The intense positron source EPOS at Research Center Rossendorf

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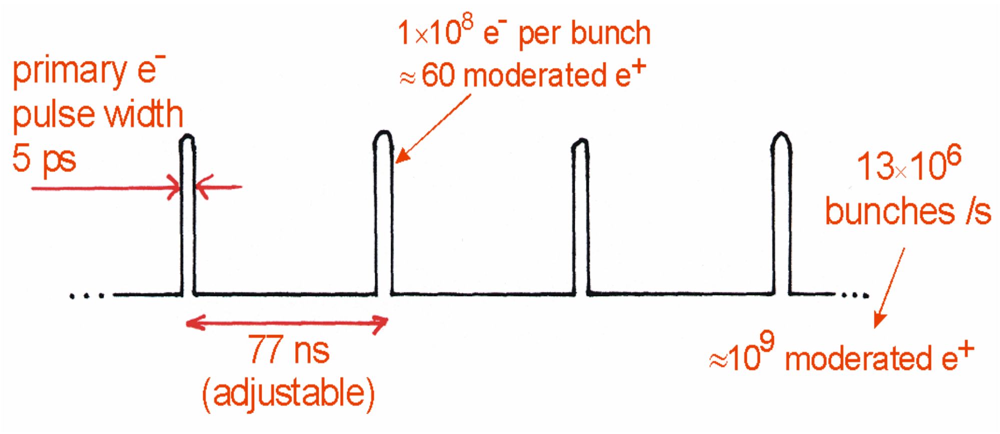
The EPOS positron source at Research Center Rossendorf

- Main experiment in Rossendorf: Radiation source ELBE = **E**lectron **L**inac with high **B**rilliance and low **E**mittance
- Primary electron beam (40 MeV x 1 mA = 40 kW)
- Main goal: IR Free-electron Laser
- Very interesting time structure: cw-mode of short bunches

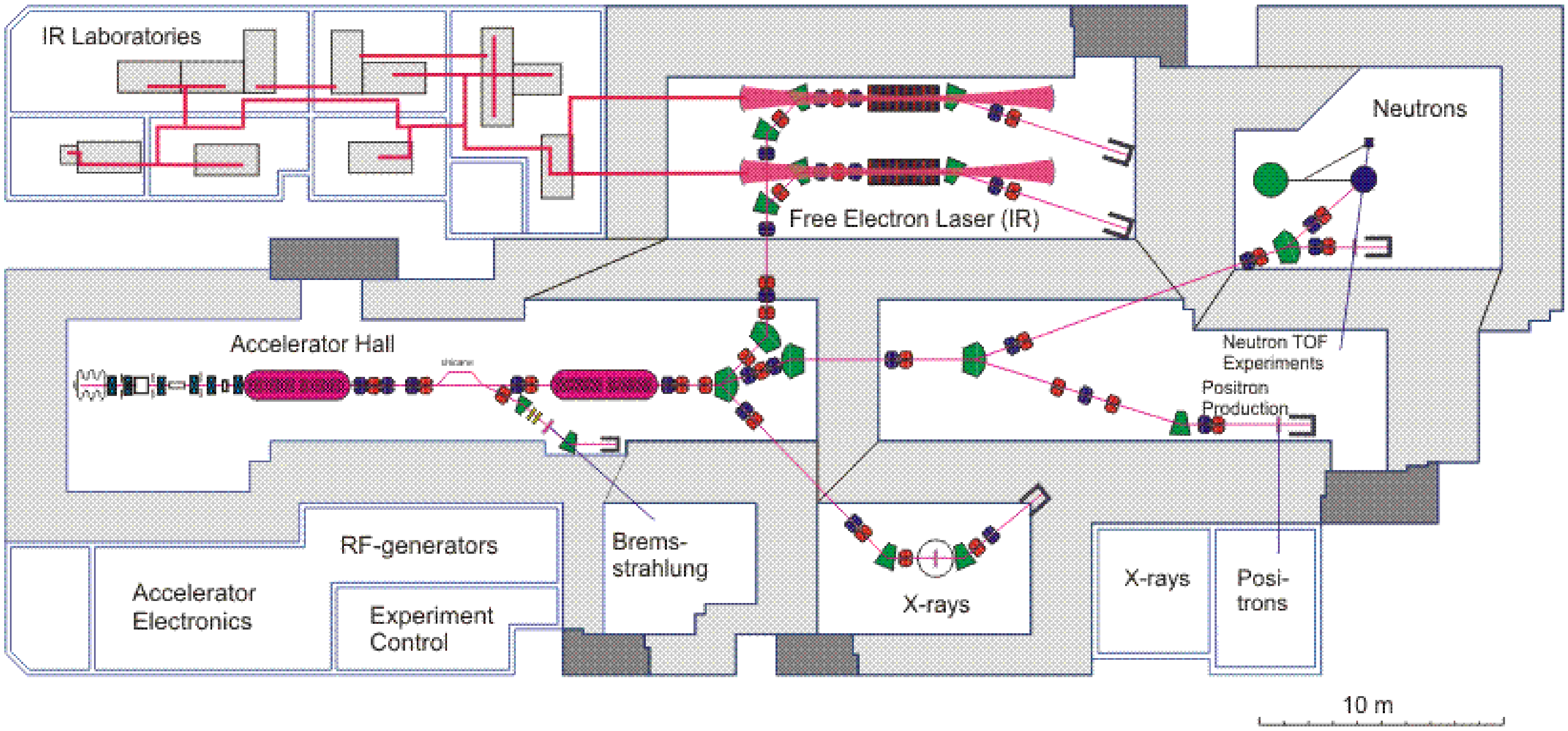


electron bunches

EPOS = ELBE Positron Source

- Intense beam of slow (monoenergetic) positrons
- All relevant positron techniques for materials research (positron lifetime, Coincidence Doppler broadening, AMOC)
- EPOS is external facility of Martin-Luther-University Halle at Research center Rossendorf
- User-dedicated facility
- Remote controlled via internet
- Financing by University Halle, Land Sachsen-Anhalt and European Community

