News of the EPOS Project at the ELBE Radiation Source in the Research Center Dresden-Rossendorf

EPOS-Team & R. Krause-Rehberg

- Extended Concept of EPOS
- Progress of the mono-energetic Positron Beam (MePS)
- Gamma-induced Positron Spectroscopy (GiPS)
- Digital detector system

Friedrich-Schiller-Universität Jena

Workshop Ionenstrahlphysik
6. - 8. April 2009

Martin-Luther-University Halle

Extended Concept of EPOS (ELBE Positron Source)

MePS

Mono**e**nergetic **P**ositron **S**pectroscopy

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

Information Depth: 0…5 µm

CoPS

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

- LT, CDBS, AMOC
- using ^{22}Na foil sources
- He-cryostat
- automated system
- digital detector system

Information Depth: 10…200 µm

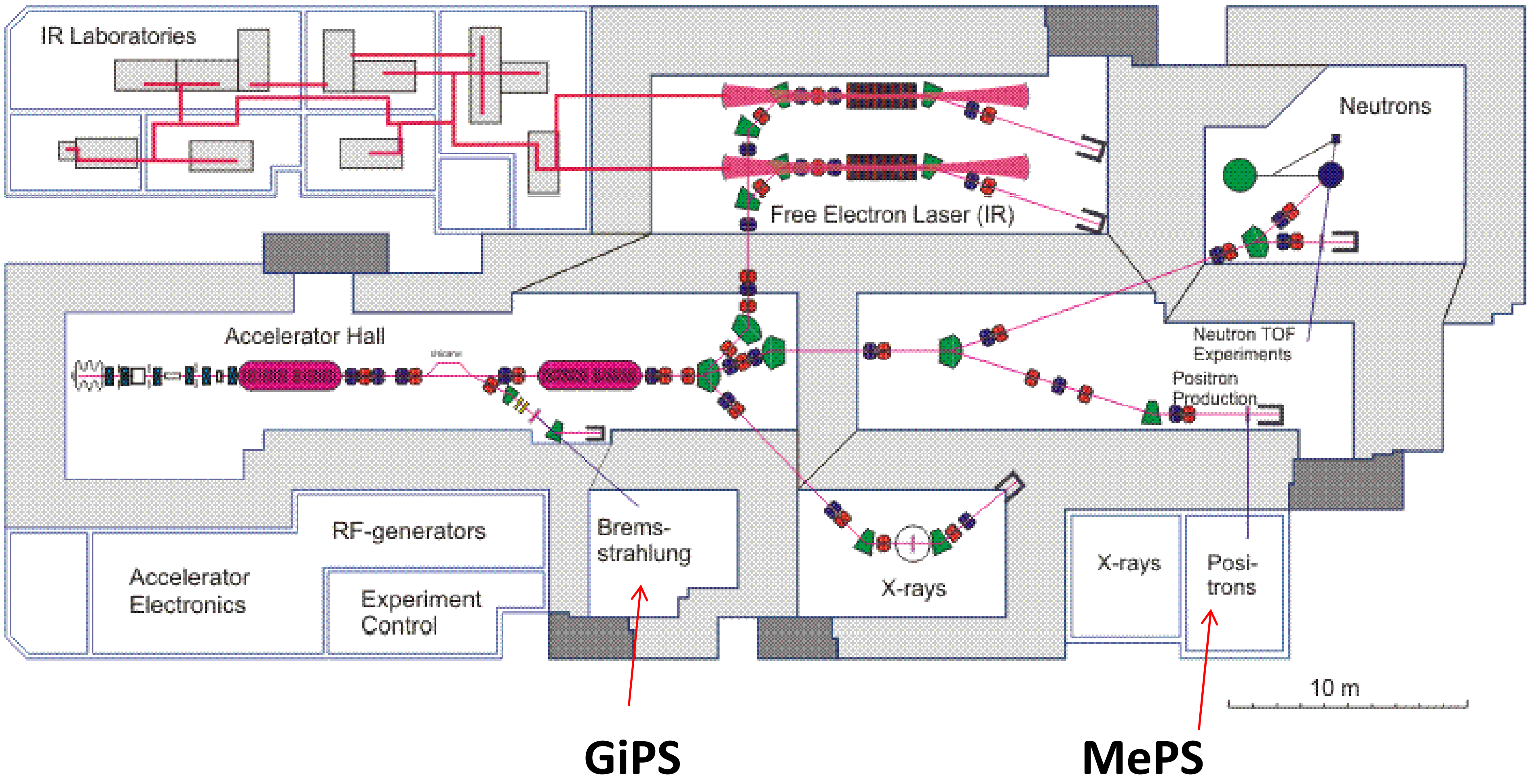
GiPS

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

- Cave 109 (nuclear physics)
- Positron generation by Bremsstrahlung
- Information in complete bulky sample (up to 100 cm^3)
- all relevant positron techniques (LT, CDBS, AMOC)

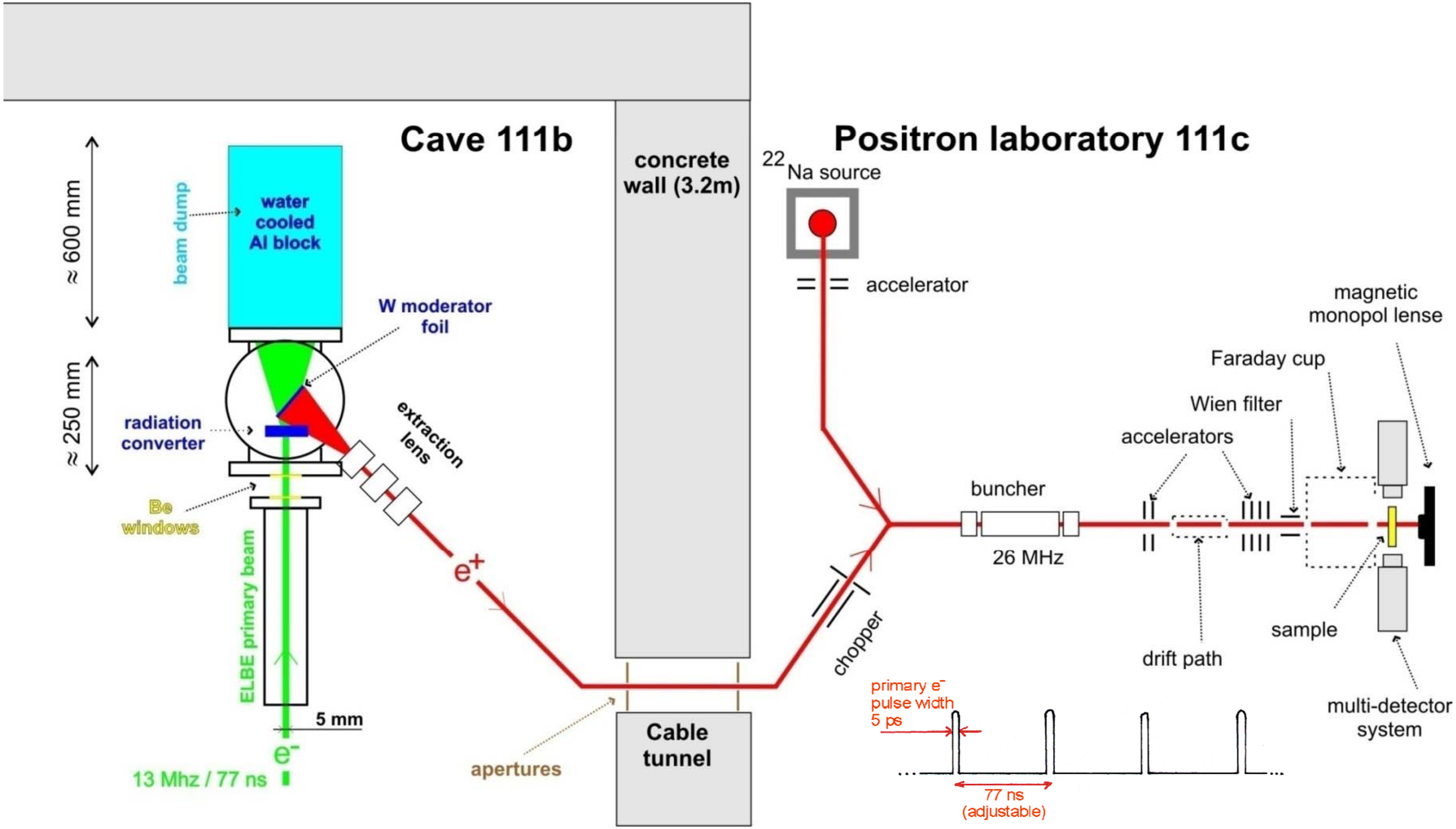
Information Depth: 0.1 mm …5 cm

Ground plan of the ELBE hall

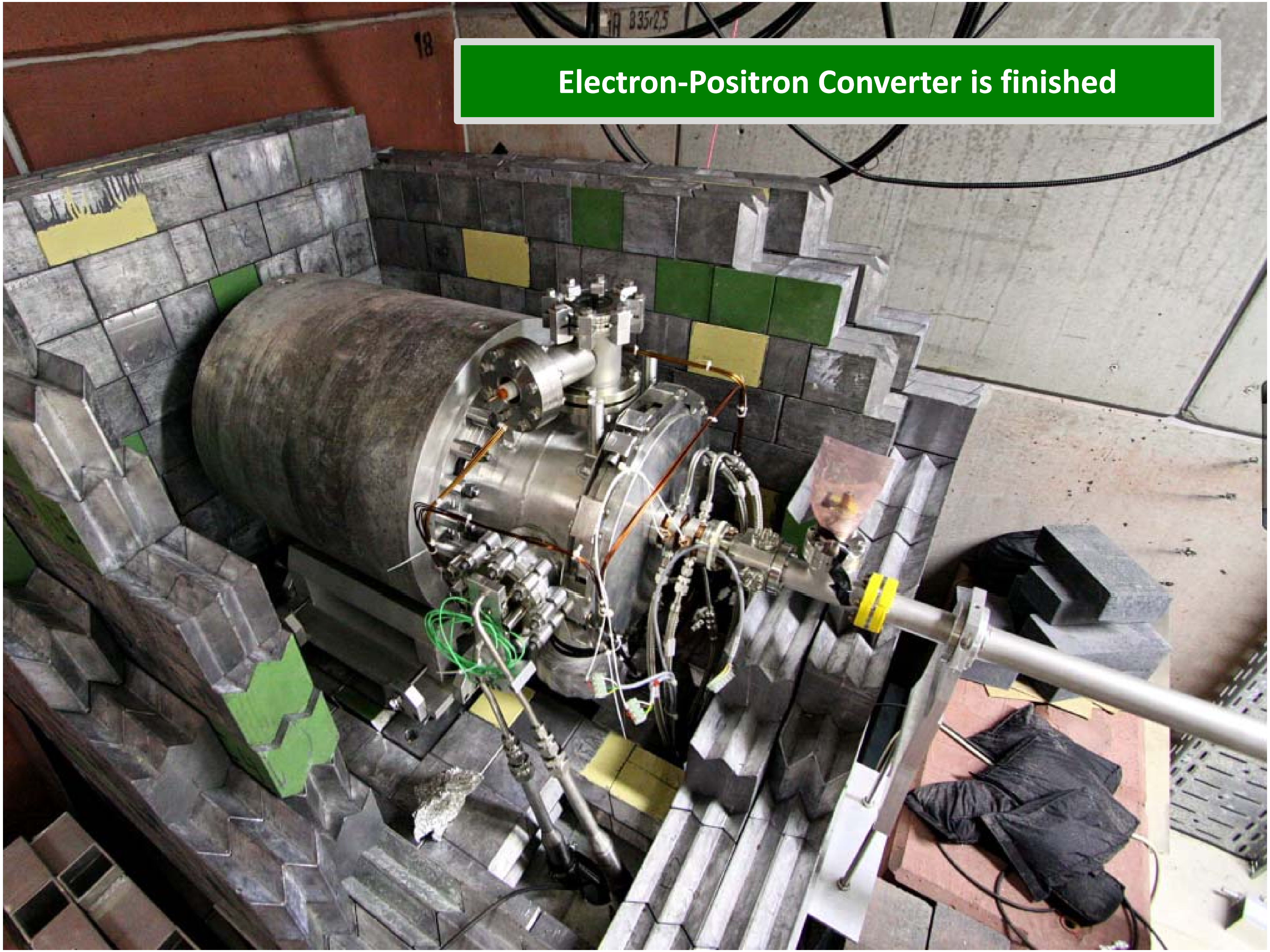


Progress of Mono-energetic Positron Beam

- 40 MeV, 1 mA, 26 MHz repetition time in cw mode; lifetime, CDBS and AMOC with slow e^+
- Retain original time structure for simplicity and best time resolution

