Comparison of Lattice Codes

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ALBA-CELLS

NLBD-Workshop

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- Codes to compare
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Codes

MAD (Zeus Marti, CELLS)

DIMAD (Les Dallin, CLS)

BETA (Laurent Nadolski, SOLEIL)

OPA (Andreas Streun, SLS)

AT (Xiabiao Huang, SPEARE III)

TRACY (Laurent Nadolski)

ELEGANT (Mike Borland and Louis Emery, APS)

ACCELERATICUM (Pavel Piminov, BINP)

The detail's of the codes will be described in the Appendix

Lattices for Comparison

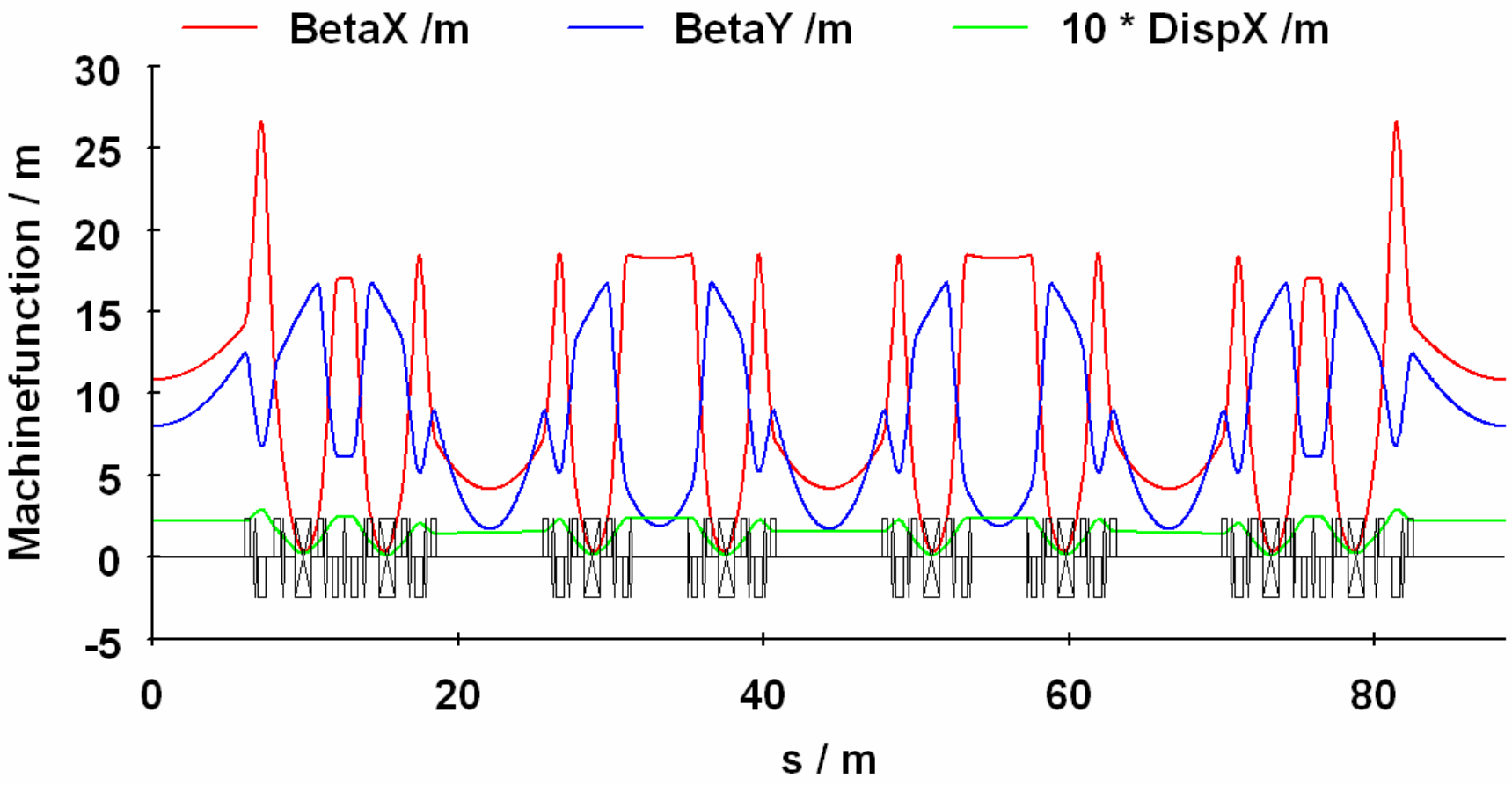
Lattice

SOLEIL: High field in the bendings.

ALBA: Like SOLEIL but with a gradient in the bendings

APS: High energy machine

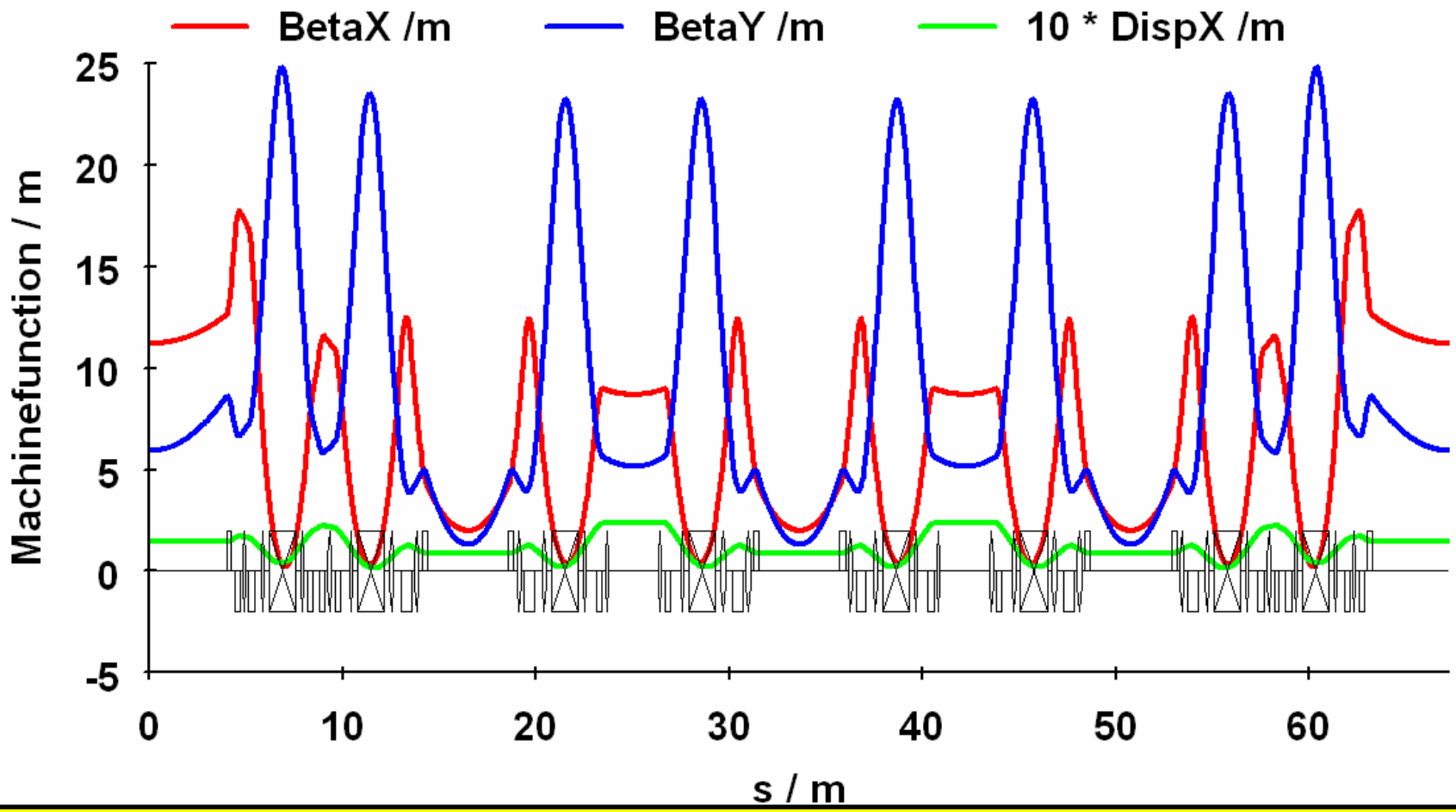
Lattice of Soleil



Four fold symmetry with 2 unit cells and 2 matching sections in a quadrant.

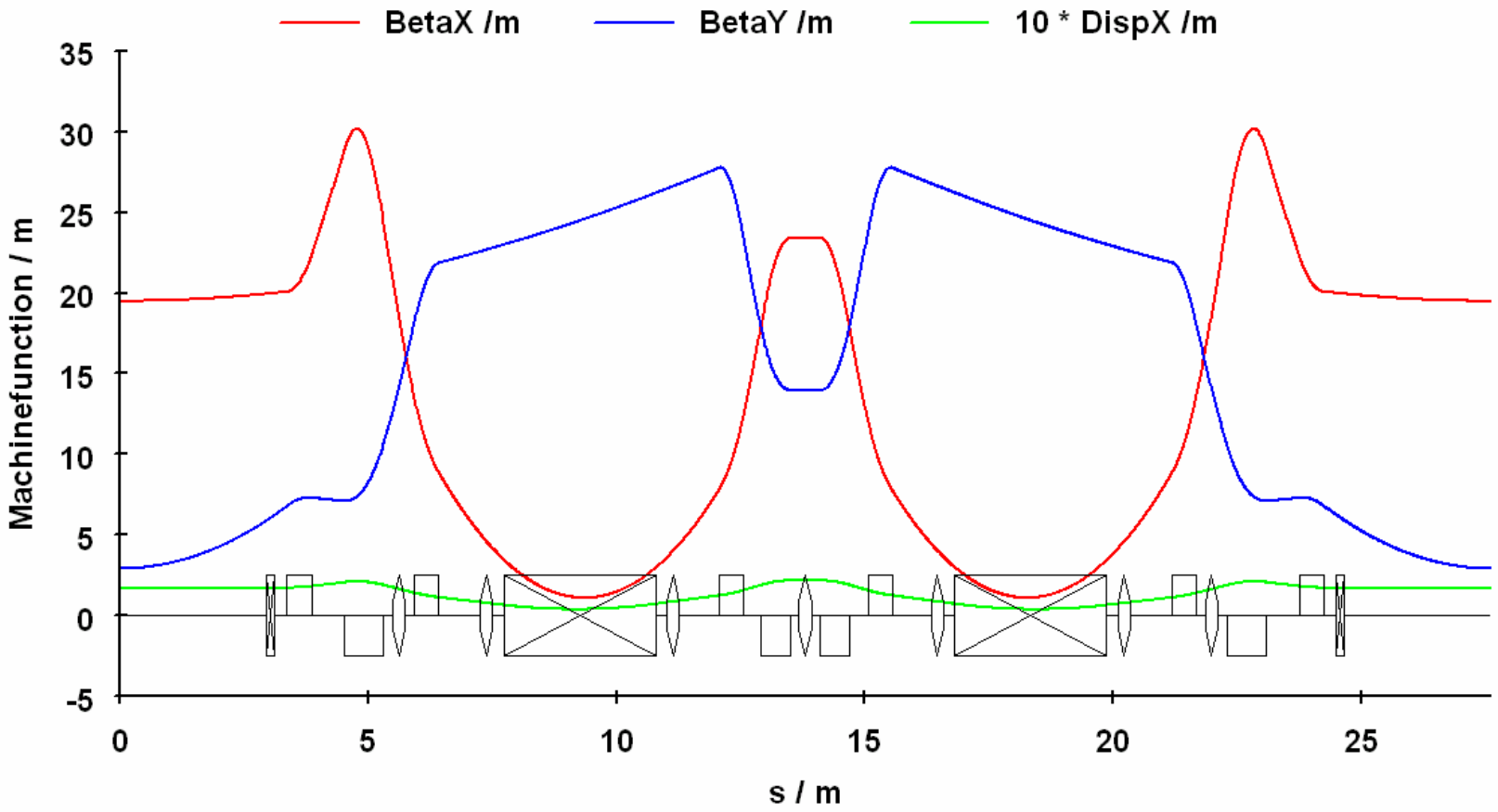
C = 354,1 m, E = 2.75 GeV, RF= 352MHz, Qx = 18.2 and Qy = 10.3

Lattice of ALBA



Four fold symmetry with 2 unit cells and 2 matching sections in a quadrant like SOLEIL. In comparison to SOLEIL, ALBA has a gradient in the bending magnets.C = 268.8 m, E = 3.00 GeV, RF= 500MHz, Qx = 18.18 and Qy = 8.37

Lattice of APS



It is a typical DBA – lattice with 40 cells. C = 1104. m, E = 7.00 GeV, RF= 500MHz, Qx = 36.2 and Qy = 19.27

Linear Parameters

As "Linear Parameters" we compare:

Circumference, Tunes, Beta functions, Dispersion functions, Natural chromaticity's, Damping times, Partition numbers, Emittance's, Momentum compaction factor, Energy Spread, Synchrotron Integrals, Corrected chromaticity's

Linear Parameters for the Lattice ALBA

Calculation for the Lattice ALBA

Parameter	Unit	MAD	Tracy II	BETA	ELEG.	DIMAD	AT	OPA	Accel.
Energy	GeV	3	3.000	3	3	3	3	3	3
Circumference	m	268.8003	268.8003	268.8000	268.8000	268.8000	268.8003	268.8000	268.8003
Horizontal Tune Q(x)		18.1790	18.1789	18.1791	18.1790	18.1790	18.1790	18.1790	18.1790
Vertical Tune (Qy)		8.3720	8.3715	8.3710	8.3379	8.3720	8.3720	8.3720	8.3720
Beta_x (β(x))		11.1986	11.1980	11.1950	11.1967	11.1960	11.1966	11.1970	11.1970
Beta_y (β(y))		5.9288	5.9270	5.9250	5.7711	5.9290	5.9287	5.9290	5.9288
Dispersion_x (η(x))		0.1461	0.1470	0.1462	0.1462	0.1460	0.1461	0.1462	0.1465
Horiz.-Natur.-Chromaticity ξ(x)		-39.4893	-39.4976	-39.4400	-39.4433	-39.4433	-39.4155	-39.6480	-39.6481
Vertic.-Natur.-Chromaticity ξ(y)		-28.0677	-28.1603	-28.7700	-29.4241	-28.7558	-28.7372	-26.8830	-26.8831
Momentum Compaction Factor (α)		8.8230E-04	8.7580E-04	8.8290E-04	8.8293E-04	8.8230E-04	8.8316E-04	8.8300E-04	8.8229E-04
Energy Spread (δE/E)		1.0489E-03	1.0600E-03	1.0500E-03	1.0515E-03	1.0500E-03	1.0512E-03	1.0490E-03	1.0515E-03
Natural emittance	nm*rad	4.4874	4.4880	4.48922	4.4571	4.4600	4.4545	4.4880	4.4570
Horiz.-Damping-Time (τ(x))	msec	4.0826	4.0830	4.0810	4.0550	4.0551	4.0531	4.0840	4.0550
Vert.-Damping-Time (τ(y))	msec	5.2908	5.2910	5.2880	5.2908	5.2910	5.2887	5.2910	5.2908
Long.-Damping-Time (τ(s))	msec	3.1048	3.1040	3.1030	3.1210	3.1211	3.1199	3.1050	3.1210
Energy Loss per Turn (U(0))	MeV	1.0168	1.0168	1.0170	1.0168	1.0168	1.0172	1.0167	1.0156
Horiz.-Partition Number (J(x))		1.2959	1.2960	1.29576	1.3048	1.3048	1.3048	1.2958	1.3048
Vert.-Partition Number (J(y))		1.0000	1.0000	1.00000	1.0000	1.0000	1.0000	1.0000	1.0000
Long.-Partition Number (J(s))		1.7041	1.7040	1.70424	1.6952	1.6952	1.6952	1.7042	1.6952
Synchr.-Integrat (I1)		0.2375	0.2354	0.2373	0.2373	0.2373	0.2374	0.2373	0.2373
Synchr.-Integrat (I2)		0.8916	0.8916	0.8916	0.8916	0.8916	0.8916	0.8916	0.8916
Synchr.-Integrat (I3)		0.1265	0.1265	0.1265	0.1265	0.1265	0.1265	0.1265	0.1265
Synchr.-Integrat (I4)		-0.2717		-0.2637	-0.2717	-0.2717	-0.2718	-0.2637	-0.2717
Synchr.-Integrat (I5)		3.9356E-04		3.9256E-04	3.9258E-04	3.9258E-04	3.9258E-04	3.9250E-04	3.9258E-04

How do we make an evaluation? We don't know what the exact solutions is.
So, I took the average from all the codes and compared the results to this average

Average Values and Standard Deviations: ALBA

Evaluation for the ALBA -Lattice

		Average	Stand.-Deviat.	Deviation in %
Parameter	Unit			
Energy	GeV	3	0	0
Circumference	m	268.800150	0.000160	0.000059
Horizontal Tune Q(x)		18.178994	0.000054	0.000297
Vertical Tune (Qy)		8.367541	0.012000	0.143412
Beta_x (β(x))	m/rad	11.196861	0.001112	0.009932
Beta_y (β(y))	m/rad	5.908420	0.055511	0.939528
Dispersion_x (η(x))	m	0.146274	0.000330	0.225908
Horiz.-Natur.-Chromaticity ξ(x)		-39.503124	0.093399	-0.236434
Vertic.-Natur.-Chromaticity ξ(y)		-28.210149	0.918679	-3.256553
Momentum Compaction Factor (α)		0.000882	0.000002	0.279503
Energy Spread (δE/E)		0.001051	0.000004	0.341104
Natural emittance	nm*rad	4.470287	0.016461	0.368239
Horiz.-Damping-Time (τ(x))	msec	4.068592	0.015052	0.369968
Vert.-Damping-Time (τ(y))	msec	5.290260	0.001208	0.022833
Long.-Damping-Time (τ(s))	msec	3.112472	0.008860	0.284649
Energy Loss per Turn (U(0))	MeV	1.016717	0.000480	0.047176
Horiz.-Partition Number (J(x))		1.300974	0.004751	0.365165
Vert.-Partition Number (J(y))		1.000000	0.000000	0.000008
Long.-Partition Number (J(s))		1.699021	0.004756	0.279913
Synchr.-Integrat (I1)		0.237116	0.000690	0.290827
Synchr.-Integrat (I2)		0.891605	0.000003	0.000371
Synchr.-Integrat (I3)		0.126522	0.000001	0.000661
Synchr.-Integrat (I4)		-0.269445	0.003925	-1.456688
Synchr.-Integrat (I5)		3.9271E-04	3.7685E-07	0.095962

For the lattice ALBA, there are 8 parameters marked with red, which means they are out of good agreement. The largest differences are for the vertical beta function (1%) and the vertical Chromaticity (3.3%)

Remarks: "Average" is the average value of all the codes“

Stand.-Deviat." is the standard deviation according to the "Gaussian distribution"

“Deviation in %" is the quotient of the standard deviation divided by the average value.