Ground map of the ELBE hall



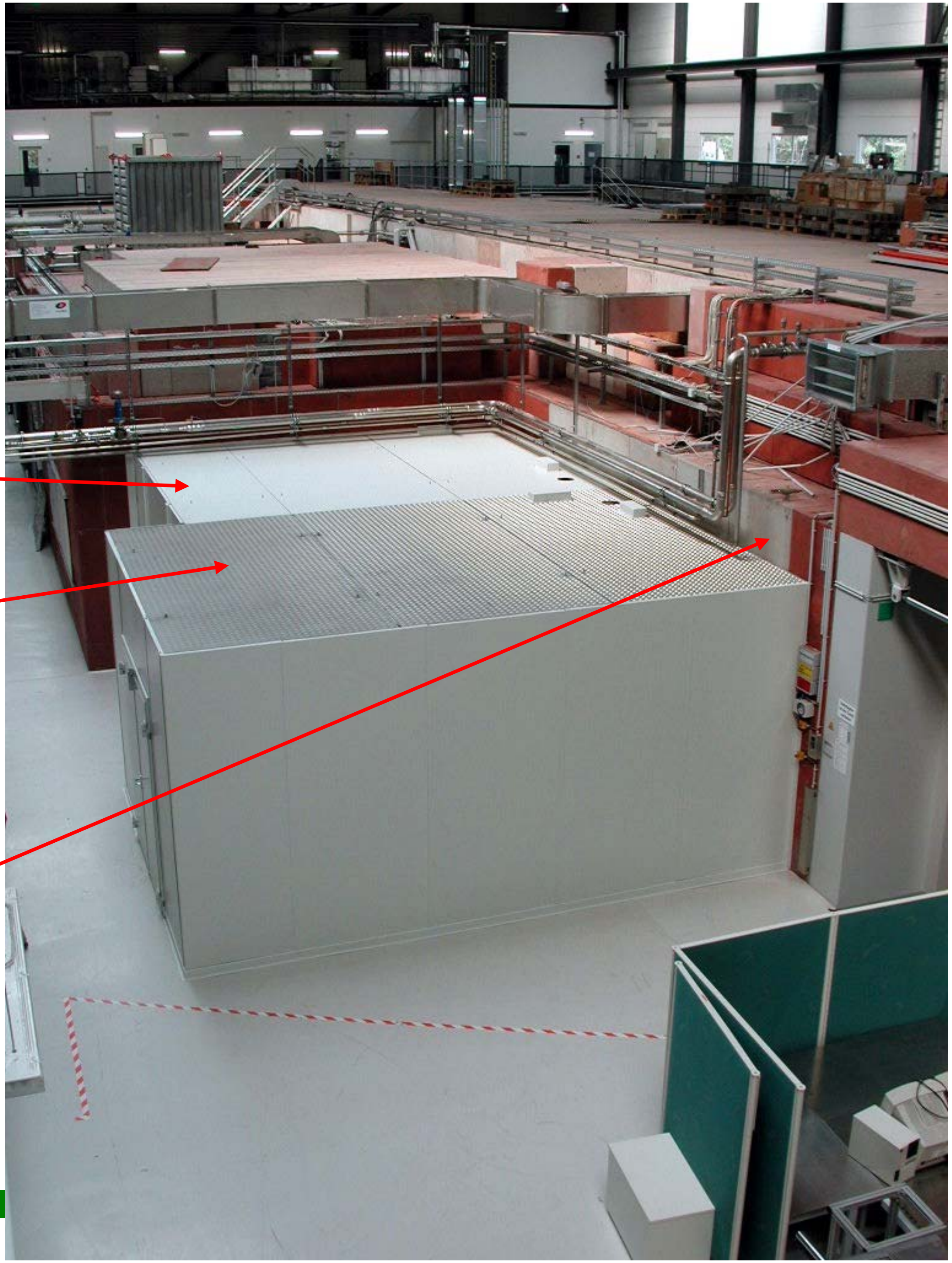
Positron Lab

- positron lab in ELBE hall already available

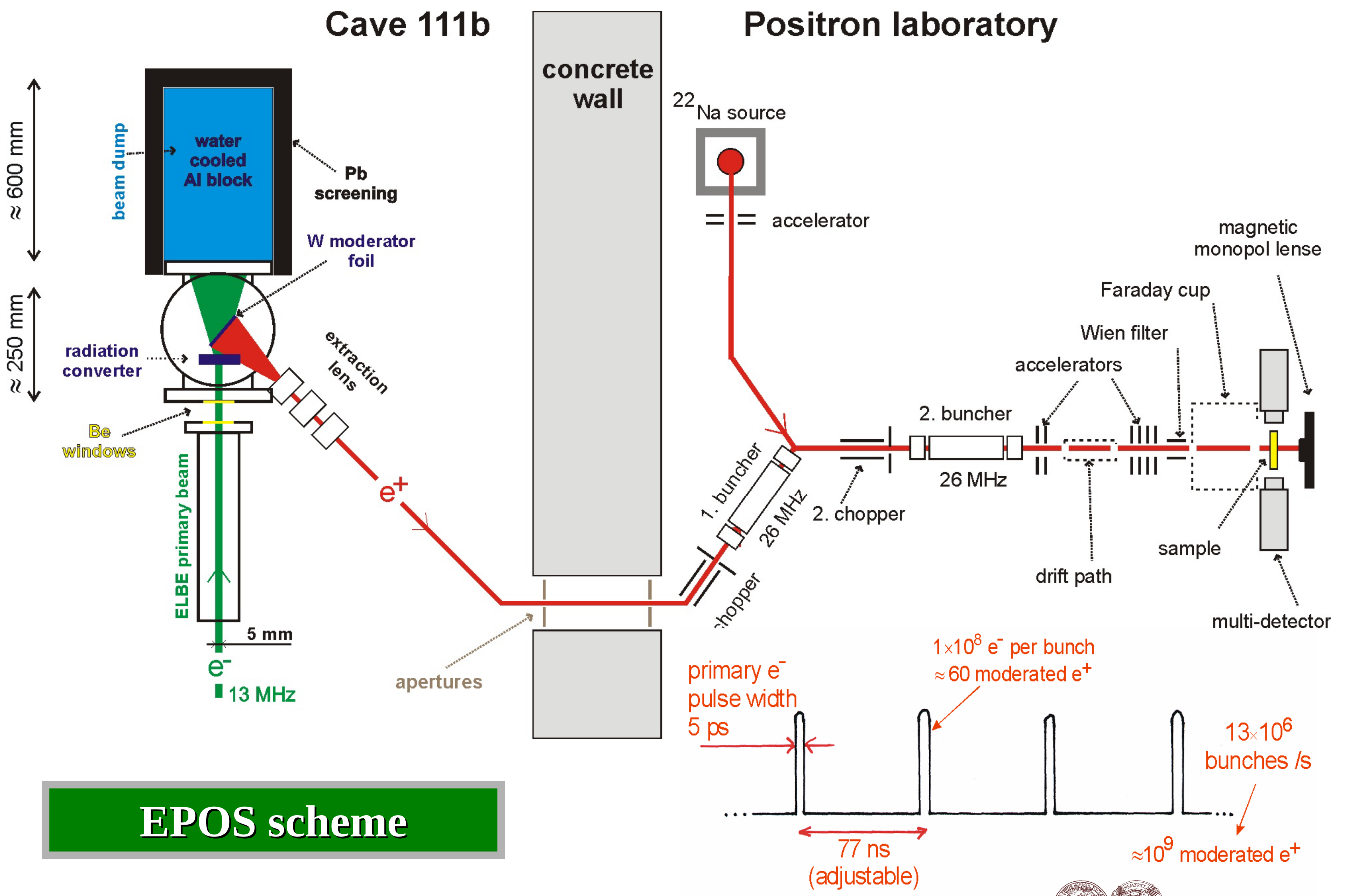
X-ray Lab

Positron Lab

concrete screening of Cave 111b (location of e^+ converter)

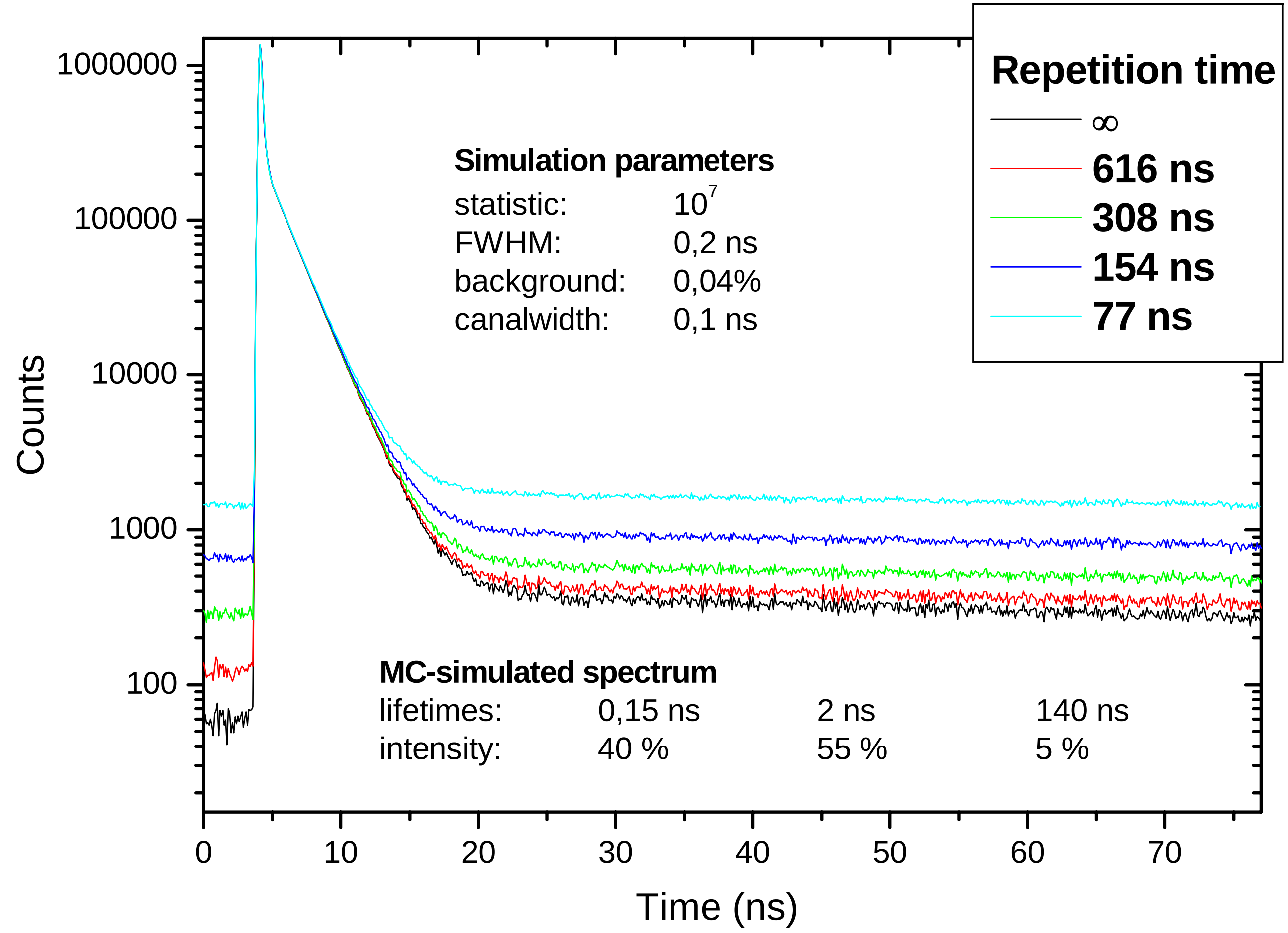



3,2 m concrete screening
of Cave 111b
cable tunnel to be used for e+
beamline
photo taken in November 2003


Cave 111b
concrete wall
Positron laboratory
≈ 600 mm
≈ 250 mm
beam dump
water cooled Al block
Pb screening
W moderator foil
radiation converter
extraction lens
Be windows
ELBE primary beam
5 mm
e-
13 MHz
e+
apertures
22 Na source
accelerator
1. buncher
26 MHz
chopper
2. chopper
2. buncher
26 MHz
accelerators
Wien filter
Faraday cup
magnetic monopol lense
drift path
sample
multi-detector
primary e- pulse width 5 ps
1×10^8 e- per bunch
≈ 60 moderated e+
13×10^6 bunches /s
77 ns (adjustable)
≈10^9 moderated e+

