The ALBA project II

Wednesday 24 Nov 2010 at 10:00 (01h00')

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Co-authors :

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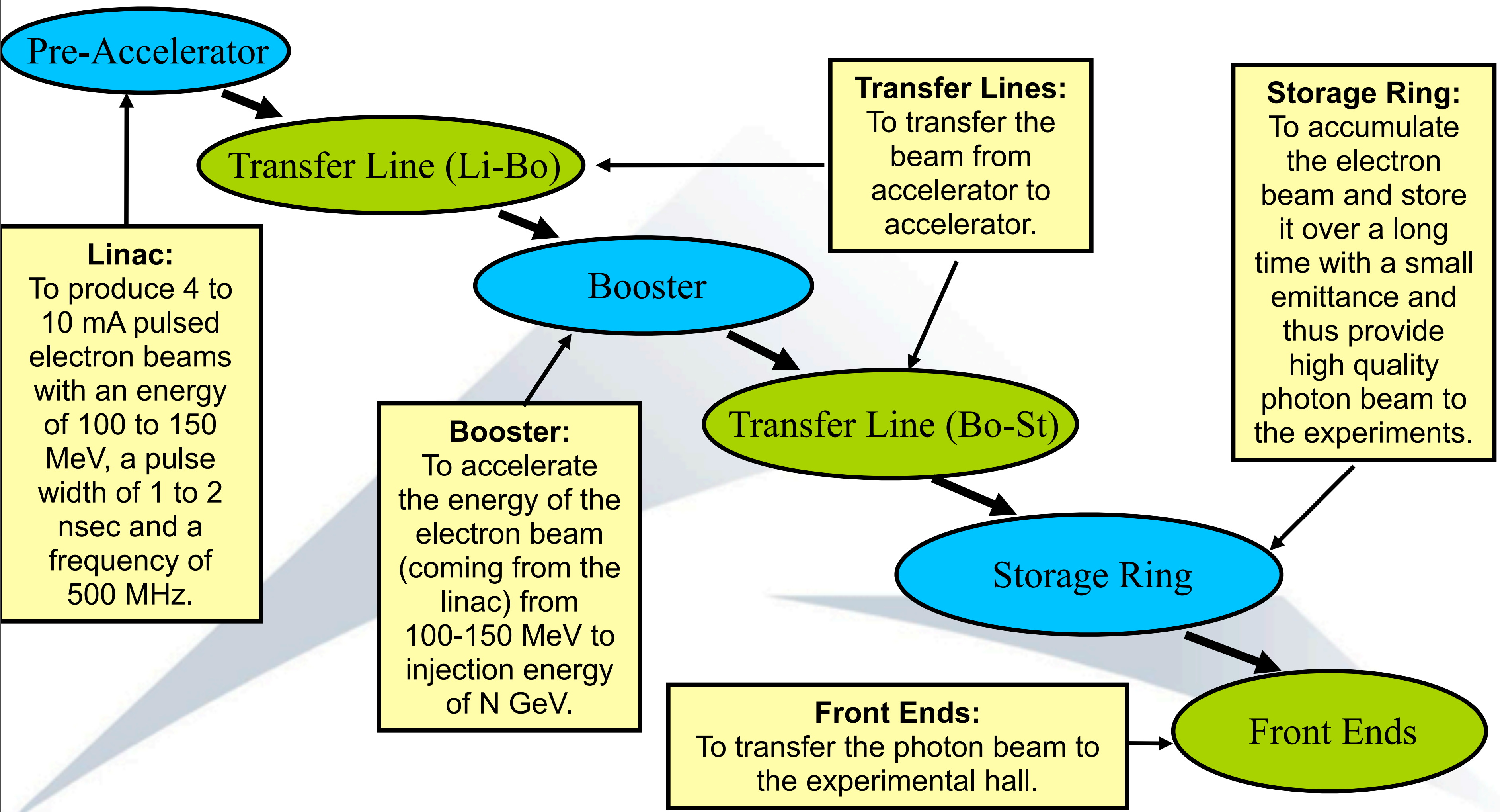
ALBA

Joan Bordas
CELLS

An accelerator complex for a synchrotron light source



First order choices:

Accelerator energy of 3 GeV to have some overlap with the ESRF and to use undulators to deliver intermediate energy X-rays (i.e. 10-20 keV).

The natural emittance should be $\varepsilon_x < 5$ nm.rad. We would have liked a smaller emittance but it quickly became clear that the size of budget and site did not allow it.

Other decisions were that the accelerator should:

operate in the top-up mode;
use FOFB to achieve sub-μm stability;
base the RF system on HOM free cavities (not superconducting);
have a bean lifetime > 10 h;
have a lattice energy acceptance > 3%, and;
contain as many as possible straight sections for user IDs.

(at the end 38% of perimeter is devoted to SS)

Many SR lattices were investigated, the most promising among them were a:

4-fold, 16 cell TBA: ε_x= 1.8 nm.rad, 16 straights, but showed a bad dynamic aperture (DA) and a poor lifetime.

4-fold, 16 cell expanded DBA: ε_x= 4.3 nmrad, 24 straights, good DA and lifetime.

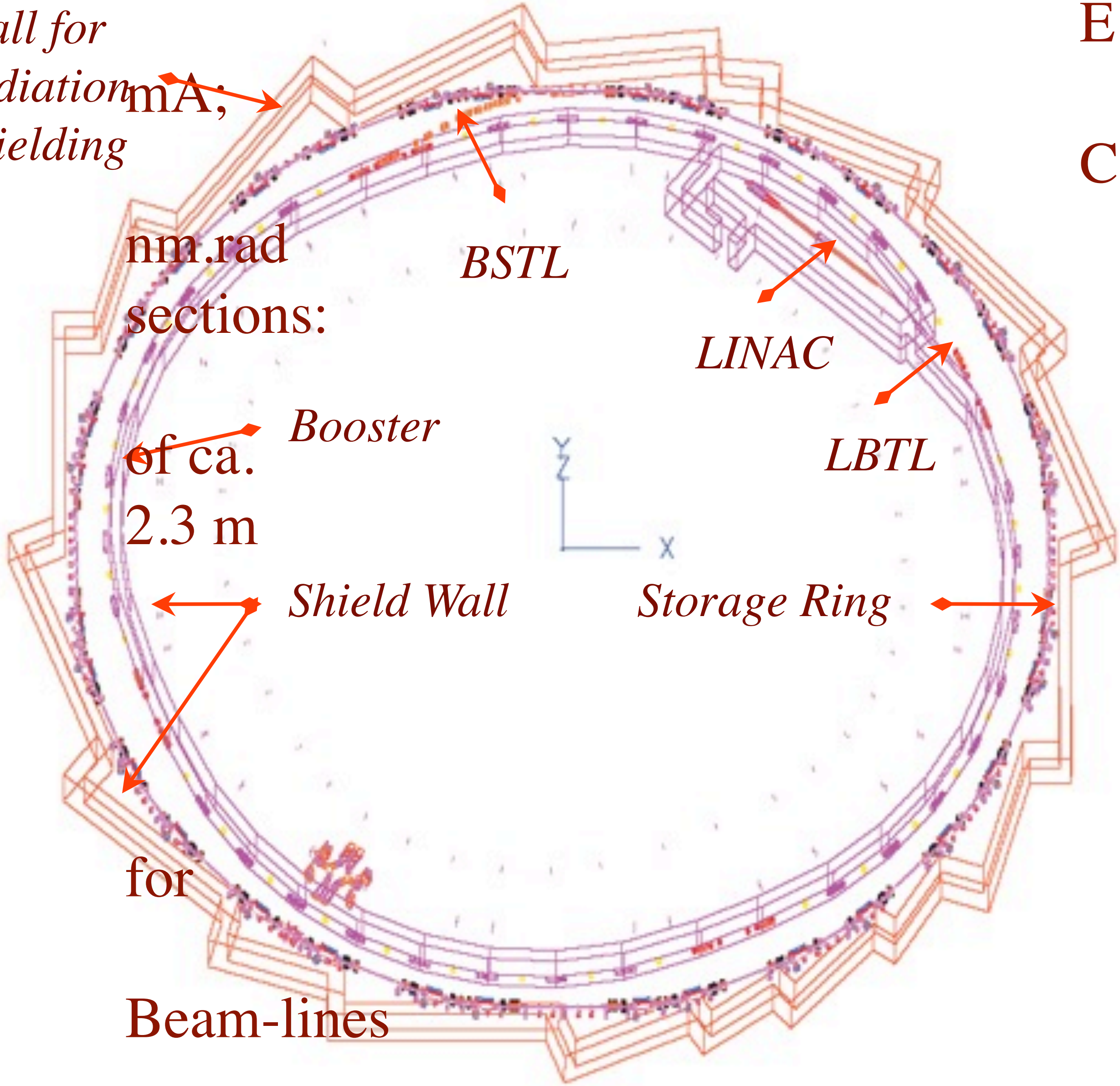
3-fold, 18 cell DBA: ε_x= 2.7 nm.rad, but has a smaller DA, shorter lifetime, and larger beam cross-section.

4-fold, 16 cell DBA: ε_x= 4.3 nm.rad, 16 straights, chromaticity is rather large.

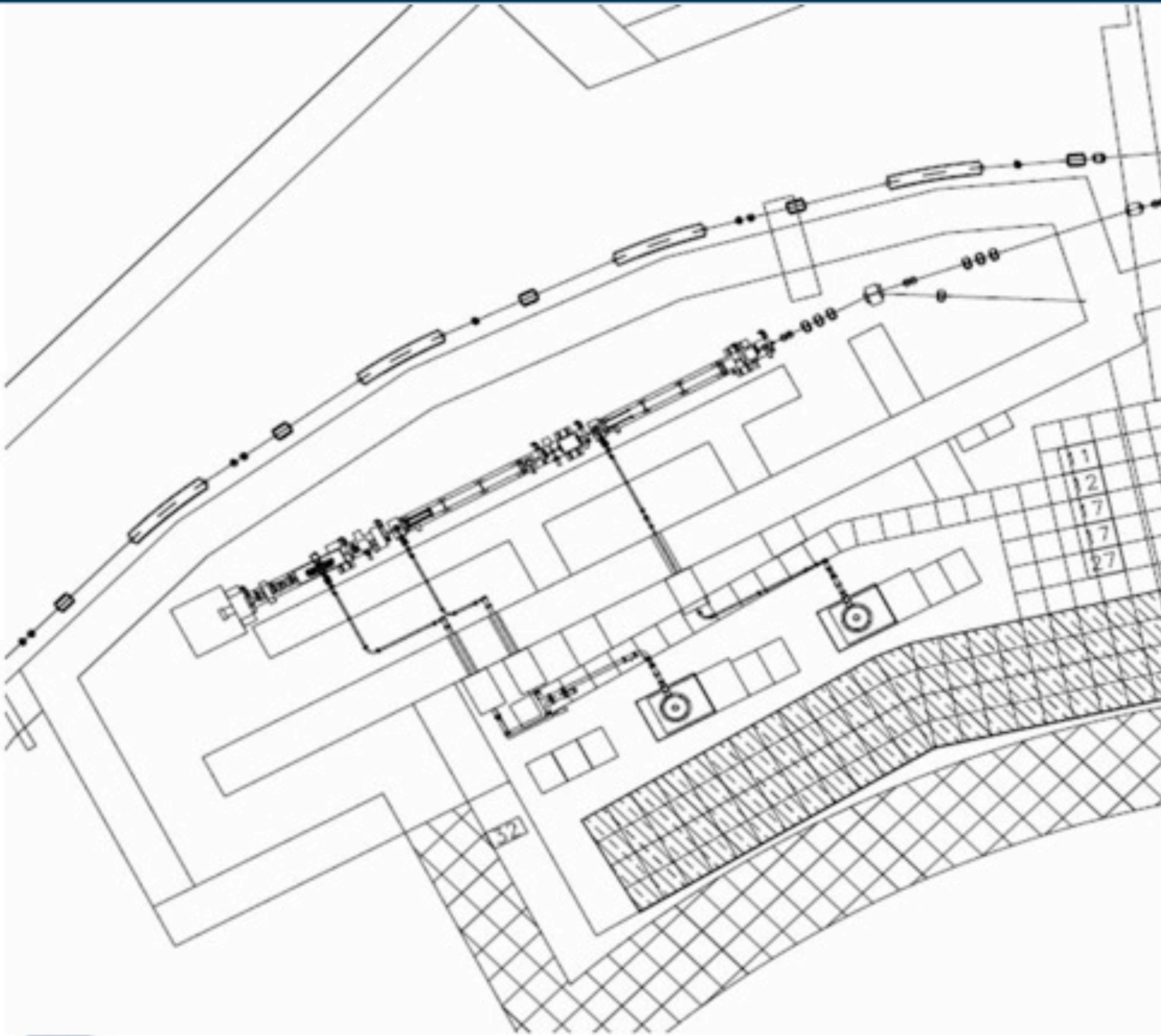
Decision: use the 4-fold, 16 cell expanded DBA!

Complex of accelerators

- $E = 3.0$ GeV; $I = 400$ mA;
- $C = 268.8$ m; $\varepsilon = 4.3$ nm.rad
- Straight sections: 4 of ca. 8 m; 12 of ca. 4.3 m; 8 of ca. 2.3 m
- 32 BM
- Capacity for 33 Beam-lines



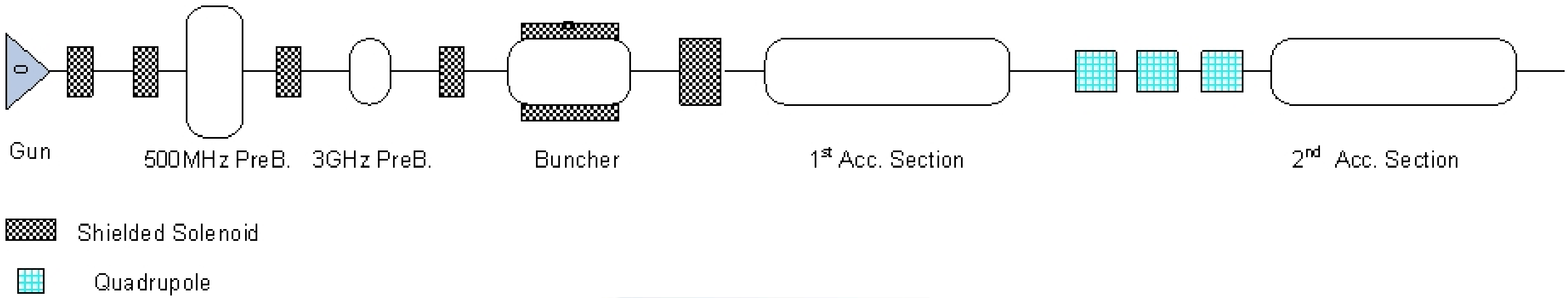
LINAC



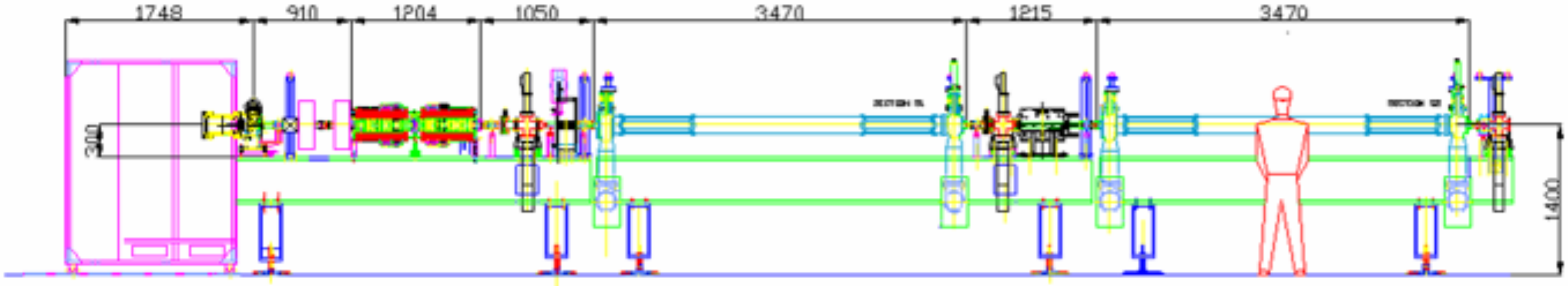
Parameter	Single-bunch	Multi-bunch
Frequency	3 GHz	3 GHz
Bunch length	< 1ns (FWHM)	0.3 to 1μs
Charge	≥ 2 nC	≥ 4 nC
Energy	≥100MeV	≥100MeV
Pulse to pulse (δE)	≤0.25 % (rms)	≤0.25 % (rms)
Energy spread (ΔE/E)	≤0.5 % (rms)	≤0.5 % (rms)
Norm. Emitt. ($1\sigma_{x,y}$)	≤ 30 π mm mrad	≤ 30 π mm mrad
Repetition rate	3 to 5 Hz	3 to 5 Hz

