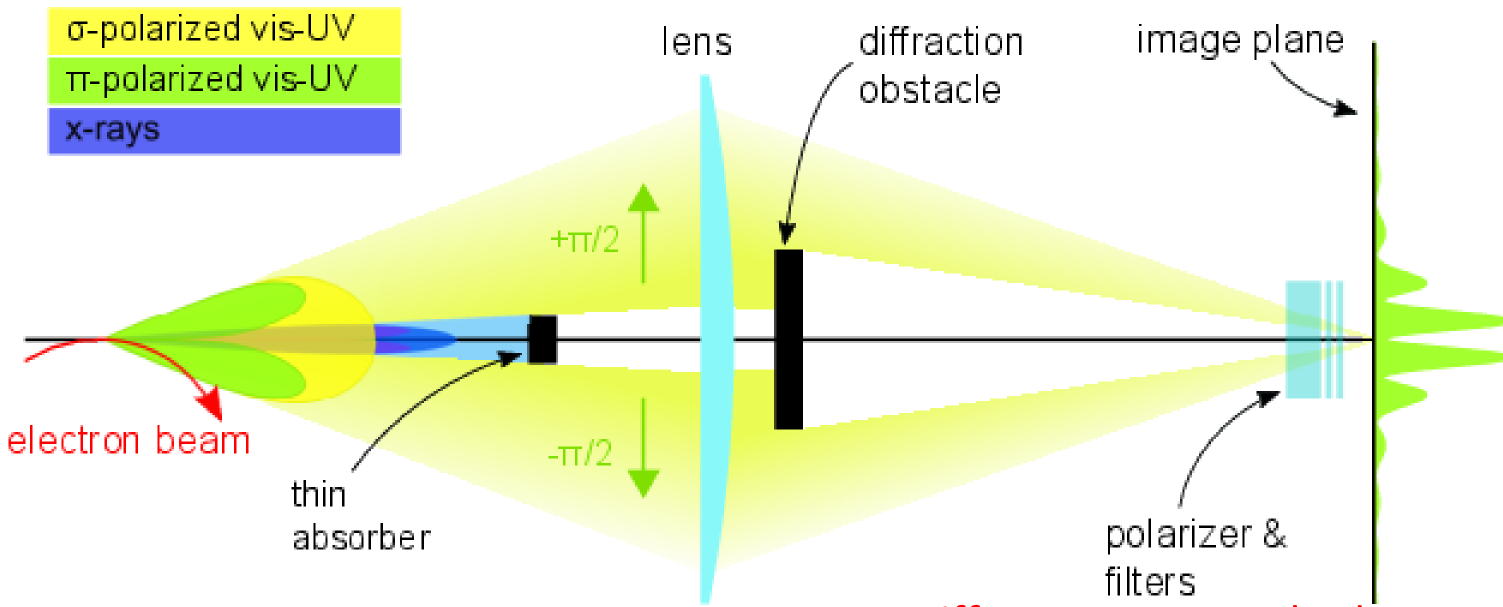
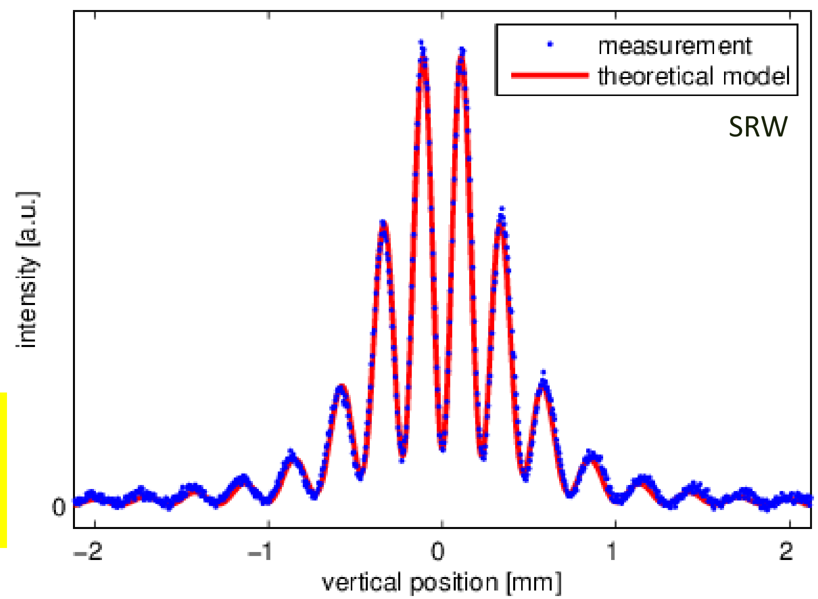
On-going emittance and energy spread measurements, at the MAX IV 3 GeV ring light source

Åke Andersson
MAX IV Laboratory

Resolving a vertical beam size < 5 µm



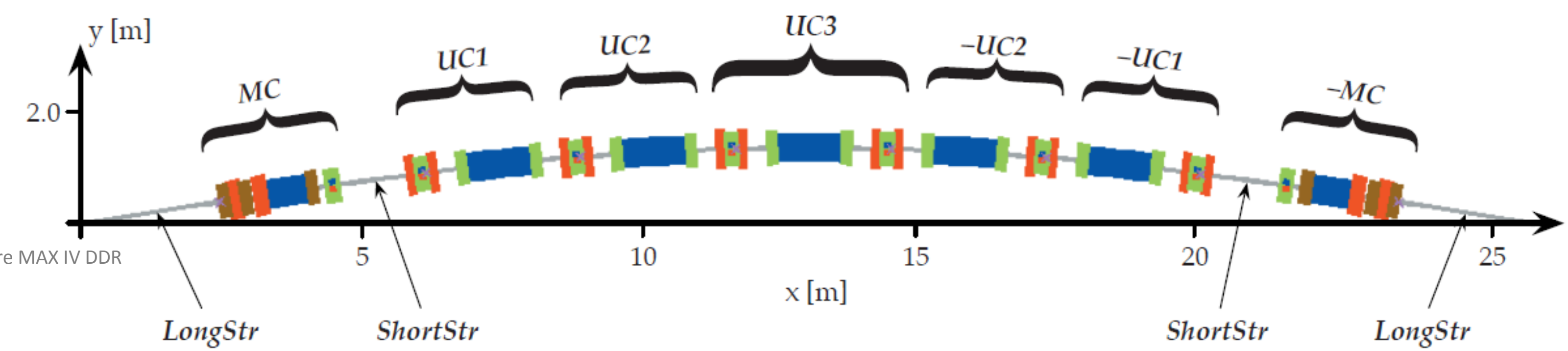
Diffractometer Method:



The **diffractometer** method was implemented at the SLS (TIARA collaboration): $\sigma_y = 4.7 \pm 0.1$ µm

J. Breunlin et al, "Methods for measuring sub-pm rad vertical emittance at the Swiss Light Source", Nucl. Instrum. Meth. A 803, 55-64 (2015).

MAX IV 3 GeV ring



Picture MAX IV DDR

7-Bend Achromat lattice

- MAX IV, the first realization of the multi-bend achromat (MBA) concept for a synchrotron radiation source.

First ideas, M. Eriksson, 2002

M. Eriksson, "The MAX4 accelerator system", unpublished internal note, (2002). http://www.maxiv.lu.se/publications

In User operation, 2017

Some 3 GeV ring publications:

PRST-AB **12**, 120701 (2009).

Tavares P.F., Leemann S.C., Sjöström M. & Andersson Å., Journal of Synchrotron Radiation, (21), 862-877 (2014).

