# SIMULATION OF HOLLOW ION BEAM FORMATION LINE

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*Abstract*

Heavy ion beam may be used for the matter extreme state creation [1], a forming line must satisfy to certain requirements on beam brightness, spot size and focus position. The original method of hollow ion beam formation - wobbler system - was proposed to deposit the beam energy at cylindrical target [2]. To verify wobbler parameters the beam dynamics simulation was carried out by means of two codes – "Transit", that is a modified code "DINAMION" [3], and G4Beamline [4]. The results obtained are discussed.

## INTRODUCTION

Intense heavy ion beam is an effective tool to create matter extreme states in laboratory conditions. The advanced experiments in high energy density physics require the cylindrical target irradiated by the hollow beam [1]. The wobbler system [2] allows to shape such a hollow beam. Preliminary system simulation has illustrated the feasibility of the method [5]. In paper presented the beam dynamics simulation is carried out in order to consider some nonlinear effects that may influence on the beam spot size and focus position.

## ITEP WOBBLER SYSTEM DESCRIPTION

A layout of the wobbler system for hollow beam formation line in ITEP (ITEP TWAC project) is based on the system layout for GSI FAIR project [2]. The ITEP wobbler system consists of two four-cell RF-cavities and focusing triplet of quadrupole magnetic lenses. RF-cavities deflect the beam in x- and y-directions. The phase shift between RF-fields in first and second cavities is chosen so that the particle with zero deflection in the first, x-cavity, gains the maximum deflection in the second, y-cavity, and vice versa.

The general requirements for layout were the target size satisfaction and the beamline length limitation in case of the real initial parameters of ITEP beam. In Fig.1 designed layout of the ITEP wobbler system is shown.

The asymmetric quadrupole magnetic triplet follows by the second cavity, the triplet focusing the beam on the target. In this project the target assume to be irradiated from one side.

The whole length of the system is about 8 m, and it is sufficient length under conditions of the ITEP experimental area limitation.

The structure of the channel as well as preliminary parameters of beamline elements are shown in Table 1.

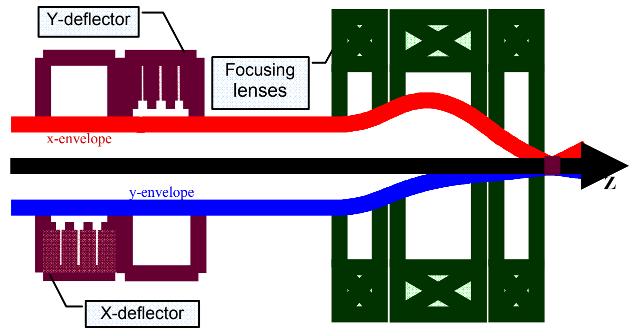


Figure 1: A principal layout of ITEP wobbler system.

Table 1: System structure.

| Element | Field value | Element length, mm | Aperture radius, mm |
|---|---|---|---|
| Drift | - | 800 | 100 |
| Wobbler X | 1.5 MV/m | 4*368 | 100 |
| Drift | - | 184 | 100 |
| Wobbler Y | 2.5 MV/m | 4*368 | 100 |
| Drift | - | 800 | 100 |
| 1st magnetic quadrupole lense | 15.3 T/m | 400 | 100 |
| Drift | - | 160 | 100 |
| 2nd magnetic quadrupole lense | -16.3 T/m | 800 | 100 |
| Drift | - | 160 | 100 |
| 3rd magnetic quadrupole lense | 18.8 T/m | 400 | 100 |
| Drift | - | ~ 900 | 100 |

## PARTICLE DYNAMICS SIMULATION

The first simulation was carried out for ions $Co^{27+}_{59}$ by means of "Transit-DINAMION" code, developed in ITEP [3]. The beam parameters taken for simulation are close to the real beam parameters in ITEP project. For cobalt ions the beam energy was taken 450 MeV, the pulse duration – 120 ns. Energy spread was varied between 1% and 0.1%. Maximum beam intensity per pulse – $2*10^{12}$ particles. Normalized effective x-emittance (4 rms) was 8 $\pi$ mm mrad, and normalized effective y-emittance was the same. Initial radius of the beam (at the entrance to the first cavity) was 40 mm.

