The pulsed high-brightness positron source EPOS

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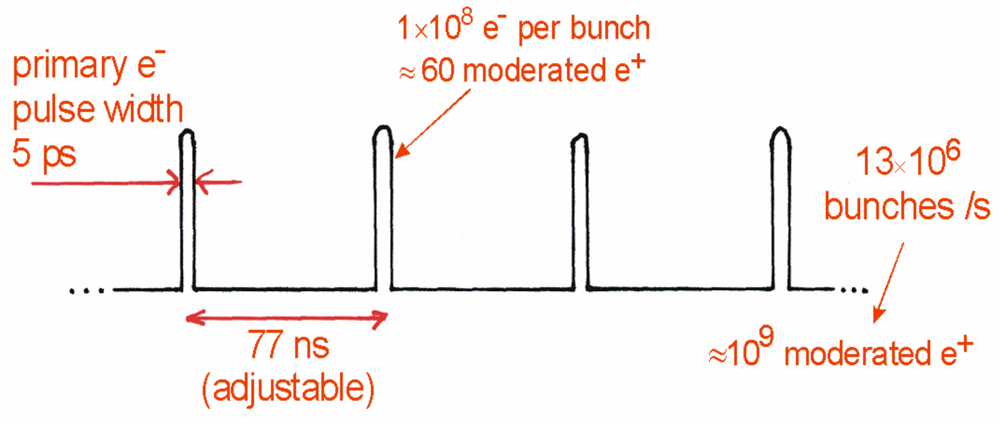
- ELBE radiation source in Rossendorf
- EPOS project
  - general concept
  - timing system
  - digital lifetime measurement

ICPA 14
Hamilton, Canada

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) for 5 experiments
- Main experiment: tunable IR free-electron Laser
- Very interesting time structure: cw-mode of short bunches

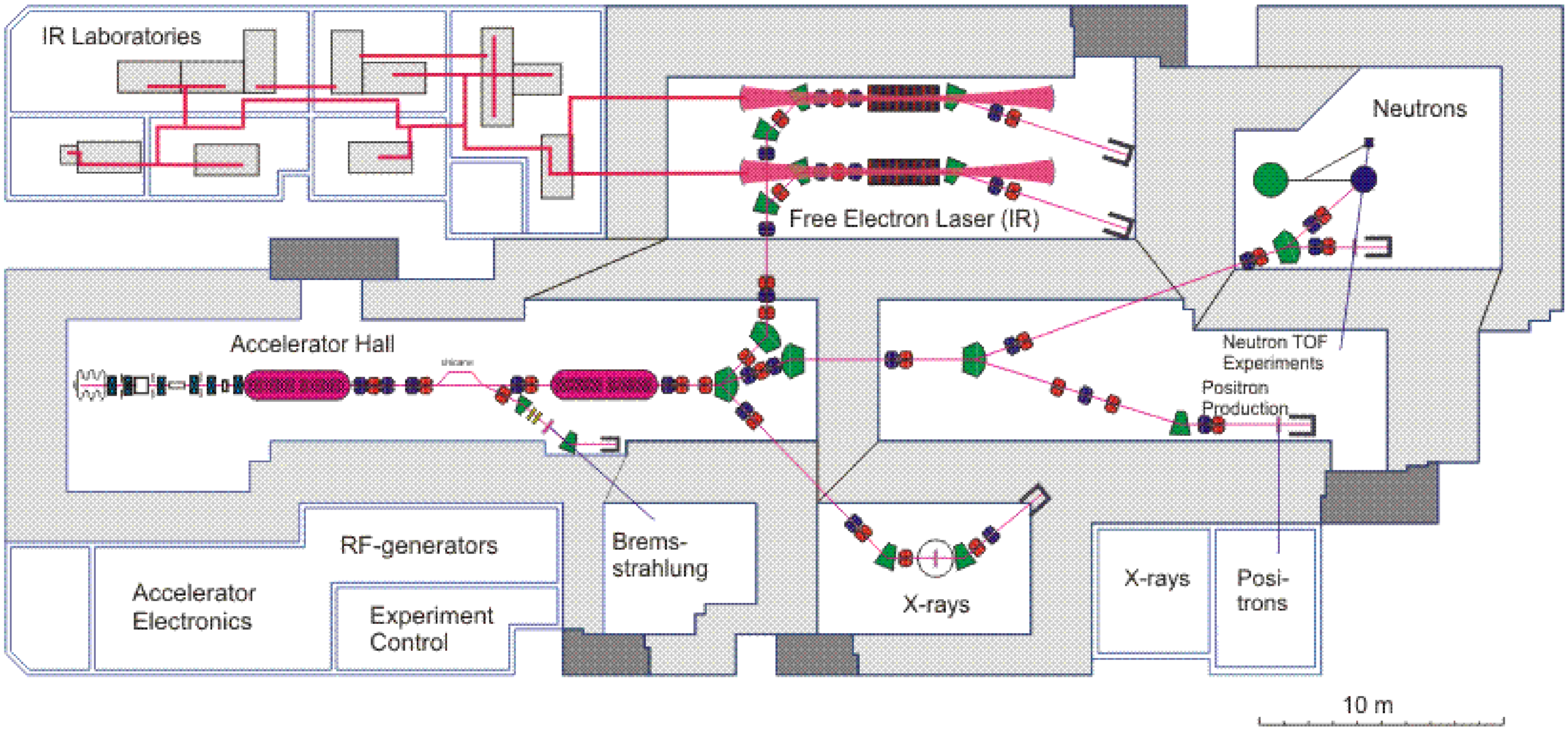


electron bunches

EPOS = ELBE Positron Source

- Intense bunched beam of mono-energetic 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 plan of the ELBE hall

