First Experiments with the MePS system

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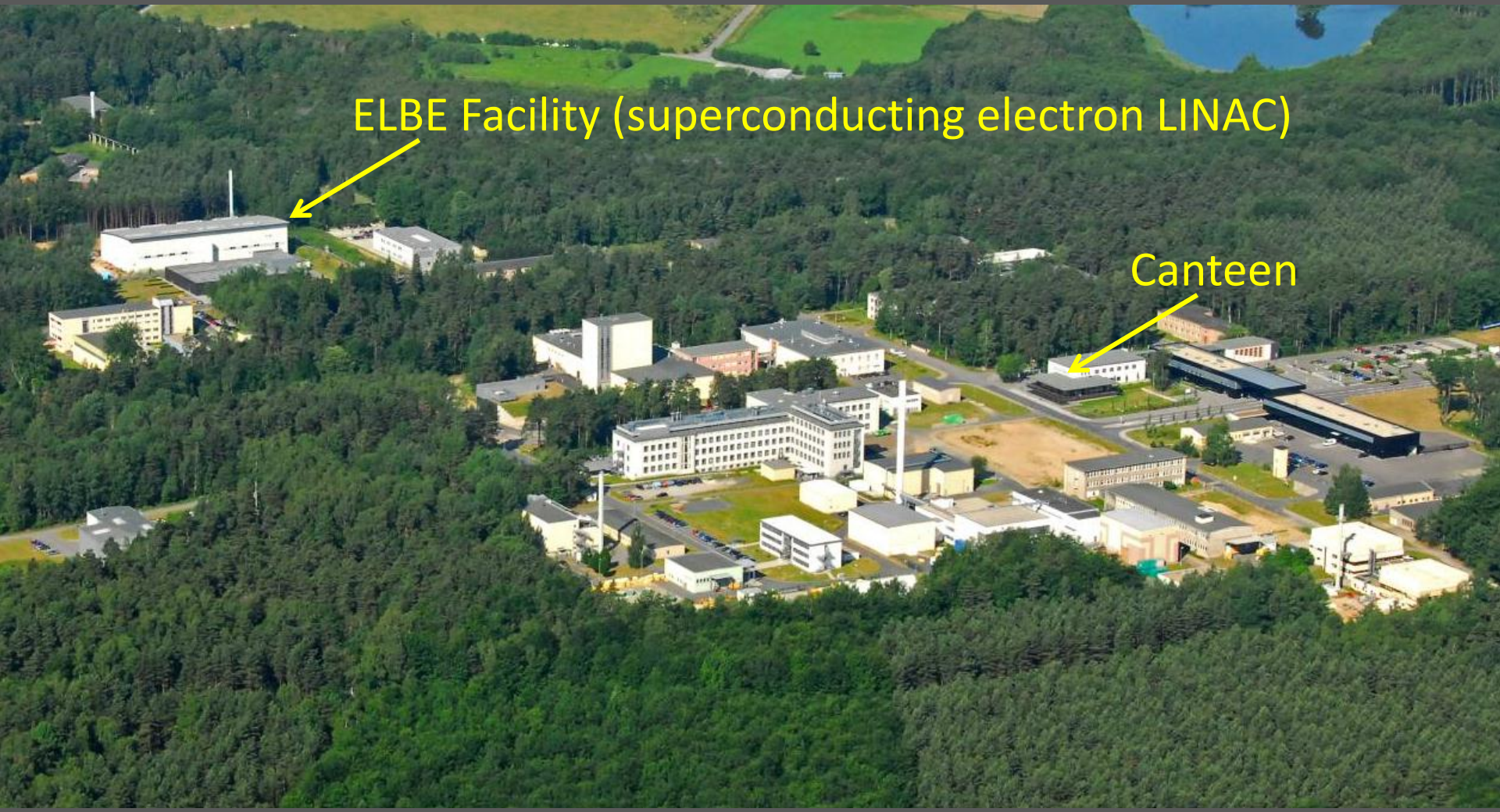
- Superconducting electron LINAC at ELBE
- The MePS System (**M**ono-**e**nergetic **P**ositron **S**ystem) as part of EPOS
- First use: Low-K dielectric layers

ICPA-16

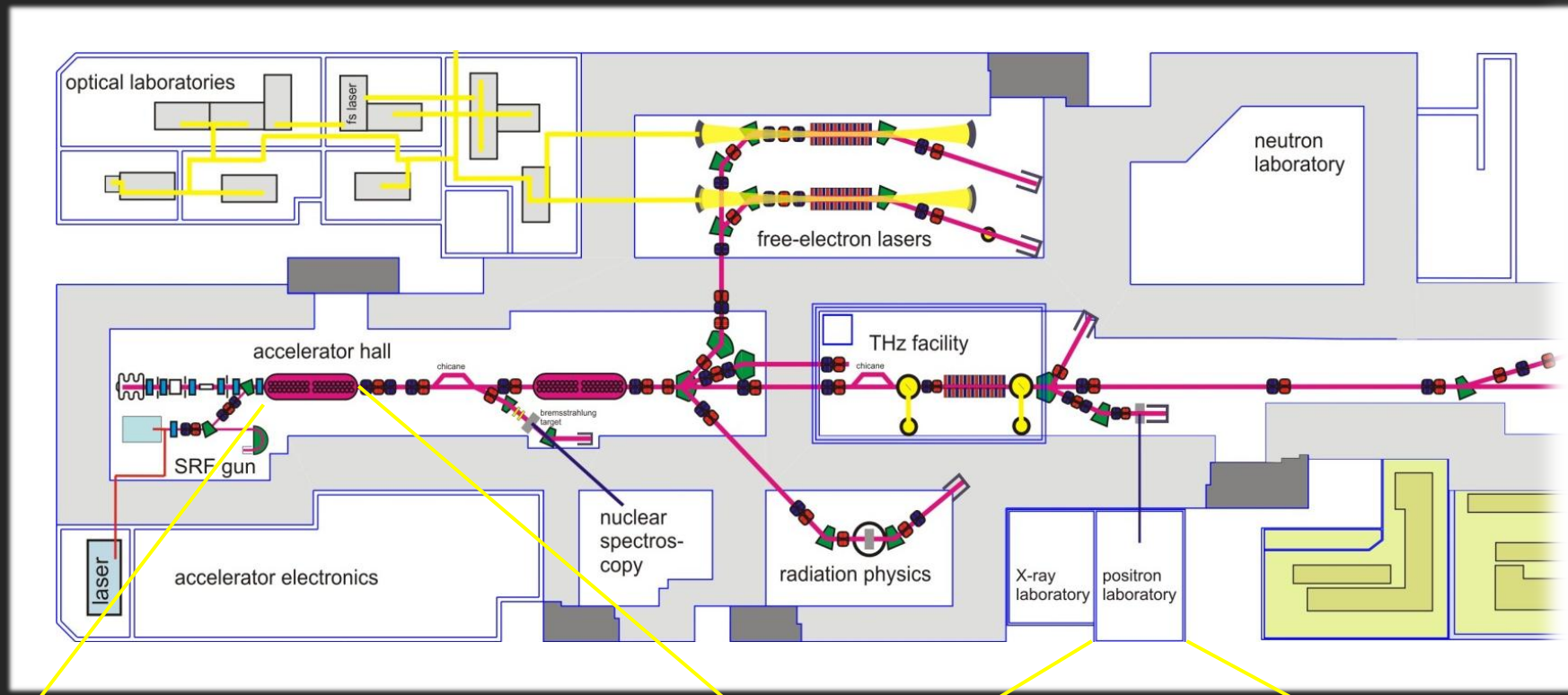
Martin-Luther-University
Halle-Wittenberg

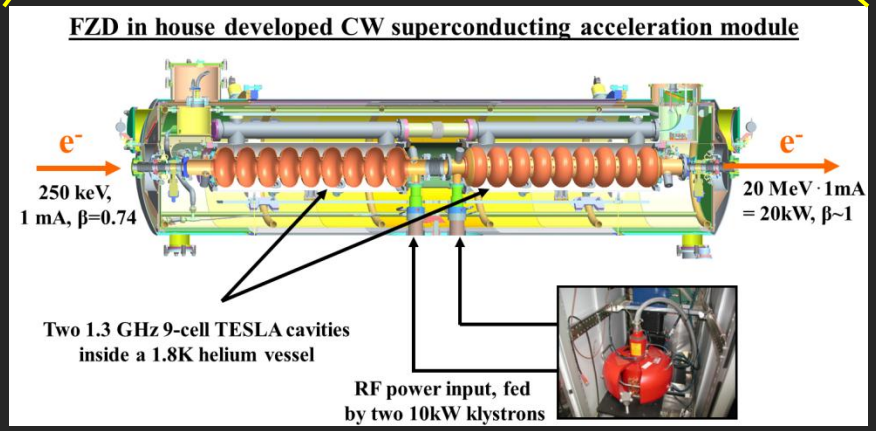
HZDR = Helmholtz Zentrum Dresden-Rossendorf



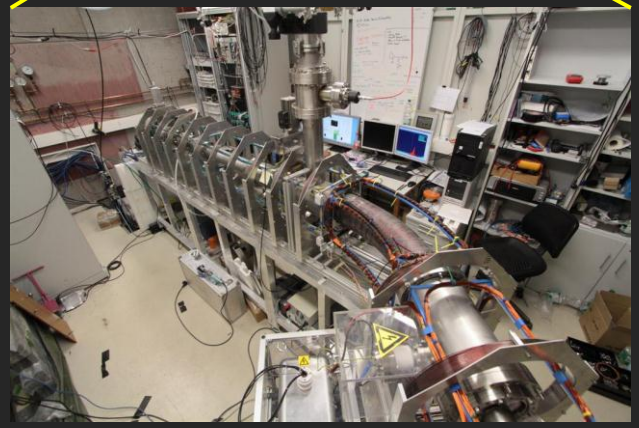
- electron beam repetition frequency $26/2^n$ MHz
- pulse width 5 ps
- 40 kW, 1 mA cw (2 mA planned)

