Transverse beam size diagnostics with visible SR

MAX IV LABORATORY

Outline

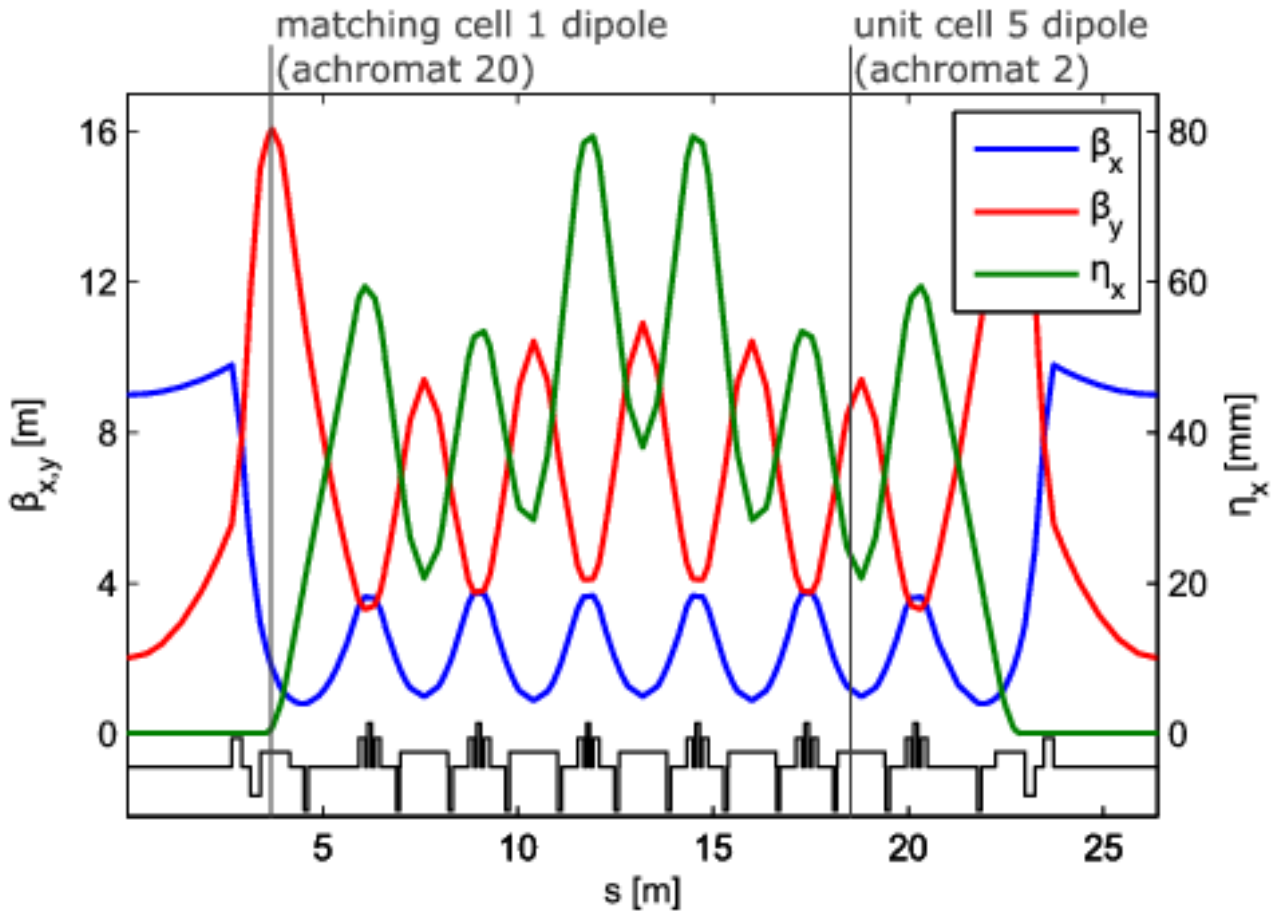
- Measurements at the MAX IV 3 GeV ring.
- What way to go at the coming DLSR?
- Our nearest plans & Summary

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
Rms energy spread (bare lattice)	0.77×10-4
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

Ring lattice & Monitor positions



Two monitor positions with a large ratio in dispersion.
➔ Both emittance and energy spread are measurable!

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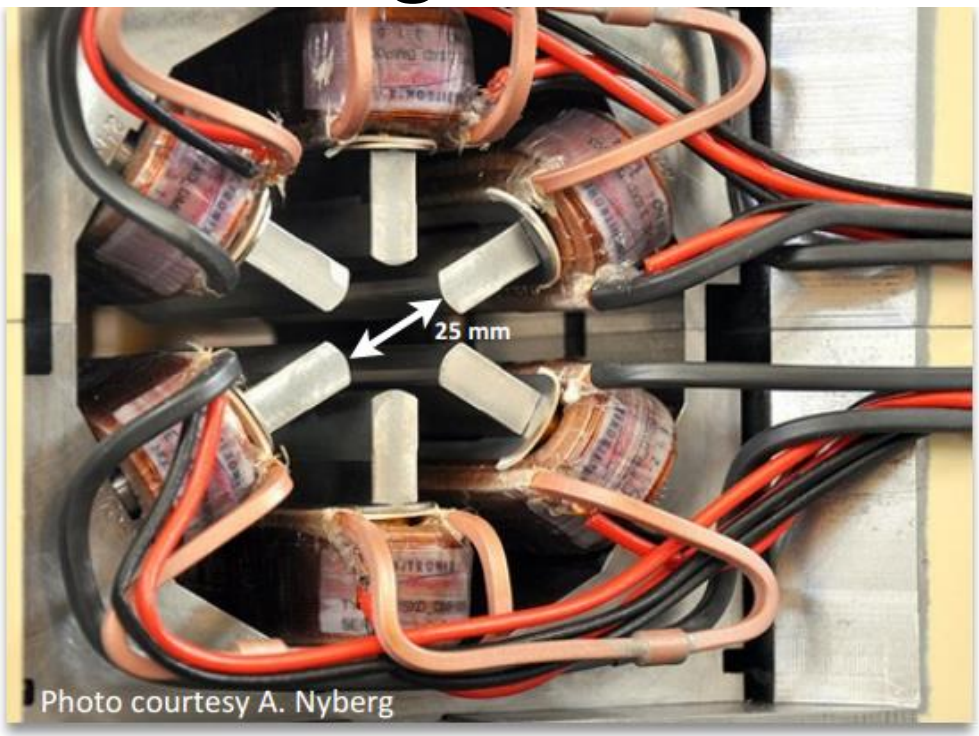
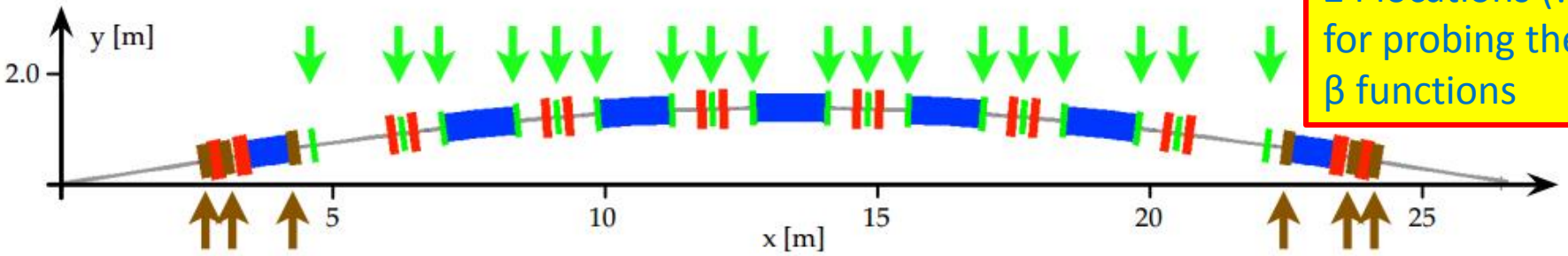
Non-linear magnets

Strong, 25 mm bore, sextupoles & achromatic octupoles for non-linear optics.

