Initial Commissioning Experience with the Superconducting RF Photoinjector at ELBE

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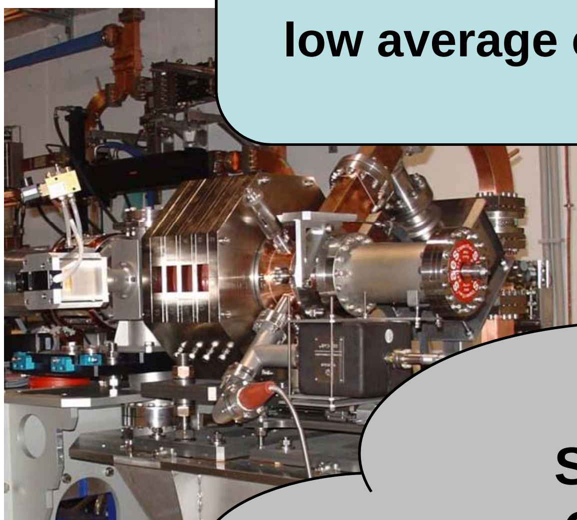
for the BESSY-DESY-FZD-MBI collaboration

Bundesministerium für Bildung und Forschung

30th International Free Electron Laser Conference, Gyeongju, Korea, 2008

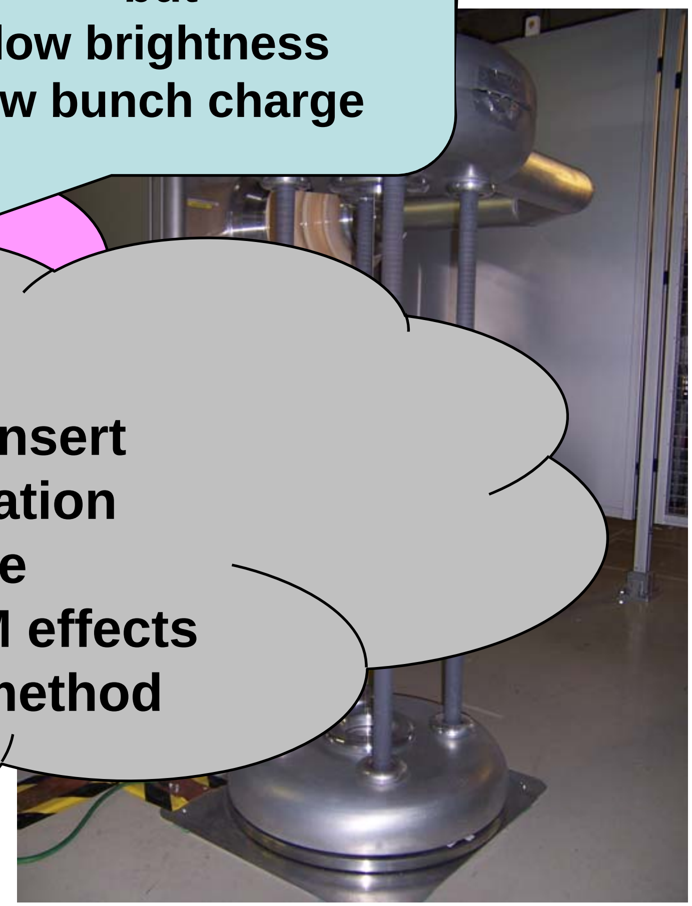
Int. FEL Community



NC RF photogun
highest brightness
but
low average current

high
4th
ligh

Radiation Source ELBE



thermionic Gun
CW operation
but
low brightness
low bunch charge

NEW CHALLANGES
SC Cavity Design with Cathode Insert
Cavity Degradation during Operation
Choice of Photo cathode type
Coupling RF power in cavity & HOM effects
emittance growth compensation method

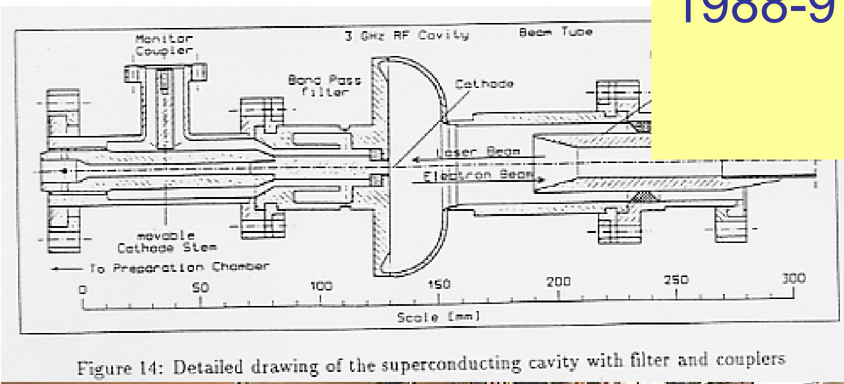
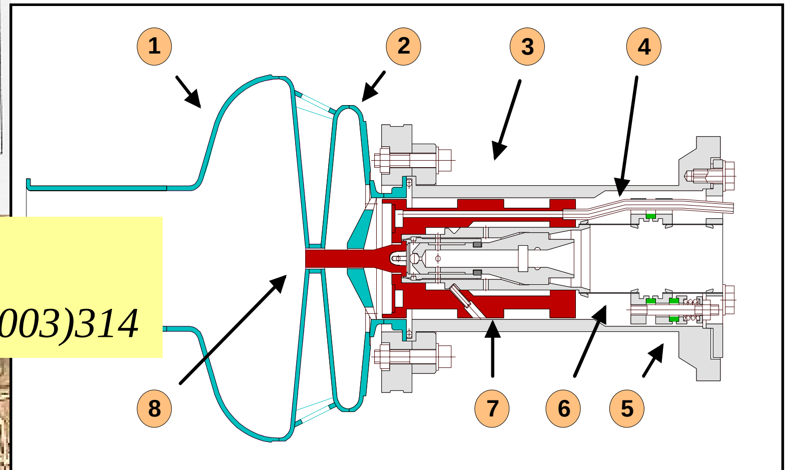


Figure 14: Detailed drawing of the superconducting cavity with filter and couplers

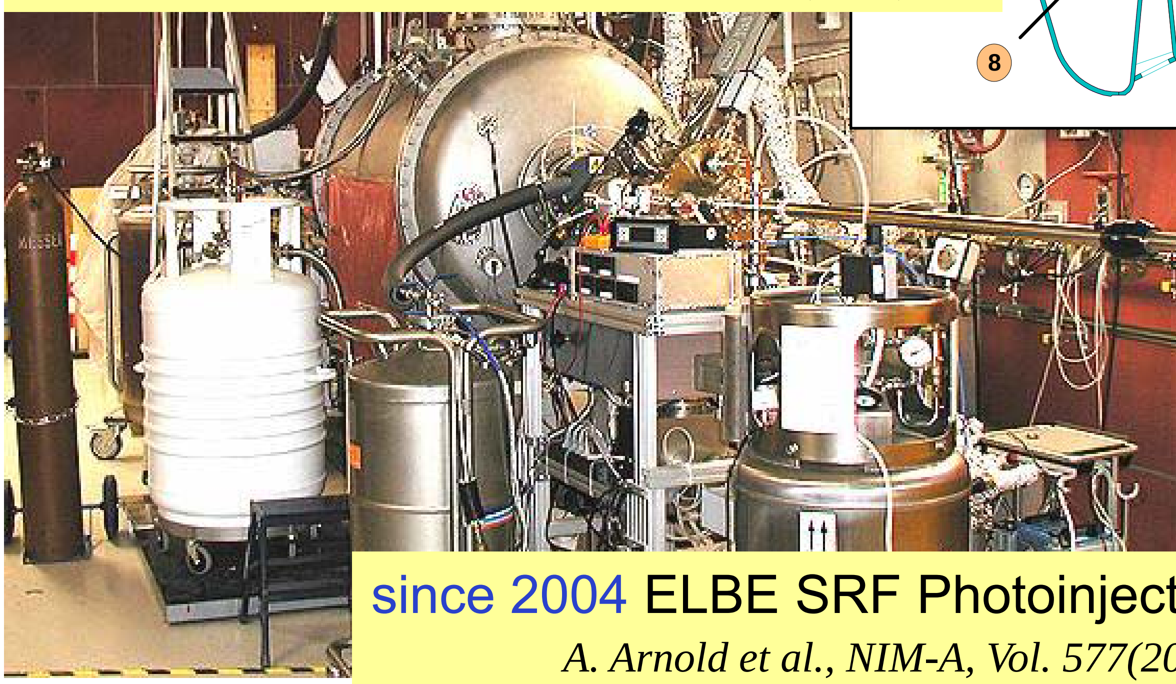
1988-91 proposal & first experiment

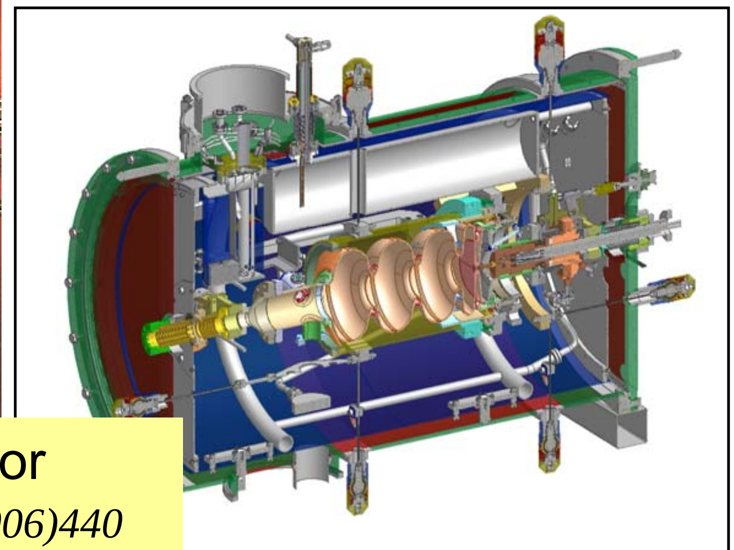
A. Michalke, PhD Thesis, WUB-DIS 92-5 Univ. Wuppertal, 1992