ELBE labs

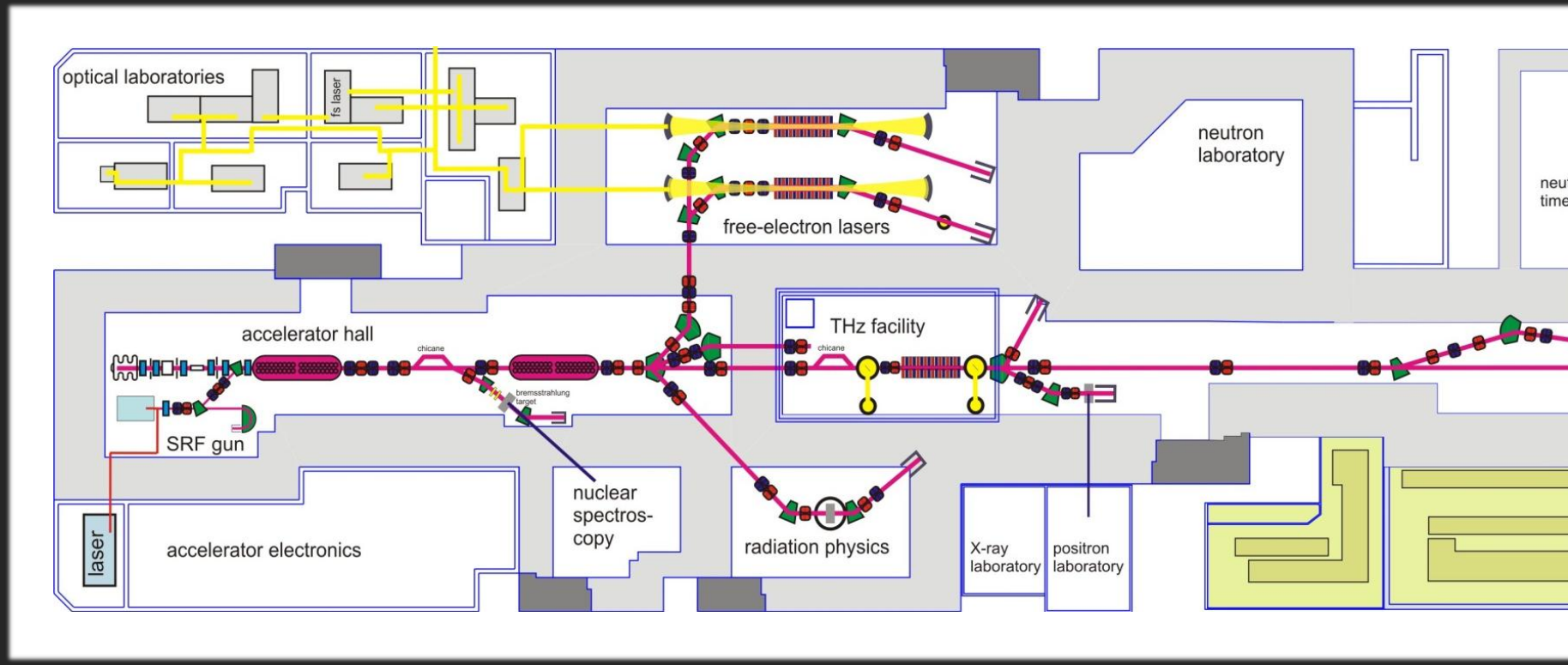




MePS System



Upgrade of the Dresden ELBE labs



- Extension of ELBE hall started 2011
- electrons back in positron cave in December 2012

Concept of EPOS (Elbe Positron Source)

MePS

Monoe**e**nergetic **P**ositron **S**pectroscopy

- Cave 111b / Lab 111d
- monoenergetic (slow) positrons
- pulsed system
- LT, CDBS, AMOC
- 25000 cps @ 750 W
- free of side peaks
- 10^4:1 Peak-to-BG even without chopper

Information Depth:
0…5 µm

CoPS

Conventional **P**ositron **S**pectroscopy

- 4-tubes PALS digital spectrometer
  - CDBS, AMOC
  - using ^{22}Na foil sources
  - He-cryostat
  - automated system
- SPONSOR: continuous slow-positron beam

Information Depth:
0…200 µm

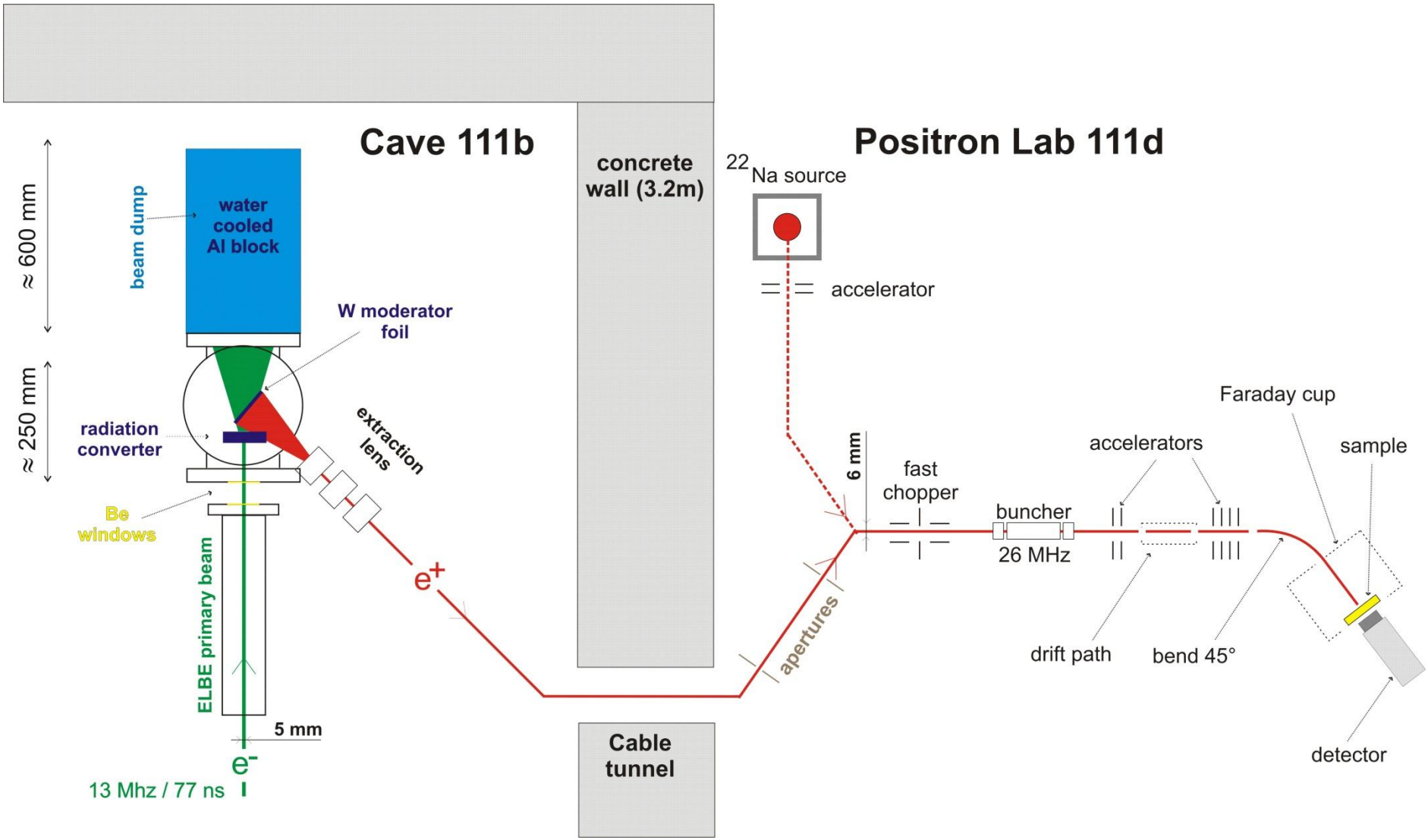
GiPS

Gamma-**i**nduced **P**ositron **S**pectroscopy

- Cave 109 (nuclear physics)
- Positron generation by Bremsstrahlung
- Information in complete bulky sample (up to 10 cm^3)
- all relevant positron techniques (LT, CDBS, AMOC)

