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PSI

Wir schaffen Wissen – heute für morgen

Phase-I ARAMIS instruments:
Experimental Station A

Rafael Abela

Goals Agenda

Workshop format and goal:
A „hands-on“ working meeting to formulate concrete plans for the ESA station and to define the next steps in its realization.

Tentative agenda:

09:30 – 10:00	Applications and plans for ESA (R. Abela)
10:00 – 10:45	Experiments from FEMTO to SwissFEL (Ch. Milne)
10:45 – 11:30	The FXE Station at European XFEL (Ch. Bressler)
11:30 – 12:15	Single Shot XAS/XES (J. Szlachetko)
12:15 - 13:30	Lunch in the Oase Restaurant (PSI)
13:30 – 14:15	Detector Development (B. Schmitt)
14:30 – 16:00	Open discussion of additional user requirements
16:30 – 17:00	Summary, definition of next steps

Chronology

- SwissFEL Science Case (Sept. 2009)
- High-priority experiments (2010)
  - Biochemical structure and dynamics
  - Photochemistry in solution
  - Surface catalysis and artificial photosynthesis
  - Dynamics in nuclear materials
  - Switching in electronic materials
  - X-ray non-linear optics
- ARAMIS instrument workshops (12.9, 21.11.2011)
  - in Bern, 40 + 80 participants
- ES-A,B,C instrument workshops at PSI: 13.3, 27.3, 24.4, 22.5.2012
- Data Acq. / Scientific Computing at PSI: 19.6.2012
- Beamline and instrument scientists hired: 2012-2013
- ≥2 instruments ready for beam: mid 2016

Endstations new

2016	2016	2017	201X
ES-A	**ES-B**	**ES-C**	**ES-O**
Multi-purpose Pump-Probe	Pump-Probe Crystallography	Coherent diffraction imaging	“Others”

Endstations new

2016

ES-A

Multi-purpose Pump-Probe

2016

ES-B

Pump-Probe Crystallography

2017

ES-C

Coherent diffraction imaging

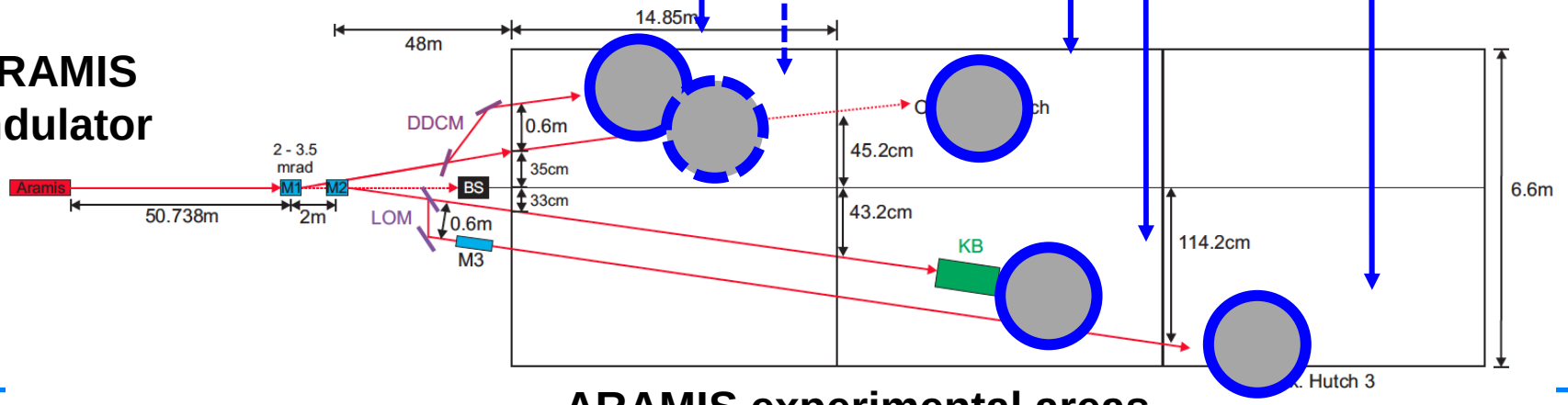
201X

ES-O

“Others”

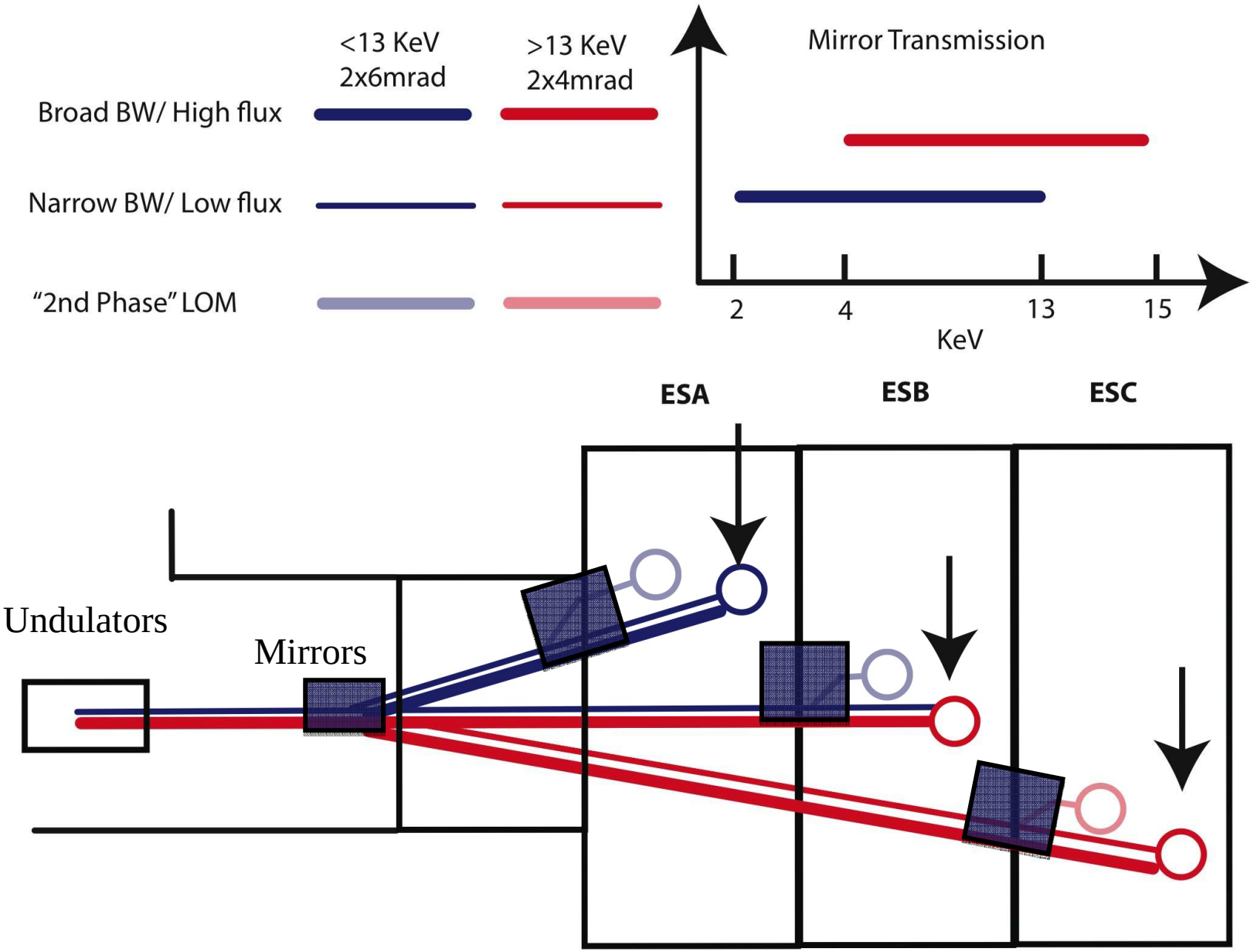
????

