Radiation Source ELBE
- Status and SRF gun activities -

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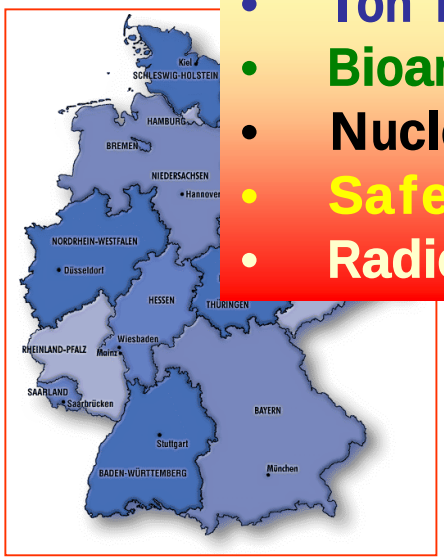
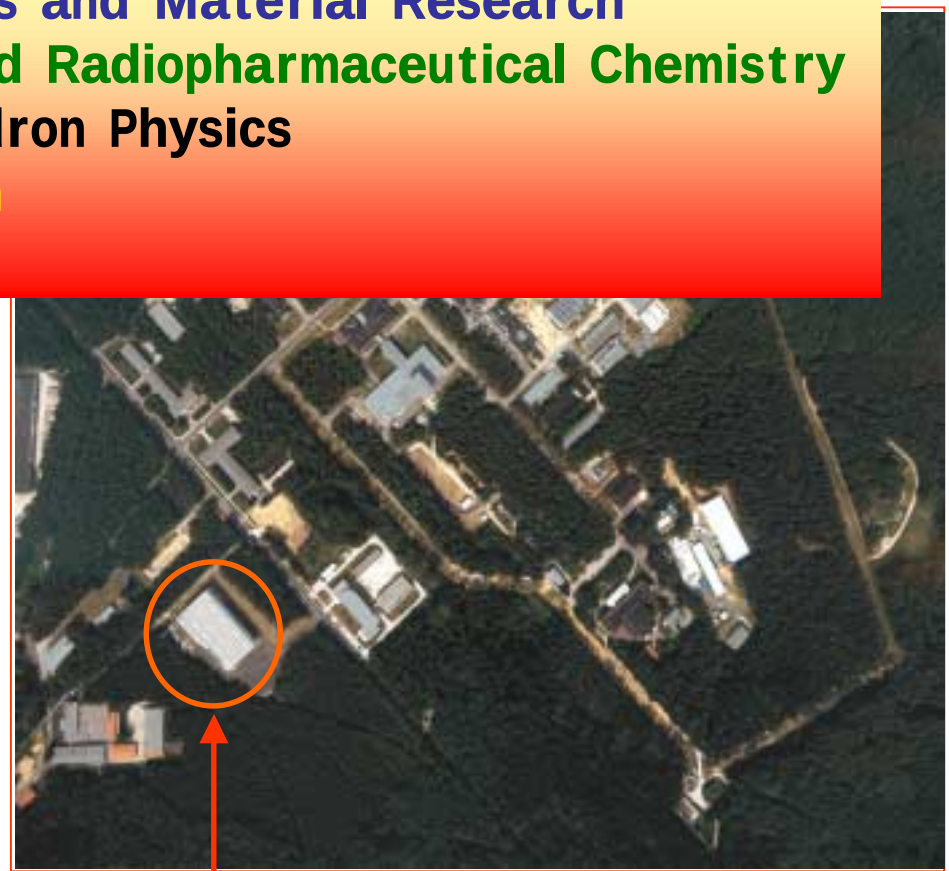
Outline

- *ELBE@FZ-Rossendorf*
- *ELBE - LINAC*
- *Secondary radiation generation & associated research program*
- *superconducting-rf-foto gun for ELBE*

The Radiation Source ELBE at Research Center Rossendorf (FZR)



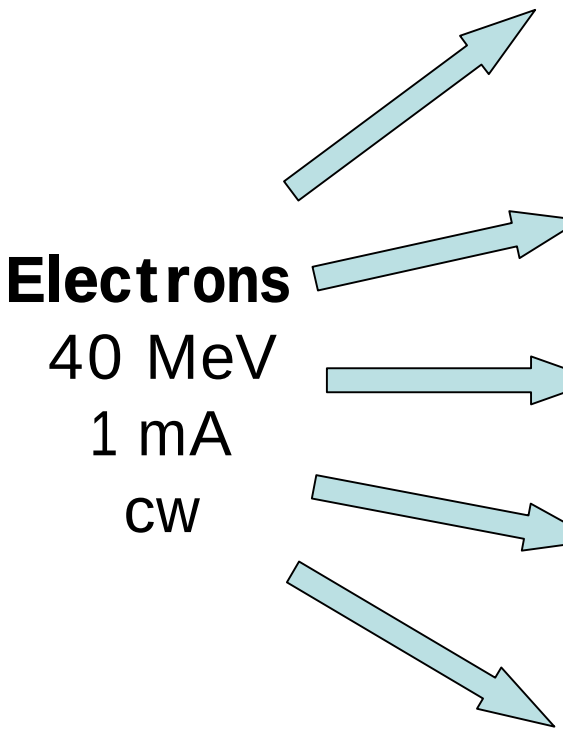
- Ion Beam Physics and Material Research
- Bioanorganics and Radiopharmaceutical Chemistry
- Nuclear and Hadron Physics
- Safety Research
- Radiochemistry



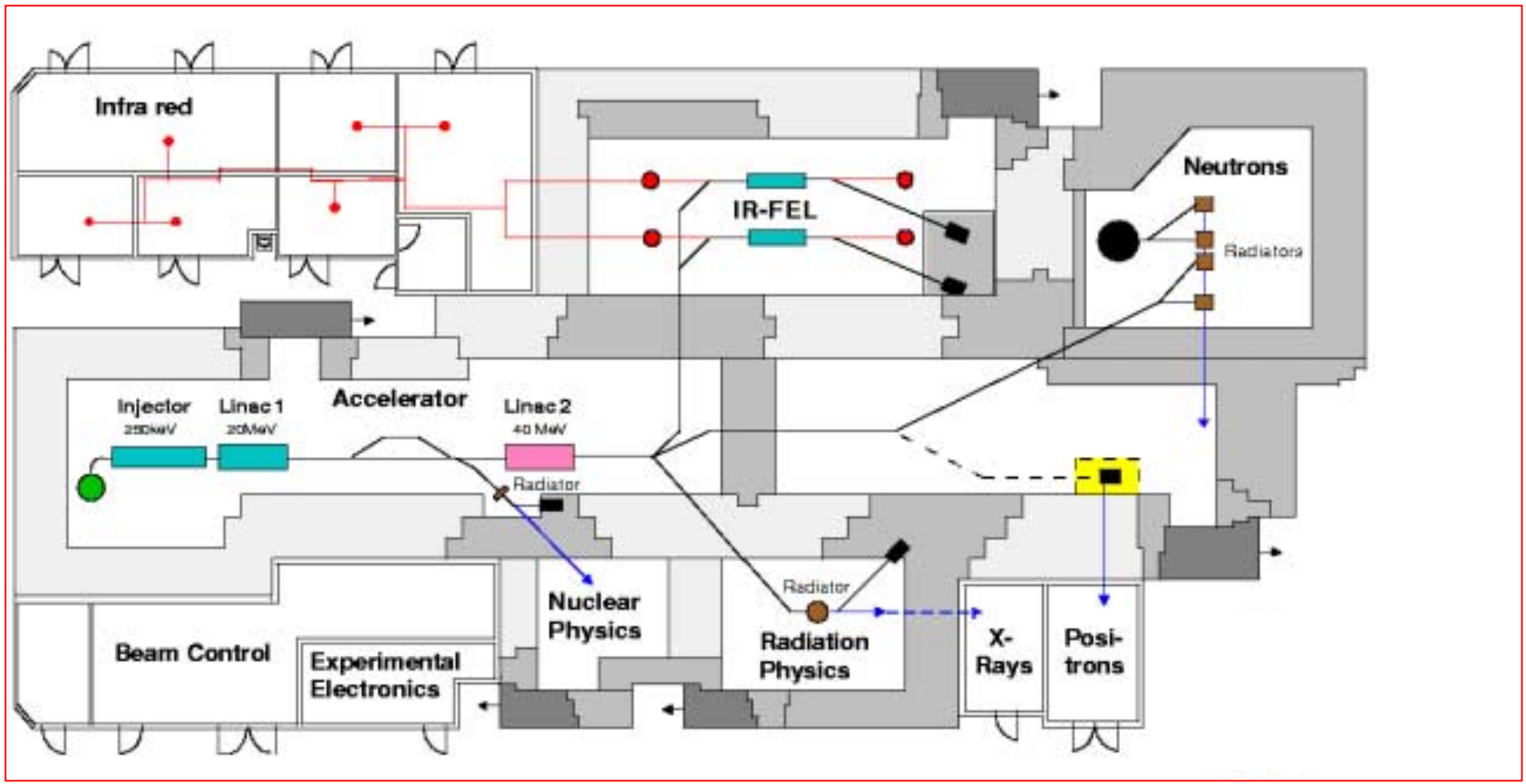
Radiation Source ELBE

Radiation Source ELBE

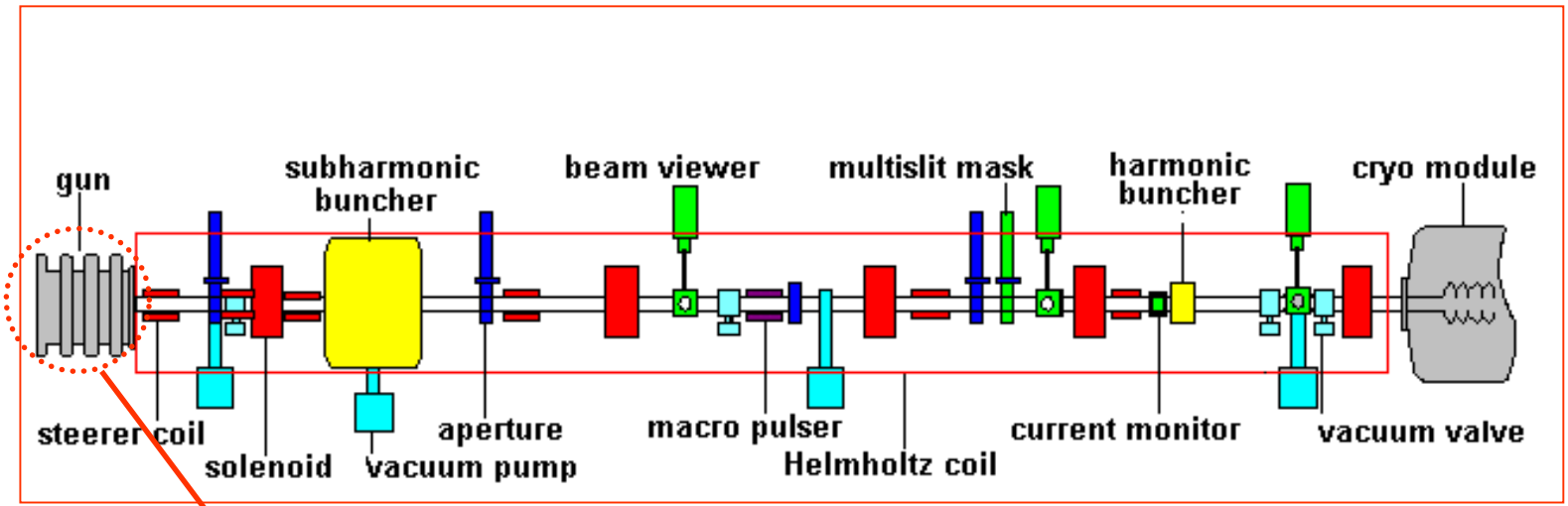
superconducting Electron Linac
of high Brilliance and low Emittance



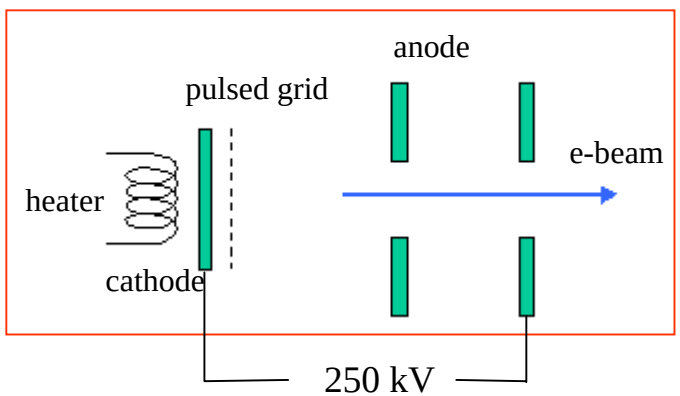
γ-radiation	0 – 20 MeV	nuclear phys. cave
X-rays	10 – 100 keV	radiation phys. cave
IR-radiation	5 – 150 (200) µm	FEL cave
neutrons	0 – 30 MeV	neutron phys. cave
positrons	0 – 30 keV	positron cave (EPOS)


Infra red
IR-FEL
Neutrons
Radiators
Injector
250keV
Linac 1
20MeV
Accelerator
Linac 2
40 MeV
Radiator
Radiator
Nuclear
Physics
Radiation
Physics
X-
Rays
Posi-
trons
Beam Control
Experimental
Electronics

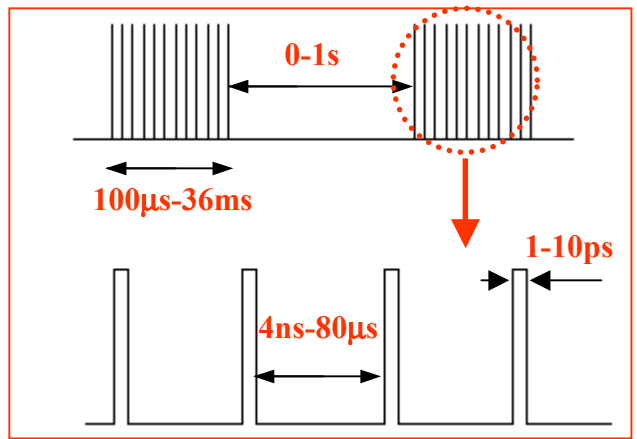
Electron source and injection



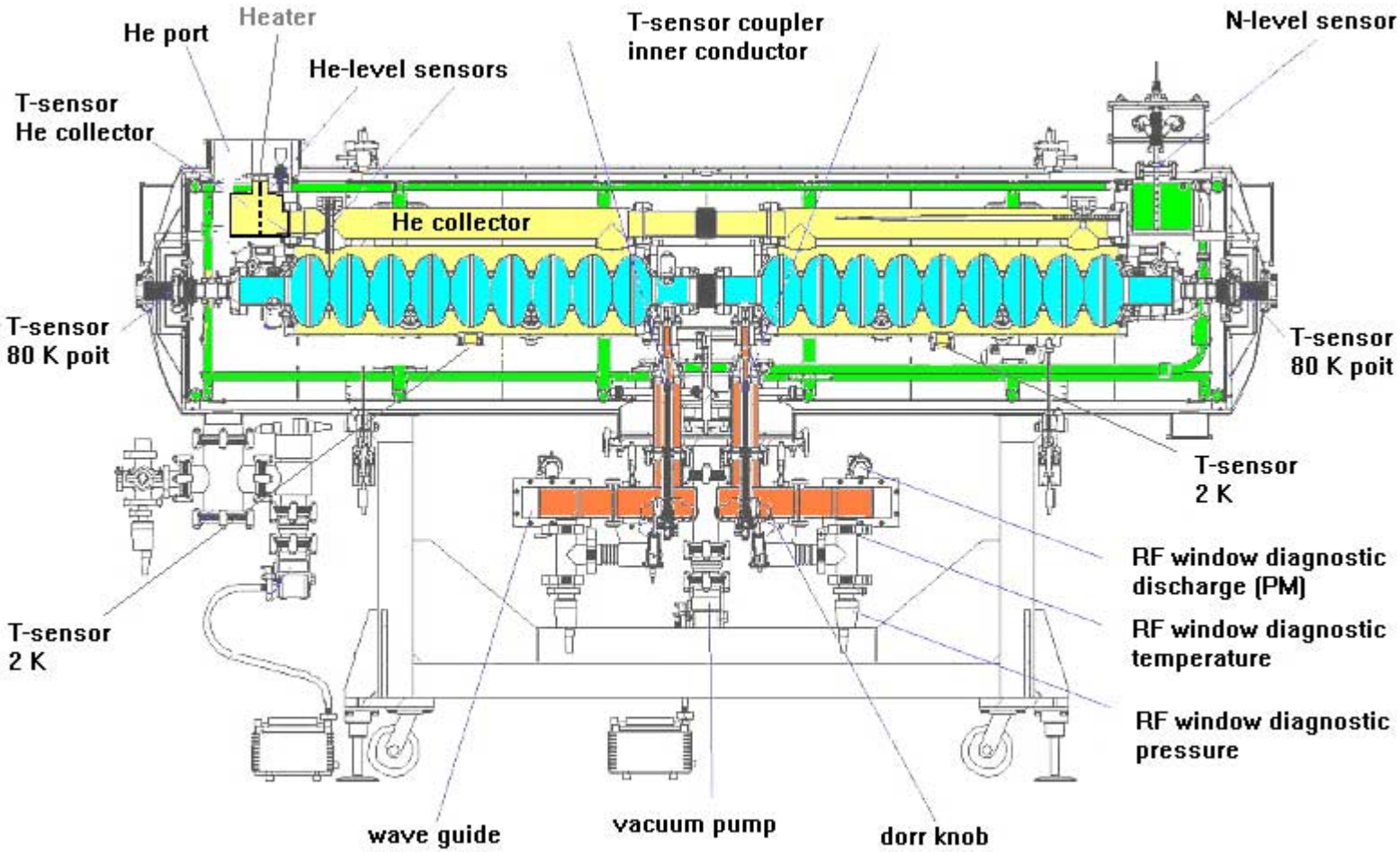
Thermionic gun



Puls structure of electron beam



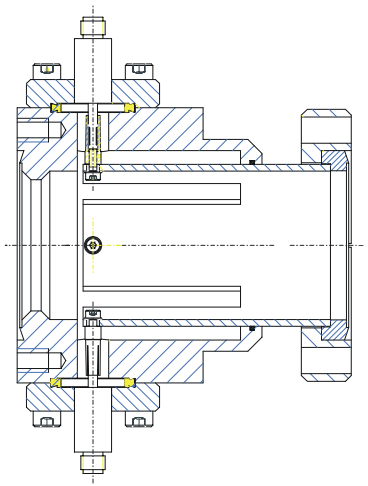
ELBE Cryomodule



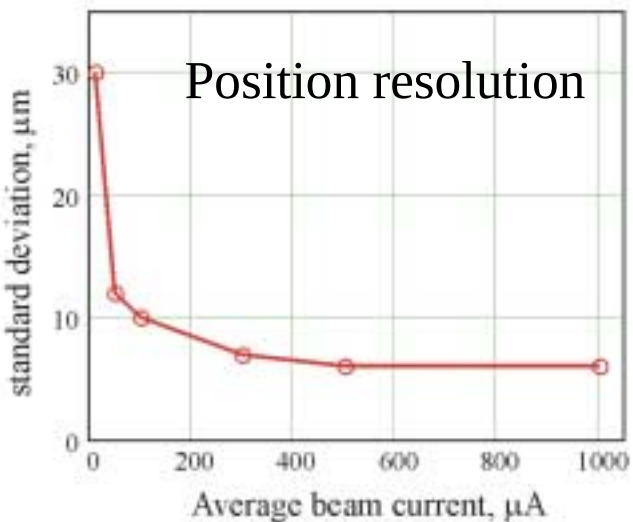
Beam lines & Diagnostics & Others

• vacuum system	DN 40 UHV + ion getter pumps (< 10^{-9}mbar)
• magnets	DANFYSIK dipole/quadrupol (< 80 MeV electrons)
• beam viewer	OTR→digital frame grabber→online imaging/evaluation
• emittance measurement	pepperpot mask / automated quadrupol scan
• online beam position	stripline detectors
• bunch length	MP interferometer, Golay cells for BL optimization
• beam loss	long ionization chambers (machine protection) current difference monitors
• dumps	radiation cooled graphite (50 kW) + steel/concrete/water shielding
• control system	PC based , Simatic-PLC/WINCC