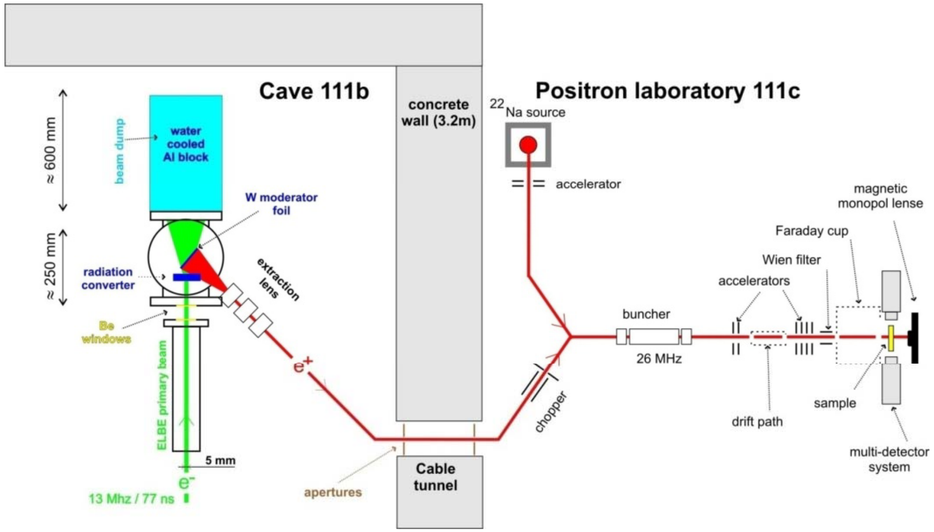


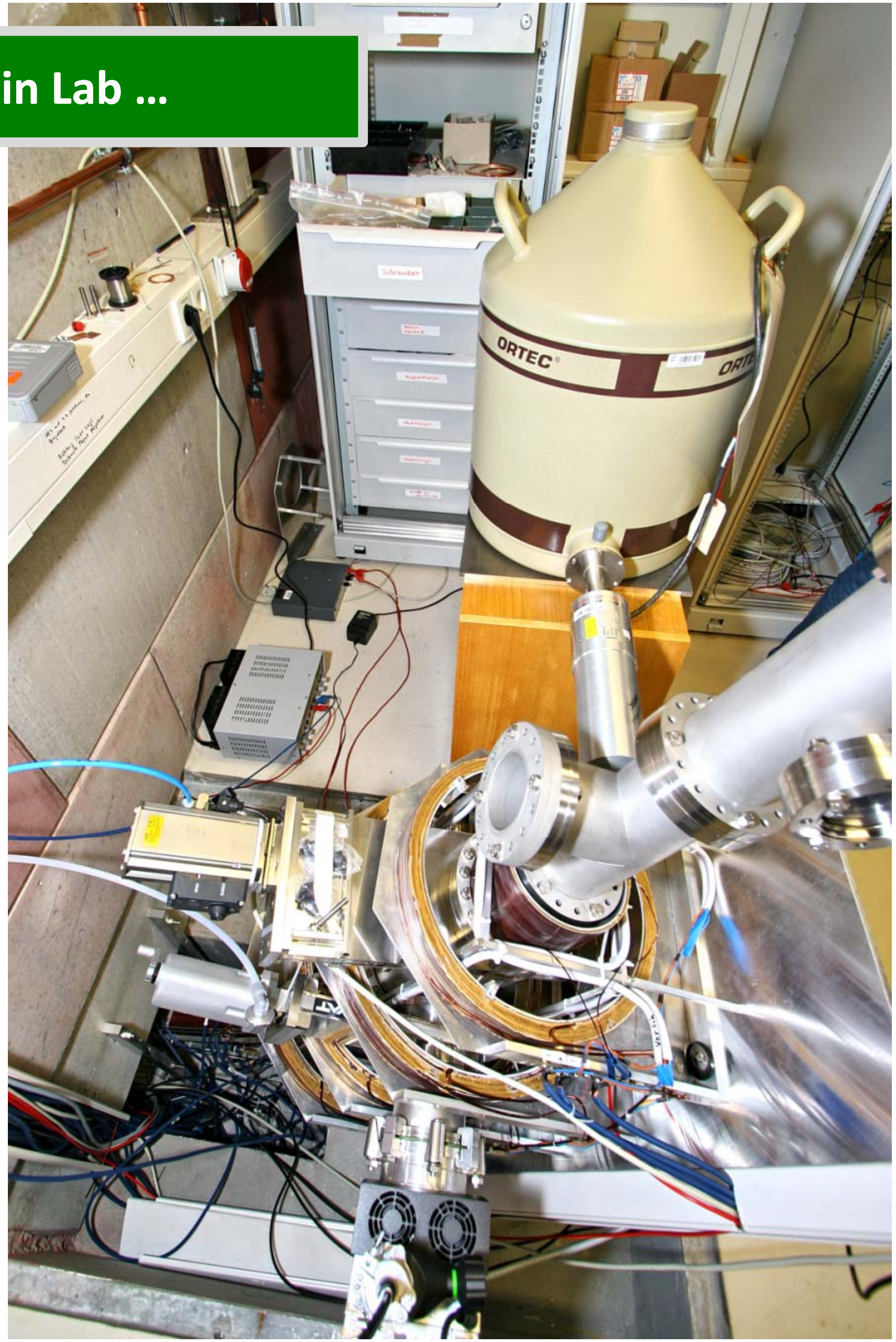
Electron-Positron Converter is finished

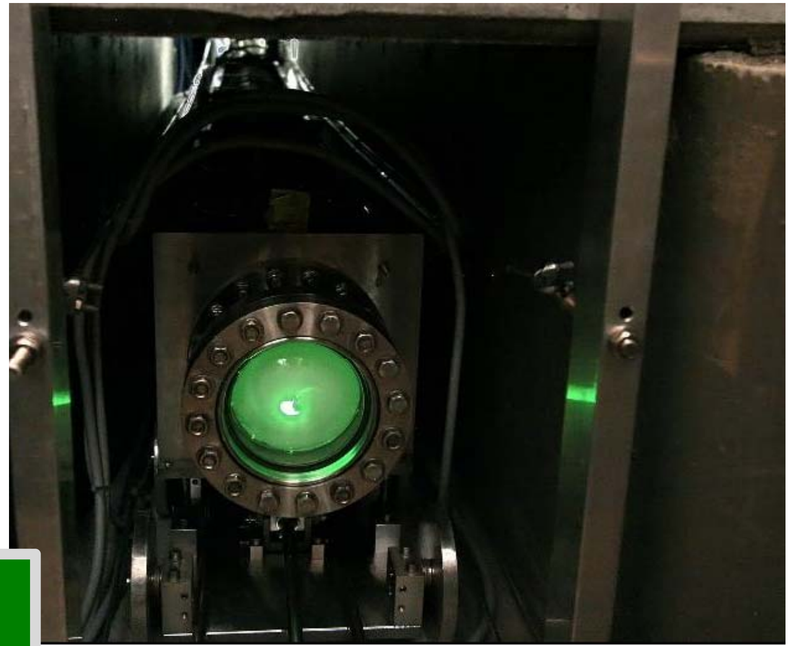


Still waiting for γ Quanta in Lab …

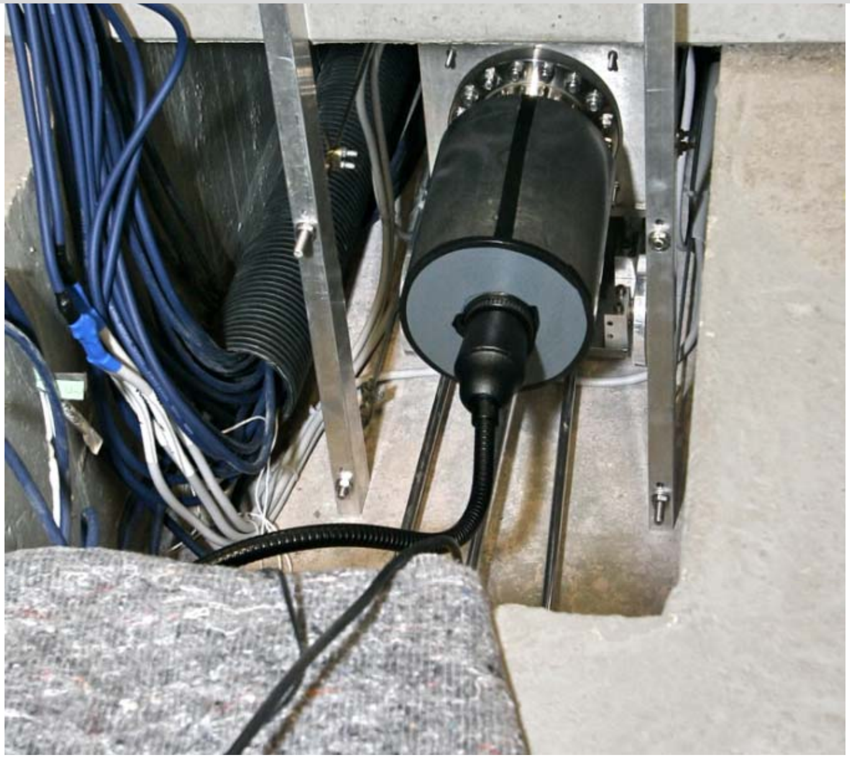
- Problem: 10 x 2 steering coils must be adjusted
- automatic LabView program is looking for annihilation gamma at end of beam line







Test of Beam Guidance with an Electron Source



Gamma-induced Positron Spectroscopy

ELSEVIER

Nuclear Instruments and Methods in Physics Research A 495 (2002) 154–160

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

www.elsevier.com/locate/nima

Bremsstrahlung-induced highly penetrating probes for nondestructive assay and defect analysis

