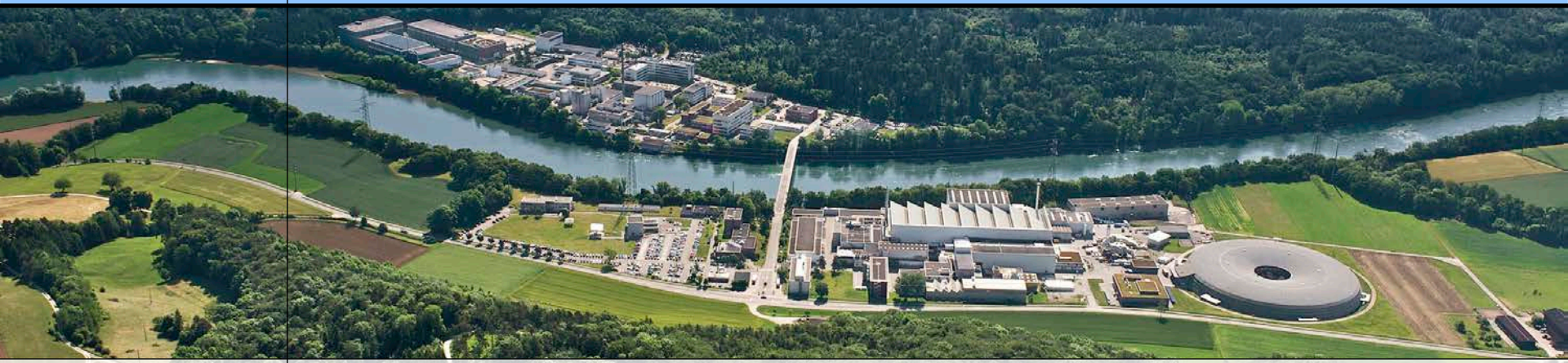
PAUL SCHERRER INSTITUT

PSI



Wir schaffen Wissen – heute für morgen

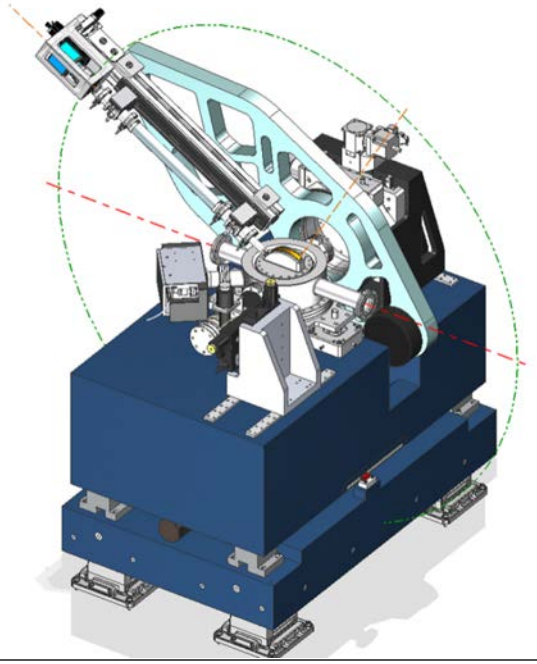
Paul Scherrer Institut

Pavle Juranić, R. Ischebeck, L. Patthey, V. Schlott, C. David, C. P. Hauri, I. Gorgisyan

Single Shot Spectrometer and Pulse and Arrival Time Monitor Progress

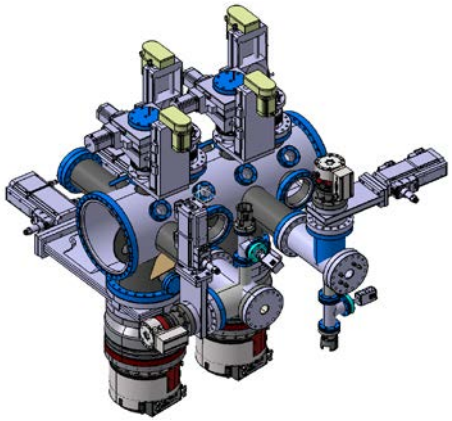
Introduction

Photon Single-Shot Spectrometer (PSSS)

- X-ray spectrometer for SwissFEL.
- Measures 0.5% of FEL bandwidth every shot.
- Resolution on the order of 10^{-5}.
- 

Pulse Arrival and Length Monitor(PALM)

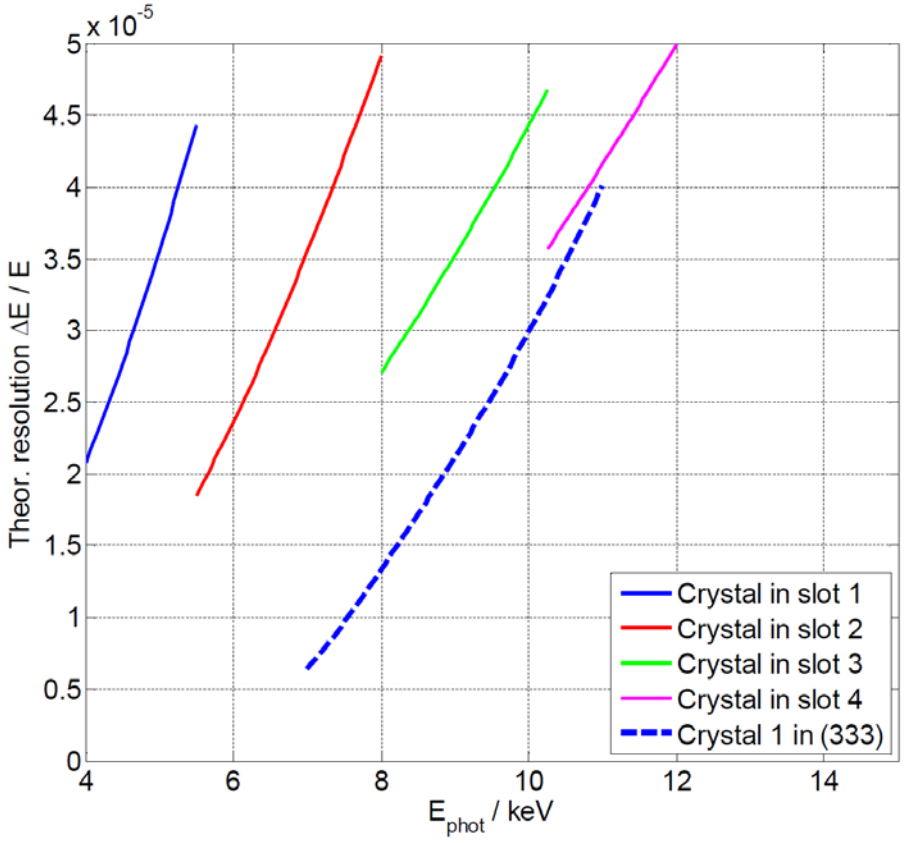
- FEL X-ray pulse length and arrival time measurement.
- 5 fs RMS arrival time and pulse length accuracy.
- Measurements relative to the user (probe) laser.
- Non-destructive for FEL beam.



