Nickel: energy and temperature dependence of the relaxation rate and asymmetry in ZF and 50 G

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Abstract

This document summarizes the results of LEM experiment on nickel during December 2010. The fits are done using asymmetry and single histogram fits. The effect of NPP and PPC is shown. The results presented here are done with an exponential fit. The data reveals a weak relaxation ($\lambda \sim$ 0.02-0.05 MHz) of the tail (slow relaxing part) of the asymmetry. This relaxation is weakly temperature-dependent, and independent of energy.

I. INTRODUCTION

Nickel is a ferromagnetic metal that we sometimes use as a background suppression material. The fraction of muons that miss the sample and land into nickel, experience a broad distribution of static magnetic fields, and hence exhibits a very fast relaxing asymmetry during the first few ns, minimizing the background contribution to the overall signal. This helps to resolve a weak relaxing signal, for example due to weak spontaneous magnetization. Nickel is also used as a backing material for small crystals, where the signal of the large fraction of the muons that miss the crystals is suppressed. This experiment sheds light on the real behavior of the muon spin relaxation in nickel studied in zero and low applied field. The experiment is done on a plate sputtered by Ni (M. Horisberger), and addresses these questions: (i) What is the temperature and energy dependence of the slow relaxing part? For this we do a temperature scan at different energies (2, 14 keV). (ii) What is the field dependence of the asymmetry and rate?

II. SUMMARY OF THE RESULTS

- Initial asymmetry (fast component) is $a_f \sim 0.27$, while the slow component is $a_s \sim 0.11$ (see Fig. 1). The slow component has a lower asymmetry at 50 G ($a_s \sim 0.06$) than ZF? (see Fig. 2).

- The slow component is fit in this analysis using a single exponential from 0.15 to 8 μs (see Fig. 3). Fitting with a Gaussian does not change the trends, but λ is higher by about a factor of 2.4.

- In all fits, α is fixed to 1. Fits using asymmetry or single histograms have been compared, where in the single histogram fits the background is a "free" parameter (see the fitting template in Fig. 17).

- NPP or PPC fits have also been done. The background was estimated from the bin region between 65000 and 66500 for NPP, and between 100 and 2000 for PPC.

- PPC leads to a smaller and flatter T-dependent λ (see Figs. 5, 6, and 7).

- λ in ZF is found to be slightly temperature dependent at 2 keV and 14 keV, and ranges from 0.05 MHz at 250 K to 0.02 MHz at 5 K. The asymmetry is T-independent (see Figs. 5, 6, and 7).
- λ in ZF is not energy-dependent, while the asymmetry drops with the higher the energy from 0.12 at 2 keV to 0.1 at 23 keV. (see Figs. 8, 9, and 10).
- At 50 G, no temperature dependence of the relaxation at 2 keV and 14 keV is observed, but it is scattered between 0.02 and 0.1 MHz. The asymmetry is also T-independent $a_s \sim 0.06$, but it is lower than in ZF!!! (see Figs. 13, 14, 15, and 16).

III. LIST OF RUNS

- T scan in ZF and 2 keV: 3066 3073 3078 3079 3080 3081 3082 3083 3084 3085
- E scan in ZF and 5 K: 3062 3063 3064 3065 3066 3067 3068
- T scan in ZF and 14 keV: 3061 3062 3069 3070 3071 3075 3075 3076 3077
- E scan in ZF and 100 K: 3061 3072 3073 3074
- E scan in 50 G and 5 K: 3086 3087 3088 3089 3090 3091
- T scan in 50 G and 2 keV: 3086 3092 3093 3095 3096 3099 3100 3103
- T scan in 50 G and 14 keV: 3090 3094 3097 3098 3101 3102

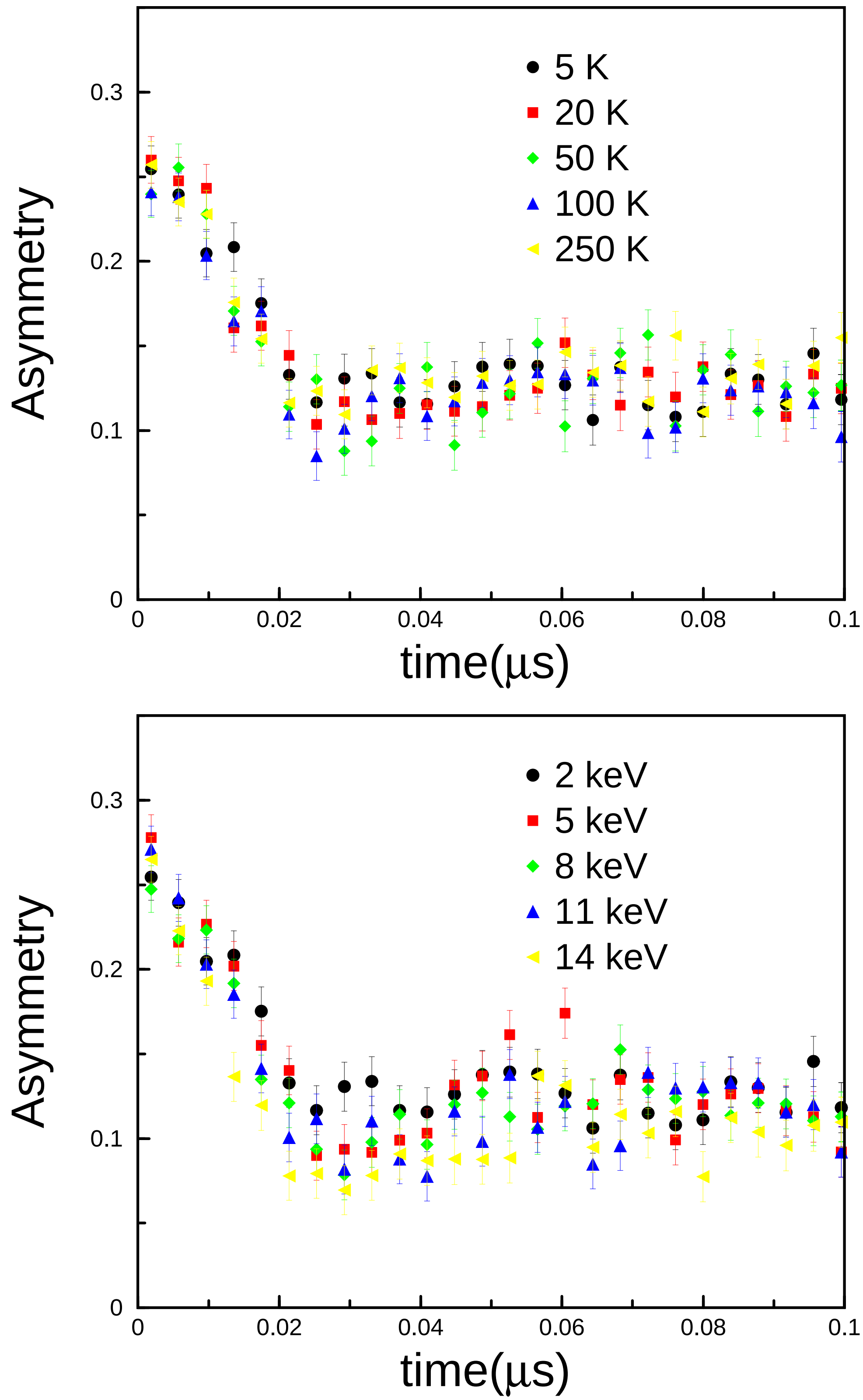

FIG. 1: Asymmetry during the first 100 ns in ZF: (a) T scan at 2 keV, (b) E scan at 5 K.

