Diagnostics at the MAX IV 3 GeV storage ring during commissioning

Åke Andersson
On behalf of the MAX IV team
IBIC 2016, Barcelona

MAX IV LABORATORY

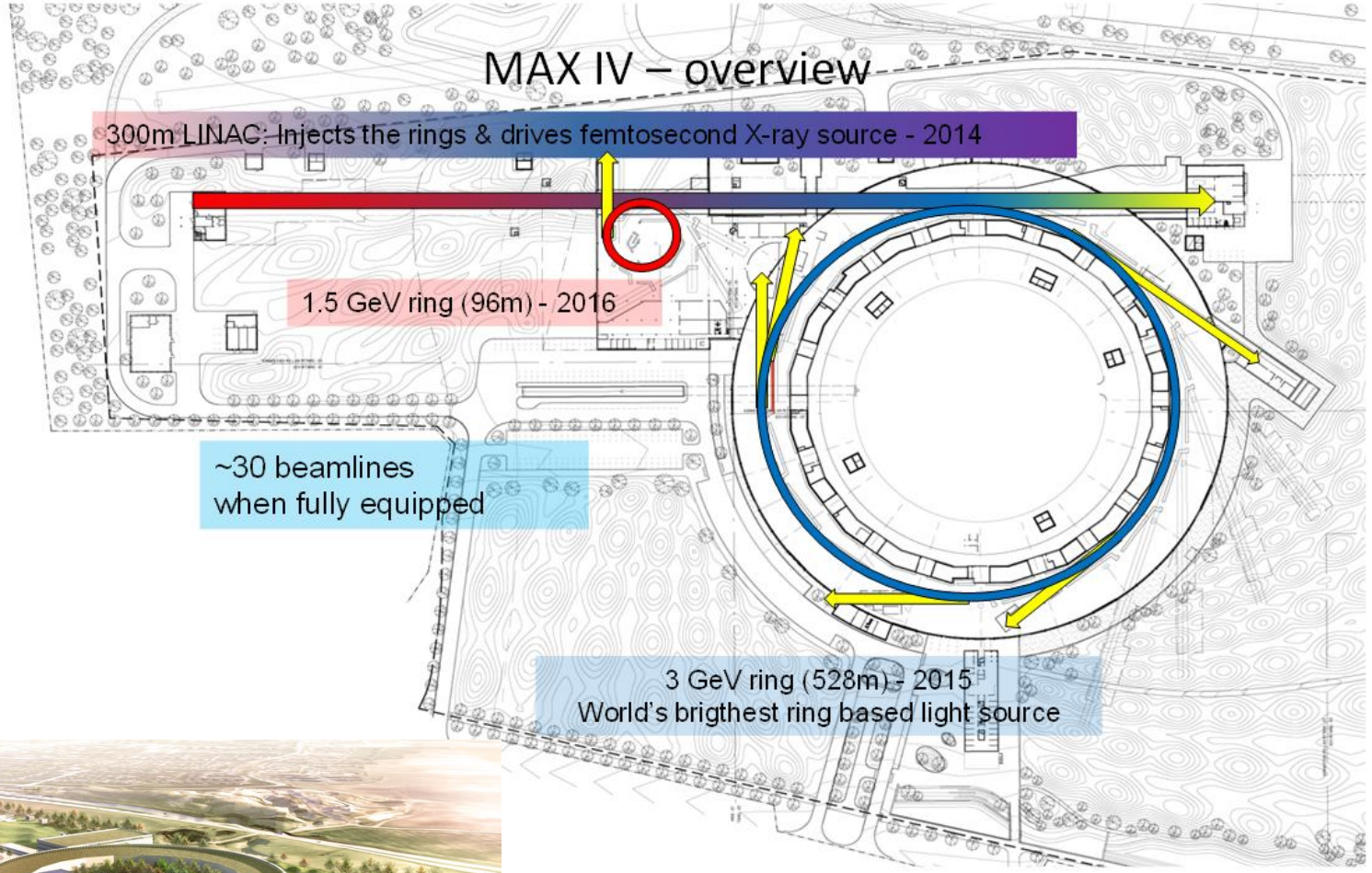
Outline

- MAX IV facility overview
- Linac “injector mode” diagnostics
- 3 GeV ring diagnostics

The MAX IV facility: Concept

- **Different machines for different uses:**
  - A high energy ring with ultra-low emittance for hard X-ray users.
  - A low emittance low energy ring for soft radiation users
  - A LINAC based source for generating short pulses and allowing for future development of FEL source.

MAX IV – overview



Inauguration was June 21, 2016

MAX IV LABORATORY

3 GeV ring design parameters

MAX IV 3 GeV storage ring parameters.

Operating energy	3 GeV
Circulating current	500 mA
Circumference	528 m
Horizontal emittance (bare lattice)	330 pm rad
Horizontal emittance (incl. IDs)	180 pm rad
Vertical emittance	2 – 8 pm rad
Total beam lifetime at 500 mA	>10 h
Qx, Qy	42.20, 16.28
Chromx, Cromy (natural)	-50.0, -50.2
Momentum compaction factor	3.06×10-4
Required momentum acceptance	>4.5 %

