E1-2012-17

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FIRST EXTRACTION OF THE $3.42A$ GeV ^{12}C BEAM FOR STUDIES OF BARYONIC MATTER AT THE NUCLOTRON

Submitted to «Particles and Nuclei, Letters»

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Первый вывод пучка углерода ^{12}C с энергией $3{,}42A$ ГэВ для изучения барионной материи на нуклотроне

Представлены результаты первого вывода и транспортировки пучка углерода с энергией $3{,}42A$ ГэВ на нуклотроне. Продемонстрировано, что параметры пучка удовлетворяют требованиям для первой фазы экспериментов по изучению плотной барионной материи на нуклотроне.

Работа выполнена в Лаборатории физики высоких энергий им. В. И. Векслера и А. М. Балдина ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна, 2012

Piyadin S. M. et al. E1-2012-17

First Extraction of the $3.42\,A$ GeV ^{12}C Beam for Studies of Baryonic Matter at the Nuclotron

The results of the first extraction of the $3.42A$ GeV ^{12}C beam at the Nuclotron and its transportation to the experimental area are presented. It is demonstrated that the beam parameters are sufficient for the first phase of the experiments on the studies of the dense baryonic matter at the Nuclotron.

The investigation has been performed at the Veksler and Baldin Laboratory of High Energy Physics, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna, 2012

INTRODUCTION

The study of the dense baryonic matter at the Nuclotron (BM@N project) is one of the main scientific directions at the JINR LHEP. The research program of BM@N project will be focused on the production of strange matter in heavy-ion collisions at beam energies between 2 and $6A$ GeV. For these purposes it is proposed to install an experimental setup at the 6V beamline in the fixed-target hall of the Nuclotron. The basic setup will comprise a large-acceptance dipole magnet with inner tracking detector modules. The outer tracking will be based on the drift chambers and straw tube detector. Particle identification will be based on the time-of-flight measurements. This setup will be sufficient to perform a comprehensive study of strangeness production in heavy-ion collisions, including multistrange hyperons, multistrange hypernuclei and exotic multistrange heavy objects. The observation of those objects would represent a breakthrough in our understanding of strange matter, and would pave the road for the experimental exploration of the 3rd dimension of the nuclear chart. These studies are complementary to the CBM experimental program at SIS100 [1]. The other topics of the experimental program can be related with the study of in-medium effects for vector mesons decaying in hadronic modes, hard probes, soft photons, polarization effects, etc.

In this paper the results of the first extraction of the $3.42A$ GeV ^{12}C beam and its transportation to the 6V beamline are presented.

1. EXPERIMENT

The BM@N setup will be placed in building 205 at a distance of about 110 m from the slow-extraction line of the Nuclotron. The magnetic scheme of the 6V line is shown in Fig. 1. The doublet of quadrupole magnets allows one to focus the beam in the target point, while two small dipole magnets can deflect the beam in the horizontal and vertical directions. The large-aperture magnet SP41 (GIBS magnet) can be used as an analyzing magnet at the first stage of the experiment. The field integral of this magnet is approximately 2 $\mathrm{T \cdot m}$ at the maximal current in the coils.

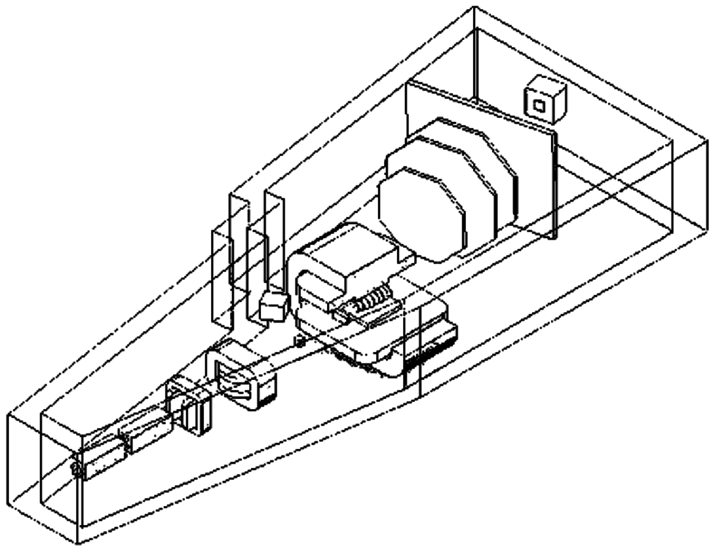

Fig. 1. The 6V beamline with GIBS magnet in building 205, consisting of the doublet of quadrupole magnets, two small dipole magnets and large-aperture magnet SP41

