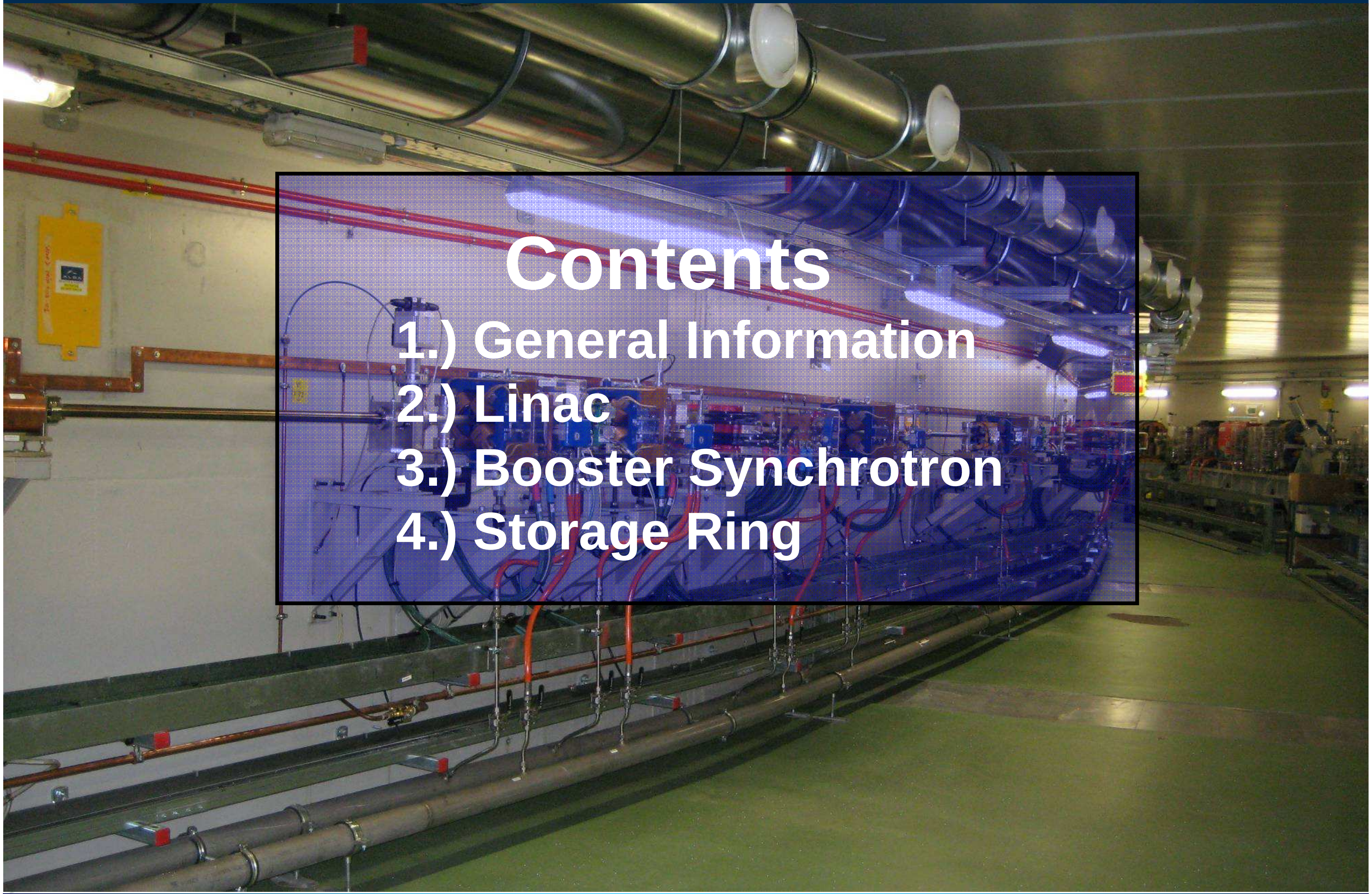


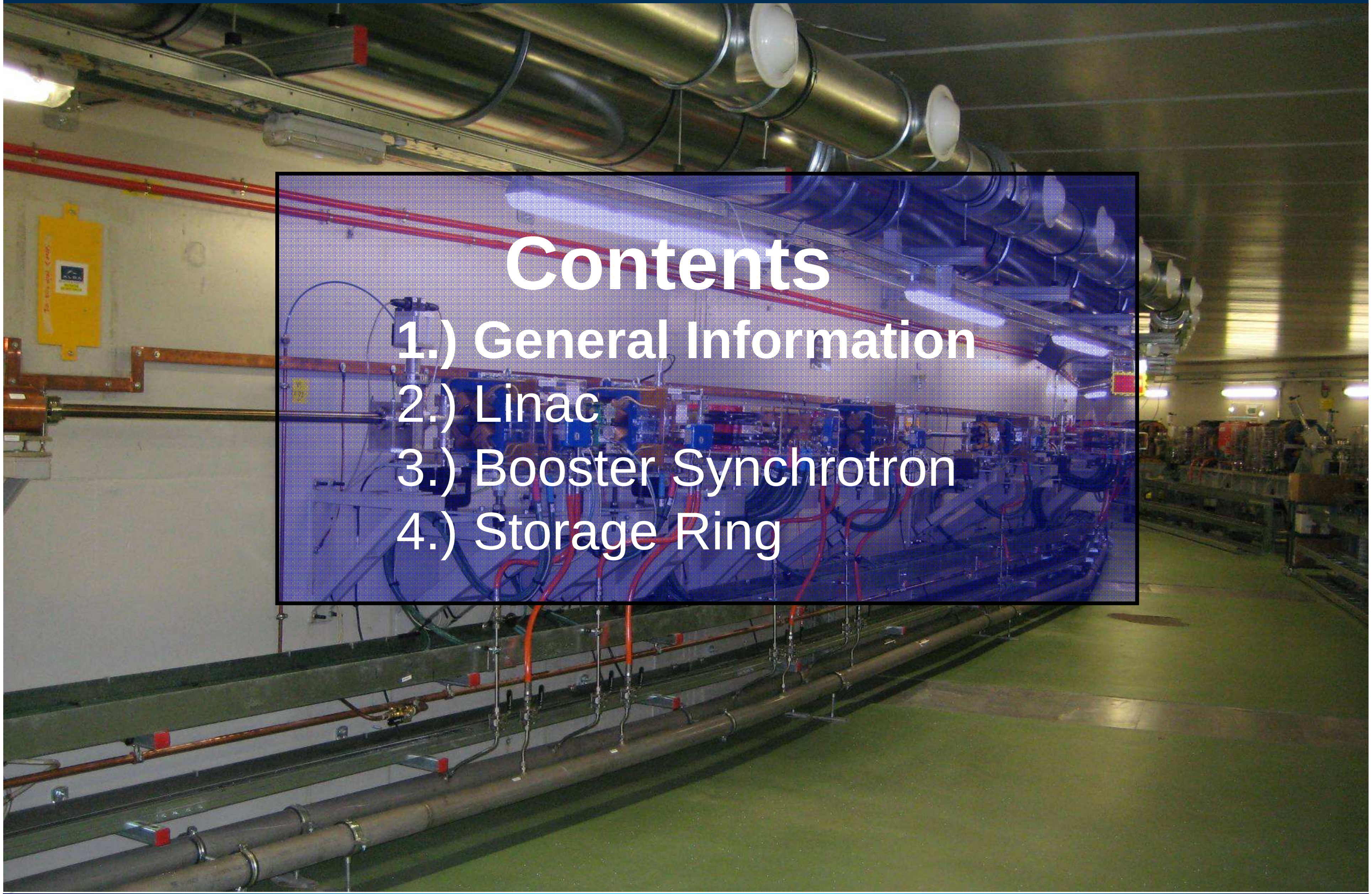
Contents

1.) General Information

2.) Linac

3.) Booster Synchrotron

4.) Storage Ring



Contents

1.) **General Information**
2.) Linac
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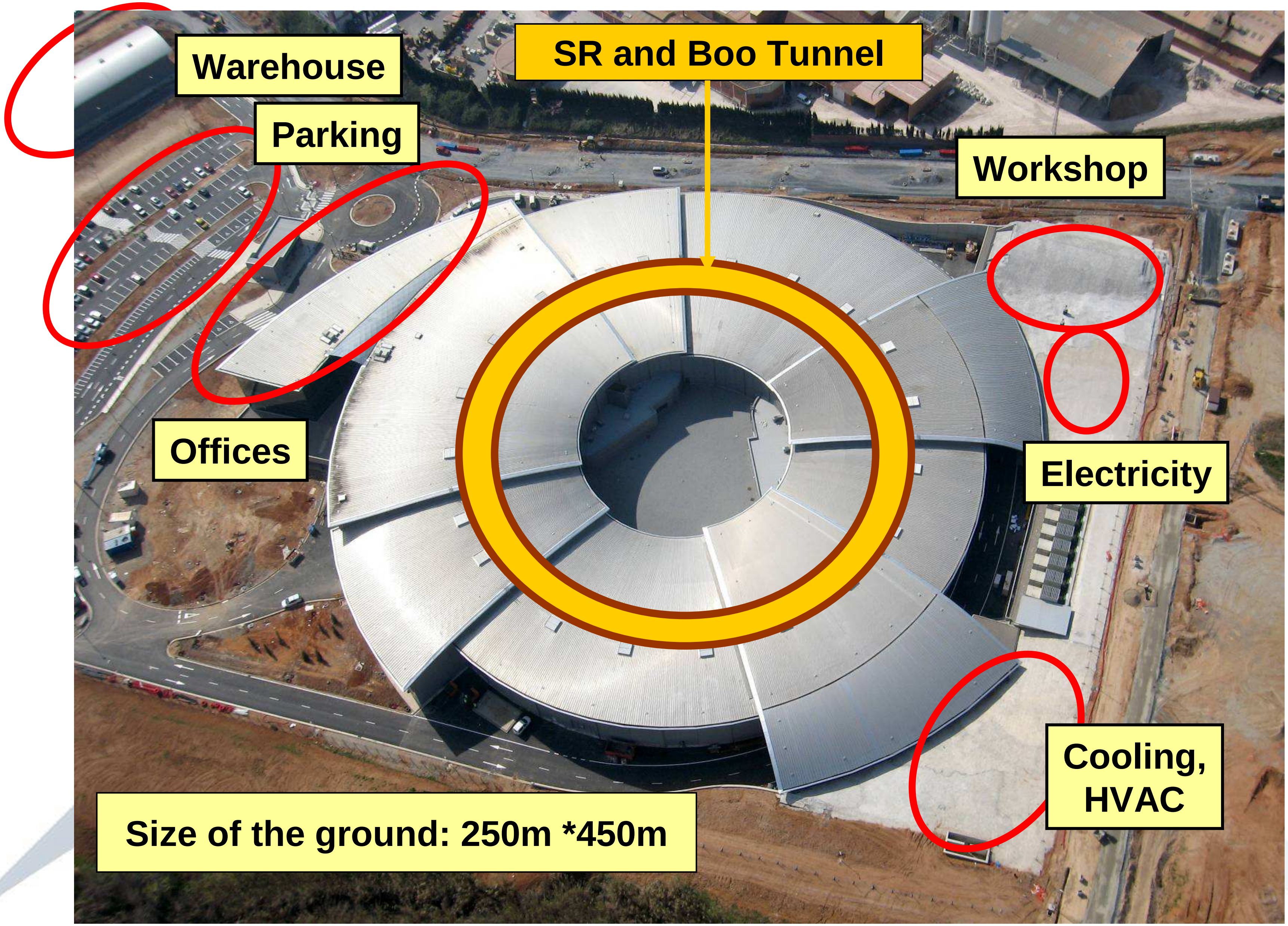
History of the Project

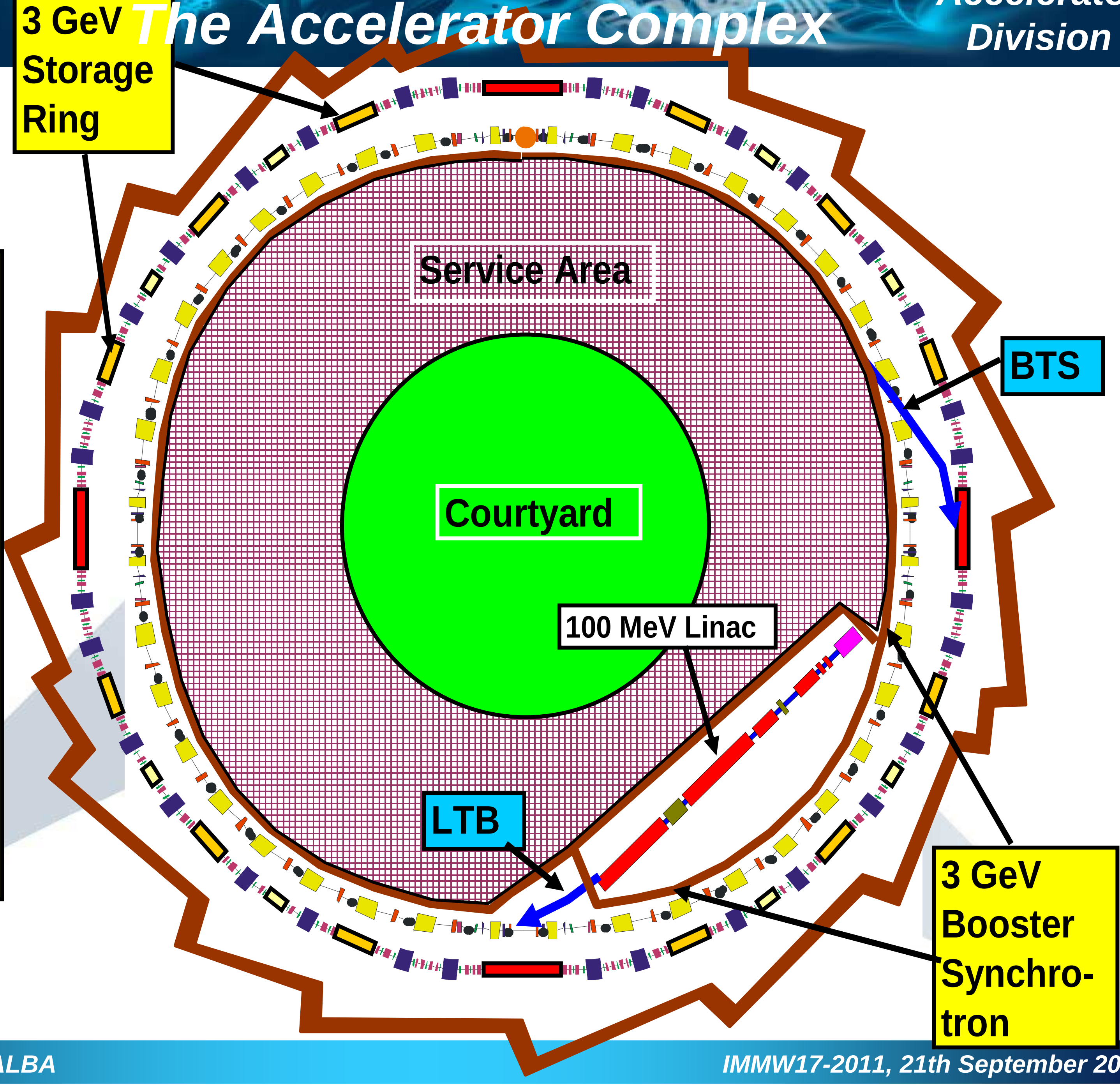
- 1992-4: First plans for a light source in Spain.
- 1997: Finishing the conceptual design report
- 2003: Approval of the project by the Spanish- and the Catalonian Government. Site selected in the Valles area, close to Barcelona.
- 2003-05: Users meeting and workshops to establish the scientific program. 7 beam lines approved.
- 2004: Location of CELLS at theUAB
- 2004-05: Redesign of the machine, Staff recruiting (13 different nationalities)
- 2005-08: Building.
- 27th July 2006: ground breaking
- 2008-10: Mechanical installation.
- 2008: Linac installation and commissioning
- Eastern 2009 : Movement from UAB to the new Building
- 2009-10: Booster commissioning
- 22nd March 2010: Official Inauguration
- 2011: SR commissioning

The ALBA - Building

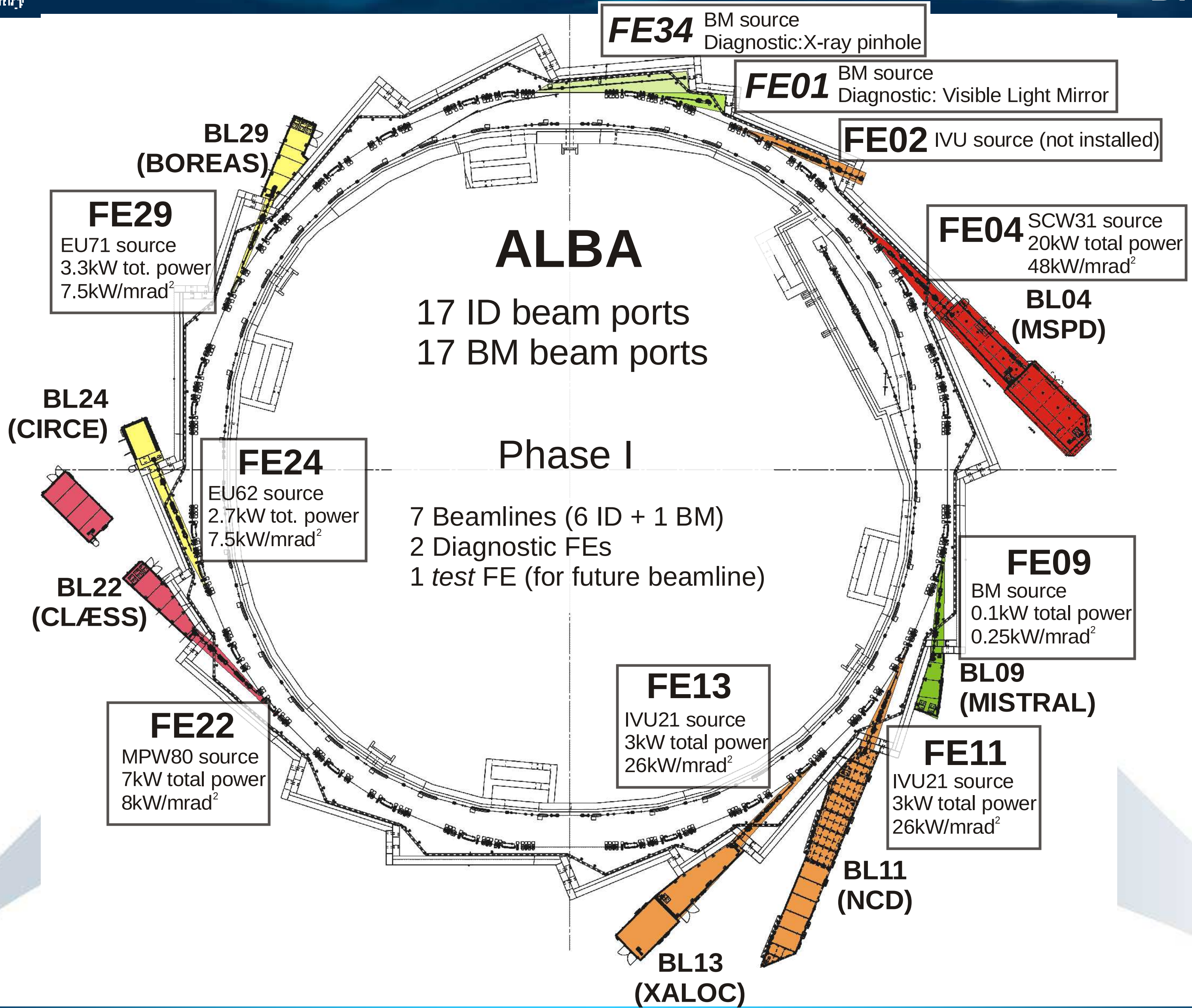


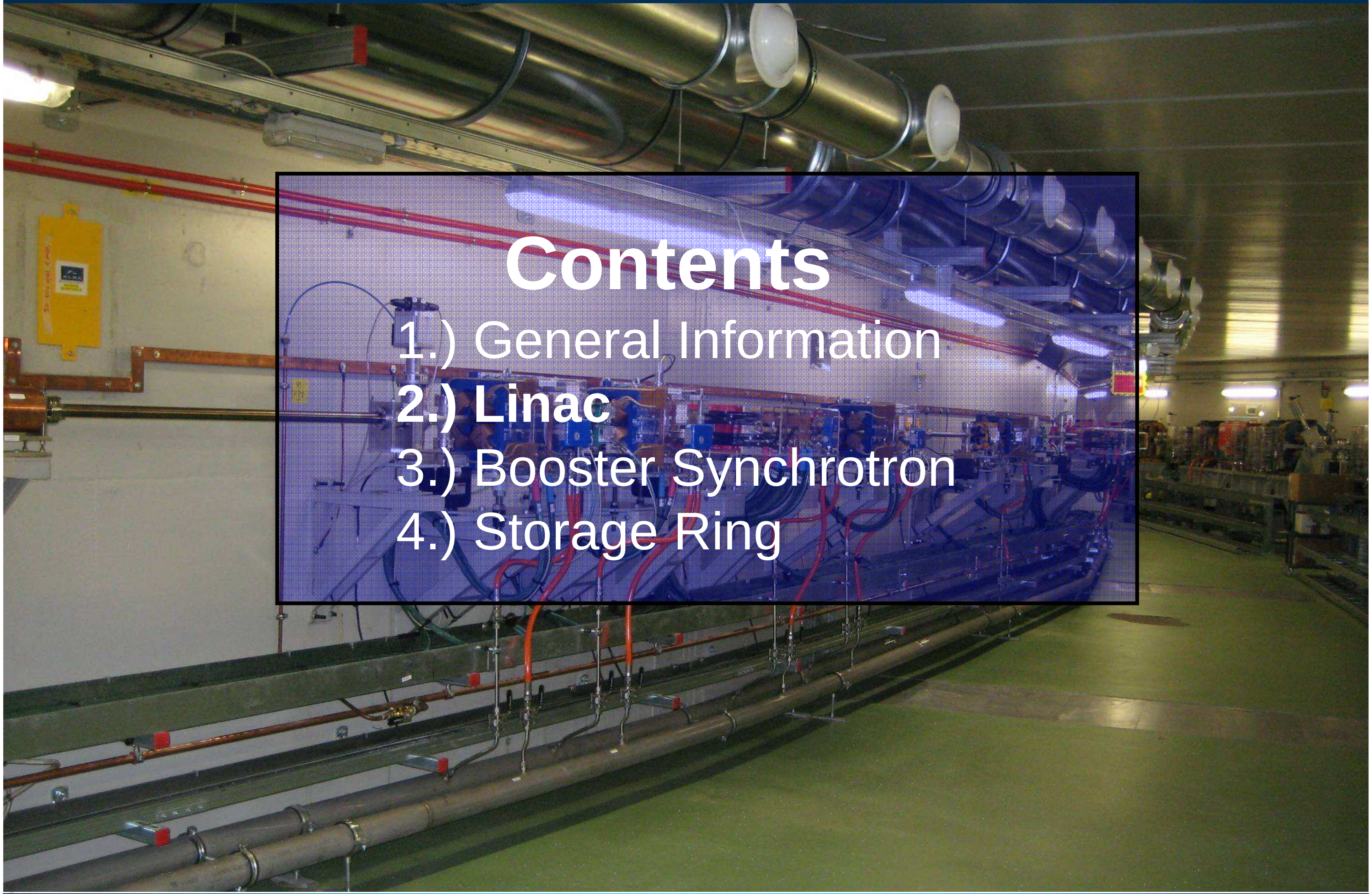
The Accelerator Complex

Accelerator complex of ALBA: We followed the concept of the SLS to have the booster and the storage ring in the same tunnel. The preinjector is a 100 MeV Linac



ID's, Front Ends and Beam Lines





Contents

1.) General Information

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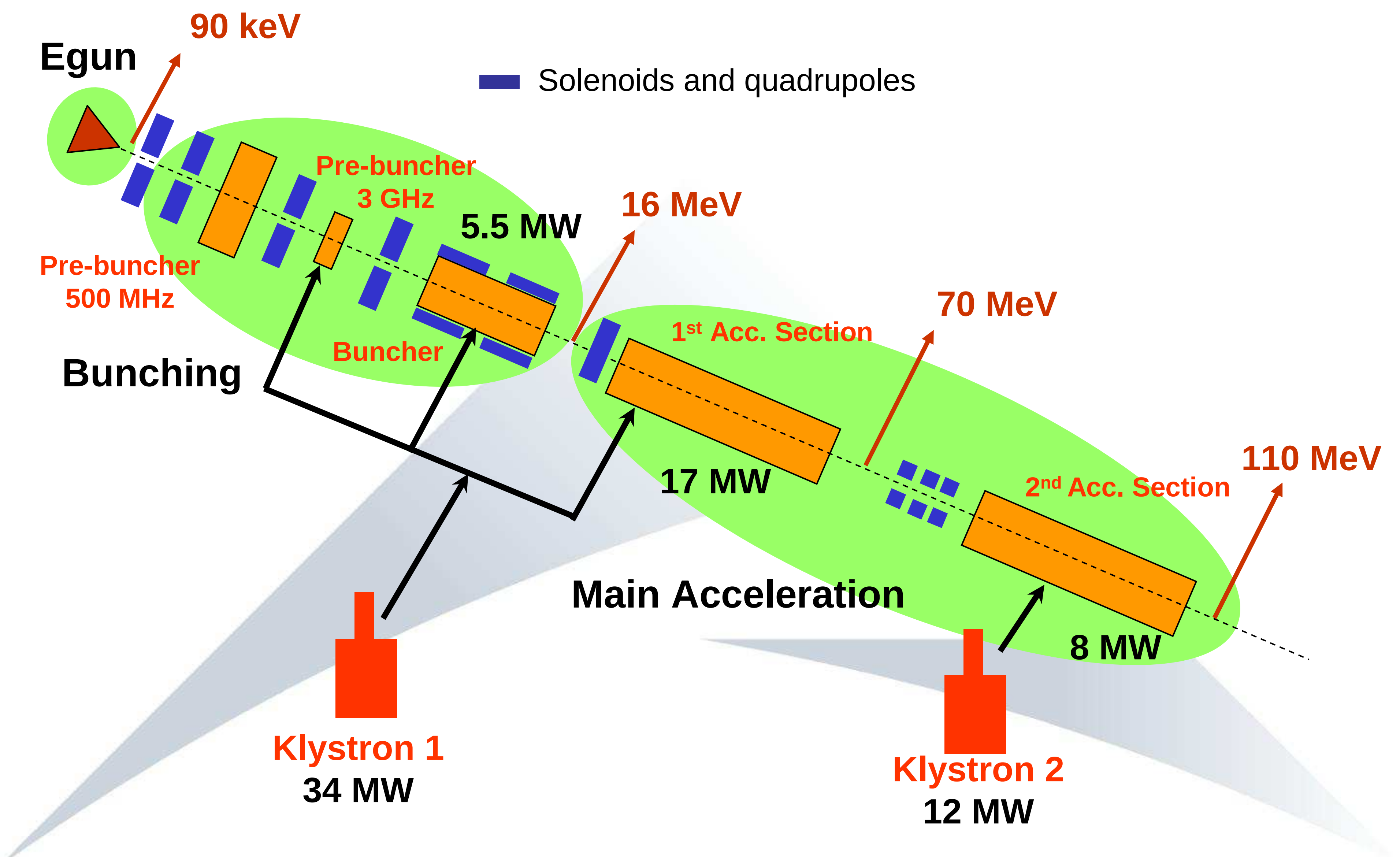
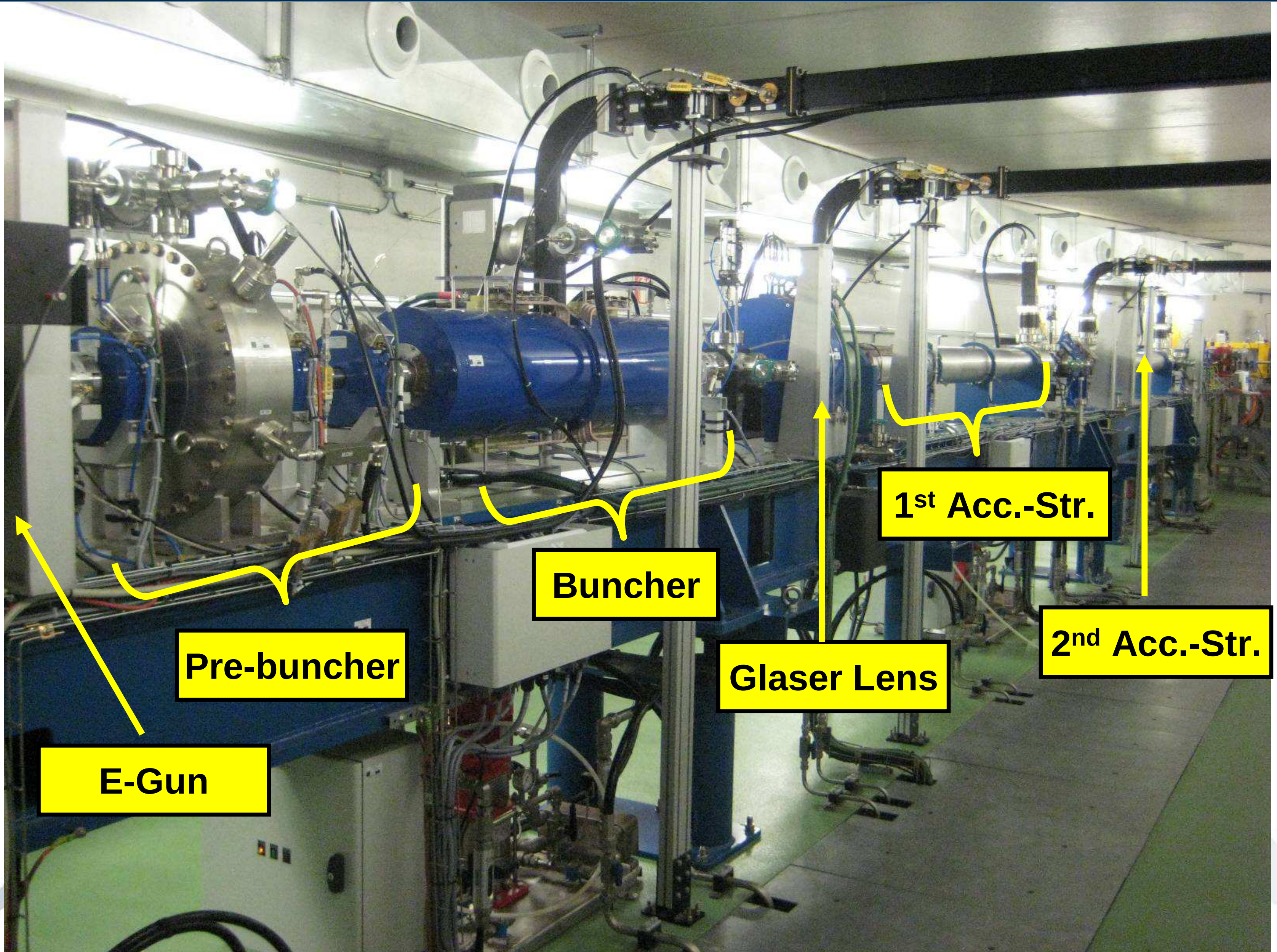
Milestones for the Linac

1.) Installation of Linac:	Febr. 2008 to May 2008
2.) First beam out of the Linac:	July 2008
3.) Phase 1 Commissioning of Linac:	October 2008
4.) Acceptance of Linac:	October 2008
5.) Phase 2 Commissioning of Linac:	October 2009
6.) Operation of Linac for booster commissioning:	Dec. 2009 to Jan. 2010
7.) Reparation of Linac structure 1:	April 2010
8.) Restart of Linac:	May 2010
9.) Optimisation of Linac:	June – July 2010
10.) Normal operation of Linac:	since July 2010

