Development of a Gas Scintillation Counter for RI Beams

II. 2. Development of a Gas Scintillation Counter for RI Beams

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In many experiments with RI beams, the identification of the beam particles should be performed. A plastic scintillator is often used as a time of flight (TOF) counter. The required specification is constant timing of the signal, constant intrinsic time resolution, fast decay time to identify the particles in highly intense RI beams and 100% detection efficiency. However, due to the radiation damages, the number of photons from the plastic scintillator gradually decreases. In order to solve the problem, we have developed a gas scintillation counter. The gas scintillation counter can ignore the radiation damage by flowing the gas continuously. Since outgas from the counter decreases the number of photons, it is important to flow the gas in this sense. As a counter gas, pure rare gas such as Xe gas is the best since the energy to produce a scintillation photon is lower than that of the plastic scintillator and the decay time is as fast as that of the plastic scintillator. However, the cost of pure Xe gas is high and the gas handling is difficult. Therefore, we investigated another candidate which is cheap and easy to handle the gas.

We can identify the heavy ions by measuring the TOF, the energy loss, and the magnetic rigidity. The resolution of the mass number is written as,

$$\left(\frac{\sigma A}{A}\right)^2 = \left(\gamma^2 \frac{\sigma\beta}{\beta}\right)^2 + \left(\frac{\sigma B\rho}{B\rho}\right)^2 + \left(\frac{\sigma Z}{Z}\right)^2,$$

where A is the mass number, γ is the Lorentz factor, Z is the atomic number, β is the velocity, and $B\rho$ is the magnetic rigidity. In case of experiments with Big-RIPS in RIKEN-RIBF, the TOF resolution has to be less than 225 ps in order to identify 300 MeV/u ^{132}Sn.

The experiment was performed at the 33 course in CYRIC. The picture of the experimental setup is shown in Fig. 1. Two gas scintillation counters (Gas1, Gas2) and two plastic scintillators (*ΔE*, *E*) were irradiated with a 19.3 MeV/u ^{14}N beam accelerated by the 930 AVF cyclotron. Energy loses in each detector are shown in Table 1. The size of the gas volume is 50 mm (H) × 65 mm (V) × 55 mm (D). The thicknesses of *ΔE* and *E* are 30 μm and 1.0 mm, respectively. In this experiment, we flew pure Xe gas, pure Ar gas, pure Kr gas and pure N_2 gas at a pressure of 1 atm in the gas volume. In addition, N_2 gas was also mixed with Xe gas to reduce the purity of Xe gas. Two PMTs were directly attached to the left and right sides of the gas volume. For Gas1 and Gas2, R6041-406 and R6041-506 were used, respectively. The anode signals from the PMTs are shown in Fig. 2. Since the number of dynodes in left R6041-406 was less than that in right side, the timing between the left side and the right side was different. For Xe-N_2 gas as well as 100% Xe gas and 100% Kr gas, the decay time is less than 20 ns and the signal separates from the noise level completely. The decay time of 100% N_2 gas is also fast even though the pulse height is not enough for 19.3 MeV/u ^{14}N. N_2 gas also seems to be candidate since the energy loss of 300 MeV/*u* ^{132}Sn in the gas volume is about 50 MeV. The distribution of the time difference between Gas1 and *dE* for 99.6% Xe gas is shown in Fig.3. The spread of each time difference is written as,

$$\sigma T^2_{dE-Gas1} = \sigma T^2_{dE} + \sigma T^2_{Gas1},$$
$$\sigma T^2_{dE-Gas2} = \sigma T^2_{dE} + \sigma T^2_{Gas2,}$$
$$\sigma T^2_{Gas1-Gas2} = \sigma T^2_{Gas1} + \sigma T^2_{Gas2}\ .$$

Threfore, the intrinsic time resolutions are,

$$\sigma T^2_{Gas1} = \frac{(\sigma T^2_{dE-Gas1} + \sigma T^2_{dE-Gas2} + \sigma T^2_{Gas1-Gas2})}{2} - \sigma T^2_{dE-Gas2},$$
$$\sigma T^2_{Gas2} = \frac{(\sigma T^2_{dE-Gas1} + \sigma T^2_{dE-Gas2} + \sigma T^2_{Gas1-Gas2})}{2} - \sigma T^2_{dE-Gas1}.$$

The intrinsic time resolutions are shown in Table 2. Here, we ignore the time jitter of the PMT since the intrinsic time resolution is considered to be larger than the time jitter.

Figure 4 shows the resolution of mass number as a function of TOF resolution. The TOF resolution for 99.6% Xe gas is less than 225 ps, which corresponds to 5σ resolution for 300 MeV/*u* ^{132}Sn. The difference of the resolution between 100% Xe gas and 99.6% Xe gas is about 0.03. This result shows that it is possible to identify the particle around A~100 with Xe-N_2 gas.