Inside the Linac building

Klystron gallery

Photo Annika Nyberg

Linear accelerator

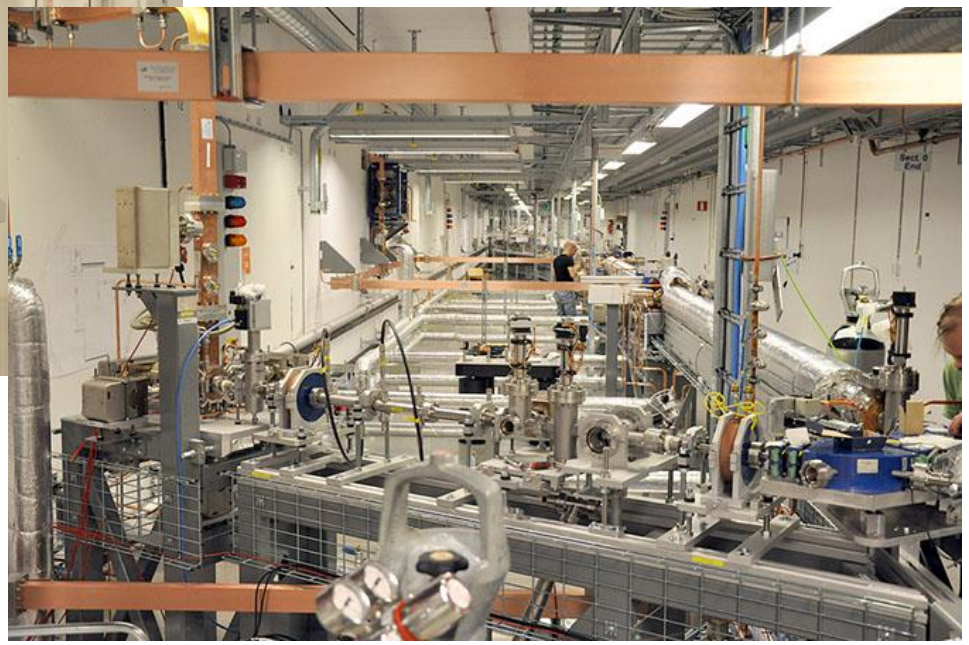


Photo Annika Nyberg

MAX IV LABORATORY

Inside the 3 GeV building

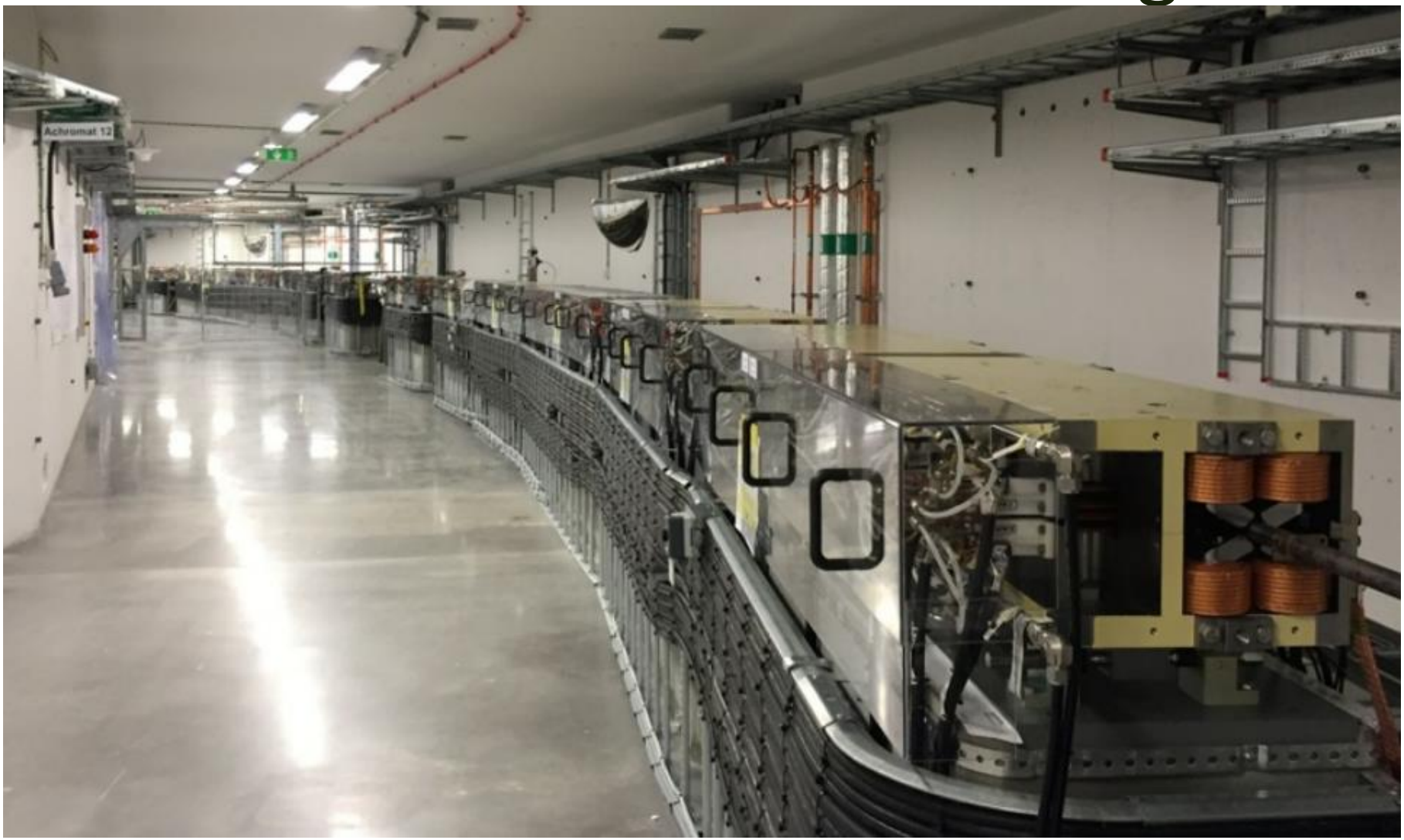


Photo Simon Leemann

MAX IV LABORATORY

Outline

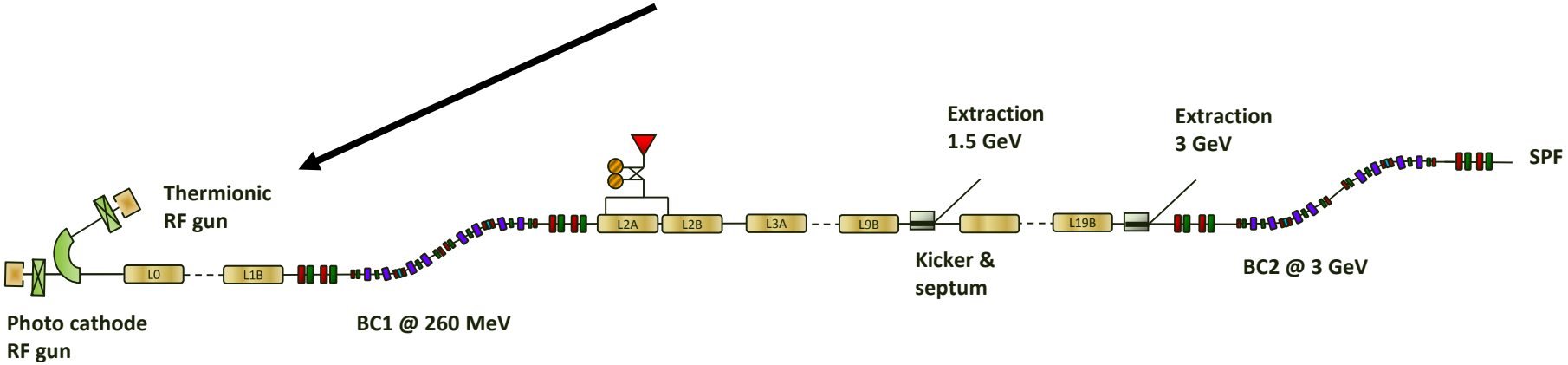
- MAX IV facility overview
- Linac “injector mode” diagnostics
- 3 GeV ring diagnostics

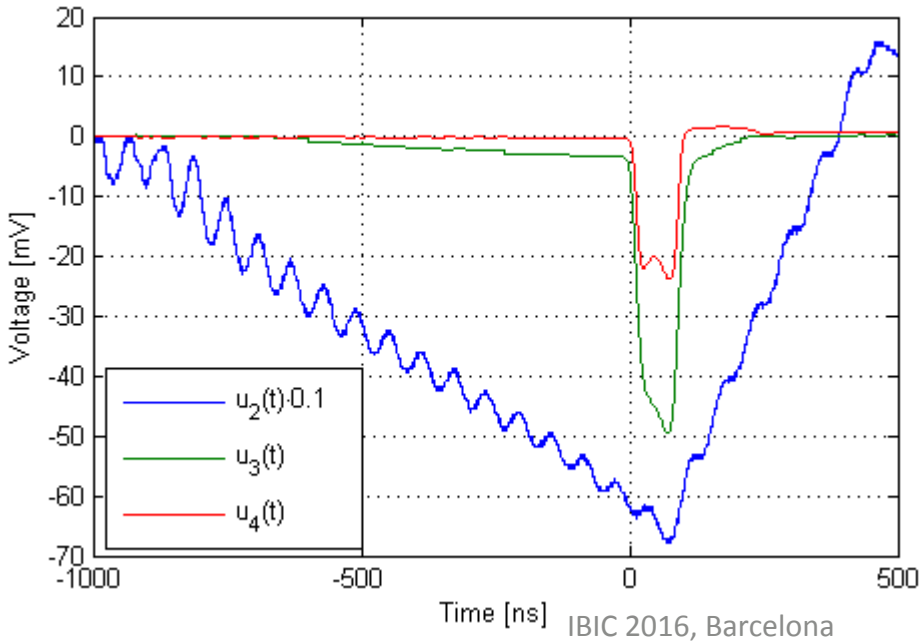
Linac injector mode

Injector linac design parameter values.

End energy	3 GeV
RF	2.9985 GHz
Field gradient	17 MV/m
Acc cell length	5.2 m
No of structures	39
Norm emittance	6 mm*mrad

Linac injector mode



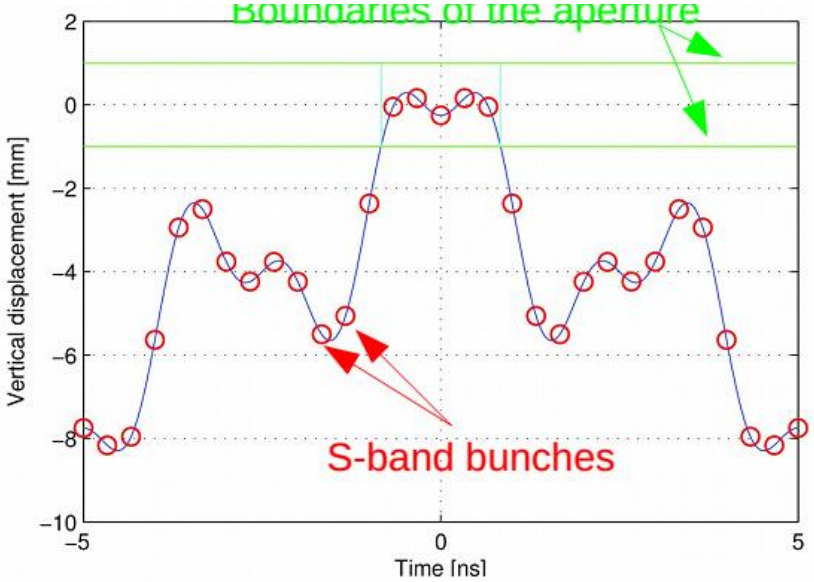


Current Transformer signals (Z=1 Ω) after thermionic gun (blue), chopper system (green) and energy filter (orange).

Slide by S.Thorin

MAX IV LABORATORY

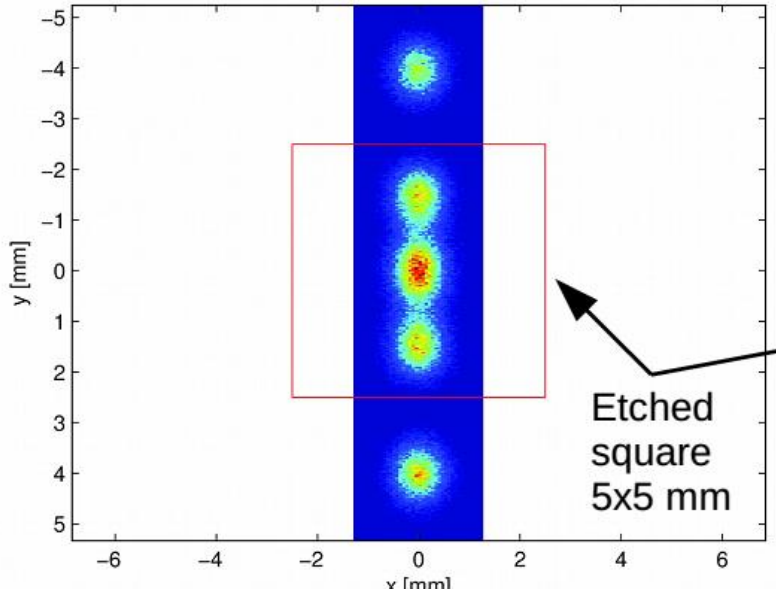
Linac injector mode

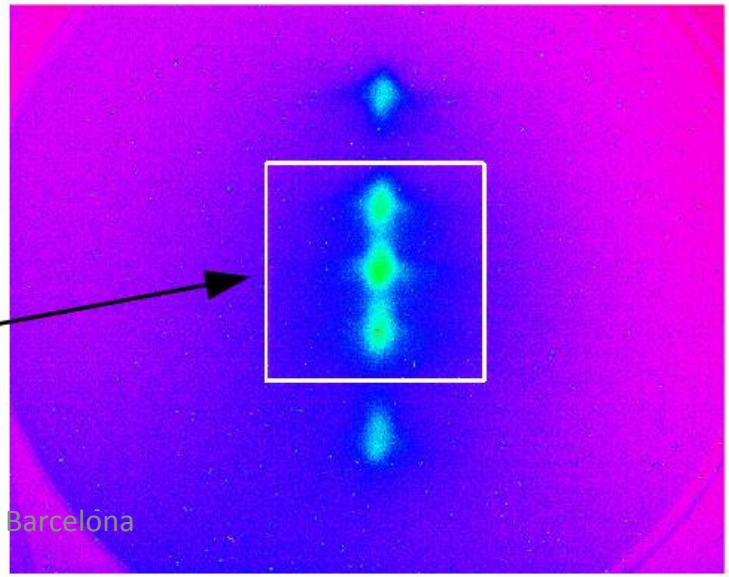


Top Left: Simulated transverse displacement in TD of the S-band bunches at the position of the aperture scraper.

