COMPARISON OF TRACKING SIMULATION WITH EXPERIMENT ON THE GSI UNILAC*

X.Yin[1,2]#, W. Bayer[2], I. Hofmann[2], L. Groening[2], W. Barth[2], S.Richter[2], S. Yaramishev[2],
[1]Institute of Modern Physics of Chinese Academy of Sciences, Lanzhou, China
[2]GSI Darmstadt, Darmstadt, Germany
A. Franchi, Accelerator Beam Physics Group, CERN. Switzerland
A. Sauer, IAP Frankfurt University, Frankfurt, Germany

Abstract

In the European framework "High Intensity Pulsed Proton Injector" (HIPPI), the 3D linac code comparison and benchmarking program with experiment have been carried out. HALODYN and PARMILA are two of the codes involved in this work. In this paper, we compare the simulation results with experiment results which were carried out on the UNILAC Alvarez DTL. The phase space distribution input and output of the DTL are compared using the obtained distribution as the input parameters for both codes. Between the predictions from two codes, these results show some agreement comparing with the experiment results for low current case.

INTRODUCTION

The main tasks of beam dynamics work package of HIPPI project are the validation and benchmarking of 3D linac codes [1]. Another important task, "Tracking Vs Experimental ", is to perform the tracking simulation with the beam experiments, which are also proposed at GSI based on UNILAC Alvarez DTL, to find how much agreement with measurement results both at the entrance and exit of the DTL and analysis the code validation based on the simulation results and experiment.

CODES

The HALODYN code has been written by the Department of Physics at the University of Bologna [2] and is a Particle-In-Cell code. The main feature of this code is the space-charge field can be computed by a micromap approach on a 3D spatial grid at each time step by using the Vlasov model.

PARMILA is a scalar code developed in Los Alamos (LANL) [3]. Either a 2D *r-z* (SCHEFF) or a 3D (PICNIC) PIC Poisson solver can be chose with open boundary conditions.

Additionally HALODYN code has been developed under the UNIX environments system, but PARMILA runs in the Windows platform. In the simulation, 5000 and 100000macroparticles are employed in HALODYN and PARMILA respectively.

EXPERIMENT SET-UP

The UNILAC [4] was designed to accelerate all ion species with mass over charge ratios of up to 8.5 and to fill the heavy ion synchrotron SIS up to its space charge limit. Figure 1 shows the schematic overview of the GSI UNILAC. The Alvarez DTL (108 MHz) will accelerate the particles from 1.4 MeV/u to 11.4 MeV/u. Measurements of transverse phase space distributions were performed before and after the Alvarez DTL with a periodic focusing channel respectively. The set-up of the experiment is also shown in Fig 1. Both transverse planes were measured simultaneously.

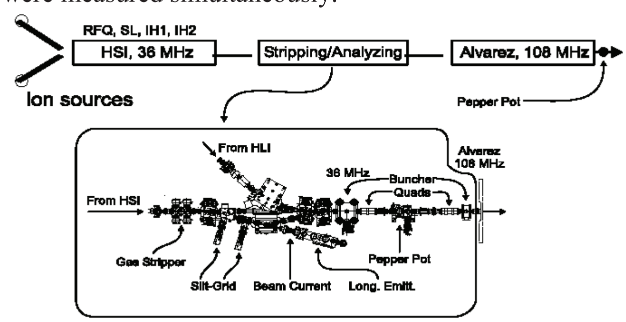

Figure1: Schematic overview of the GSI UNILAC.

EXPERIMENTAL RESULTS

As part of HIPPI-Beam Dynamics work package duty, we carried out beam experiment with $^{40}Ar^{+10}$ beam at 3uA.

Figure 2 shows the transverse phase-space distributions obtained in the measurement with a slit-grid device before Alvarez DTL for low currents. The measured values, 9.70mm-mrad and 7.91mm-mrad, are 90% of unnormalized emittances in the horizontal and vertical planes, respectively. Figure 3 shows the obtained emittances after the Alvarez DTL where is the beam exit. The emittance were 4.5 mm-mrad and 2.83 mm-mrad of unnormalized emittances in the horizontal and vertical planes, respectively.

*Work supported by the "FP6" Structuring the European Research Area" program
#yinxj@impcas.ac.cn

ISBN 978-3-95450-122-9

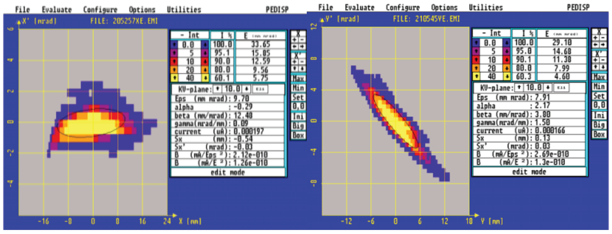

Figure 2: Measured horizontal (left) and vertical (right) phase-space distribution before Alvarez DTL.

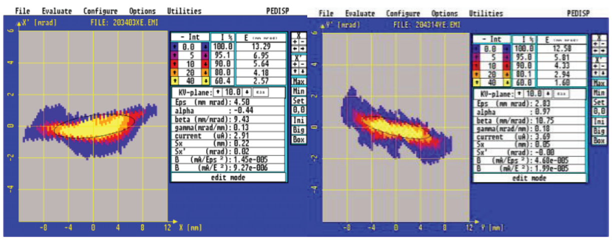

Figure 3: Measured horizontal (left) and vertical (right) phase-space distribution after Alvarez DTL.