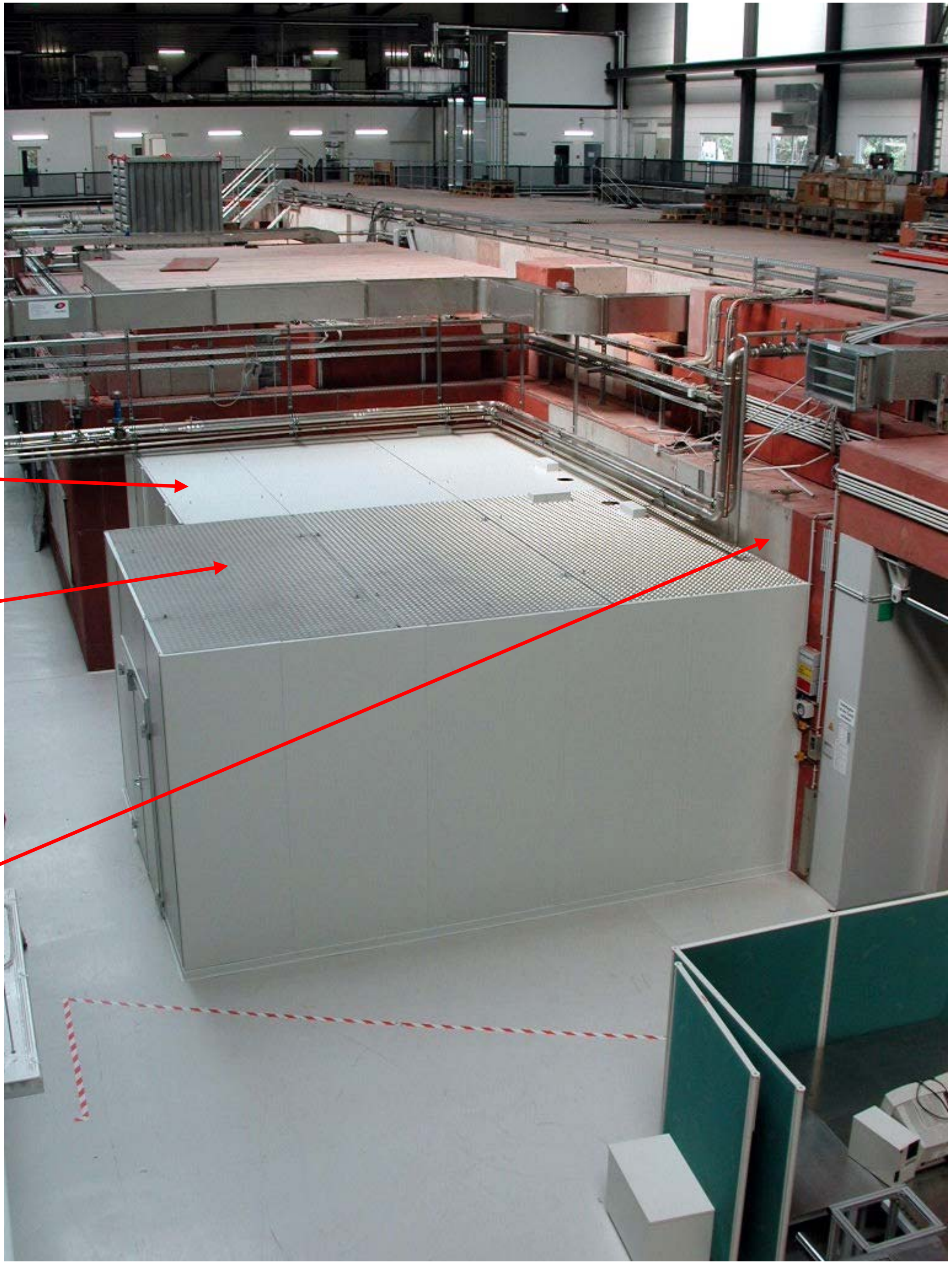


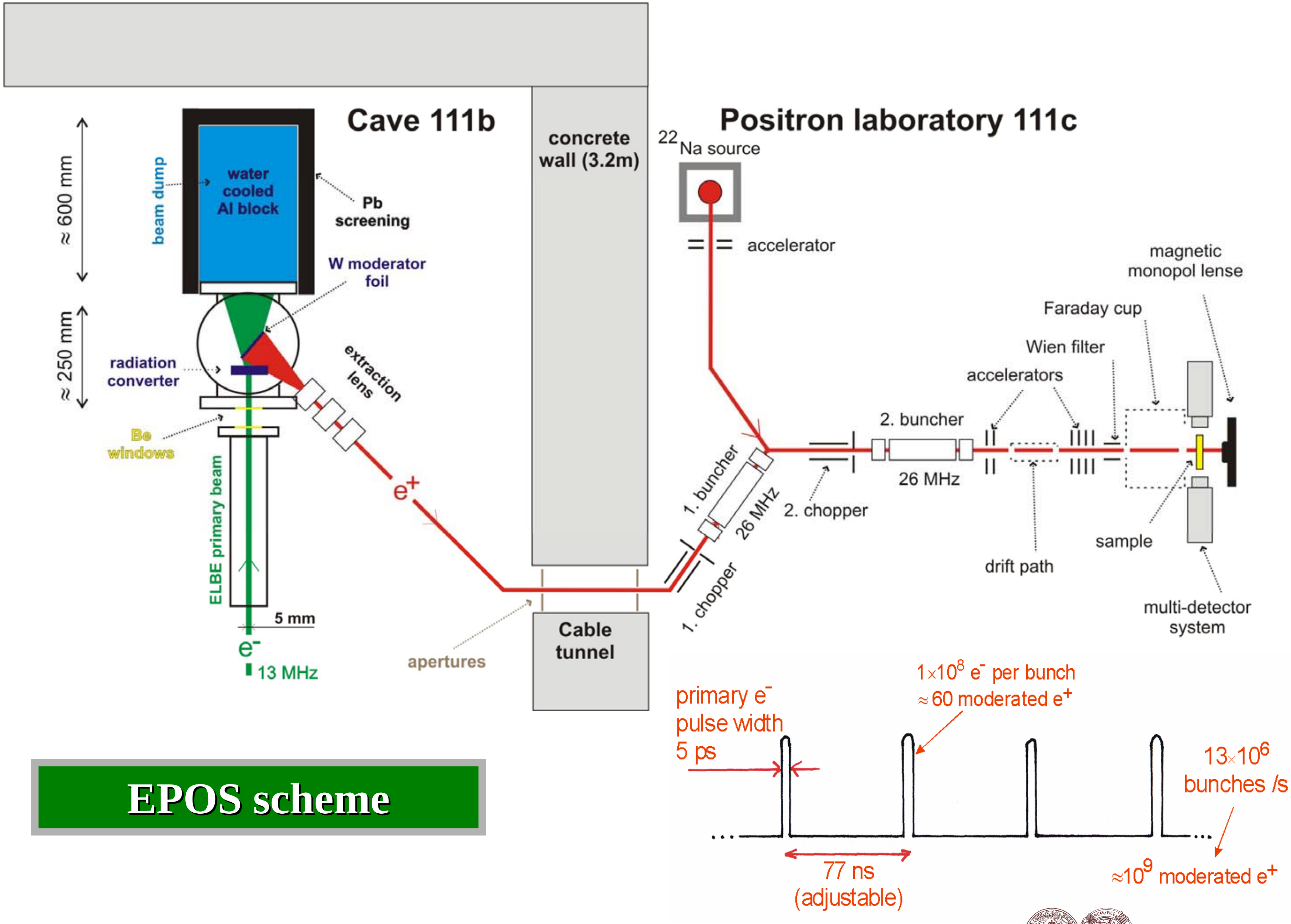
Positron Lab

X-ray Lab

Positron Lab 111c

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

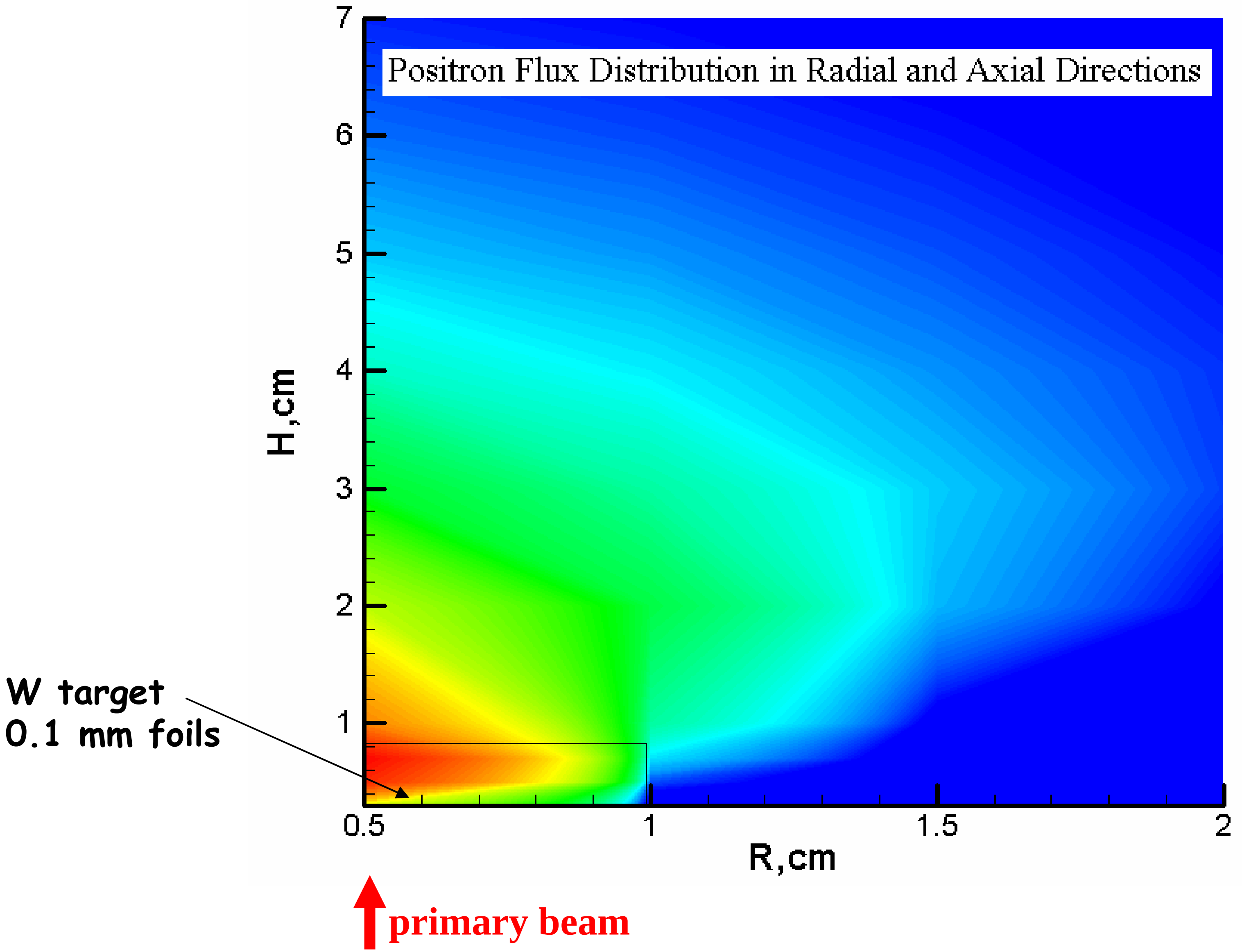




Cave 111b
concrete wall (3.2m)
Positron laboratory 111c
≈ 600 mm
≈ 250 mm
beam dump
water cooled Al block
Pb screening
W moderator foil
radiation converter
Be windows
extraction lens
ELBE primary beam
5 mm
e-
13 MHz
e+
apertures
Cable tunnel
22Na source
accelerator
1. buncher
26 MHz
1. chopper
2. chopper
2. buncher
26 MHz
accelerators
Wien filter
Faraday cup
magnetic monopol lense
drift path
sample
multi-detector system
primary e- pulse width 5 ps
1×10^8 e- per bunch
≈ 60 moderated e+
13×10^6 bunches /s
≈10^9 moderated e+
77 ns (adjustable)