PSSS: basic concept

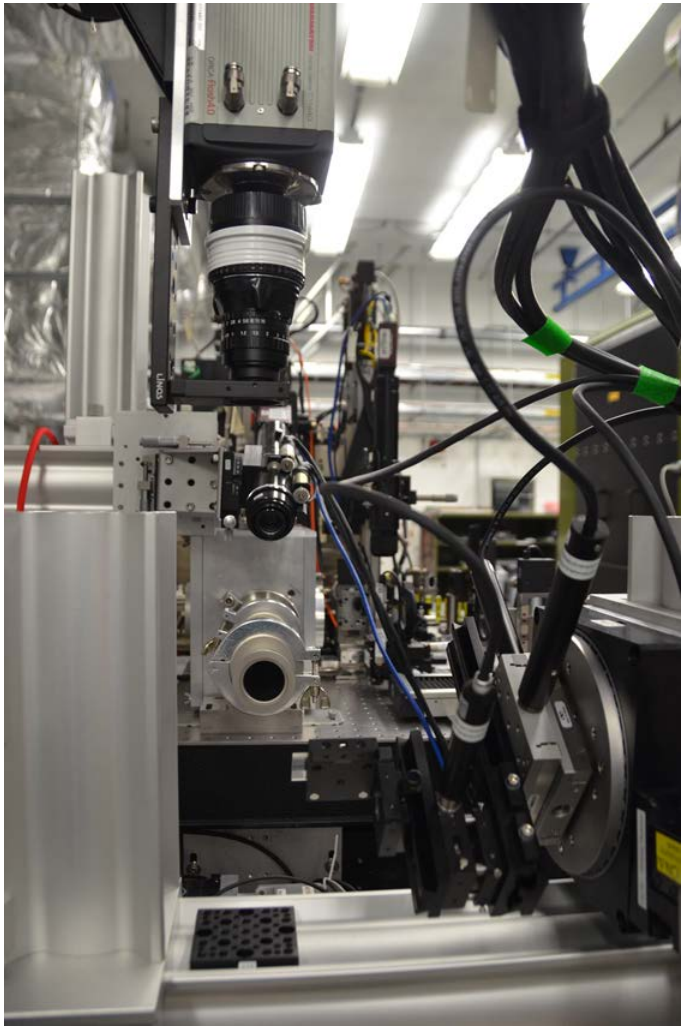
- Use Bragg reflections and bent Si crystals for spectrometer. Crystals with different orientations and radii for different energies. Idea already used at LCLS (Zhu et al., Appl. Phys. Let. 101, 034103 (2012)).

Slot #	Orientation	R / mm	Energy range / keV
1	(111)	155	4 – 5.5
2	(220)	75	5.5 – 8
3	(220)	145	8 – 10.25
4	(220)	200	10.25 – 12

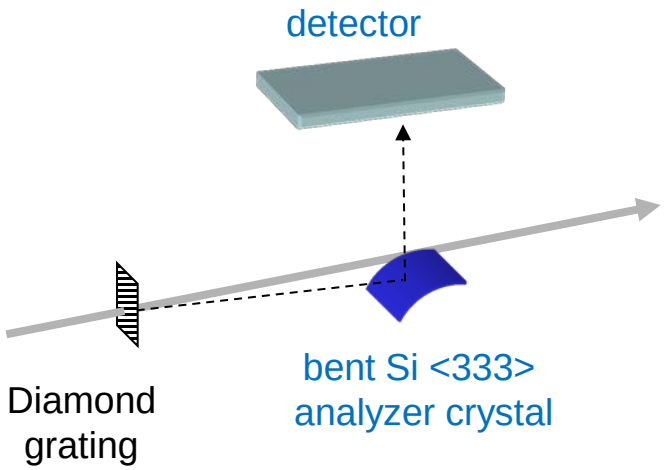


PSSS: Make it non-desctructive

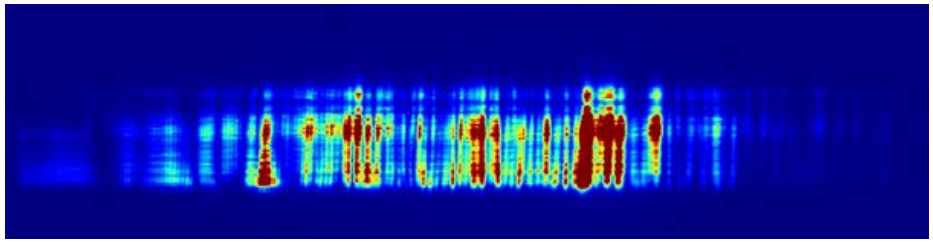
- Add a diamond diffraction grating that peels off a portion of the FEL light and sends it into the spectrometer (Karvinen et. al., Opt. Lett. 37, 5073 (2012)).

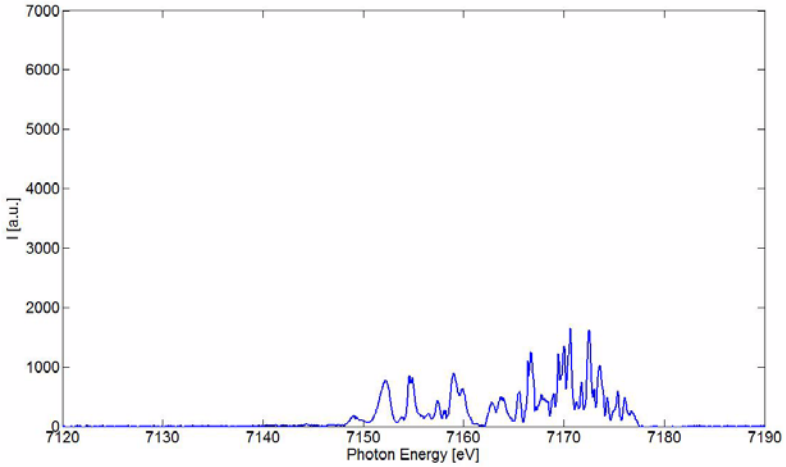


Shot-to-shot spectral analysis of X-FEL radiation



- Tested at LCLS in collaboration with SwissFEL and SLAC
- Excellent resolution: 0.1 – 0.2 eV

