High-Field μSR instrument: detector solutions

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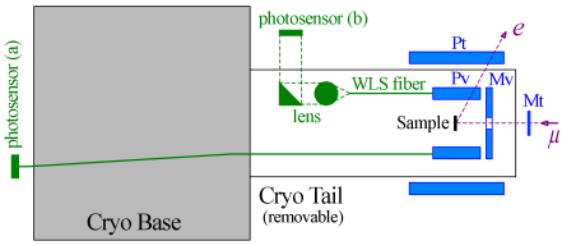
Solutions to the detector system of the High-Field μSR instrument at PSI are presented.
The strict technical requirements are fulfilled through application of Geiger-mode Avalanche Photodiodes.
Unprecedented values of the time resolution are demonstrated.

max. field **9.5 T** (**10 ppm** uniformity) | Detector: **σ < 140ps**, compact, non-magnetic | Cryostats: He-flow & dilution refrigerator

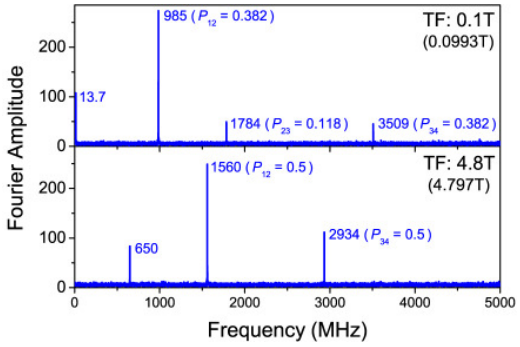


Timing detector: **Mt** (1x) and **Pt** (16x) – muon and positron timing counters at RT.

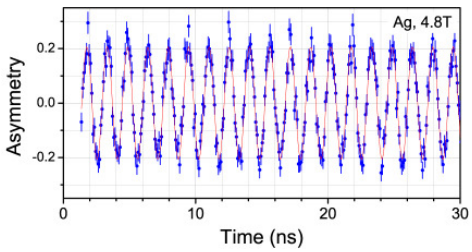
Veto detector: **Mv** (1x) and **Pv** (4x) – muon veto and positron validation counters.
The scintillators with embedded WLS fibers – in the vicinity of the sample at a cryogenic temperature, photosensors – at RT.
Optical coupling schemes: **(a)** a continuous fiber light guide (flow cryostat);
(b) a discontinuous lens light guide (dilution refrigerator; details in [A.Stoykov et al., 2011 JINST 6 P02003]).

Timing detector (prototype, Ring ø30mm). Scintillators: ø7x0.3mm (M), 12x12x5mm (P)

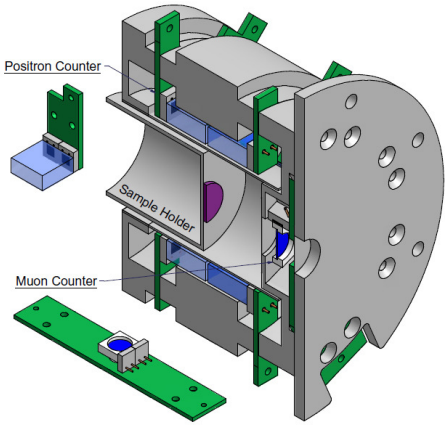
μSR-measurements (Ag, quartz):
- ▶ muon beam 29 MeV/c, ø5mm;
- ▶ TF, 42° muon-spin rotation;
- ▶ sample holder at 313K

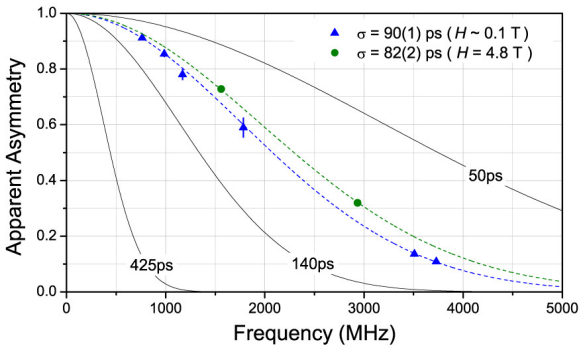


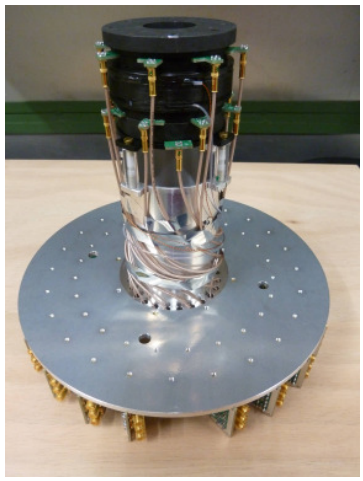
Synthetic quartz crystal (TF: 0.1T, 4.8T).
Diamagnetic fraction – 14%, muonium – 86%.
Muonium: isotropic, hyperfine splitting 4494 MHz.
P_{ij} – calculated polarization of each muonium signal.



Ag-sample in 4.8T (damping rate < 6 kHz)







Reduction of the apparent asymmetry with increasing the signal frequency **ν** due to the finite time resolution of the detector **σ**:

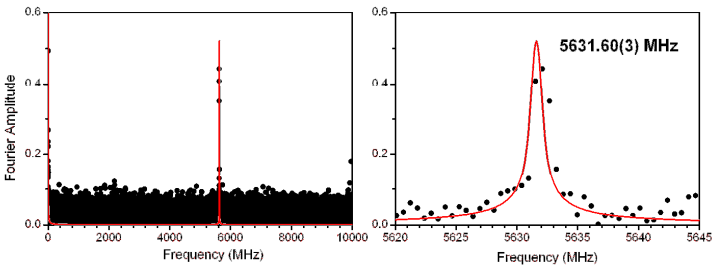
$$A(\nu) / A_0 = exp\ [\ -\ 2\ (\pi\ \sigma\ \nu)^2\ ] \qquad (1)$$

[E. Holzschuh, Phys. Rev. B 27 (1983) 102]

The data points are from quartz measurements in 0.07, 0.1, and 4.8T.
For each observed muonium signal the asymmetry obtained from the time-domain fit A_i divided by the calculated polarization P_{ij} gives the full muonium asymmetry A_{Mu} (apparent value), which is reduced with respect to its true value $A_{Mu,0}$ in accordance with (1).

Indicated values of the time resolution:
90(1), **82(2)ps** – low-field and 4.8T quartz data (including σ_{TDC} = 50ps);
425ps – characteristic value for a "standard" μSR-spectrometer;
140ps – accepted upper limit for the High-Field instrument at PSI;
50ps – possible detector upgrade.

Time resolution: potential of the technology



A high-time resolution setup: **σ = (41 – 45)ps**.
Mt – double-side readout; Pt – 5x5x5mm, one G-APD.
Muonium hyperfine oscillation in quartz in 0.12T LF (P_{24} = 0.32).