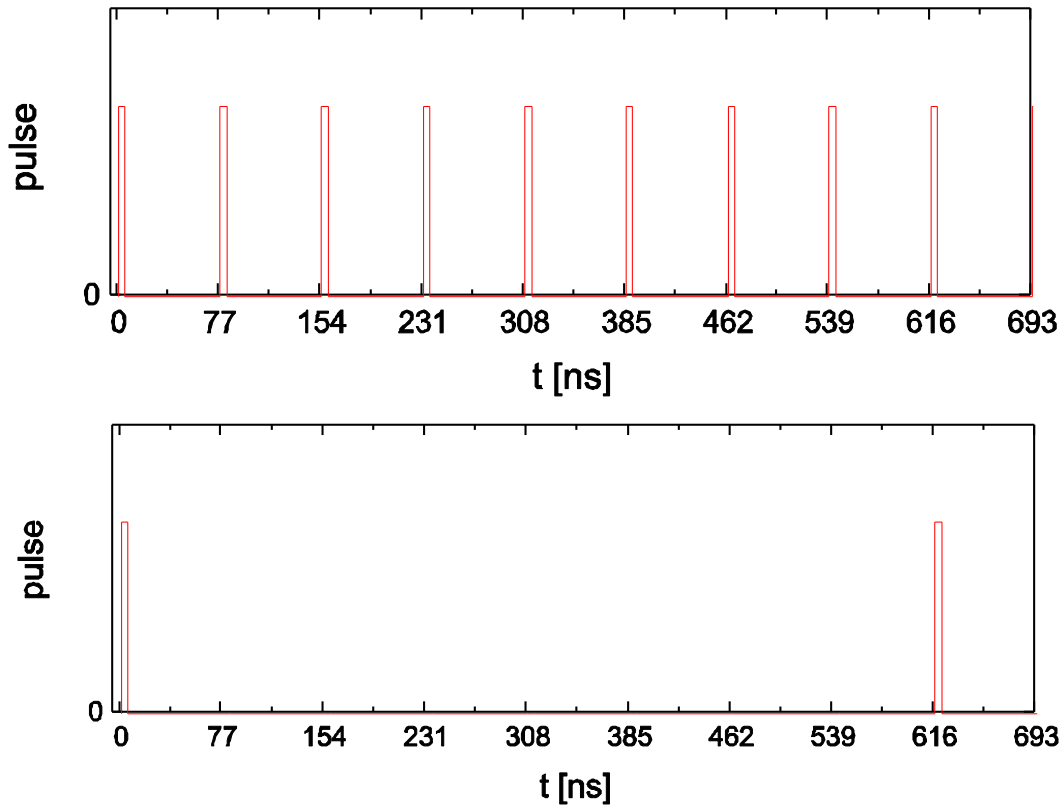
Information Depth:
0.1 mm …5 cm

Scheme of MePS System



Time Structure of Bunches

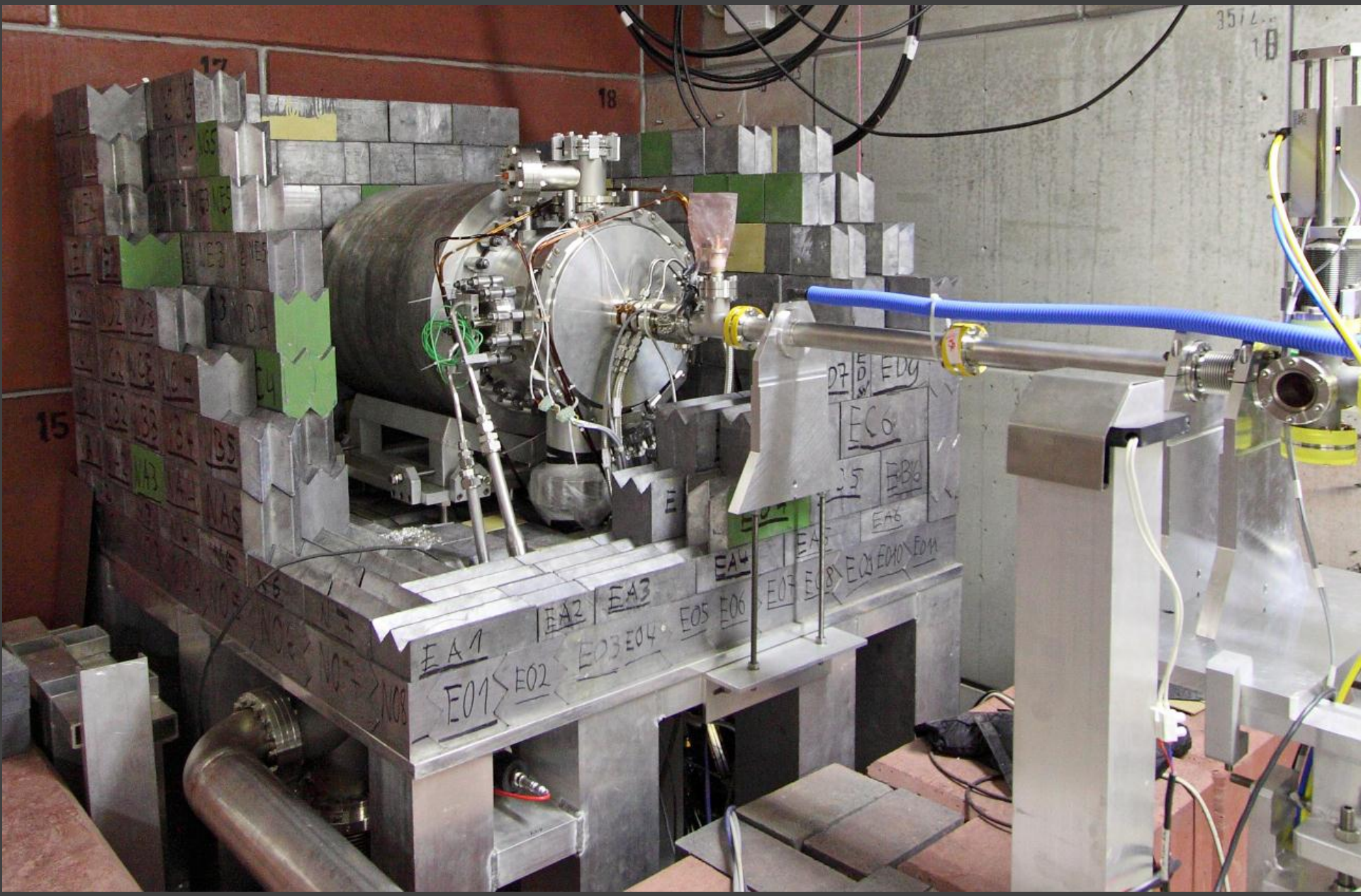
- Bunch repetition frequencies can be adjusted: **$26/2^n$ MHz**
- positron annihilation 0….500 ps ⇨ 13 MHz / 77 ns
- porosimetry 1…142 ns ⇨ 1.625 MHz / 616 ns
- **electron bunch charge can be adjusted** to have always full average power



