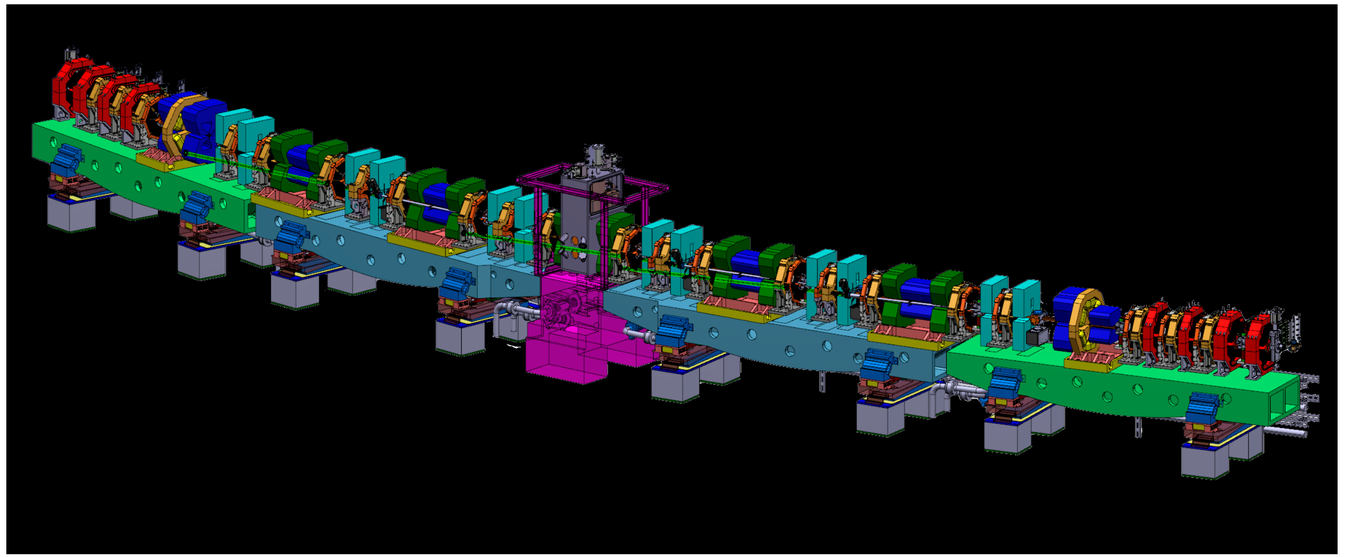
PAUL SCHERRER INSTITUT

PSI

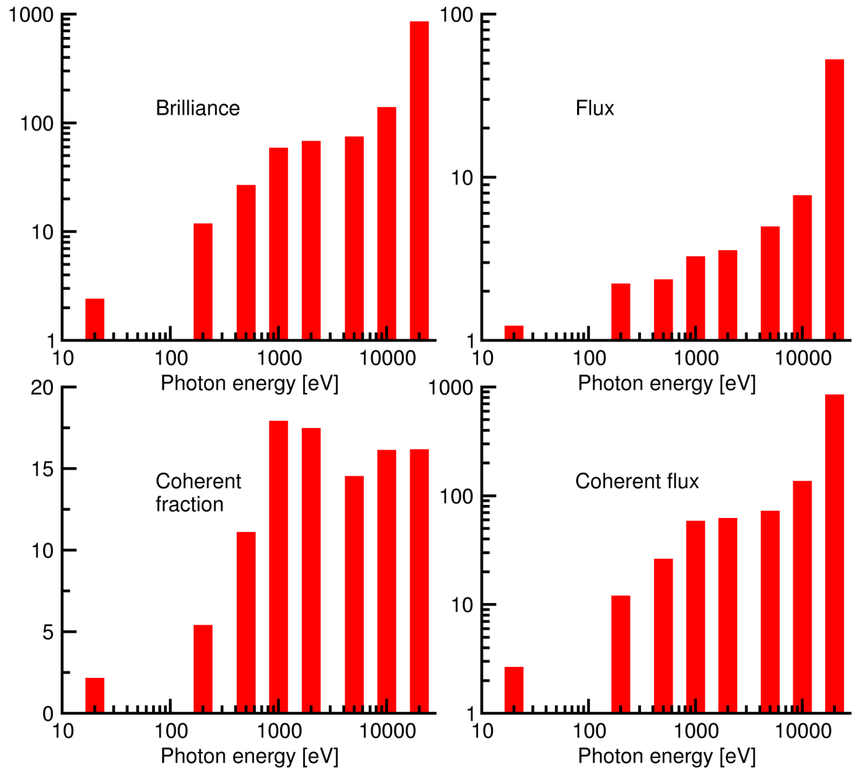
Bernd Schmitt :: Photon Science Detector Group :: Paul Scherrer Institut

