Calibration Infrastructure and Calibration Working Group

Jola Sztuk-Dambietz (XFEL)

on behalf of

the European XFEL Calibration Group

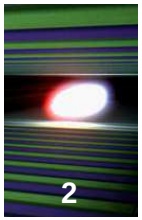
December, 9th 2014

17th Meeting of the XFEL Detector Advisory Committee

European XFEL GmbH, Hamburg

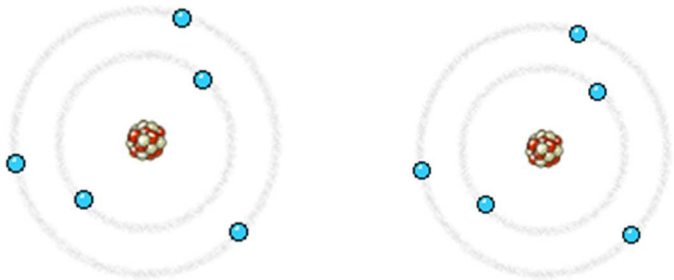
European XFEL

Outline



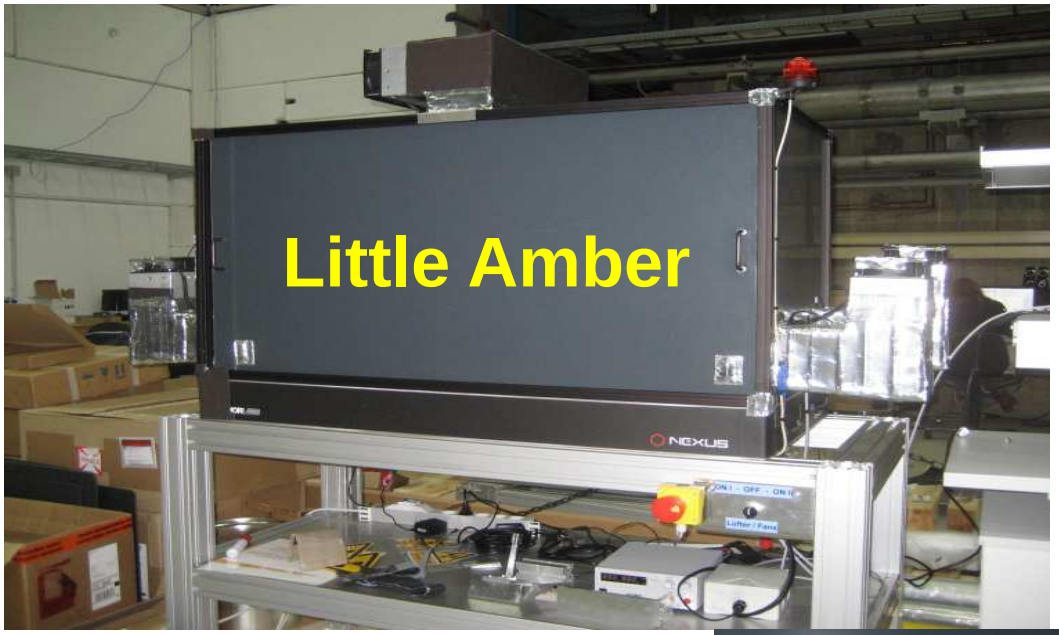
- **Introduction**
- **Infrastructure for detector calibration and tests at the XFEL – status and plans**
  - **Little Amber** (Ambient X-ray Test Setup for Small Prototype Detectors)
  - **Pheobe** (Fe-55 Multi-Purpose Vacuum Test Setup)
  - **Big Amber** (Ambient X-ray Test Setup for 1/4 Mpx detectors)
  - **PulXar** (Pulsed Multi-Target X-ray Test Setup) and PANTER
  - Reference SDD detector
- **Calibration schedule and plan - status**
- **Summary**

Status of Laboratory Calibration Infrastructure

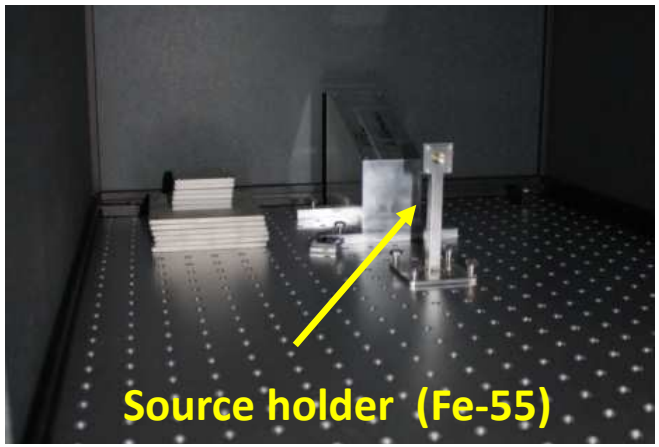


European XFEL

Portable Detector X-ray Test Stand – Little Amber



- Movable ambient test stand for calibration and test of detector prototypes
- Housing (3mm SS+ 1.5 mm Pb) was designed to be compliant to different types of X-ray source (rad. isotopes, portable low power X-ray tubes)



