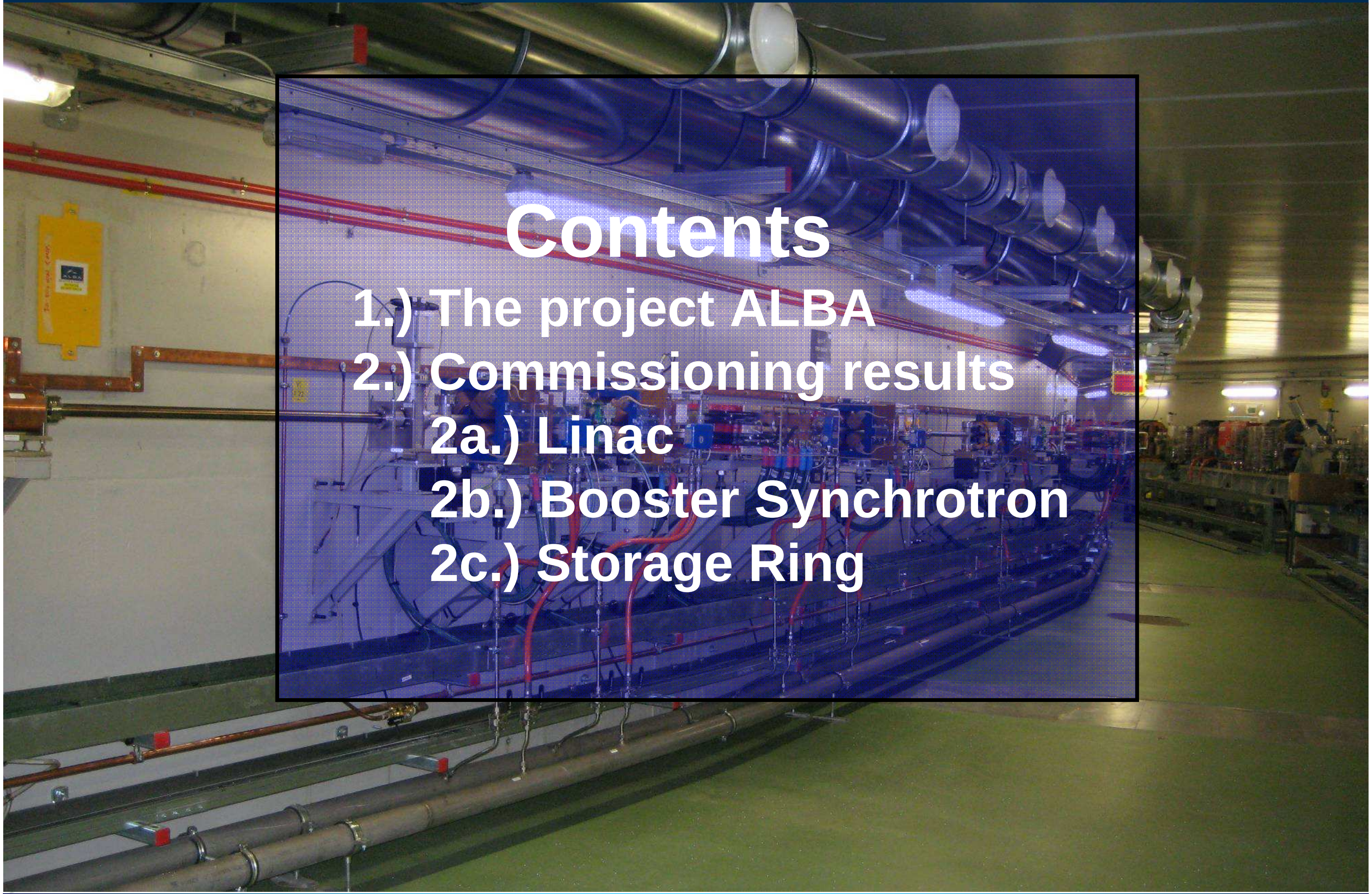
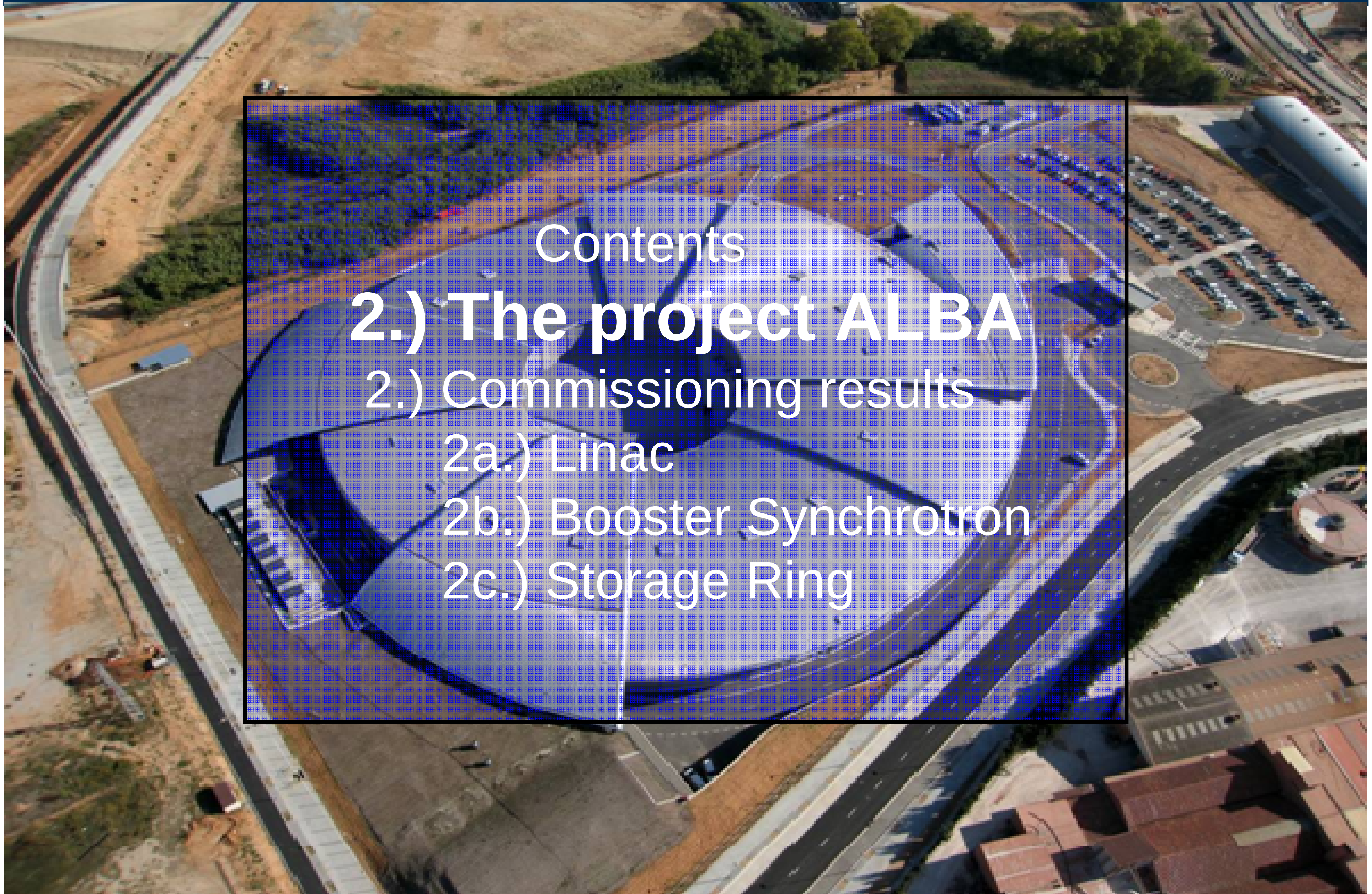
ALBA
Synchrotron Light Source Commissioning

D. Einfeld, CELLS-ALBA
on behalf of the Commissioning Team



Contents

1.) The project ALBA
2.) Commissioning results
2a.) Linac
2b.) Booster Synchrotron
2c.) Storage Ring



Contents

2.) The project ALBA

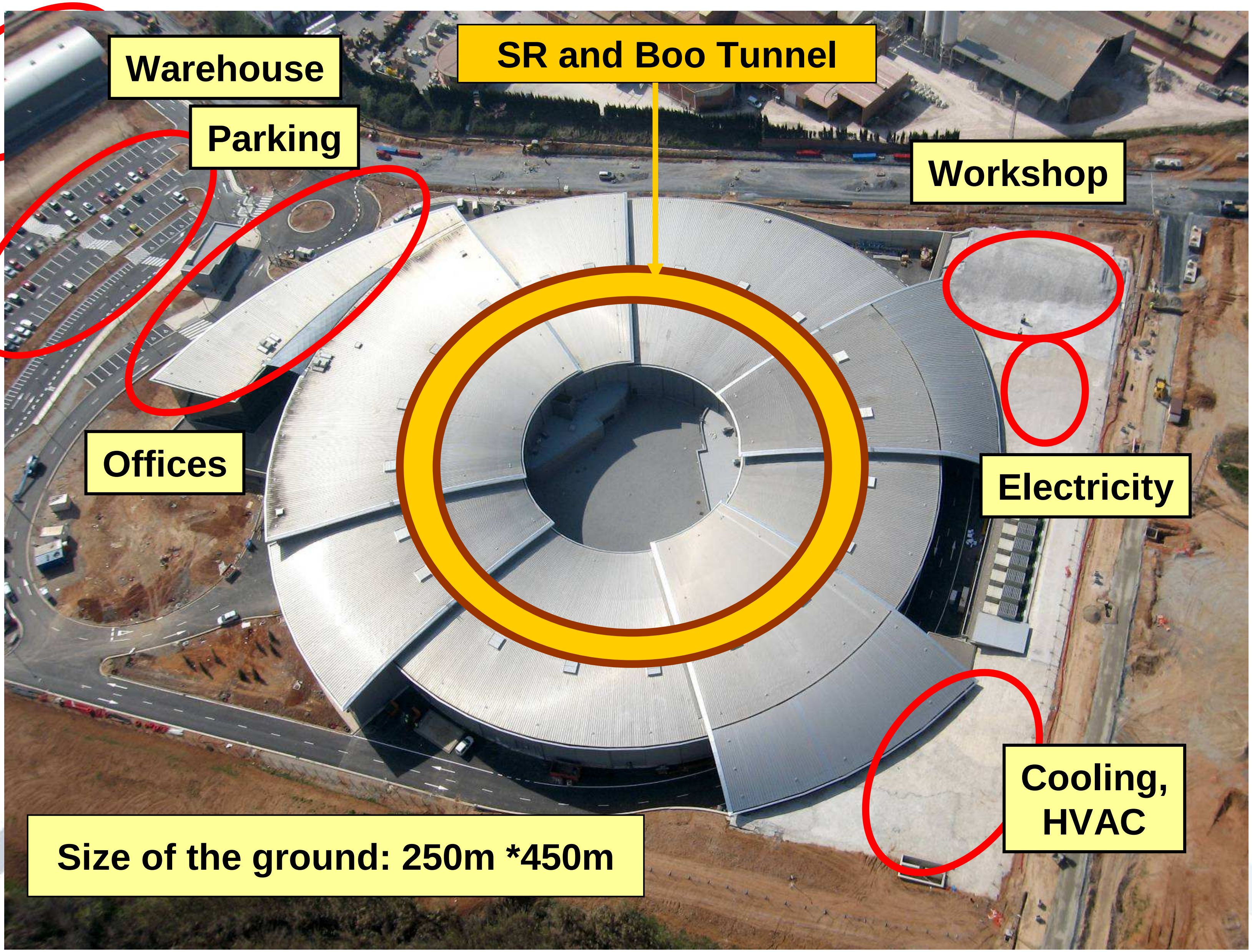
2.) Commissioning results

2a.) Linac

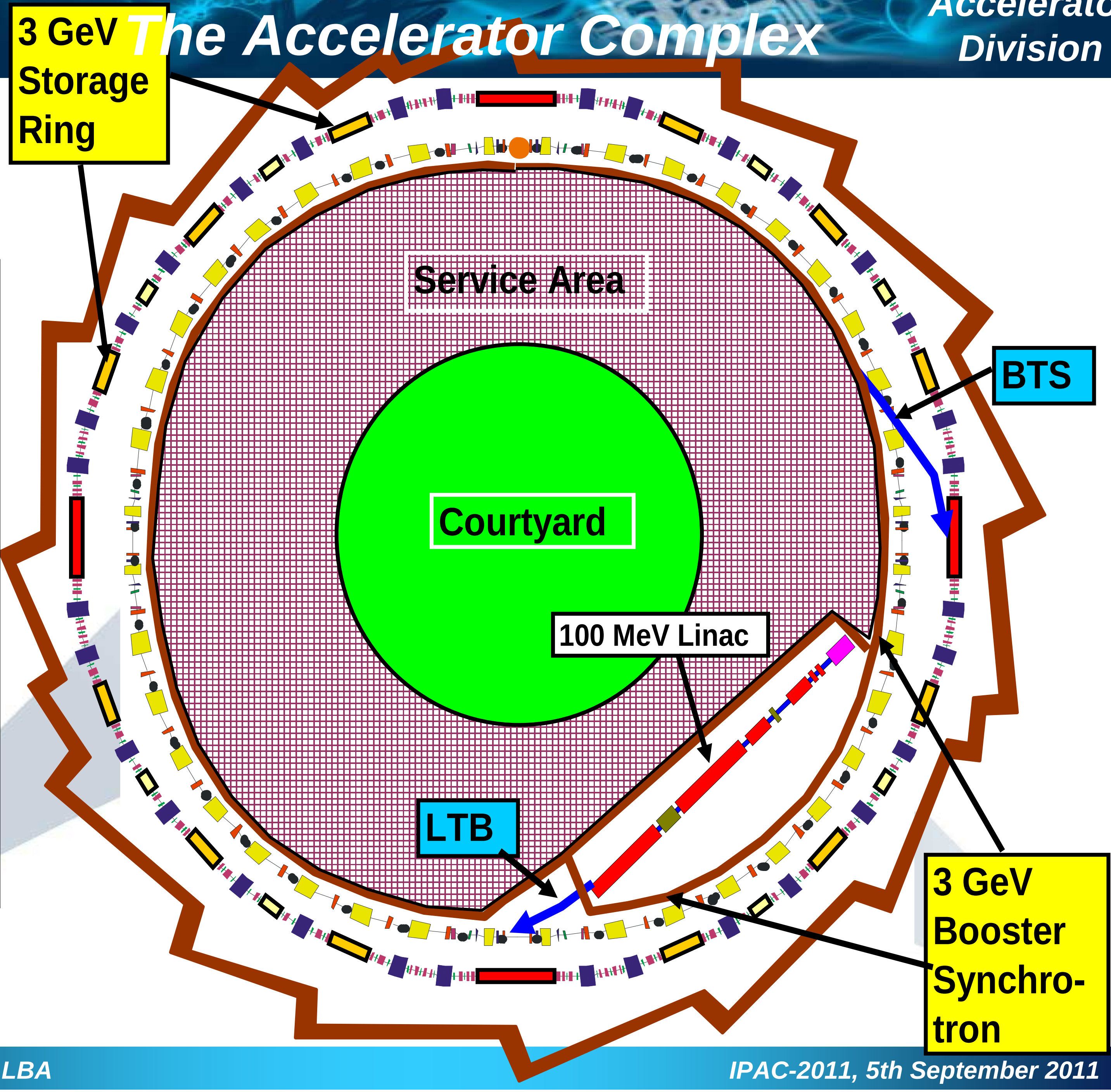
2b.) Booster Synchrotron

2c.) Storage Ring

The ALBA - Building

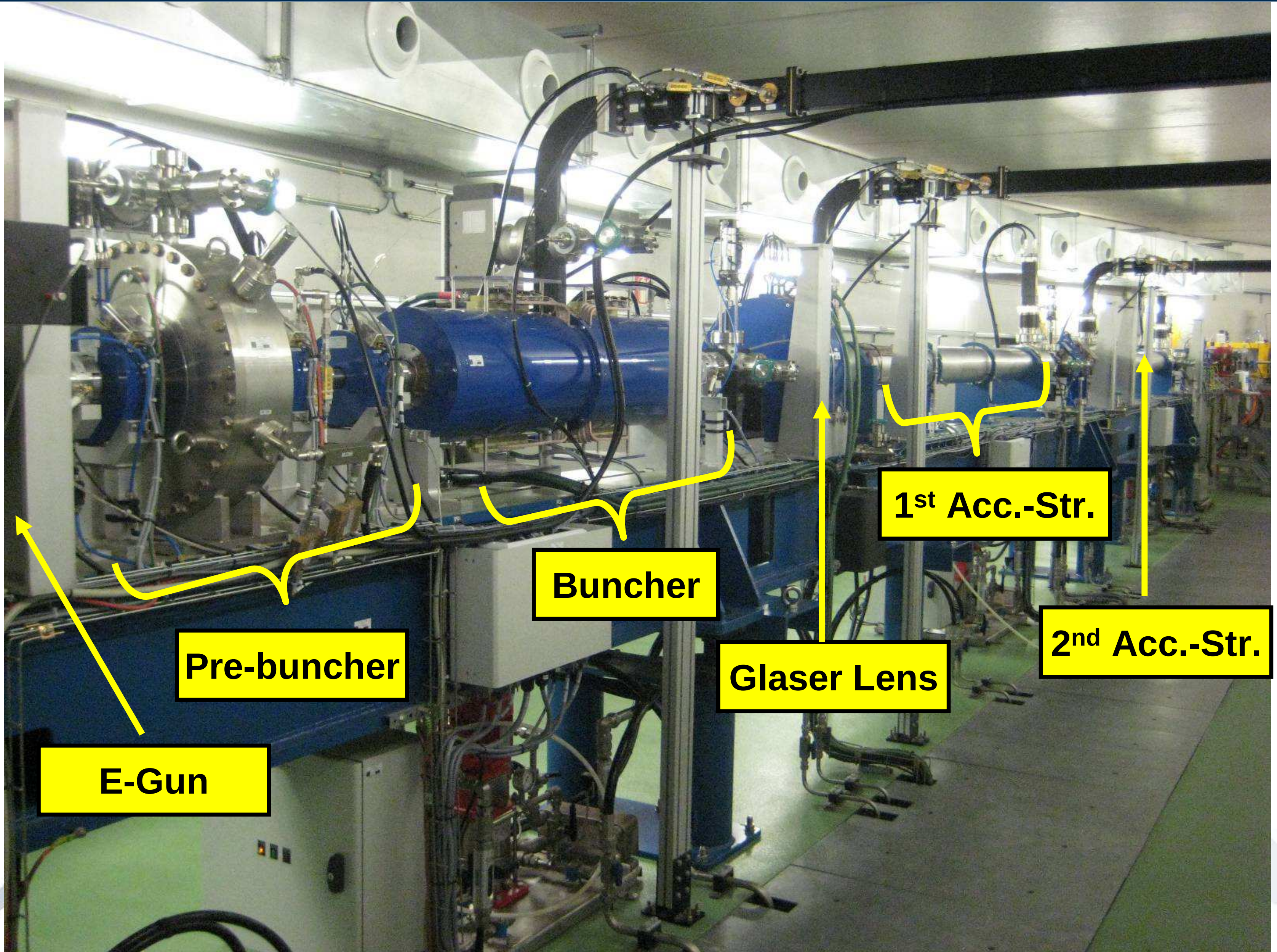


The Accelerator Complex



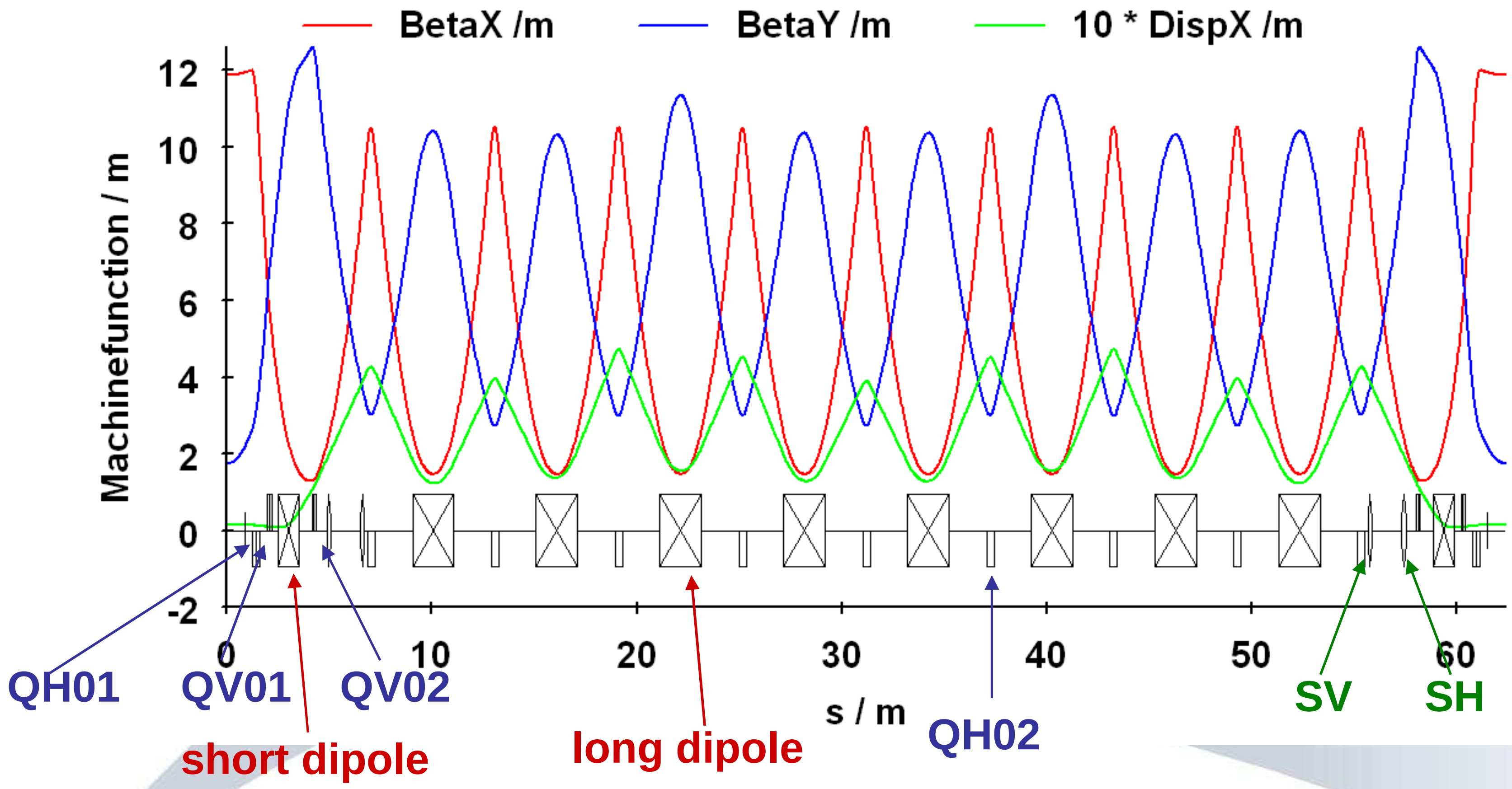
Accelerator complex of ALBA: We followed the concept of the SLS to have the booster and the storage ring in the same tunnel. The preinjector is a 100 MeV Linac

