14 Injector

D. Einfeld

14.1 Booster synchrotron

The booster synchrotron should deliver a small beam size to the storage ring in order to minimize the beam losses during injection and accordingly the radiation dose. To minimize the emittance, a large number of bending magnets has to be installed, and this is possible if the booster synchrotron is placed in the same tunnel as the storage ring. This was first done at the Swiss light source [14.1] and after that at ALBA [14.2] as well as the TPS [14.3]. To minimize the number of magnets, the bending magnets will have a vertical focusing component. With this type of magnet the horizontal partition number J_x will be increased, which further reduces the emittance (see section 14.4).

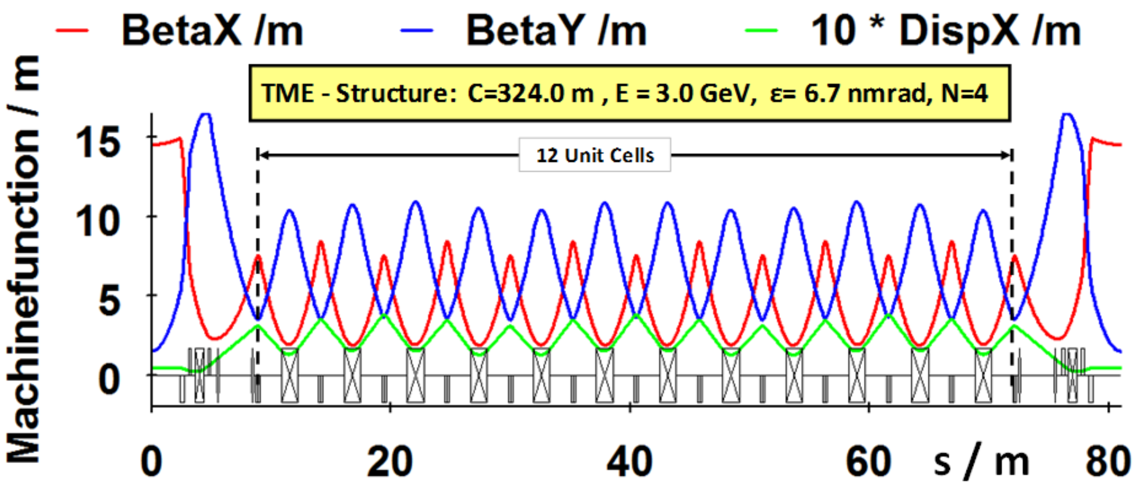


Fig. 14.1: The machine functions of the booster in one achromat (one quadrant of the ring)

For the booster synchrotron at least two straight sections are needed: one for the injection and one for the installation of the cavity. Like ALBA and the TPS, a four-fold symmetry with four straight sections was chosen. The circumference of the booster was chosen to 324 m, which corresponds to a harmonic number of 108. The average distance between the storage ring and the booster is 3.82 m in this case. The machine functions within one achromat, shown in Fig. 14.1, are similar to those of ALBA and the TPS, yielding an emittance of 6.7 nmrad at 3 GeV and 4.7 nmrad at 2.5 GeV. The cross-sections of the beam are: σ_x = 311 µm and σ_y = 17 µm. The lattice consists of the two matching sections at the beginning and end of the achromat (Fig. 14.3) along with 12 'unit cells' (Fig. 14.2) forming the middle of the arc. The lattice functions have to be optimized further in order to achieve a sufficient dynamic aperture.

The specifications of the magnets are as follows.

- Bending: L = 1.393 m, ϕ = 6.9231°, ρ = 11.5286 m, G = 3.1 T/m, B_{max} = 0.868 T (3 GeV).
- Quadrupole: L = 0.36 m, G = 15.01 T/m (3 GeV).

These specifications are roughly the same as for the ALBA booster synchrotron (see Fig. 14.4).

https://doi.org/10.23731/CYRM-2020-001.131

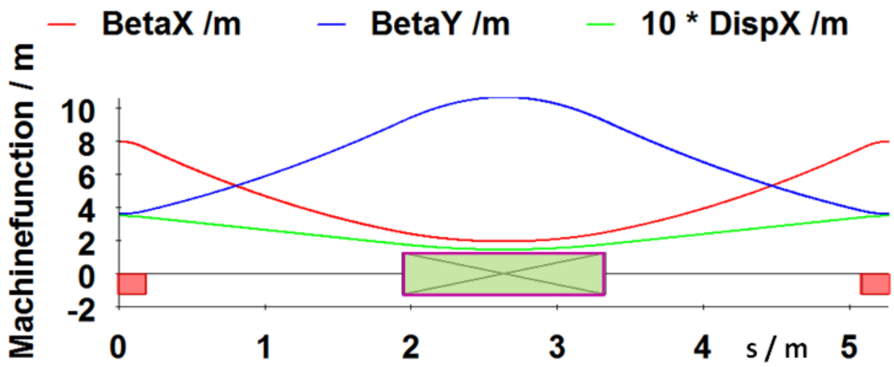


Fig. 14.2: The machine functions within the 'unit cell' of the booster synchrotron

