

ELBE Upgrade

„Pushing the ELBE CW RF-System to high Average Beam Current“

Accelerator R&D (ARD) Workshop Dresden March 14.-15. 2013

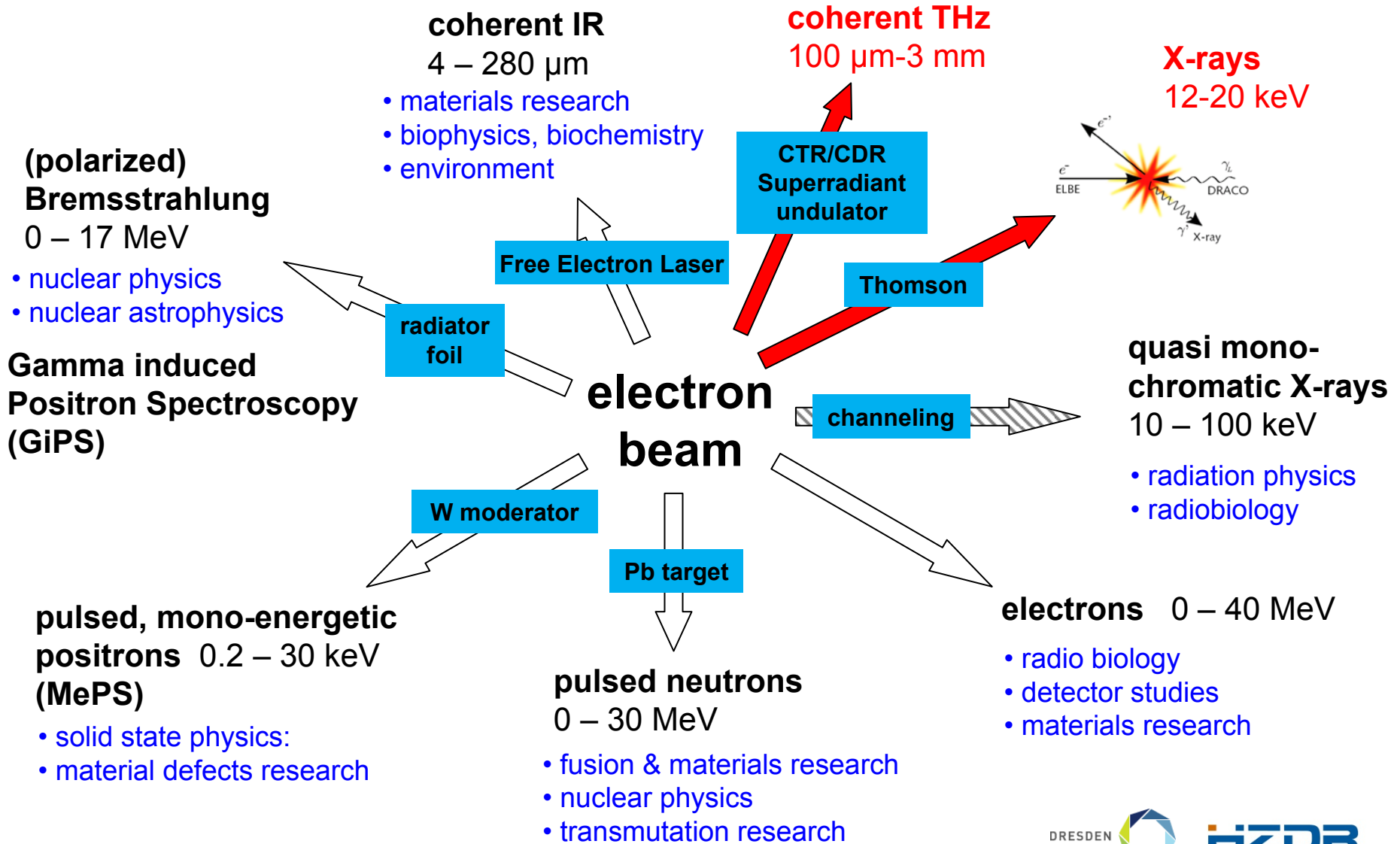
p.michel

- Introduction - ELBE concept
- New sources @ ELBE
- Motivation for higher beam currents/gradients

There are many things that you can do with electrons !



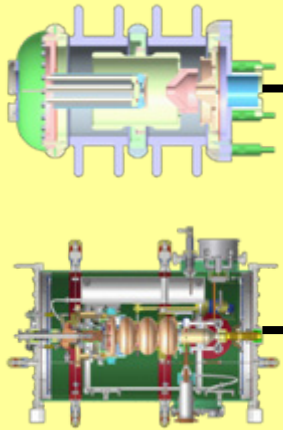
ELBE Beams



ELBE Electron Linac

250 kV DC gun
80 pC (...120)
10 mm mrad

RF bunch
compressor

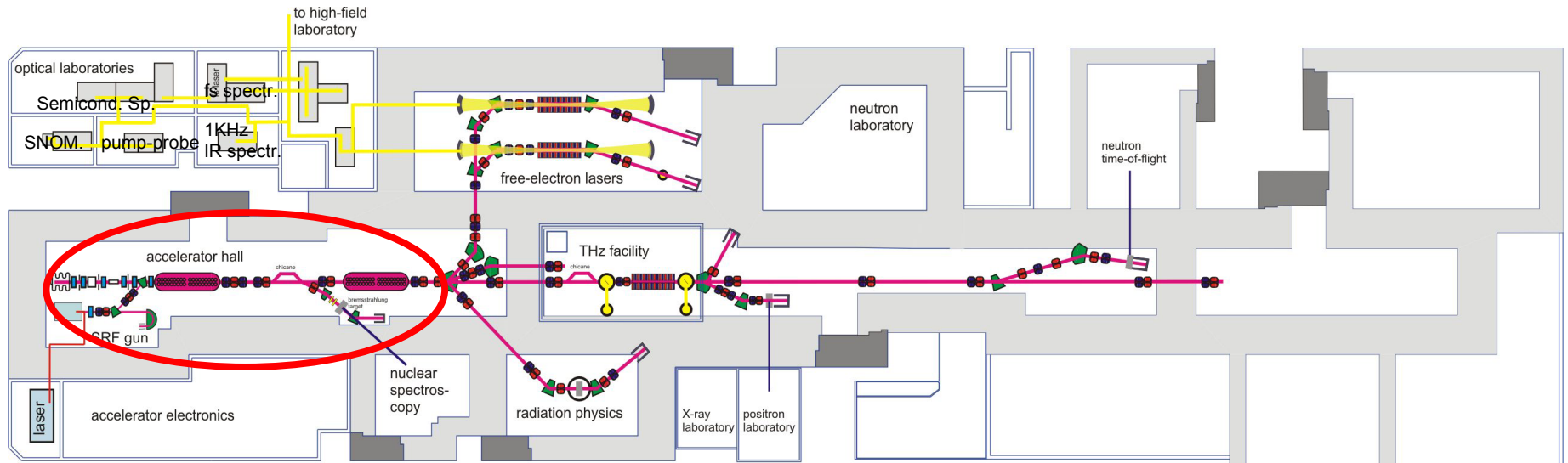
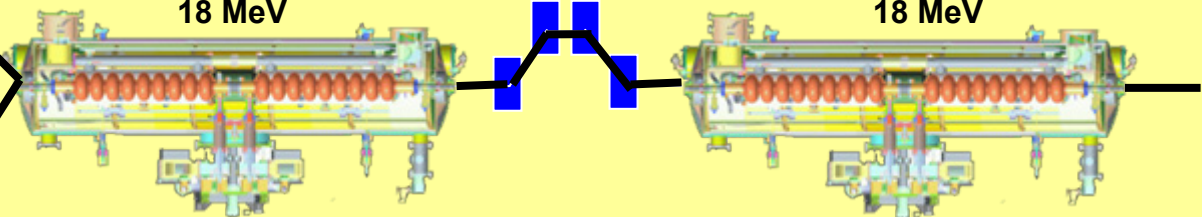