The transportation line consists of 7 lenses doublets (including the lenses doublet of the 6V beamline) of K200 type and 3 bending magnets. The standard optical scheme between the last point of the slow-extraction line (focus F3) and the entrance of the SP41 magnet with 3 intermediate focuses at F4, F5 and F6 points was applied. The detection apparatus of the experiment consisted of multiwire ionization chambers placed at the focus points F4 and F5 of the VP1 beam transportation line for the estimation of the beam intensity and the beam size parameters.

The additional multiwire ionization chamber and two scintillation hodoscopes consisting of 8 scintillators with the size of $400 \times 40 \times 4$ mm viewed by PMTs FEU85 from both sides each $[2, 3]$ were mounted at ~ 2 m and at ~ 1.5 m upstream the SP41 pole, respectively. The first and second hodoscopes provided the coordinate measurements in the horizontal and vertical planes, respectively. The start scintillation counter based on the use of XP2020Q PMT was placed in front of the first quadrupole magnet. The size of the scintillator was $100 \times 40 \times 4$ mm. The scheme of the experiment is presented in Fig. 2.

The beam was accelerated up to $3.42A$ GeV, extracted and transported using VP1 and 6V beamlines to the point where the scintillation counters hodoscopes and ionization chamber were installed. During the experiment the lenses doublet of the 6V beamline was switched off; therefore, the beam was focused on the scintillation hodoscopes using last lenses doublet of the VP1 beamline.

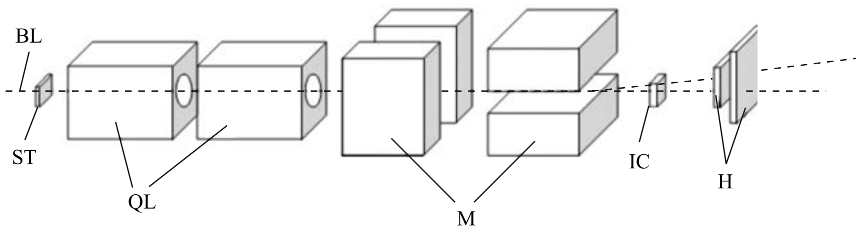

Fig. 2. The layout of the experiment. BL is the optical axis of the 6V beamline, QL and M are the quadrupole and dipole magnets, respectively. IC is the coordinate ionization chamber, ST is the start scintillation counter, H are the two planes of the scintillation counters hodoscopes

2. RESULTS

The typical beam size distributions at the focuses F4 and F5 obtained with the multiwire ionization chambers are demonstrated in Figs. 3 and 4, respectively. The beam size (1σ) in the horizontal direction is ~ 2 and ~ 3 mm at the F4 and F5 focus points, respectively. The beam size in the vertical direction is a bit larger, namely, it is ~ 5 and ~ 6.7 mm at the F4 and F5 focus points, respectively.

The VME-based data acquisition system was used for the data taking from scintillation detectors. TQDC16 [4] module allows one to measure the amplitude and appearance time of the signal. The correlation of the signal amplitudes taken from the both sides of one of the scintillation detectors of the hodoscope is presented in Fig. 5.

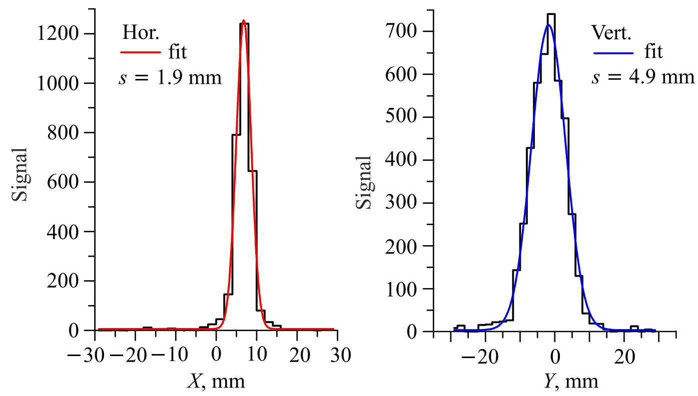

Fig. 3. The X- (left) and Y- (right) coordinate beam profile at the focus F4. The lines are the results of the Gaussian fit

