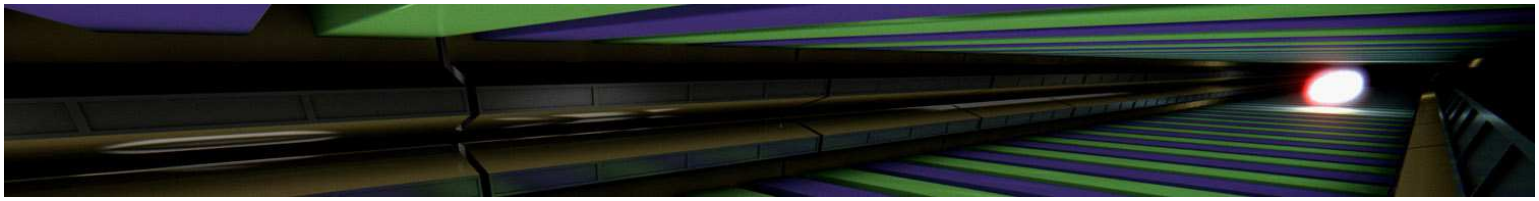
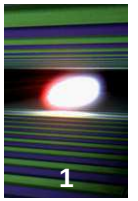


MID Beam Parameters and Optics

Thomas Roth

Outline



- SASE 2 beam parameters
- Focusing with CRLs and beamsizes
- Monochromators
- Split and Delay Line
- more X-ray optics
- MID Hutches Overview

Outline

- SASE 2 beam parameters
- Focusing with CRLs and beamsizes
- Monochromators
- Split and Delay Line
- more X-ray optics
- MID Hutches Overview

SASE 2 beam parameters

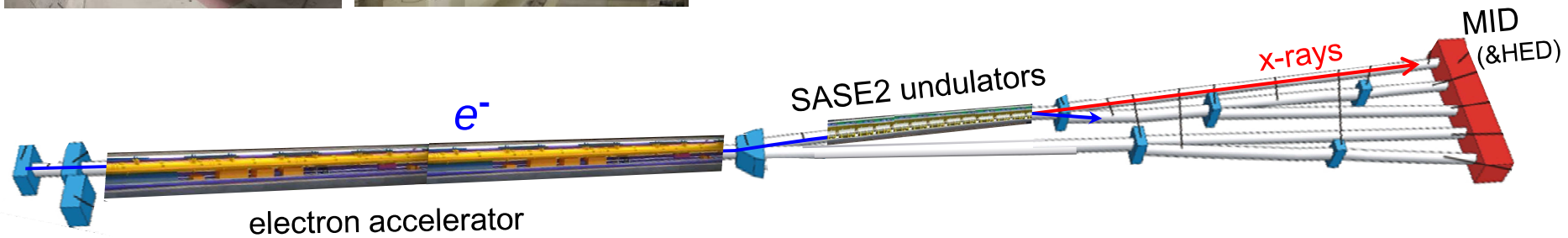
e^- electron beam operates at different energies and different bunch charges:

E_{e-} = 17.5 GeV
E_{e-} = 14 GeV
E_{e-} = 12.5 GeV

(also E_{e-} = 8 GeV)

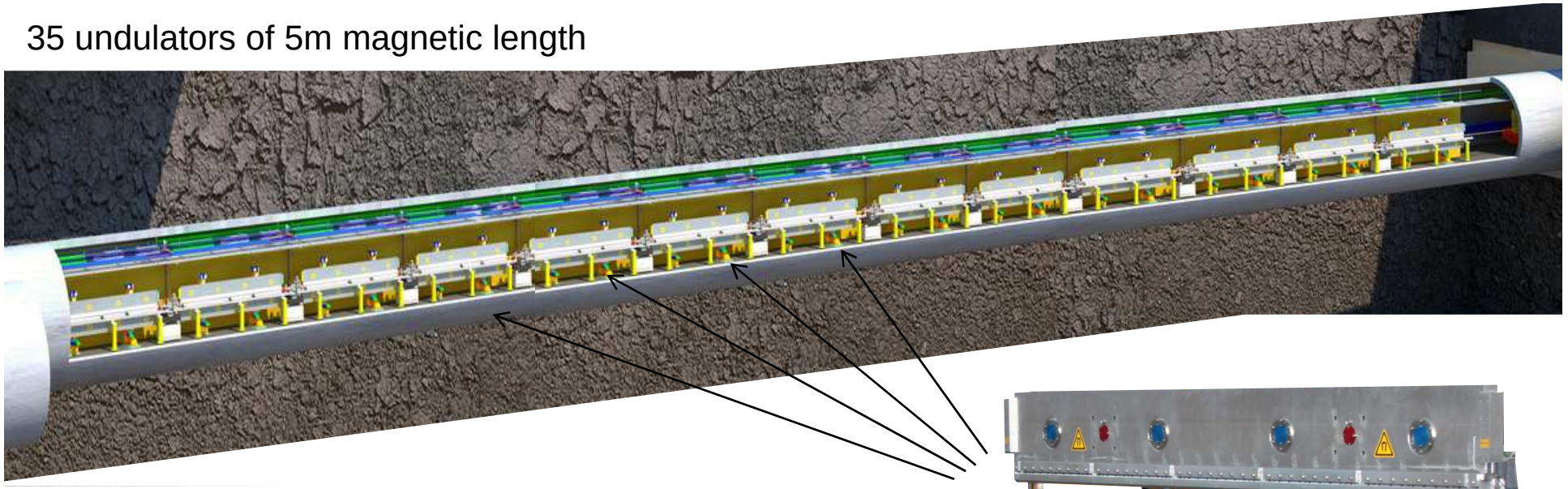
q_{e-} = 20 pC
q_{e-} = 250 pC
q_{e-} = 500 pC
q_{e-} = 1 nC

initial operation probably at 500 pC



SASE 2 beam parameters

35 undulators of 5m magnetic length



E_{e-} = 17.5 GeV

E_{e-} = 14 GeV

E_{e-} = 12.5 GeV

undulator period λ_u= 40 mm

10 mm minimum gap (up to >20 mm)

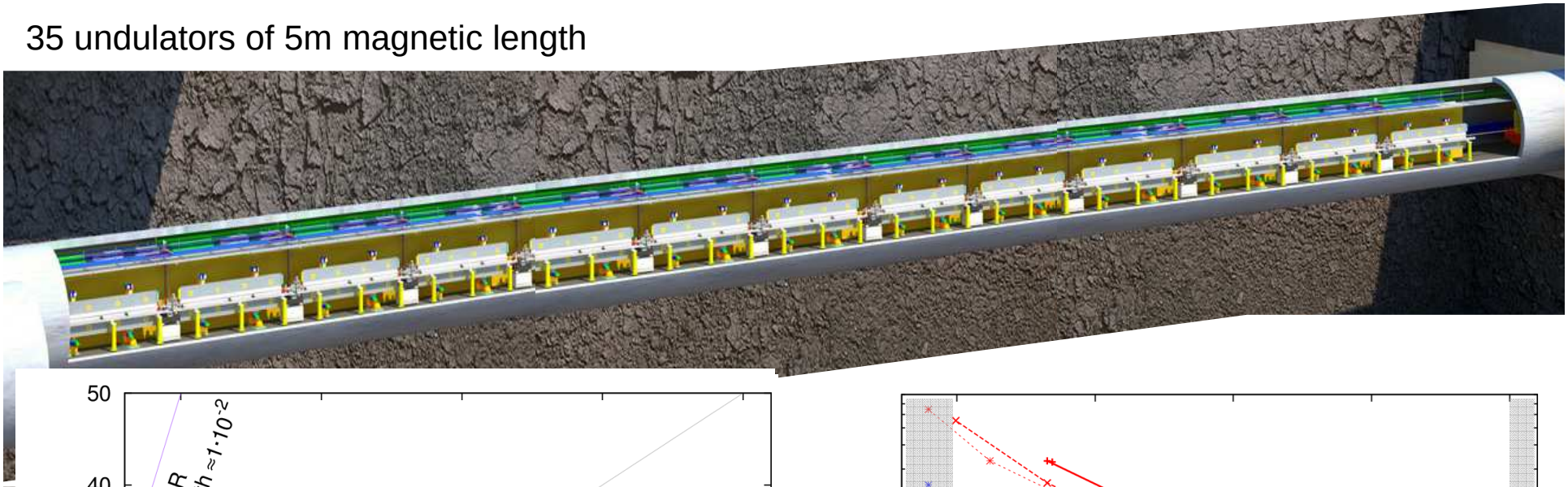
always using 1st undulator harmonic

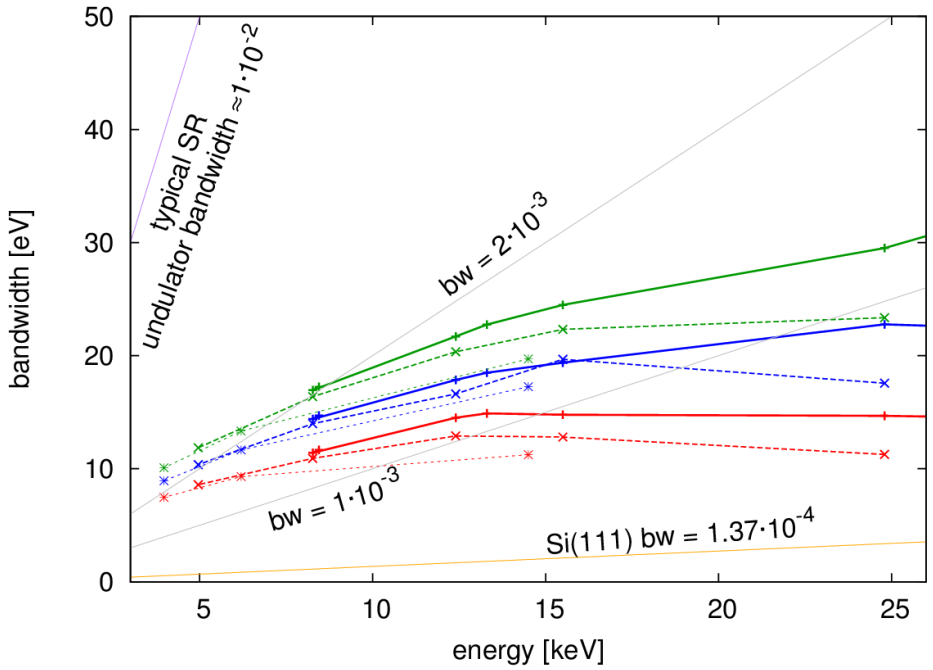
(3rd harmonic is 3 orders of magnitude less, unless seeding on 3rd)

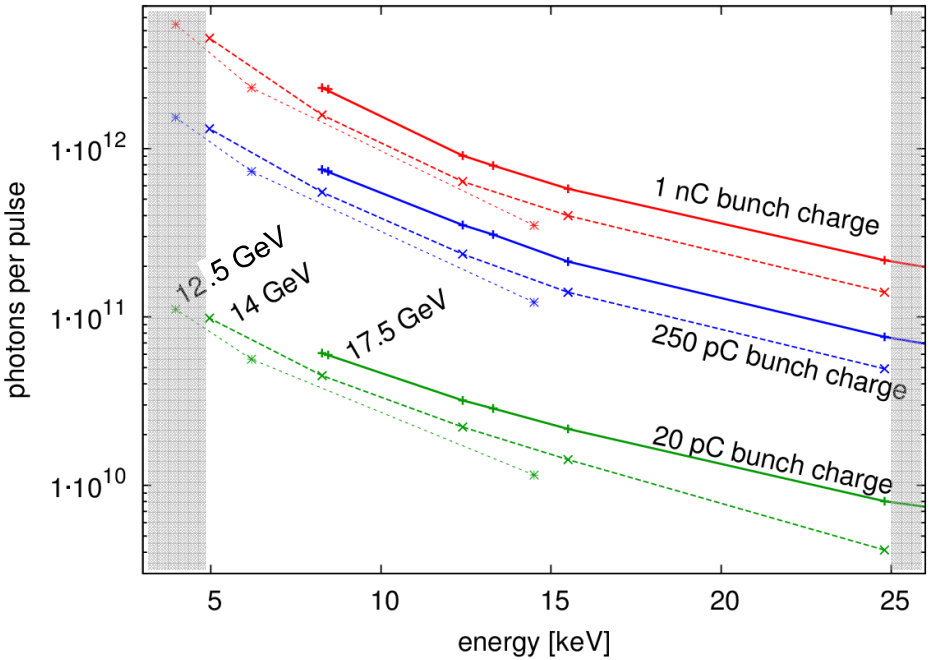
European XFEL

SASE 2 beam parameters, at saturation length

35 undulators of 5m magnetic length





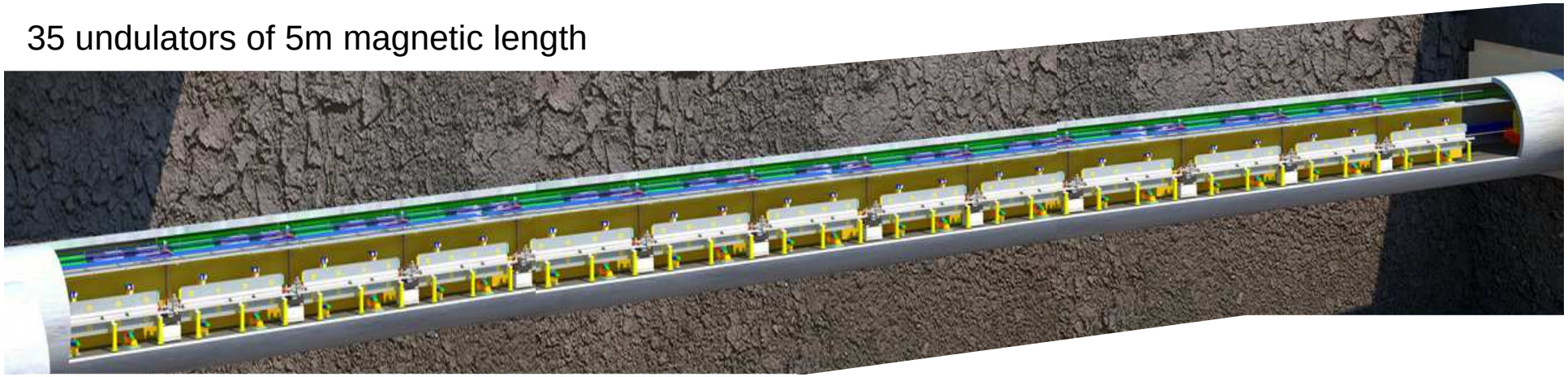


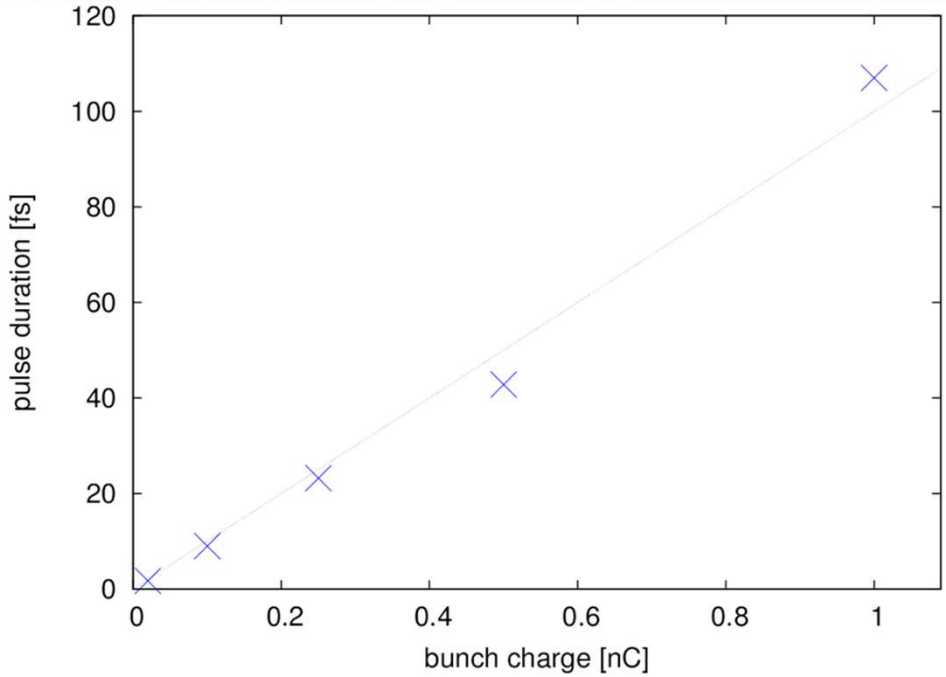
Schneidmiller & Yurkov: „Photon beam properties at the Europ. XFEL“ 2011/2013

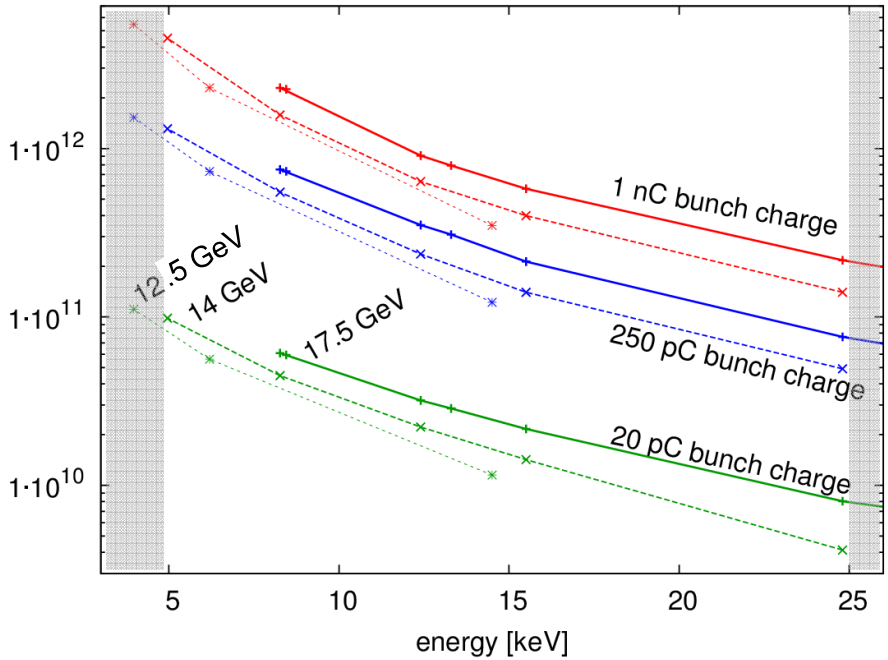
European XFEL

SASE 2 beam parameters, at saturation length

35 undulators of 5m magnetic length





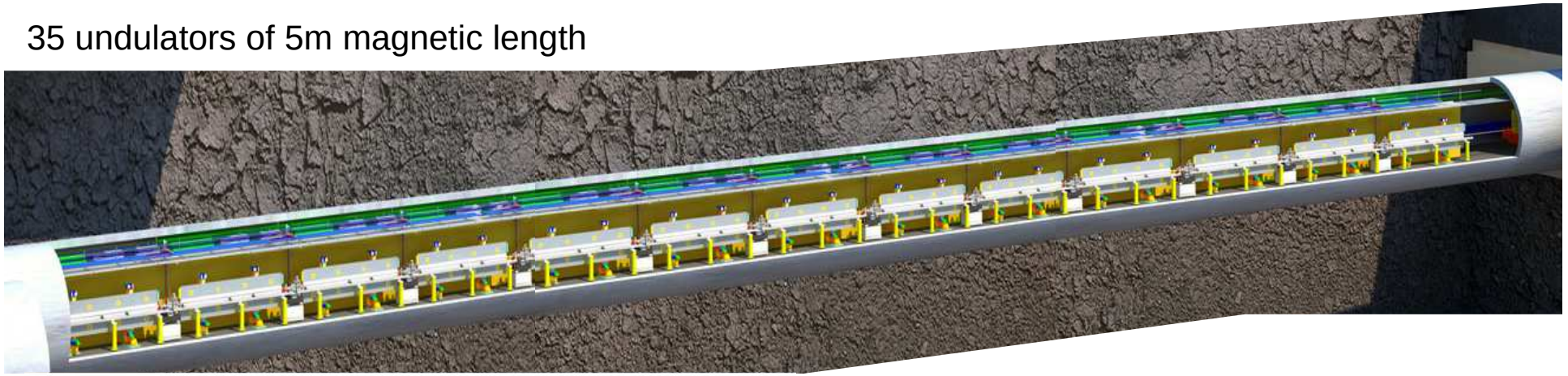


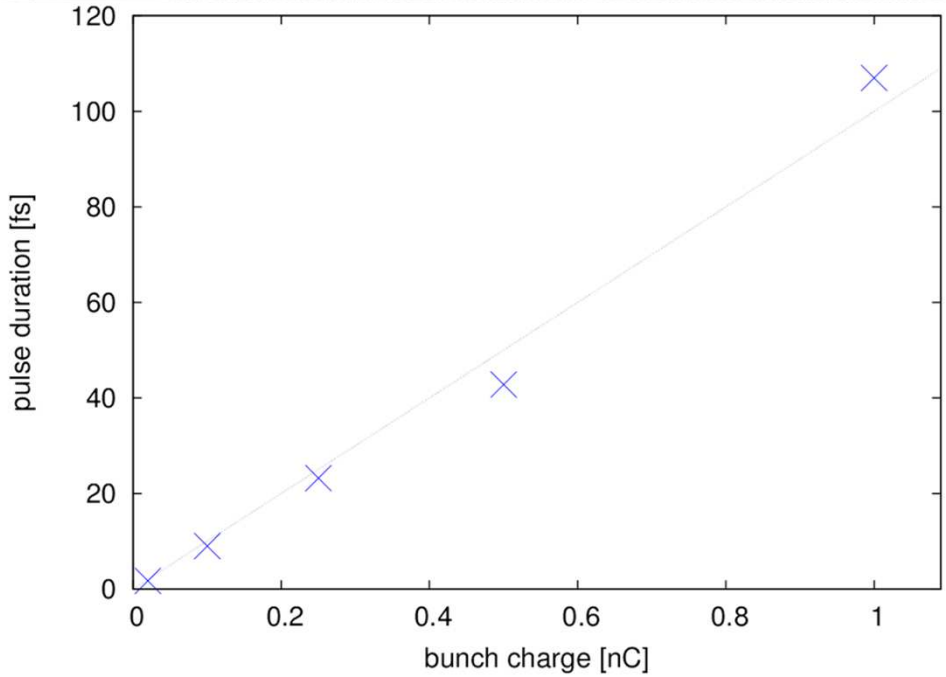
Schneidmiller & Yurkov: „Photon beam properties at the Europ. XFEL“ 2011/2013

