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# Introduction

This python script could transform string-type input file into `ImpactZ.in` file. Users have experiences with `ELEGANT` will enjoy this tool. Right now, not all `IMPACT-Z` elements are added in the code. Users could go to the python scipts: `impactz_parser.py/__default_lattice()` and `impactz_parser.py/impactzin_lattice()` to add the new elements you want to use.

# How to run it

Add `genimpactzin` into your `PATH`, for my  case, add the following line to your `.bashrc`:

```
export PATH=/mnt/d/githubProj/IMPACT-Z/utilities/lattice_parser:$PATH
```

Given the `lte.impz` input file:

```
genimpactzin lte.impz line
```

which will generate the `ImpactZ.in` file. Now you can run the `ImpactZexe` in parallel version as:

```
mpirun -np 4 ImpactZexe
```

4 processes are used as $core\_num\_T \times core\_num\_L = 4$.

If you are using the single process version, `core_num_T=1,core_num_L=1` should be given. Then just type:

```
ImpactZ.exe
```

`ImpactZ.in` is automatically read.

The user is encouraged to have a look in `utilities/lattice_parser/examples`, one example is given to show how this work.

# A simple example

For the convenience of illustration, `lte.impz` refers to the python level read-in file, `ImpactZ.in` refers to `ImpactZexe` read-in file. You can rename `lte.impz`  any other names you like.

The `lte.impz` file mainly consists of three sections, `control, beam and lattice` sections. The detailed mapping relationships between `ImpactZ.in` and `lte.impz` are listed in the following section. Here we give a simple example for the  usage of `lte.impz` :

```
!control section
!===============
&control

core_num_T = 2;
core_num_L = 2;
meshx = 32;
meshy = 32;
meshz = 64;
kinetic_energy = 300e6;
freq_scale = 1.3e9;

&end

!beam section
!==============
&beam
mass = 0.511001e6;
charge = -1.0;

distribution_type = 2;
Np = 5000;
total_charge = 1e-9;

emit_nx=0.176e-6, beta_x=12.73, alpha_x=-0.85;
emit_ny=0.176e-6, beta_y=12.73, alpha_y=-0.85;

sigz=1e-3, sigE=5e3;

&end

!lattice section
!====================
&lattice

!rpn expression is supported,
!only a few mathematical operator are added, please see
!lattice_parser.py/rpn_cal() for more details.
!-----------------------------------------------------
% 0.2 sto LB1
% -4.410 pi * 180 / sto AB1  ! Bend angle

BCX11: BEND,L= LB1,ANGLE=AB1,       E2=AB1,       steps=1,
pipe_radius=2.1640E-02, fint=0.3893
BCX12: BEND,L= LB1,ANGLE= "0 AB1 -",E1= "0 AB1 -",steps=1,
pipe_radius=2.1640E-02, fint=0.3893
BCX13: BEND,L= LB1,ANGLE= "0 AB1 -",E2= "0 AB1 -",steps=1,
pipe_radius=2.1640E-02, fint=0.3893
BCX14: BEND,L= LB1,ANGLE=AB1,       E1=AB1,       steps=1,
pipe_radius=2.1640E-02, fint=0.3893

D1  : DRIF, L=5.0
Dm  : DRIF, L=0.5

BC1 : LINE=(BCX11,D1,BCX12,Dm,BCX13,D1,BCX14)
```

```
W0:   watch, filename_ID=1000
W1:   watch, filename_ID=1001

Line : LINE=(W0,BC1,W1)

&end
```

# Control and beam section

The mapping relationship between `ImpactZ.in` and `lte.impz` in `control` sections are listed as following:

```
line1:
core_num_T core_num_L

line2:
6 Np integrator error output_ratio

line3:
meshx meshy meshz flagbc x_pipe_width y_pipe_width period_len

line4:
distribution_type restart sub_cycle 1

line5:
Np

line6:
current  #Q*f_scale

line7:
# value defined automatically by charge/mass in the code;
# the definition of charge and mass, see beam section.

line8-line10:
# defined by beam section
alpha_x beta_x emit_x mismatchx mismatchpx offsetX     offsetPx
alpha_y beta_y emit_y mismatchy mismatchpy offsetY     offsetPy
alpha_z beta_z emit_z mismatchz mismatchE  offsetPhase offsetEnergy

line11:
current kinetic_energy mass charge freq_scale ini_phase