Bottom Left: Simulated charge projection at the aperture scraper without any offset.

Bottom Right: Measured charge projection on a YAG screen directly after the aperture scraper without offset. Note that the aperture obstacle is removed and the etched square is enhanced.



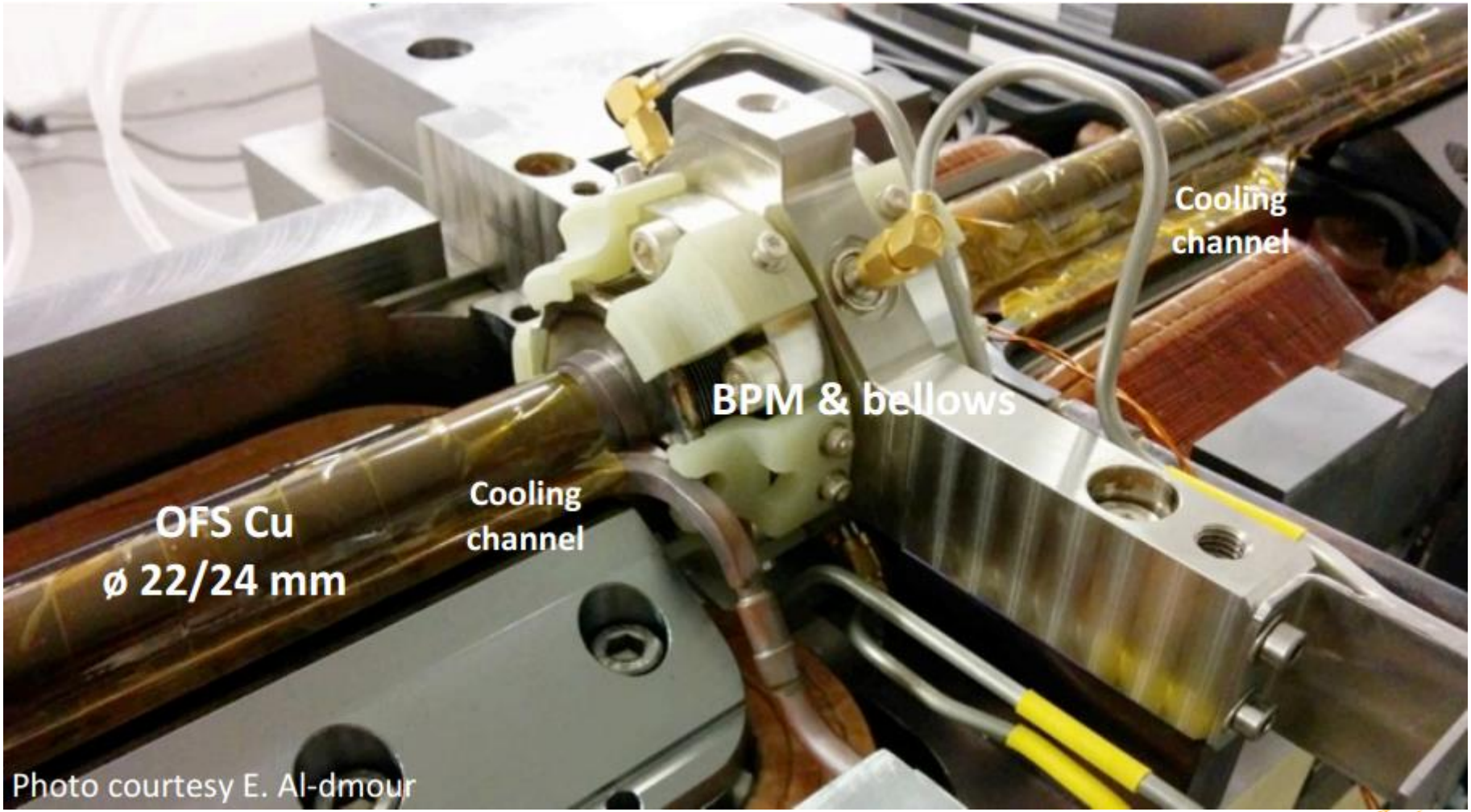


YAG-Screen measur-ements

Outline

- MAX IV facility overview
- Linac “injector mode” diagnostics
- 3 GeV ring diagnostics

Beam Position Monitors



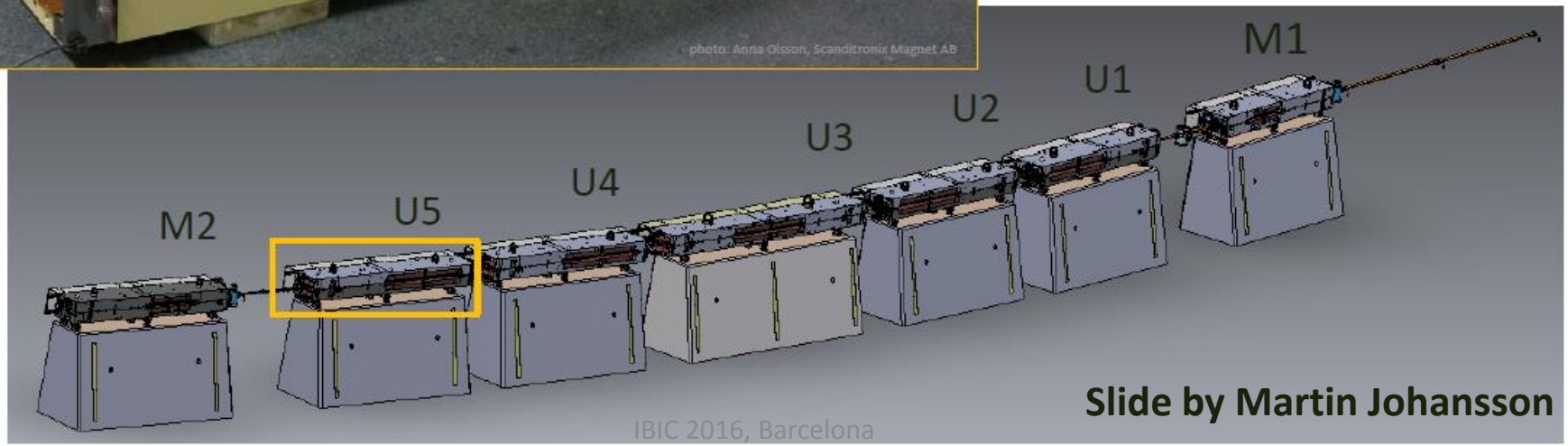
MAX IV LABORATORY

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.

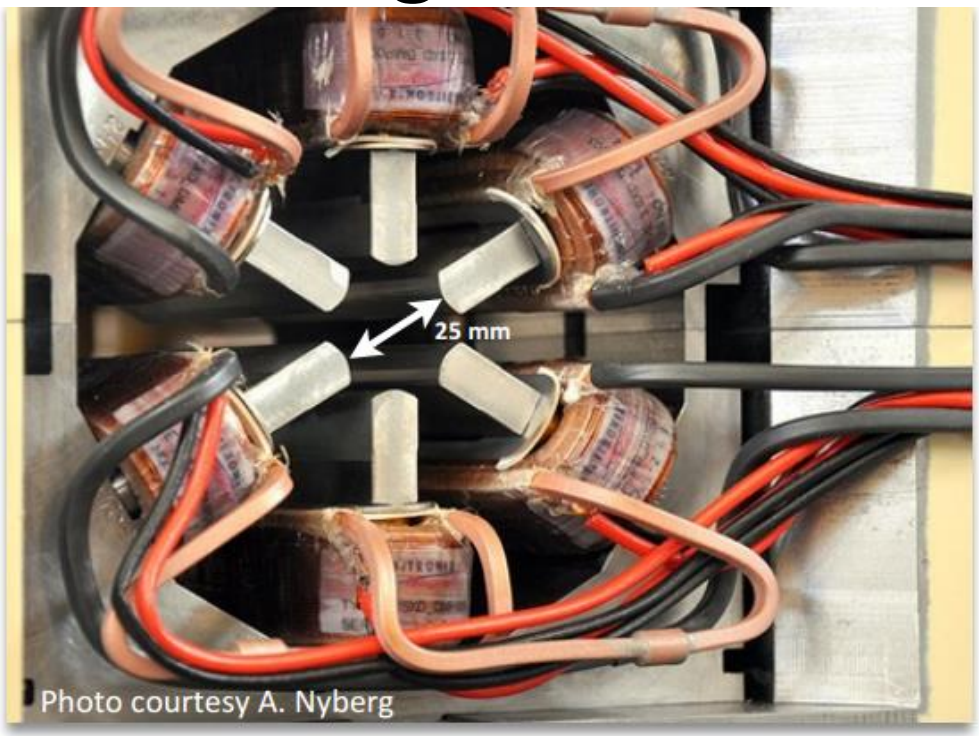
- a U5 bottom half →
- ↓ an assembled U5