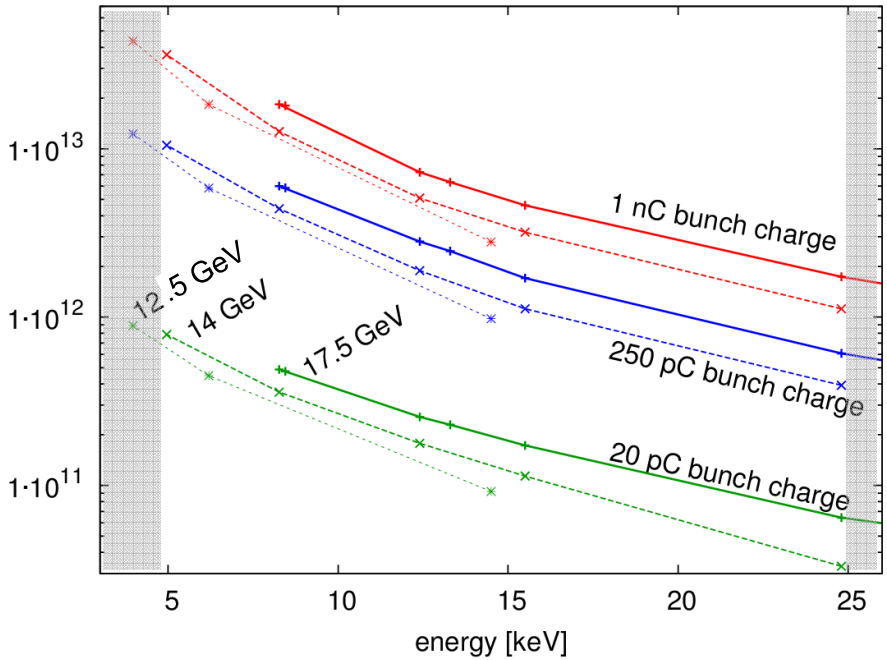
European XFEL

SASE 2 beam parameters, tapered

35 undulators of 5m magnetic length

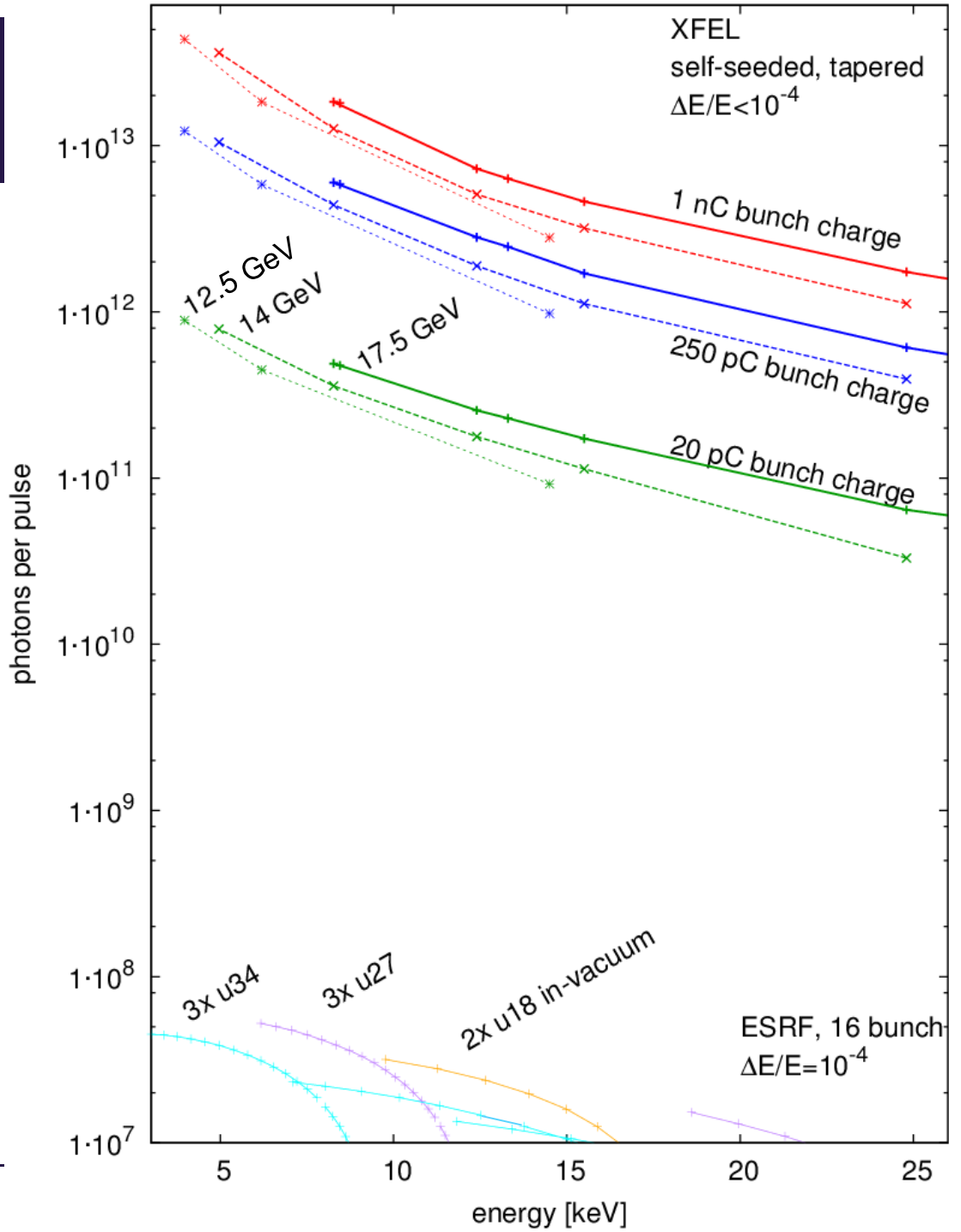






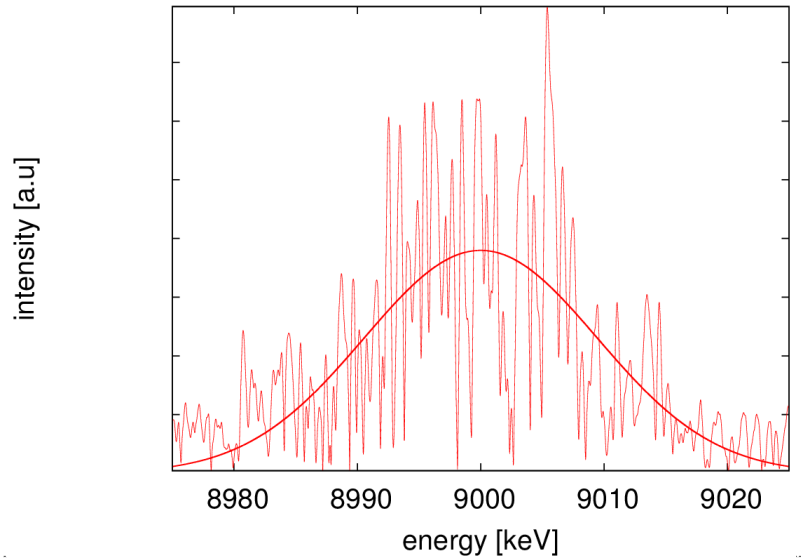
European XFEL

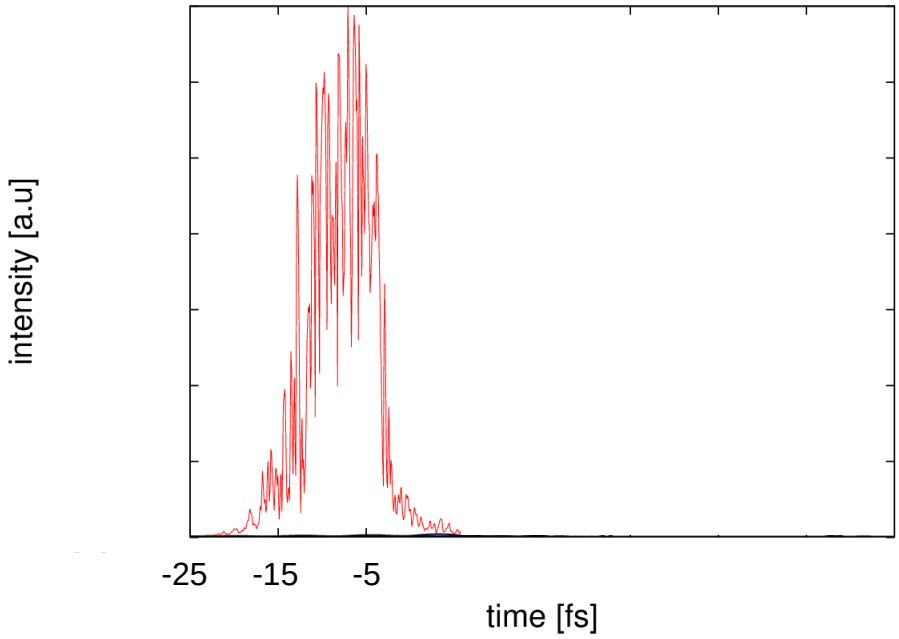
SASE 2 / ESRF



9 keV pulse at 0.25 nC bunch charge, tapered

SASE radiation



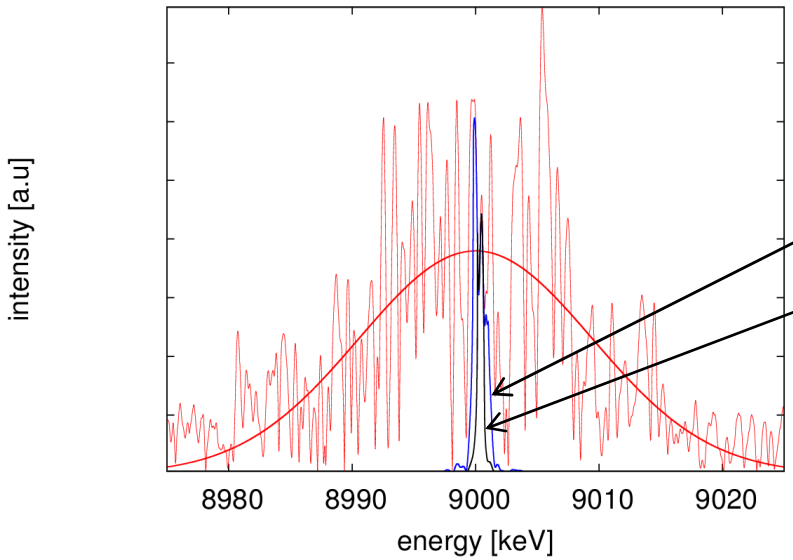


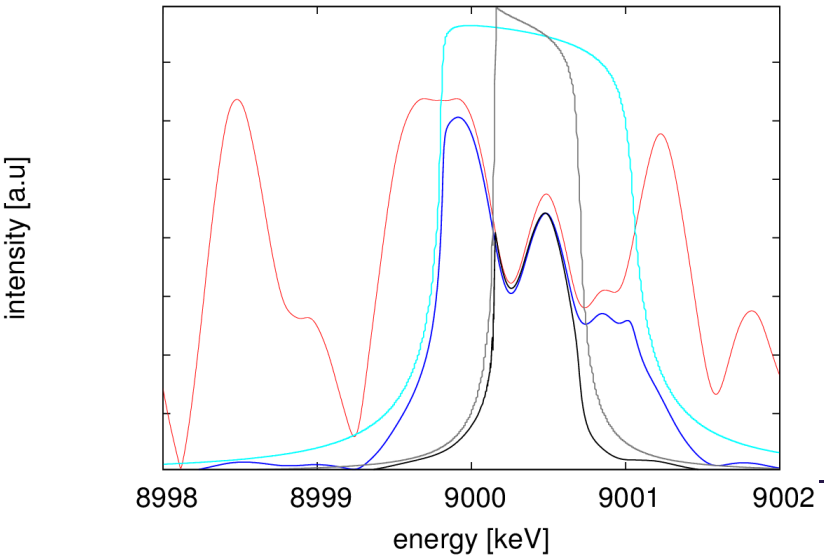
spectra courtesy of V. Kocharyan, I. Agapov *et al.*

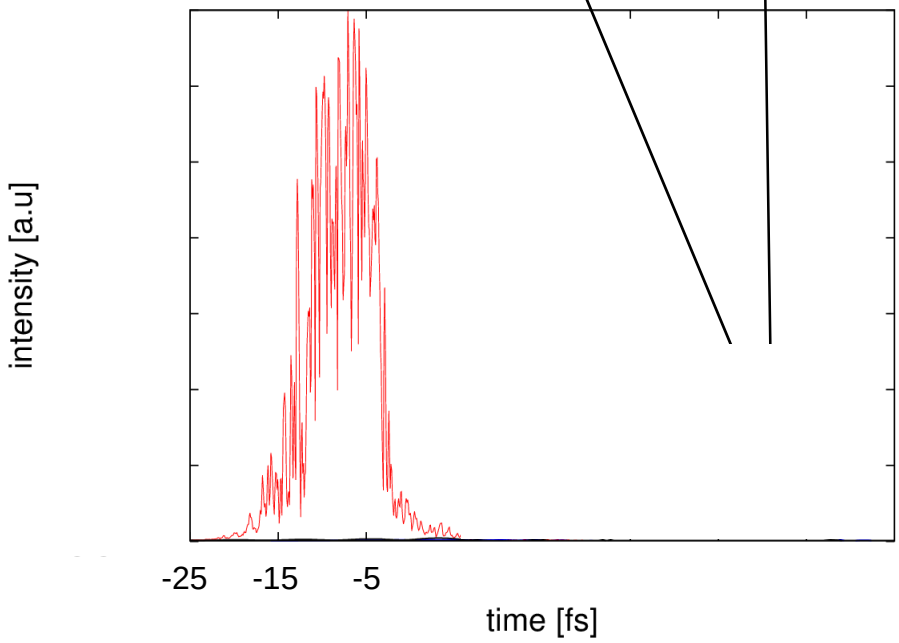
9 keV pulse at 0.25 nC bunch charge, tapered

SASE radiation, filtered by Si(111), filtered by Si(220)

(calculations W. Lu & I. Agapov)





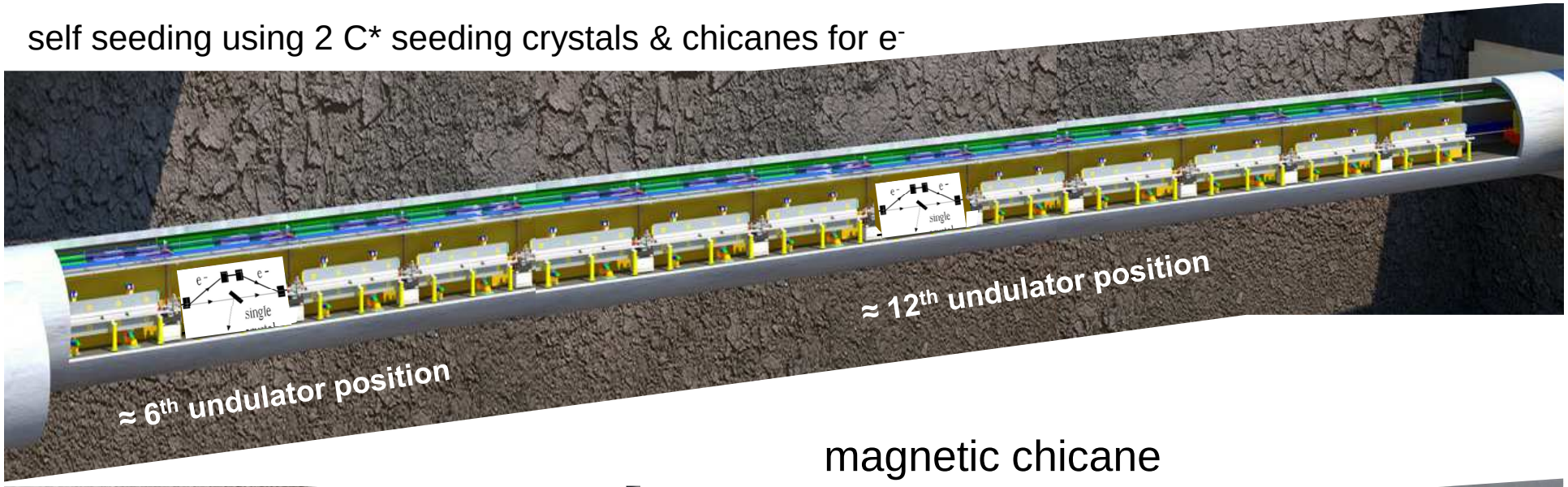


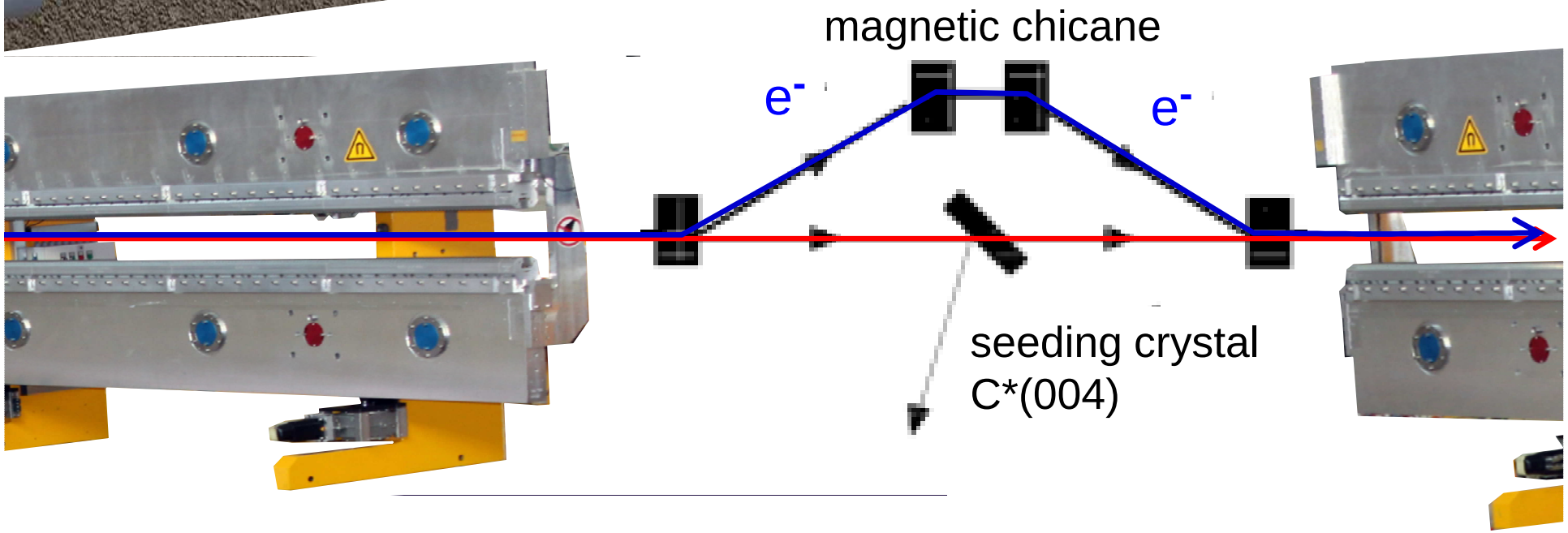
spectra courtesy of V. Kocharyan, I. Agapov *et al.*

European XFEL

SASE 2 beam parameters, seeding

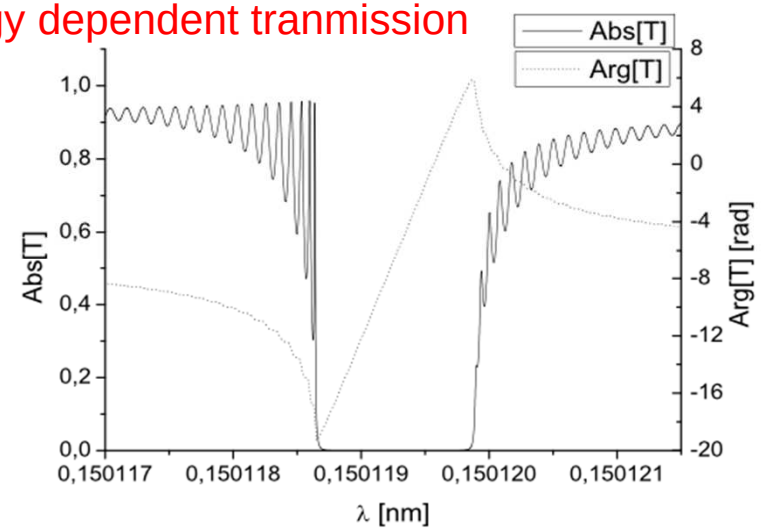
self seeding using 2 C* seeding crystals & chicanes for e-