ARAMIS undulator

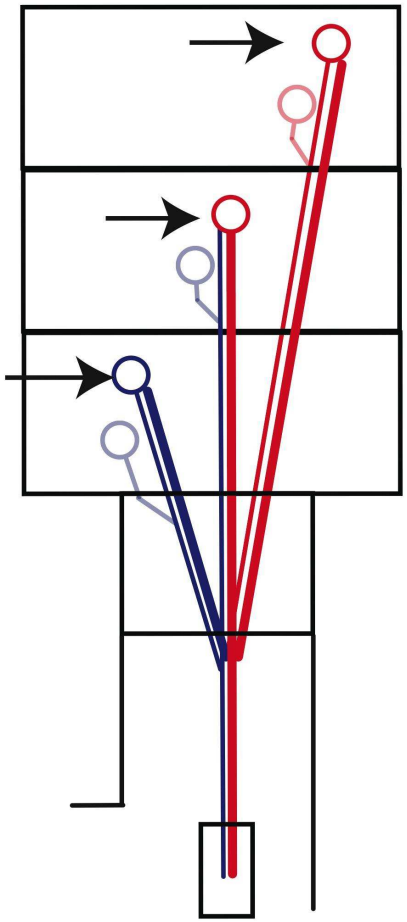


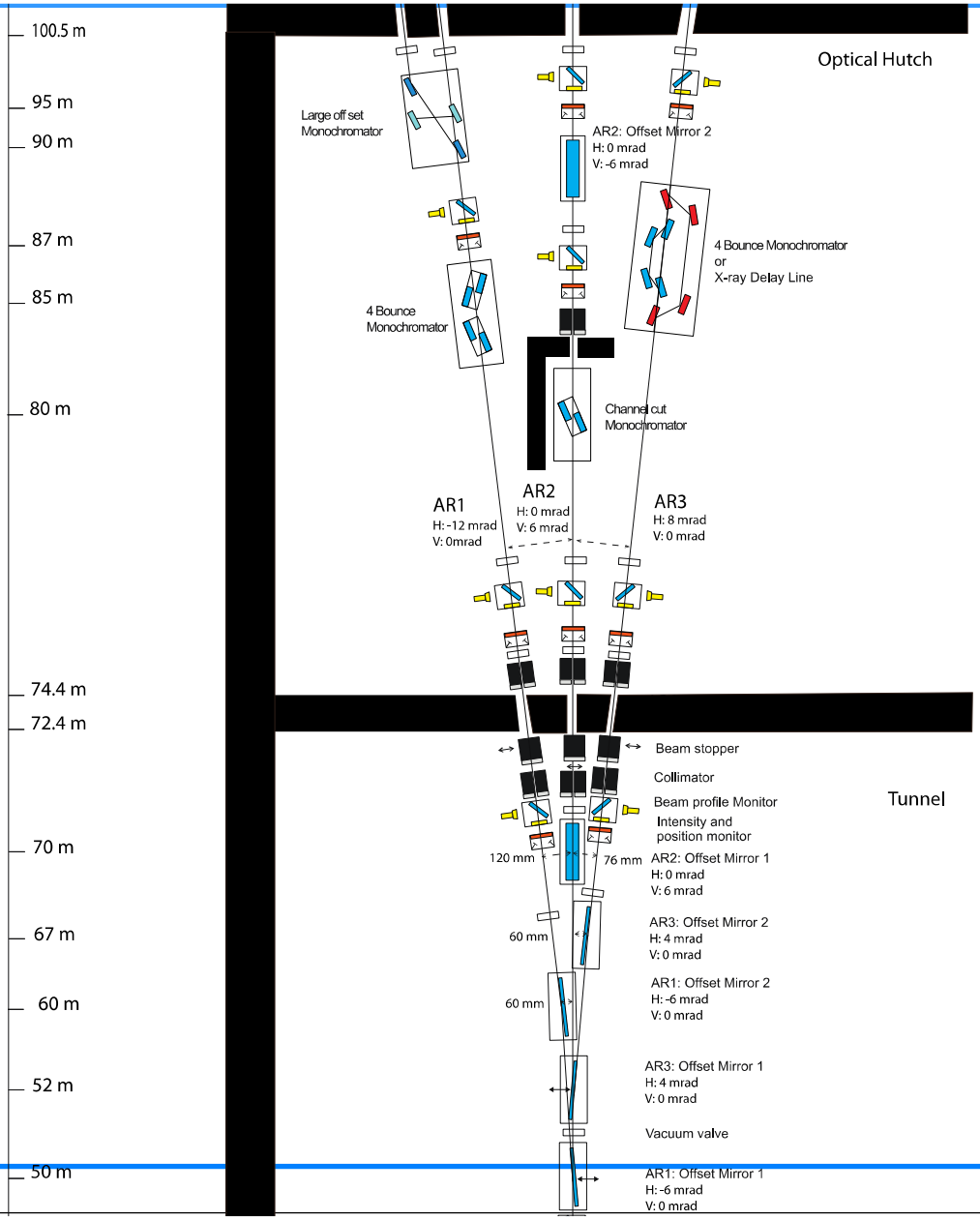
ARAMIS experimental areas

Optical Scheme for ARAMIS



Offset Mirrors / Optical Hutch





ES-A: Multi-purpose pump-probe

Ultrafast chemical reactions (time-resolved spectroscopies)

- Photosynthesis
- Catalysis
- ....

Time-resolved scattering on molecules in solution