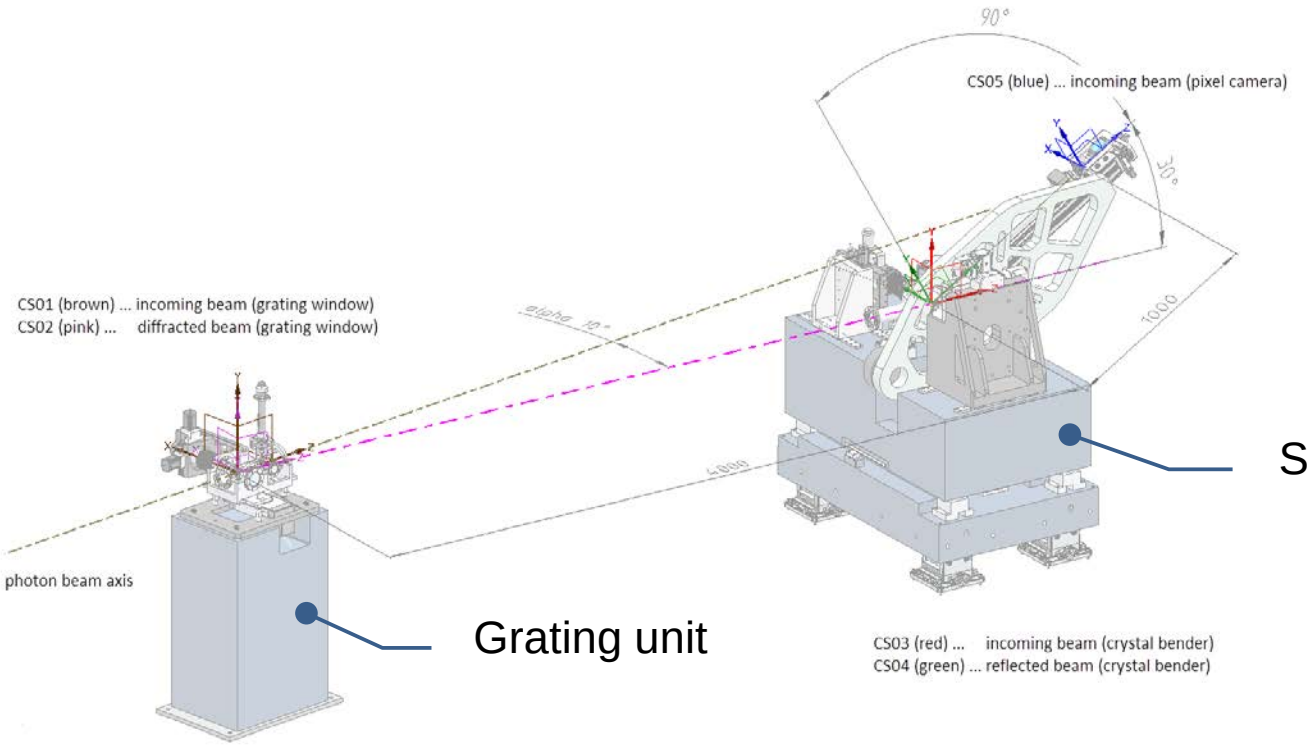




Courtesy of Dr. Mikako Makita

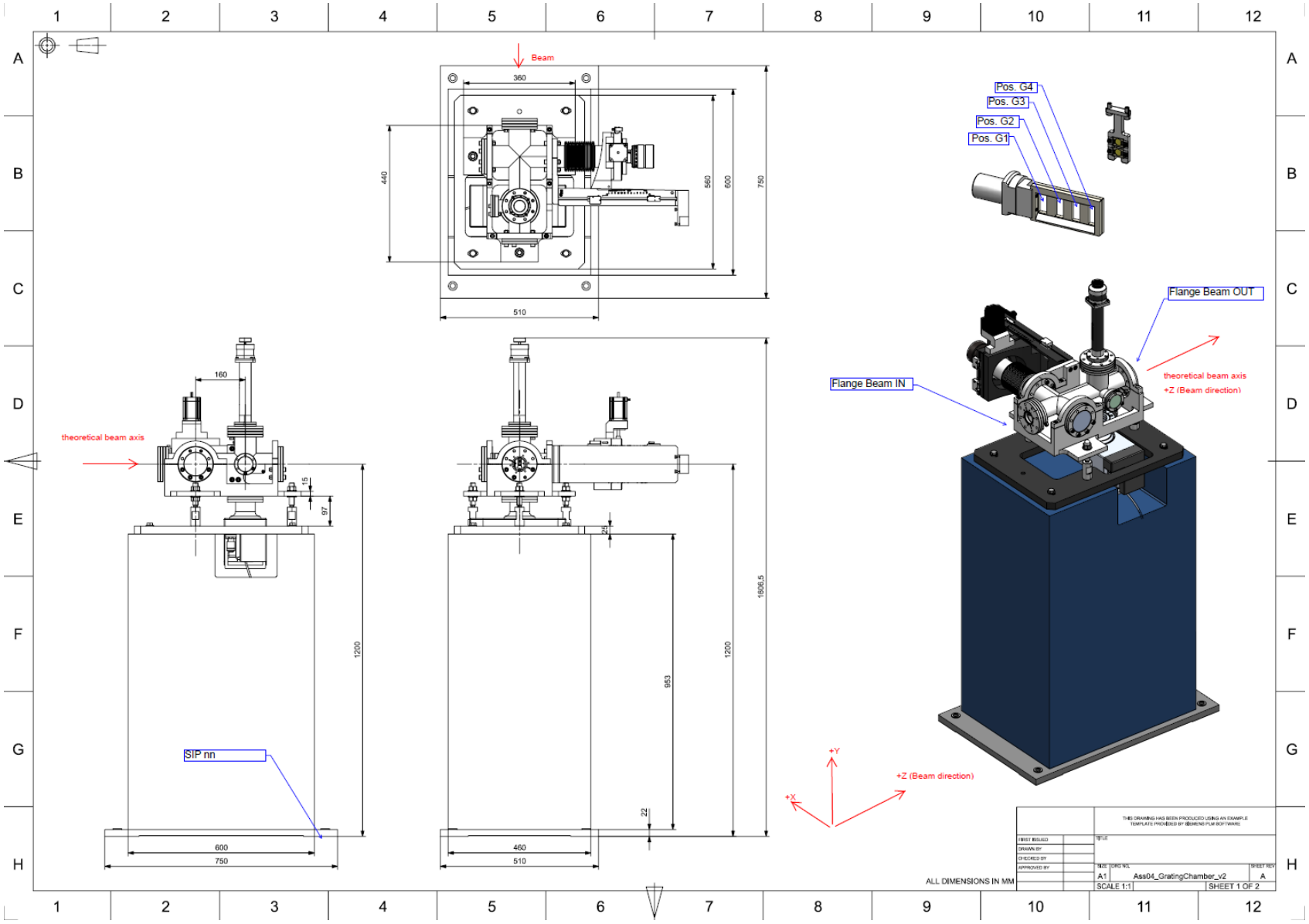
PSSS components

- Combine it all in vacuum, and along the beam, in the tunnel of SwissFEL:

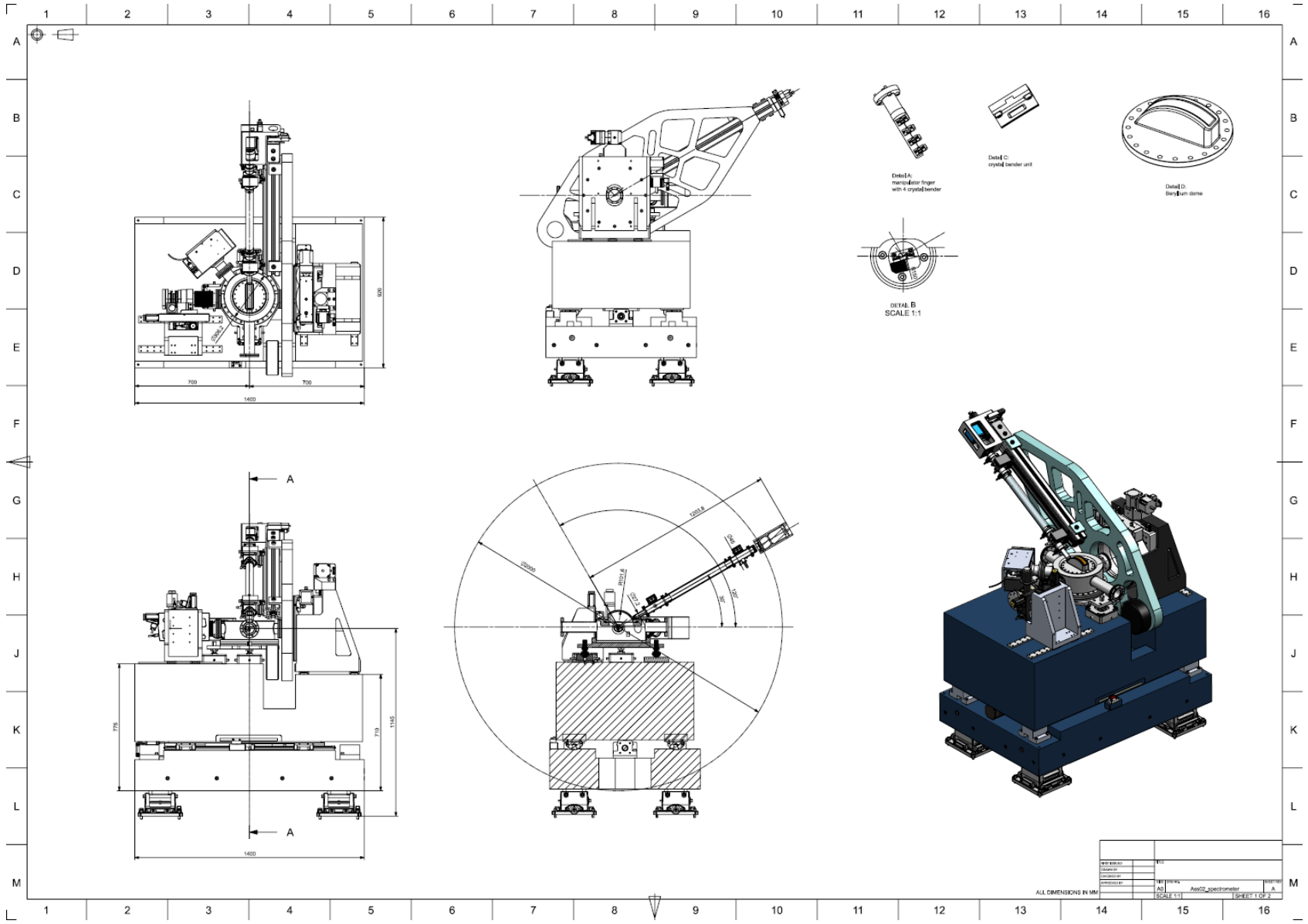


Spectrometer unit

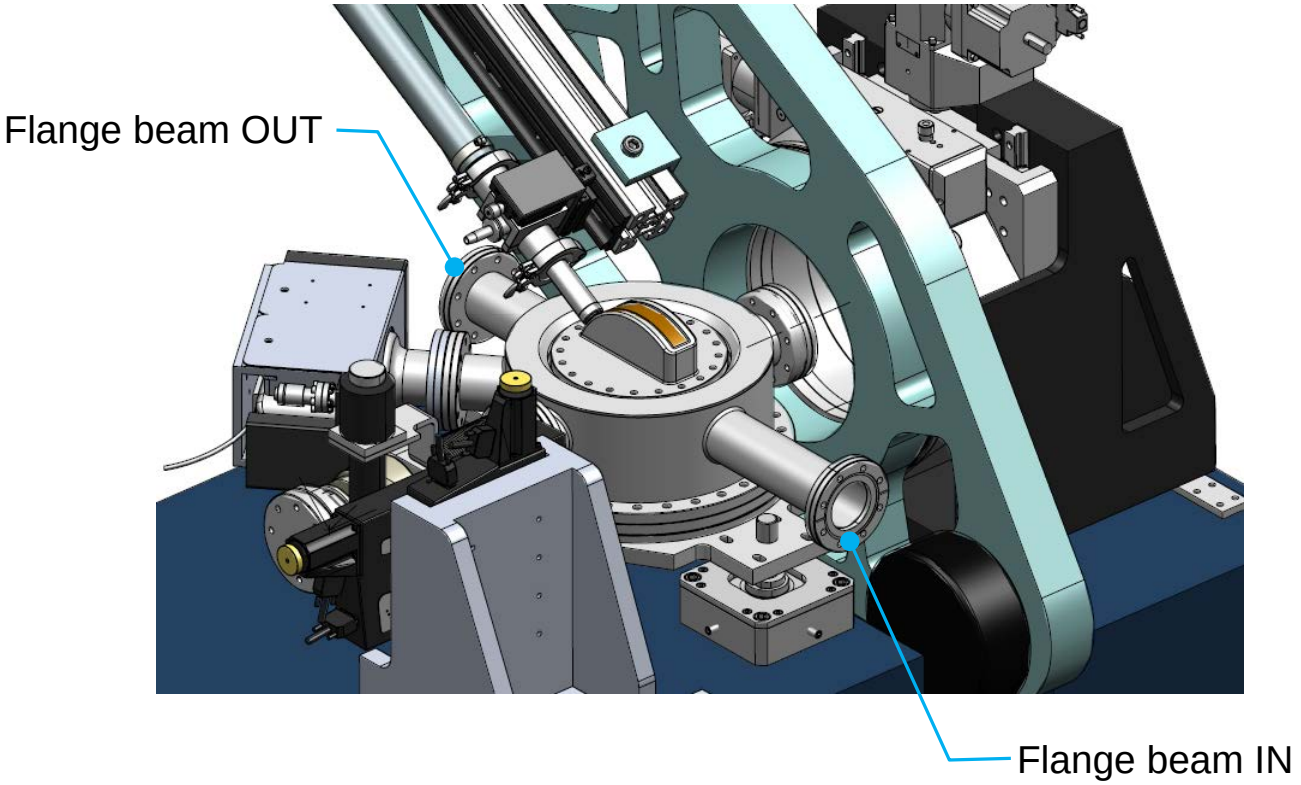
PSSS Grating Unit



PSSS Spectrometer Unit

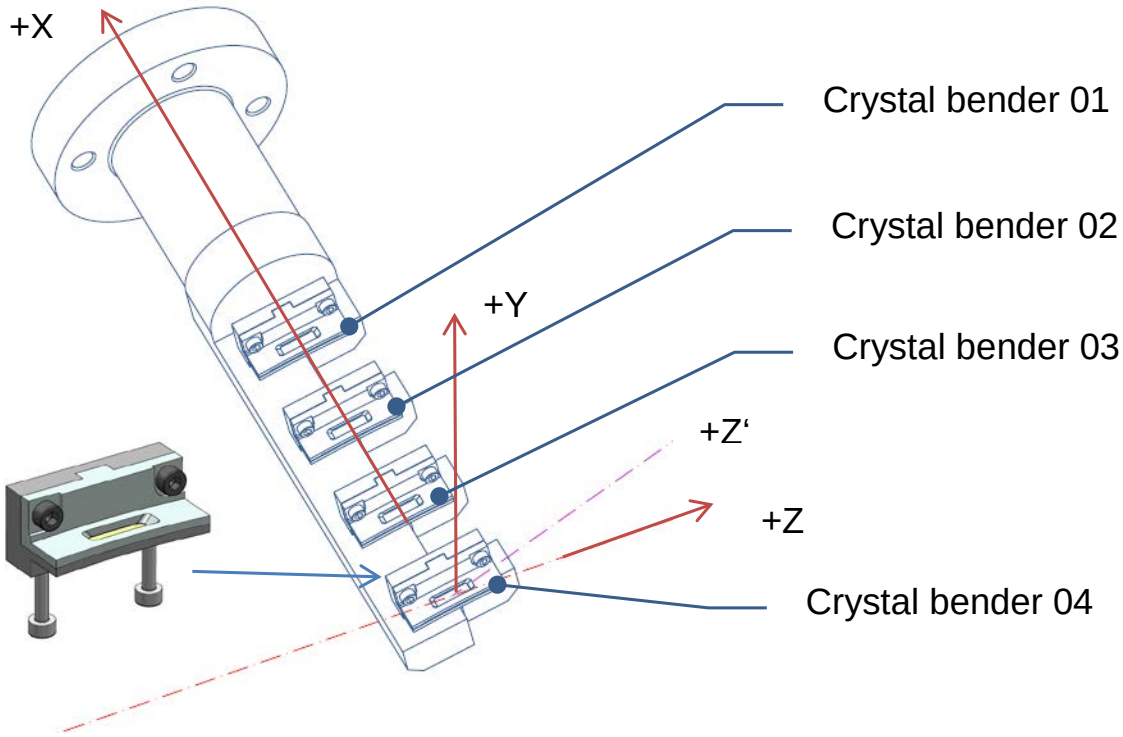


PSSS: Spectrometer Unit Closeup



