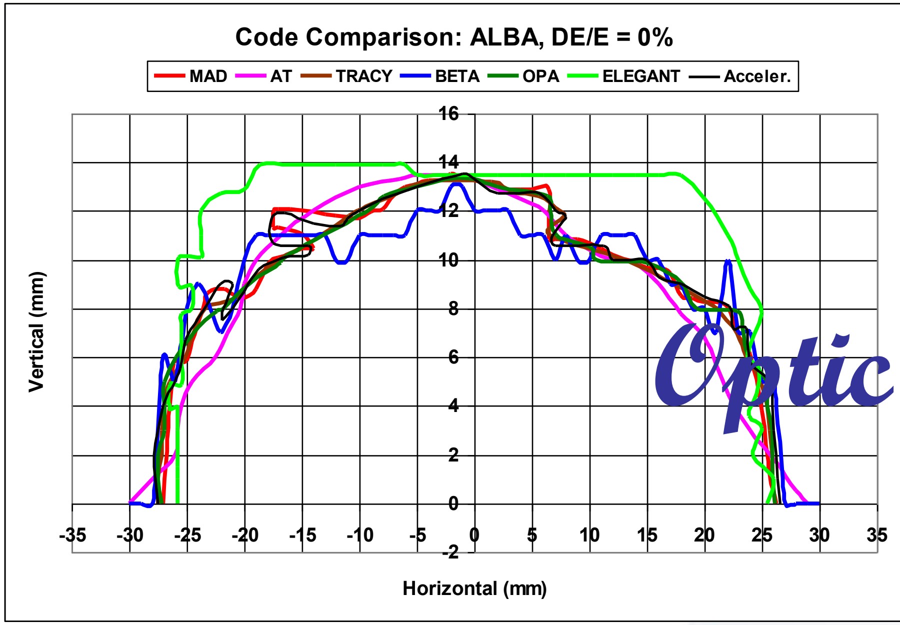
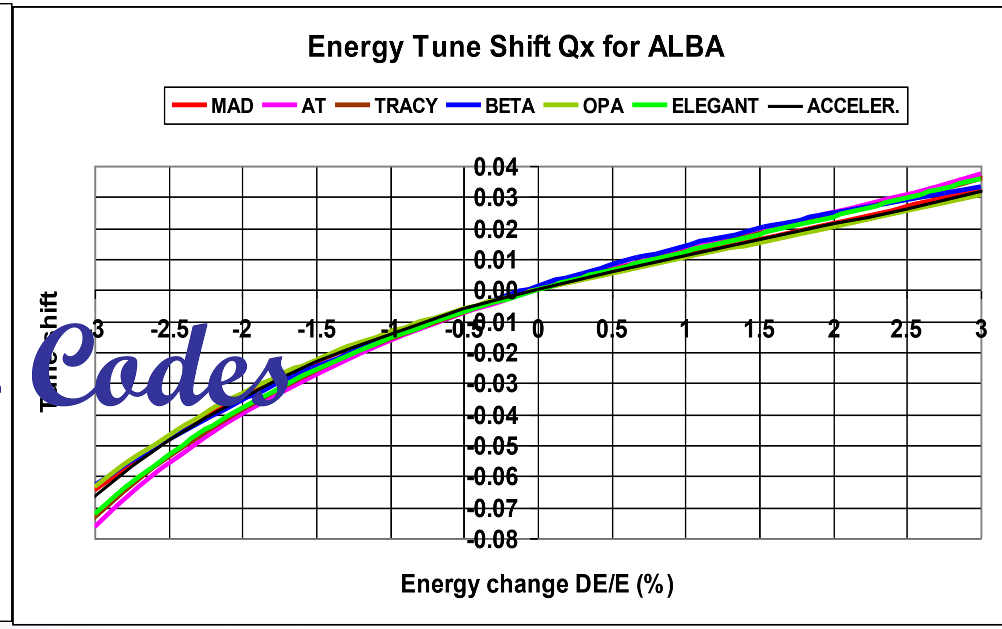




Optic Codes

D. Einfeld, ALBA-CELLS, OMCM - Workshop

CERN, 20th - 22nd June 2011

ACCELERATICUM, AT, BETA, BMAD, COMFORT, COSY-INFINITY, DIMAD, ELEGANT, LEGO, LIAR, LUCRETIA, MAD, MARYLIE, MERLIN, ORBIT, OPA, PETROS, PLACET, PTC, RACETRACK, SAD, SIXTRACK, SYNCH, TEAPOT, TRACY, TRANSPORT, TURTLE, UAL

Contents

- History of the code comparison
- Lattices and codes to compare
- Linear parameters
- Tune shifts with energy
- Tunes shifts with amplitude
- Dynamic Apertures
- Conclusion
- Appendix

Single Particle Beam Dynamics Codes

Winni Decking
DESY –MPY

HHH Workshop CERN 2004

This is an excellent overview of the different lattice codes

Winni Decking: Point of view

- The physicist who cares only about the methods/assumptions used
- The programmer who wants to implement the newest programming techniques
- The user (also a physicist/programmer) who doesn't care about methods and programming but likes a well documented, usable, cross-checked code to get the work done

The user of the codes belongs to the third category and will concentrate on this aspect

A legacy of beam dynamics codes

- Many beam dynamics codes written over the years
- Here is a – surely – not complete list:

ACCELERATICUM, AT, BETA, BMAD, COMFORT, COSY-INFINITY, DIMAD, ELEGANT, LEGO, LIAR, LUCRETIA, MAD, MARYLIE, MERLIN, ORBIT, OPA, PETROS, PLACET, PTC, RACETRACK, SAD, SIXTRACK, SYNCH, TEAPOT, TRACY, TRANSPORT, TURTLE, UAL

History of Code Comparison

23rd Particle Accelerator Conference

4-8 May, 2009

Vancouver, British Columbia, Canada

Meeting at the PAC 2009 to discuss the code comparison again (initiated by Riccardo Bartolini, Diamond)

Codes, Experts and Lattices

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 following lattices have been chosen:

SOLEIL: High field in the bendings (1.72 T).
ALBA: Like SOLEIL but with a gradient in the bendings (5.6 T/m)
APS: High energy machine (8 GeV)

Procedure

The results were calculated by the different colleagues.
The summary and comparison has been done by D. Einfeld
The results were presented and discussed at the 2nd NLBD Workshop as well at the 16th ESLS-Workshop at DESY

43 Participants from 14 countries and 24 Labs

J.A.I.
2nd nonlinear beam dynamics workshop
Diamond, 02 November 2009
diamond

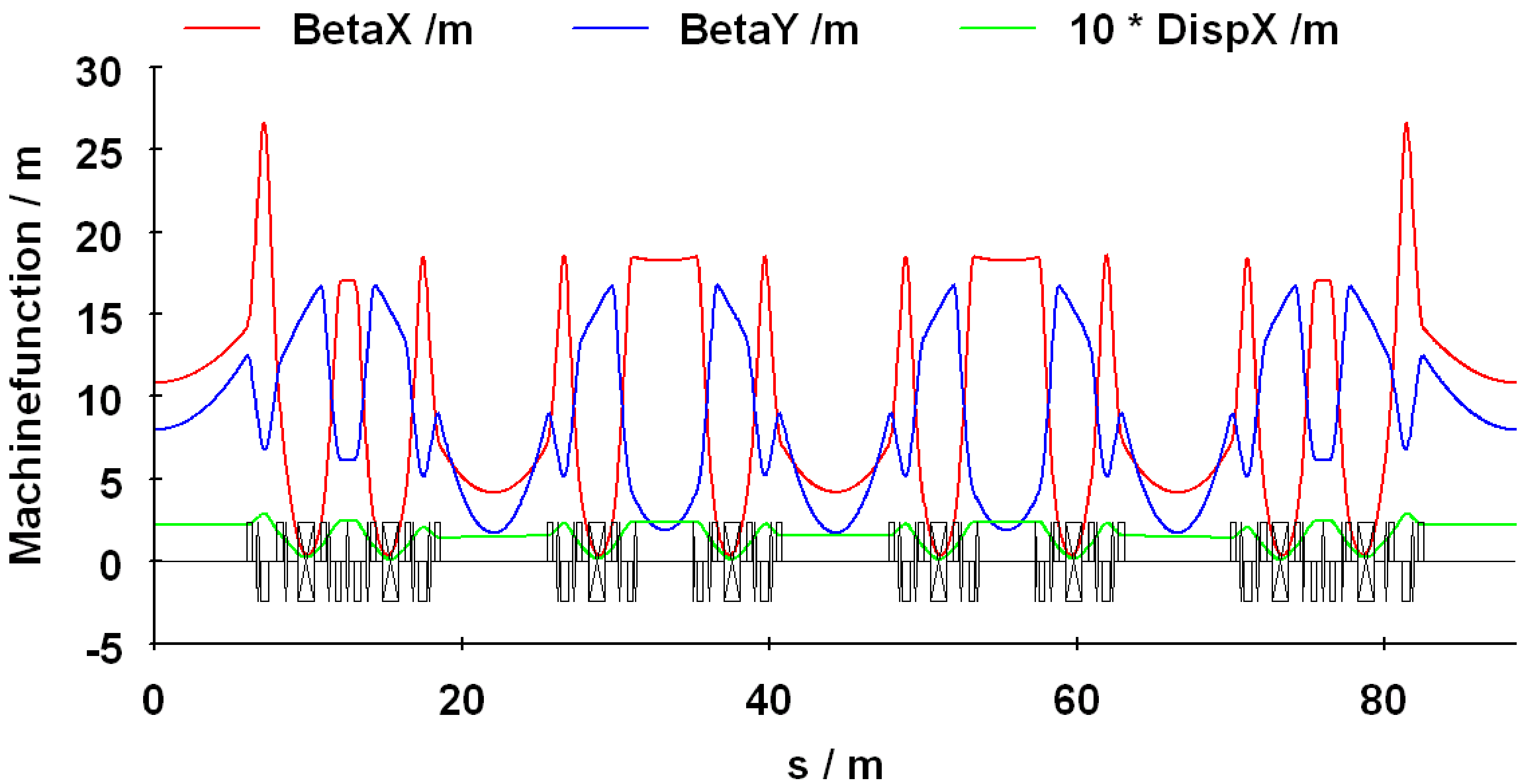
http://www.diamond.ac.uk/Home/Events/Past_events/NBD_workshop.html

