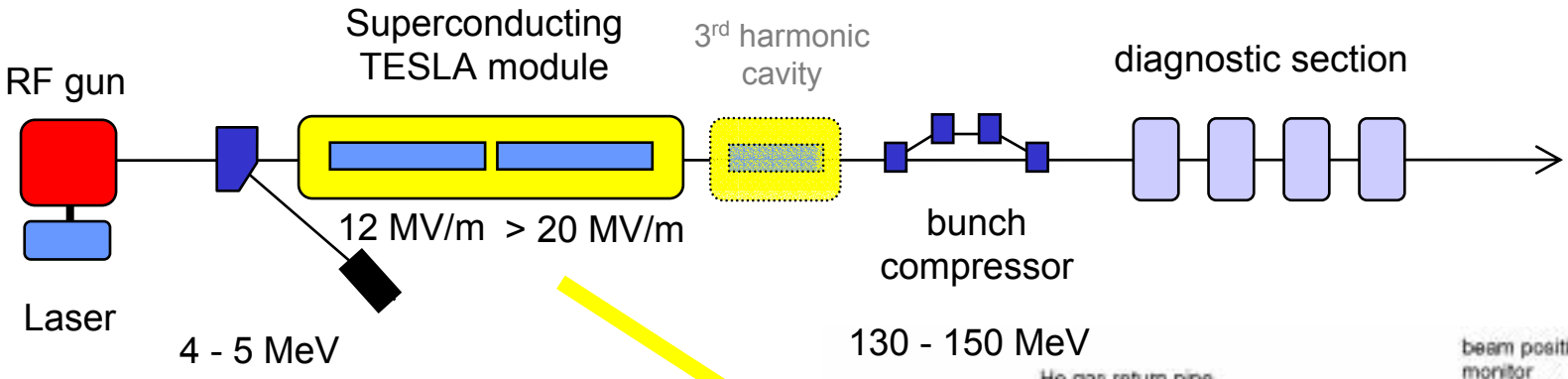





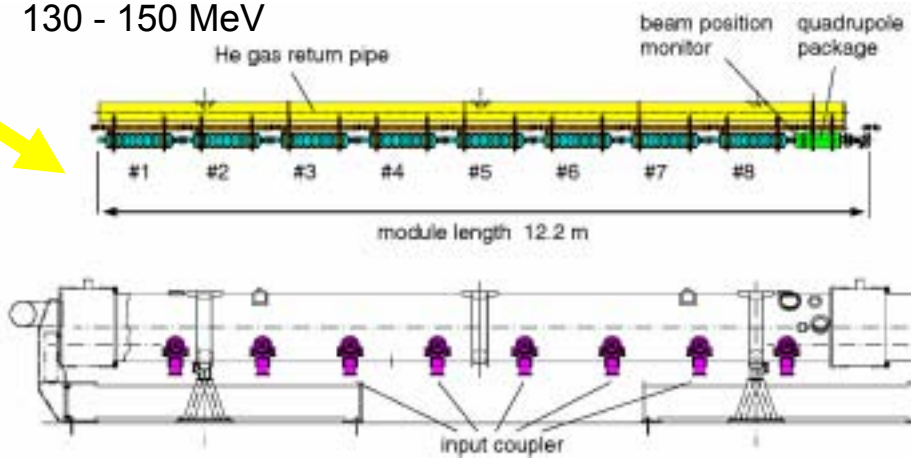



250 m

Injector layout



- Laser driven RF gun
- A complete TESLA module with eight 9-cell Nb accelerating cavities to boost the beam energy to 130 – 150 MeV
  - The first 4 cavities are operated with moderated gradient (12 MV/m)
  - The last 4 cavities with higher gradient (20 MV/m)
  - During commissioning all cavities have been operated with 12 MV/m (beam energy 100 MeV)
- Bunch compressor and diagnostics section
- Injector commissioned in March – June 2004



RF Gun

- 1.5 cell L-band cavity powered by 5 MW klystron
- Two solenoid magnets
  - Main solenoid to reduce space charge induced emittance growth
  - Bucking coil to zero the magnetic field on the cathode
- Commissioned and characterized at PITZ (DESY Zeuthen)
  - 10 Hz, 3 MW, 0.9 ms
- Installed to TTF in January 2004
  - Performance similar as at PITZ
  - For convenience, operated mostly with 5 Hz and shorter RF pulse length