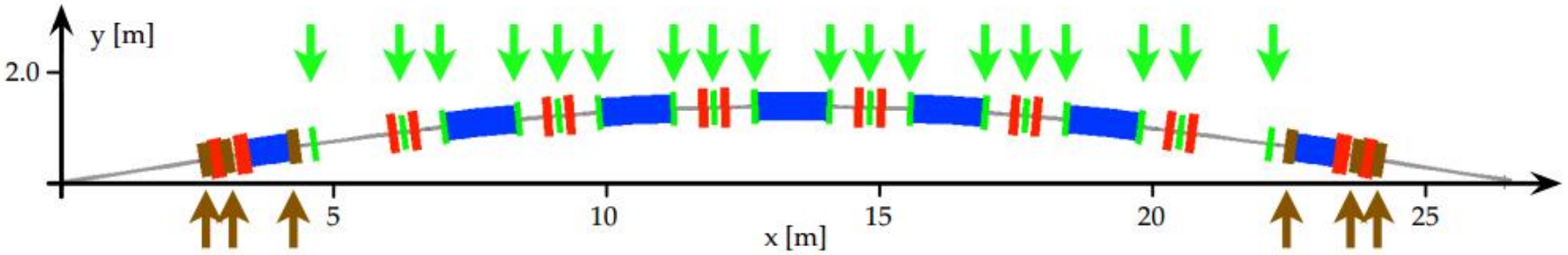


Non-linear magnets

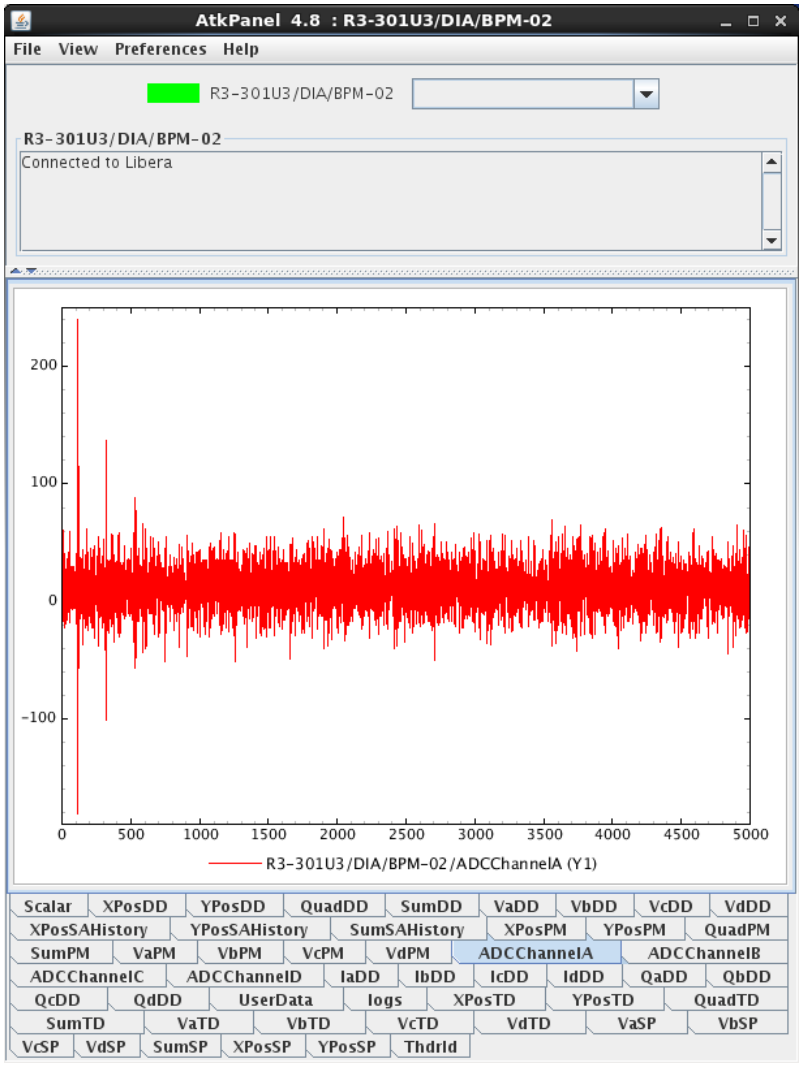
Strong, 25 mm bore, sextupoles & achromatic octupoles for non-linear optics.
All those carry auxiliary windings that can be used as:

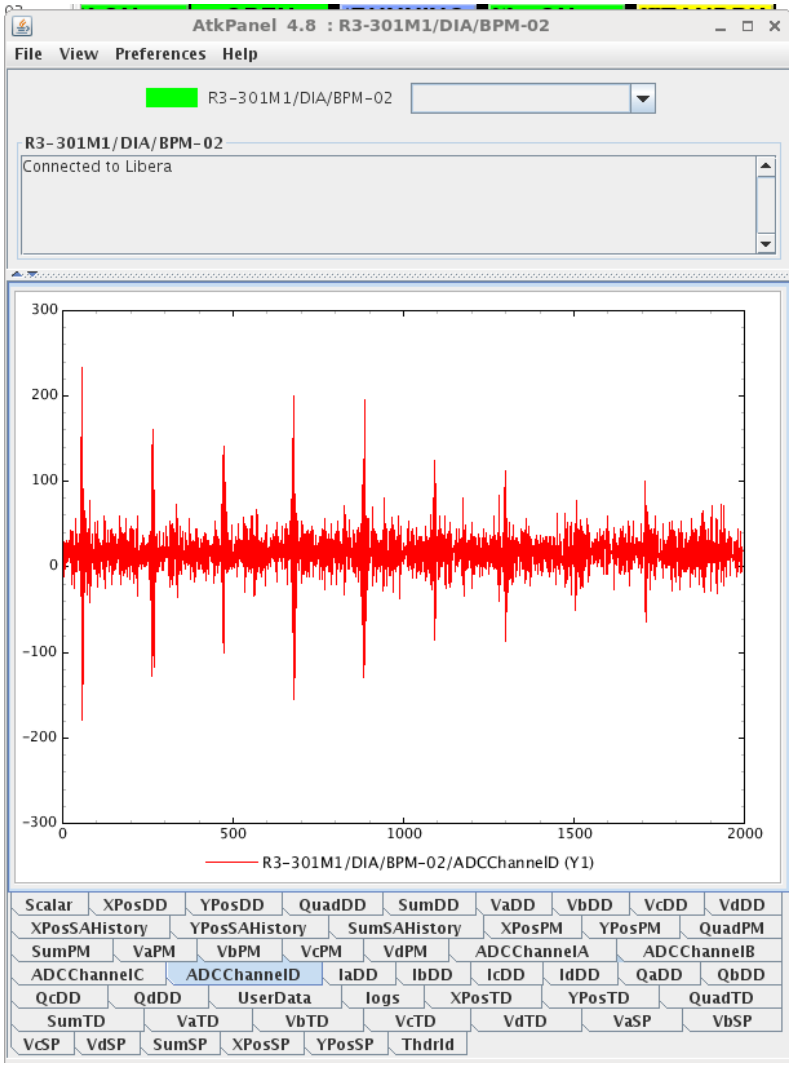
- Additional H/V correctors
- Auxiliary sextupoles
- Skew quadrupoles (**coupling & vertical dispersion correction**)
- Upright quadrupoles (**calibrate BPMs to the center of adjacent sextupole/octupole)**





