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Accelerator physics colde comparison

Z. Parsa

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Collider Accelerator Department
Brookhaven National Laboratory

U.S. Department of Energy
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ACCELERATOR DEVELOPMENT DEPARTMENT

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Accelerator Physics Technical Note No. 8

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ABSTRACT

We present a comparison between results obtained from accelerator physics codes used in the design and analysis of accelerators.

I. INTRODUCTION

Comparison of accelerator codes have been the topic of investigation and speculation by many (for sample notes on code comparisons see past issues of the Proceedings of Accelerator conferences). There are several beam optics programs that have been considered as standard codes for design and analysis of accelerators. For example, we have used programs SYNCH (as standard) and MAD for the design and analysis of the AGS - Booster and the proposed Super Conducting Super Collider (SSC).

In Section II, we Tabulate the parameters obtained from the recent Vax - Version of SYNCH* (Table I) for comparison with those obtained from program MAD - Versions 6.01 (Table II) and 4.03 (Table III) for the same sample (AGS - Booster) lattice. Comparison of the parameters in Tables I-III (e.g. items 6) shows a good agreement between the values of the tune shifts (Qx, QZ), lattice functions etc. for DELTA(P)/P = 0 but somewhat differs for DELTA(P)/P $\neq$ 0. The difference become larger when the sextupoles (e.g. Eddy Current) are included in the input lattices since they are handled differently by these programs.

Table II, was obtained using the recent Vax Version of SYNCH* which includes the correction to the chromaticity calculation that was not included (and was inaccurate) in the CDC and previous VAX versions of SYNCH. The effect of the chromaticity calculation correction is two fold:

1) In finding the closed orbit for off momentum, CDC - Version produces the wrong bending angles except for zero - gradient rectangular magnet.

2) In computing chromaticity for bending magnets with nonzero exit and entrance angle one term in the chromaticity formula had the wrong sign, resulting in the wrong sextupole strength correction.

Thus, we recommend the use of the parameters obtained from the corrected Version of SYNCH for the design, analysis or code comparison, since the data produced from the CDC Version of SYNCH is inaccurate.

In conclusion, the parameters obtained from several beam optics programs agree for DELTA(P)/P = 0, but there still are differences in the results obtained from programs SYNCH [1] and MAD [2] for DELTA(P)/P $\neq$ 0.

Acknowledgement

We thank Dr. E. Courant for the information on SYNCH and note that, this code comparison was made at his recommendation for the presentation at the Oct. 15, 1987 A.P. meeting.

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* available in BNLDAG::DUA0:[PARSA1.SYNCH]SYNSEP.EXE

[1]. A. A. Garren, principal author.

[2]. F. C. Iselin, principal author.

TABLE I

SYNCH VAX - Version 987

SYNCH RUN BST AGS-BOOSTER 14-OCT-87 15:40:17

1. DELTA(P)/P = -0.0100 :

CIRCUMFERENCE = 201.6976 M QX = 4.87006 QY = 4.88460
QX'= -5.03758 QY'= -5.60968
THETX = 6.28318530 RAD
RADIUS = 32.1012 M THETY = 0.00000000 RAD
(DS/S)/(DP/P)= 0.0393852 GAMMA(TR)=(5.03887, 0.00000)
MAXIMA --- BETX(21) = 13.84289 BETY(18) = 13.65464
DX(35) = 3.00980 DY(52) = 0.00000
MINIMA --- BETX(18) = 3.50410 BETY(47) = 3.63202
DX(1) = 0.44193 DY(52) = 0.00000
MAXIMA XCO(1)= -4.89001 YCO(52)= 0.00000
MINIMA XCO(35)= -29.66112 YCO(52)= 0.00000