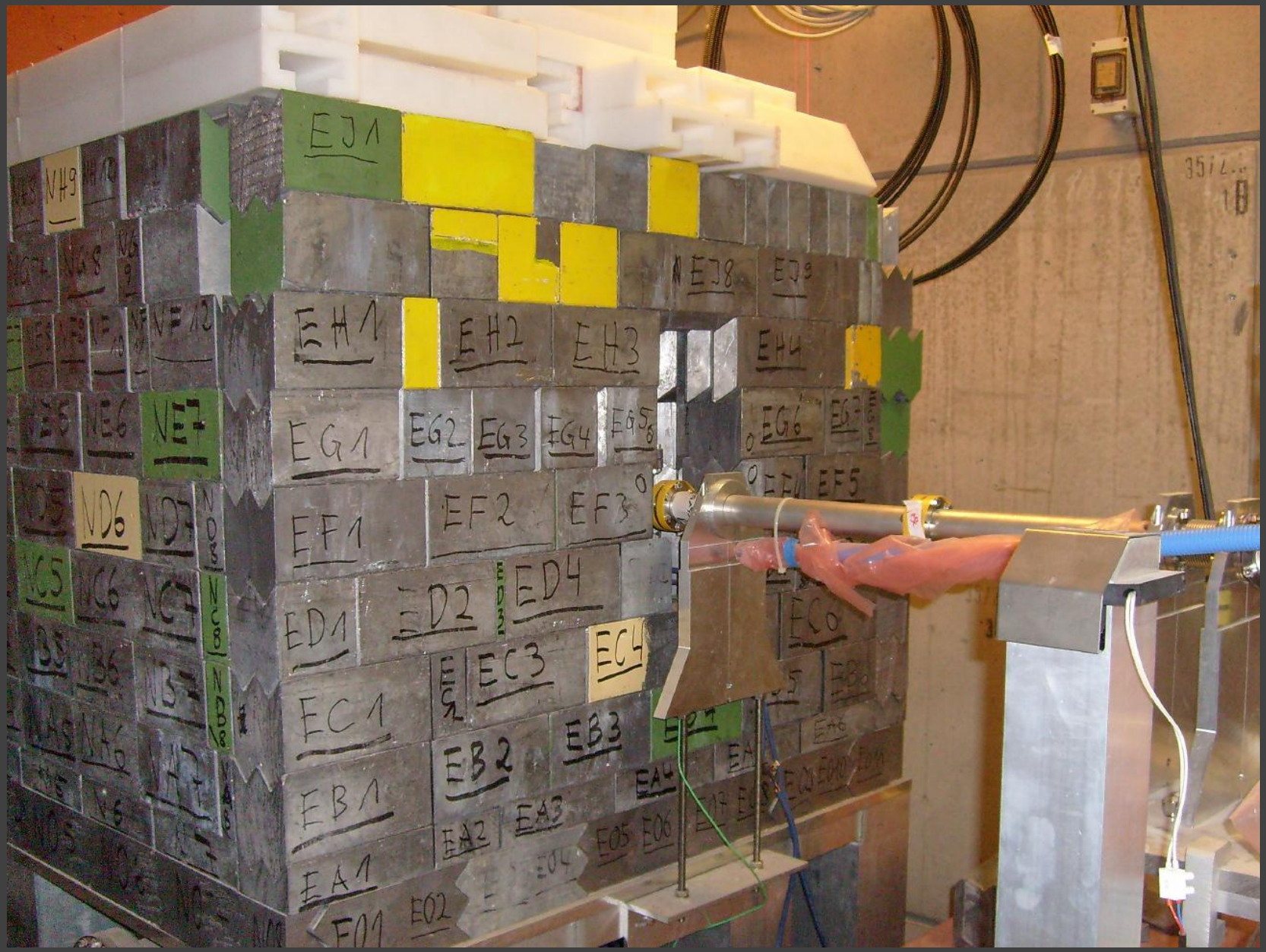
positrons
0… 500 ps

positronium
0… 142 ns

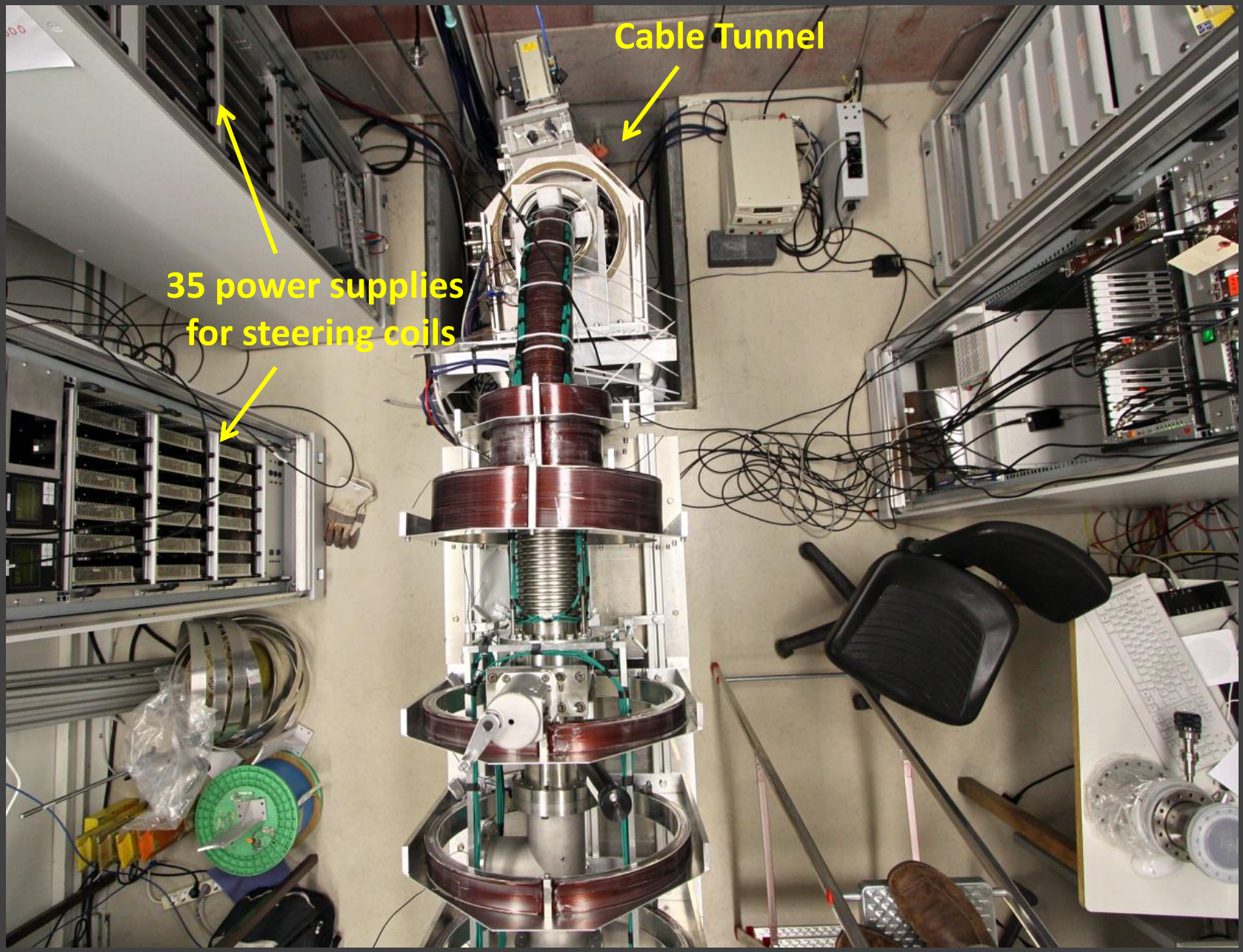
Electron-Positron Converter in Cave 111B



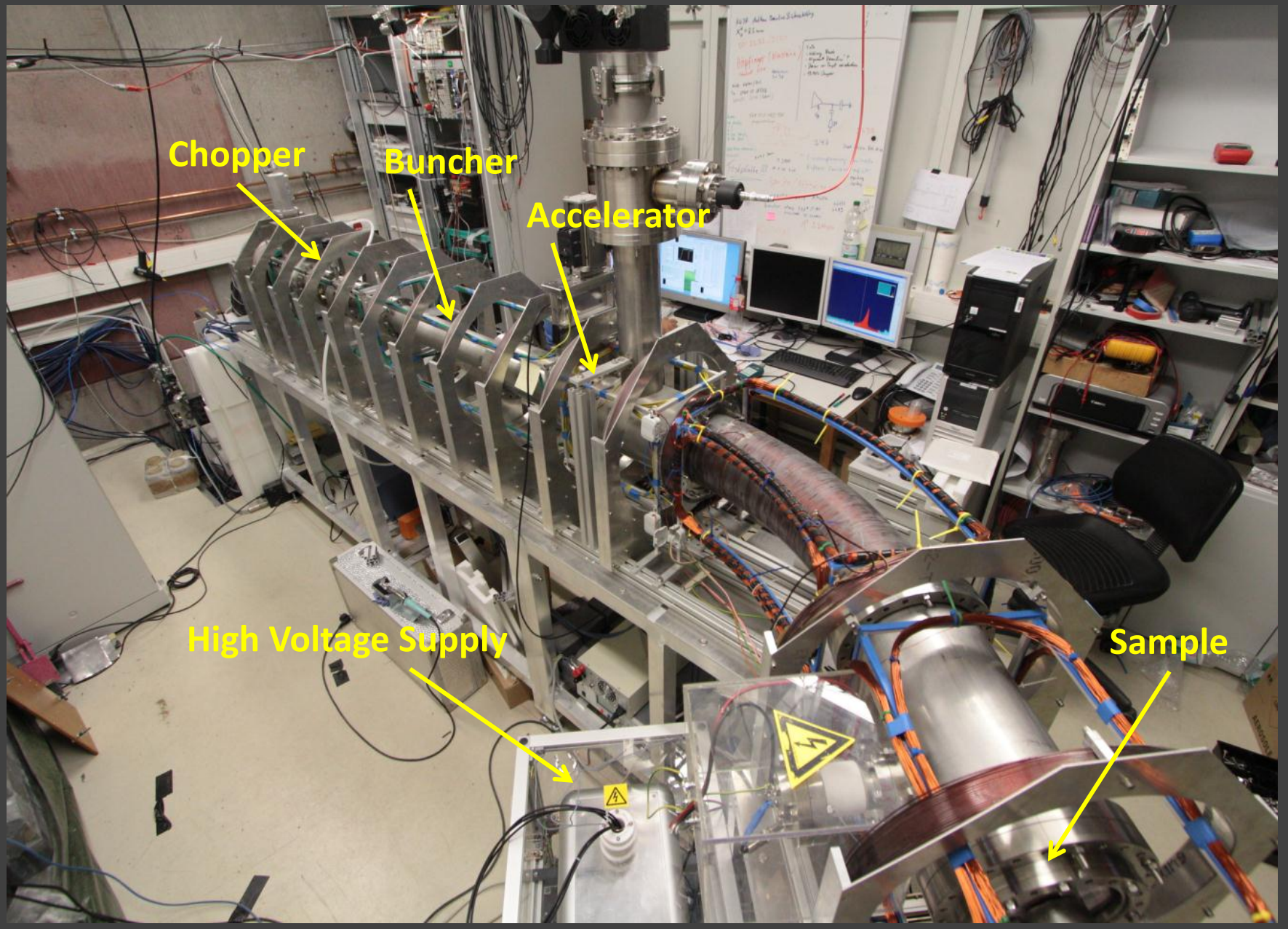
Electron-Positron Converter in Cave 111B