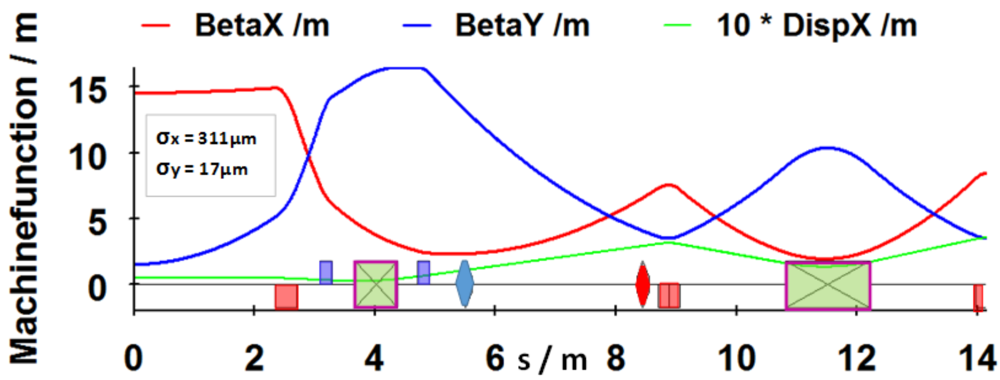


Fig. 14.3: The machine functions within the 'matching cell' of the booster synchrotron

