2006/2016

10 YEARS

DECTRIS®

detecting the future

EIGER X – highlights from cutting–edge synchrotron research

Clemens Schulze-Briese, DECTRIS Ltd.

ACA Meeting, Denver, CO, USA, July 23st 2016,

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EIGER

DETECTOR SERIES

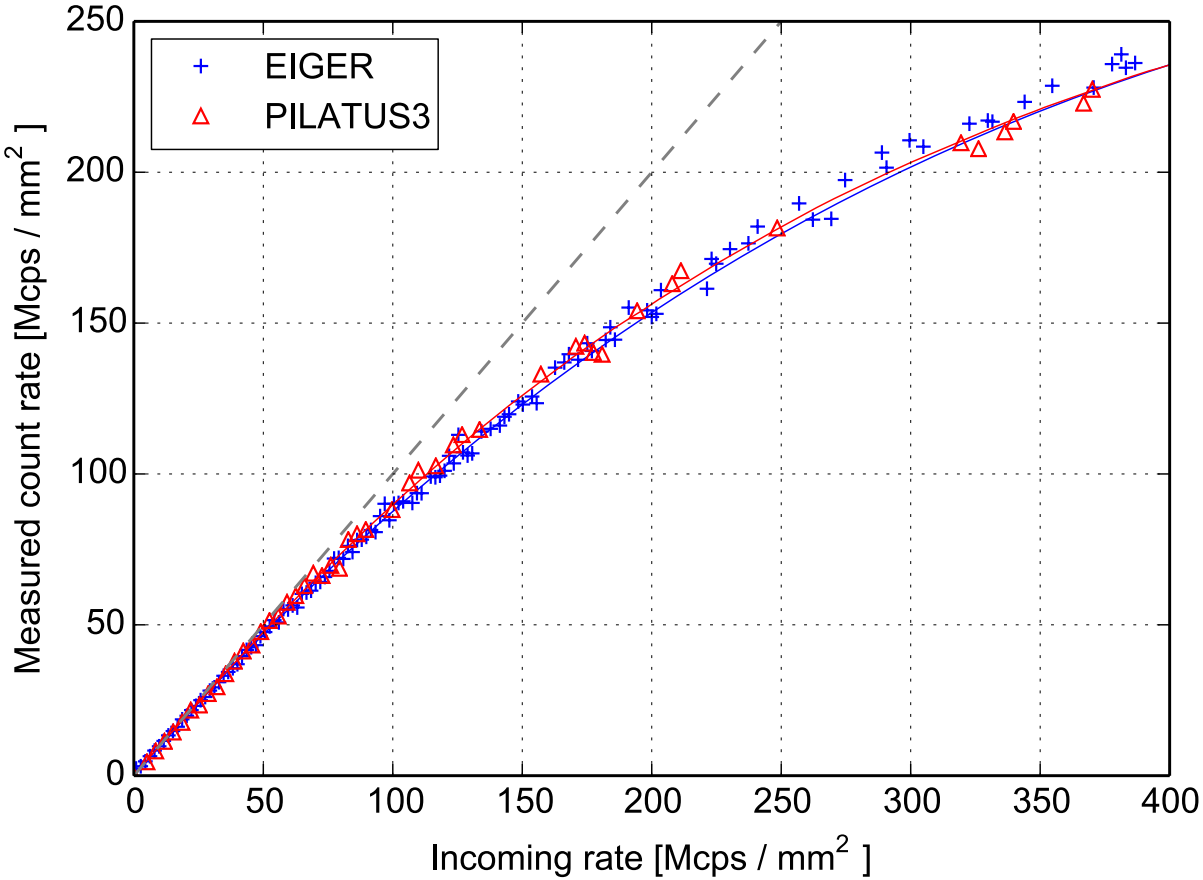


EIGER X Series

EIGER and PILATUS3 – What is the difference

	EIGER	PILATUS3
pixel size [μm²]	75 x 75 μm²	172 x 172 μm²
pixel density [mm⁻²]	178	34
max. count rate [Mcps/mm²]	500	500
continuous readout	YES	NO
readout dead time [μs]	3	950
frame rates [Hz]	133 – 3000	100 – 500
counter depth [bit]	12	20
image depth [bit]	32/16	32
duty cycle at max. frame rate [%]	> 99	90 - 52
silicon sensor thickness [μm]	450	450, 1000

EIGER and PILATUS3 - High count rates



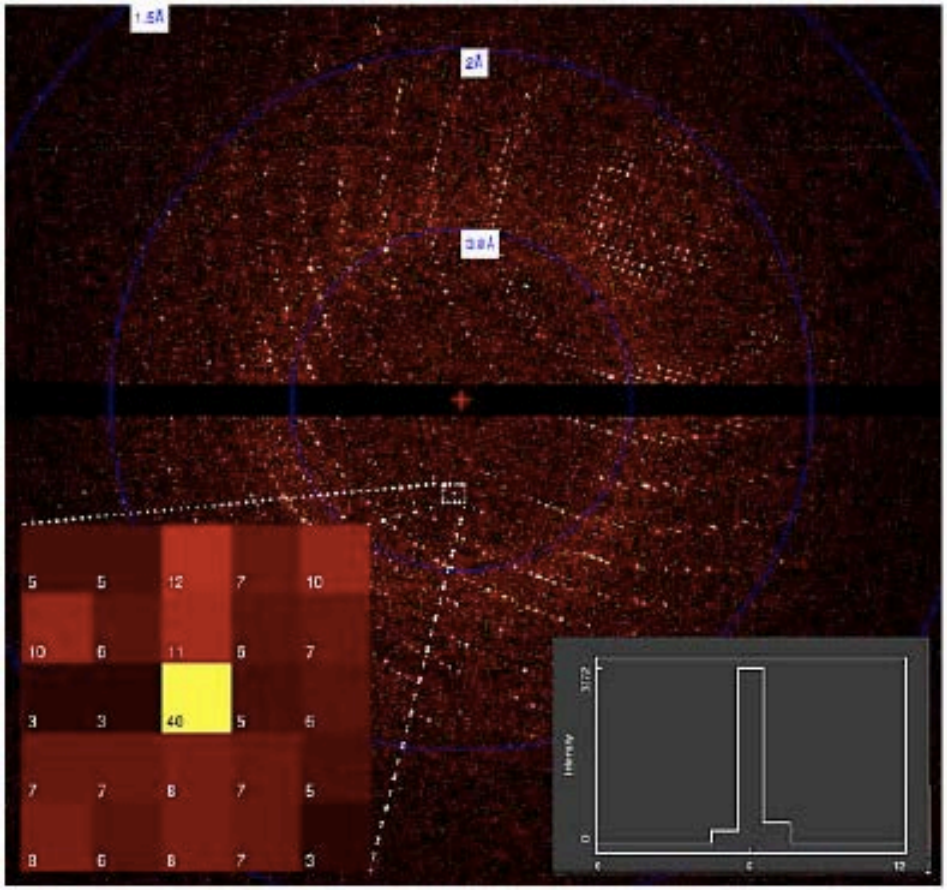
Maximal count rates [phts/pixel/s]