Serial crystallography

- Microcrystals in jet

X-ray Absortion Spectroscopy
X-Ray Emission Spectroscopy
Inelastic X-Ray Scattering
Small Angle Scattering/Diffuse Scattering
Time-resolved Protein Crystallography

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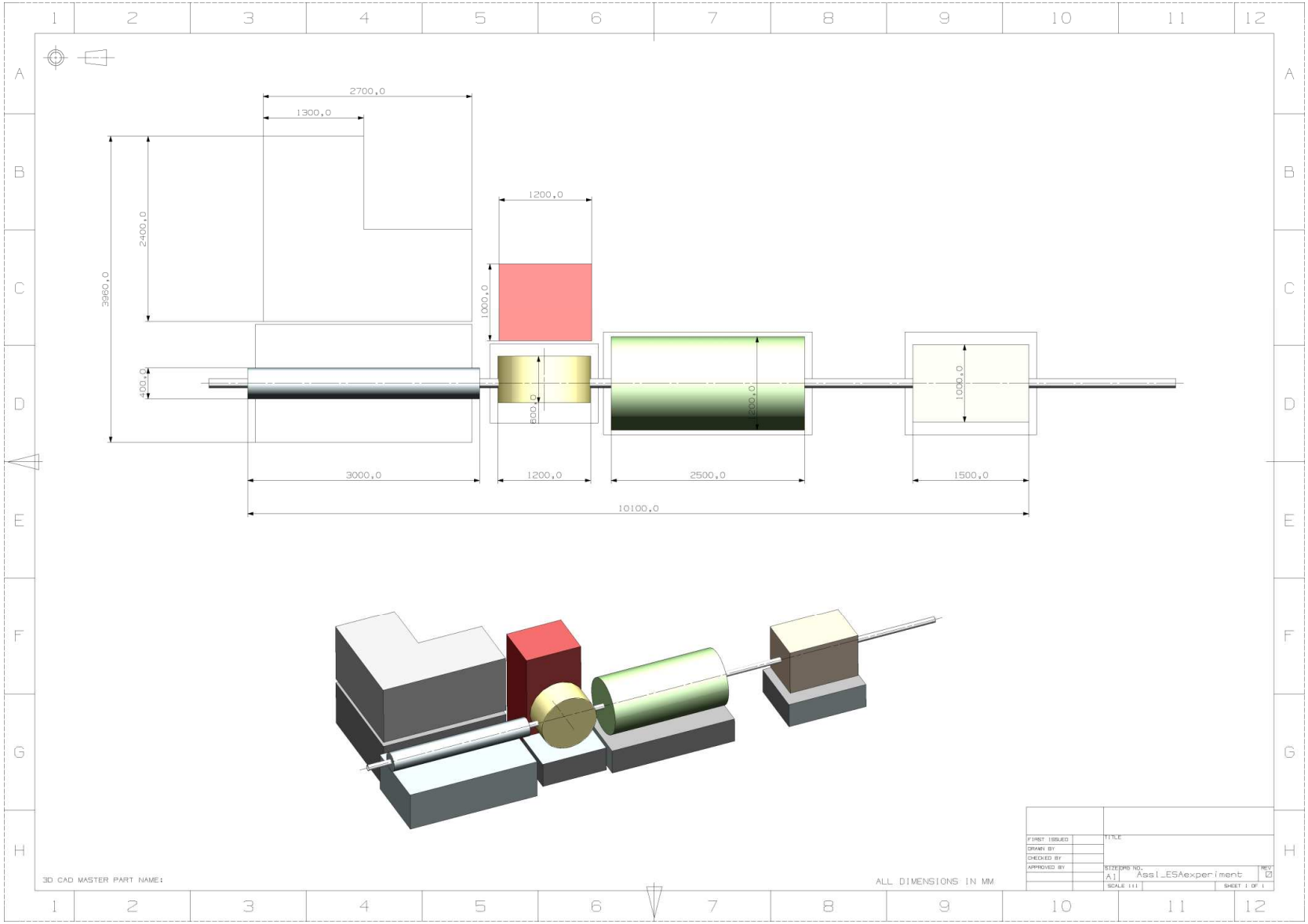
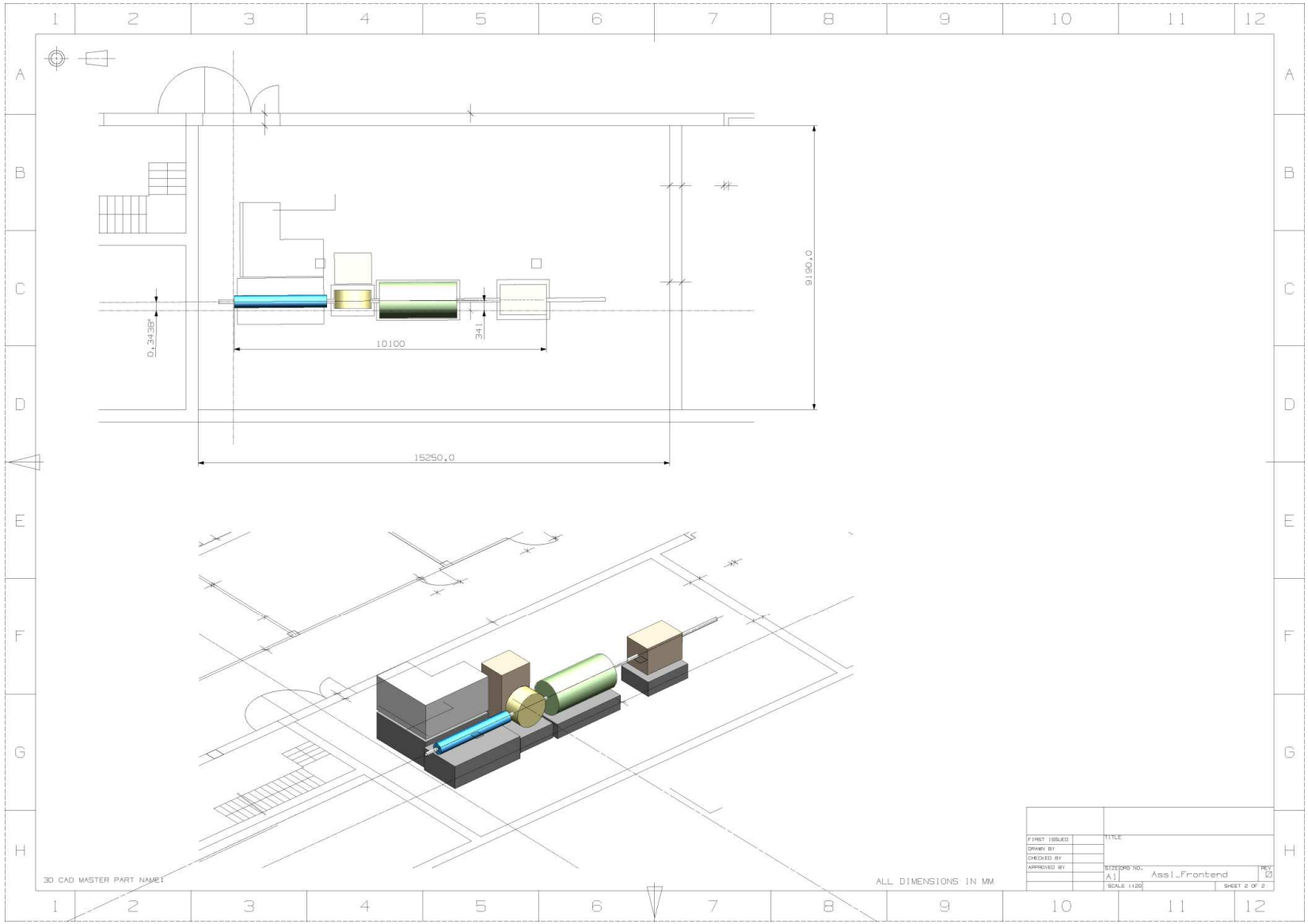
ES-A: Parameters