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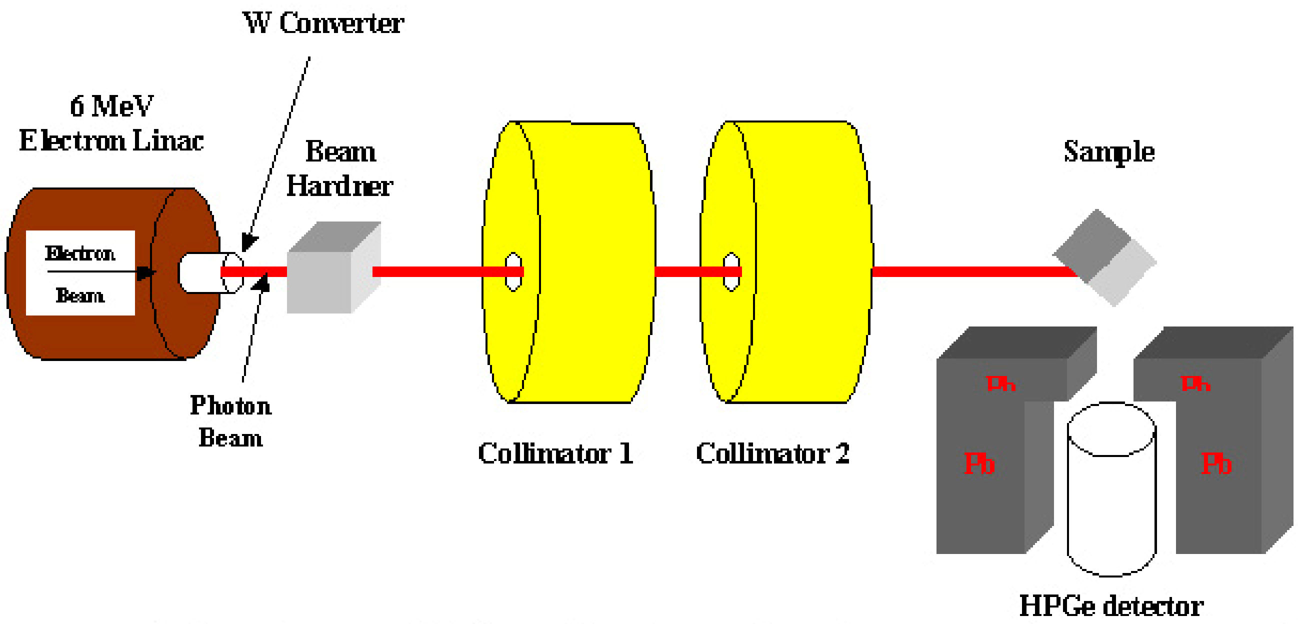


First spectra

Advantages

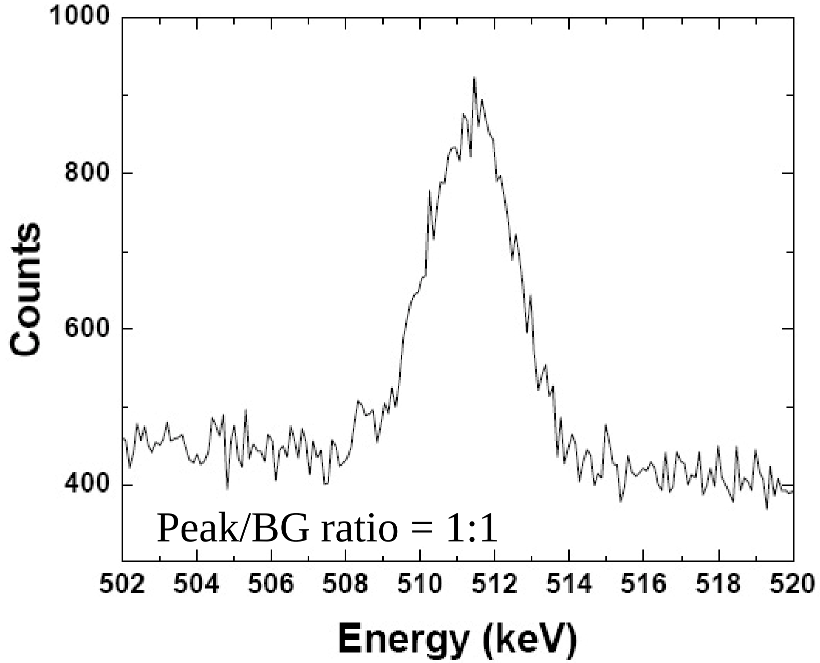
- information depth 0.1 … 5 cm; whole sample
- ideal for bulky samples (NDT), liquids, gases, biological objects, coarse powder, dispersions …

Disadvantage of slow LINACs

- Use of “normal” LINAC with 200 Hz has the problem of high gamma flux in only very few bunches
- Count rate very low, thus no coincidence techniques applicable such as CDBS or AMOC
- Peak / BG ratio bad (1:1)
- no lifetime spectroscopy possible

All this **disadvantages can be overcome** by use of a superconducting LINAC with > 10 MHz

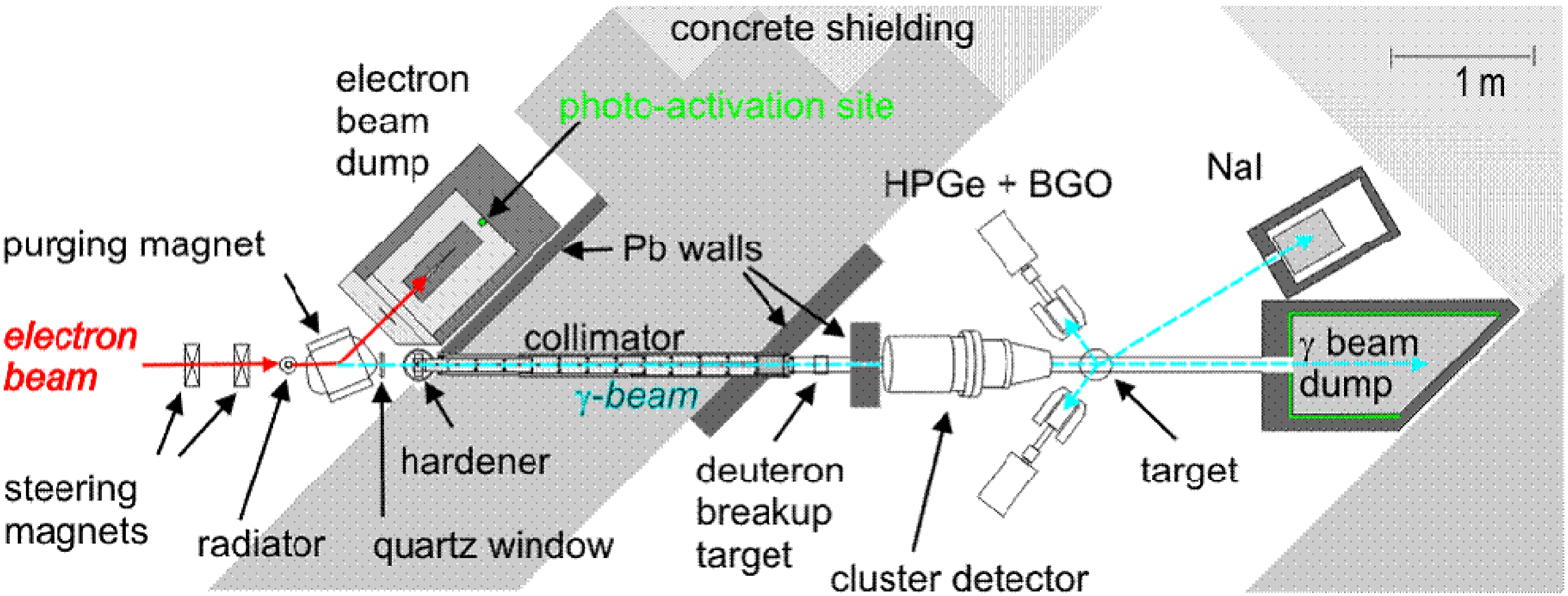
Annihilation line in steel



F.A. Selim et al., NIM B 192 (2002) 197

Bremsstrahlung Gamma Source of ELBE (FZ Dresden-Rossendorf)

- Pulsed gamma source using superconductive Linac ELBE
  - repetition frequency 26 MHz (or smaller by factor 2^n) in CW mode!
  - bunch length < 5 ps
  - up to 20 MeV (we used 16 MeV), no activation of samples by γ-n processes was found
  - average electron current 1 mA = 20 kW beam power; electron beam dump outside lab
  - thus gamma background at target position is very low (Ge detectors with 100% efficiency)
- **Ideal for GiPS ! Is now part of EPOS project – user dedicated positron source.**