Linac - Layout

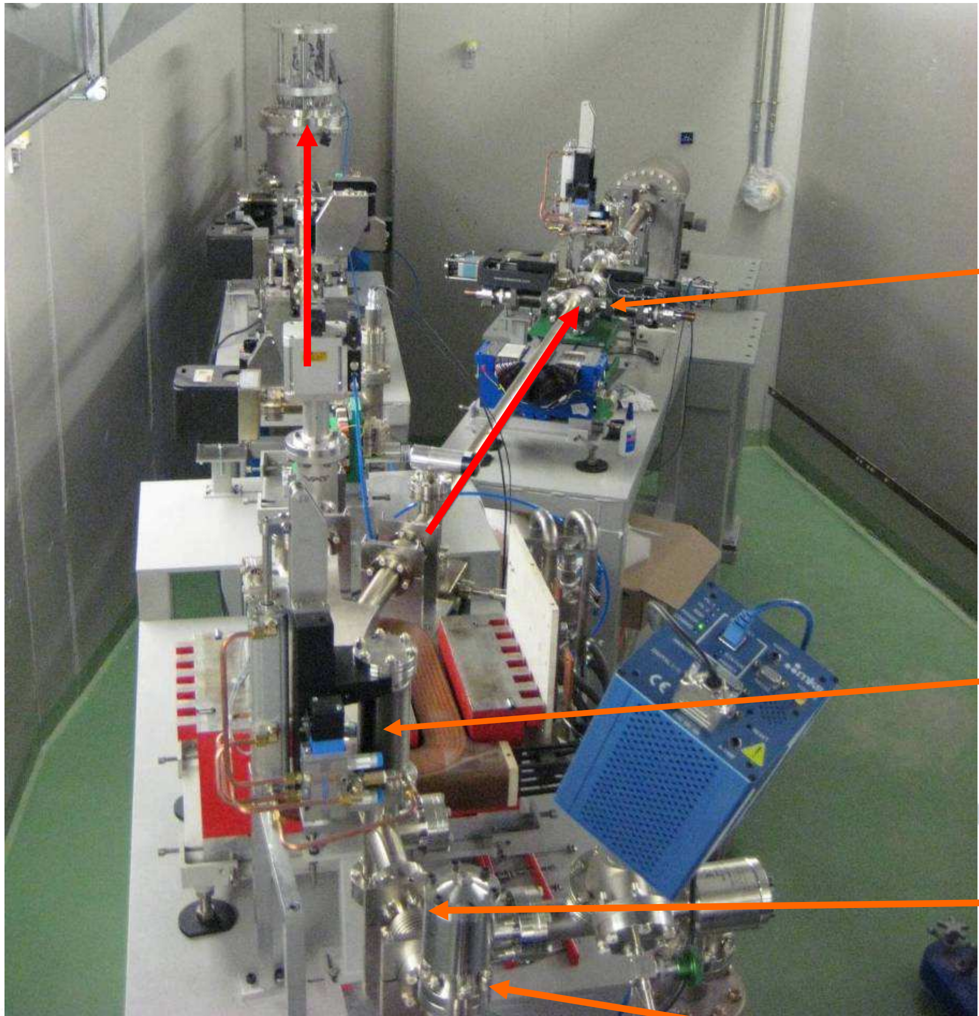


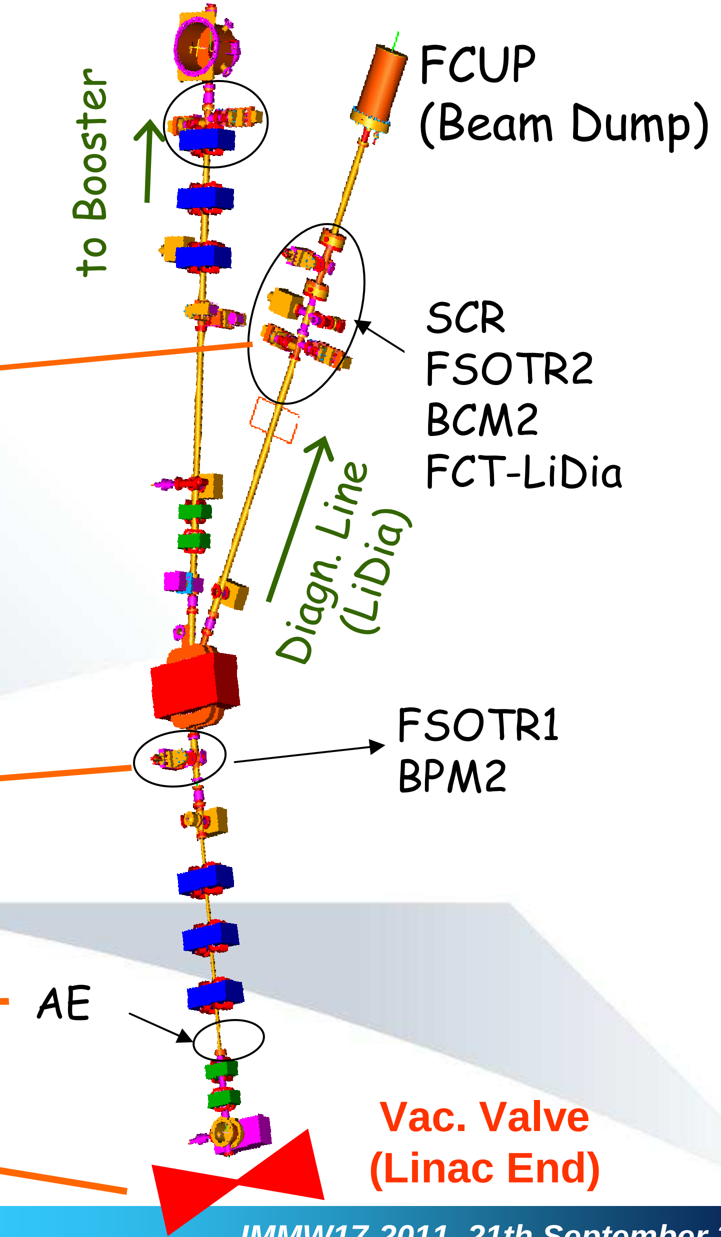
LINAC in the Tunnel



LTB-Transfer and Diagnostic Line

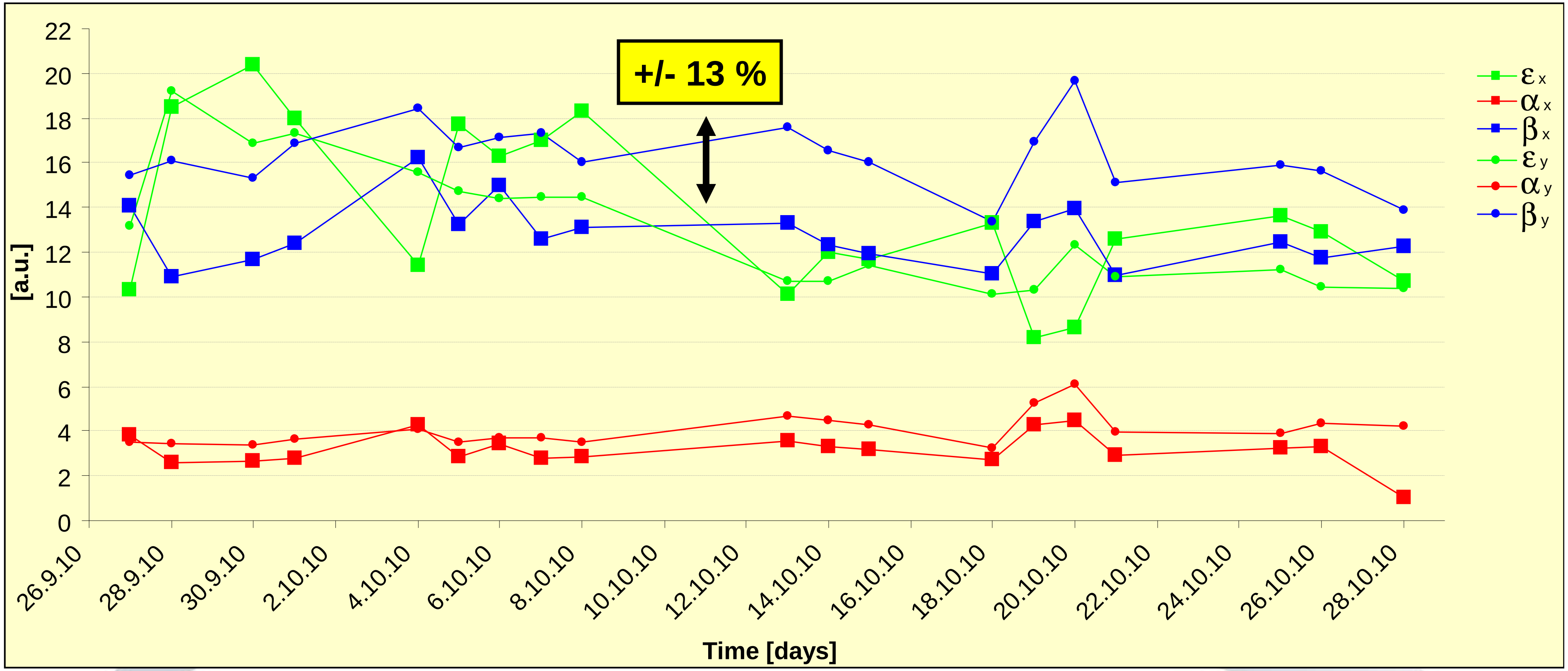
SR + Boo-Tunnel **Diagnostic Line**



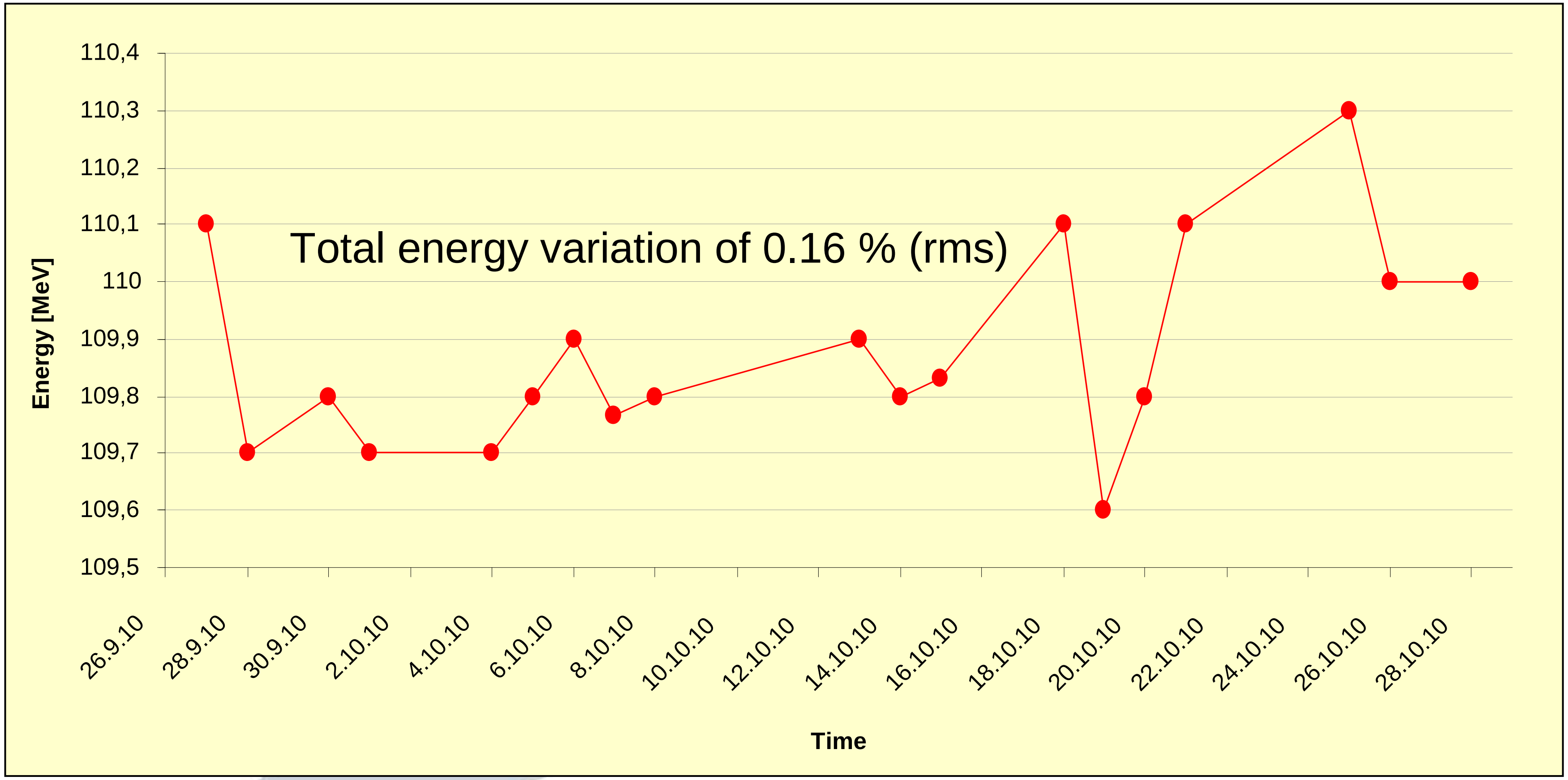


All parameters are within specifications

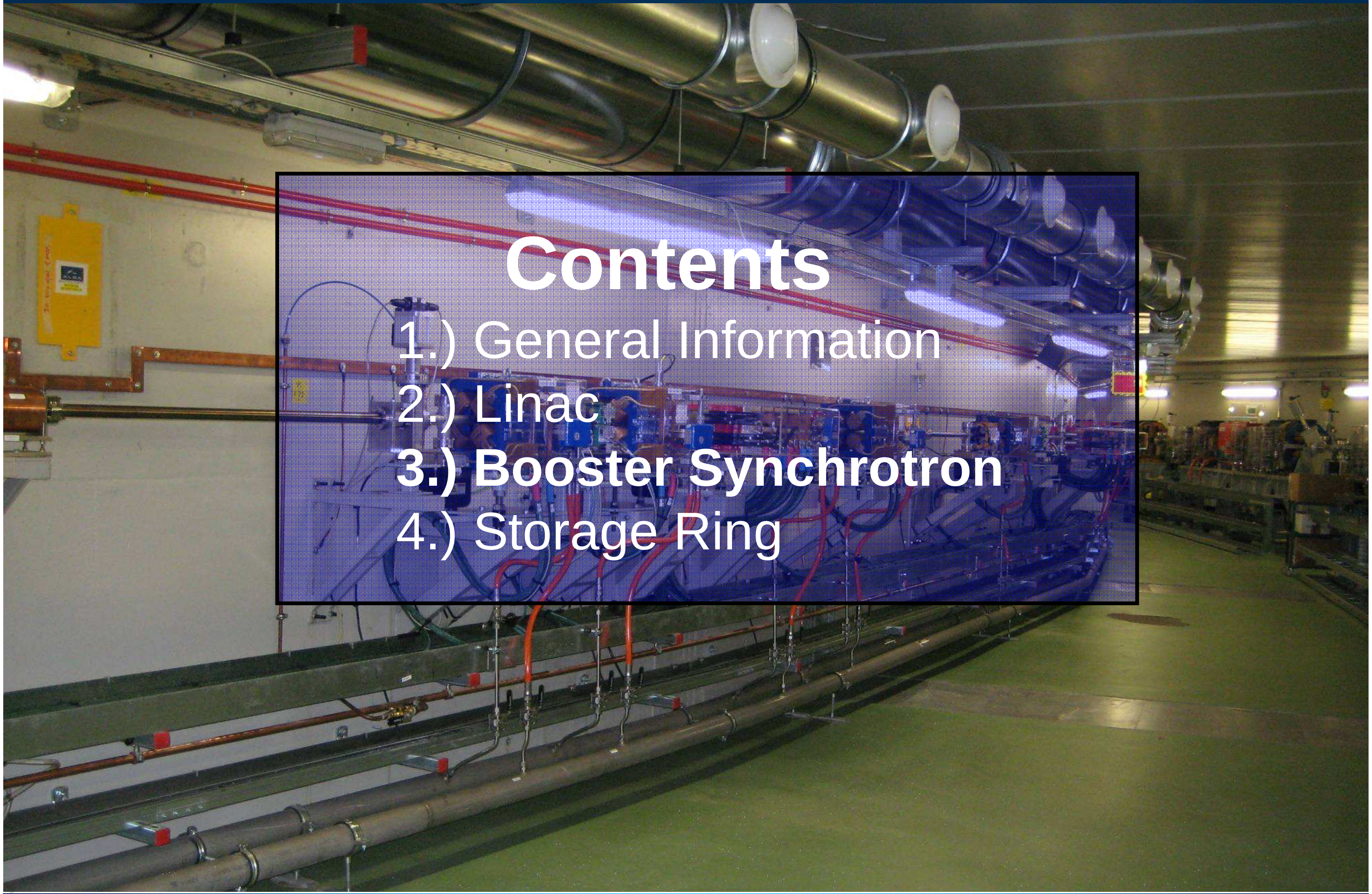
Twiss Parameters in x and y directions:



Linac Beam Parameters



Summary: **Some specifications of the Linac are much better as given by the specifications (for example the emittance is by a factor 1.5 smaller). The Linac operation is very reliable for the different modes: long bunch, small bunch, single bunch, large charge (4 nC), small charge (0.5 nC), etc.**



Contents

Milestones for the Installation, Commissioning, and Operation of the Booster Synchrotron

1.) Mechanical installation of booster:	Jan. 2009 to March 2009
2.) Installation of RF-System :	Febr. 2009
3.) Installation of secondary piping:	July to Sept. 2009
4.) Cooling available:	September 2009
5.) Personal safety system finished:	November 2009
6.) Alignment of booster synchrotron :	Nov. to Dec. 2009
7.) Control system finished:	December 2009
8.) Pre-commissioning of booster components:	Nov. to Dec.2009
9.) CSN- certificate for booster commissioning:	December 2009
10.) First beam in the booster synchrotron :	21st December 2009
11.) Phase 1 of booster commissioning:	10th to 24th Jan. 2010
12.) Phase 2 of booster commissioning:	July 2010
13.) Phase 3 of booster commissioning:	Sept.- Octob. 2010
14.) Reaching 3 GeV:	4th October 2010
14.) Extraction of 3 GeV beam out of booster:	28th October 2010
15.) Normal operation of booster synchrotron:	since Nov. 2010

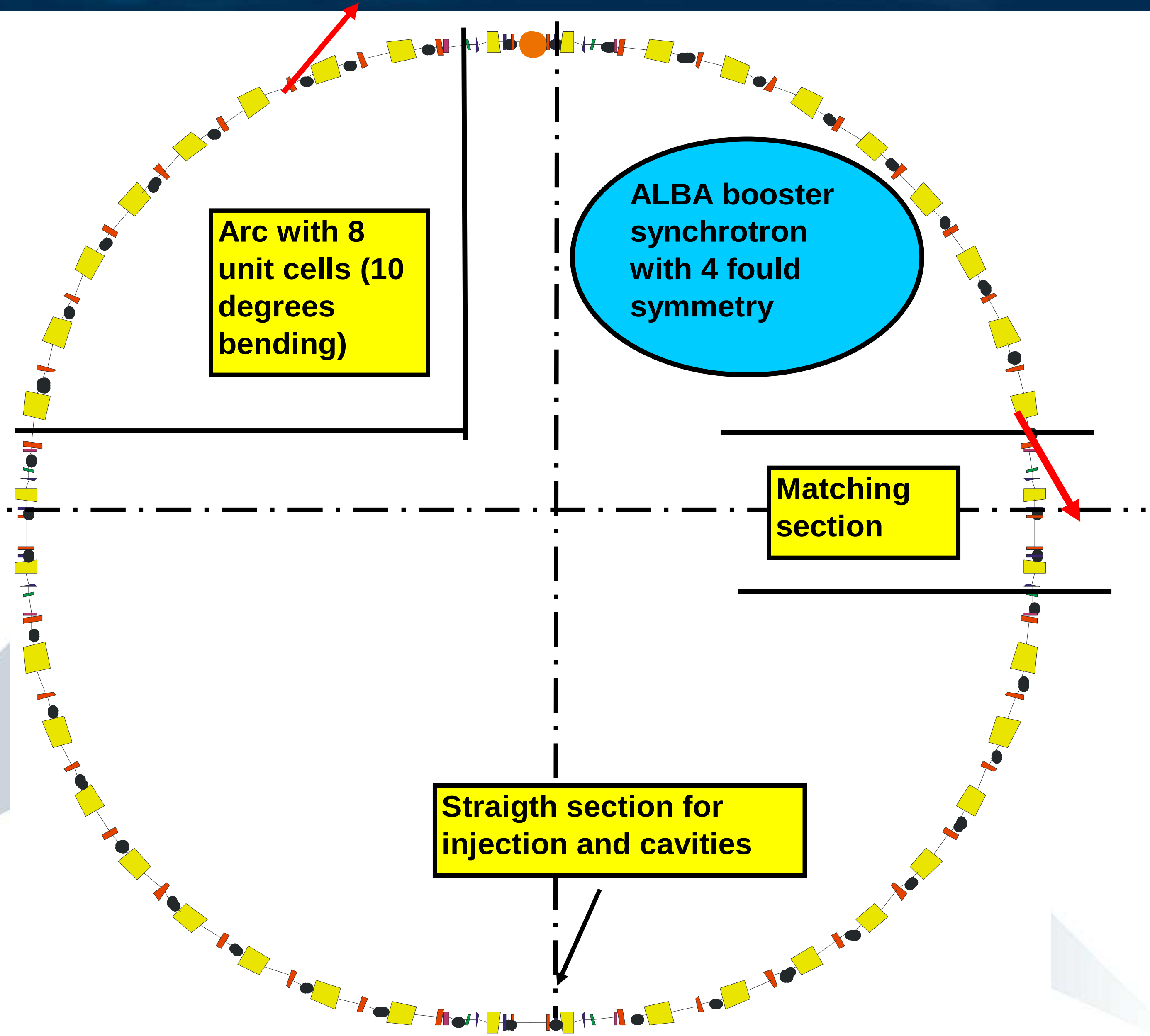
Summary: **The booster synchrotron runs reliable. The behaviour of the booster is pretty well understood. It is ready, working as an injector for the storage ring, but we have to make some optimisation.**

Layout of Booster Synchrotron

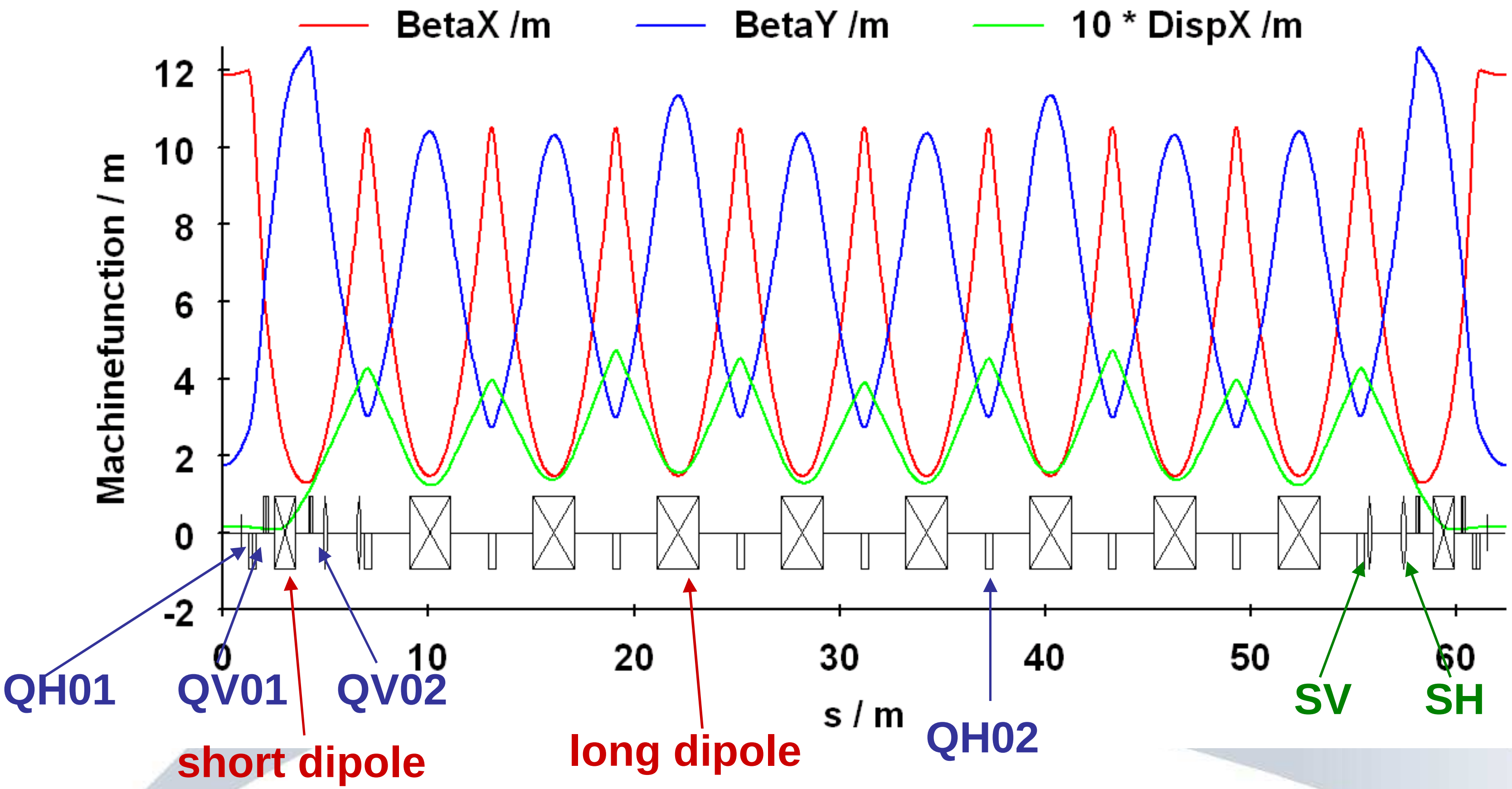
3 GeV Booster
gradient dip.,
with built-in
sextupole.
Circumference:
249.6 m

4 superperiods:
32 long dip. 2 m
8 short dip. 1 m
60 quads in
4 families

Emittance
10 nm·rad



The lattice is a TME-structure
The ALBA synchrotron should have the smallest emittance in the world

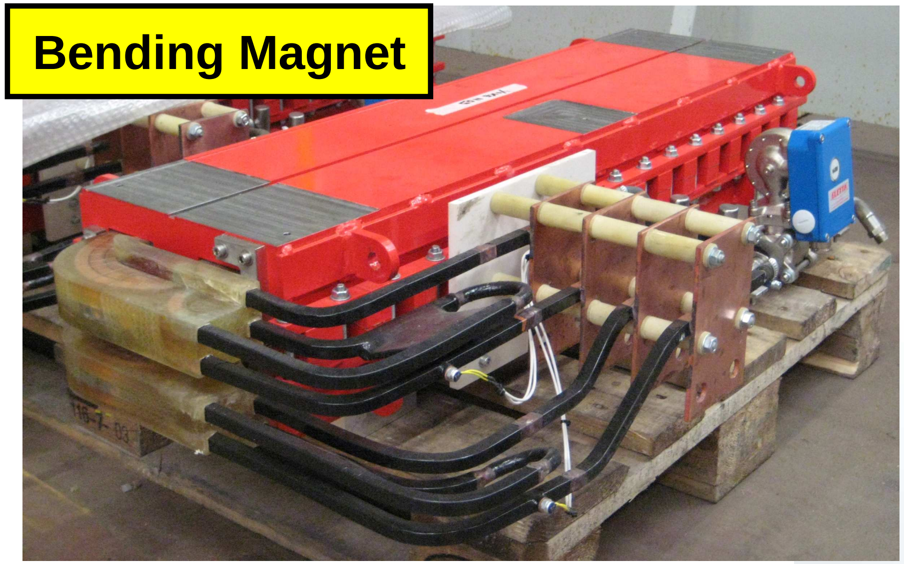


Q(x) is given by QH02 and Q(y) is given by the bends. All the other quads for fine tuning

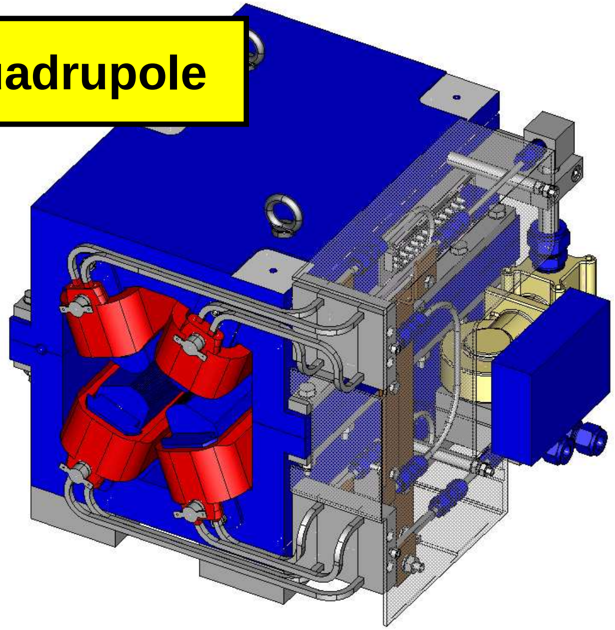
Design working point: $Q_x = 12.42$, $Q_y = 7.38$

Magnets for Booster Synchrotron

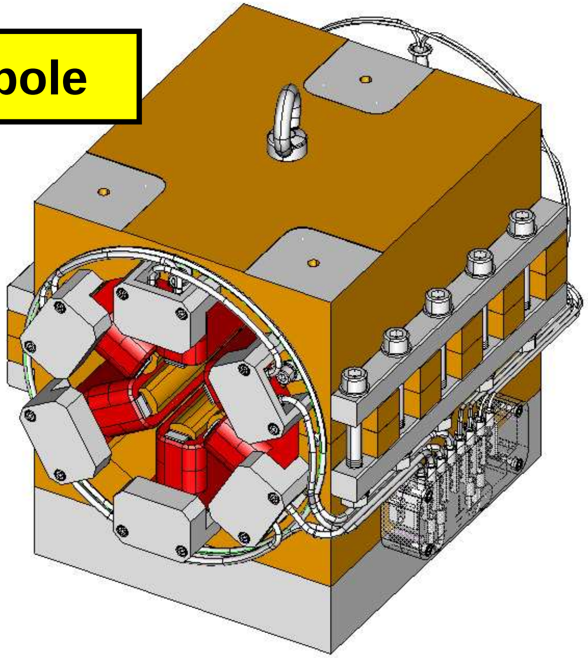
Bending Magnet



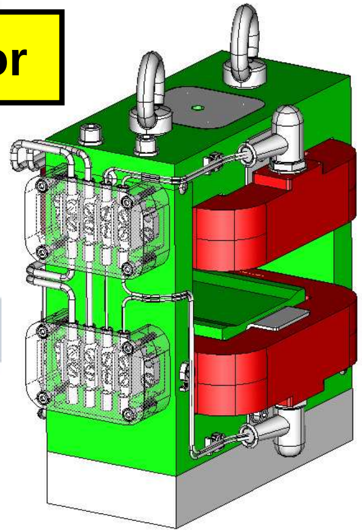
Quadrupole



Sextupole

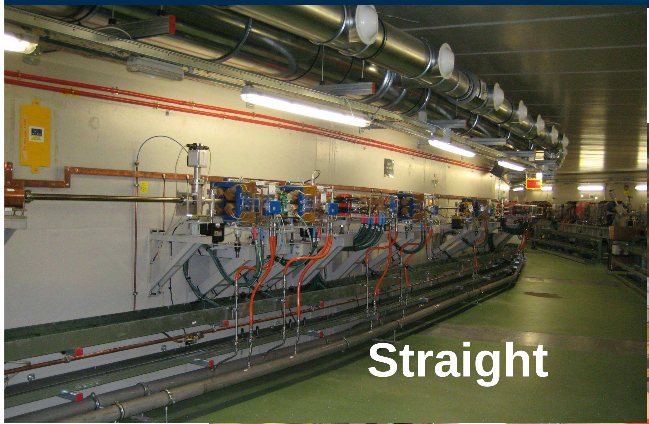


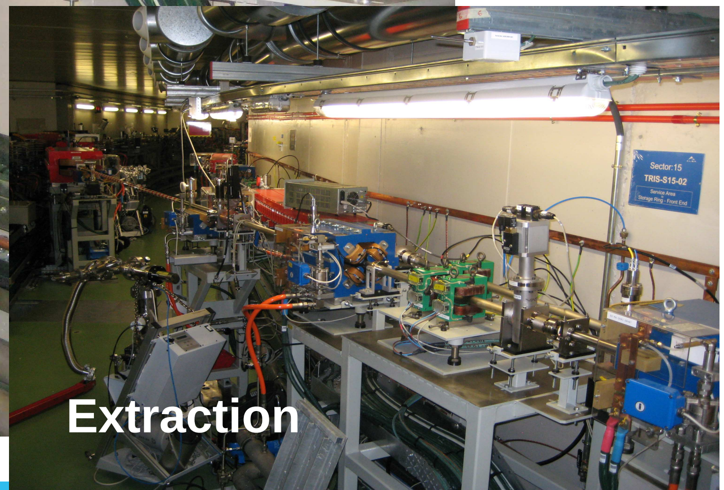
Corrector



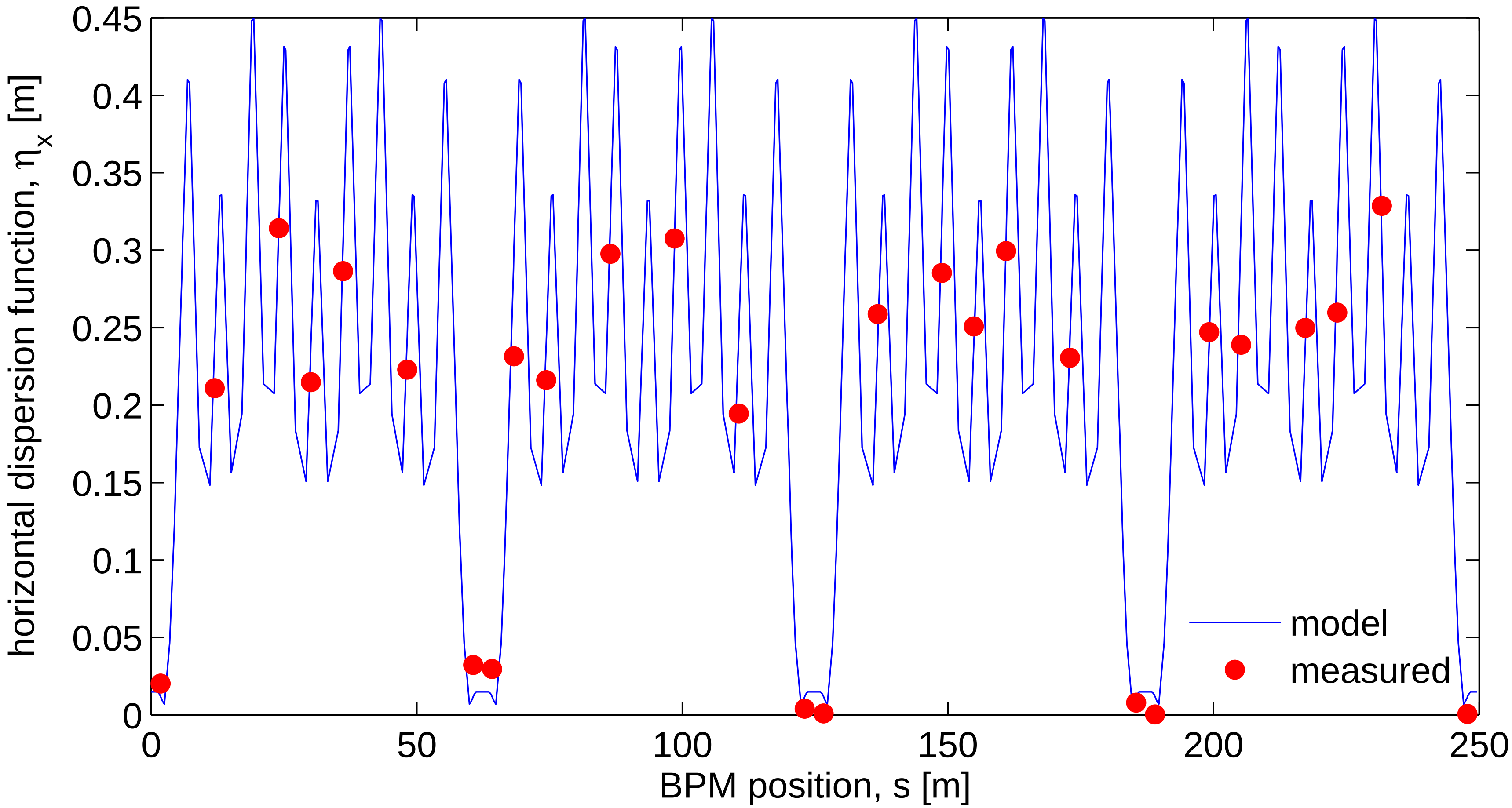
Booster Components

Accelerator Division





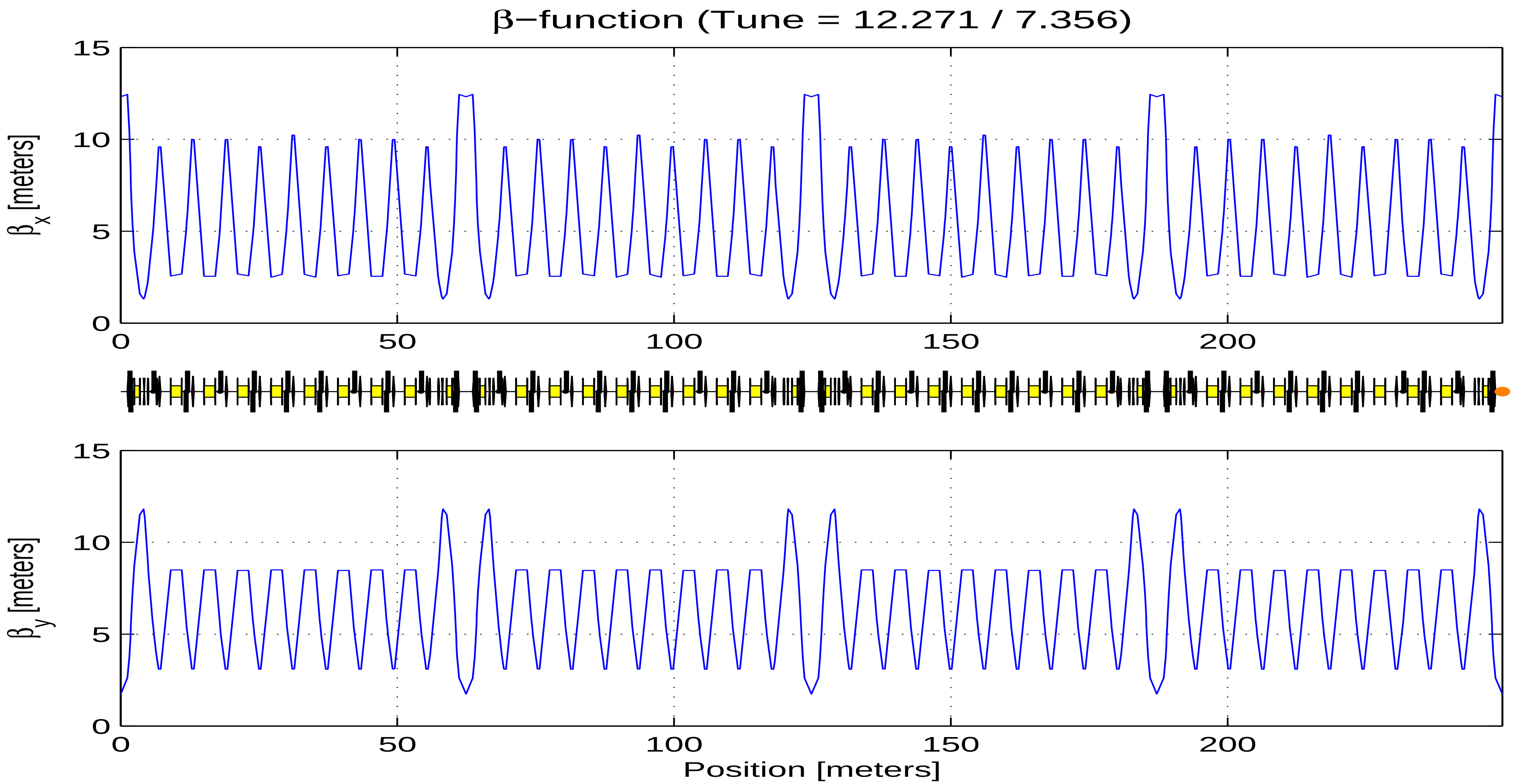
Disprsion Functions (DC)



Good agreement with the model

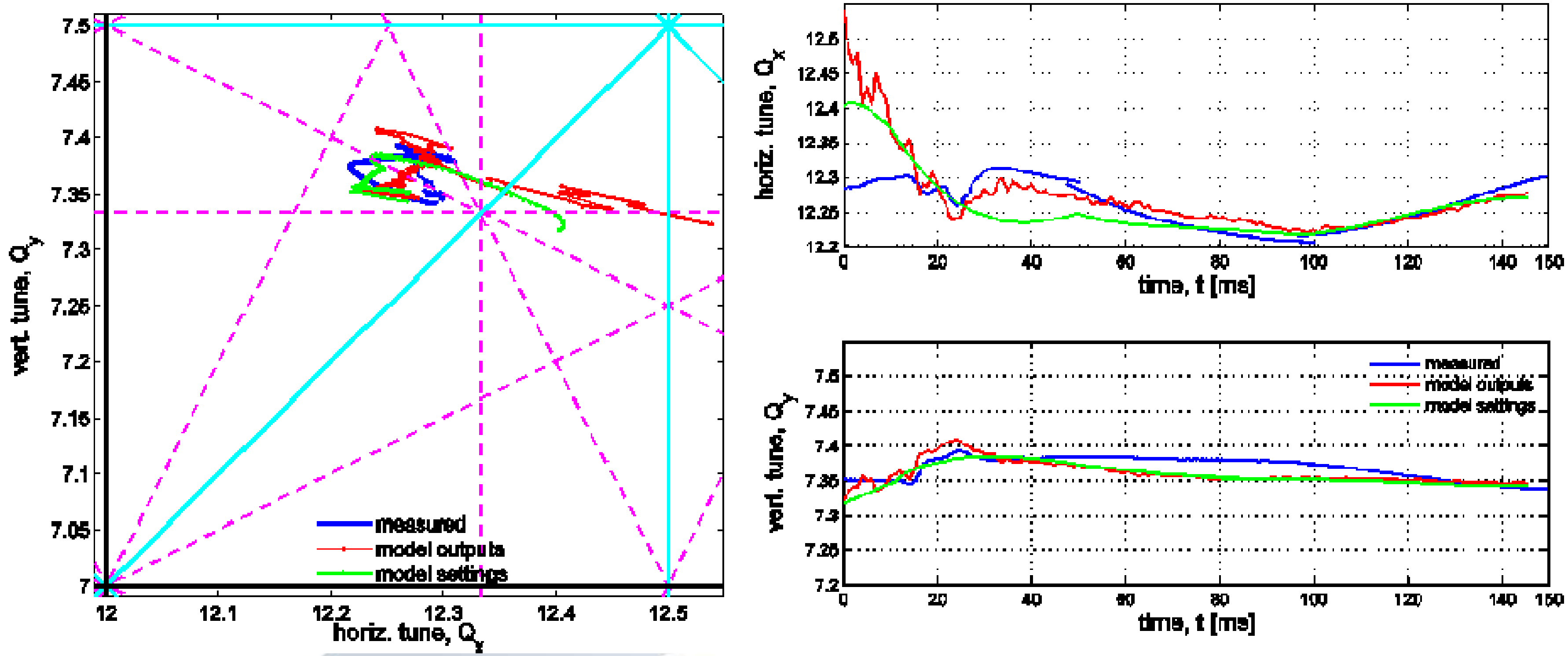
LOCO: Beta Functions (DC)

Accelerator Division



Good agreement with the model

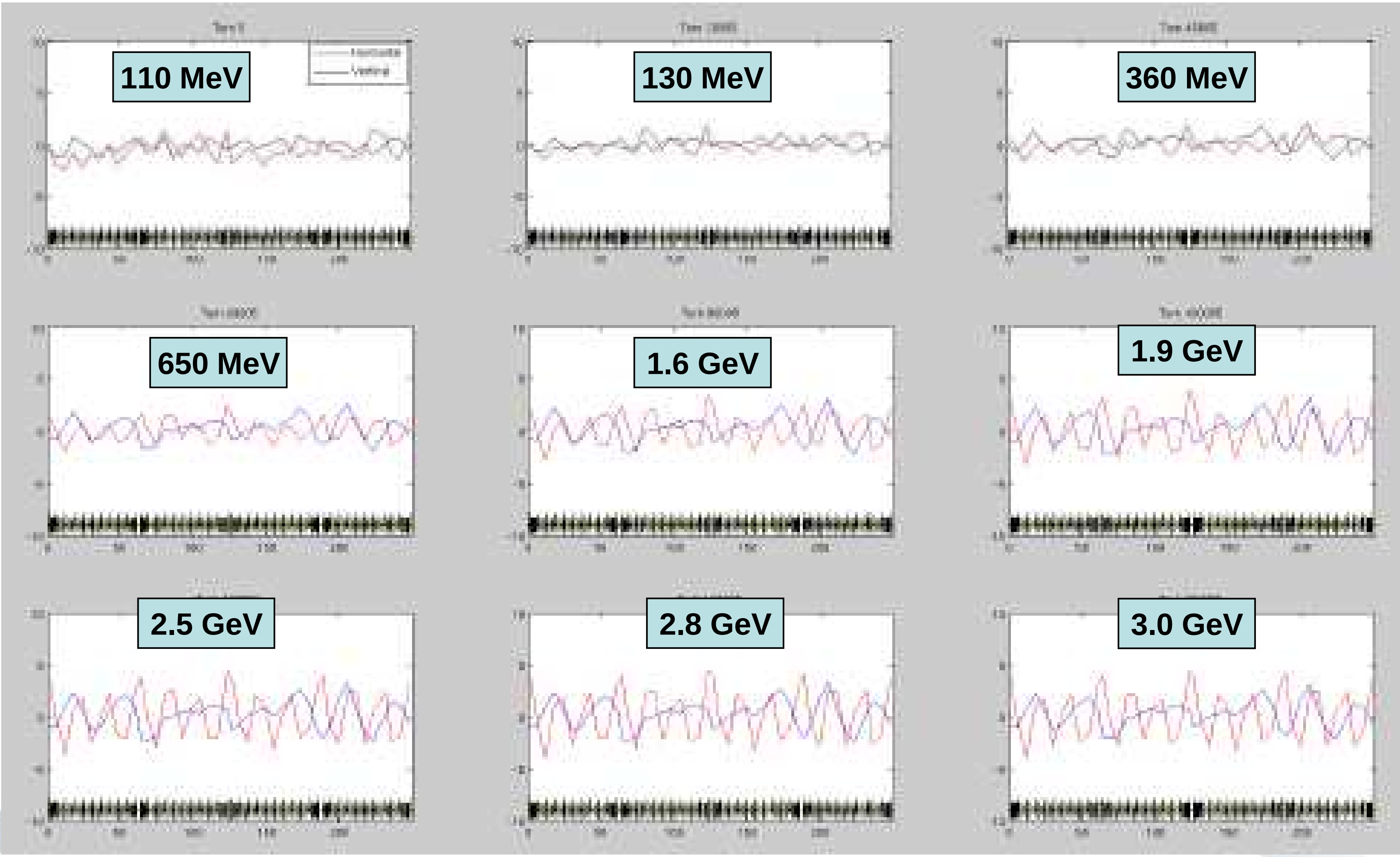
Ramping: Tunes



- First beam to 3 GeV: injection on w.p. (12.42, 7.38)
- Large drop of Qx at the start due to nonlinear magnet calibration
- Vertical tune is flat: most of the vertical focusing is provided by the gradient bending