2. DELTA(P)/P = -0.00800 :

CIRCUMFERENCE = 201.7137 M QX = 4.85992 QY = 4.87337
QX' = -5.01543 QY' = -5.54011
THETX = 6.28318530 RAD
RADIUS = 32.1037 M THETY = 0.00000000 RAD
(DS/S)/(DP/P)= 0.0399131 GAMMA(TR)=(5.00544, 0.00000)
MAXIMA --- BETX(21) = 13.84715 BETY(18) = 13.65237
DX(35) = 2.99672 DY(52) = 0.00000
MINIMA --- BETX(18) = 3.51844 BETY(47) = 3.64632
DX(52) = 0.46227 DY(52) = 0.00000
MAXIMA XCO(52)= -3.99552 YCO(52)= 0.00000
MINIMA XCO(35)= -23.70182 YCO(52)= 0.00000

3. DELTA(P)/P = -0.00600 :

CIRCUMFERENCE = 201.7300 M QX = 4.84985 QY = 4.86229
QX' = -4.99358 QY' = -5.47090
THETX = 6.28318530 RAD
RADIUS = 32.1063 M THETY = 0.00000000 RAD
(DS/S)/(DP/P)= 0.0404352 GAMMA(TR)=(4.97302, 0.00000)
MAXIMA --- BETX(21) = 13.85156 BETY(18) = 13.65018
DX(35) = 2.98438 DY(52) = 0.00000
MINIMA --- BETX(18) = 3.53273 BETY(47) = 3.66060
DX(52) = 0.48223 DY(52) = 0.00000
MAXIMA XCO(52)= -3.05855 YCO(52)= 0.00000
MINIMA XCO(35)= -17.75746 YCO(52)= 0.00000

4. DELTA(P)/P = -0.00400:

```
CIRCUMFERENCE =    201.7465 M     QX =    4.83984   QY =    4.85137
                                  QX' =   -4.97202  QY'=   -5.40198
                                  THETX =   6.28318530 RAD
  RADIUS =    32.1089 M           THETY =   0.00000000 RAD
 (DS/S)/(DP/P)= 0.0409518        GAMMA(TR)=(   4.94155,   0.00000)
 MAXIMA    --- BETX(   21) =    13.85613    BETY(   18) =    13.64807
 DX(   35) =     2.97275     DY(   52) =     0.00000
 MINIMA    --- BETX(   18) =     3.54698    BETY(   47) =     3.67487
 DX(   52) =     0.50183     DY(   52) =     0.00000
 MAXIMA      XCO(   52)= -2.07984     YCO(   52)=   0.00000
 MINIMA      XCO(   35)=-11.82661     YCO(   52)=   0.00000
```

5. DELTA(P)/P = -0.00200

```
CIRCUMFERENCE =    201.7632 M       QX =    4.82989   QY =    4.84061
                                    THETX =   6.28318530 RAD
       RADIUS =    32.1116 M        THETY =   0.00000000 RAD
 (DS/S)/(DP/P)= 0.0414633              GAMMA(TR)=(   4.91098,   0.00000)
 MAXIMA    --- BETX(   21) =    13.86084    BETY(   18) =    13.64603
 DX(   35) =     2.96178     DY(   52) =     0.00000
 MINIMA    --- BETX(   18) =     3.56119    BETY(   47) =     3.68911
 DX(   52) =     0.52109     DY(   52) =     0.00000
 MAXIMA      XCO(   52)= -1.06010     YCO(   52)=   0.00000
 MINIMA      XCO(   35)= -5.90789     YCO(   52)=   0.00000
```

6. DELTA(P)/P = 0.0000

```
CIRCUMFERENCE =    201.7800 M       QX =    4.82000  QY =    4.83000
                                    QX' =   -4.92970  QY' =   -5.26488
                                    THETX =   6.28318530 RAD
     RADIUS =    32.1143 M          THETY =   0.00000000 RAD
 (DS/S)/(DP/P)= 0.0419701              GAMMA(TR)=(   4.88124,   0.00000)
 MAXIMA    --- BETX(   21) =    13.86571    BETY(   52) =    13.64403
 DX(   35) =     2.95145     DY(   52) =     0.00000
 MINIMA    --- BETX(   18) =     3.57537    BETY(   35) =     3.70334
 DX(    1) =     0.54003     DY(   52) =     0.00000
 MAXIMA      XCO(   52)=   0.00000     YCO(   52)=   0.00000
 MINIMA      XCO(   35)=   0.00000     YCO(   52)=   0.00000
```

