10th ESLS-RF Meeting, September 27-28, Dortmund

Beam Instability Investigations at DELTA

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DELTA

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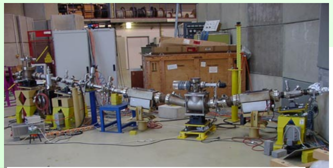
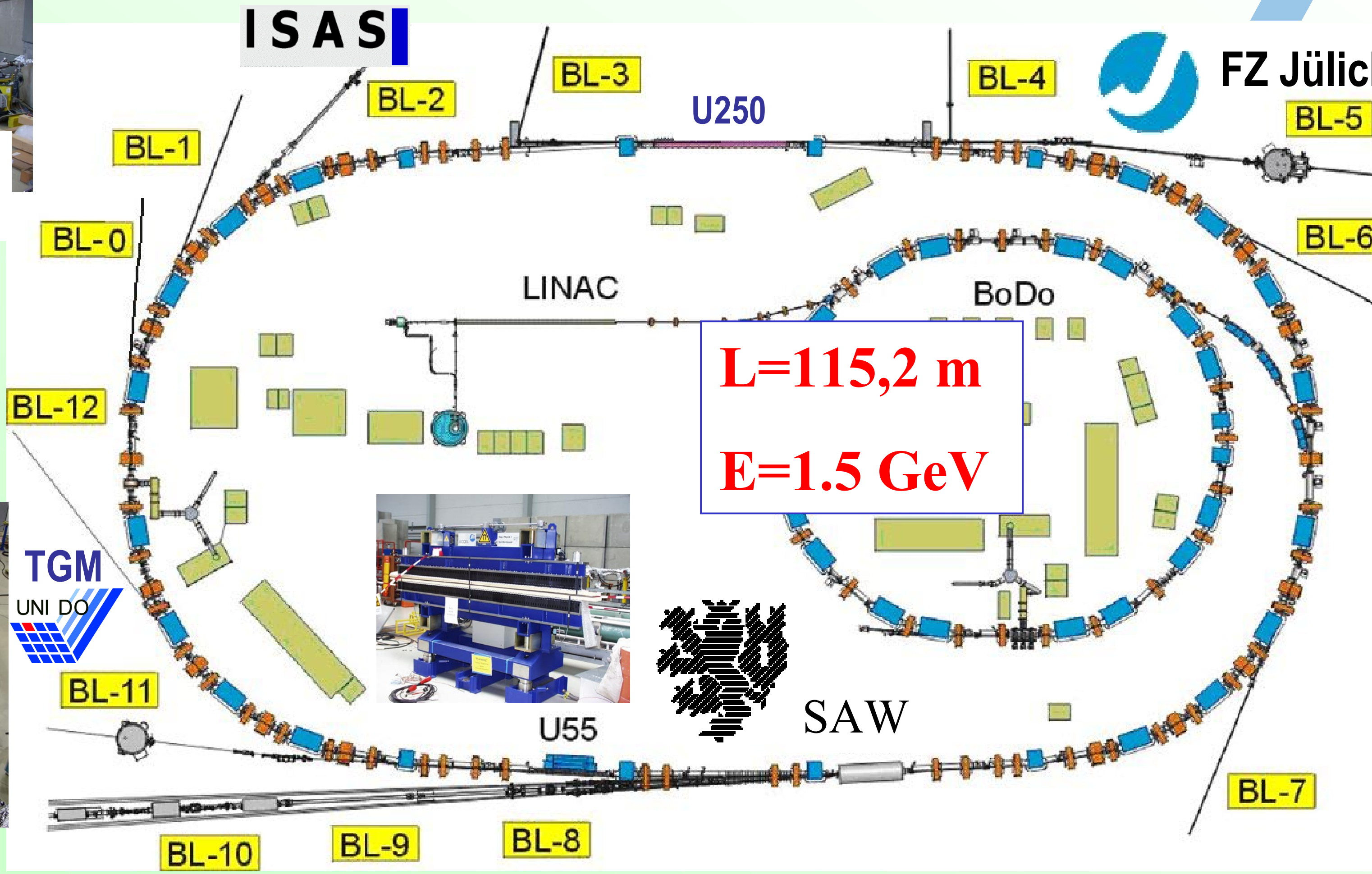
Germany

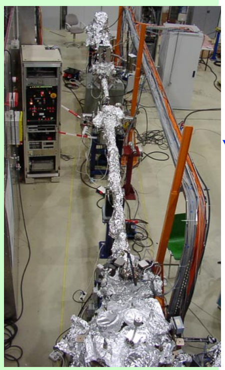
Content:
- Status of the Facility
- Instability Investigation
- EU-Cavity Beam Test
- Summary

DELTA



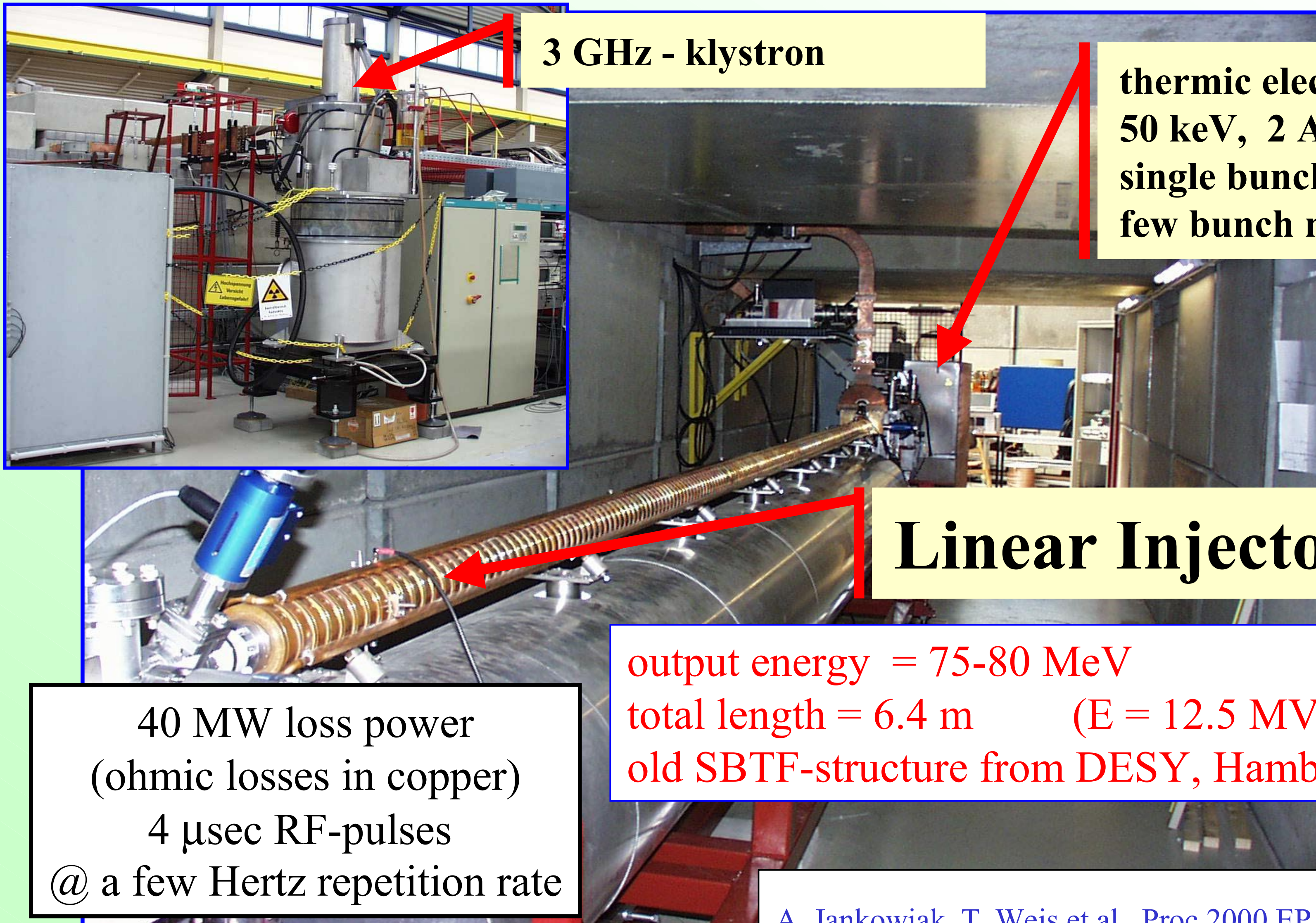
BL12: Methods (II): Soft X-Rays
- Photoemission
- Photoelectron Spectroscopy
- Fermi-Surface Mapping





full energy 1.5 GeV
ramped storage ring
~ 0.1 Hz rep. rate

Linear Injector



3 GHz - klystron

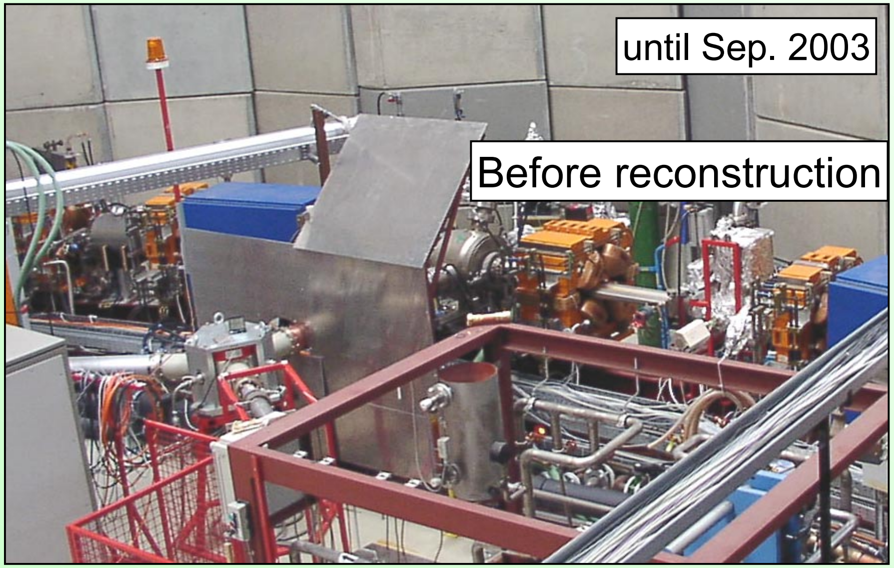
thermic electron gun
50 keV, 2 A
single bunch mode
few bunch mode

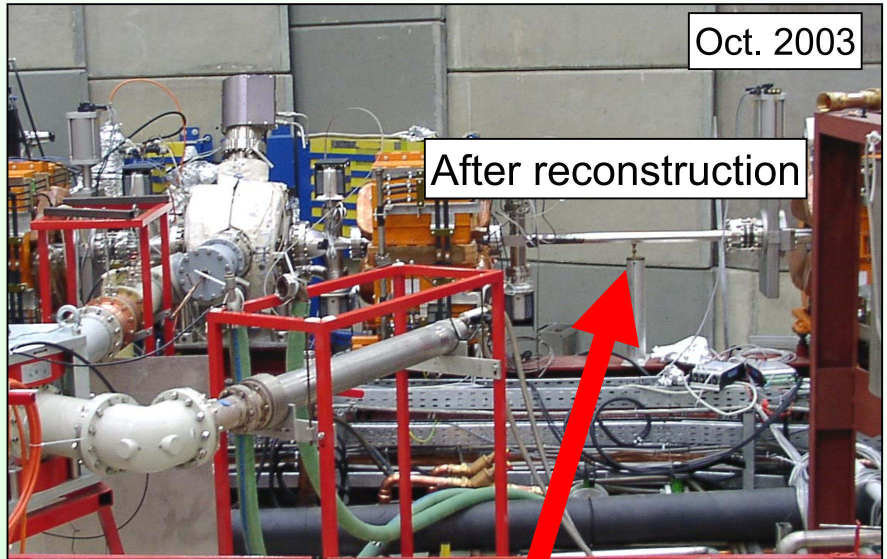
output energy = 75-80 MeV
total length = 6.4 m (E = 12.5 MV/m)
old SBTF-structure from DESY, Hamburg

40 MW loss power
(ohmic losses in copper)
4 µsec RF-pulses
@ a few Hertz repetition rate

A. Jankowiak, T. Weis et al., Proc 2000 EPAC (2000) 636

RF-Section with DORIS-type-Cavity





Single cell cavity @ DELTA

400 kV @ 500 MHz
RF-power 50 kW cw
loss power cavity 27 kW
energy transfer to beam 20 kW
shuntimpedance 3 MΩ

2nd RF ?????

no decision yet
depends on DELTA upgrade philosophy
(lifetime vs. current vs. frequent injection)

Maschine Parameters DELTA

maximum beam energy	1.5 GeV
circumference	115.2 m
nominal beam current	130 mA multi bunch @ 1.5 GeV; 25 mA single bunch @ 550 MeV
beam lifetime	> 8 h multi bunch @ 1.5 GeV; > 20 min single bunch @ 542 MeV
horizontal emittance	16 nm rad @ 1.5 GeV
natural coupling	3 %

User operation 2004/2005

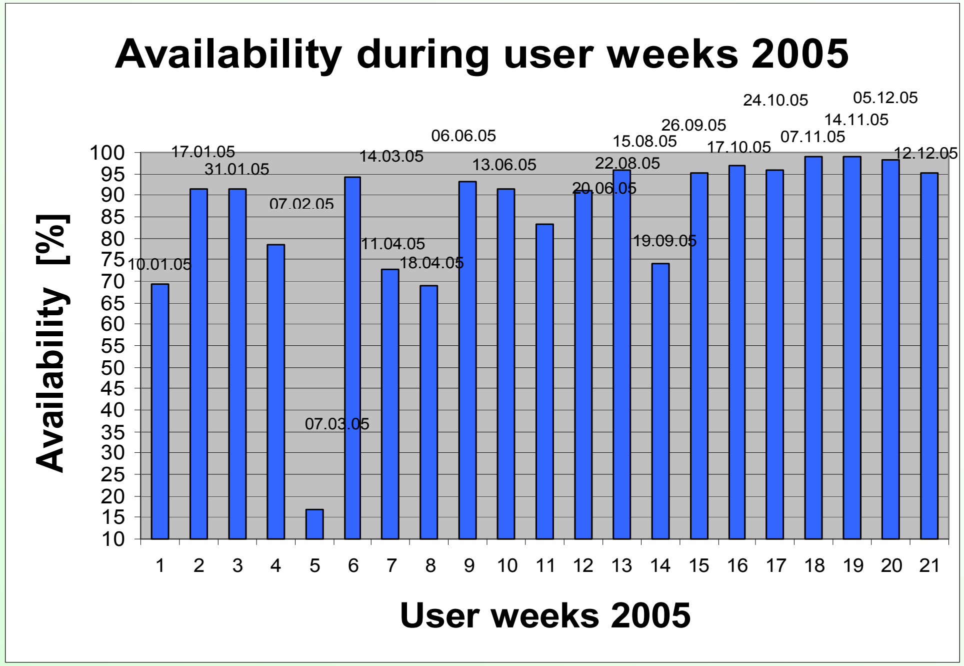
Operation 2004/2005

30 weeks (3000 h)

2000 h user operation.

