First experiments and commissioning of the MID instrument (SASE-2)

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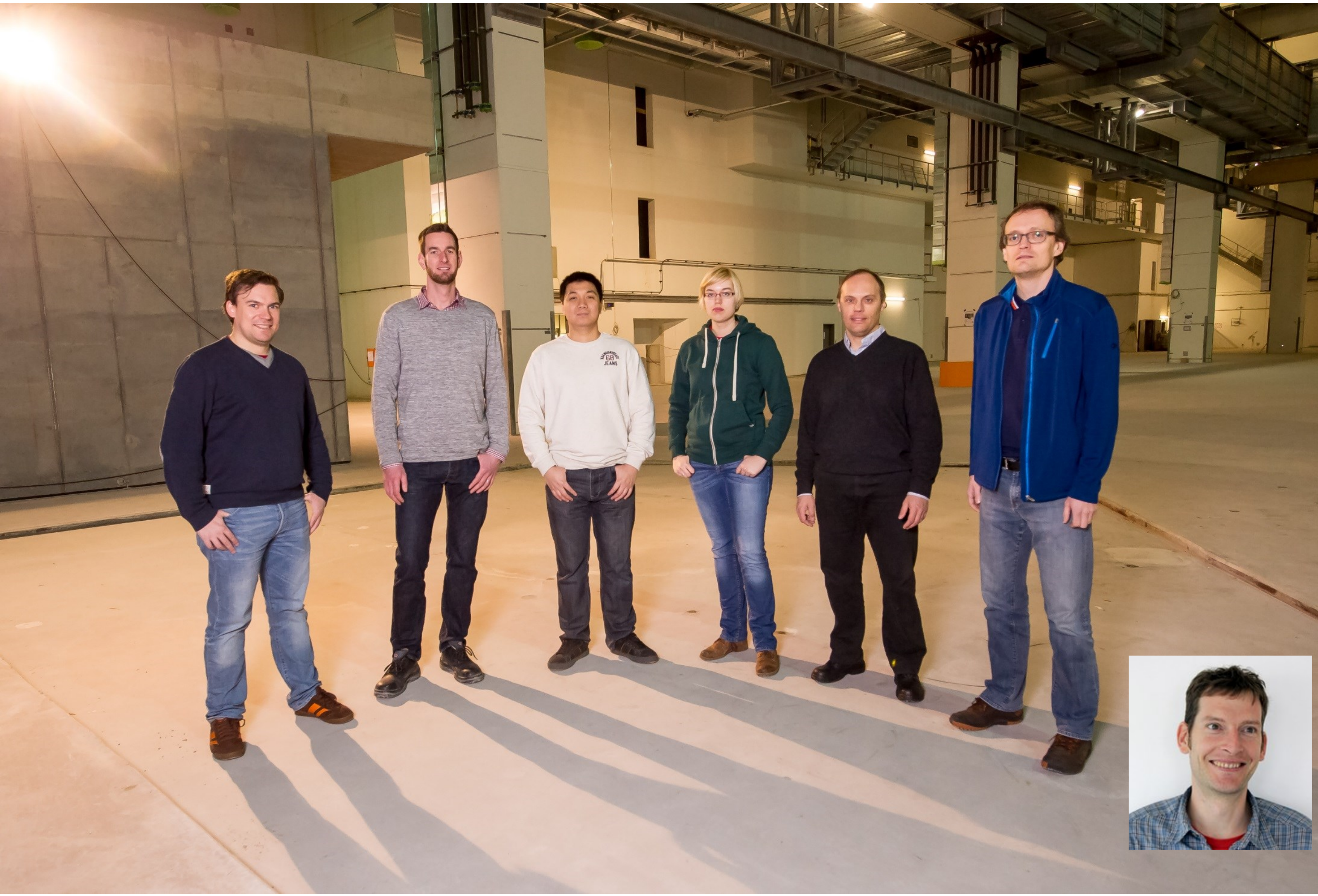
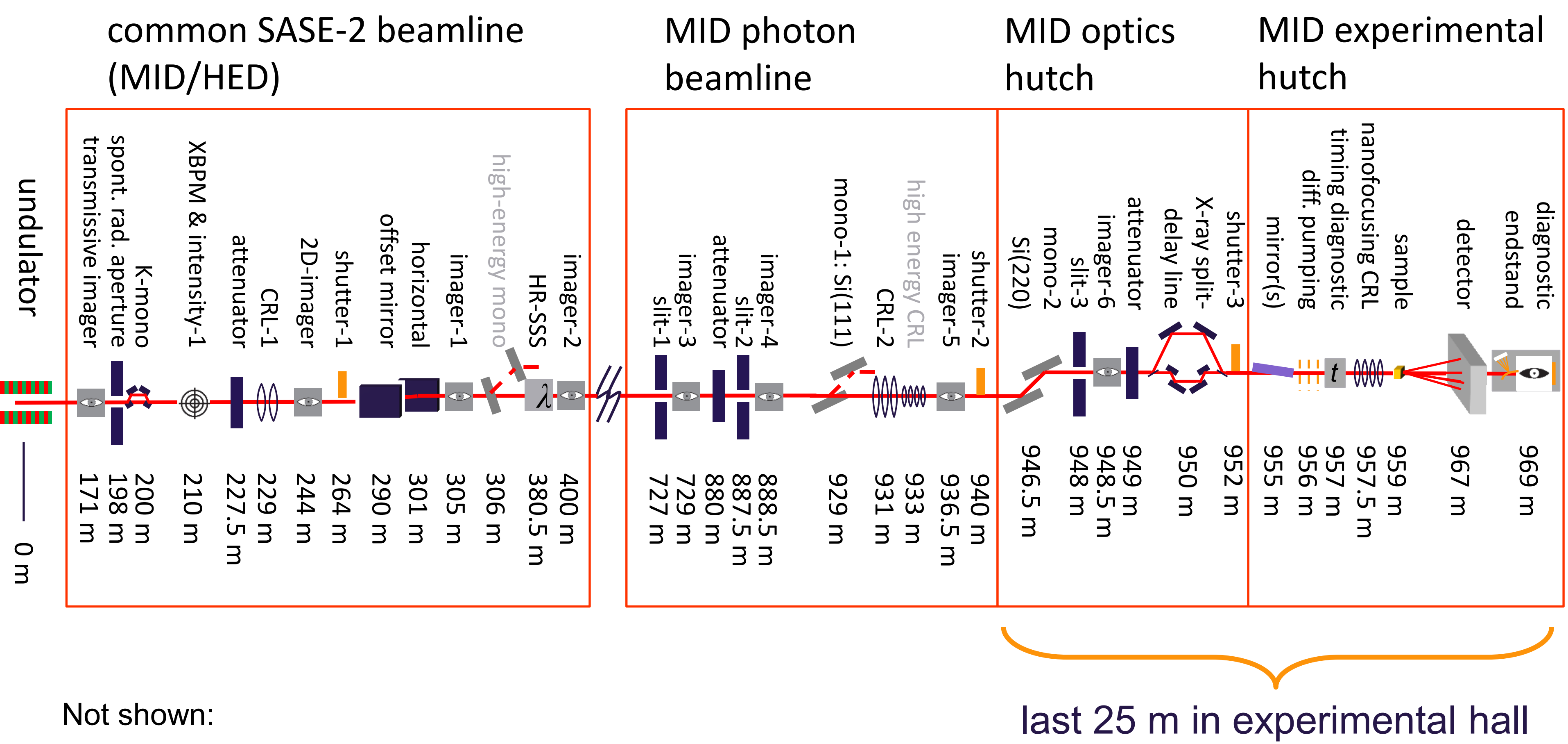


MID beamline overview



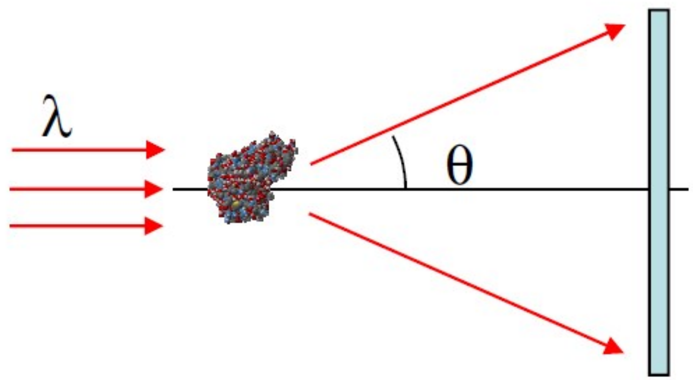
Not shown:

- MCP at 303m (fine tuning of SASE)
- Distribution mirror(s) at 390m and 395m (MID on central branch)
- Beam loss monitors, PES