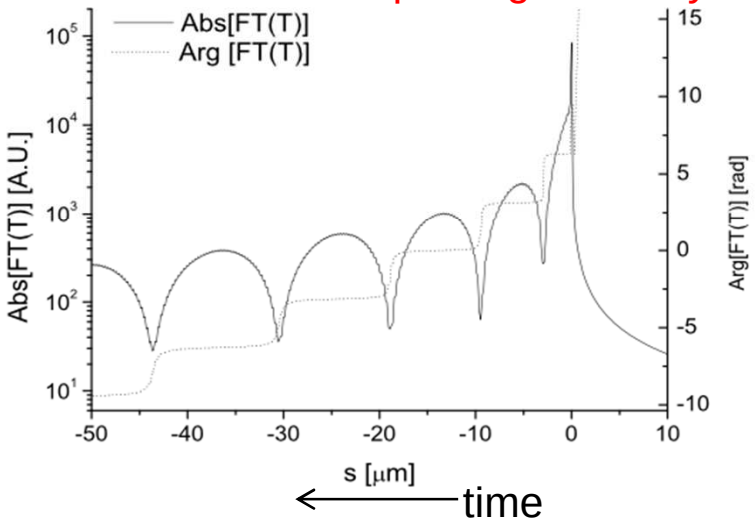


transmittance of X-ray diffraction

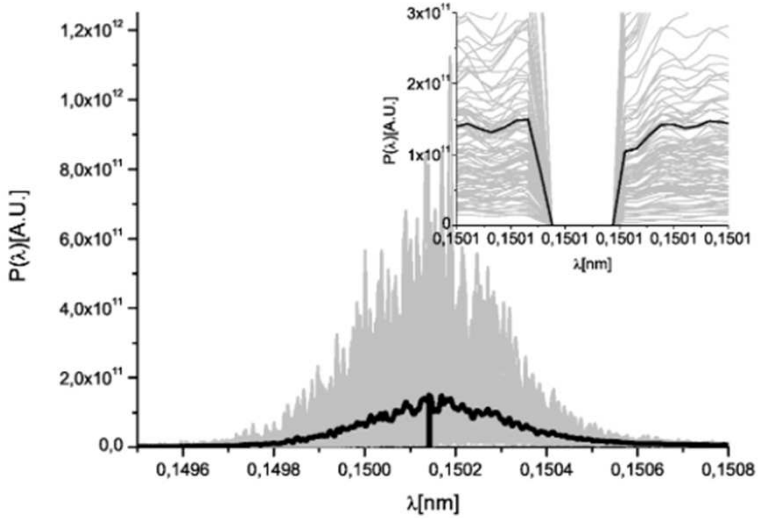
energy dependent tranmission

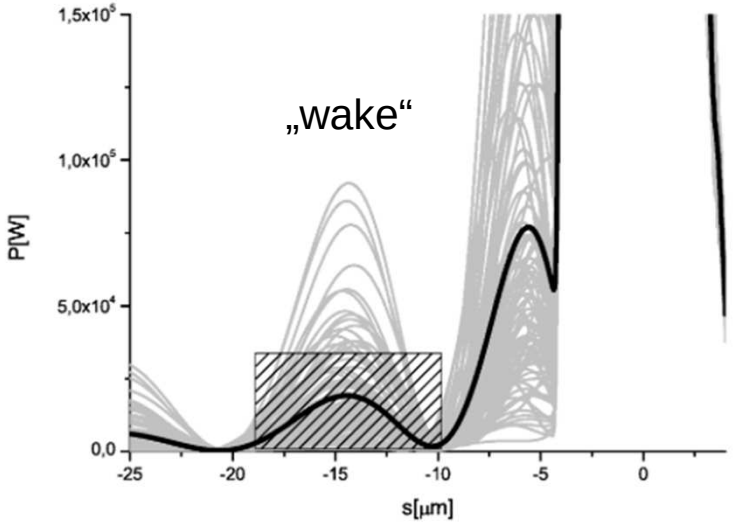


Fourier transform respecting causality



time



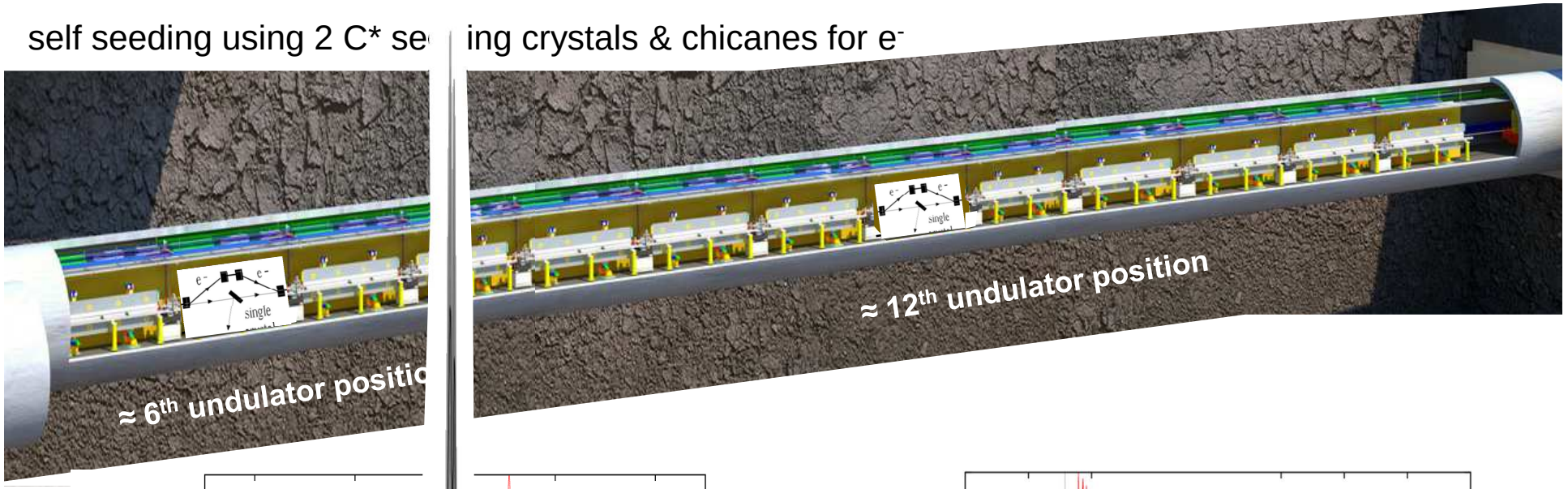


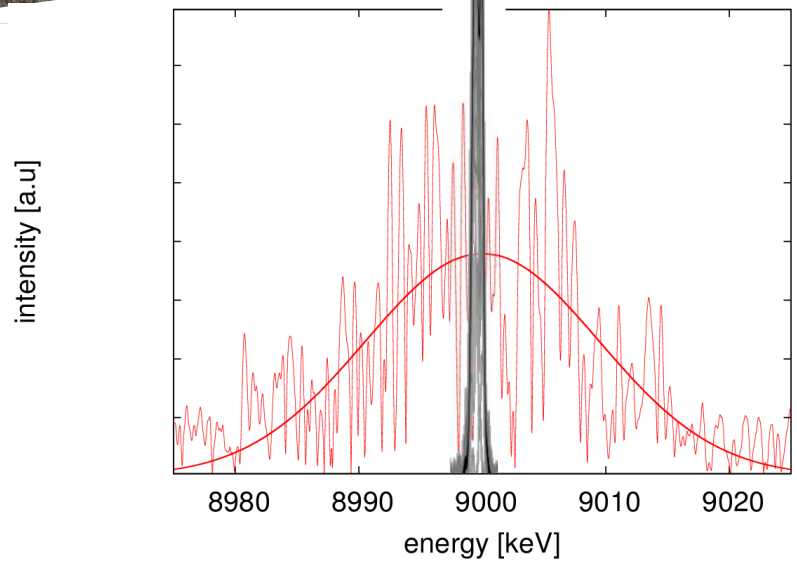
V. Kocharyan, I. Agapov, G. Geloni *et al.*

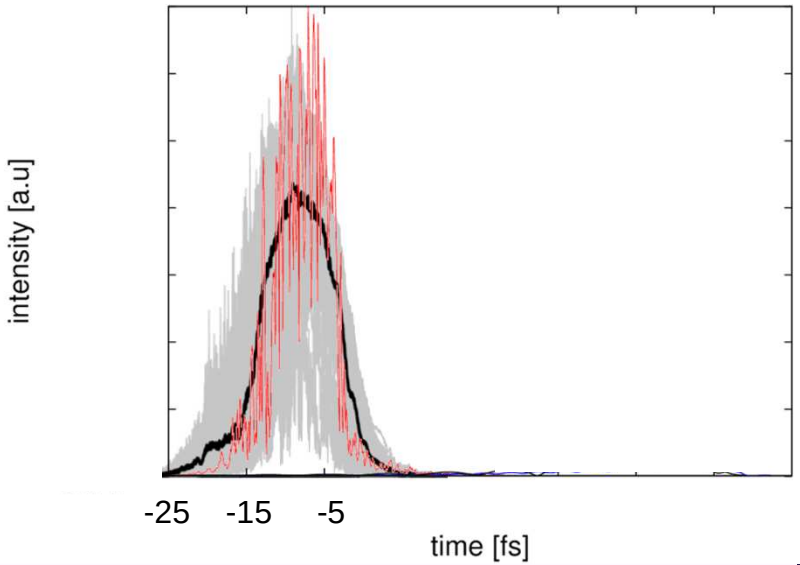
European XFEL

SASE 2 beam parameters, seeding

self seeding using 2 C* se ing crystals & chicanes for e-





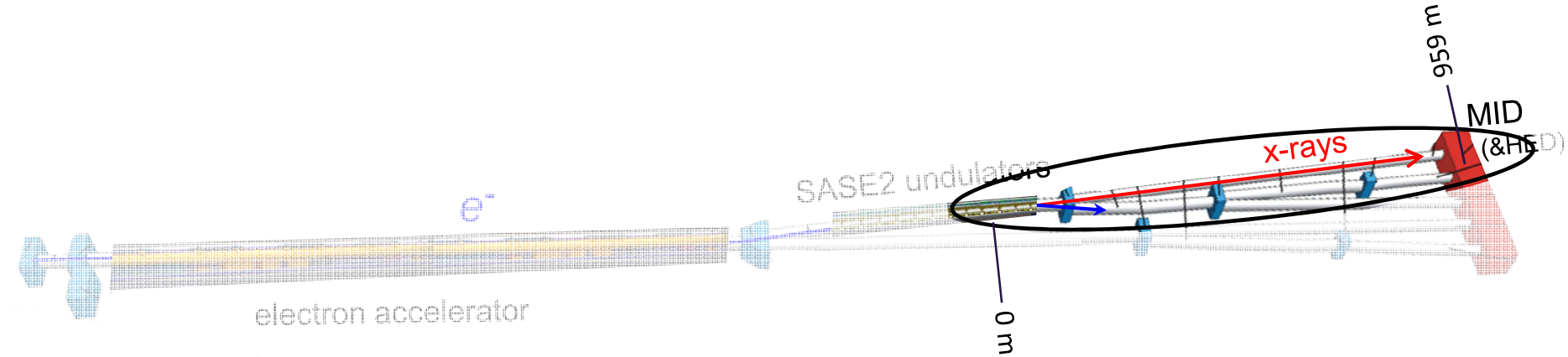


spectra courtesy of V. Kocharyan, I. Agapov, G. Geloni *et al.*

MID/HED photon tunnel

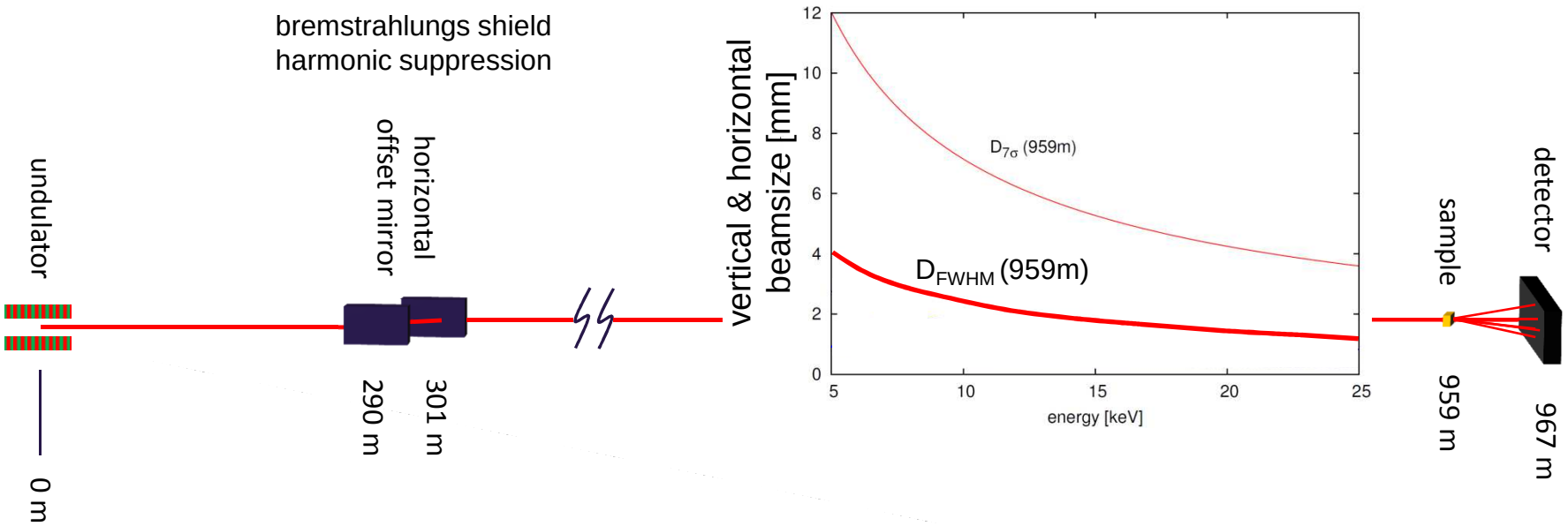
MID photon (x-ray) tunnel

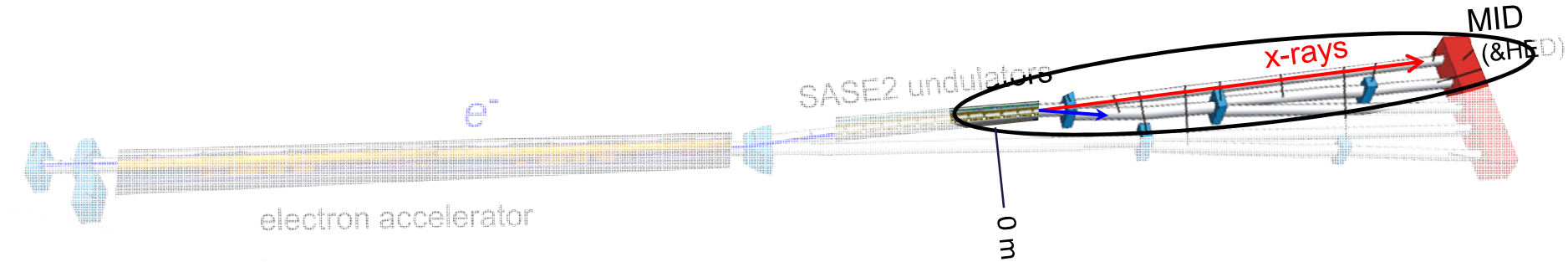
experiments site and XFEL building



MID beamline overview

beam size at sample without focusing:

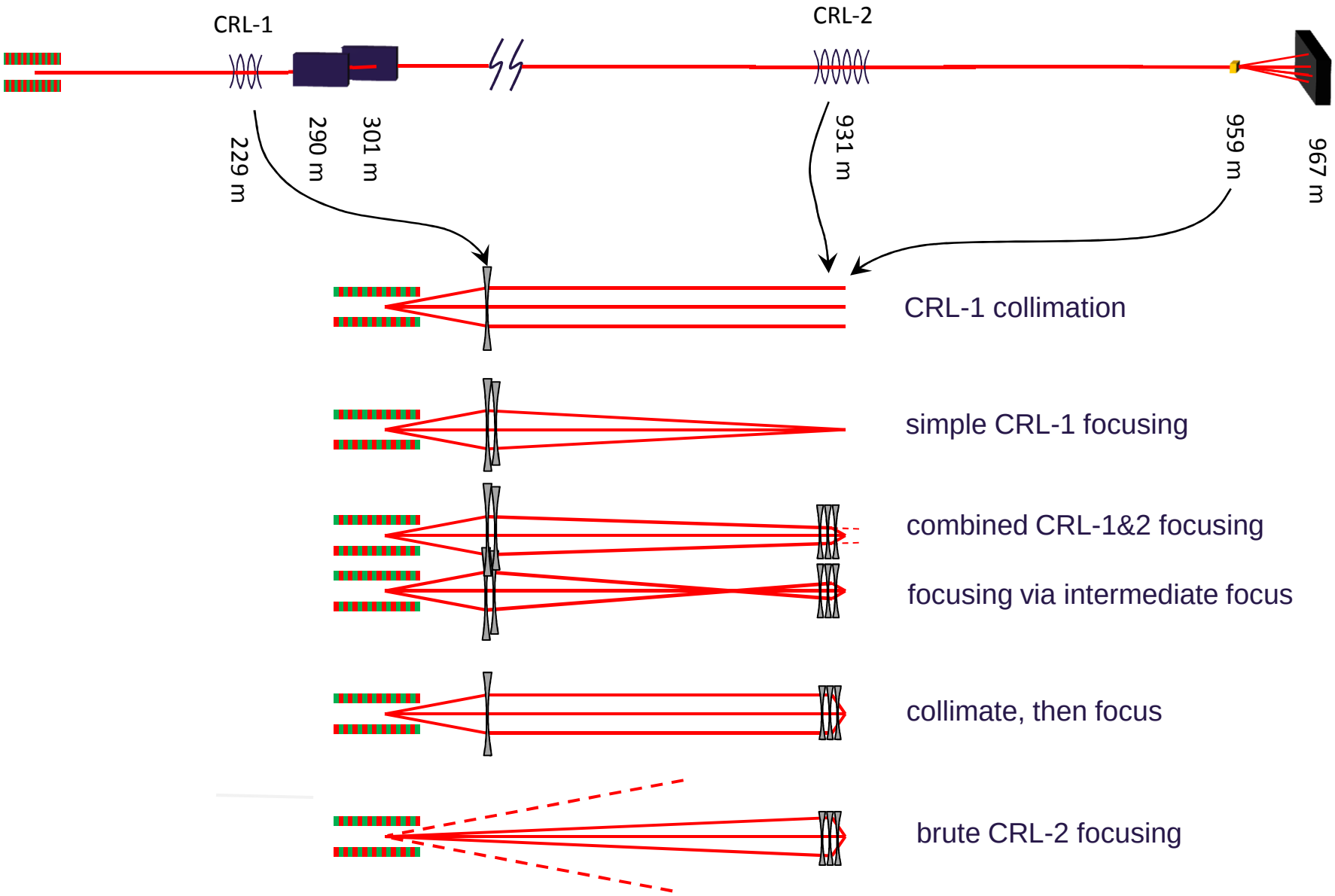




Outline

- SASE 2 beam parameters
- Focusing with CRLs and beamsizes
- Monochromators
- Split and Delay Line
- more X-ray optics
- MID Hutches Overview

Focusing with CRLs



European XFEL

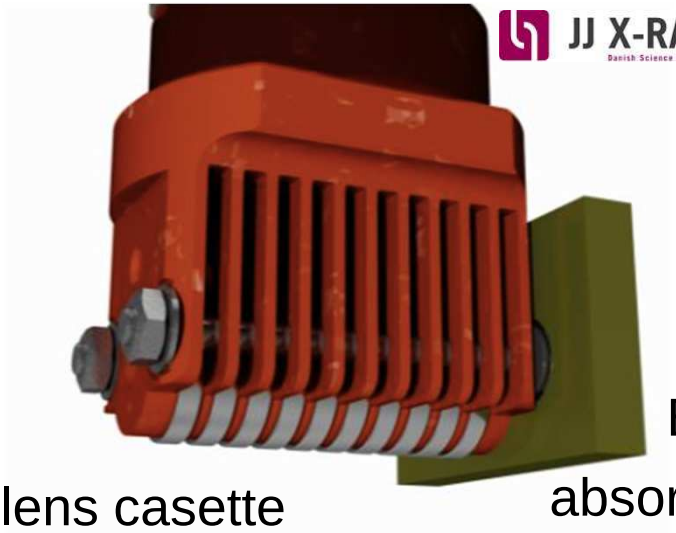
Focusing with CRLs

CRL 1

actuator	1	2	3	4	5	6	7	8
filled with	1x5.8	1x4.9	1x4.0	1x3.3	2x5.8	3x4.0	7x4.0	7x2.0

CRL 2

actuator	1	2	3	4	5	6	7	8
filled with	1x5.8	2x5.8	4x5.8	7x5.8	10x4.0	10x2.0	10x1.0	10x0.5