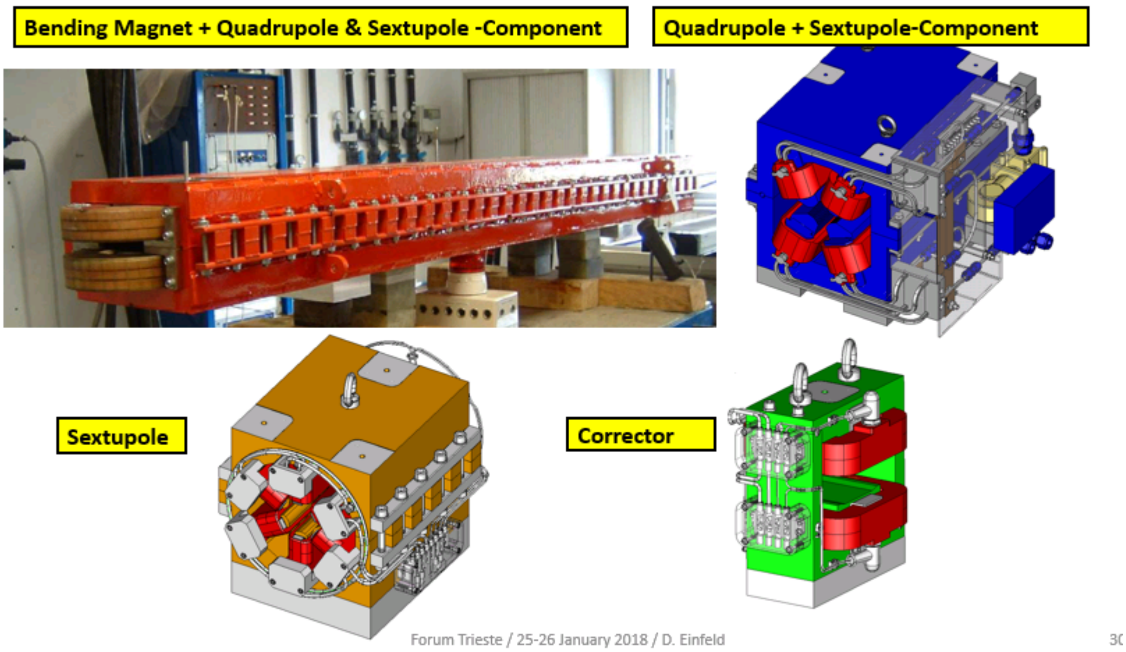
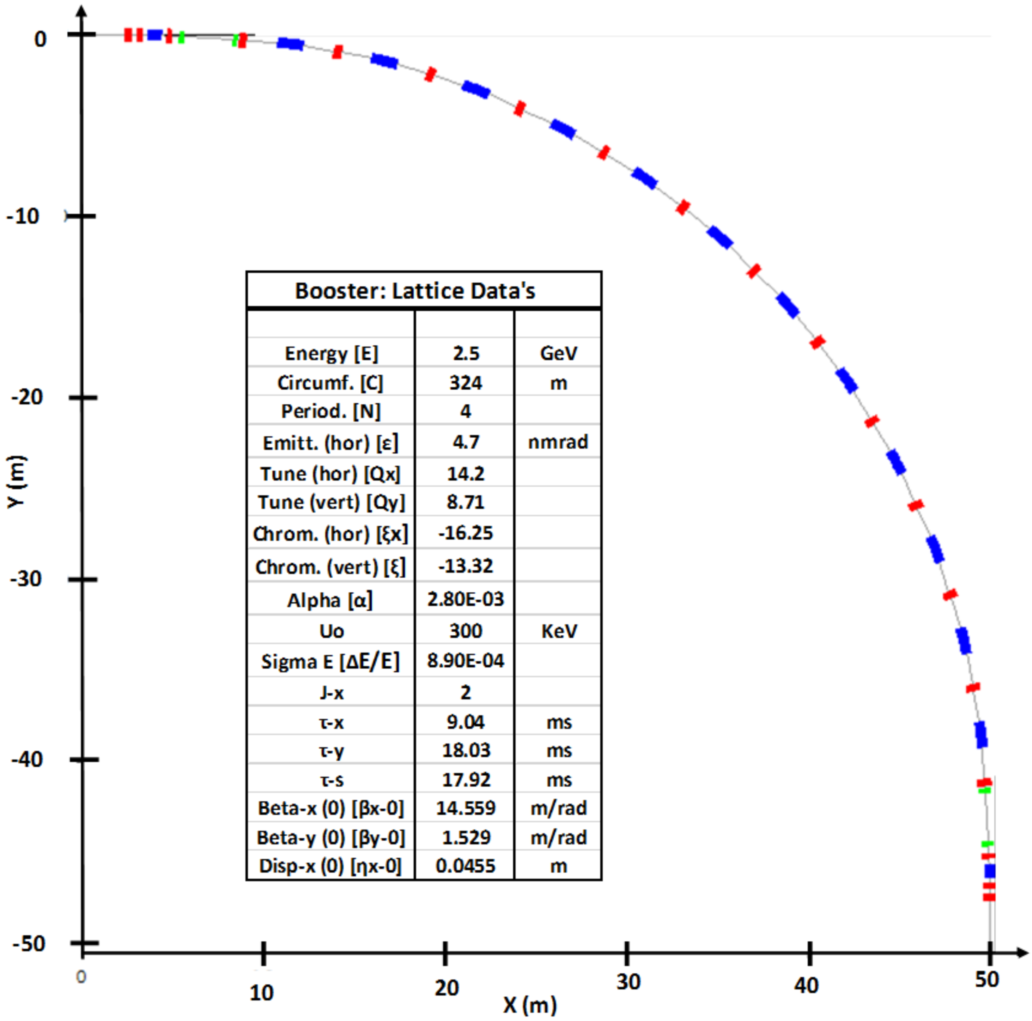


Fig. 14.4: The magnets used for the ALBA booster synchrotron

The magnetic layout of one achromat (one quadrant), together with the lattice data, is presented in Fig. 14.5. The compensation for the chromaticities will be done with some sextupole components in the bending magnets and in the quadrupoles and with some sextupoles in the matching region. The injection energy of the booster will be 100 MeV, and it will be ramped up with a frequency of around 1–3 Hz to 2.5 or 3 GeV.



Booster: Lattice Data's		
Energy [E]	2.5	GeV
Circumf. [C]	324	m
Period. [N]	4	
Emitt. (hor) [ε]	4.7	nmrad
Tune (hor) [Qx]	14.2	
Tune (vert) [Qy]	8.71	
Chrom. (hor) [ξx]	-16.25	
Chrom. (vert) [ξ]	-13.32	
Alpha [α]	2.80E-03	
Uo	300	KeV
Sigma E [ΔE/E]	8.90E-04	
J-x	2	
τ-x	9.04	ms
τ-y	18.03	ms
τ-s	17.92	ms
Beta-x (0) [βx-0]	14.559	m/rad
Beta-y (0) [βy-0]	1.529	m/rad
Disp-x (0) [ηx-0]	0.0455	m

Fig. 14.5: The magnetic structure within one achromat (one quadrant) of the booster synchrotron, together with the lattice data.