All those carry **auxiliary windings** that can be used as:

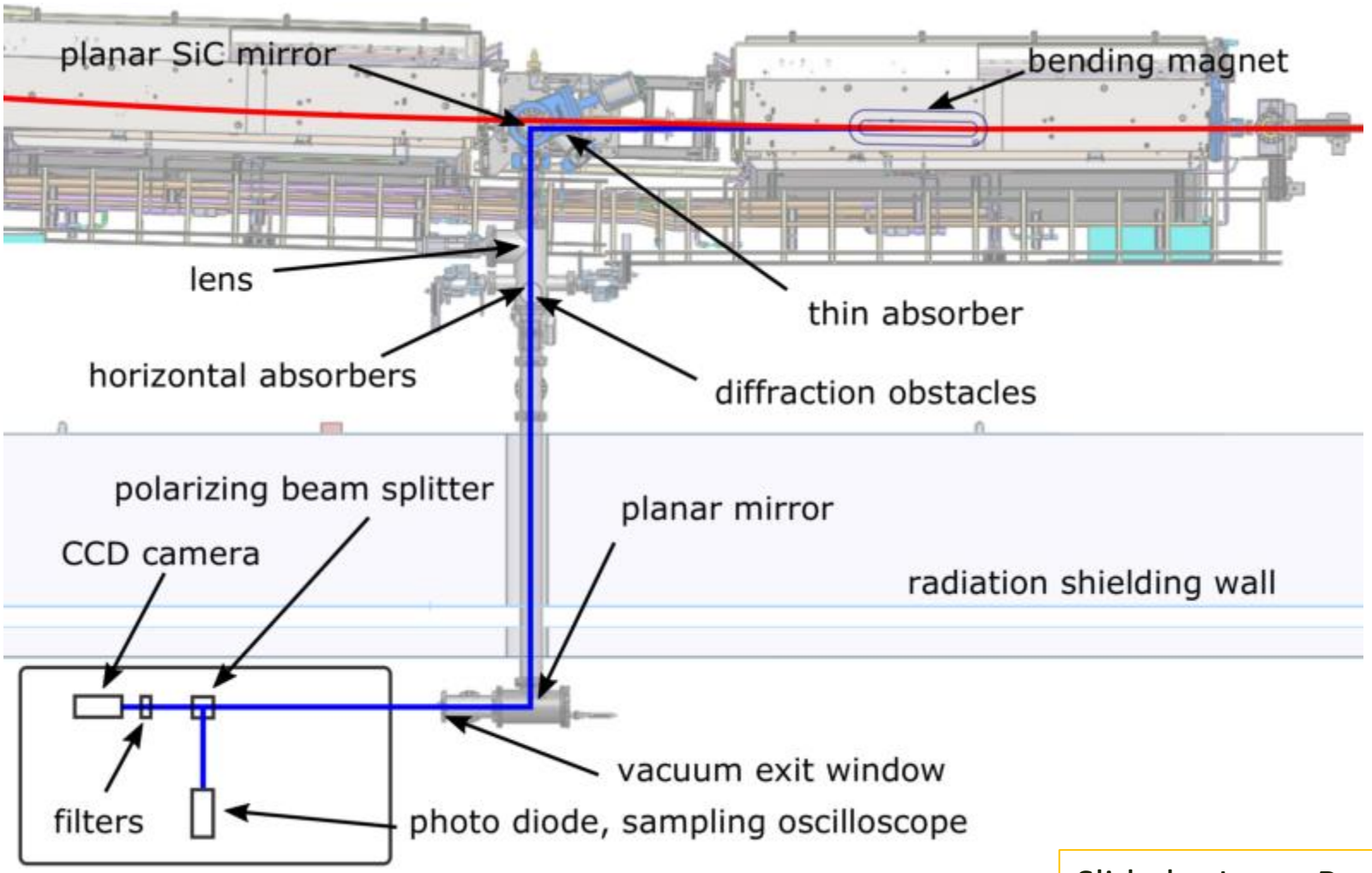
- Skew quadrupoles (**coupling & vertical dispersion correction**)
- Upright quadrupoles (**calibrate BPMs to the center of adjacent sextupole/octupole)**
- Upright quadrupoles inducing tuneshifts ➔ **β functions**





24 locations (!) for probing the β functions

Beam size measurements



Slide by Jonas Breunlin

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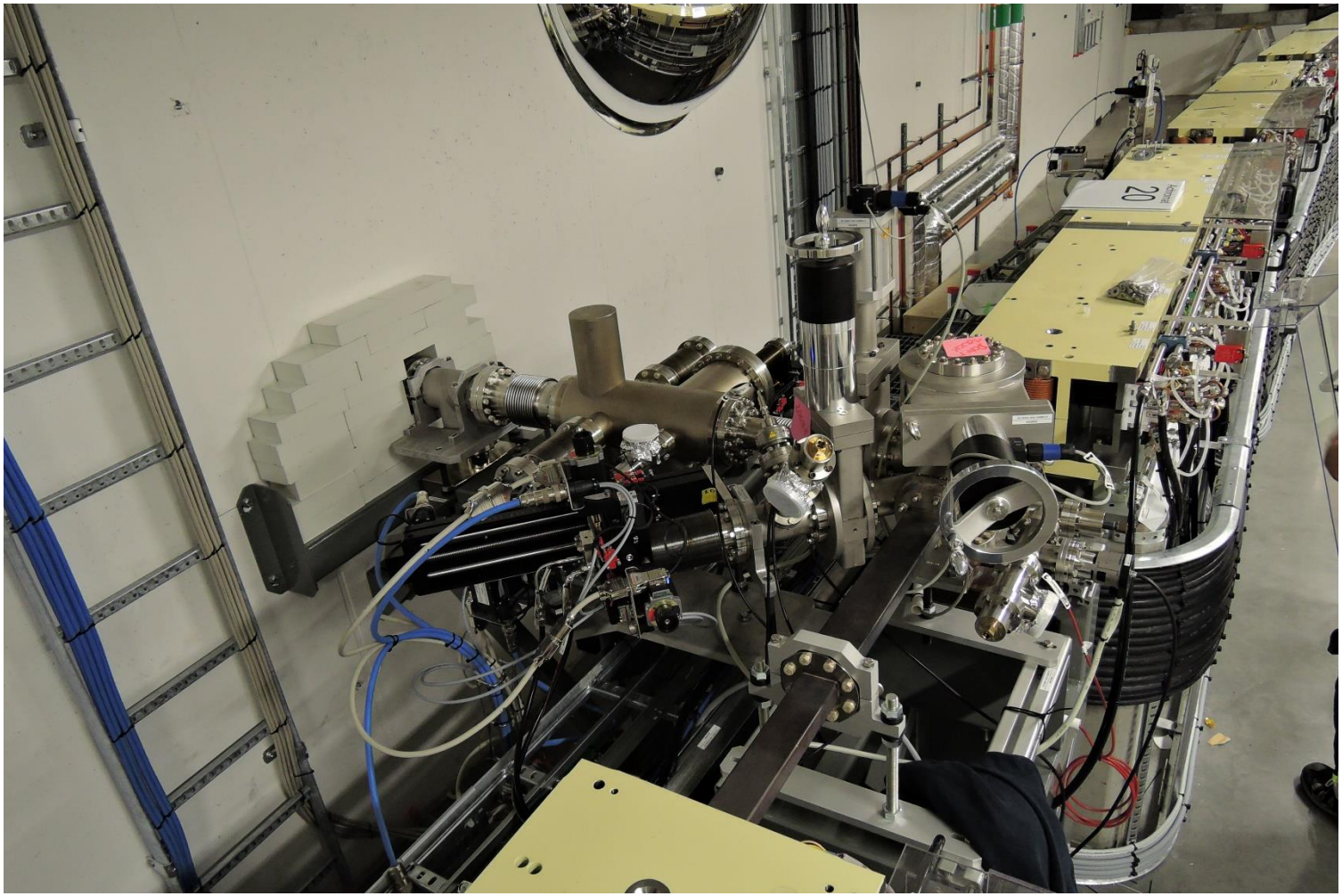
Emitt. Meas.: Extraction in S1