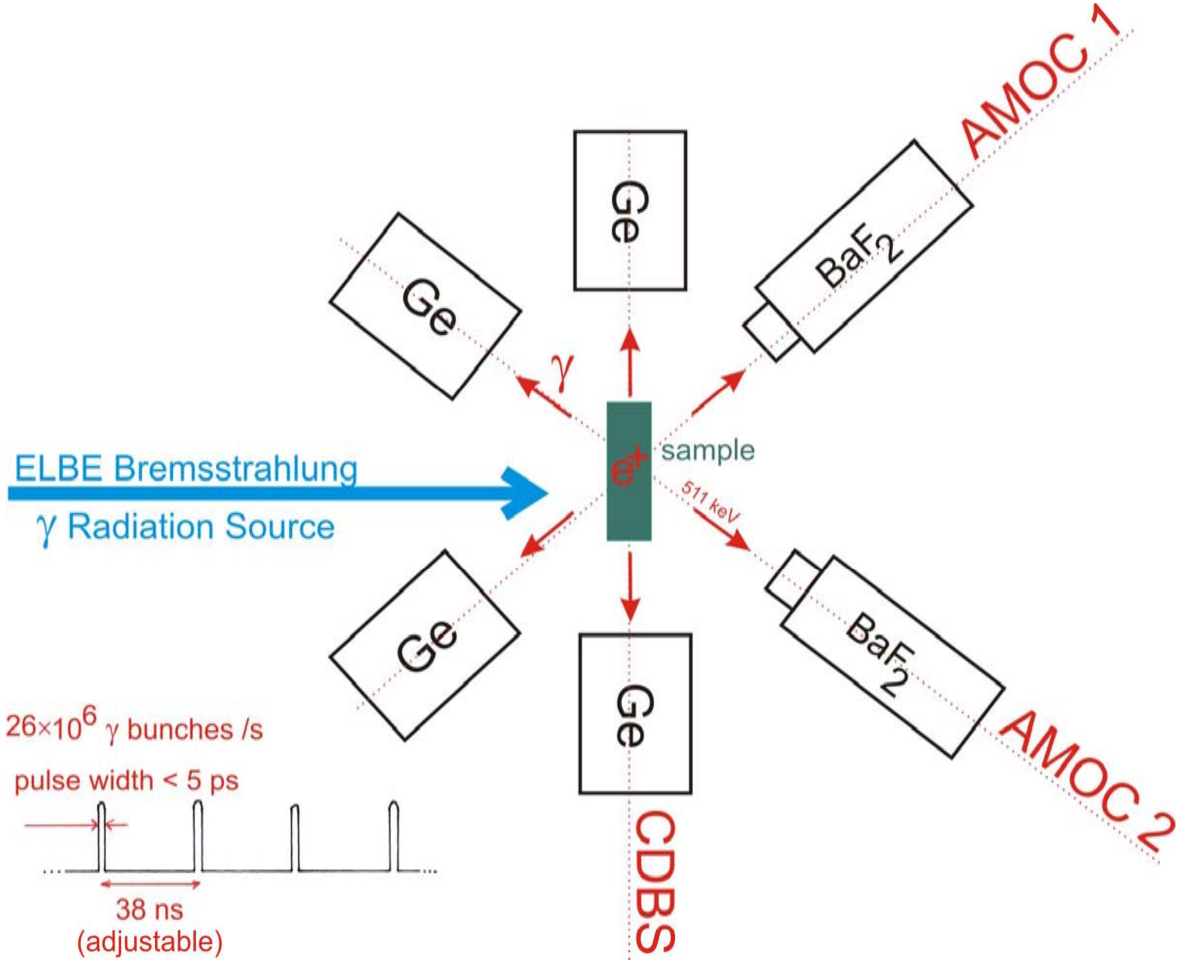


Setup extended by BaF_2 detectors for lifetime measurement

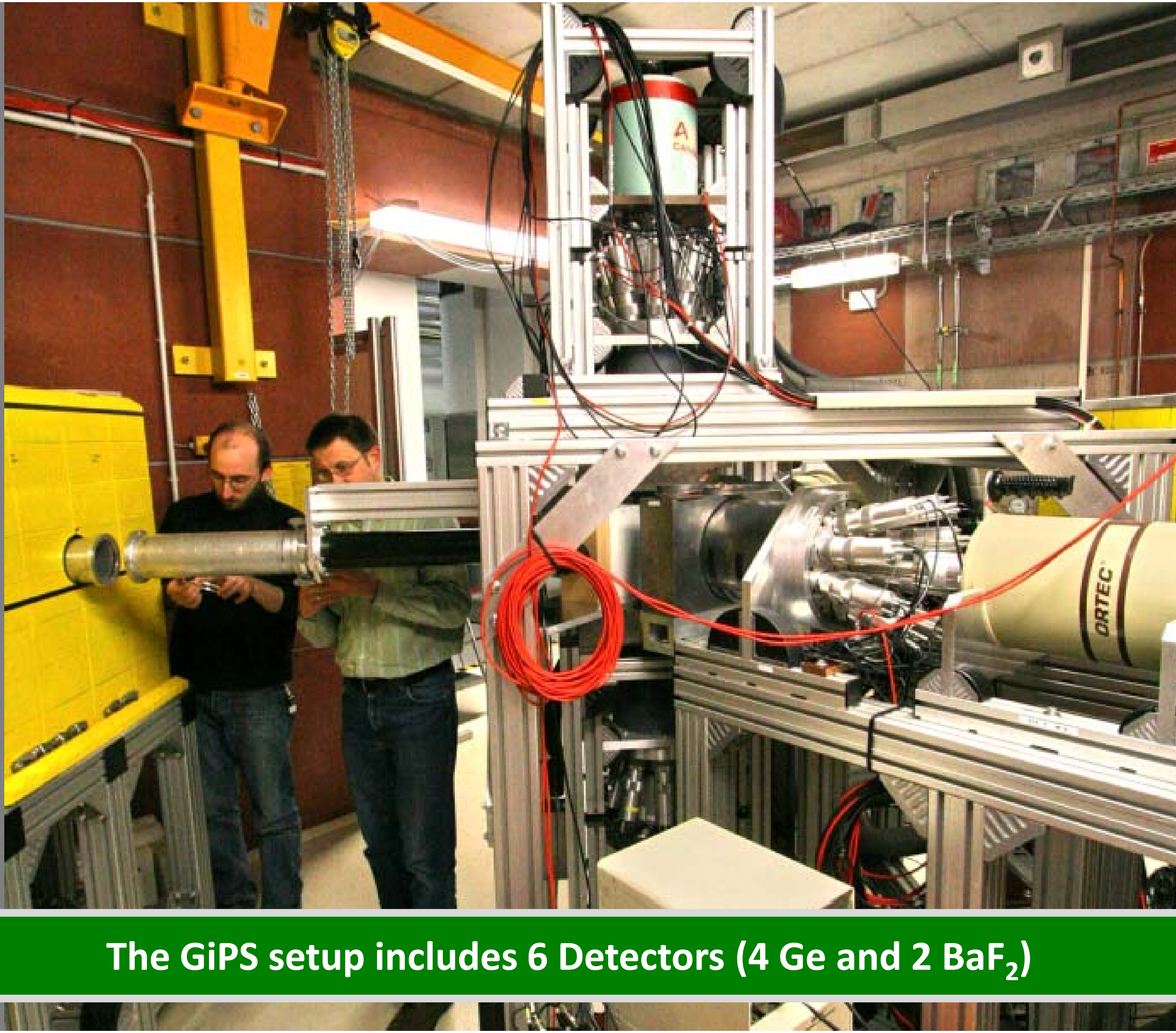
- 3 coincident setups were used: 2 AMOC and 1 CDBS spectrometer
- only coincident detection ensures high spectra quality

Problem

- all scattered quanta appear within positron lifetime – time coincidence alone does not reduce background at all
- but distance helps: for 2 x 511 keV quanta in coincidence the distance dependence is proportional to r^{-2}
- for arbitrary scattered gamma it is $\propto r^{-4}$



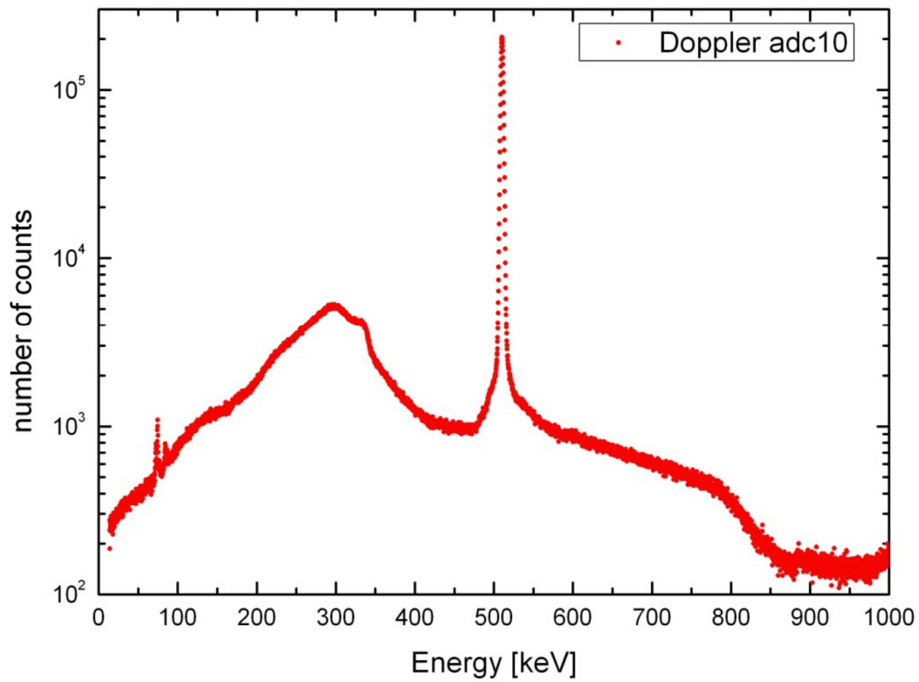
AMOC: Age-Momentum Correlation
CDBS : Concidence Doppler-Broadening Spectroscopy

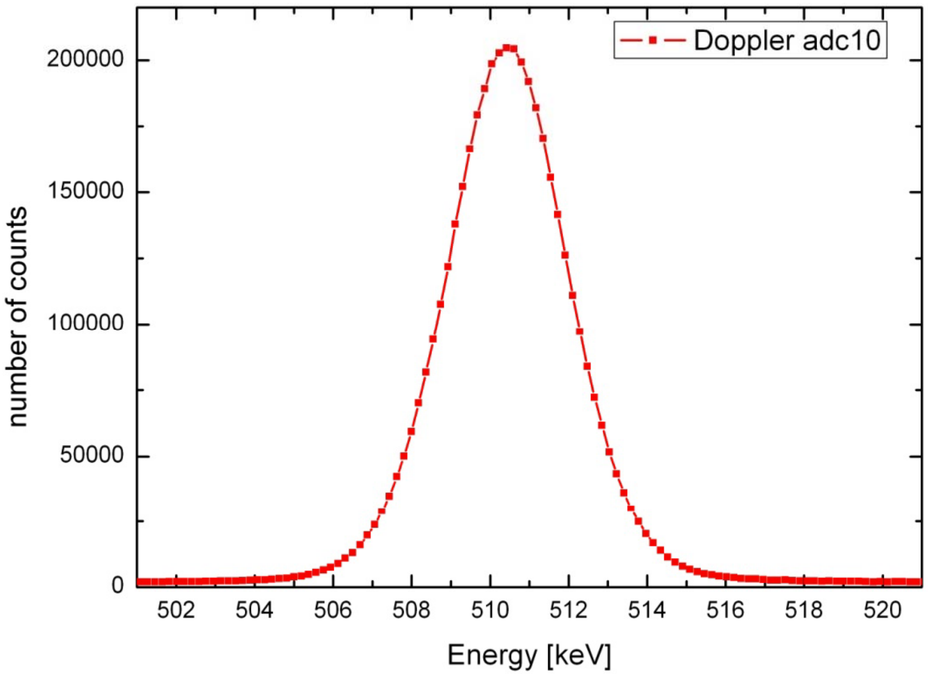


The GiPS setup includes 6 Detectors (4 Ge and 2 BaF_2)