The injection energy of the booster will be 100 MeV and it will be ramped up with a frequency around 1 to 3 Hz to 2.5 or 3 GeV.

14.2 Linac

The principal layout of the 100 MeV linac is presented in Fig. 14.6. The electron gun delivers a beam with an energy of 90 keV, which goes through a 500 MHz and a 3 GHz pre-buncher and then a buncher to reach an energy of 16 MeV. With two other accelerating sections, the final energy of the beam will be 110 MeV. The dimensions of the linac are shown in Fig. 14.7; the overall length is approximately 14 m.

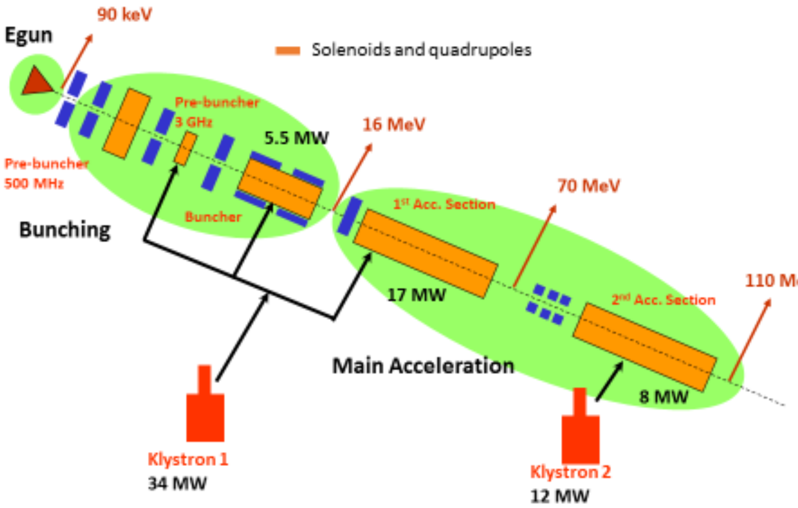


Fig. 14.6: The principal layout of the 10 MeV linac built by Thales for ALBA. The focusing coils and quadrupoles are in blue.

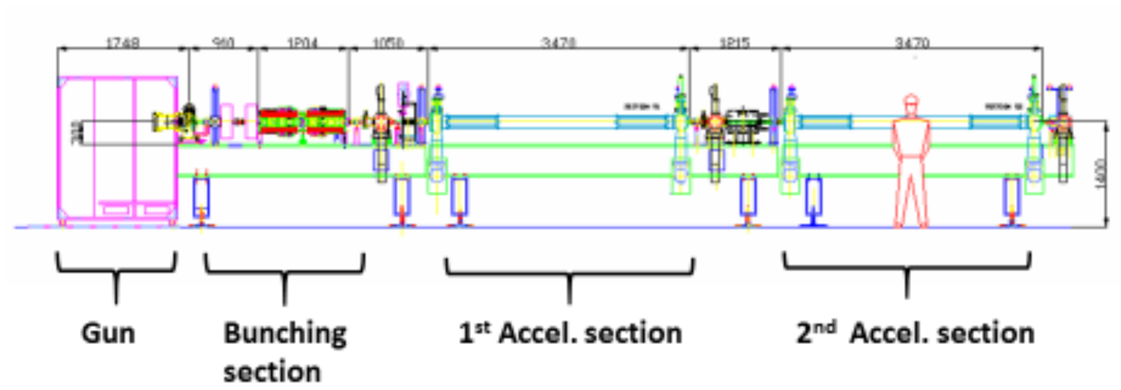


Fig. 14.7: The dimensions of the different linac components, leading to an overall length of 13.92 m

For the focusing of the beam, solenoids and quadrupoles are required, which are represented in Fig. 14.8 by blue boxes. The specifications of the 110 MeV beam are given in Table 14.1. The normalized emittance should be smaller than 30π mm rad with an energy spread of less than 0.25%. The linac has to be run in single- as well as multi-bunch mode.

For the diagnostics of the beam, six FCTs, three fluorescent screens, and one BPM are installed. The arrangements of the different components are presented in Fig. 14.8. A picture of the 110 MeV linac installed at ALBA is shown in Fig. 14.9.