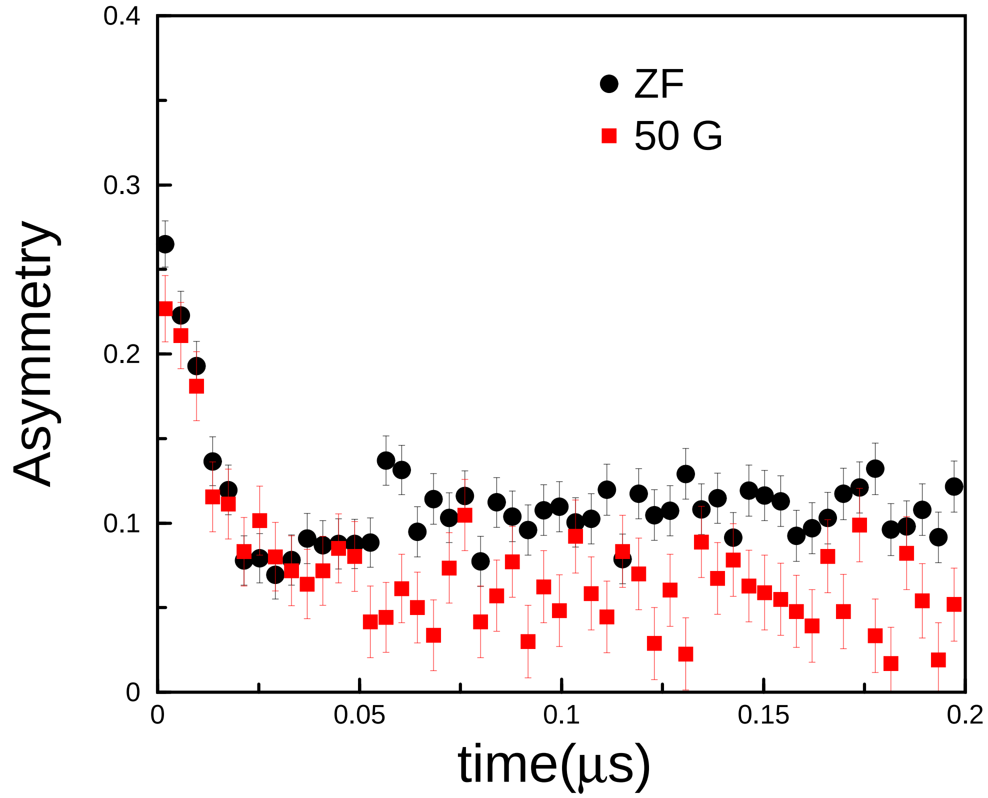

FIG. 2: Comparison between 50 G and ZF asymmetry at 5 K during the first 200 ns.

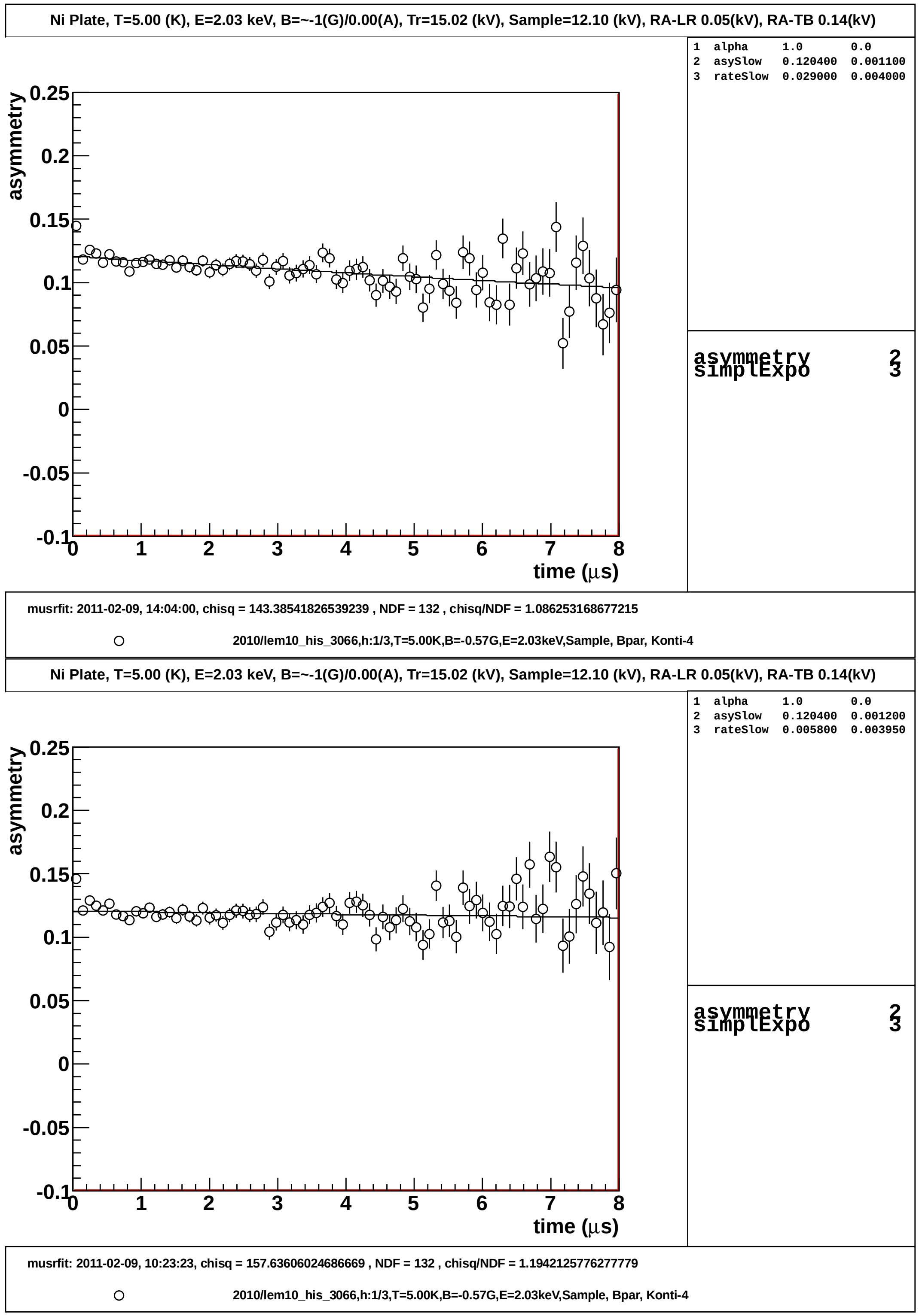

FIG. 3: ZF and 2 keV and 5K: comparison between NPP and PPC.

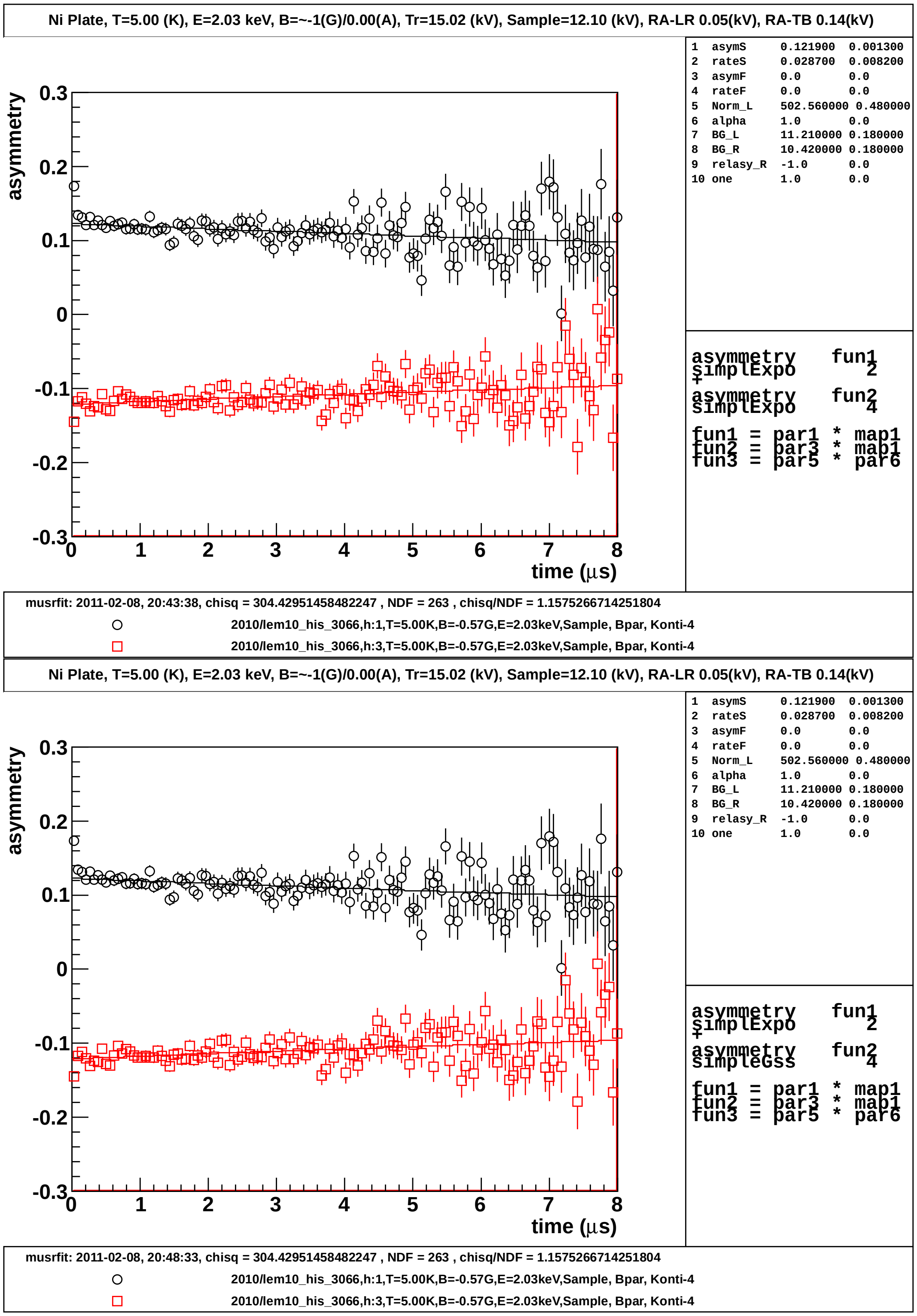

FIG. 4: ZF and 2 keV and 5K: comparison between single histograms using NPP and PPC.