LAY-OUT AND SPECIFICATIONS

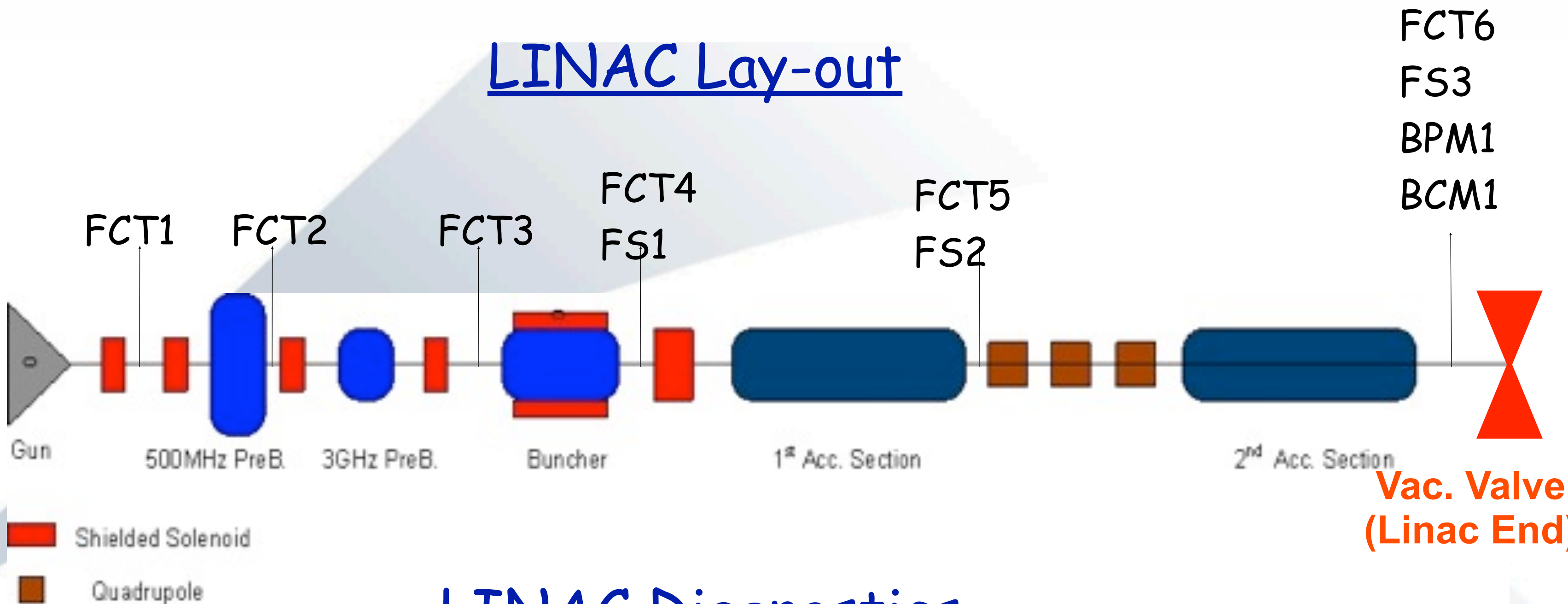
LINAC:



- *90 kV thermo-ionic gun; 500 MHz sub-harmonic pre-buncher; 3GHz pre-buncher, and; 3 GHz, 22 cells standing wave buncher. Bunching system minimises energy spread and losses; ca. 80% transmission from gun to LINAC exit.*
- *Two travelling wave, constant gradient accelerating section increase energy up to 125 MeV.*
- *Two TH2100 pulsed klystrons feed accelerating sections and 3GHz buncher; an independent RF amplifier feeds the 500 MHz and 3 GHz pre-bunchers.*
- *Beam focusing achieved by solenoids up to bunching section, and a triplet of quadrupoles between the two accelerating sections.*

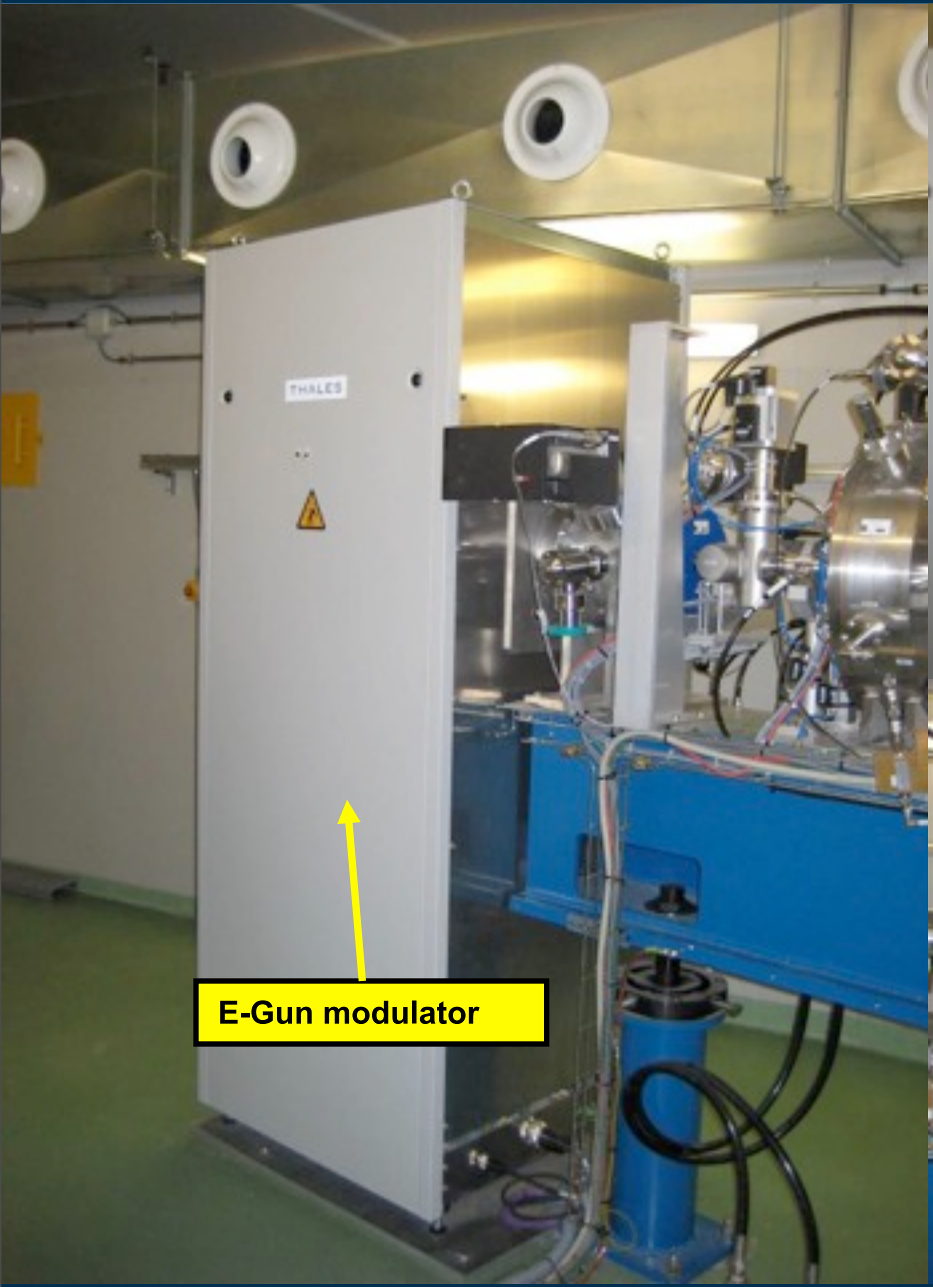


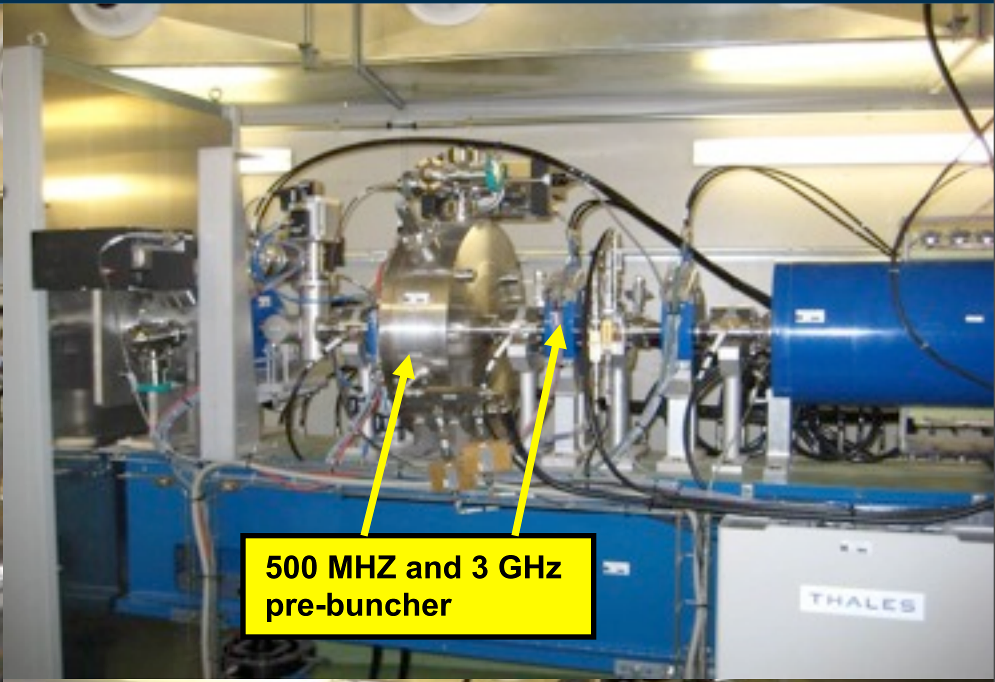
LINAC Lay-out

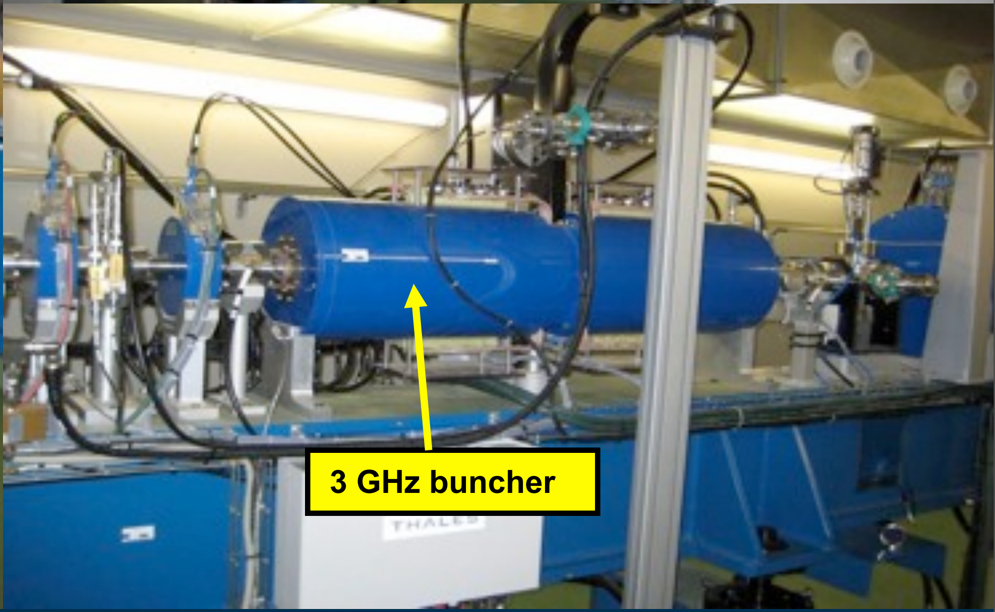


LINAC Diagnostics

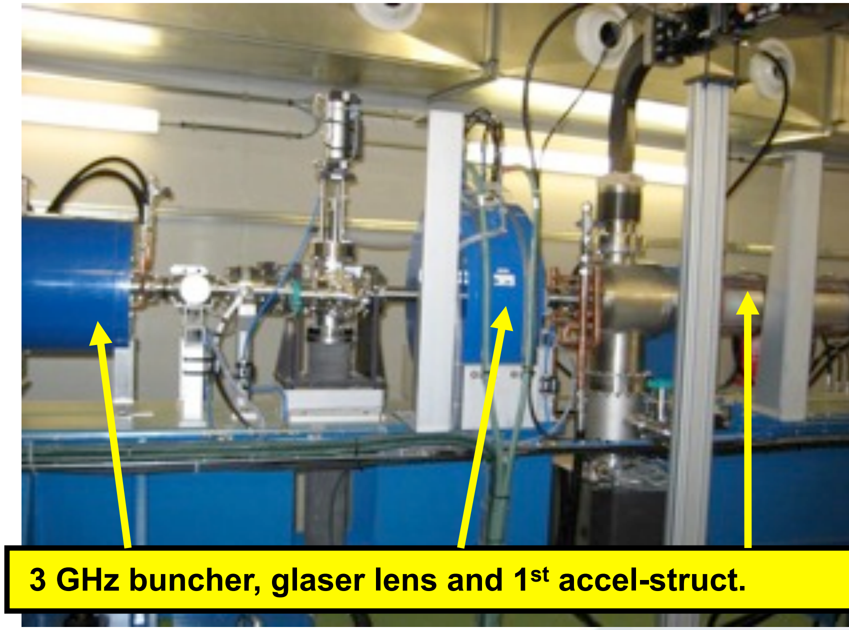
Gun and Bunching System



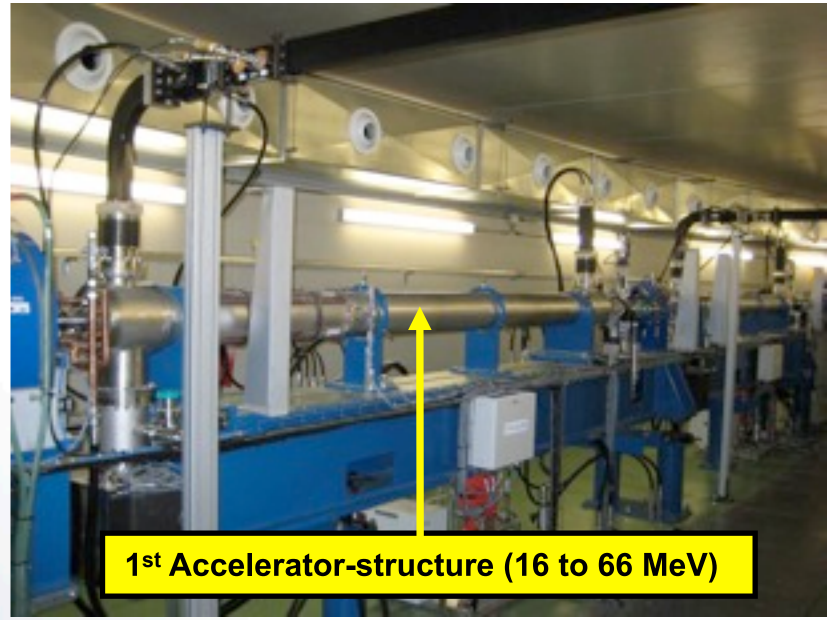




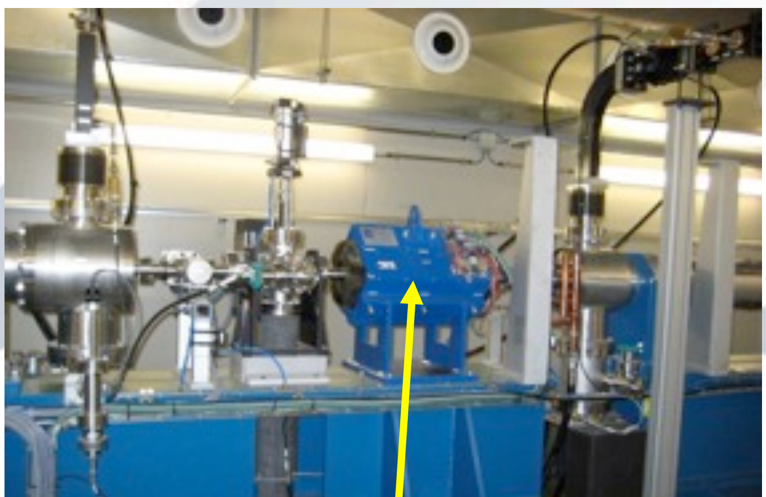
Glaser lens and 1st Accelerator Structure



3 GHz buncher, glaser lens and 1st accel-struct.

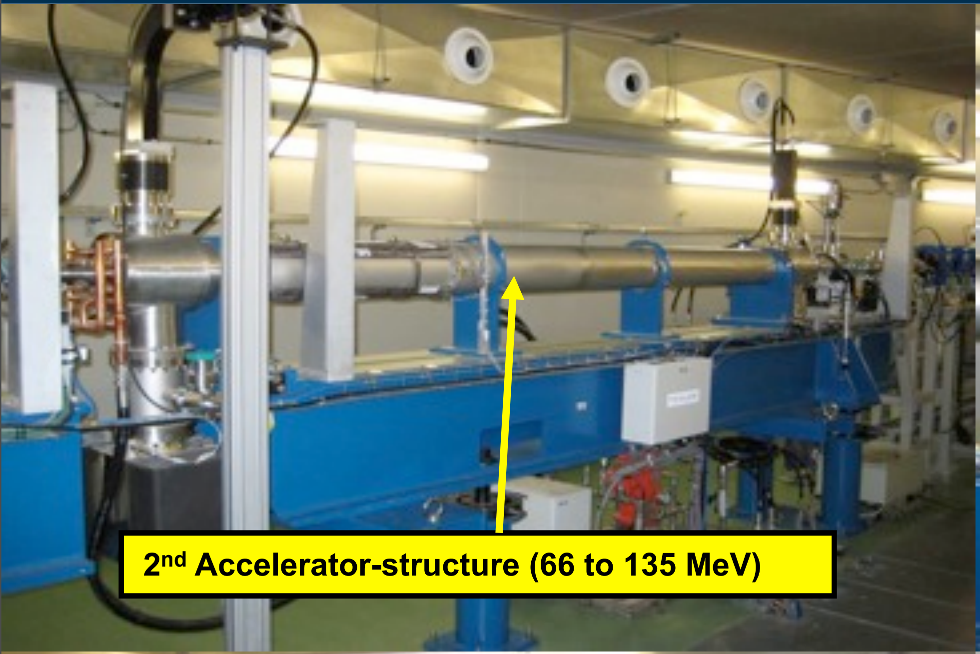


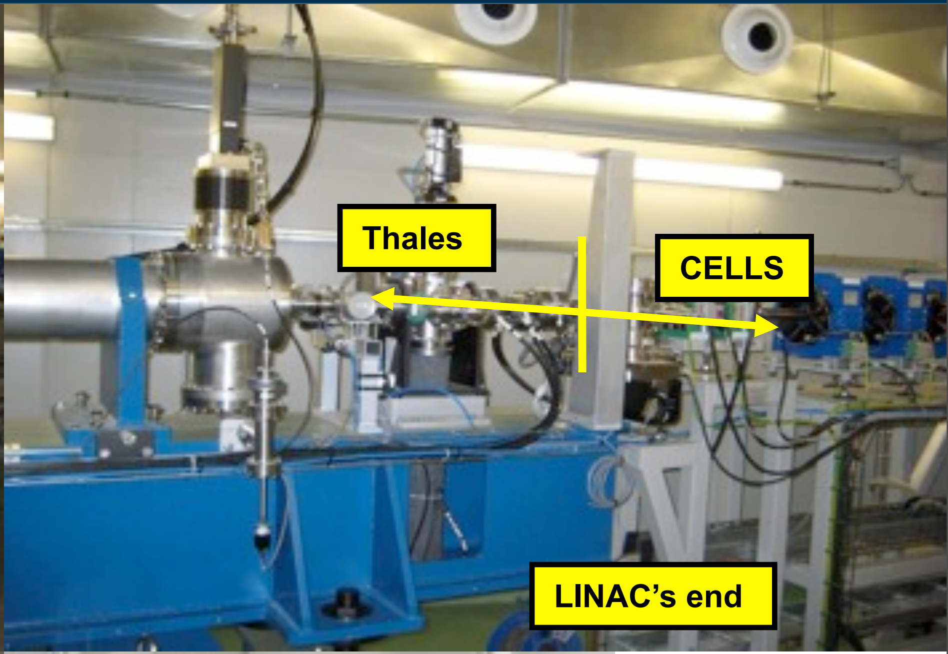
1st Accelerator-structure (16 to 66 MeV)

