Overview of existing injectors

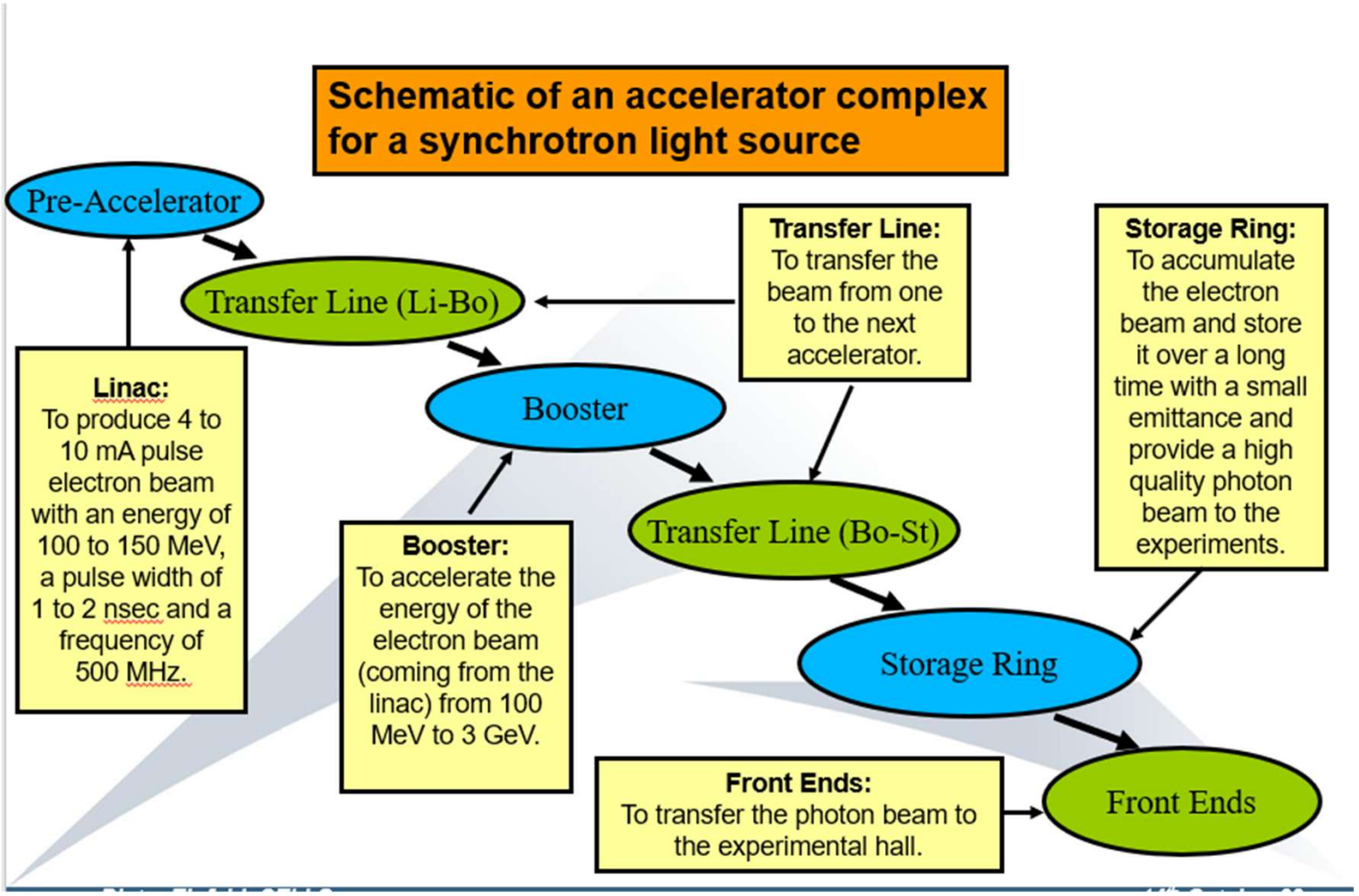
According to www.lightsources.org there are more than 50 light sources in the world (10 in Americas, 15 in Asia and Australia plus 20 in Europe and the Middle East).

Because it is not possible to present the injectors of all Light Sources, I made a selection of 10 sources:

NSLS I	ESRF	ALS	APS / ELETTRA	BESSY II	SLS	KARA

ANSTO / NSLS II	SOLEIL / Diamond / CLS	ALBA / SIRIUS / TPS

I. Fast workshop on “Injectors for storage ring based light sources”



NSLS I – X-RAY and VUV-Source (1982)

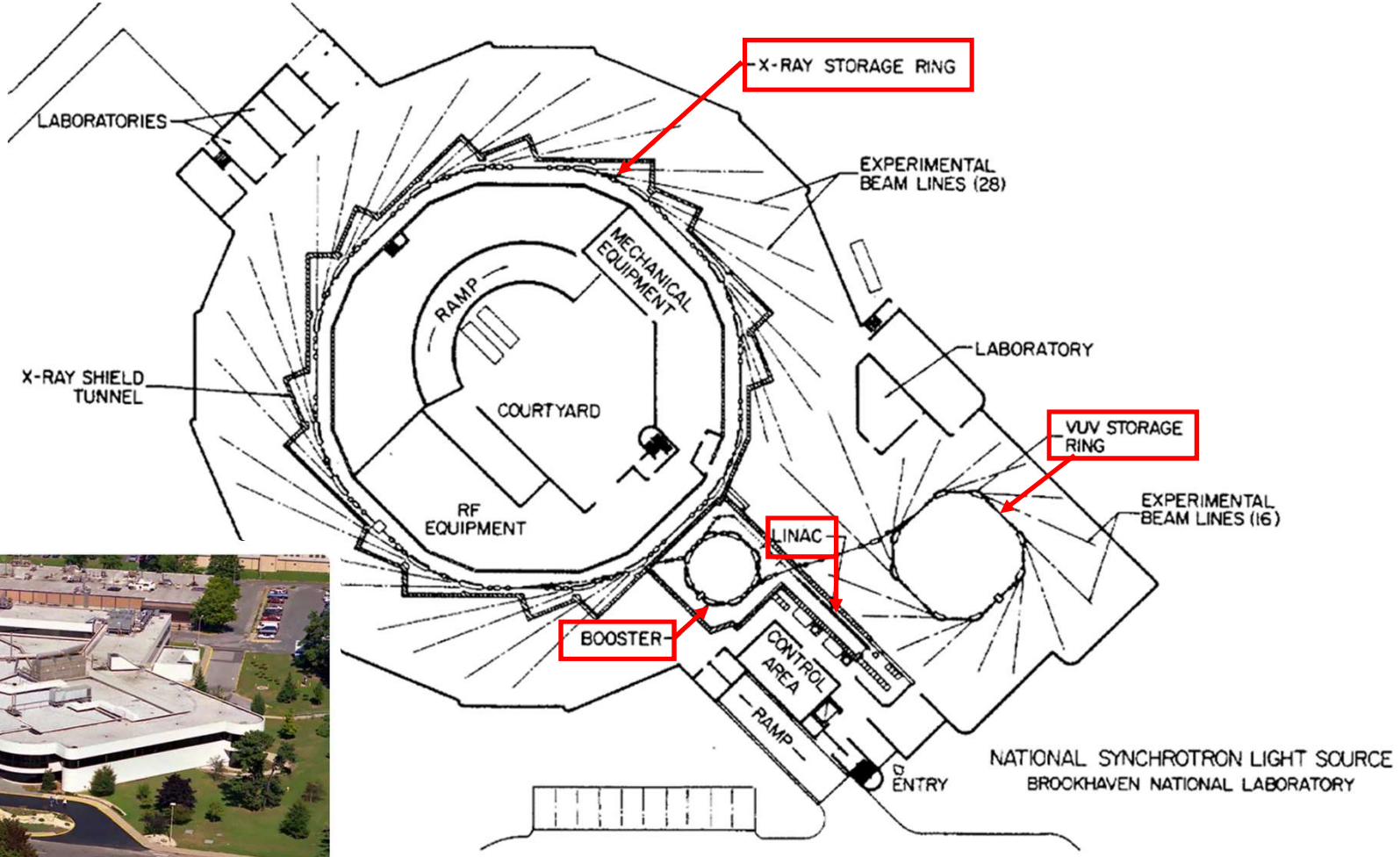
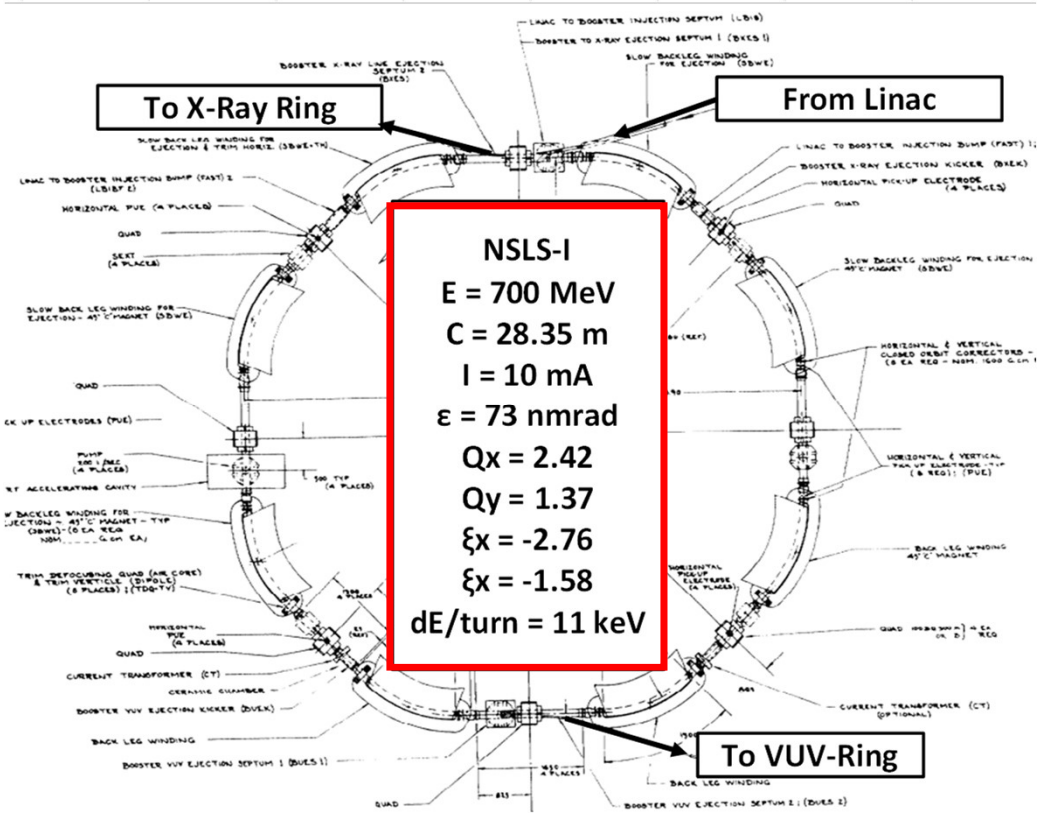
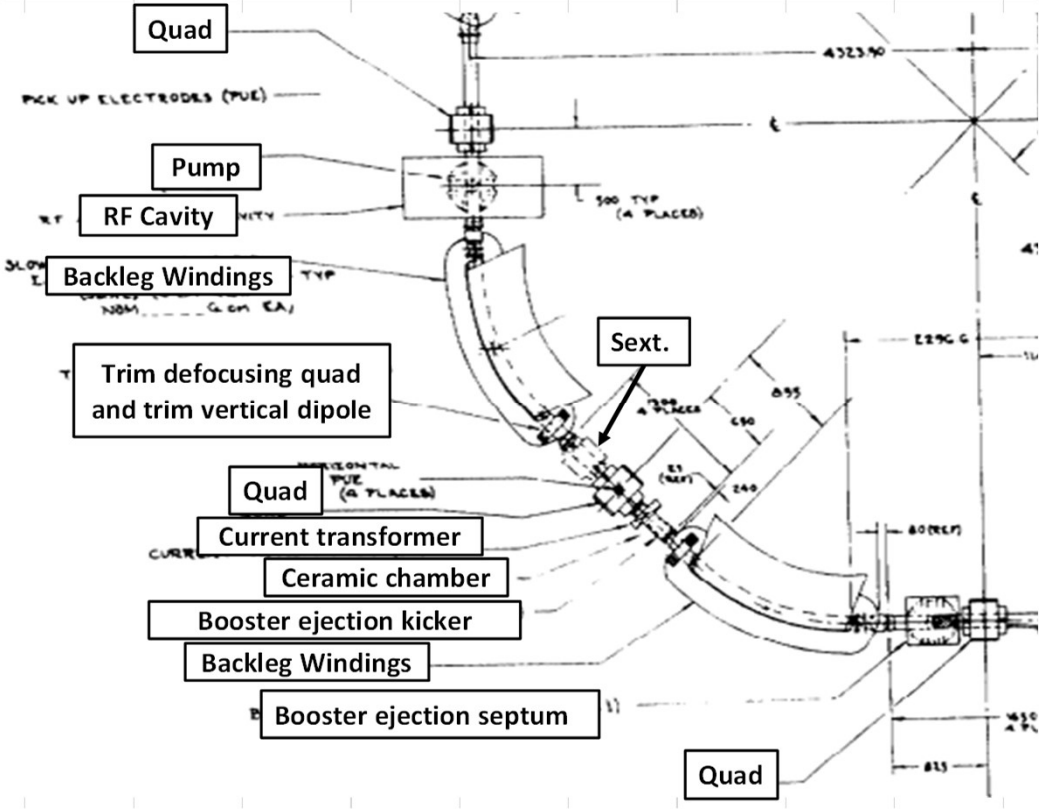


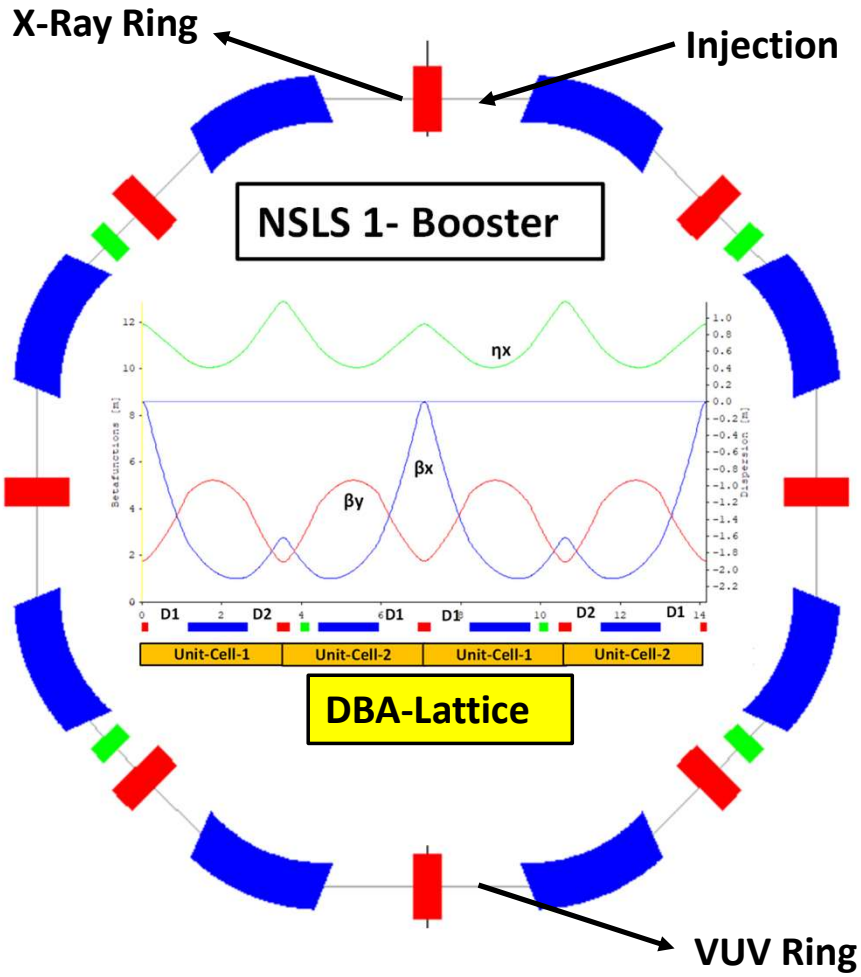
Figure 1.

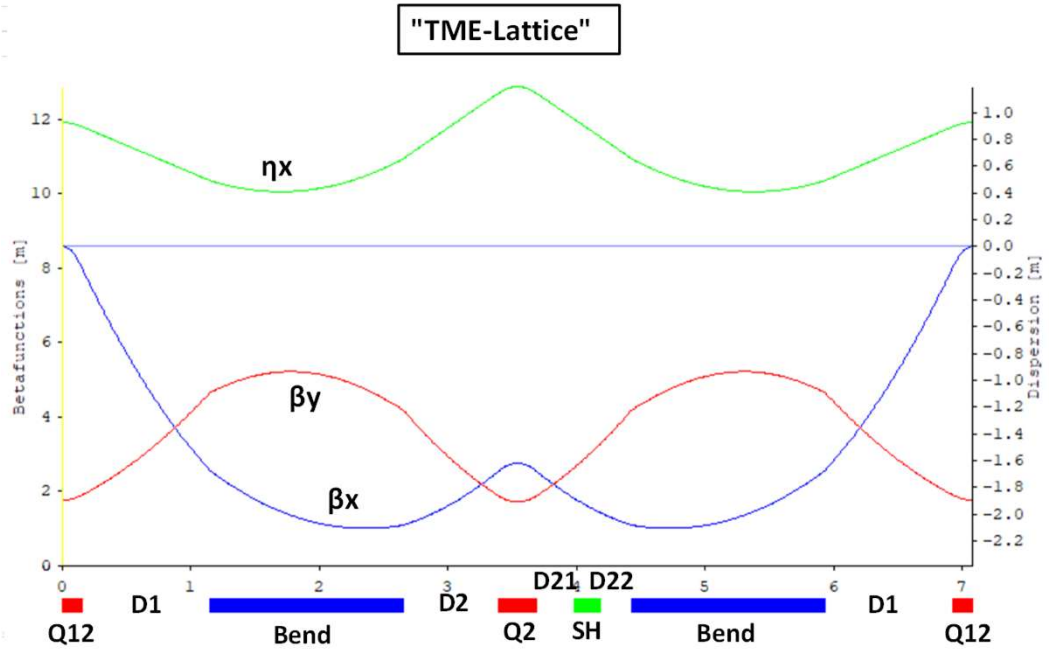
NSLS I - Booster





NSLS I - Booster





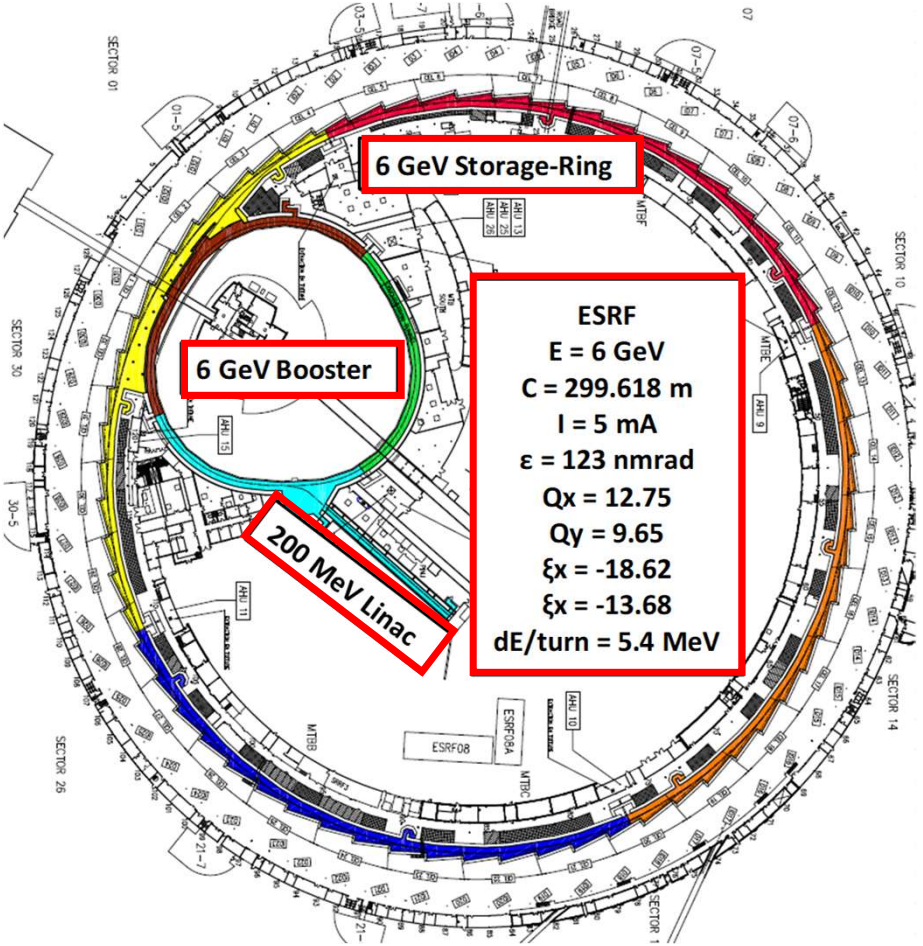
Bend: L = 1.5 m, ϕ = 45°, ρ = 1.91, ϕ1 = ϕ2 = 22.5°, B = 1.222 T, G = -0.744 T/m, B" = -11.7 T/m^2