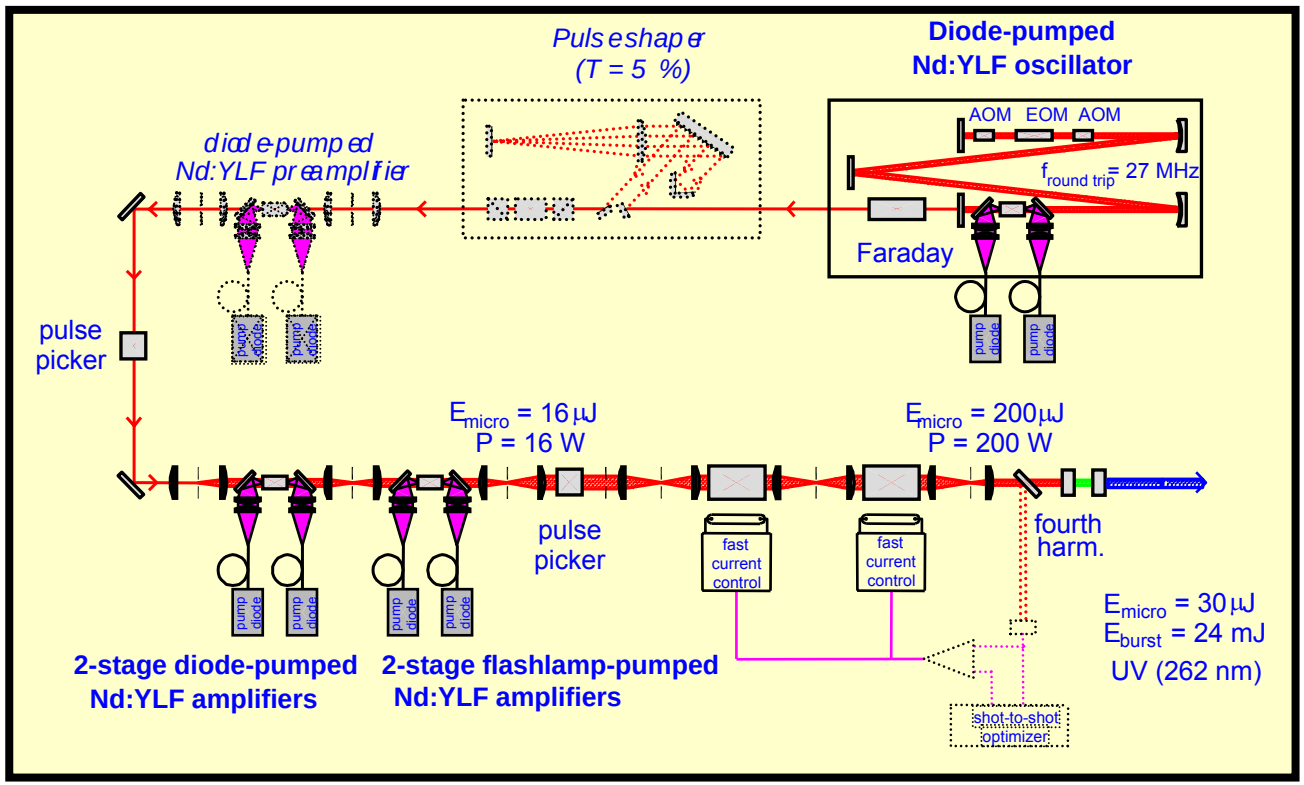
- Photocathode system using Cs_2Te emissive film on Molybdenum cathode plugs
- Cathodes prepared at INFN-LASA (Milano) and shipped to DESY

More about PITZ results:
Posters TUPOS03, TUPOS09
Talk THBOC02

Laser system

- Mode-locked pulse train oscillator synchronized to the 1.3 GHz RF of the accelerator
- Design laser pulse shape: longitudinal flat-hat profile
  - Pulse shaper not yet installed: gaussian laser shape