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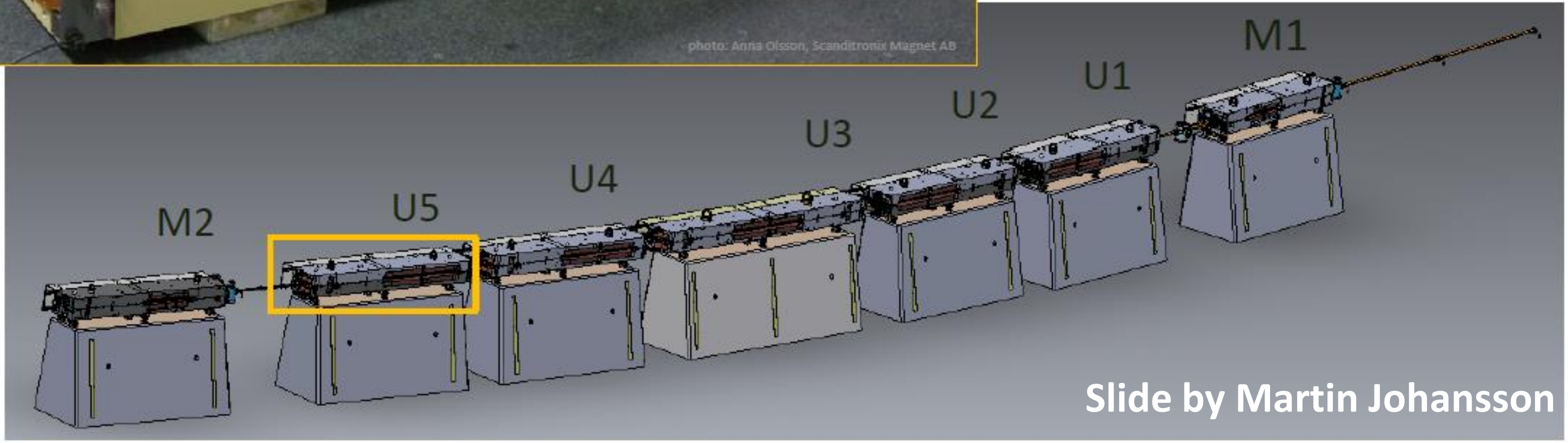
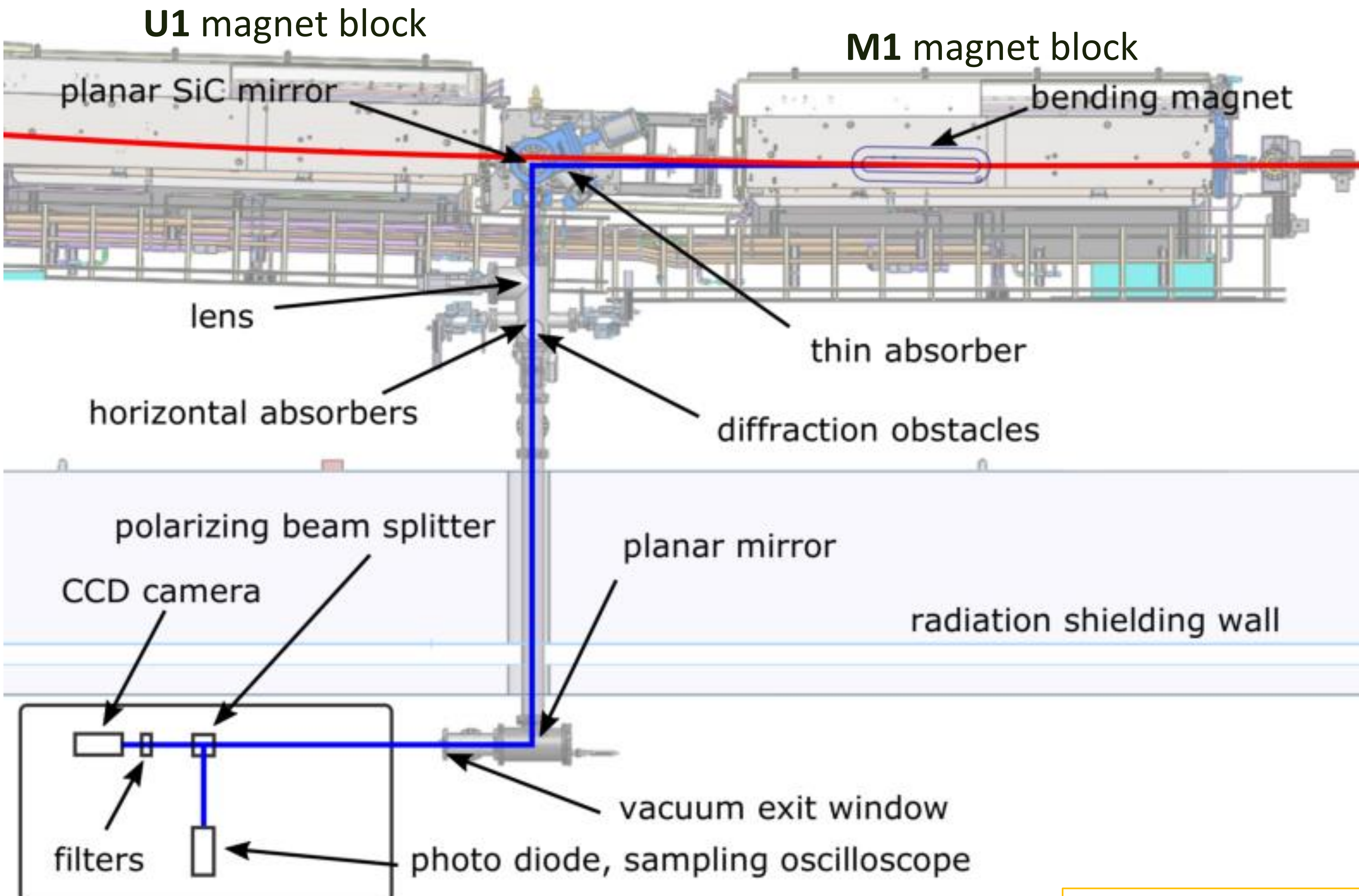
MAX IV 3 GeV ring DC magnets