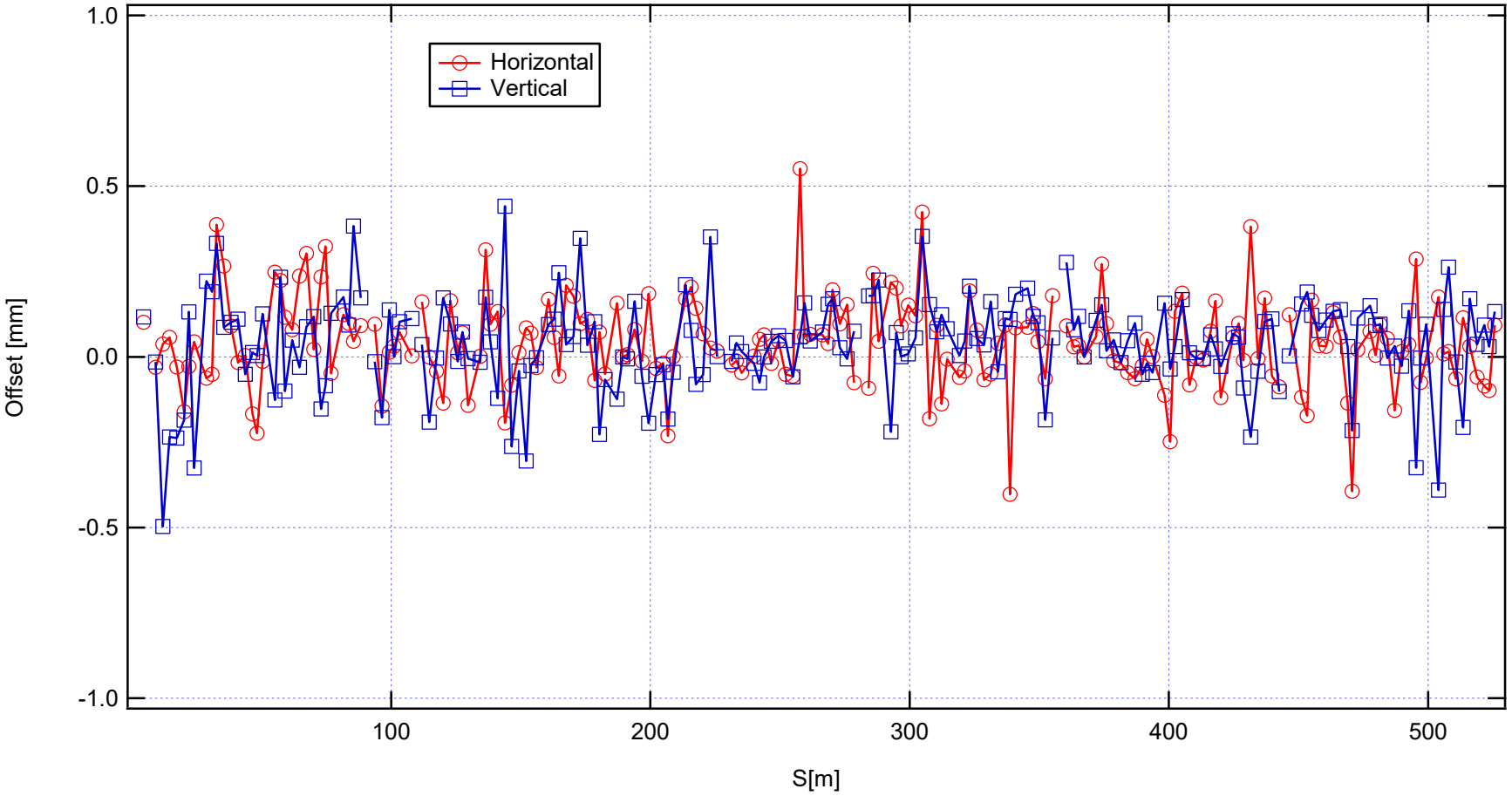
BPMs – first turns





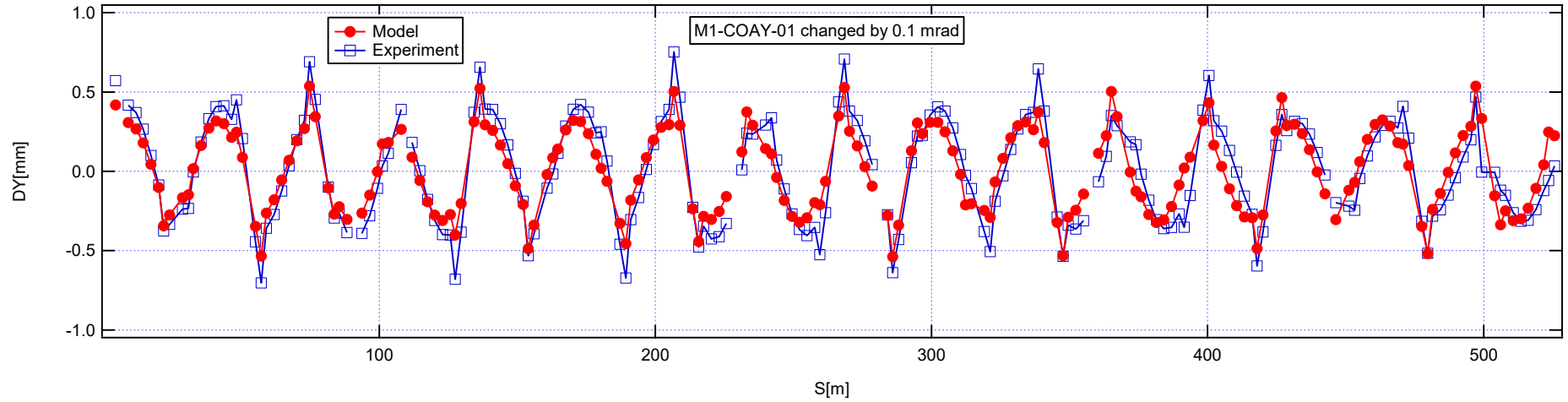
MAX IV LABORATORY

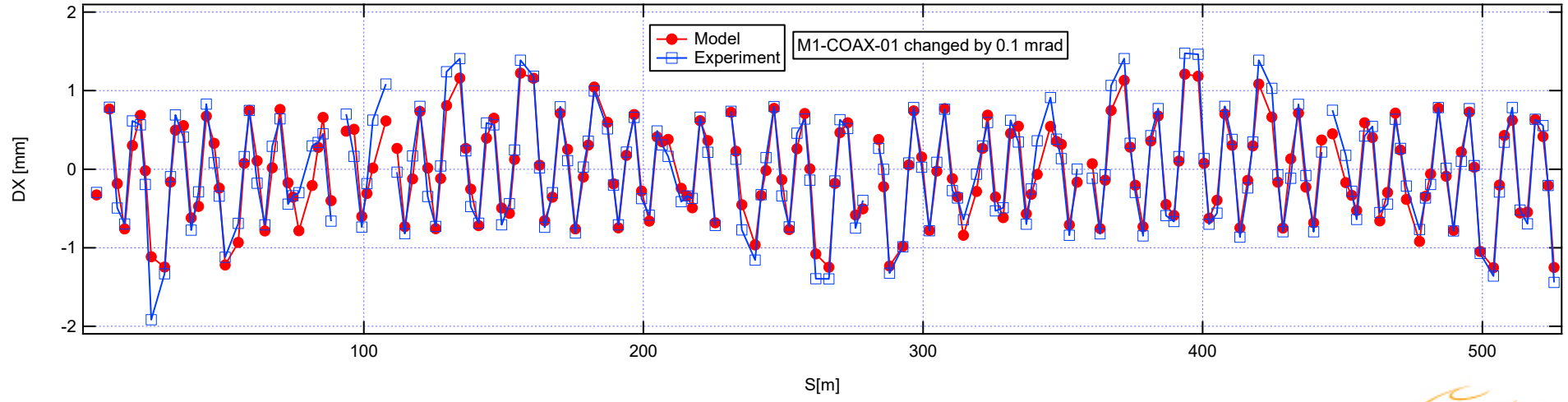
Once beam is stored: BPM offsets



MAX IV LABORATORY

Once beam is stored: Tune integers

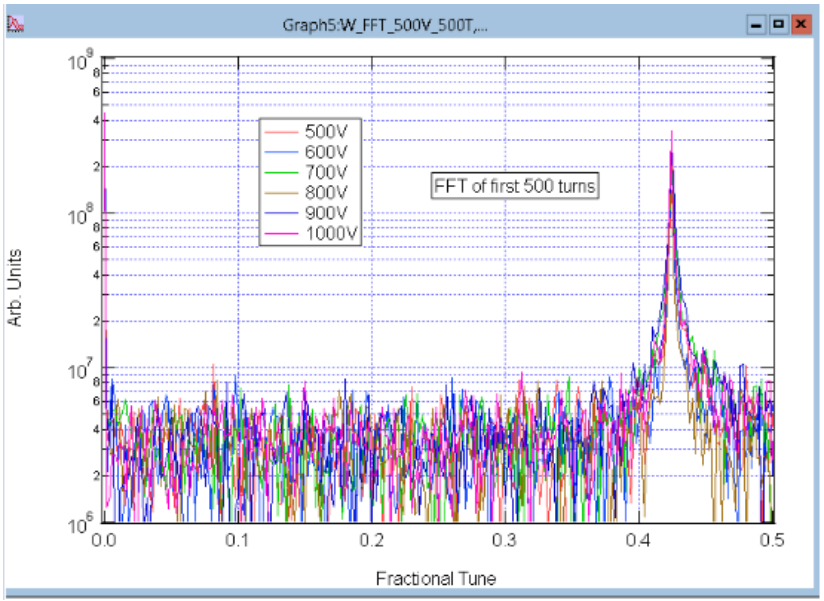




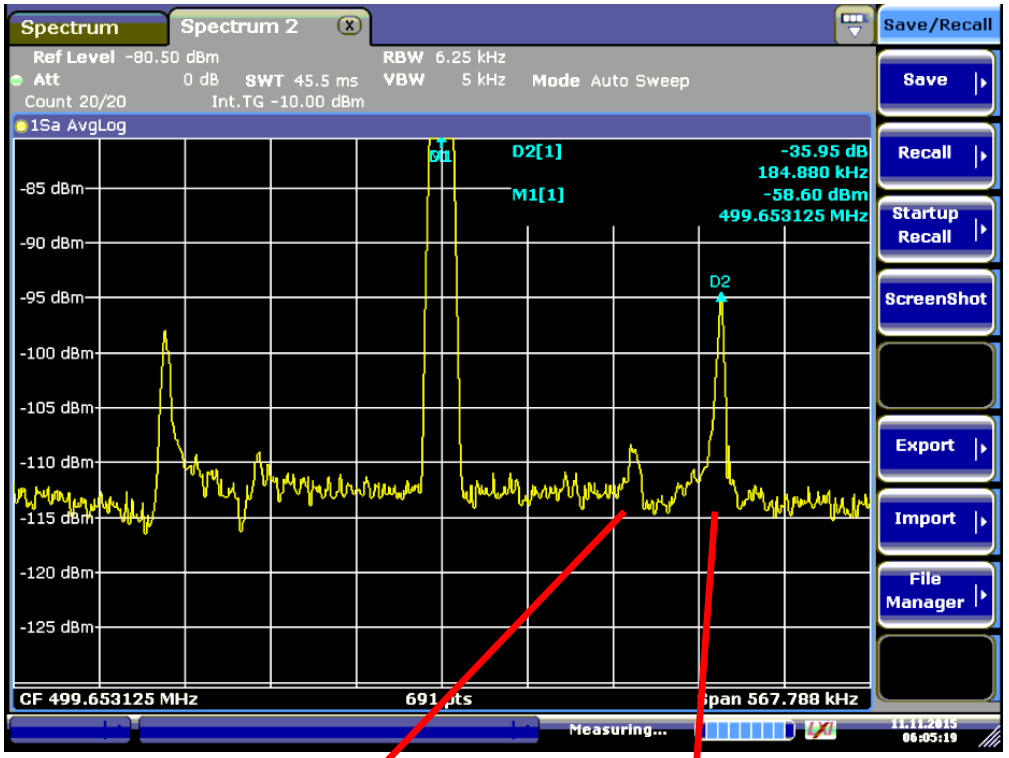
MAX IV LABORATORY

Fractional Tunes

Horizontal Tune from TBT data
Excitation by Kicker&Pinger



Tunes on Spectrum Analyzer
