MAX IV Commissioning

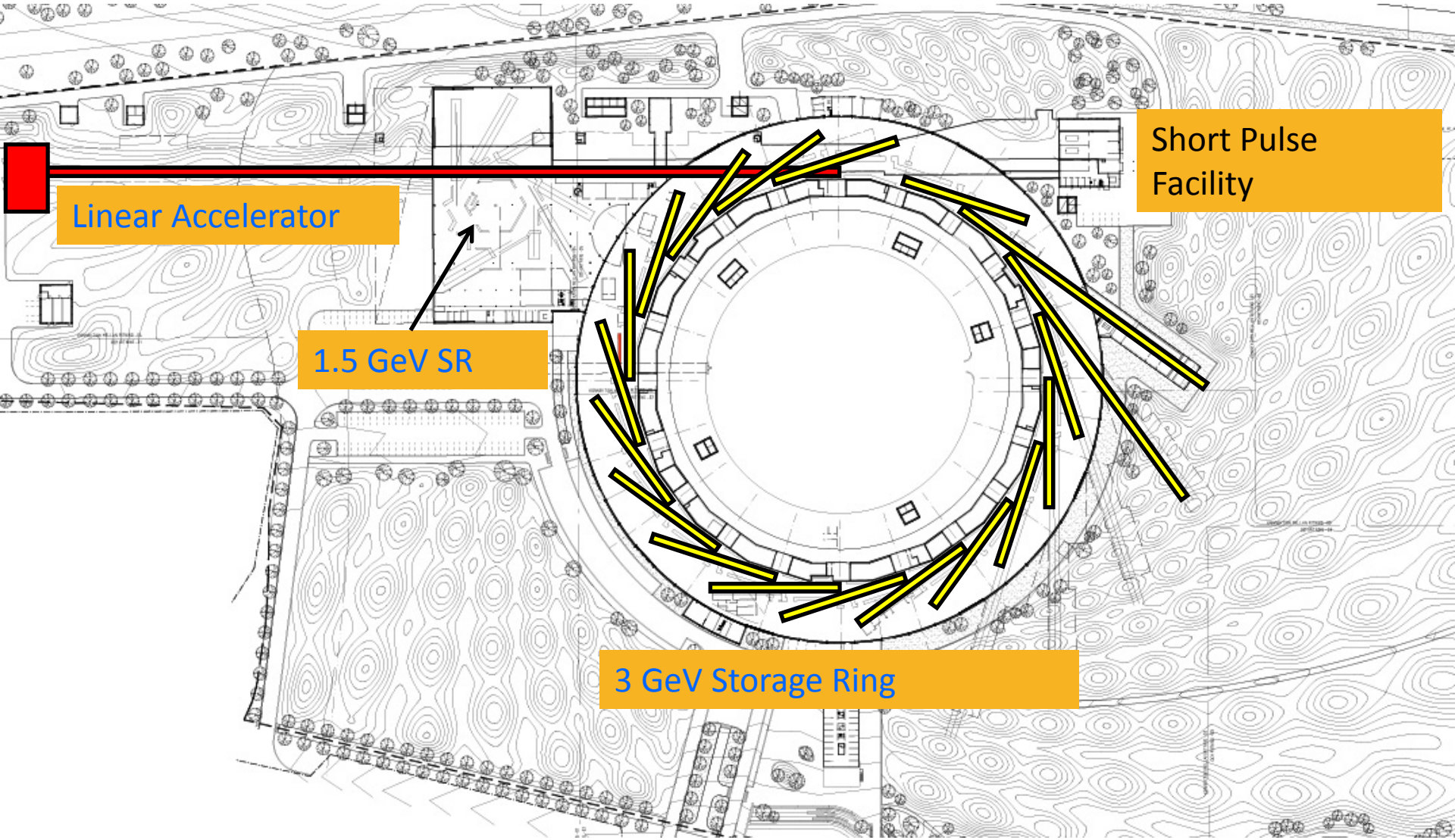
Mikael Eriksson on behalf of the MAX IV team

IPAC 16/Busan

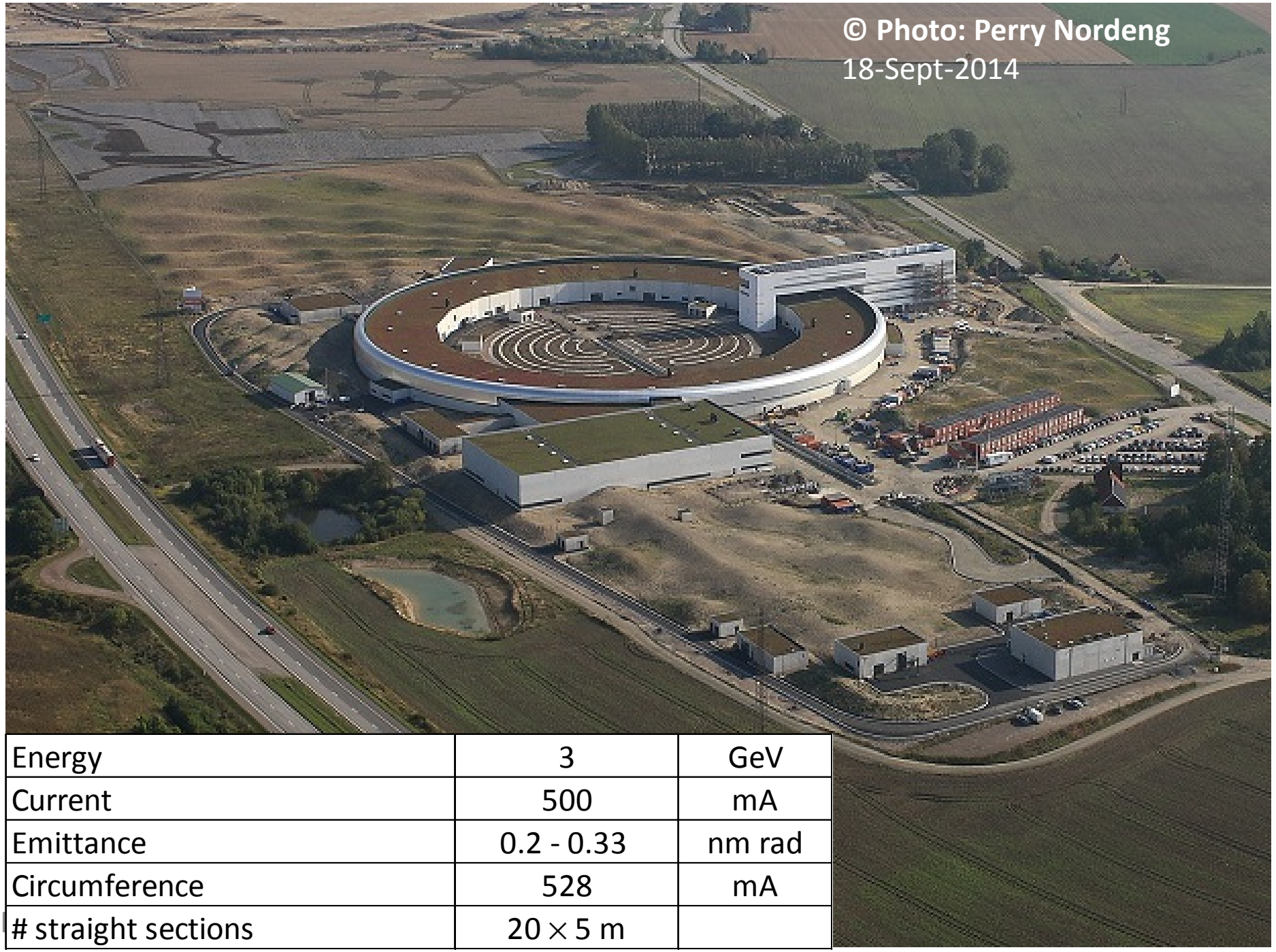
Summary

- The MAX IV Facility
- The MAX IV 3 GeV Ring
- Commissioning Highlights
- Conclusions – Next Steps

MAX IV – an overview

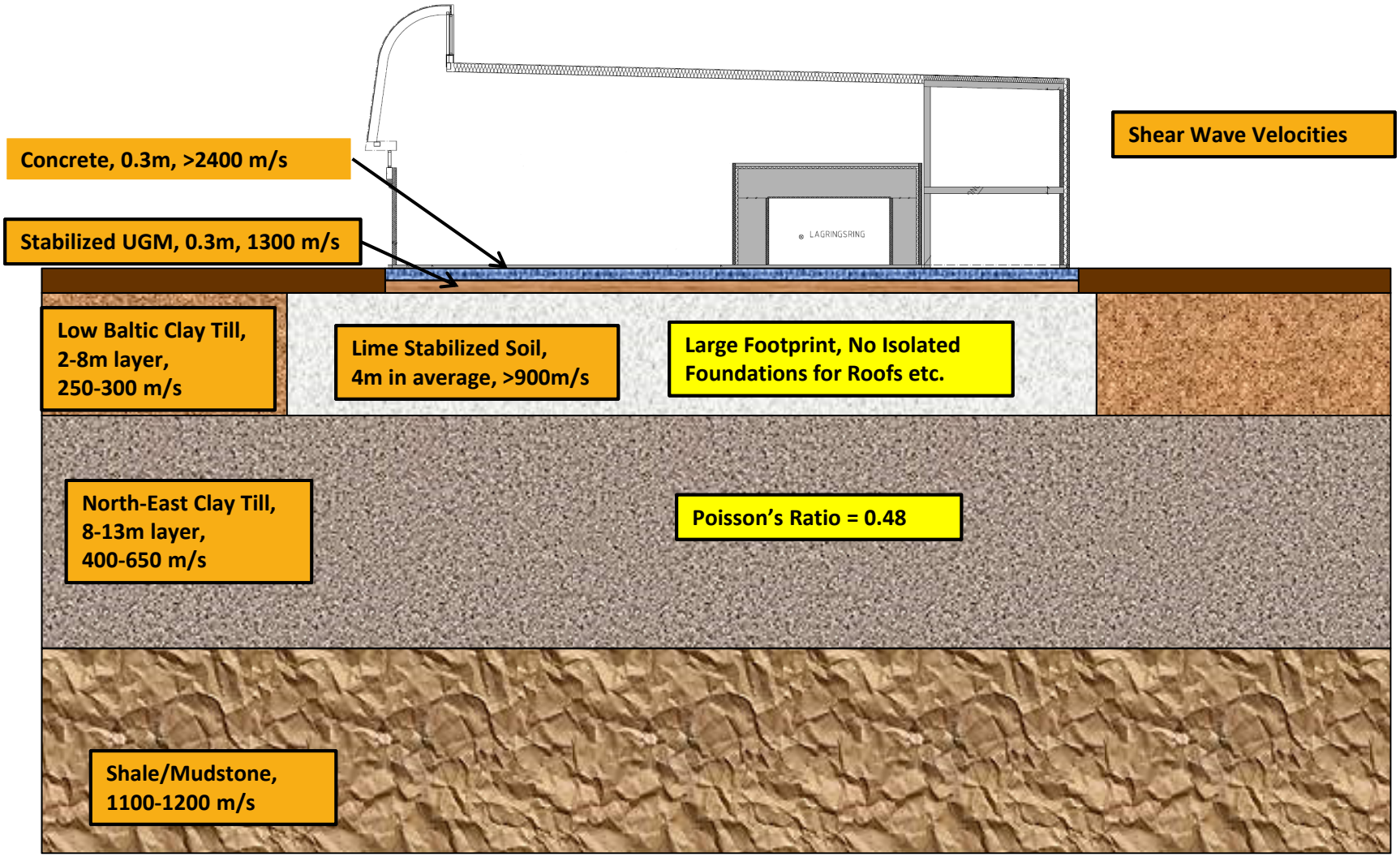


Annika Nyberg, MAX IV-laboratoriet, 2012



Energy	3	GeV
Current	500	mA
Emittance	0.2 - 0.33	nm rad
Circumference	528	mA
# straight sections	20 × 5 m	