EIGER	**$2 \cdot 10^6$**
PILATUS3	**$10 \cdot 10^6$**

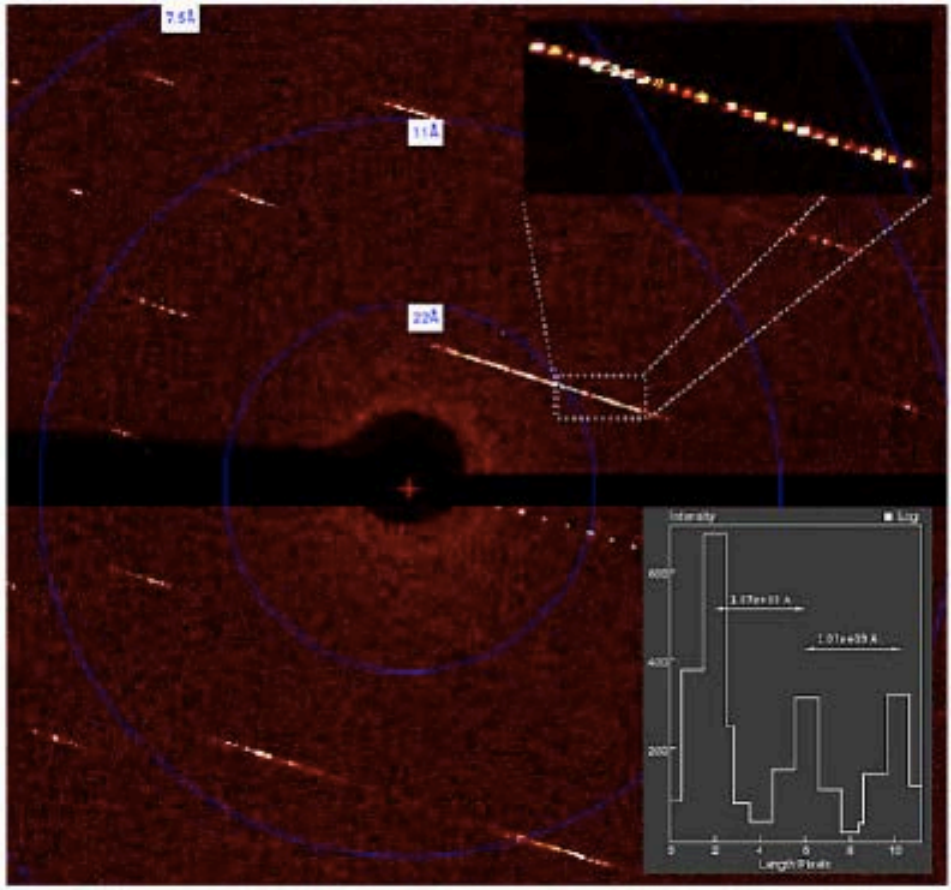
10 keV, 50% threshold

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EIGER - Spatial resolution



Insulin



1044 Å axis at 2.2 Å resolution

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EIGER X product line



	Active area [mm²]	Pixel array	Frame rate [Hz]
16M	311.7 × 327.8	4150 × 4371	133
9M	233.2 × 245.2	3110 × 3269	238
4M	155.2 × 162.5	2070 × 2167	750
1M	77.2 × 79.9	1030 × 1065	3000

EIGER X product line

Common properties

Sensor thickness [µm]	450
Energy threshold [keV]	2.7–18
Dead time [µs]	3
Count rate [$s^{-1} \times mm^{-2}$]	5×10^8
Gap h/v [pixel]	10/37
Water cooling	

Distinguishing properties

ROI readout	9M, 16M
Vacuum compatibility	1M, 4M

	Active area [mm^2]	Pixel array	Frame rate [Hz]
16M	311.7 × 327.8	4150 × 4371	133
9M	233.2 × 245.2	3110 × 3269	238
4M	155.2 × 162.5	2070 × 2167	750
1M	77.2 × 79.9	1030 × 1065	3000