Differences to the Average Value of ALBA

Differencess of the codes (in percentages) in comparison to the "average value"

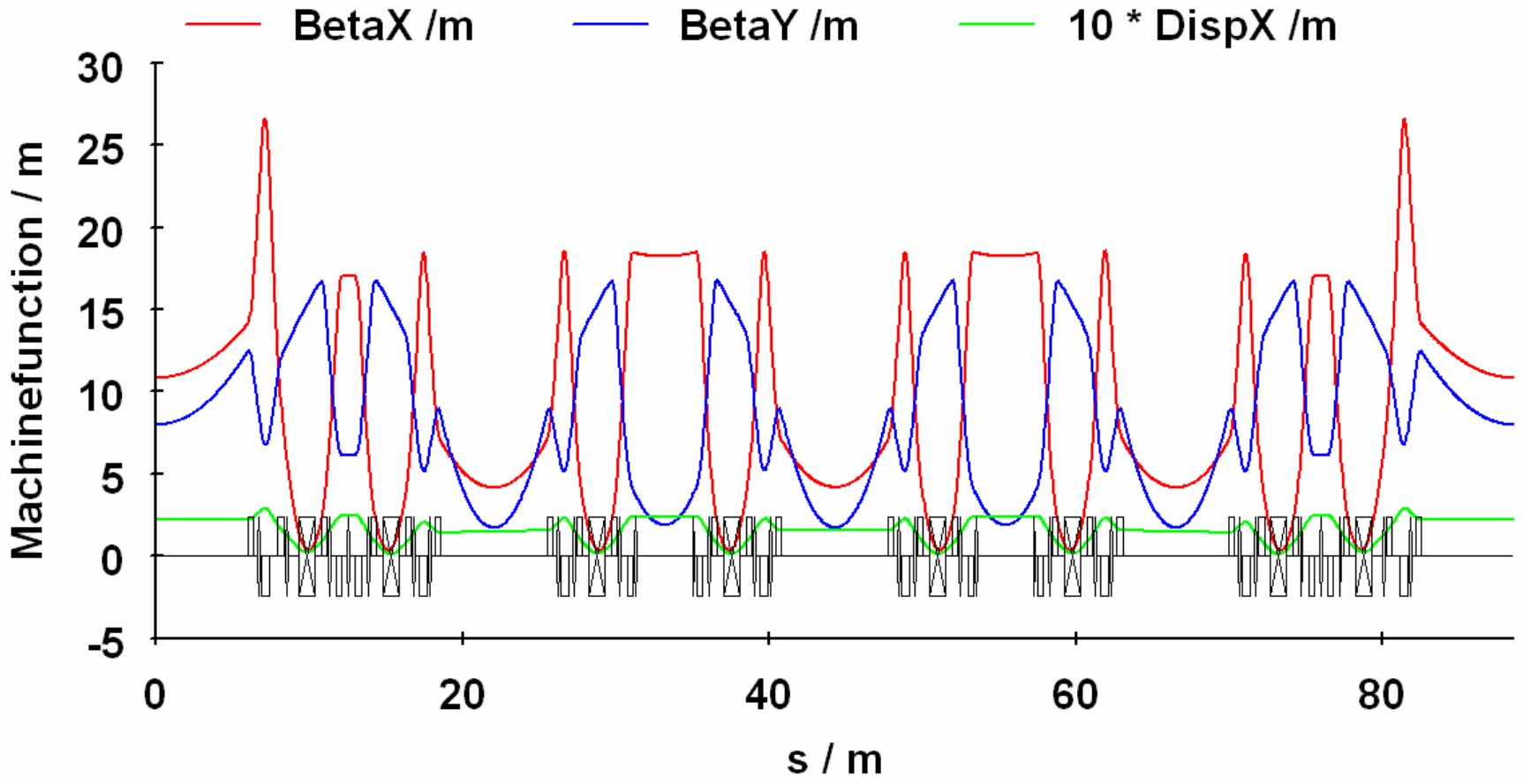
Parameter	Unit	Averag	MAD	Tracy II	BETA	ELEG.	DIMAD	AT	OPA	Accel.
Energy	GeV	3	0	0	0	0	0	0	0	0
Circumference	m	2.688E+02	5.599E-05	5.450E-05	-5.562E-05	-5.562E-05	-5.562E-05	5.599E-05	-5.562E-05	5.599E-05
Horizontal Tune Q(x)		18.17899	3.03E-05	-5.20E-04	5.80E-04	-2.47E-05	3.03E-05	-4.73E-05	3.03E-05	-7.97E-05
Vertical Tune (Qy)		8.36754	0.0533	0.0473	0.0413	-0.3548	0.0533	0.0530	0.0533	0.0533
Beta_x (β(x))		11.19686	0.0155	0.0102	-0.0166	-0.0019	-0.0077	-0.0020	0.0012	0.0012
Beta_y (β(y))		5.90842	0.3449	0.3145	0.2806	-2.3245	0.3483	0.3429	0.3483	0.3449
Dispersion_x (η(x))		0.14627	-0.1437	0.4960	-0.0509	-0.0709	-0.1876	-0.1462	-0.0509	0.1542
Horiz.-Natur.-Chromaticity ξ(x)		-39.50312	-0.0350	-0.0140	-0.1598	-0.1516	-0.1514	-0.2219	0.3667	0.3670
Vertic.-Natur.-Chromaticity ξ(y)		-28.21015	-0.5049	-0.1767	1.9846	4.3033	1.9342	1.8682	-4.7045	-4.7042
Momentum Compaction Factor (α)		0.00088	0.0528	-0.6845	0.1206	0.1244	0.0526	0.1505	0.1320	0.0515
Energy Spread (δE/E)		0.00105	-0.2509	0.8085	-0.1426	-0.0039	-0.1426	-0.0271	-0.2377	-0.0037
Natural emittance	nm*rad	4.47029	0.3830	0.3962	0.4235	-0.2959	-0.2301	-0.3523	0.3962	-0.2972
Horiz.-Damping-Time (τ(x))	msec	4.06859	0.3432	0.3541	0.3050	-0.3343	-0.3316	-0.3808	0.3787	-0.3343
Vert.-Damping-Time (τ(y))	msec	5.29026	0.0103	0.0140	-0.0427	0.0104	0.0140	-0.0303	0.0140	0.0104
Long.-Damping-Time (τ(s))	msec	3.11247	-0.2450	-0.2722	-0.3043	0.2736	0.2772	0.2375	-0.2401	0.2733
Energy Loss per Turn (U(0))	MeV	1.01672	0.0089	0.0082	0.0279	0.0088	0.0082	0.0495	-0.0016	-0.1098
Horiz.-Partition Number (J(x))		1.30097	-0.3878	-0.3823	-0.4008	0.2914	0.2910	0.2974	-0.4008	0.2912
Vert.-Partition Number (J(y))		1.00000	1.800E-05	-3.000E-06	-3.000E-06	-3.000E-06	-3.000E-06	-3.000E-06	-3.000E-06	-3.000E-06
Long.-Partition Number (J(s))		1.69902	0.2973	0.2931	0.3072	-0.2228	-0.2225	-0.2274	0.3072	-0.2249
Synchr.-Integrat (I1)		0.23712	0.1579	-0.7171	0.0904	0.0916	0.0915	0.1174	0.0904	0.0778
Synchr.-Integrat (I2)		0.89160	0.0001	0.0001	-0.0005	0.0001	0.0006	0.0001	-0.0005	0.0001
Synchr.-Integrat (I3)		0.12652	0.0002	0.0003	-0.0013	0.0002	0.0009	0.0002	-0.0005	0.0002
Synchr.-Integrat (I4)		-0.26945	0.8479		-2.1323	0.8479	0.8478	0.8738	-2.1323	0.8473
Synchr.-Integrat (I5)		3.927E-04	0.2169		-0.0373	-0.0311	-0.0310	-0.0322	-0.0525	-0.0328
	∑Stand.-Dev.=		0.2239	0.3514	0.4597	1.0785	0.4463	0.4392	1.0355	1.0257
	SUM(ST.-Dev.)=		5.0602							

Comments to the Average Values of ALBA

Comments by "Dieter" to the deviation of the codes in %

Parameter	Unit	Comments by Dieter
Energy	GeV	
Circumference	m	The circumference is for all codes correct
Horizontal Tune Q(x)		Good agreement between all codes
Vertical Tune (Qy)		ELEGANT is away by 0.36 %
Beta_x (β(x))		Good agreement between all codes
Beta_y (β(y))		ELEGANT is away by 2.3 %
Dispersion_x (η(x))		TRACY II is away by 0.5 %
Horiz.-Natur.-Chromaticity ξ(x)		OPA and Aceler. are away by 0.36%
Vertic.-Natur.-Chromaticity ξ(y)		Bad agreement between the codes (+/- 4%)
Momentum Compaction Factor (α)		TRACY II is away by 0.68 %
Energy Spread (δE/E)		TRACY II is away by 1.06%
Natural emittance	nm*rad	No good agreement between the codes
Horiz.-Damping-Time (τ(x))	msec	No good agreement between the codes
Vert.-Damping-Time (τ(y))	msec	Good agreement between all codes
Long.-Damping-Time (τ(s))	msec	No good agreement between the codes
Energy Loss per Turn (U(0))	MeV	Good agreement between the codes
Horiz.-Partition Number (J(x))		No good agreement between the codes
Vert.-Partition Number (J(y))		Good agreement between the codes
Long.-Partition Number (J(s))		No good agreement between the codes
Synchr.-Integrat (I1)		Good agreement between the codes
Synchr.-Integrat (I2)		There is a good agreement between the codes
Synchr.-Integrat (I3)		There is a good agreement between the codes
Synchr.-Integrat (I4)		No good agreement between the codes
Synchr.-Integrat (I5)		Good agreement between the codes

Comparison of Codes for SOLEIL



Linear Parameters for the Lattice SOLEIL

Calculation for the Lattice SOLEIL

Parameter	Unit	MAD	Tracy II	BETA	ELEG.	DIMAD	AT	OPA	Accel.
Energy	GeV	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.7
Circumference	m	354.0975	354.0967	354.0960	354.1000	354.1000	354.0967	354.0970	354.09672
Horizontal Tune Q(x)		18.2000	18.1996	18.2000	18.2000	18.2000	18.2000	18.1999	18.1999
Vertical Tune (Qy)		10.3000	10.2998	10.2998	10.2714	10.3000	10.2998	10.2998	10.3742
Beta_x (β(x))		10.8740	10.877	10.8735	10.8740	10.8740	10.8740	10.8740	10.8743
Beta_y (β(y))		7.9970	7.9970	7.9974	7.8838	7.9970	7.9974	7.9970	8.1189
Dispersion_x (η(x))		0.2205	0.2210	0.2205	0.2205	0.2200	0.2205	0.2205	0.2206
Horiz.-Natur.-Chromaticity ξ(x)		-52.9047	-52.8769	-52.9022	-52.9026	-52.9026	-52.9027	-52.9870	-52.9867
Vertic.-Natur.-Chromaticity ξ(y)		-22.4212	-22.3640	-22.4442	-22.3046	-22.4450	-22.4450	-21.0050	-21.2814
Momentum Compaction Factor (α)		4.4983E-04	4.3790E-04	4.4980E-04	4.4983E-04	4.4983E-04	4.4991E-04	4.5000E-04	4.4984E-04
Energy Spread (δE/E)		1.0166E-03	1.0320E-03	1.0163E-03	1.0182E-03	1.0181E-03	1.0179E-03	1.0160E-03	9.9965E-04
Natural emittance	nm*rad	3.6300	3.5670	3.6284	3.5983	3.5979	3.5975	3.6270	3.5983
Horiz.-Damping-Time (τ(x))	msec	6.9114	7.0030	6.9152	6.8639	6.8642	6.8611	6.9200	6.8639
Vert.-Damping-Time (τ(y))	msec	6.8748	6.9660	6.8787	6.8823	6.8826	6.8795	6.8830	6.8823
Long.-Damping-Time (τ(s))	msec	3.4283	3.4740	3.4303	3.4458	3.4459	3.4444	3.4320	3.4458
Energy Loss per Turn (U(0))	MeV	0.9515	0.9430	0.9446	0.9439	0.9439	0.9443	0.9438	0.9439
Horiz.-Partition Number (J(x))		0.9946	0.9949	0.9947	1.0027	1.0027	1.0027	0.9947	1.0027
Vert.-Partition Number (J(y))		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Long.-Partition Number (J(s))		2.0054	2.0060	2.0053	1.9973	1.9973	1.9973	2.0053	1.9973
Synchr.-Integrat (I1)		0.1594	0.1551	0.1593	0.1593	0.1593	0.1593	0.1593	0.1593
Synchr.-Integrat (I2)		1.1722	1.1722	1.1722	1.1722	1.1722	1.1722	1.1722	1.1722
Synchr.-Integrat (I3)		0.2187	0.2187	0.2187	0.2187	0.2187	0.2187	0.2187	0.2187
Synchr.-Integrat (I4)		-2.661E-03		6.194E-03	-3.144E-03	-3.144E-03	-3.144E-03	6.194E-03	-3.144E-03
Synchr.-Integrat (I5)		3.857E-04		3.811E-04	3.811E-04	3.811E-04	3.812E-04	3.811E-04	3.811E-04

Average Values and Standard Deviations: SOLEIL

Evaluation for the SOLEIL -Lattice

		Average	Stand,-Deviat.	Deviat. in %
Parameter	Unit			
Energy	GeV	2.750000	0.000000	0.000000
Circumference	m	354.097706	0.001629	0.000460
Horizontal Tune Q(x)		18.199959	0.000044	0.000240
Vertical Tune (Qy)		10.306423	0.031709	0.307662
Beta_x (β(x))		10.873972	0.000236	0.002168
Beta_y (β(y))		7.998188	0.062865	0.785988
Dispersion_x (η(x))		0.220498	0.000269	0.122217
Horiz.-Natur.-Chromaticity ξ(x)		-52.923300	0.044476	-0.084038
Vertic.-Natur.-Chromaticity ξ(y)		-22.038026	0.618458	-2.806323
Momentum Compaction Factor (α)		0.000448	0.000004	0.943364
Energy Spread (δE/E)		0.001017	0.000009	0.856395
Natural emittance	nm*rad	3.605550	0.021690	0.601580
Horiz.-Damping-Time (τ(x))	msec	6.900348	0.048939	0.709222
Vert.-Damping-Time (τ(y))	msec	6.891163	0.030366	0.440652
Long.-Damping-Time (τ(s))	msec	3.443310	0.014561	0.422887
Energy Loss per Turn (U(0))	MeV	0.944854	0.002724	0.288256
Horiz.-Partition Number (J(x))		0.998708	0.004249	0.425442
Vert.-Partition Number (J(y))		1.000000	0.000000	0.000034
Long.-Partition Number (J(s))		2.001404	0.004374	0.218538
Synchr.-Integrat (I1)		0.158771	0.001500	0.945032
Synchr.-Integrat (I2)		1.172240	0.000000	0.000000
Synchr.-Integrat (I3)		0.218702	0.000001	0.000384
Synchr.-Integrat (I4)		-0.000407	0.004513	-1108.65
Synchr.-Integrat (I5)		3.8177E-04	1.7325E-06	0.453807

For the lattice SOLEIL, there are 13 parameters marked with red, which means they are out of good agreement.