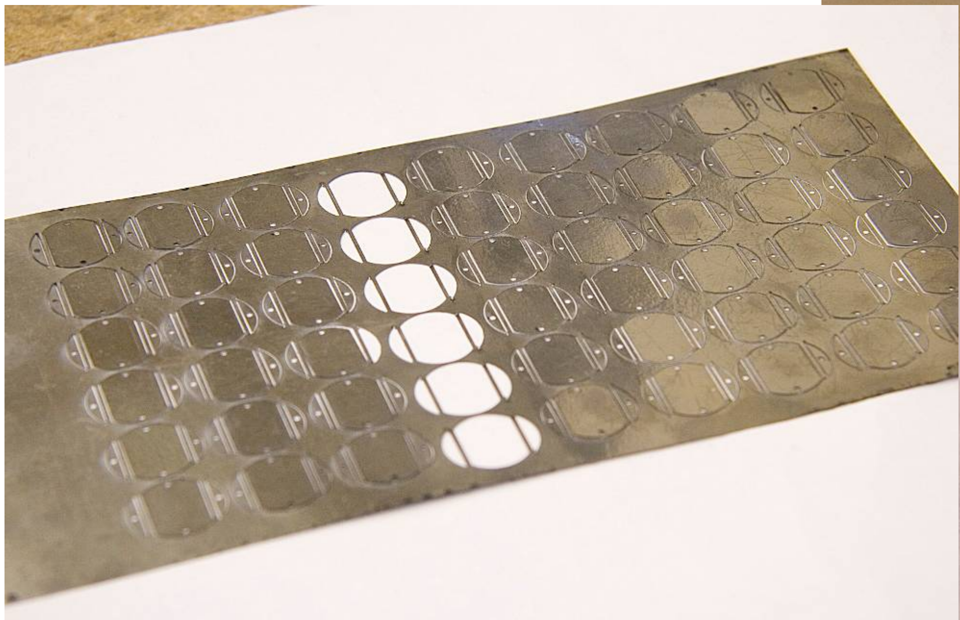
EPOS scheme

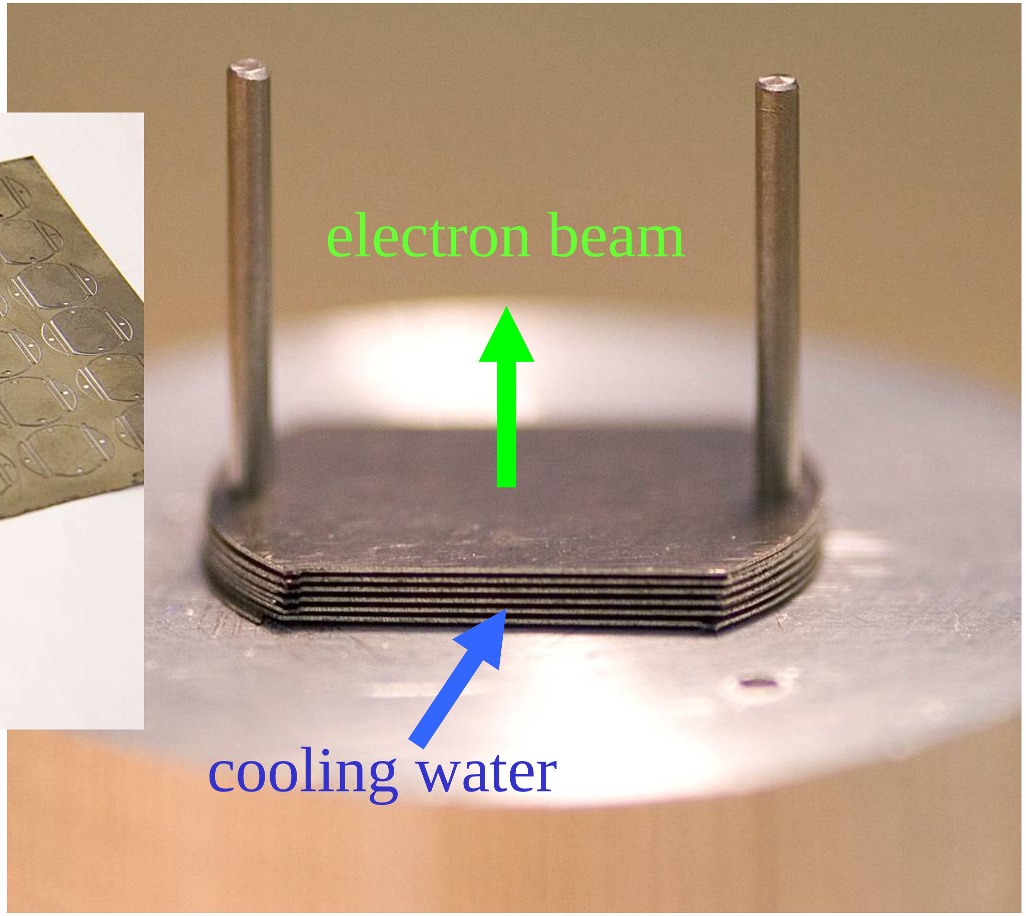
Simulation of Positron distribution

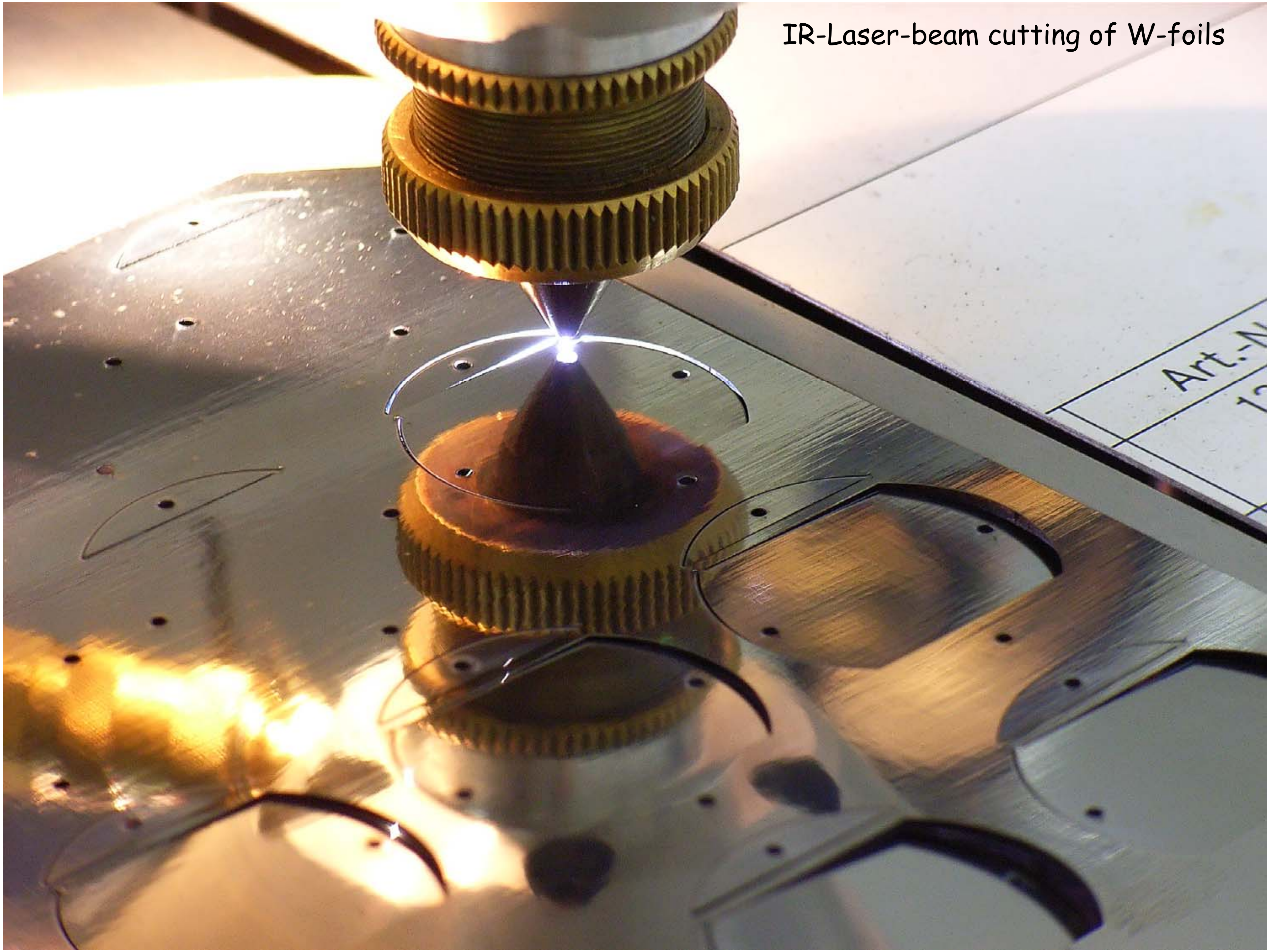


Directly water-cooled Electron-Positron Converter

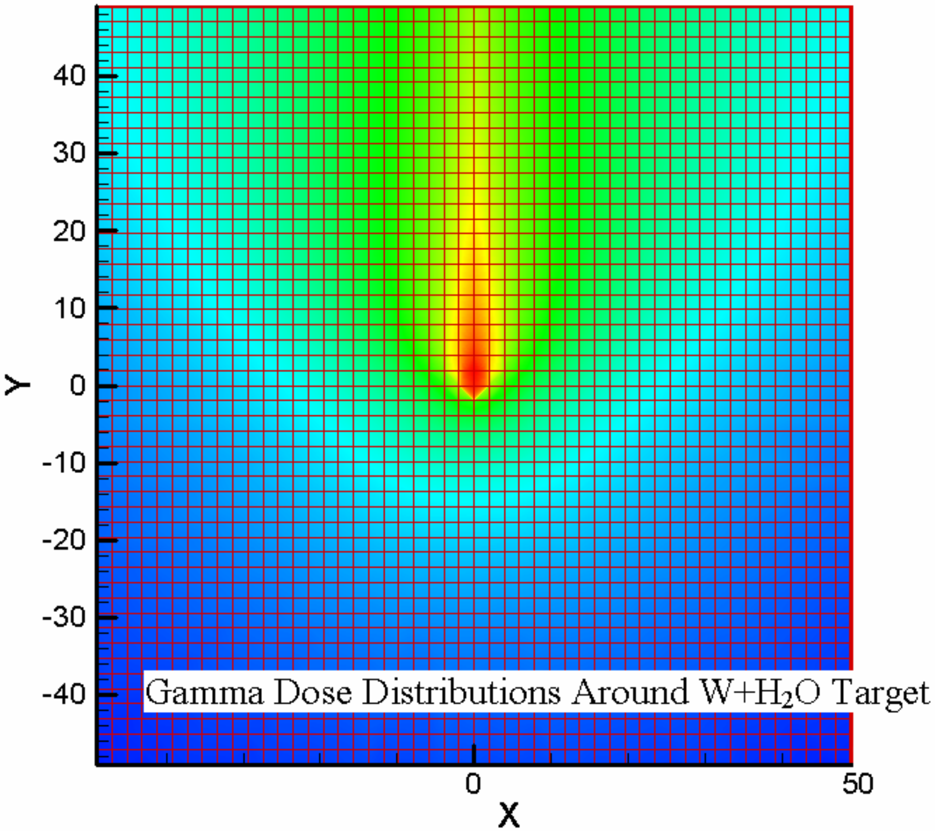
- stack of 50 pieces W-foils 0,1 mm separated by 0,1 mm -> 13,5 l water at 1,5 bar
- foils cut by IR-laser in our workshop