```

## Control parameters

All control parameters in `lte.impz` are listed:

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| core_num_T | | int | 1 | processor number for the transverse direction. |
| core_num_L | | int | 1 | processor number for the longitudinal direction. |
| integrator | | int | 1 | 1 for linear map integrator, 2 for nonlinear Lorentz integrator. |
| error | | int | 0 | 0 for OFF, 1 for ON error studies. |
| output_ratio | | int | 1 | 1 for standard output. |
| meshx | | int | 64 | space charge grid for x-direction. |
| meshy | | int | 64 | space charge grid for y-direction. |
| meshz | | int | 64 | space charge grid for z-direction. |
| flagbc | | int | 1 | space charge boundary situation, 1 for 3D open. See Ji's manual for more details. |
| x_pipe_width | m | double | 0.014 | x pipe width. |
| y_pipe_width | m | double | 0.014 | y pipe width. |
| period_len | m | double | 0.10 | period length. |
| restart | | int | 0 | 0 for OFF restart, 1 for ON. Restart from some point after stop. |
| sub_cycle | | int | 0 | 0 for no sub-cycle, 1 for ON. |
| kinetic_energy | eV | double | 0 | kinetic energy of the beam. |
| freq_rf_scale | Hz | double | 2856e6 | scale frequency $f_{scal}$, $Scxl = c/(2\pi f_{scal})$. |
| ini_phase | | double | 0.0 | initial phase of the reference particle. |
| steps_permeter | | int | 0 | how many sc kicks per meter in a single element. `steps_permeter=0`, element `steps=1`. |
| maps_permeter | | int | 0 | how many maps per meter in a single element. `maps_permeter=0`, element `maps=1`. |
| sample_out | | int | 1e5 | how many particles to sample out in `watch` elements. |
| slice_bin | | int | 128 | how many slice bins are used in `watch` elements. |

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| pipe_radius | m | double | 0.014 | pipe radius for all elements, which are not given values to `pipe_radius` by users in lattice section (default is `pipe_radius=0.0` m). |

## Beam parameters

All beam section parameters in `lte.impz` are listed:

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| mass | eV | double | 0.511e6 | mass of the particle. |
| charge | | double | -1.0 | -1 for electron. |
| distribution_type | | int | 2 | 6D gaussian distribution. See more options in Ji's manual. |
| Np | | int | 1e3 | particle number. |
| total_charge | C | double | 1e-9 | charge of the beam. |
| emit_x | m rad | double | 0.0 | emitance. |
| emit_nx | m rad | double | 0.0 | normalized emittance. |
| beta_x | m | double | 1.0 | twiss para. |
| alpha_x | | double | 0.0 | twiss para. |
| sigx | m | double | 0.0 | rms bunch size. |
| sigpx | | double | 0.0 | rms value of $\gamma\beta_x/\gamma_0\beta_0$ |
| emit_y | m rad | double | 0.0 | emittance. |
| emit_ny | m rad | double | 0.0 | normalized emittance. |
| beta_y | m | double | 1.0 | twiss para. |
| alpha_y | | double | 0.0 | twiss para. |
| sigy | m | double | 0.0 | rms bunch size. |
| sigpy | | double | 0.0 | rms value of $\gamma\beta_y/\gamma_0\beta_0$ |
| emit_z | deg MeV | double | 0.0 | twiss para. |
| beta_z | deg/MeV | double | 1.0 | twiss para. |
| alpha_z | | double | 0.0 | twiss para. |

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| sigz | m | double | 0.0 | rms bunch length. |
| sigE | eV | double | 0.0 | rms energy spread. |

Users could either use twiss parameters to define initial beam distribution, or use rms values. For $\sigma_{ij} \neq 0$ cases, please use twiss-para.