LINAC in the Tunnel



Lattice of Booster Synchrotron

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

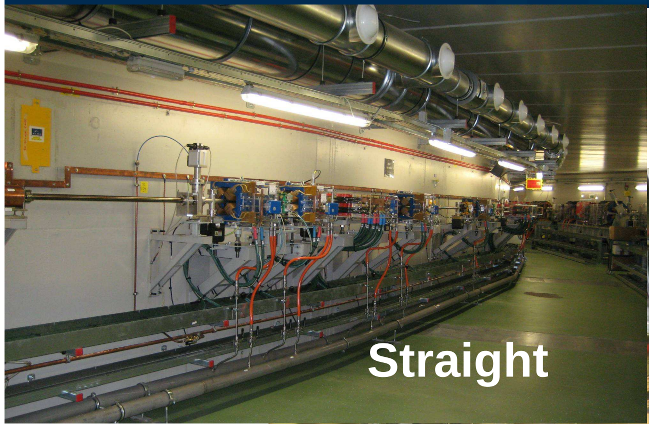


Q(x) is given by QH02 and Q(y) is given by the bends. All the other quads for fine tuning

Design working point: $Q_x = 12.42$, $Q_y = 7.38$, emittance $\varepsilon = 9$ nmrad

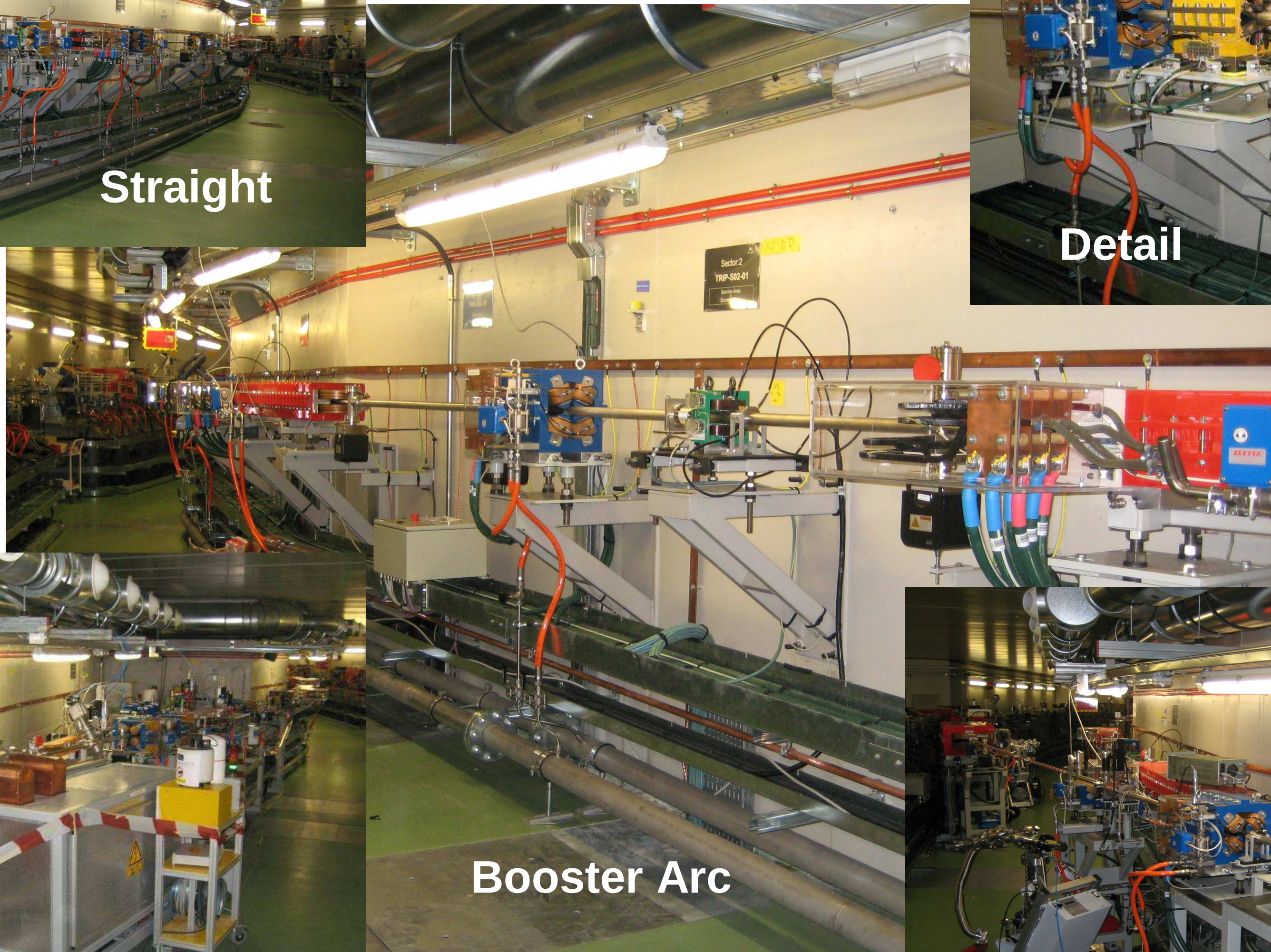
Booster Installation

Accelerator Division



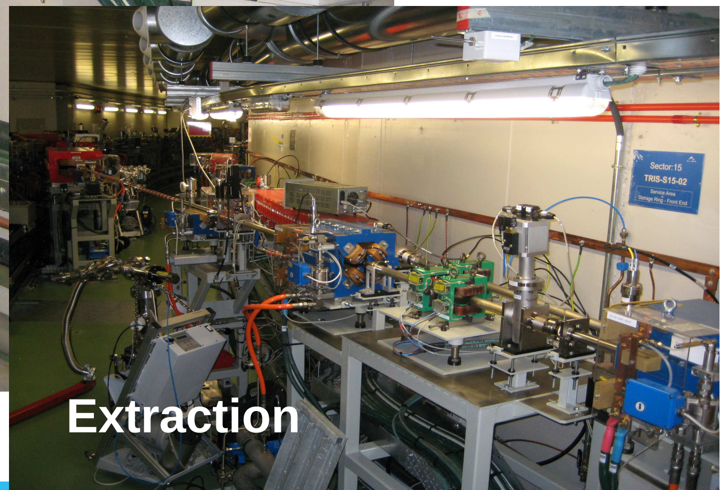
Straight

Detail



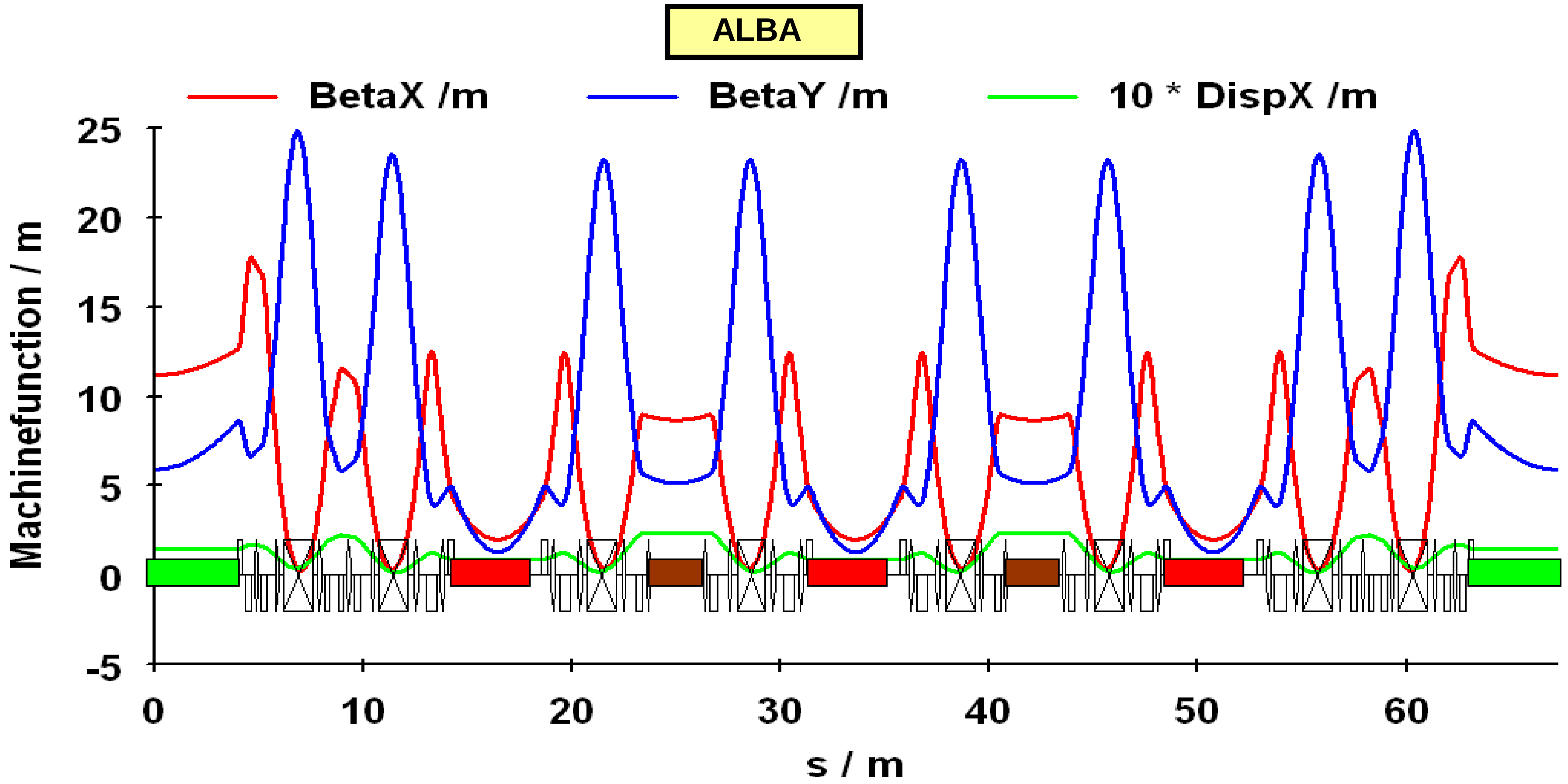
Booster Arc

Injection



Extraction

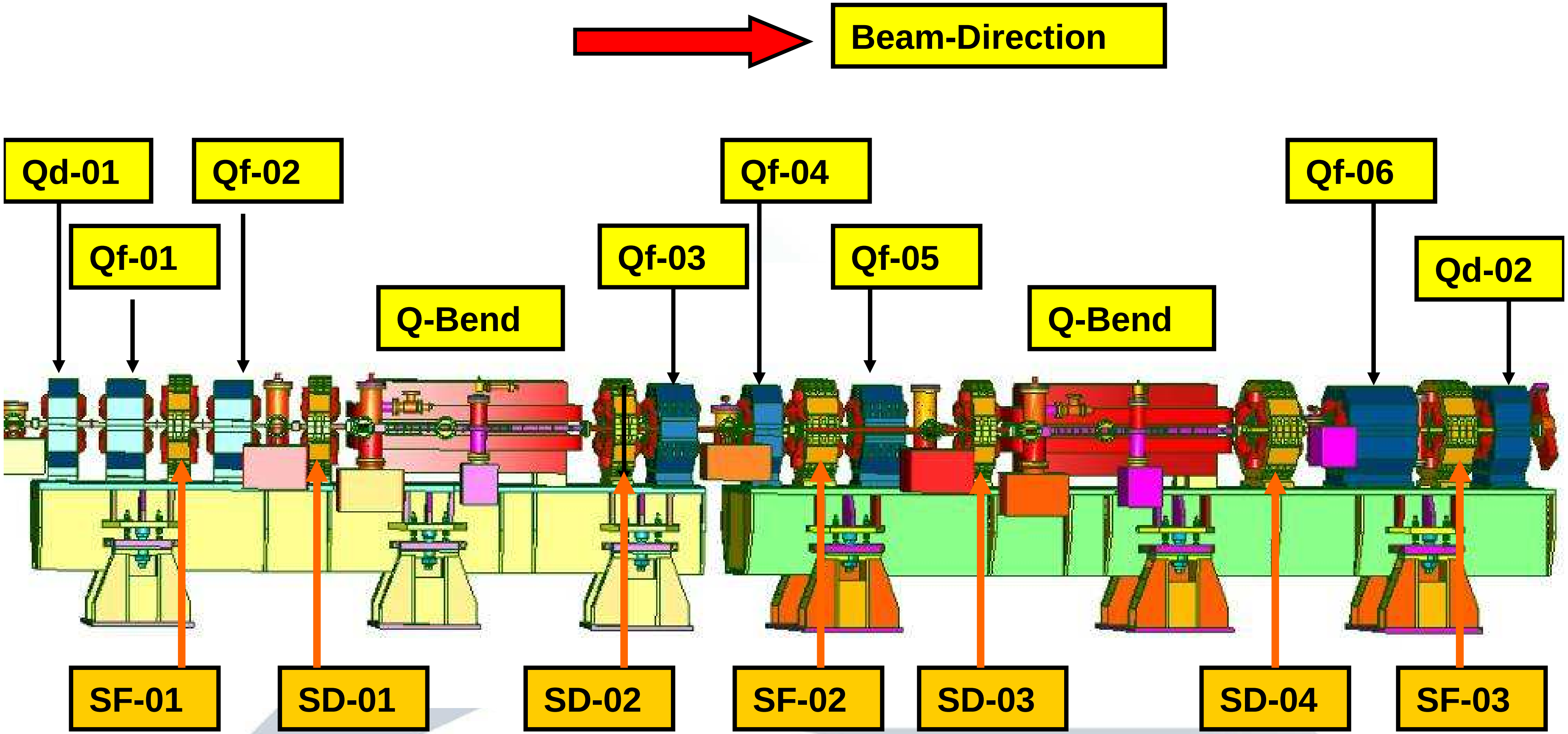
Storage Ring Lattice



green	4 long straights with a length of 7.8 m
red	12 medium straights with a length of 4.3 m
brown	8 short straights with a length of 2.3 m

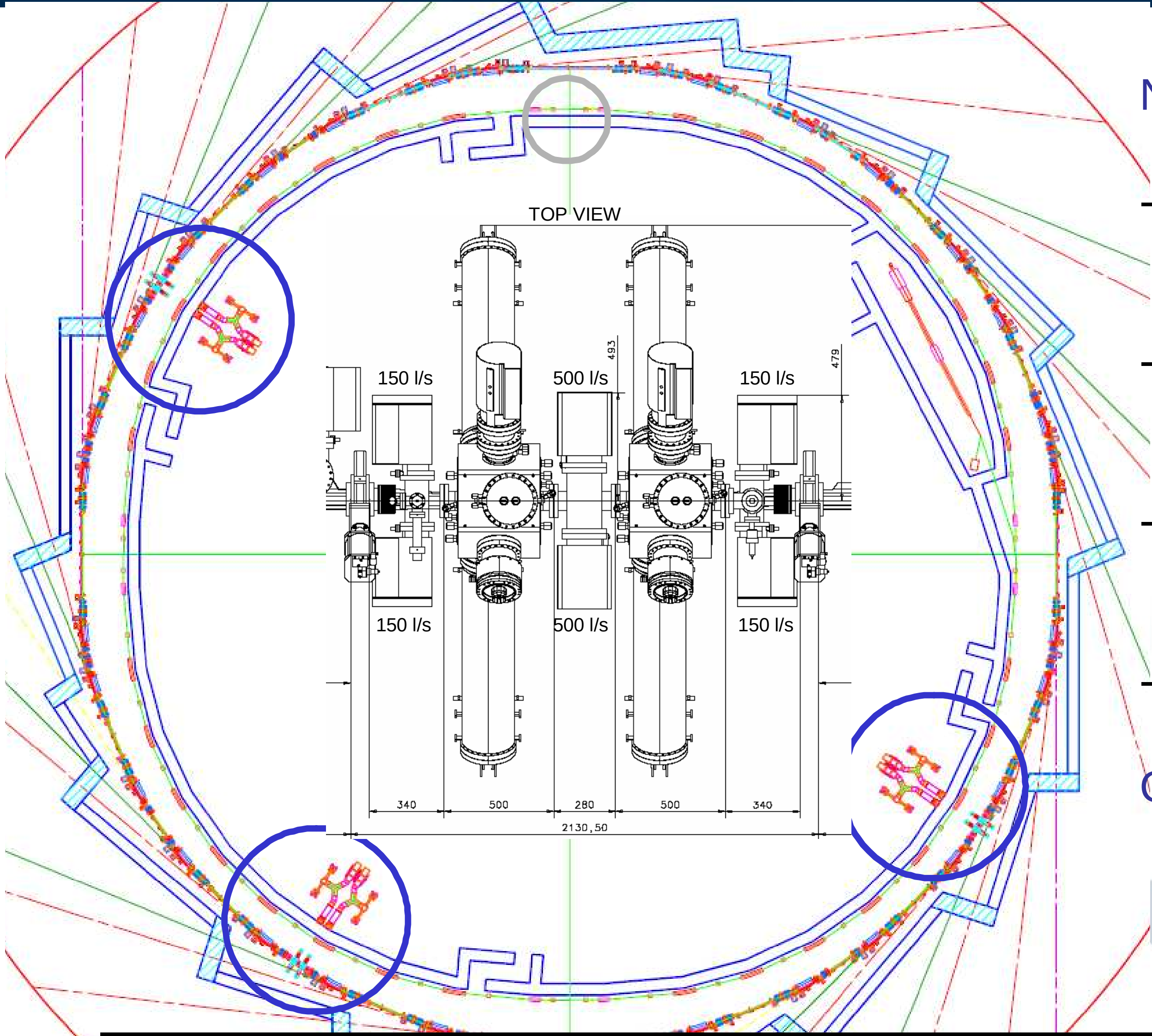
Circumf.= 268.8 m
4 fold symmetry
Emitt. = 4.5 nmrad

Girder of Matching Cell



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

RF-System



New developments:

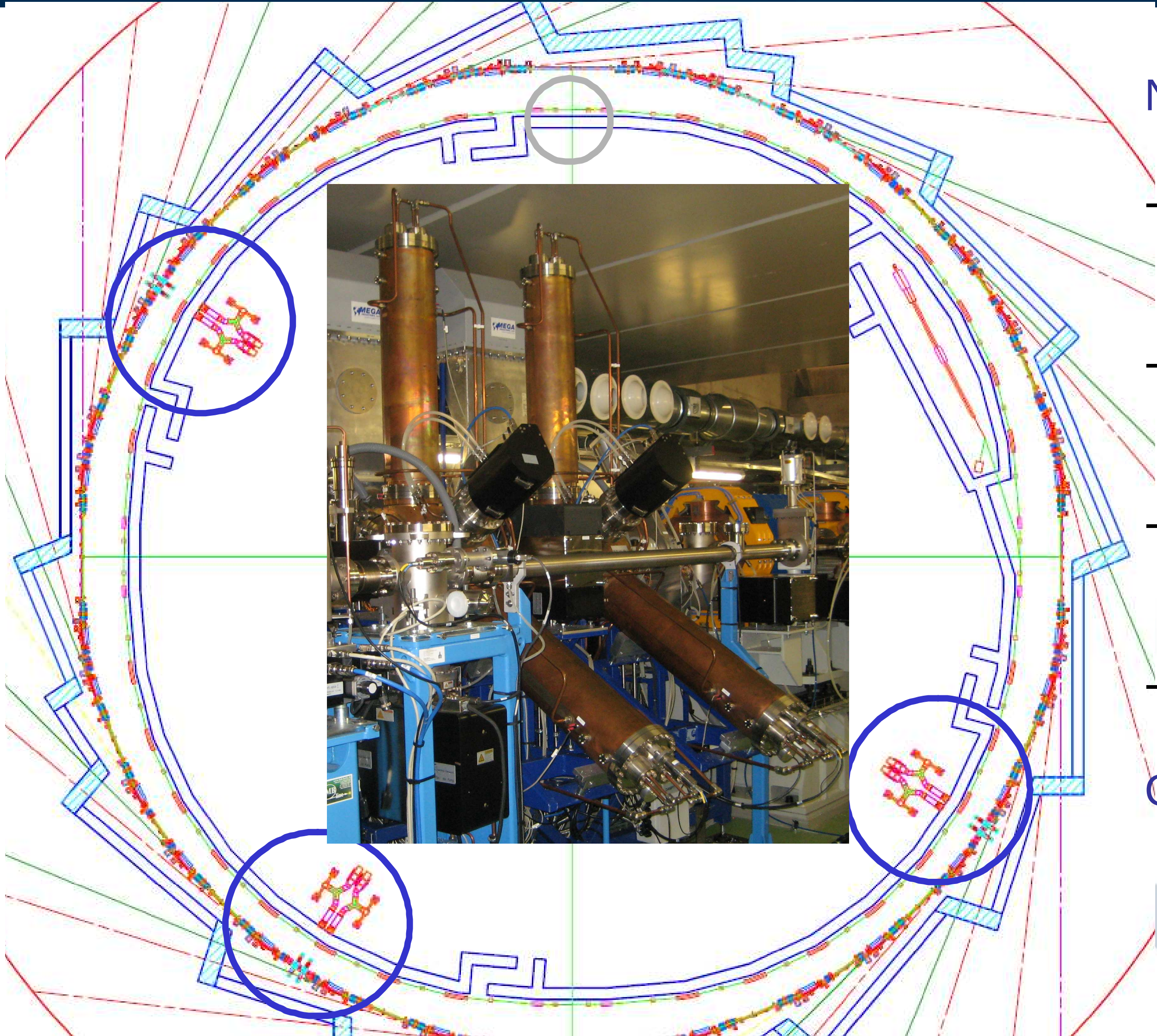
- Normal conducting HOM damped cavities.
- Watrax, transition from WG to Coaxial
- CaCo, cavity combiner of 2x80 kW IOTs
- Digital LLRF

Check posters today:

MOPC045
MOPC046

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

RF-System



New developments:

- Normal conducting HOM damped cavities.