- *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

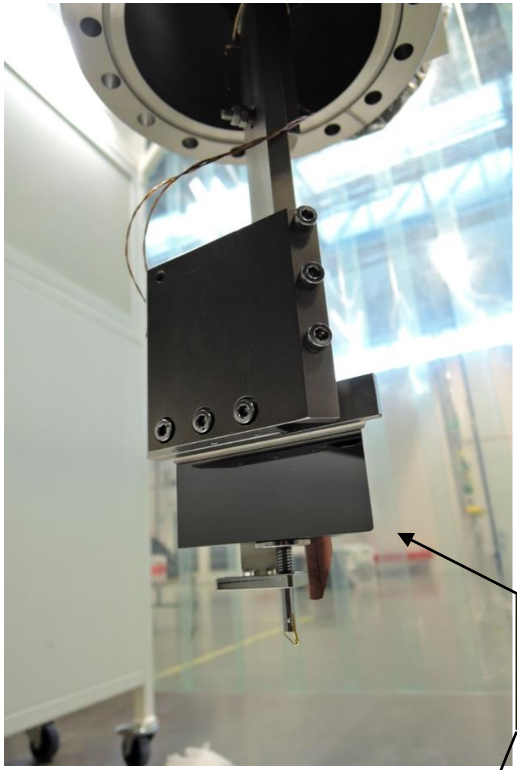


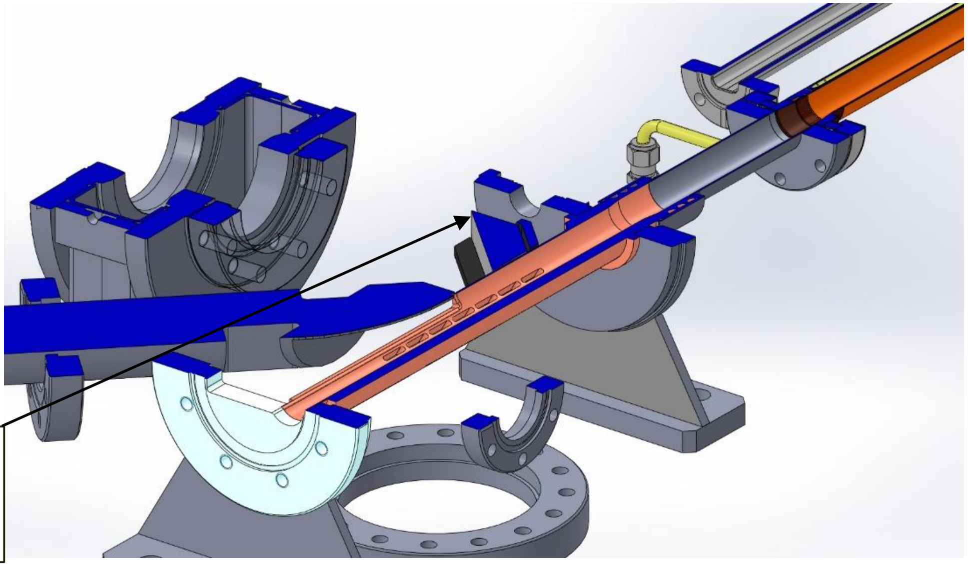
Emittance monitor B320B



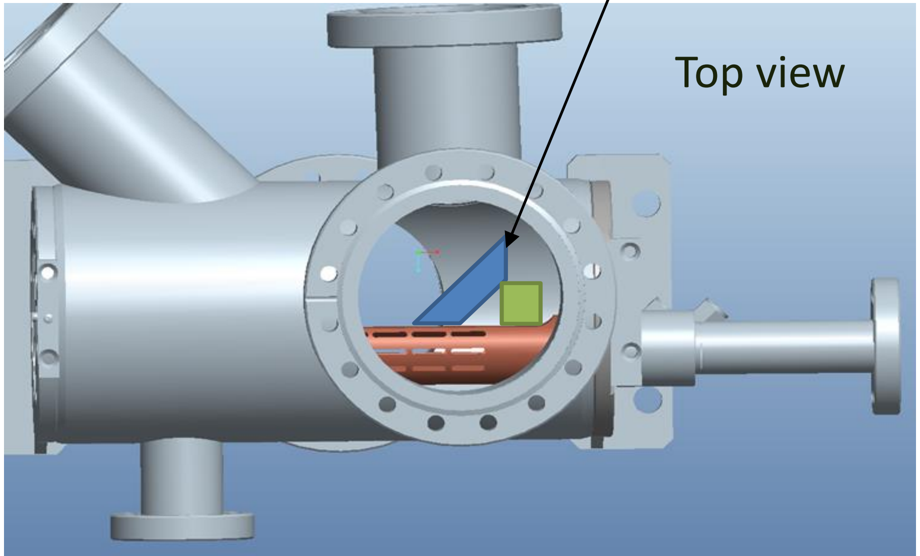
Slide by Jonas Breunlin

B320B "Cold Finger" Absorber & Mirror

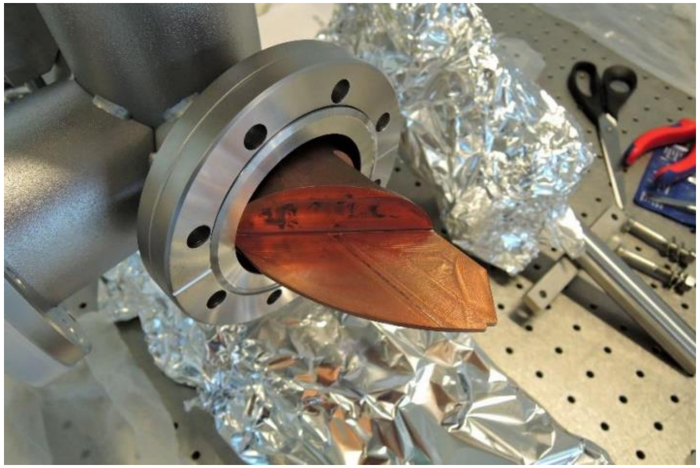




Planar SiC-
Mirror



Top view



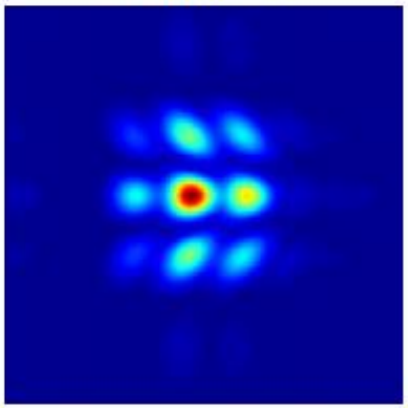
Cold Finger Absorber

Horizontal & vertical beam size

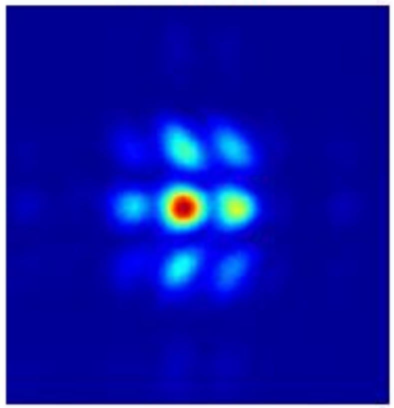
Everyday beam size monitoring scheme:

- Wavelength 488 nm, horizontal acceptance 6 mrad
- Diffraction from
  - Vertical obstacle, 2.1 mrad
  - Horizontal obstacle, 2 mrad