Detector Development for Photon Science at PSI Facility Report

Upgrade of SLS to SLS2.0



- Electron energy: 2.7 GeV (previously 2.41 GeV)
- Maximum photon energy: 80 keV (previously 45 keV)
- Increase of coherent flux at cSAXS: ~40



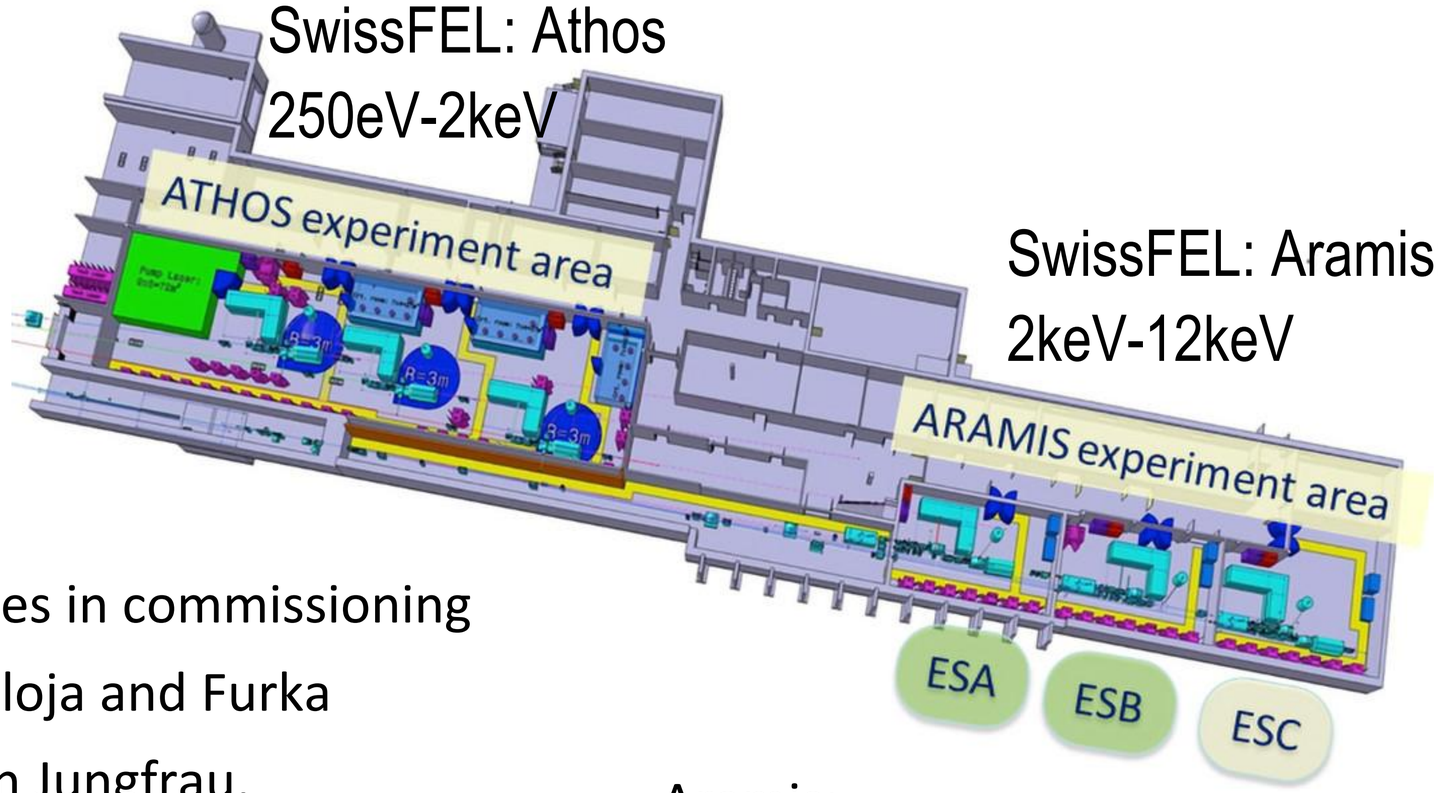
Tentative SLS2.0 schedule

	2023												2024												2025												2026											
	Q1			Q2			Q3			Q4			Q1			Q2			Q3			Q4			Q1			Q2			Q3			Q4			Q1			Q2			Q3			Q4		
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Overall	SLS user operation									Dark period																				SLS2 user operation with reduced number of beamlines						shutdown			com-mis-sioning			SLS2 User operation					
Machine	"									Dismantling SLS			Installation new ring												Beam commissioning and vacuum conditioning						user operation						ScSB & BI-Gr2 ld installation			SB com-mis-sioning			user oper-ation			user operation		
Beamlines group 1	"									installations, modifications and upgrades as 2nd priority															inst., modif. and upgr. 1st priority			commissioning									modifi-cations			com-mis-sioning								
Beamlines group 2	"									installations, modifications and upgrades as 3rd priority															inst., modif. and upgr. 2nd priority			installations, modifications and upgrades as 1st priority						front end completion			commissioning								