https://indico.desy.de/contributinsListDisplay.py?confId=2325

Lattice of Soleil

Aver.[α(x)] = 5.4

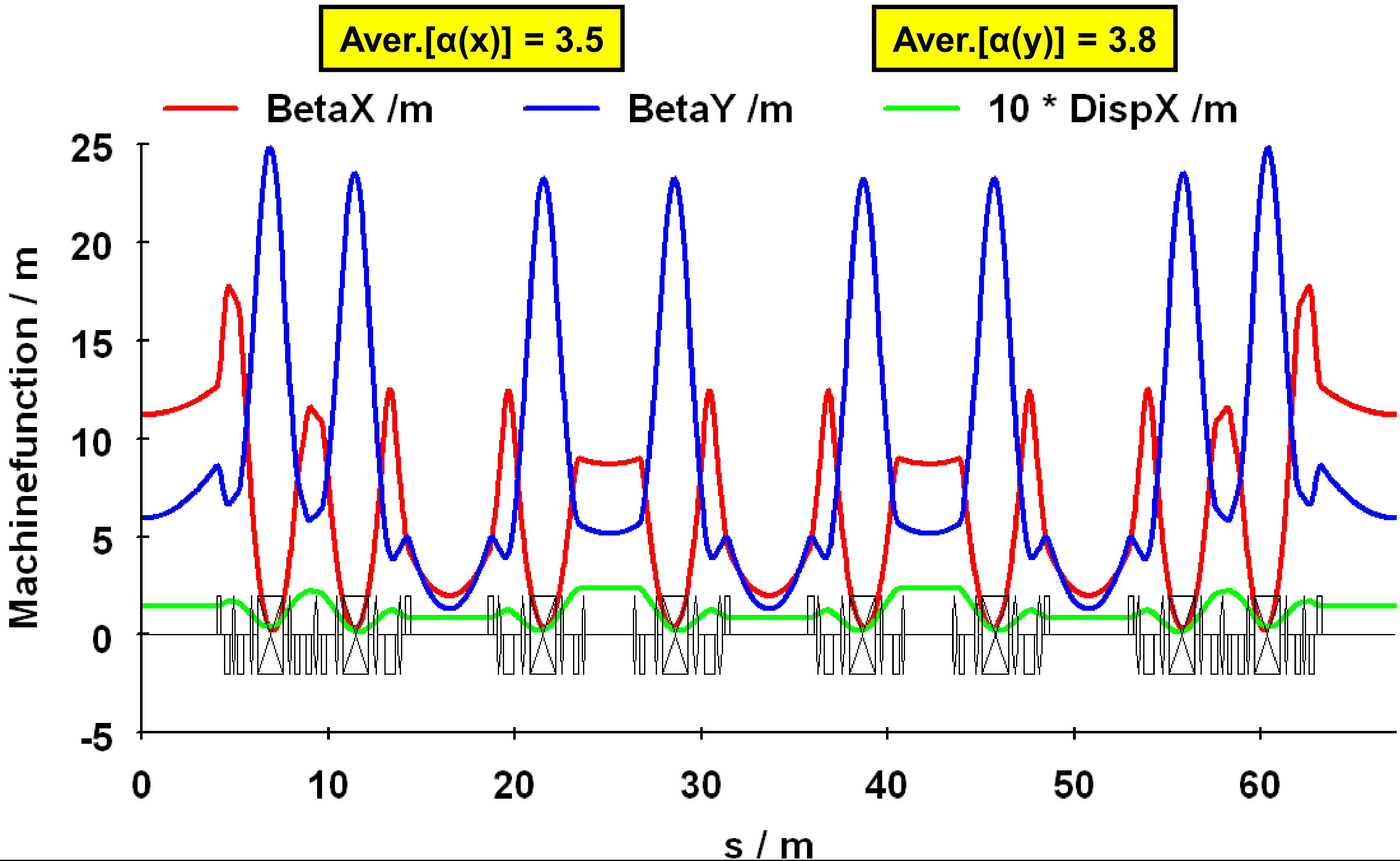
Aver.[α(y)] = 3.5



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

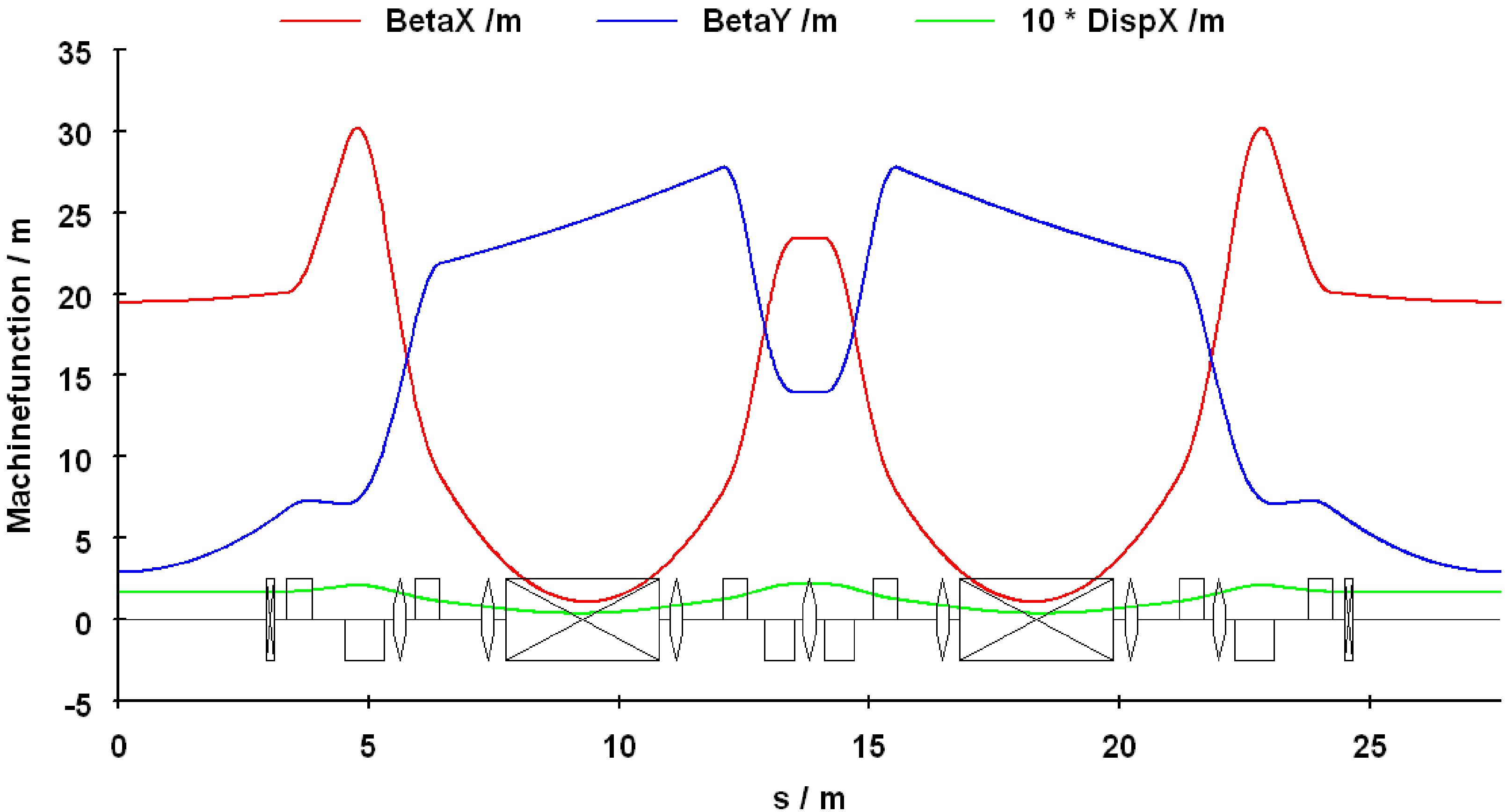


Four fold symmetry with 2 unit cells and 2 matching sections in a quadrant like SOLEIL. In comparison to SOLEIL, ALBA has a gradient in the bending magnets.C = 268.8 m, E = 3.00 GeV, RF= 500MHz, Qx = 18.18 and Qy = 8.37

Lattice of APS

Aver.[α(x)] = 3.2

Aver.[α(y)] = 2.0



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 for Comparison

As “Linear Parameters” we compare:

- Beta functions
- Dispersion functions
- Tunes
- Natural chromaticity's
- Corr. chromaticity’s
- Mom.-Comp.-Factor
- Emittance’s,
- Energy spread
- Damping times,
- Partition numbers,
- Synchrotron integrals,

Linear Parameters for 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

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 (;larger as 0.3%). The largest differences are for the vertical beta function (1%) and the vertical Chromaticity (3.3%). The agreement is in the horizontal direction pretty good, but not so good in the vertical direction

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: ALBA

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

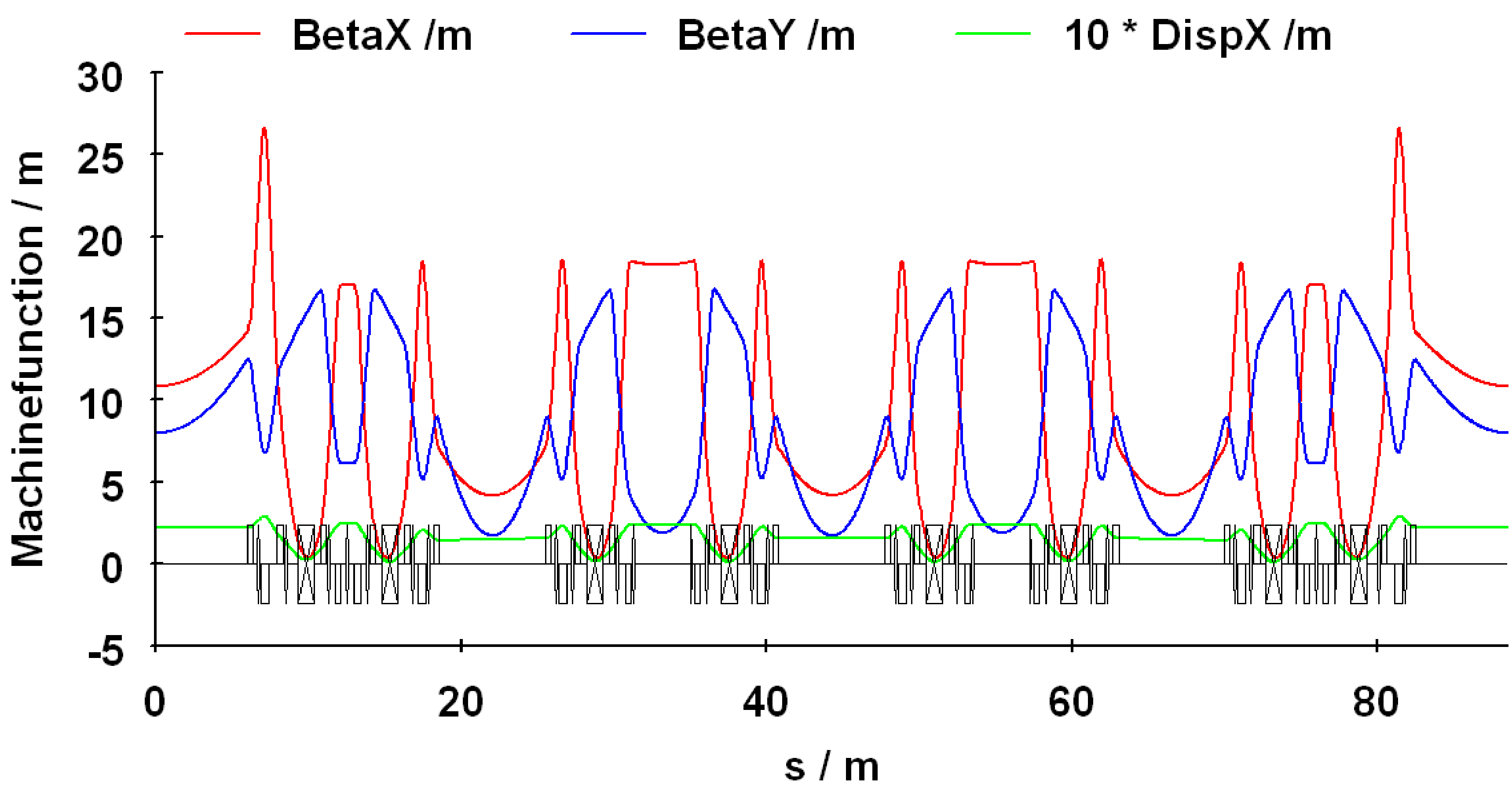
	MAD	Tracy II	BETA	ELEG.	DIMAD	AT	OPA	Acceler.
Horiz. Corr. Chrom.	1.3440	1.3402	1.4200	1.4211	1.4420	1.4197	1.2200	1.2160
Vert. Corr. Chrom	0.5535	0.3992	-0.1110	-0.0065	-0.1133	-0.1129	1.7700	1.7590
Horiz.Chrom. ξ(x) by sextupoles	-38.1453	-38.1574	-38.0200	-38.0221	-38.0013	-37.9957	-38.4280	-38.4321
Vertic.-Chrom. ξ(y) by sextupoles	-27.5142	-27.7611	-28.8810	-29.4306	-28.8691	-28.8501	-25.1130	-25.1241

Comments to the corrected Chromaticity's

1.) Horizontal corrected chromaticity:
The agreement between the codes is very well. The deviations are between 1.442 and 1.216 which is 0.226. This for an overall value of 39.5 makes a percentage of 0.6% which means a good agreement. For the calculated chromaticity (linear parameter) there is also a difference between the codes of 0.21 (39.6481-39.4400), which means a percentage 0f 0.5%

2.) Vertical corrected chromaticity:
The agreement between the codes is not so good as for the horizontal direction. The deviations are between 1.77 and -0.1129 which is 1.8829. This for an overall value of -28.2 makes a percentage of 6.7% 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 2.541 (29.4241-26.8831), which means a percentage of 9.24 %
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.