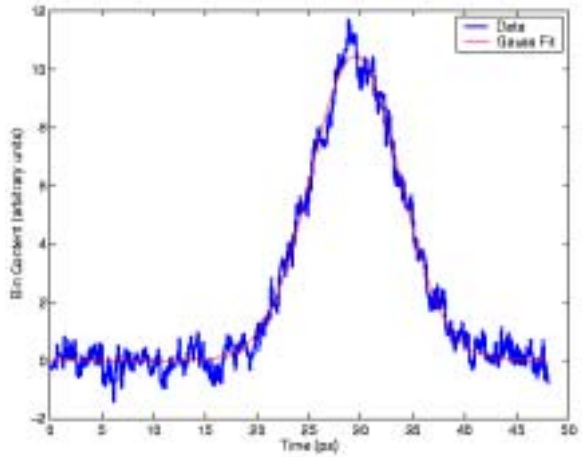
Max-Born-Institute, Berlin



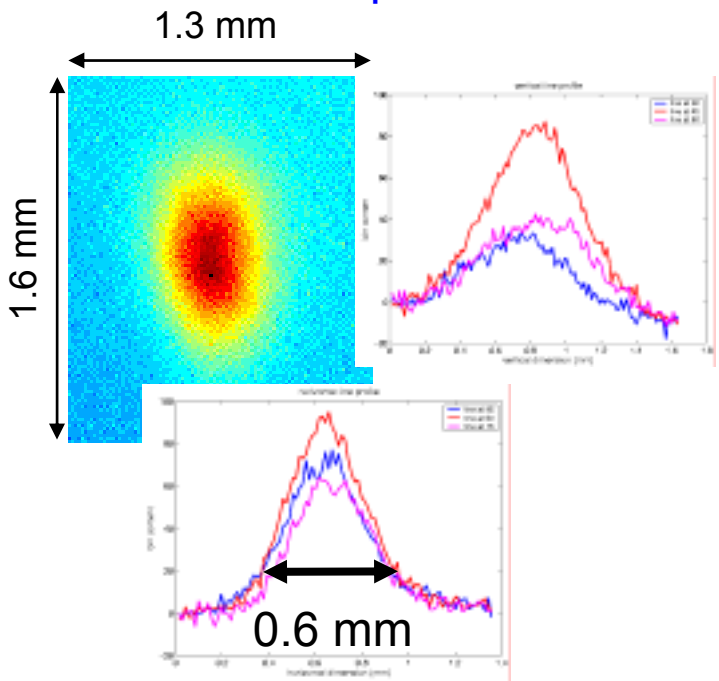
Laser pulse shape

- Pulse shaper not yet installed: longitudinal shape gaussian
  - Pulse length measured with a streak camera σ = 4.4 ± 0.1 ps (UV)