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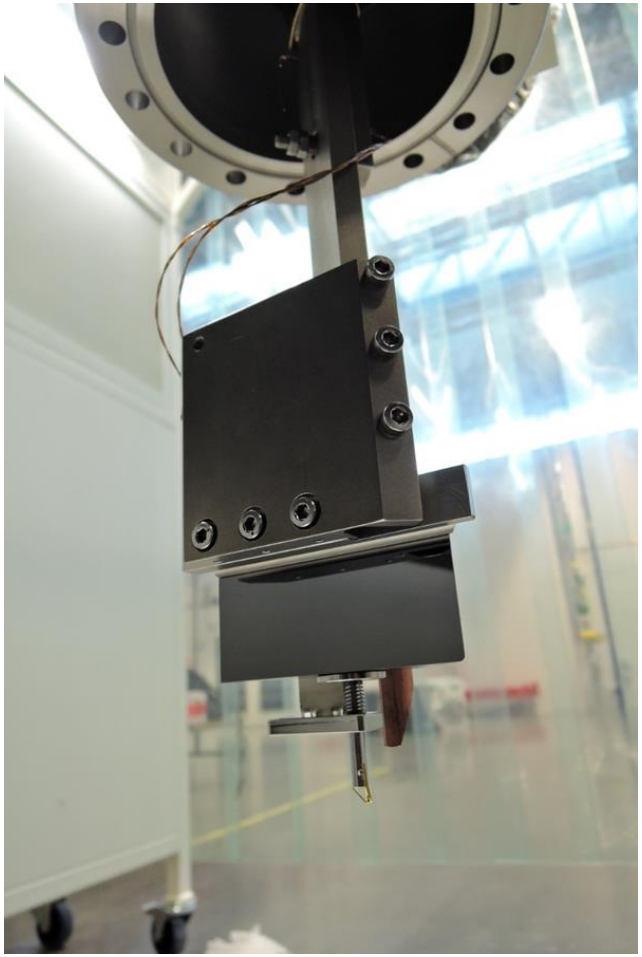
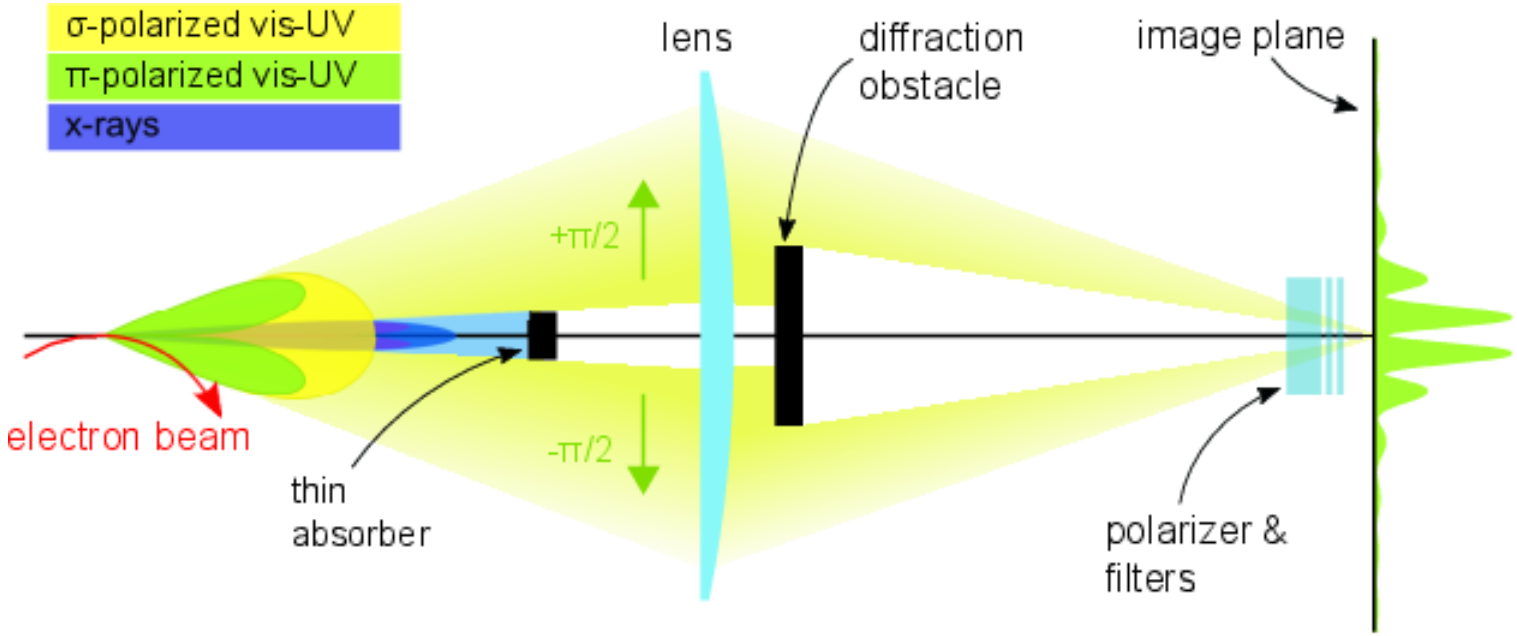
Emitt. Meas.: Extraction SiC mirror

- 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 future improved diagnostics.



Emitt. Meas.: Vertical beam size



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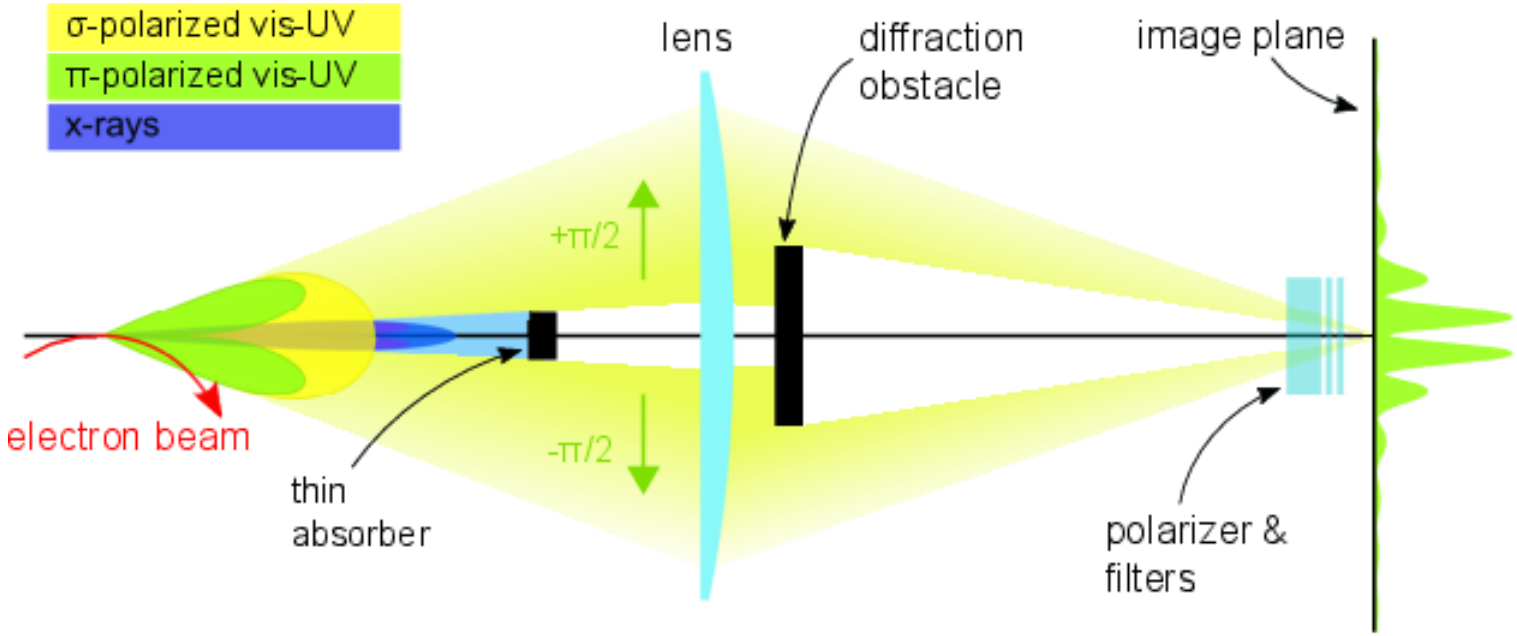
Emitt. Meas.: Vertical beam size