Comparison of Codes for SOLEIL



Linear Parameters for 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

Parameter	Unit	Average	Stand,-Deviat.	Deviat. in %
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 8 parameters marked with red, which means they are out of Good agreement. The Largest differences are for the vertical beta function (0.8%) and the vertical Chromaticity (2.8%). The agreement is in the horizontal direction pretty good, but not so good in the vertical direction

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

	MAD	Tracy II	BETA	ELEG.	DIMAD	AT	OPA	Accel.
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:

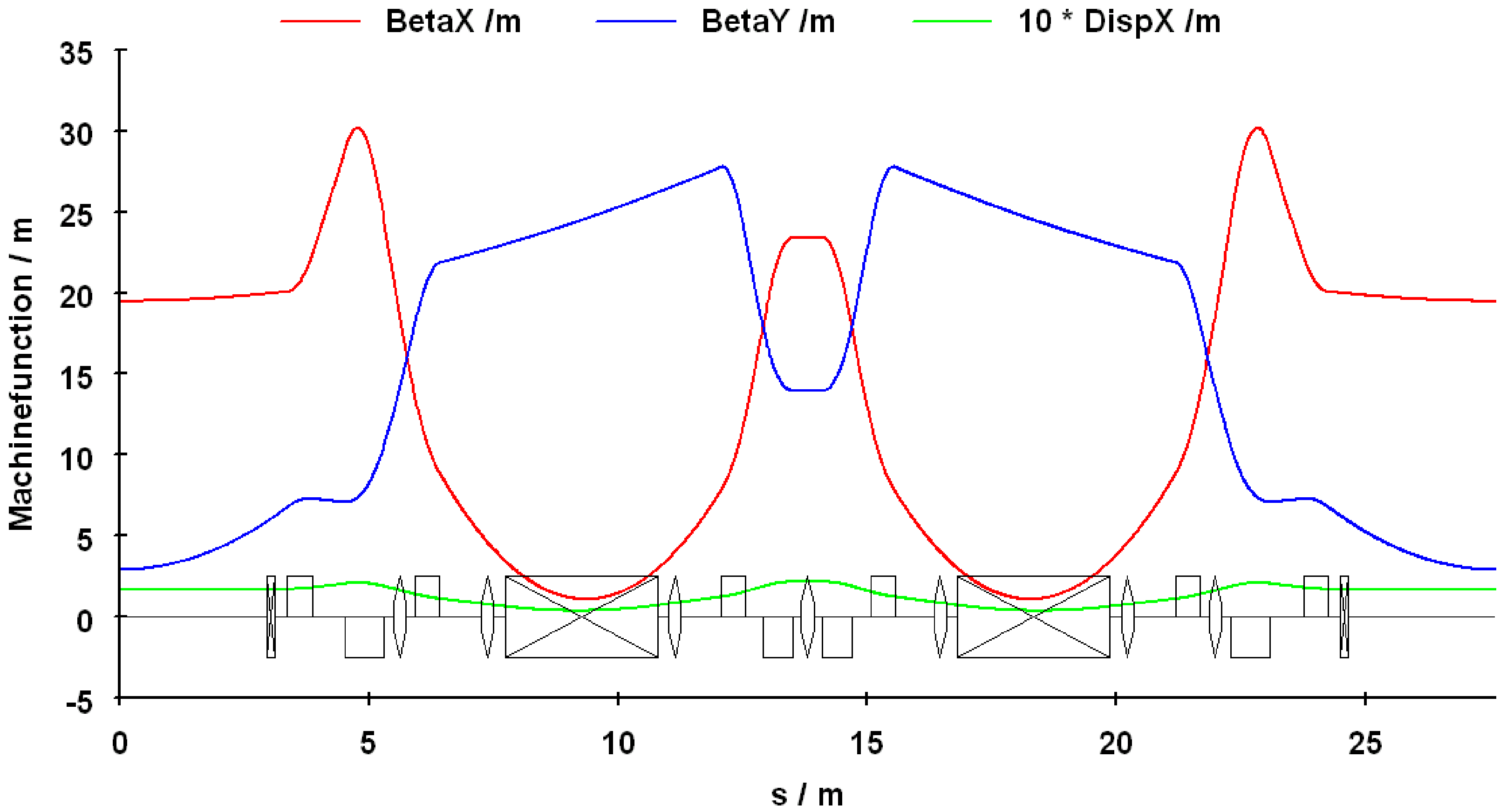
The agreement between the codes is very well. The deviations are between -0.0646 and 0.0471 which is 0.112. This for an overall value of 52.9 makes a percentage of 0.2% which means a good agreement. For the calculated chromaticity (linear parameter) there is also a difference between the codes of 0.0844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

Comparison of Codes for APS

Lattice of APS



Linear Parameters for 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.

Chromaticity Evaluation: APS

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

	MAD	Tracy II	BETA	ELEGANT	DIMAD	AT	OPA	Acceler.
Horiz. Corr. Chrom.	6.7043	5.8687	6.7020	6.7043	6.7043	6.7066	6.6500	6.6650
Vert. Corr. Chrom	6.4712	6.8007	6.4670	6.4712	6.4652	6.5346	6.7700	6.8430

	MAD	Tracy II	BETA	ELEGANT	DIMAD	AT	OPA	Acceler.
Horiz.Chrom. ξ(x) by sextupoles	-83.6400	-84.4690	-83.6480	-83.6400	-83.6400	-83.6276	-83.7340	-83.7188
Vertic.-Chrom. ξ(y) by sextupoles	-36.6720	-36.2104	-36.4130	-36.4027	-36.4148	-36.5994	-35.8030	-35.9919

Comments to the corrected Chromaticity's

1.) Horizontal corrected chromaticity:
The agreement between the codes is very well. The deviations are between 5.8687 and 6.7066 which is 0.8379. This for an overall value of 90.3 makes a percentage of 0.93% which means a good agreement. For the calculated chromaticity (linear parameter) there is also a difference between the codes of 0.0496 (90.3838-90.3342), which means a percentage of 0.05%

2.) Vertical corrected chromaticity:
The agreement between the codes is very well. The deviations are between 6.8430 and 6.4712 which is 0.3718. This for an overall value of -42.8 makes a percentage of 0.87% which means a good agreement. For the calculated chromaticity (linear parameter) there is also a difference between the codes of 0.5702 (43.1432-42.573), which means a percentage of 1.33 %

This is completely different as for the lattices ALBA and SOLEIL

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

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:

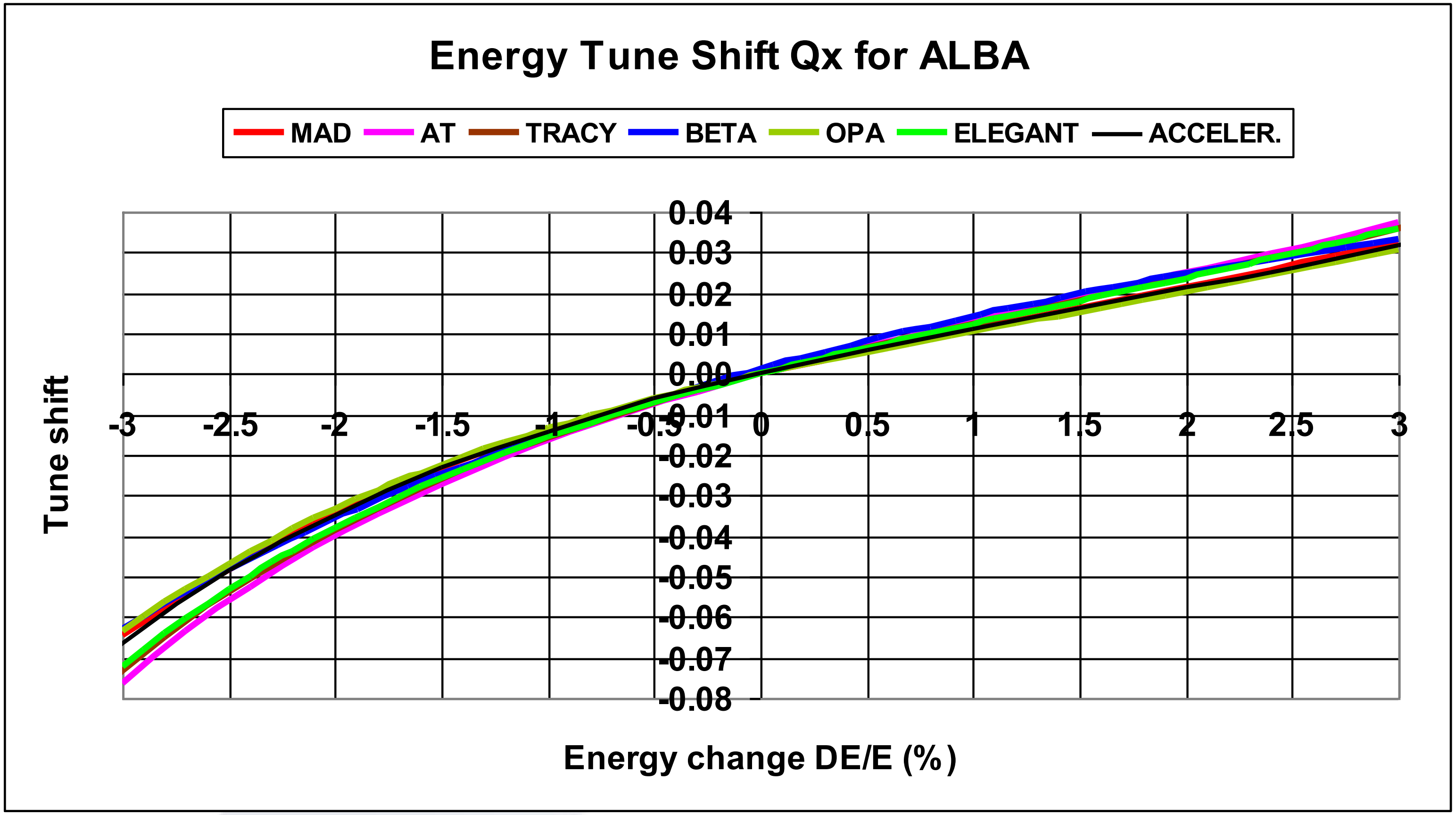
1.) Qi = F(DE/E)