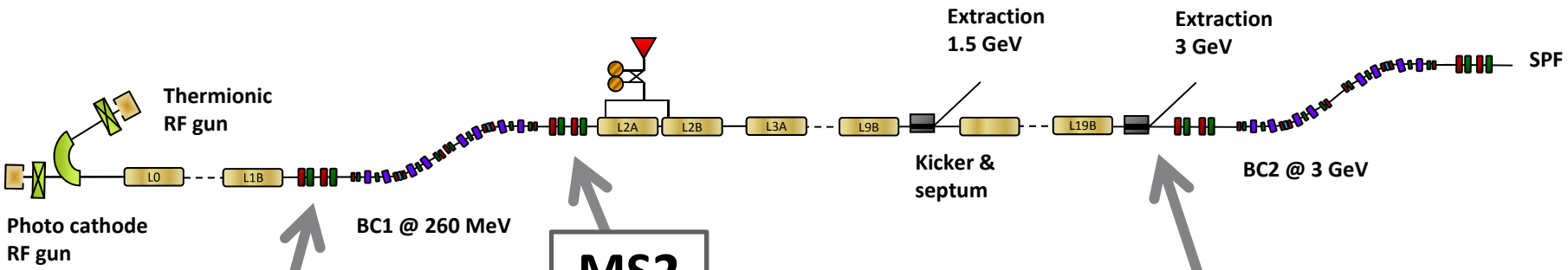
Civil Engineering



www.ekdahlgeo.se


Sect. 4
End
Första hjälpen

Beam parameters Thermionic Gun



MS1

Energy	270 MeV
Energy spread	0.5 % (fwhm)
Norm emittance x	5.5 mm mrad
Charge	~ 280 pC

MS2

Energy	270 MeV
Energy spread	0.5 % (fwhm)
Norm emittance x	12 mm mrad
Norm emittance y	4.7 mm mrad
Charge	~ 280 pC

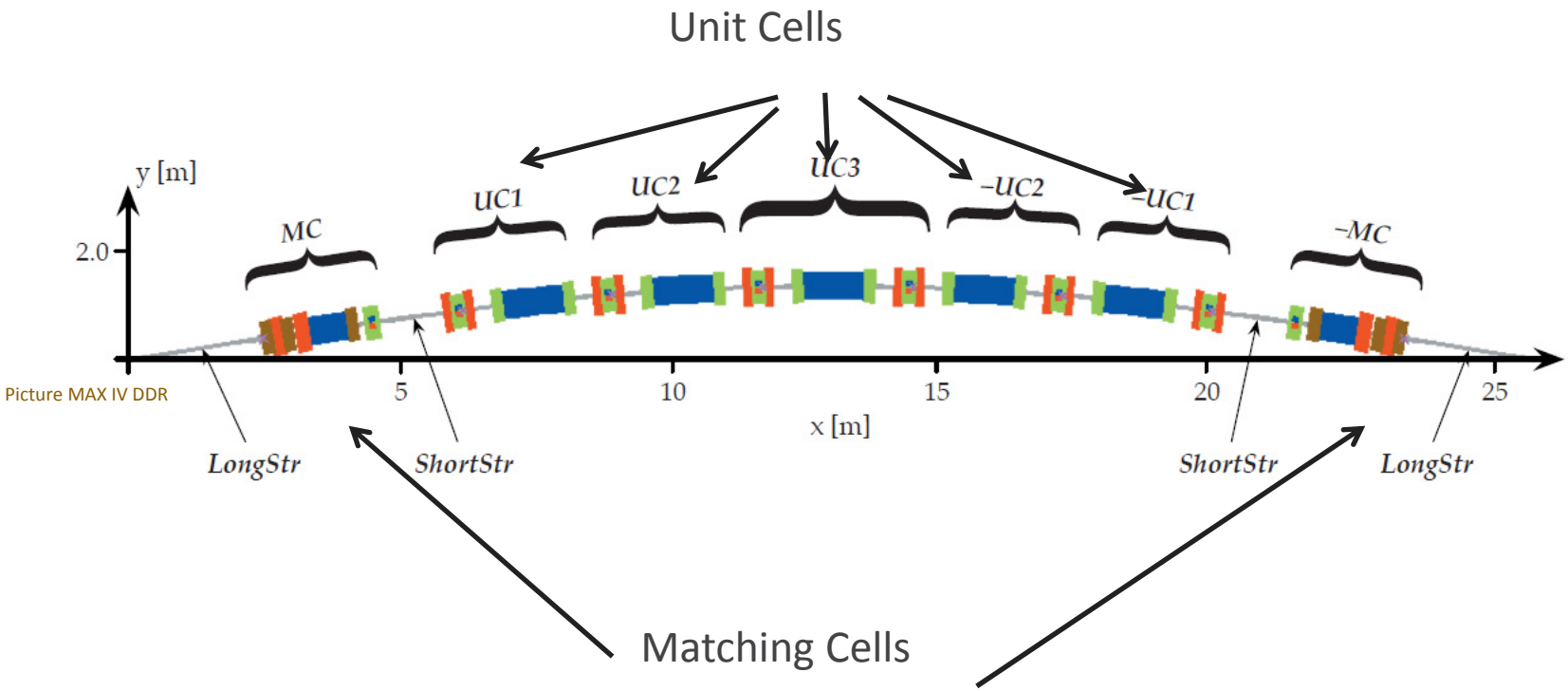
MS3/TR3

Energy	3 GeV
Energy spread	0.6 % (fwhm)
Norm emittance x	15 mm mrad
Charge	~ 220 pC

Slide by S.Thorin

The MAX IV 3 GeV ring Lattice

7-bend achromat
20 periods



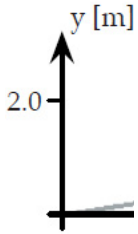
Picture MAX IV DDR

The MAX IV 3 GeV ring Lattice

7-bend achromat

20 perio

Periodicity	20
Circumference	528 m
Horizontal tune ν_x	42.20
Vertical tune ν_y	16.28
Natural horizontal chromaticity ξ_x	−49.984
Natural vertical chromaticity ξ_y	−50.198
Momentum compaction (linear) α_c	3.06×10^{-4}
Horizontal damping partition J_x	1.8471
Bare lattice emittance ε_0	0.328 nm rad
Bare lattice energy loss per turn	363.8 keV
Bare lattice natural energy spread σ_δ	0.769×10^{-3}
Bare lattice horizontal damping time τ_x	15.725 ms
Bare lattice vertical damping time τ_y	29.047 ms
Bare lattice longitudinal damping time τ_E	25.194 ms
Horizontal beta function at center of LS β_x^* (bare lattice)	9.00 m
Vertical beta function at center of LS β_y^* (bare lattice)	2.00 m



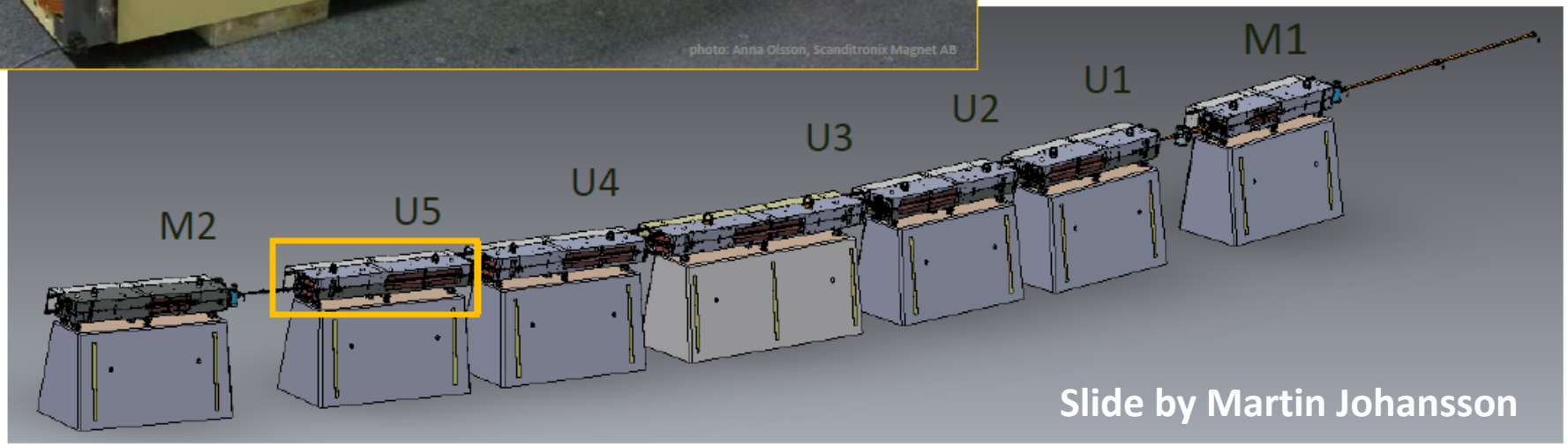
Picture MAX IV DDR

May 2016

MAX IV 3 GeV Ring DC Magnets

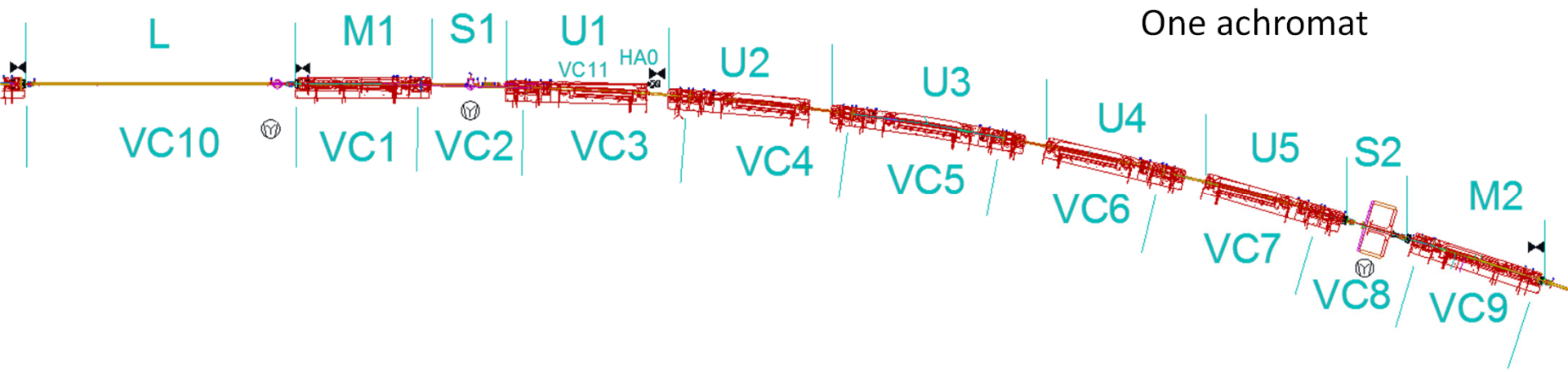
- *Each cell is realized as one mechanical unit containing all magnet elements.*
- *Each unit consists of a bottom and a top yoke half, machined out of one solid iron block, 2.3-3.4 m long*.