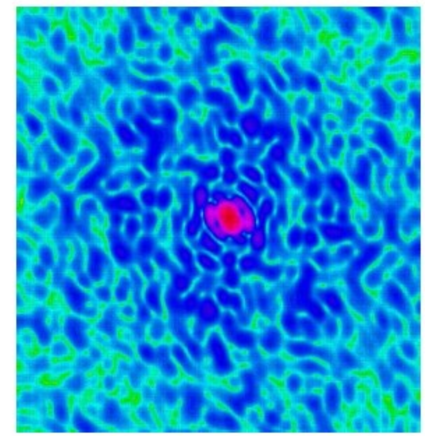
Coherent scattering and speckle

Isolated object

Diffraction microscopy:
Phase retrieval required
but no limiting optics

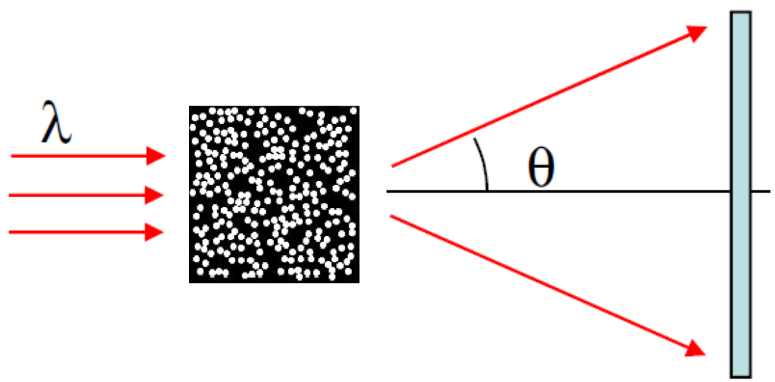


Static speckle

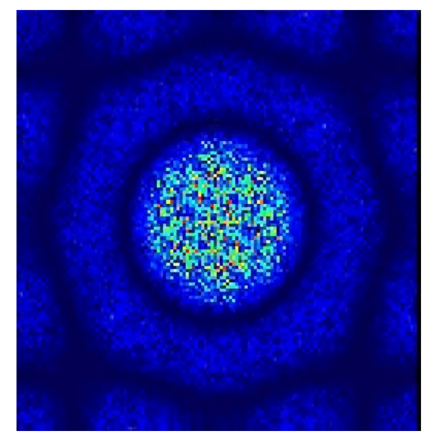


Ensemble of objects

Correlation spectroscopy:
Temporal: XPCS
Spatial: XCCA

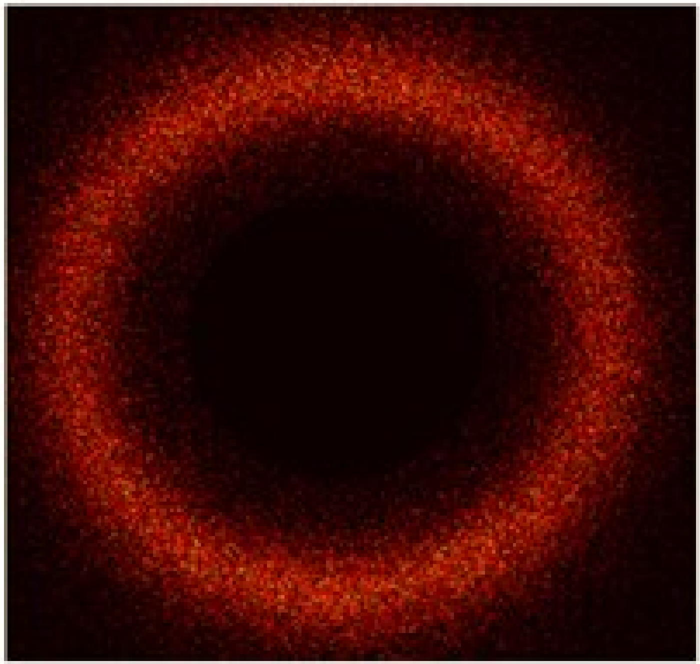


Dynamic speckle



Possible 1st experiment

High-Q coherent scattering from a glass former



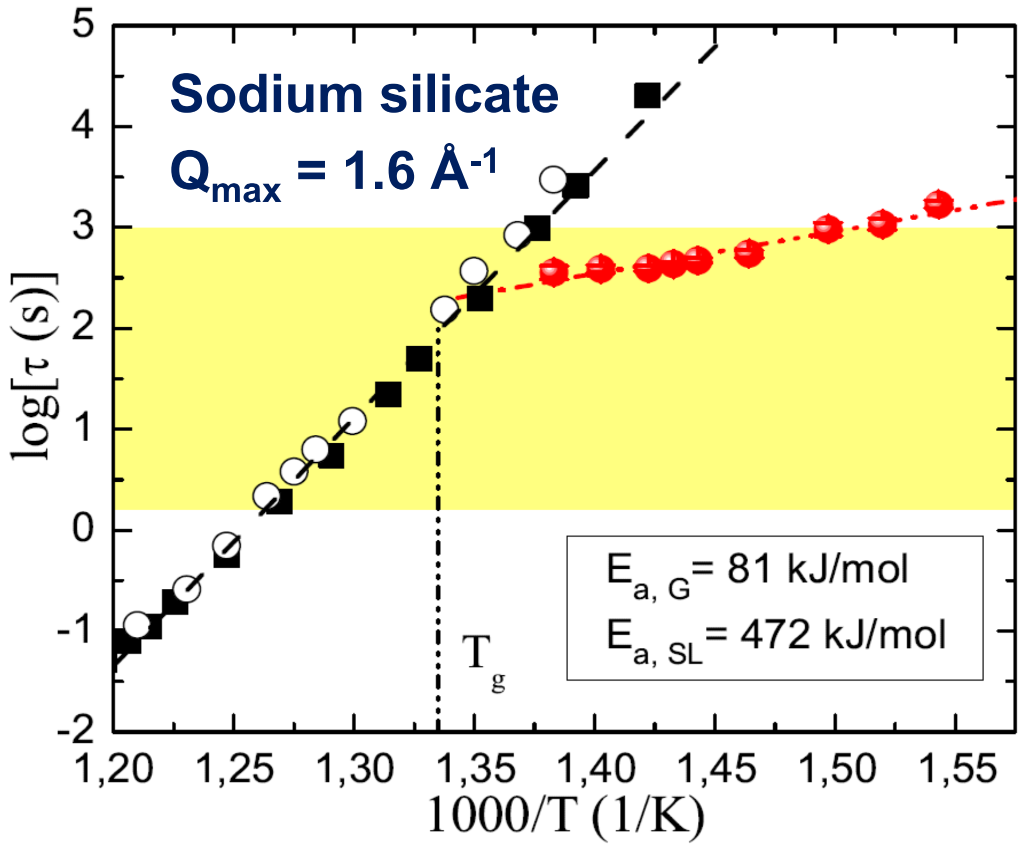
Vitreous
GeO_2

1st peak in S(Q)
at 15.5 nm^{-1}

Application: Study of structural dynamics in the supercooled liquid state
Techniques: X-ray Photon Correlation Spectroscopy (XPCS),
Time-resolved X-ray Cross Correlation Analysis (XCCA)

Possible 1st experiment

The deepest and most interesting unsolved problem in solid state theory is probably the nature of glass and the glass transition”, Philip W. Anderson: "Viewpoint: The Future," Science, vol. 267, pp. 1615-1616 (1995)



1) What causes the dramatic increase of viscosity (~13 orders of magnitude) over 2 orders of magnitude in T, without any apparent change of structure?

2) Why is the structural dynamics only tracking the viscosity in a certain range of temperatures (or timescales)?

3) Can we understand the length-scale (Q) dependence of 2)

Assumed parameters for first experiment

Electron energy	17.5 GeV
Photon energy	8.4 keV
Repetition rate	100 kHz (10 μs)
Max. number pulses per train	60
Undulator K-value	3.9
Undulator Gap	10 mm
Pulse energy	2 mJ (slightly oversaturated)
Divergence	2.2 urad
Pulse duration	43 fs
Saturation length	58 m

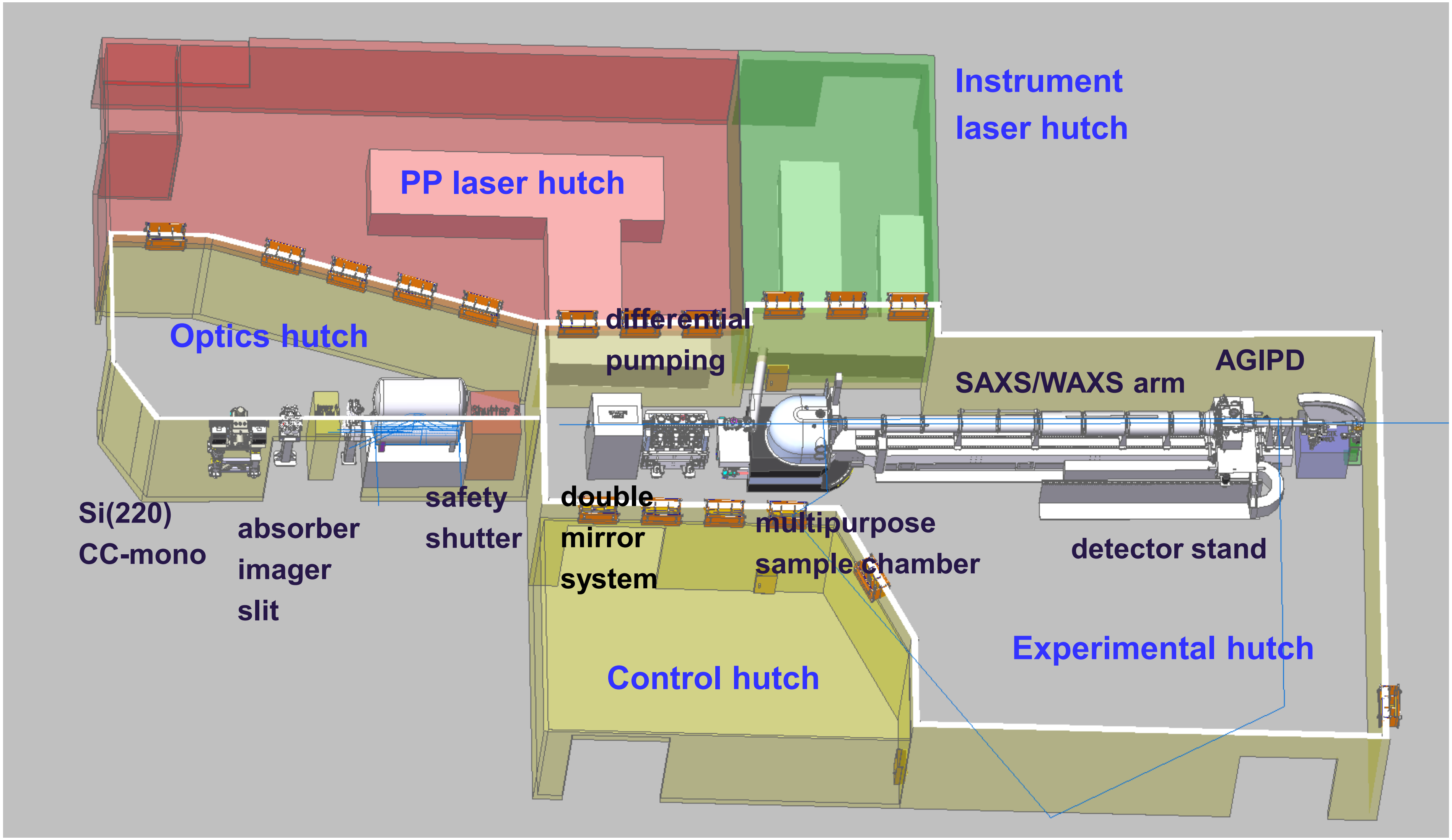
1 mJ ~ 1e12 ph @ 7 keV

Courtesy of H. Sinn

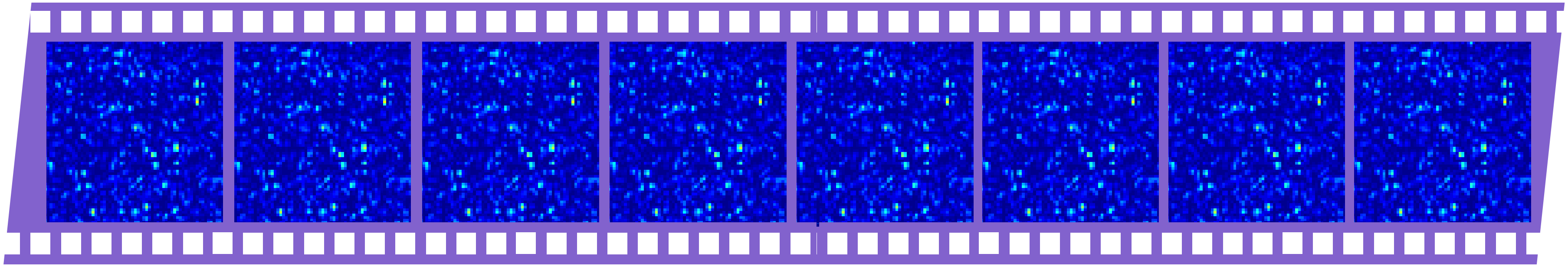
For the GeO_2 glass experiment we need

- 10^{10} or more photons per pulse
- 1e-4 bandwidth or less (SASE is only ~1e-3 so mono and/or seeding is needed)
- As high repetition rate as possible (100 kHz is fine to start with but…)
- As many pulses/train as possible (AGIPD detector can store ~350 images/train)
- A focused beam, ~10 x 10 micron (refractive lens system)
- A furnace (up to 1200 K)
- A good photon detection system, 2θ up to 25° (AGIPD and SAXS/WAXS arm…)
- Slits, attenuators, diagnostics
- …