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As far as concerns the wobbler parameters, the resonant frequency of both cavities was 297 Mhz, the shift between RF-fields in cavities used in our simulation was π/2. For ITEP project it is practically sufficient to use four-cell cavity so the field mode chosen was $H_{114}$.

The results obtained are shown at Fig. 1-4. The values of the outer and inner radii of the target were 2.1 mm and 0.6 mm respectively. One can see the beam focus after third lens from Fig.1, where x- and y-envelopes are presented.

Simulation with and without beam space charge shows that own space charge weakly affects on the spot size (see Fig.2-4), but it leads to the focus position displacement. For cobalt ion beam with 450 MeV energy and with intensity equal to $2*10^{12}$ particle per pulse this displacement was about 10 mm [5]. Nonzero beam emittance is found to affect on the shape of the final ring (at the target), but the energy maximum position is the same. In this simulation the particle distribution was supposed to be Gaussian in both transverse planes. Longitudinal distribution has been assumed uniform.

For the simplicity the beam was assumed to have axial-symmetric shape and zero divergence angle at the entrance to the wobble system (the preliminary forming optics system is not considered here).

To verify the system parameters and to take into account the possible aberrations and some other nonlinear effects simulation was carried out by means of G4Beamline code [4], developed by Tom Roberts, Muons Inc. The dynamics of the equivalent proton beam was simulated in order to minimize the time of simulation. The system parameters were re-calculated in according to charge-mass ratio. The simulation results coincide with the results of the previous simulation in whole, if we neglect the fringe field of the lens. The lens fringe field existence leads to lens effective length decreasing and to the beam focus displacement along the longitudinal axes.

The error in the lens magnetic field gradient equal to 0.1% leads to significant beam defocusing, so it is very important to transit the beam in the "linear" area of the channel.

During simulation we didn't consider nonlinear effects in RF-cavities assuming the cavity aperture essentially more than the beam radius for 95% of the particles and the field harmonic characteristic spatially stable along the cavity axis. But it would be interesting to take into account these complicated effects for two deflecting cavities with the field phase shift.

## CONCLUSIONS

Wobbler system allows to obtain the focused hollow beam on the target with size and position required.

Simulation of the wobbler system have shown that parameters of the system should be chosen with nonlinear effects in the lenses and in the cavities taken into account because of the beam focus displacement.

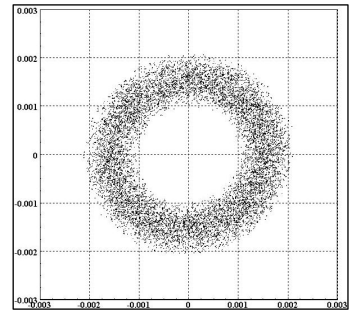

Fig.2. Cross-section of the particle distribution on the target (with zero own space charge).

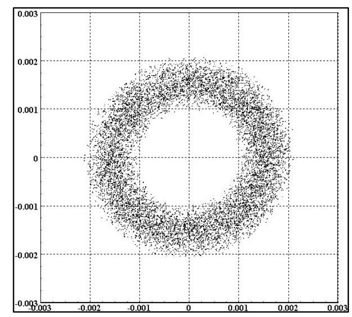

Fig.3 Cross-section of the particle distribution on the target (with nonzero own space charge).

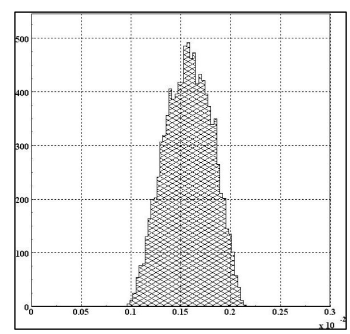

Fig.4. Particle radial distribution on the target.

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