31st International Linear Accelerator Conference (LINAC2022)
August 28th - September 2nd, Liverpool, England

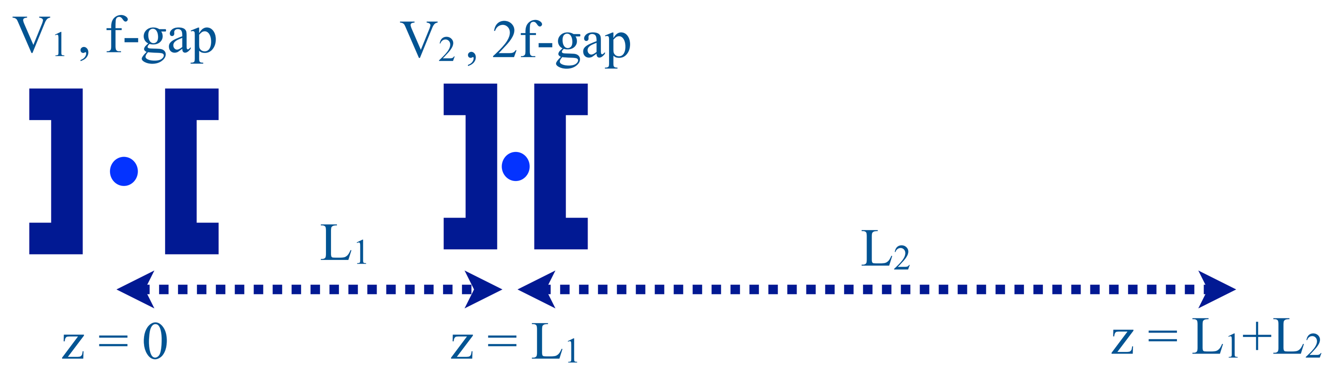
HARMONIC BUNCH FORMATION AND OPTIONAL RFQ INJECTION

E. Sunar *, U. Ratzinger, M. Syha, R. Tiede
IAP, Goethe University, Frankfurt, Germany

SUPCPA08
TUPORI06

ABSTRACT : With the aim of reduced beam emittances, a pre-bunching concept into an RFQ or a DTL has been developed. The structure has been designed by using a two harmonics double drift buncher which consists of two bunchers: the first one is driven by a fundamental frequency whereas the other is excited with the second harmonic including a drift in between. This well-known "Harmonic Double-Drift-Buncher" is reinvestigated under space charge conditions for RFQ, cyclotron, and for direct DTL-injection. There are significant benefits for this design such as to catch as many particles as possible from a dc beam into the longitudinal linac acceptance, or to reduce/optimize by up to an order of magnitude the longitudinal emittance for low and medium beam currents. In accordance to these advantages, a new multi-particle tracking beam dynamics code has been developed which is called "Bunch Creation from a DC beam - BCDC". In this paper we present this new code and some stimulating examples.

CONCEPT OF DDHB



$$Z = 0: \quad \Delta W_i\big(\Delta\phi_i(0)\big) = q \cdot \boxed{V_1} \cdot \sin\big(\Delta\phi_i(0)\big)$$

$$\Delta\phi_i(L_1) = \Delta\phi_i(0) - \frac{\omega \boxed{L_1}}{\beta_s^3\gamma_s^2\, c} \cdot \frac{\Delta W_i\big(\Delta\phi_i(0)\big)}{W_s} \quad *$$

$$Z = L1: \quad \Delta W_i\big(\Delta\phi_i(L_1)\big) = \Delta W_i\big(\Delta\phi_i(0)\big) - q \cdot \boxed{V_2} \cdot \sin\big(2\Delta\phi_i(L_1)\big)$$