1000 hours machine optimisation

and machine physics



Performance 2004/2005:

Average availability during 20 user weeks 94/89 %.

Max. beam current 120 mA.

Average lifetime ~ 7hrs

only minor vacuum openings

Performance 2006:

availability ~ 90%

Max. beam current 130 mA.

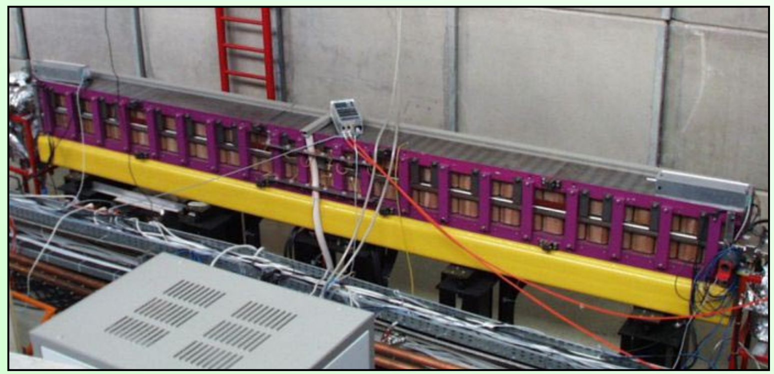
Average lifetime ~ 8-10 hrs

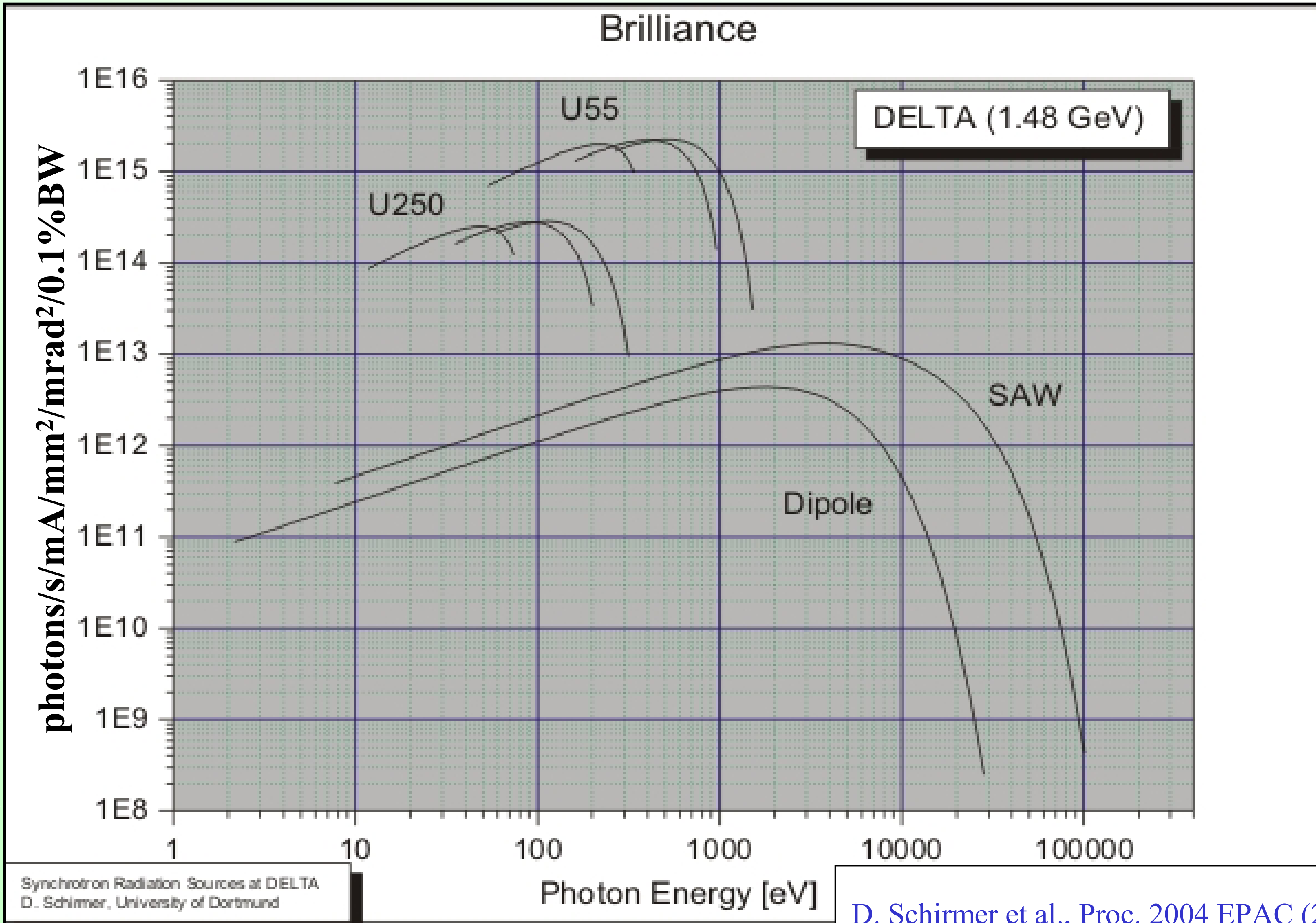
Insertion devices @ DELTA

U55 permanent magnet undulator
ACCEL Instruments

SAW superconducting 5.3 T asymmetric multipole wiggler
ACCEL Instruments

U250 electromagnetic undulator
in house fabrication, also acting as FEL undulator





D. Schirmer et al., Proc. 2004 EPAC (2004) 2296

Superconducting 5.3 T asymmetric multipole wiggler @ DELTA

Parameter	Dipole	Wiggler (sym. mode)	Wiggler (asym. mode)
Magnetic field [T]	1.51	2.79	5.30
Critical current [A] @ 5T and 4.2 K			471
Number of periods		10	5
Beam stay clear [mm]	40	10	10
Horizontal opening angle θ of radiation [mrad]		± 13	± 25
Critical energie ε_C [keV]	2.26	4.18	7.93
Critical wavelength λ_C [Å]	5.49	2.97	1.56
Power P [W/mrad]	4.30	166.89	317.04
Vertical integrated photon flux @ ε_C [photons/s/mrad/0.1%BW]	$4.61 \cdot 10^{12}$	$6.86 \cdot 10^{13}$	$2.16 \cdot 10^{13}$
Type of radiation (off-plane)	elliptical polarised	linear polarised high intensity	great fraction of circular polarisation at high intensity
Liquid He consumption			~ 12 liters/day with beam

serving 3 hard-X-ray beamlines

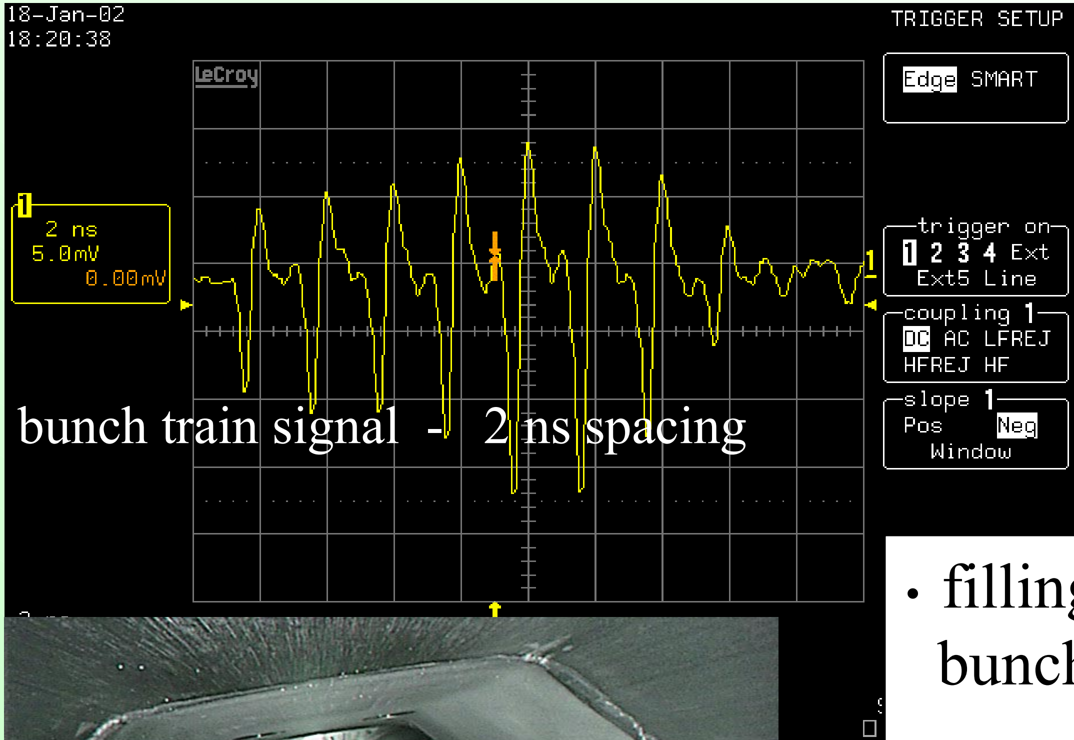
D. Schirmer, Int. J. Mod. Phys. 2B (1993) 644

first superconducting multpole wiggler worldwide

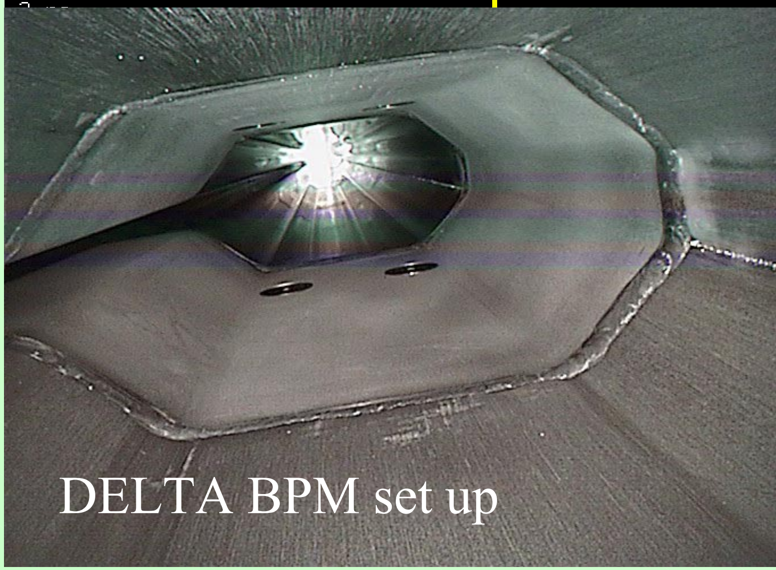
SR-Beamlines @ DELTA

Beamline	Experiments	Photon energy	Present status
BL 2 / dipole (ISAS)	X-ray fluorescence spectroscopy	white beam	user operation
BL 5 / U250 (FZ Jülich)	photoemission, spectroscopy	5 - 400 eV	user operation
BL 8 / SAW 3 (U Wuppertal)	material science, EXAFS, diffraction	2 - 30 keV	under commisioning operational end 2006
BL 9 / SAW 2 (U Dortmund)	grazing incidence X-ray diffraction, SAXS, XSW, inelastic X-ray scattering	4 - 30 keV	user operation **Wiggler Beamlines**
BL 10 / SAW 1 (U NRW)	EXAFS	4 - 30 keV	under construction operational 2007
BL 11 / U55 (U Dortmund)	photoemission spectroscopy, photoelectron diffraction	55 - 1500 eV	user operation
BL 12 / dipole (U Dortmund)	valence band spectroscopy, Fermi-surface mapping	6 – 200 eV	under commissioning operational end 2006