EPOS scheme

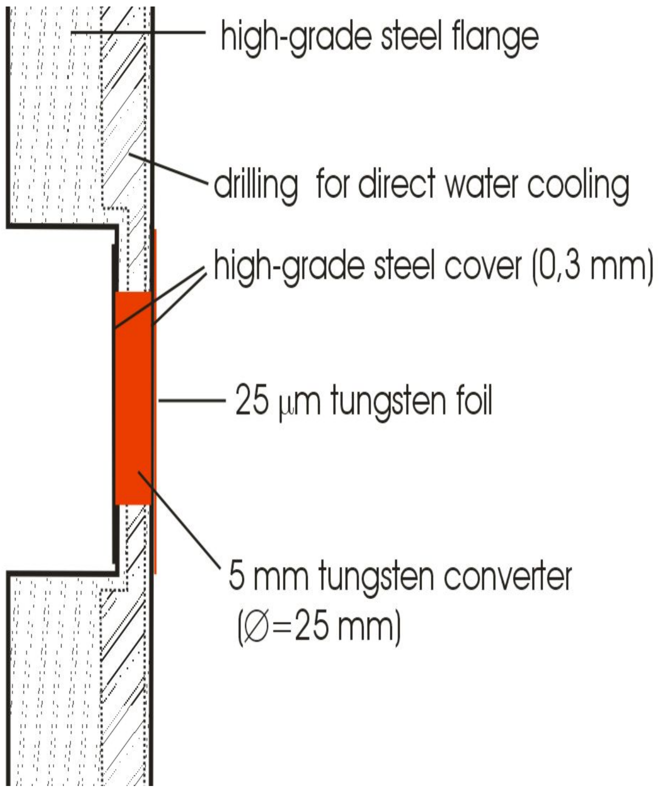
Second timing mode needed for long lifetimes (porous material)

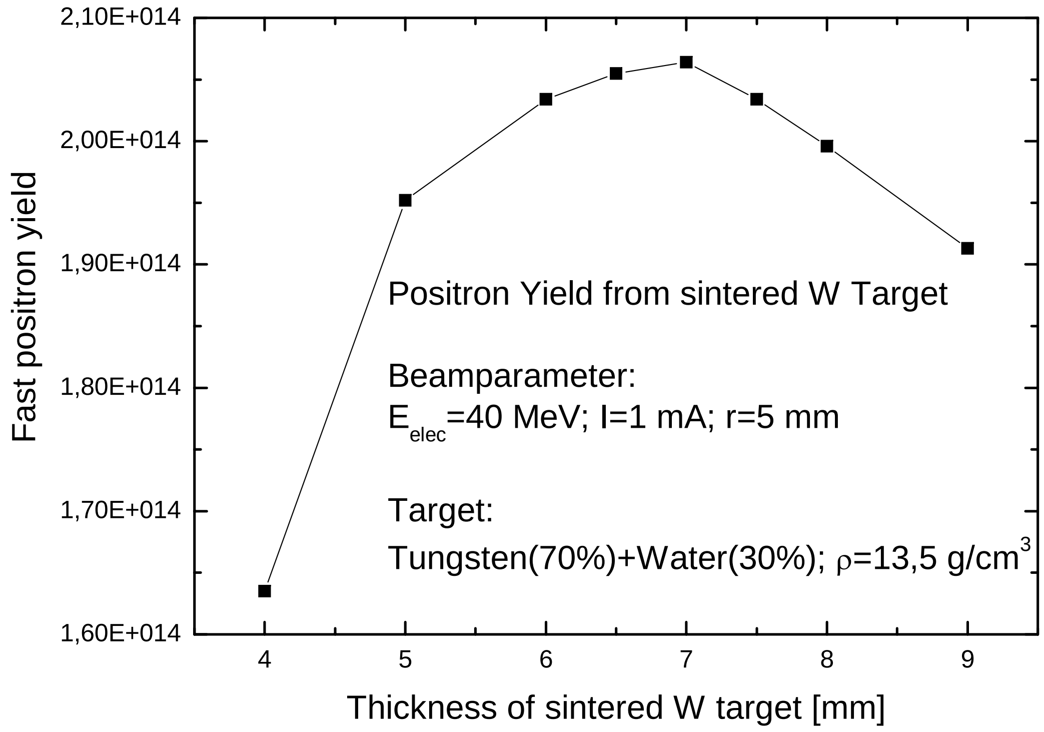


Result of Fit:

Repetition time	Lifetime	Intensity
616 ns	141 ns	5,1 %
308 ns	124 ns	4,9 %
154 ns	75 ns	3,3 %
77 ns	35 ns	1,7 %

Converter

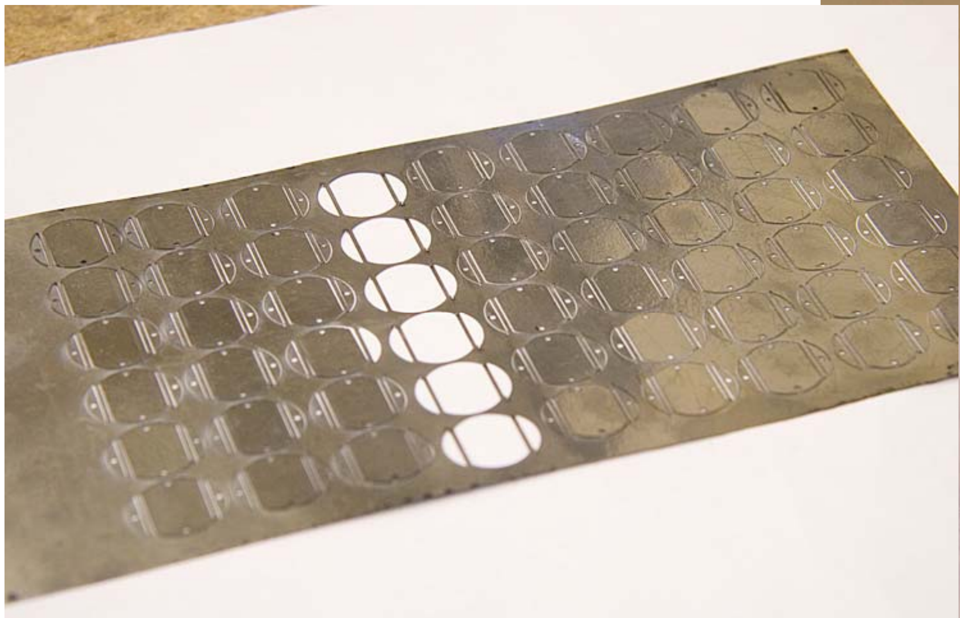


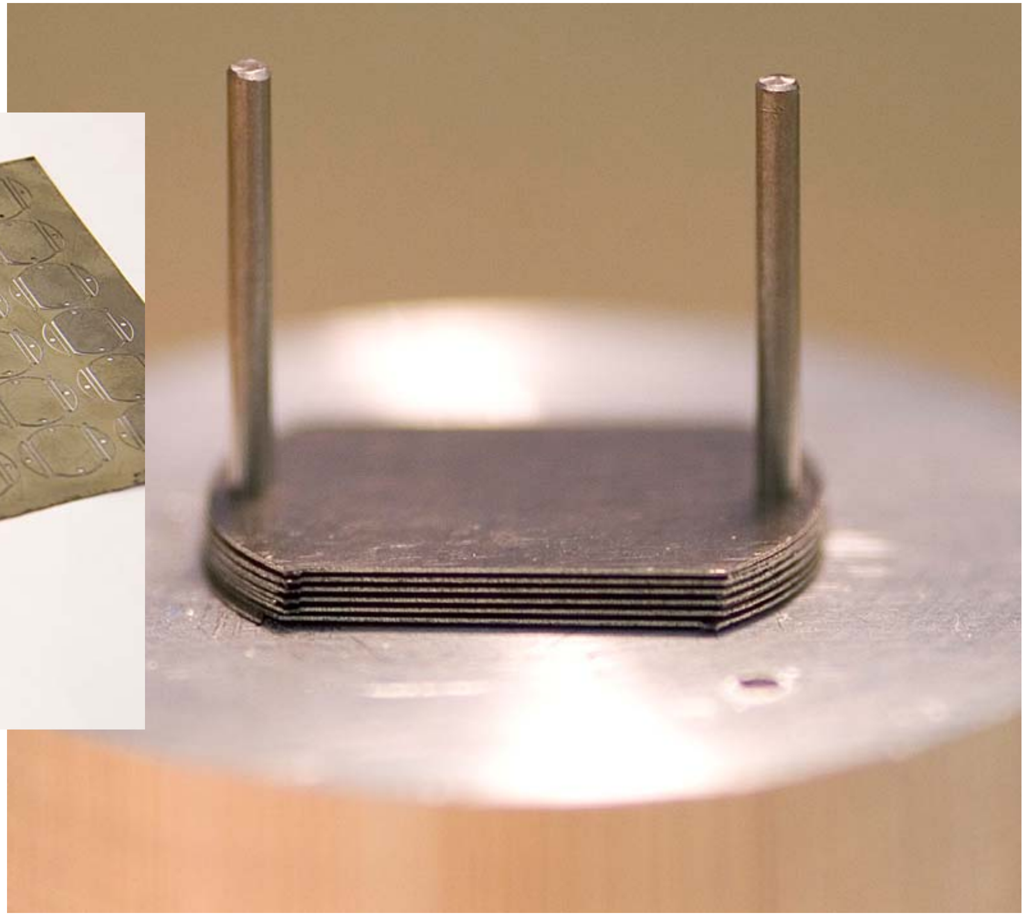


MCNP-Simulationen A. Rogov und K. Noack (FZR)