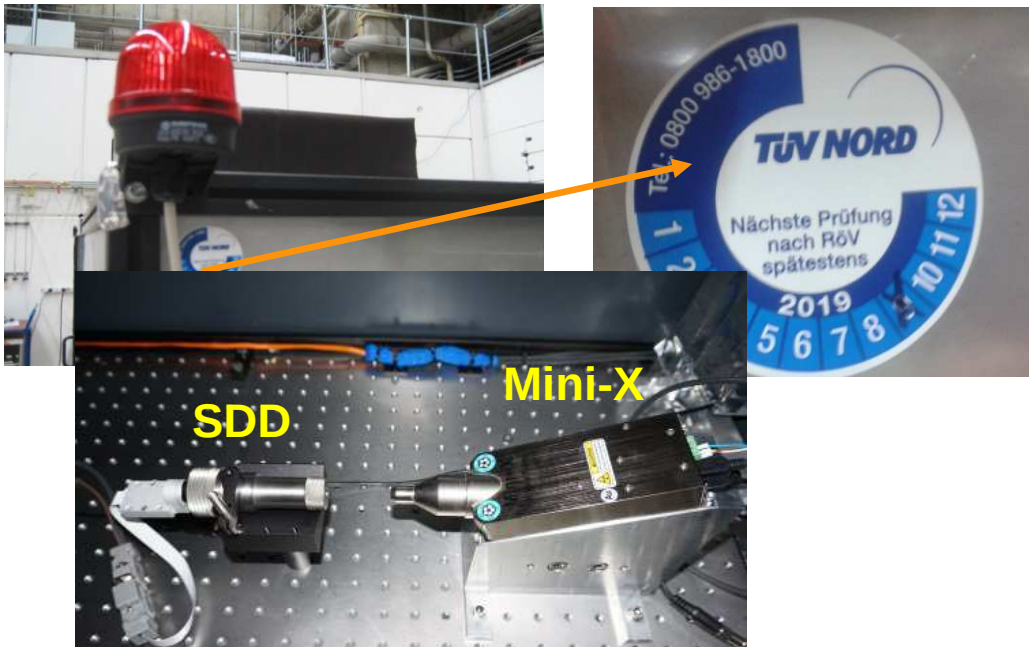
X-ray sources:

- Fe-55 (A = 1,85 GBq)
- Low power X-ray tubes: Amptek Mini-X with Au and Rh targets (I< 80 μA, V< 50kV)

Portable ambient X-ray Setup - Little Amber

Status since the last XDAC:

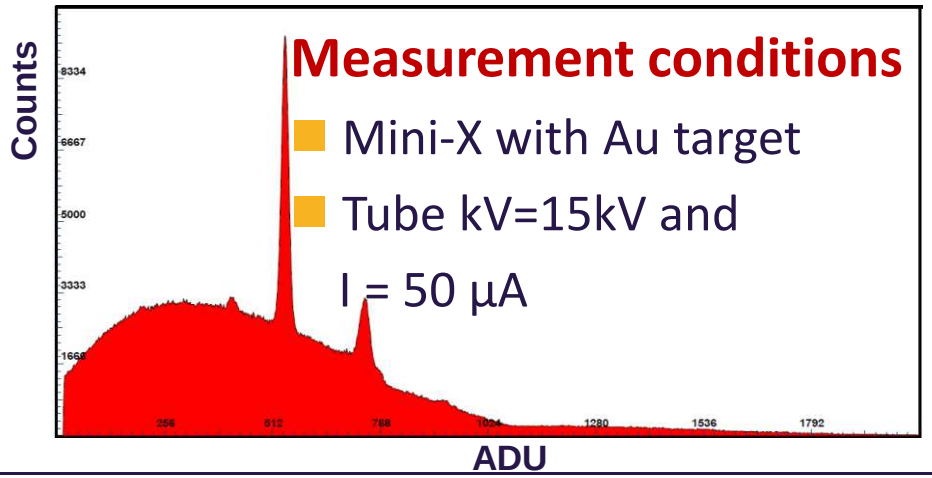
- Ventilators and interlocks installed
- **Approved** by TÜV in September and HH authority in November **for operation with low power X-ray tubes - Mini-X with Au and Rh target**