- a U5 bottom half →
- ↓ an assembled U5



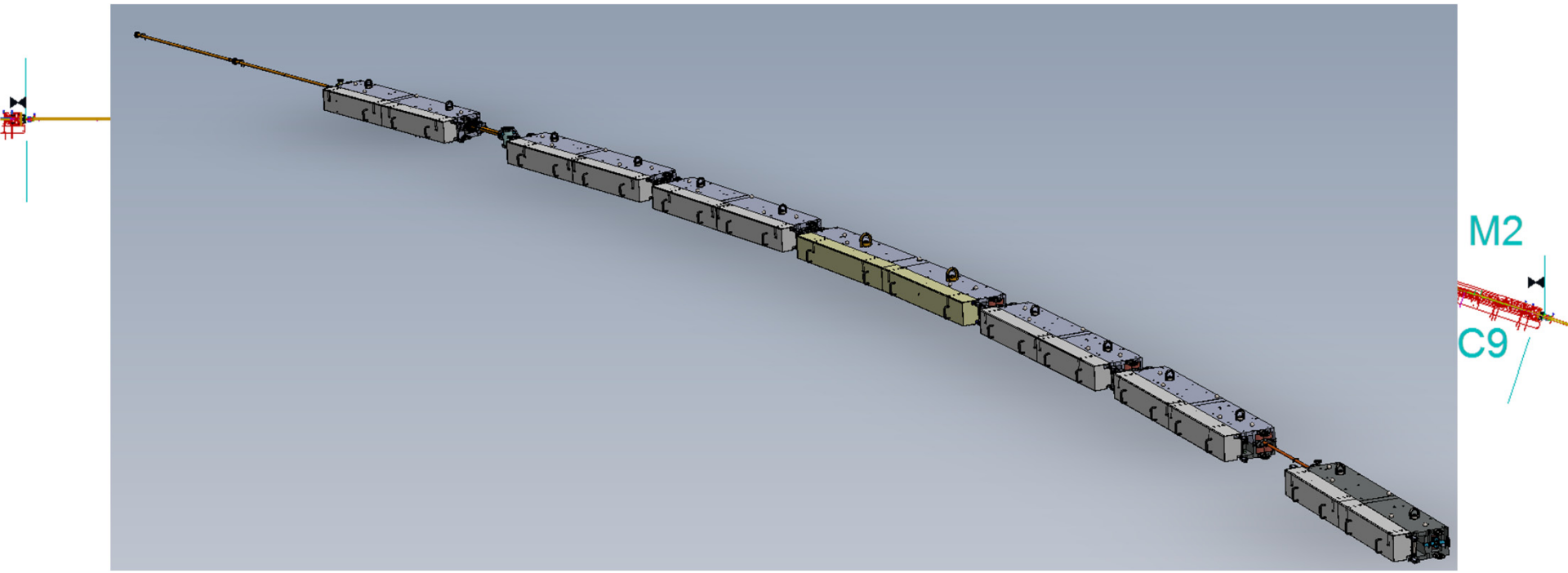
MAX IV 3 GeV ring vacuum system layout

Slide by E.Al-dmour

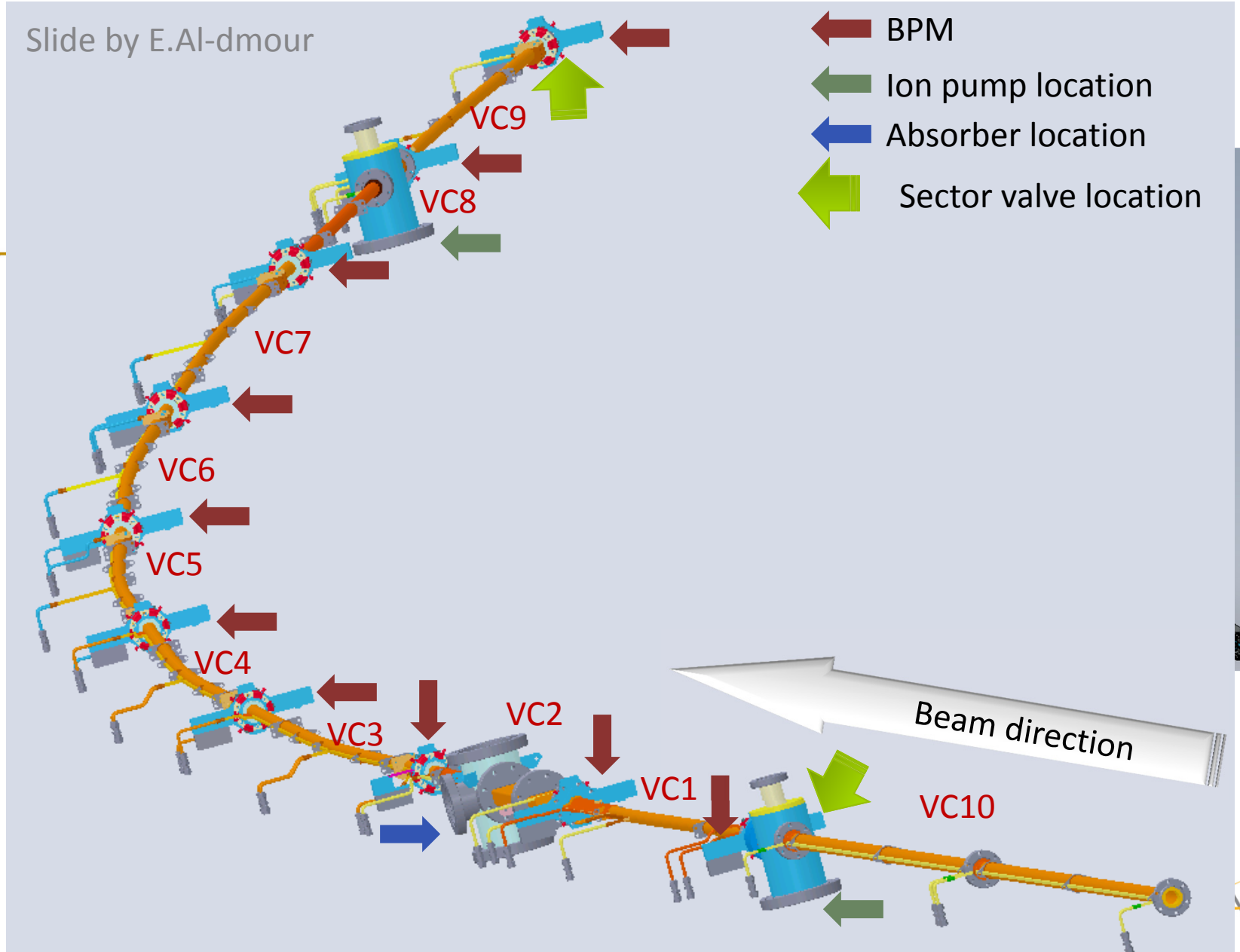


MAX IV 3 GeV ring vacuum system layout

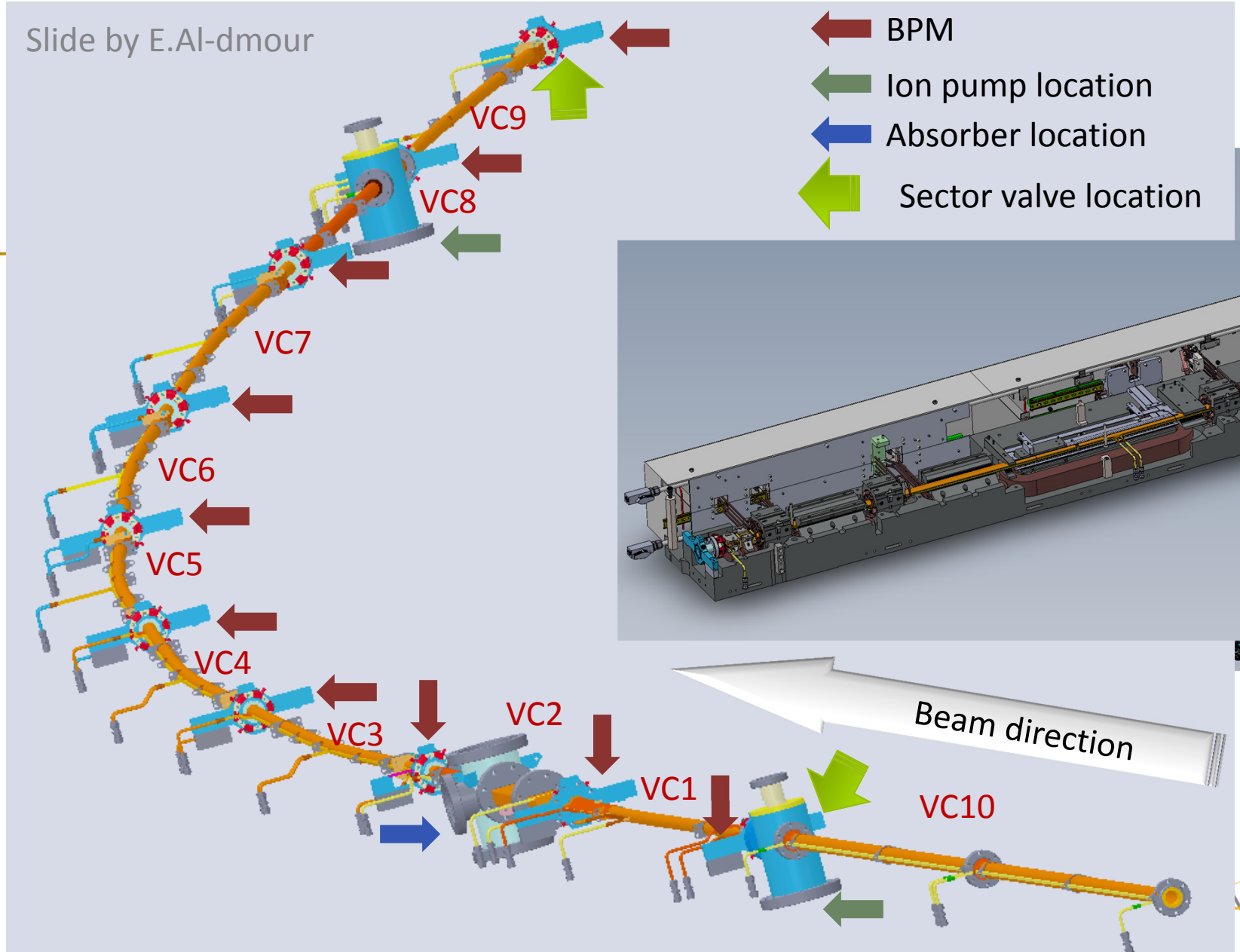
Slide by E.Al-dmour



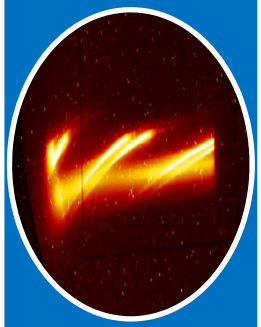
MAX IV 3 GeV ring vacuum system layout



MAX IV 3 GeV ring vacuum system layout



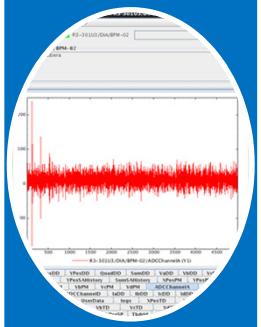
3 GeV Ring Commissioning Timeline



Beam in TR3

Aug 11

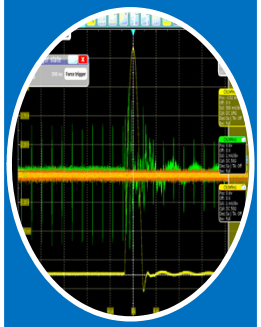
2015



First Turn

Aug 25

2015

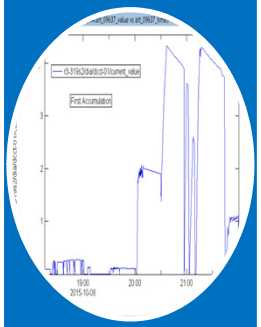


Stored Beam

0.1 mA

Sep 15

2015



Stacking

4 mA

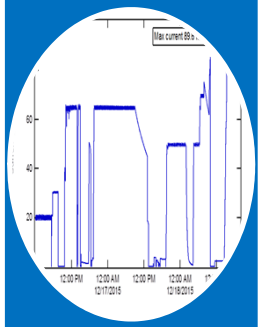
Oct 08

2015

First Light

Nov 2

2015

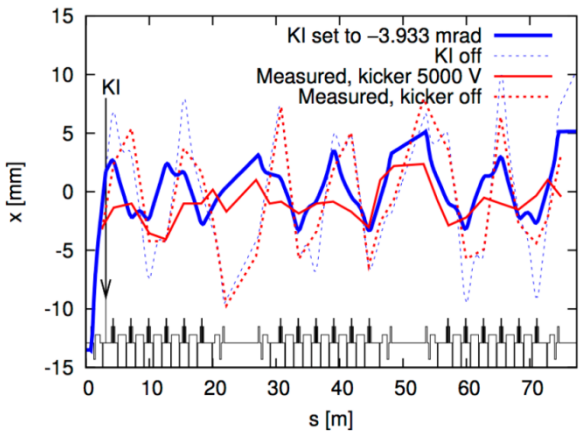


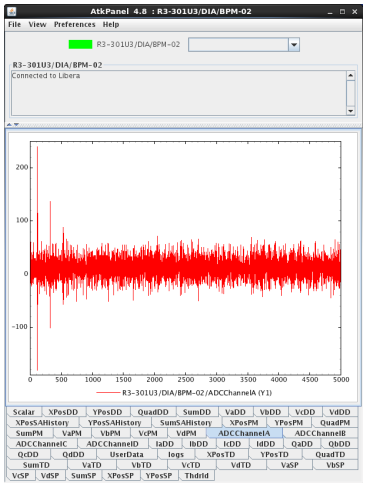
120 mA

Jan/31

2016

Threading the beam – first turn – many turns

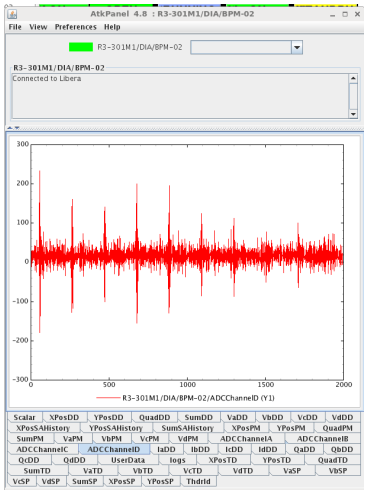




2015/08/25

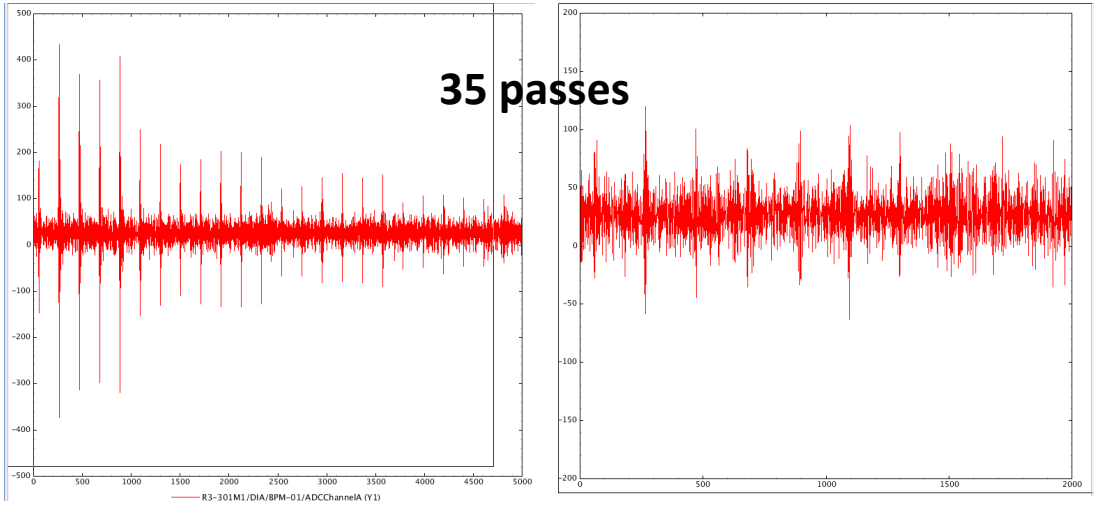
3 passes

All correctors OFF



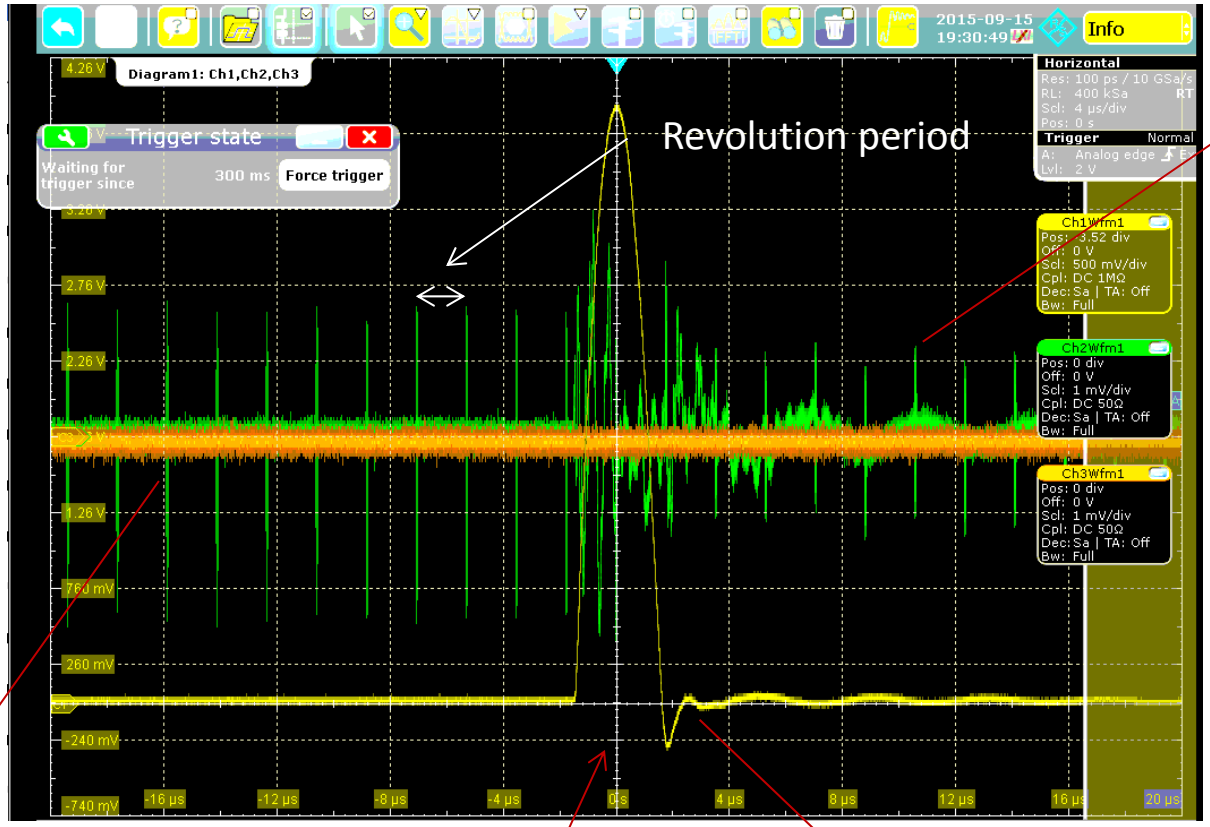
2015/08/26

35 passes



2015/08/27

First Stored Beam



Revolution period

Injected beam

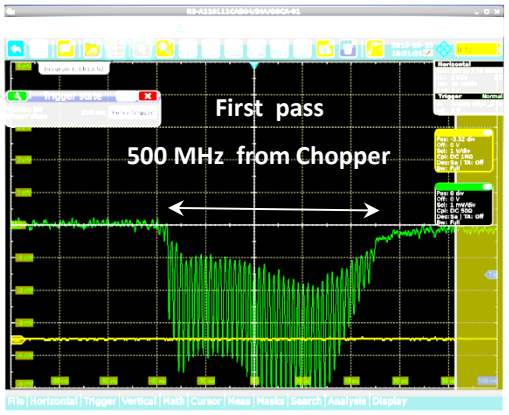
Stored beam 2 seconds after previous injection pulse