Fast Beam and Instability Investigation

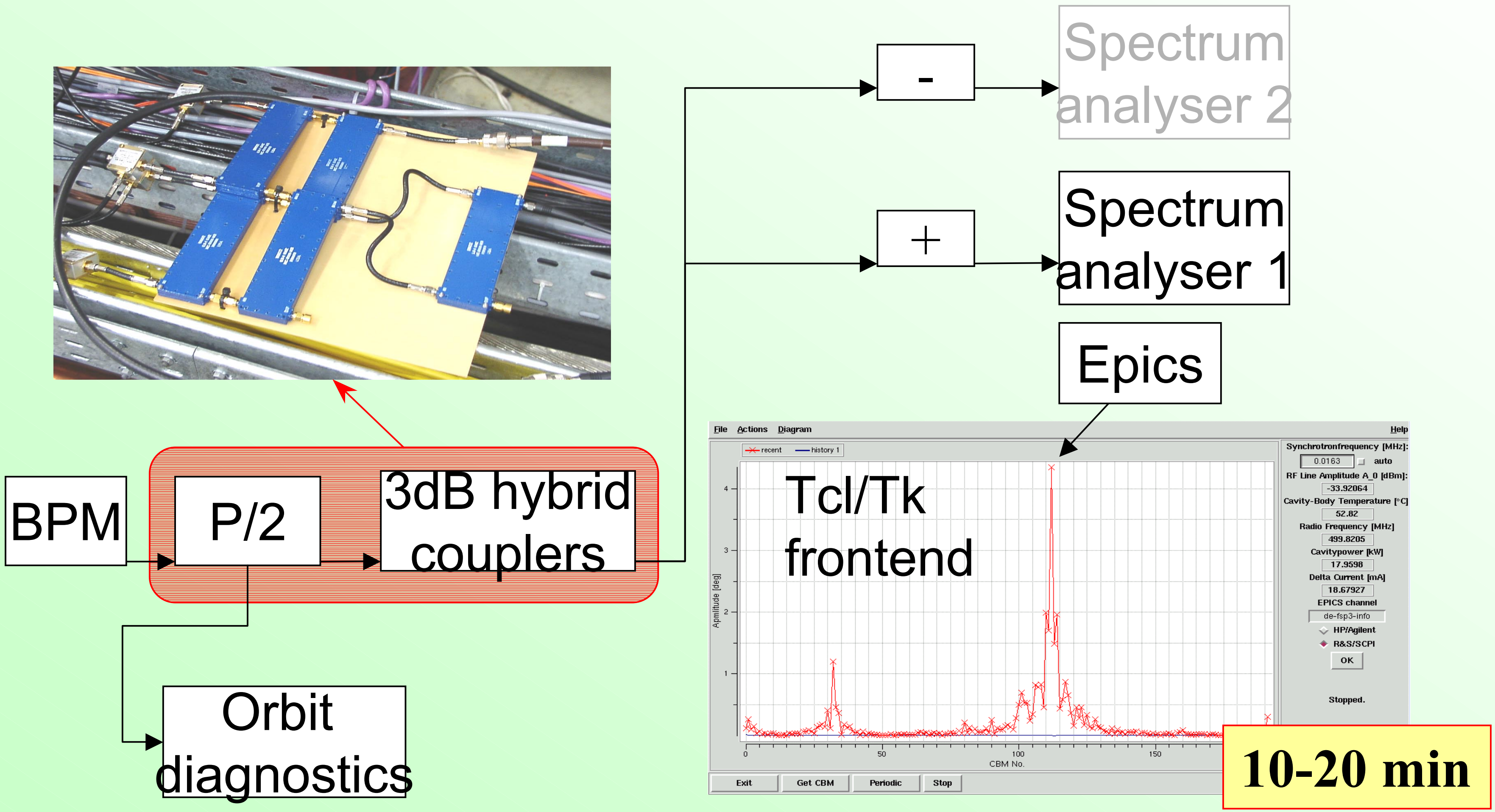


bunch train signal - 2 ns spacing

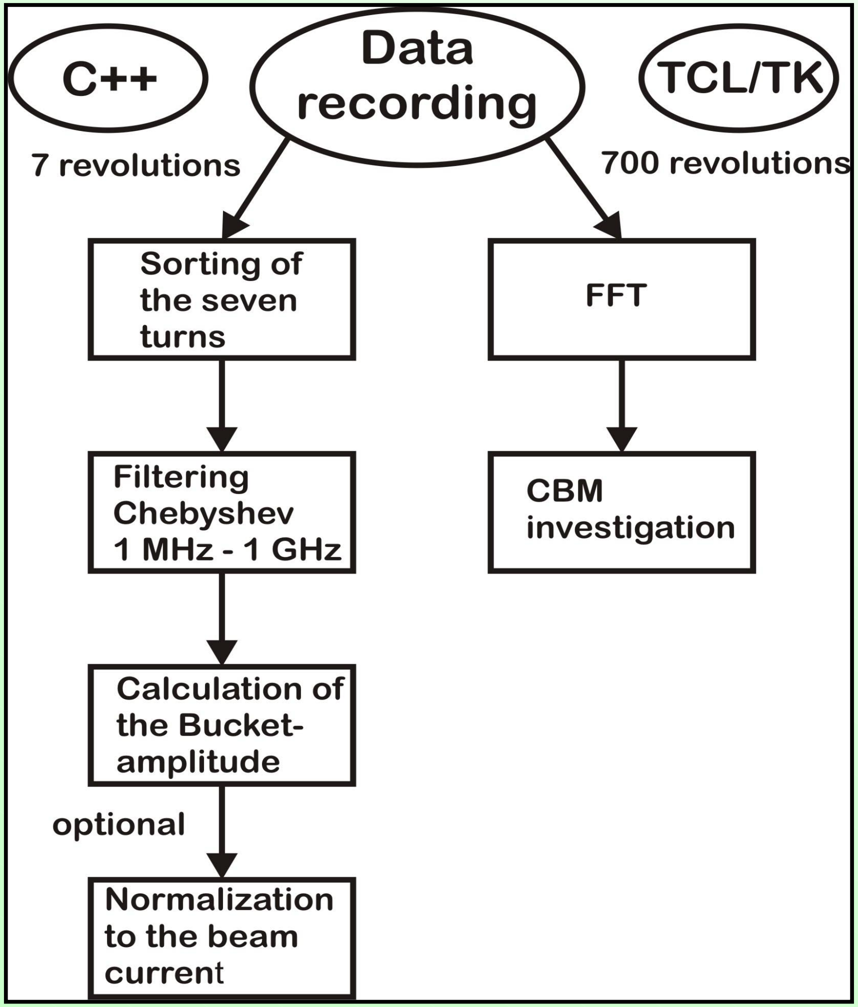

DELTA BPM set up

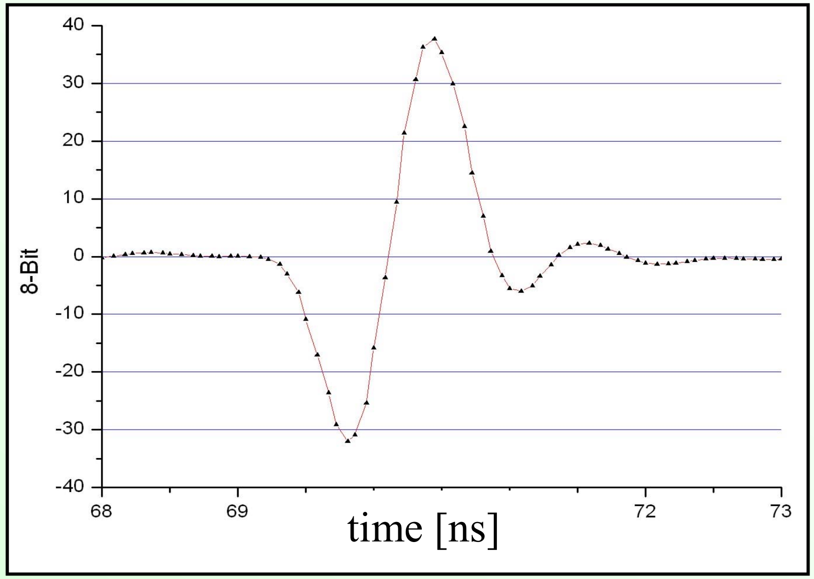
- filling pattern measurement bunch by bunch, turn by turn
- postmortem analysis of beam loss due to coupled bunch mode CBM instabilities
- real time longitudinal CBM instability detection

so far: CBM-detection via synchrotron side band analysis



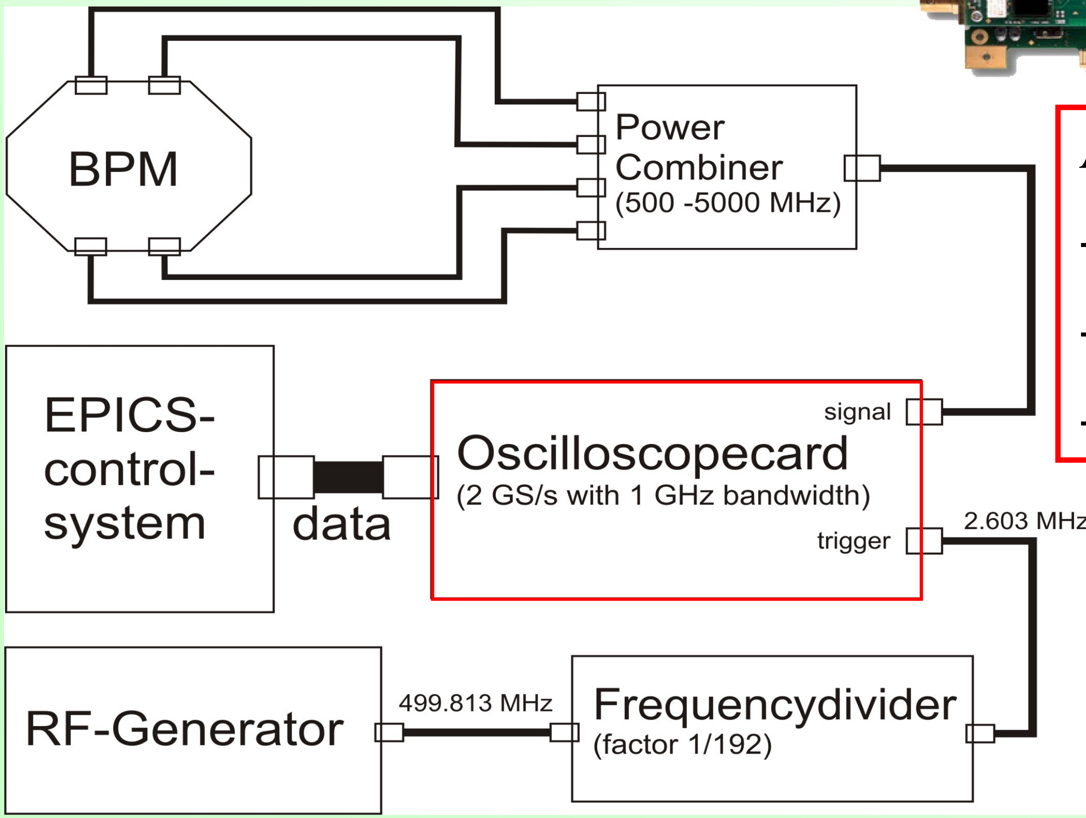
new: Bunch by Bunch Beam Analysis

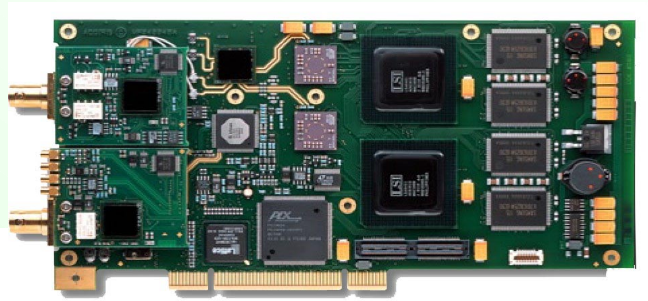




- sampling of BPM sum signal at 2 GS/s, bandwith 1 GHz
- oversampling technique using shift between RF frequency and sampling frequency