# Lattice section

Right now, only a few frequently used elements in `ImpactZ.in` are added into the python parser.

## Elements

### DRIFT

0 element.

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| L | m | double | 0.0 | length of drift |
| steps | | int | 0 | how many sc kicks for this element. |
| maps | | int | 0 | each half-drift involves computing a map for that half-element, computed by numerical integration with 1 maps |
| pipe_radius | m | double | 0.0 | pipe radius |

### QUAD

1 element.

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| L | m | double | 0.0 | length |
| steps | | int | 0 | how many sc kicks for this element. |
| maps | | int | 0 | map steps. |
| $K_1$ | $/\mathrm{m}^2$ | double | 0.0 | quadrupole strength, $K_1 = \frac{1}{(B\rho)_0}\frac{\partial B_y}{\partial x}$ |

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| | | | | |
| pipe_radius | m | double | 0.0 | pipe radius |
| Dx | m | double | 0.0 | x misalignment error |
| Dy | m | double | 0.0 | y misalignment error |
| rotate_x | rad | double | 0.0 | rotation error in x direction |
| rotate_y | rad | double | 0.0 | rotation error in y direction |
| ratate_z | rad | double | 0.0 | rotation error in y direction |

## BEND

4 element. A magnetic dipole implemented as a matrix, up to 2nd order. See K. Brown paper for more information.

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| L | m | double | 0.0 | arc length |
| steps | | int | 0 | how many SC/CSR kicks for this element. |
| maps | | int | 0 | map steps |
| angle | rad | double | 0.0 | bend angle |
| E1 | rad | double | 0.0 | entrance edge angle |
| E2 | rad | double | 0.0 | exit edge angle |
| $K_1$ | $1/\mathrm{m}^2$ | double | 0.0 | quadrupole strength, $K_1 = \frac{1}{(B\rho)_0}\frac{\partial B_y}{\partial x}$, not added yet in V2.1 version. |
| PIPE_RADIUS | m | double | 0.0 | pipe radius |
| h1 | 1/m | double | 0.0 | entrance pole-face curvature |
| h2 | 1/m | double | 0.0 | exit pole-face curvature |
| fint | | double | 0.5 | integrated fringe field, set to 0.5 to keep same with ELEGANT. |
| Dx | m | double | 0.0 | x misalignment error |
| Dy | m | double | 0.0 | y misalignment error |
| rotate_x | rad | double | 0.0 | rotation error in x direction |

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| rotate_y | rad | double | 0.0 | rotation error in y direction |
| ratate_z | rad | double | 0.0 | rotation error in y direction. This parameter could be used as TILT from ELEGANT. BUT REMEMBER TO SET ERROR=1 IN CONTROL SECTION. |
| CSR | | int | 0 | 0/1, whether to include 1D-CSR effects or not. |

## RFCW

Ideal sinusoidal RF model, combined with -41 wake element.

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| L | m | double | 0.0 | length |
| steps | | int | 0 | how many SC kicks for this element. |
| maps | | int | 0 | map steps |
| volt | V | double | 0.0 | peak voltage |
| gradient | V/m | double | 0.0 | peak acceleration gradient. |
| phase | degree | double | 0.0 | driven phase, sin() function is used (same as ELEGANT, different with IMPACT-Z), $E_z = A \cdot \sin(\mathrm{kz} + \phi)$, phase=90 is the crest for acceleration |
| freq | Hz | double | 2.856e9 | RF frequency |
| pipe_radius | m | double | 0.0 | pipe radius |
| Dx | m | double | 0.0 | x misalignment error |
| Dy | m | double | 0.0 | y misalignment error |
| rotate_x | rad | double | 0.0 | rotation error in x direction |
| rotate_y | rad | double | 0.0 | rotation error in y direction |
| ratate_z | rad | double | 0.0 | rotation error in z direction |
| | | | | |

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| wakeflag | | int | -1 | `wakeflag=-1` turn off RF wakefield, `wakeflag=5` only turn on longitudinal wake, `wakeflag=15` include both longitudinal and transverse wake. |
| wakefile_ID | | int | None | If WAKEFIEL_ID=41, it refers to `rfdata41.in` , which contains RF structure wakefield, 1st column is s [m], 2nd column is longitudinal wakefield $w_L$ [V/C/m], 3rd and 4th columns are transverse wakefield $w_x, w_y$ [$\mathrm{V/C/m^2}$]. |

## DTL

`101` element.

