実験報告書様式（一般利用課題・成果公開利用）

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CROSS TOKAI **Experimental Report** J-PARC	承認日 Date of Approval 2017/6/5 承認者 Approver Ryoichi Kajimoto 提出日 Date of Report 2017/6/5
課題番号 Project No. 2017A0162 実験課題名 Title of experiment Microscopic mechanism of large magnetoelectric coupling in $Co_4Nb_2O_9$ 実験責任者名 Name of principal investigator Hajime Sagayama 所属 Affiliation High energy accelerator research organization	装置責任者 Name of Instrument scientist Ryoichi Kajimoto 装置名 Name of Instrument/（BL No.） 4SEASONS/BL01 実施日 Date of Experiment 2017/06/08 ～ 2017/06/14

試料、実験方法、利用の結果得られた主なデータ、考察、結論等を、記述して下さい。（適宜、図表添付のこと）
Please report your samples, experimental method and results, discussion and conclusions. Please add figures and tables for better explanation.

1. 試料 Name of sample(s) and chemical formula, or compositions including physical form.

Chemical formula of the sample is $Co_4Nb_2O_9$.
Two bars of single crystals grown by the floating-zone method were co-aligned by measuring backscattering Laue photographs.

2. 実験方法及び結果（実験がうまくいかなかった場合、その理由を記述してください。）
Experimental method and results. If you failed to conduct experiment as planned, please describe reasons.

$Co_4Nb_2O_9$ which crystallizes in a layered structure belonging to a centrosymmetric trigonal space group $P\bar{3}c1$. This material shows linear ME effect below T_N = 27.4 K, in which magnetic moment of Co2+ ions are aligned as in-plane antiferromagnetic with propagation vector of $\boldsymbol{q}$ = (0 0 0).

A linear ME coupling constant of this material (-30 ps/m) is quite large compared to that of other typical linear ME compounds. To investigate mechanism of the large electromagnetic effects in a microscopic view, information about magnetic and electronic state of Co ions are important. Therefore, we have conducted inelastic neutron scattering experiment at BL01.

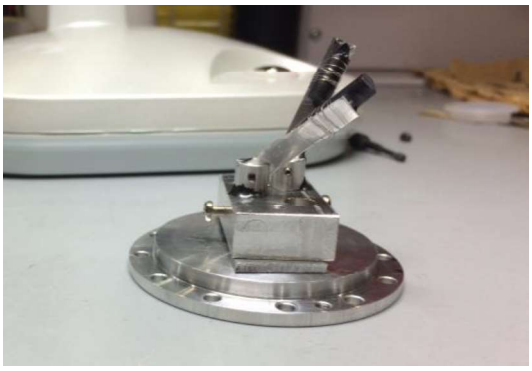

Figure 1 Single crystalline sample of $Co_4Nb_2O_9$

2. 実験方法及び結果（つづき） Experimental method and results (continued)

The single crystalline sample (see fig. 1) was set into a closed-cycle He refrigerator and its temperature was controlled to 5K (lowest temperature). Incident energies of neutrons were selected to be 75.0, 30.0, 16.1 and 10.0 meV by a Fermi chopper with 200 Hz rotation. The sample was rotated ~150 degree around [001] by a 0.5-degree step per 20 minute. We used the software Utsusemi for the experimental data analysis.

At 5 K, we observed spin-wave like dispersive magnetic excitations. Figure 2 shows counter map observed with Ei = 16 meV sliced along (0 0 1) line. We can confirmed one acoustic mode below 4meV and three optical mode around 4meV and 7meV. In addition to those, we found non-dispersive excitations around dE ~ 18 meV. Origin of the excitations remain unknown at this time. To clarify that, we would like to perform theoretical analysis including spin-orbital coupling. We expect that the experimental result provides us useful information about electronic and magnetic state of Co^{2+} ions, which would be essential information to understand the large electromagnetic coupling in this material.

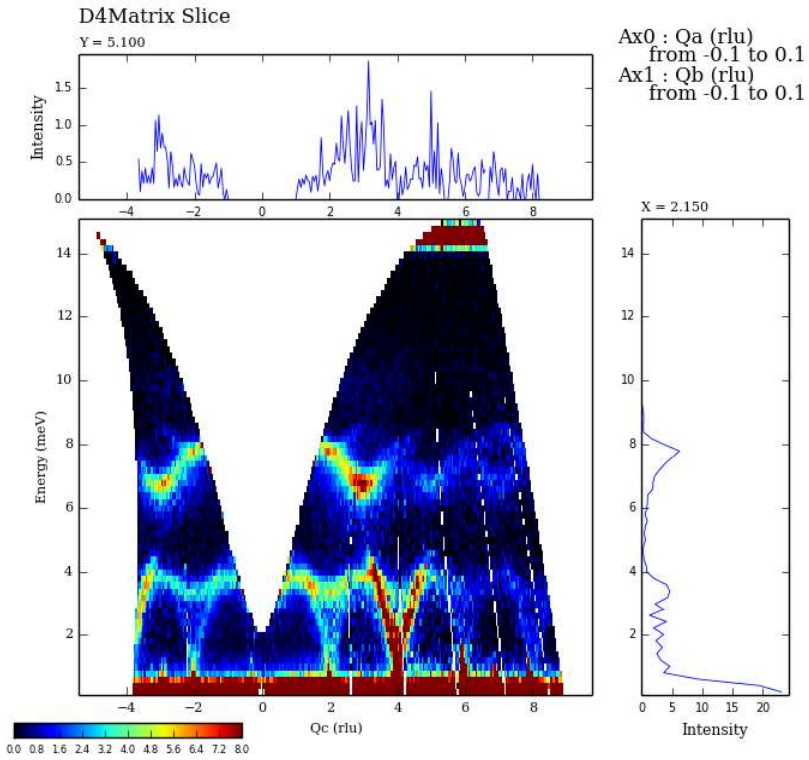

Figure 2 Representative experimental result, counter map observed at 5K with Ei = 16 meV sliced along (0 0 1) line.