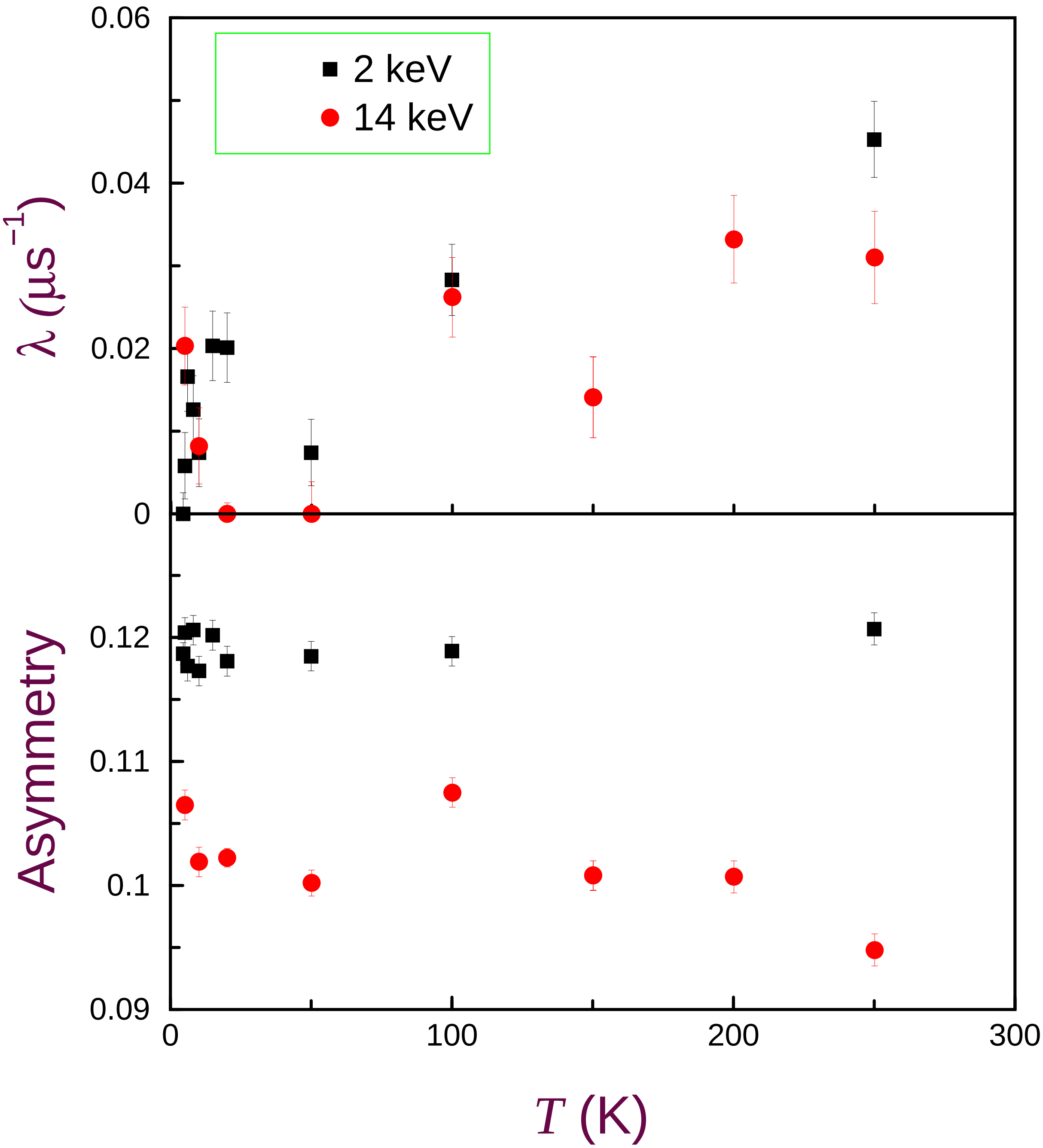

FIG. 5: The temperature dependence of the relaxation rate and asymmetry in nickel at 2 keV (black squares) and 14 keV (red circles) and in zero field. Fits are done using one exponential of the asymmetry, PPC, and fixed $\alpha = 1$.

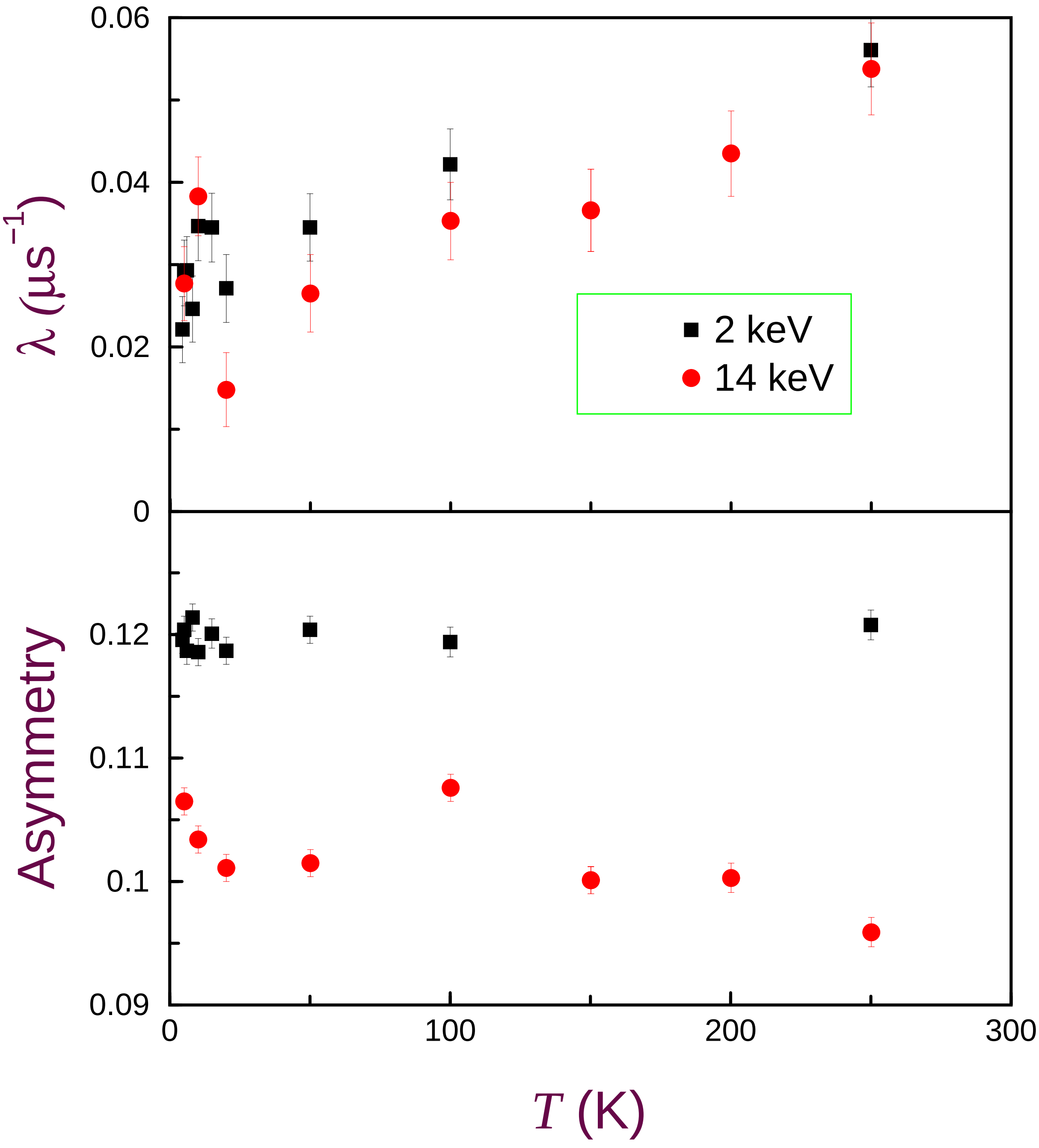

FIG. 6: The temperature dependence of the relaxation rate and asymmetry in nickel at 2 keV (black squares) and 14 keV (red circles) and in zero field. Fits are done using one exponential of the asymmetry, NPP, and fixed $\alpha = 1$.