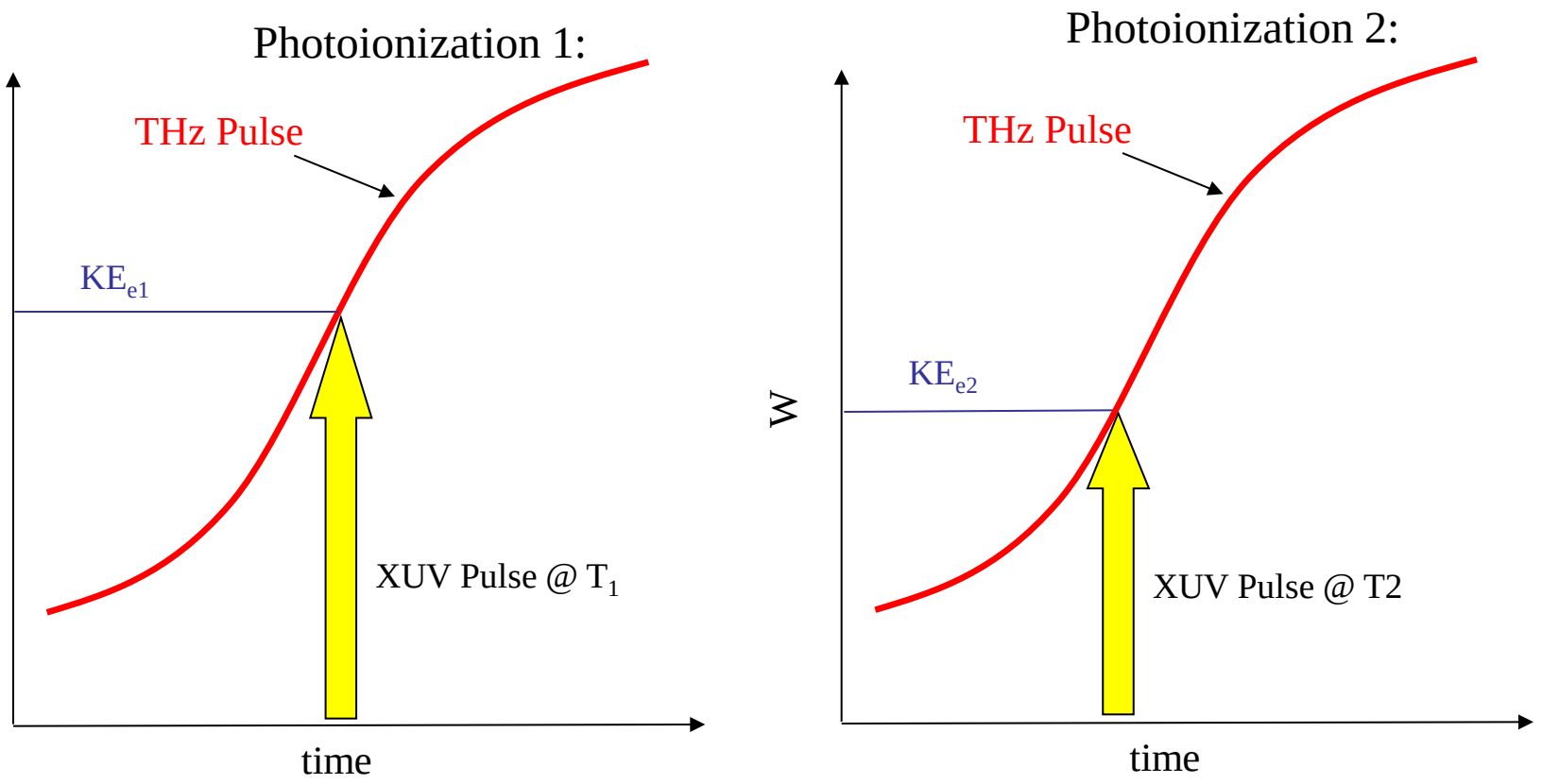
PSSS: Last Challenges

- The bent crystal holders are being tested for an optimum design that would give us the minimum of fuss, and the easiest mounting method.