2.) Qi = F(amplitude x)

3.) Qi = F(amplitude y)

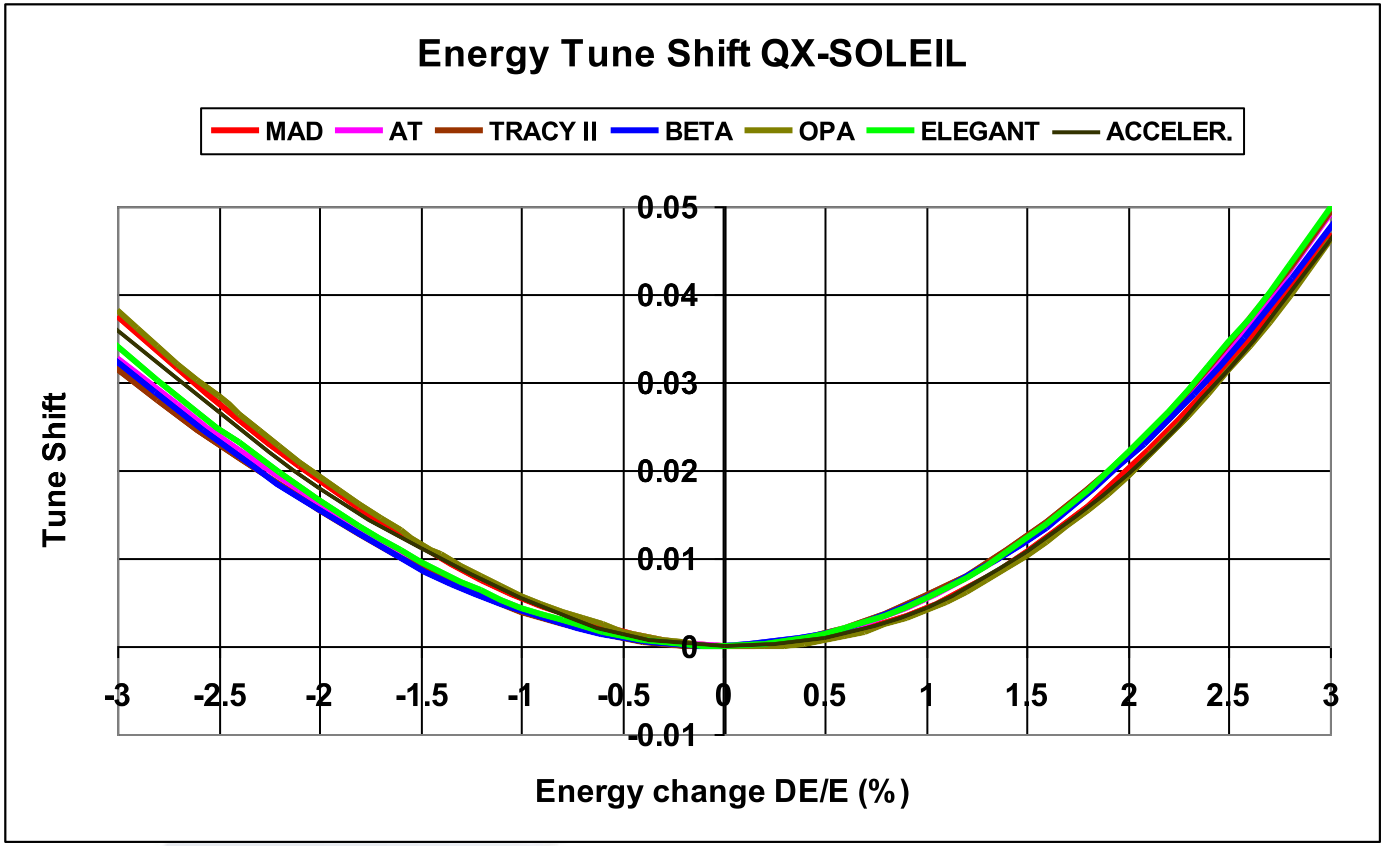
4.) Dynamic aperture

Tune Shift with Energy for ALBA



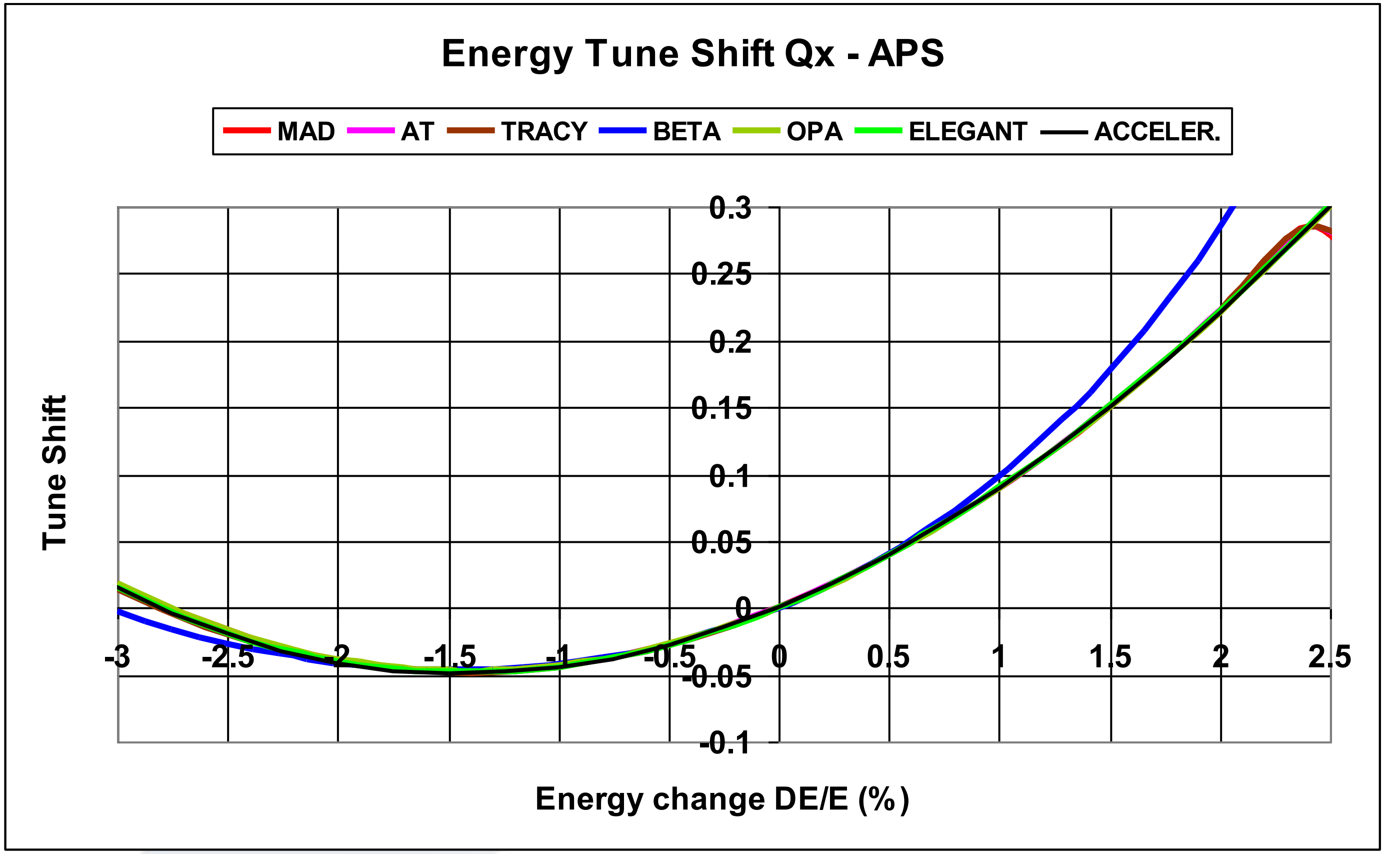
All the codes overlapping more or less, which means they should agree with each other, but for positive energy deviations the differences between the codes are up to 20% at DE/E = 2.5%, for negative energy deviations the difference goes up to 25 %. This means that the agreement between the codes are 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 SOLEIL



All the codes overlapping more or less, which means there is a good agreement between the codes. For positive energy deviations the differences between the codes are up to 10% at DE/E = 2.5%, for negative energy deviations the difference goes up to 18 %.
The chromaticity according to these plot is roughly 0, which agrees very well with the data of the linear parameters.

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.

Conclusions for Tune-shift with Energy

CODE Comparison: Tune Shift with Energy

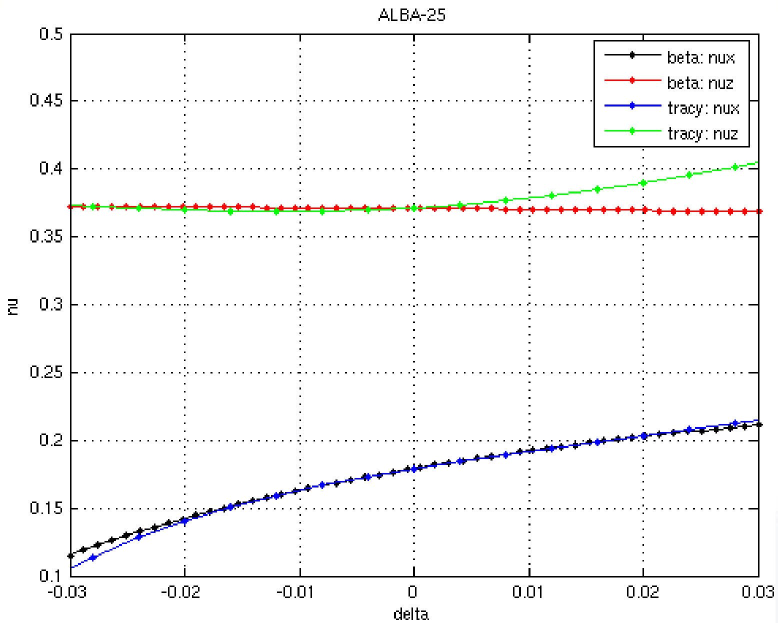
		MAD	TRACY	BETA	ELEGANT	AT	OPA	ACCEL.	Tolerances
APS:	Qx	+	+	-	+	+	+	+	3%
	Qy	+	+	-	+	+	+	+	10%
SOLEIL:	Qx	+	+	+	+	+	+	+	18%
	Qy	-	+	+	-	+	-	-	+(40%), -(16%)'
ALBA:	Qx	+	+	+	+	+	+	+	22%
	Qy	+	-	-	+	-	+	+	+(16%), -(70%)'