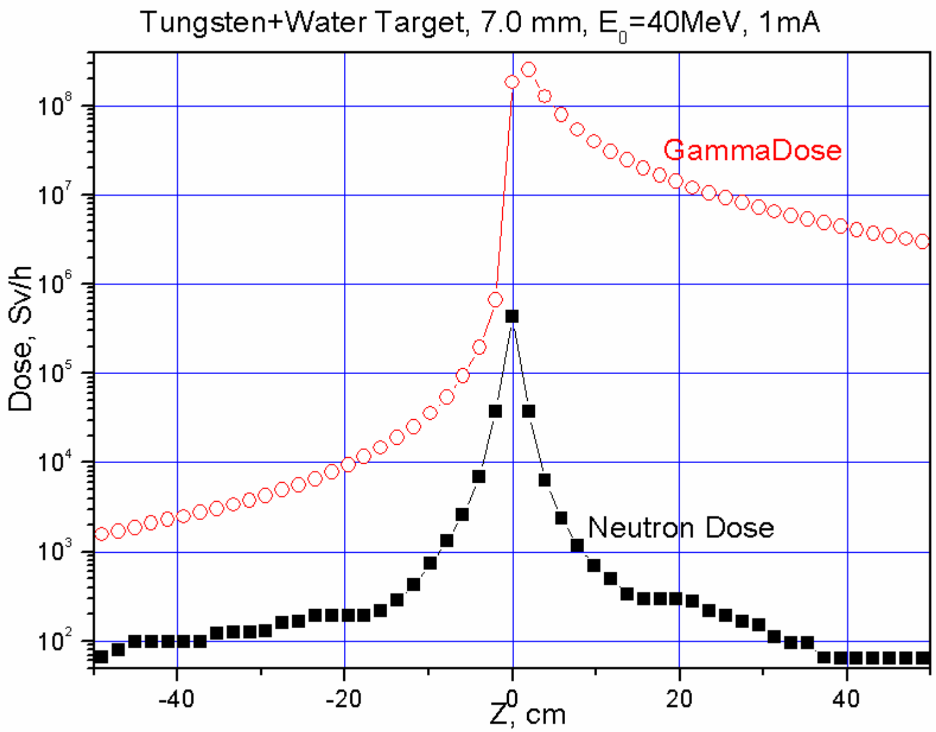



IR-Laser-beam cutting of W-foils

Simulation of expected γ and n dose

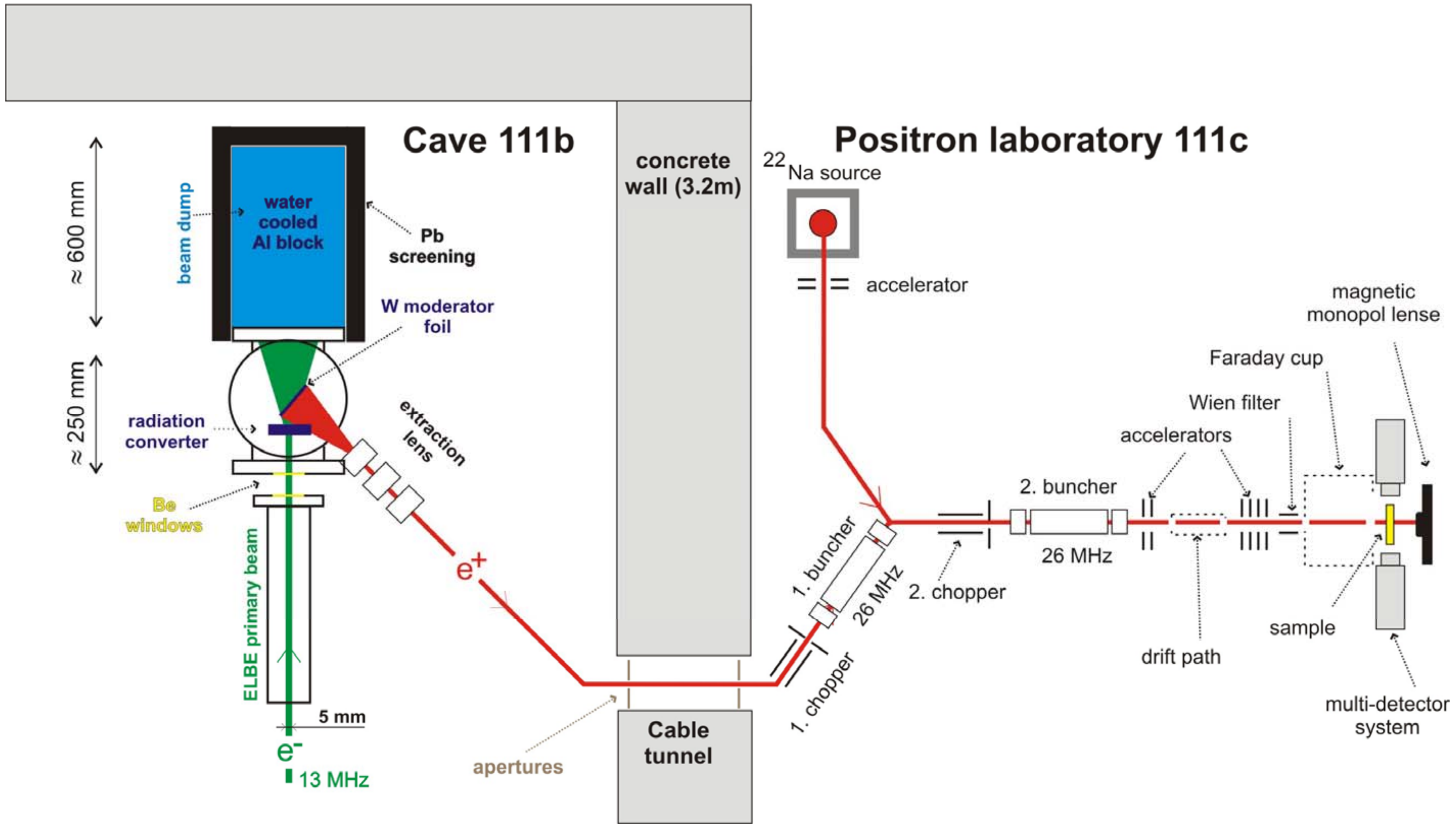


Gamma Dose Distributions Around W+H_2O Target



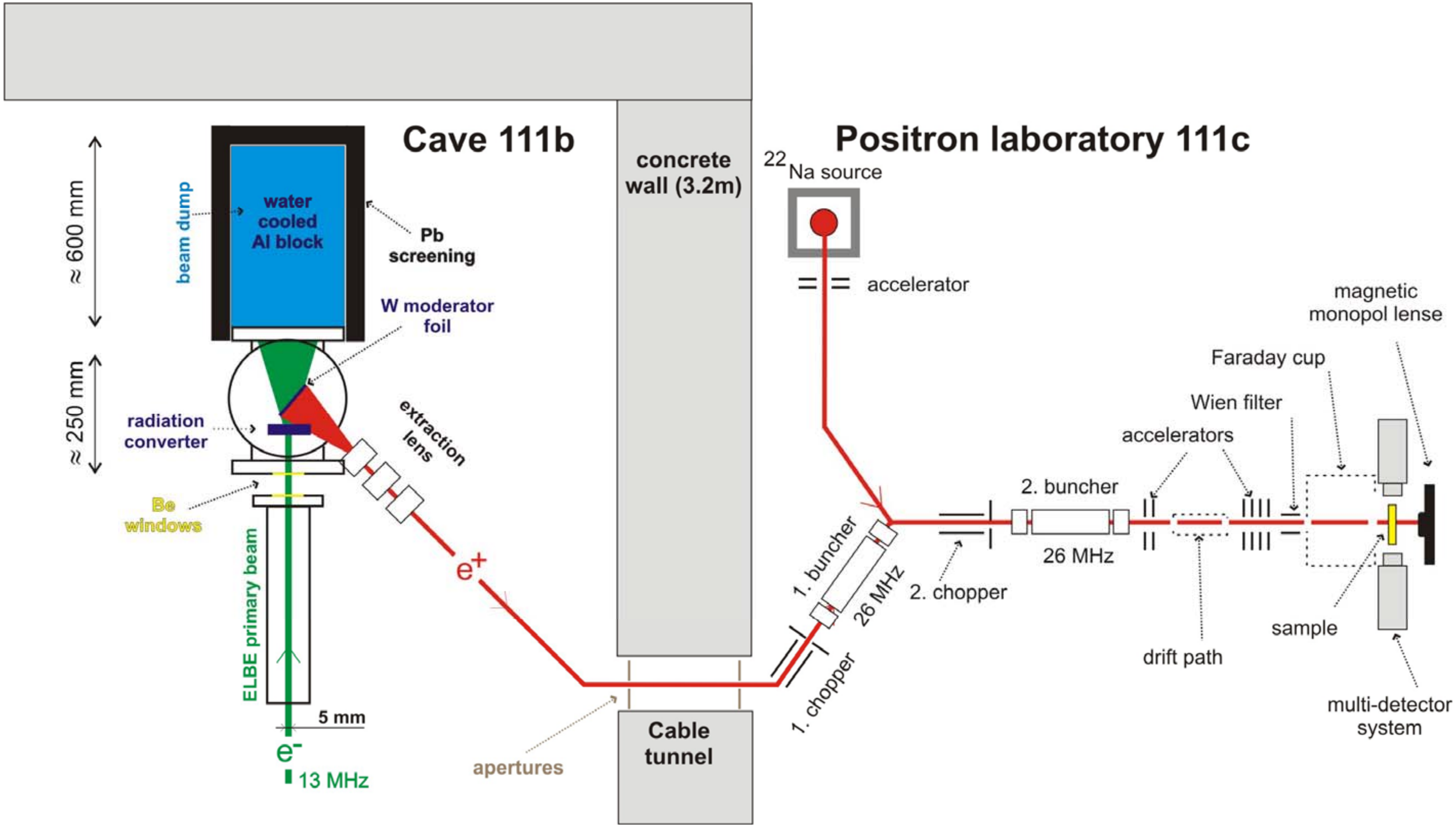
Neutron and Gamma Dose Distributions Around W+H_2O Target in Axial Direction

Additional Screening in the cave by lead blocks and heavy concrete



Cave 111b
Positron laboratory 111c
concrete wall (3.2m)
22 Na source
accelerator
≈ 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
Cable tunnel
1. chopper
1. buncher
26 MHz
2. chopper
2. buncher
26 MHz
accelerators
Wien filter
Faraday cup
magnetic monopol lense
drift path
sample
multi-detector system

- Stability test of beam-dump stand
- beam dump made from 4N-Al (no alloy)



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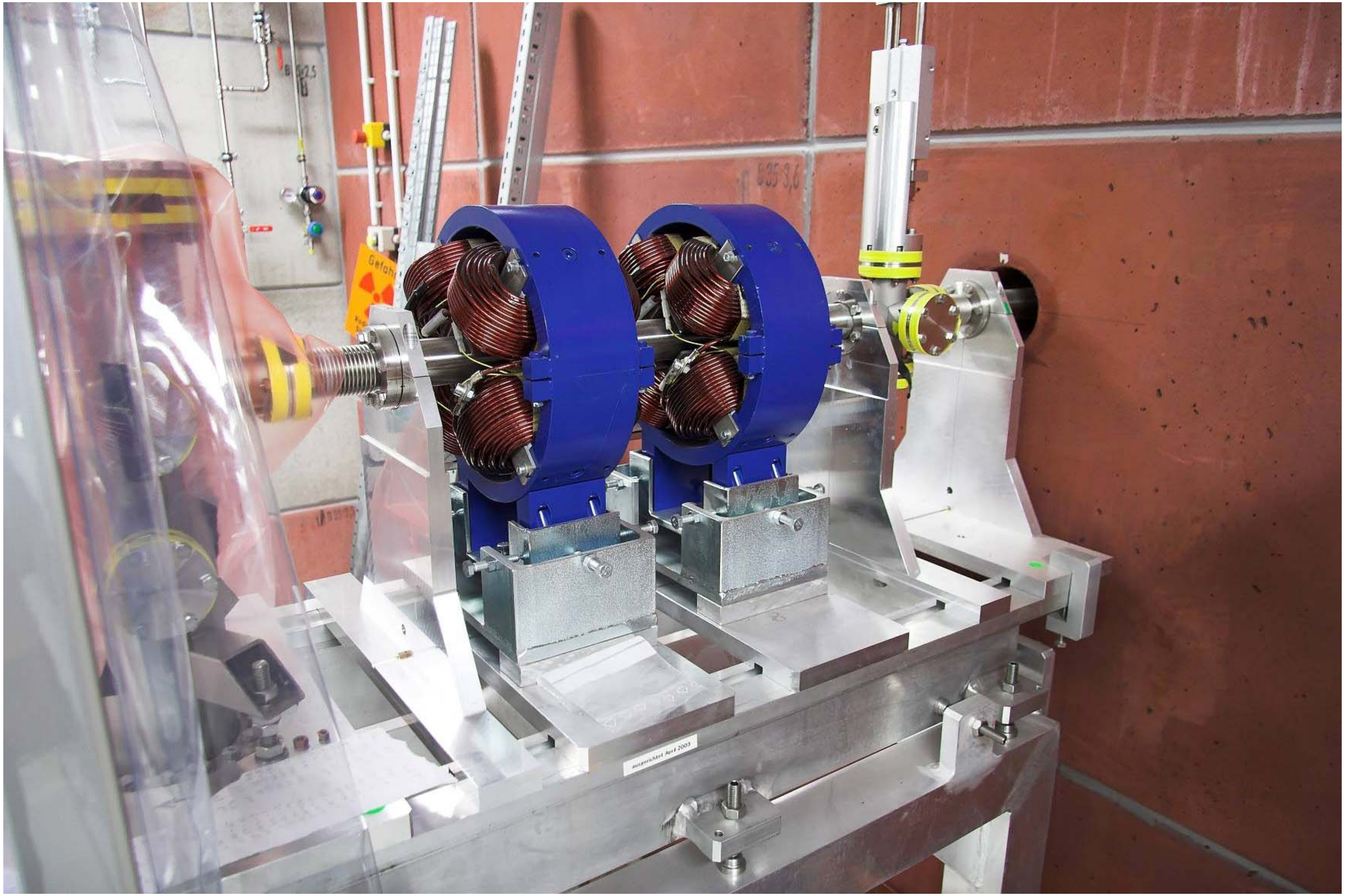
- Position of electron-positron converter

- Primary electron beam line entrance into our cave 111b

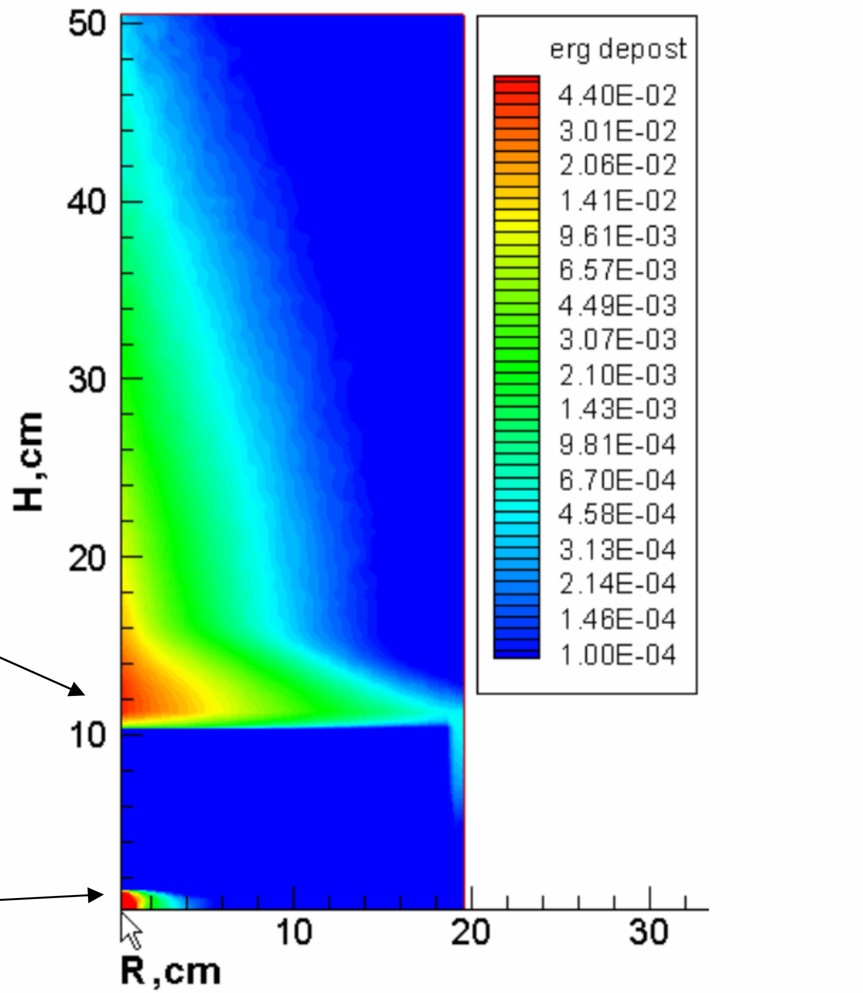


Simulation of Energy deposition

total power of
electron beam 40 kW

Al beam dump 21 kW
(made of 4N-purity)