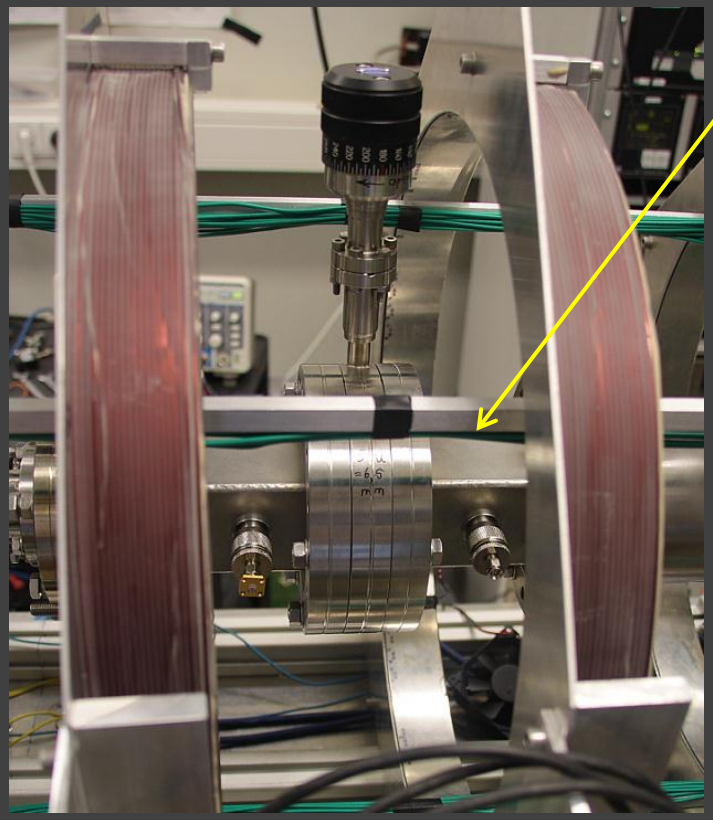
Positron Laboratory 111D

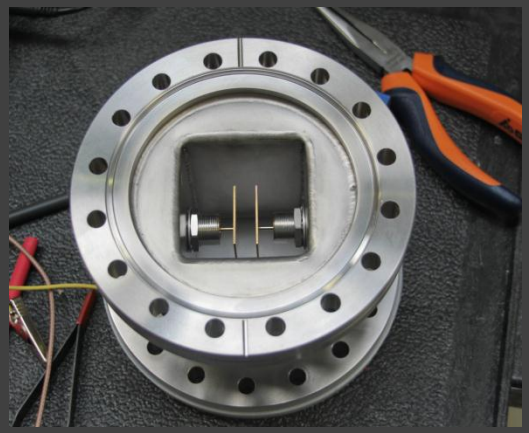


Beamline in Cave 111D



Chopper and double-slit Buncher



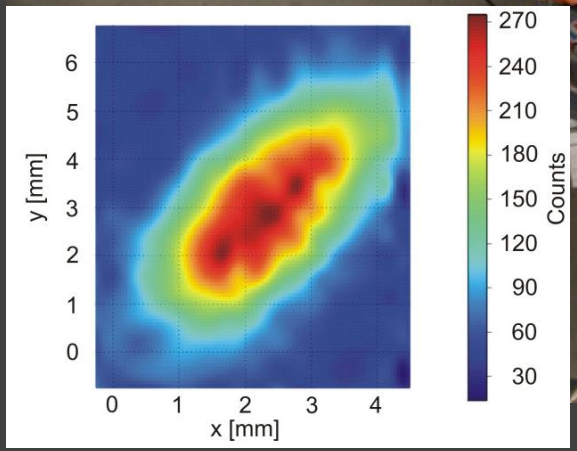


Beamline is bent to avoid reflected positrons

PMT

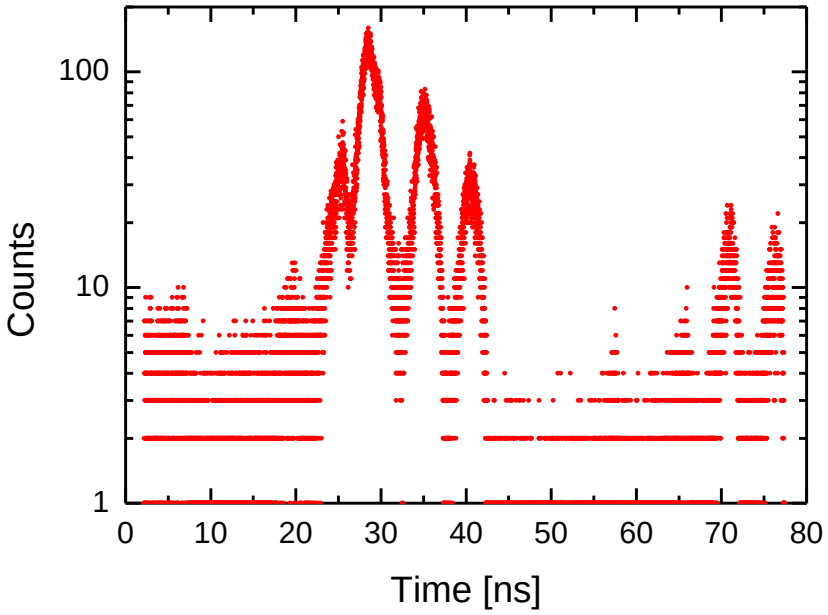
High Voltage Supply

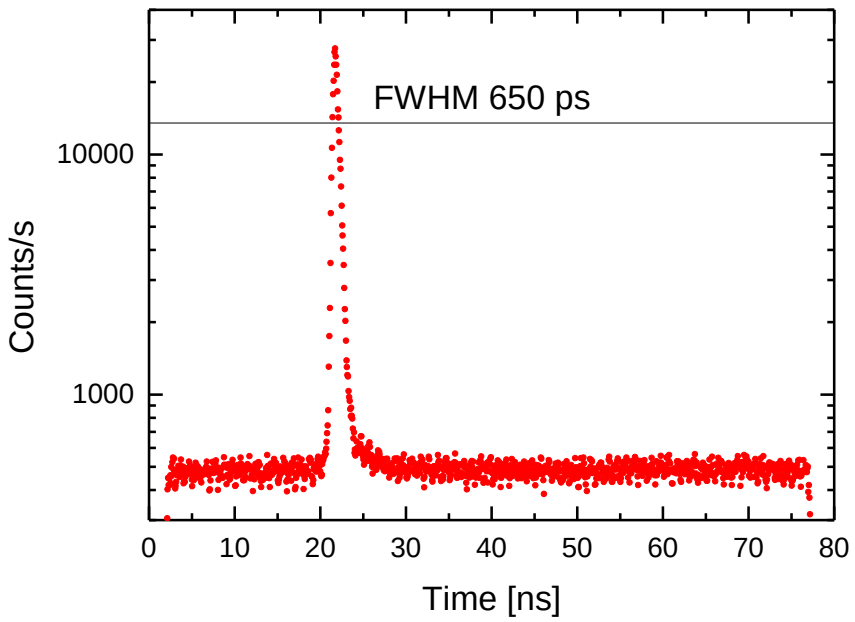
Spot size



Time Resolution Function

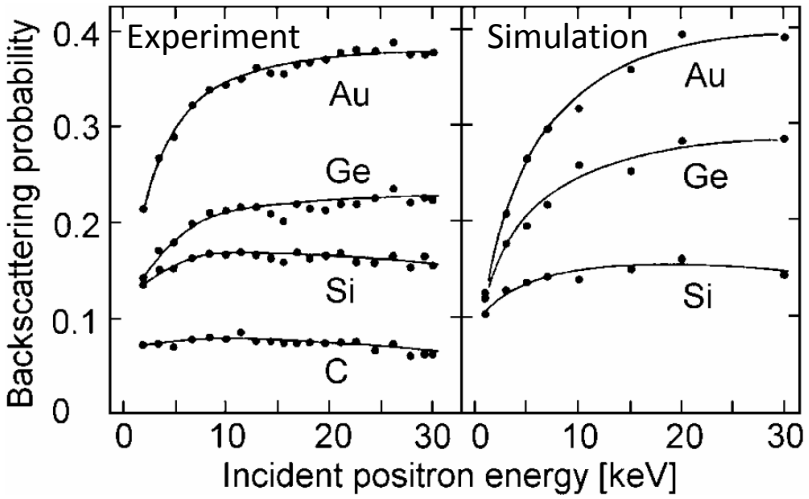
- time spectrum was very bad in the beginning
- adjustments, apertures, aligning, more steering coils, ….
- still no chopper in use





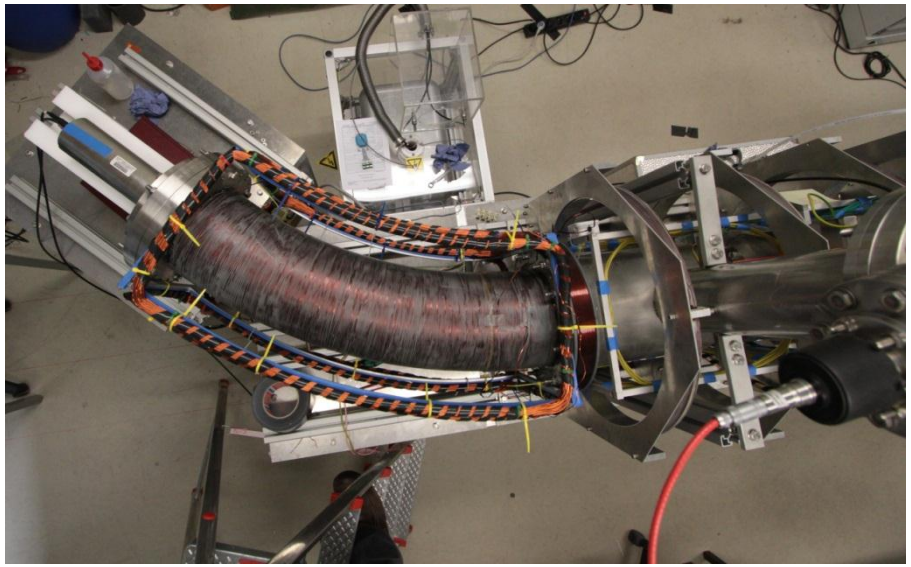
Backscattered Positrons

- Problem: large fraction of positrons will be **backscattered** from for high-z sample



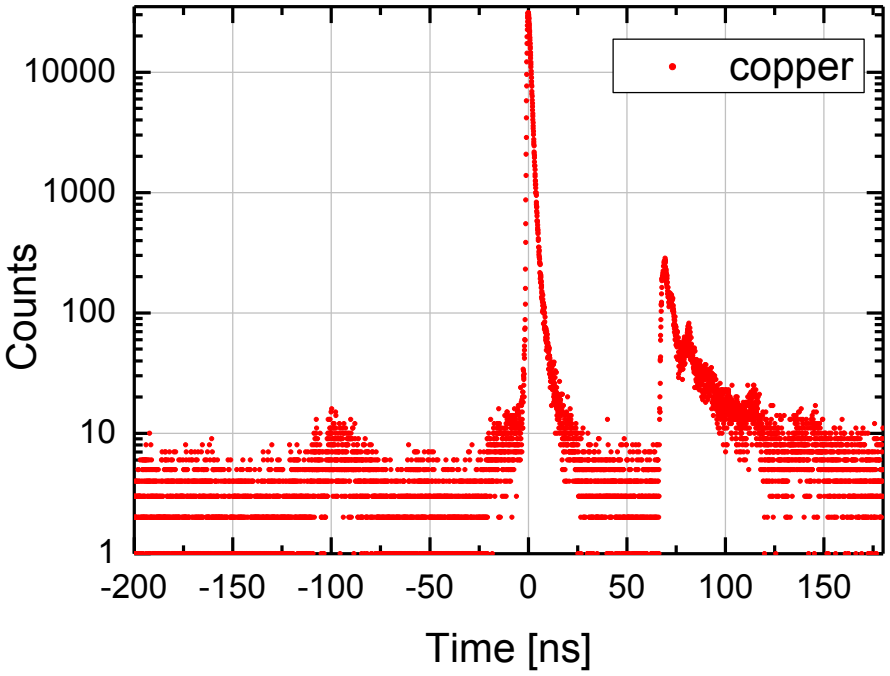
Mäkinen et al., 1992

- in many systems: E×B filter in beam line prevents backscattered positrons from being re-accelerated
- in spite of this ⇨ often **side peaks** in spectrum
- **our solution: a bent beamline** ⇨ steering coils guide positrons to sample but backscattered to the wall in some distance

