Longitudinal muon spin relaxation in aluminium and silver

TWIST (TRIUMF Weak Interaction Symmetry Test) and TRIUMF Experiment 1111

TRIUMF

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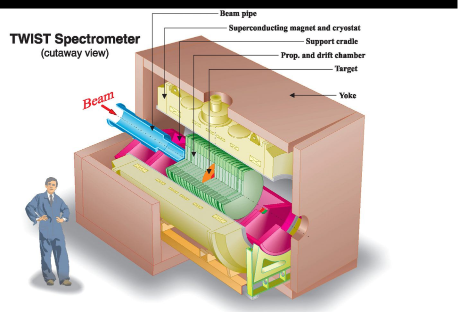
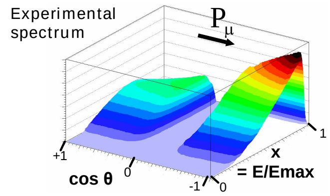
Motivation: the TWIST experiment



- Most precise test of the standard model prediction for μ^+ decay.
- Highly polarised μ^+ from pion decay stopped in aluminium or silver foils, inside a 2T longitudinal magnetic field.
- Decay e^+ tracked by symmetrically placed drift chambers.
- Positron trajectories reconstructed to give momentum and angle.

Experimental spectrum



- Shape of spectrum can be described by muon decay parameters ρ, ξ, δ and η.
- TWIST measures ρ, δ and Pμξ, where Pμ is the muon polarisation at creation.
- TWIST has already published measurements:

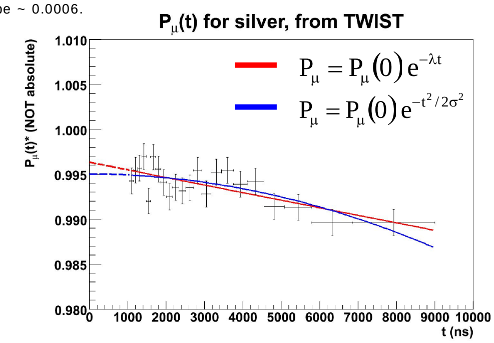
$\rho =$	0.7508	± 0.0003 (stat.)	± 0.0010 (syst.)	[1]
$\delta =$	0.7496	± 0.0007 (stat.)	± 0.0011 (syst.)	[2]
$P_\mu \xi =$	1.0003	± 0.0006 (stat.)	± 0.0038 (syst.)	[3]

[1] J.R. Musser et al. Phys. Rev. Lett. 94 (2005)
[2] A. Gaponenko et al. Phys. Rev. D 71 (2005)
[3] B. Jamieson et al. Phys. Rev. D 74 (2006)

Final measurements due in 2009.
Uncertainty of 0.0010 expected on PμΞ.

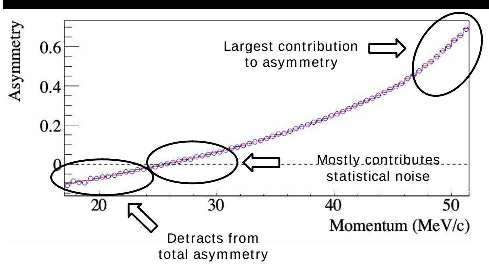
To measure Pμξ, the time dependence of Pμ in aluminium and silver (at room temperature) must be known with high precision. For Ref. [3], the uncertainty due to the depolarisation's form was 0.0012. For the final round, we need it to be ~ 0.0006.

$P_\mu(t)$ for silver, from TWIST



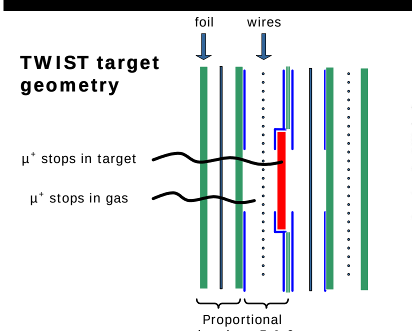
TWIST cannot measure times less than ~500ns, and has not been able to verify the expected exponential form of the depolarisation.