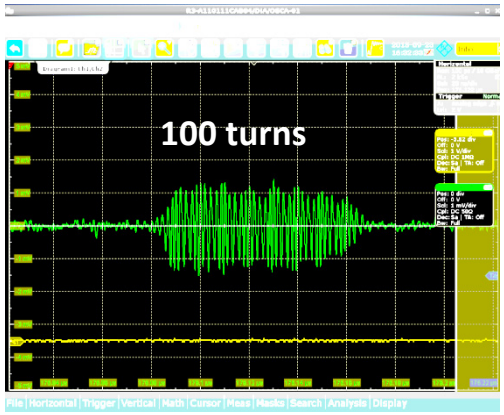
Injection

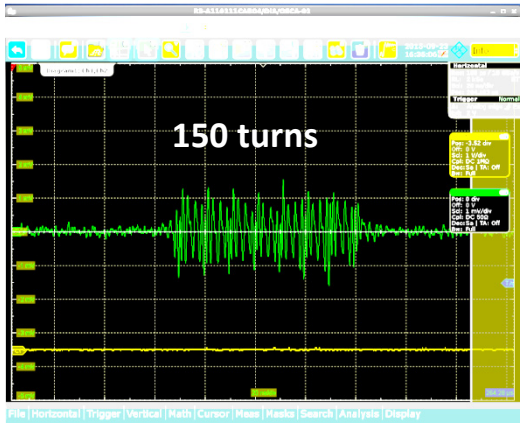
Kicker Current

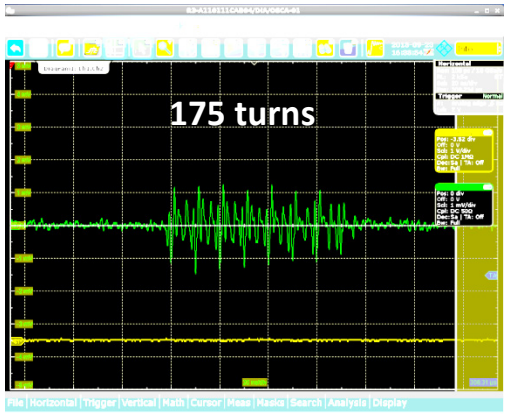
2015/09/15

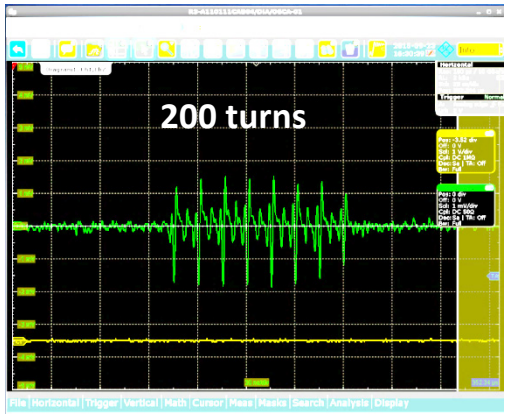
Capture and Bunching







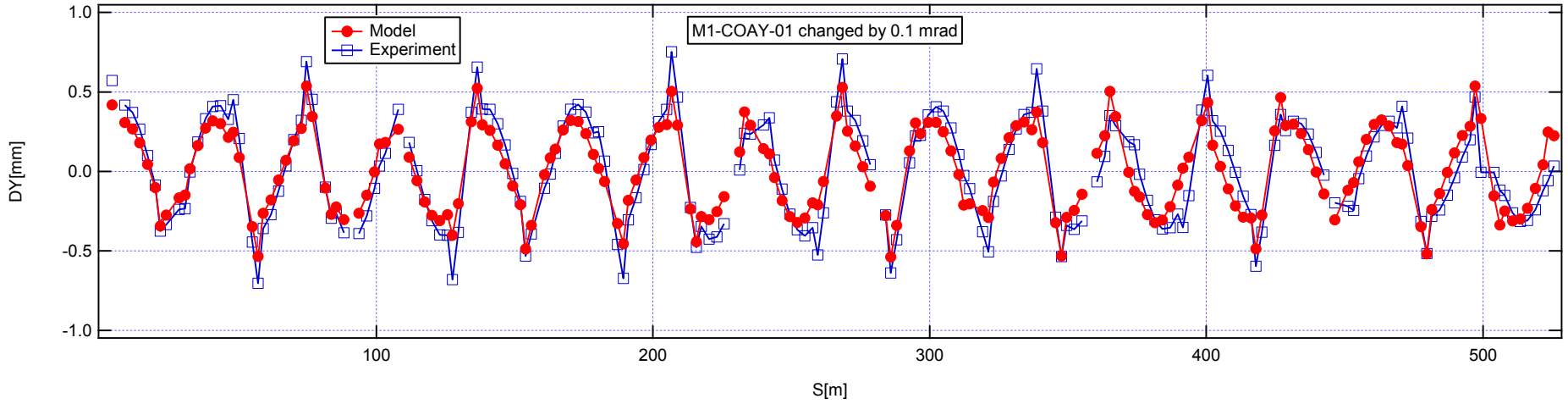


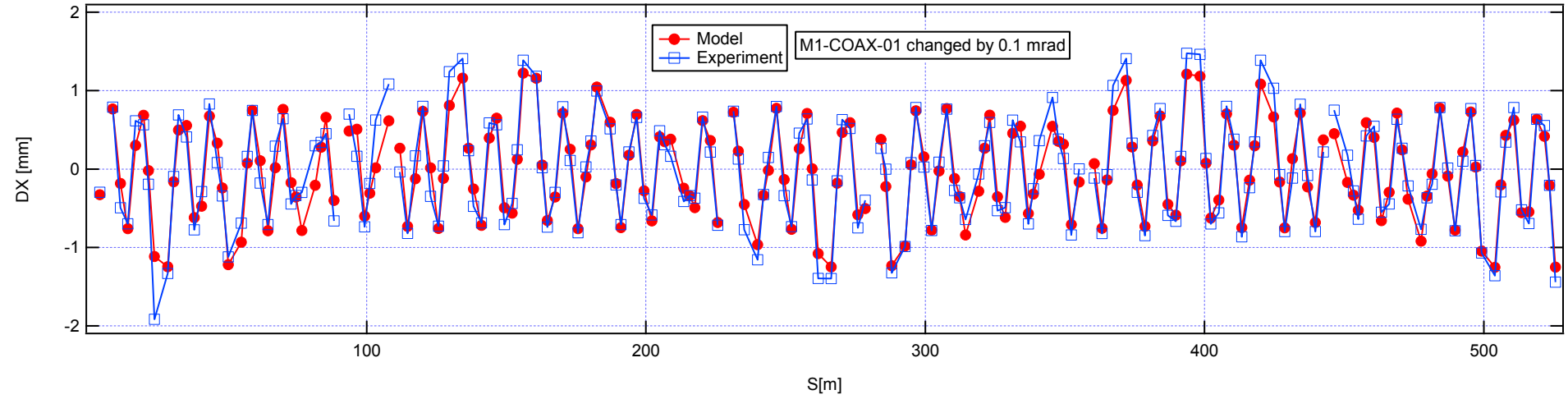


Plots S.Leeman

2015/09/23

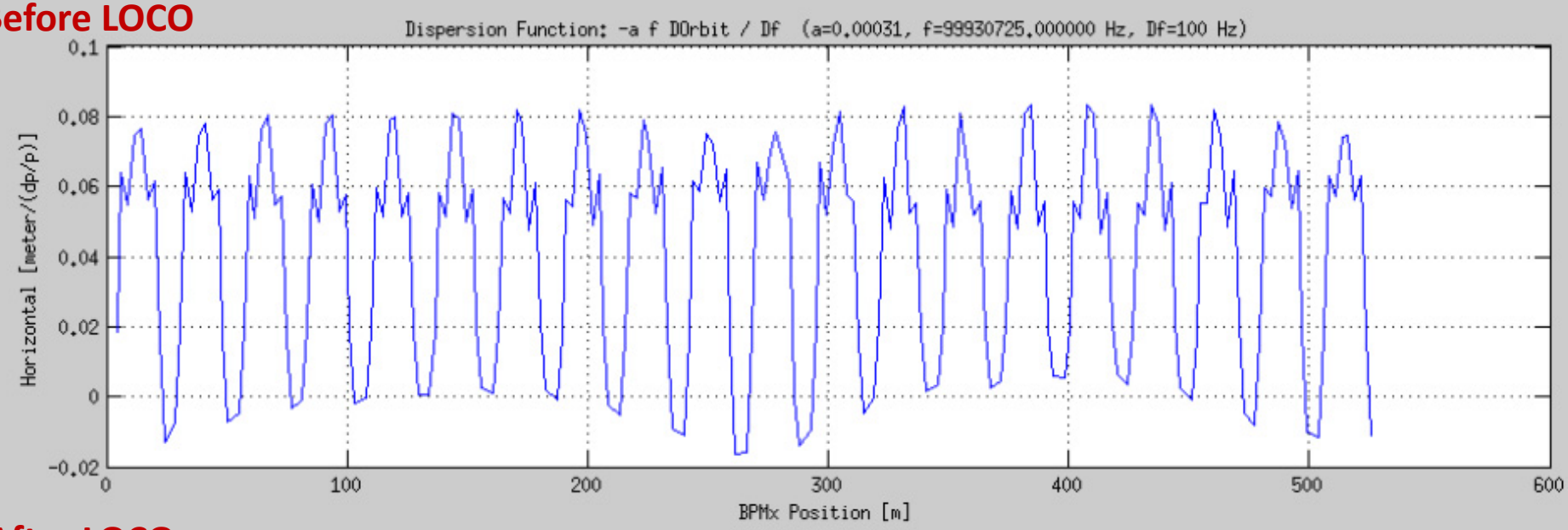
Linear Optics Characterization: Integer Tunes