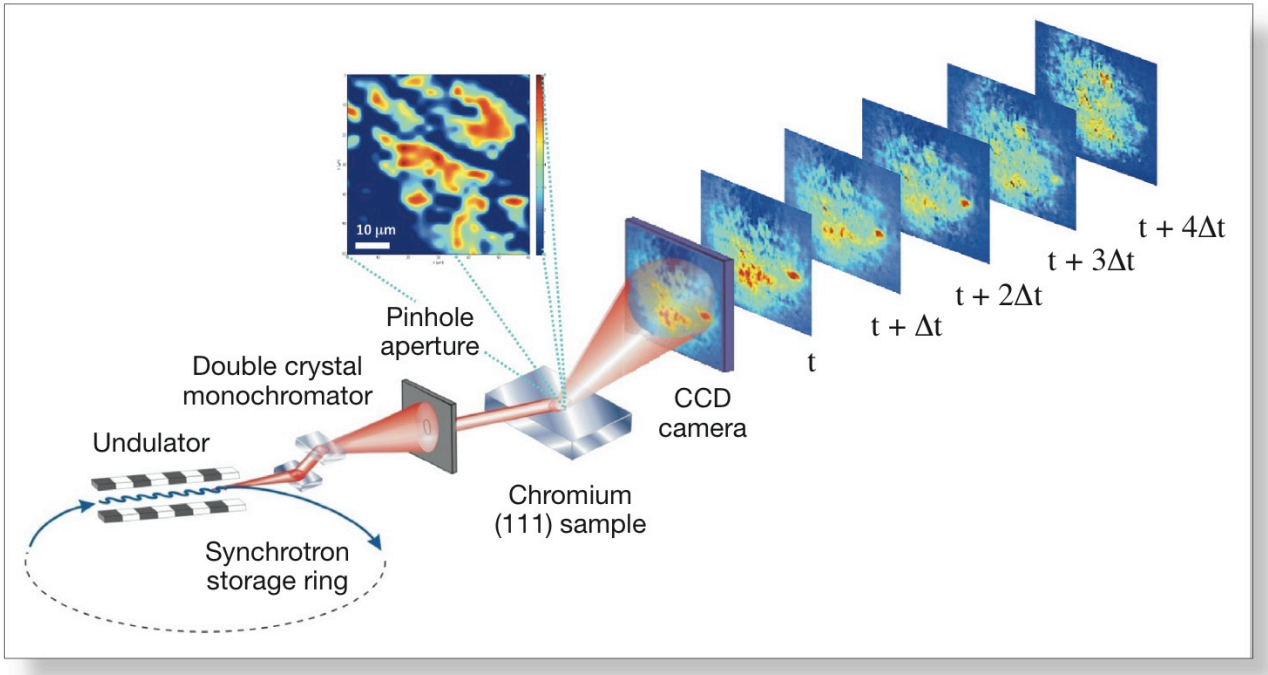
Efficient compression

bit-shuffle LZ4 (Kiyoshi Masui, github.com/kiyo-masui/bitshuffle)
=> Numbers from EIGER X 16M @ SLS (X06SA)

	Compression method	Angular increment [°]	Frame rate [Hz]	Image size [MB]	Compression factor	Data per 360° [GB]	Data rate [MB/s]
	none	-	-	72	1	-	
	CBF	0.25	4	18	4.0	25	72
32-bit	bs-LZ4	0.25	4	11	**6.5**	15	44
	bs-LZ4	0.1	10	6.5	**11.1**	23	65
	bs-LZ4	0.05	20	5.5	**13.1**	39	110
16-bit	bs-LZ4	0.02	50	3.5	**10.3**	62	175
	bs-LZ4	0.01	100	2.7	**13.3**	95	270
	bs-LZ4	0.01	133	2.5	**14.4**	88	**333**
	CBF	0.01	133	18	2.0	633	2394
	none	-	-	36	1	-	