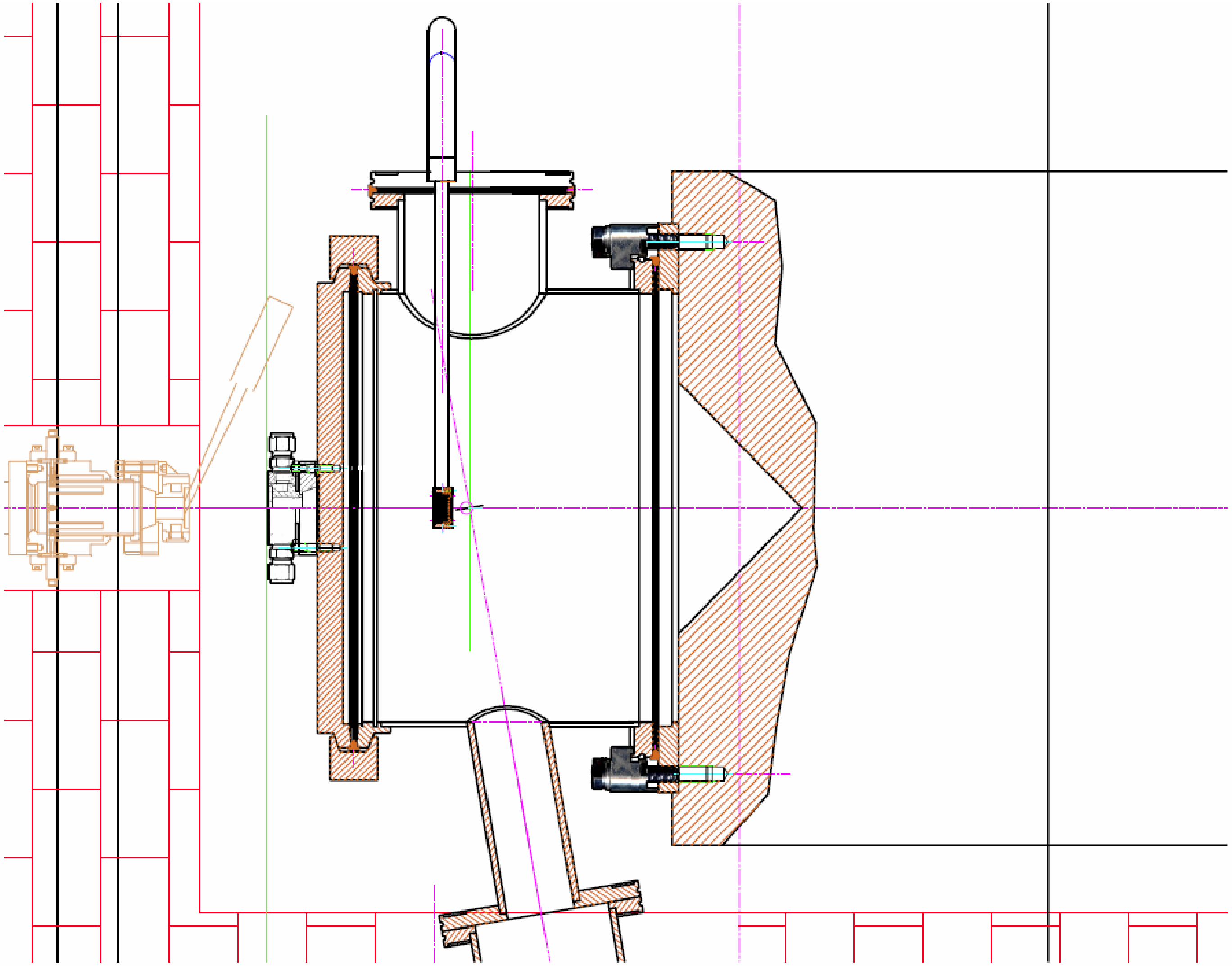
Directly water-cooled Electron-Positron Converter

- first attempt: porous W (30 % porosity) -> too low water flux at 10 bar
- stack of 50 pieces W-foils 0,1 mm separated by 0,1 mm -> 13,5 l water at 1,5 bar
- foils cut by IR-laser in our workshop