7. DELTA(P)/P = 0.00200

```
 CIRCUMFERENCE =    201.7970 M     QX =    4.81017    QY =    4.81955
                                   QX' =   -4.90893   QY' =   -5.19663
                                   THETX =   6.28318530 RAD
    RADIUS =    32.1170 M          THETY =   0.00000000 RAD
 (DS/S)/(DP/P)= 0.0424725          GAMMA(TR)=(   4.85229,   0.00000)
 MAXIMA    --- BETX(   21) =    13.87071    BETY(   52) =    13.65707
 DX(   35) =     2.94173     DY(   52) =     0.00000
```

```
MINIMA     --- BETX(   18) =     3.58950     BETY(   21) =     3.71581
DX(   52) =     0.55866     DY(   52) =     0.00000
MAXIMA      XCO(   35)=   5.89831      YCO(   52)=   0.00000
MINIMA      XCO(   52)=   1.09981      YCO(   52)=   0.00000
```

---

8. DELTA(P)/P = 0.00400

```
CIRCUMFERENCE =    201.8142 M      QX =    4.80040     QY =    4.80925
                                   QX' =   -4.88841    QY' = -5.12853
                                  THETX =   6.28318530 RAD
        RADIUS =    32.1197 M     THETY =   0.00000000 RAD
 (DS/S)/(DP/P)= 0.0429707          GAMMA(TR)=(   4.82407,   0.00000)
 MAXIMA     --- BETX(   21) =    13.87587     BETY(   52) =    13.67025
 DX(   35) =     2.93261     DY(   52) =     0.00000
 MINIMA     --- BETX(   18) =     3.60361     BETY(   21) =     3.72813
 DX(   52) =     0.57700     DY(   52) =     0.00000
 MAXIMA      XCO(   35)=  11.78824      YCO(   52)=   0.00000
 MINIMA      XCO(   52)=   2.23873      YCO(   52)=   0.00000
```

---

9. DELTA(P)/P = 0.00600

```
CIRCUMFERENCE =    201.8316 M      QX =    4.79069   QY =    4.79911
                                   QX' =   -4.86812  QY' =   -5.06055
                                  THETX =   6.28318530 RAD
     RADIUS =    32.1225 M        THETY =   0.00000000 RAD
 (DS/S)/(DP/P)= 0.0434650          GAMMA(TR)=(   4.79656,   0.00000)
 MAXIMA     --- BETX(   21) =    13.88116     BETY(   52) =    13.68358
 DX(   35) =     2.92405     DY(   52) =     0.00000
 MINIMA     --- BETX(   18) =     3.61768     BETY(   21) =     3.74028
 DX(   52) =     0.59506     DY(   52) =     0.00000
 MAXIMA      XCO(   35)=  17.67094      YCO(   52)=   0.00000
 MINIMA      XCO(   52)=   3.41617      YCO(   52)=   0.00000
```

---

10. DELTA(P)/P = 0.00800

```
CIRCUMFERENCE =    201.8492 M      QX =    4.78104     QY =    4.78913
                                   QX' =   -4.84806    QY' =   -4.99265
                                  THETX =   6.28318530 RAD
    RADIUS=    32.1253 M          THETY =   0.00000000 RAD
 (DS/S)/(DP/P)= 0.0439557          GAMMA(TR)=(   4.76971,   0.00000)
 MAXIMA     --- BETX(   21) =    13.88659     BETY(   52) =    13.69704
 DX(   35) =     2.91603     DY(   52) =     0.00000
 MINIMA     --- BETX(   18) =     3.63171     BETY(   21) =     3.75227
 DX(   52) =     0.61285     DY(   52) =     0.00000
 MAXIMA      XCO(   35)=  23.54750      YCO(   52)=   0.00000
 MINIMA      XCO(   52)=   4.63157      YCO(   52)=   0.00000
```