2002 first beam from a SRF gun

D. Janssen et al., NIM-A, Vol. 507(2003)314



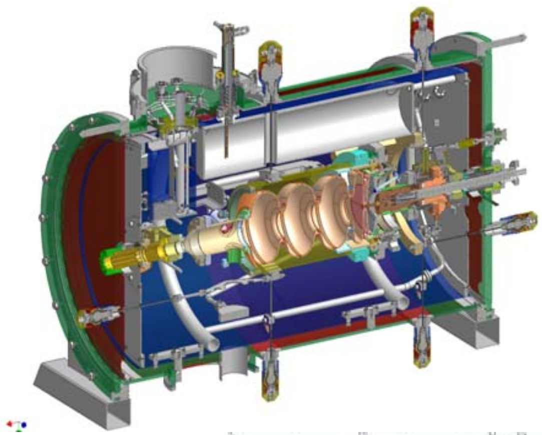


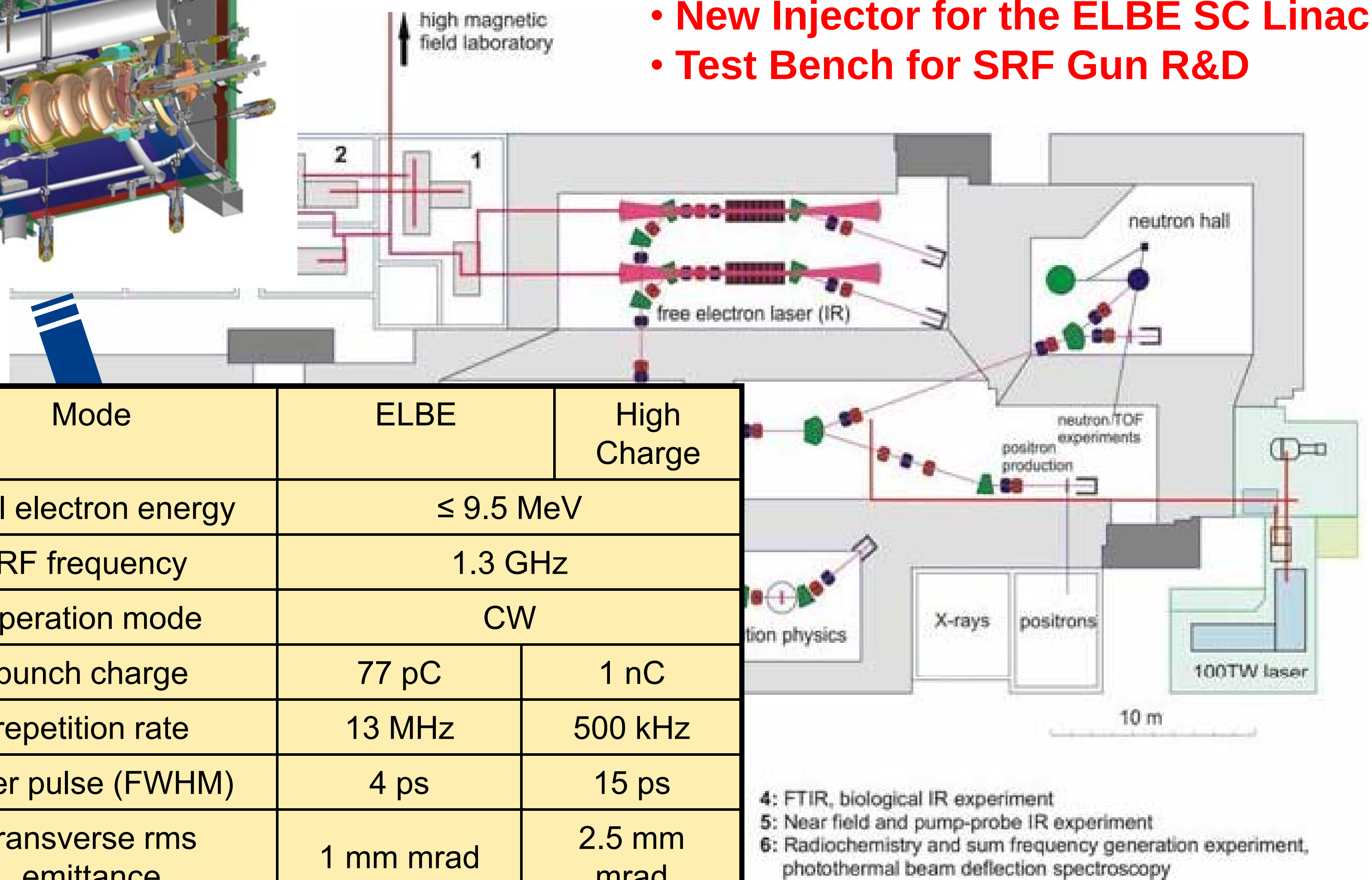
since 2004 ELBE SRF Photoinjector

A. Arnold et al., NIM-A, Vol. 577(2006)440

ELBE Superconducting RF Photoinjector

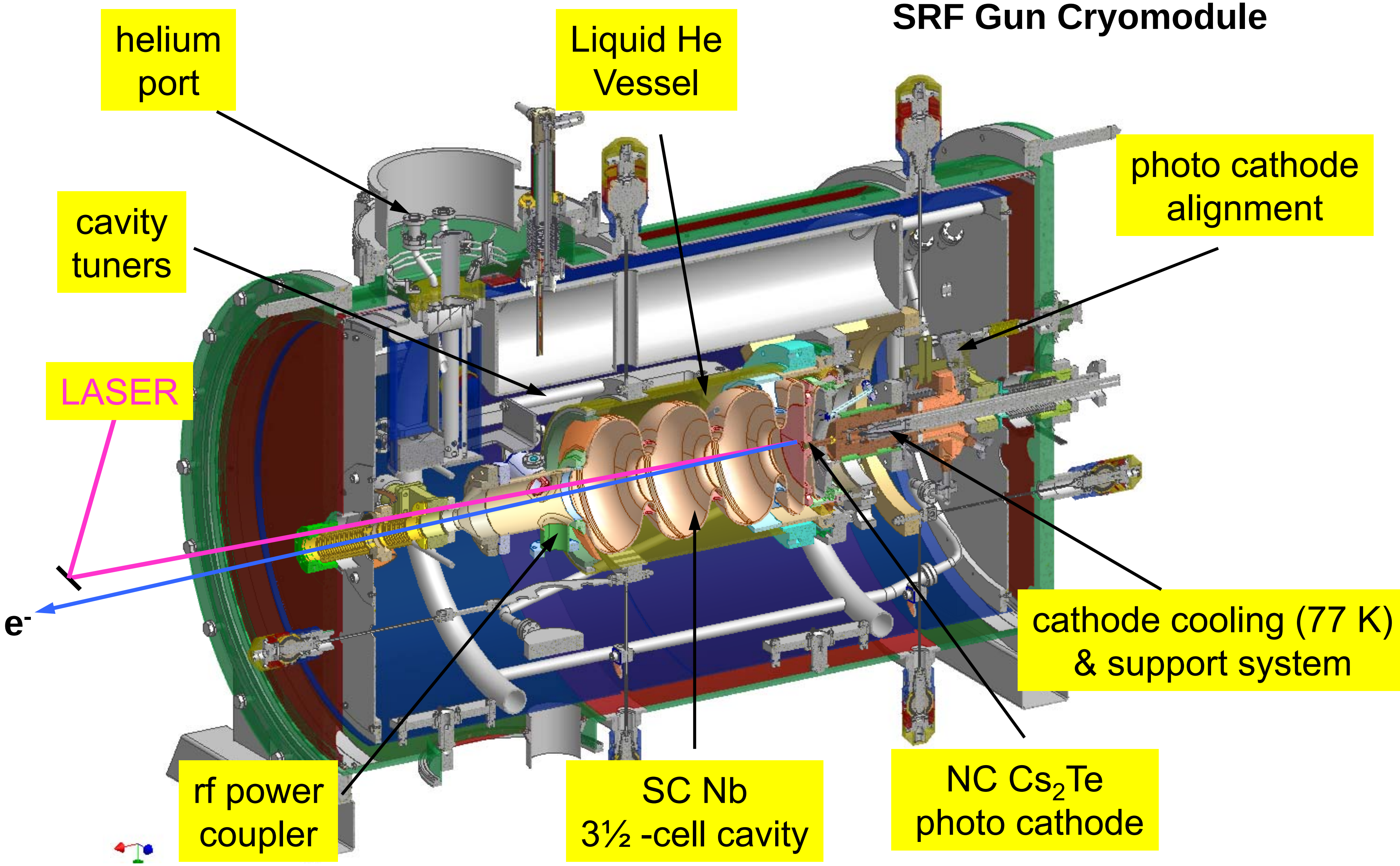
- New Injector for the ELBE SC Linac
- Test Bench for SRF Gun R&D