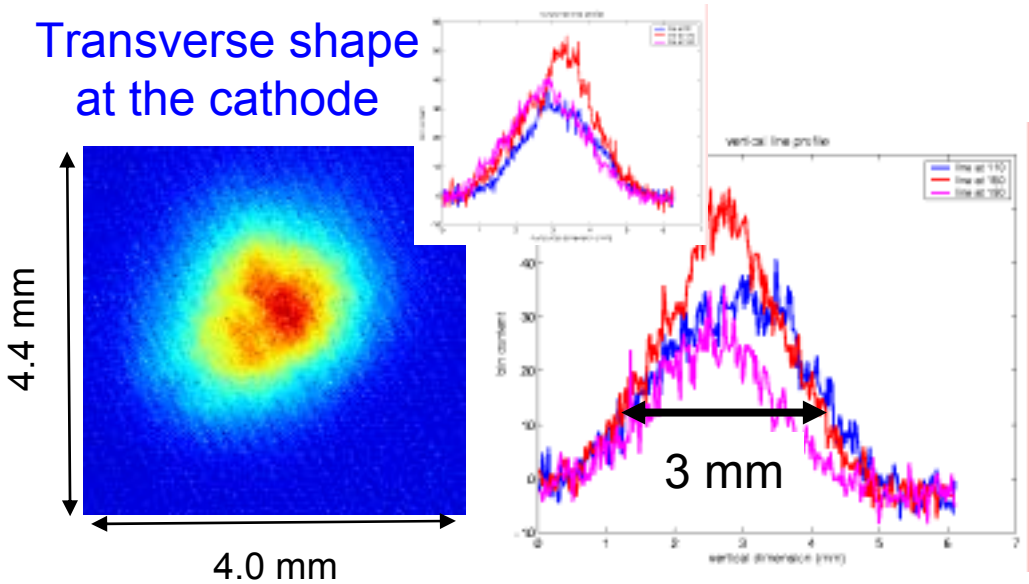
Longitudinal laser profile



Transverse shape at exit of laser



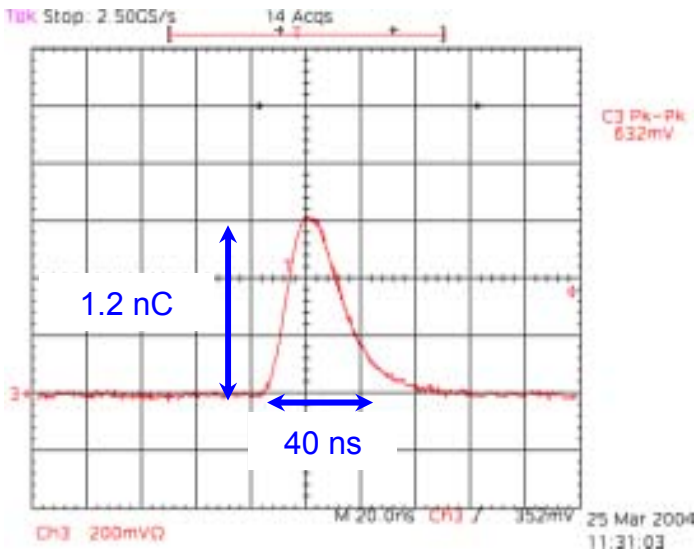
Transverse shape at the cathode



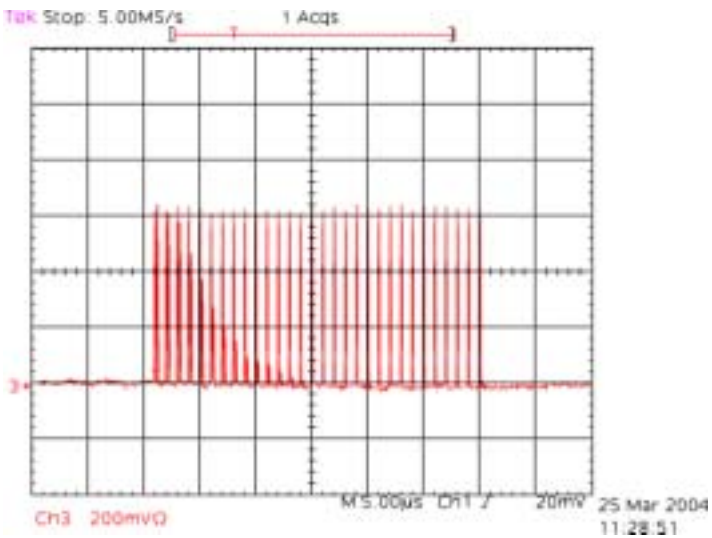
Charge measurements

- Charge measured with toroids and Faraday cups
- Charge jitter from shot to shot 1 % rms
- During commissioning we operated typically with 1-10 bunches of 1 nC

Toroid signal of 1 bunch



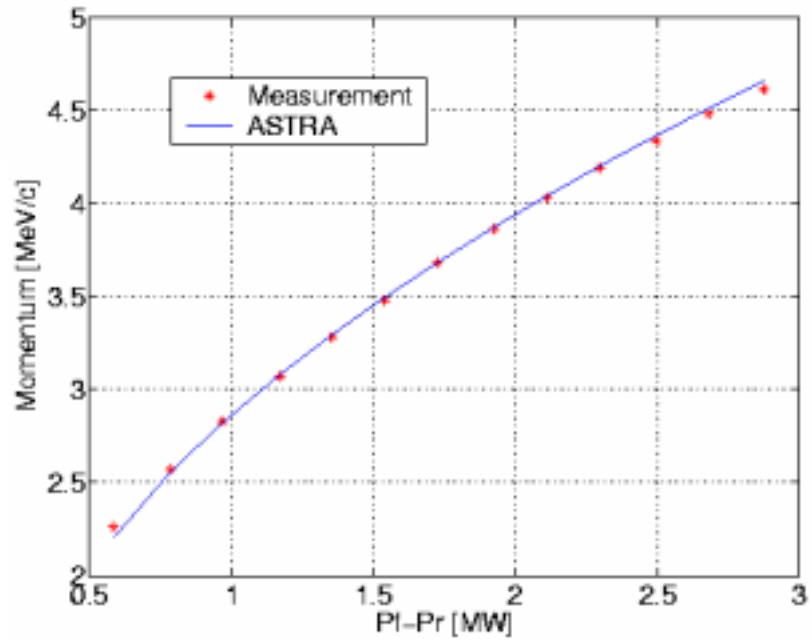
Toroid signal of bunch train
(30 bunches, 1 MHz)