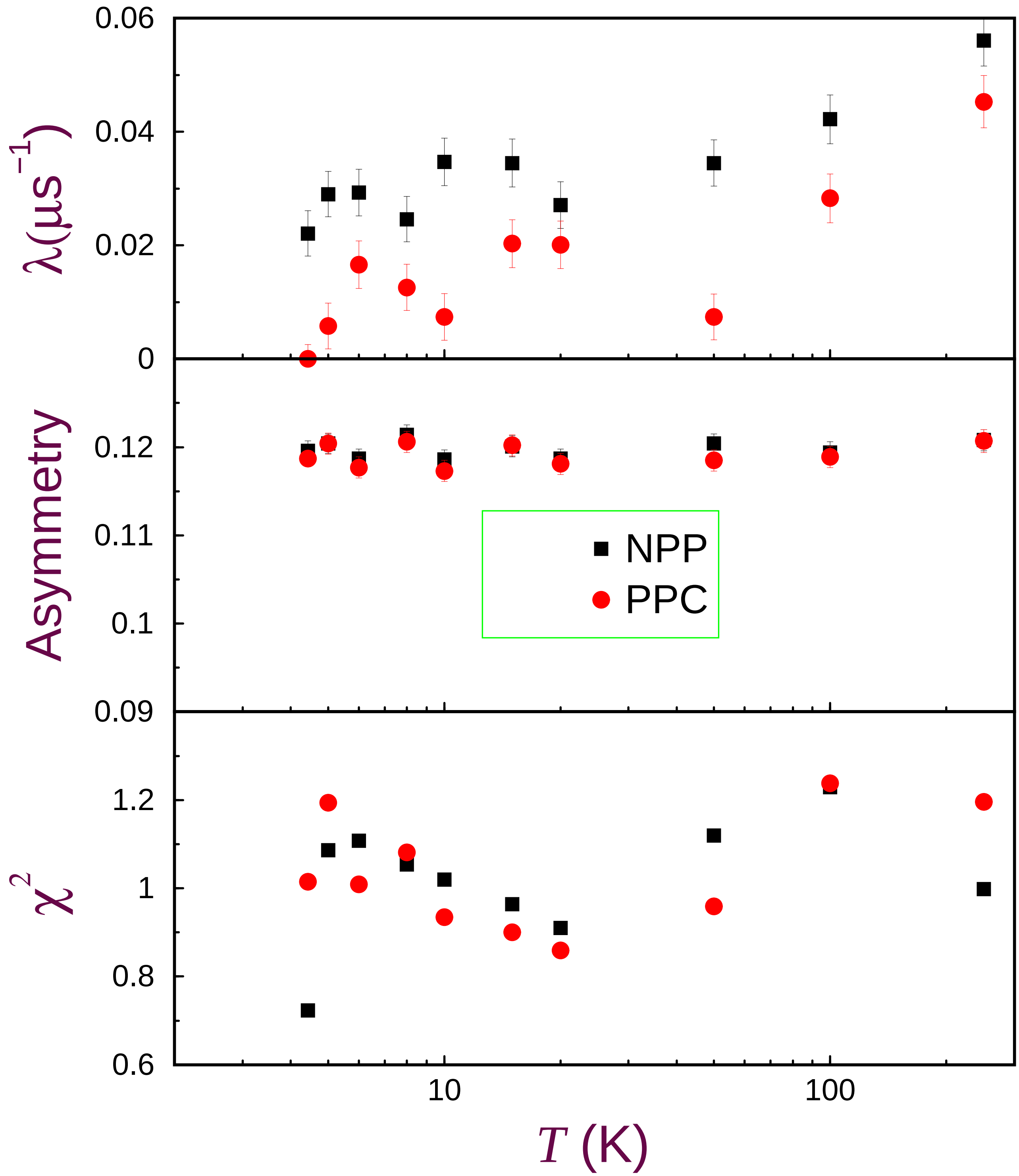

FIG. 7: Temperature dependence of the relaxation rate, asymmetry and χ^2 in ZF and 2 keV: comparison between NPP and PPC using $\alpha = 1$, and fitting the asymmetry.

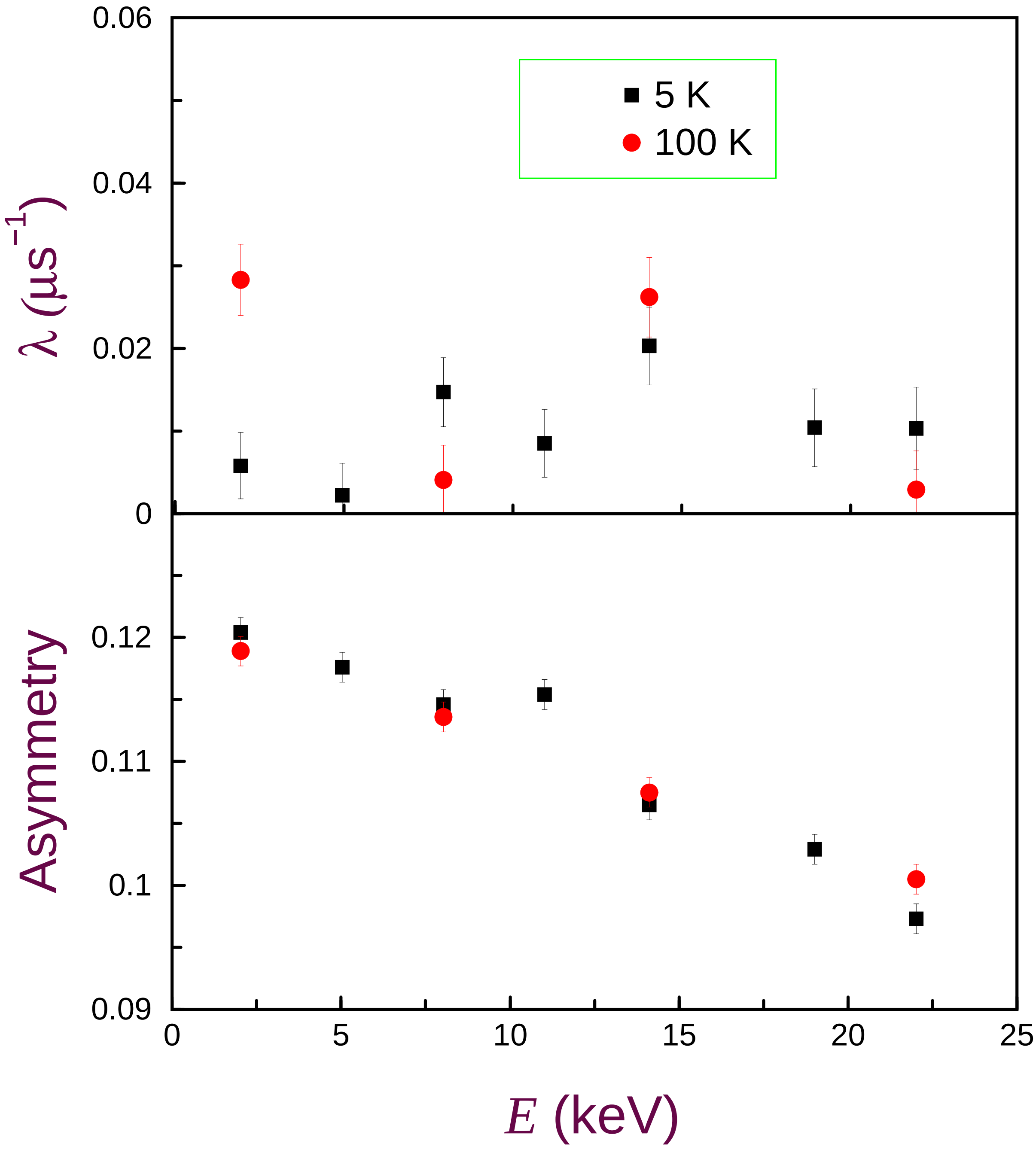

FIG. 8: The energy dependence of the relaxation rate, and the asymmetry in Nickel at 5 (black squares) and 100 K (red circles) and in zero field. Fits are done using one exponential of the asymmetry, PPC, and fixed $\alpha = 1$.