Beam position monitoring



Compact version of Beam Position Monitor



- strip length 40 mm
- total length 85 mm

$$L = \frac{c}{4 \cdot f_0}$$

Beam loss interlock & monitoring

20...40 MeV electrons ⇒ range 1,5..4 cm in stainless steel

$$T = T_c e^{-\lambda t}$$

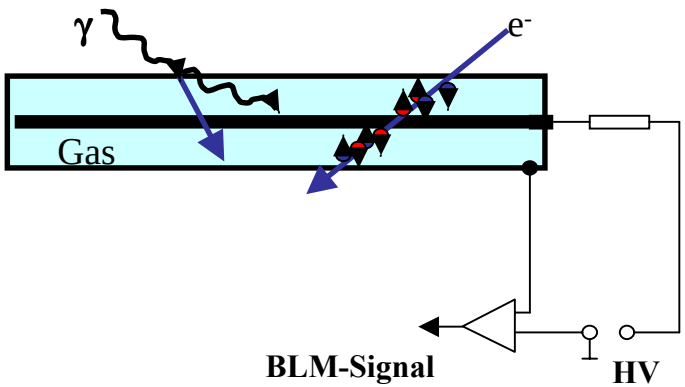
$$\frac{dT}{dt} = \frac{S_c}{c \cdot m} I_e(t) - \lambda (T - T_{RT})$$

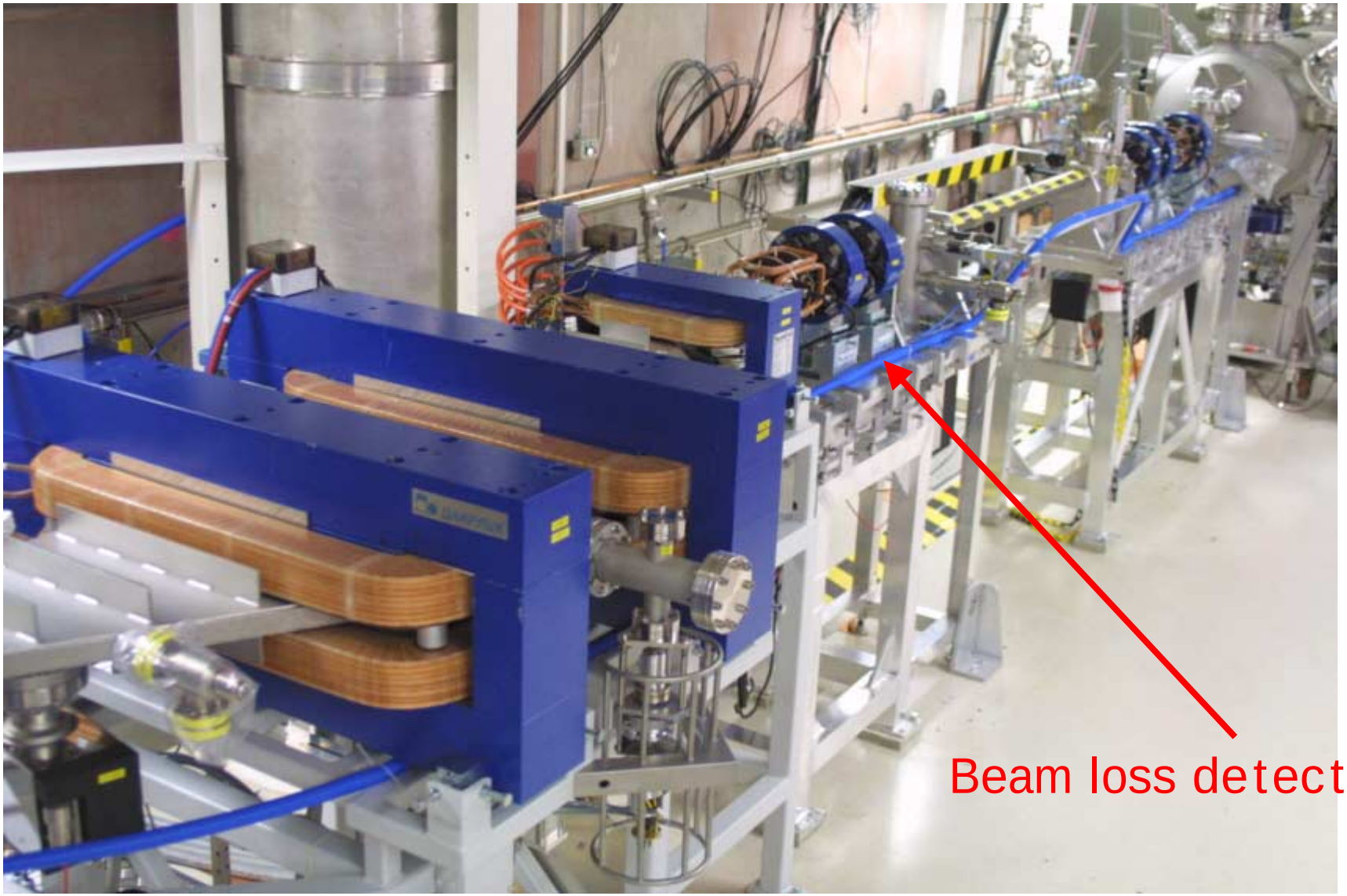
$$t_{crit} = \frac{T_M \cdot c \cdot m}{S_c \cdot I_e}$$

S_c = 20MeV
I_e = 1mA
c = 450J/Kg K
m= ΔVς= 63mg (d_{beam}=1mm, r= 10mm)
T_M=1400 °C

t_{crit}~ 2 ms

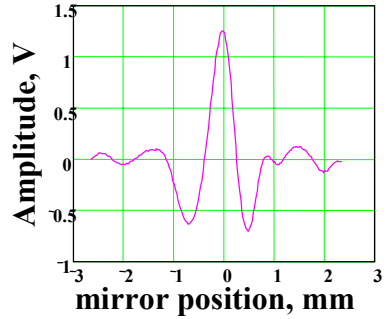
How to measure ? ⇒ long ionisation chambers (LIC)

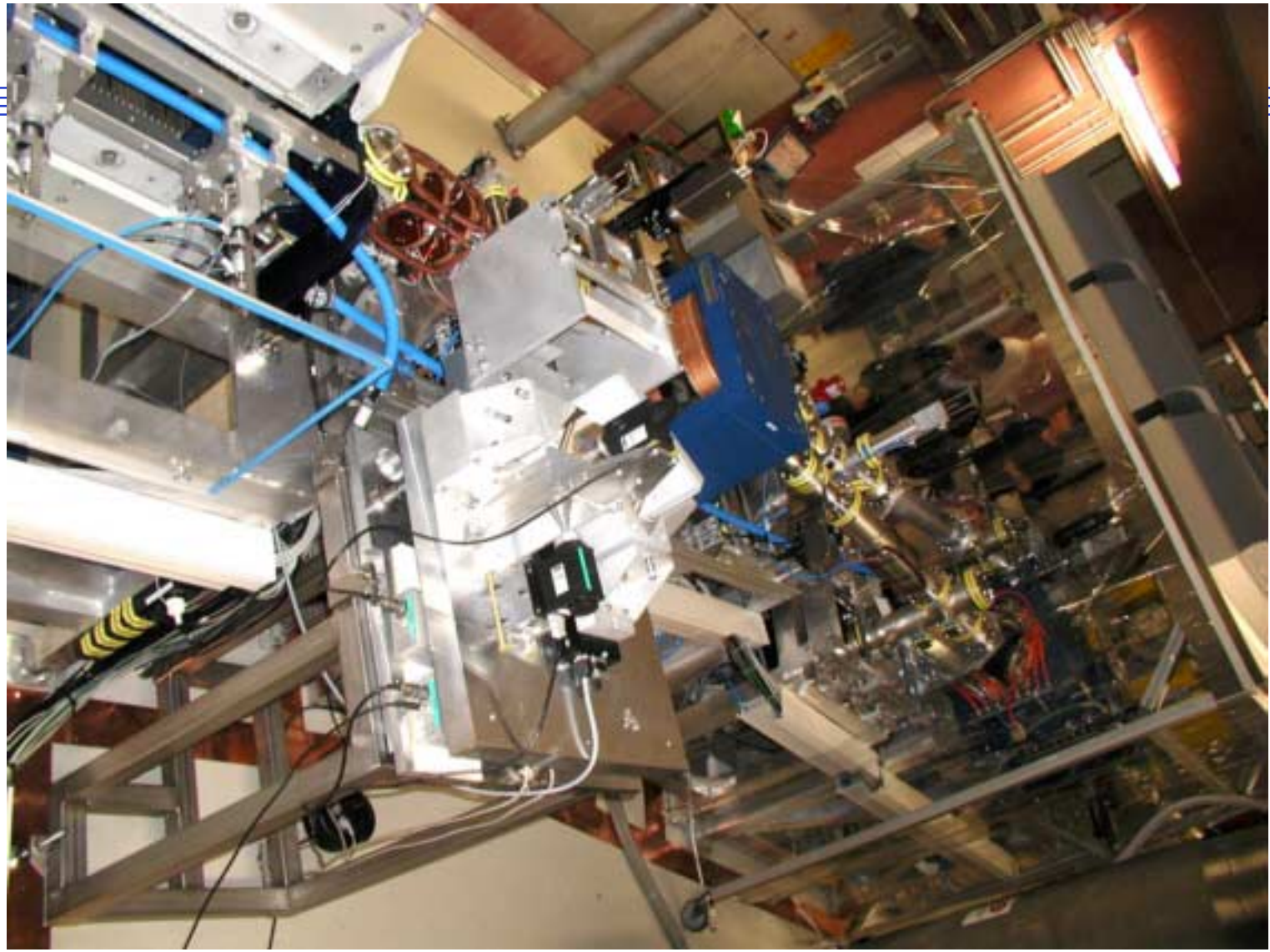



Beam loss detector

Bunch length measurement

The Martin-Puplett Interferometer
(polarizing Michelson interferometer)

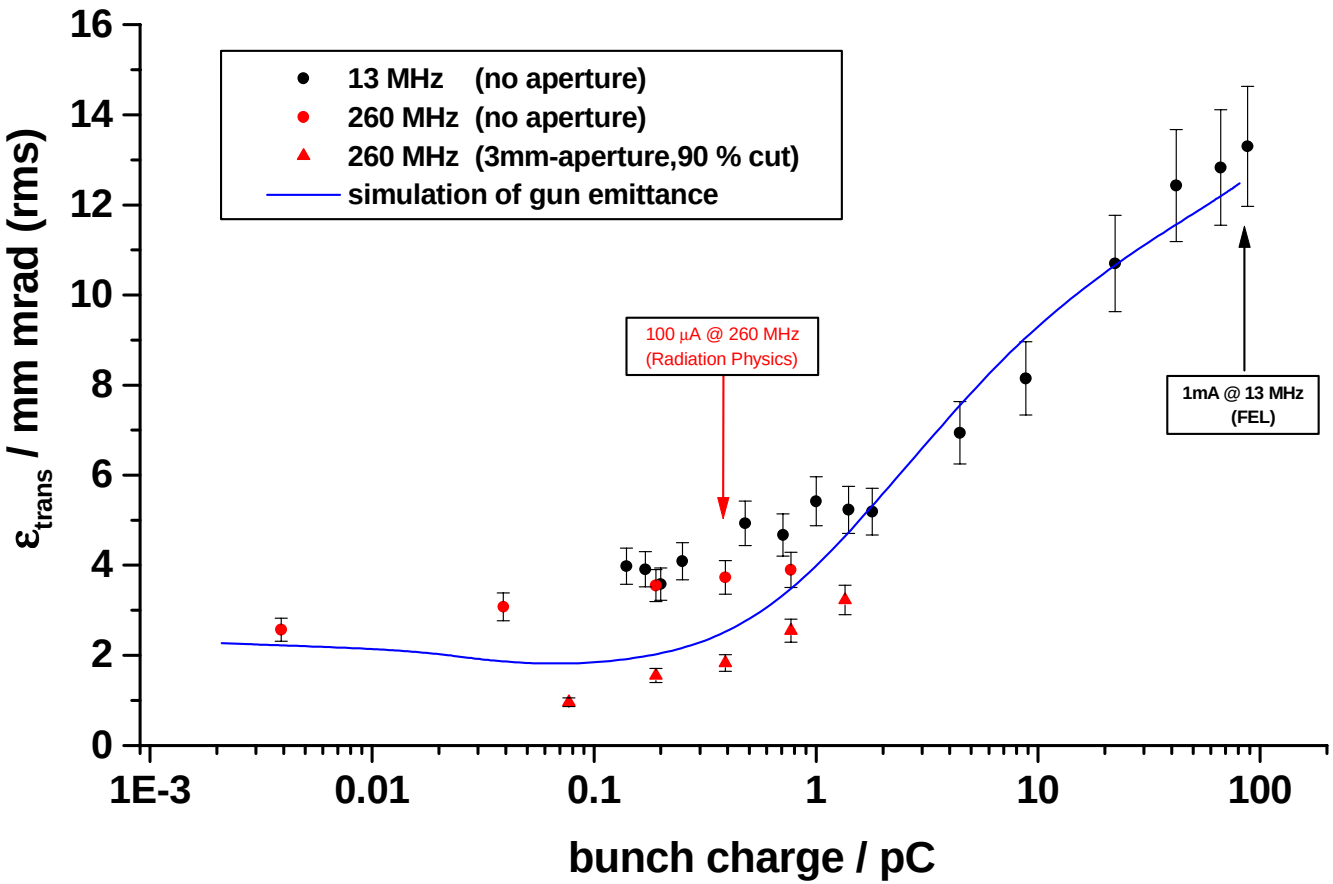




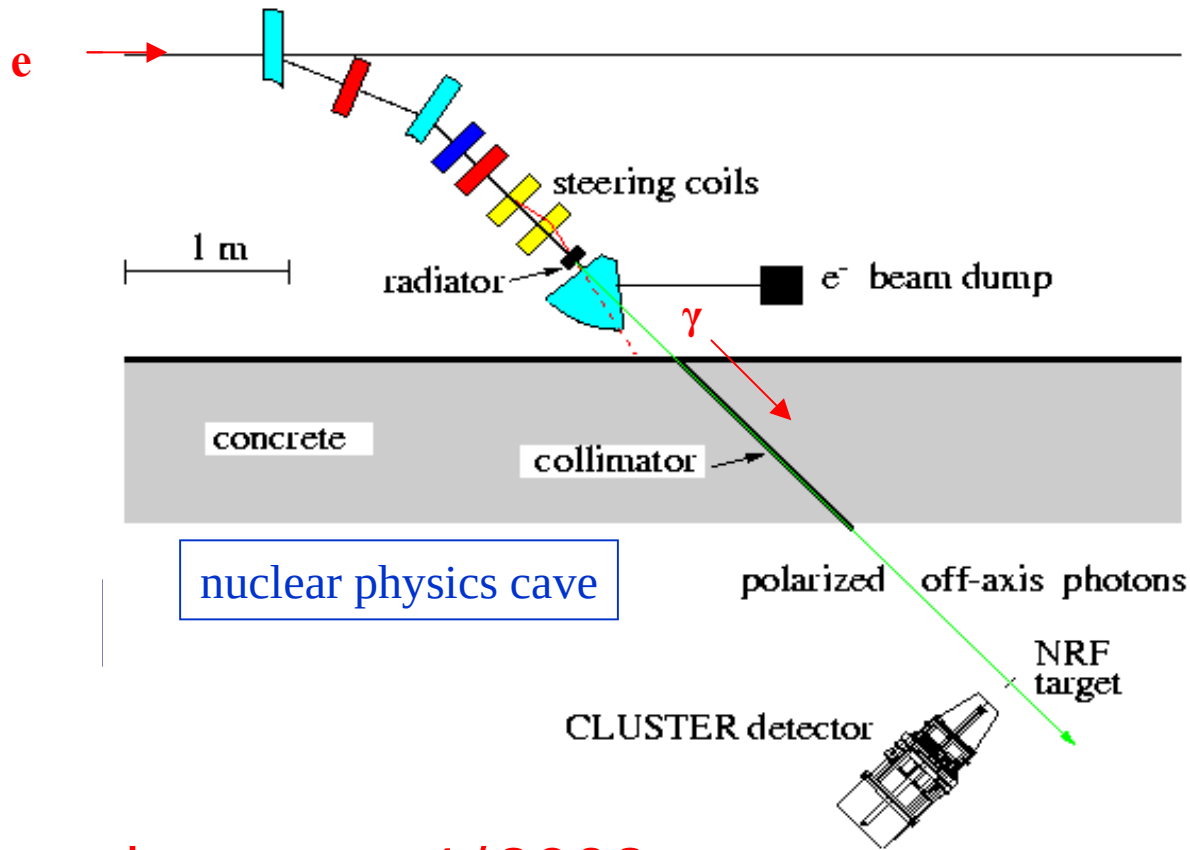
Electron beam parameters of ELBE

maximum beam energy		**20 MeV → 40 MeV**
maximum bunch charge		**77 pC**
maximum beam current		**0.85 mA**
	Channeling at 1 pC	**FEL operation at 77pC**
energy spread ΔE (FWHM)	**35 keV**	**55 keV**
transverse emittance ε_{RMS}	**2 mm mrad** < 0.5 needed	**12 mm mrad**
bunch length σ_{RMS}	**>3ps**	**1 ps**

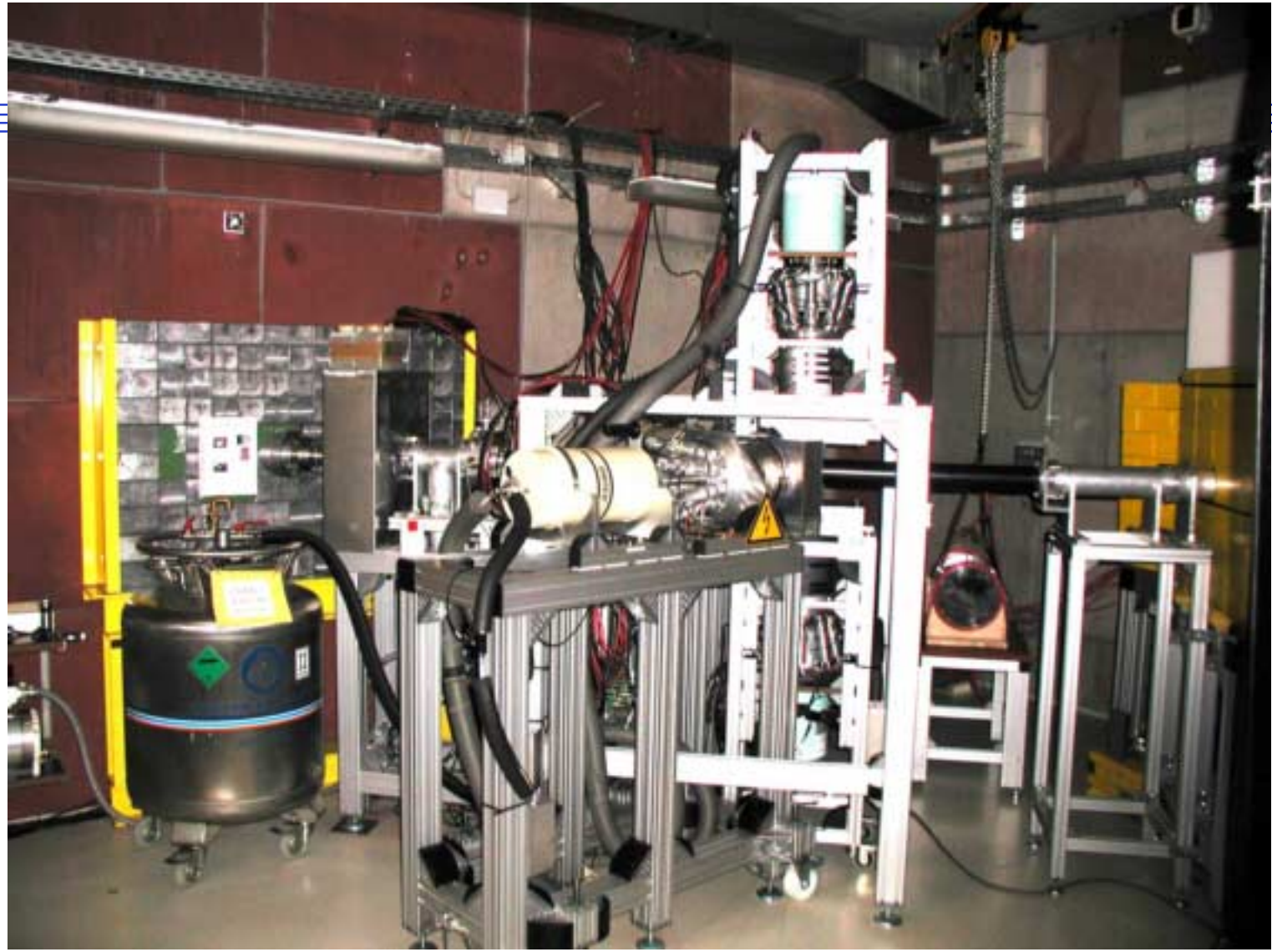
Transverse emittance of the ELBE electron beam