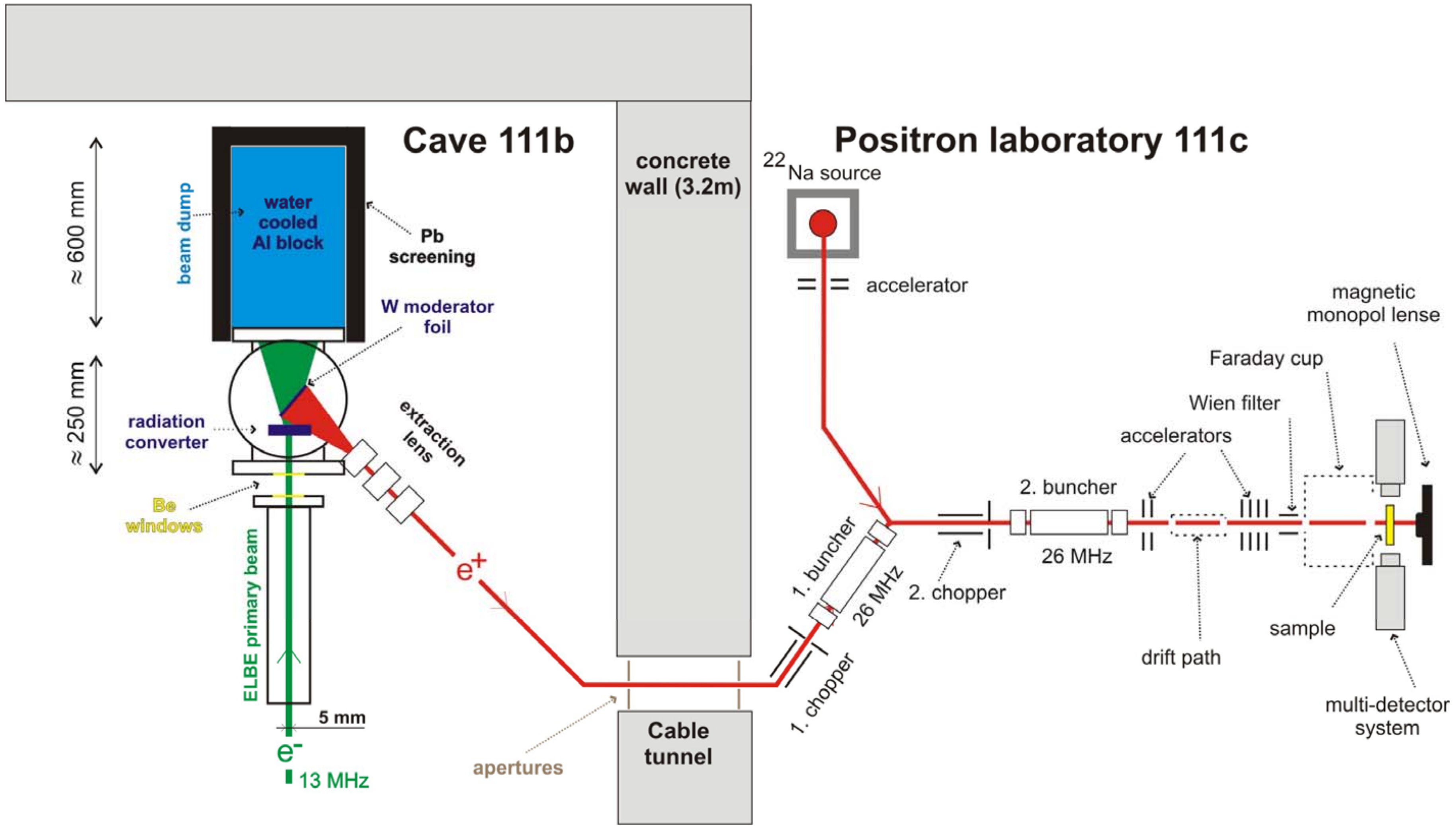
W target 14 kW



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

primary beam

- Water-cooling system ready for use (beam dump; W-Converter, and two Be-windows)
- consists of 2 independent water circulations with heat exchanger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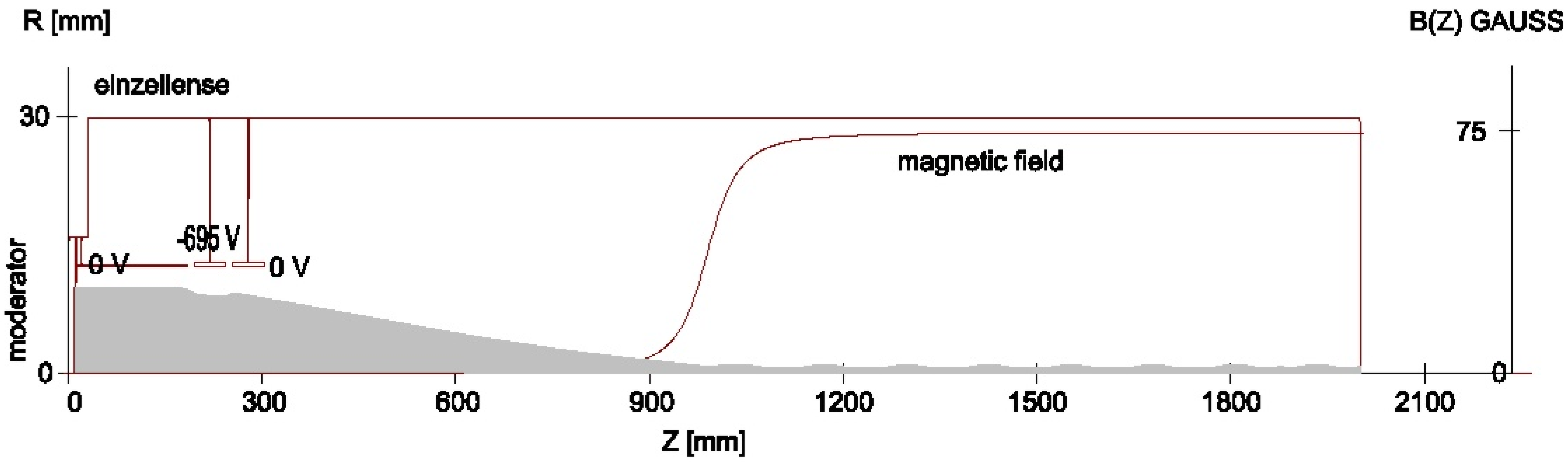
Simulation of positron extraction

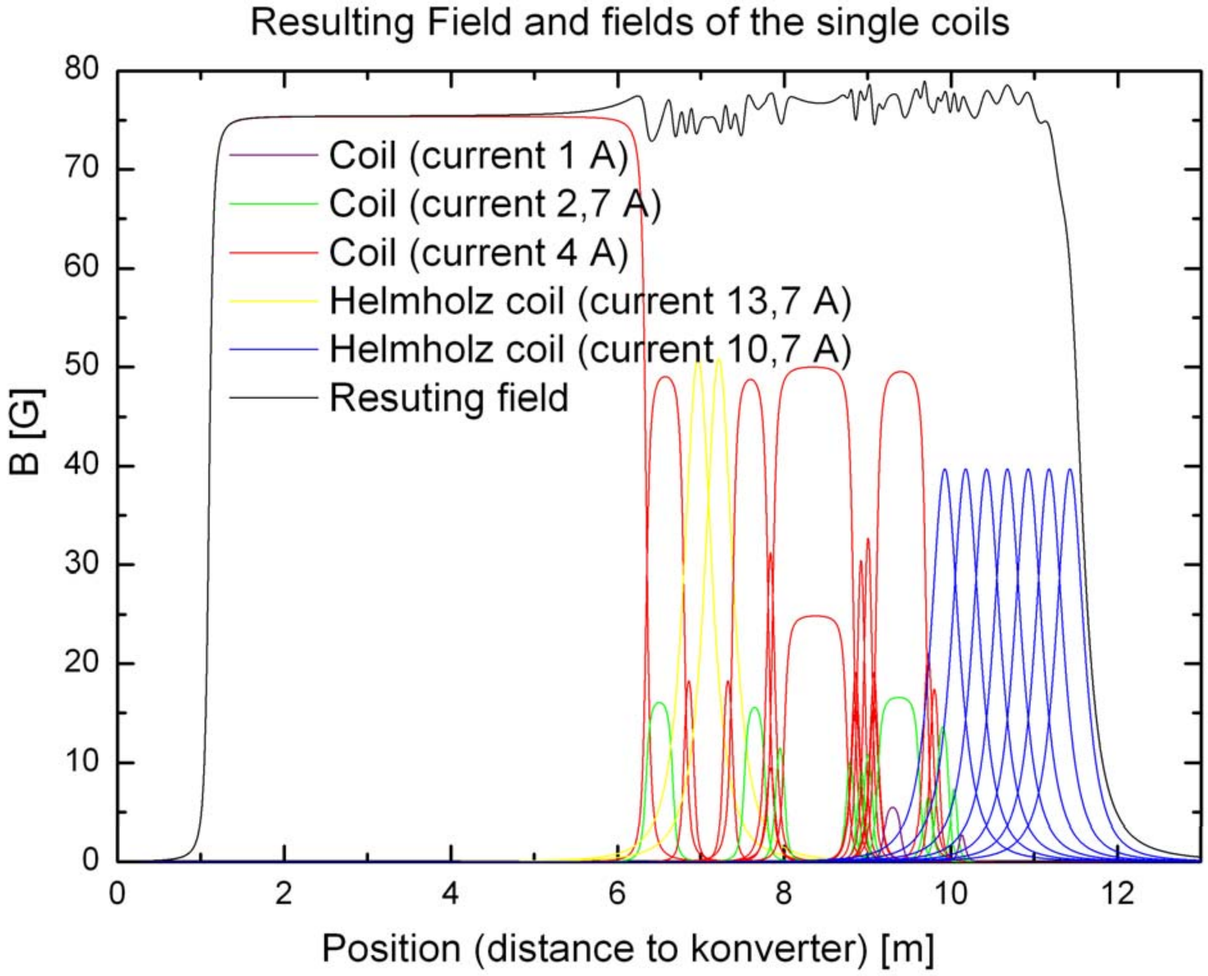
- simulation done by EGUN
- area of 20 mm diameter at moderator is used and squeezed to about 2 mm



Magnetic Beam Guidance

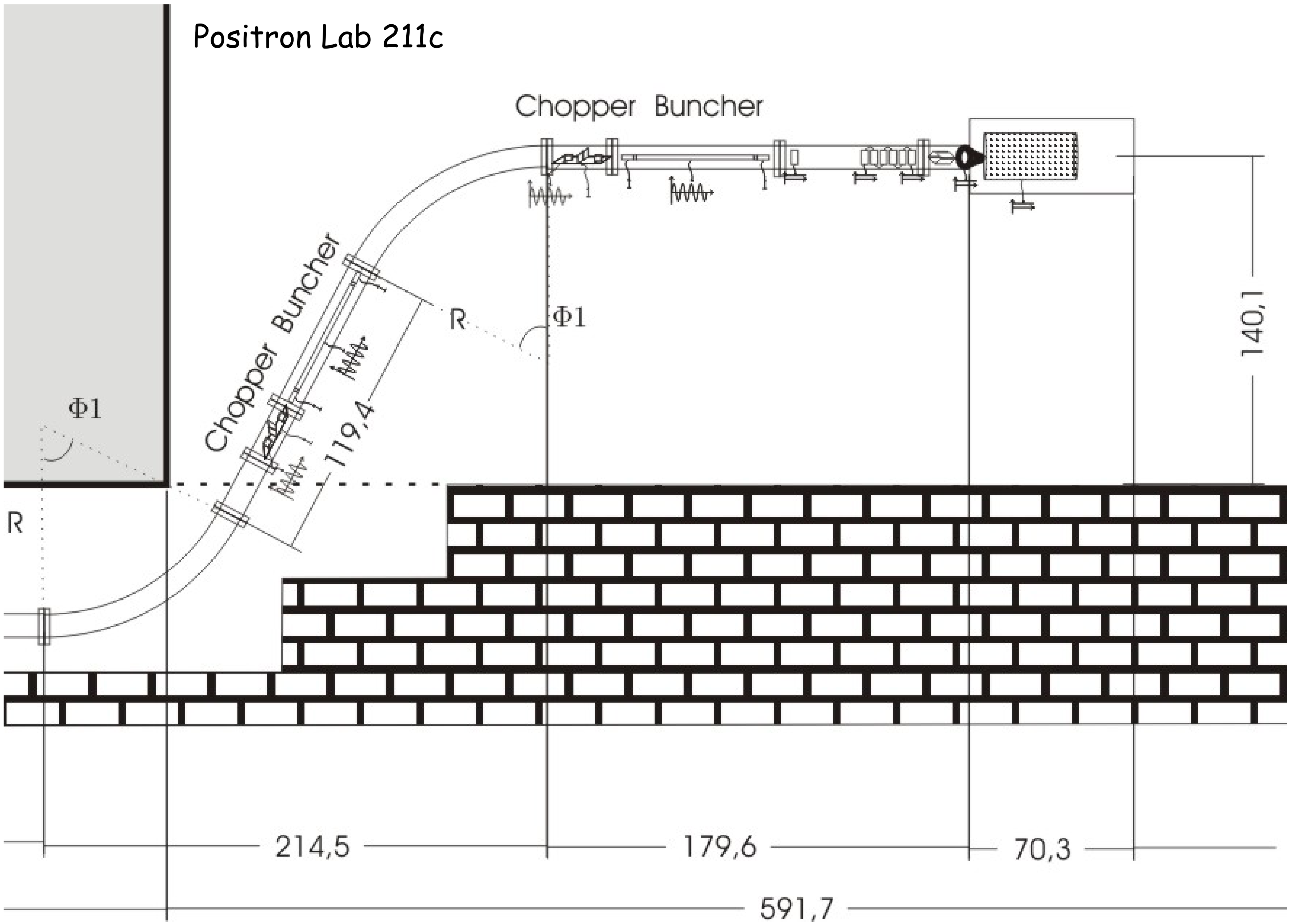
Magnetic guidance field of 75 Gauss

- 45 coils but only
- 5 different currents
- thus only 5 Power supplies
- maximum change 6 G
- gradient < 0,11 G/mm