The forthcoming theoretical predictions are based on the code SRW:

O. Chubar and P. Elleaume, "Accurate and efficient computation of synchrotron radiation in the near field region", EPAC1998, Stockholm, Sweden, p. 1177.

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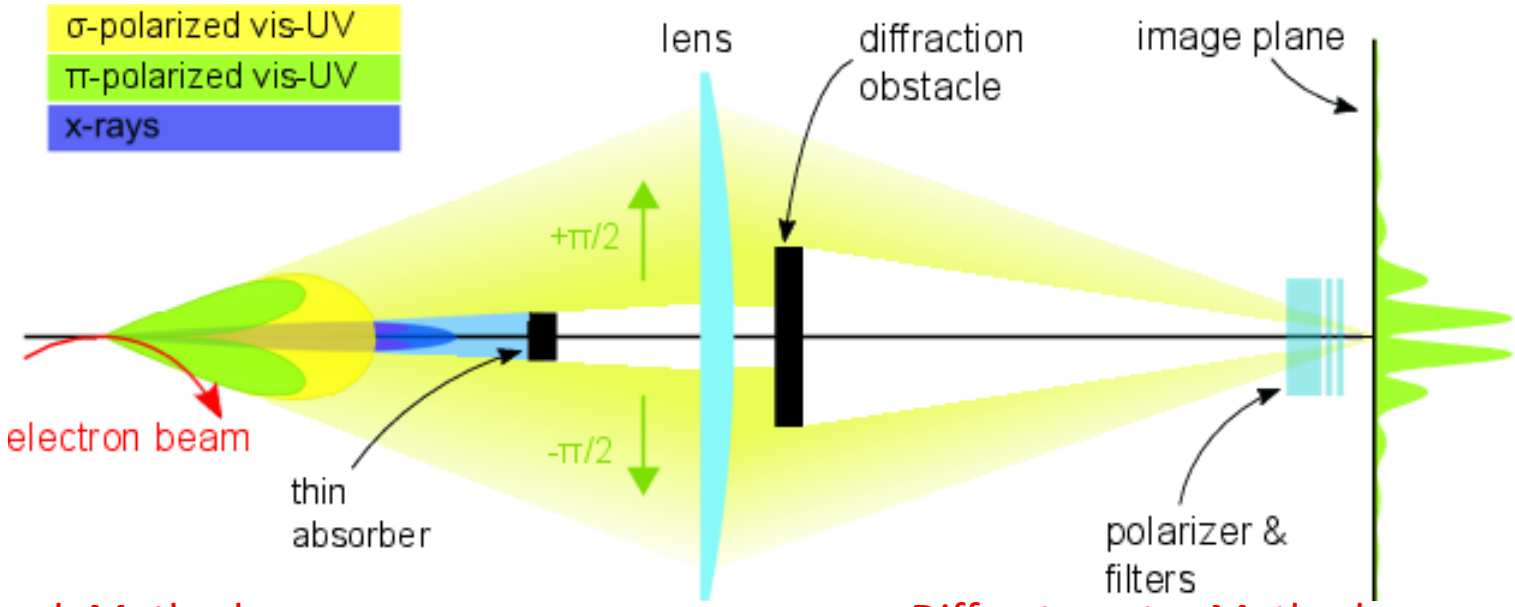
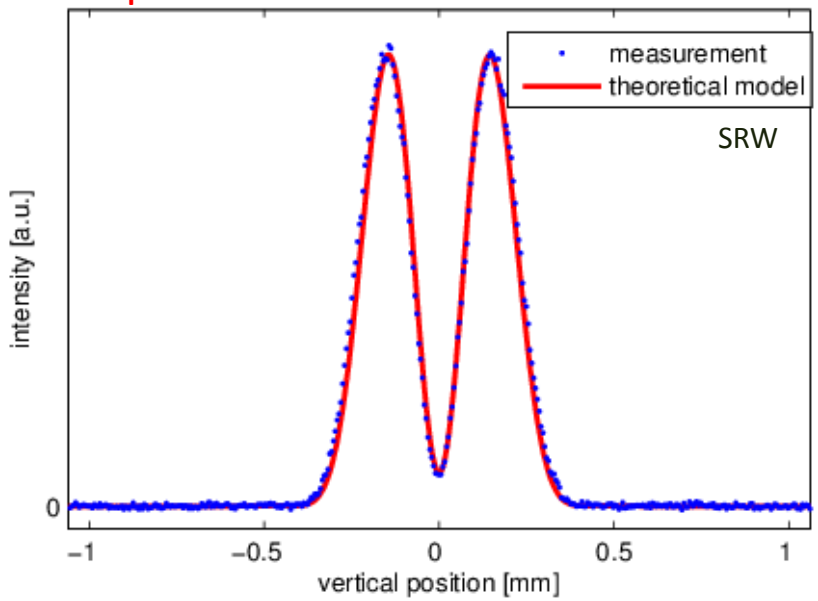
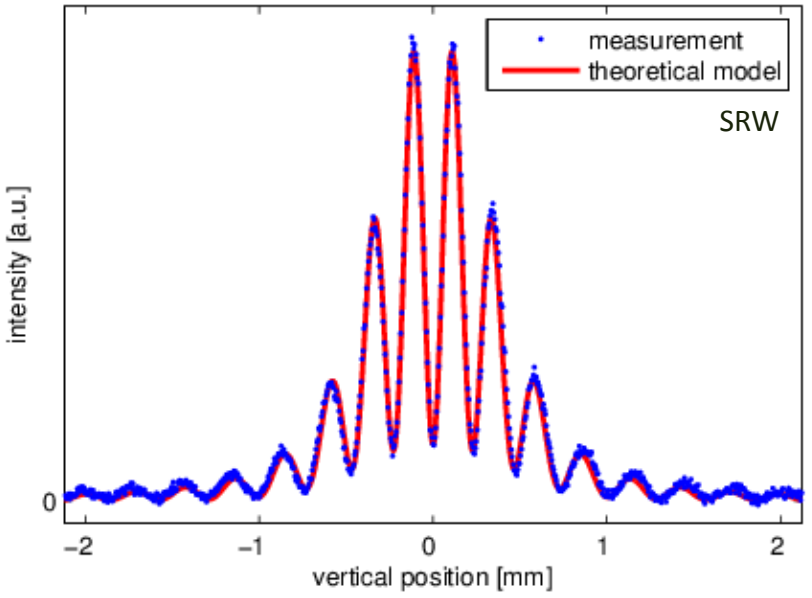
Emitt. Meas: Vertical beam size