MID Experimental area @ SASE-2



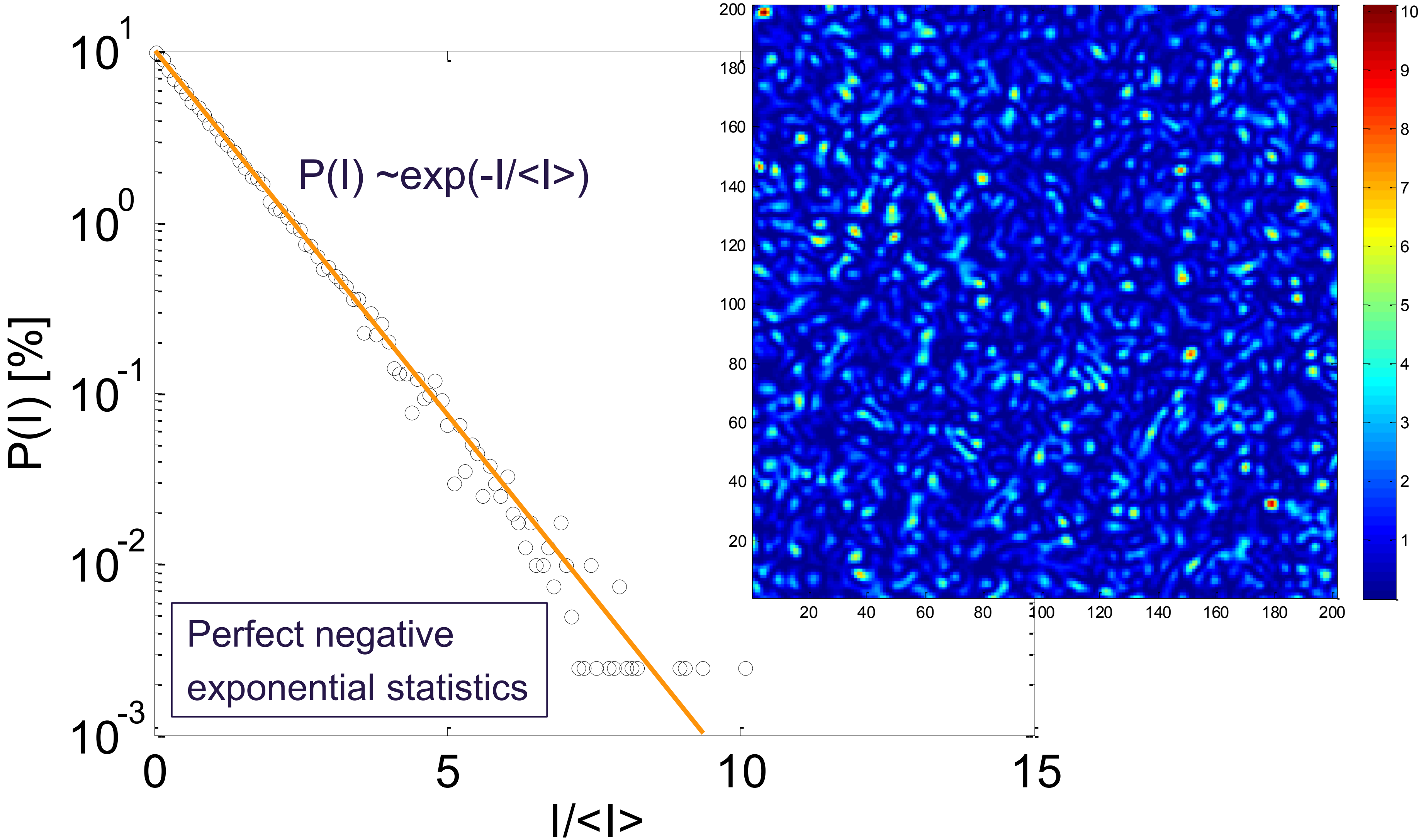
Detector task



#1 #2 #3 #4 #5

- Recording movies of weak speckle patterns
- Average count rate: 1 ph/pixel/image, or less
- Up to 4.5 MHz and as many images per train as possible
- E range: 5 - 25 keV, typically 7-15 keV
- SNR $\propto$ 1/(pixel area), smaller pixels are better
- SNR $\propto$ number of pixels
- Important that image sequence (#1, #2, #3,…) is maintained
- Minimize image distortions.…

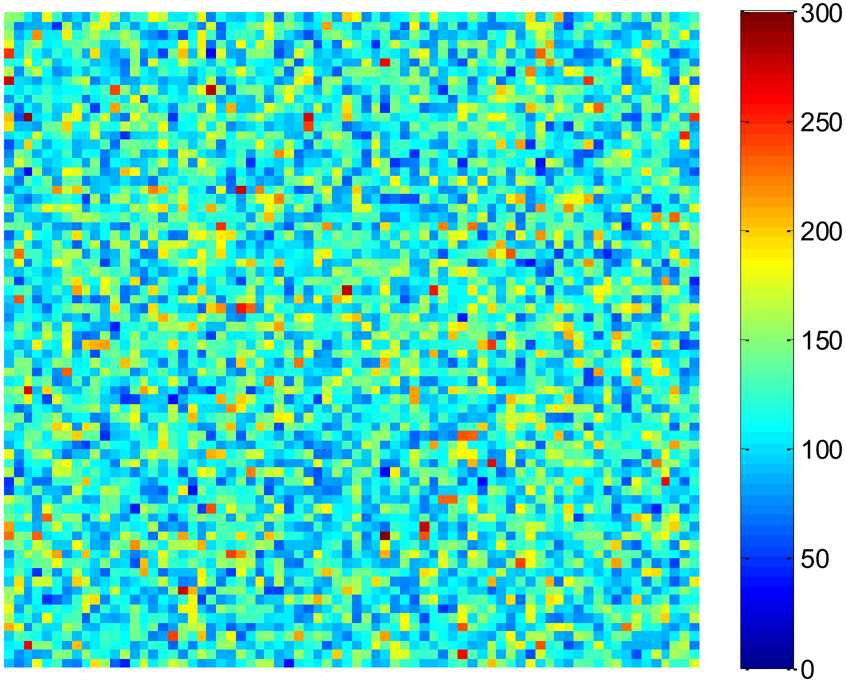
100% contrast speckle pattern, mean Int = 1



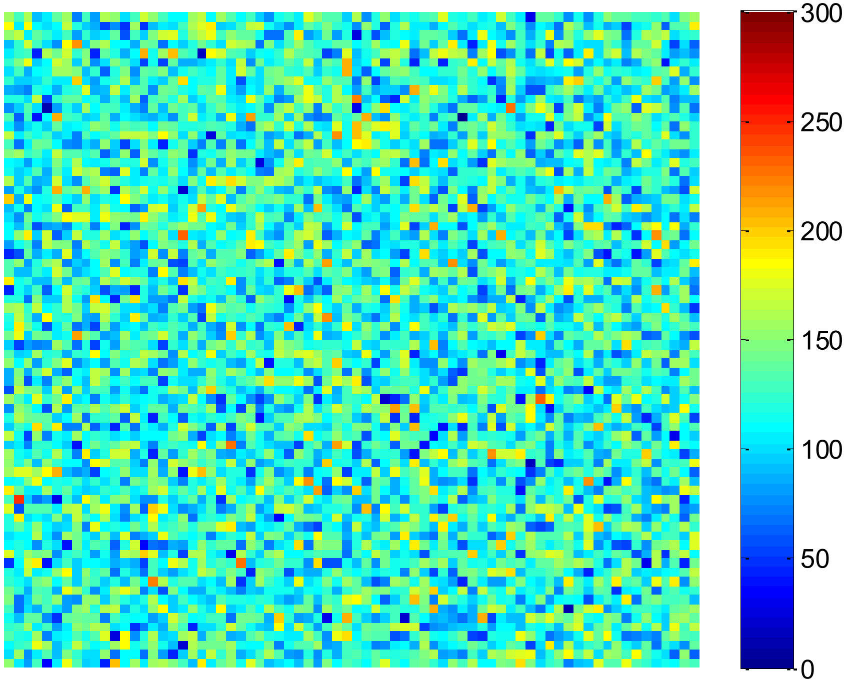
The effect of BIG pixels

Challenge to distinguish between:

Undersampled speckle pattern
8% contrast (AGIPD case, 8m distance)