Set up



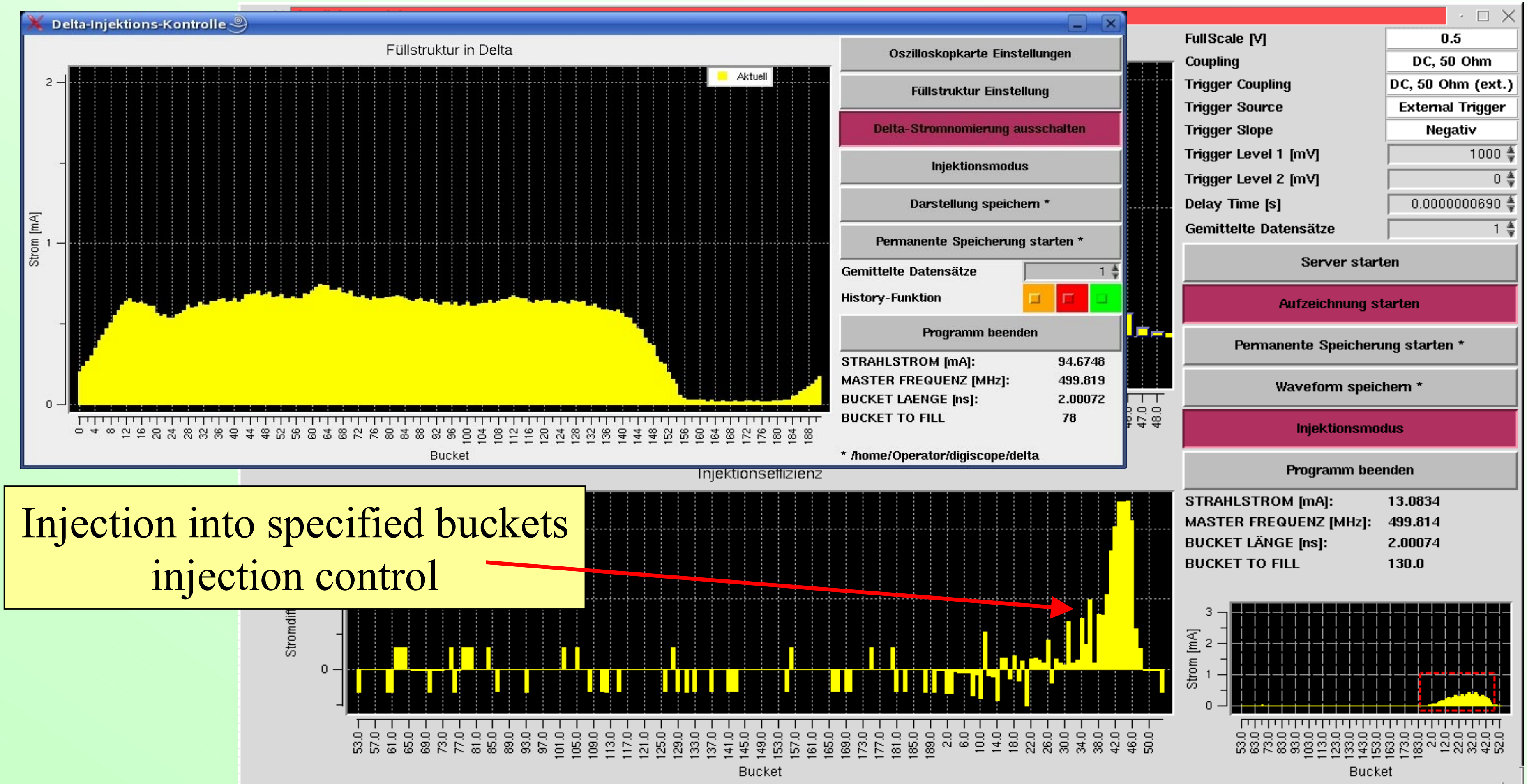


Acqiris DP214

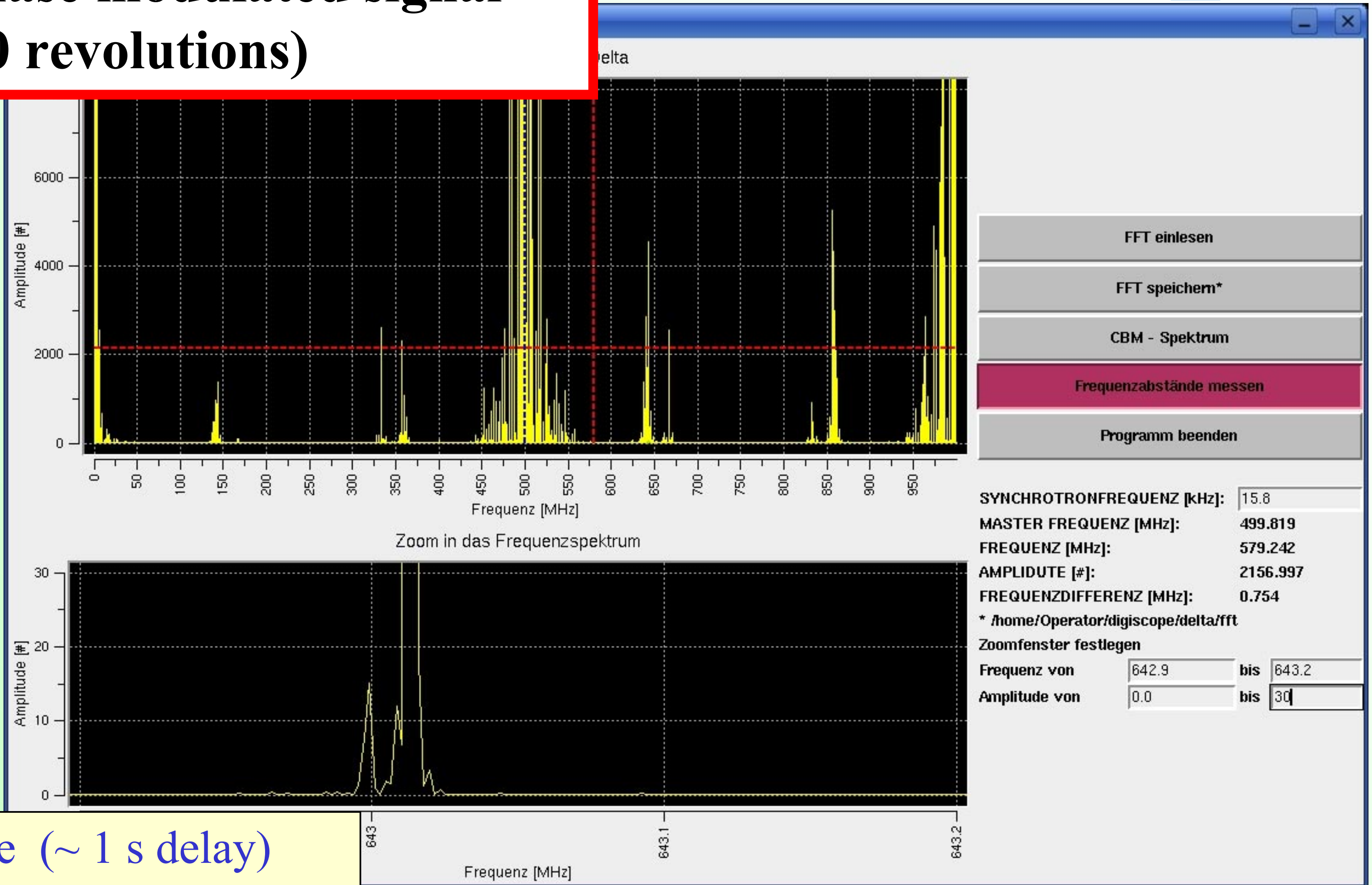
- 2Gs/s sampling rate
- 8 Bit resolution
- 1Ghz bandwidth

J. Kettler et al., Proc. 2006 EPAC (2006) 1034

Filling Pattern from bunch by bunch signal (averaged over 7 turns)



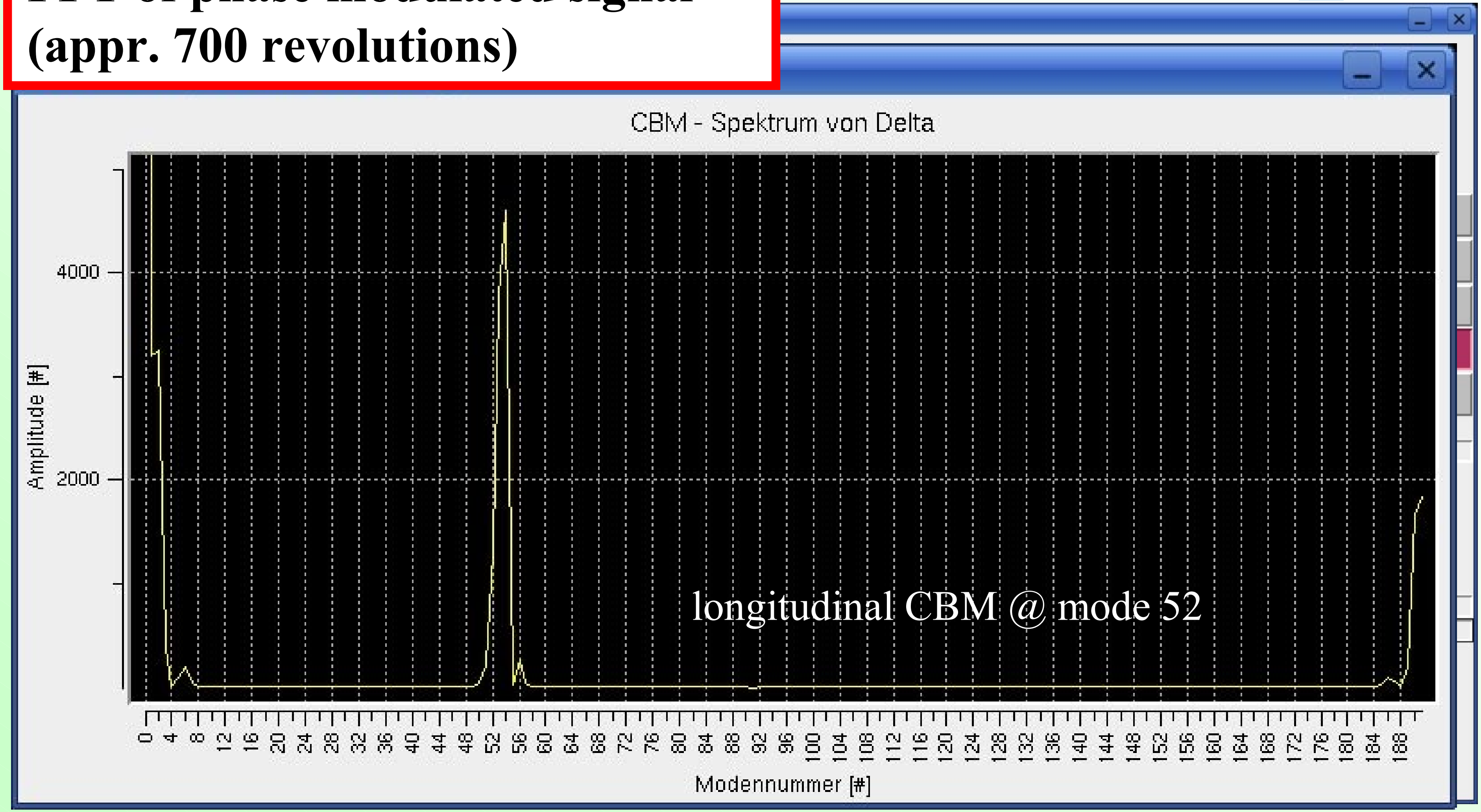
FFT of phase modulated signal (appr. 700 revolutions)



real time (~ 1 s delay)

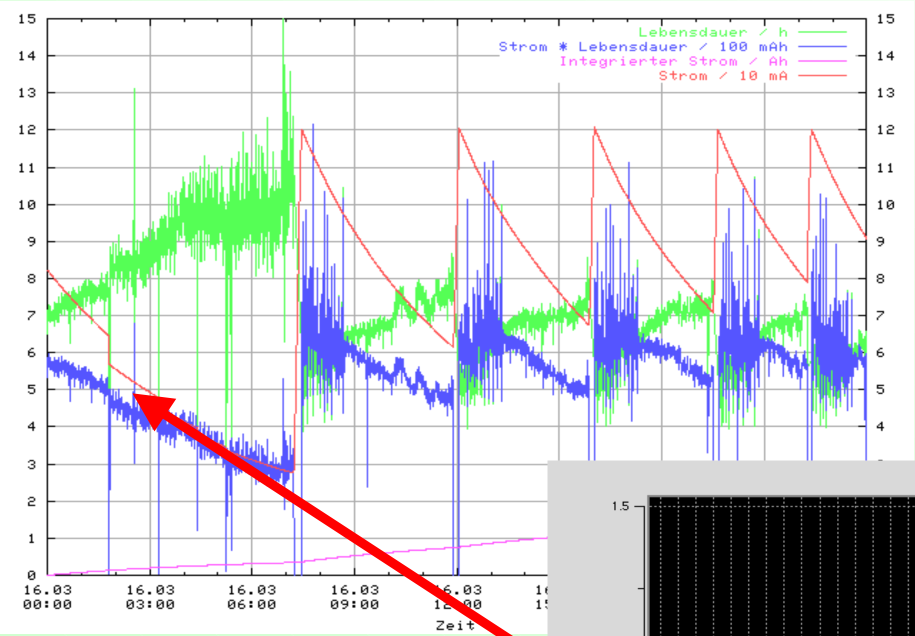
J. Kettler et al., Proc. 2006 EPAC (2006) 1034

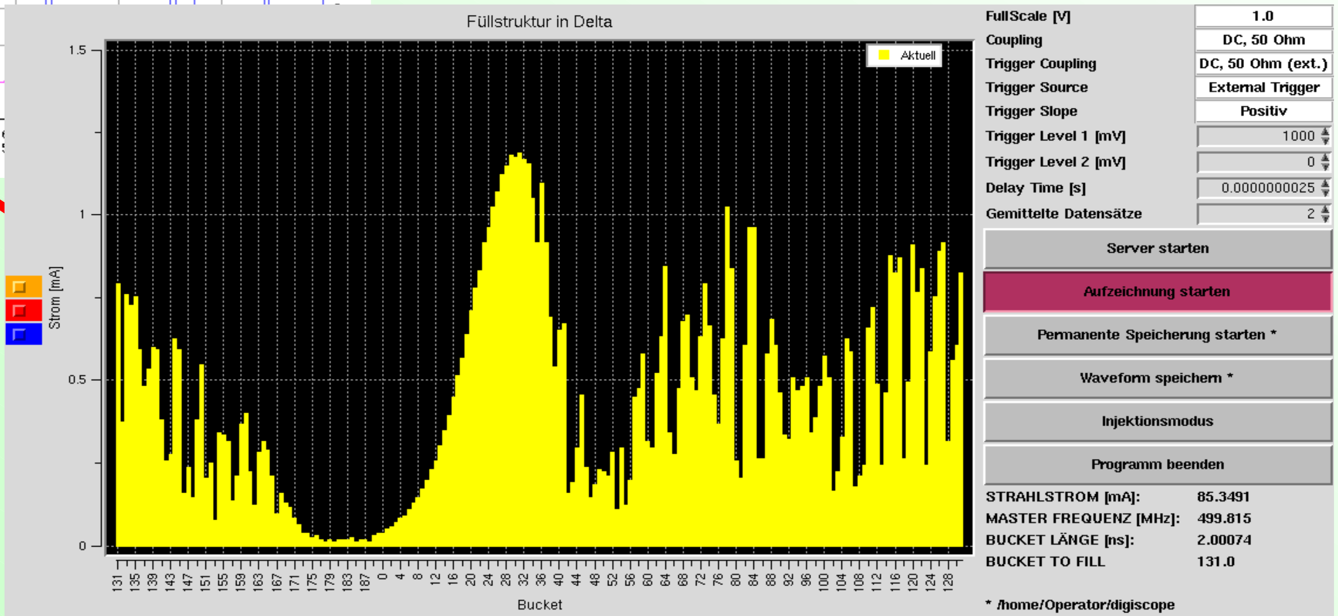
FFT of phase modulated signal (appr. 700 revolutions)



