The MePS System at Helmholtz-Zentrum Dresden-Rossendorf and its special Capability for Positronium Lifetime Spectroscopy

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and many colleagues of Univ. Halle and HZDR

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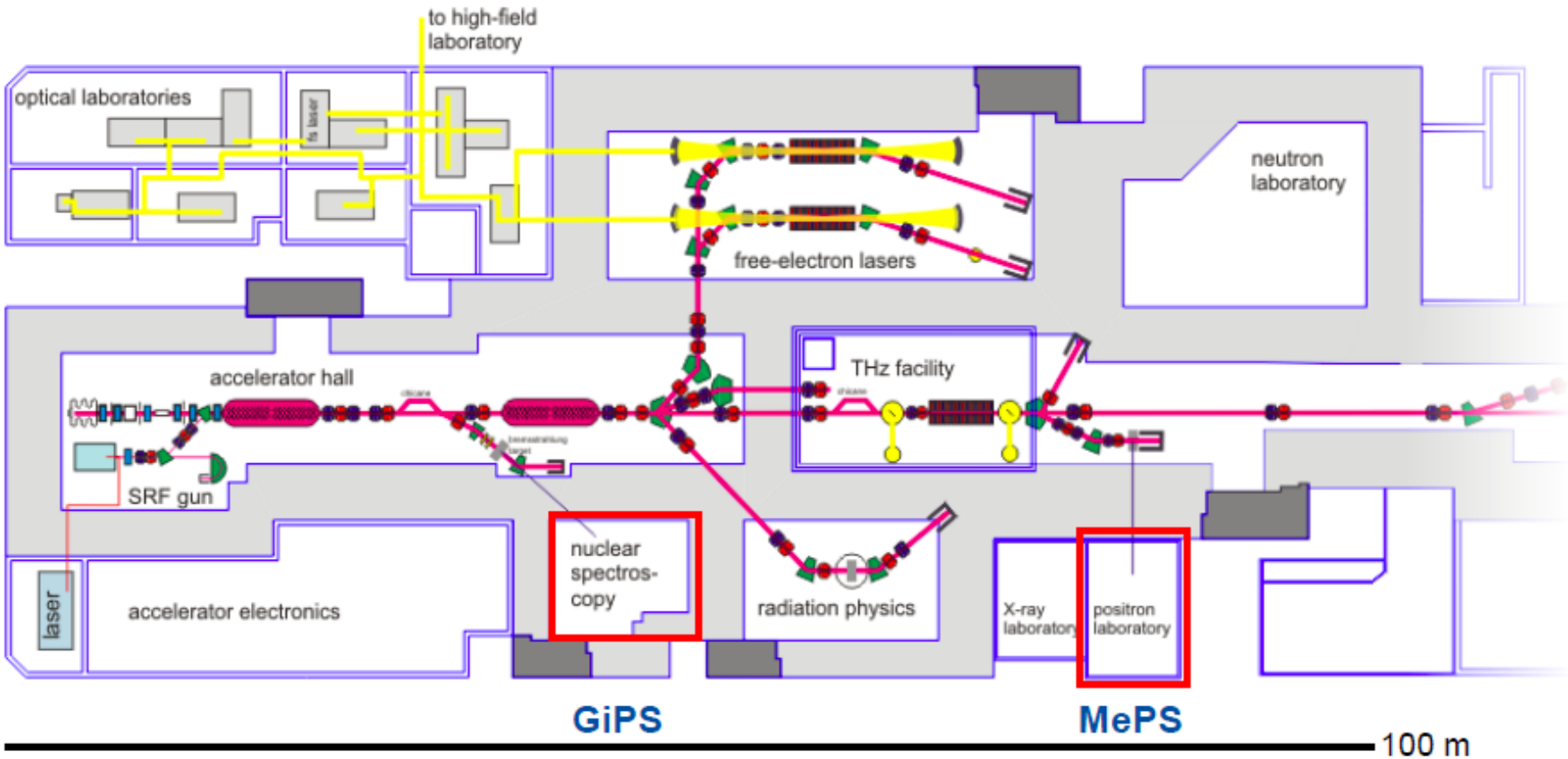
Helmholtz-Zentrum Dresden-Rossendorf

HZDR = Helmholtz Zentrum Dresden-Rossendorf

- electron beam repetition frequency $26/2^n$ MHz
- pulse width 5 ps
- 30 MeV, 1 mA cw → 30kW (2 mA planned)

Ground plan of the ELBE hall



Concept of EPOS (ELBE Positron Source)

MePS

Monoe**n**ergetic **P**ositron **S**pectroscopy

- Cave 111b / Lab 111d
- monoenergetic (slow) positrons
- pulsed system
- LT, CDBS, AMOC

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

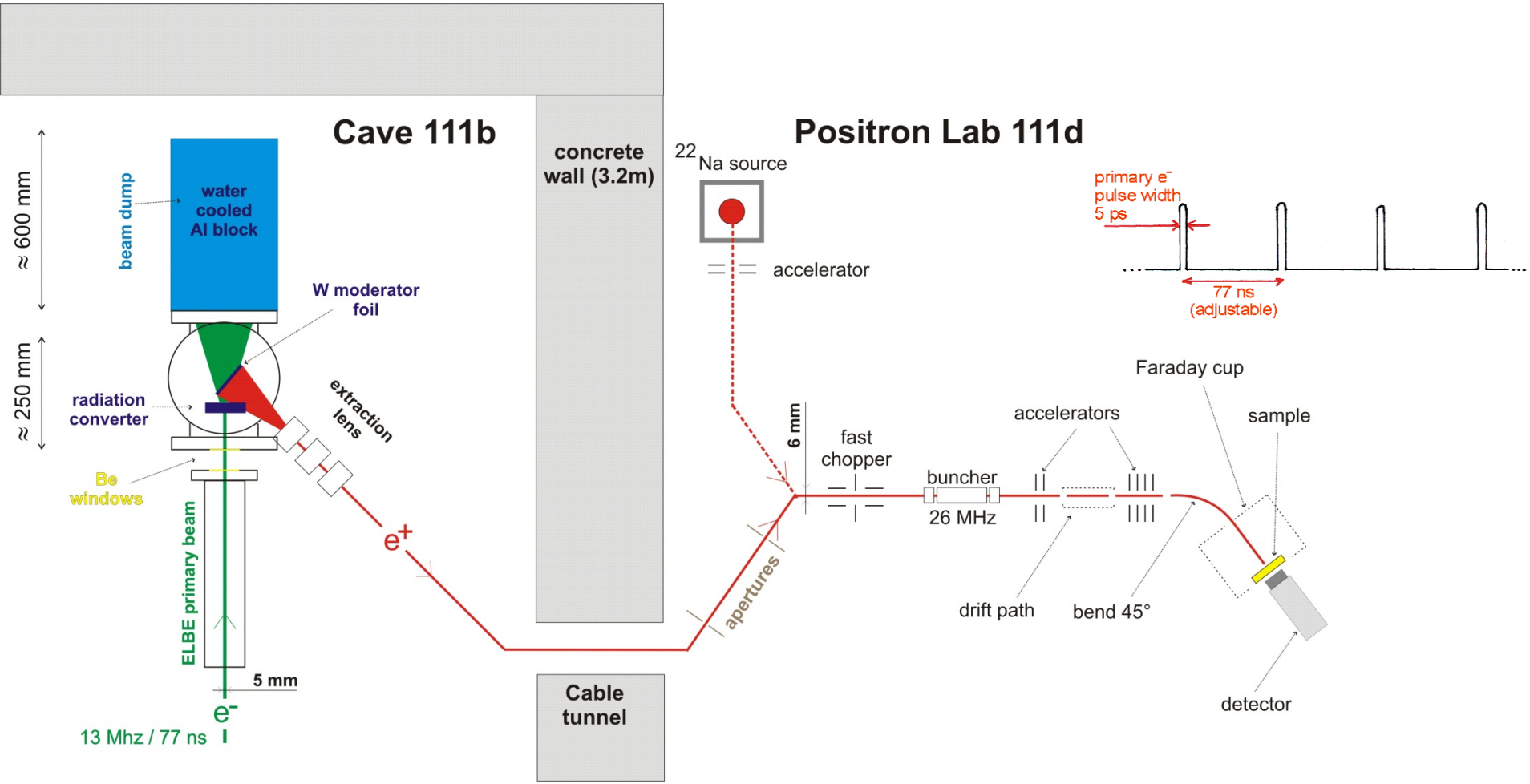
Gamma-**i**nduced **P**ositron **S**pectroscopy

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

Information Depth: 0.1 mm …5 cm

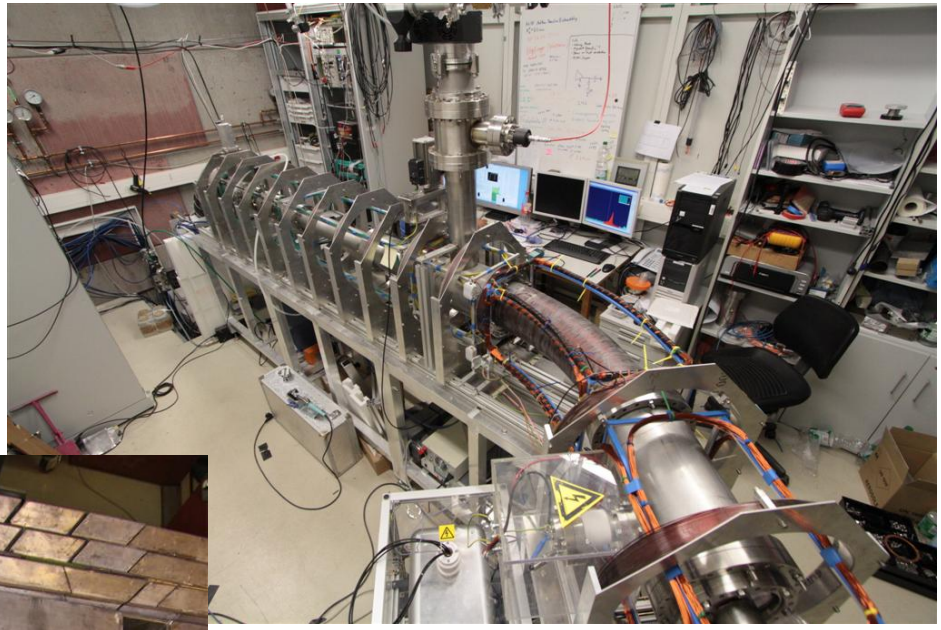
Mono-energetic Positron System - MePS

- 30 MeV, 1 mA, 13 MHz repetition time in cw mode; lifetime, CDBS and AMOC with slow e^+
- Only possible due to superconducting LINAC
- Retain original time structure for simplicity and best time resolution