Q1: L = 0.3 m, G = 6.88 T/m, Q12 = Q1/2, Q2 : L = 0,3 m, G = 8.74 T/m

SH: L = 0.2 m, B" = 105 T/m^2

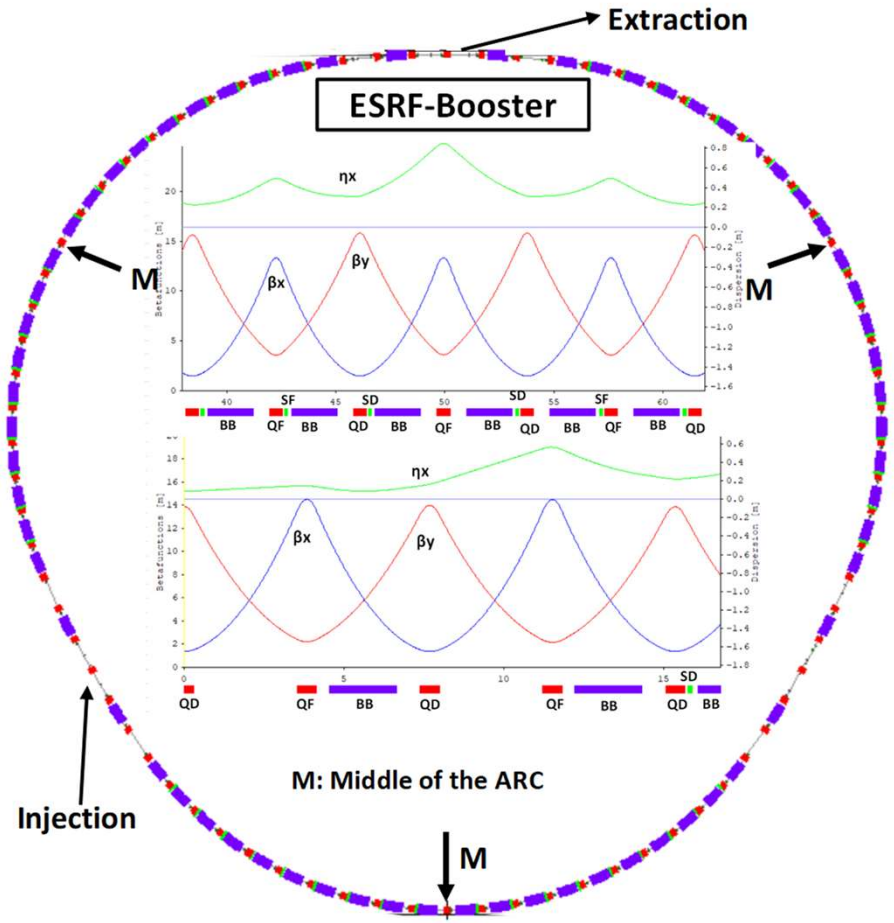
D1: L = 1.0 m, D2: L = 0.74 m, D21: L = 0.29 m, D22: L = 0.25 m

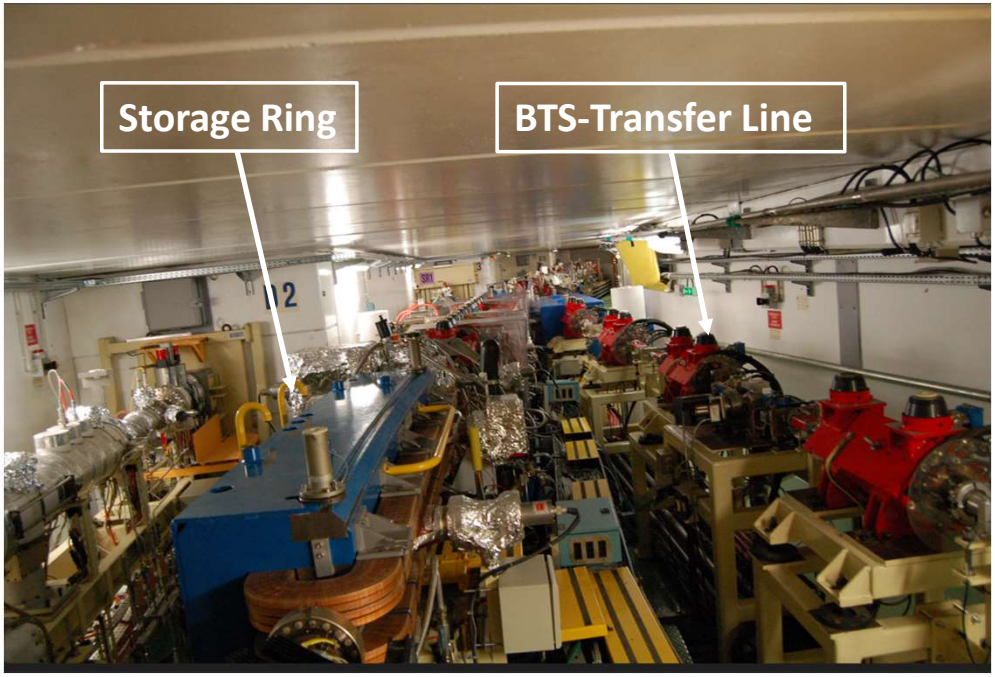
ESRF – Injector (1992)



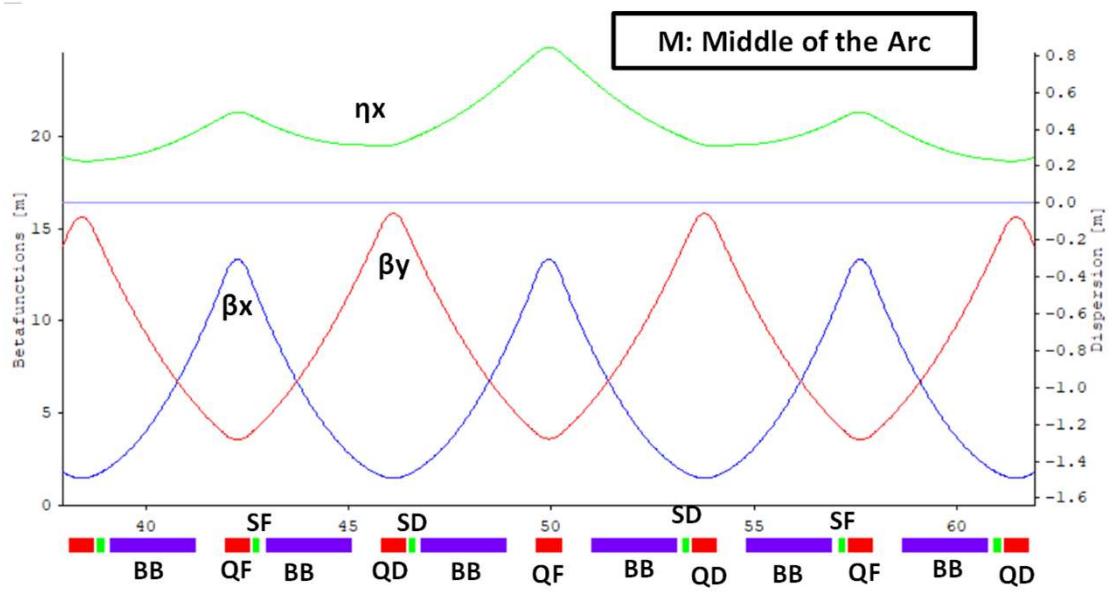
Thomas Perron

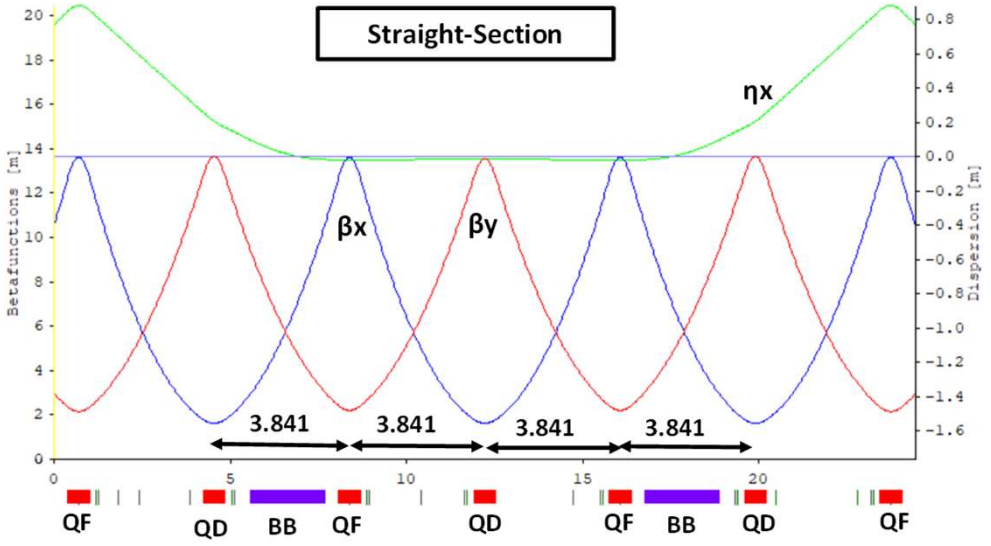
ESRF - Injector





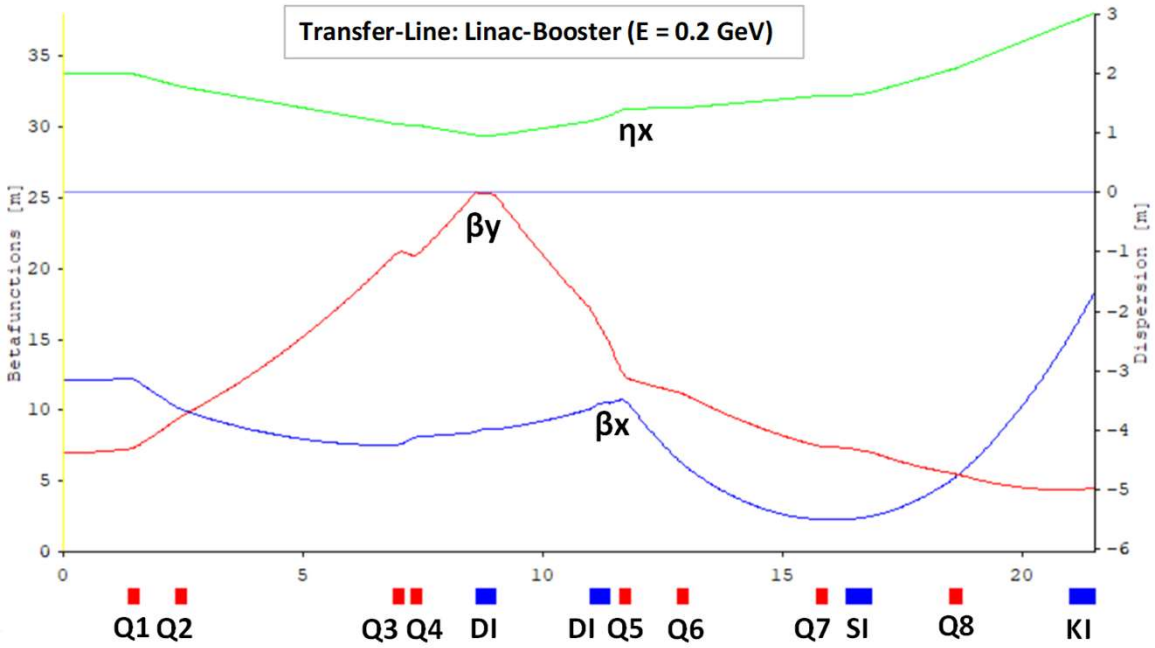
ESRF – Booster: Lattice

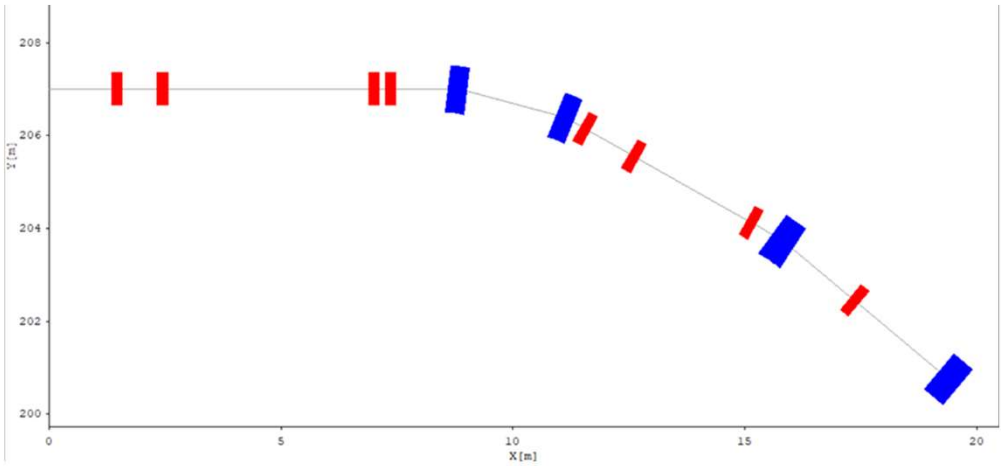




BB: L = 2.094 m, ϕ = 5.4545 °, ρ = 22 m, B = 0.91 T
QF: L = 0.3 m, G = 14.73 T/m, QD: L = 0.3 m, G = 13.21 T/m,
SF: L = 0.14 m, B" = 218 T/m^2, SD: L = 0.14 m, G = 252 T/m^2,

ESRF – Booster: LTB-Transfer-Line





DI: L = 0.3989 m, ρ = 3.05 m, ϕ = 14.725°, ϕ1 = ϕ2 = 7.36°, B = 0.219 T

SI: L = 0.528 m, ρ = 2.87 m, ϕ = 10.5405°, ϕ1 = ϕ2 = 5.27°, B = 0.232 T

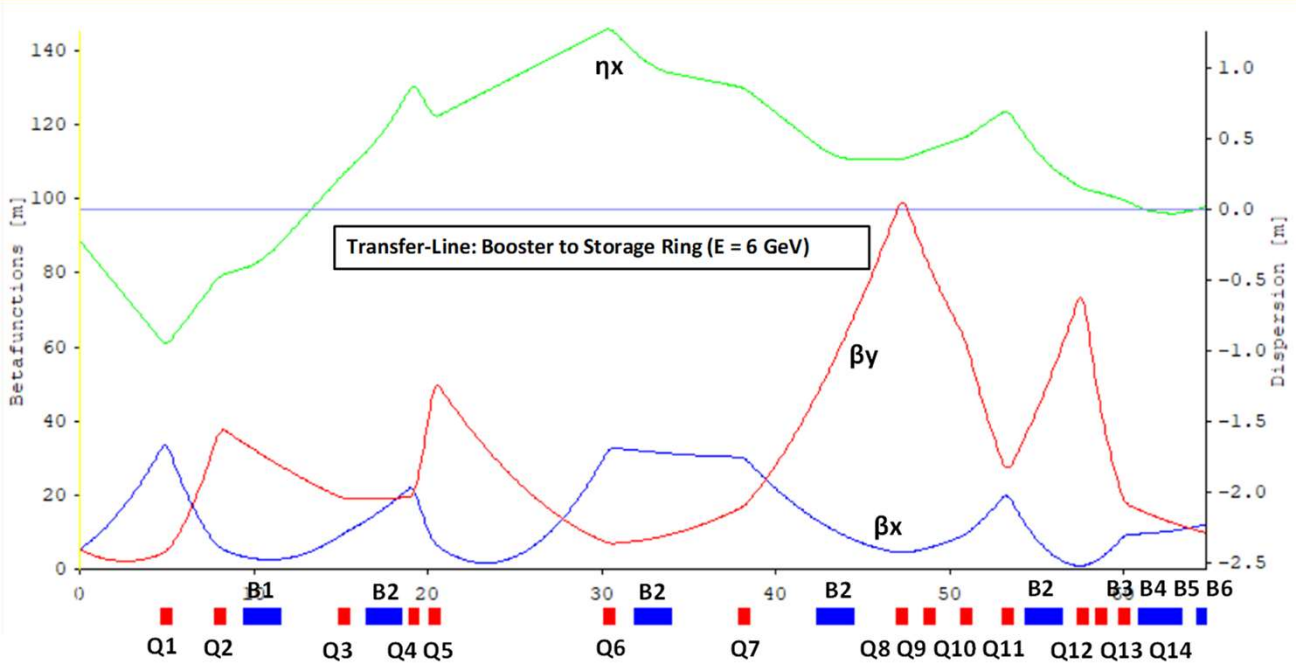
Q1: L = 0.222, G = 0.334 T/m, Q2 =Q6 = -Q7 = Q8 : L = 0.22 m, G = -0.133 T/m,

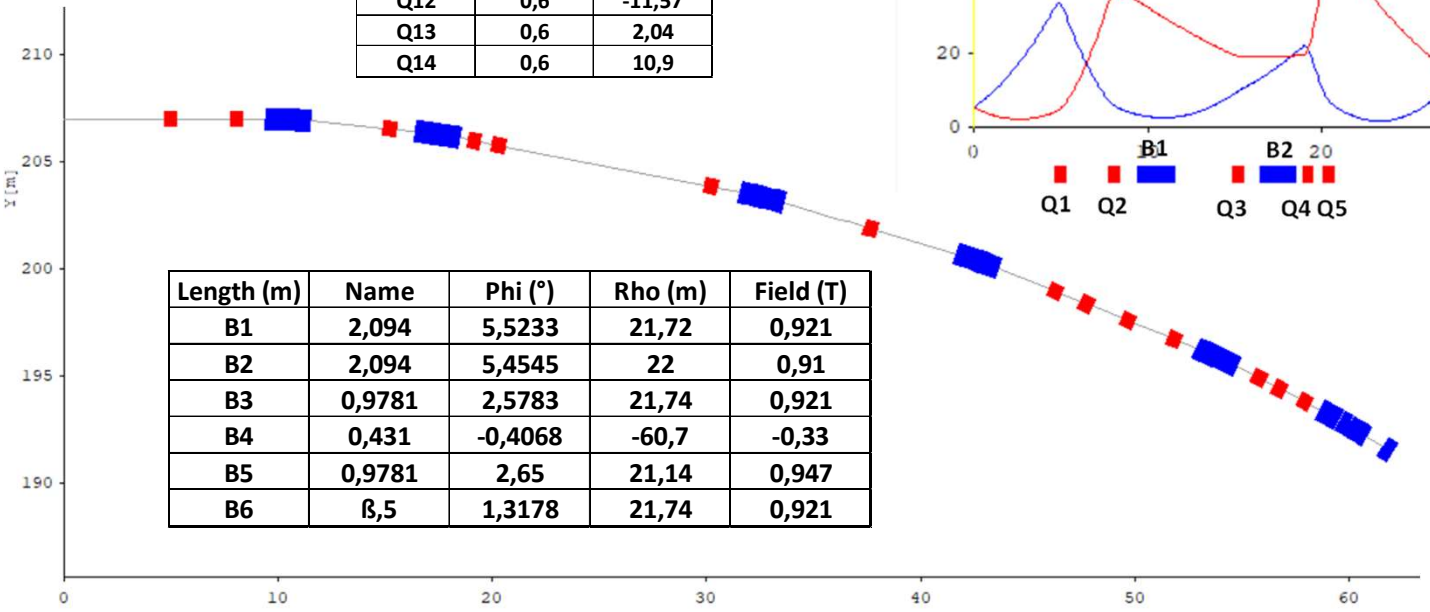
Q3 = -Q4 : L = 0.22 m, G = -0.334 T/m, Q6 : L = 0.22 m, G = 0.8 T/m