Ramping: Closed Orbit

Correcting the orbit while ramping



orbit corrected to ± 3 mm along the ramp

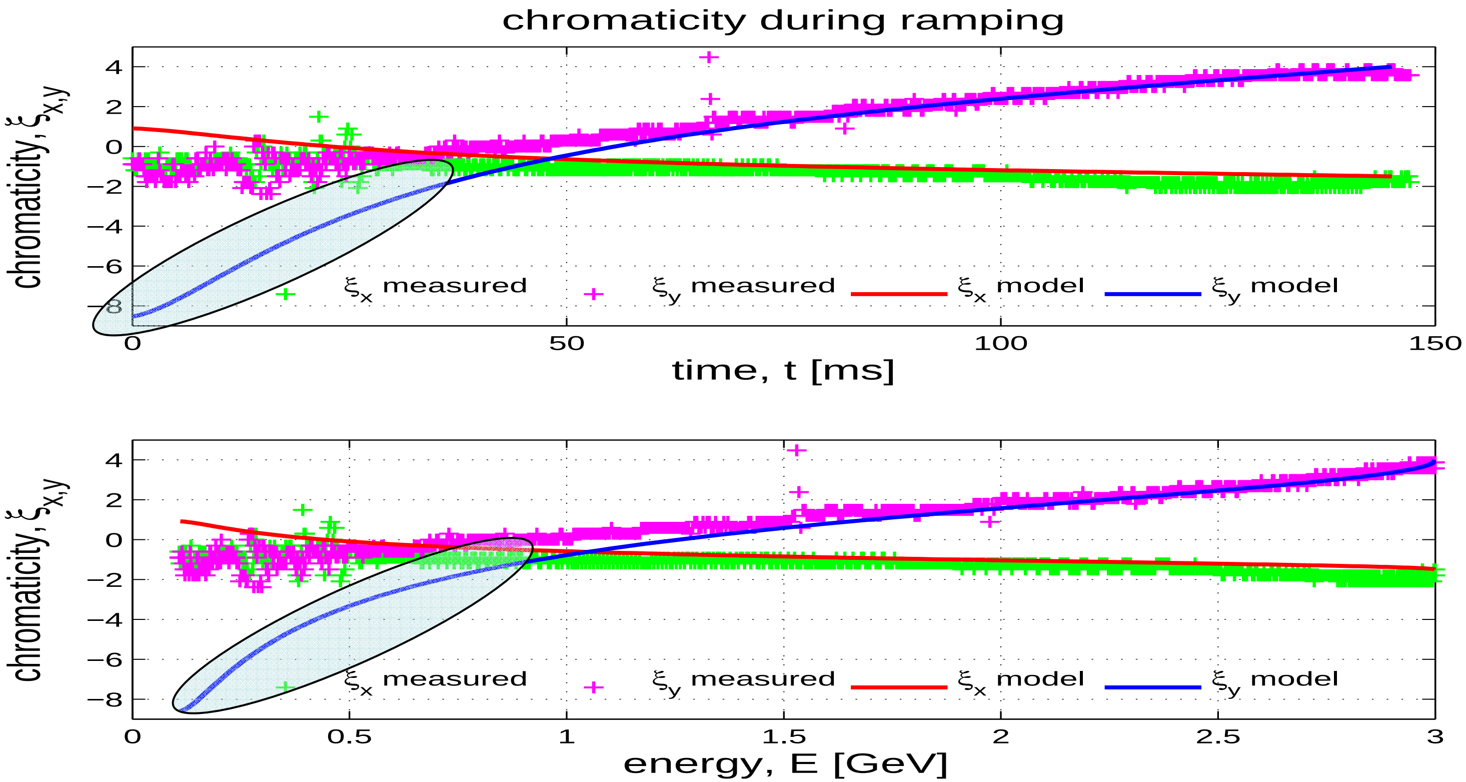
Chromaticity and Sextupoles

Accelerator Division

Chromaticity was measured during ramp by varying the RF

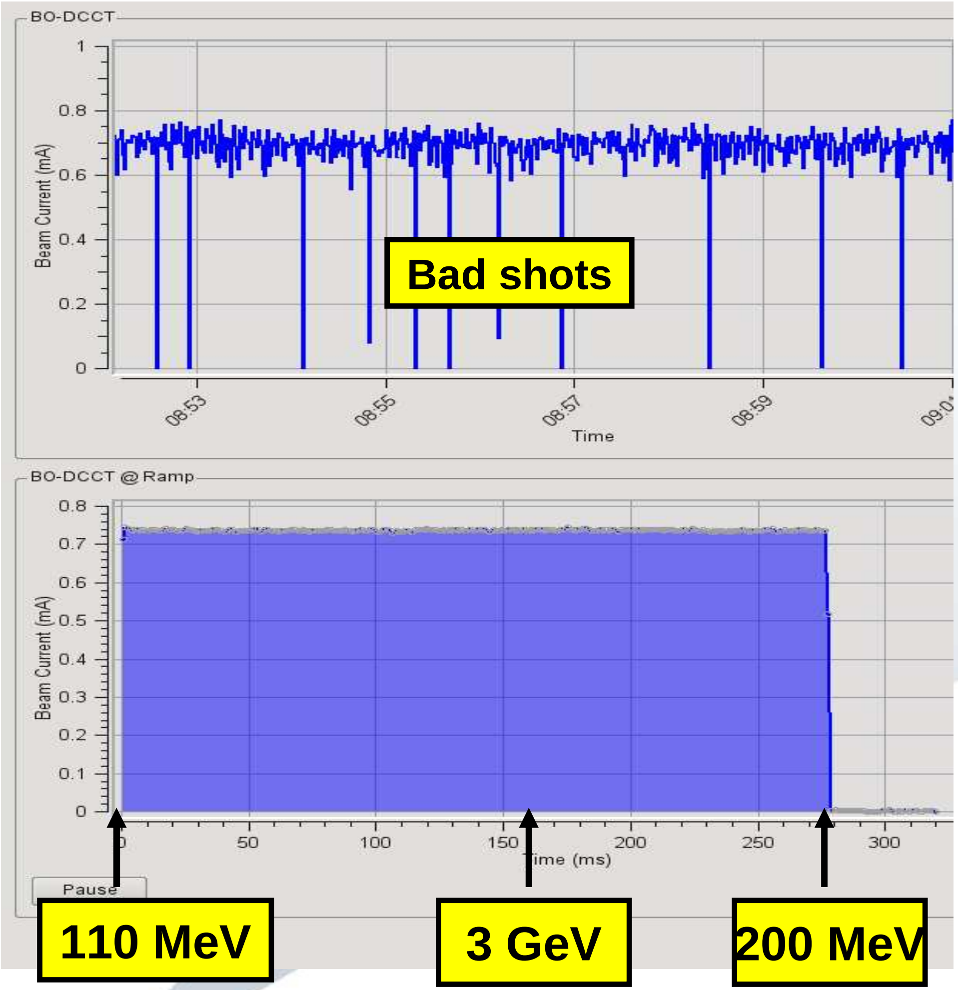
Integrated sextupole component in combined bendings corrects natural chromaticity

The two additional sextupole families to control the eddy current effects no needed so far

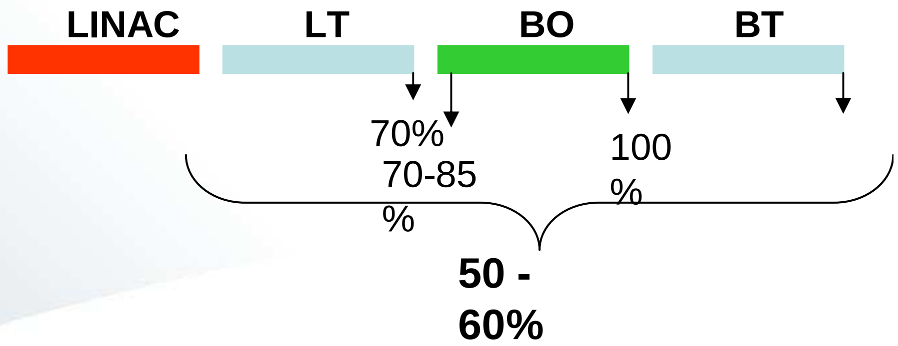


the measurements agree very well with the model at energy higher than 1 GeV while at low energy chromaticity is hard to be measured (still investigating)

Beam in the Booster Synchrotron

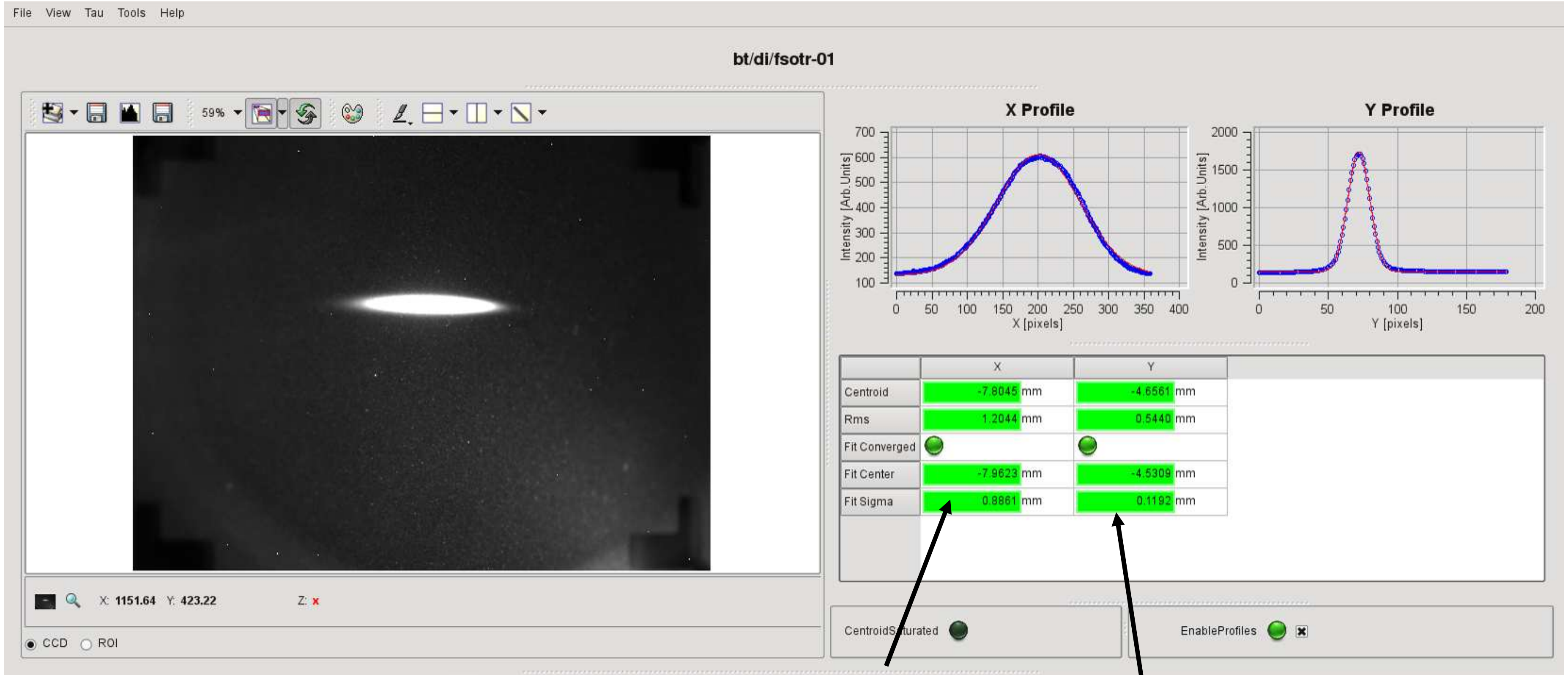


- Increase transmission



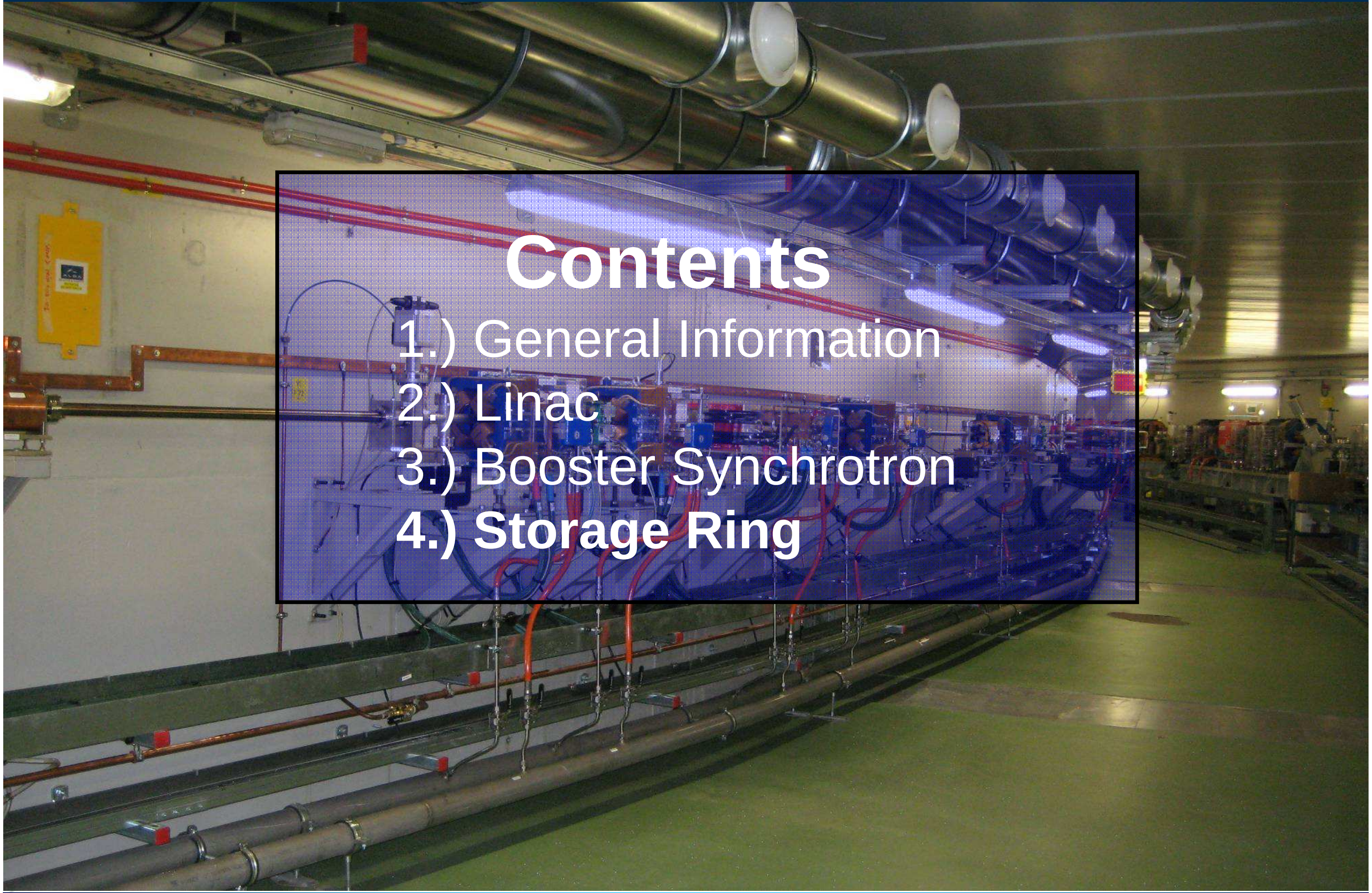
Booster Emittance

1st extracted Beam from the Booster Synchrotron, 28th of October 2010



σ(x) = 0.86 mm, σ(y) = 0.19 mm
ε(x) = 13 nmrad, ε(y) = 2,6 nmrad

We are 30 % off to the theoretical emittance and have a coupling factor of roughly 20%.



Contents

1.) General Information
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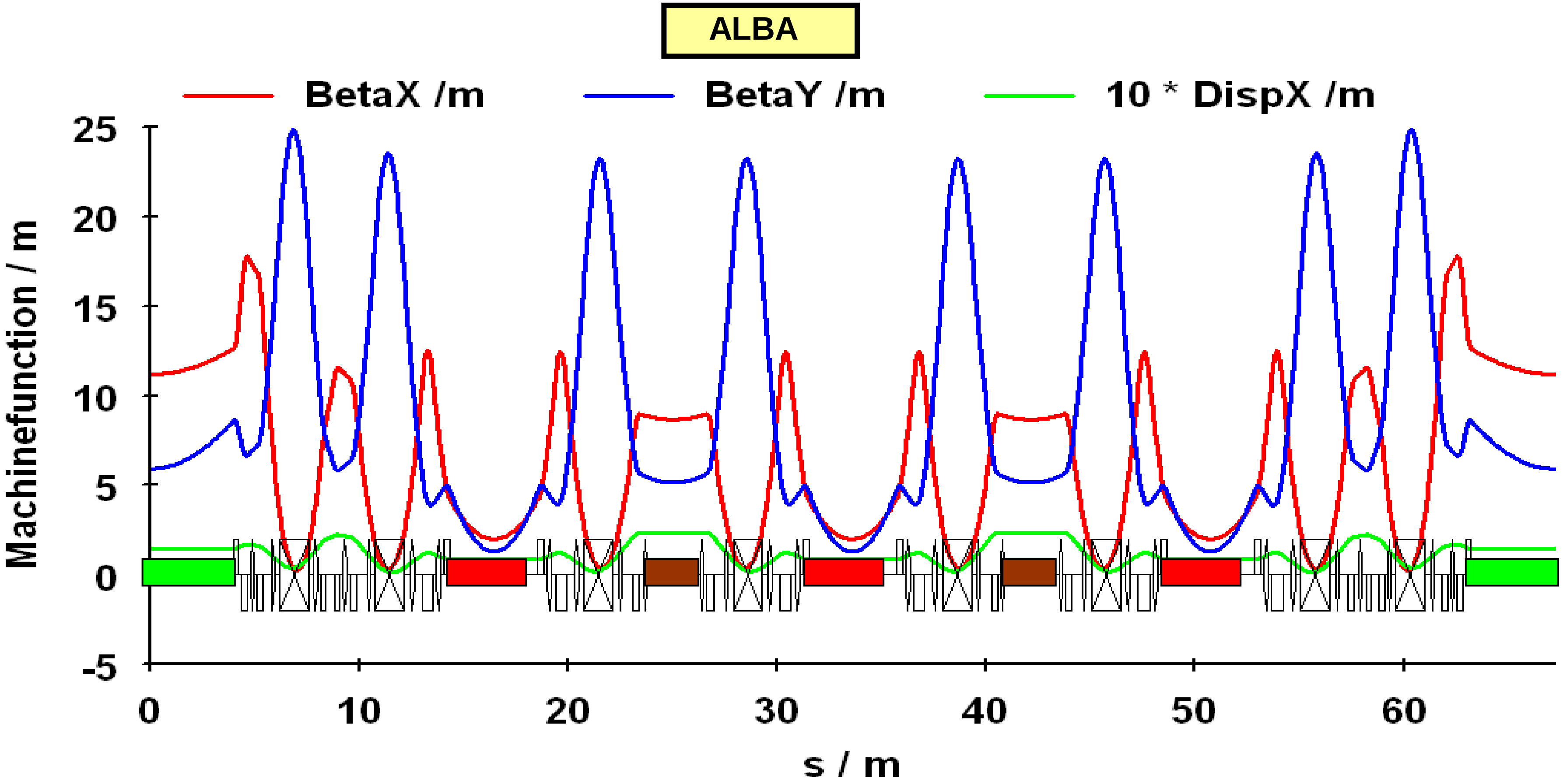
Storage Ring Milestones

1.) Mechanical installation of storage ring:	April to Nov. 2009
2.) Storage ring under vacuum	November 2009
3.) SAT of power supplies :	Oct. 2009 to June 2010
3.) Radio frequency installation:	Dec. 2009 to April 2010
4.) Installation of injection straight:	May to June 2010
5.) Cabling of magnets and power supplies:	Dec. 2009 to March 2010
6.) Cabling of signals, EPS, and MPS :	Jan. to Sept. 2010
7.) Magnetic measurements of W80 and EPU's	Jan. to Sept. 2010
8.) SAT of superconducting wiggler	October 2010
9.) BTS installation finished:	September 2010
10.) Pre-commissioning of subsystems:	July to Octob. 2010
11.) Ready for storage ring commissioning:	22nd of Nov. 2010
12.) Installation of 3 insertion devices:	Jan. to Febr, 2011
13.) Weekend for storage ring commissioning:	12th / 13th Febr. 2011
14.) License for storage ring commissioning:	8th of March 2010
15.) Bake out of in-vacuum undulators:	March to May 2011
16.) Phase 1 of storage ring commissioning:	8th to 26th of March
17.) Phase 2 of storage ring commissioning:	1st of April to 14th of May
18.) Phase 3 of storage ring commissioning:	25th of May to 10th of June
19.) Installation of in-vacuum undulators and SCW:	10th of June to 22nd of August
20.) Restart of the machine:	29th of September

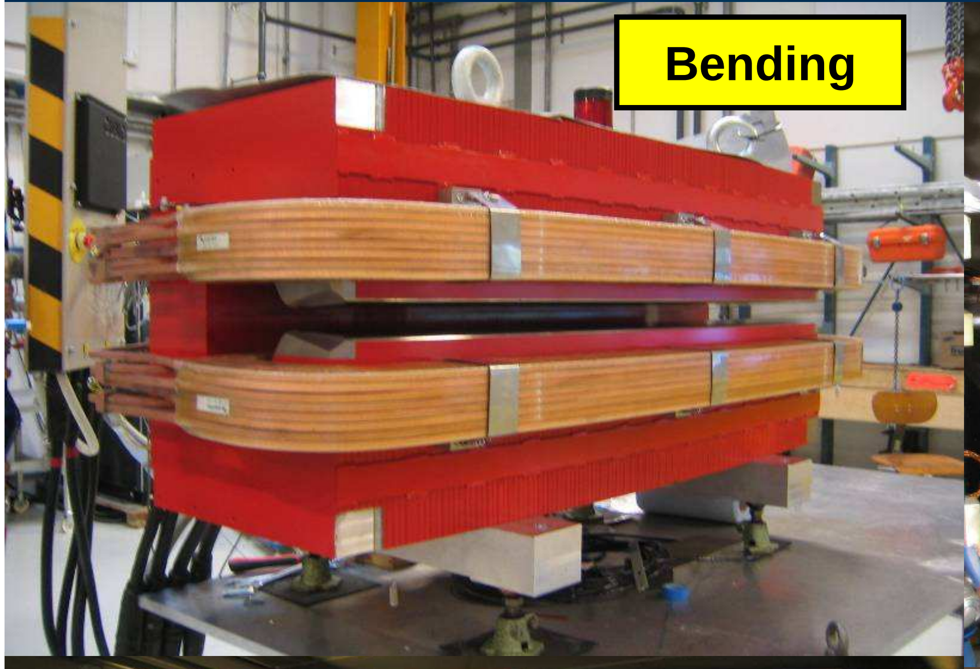
Storage Ring Lattice

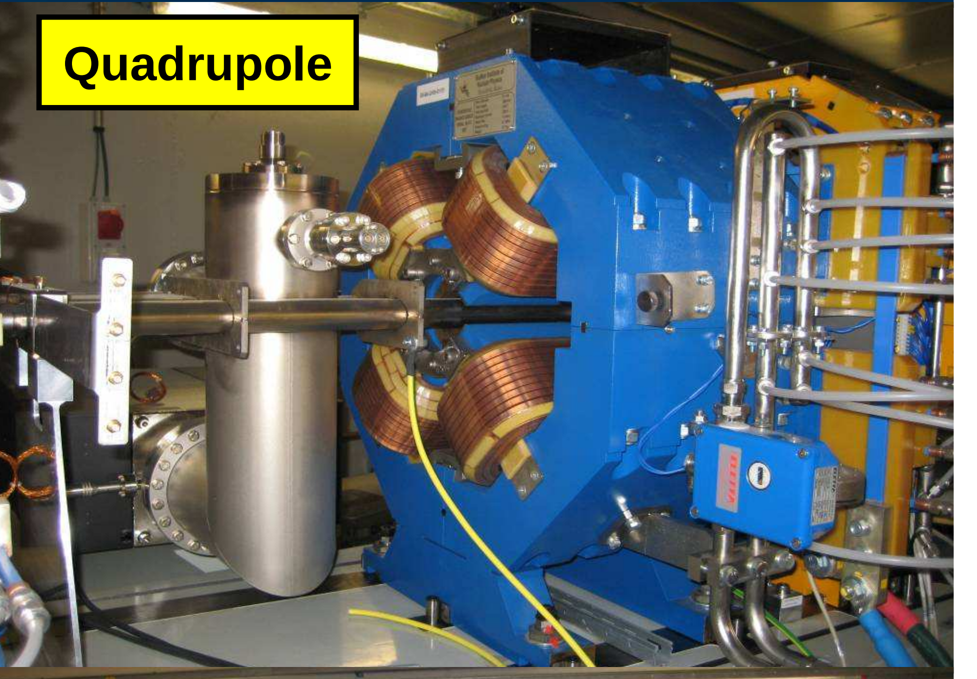


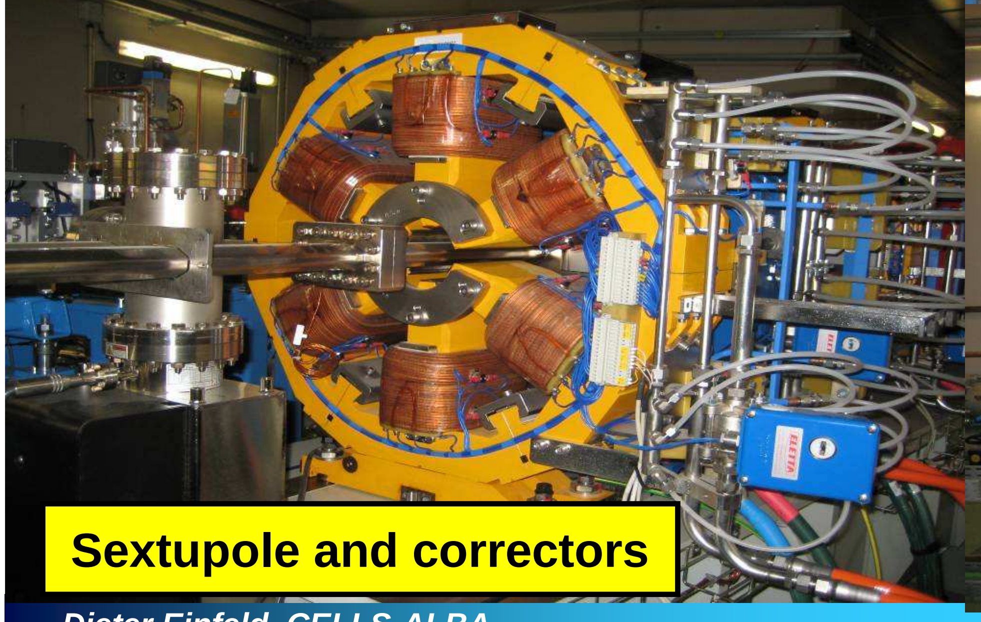
- 4 long straights with a length of 7.8 m
- 12 medium straights with a length of 4.3 m
- 8 short straights with a length of 2.3 m

Circumf.= 268.8 m
4 fold symmetry
Emitt. = 4.5 nmrad

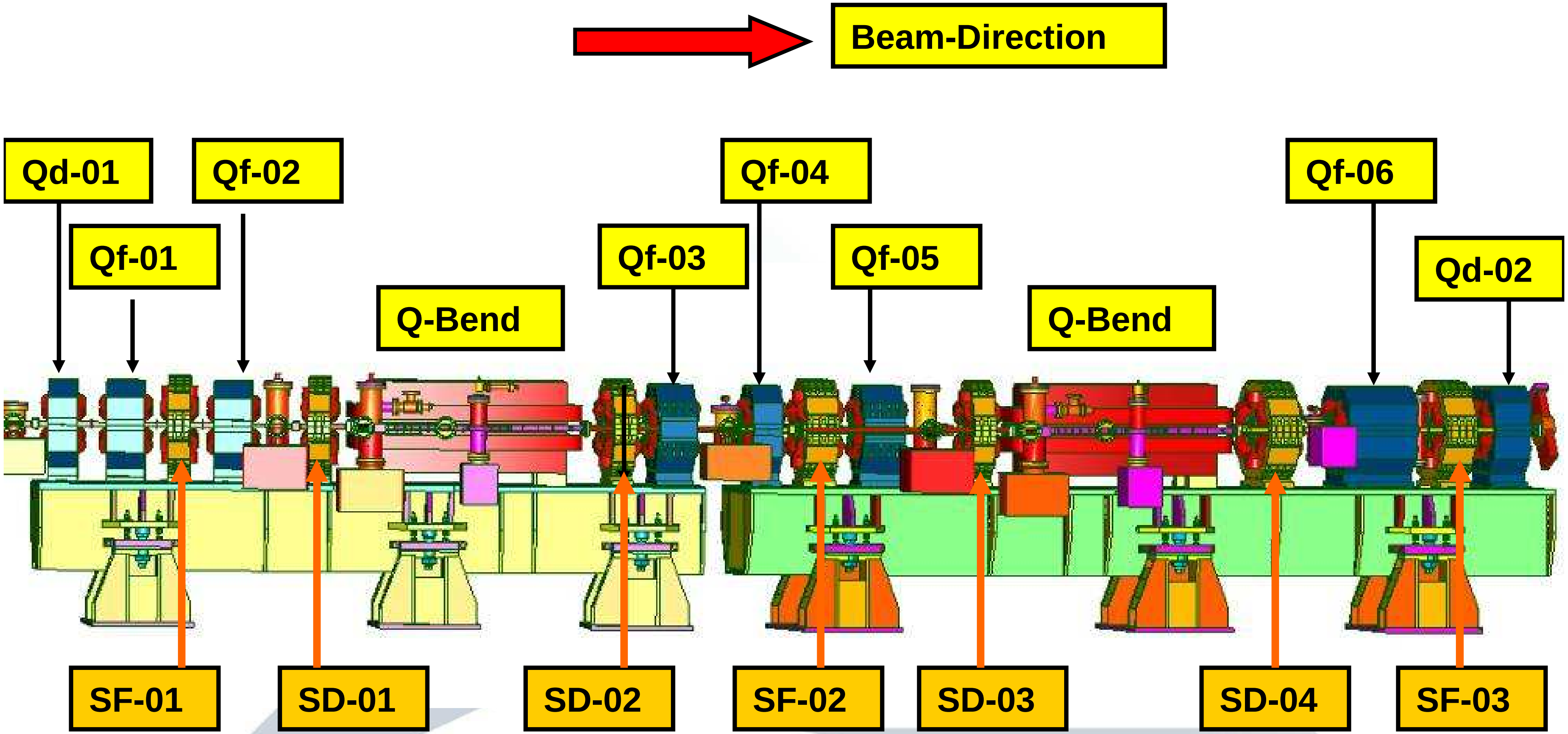
Storage Ring Components





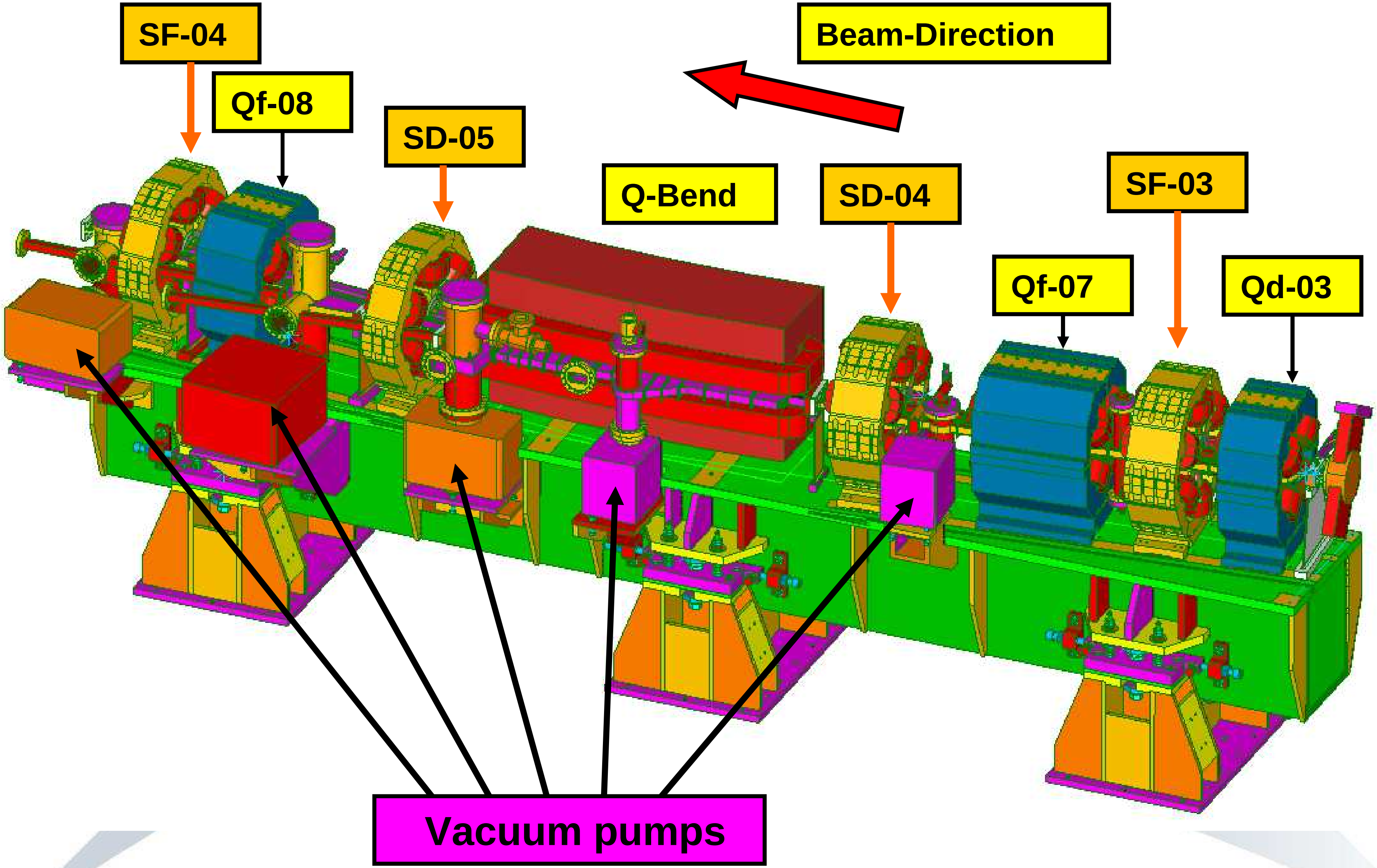


Girder of Matching Cell



There are: 8 foc. and 3 def. families of quadrupoles
4 foc. And 5 def. families of sextupoles

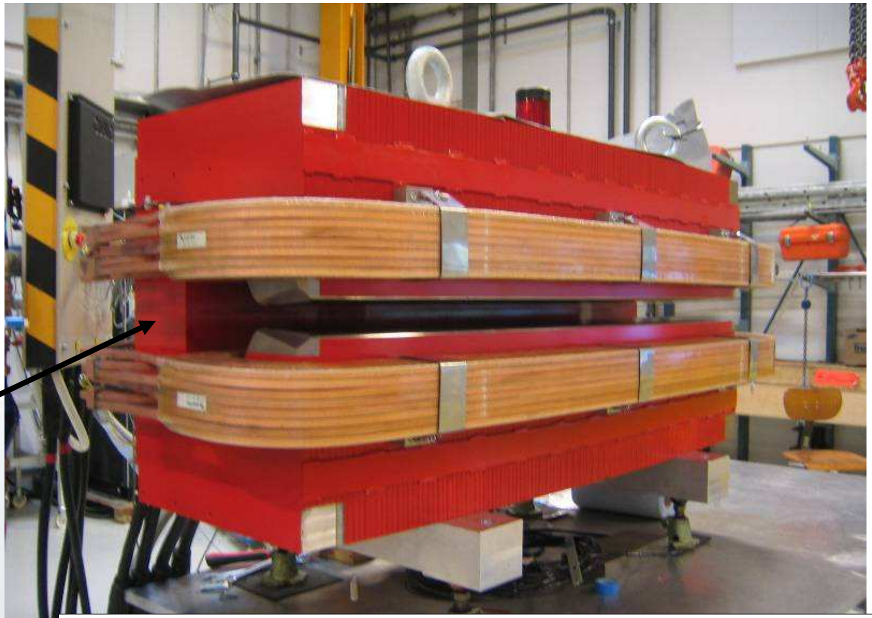
Girder of Unit Cell

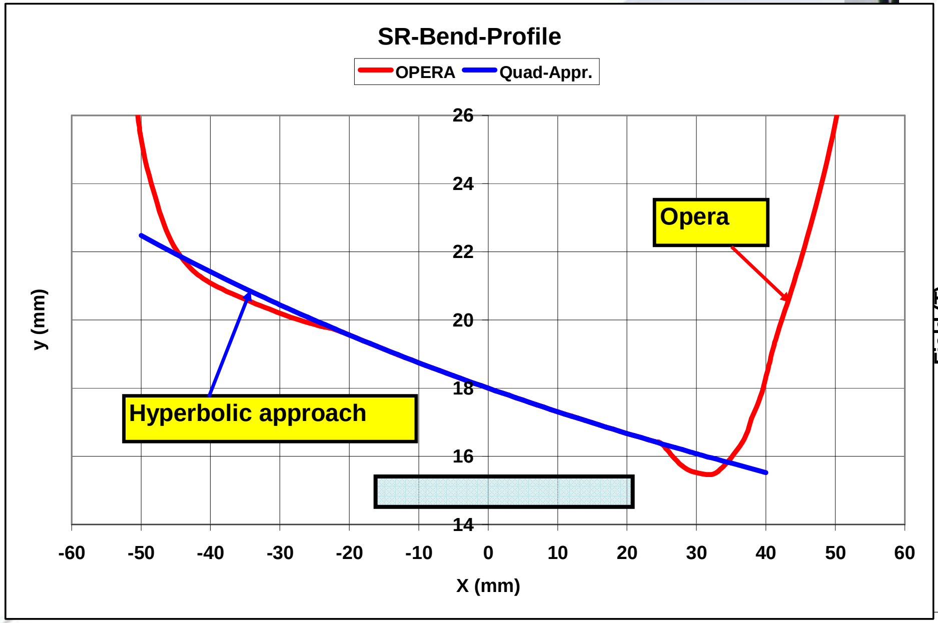


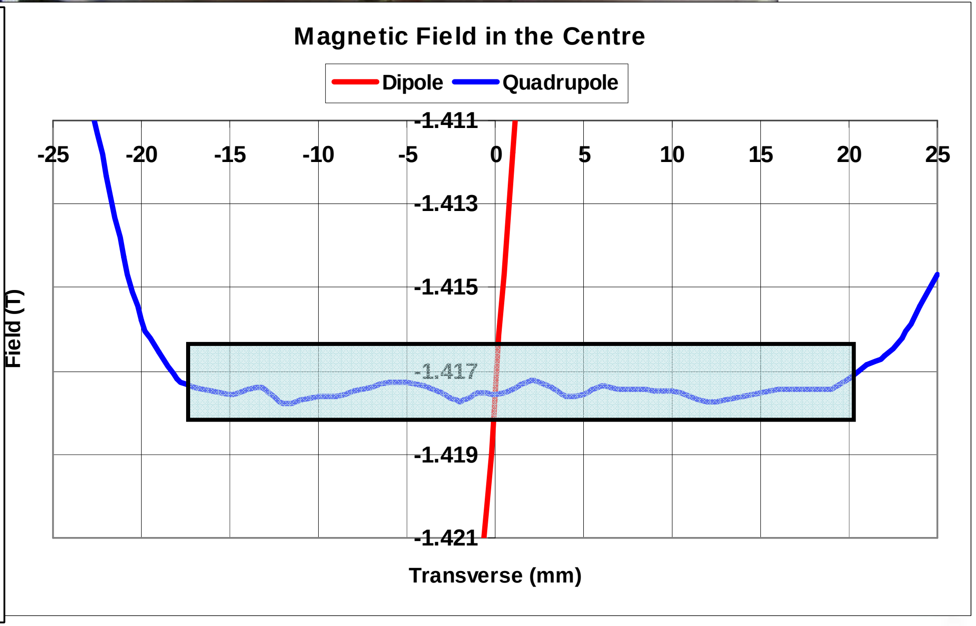
Bending Magnets

Magnetic field:	1.42 T
Bending angle:	11.25 deg.
Gradient:	5.6 T/m
Bending radius:	7.047 m
Gap:	36 mm
Current:	520 A
Field accuracy:	$<3*10^{-3}$
Grad. accuracy:	$<5*10^{-3}$

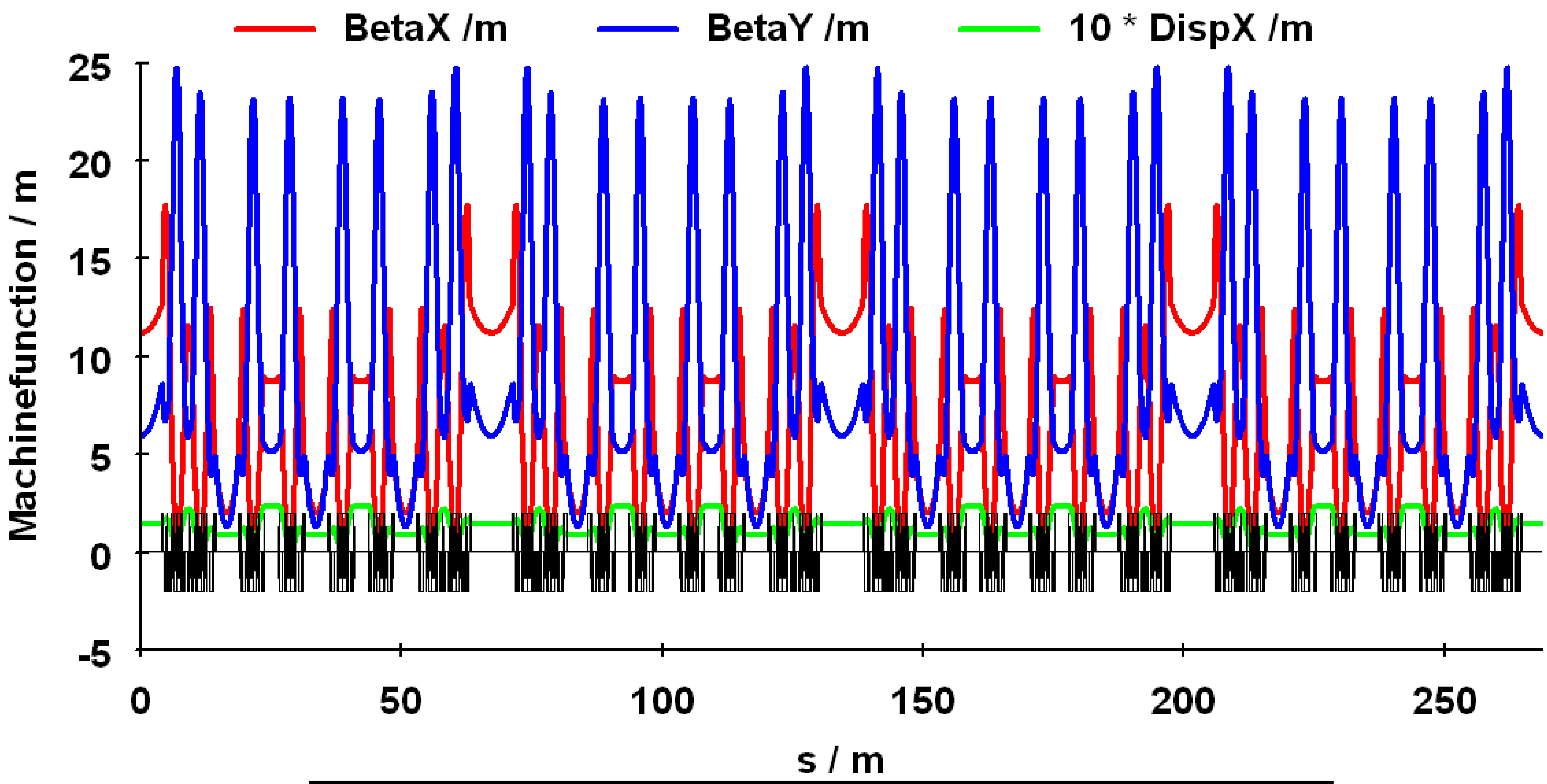
The dipole is split in the middle of the magnet for machining of both pole faces with an accuracy of +/- 15 µm.