Single-channel Ge Spectrum of annealed Fe

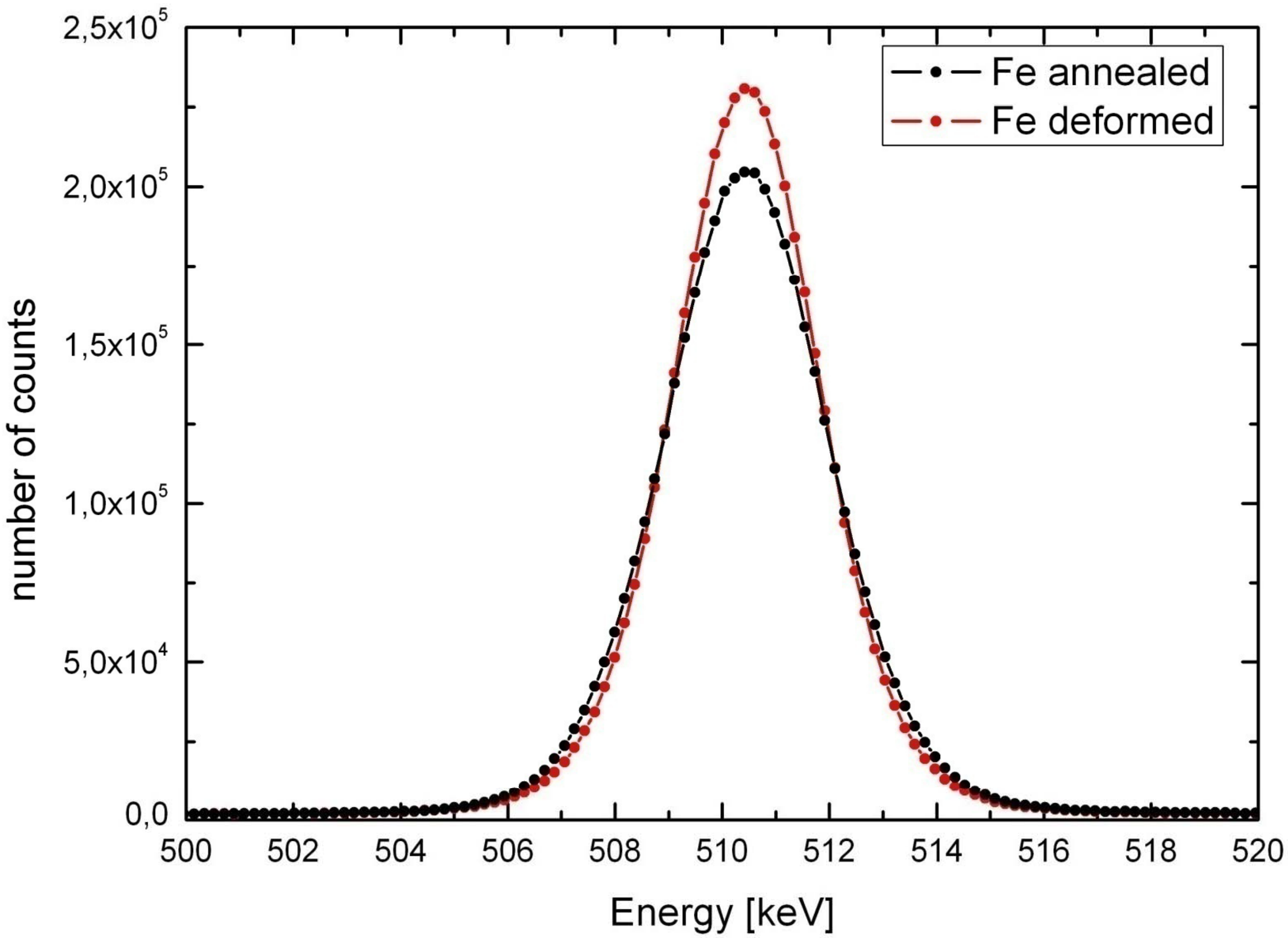
- count rate about 20 kHz (200 kHz would be theoretically possible); total counts in example: $8x10^6$
- about 50% of intensity in 511 peak of annihilation line
- decrease below 350 keV due to 5 mm Cu absorber plates in front of Ge detectors
- detection with analog electronics





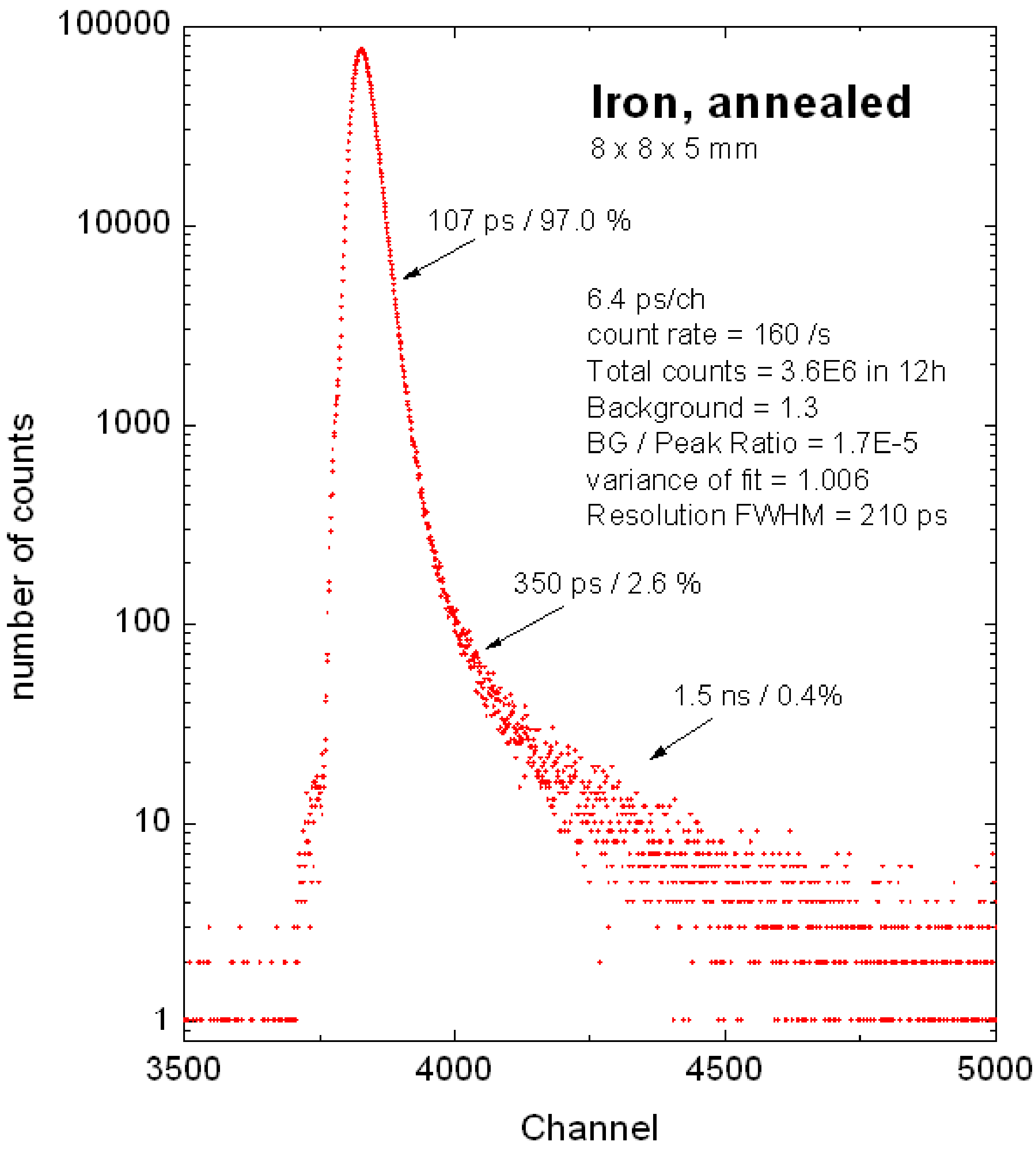
Comparison annealed and deformed Fe

- expected behavior
- curve of deformed Fe is distinctly taller due to open-volume defects and thus increased fraction of annihilation with valence electrons (small energies – small Doppler shift)



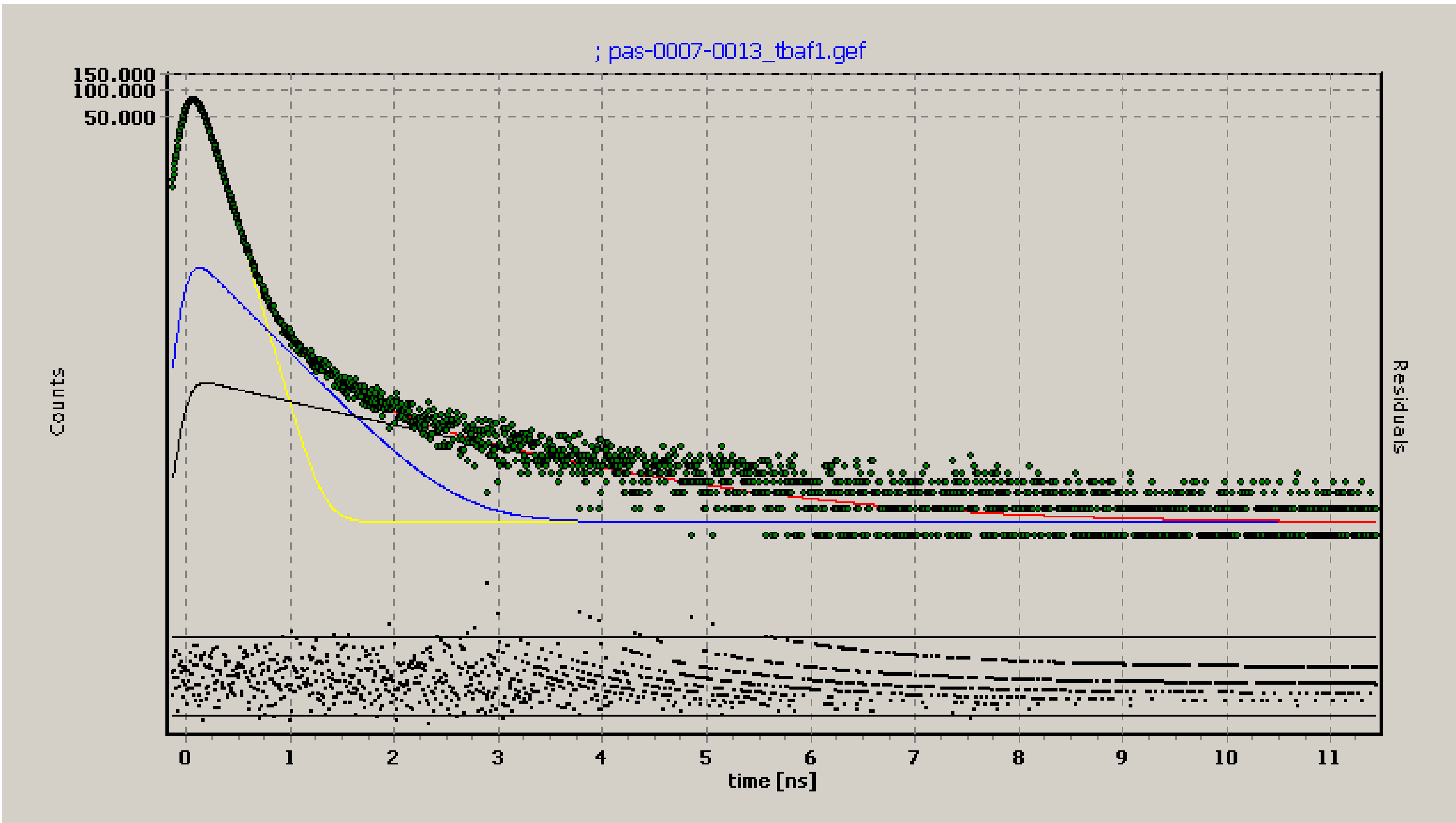
Coincident lifetime spectrum: annealed Fe

- here coincidence with Ge detector
- spectrum is projection to the time scale of AMOC spectrum
- Count rate for AMOC spectrum = 320 /s
- One spectrum in 2h
- Time resolution = 210 ps
- BG/Peak = 1.7 x 10-5
- 350 ps & 1.5 ns: annihilation at vacuum tube (polyethylene)



