Guide and Examples for AT 2.0: Elements and Integrators

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Abstract

We guide the reader through the elements of AT 2.0. We also describe the integration methods and explain how to write a new one.

1 Classes and integrators

The different classes represent different element type. These are *Drift*, *Bend*, *Quadrupole*, *Sextupole*, *Octupole*, *Multipole*, *ThinMultipole*, *Wiggler*, *KickMap*, *RFCavity*, *QuantDiff*, *Monitor*, *Corrector*, *Solenoid*, *Matrix66*, and *RingParam*. Each one of these is created by a particular element creation function. We structure the documentation in this chapter around these classes and the corresponding element creation function.

1.1 Drift

The first element class is drift, which is simply empty space with no magnetic field. A drift may be created with **atdrift**. The required fields (positional arguments...) are *FAMNAME*, *LENGTH*, and *PASSMETHOD*

The passmethod is called `DriftPass`. The map across a drift is given by

$$x_2 = \frac{L}{1+\delta}p_{x1} \tag{1}$$

$$y_2 = \frac{L}{1+\delta}p_{y1} \tag{2}$$

$$z_2 = \frac{L}{2(1+\delta)^2}(p_{x1}^2 + p_{y1}^2) \tag{3}$$

$$\tag{4}$$

1.2 Bend

A bending magnet is a uniform magnetic field.

$$\vec{B} = B_0\hat{y} \tag{5}$$

For a fixed momentum we know the value of $B\rho$

$$B\rho = \frac{e}{c}P \tag{6}$$

Thus, the bending radius R is

$$R = \frac{B\rho}{B_0} \tag{7}$$

The bending angle θ for a given arc length L traversed is given by

$$\theta = \frac{L}{R} \tag{8}$$

A bending magnet may be created with the function **atrbend** for a rectangular bend or **atsbend** for a sector bend. The fields are *FAMNAM*, *LENGTH*, *BENDINGANGLE*, *K*, and *PASSMETHOD*. Here, *LENGTH* is L and *BENDINGANGLE* is θ. The field in the dipole magnet may be computed with equation 7.

A bending magnet should also be specified with an entrance angle θ_1 and an exit angle θ_2.

The pass methods that may be used for a dipole are `BndMPoleSymplectic4Pass`, `BndMPoleSymplectic4RadPass` `BndMPoleSymplectic4E2Pass`, `BndMPoleSymplectic4E2RadPass` `BndMPoleSymplectic4FrgFPass`, `BndMPoleSymplectic4FrgFRadPass` `BendLinearPass`

```
>> [a,b]=BndMPoleSymplectic4E2Pass

a =

    'Length'
    'BendingAngle'
    'EntranceAngle'
    'ExitAngle'
    'PolynomB'
    'MaxOrder'
    'NumIntSteps'


b =

    'FullGap'
    'FringeInt1'
    'FringeInt2'
    'H1'
    'H2'
    'T1'
    'T2'
    'R1'
    'R2'
```

1.3 Quadrupole

A quadrupole magnet has a magnetic field

$$\vec{B} = k(x\hat{y} + y\hat{x}) \tag{9}$$

A quadrupole may be created with the creation function **atquadrupole**. The fields are *FAMNAME*, *LENGTH*, *K*, and *PASSMETHOD*.

The passmethods that may be used for a quadrupole are StrMPoleSymplectic4Pass, StrMPoleSymplectic4RadPass QuadLinearPass, QuadMPoleFringePass, QuadMPoleFringeRadPass ThinMPolePass

1.4 Sextupole

A sextupole magnet has a magnetic fields

$$\vec{B} = m(xy\hat{x} + \frac{1}{2}(x^2 - y^2)\hat{y}) \tag{10}$$

A sextupole may be created with the function **atsextupole**. The fields are *FAMNAME*, *LENGTH*, *S*, and *PASSMETHOD*.

The pass methods that may be used with a sextupole are StrMPoleSymplectic4Pass, StrMPoleSymplectic4RadPass ThinMPolePass

1.5 RF Cavity

A radio frequency cavity is a standard element in all storage rings. It adds back energy lost to synchrotron radiation and also provides longitudinal focusing.

An RF cavity may be created using the function **atrfcavity**. The fields are *FAMNAME*, *LENGTH*, *VOLTAGE*, *FREQUENCY*, *HARMNUMBER*, *ENERGY*, *PASSMETHOD* The pass method for an RF cavity is CavityPass

1.6 Wigglers and Undulators

There are several different models for wigglers and undulators in AT.

A wiggler may be created with the function **atwiggler**. The fields are *FAMNAME*, *Ltot*, *Lw*, *Bmax*, *Nstep*, *Nmeth*, *By*, *Bx*, *method*

The pass methods available for a wiggler are GWigSymplecticPass WiggLinearPass

And undulator or wiggler may also be represented with a kick map. This element may be created with the function **atidtable**. The fields are *Nslice*, *filename*, *Energy*, *method* The pass method for a Kick Map is IDTablePass

1.7 Quantum Diffusiom

The pass method for quantum diffusion is QuantDiffPass

1.8 Monitor

1.9 Corrector

1.10 Octupole

The pass methods that may be used for an octupole are StrMPoleSymplectic4Pass, StrMPoleSymplectic4RadPass

1.11 Multipole

The pass methods available for a multipole are StrMPoleSymplectic4Pass, StrMPoleSymplectic4RadPass ThinMPolePass

1.12 Thin Multipole

A thin multipole may use the pass method ThinMPolePass

1.13 Solenoid

A pass method for a solenoid is SolenoidLinearPass

1.14 Matrix66

A matrix may be created with the pass method Matrix66Pass

2 Misalignment and rotation and fringe fields

All elements may be misaligned or rotated. These are set through the parameters $T_{1,2}$ and $R_{1,2}$.

3 Pass methods

Description of existing pass methods and how to write your own. The field in the magnets is defined by a multipole expansion

$$\frac{B_y + iB_x}{B\rho} = \sum_{n=0}^{N} (iA_n + B_n)(x + iy)^n \tag{11}$$

The kick in going through a thin section of magnetic field is given by

$$\begin{aligned} \Delta x' &= -L\frac{B_y}{B\rho} \\ \Delta y' &= L\frac{B_x}{B\rho} \end{aligned} \tag{12}$$

The A_n and B_n in Eqn. 11 are polynomA and polynomB in the integration routines.

4 Interface to Matlab and writing your own pass method

The electron is passed through an element using the pass method function. The pass method functions are written in C and interfaced to Matlab via the Mex interface. In practice this means that one must write two additional functions for each passmethod. One is called passfunction and the other is called Mex-Function.

References

[1] A. Terebilo *Accelerator Toolbox for Matlab*, SLAC-PUB 8732 (May 2001)

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[3] B. Nash et. al. *New Functionality for Beam Dynamics in Accelerator Toolbox*, IPAC 2015

[4] D. Sagan, D. Rubin, *Linear Analysis of Couled Lattices*, Phys. Rev. Special Topics - Accelerators and Beams, Vol 2,(1999)