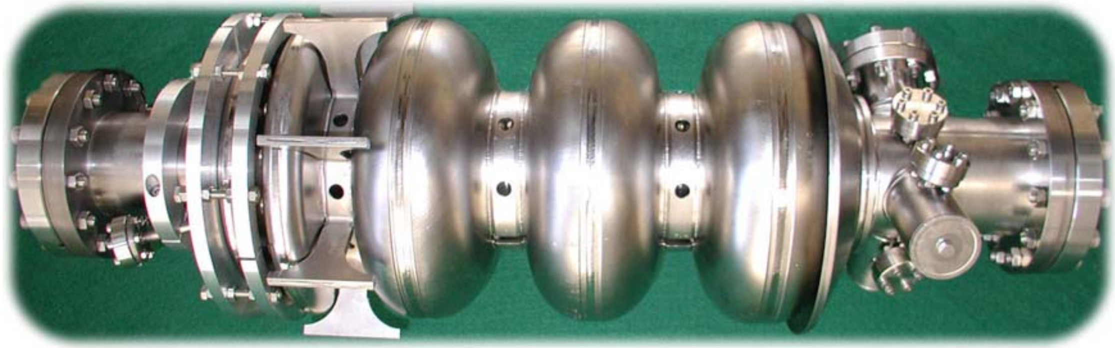
Mode	ELBE	High Charge
final electron energy	≤ 9.5 MeV	
RF frequency	1.3 GHz	
operation mode	CW	
bunch charge	77 pC	1 nC
repetition rate	13 MHz	500 kHz
laser pulse (FWHM)	4 ps	15 ps
transverse rms emittance	1 mm mrad	2.5 mm mrad
average current	1 mA	0.5 mA

SRF Gun Cryomodule

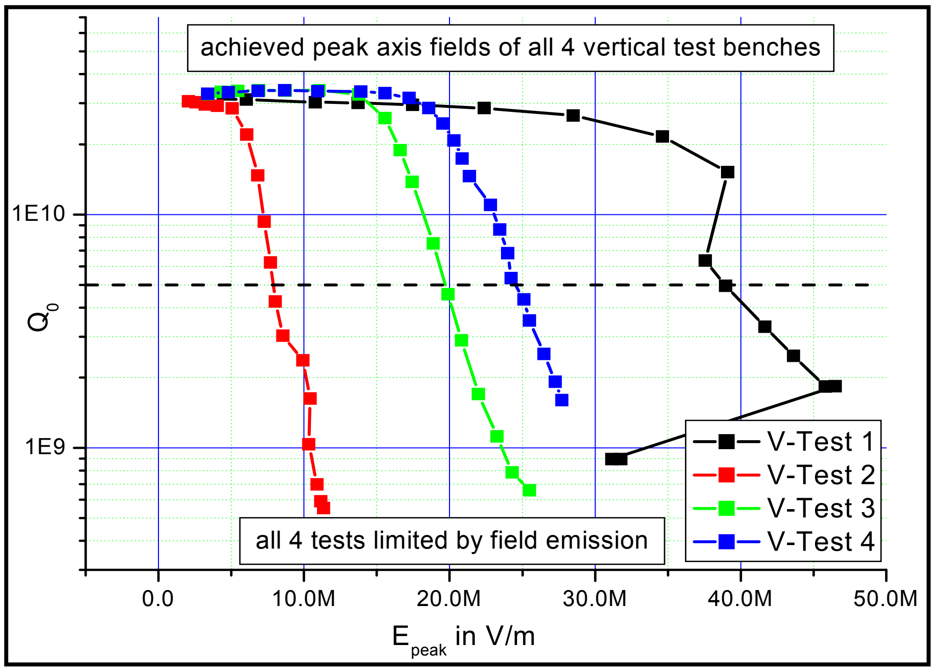


Niobium Cavity

Nb RRR 300 cavity –design values
E_{acc}= 25 MV/m in TESLA cells, Q_0=1x10^{10}
110 mT maximum magnetic surface field
E_{peak} (TESLA cells) = 50 MV/m
E_{peak} (half-cell) = 30 MV/m
$E_{cathode}$ = 20 MV/m (retreated cathode)

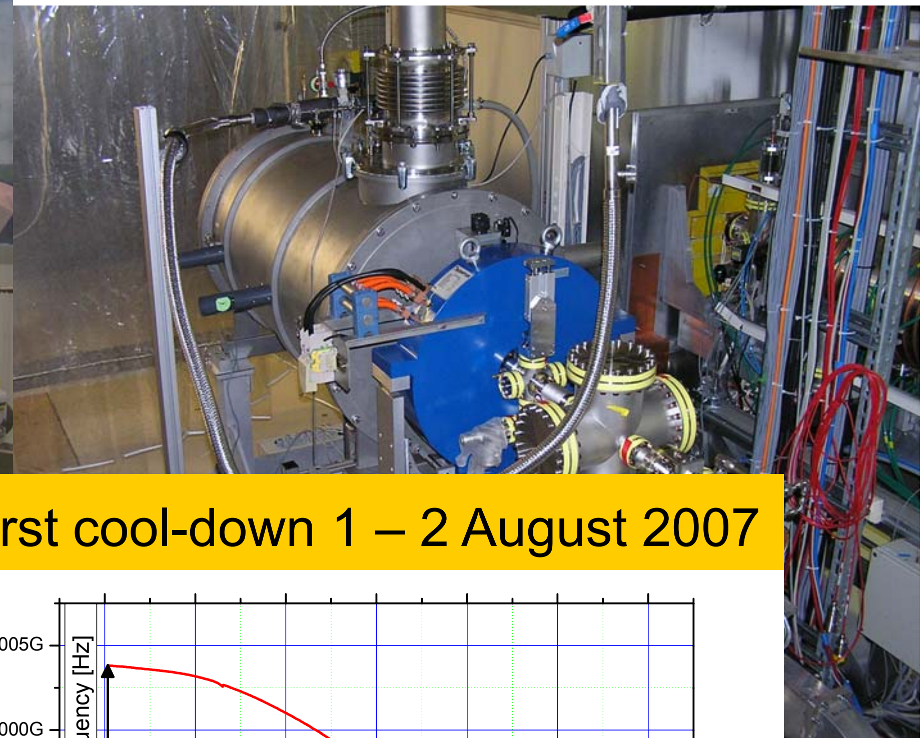


Results of the 4 vertical tests at DESY

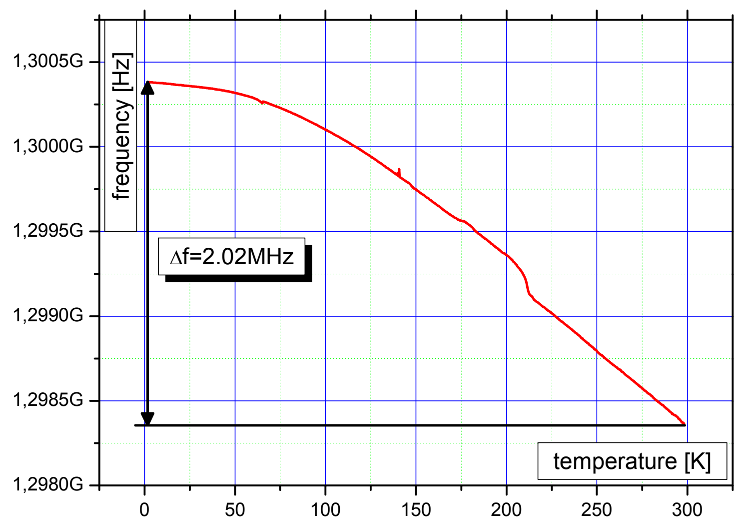


HPR cleaning very difficult
demage produced

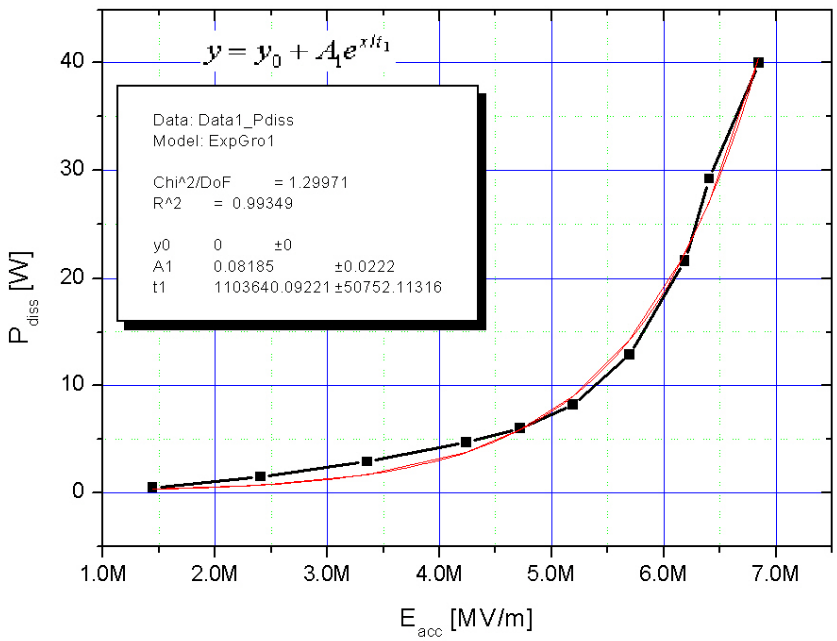
use of the cavity, since further improvement not expected