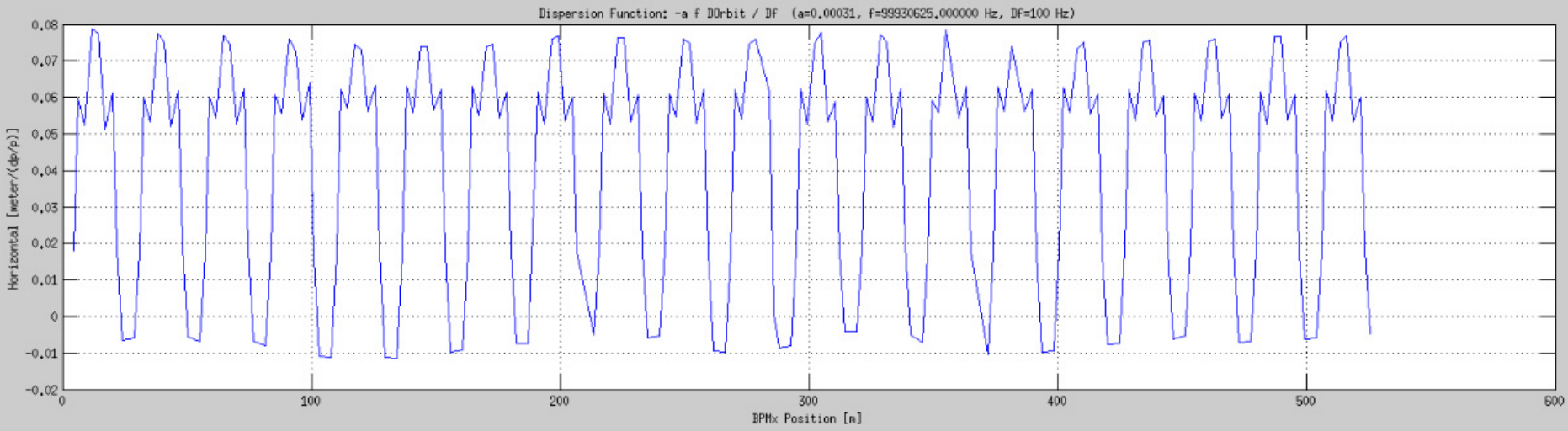


LOCO: reduction in dispersion beating

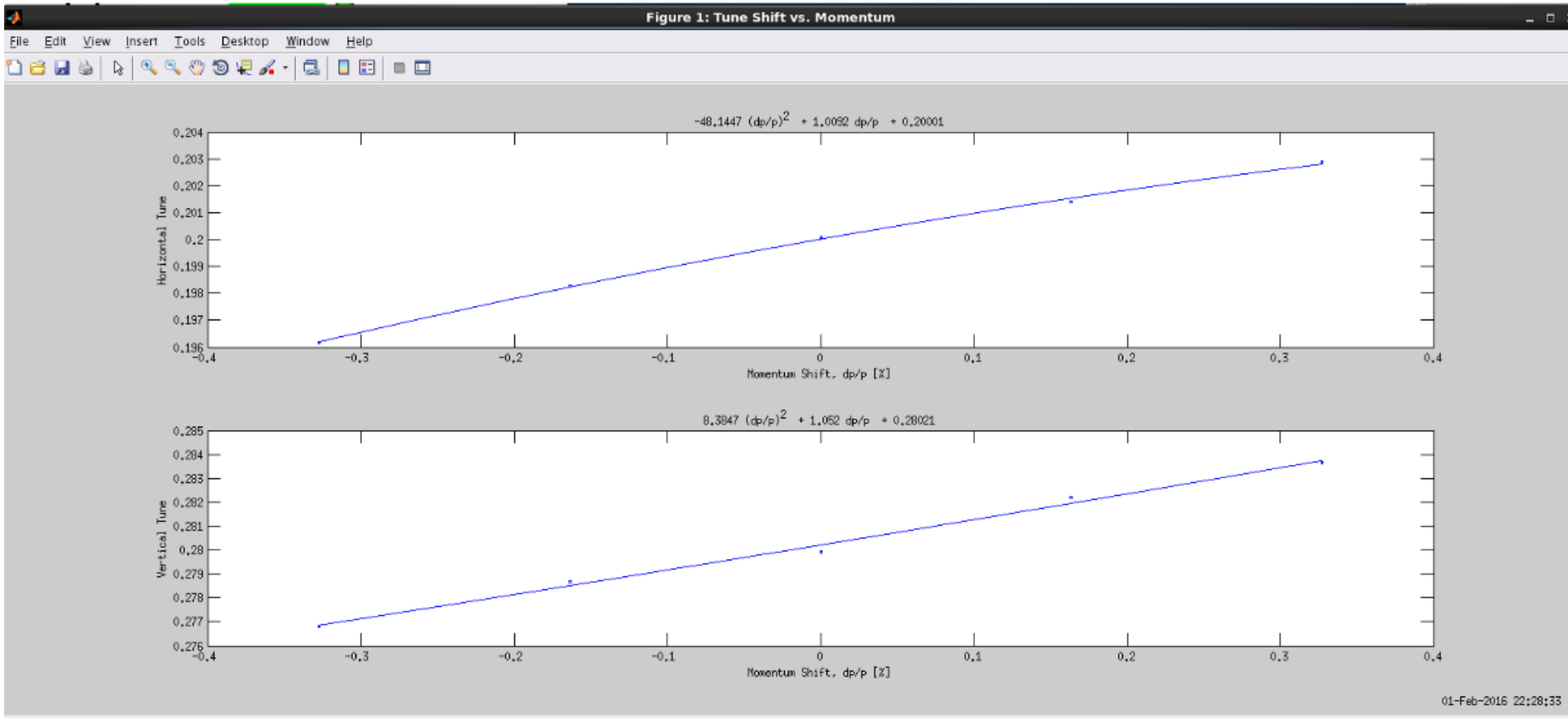
Before LOCO



After LOCO



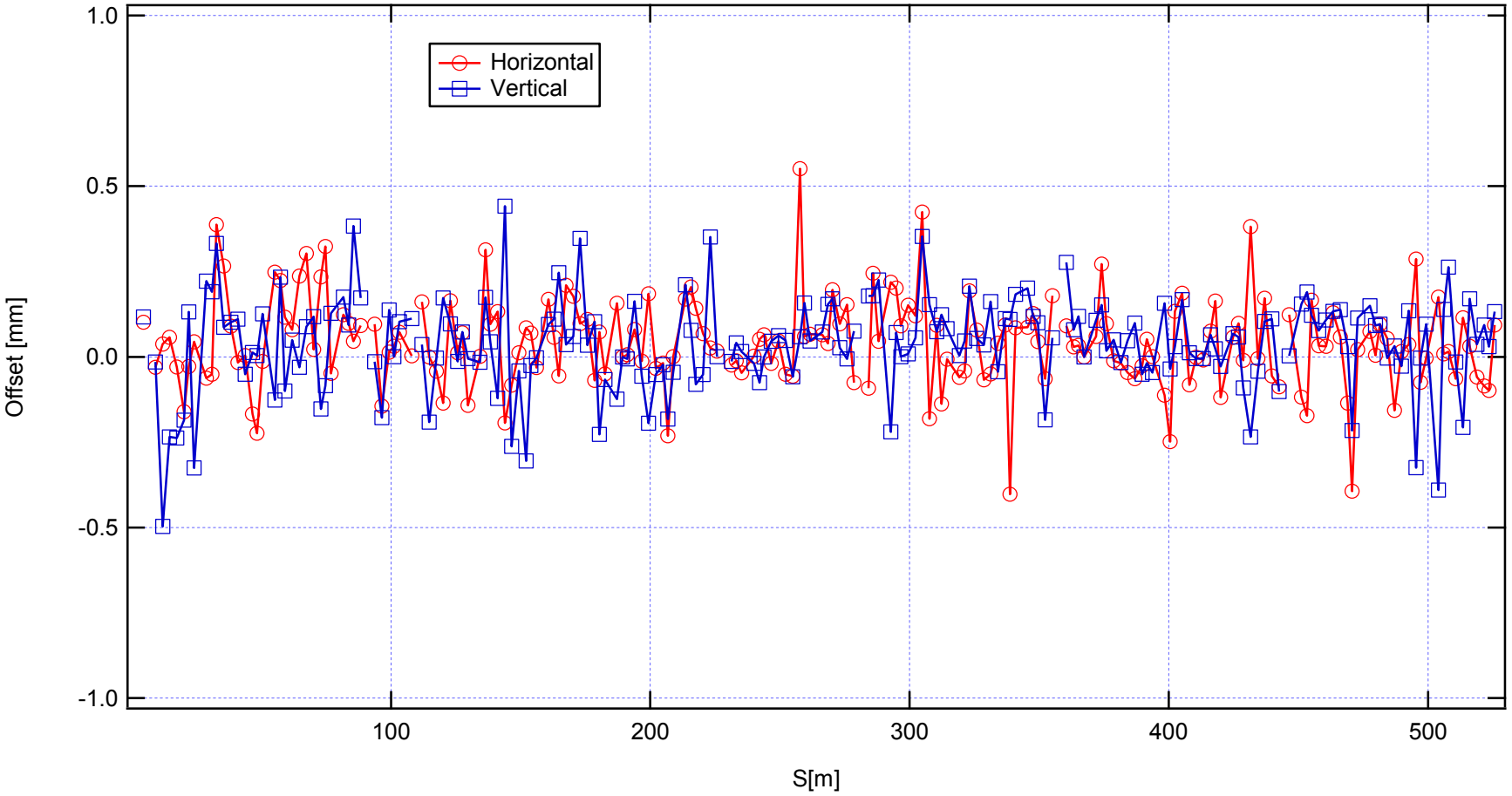
Chromaticities:



BPM Offsets

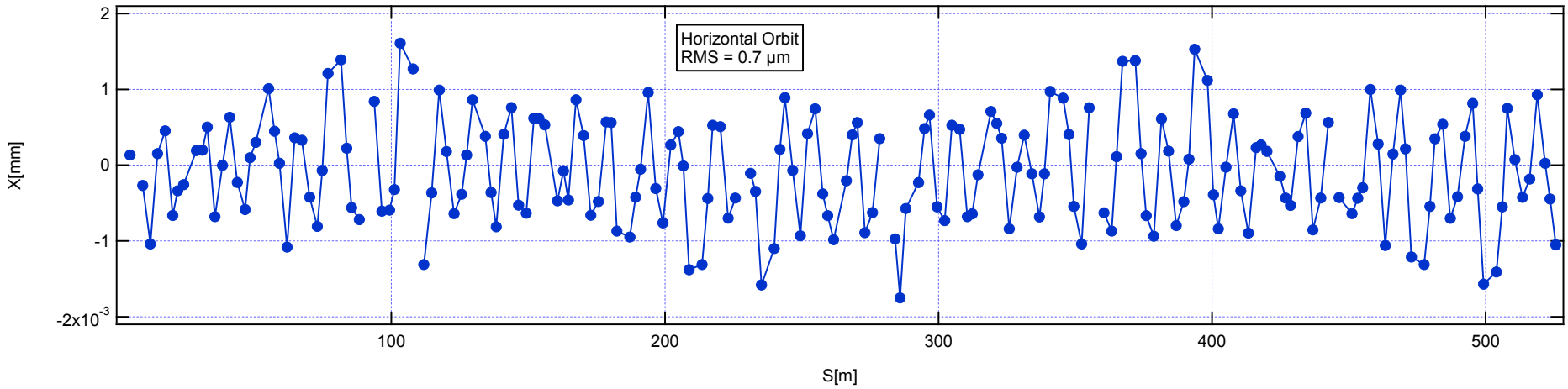
- Measured by BBC using trim coils in sextupole magnets