These are 5 more as for the lattice ALBA

Remarks: "Average" is the average value of all the codes“

Stand.-Deviat." is the standard deviation according to the "Gaussian distribution"

“Deviation in %" is the quotient of the standard deviation divided by the average value.

Chromaticity Evaluation: SOLEIL

The corrected chromaticity's and the chromaticity's resulting from the sextupoles are given in the two tables below:

	MAD	Tracy II	BETA	ELEG.	DIMAD	AT	OPA	Accel.
Horiz. Corr. Chrom.	0.0195	0.0471	0.0195	0.0195	0.0193	0.0201	-0.0500	-0.0646
Vert. Corr. Chrom	-0.1046	-0.0237	-0.1046	0.0167	-0.1046	-0.1041	1.3400	1.3440

Horiz.Chrom. ξ(x) by sextupoles	-52.8851	-52.8298	-52.8828	-52.8830	-52.8833	-52.8826	-53.0370	-53.0513
Vertic.-Chrom. ξ(y) by sextupoles	-22.5258	-22.3877	-22.5488	-22.2879	-22.5496	-22.5491	-19.6650	-19.9374

Comments to the corrected Chromaticity's

1.) Horizontal corrected chromaticity:
The agreement between the codes is very well. The deviations are between -0.0646 and 0.0471 which is 0.112. This for an overall value of 52.9 makes a percentage of 0.2% which means a good agreement. For the calculated chromaticity (linear parameter) there is also a difference between the codes of 0.0844 (52.987-52.9026), which means a percentage 0f 0.16%

2.) Vertical corrected chromaticity:
The agreement between the codes is not so good as for the horizontal direction. The deviations are between 1.34 and -0.1046 which is 1.4446. This for an overall value of -22.4 makes a percentage of 6.5% which is really pretty high and means no good agreement. For the calculated chromaticity (linear parameter) there is also a difference between the codes of 1.445 (22.4500-21.0050), which means a percentage of 6.6 %
The reason of the bad agreement for the vertical corrected chromaticity could be the calculation of the fringe field contribution of the bending magnet. Independent of the fringe field calculation is only the contribution of the sextupoles.

Comments to the Chromaticity's: SOLEIL

Comments to Chromaticity's of the Sextupoles:
The difference between the natural chromaticity and the corrected chromaticity is the chromaticity contribution by the sextupoles.

3.) Horizontal chromaticity by sextupoles:
The contribution of the sextupoles to the chromaticity is around -53.The deviations are between -53.0513 and – 52.8298 which is 0.2215, which in percentage is 0.42%. This is a good agreement

4.) Vertical chromaticity by sextupoles:
The contribution of the sextupoles to the chromaticity is around -22.5.The deviations are between -22.5496 and – 19.6650 which is 2.8846, which in percentage is 12.8%. This is really a bad agreement.

This is strange: there is a good agreement in the chromaticity contribution of the sextupoles for the horizontal direction (0.42%), but not for the vertical ones (12.8%).

Differences to the Average Value for SOLEIL

Differencess of the codes (in percentages) in comparison to Average

Parameter	Unit	Average	MAD	Tracy II	BETA	ELEG.	DIMAD	AT	OPA	Accel.
Energy	GeV	2.75	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Circumference	m	354.097706	-5.810E-05	-2.784E-04	-4.817E-04	6.479E-04	6.479E-04	-2.784E-04	-1.993E-04	-2.784E-04
Horizontal Tune Q(x)		18.199959	0.00023	-0.00197	0.00019	0.00001	0.00023	-0.00001	-0.00032	-0.00032
Vertical Tune (Qy)		10.306423	-0.06232	-0.06426	-0.06448	-0.33962	-0.06232	-0.06455	-0.06426	0.65755
Beta_x (β(x))		10.873972	0.00026	0.02785	-0.00416	-0.00002	0.00026	0.00013	0.00026	0.00327
Beta_y (β(y))		7.998188	-0.01486	-0.01486	-0.00969	-1.43013	-0.01486	-0.01009	-0.01486	1.50934
Dispersion_x (η(x))		0.220498	-0.01034	0.22753	-0.00957	-0.00962	-0.22599	-0.00938	0.00077	0.03660
Horiz.-Natur.-Chromaticity ξ(x)		-52.923300	-0.03519	-0.08772	-0.03987	-0.03919	-0.03919	-0.03893	0.12036	0.11986
Vertic.-Natur.-Chromaticity ξ(y)		-22.038026	1.73871	1.47930	1.84306	1.20947	1.84646	1.84667	-4.68747	-3.43314
Momentum Compaction Factor (α)		0.000448	0.32632	-2.33444	0.31964	0.32633	0.32633	0.34412	0.36425	0.32745
Energy Spread (δE/E)		0.001017	-0.02364	1.49086	-0.05216	0.12988	0.12388	0.10439	-0.08264	-1.69057
Natural emittance	nm*rad	3.605550	0.67701	-1.06919	0.63430	-0.20053	-0.21217	-0.22381	0.59491	-0.20053
Horiz.-Damping-Time (τ(x))	msec	6.900348	0.15987	1.48763	0.21567	-0.52776	-0.52386	-0.56814	0.28479	-0.52821
Vert.-Damping-Time (τ(y))	msec	6.891163	-0.23745	1.08598	-0.18101	-0.12801	-0.12427	-0.16860	-0.11846	-0.12818
Long.-Damping-Time (τ(s))	msec	3.443310	-0.43511	0.89129	-0.37842	0.07208	0.07521	0.03140	-0.32847	0.07202
Energy Loss per Turn (U(0))	MeV	0.944854	0.70348	-0.19622	-0.02900	-0.10058	-0.10520	-0.05997	-0.11155	-0.10096
Horiz.-Partition Number (J(x))		0.998708	-0.41119	-0.38131	-0.39974	0.39789	0.39789	0.39789	-0.39934	0.39789
Vert.-Partition Number (J(y))		1.000000	0.00008	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001	-0.00001
Long.-Partition Number (J(s))		2.001404	0.19971	0.22962	0.19364	-0.20418	-0.20408	-0.20417	0.19364	-0.20418
Synchr.-Integrat (I1)		0.158771	0.38767	-2.33815	0.32231	0.32249	0.32247	0.34030	0.32250	0.32042
Synchr.-Integrat (I2)		1.172240	0.00000		0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Synchr.-Integrat (I3)		0.218702	0.00020		-0.00036	0.00019	0.00020	0.00020	0.00020	-0.00082
Synchr.-Integrat (I4)		-4.0706E-04	553.808		-1621.659	672.425	672.374	672.307	-1621.666	672.411
Synchr.-Integrat (I5)		3.8177E-04	1.02888		-0.17560	-0.17630	-0.17634	-0.14874	-0.17631	-0.17560

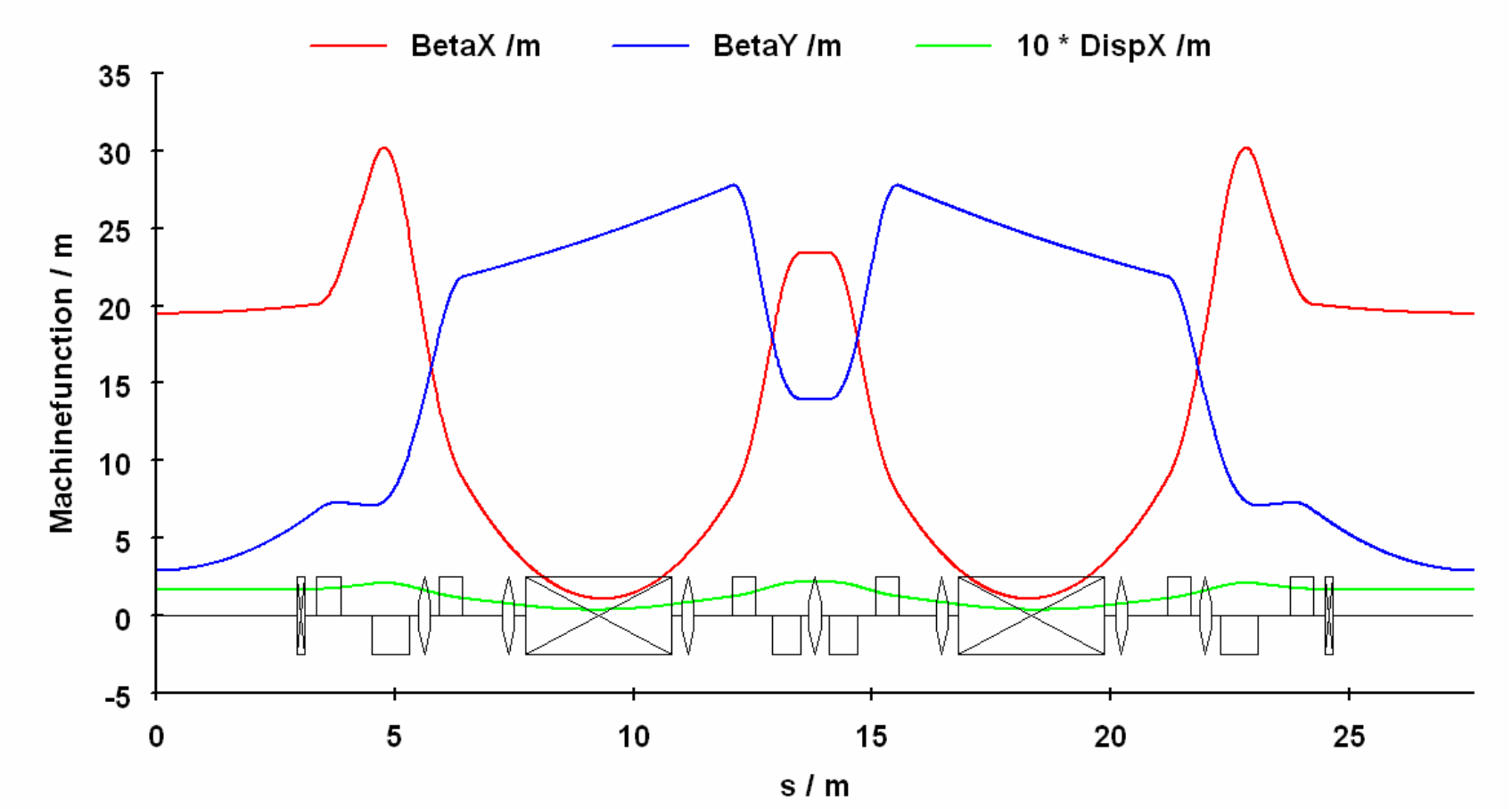
Comments to the Average Values

Comments by "Dieter" to the deviation of the codes in %

		Comments by Dieter
Parameter	Unit	
Energy	GeV	The energy is for all codes correct
Circumference	m	The circumference is for all codes correct
Horizontal Tune Q(x)		Good agreement between all codes
Vertical Tune (Qy)		ELEGANT and ACCEL. are away by 0.34 and 0.66%
Beta_x (β(x))	m/rad	Good agreement between all codes
Beta_y (β(y))	m/rad	ELEGANT and ACCEL are away by 1.5 %
Dispersion_x (η(x))	m	Good agreement between all codes
Horiz.-Natur.-Chromaticity ξ(x)		Good agreement between all codes
Vertic.-Natur.-Chromaticity ξ(y)		No good agreement between the codes
Momentum Compaction Factor (α)		TRACY II is away by -2.3%
Energy Spread (δE/E)		Tracy II and ACCEL. are away by 1.5 and 1.7 %
Natural emittance	nm*rad	No good agreement between the codes
Horiz.-Damping-Time (τ(x))	msec	No good agreement between the codes
Vert.-Damping-Time (τ(y))	msec	TRACY II is away by 1.5 %
Long.-Damping-Time (τ(s))	msec	Tracy II and MAD are away by 0.9 and 0.44 %
Energy Loss per Turn (U(0))	MeV	Only MAD is away by 0.7 %
Horiz.-Partition Number (J(x))		No good agreement between the codes
Vert.-Partition Number (J(y))		Good agreement between all codes
Long.-Partition Number (J(s))		Good agreement between all codes
Synchr.-Integrat (I1)		TRACY II is away by 2.4 %
Synchr.-Integrat (I2)		Good agreement between all codes
Synchr.-Integrat (I3)		Good agreement between all codes
Synchr.-Integrat (I4)		Bad agreement between all codes
Synchr.-Integrat (I5)		MAD is away by 1 %

Comparison of Codes for APS

Lattice of APS



Linear Parameters for the Lattice APS

Calculation for the Lattice APS

Parameter	Unit	MAD	Tracy II	BETA	ELEG.	DIMAD	AT	OPA	Accel.
Energy	GeV	7.0000	7.0000	7.0000	7.0000	7.0000	7.0000	7.0000	7.0000
Circumference	m	1104.000	1104.000	1104.000	1104.000	1104.000	1104.000	1104.000	1104.000
Horizontal Tune Q(x)		36.2045	36.2043	36.2045	36.2045	36.2050	36.2045	36.2045	36.2045
Vertical Tune (Qy)		19.2658	19.2688	19.2657	19.2658	19.2660	19.2719	19.2658	19.2719
Beta_x (β(x))		19.4874	19.4870	19.4888	19.4874	19.4870	19.4875	19.4870	19.4874
Beta_y (β(y))		2.9251	2.9110	2.9252	2.9251	2.9250	2.9031	2.9250	2.9030
Dispersion_x (η(x))		0.1718	0.1720	0.1719	0.1719	0.1720	0.1719	0.1719	0.1719
Horiz.-Natur.-Chromaticity ξ(x)		-90.3443	-90.3377	-90.3500	-90.3443	-90.3443	-90.3342	-90.3840	-90.3838
Vertic.-Natur.-Chromaticity ξ(y)		-43.1432	-43.0111	-42.8800	-42.8739	-42.8800	-43.1340	-42.5730	-42.8349
Momentum Compaction Factor (α)		2.8420E-04	2.8303E-04	2.8430E-04	2.8435E-04	2.8435E-04	2.8437E-04	2.8400E-04	2.8435E-04
Energy Spread (δE/E)		9.5410E-04	1.0020E-03	9.5380E-04	9.5415E-04	9.5409E-04	9.5391E-04	9.5400E-04	9.5415E-04
Natural emittance	nm*rad	2.5270	2.5346	2.5220	2.5275	2.5272	2.5266	2.5320	2.5275
Horiz.-Damping-Time (τ(x))	msec	9.6530	9.6660	9.6682	9.6533	9.6537	9.6494	9.6710	9.6533
Vert.-Damping-Time (τ(y))	msec	9.6530	9.6580	9.6563	9.6582	9.6586	9.6542	9.6590	9.6582
Long.-Damping-Time (τ(s))	msec	4.8283	4.8270	4.8252	4.8303	4.8305	4.8283	4.8270	4.8303
Energy Loss per Turn (U(0))	MeV	5.3380	5.3379	5.3390	5.3380	5.3378	5.3402	5.3376	5.3380
Horiz.-Partition Number (J(x))		1.0050	0.9996	0.9988	1.0005	1.0005	1.0005	0.9988	1.0005
Vert.-Partition Number (J(y))		1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Long.-Partition Number (J(s))		2.0000	2.0020	2.0012	1.9995	1.9995	1.9995	2.0012	1.9995
Synchr.-Integrat (I1)		0.3139	0.3125	0.3139	0.3139	0.3139	0.3139	0.3139	0.3139
Synchr.-Integrat (I2)		0.1579	0.1592	0.1579	0.1579	0.1579	0.1579	0.1579	0.1579
Synchr.-Integrat (I3)		3.9970E-03	4.0314E-03	3.9975E-03	3.9975E-03	3.9975E-03	3.9975E-03	3.9975E-03	3.9975E-03
Synchr.-Integrat (I4)		-7.8920E-05		1.93814E-04	-7.8915E-05	-7.892E-05	-7.8907E-05	1.94E-04	-7.892E-05
Synchr.-Integrat (I5)		5.5530E-06		5.55259E-06	5.5532E-06	5.5532E-06	5.5540E-06	5.5533E-06	+5.5532E-06

Average Value and Standard Deviations: APS

Evaluation for the APS -Lattice

Parameter	Unit	Average	Stand.-Dev.	Deviation in %
Energy	GeV	7	0	0
Circumference	m	1104	4.085E-12	3.700E-13
Horizontal Tune Q(x)		36.20455	0.00020	0.00054
Vertical Tune (Qy)		19.26771	0.00312	0.01620
Beta_x (β(x))		19.48744	0.00066	0.00340
Beta_y (β(y))		2.91782	0.01137	0.38979
Dispersion_x (η(x))		0.17191	0.00005	0.02710
Horiz.-Natur.-Chromaticity ξ(x)		-90.35281	0.02163	-0.02394
Vertic.-Natur.-Chromaticity ξ(y)		-42.91627	0.17834	-0.41556
Momentum Compaction Factor (α)		2.841E-04	1.41707E-07	0.04988
Energy Spread (δE/E)		9.600E-04	1.4154E-07	0.01474
Natural emittance	nm*rad	2.52805	0.00318	0.12582
Horiz.-Damping-Time (τ(x))	msec	9.65850	0.00903	0.09351
Vert.-Damping-Time (τ(y))	msec	9.65694	0.00181	0.01870
Long.-Damping-Time (τ(s))	msec	4.82836	0.00217	0.04499
Energy Loss per Turn (U(0))	MeV	5.33832	0.00099	0.01849
Horiz.-Partition Number (J(x))		1.00052	0.00089	0.08921
Vert.-Partition Number (J(y))		1.00000	0.00000	0.00000
Long.-Partition Number (J(s))		2.00031	0.00089	0.04466
Synchr.-Integrat (I1)		0.31374	0.00001	0.00380
Synchr.-Integrat (I2)		0.15807	0.00000	0.00011
Synchr.-Integrat (I3)		4.0017E-03	0.00000	0.00013
Synchr.-Integrat (I4)		-2.4367E-05	0.00014	-559.638
Synchr.-Integrat (I5)		5.5533E-06	0.00000	0.00737

For the lattice APS, there are only 3 parameters marked in red.