3 MeV SRF photo gun
< 100 pC
3 mm mrad

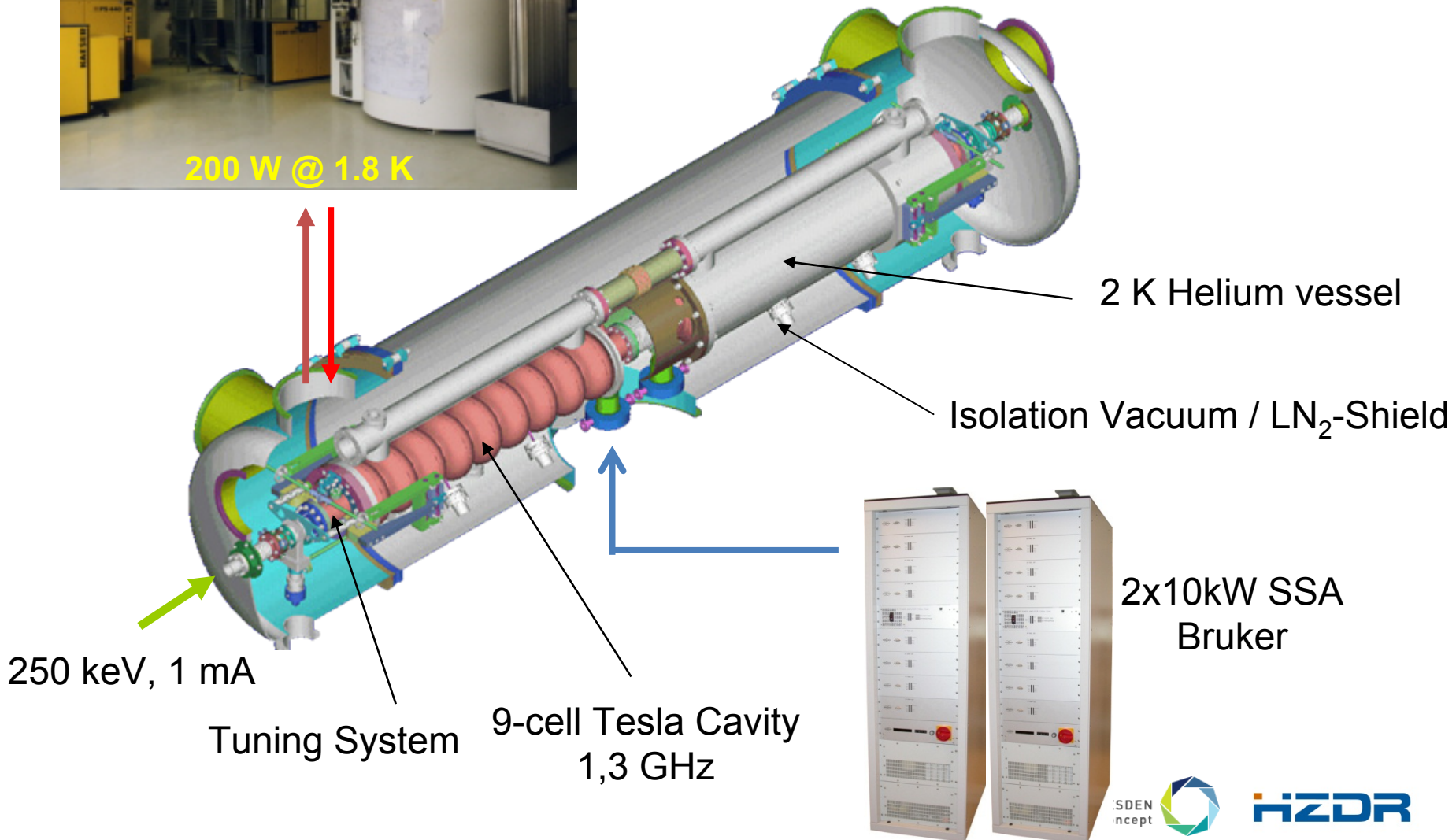
1.3 GHz sc linac
18 MeV

magnetic bunch
compressor

1.3 GHz sc linac
18 MeV

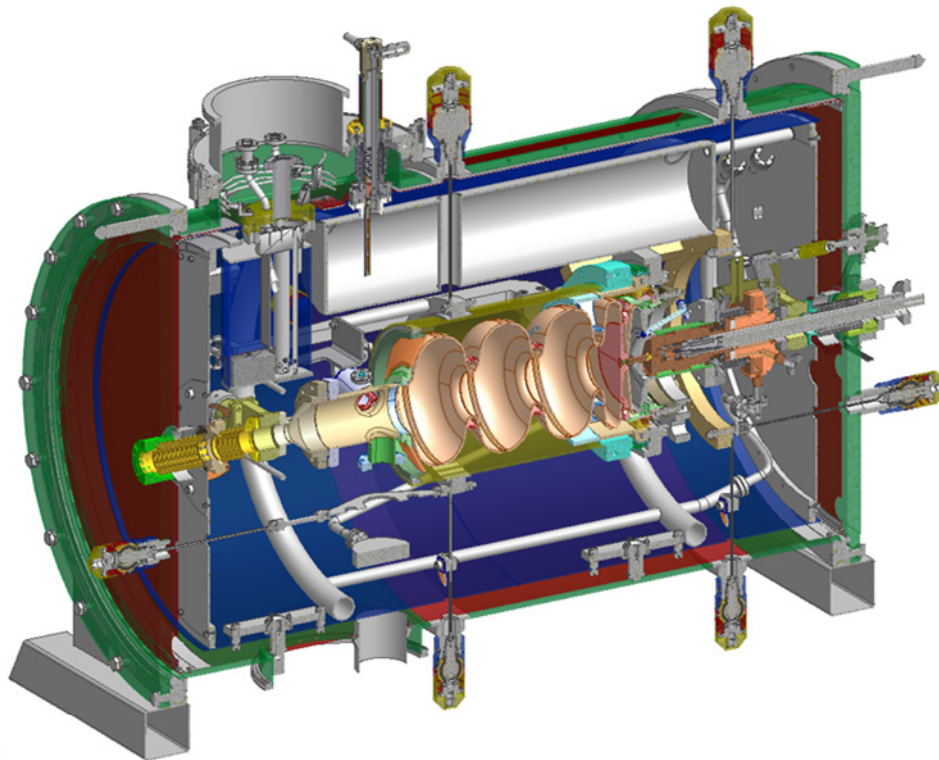


ELBE CW-Linac Module



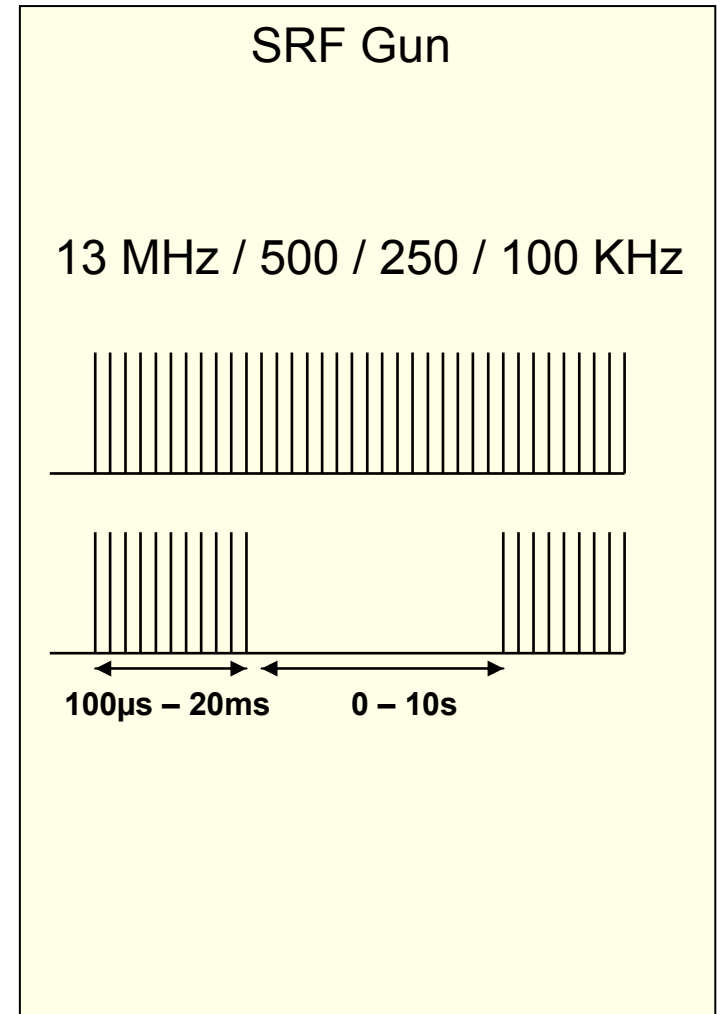
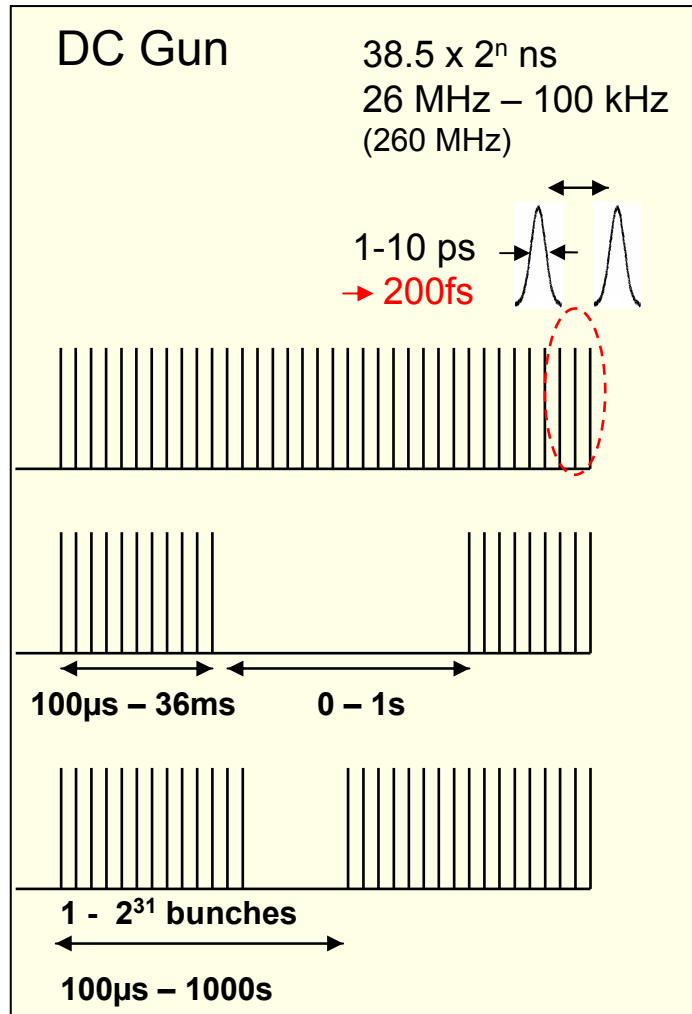
Superconducting RF Photoinjector (SRF gun)

- high bunch charge (1 nC) for pulsed neutron and positron beam production
- low emittance, medium to high charge with short pulses for THz-radiation and x-rays by Thomson scattering
- high peak current operation for CW-IR-FELs with 13 MHz, 80...120 pC



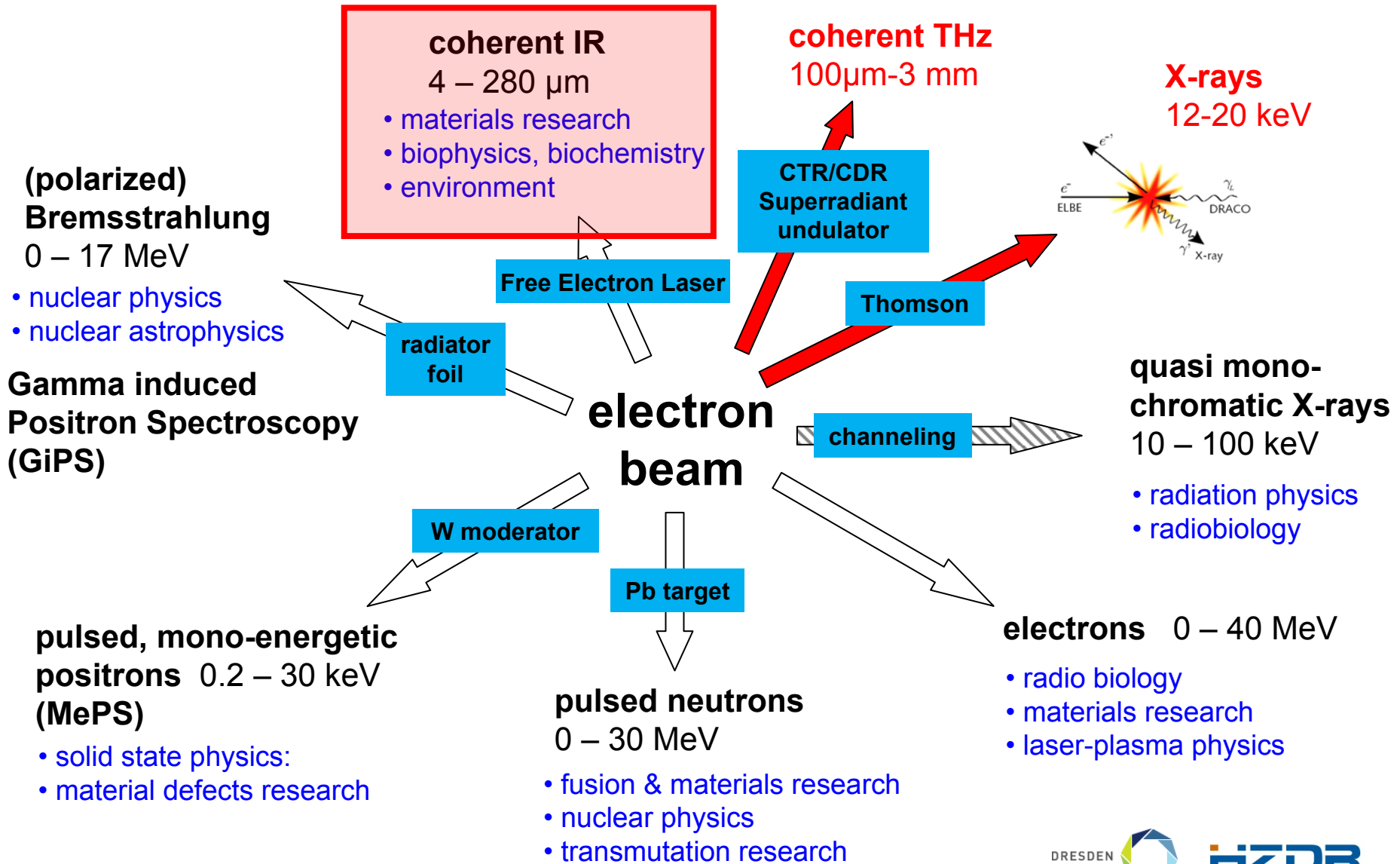
Mode	ELBE	High Charge
final electron energy	≤ 9.5 MeV	
RF frequency	1.3 GHz	
operation mode	CW	
Photo cathode	Cs ₂ Te	
bunch charge	80 pC	1 nC
repetition rate	13 MHz	500 kHz
laser pulse (FWHM)	4 ps	15 ps
transverse rms emittance	1 mm mrad	2.5 mm mrad
average current	1 mA	0.5 mA

ELBE electron beam modes



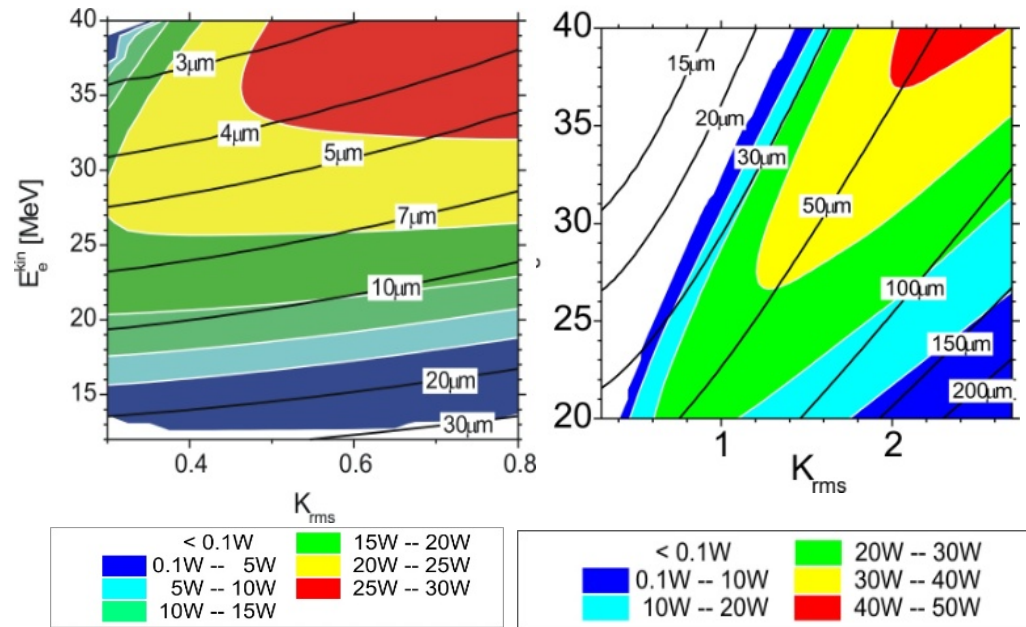
Main user modes: **13 MHz cw (FEL)** 100KHz cw (nTOF) 26 MHz cw (GiPS)