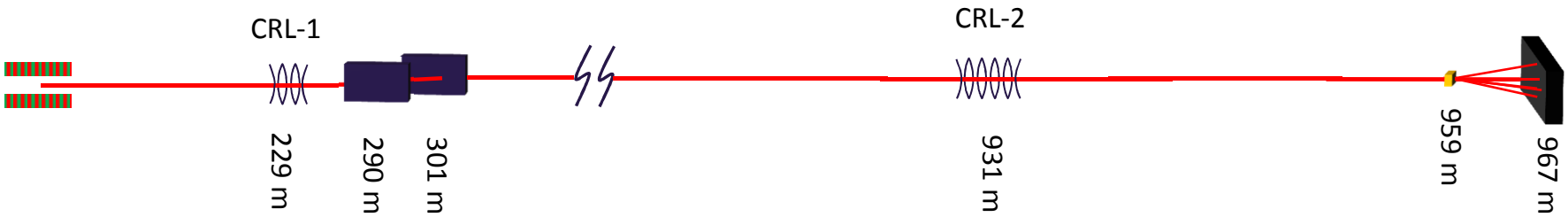


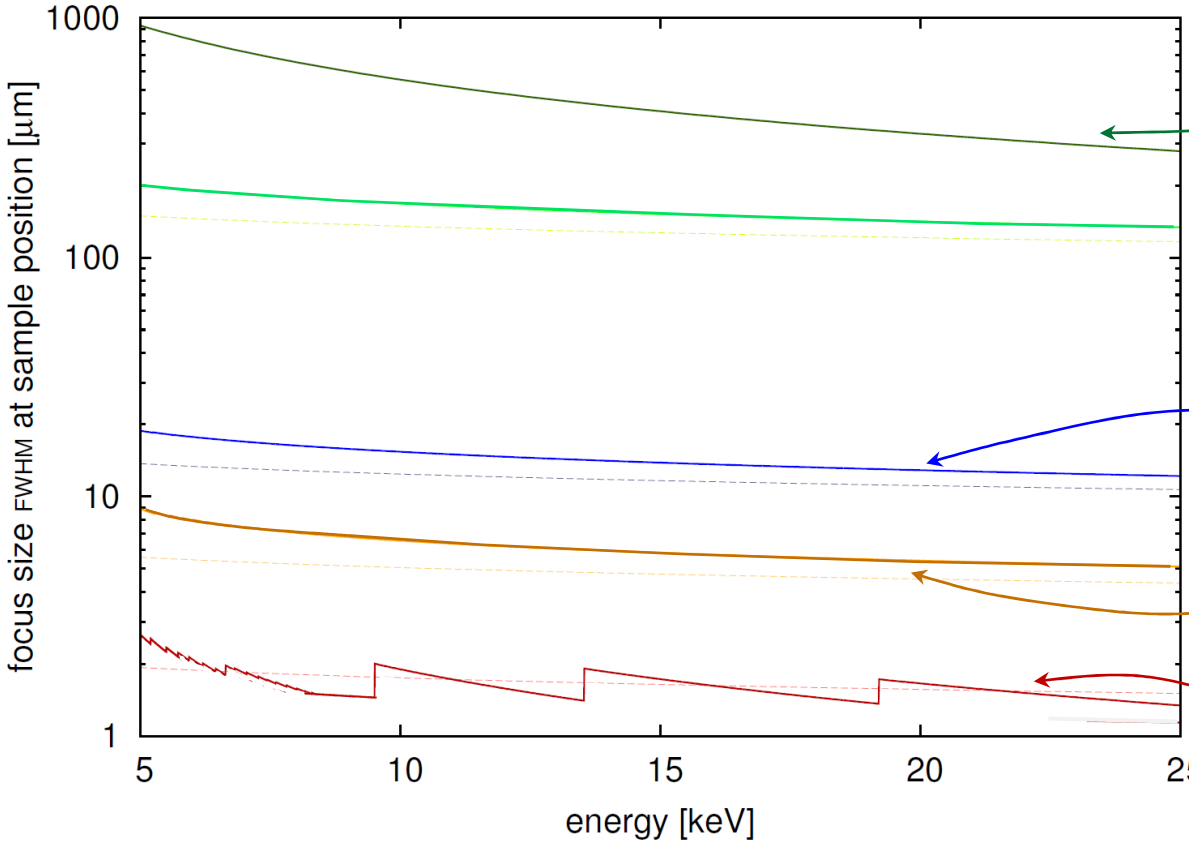
lens casette

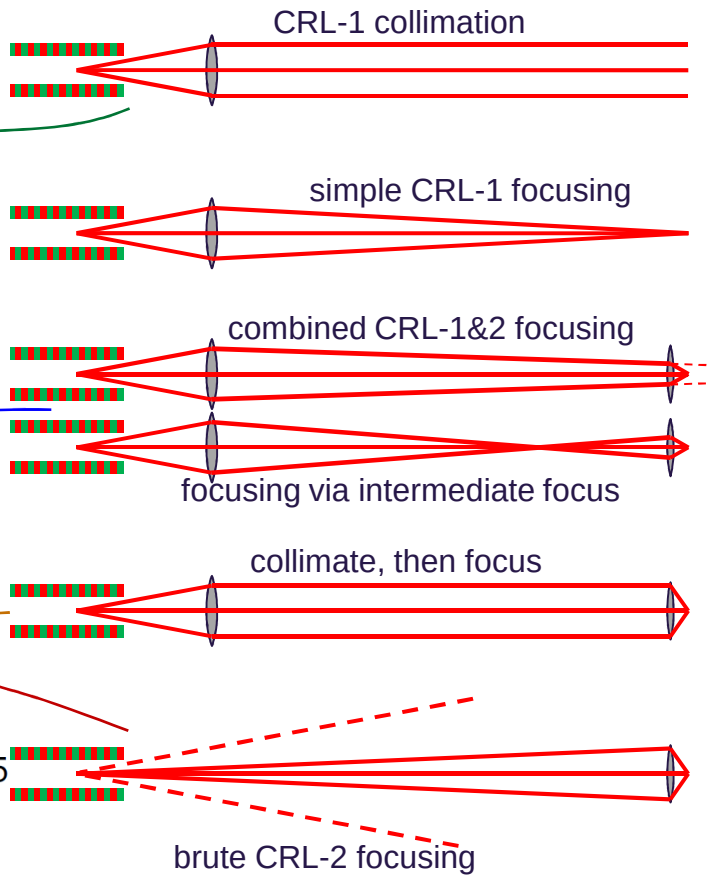
B_4C absorber

JJ X-ray & L. Batchelor

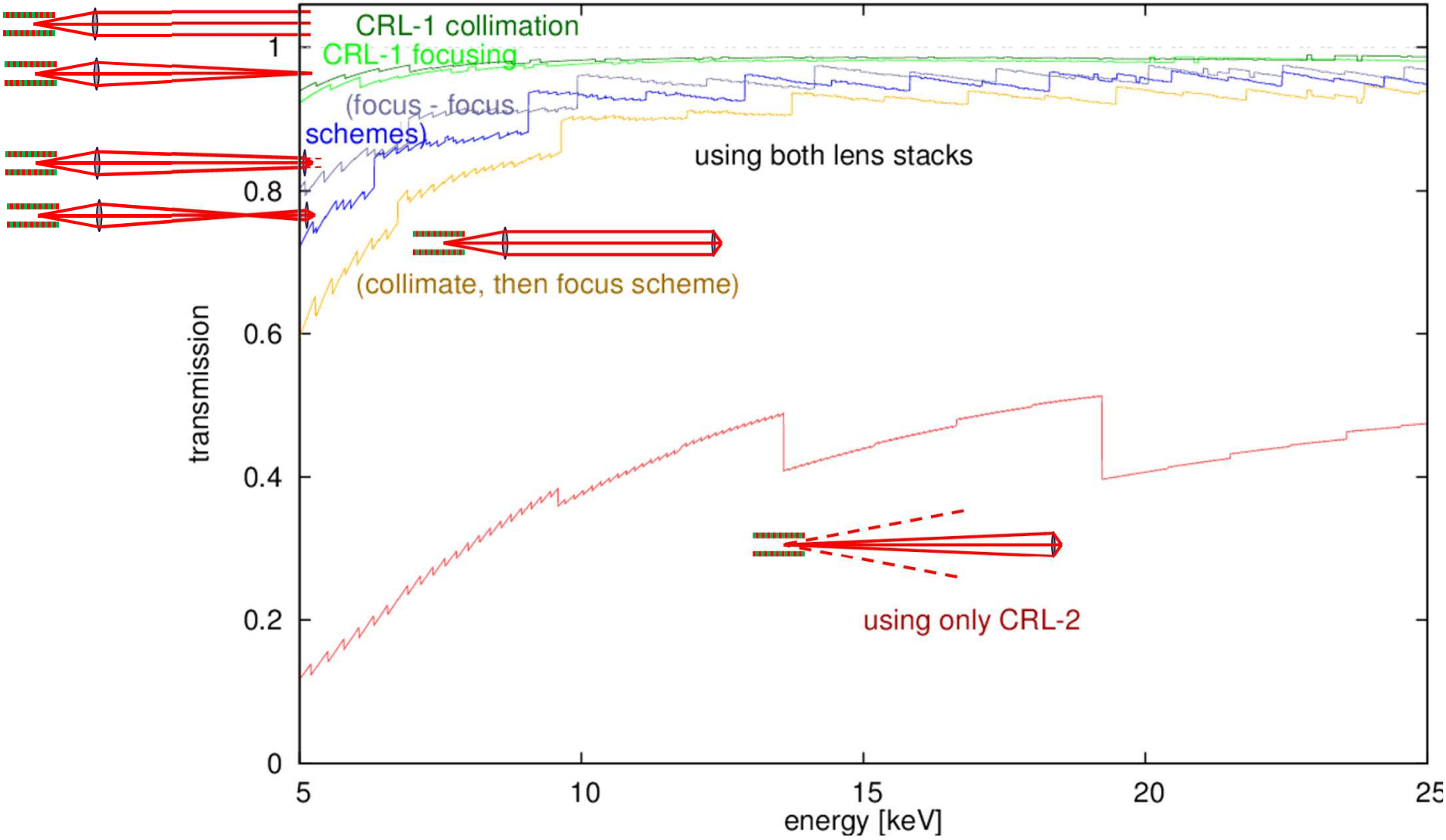
Focusing with CRLs







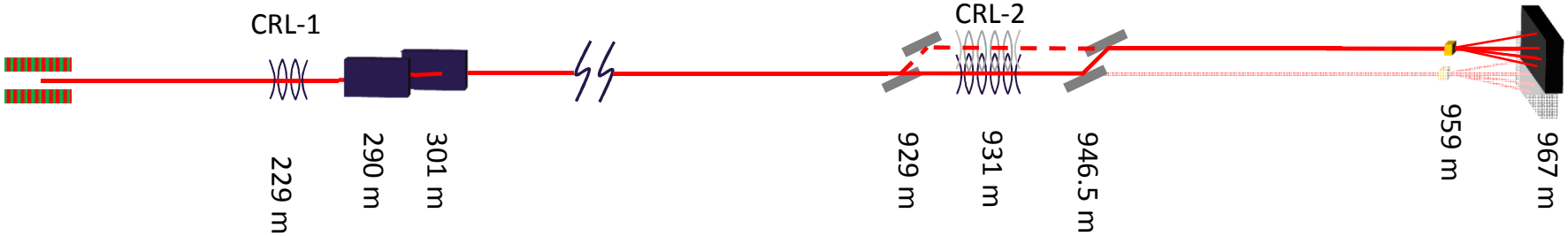
Focusing with CRLs



Outline

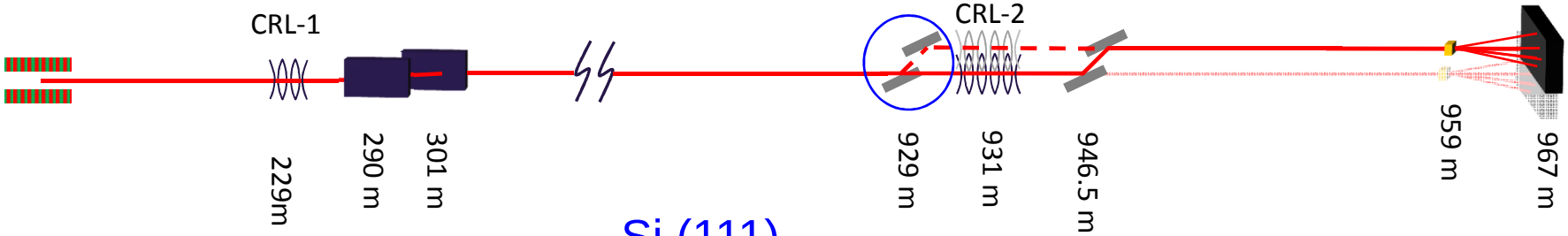
- SASE 2 beam parameters
- Focusing with CRLs and beamsizes
- Monochromators
- Split and Delay Line
- more X-ray optics
- MID Hutches Overview

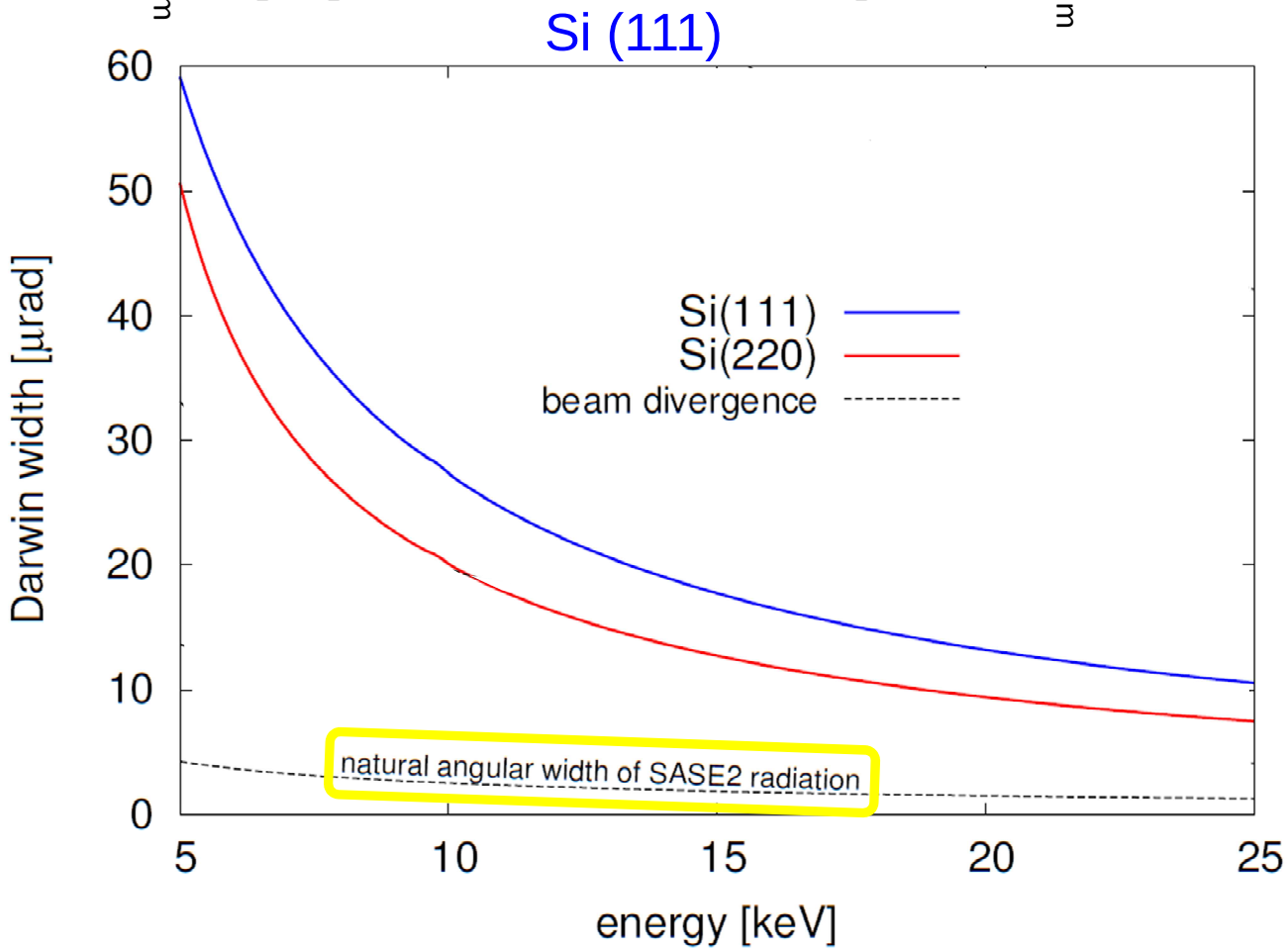
Monochromators



Si (111) Si (220)

Monochromators

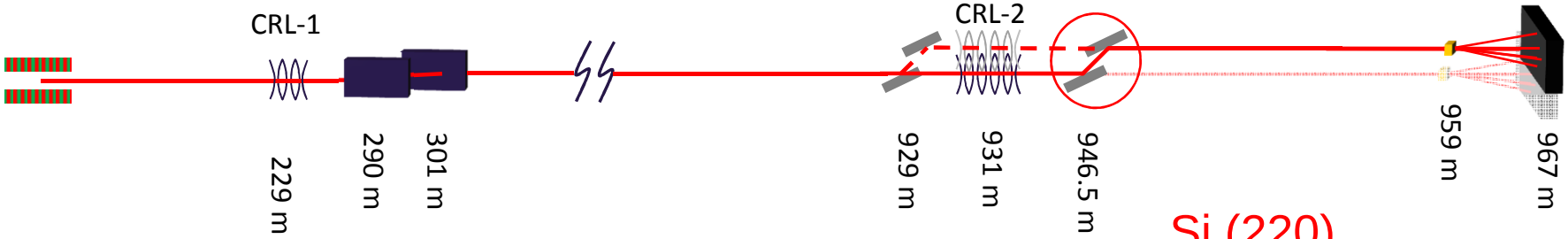




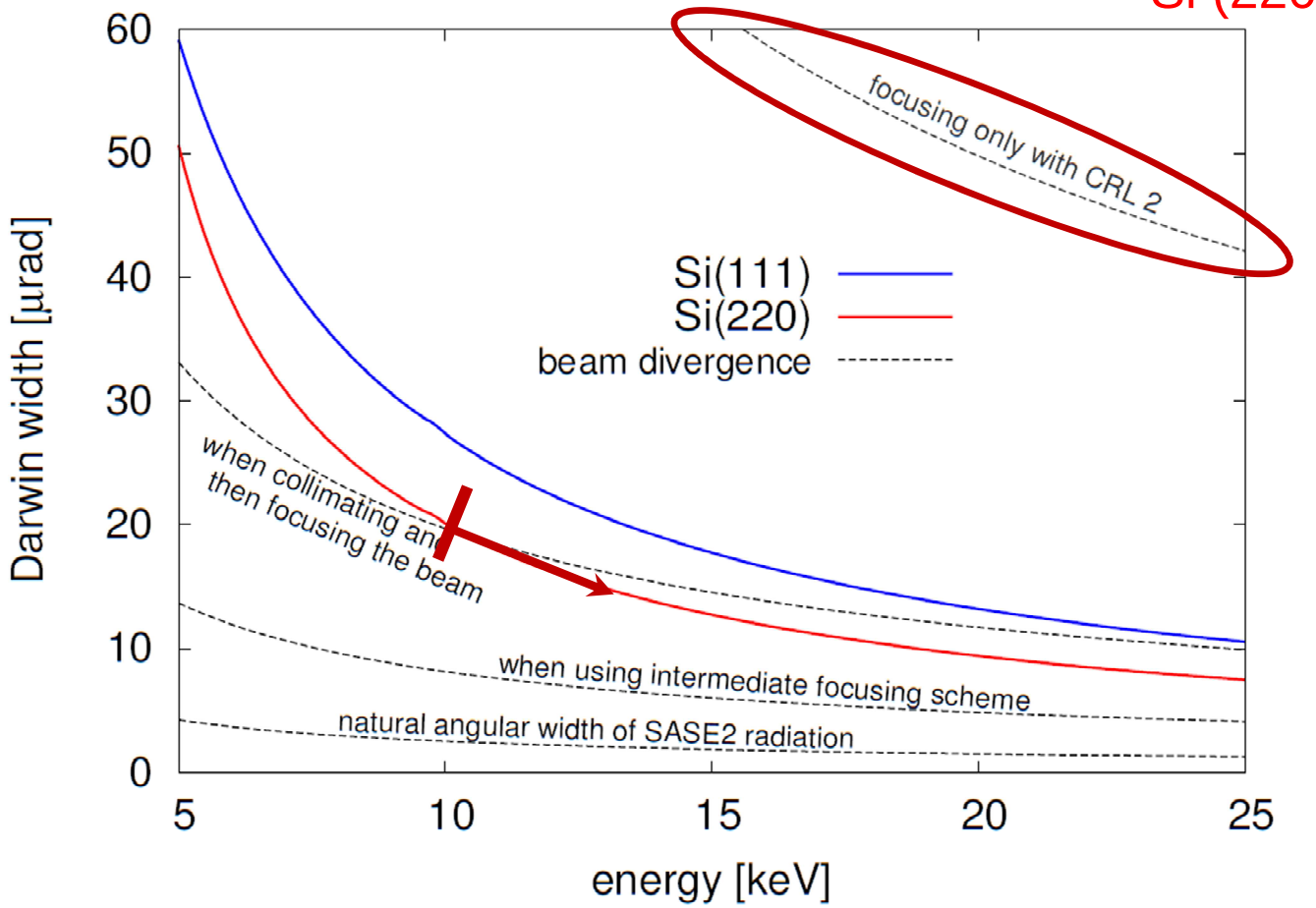
Si(111)

can be used with all focusing schemes

Monochromators



Si (220)



Si(220)

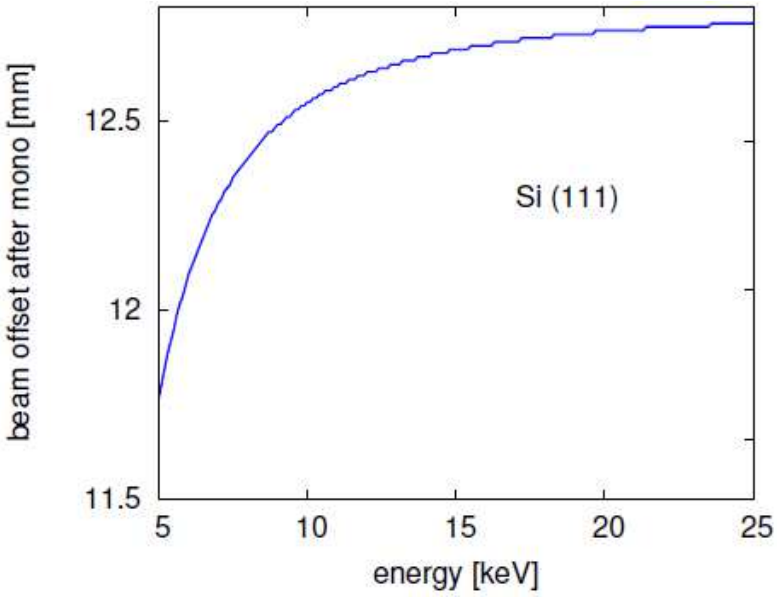
can not be used for brute CRL-2 focusing.