---

11. DELTA(P)/P = 0.01000

CIRCUMFERENCE = 201.8669 M QX = 4.77144 QY = 4.77930
QX' = -4.82823 QY' = -4.92482
THETX = 6.28318530 RAD
RADIUS = 32.1281 M THETY = 0.00000000 RAD
(DS/S)/(DP/P)= 0.0444431 GAMMA(TR)=(4.74349, 0.00000)
MAXIMA --- BETX(21) = 13.89216 BETY(52) = 13.71064
DX(35) = 2.90853 DY(52) = 0.00000
MINIMA --- BETX(18) = 3.64572 BETY(21) = 3.76410
DX(52) = 0.63039 DY(52) = 0.00000
MAXIMA XCO(35)= 29.41897 YCO(52)= 0.00000
MINIMA XCO(52)= 5.88440 YCO(52)= 0.00000

END OF SYNCH RUN BST

TABLE II

"MAD" VERSION 6.01/03:

MAD6.01 OUTPUT FOR THE BOOSTER LATTICE WITHOUT SEXTUPOLES [SF, SD, SV=0]

1. For DELTA(P)/P = -0.01:

TOTAL LENGTH = 201.780000 QX = 4.869524 QY = 4.882689
QX'= -4.974135 QY'= -5.314419
ALFA = 0.397978E-01 BETAX(MAX)= 13.981287 BETAY(MAX) = 13.795012
GAMMA(TR) = 5.012688 DX(MAX) = 3.039104 DY(MAX) = 0.000000
XCO(MAX) = 29.938897 YCO(MAX) = 0.000000
XCO(R.M.S.)= 16.640292 YCO(R.M.S.)= 0.000000

2. FOR DELTA(P)/P = -0.008000:

TOTAL LENGTH = 201.780000 QX = 4.859582 QY = 4.872144
QX'=-4.965049 QY'= -5.304147
ALFA = 0.402414E-01 BETAX(MAX) =13.957912 BETAY(MAX) = 13.764037
GAMMA(TR) = 4.984983 DX(MAX) = 3.020217 DY(MAX) = 0.000000
XCO(MAX) =23.879696 YCO(MAX) = 0.000000
XCO(R.M.S.) =13.311186 YCO(R.M.S.)= 0.000000

3. FOR DELTA(P)/P = -0.006000:

TOTAL LENGTH = 201.780000 QX = 4.849659 QY = 4.861603
QX' = -4.956066 QY' = -5.294075
ALFA = 0.406801E-01 BETAX(MAX) = 13.934668 BETAY(MAX) = 13.733463
GAMMA(TR)= 4.958030 DX(MAX) = 3.002033 DY(MAX) = 0.000000
XCO(MAX) = 17.857561 YCO(MAX) = 0.000000
XCO(R.M.S.) = 9.983220 YCO(R.M.S.)= 0.000000

4. FOR DELTA(P)/P = -0.004000:

TOTAL LENGTH = 201.780000 QX = 4.839755 QY = 4.851065
QX' = -4.947183 QY'= -5.284184
ALFA = 0.411142E-01 BETAX(MAX) = 13.911553 BETAY(MAX) = 13.703278
GAMMA(TR) =4.931783 DX(MAX) = 2.984527 DY(MAX) = 0.000000
XCO(MAX) = 11.871112 YCO(MAX) = 0.000000
XCO(R.M.S.) = 6.655764 YCO(R.M.S.)= 0.000000

5. FOR DELTA(P)/P = -0.002000:

TOTAL LENGTH = 201.780000 QX = 4.829868 QY = 4.840531
QX'= -4.938396 QY' = -5.274457
ALFA = 0.415441E-01 BETAX(MAX) = 13.888567 BETAY(MAX) = 13.673471
GAMMA(TR) = 4.906198 DX(MAX) = 2.967673 DY(MAX) = 0.000000

XCO(MAX) = 5.919019 YCO(MAX) = 0.000000
XCO(R.M.S.) = 3.328215 YCO(R.M.S.) = 0.000000

---

6. FOR DELTA(P)/P = 0.000000:

TOTAL LENGTH = 201.780000 QX = 4.820000 QY = 4.829999
QX' = -4.929702 QY' = -5.264883
ALFA = 0.419701E-01 BETAX(MAX) = 13.865707 BETAY(MAX) = 13.644032
GAMMA(TR) = 4.881238 DX(MAX) = 2.951449 DY(MAX) = 0.000000
XCO(MAX) = 0.000000 YCO(MAX) = 0.000000
XCO(R.M.S.) = 0.000000 YCO(R.M.S.) = 0.000000