User beams at ELBE



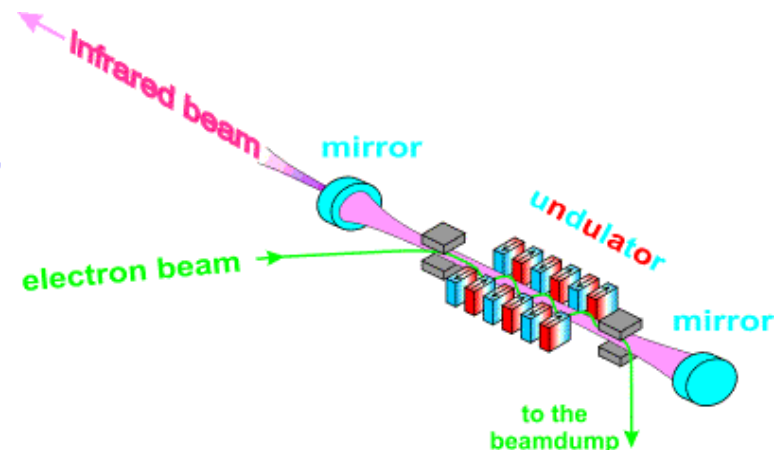
Free Electron Lasers @ ELBE → FELBE

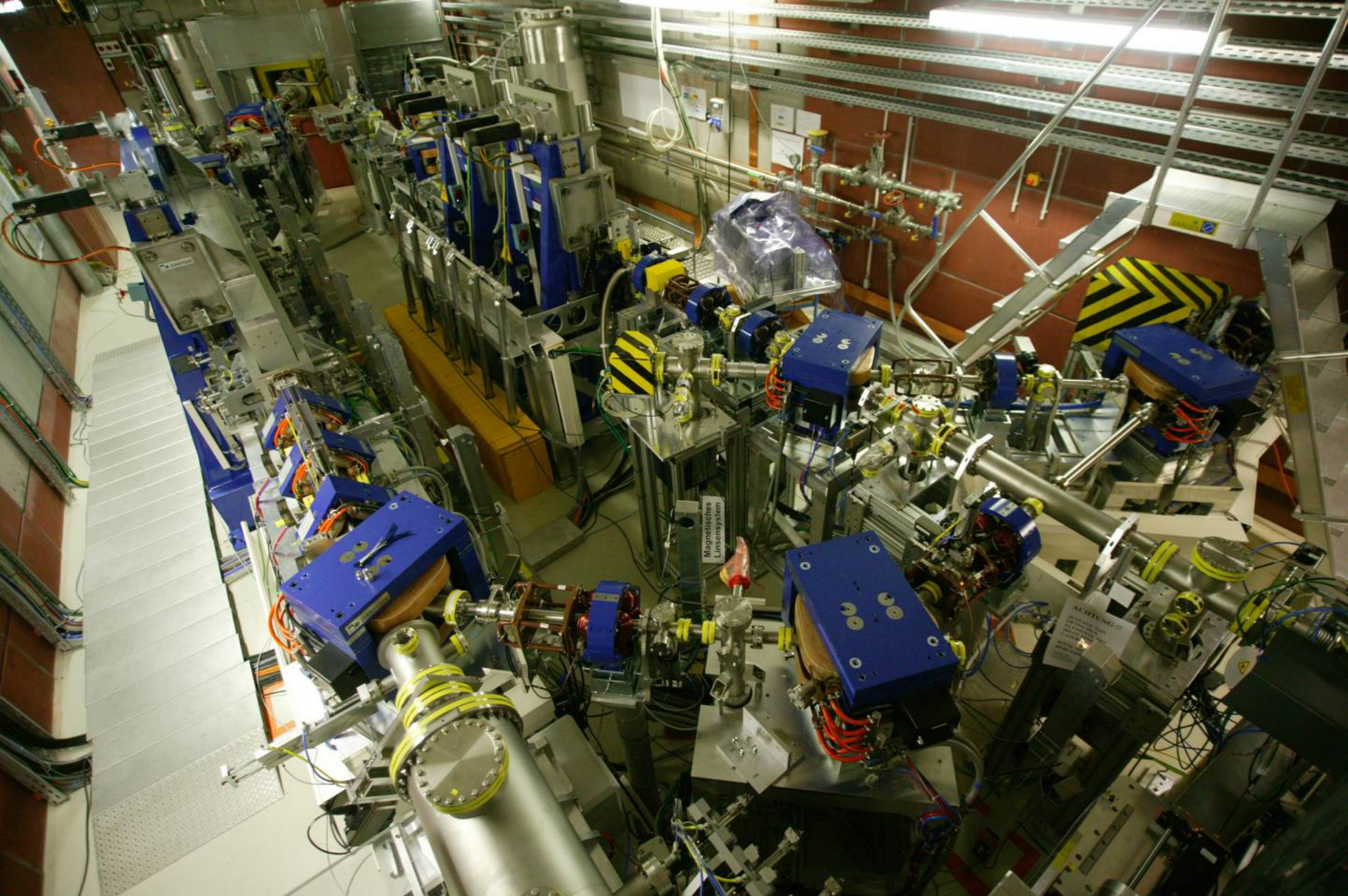
FEL Properties	FEL 1 - U27	FEL2 - U100
undulator period	27.3 mm	100 mm
design	2 x 34 periods vacuum chamber	38 periods waveguide
undulator param.	0.3...0.7	0.3...2.7 μm
wavelength	4...22 μm	20...280 μm
max. power (out)	30 W	70 W
max. pulse energy	2 μJ	5 μJ
pulse length	0.5...4 ps	1...10 ps



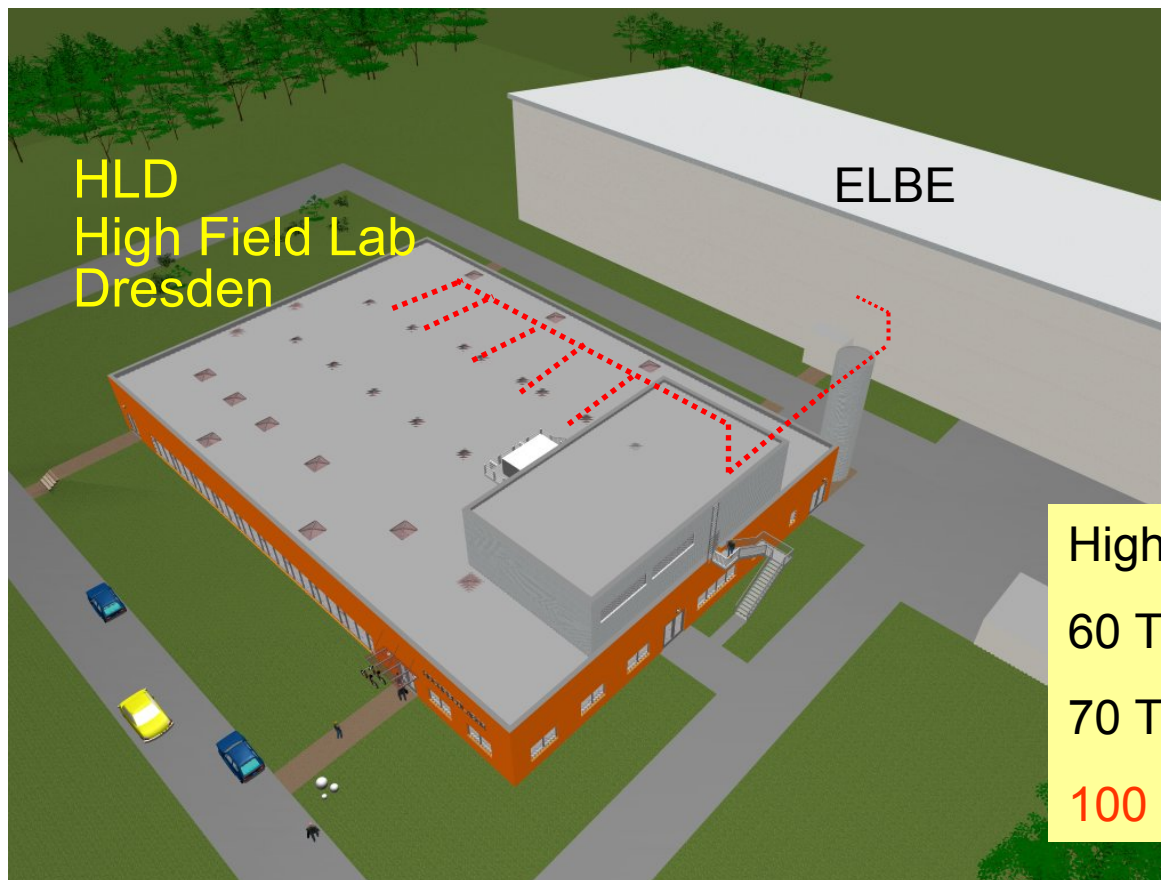
Experiments:

- IR spectroscopy of semiconductors, quantum structures, bio-molecules
- migration spectroscopy of radioactive compounds
- IR near field microscopy & spectroscopy
- pump-probe experiments in the sub-ps range
- spectroscopy under high, pulsed magnetic fields





High Magnetic Field Lab & FELBE



HLD
High Field Lab
Dresden

ELBE

94,2 T achieved in 2012 !!

High Field Lab Dresden

60 T @ 1000 ms

70 T @ 100 ms

100 T @ 10 ms

Combination of ELBE FEL (4 ... 280 μm) and High Magnetic Field Lab
IR spectroscopie at high magnetic fields

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

Beamtime distribution Runs II/2011 – I/2012

Available beam time:
285 days (~6300 hours)
24/7 regime , four 11-week-runs/year

Machine Development
(machine studies + tuning)