Losses above 10 keV for collimate, then focus scheme

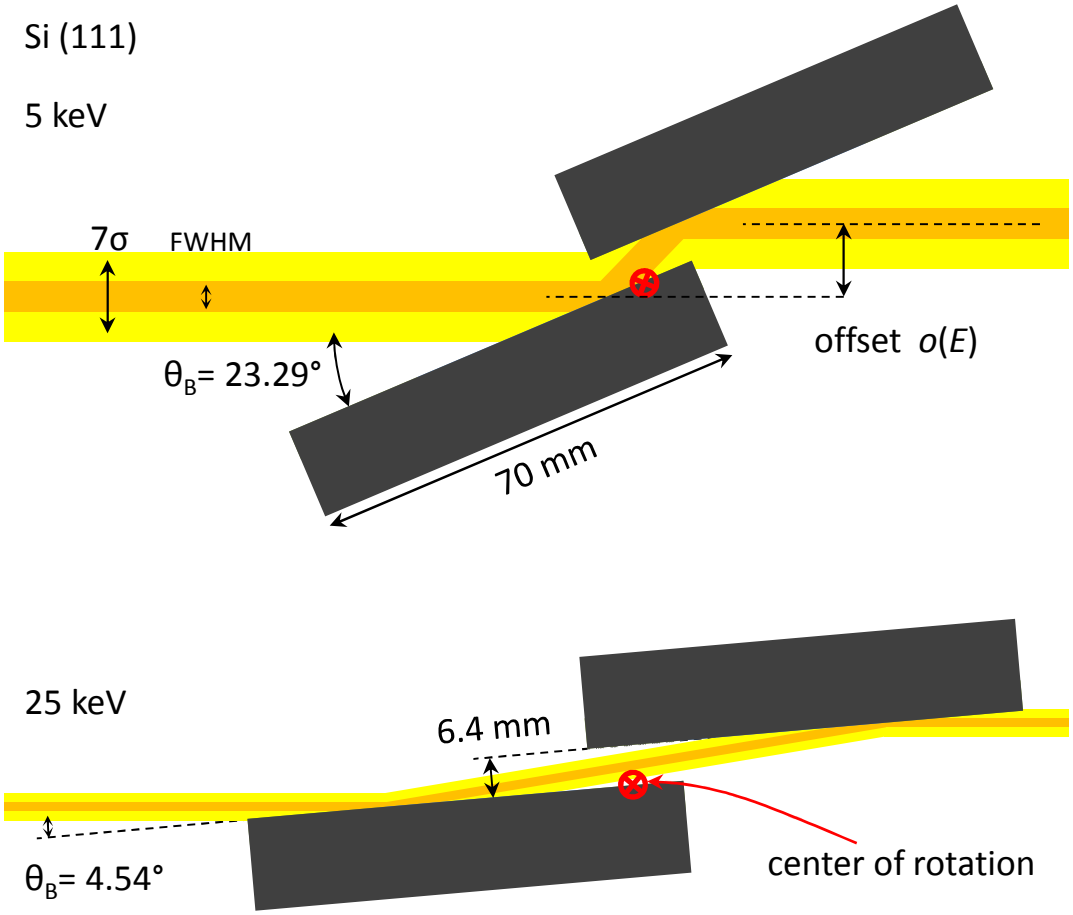
European XFEL

Si(111)

channel cut gap	6.4 mm	
crystal length	70 mm	
required angle stroke	18.75°	
	5 keV	25 keV
Bragg angle θ_B	23.29°	4.54°
beam offset $o(E)$	11.76 mm	12.76 mm



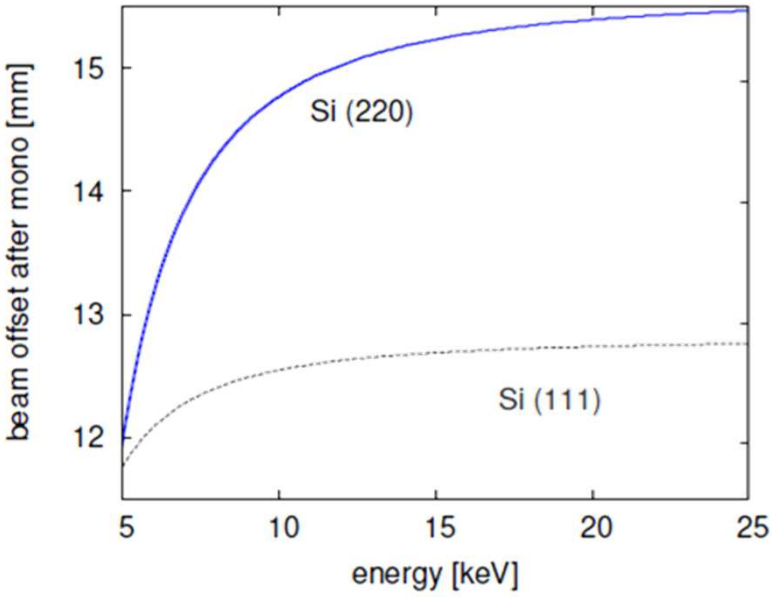
artificial channel cut → variable offset

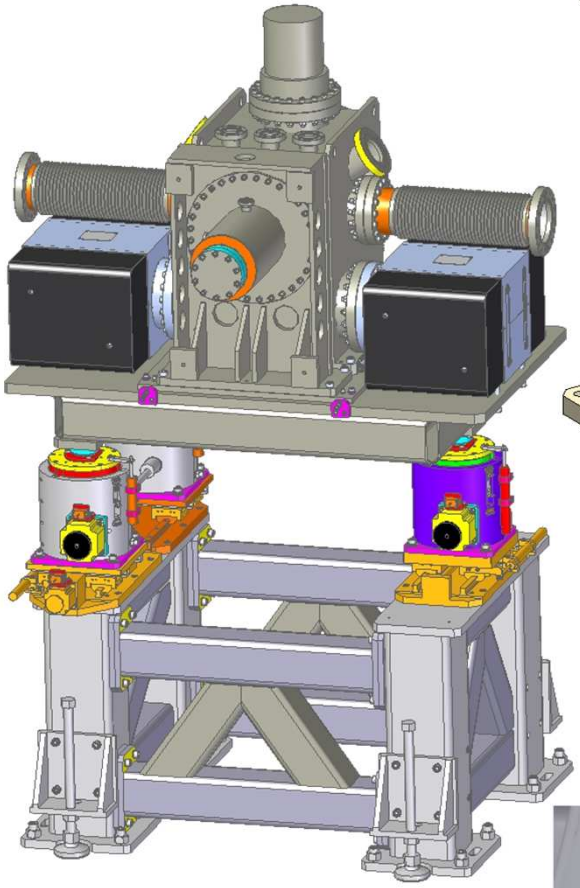


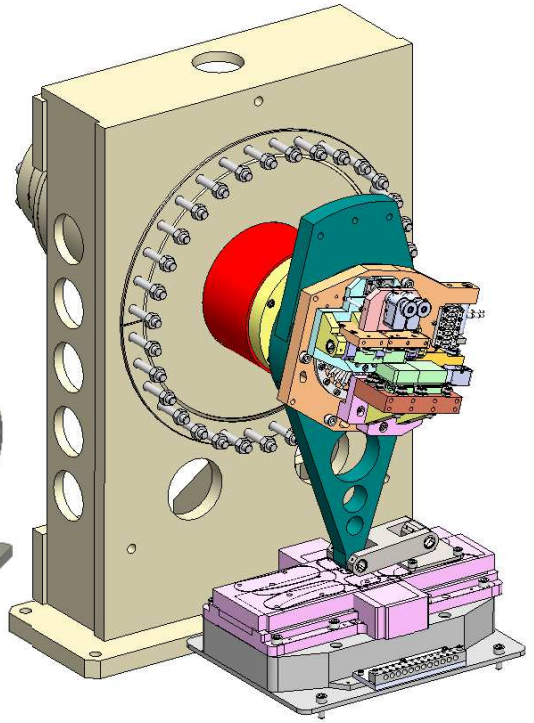
European XFEL

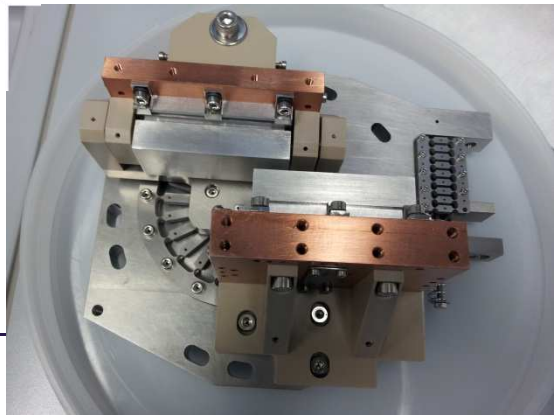
Si(220)

channel cut gap	7.8 mm	
crystal length	48.3 mm	
required angle stroke	32.80°	
	5 keV	25 keV
Bragg angle θ_B	40.22°	7.42°
beam offset $o(E)$	11.88 mm	15.43 mm







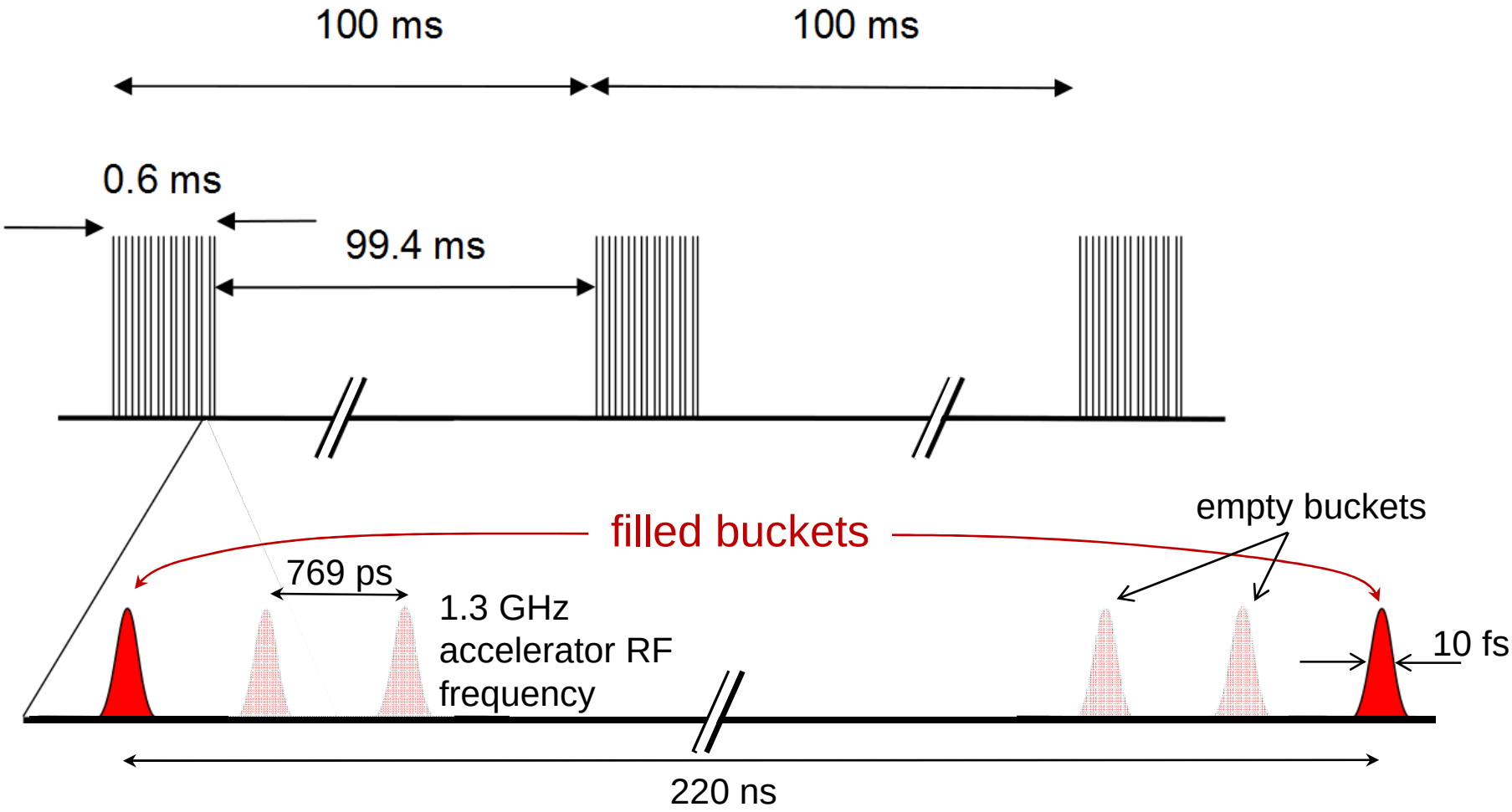


D. Shu (APS) & X. Dong

Outline

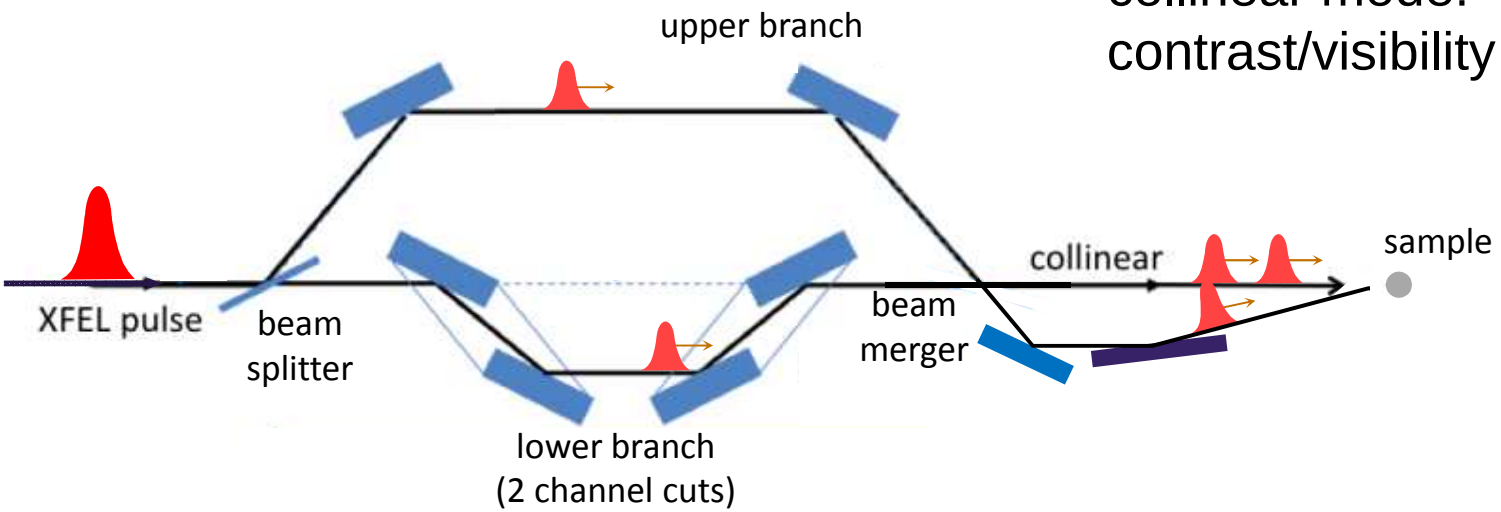
- SASE 2 beam parameters
- Focusing with CRLs and beamsizes
- Monochromators
- Split and Delay Line
- more X-ray optics
- MID Hutches Overview

Timing experiments at X-FEL: standard time structure:



Split and Delay Line (SDL)

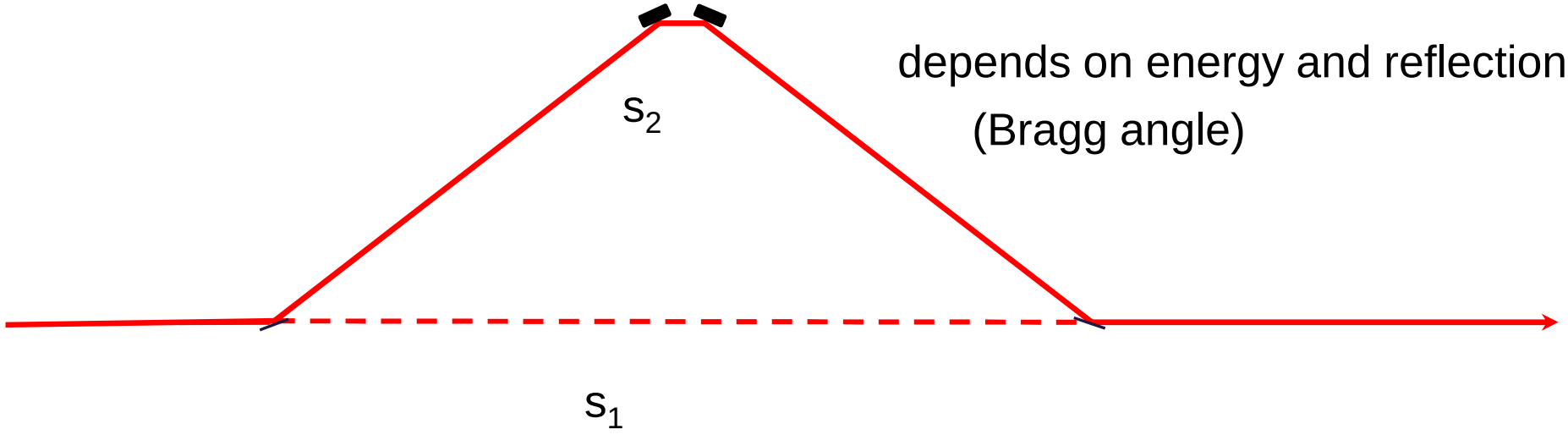
X-ray pump X-ray prope experiments, XPCS and other fast scattering experiments with Δt < 800 ps require an X-ray split and delay line (SDL)



collinear mode:
contrast/visibility changes

Upper branch

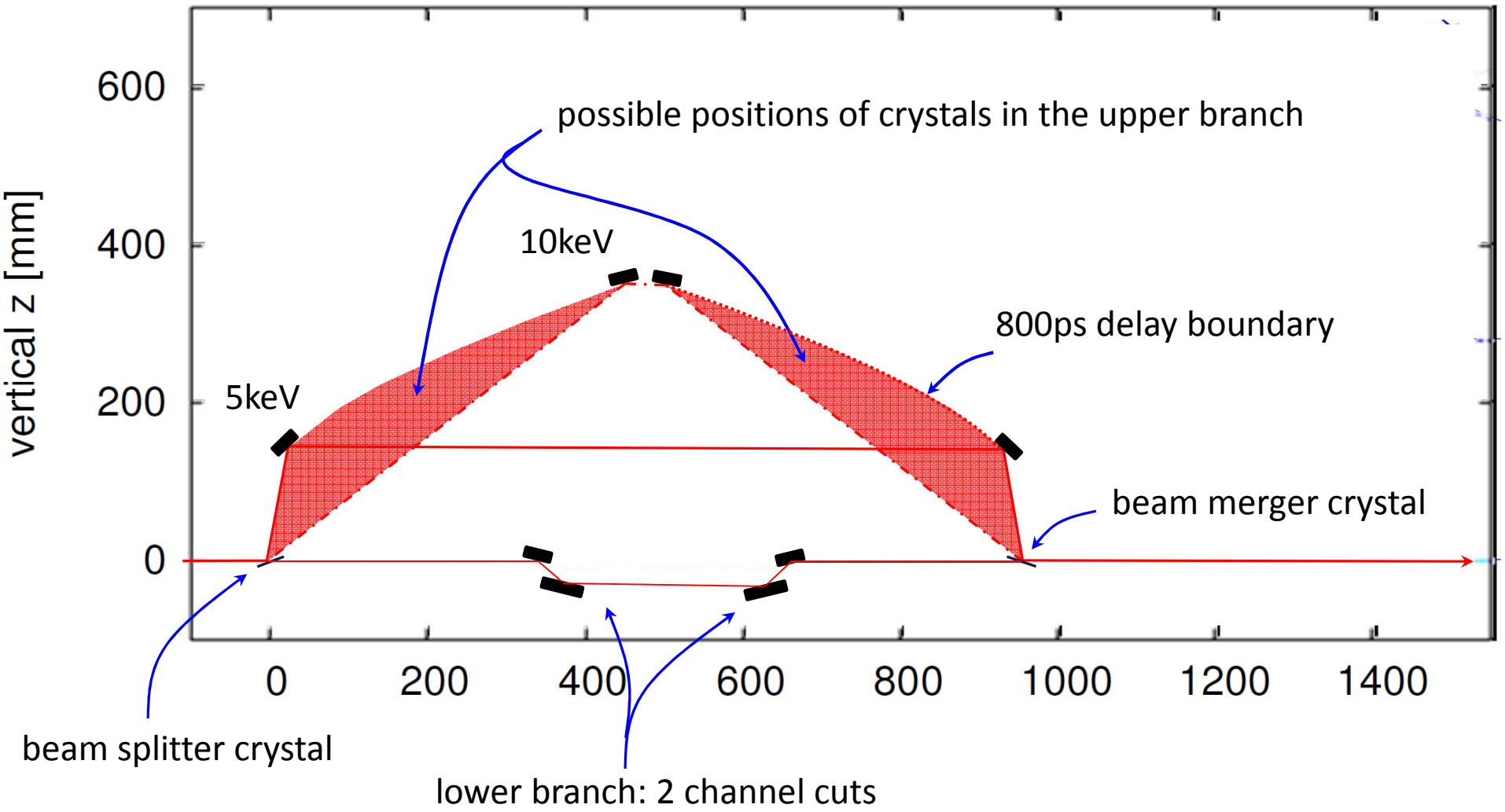
Needed detour to achieve 800 ps delay in the upper branch:



depends on energy and reflection (Bragg angle)

$$\Delta t = \Delta s / c$$

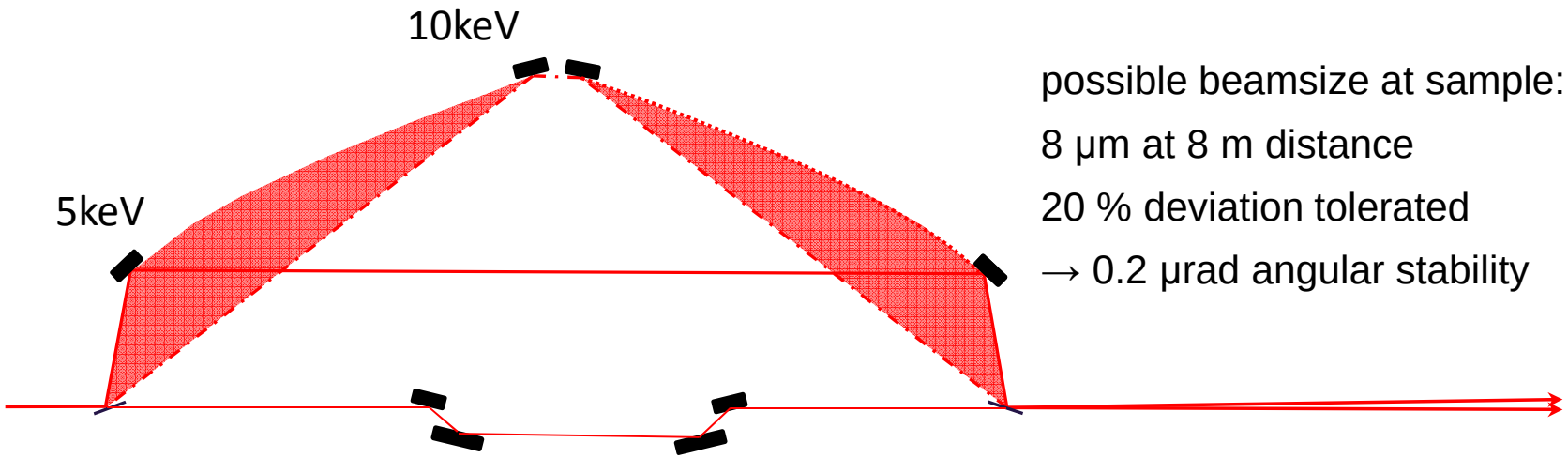
Upper branch, Si(220)