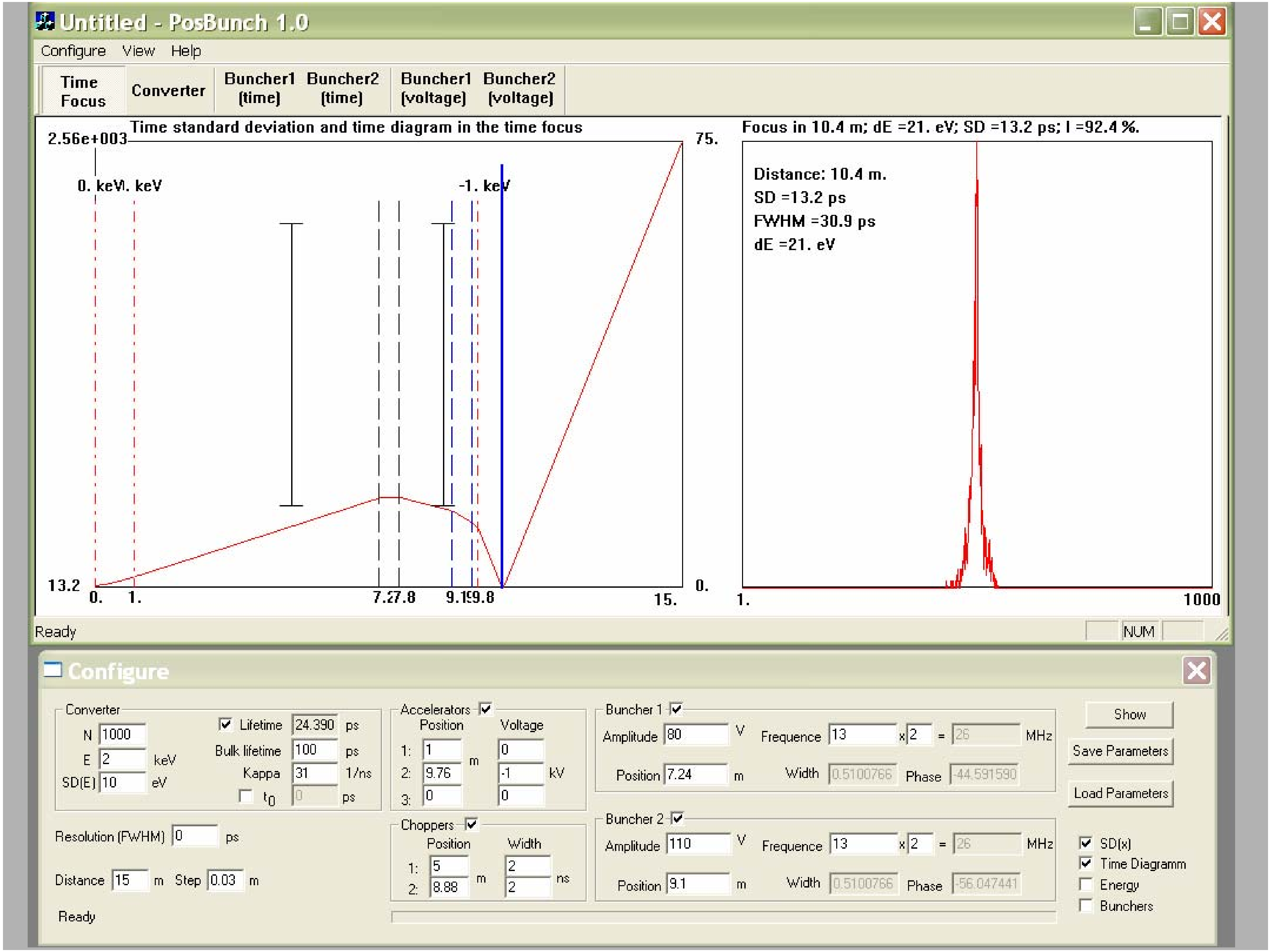
- in addition:
- 30 steering coils along the tubes with different (computer-driven) currents

Positron Lab 211c



Monto-Carlo Simulations of Bunching System

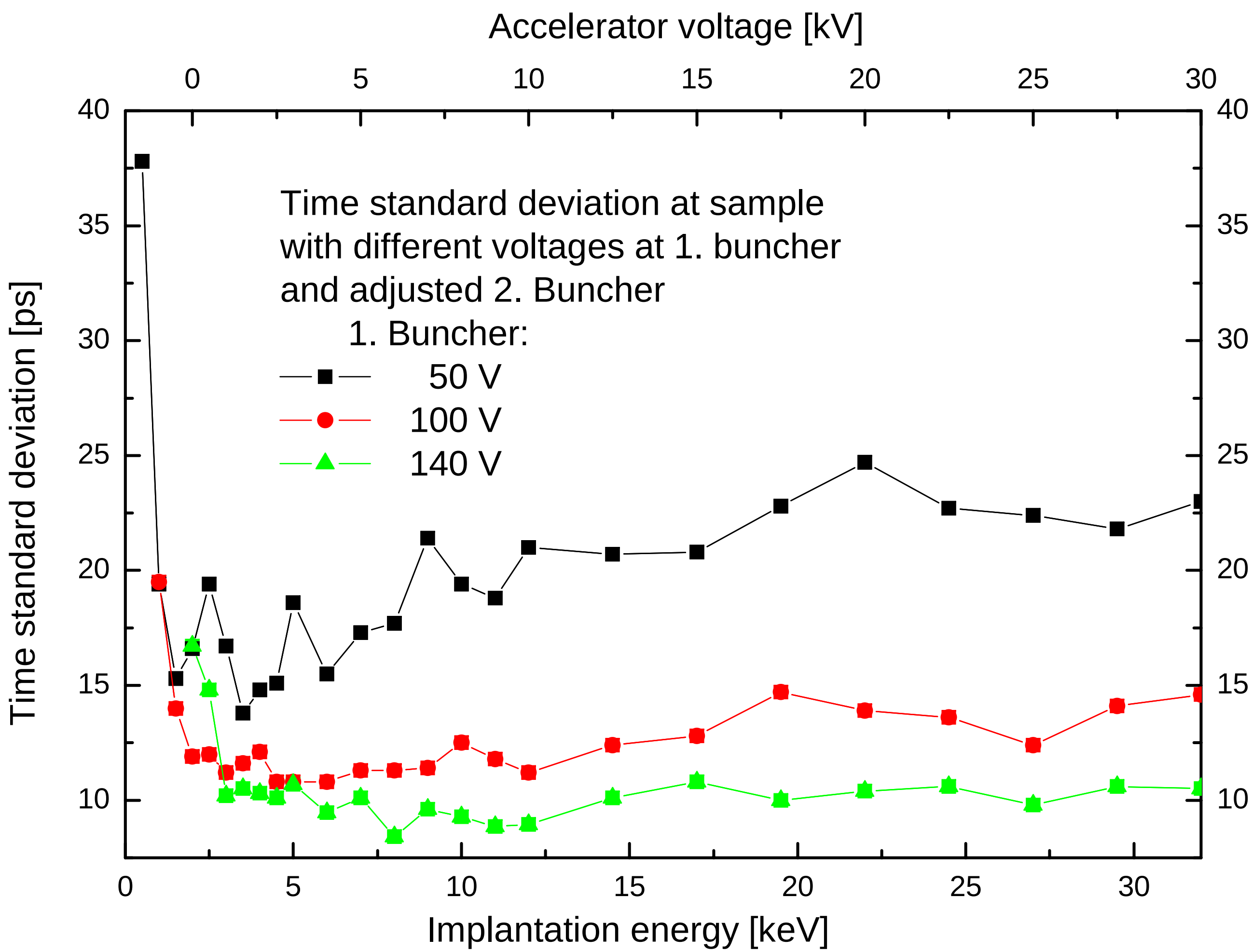
- problem: time focus shifts with different acceleration voltage
- especially difficult for low positron energies (< 1keV)
- Simulation of bunching by POSBUNCH
- C++ code; author: Dr. V. Bondarenko



Untitled - PosBunch 1.0
Configure View Help
Time Focus
Converter
Buncher1 (time)
Buncher2 (time)
Buncher1 (voltage)
Buncher2 (voltage)
Time standard deviation and time diagram in the time focus
2.56e+003
75.
0. keV
1. keV
-1. keV
13.2
0.
0.
1.
7.2
7.8
9.1
9.8
15.
Focus in 10.4 m; dE =21. eV; SD =13.2 ps; I =92.4 %.
Distance: 10.4 m.
SD =13.2 ps
FWHM =30.9 ps
dE =21. eV
1.
1000
Ready
NUM
Configure
Converter
N 1000
E 2 keV
SD(E) 10 eV
Lifetime 24.390 ps
Bulk lifetime 100 ps
Kappa 31 1/ns
t_0 0 ps
Resolution (FWHM) 0 ps
Distance 15 m Step 0.03 m
Ready
Accelerators
Position
Voltage
1: 1 0
2: 9.76 -1
3: 0 0
m
kV
Choppers
Position
Width
1: 5 2
2: 8.88 2
m
ns
Buncher 1
Amplitude 80 V
Frequence 13 x 2 = 26 MHz
Position 7.24 m
Width 0.5100766
Phase -44.591590
Buncher 2
Amplitude 110 V
Frequence 13 x 2 = 26 MHz
Position 9.1 m
Width 0.5100766
Phase -56.047441
Show
Save Parameters
Load Parameters
SD(x)
Time Diagramm
Energy
Bunchers

Simulation of Buncher Voltages

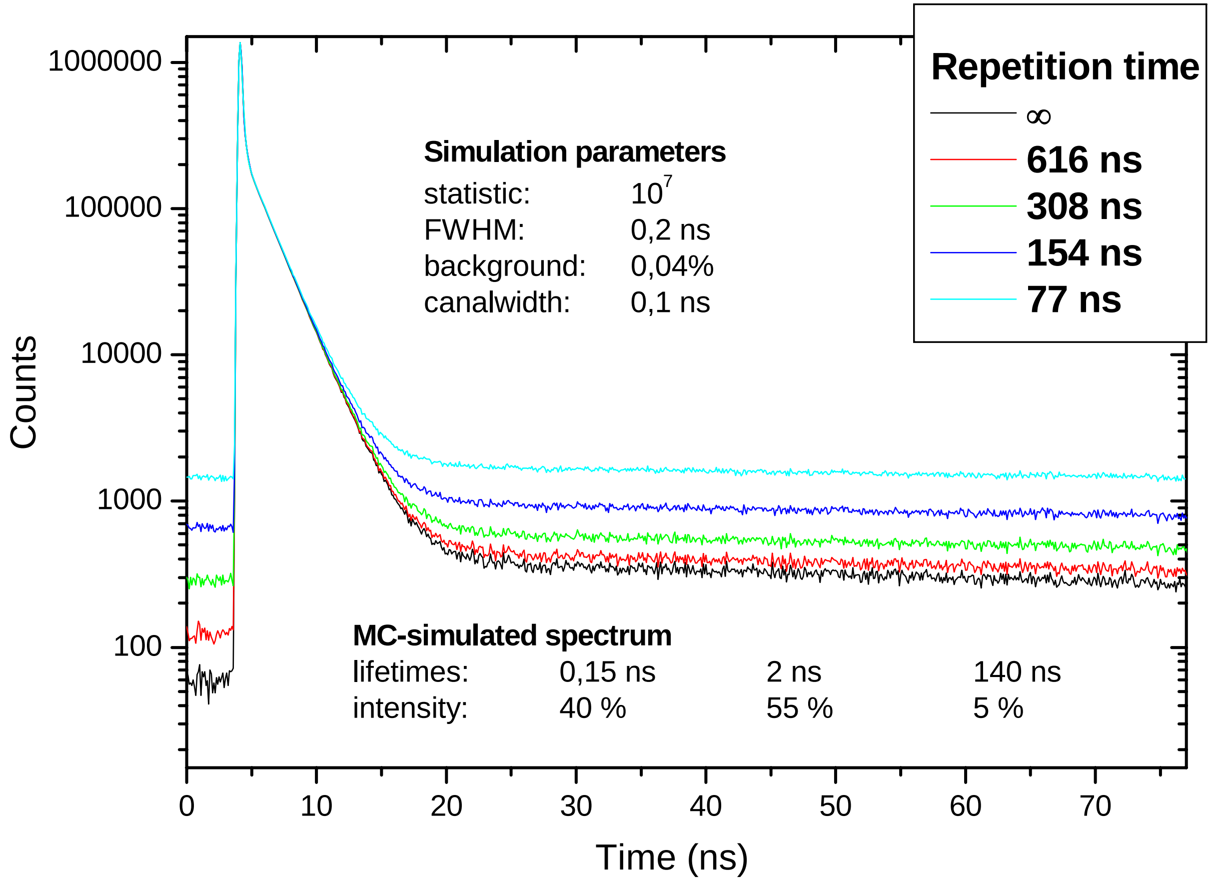
Both buncher RF-voltage amplitudes and the drift path energy must be adjusted for each beam energy for optimum time resolution