Group 1: PX1,2,3, SX-ARPES, MS, I-TOMCAT, SIM, cSAXS, RIXS

Group 2: 3 x SCSB BLs, PolLuX, XIL, VUV, microXAS, QUEST, Phoenix/Xtreme

SwissFEL: low energy branch Athos and Cristallina endstation at Aramis



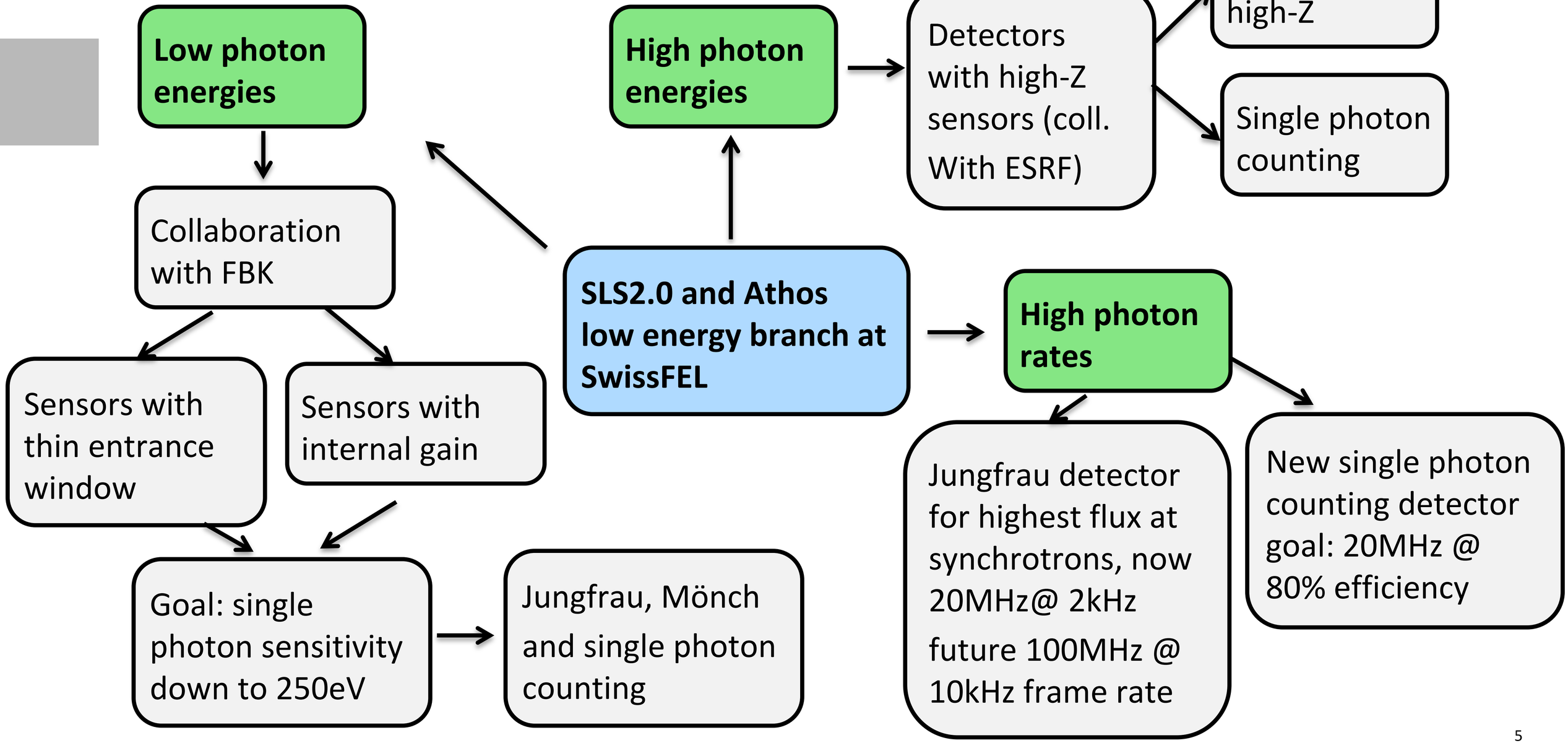
Athos:

- First light, beamlines in commissioning
- 2 end stations: Maloja and Furka
- Detectors based on Jungfrau, commercial detector for RIXS

Aramis:

- Third endstation Cristallina for SFX
- 9M Jungfrau

Overview


Low photon energies
Collaboration with FBK
Sensors with thin entrance window
Sensors with internal gain
Goal: single photon sensitivity down to 250eV
Jungfrau, Mönch and single photon counting
High photon energies
Detectors with high-Z sensors (coll. With ESRF)
Jungfrau with high-Z
Single photon counting
SLS2.0 and Athos low energy branch at SwissFEL
High photon rates
Jungfrau detector for highest flux at synchrotrons, now 20MHz@ 2kHz
future 100MHz @ 10kHz frame rate
New single photon counting detector goal: 20MHz @ 80% efficiency

Detector projects I

Installation of Mythen3: → see talk from Anna Bergamaschi

Gotthard2 development (with EU-XFEL) all modules to EUXFEL this year: →see talk Jiaguo Zhang and Marco Ramilli

Installation of Jungfrau detectors at PSI (hard x-rays):

- 9M and 1.5M Jungfrau for Cristallina endstation at SwissFEL (in 22)
- 4M (this year) and 10M Jungfrau Detector for MX at SLS (in 22)

  → High data rate: 2.2kHz 20Mbyte/image: 44Gbyte/s

    → Work on specific data backend using IBM Power9 and in FPGA data conversion

Detector projects II

Low x-ray energies (250eV-2keV):

- Collaboration with FBK for the development of sensors with a thin entrance window and LGADs

  → will soon get a batch with variations to optimize entrance window

  → will get a first iLGAD batch with thin entrance window in September

- Detectors at Athos based on Jungfrau with thin entrance window sensors from FBK:
  Maloja: first 4M Jungfrau detector will be installed after eastern
  second 4M later this year
  Furka: 1M for diffraction in UHV RIXS chamber this year, commercial detector for RIXS
  → see talk from Aldo Mozzanica

will probably be replaced with new FE modules with new sensors with higher QE in 22