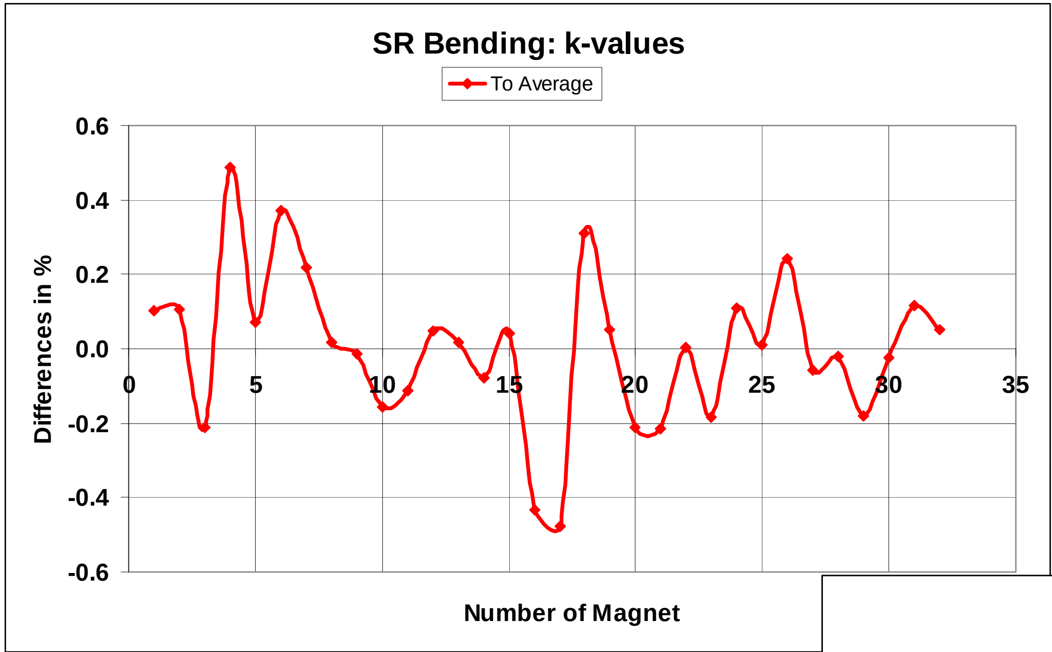


ALBA-Lattice with nominal Settings



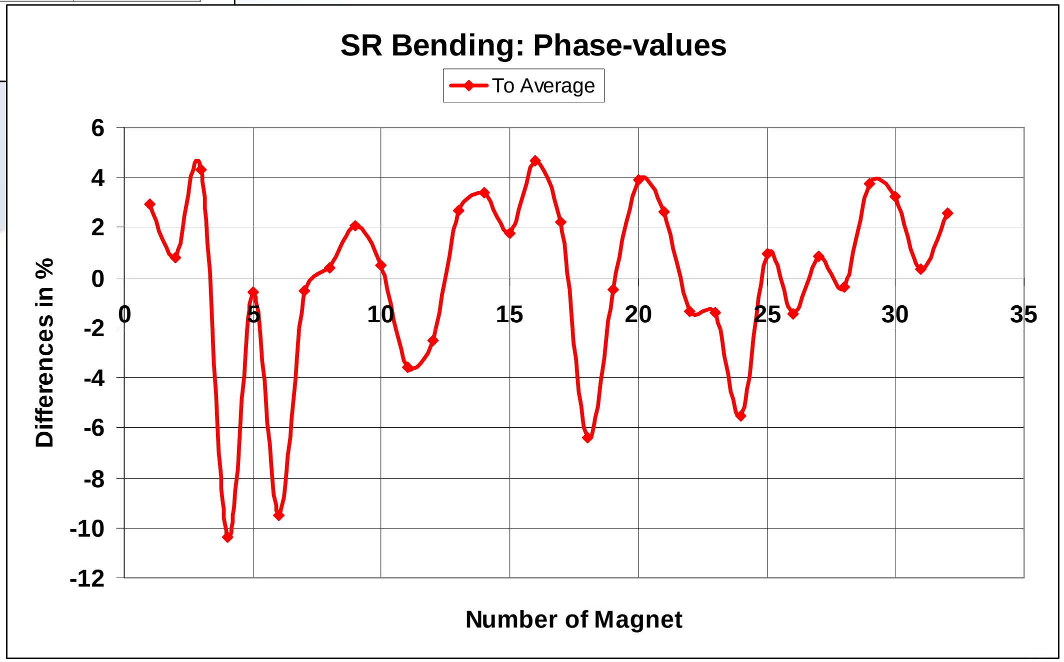
C = 268.8 m, Qx = 18.182, Qy = 8.373, ε = 4.42 nmrad

Rho = 7.0470423, l = 1.383684 m, k = 0.565618, phi = 5.625,



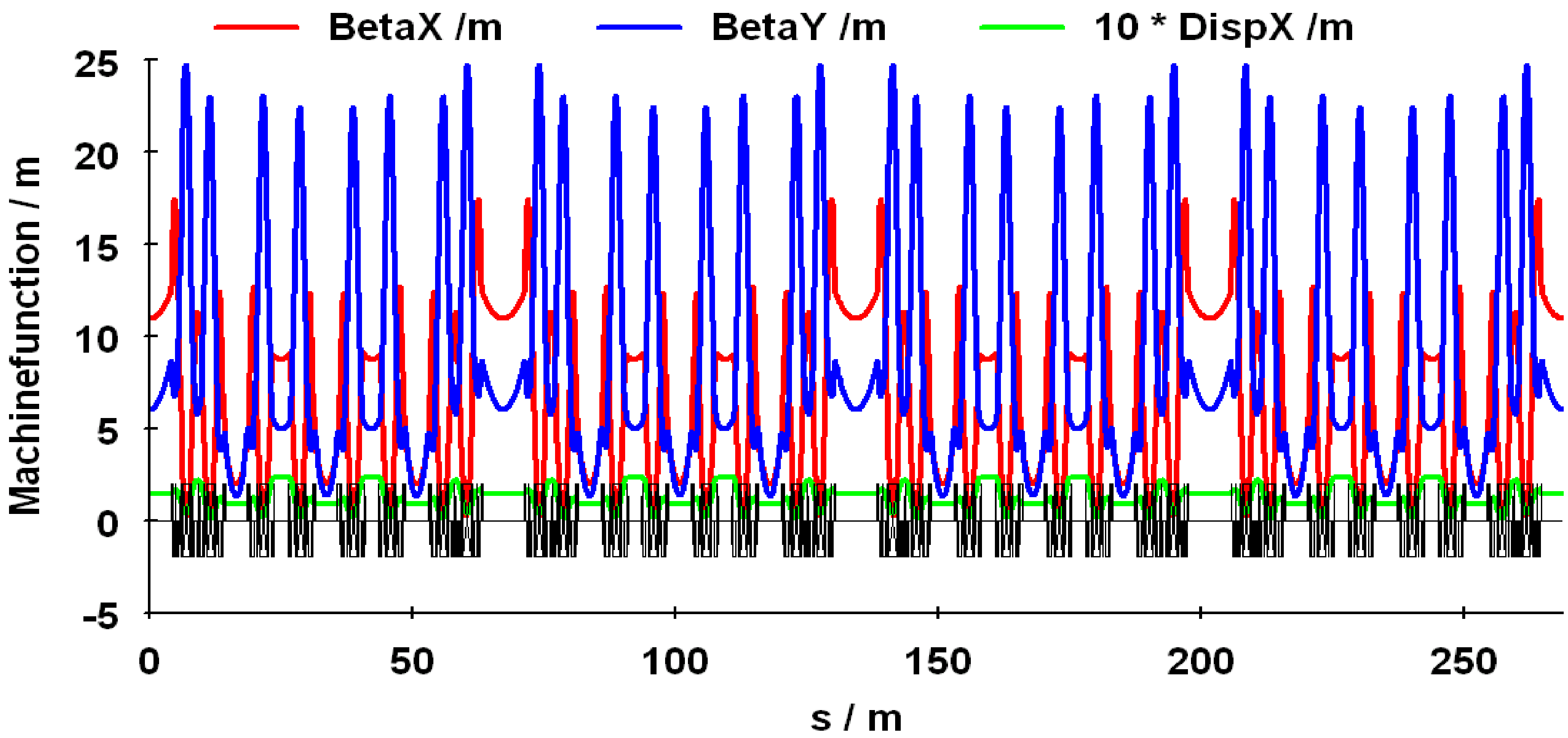
Change of k-Values of the individual magnets.

Change of pole phase rotation of the individual Magnets.



ALBA-Lattice with average Settings

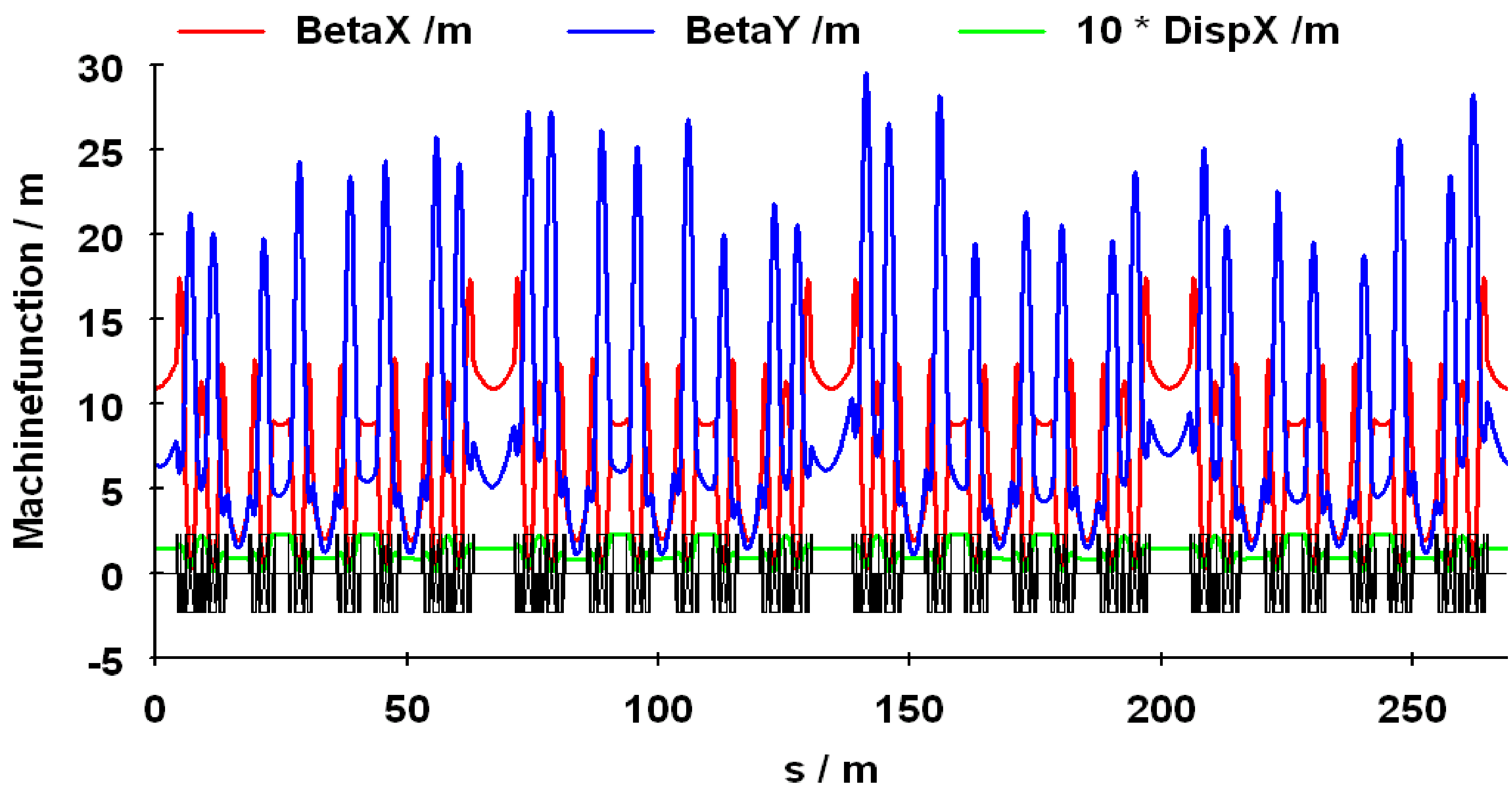
Accelerator Division



C = 268.8 m, Qx = 18.183, Qy = 8.395, ε = 4.44 nmrad

Rho = 6.99718, l = 1.373893 m, k = 0.568103, phi = 5.9395,

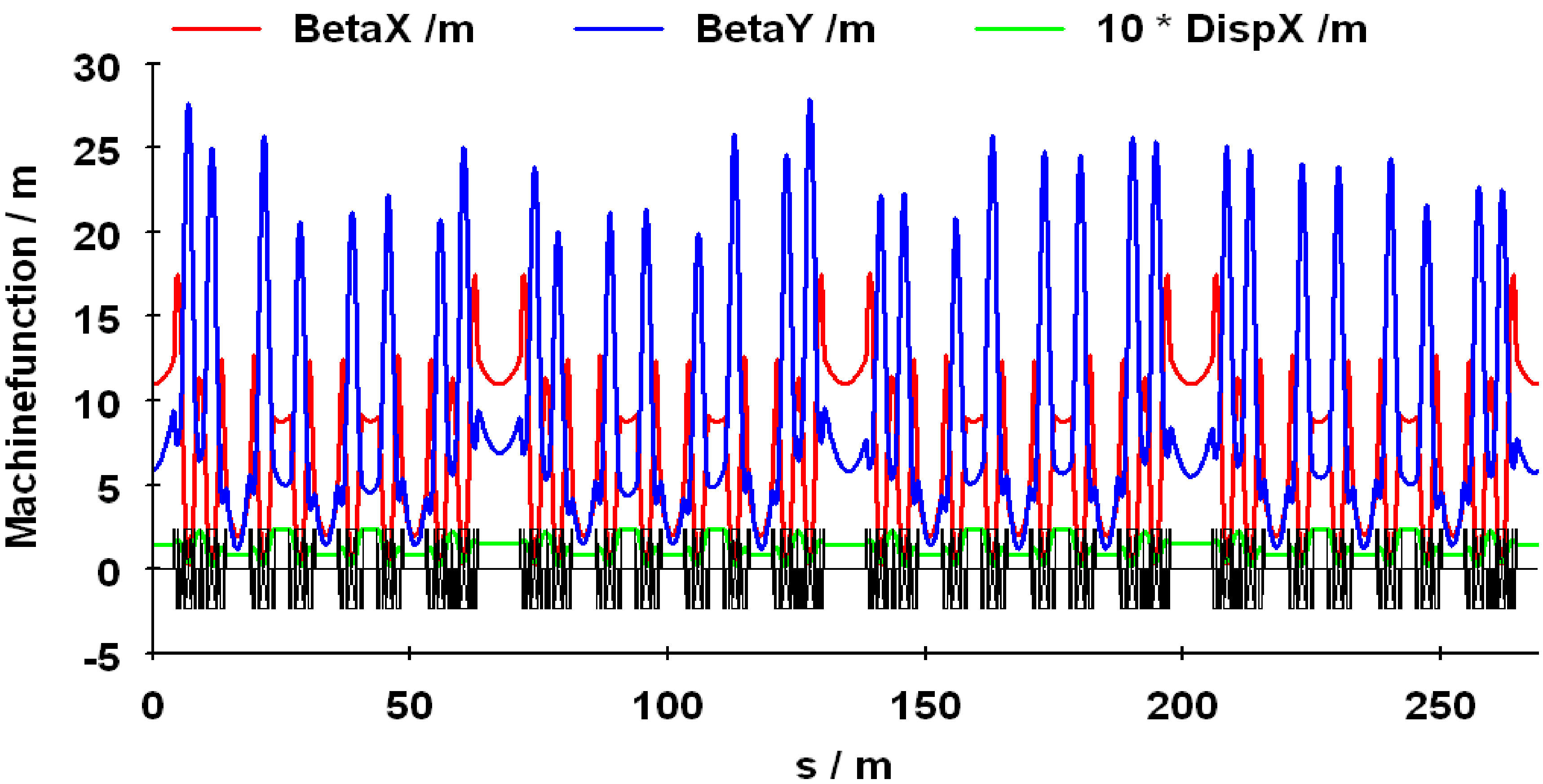
ALBA-Lattice with individual Settings



C = 268.8 m, Qx = 18.183, Qy = 8.396, ε = 4.44 nmrad

Rho = 6.99718, l = 1.373893 m, k = individual, phi = 5.9395,

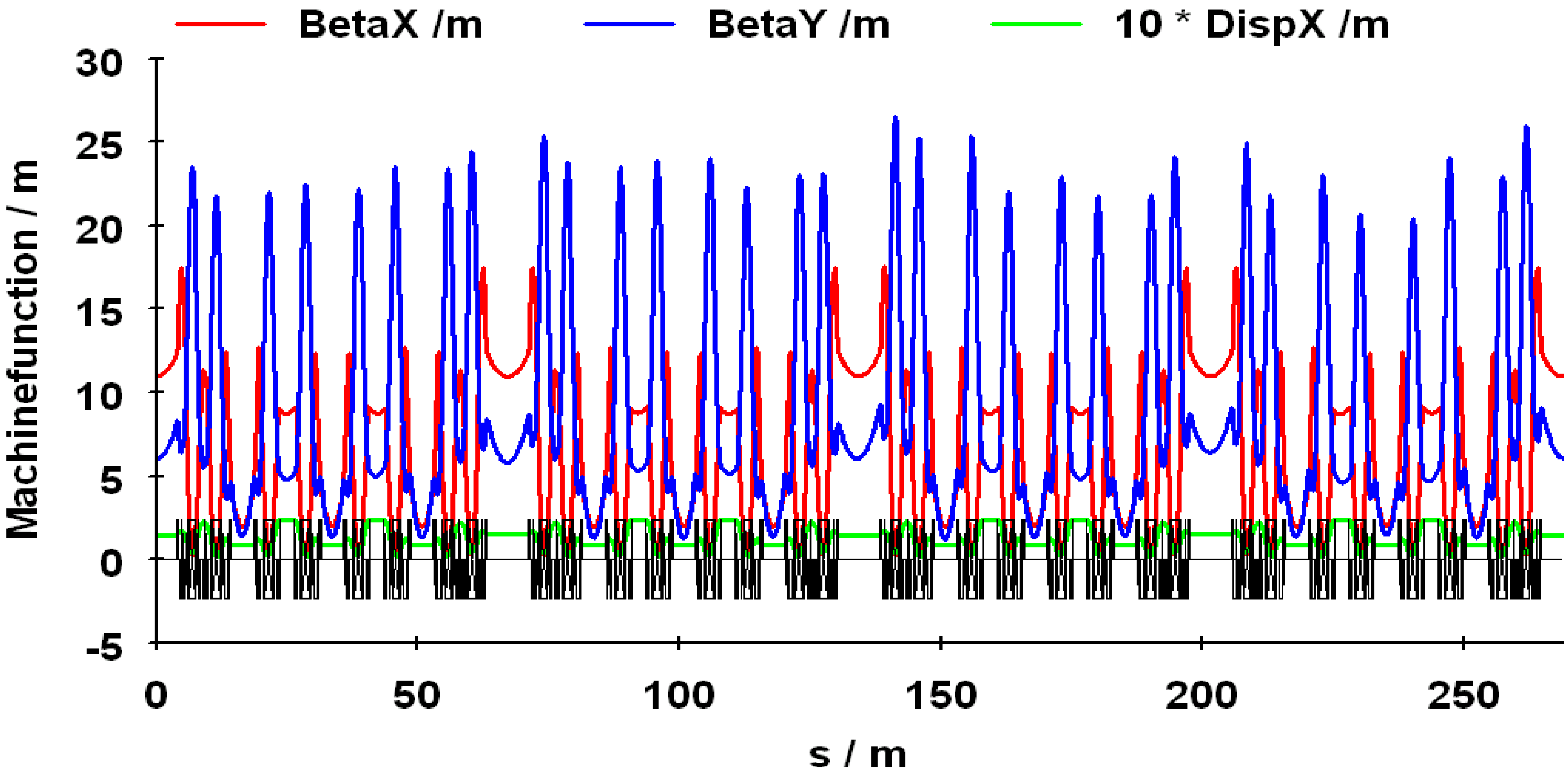
ALBA-Lattice with individual Settings



C = 268.8 m, Qx = 18.183, Qy = 8.396, ε = 4.44 nmrad

Rho = 6.99718, l = 1.373893 m, k = 0.568103, phi = individual

ALBA-Lattice with individual Settings

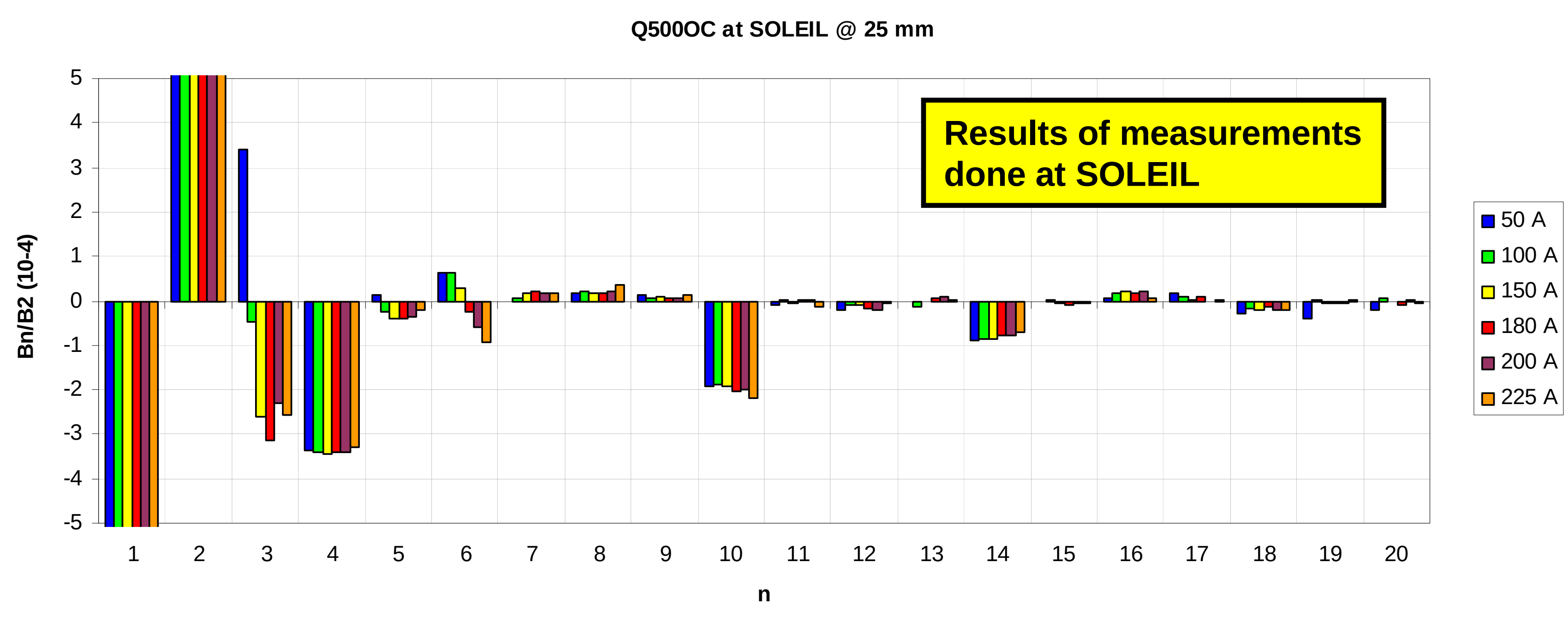


C = 268.8 m, Qx = 18.183, Qy = 8.395, ε = 4.44 nmrad

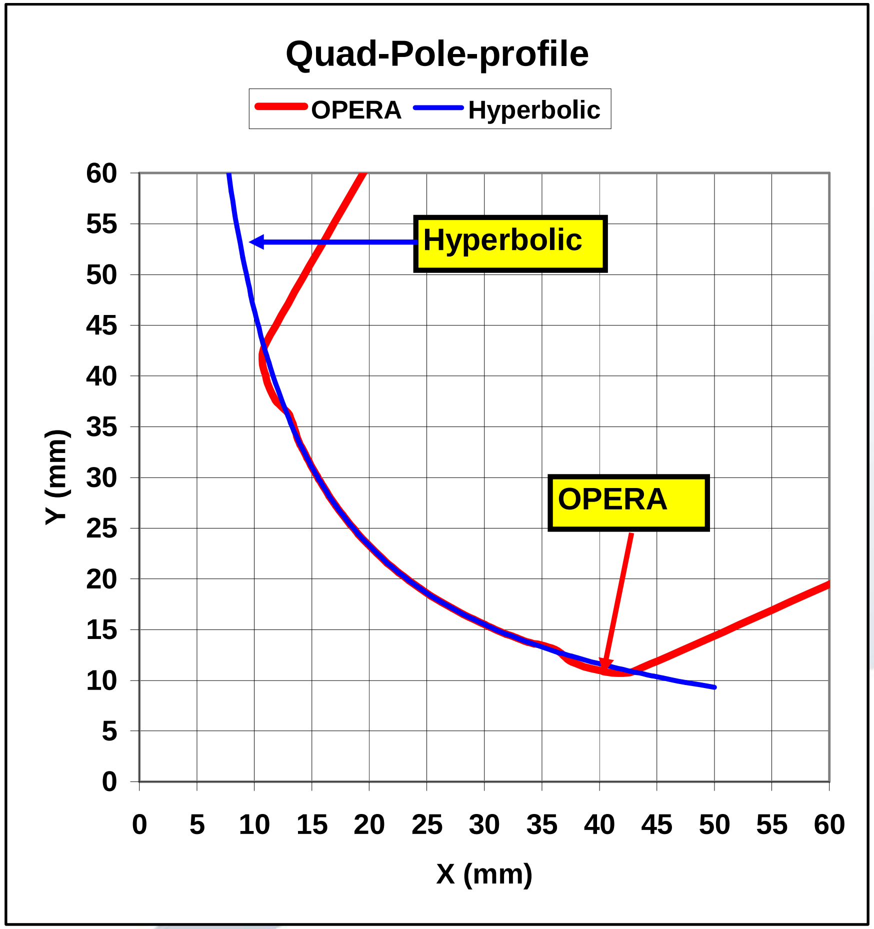
Rho = 6.99718, l = 1.373893 m, k = individual, phi = individual

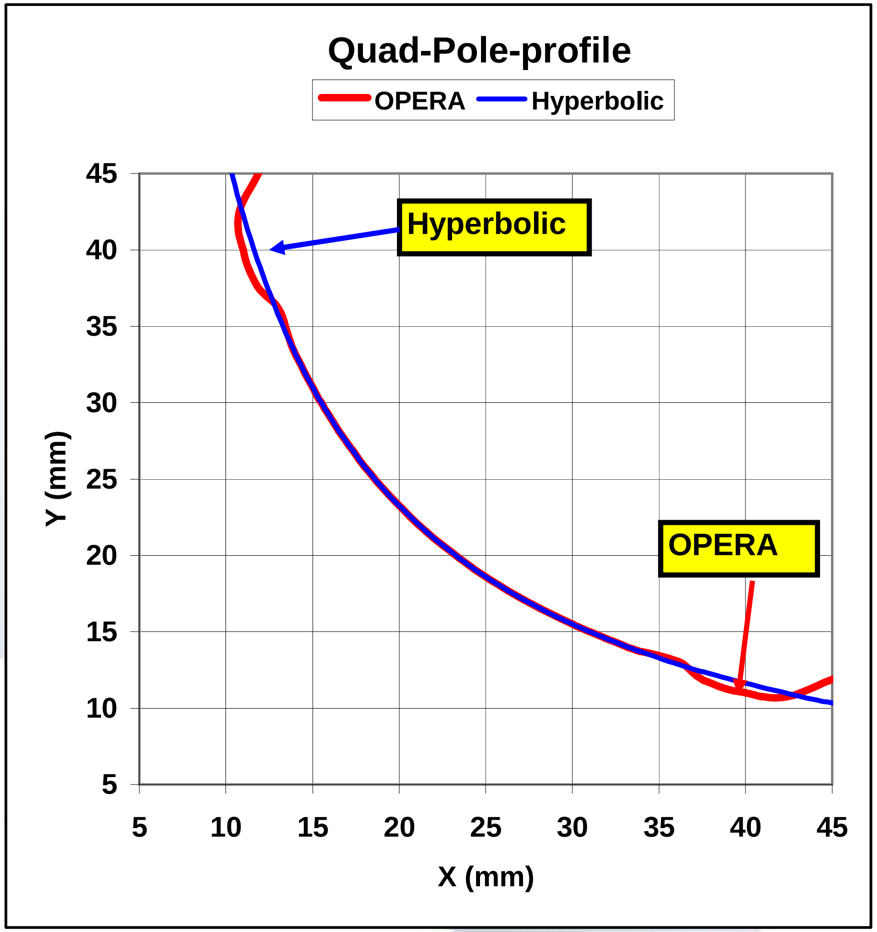
Quadrupole magnets:

Field at pole tip:	0.715 T
Gradient:	23.43 T/m
Aperture:	61 mm
Current:	190 A
Field accuracy:	$<3*10^{-3}$
Grad. accuracy:	$<2*10^{-3}$
Length (mm):	200, 260
	310, 530



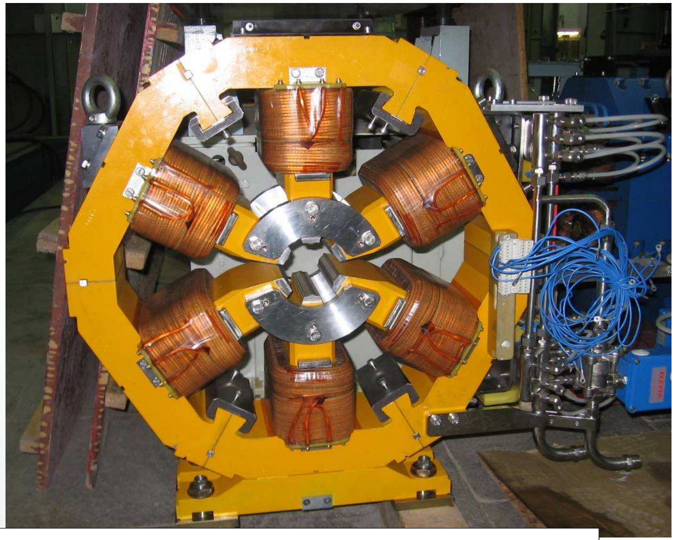
Pole Profile of SR - Quadrupole

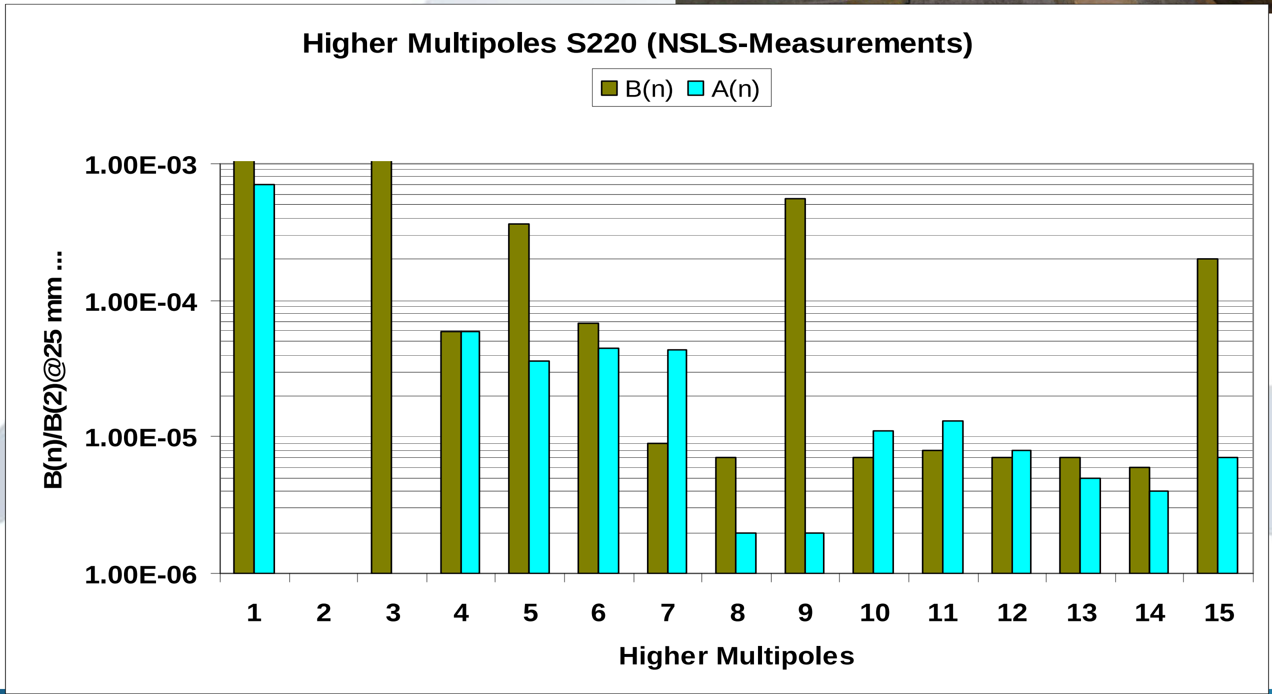




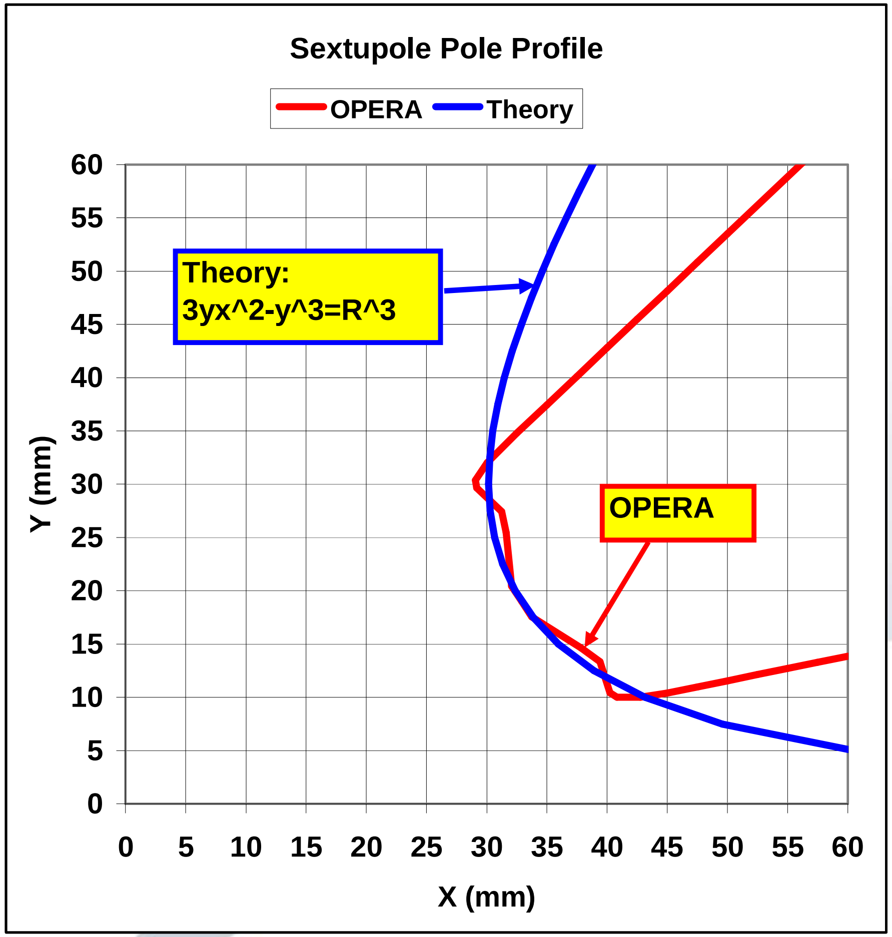
Sextupole Magnets

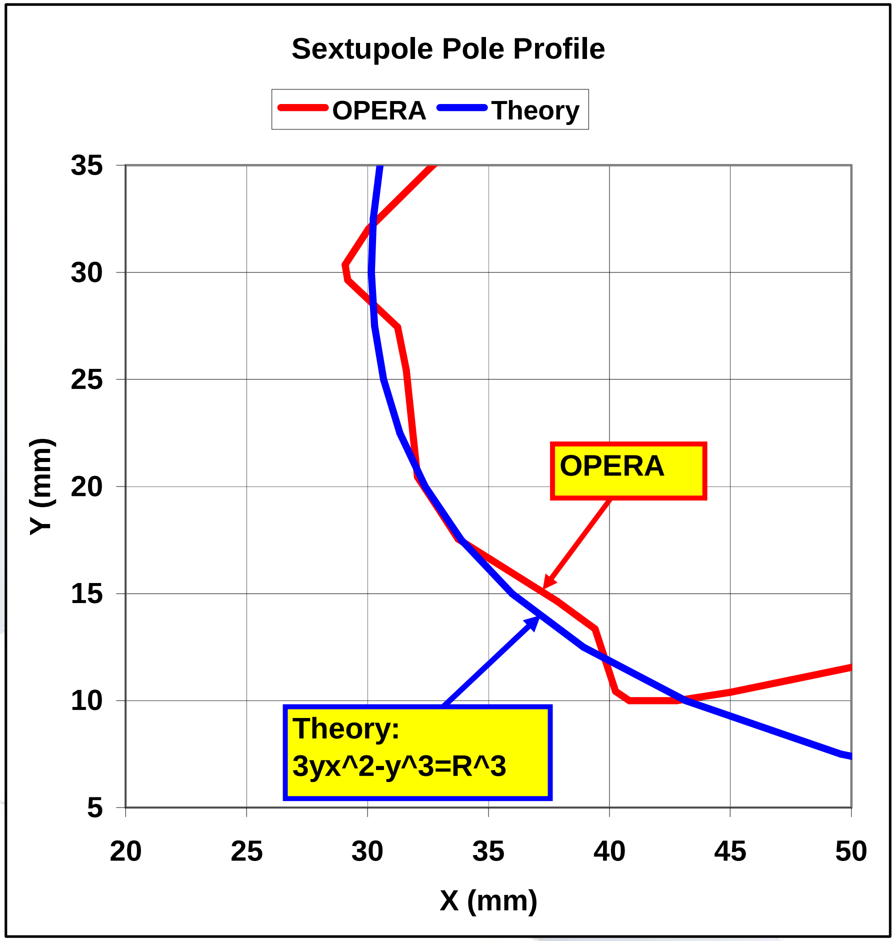
Field at pole tip:	0.450 T
Diff. Gradient:	700 T/m^2
Aperture:	72 mm
Current:	200 A
Field accuracy:	<3*10^{-3}
Grad. accuracy:	<2*10^{-3}
Length (mm):	150, 220