Second timing mode needed for long lifetimes

- question: How long repetition time to measure a lifetime of 142 ns?
- we MC-simulated a 3-component spectrum with τ_1=150 ps, τ_2 = 2 ns, τ_3 = 140 ns

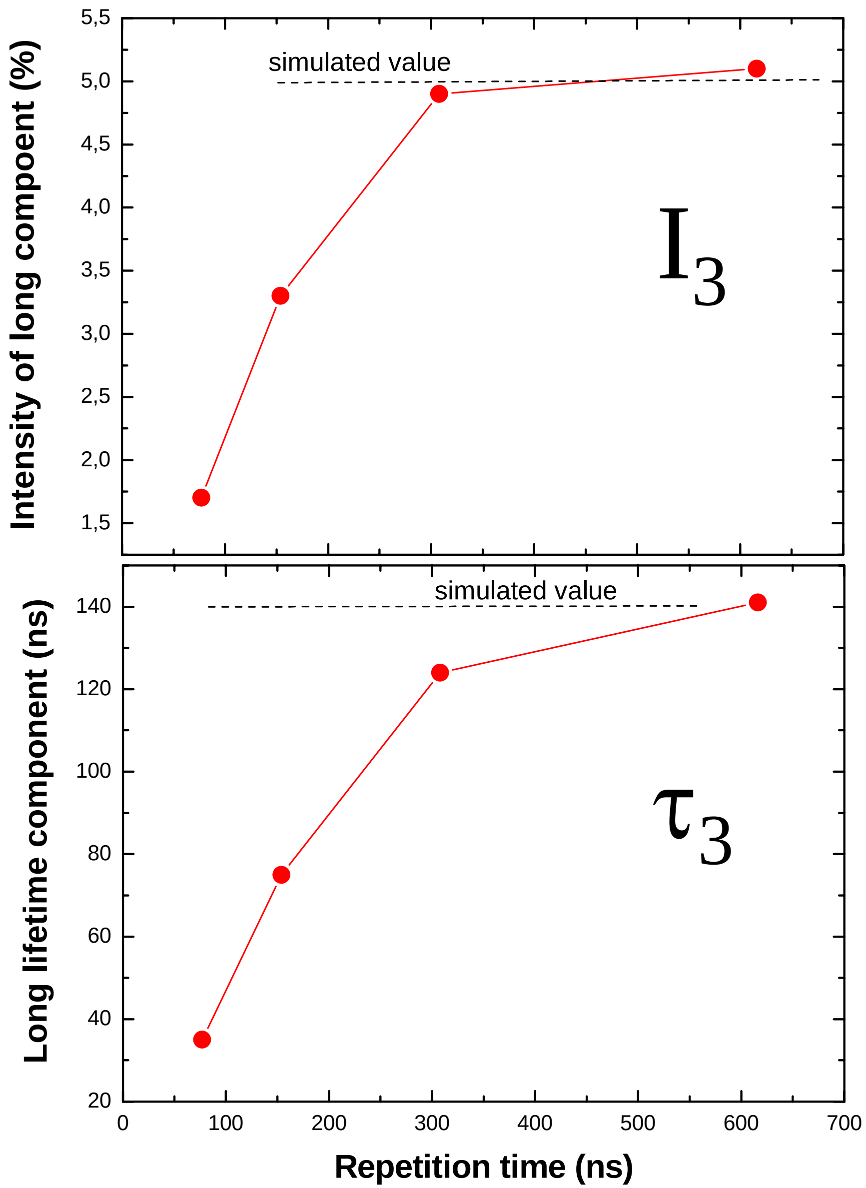
- we simulated different repetition times from 77 … 616 ns
- spectra were analyzed and compared to the original one



Second timing mode needed for long lifetimes

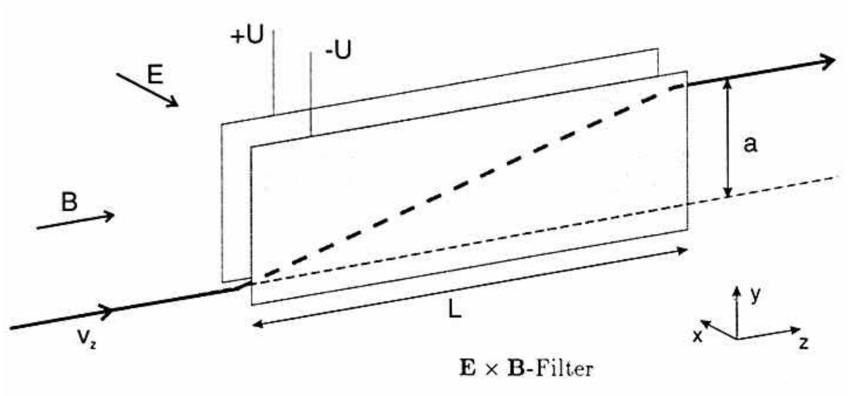
Result:

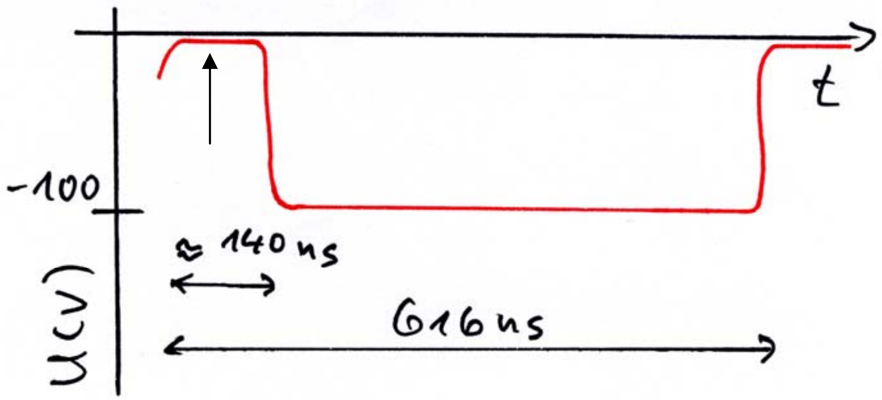
- repetition time must be at least 8-times longer than longest lifetime to be measured
- 77ns-system: up to 10 ns only
- Thus: EPOS needs a 616ns-timing mode (616 = 8 x 77)
- ELBE electron beam allows such a mode already: 7 of 8 electron bunches are suppressed

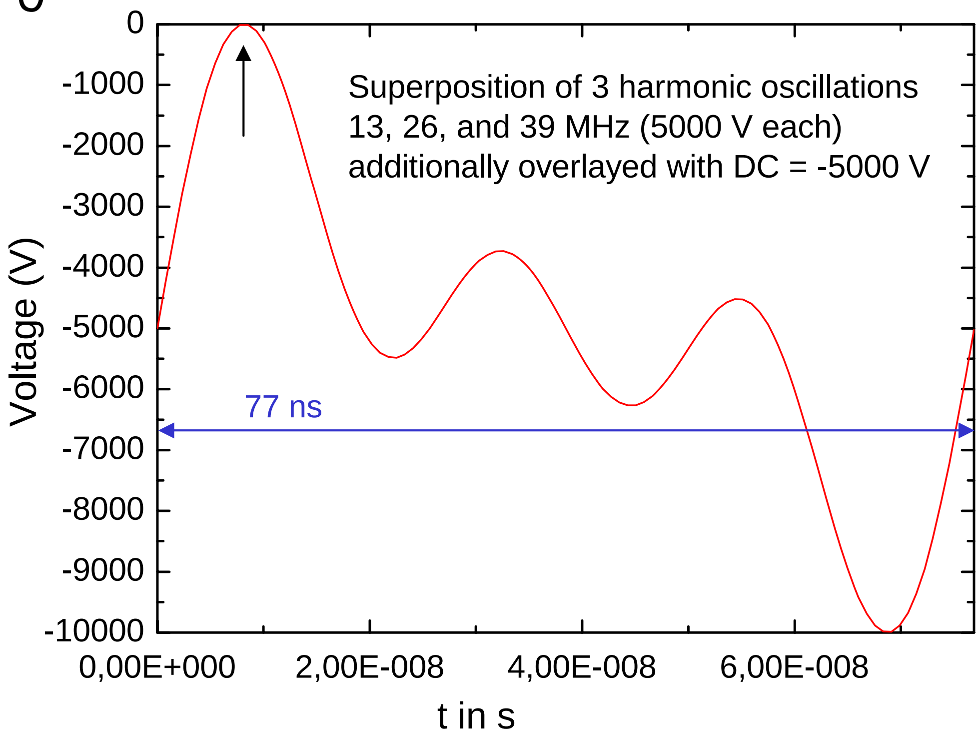


Chopper System

- problem: beam energy of 2 keV is relatively high for a chopper
- original idea: triggerable rectangular pulse (2 ns width; >100V)
- very difficult to obtain the required amplitude
- new: 3 superimposed sinusoidal voltages
- beam fit through aperture with voltage of U < 80 V
- for the simulated voltage U < 80 V corresponds to Δt = 2 ns
- in 616 ns-mode we will use additional slow chopper