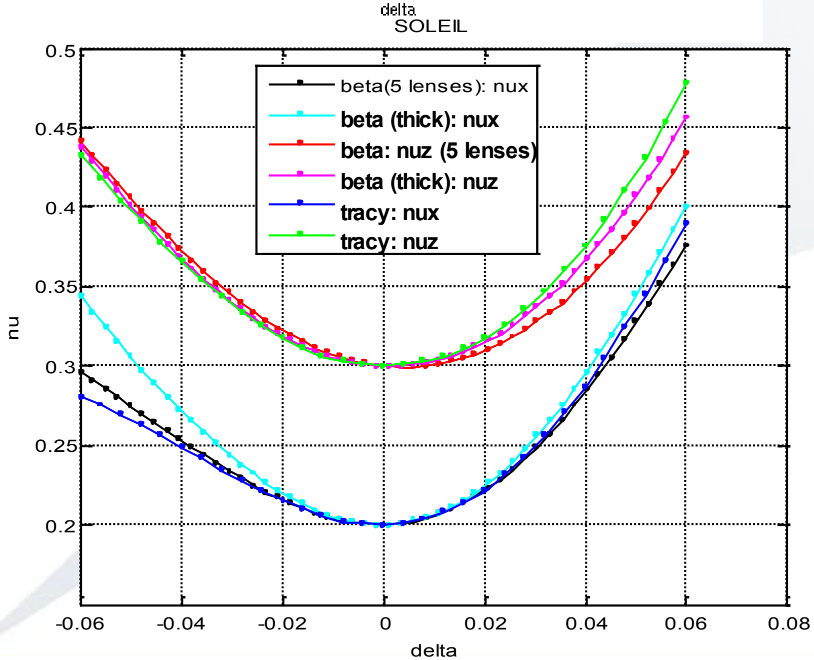
Explanations to the above table:

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%

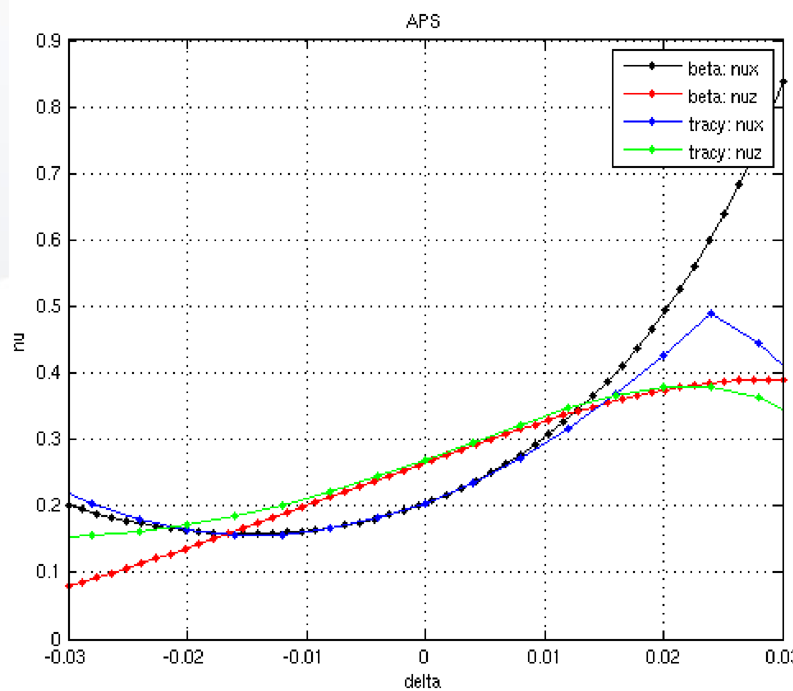
For the changes of the horizontal tune (Qx) with the energy all codes agree relative with each other with tolerances from 3% (APS) to 22% (ALBA). The agreement for the vertical tune shift (Qy) with energy is pretty bad. The tolerances go from 10% (APS) to 70% (ALBA) The tolerances are much smaller for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

Comparison BETA / Tracy





Results from Laurant Nadolski



Non - Linear Parameters

For all codes:

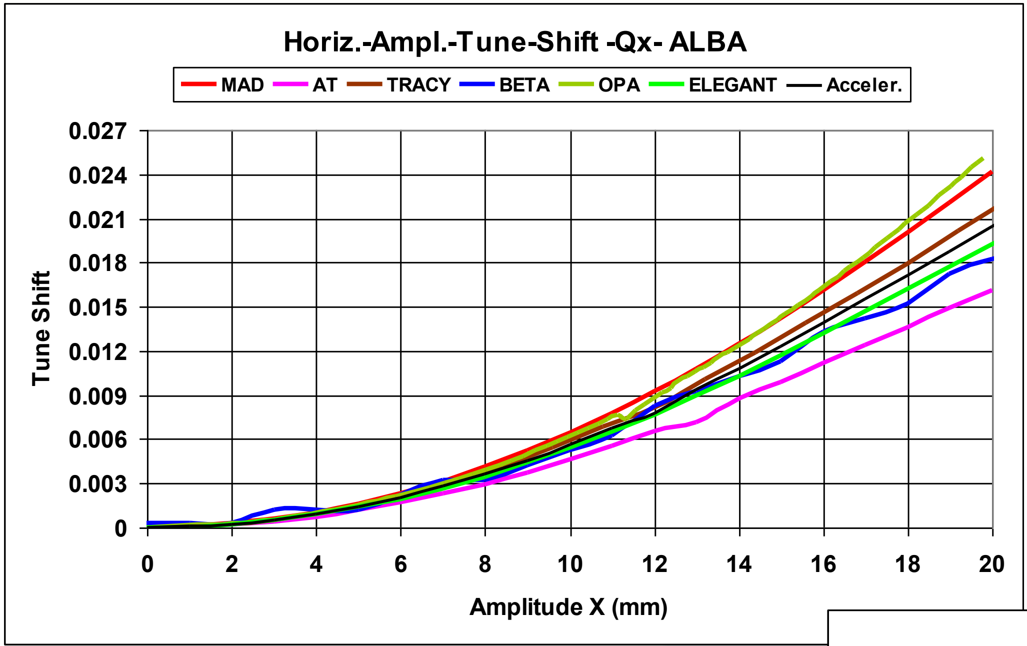
1.) Qi = F(DE/E)

2.) Qi = F(amplitude x)

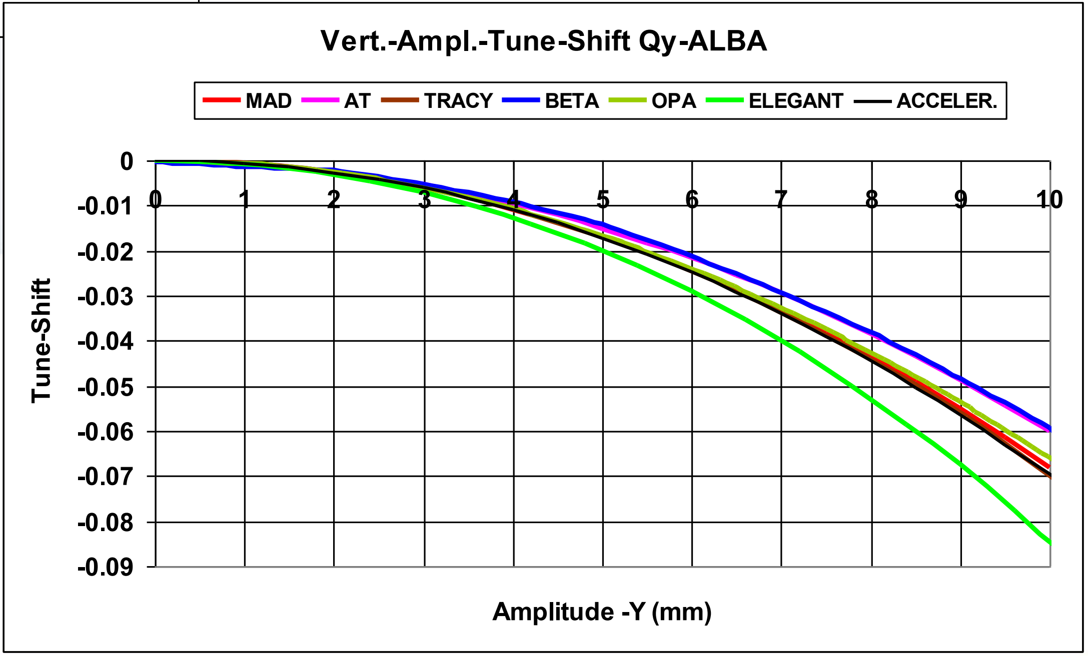
3.) Qi = F(amplitude y)

4.) Dynamic aperture

Tune Shift with horizontal Amplit. for ALBA

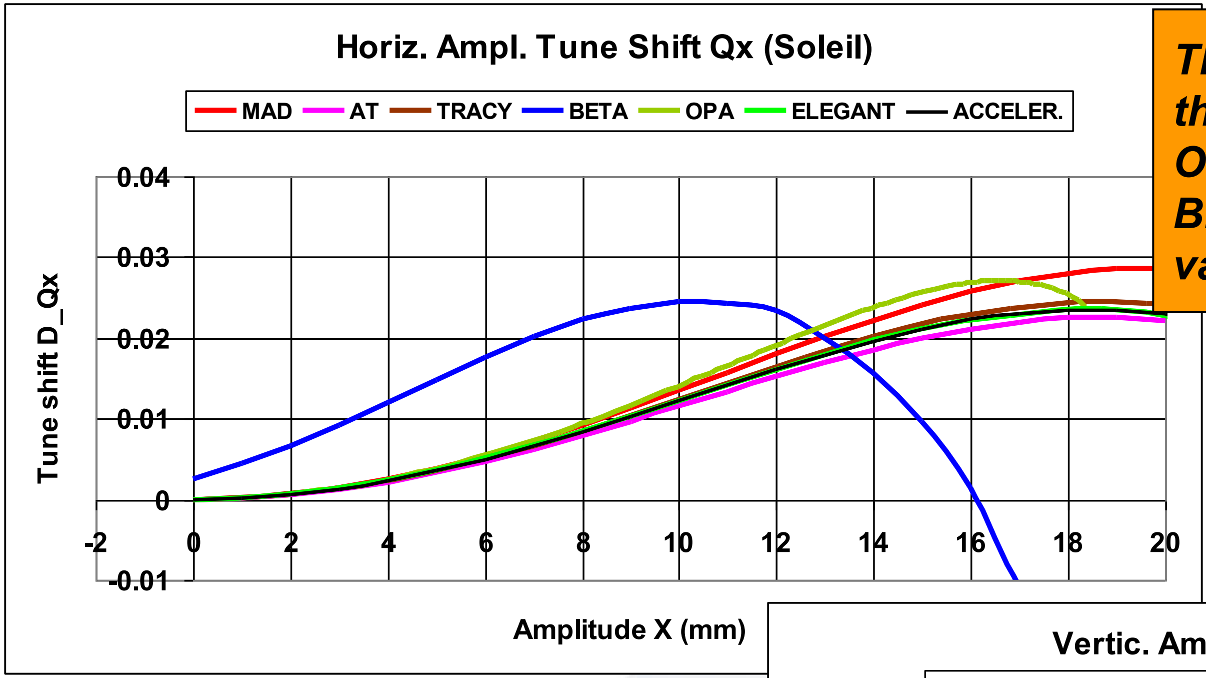


The agreements between the codes is not good. At an amplitude of 18 mm the codes agree within a tolerance of 60%.