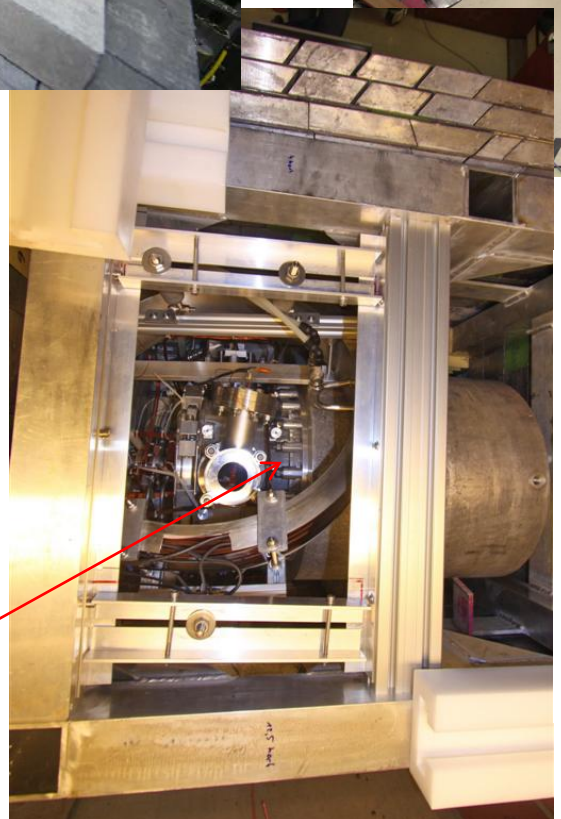


Cave and Laboratory

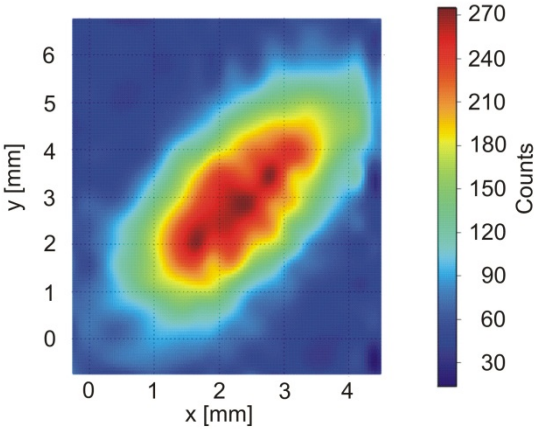
electron-positron converter



Laboratory



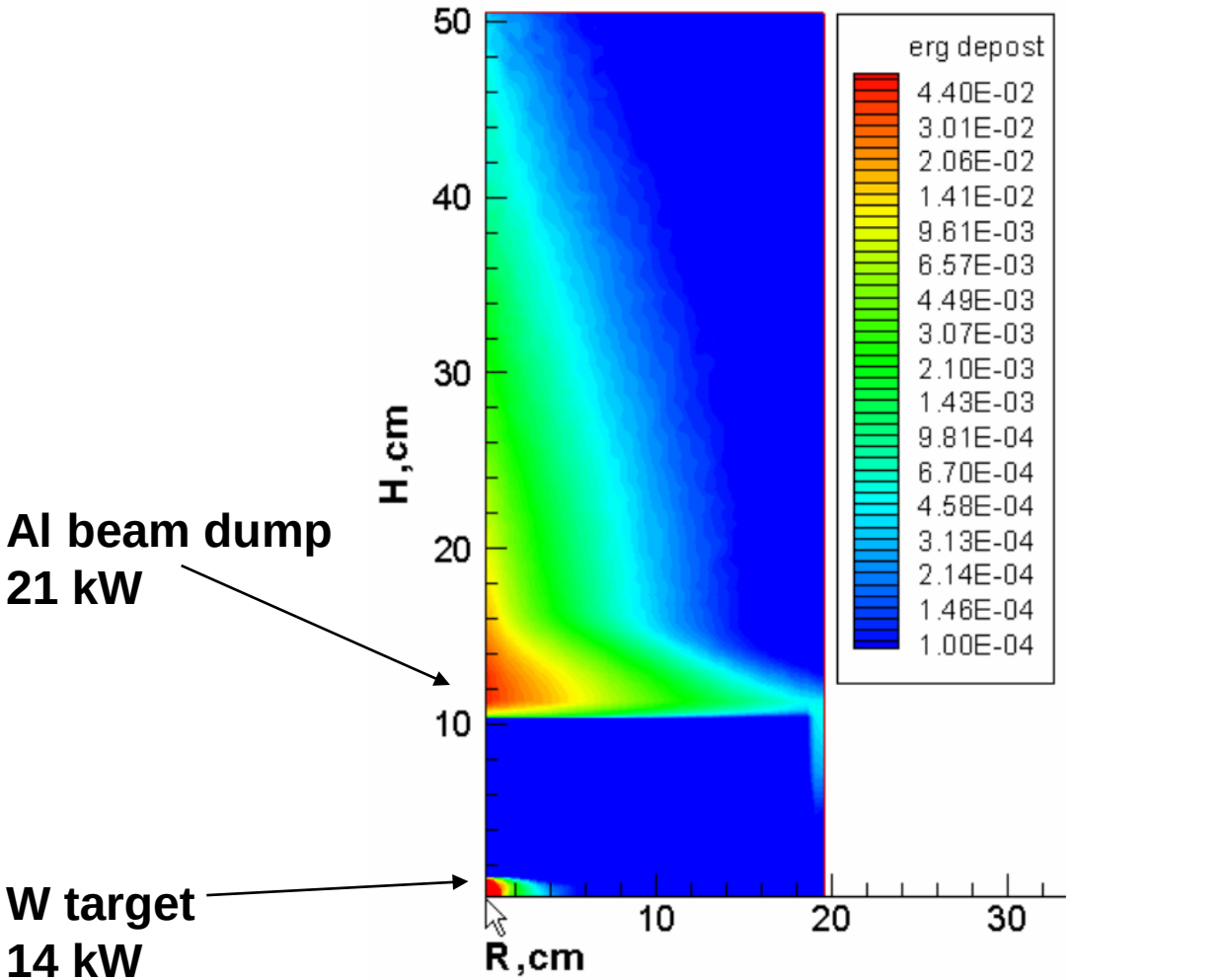
converter and beam dump



beam spot

October 2014

Simulation of Energy deposition

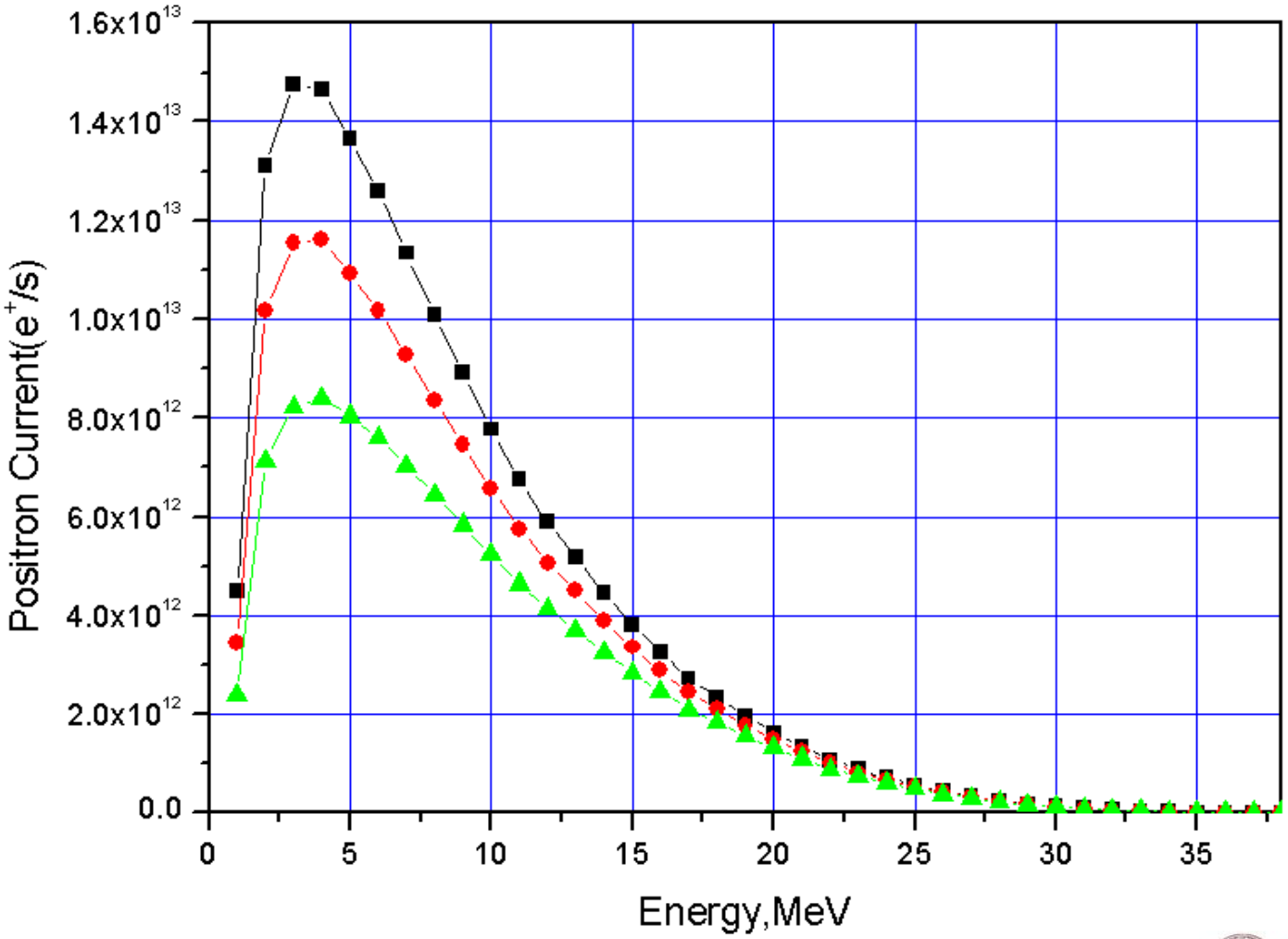


EPOS Density Energy Deposition (in MeV/cm^3) for Distance = 10cm

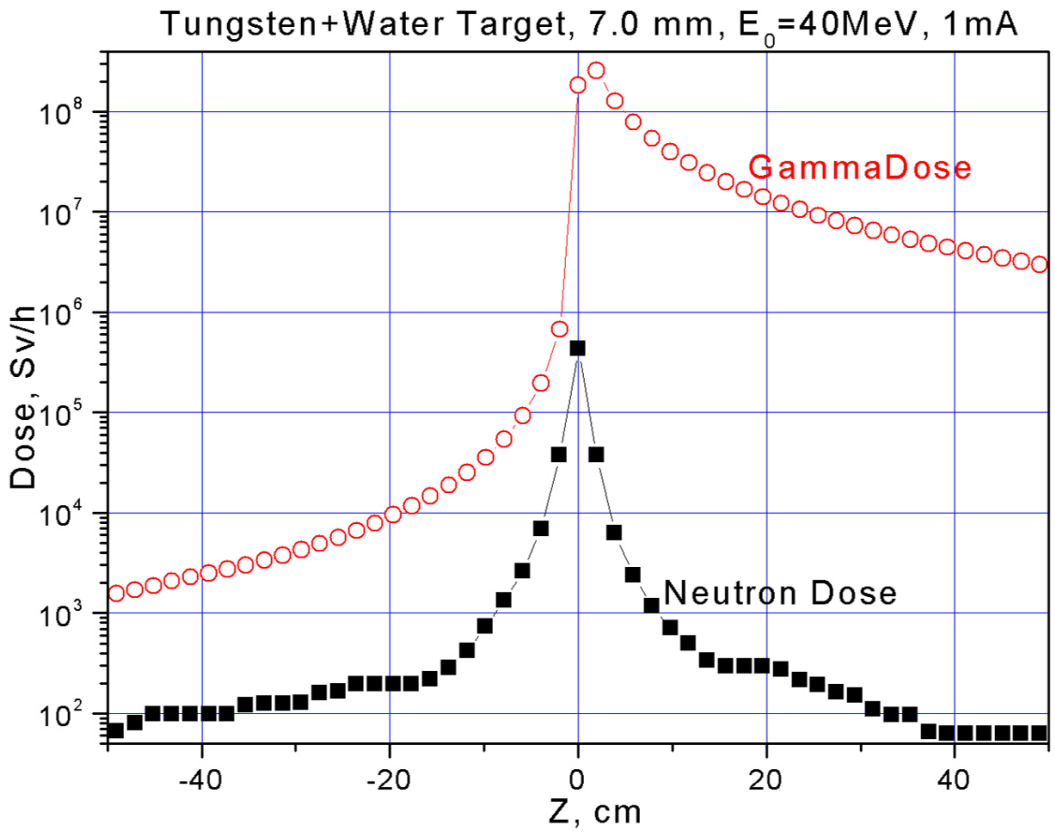
primary beam