Excitation by Stripline

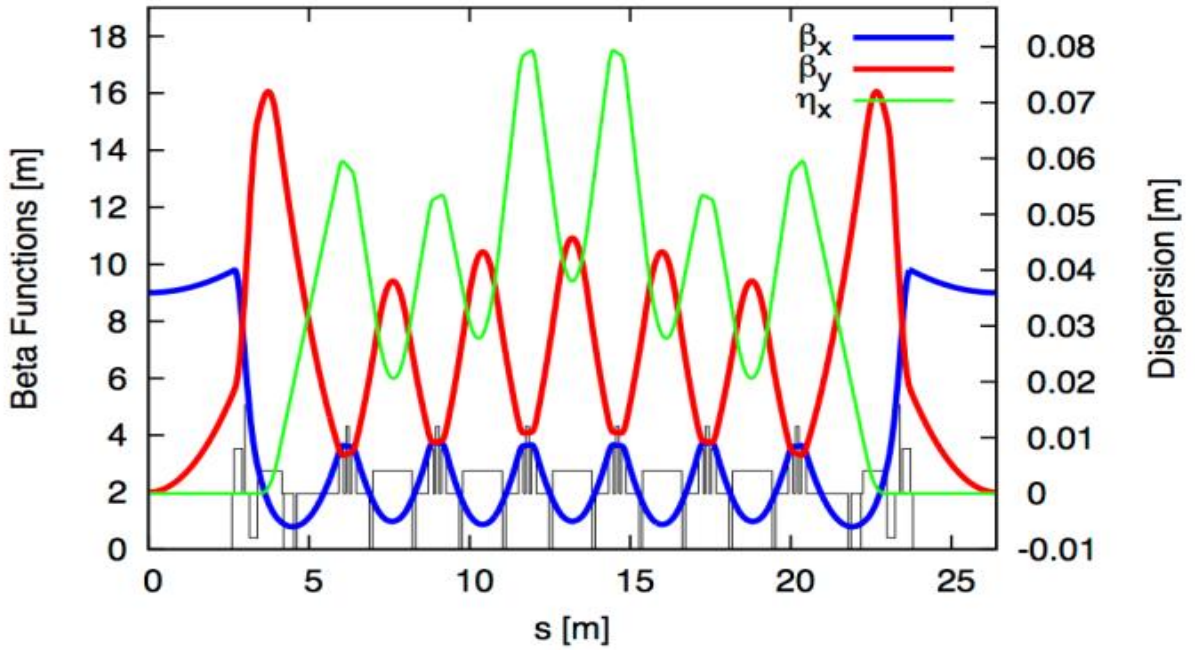


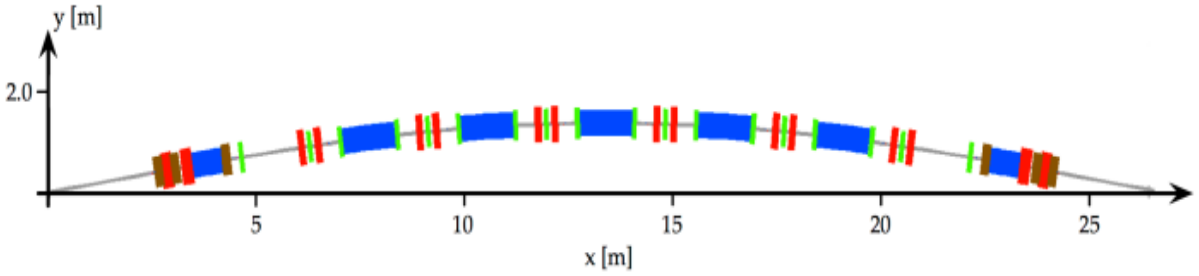
qy=0.22

qx=0.32

MAX IV LABORATORY

Monitoring the machine functions





Two ways:

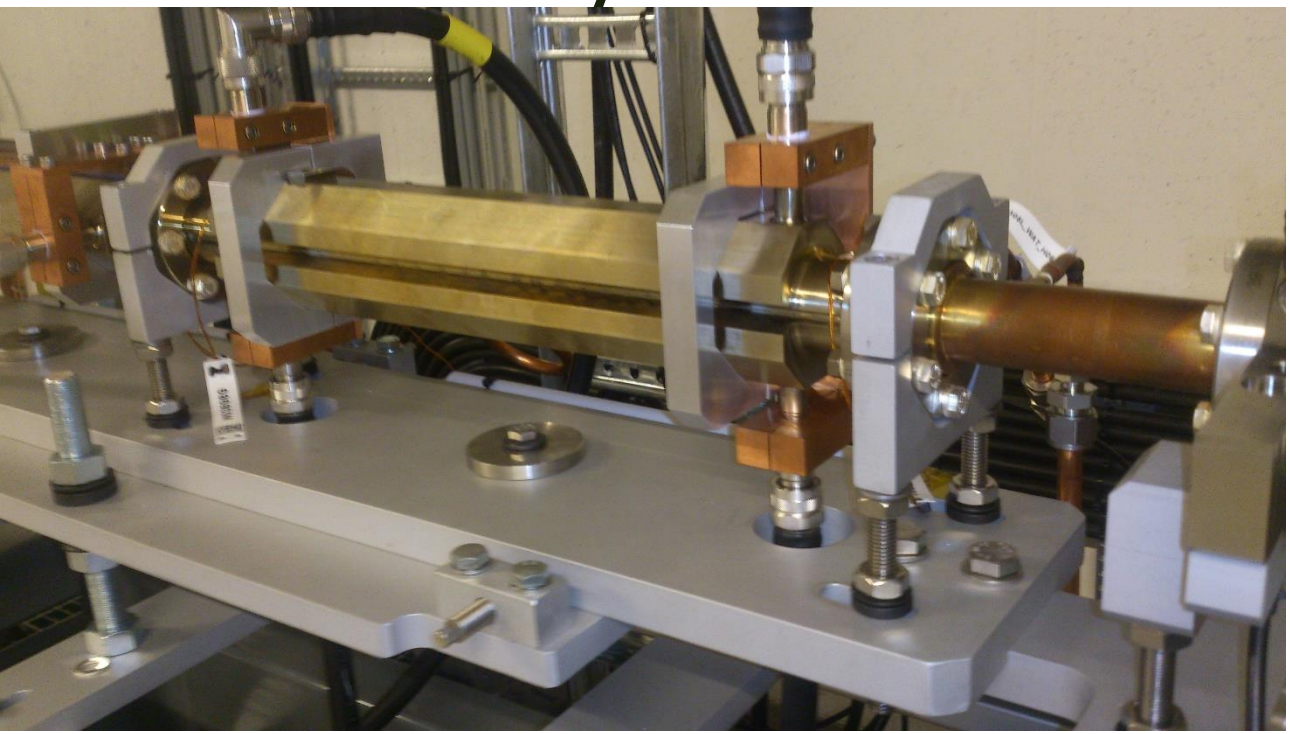
1. LOCO – orbit response measurements.
2. Induced tune-shifts from quadrupole strength variations.

2. Is with our 24 trim coils per achromat probing densly the beta-functions

Bad news: So far we get way too large discrepancies!!!