KI: L = 0.528 m

ESRF – Booster: BTS-Transfer-Line

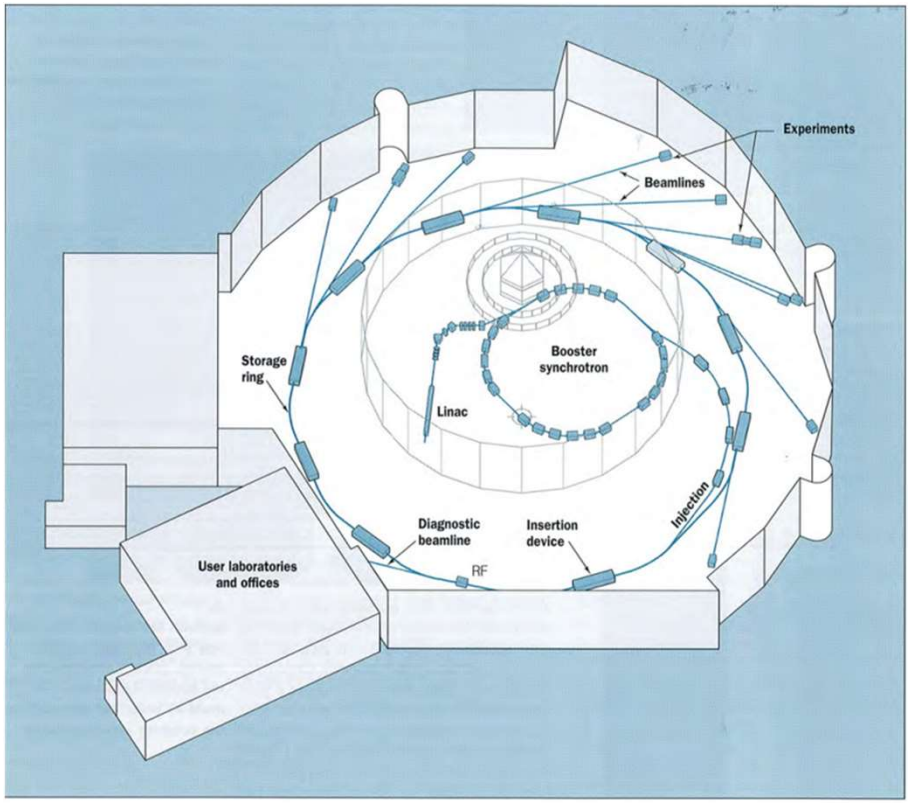
Name	Length	Grad. (T/m)
Q1	0,6	11,16
Q2	0,6	-8,76
Q3	0,6	1,77
Q4	0,6	16,8
Q5	0,6	-13,87
Q6	0,6	7,27
Q7	0,6	2,79
Q8	0,6	-4,35
Q9	0,6	0,33
Q10	0,6	-2,66
Q11	0,6	12,7
Q12	0,6	-11,57
Q13	0,6	2,04
Q14	0,6	10,9





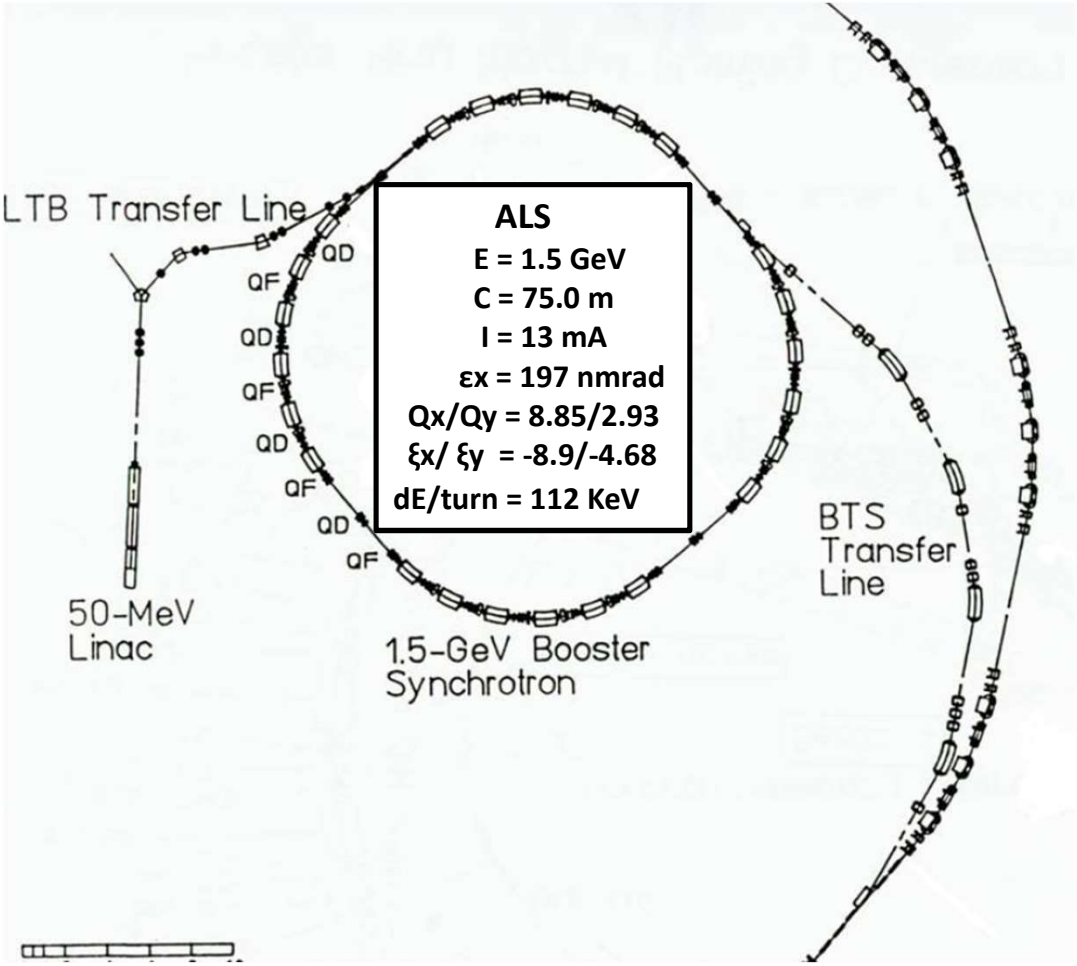
Length (m)	Name	Phi (°)	Rho (m)	Field (T)
B1	2,094	5,5233	21,72	0,921
B2	2,094	5,4545	22	0,91
B3	0,9781	2,5783	21,74	0,921
B4	0,431	-0,4068	-60,7	-0,33
B5	0,9781	2,65	21,14	0,947
B6	ß,5	1,3178	21,74	0,921

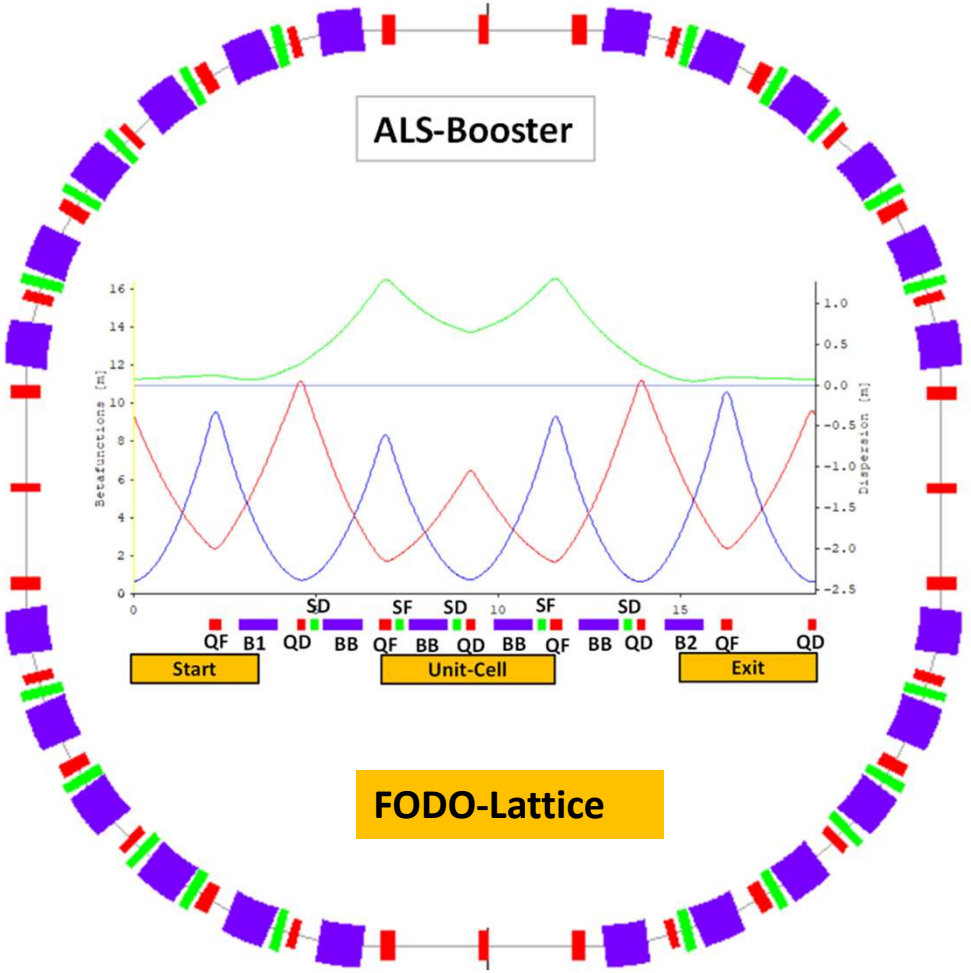
ALS – Injector (1993)



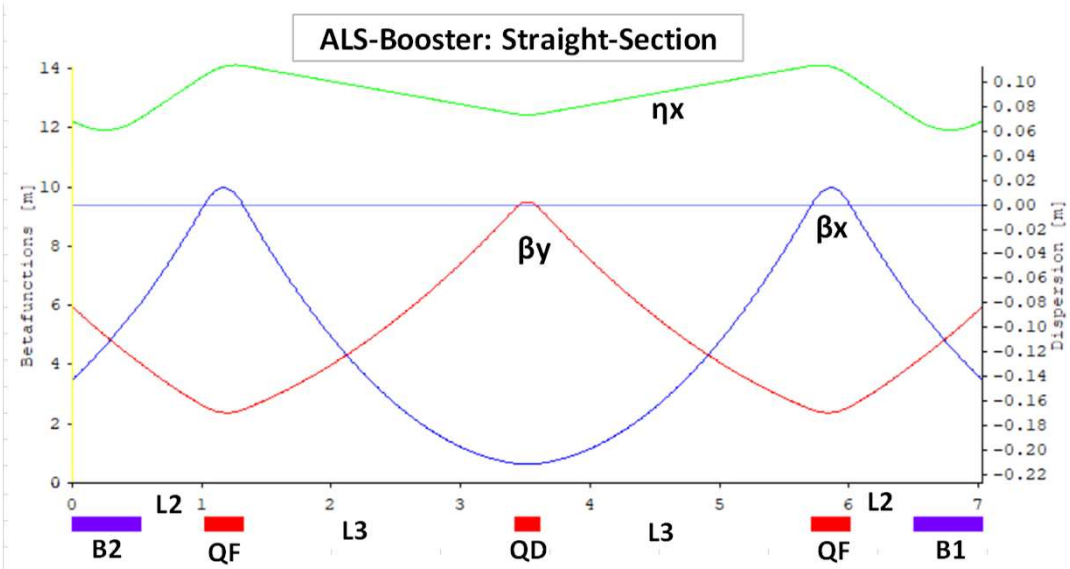
Christoph Steier

ALS – Injector

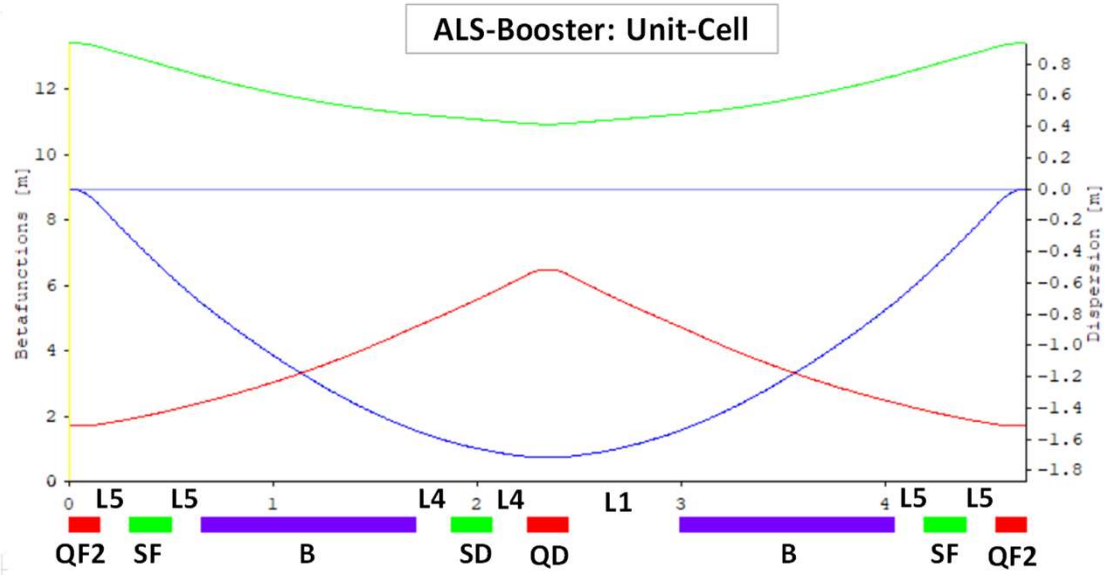




ALS – Booster-Lattice



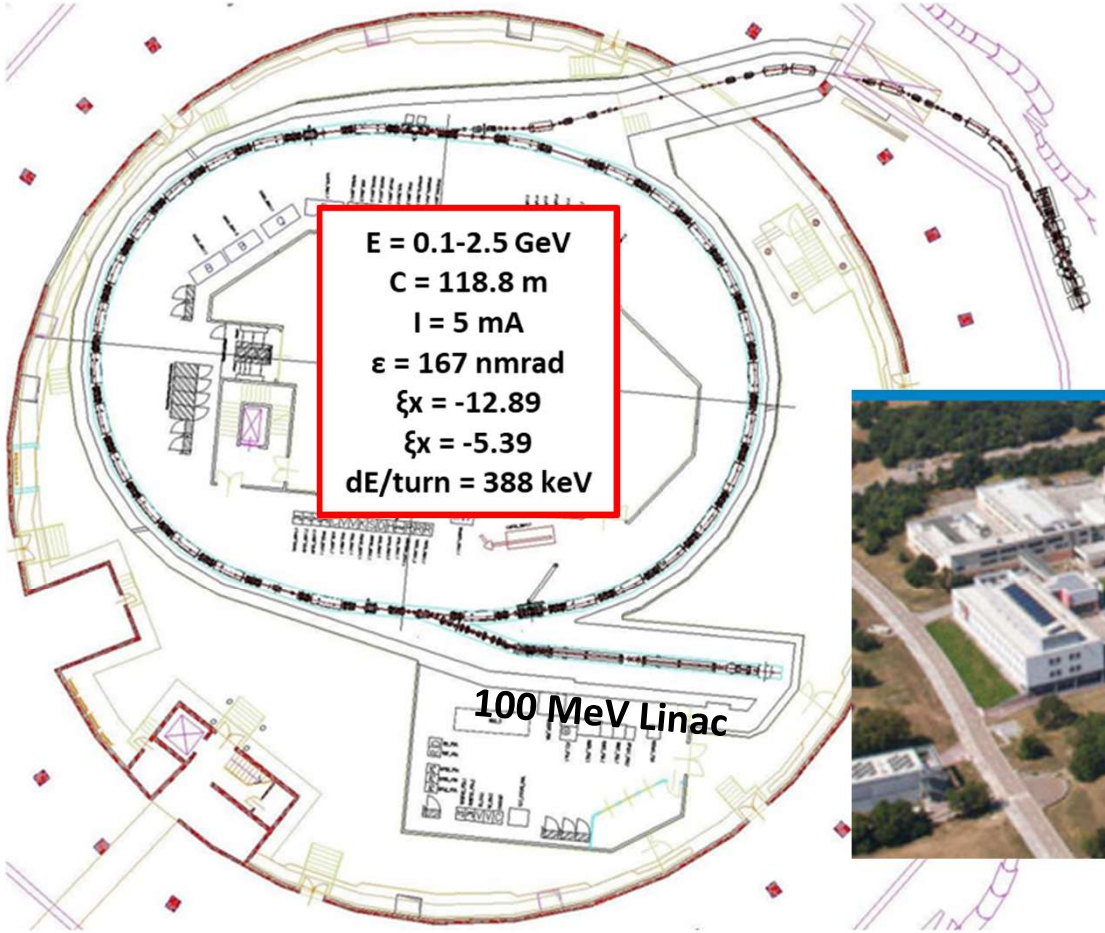
B1: L = 0.525 m, ρ = 4.011, ϕ = 7.5°, ϕ1 = 7.5°, ϕ2 = 0.0°, B = 1.247 T
B2: L = 0.525 m, ρ = 4.011, ϕ = 7.5°, ϕ1 = 0.0°, ϕ2 = 7.5°, B = 1.247 T
QF: L = 0.3 m, G = 13.3 T/m, QD: L = 0,2 m, G = 12.71 T/m
L2: L = 0.4968 m, L3: L = 2.0938 m

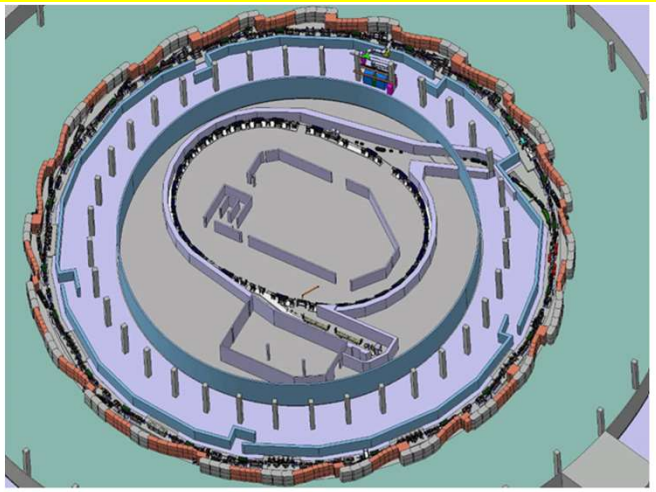


B: L = 1.05 m, ρ = 4.011, ϕ = 15°, ϕ1 = ϕ2 = 7.5°, B = 1.247 T
QF: L = 0.3 m, G = 13.3 T/m, QF2 = QF/2, QD: L = 0,2 m, G = 12.71 T/m
L1: L = 0.547 m, L4: L = 0.1734 m, L5: L = 0.1485 m

ELETTRA – Injector (1993 / 2008)

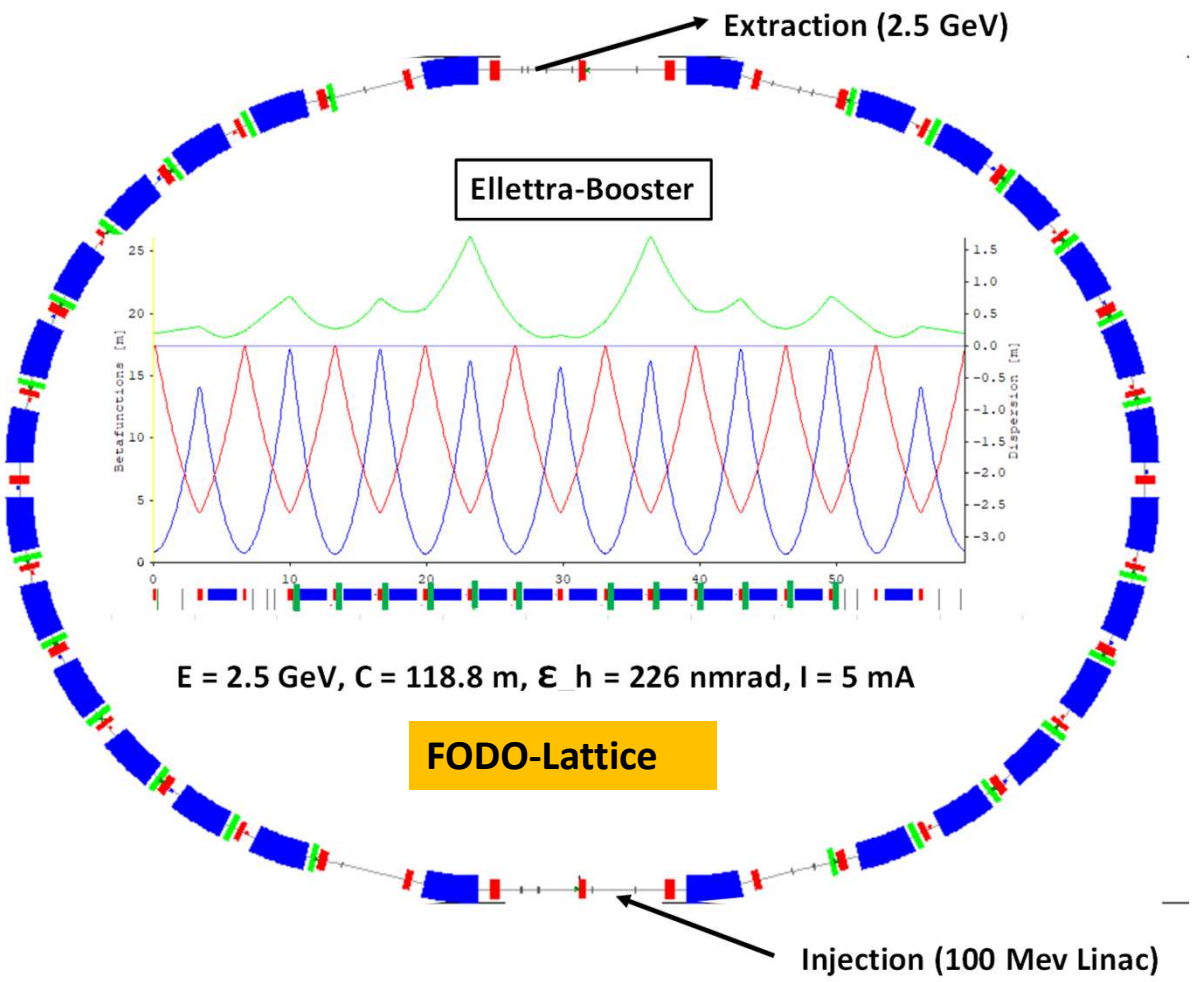
The lattice is the same as for APS (1995)