J. Kettler et al., Proc. 2006 EPAC (2006) 1034

filling pattern analysis after partial beam loss induced by longitudinal CBM

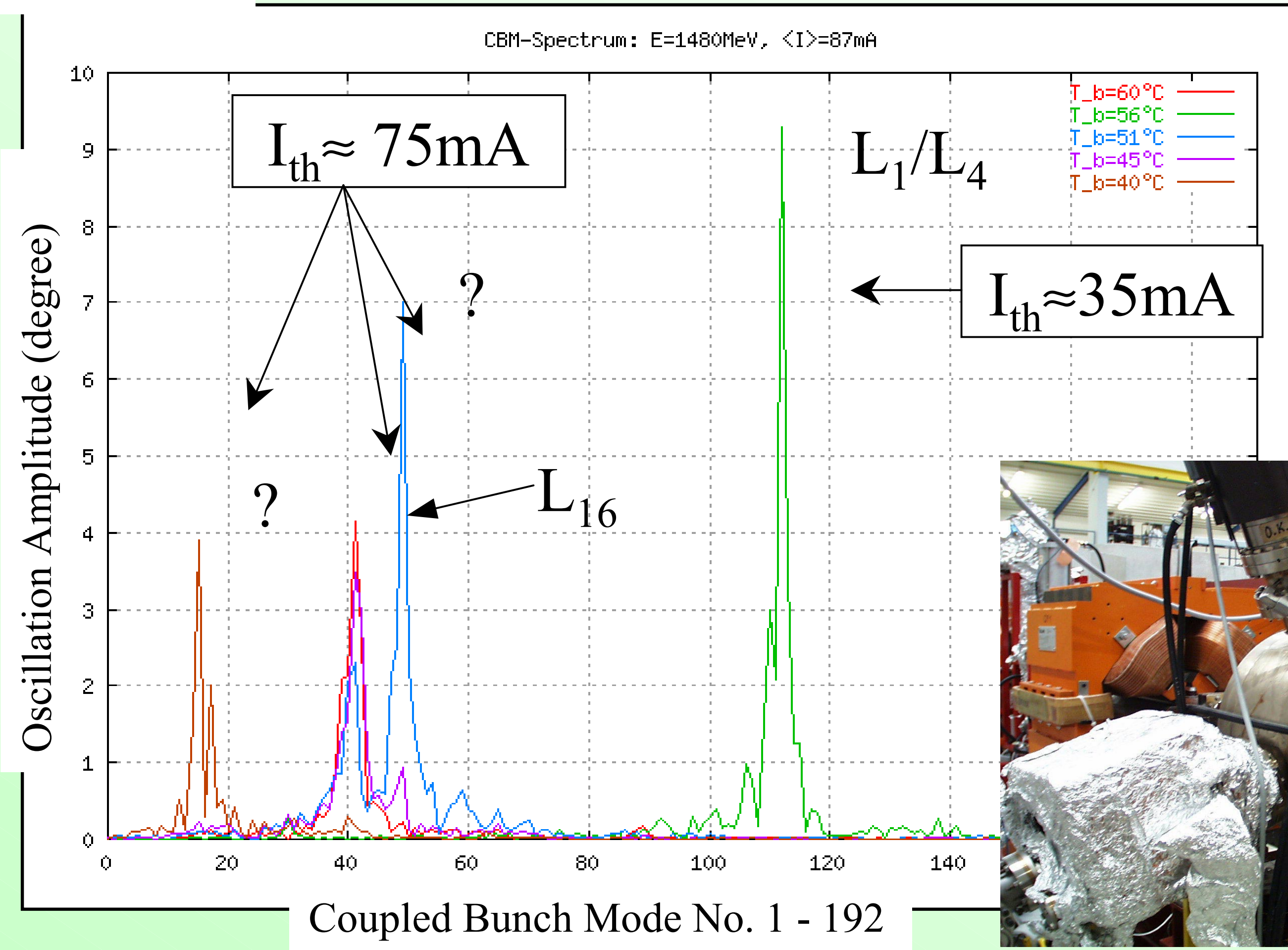


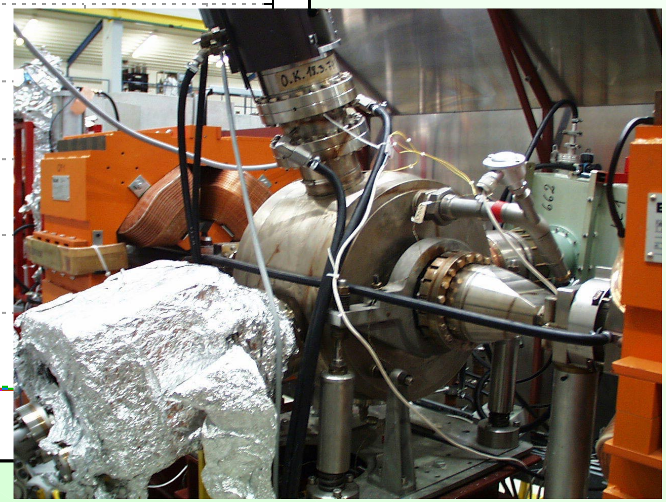


CBM Investigations @ DELTA
DORIS type cavity

E= 1.5 GeV

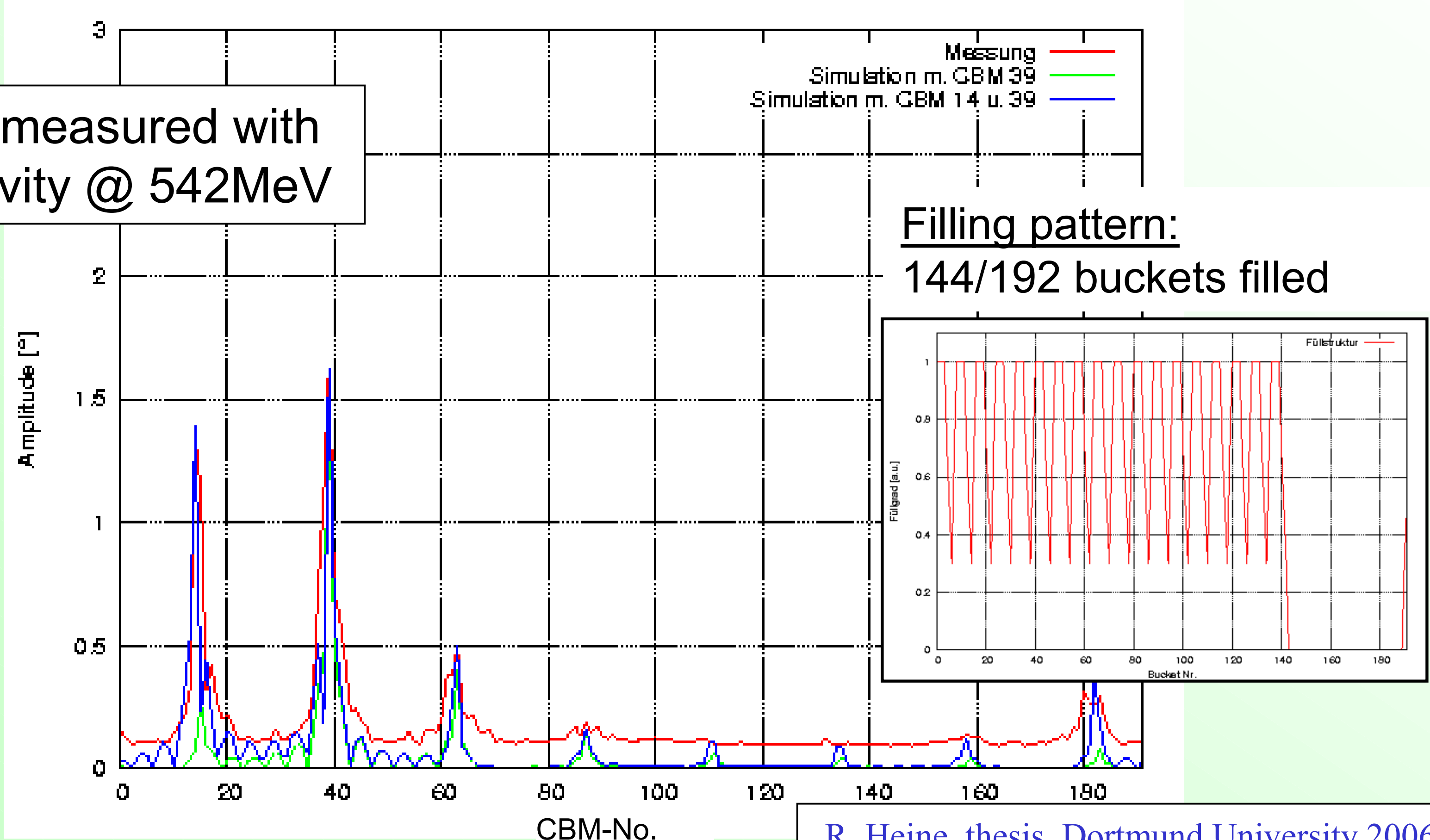
T = 40-60 °C
I= 87mA





full understanding of filling pattern induced mode spectra

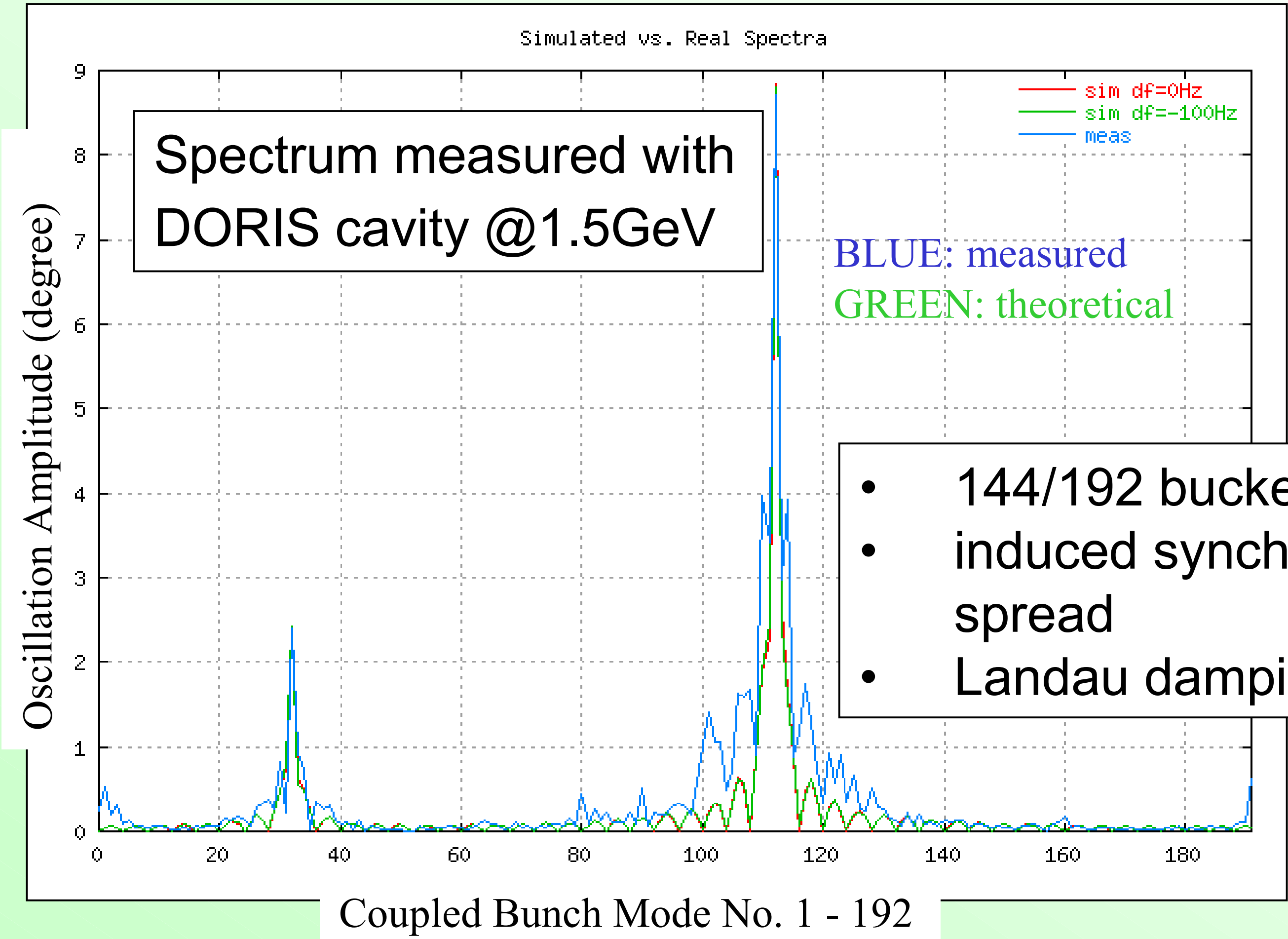
Spectrum measured with DORIS cavity @ 542MeV