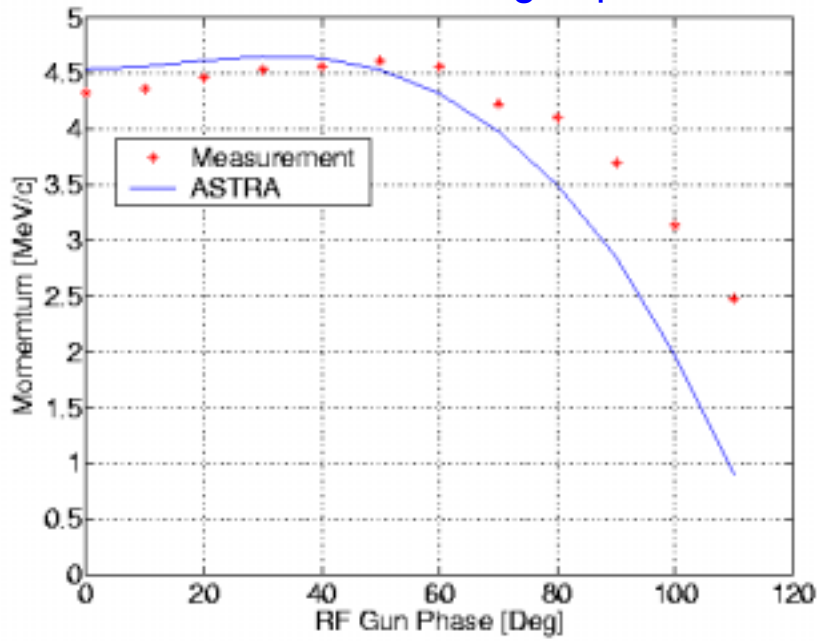
Momentum measurements

- Electron beam momentum measured in dispersive section after the RF gun
- Energy corresponding to the nominal RF power of 3 MW is 4.6 MeV