* The same transformation is valid for second drift L_2

BCDC

Space Charge

- Direct Coulomb grid-grid Interaction

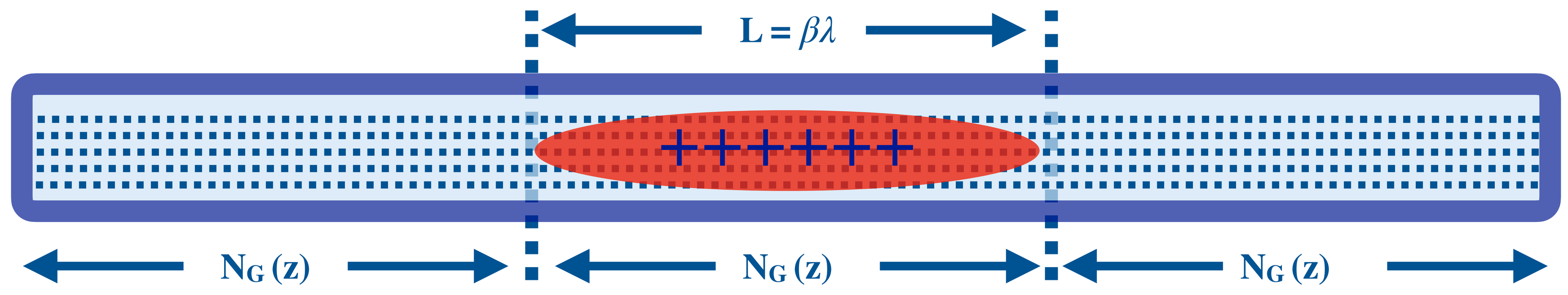
- Distribution of macro-particles on a Cartesian grid
- Calculation of the electric field components on the grid points from assigned charge density on the grid
- Extension of the electric field from the main grid box longitudinally to the neighboured cells
- Calculation of the total field on the main box including the effects of the next neighboured bunches