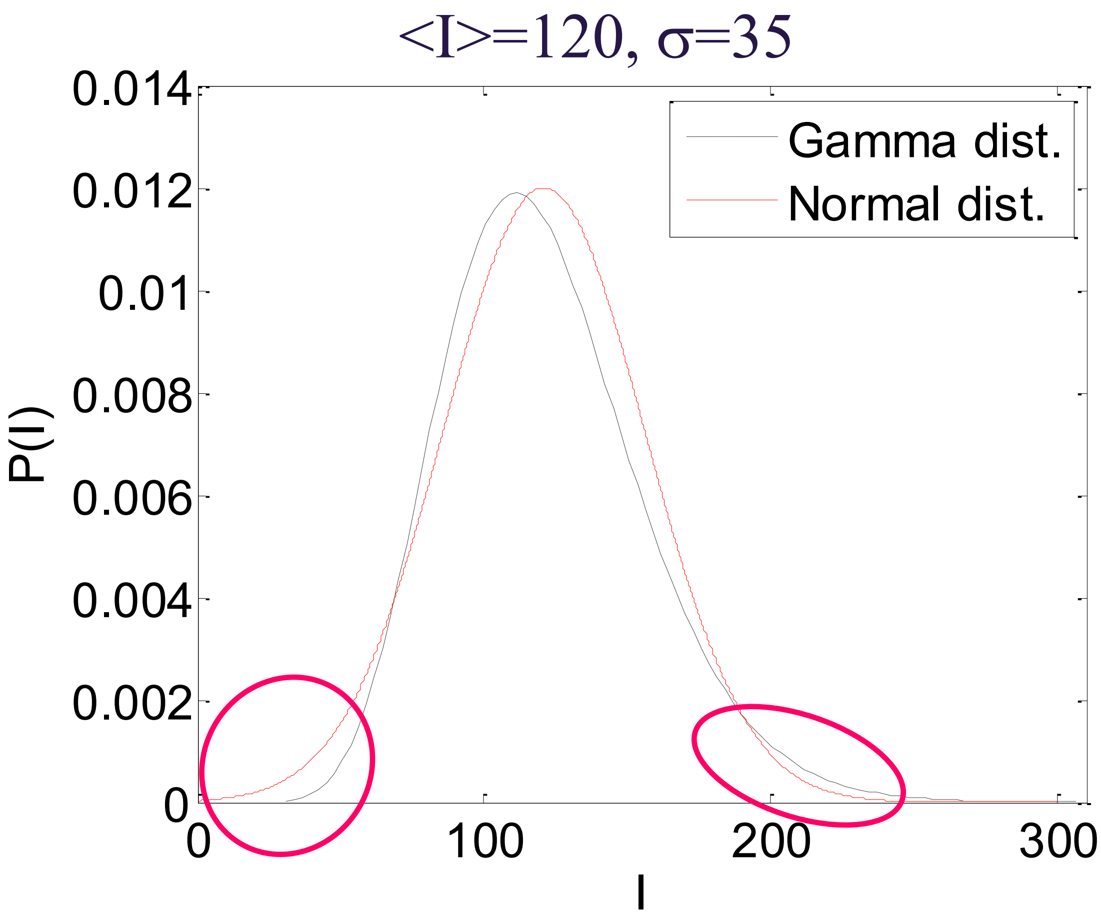


Random, normal-distributed
intensity pattern



<I>=120, σ=35

Photon Statistics of 8% Speckle Pattern

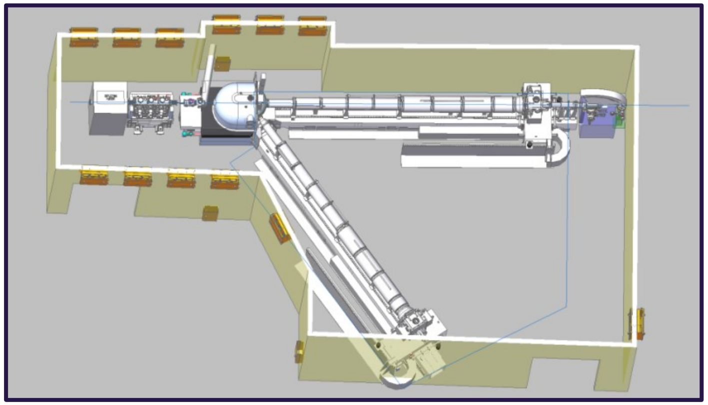


$\beta=(\sigma/\langle I\rangle)^2$

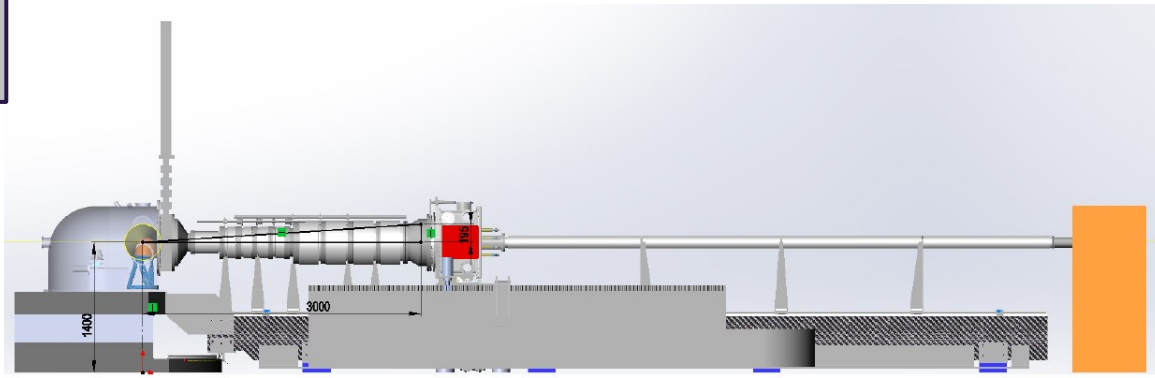
If detector isn't precise we cannot measure speckle patterns in low contrast conditions

Direct illumination CCDs can do it. Can AGIPD?

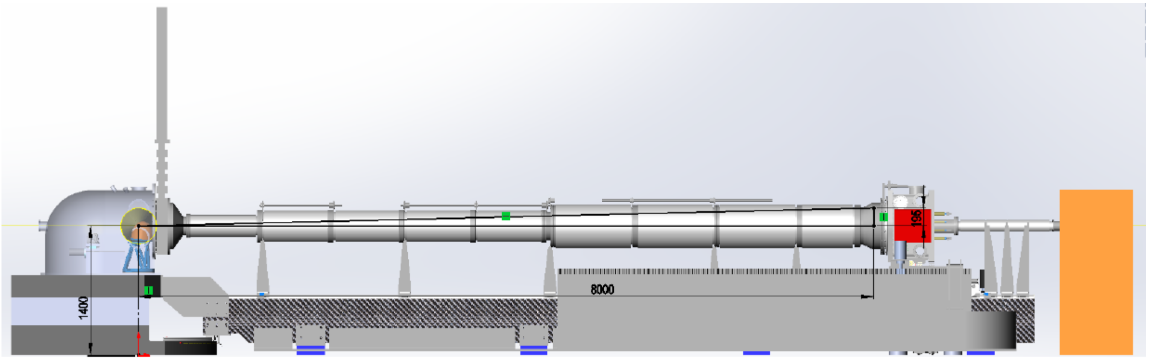
Long SAXS/WAXS arm



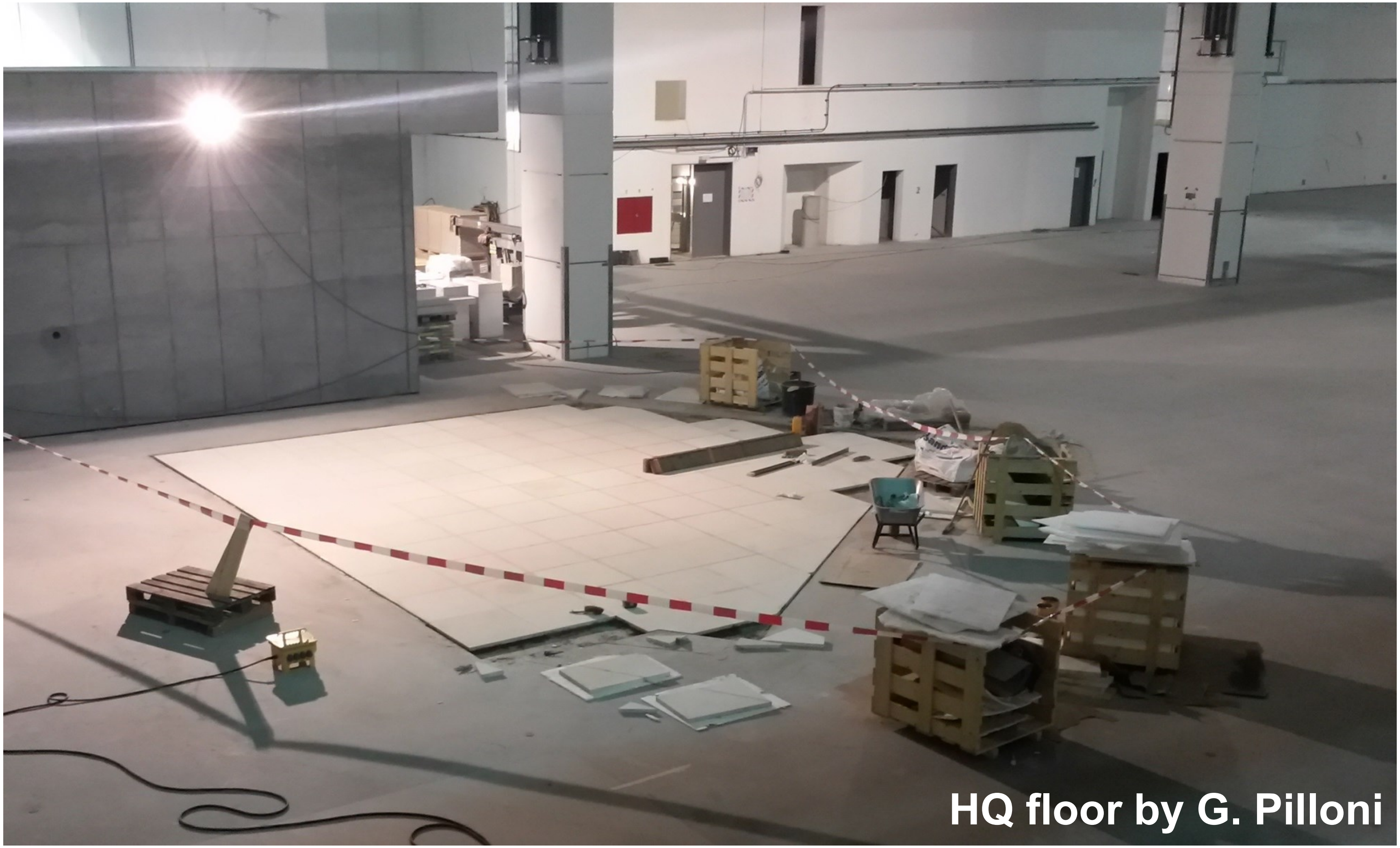
Under design in collaboration with ESRFs engineering group