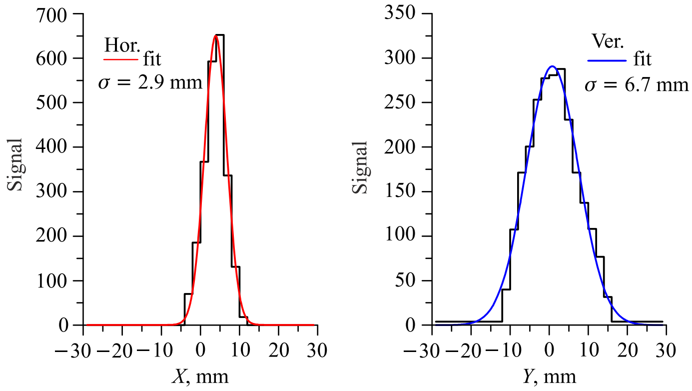

Fig. 4. The X- (left) and Y- (right) coordinate beam profile at the focus F5. The lines are the same as in Fig. 7

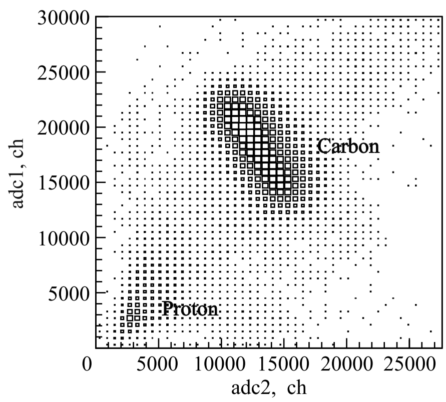

Fig. 5. The signal amplitudes correlation for one of the scintillation detectors of the hodoscope

One can see the clean separation of the primary carbon nuclei and background single charged particles.

The beam profiles in the horizontal (X) and vertical (Y) planes are presented in Figs. 6 and 7, respectively. The open and dashed histograms are the distributions for carbon and single charged particles, respectively. The particles were selected using the signal amplitudes correlation as shown in Fig. 5.

The $X-Y$ coordinates correlation for carbon nuclei is shown in Fig. 8. The carbon beam size in the X plane is ~ 4 cm (1σ). One can see that the size of the carbon beam in Y direction is wider. Further transportation beamline magnetic optics optimization is required.

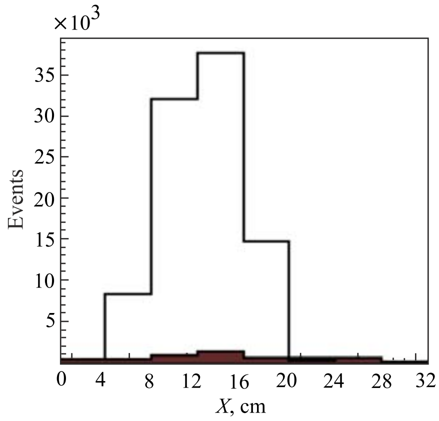

Fig. 6. The X-coordinate beam profile measured by scintillation hodoscope. The open and dashed histograms are the carbon and single charged particles, respectively

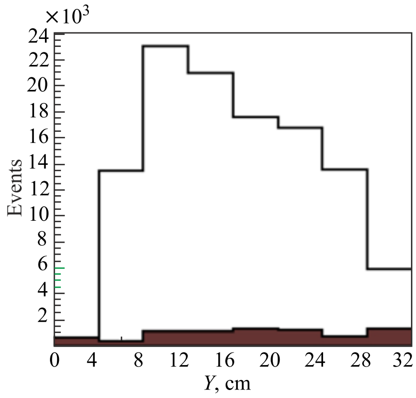

Fig. 7. The Y-coordinate beam profile measured by scintillation hodoscope. The histograms are the same as in Fig. 6

