Digital positron lifetime spectroscopy at EPOS

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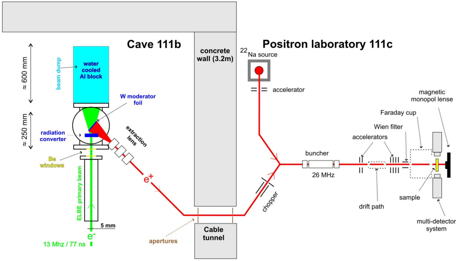
EPOS in a nutshell



- ELBE at FZ Dresden-Rossendorf is a pulsed electron beam
- EPOS tries to create a pulsed positron beam by pair-production
- Positron beam is bunched and chopped to have a sharper pulse
- Positron annihilation in the sample is detected by
  - 4 pairs of detectors in coincidence for lifetime
  - one pair of Ge-detectors for Doppler- and AMOC-measurements

Special needs for EPOS

- All calculations done online
  (Saving the raw-data only for debugging/testing)
- Server stores only the final spectrum
- Easy extensions via exchangable plugins
- Total control on the whole lab and experiment via pc
- Preparation of experiments and fetching of results via internet

Replacing analog equipment with digital devices

Replacing the standard analog equipment...

...with digitizers (4GS/s 8bit) and computers.

Replacing analog equipment with digital devices

Problems with digitalization

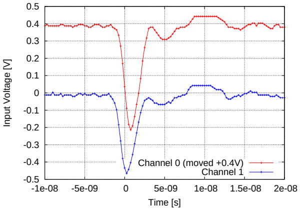
- Conversion from continuous signal to discrete signal
- Both on time and amplitude
- Interpolation is needed between the discrete points
- Noise of the adc and time-jitter are serious problems

Comparison of different methods

Task

To find the best interpolation- and extraction-method for digital lifetime measurements.

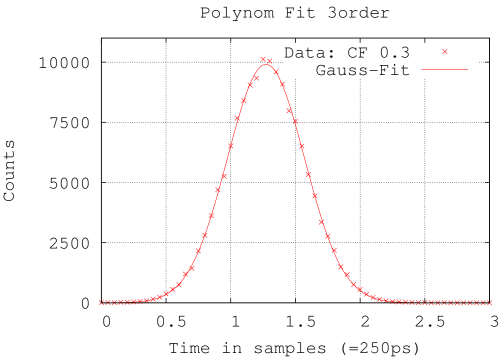
Comparison of different methods



Doing the tests:

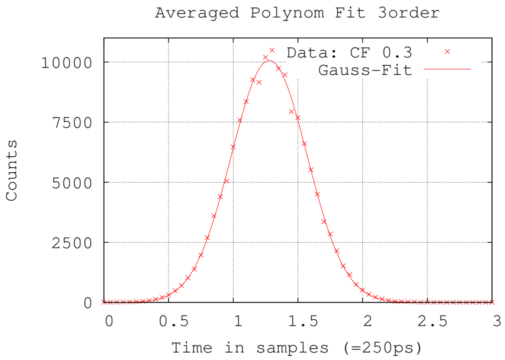
- One raw-dataset of ^{60}Co spectrum for all tests
- Obtained by Acqiris DC211, 4GS/s 1GHz bandwidth, 8bit resolution (6.5bit effective)
- Same windows for all tests (-0.8V - -0.1V)
- $\sim$ 150 000 events in total
- Minimum of the pulses obtained via 2nd- or 3th-order polynom-fit.
- EODE (Epos Offline Data Evaluation) allows for different modules to be exchanged at run-time
  $\Rightarrow$ only the relevant parts in the process are changed.

Comparison: Simple Polynom Interpolation



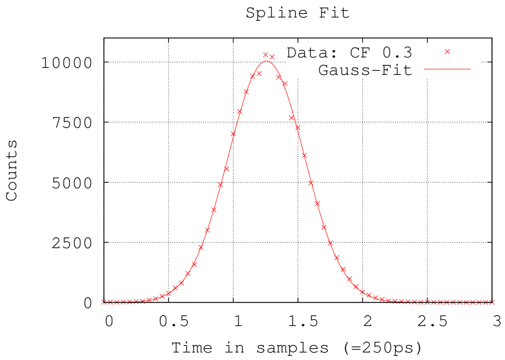
- Constant fraction between baseline and extremum simply by interpolation with polynom of *N*th-order
- 3th-order interpolation proves useful and without too much overhead
- FWHM with constant fraction of 30%: **174.84ps**

Comparison: Averaging and Polynom Interpolation



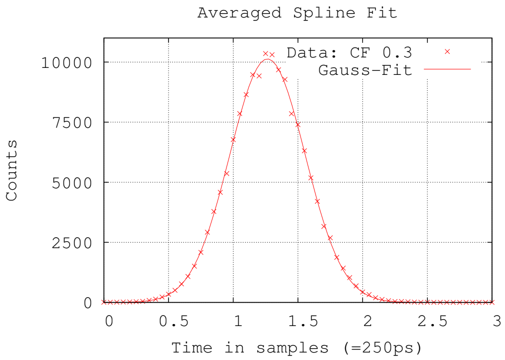
- Averaging the sampled data + polynom fit afterwards reduces effect of digitizer noise
- FWHM with constant fraction of 30%: **172.08ps**
- FWHM of 167ps with some mathematical tricks.