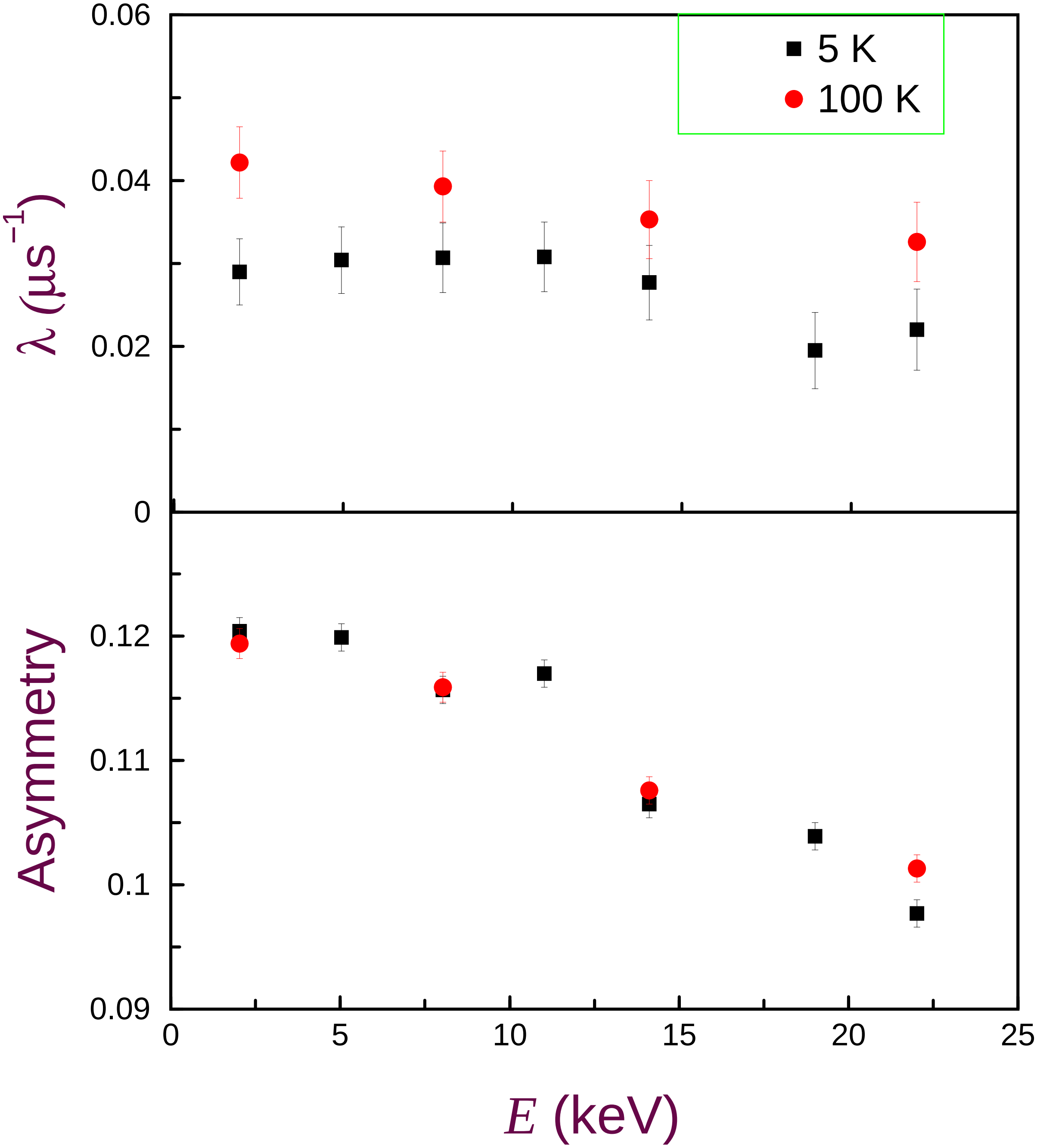

FIG. 9: The energy dependence of the relaxation rate, and the asymmetry in Nickel at 5 (black squares) and 100 K (red circles) and in zero field. Fits are done using one exponential of the asymmetry, NPP, and fixed $\alpha = 1$.

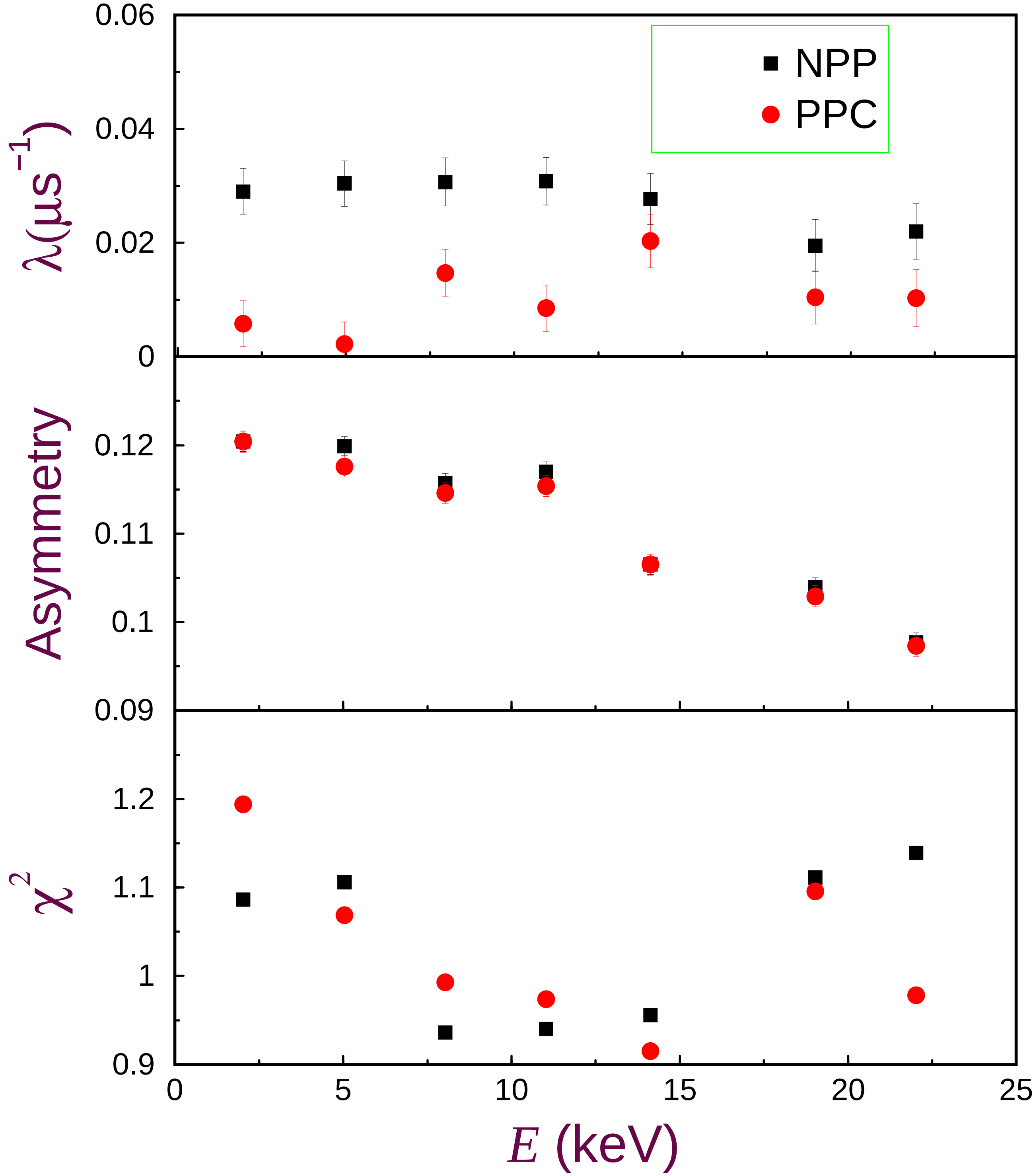

FIG. 10: ZF and 5 K: comparison between NPP and PPC. Fits are done using one exponential of the asymmetry with $\alpha = 1$.