Simulation of Positron Energy Distribution

primary electron beam 40 MeV

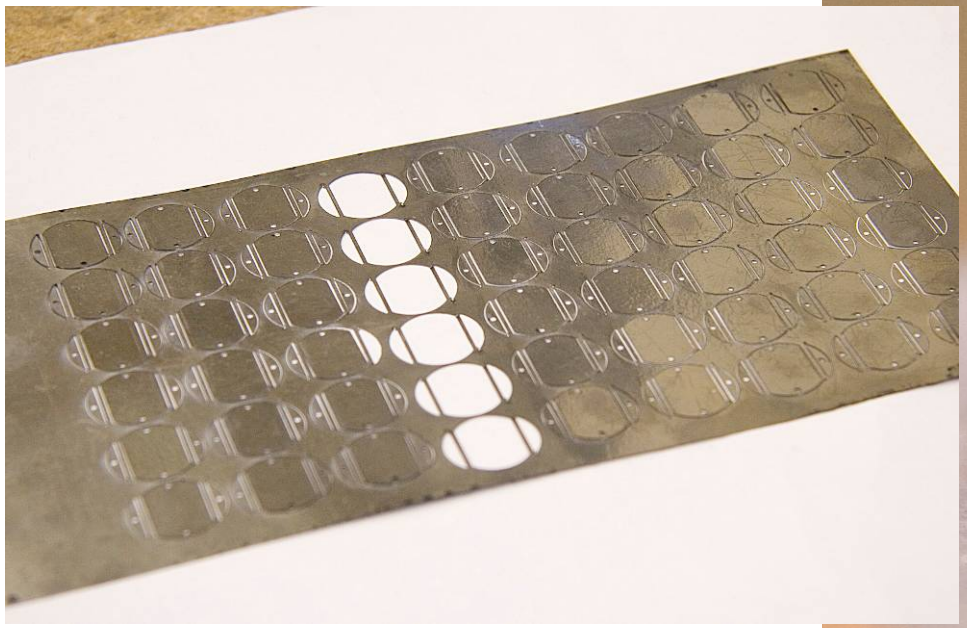


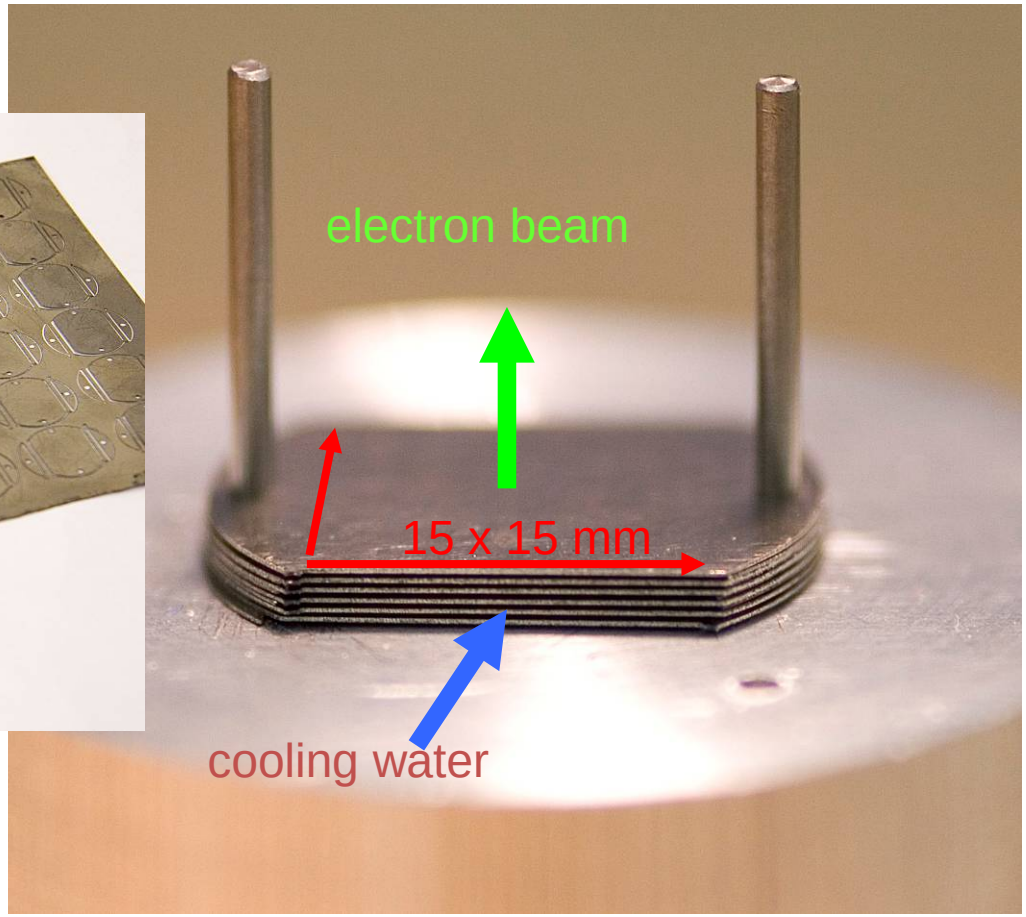
Kapton spectrum obtained at MePS



Directly water-cooled Electron-Positron Converter

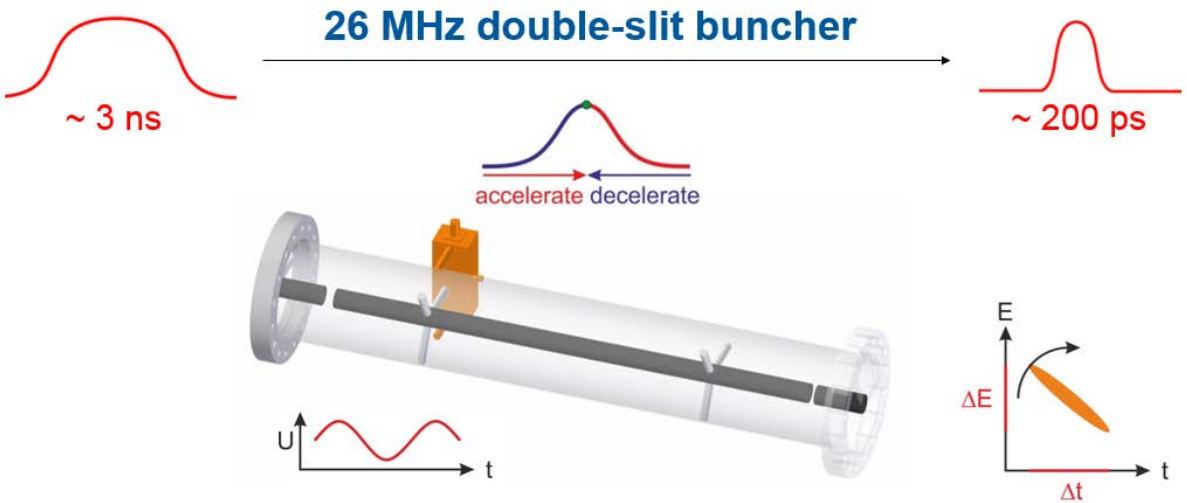
- stack of 50 pieces W-foils 0,1 mm separated by 0,1 mm -> 13,5 l water at 1,5 bar (10 bar maximum pressure)
- foils cut by IR-laser in our workshop