Energy range :	2. – 12.8 keV (defined by the optics)
Source size.	26 microns
Source divergence:	2.0 microrads
Pulse duration	5 – 20 fsec
Bandwidth	0.05%
	3 % (special chirped mode)
Number of photons	0.7×10^{11}
Beam size at sample :	150 - 200 microns unfocussed
	1 micron (0.1 ?) focussed

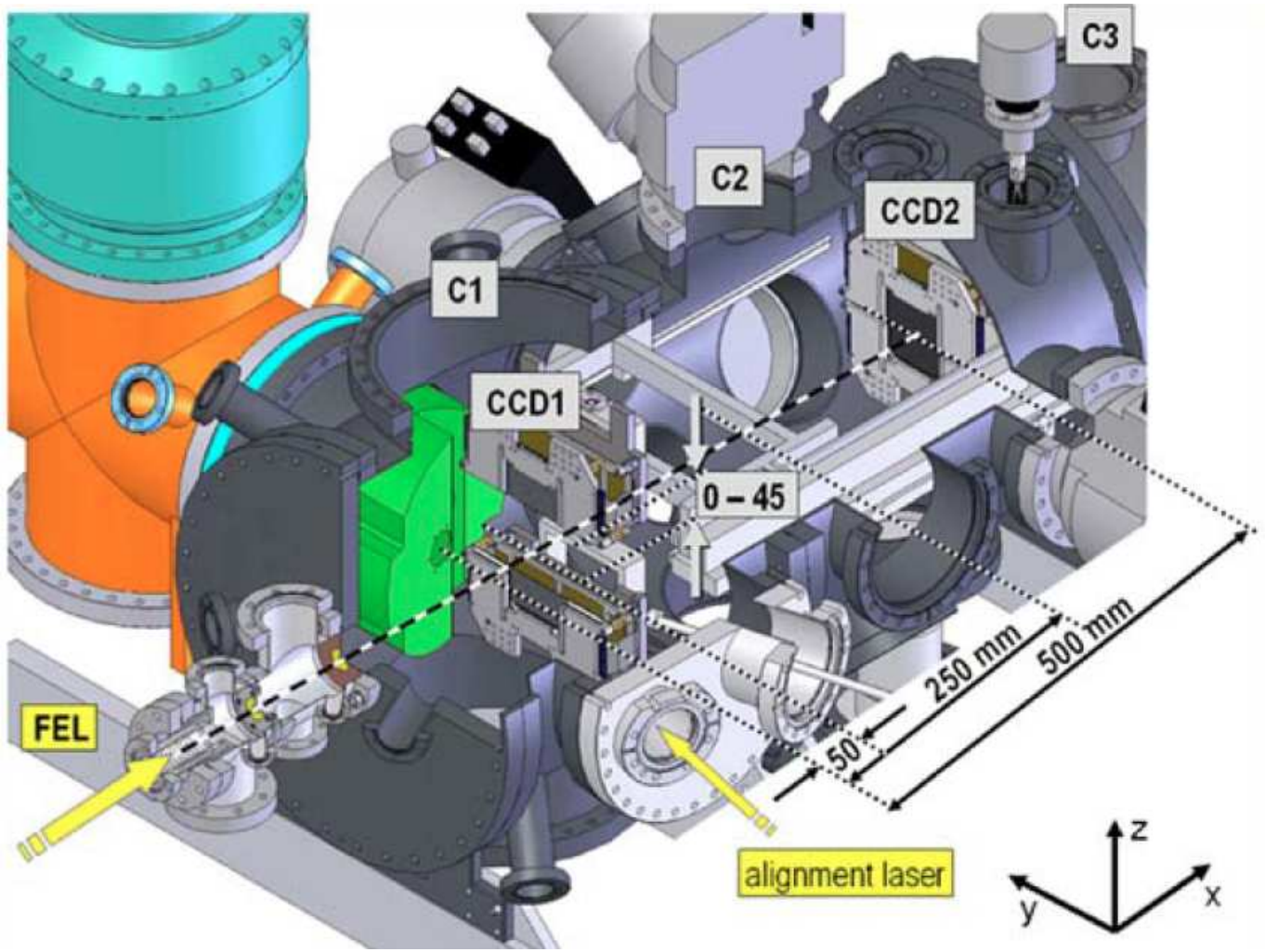
ES-A: Draft Layout



ES-A: Draft layout



e.g., 'CAMP' chamber at LCLS



Strüder, NIM A (2010)

ES-A: Technical challenges

X_Ray diagnostics

intensity	±10-3	to be measured at the experiment
pump-probe timing	±10 fs	close to experiment
Time structure		shot-to-shot
position	±5 μm	unfocussed beam
spectrum	±1 eV	shot-to-shot

ES-A: Technical challenges

Monochromaticity

X-Ray Diffraction :	10^{-3} for diffuse scattering 3×10^{-2} for Crystallography