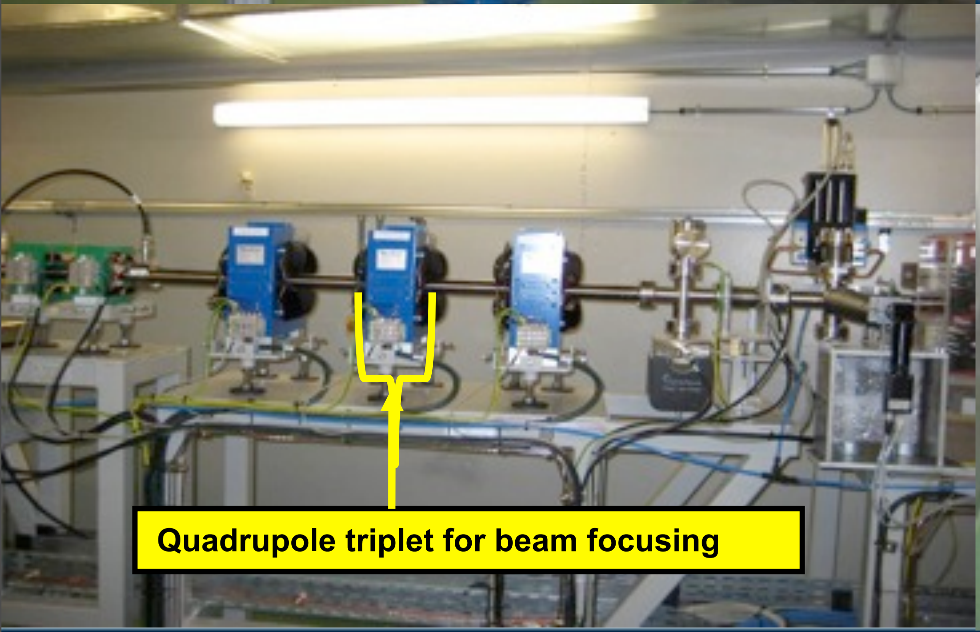


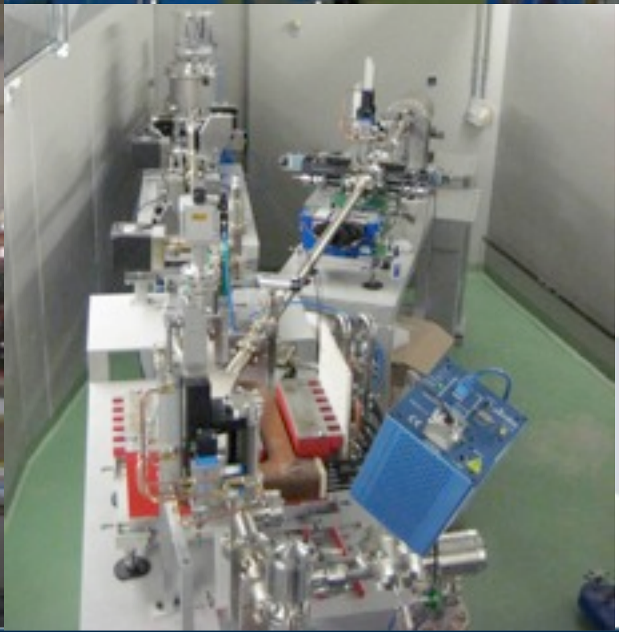
Quadrupole triplet between the accelerating structures

2^{nd} Accelerating Structure, Transfer and Diagnostics Line





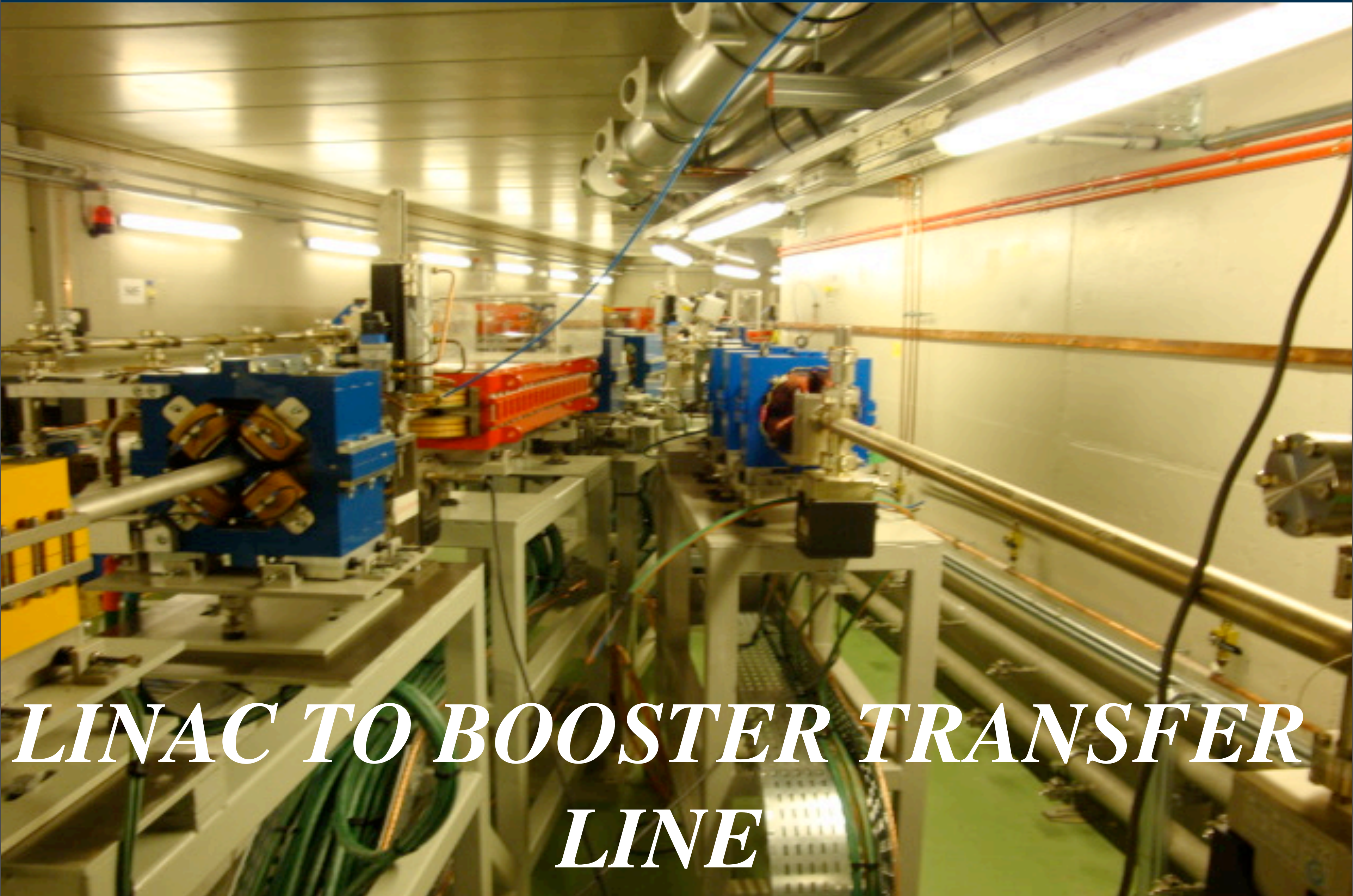




Transfer and Diagnostics Line

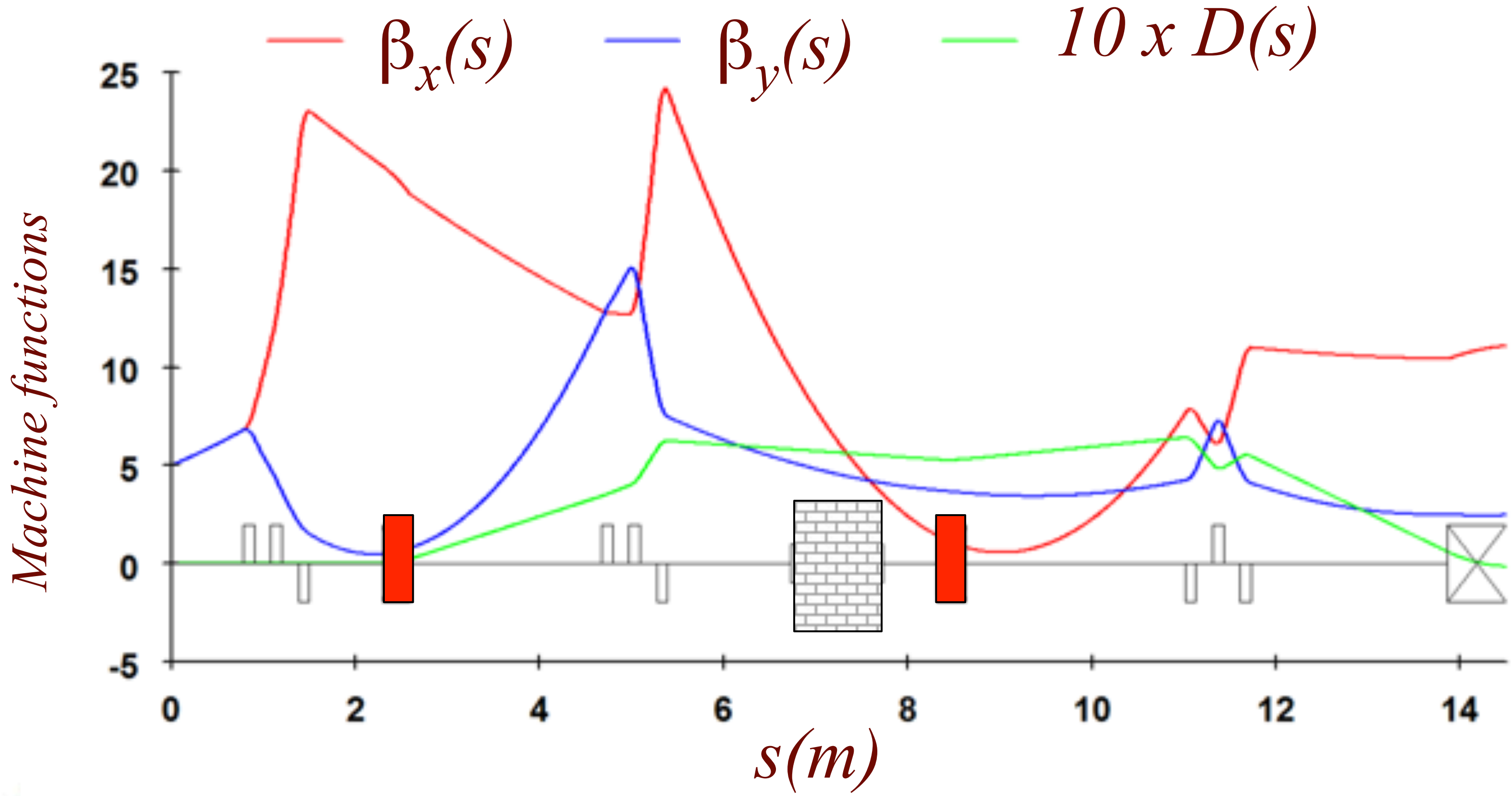
Linac Specifications and performance

Parameter	Specs	Measurements	
Bunch length	1ns (FWHM)	**0.420 ns**	✓
Charge	≥1.5nC	**1.96 nC (8 pulses, spaced 50ns each)**	✓
Energy	≥100MeV	**108 MeV***	✓
Energy variation, ptp	≤0.25 % (rms)	**0.08%**	✓
Relative energy spread	≤0.5 % (rms)	**0.28%**	✓
Norm. Emittance (1σ)	≤30 mm mrad (both planes)	**ε_x = 25 mm mrad** **ε_y = 25 mm mrad**	✓ ✓
Single bunch purity	Better than 1%	**< 3%****	✓
Pulse to pulse time jitter	≤100ps (rms)	**≤28ps (rms)**	✓
Repetition rate	3 to 5 Hz	**1-3 Hz*****	✓

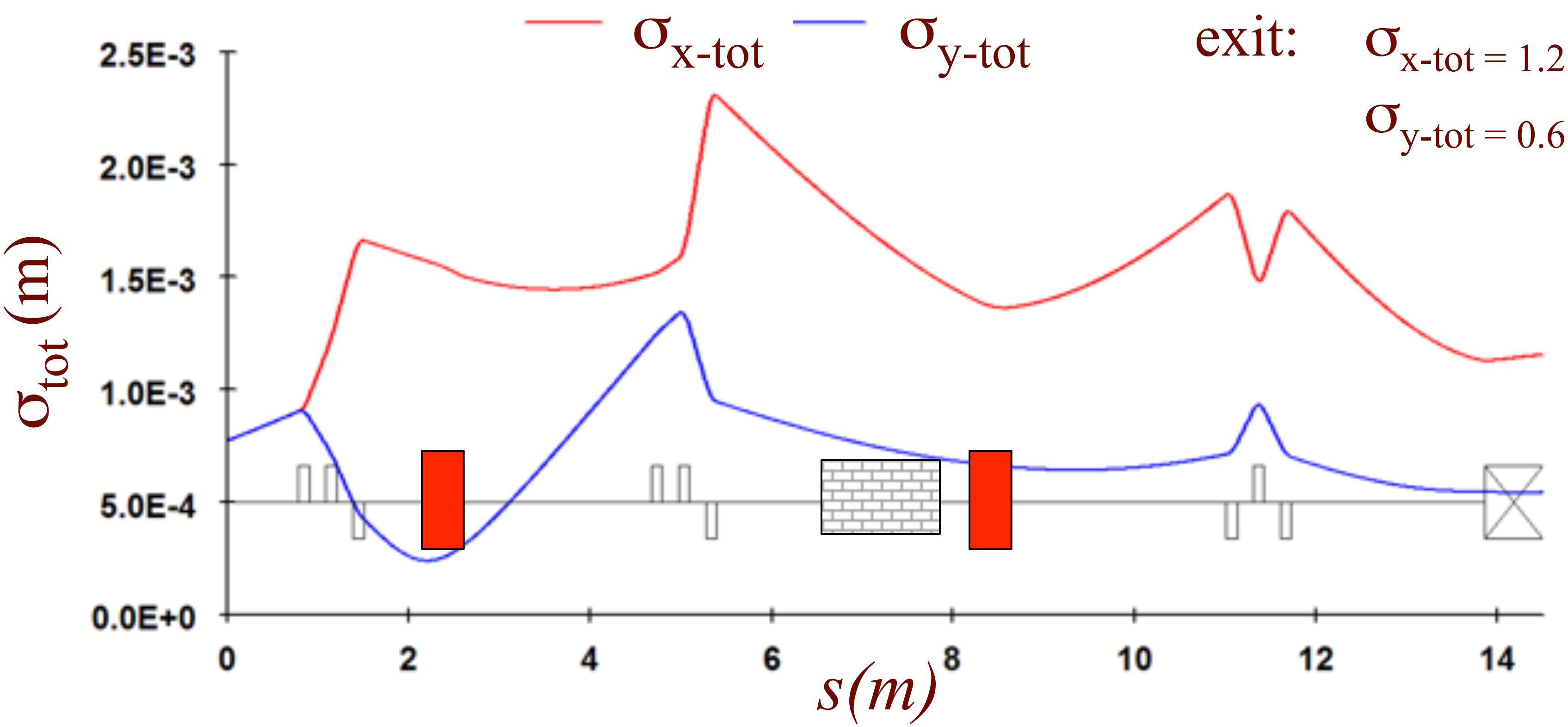


LINAC TO BOOSTER TRANSFER LINE

LINAC to Booster Transfer Line



LINAC to Booster Transfer Line



At LINAC's exit: $\sigma_{x\text{-tot}} = 1.2$ mm

$\sigma_{y\text{-tot}} = 0.6$ mm

Conditions at LINAC's exit:

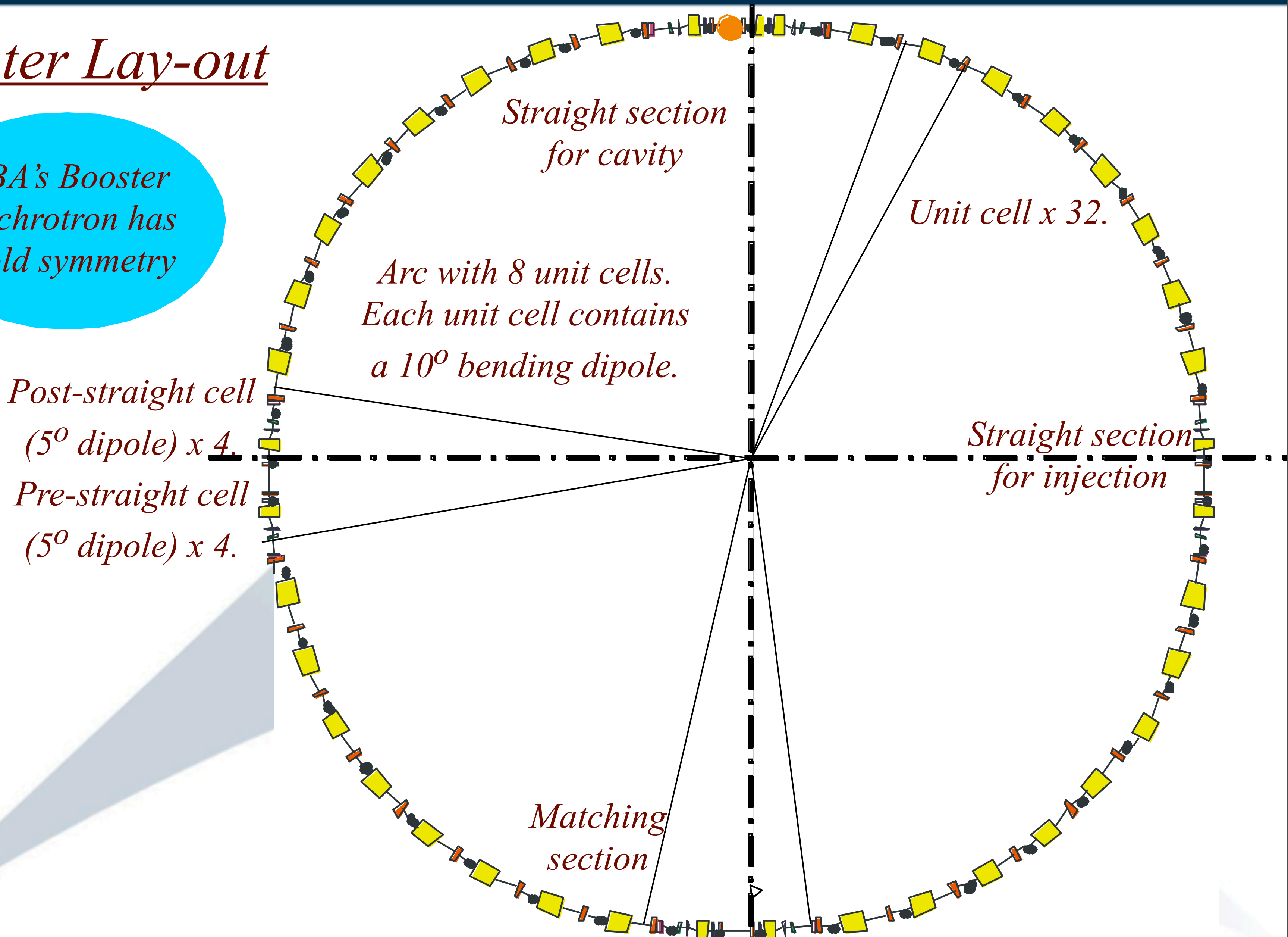
$\varepsilon_{norm} = 30\ \pi$ mm.mrad; $\varepsilon_{100} = 150\ \pi$ mm.mrad;

$\beta = 2$ to 10 m/rad; $\alpha = -2$ to 0, and; $\Delta E/E = 0.005$

BOOSTER

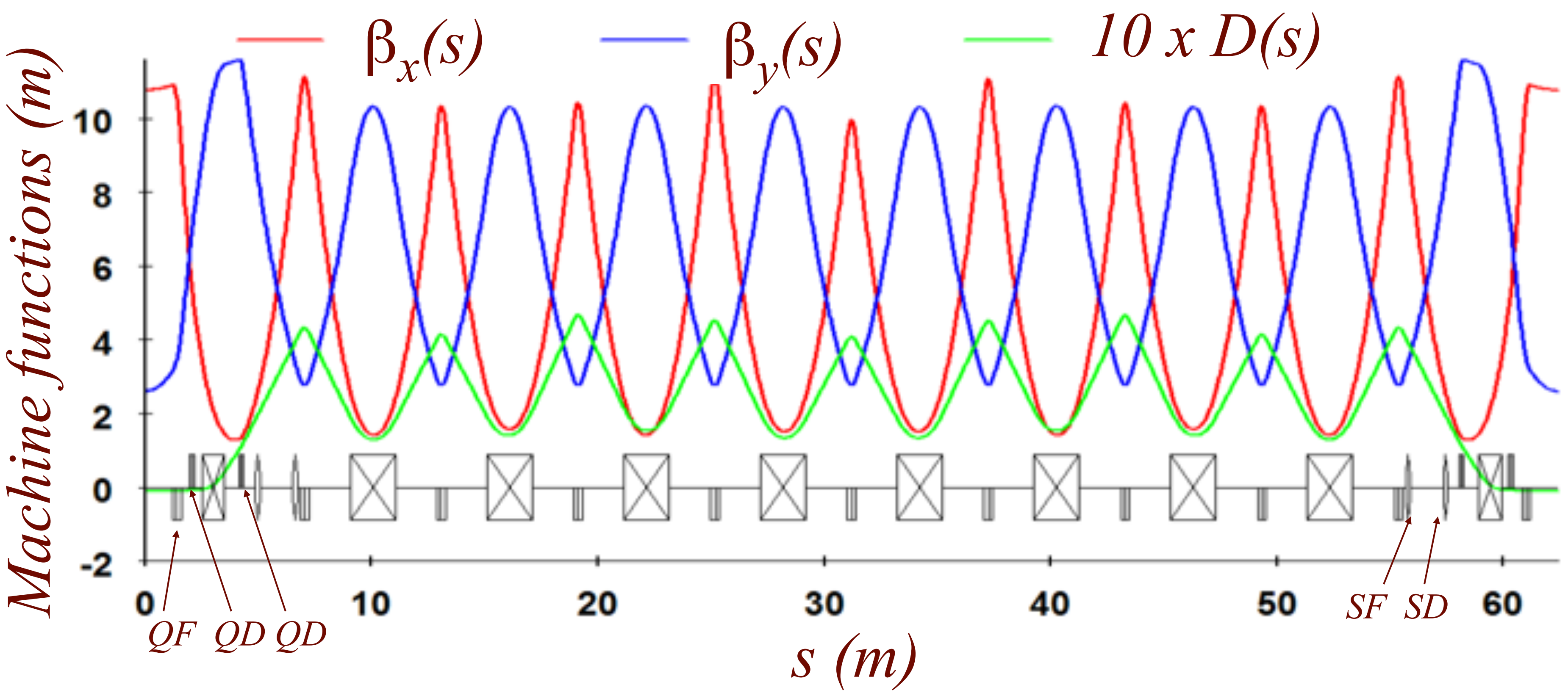
Booster Lay-out

ALBA's Booster Synchrotron has 4-fold symmetry



Booster lattice:

- *Design uses defocusing bending magnets and focusing quadrupoles;*
- *Sextupole components within the bending magnets and quadrupoles;*
- *achieves low emittance, higher flexibility and lower costs, and;*
- $\varepsilon_x = 10$ *nm.rad*

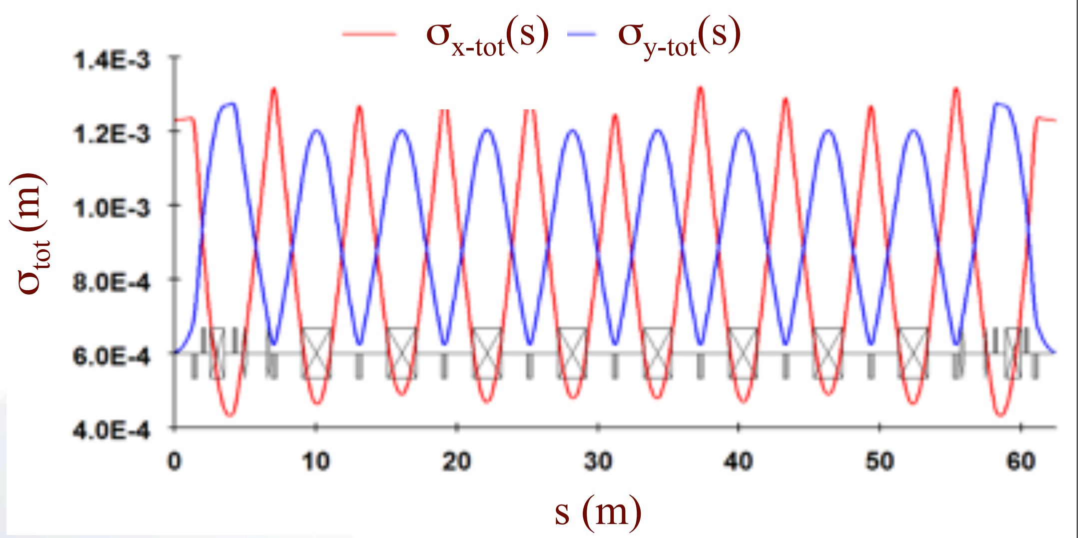


Booster Synchrotron

Beam size at injection:

ε_x = 140 nm.rad; 100% coupling.

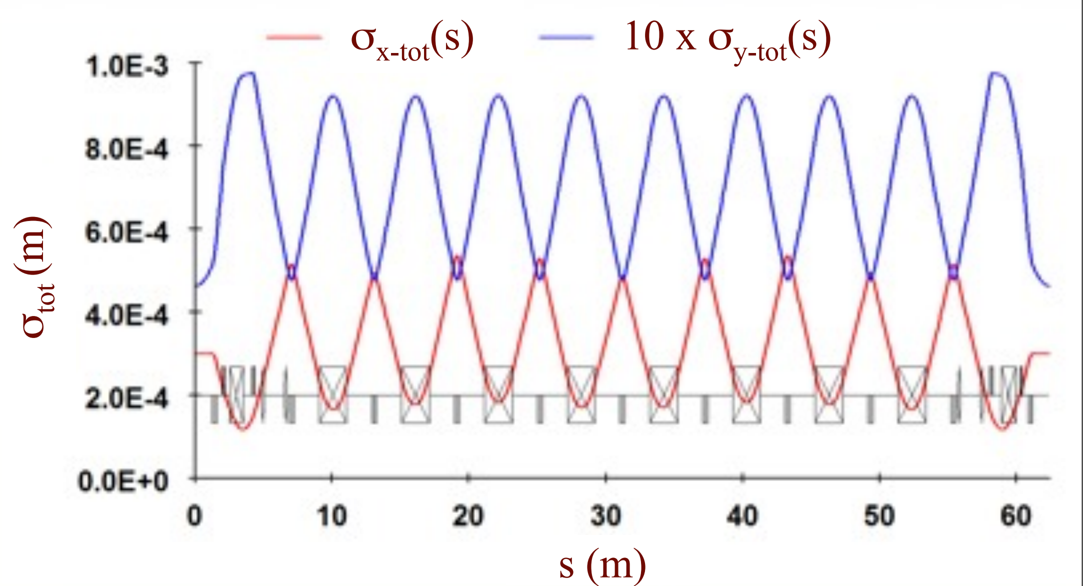
$\sigma_{x,tot}$ = 1.3 mm, $\sigma_{y,tot}$ = 1.25 mm



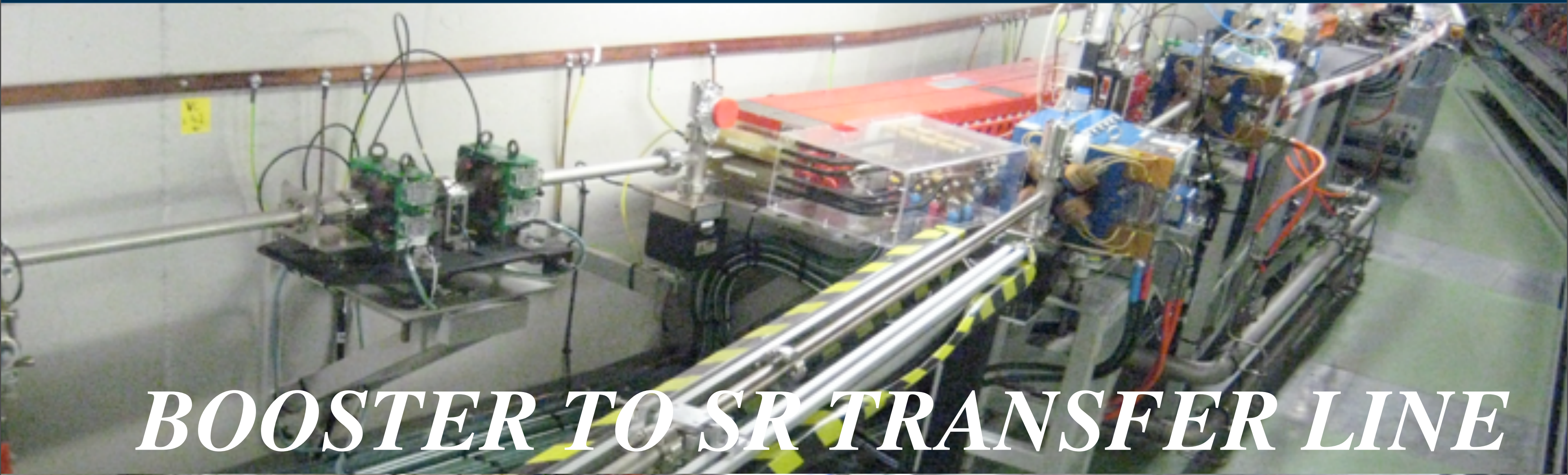
Beam size at extraction:

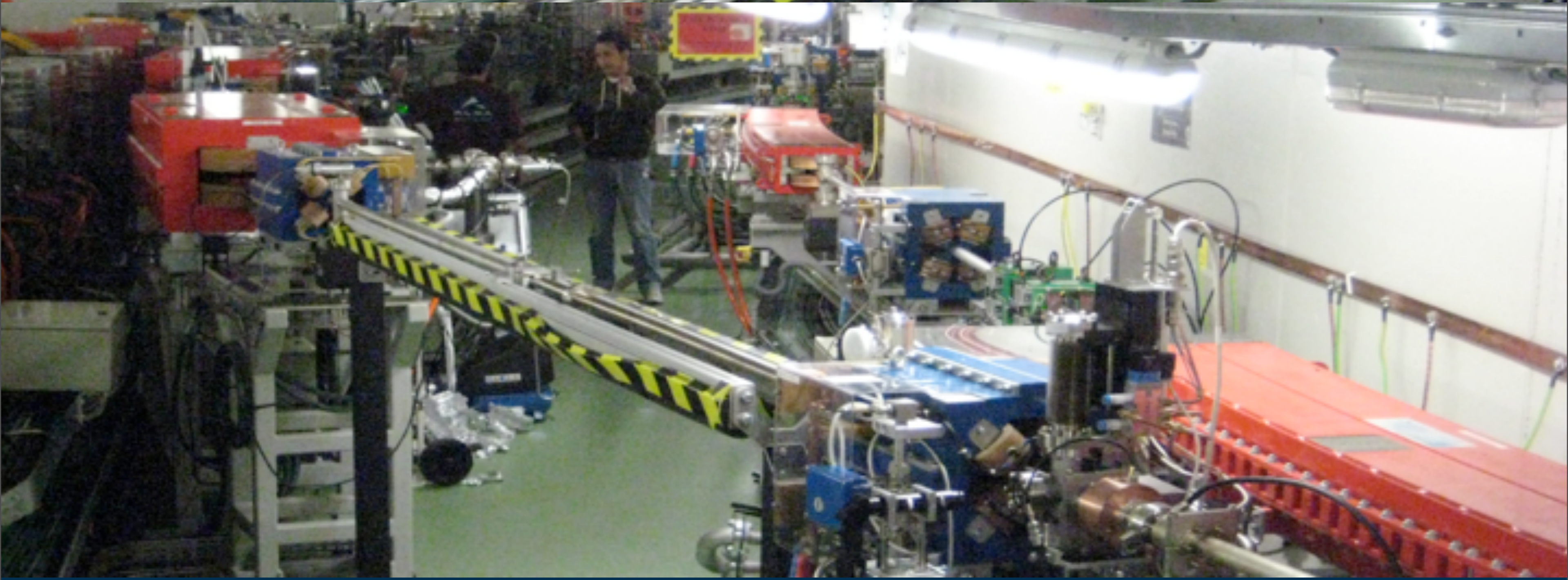
ε_x = 9 nm.rad; 10% coupling.

$\sigma_{x,tot}$ = 0,5 mm, $\sigma_{y,tot}$ = 0.1 mm

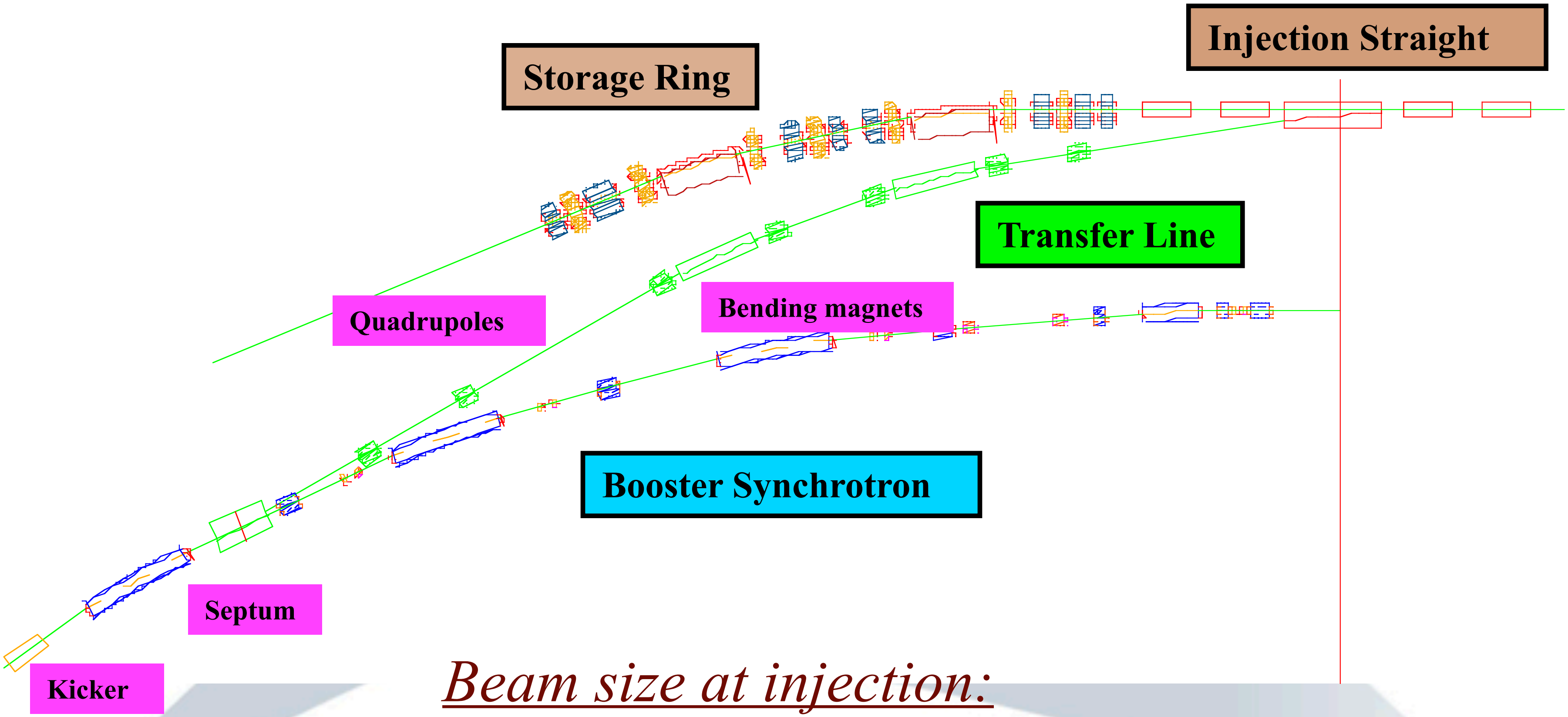


BOOSTER TO SR TRANSFER LINE





Booster to Storage Ring Transfer Line



Beam size at injection:

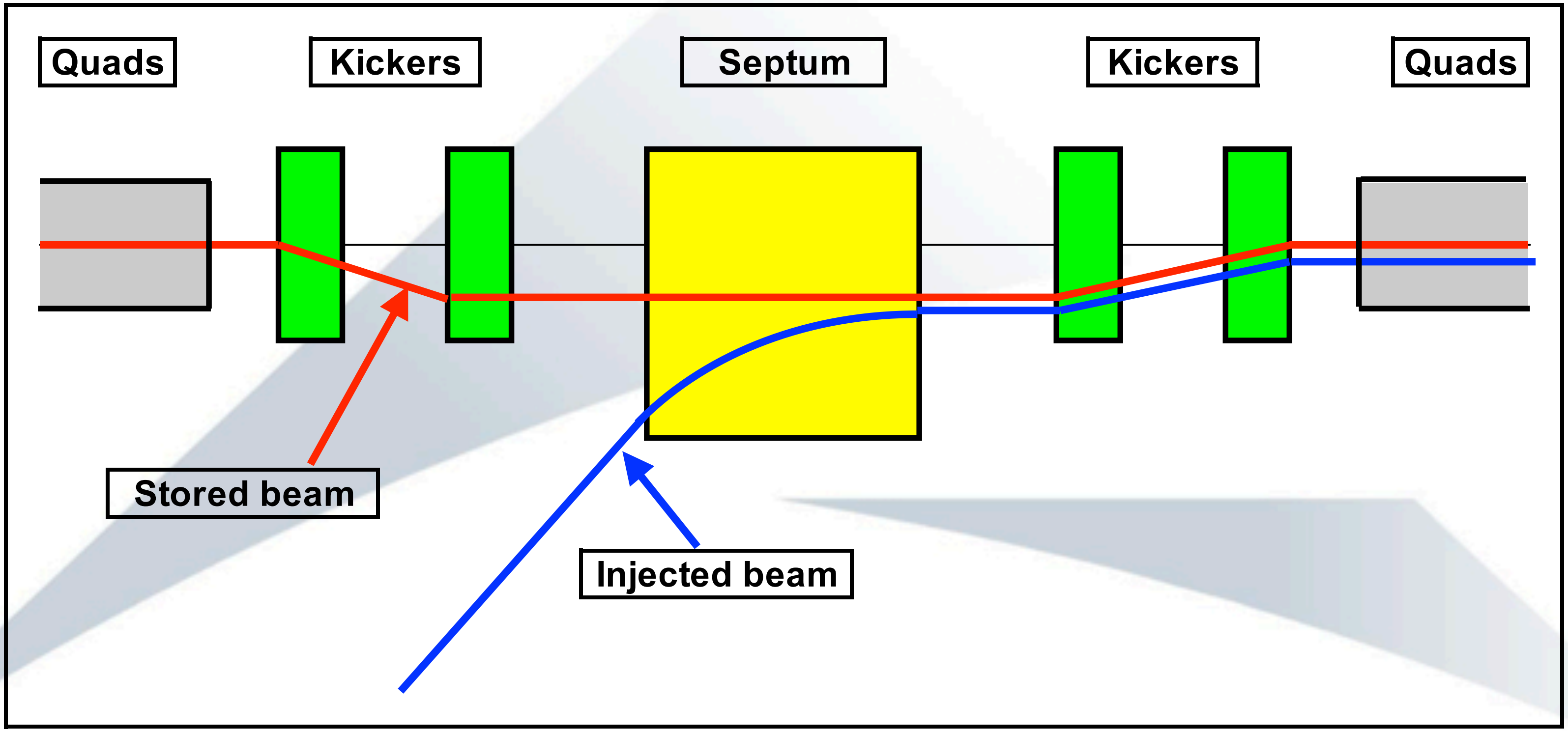
$\varepsilon_x = 9$ *nm.mrad;*

$\sigma_{x,tot} = 0{,}5$ *mm,* $\sigma_{y,tot} = 0.2$ *mm*

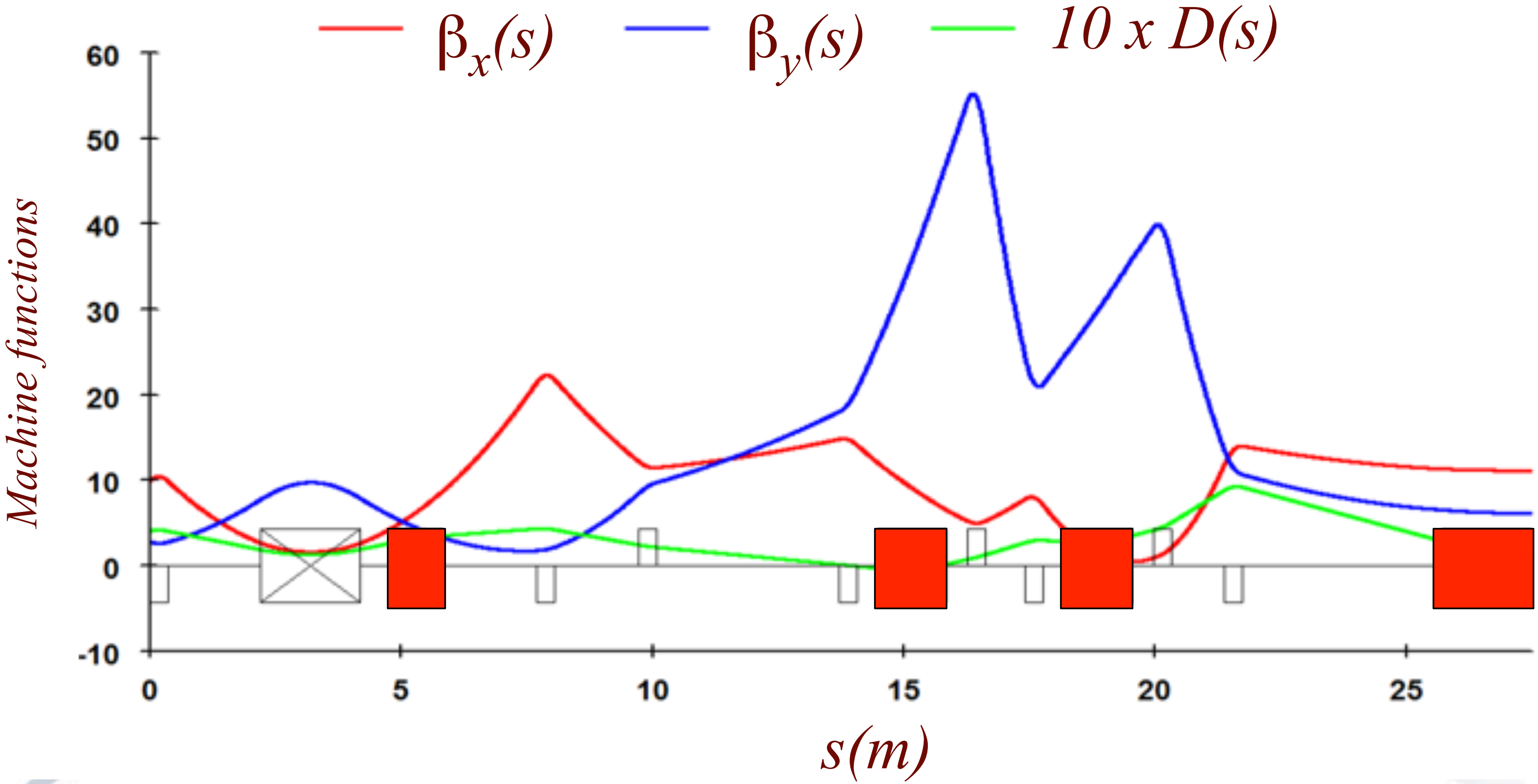
The injection scheme for a 3rd generation light source:

All elements (4 kickers and one septum) have to be in one straight. For 3 GeV the length has to be at least 8 m.

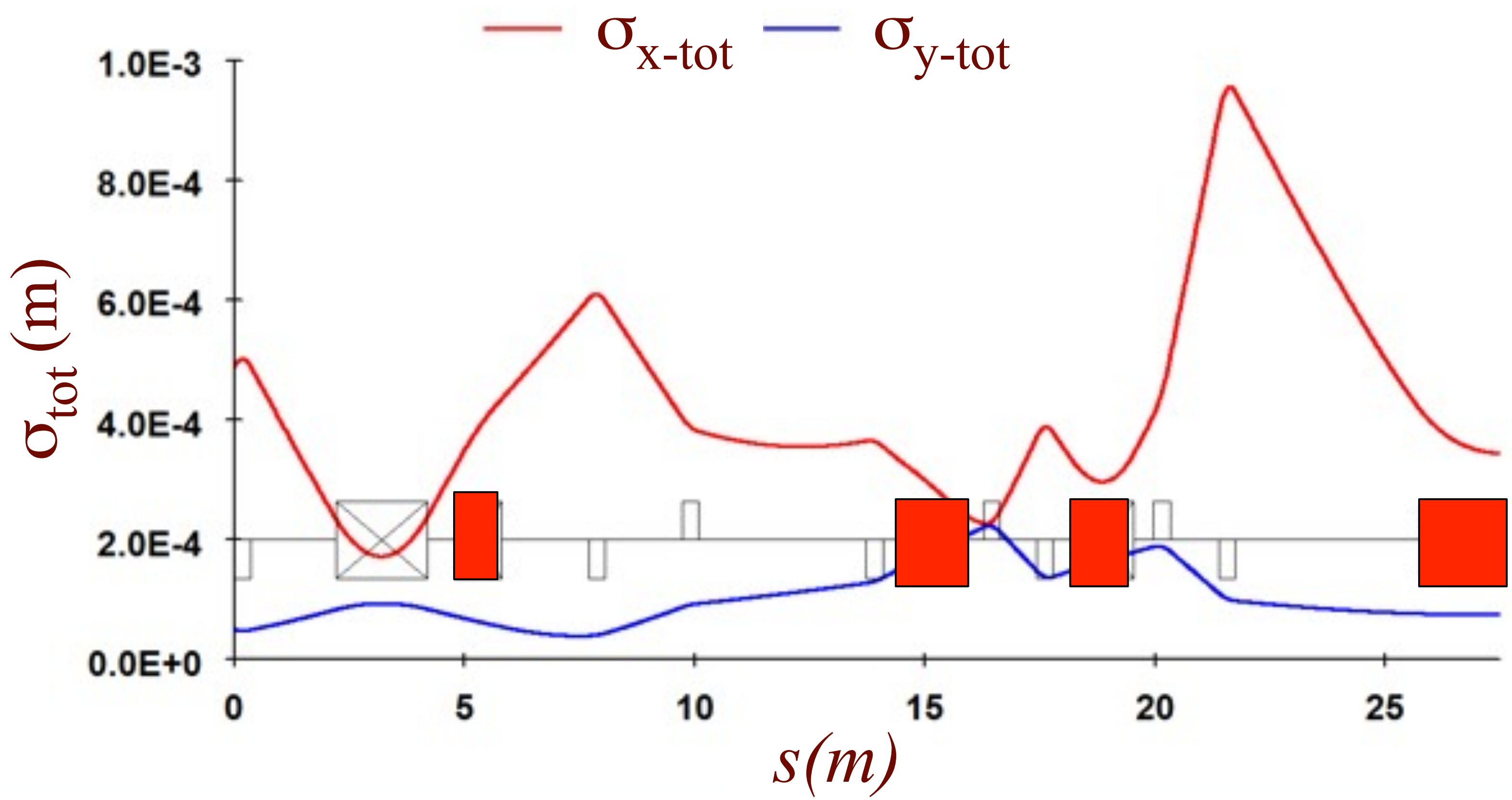
Diamond's concept



Booster to Storage Ring transfer line



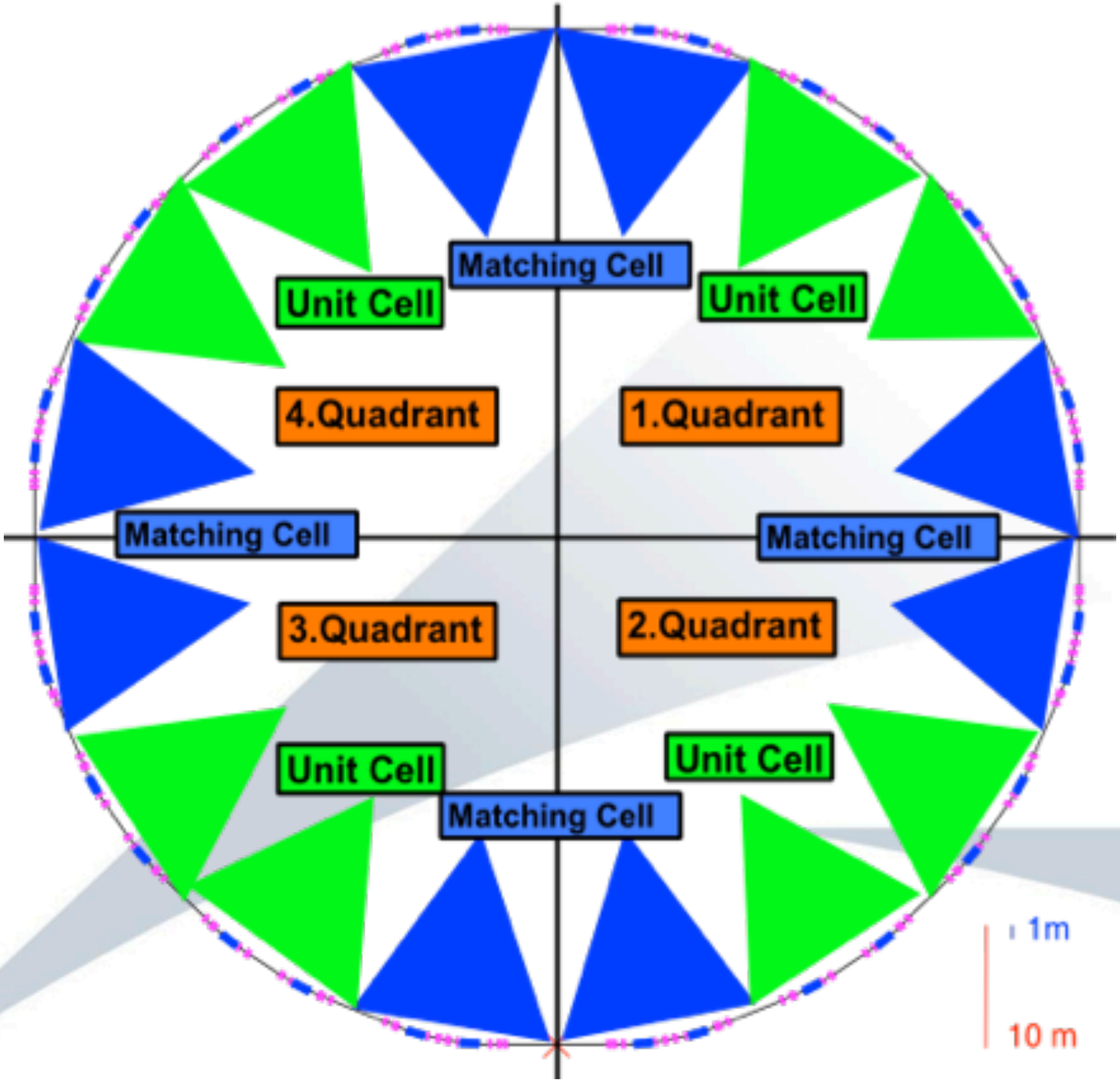
Booster to Storage Ring Transfer Line



Beam size at injection: $\sigma_{x,tot}$ = 0,5 mm and $\sigma_{y,tot}$ = 0.2 mm

STORAGE RING

SR: a 4-fold, 16 cell, expanded DBA lattice



Parameters:

E = 3.0 GeV

C = 268.8 m

N = 4 fold

φ = 11.25 degr.