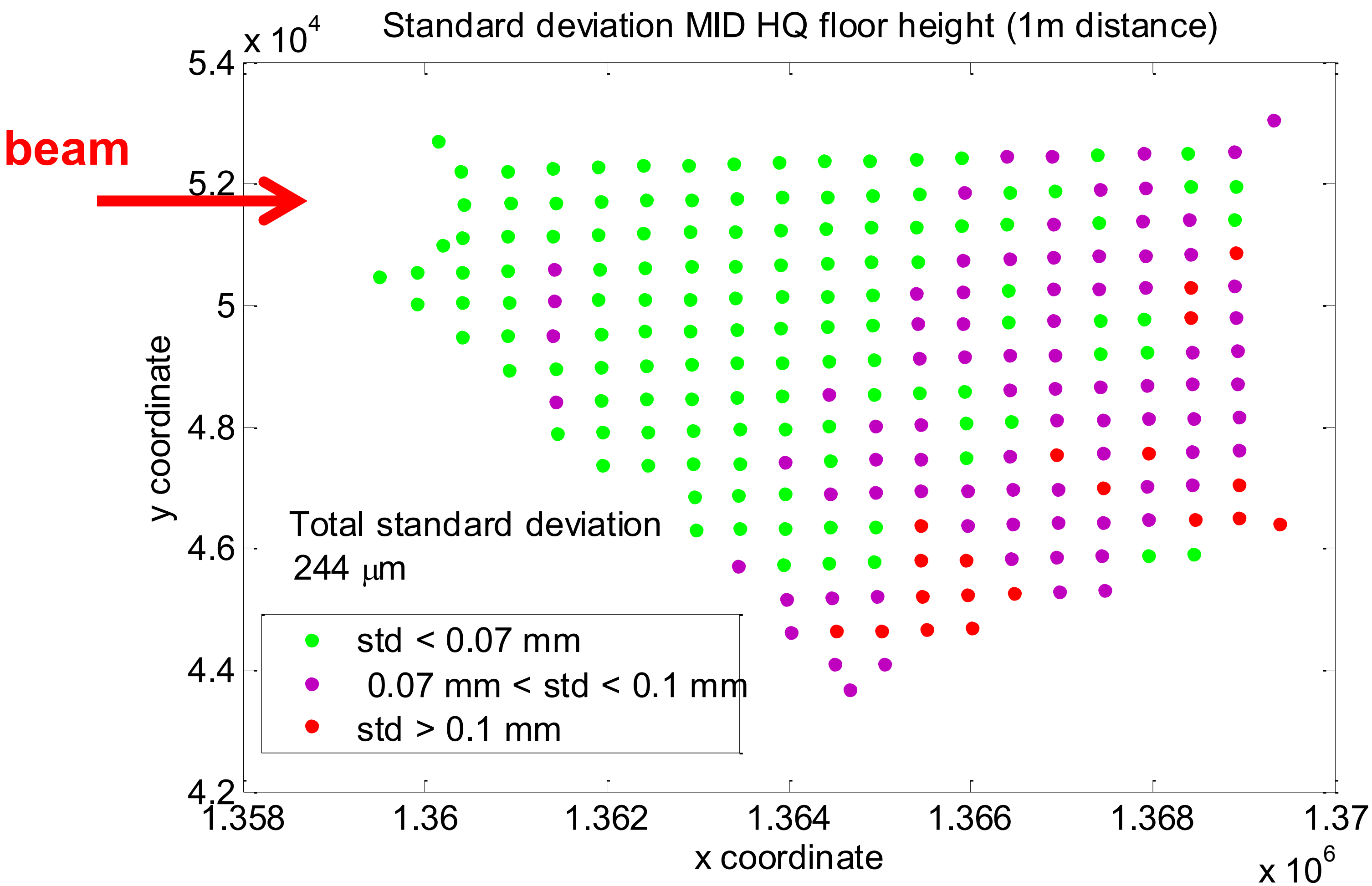
Air pads ensure the motion of the arm on a high precision floor



High precision floor is in a good state…

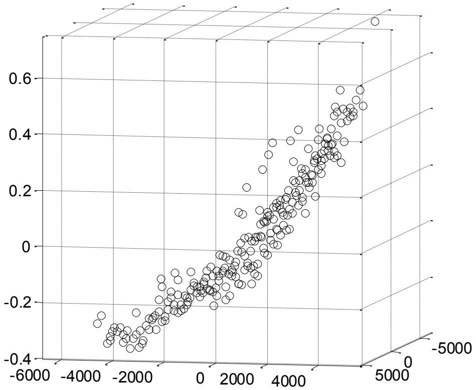


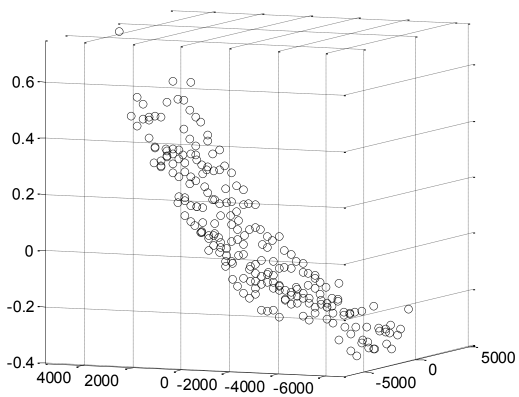
Floor quality

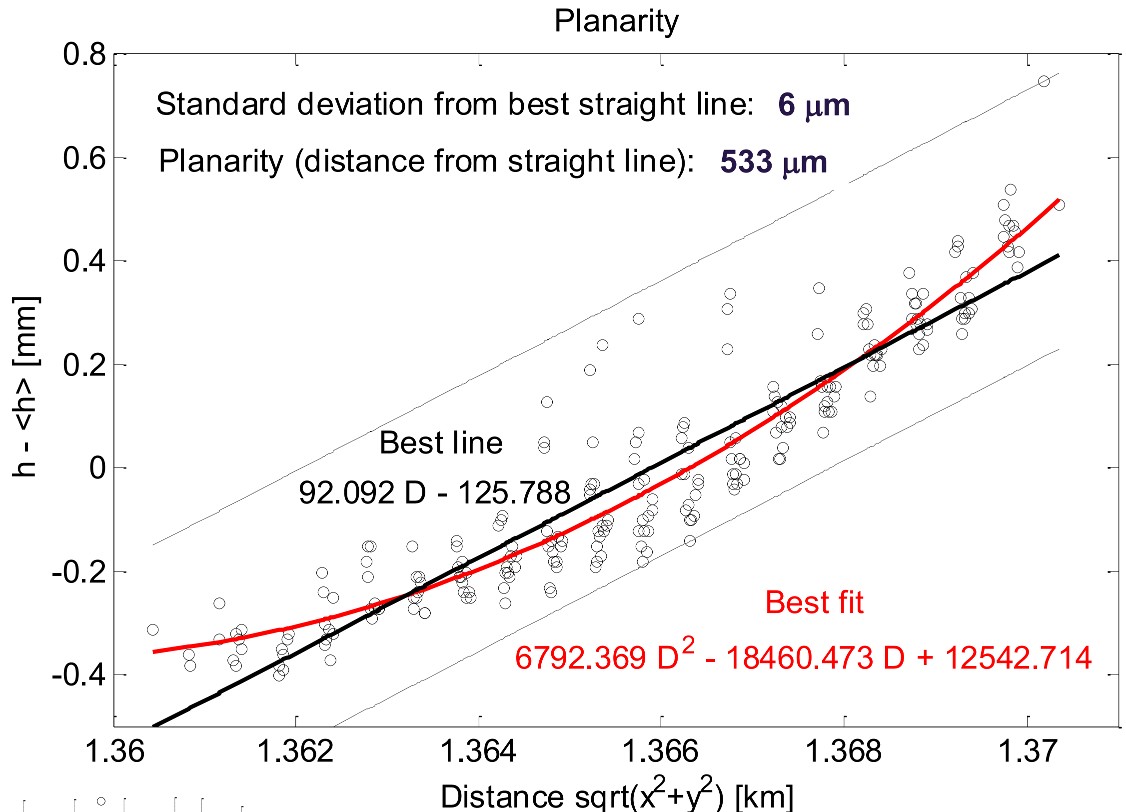


Height measurements by MEA2 (DESY)

Floor quality

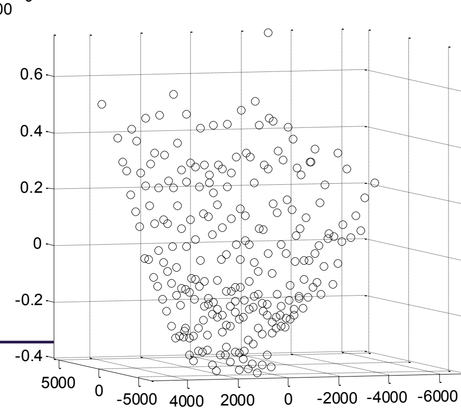






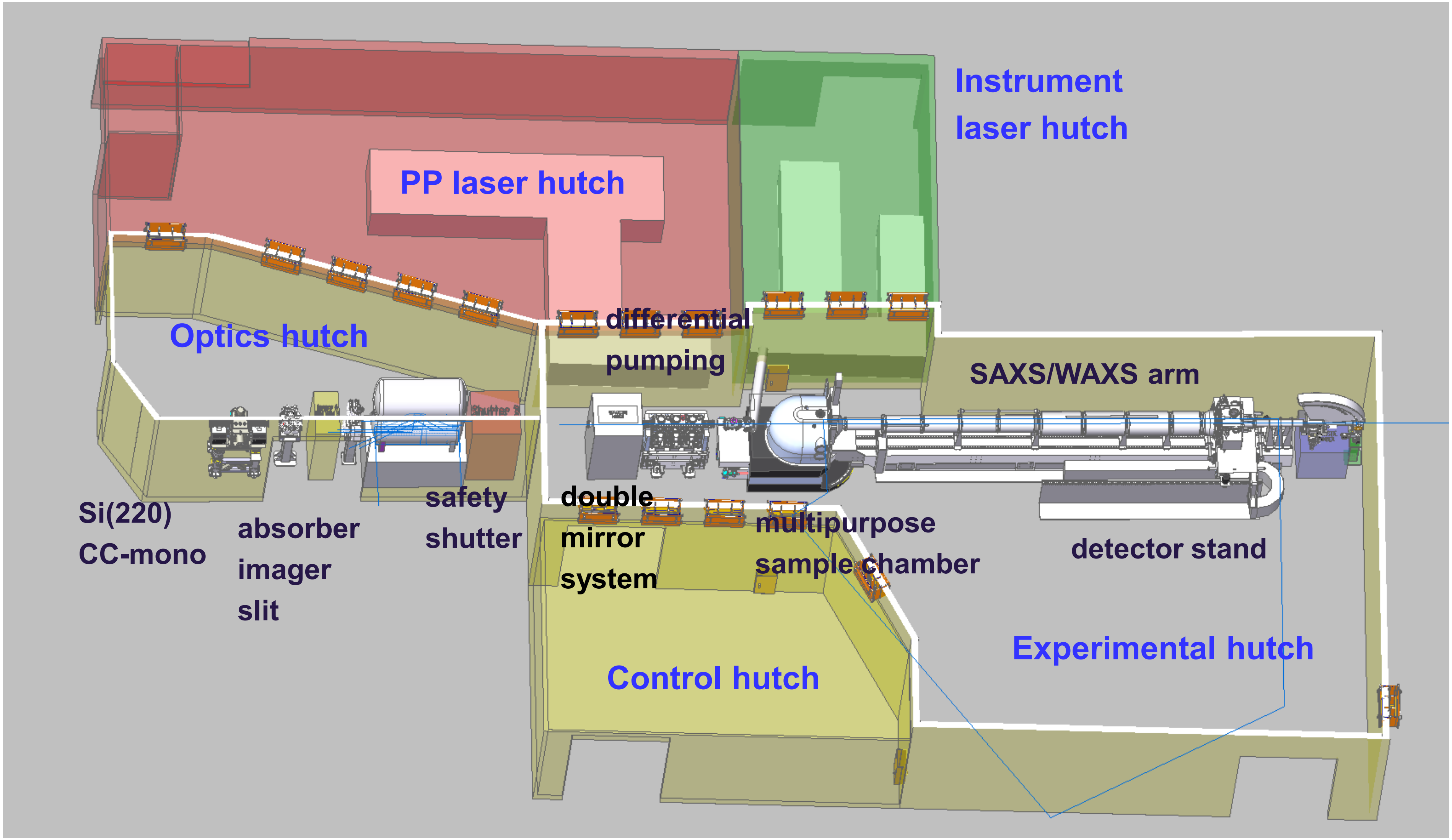
Height depends almost only on distance along beam (z coordinate).