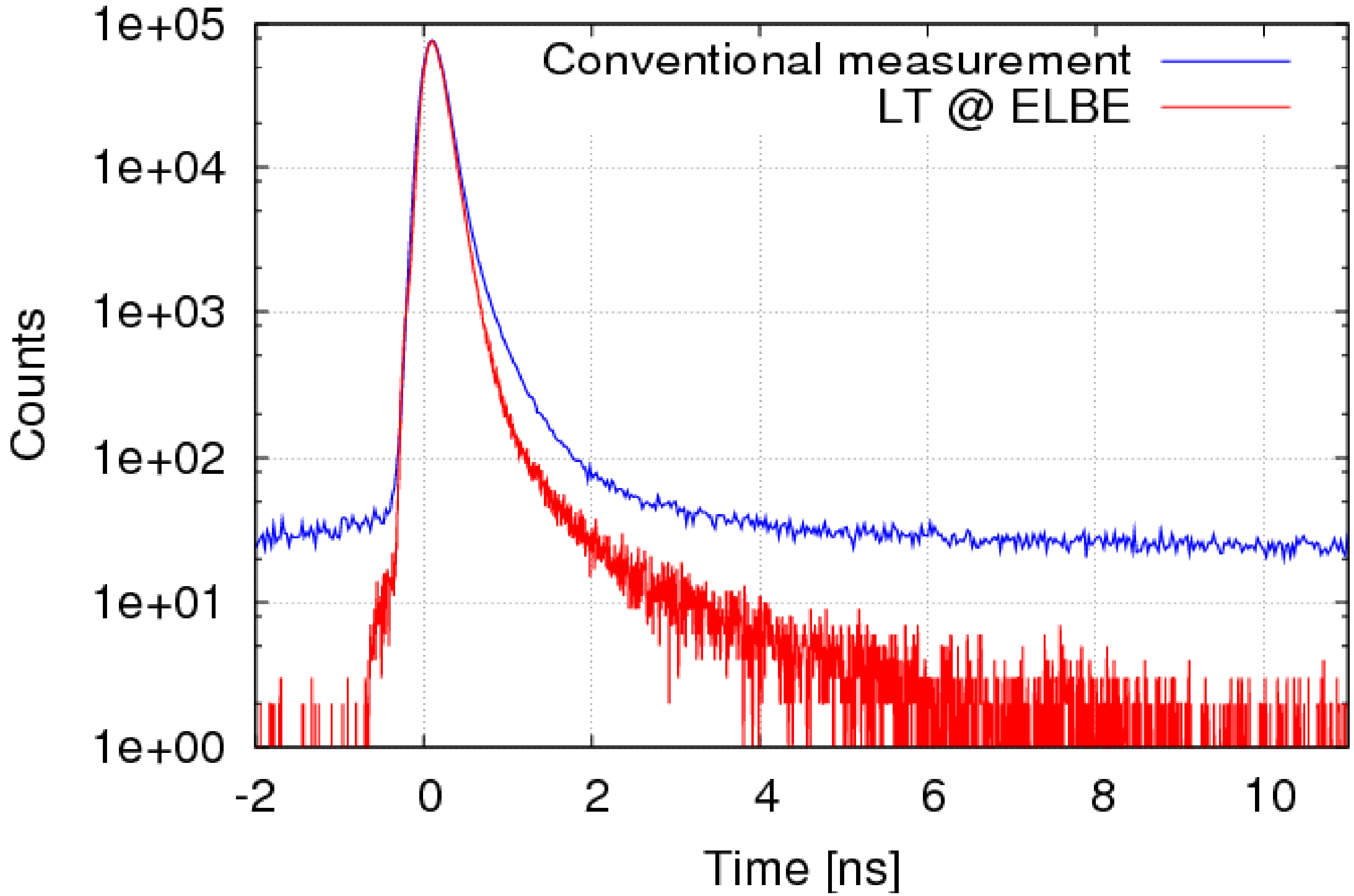
Residuals of fit show perfect fit

- analysis by LT 9.0 (J. Kansy)



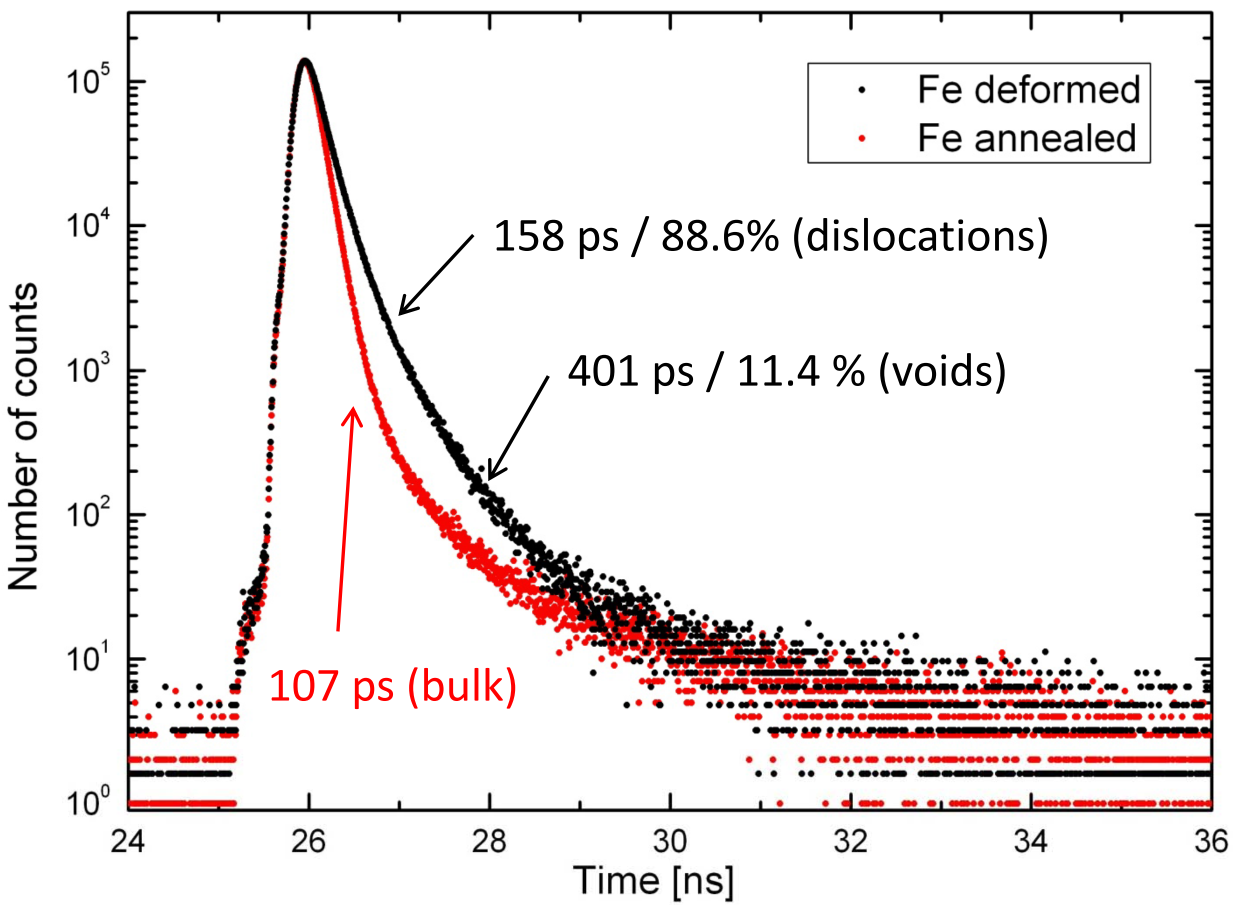
Comparison: GiPS spectrum with conventional measurement

- same sample material – almost same statistics, similar time resolution
- conventional measurement with ^{22}Na source 20 µCi (0.7 MBq) in sandwich geometry
- advantage of periodic positron source is obvious: background distinctly reduced
- result of spectra analysis is the same: 107 ps (bulk value for Fe; corresponds to literature)



Comparison annealed and deformed Fe

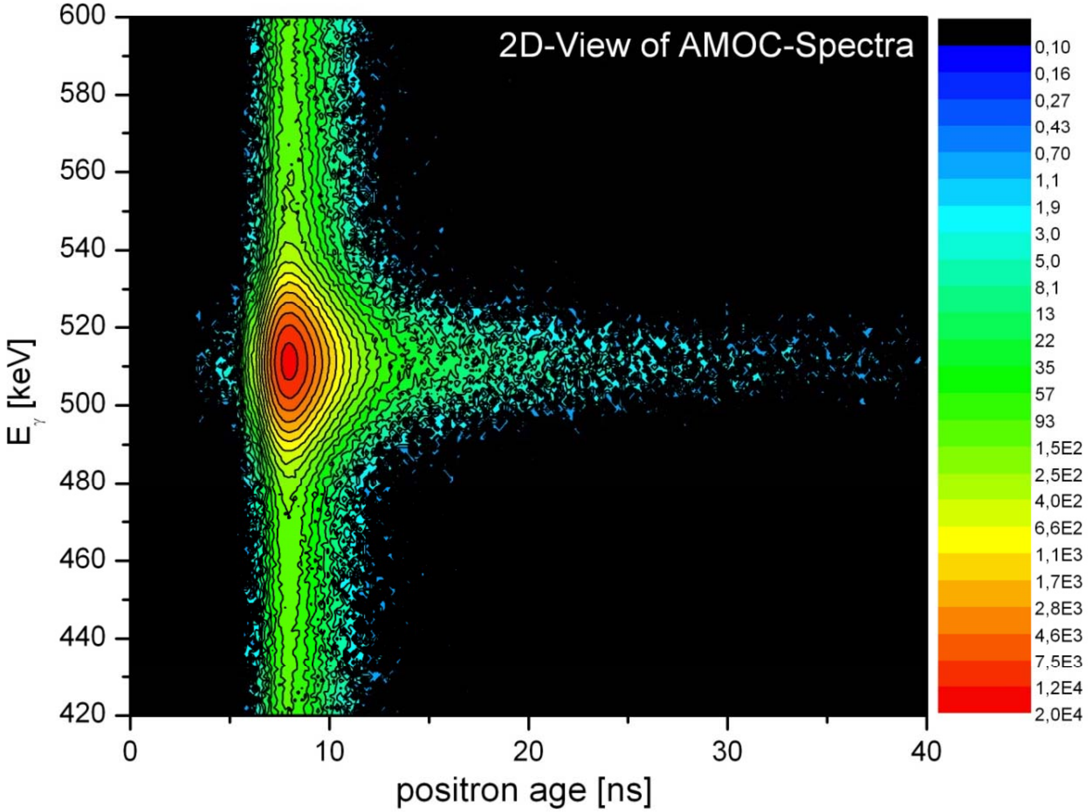
- two mechanically identical samples were prepared
- Fe annealed (1100°C; 2h in vacuum) and Fe (50% thickness reduction by cold rolling)
- spectra were easily decomposed
- expected results: annealed sample – one component 107 ps; deformed sample has 158 and 401 ps (dislocations and small vacancy clusters)