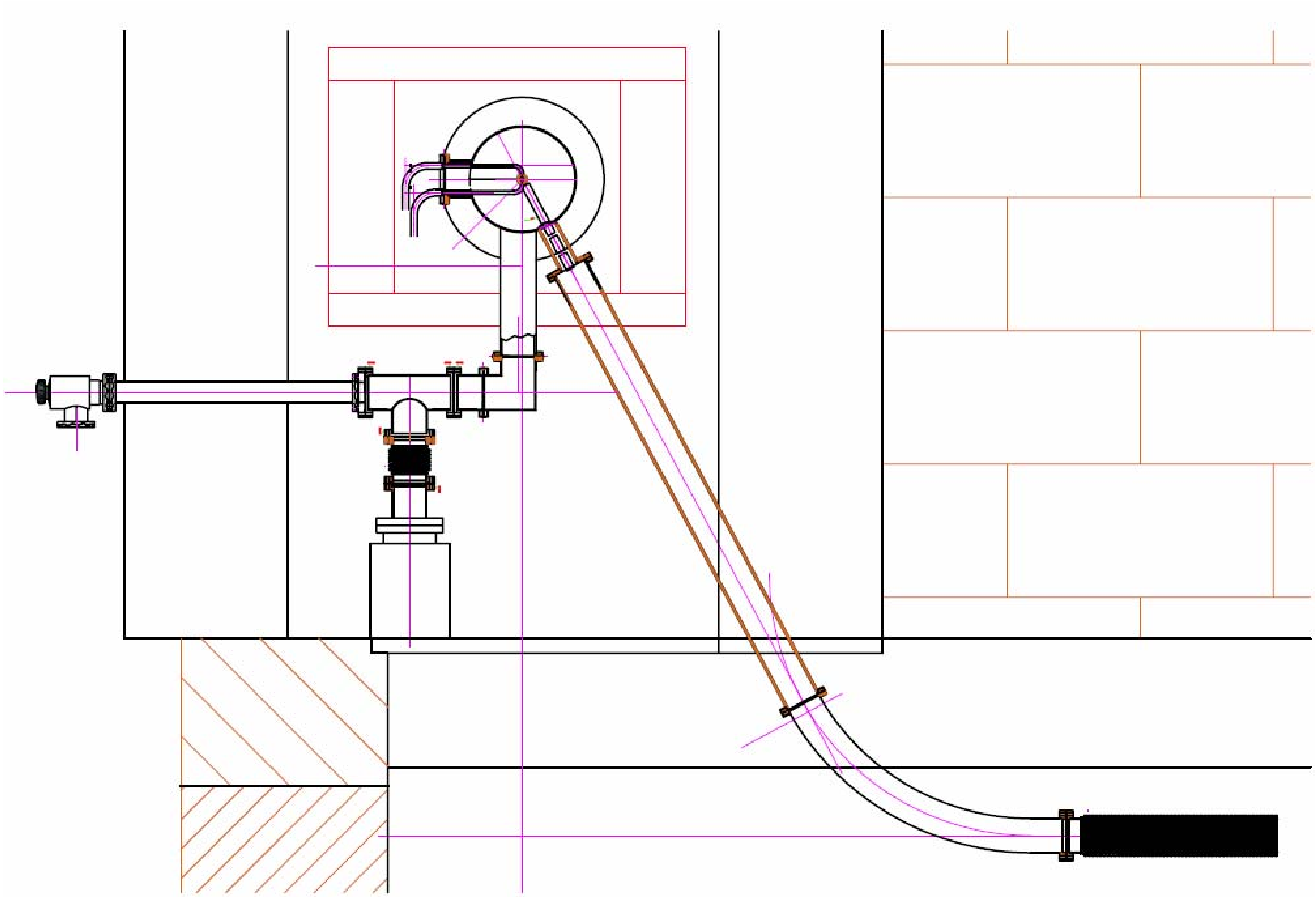


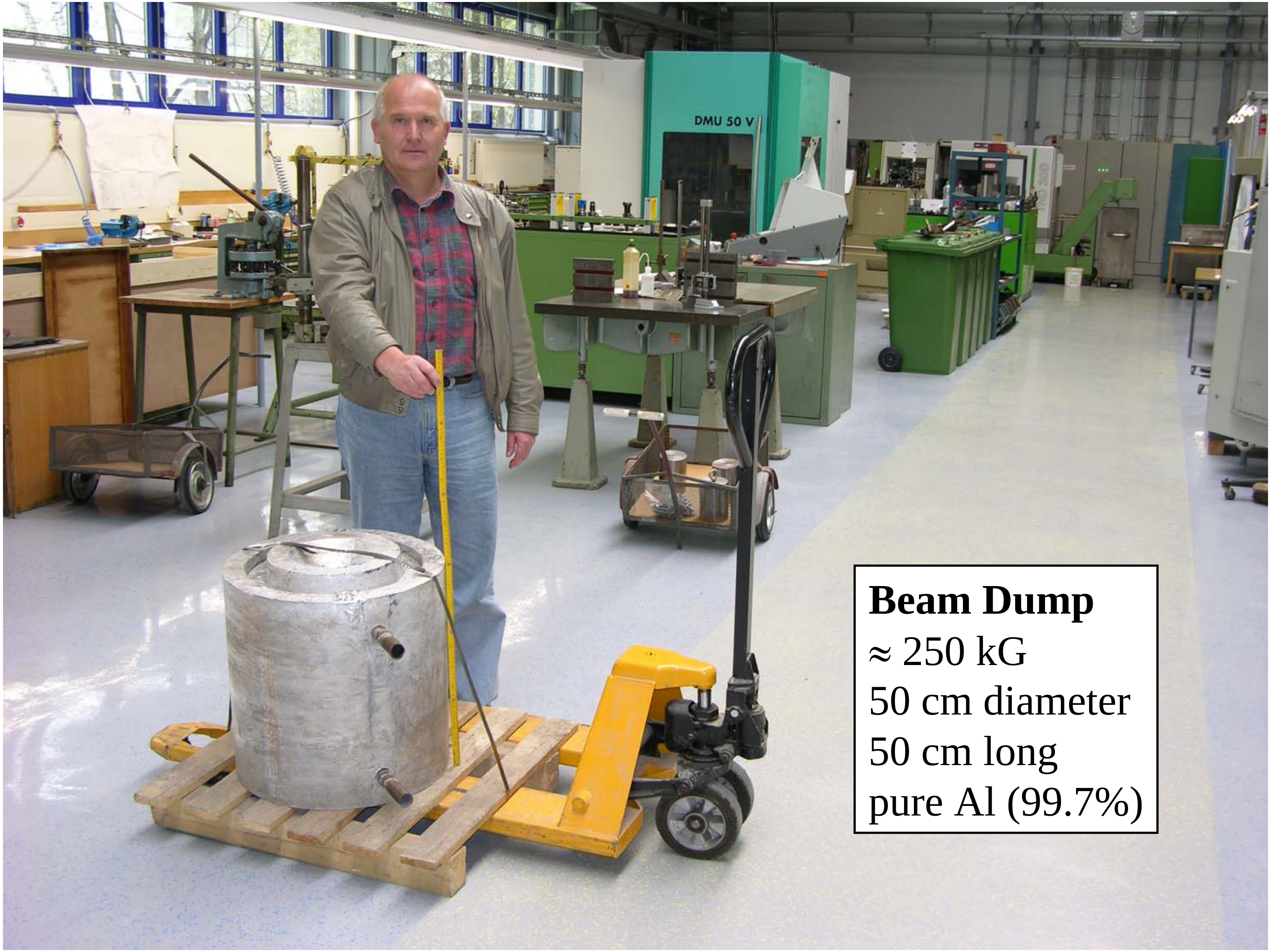


Converter Chamber



Converter Chamber





Beam Dump

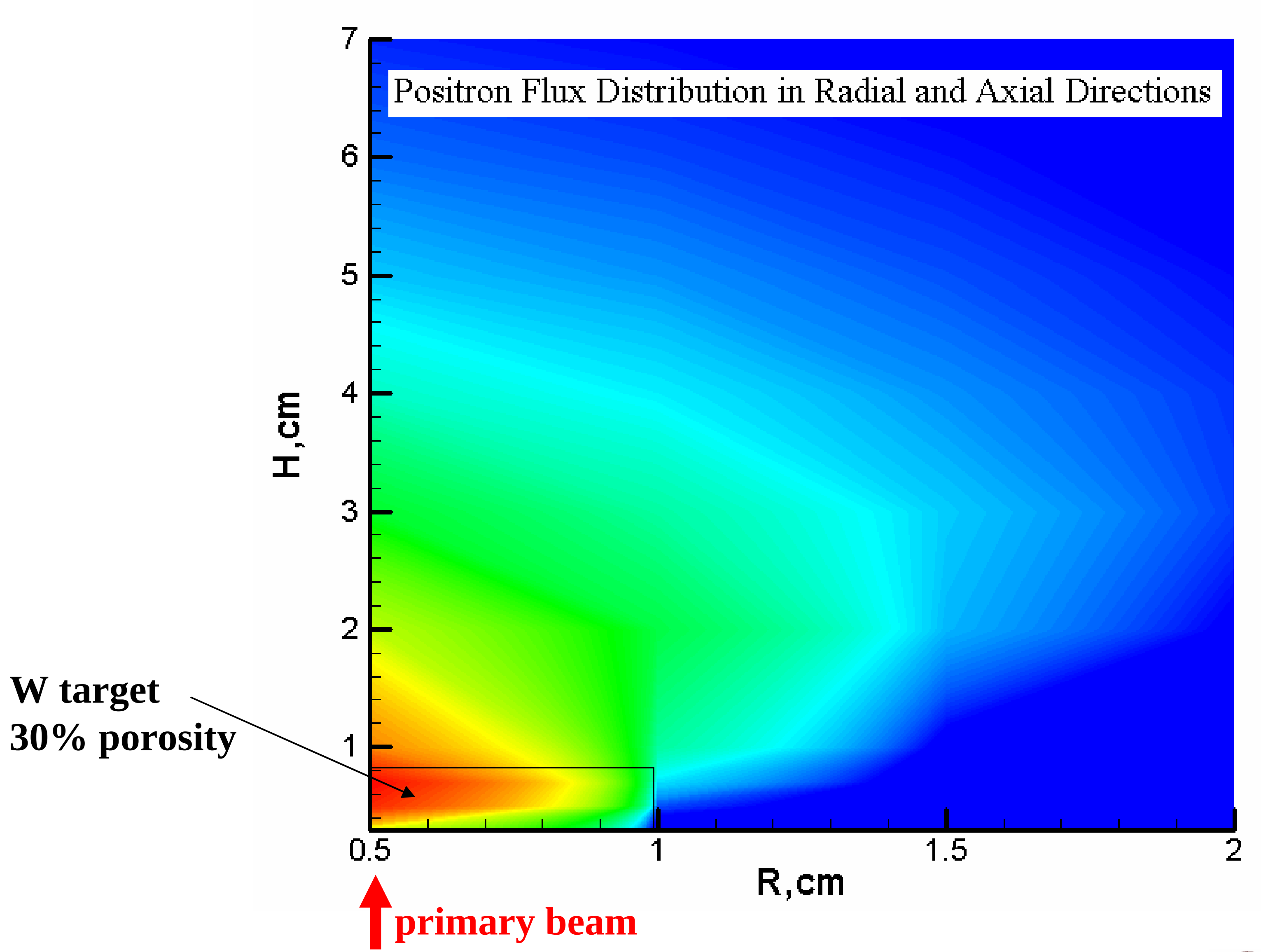
≈ 250 kG

50 cm diameter

50 cm long

pure Al (99.7%)

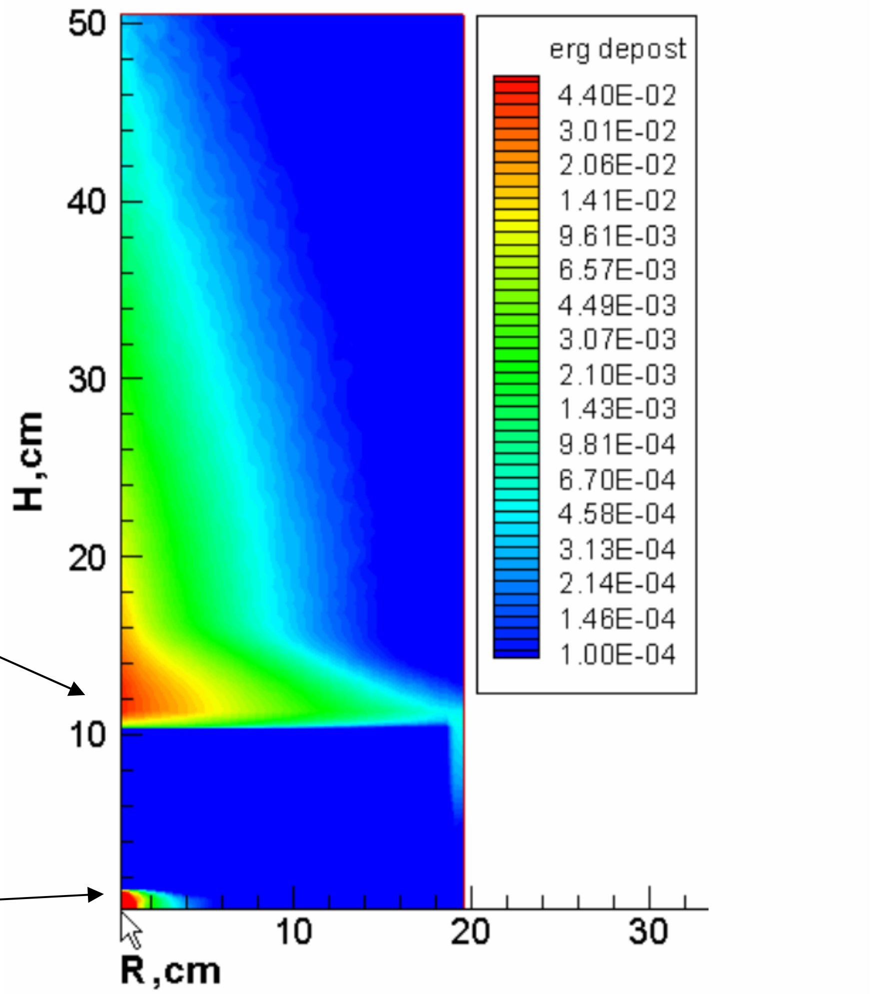
Simulation of Positron distribution



Simulation of Energy deposition

Al beam dump 21 kW
(made of 5N-purity)