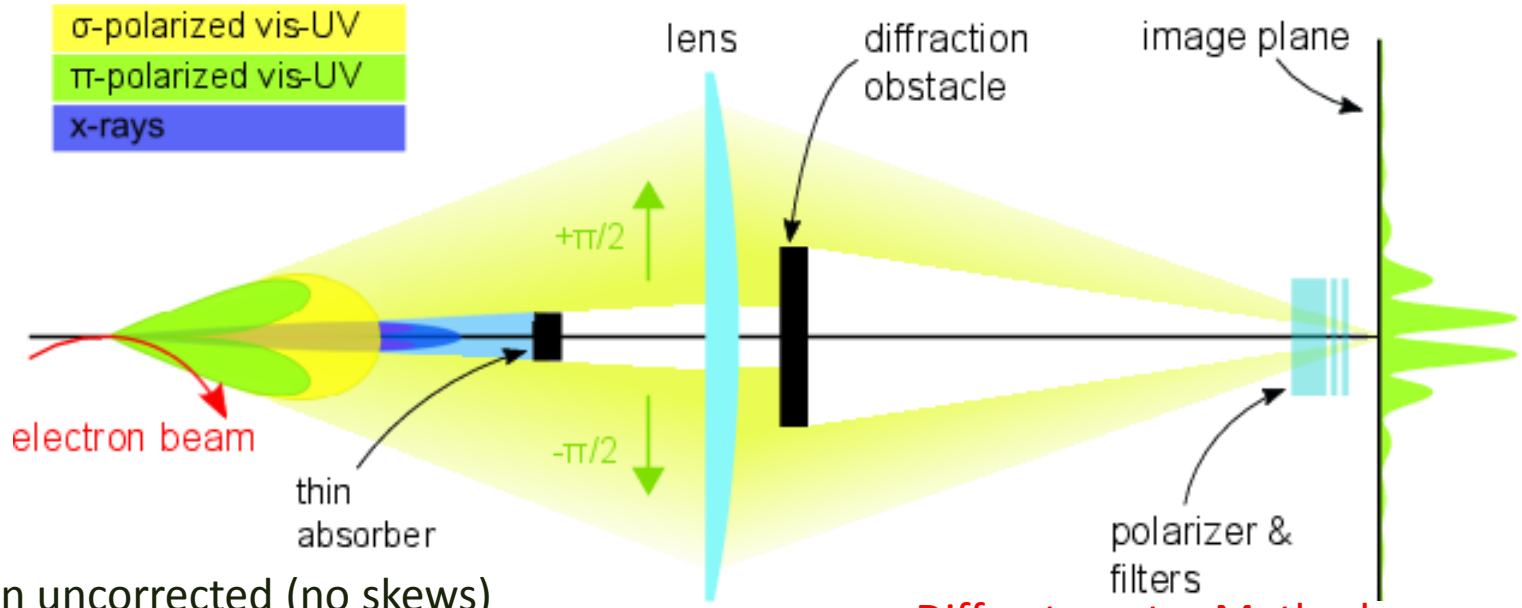
Pi-pol. Method:



Diffractometer Method:

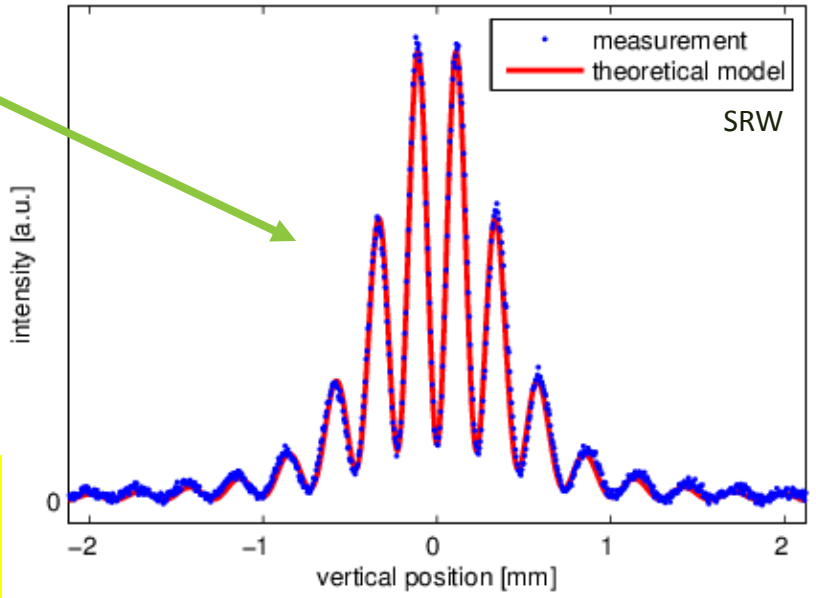


Emitt. Meas.: Vertical beam size



An uncorrected (no skews)
3 GeV ring meas. gives: $\sigma_y = 11.3 \pm 0.2$ µm
Design $\beta_y = 16$ m implies $\varepsilon_y = 8.0$ pm rad

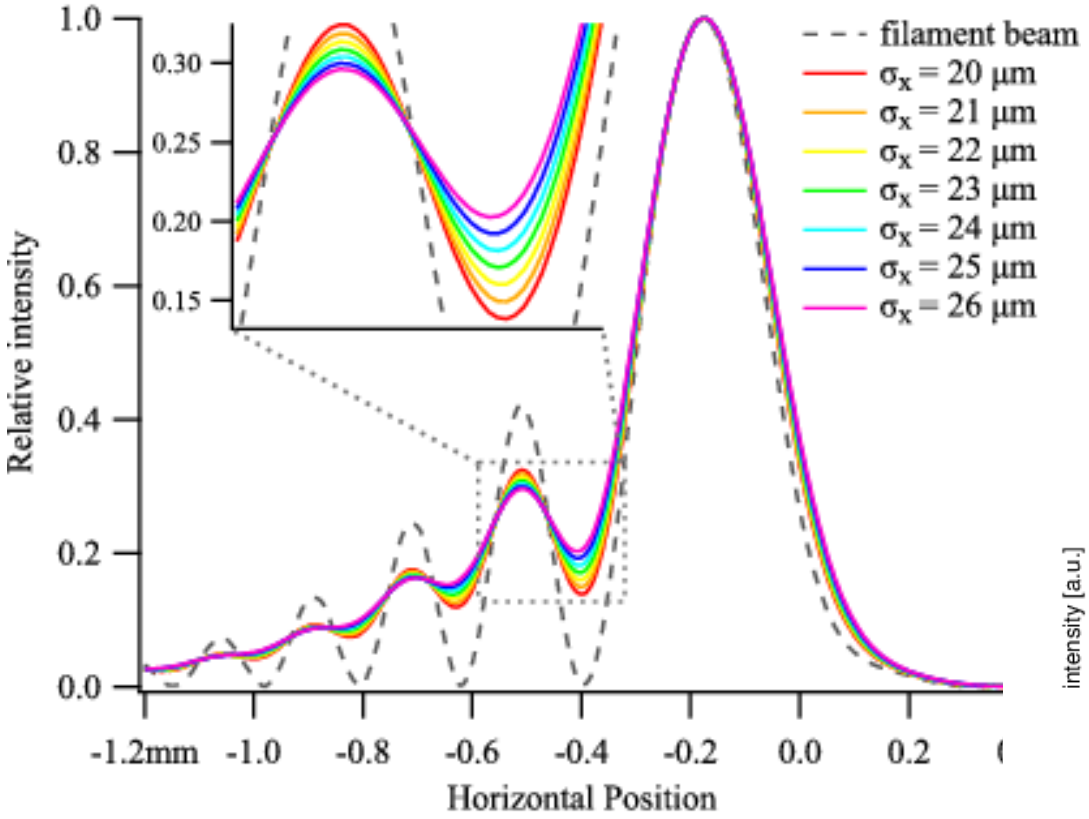
Diffractometer Method:



The **diffractometer** method was implemented at the SLS (TIARA collaboration): $\sigma_y = 4.7 \pm 0.1$ µm, $\sigma_y = 3.0 \pm 0.3$ µm would have been possible.