XAS/XES	10^{-3} in most of the cases shot-to shot spectrum measured at the end (?) 10^{-4} for RIXS
XANES	10^{-2} suitable. Dispersive set up?

ES-A: Technical challenges

liquid jet

- thin (2 μm), continuous stream
- detect (synchronize?) sub-μm crystals in beam
- time-vernier mode +

2D-detectors

- minimize central hole
- long-λ limit?

single-shot XAS and XES spectrometers (±1 eV) +

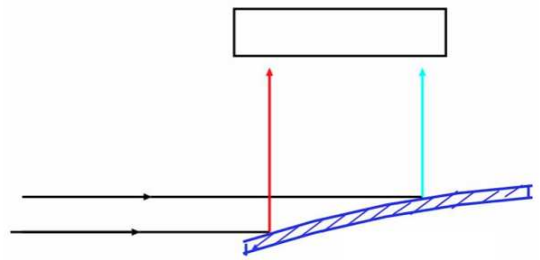
pump laser +

- wide range of wavelengths, variable attenuator, delay
- synchronization (±100 fs?)

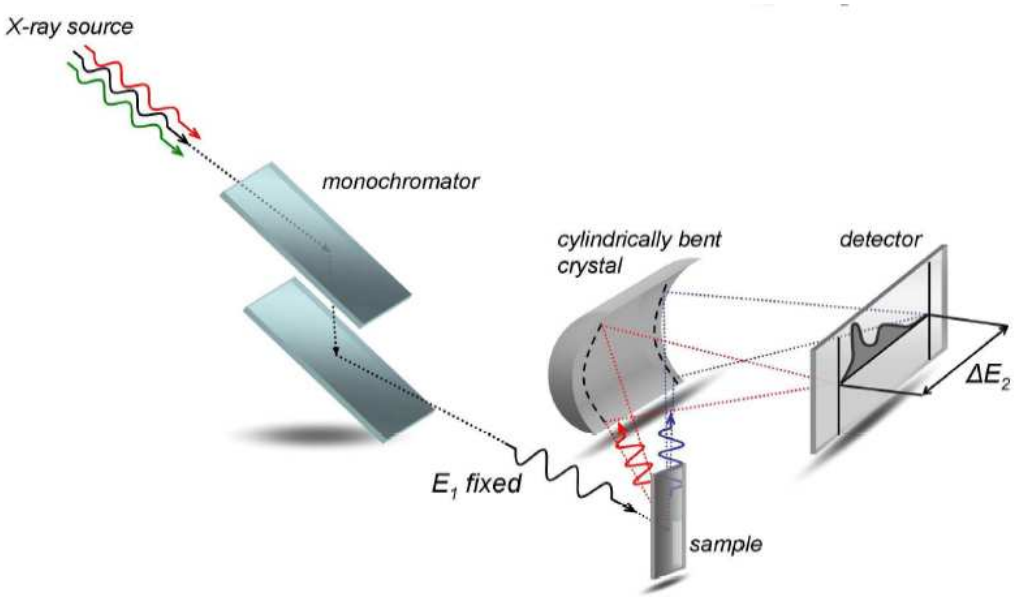
sample movement, 77K goniometer

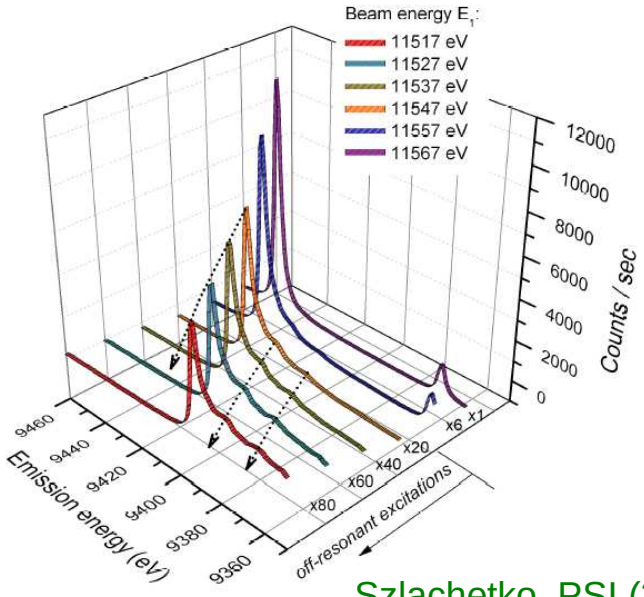
single-shot XAS / XES spectrometers

- X-ray absorption spectroscopy (XAS)