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| L | m | double | 0.0 | length |
| steps | | int | 0 | how many segments for the element. DIFFERENT from steps in control section, not nseg/m. |
| maps | | int | 0 | map steps |
| scale | | double | 1.0 | |
| freq | Hz | double | 324e6 | RF frequency |
| phase | degree | double | 0.0 | driven phase, sin() function is used (same as ELEGANT, different with IMPACT-Z), $E_z = A \cdot \sin(\mathrm{kz} + \phi)$, phase=90 is the crest for acceleration |
| ID | | int | 100 | file ID for the external field |
| pipe_radius | m | double | 0.0 | pipe radius |
| Lq1 | m | double | 0.0 | quad 1 length |
| grad1 | T/m | double | 0.0 | quad 1 gradient |
| Lq2 | m | double | 0.0 | quad 2 length |
| grad2 | T/m | double | 0.0 | quad 2 gradient |
| | | | | |

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| Dx_q | m | double | 0.0 | x misalignment error for quad |
| Dy_q | m | double | 0.0 | y misalignment error |
| rotate_x_q | rad | double | 0.0 | rotation error in x direction |
| rotate_y_q | rad | double | 0.0 | rotation error in y direction |
| ratate_z_q | rad | double | 0.0 | rotation error in z direction |
| | | | | |
| Dx_RF | m | double | 0.0 | x misalignment error for quad |
| Dy_RF | m | double | 0.0 | y misalignment error |
| rotate_x_RF | rad | double | 0.0 | rotation error in x direction |
| rotate_y_RF | rad | double | 0.0 | rotation error in y direction |
| ratate_z_RF | rad | double | 0.0 | rotation error in z direction |

## SC

104 element.

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| L | m | double | 0.0 | length |
| steps | | int | 0 | how many segments for the element. DIFFERENT from steps in control section, not nseg/m. |
| maps | | int | 0 | map steps |
| scale | | double | 1.0 | field scale factor |
| ID | | int | 100 | file ID for the external field |
| phase | degree | double | 0.0 | driven phase, sin() function is used (same as ELEGANT, different with IMPACT-Z), $E_z = A \cdot \sin(\mathrm{kz} + \phi)$, phase=90 is the crest for acceleration |
| freq | Hz | double | 324e6 | RF frequency |
| pipe_radius | m | double | 0.0 | pipe radius |
| Dx | m | double | 0.0 | x misalignment error |

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| Dy | m | double | 0.0 | y misalignment error |
| rotate_x | rad | double | 0.0 | rotation error in x direction |
| rotate_y | rad | double | 0.0 | rotation error in y direction |
| ratate_z | rad | double | 0.0 | rotation error in z direction |

## FIELDMAP

110 element.

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| L | m | double | 0.0 | length |
| steps | | int | 0 | how many segments for the element. DIFFERENT from steps in control section, not nseg/m. |
| maps | | int | 0 | map steps |
| scale | | double | 1.0 | |
| ID | | int | 100 | file ID for the external field |
| phase | degree | double | 0.0 | driven phase, sin() function is used (same as ELEGANT, different with IMPACT-Z), $E_z = A \cdot \sin(\mathrm{kz} + \phi)$, phase=90 is the crest for acceleration |
| freq | Hz | double | 324e6 | RF frequency |
| Xradius | m | double | 0.0 | pipe radius |
| Yradius | m | double | 0.0 | pipe radius |
| Dx | m | double | 0.0 | x misalignment error |
| Dy | m | double | 0.0 | y misalignment error |
| rotate_x | rad | double | 0.0 | rotation error in x direction |
| rotate_y | rad | double | 0.0 | rotation error in y direction |
| ratate_z | rad | double | 0.0 | rotation error in z direction |
| datatype | | int | 1 | 1 using discrete data, 2 using both discrete data and analytical function, other using analytical function only |

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| coordinate | | int | 2 | 1 in cylindrical coordinate, 2 in Cartesian |

## SHIFTCENTER

-1 and -19 element.

