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An Introduction to "WIENFILTER"
Exercise 1: A Parallel Plate Electrostatic Deflector

Recommended readings

- Section "3.1 - Wien filter" in "Generalization of the Zgoubi method for ray-tracing to include electric fields", ../../documentation/electrificationOfZgoubi.pdf
- Zgoubi Users' Guide, regarding the keywords used in the exercise (WIENFILTER, OBJET/KOPT=2, OPTIONS/CONSTY, SEPARA in question 6/, etc.). Hint: use the index (last 3 pages of the Guide) to locate the related sections in Part A and Part B.
- During the exercise, it is recommended to keep 2 copies of the guide at hand, with one copy opened at the Index (last 3 pages of the document).

Keywords we play with in this exercise

`WIENFILTER` is the optical element used (pp. 168 and 306 in the Users' Guide), with B=0 so that it operates as a simple parallel plate electrostatic deflector.
Note: `ELMIR, ELMIRC` and even `ELMULT` or `EBMULT` could be used as well, they would be able to provide this dipole $\vec{E}$ field simulations (see "Optical elements versus keywords" in the Users' Guide).

Working hypotheses

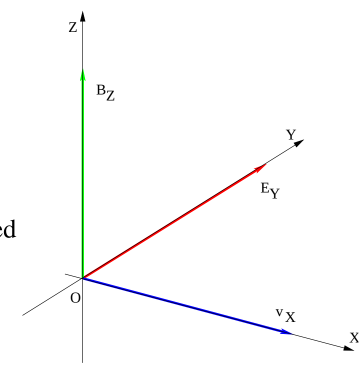
- The Wien filter length is L. Take $\vec{E} = \vec{E}_Y \parallel \vec{Y}$. Take hard-edge E-field model so to allow tight comparison with theory[1].
- In order to check numerical outcomes, the following can be used:
  - The expected trajectory is a catenary with equation

$$Y_{th}(X) = \frac{E_i}{qE_Y}\left(\cosh\frac{qE_Y X}{\beta_i E_i} - 1\right)$$

with E_i initial total energy, $c\beta_i$ initial velocity, q particle charge

  - Spin rotation: assume we manage to maintain $\vec{E} \perp \vec{v}$, namely, $\vec{v} = v_X$, always. Thus expected spin rotation over L is (Eq. 2.1.4 in Zgoubi Users' Guide)

$$\theta_s = (a\gamma + \frac{\gamma}{1+a\gamma})\beta_X^2 \frac{E_Y cL}{B\rho}$$



Numerical experience

1/ Let's first walk through the fortran, see what happens when the execution pointer meets 'WIENFILTER' in zgoubi.dat sequence...

- Open zgoubi_main.f : it calls zgoubi. The rest of the it essentially manages the 'FIT' procedure.
- Open zgoubi.f
  - find include/LSTKEY.H: take a look into it, spot WIENFILTER - and all of zgoubi keywords! If you need to add a keyword, that's here
  - find 'CALL RWIENF', look into rwienf.f. What does it do?
  - it is followed by'CALL QUASEX'. Optical elements call either QUASEX, or AIMANT (check that statement, scrolling through zgoubi.f), what's the difference between the two?
  - Open quasex.f. In there, find 'CALL CHXC'. What does it do?

[1] G. Leleux, INSTN Saclay, 1978 (unpublished)

- ∗ open chxc.f
  - · find WIENF therein. Open wienfi.f, take a look to the various “data initializations” necessary prior to tracking
- ∗ find ’CALL TRANSF’ in quasex, open transf.f: it pushes the particles, one by one, through ’INTEGR’
  - · find ’CALL INTEGR’, open integr.f: it pushes a particle, step by step, through WIENF (or any other element)
  - · In integer.f look for (i) ’CALL CHAMC’, (ii) ’CALL CHAMK’, (iii) ’CALL DEVTRA’: Figure out what each does.

2/ Set up a Wien filter sequence with $E_Y = 0.98\,$MV/m, $L = 0.5\,$m. Consider an electron with 350 keV energy[2].
Run that sequence and check (in zgoubi.res) final $Y(X \equiv L)$, particle deviation, compare with result from catenary equation above.

3/ Check the effect of step size:
Using REBELOTE, get a scan of Y values for $\Delta s = .001 : 10\,$cm. Plot $(Y - Y_{th})/Y_{th}$ versus step size (can use gnuplot to plot data read from zgoubi.fai).

4/ Force Y=0 across the Wien filter, by means of OPTIONS/CONSTY.
Check the rotation of an initial $\vec{S} \equiv \vec{S}_X$, at the downstream end of the condenser (X=L), compare to expected θ_s.
Check convergence of result versus integration step size.

5/ Check SEPARA keyword in Zgoubi Users’ Guide. What is the difference in SEPARA method, compared to WIENFILTER?
Try it and compare with WIENFILTER outcomes in questions 2/ and 3/.

6/ Add fringe-fields.
3.a Plot the particle trajectory and the E_Y and B_Z fields along the trajectory.
3.b Plot particle energy versus distance, conclude on the importance of fringe fields as to 6-D symplecticity.

[2] Data after E. Wang, see documentation in exercise 2