calculation

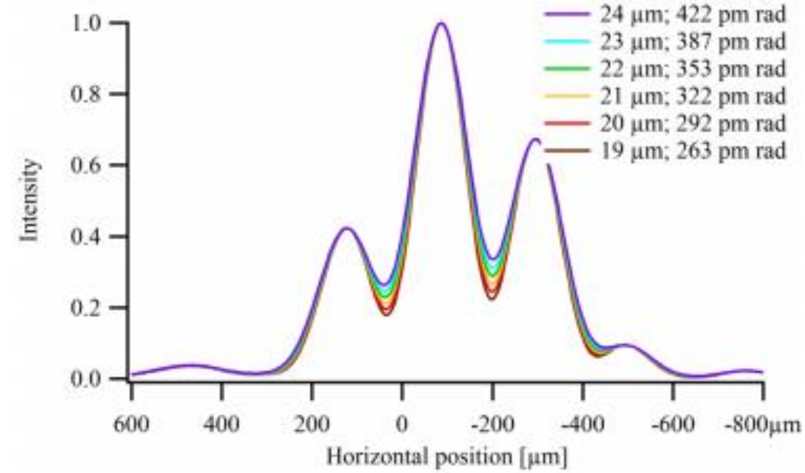


measurement

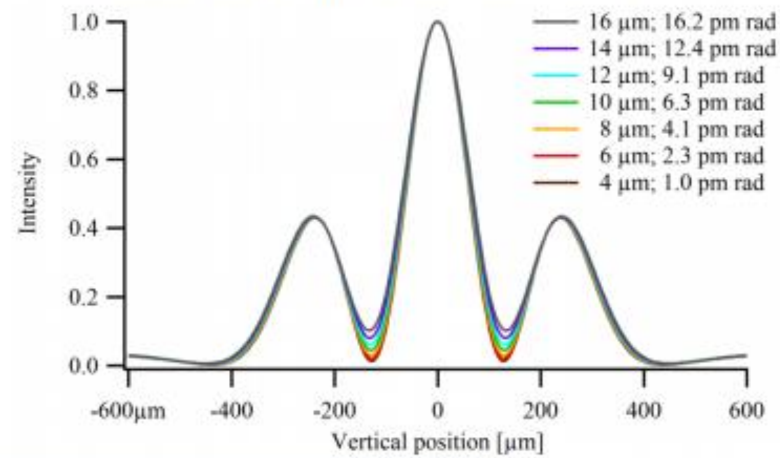


Horizontal diffraction obstacle and ‚footprint' of the SR

Horizontal intensity profile, sensitive to σ_x

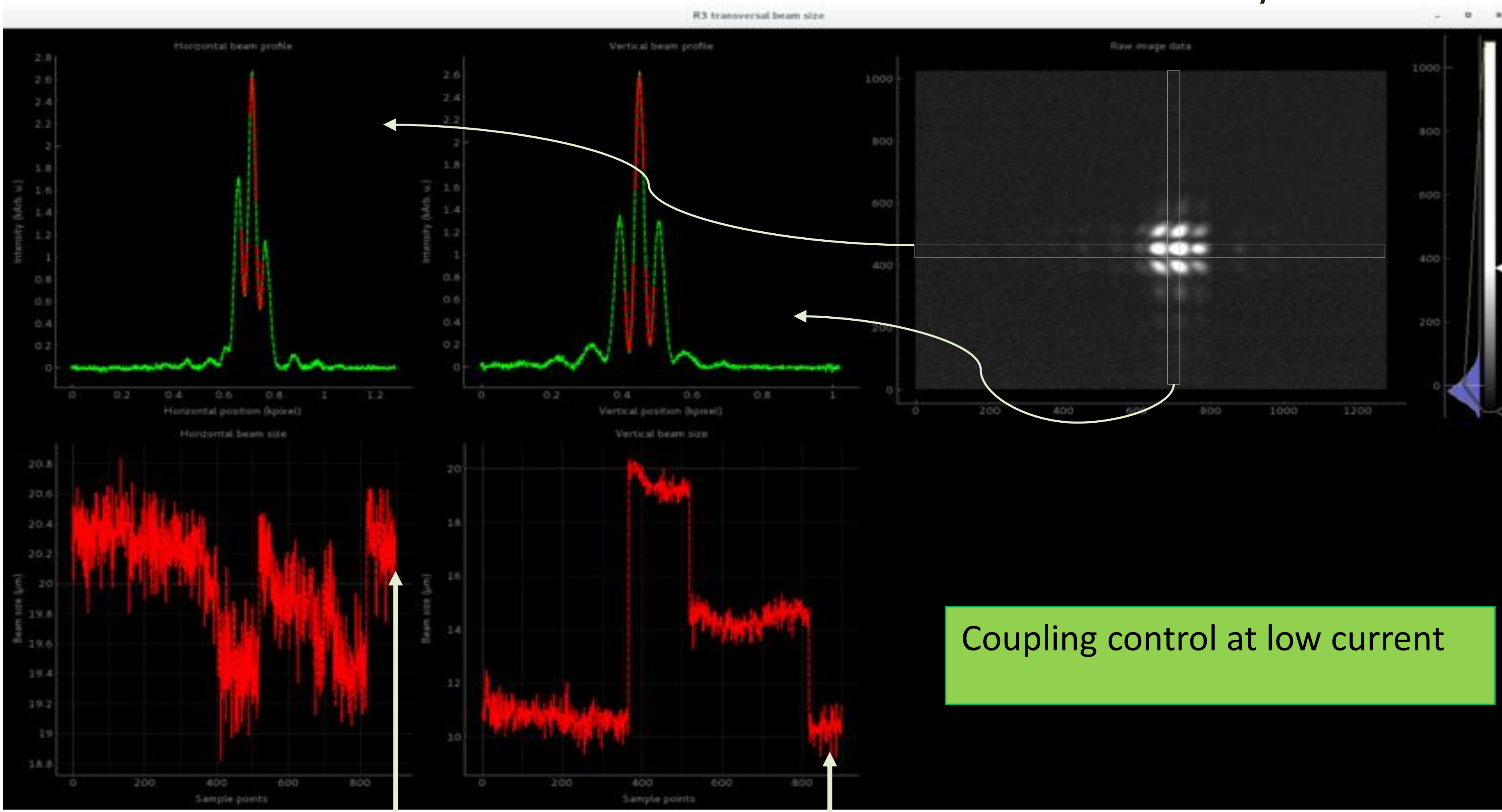


Vertical intensity profile, sensitive to σ_y



Courtesy J. Breunlin

Everyday 2-D measurements where $\eta_x \sim \eta_y \sim 0$



Coupling control at low current

σ_x=20.2 ± 0.2 μm

σ_y=10.2 ± 0.4 μm

ε_x=323 ± 15 pm.rad

ε_y=6.6 ± 1 pm.rad

Beta functions from LOCO;
Errors on emittances includes systematics.

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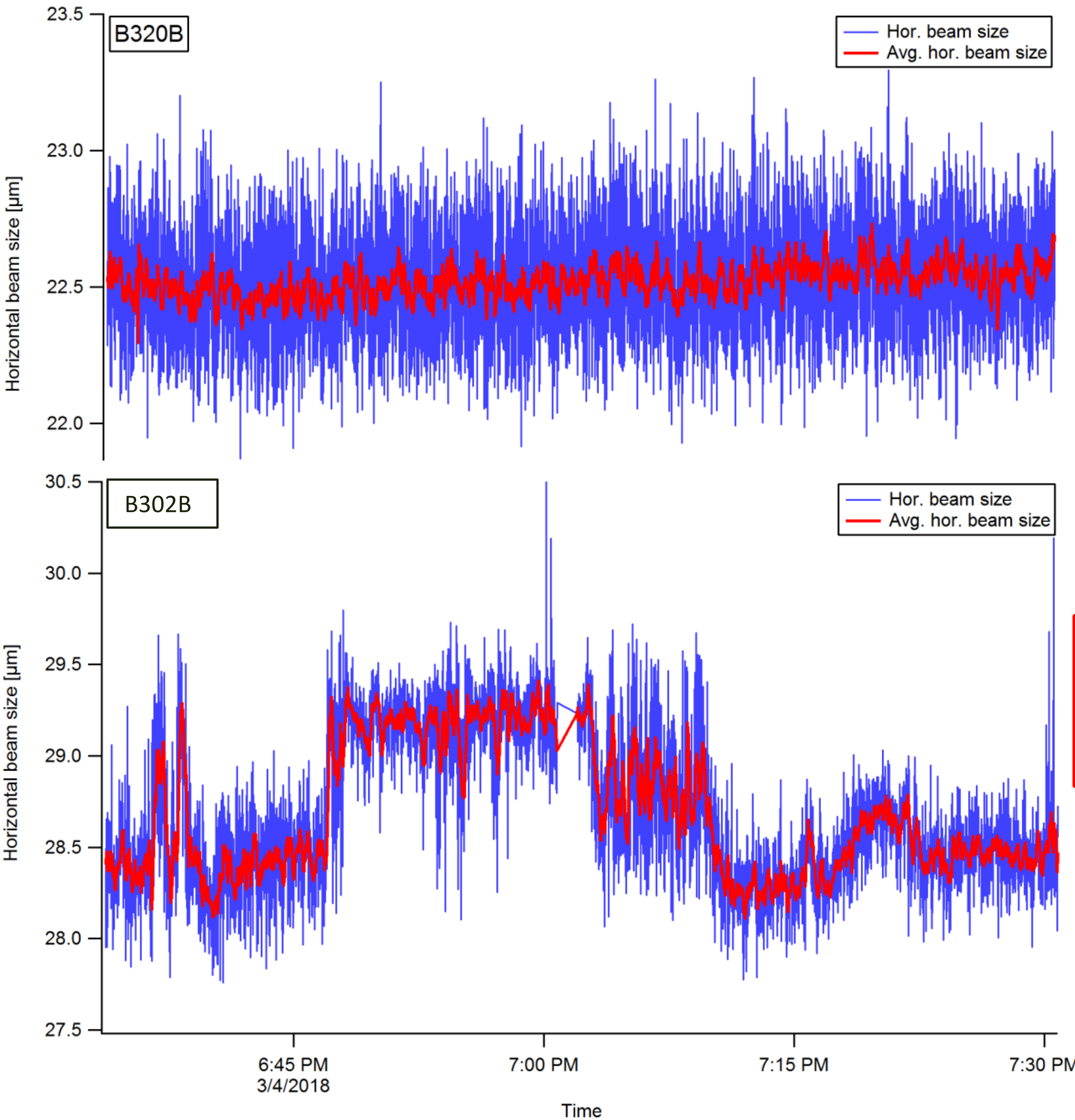
A second monitor, B302B, where $\eta_x \neq 0$

- Will enable us to measure both horizontal emittance and energy spread
- Necessary at higher currents, since we are in the IBS regime

$$\mathbb{E}_x = \frac{\sigma^2_{x,2} - \left(\frac{\eta_{x,2}}{\eta_{x,1}}\right)^2 \sigma^2_{x,1}}{\beta_{x,2} - \left(\frac{\eta_{x,2}}{\eta_{x,1}}\right)^2 \beta_{x,1}} \qquad \sigma_\delta = \left[\frac{\sigma^2_{x,2} - \left(\frac{\beta_{x,2}}{\beta_{x,1}}\right) \sigma^2_{x,1}}{\eta^2_{x,2} - \left(\frac{\beta_{x,2}}{\beta_{x,1}}\right) \eta^2_{x,1}}\right]^{1/2}$$

- Both dispersions and sigmas are measured
- Only beta-functions are provided by LOCO (or by other means)