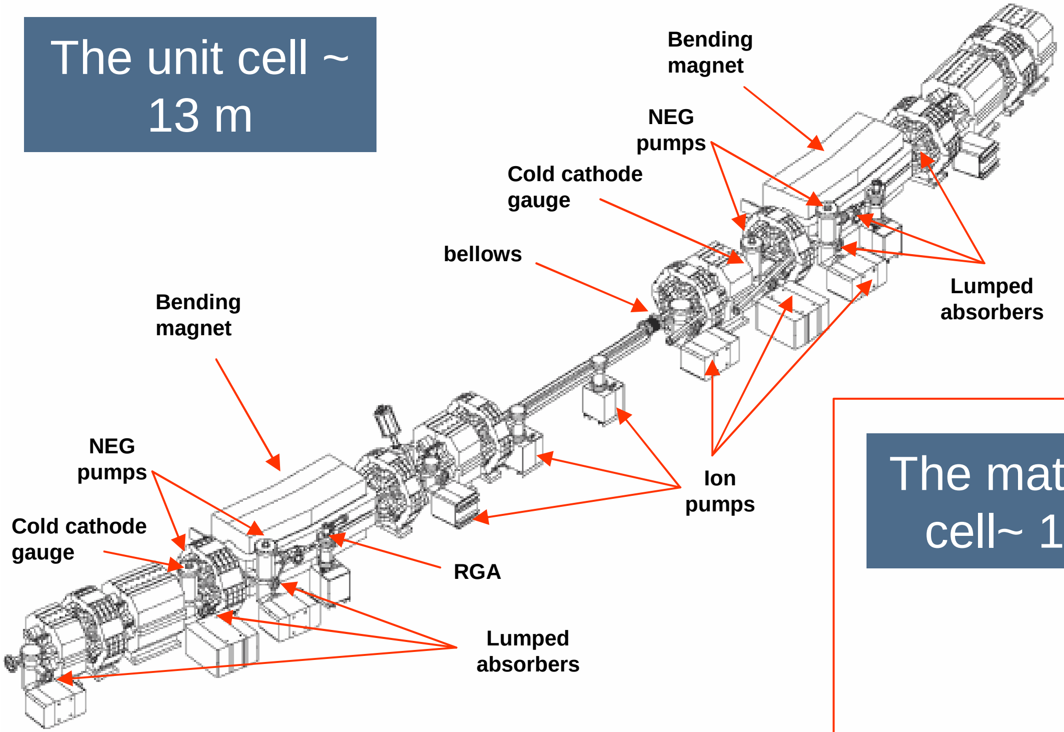
Pole Profile of SR - Sextupole



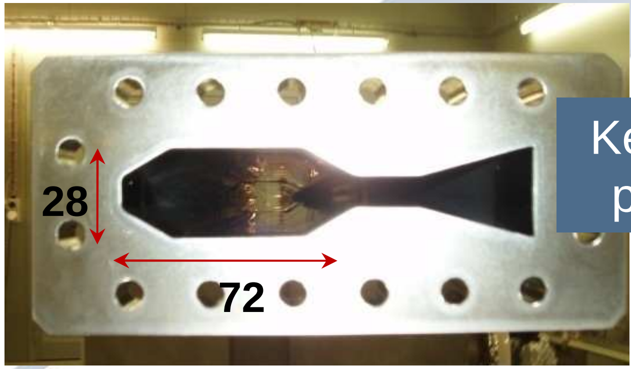


Vacuum System Layout

The unit cell ~ 13 m

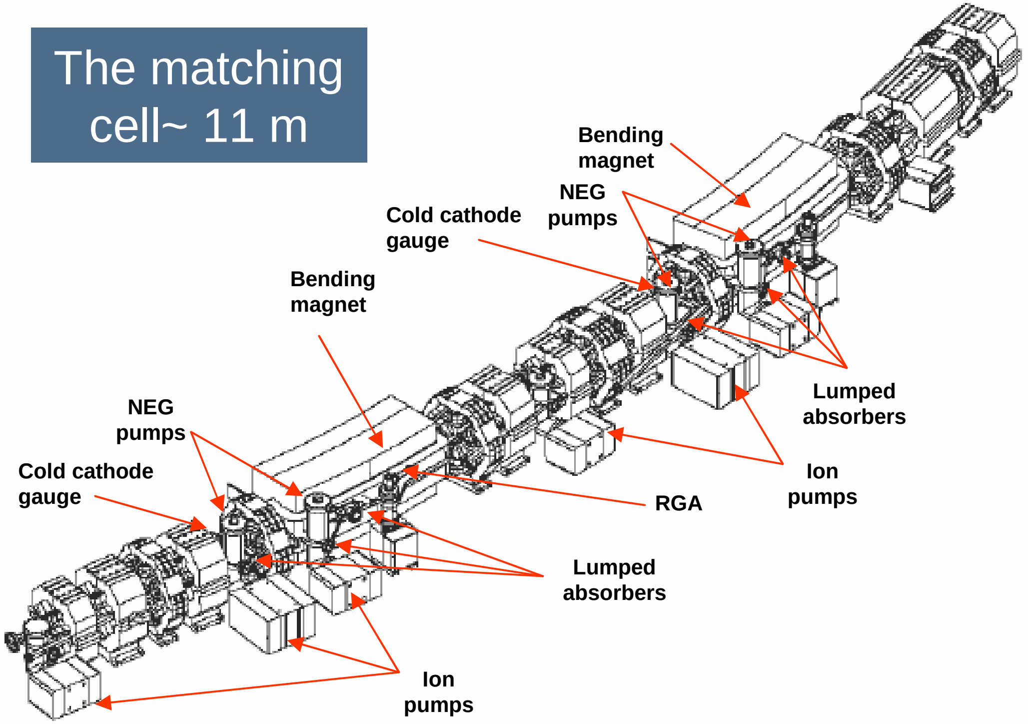


- Antechamber design with lumped copper absorbers.
- Keyhole profile 28x72 mm.
- Stainless steel 316LN.
- Pumping mainly by ion and NEG pumps.



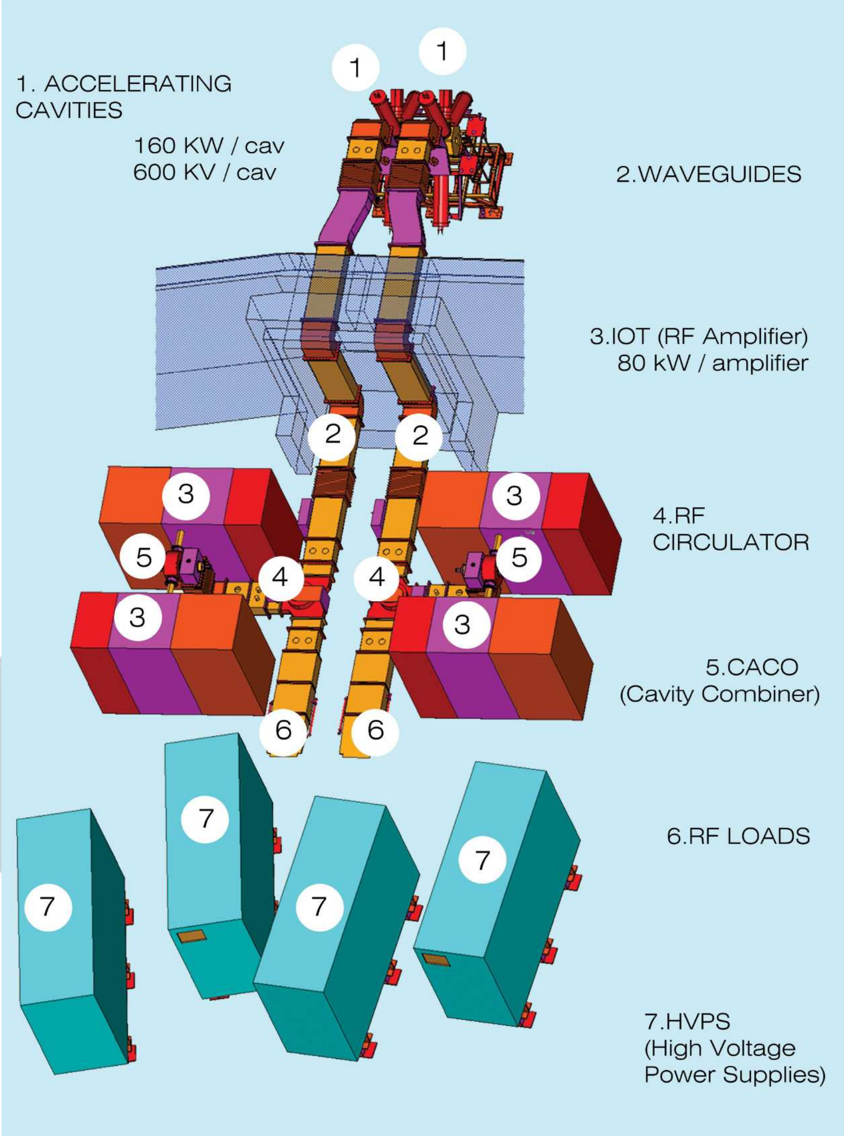
Keyhole profile

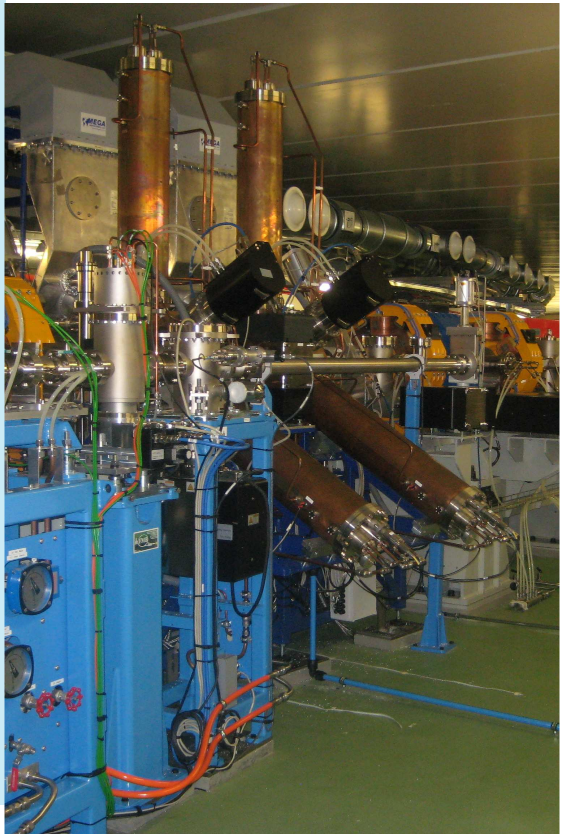
The matching cell~ 11 m



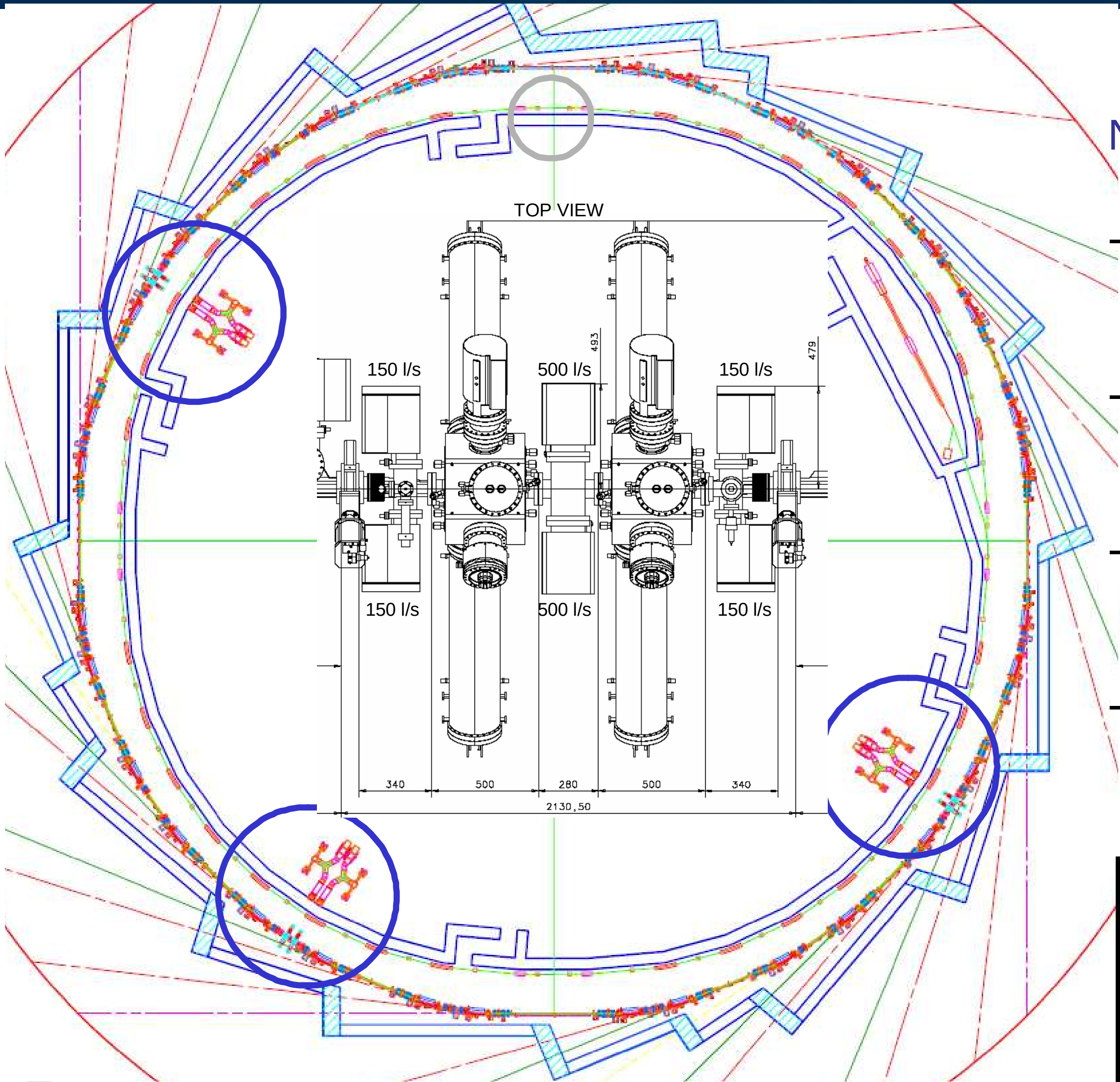
RF - System

RADIOFREQUENCY SYSTEM (RF), f = 500 MHz





RF-System

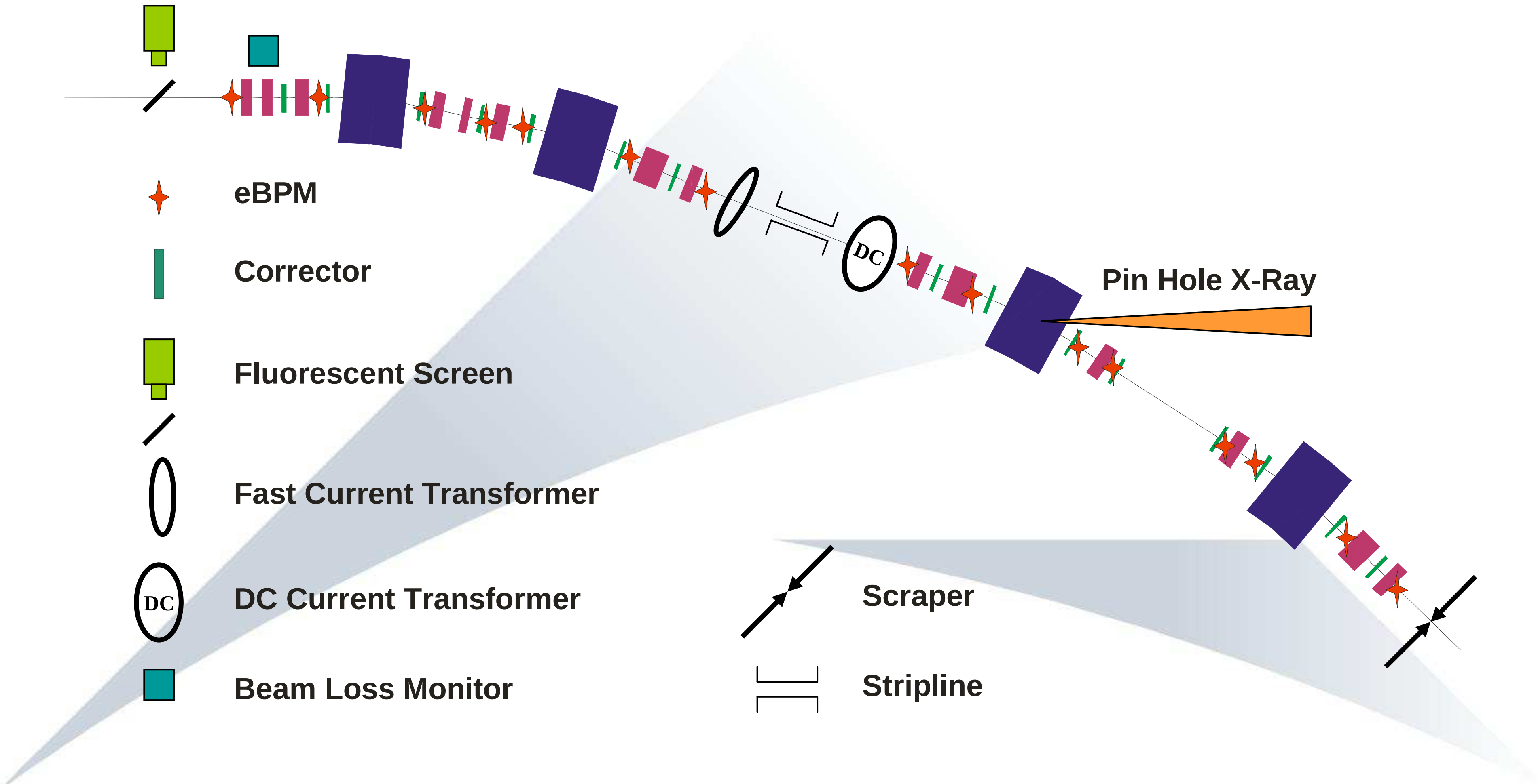


New developments:

- Normal conducting HOM damped cavities.
- Watrax, transition from WG to Coaxial
- CaCo, cavity combiner of 2x80 kW IOTs
- Digital LLRF

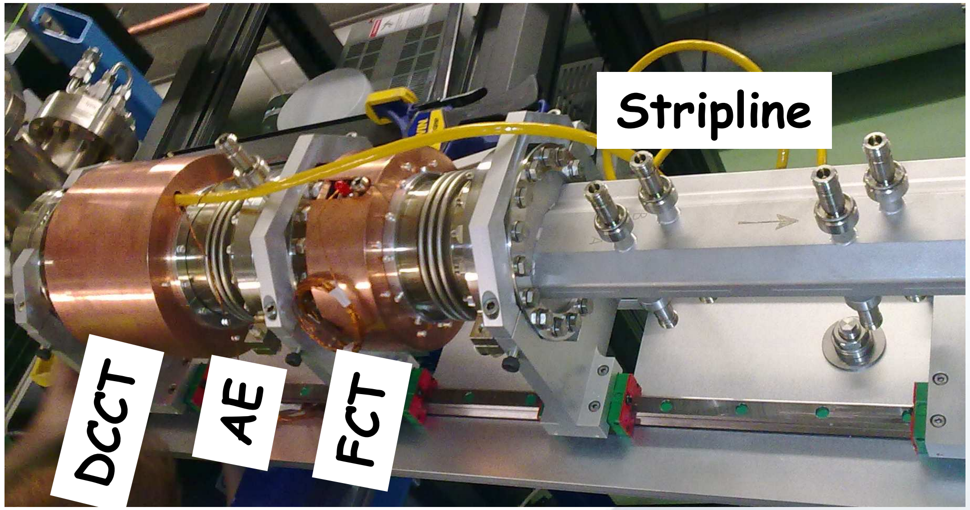
RF Voltage: 3600 kV, beam current: 400 mA, losses: 1.3 MeV/turn, beam power: 520 kW

DIAGNOSTIC SYSTEM

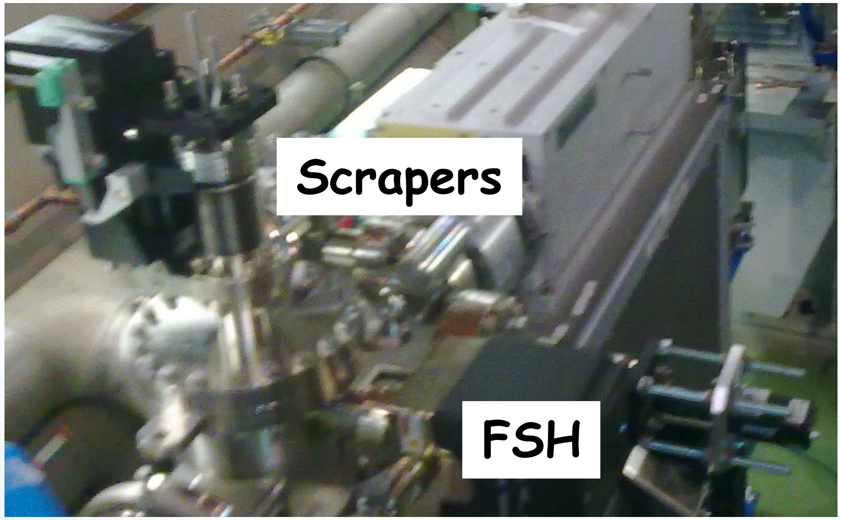


1. Di Components

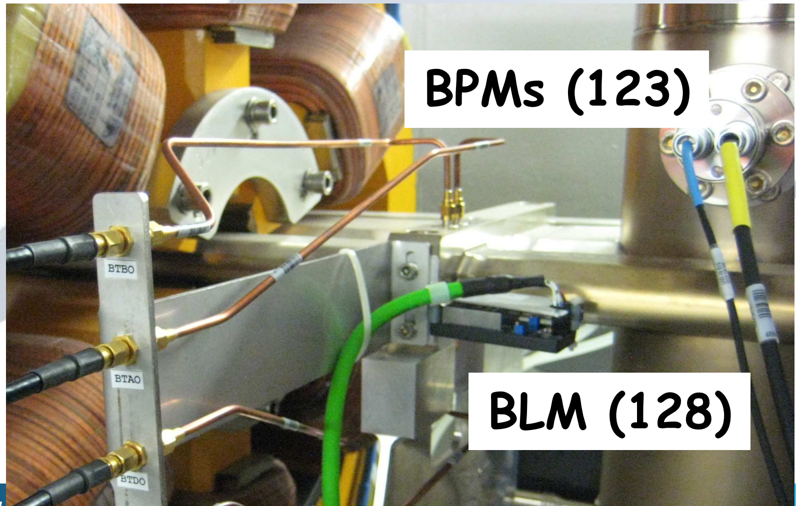
AT DIAGNOSTICS SECTION:



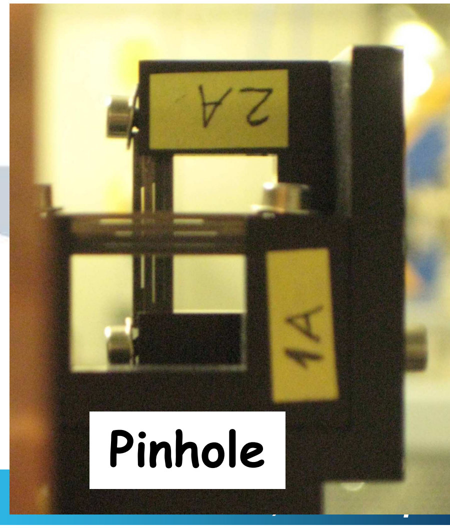
AT INJECTION STRAIGHT:



ALL AROUND THE RING:

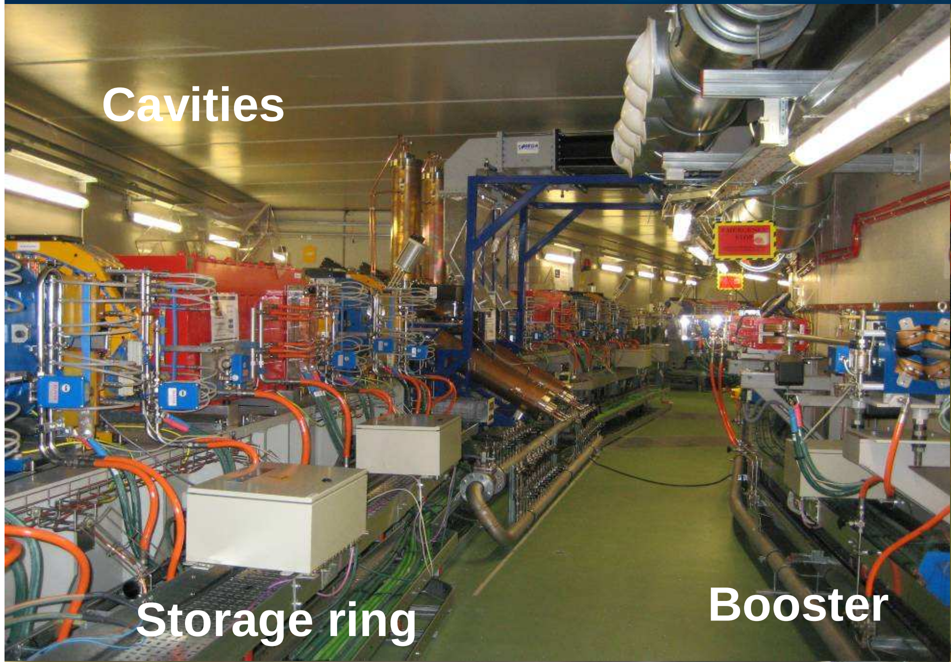


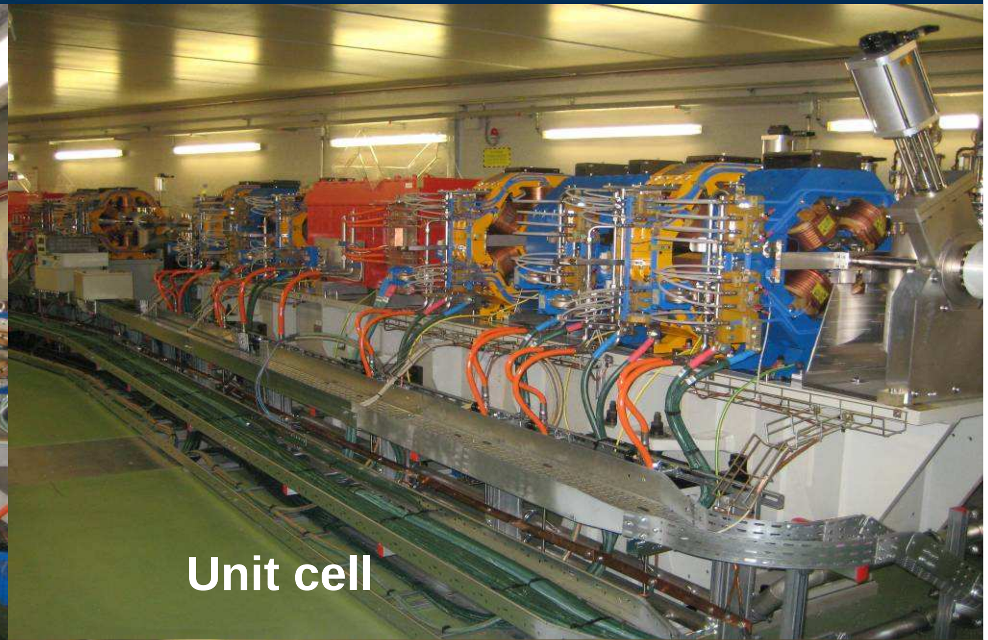
DI FRONT ENDS:



Storage Ring in the Tunnel

Accelerator Division





The commissioning of the ALBA storage ring started at Monday the 8th of March in the afternoon with the following steps:

1.) Optimization of the booster and injection to SR 8th of March
2.) The first turn was reached in the evening of the 9th of March with on axis injection (adjustment of energy)
3.) 10th of March: 20 turns with off axis injection
4.) 13th of March: 1 sec stored beam.
5.) 16th of March: first accumulated beam in ALBA (20 mA)
6.) 1st of April: stored beam of 100 mA
7.) 7th of June: stored beam 170 mA
8.) At the beginning of June the 1st phase of commissioning has been finished. (Reminder: The specifications of ALBA are to deliver a beam of 250 mA to the user)
9.) June to August: installation of SCW and 2 IVU's.
10.) 12th of September: restarting the machine again
11.) 19th to 30th September: optimization of components
12.) 3rd of October: start of 2nd phase of commissioning

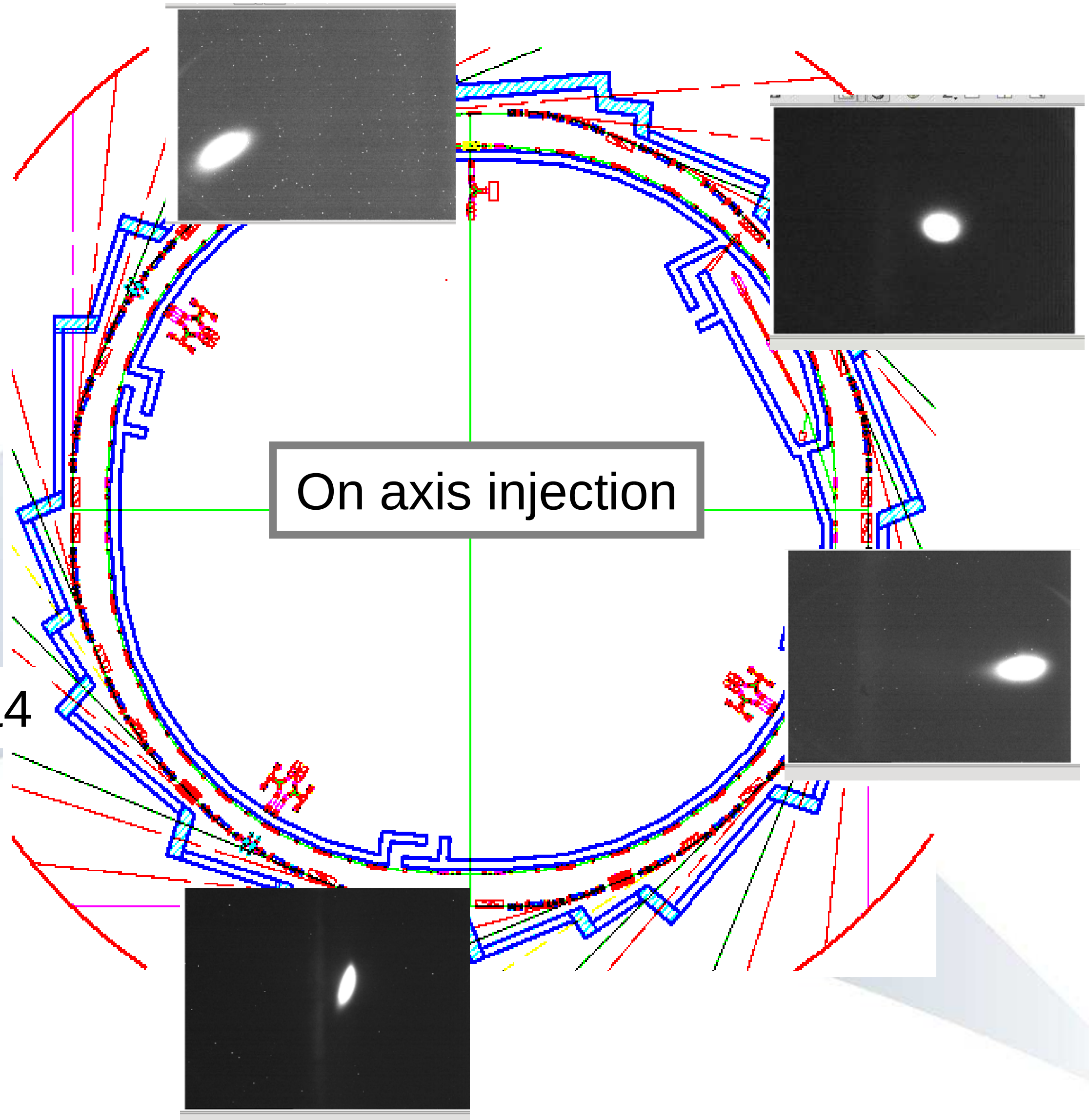
- ➢ Recabling Quads:

✓ Sectors 1&2

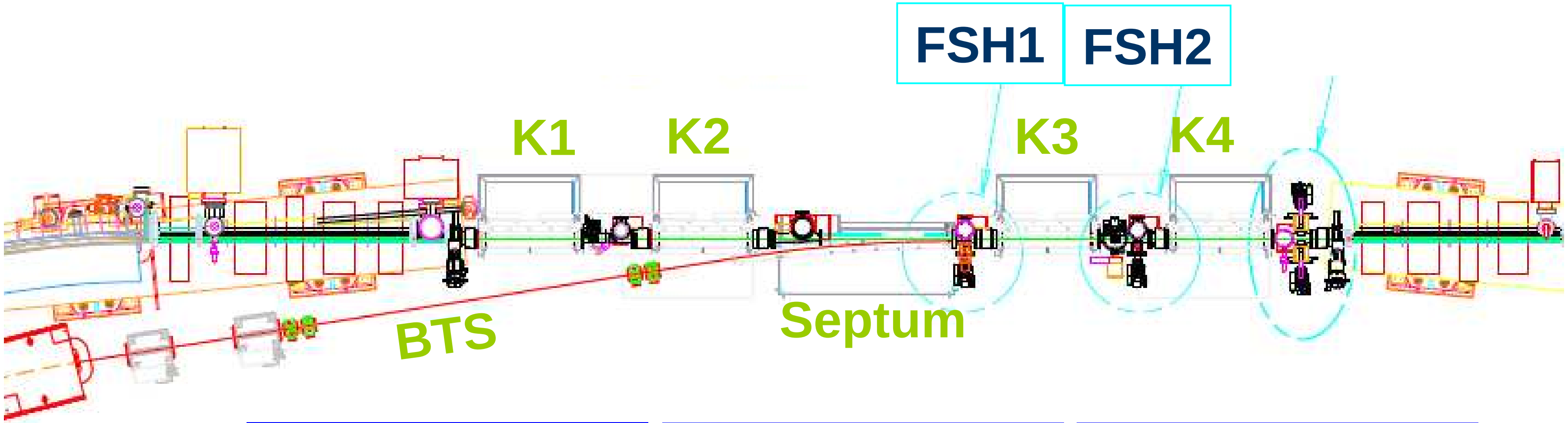
✓ Quadrant 1

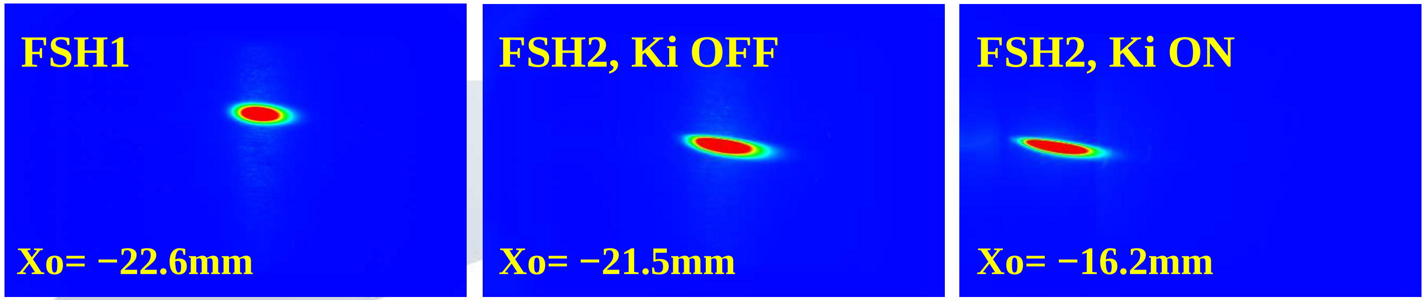
✓ Quadrant 2

✓ Quadrants 3&4



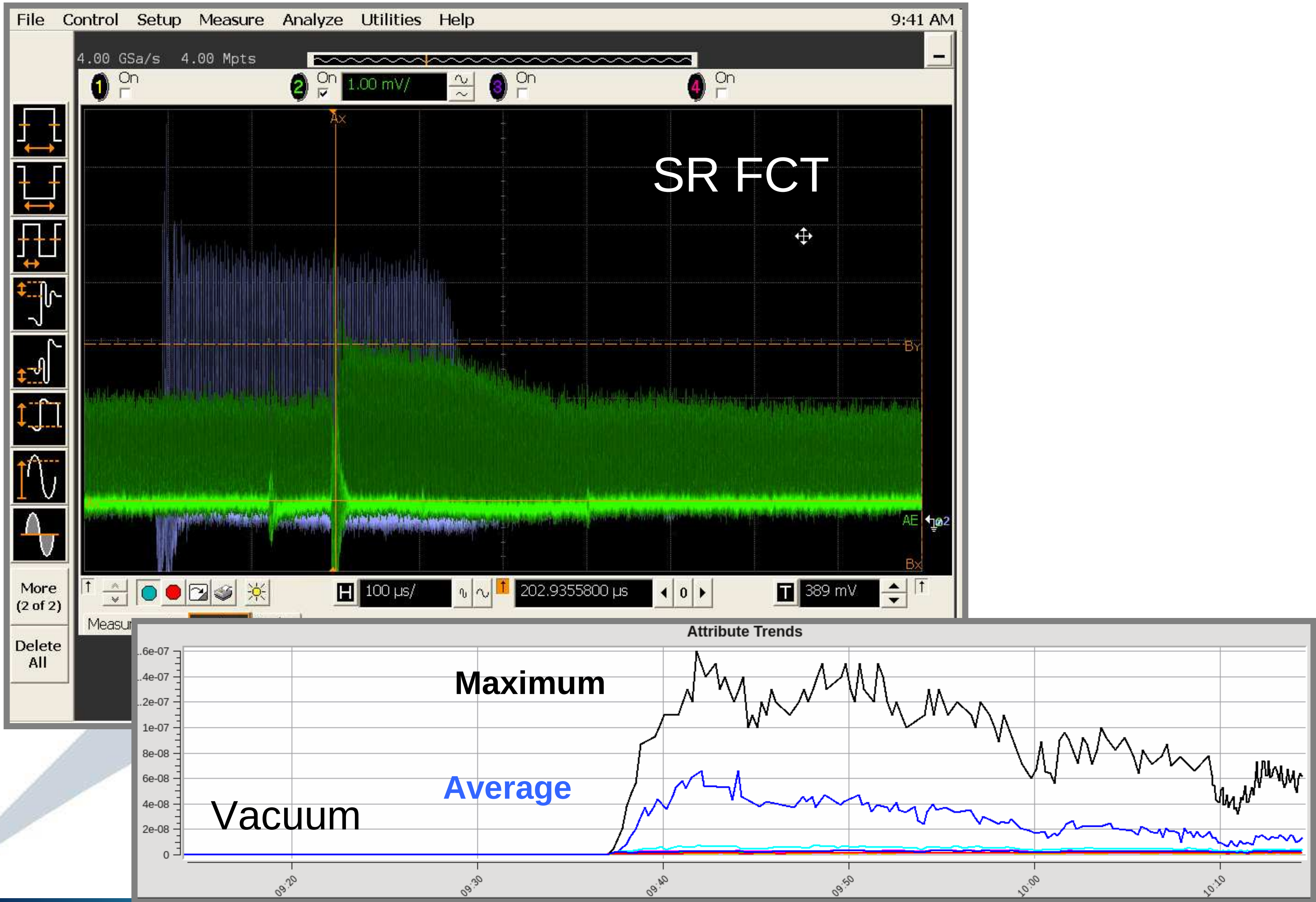
19h35: 1st turn !