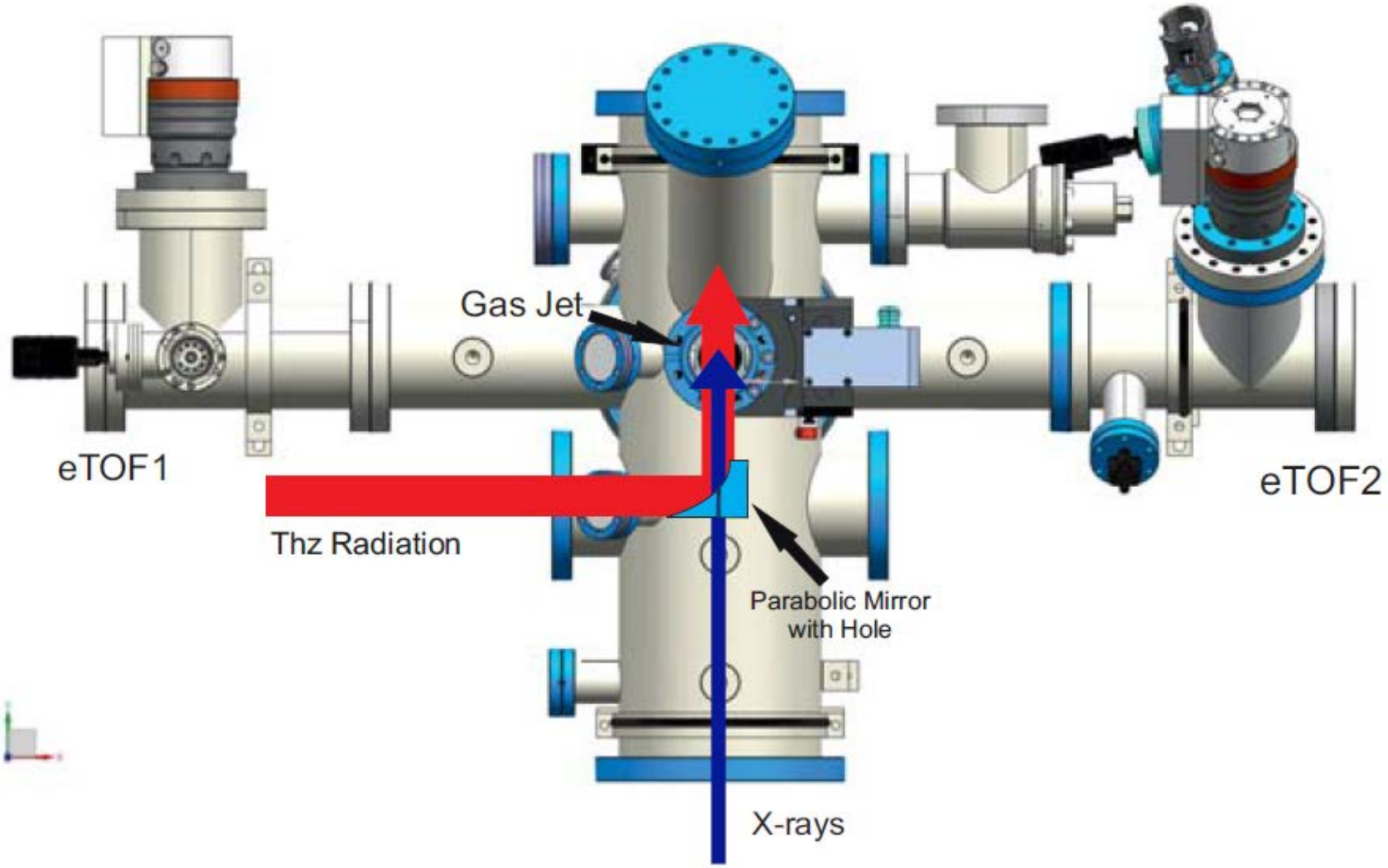
PALM: basic concept

- Uses the THz streak camera concept to measure the arrival time and pulse length of FEL x-ray pulses (U. Fruehling et. al., Nature Photon. 3 523 (2009), I. Grguras et al., Nature Photon. 6 852 (2009)).



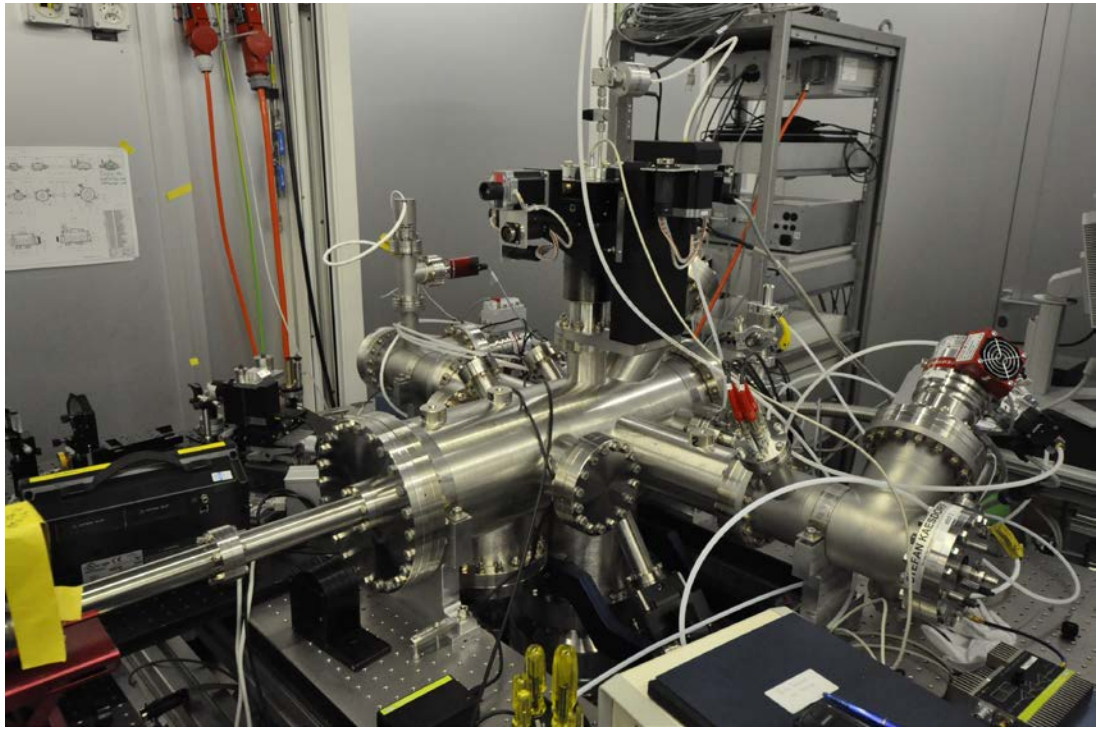
KE_{e2}-KE_{e1} ➡ T_2-T_1

PALM: prototype design



PALM: prototype testing

- Initial tests of PALM done with HHG source at PSI (P. Juranić et. al., JINST 9 P03006 (2014)).



- Later on, the prototype was taken to SACLA for tests with FEL X-ray pulses (P. Juranić et. al., Opt. Expt. 22, 30004 (2014).)

PALM @ SACLA

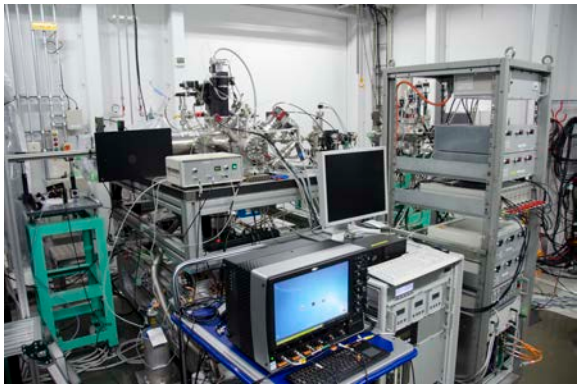
Team Members:

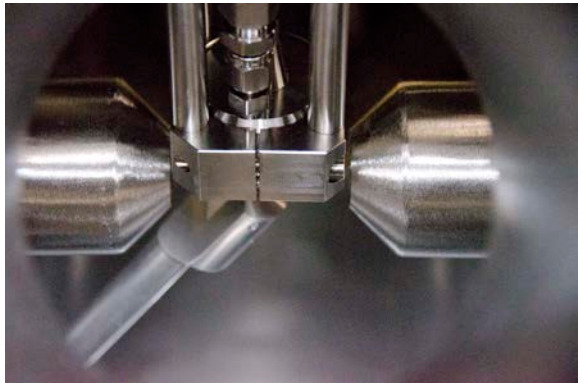
PSI:
Pavle Juranić
Luc Patthey
Rasmus Ishebeck
Ishkhan Gorgisyan
Andrey Stepanov
Claude Pradervand
Beat Rippstein
Milan Radovic
Balazs Monoszlai