A second monitor, B302B, where $\eta_x \neq 0$



- Recent results from on-line measurements at 150 mA:
- Red is a rolling average over ten seconds (about ten measurements)

Note! Discovered lately that the large variations are mainly due to a bad BP filter

Courtesy Robin Svärd, Operator, speciality diagnostics

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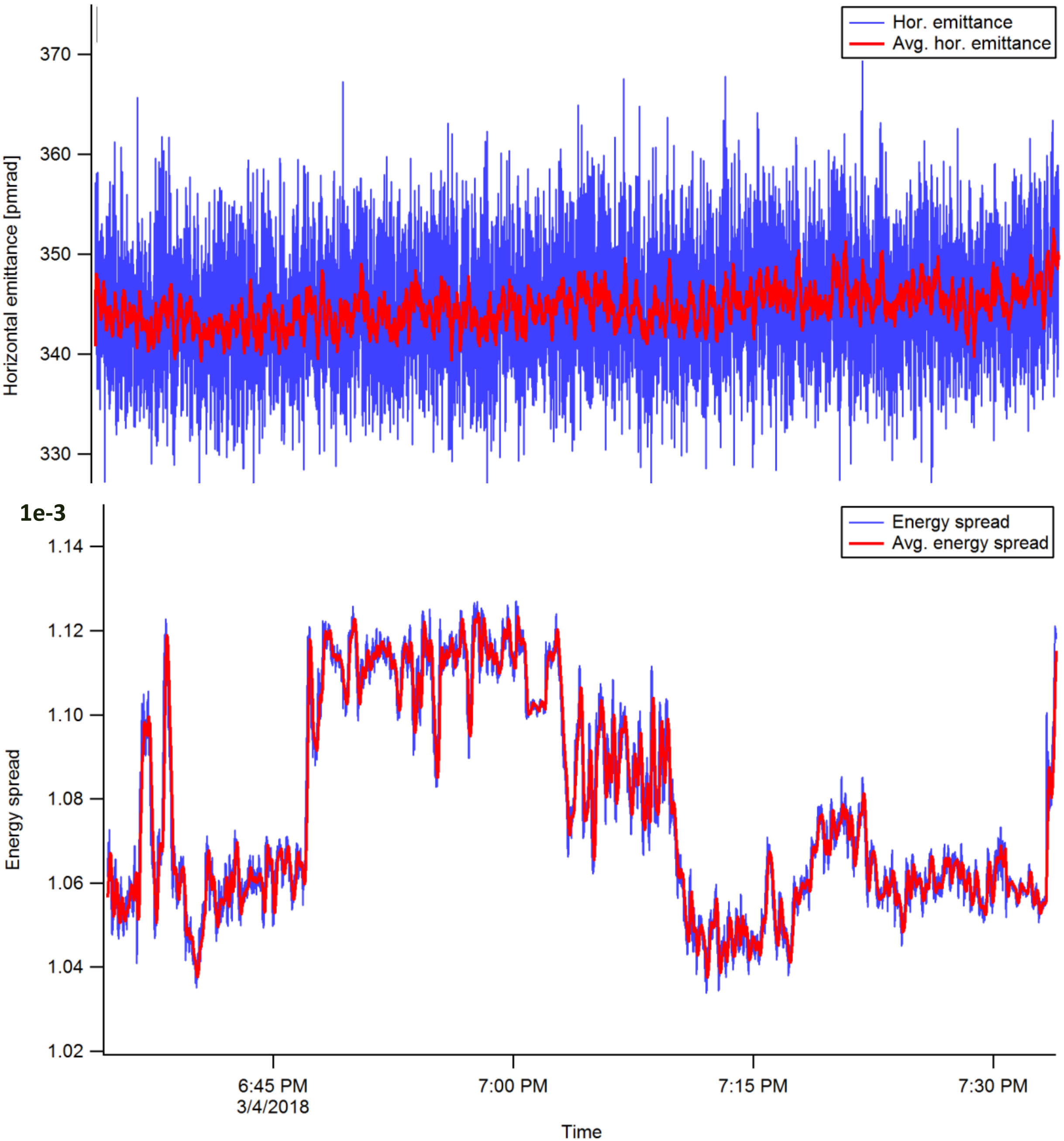
Combined results, monitors B302B & B320B



- Recent results from on-line measurements at 150 mA:
- Hor. Emittance pretty stable at 345 ± 5 pmrad.
- Relative energy spread changes of less than 2e-5 (!), can be detected.

Courtesy Robin Svärd, Operator, speciality diagnostics

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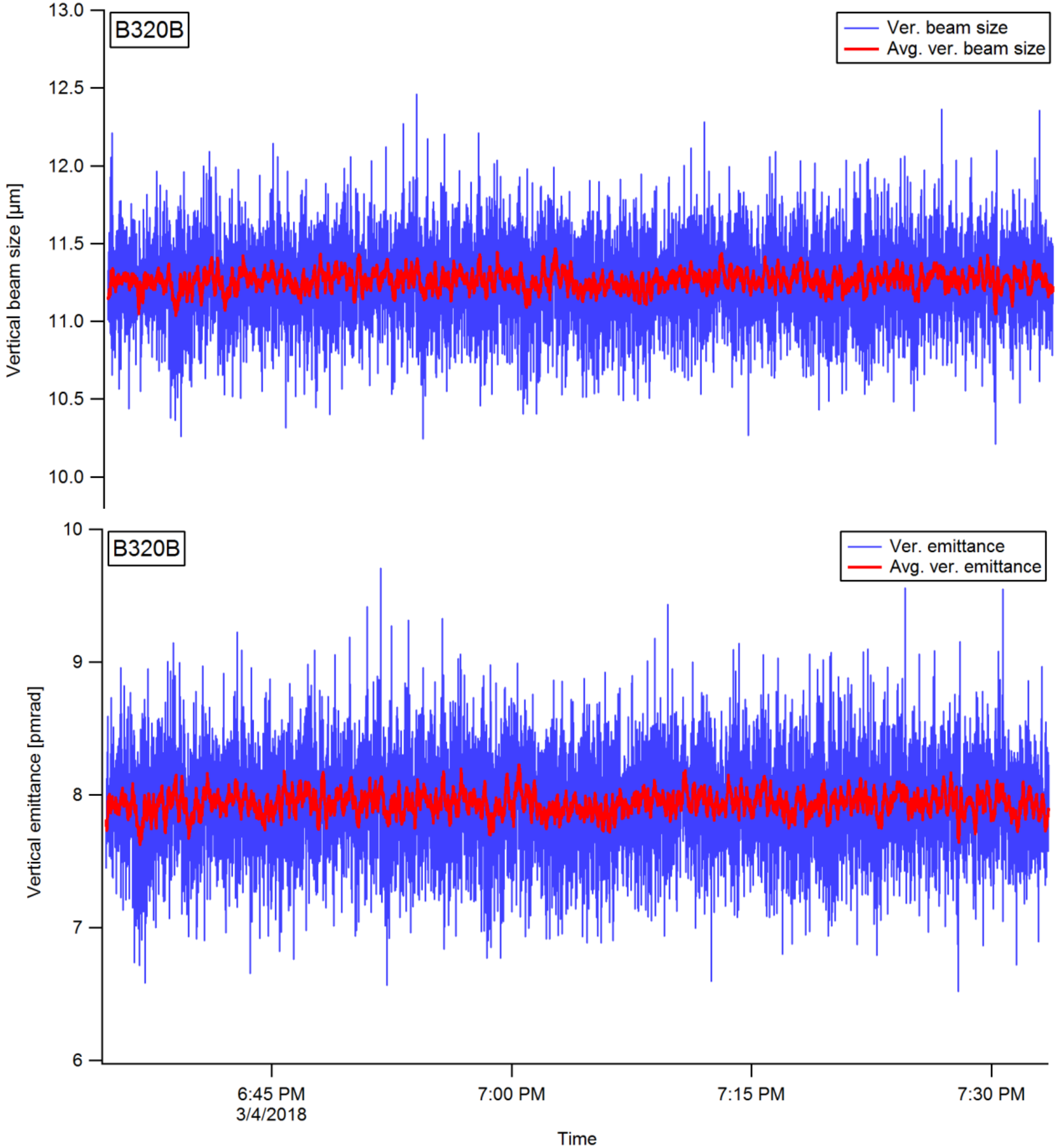
Backup slides

