Development of ZeroDegree Large Acceptance Dispersive mode

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The ZeroDegree spectrometer[1)] is an RI-beam delivery line following the BigRIPS separator.[2)] Four operating modes are provided: two achromatic and two dispersive modes with different momentum resolutions and acceptances. Among them, the Large Acceptance Achromatic (LAA) mode is the standard one, and most experiments have been conducted in this mode so far.

A parasitic experiment is proposed using ZeroDegree, where the online commissioning of a SLOWRI gas catcher and a multi-reflection time-of-flight mass spectrograph (MRTOF-MS) located at the final focal plane F11 will be performed symbiotically with other ZeroDegree experiments. For this purpose, mono-energetic beams are desired to improve the stopping efficiency because the material thickness of a gas cell is very thin.

In order to realize such beams, a straight-forward solution is to employ a mono-energetic wedge degrader at the dispersive focal plane (F9 or F10) in the standard LAA mode. However, transmission loss due to the degrader may be a problem. Another option is to use a dispersive mode of ZeroDegree with a mono-energetic degrader located immediately before the gas cell to minimize the transmission loss. Both the previously prepared dispersive modes (MRD and HRD[1)]) are undesirable because they have a smaller acceptance compared to the LAA mode as a result of aiming at a high momentum resolution. Thus, a new dispersive mode with a larger acceptance, named the Large Acceptance Dispersive (LAD) mode, was developed. Figure 1 shows the first-order ion optics in the LAD mode of ZeroDegree. The horizontal acceptance and momentum resolution $p/\Delta p$ are ±35 mrad and 2100, respectively, while they are ±20 mrad and 4200 for the MRD mode and ±10 mrad and 6500 for the HRD mode, respectively.

A machine study with a ^{80}Zn beam produced by the in-flight fission of a ^{238}U beam at 345 MeV/nucleon with a 4 mm-thick Be target was conducted to examine the LAD mode. The LAA mode with a mono-energetic degrader (LAAmono mode) was also tested[3)] in the same machine study. We report the results for the LAD mode here.

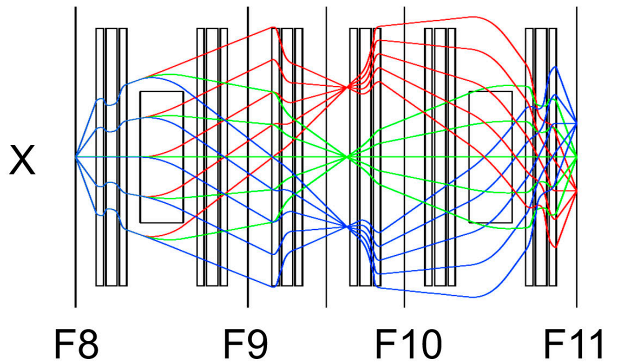

Fig. 1. First-order ion optics in the LAD mode of ZeroDegree in the horizontal (X) plane. Red, green, and blue curves correspond to the momentum deviation $\delta = -1.5$, 0, and 1.5%, respectively.

Table 1. Measured (Exp.) and designed (COSY) F8-F11 first-order transfer matrix elements in the LAD mode. The units are mm, mrad, and % in x, a, and δ, respectively.

	$(x\|x)$	$(x\|a)$	$(a\|x)$	$(a\|a)$	$(x\|\delta)$	$(a\|\delta)$
Exp.	1.02	0.27	−0.35	0.89	20.3	−5.49
COSY	1.0	0.0	0.0	1.0	21.0	0.0

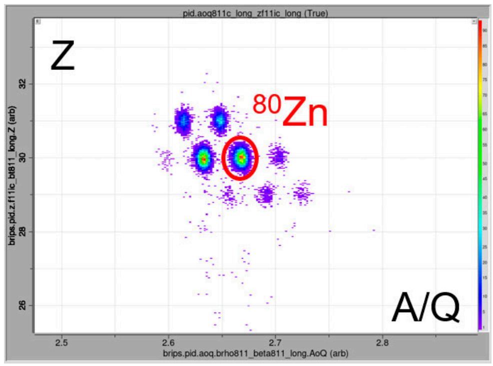

Fig. 2. Z versus A/Q plot measured in the ZeroDegree LAD mode. The ^{80}Zn beam is clearly separated.

The RI beam was identified and tagged[4)] in the BigRIPS separator and delivered to the ZeroDegree spectrometer. We first measured the transfer matrix elements in the LAD mode. The results are summarized in Table 1 and compared with the designed values calculated by COSY INFINITY. The main features are well reproduced.

By using these matrix elements, particle identification was performed independently in the ZeroDegree spectrometer. The measured Z versus A/Q particle identification plot is shown in Fig. 2. The A/Q resolution was measured at narrow (±0.1%) and wide (±3%) momentum slit settings. The results were 0.15% and 0.17% in σ, respectively. Higher-order aberration correction is required to reach an expected value of 0.05% estimated from detector resolutions and ion-optical parameters. Analysis is in progress.

The transmission efficiency was also measured by comparing the number of ^{80}Zn with BigRIPS and ZeroDegree. The results were 85.5% (narrow) and 70.2% (wide). The transmission losses mainly occur at F10, where the beam spreads for a large momentum deviation (δ) (see Fig. 1). The readjustment of ion optics is necessary to reduce the beam spread.

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