Applications

X-ray Photon Correlation Spectroscopy



Requirements

- *Highest frame rates*
- *Small pixel size to resolve speckle patterns*

Results

Fluctuations in the

- *structural,*
- *chemical, or*
- *magnetic order in the material*

Continuous high frame rate XPCS data acquisition

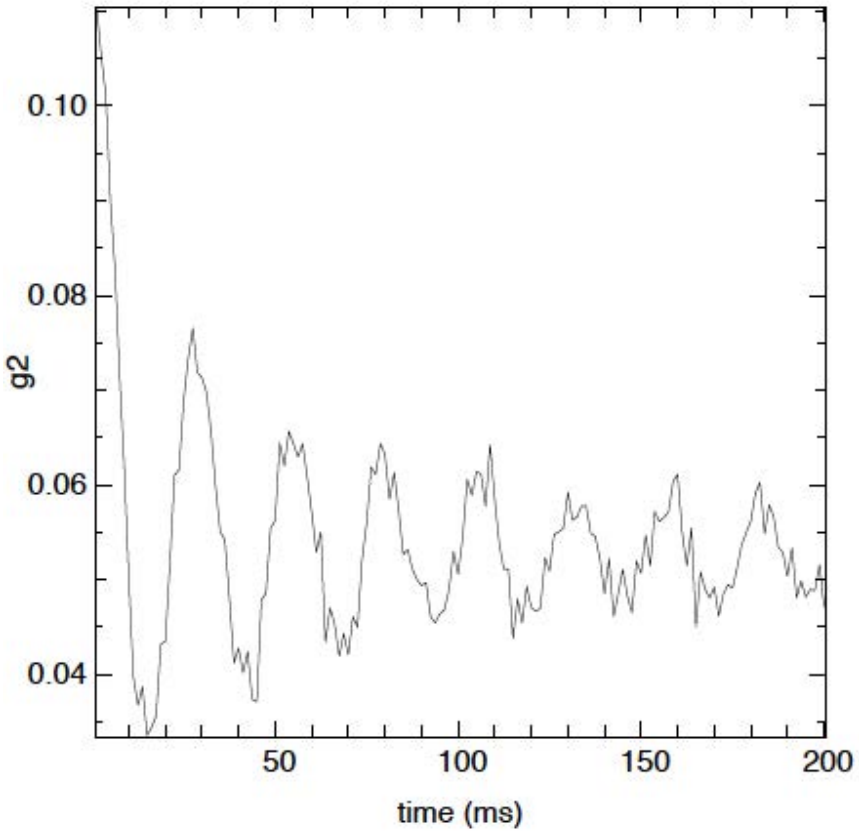


Image rate	800 Hz
Number of frames	10000
Photon energy	7.35 keV

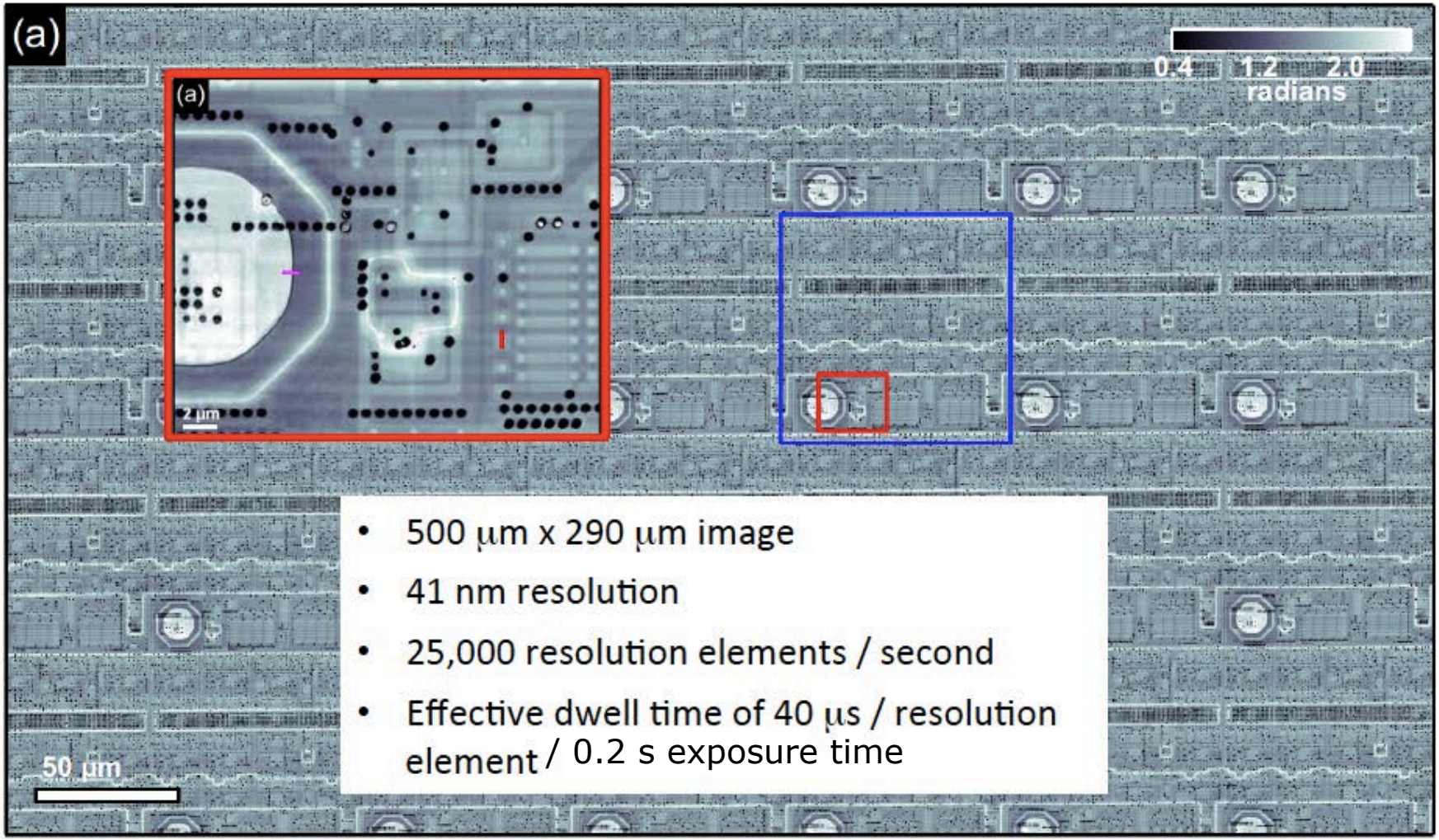
Correlation function

- *silica spheres suspended in glycerol flowing in rectangular channel*
- *Oscillations are measure of velocity profile*
- *Higher velocities are higher frequencies*

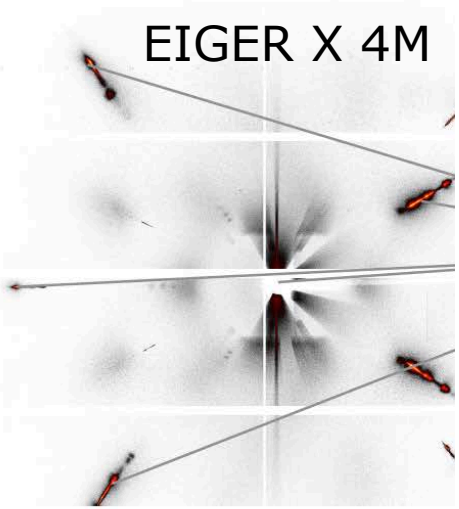
Courtesy of Mark Sutton, McGill University
All measurements at APS