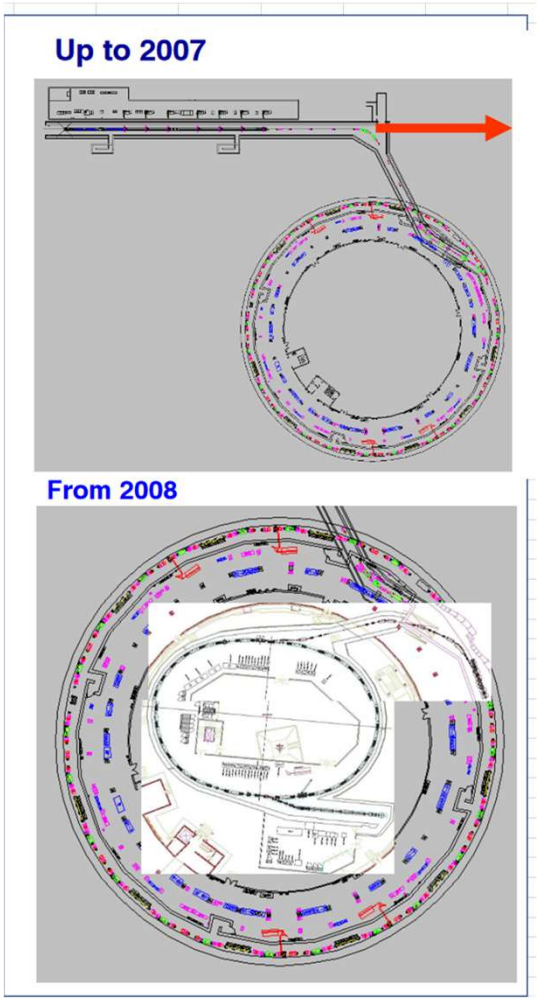




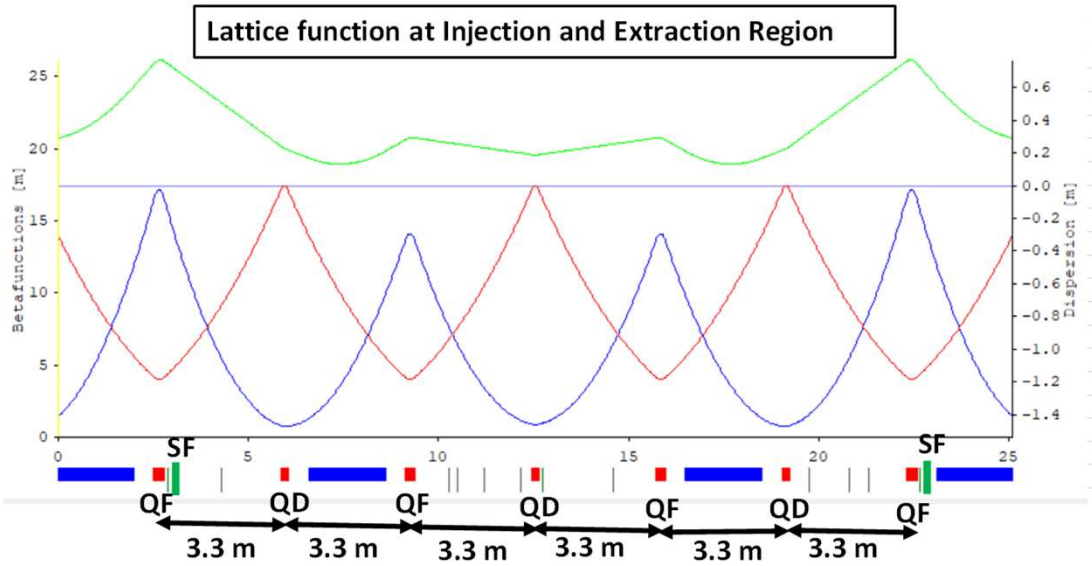
Stefano Krecic

ELETTRA – Booster (2008)





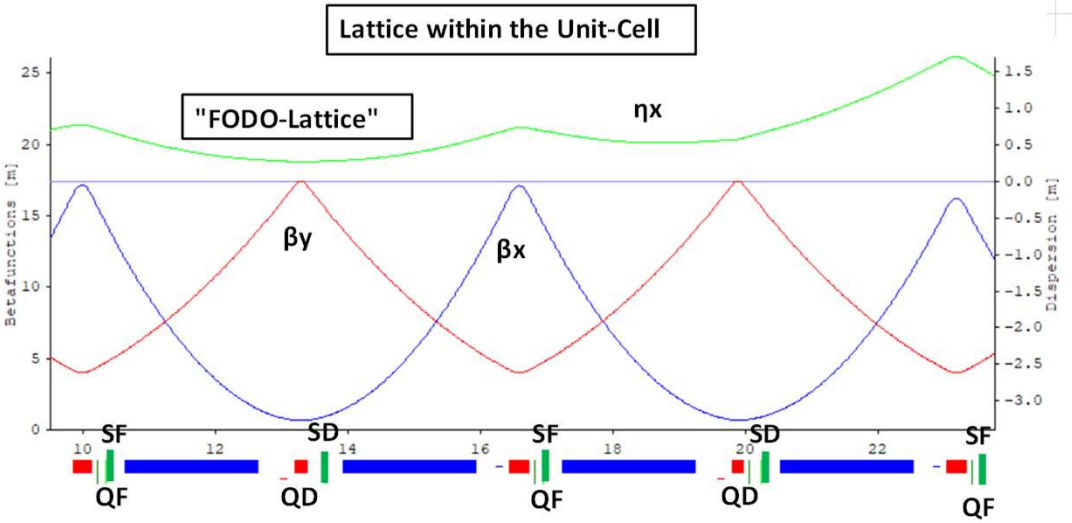
ELETTRA – Booster-Lattice



Bending: L = 2m, ϕ = 12.857 degrees, ρ = 8.909 m, B = 0.936 T

QF: L = 0.28 m, k= 2.033, G = 16.95 T/m QD: L = 0.175 m, k= -2.0022, G = 16.86 T/m

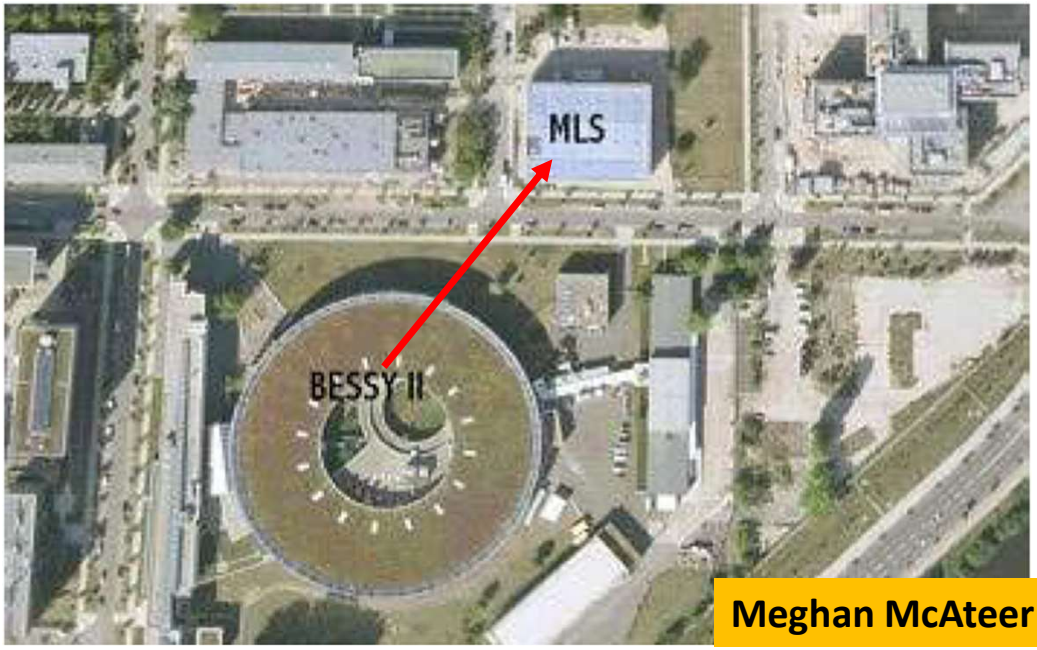
SF: L = 0.2 m, m = 5,575, B'' = 43 T/m^2



SF: L = 0.2 m, B'' = 43 T/m^2 SD: L = 0.2 m, B'' = 65 T/m2

BESSY II – Booster (1997)

MLS:
Metrology Light SOURCE



Meghan McAteer

BESSY II - Booster

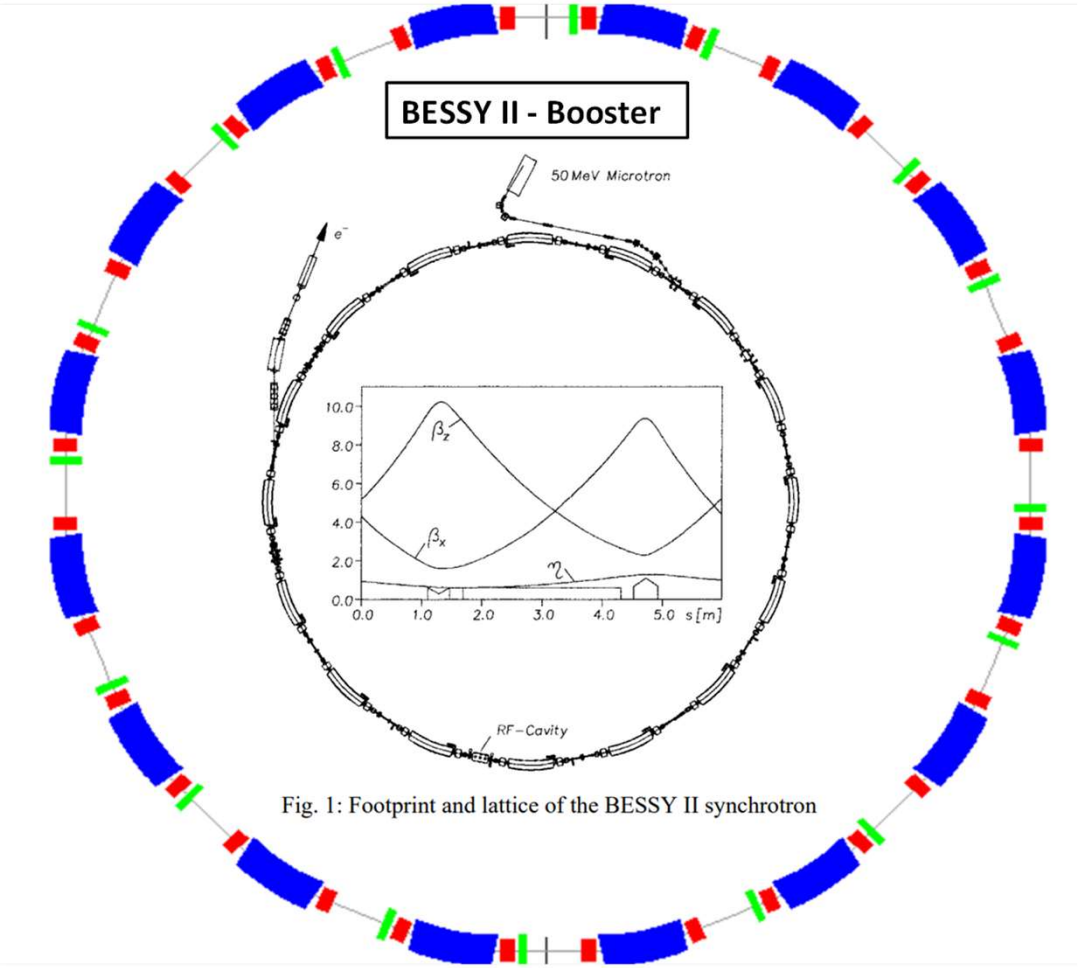
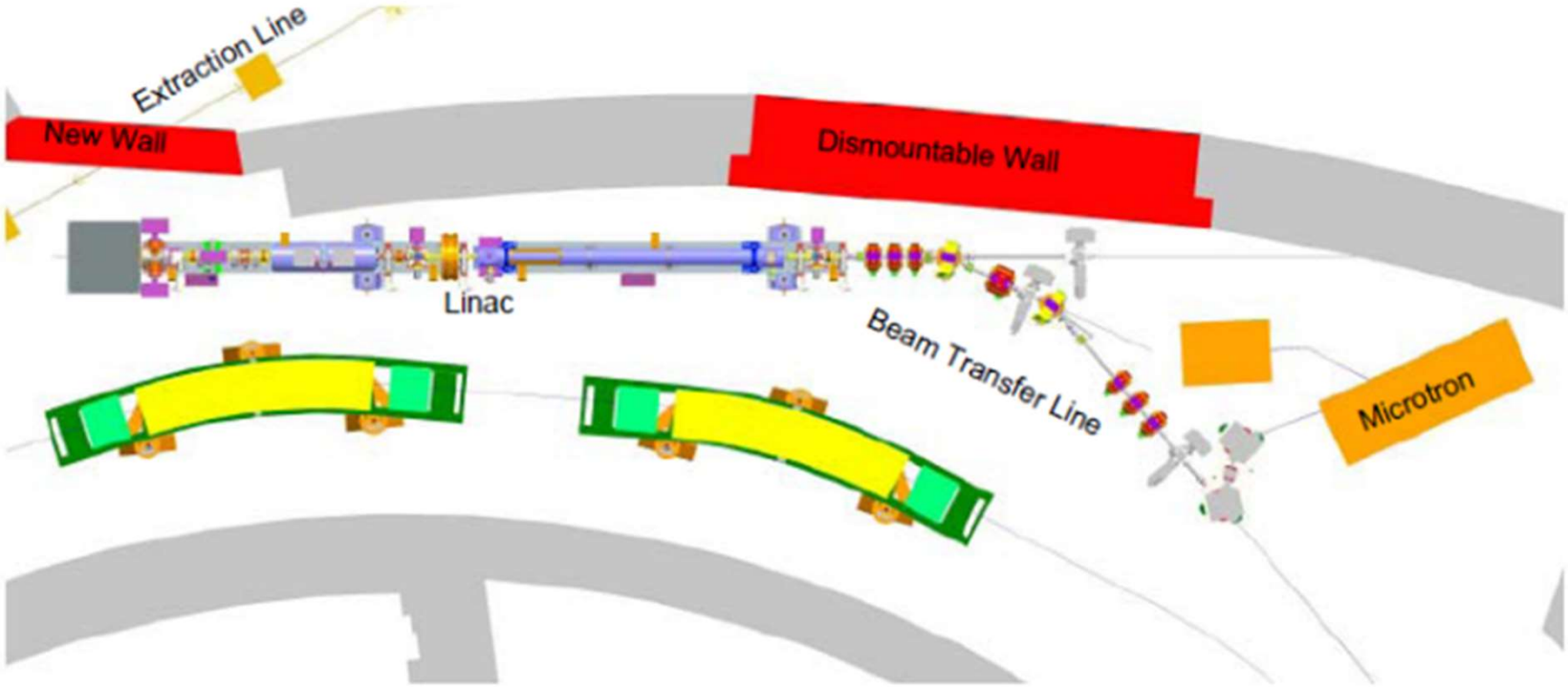


Fig. 1: Footprint and lattice of the BESSY II synchrotron

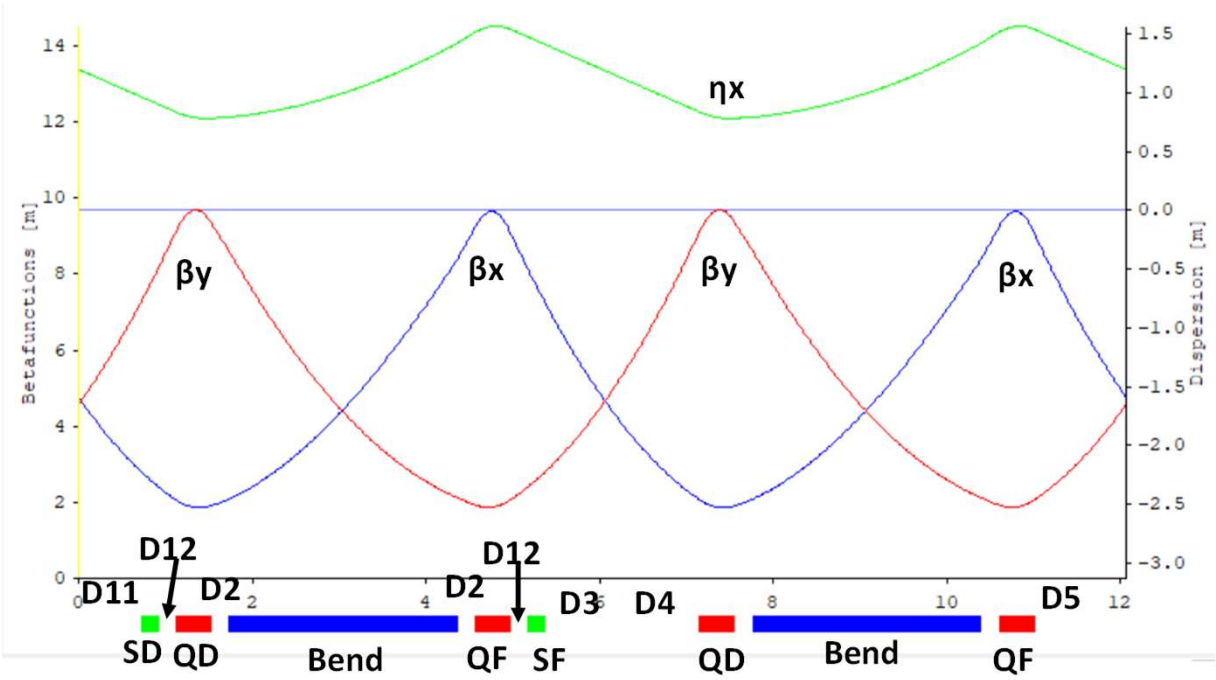
BESSY II -Booster
E = 0.1 - 2.0 GeV
C = 96 m
I = 3 mA
ε = 200 nmrad
Qx = 4.42
Qy = 3.38
ξx = -4.7
ξx = -3.9
dE/turn = 388 keV

Magnet	Number	Strength	Length	Gap/Radius
Dipoles	16	1. T	2621 mm	h = 36 mm
Quads	32	14. T/m	300 mm	r = 35 mm
Sext.	16	70 T/m^2	150 mm	r = 35 mm
Steerer	16	0.05 T	150 mm	h = 120 mm