Slope: 92 μm/m

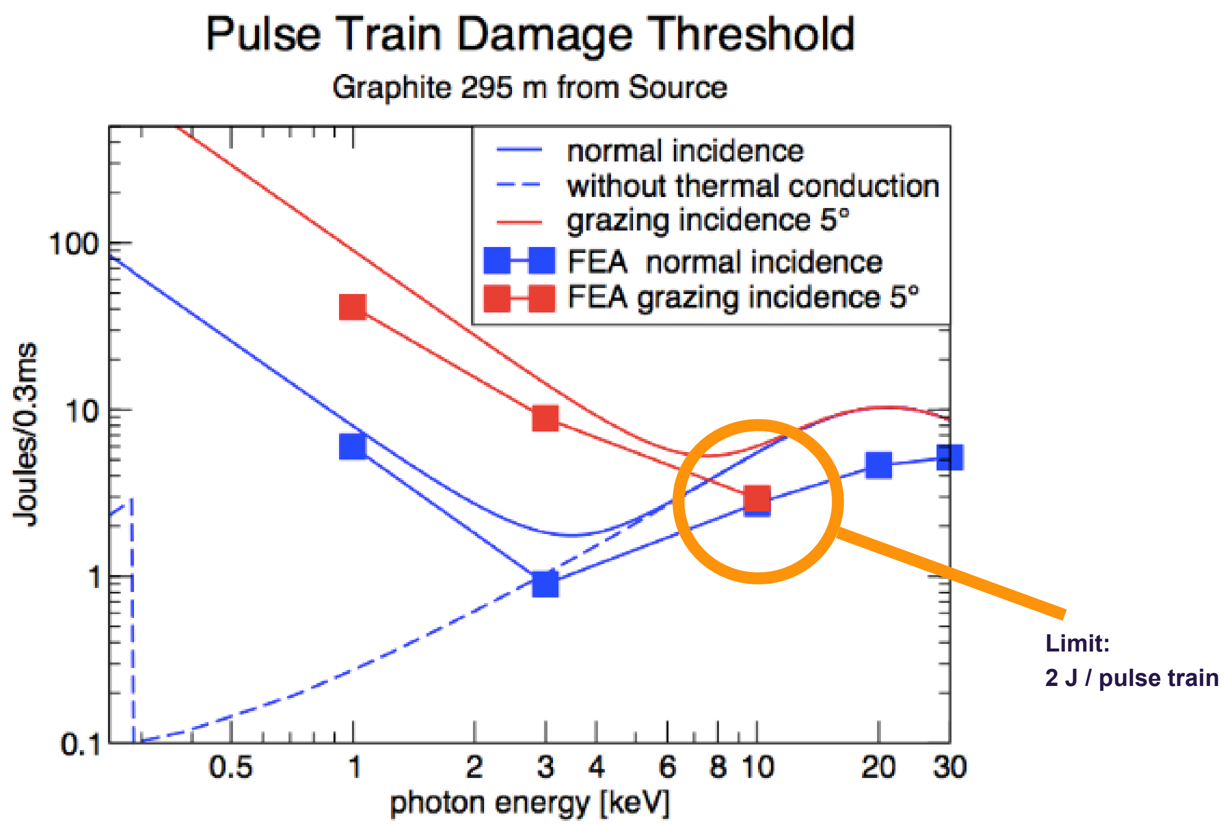


Height measurements by MEA2 (DESY)

MID Experimental area @ SASE-2



Damage on shutters



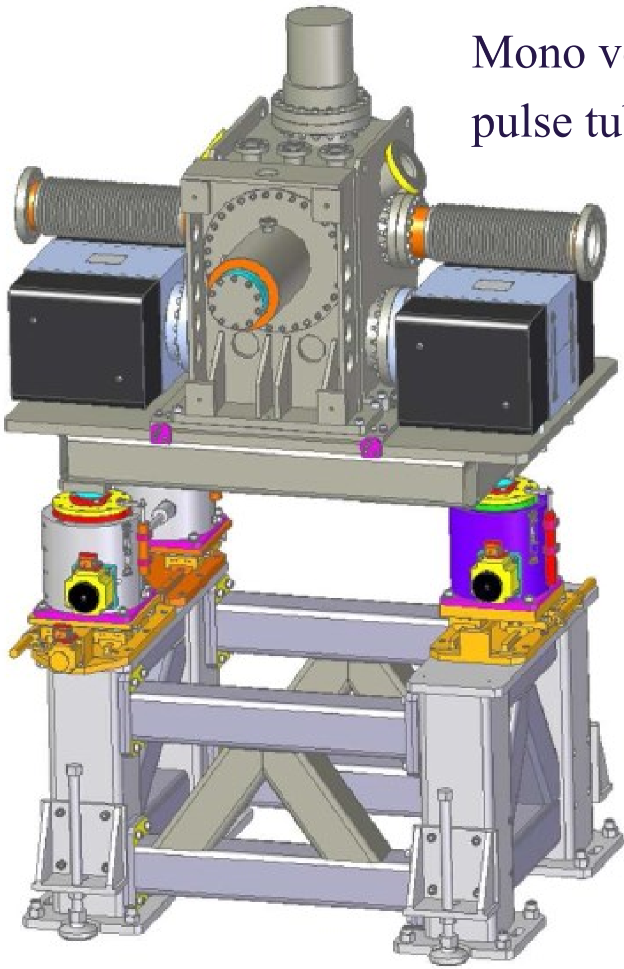
Actual load on shutter: 60 x 2 mJ = 0.12 J /pulse train

No problem with shutters, collimators etc.

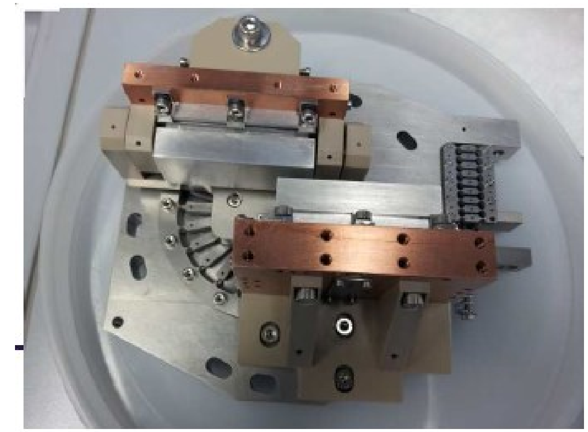
Courtesy of H. Sinn

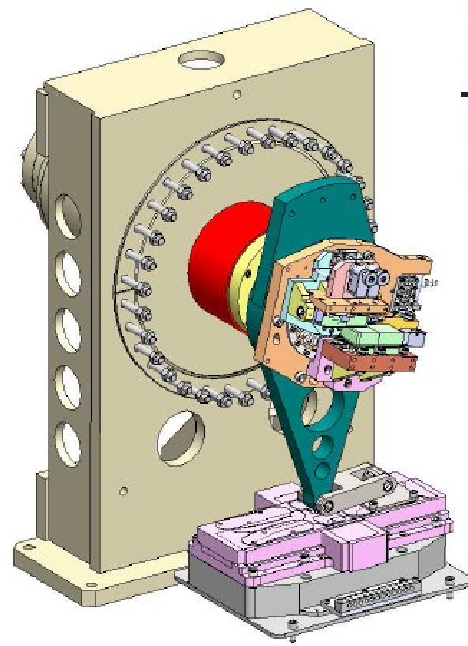
Monochromators for MID

Mono vessel with
pulse tube cryo cooler



Artificial channel-cut





Sine bar guided motion
for optimum stability

D. Shu (APS), and X. Dong (WP-73, XFEL.EU)

Silicon monochromator

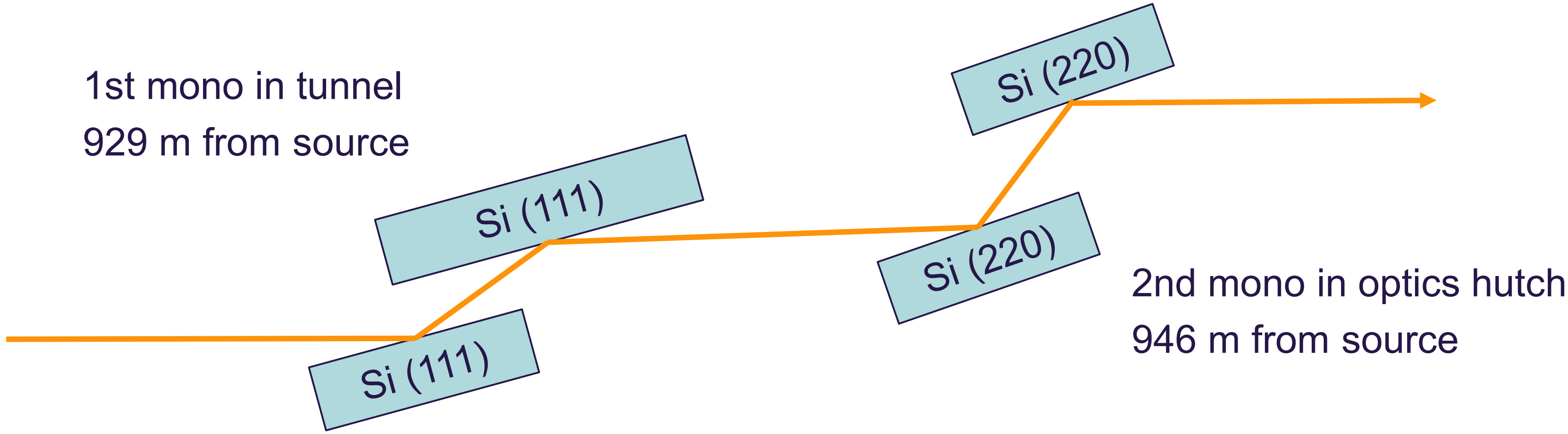


***Table 13:** Maximum temperature drifts for silicon and diamond monochromators*

	Temperature [K]	Tolerable relative drift [10^{-4}]	Max. ΔT	W_{max} /grams	W_{max} /atom	W_{damage} /atom
Si (111)	300	1.4	50 K	36.3 J/g	10.5 meV	0.4 eV
Si (111)	100	1.4	144 K	64.3 J/g	18.7 meV	0.4 eV
C (111)	300	0.65	52 K	31.4 J/g	3.9 meV	1 eV
C (111)	100	0.65	168 K	29.0 J/g	3.6 meV	1 eV

Courtesy of H. Sinn

European XFEL

Do we need cryo-cooling for the monos?