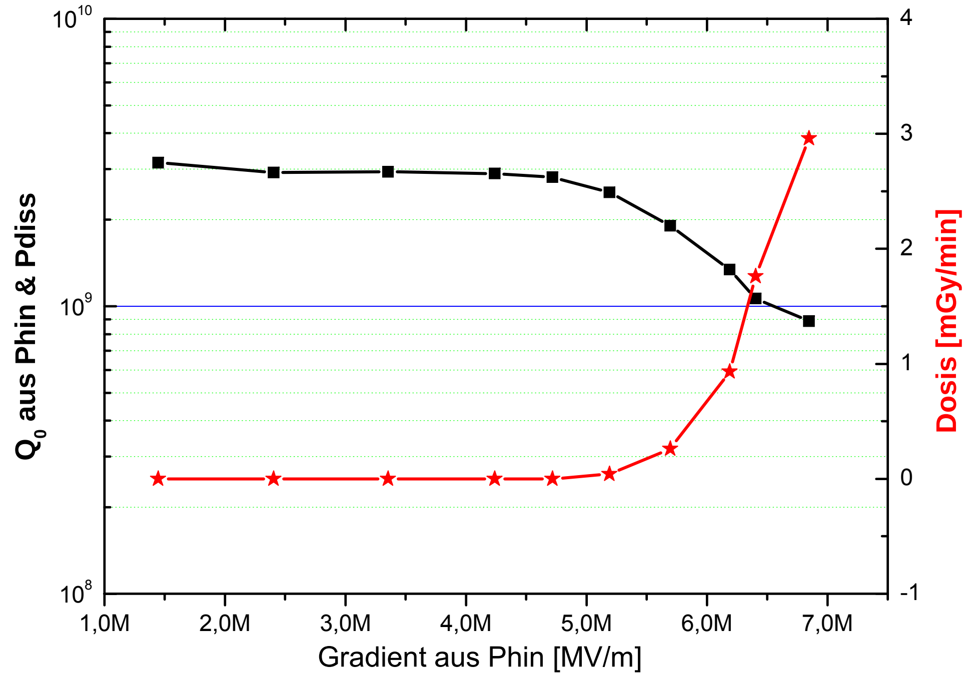


first cool-down 1 – 2 August 2007



Quality factor and Gradient measurements

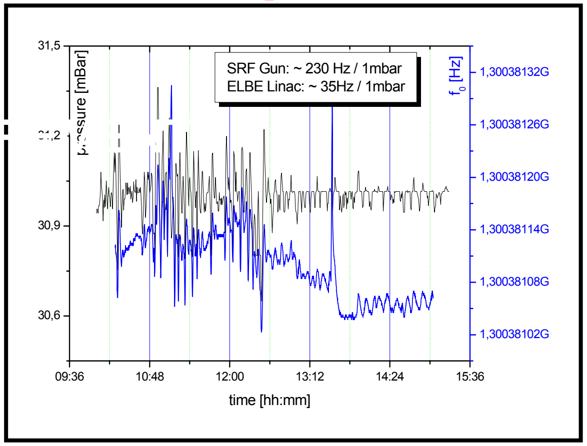


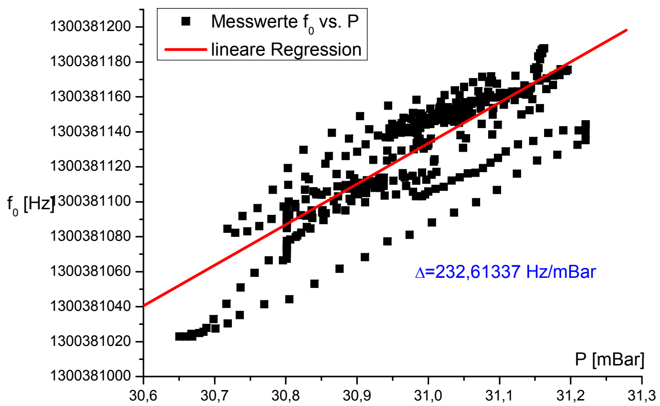


He consumption measurement
and calibrated pick-up
constant He flow
change of electrical heater power

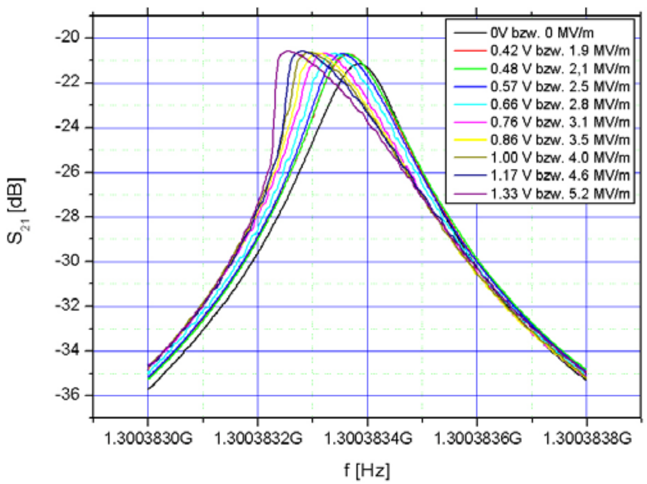
E_{acc}	E_{peak}	E_{acc}(TESLA)	$E_{electron}$
5.5 MV/m	15.5 MV/m	8 MV/m	2.5 MV