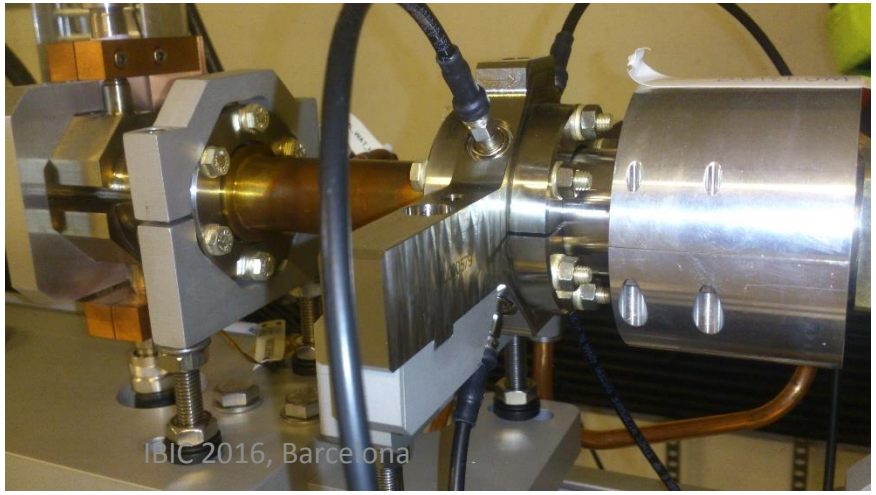
MAX IV LABORATORY

Bunch-by-bunch feedback system



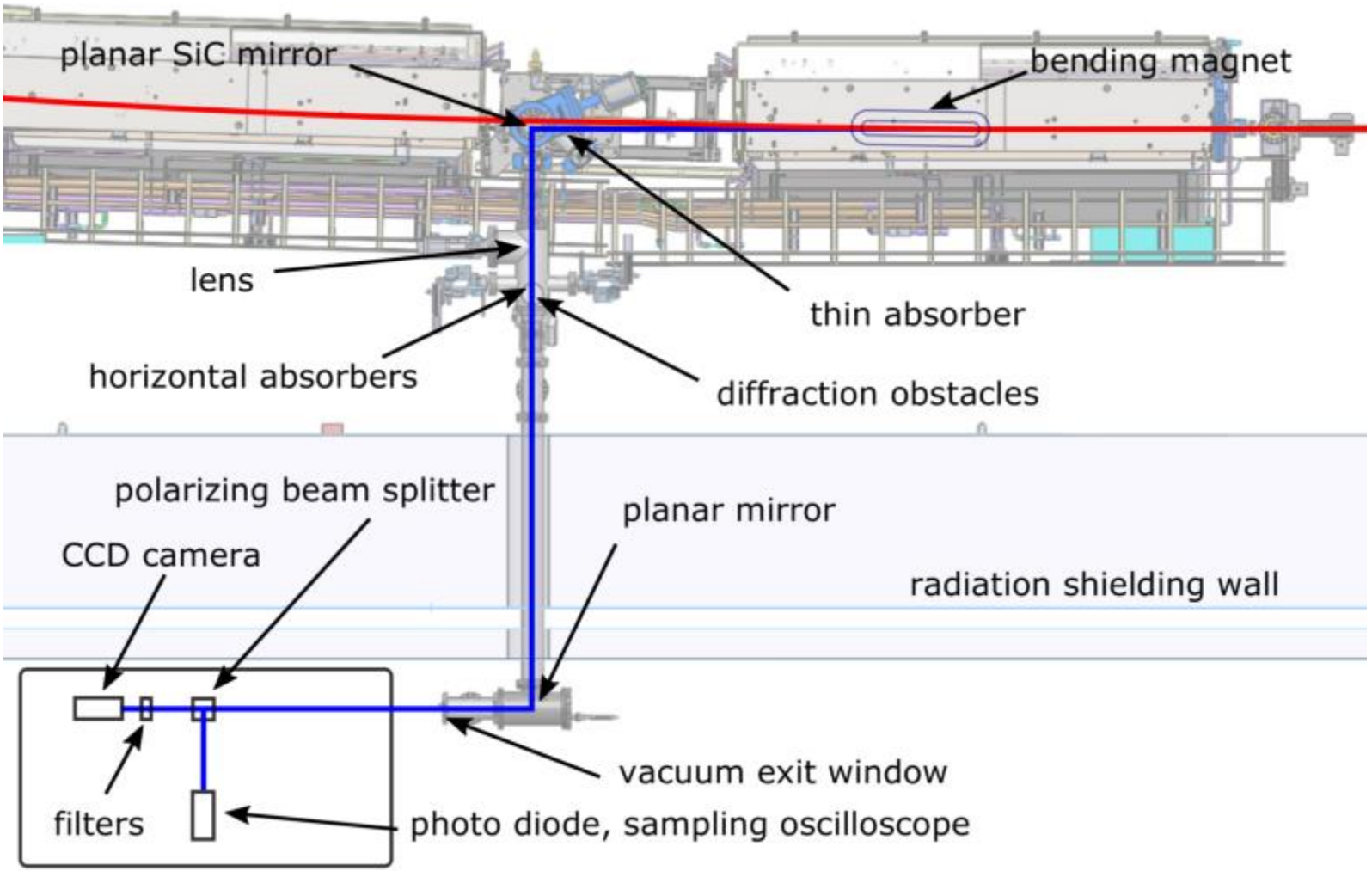
- This is a powerful diagnostics system!
- Presently, we measure growth rates of CBIs driven by long. cavity HOMs.
- ➔ Guides nicely the cavity temp tuning.
- Long stability up to 120 mA, using a weak long. common mode excitation at one strip-line pair.