Momentum vs. RF power in the gun

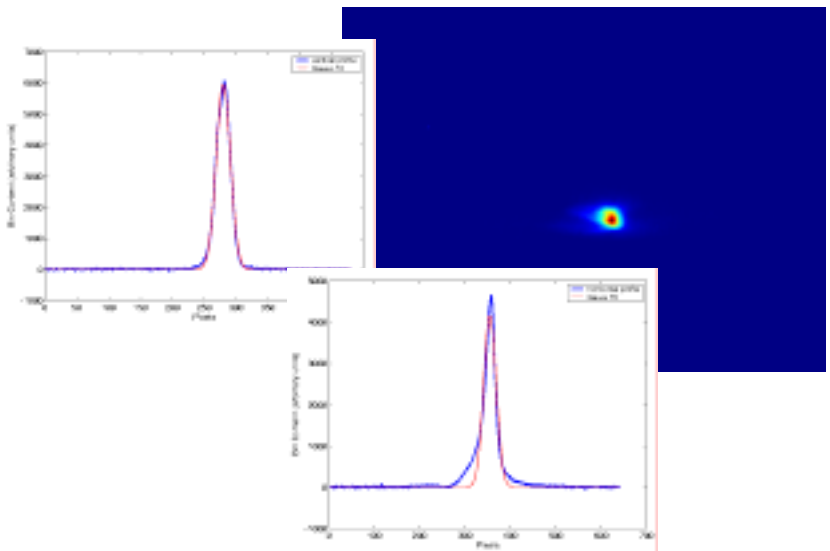


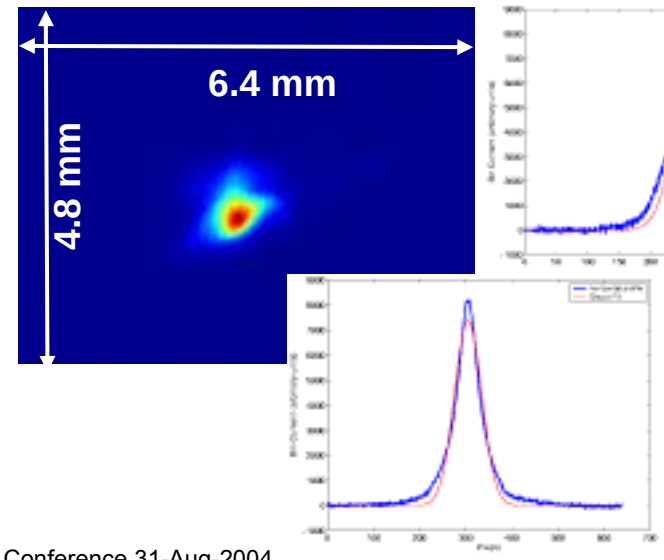
Momentum vs. RF gun phase



Transverse beam shape and size measurements

- Use of optical transition radiation (OTR)
- OTR system designed and constructed by INFN-LNF, INFN-Roma2 in collaboration with DESY
- Based on digital cameras
- Remote controlled, 3 different magnifications
- Resolution down to 10 μm (rms)

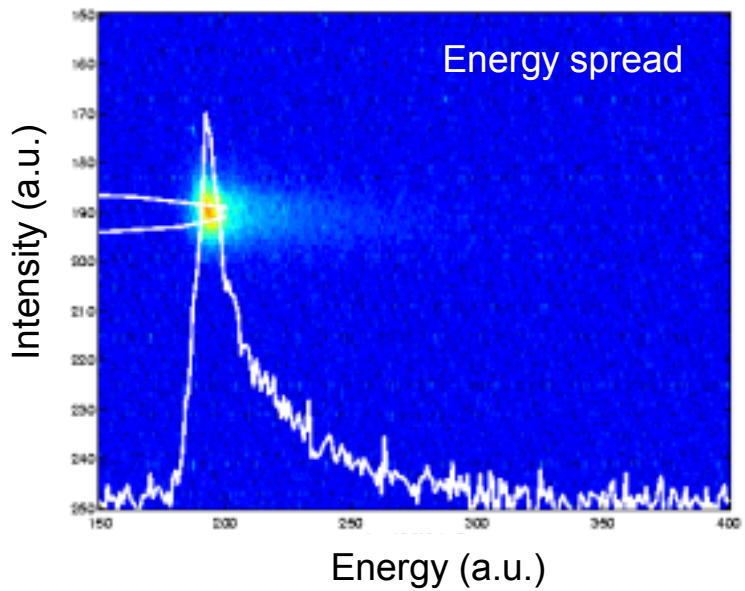




Energy and energy spread

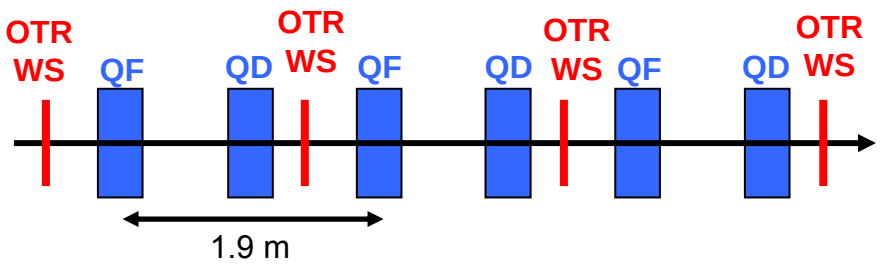
- Energy after acceleration is measured using the dipoles of the bunch compressor
- All 8 cavities of the accelerating module are operated with 12 MV/m providing a beam energy of 100 MeV
- Energy stable within 0.1 % ($8.5 \cdot 10^{-4}$ rms)