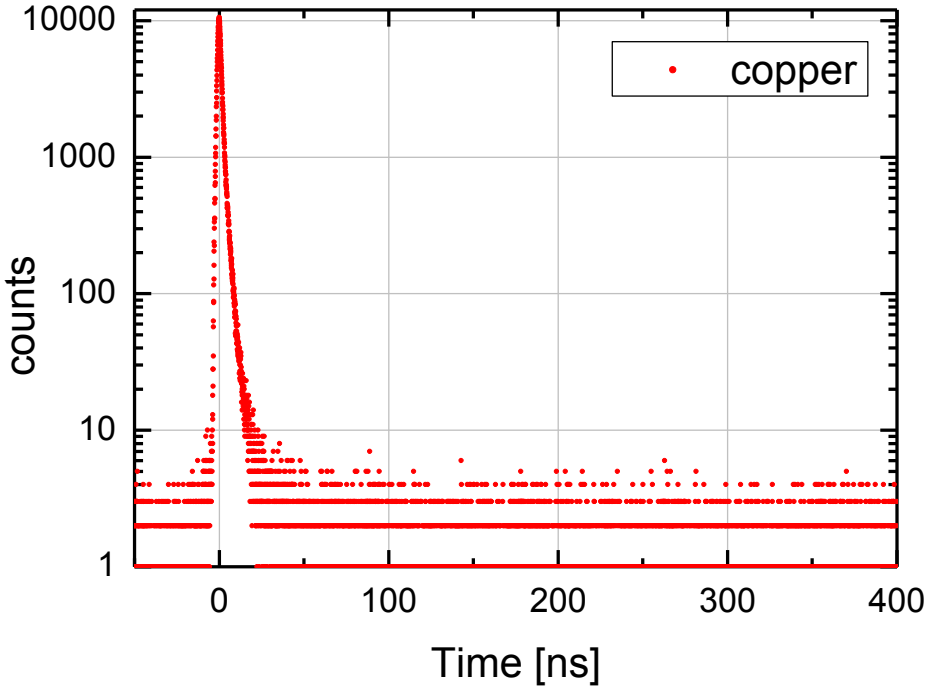


Backscattered Positrons

- straight beamline
- accelerator is on
- strong side peak due to re-acceleration of backscattered positron

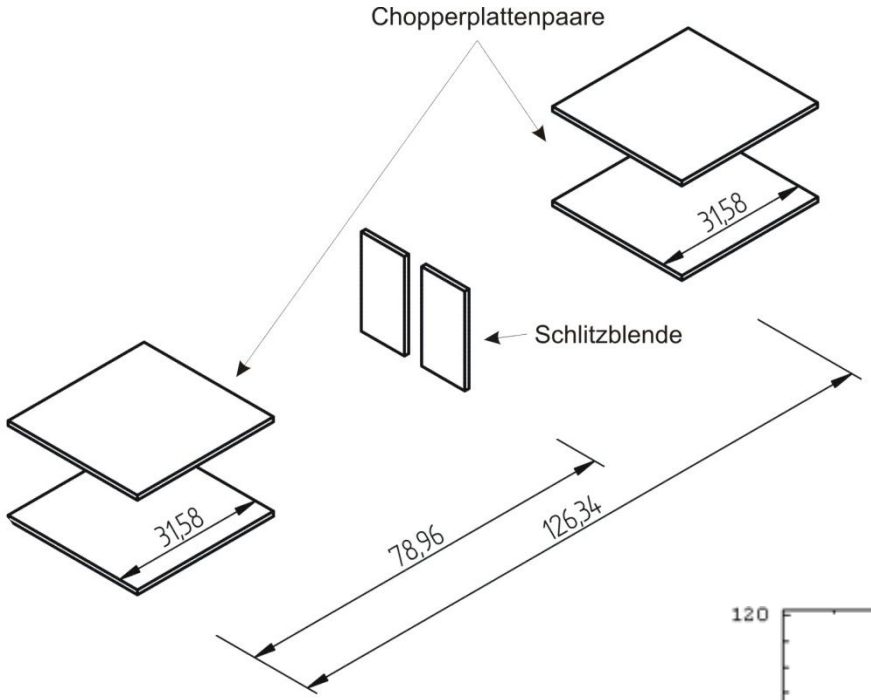


- bent beamline: 45°
- accelerator is on
- no side peaks
- less background ≈ 1 : 10^4
- still no chopper in use



- count rate at 25 µA @ 30 MeV (750 W) electron beam power ≈ **25 000 cps at PMT output**
- maximum current is 1 mA (40 kW): expected 10^6 cps (linear estimation)

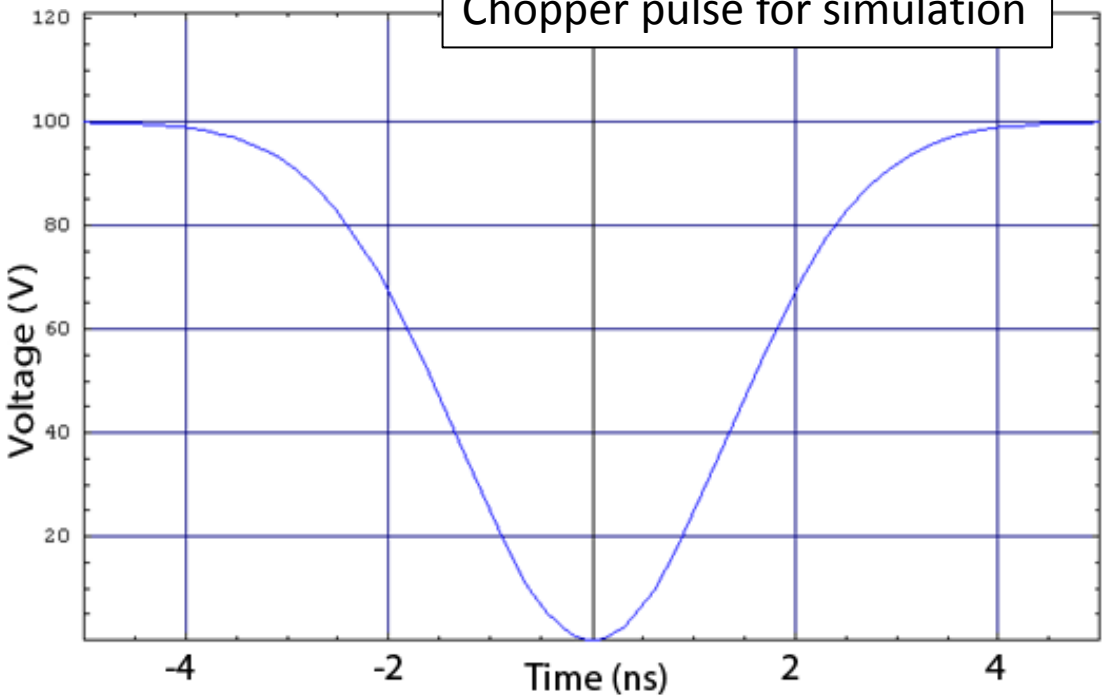
Problem: chopper pulse generator



- pulse generator for chopper still not working
- thus time resolution now ≈ 500 ps
- we placed on order at external company
- we simulated required pulse shape by SIMION 8
- assumed: Gaussian shape