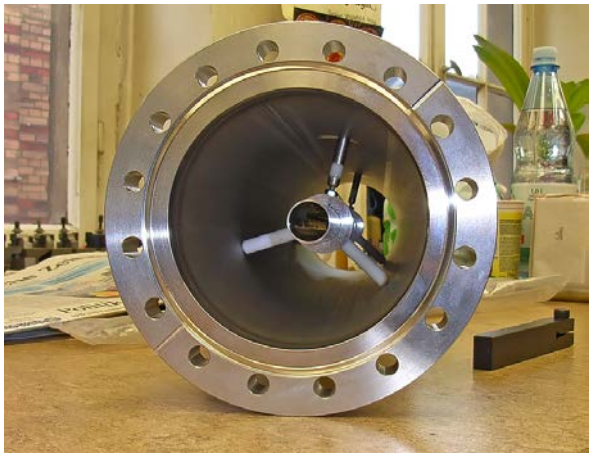


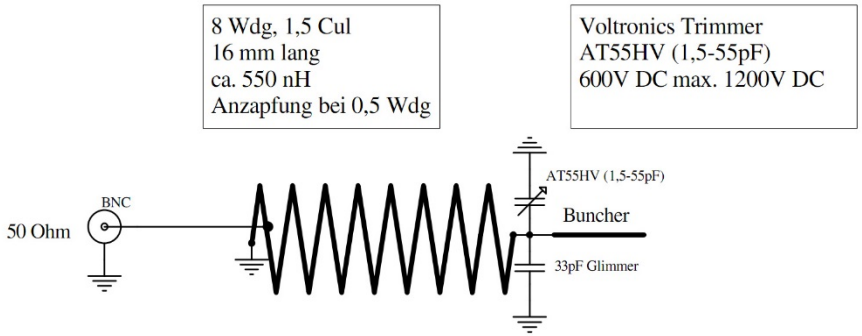


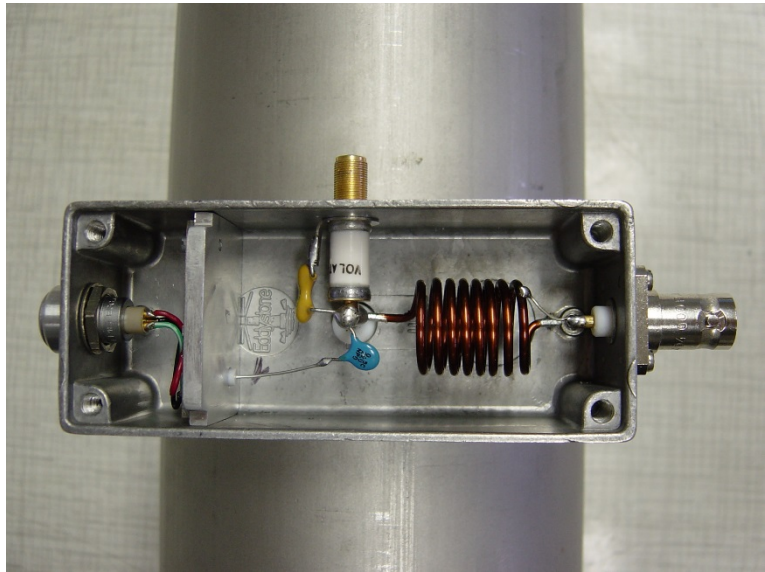
IR-Laser-beam cutting of W-foils

Double-Slit Buncher



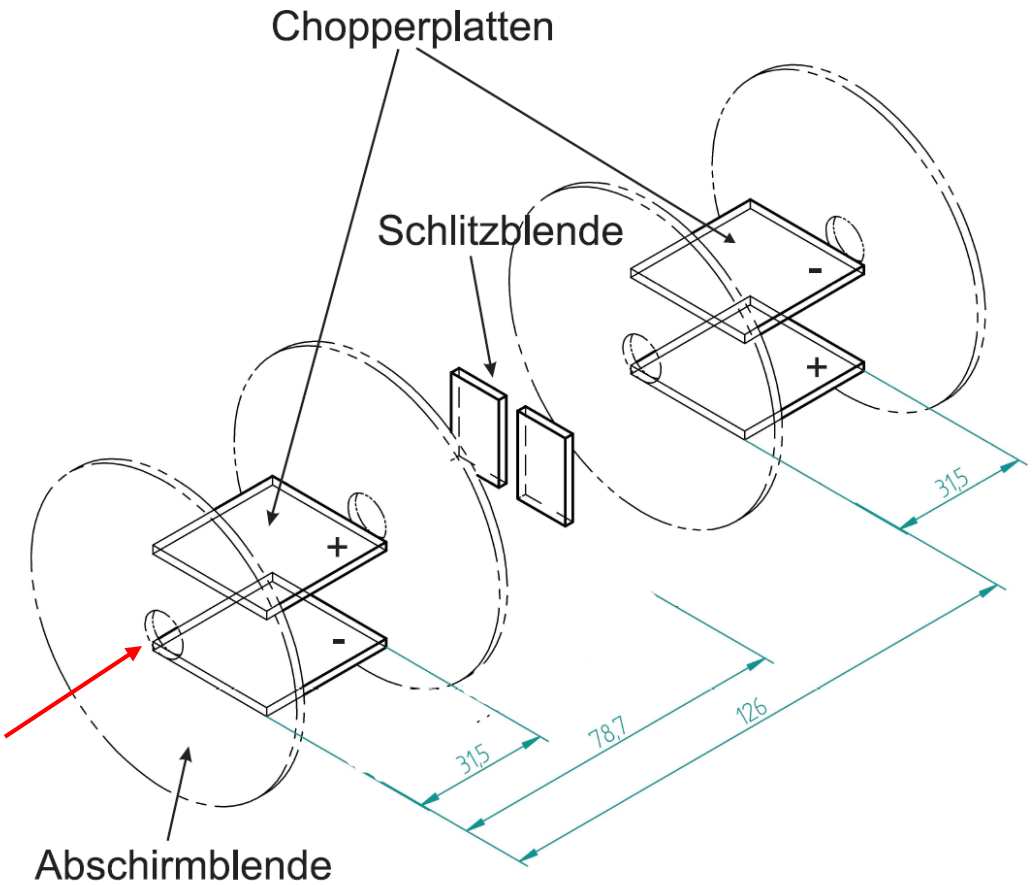


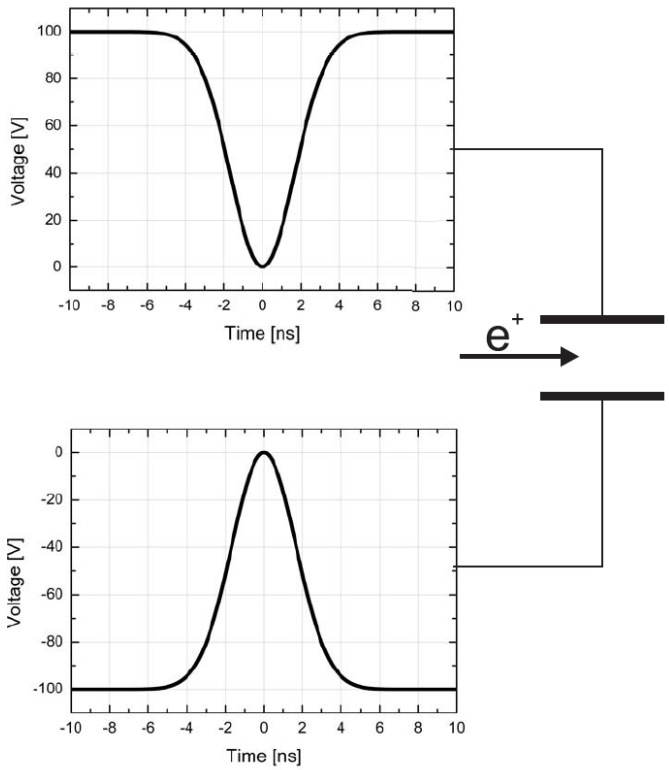




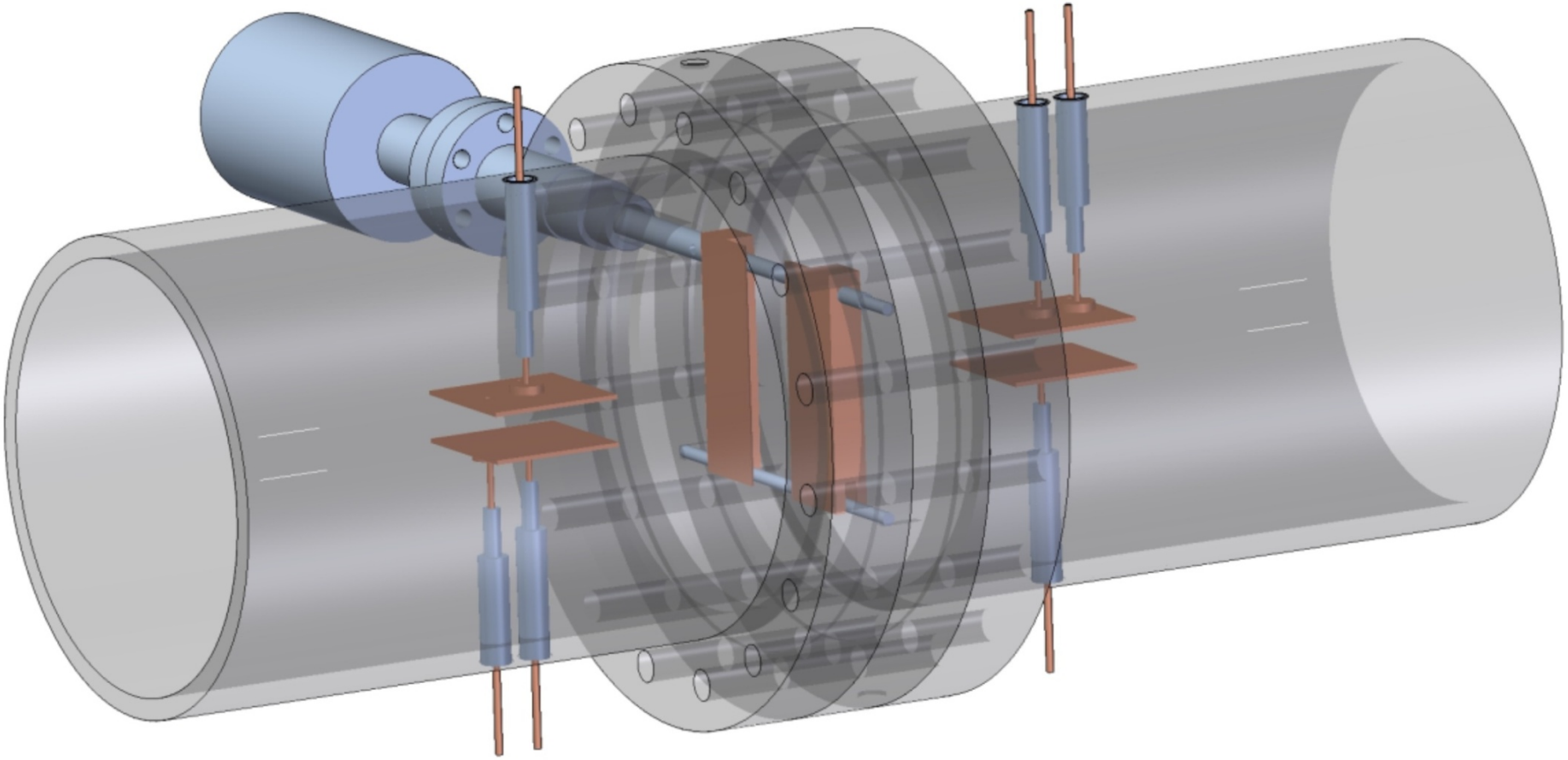
Chopper

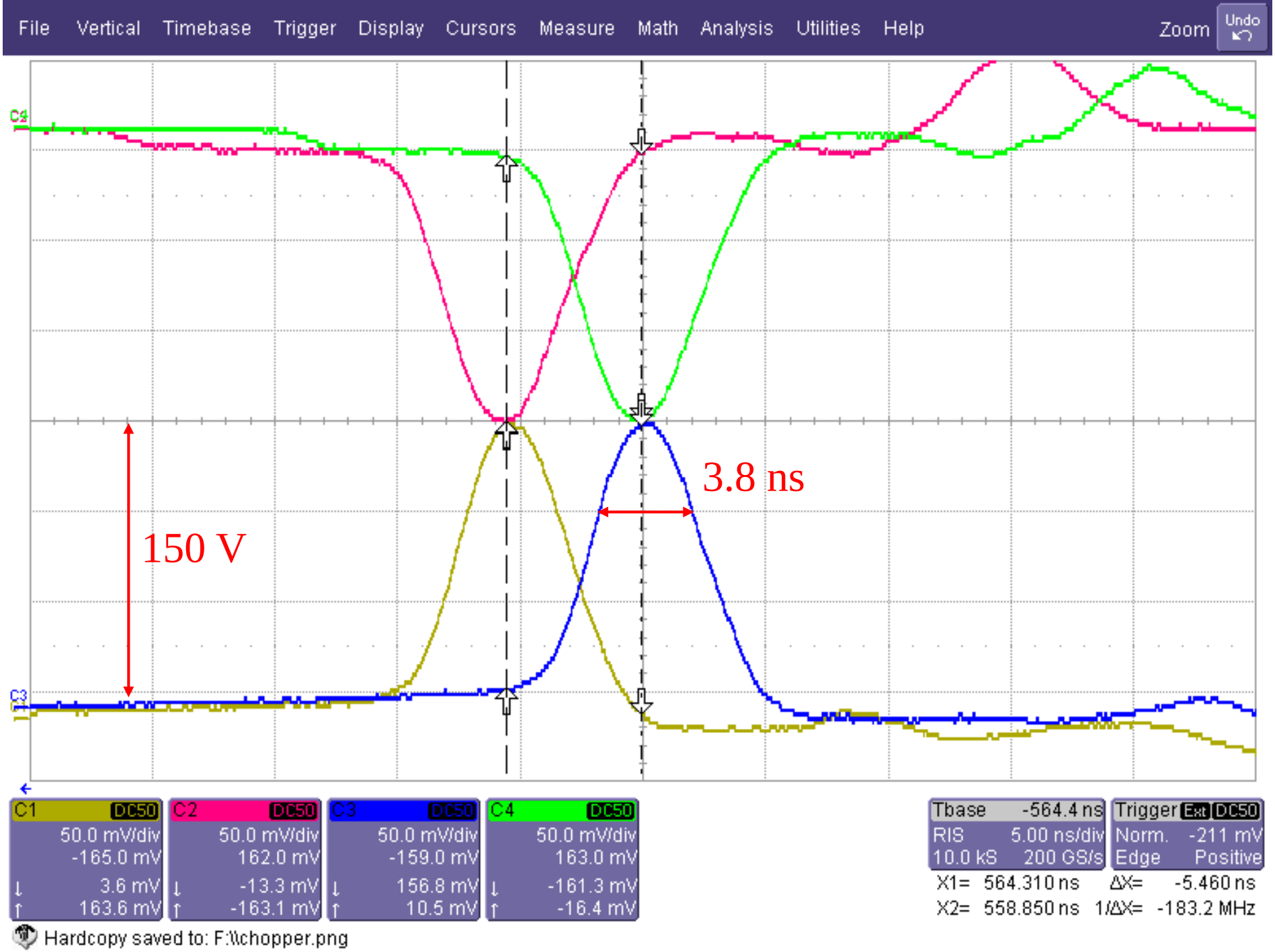
- Plate capacitor ≈ 1 pF
- 2 stages -> delay of e^+ bunch ≈ 5 ns
- bias voltage of ≈ 100V keeps the beam deflected -> chopper pulse kicks it in