In summary, we measured number of photons, decay time of scintillation lights, and intrinsic time resolution for 100% Xe gas, 100% Kr gas, 100% Ar gas, 100% N_2 gas and Xe-N_2 gas.

These quantities of Xe-N_2 gas as well as 100% Xe gas and 100% Kr gas are enough to identify 300 MeV/u ^{132}Sn in highly intense RI beams. N_2 gas also seems to be candidate even though the pulse height is smaller than that of 100% Xe gas.

Table 1. Energy loss in each detector.

Detector	pla(30 μm)	gas					pla(1.0 mm)
		Xe 100%	Kr 100%	Ar 100%	N_2 100%	Xe 99.6%	
Energy loss	15.0 MeV	29.4 MeV	24.0 MeV	18.3 MeV	14.0 MeV	29.3 MeV	9.72 MeV

Table 2. Intrinsic time resolution.

Resolution[ps]	Xe 99.6%	Kr 100%	Xe 100%
dE	70 ± 100	50 ± 200	90 ± 60
Gas1	200 ± 40	270 ± 40	170 ± 30
Gas2	230 ± 30	360 ± 30	170 ± 30

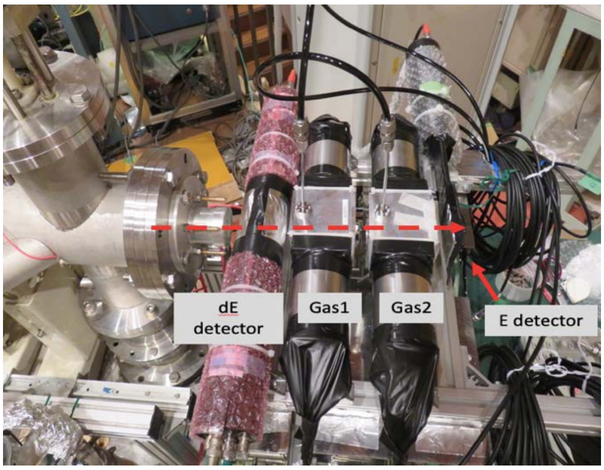

Figure 1. Experimental setup.