---

7. FOR DELTA(P)/P = 0.002000:

TOTAL LENGTH = 201.780000 QX = 4.810150 QY = 4.819471
QX' = -4.921099 QY' = -5.255452
ALFA = 0.423924E-01 BETAX(MAX)= 13.842974 BETAY(MAX) = 13.629735
GAMMA(TR) = 4.856865 DX(MAX) = 2.935830 DY(MAX) = 0.000000
XCO(MAX) = 5.887179 YCO(MAX) = 0.000000
XCO(R.M.S.) = 3.329428 YCO(R.M.S.) = 0.000000

---

8. FOR DELTA(P)/P = 0.004000:

TOTAL LENGTH = 201.780000 QX = 4.800317 QY = 4.808946
QX' = -4.912583 QY'= -5.246156
ALFA = 0.428113E-01 BETAX(MAX) = 13.820366 BETAY(MAX) = 13.615495
GAMMA(TR) = 4.833046 DX(MAX) = 2.920797 DY(MAX) = 0.000000
XCO(MAX) = 11.743710 YCO(MAX) = 0.000000
XCO(R.M.S.) = 6.660591 YCO(R.M.S.) = 0.000000

---

9. FOR DELTA(P)/P = 0.006000:

TOTAL LENGTH = 201.780000 QX = 4.790501 QY = 4.798424
QX' = -4.904152 QY' = -5.236988
ALFA = 0.432270E-01 BETAX(MAX) = 13.797883 BETAY(MAX) = 13.601316
GAMMA(TR) = 4.809750 DX(MAX) = 2.906327 DY(MAX) = 0.000000
XCO(MAX) = 17.570742 YCO(MAX) = 0.000000
XCO(R.M.S.) = 9.993989 YCO(R.M.S.) = 0.000000

---

10. FOR DELTA(P)/P = 0.008000:

TOTAL LENGTH = 201.780000 QX = 4.780703 QY = 4.787905
QX' = -4.895804 QY' = -5.227943
ALFA = 0.436398E-01 BETAX(MAX) = 13.775524 BETAY(MAX) = 13.587203
GAMMA(TR) = 4.786948 DX(MAX) = 2.892402 DY(MAX) = 0.000000
XCO(MAX) = 23.369382 YCO(MAX) = 0.000000
XCO(R.M.S.) = 13.330097 YCO(R.M.S.)= 0.000000

---

11. FOR DELTA(P)/P = 0.010000 :

TOTAL LENGTH = 201.780000 QX = 4.770922 QY = 4.777389
QX' = -4.887536 QY'= -5.219016
ALFA = 0.440499E-01 BETAX(MAX) = 13.753287 BETAY(MAX) = 13.573160
GAMMA(TR) = 4.764614 DX(MAX) = 2.879003DY(MAX) = 0.000000
XCO(MAX) = 29.140701 YCO(MAX) = 0.000000
XCO(R.M.S.) = 16.669372 YCO(R.M.S.) = 0.000000

TABLE III

"MAD" VERSIN 4.03

MAD403 OUTPUT FOR AGS BOOSTER LATTICE WITHOUT SEXIUPOLES [SF,SD,SV=0]

1. FOR DELTA(P)/P = -0.010000 :

TOTAL LENGTH = 201.780000 QX = 4.869536 QY = 4.882249
QX' = -4.974658 QY' = -5.291287
ALFA = 0.397978E-01 BETAX(MAX) = 13.981250 BETAY(MAX)= 13.796343
GAMMA(TR) = 5.012688 DX(MAX) = 3.039108 DY(MAX) = 0.000000