Detector projects III

Full size Mönch: currently 400x400 channels (1x1 cm^2)

→ 2 x 3cm^2 with 4x3cm^2 modules

New single photon counting detector for SLS2:

- Goal: increased count rate capability: 20MHz/channel at >80% efficiency
  compatible with electron and hole collection (std Silicon sensors, LGADs and high-Z)
  will most likely use 100G readout board, frame rate still undefined a few to 10KHz

For use at SLS2 and at cSAXS potentially very larger detector (>49M)

Higher frame rates:

- Currently limited by 2x10Gbit links on Jungfrau and Eiger readout boards
  → started to work on new 100Gbit readout board
  → will be used for Jungfrau2 and new single photon counting detector
  → Jungfrau2 at ~6-10kHz

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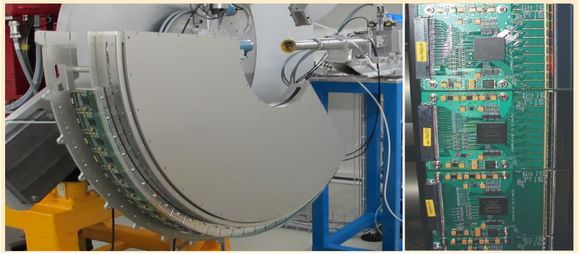
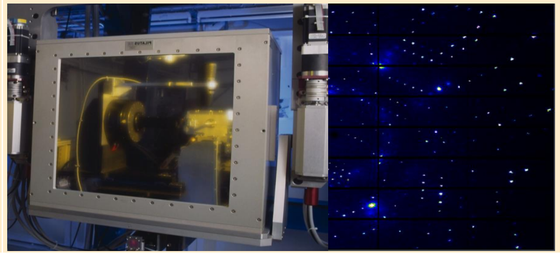
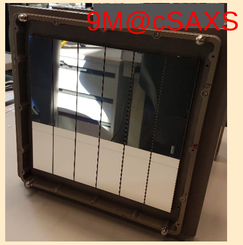
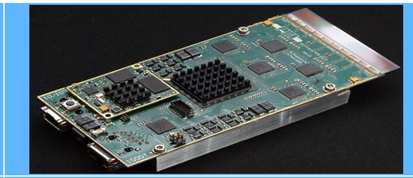
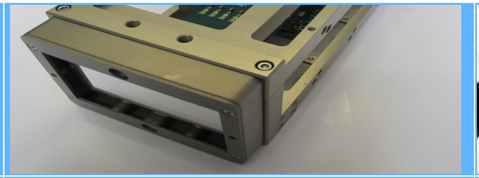
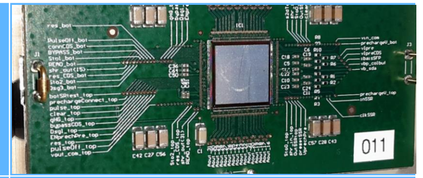
Single Photon Counting Detectors (since 1999)

	MYTHEN	PILATUS	EIGER
			 9M@cSAXS
Status	at beamline	at beamline	9M at beamline
Pixel size	**50 µm x 8mm (Strips)**	172 x 172 µm^2	**75 x 75 µm^2**
Maximum system size	**120º (=48 modules)**	**6M (=42 x 43 cm^2)**	**9M (=23 x 23 cm^2)**
Minimum threshold	< 5 keV	**< 2 keV**	**< 2.5 keV**
Count rate capability	0.6 MHz/Strip (10% deviation, Standard)	0.5-1.0 MHz/Pixel (10% deviation)	0.2-0.7 MHz/Pixel (10% deviation)
Maximum frame rate	**1 kHz/Module**	300 Hz/Module	**23 kHz (4-bit)**
Applications **(Examples)**	•Powder Diffraction •Energy dispersive Spectrometer •Beam Position Monitors	•Protein Crystallography •Time-resolved experiments •Small and wide-angle X-Ray Scattering (SAXS/WAXS)	•Protein Crystallography • XPCS • Coherent X-Ray Imaging • Photoelectron detection