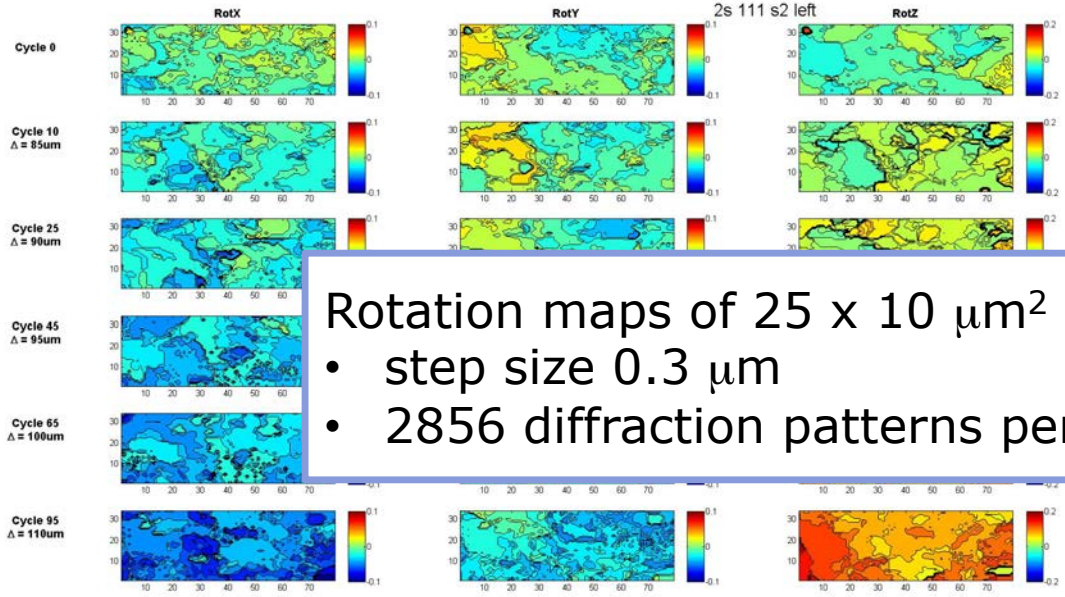
High throughput ptychography

The EIGER "selfie" M. Guizar-Sicairos *et al.*, Opt. Express **22** (2014) 14859



Crystal orientation mapping of Cu foils by Laue diffraction – EIGER X 4M

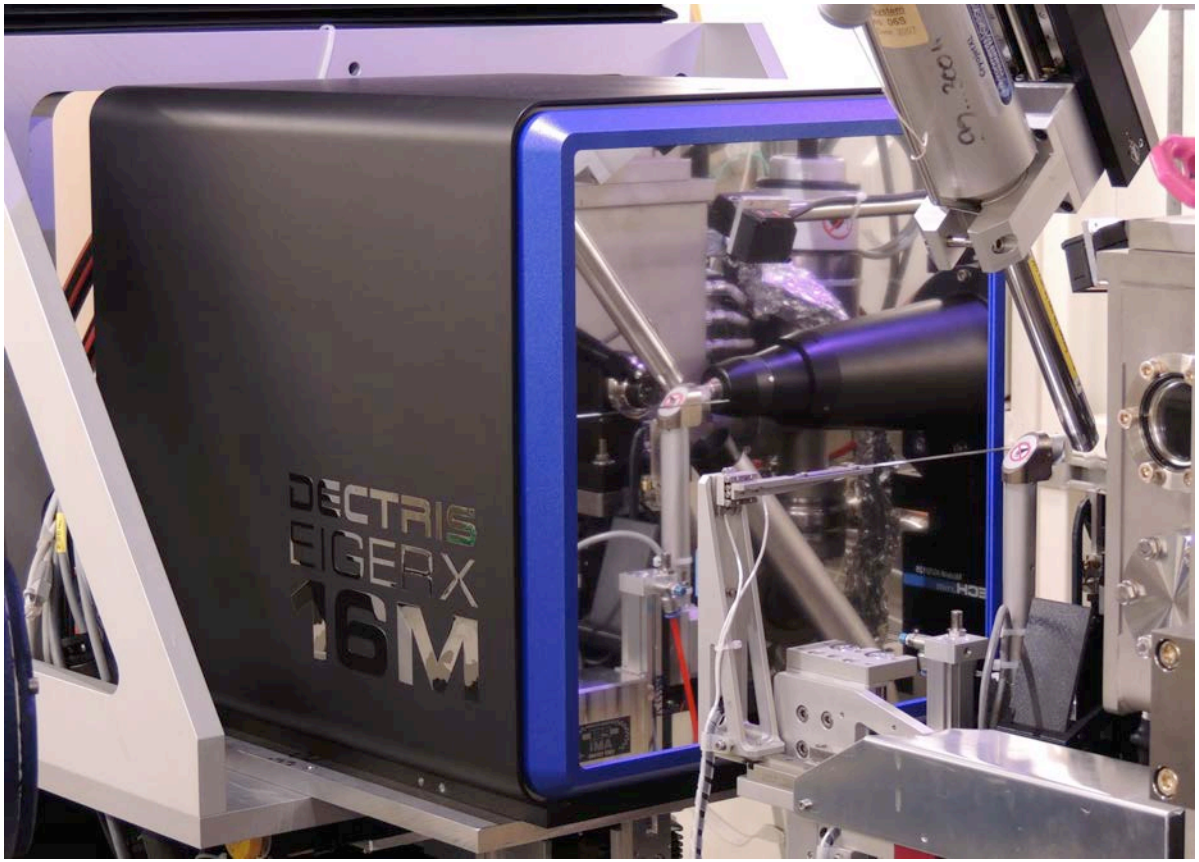




Rotation maps of 25 x 10 μm²
- step size 0.3 μm
- 2856 diffraction patterns per map

- high dynamic range and suppression of the fluorescence signal => resolve very weak peaks
- high frame rates => detailed grain rotation maps