BESSY II - Booster



BESSY II – Booster: Unit-Cell



Bend: L = 2.61 m, ϕ = 22.5 °, ρ = 6. 67 m, B = 1.0 T

QF: L = 0.4 m, k = 1.235 , G = 8.46 T/m, QD = 0.4 m, k = -1.157, G = -7.97 T/m

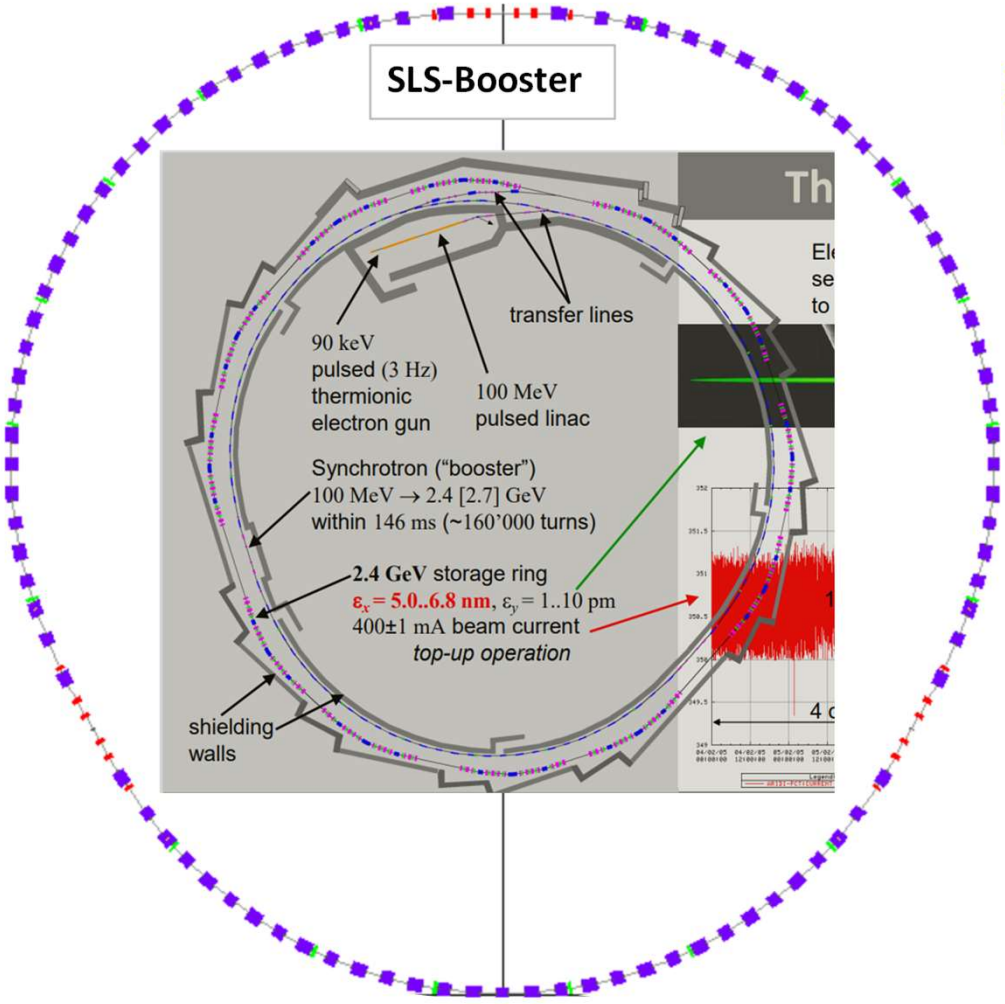
SF: L = 0.2 m, B'' = 34.2 T/m^-2 , SD: L = 0 2 m, B'' = -53 T/m^-2

D11: L = 0.72 m, D12 = 0.2 m, D2 = 0.215 m, D3: L = 0.66 m, D4: L= 1.12 m, D5 = 1,06 m

Paul Scherrer Institut: SLS – Booster (2001)

Jonas Kallestrup

SLS - Booster



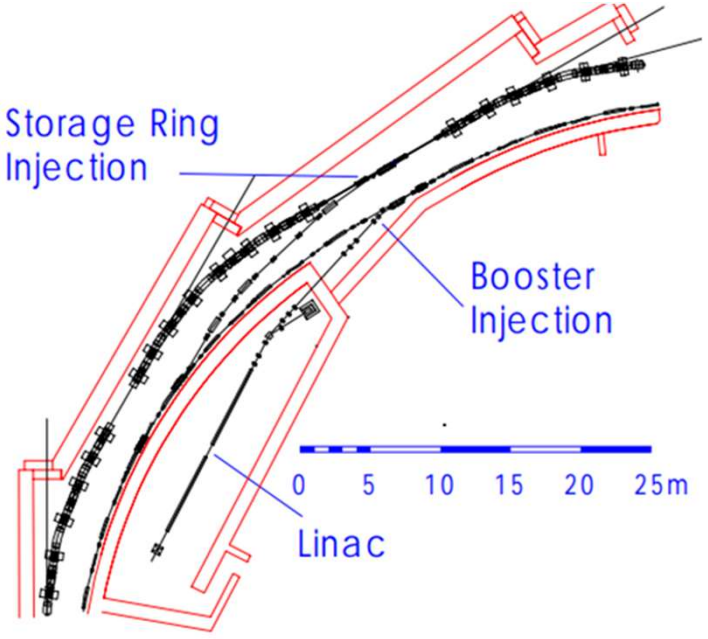
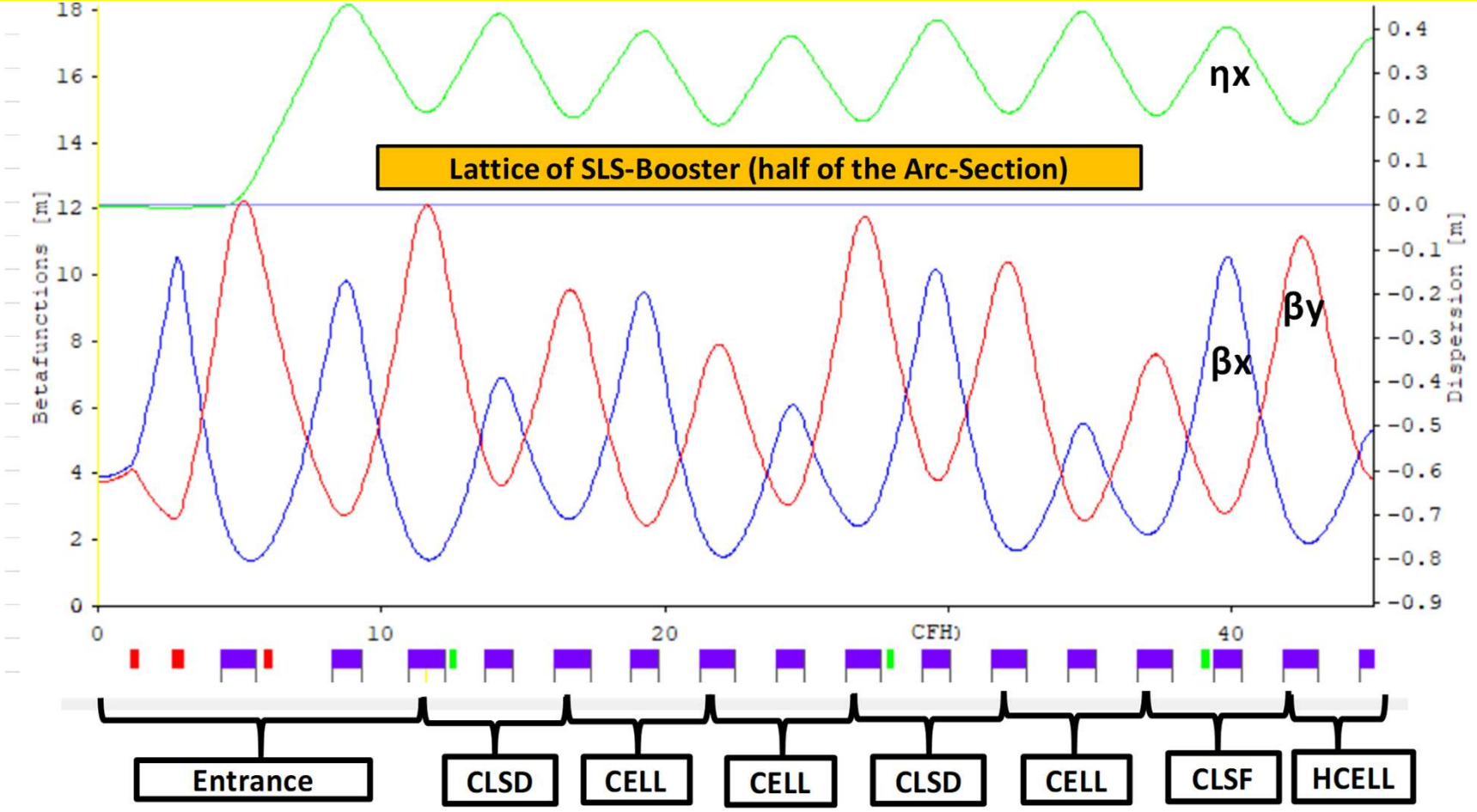


Figure 1: Layout of the tunnel, showing the storage ring, booster, linac and the transfer lines.

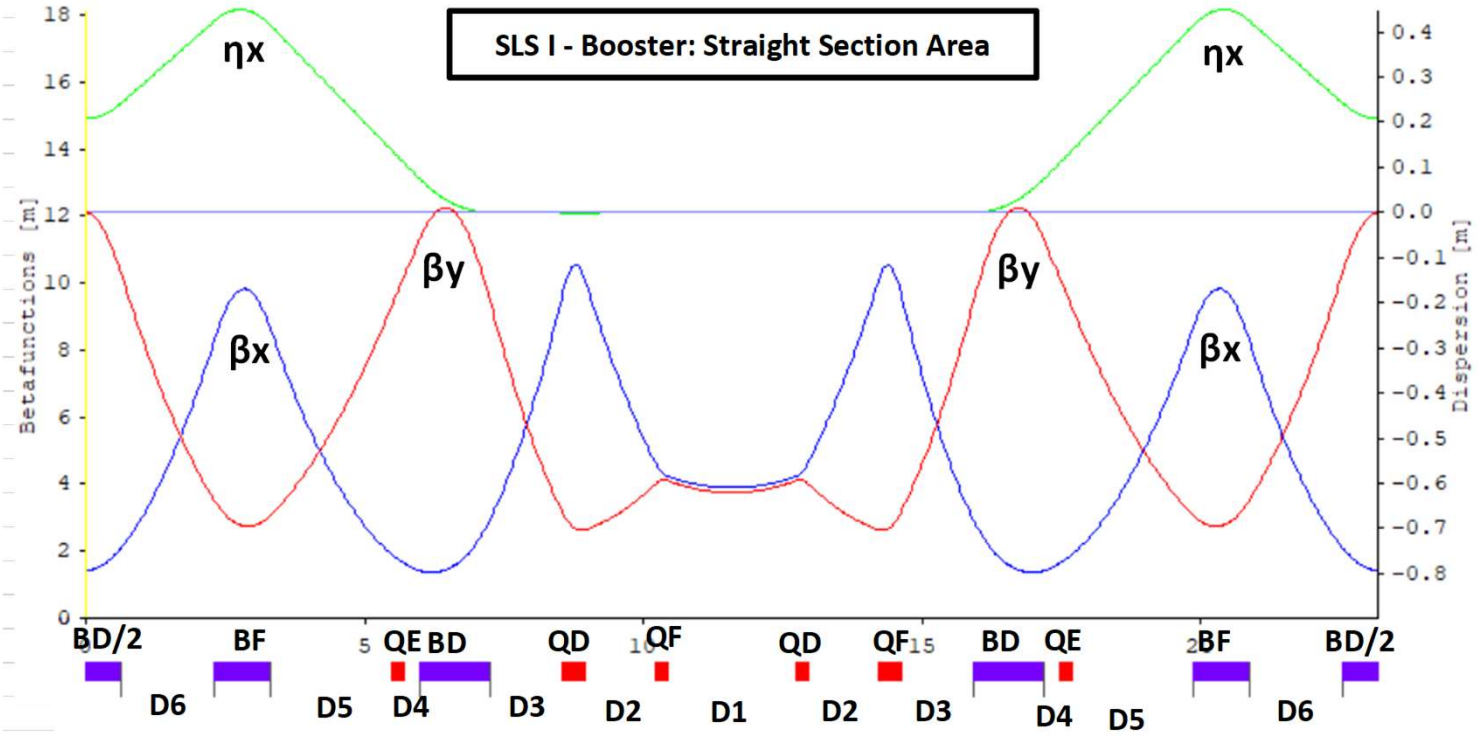
E = 0.1-2.4 GeV
C = 270 m
I = 12 mA
ε = 9.1 nmrad
ξx = -14.6
ξx = -11.6
dE/turn = 233 keV

At SLS it was for the first time to build the storage ring and the booster in the same tunnel.

SLS - Booster


Lattice of SLS-Booster (half of the Arc-Section)
ηx
βx
βy
Betafunctions [m]
Dispersion [m]
CFH)
Entrance
CLSD
CELL
CELL
CLSD
CELL
CLSF
HCELL

SLS - Booster



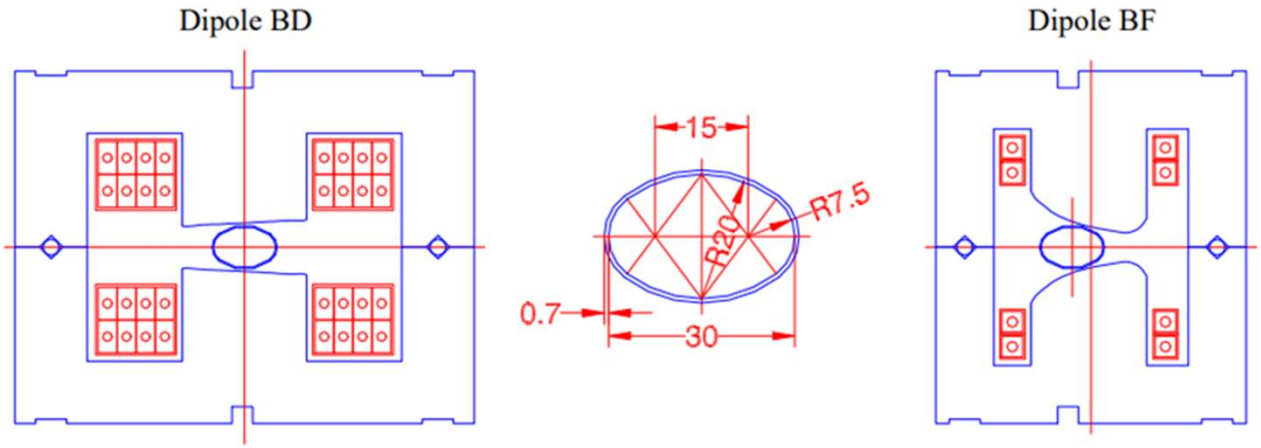
BF: L = 1 m, ϕ = 1.1296, B = 0.157 T, ρ = 50.72 m, G = 4.66 T/m, B" = 15.0 T/m^3, CFH = half of CF

BD: L = 1.26 m, ϕ = 6.441, B = 0.714 T, ρ = 11.21 m, G = 3.09 T/m, B" = 19.5 T/m^3, CFH = half of CF

QD: L = 0.22 m, G = 3.09 T/m, QF: L = 0.4 m, G = 12.25 T/m, QE: L = 0.22 m, G = 0.8 T/m

D1: L = 2,32 m, D2: L = 1.25 m, D3: L = 1.31 m, D4: L = 0.29 m, D5: L = 2.17 m, D6 = 1.68 m

SLS - Booster



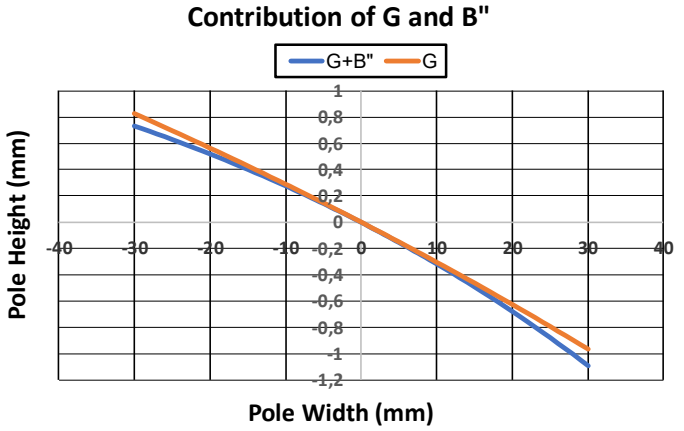


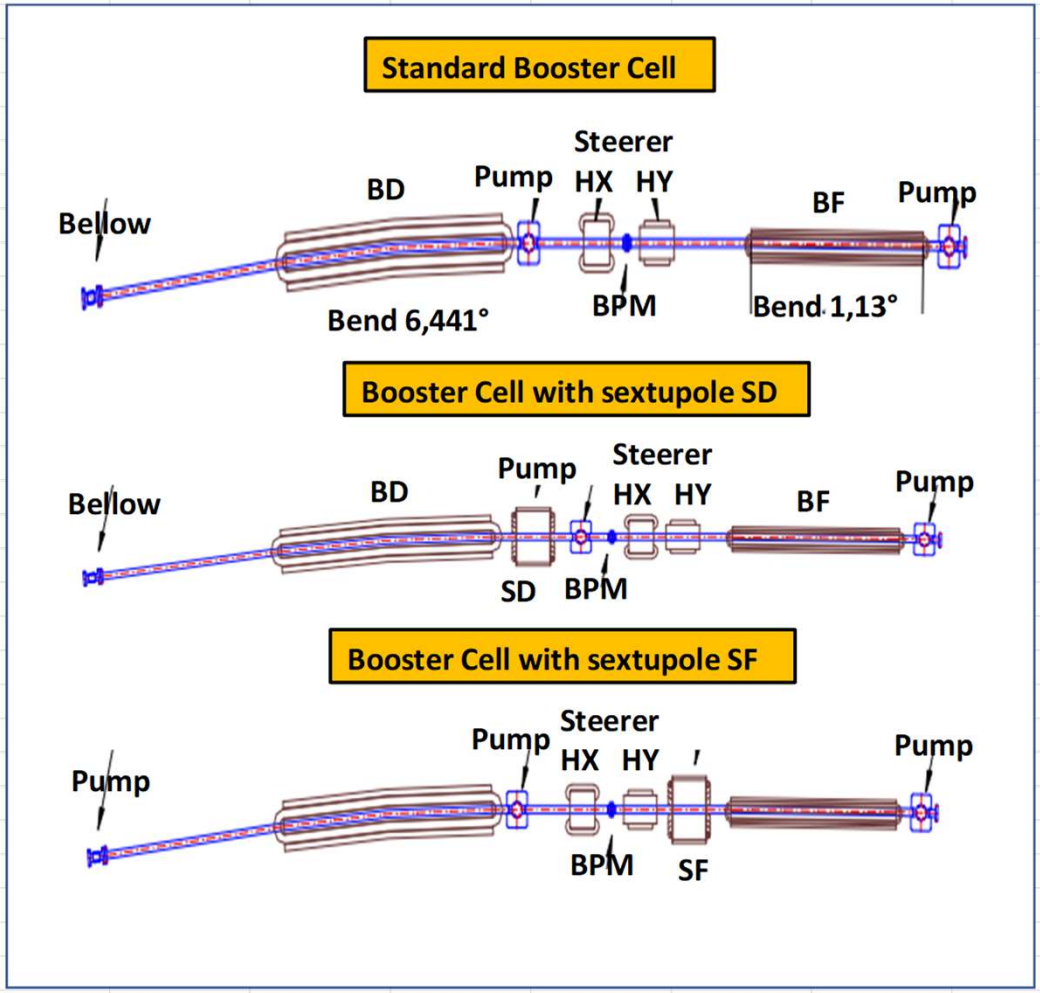
Figure f324 a: Cross section of the beam pipe with the dipoles BD and BF.