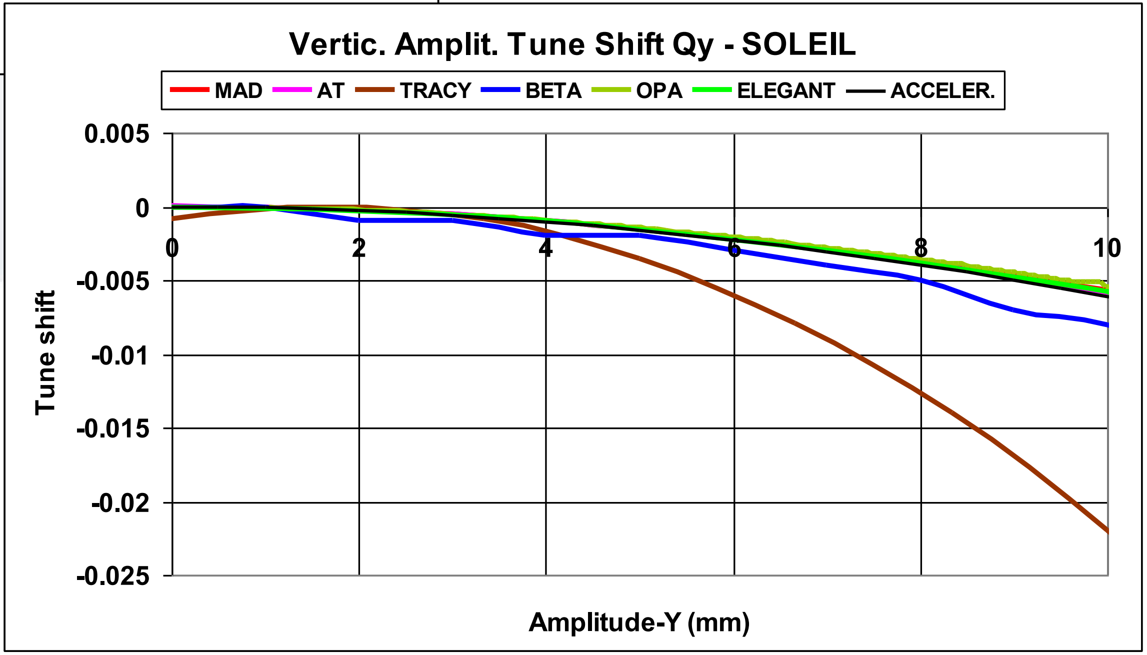


***There is a good agreement between the codes MAD, AT, TRACY, OPA and ACCELER..
ELEGANT and BETA have differences of up to a 17 %***

Tune Shift with horizontal Amplit. for SOLEIL

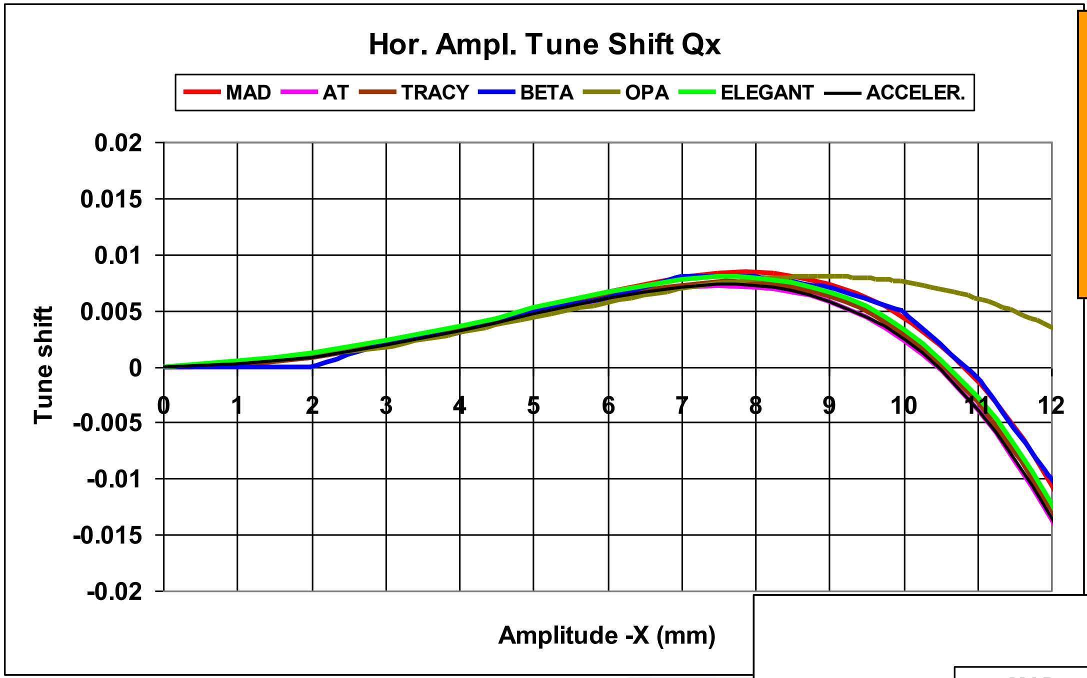


There is an agreements between the codes within a tolerance of 7%. OPA and MAD disagree to 20 %. BETA is far away from these values

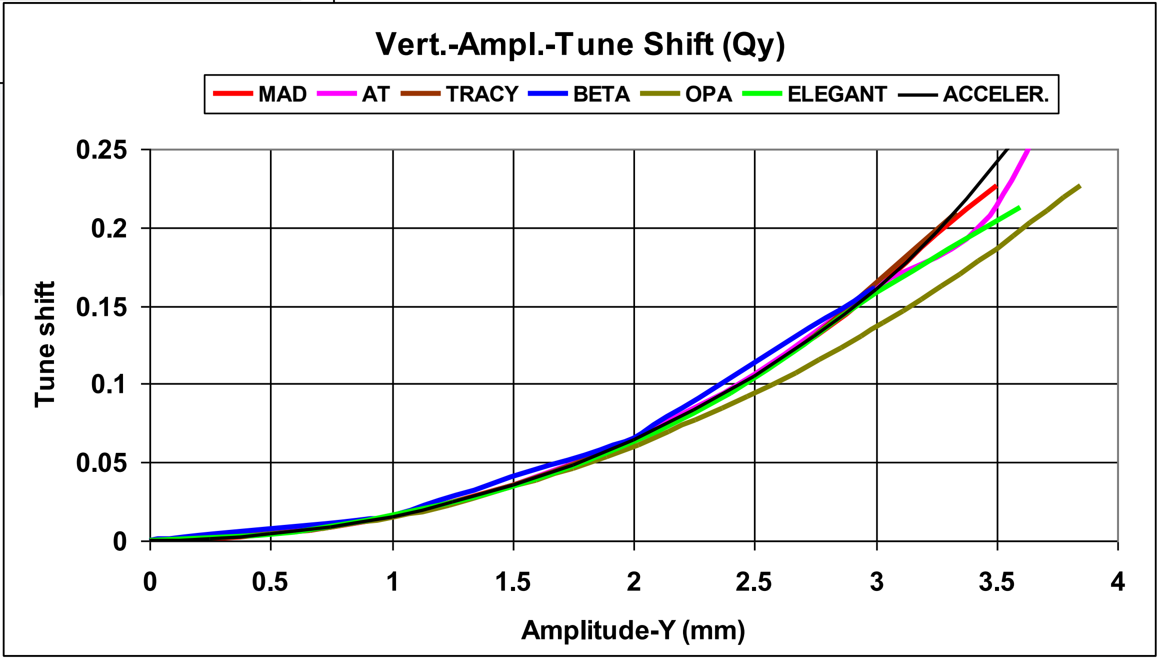


There is a good agreement between the codes MAD, AT, OPA ELEGANT and ACCELER.. Tracy has differences of up to a factor 2 to 3 and BETA is away by 20 %

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

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

Comparison of non-linear parameters

B.) Tune-shift with Amplitudes

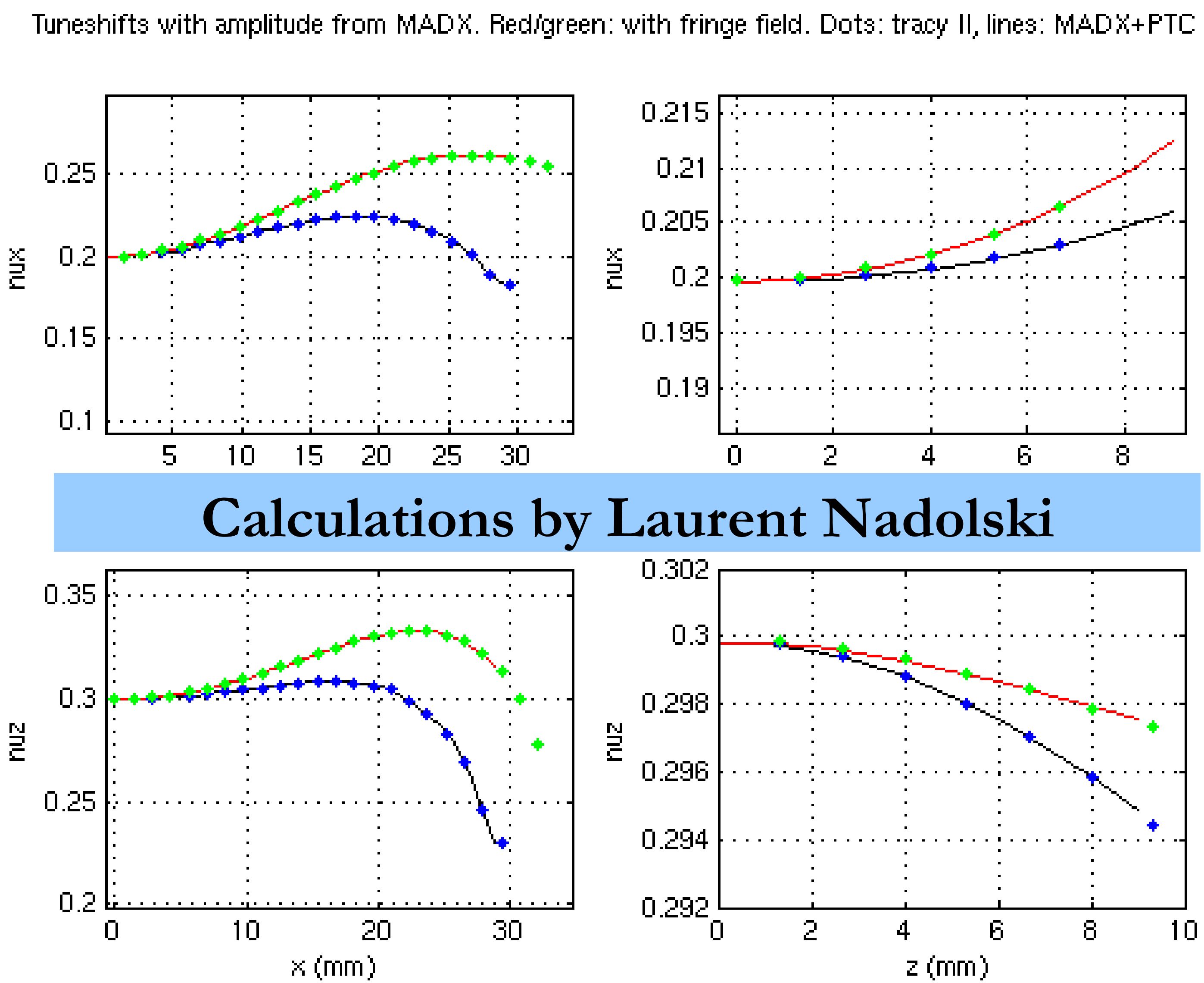
1.) The agreement between the codes are not so good.