Table 14.1: The specification of the 110 MeV electron beam delivered by the linac

Parameter	Single-bunch	Multi-bunch
Frequency	3 GHz	3 GHz
Bunch length	<1 ns (FWHM)	0.3–1 μs
Charge	>2 nC	>4 nC
Energy	>100 MeV	>100 MeV
Pulse to pulse (δE)	<0.25% (r.m.s.)	<0.25% (r.m.s.)
Energy spread ($\Delta E/E$)	<0.5% (r.m.s.)	<0.5% (r.m.s.)
Normalized emittance ($1\sigma_{x,y}$)	<30π mm mrad	<30π mm mrad
Repetition rate	3–5 Hz	3–5 Hz

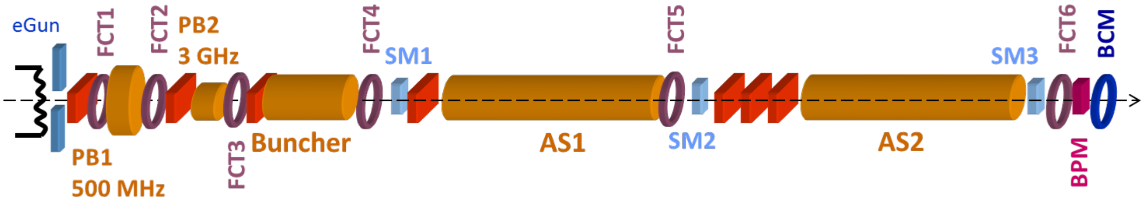


Fig. 14.8: The diagnostic elements for the linac and their locations

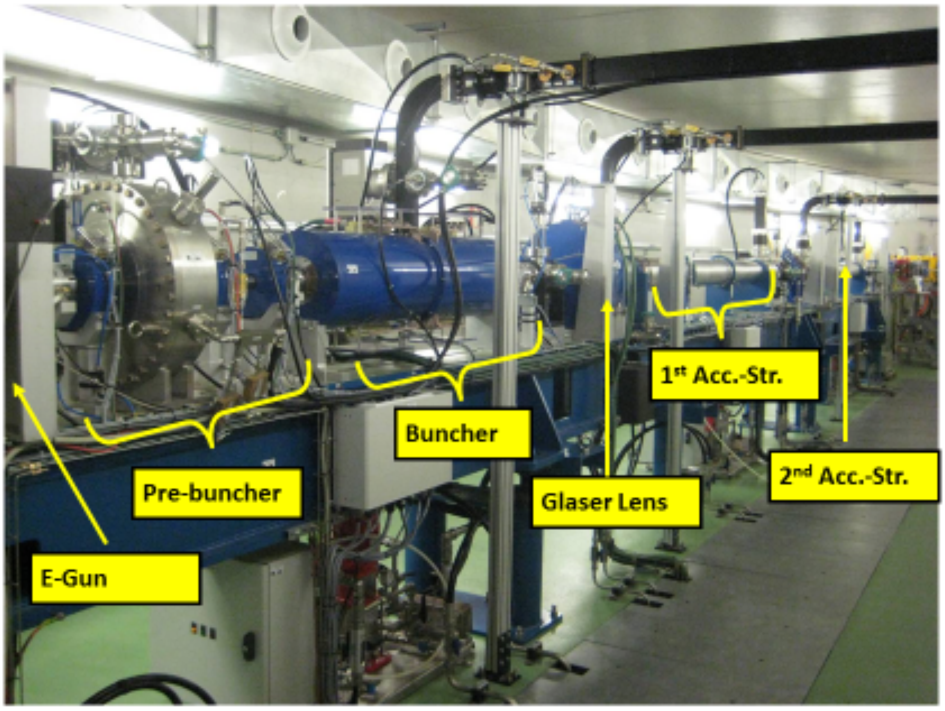


Fig. 14.9: Picture of the 110 MeV linac installed at ALBA

14.3 Diagnostic beam line

For the measurement and determination of the specification of the electron beam coming from the linac a special diagnostic line is needed. The set-up of this diagnostic line is shown in Fig. 14.10. The linac ends with a vacuum valve and the linac-to-booster transfer line (LTB) starts with two correctors, a quadrupole triplet, and a bending magnet. The bending magnet has two settings, one for the operation, bringing the beam to the booster, and one for the diagnostic, switching the beam into the diagnostic line. The diagnostic line is equipped with a scraper (SCR), a fluorescent monitor (FSOTR), a beam charge monitor (BCM2), a fast current transformer (FCT), and a Faraday cup (FCUP) for a beam dump.