Charge integrating detectors (since 2008)

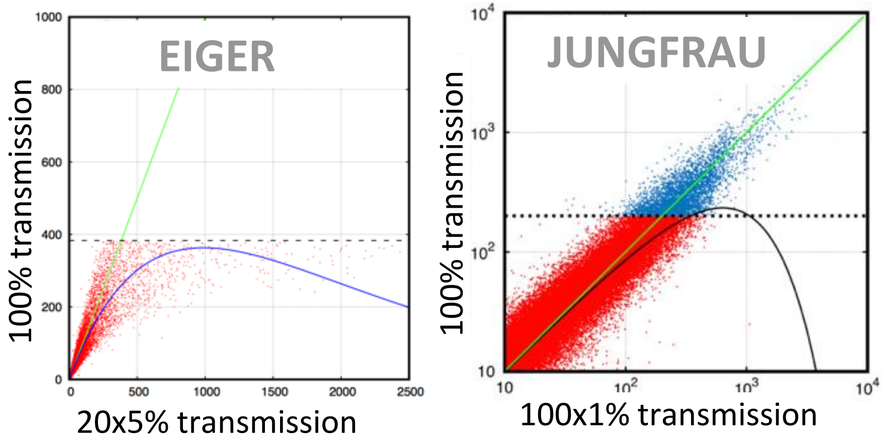
	GOTTHARD[1]	AGIPD[2]	JUNGFRAU	MÖNCH
				
Status	Modules available	At beamline (EUXFEL)	2x 16M at SwissFEL	(Advanced) Prototyping
Pixel size	50 µm (Strips)	200 x 200 µm^2	**75 x 75 µm^2**	**25 x 25 µm^2**
Maximum system size	Modules (=10 ASICs)	1Mpixel (=16 Modules)	16Mpixel (=32 Modules)	Single Chips (=2x3 cm^2)
Noise (r.m.s.)	<200 e$^-$ ENC	< 322 e$^-$ ENC < 214 e$^-$ ENC (HG)	**< 100 e$^-$ ENC (G0)** **< 55 e$^-$ ENC (HG0)**	**<35 e$^-$ ENC**
Dynamic range	**< 1·10^4 x 12.4 keV (3 gain stages)**	**< 1·10^4 x 12.4 keV (3 gain stages)**	**< 1·10^4 x 12.4 keV (3 gain stages)**	< 500 x 12.4 keV (2 gain stages)
Maximum frame rate	40 kHz (cont.) 1 MHz (burst)	**< 5 MHz (burst*)** *** 352 frames**	**2.4 kHz (cont.)** **< 1 MHz (burst)**	**6-8 kHz (cont.)**

[2] Common development with University of Bonn (GER), University of Hamburg (GER) and DESY (GER), [1] Common development with Desy

Benefits of charge integrating JUNGFRAU for MX

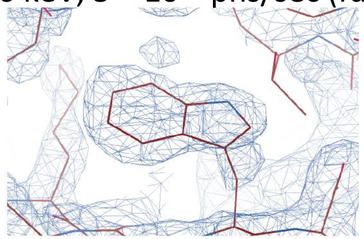
in collaboration with M.Wang et al., SLS PX1