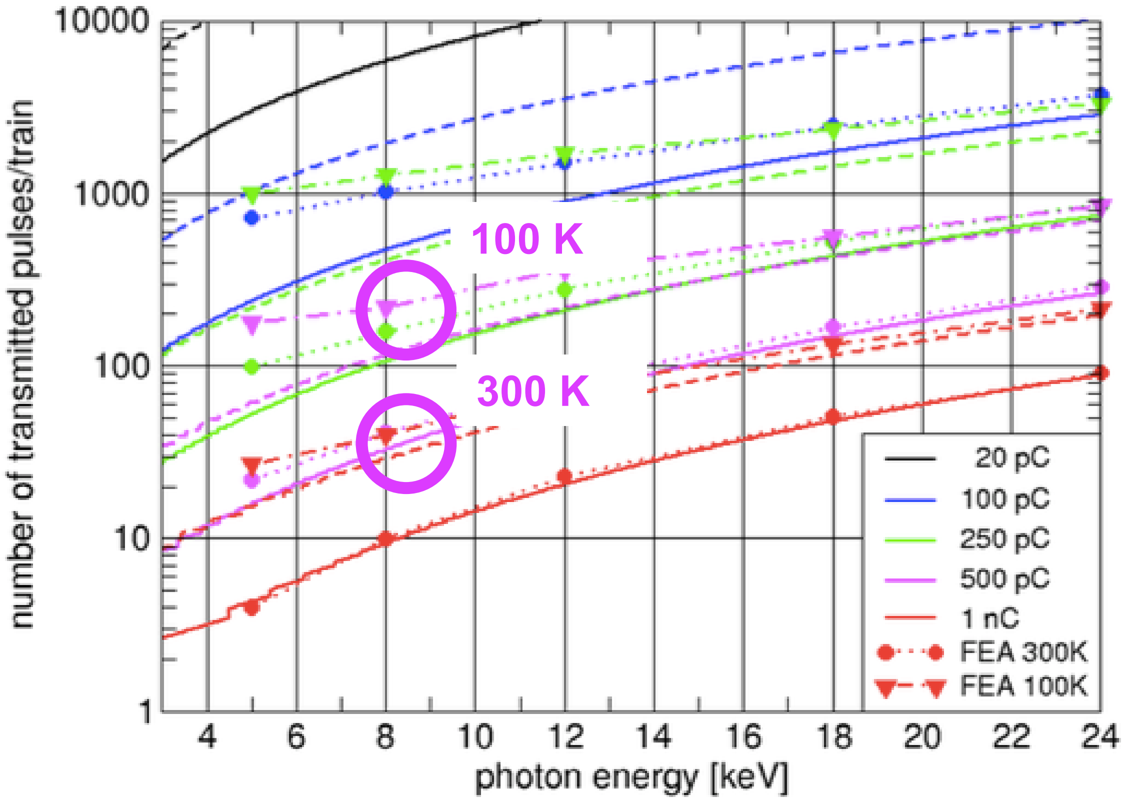


Figure 46: *Number of transmitted pulses through a Si (111) monochromator including heat flow perpendicular to the surface. Solid lines are 300 K, dashed lines 100 K. Dots are FEA results at 300K, triangles FEA at 100 K.*

YES!
(on both 111 and 220)

~30 pulses/train will get through at 300K

~200 pulses/train will get through at 100K

Courtesy of H. Sinn

Focusing system at MID

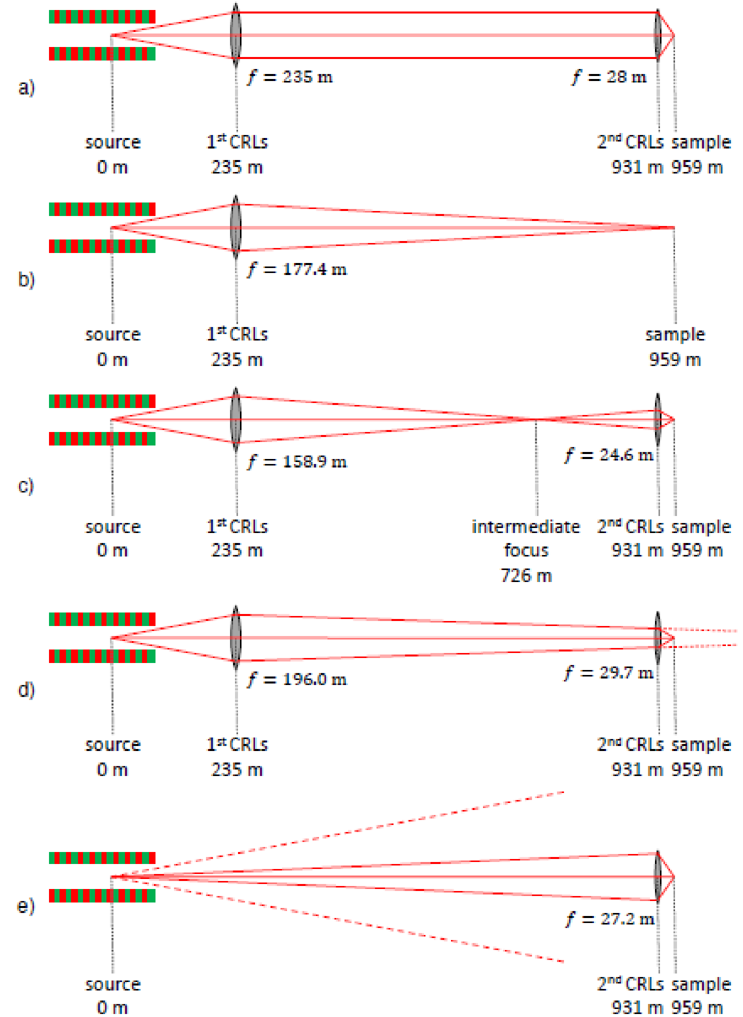
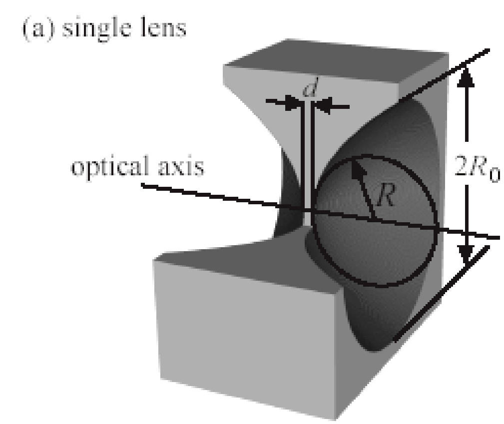


Figure 5.2: Focusing schemes for the MID beamline: (a) *Collimating then focusing* scheme. (b) *Direct focusing* with the first CRL transfocator (CRL-1). (c) Use of an *intermediate focus*. (d) *Combined focusing* scheme. (e) *Brute focusing* using only the second CRL transfocator (CRL-2).

Best choice for Day-1

- CRL-1 @ 235m
- CRL-2 @ 931m

Too “dangerous“ for Day-1

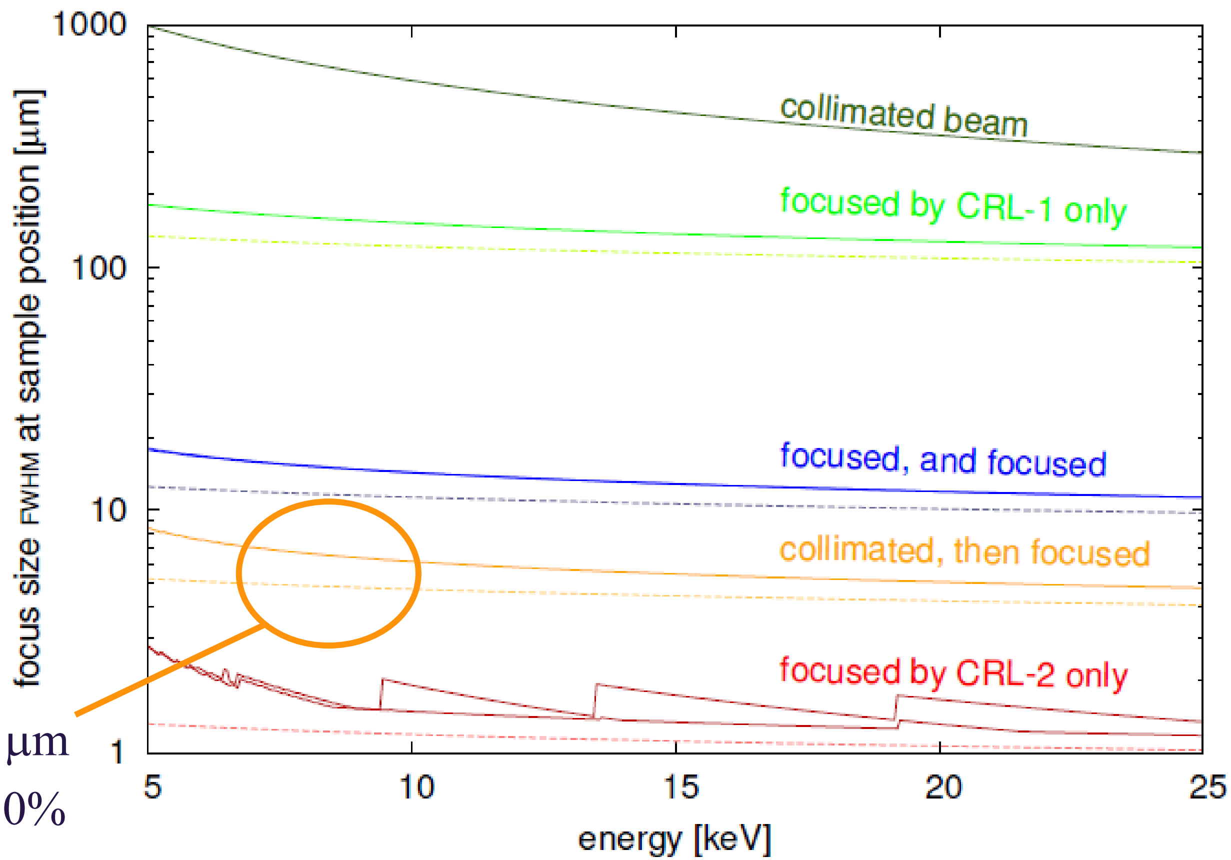


Too small focus for the GeO_2 exp

Source: MID TDR

doi:10.3204/XFEL.EU/TR-2013-005

Focal spot size



Spot size: 5-8 µm

Efficiency: ~80%

Solid lines: Abbe's equation; Dashed lines: source size demagnification using geometrical optics