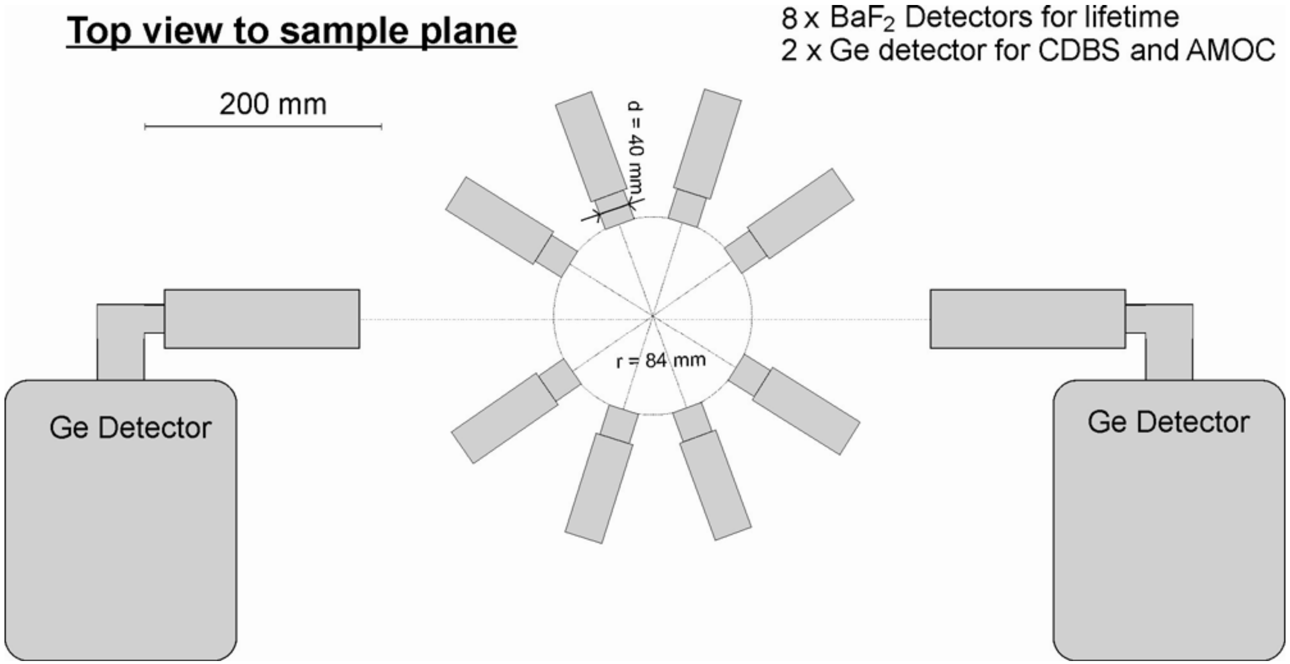




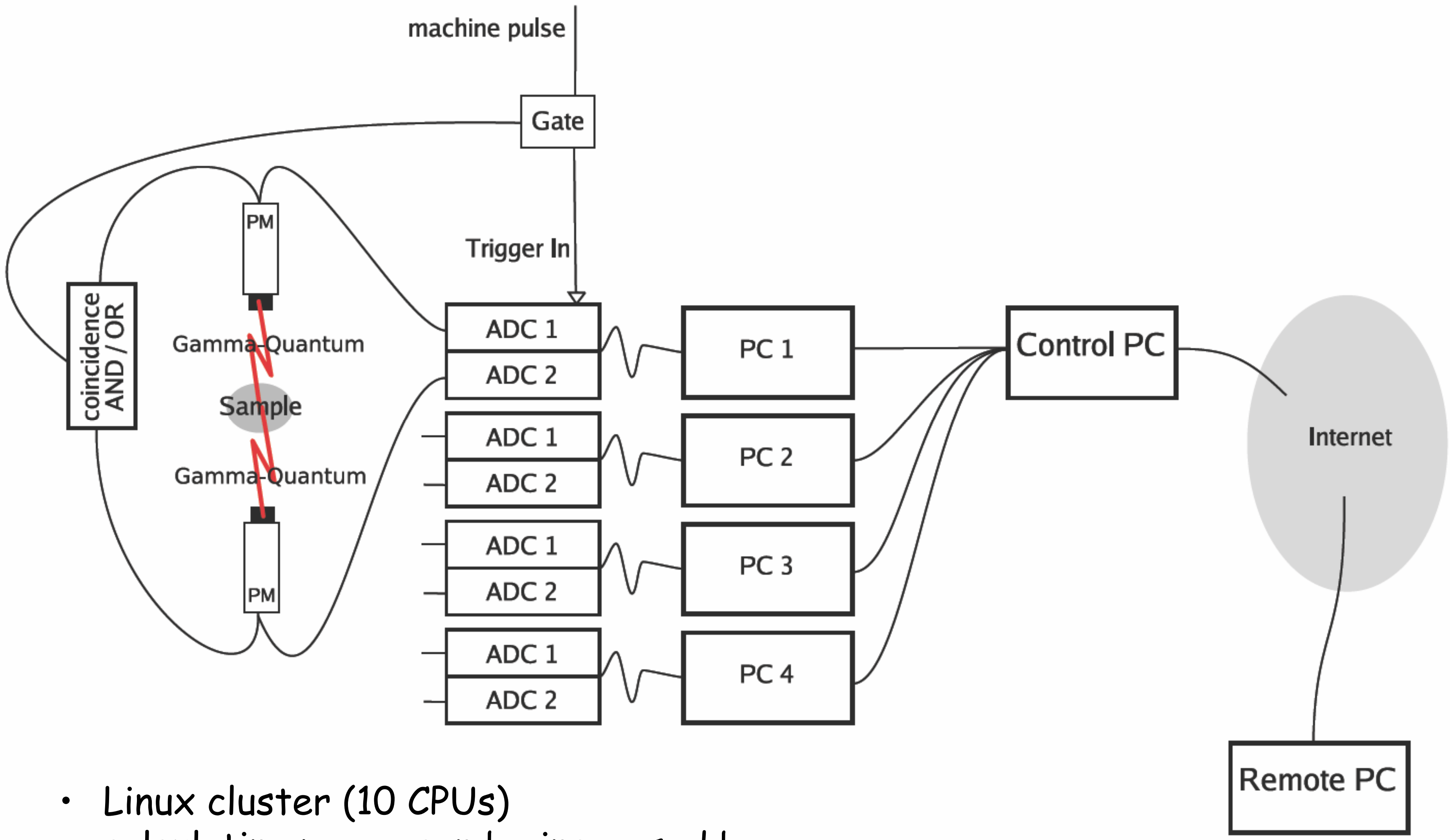


Detector system

- **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

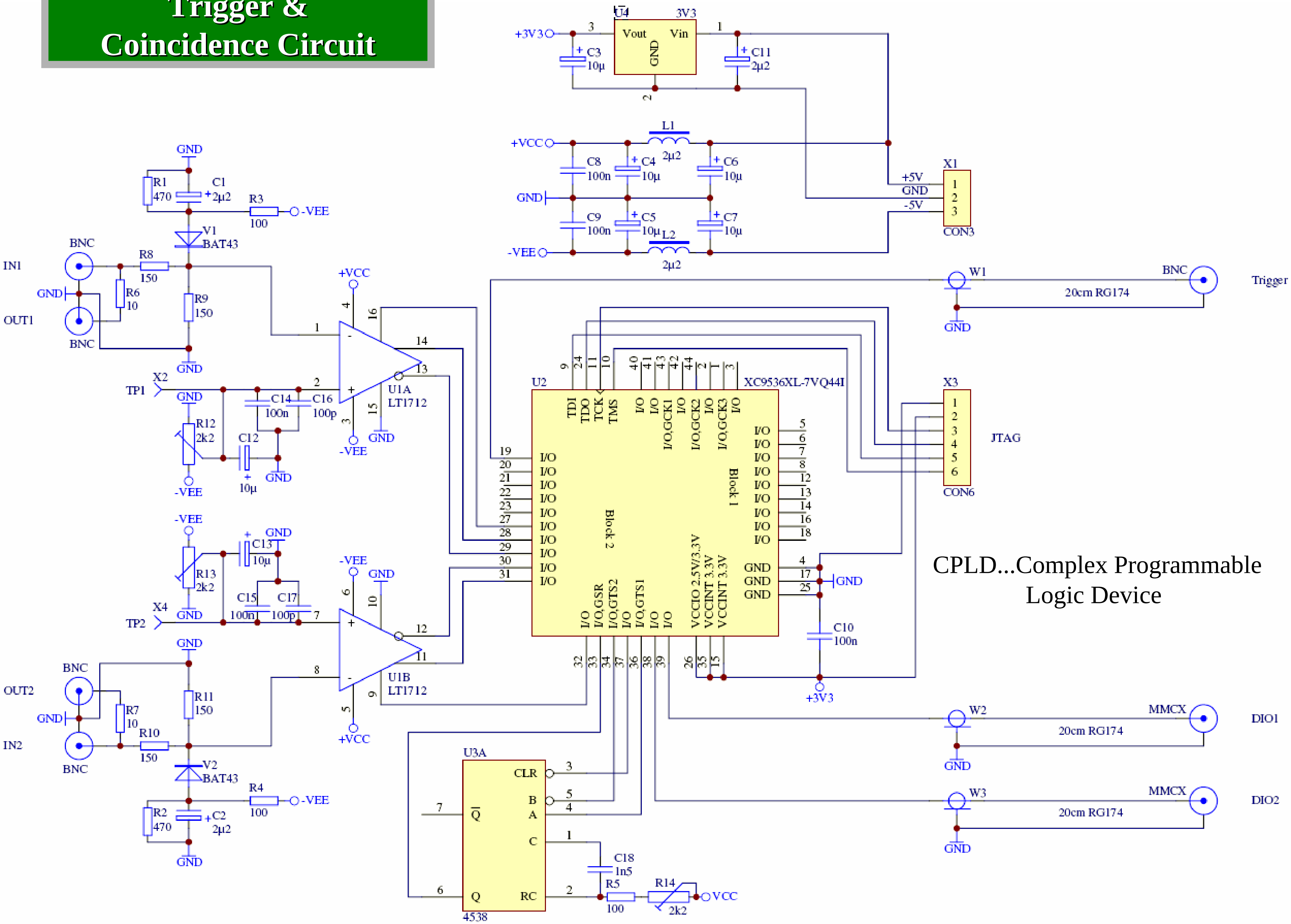


Lifetime detector system



- Linux cluster (10 CPUs)
- calculating power can be increased by adding more PCs to the Control PC

Trigger & Coincidence Circuit



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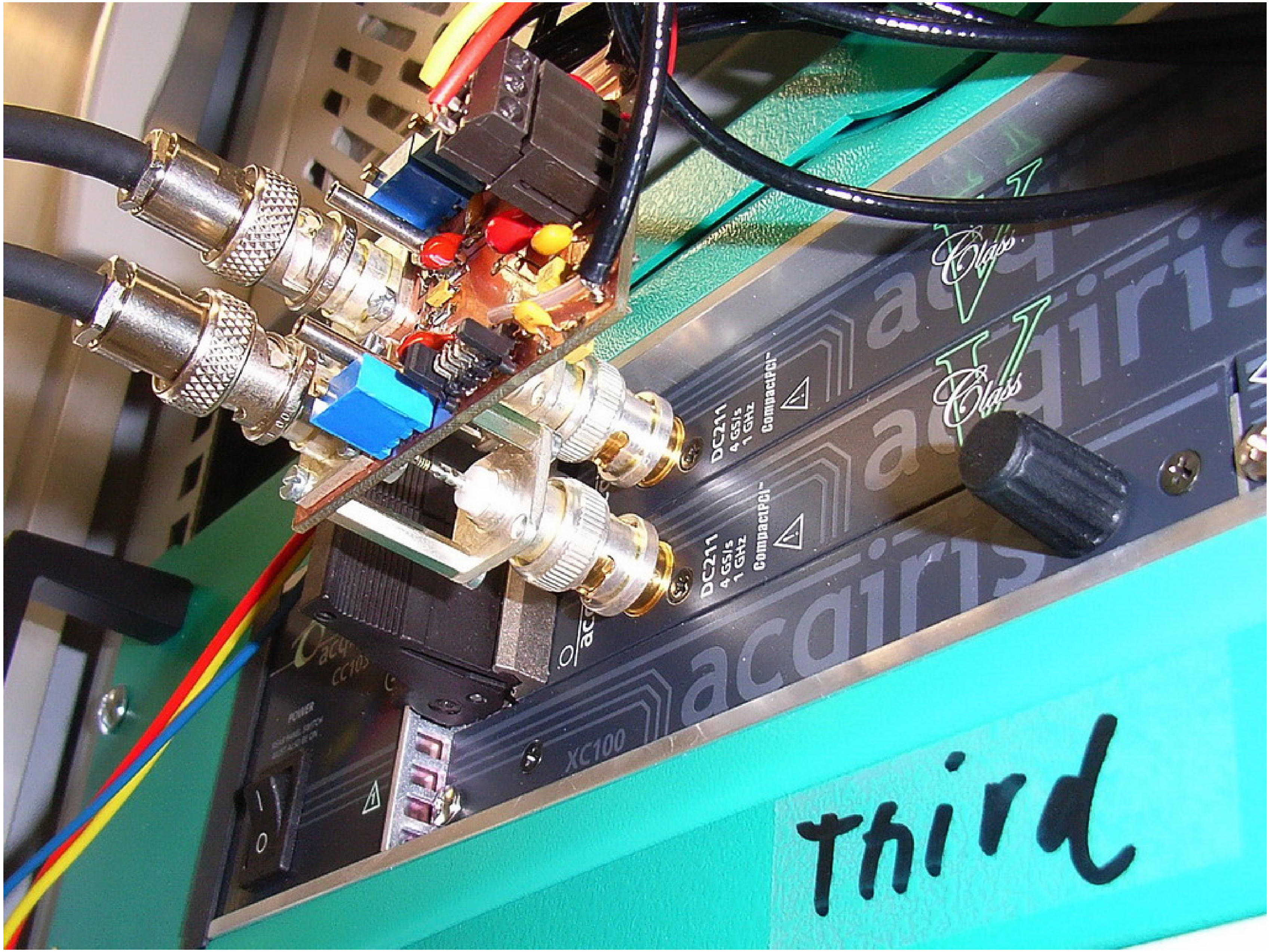

- digitally measured lifetime spectrum (usual ^{22}Na setup)
- time interpolation by polynoms (can be improved)
- ^{60}Co resolution = 170 ps (FWHM)