- Energy spread measured from horizontal beam profile in the dispersive section of the bunch compressor
- Uncorrelated energy spread estimated from the rising edge about 30 keV (rms), tail of about 200 keV

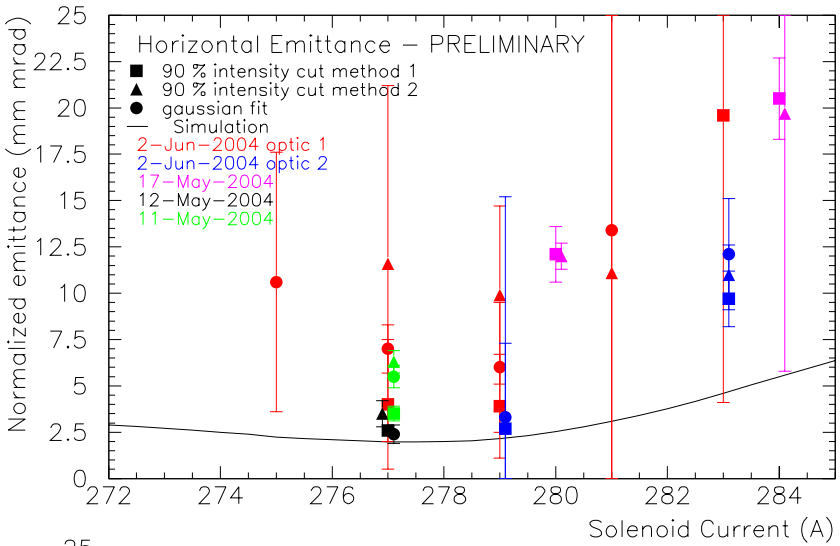


Emittance Measurements

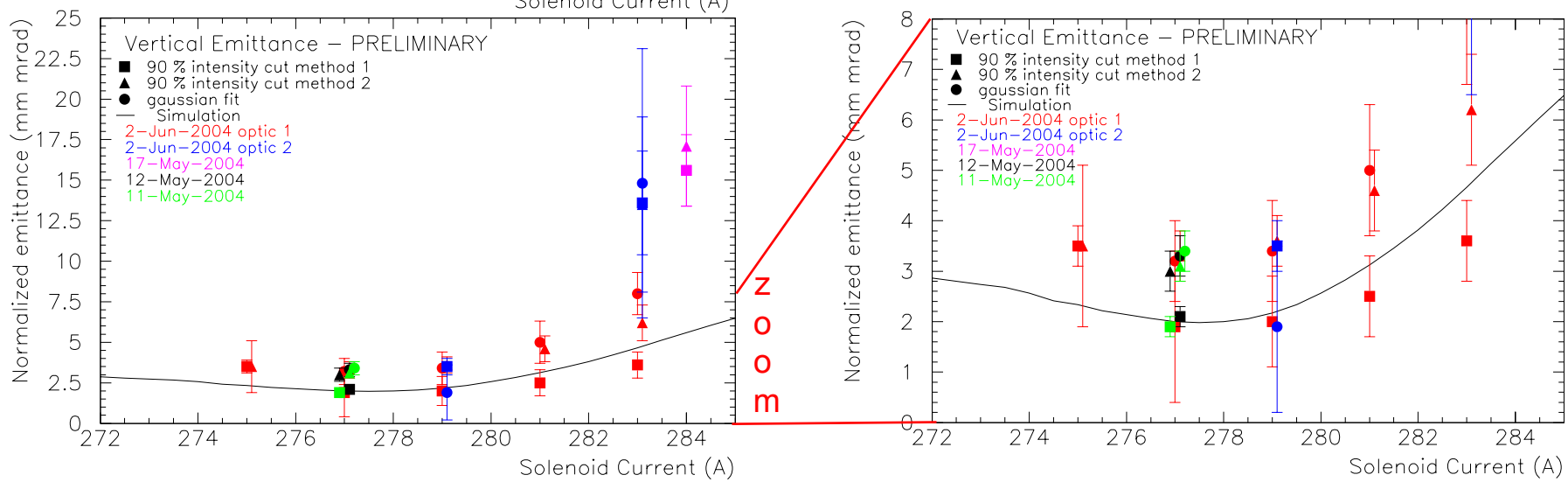
- Four monitor method using OTR monitors or wire scanners
  - During commissioning only the OTR monitors in operation
- Beam size measured at four screens in a FODO lattice of six quadrupoles (fixed quad current)
- Emittance and Twiss parameters calculated from the measured beam sizes and beam size errors using chi-square fitting
- Gun parameters as optimized at PITZ (except solenoid current)
- Bunch compressor by-passed



