EUROPEAN SYNCHROTRON RADIATION FACILITY

INSTALLATION EUROPEENNE DE RAYONNEMENT SYNCHROTRON

Experiment Report Form

The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF.

Once completed, the report should be submitted electronically to the User Office via the User Portal:
https://wwws.esrf.fr/misapps/SMISWebClient/protected/welcome.do

Deadlines for submission of Experimental Reports

Experimental reports must be submitted within the period of 3 months after the end of the experiment.

Experiment Report supporting a new proposal ("relevant report")

If you are submitting a proposal for a new project, or to continue a project for which you have previously been allocated beam time, you must submit a report on each of your previous measurement(s):

- even on those carried out close to the proposal submission deadline (it can be a *"preliminary report"),*
- even for experiments whose scientific area is different form the scientific area of the new proposal,
- carried out on CRG beamlines.

You must then register the report(s) as "relevant report(s)" in the new application form for beam time.

Deadlines for submitting a report supporting a new proposal

- 1st March Proposal Round - **5th March**
- 10th September Proposal Round - **13th September**

The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

Reports on experiments relating to long term projects

Proposers awarded beam time for a long term project are required to submit an interim report at the end of each year, irrespective of the number of shifts of beam time they have used.

Published papers

All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report in English.
- include the experiment number to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.

ESRF	**Experiment title:** Detecting non-classical x-ray radiation by measuring the second-order correlation function.	**Experiment number**: HC-2766
Beamline:	**Date of experiment**: from: 09.09.2016 to: 14.09.2016	**Date of report**: 08.03.2021
Shifts:	**Local contact(s)**: Rudolf Rüffer	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

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Report:

The experiment's aim was to measure the second order correlation function of a resonant x-ray cavity into which ^{57}Fe atoms had been placed. This is a quantum cavity electrodynamical experiment in the intermediate regime, meaning that the coupling strenght between cavity and ^{57}Fe nuclei is larger than the decay constant of the nuclei, but smaller than the decay constant of the cavity. Theoretical work indicates that the second-order correlation function of such an intermediate coupling system can display highly non-classical behaviour. Our estimates indicated that the ESRF 4-bunch mode would yield sufficient 2-resonant photon events to satisfy counting statistics.
Unfortunately, the experiment failed, for two main reasons:

A) We had several concurrent problems with our sample cavities. A production problem occuring during the preparation of the beamtime yielded several cavities of unsatisfactory quality. In particular, the reflectivity was much lower than anticipated. We did not manage to fix the problem meaningfully in the run-up to the experiment. We anticipated that this might turn out to be a problem, and brought several older cavities used in previous experiments along, but these turned out to display a hyperfine splitting of the ^{57}Fe, which also would have spoiled, or at least encumbered the experiment. We hence stuck with an inferior-reflectivity sample, leading to many fewer counts than anticipated in the proposal.
B) We had recurring problems with the setup used to record the incident photons. In our zeal to measure as many photons as possible, we had minimized the veto time of the APDs. About half-way through the experiment, when taking a first look at the data (the analysis took somewhat longer since the data was taken with a custom setup) we noticed that there was a gap of about 10 ns *after* the veto, in which the first diode had measured nothing, probably due to the CFD being overwhelmed. Since the vast majority of delayed photons arrive very early on, this drastically reduced the signal. Photon pairs where both photons arrived within this time (or the veto) were not

recorded at all; photon pairs where only the first photon had arrived within that time, or where the second had been logged by a different APD, were not identifiable as pairs in post-processing.

Having fixed this issue by omitting the CFD and feeding the signal of three APDs directly into the ADC, we noticed, again somewhat later, that the Start signals were not logged any more. This meant that photon counting events were not assignable to a single bunch, which meant in turn that only those photon pairs could be identified that had been measured by the same diode – photon pairs where one had been detected at time A by APD 1 and the other at time B by APD 2 were not identifiable as photon pairs, which also strongly suppressed the 2-photon count rate.

A third issue arose when the other two were fixed. There was some uncertainty on our part what the best cavity detuning (i.e. angular setting) was. The setting where the second order correlation function displayed the largest non-classicality would not necessarily be identical to the one where the count rate was largest. We tried to navigate this problem by making measurements at different angular settings, spreading the remaining experimental times between two settings. Unfortunately, it turned out that there were simply too few 2-photon events to get meaningful results in the remaining time; having different settings (which would return different second order correlation fucntions) only excacerbated the problem. No meaningful second-order correlation function could be measured at all in the end; not to speak of measuring whether it exceeded non-classicality bounds.