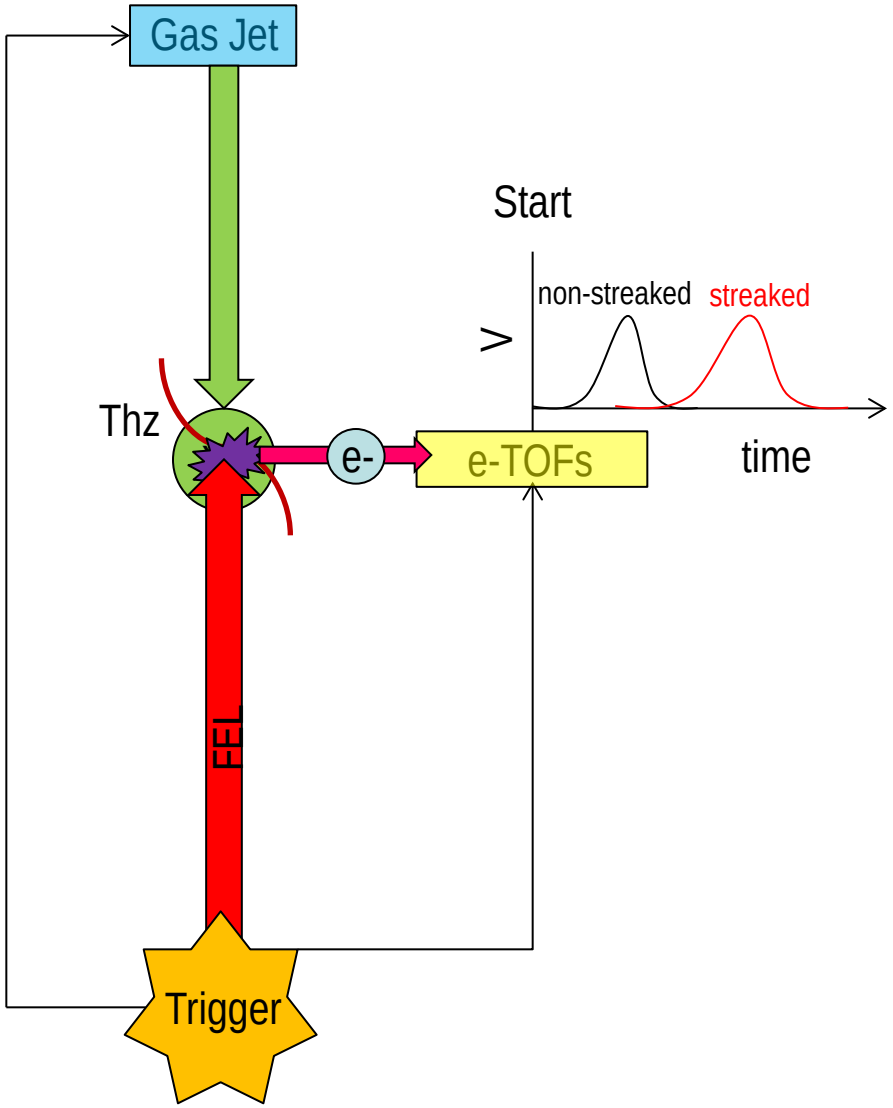
SACLA:
Makina Yabashi
Ogawa Kanade
Tadashi Togashi
Sigeki Owada

DESY:
Rosen Ivanov

XFEL.EU:
Jia Liu

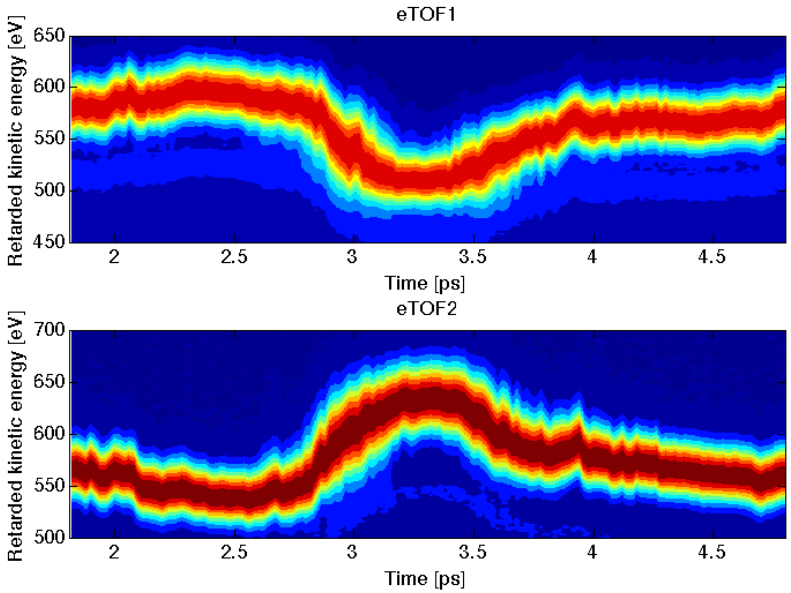






PALM @ SACLA: measurement

Streak scan for the Xe $2p_{3/2}$ electrons at a photon energy of 10 keV. 100 spectra were taken at each time step.



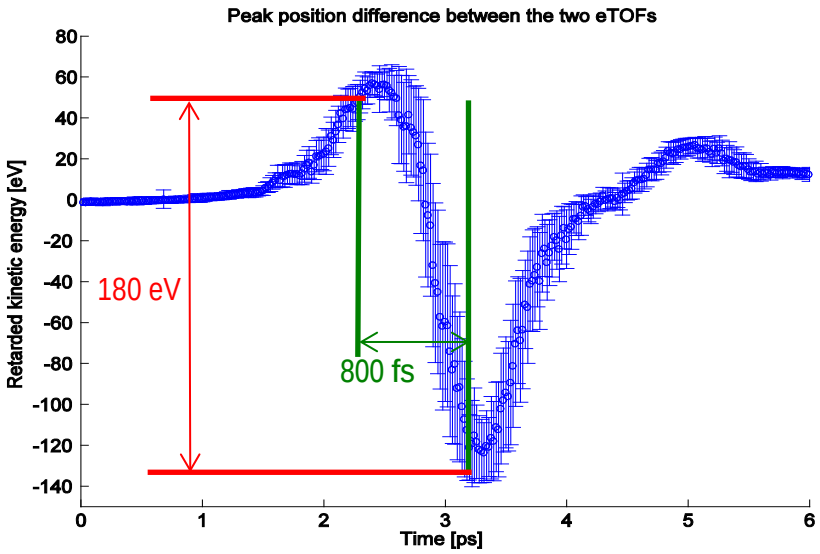
1

2

We get rid of the error due to the photon energy jitter by taking the difference between the two sets of signals. The vertical bars show the RMS distribution of peak positions at each time step.

1 - 2

Photon energy jitter correction



The analysis of the difference of the spectra yield the accuracy of the streak measurement (when convoluted with the eTOF resolution)

E-TOF Mean Peak Energy Accuracy: 0.5-1.2 eV RMS

Streak Slope: 0.15-0.35 ev/fs ($h\upsilon$ dependent)

FEL vs Laser Jitter: 100-150 fs RMS

PALM @ SACLA: FEL vs. Laser Jitter

Photon Energy, mode	Arrival time jitter (rms)	Estimated Accuracy
5 keV, pink	141 fs	6.9 fs
6 keV, pink	99 fs	9.5 fs
7 keV, pink	121 fs	6.8 fs
8 keV, pink	95 fs	5.1 fs
9 keV, pink	172 fs	4 fs
10 keV, pink	119 fs	5.8 fs
6 keV, mono	152 fs	4.7 fs
7 keV, mono	152 fs	9.5 fs
8 keV, mono	91 fs	7.5 fs
9 keV, mono	157 fs	8 fs

P. Juranić et. al., Opt. Expt. 22, 30004 (2014).

- Accuracy is a combination of the e-TOF mean energy measurement jitter and steepness of the THz streaking slope.

- The e-TOFs had to be set differently at every photon energy, which causes some variations in accuracy even for similar slopes. Practice will make it more consistent.

