

Development of the Beam Transport System for the Study on Atomic Parity Non Conservation

著者	Oikawa A., Hayamizu T., Yoshida H., Itoh M., Takahashi T., Sakemi Y.
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I. 5. Development of the Beam Transport System for the Study on Atomic Parity Non Conservation

Oikawa A., Hayamizu T., Yoshida H., Itoh M., Takahashi T., and Sakemi Y.

Cyclotron and Radioisotope Center, Tohoku University

Francium is one of the best candidates for measurements of atomic Parity Non Conservation (PNC) and in the search for permanent Electric Dipole Moment (EDM). These precise measurements to study the fundamental symmetries, such as parity and time reversal can be achieved by the accurate atomic spectroscopy with the experimental technique of the laser cooling and magneto-optical trap (MOT)¹⁾. At present, we are constructing the high intensity laser cooled francium factory at CYRIC. It is important to get the high accumulation yield of Fr in the MOT, and the key point to realize it is to transport the Fr beam with high transmission efficiency. The present status of the development of the Fr beam transport system is reported here.

Our goal is to study the atomic PNC with the search for an anapole moment to understand the propagation mechanism of weak interaction between the nucleons in the nucleus, PNC ingredient's amplitude in nuclear force experimentally, and neutral current of neutral weak boson Z^0 . The reason of studying the atomic PNC using Fr atom is that the PNC effect is enhanced in proportion to atomic number Z^3 as well as studying electron EDM with Fr atom²⁾. The Fr atom needs to be accumulated in the MOT to reduce the error due to the ununiformity of the external field, which is the dominant component of the systematic errors, by confining the atoms in the small region. However at the MOT, we have to realize the high vacuum with $\sim 10^{-9}$ (Torr) to obtain a long life time of accumulated atoms, and the MOT should be placed at the radiation free area since the detector to measure the number of the Fr atoms will be damaged due to the neutrons and gammas. At the nuclear reaction point, the neutrons and gammas with the energy of a few MeV are produced together with Fr, so we need to transport the Fr far from the reaction point. Therefore we designed the Fr beam transport system with the total length ~ 10 m at the 51

course from the TR5 to TOF. This beam transport system also has the function to realize the high vacuum with the differential pumping. It consists of Electrostatic Quadrupole Triplet (Triplet-Q), Electrostatic Prism (Prism) and Beam Diagnosis System (Diagnosis System).

Triplet-Q (Q1, Q2, Q3) has some unique features. The Triplet-Q is segmented into two regions, which means the inner region where the beam is transported with the high vacuum, and the outer region where the electrodes and cables are installed. These two regions are separated by the quartz pipe with the baking heater. The electrostatic lenses consist of three sets of electrodes with F(focus)D(defocus)F or DFD function. At the both ends of the Triplet-Q, we set the earth plates, and the heater on the surface of the quartz pipe is also used as the earth plates. We realize the definite effective field boundary with earth plates. The structure of the Triplet-Q is shown in Fig. 1. The development of the Prism is now in progress. It consists of main electrodes, steering electrodes, earth plates and movable silicon detector (SSD). The two holes are prepared in the outer main electrode, which are used for the alignment of the beam line and the measurement of the Fr ions and the temperature of the Thermal Ionizer. Steering electrodes adjust the tracks of the Fr ion beam. The earth plates suppress the turbulence of the electric fields. The model of these features is shown in Fig. 2. The Diagnosis System is designed to enable us to select some kinds of detectors. First, SSD detects Fr alpha decay energy spectrum. Second, Faraday Cup counts Rb ion's beam current. Third, ZnS Viewer shows us the Rb ion's beam profile. The model of these detectors is shown in Fig. 3.

In July 2009, we have performed the experiment to measure transmission efficiency with prototype Triplet-Q (Q0) whose size is half of the Q1~3 and without quartz pipe. Experimental setup is shown in Fig. 4. At first, 100 MeV $^{18}\text{O}^{5+}$ beam accelerated by AVF cyclotron (Beam Intensity: 120~170 nA) was injected into ^{197}Au target in Thermal Ionizer and ^{210}Fr was produced by fusion reaction ($^{18}\text{O} + ^{197}\text{Au} \rightarrow ^{210}\text{Fr} + 5\text{n}$). Produced Fr atoms were ionized into Fr ion when Fr atom reached to the surface of Au target. Then Fr ions were extracted by extraction electrodes with a small beam emittance ($\sim 40 \pi$ mm mrad). This beam was transported into the SSD by Q0. So we measured alpha decay spectrum from ^{210}Fr that adhered on the surface of the SSD. These experimental results are shown in Fig. 5 and Fig. 6. As a result of this experiment, Q0 worked as well as we anticipated, and Fr yields on the SSD were ~ 70 atoms/sec. The analysis of the beam transport efficiency is in progress. Until 2011, high intensity laser cooled francium factory will be built at CYRIC. To trap a lot of Fr atom at MOT, we designed and are developing the Fr beam

transport system with high transmission efficiency (80~100%).