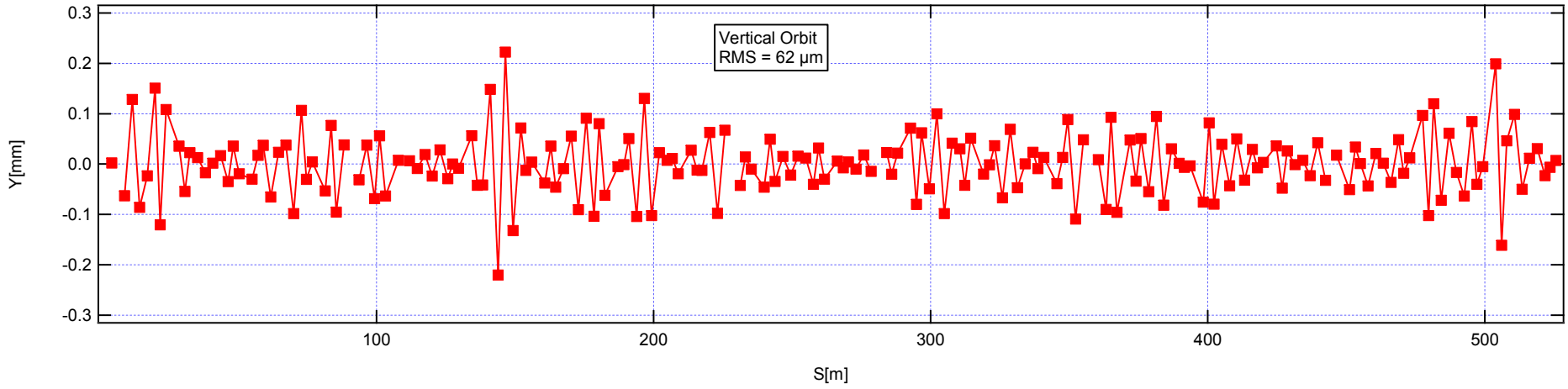
RMS: 144 µm H / 138 µm V



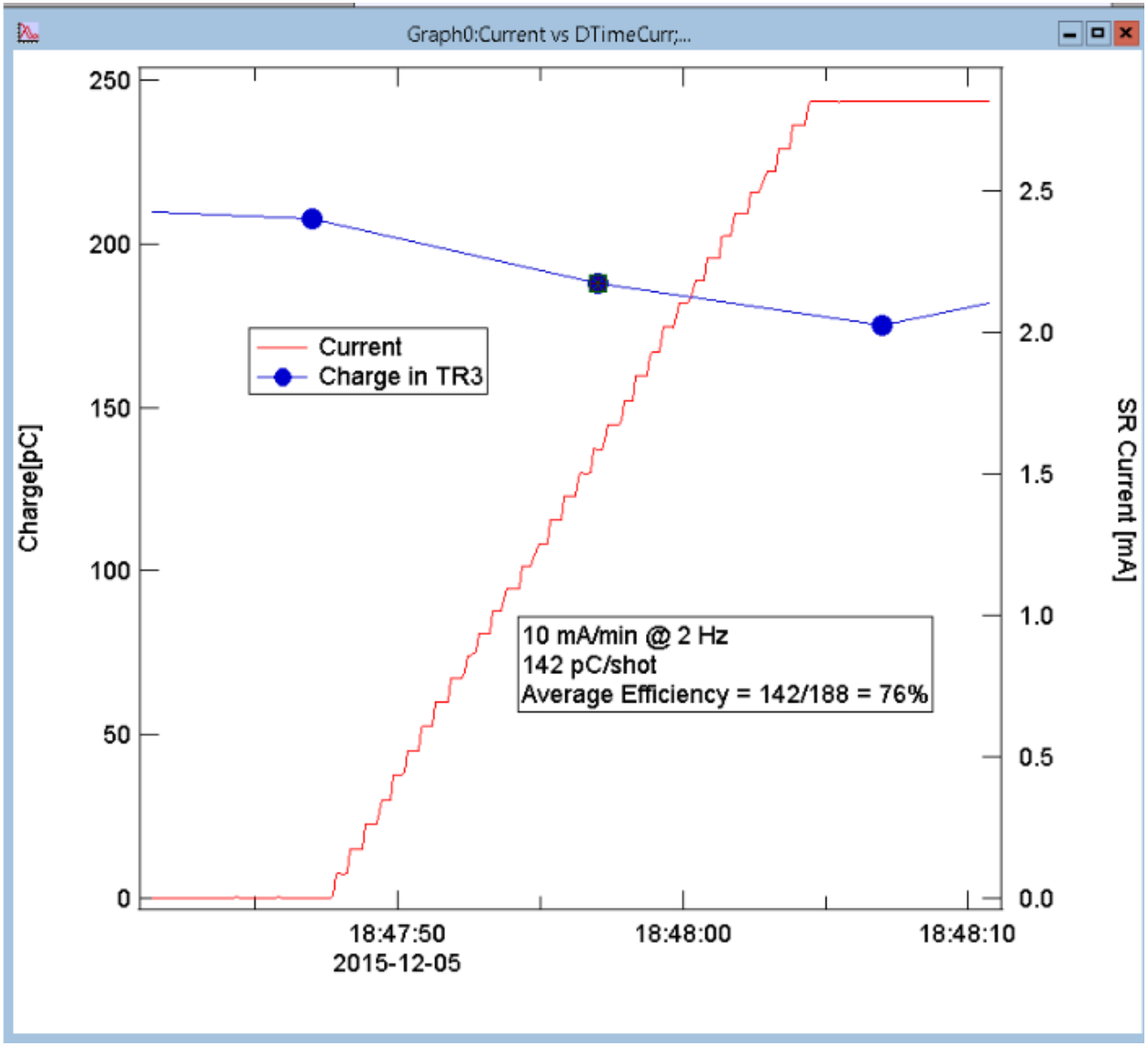
Orbit Correction

Residual RMS: 0.7 µm H / 62 µm V

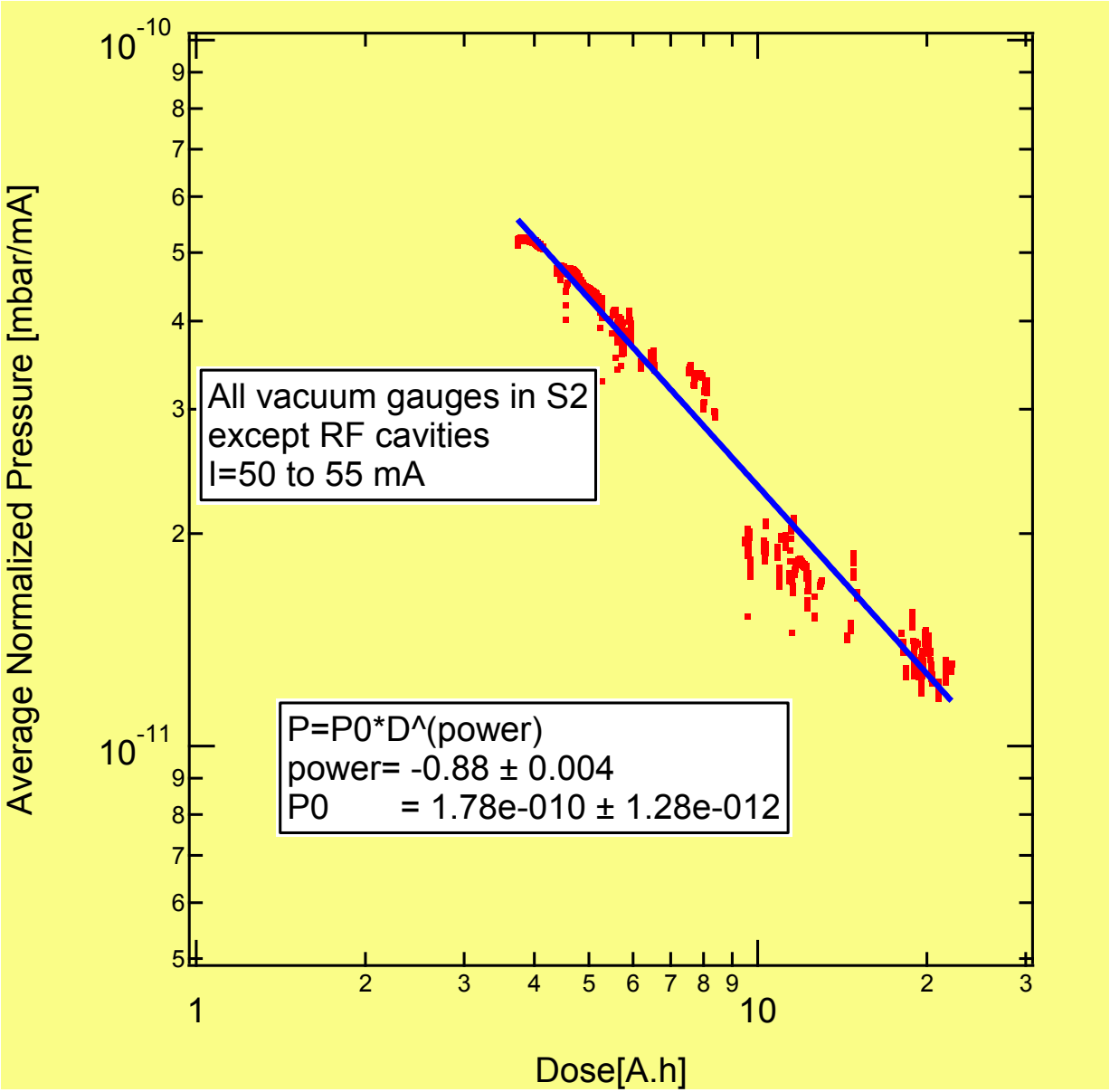




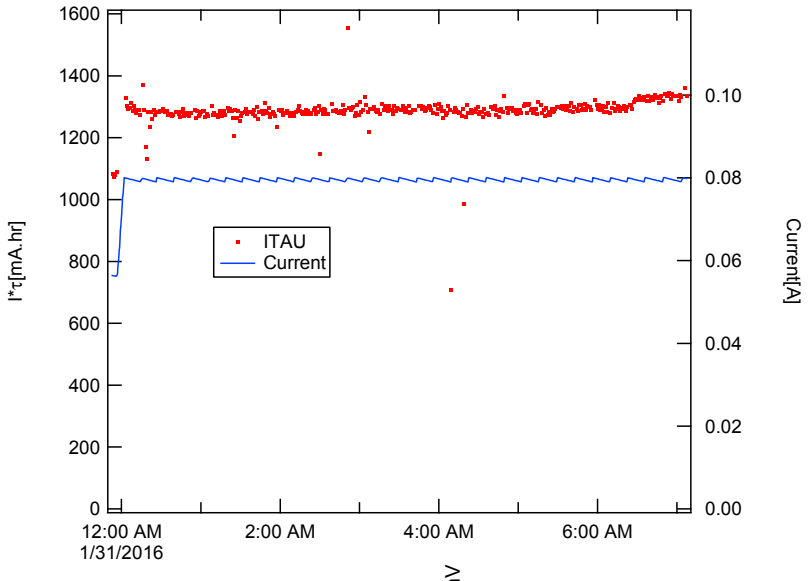
Injection Efficiency - 2

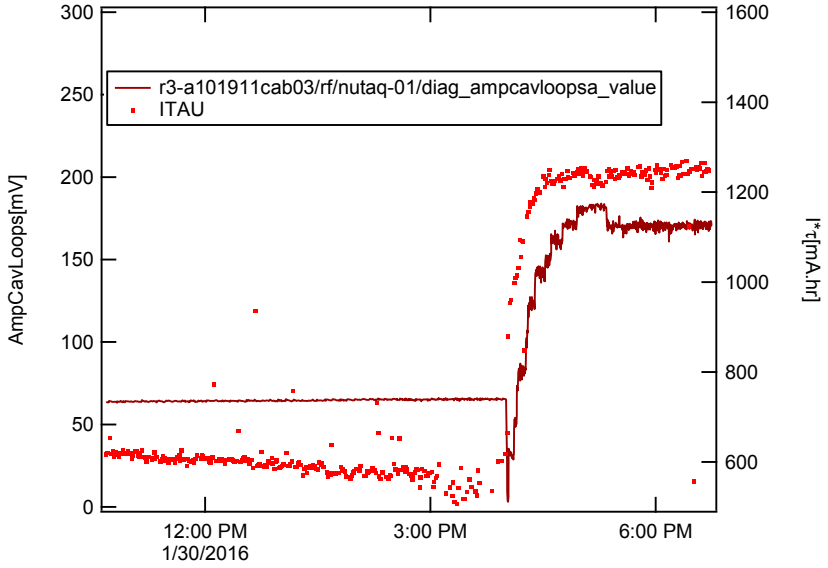


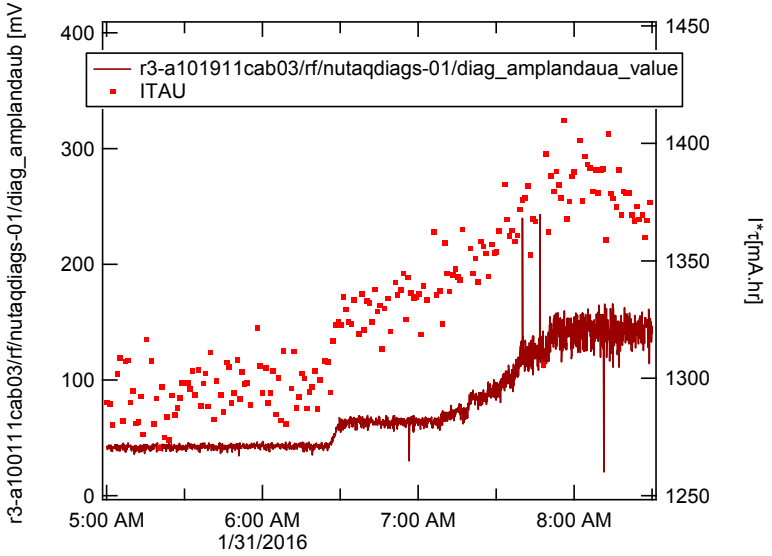
Vacuum Conditioning - pressure