For SOLEIL there are 13 parameters and for ALBA 8 parameters marked with red.

This means that the agreement of the codes are much better for APS as for ALBA and SOLEIL

Reason: The lattices of ALBA and SOLEIL are more complex as APS

Remarks: "Average" is the average value of all the codes“

Stand.-Deviat." is the standard deviation according to the "Gaussian distribution"

“Deviation in %" is the quotient of the standard deviation divided by the average value.

Comments to the Average Values of APS

Comments:

1.) For most of the calculated linear parameters there is a good agreement between the codes. Only for the vertical beta function, the vertical chromaticity and the 4th synchrotron radiation integral, there are deviations from the average of more than 0.3%.

2.) Vertical beta function: The deviation goes up to 0.39 %, this is given by the codes AT and ACCEL.

3.) Vertical natural chromaticity: The deviations are given by the codes OPA and MAD.

4.) Synchrotron radiation integral I4: There is a difference between the codes MAD, ELEGANT, DIMAD, AT, ACCEL. on one side and BETA and OPA at the other side. The deviation between the these codes are up to a factor of 2.4.

Differences to the Average Value for APS

Differencess of the codes (in percentages) in comparison to AVERAGE

Parameter	Unit	AVERAGE	MAD	Tracy II	BETA	ELEGANT	DIMAD	AT	OPA	Accel.
Energy	GeV	7	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Circumference	m	1104.00000	-1.236E-13	-1.236E-13	-1.236E-13	-1.236E-13	-1.236E-13	7.826E-13	-1.236E-13	-1.236E-13
Horizontal Tune Q(x)		36.20455	-1.437E-04	-6.326E-04	-1.437E-04	-6.087E-05	1.237E-03	-5.172E-05	-1.437E-04	-6.087E-05
Vertical Tune (Qy)		19.26771	-9.919E-03	5.880E-03	-1.044E-02	-9.867E-03	-8.881E-03	2.156E-02	-9.919E-03	2.158E-02
Beta_x (β(x))		19.48744	-2.119E-04	-2.265E-03	6.972E-03	-1.093E-04	-2.265E-03	1.492E-04	-2.265E-03	-6.652E-06
Beta_y (β(y))		2.91782	0.2496	-0.2337	0.2530	0.2505	0.2461	-0.5055	0.2461	-0.5062
Dispersion_x (η(x))		0.17191	-6.158E-02	5.476E-02	-3.410E-03	-1.772E-02	5.476E-02	-5.742E-03	-3.410E-03	-1.766E-02
Horiz.-Natur.-Chromaticity ξ(x)		-90.35281	-9.457E-03	-1.672E-02	-3.107E-03	-9.460E-03	-9.416E-03	-2.063E-02	3.452E-02	3.427E-02
Vertic.-Natur.-Chromaticity ξ(y)		-42.91627	0.5289	0.2210	-0.0845	-0.0987	-0.0845	0.5074	-0.7999	-0.1896
Momentum Compaction Factor (α)		2.8412E-04	0.0289	-0.3829	0.0641	0.0803	0.0817	0.0889	-0.0415	0.0803
Energy Spread (δE/E)		9.6002E-04	-0.6171	4.3724	-0.6483	-0.6120	-0.6181	-0.6373	-0.6275	-0.6119
Natural emittance	nm*rad	2.52805	-0.0415	0.2597	-0.2393	-0.0220	-0.0336	-0.0575	0.1562	-0.0219
Horiz.-Damping-Time (τ(x))	msec	9.65850	-0.0569	0.0777	0.1002	-0.0533	-0.0497	-0.0939	0.1294	-0.0534
Vert.-Damping-Time (τ(y))	msec	9.65694	-4.077E-02	1.101E-02	-6.491E-03	1.279E-02	1.722E-02	-2.785E-02	2.136E-02	1.272E-02
Long.-Damping-Time (τ(s))	msec	4.82836	-1.302E-03	-2.823E-02	-6.571E-02	3.997E-02	4.426E-02	-6.793E-04	-2.823E-02	3.991E-02
Energy Loss per Turn (U(0))	MeV	5.33832	-6.040E-03	-7.914E-03	1.269E-02	-5.385E-03	-9.787E-03	3.528E-02	-1.353E-02	-5.310E-03
Horiz.-Partition Number (J(x))		1.00052	0.4480	-0.0917	-0.1744	-0.0018	-0.0018	-0.0018	-0.1747	-0.0018
Vert.-Partition Number (J(y))		1.00000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Long.-Partition Number (J(s))		2.00031	-1.537E-02	8.461E-02	4.612E-02	-4.037E-02	-4.037E-02	-4.036E-02	4.612E-02	-4.037E-02
Synchr.-Integrat (I1)		0.31374	0.0519	-0.4054	0.0551	0.0576	0.0576	0.0663	0.0586	0.0583
Synchr.-Integrat (I2)		0.15807	-0.0982	0.6883	-0.0982	-0.0984	-0.0984	-0.0984	-0.0985	-0.0982
Synchr.-Integrat (I3)		4.0017E-03	-0.1166	0.7420	-0.1044	-0.1042	-0.1042	-0.1042	-0.1044	-0.1041
Synchr.-Integrat (I4)		-2.4367E-05	2.239E+02		-8.954E+02	2.239E+02	2.239E+02	2.238E+02	-8.954E+02	2.239E+02
Synchr.-Integrat (I5)		5.5533E-06	-6.217E-03		-1.360E-02	-2.994E-03	-2.994E-03	1.244E-02	-2.358E-04	-2.615E-03

Comments to the Average Values of APS

Comments by "Dieter" to the deviation of the codes in %

		Comments by Dieter
Parameter	Unit	
Energy	GeV	
Circumference	m	The circumference is for all codes correct
Horizontal Tune Q(x)		Good agreement between all codes
Vertical Tune (Qy)		Good agreement between all codes
Beta_x (β(x))		Good agreement between all codes
Beta_y (β(y))		AT and ACCELER. are away by 0.5 % and 0.7%
Dispersion_x (η(x))		Good agreement between all codes
Horiz.-Natur.-Chromaticity ξ(x)		Good agreement between all codes
Vertic.-Natur.-Chromaticity ξ(y)		MAD, AT and OPA are away by 0.5 and 0.7%
Momentum Compaction Factor (α)		TRACY II is away by 0.4%
Energy Spread (δE/E)		Tracy II is away by 4.4 %
Natural emittance	nm*rad	Good agreement between all codes
Horiz.-Damping-Time (τ(x))	msec	Good agreement between all codes
Vert.-Damping-Time (τ(y))	msec	Good agreement between all codes
Long.-Damping-Time (τ(s))	msec	Good agreement between all codes
Energy Loss per Turn (U(0))	MeV	Good agreement between all codes
Horiz.-Partition Number (J(x))		MAD is away by 0.45 %
Vert.-Partition Number (J(y))		Good agreement between all codes
Long.-Partition Number (J(s))		Good agreement between all codes
Synchr.-Integrat (I1)		TRACY II is away by 0.4%
Synchr.-Integrat (I2)		TRACY II is away by 0.7 %
Synchr.-Integrat (I3)		TRACY II is away by 0.7%
Synchr.-Integrat (I4)		No good agreement between all codes
Synchr.-Integrat (I5)		Good agreement between all codes

Comparison of the Codes for all Lattices

Standard deviation in % for the different codes and lattices

	MAD	Tracy II	BETA	ELEGANT	DIMAD	AT	OPA	Accel.
Lattice ALBA								
∑Stand.-Dev.=	0.2239	0.3514	0.4597	1.0785	0.4463	0.4392	1.0355	1.0257
SUM(ST.-Dev.)=	5.0602							
Lattice SOLEIL								
∑Stand.-Dev.=	0.454	1.050	0.446	0.457	0.443	0.444	1.030	0.920
SUM(ST.-Dev.)=	5.2444							
Lattice APS								
∑Stand.-Dev.=	0.2137	0.9599	0.1672	0.1490	0.1507	0.2109	0.2319	0.1713
SUM(ST.-Dev.)=	2.2546							

Conclusion:

1.) Lattice ALBA: ELEGANT, OPA and ACCEL. have the largest deviation from the average

2.) Lattice SOLEIL: TRACY, OPA and Acceler. have the largest deviation from the average

3.) Lattice APS: TRACY II has the largest deviation from the average

4.) The deviation are much smaller (by a factor of two) for APS as for ALBA and SOLEIL

Comparison of the Codes for all Lattices

		MAD	TRACY II	BETA	ELEGANT	DIMAD	AT	OPA	ACCELER.
Energy	GeV								
Circumference	m								
Horizontal Tune Q(x)									
Vertical Tune (Qy)					A / S /				/ S /
Beta_x (β(x))									
Beta_y (β(y))		A	A		A / S /	A	A / / P	A	A / S / P
Dispersion_x (η(x))			A						
Horiz.-Natur.-Chromaticity ξ(x)								A	
Vertic.-Natur.-Chromaticity ξ(y)		A / S / P	/ S /	A / S /	A / S /	A / S /	A / S / P	A / S / P	A / S /
Momentum Compaction Factor (α)		S	A / S / P	/ S /	/ S /	/ S /	/ S /	/ S /	/ S /
Energy Spread (δE/E)			A / S / P						/ S /
Natural emittance	nm*rad	A / S	A / S /	A / S /			A	/ S /	
Horiz.-Damping-Time (τ(x))	msec	A	A / S /	A	A / S /	A / S /	A / S /	A	/ S /
Vert.-Damping-Time (τ(y))	msec		/ S /						
Long.-Damping-Time (τ(s))	msec	/ S /	/ S /	A / S /				/ S /	
Energy Loss per Turn (U(0))	MeV	/ S /							A
Horiz.-Partition Number (J(x))		A / S /	A / S /	A / S /	/ S /	/ S /	/ S /	A / S /	/ S /
Vert.-Partition Number (J(y))									
Long.-Partition Number (J(s))				A					
Synchr.-Integrat (I1)		/ S /	/ P	/ S /	/ S /	/ S /	/ S /	/ S /	/ S /
Synchr.-Integrat (I2)			/ P						
Synchr.-Integrat (I3)			/ P						
Synchr.-Integrat (I4)		A / S / P		A / S / P	A / S / P	A / S / P	A / S / P	A / S / P	A / S / P
Synchr.-Integrat (I5)									
Nominations:		**16**	**20**	**15**	**14**	**11**	**14**	**15**	**15**

This table shows which codes have a difference of more than 0.3% from the average value of the different linear parameters and for which lattice (A = ALBA, S = SOLEIL, P = APS) . Most of the deviations are for TRACY II and less for DIMAD.

Comparison of the Codes for all Lattices

		MAD	TRACY II	BETA	ELEGANT	DIMAD	AT	OPA	ACCELER.
Energy	GeV								
Circumference	m								
Horizontal Tune Q(x)									
Vertical Tune (Qy)									
Beta_x (β(x))									
Beta_y (β(y))					A / S /				/ S /
Dispersion_x (η(x))									
Horiz.-Natur.-Chromaticity ξ(x)									
Vertic.-Natur.-Chromaticity ξ(y)		/ S /	/ S /	A / S /	A / S /	A / S /	A / S /	A / S /	A / S /
Momentum Compaction Factor (α)			/ S /						
Energy Spread (δE/E)			/ S / P						/ S /
Natural emittance	nm*rad	/ S	/ S /	/ S /				/ S /	
Horiz.-Damping-Time (τ(x))	msec		/ S /						
Vert.-Damping-Time (τ(y))	msec		/ S /						
Long.-Damping-Time (τ(s))	msec								
Energy Loss per Turn (U(0))	MeV								
Horiz.-Partition Number (J(x))									
Vert.-Partition Number (J(y))									
Long.-Partition Number (J(s))									
Synchr.-Integrat (I1)									
Synchr.-Integrat (I2)									
Synchr.-Integrat (I3)									
Synchr.-Integrat (I4)		/ S / P		A / S / P	/ S / P	/ S / P	/ S / P	/ S / P	/ S / P
Synchr.-Integrat (I5)									
Nominations:		**4**	**7**	**6**	**6**	**4**	**4**	**5**	**6**

This table shows which codes have a difference of more than 1.0% from the average value of the different linear parameters and for which lattice (A = ALBA, S = SOLEIL, P = APS) . Most of the deviations are for TRACY II and less for DIMAD and AT.

Comparison of the Codes for all Lattices

Conclusions for linear parameters

1.) For the table with the differences in percentages I made the statement that everything which is larger as 0.3 % is not in an agreement.