Accelerator Physics

Laser Physics

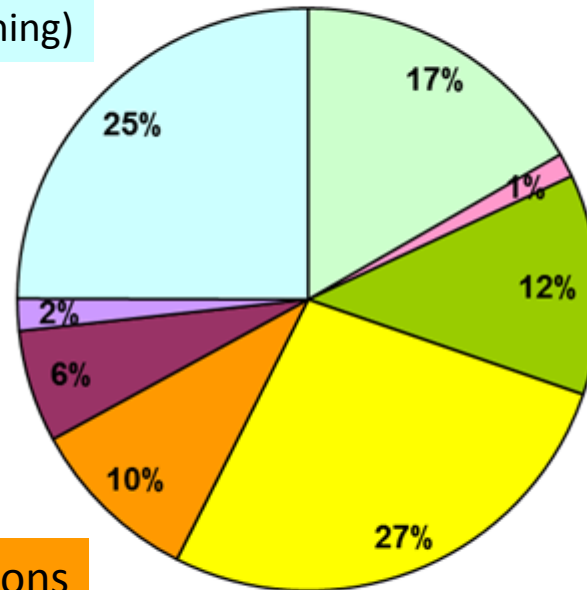
Positrons

Bremsstrahlung

Radiobiology
& Detector Studies

Neutrons

FEL



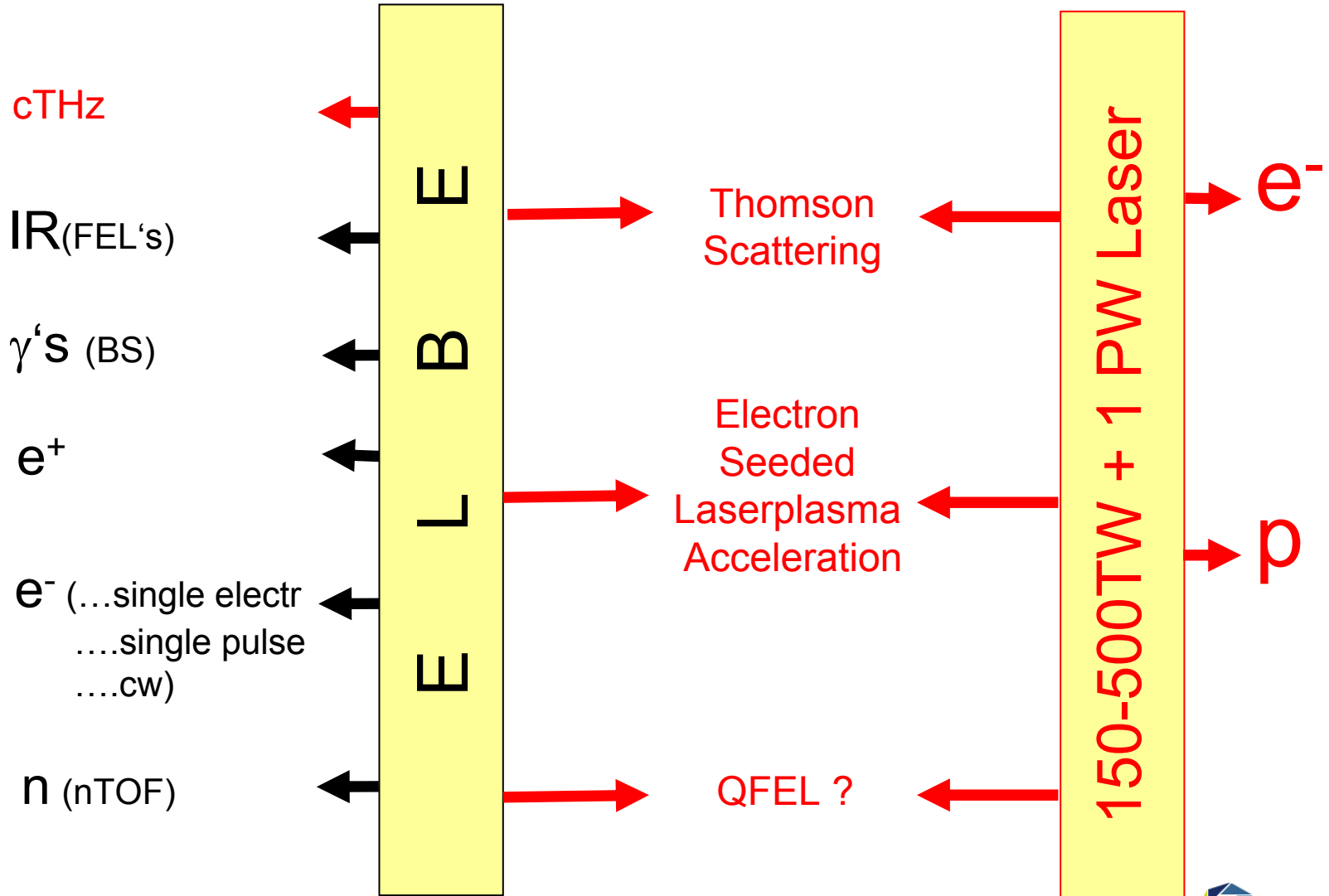
Beam efficiency * ~ 90%

*

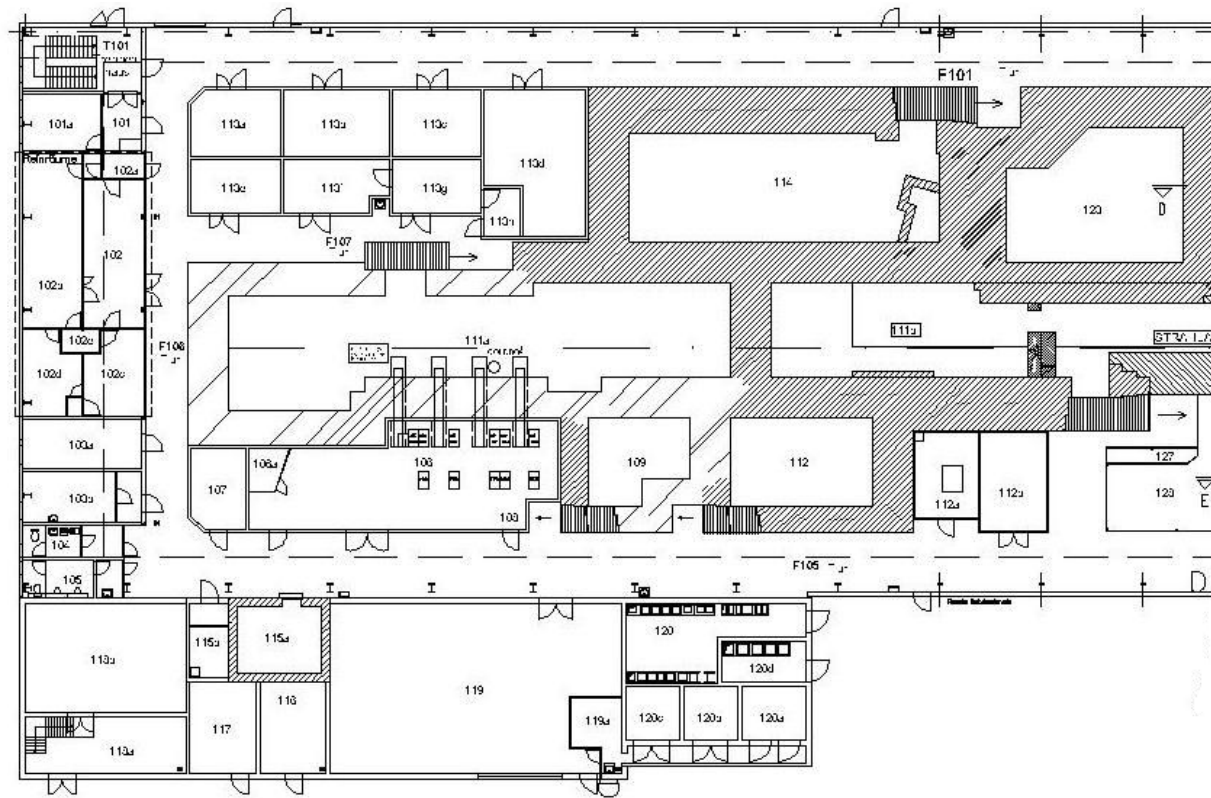
$$\text{Beam efficiency} = \frac{\text{user evaluated „good“ beam time}}{\text{scheduled beam time}}$$

ELBE Upgrade to a National Center for High Power Radiation Sources

1 mA → 1.6 mA



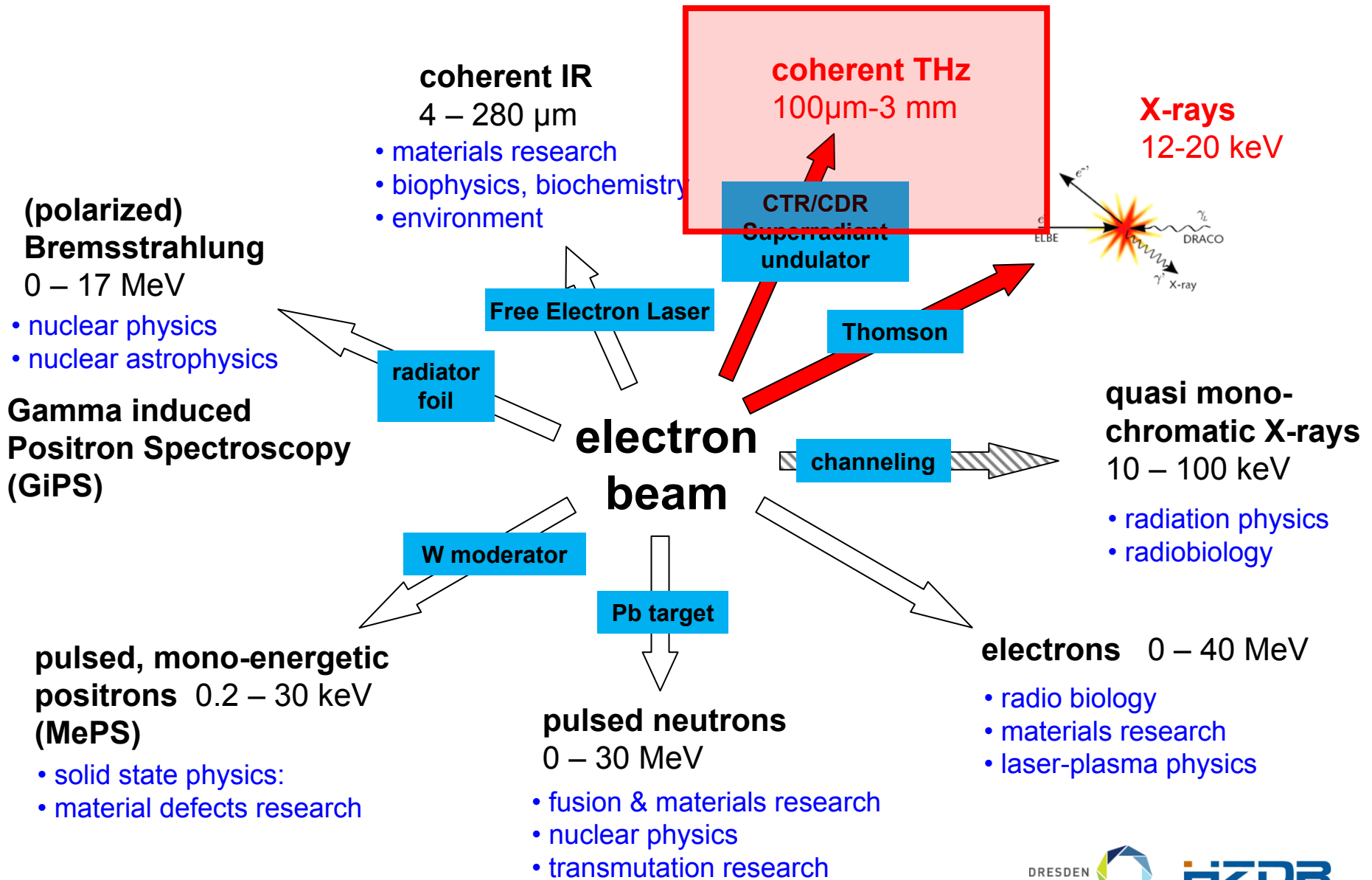
ELBE Upgrade to a National Center for High Power Radiation Sources