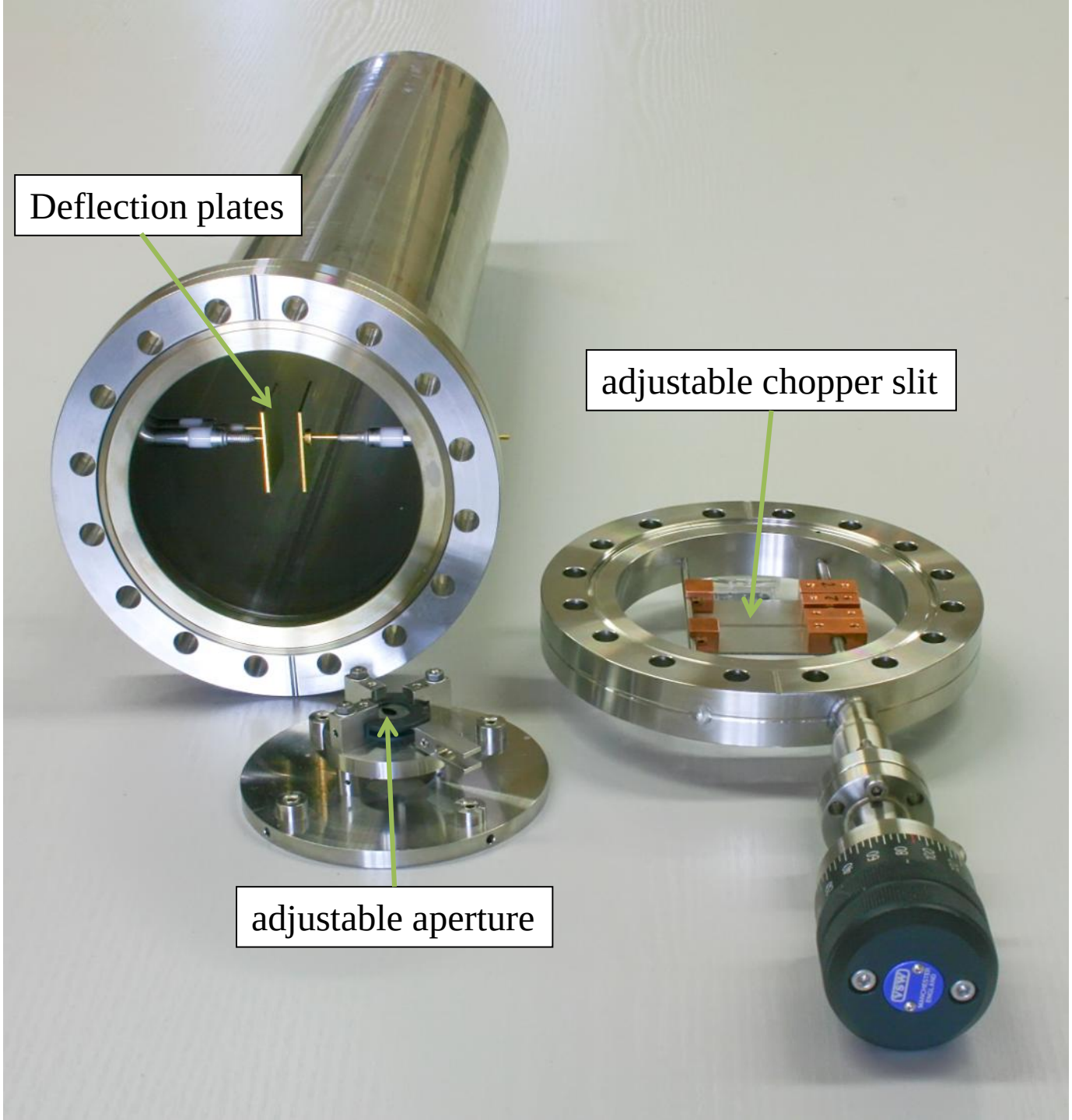




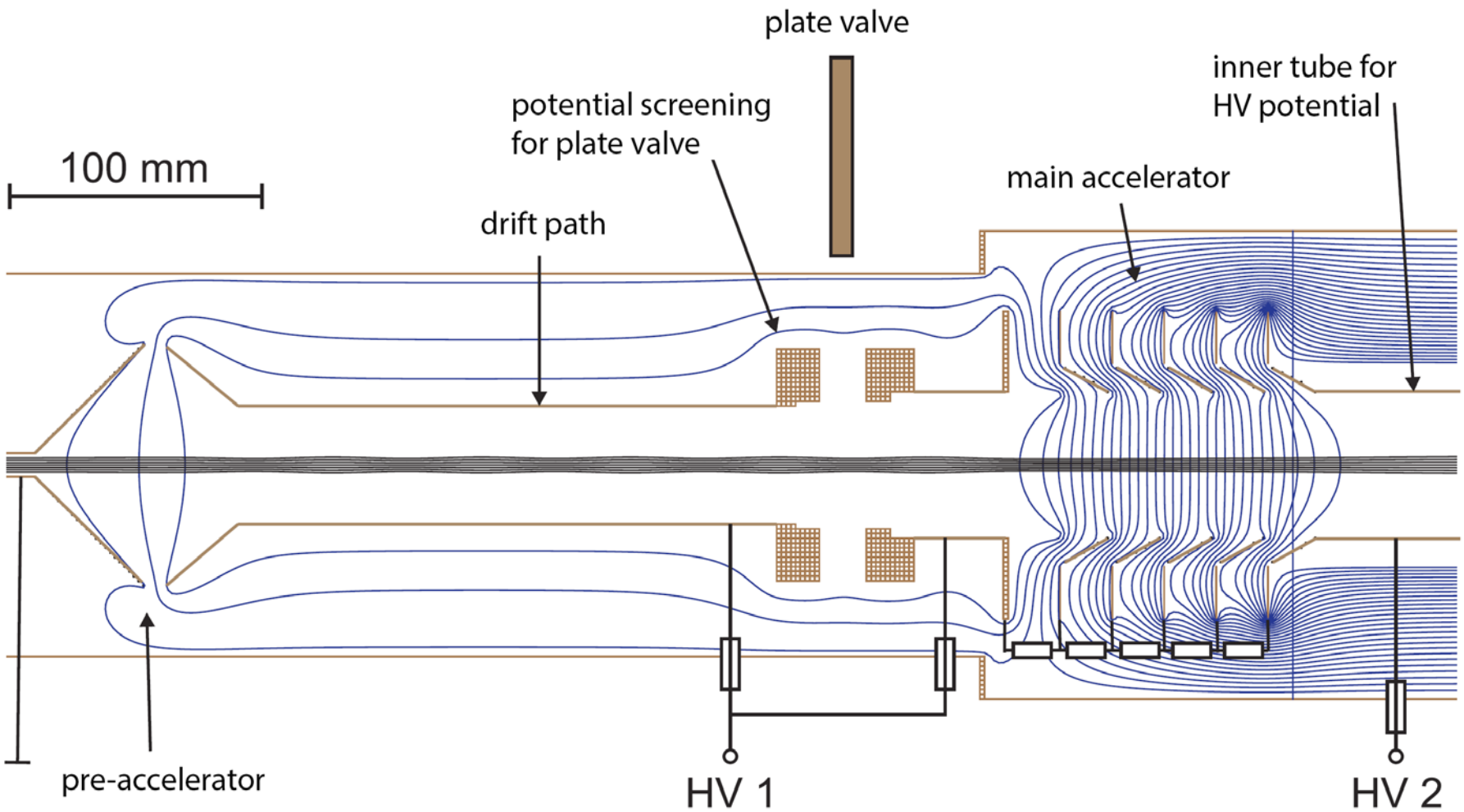
Chopper




File Vertical Timebase Trigger Display Cursors Measure Math Analysis Utilities Help
Zoom
Undo
C4
C3
150 V
3.8 ns
C1 DC50
50.0 mV/div
-165.0 mV
3.6 mV
163.6 mV
C2 DC50
50.0 mV/div
162.0 mV
-13.3 mV
-163.1 mV
C3 DC50
50.0 mV/div
-159.0 mV
156.8 mV
10.5 mV
C4 DC50
50.0 mV/div
163.0 mV
-161.3 mV
-16.4 mV
Tbase -564.4 ns
RIS 5.00 ns/div
10.0 kS 200 GS/s
Trigger Ext DC50
Norm. -211 mV
Edge Positive
X1= 564.310 ns ΔX= -5.460 ns
X2= 558.850 ns 1/ΔX= -183.2 MHz
Hardcopy saved to: F:\\chopper.png

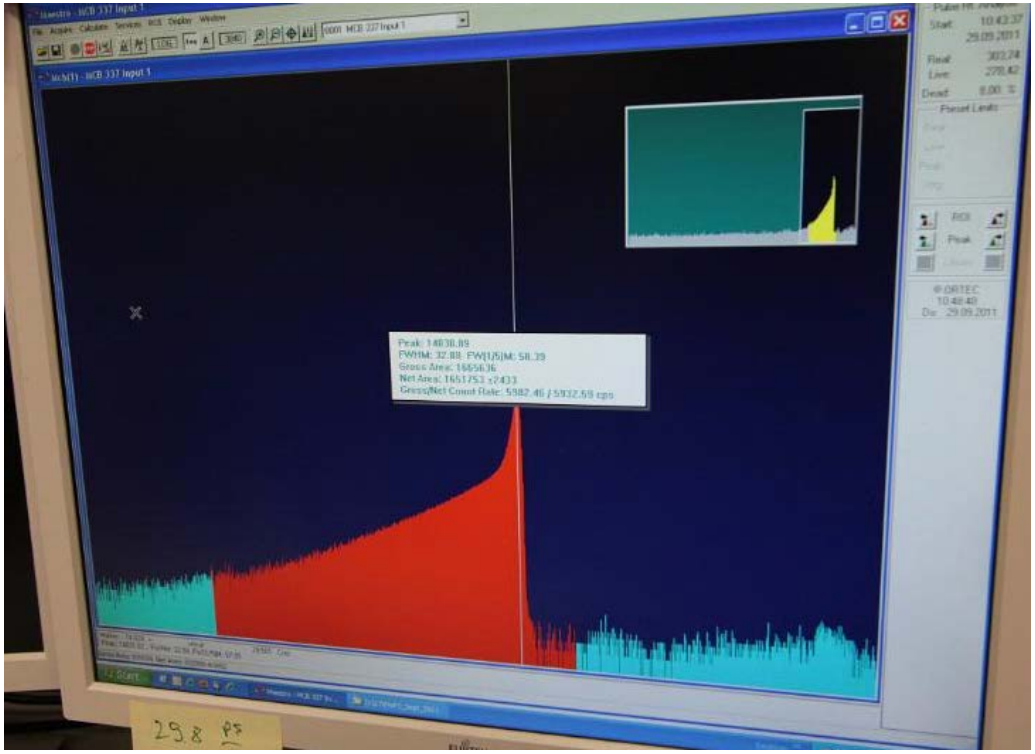

Deflection plates
adjustable chopper slit
adjustable aperture

Accelerator

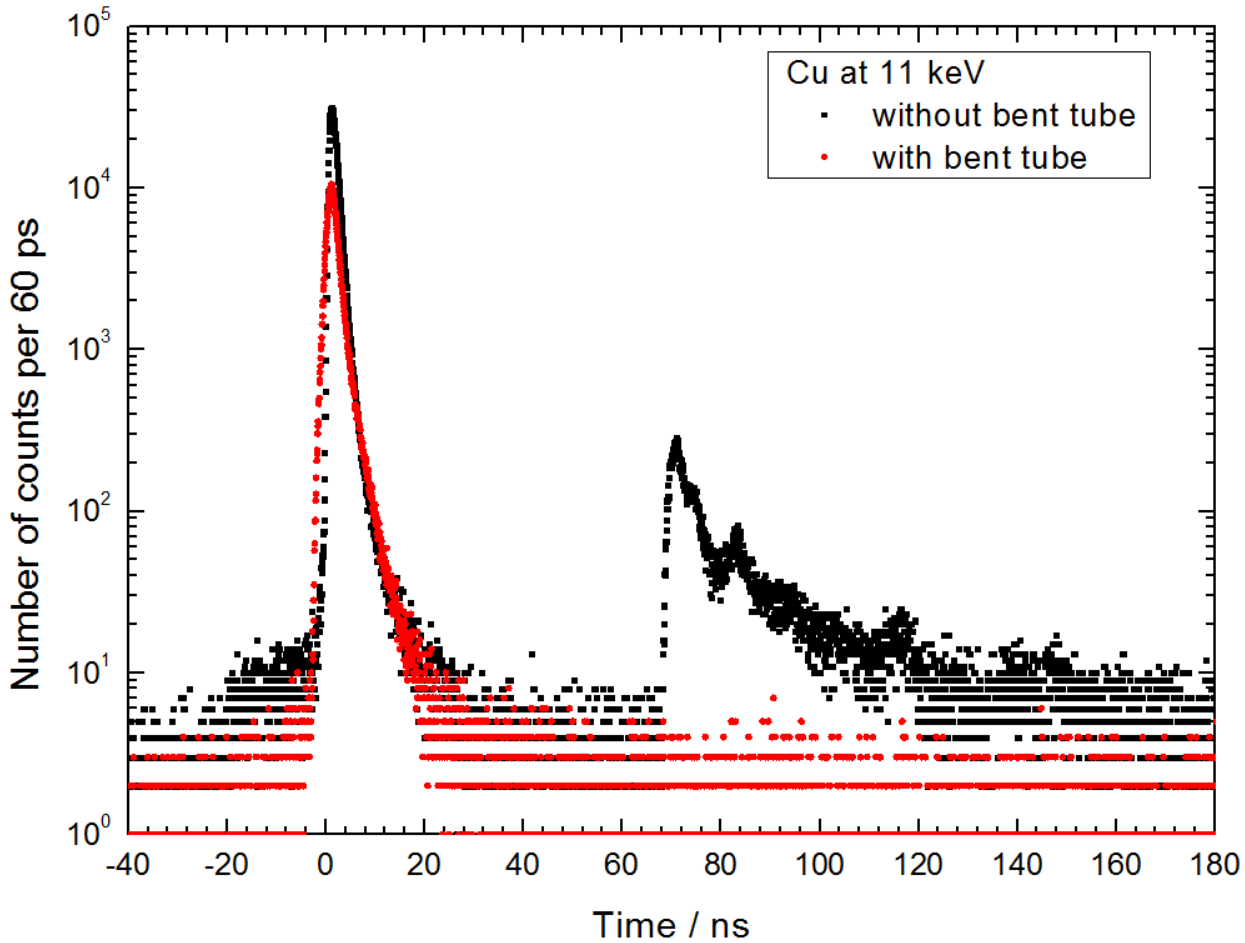


MePS characteristics

- Count rate @ 45 µA (1.35 kW): 30000 cps (maximum current 1 mA; in future 2 mA)
- time resolution today: 400 ps FWHM (but complex resolution function)
- signal-to-BG ratio: about 10^4
- no spurious signals
- user-dedicated facility – user operation started in 2013