2.) The deviations from the average values are:
ALBA up to 5.%(ELEGANT, OPA and ACCELER), for the vert. chromaticity
SOLEIL up to 5 %(OPA), for the vert. chromaticity
APS up to 4 %(Tracy). For the energy spread

3.) The biggest differences are for the vertical chromaticity's

4.) The biggest differences are for the lattices ALBA and SOLEIL. They are a factor of two higher as for the lattice APS

5.) Most of the deviations are for the code TRACY II

6.) DIMAD agrees very well with the average value

Non-Linear Parameters

For all codes:

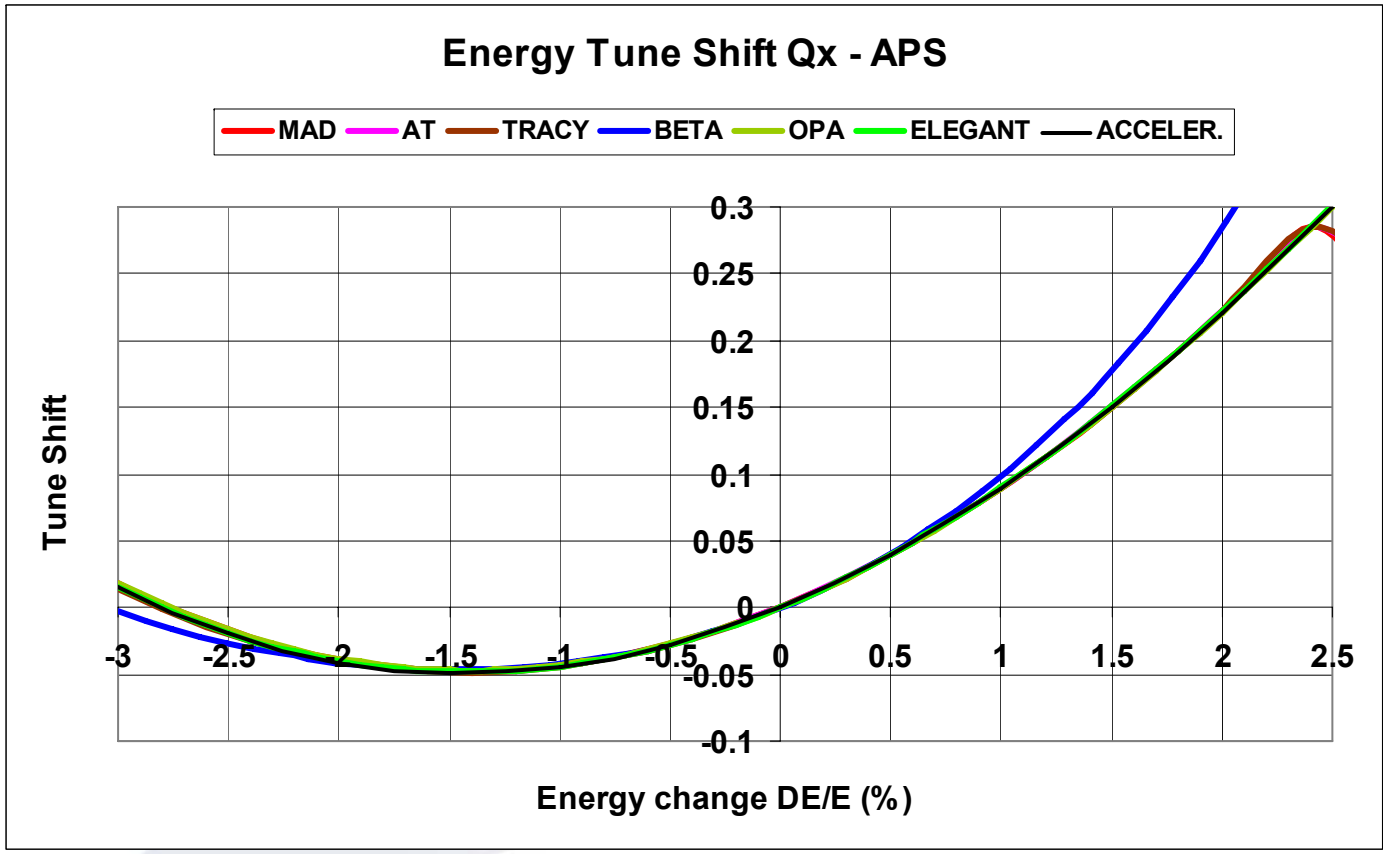
1.) Qi = F(DE/E)

2.) Qi = F(amplitude x)

3.) Qi = F(amplitude y)

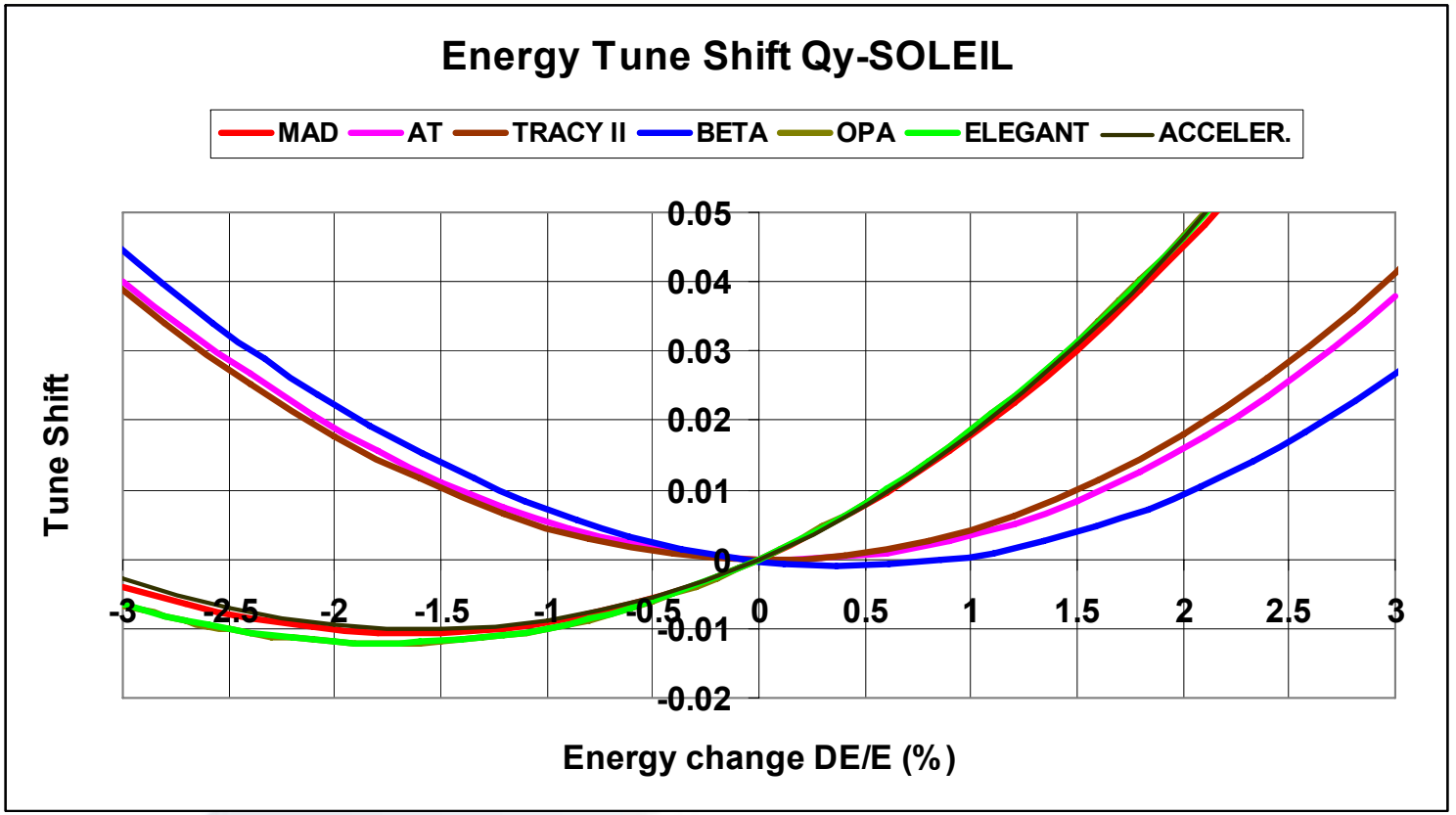
4.) Dynamic aperture

Tune Shift with Energies for APS



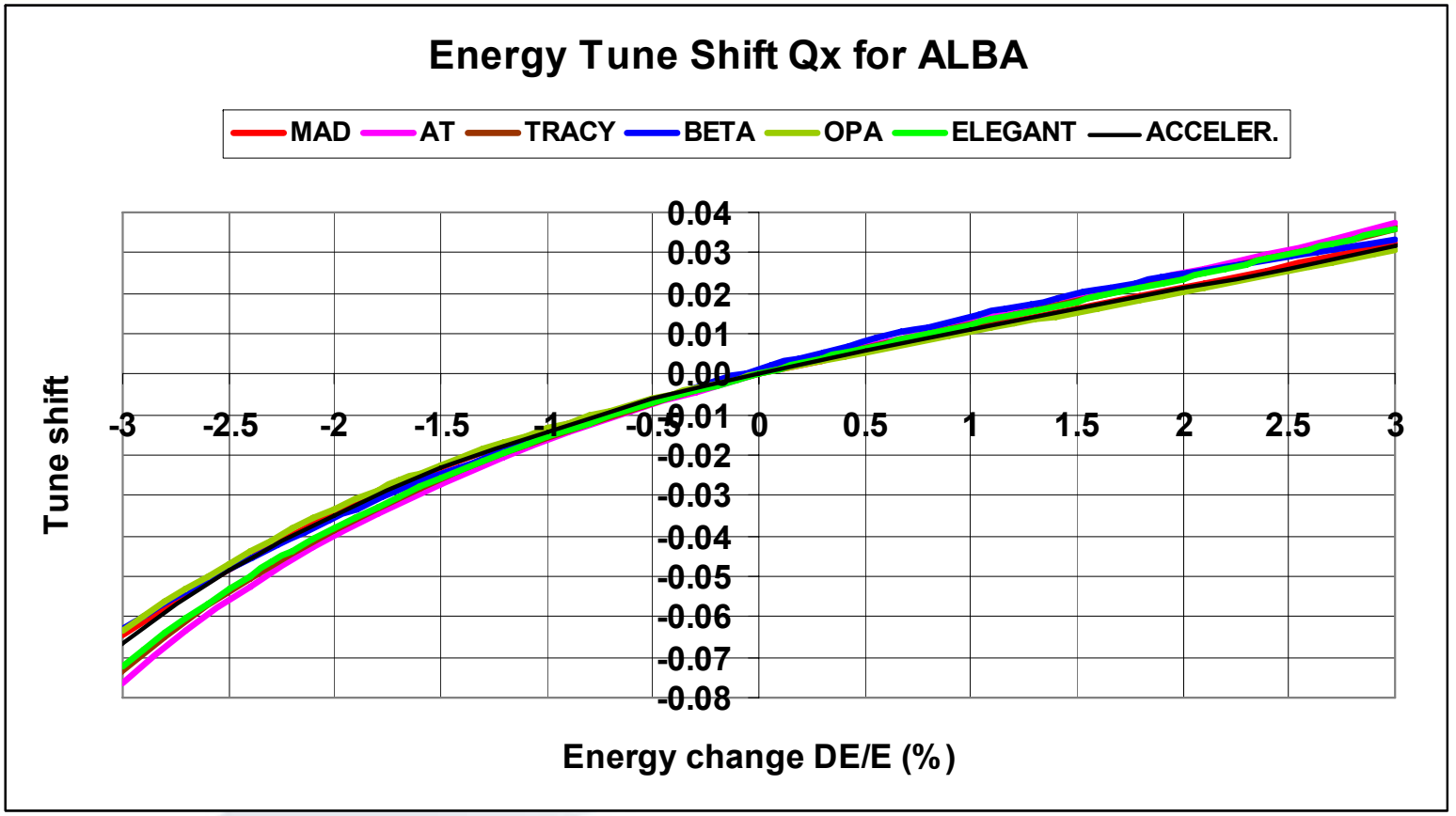
The horizontal working point of APS is 36.205. The tune increases with positive energy deviations and at DE/E = 2.5 % it is crossing the half integer line. For negative energy deviation the decreases slightly but recovers later too.
There is a really good agreement between the different codes but only BETA is away by roughly 20% at DE/E = 2%. The chromaticity according to these plot is 6.75, which is in good agreement with the calculations.

Tune Shift with Energy for SOLEIL



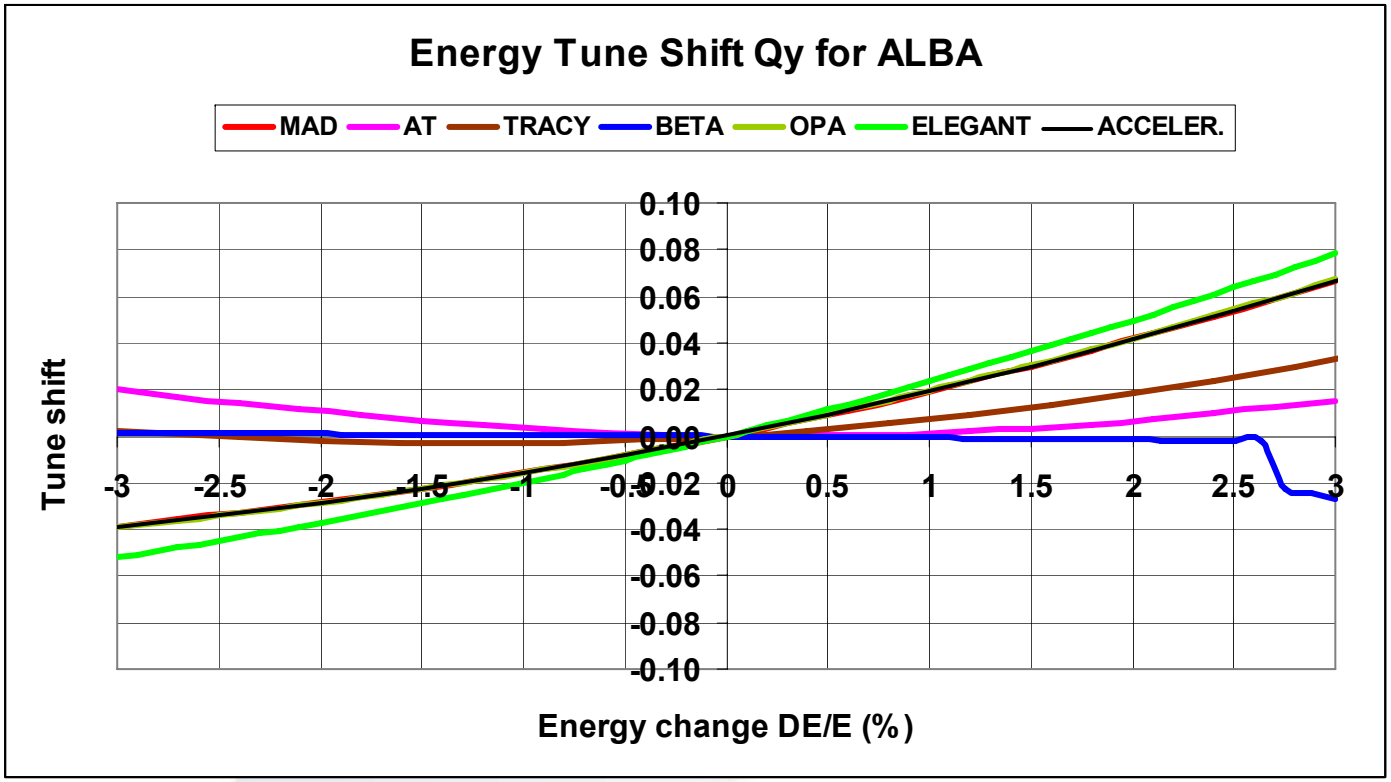
In this case the situation is completely different, there is a good agreement between the Codes: AT, TRACY and BETA, as well the codes: MAD, ELEGANT, OPA and ACCELER. For the 1st codes (AT, TRACY and BETA) the agreement is within 40%. The chromaticity according to this plot is roughly 0 or slightly negative which agrees with the above calculations. For the 2nd type of codes the agreement is within 16%of codes. The chromaticity is around 2.2, which is not in agreement with the above calculations

Tune Shift with Energy for ALBA



All the codes overlapping more or less, which means they should agree with each other, but for positive energy deviations the differences between the codes are up to 20% at DE/E = 2.5%, for negative energy deviations the difference goes up to 25 %. This means that the agreement between the codes are not so good. The chromaticity according to these plot is roughly 1.5, which agrees very well with the data of the linear parameters.