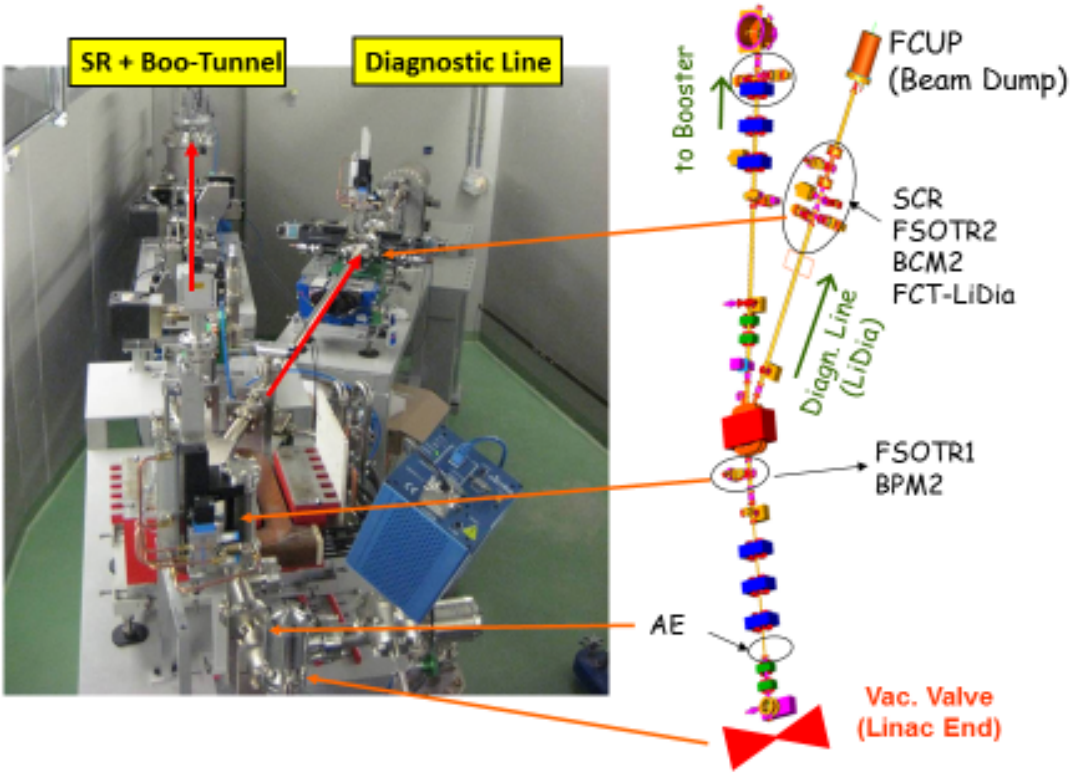


Fig. 14.10: The layout of the beginning of the LTB and the diagnostic line

The layout of such a diagnostic beam line installed at ALBA could also be used for the SEE-LS-project. A picture of the ALBA set-up is shown in Fig. 14.11.