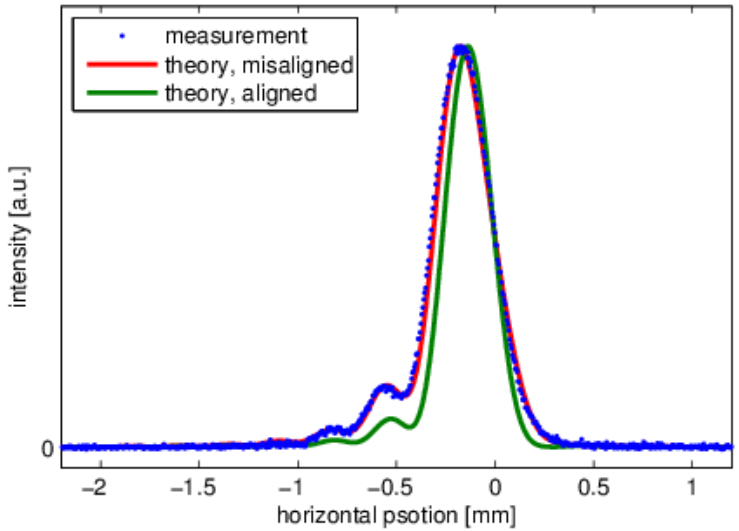
J. Breunlin et al, "Methods for measuring sub-pm rad vertical emittance at the Swiss Light Source", Nucl. Instrum. Meth. A 803, 55-64 (2015).

Emitt. Meas.: Horizontal beam size



Theorethical horizontal profiles:
- 15 $mrad_H$
- Wavelength is 930 nm

Measured horizontal profile at 930 nm:
- 8.2 $mrad_H$ ➔ less pronounced fringes



An uncorrected (beta beating) 3 GeV ring meas. gives: $\sigma_x = 24.5 \pm 1.5$ µm

IPAC & IBIC 2016, J. Breunlin et al.

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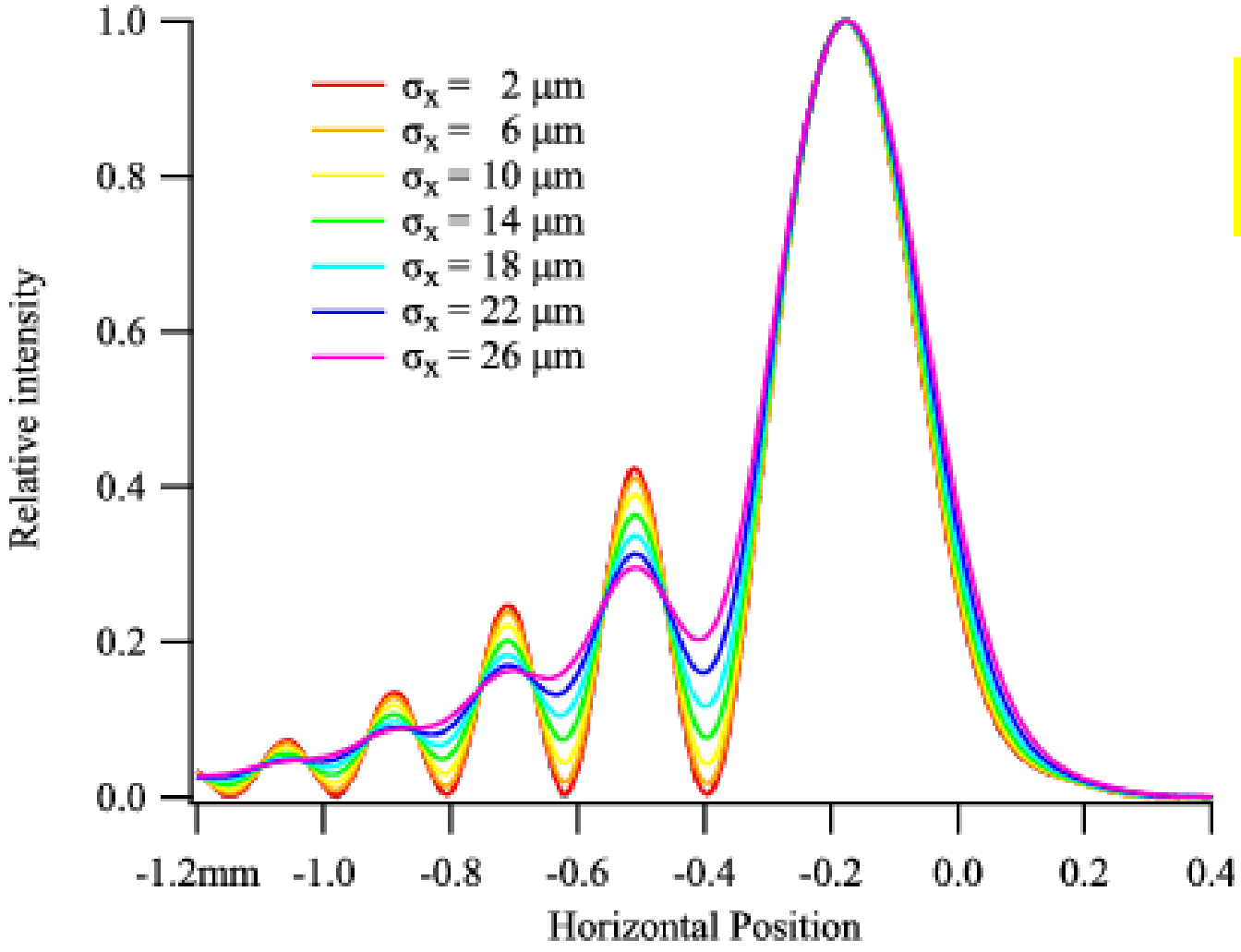
Towards smaller horizontal beam sizes