Tune Shift with Energy for ALBA



In this case the situation is completely different, there is a good agreement between the Codes: MAD, OPA, ELEGANT and ACCELERATICUM, but there are differences to the codes: AT, TRACY and BETA.
For the 1st codes (MAD, OPA and ACCELER.) the agreement is within 16 %. The chromaticity according to this plot is roughly 2, these doesn't agree with the linear parameters. For the 2nd type of codes the agreement is within 70% and the chromaticity is around 0, which is in agreement with the above calculations

Comparison of the nonlinear Parameters

Conclusions for Tune-shift with Energy

CODE Comparison: Tune Shift with Energy

		MAD	TRACY	BETA	ELEGANT	AT	OPA	ACCEL.	Tolerances
APS:	Qx	+	+	-	+	+	+	+	3%
	Qy	+	+	-	+	+	+	+	10%
SOLEIL:	Qx	+	+	+	+	+	+	+	18%
	Qy	-	+	+	-	+	-	-	+(40%), -(16%)'
ALBA:	Qx	+	+	+	+	+	+	+	22%
	Qy	+	-	-	+	-	+	+	+(16%), -(70%)'

Explanations to the above table:

1.) The codes with a + (plus) agree relative with each other.
2.) The codes with a - (minus) agree relative with each other
3.) +(40%) means that the codes (+) agree within a tolernce of 40%
4.) -(16%) means that the codes (-) agree within a tolerance of 16%

For the changes of the horizontal tune (Qx) with the energy all codes agree relative with each other with tolerances from 3% (APS) to 22% (ALBA). The agreement for the vertical tune shift (Qy) with energy is pretty bad. The tolerances go from 10% (APS) to 70% (ALBA) The tolerances are much smaller for APS as for SOLEIL and ALBA

Non-Linear Parameters

For all codes:

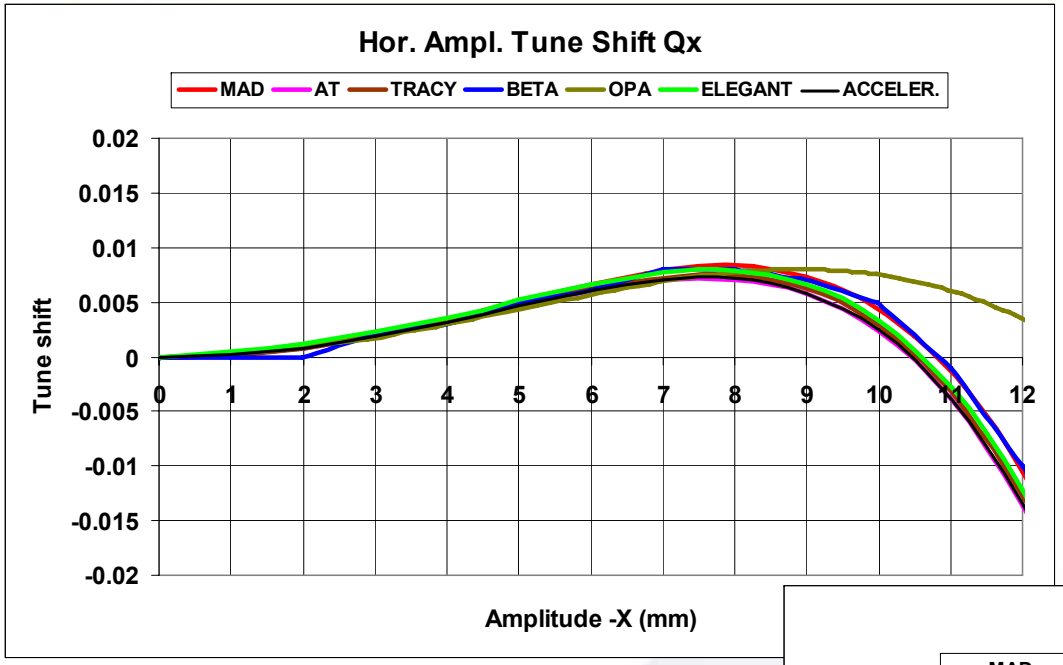
1.) Qi = F(DE/E)

2.) Qi = F(amplitude x)

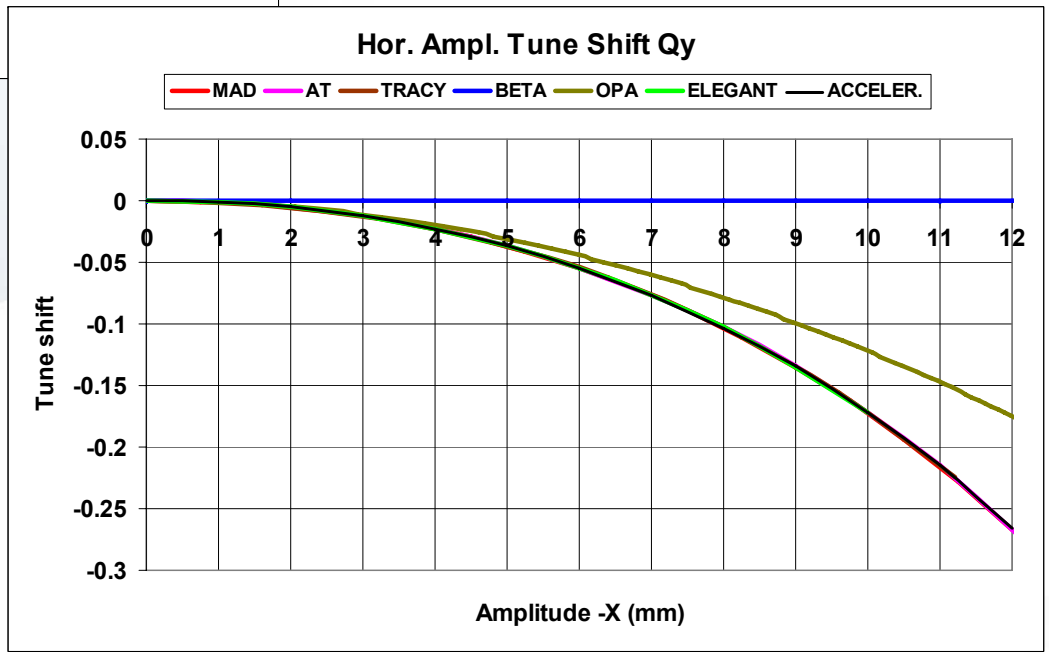
3.) Qi = F(amplitude y)

4.) Dynamic aperture

Tune Shift with horizontal Amplit. for APS

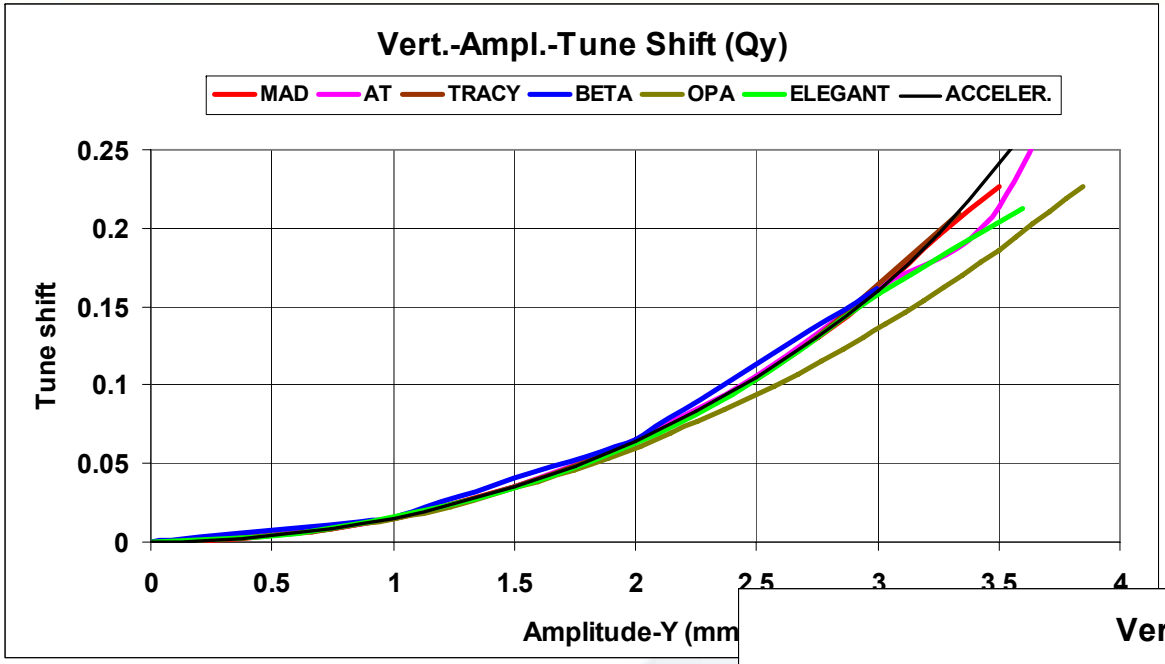


There is a really good agreement between the different codes, but only OPA is away for large amplitudes. The other codes agree within a tolerance of 20%

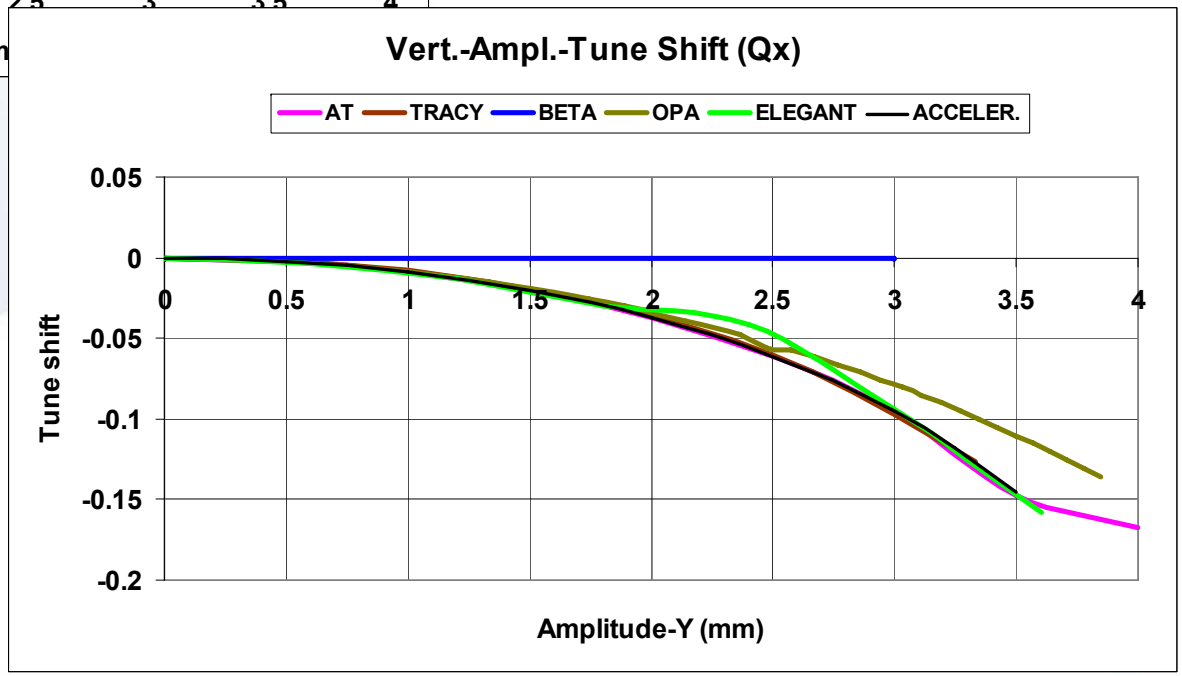


There is a really good agreement between the different codes within a tolerance of 4%.OPA is 40 % lower for large amplitudes and BETA doesn't make the corresponding calculations

Tune Shift with vertical Amplit. for APS

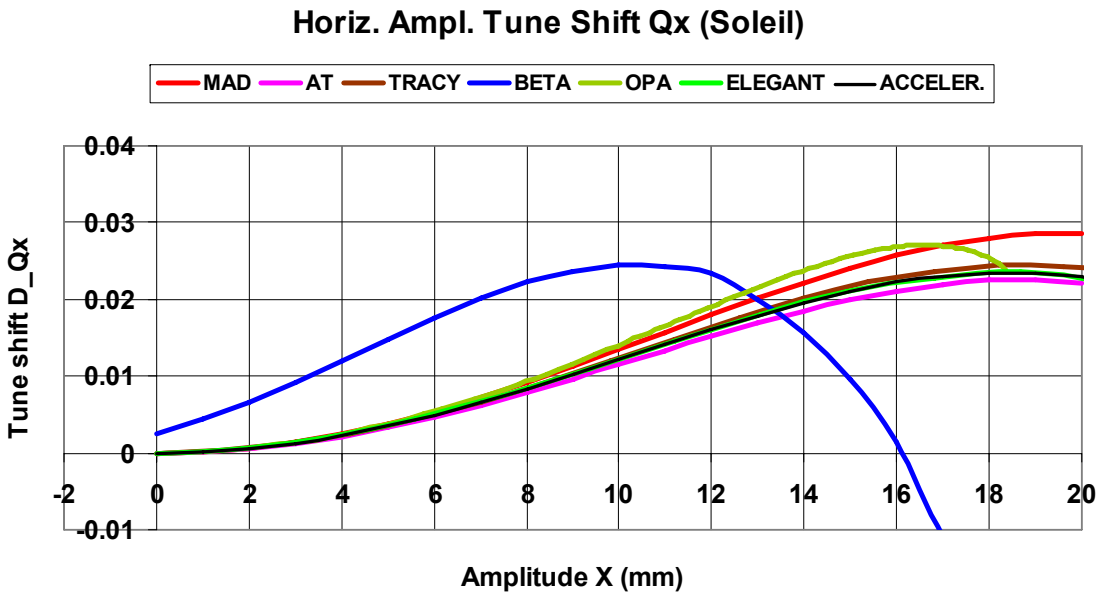


There is an agreement between the different codes (10%), Only OPA is away for large amplitudes by 20%.

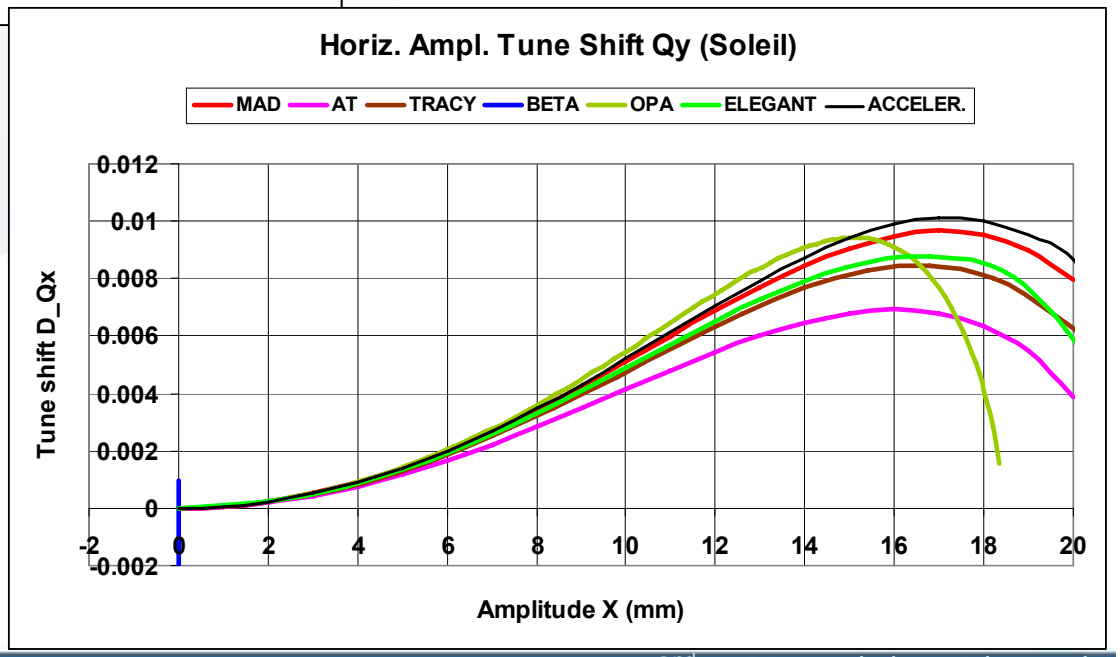


There is a agreement between the different codes (10%). Only OPA is away for large amplitudes by 20%.