From first monitor, B320B, ε_y = 8±0.5 pm.rad



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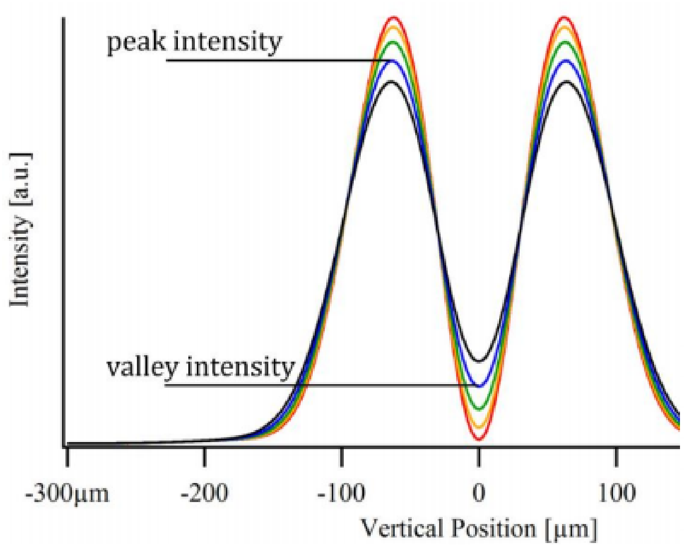
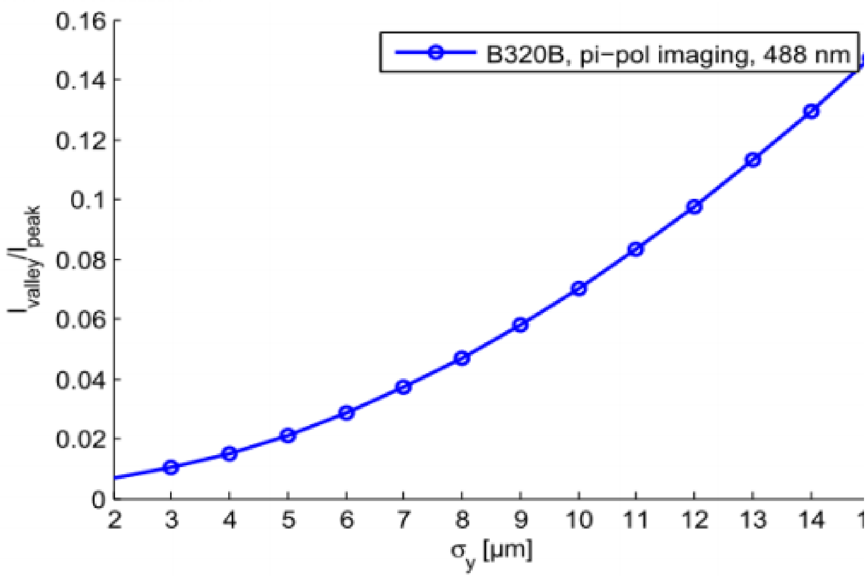
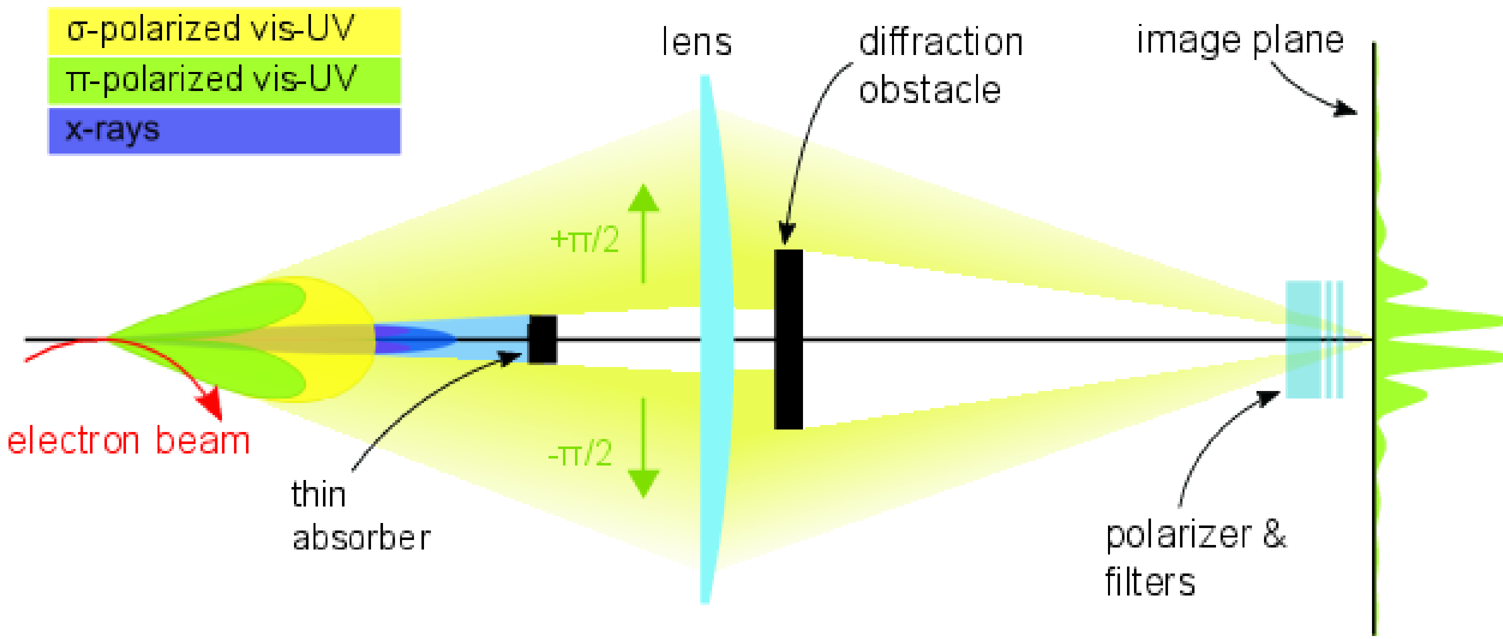
Courtesy Robin Svärd, Operator, speciality diagnostics

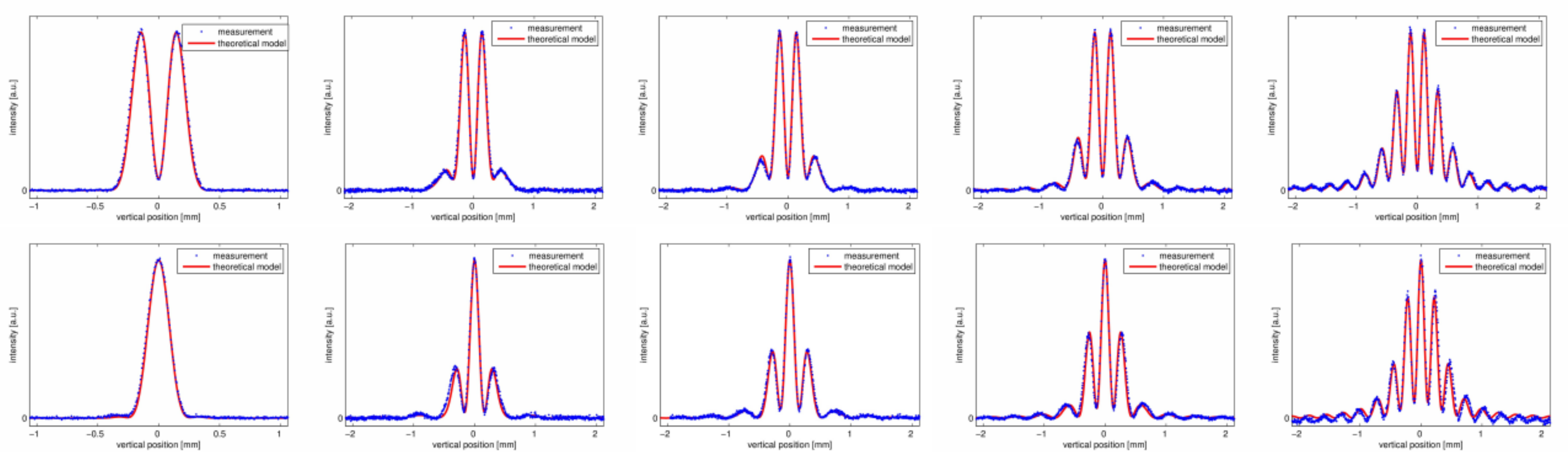
Resolving a vertical beam size < 5 µm





Resolving a vertical beam size < 3 µm





J. Breunlin et al, “Emittance diagnostics at the MAX IV 3 GeV storage ring", IPAC 2016.

Vertical profiles at 488 nm for pi- and sigma- polarized SR. Measurement and theoretical calculation. Imaging (left) and with diffraction obstacles of increasing height (4 to 9mm, 1.6 to 3.7 mrad).