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

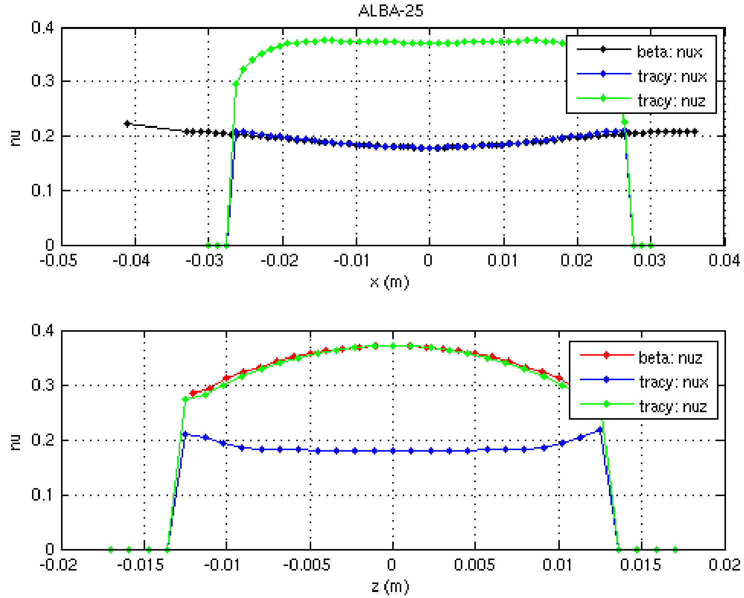
3.) OPA and TRACY are sometimes away by a factor 2 to 4.

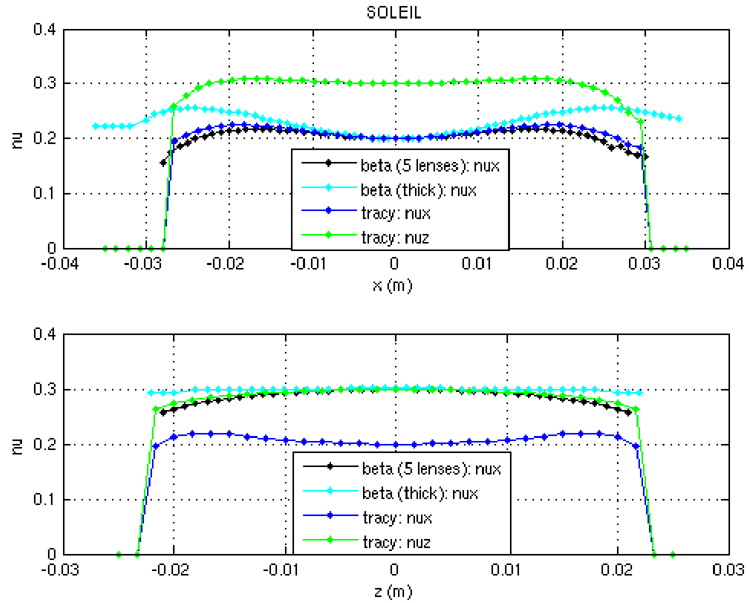
4.) The tolerances are much smaller for APS as for SOLEIL and ALBA

Comparison BETA / Tracy

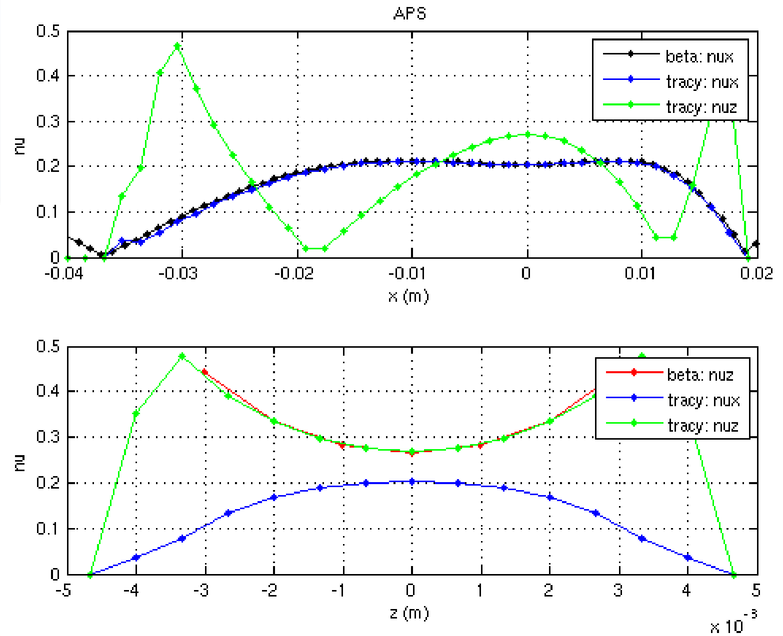


Comparison BETA / Tracy





Results from Laurant Nadolski



Conclusion of the 2nd NLBD-Workshop

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). Either a thin sextupole, many thin lenses, 4th order integrator, and ...A 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.

Non - Linear Parameters

For all codes:

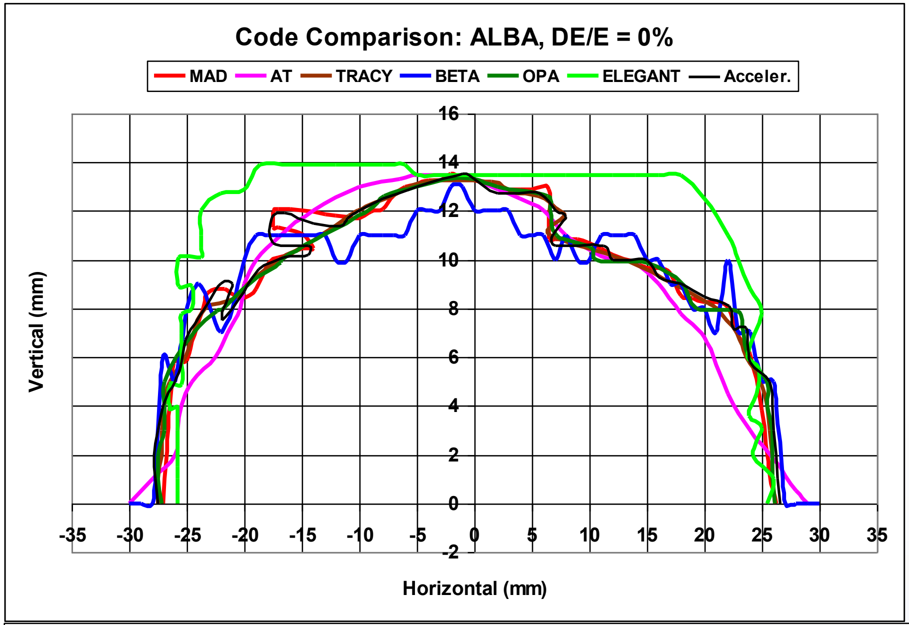
1.) Qi = F(DE/E)

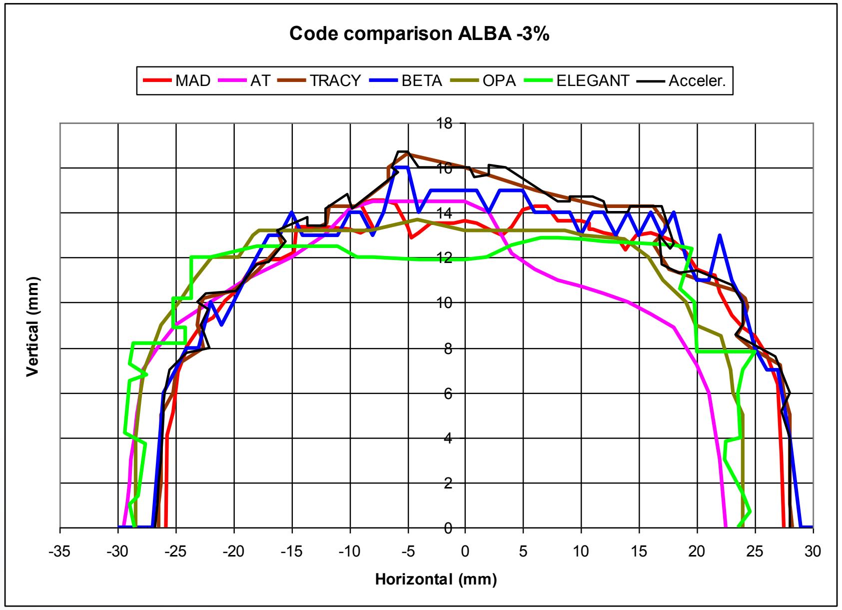
2.) Qi = F(amplitude x)

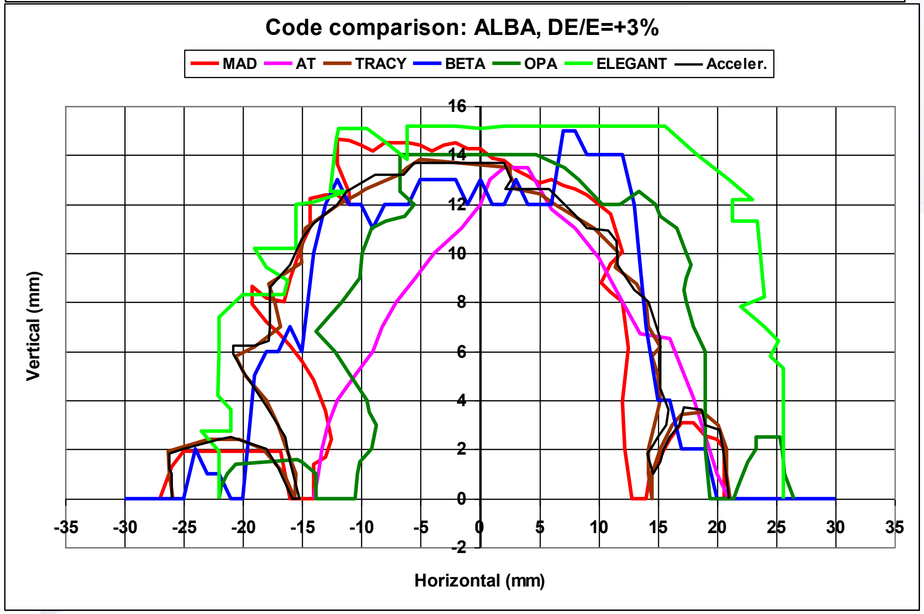
3.) Qi = F(amplitude y)