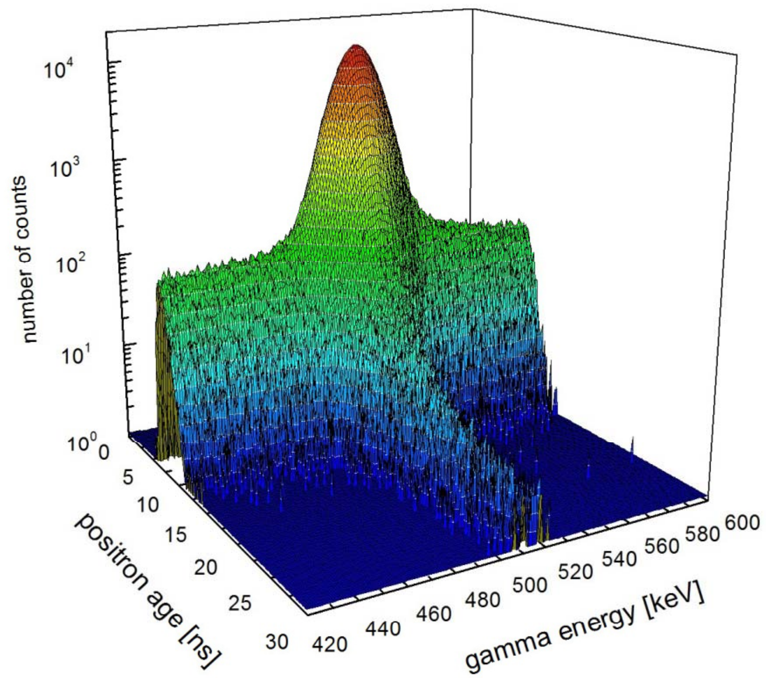
AMOC spectrum of annealed Fe

- AMOC: measurement of momentum of annihilating electron as function of positron age
- AMOC detection is not an extra gimmick, but is required to maintain quality of spectra
- only by coincident measurement of 511 keV annihilation line: suppression of scattered gamma (can be concluded from lifetime spectra)

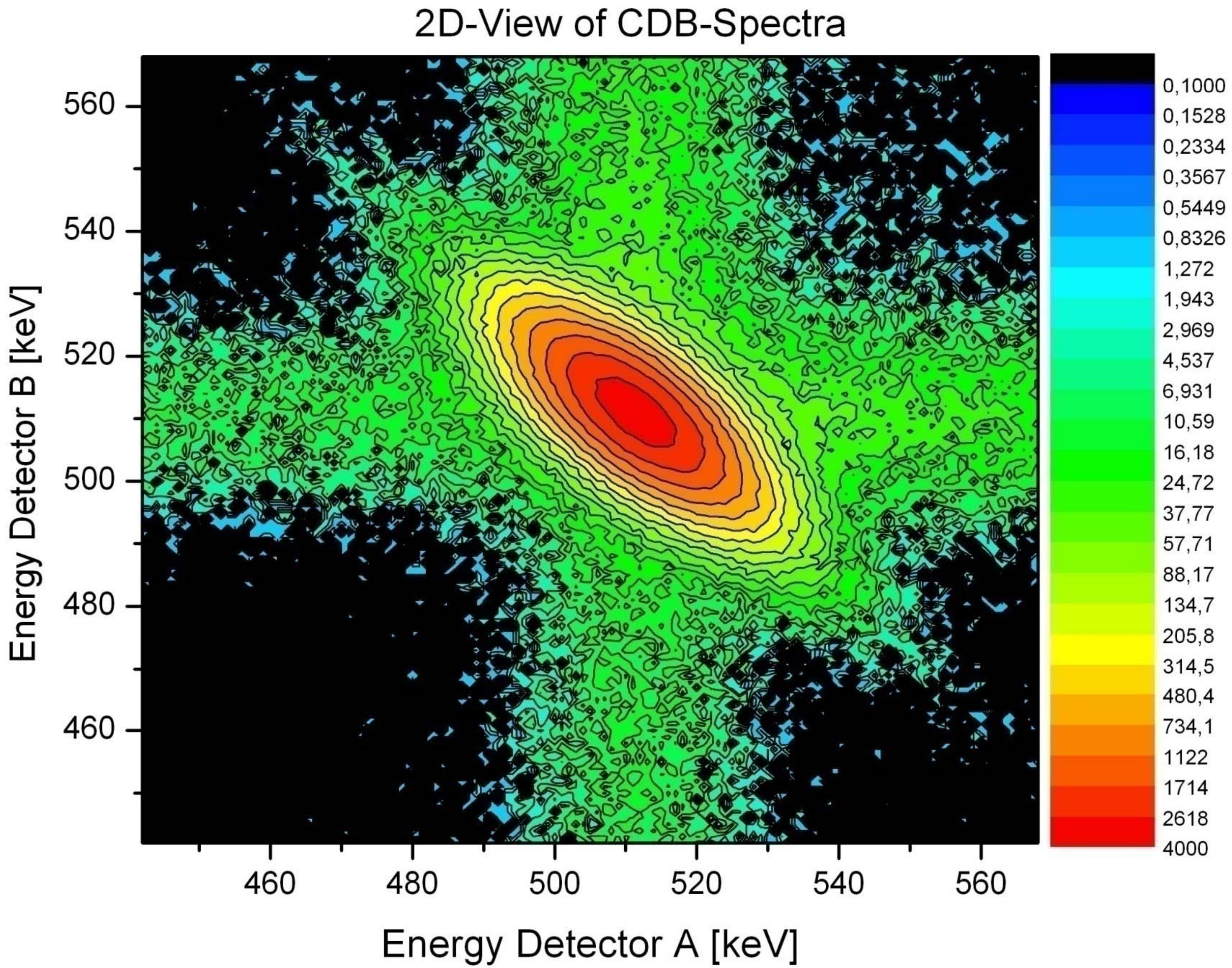
2D-Plot



3D-Plot

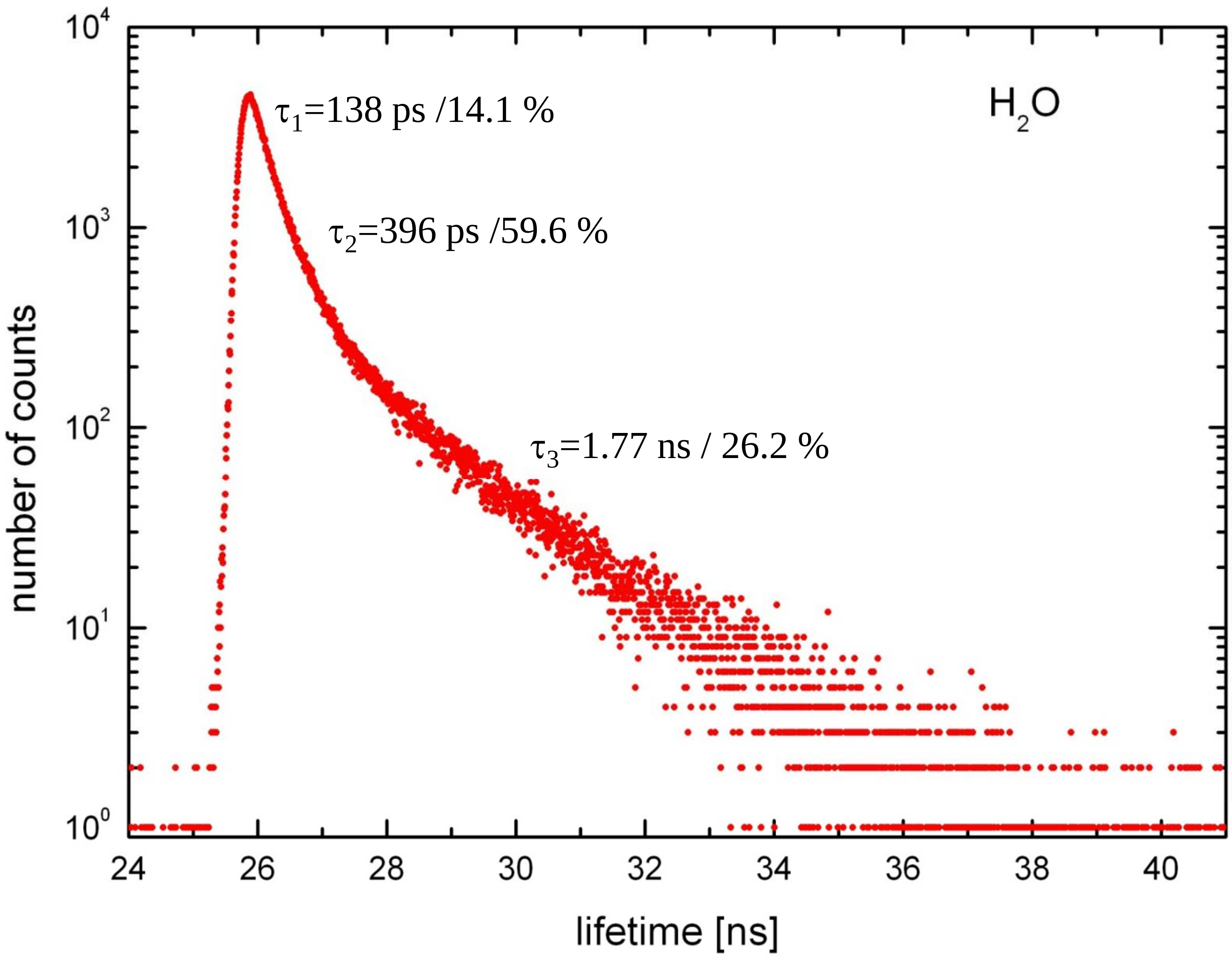


Coincidence Doppler-Broadening Spectroscopy of Fe sample



Water at RT

- total count rate: $5x10^5$
- no such visible deviations on $t < t_0$ like for Fe (due to much smaller gamma scattering compared to Fe)