Filling pattern:
144/192 buckets filled

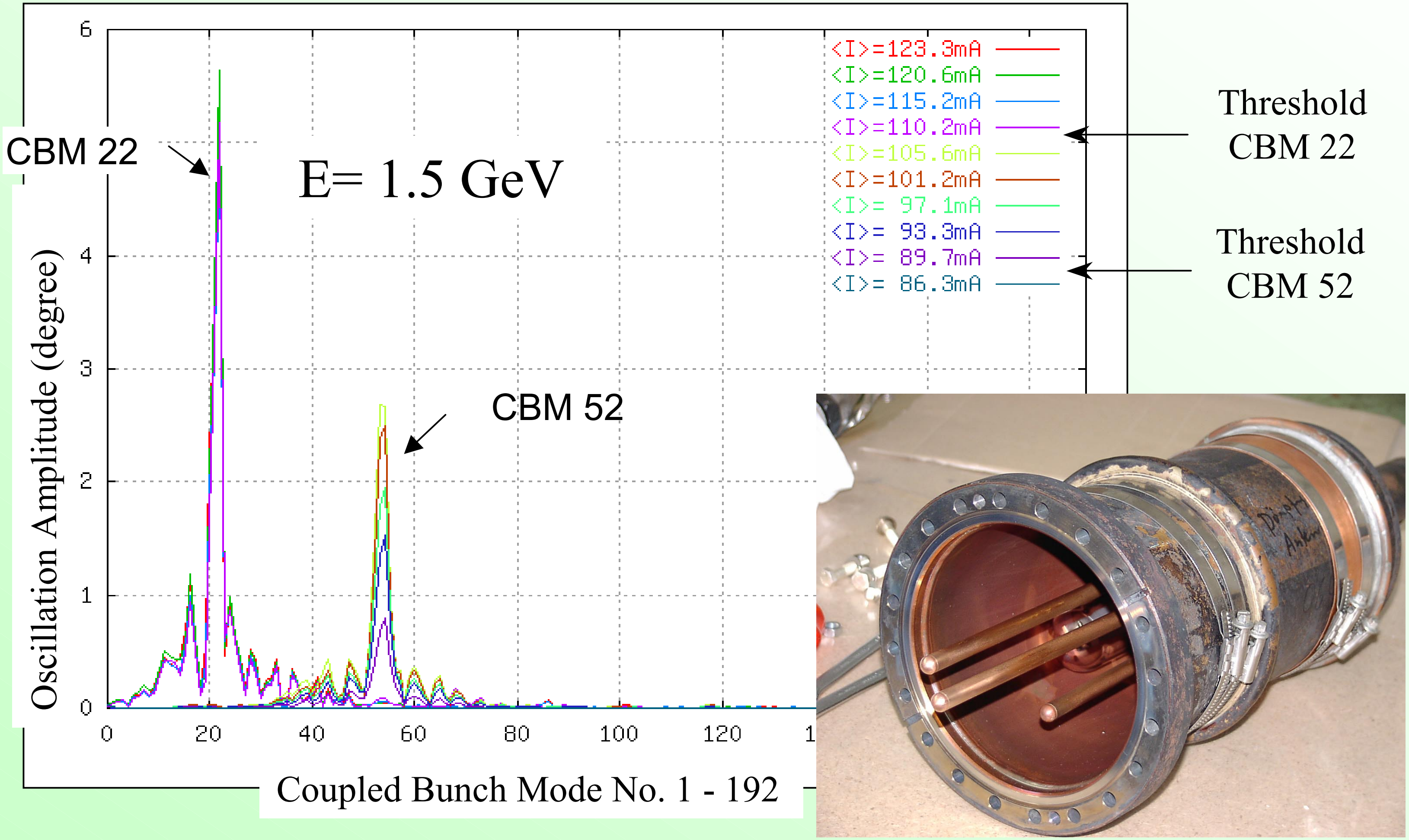
R. Heine, thesis, Dortmund University 2006

another comparision with a simulated spectrum

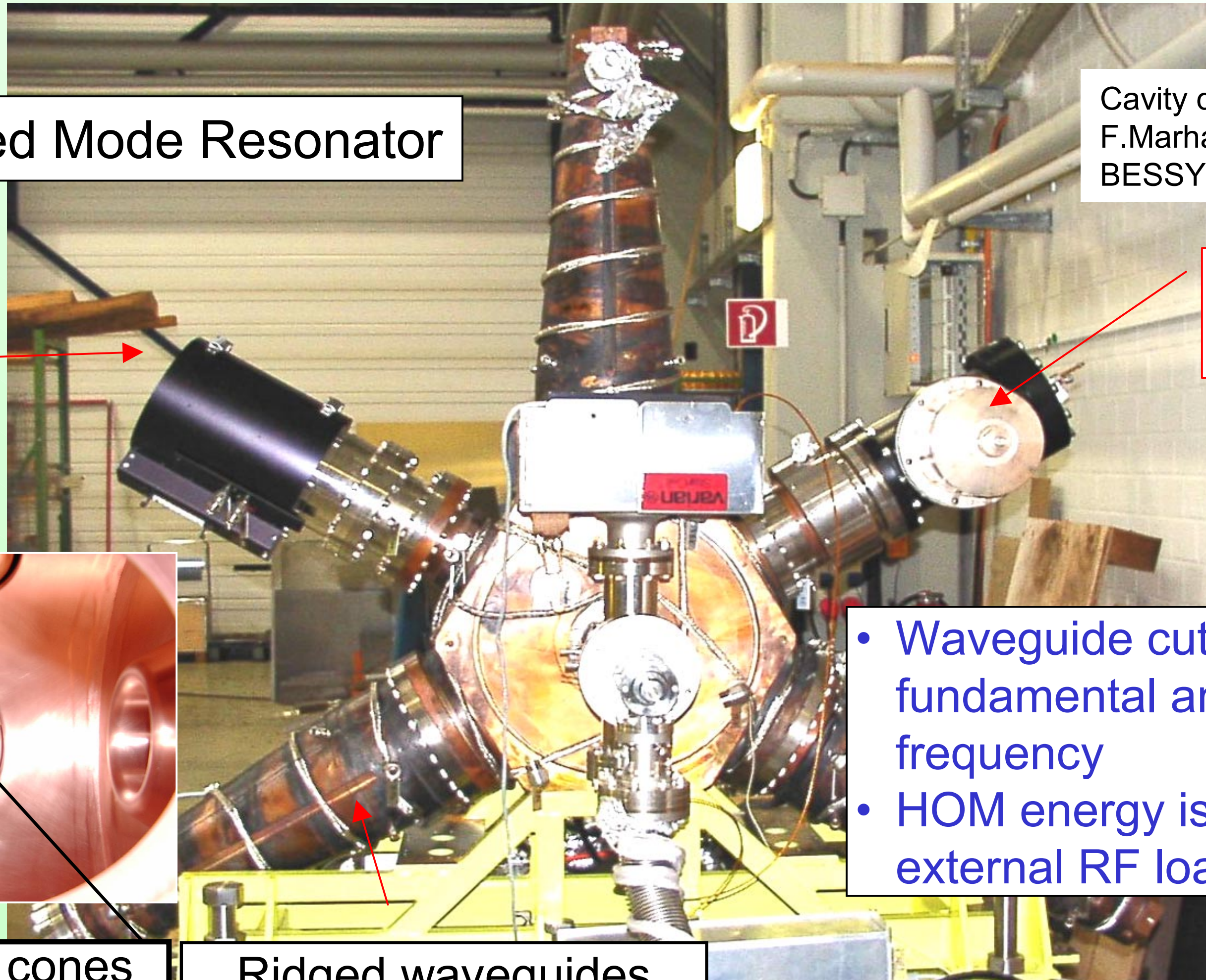


- 144/192 buckets filled
- induced synchr. frequency spread
- Landau damping

CBM Investigations @ DELTA
DORIS type cavity with damping antennas



The HOM-Damped EU-Cavity

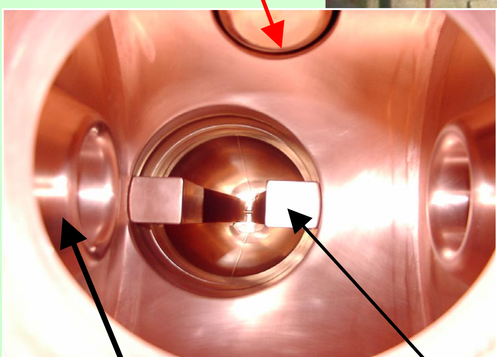


Single Trapped Mode Resonator

Cavity design:
F.Marhauser & E.Weihreter
BESSY, Berlin

RF window

Plunger

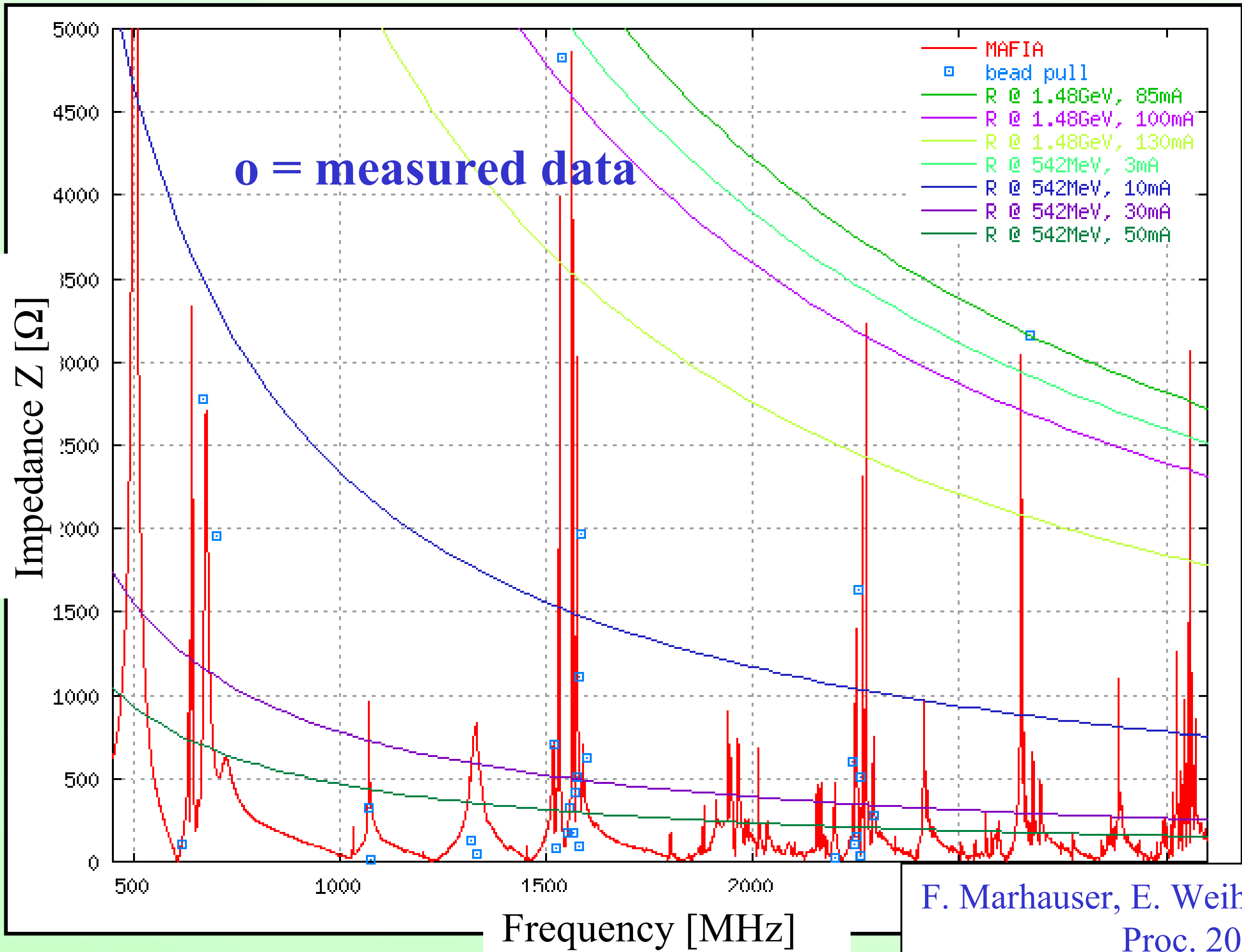


- Waveguide cut-off between fundamental and first HOM frequency
- HOM energy is dissipated in external RF loads

Nose cones

Ridged waveguides

Residual Longitudinal Impedance



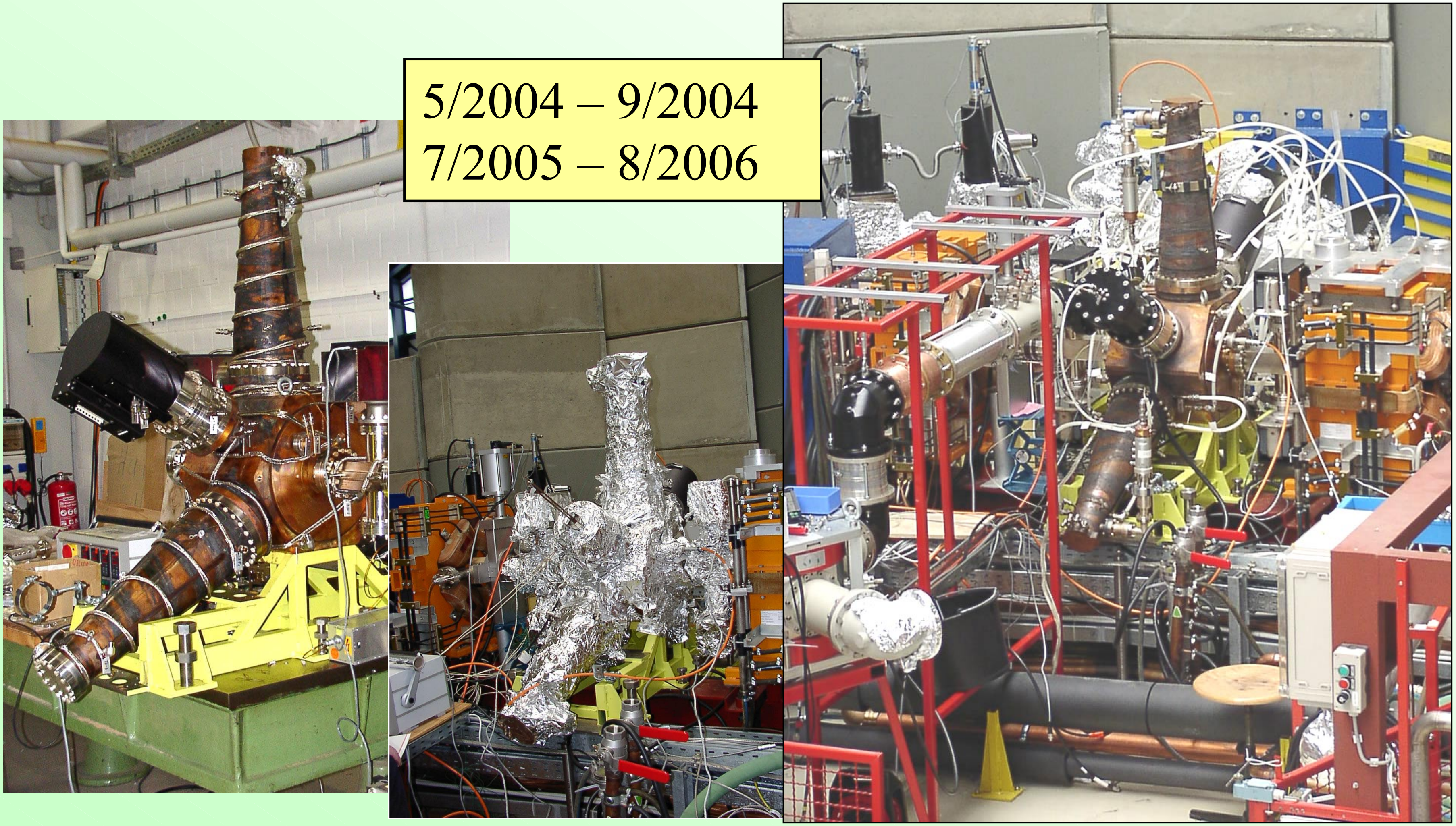
$Z_{||} < 5\ \mathrm{k}\Omega$

- complex time domain calculations for a very complex geometry
- full validation of calculations by bead-pull measurements (o)
- effective damping also of transverse Z