SDL mechanics tolerances

1 µm takes 3.3 fs

→ 0.5 - 1 µm translational stability



possible beamsize at sample:

8 µm at 8 m distance

20 % deviation tolerated

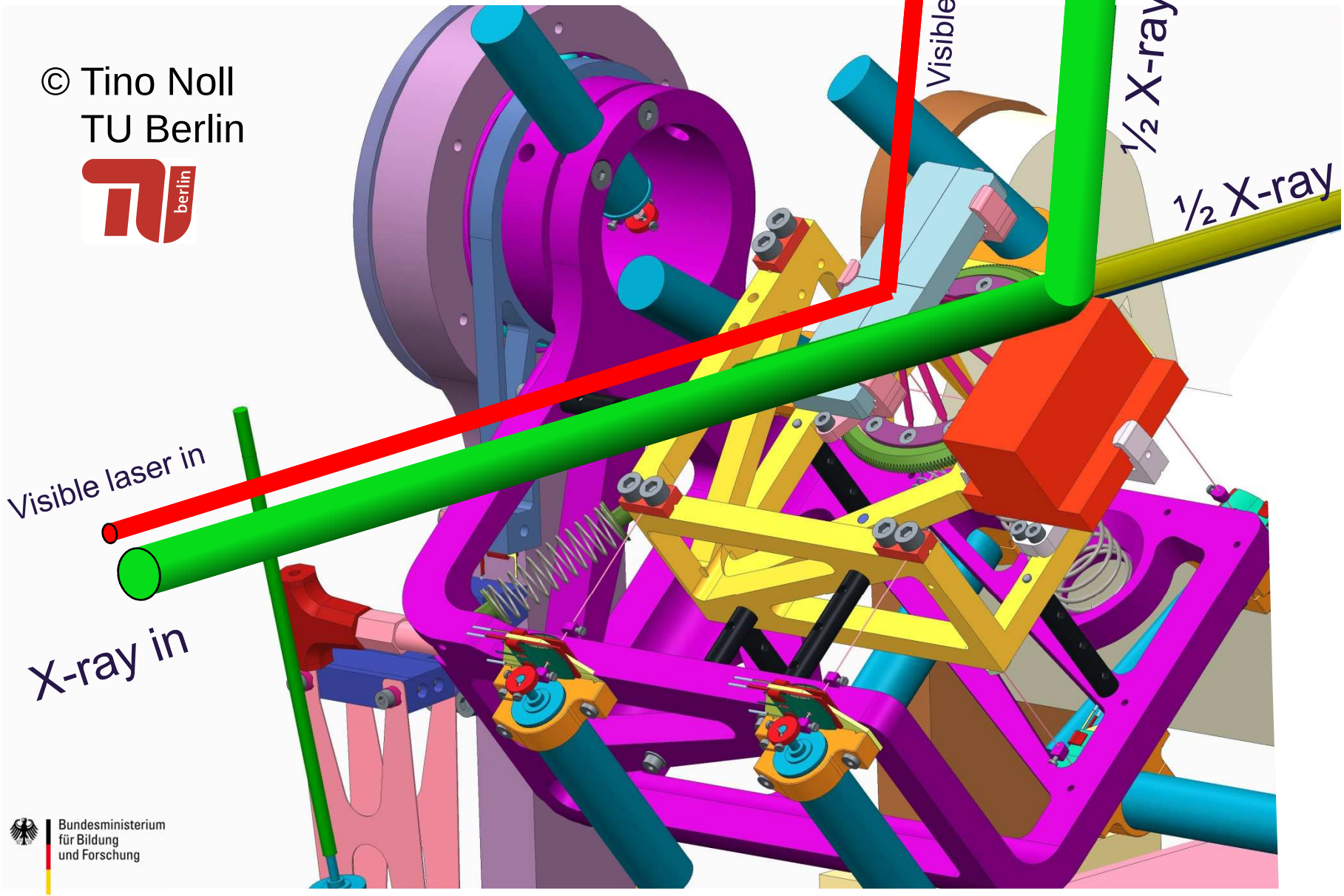
→ 0.2 µrad angular stability

BMBF funding

TU Berlin (S. Eisebitt, T. Noll, W. Lu) and MID work on it

European XFEL

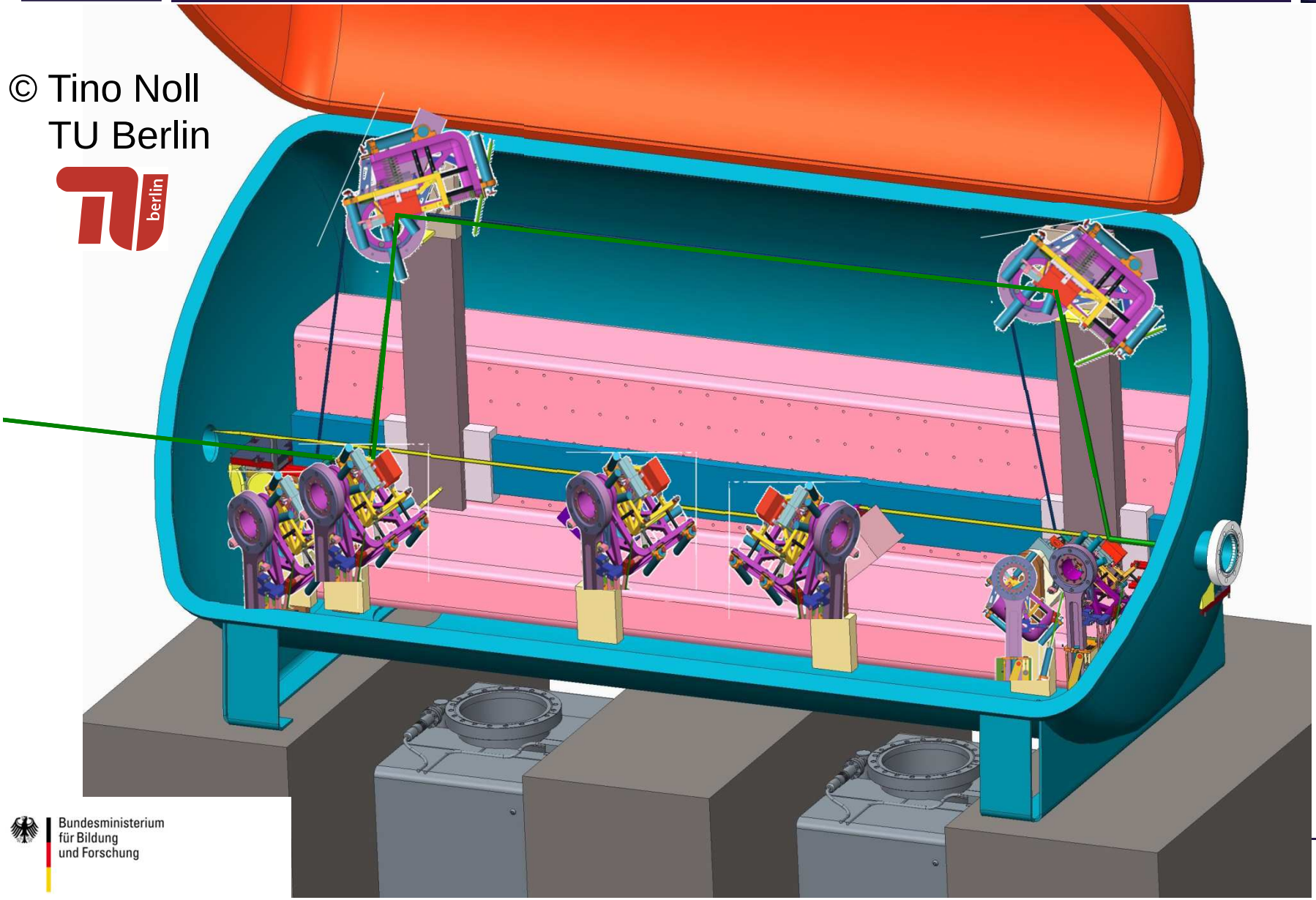
SDL model



Bundesministerium
für Bildung
und Forschung

European XFEL

SDL model



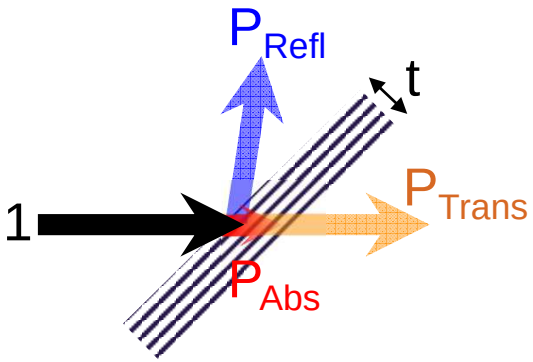
Bundesministerium
für Bildung
und Forschung

Intensity splitting of an X-ray beam

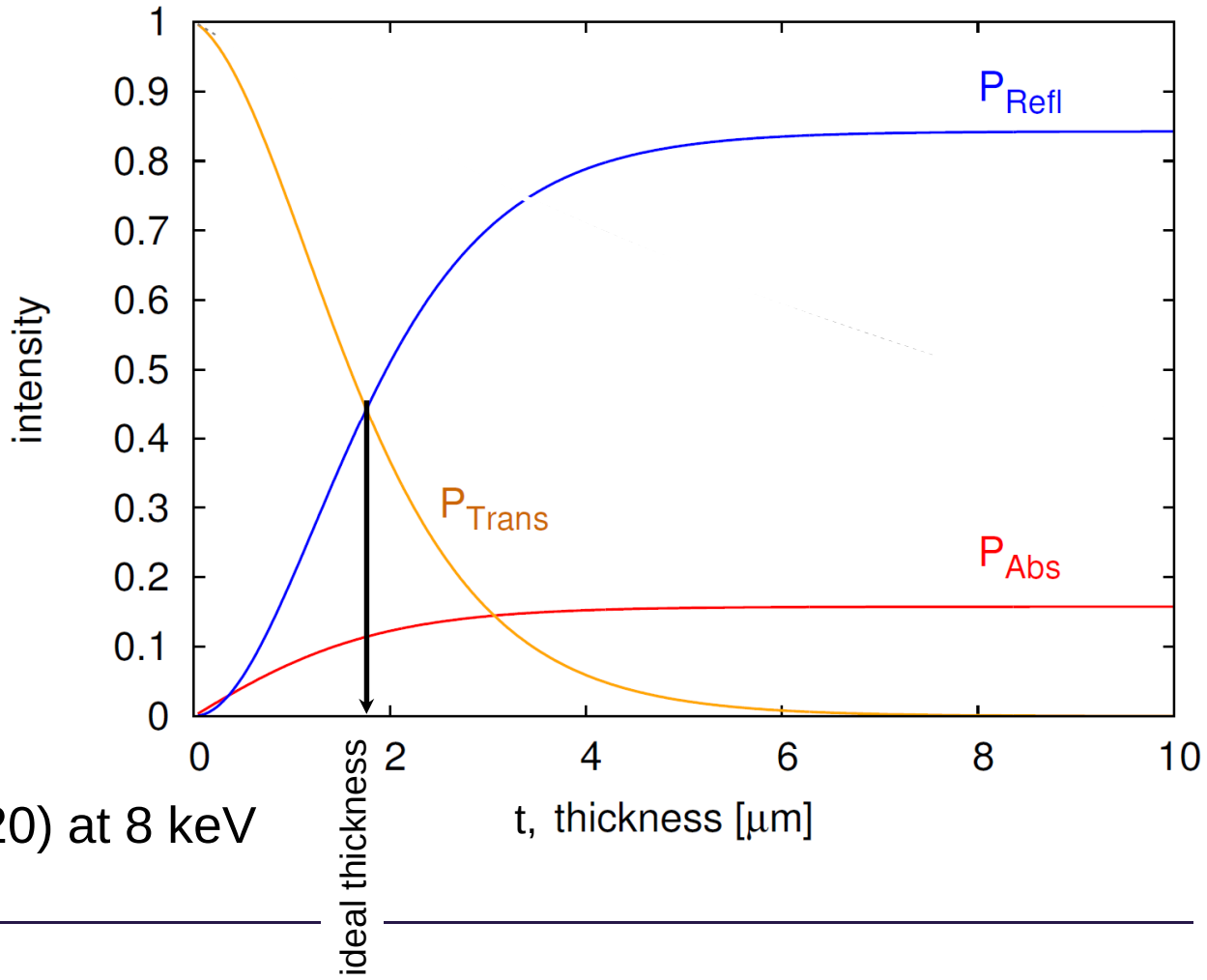
different beams at a Bragg beam splitter

Bartels, *J. Vac. Sci. Technol. B,* **1** (1983) p. 338

Bartels et al., *Acta Cryst. A,* **42** (1986) p. 539



on Bragg condition



Si(220) at 8 keV

Beam splitter fabrication

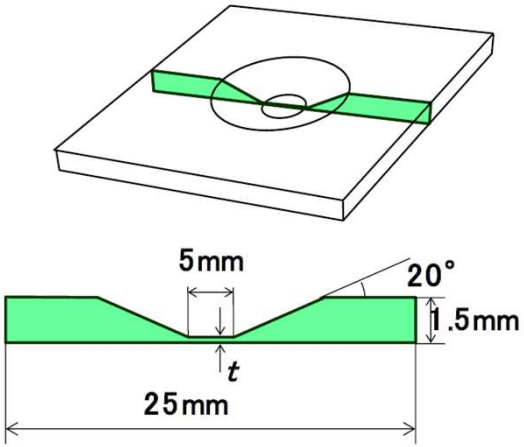
Optics Express **21** (2013) p.2823

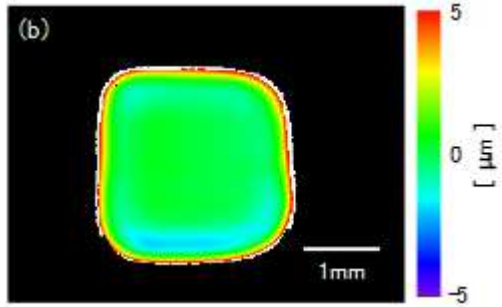
A Bragg beam splitter for hard x-ray free-electron lasers

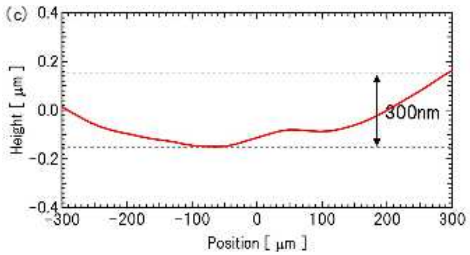
Taito Osaka,[1,*] Makina Yabashi,[2] Yasuhisa Sano,[1] Kensuke Tono,[3] Yuichi Inubushi,[2] Takahiro Sato,[2] Satoshi Matsuyama,[1] Tetsuya Ishikawa,[2] and Kazuto Yamauchi[1]

[1]Department of Precision Science and Technology, Graduate School of Engineering, Osaka University, 2-1Yamada-oka, Suita, Osaka 565-0871, Japan
[2]RIKEN SPring-8 Center, 1-1-1 Kouto, Sayo-cho, Sayo-gun, Hyogo 679-5148, Japan
[3]Japan Synchrotron Radiation Research Institute (JASRI), 1-1-1 Kouto, Sayo-cho, Sayo-gun, Hyogo 679-5198, Japan
[*]osaka@up.prec.eng.osaka-u.ac.jp

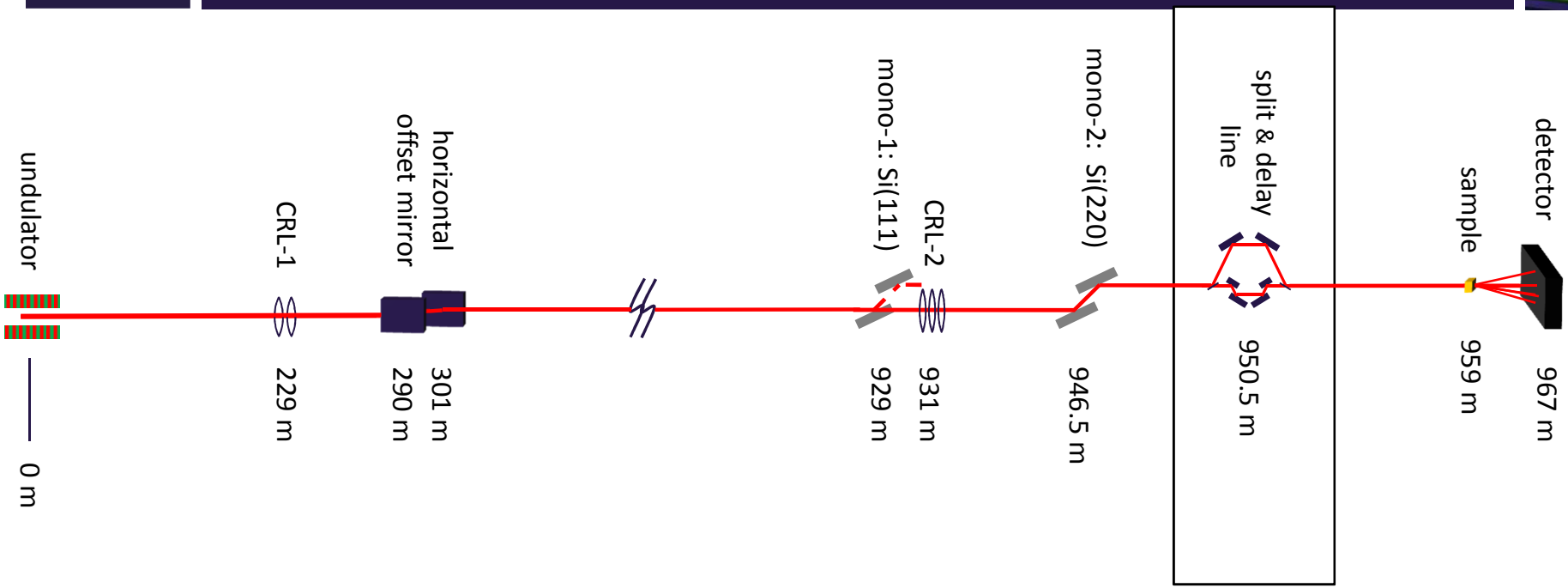
thickness down
to 4.4µm
Si(110)







MID beamline overview

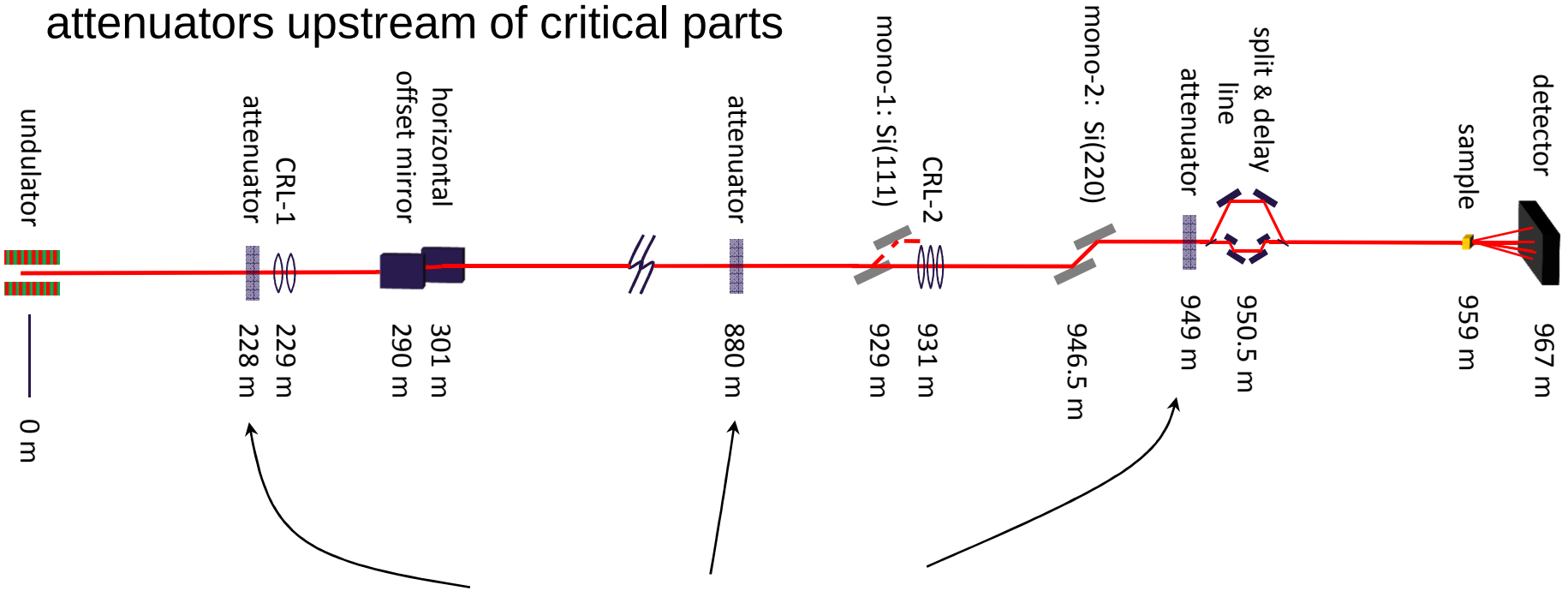


Outline

- SASE 2 beam parameters
- Focusing with CRLs and beamsizes
- Monochromators
- Split and Delay Line
- more X-ray optics
- MID Hutches Overview