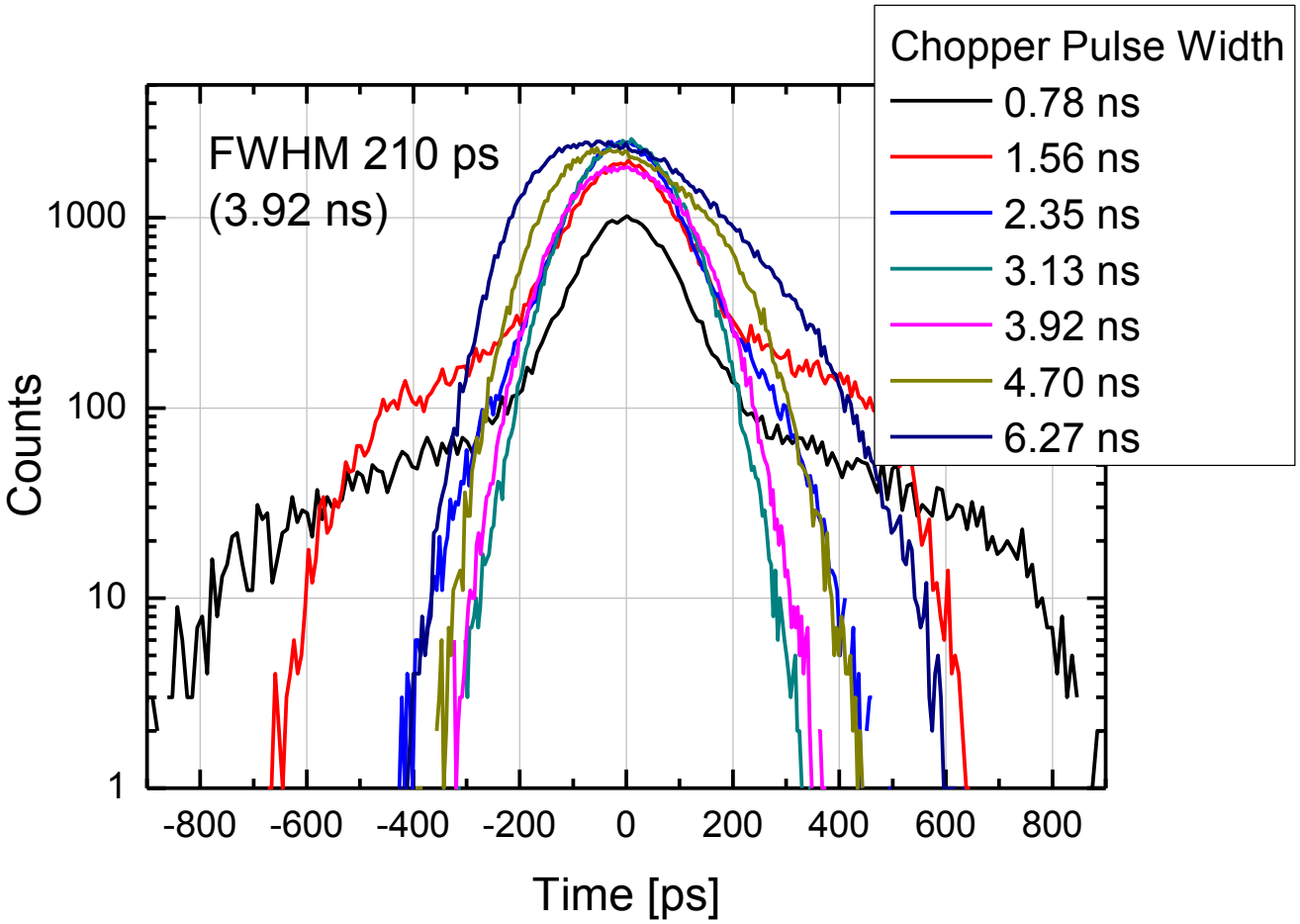
- at 2 keV: 1.19 ns time of flight through the chopper plates
- field outside of the chopper has an influence on the positron path
- simulation is important

Chopper pulse for simulation



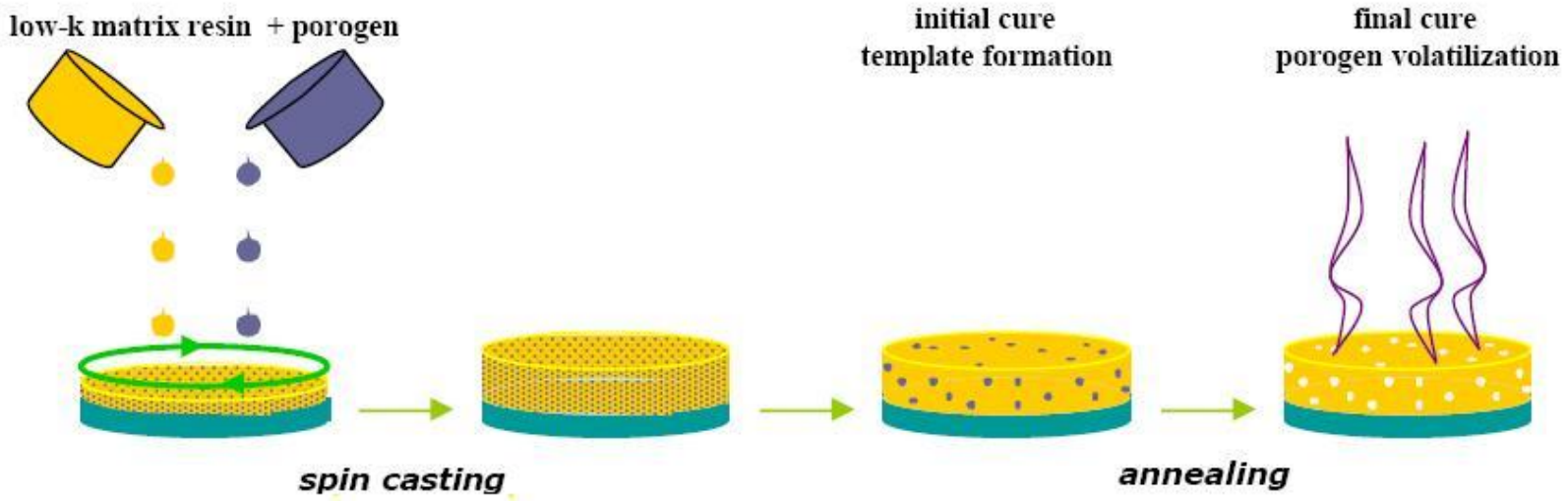
Simulation of Time Resolution Function

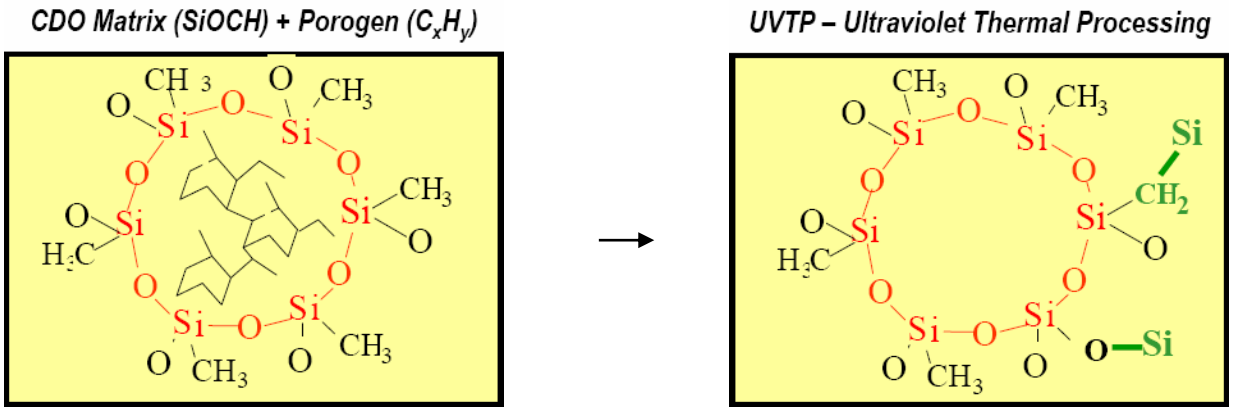
- time-dependent simulation of time resolution function with SIMION-8
- simulation over the whole system from moderator to PMT
- PMT contribution is included
- result of simulation ⇨ we need: 13 MHz / 100 V / Gaussian Shape / 4 ns width
- under these conditions ⇨ expected time resolution FWHM = 210 ps



First Use: Study of low-K dielectric layers

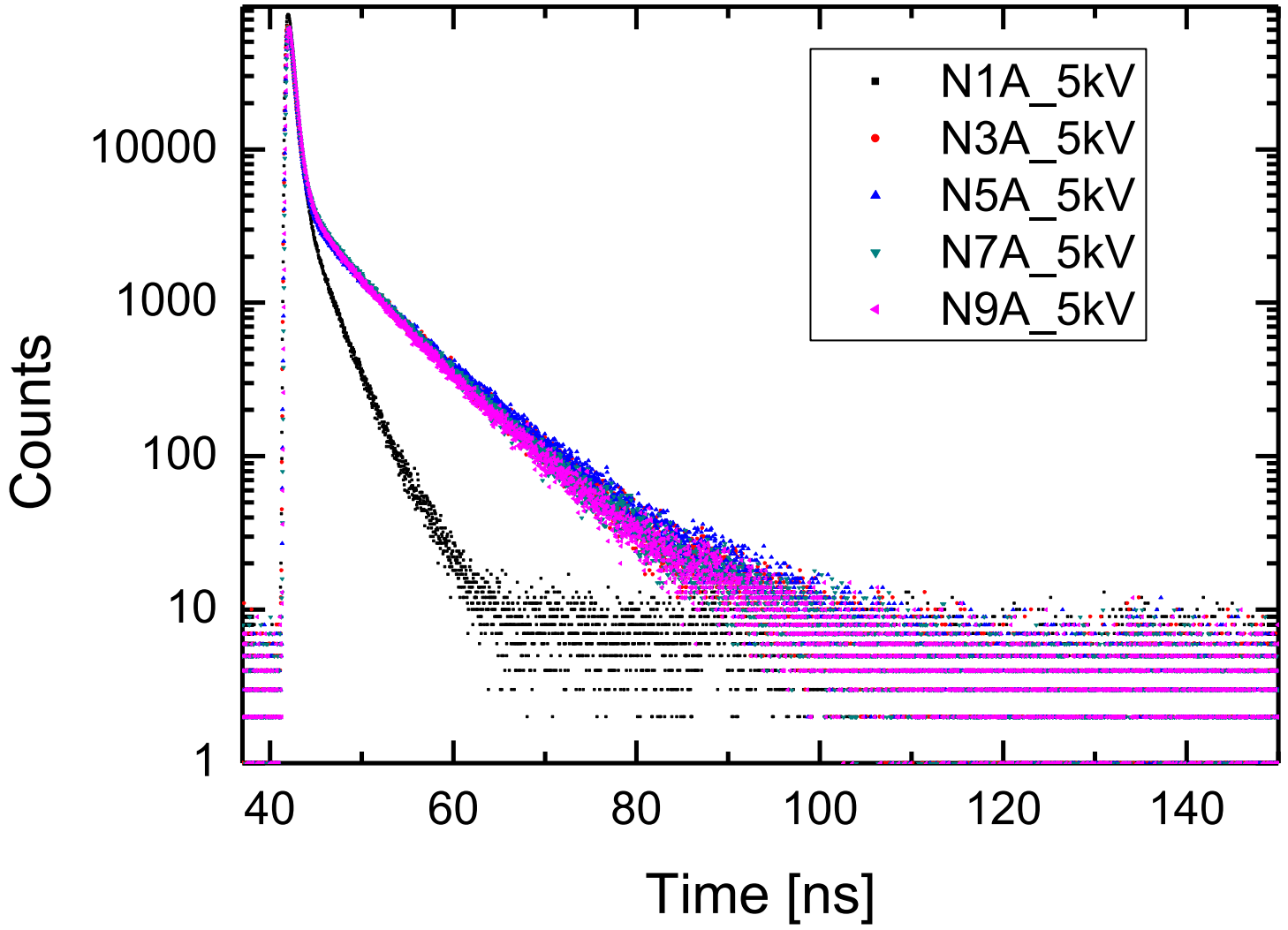
- low-K layers are used to reduce product R×C in isolation layers in ULSI integrated circuits
- layers produced by CVD or spin coating
- porogen is cured and produces pores with ≈ 1nm diameter
- closed pore system