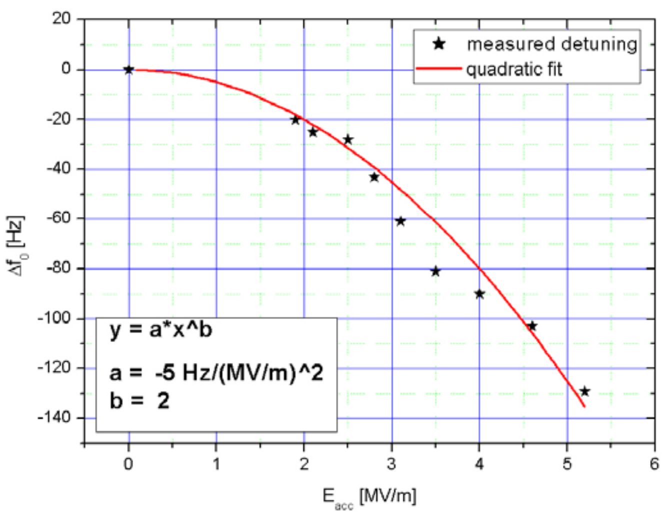
He pressure effect on cavity frequency





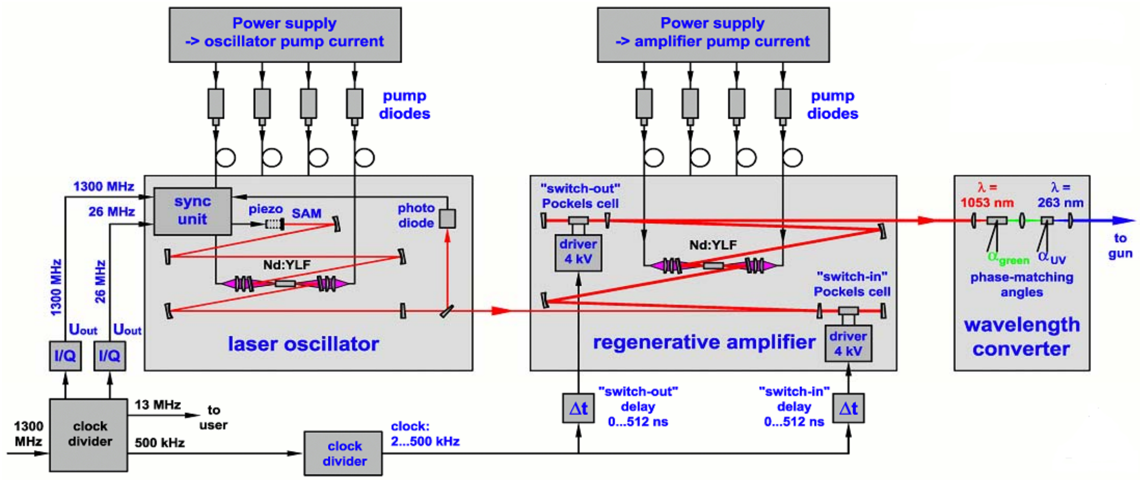
Lorentz force detuning



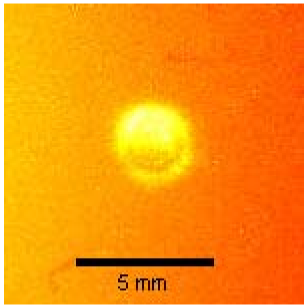


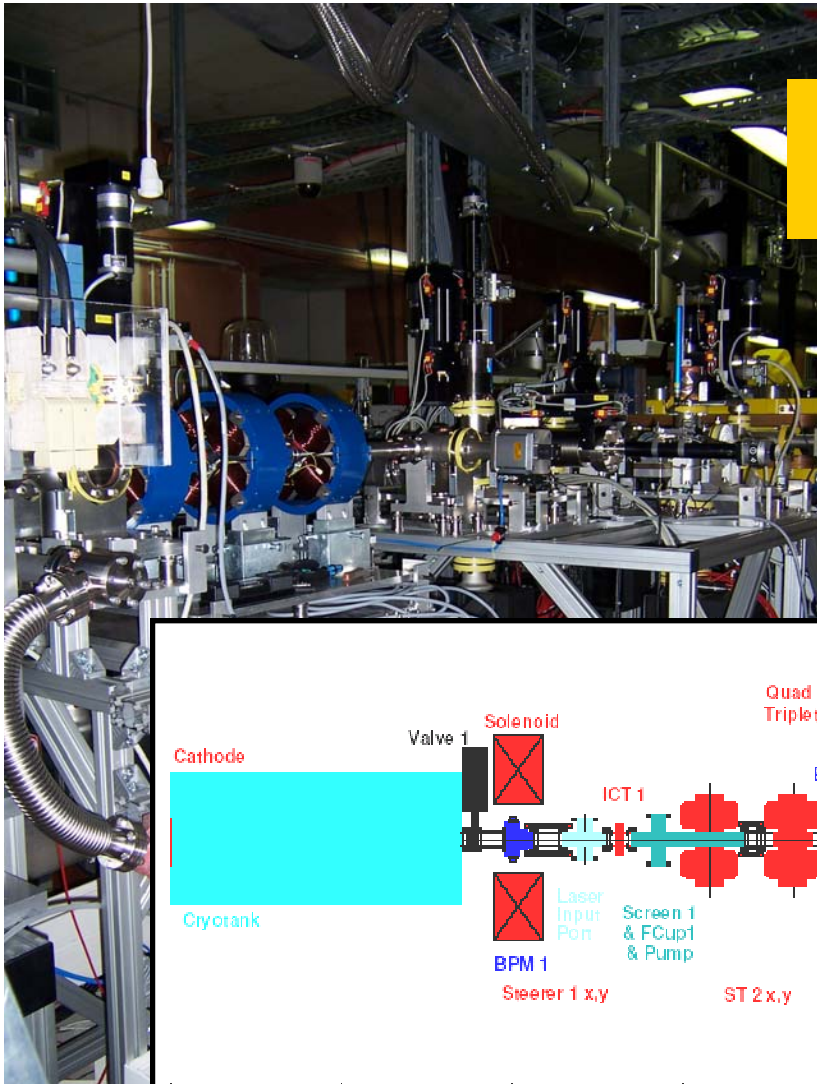
500 kHz Laser system developed by MBI

262 nm CW laser mit 0.5 W /UV)
Nd:YLF oscillator
Nd:YLF regenerative amplifier
two-stage frequ. conv. (LBO, BBO)
15 ps FWHM Gaussian



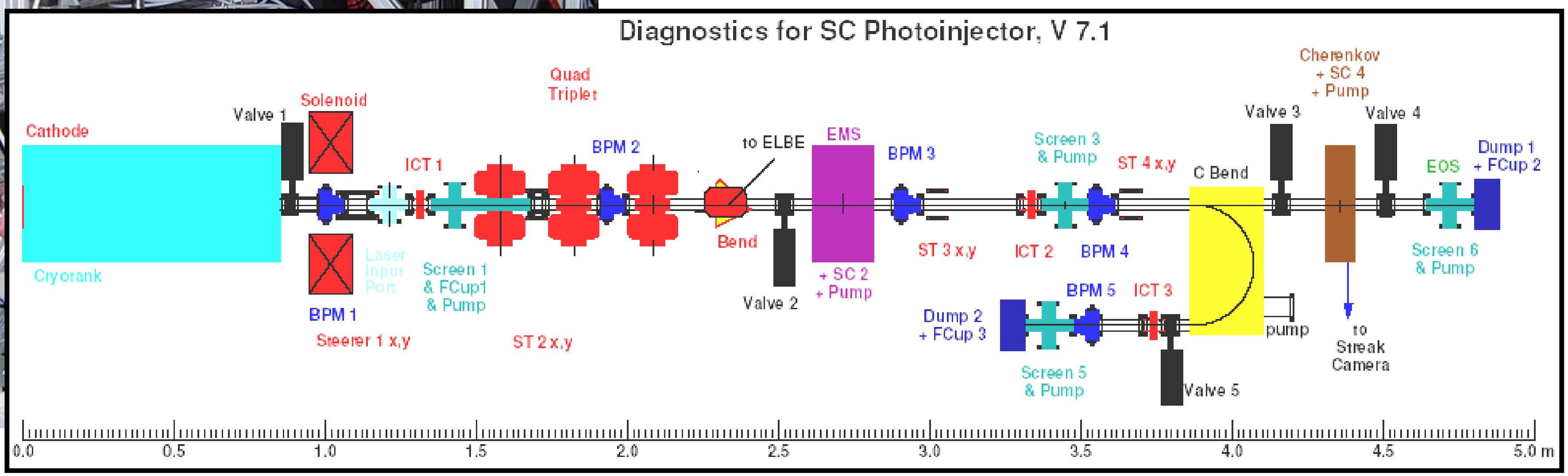
Laser pulse lateral:
shaped with aperture to Ø 2.7 mm





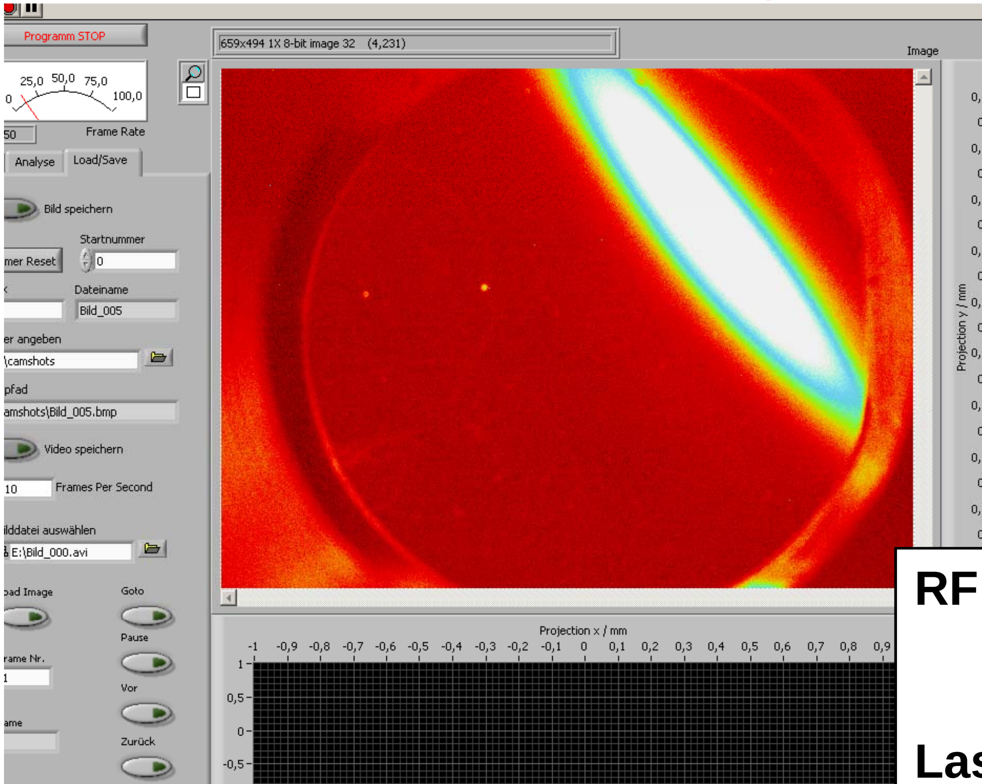
ELBE shut-down, Oct. 15 – 26, 2007
Installation of BESSY diagnostics beamline

- Emittance measurement (slit mask)
- C bend (E, ΔE)
- Cherenkov radiatior with optical beamline and streak camera