ε_x= 4.30 nmrad

α = 8.42E-04

$\delta E/E$ = 1.0E-03

δE = 3 MeV

$Q_{x,y}$ = 18.2 / 8.37

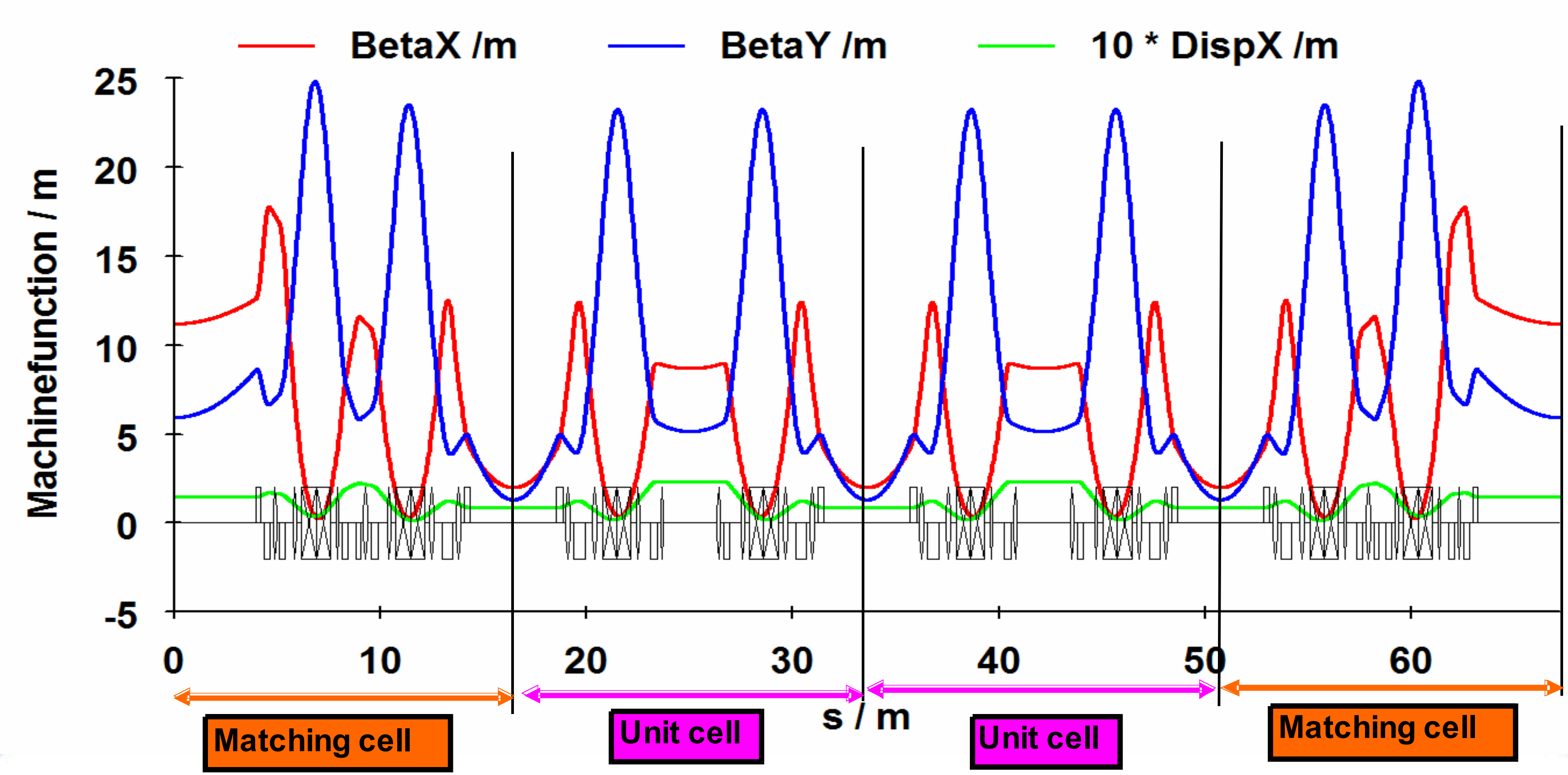
$\xi_{x,y}$ = -40.0 / -25.5

L = 8.0 / 4.4 / 2.6

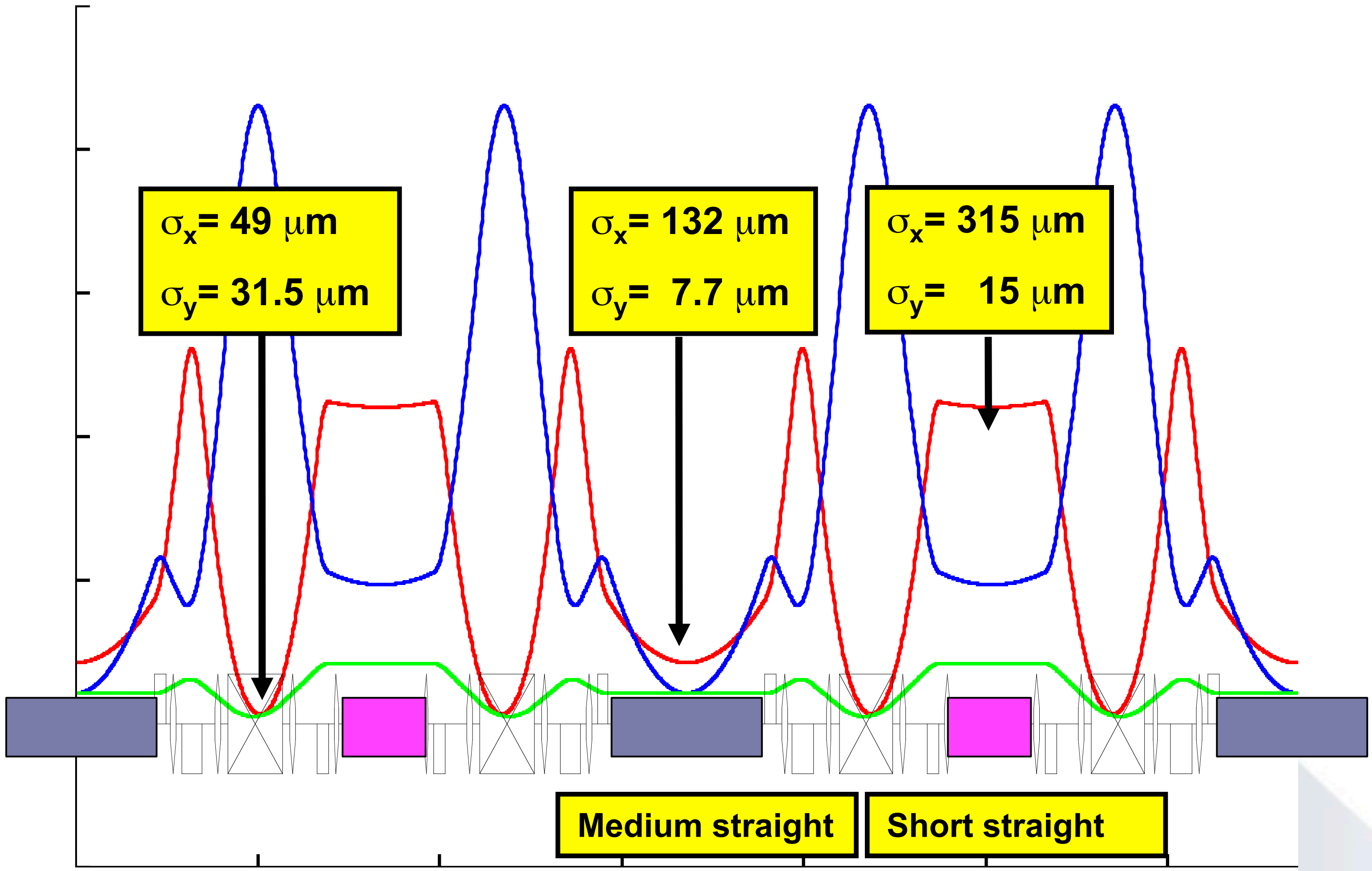
It was decided to use combined bending magnets because they have two advantages, i.e.:

1) **reduction of the emittance by roughly 30 % because of Jx, and;**
2) **results in a more compact machine and, therefore, there is more space for insertion devices.**

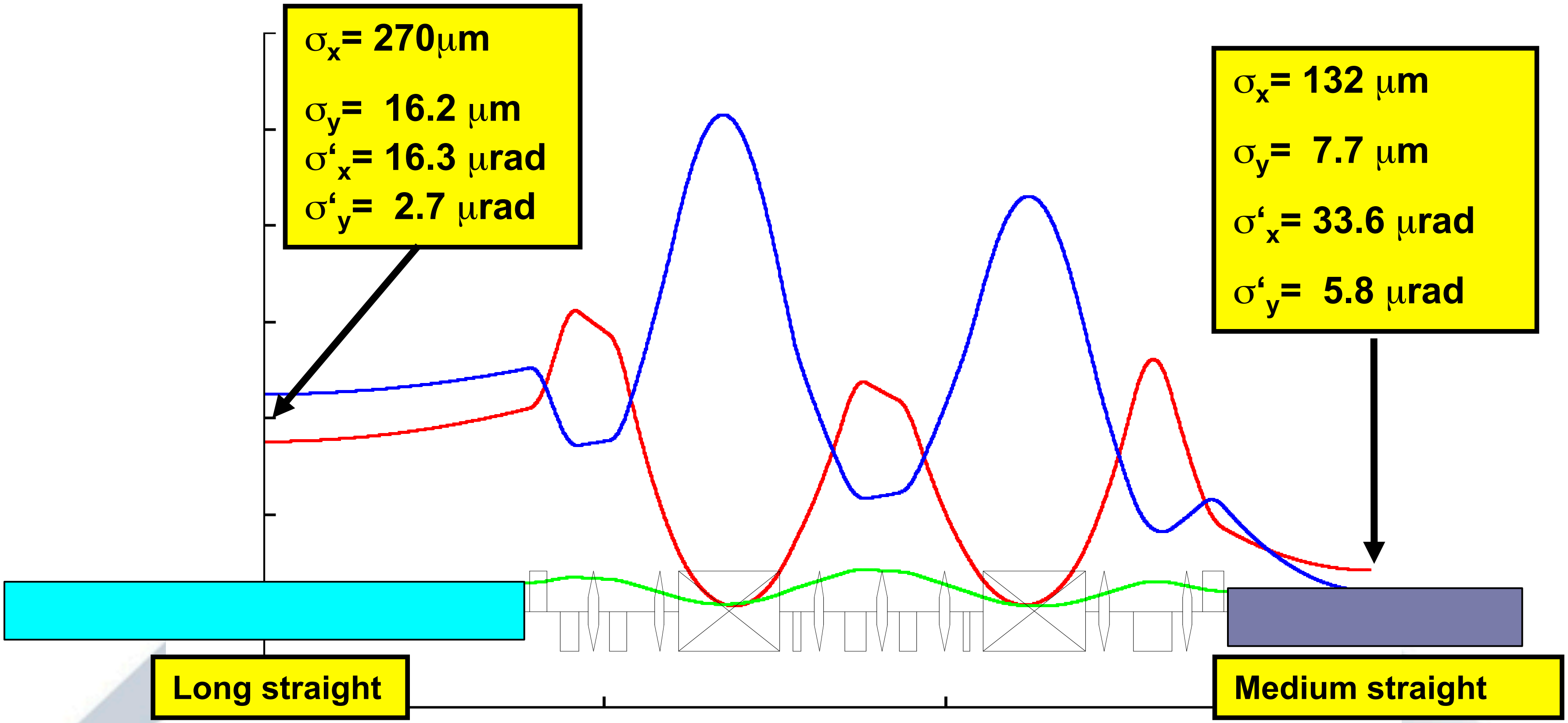
The ALBA lattice within a quadrant



Machine functions within two Unit Cell



Machine functions within the matching section

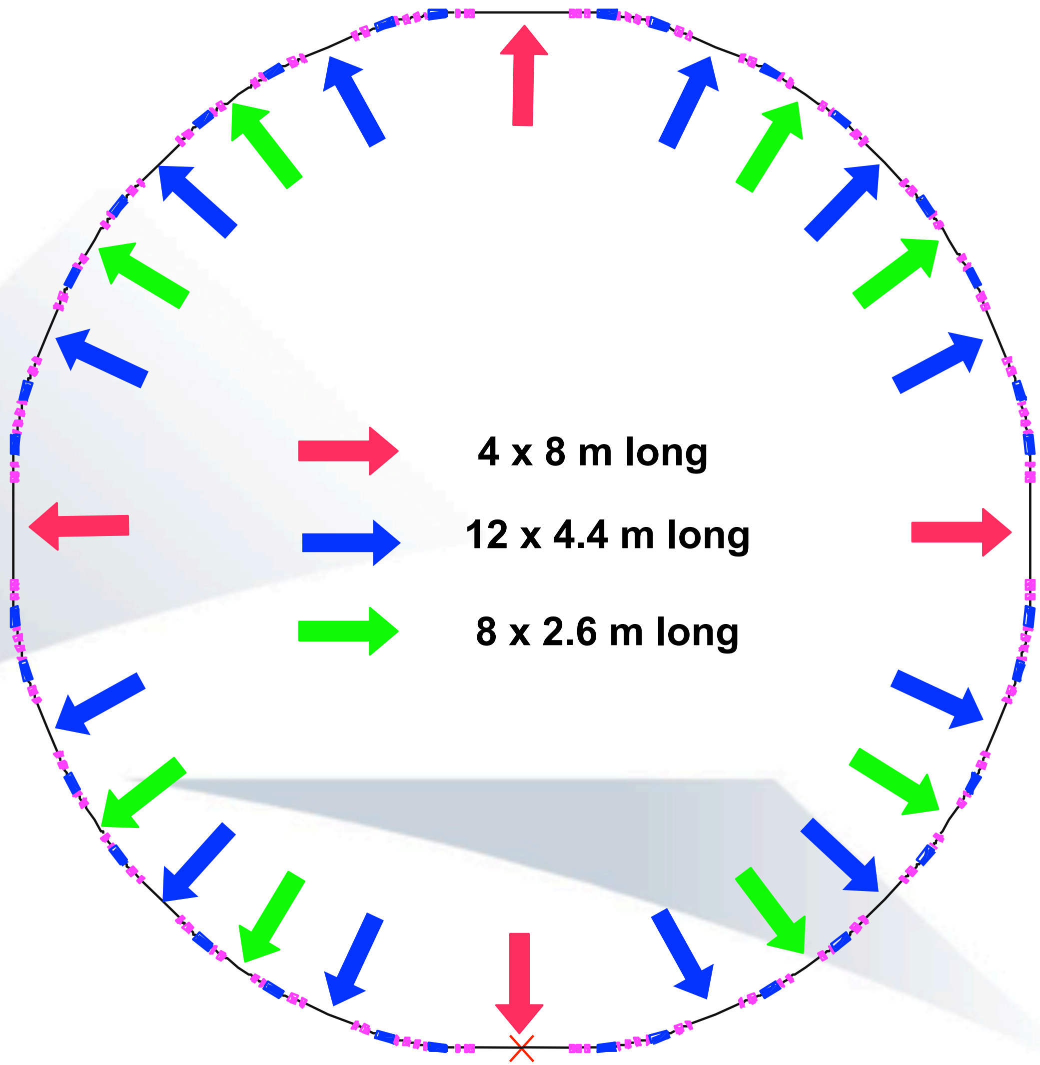


Beam-lines and experimental stations

Straight sections in ALBA's SR lattice

In a third generation SL source it is important to have as many as possible straight sections for housing IDs. However, large perimeter means significantly greater costs. Therefore, it is important to optimise the ratio of straight sections to the total perimeter of the SR.

This has played a major role in the design of the lattice of ALBA's Storage Ring.



It is also important to try to optimise the lattice design so that the possible trade between source size and collimation is used to tailor points of light extraction to specific needs - e.g. spectroscopy benefits from collimation, whilst imaging benefits from a small and round source size -.

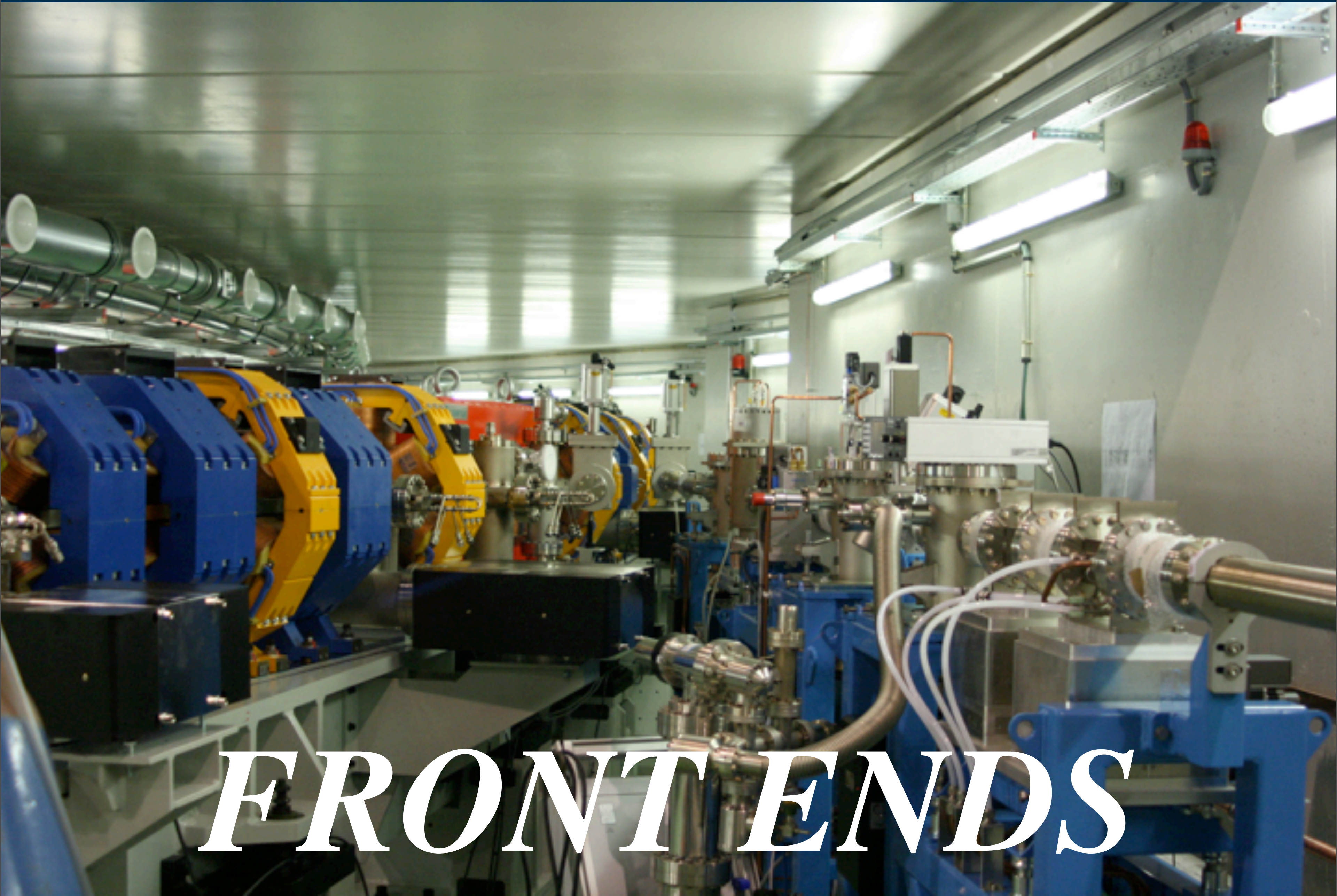
SUMMARY OF THE PARAMETERS OF THE 4-FOLD, 16 CELL, EXPANDED DBA LATTICE:

$E = 3.0$ GeV $\quad$ $C = 268.8$ m $\quad$ ε ca. 4.5 nm.rad

4 straight sections 8 m long each: 3 useful for Beam-lines
12 straight sections 4.3 m long each: 12 useful for Beam-lines
8 straight sections 2.58 m long each: 2 useful for Beam-lines
32 Bending Magnets: 16 useful for Beam-lines
i.e. 33 FE for beam-lines

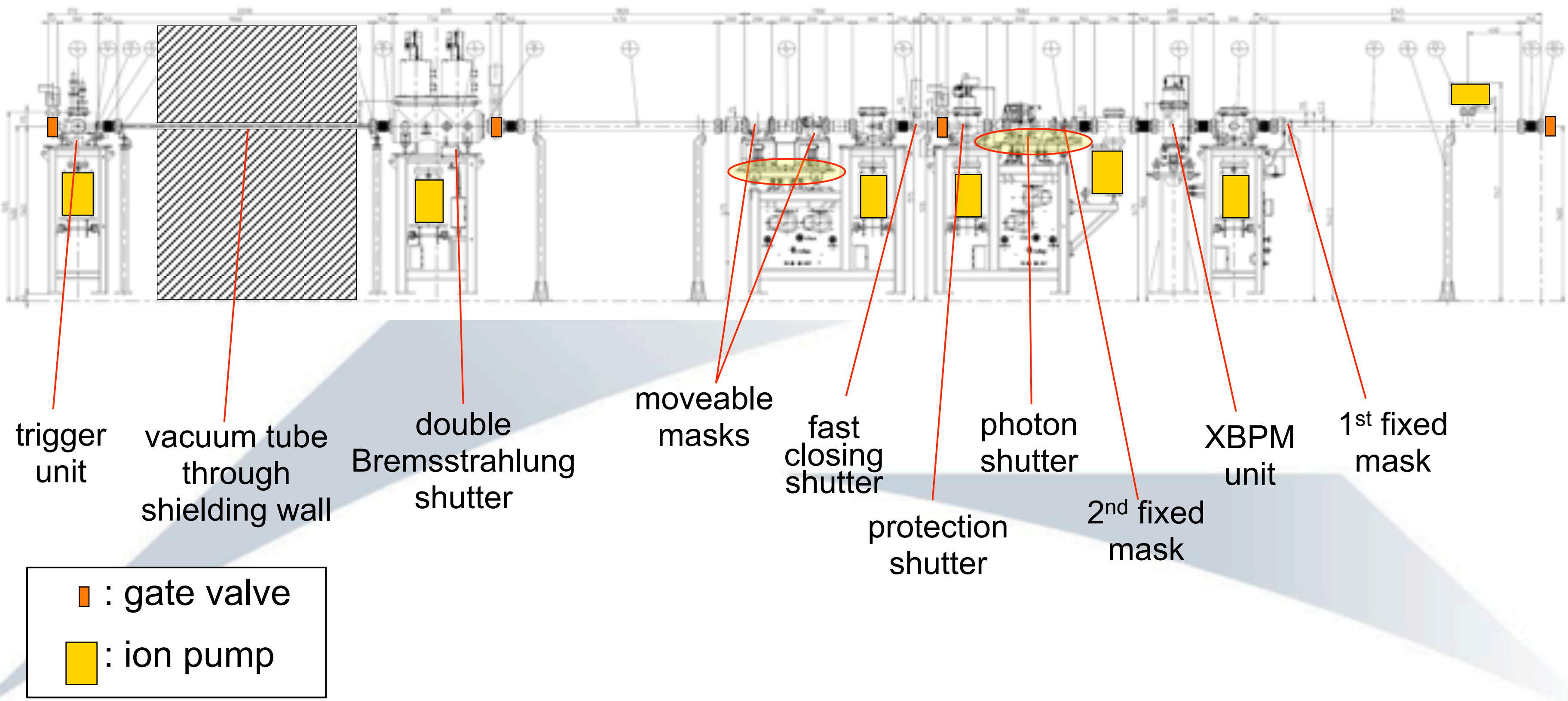
Source point	β_x (m)	α_x	β_y (m)	α_y	D_x (m)	D'_x	σ_x (μm)	σ'_x (μrad)	σ_y (μm)	σ'_y (μrad)
Long S.	10.20	0	5.22	0.05	0.15	0	263	21	15	3
Med-1 S.	1.98	0	1.153	0.05	0.09	0	133	47	7	6
Med-2-S.	1.98	0	1.21	0.10	0.09	0	133	47	7	6
Short S.	8.63	0	5.79	0.04	0.23	0	310	23	16	3
Bending	0.36	0.25	23.93	0.83	0.02	0.02	44	116	32	2

FRONT ENDS

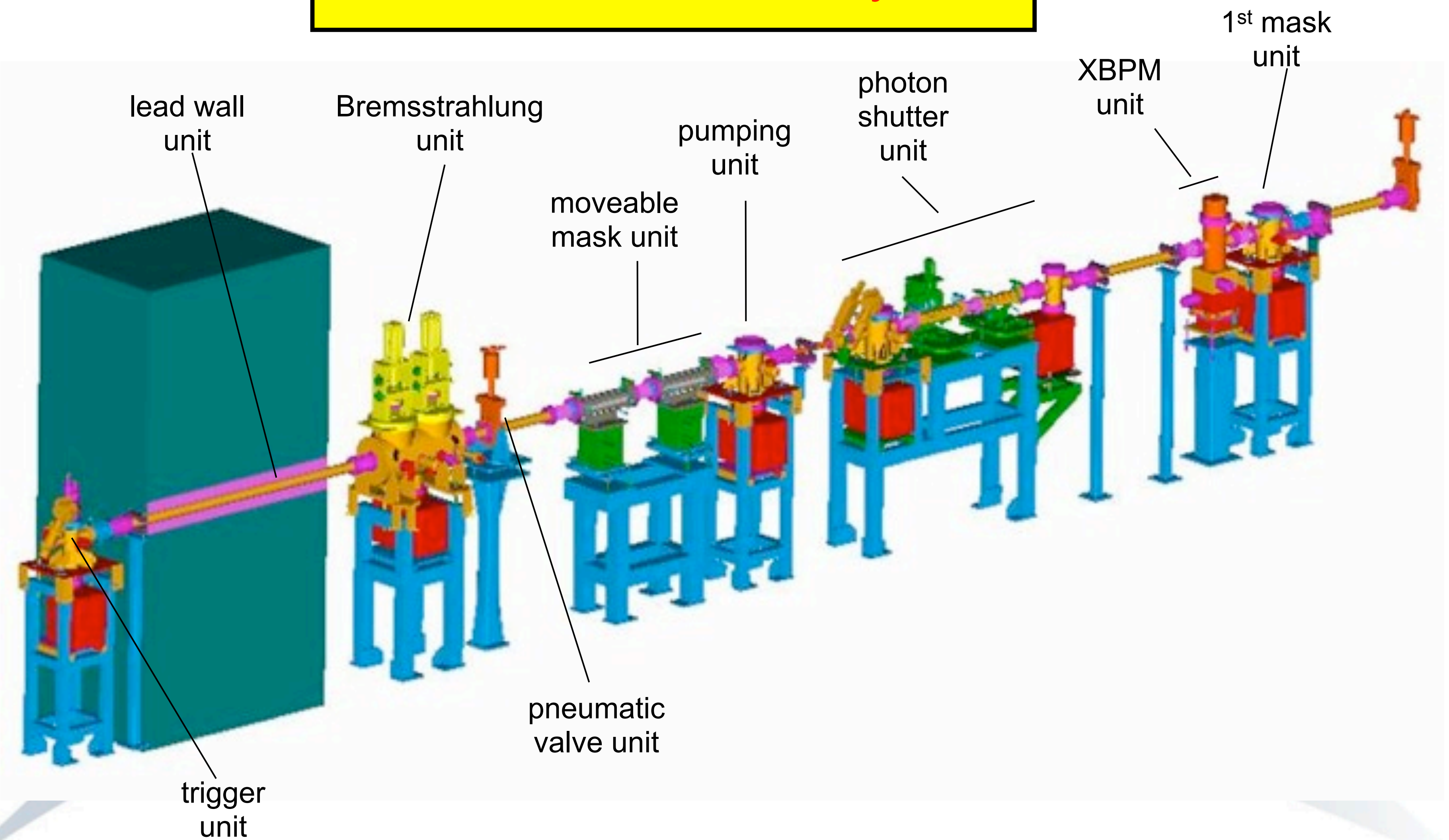


General layout

FMB design (example for FE02)



Front End: General layout



EPS: Equipment protection system!

PSS: Personnel Safety System!
Shield walls, radiation shutters, shadow shields, Bremsstrahlung shutters, etc..

Redundancy and diversity!

Needed defining accurately and soon! CSN license takes time.

A REQUIREMENT ON CELLS WAS TO DEFINE THE SCIENTIFIC AND TECHNICAL OBJECTIVES OF THE BEAM-LINES.

THIS PROCESS OF DEFINITION FOR THE INITIAL SET OF BEAM-LINES WAS COMPLETED BY THE MIDDLE OF 2005.

AUSE (Spanish Synchrotron Radiation Users Association). AUSE is funded by the MEC.

SEVERAL WORKSHOPS ORGANISED UNDER THE AUSPICES OF AUSE WERE USED AS PART OF THE PROCEDURE TO PREPARE THE SCIENTIFIC CASES.

SAC AND SAC APPOINTED INDEPENDENT REFEREES WERE USED TO EVALUATE AND RANK THE PROPOSALS.

ALBA's initial set of beam-lines:

- *Soft X-ray BL for polarisation dependent microscopy (PEEM) and electron emission spectroscopies of ¨real¨ surfaces, i.e. relatively high pressure. Two end stations (Phys., Mat. Sci.).*
- *Soft X-ray BL for XMCD and resonant scattering. Two end stations (Phys., Mat. Sci.).*
- *BL for high resolution powder diffraction with micro-focus option (Mat. Sci.).*
- *High brilliance XAS (Chemistry,Biology, Mat. Sci.).*
- *Non-crystalline diffraction with micro-focus option (Biology +Mat. Sci.).*
- *Crystallography of very large macromolecules (Biology).*
- *X-ray microscopy BL (Biology).*

Light sources for the initial beam-lines

2 Multipole wigglers (1 super-conducting):

X-ray spectroscopy (MW) and Powder Diffraction (SCW).

Status: delivered and undergoing lab. tests

2 in vacuum undulators:

Biomol. Xtallography (1) and Non-Xtalline scat/dif. (1)

Status: delivery expected this summer.

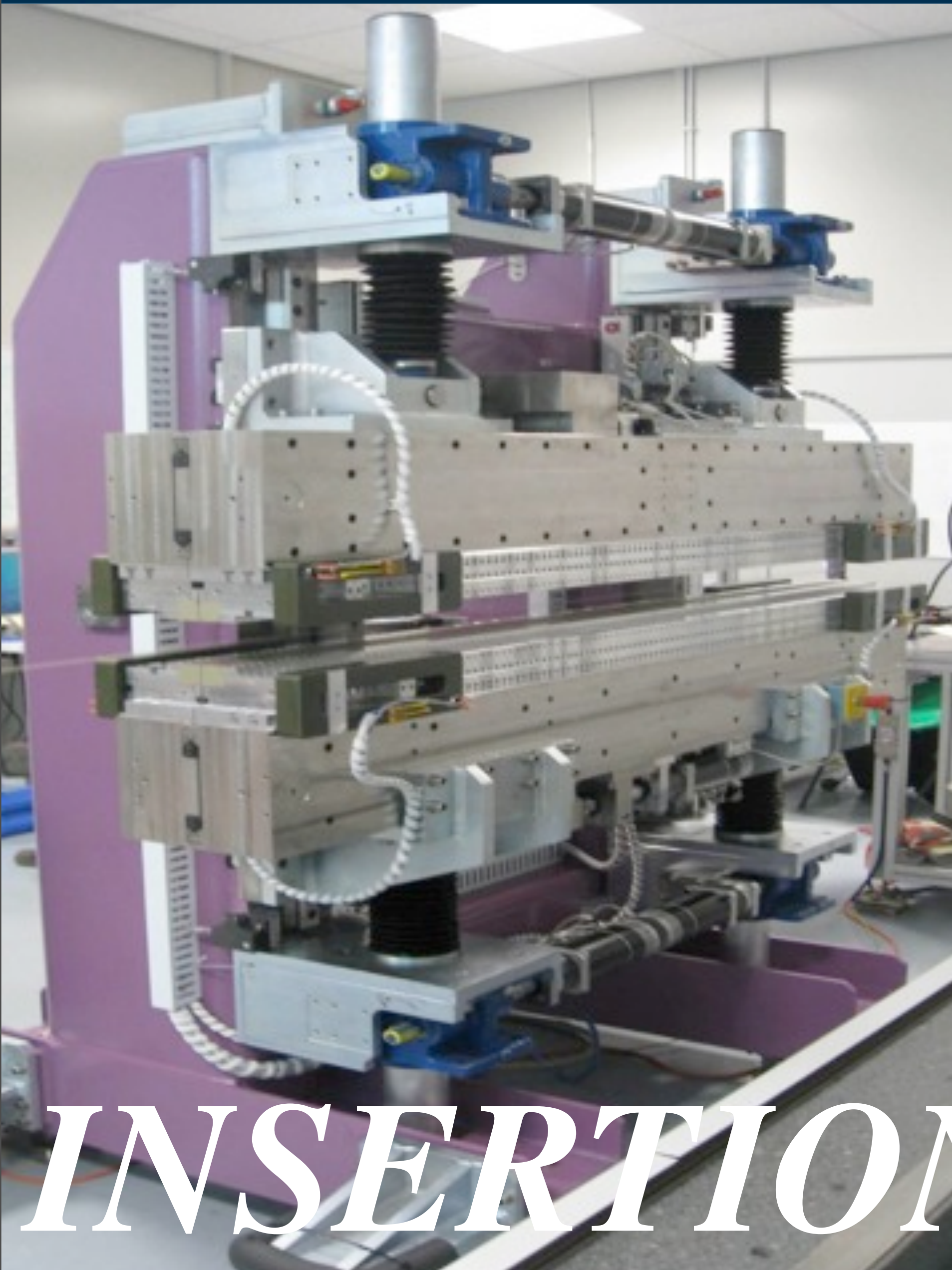
2 Apple type undulators:

XMCD+PE Spec. (1) and PEEM+PE Spec. (1)

Status: delivered and undergoing lab. tests

1 BM:

X-ray microscopy(1), primarily water window BL.



INSERTION DEVICES

Conventional wiggler W80

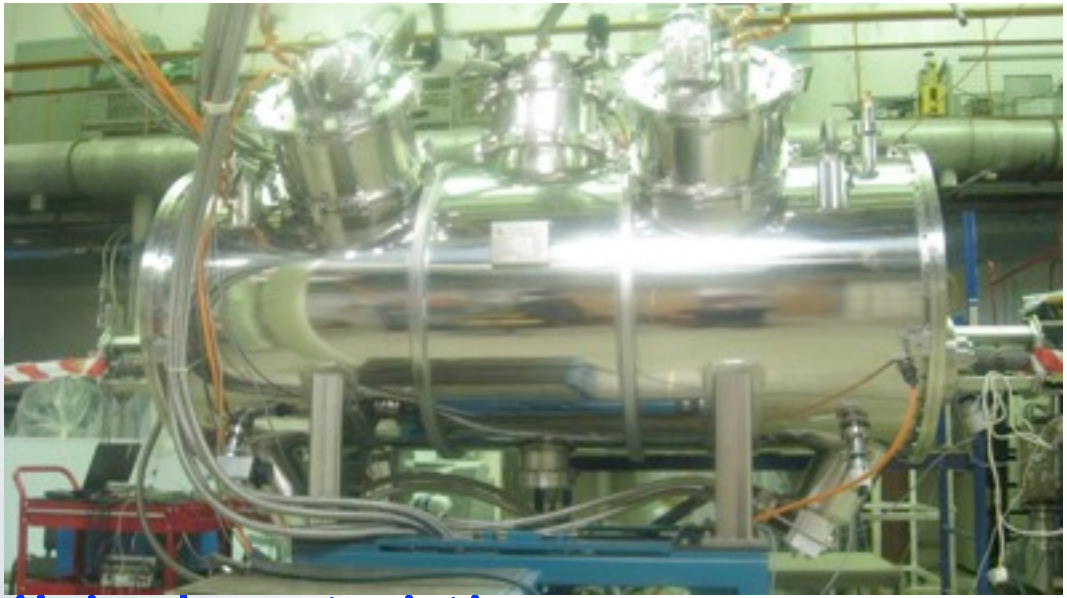
Main characteristics

- Hybrid structure, NdFeB magnet blocks
- 12,5 mm minimum gap
- Block size: 90 x 70 mm. Pole size: 55 x 55 mm
- Num. periods full size: 25
- Length: 1.070 m
- Bmax: 1.782 T
- K: 13.32
- Ripple @ low energies ~6%

Status

- Measured at CELLS – OK
- A number of mechanical imperfections not affecting performance were detected

Superconducting wiggler SC-W31



Main characteristics

- Superconducting wiggler
- 12,6 mm magnetic gap
- Period: 30,16 mm
- Num. poles full field: 117
- Length: 1.764 m
- Bmax: 2.16 T
- K: 6.08

Status

- FAT passed OK
- Shipment ongoing
- SAT pending installation

In-vacuum undulators IVU-21

Main characteristics

- PPM undulator
- SmCo magnet blocks.
- 5,7 mm minimum gap
- Block size: 50 x 16 mm
- Period length: 21.8 mm
- Num. Periods full size: 92
- Length: 2.1 m
- Beff: 0.797 T
- K: 1.62

Status

- 15 monts delay
- IVU-1 shimmed OK
- Assembly in wk 18
- IVU-2 shimming ongoing

Apple-II undulators EU62, EU71

EU62 for CIRCE

Magnitude	*Simplex*
Period [mm]	62.76
W x H [mm x mm]	32 x 32
L [mm]	1769
Full period blocks	108
Bmax , K (V)	0.86 , 5.02
Bmax , K (H)	0.61 , 3.60
Bmax , K (C)	0.50 , 2.94