Matches other SACLA measurements quite well!

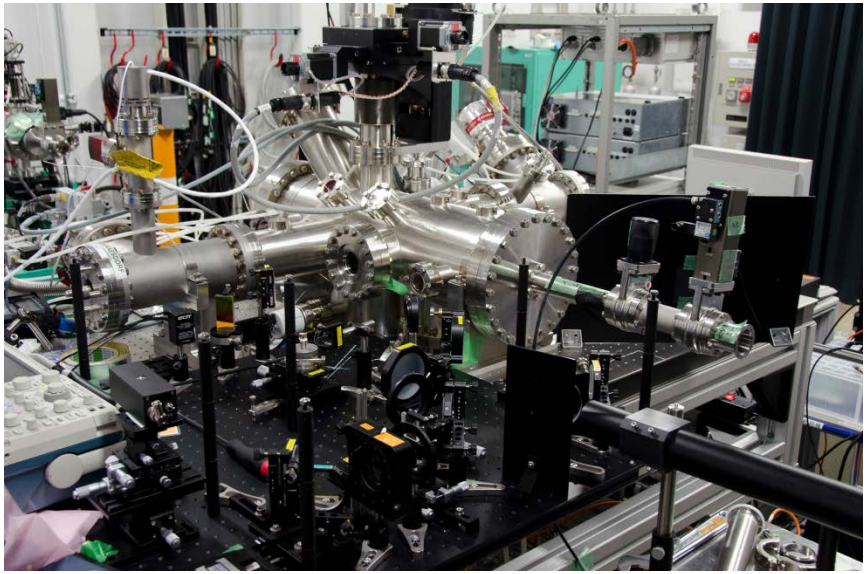
PALM@SACLA: summary

THz Setup:

- Laser: 800 nm, ~7 mJ input power, 3-5% intensity jitter
- Online monitoring of laser power shot-to-shot
- $LiNbO_3$ generation for THz pulse
- Pulse frequency about 0.52 THz
- Measured THz field in interaction region of about 50 kV/cm
- No air conditioning in hutch

FEL Parameters:

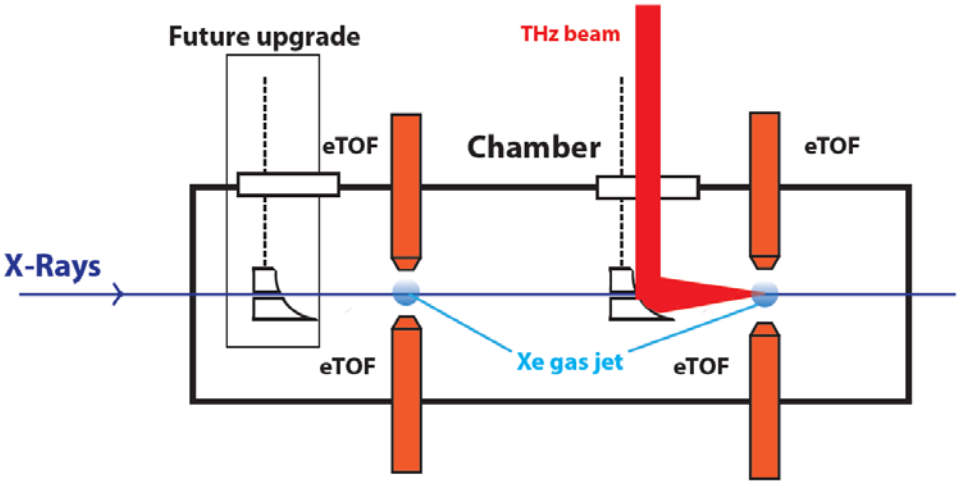
- Pulse energies between 120-250 μJ
- Used 5 keV, 6 keV, 7 keV, 8 keV, 9, keV, 10 keV, and 12.6 keV photon energies
- Measured with and without the monochromator at most photon energies
- Tested device with a 0.2 mm Si attenuator at 10 keV

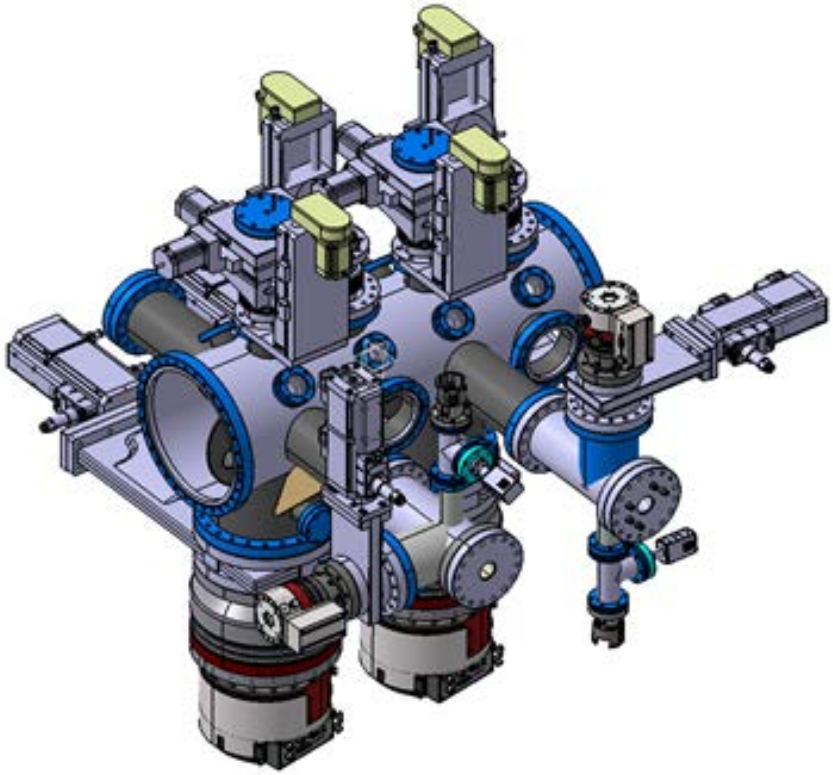


It all worked great!

PALM: final design

- Streaked and non-streaked interaction regions for shot-by-shot comparison.
- Double streak camera design allows for future upgrades to multi-cycle concept.





- Working to integrate design into SwissFEL end stations.
- Another beamtime at SACLA hopefully coming.
- Should be up and operational by late 2016!

Acknowledgments: Institutions

Many thanks to:
Jakub Szlachetko, Mikako Makita, Jan Gruenert, Nick Schlumpf, Patrick Pollet, Simon Ratihauser, Julia Smith, Elke Zimoch, Dirk Zimoch, Sven Reiche, Peter Peier, Ishkhan Gorgisyan, Beat Rippstein, Peter Wiegand, Peter Heimgartner, Chris Milne, Leonardo Sala, Timo Korhonen, Claude Pradervand, Peter Fischer, Peter Ming, Lothar Schulz, Gaiffi Nazareno, Dilling Zhu, Peter Huber, Rafael Abela, Helge Brands, Christian David, Petri Karvinen, Aldo Mozzanica, Dennis Armstrong, Adrian Cavalieri, Milan Radovic, Franziska Frei, Christoph Hauri, Goran Marinkovic, Makina Yabashi, Togashi Tadashi, Claude Pradervand, Leonid Rivkin, Rafael Abela the great nation of Japan, and many, many more.