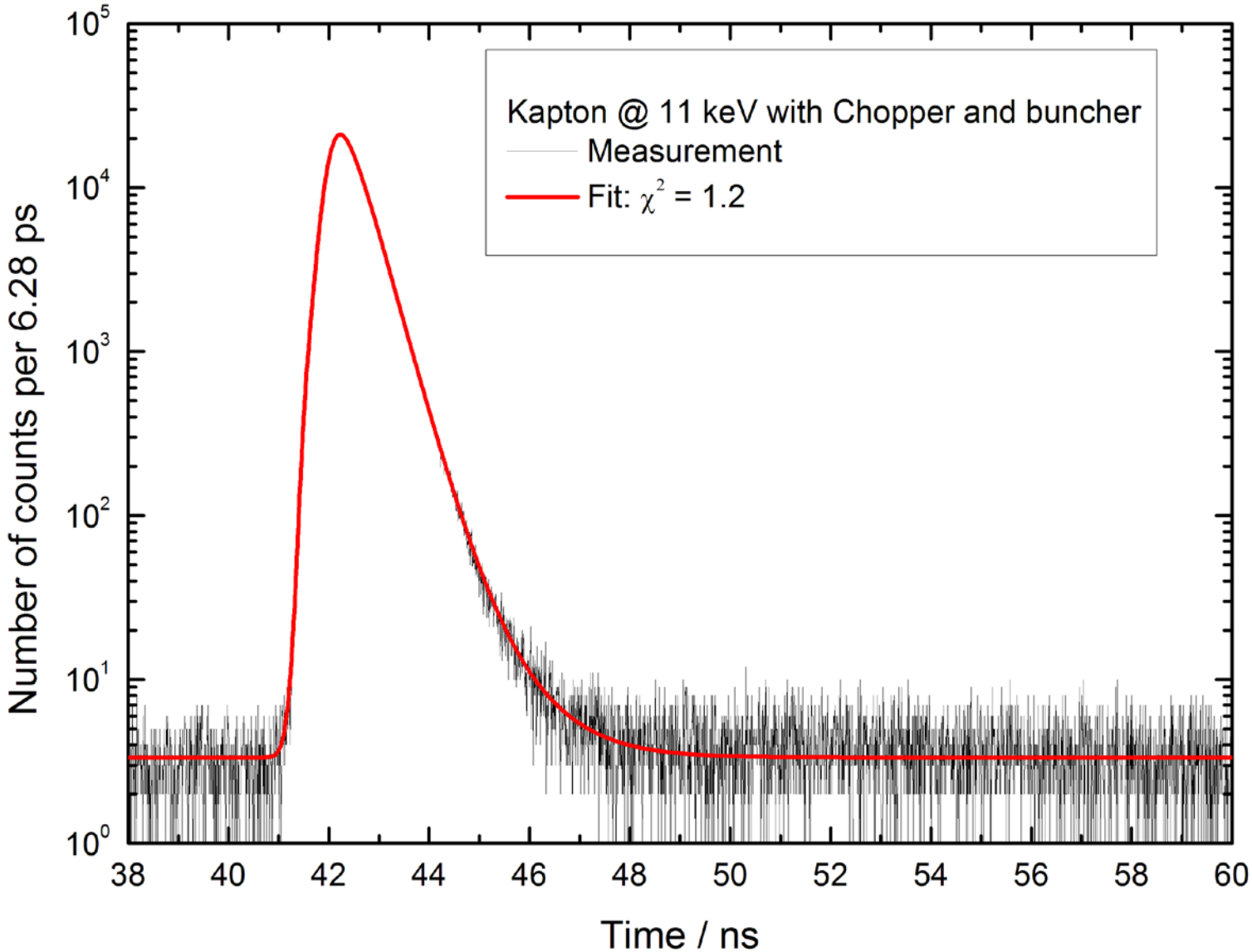


Effect of bent tube after accelerator



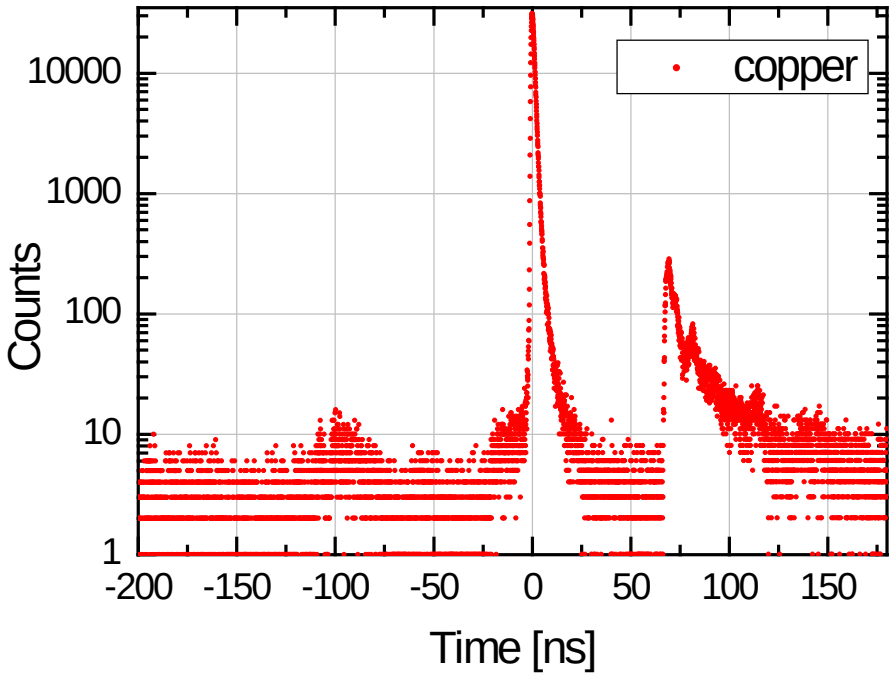
- reflected positrons are re-accelerated and have disastrous effect
- can be avoided by bent tube
- effect on resolution?

Kapton spectrum obtained at MePS

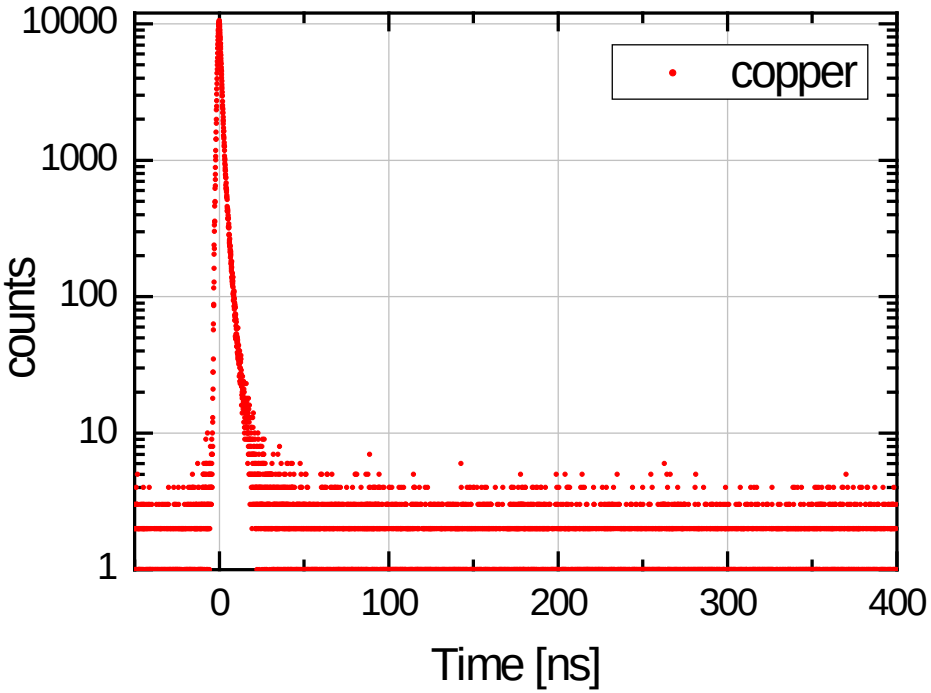


Avoid backscattered Positrons

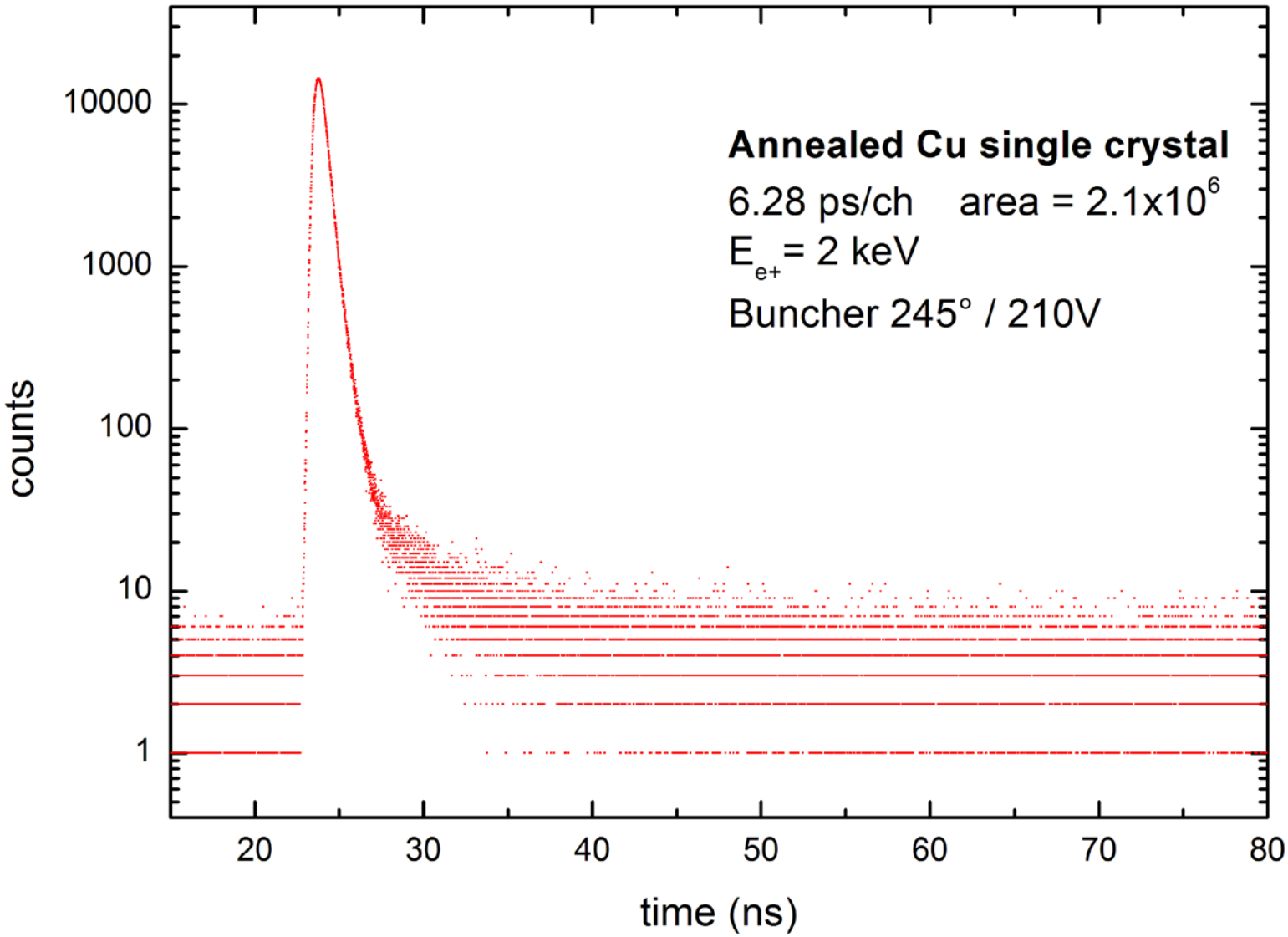
- straight beamline
- accelerator is on
- strong side peak due to re-acceleration of backscattered positron