- X-ray emission spectroscopy (XES)

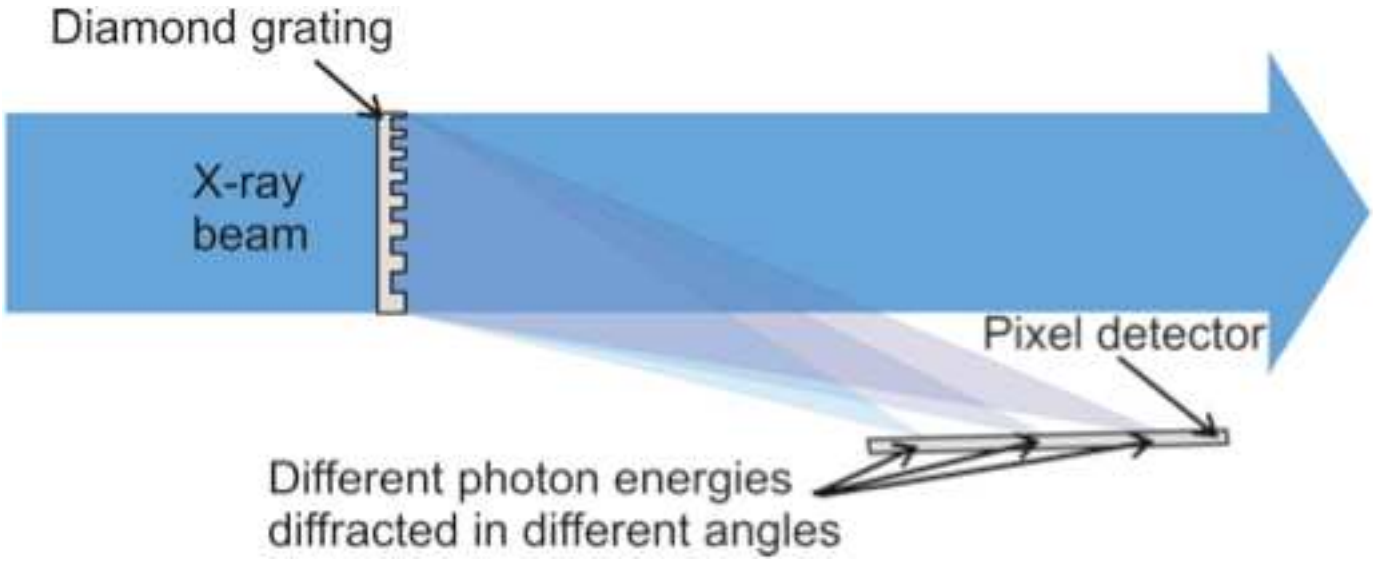




Szlachetko, PSI (2011)

A single-shot spectrometer setup

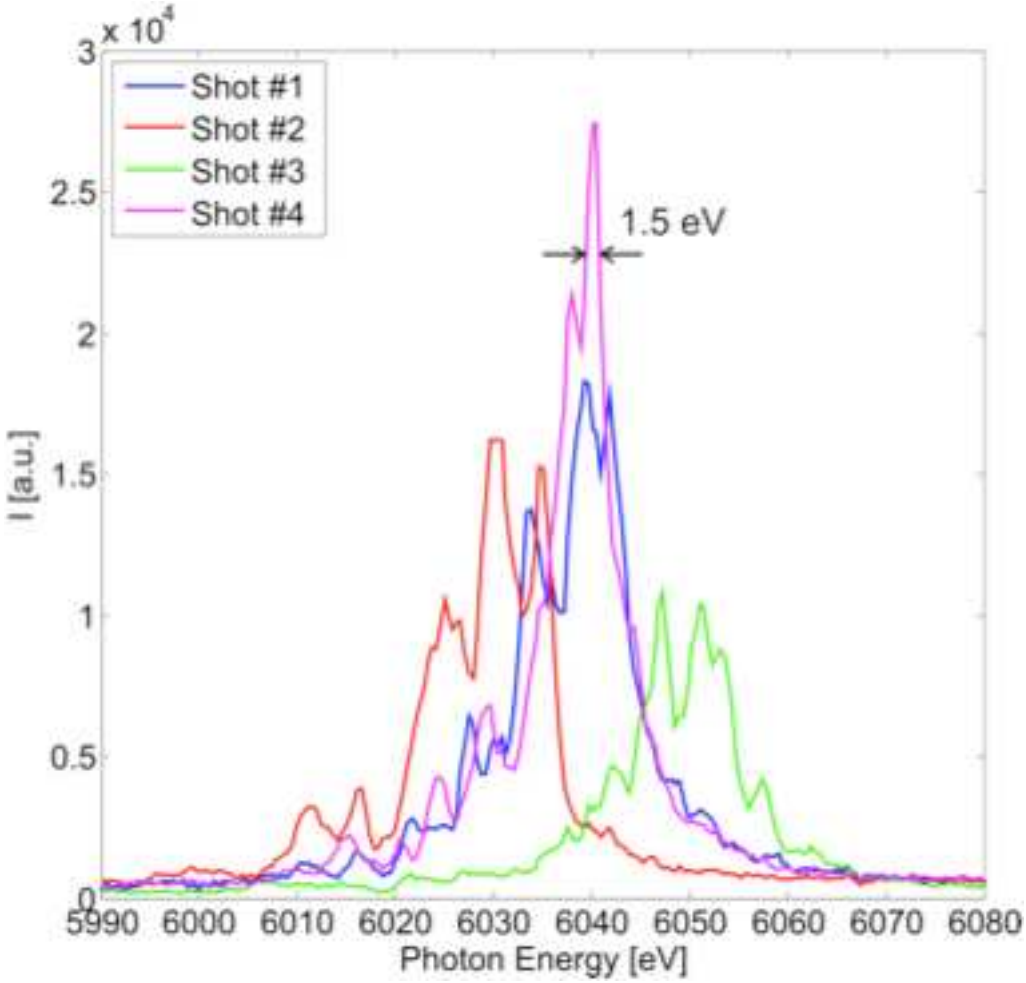
C. David et al., Laboratory for Micro- and Nanotechnology