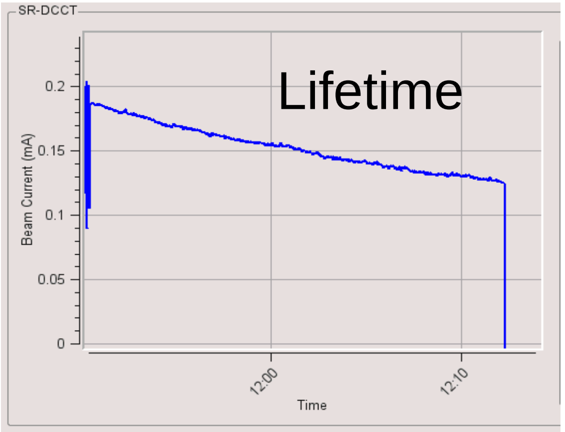


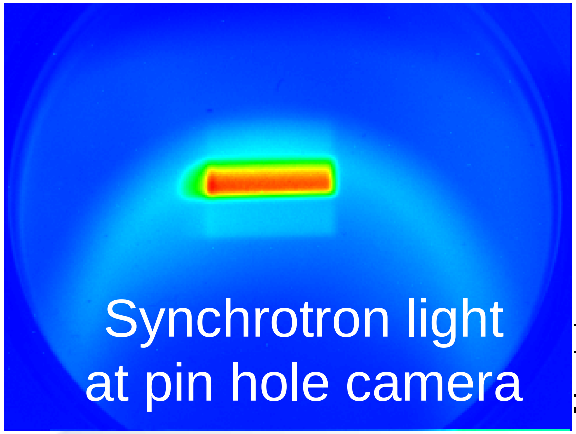
1.) On axis injection: Adjustment of energy
2.) Off axis injection: Accumulation of beam

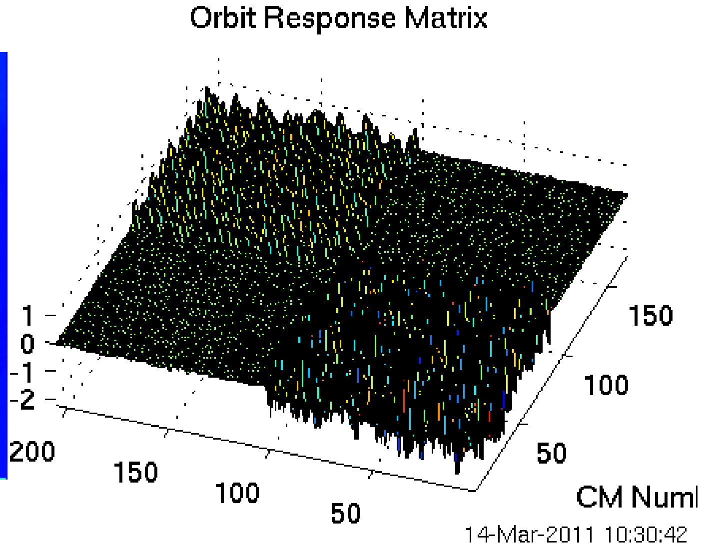
13th March, 9h38: 1 second stored beam

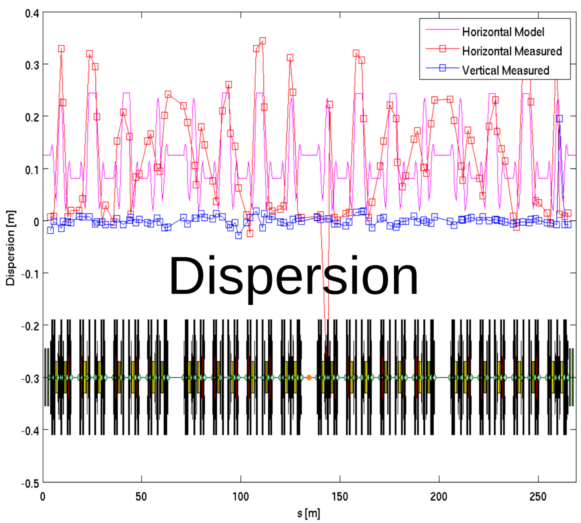


13 -14 March: Firsts measurements

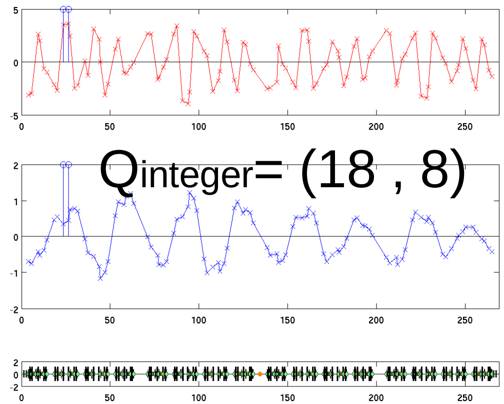




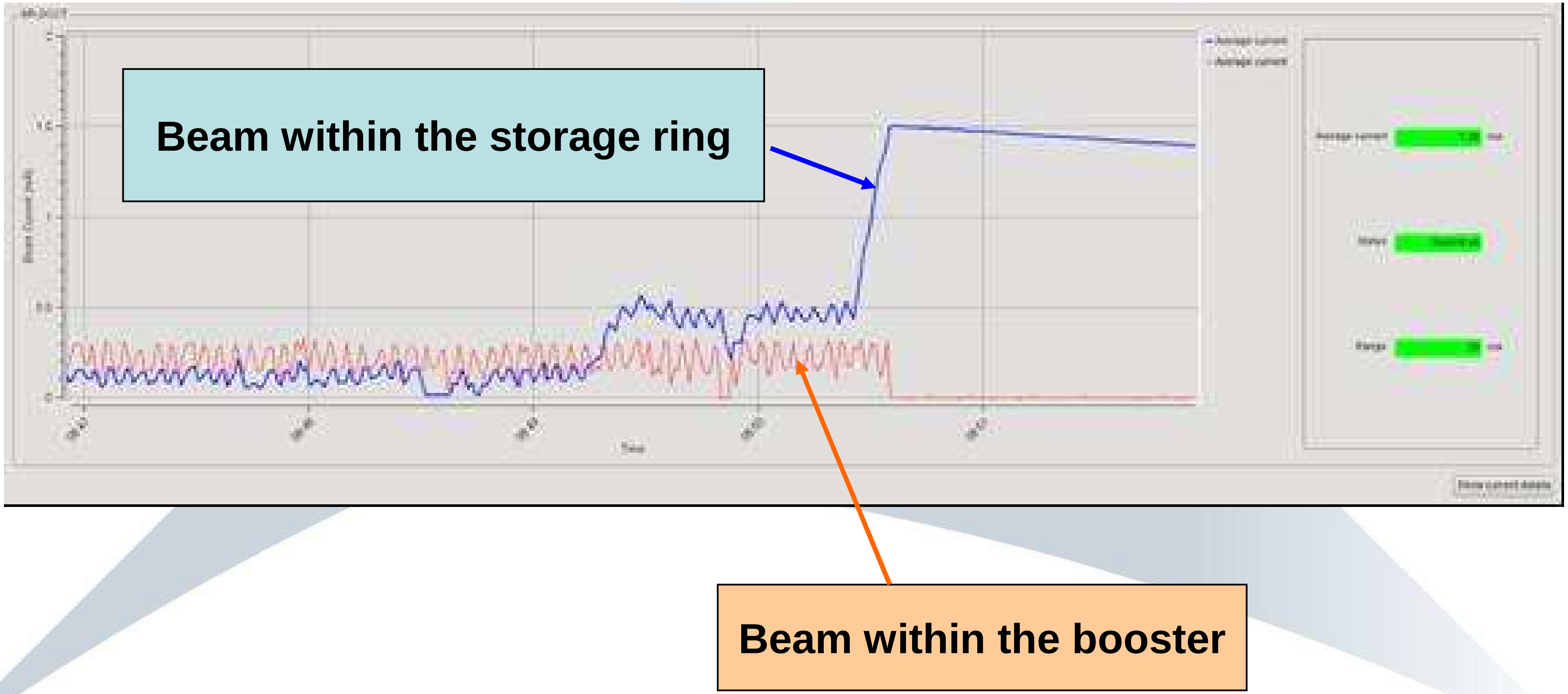




Energy = 2.97 GeV

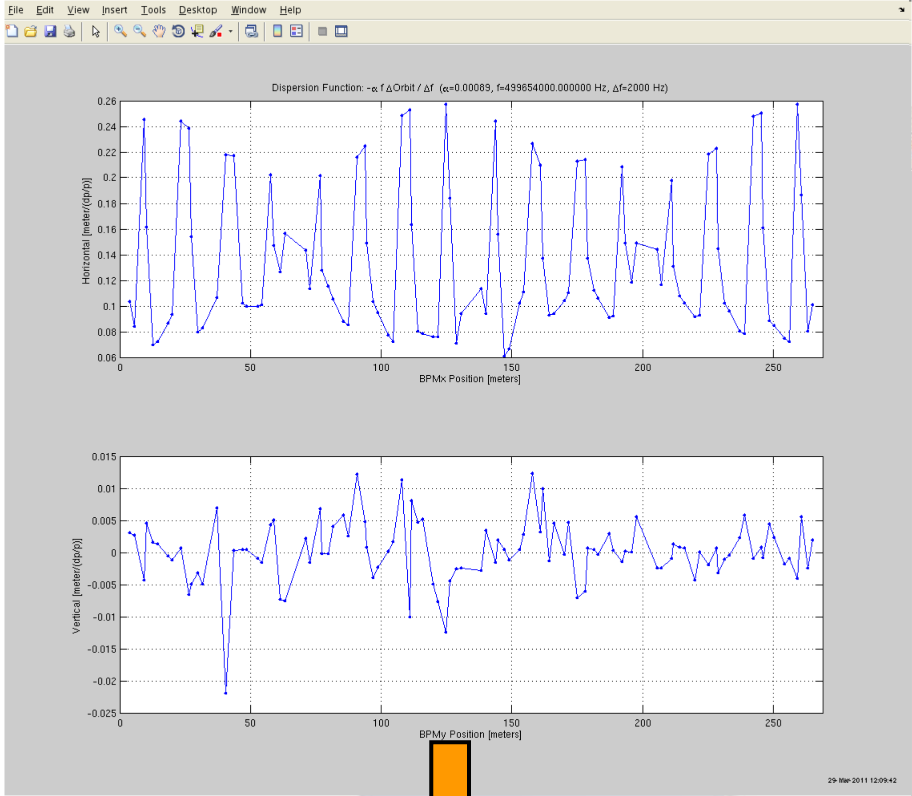


**16th of March 2011:
a historical day of the ALBA – project:
the first accumulated beam at ALBA.**

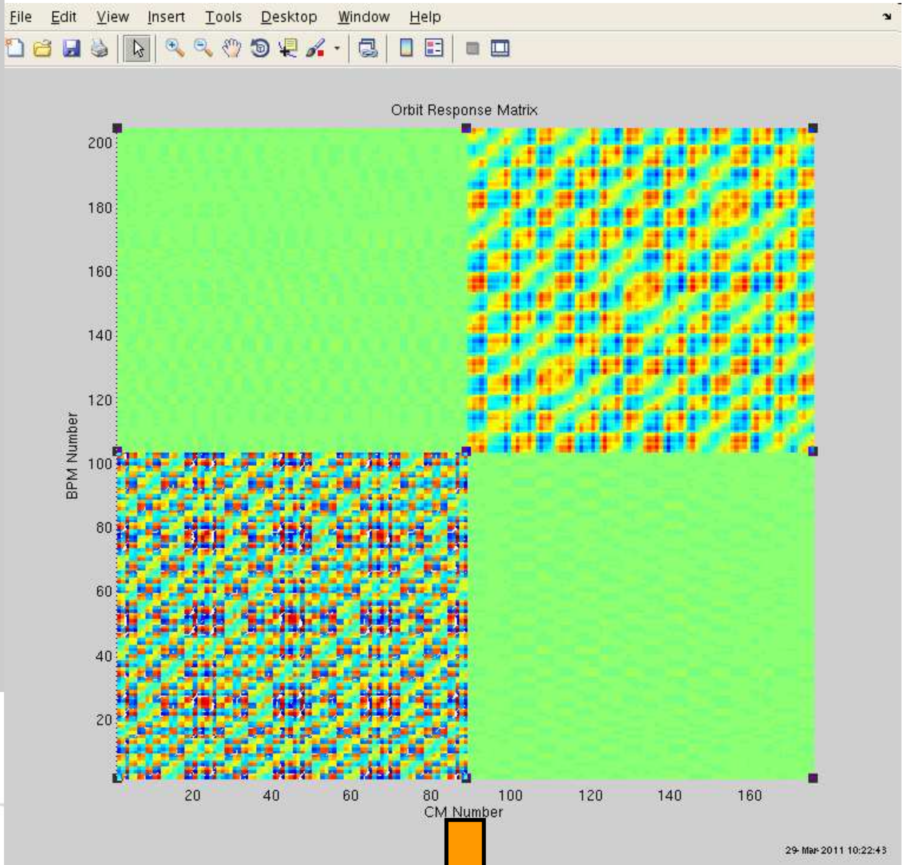


1st Accumulated Beam at ALBA

LOCO-Measurements



Measurements 17th March

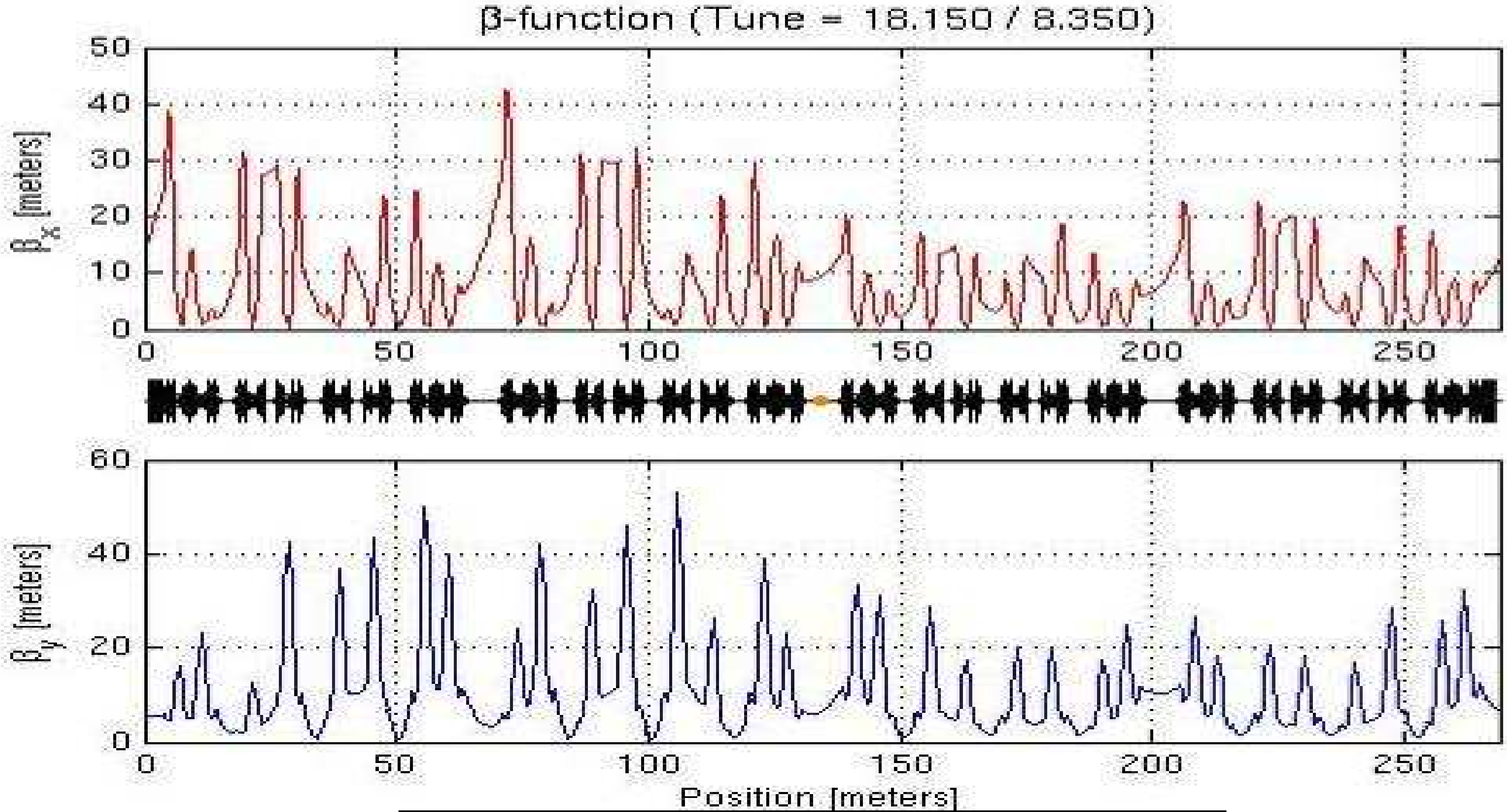


Asymmetry in the η-Function: ΔQ/ΔI ► two quadrupoles in S8 are swapped

Good result: cabling of BPM's and correctors are okay

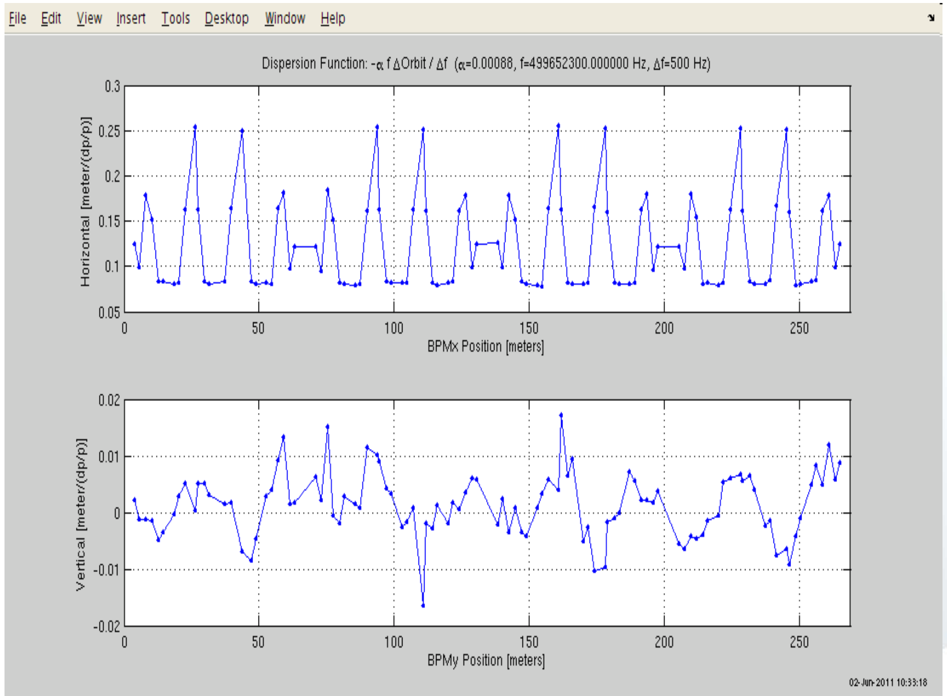
Beta-Functions of the SR

First measurements of beta function with LOCO: there is a asymmetry in the machine

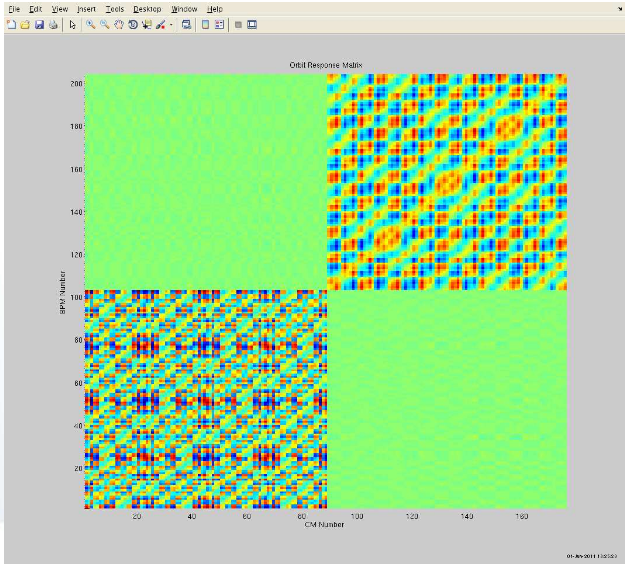


Result: QF1 and QD1 in sector 8 are swapped

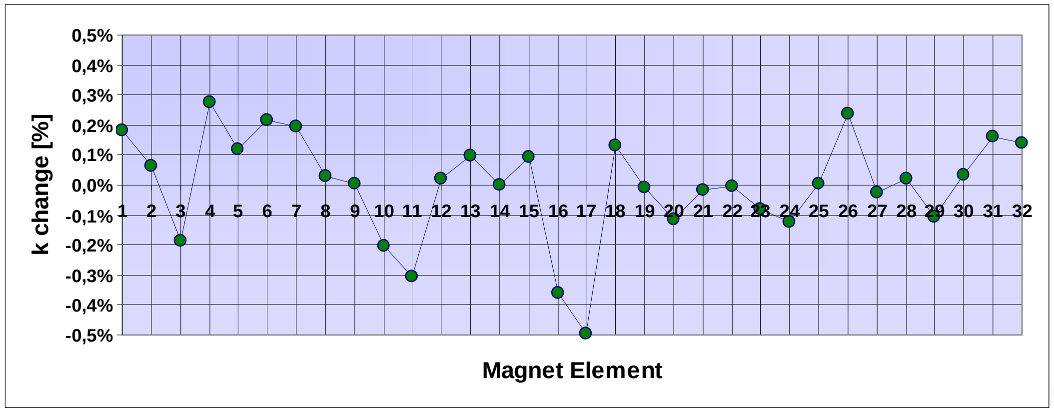
LOCO - Measurements



Measurements of June

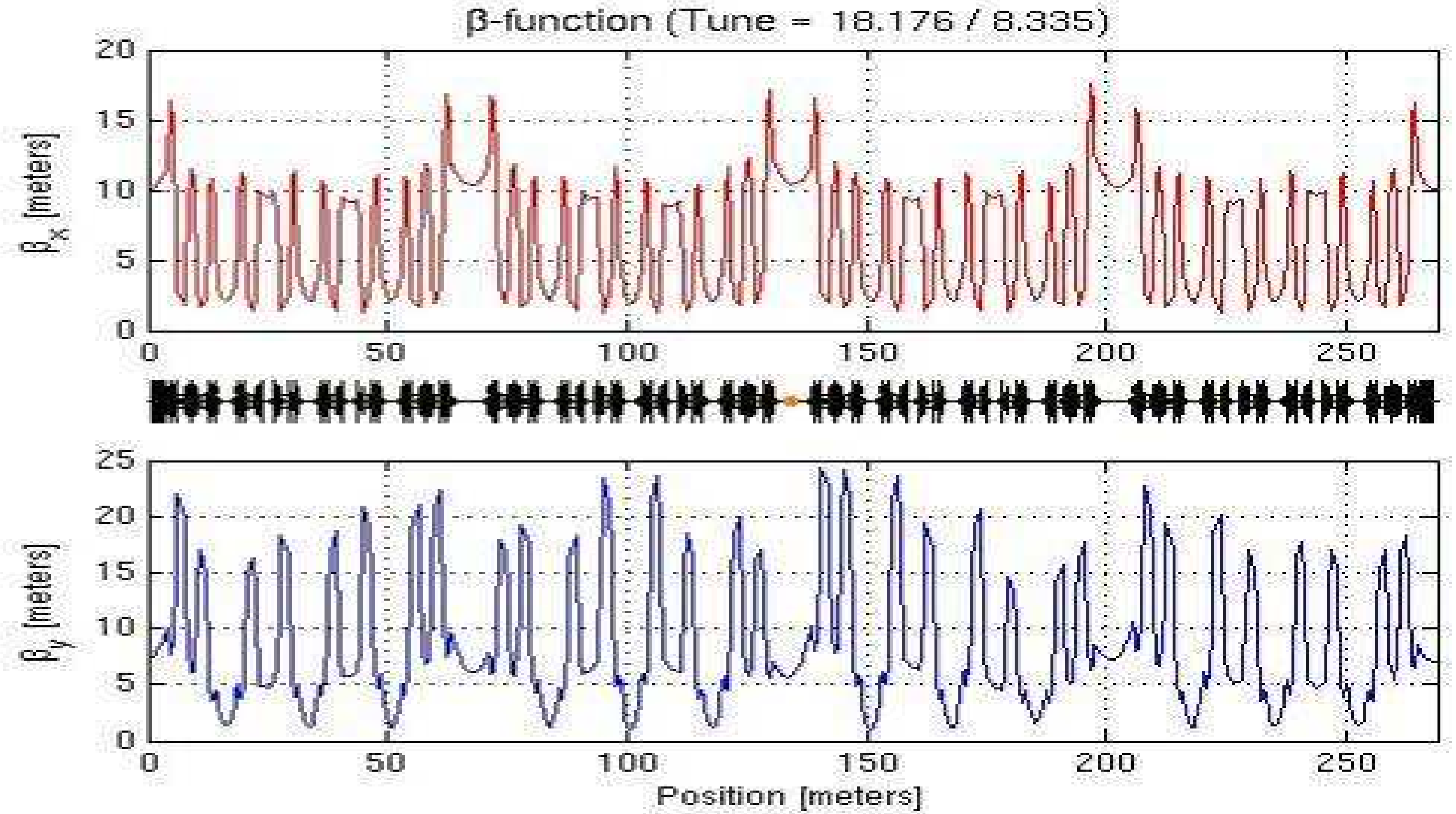


After re-cabling and applying LOCO correction



Beta-Functions of the SR

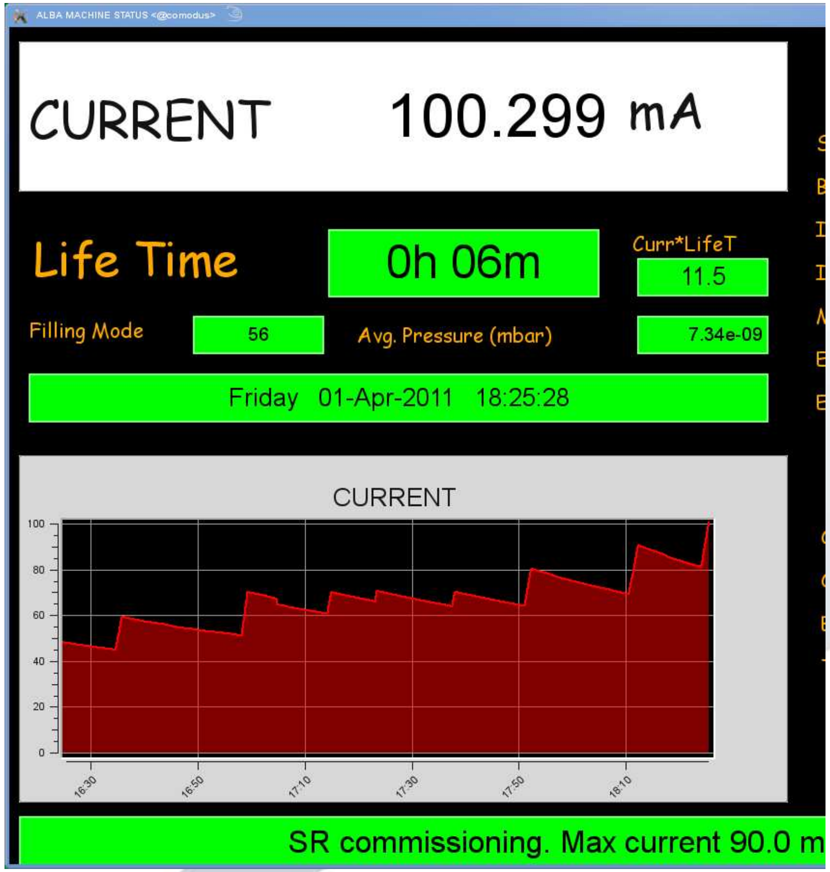
Beta functions reconstructed by LOCO after recabling QF1 and QD1



Result: It looks much better, but there is still an asymmetry in the machine (vertical)

Evening 1st April 2011

Once the MPS was operational…



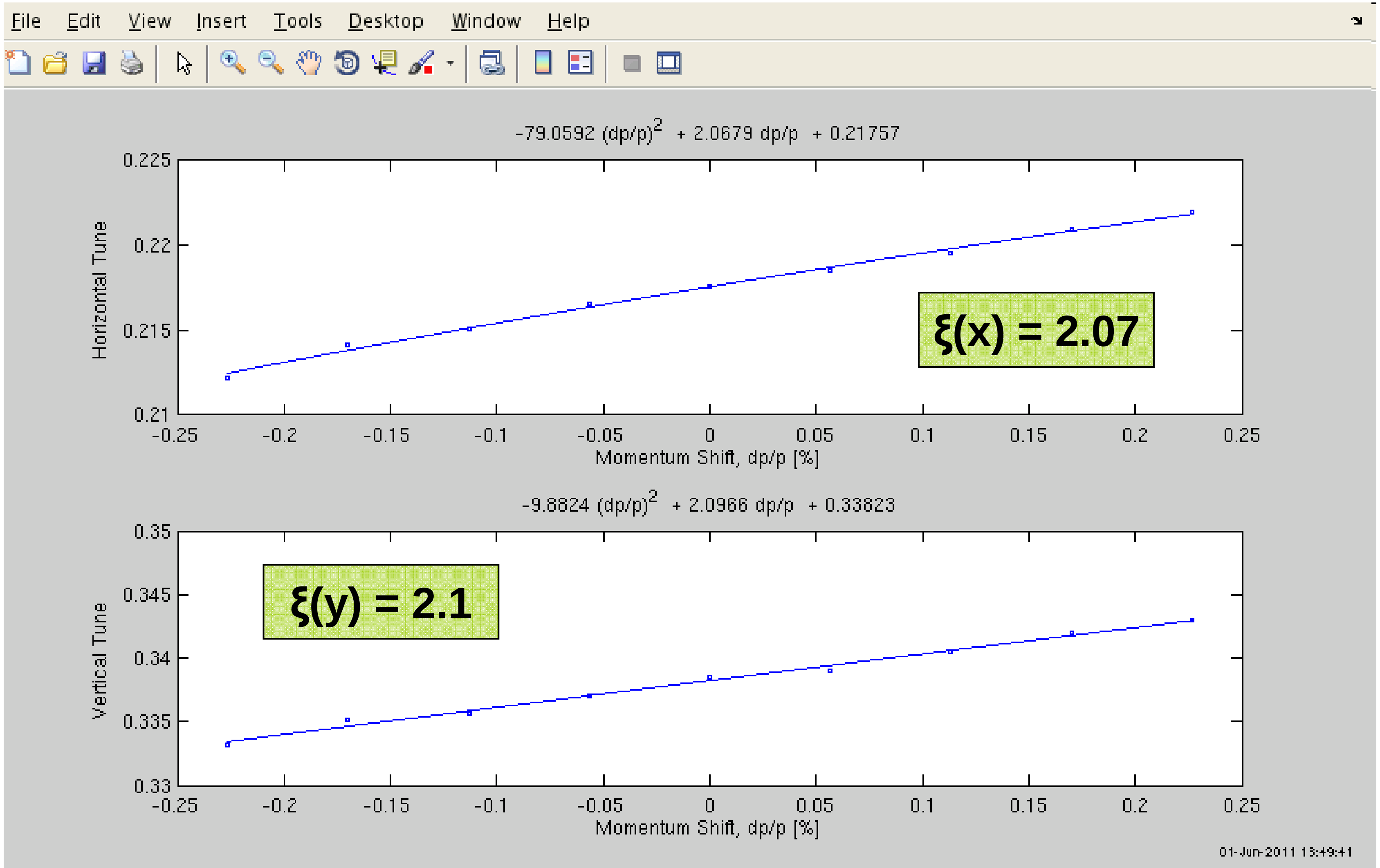
Measurements

- Tune
- Chromaticity
- Beam Based Alignment
- Orbit correction, including frequency adjustment
- LOCO measurements:

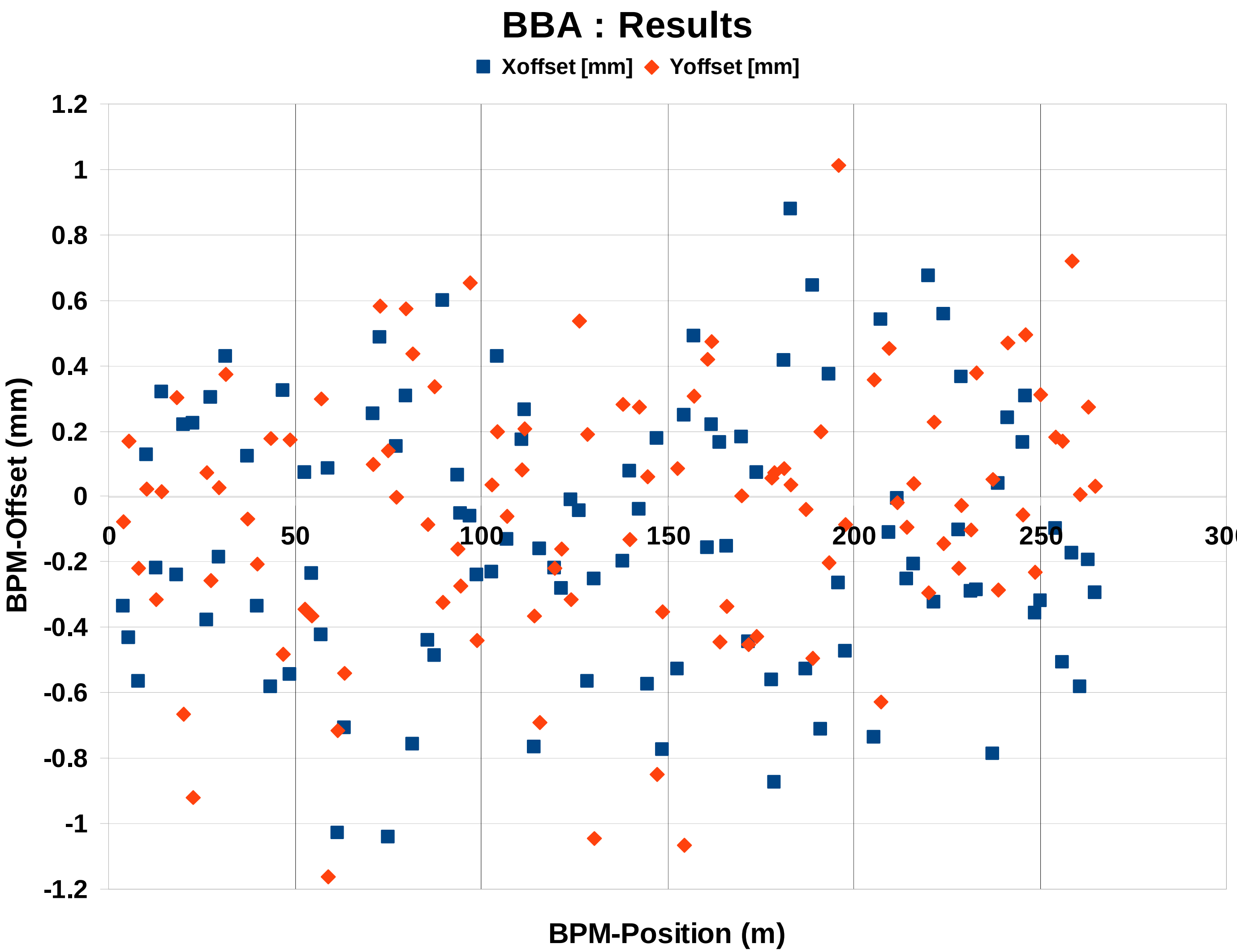
  Beta functions, dispersion and beating correction
- Beam size
- Bunch length
- Vacuum performance
- Closing IDs
- Slow orbit correction system
- Others

(Most of these measurements were done with 10~20 mA)

Chromaticity's



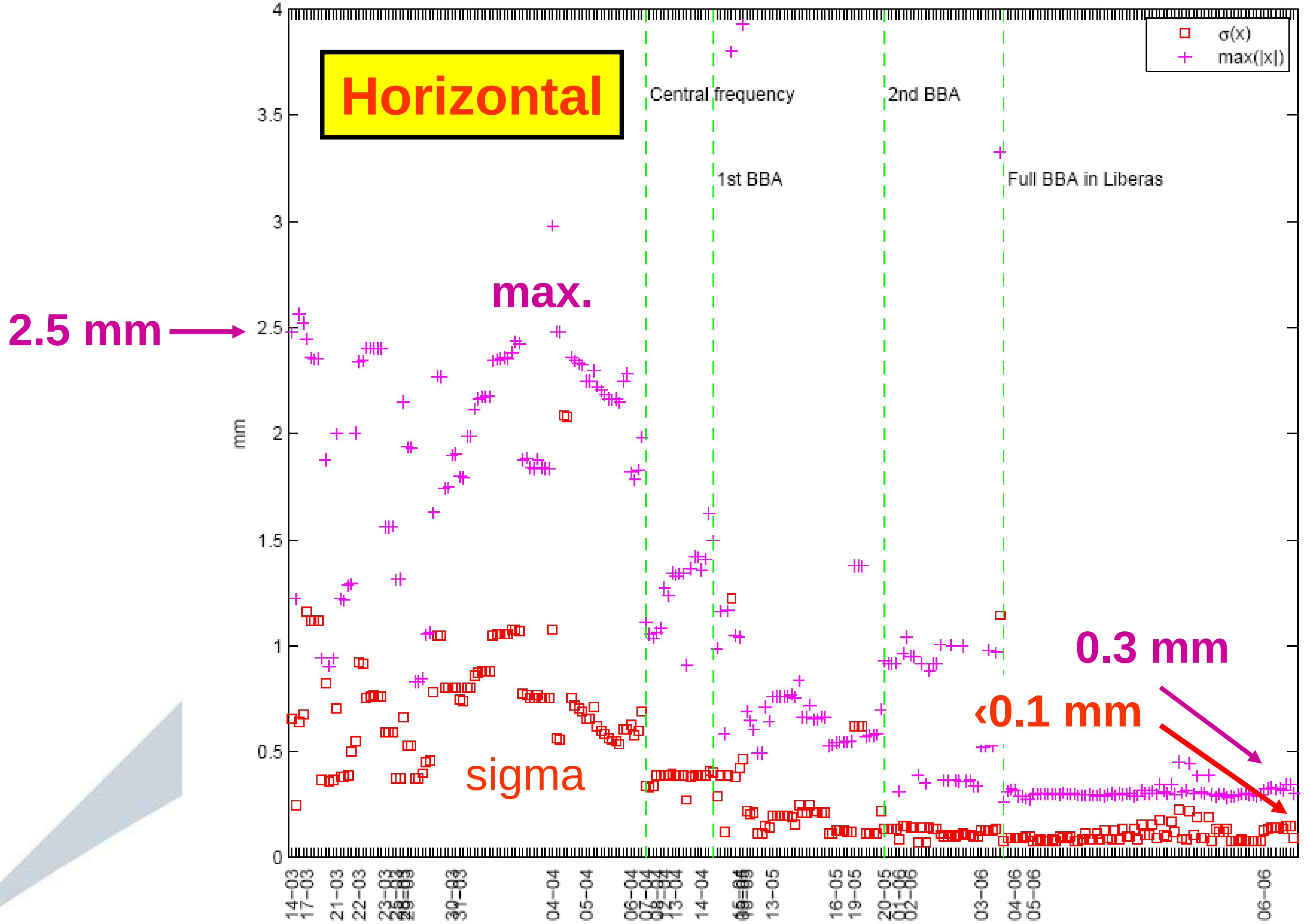
Normally working with (+2 , +2)