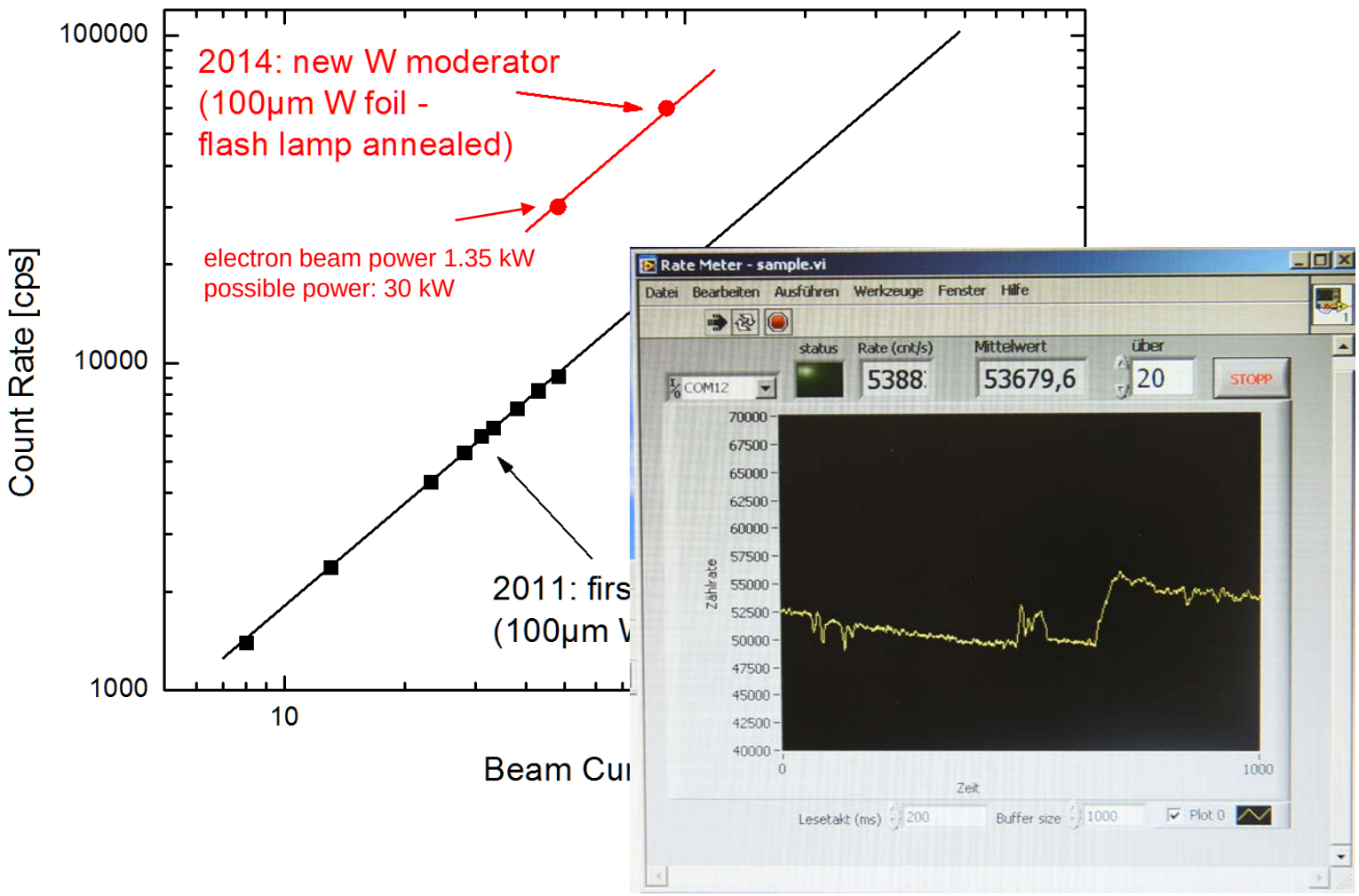
- bent beamline: 45°
- accelerator is on
- no side peaks
- less background ≈ 1 : 10^4
- still no chopper in use



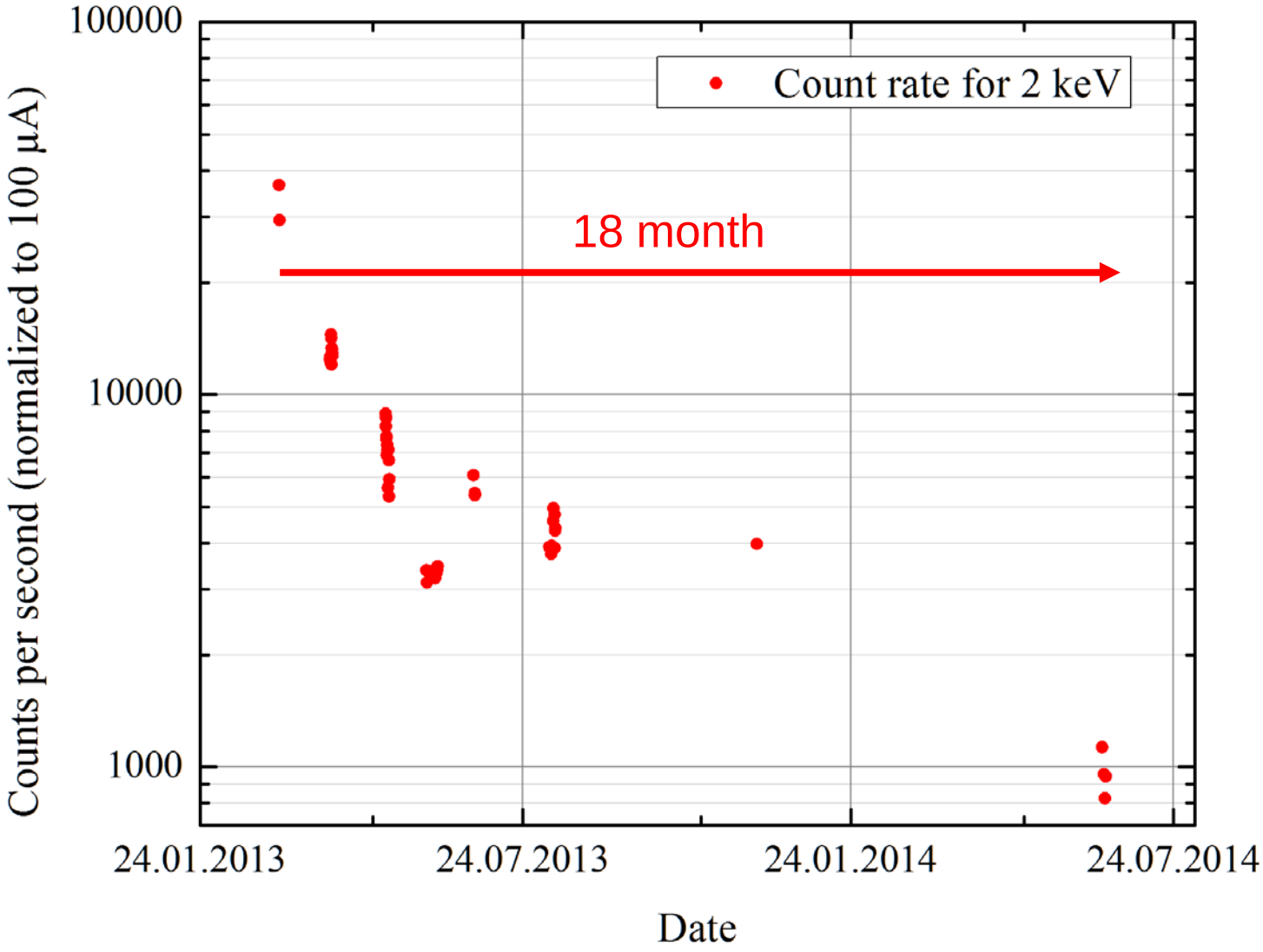
Cu spectrum obtained at MePS



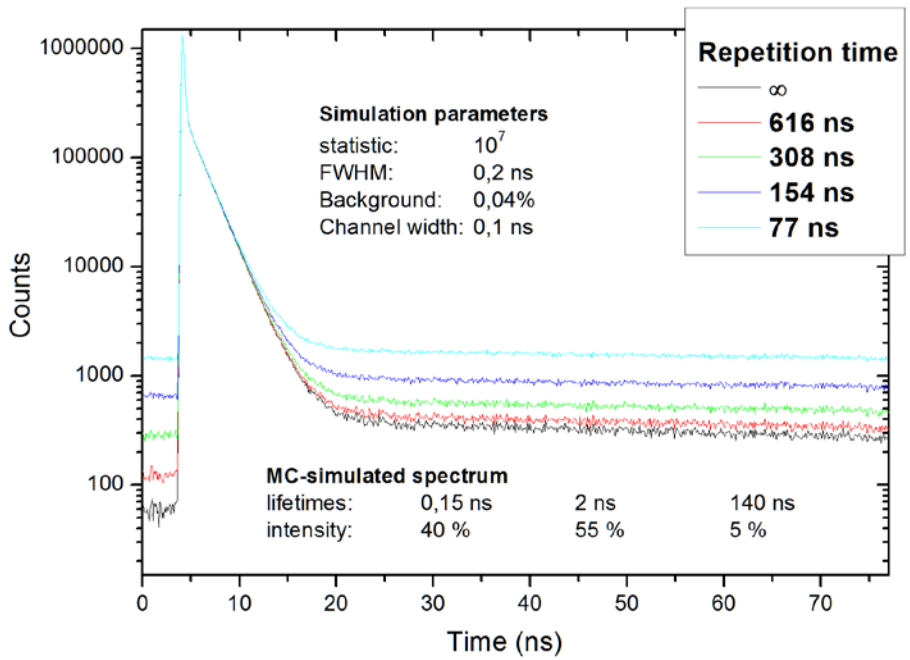
Count Rate


100000
10000
1000
10
Count Rate [cps]
Beam Cu
2014: new W moderator
(100µm W foil -
flash lamp annealed)
electron beam power 1.35 kW
possible power: 30 kW
2011: firs
(100µm V
Rate Meter - sample.vi
Datei Bearbeiten Ausführen Werkzeuge Fenster Hilfe
status
Rate (cnt/s)
Mittelwert
über
COM12
5388
53679,6
20
STOPP
70000
67500
65000
62500
60000
57500
55000
52500
50000
47500
45000
42500
40000
Zählrate
0
1000
Zeit
Lesetakt (ms)
200
Buffer size
1000
Plot 0

Deterioration of first W Moderator



Necessary Repetition Time to measure 142 ns



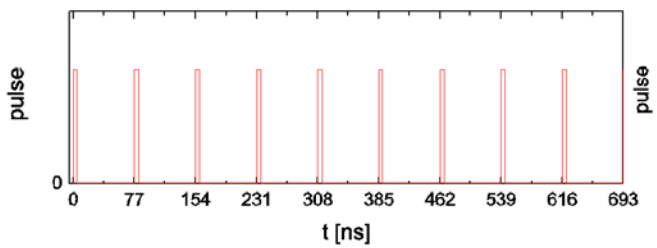
- MC simulated lifetime spectra with 140 ns / 5%
- positrons survive from earlier bunches

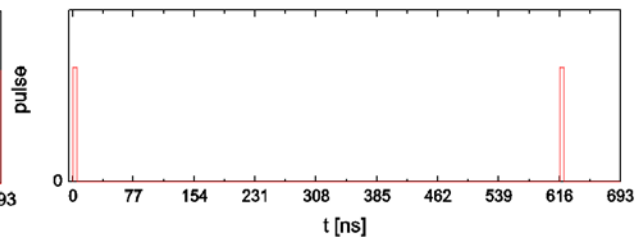
Repetition Time (ns)	Lifetime Component τ_3 (ns)	Intensity I_3 (%)
77	35	1.7
154	75	3.3
308	124	4.9
616	141	5.1
∞	140	5.0