Particle Generator

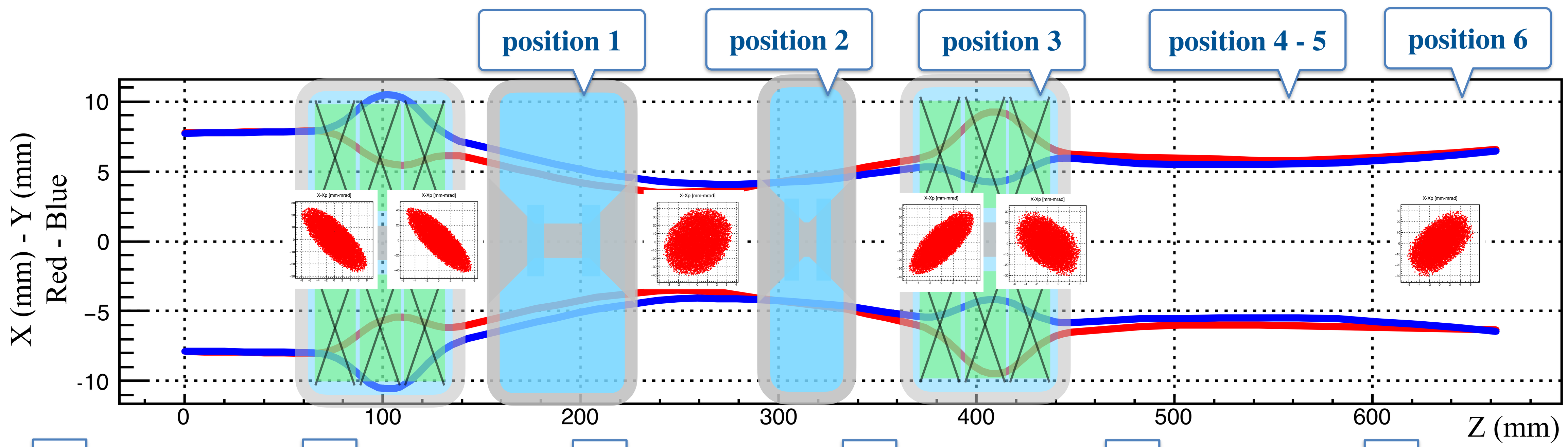
- Waterbag 6d
- Uniform 4d+2d

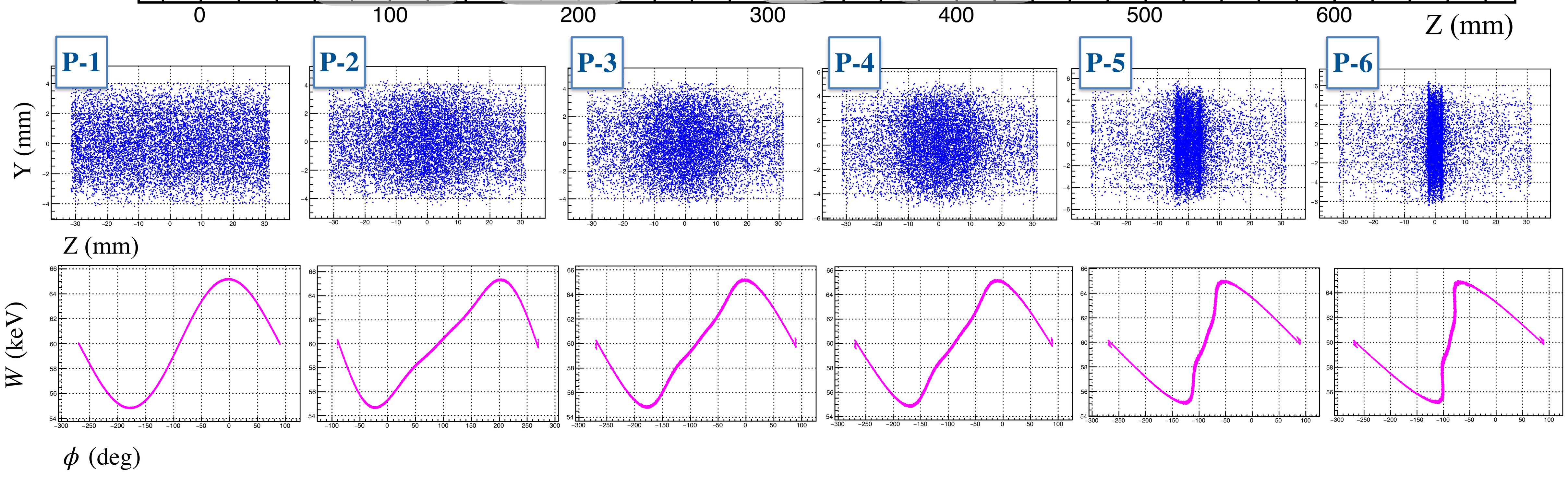
Elements

- Accelerating Gap
- Drift Space
- Magnetic Quadrupole Lens

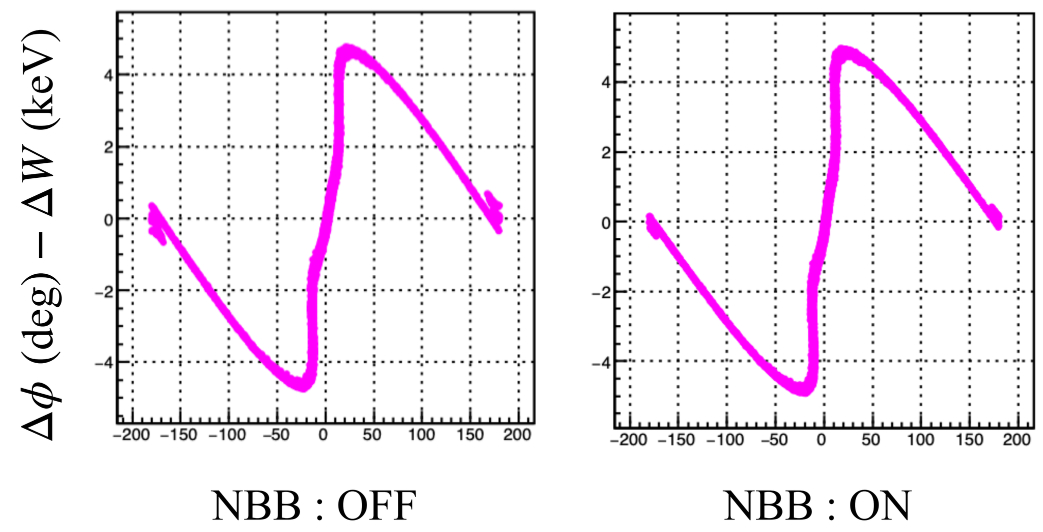


SIMULATION : The simulation results for a 15 mA, 60 keV proton beam.





EFFECT OF NBB : The graphs show the longitudinal phase spaces with and without the effects of neighbored bunches (NBB) for a 60 keV, 15 mA beam in 30 mm radial and 62.7 mm longitudinal sizes of the grid box.



Parameters	@S1	@S2
W_s	60 keV	—
Frequency	54 MHz	108 MHz
I_{beam}	15 mA	15 mA
L_1, L_2	73.35 mm	458 mm
V_1, V_2	2.6 kV	1.2 kV
Capture %	—	72.24%

Emittance	Input	Output
$\epsilon_{x,n,rms}$	0.268 mm.mrad	0.273 mm.mrad
$\epsilon_{l,n,rms}$	0.0287 keV.deg	1.515 keV.deg

CONCLUSION :

The application of the DDHB's concept for different types of injection into a DTL, an RFQ, or a cyclotron has excellent potentials for :

- Beams in 10 to 100 A keV energy range
- Currents up to a few 10 mA

As outputs with :

- High capture efficiency (70% - 80% depending on the L_1/L_2 -ratio)
- Smaller emittances

The BCDC simulation code considering the effects of the next neighbored bunches has been developed, benchmarked and reliably on process. With the implementation of NBB, outputs from BCDC would be more accurate for a d.c. beam injection.