Tune Shift with horizontal Amplit. for SOLEIL

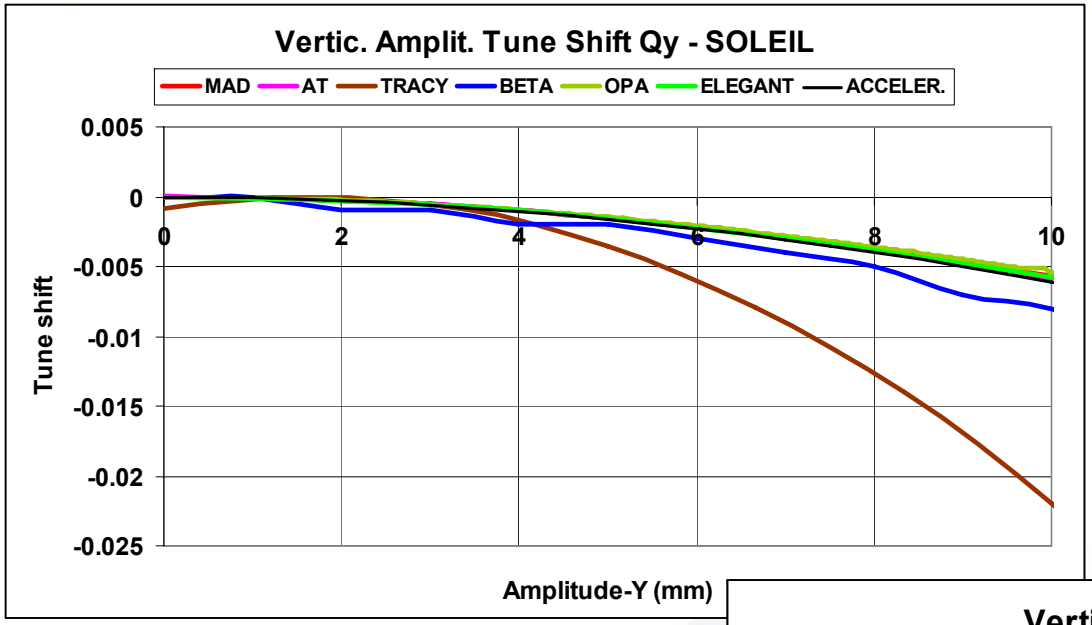


There is an agreements between the codes within a tolerance of 7%. OPA and MAD disagree to 20 %. BETA is far away from these values

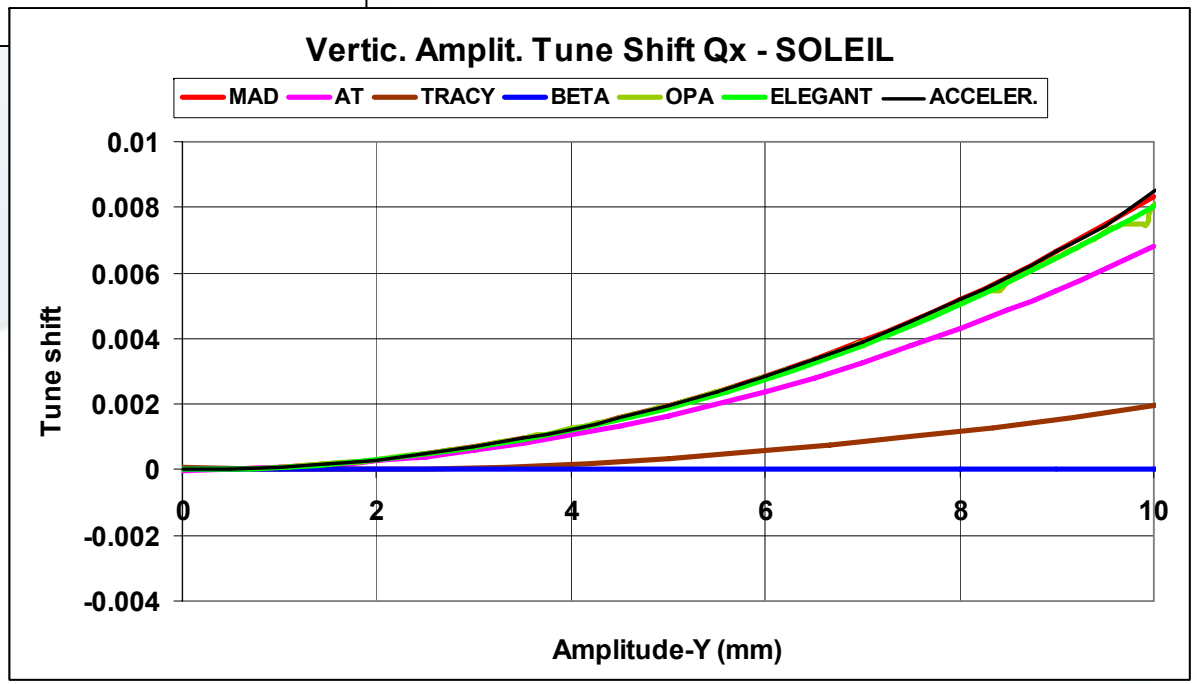


There is an agreement between the codes. The values vary between +/- 20%. AT is way by 40%. The code BETA doesn't make this calculations

Tune Shift with vertical Amplit. for SOLEIL



There is a good agreement between the codes MAD, AT, OPA ELEGANT and ACCELER.. Tracy has differences of up to a factor 2 to 3 and BETA is away by 20 %



There is a good agreement between the codes MAD, OPA, ELEGANT and ACCEL. agree within 5%. TRACY is by a factor 3 to 4 lower and BETA doesn't make the corresponding calculations

Comparison of the nonlinear Parameters

Conclusions for Tune-shift with Amplitude

CODE Comparison: Tune Shift with Amplitude

		MAD	AT	TRACY	BETA	OPA	ELEGANT	ACCEL.	Tolerances
APS:	Qx=f(x)	+	+	+	+	-	+	+	20%
	Qy=f(x)	+	+	+		-	+	+	4%, OPA 60% lower
	Qy=f(y)	+	+	+	+	-	+	+	10%, OPA 20 % away
	Qx=f(y)	+	+	+		-	+	+	10%, OPA 20 % lower
SOLEIL:	Qx=f(x)	+	+	+	-	+	+	+	20%, OPA is wrong
	Qy=f(x)	+	+	+	+	+	+	+	20%. TRACY factor 2 away
	Qy=f(y)	+	+	-	+	+	+	+	20%, TRACY factor 2 away
	Qx=f(y)	+	+	-		+	+	+	+5%', TRACY factor 4 away
ALBA:	Qx=f(x)	+	+	+	+	+	+	+	60%
	Qy=f(x)	+	+	+		+	+	+	30%
	Qy=f(y)	+	+	+	+	+	+	+	35%
	Qx=f(y)	+	-	+		+	-	+	16%, AT and ELEG. away

Explanations to the above table:

1.) The codes with a + (plus) agree relative with each other.
2.) The codes with a - (minus) have large differences to the other codes
3.) 10%) means that the codes (+) agree within a tolernce of 10%

The agreement between the codes are not so good. The differences between the codes are going up to 20 and 40%. OPA and TRACY are sometimes away by a factor 2 to 4. The tolerances are much smaller for APS as for SOLEIL and ALBA

Non-Linear Parameters

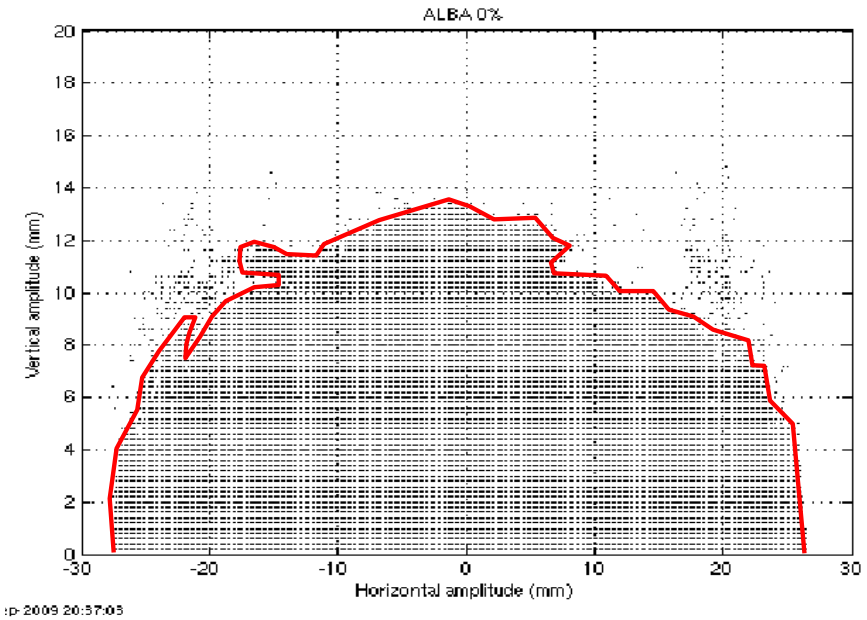
For all codes:

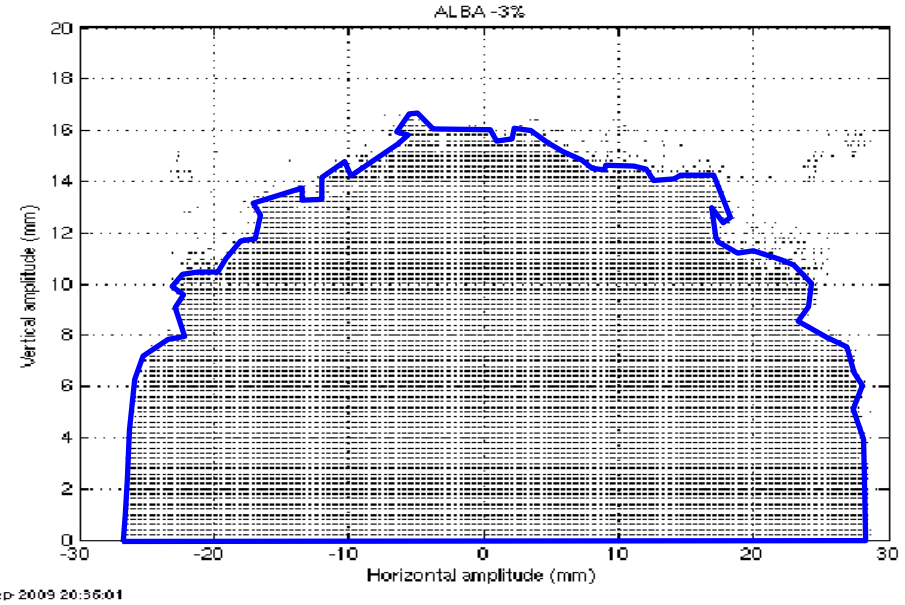
1.) Qi = F(DE/E)

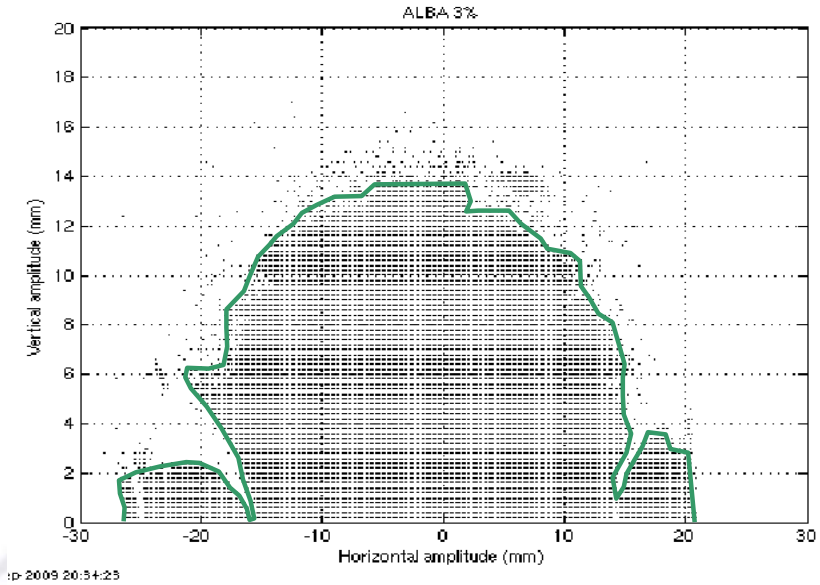
2.) Qi = F(amplitude x)

3.) Qi = F(amplitude y)