λ = 930 nm
Good resolution for
σ_x = 10 to 26 µm

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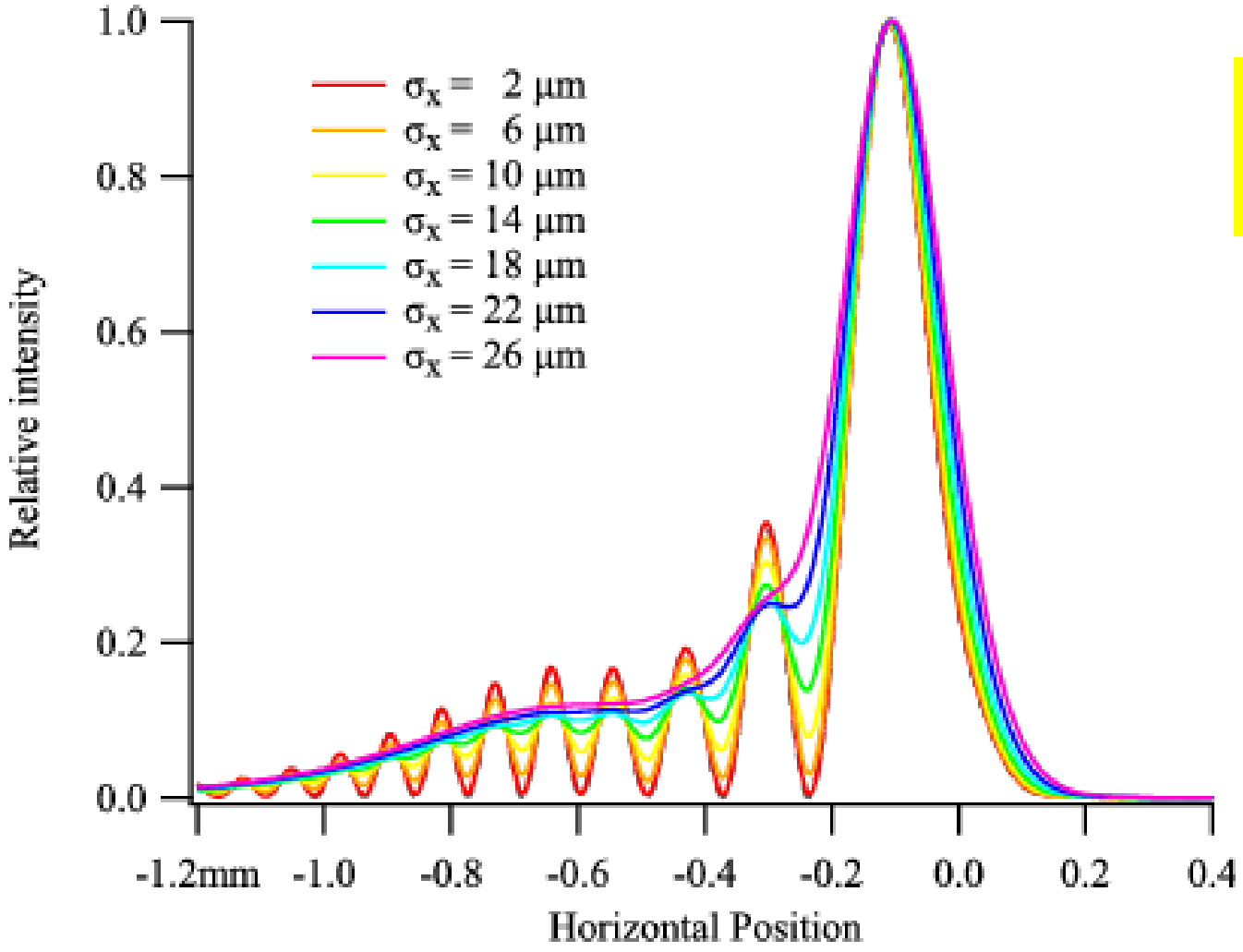
Towards smaller horizontal beam sizes



λ = 488 nm
Good resolution for
σ_x = 6 to 18 μm

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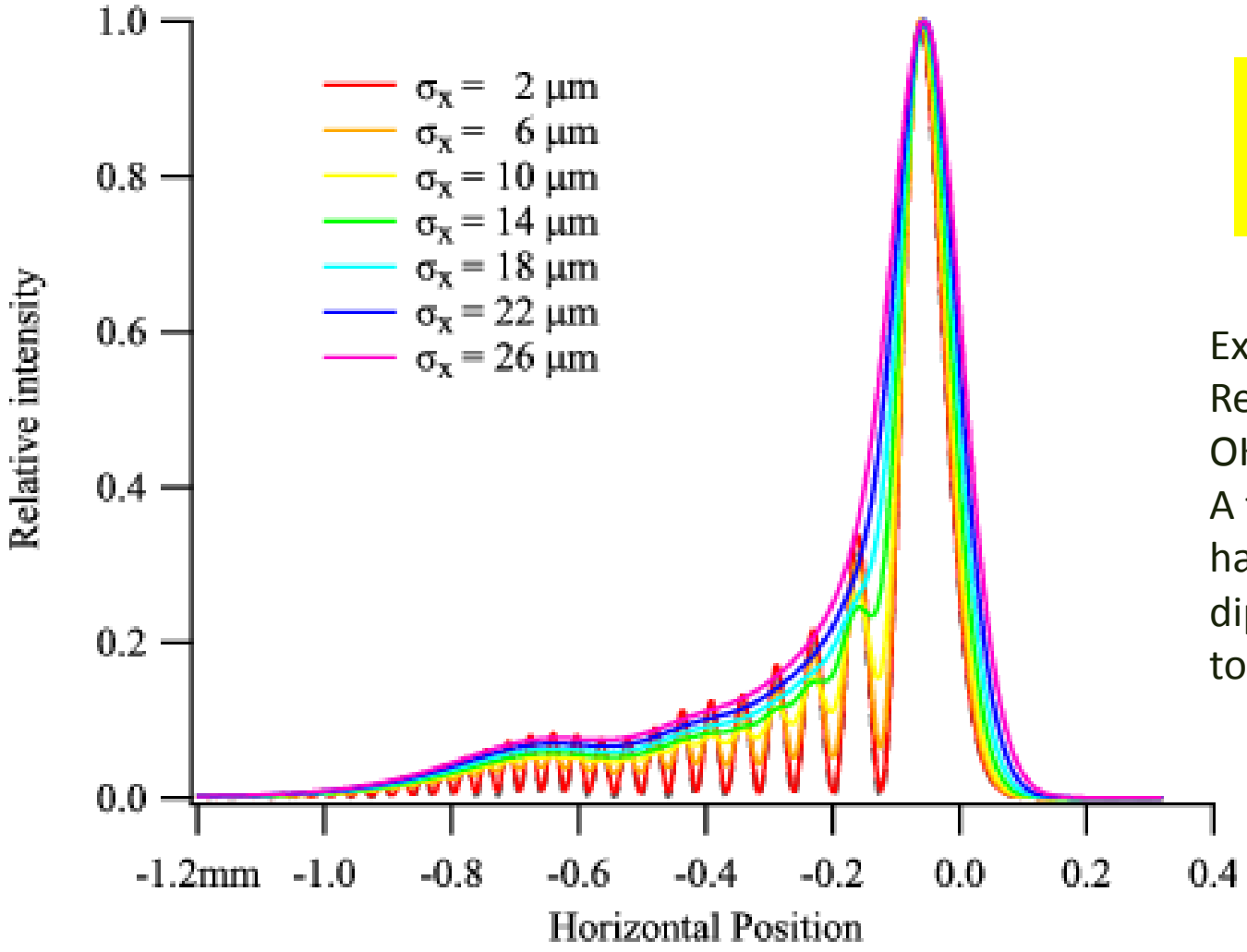
Towards smaller horizontal beam sizes



λ = 266 nm
Good resolution for
σ_x = 2 to 14 μm

Example:
Resolving σ_x ~ 4 μm is OK.
A future MBA might have a β_x ~ 2 m in the dipole ➔ Corresponds to **ε_x = 8 pm rad**