- **Monitoring of the shot-to-shot spectra:**
  as reference for users and as feed-back for machine (e.g. for seeding)
- **Non-invasive: does not affect user experiments down-stream**
  (diffracts less than 1%)
- **Could also be used for ultra-fast x-ray absorption spectroscopy**

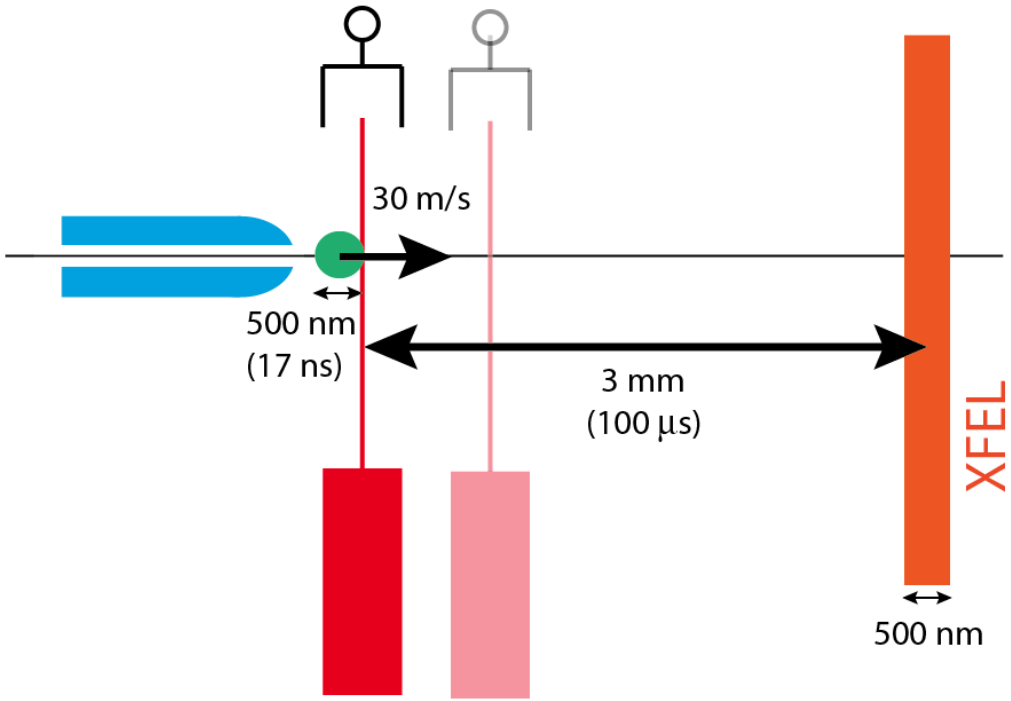
Shot-to-shot spectral analysis of LCLS

at LCLS-XPP station, diamond spectrometer grating with p=150 nm,
3rd diffraction order, 2.5 m grating-to-detector distance, Gotthard detector



- Spectral resolution of 1 – 2 eV (close to diffraction limit)
- Typical spectral pulse width: 0.2% (as predicted)
- Typical shot-to-shot jitter: 0.5% (as predicted)
- Simple, robust, radiation-hard,…

time-vernier mode



- increase hit probability at 100 Hz:

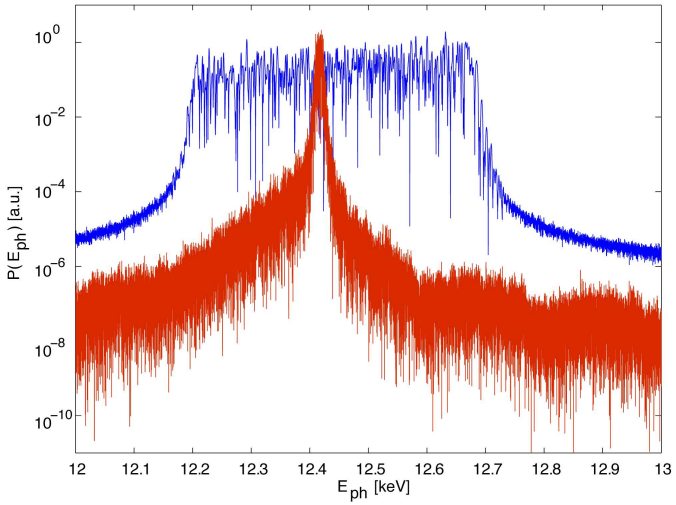
  laser measurement of particle emission time (and velocity?)
  use UV fluorescence or visible light scattering
  predict arrival time at XFEL beam (100 µs in advance)
  adjust XFEL pulse arrival time (±5 µs, 7 ns accuracy) for hit