COMPARISON OF TRACKING SIMULATION WITH EXPERIMENTAL RESULTS

In the tracking simulations, the Twiss parameters listed in Table 1 were obtained from the experiment results. The initial distribution is as usual a 6D-Gaussian (truncated in each phase space at 3σ), representing a $^{40}Ar^{+10}$ beam of kinetic energy W=1.396 MeV/u. Figure 4 shows the initial transverse distributions which were calculated based on the measurement. The initial longitudinal emittances measurement and simulations are also shown in the Fig. 5. As can be seen, the simulations results of two codes properly reproduce the measurement results both in the transverse phase space and longitudinal phase space.

Table1: Initial Distribution Parameters

	x-x'	y-y'	z-z'
α	-0.29	2.17	-0.15
β[mm/mrad]	12.48	3.80	2.75784
γ[mrad/mm]	0.09	1.05	0.37

Figure 6 shows the final distributions in the transverse phase spaces at the exit of DTL.As can be found, the simulations results of both codes are basically agreement with experiment as shown in Fig. 3. Furthermore, we can observe that a little discrepancy occurs between two codes. The simulation results of PARMILA are much more agreement with the experiment measurement than those of HALODYN. But we cannot conclude that HALODYN has no sufficient accuracy. It depends on the numerical algorithms which were applied in both codes.

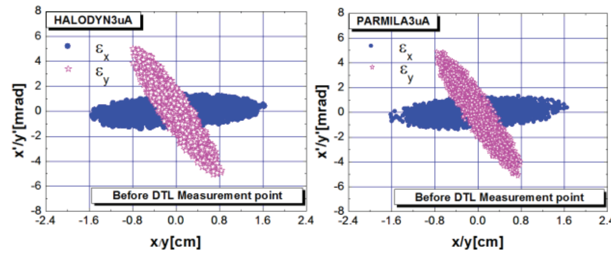

Figure 4: Calculated horizontal (dot) and vertical (star) phase-space distribution before Alvarez DTL.

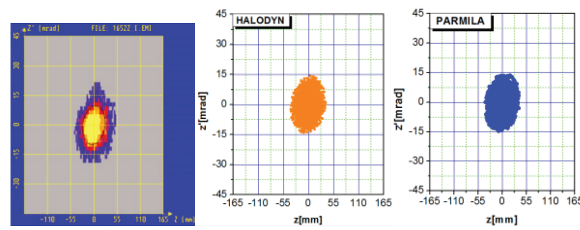

Figure 5: Measured and calculated longitudinal phase-spaces distributions before Alvarez DTL.

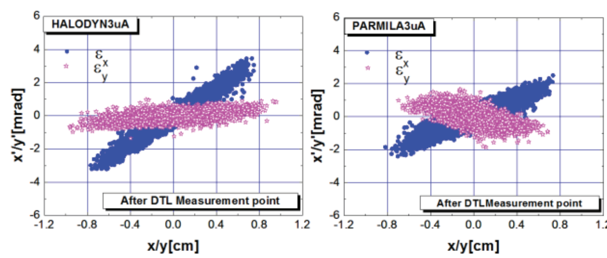

Figure 6: Calculated horizontal (dot) and vertical (star) phase-space distribution after Alvarez DTL.

The measured and calculated rms emittance and growth ratios were summarized in Table2. Basically the both codes get excellent agreement in terms of the transverse RMS emittances. The calculate results are little small comparing with experiment results. This is acceptable in principle. But the emittance growth factors in vertical plane are larger than that of horizontal plane in both codes. This is reverse in the measurement.

CONCLUSION

Using the measured results, the tracking simulations were performed with HALODYN and PARMILA codes. Between the predictions from two codes using different mathematic model, these results presented here show some agreement comparing with the experiment results for low current case. Due to the lack of the longitudinal emittance after DTL, the emittance growth factor is not presented in this paper. However two codes get excellent agreement both in transverse and longitudinal plane. It leads to conclusion that no gross errors have been made in the physics or methods of the codes. Further studies on the comparison should be carried out in high current region. And these studies should be investigated further with other codes.

Table 2: The Measured and Calculated Emittance and Growth Ratios

	Before DTL (hor./ver./lon.)	After DTL (hor./ver./lon.)	Emittance growth factor(hor./ver./lon.)
$\beta\gamma$	0.05472	0.1569	
Experiment[mm;mrad] (Uni, u,t)	9.7/7.91/256.6	4.5/2.83	
Experiment[mm;mrad] (Uni, rms,n)	0.133/0.108/0.351	0.177/0.111	1.34/1.028
HALODYN[mm;mrad](Gau ,rms,n)	0.125/0.106/0.333	0.134/0.117/0.663	1.07/1.11/1.99
PARMILA[mm;mrad](Gau ,rms,n)	0.125/0.103/0.333	0.135/0.114/0.534	1.08/1.11/1.6

ACKNOWLEDGEMENT

The authors wish to thank Prof. Ingo Hofmann for frequent valuable discussions and the GSI UNILAC group in carrying out the experiment. We are also grateful to Dr.A.Franchi and Dr.A.Sauer for their continue support on HALODYN and PARMILA.

We acknowledge the support of the European Community-Research Infrastructure Activity under the “FP6” Structuring the European Research Area” program.

REFERENCES

[1] A.Franchi, W.Bayer, G.Franchetti, L.Groening, I.Hofmann, A.Orzhekhovskaya, S.Yaramyshev, X.Yin Linac code benchmarking for the UNILAC experiment, Proceeding of Linac 2006.

[2] G. Turchetti et al., Accuracy analysis of a spectral Poisson solver, Nucl. Intr. & Meth. A, vol. 561 Issue 2 (2006), pp. 223-229.

[3] D.A.Swenson, and J.E.Stovall, PARMILA, Los Alamos national Laboratory internal Memorandum, MP-3-19,January 1968.

[4] P. Forck, A.Peters, P.Strehl, Beam diagnostic for the upgraded UNILAC at GSI, Proceeding of 6th EPAC,Stockholm,Sweden,p.1500(1998).