Source: MID TDR

doi:10.3204/XFEL.EU/TR-2013-005

CRL transfocator

CRL 1

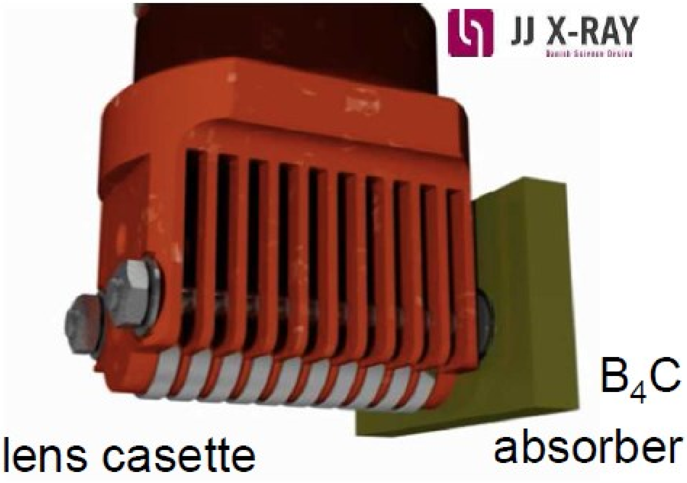
actuator	1	2	3	4	5	6	7	8
filled with	1x5.8	1x4.9	1x4.0	1x3.3	2x5.8	3x4.0	7x4.0	7x2.0

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

CRL 1: 23 lenses in total

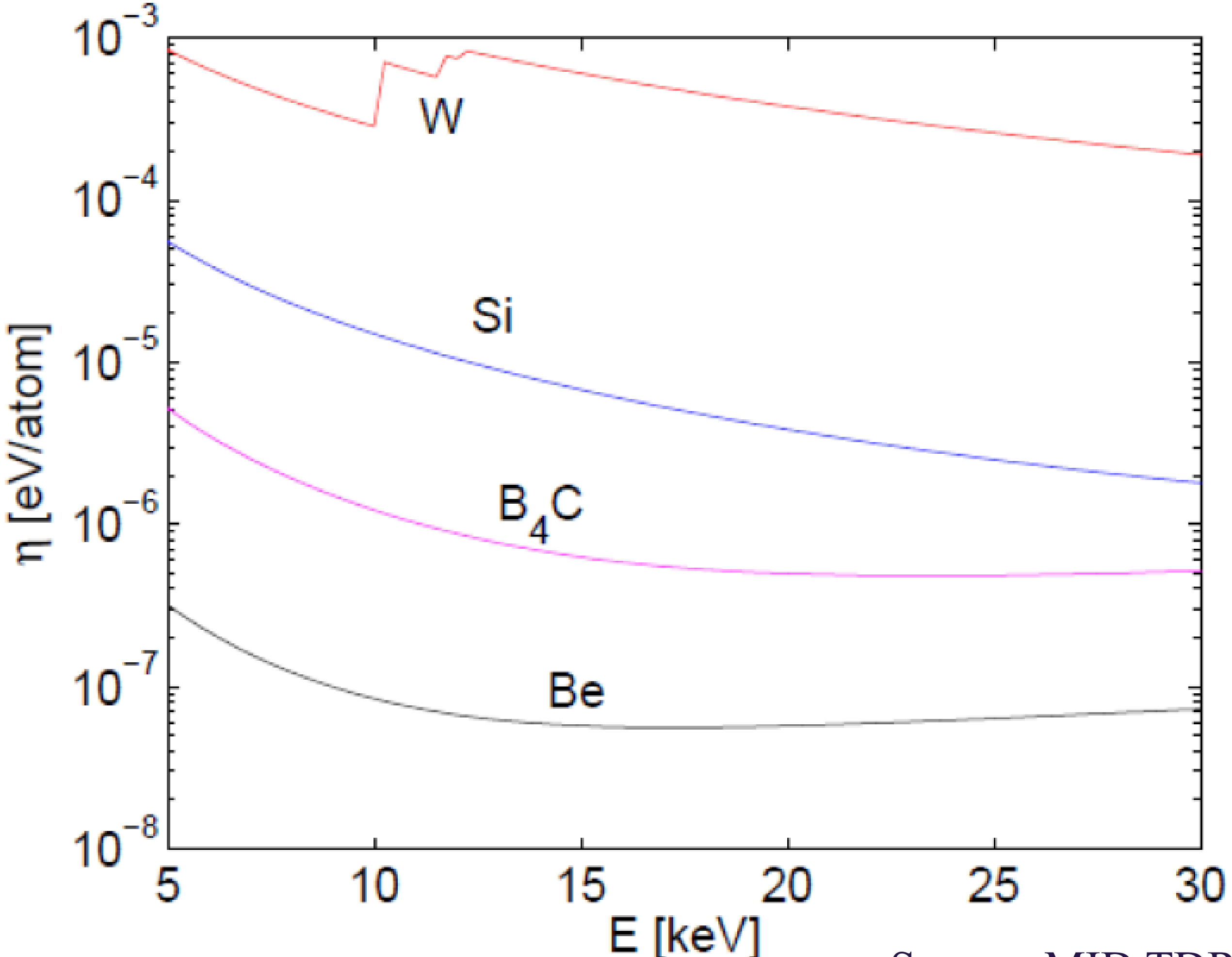
CRL 2: 54 lenses in total



JJ X-ray & L. Batchelor

Ablation

Example: 10^{10} photons in a 1x1 mm^2 beam



Source: MID TDR

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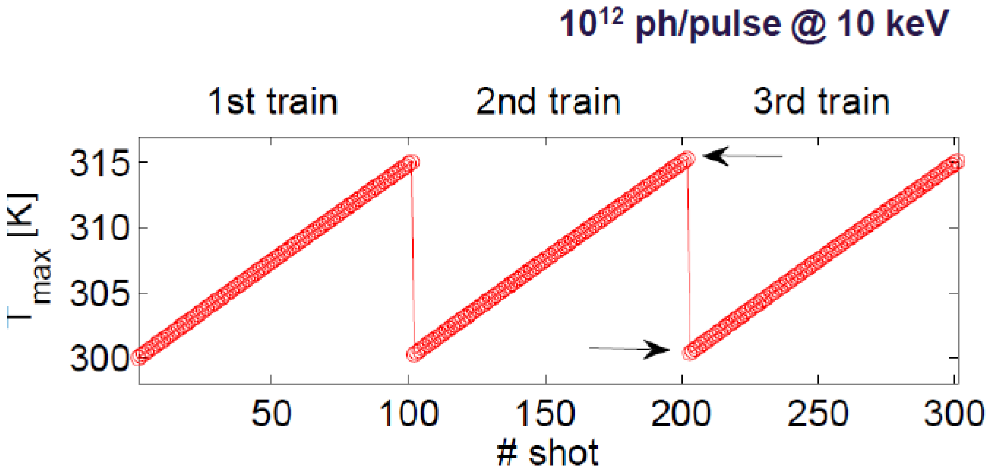
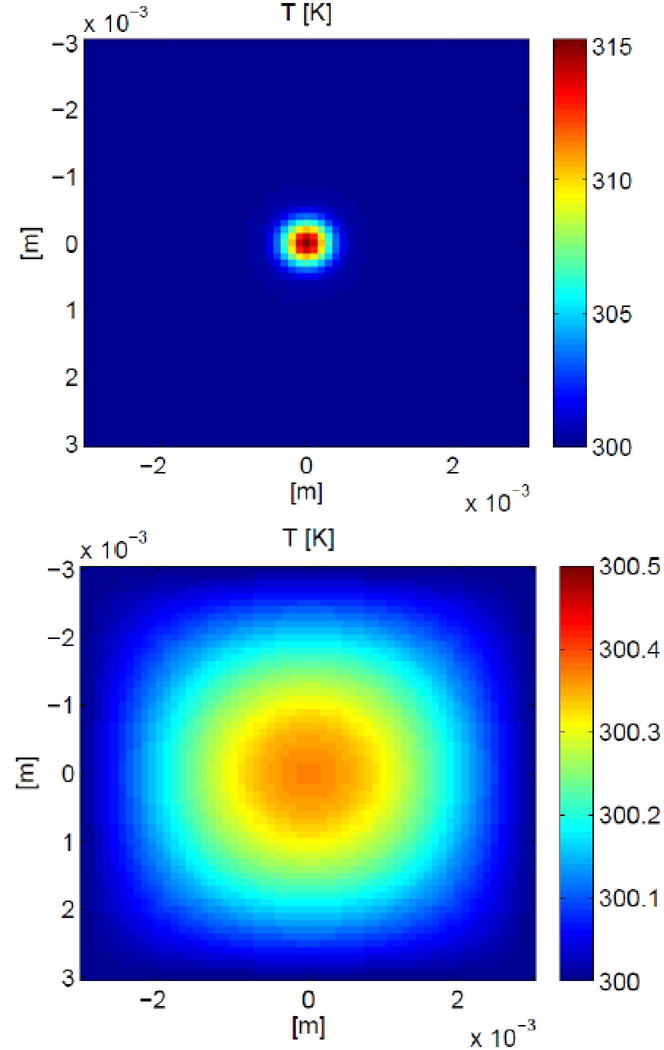
CRL beam damage

Adiabatic heating during trains, cooling in between





Limit on number of pulses per train.

Concern: repeated temperature cycles of Be

Shear stress limit?

Source: MID TDR

doi:10.3204/XFEL.EU/TR-2013-005

Commissioning toward 1st experiment

CRL-1 set for parallel beam at 8.4 keV (10 mm gap at 17.5 GeV)
CRL-2 to focus the beam on sample position (option a)
Diagnostics: screens, determination of focus size & Rayleigh length
(2 shifts)

Mono-1, Si(111) diffracting at 8.4 keV. Stability & heatload tests
Mono-2, Si(220) diffracting at 8.4 keV. Stability & heatload tests
Mono-1 & Mono-2 together
(3 shifts)

Coherence tests in SAXS geometry. Tuning of beamsize & intensity. Ptychography and Speckle statistics. Scanning stage, Diagnostics & Detector tune up
(4 shifts)

1^{st} experiment

Data taking on GeO_2 at 100 kHz. Detector & diagnostics tweaking.
Large arm motion to change Q. Verification of mechanics precision.
On the fly-ish data analysis. Furnace regulation over a range of temperatures (5 shifts)

TOTAL: 14 shifts (one week)

Very optimistic: Everything else has to work smoothly: Machine, Undulators, WP-74 diagnostics, Offset mirrors, Safety, IT, Karabo & DAQ,….

Also: Enough time for installation and technical commissioning required prior to commissioning with beam.

Important SASE-2 dates

Hutches CfT	May 2015
Infrastructure CfT	Oct 2015
Hutches + infrastructure ready (installation of sensitive components possible)	June 2016
1st SASE beam	April 2017