Comparison: Spline Interpolation



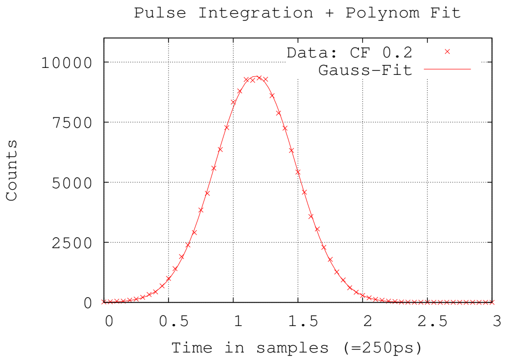
- Interpolation at constant fraction point by Spline-Interpolation
- FWHM with constant fraction of 30%: **172.43ps**

Comparison: Averaging and Spline Interpolation



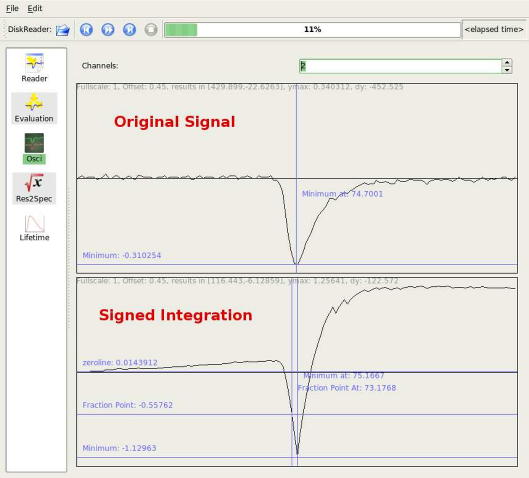
- Averaging the sampled data first
- followed by spline-interpolation of the constant fraction point
- FWHM with constant fraction of 30%: **171.08ps**

Comparison: Integration of pulses and Polynom Int.



- Integrating the pulse
- Constant fraction on the integrated pulse by interpolation with polynom of *N*th-order
- FWHM with constant fraction of 20%: **184.35ps**

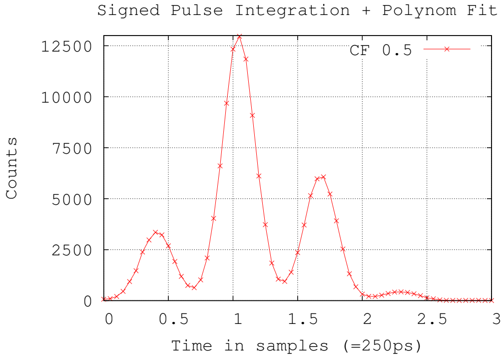
Comparison: Signed Integration and Polynom Int.



- Integrating the pulse, signed by difference from previous sample
  $\Rightarrow$ Results in pulses instead of rising slope
- Constant fraction on the integrated pulse by interpolation with polynom of Nth-order
- FWHM with constant fraction of 50%: **75.61ps**

Comparison: Signed Integration and Polynom Int.

But:



- Integrating the pulse, signed by difference from previous sample $\Rightarrow$ Results in pulses instead of rising slope
- Constant fraction on the integrated pulse by interpolation with polynom of *N*th-order
- FWHM with constant fraction of 50%: 75.61ps
- **Spectrum contains several maxima!**

Conclusion: Comparing the results

Method	*Resolution*
Analog measurements	our lab: >200ps
Polynom-Int.	[Becvar, 2004] 4GS/s 1GHz 8bit: 130ps own: ∼170ps
Gauss-Int.	[Aavikko 2005] 4GS/s 1GHz 8bit: 200ps
(Smoothing) Spline	[Saito, 2001] 4GS/s 1GHz 8bit: 118ps - 144ps [Bardelli, 2004] 100MS/s 50MHz 12bit: 100ps - 125ps own: ∼170ps
Integral CF	Bečvář, Prague: ∼100ps own: ∼185ps
Signed Integral CF	own: ∼75ps but not working right :-(

Conclusion: Literature, Links, Thanks

Thanks for your attention!

Get the slides at http://positron.physik.uni-halle.de/.

J. Nissilä, K. Rytsölä, R. Aavikko, A. Laakso, K. Saarinen, P. Hautojärvi
Performance analysis of a digital positron lifetime spectrometer
NIM A 538 (2005) 778-789

F. Bečvář, J. Čížek, I. Procházka, J. Janotová
The asset of ultra-fast digitizers for positron-lifetime spectroscopy
NIM A 539 (2005) 372-385

H. Saito, Y. Nagashima, T. Kurihara, T. Hyodo
A new positron lifetime spectrometer using a fast digital oscilloscope and BaF_2 scintillators
NIM A 487 (2002) 612-617

L.Bardelli, G. Poggi, M. Bini, G. Pasquali, N. Taccetti
Time measurements by means of digital sampling techniques: a study case of 100ps FWHM time resolution with a 100 MS/s 12 bit digitizer
NIM A 521 (2004) 480-492