→The vertical beam size was measured 11±0.3 µm, corresponding to a vertical emittance of 6.4±0.9 pm rad.

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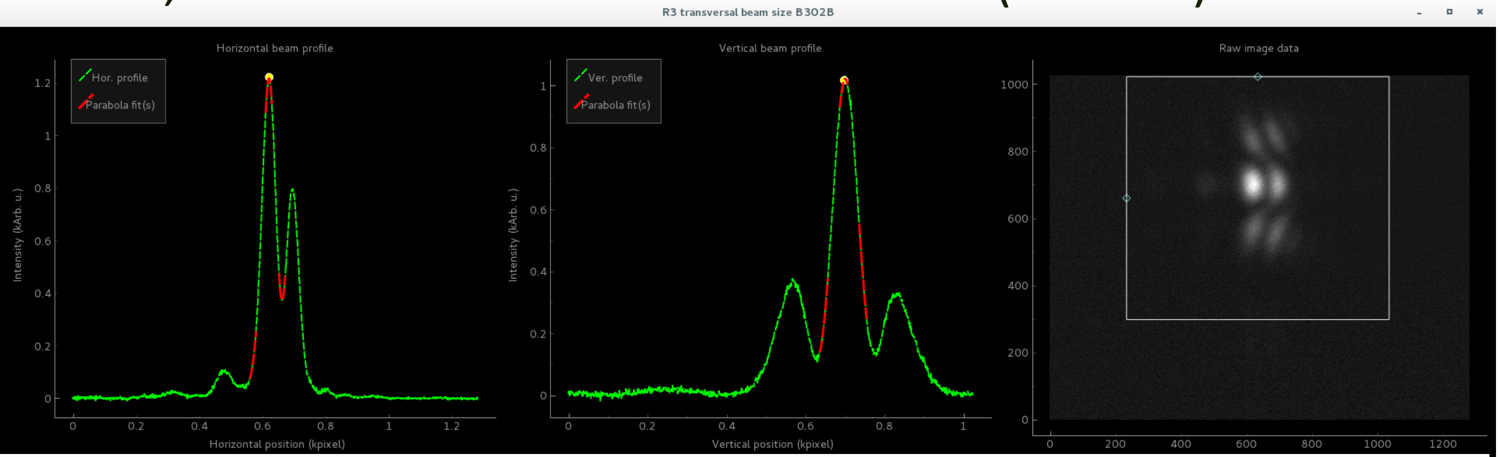
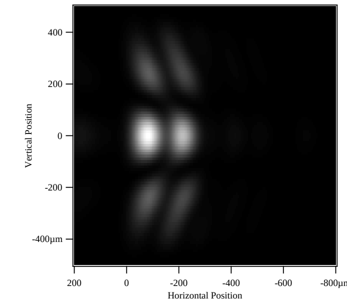
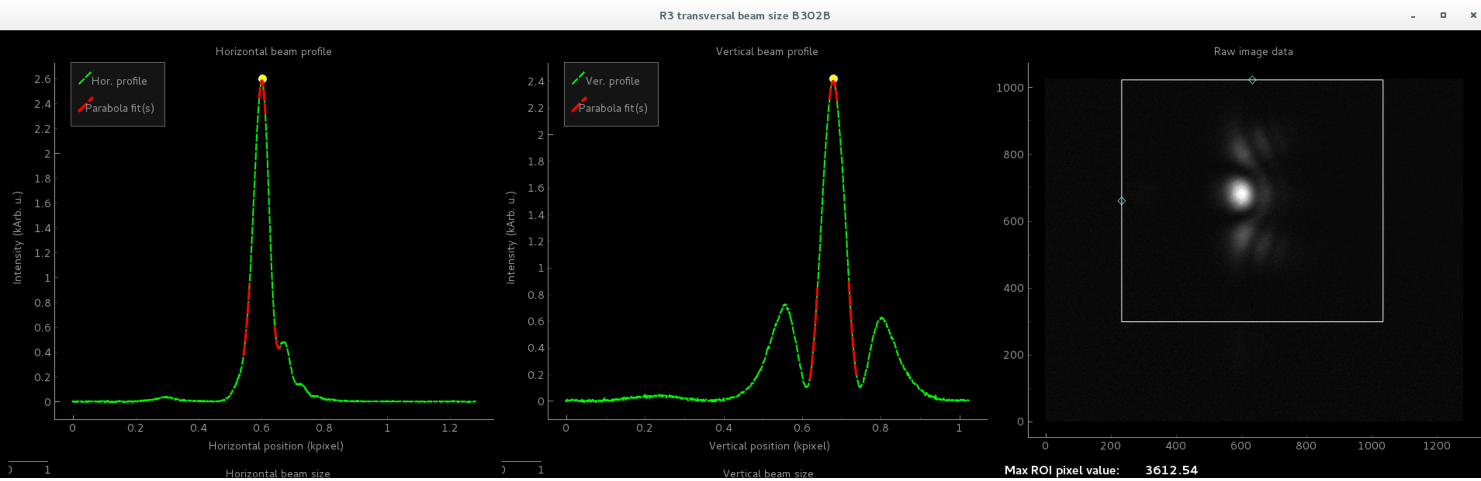
Possible imaging at the future ring LSs

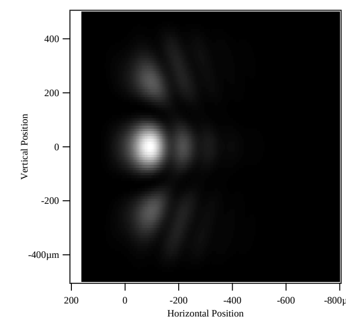
First, some measurements with NIR SR (930 nm) at B302B

Theory SRW









The assymetry is clearly predicted by SRW!!!

Both images with σ-pol SR @ 930 nm NIR and a thin 1.7 $mrad_V$ x-ray absorber.

Top: Horizontal accept. A=10.66 $mrad_H$; Upright obstacle 2.25 $mrad_H$

Bottom: Horizontal acceptance 12 $mrad_H$; **No upright obstacle, just pure imaging**