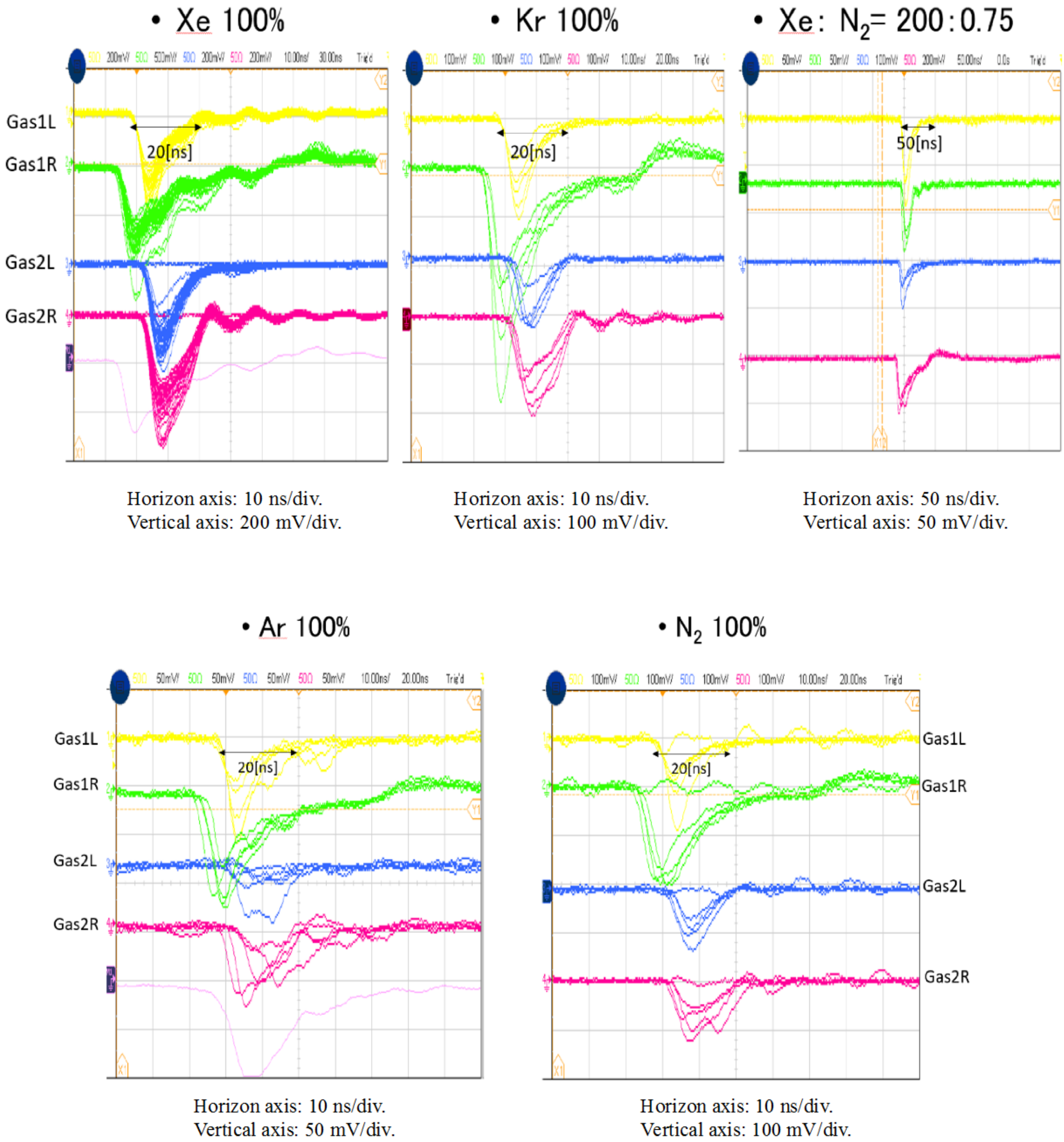

Figure 2. Output signals from PMTs.

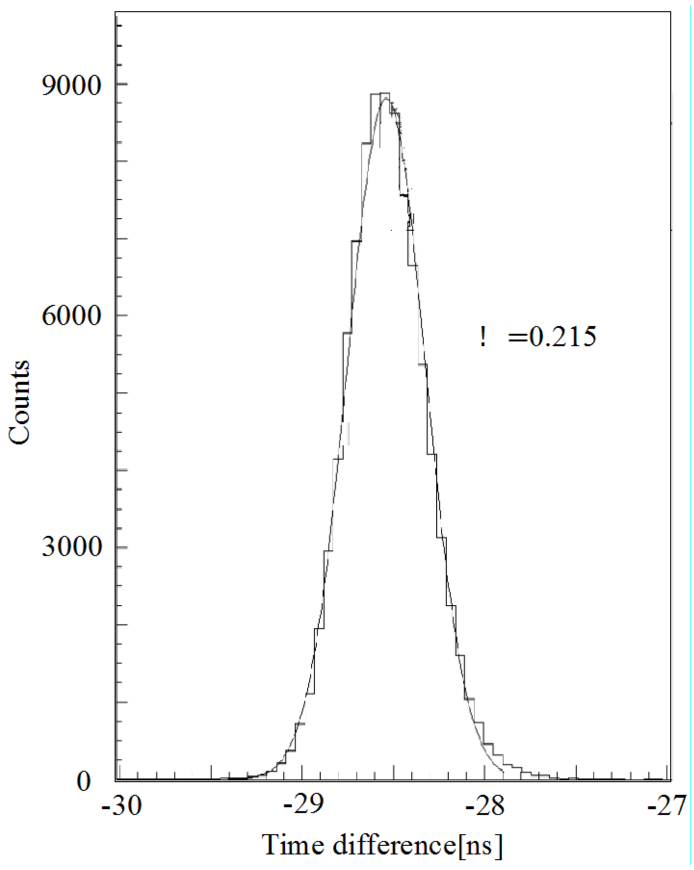

Figure 3. Time difference between Gas1 and dE for 99.6% Xe gas.

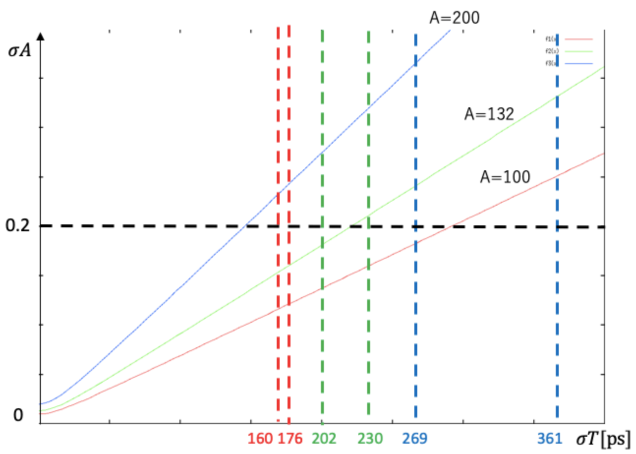

Figure 4. Relation between resolution of mass number and resolution of TOF. Red line:A=100, green line: A =132, blue line: A =200, red broken lines: intrinsic time resolutions of gas1 and gas2 for Xe 100%, green broken line: intrinsic time resolutions of gas1 & gas2 in Xe 99.6%, blue broken line: intrinsic time resolutions of gas1 & gas2 in Kr 100%, black broken line: 5σ resolution of mass number.