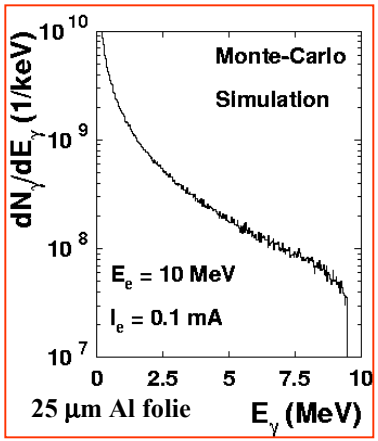
Bremsstrahlung



User operation starts 1/2003

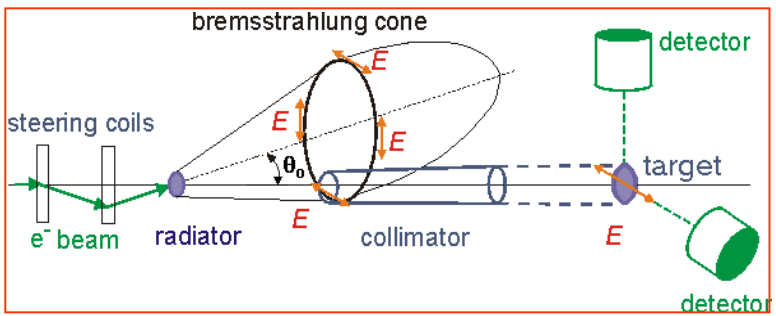


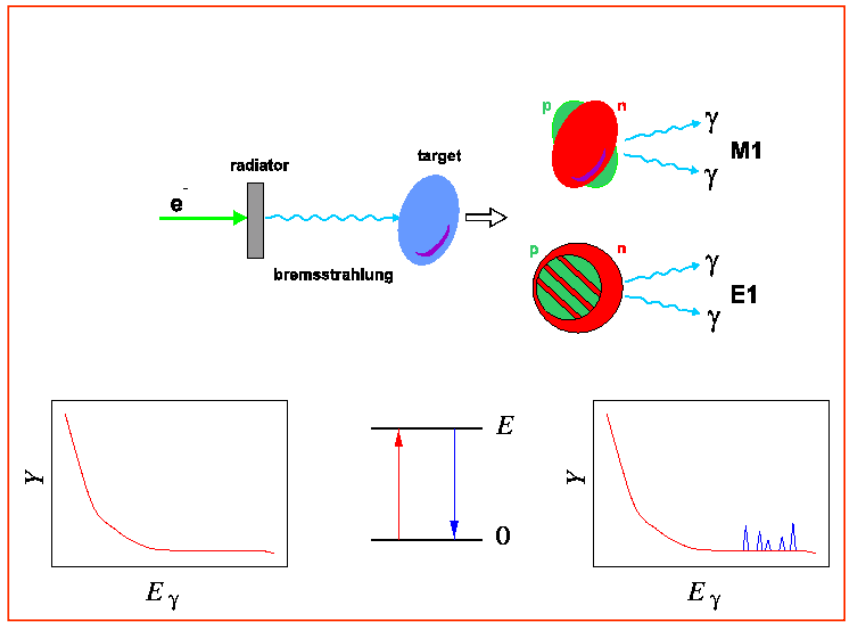
Nuclear spectroscopy at ELBE



γ-beam

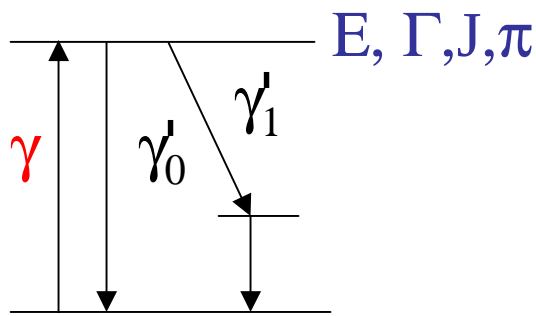
~ 10^7 γ MeV^{-1} s^{-1}
~ 10^{-5} sr

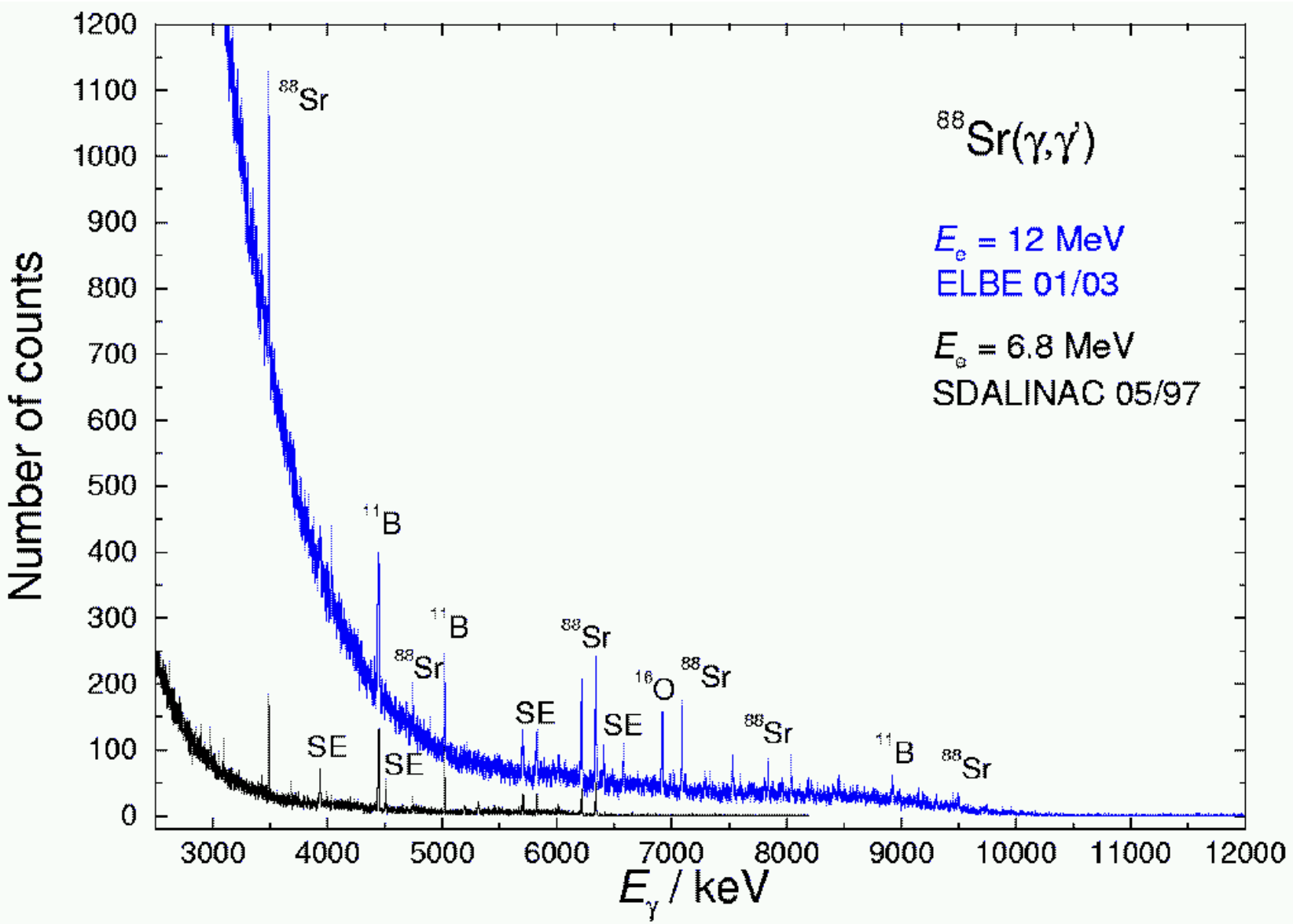




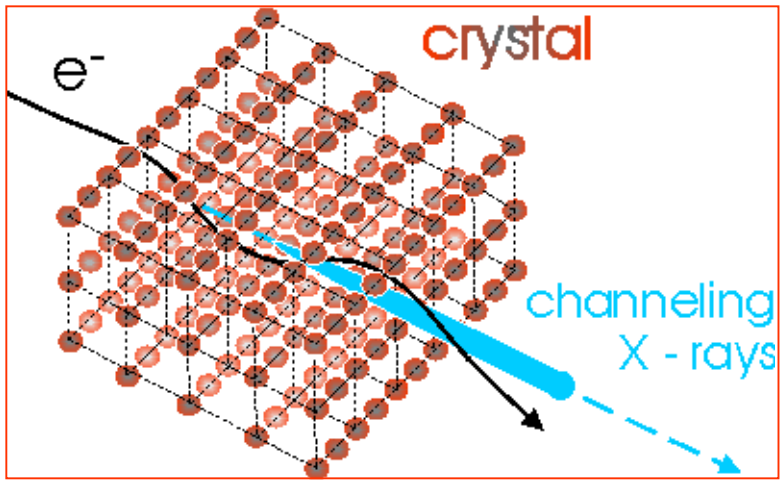
precise and systematic investigation of the structure of stable nuclei

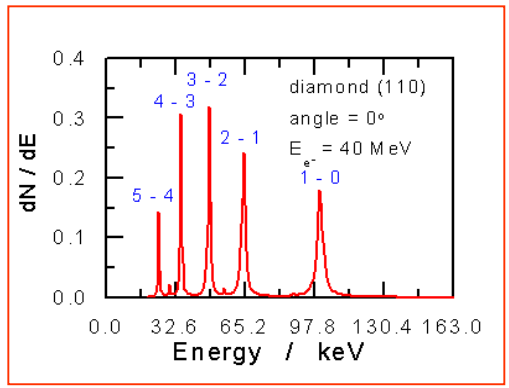
- **Energy** → **excitation energy E**
- **Intensity** → **with G**
- **Angular distribution** → **spin J**
- **Polarization** → **parity p**




^{88}Sr(γ,γ')
E_e = 12 MeV
ELBE 01/03
E_e = 6.8 MeV
SDALINAC 05/97
Number of counts
E_γ / keV
^{88}Sr
^{11}B
SE
^{16}O

X-rays at ELBE



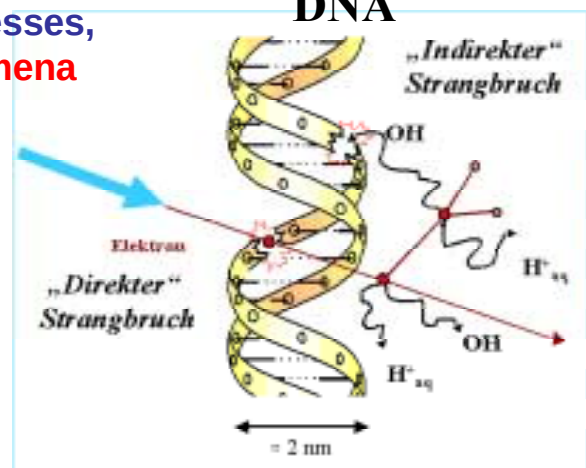


X-ray's

~ 10-100 keV
~ 10^{11} s^{-1}

- **Investigation of elementary processes of radiation damage in living cells**
- **Measurement of relative biological effectiveness of photons**
- **Material science: Time resolved melting and solidification processes, visualizing phase transitions and flow phenomena in liquid metals**

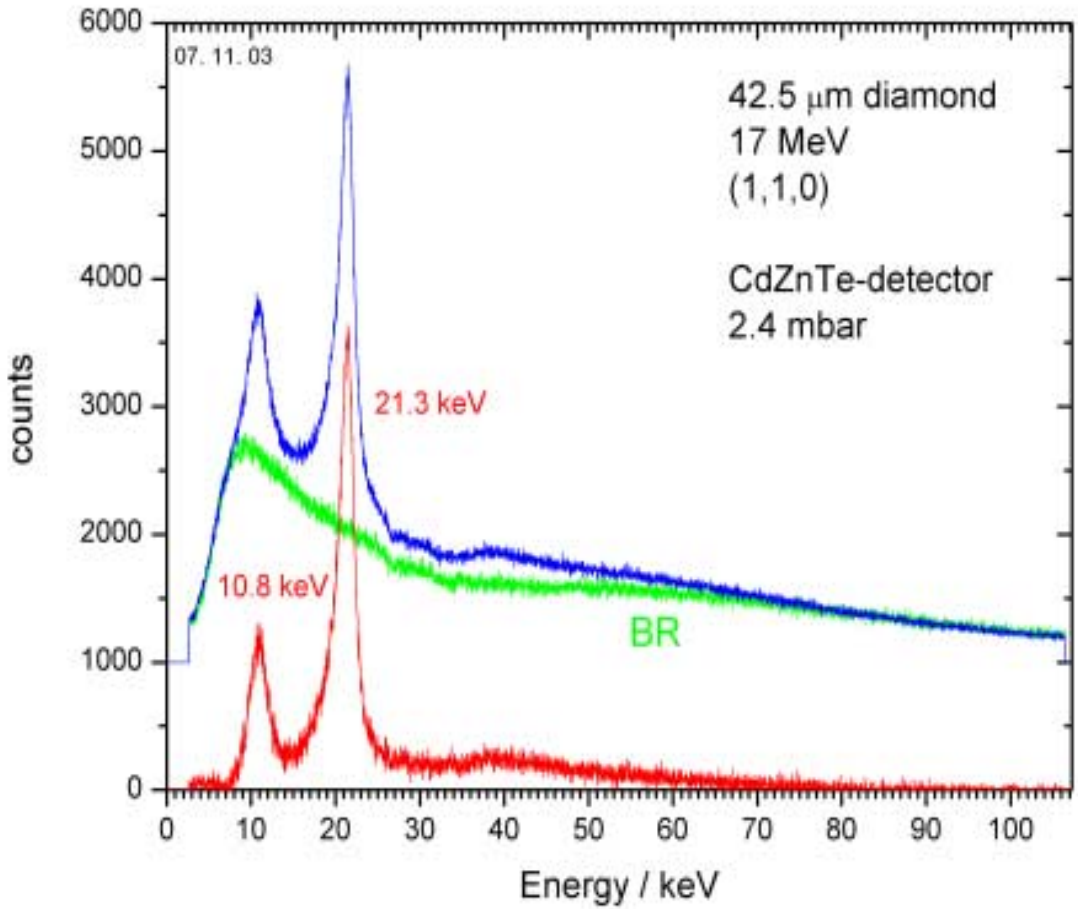
DNA

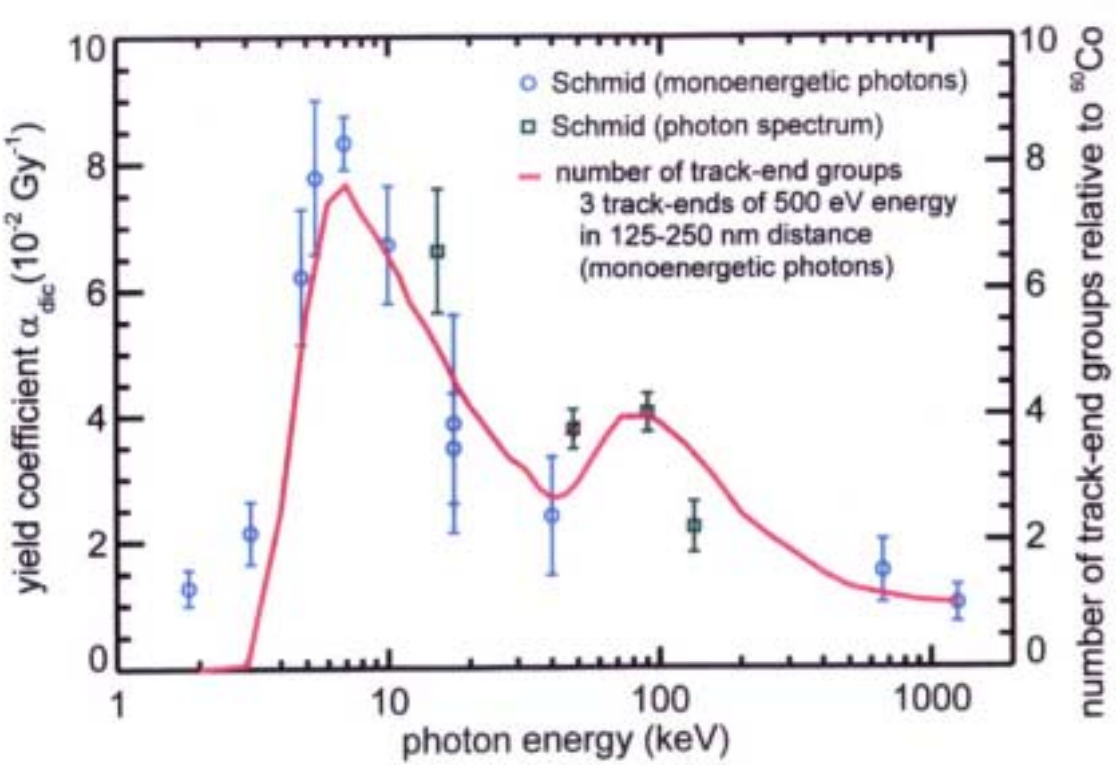


User operation starts 10/2003

Channeling Radiation

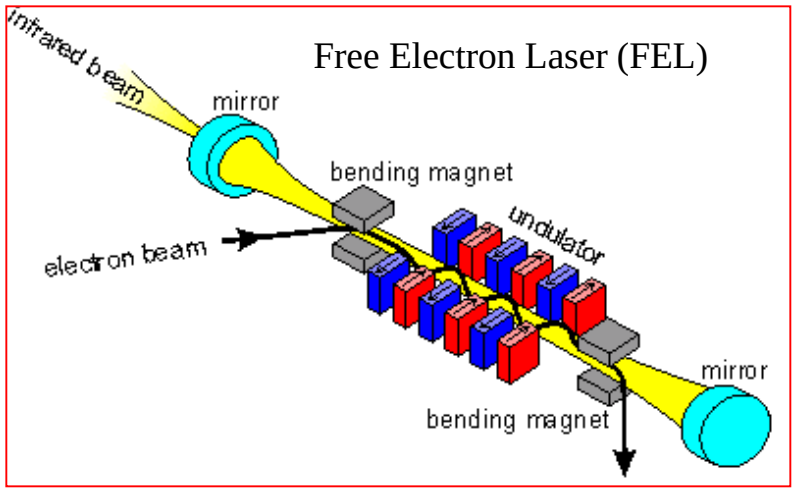
Planar (1,1,0) 17 MeV

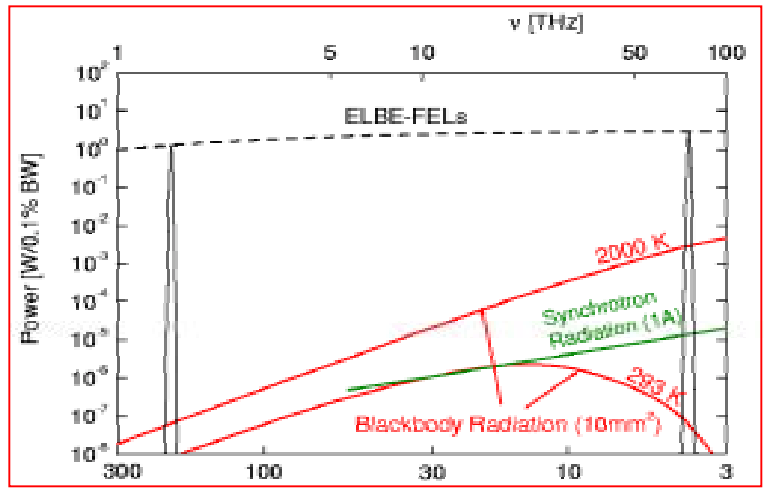


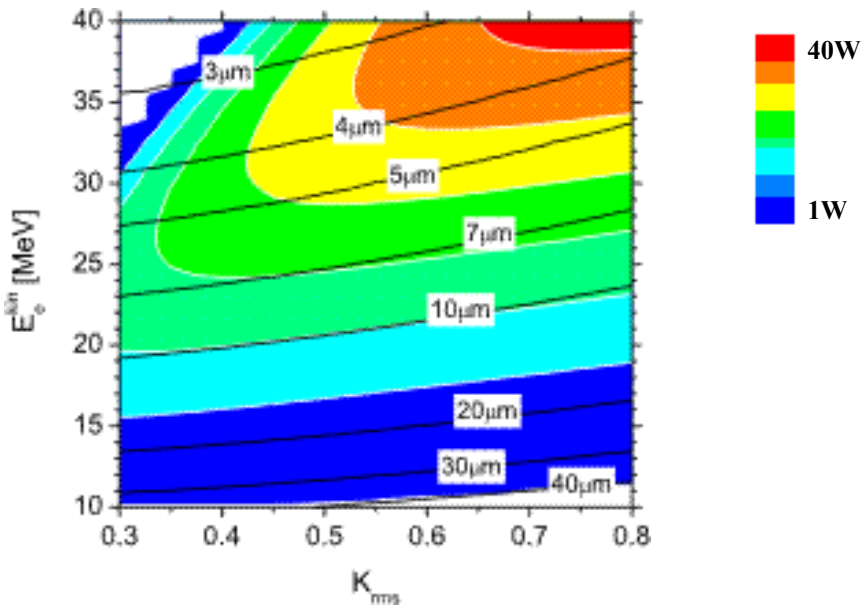


Dose limits for diagnostics ?
Parameter for an effective therapie ?