Dipoles (comb. function)	**BD**	**BF**
Total number	48	45
magnetic length	1.26 m	1.0 m
Bend angle	6.441 ^{0}	1.1296 ^{0}
Bend radius	11.21 m	50.72 m
gap at beam center	23.3 mm	26.45 mm
maximum field at 2.4 GeV	0.714 T	0.158 T
maximum gradient	-3.09 T/m	4.66 T/m
max. sext. gradient B_0/a^2	-10 T/m^2	7 T/m^2
turns/pole	8	2
maximum current	840A	840A
average power	2.2 kW	0.6 kW
weight	300 kg	160 kg

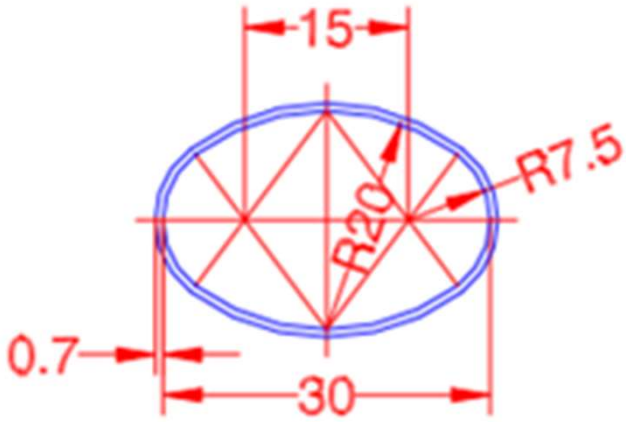
Booster Quads type	long	short
number of quads	6	12
magnetic length	0.4 m	0.22 m
iron length	0.38 m	0.2 m
aperture radius a	18 mm	18 mm
max. gradient at 2.4 GeV	16 T/m	16 T/m
max. poletip field	0.29 T	0.29 T
number of turns/pole	15	15
resistance	65 mΩ	40 mΩ
inductance	5 mH	3 mH
max. current	140 A	140 A
max. voltage	15 V	10 V
max. average power	0.5 kW	0.3 kW
weight	130 kg	70 kg

number of sextupoles	18
magnetic length	0.2 m
aperture radius a	18 mm
max. $B_0/a^2 = 0.5 \cdot B"$	200 T/m^2
max. poletip field B_0	0.063 T
Ampturns/pole	300
number of turns/pole	50
resistance	1.0 Ω
inductance	40 mH
max. current SF/SD	6 A / 4 A
max. voltage SF/SD	8 V/ 5 V
max. average power	ca. 20 W
weight	30 kg

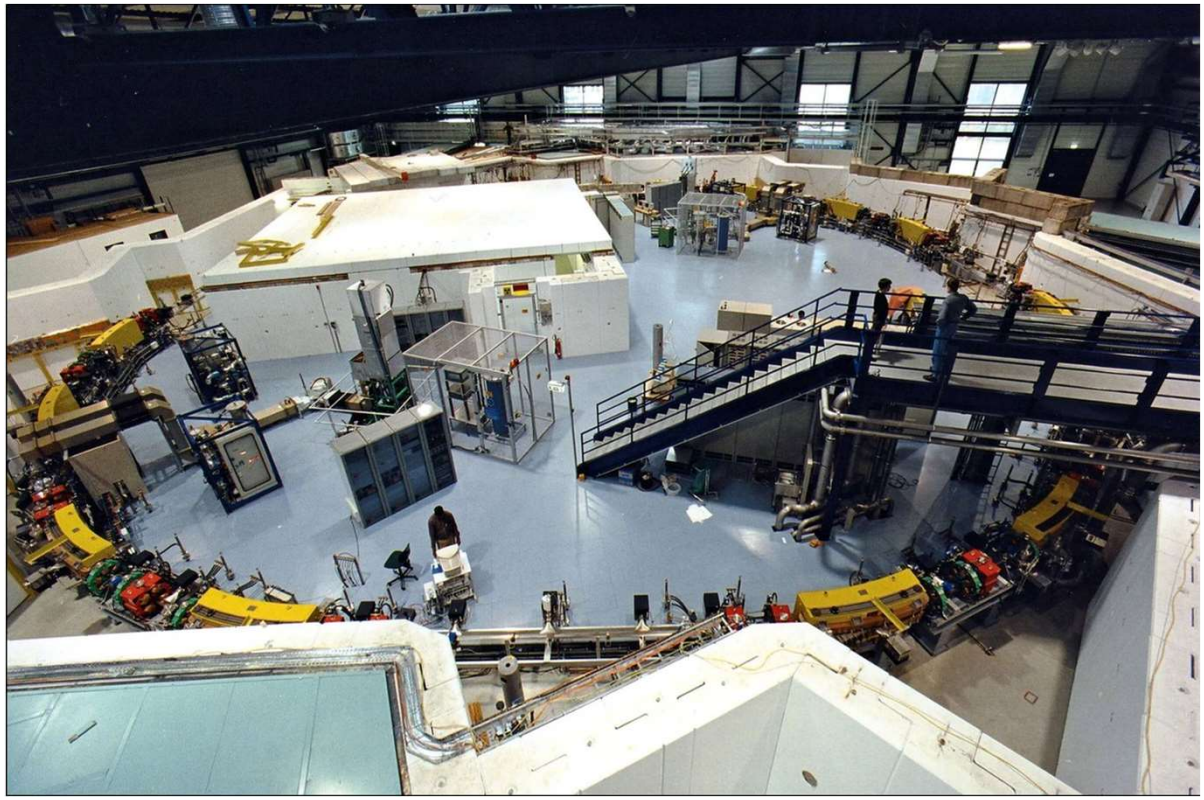
SLS – Booster: Vacuum System



Top view of the FODO cells in the SLS booster with the dipoles BD and BF. After each dipole a small pump is installed

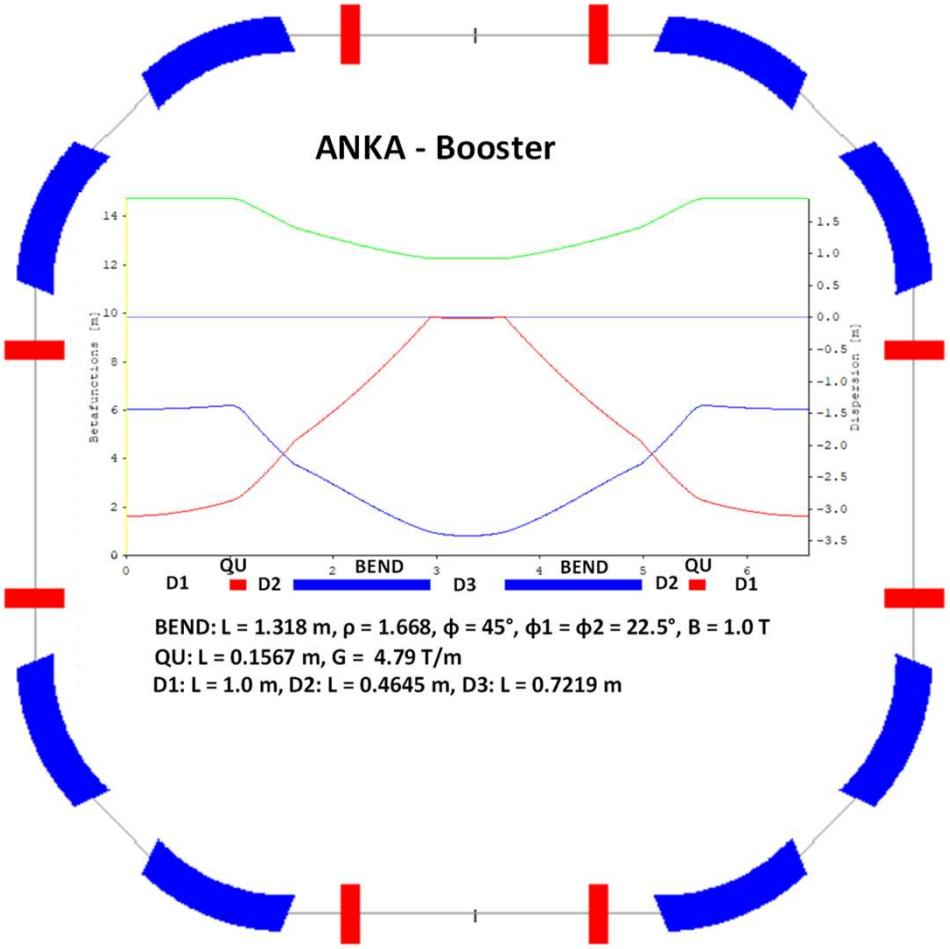


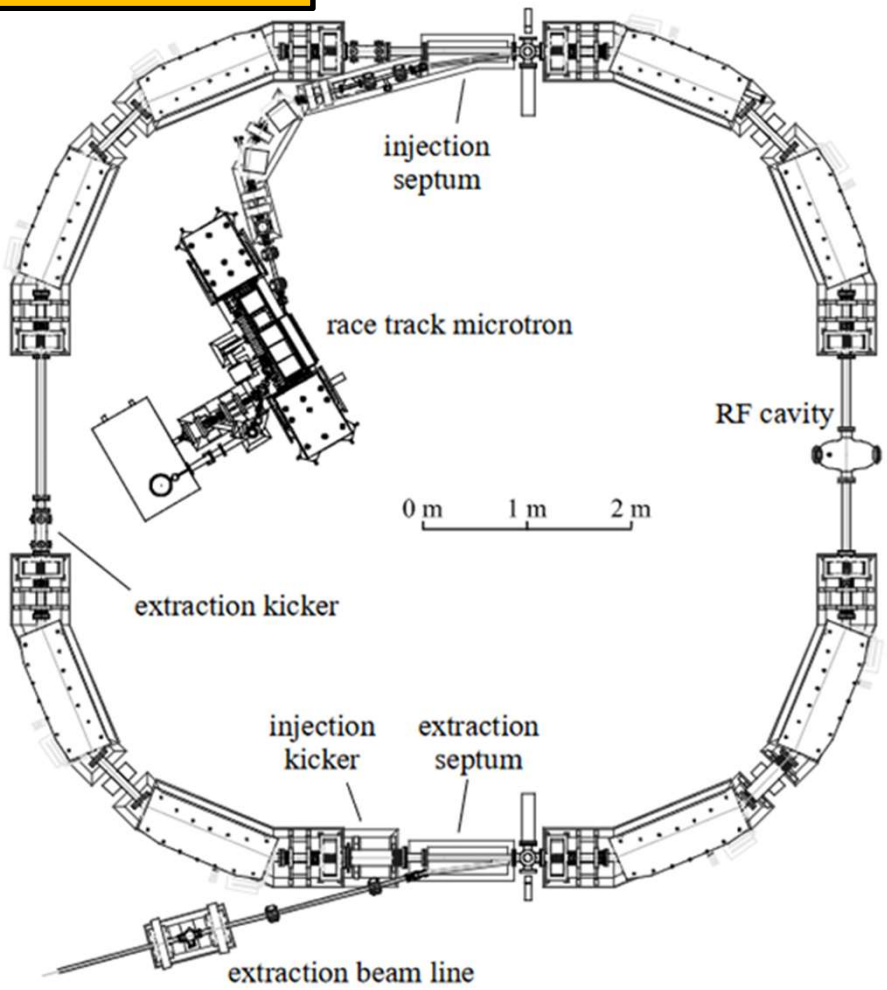
ANKA / KARA (2001)



ANKA - Booster

The Booster was built by Danfysik



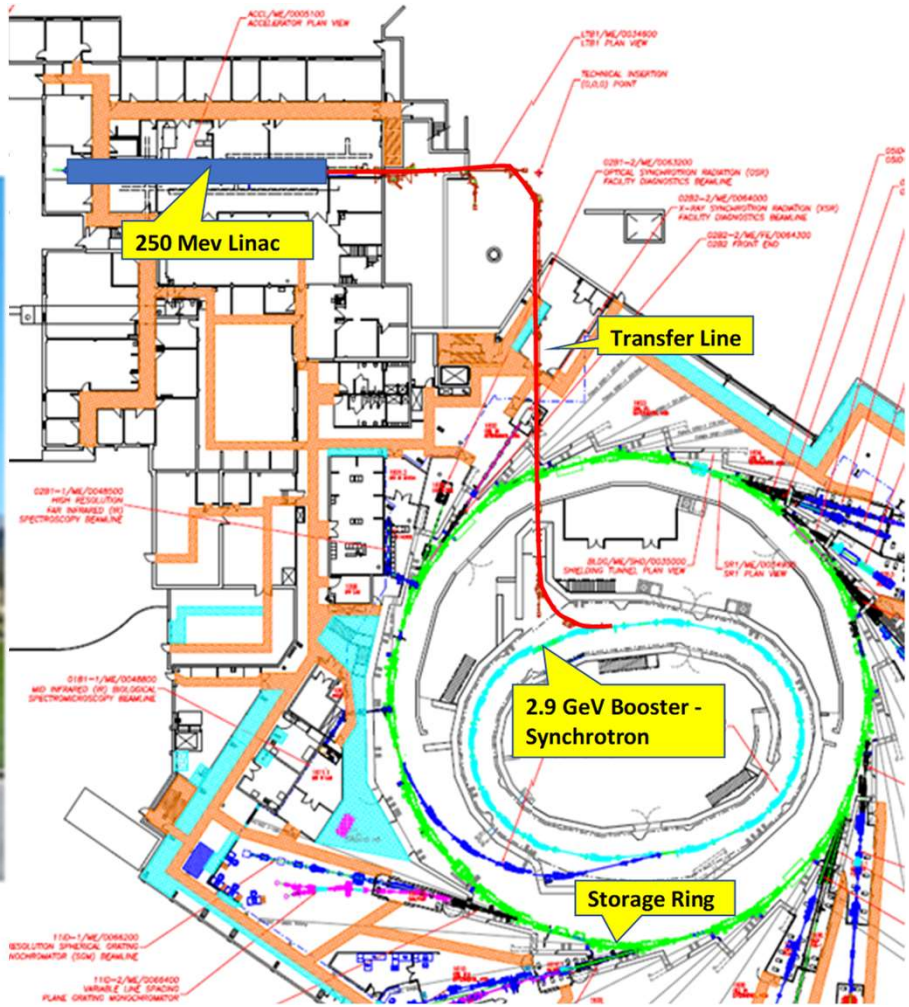


ANKA - Booster

Canadian Light Source (CLS) – Injector (2006)

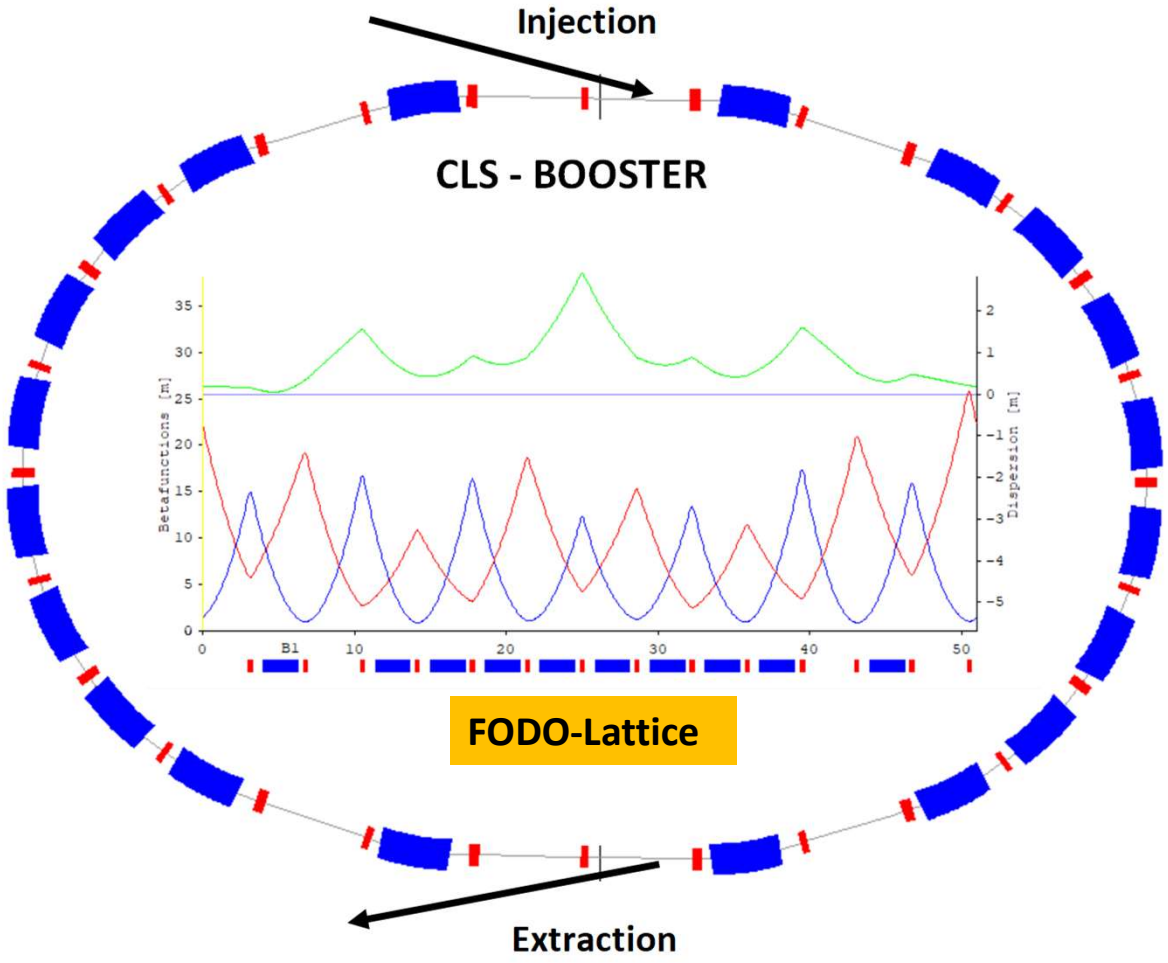
The lattice is the same as for Diamond (2006) and for SOLEIL (2006)

Figure 8. CLS Building.



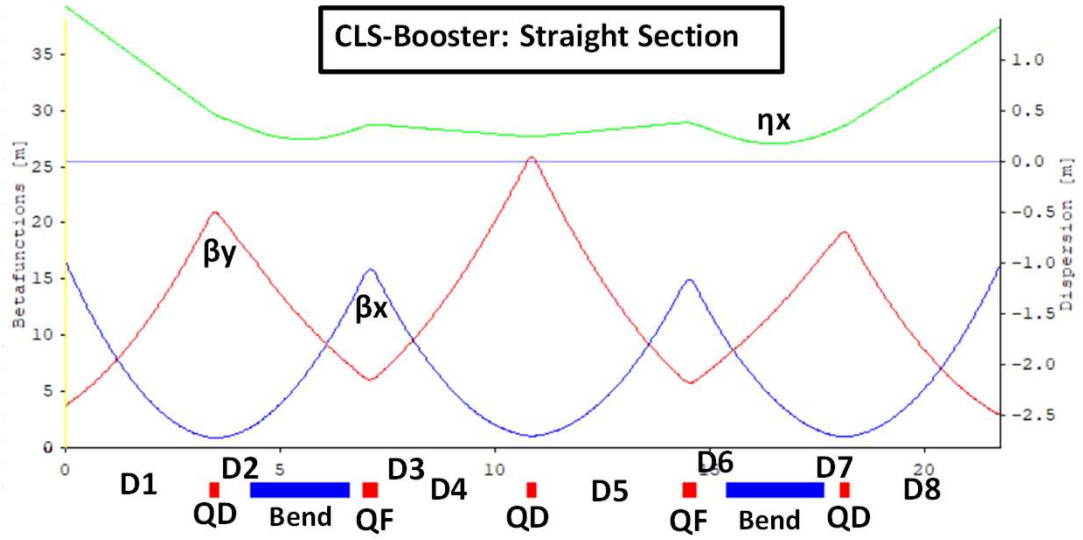
The booster was built by Danfysik

CLS – Injector: Layout and Parameters

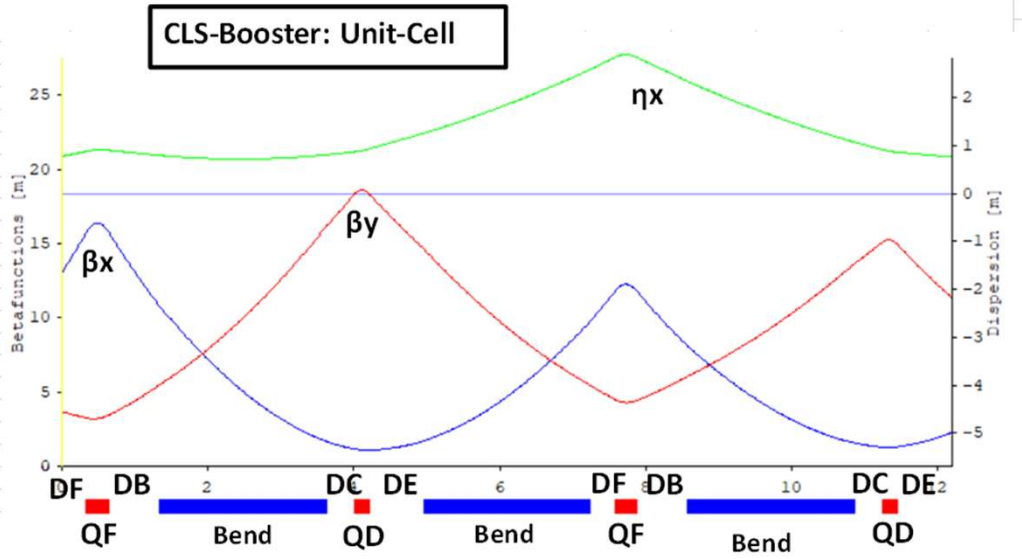


CLS
E = 2.9 GeV
C = 102.528 m
I = >10 mA
ε = 523 nmrad
Qx = 5.18
QY = 2.38
ξx = -6.87
ξx = -4.03
dE/turn = 863 keV

CLS - Booster



Bend: L = 2.61 m, ϕ = 22.5 °, ρ = 6. 67 m,B = 1.45 T
QF: L = 0.3 m, G = 14.61 T/m , QD = 0.2 m, G= -16.49 T/m
D1 = 3.37 m, D2 = 0.75 m, D3 = 0.335 m, D4: L = 3.516 m, D5: L= 3.42 m,
D6 = 0,705 m, D7 = 0.385 m, D8 = 3.516 m



Bend: L = 2.61 m, ϕ = 22.5 °, ρ = 6. 67 m
QF: L = 0.3 m, G = 14.61 T/m , QD = 0.2 m, G= -16.49 T/m
DF = 0.335 m, DB = 0.705 m, DC = 0.385 m, DE: L = 0.755 m

Sextupole magnets are not implemented in the lattice for correction of the natural chromaticity's to positive values since the head-tail is not considered to cause any problems for beam current below ≈50 mA

CLS - Booster

Figure 5: Fully installed section of the booster synchrotron with 4 girder.