2. FOR DELTA(P)/P = -0.008000 :

TOTAL LENGTH = 201.780000 QX = 4.859589 QY = 4.871899
QX' = -4.965323 QY' = -5.292399
ALFA = 0.402414E-01 BETAX(MAX) = 13.957891 BETAY(MAX) = 13.764777
GAMMA(TR) = 4.984983 DX(MAX) = 3.020219 DY(MAX) = 0.000000

3. FOR DELTA(P)/P = -0.006000 :

TOTAL LENGTH = 201.780000 QX = 4.849663 QY = 4.861481
QX' = -4.956193 QY' = -5.288761
ALFA = 0.406801E-01 BETAX(MAX)= 13.934657 BETAY(MAX) = 13.733831
GAMMA(TR)= 4.958030 DX(MAX) = 3.002034 DY(MAX) = 0.000000

4. FOR DELTA(P)/P = -0.004000 :

TOTAL LENGTH = 201.780000 QX = 4.839756 QY = 4.851017
QX' = -4.947229 QY' = -5.282268
ALFA = 0.411142E-01 BETAX(MAX) = 13.911549 BETAY(MAX) = 13.703424
GAMMA(TR) = 4.931783 DX(MAX) = 2.984527 DY(MAX) = 0.000000

5. FOR DELTA(P)/P = -0.002000 :

TOTAL LENGTH = 201.780000 QX = 4.829869 QY = 4.840520
QX' = -4.938405 QY' = -5.274067
ALFA = 0.415441E-01 BETAX(MAX) = 13.888566 BETAY(MAX) = 13.673504
GAMMA(TR) = 4.906198 DX(MAX) = 2.967673 DY(MAX) = 0.000000

6. FOR DELTA(P)/P = 0.000000 :

TOTAL LENGTH = 201.780000 QX = 4.820000 QY = 4.829999
QX' =-4.929702 QY' = -5.264883
ALFA = 0.419701E-01 BETAX(MAX) =13.865707 BETAY(MAX) = 13.644032
GAMMA(TR) = 4.881238 DX(MAX) = 2.951449 DY(MAX) = 0.000000

7. FOR DELTA(P)/P = 0.002000:

TOTAL LENGTH = 201.780000 QX = 4.810150 QY = 4.819462
QX' = -4.921105 QY' =-5.255196
ALFA = 0.423924E-01 BETAX(MAX) = 13.842973 BETAY(MAX) = 13.629764
GAMMA(TR) = 4.856865 DX(MAX= 2.935830 DY(MAX)= 0.000000

8. BEAM DELTA(P)/P = 0.004000:

TOTAL LENGTH = 201.780000 QX = 4.800318 QY = 4.808910
QX' = -4.912603 QY' =-5.245338
ALFA = 0.428113E-01 BETAX(MAX) = 13.820363 BETAY(MAX)= 13.615603
GAMMA(TR) = 4.833046 DX(MAX) = 2.920797 DY(MAX) = 0.000000

9. FOR DELTA(P)/P = 0.006000:

TOTAL LENGTH = 201.780000 QX = 4.790504 QY = 4.798347
QX' = -4.904188 QY' = -5.235560
ALFA = 0.432270E-01 BETAX(MAX) = 13.797876 BETAY(MAX)= 13.601548
GAMMA(TR) = 4.809750 DX(MAX) = 2.906328 DY(MAX) = 0.000000

10. FOR DELTA(P)/P = 0.008000 :

TOTAL LENGTH = 201.780000 QX = 4.780707 QY = 4.787774
QX' = -4.895849 QY'= -5.226062
ALFA = 0.436398E-01 BETAX(MAX) = 13.775511 BETAY(MAX)= 13.587601
GAMMA(TR) = 4.786948 DX(MAX) = 2.892404 DY(MAX) = 0.000000

11. FOR DELTA(P)/P = 0.010000 :

TOTAL LENGTH = 201.780000 QX = 4.770928 QY = 4.777190
QX' = -4.887580 QY'= -5.21701
ALFA = 0.440499E-01 BETAX(MAX) = 13.753267 BETAY(MAX) = 13.573763
GAMMA(TR) = 4.764614 DX(MAX) = 2.879005 DY(MAX) = 0.000000