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| option | | string | “zdE” | (1). `option=”zdE”`, then shift the beam longitudinally to the bunch centroid so that $< z >=< \Delta E >= 0$. (2). `option=“xy”`, then shift the beam so that $< x >=< y >= 0$. |

usage:

```
elem1: shiftcenter, option="zdE";
```

## WATCH

-2 and -8 elements.

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| filename_ID | | int | 9999 | number larger than 1000 is recommended. |
| sample_freq | | int | 0 | particles sample out frequency. If not set, `sample_out` in `control` section will take effects. |
| slice_bin | | int | 0 | bins number for getting histogram slice information. If not set, `slice_bin` in `control` section will take effects. |
| coord_info | | int | 1 | `0/1`, whether to output particles phase space, i.e. whether to add -2 element. |
| slice_info | | int | 1 | `0/1`, whether to output slice information, i.e. whether to add -8 element. |

Output particle distribution and beam slice information into `fort.N` and `fort.(N+1e4)` files repectively, where N is the filename_ID.

If `filename_ID = 1001`, then the output file would be `fort.1001` and `fort.11001`. `fort.11001` refers to Impact-Z `-8` element output file (+10000), which outputs slice information. The columns in this file are as following:

| Column number | Units | Description |
|---|---|---|
| 1 | m | bunch length |
| 2 | | particle number per slice |
| 3 | A | current per slice |
| 4 | mrad | x-direction normalized slice emittance |
| 5 | mrad | y-direction normalized slice emittance |
| 6 | | relative slice energy spread, dE/E |
| 7 | eV | uncorrelated energy spread per slice |
| 8 | m | $< x >$ |
| 9 | m | $< y >$ |

## RCOL

-13 element, collimate the beam with transverse rectangular aperture sizes. Name same with Elegant.

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| x_max | m | double | 0.04 | xmax for x direction. |
| y_max | m | double | 0.04 | ymax for y direction. |
| x_min | m | double | None | By default, x_min=None, then x_min=-x_max is applied. |
| y_min | m | double | None | By default, y_min=None, then y_min=-y_max is applied. |

The None default values are from the reason that ELEGANT only has `x_max` and `y_max` settings.

## ECOL

-14 element, collimate the beam with transverse elliptical aperture size.

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| x_max | m | double | 0.04 | half-axis in x direction. |

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| y_max | m | double | 0.04 | half-axis in y direction. |

## ROTATE

-18 element, rotate the beam with respect to the longitudinal axis.

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| angle | rad | double | 0 | Both (x,y), and (px,py) are rotated. |

This element refers to `-18` element, the souce code is:

```
do i = 1, innp
    tmpx = Pts1(1,i)*cos(phi)+Pts1(3,i)*sin(phi)
    tmpy = -Pts1(1,i)*sin(phi)+Pts1(3,i)*cos(phi)
    tmppx = Pts1(2,i)*cos(phi)+Pts1(4,i)*sin(phi)
    tmppy = -Pts1(2,i)*sin(phi)+Pts1(4,i)*cos(phi)
    Pts1(1,i) = tmpx
    Pts1(2,i) = tmppx
    Pts1(3,i) = tmpy
    Pts1(4,i) = tmppy
enddo
```

## SCATTER

-20 element.

| Parameter Name | Units | Type | Default | Description |
|---|---|---|---|---|
| dE | eV | double | 0 | rms scattering for $\Delta E$ [eV]. dE=1000, then increase energy spread 1keV. |