| ESRF | **Experiment title:** Interancy of cerium magnetism in α-Ce and $CePd_{1-X}Rh_X$. | **Experiment number**: HE-3156 |
|---|---|---|
| **Beamline**: ID15a | **Date of experiment**: from: 15/07/09 ***to:*** 21/07/09 | **Date of report**: 20/10/09 |
| **Shifts:** 18 | **Local contact(s)**: Thomas Buslaps | *Received at ESRF:* |


**Names and affiliations of applicants** (* indicates experimentalists):

**Jonathan A. Duffy (University of Warwick)***

**Jonathan W. Taylor (Rutherford Appleton Laboratory)***

**Matthew Butchers (University of Warwick)***


## Report:

Magnetic Compton scattering was used to investigate the spin magnetic moment in the cerium compounds $CePd_{0.3}Rh_{0.7}$, $CePd_{0.15}Rh_{0.85}$ and $Ce_{0.9}Sc_{0.1}$. The experiment suffered from two main problems: firstly 3 shifts were lost when the ESRF liquid helium supply ran out; secondly the new undulator (that only provides a linearly polarised beam) on ID15 was being used for an experiment on the b-hutch but this caused significant heating of our monochromator, resulting in a major beam stability problem which we had to determine how to overcome: this was exacerbated by a faulty motor unit. Whilst we were unable to collect sufficient data during the experiment, we were able to demonstrate that good data can be obtained despite the background from the new undulator.

$CePd_{1-x}Rh_x$ is an example of a 4*f* system that exhibits a FQCP [1], around x = 0.85. Doping CePd, a ferromagnet with $T_C$ = 6.6K with Rh yields a continuous transition from a ferromagnetism to a mixed valance state with $T_C$ going to zero around x = 0.85. The itinerancy of Ce is key to understanding a wide range of phenomena in Ce containing systems. The degree to which the Ce ion is delocalised is thought to be vital to both non-Fermi liquid systems and quantum critical systems alike. As yet there has not been a definitive measurement of the degree of itinerancy of Ce either in α-Ce or in any of the key non Fermi liquid systems [2]. This is due to the inherent difficulty in measuring spin density close to Q = 0 using polarised neutron diffraction and the low spin moments (0.1 $\mu_b$/FU) which in the past have made magnetic Compton scattering difficult. Compton scattering is sensitive to all spin polarised electrons, sampling the entire Q distribution of the spin density. It is therefore straightforward to determine to the itinerancy of the spin density.

Spin polarised Compton scattering samples the spin-dependent electron momentum density through the use of circularly polarised synchrotron radiation. The technique involves high-energy inelastic scattering of a monochromatic beam of circularly polarised photons $E_I$=200-250keV. The energy dispersion of the scattered beam is directly related to the electron momentum distribution. In this case, an energy of ~215keV was used, with a scattering angle of 174 degrees, which gives the optimal resolution and countrate. In order to extract the spin polarised signal two measurements were made with parallel and antiparallel applied field directions with respect to the scattering vector. This experiment used the new 9T cryomagnet that has been installed by the Warwick group (long term proposal HE1675, and recent publication [3]).

We can determine, by comparison with our experiment HE-2727 [4] (a study of $Sr_3Ru_2O_7$), that we are able to make measurements of sufficient statistical accuracy to comment on the itinerancy of the spin. However, this was performed without the new udulator. We use elliptically polarised photons using the ID15 asymmetric wiggler. The undulator produces only linearly polarised photons. Because of its lower critical energy, by choosing an incident energy for our experiment of 250keV, the contribution to our signal is negligible. However, there is still a high flux (at relatively "low" energy) incident on our monochromator, which causes significant heating, as we observed in experiment HE-2869 [5]. However, the level of problem was not fully apparent then, since we were measuring $Ca_3Co_2O_6$, which has a large spin moment, making normalisation significantly easier: despite difficulties, that experiment was successful. During HE-3156, we had to spend time determining how to obtain normalised data of the quality obtainable prior to the installation of the undulator. We had a new "wedge" device, using a Perspex wedge supplied by the beamline that was progressively moved into the beam using a feedback system to keep the count rate constant as the electron beam in the synchrotron decayed. Unfortunately, it became apparent that there was a fault with the motor, such that it slowly lost steps, and hence its position. A number of shifts were lost because of the lack of liquid helium onsite: our magnet requires the helium in order to operate.

Despite the problems encountered during the experiment, we determined how to obtain good measurements despite the undulator. We obtained data for the sample (which has the largest moment of the samples studied), and could show that there is a spin moment of $-(0.24 \pm 0.04)\mu_B$, compared to the bulk moment of $(0.59 \pm 0.05)\mu_B$, so that there must be an orbital moment of $(0.83 \pm 0.07)\mu_B$. In the final shift of the experiment, we were able to obtain well-normalised data on $Ce_{0.9}Sc_{0.1}$, but there was insufficient time to obtain sufficient statistical accuracy. For future experiments with the undulator running, we will also use a molybdenum filter to reduce the heat load on the monochromator, which should significantly reduce the problem. This may need cooling, as it will be in the white beam: the beam burnt through a tin filter used briefly during the experiment.

**References:**

1. P. Coleman and A.J. Schofield. Nature **433** 226 (2005)
2 E. Murani, S.J. Levett and J.W. Taylor, Phys. Rev. Lett. **95** 256403 (2005)
3. C. Shenton-Taylor *et al.*, *J. Phys. Condens. Matter* **19** 186208 (2007).
4. Experimental report HE2727
5. Experimental report HE2869