W target
14 kW

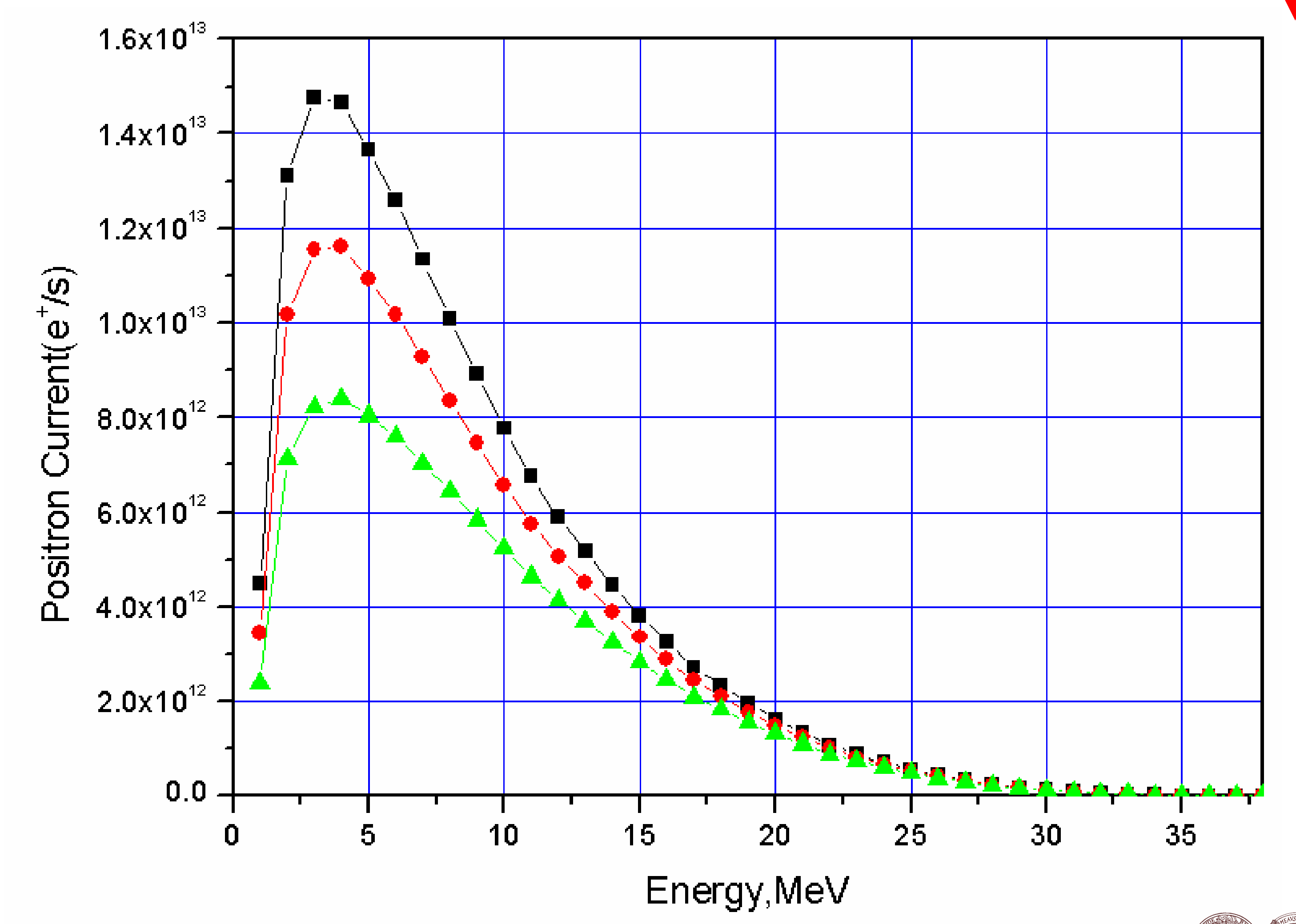


EPOS Density Energy Deposition (in MeV/cm^3) for Distance = 10cm

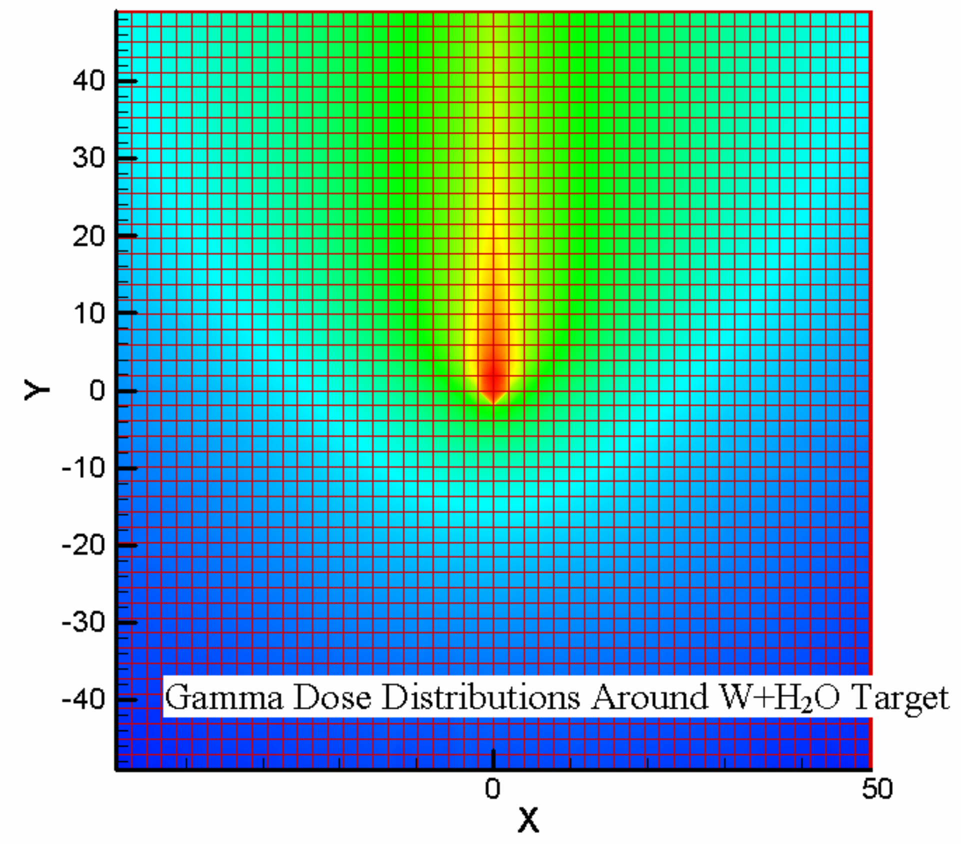
primary beam

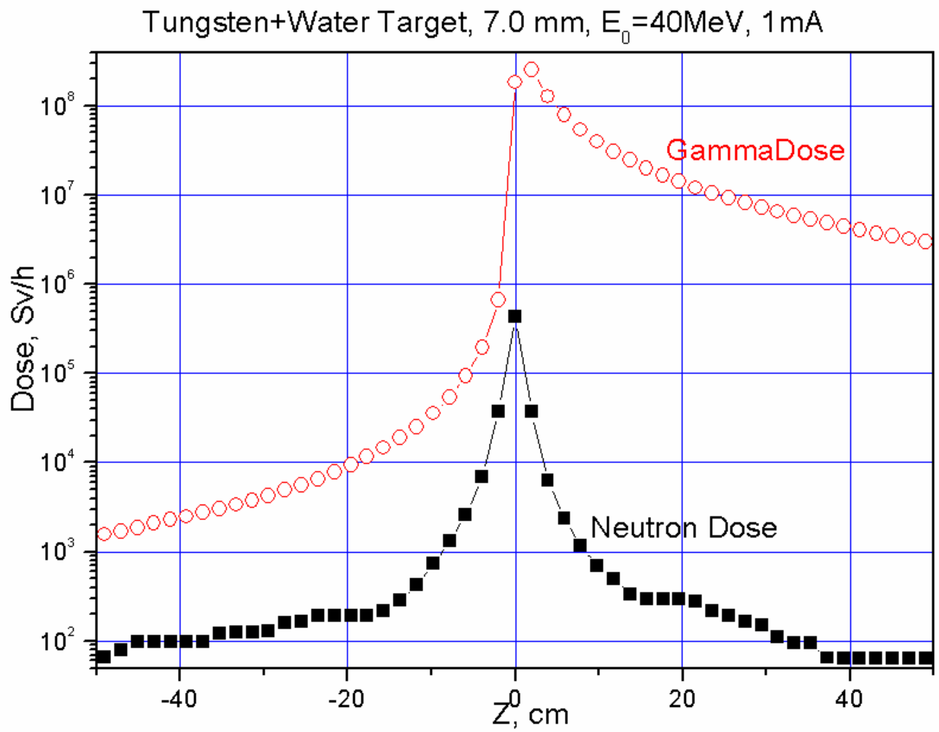
Simulation of Positron Energy Distribution