EIGER - Macromolecular Crystallography



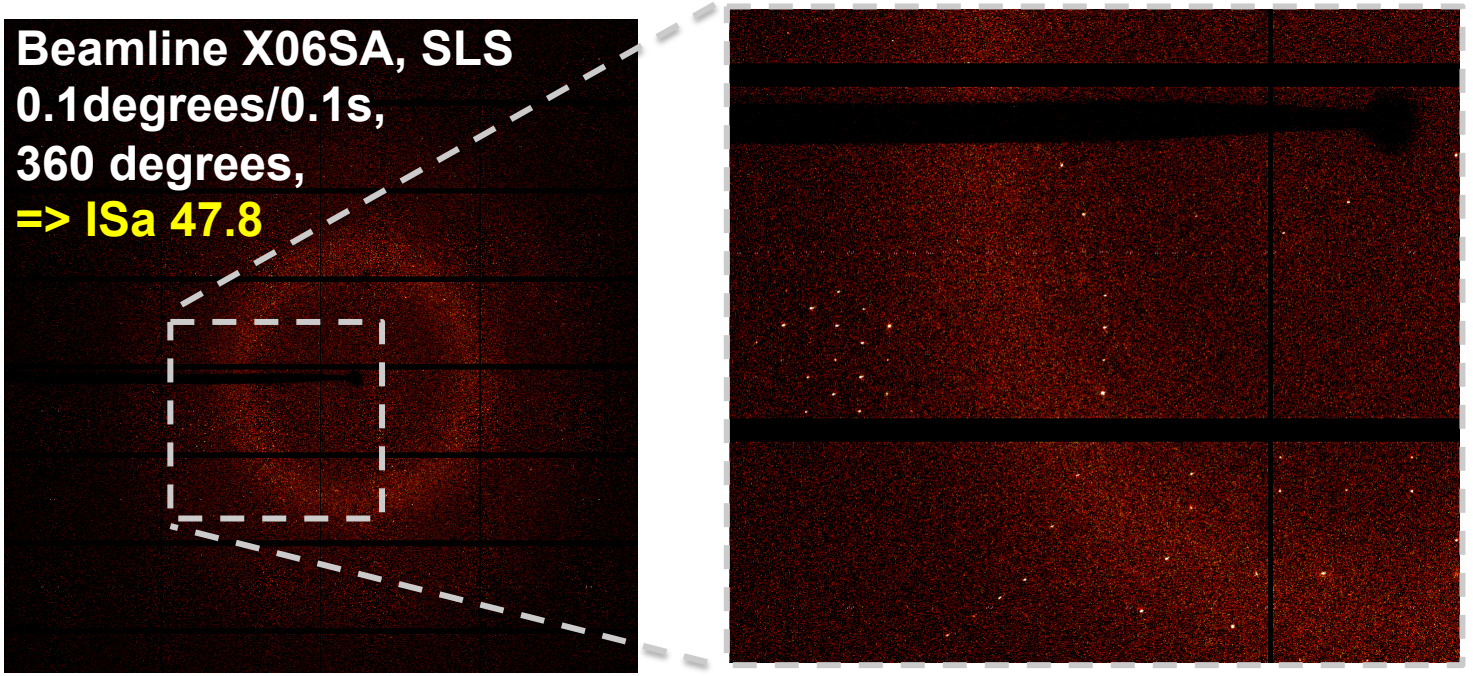
EIGER X 16M at the MX beamline X06SA, SLS

In user operation since Nov 2015

EIGER 16M data from insulin crystal

SUBSET OF INTENSITY DATA WITH SIGNAL/NOISE >= -3.0 AS FUNCTION OF RESOLUTION

RESOLUTION LIMIT	NUMBER OF REFLECTIONS OBSERVED	UNIQUE	POSSIBLE	COMPLETENESS OF DATA	R-FACTOR observed	R-FACTOR expected	COMPARED	I/SIGMA	R-meas	CC(1/2)	Anomal Corr	SigAno	Nano
3.88	29669	778	780	99.7%	1.8%	1.9%	29669	218.03	1.8%	100.0*	71*	1.934	623
2.75	56210	1350	1350	100.0%	2.4%	2.4%	56210	164.30	2.4%	100.0*	33*	1.240	1194
2.24	68309	1704	1694	100.6%	4.7%	4.5%	68309	88.36	4.8%	100.0*	19*	1.054	1546
1.95	82794	1986	1996	99.5%	9.0%	8.4%	82794	48.78	9.1%	100.0*	6	0.947	1836
1.74	91128	2275	2275	100.0%	19.6%	18.5%	91128	22.43	19.8%	99.7*	-3	0.854	2113
1.59	99814	2491	2480	100.4%	46.5%	45.0%	99814	9.52	47.1%	98.3*	0	0.832	2340
1.47	99707	2708	2719	99.6%	85.8%	89.6%	99707	4.29	87.0%	91.6*	-1	0.775	2547
1.38	67486	2895	2895	100.0%	131.6%	147.4%	67486	1.78	134.5%	58.6*	2	0.706	2745
1.30	34441	2863	3078	93.0%	192.3%	222.3%	34408	0.64	200.7%	10.7*	-2	0.619	2160
total	629558	19050	19267	98.9%	3.7%	3.7%	629525	38.44	3.7%	100.0*	2	0.880	17104