ASP/ANSTO – Booster (2007)

The lattice is the same as for NSLS II (2015)

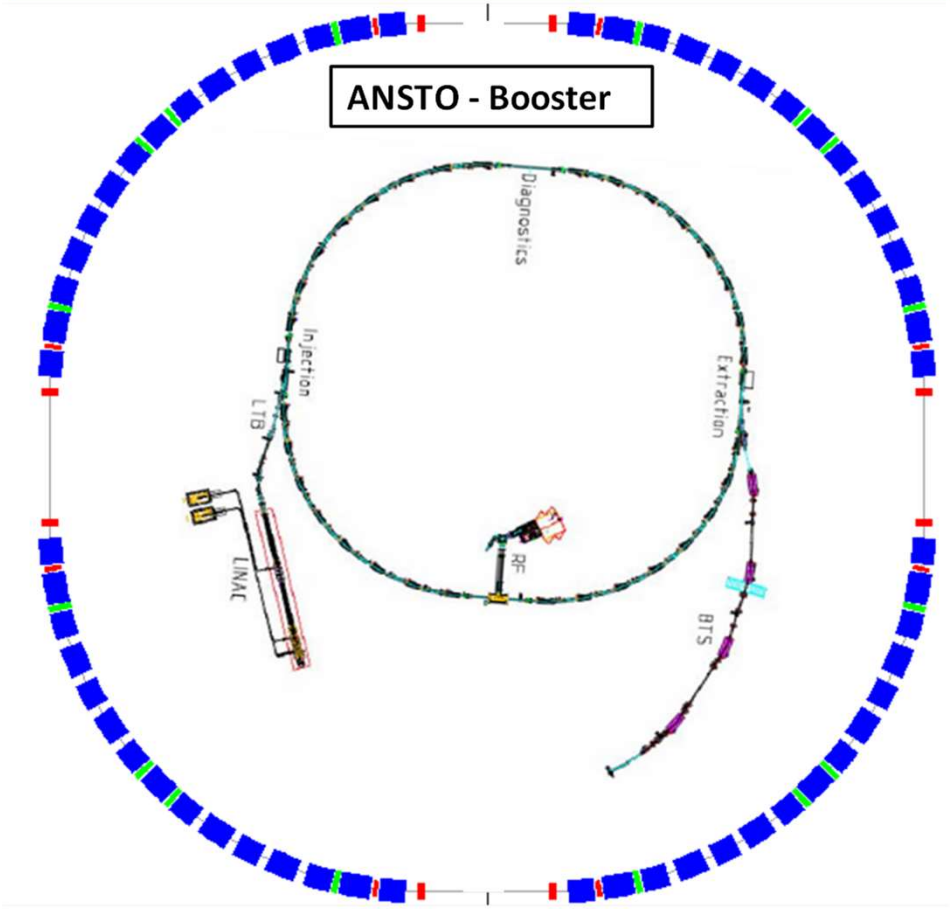
Australian Synchrotron Project

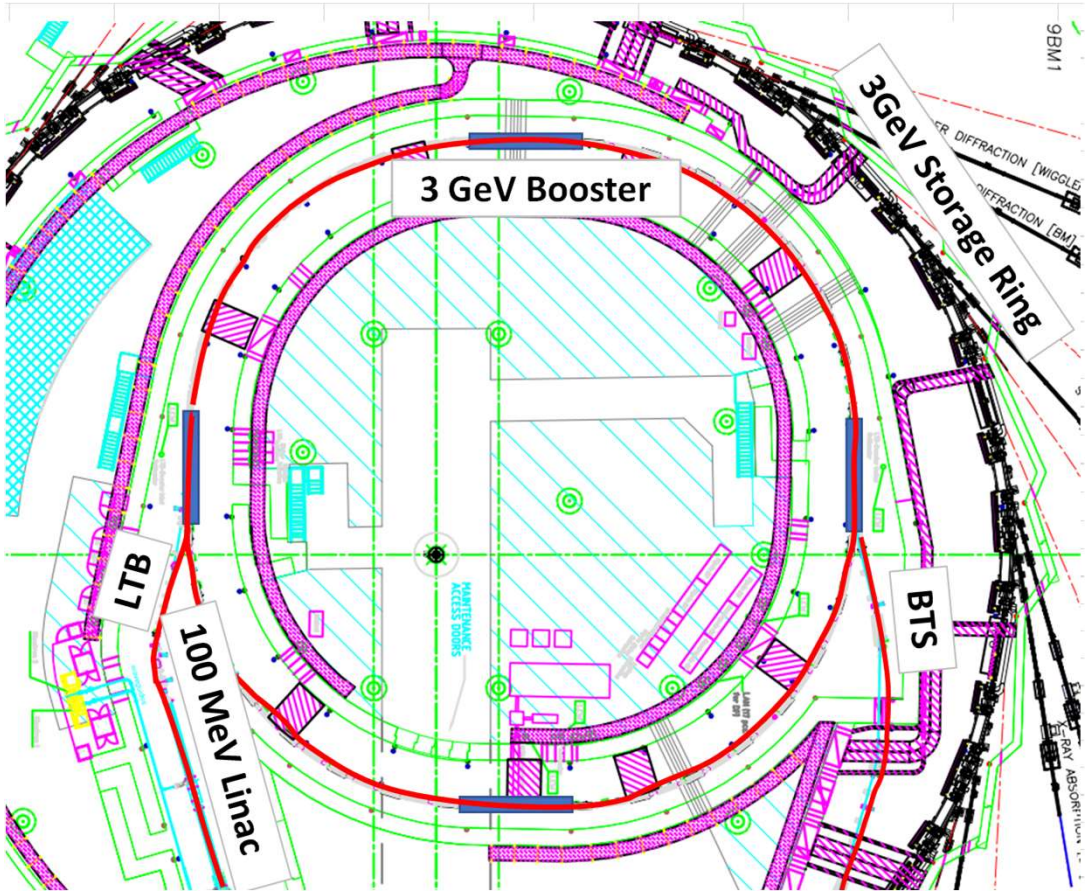
Turn-key booster

Lattice:	Combined function
Booster circumference:	130m
Injection energy:	100MeV
Peak energy:	3.0GeV
Beam current (multi bunch train):	5mA
Cycle rate:	1Hz

DANFYSIK

ASP/ANSTO - Booster

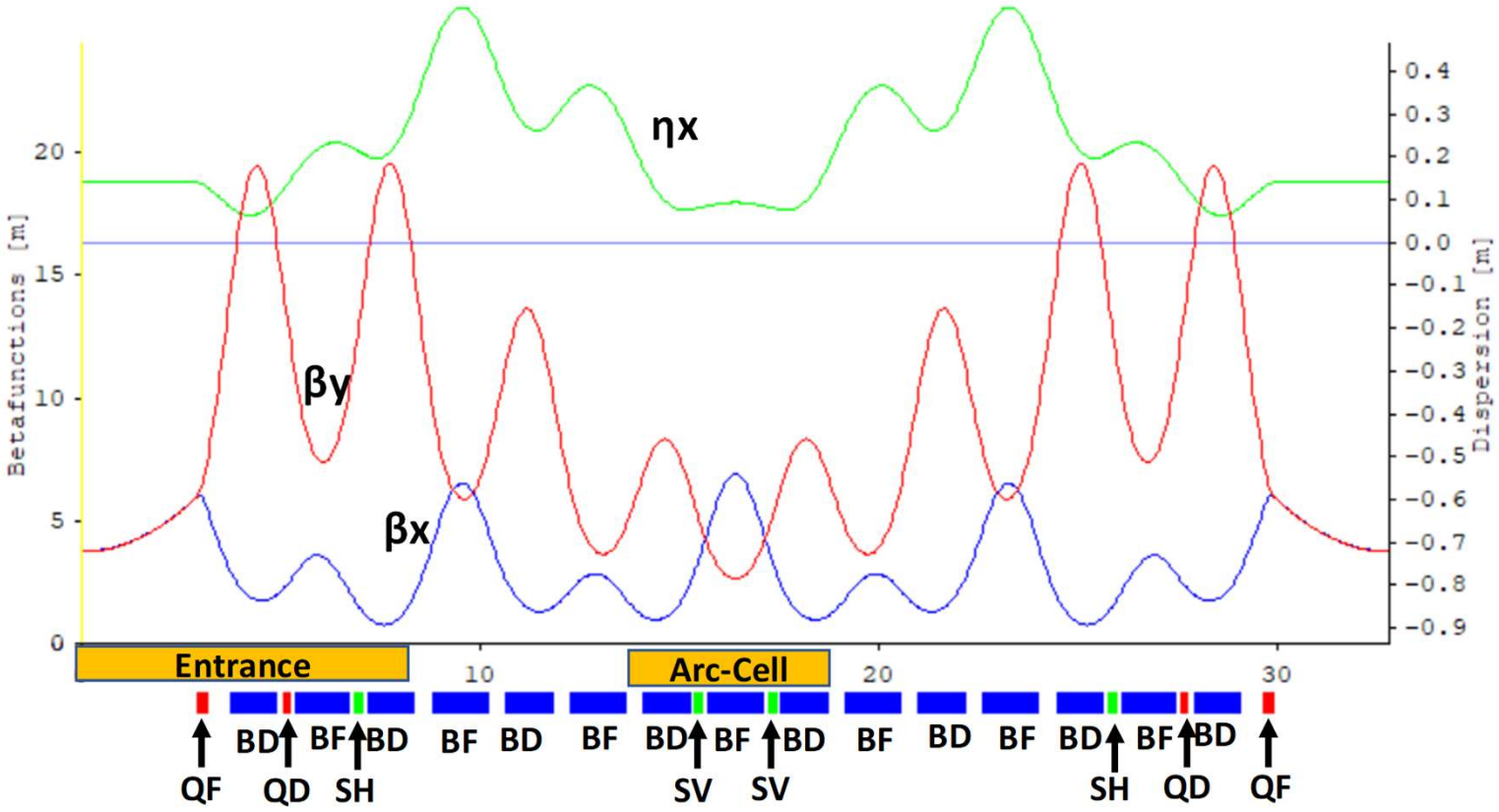




The Booster was built by Danfysik

ASP / ANSTO - Injector

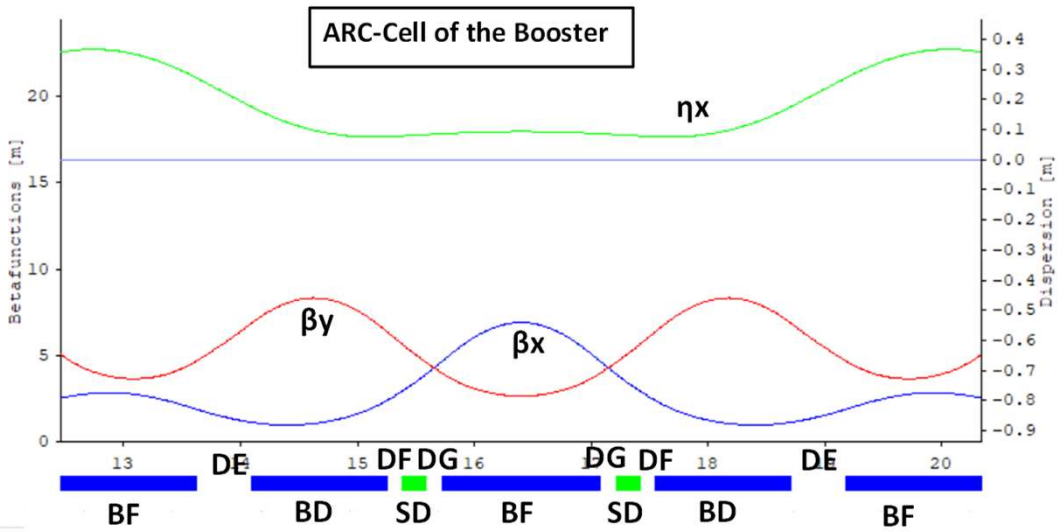
Machine functions within one quarter of the Booster



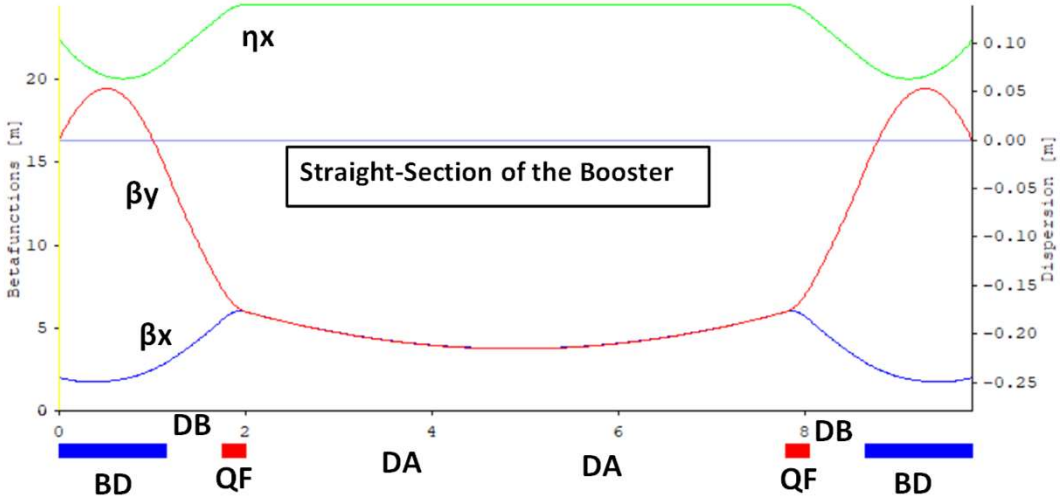
The design is similar to NSLS II

ANSTO
E = 3 GeV
C = 130.2 m
I = > 5 mA
ε = 42 nmrad
Qx = 9.2
Qy = 3.25
ξx = -8.8
ξx = -11.5
dE/turn = 862 keV

ASP/ANSTO - Booster



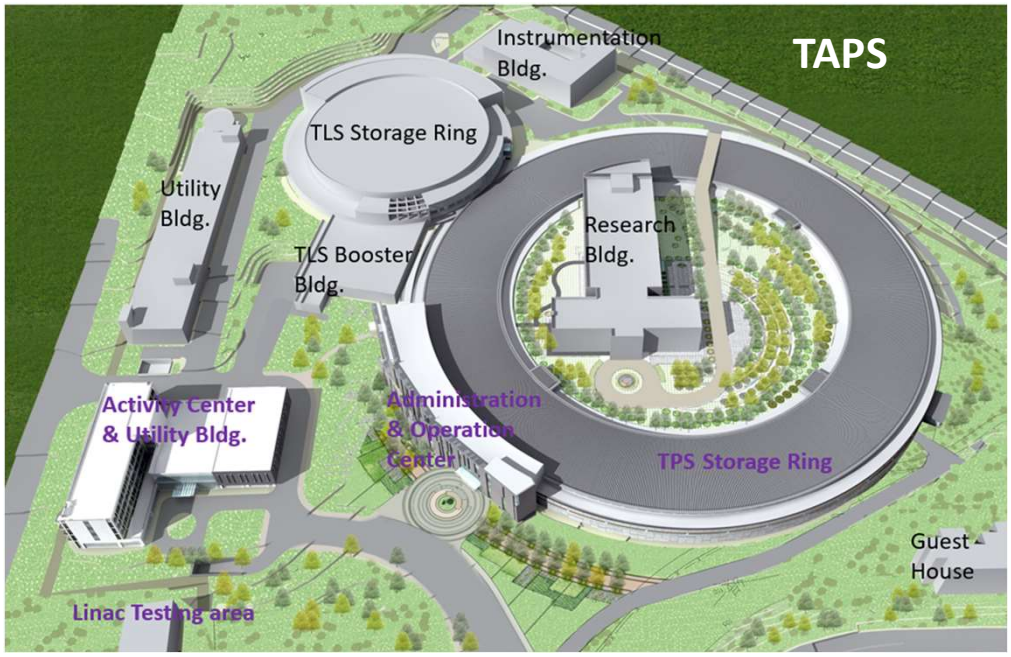
BF: L = 1.35 m, ϕ = 3.429 °, ρ = 22. 357 m, B = 0.444 T, G = 8.26 T/m,
B" = -35.41 T/m^2
BD: L = 1.15 m, ϕ = 8.25 °, ρ = 7. 99 m, B = 1.25T, G = -6.7 T/m,
B" =- 49.3 T/m^2
SD: L = 0.20 m, B" = 393 T/m^2 , SD: L = 0.16 m, B" = -73.35 T/m
DE = 0.3 m, DF= 0.12 m, DG = 0.24 m



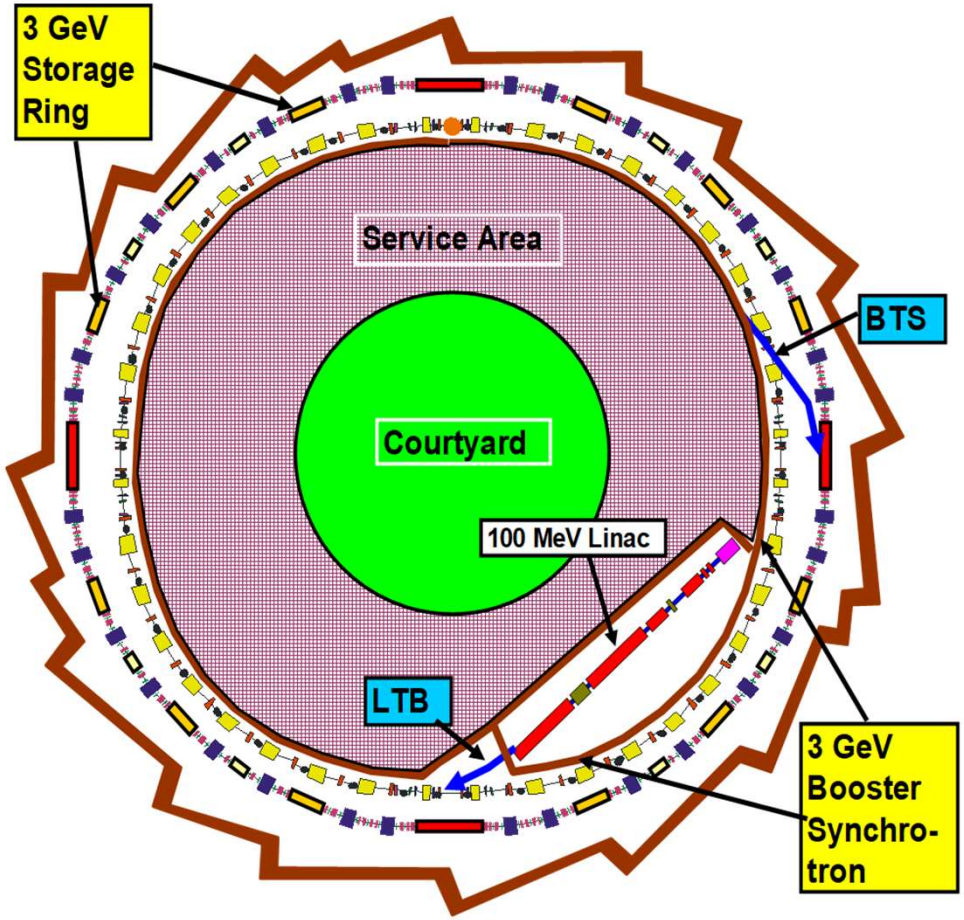
BD: L = 1.15 m, ϕ = 8.25 °, ρ = 7. 99 m, B = 1.25T, G = -6.7 T/m,
B" =- 49.3 T/m^2
QF: L = 0.25 m, G = 23.51 T/m
DA =2.894 m, DB = 0.6 m

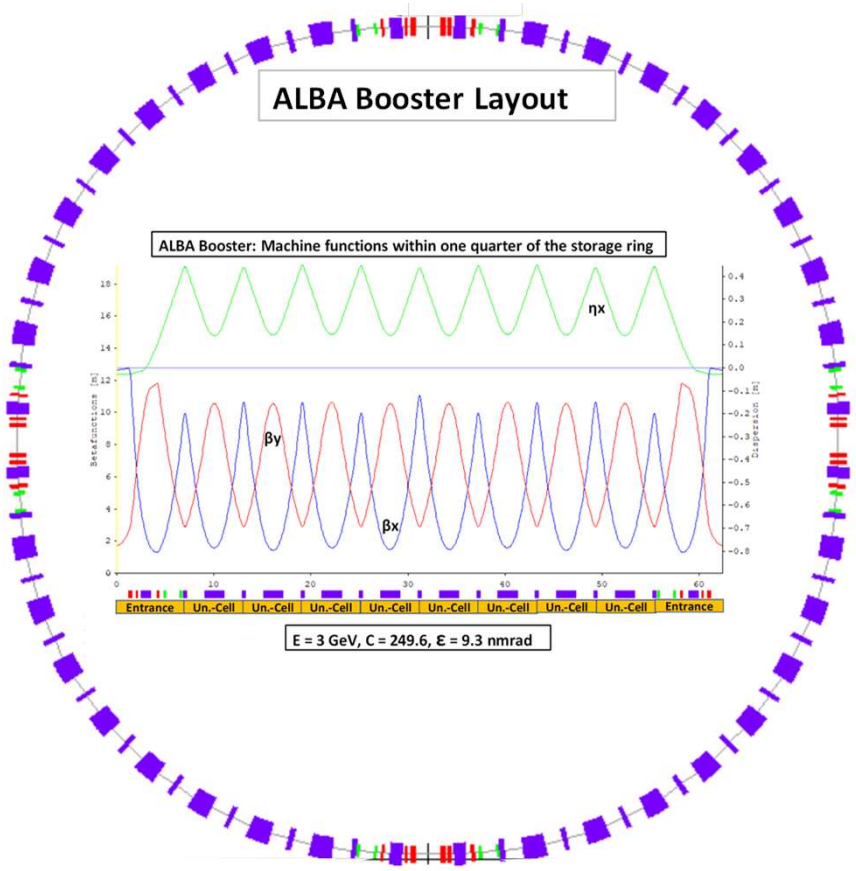
ALBA – Injector (2011)