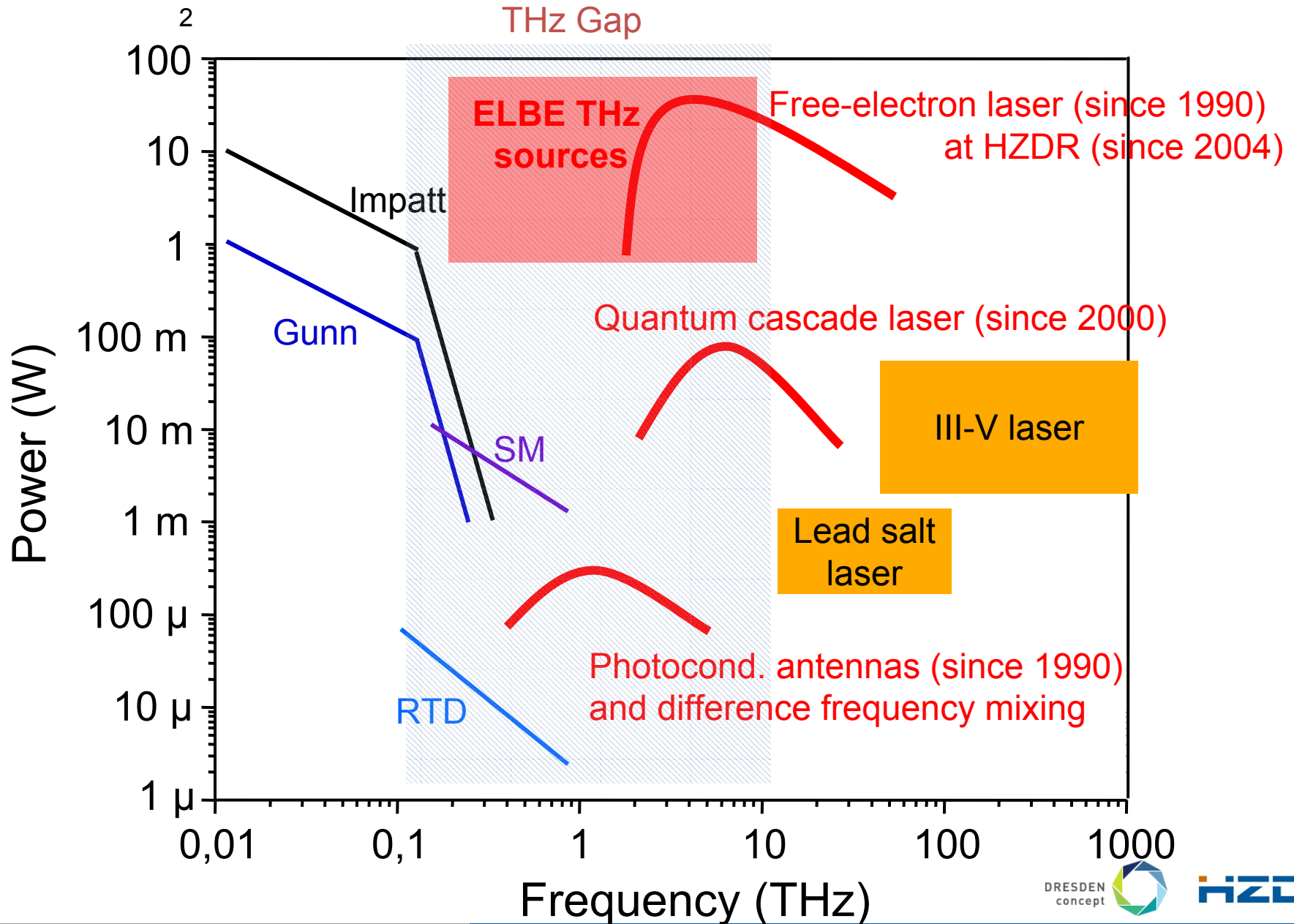
Budget: 55 Mio €
2010-2014



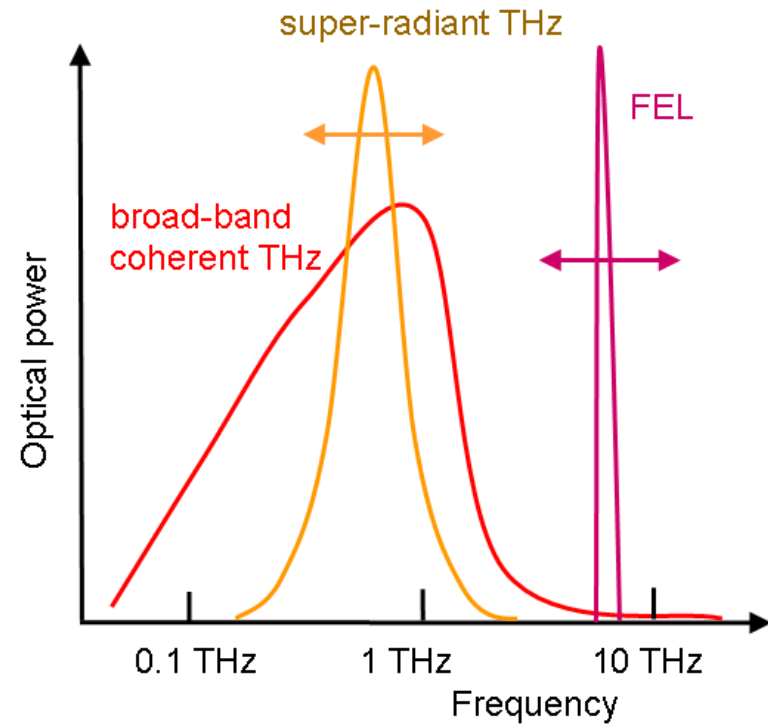
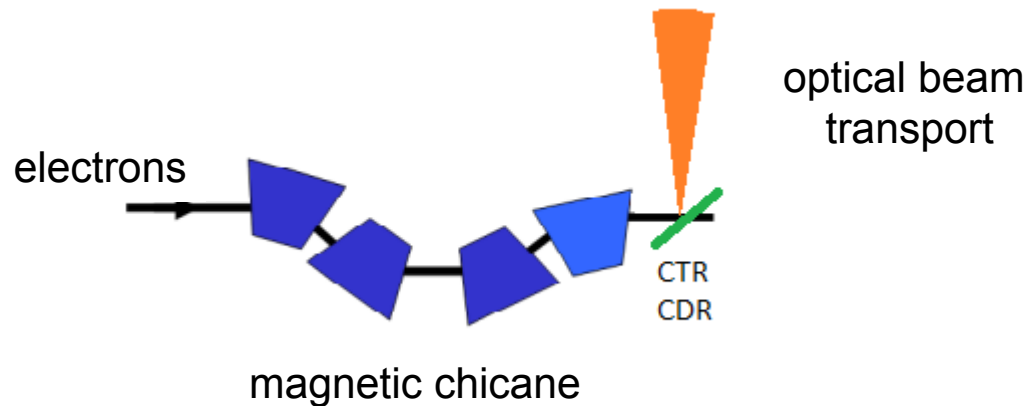
User beams at ELBE



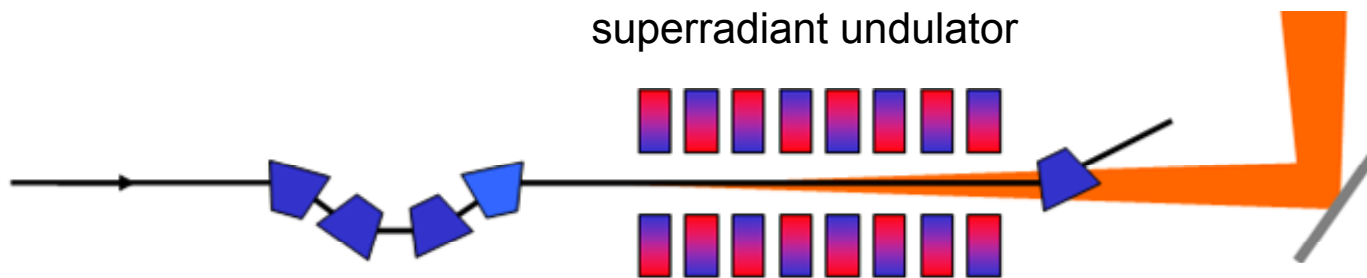
ELBE Upgrade: THz sources



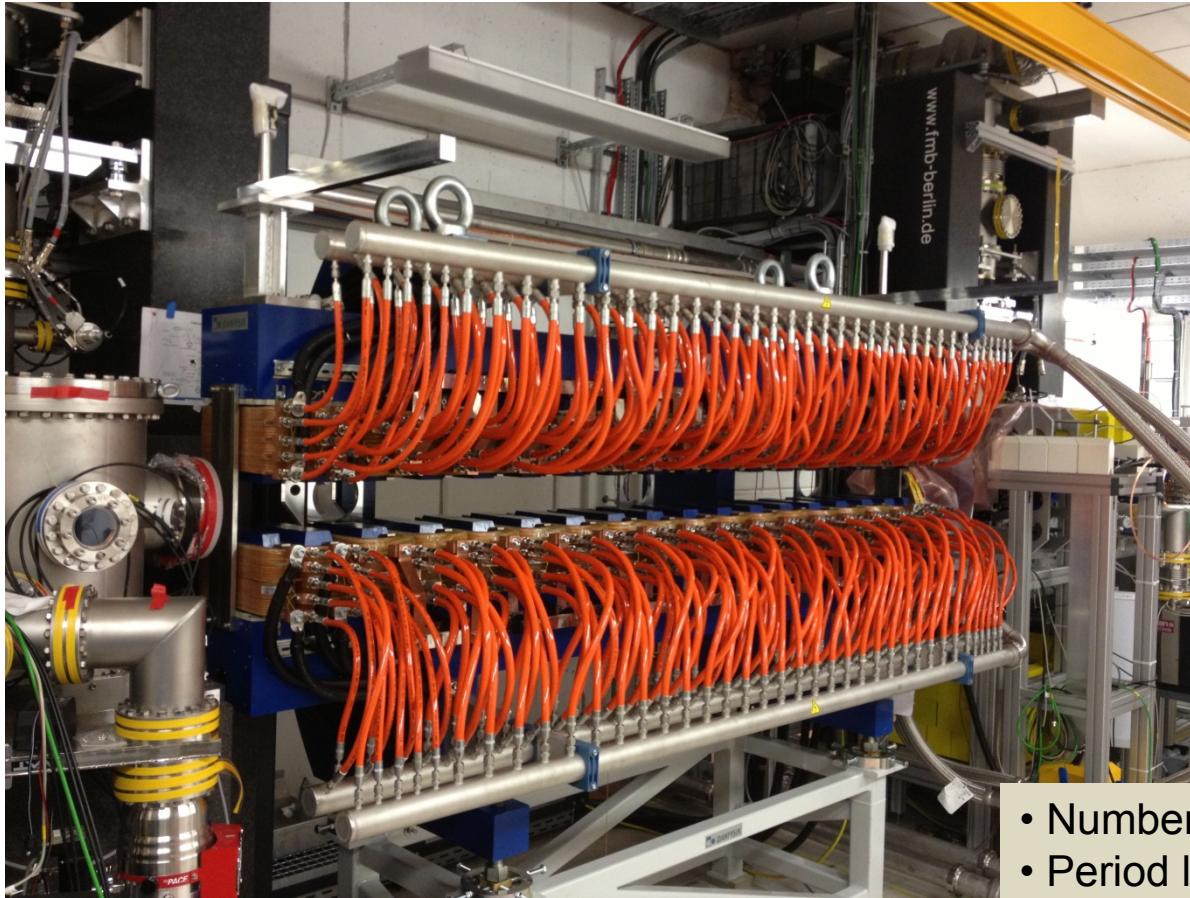
Broad band THz source



Narrow band THz source



Electromagnetic undulator

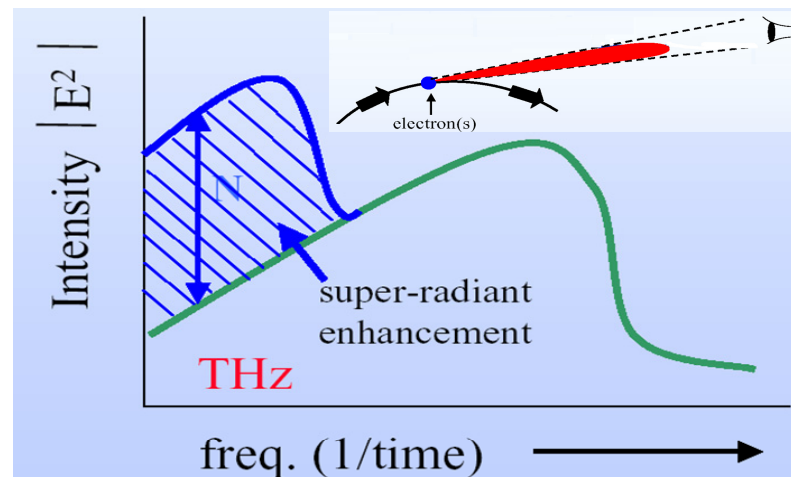
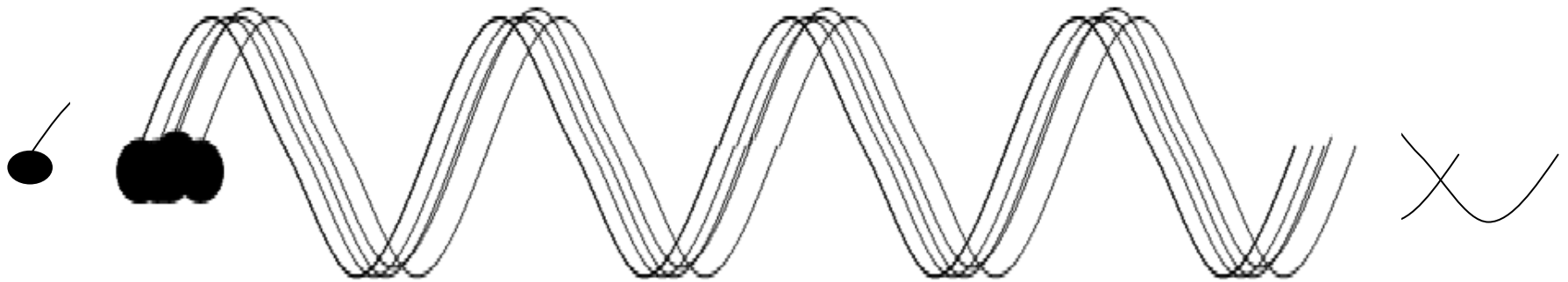