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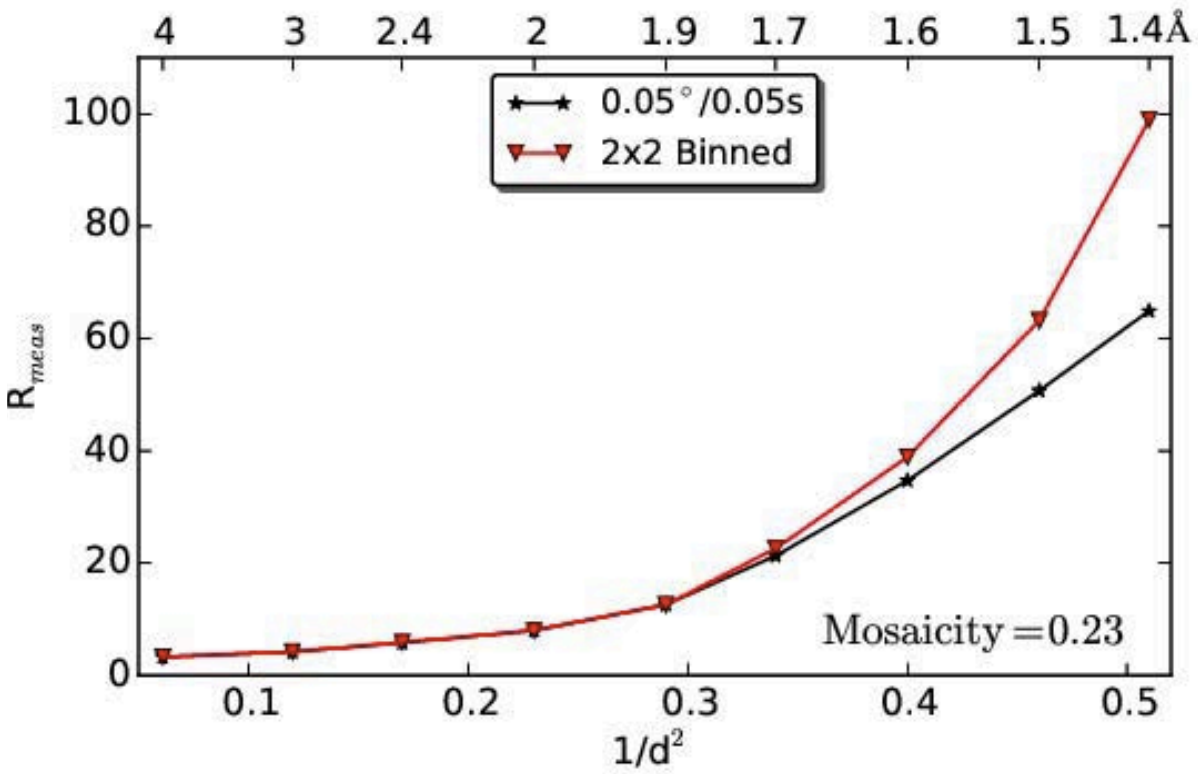
One second native-SAD experiment

Insulin data
8 keV (1.54 Å)
64 °/sec rotation speed
160 Hz frame rate

EIGER X 4M Data processing statistics for one second native-SAD data set ins
ROI

Resolution (Å)	R_{meas} (%)	$\langle I/\sigma(I) \rangle$	$CC_{1/2}$ (%)
6.81	2.2	62.86	99.9
4.85	2.1	59.52	99.9
3.97	2.2	55.75	99.9
3.45	2.6	47.17	99.9
3.08	3.9	32.67	99.8
2.82	5.9	19.53	99.6
2.61	9.4	10.91	99.8
2.44	13.4	6.05	97.3
2.30	24.4	2.99	91.9
total	2.8	29.59	99.9

EIGER - pixel size

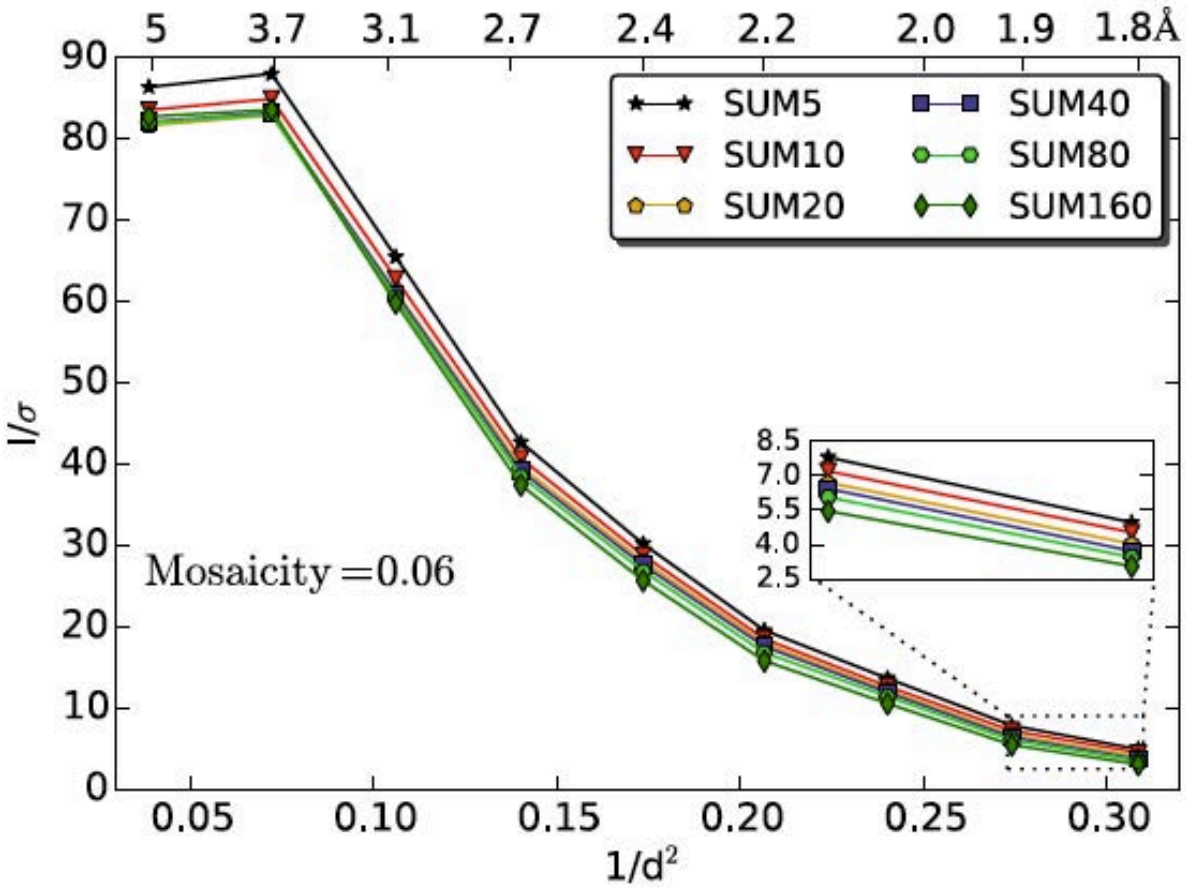


Effect of 2x2 binning on EIGER 1M data corresponding to data collection with four time larger detector pixels. Comparison of a lysozyme data set (lys_1) collected with an EIGER 1M with the same data set with all the diffraction images 2 x 2 binned.