- Watrax, transition from WG to Coaxial

- CaCo, cavity combiner of 2x80 kW IOTs

- Digital LLRF

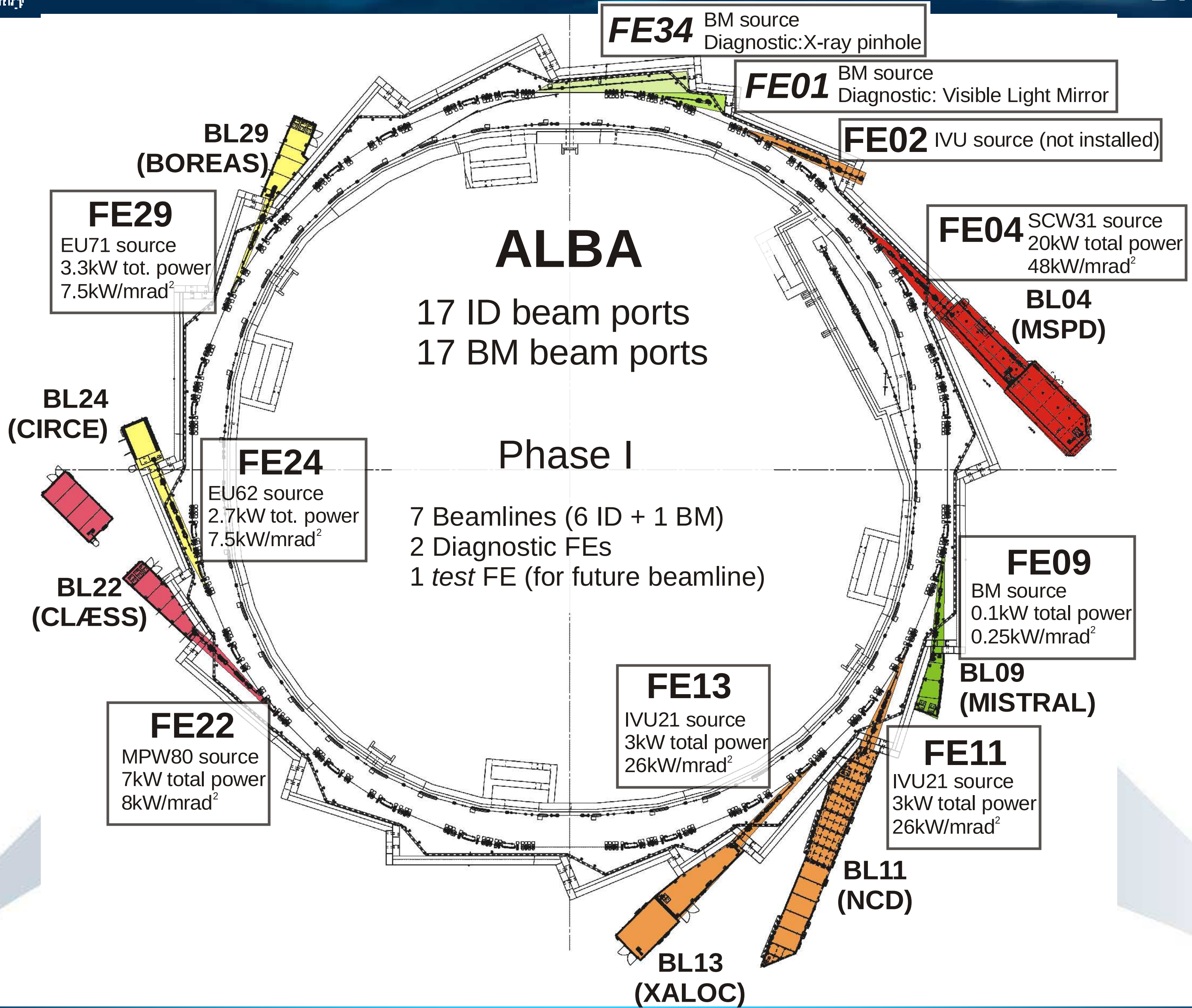
Check posters today:

MOPC045
MOPC046

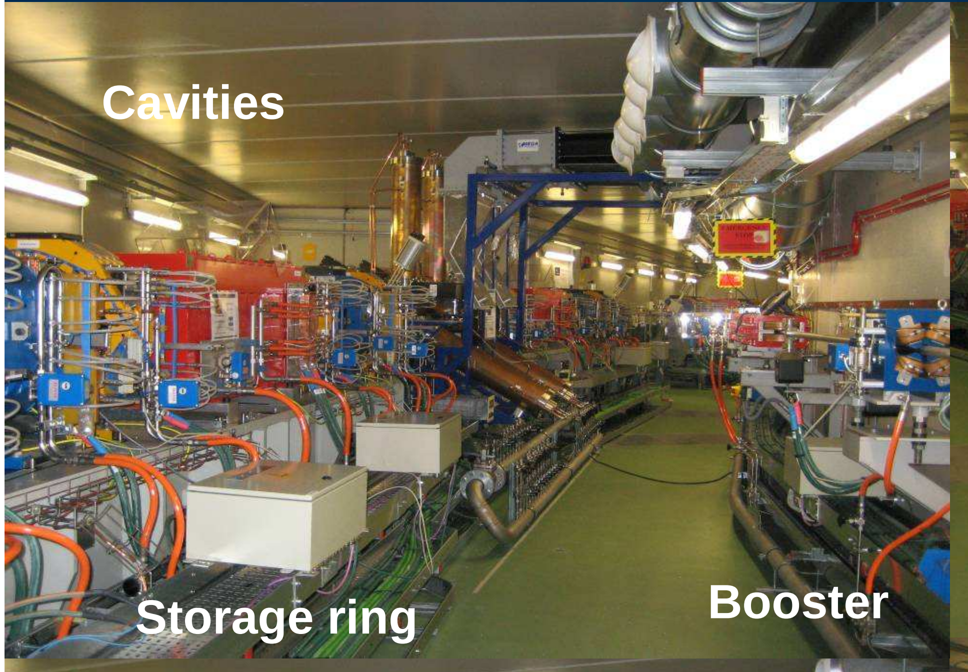
RF Voltage: 3600 kV, beam current: 400 mA, losses: 1.3 MeV/turn, beam power: 520 kW

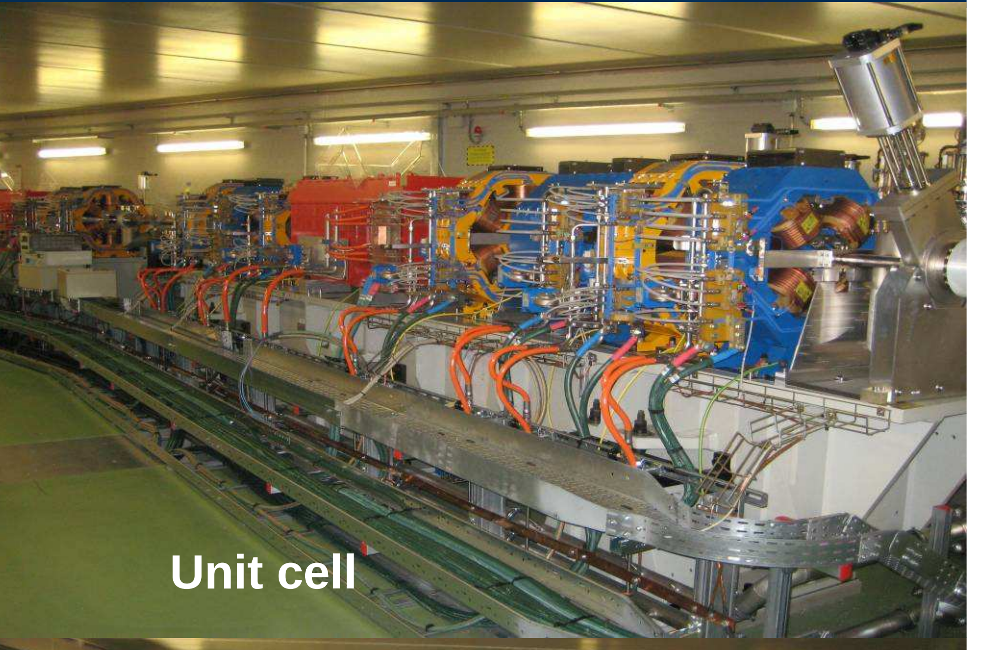
ID's, Front Ends and Beam Lines

Accelerator Division

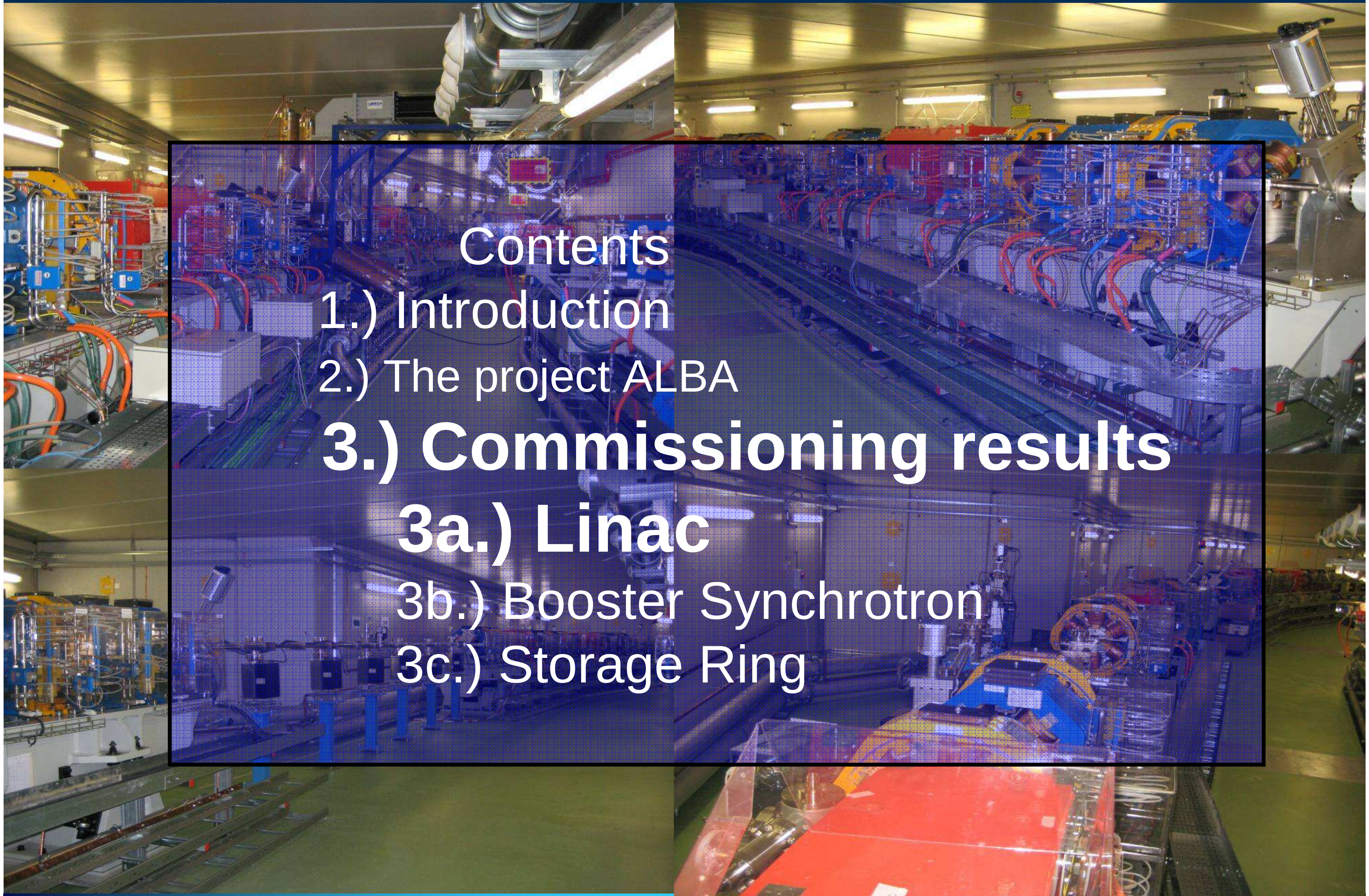


Storage Ring in the Tunnel





Storage Ring in the Tunnel



Contents

1.) Introduction

2.) The project ALBA

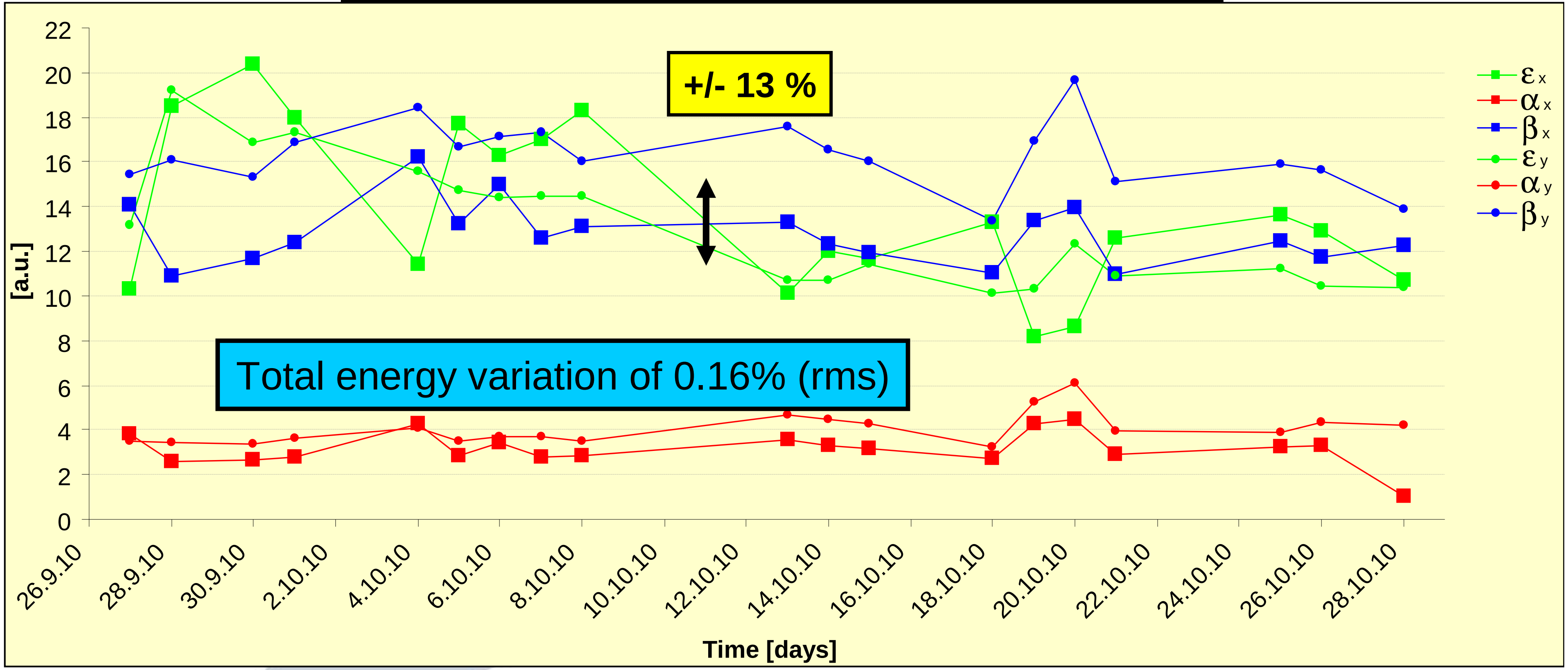
3.) Commissioning results

3a.) Linac

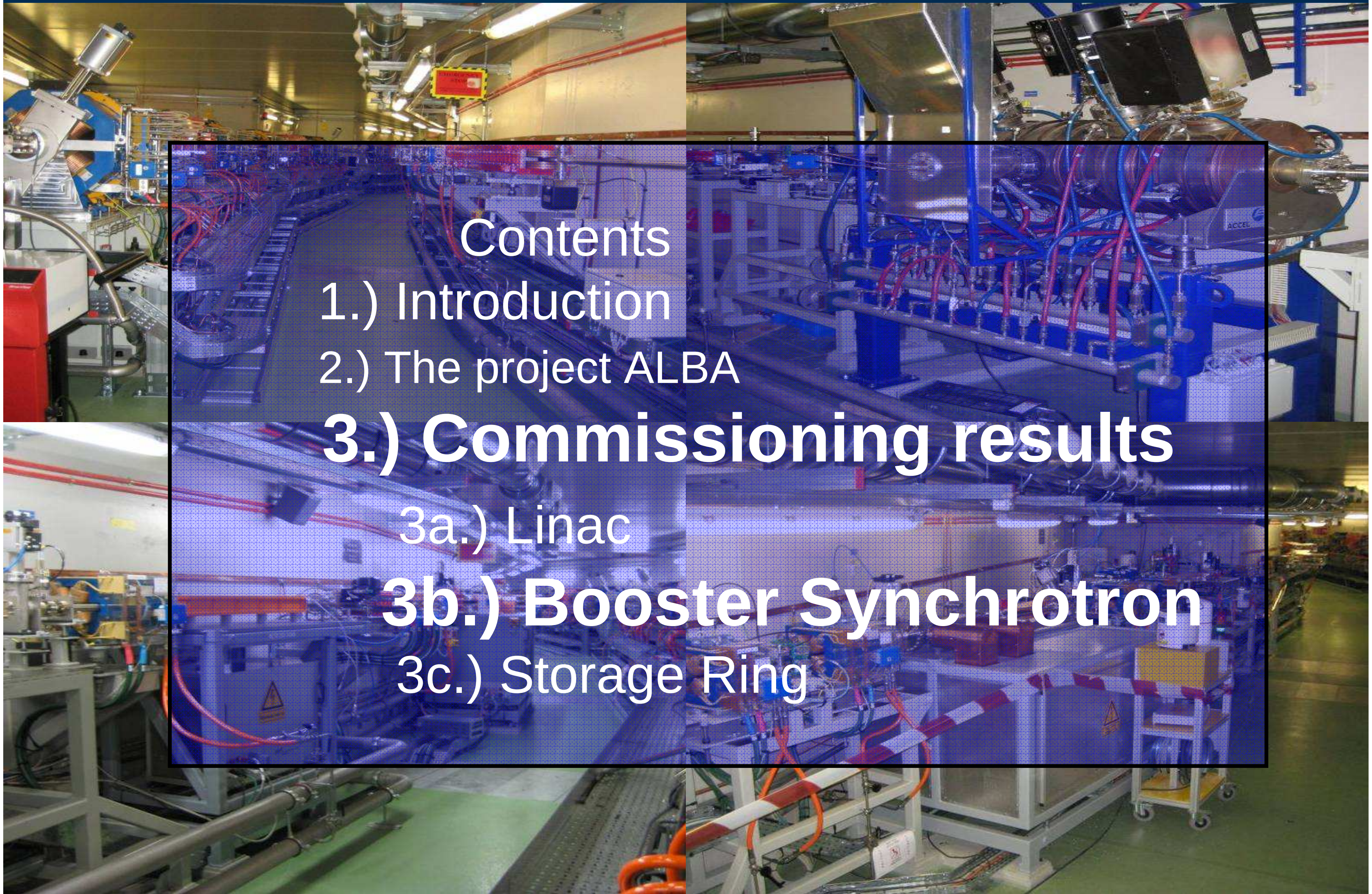
3b.) Booster Synchrotron

3c.) Storage Ring

All parameters are within specifications



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

1.) Introduction

2.) The project ALBA

3.) Commissioning results

3a.) Linac

3b.) Booster Synchrotron

3c.) Storage Ring

Booster Commissioning

22.12.2009, 3:00 first beam in the booster

1. Phase: 10th to 24th of January 2010

The goal was to cross check all the sub-systems. We reached a beam up to 600 MeV and later to 2.8 GeV

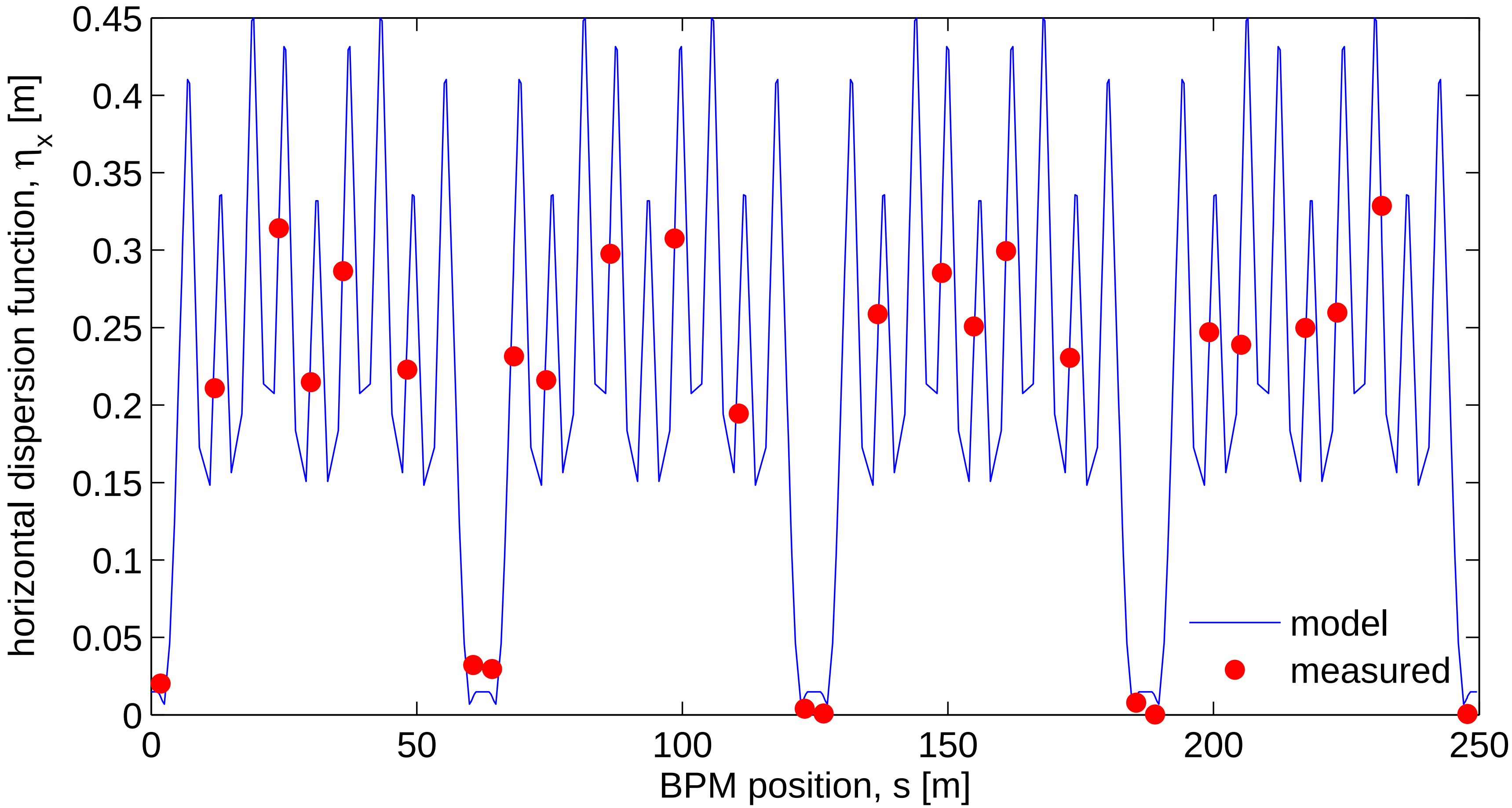
2. Phase: July 2010

We have had problems with the Linac, the booster power supplies and also the injection elements. No success and progress.