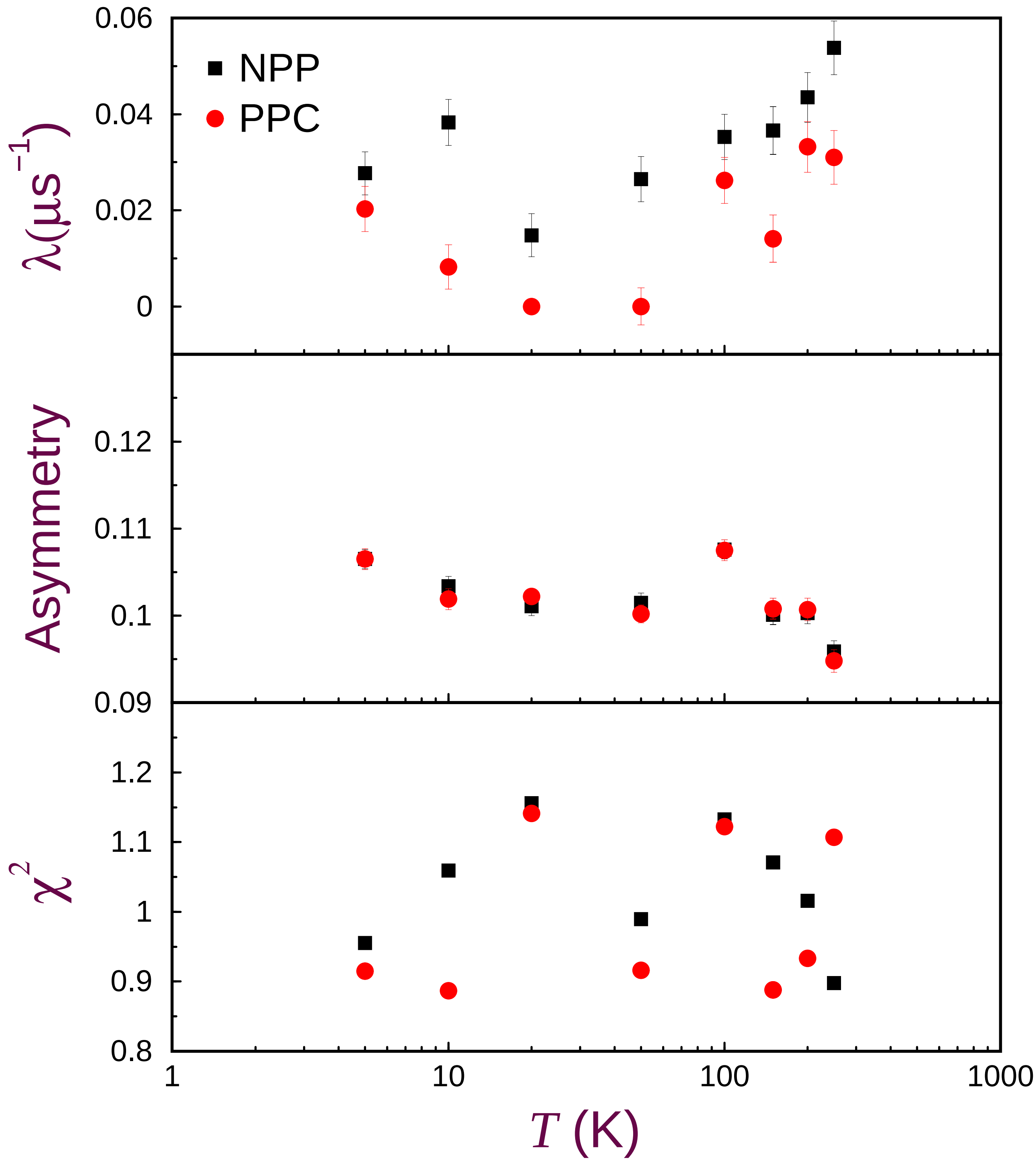

FIG. 11: ZF and 14 keV: comparison between NPP and PPC. Fits are done using one exponential of the asymmetry with $\alpha = 1$.

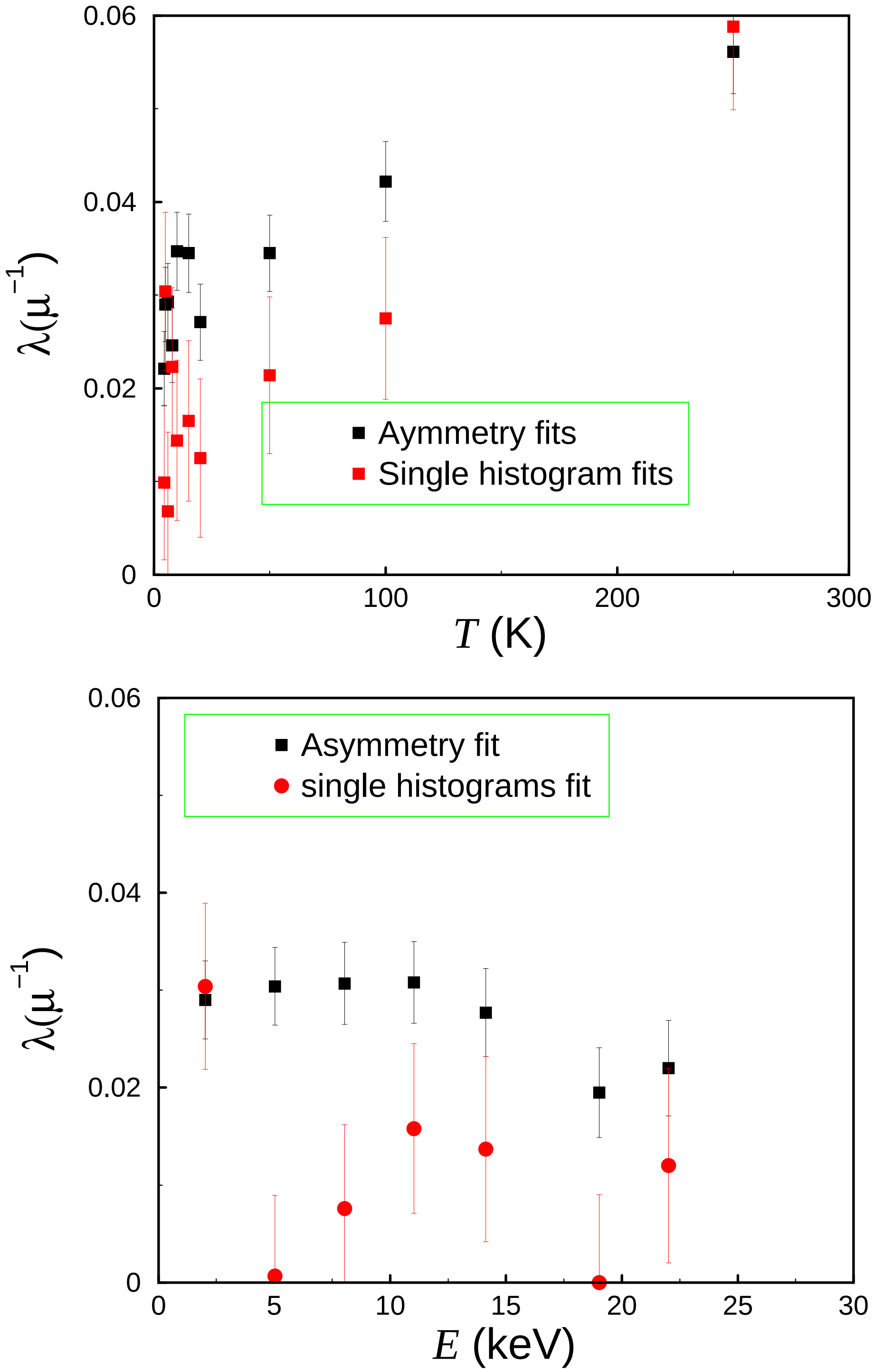

FIG. 12: Top: comparison between asymmetry and single histogram fits ZF and 2 keV. Bottom: comparison between asymmetry and single histogram fits at ZF and 5 K.