Superradiant undulator
DANFYSIK, delivery November 2012

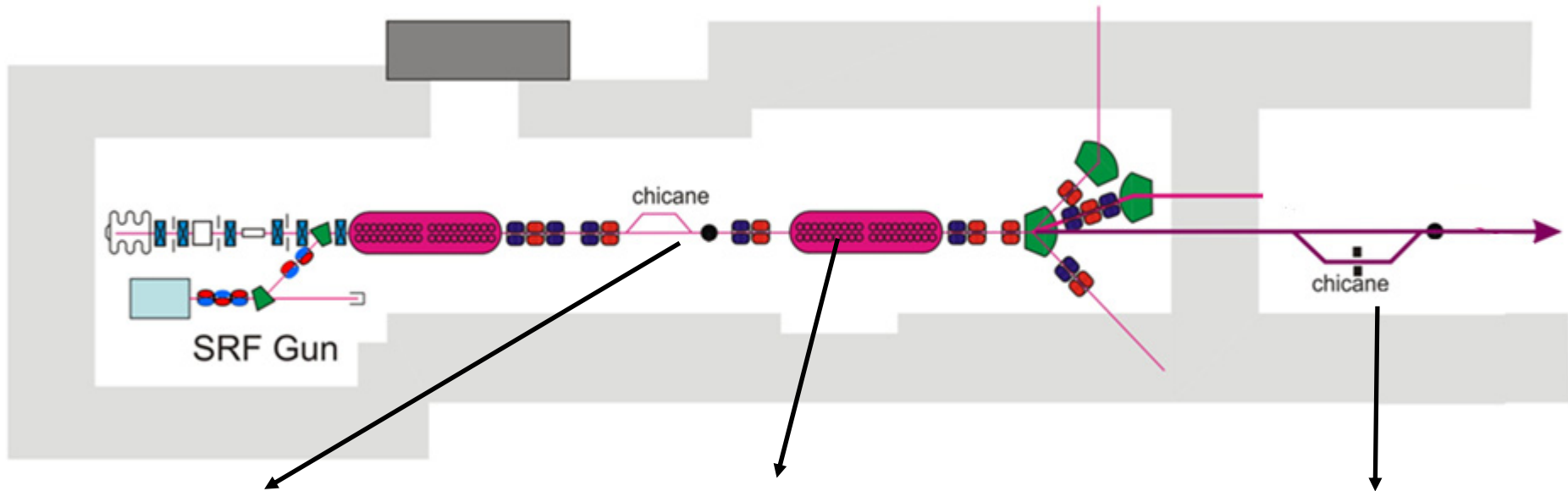
- Number of full-size periods: 8
- Period length: 300mm
- Peak magnetic field: 0.4T
- Krms: 8.0
- Cooling water flow rate: 153l/min
- Power consumption: 127kW

short pulses, high bunch charge \rightarrow coherent THz radiation

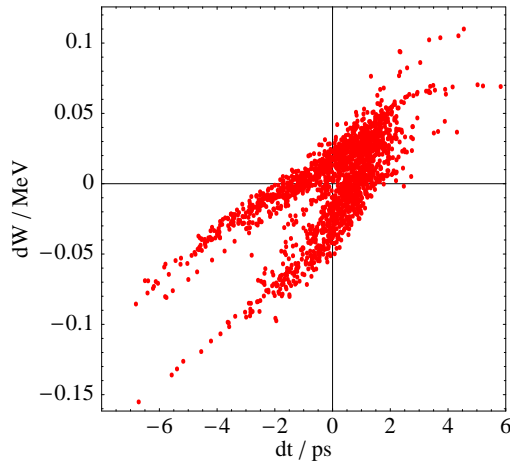
Coherent radiation $\propto N_e^2$



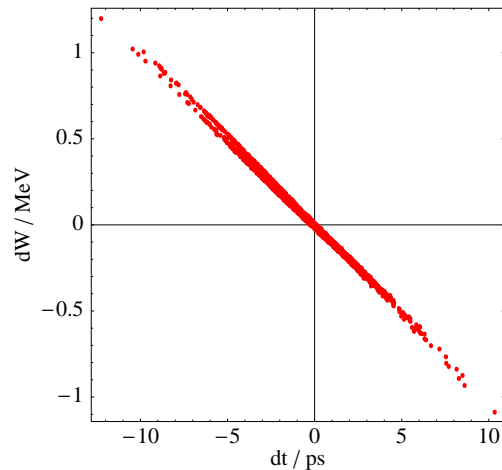
Key: Generation of short electron bunches



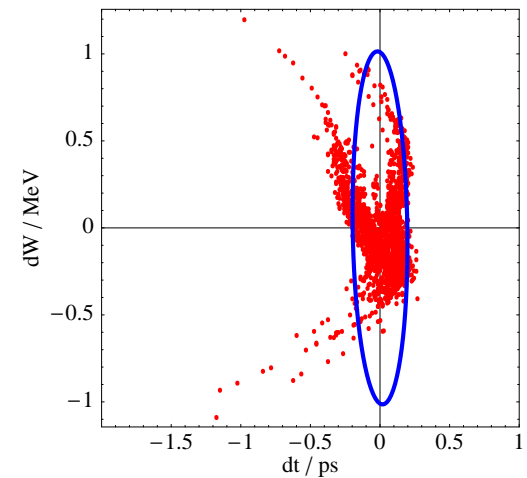
1. stretching (3 ps)



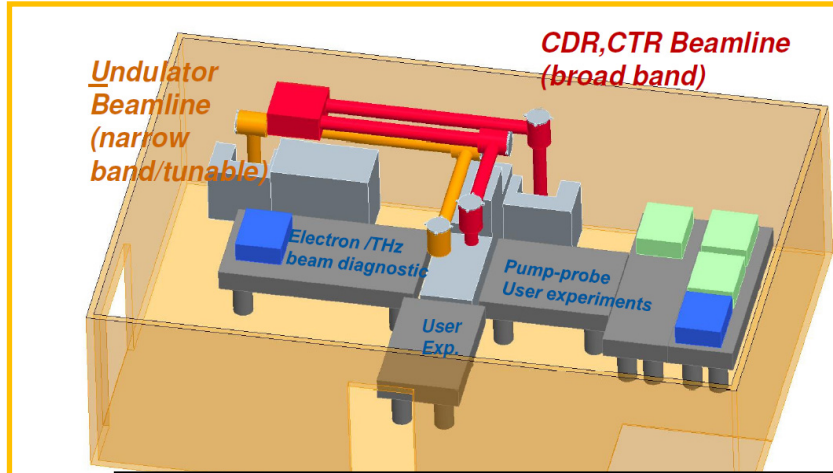
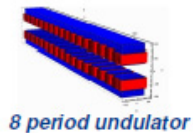
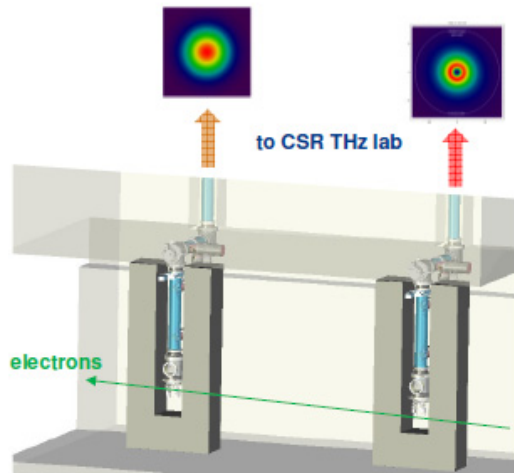
2. Energy modulation (Chirp)



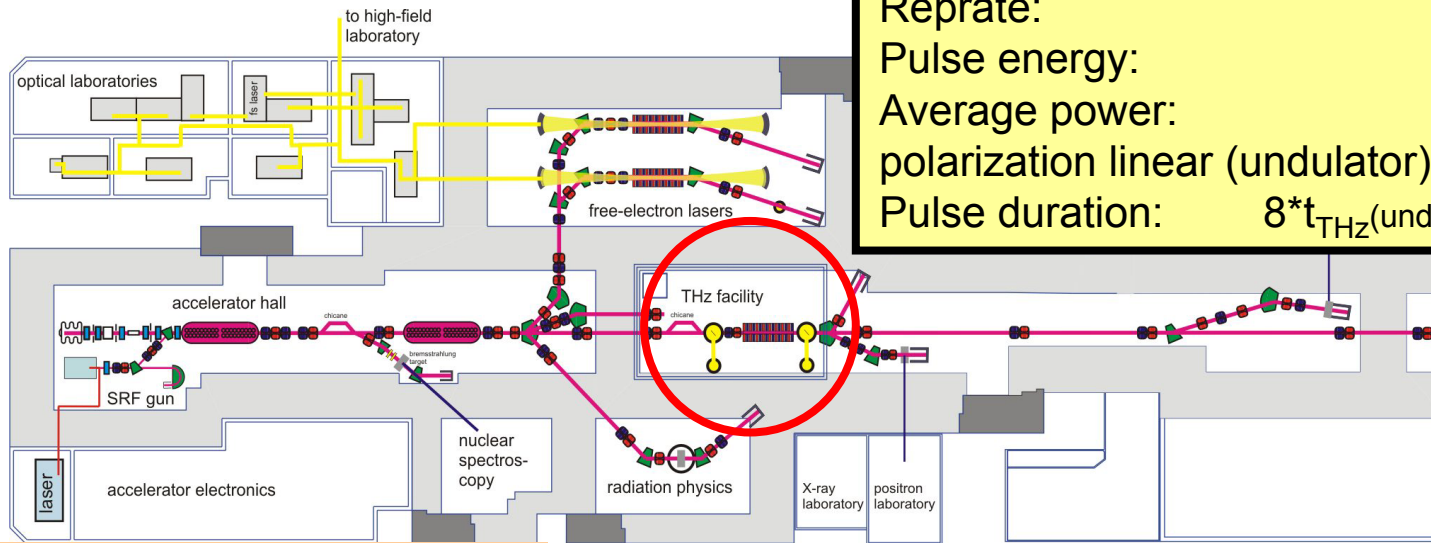
3. compression (200 fs)



THz Beams - TELBE

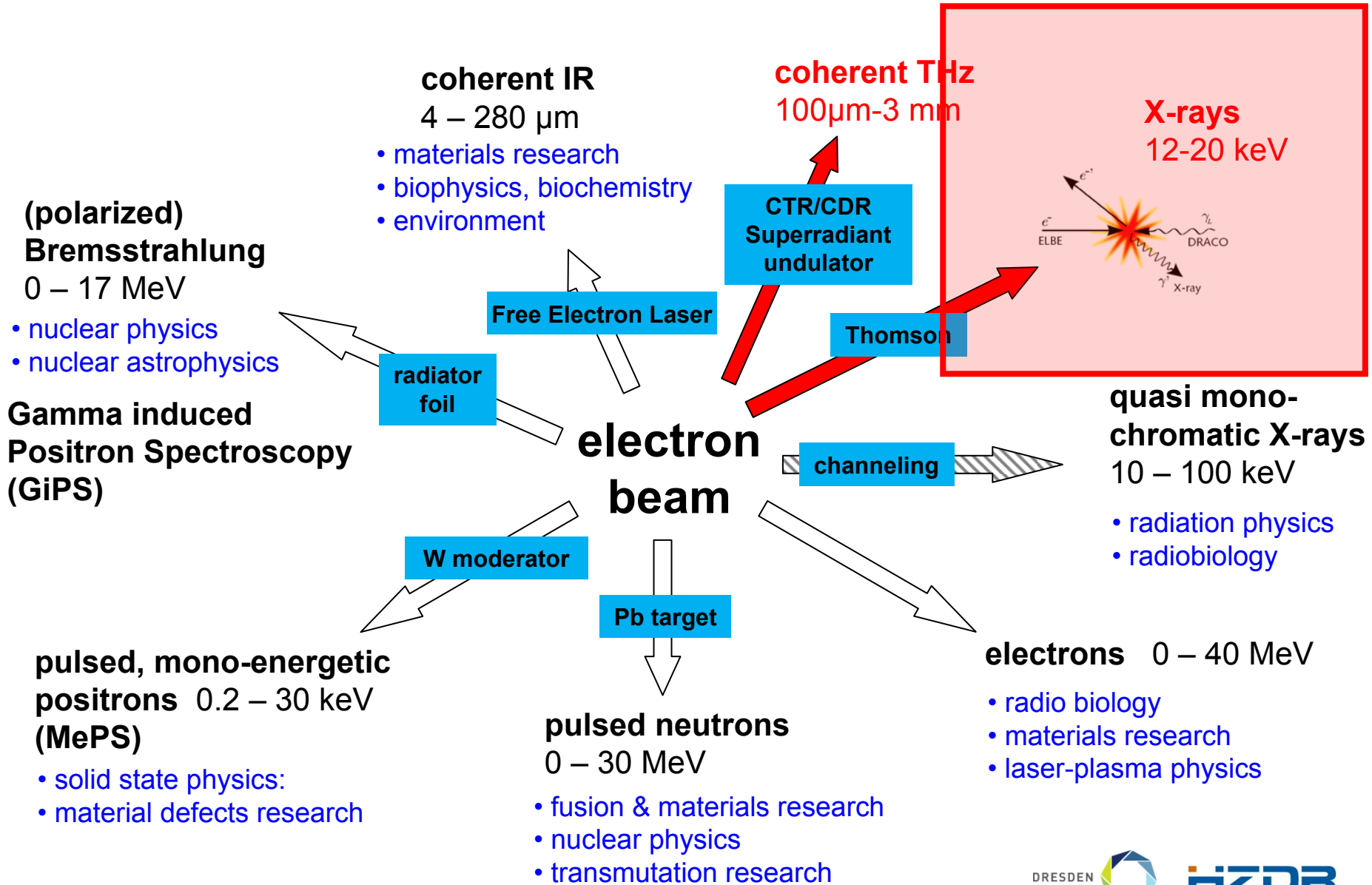


Expected parameters	
Spectral range:	100 μ m – 3mm
Spectral bandwidth:	12% (undulator), 100% (CDR/CTR)
Reprate:	100 kHz...13 MHz
Pulse energy:	100 μ J...1 μ J
Average power:	10 W
polarization	linear (undulator), radial (CTR)
Pulse duration:	8*t _{THz} (undulator), < 1 ps (CDR/CTR)