3.) Phase: September - October 2010

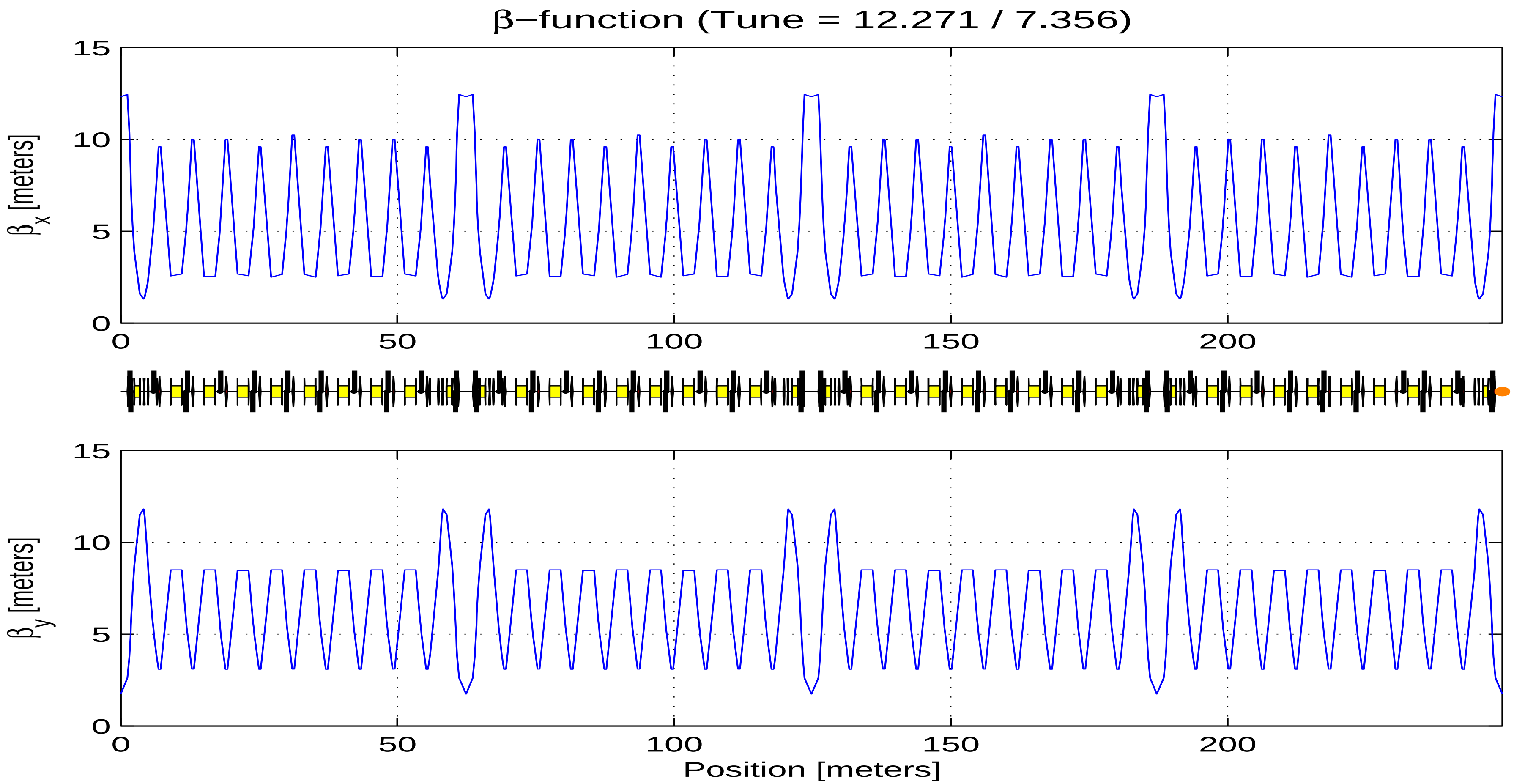
We changed the philosophy: tunnel open in the morning for storage ring installation and tunnel closed in the afternoon for booster commissioning. We could characterize the booster and got a 3 GeV beam at the 4th October 2010.28th of October a beam of 3 GeV into the BTS transfer line

Disprsion Functions (DC)



Good agreement with the model

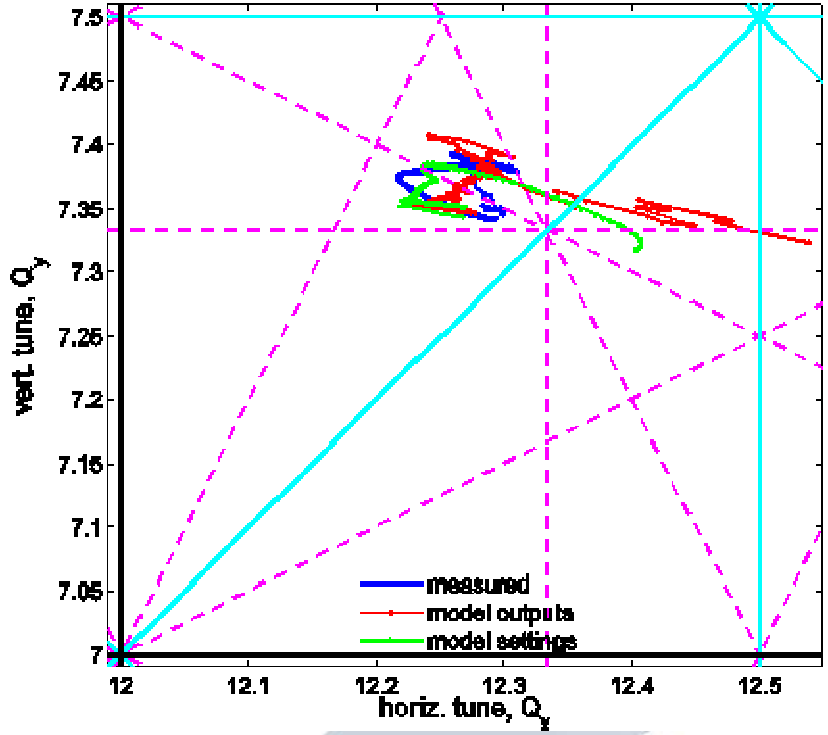
LOCO: Beta Functions (DC)

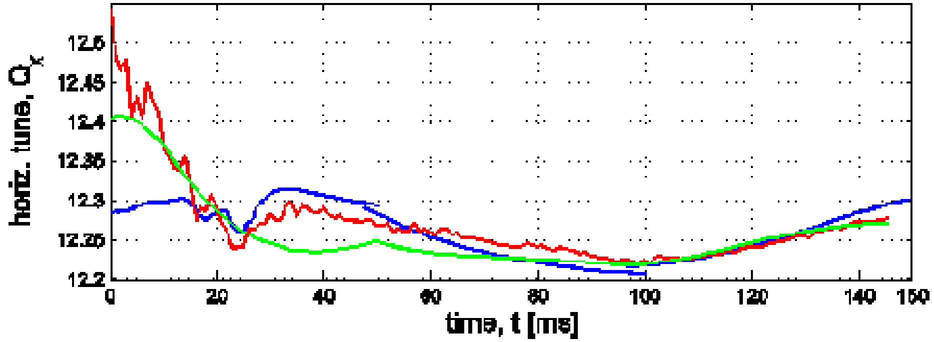


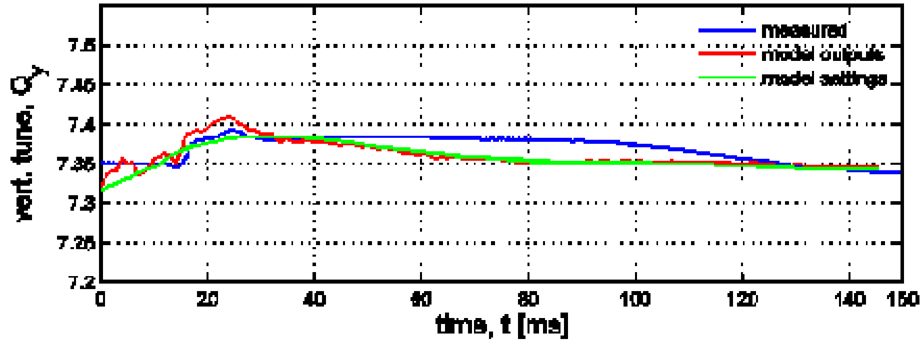
Good agreement with the model

Ramping: Tunes

4th October 2010: beam accelerated up to 3 GeV



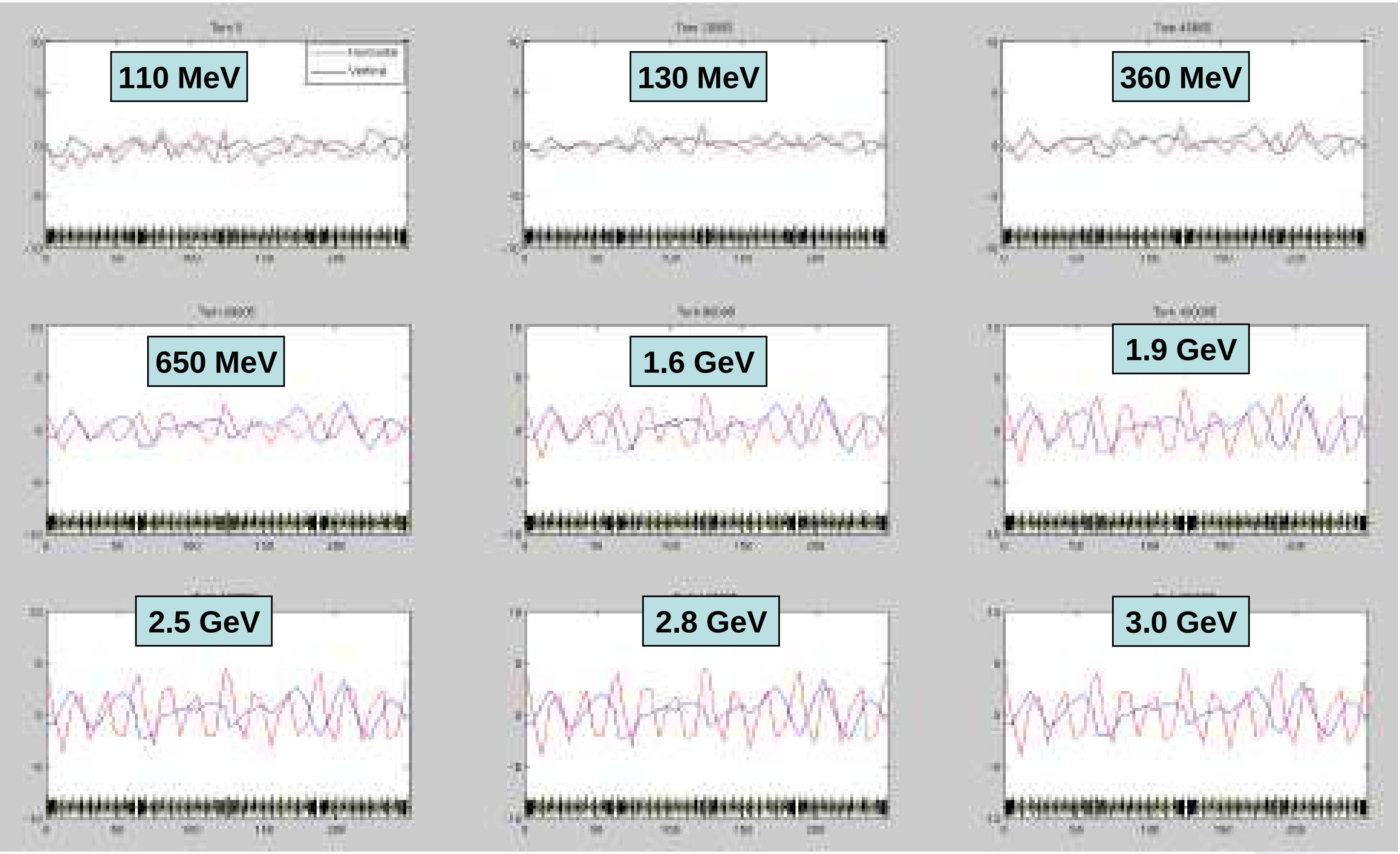




- First beam to 3 GeV: injection on w.p. (12.42, 7.38)
- Large drop of Qx at the start due to nonlinear magnet calibration
- Vertical tune is flat: most of the vertical focusing is provided by the gradient bending