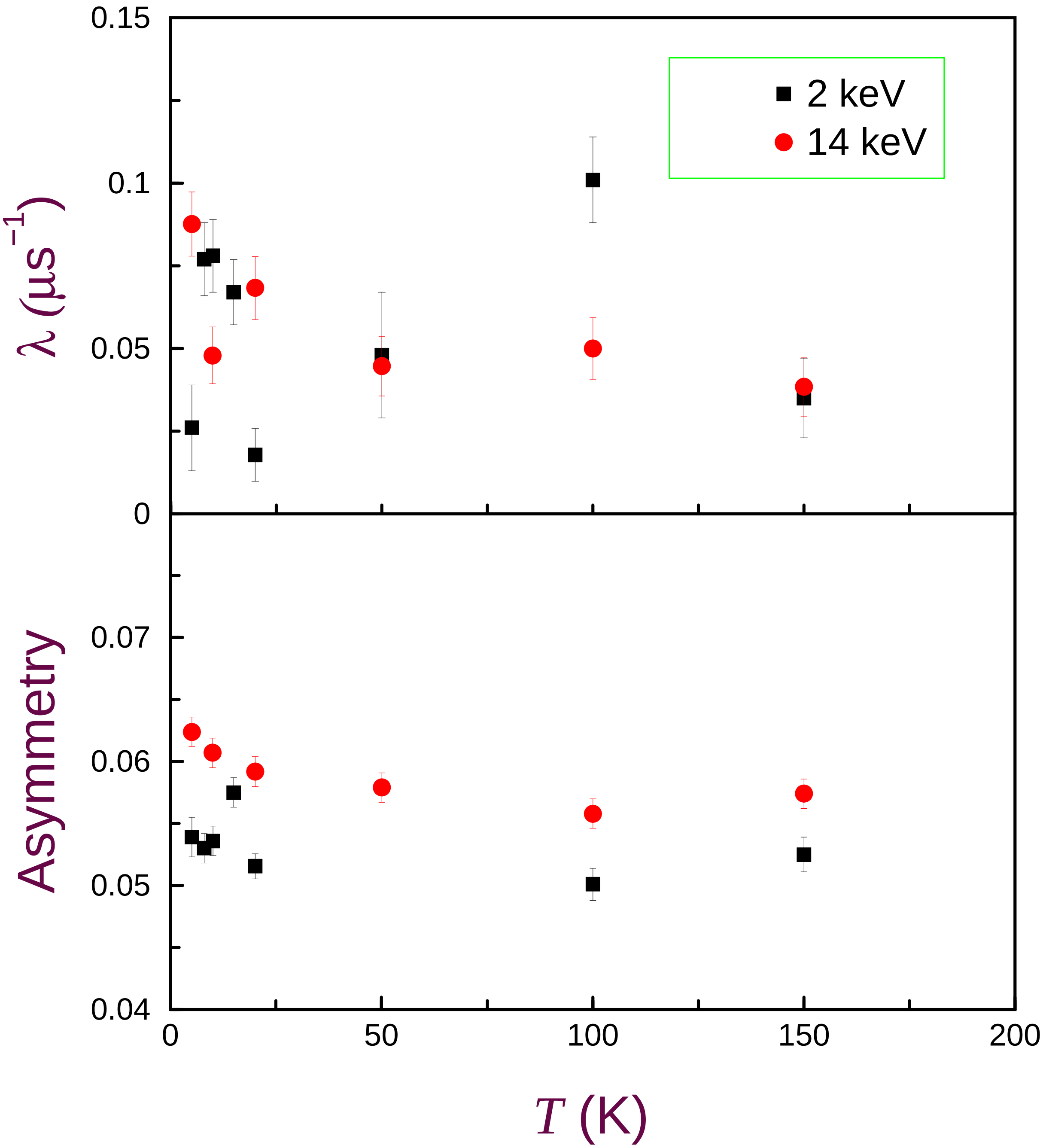

FIG. 13: At 50 G: The temperature dependence of the relaxation rate, and the asymmetry in Nickel at 2 keV (black squares) and 14 keV (red circles) and 50 G. Fits are done using one exponential of the asymmetry using NPP and fixed $\alpha = 1$.

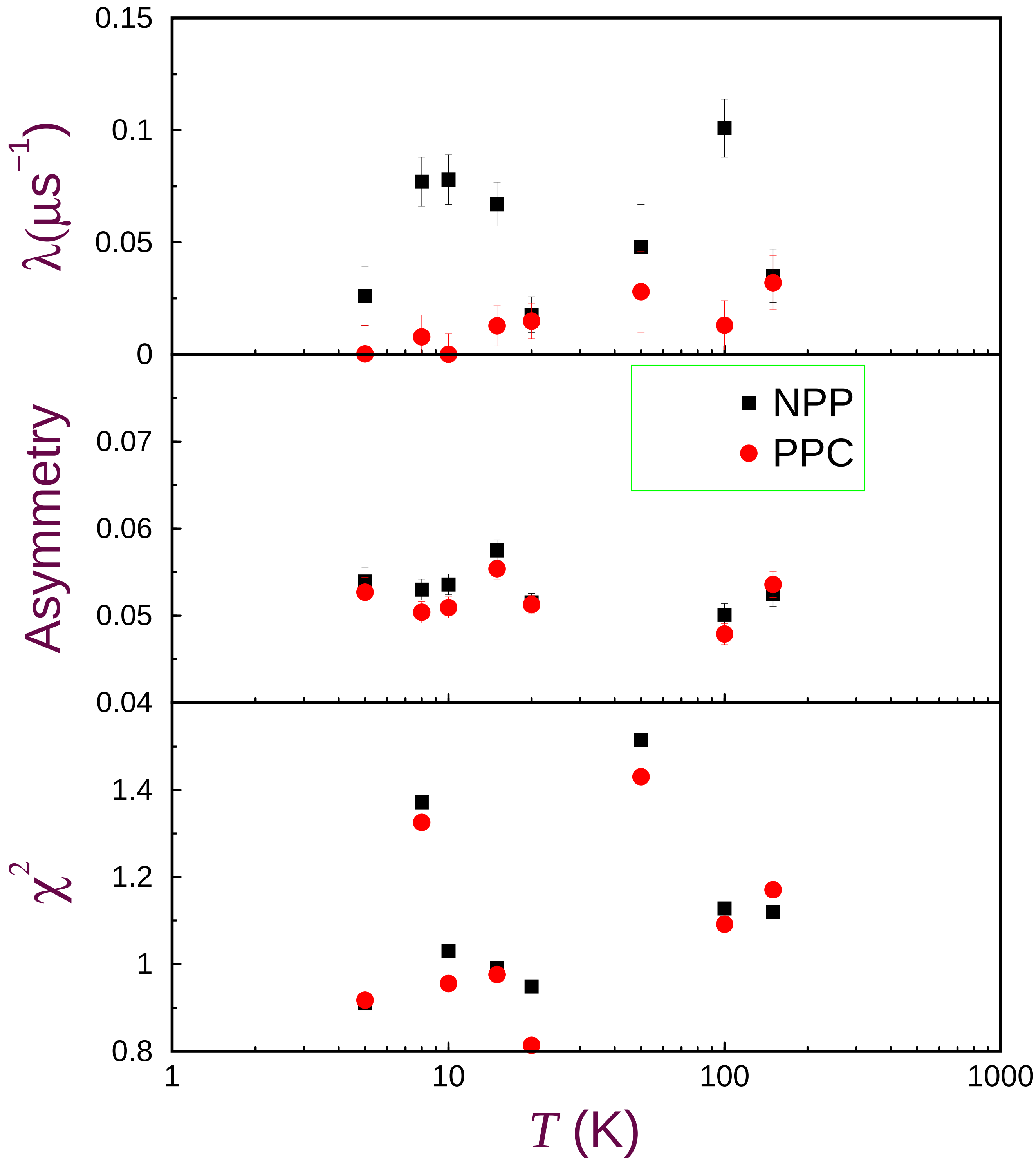

FIG. 14: At 50 G: T scan of the relaxation rate, asymmetry and χ^2 at 50 G and 2 keV: comparison between NPP and PPC.