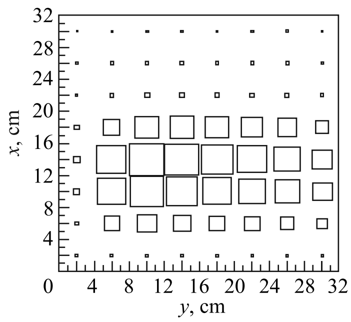

Fig. 8. The X–Y coordinates correlation for carbon nuclei

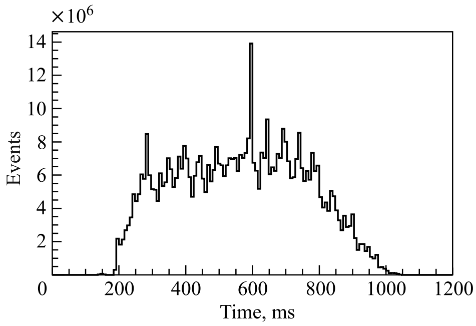

Fig. 9. The time distribution of the trigger signal appearance with respect to the beginning of the acceleration cycle

Figure 9 demonstrates the time dependence of the nonblocked counting rate from the hodoscopes. One can observe the uniform distribution of the events versus the appearance time of the signal with respect to the beginning of the acceleration cycle.

The dependence of the X-position of the beam versus the current in the last bending magnet of VP1 beamline is shown in Fig. 6. The line is the result of the fitting by the linear function. One can see that the X-position of the carbon beam strongly varied with the current in the bending magnet coil, but the dependence is linear with the accuracy of the measurements.

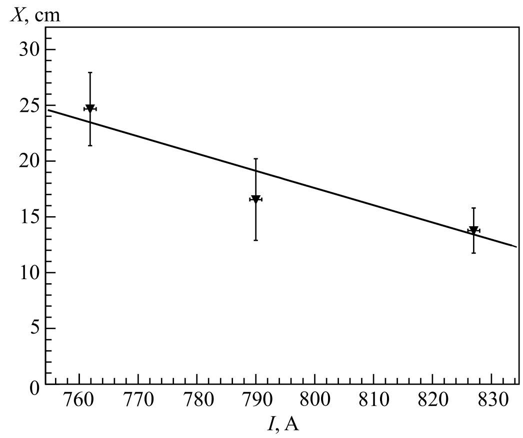

Fig. 10. The dependence of the X-position on the current in the last bending magnet of VP1 beamline. The line is the result of the fitting by the linear function

CONCLUSION

The first extraction of the $3.42A$ GeV ^{12}C beam from the Nuclotron and its transportation to the 6V beamline has been performed.

The results demonstrate that the beam size at the F4 and F5 points of the VP1 transportation line satisfies the BM@N experiment requirement. On the other hand, further magnetic optics optimization is necessary to obtain the required beam size at the entrance of the SP41 magnet at the 6V beamline.

The results of this work is the first step in realization of the BM@N experiment.

The authors express their thank to P. A. Rukoyatkin for providing good conditions of the experiment. The authors are grateful to the Nuclotron staff. They thank I. Ya. Nefediev, V. I. Ryazantsev and V. G. Tchurkin for their assistance in the preparation of the 6V beamline.

The work has been supported in part by RFBR grant No. 10-02-00087a.

REFERENCES

1. *Senger P., Friese V.* CBM Report 2011-1; https://www.gsi.de/documents/DOC-2011-Aug-29-1.pdf.
2. *Terekhin A. A. et al.* // News of the Tula State University, Natural Sciences Ser. V. 3. P. 151–160.
3. *Terekhin A. A. et al.* // XVI Conf. AYSS, JINR. 2010. P. 159–162.
4. http://afi.jinr.ru/TQDC-16.

Received on February 24, 2012.

Редактор *Е. И. Кравченко*

Подписано в печать 25.06.2012.
Формат 60 × 90/16. Бумага офсетная. Печать офсетная.
Усл. печ. л. 0,56. Уч.-изд. л. 0,71. Тираж 345 экз. Заказ № 57688.

Издательский отдел Объединенного института ядерных исследований
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