^{96}Zr beam acceleration for isobar experiment in RHIC

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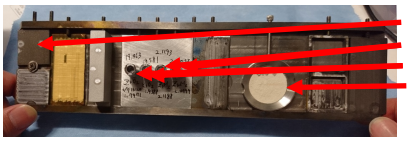
To investigate chiral magnetic effect, ^{96}Zr and ^{96}Ru beams have been accelerated at relativistic heavy ion collider (RHIC) in Run18 at Brookhaven National Laboratory (BNL). ^{96}Zr and ^{96}Ru beams were provided from electron beam ion source (EBIS) injector and tandem Van de Graaff, respectively. The total provided shots from laser ion source was counted as 489910. $^{96}Zr^{16+}$ beam had been provided at very stable condition without major interruption. Successful data acquisition was achieved at STAR detector at RHIC.

What is the best material to provide ^{96}Zr beam from laser ion source

Mass number	90	91	92	94	96
Natural	51.45 %	11.22 %	17.15 %	17.38%	2.8 %
Enriched	19.27 %	5.10 %	7.86 %	8.17 %	59.60 %

Natural abundance of ^{96}Zr is only 2.8%.
Metal enriched Zr plate was not available, although target performance is great.
Enriched Zr hydride was not available at that time.
Only choice was ZrO_2 powder which can be obtained in the market.



Metal Zr plate showed the best performance.
Zr hydride could last for several hundreds laser shots.
ZrO_2 compressed powder could stand only a few laser shot.
Enriched Zr coated film last several shots.

1.0 g of enriched ZrO_2 = almost a compact car
We needed estimate accurate consumption rate.

➡ We needed to develop a new laser target using enriched ZrO_2 powder.

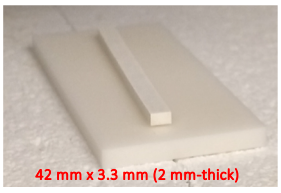
Sintering ZrO_2 powder to form laser target

Intensive study of the enriched target had been carried out through mid of the RUN18 (Feb. 27 ~ May. 6).

Using natural abundance ZrO2 powder, sintering process was developed in RIKEN.

Compressed in die (several tons)

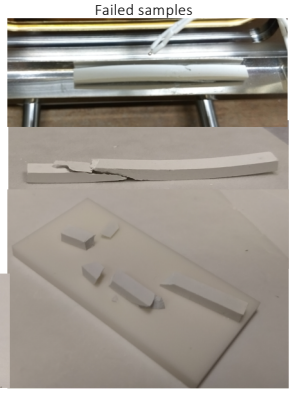
Heated in oven up to 1400 ℃



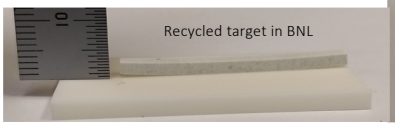
Sintered enriched target made in BNL

Recycle process was developed in RIKEN
(Used target was dissolved in HF)

Failed samples



Die, compression pressure and temperature control were studied. ~ Mar. 2018
6 pieces 1.5 g enriched targets were prepared. ~ June. 2018
Recycling process from used targets was studied and established in RIKEN. ~ July, 2017
0.5 g of enriched hydride sample was produced for back up operation of the Tandem accelerator. ~ May, 2018



Recycled target in BNL

Laser irradiation condition survey

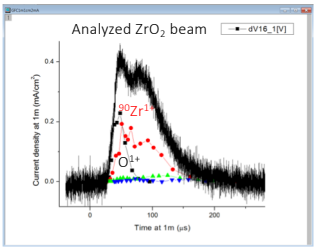
Using natural abundance ZrO_2 targets, huge patterns of laser irradiation conditions had been tested.

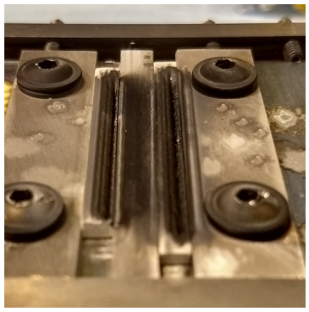
- What is the adequate target shape?
- Laser energy?
- Laser pot size?
- Target scanning direction VS. incident laser angle?
- Target scanning velocity?
- Estimate consumption rate?
- Laser spot positions for RHIC and NSRL?

Target ID: 3mm-1R
Laser1
Total 8861 shots
11.5 microgram/shot

Target ID: 3mm-1
Laser1 and Laser2
Total 73178 shots
1.8 microgram/shot

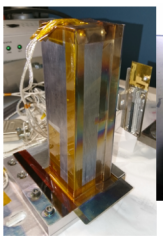
Target consumption had to be minimized.

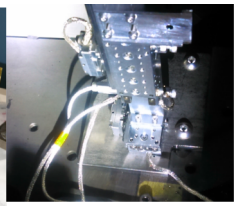




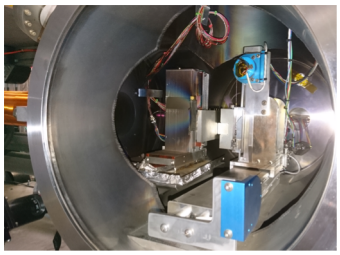
Mechanical development

Target translation mechanism





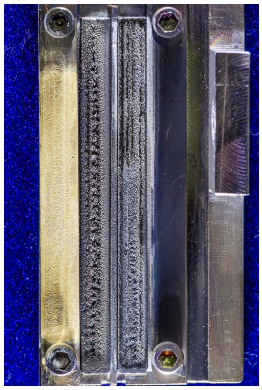
Piezo was stage



Stepper motor translation mechanism

Laser plasma creates micro particles.
The emitted particle stocked to the driving plate of piezo stages and caused malfunction of the translation.

Middle of the run, the stages were replaced by stepper motor driven assembly.



Enriched Zr targets used in Run18

Beam performance

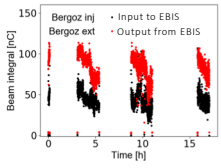
EBIS output	After IH-LINAC	F.C. at bend	Before Booster	Typical Au32+ Before Booster
65 nC	8.2 nC	5.9 nC	3.8 nC	6 nC

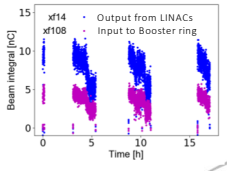
At the test, equivalent particle number of $^{96}Zr^{16+}$ to Au^{32+} was achieved.

No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
317888	143822	12885	15315	-	-

Provided Zr shots from laser ion source

Typical operation status of $^{96}Zr^{16+}$ beam at the EBIS injector





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