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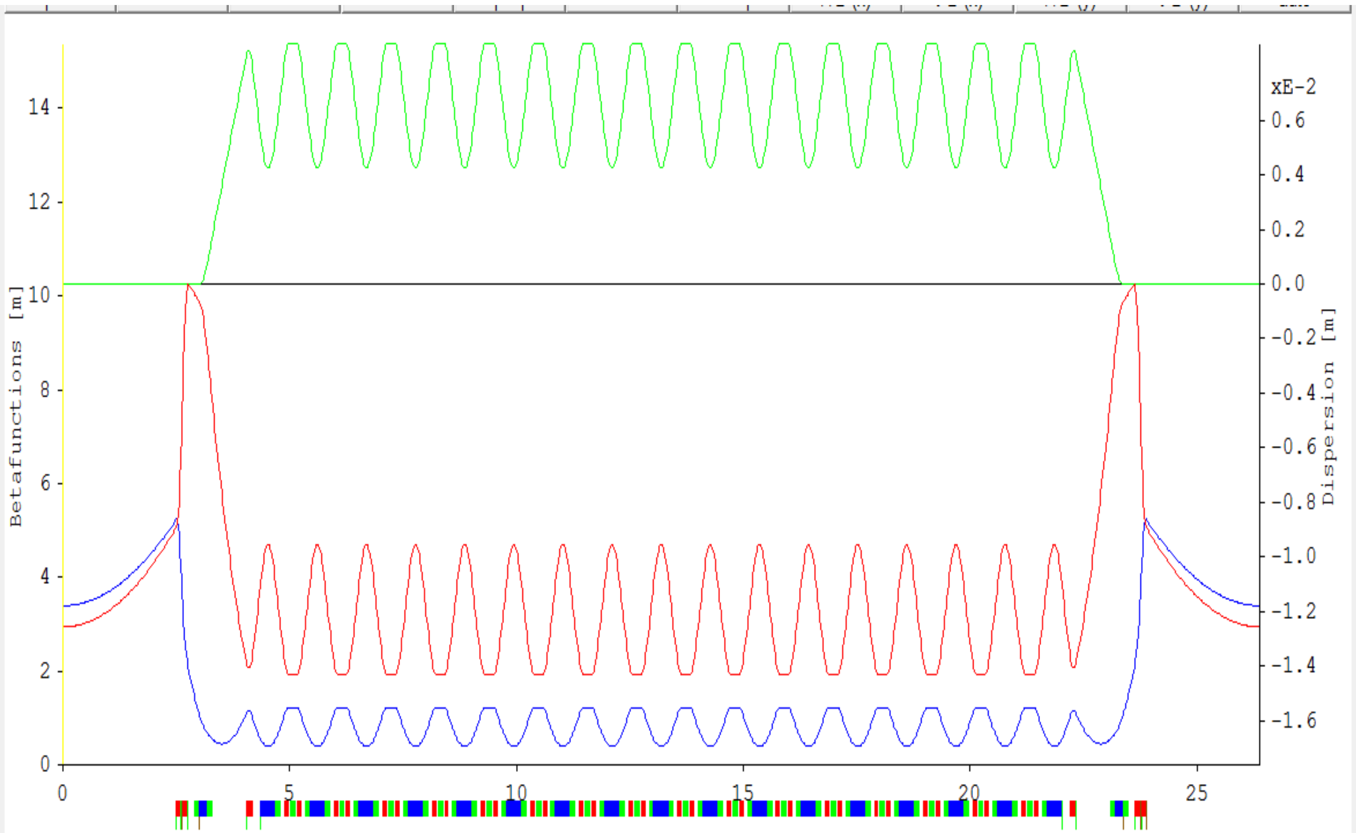
Possible imaging at the future ring LSs

Optical functions of a proposed 19-BA lattice, to replace the present MAX IV 3 GeV lattice.

Tavares P.F., Andersson Å. & Bengtsson J., J. Electron Spectrosc. Rel.d. Phenom. (2017) https://doi.org/10.1016/j.elspec.2017.09.010



ε_x = 16 pm.rad

In the dipoles:
β_x ~ 0.5 m

=> σ_x ~ 3 µm

Magnet design study: Talk tomorrow by Dr. A. Vorozhtsov

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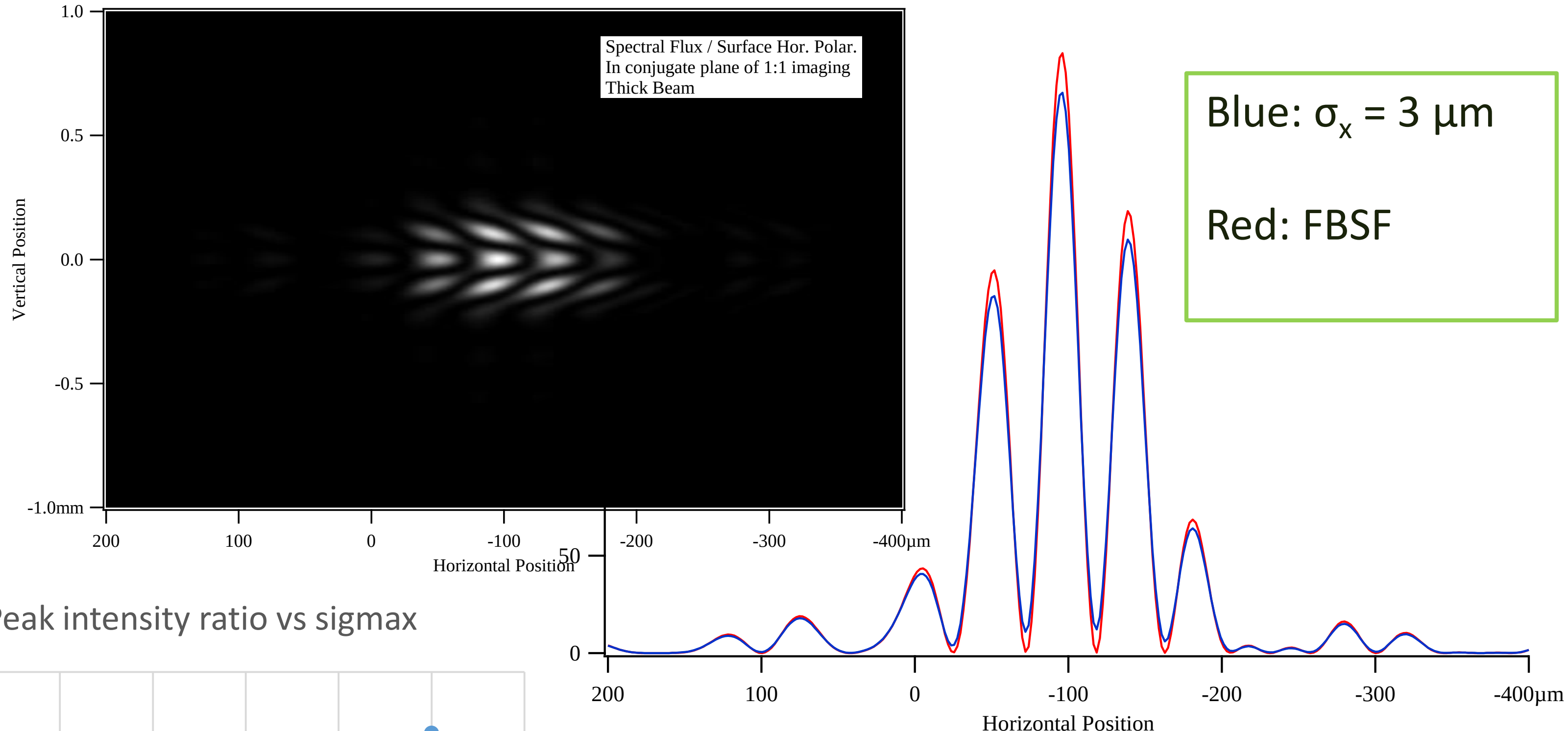
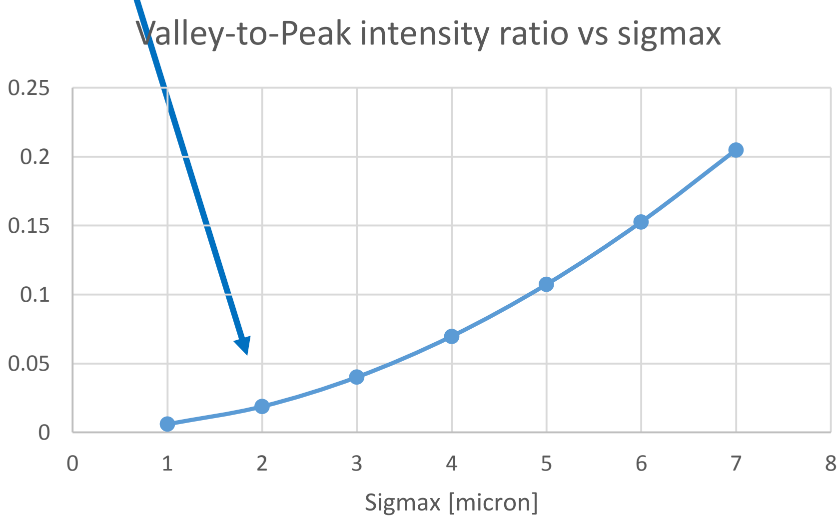
Possible imaging at the future ring LSs



Blue: σ_x = 3 µm

Red: FBSF

Sensitivity is OK!



SRW images with σ-pol SR @ **266 nm** and a thin 1.7 $mrad_V$ x-ray absorber.

Horizontal acceptance ±4 $mrad_H$;

Upright obstacle ±2 $mrad_H$