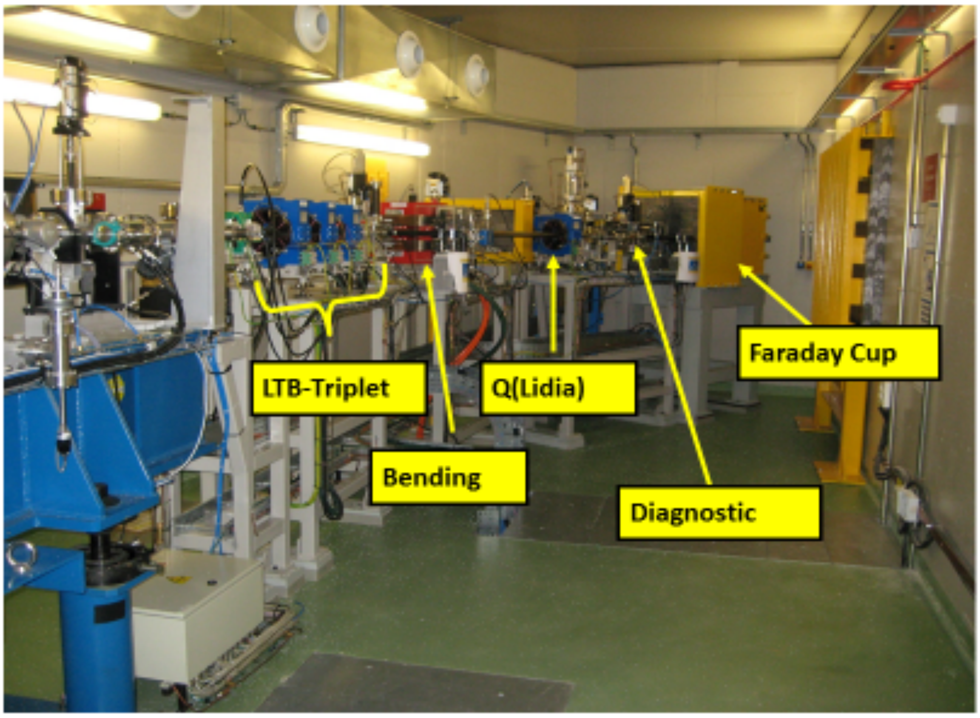


Fig. 14.11: A picture of the linac diagnostic beam line at ALBA

14.4 Linac-to-booster transfer line (LTB)

For optimization reasons the linac bunker has to be near the inner shielding wall of the machine tunnel; this means that the inner shielding wall should be the shielding wall for the machines in the tunnel and the linac. This arrangement is shown in Fig. 14.12.

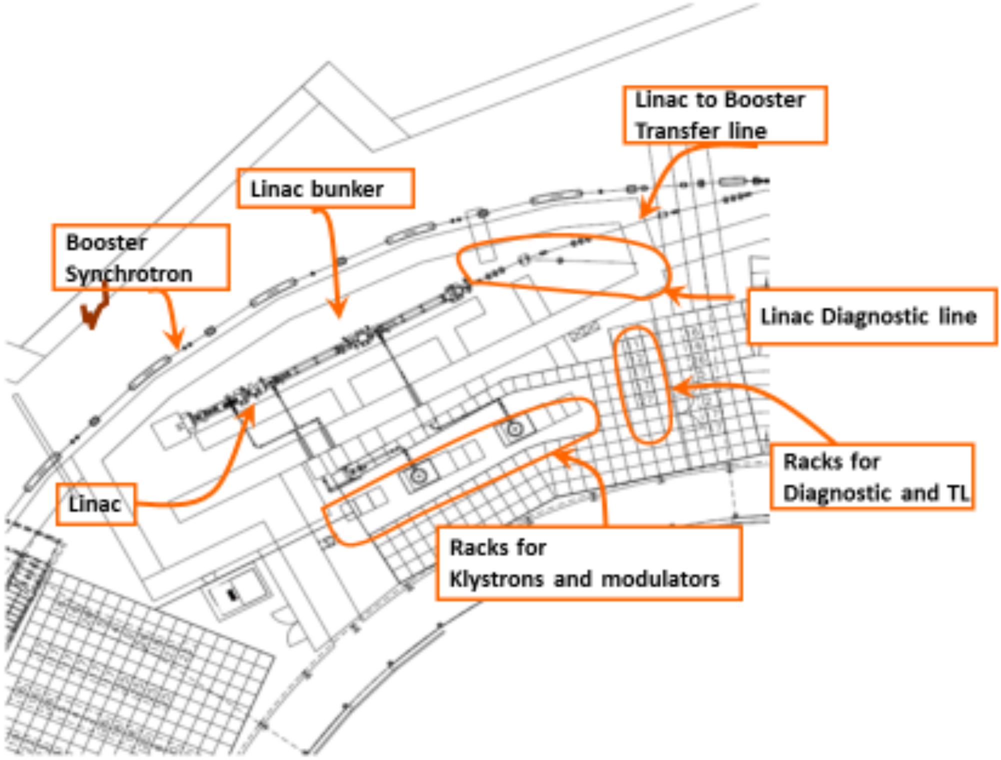


Fig. 14.12: The arrangement and layout of the linac bunker near the machine tunnel

With this arrangement the LTB needs a deflection angle for proper injection into the booster synchrotron. That is the reason for the bending magnet B1 at the beginning of the diagnostic beam line (see Fig. 14.10).

The LTB has to perform a matching of the beam parameters from the linac to the booster synchrotron. This can be done with an arrangement like the one in Fig. 14.13. In the middle of the transfer line is the shielding wall to the machine tunnel. In the linac bunker one bending magnet (B1) and two quadrupole triplets (Q1–Q3 and Q4–Q6) are needed. After the shielding wall another bending magnet (B2) and a quadrupole triplet (Q7–Q9) are required.