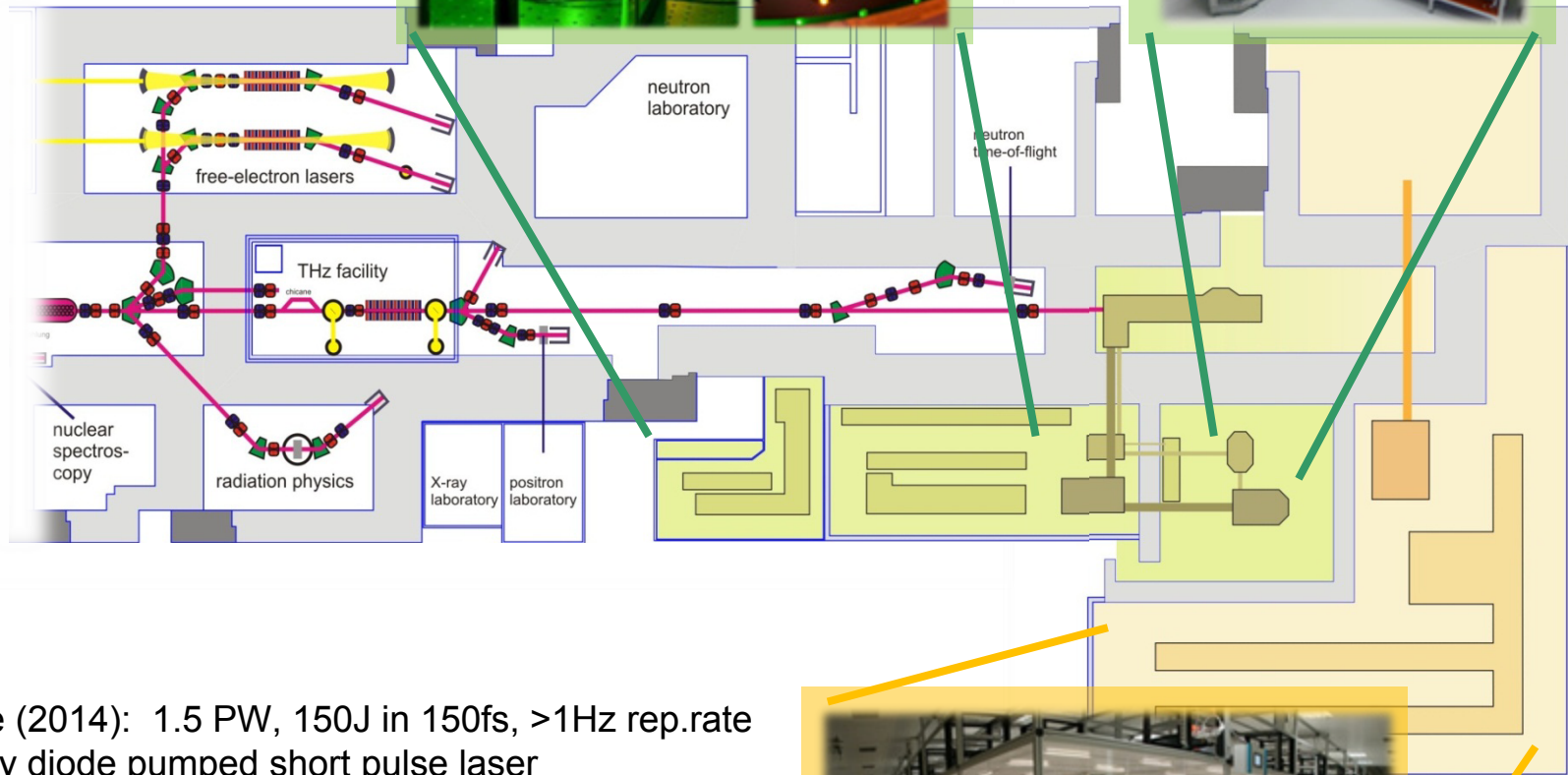
Under construction

User beams at ELBE



High power laser systems @ ELBE

150 TW laser Draco (4J in ~30fs)
upgrade to dual-beam facility
with PW ampl. (30J/30fs @1Hz)
dedicated target areas

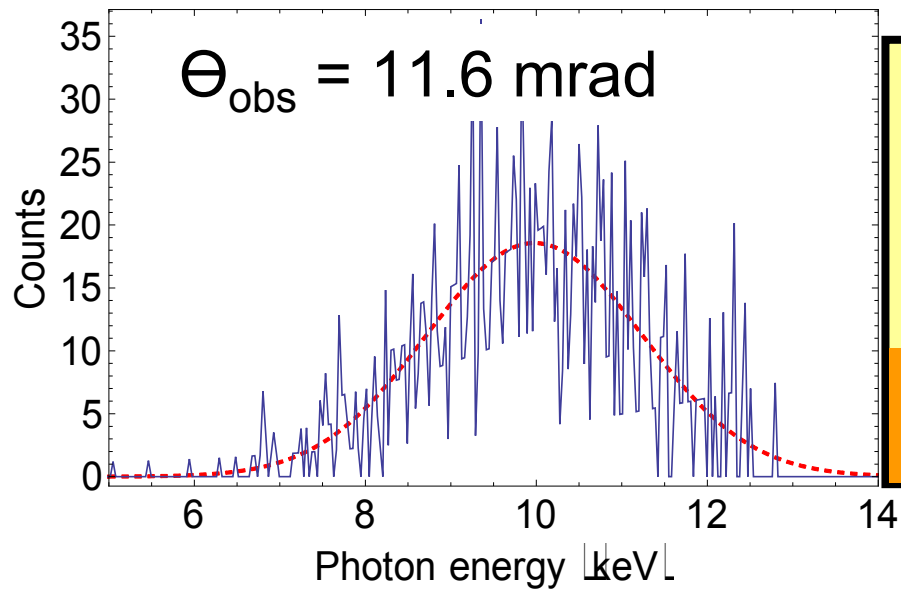


Penelope (2014): 1.5 PW, 150J in 150fs, >1Hz rep.rate
directly diode pumped short pulse laser
active medium (Yb:CaF₂)
as driver for medical applications



ZDR

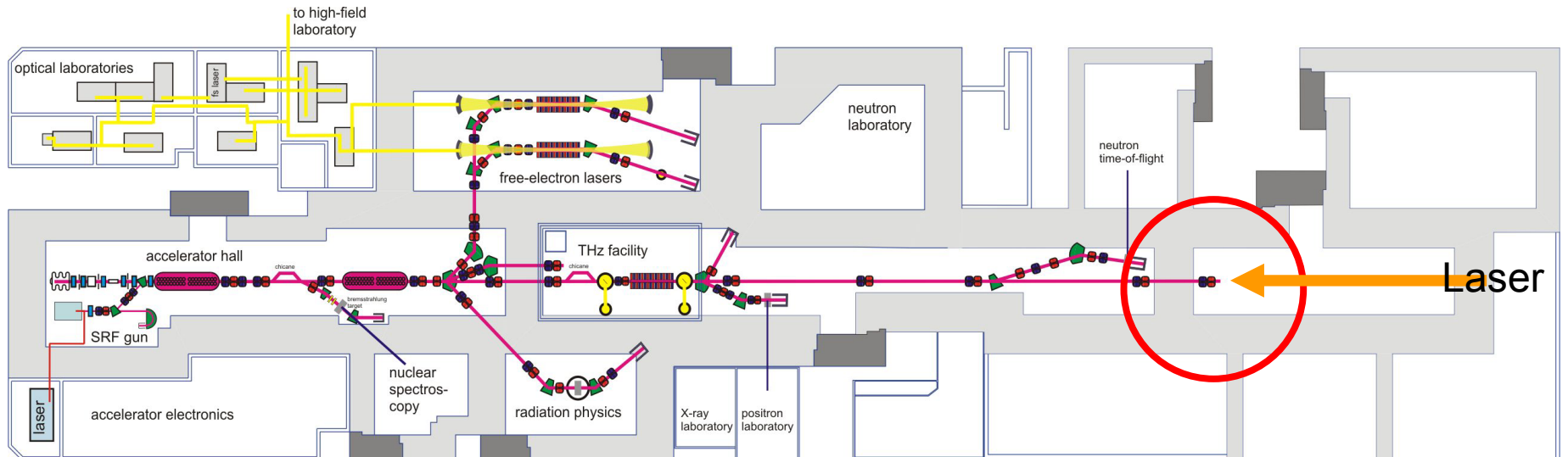
Electron – Laser Interaction



First Thomson data:

Tunability:	12 keV - 20 keV (on axis)
ΔE_{FWHM} :	1.05 keV
Pulse duration:	2 ps
Collimation:	20mrad ($1/\gamma$)
Flux @ 40 fC:	150 photons

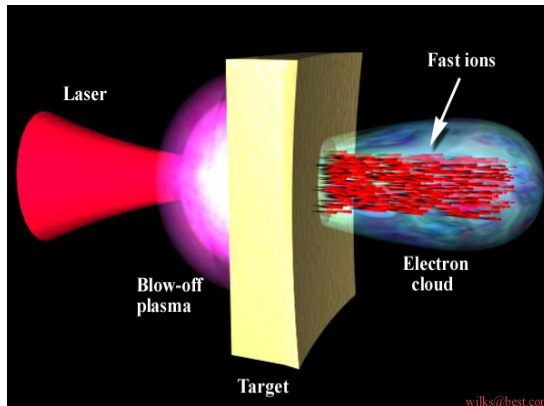
Optimistic extrapolation:
 $1 \text{ nC} / 1 \pi \text{ mmmrad beam} \sim 10^7 \text{ photons}$



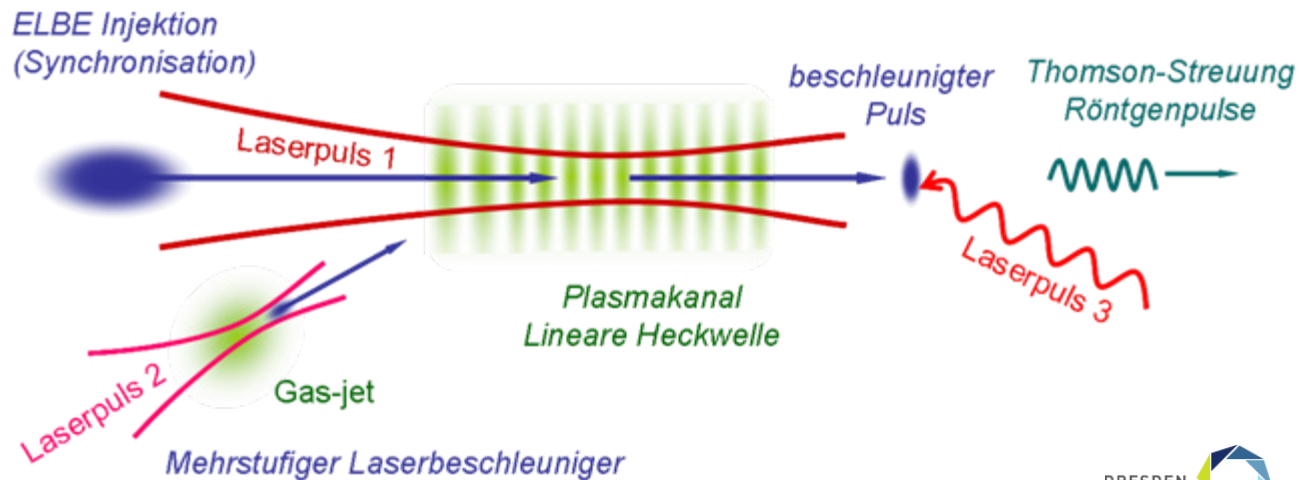
Under construction / recommissioning

High power laser systems @ ELBE

Laser accelerated protons (ions) as compact accelerators for hadron therapy



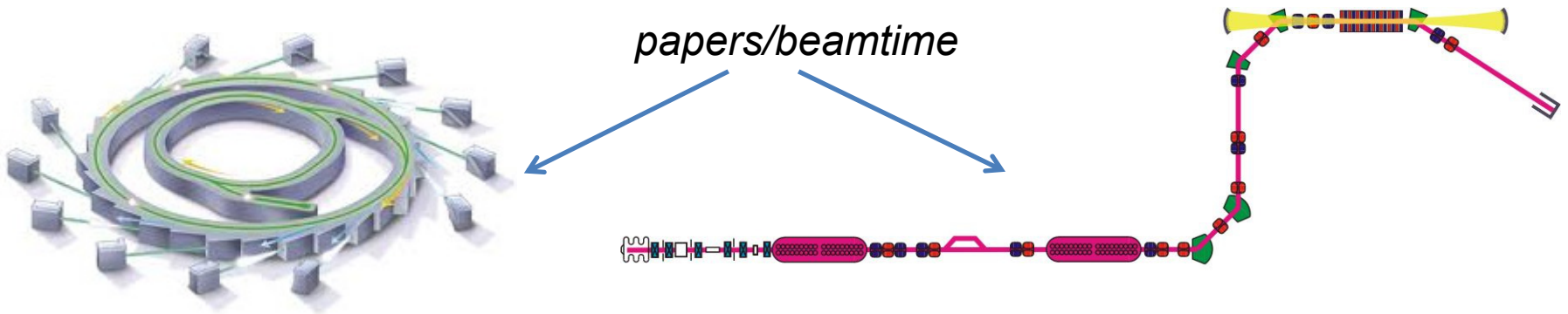
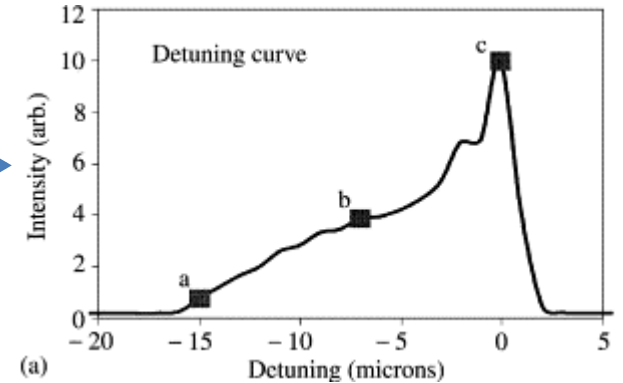
Laser plasma acceleration, Thomson x-rays, ultrafast probes