Data processed with XDS and extracted from CORRECT.LP

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EIGER – ultra fine Φ-slicing



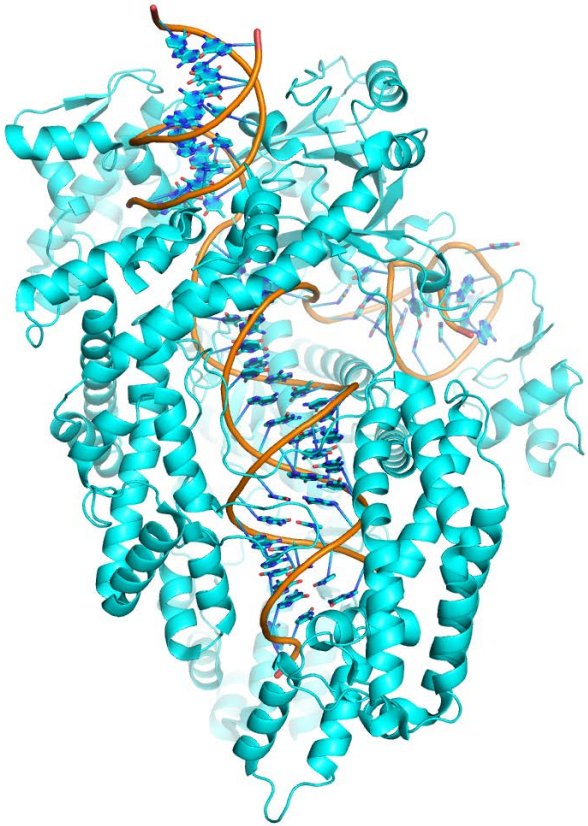
EIGER X 1M

ΔΦ 0.00125 °

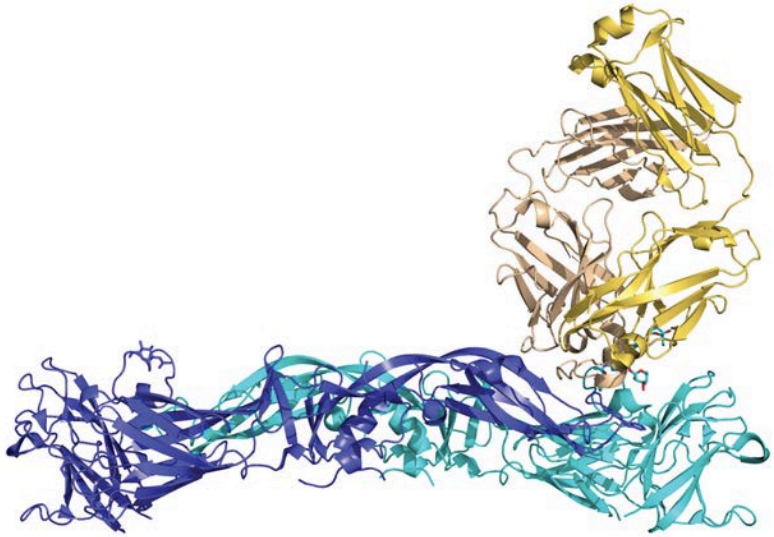
Summing of frames to simulate different oscillation angles

Rms-mosaicity	[°]
Lysozyme	0.23
Insulin	0.06

EIGER X for high impact crystallography



CRISRP-Cpf1 with crRNA and target DNA
Yamano et al. (2016) Cell 165:949
(EIGER X 16M)



Zika envelope protein with Fab fragment
Barba-Spaeth et al. (2016) Nature online
(EIGER X 9M)

EIGER User Experience

EIGER X 9M installed in LS-CAT, 21-ID-D, APS

Joshua Carter, Ardian Soca Wibowo,
Shamrock Structures LLC

EIGER increases the throughput in *industrial crystallography*

- 14-16 data-sets per hour with EIGER
- 8 - 10 with PILATUS
- 8 with Rayonix HS (> 0.5 deg, no fine-phi slicing)
- 4 with Rayonix

Visibly better data and spot to background ratio.



The Eiger 9M



Keith Brister
Northwestern University Synchrotron Research Center
LS-CAT

Brister TWG Meeting June 16, 2016

Conclusions

EIGER – high impact & high throughput

EIGER providing highest spatial resolution and ultimate speed

- *Continuous readout with > 99% duty cycle*
- *Ideally suited for XPCS, scanning beam applications (ptychography, scanning SAXS, nano-diffraction, etc.)*

Macromolecular Crystallography

- *Improved data quality thanks to smaller pixel*
- *Optimal fine phi-slicing angle: mosaicity / 10*
- *A posteriori optimisation of optimal oscillation angle*
- *Ideal for serial synchrotron crystallography*
- *Efficient compression (bit-shuffle – lz4)*

Acknowledgement

- *MX group at SLS, PSI*
- *cSAXS and microXAS teams at SLS*
- *Proxima II at SOLEIL*
- *LS-CAT at APS*
- *Kay Diederichs, Wolfgang Kabsch, Clemens Vonrhein*
- *beamline scientist & controls groups at various synchrotrons*
- *Herbert Bernstein, http://hdrmx.medsbio.org/*

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Thank you for your attention!

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