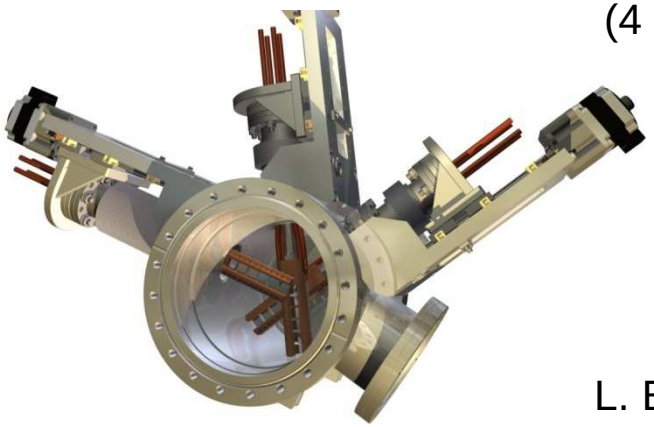
more MID beamline instrumentation

attenuators upstream of critical parts



attenuation by up to many orders of magnitude

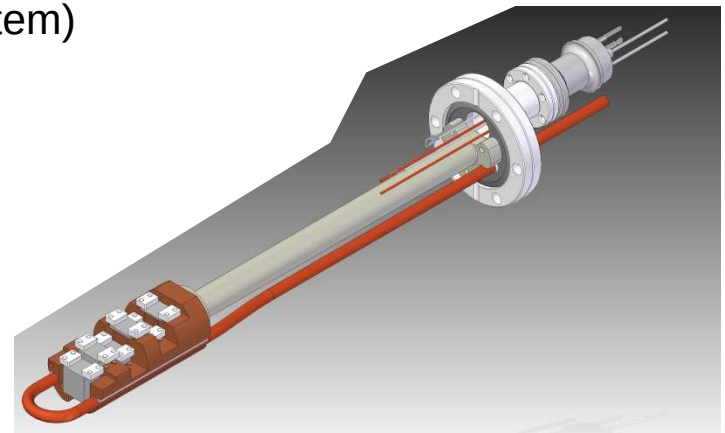
(4 orders at 25 keV by one system)



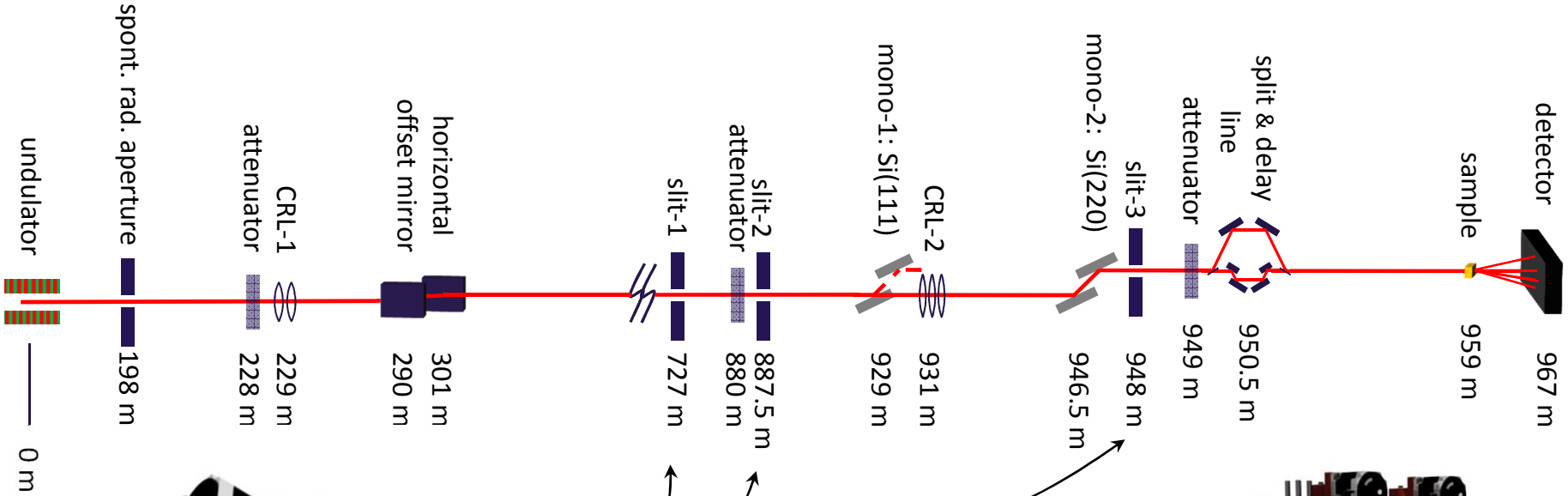
15 attenuators on 4 arms
water-cooled foils

B_4C, Si and diamond

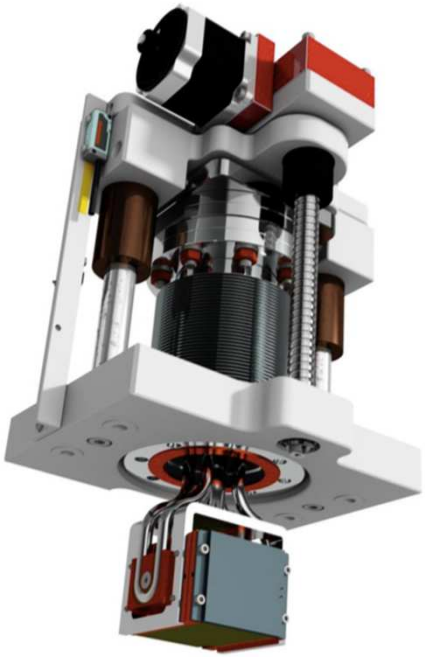
L. Batchelor & JJ X-RAY

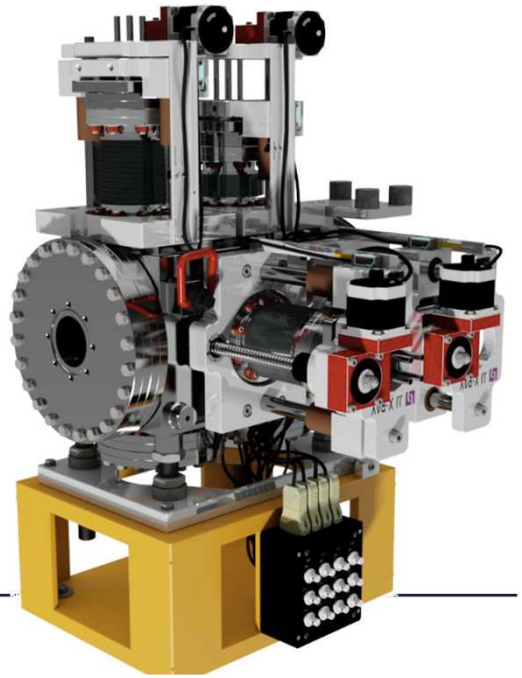


more MID beamline instrumentation

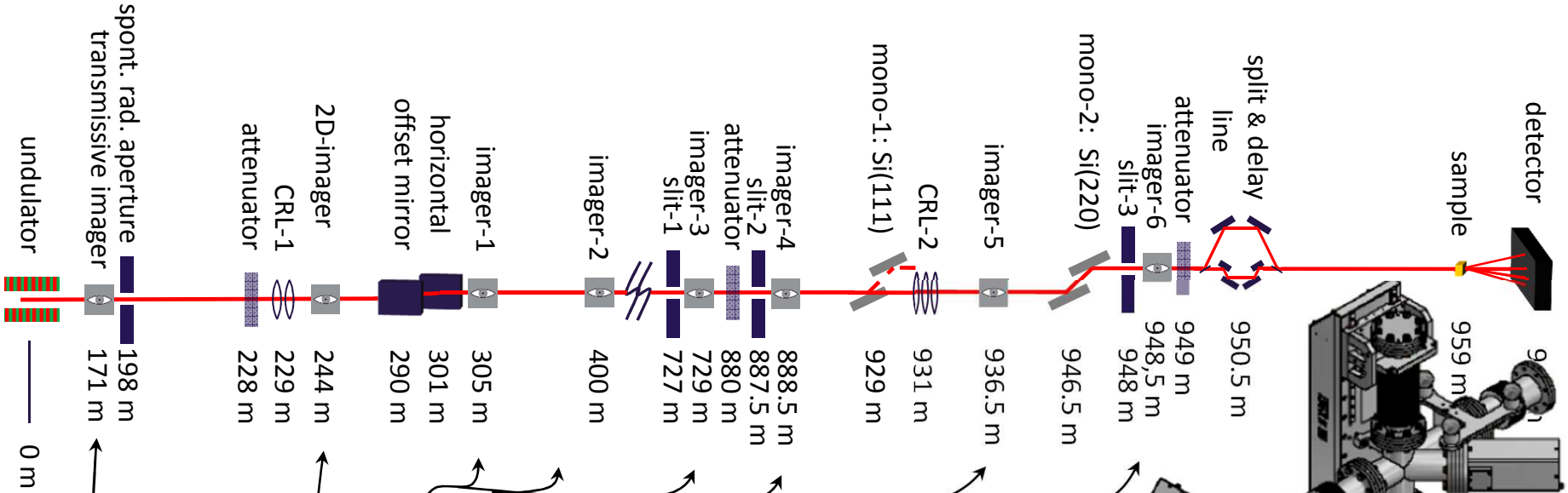


slits to clean the beam





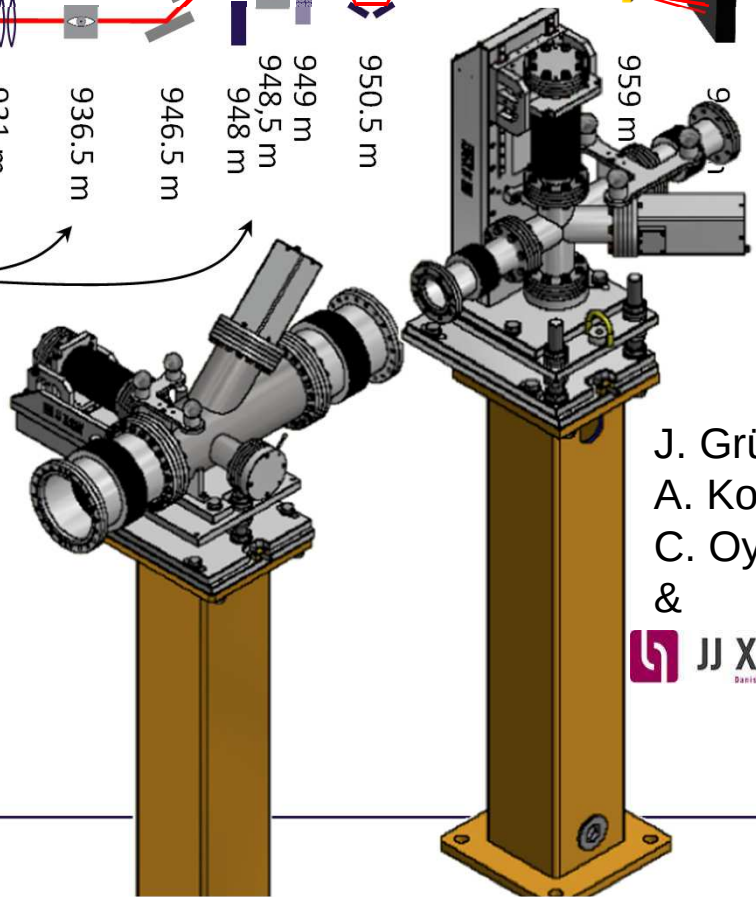
more MID beamline overview



pop-in monitors for SASE radiation

pop-in monitor for SR and SASE radiation, „transmissive“ for pointing info with 2D-imager

sensitive pop-in monitor for SR and SASE radiation, high resolution

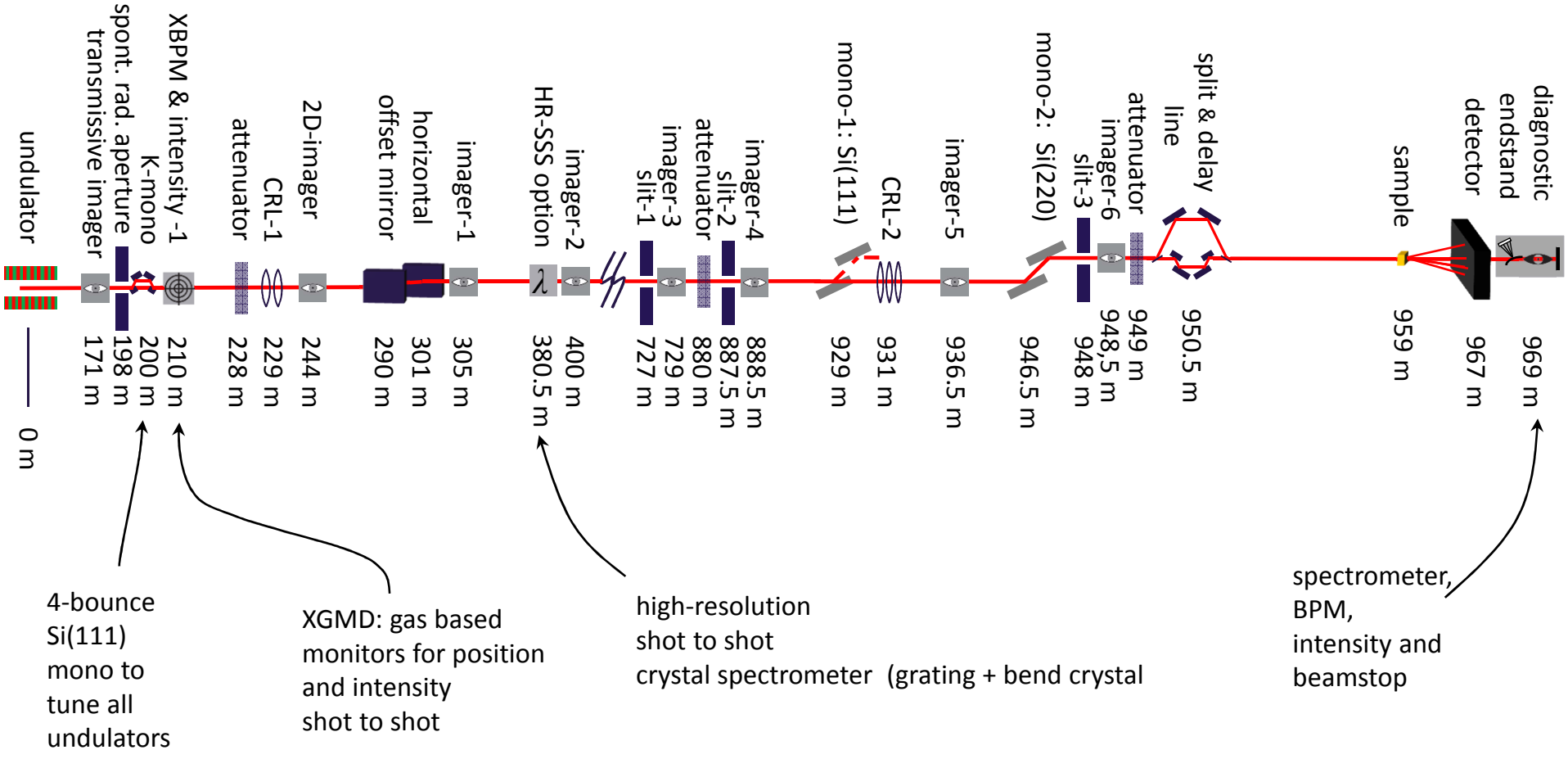


J. Grünert
A. Koch,
C. Oykan
&
JJ X-RAY

X-ray diagnostics:

Imagers

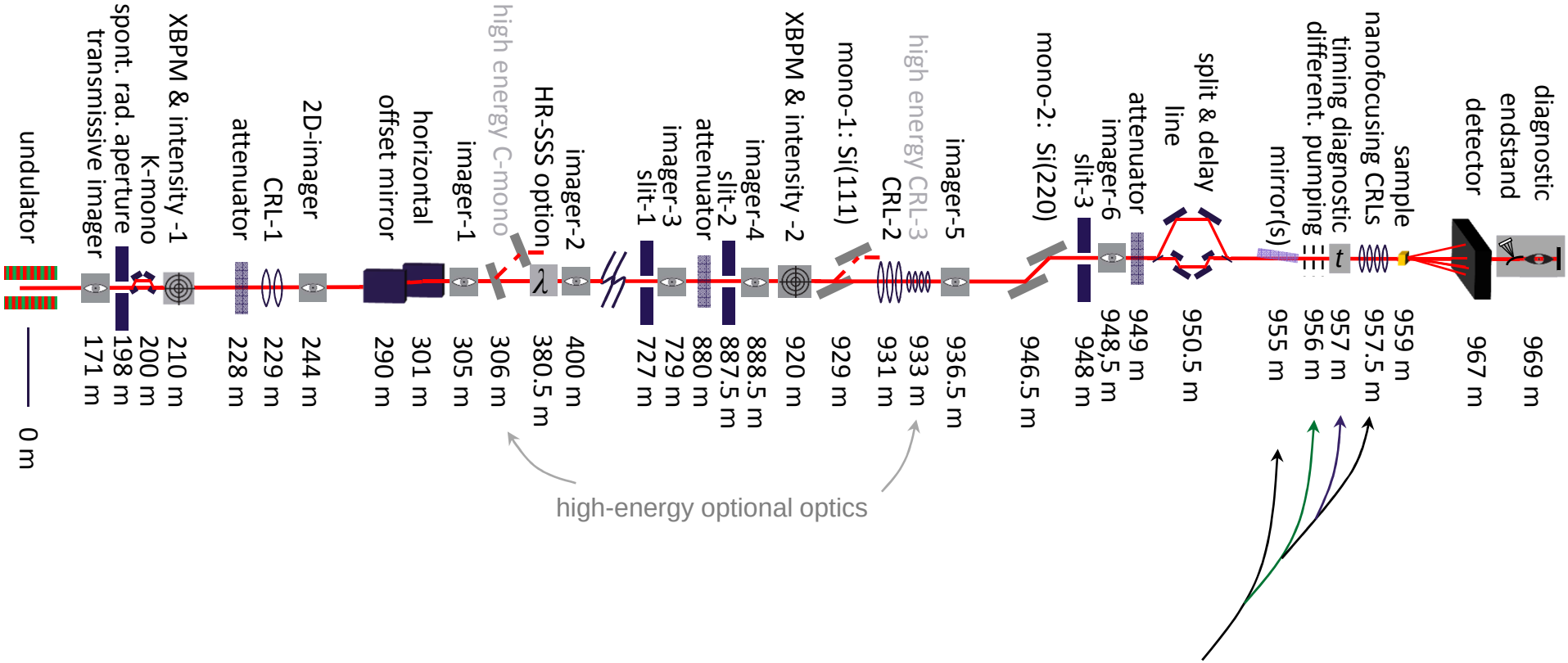
MID beamline overview



more X-ray diagnostics

J. Grünert *et al.* (X-ray diagnostic group)

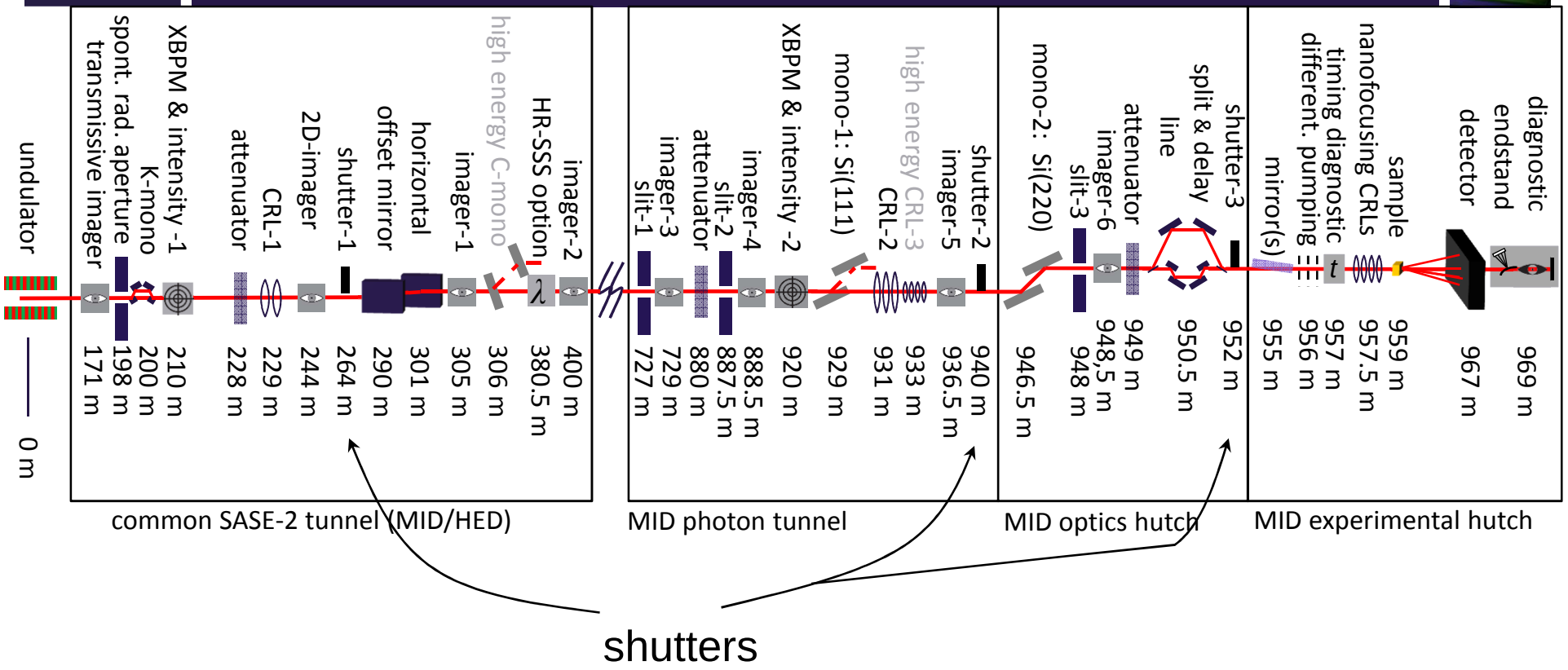
MID beamline overview



additional optical elements in experimental hutch,

timing diagnostics and differential pumping section

MID beamline overview

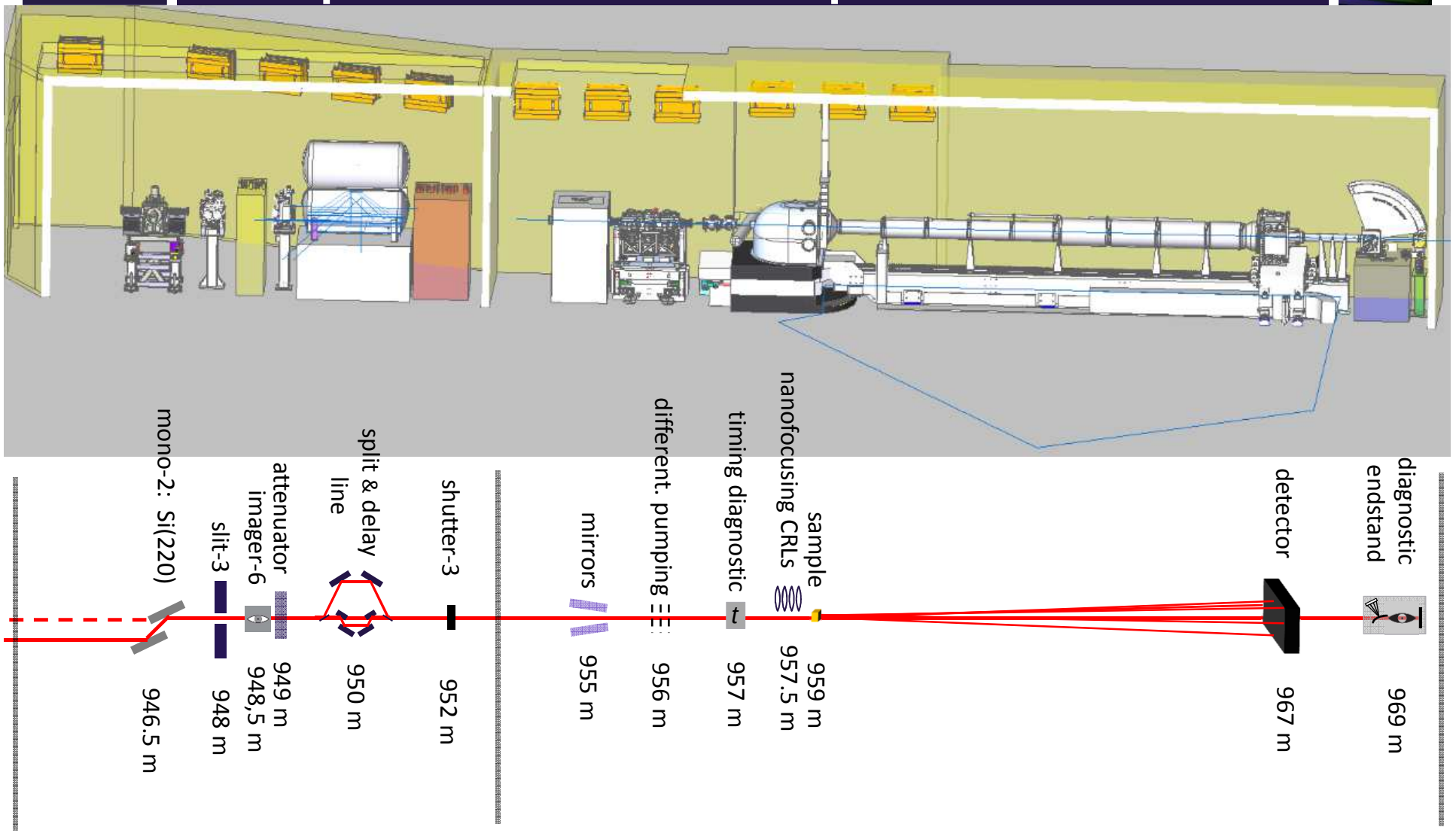


Outline

- SASE 2 beam parameters
- Focusing with CRLs and beamsizes
- Monochromators
- Split and Delay Line
- more X-ray optics
- MID Hutches Overview

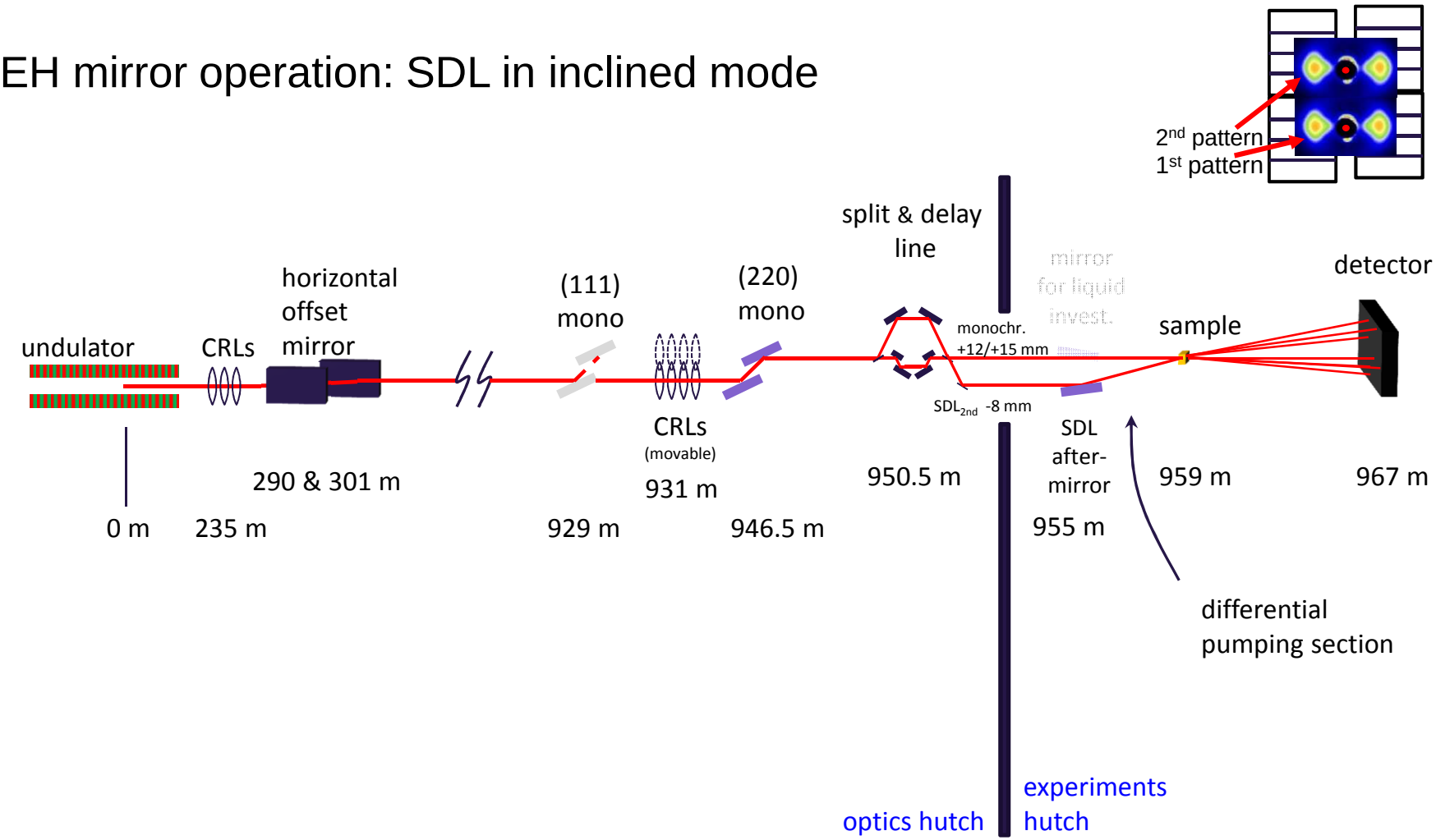
European XFEL

MID optics hutch OH and experimental hutch EH



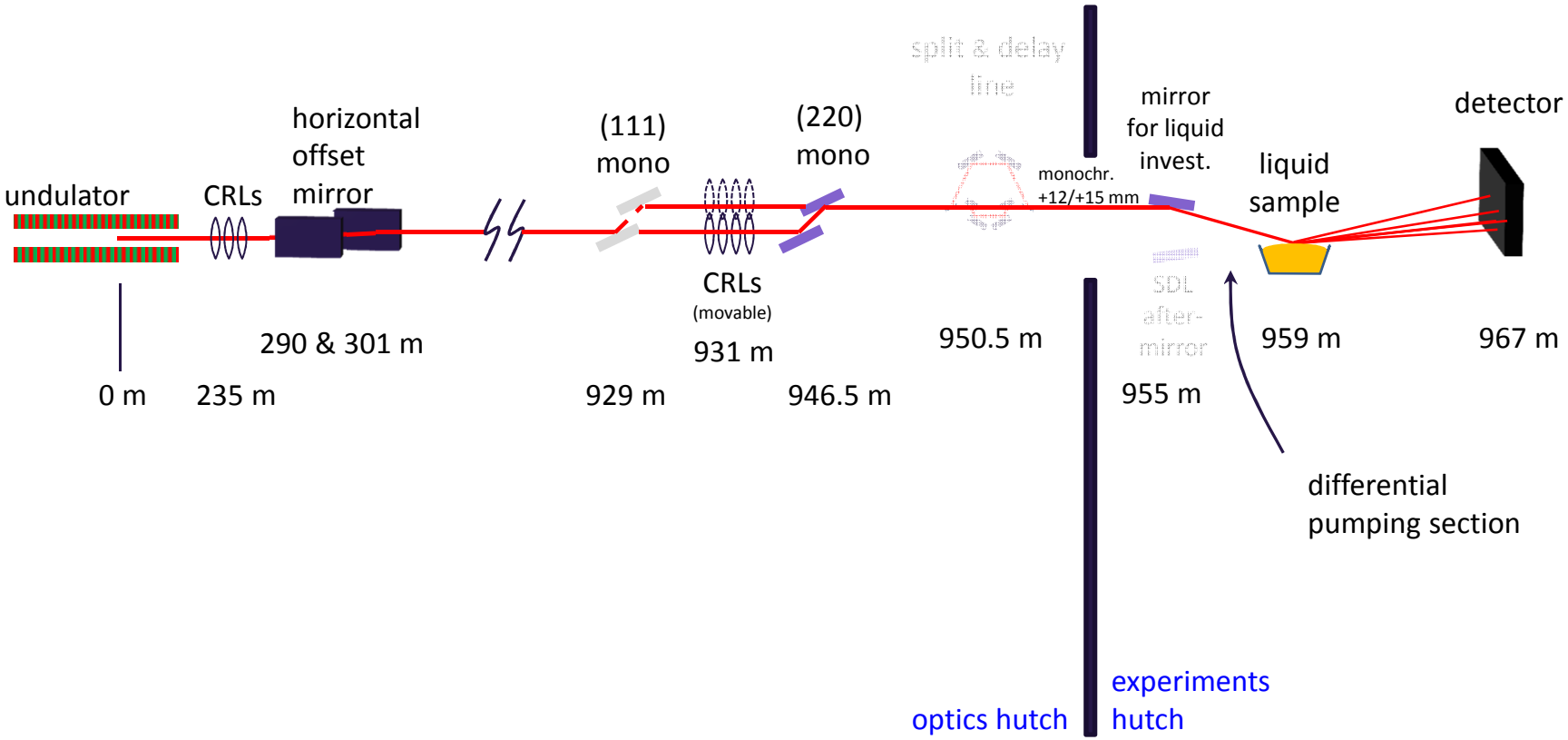
EH mirror

EH mirror operation: SDL in inclined mode

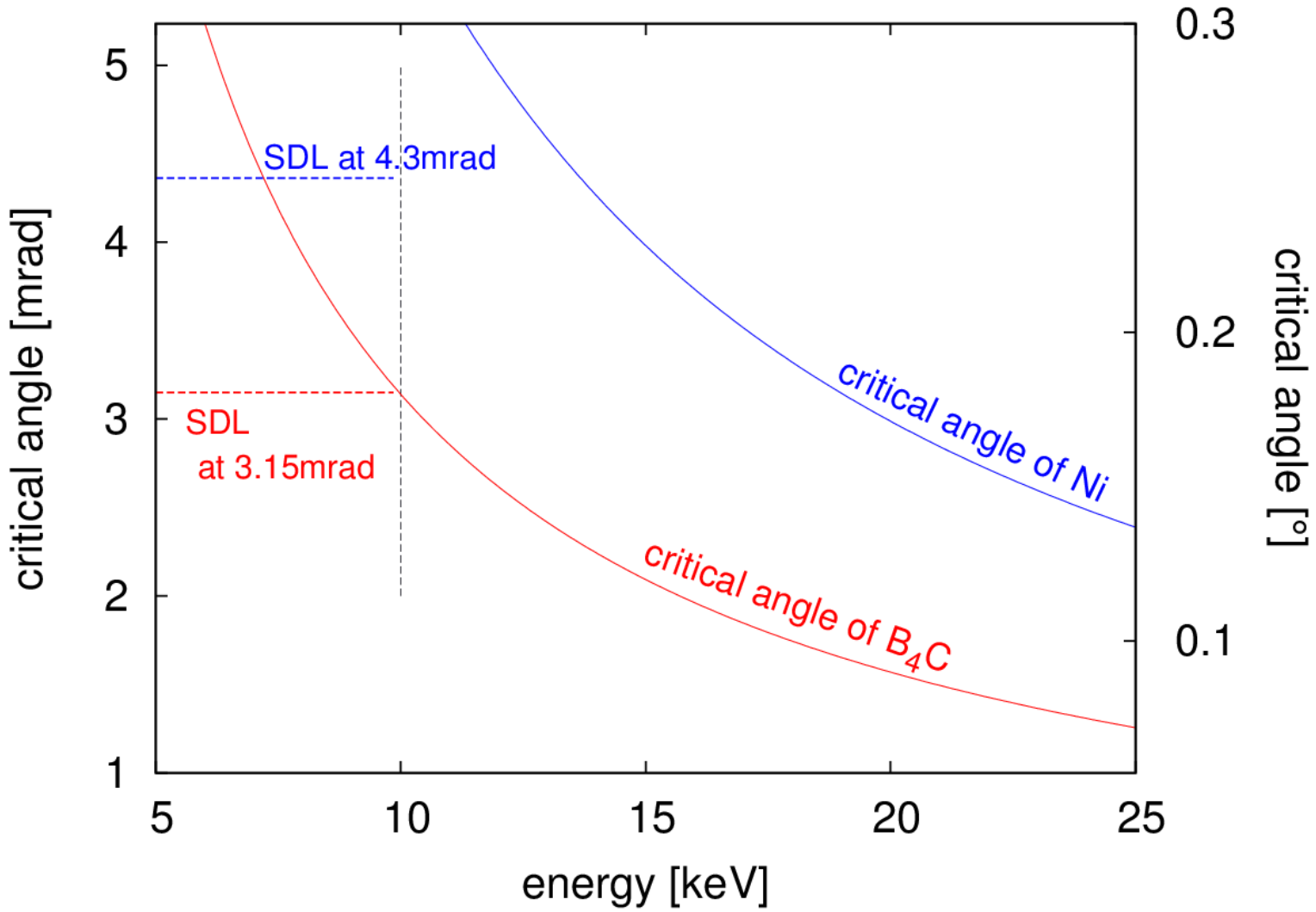


EH mirror

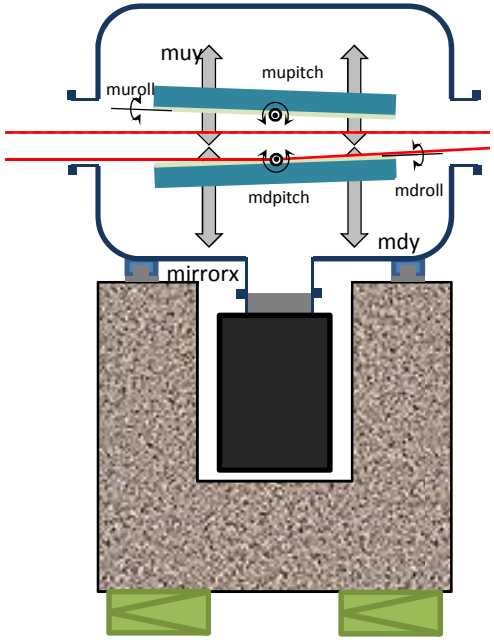
EH mirror operation: liquid surfaces



EH mirror

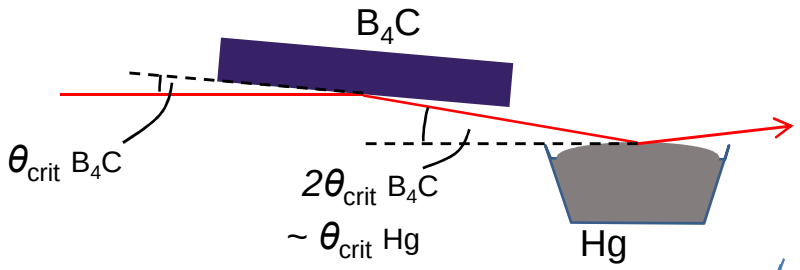

critical angle [mrad]
critical angle [°]
energy [keV]
SDL at 4.3mrad
SDL
at 3.15mrad
critical angle of Ni
critical angle of B4C
1
2
3
4
5
0.1
0.2
0.3
5
10
15
20
25

EH mirror



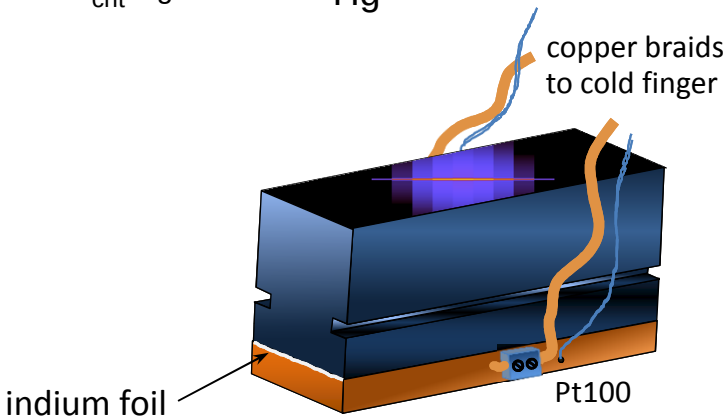
- 1 chamber, 1 m long
- 2 mirrors:
  1 facing up, 1 facing down
- 500 mm substrate length
- B_4C and one higher-Z coating (Ni ?)

  (B_4C coating is already sufficient to reach the critical angle of mercury at sample)



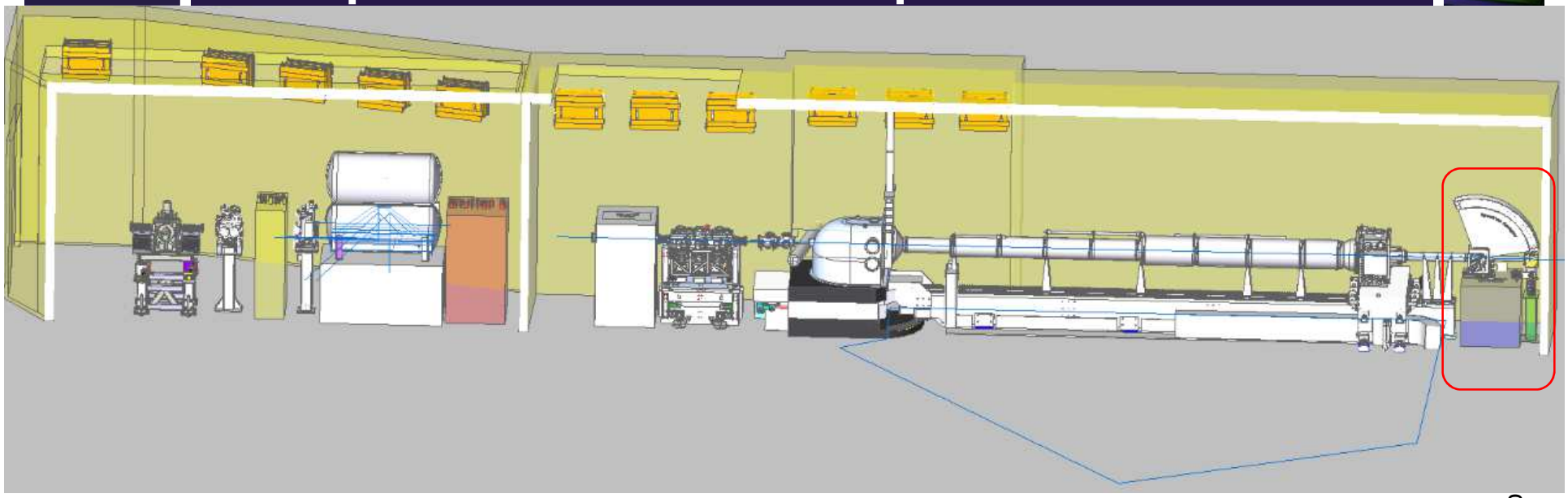
- 0.25 µrad slope error

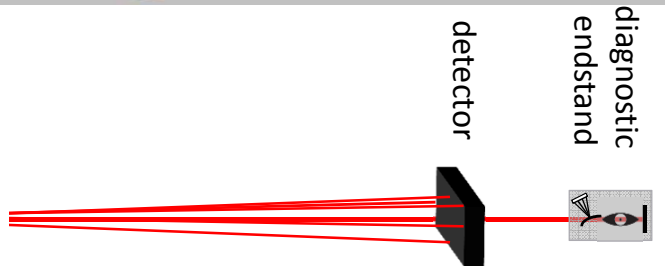
- cooling option at a later stage



European XFEL

MID optics hutch OH and experimental hutch EH





diagnostic endstand:

- single shot spectrometer (bent crystals and Gotthard detector) B. Kist
- beam position monitor
- intensity measurement and beamdump V. Lyamayev

Summary

- 5-25 keV
- pink, Si(111), Si(220)
- 220 ns spacing, or 0-800 ps (SDL)
- 2-1000 µm spot size at sample
- straight and down-deflected (liquids) beams
- up to ~ $1 \cdot 10^{13}$ photons/pulse
- bandwidth $\frac{\Delta E}{E} \sim 1 \cdot 10^{-4}$ in self-seeding (expected)
- ~ 2 - 107 fs pulses
- attenuators, slits, diagnostic

European XFEL

End

Thank you.

Acknowledgements:

A. Madsen, J. Hallmann, G. Ansaldi, W. Lu, B. Kist (European XFEL, MID)

X. Dong, D. La Civita, V. Lyamayev, I. Agapov, G. Geloni, L.Batchelor, J. Grünert, A. Koch, H. Sinn (European XFEL)

T. Noll (TU Berlin)

V. Kocharyan, E. Saldin, E. Schneidmiller, M. Yurkov (DESY)