primary electron beam 40 MeV



Simulation of expected γ and n dose



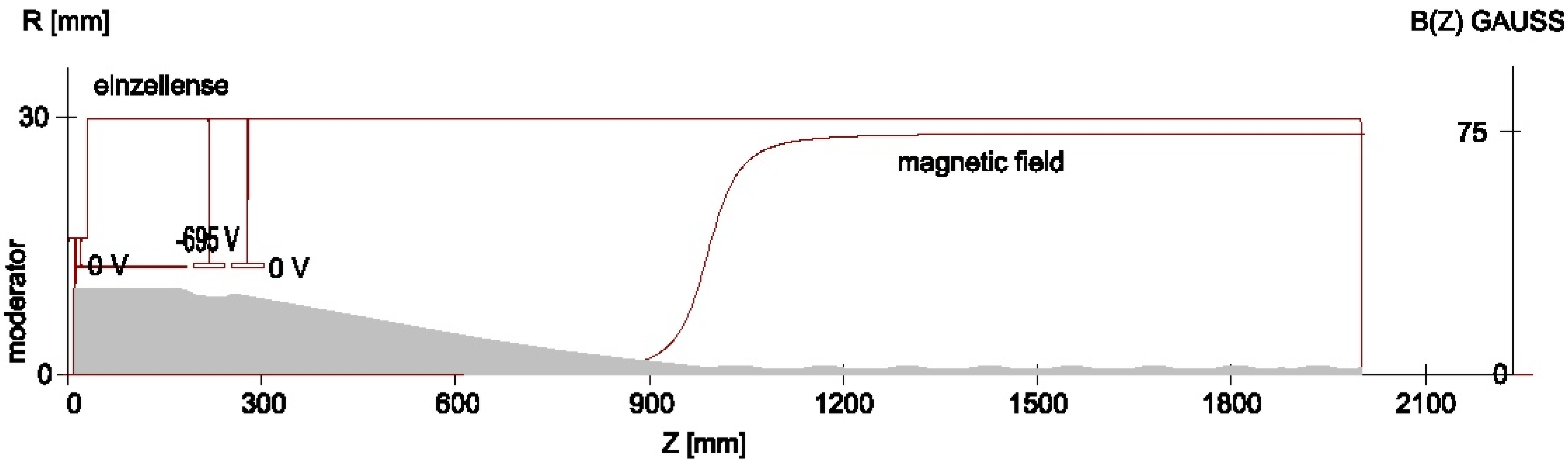


Neutron and Gamma Dose Distributions Around $W+H_2O$ Target in Axial Direction

Screening by lead blocks, Polyethylene bricks and heavy concrete

Simulation of positron extraction

- simulation done by EGUN
- area of 20 mm diameter at moderator is used and squeezed to about 2 mm



Magnetic Beam Guidance

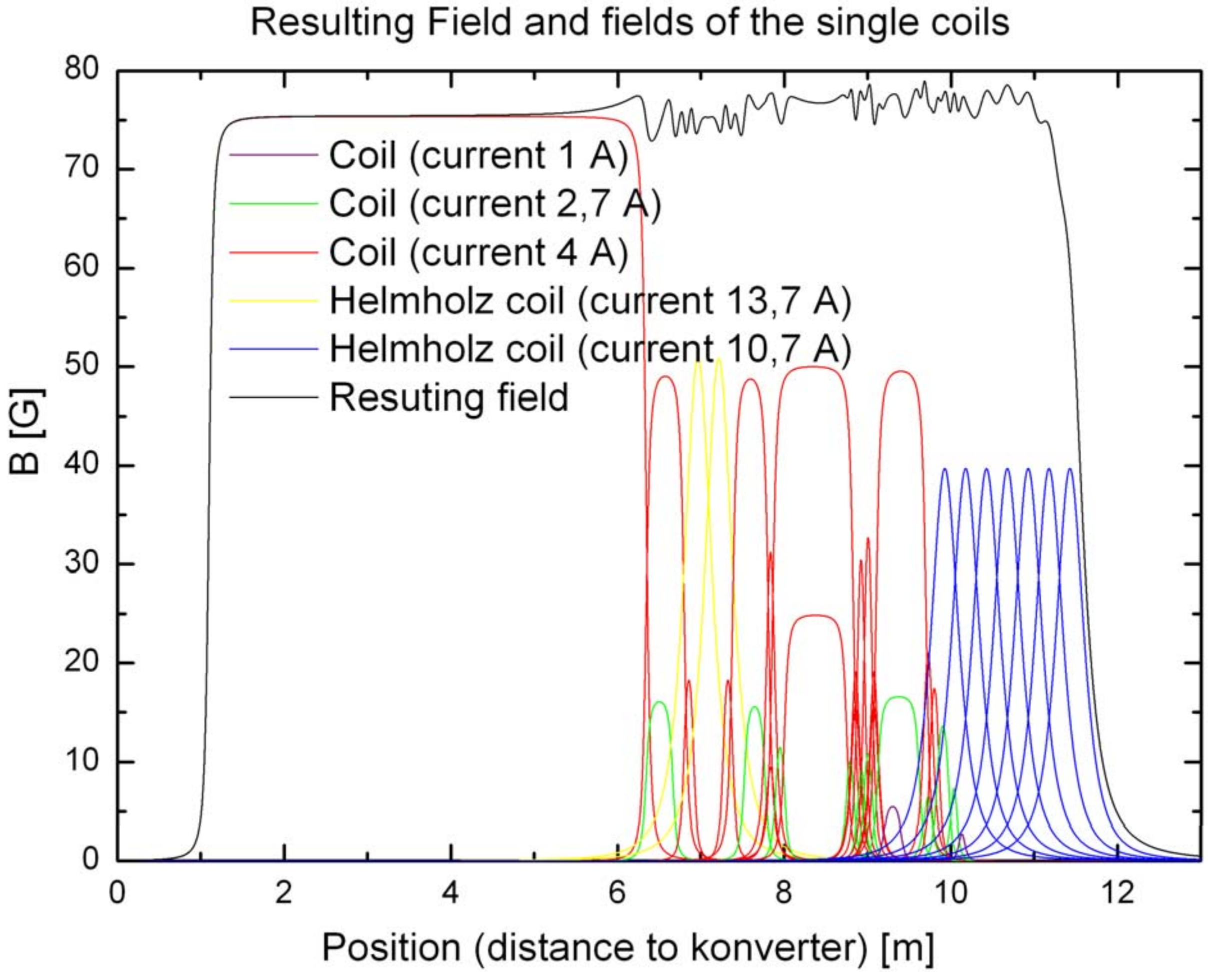
Magnetic field of 75 Gauss

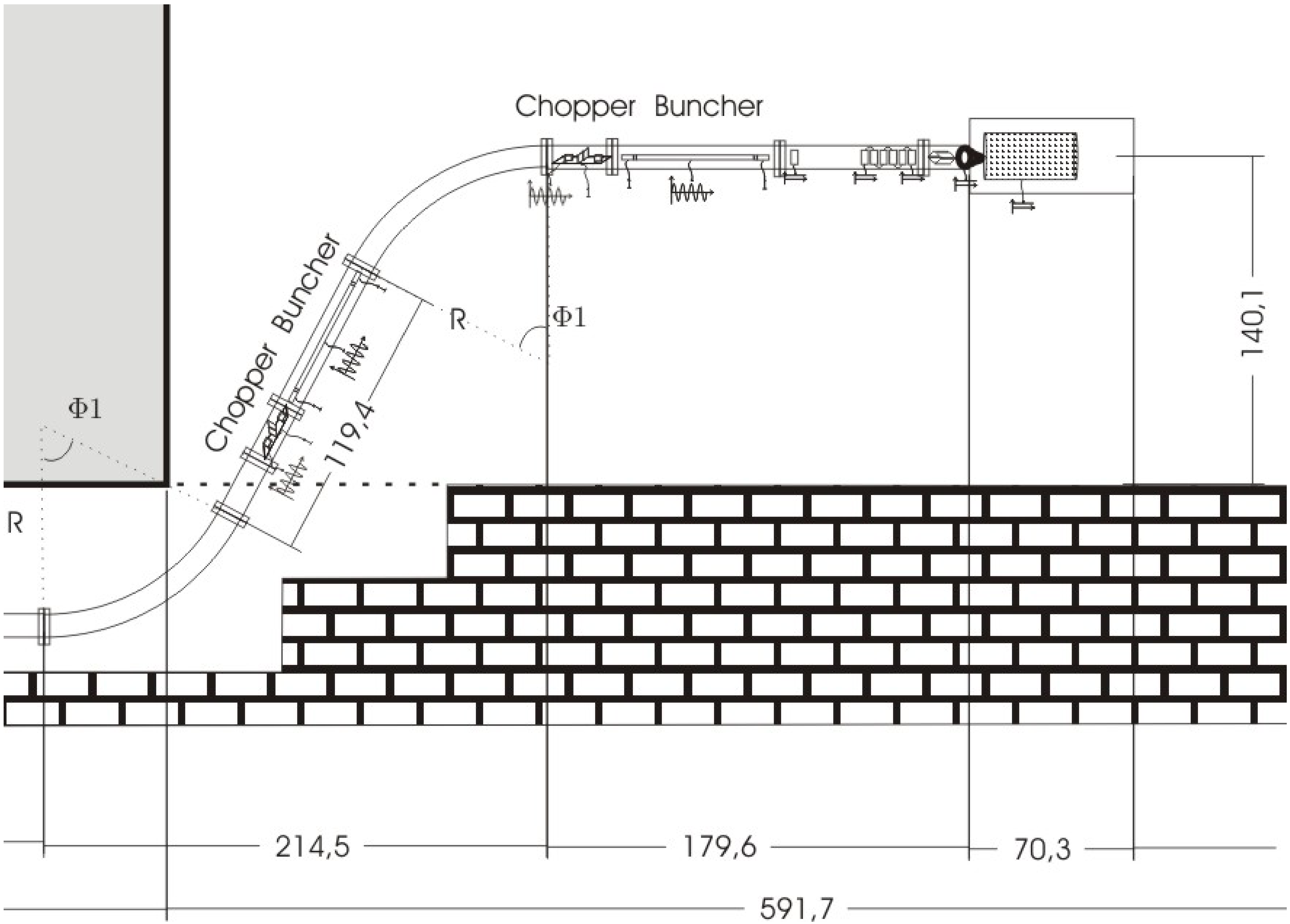
45 coils but only
5 different currents
5 Power supplies
2.7 kW Power together