REFERENCES :

[1] Kutsaev, S. V. and Smirnov, et al., "Four-harmonic buncher for radioactive and stable beams switching at the ATLAS facility", 2018, vol. 905, doi:10.1016/j. nima.2018.07.054

[2] A. Plastun, P. Ostroumov, A. Villari and Q. Zhao, "Longitudinal Beam Dynamics in FRIB and ReA Linacs", doi: 10.18429/JACoW-ICAP2018-WEPAF04

[3] E. Pozdeyev, W. Hartung, J. P. Holzbauer, F. Marti and Q. Zhao, "Electromagnetic Design of a Multi-harmonic Buncher for the FRIB Driver Linac", Conf. Proc. C 110328 (2011), 1000-1002 PAC-2011-TUP091.

[4] C. Goldstein and A. Laisne, "Third Harmonic Simulated Buncher", Nuclear Instruments and Methods (1968) vol. 61, pages 221-225, 0029-554X, doi:10.1016/0029-554X(68)90546-6

[5] Knott, J. and Warner, D. and Weiss, M.,"Adjustment of a Double Drift Harmonic Buncher and Bunch Shape Measurements", 1976 Proton Linear Accelerator Conference, CERN-PS-LIN- 76-4,

[6] T. P. Wangler, "RF Linear Accelerators", Wiley-VCH Ed. 2008

[7] D. Uriot and N. Pichoff, https://www.dacm-logiciels. fr

[8] R. Tiede, G. Clemente, H. Podlech, U. Ratzinger, A. C. Sauer and S. Minaev, "LORASR Code Development", Conf. Proc. C 060626 (2006), 2194-2196

* Ezgi Sunar - Institute of Applied Physics - Max-von-Laue Str. 1 - 60438 Frankfurt am Main – sunar@iap.uni-frankfurt.de