Broadband mode

- Over-compressed broadband mode

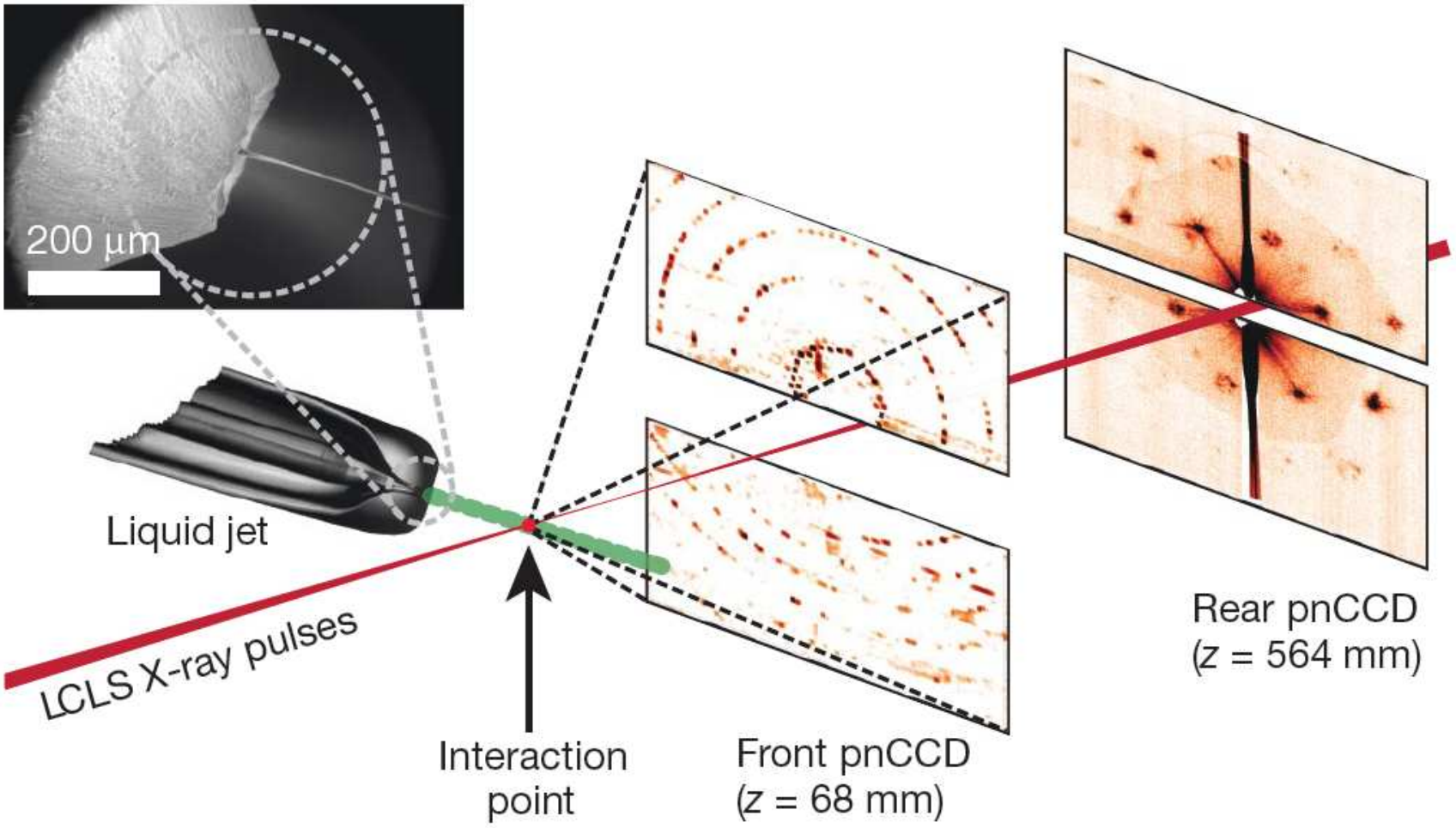
single-shot *p-p* Laue diffraction

use accumulated wake fields (4% FWHM bandwidth)



Reiche (2011)

ES-A: Multi-purpose pump-probe

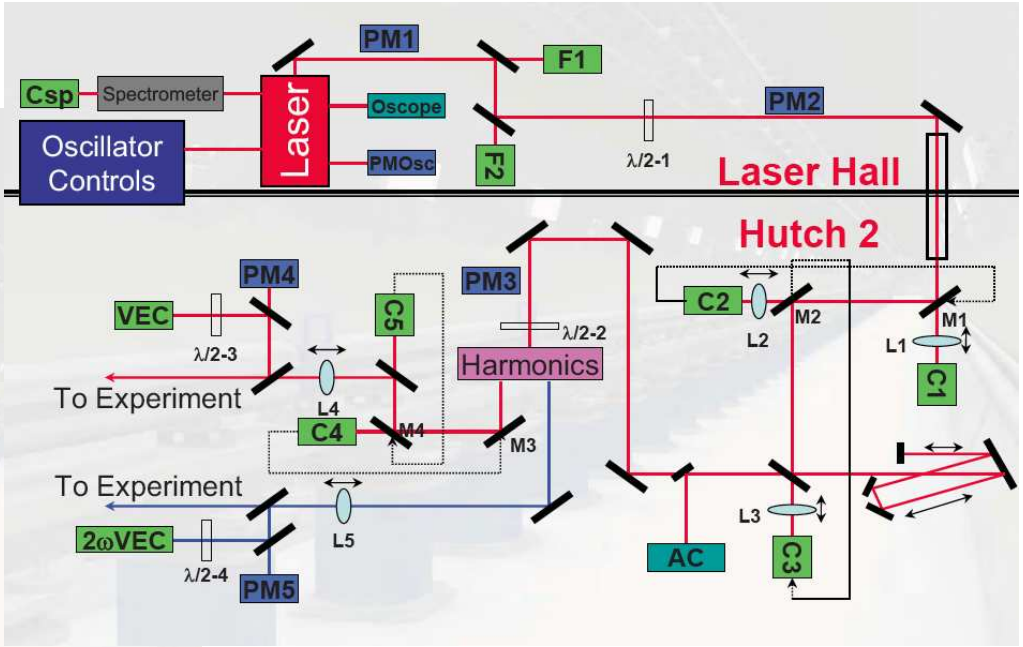


Chapman, Nature (2011)

pump laser

LCLS – XPP specifications

- XPP Laser System
  - Will utilize and expand upon AMO laser system
  - AMO Laser Requirements
    - > 3 mJ per pulse energy at sample (800 nm)
    - < 50 fs pulse duration
    - 120 Hz
    - < 100 fs phase jitter to LCLS RF
  - Multipass amplifier
    - >20 mJ per pulse energy (800 nm)
    - < 50 fs pulse duration
    - 120 Hz
  - Frequency conversion capability
    - OPA
    - Harmonic generation
    - + THz
  - Temporal pulse shaping capability
  - Diagnostics suite
  - System designed such that a non-laser trained user can perform an XPP experiment
    - Sufficient automation to control laser parameters
    - Sufficient engineering controls to provide safe working environment



Fritz, SLAC (2009)

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Thank you for your attention.