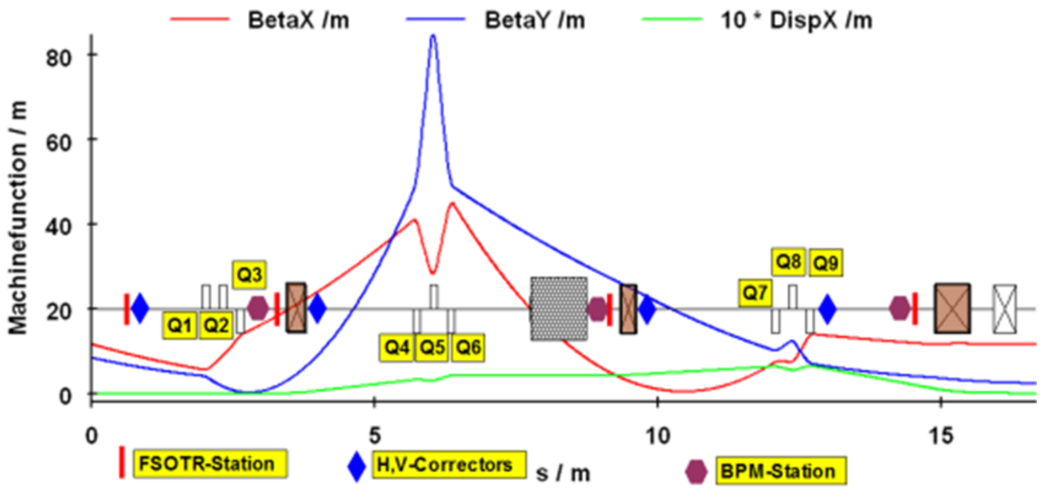


Fig. 14.13: The layout and machine functions of the LTB

14.5 Booster-to-storage ring transfer line (BTS)

The BTS has to perform a matching of the beam parameters from the booster synchrotron to the storage ring. A possible layout is presented in Fig. 14.14. The transfer line consists of (including septa and kicker) five bending magnets and seven quadrupoles. For the design it is important to have a magnet-free section in the middle of the transfer line, leaving space for transport in the machine tunnel.

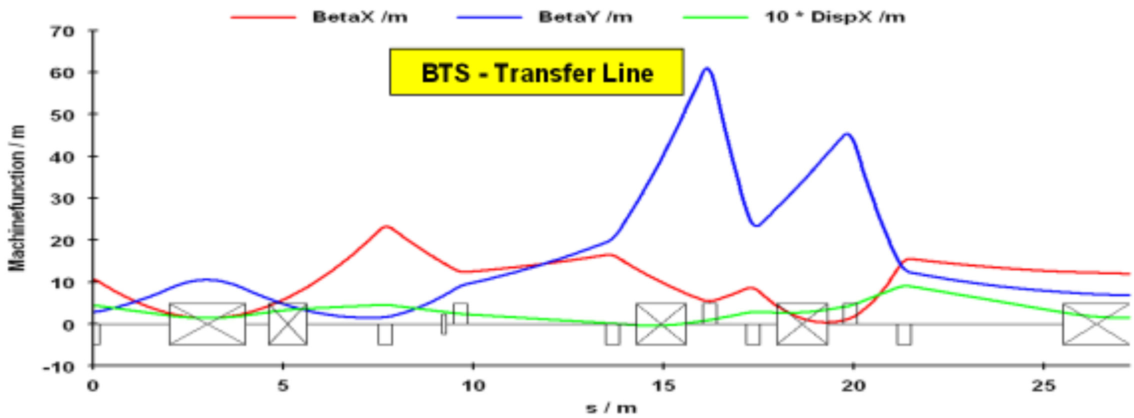


Fig. 14.14: The layout and machine functions of the BTS

References

[14.1] W. Joho, M. Munoz, and A. Streun, *Nucl. Instrum. Methods Phys. Res. A* **562** (2006) 1, https://doi.org/10.1016/j.nima.2006.01.129

[14.2] G. Benedetti *et al.*, Optics for the ALBA Booster Synchrotron, Proc. EPAC2008, Genoa, Italy, 23–27 June 2008 (CERN, Geneva, 2008), p. 2148. https://inspirehep.net/record/795036/

[14.3] H. C. Chao *et al.*, Current Design Status of TPS 3 GeV Booster Synchrotron, Proc. PAC2009, Vancouver, Canada, 4–8 May 2009 (TRIUMF, Vancouver, 2011), p. 2258. https://inspirehep.net/record/1378770