EUROPEAN SYNCHROTRON RADIATION FACILITY

INSTALLATION EUROPEENNE DE RAYONNEMENT SYNCHROTRON

ESRF

# 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:** Determining the nature of the high energy quasi-circular dynamic correlations in cuprates with polarimetric RIXS | **Experiment number**: HC-5239 |
|---|---|---|
| **Beamline**: ID32 | **Date of experiment**: from: 04 April 2023 to: 11 April 2023 | **Date of report**: 7/31/2023 |
| **Shifts:** 18 | **Local contact(s)**: Flora Yakhou | *Received at ESRF:* |

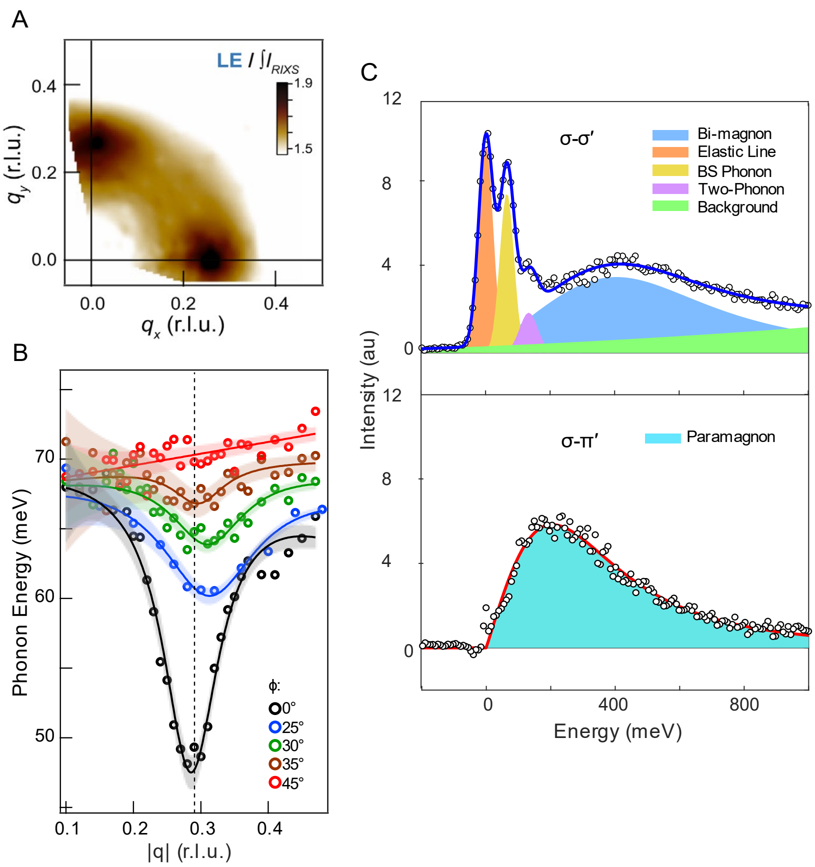
**Names and affiliations of applicants** (* indicates experimentalists):


Prof Eduardo Higino da Silva Neto | Yale University, Dept of Physics
Prof. Fabio Boschini | INRS Centre Energie Materiaux Télécommunications
Dr. Alex Frano | UCSD, Dept. of Physics
Kirsty Scott* | Yale University, Dept of Physics
Xinze Yang*| Yale University, Dept of Physics
Rourav Basak* | UCSD, Dept. of Physics


**Report:**

**The goal of the experiment was to determine the nature of the high energy quasi-circular dynamic correlations observed by Cu-$L_3$ RIXS.**

Figure 1




Recently, our group and collaborators found charge order (CO) correlations in Bi-2212 (via Cu-$L_3$ RIXS measurements at ALS) that, while strongest in the static CO direction (i.e., the Cu-O bond direction), persist in all directions of the Cu-O plane with a finite q = $q_{CO}$, forming a quasi-circular manifold of dynamic electron correlations, see Fig. 1A [1]. The quasi-circular dynamic correlations (QCDCs) were detected with low energy resolution (~800meV) in the sub-1eV region. We expanded upon this finding with high-resolution (38meV) RIXS measurements (at NSLS-II and Diamond) and confirmed the presence of the QCDCs at low energies by using the softening of the bond-stretching phonon as a marker for charge correlations, see Fig. 1B [2].

Despite the success of the high-resolution experiments in detecting the low-energy

QCDCs via phonon softening, we were unable to extract the precise energy profile of the QCDCs. While the momentum space quasi-circular pattern is observed in the energy integrated data from 100 to 700meV, the QCDCs are likely broad over energy and weaker than the overlapping paramagnon contributions, precluding the extraction of their spectral shape in a traditional RIXS measurement.