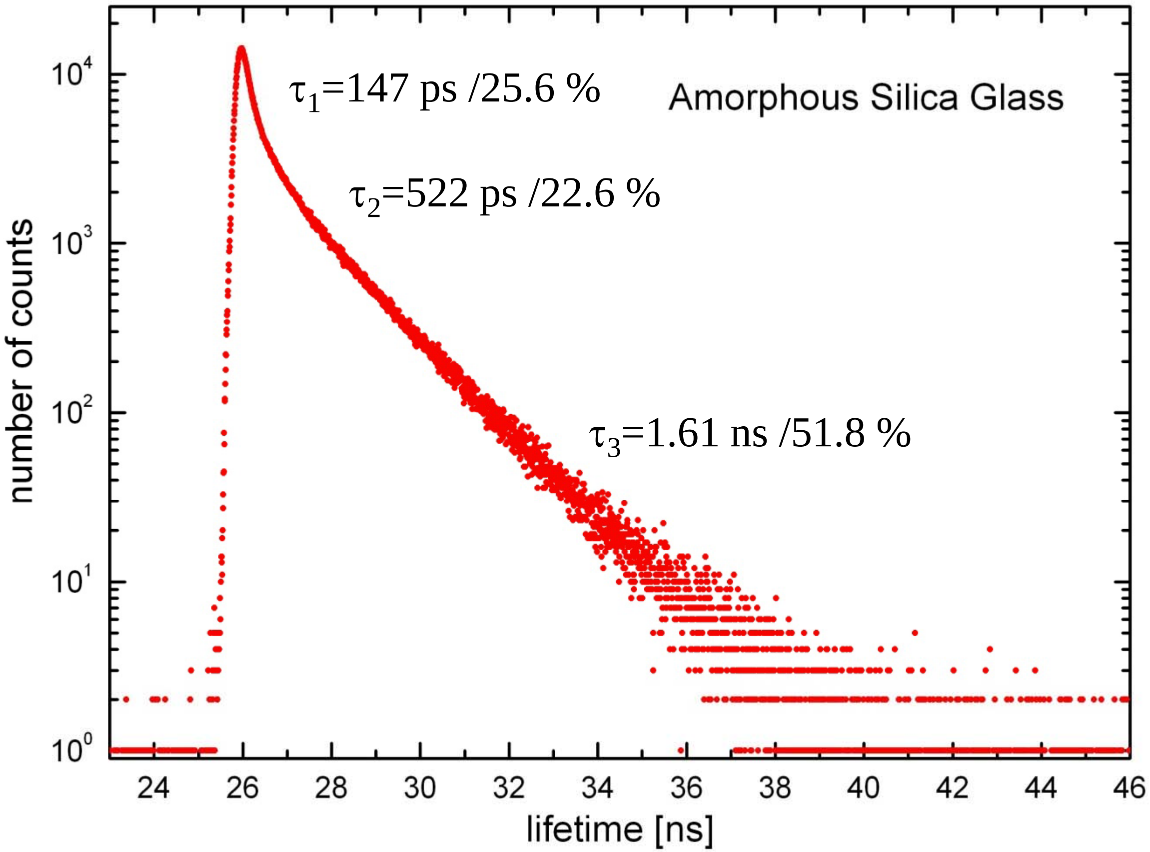


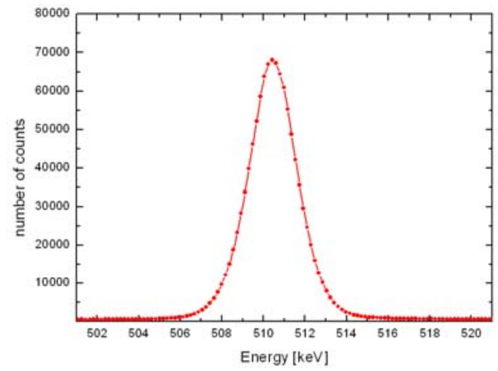
Amorphous Silica Glass

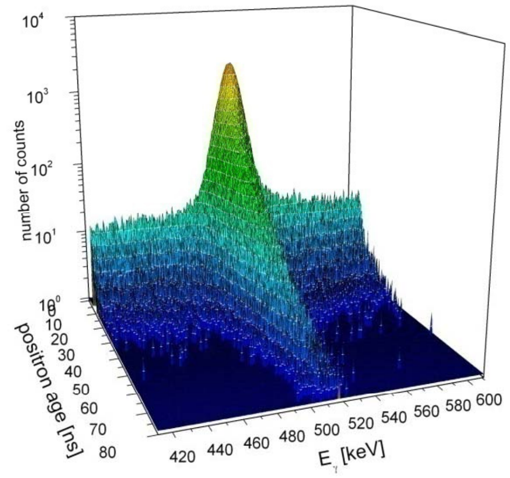
- round piece 1.5 cm thick, about 5 cm^3
- lifetime spectrum: total count rate: $2x10^6$
- same sample was measured conventionally in 1978 also in the same institute (former ZfK Rossendorf):

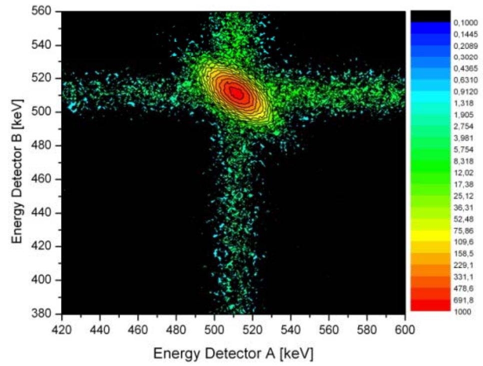
  151 ps - 523 ps - 1.57 ns (FWHM ≈350 ps)

  G. Brauer et al., Appl. Phys. 16 (1978) 231





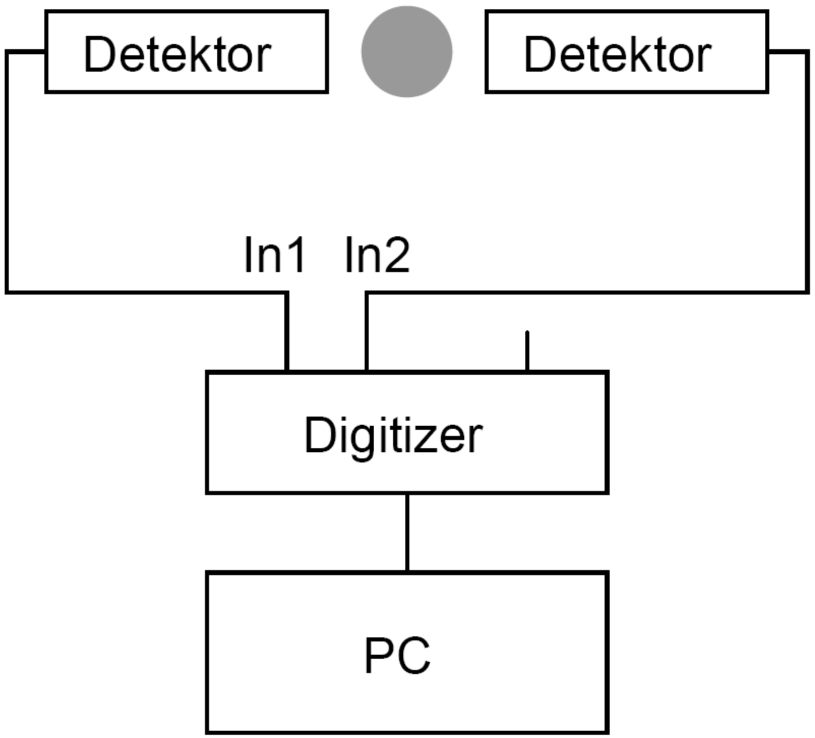


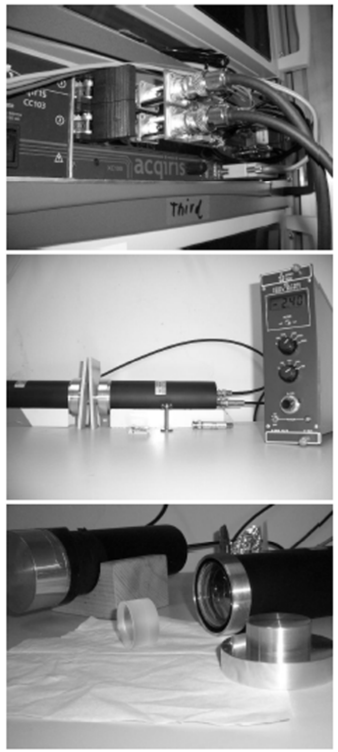


Digital Detector System for EPOS and many more Applications

Many advantages:

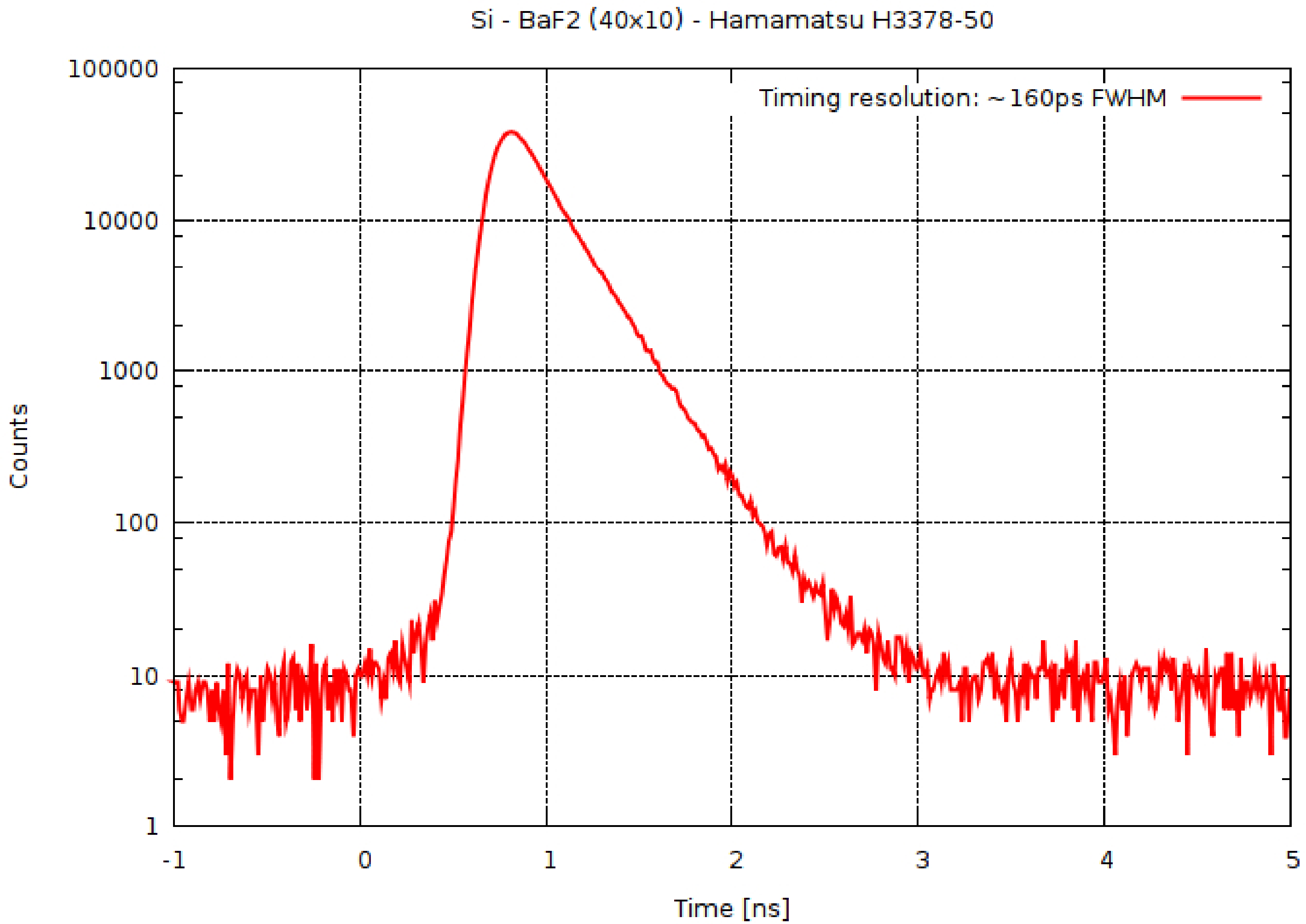
- Pulse shape discrimination
- Exact time base
- extremely simple setup: nothing to adjust





Digital Lifetime Measurement

- Timing routines now available
- Online computation using a Linux cluster



Research Center Dresden-Rossendorf, 28.-30. September 2009

Workshop on Digital Signal Processing in Nuclear Science

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

Open-source Project

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

Conclusions

- new concept of EPOS project is now extended to use mono-energetic Positrons (MePS), Gamma-induced (GiPS) and conventional spectroscopy (CoPS)
- all spectrometers are equipped with LT, CDB, AMOC
- fully digital system (in the future)
- EPOS can cover sample thickness range from 10 nm to 10 cm (7 orders of magnitude)
- MePS still under construction
- GiPS has been tested successfully
  - GiPS only possible because of the unique properties of the ELBE Linac (cw mode of 26 MHz intense and extremely short electron bunches, < 5ps bunch length)
  - background suppression by coincident measurement of Lifetime and Doppler (AMOC)
  - surprisingly good spectra quality
  - coincidence between 2 BaF_2: resolution improves by 24% (FWHM = 160 ps)
  - problem: heating / cooling of sample because in holder positrons are also generated

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