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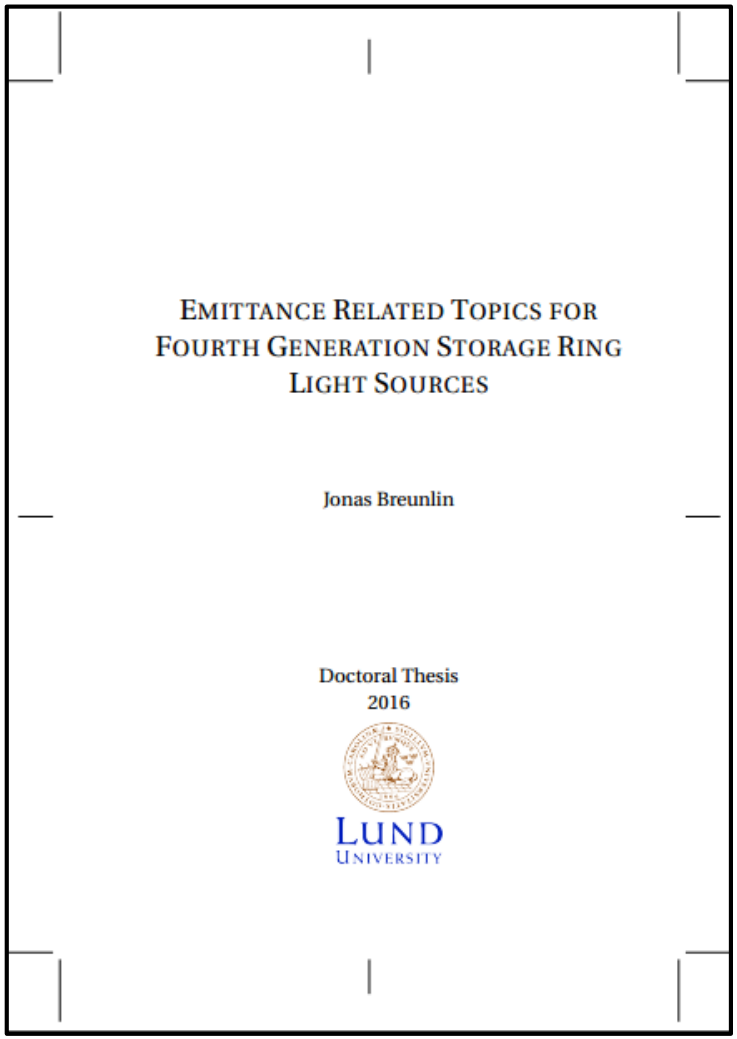
”Emittance related topics ….”

More information can be found in:



EMITTANCE RELATED TOPICS FOR
FOURTH GENERATION STORAGE RING
LIGHT SOURCES

Jonas Breunlin

Doctoral Thesis
2016

LUND
UNIVERSITY

To be defended in public 3rd of October 2016 at Lund University.

MAX IV LABORATORY

Outline

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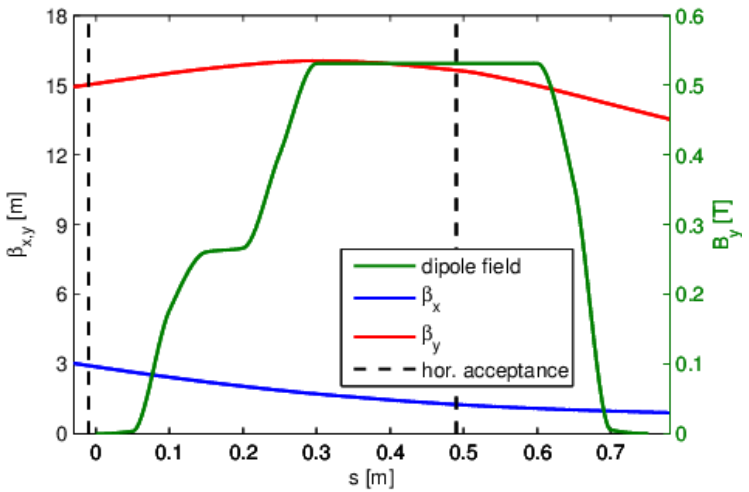
Our nearest plans

- The theoretical model includes the longitudinal dipole field variation:



- However, since the collect horizontal SR fan is originating from about 0.4 m length, the variation in betax is no longer negligible.
- We have invited Dr. Oleg Chubar to MAX IV for further code development, taking into account this effect.

Summary

- Designing and building a diagnostic beam line at the coming upgraded SRs, that can collect ~ 15 $mrad_H$ of the SR in the near visible region, seems beneficial.
- Simple imaging of this light pruduces an asymetric fringe patter that can resolve horizontal rms beam sizes down to a few µm.

Thank You for your attention!

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Extra slides

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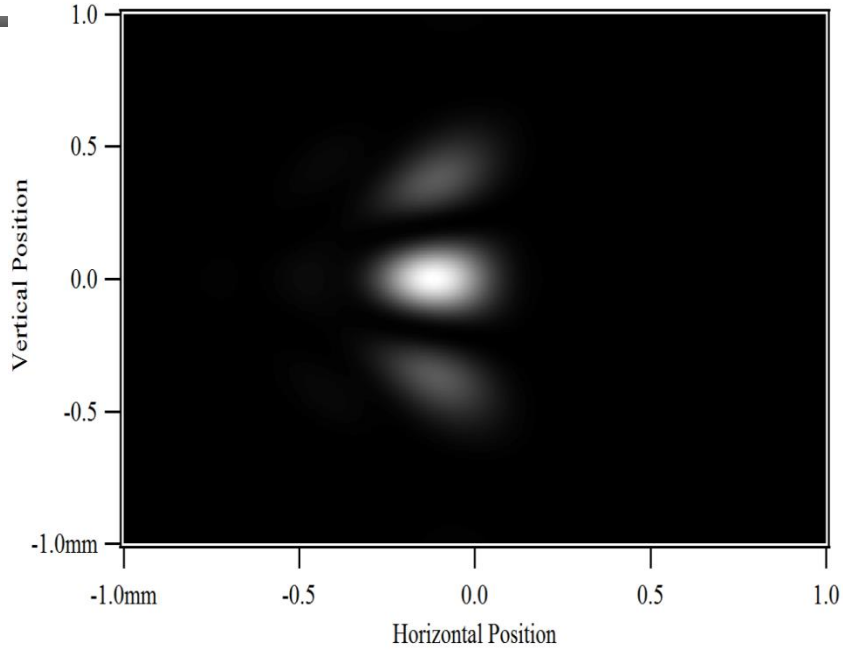
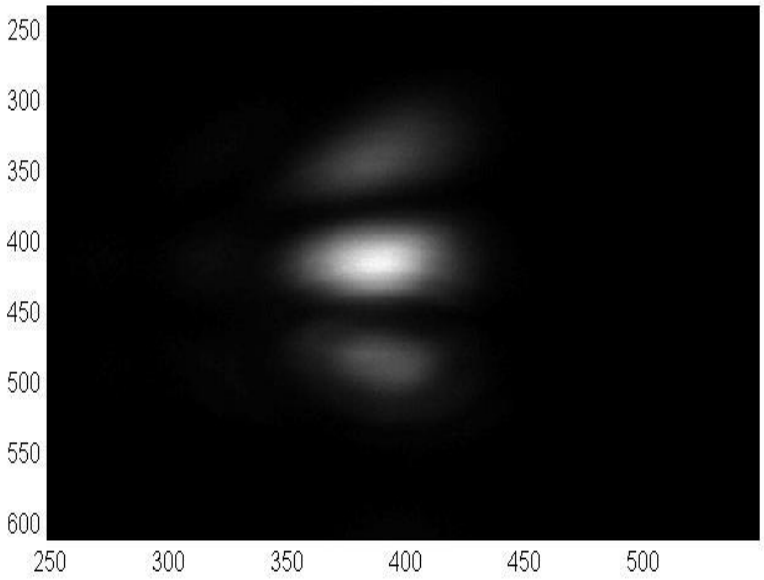
Our wish for industrial ”help”

- The beam lines are designed for transmission optics and can go down to λ = 180 nm. We would like a larger offer of narrow band-pass filters (~ 1 nm) in the range 180 to 260 nm.

3 GeV ring emittance





Sigma polarized SR, 632.8 nm, SRW calculation (left) and measured image (right).
The simulation is done for ε_x = 320 pm rad, β_x = 1.5 m (σ_x = 22 μm).
Both figures show a 2 x 2 mm^2 area of the image plane.

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

Slide by Jonas Breunlin
SRW:Synchrotron radiation Workshop, O. Chubar, P. Ellaume