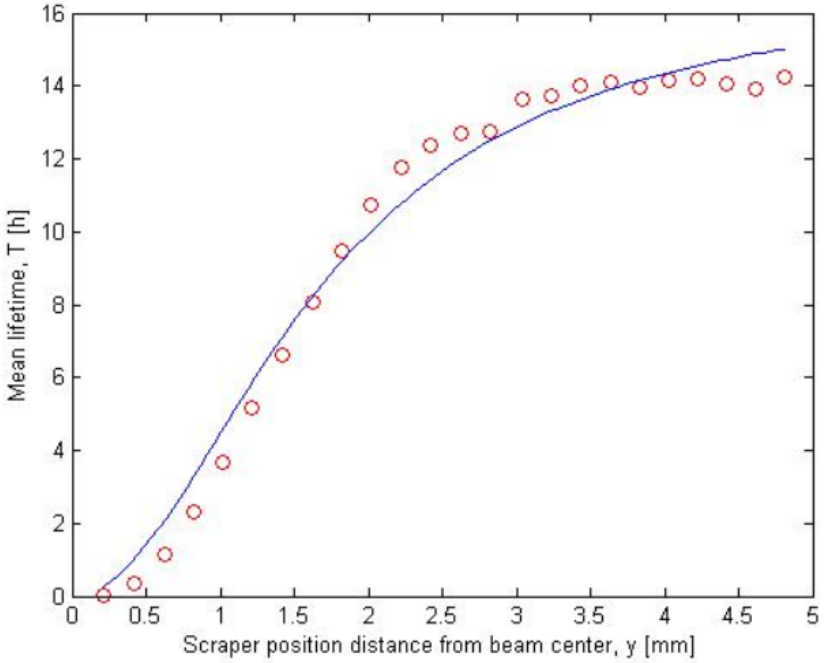
Beam Lifetime



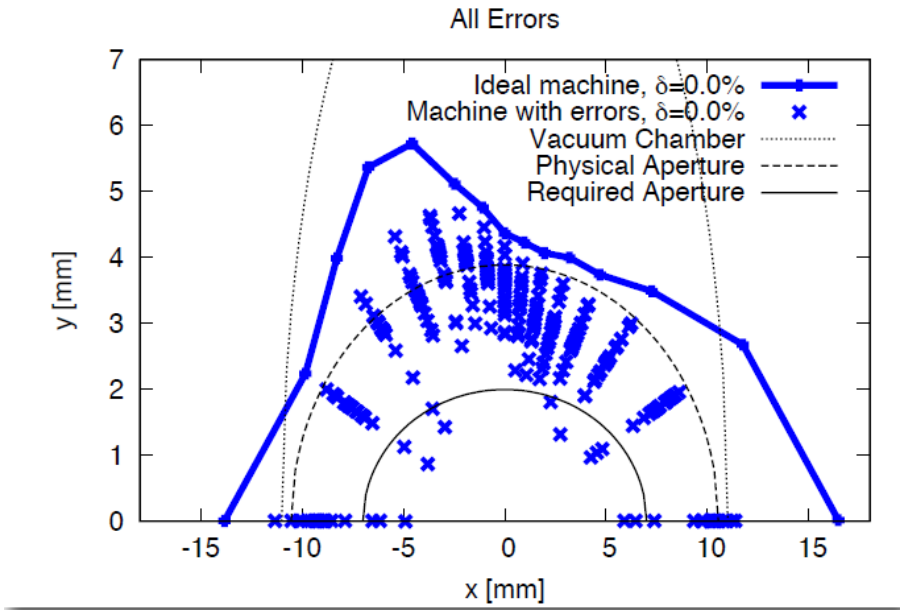




Aperture Scans – scraper measurements



Plot by Jens Sundberg

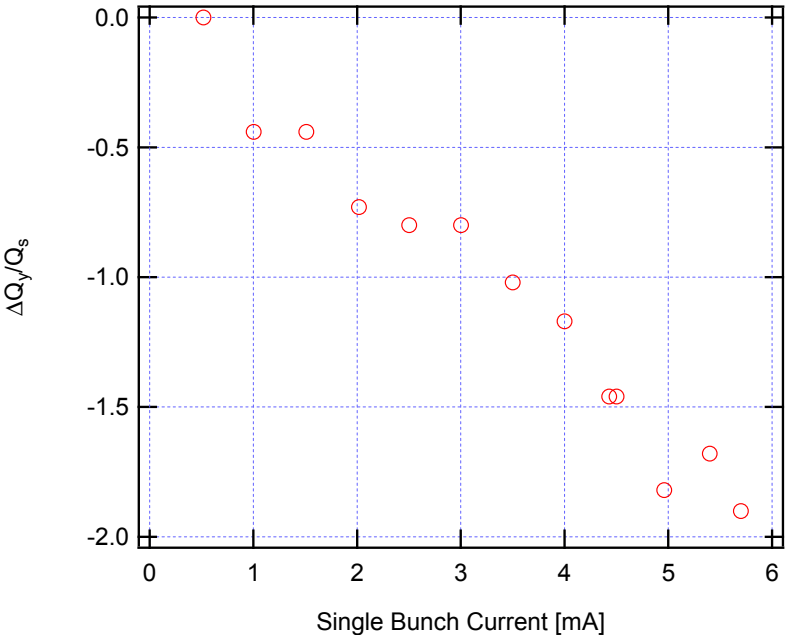


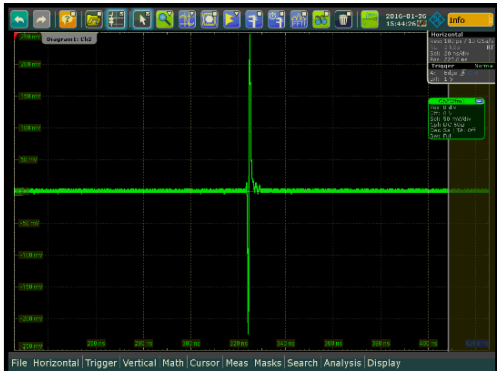
2011 simulations by S.Leemann

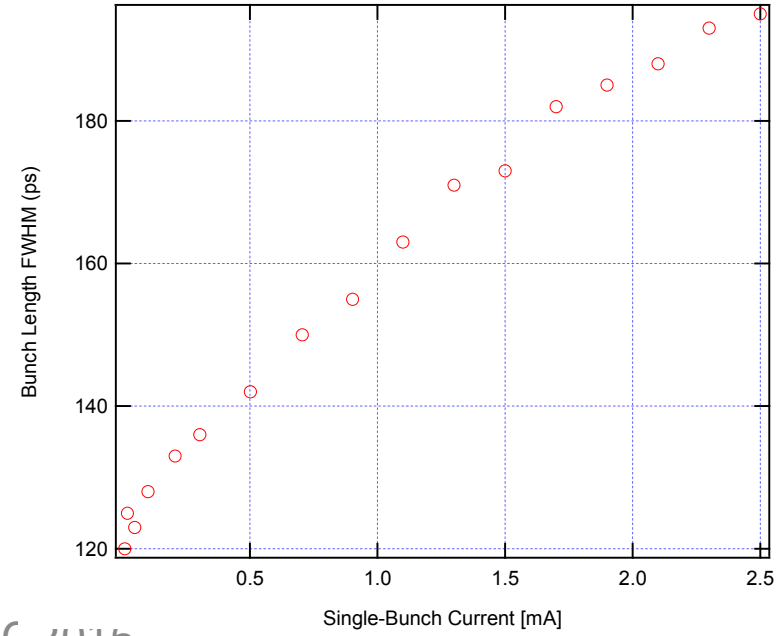
Vertical aperture scaled to center of LS 2.3 mm