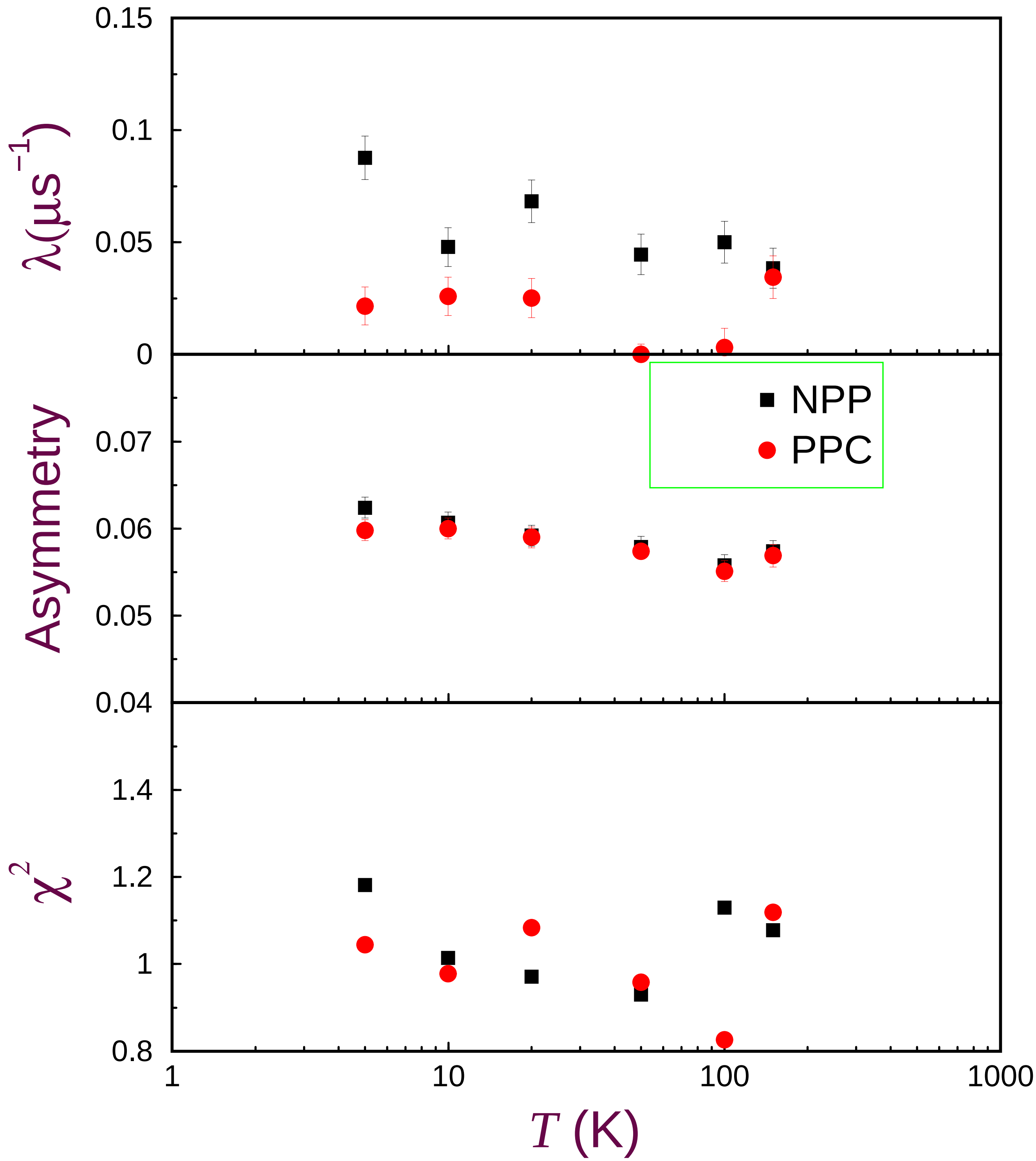

FIG. 15: At 50 G: T scan of the relaxation rate, asymmetry and χ^2 at 50 G and 14 keV: comparison between NPP and PPC.

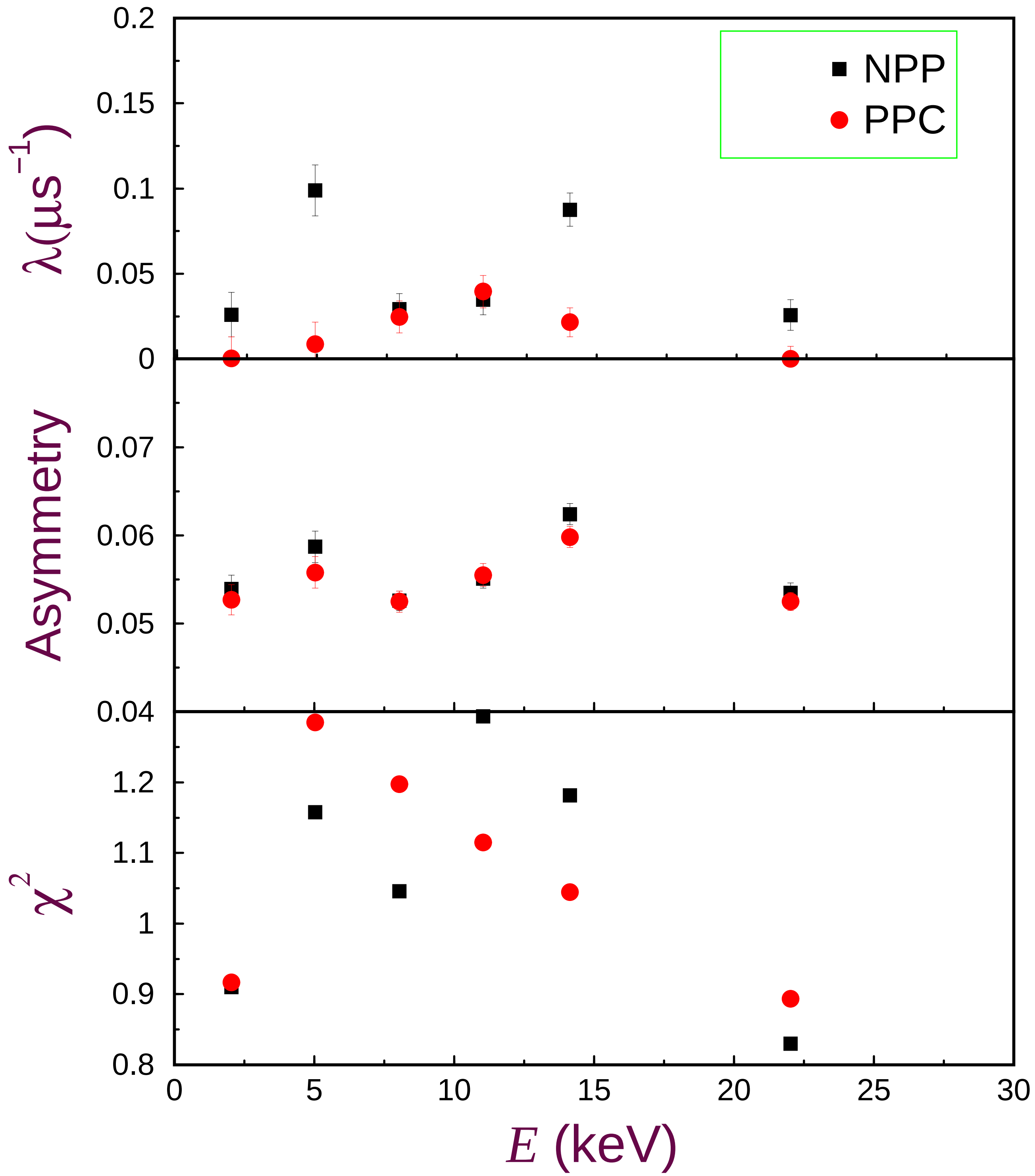

FIG. 16: At 50 G: Energy scan of the relaxation rate, asymmetry and χ^2 at 50 G and 5 K: comparison between NPP and PPC.

```
3088_zf_shist_exp_npp.msr*

Ni Plate, T=5.00 (K), E=8.03 keV, B=~48(G)/1.50(A), Tr=15.02 (kV), Sample=6.10 (kV), RA-LR
0.05(kV), RA-TB 0.14(kV)
###############################################################
FITPARAMETER
#       No Name        Value     Step        Pos_Error   Boundaries
        1 asymS       0.05238   -0.00092    0.00092     0       0.3
        2 rateS       0.0000000033  -0.0000000033 0.0074343889 0       1
        3 asymF       0         0           none        0       0.3
        4 rateF       0         0           none        0       100
        5 Norm_L      640.05    -0.59       0.59
        6 alpha       1         0           none        0       2
        7 BG_L        47.19     -0.17       0.18
        8 BG_R        45.24     -0.17       0.17
        9 relasy_R    -1        0           none        0.2     2
       10 one         1         0           none
###############################################################
THEORY
asymmetry   fun1
simplExpo      2          (rate)
+
asymmetry   fun2
simplExpo      4          (rate)
###############################################################
FUNCTIONS
fun1 = par1 * map1
fun2 = par3 * map1
fun3 = par5 * par6
###############################################################
RUN 2010/lem10_his_3088 MUE4 PSI ROOT-NPP   (name beamline institute data-file-format)
fittype         0         (single histogram fit)
norm            5
backgr.fit      7
lifetimecorrection
map             10   0    0    0    0    0    0    0    0    0
forward         1
data            3419    63000
fit             0.15    8
packing         300

RUN 2010/lem10_his_3088 MUE4 PSI ROOT-NPP   (name beamline institute data-file-format)
fittype         0         (single histogram fit)
norm            fun3
backgr.fit      8
lifetimecorrection
map             9    0    0    0    0    0    0    0    0    0
forward         3
data            3419    63000
fit             0.15    8
packing         300
```

FIG. 17: Template used to fit single histogram data, where $\alpha = 1$, and the backgournd is free.