Processors by:
http://www.dimtel.com/



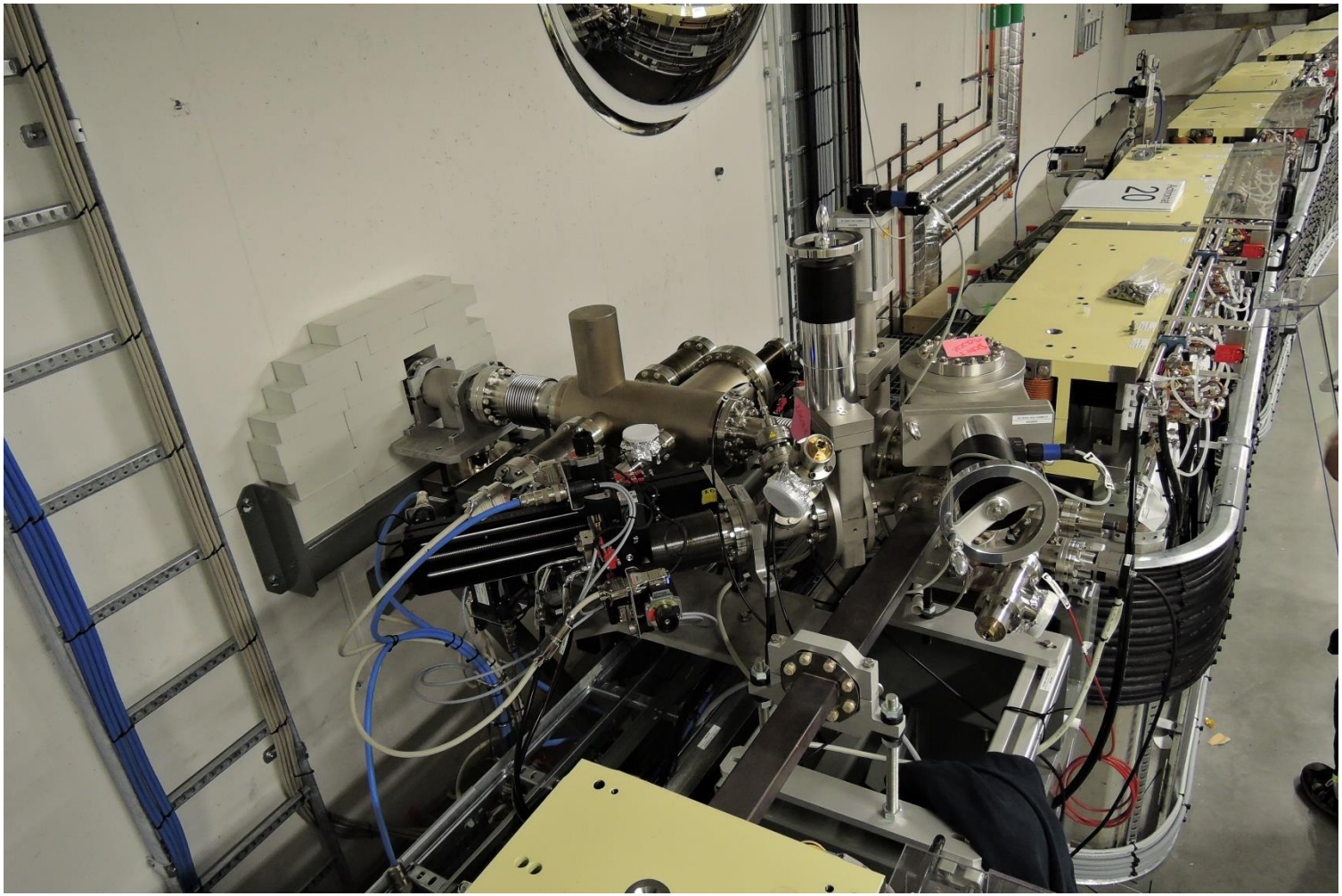
MAX IV LABORATORY

Emittance measurements



MAX IV LABORATORY

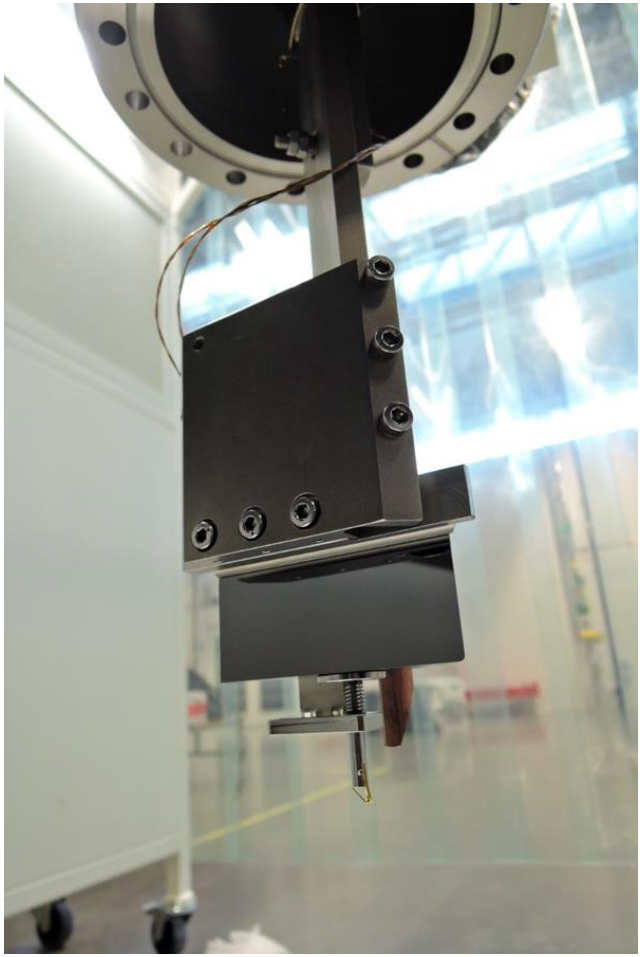
Emitt. Meas.: Extraction in S1



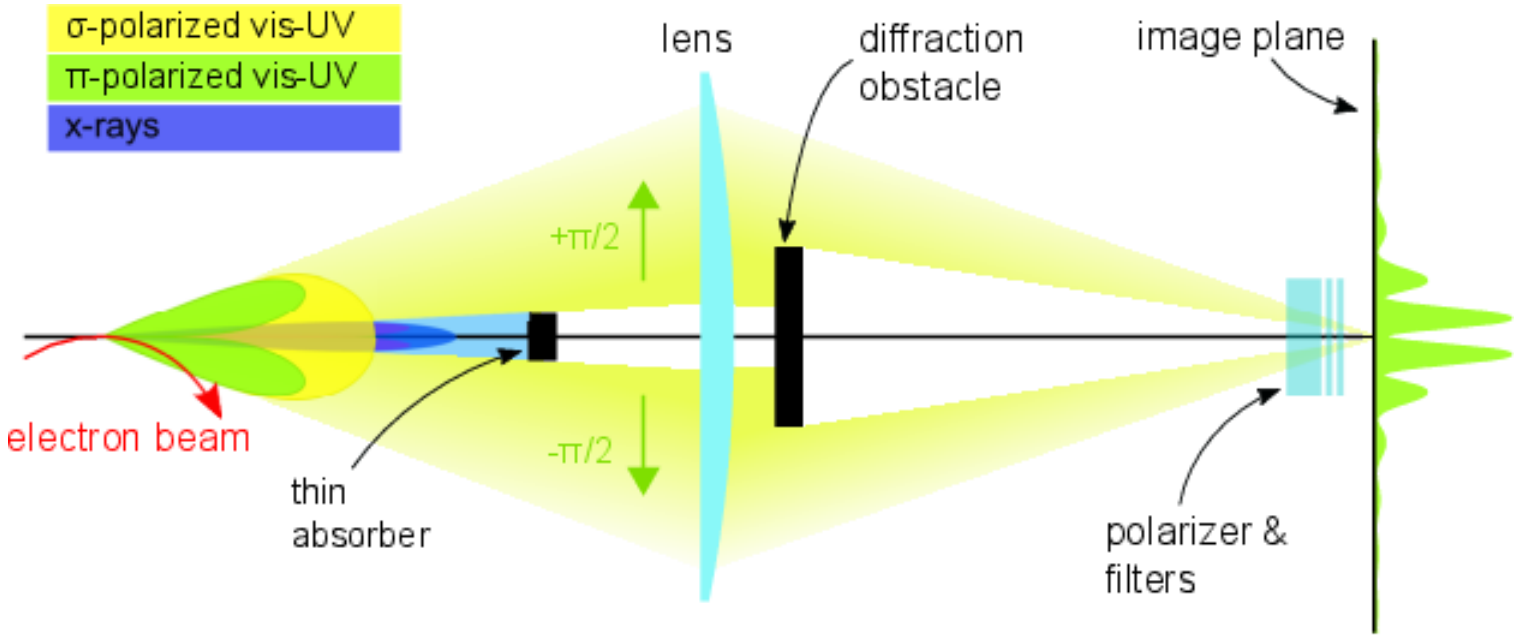
MAX IV LABORATORY

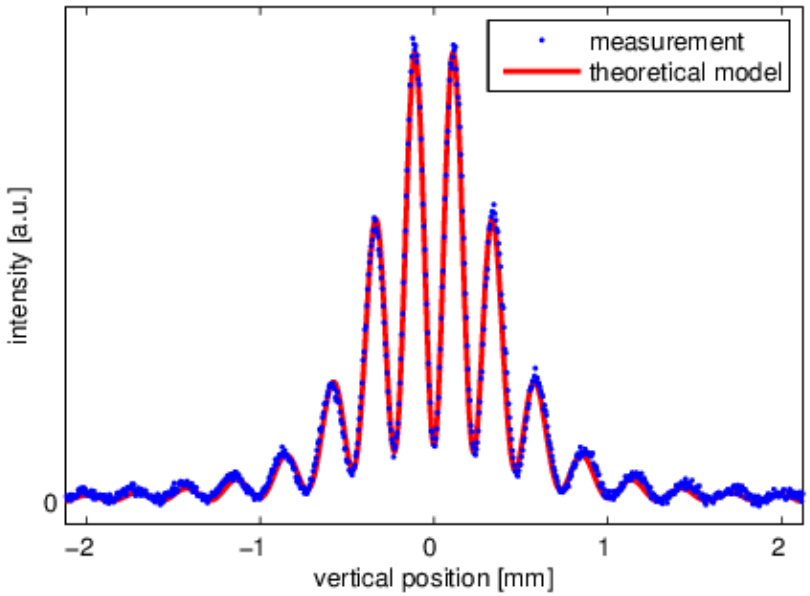
Emitt. Meas.: Extraction SiC mirror

- The extraction mirror (lowest black piece) is prisma shaped in order to come as close as possible to the electron beam.
- 15 to 18 horizontal mrads of the SR fan is extracted.
- Fringe field radiation is extracted as well for improved diagnostics.



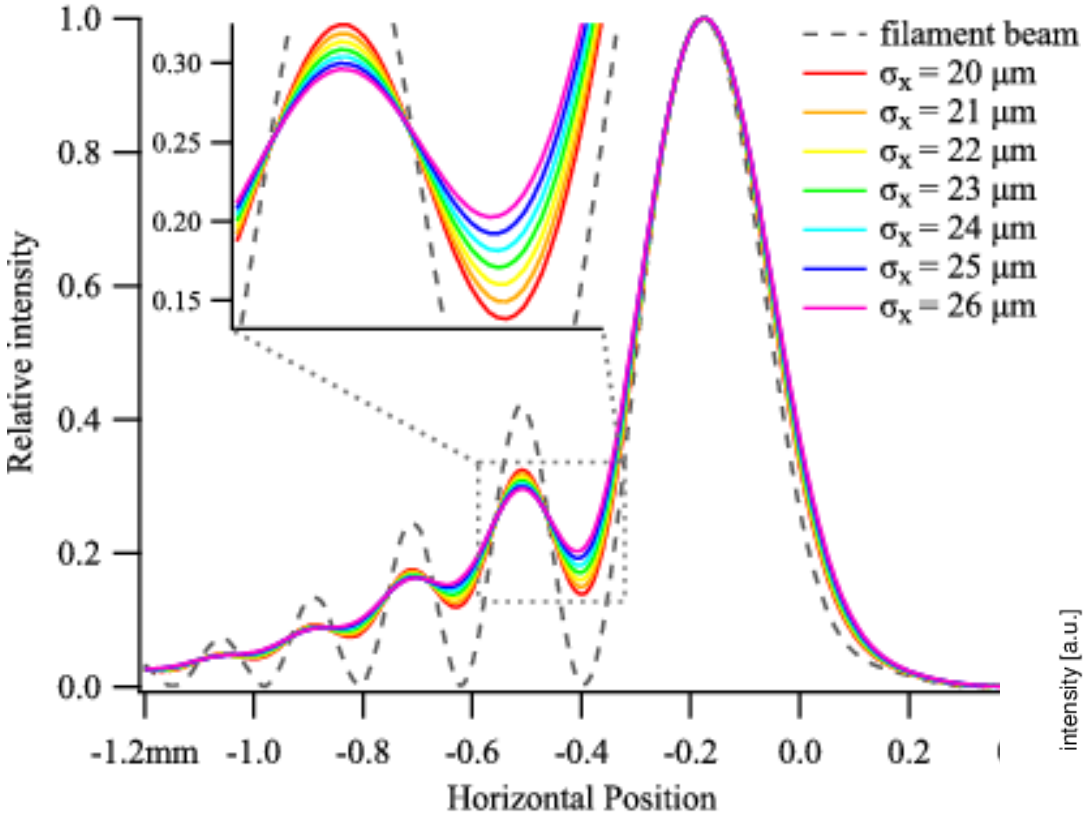
Emitt. Meas.: Vertical beam size





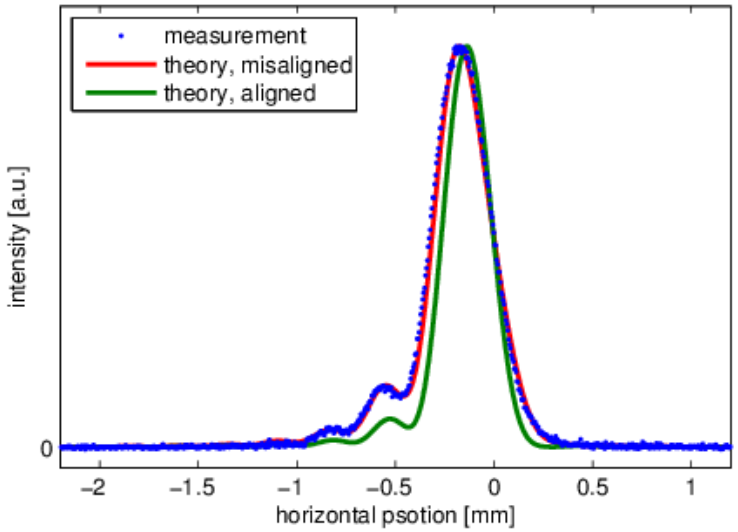
MAX IV LABORATORY

Emitt. Meas.: Horizontal beam size



Measured horizontal profile:

- 8.2 $mrad_H$ ➔ less pronounced fringes
- At 930 nm



Theorethical horizontal profiles:

- 15 $mrad_H$
- Wavelength is 930 nm
- Future DLSR, using visible SR ➔ A few micron rms beam sizes might be resolvable

MAX IV LABORATORY

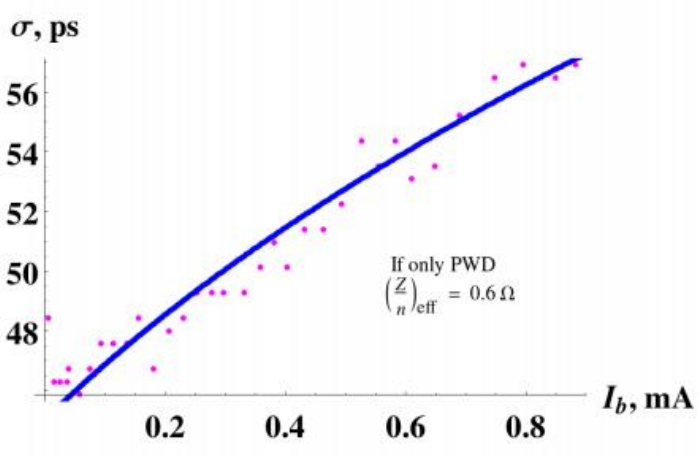
Longitudinal bunch profiles

- Not yet observed the ”flat potential ” case at MAX IV.
- We still need to further temperature tune the cavities to avoid longitudinal CBIs, when Landaus are engaged.

- Single bunch operation
- Assuming only PWD, effective impedance is 0.6 Ω (0.5 Ω predicted)

Photo: J. Breunlin

Optical sampling oscilloscope



MAX IV LABORATORY

Summary

- Still a lot of commissioning to be done!
- We believe we have the necessary diagnostics!
- We just need to carefully observe them!

MAX IV LABORATORY

Thank You for your attention!

MAX IV LABORATORY