4.) Dynamic aperture

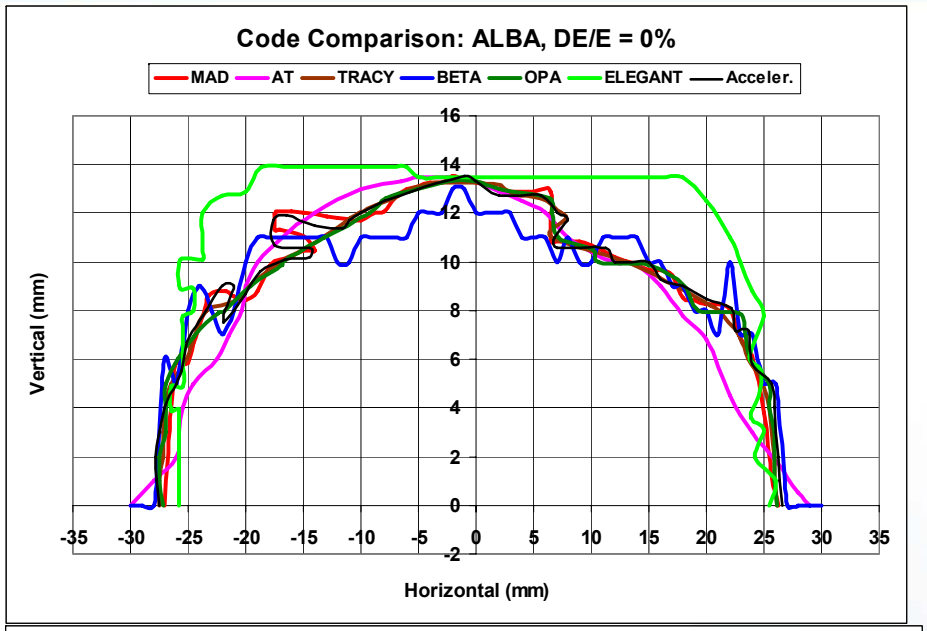


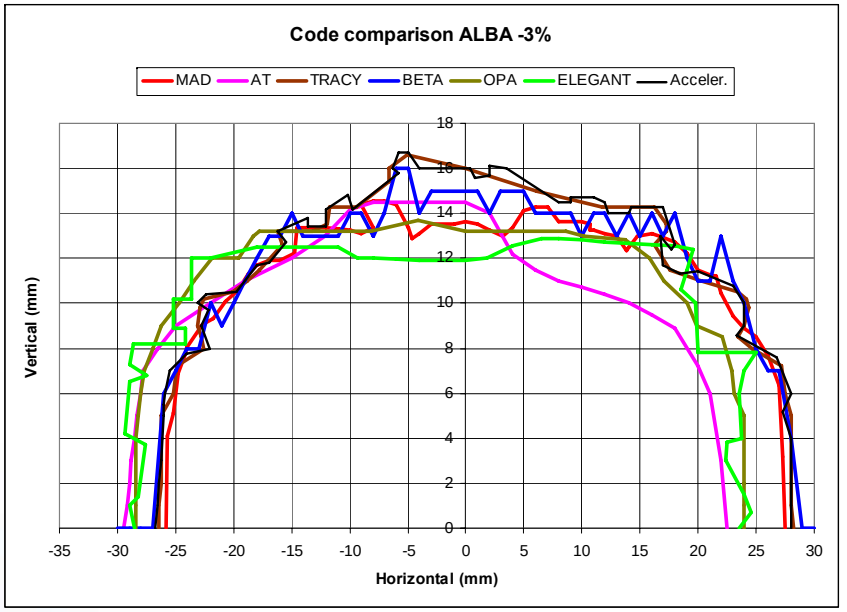


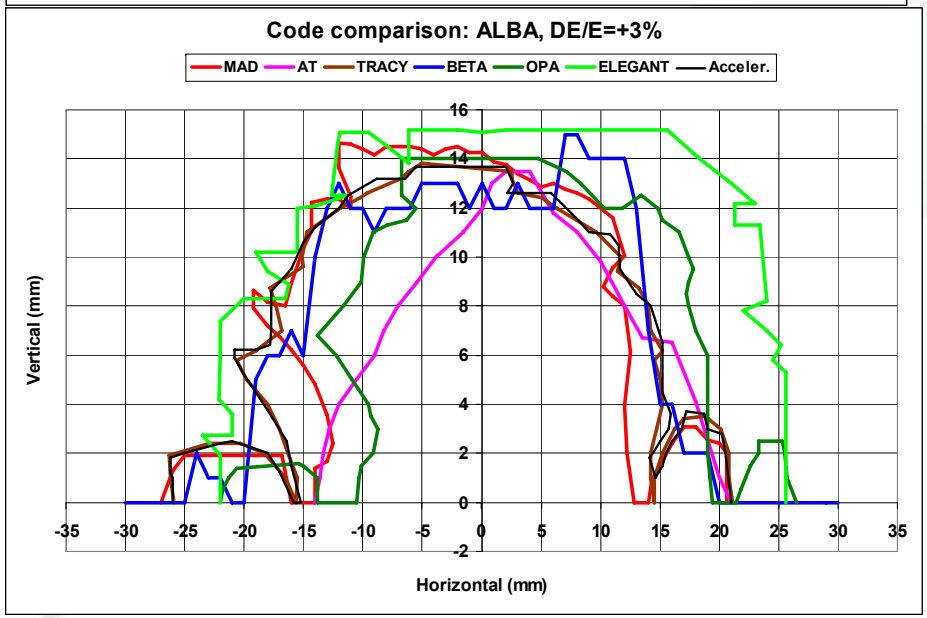


Procedure for the determination of the dynamic aperture

DA: ALBA





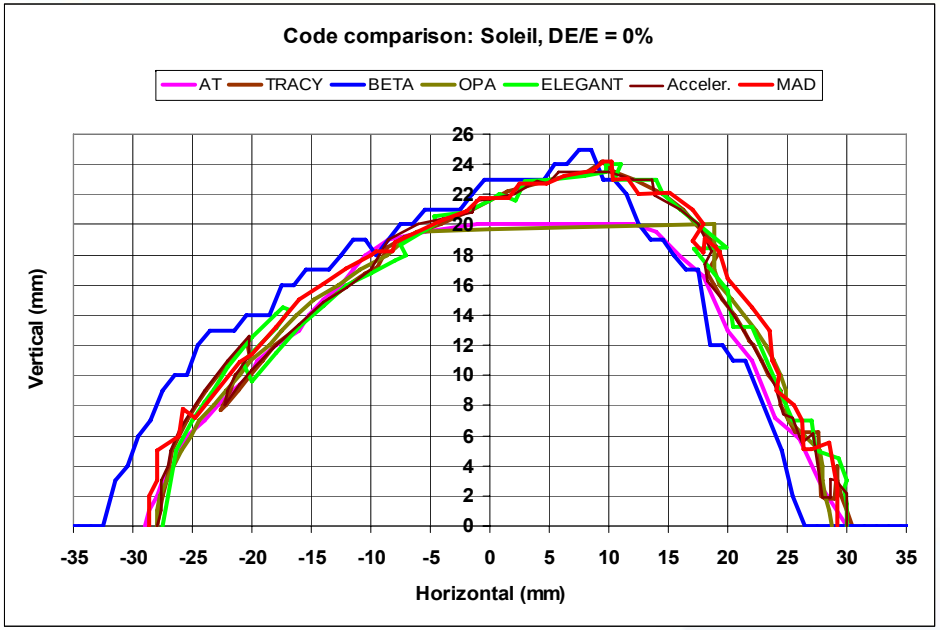


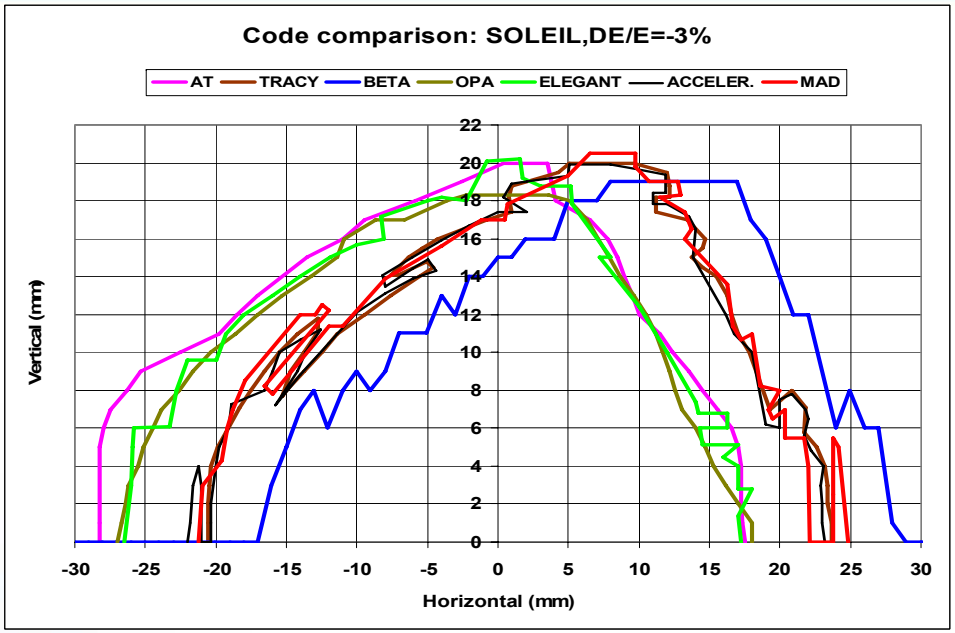
DE/E =0:Good agreement between the codes:
MAD, TRACY, OPA and Acceler.
No good agreement for the codes:
ELEGANT, BETA and AT

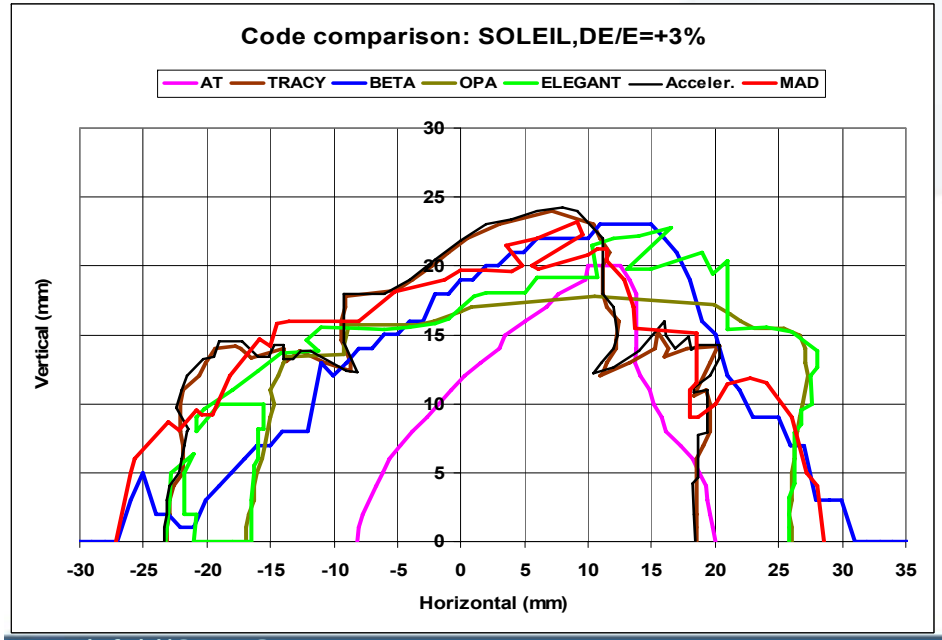
DE/E=-3%:Good agreement between the codes:
MAD, TRACY, BETA and Acceler.
No good agreement for the codes:
ELEGANT, AT and OPA

DE/E=+3%:Good agreement between the codes:
TRACY and Acceler.
No good agreement for the codes:
ELEGANT, AT, BETA ,MAD, and OPA

DA: SOLEIL





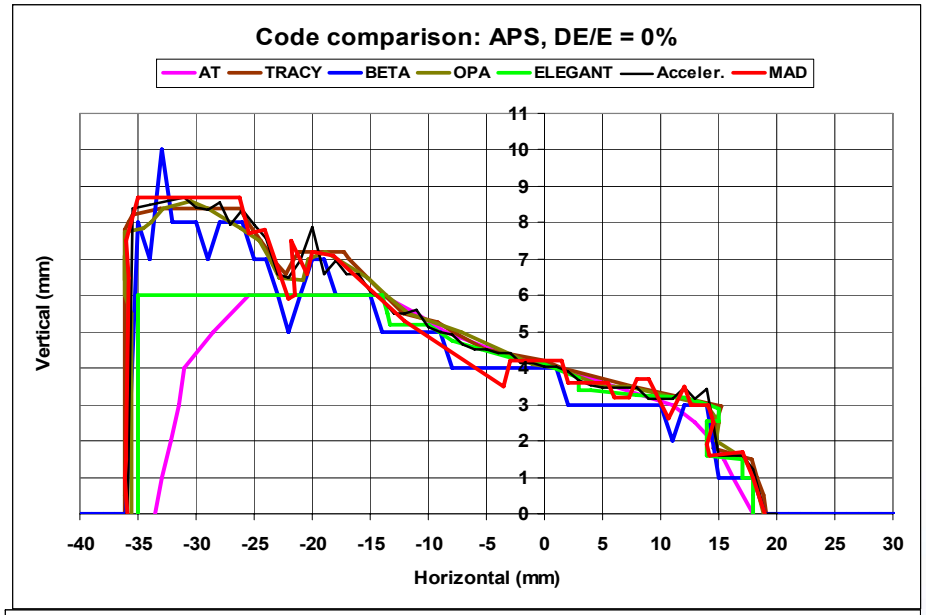


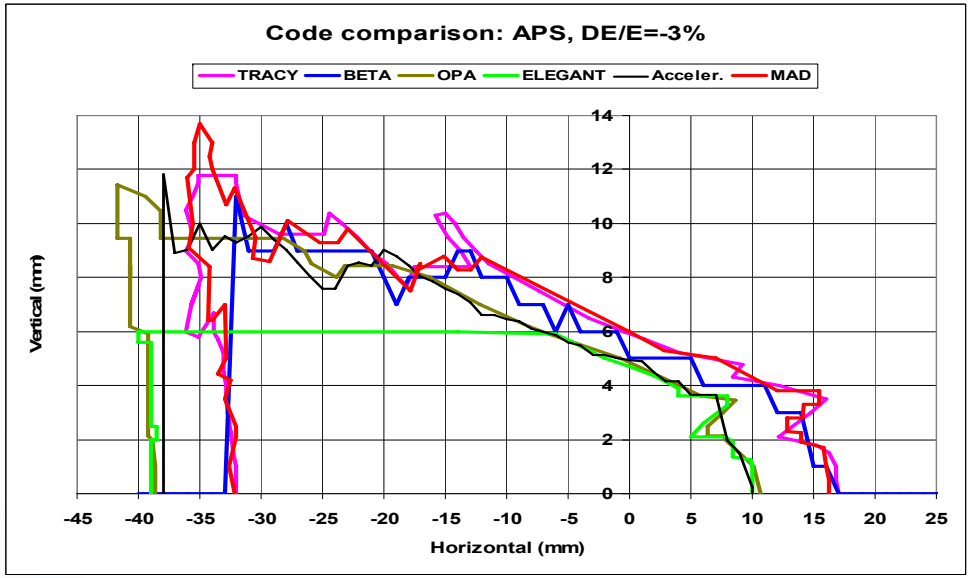
DE/E=0%: Good agreement between the codes:
MAD, AT, TRACY, OPA, ELEGANT and Acceler.
No good agreement for the code: BETA

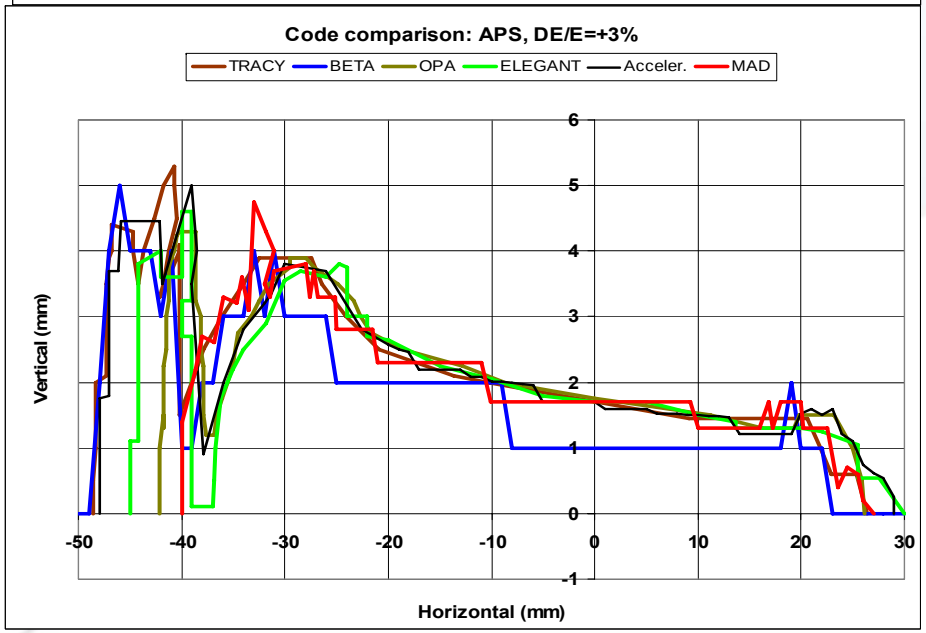
DE/E =-3%: Good agreement between the codes:
MAD, TRACY, and Acceler.
No good agreement for the code:
BETA, AT, OPA and ELEGANT

DE/E = +3%:No good agreement between all the codes

DA: APS







DE/E=0%:Good agreement between the codes:
MAD, AT, TRACY, BETA, OPA, ELEGANT and Acceler.
No good agreement for the code: AT

DE/E=-3%:Good agreement between the codes:
MAD, TRACY and BETA
No good agreement for the codes:
ELEGANT, OPA, Acceler., AT(no results)

DE/E =+3%:No good agreement between all codes

Comparison of the nonlinear Parameters

Conclusions for the Dynamic Aperture

CODE Comparison: Dynamic aperture

	MAD	AT	TRACY	BETA	OPA	ELEG.	ACCEL.	SUM
ALBA -3%	+	-	+	+	-	-	+	4+
ALBA 0%	+	-	+	-	+	-	+	4+
ALBA +3%	-	-	+	-	-	-	+	2+
SOLEIL -3%	+	-	+	-	-	-	+	3+
SOLEIL 0%	+	+	+	-	+	+	+	6+
SOLEIL +3%	-	-	-	-	-	-	-	
APS -3%	+	-	+	+	-	-	-	3+
APS 0%	+	-	+	+	+	+	+	6+
APS +3%	-	-	-	-	-	-	-	
SUM:	6+	1+	7+	3+	3+	2+	6+	

Explanations to the above table:

1.) The codes with a + (plus) agree relative with each other.

2.) The codes with a - (minus) dont agree with the + (plus) codes

The agreement between the codes are not so good. The best agreement is for the nominal energy and for negative energy deviations. The agreement between the codes for positive energy deviations is not good.

Conclusions for Dynamic Aperture Calculations

1.) For the nominal energy (DE/E = 0%) the agreement between the codes is pretty good.

2.) For negative energy deviations (DE/E=-3%) the agreement is not any more so good.

3.) For positive energy deviations (DE/E = +3%) there isn't a good agreement between the codes.

Summary: Comparison of Lattice Codes

Comparison of linear parameters

1.) For the table with the differences in percentages I made the statement that everything which is larger as 0.3 % is not in an agreement.

2.) The deviations from the average values are:
ALBA up to 5.%(ELEGANT, OPA and ACCELER), for the vert. chromaticity
SOLEIL up to 5 %(OPA), for the vert. chromaticity
APS up to 4 %(Tracy). For the energy spread

3.) The biggest differences are for the vertical chromaticity's

4.) The biggest differences are for the lattices ALBA and SOLEIL. They are a factor of two higher as for the lattice APS

5.) Most of the deviations are for the code TRACY II

6.) DIMAD agrees very well with the average value

Summary: Comparison of Lattice Codes

Comparison of non-linear parameters

A.) Tune-shift with Energy

1.)For the changes of the horizontal tune (Qx) with the energy all codes agree relative with each other with tolerances from 3% (APS) to 22% (ALBA).

2.)The agreement for the vertical tune shift (Qy) with energy is pretty bad.

3.)The tolerances go from 10% (APS) to 70% (ALBA)

4.)The tolerances are much smaller for APS as for SOLEIL and ALBA

Summary: Comparison of Lattice Codes

Comparison of non-linear parameters

B.) Tune-shift with Amplitudes

1.) The agreement between the codes are not so good.

2.) The differences between the codes are going up to 20 and 40%.

3.) OPA and TRACY are sometimes away by a factor 2 to 4.

4.) The tolerances are much smaller for APS as for SOLEIL and ALBA

C.) Tune-shift with Amplitudes

1.) The agreement between the codes are not so good.

2.) The best agreement is for the nominal energy and for negative energy deviations.

3.) The agreement between the codes or positive energy deviations is not good.

Summary: Comparison of Lattice Codes

Comments from Laurent Nadolski

Dear Dieter,

I have read your detailed presentation.

I am very impressed with the analysis you did. Thank you.

Concerning one big discrepancy between codes, I am the following comment: For the tune shift with amplitude, I did some calculation for SOLEIL between MAD_PTC and Tracy II or AT.

The agreement is very good. This is not what you show in your slides.

I do think the issue comes from the way the sextupole is modeled in the various codes (even for the same Hamiltonian).

Summary: Comparison of Lattice Codes

Comments from Laurent Nadolski

Either a thin sextupole, many thin lenses, 4th order integrator, and ...
At least for SOLEIL, if I compare MAD and Tracy II with the same integrator, the results are the same (cf. my talk at Diamond).
When doing the comparison, we did not communicate on this modeling point. As we see in your slides this is critical.
So for me the amazing discrepancy between codes has its origin mainly in the integrator scheme.
See you soon,
Best Regards,
Laurent.

Summary: Comparison of Lattice Codes

Thanks to all the colleagues who made the calculations:

MAD (Zeus Marti, CELLS)

DIMAD (Les Dallin, CLS)

BETA (Laurent Nadolski, SOLEIL)

OPA (Andreas Streun, SLS)

AT (Xiabiao Huang, SPEARE III)

TRACY (Laurent Nadolski)

ELEGANT (Mike Borland and Louis Emery, APS)

ACCELERATICUM (Pavel Piminov, BINP)

Please make your own conclusion.

Thank you very much