F. Marhauser, E. Weihreter, Proc. 2004 EPAC (2004) 979
Proc. 2002 EPAC (2002) 2172

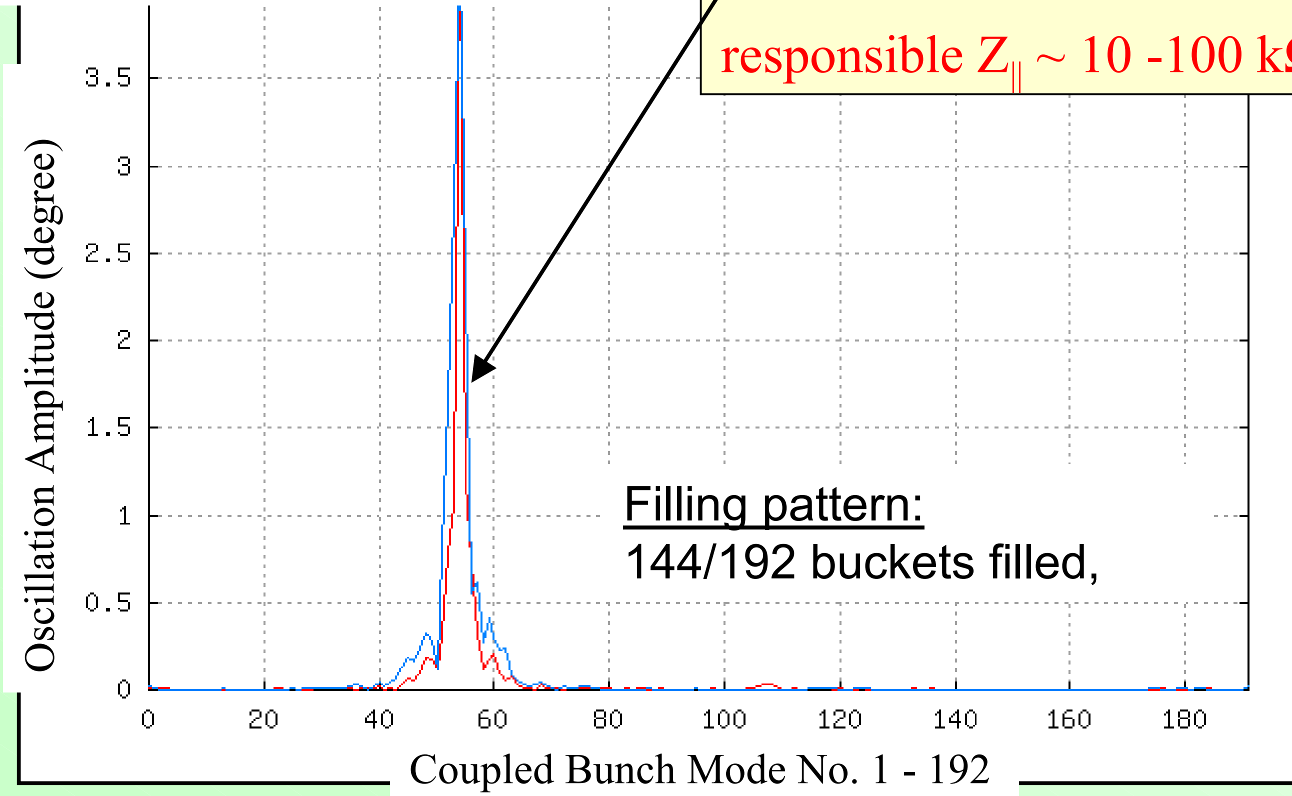
EU-Cavity Test @ DELTA

5/2004 – 9/2004
7/2005 – 8/2006



CBM Characterisation of EU-Cavity

Spectrum measured with EU cavity @1.5GeV



CBM 52 not induced by cavity, also seen with the DORIS-type cavity

responsible $Z_{\parallel}$ ~ 10 -100 kΩ

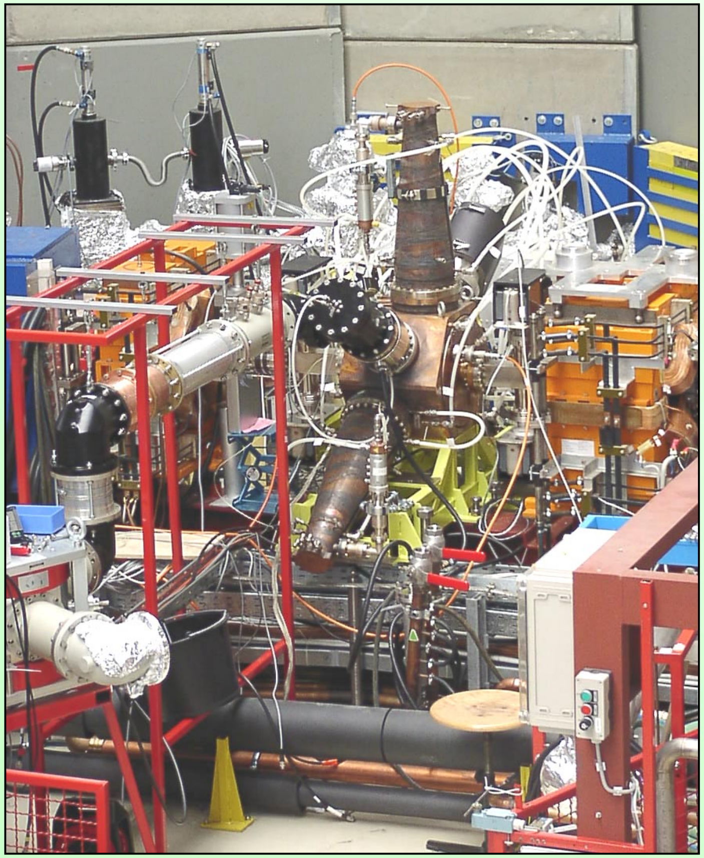
reason still unknown:

candidates:

- strip line kickers
- broken RF-contacts in bellows, valves
- resonant vacuum chambers and tapers

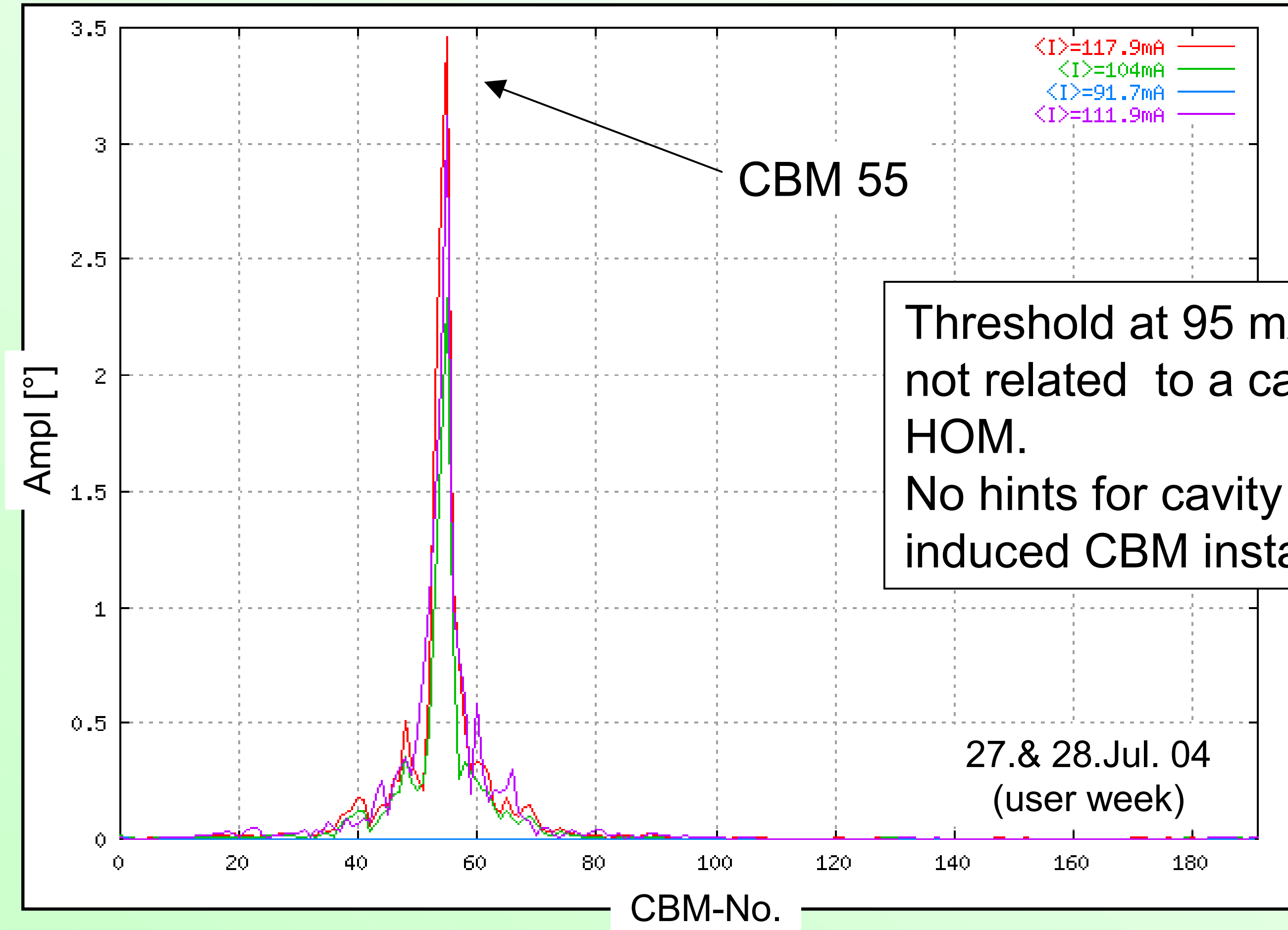
HOM-Damped Cavity Installed

1. Period 5/2004 - 9/2004



- The cavity was preconditioned up to 30 kW (thermal load, CW) at BESSY and delivered to DELTA (17.May `04).
- Reconditioning within one day (0-30 kW, 5% duty cycle) (02.Jun. `04)
- 28 kW CW were reached the next day.
- 28.Jun. `04: First beam stored with EU-cavity up to 25 mA
- 29.Jun. `04: Vacuum limited 60 mA stored
- 30.Jun. `04: 100 mA stored.
- 14.Jul. `04: 130 mA stored. (I_{max} of DELTA)
- Sep. 2004 taken out due to leakage in one HOM-damper