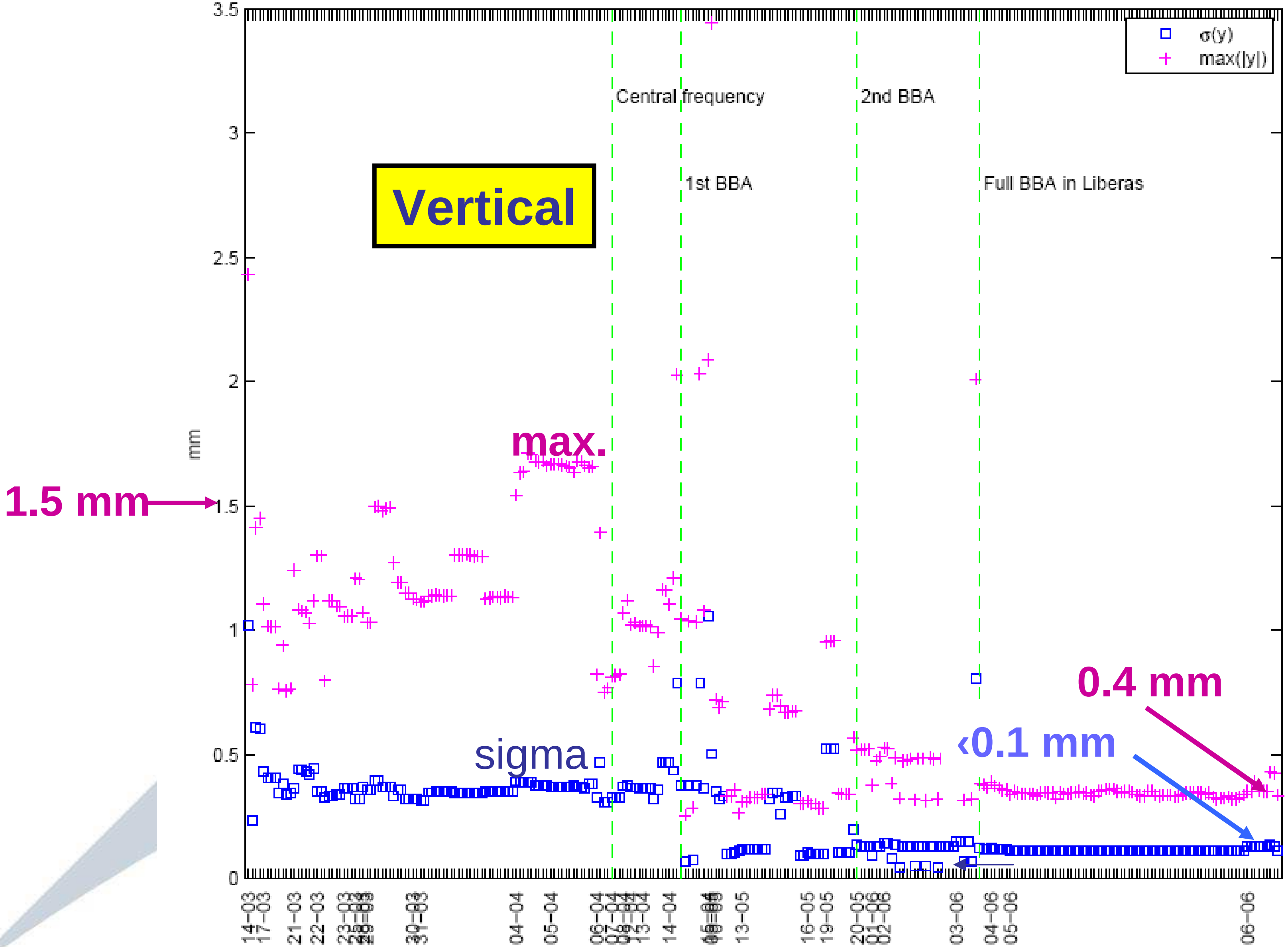
Horizontal offsets:
+1.0 mm to -1.1 mm

Vertical offsets:
+0.9 mm to -1.1 mm

Orbit Correction, evolution



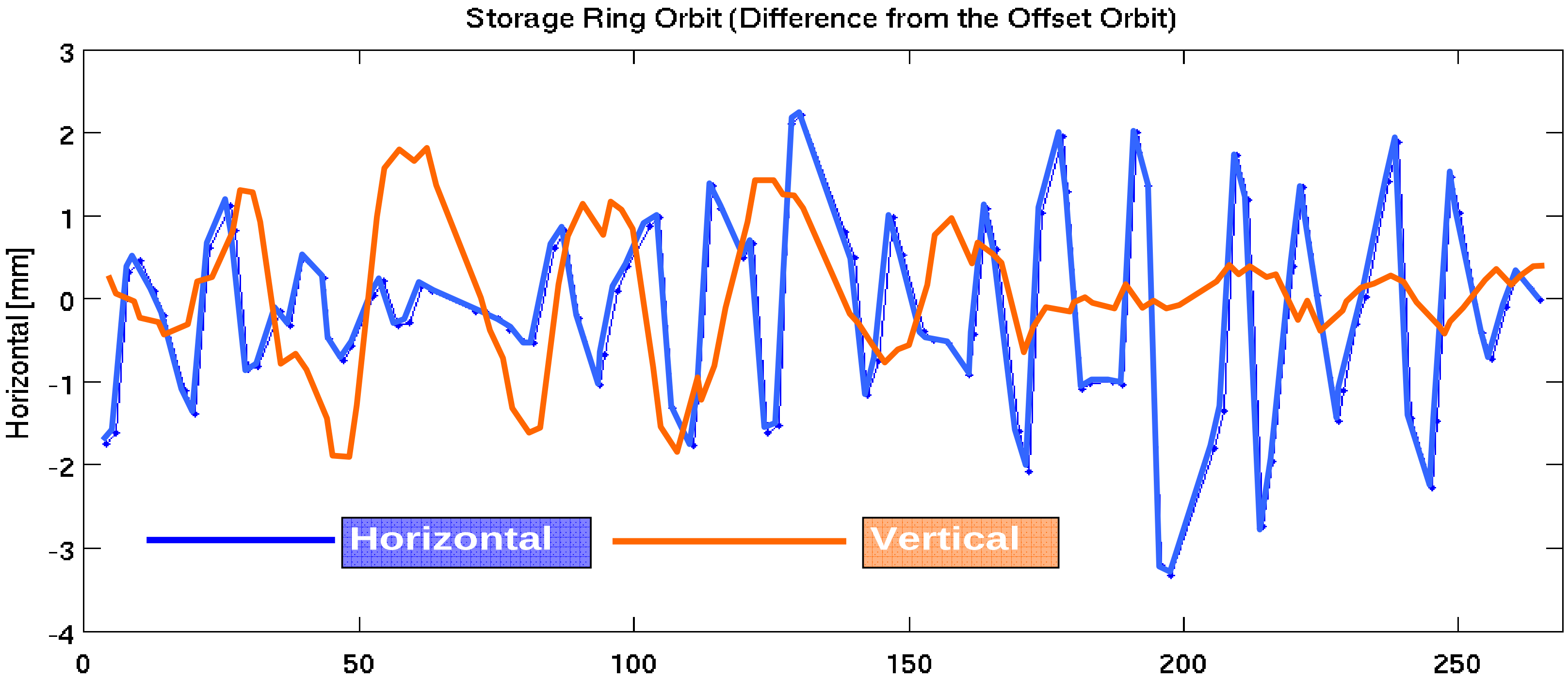
Orbit Correction, evolution



Orbit Correction

Raw orbit without correctors

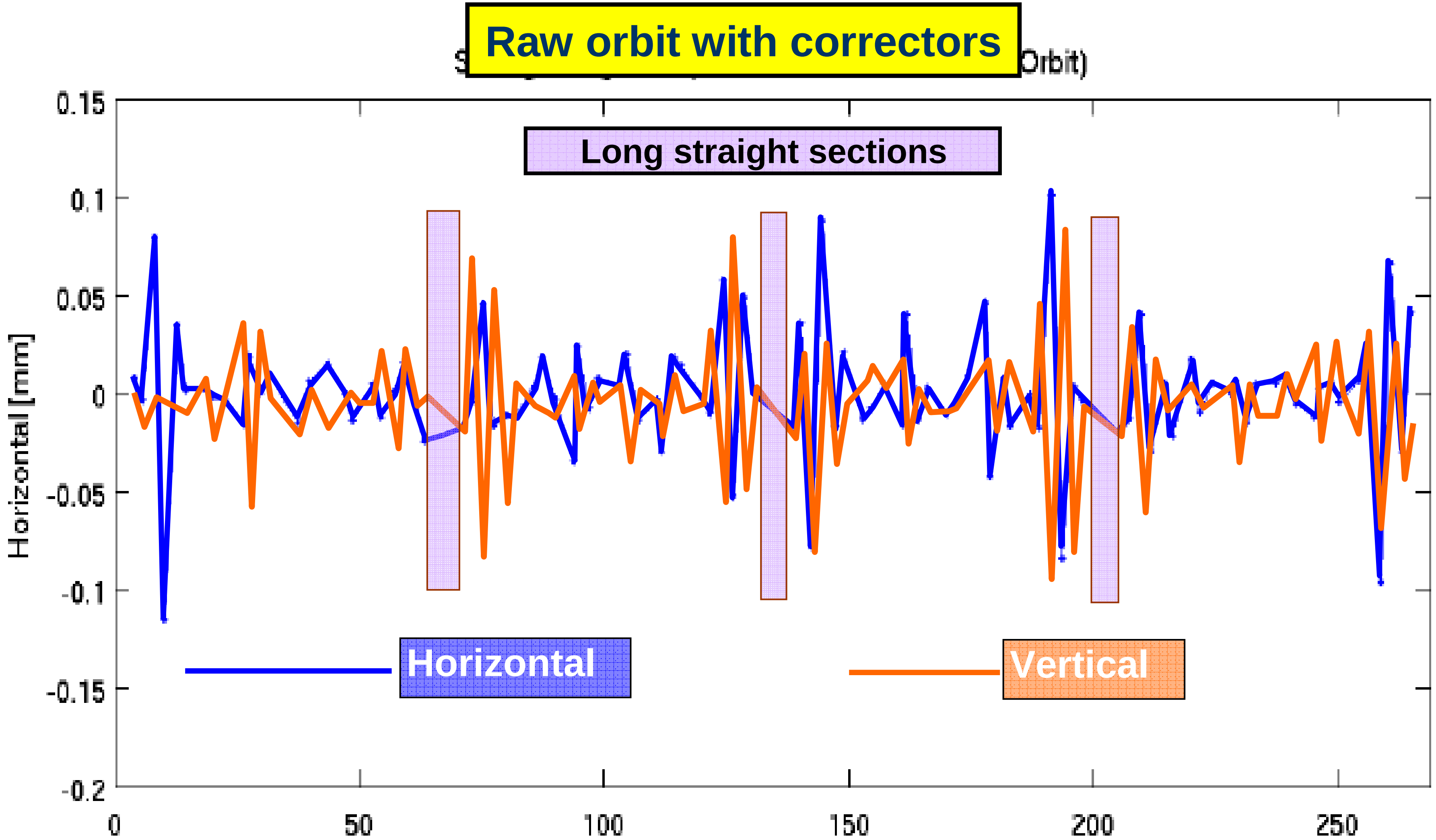
Offsets of BBA included and RF frecuency adjusted



Horizontal orbit < 3mm
Vertical orbit < 2 mm

Good alignment

Orbit Correction: Reproducibility

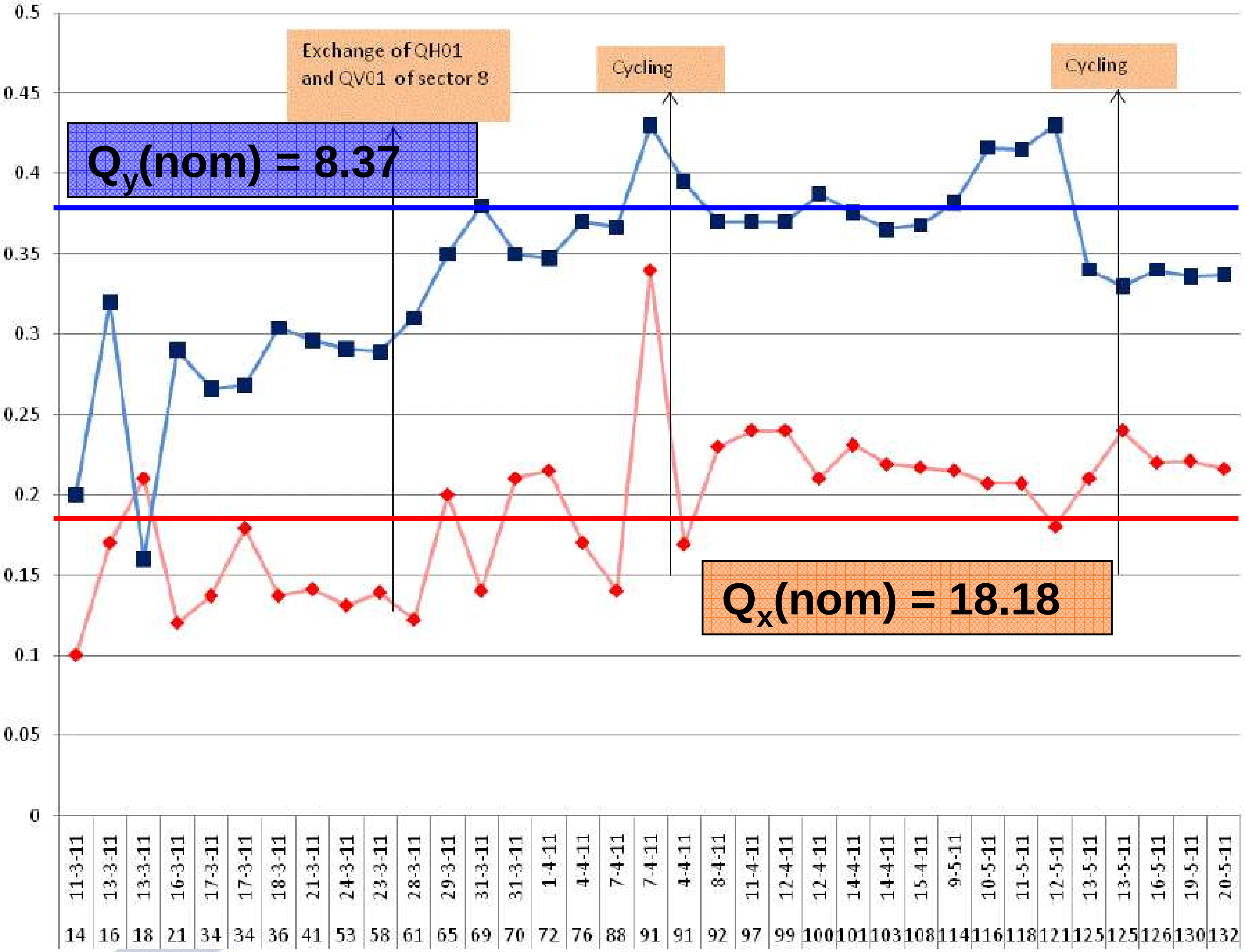


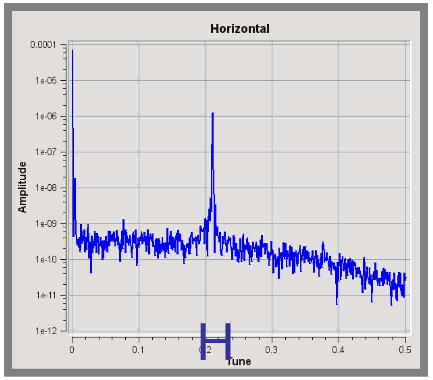
Horizontal rms error 32 um

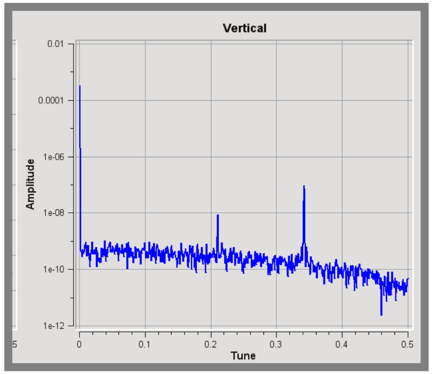
Vertical rms error 29 um

to reference orbit

Tune during the commissioning:





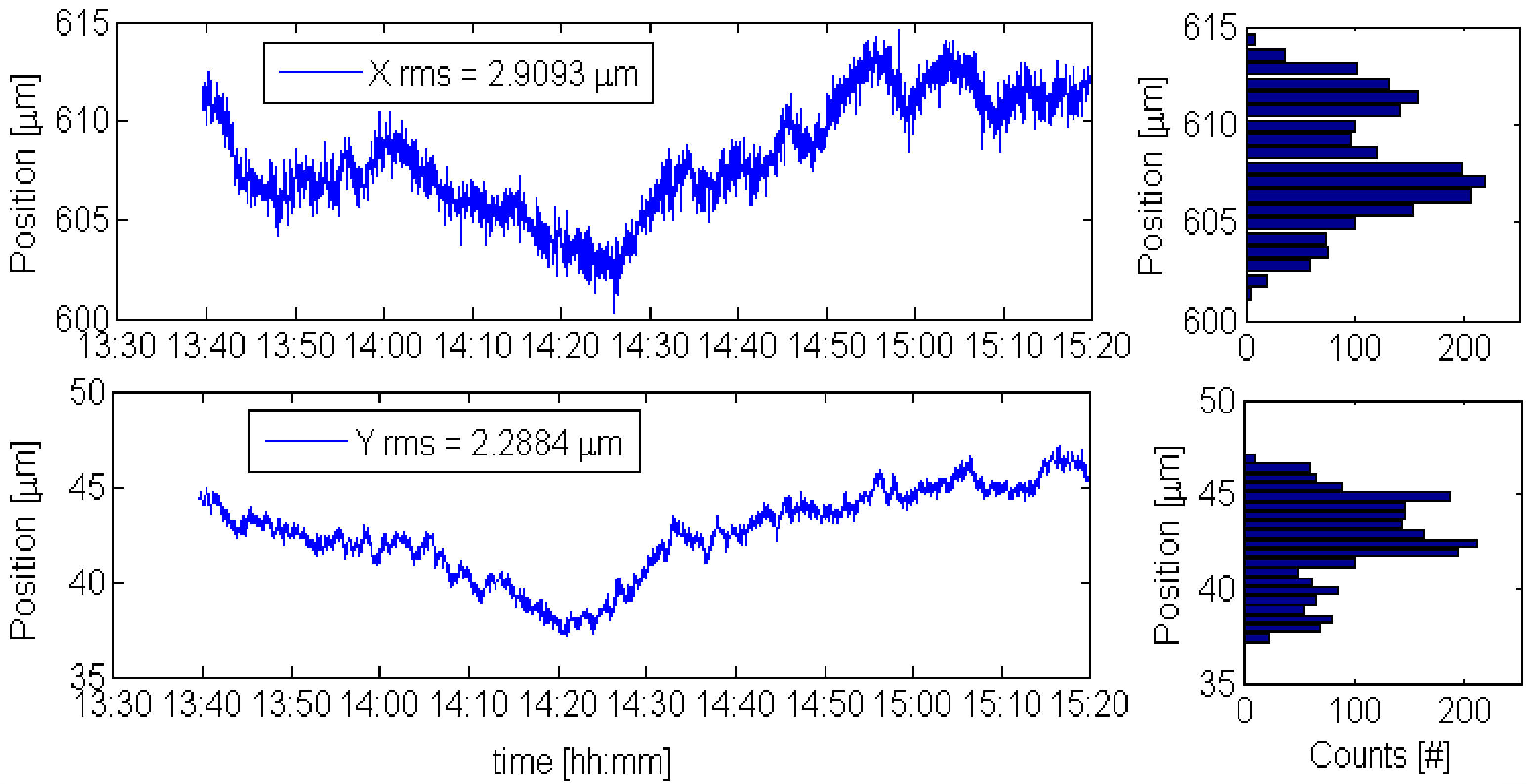


V

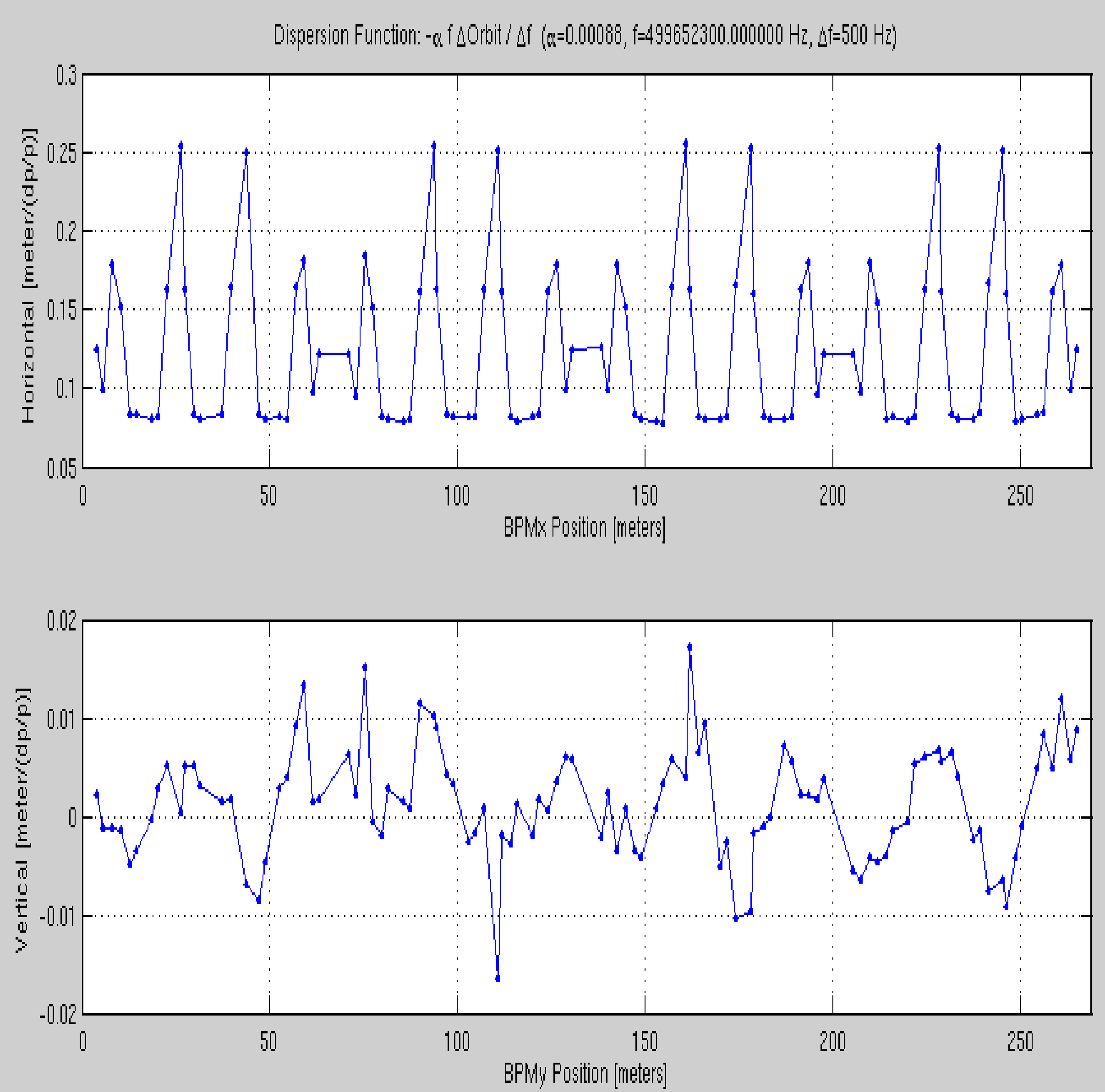
Normally working with chromaticity: +2 , +2

- 7 or 8 BPM/cell (120 BPMs): orbit control and interlock system
- Low-loss phase matched (<10deg) RF cables of wide variety of lengths [15m – 45m]

Example: raw position meas during 40min @20mA



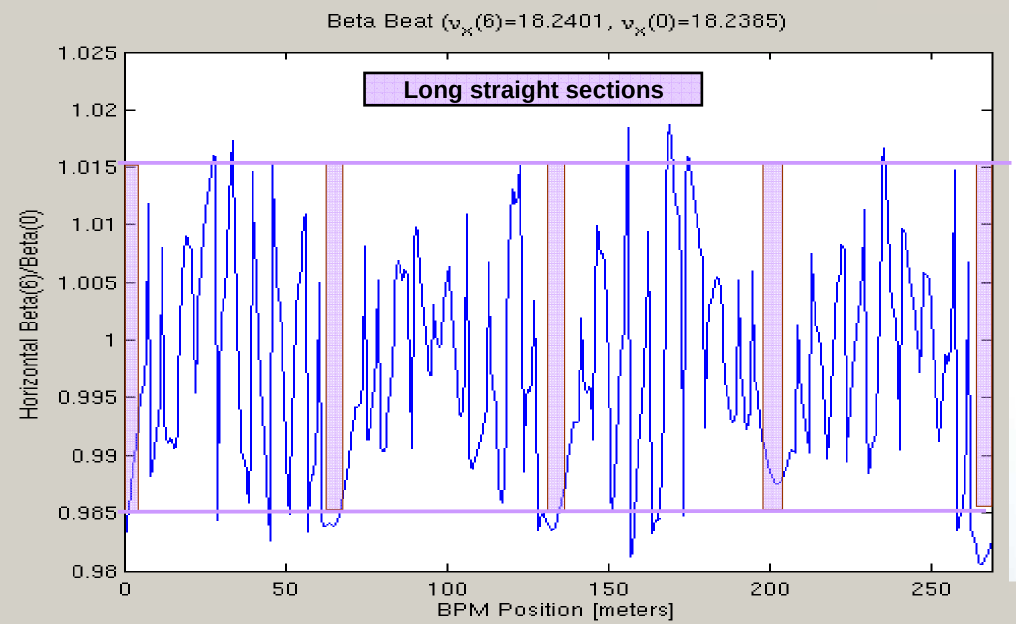
Final LOCO - Measurements



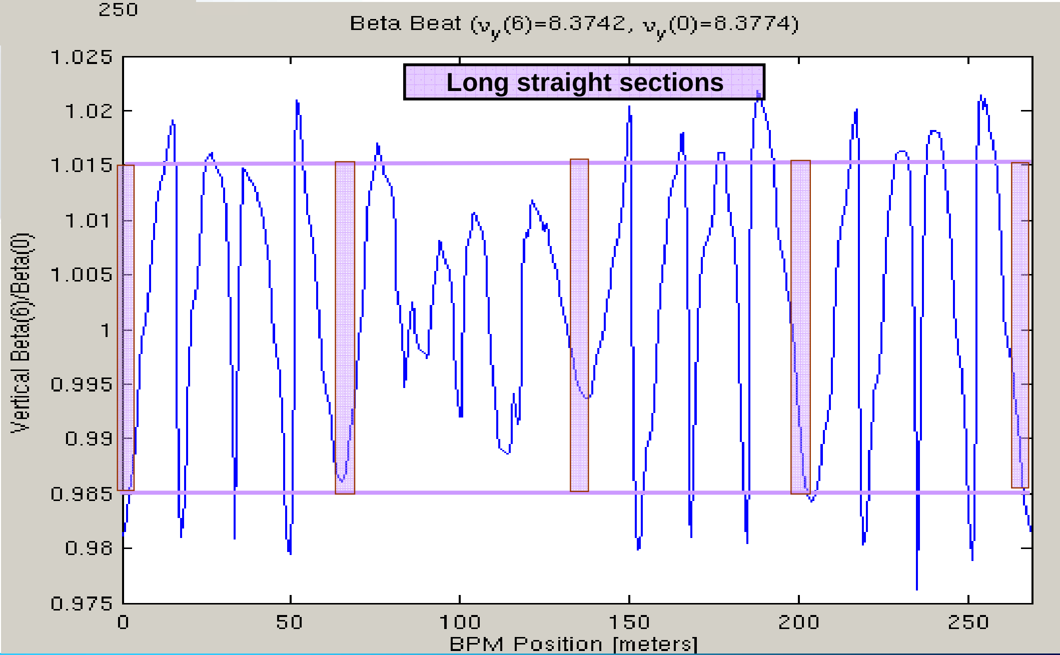
Horizontal Dispersion: The deviations to the model are +/- 5 mm. Good agreement.

Vertical Dispersion: +/- 15 mm the vertical dispersion is given by the cross talk of the BPM's. With the introduction to LOCO, it could be decreased to 1 mm

LOCO - Results

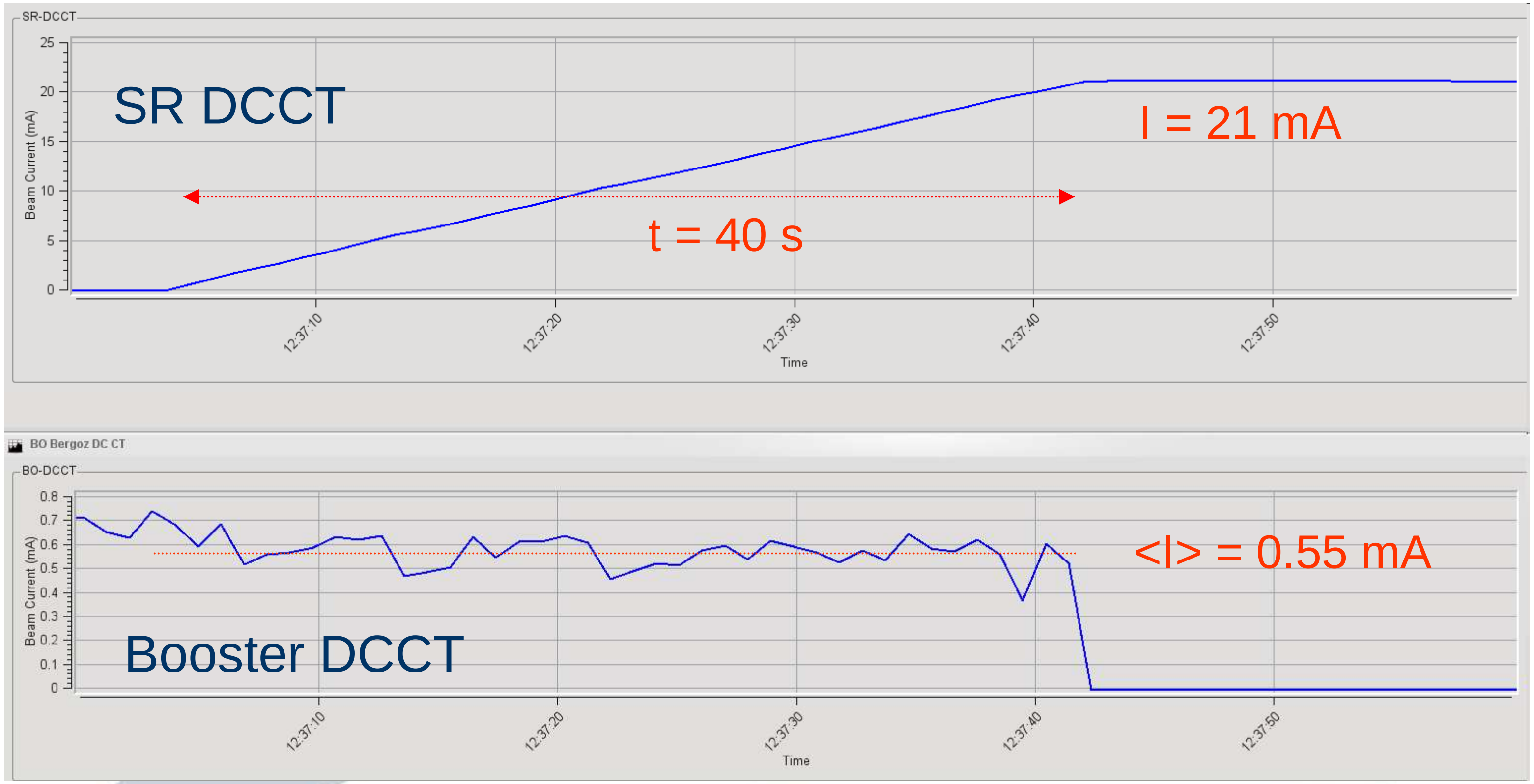


The maximum differences after the LOCO fitting are +/- 2%



In the vertical direction there are 32 peaks and we have 32 bendings

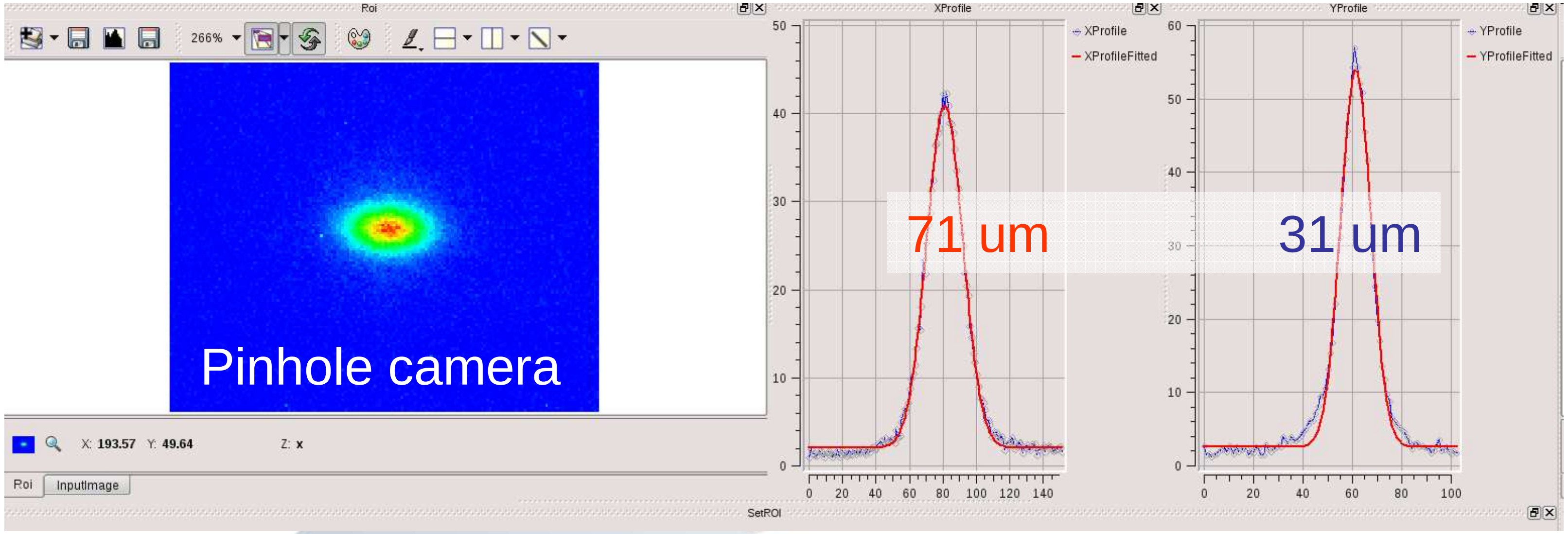
Injection Efficiency



Injection efficiency ~ 95%

Beam Size

And…



Quite ok with model:
Emittance = 4.5 nmrad
Coupling = 0.4 %

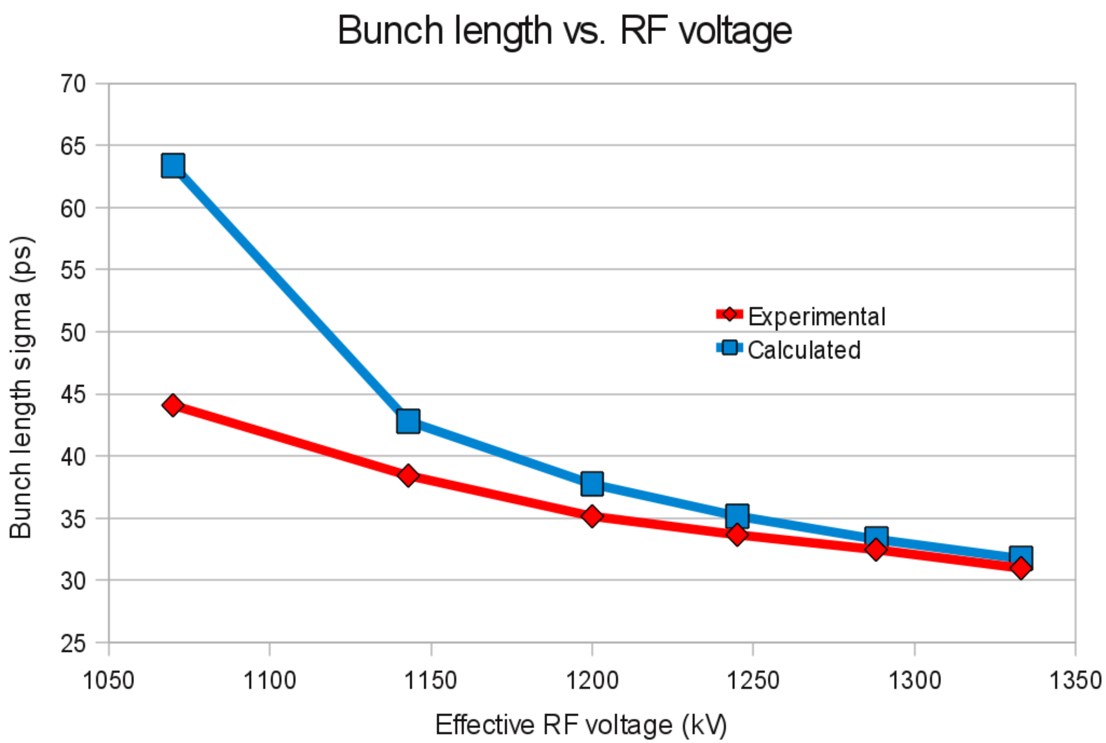
Emittance X = 6.07 nmrad
Emittance Y = 0.03 nmrad
Coupling = 0.5%

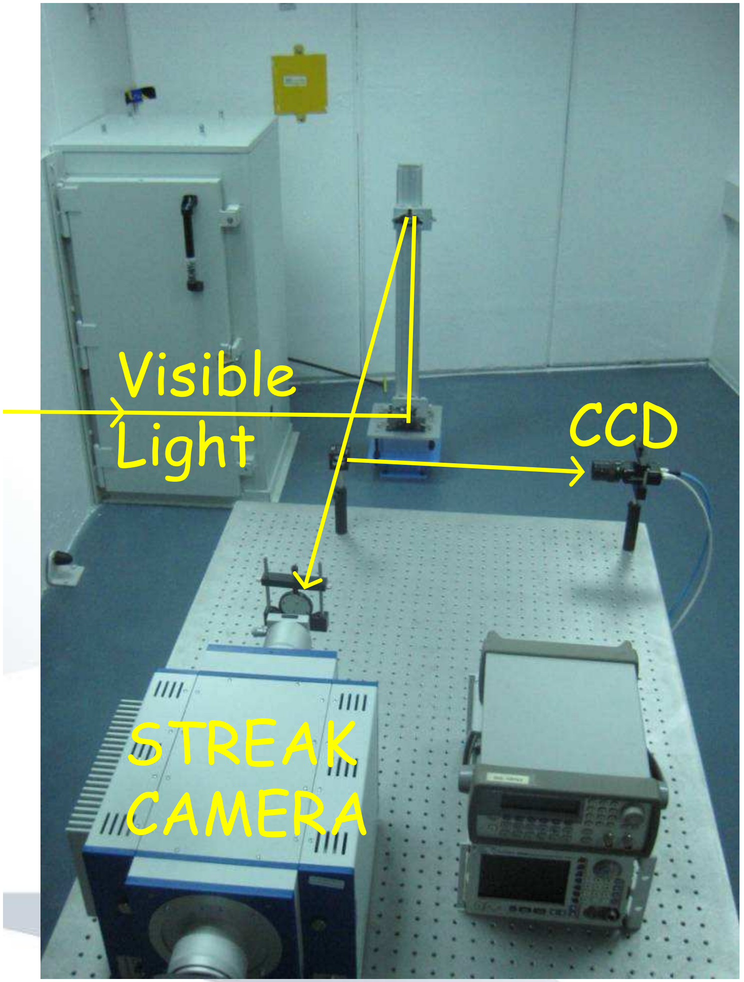
Apple II EU62 , EU71 and MPW are installed

Streak Camera

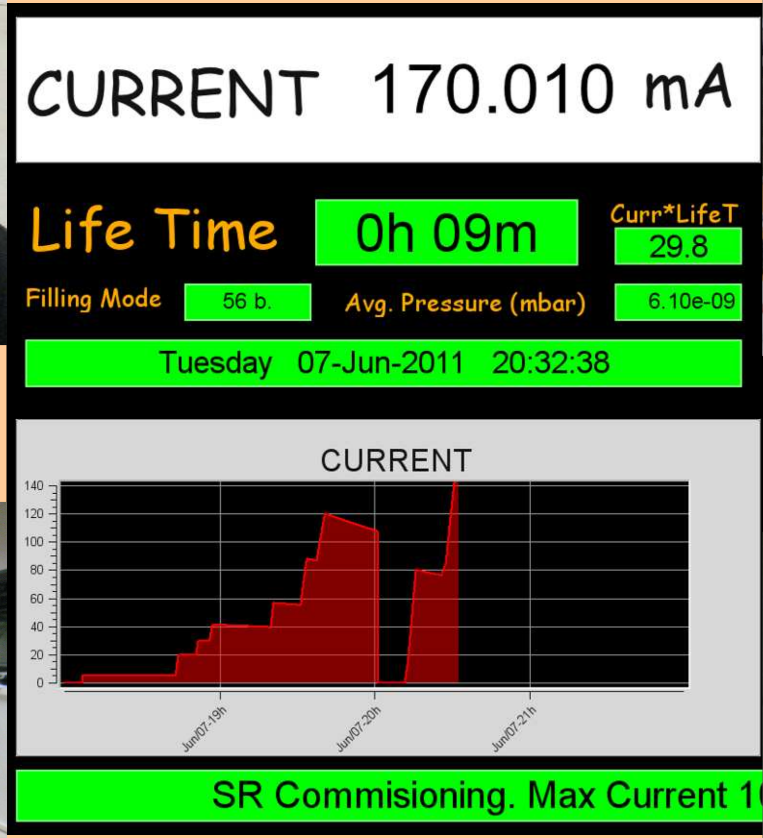
• Visible Radiation from a dipole is extracted using a mirror
•Mirror position (in-vacuum) controlled with thermocouples