➔maximum change 6 G
➔Gradient < 0,11 G/mm

Steering coils

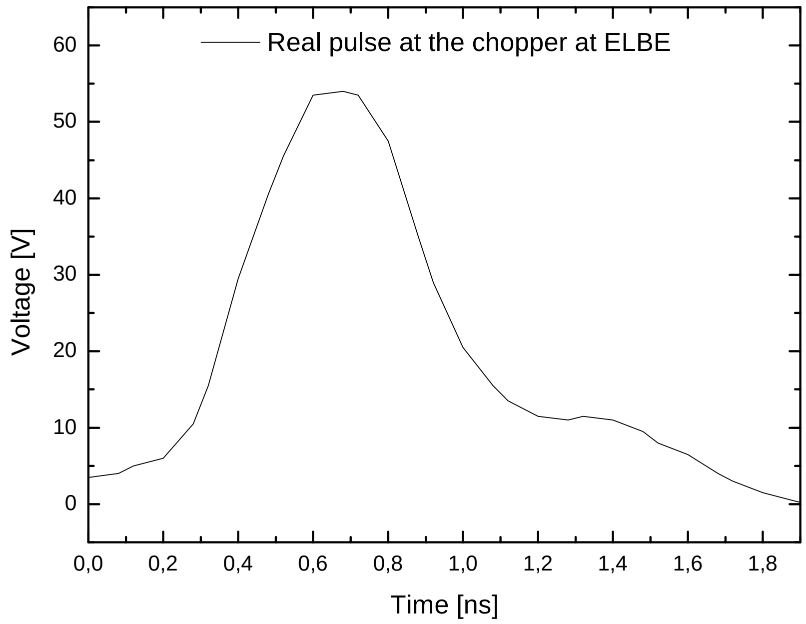
30 coils with different (computer-driven) currents

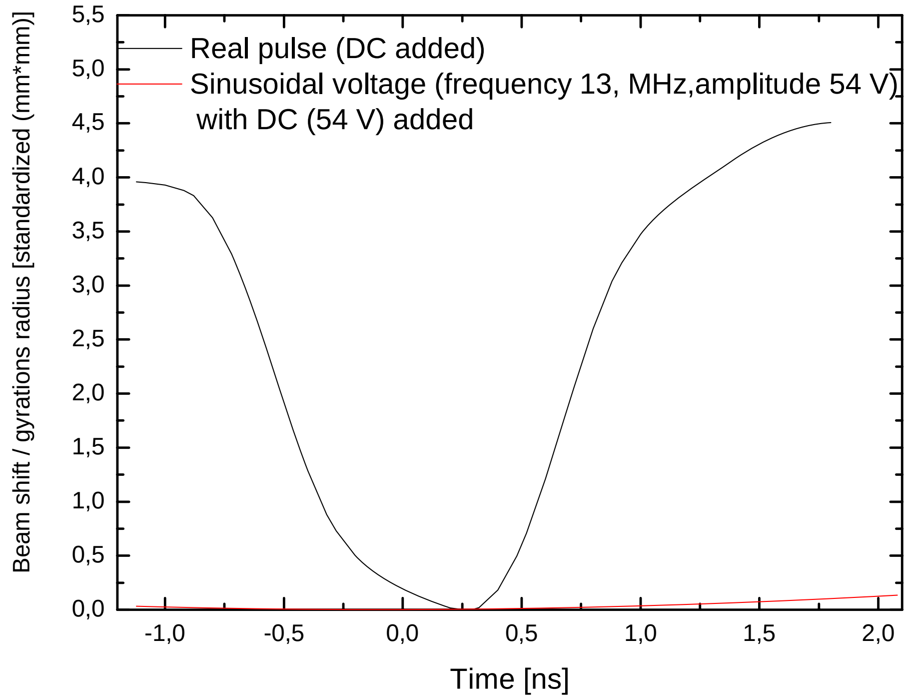



Chopper Buncher
Chopper Buncher
R
Φ1
Φ1
R
119,4
140,1
214,5
179,6
70,3
591,7

- Simulation of bunching by POSBUNCH
- C++ author: V. Bondarenko
- source code available on request

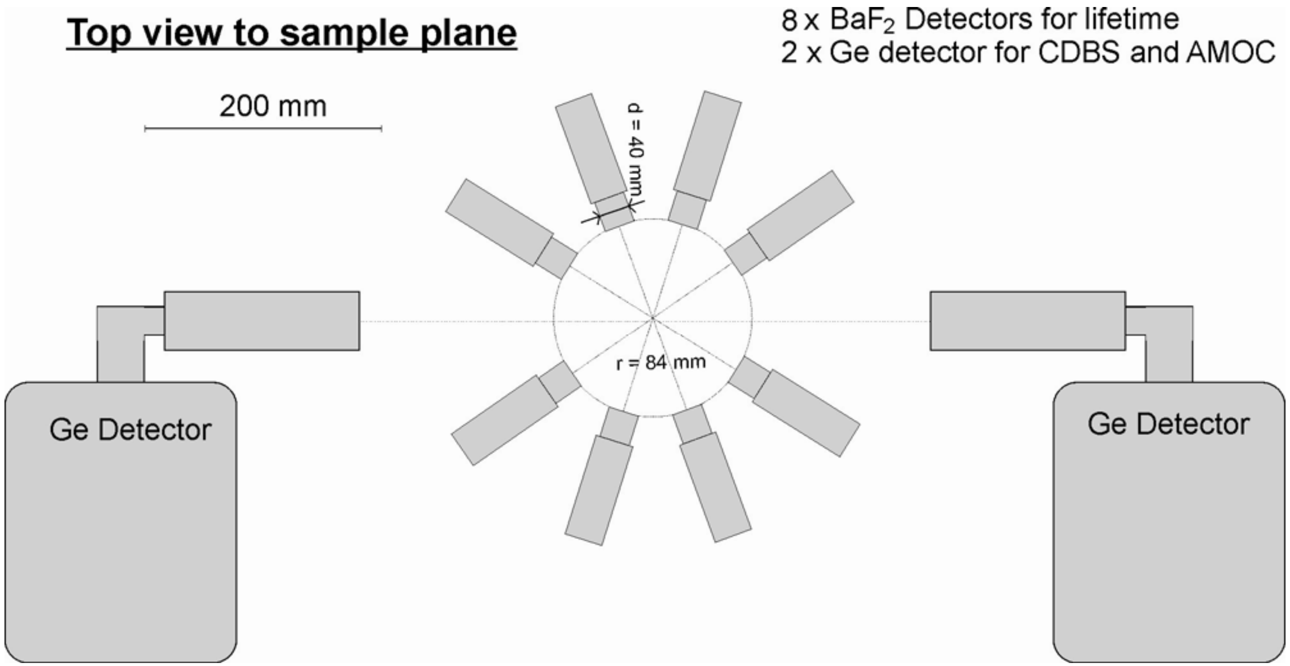
Chopper


Real pulse at the chopper at ELBE
Voltage [V]
Time [ns]
60
50
40
30
20
10
0
0,0
0,2
0,4
0,6
0,8
1,0
1,2
1,4
1,6
1,8


Real pulse (DC added)
Sinusoidal voltage (frequency 13, MHz,amplitude 54 V)
with DC (54 V) added
Beam shift / gyrations radius [standardized (mm*mm)]
Time [ns]
5,5
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
-1,0
-0,5
0,0
0,5
1,0
1,5
2,0

Detector system

- **3 experiments**: lifetime spectroscopy (8 BaF_2 detectors); Doppler coincidence (2 Ge detectors), and AMOC (1 Ge and 1 BaF_2 detector)
- **digital detection system**:
  - lifetime: almost nothing to adjust; time scale exactly the same for all detectors; easy realization of coincidence
  - Doppler: better energy resolution and pile-up rejection expected
  - pulse-shape discrimination improves spectra quality



Time Schedule

	1. Year	2. Year	3. Year
Laboratory			
Simulation e^+ converter			
Simulation beam			
Converter chamber and vacuum system in tunnel			
Screening of converter chamber			
First chopper / buncher			
Test converter / beam transport			
Vacuum system completion			
Conventional source chamber			
2. Chopper / buncher			
Sample chamber			
Completion of beam electronics			
Test transport system			
Detector system and software			
Automation			
Software lifetime / Doppler spectra			
Optimization of time resolution			

EPOS - Applications

Variety of applications in all field of materials science:

- defect-depth profiles due to surface modifications and ion implantation
- tribology (mechanical damage of surfaces)
- polymer physics (pores; interdiffusion; …)
- low-k materials (thin high porous layers)
- defects in semiconductors, ceramics and metals
- epitaxial layers (growth defects, misfit defects at interface, …)
- fast kinetics (e.g. precipitation processes in Al alloys; defect annealing; diffusion; …)
- radiation resistance (e.g. space materials)
- many more …