Weighted asymmetry with TWIST

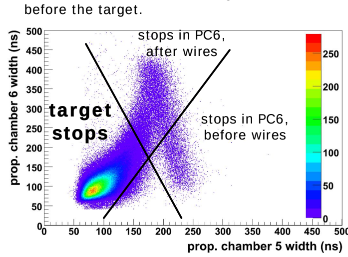


- Can just remove all e^+ with p < ~40MeV/c, but better approach is to weight each e^+, based on its momentum.
- A good weighting factor is the theoretical asymmetry raised to a power.
- Using this technique, and removing e^+ below 31MeV/c, the uncertainty on λ in exponential fits is halved.

Selecting target stops with TWIST

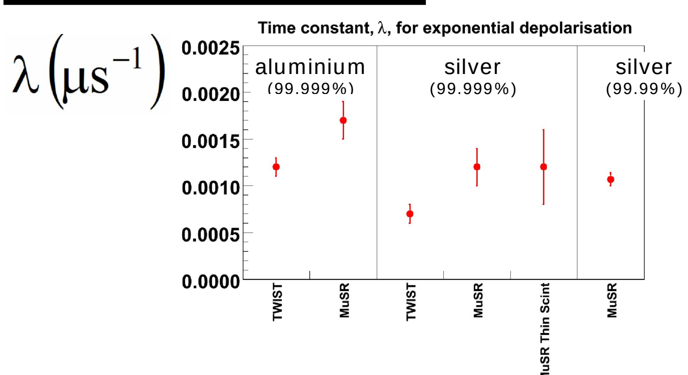


Pulse widths in final proportional chambers are used to select muons that stop in target, instead of the CF4/Isobutane gas immediate before the target.



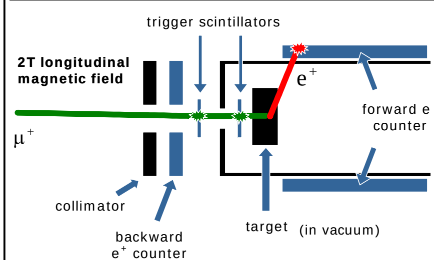
Results

(negligible systematic uncertainties due to rate, background, DC separator)



E1111 (μ^+SR): no fast depolarisation down to ~5ns

E1111: MuSR at TRIUMF



- Standard μ^+SR setup using TRIUMF M20 beamline
- Fitted the forward and backward counts using the equations,

$$n_b(t) = b_b + N_0 e^{-t/\tau_\mu}\left[1 + A_b P_\mu(t)\right]$$
$$n_f(t) = b_f + r N_0 e^{-t/\tau_\mu}\left[1 + A_f P_\mu(t)\right]$$

- Fitting was done using MSRFIT (while taking data) and specially written software (for the final analysis).

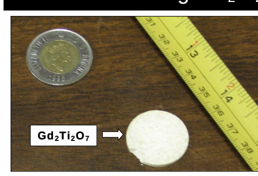
Background determination

To determine background:

1. 1μs of t<0 data was taken. Fits were done with b_b and b_f fixed to the average of t<0 data.
2. Fits were also done with b_b and b_f as free parameters.

Background from t<0 and from free fits were different in a statistically significant way, **but** this was not the leading uncertainty.

Calibration using $Gd_2Ti_2O_7$



- Spin glass $Gd_2Ti_2O_7$ used to determine A_b and A_f,. It depolarised with a single exponential function, with $\lambda = 0.88\ \mu s^{-1}$.
- A_b and A_f then fixed for the metal samples. But to do this, we had to keep the amount of material constant.

  → $Gd_2Ti_2O_7$ AND metal sample were used, then the target was carefully turned around.

Scintillator stops

Data were taken with scintillators of thickness 127μm, 254μm (nominal) and 508μm.

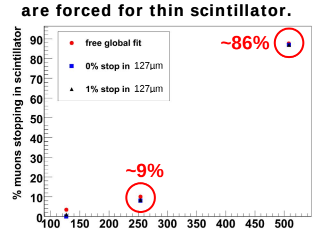
- **Fits to data** show scintillator depolarisation can be approximated by a single exponential with $\lambda \sim 0.0012\ \mu s^{-1}$.
- Data suggest the stopping fractions are:

Scintillator	% muons stopping
127μm	between 0% and 6%
254μm	between 0% and 12%
507μm	between 82% and 89%

- **Simulation** used SRIM software.
- Results were sensitive to initial momentum distribution, and found the following

Scintillator	% muons stopping
127μm	< 1%
254μm	between 1% and 6%
507μm	81% to 86%

What can the data tell us if % stops are forced for thin scintillator.



Dependence of relaxation rate on % stopping in scintillator