Motivation for higher currents

- Higher intensity of secondary radiation
- Higher stability of secondary beams
- Beam splitting and multi user operation

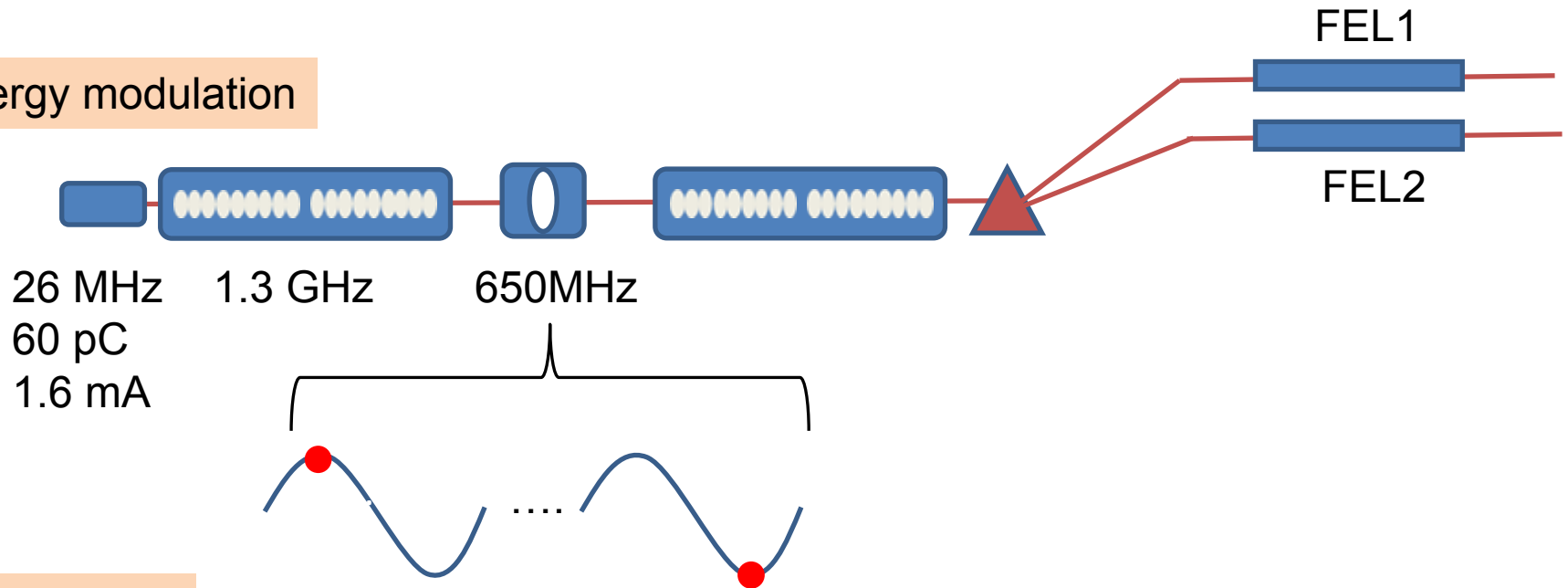
FEL →



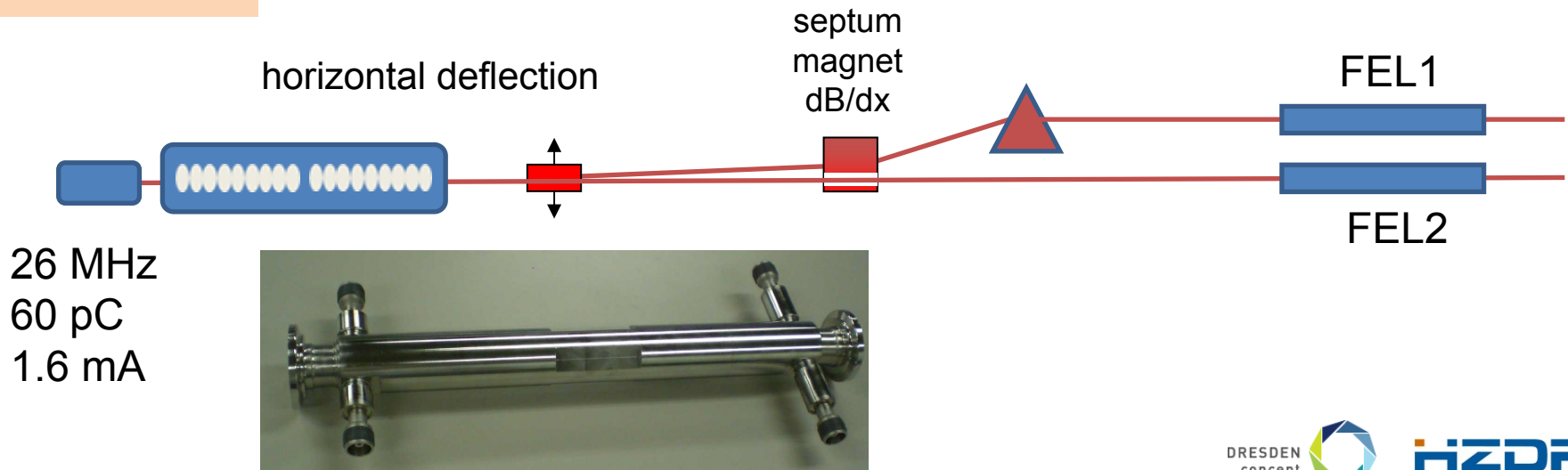
- Test of accelerator components at high currents – studies for future projects

Possible beam splitting schemes

Energy modulation

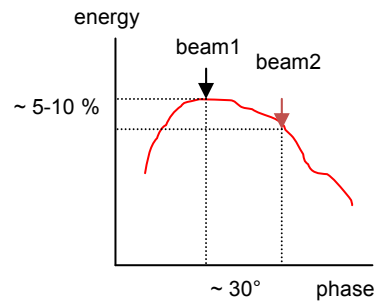
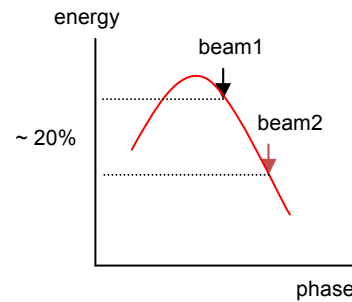
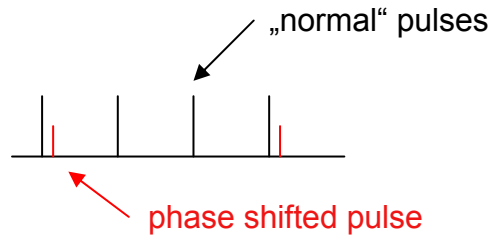
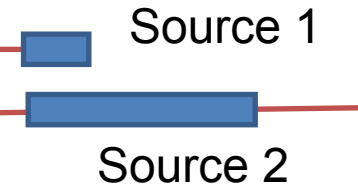
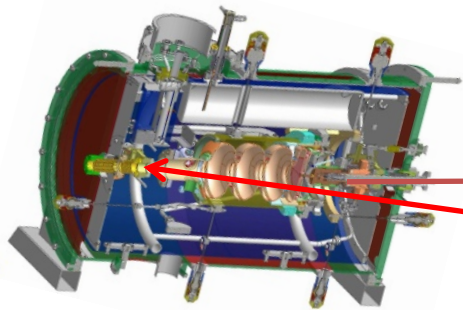


Beam kicker



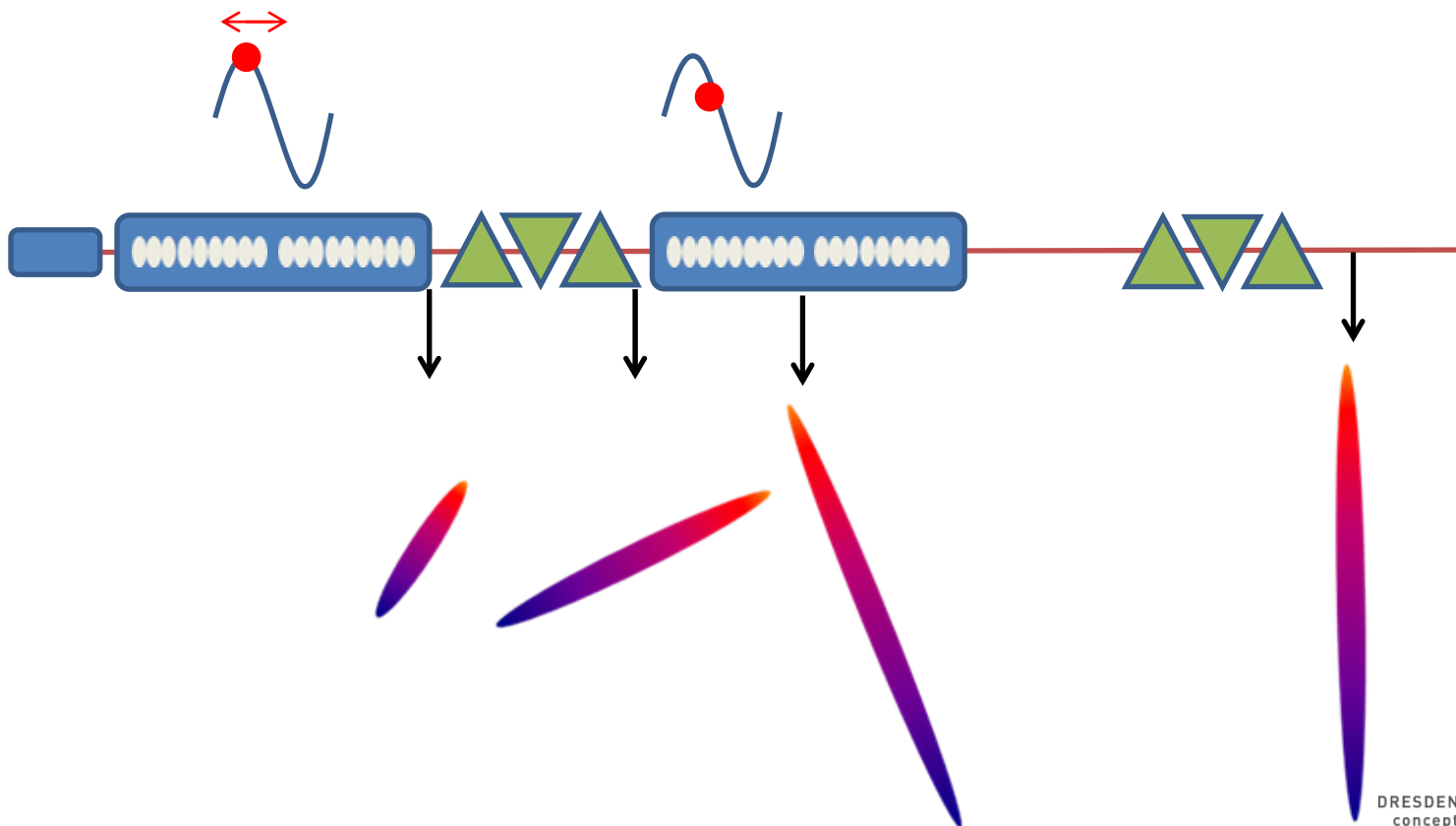
Multiple gun beams

RF photo gun



Motivation for higher gradients

- Higher beam energy
- Beam tuning by off crest operation



Summary

ELBE works successfully in routine user operation with multiple beams for a wide range of applications

ELBE (TESLA) technology is quite feasible for compact high average power beams facilities!!

Higher beam current / acceleration gradients are essential for performance improvement

- intensity
- stability
- flexibility