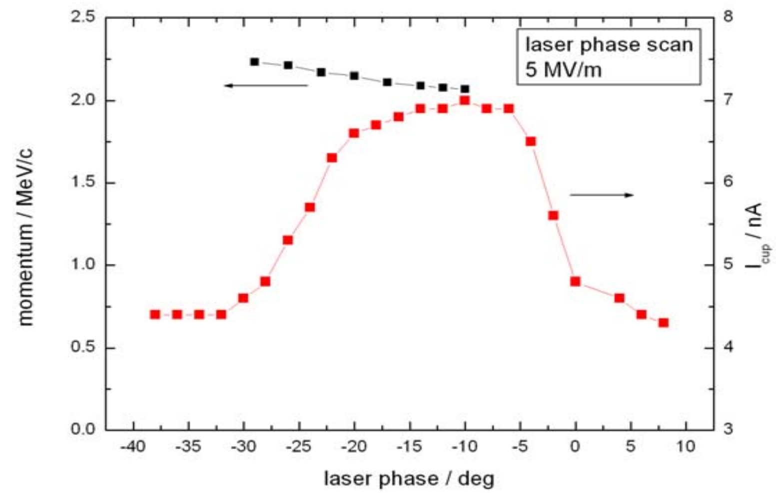


FIRST ELECTRON BEAM

First beam of the 3½ cell superconducting rf photo gun on November 12th, 2007



Beam spot on the first YAG screen in the BESSY diagnostics beamline



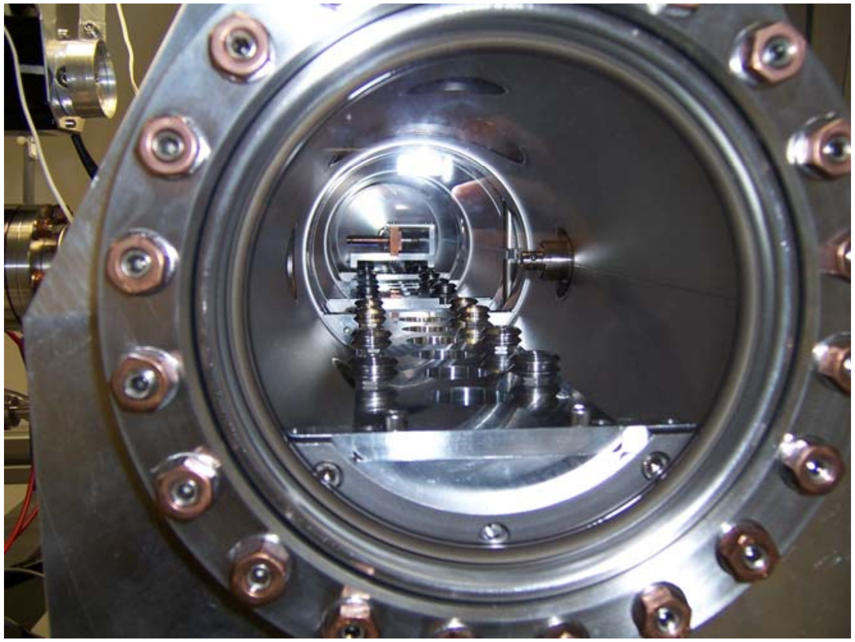
RF: E_{acc} = 5 MV/m
f = 1300. 38327 MHz, 150 Hz bandwidth
P_{diss} = 6 W

Laser: 263 nm, 100 kHz reprate
0.4 W power (4 μJ)
temporal profile: 15 ps FWHM Gaussian
lateral profile: 4 mm x 6mm spot, Gaussian

Cathode: Cu, Q.E. ≈ 10^{-6}

Electron beam: 2.0 MV energy
50 nA average current,0.5 pC bunch charge

installation in the shut-downs of ELBE in Jan. + March 08 at the SRF gun



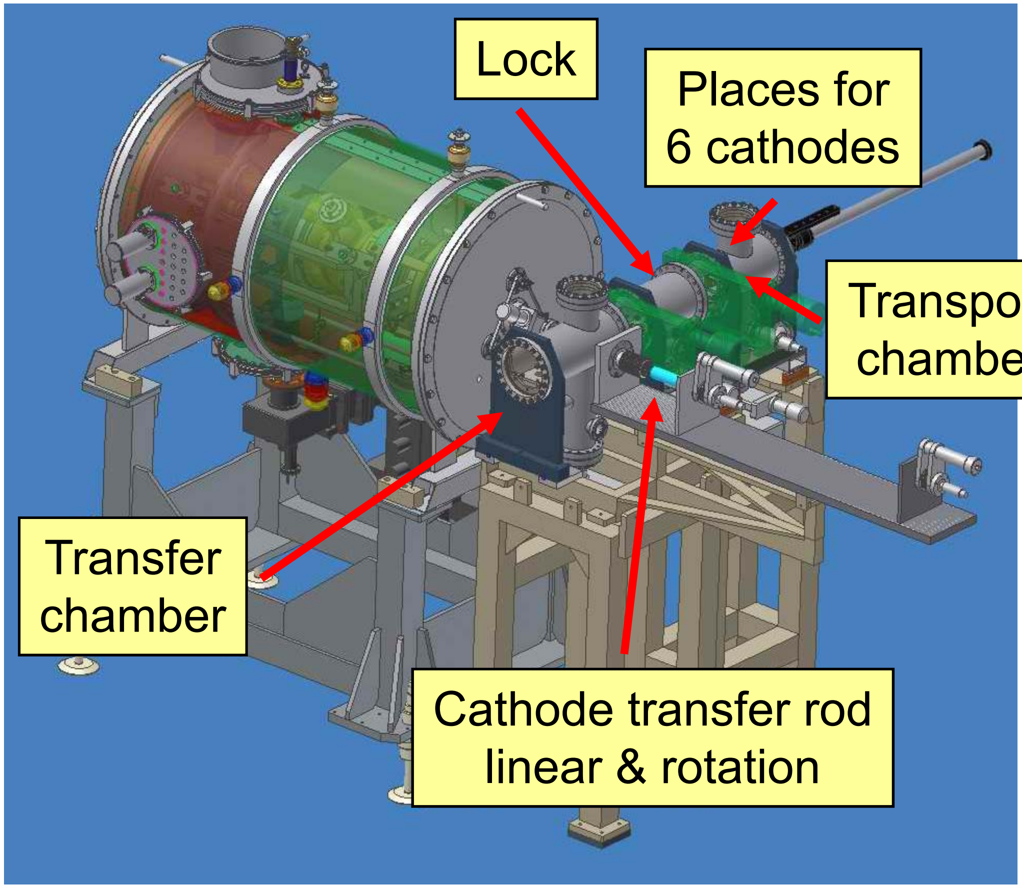
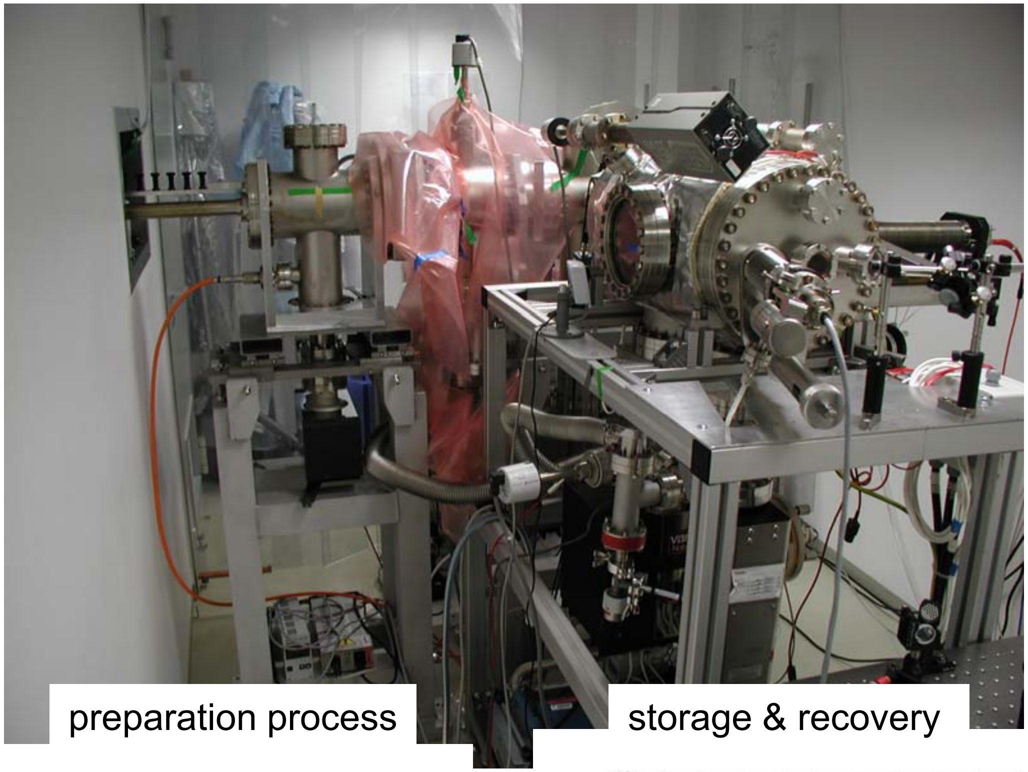
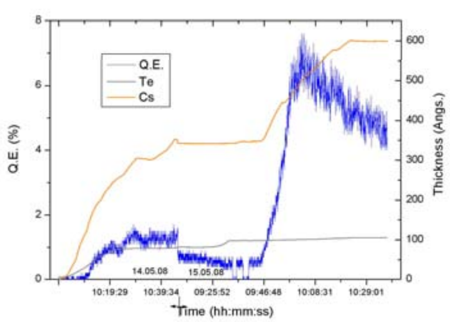