Transverse emittance vs. solenoid current

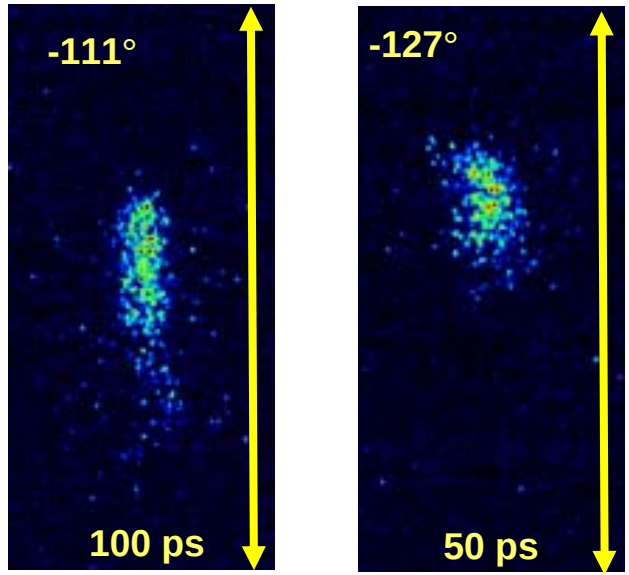


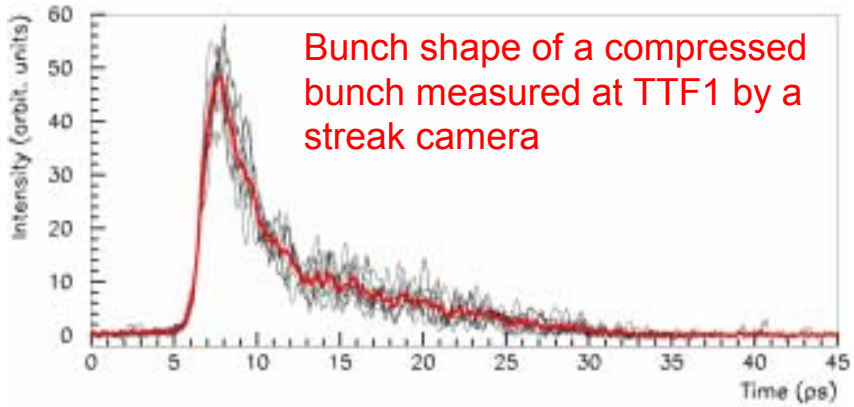
- Promising, but still preliminary results
- Study of systematics in beam size determination and measurement errors not completed yet
- Note: we have presently a gaussian laser pulse shape, not a flat one as at PITZ



Bunch shape and length

- Synchrotron radiation from the last dipole of the bunch compressor is guided out of the accelerator tunnel to a streak camera (FESCA 200) and a Martin-Puplet interferometer
- Uncompressed bunch length measured by the streak camera: 1.7 ± 0.2 mm as expected
- Clear compression observed, when the phase of the accelerating module is changed
- Accurate measurements of short bunches not yet possible
  - Not enough SR photons to operate the streak camera with a wavelength filter
- Analysis of interferometer data on going





Bunch shape of a compressed bunch measured at TTF1 by a streak camera

K.Honkavaara et al., PAC2003, Portland

Summary and Outlook

- The new photoinjector of TTF linac driving the VUV-FEL has been successfully commissioned in March - June 2004
- Beam parameters mostly understood
  - Fine tuning and more accurate measurements still needed
- After short shut-down, the commissioning of the whole linac starts in September 2004
- First goal: lasing at 30 nm by the end of year 2004
- Further milestones:

saturation 30 – 120 nm	7/2005
full beam current	12/2005
installation 3rd harmonic and 6th module	2006
saturation at 6 nm	2006