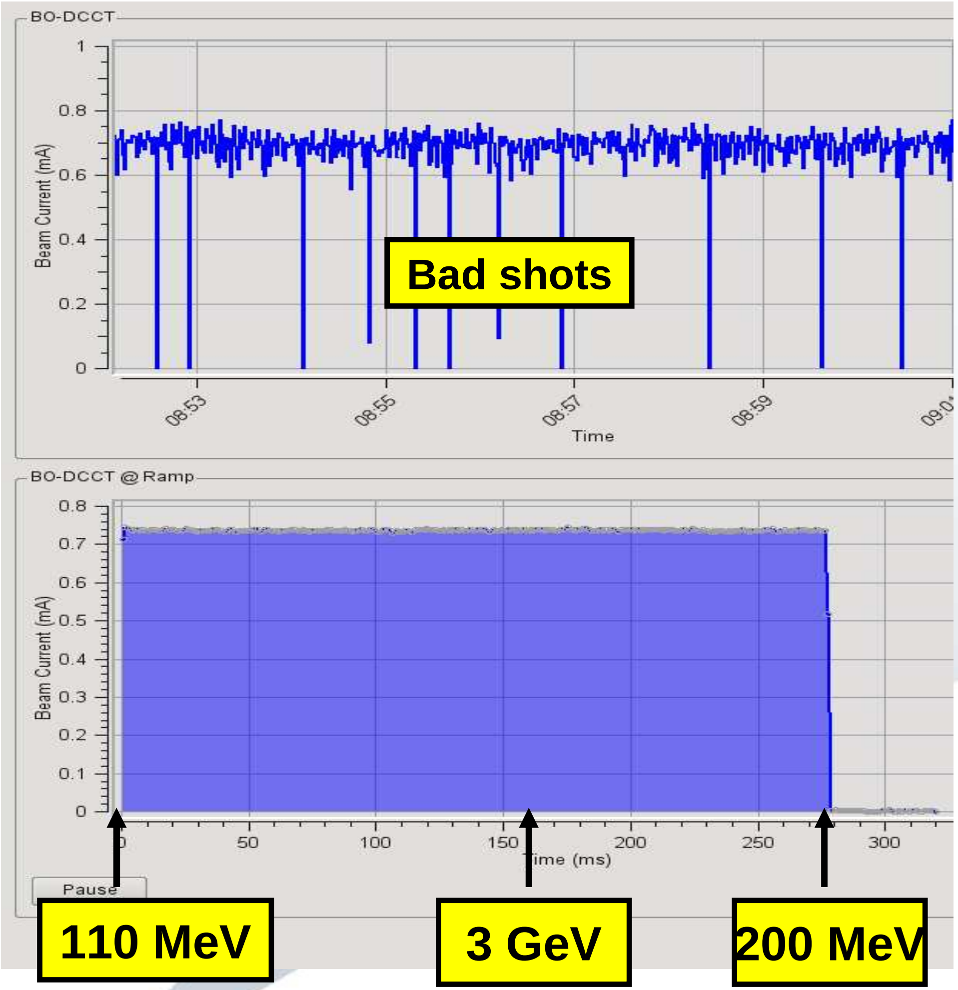
Ramping: Closed Orbit

Correcting the orbit while ramping



orbit corrected to ± 3 mm along the ramp

Beam in the Booster Synchrotron



➢ **Increase transmission**

LINAC **LT** **BO** **BT**

70%

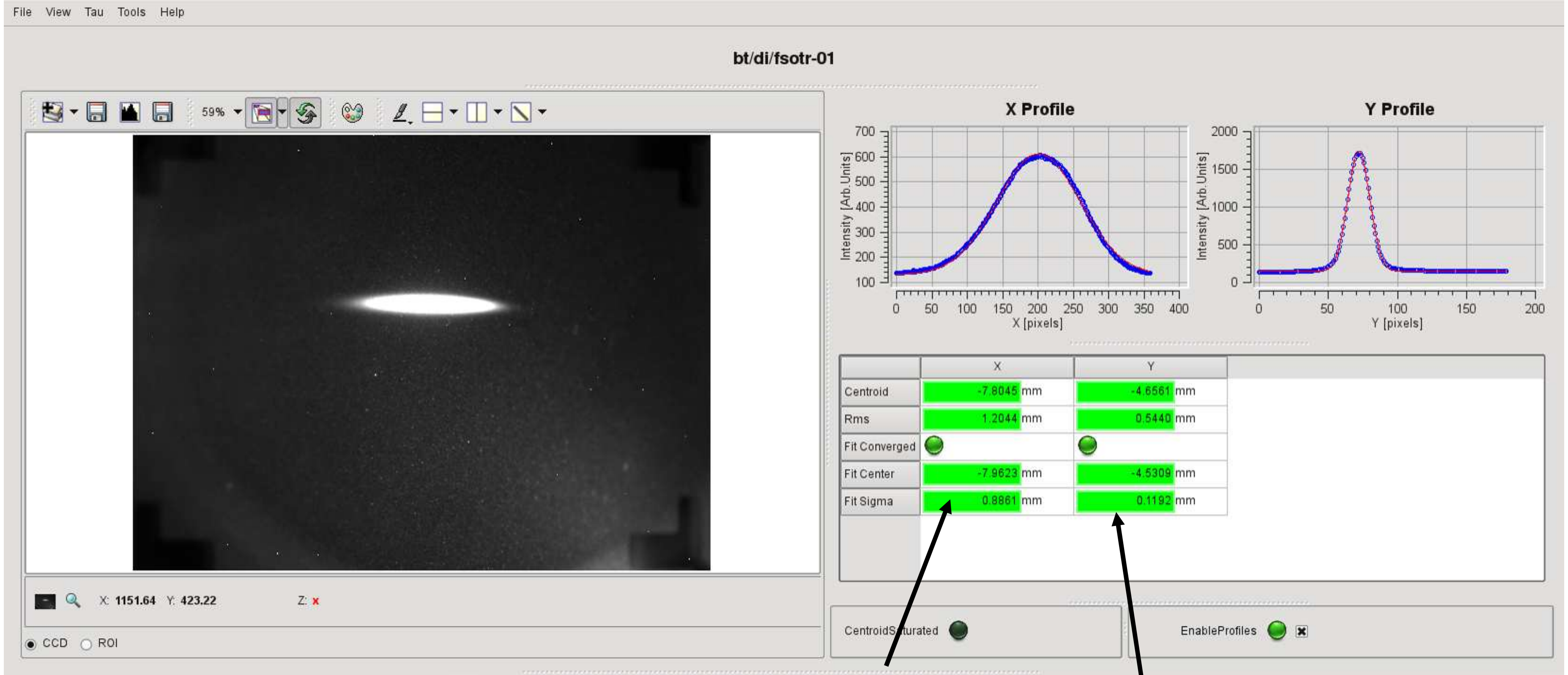
70-85 %

100 %

50 - 60%

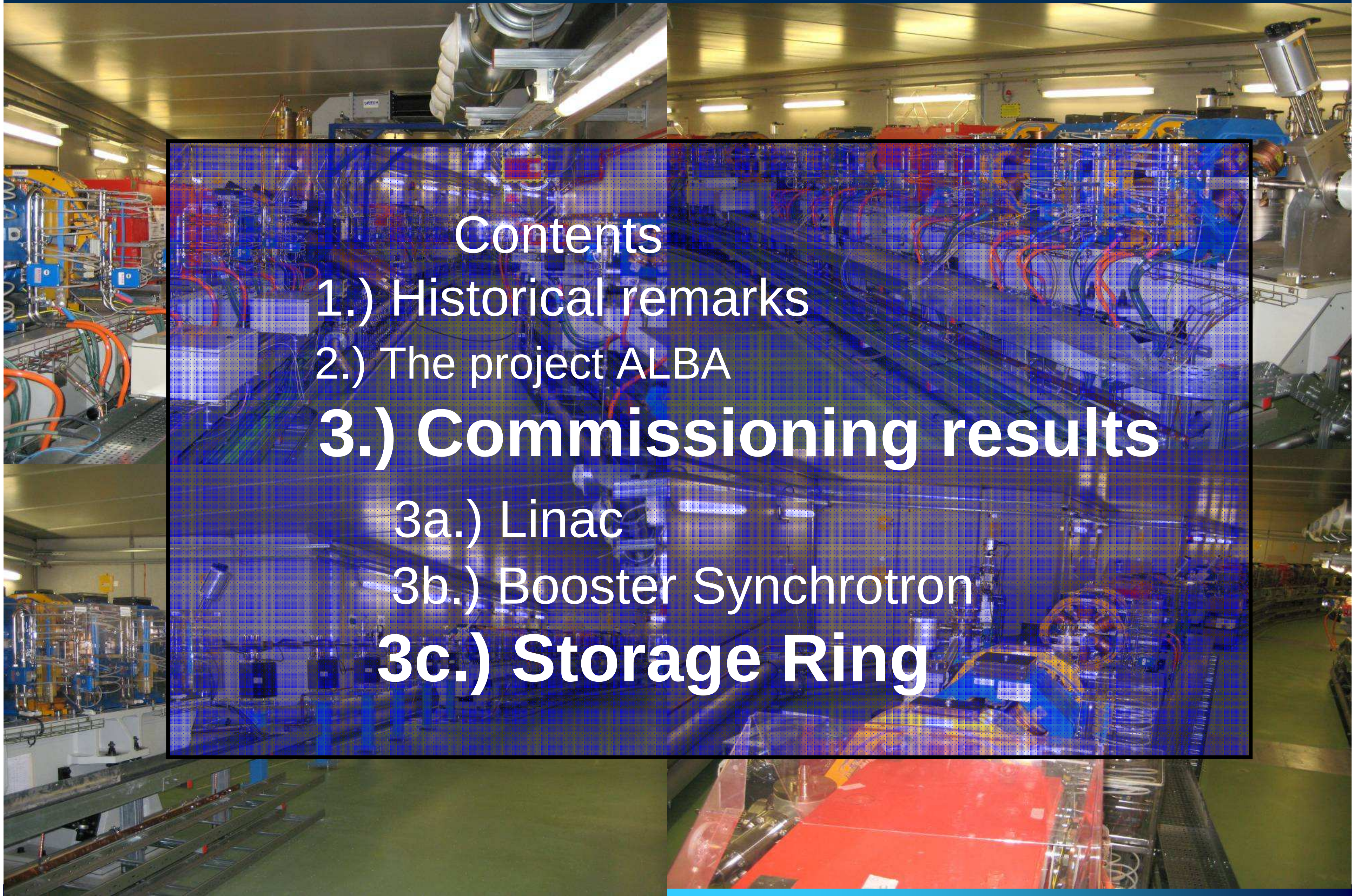
Booster Emittance

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.) Historical remarks

2.) The project ALBA

3.) Commissioning results

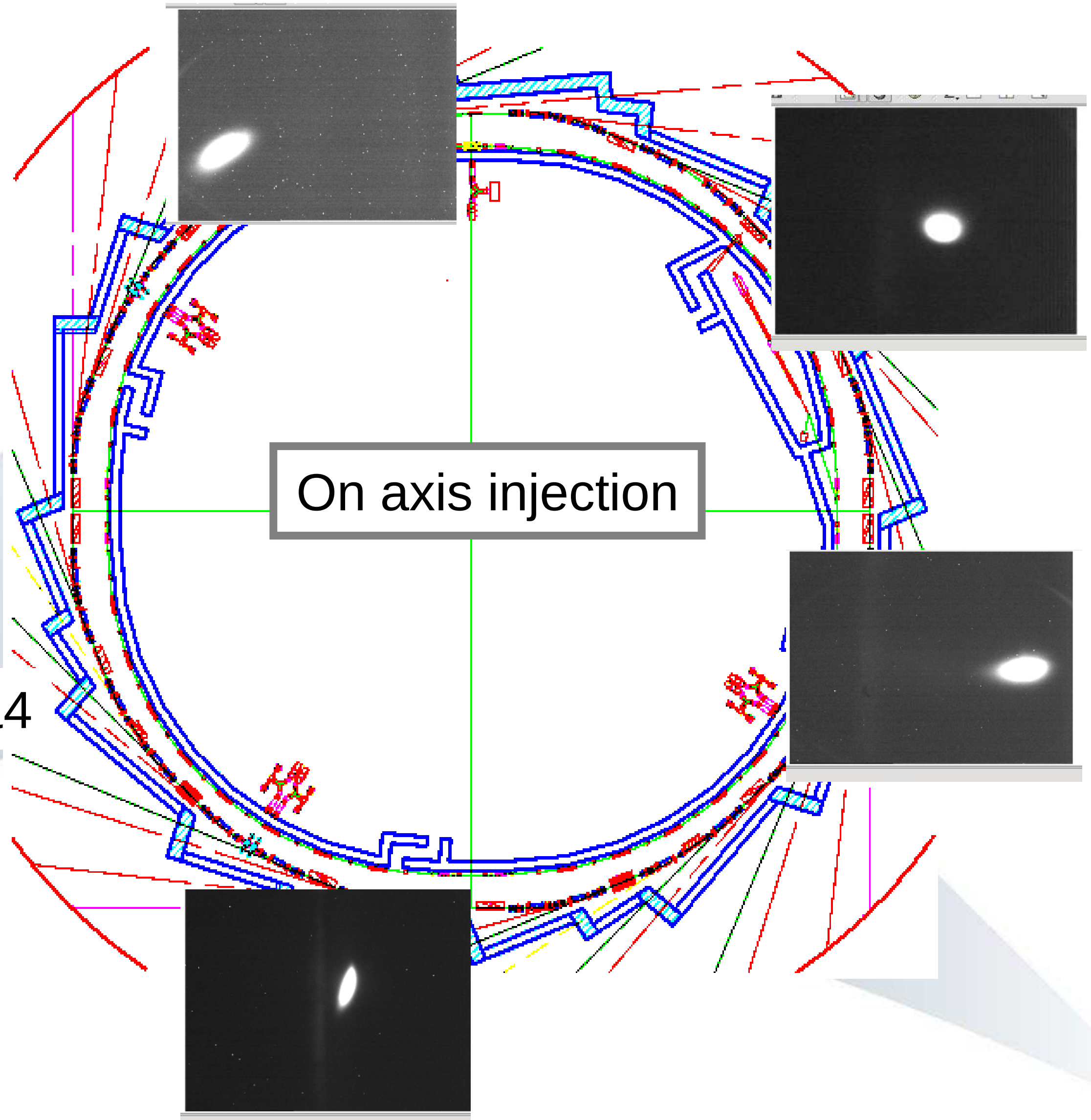
3a.) Linac

3b.) Booster Synchrotron

3c.) Storage Ring

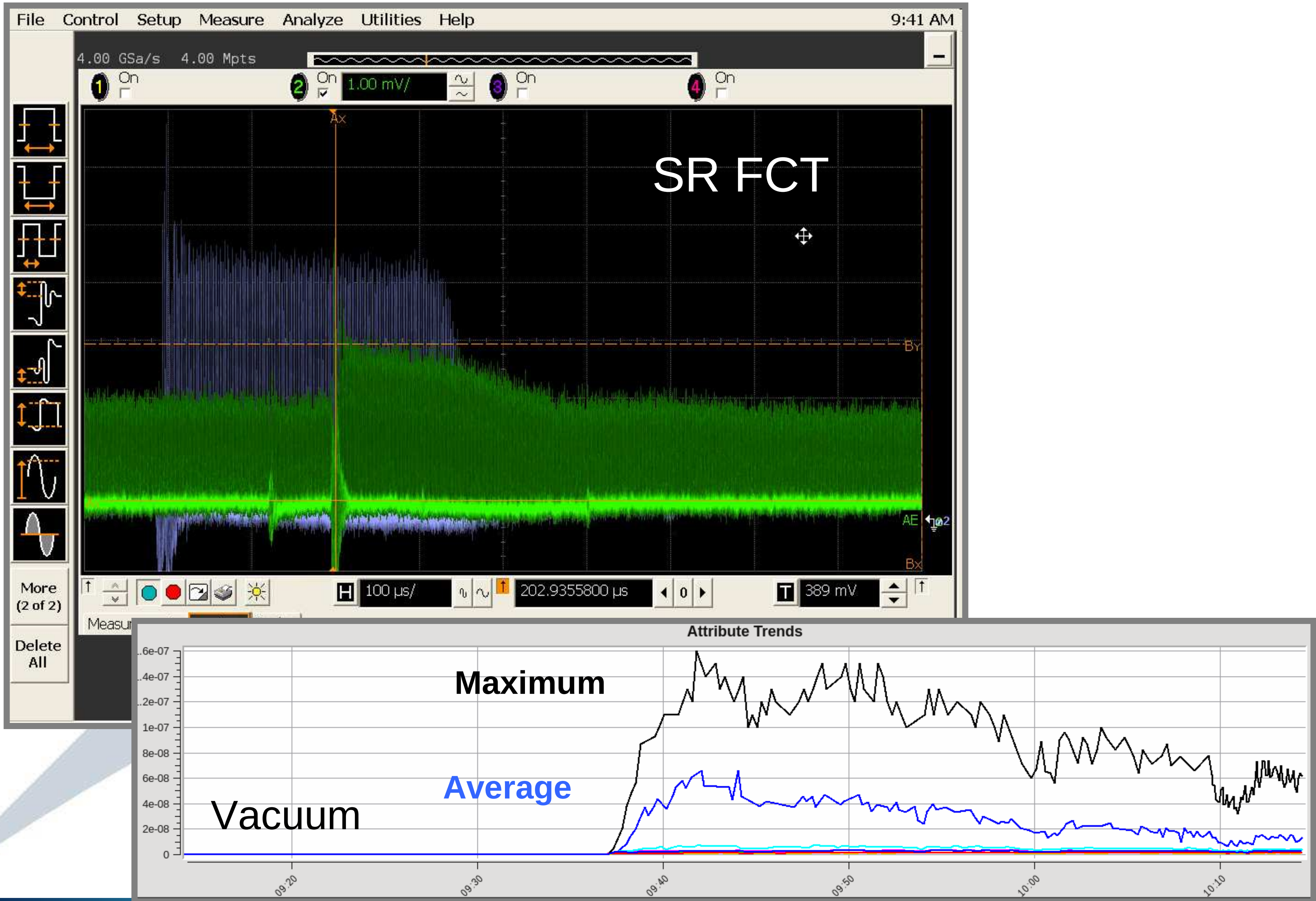
SR Commissioning: 9th March 2011

- ➢ Recabling Quads:
  - ✓ Sectors 1&2
    - ✓ Quadrant 1
      - ✓ Quadrant 2
        - ✓ Quadrants 3&4

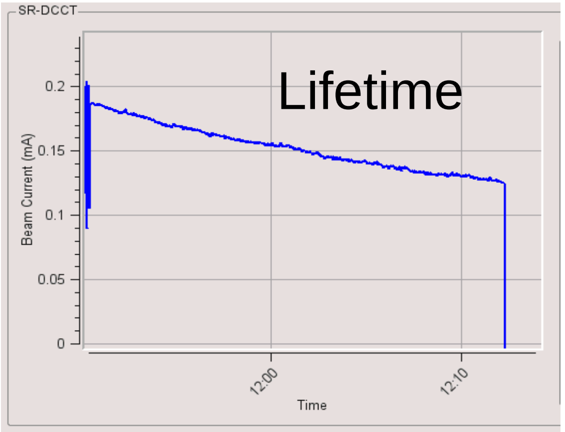


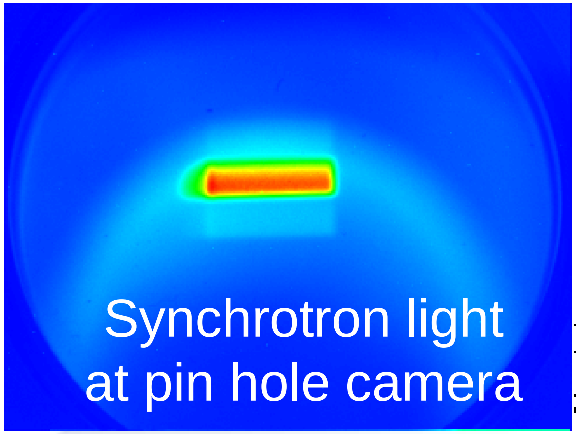
19h35: 1st turn !

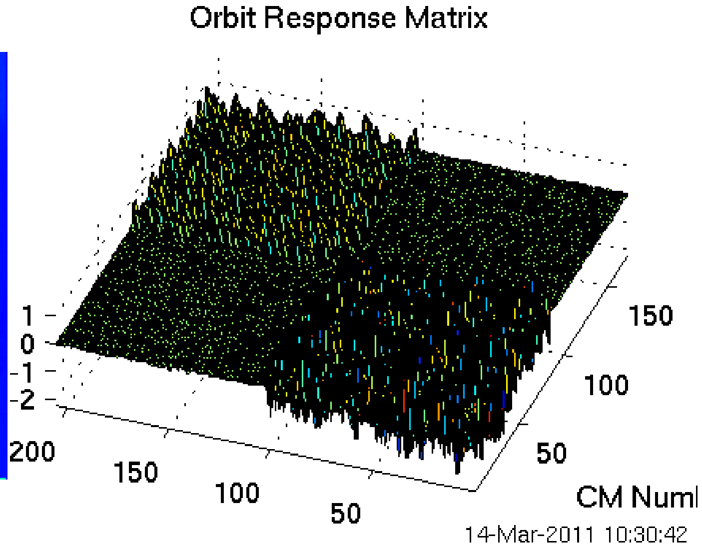
13th March, 9h38: 1 second stored beam

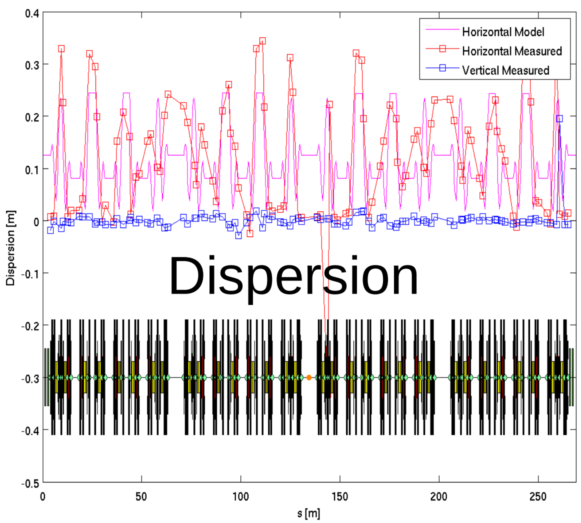


13 -14 March: Firsts measurements

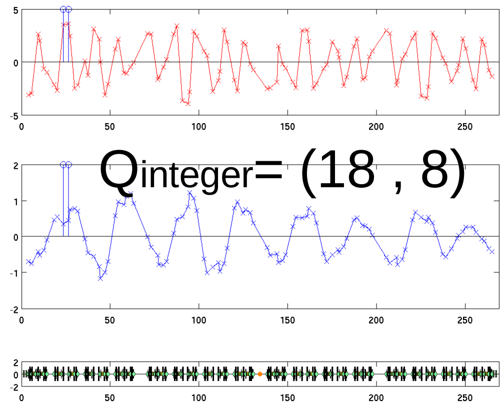






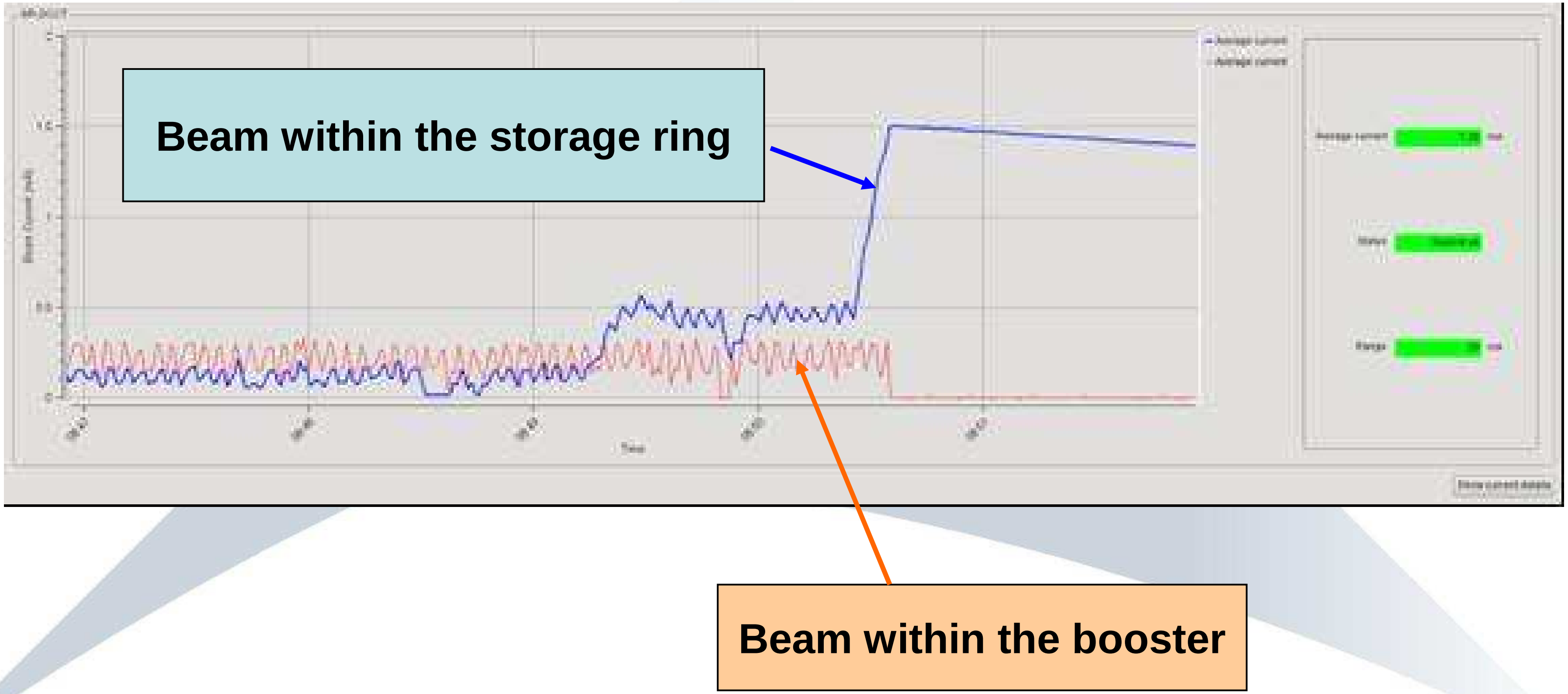


Energy =
2.92 GeV



1st Accumulated Beam at ALBA

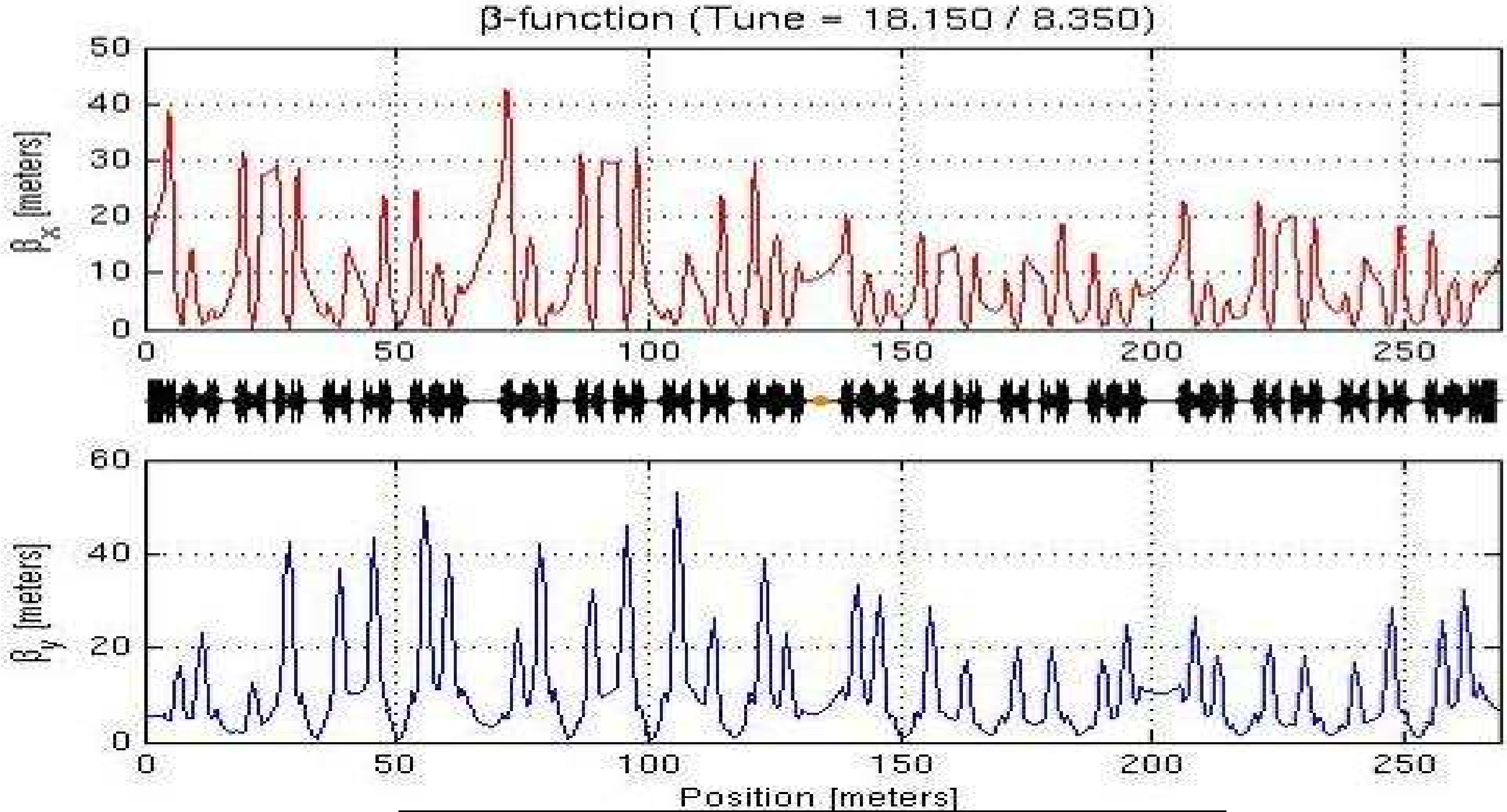
16th of March 2011:
a historical day of the ALBA – project:
the first accumulated beam at ALBA.



1st Accumulated Beam at ALBA

Beta-Functions of the SR

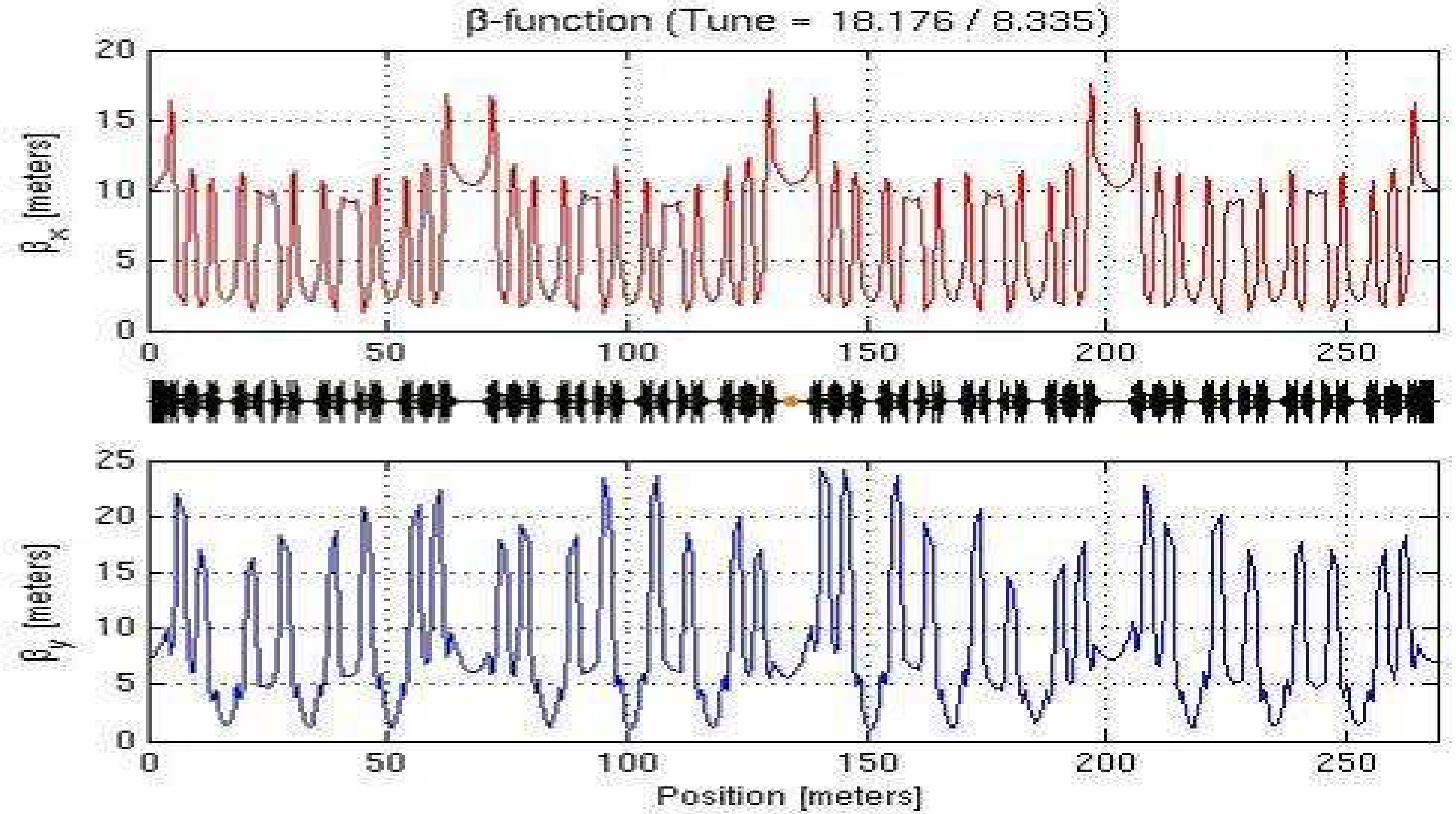
First measurements of beta function with LOCO: there is a asymmetry in the machine



Result: QF1 and QD1 in sector 8 are swapped

Beta-Functions of the SR

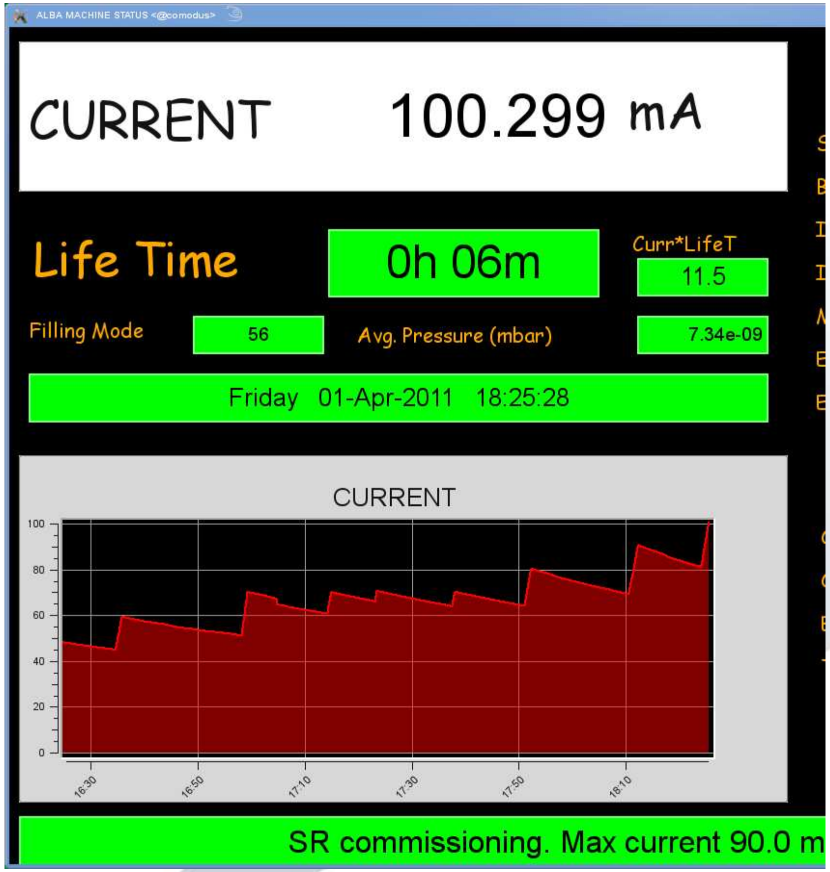
Beta functions reconstructed by LOCO after recabling QF1 and QD1