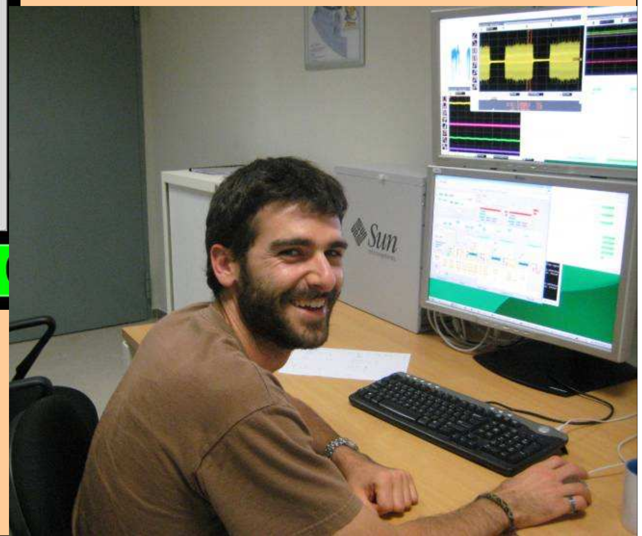
Example: Bunch Length Measurement



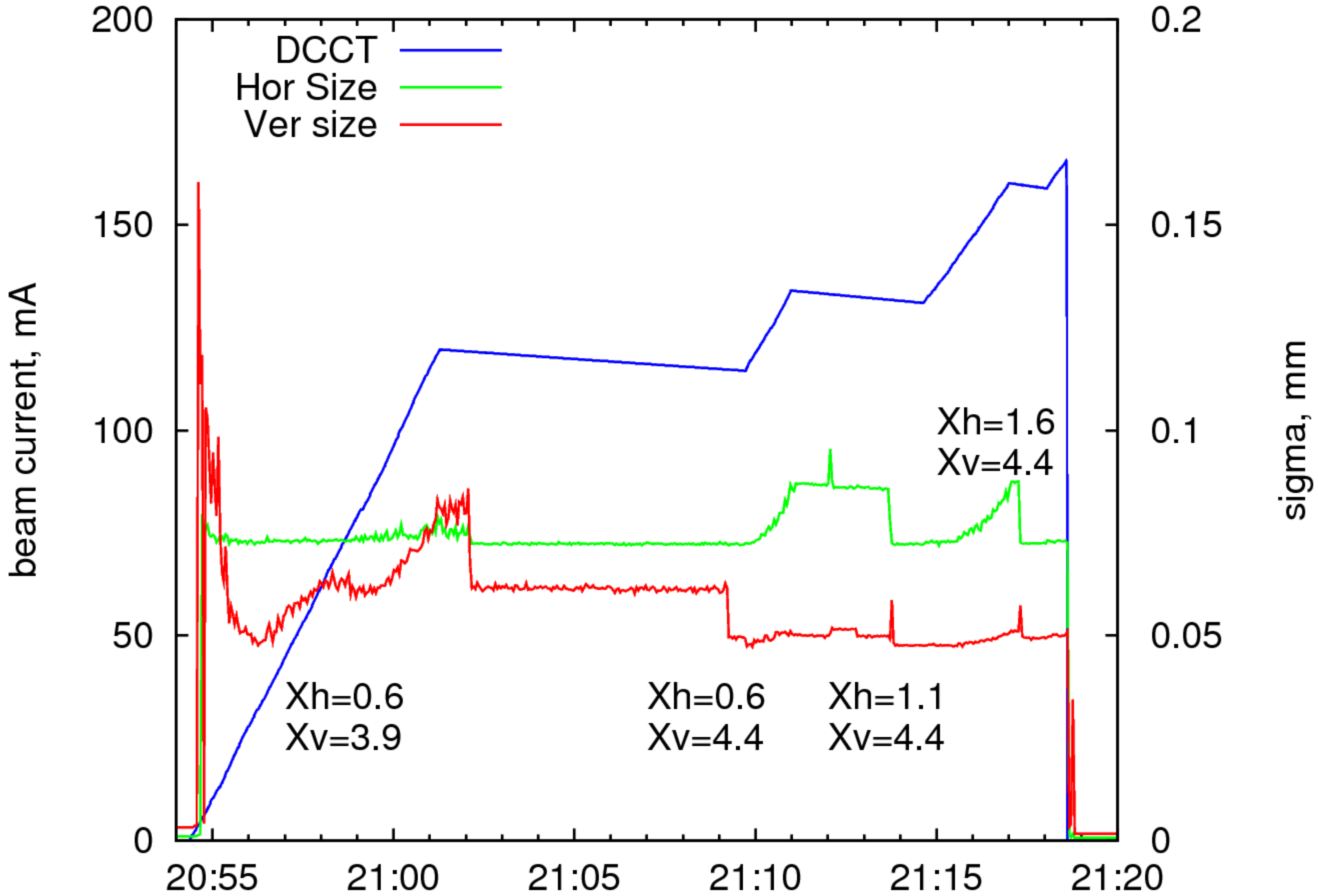


7th of June: 170 mA at ALBA

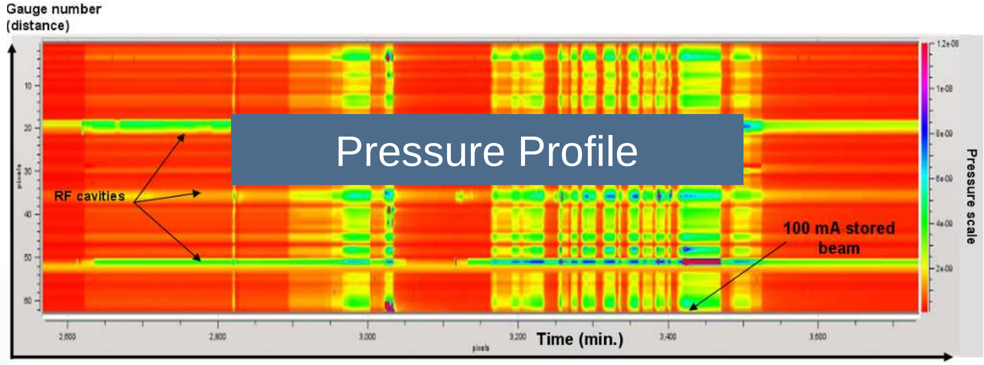


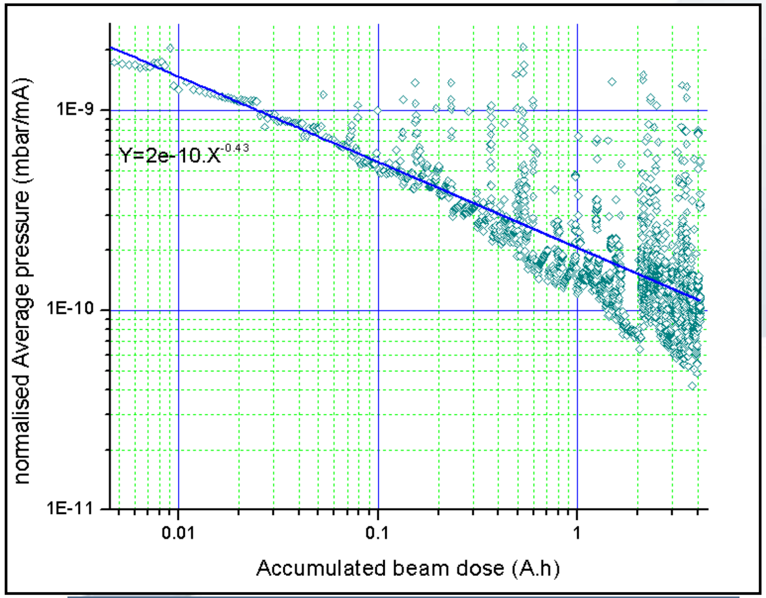


7th of June: 170 mA at ALBA

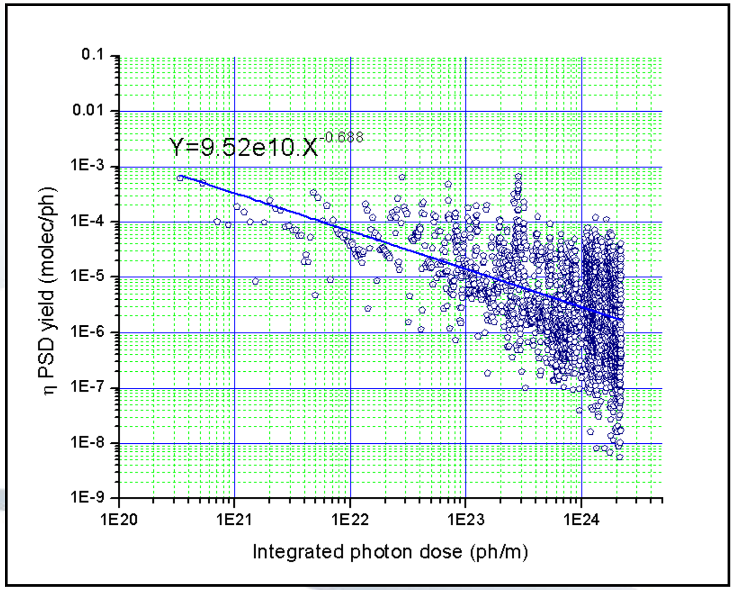


- Average pressure without beam = <u>$4 \cdot 10^{-10}$ mbar.</u>
- With 4.5 A.h. dose, the average pressure was <u>$3.2 \cdot 10^{-9}$ mbar</u> with 80 mA of beam current (multi-bunch filling mode).
- <u>Vacuum Clean-up rate estimated 0.68.</u>



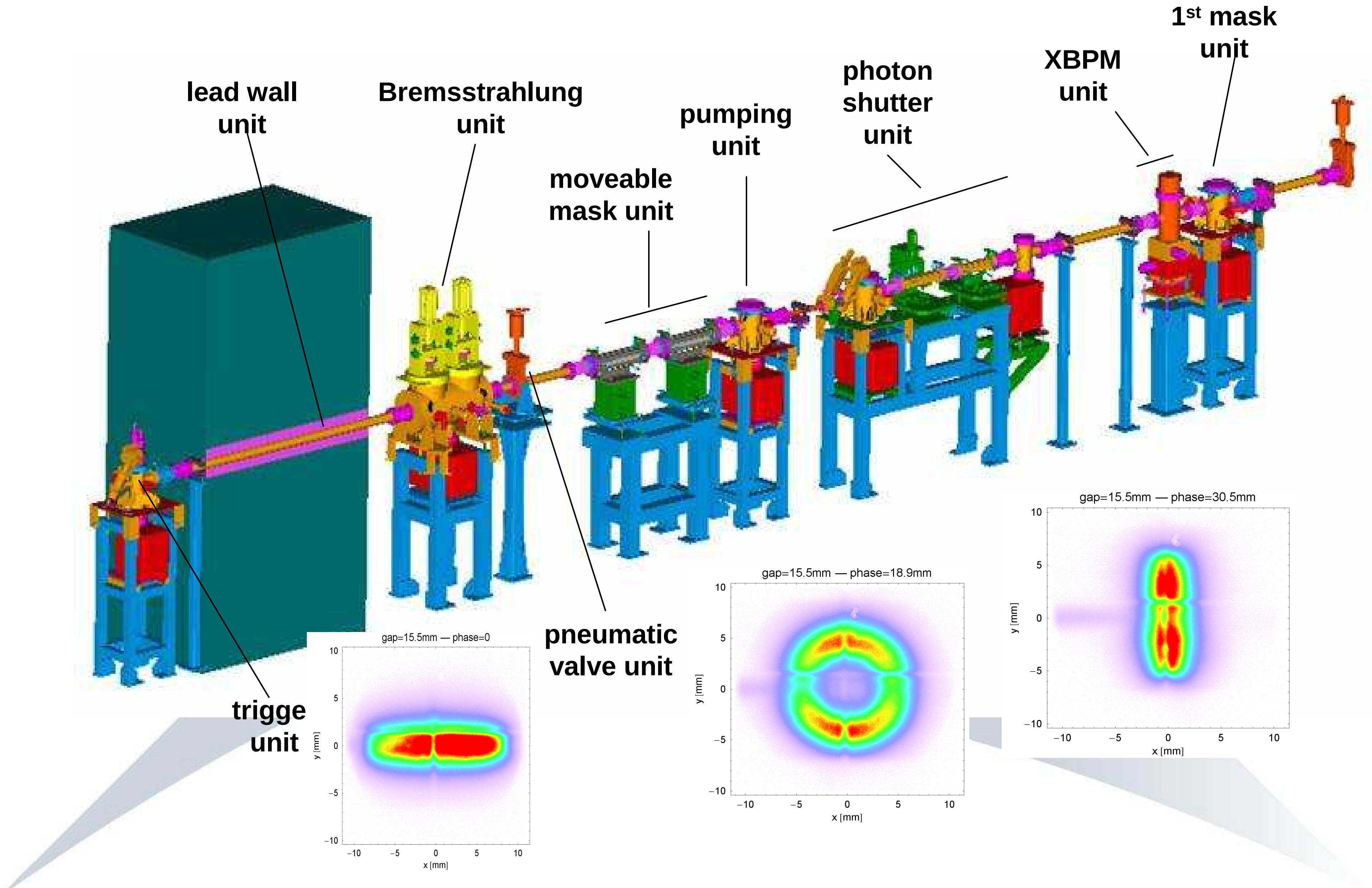


Average pressure normalized to current vs. beam dose



Photon-stimulated desorption yield (PSD) vs. beam dose.

Front End Layout



Summary of Measurements

- Tune
- Chromaticity
- Beam Based Alignment
- Orbit correction, including frequency adjustment
- LOCO measurements:

  Beta functions, dispersion and beating correction
- Beam size, emittance
- Bunch length
- Vacuum performance
- Closing IDs
- Slow orbit correction system

(Most of these measurements were done with 10~20 mA)

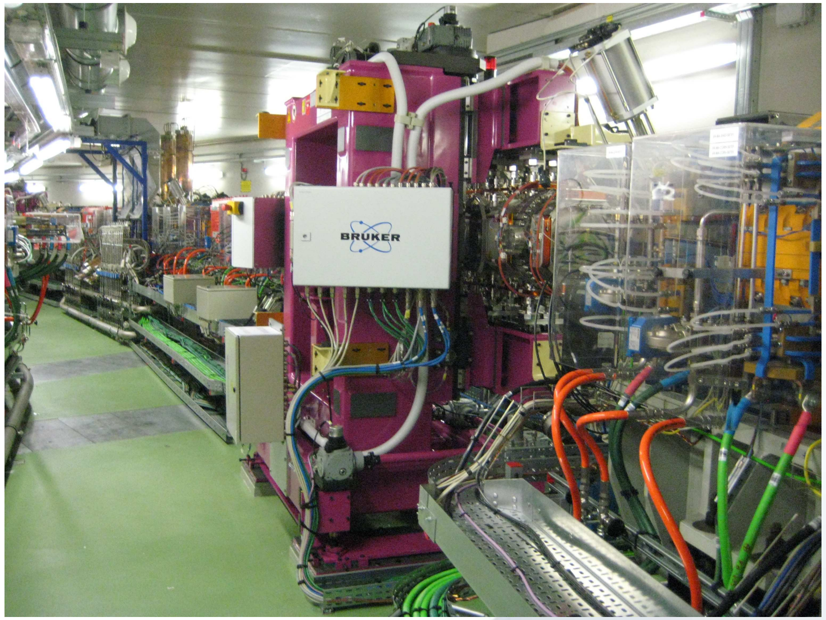
Problems and Next Steps

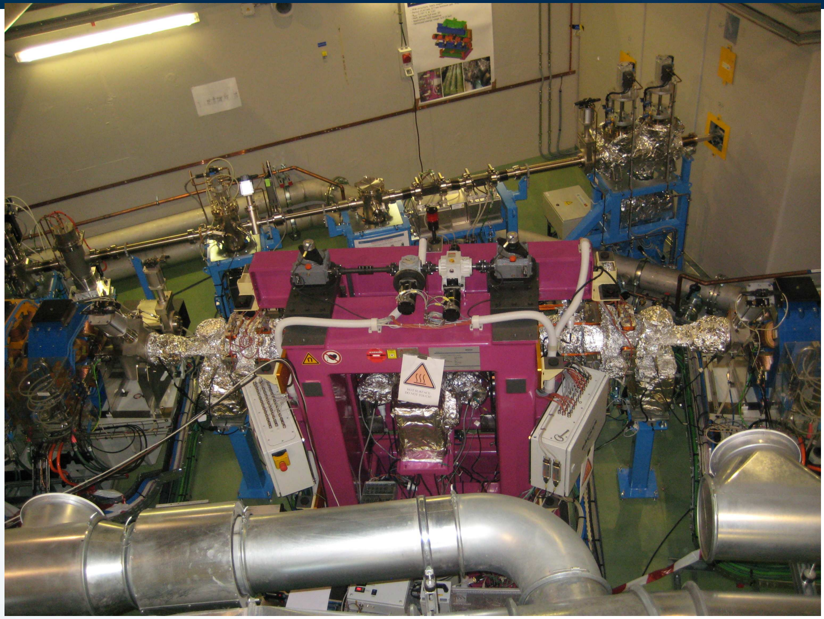
- RF problems
  LLRF deregulation, water leaks, vacuum leaks, trips ...
- Vacuum problems
  Water configuration, chamber overheating, leaks …
- Diagnostics problems
  Streak camera, Libera electronics, stack FS …
- PS problems
  Wrong cabling, correctors and quadrupoles PS …
- Control system problems
  Applications froze, motors, CCD camera, cycling, MPS, PSS, timing …

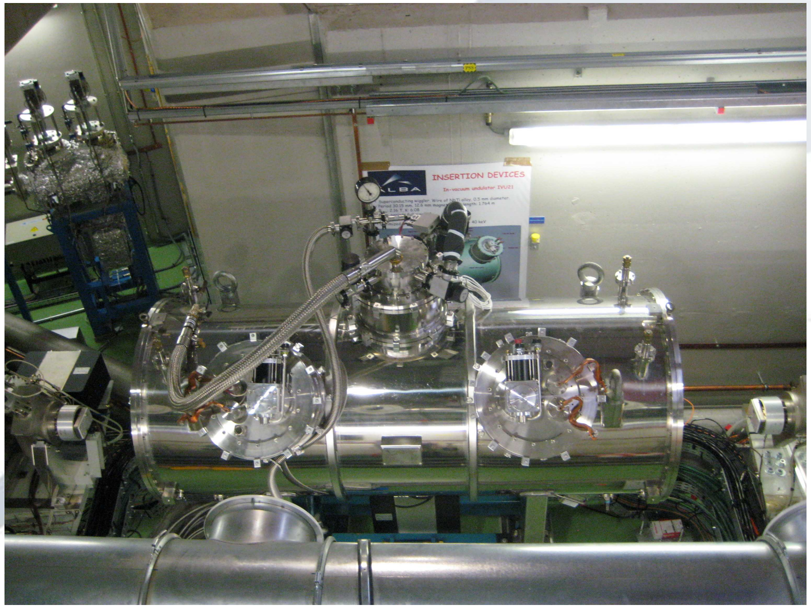
Next Steps

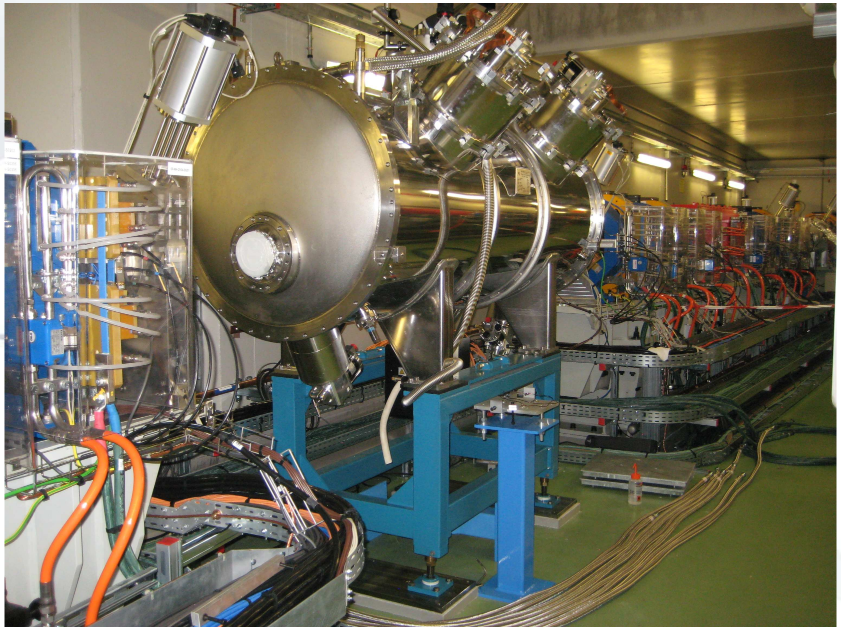
- Commissioning with ID’s
- Slow orbit feedback
- Vacuum cleaning
- Better control filling pattern
- Fast orbit feedback
- Multibunch feedback
- Topping up
- …

SCW and IVU's are installed

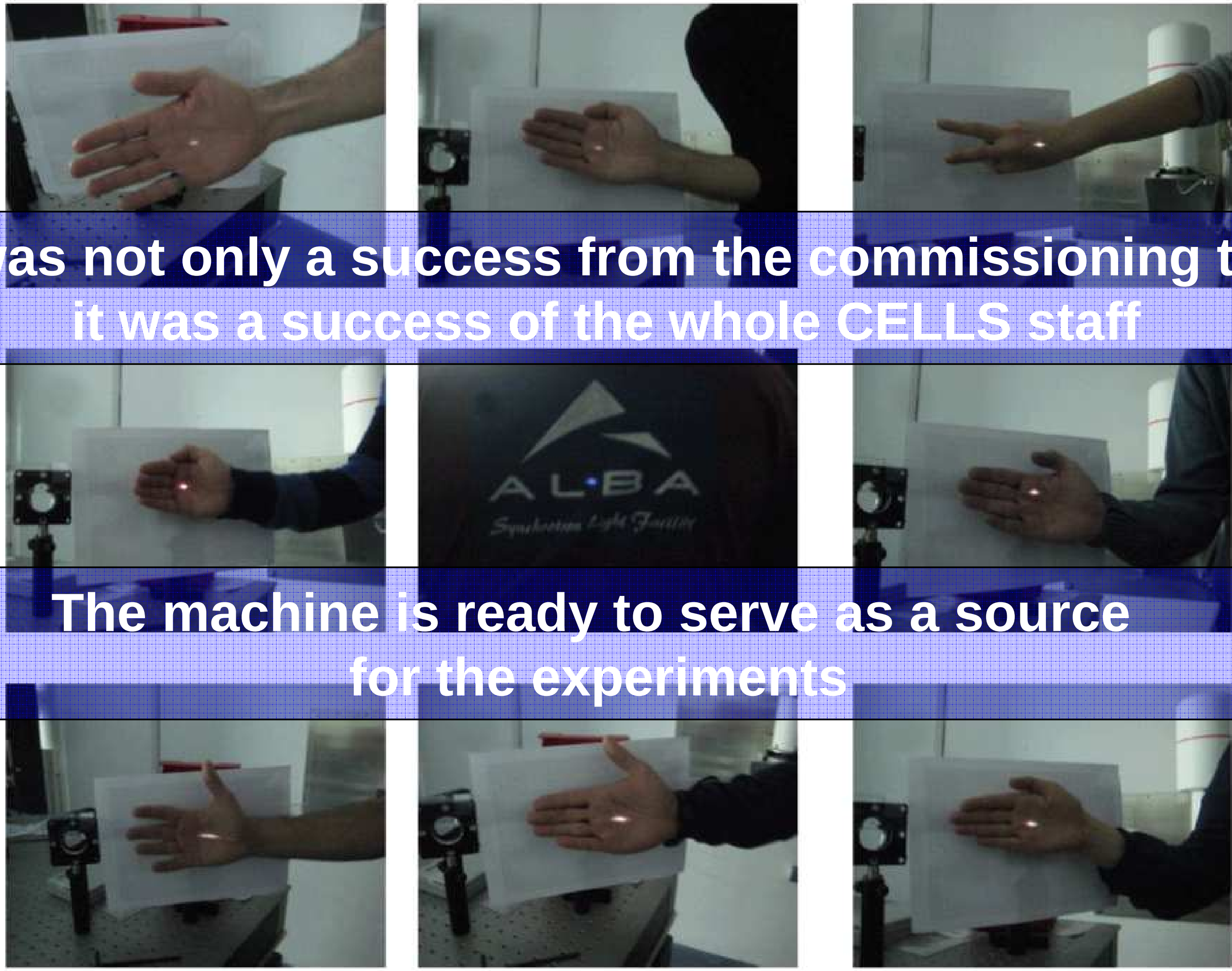








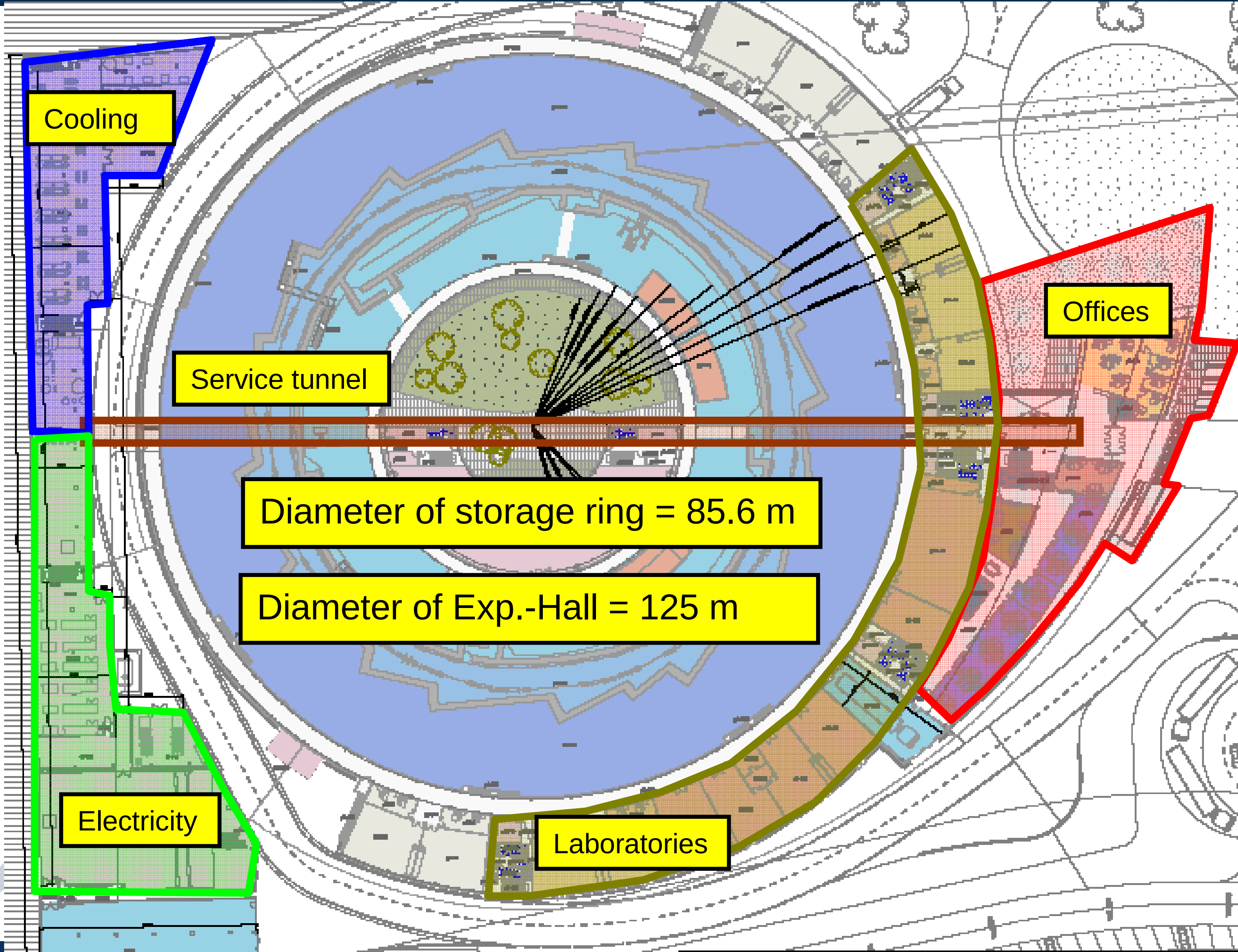
Thank you very much



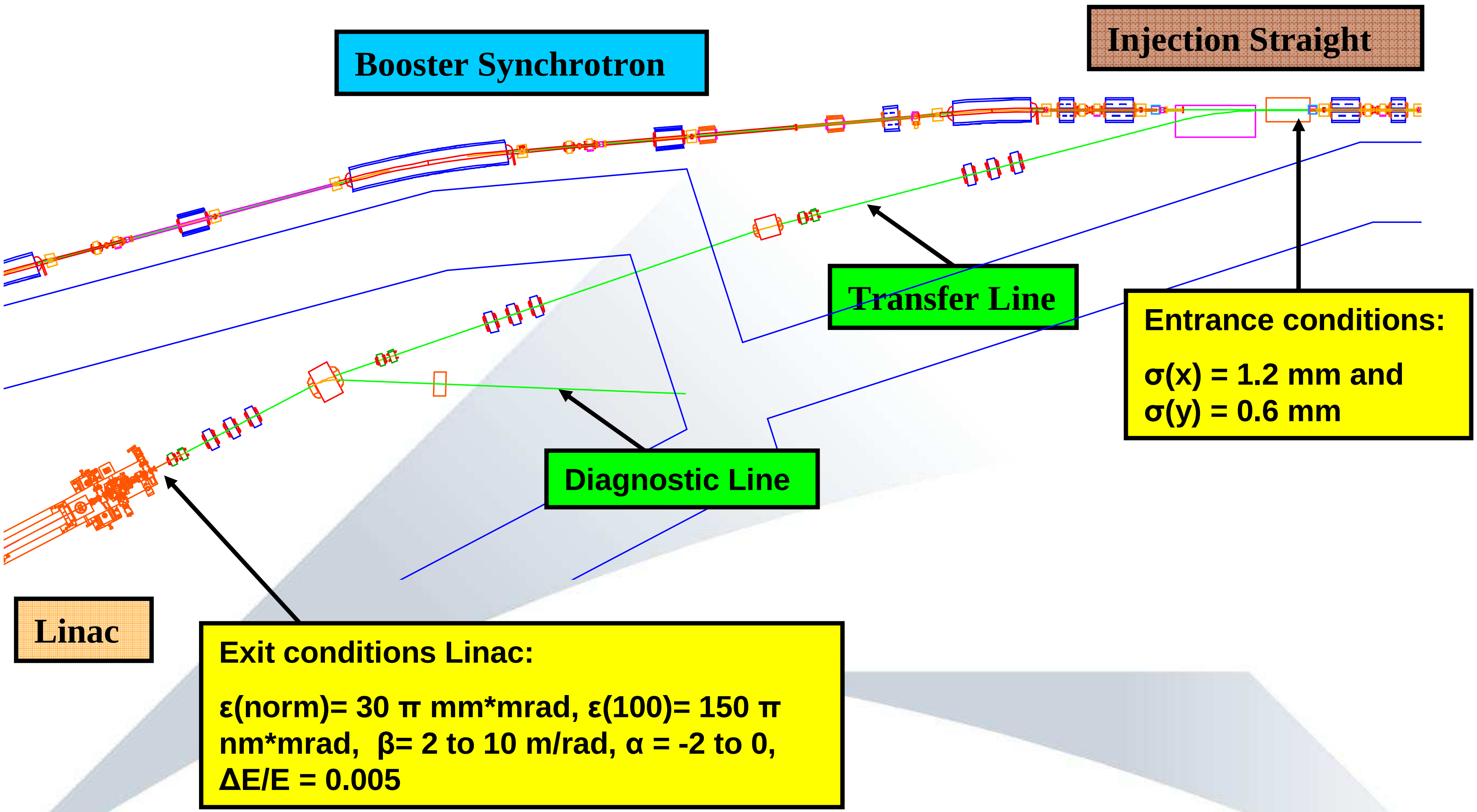
This was not only a success from the commissioning team, it was a success of the whole CELLS staff

The machine is ready to serve as a source for the experiments

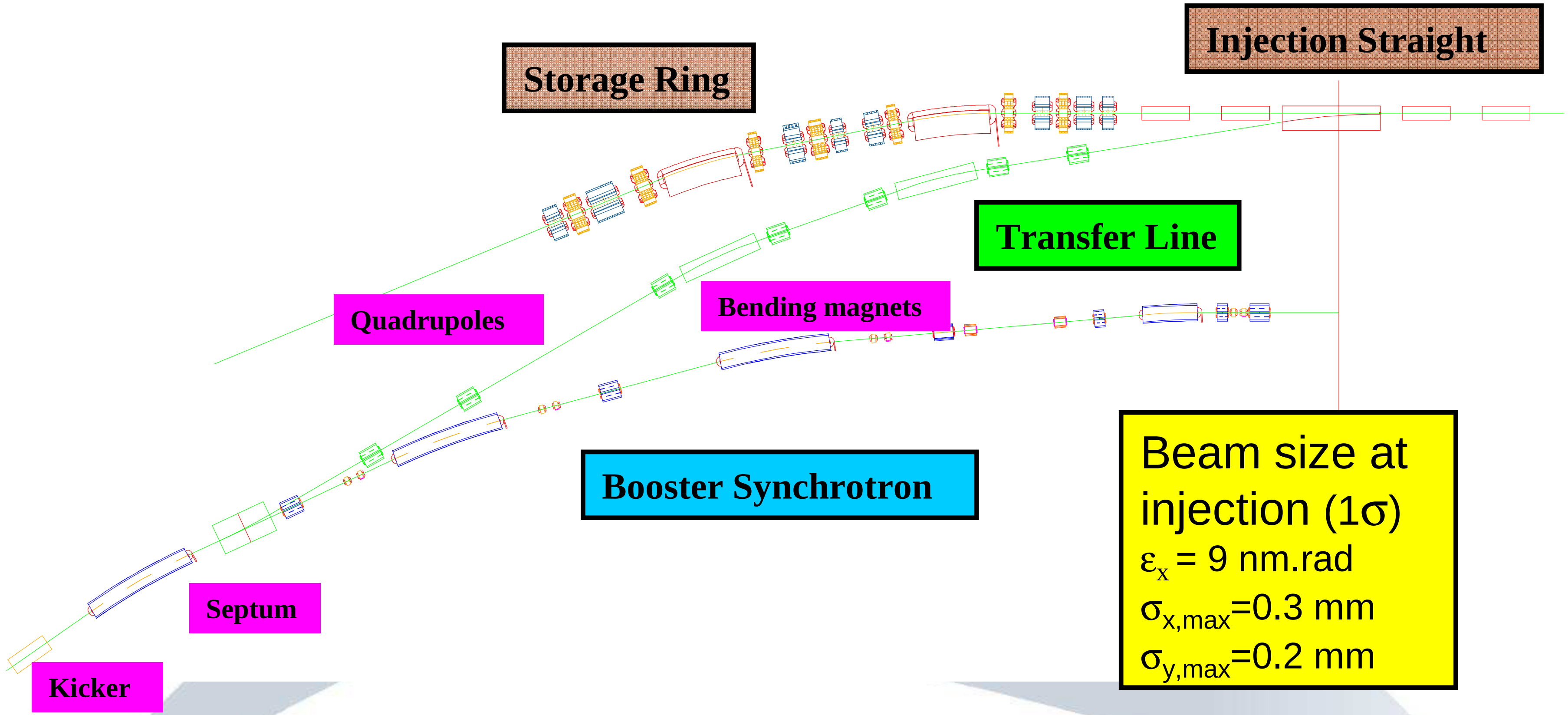
Layout and Size of Building



Layout of LTB Transfer Line



Layout of BTS Transfer Line



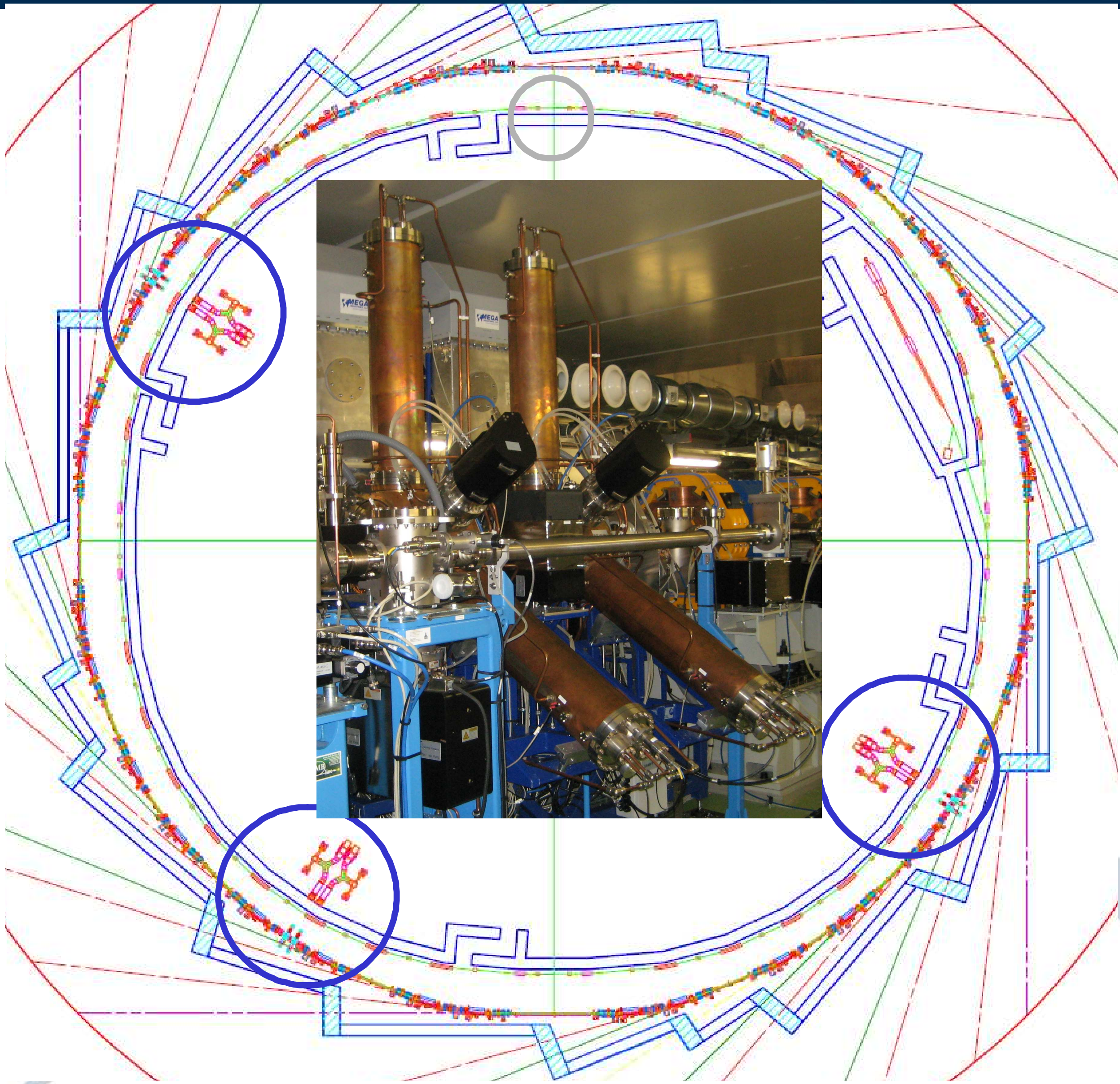
Beam size at injection (1σ)

ε_x = 9 nm.rad

$\sigma_{x,max}$=0.3 mm

$\sigma_{y,max}$=0.2 mm

RF-System



RF Voltage: 3600 kV, beam current: 400 mA, losses: 1.3 MeV/turn, beam power: 520 kW