EIGER rate limited by pile-up → JUNGFRAU enables faster data collection



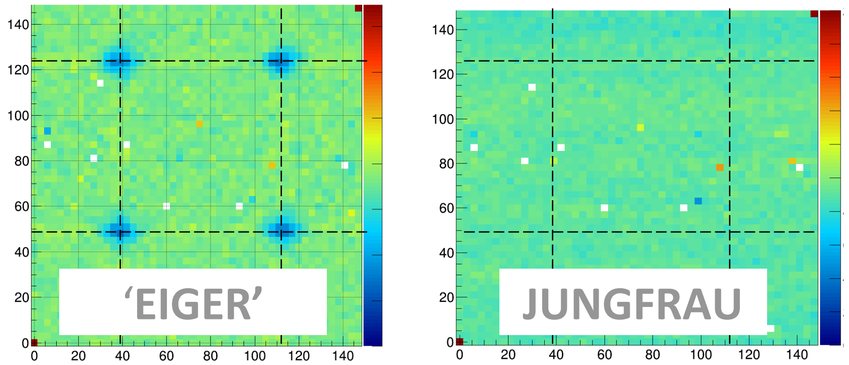
"Easy" native-SAD in 600 ms

- Thaumatin
- 100°/sec, 60°
- 6 keV, 5 × 10^{11} phs/sec (full beam)

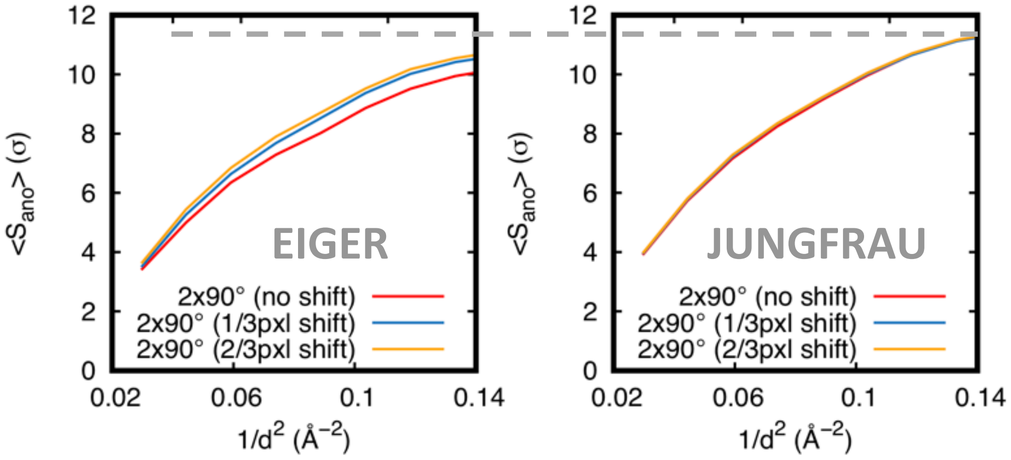


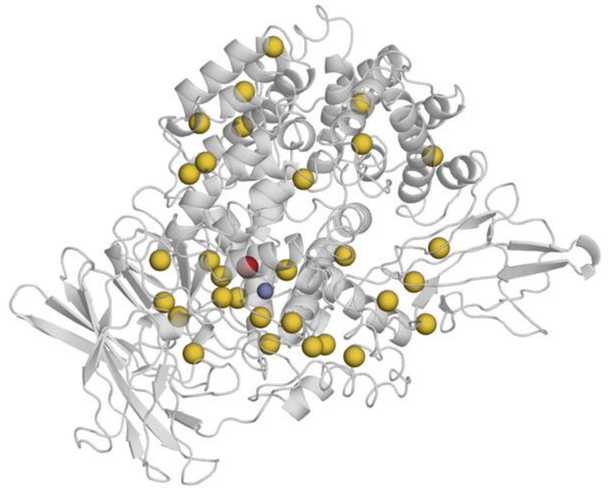
JUNGFRAU charge integrating detector compared with EIGER single photon counting detector
- same pixel, module, detector size
- almost the same sensor thickness

EIGER loses efficiency in the corner of pixels → JUNGFRAU provides better data quality



20 keV pencil beam scans





"Real-life" native-SAD in 60 s

- Aminopeptidase, 101 kDa
- 10°/sec, 600°
- 6 keV, 5 × 10^{11} phs/sec (full beam)

Leonarski et al., Fast and accurate data collection for macromolecular crystallography using the JUNGFRAU detector, *Nature Methods*, 2018