Infrared from Free Electron Lasers





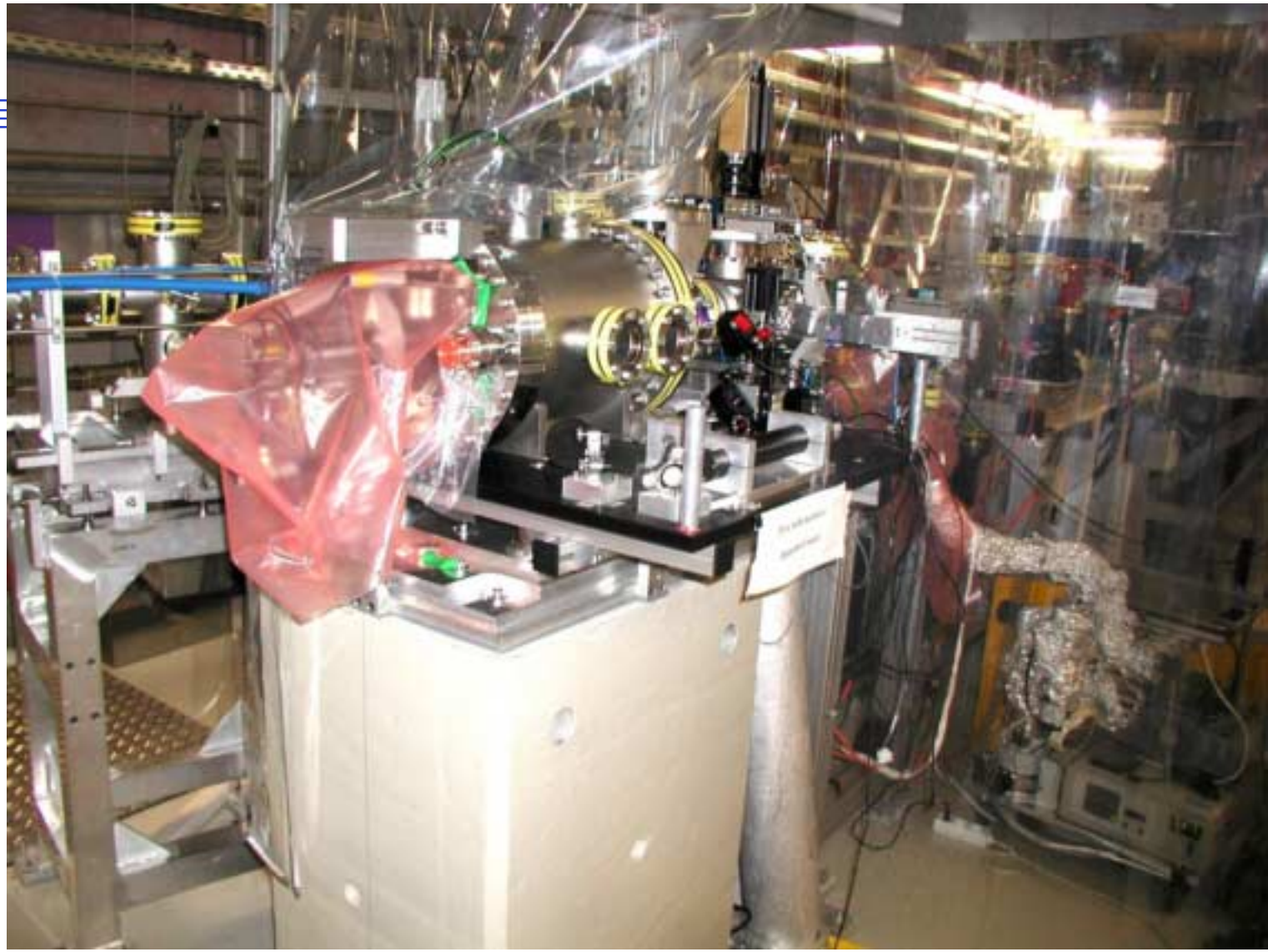


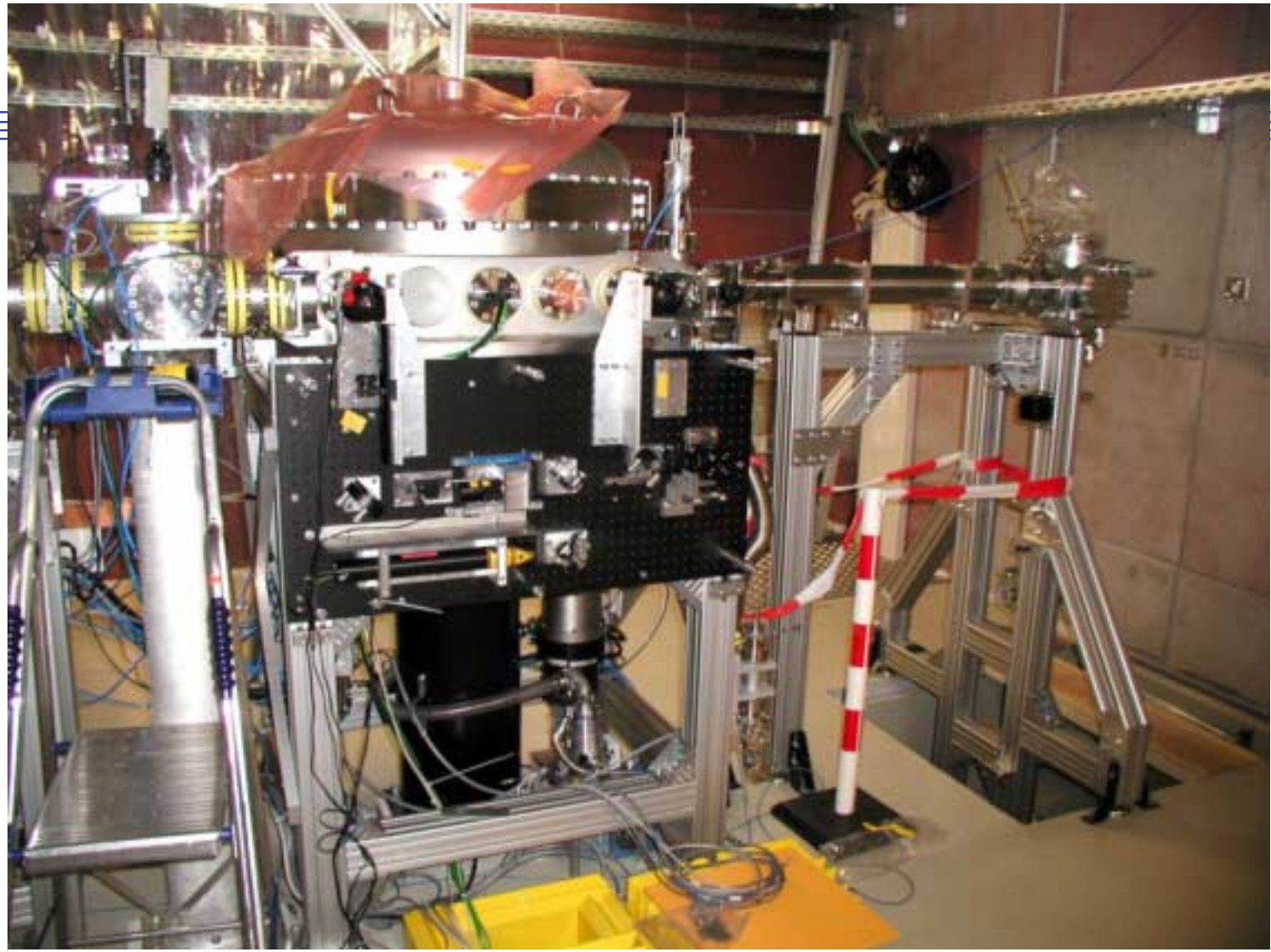
λ_U 27.3 mm
N_U 2x34
K_{rms} 0.3 – 0.8

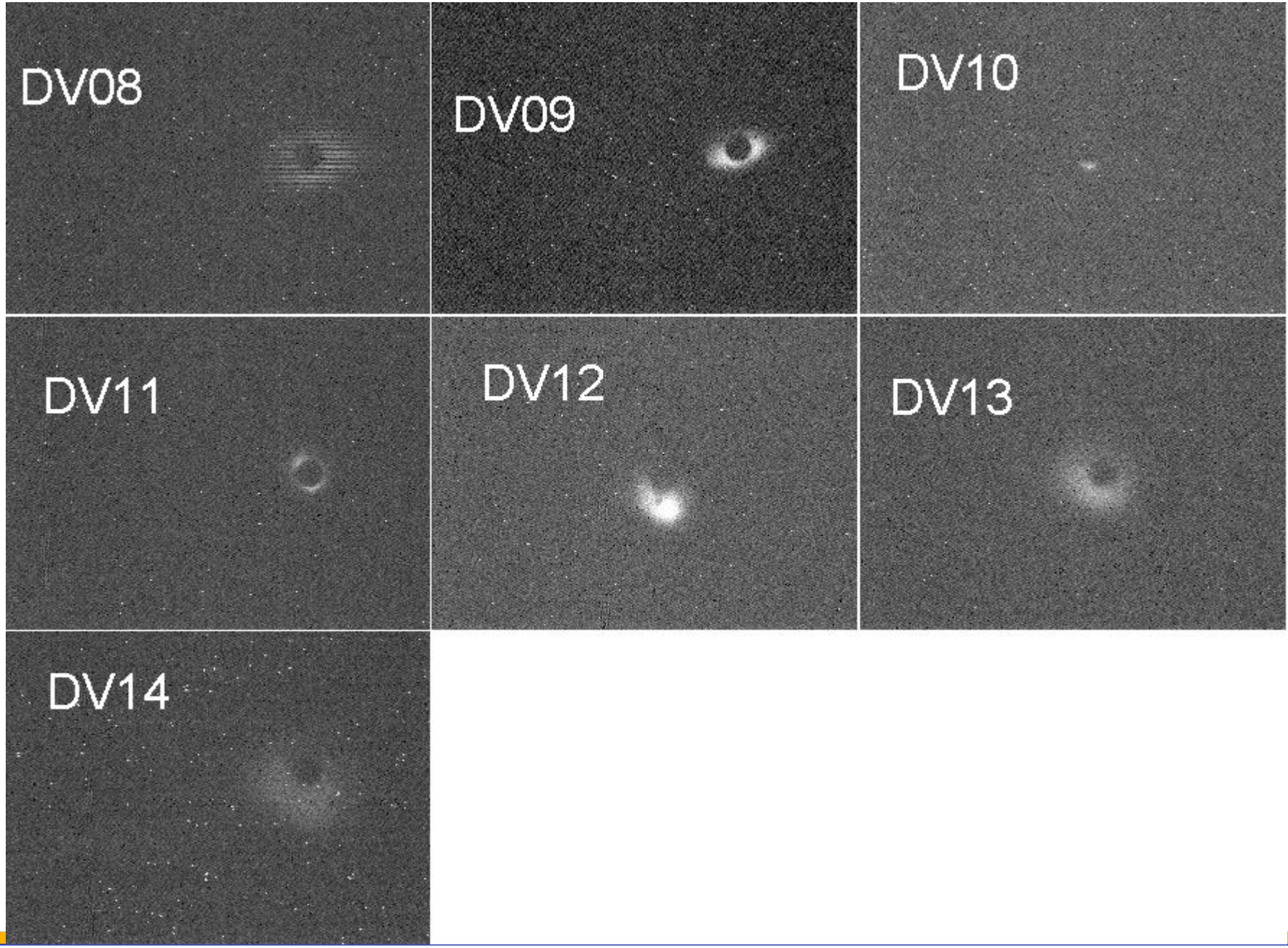
5 – 25 μm (FEL U27)
~ 5 μJ per pulse
~ 1 ps

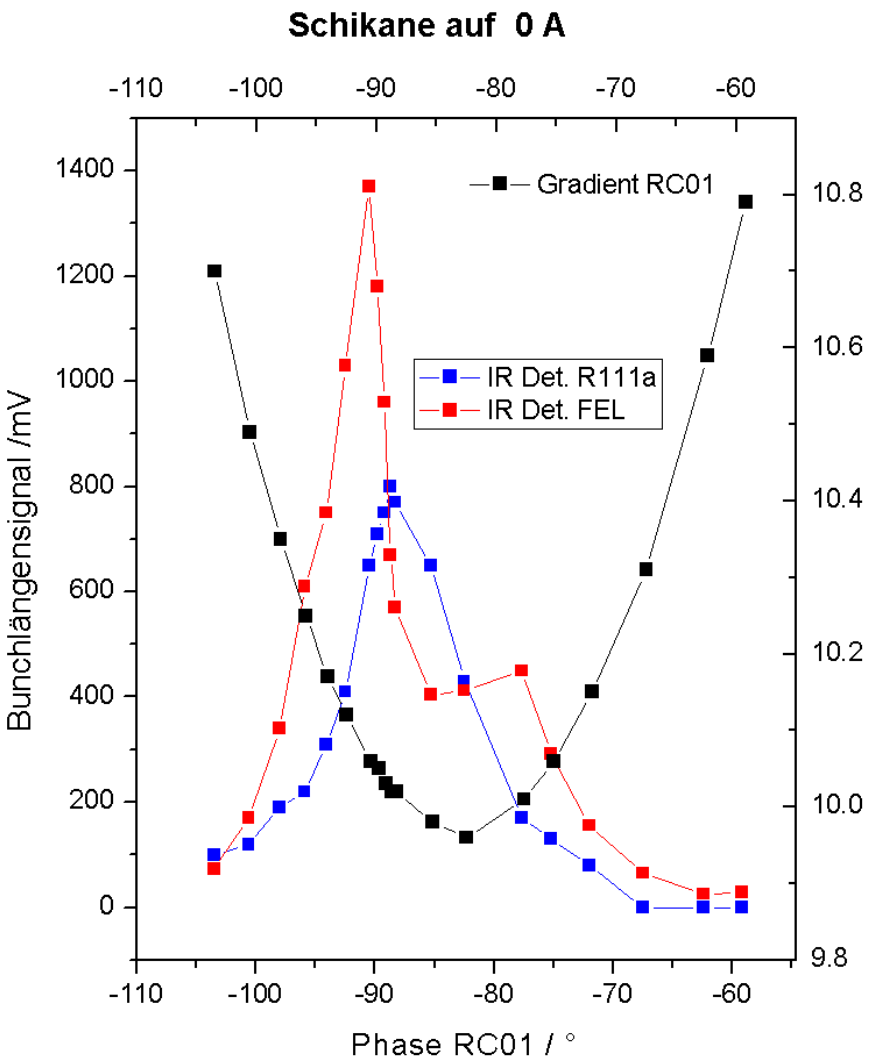
~~We are ready for lasing ….~~

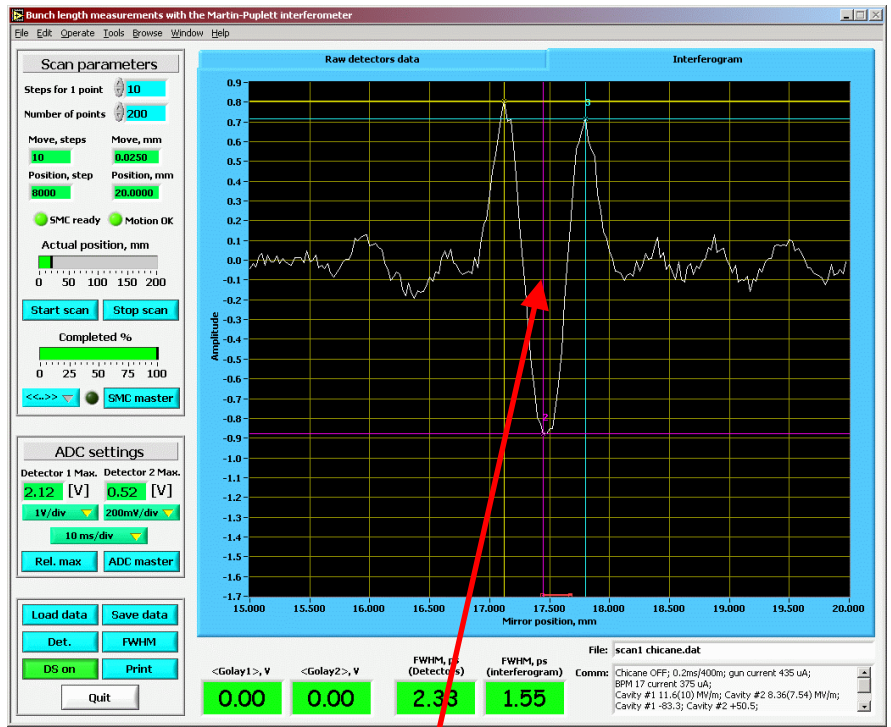
First Lasing: 7. May 19:39
~ 1.5 W @ 19,8 μm