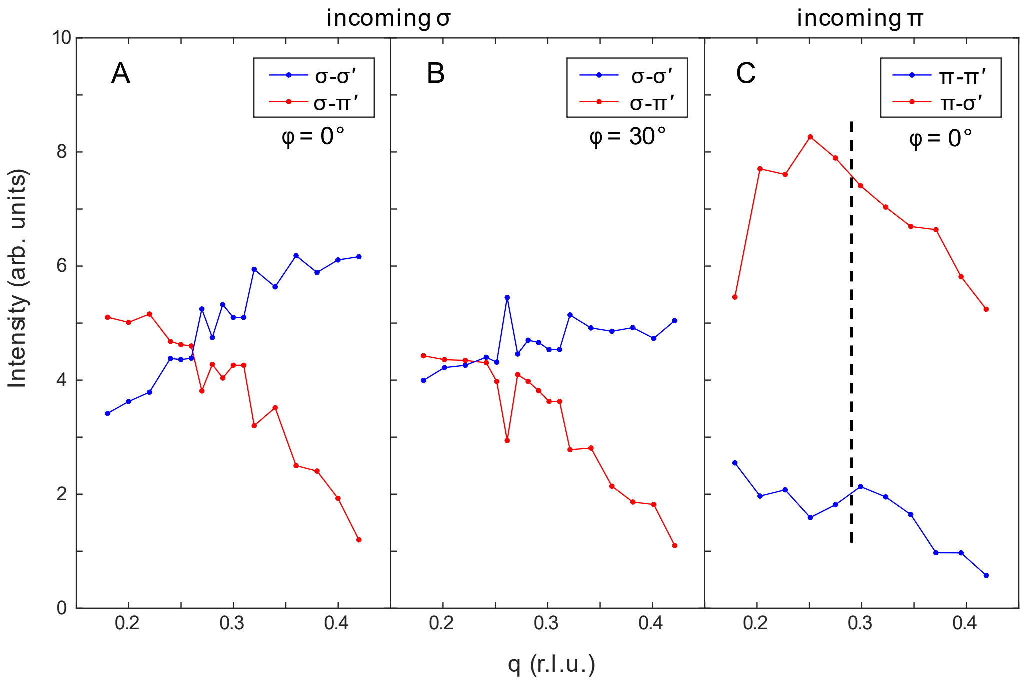
Following the methodology successfully employed in our previous high-resolution (41meV) polarimetric RIXS measurement (HC-4824), Fig. 1C, which indicated the usefulness of polarimetric RIXS to decouple the (cross polarized) spin-flip features from (non-cross polarized) charge correlations, we proposed to do polarimetric RIXS to try to disentangle QCDC contributions from paramagnon excitations. The plan was to employ polarimetric RIXS for three different azimuthal angles, φ, and a range of q-values around $q_{CO}$ to verify the charge-like nature of QCDCs.

To increase flux, we relaxed the energy resolution to ~100meV and to maximize the coupling to charge order excitation we chose incoming σ-geometry. We performed rocking scans at φ=0° and φ=30° from the Cu-O direction (Fig. 2A and B). The blue (red) data represents the integrated intensity from 200meV to 600meV of the non-cross (cross) channel. However, our ability to detect a peak is compromised by (*i*) signal-to-noise limitations due to the lower flux in a polarimetric RIXS measurement, and (*ii*) the large background slopes observed in data in Fig. 2A, B.

At that point, we modified our experimental plan, opting to repeat the φ=0° measurement with incoming π-geometry (Fig. 2C). *This data indicates a peak in intensity of the π- π' (non-cross) channel in the vicinity of q= $q_{CO}$ (marked by the dashed line), as expected in the high-energy QCDC scenario.* However, we would like to confirm this finding by performing a second measurement, with more q points and longer counting times. Additionally, as this measurement was taken along the static CO direction, we still require measurements at different φ-values to achieve the primary goal of the proposal. Still, this first beamtime allowed us to optimize several experimental parameters and led us to realize that incoming π-geometry may be preferrable for these measurements.

Using the information gained from this experiment, we intend to expand upon these measurements and apply to additional beamtime at ID32 to image high-energy QCDCs by completing polarimetric measurements at φ=30° and 45°, with incoming π-geometry.

Figure 2




[1] F. Boschini et al. Nat. Comm. **12**, 597 (2021)
[2] K Scott *et al.,* Sci. Adv. **9**, 29 (2023)