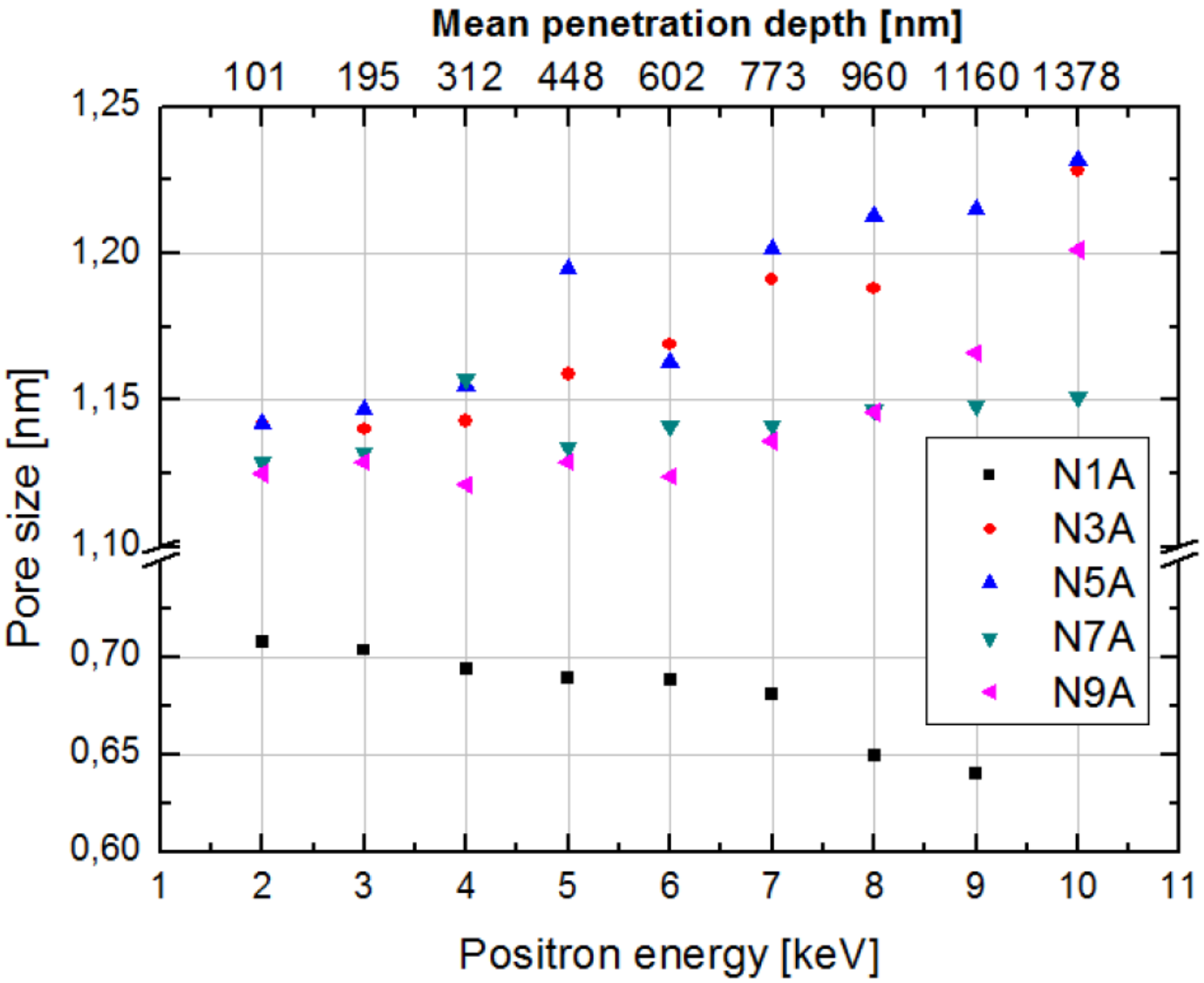
Low-K layers: Lifetime spectra

- low-K layers were studied in different states of treatment (Plasma and TiN layer growth)



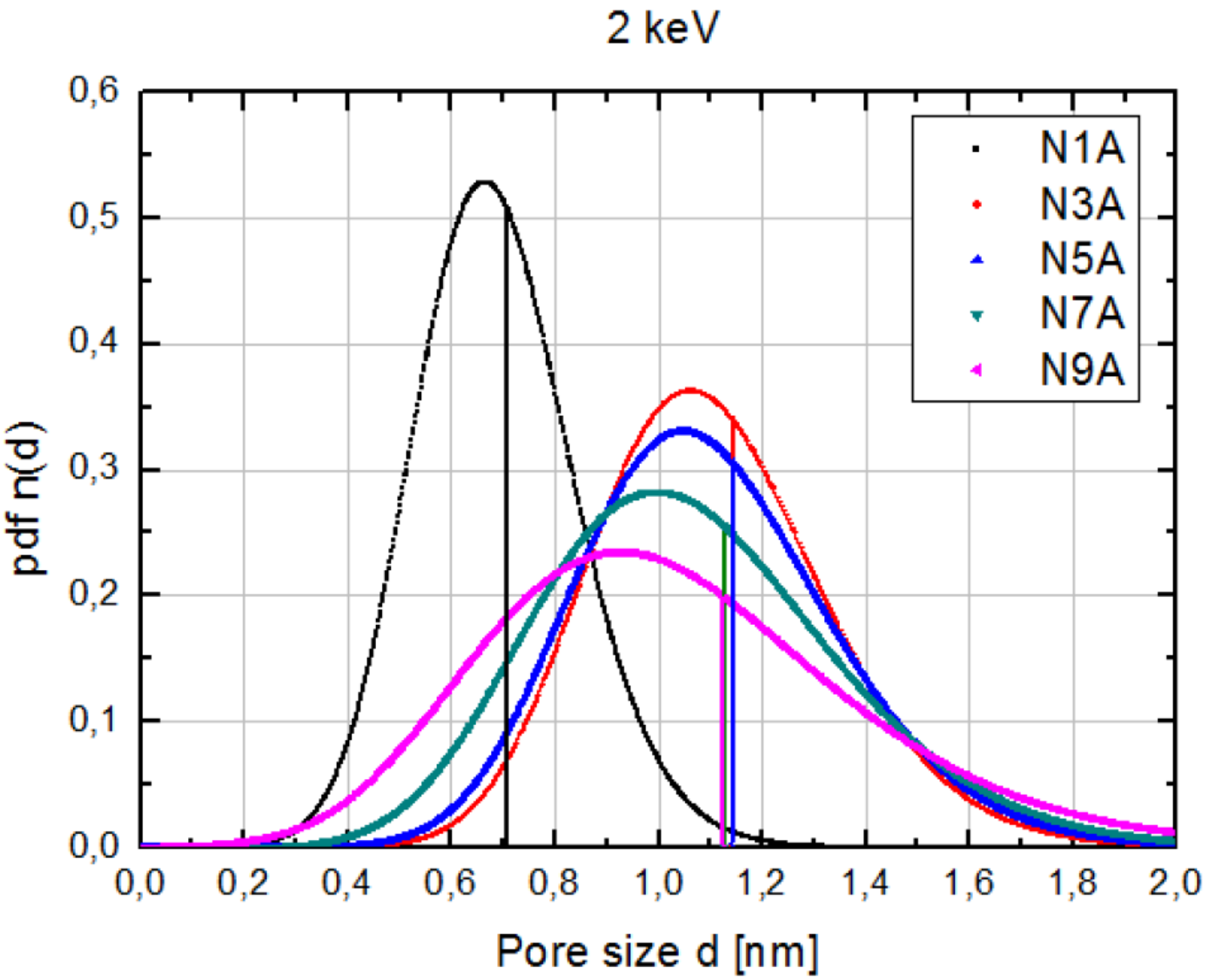
Low-K layers: Pore Size Distribution

- depth scan of pore size distribution



Low-K layers: Pore Size Distribution

- pore size distribution calculated from lifetime distribution



Conclusion

- MePS as part of EPOS is already now useful tool for porosimetry
- high counting rate: 25000 cps @ 750 W electron beam power
- already without chopper: spectra free of spurious signals and 10^4:1 Peak-to-BG
- problem of backscattered positrons solved by bended beam tube
- however: time resolution is ≈ 500 ps due to missing chopper
- we hope to add chopper soon ⇨ expected time resolution FWHM = 200 ps

Talk available: http://positron.physik.uni-halle.de

Thanks for your attention!