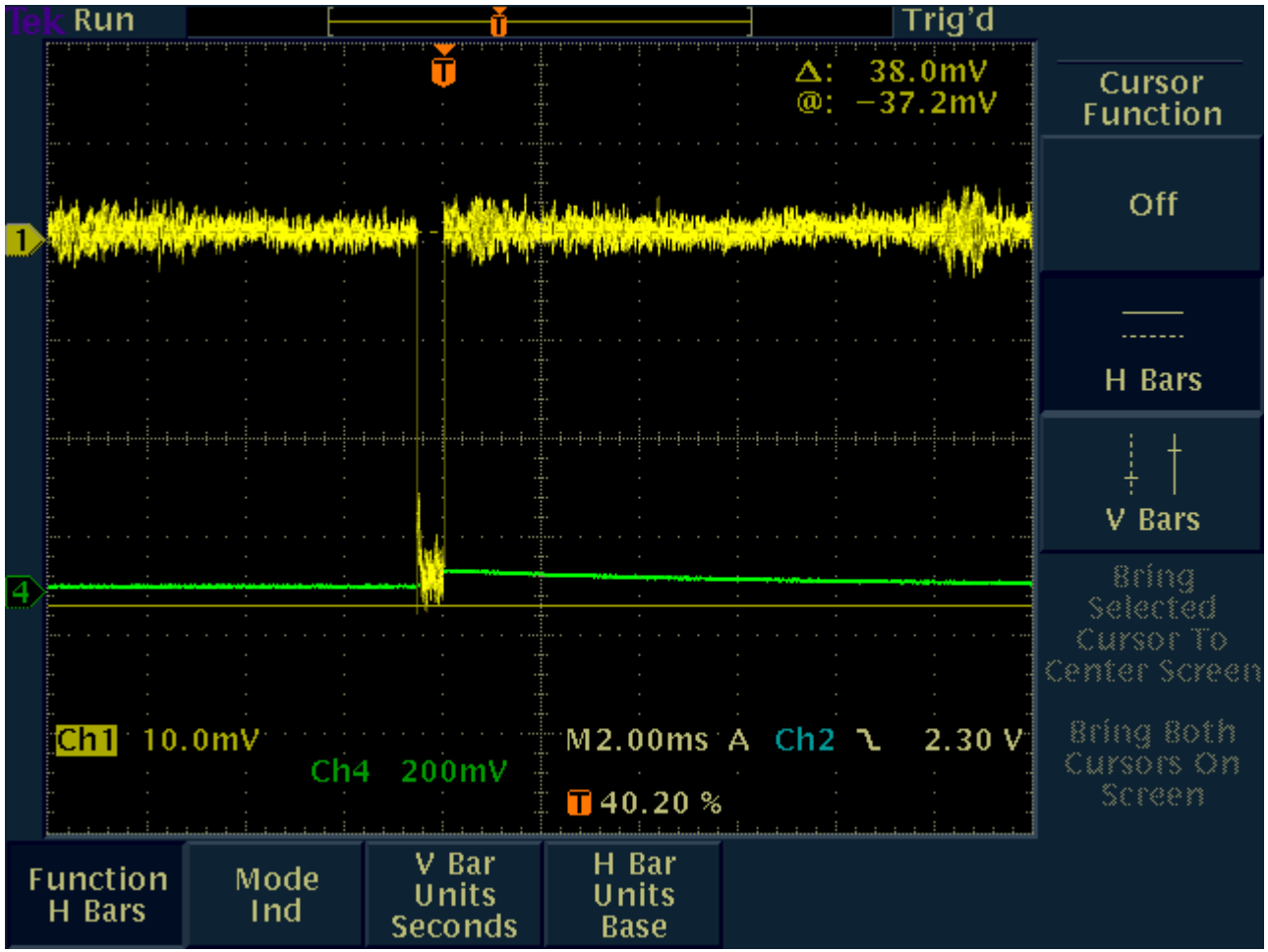

DV08
DV09
DV10
DV11
DV12
DV13
DV14

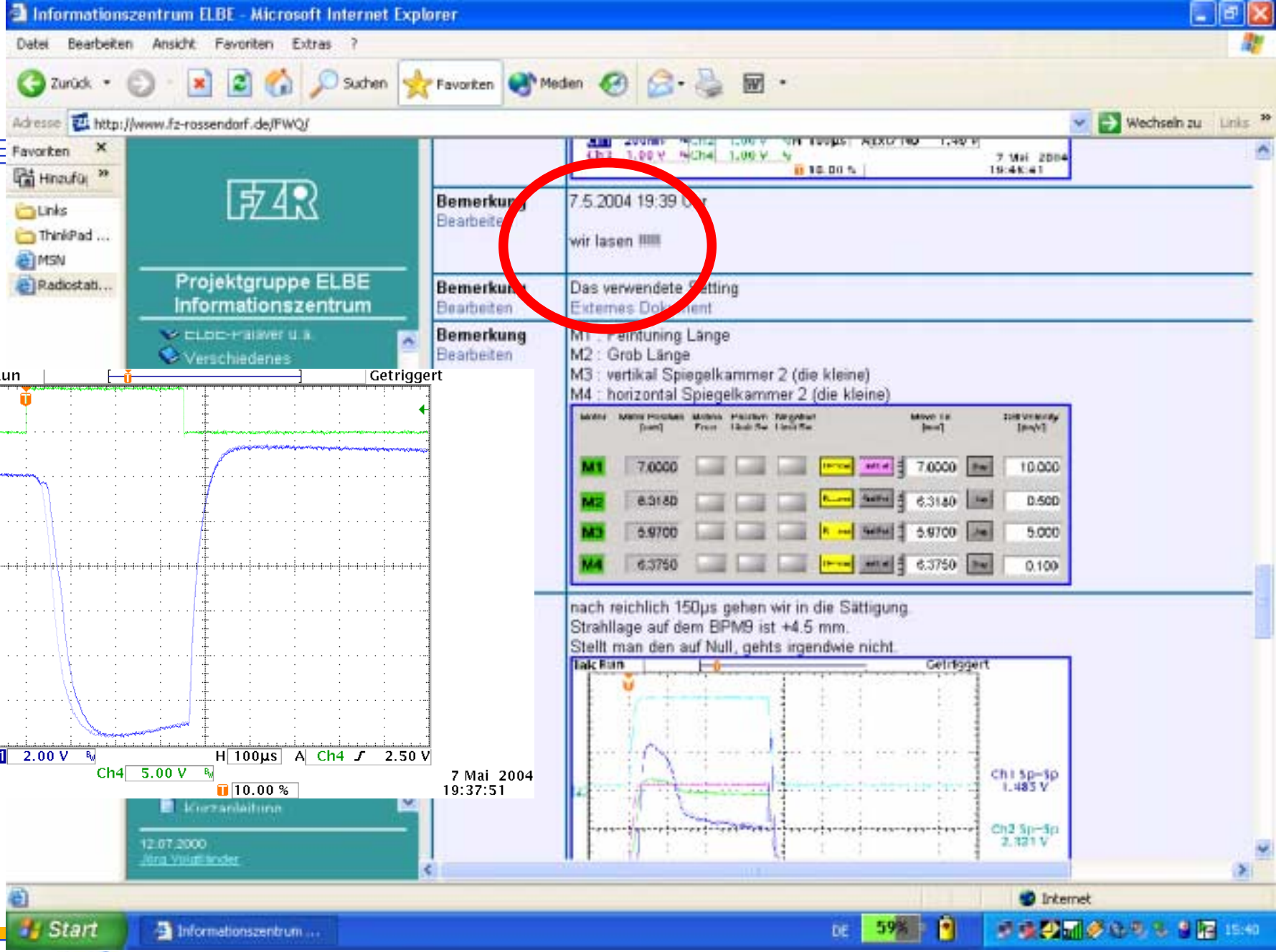

Schikane auf 0 A
Gradient RC01
IR Det. R111a
IR Det. FEL
Bunchlängensignal /mV
Gradient RC01 / MV/m
Phase RC01 / °
-110
-100
-90
-80
-70
-60
0
200
400
600
800
1000
1200
1400
9.8
10.0
10.2
10.4
10.6
10.8


Bunch length measurements with the Martin-Puplett interferometer
Scan parameters
Steps for 1 point
Number of points
Start scan
Stop scan
ADC settings
Raw detectors data
Interferogram
Mirror position, mm
Amplitude
0.00
0.00
2.33
1.55

~ 0.8 ps

Spontaneous radiation Log book 4.5.2004

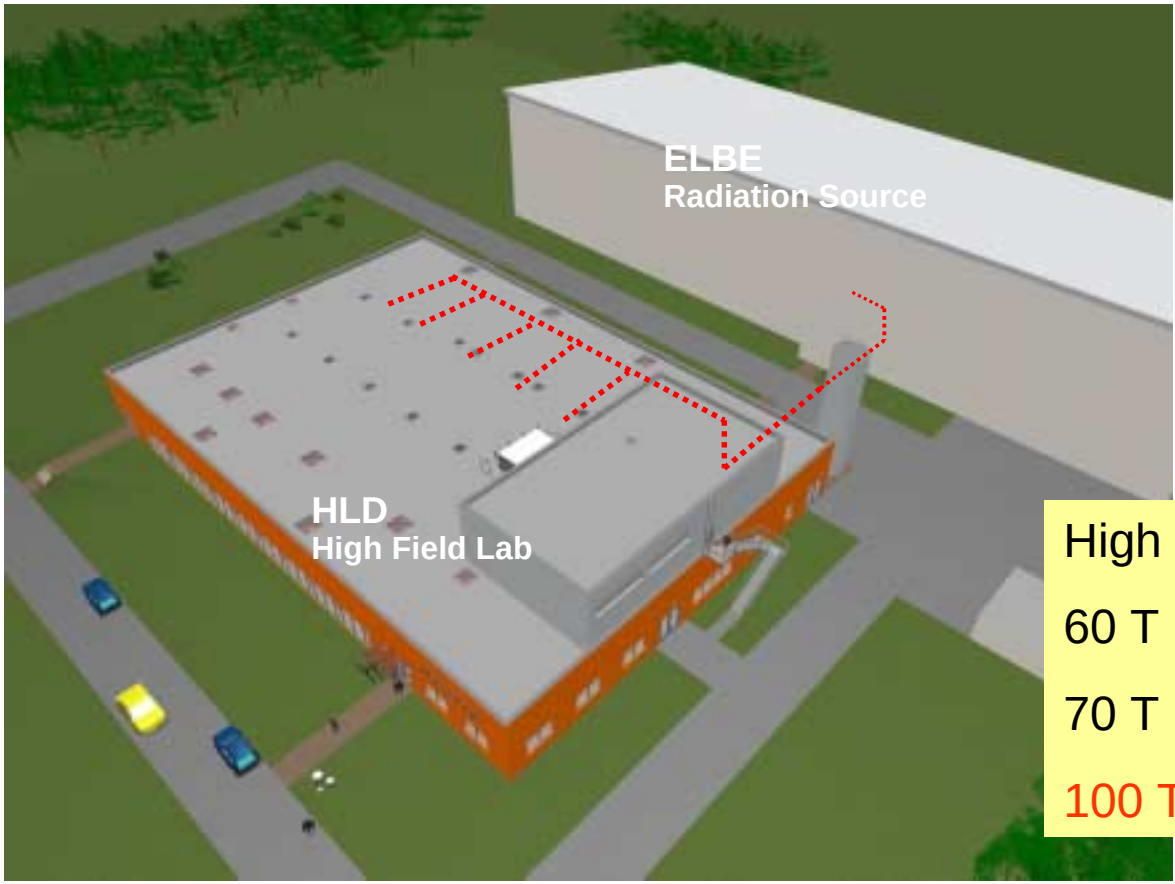



Informationszentrum ELBE - Microsoft Internet Explorer
Datei Bearbeiten Ansicht Favoriten Extras ?
Zurück Suchen Favoriten Medien
Adresse http://www.fz-rossendorf.de/PWQ/
Wechseln zu
Favoriten
Hinzufü
Links
ThinkPad ...
MSN
Radiostati...
FZR
Projektgruppe ELBE
Informationszentrum
Verschiedenes
Bemerkung
Bearbeiten
7.5.2004 19:39
wir lasen !!!!
Bemerkung
Bearbeiten
Das verwendete Setting
Externes Dokument
Bemerkung
Bearbeiten
M1 : Feintuning Länge
M2 : Grob Länge
M3 : vertikal Spiegelkammer 2 (die kleine)
M4 : horizontal Spiegelkammer 2 (die kleine)
M1 7.0000 7.0000 10.000
M2 6.3180 6.3180 0.500
M3 5.9700 5.9700 5.000
M4 6.3750 6.3750 0.100
nach reichlich 150µs gehen wir in die Sättigung
Strahllage auf dem BPM9 ist +4.5 mm.
Stellt man den auf Null, gehts irgendwie nicht.
Tek Run
Getriggert
Ch1 2.00 V
H 100µs
A Ch4 2.50 V
Ch4 5.00 V
10.00 %
7 Mai 2004
19:37:51
12.07.2000
Jörg Voigtländer
Internet
Start
Informationszentrum ...
DE
59%
15:40

Experiments with IR from FEL

- Pulse-stacking cavity ring-down measurements
- IR near-field microscopy and spectroscopy
- Pump-probe experiments in the sub-ps regime
- IR investigations of semiconductor and quantum structures
- IR spectroscopy of complex molecules
- Surface studies and modifications
- Medical and biomedical investigations
- Infrared microspectrometry of environmental samples (Radiochemistry)

High Magnetic Fields & ELBE



High Field Lab Dresden

60 T @ 1000 ms

70 T @ 100 ms

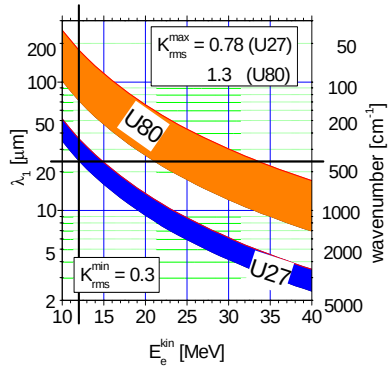
100 T @ 10 ms

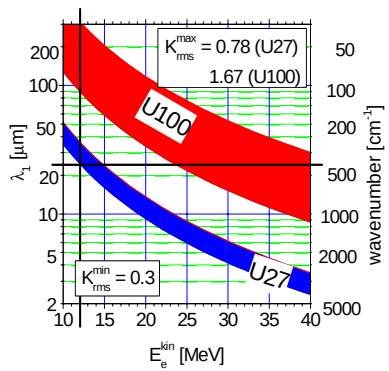
Combination of ELBE FEL (3 … 150 μm) and High Magnetic Field Lab
IR spectrosokopie at high magnetic fields

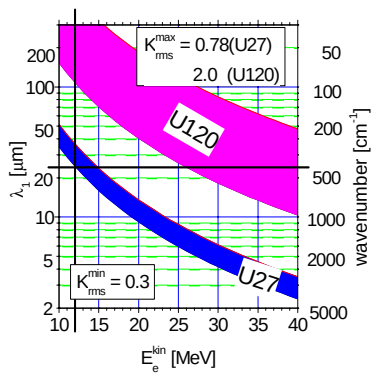
$2\mu_B \cdot 100\ T \gg h \cdot c / 100\ \mu m$

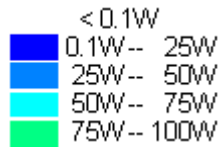
Plans for longer wavelength FEL (20-200µm)

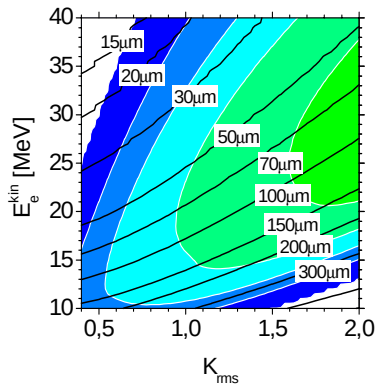
	λ_u[cm]	N_u	K_{rms}^{max}
U80	8	30	1.3
U100	10	24	1.7
U120	12	20	2







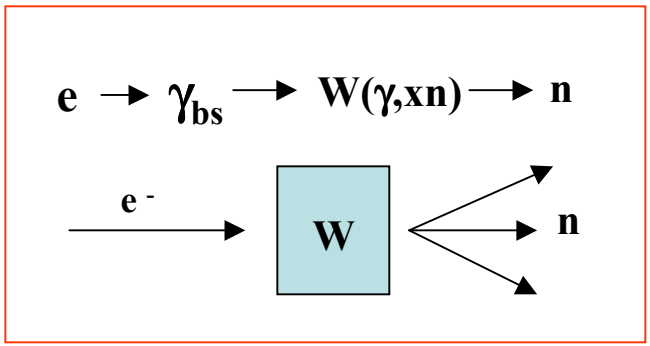




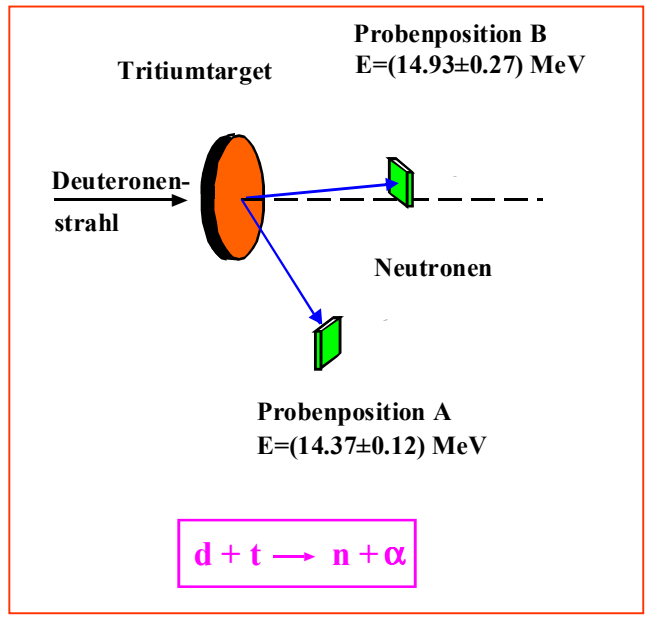
Wave guide needed !

Neutrons at ELBE
(TU Dresden)

ELBE electrons



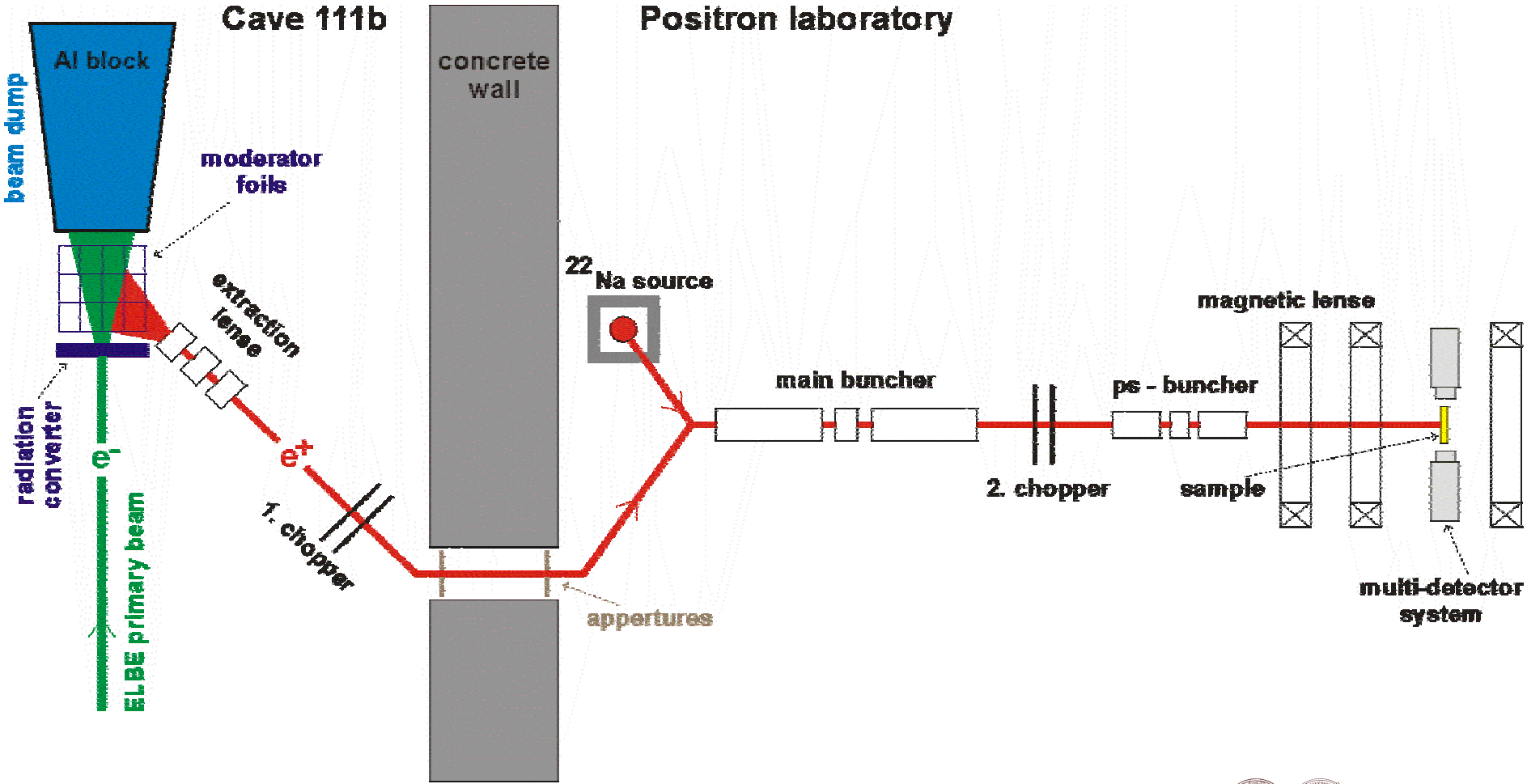
14 MeV neutron gererator



- **Fusion reactor studies (ITER): interaction of fast neutrons with construction materials**
- **study of the energy dependence of neutron – nucleus cross sections by time of flight technique**
- **triggered fission studies for the spectroscopy of neutron-rich medium mass nuclei**

neutrons
~ 10^{13} ns^{-1} (continuum)
~ 10^{12} ns^{-1} (14 MeV)
~ $\Delta\tau$<100 ps

Schematic view of EPOS (ELBE Positron Source)



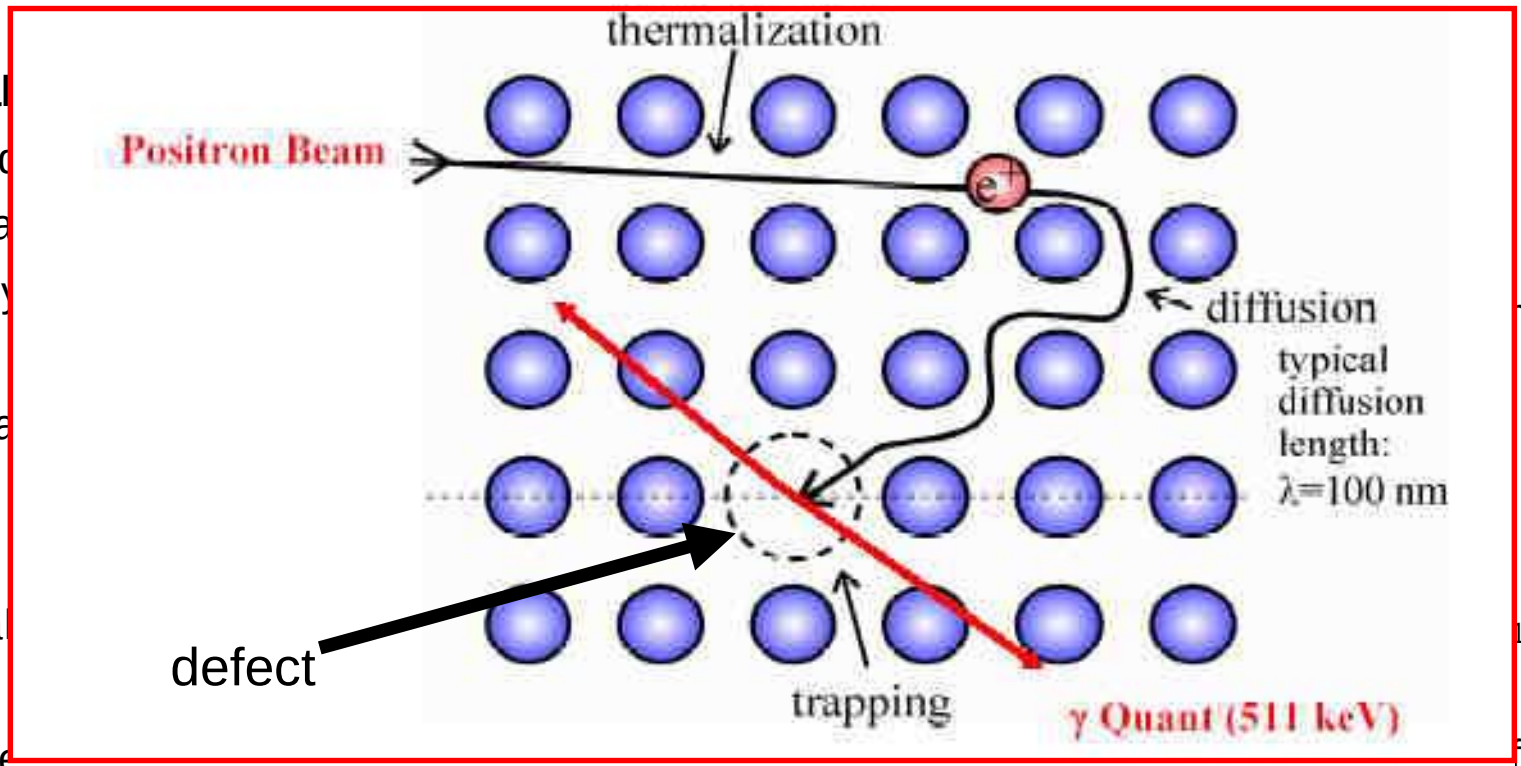
EPOS = ELBE Positron Source

- EPOS will be the combination of a positron lifetime spectrometer, Doppler coincidence, and AMOC
- main features:

Variety

material

- defect-c
  modifica
- tribology
- polymer
- low-k ma
- defects
  metals
- epitaxial
  defects
- fast kine
  Al alloys; defect annealing; diffusion; …)
- radiation resistance (e.g. space materials)
- many more …



ne

1)

for

Doppler measurements (when primary beam is not available)

- fully remote control via Internet by user

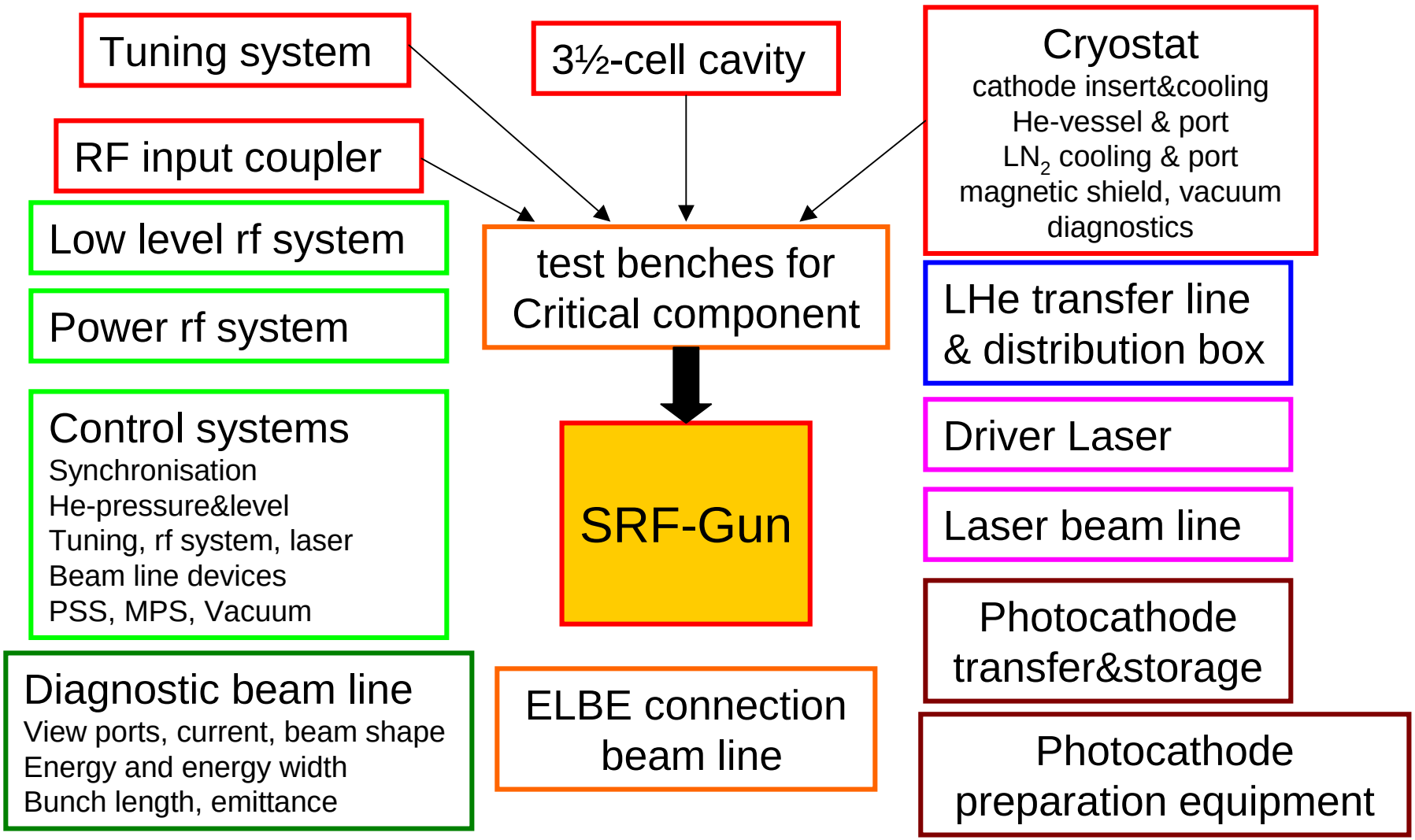
ELBE SRF Photogun – Basic Design

Normal-conducting cathode inside SC cavity

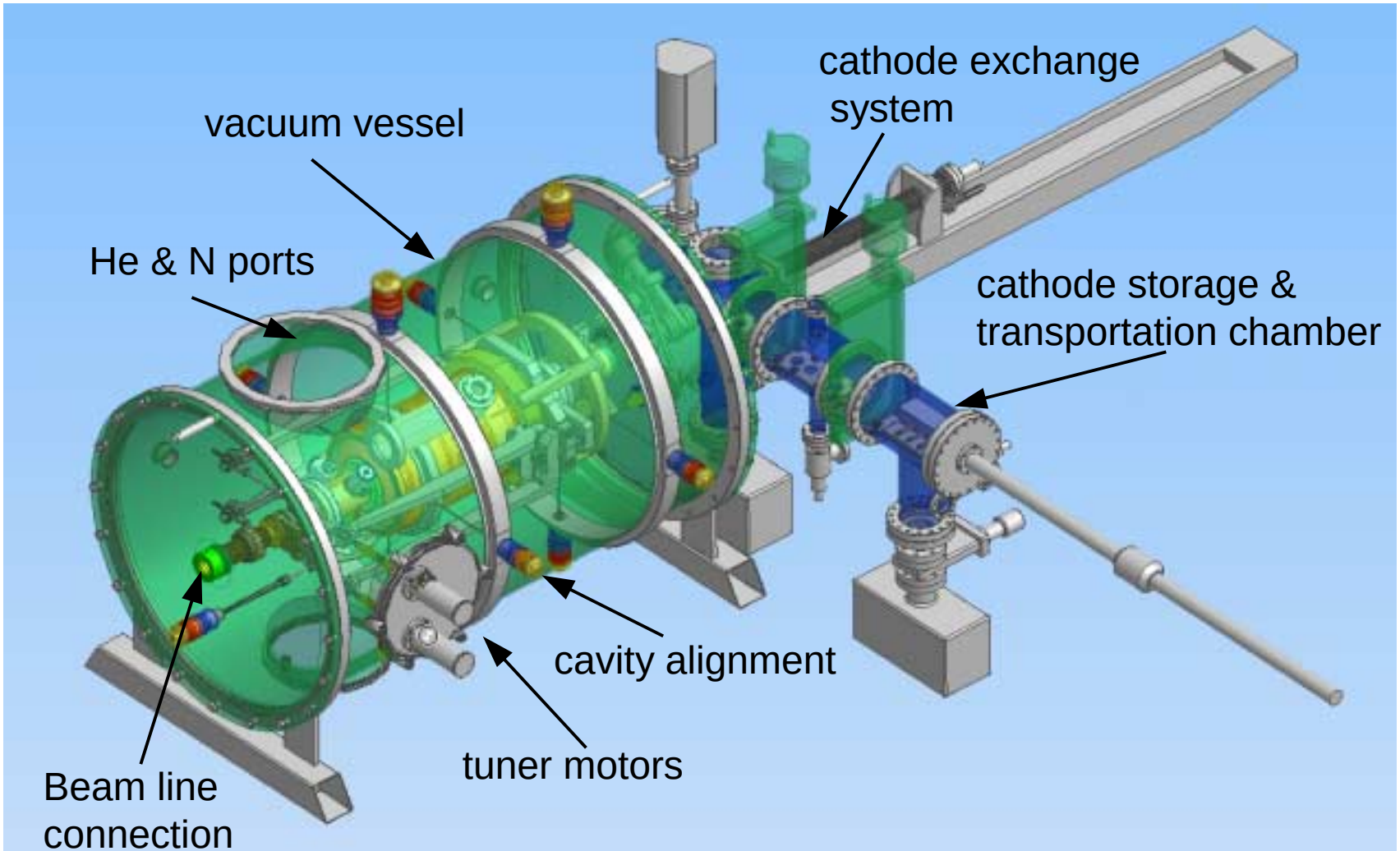
Successful Proof of Principle Experiment, D. Janssen et al., NIM A507(2003)314

Cavity:	Niobium 3+½ cell (TESLA Geometry)
	Choke filter
Operation:	T = 1.8 K
Frequency:	1.3 GHz
HF power:	10 kW
Electron energy:	10 MeV
Average current:	1 mA
Cathode:	Cs_2Te
	thermally insulated, LN_2 cooled
Laser:	262 nm, 1W
Pulse frequency:	13 MHz & < 1 MHz
Bunch charge:	77 pC & 1 nC

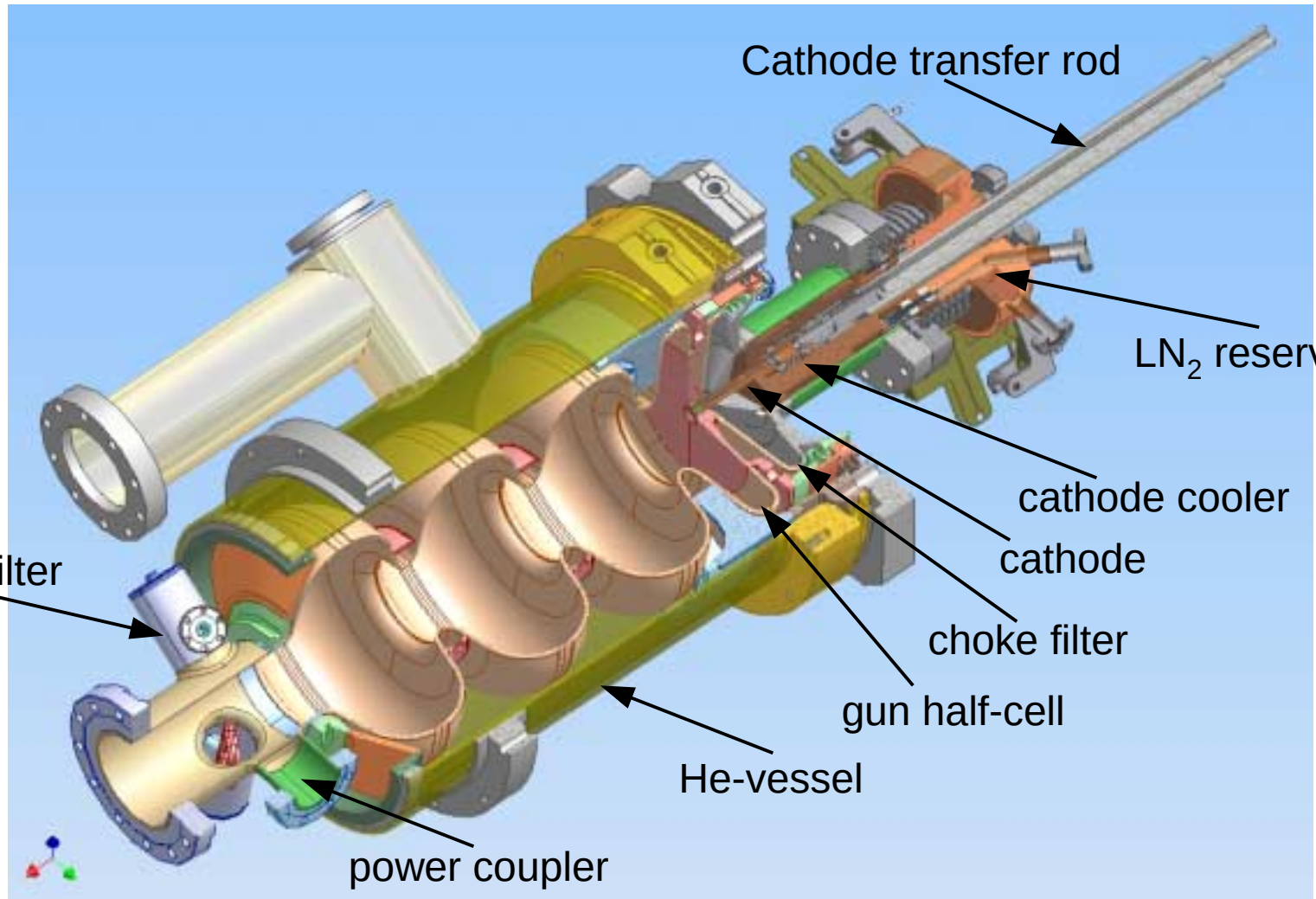
Main Components of the ELBE SRF Photogun



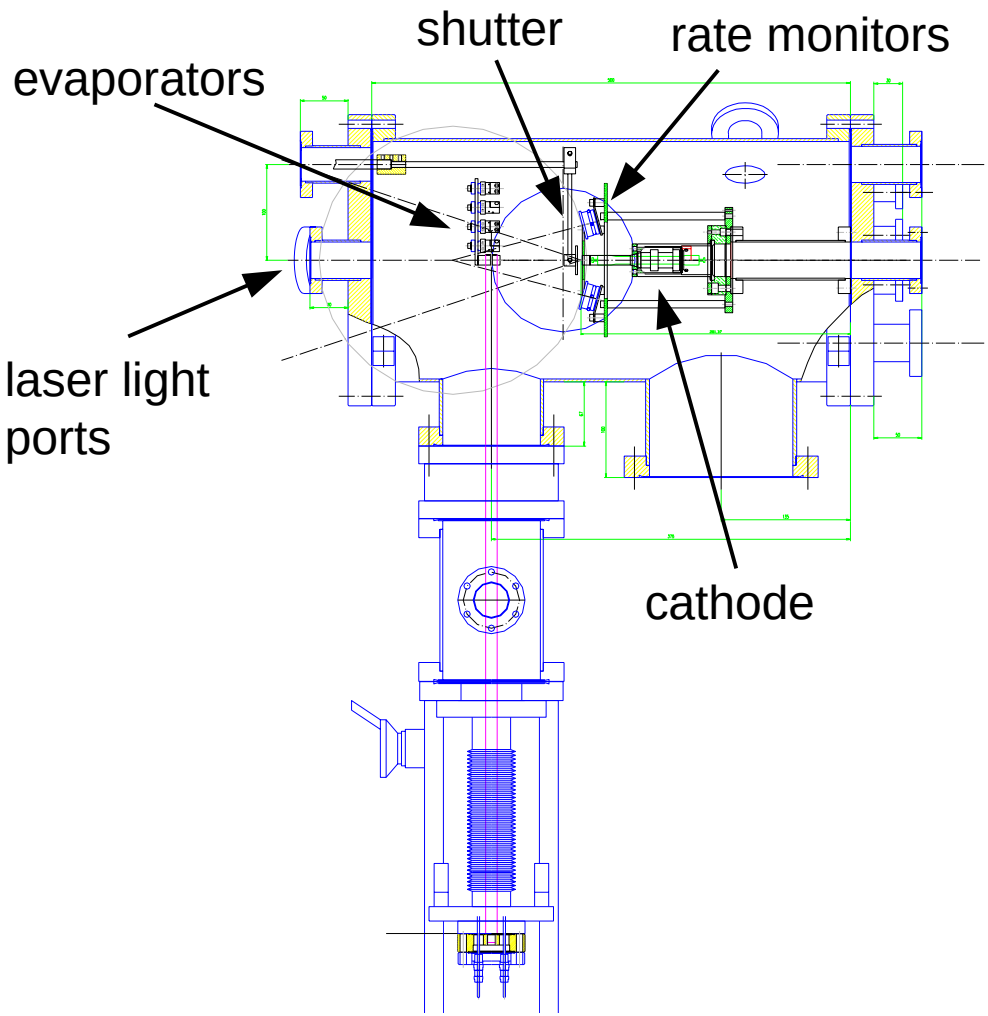
ELBE SRF Photogun – Cryomodule design



ELBE SRF Photogun – Cavity design



ELBE SRF Photogun – Cathode preparation chamber



Technology:

Co-evaporation process

from CERN

Trautner, Suberlucq, Chevallay, 2001

4 evaporators with
- tellurium
- Cs_2CrO_4 (saes getters)

2 deposition rate monitors
- separate measurements for Te and Cs
- control of 1 : 2 ratio

cathode heating

cathode cleaning (ion sputtering)

Q.E. measuring with 262 nm, 10 mW laser
- during deposition
- aging
- distribution (laser spot scan)

ELBE SRF Photogun – Present Status

Cavity: **Design finished**
Fabrication of 2 (RRR 40 & 300) cavities at ACCEL GmbH and a third cavity by Peking University

Cavity tuners: **Fabrication finished**
tests necessary

Cathode cooling system:
Design finished, in fabrication

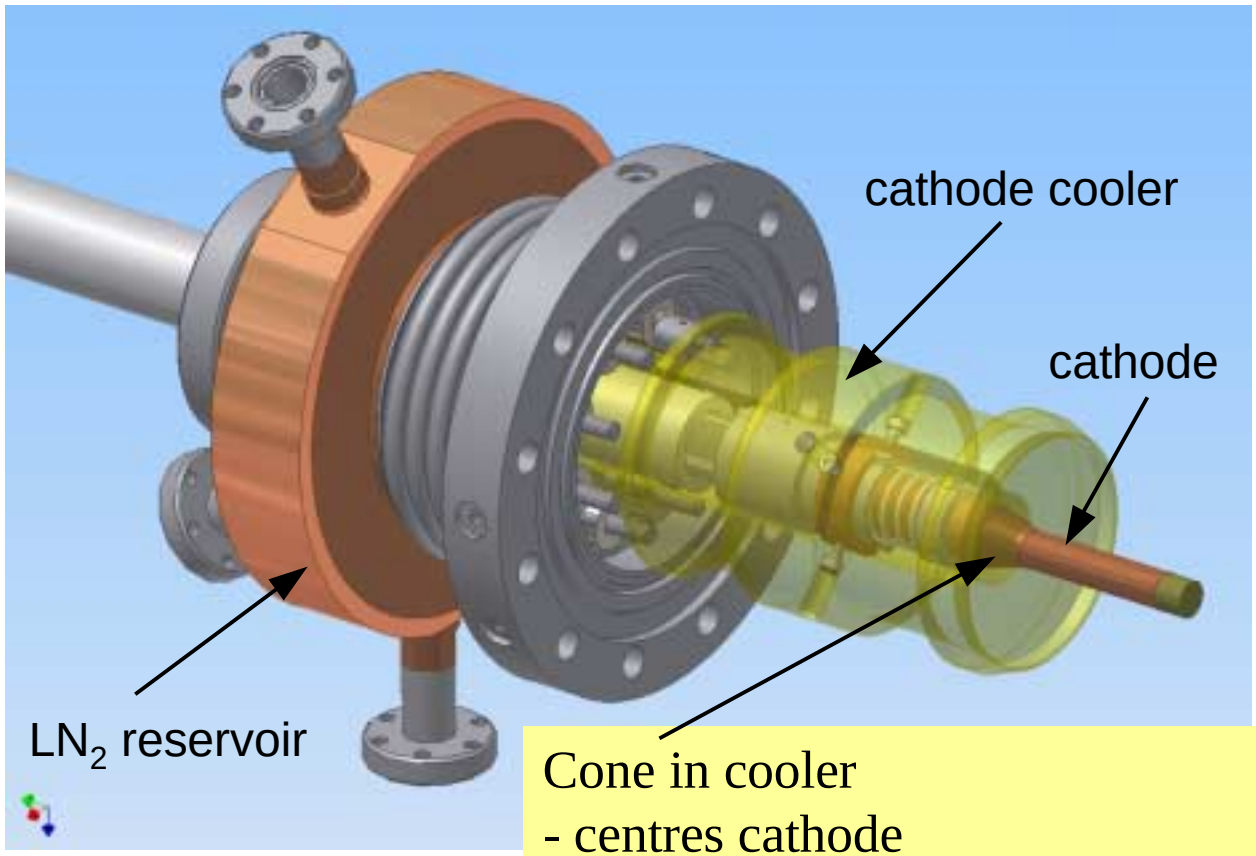
Cathode transfer system:
Design finished