- lifetime analysis with LT 9
- 616 ns repetition time is sufficient

… special Capability for Positronium Lifetime Spectroscopy

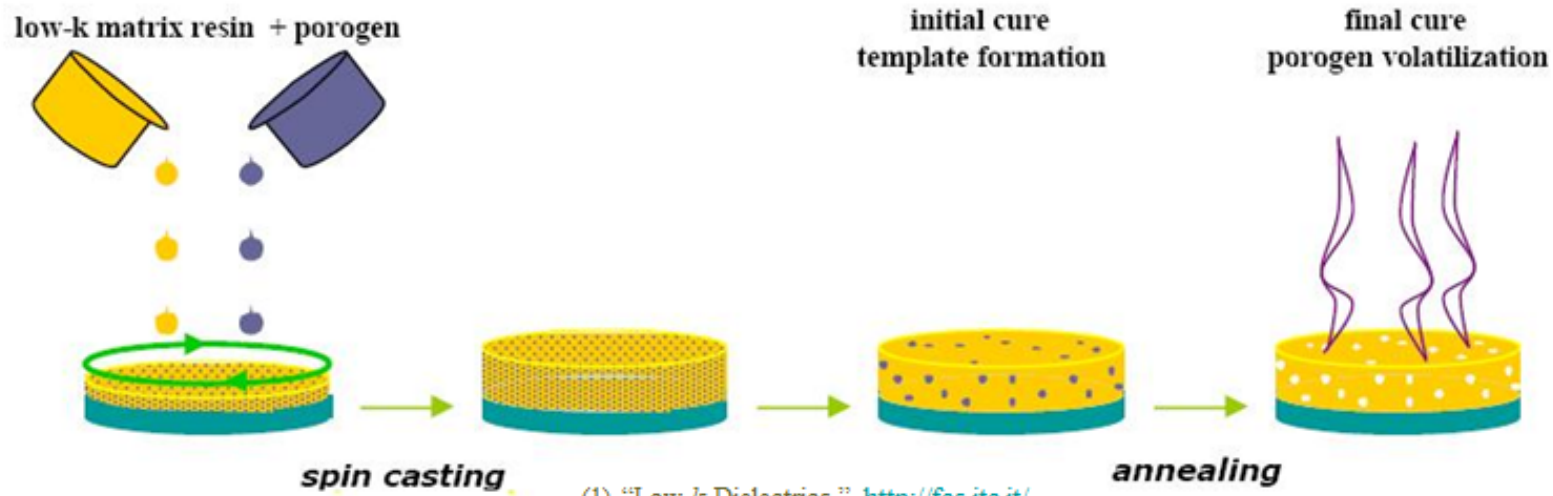
- ELBE is able to operate in cw mode with 13 MHz and a bunch charge of 77 pC
  - future plan at ELBE: increase of bunch charge to 123 pC at 40 MeV
- results at E_{-}=30 MeV in 30 kW beam power (in future 64 kW)
- we need only ≈ 2 kW beam power for ≈ 50 kcps
- thus: we can use
  - 1,625 MHZ = 616 ns repetition time at 8 kW cw beam power or
  - 0,812 MHz = 1.23 μs at 4 kW





- Conclusion: full count rate at very long repetition times
- with 616 μs -> > 10^5 cps expected
- ideal for Positronium Lifetime Spectroscopy

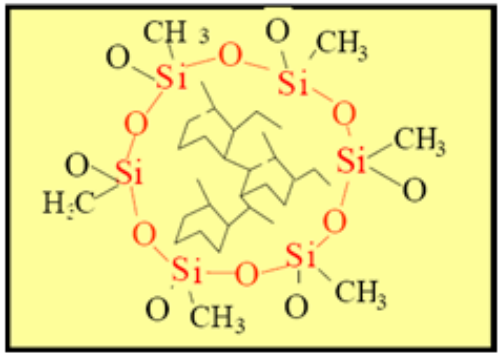
MePS: Study of low-k dielectric films



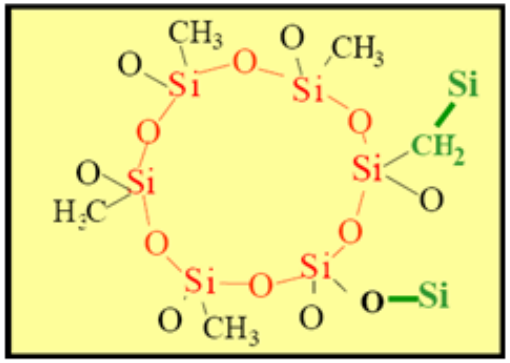
(1) "Low-*k* Dielectrics." http://fcs.itc.it/

800 nm

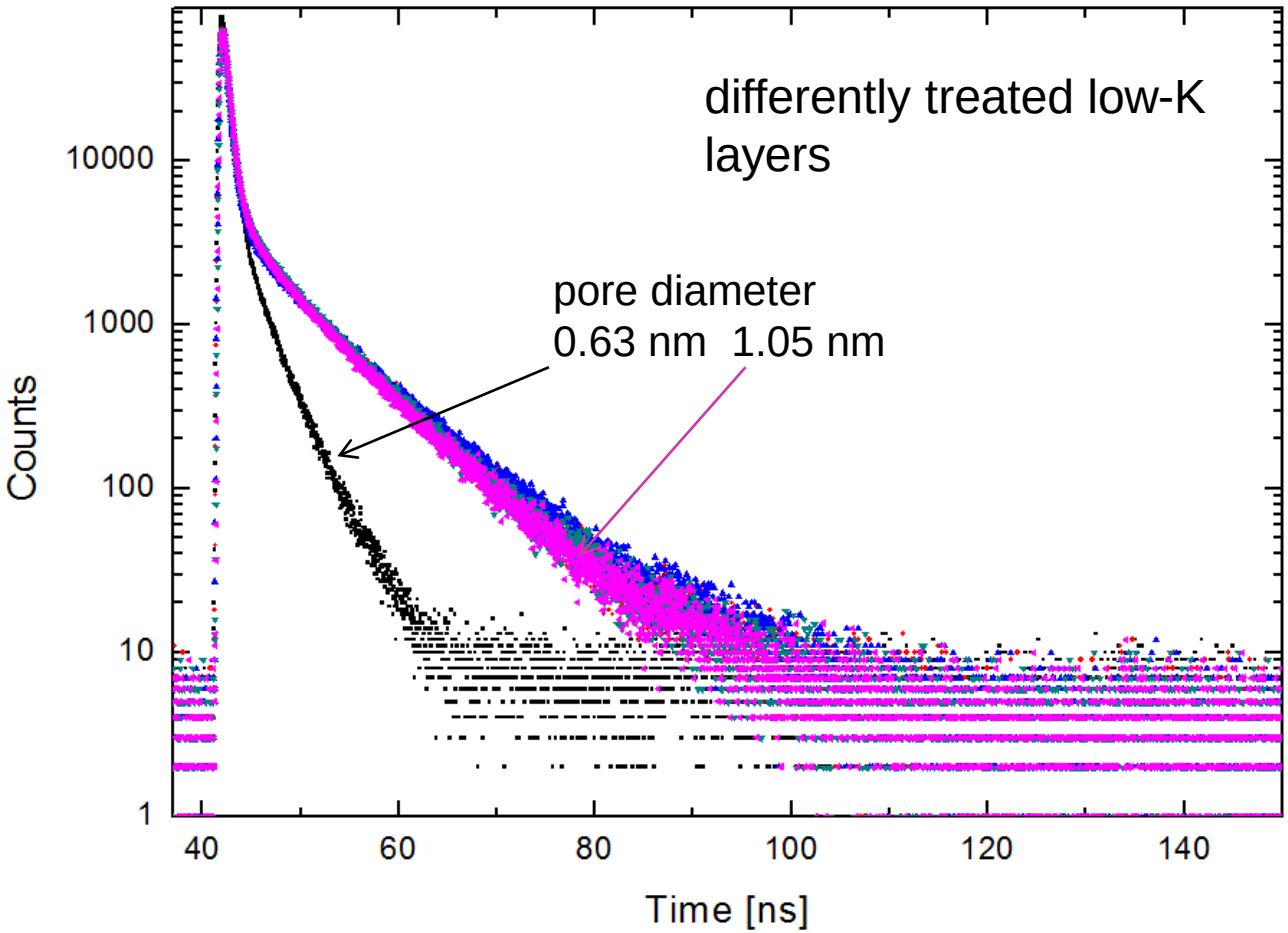
CDO Matrix (SiOCH) + Porogen (C_xH_y)



UVTP – Ultraviolet Thermal Processing

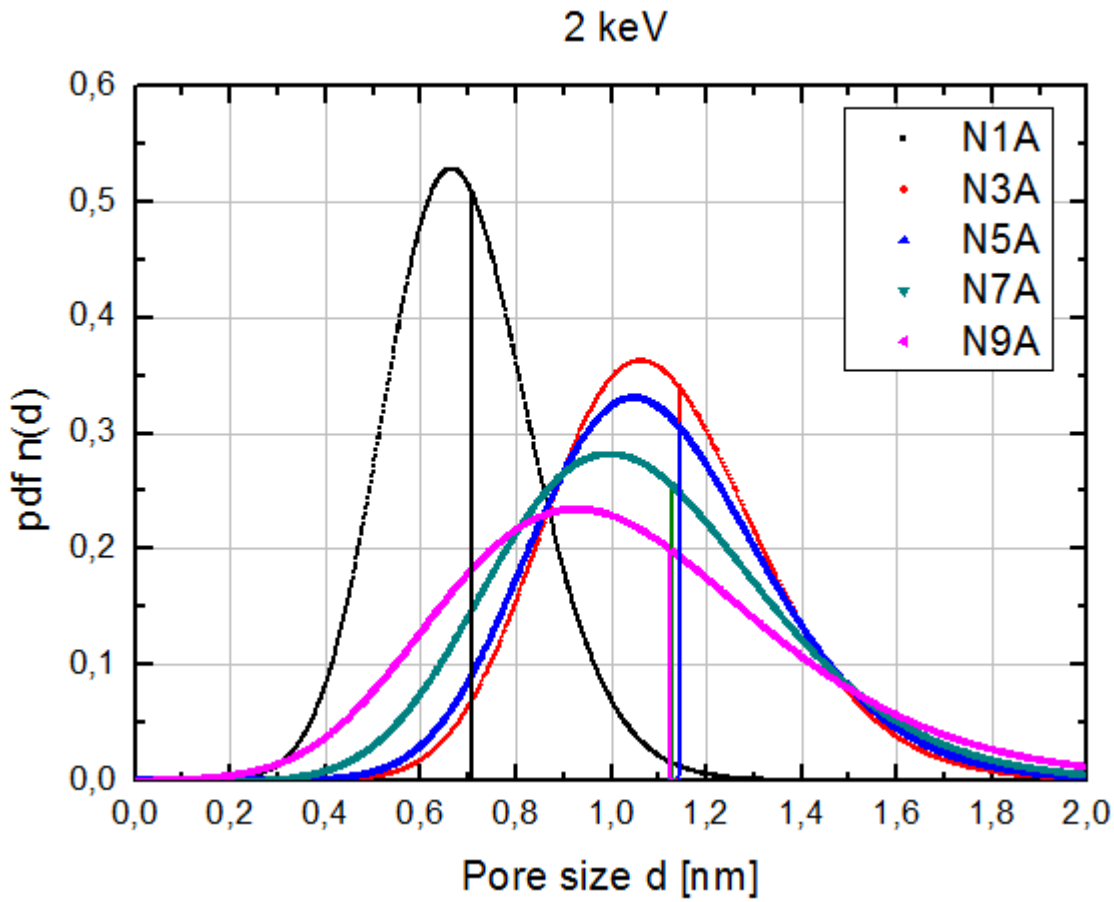


Low-K dielectric layers



- Positrons are ideal tool for closed porosity in low-k layers
- Lifetime spectra of differently treated low-K layers
- Treatment:
  - untreated porous layer
  - plasma treatment for compactation
  - TiN cap layer

Low-K dielectric layers



- dispersion of lifetime gives the size distribution of the pore system

Conclusion

- MePS as part of EPOS is already now useful tool for porosimetry
- high counting rate: 30000 cps @ 1,3 kW electron beam power
- spectra free of spurious signals and 10^4:1 Peak-to-BG
- problem of backscattered positrons solved by bended beam tube

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

Thanks for your attention!

Collaborators

University Halle

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T. E. Cowan

P. Michel

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A. Wagner

many more ….

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

HZDR Dresden-Rossendorf 9.-11. September 2015

Workshop

Methods of Porosimetry and Applications

The workshop will treat aspects of the different methods of porosimetry, such as N_2-Adsorption, Hg intrusion, SAXS, SANS and Positron Annihilation. Tutorial talks will be given about these topics. The limitations and possible applications of these techniques will be discussed. The workshop will be organized at the Institute of Radiation Physics at HZDR.

Dr. A. Wagner

Prof. D. Enke

Prof. R. Krause-Rehberg

Helmholtz-Zentrum Dresden-Rossendorf

UNIVERSITÄT LEIPZIG

Martin-Luther-Universität Halle-Wittenberg