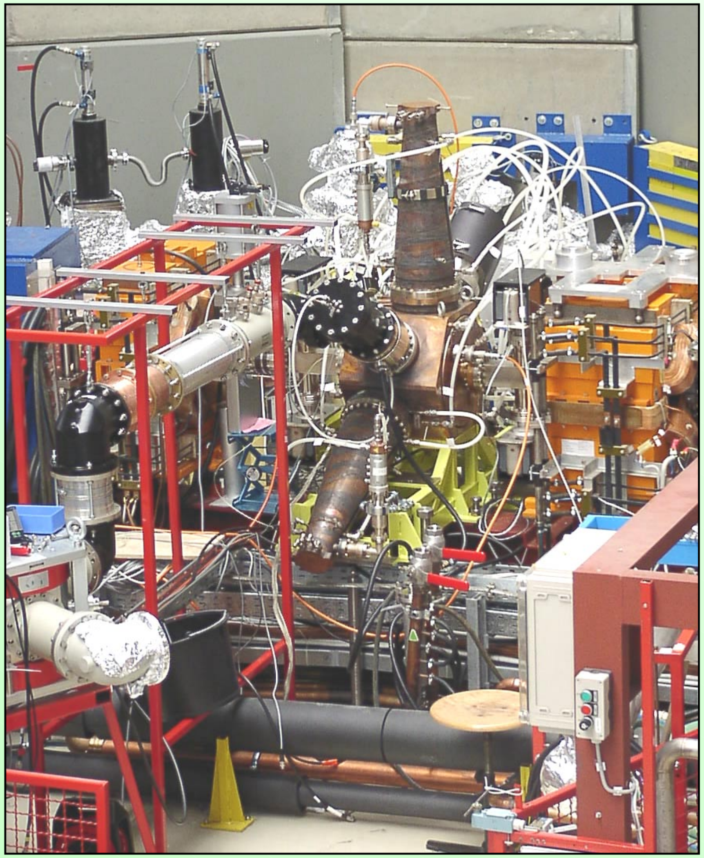
Characterisation at 1.5 GeV



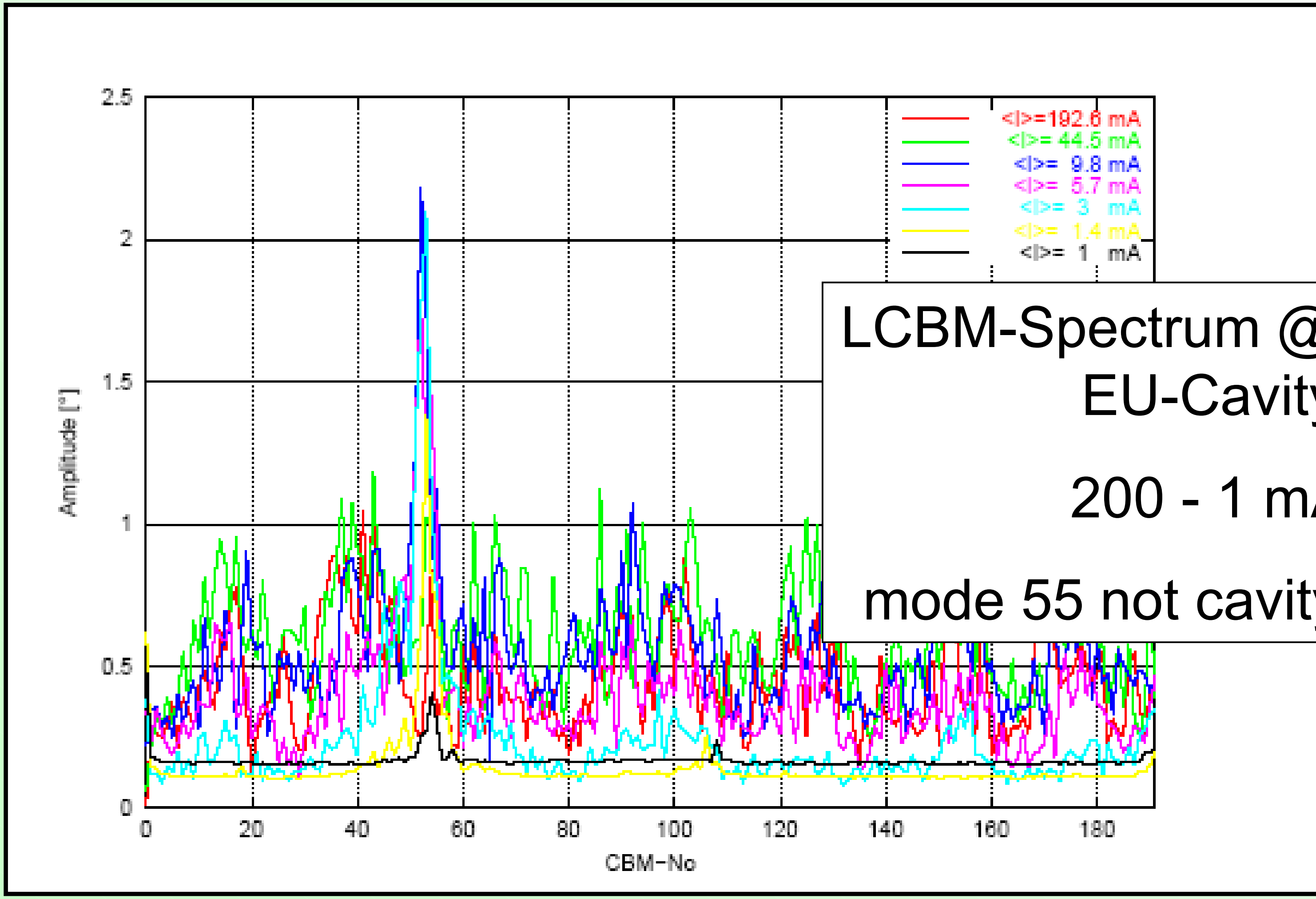
Threshold at 95 mA.
not related to a cavity HOM.
No hints for cavity induced CBM instabilities

HOM-Damped Cavity Installed

2. Period 5/2005 – 8/2006



- standard operation as single DELTA cavity
- beam characterisation @ 1.5 and 0.542 GeV
- look to cavity impedance via HOM-damper signal
- no hints for CBM-instabilities caused by the cavity
- LCBM at mode 55 detected with threshold currents ~90 mA (1.5 GeV) down to 1 mA (542 MeV). Reason for instability not found yet. Instability may hide other instabilities caused by cavity (impedance ~ 10 -100 kW). But no hints.
- Loss power capability of the prototype limited to 20 kW due to non sufficient RF contacts between HOM-dampers and body.
- New HOM-damper design with in vacuum ferrites will solve this problem (see presentation of E. Weihreter)



LCBM-Spectrum @ 542 MeV
EU-Cavity

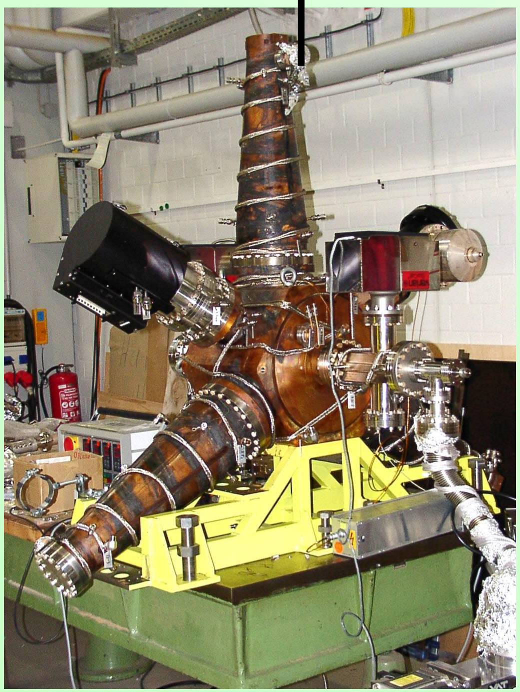
200 - 1 mA

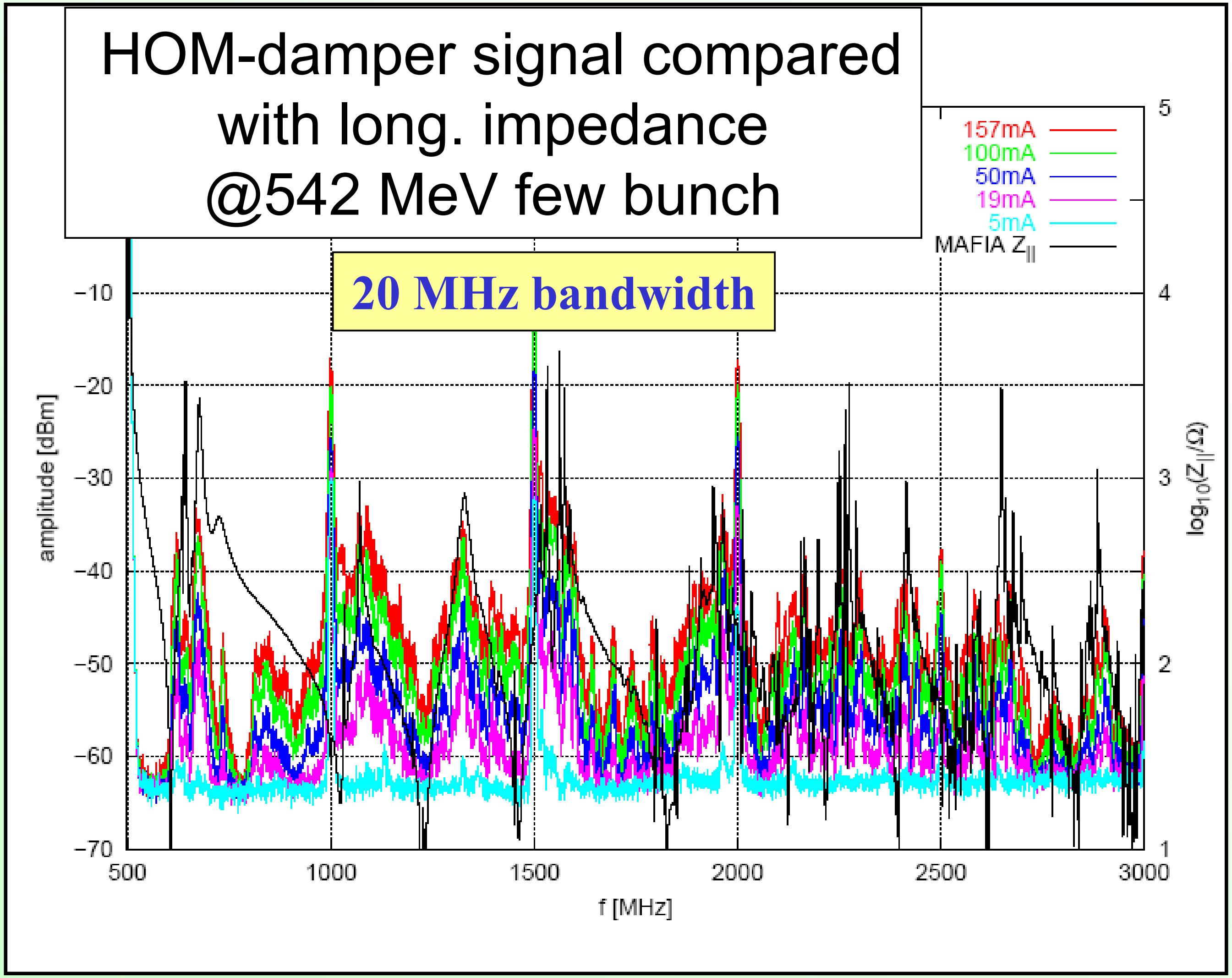
mode 55 not cavity induced

spectrum analyser

$U(\omega) = Z(\omega)\, I(\omega)$

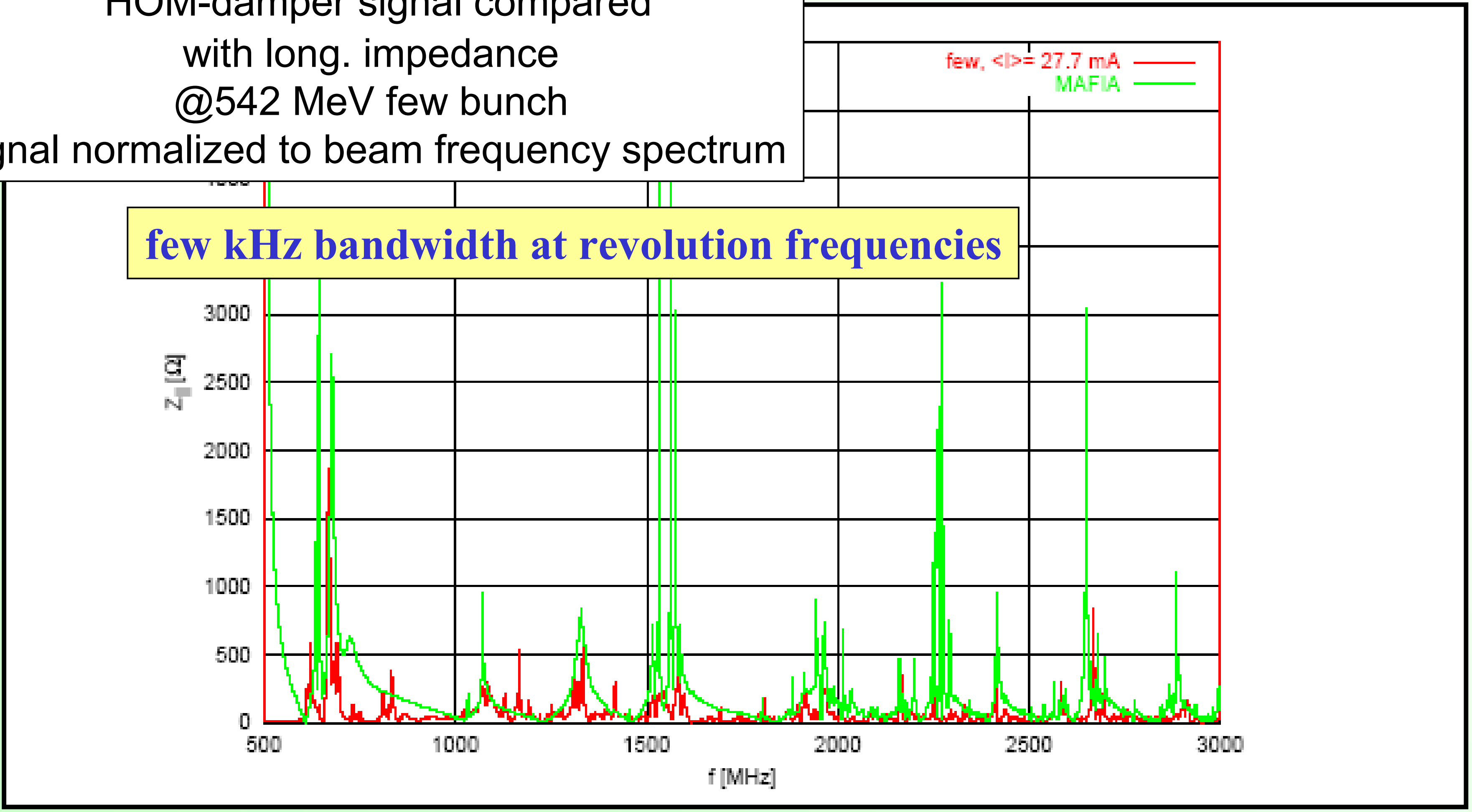
30 dB attenuator





HOM-damper signal compared
with long. impedance
@542 MeV few bunch
signal normalized to beam frequency spectrum

few kHz bandwidth at revolution frequencies



Summary

- DELTA is operating 3000 h/a with an availability of ~ 90%...
- ..... within a wide range of photon energies (eV – 30 keV).
- DELTA exhibits longitudinal CBM above ~90 mA. Source of impedance (10 – 100 kΩ) not found yet.
- Development of a fast broadband instability monitor.
- The EU-HOM-Damped-Cavity has been tested with beam at 1.5 GeV and 524 MeV for more than one year. Prototype limited to 20 kW cavity loss. No cavity induced instabilities found.
- The cavity impedance can be deduced from the HOM-signal (first steps done, no complete understanding however)

Thanks for the Attention

Acknowledgments

EU-cavity collaboration
colleagues from:
BESSY, Daresbury
CLRC, MaxLab, NTHU

**DELTA machine
and accelerator physics
group**

Help from
colleagues from
ESRF, ALBA, SLS