Cathode preparation chamber:
Design finished, in the work-shop

Cryomodule: Design will be finished in July


Thank you for your attention

ELBE SRF Photogun – Liquid N_2 Cathode Cooling

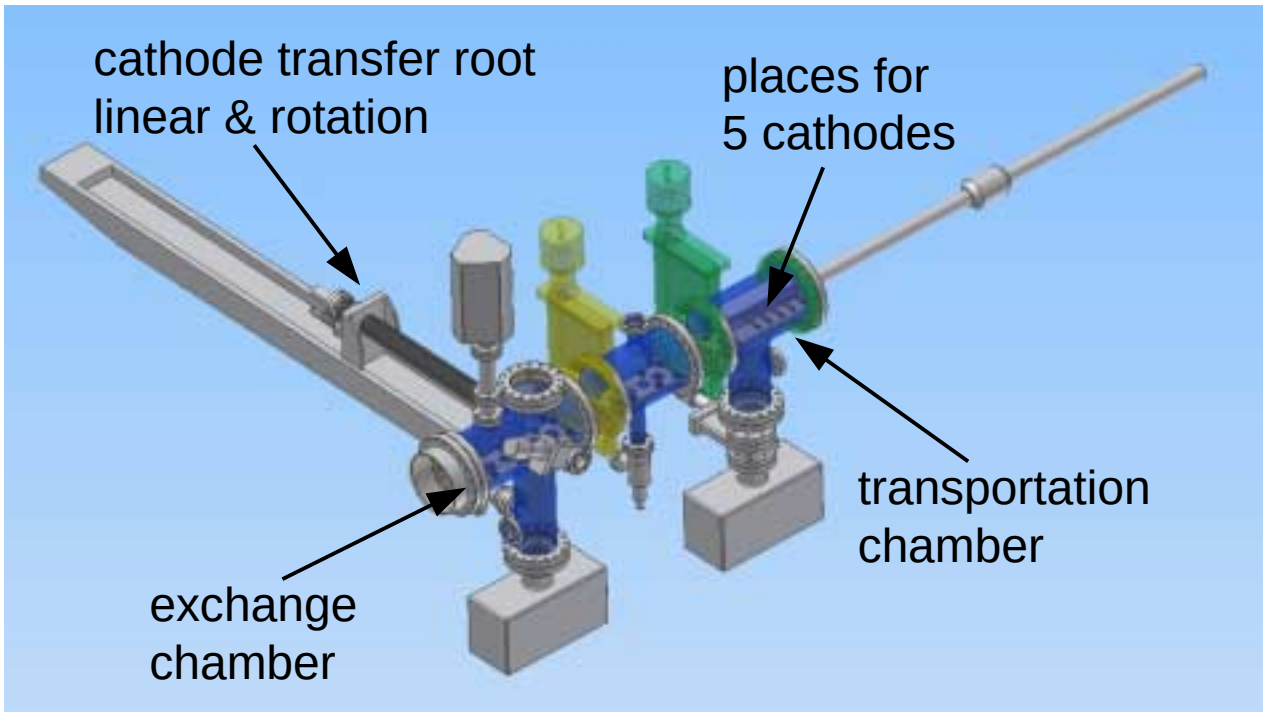


Cone in cooler
- centres cathode
- cathode is pressed in by spring
- **thermal contact of cone surface ?**

Test bench

thermal conductance measurements, cathode temperature?
&
test of the cathode transfer system

ELBE SRF Photogun – Cathode Exchange & Transport

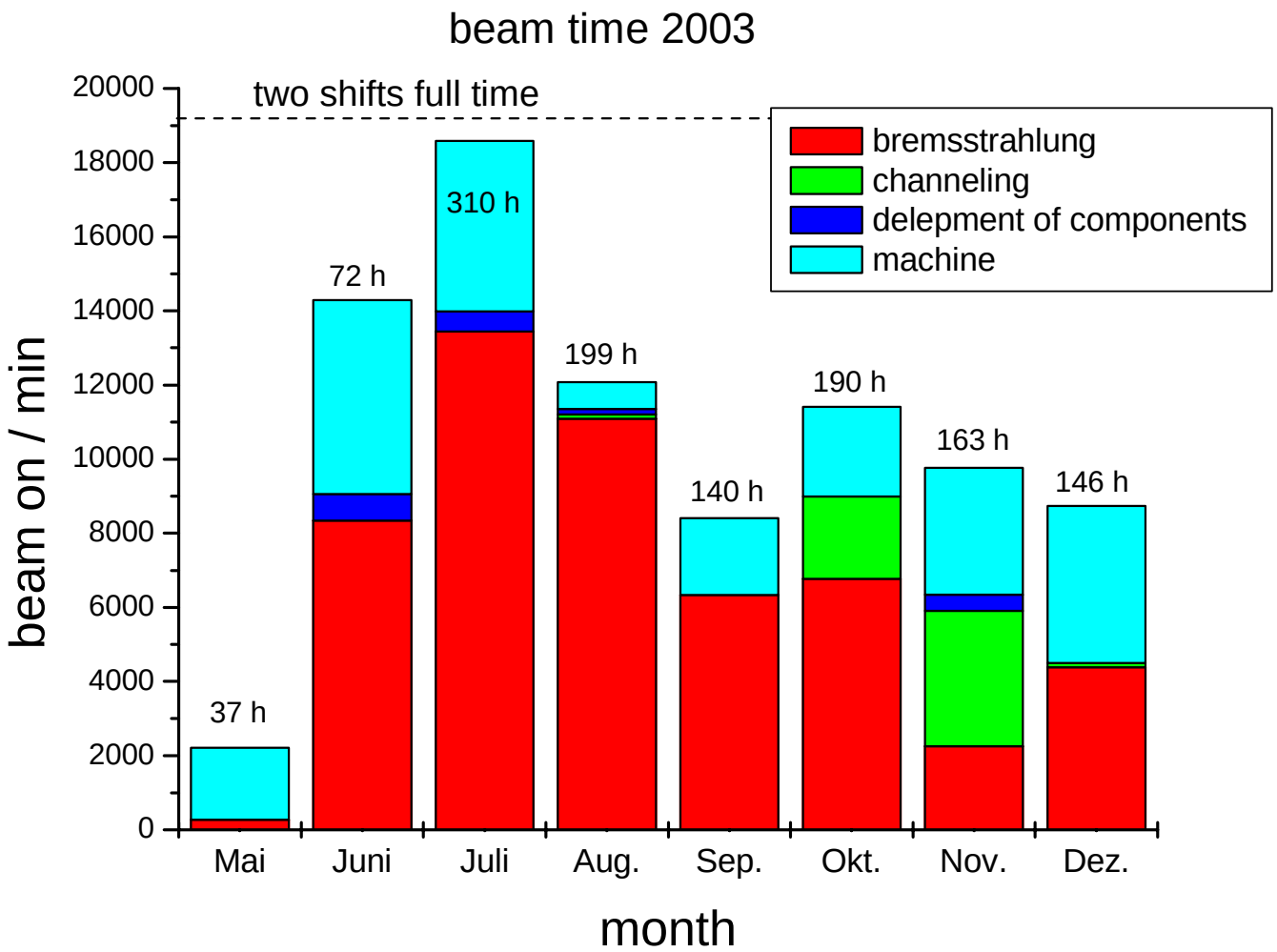


accurate adjustment of the cathode;
minimum particle generation
during exchange

2 identical systems

at the SRF-gun
(accelerator hall)
&
at the cathode
preparation
chamber
(preparation lab)

transportation
chambers allow
cathode transport
in vacuum


beam time 2003
two shifts full time
bremsstrahlung
channeling
delepment of components
machine
beam on / min
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
37 h
72 h
310 h
199 h
140 h
190 h
163 h
146 h
Mai
Juni
Juli
Aug.
Sep.
Okt.
Nov.
Dez.
month

Thank you for YOUR attention

Collaboration:

BESSY, Berlin
Max-Born-Institut, Berlin
TJNAF, Newport News
University of Peking
BINP, Novosibirsk
DESY, Hamburg & Zeuthen
ACCEL GmbH, Bergisch Gladbach
Technische Universität, Dresden
IfE-Automatisierung GmbH, Dresden
Ingenieurkontor Stephan, Dresden

The ELBE crew
(visiting the ELBE river source, Spindleruv Mlyn, Czech Republic, April 2003)

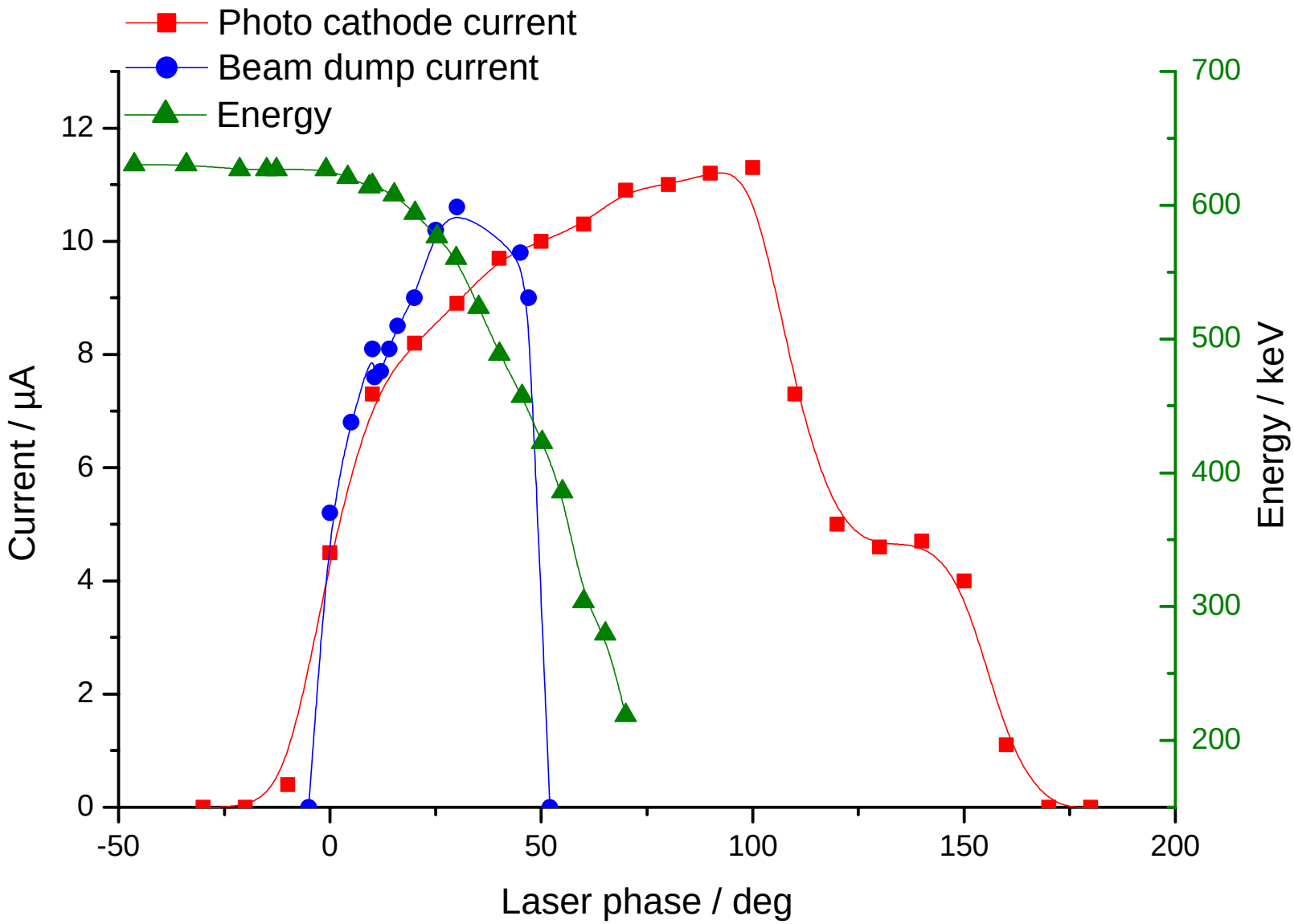


Photo cathode current
Beam dump current
Energy
Current / µA
Energy / keV
Laser phase / deg
0
2
4
6
8
10
12
200
300
400
500
600
700
-50
0
50
100
150
200

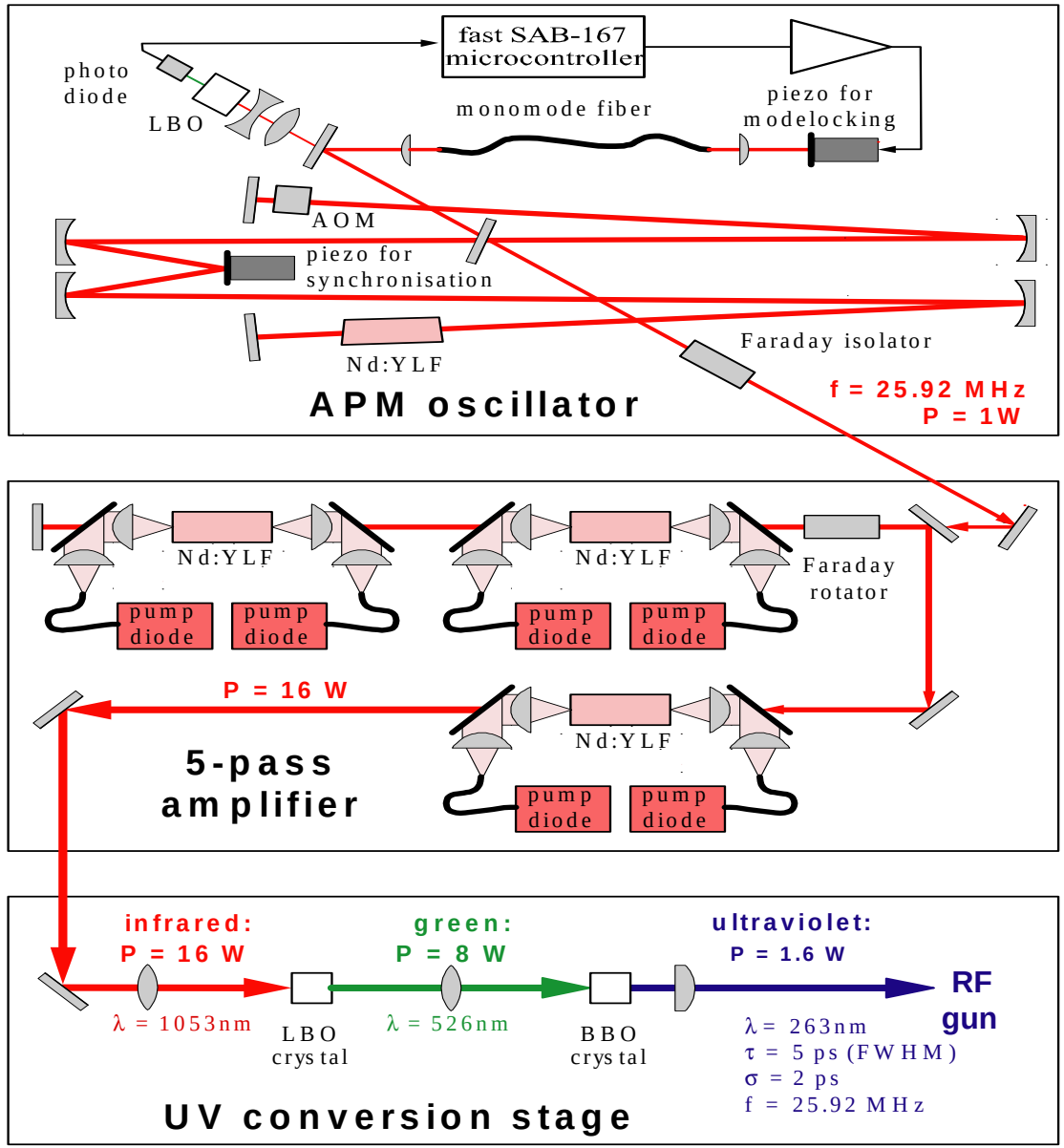
Drive laser

MBI, Berlin
I. Will, T. Quast

- diode pumped oscillator & amplifier

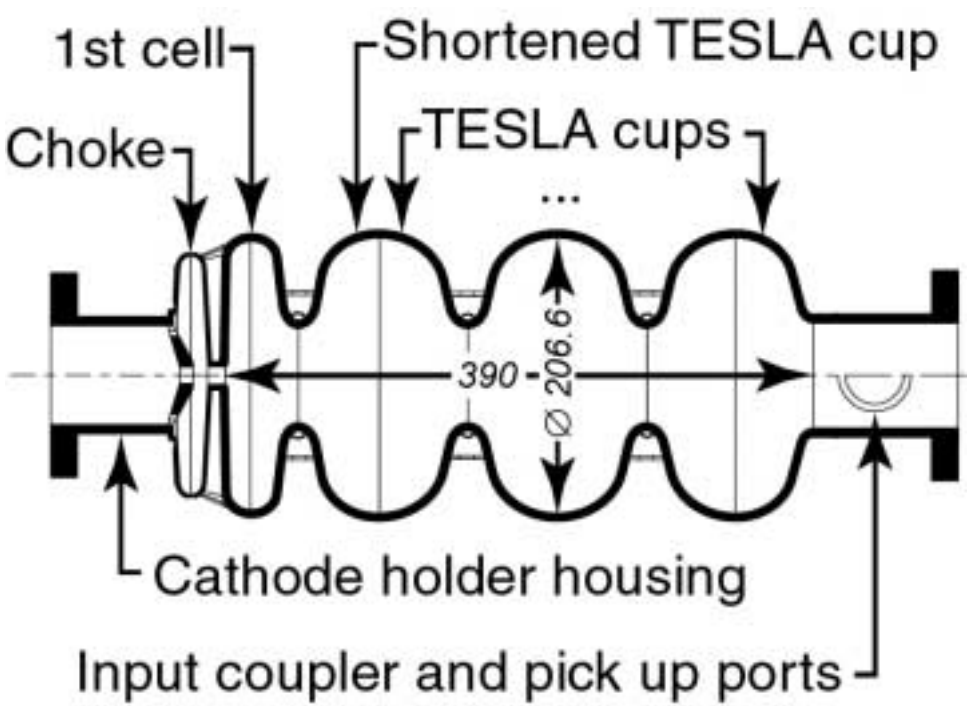
- P=1÷2W @ 262 nm
  26 MHz rep. Rate
  ~5 ps FWHM
  synchronization 1 ps

Note: 1W @ 262 nm
QE 1% ⇒ 80 pC
QE 10% ⇒ 0.8 nC



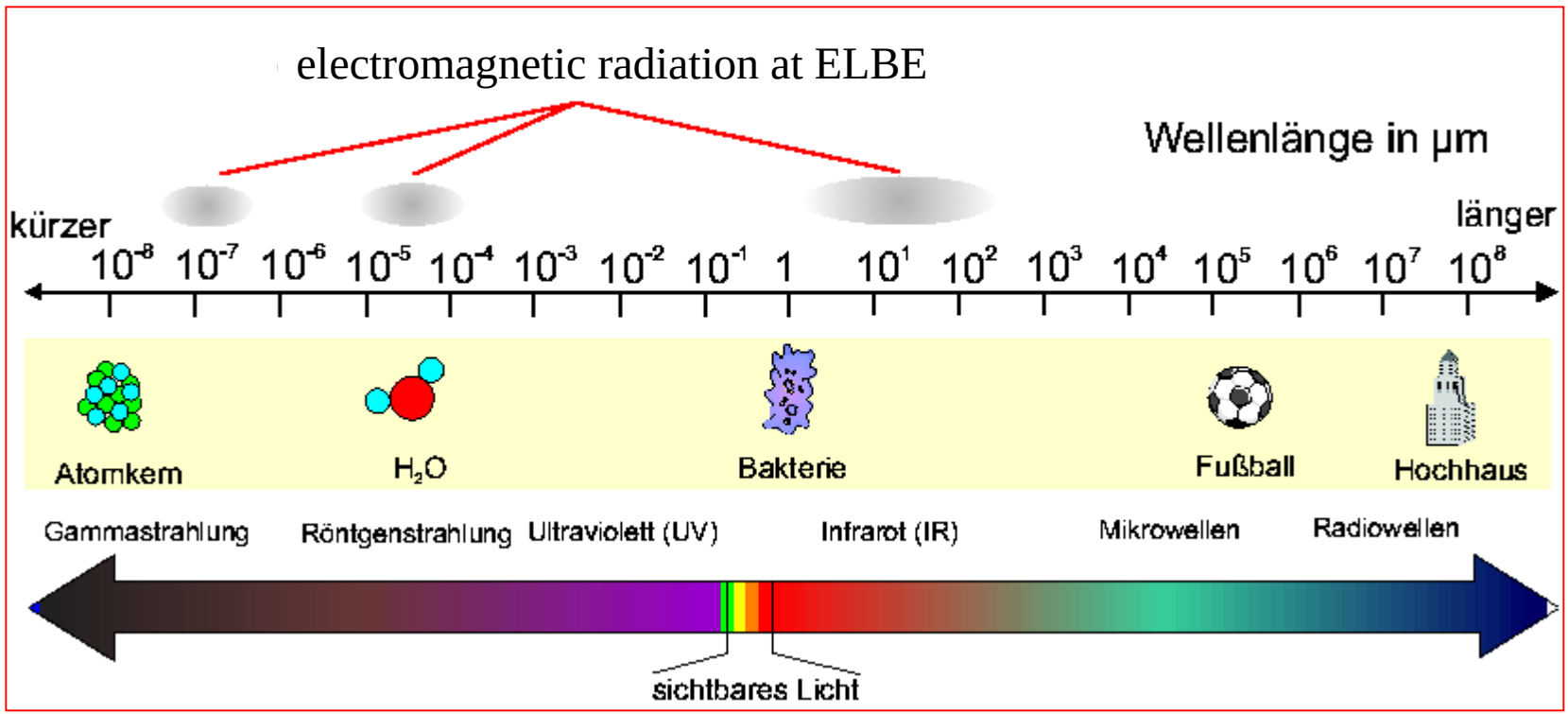
- New cavity 3½ cells, want to go to 25 MV/m
- New cryostat connected to refrigerator to work at 2 K