- 1) Stancari G., et al., Eur. Phys. J. Special Topics **150** (2007) 389.
- 2) Bouchiat M.A., Bouchiat C., Phys. **60** (1997) 1351.

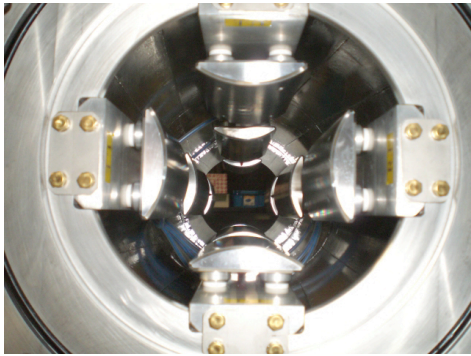


Figure 1. Sectional view of Triplet-Q.

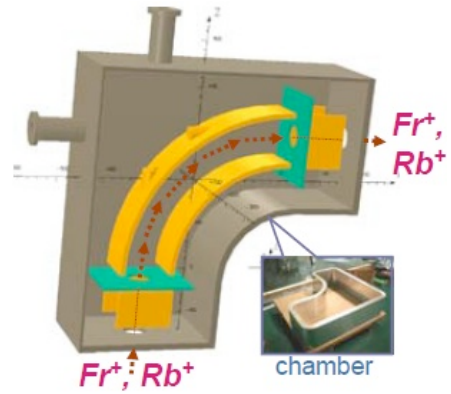


Figure 2. Model of Electrostatic Prism.

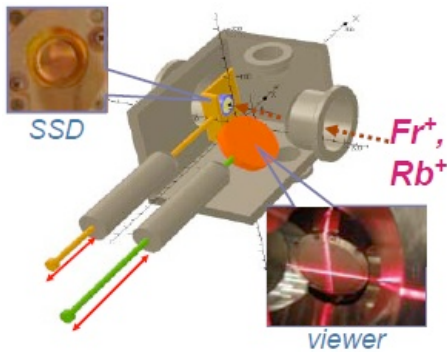


Figure 3. Model of Beam Diagnosis System.

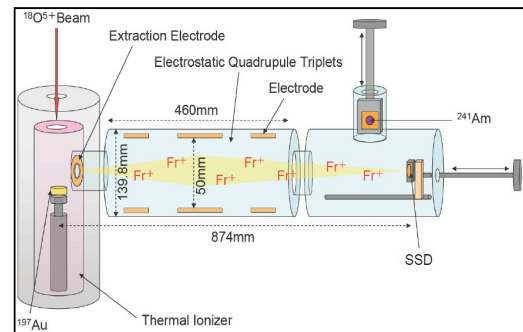


Figure 4. Experimental Setup.

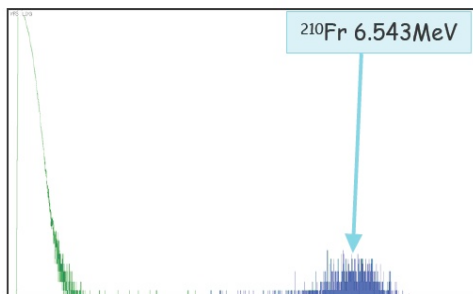


Figure 5. Fr alpha decay energy spectrum.

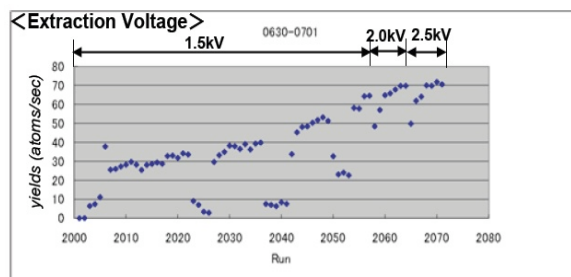


Figure 6. Fr ion's yields on the SSD.