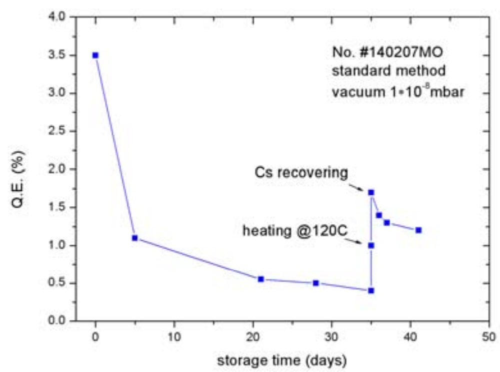
Photo cathode preparation lab at FZD



preparation process

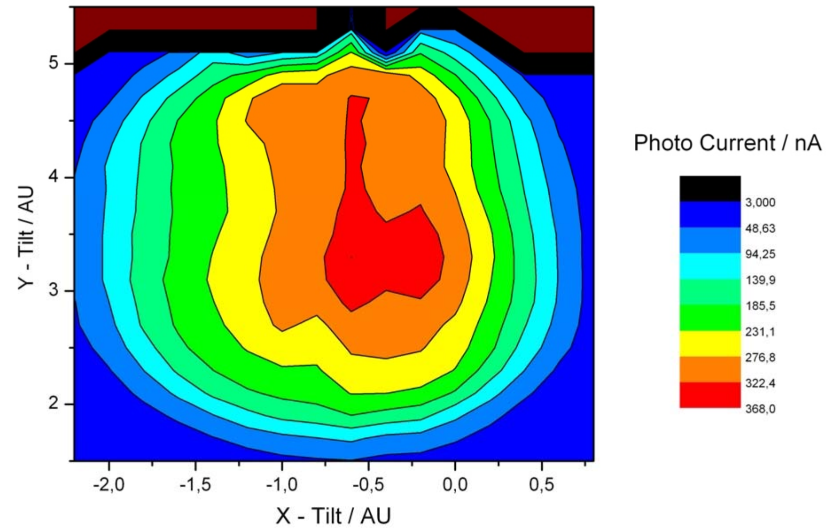


storage & recovery



May 08: First set of Cs_2Te cathodes in the SRF gun

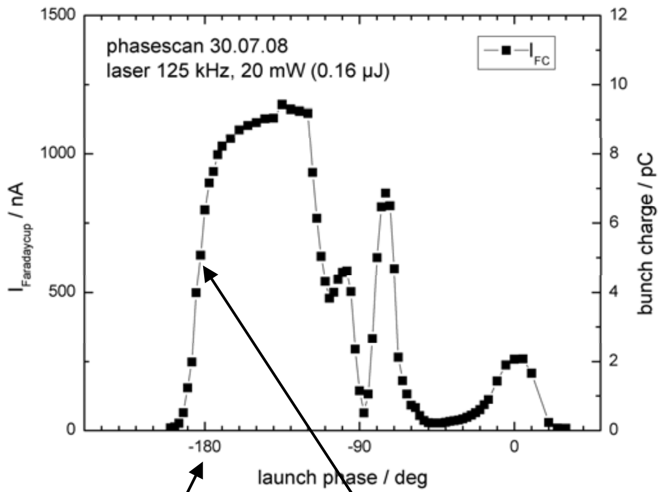
QE scan in SRF gun



QE = 10^{-3}

bad“ vacuum in transfer chamber and during manupulation

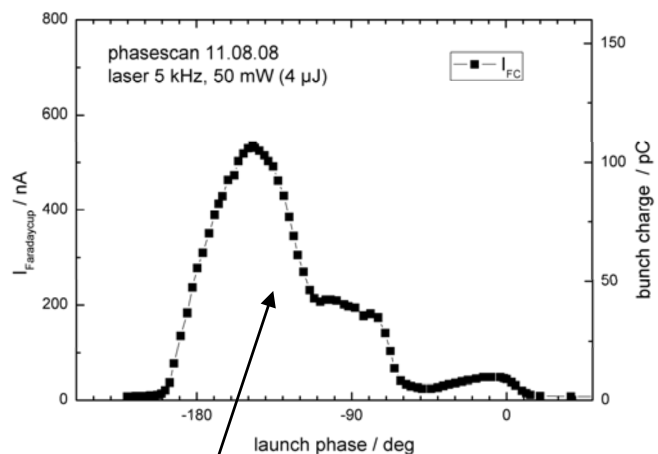
Schottky scan – laser phase variation @ constant laser power



Laser pulse rep. Rate

250, 125, 50 kHz: user operation

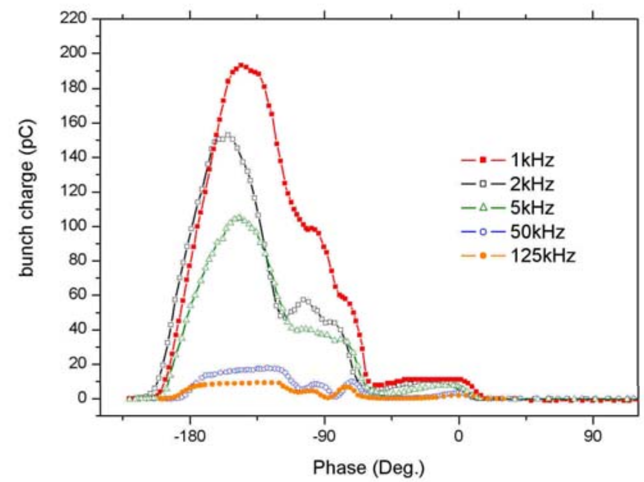
1, 2, 5 kHz: diagnostic



Φ_{laser} = 0°

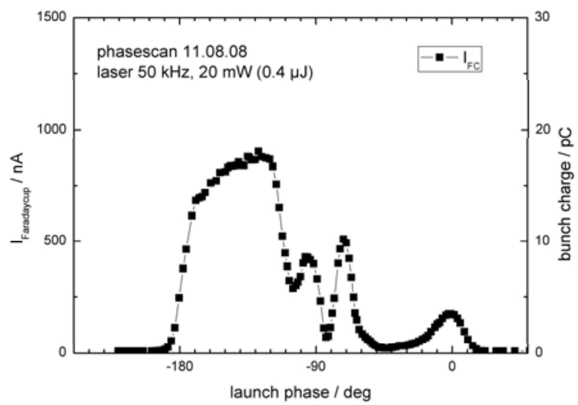
slope determined by laser pulse length

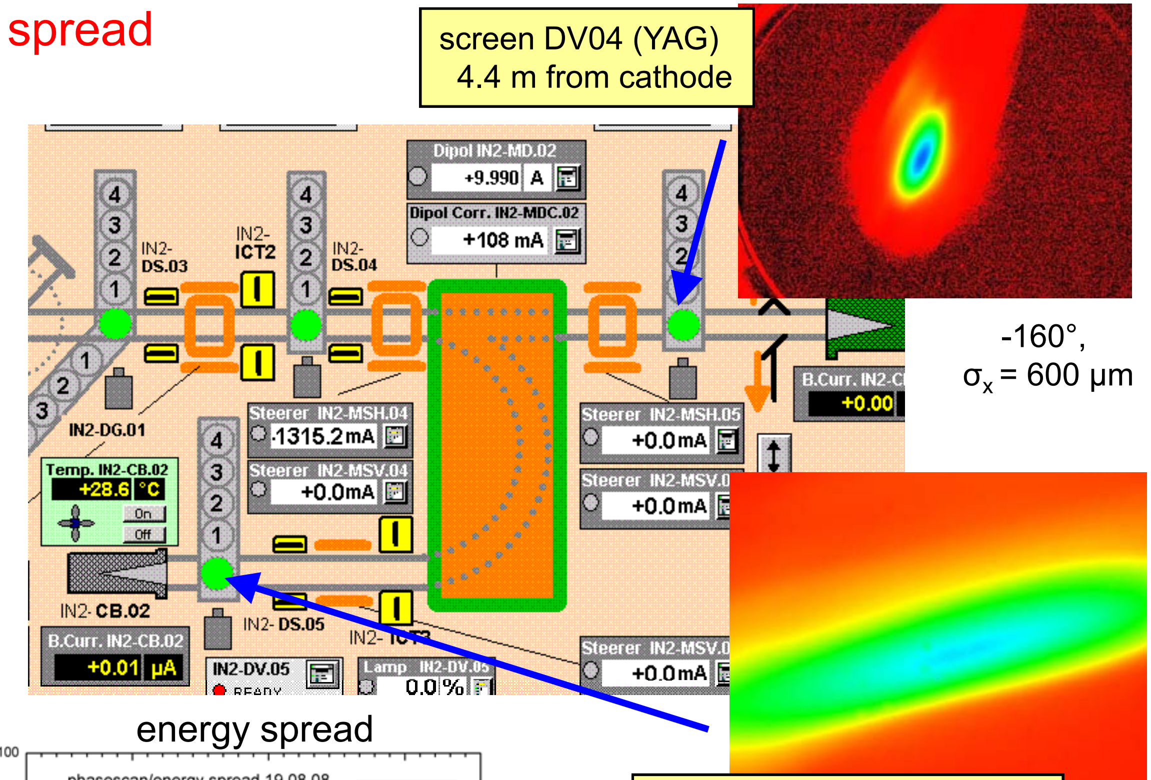
space charge smoothing



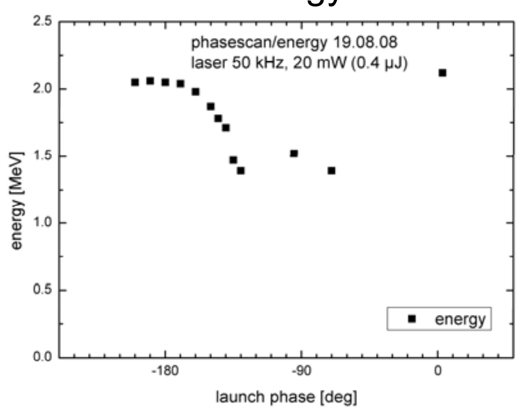
Laser temporal profile: 15 ps FWHM Gaussian
spacial profile: 3 mm spot diameter flat top
Faraday cup 0.6 m from gun exit,
1.4 m from cathode