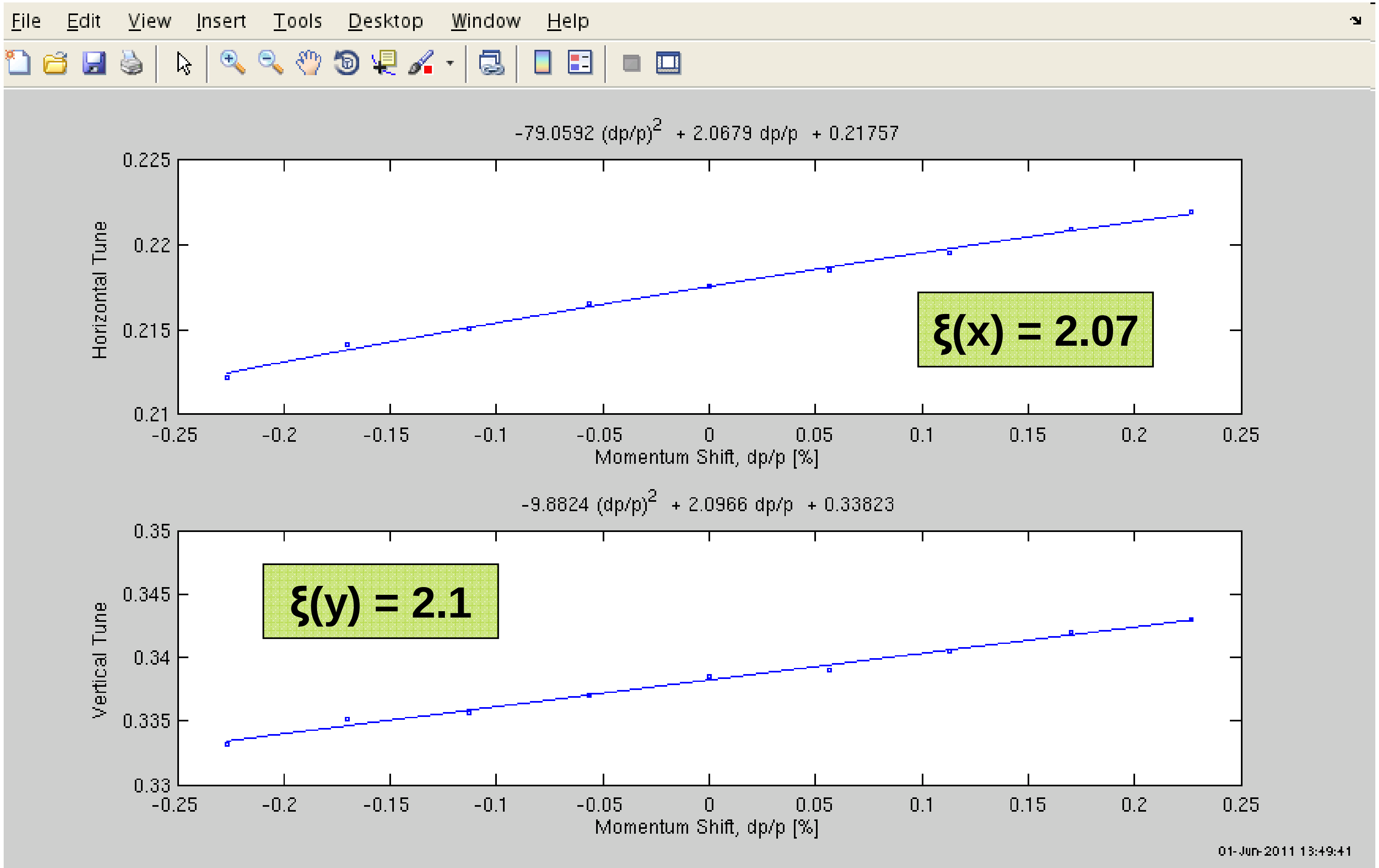
Result: It looks much better, but there is still an asymmetry in the machine (vertical)

Evening 1st April 2011

Once the MPS was operational…

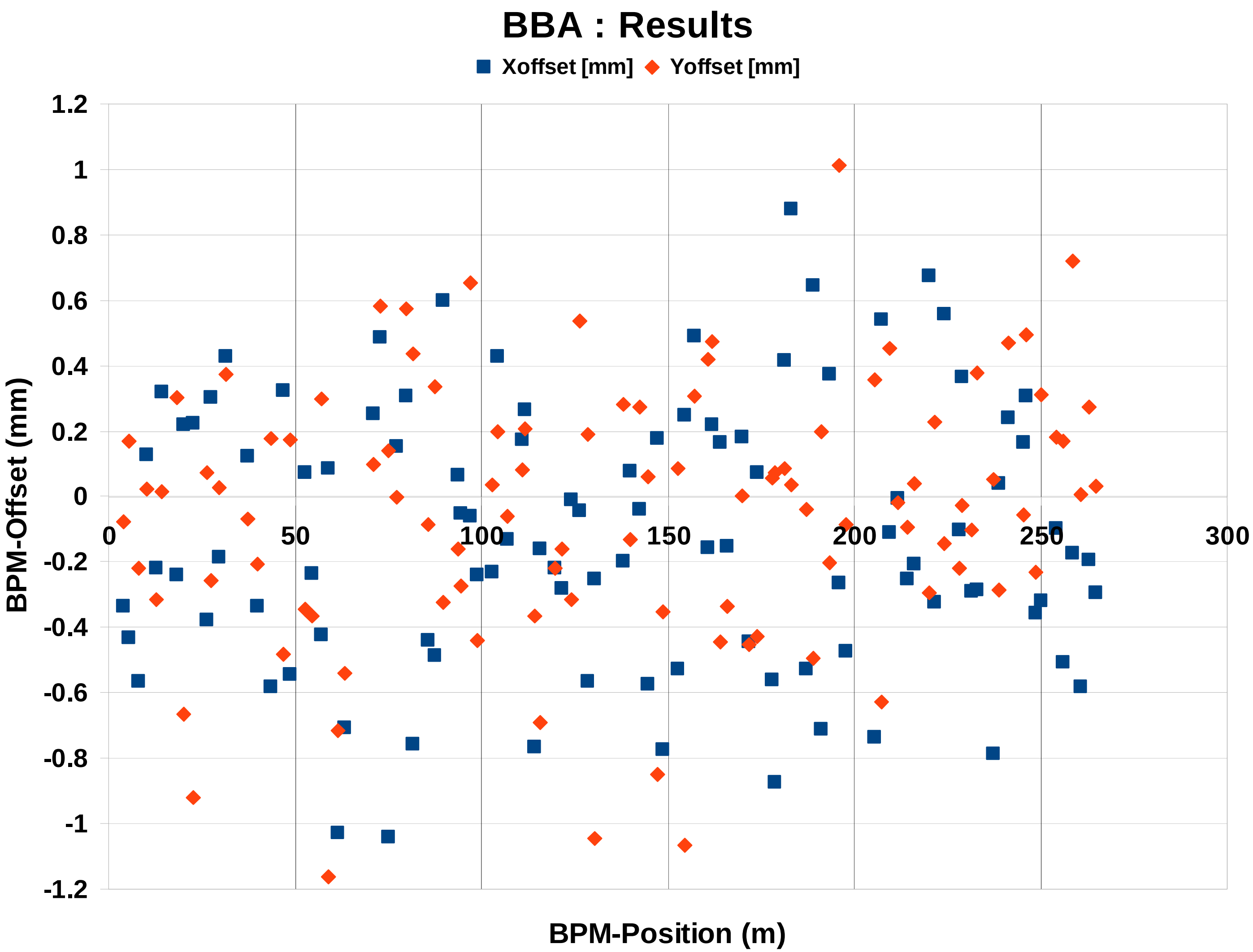


Chromaticity's



Normally working with (+2 , +2)

Beam Based Alignment

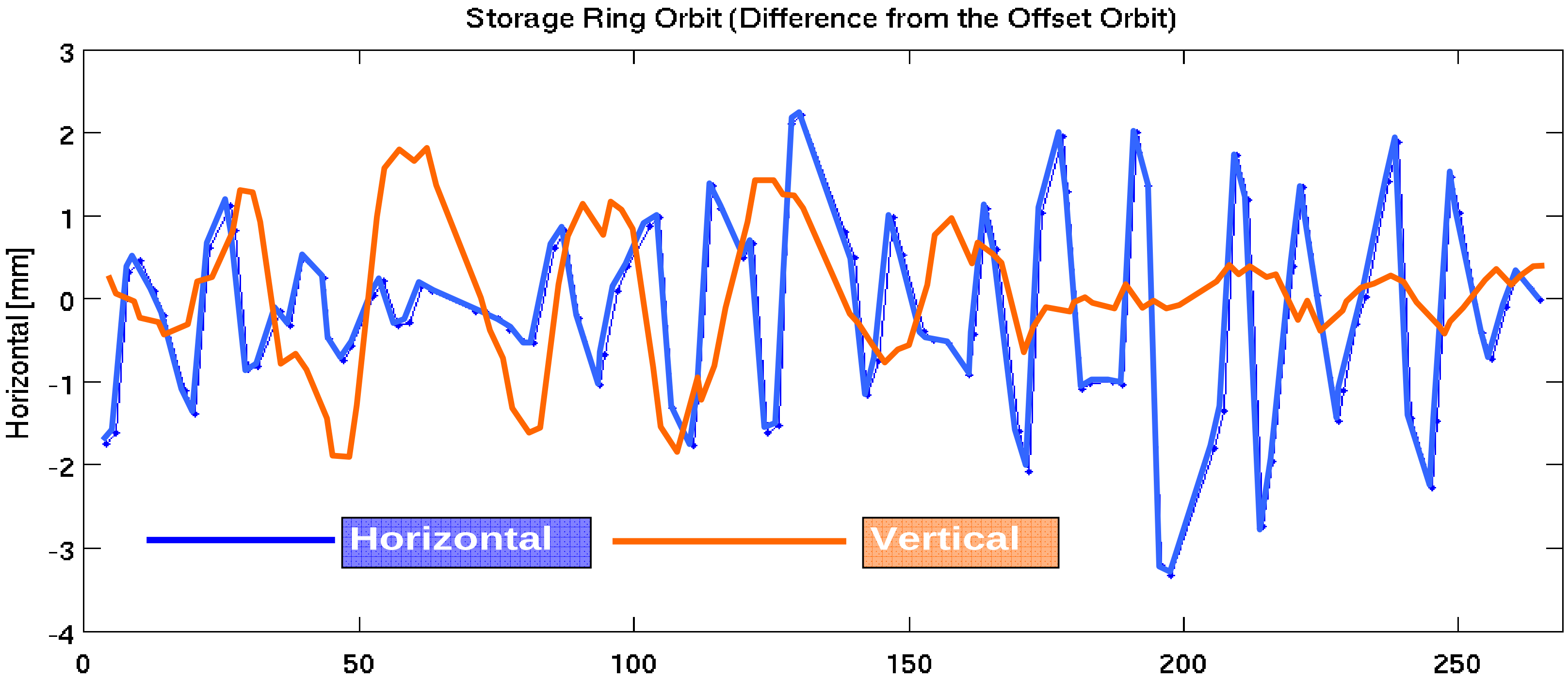


Horizontal offsets:
+1.0 mm to -1.1 mm

Vertical offsets:
+0.9 mm to -1.1 mm

Raw orbit without correctors

Offsets of BBA included and RF frequency adjusted

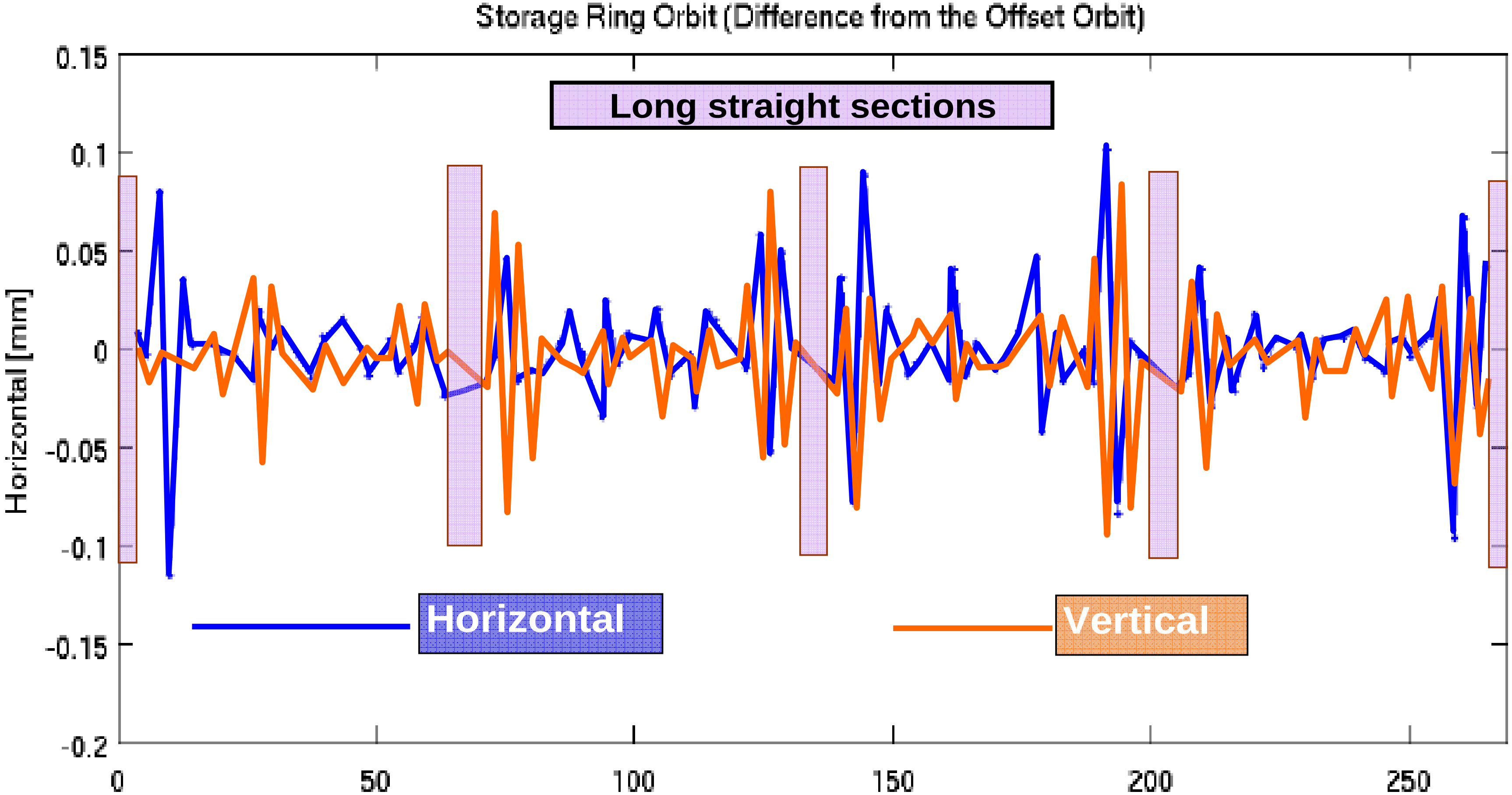


Horizontal orbit < 3mm
Vertical orbit < 2 mm

Good alignment

Orbit Correction: Reproducibility

Raw orbit with correctors

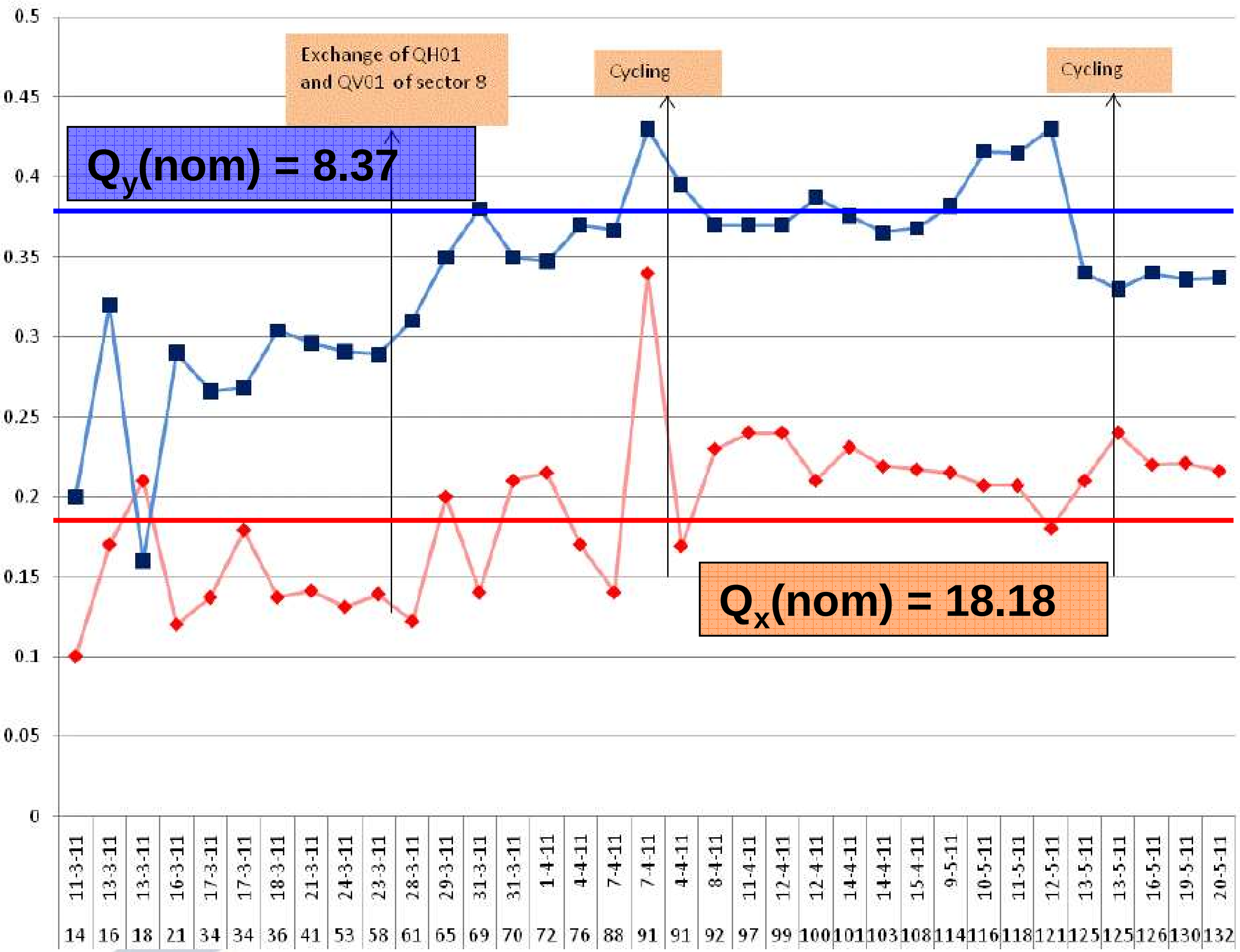


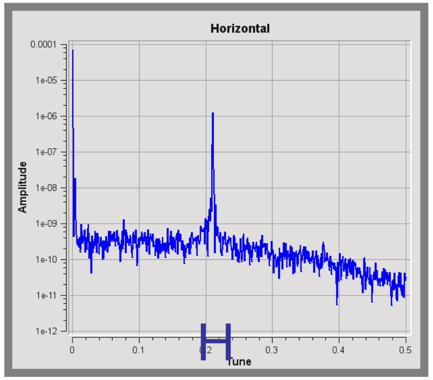
Horizontal rms error
32 um

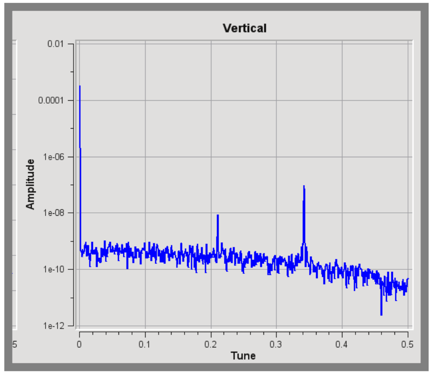
Vertical rms error
29 um

to reference orbit

Tune during the commissioning:





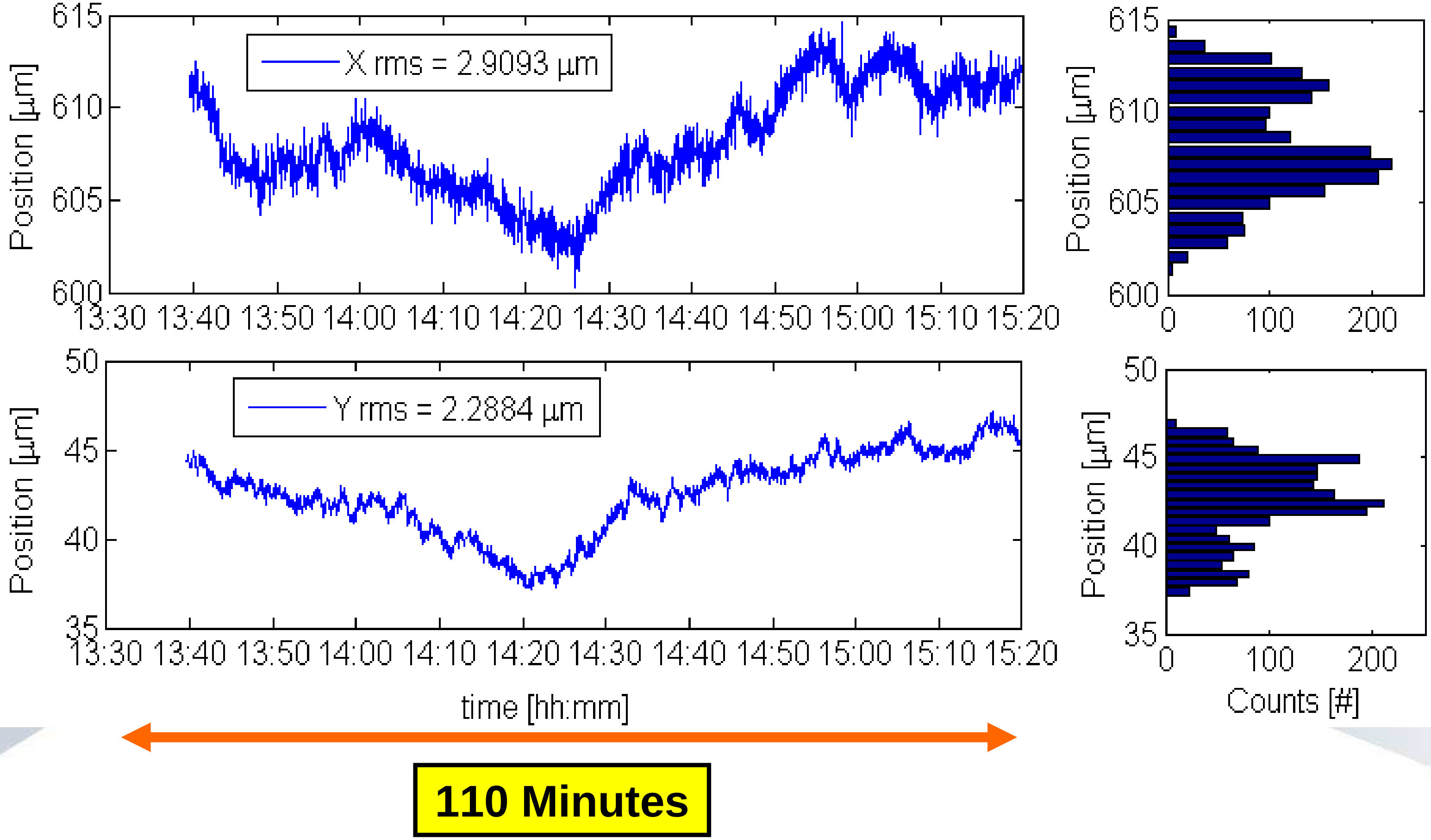


V

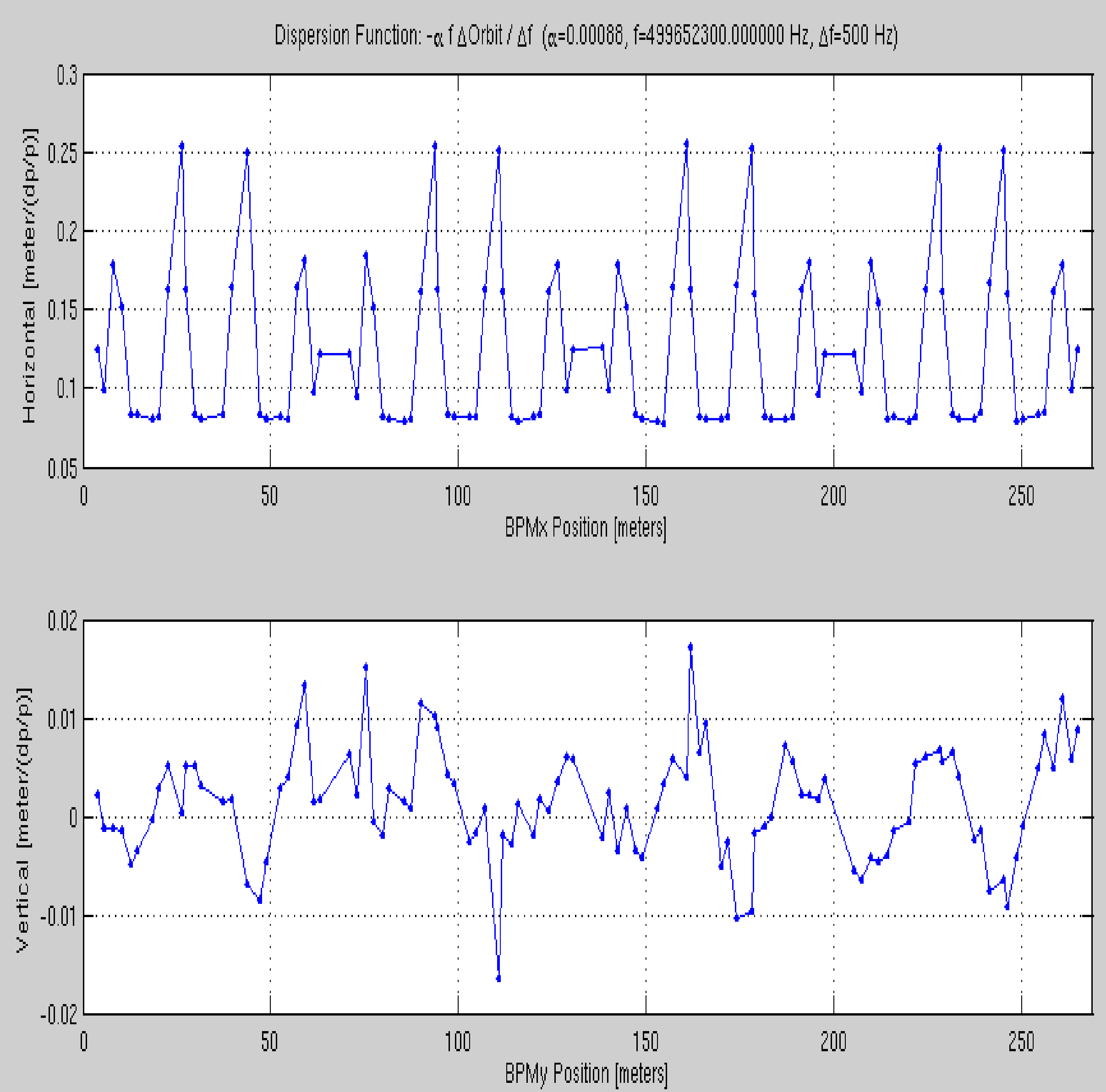
Normally working with chromaticity: +2 , +2

- 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



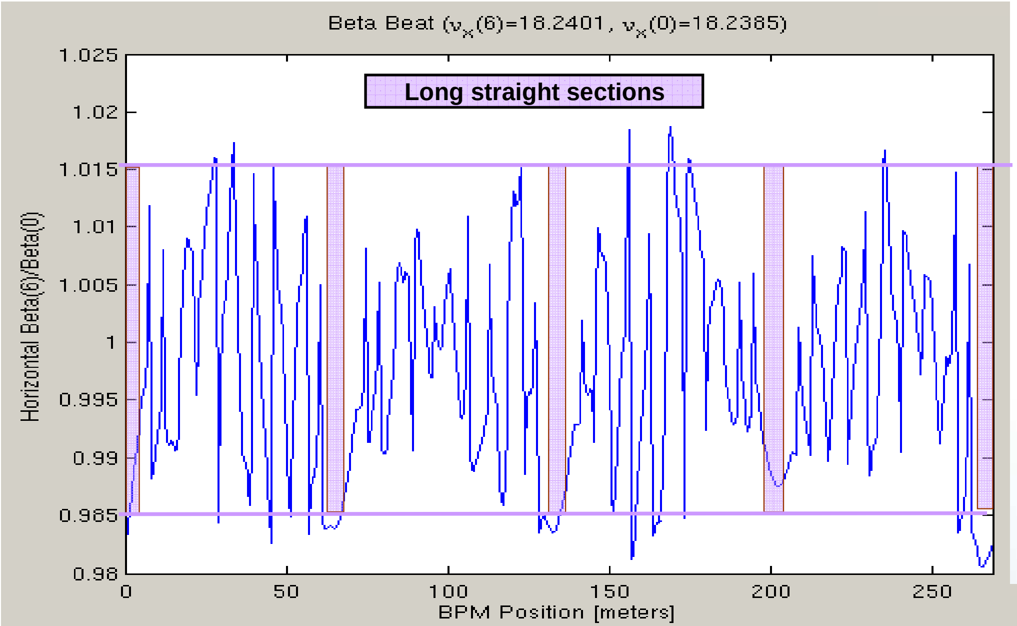
Final LOCO - Measurements



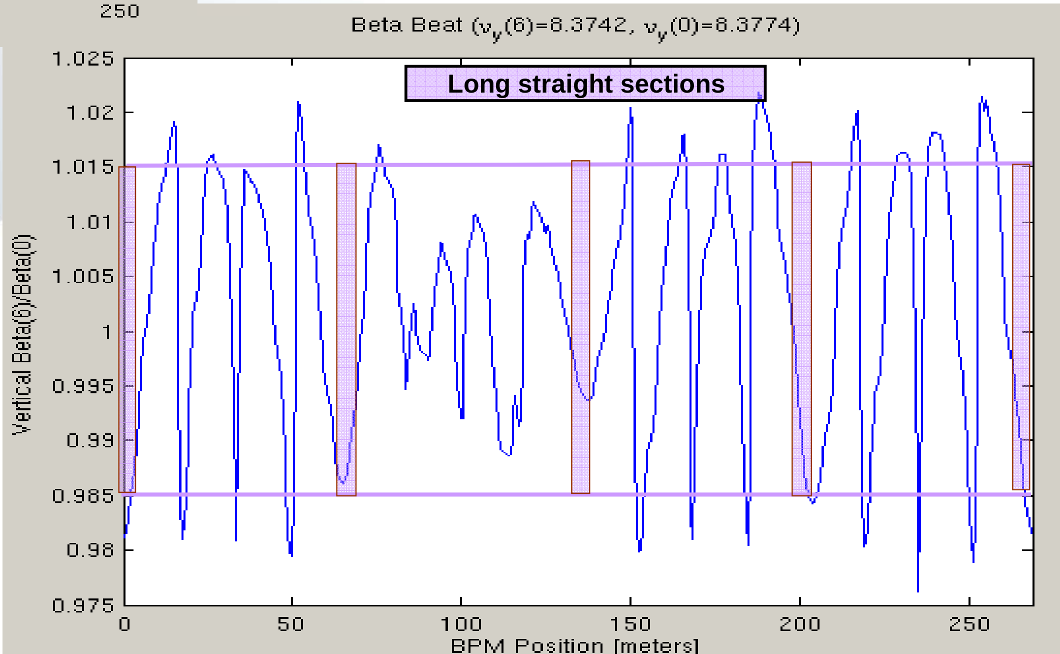
Horizontal Dispersion: the deviations to the model are +/- 5 mm. This is a good agreement.

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

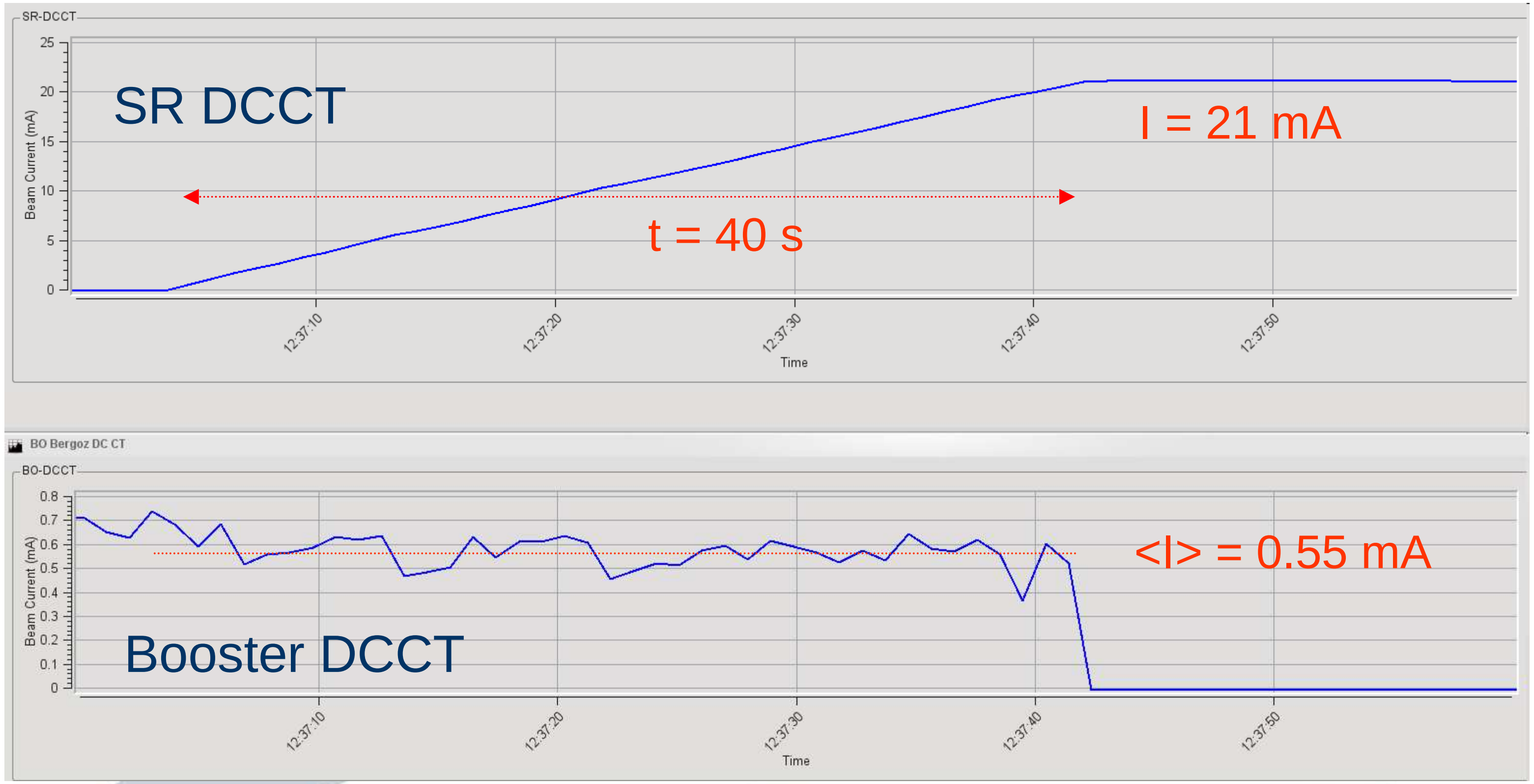


The maximum differences after the LOCO fitting are +/- 2%



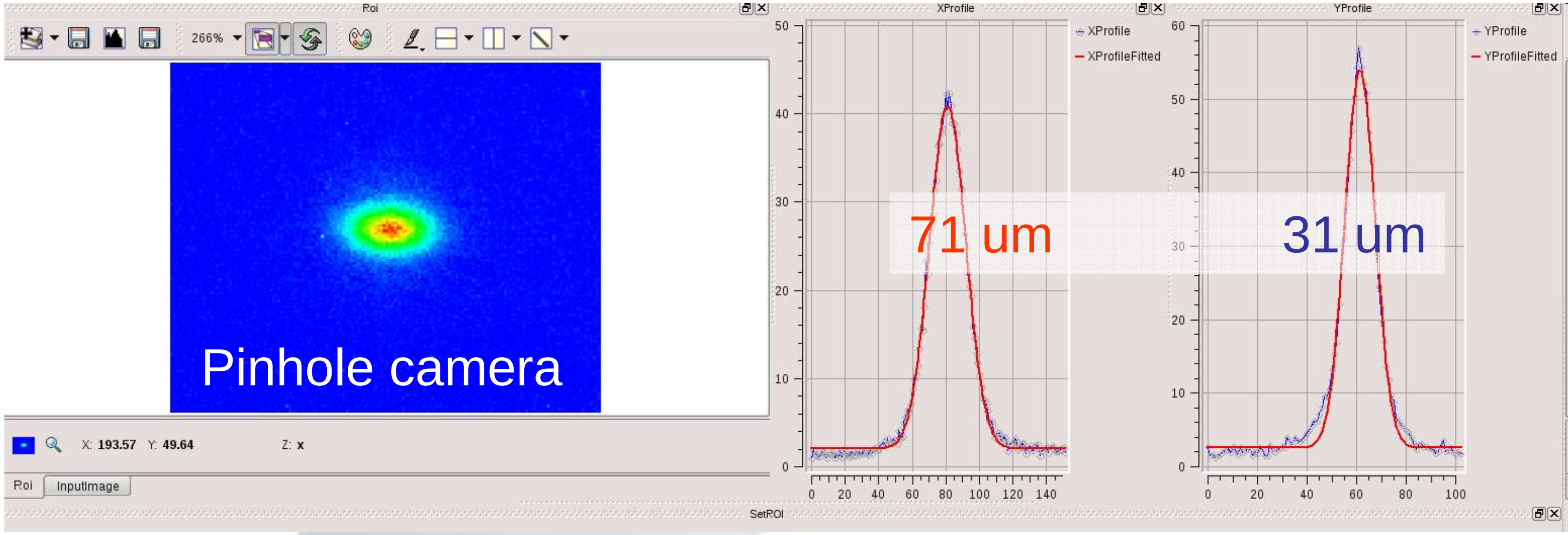
In the vertical direction there are 32 peaks and we have 32 bendings

Injection Efficiency



Injection efficiency ~ 95%

Beam Size / Emittance



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

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

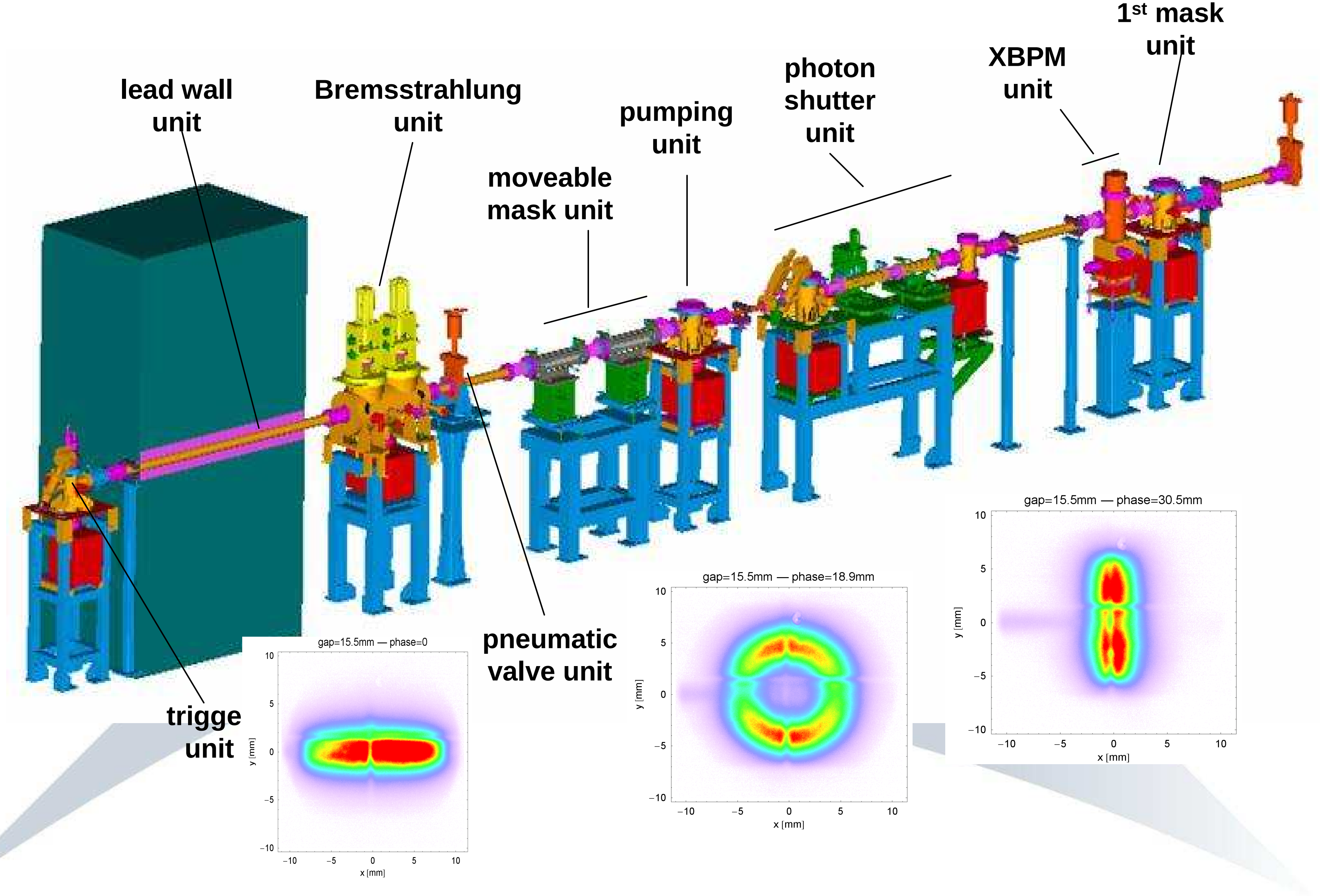
Three insertion devices have been installed and closed:

- EU62
- EU71
- MPW80

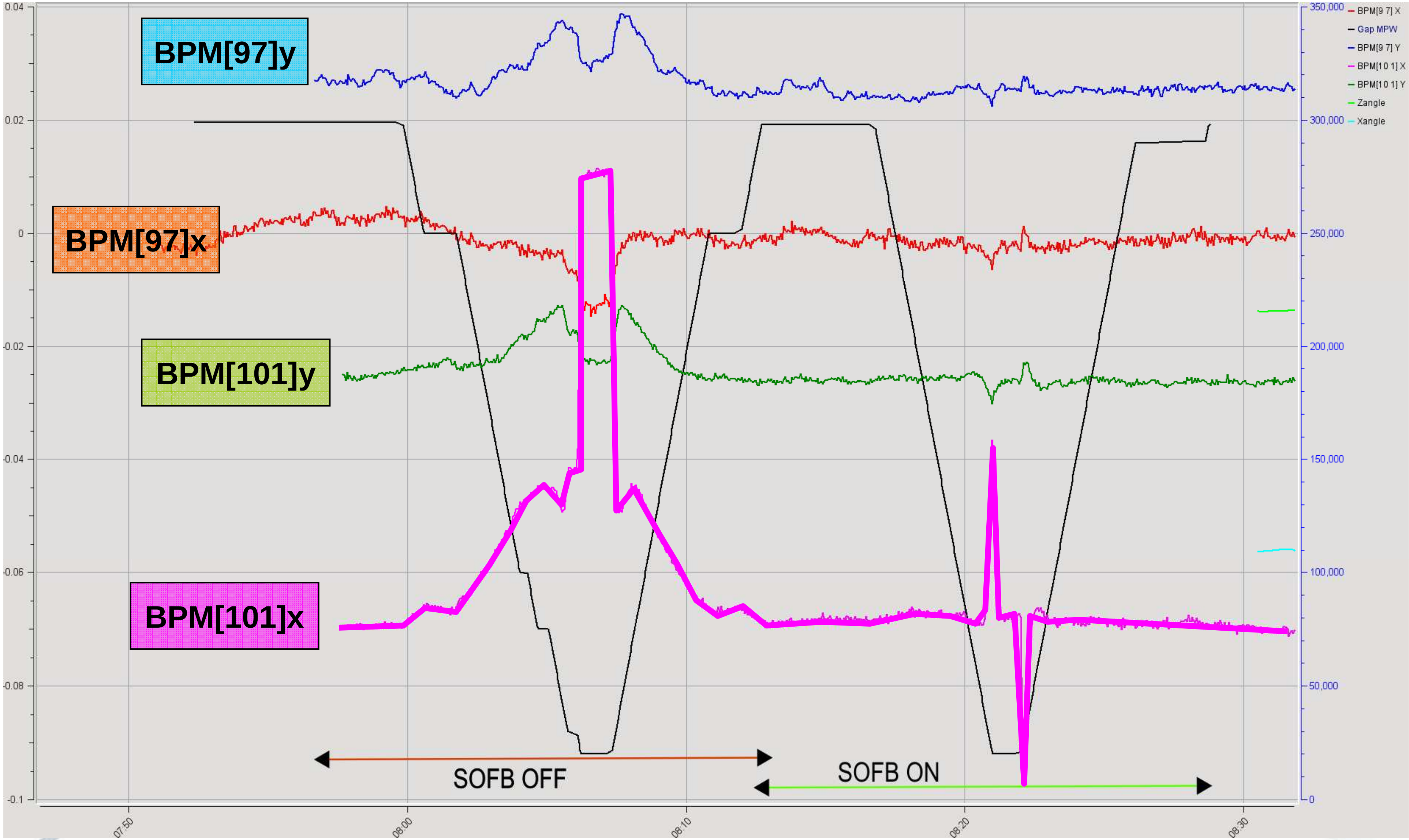
Without much influence in the machine:

MPW80 - BL22	Gap (mm)	tunes	RMS Orbit Distortion (um)	tunes change (10^-3)
OPEN	275	0.229, 0.375	0 , 0	---
1/2 CLOSED	50		11 , 57	
CLOSED	12.7	0.229 , 0.377	13 , 9	0 , 2
OPEN	275	0.229 , 0.376	14 , 14	0 , 1

EU71 - BL29	Gap (mm)	Phase (um)	tunes	RMS Orbit (um)	tunes change (10^-3)
OPEN	273	0	0.229, 0.376	0 , 0	---
HORIZONTAL (0)	15.5	0	0.230, 0.376	15, 14	+1 , 0
CIRCULAR (pi/2)	15.5	21181	0.228, 0.377	15, 14	-1, +1
VERTICAL (pi)	15.5	35650	0.228, 0.377	16, 15	-1, +1
CIRCULAR (-pi/2)	15.5	-21181	0.228, 0.377	15 , 15	-1, +1
VERTICAL (-pi)	15.5	-35650	0.228, 0.377	16 , 15	-1 , +1
OPEN	273	0	0.229, 0.376	15 , 16	0 , 0


1st mask unit
XBPM unit
photon shutter unit
pumping unit
lead wall unit
Bremsstrahlung unit
moveable mask unit
pneumatic valve unit
trigge unit
gap=15.5mm — phase=0
gap=15.5mm — phase=18.9mm
gap=15.5mm — phase=30.5mm
y [mm]
x [mm]

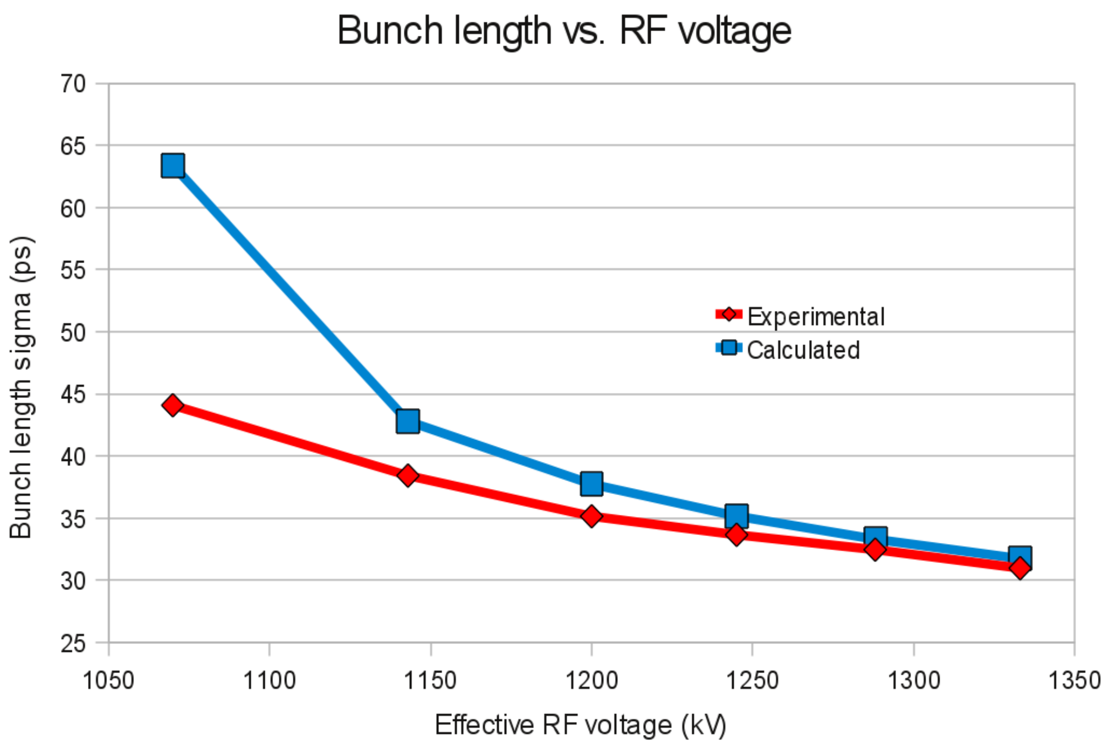
SOFB Test

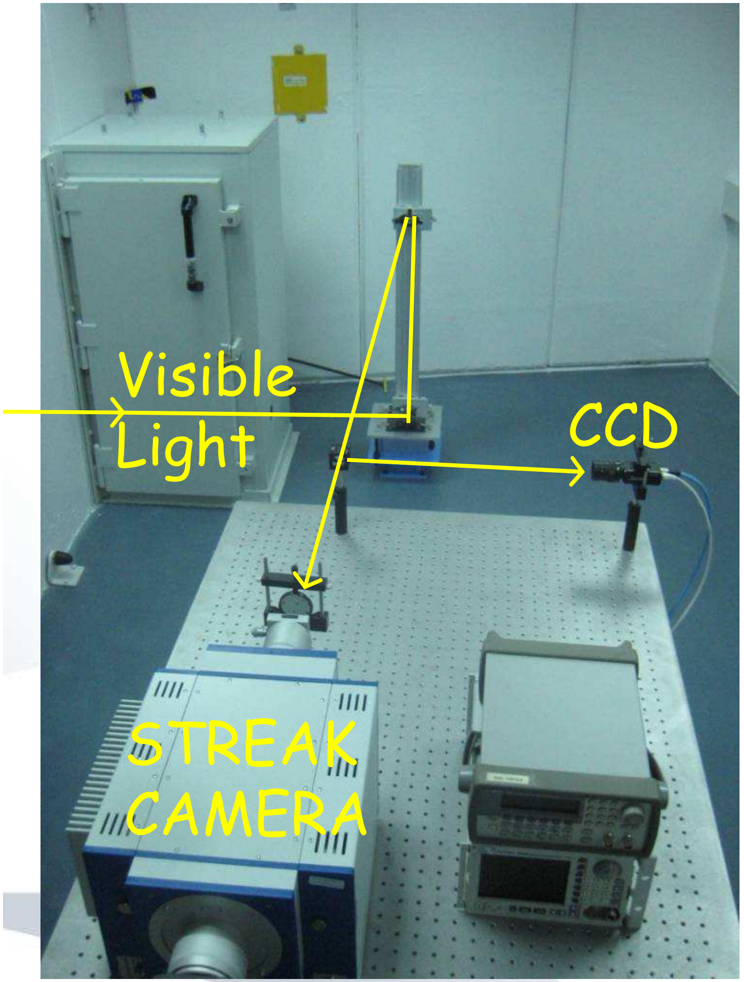

BPM[97]y
BPM[97]x
BPM[101]y
BPM[101]x
SOFB OFF
SOFB ON
BPM[9 7] X
Gap MPW
BPM[9 7] Y
BPM[10 1] X
BPM[10 1] Y
Zangle
Xangle
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
07:50
08:00
08:10
08:20
08:30

Streak Camera

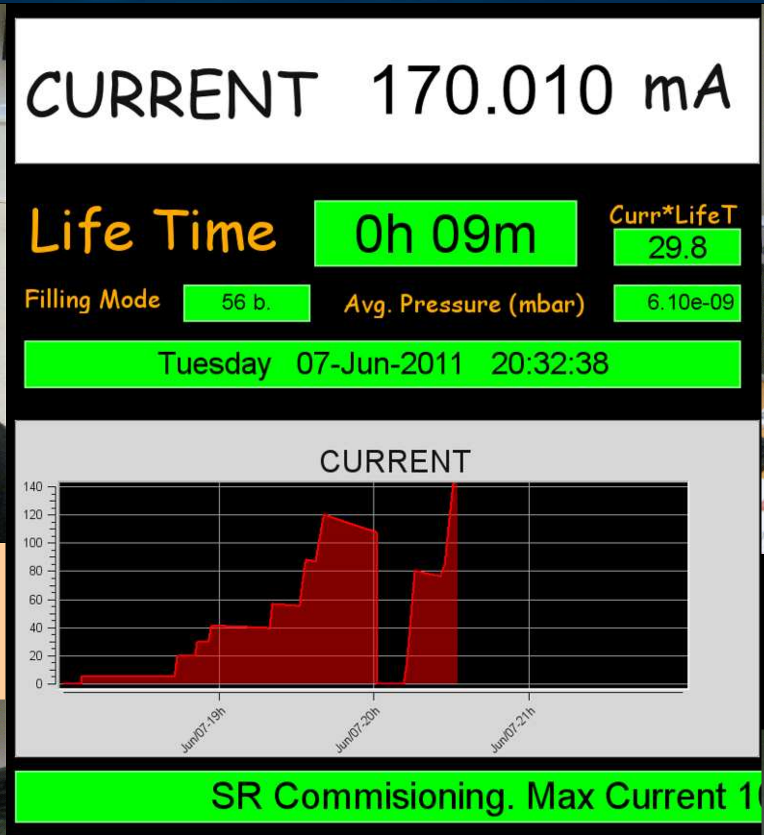
- Visible Radiation from a dipole is extracted using a mirror
- Mirror position (in-vacuum) controlled with thermocouples

Example: Bunch Length Measurement

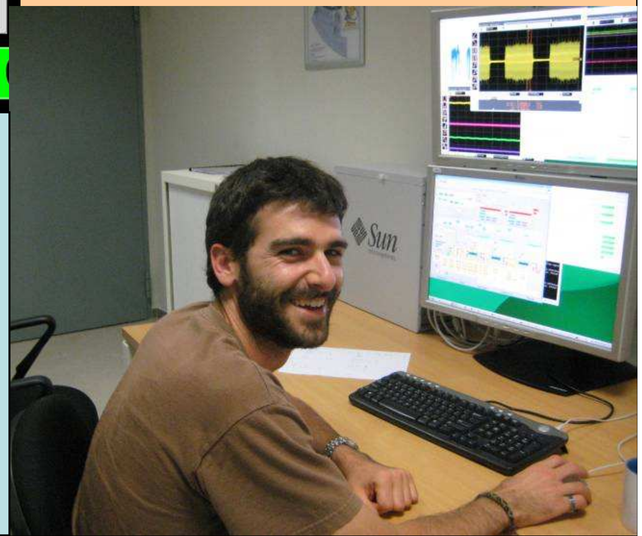




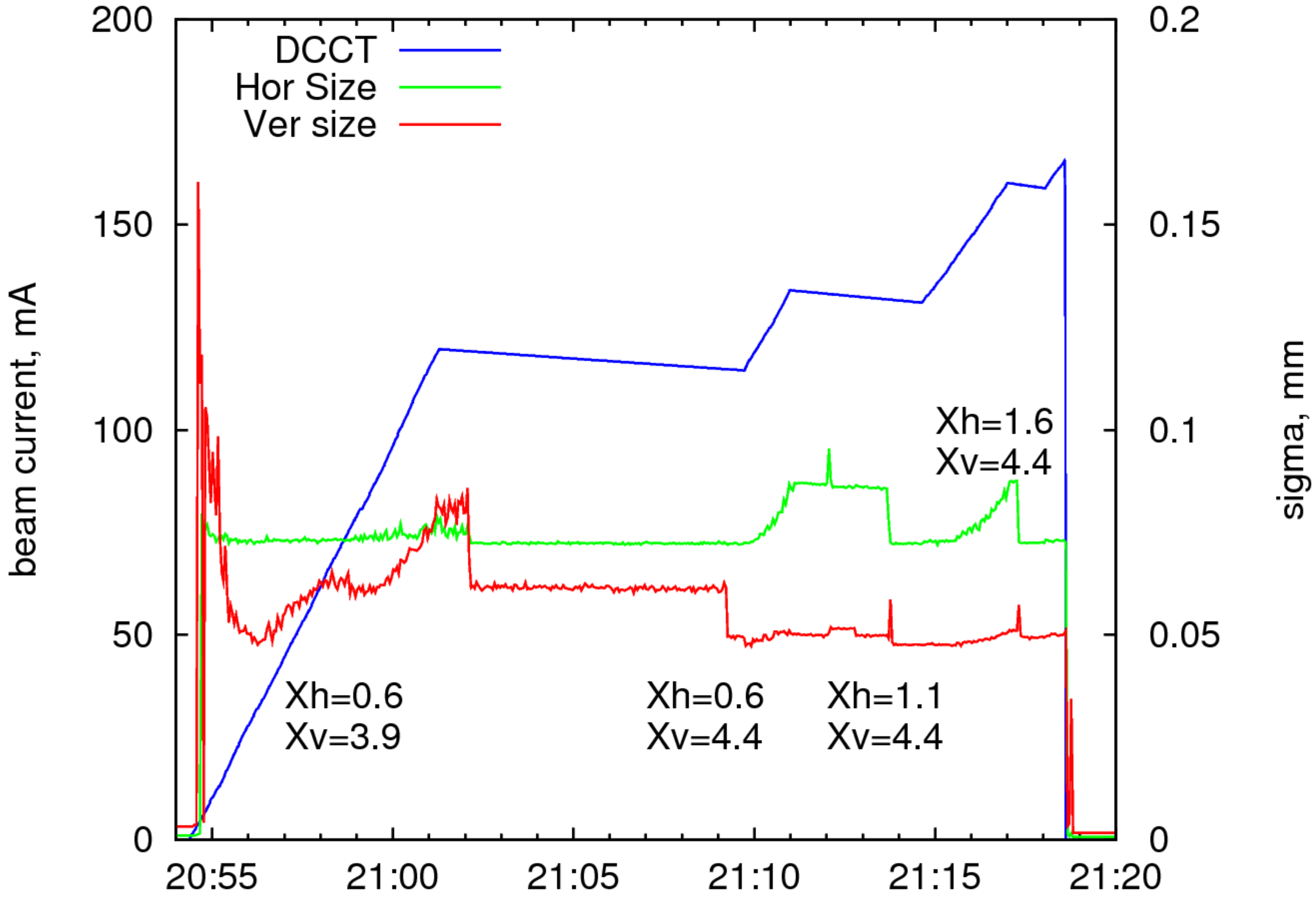
7th of June: 170 mA at ALBA



The commissioning could only be done with 3 to 4 cavities with a maximum current of 200 mA

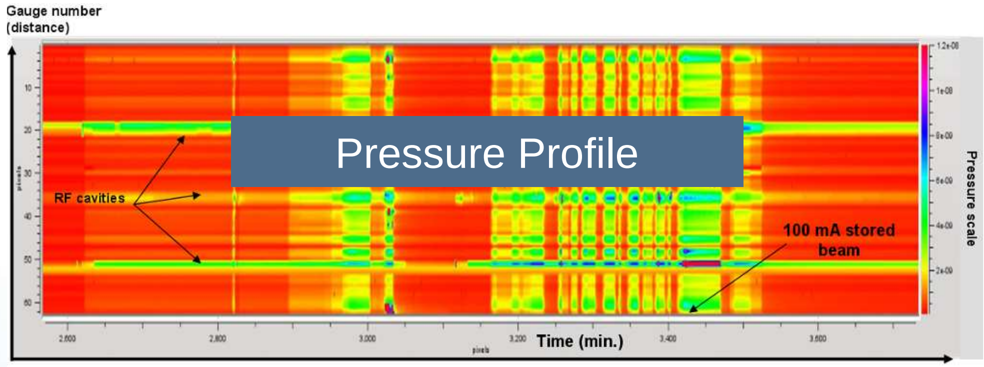


7th of June: 170 mA at ALBA

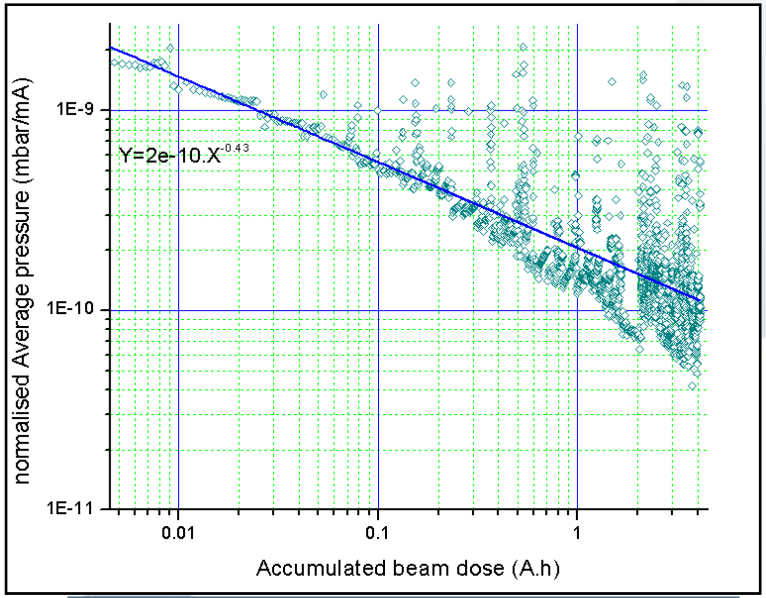


Vacuum System Commissioning

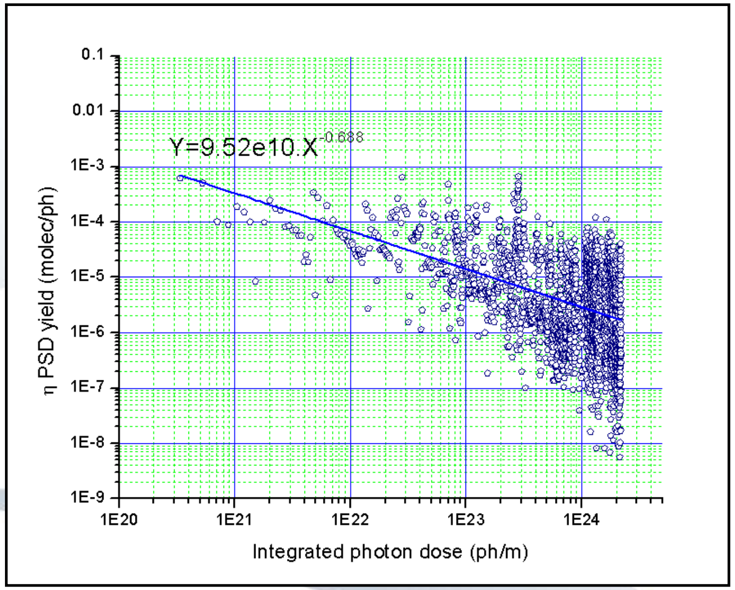
- **Average pressure without beam = <u>4·10^{-10} mbar.</u>**
- **With 4.5 A.h. dose, the average pressure was <u>3.2·10^{-9} mbar</u> with 80 mA of beam current (multi-bunch filling mode).**
- **<u>Vacuum Clean-up rate estimated 0.68.</u>**



Pressure Profile



Average pressure normalized to current vs. beam dose



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

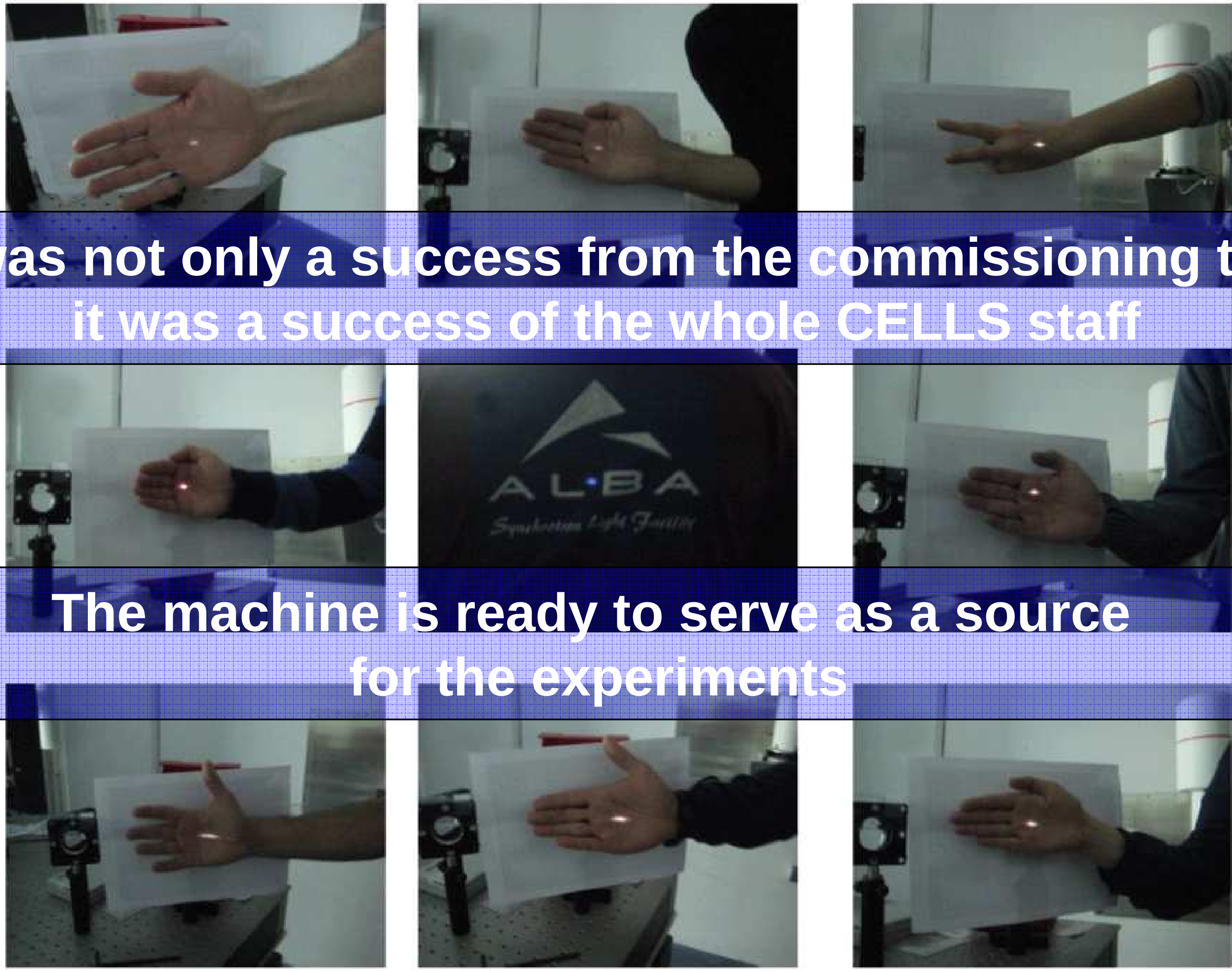
Summary of Measurements

- 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)

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

Other Contributions at IPAC 2011

[1] M.Pont et al., "Operation of the ALBA injector",
[2] G. Benedetti et al., ”Modeling Results of the ALBA
[3] M. Munoz et al., “Orbit Studies during ALBA
[4] G. Benedetti et al., “LOCO in the ALBA Storage
[5] F. Perez et al., “Commissioning of the ALBA Storage Ring RF Systems”
[6] B. Bravo et al., “CaCo: A Cavity Combiner for IOTs Amplifier”
[7] M. Pont et al., “Septum and Kicker Magnets for the ALBA ……”,
[8] J. Campmany et al., “Performance of ID at ALBA”,
[9] T.F. Guenzel, “Transverse Instability Studies at the ALBA Storage Ring”
[10] T.F. Guenzel, “Longit. Beam Stability and related Effects at the ALBA”
[11] E. Al-Dmour et. al, “ALBA storage ring vacuum system commissioning”
[12] J. Marcos et al, “Front Ends at ALBA”