Collective Effects – Single Bunch

- No signs of TMCI up to 8.55 mA (nominal 2.8 mA/bunch).
- Significant bunch lengthening even without harmonic cavities







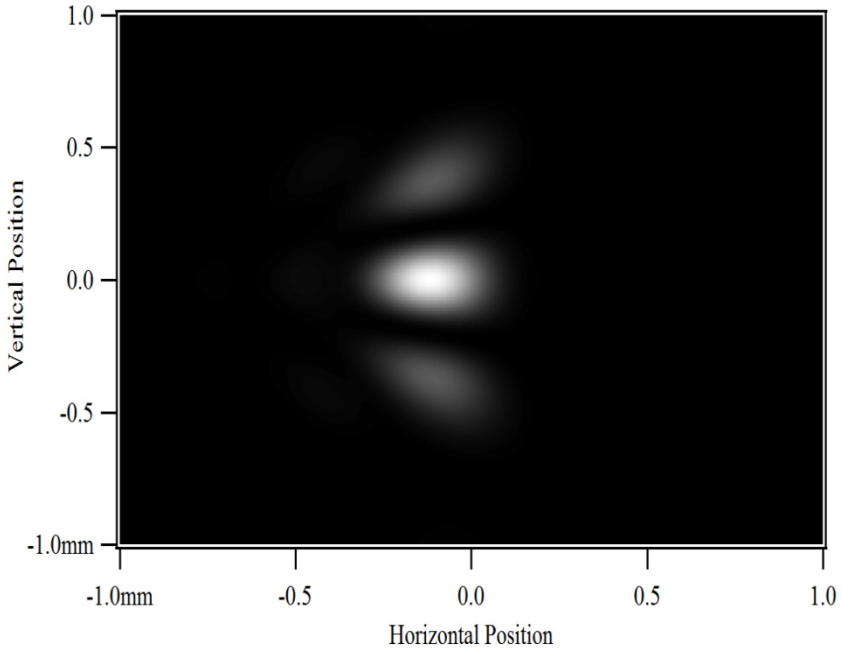
Data by J.Breunlin, A.Andersson, G.Skripka, R.Nagaoka

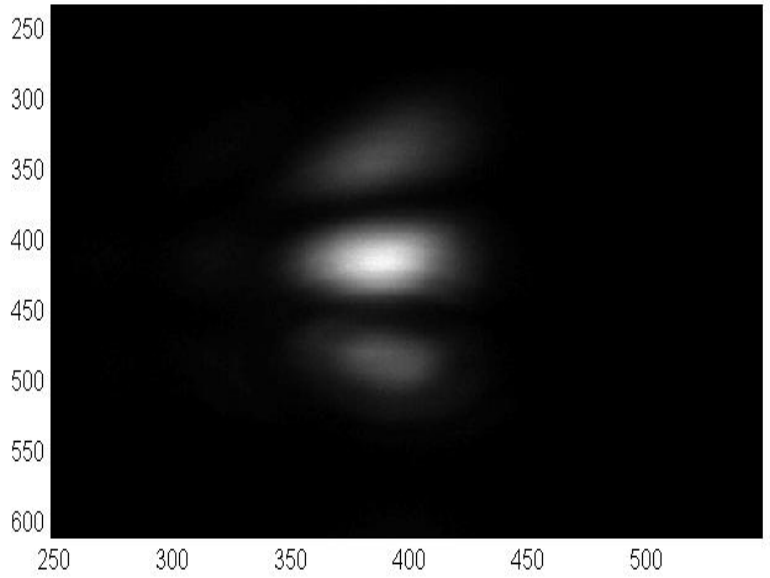
Collective Effects - Multibunch

- Possible to store >120 mA without feedback and without harmonic cavities. Predicted RW threshold was only ~ 40 mA !
- HOM driven longitudinal motion is evident at a few mA in uniform fill.
- Temperature tuning has proved effective in fighting longitudinal CBI.
- Harmonic Cavities not fully tuned-in in yet. Need more conditioning
- Preliminary BBB feedback tests using a short stripline showed a longitudinally stable beam up to 35 mA.
- Longer striplines for BBB feedback to be installed in february
- Longitudinal Actuator (cavity) under design

Emittance Measurement

Slide by J.Breulin

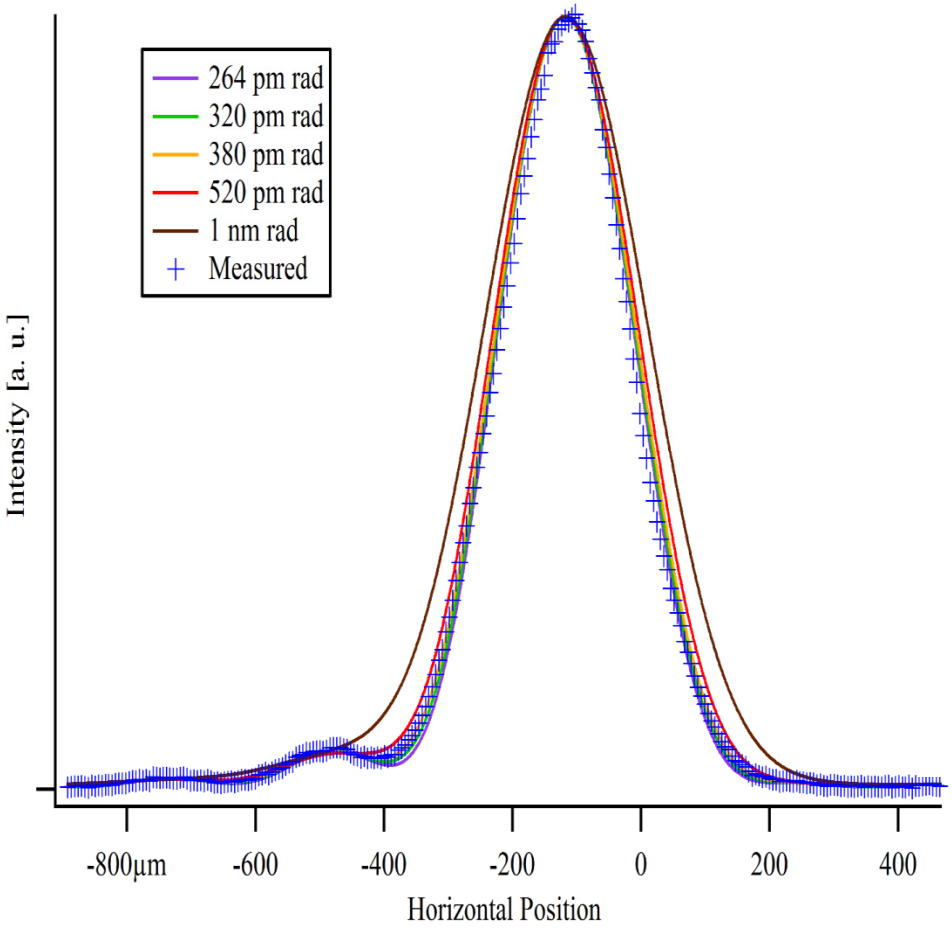


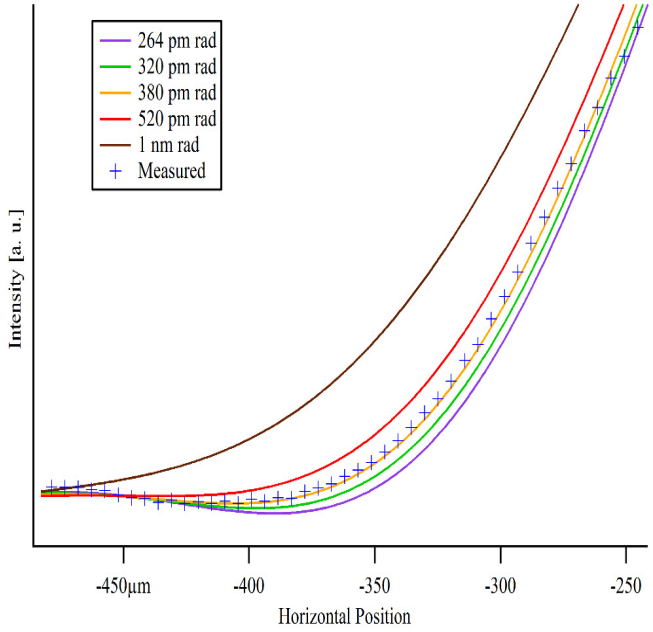


Sigma polarized SR, 632.8 nm, SRW calculation (left) and measured image (right). The simulation is done for ε_x = 320 pm rad, β_y = 1.5 m.
Both figures show a 2 x 2 mm^2 area of the image plane.
The fringe pattern is too weak to be visible.

Optical magnification of m=-2.28 is taken into account in the SRW model
Horizontal opening angle: 6 mrad
Vertical opening angle: 8 mrad
Exposure time: 2.9 ms

Slide by J.Breulin





Horizontal intensity profile of imaged sigma polarized SR. Due to the reduced horizontal opening angle the fringe pattern is not as pronounced as it could be, but easier to understand and to calculate.

Present setup is limited by optical aberations (from misalignments) and surface quality from optical components (some are inherited from MAX II, MAX III). Steady improvements during the next weeks are planned. Camera linearity might also be an issue!

Challenges on the SRW model side are to include for example: variation of dipole field, variation of beta_x, variation of vertical opening angle, along the observed electron beam path.

Main Problems/Difficulties

- RF Cavity Conditioning
- RF System commissioning (LLRF, Shunt Groups)
- Diagnostic System Commissioning
  - BPMs
- Kicker Magnet PS failure
- Gun Klystron Failures
- Long Radiation Surveys
- Cooling System Failures
- Control System Commissioning
- PS Failures

Next Steps

- February 2016: First two in-vacuum undulators
- March to July 2016:
  - Further conditioning of RF cavities
    - Main cavities
    - Harmonic cavities
  - Further linear optics trimming
    - LOCO, shunting
  - Non-linear optics trimming
  - Collective Effects studies (Harmonic cavity tuning)
  - Bunch-by-Bunch feedback commissioning
- May 2016: 2 EPUs in the 3 GeV Ring, Transfer Line and Last Achromat in 1.5 GeV ring
- September-December 2016 : 1.5 GeV ring commissioning
- November 2016: Friendly users (3 GeV ring)
- March 2017: First open call users (3 GeV ring)
- Feb 2017: First Ids in the 1.5 GeV ring
- May-June 2017: LINAC RF upgrade

Conclusions

- Progress with the initial phase of MAX IV 3 GeV ring commissioning gives us increased confidence that the MBA concept is sound.

- Much is still to be done to reach the final design specifications, but nothing indicates there is any fundamental obstacle ahead.

- Most difficulties are related to technical subystems that need time for conditioning/maturing

Thank You !