4.) Dynamic aperture

Dynamic Aperture: ALBA





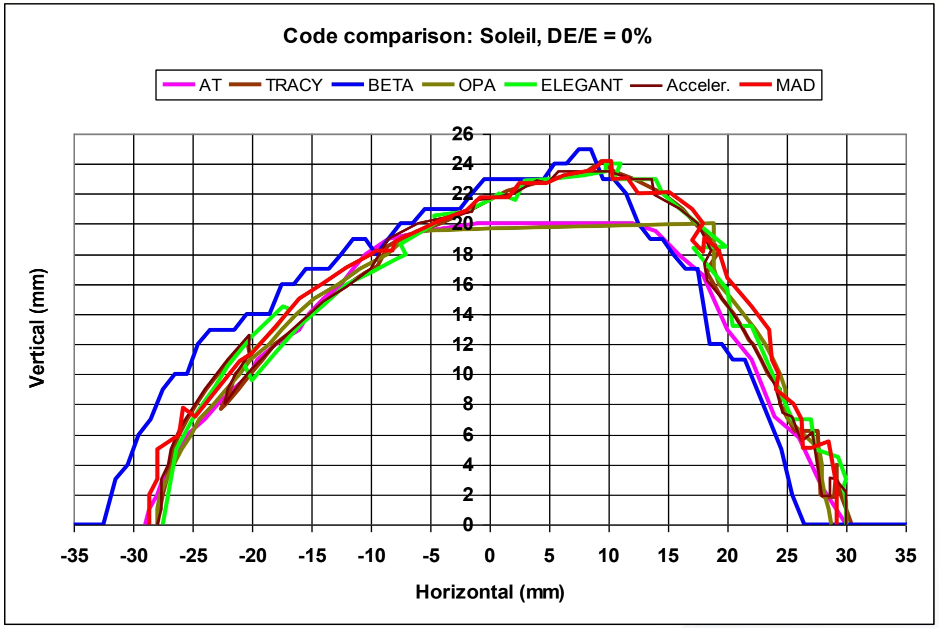


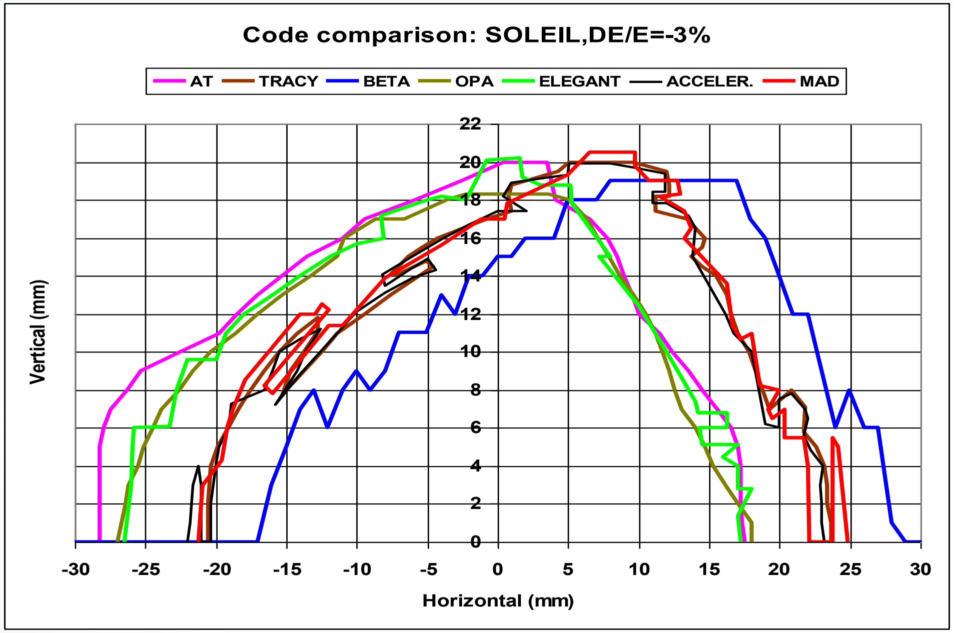
DE/E =0:Good agreement between the codes:
MAD, TRACY, OPA and Acceler.
No good agreement for the codes:
ELEGANT, BETA and AT

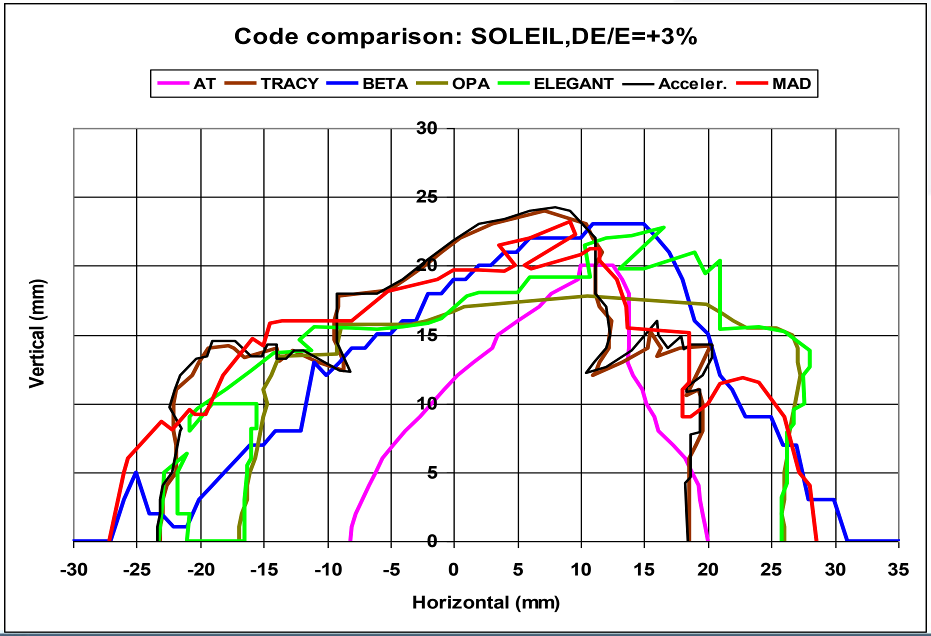
DE/E=-3%:Good agreement between the codes:
MAD, TRACY, BETA and Acceler.
No good agreement for the codes:
ELEGANT, AT and OPA

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

Dynamic Aperture: SOLEIL





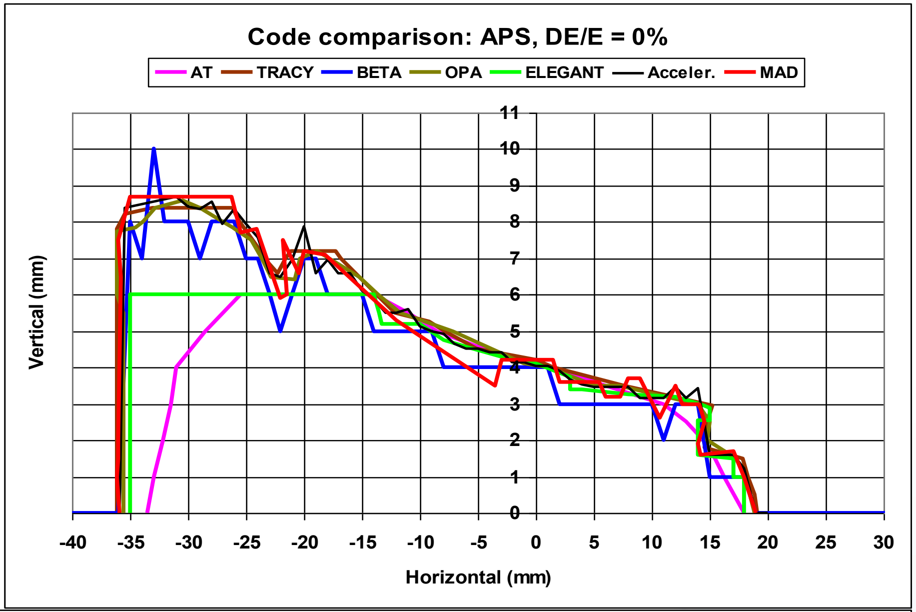


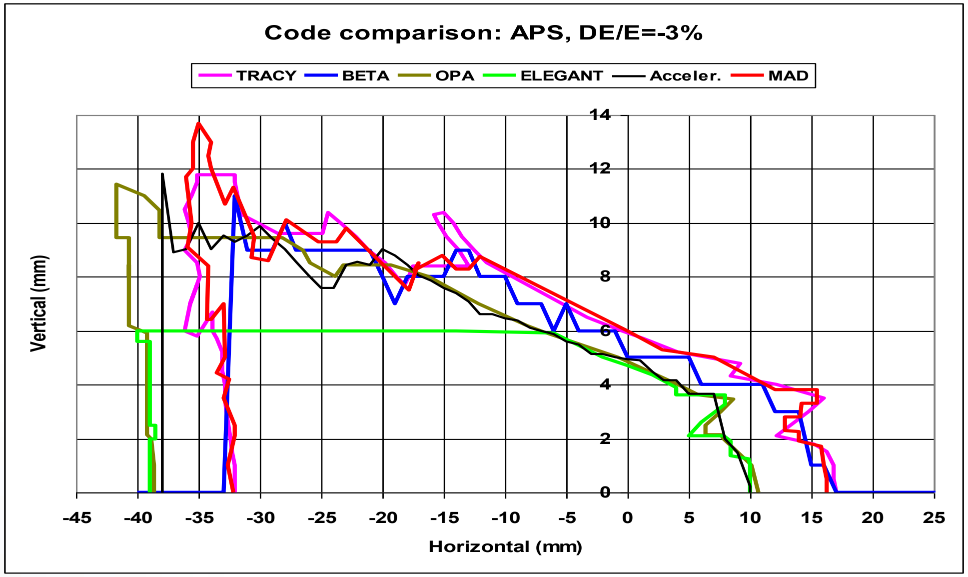
DE/E=0%: Good agreement between the codes:
MAD, AT, TRACY, OPA, ELEGANT and Acceler.
No good agreement for the code: BETA

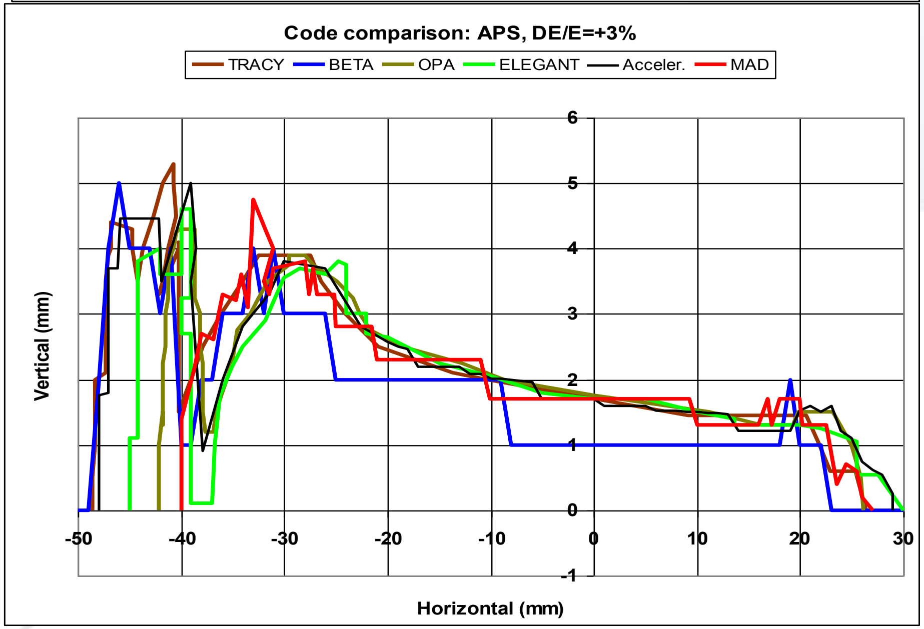
DE/E =-3%: Good agreement between the codes:
MAD, TRACY, and Acceler.
No good agreement for the code:
BETA, AT, OPA and ELEGANT

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

Dynamic Aperture: 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

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

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Please make your own conclusion.

Thank you very much