Common project proposal at BMBF FZR-BESSY-MBI

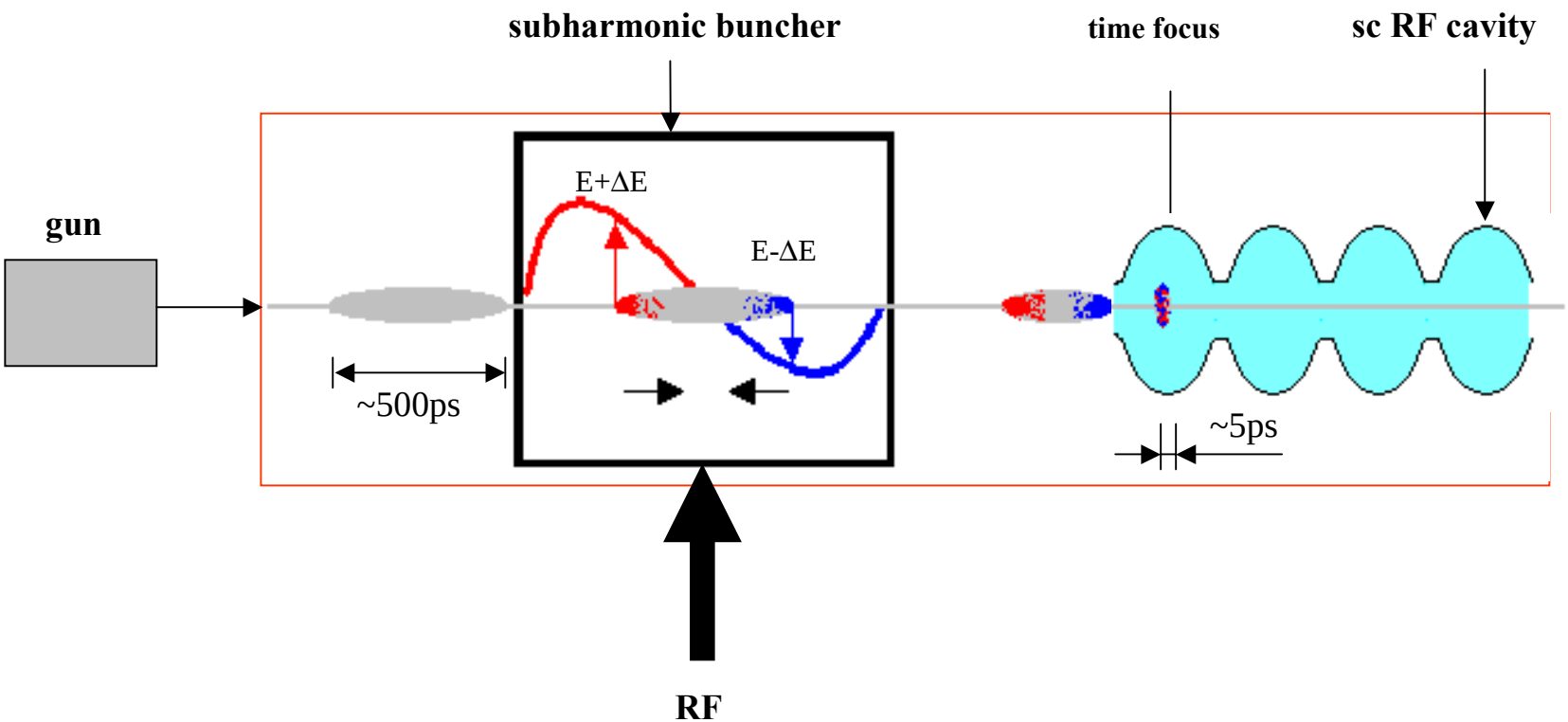


#

The Spectrum of Electromagnetic Radiation



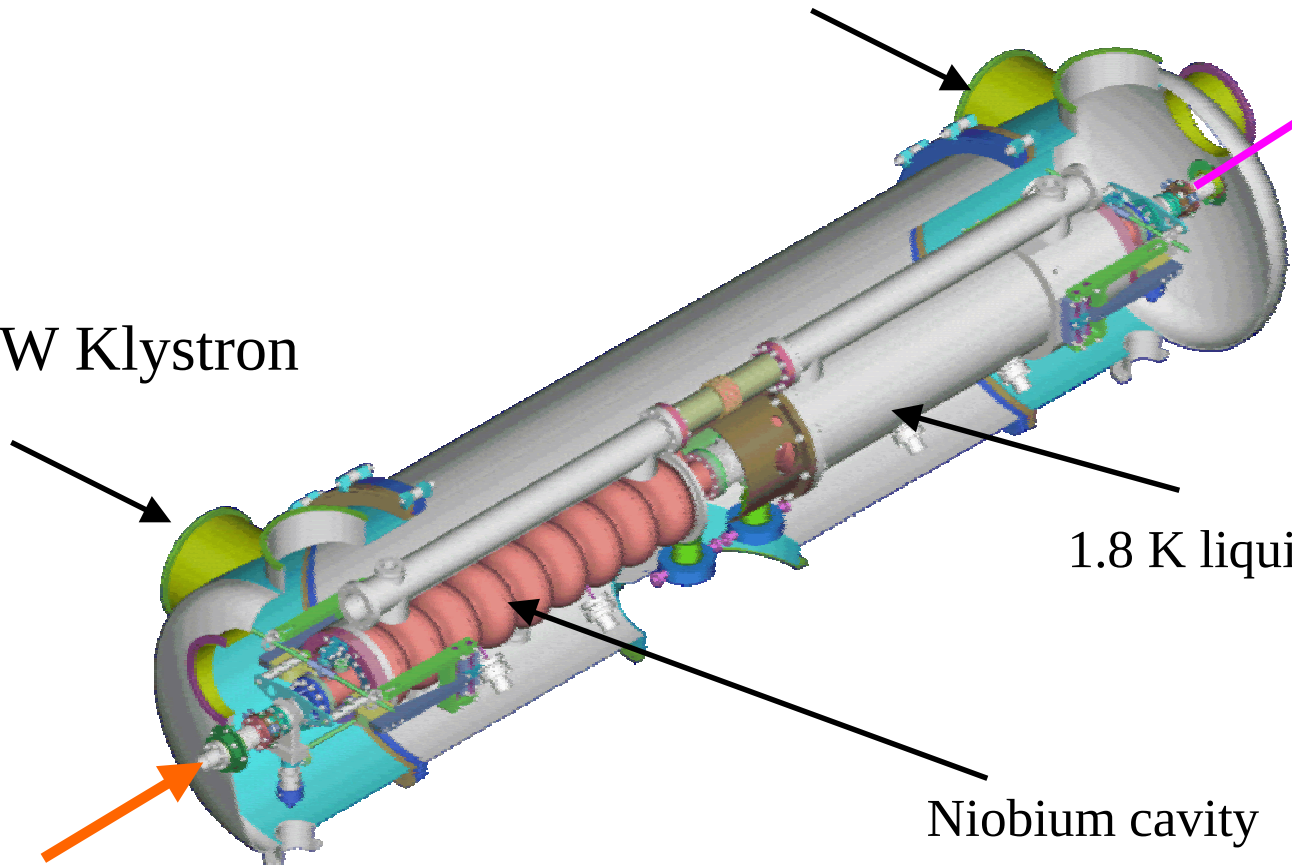
Puls compression



ELBE radio-frequency accelerator

20 MeV · 1mA = 20kW

$\beta = 0{,}999687$



10 kW Klystron

1.8 K liquid He vessel

Niobium cavity

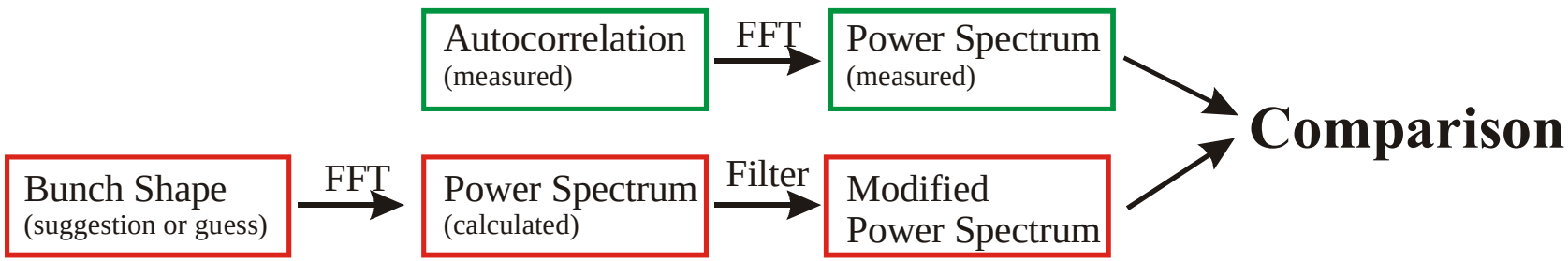
250 keV, 1 mA

$\beta = \frac{v}{c} = 0{,}74$

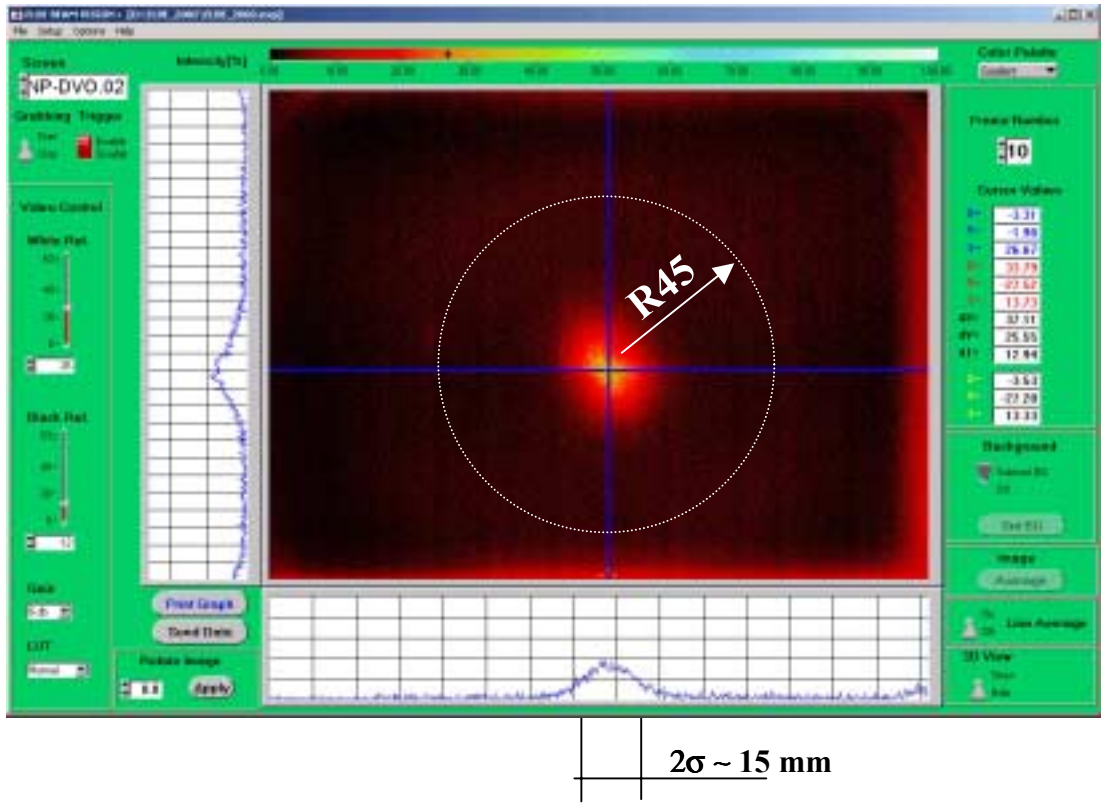
The pulse length calculation

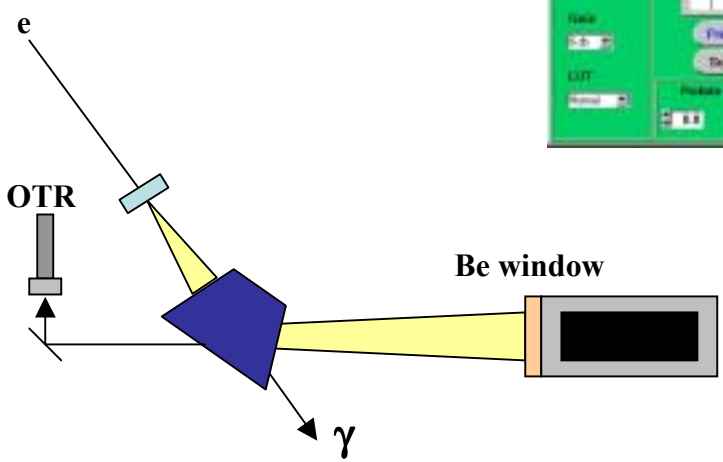
1. ***Since the phase information is lost, direct pulse shape reconstruction is impossible.***

2. ***Fourier transform of the Autocorrelation is Power Spectrum.***

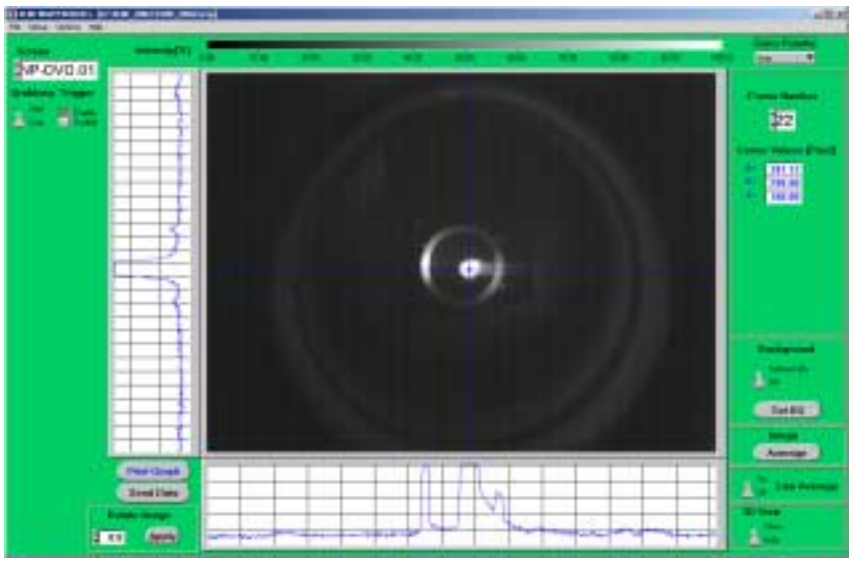


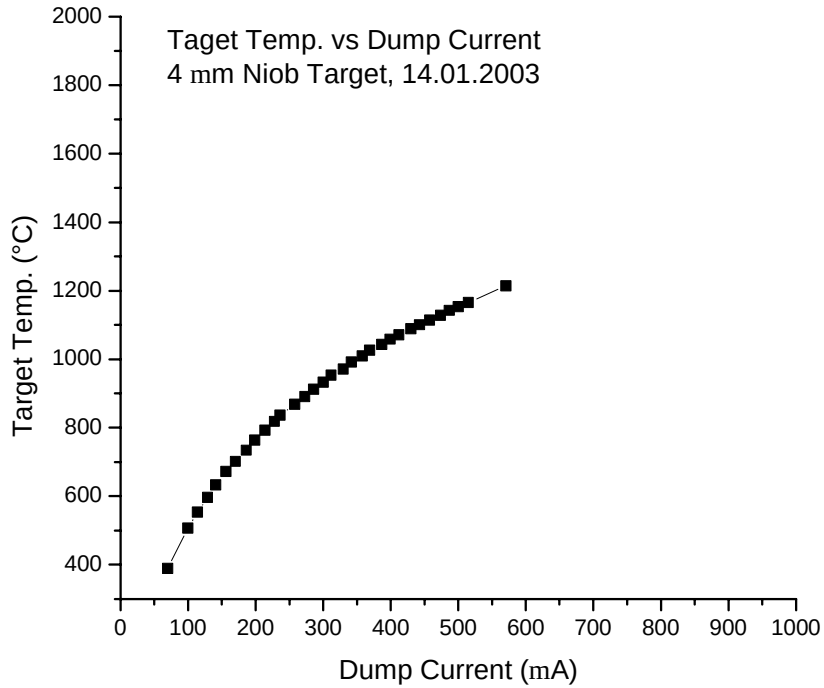
Scattering on the Bremsstrahl-radiator



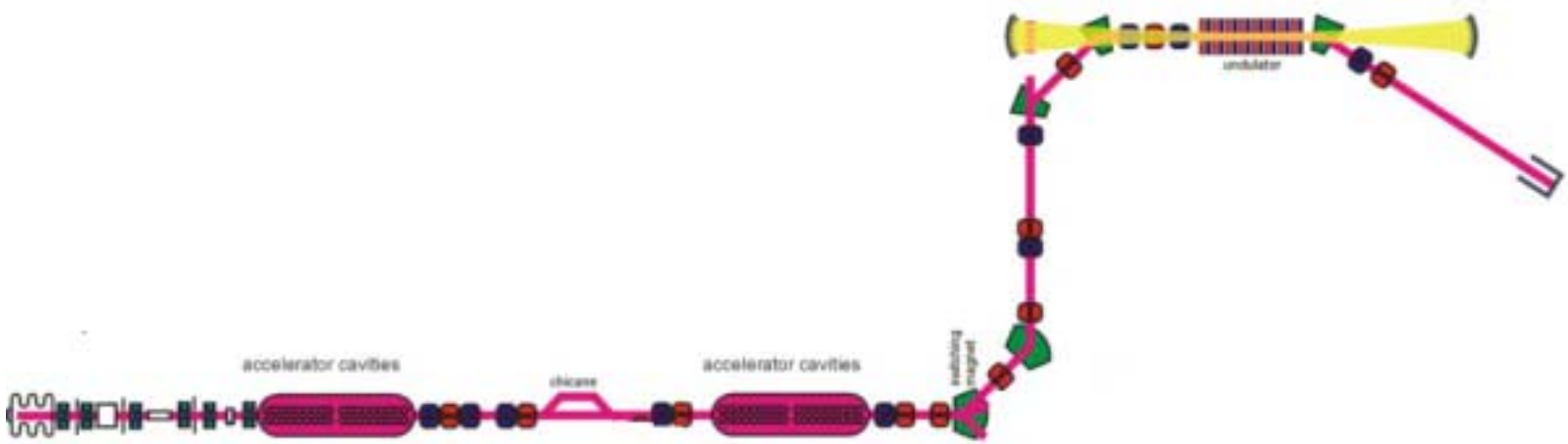


Diagnostics at the Bremsstrahl-radiator

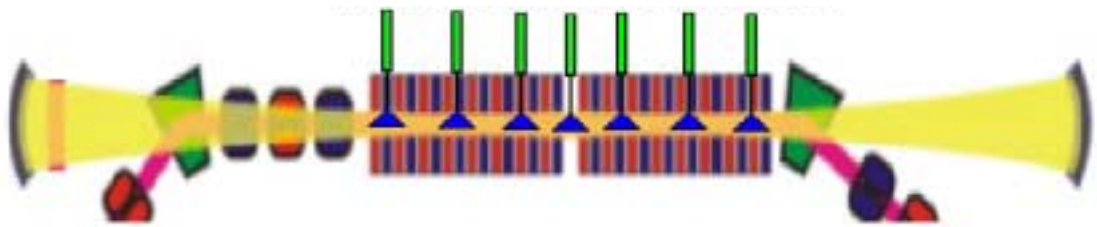




ELBE-Infrarot



7 insertable Be OTR viewer



Longitudinal movable YAG screen