Sirius (2018) and Taiwan Photo Source (2015) have the same lattice as ALBA



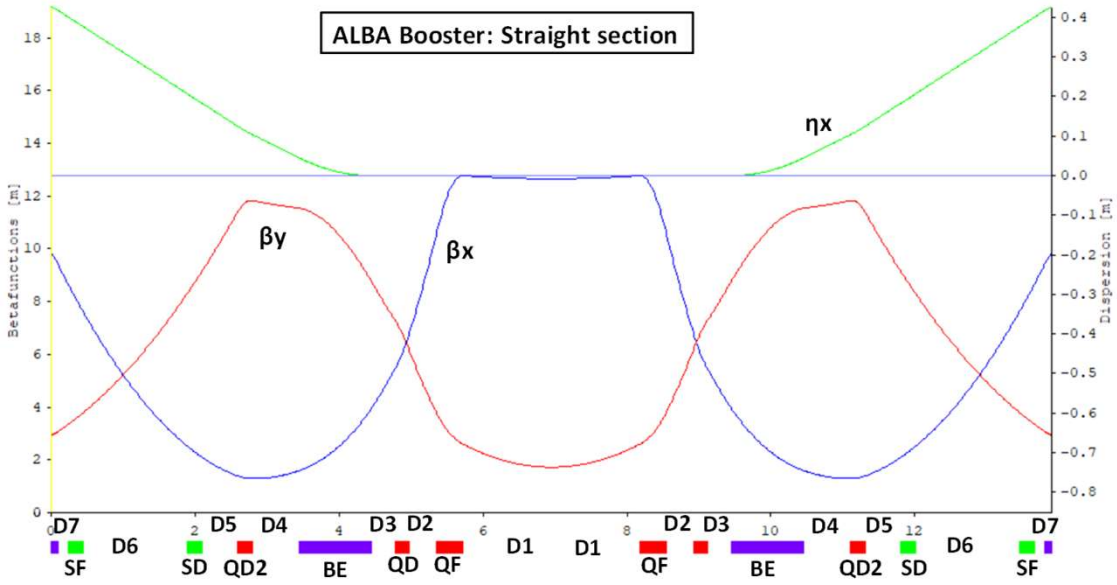
ALBA – Booster: Layout and Parameters



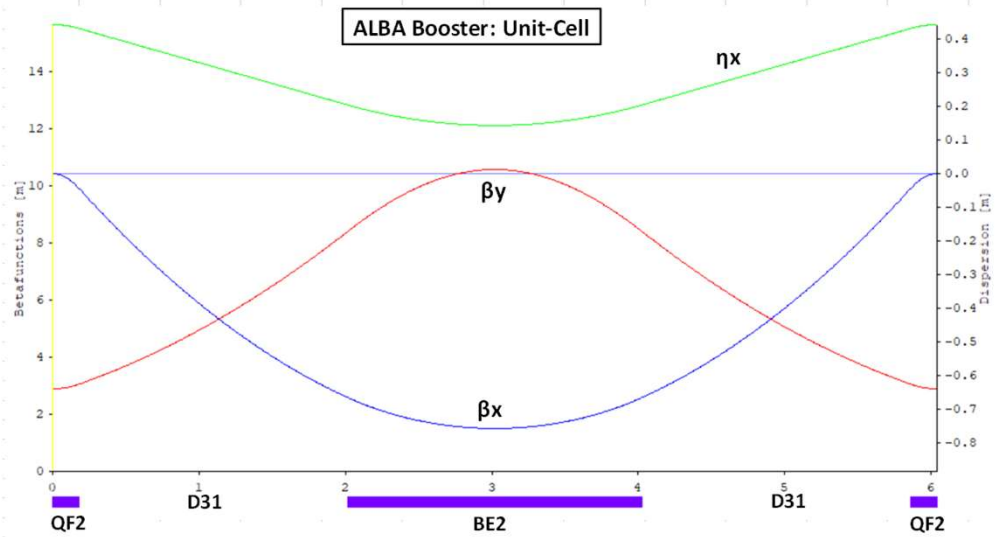


E = 3 GeV, C = 249.6 m, I = > 5 mA, ε = 9 nmrad
ξx = -16.7, ξx = -10.2, dE/turn = 622 keV

ALBA - Booster

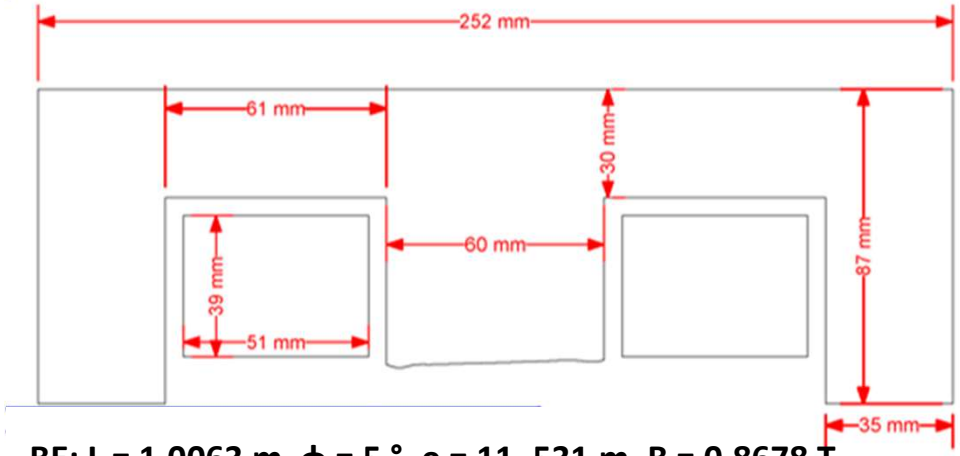


BE: L = 1.0063 m, ϕ = 5 °, ρ = 11. 531 m, B = 0.8678 T, G = -2.285 T/m, B" = -18.81 T/m^2
QF: L = 0.36 m, G = 14.08 T/m , QD: L = 0.2 m, G = -12.77 T/m, QD2: L = 0,2 m, G = -11.6 T/m
SF: L = 0.2 m, B" = 13.2 T/m ^2, SD = 0.2 m, B" = -37.4 T/m^2
D1 = 1.23 m, D2 = 0.38 m, D3 = 0.3268 m, D4 = 0.4068 m, D5 = 0.5 m, D6 = 1.45 m, D7 = 0.15 m

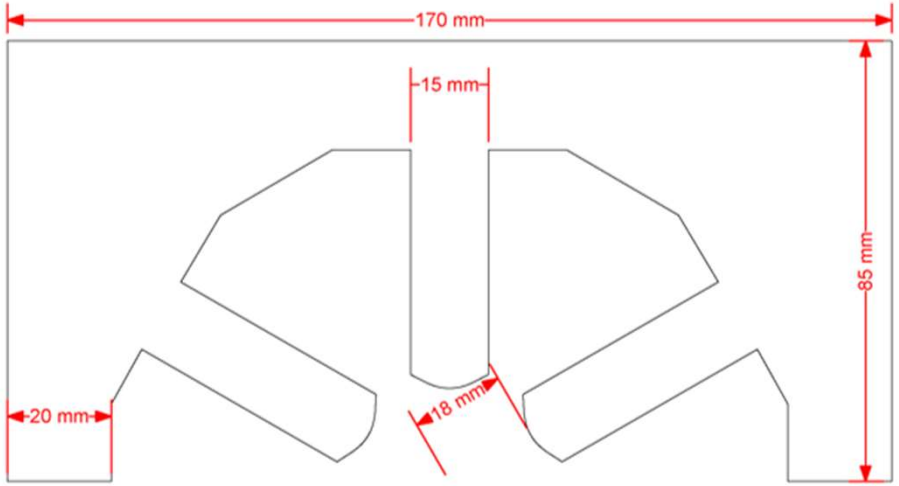


BE2: L = 2.0121 m, ϕ = 10 °, ρ = 11. 531 m, B = 0.8678 T, G = -2.285 T/m, B" = -19.91 T/m^2
QF2: L = 0.18 m, G = 15.69 T/m , B" = 19.5 T/m^2, D31 = 1.834 m

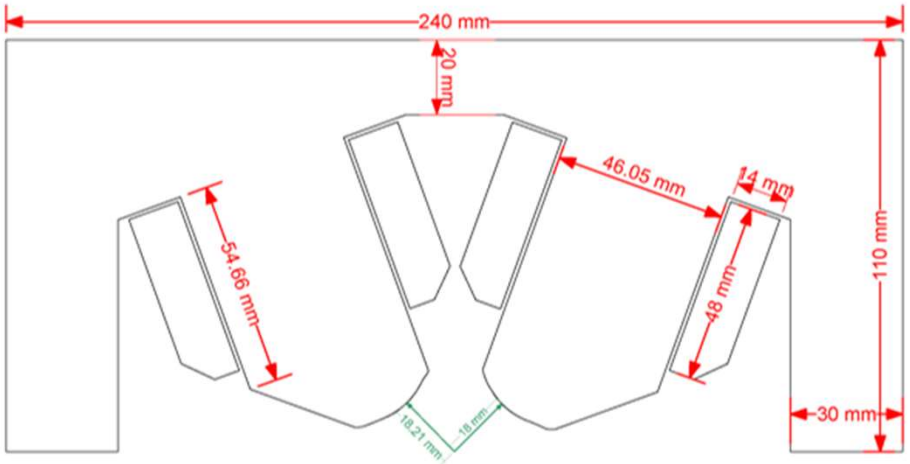
ALBA – Injector: Magnets



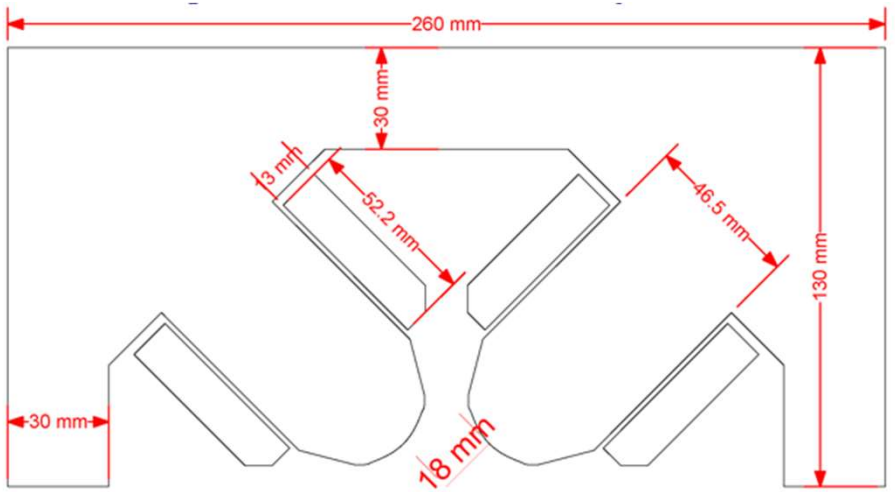
BE: L = 1.0063 m, ϕ = 5 °, ρ = 11. 531 m, B = 0.8678 T,
G = -2.285 T/m, B" = -18.81 T/m^2



SD = 0.2 m, B" = -37.4 T/m^2



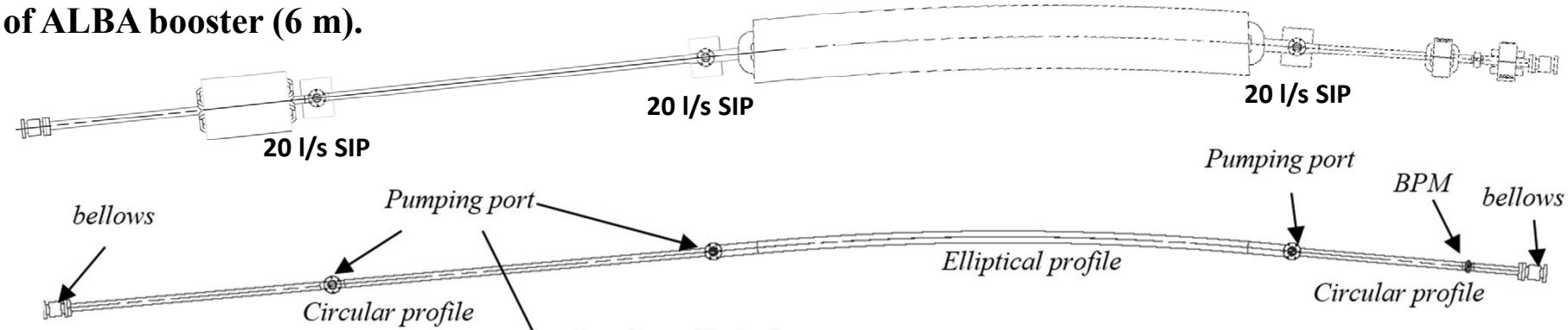
QF2: L = 0.18 m, G = 15.69 T/m , B" = 19.5 T/m^2



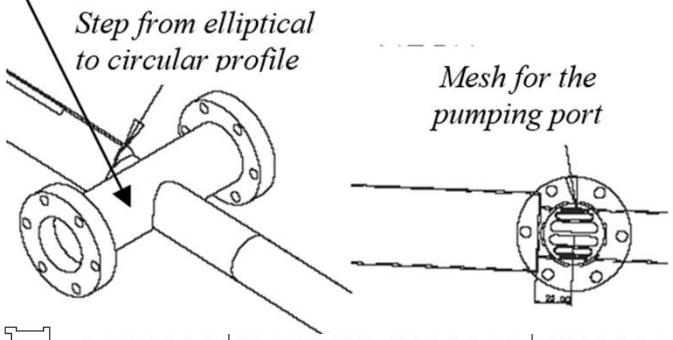
QF: L = 0.36 m, G = 14.08 T/m , QD: L = 0.2 m, G = -12.77 T/m,

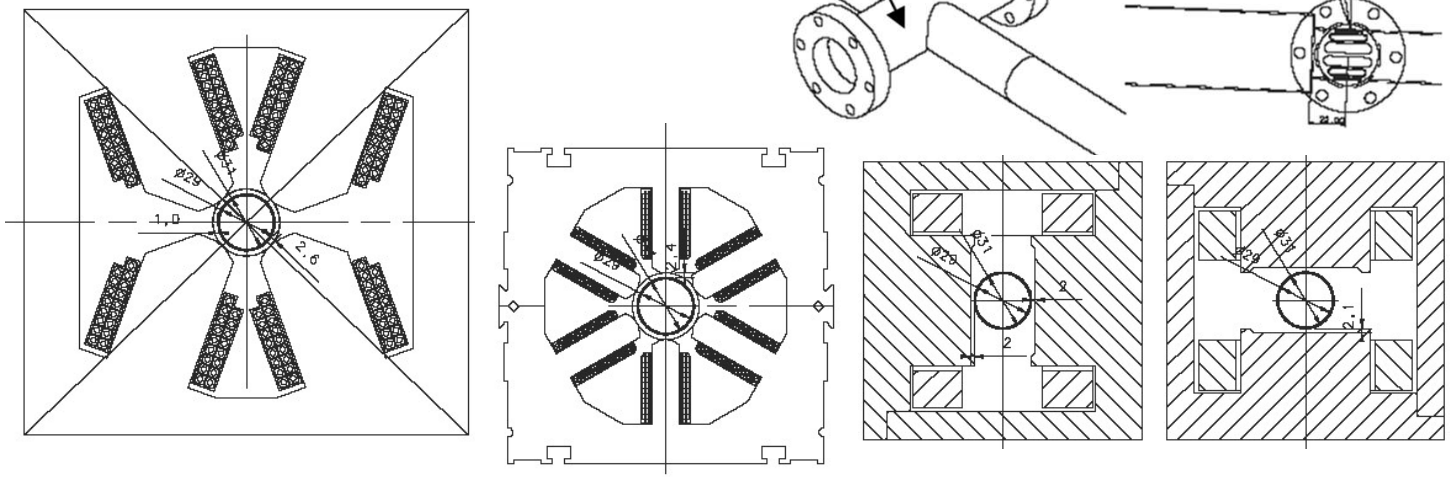
ALBA – Booster Vacuum System

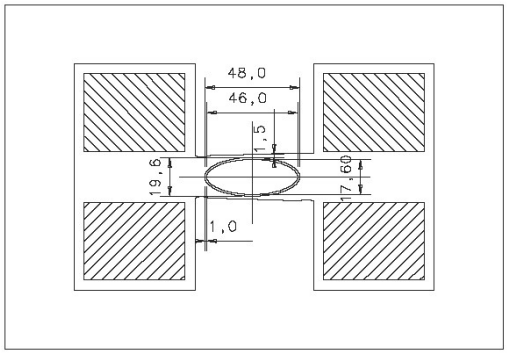
Unit cell of ALBA booster (6 m).



Inner vacuum chamber profile
Multipoles and correctors: 29 mm.





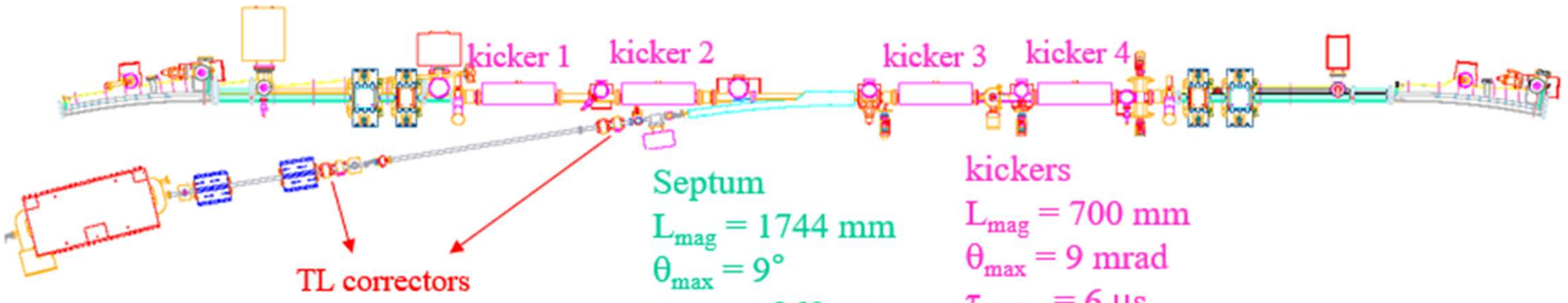


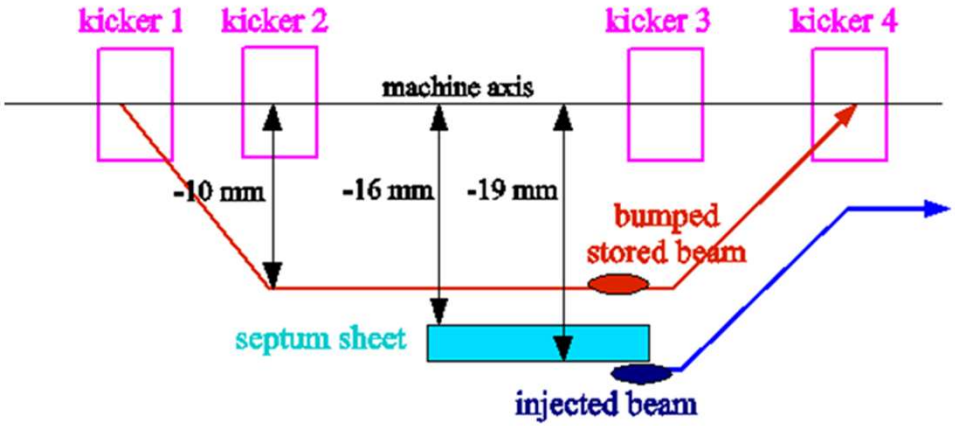
Inner vacuum chamber profile in the dipole is elliptical: 17.6 x 46mm

316l St. steel, 1 mm thickness.

ALBA – Injector

ALBA - Injector





SIRIUS - Injector

Many thanks to:

E. Al-Dmour (MAX IV), H. Bach (Danfysik. M. Böge (SLS), J.R. Calvey (APS), E. Huttel (KIT), J. Kallestrup (SLS), E. Karantzoulis (ELETTRA), I. Lobrach (APS), M. Jordi (CELLS), L. Liu (LNLS), I. Martin (Diamond), M. Mcteer (BESSY), R.T. Neuenschwander (LNLS), M. Pont (CELLS), Schulz (SLS), T. Shaftan (BNL), A. Shahveh (Diamond), Ch. Steier (ALS), M. Svandrlik (ELETTRA), E. Tan (ANSTO), P.F. Tavares (MAX IV), M.-A.-Tordeux

Many Thanks, Dieter