Schottky scan – energy & energy spread

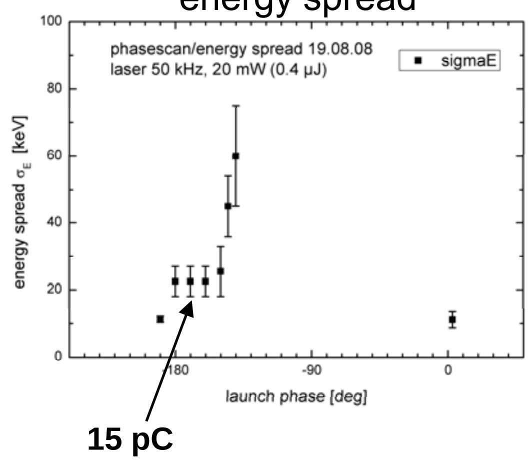




energy

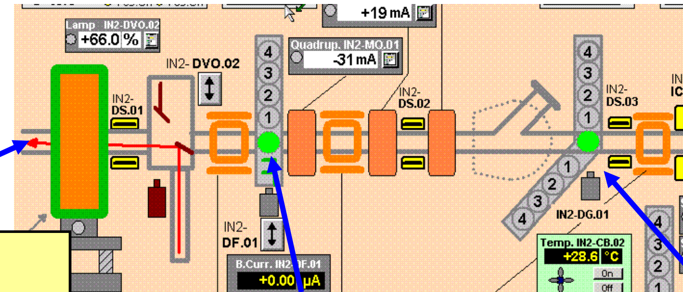


energy spread



Transverse Emittance – Solenoid scan

- not suitable for space-charge dominated beams,
- preliminary method as long as the analysis tools for the installed slit mask method are under development

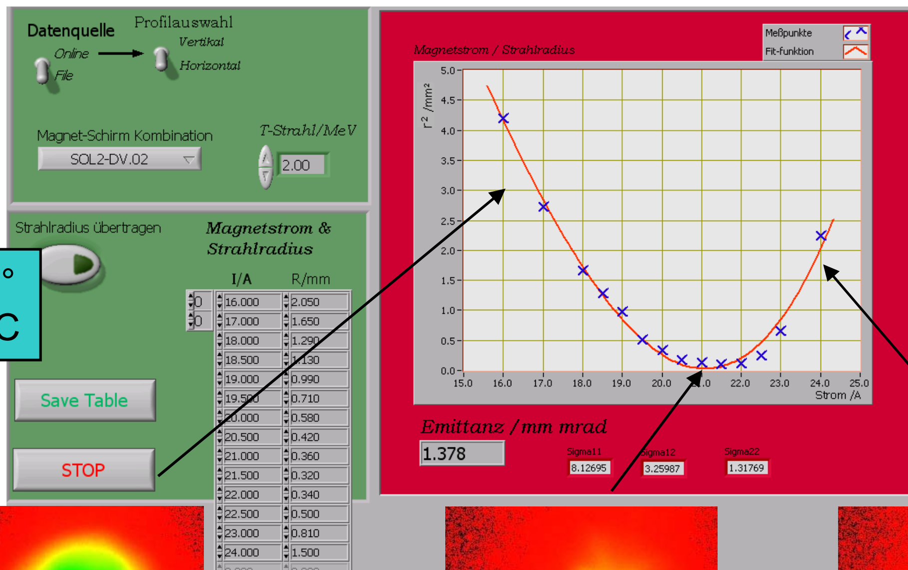


solenoid for emittance compensation, field precisely measured

screen DV01

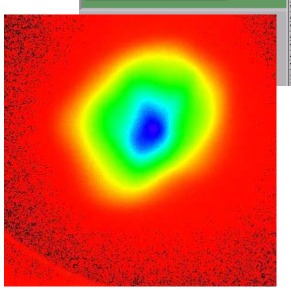
screen DV02

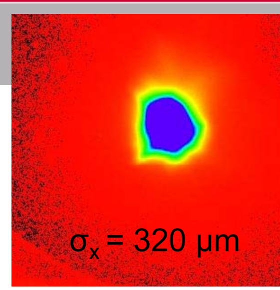
-160°
20 pC

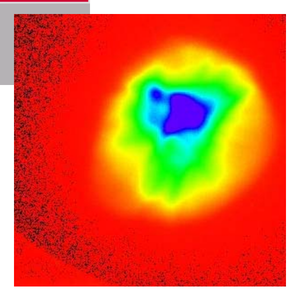


Measurement:
5 MV/m gradient
2 MeV energy
laser:
temporal:15 ps FWHM Gaussian
lateral: 2.7 mm diam. sharp edges

launch phase &
pulse energy variation

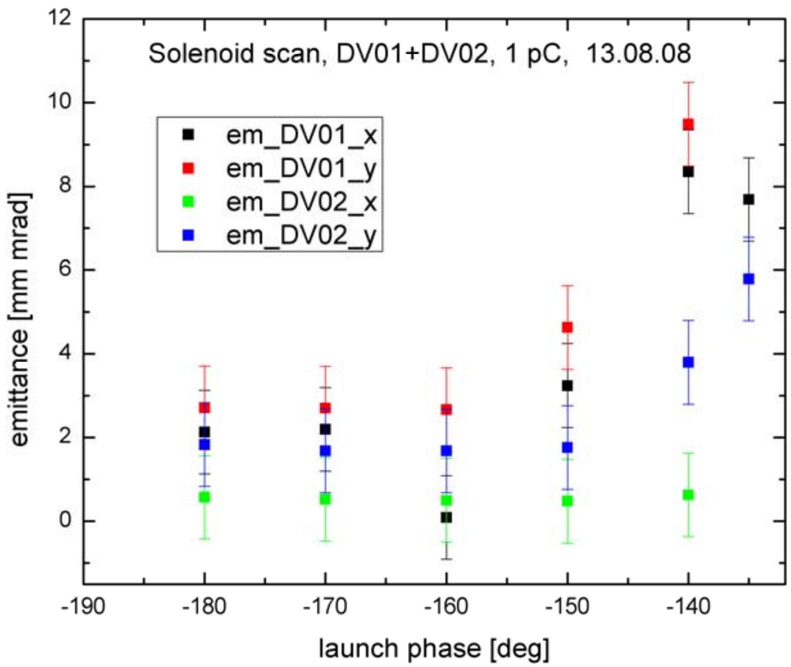






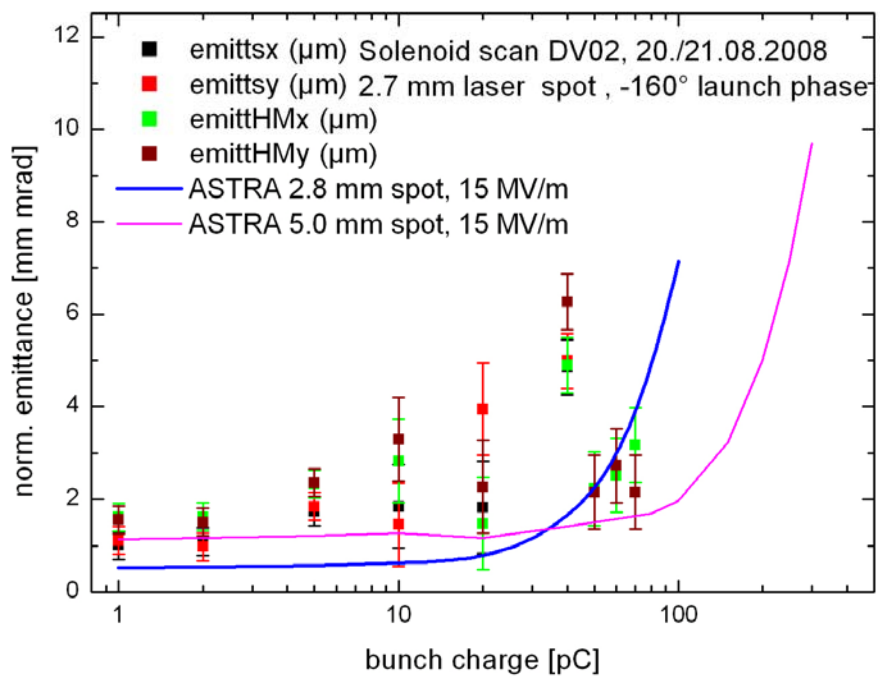
Transverse Emittance – Solenoid scan

launch phase scan – search for optimum



- 160° ⇨ Φ_{laser} = 20°

bunch charge dependence



SUMMARY

Problems during commissioning:
- Cavity cleaning and low gradient
- wrong cavity π-mode frequency at 2 K (will be corrected in shut-down)
- high level of microphonics due to membrane pumps (solved)
- tuners have hysteresis (will be repaired in shut-down)
- insufficient vacuum in cathode transfer system (improved in shut-down)

Answers to the „big“ questions:
- basic principle (NC photo cathode) works well
- no limits found, results agree with predictions
- high current operation: answer will be given in the first run in 2009
- high gradient and brightness: needs an improved cavity

Future:
- Oct.- Jan. 09: correction of π-mode frequency
- 2009: connection to ELBE, run with high current
- fabrication of two improved cavities, funded by BMBF, replacement in 2010

THANK YOU FOR YOUR ATTENTION

Thanks to the ELBE crew,
the technical staff of BESSY, DESY and MBI,
to ACCEL and all the others
supported and encouraged this project

Acknowledgements

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