EU71 for XMCD

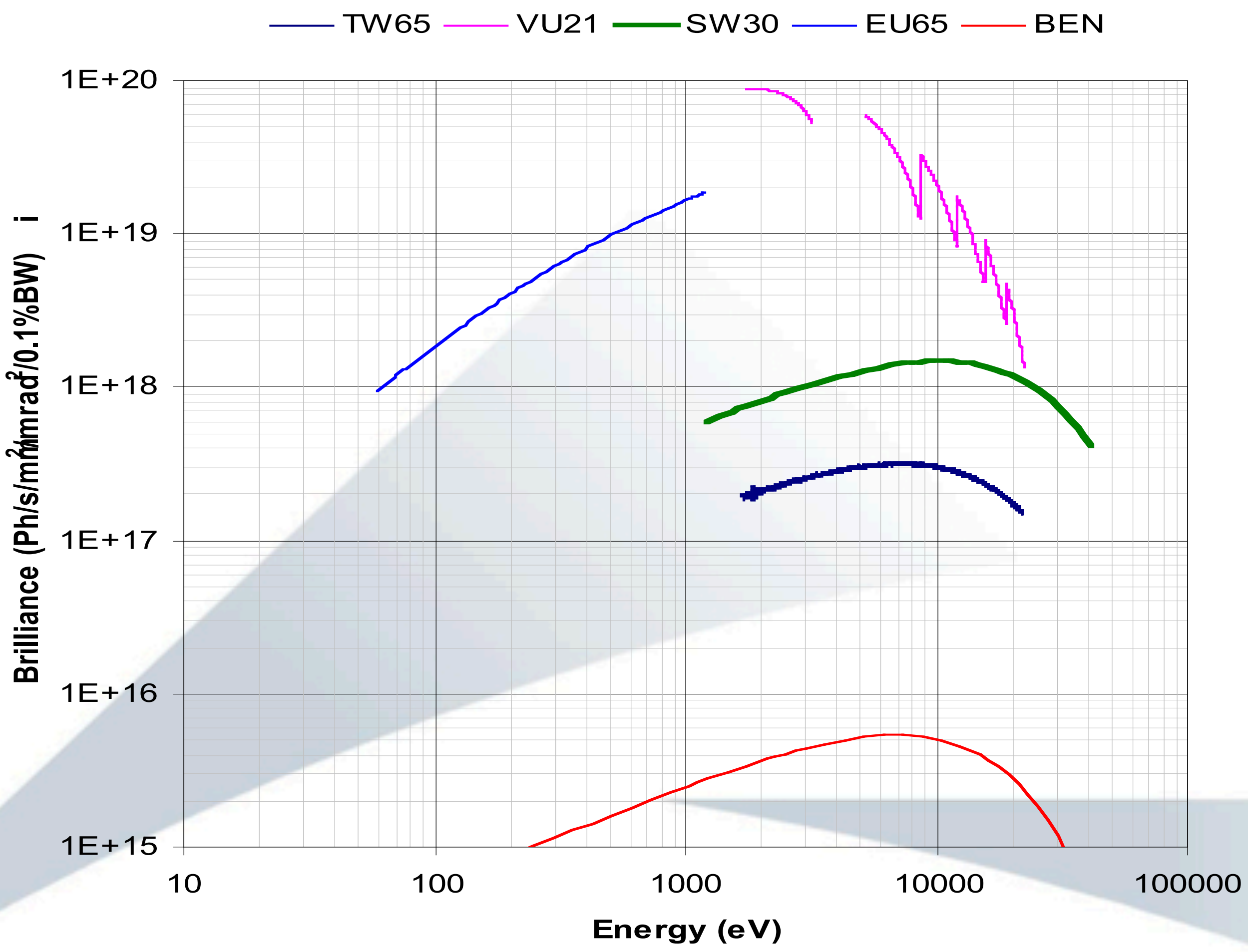
Magnitude	*Simplex*
Period [mm]	71.36
W x H [mm x mm]	32 x 32
L [mm]	1655
Full period blocks	89
Bmax , K (H)	0.92 , 6.14
Bmax , K (V)	0.73 , 4.69
Bmax , K (C)	0.56 , 3.76

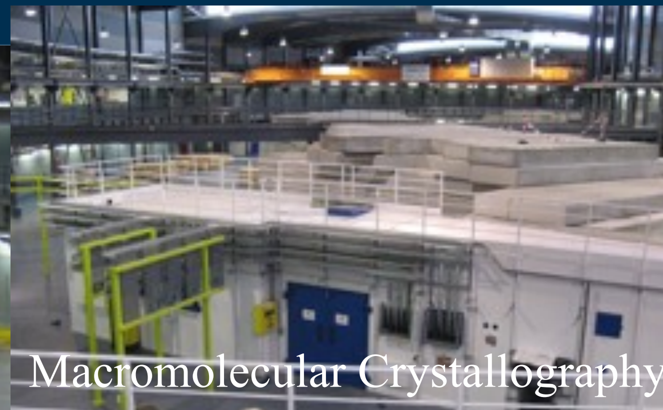
Status

- Production on time
- 1st undulator measured at CELLS - OK
- 2nd undulator measured at CELLS - OK

- Mechanical errors within tolerances
- Field and phase errors within tolerances

Brilliance of the various light sources at ALBA





Macromolecular Crystallography

Powder Diffraction

PEEM and NAPP

All hutches need an infrastructure such as cabling, gases, liquid N_2 supplies, water, etc. This should be designed into the facility.

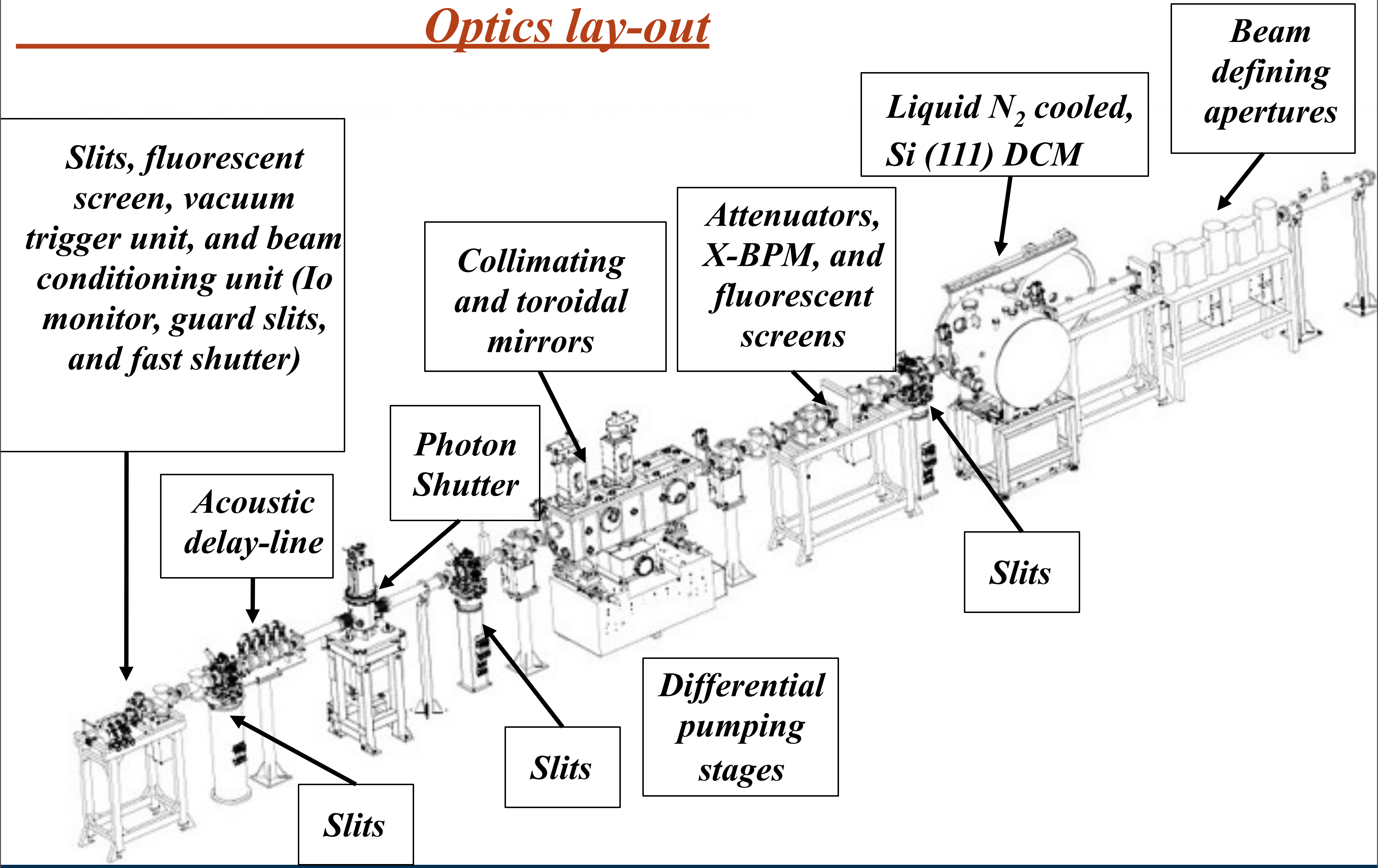
X-ray Microscopy

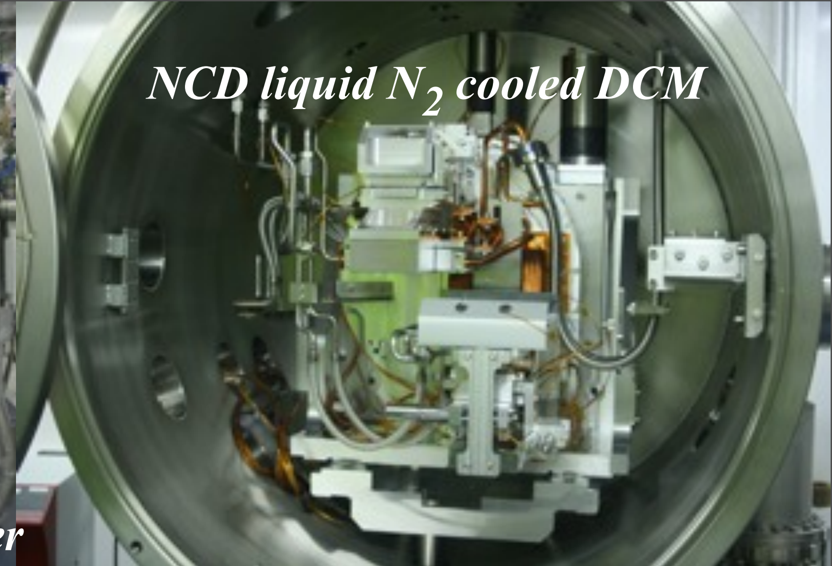
X-ray Absorption Spectroscopy

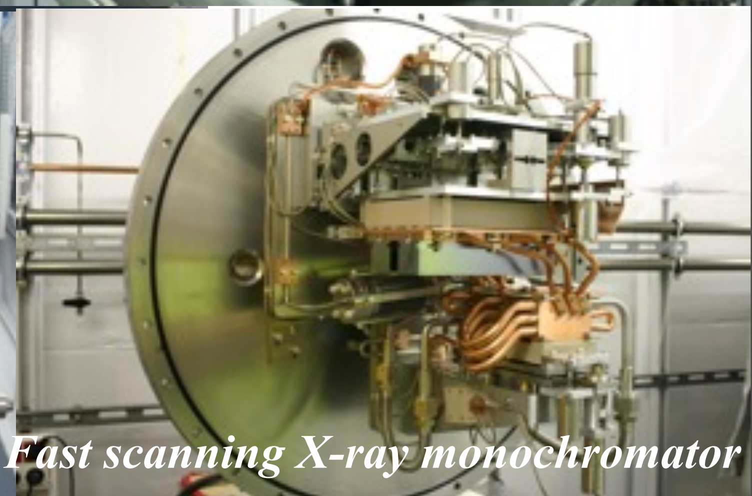
XMCD and Soft X-ray Scattering

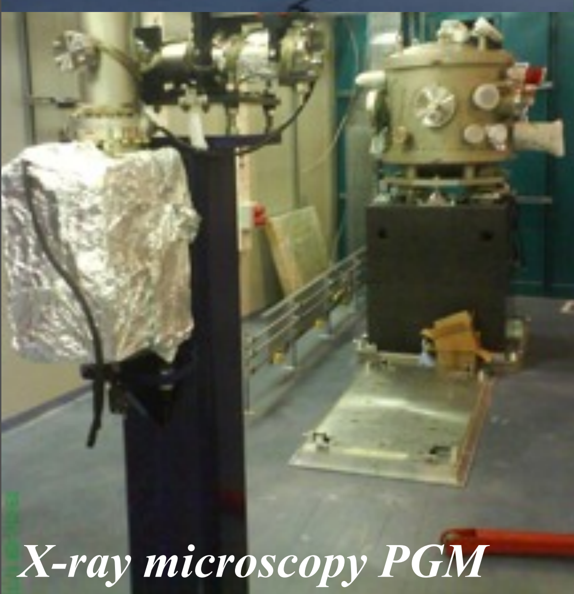
Non Crystalline Diffraction

Example: Diffraction/Scattering of Non-Crystalline systems. Optics lay-out









The optical sub-systems, i.e. mirrors systems, monochromator systems, slits, vacuum systems, etc., are being delivered and tested without beam.

Second phase beam-lines recommended by SAC and approved by ALBA's Council:

A1.- Infrared micro-spectroscopy: Biology and Materials Science (start construction 2011)

A2.- Low-Energy Ultra-High-Resolution Angular Resolved Photoemission: Physics and Materials Science (start construction 2011)

A3.- Micro-focus Macromolecular Crystallography: Structural Biology (start construction 2013 if size of user community justifies it)

What can one expect from ALBA?

How does it compare with other facilities?

The quality of a SL source is given by:

- *The range of energies of the emitted photons that depends on the energy of the accelerator* ($\approx E_e^2$).

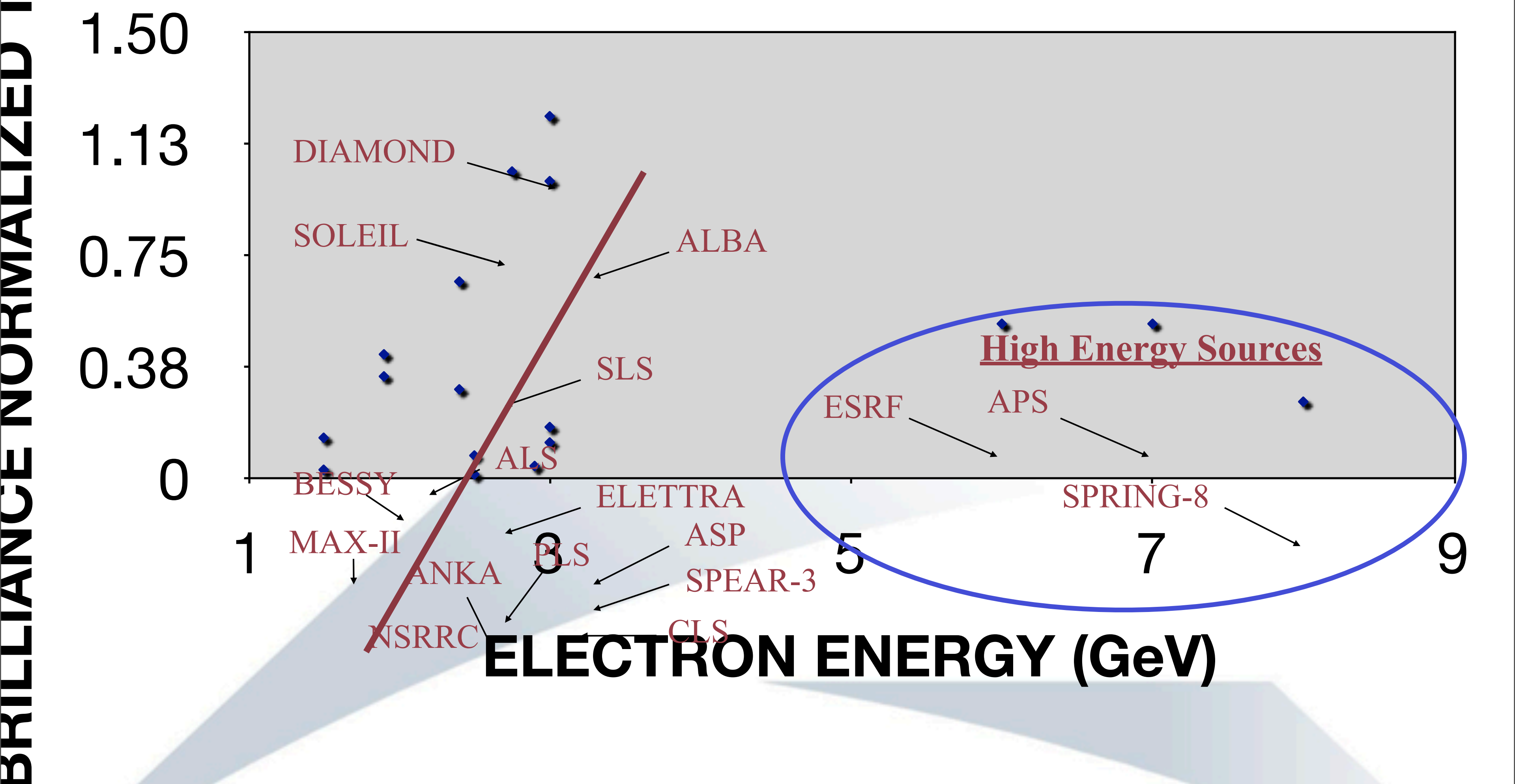
- *The Brilliance of the emitted radiation (photons/sec/mm² /mrad² in* $\Delta\lambda/\lambda=10^{-3}$*) that depends on the electron circulating current and on the emittance of the accelerator* ($B \approx I / \varepsilon^{3/2}$), *where the emittance is given:*

$$\varepsilon = \frac{E_e^2}{J_x} f_{Cell} \frac{1}{N_{BM}^3} \qquad (\mathrm{nm.rad})$$

- *The total number of straight sections available for IDs that is given by the perimeter of the accelerator.*

- *The stability of the beam given by: the buildings, the electrical supply, the RF system, the vacuum system, the optical systems, the control system, etc..*

COMPARISON BETWEEN SL SOURCES



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