Next Steps:

- Temperature sensors to be installed

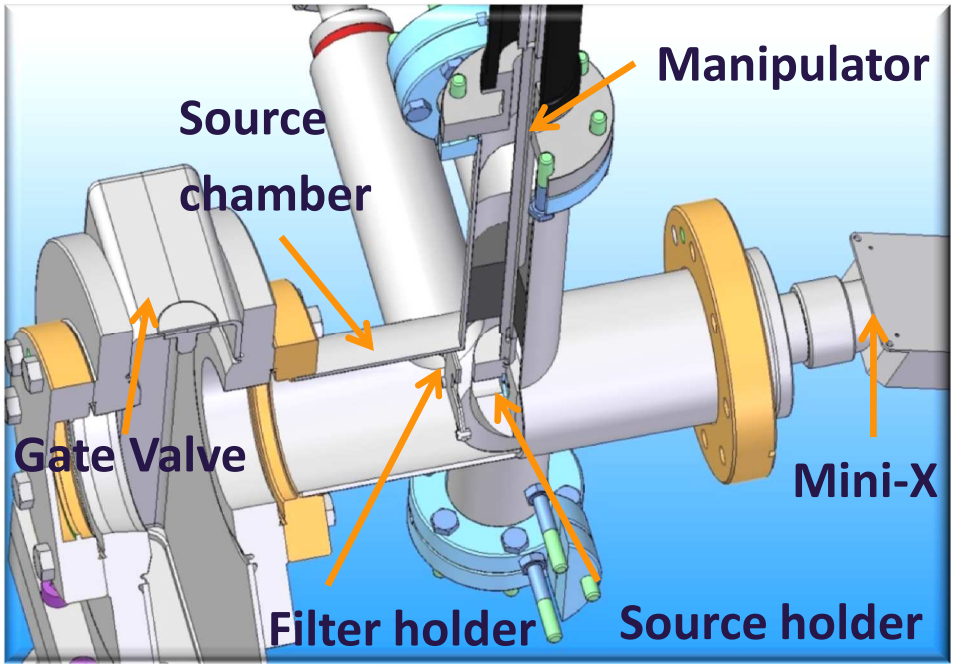
X-ray spectrum of Mini-X (Amptek) with SDD detector



European XFEL

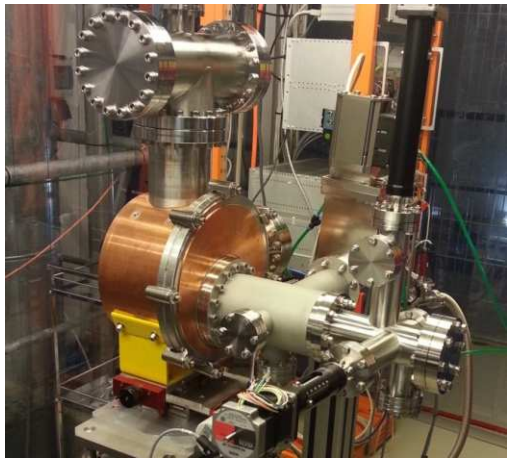
Vacuum compatible X-ray setup PHEOBE

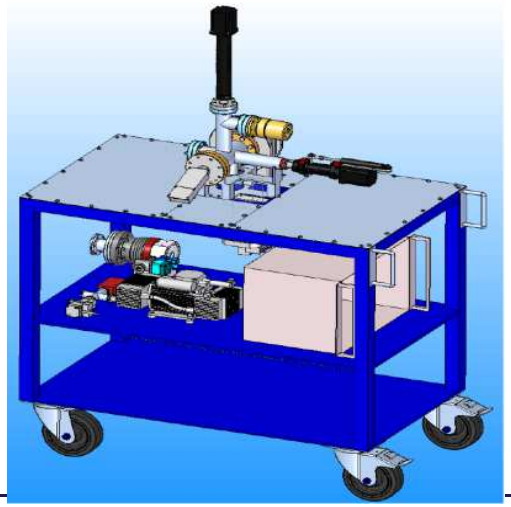
- Modular flexible device for multi-purpose usage (filters, pin-holes, collimator, etc..) with independent pumping system → can be separated from the tested detector via shutter



X-ray sources:

- Fe-55 (A = 1,85 GBq)
- Low power X-ray tubes: Amptek Mini-X with Au target (I< 80 μA, **V< 15kV**)



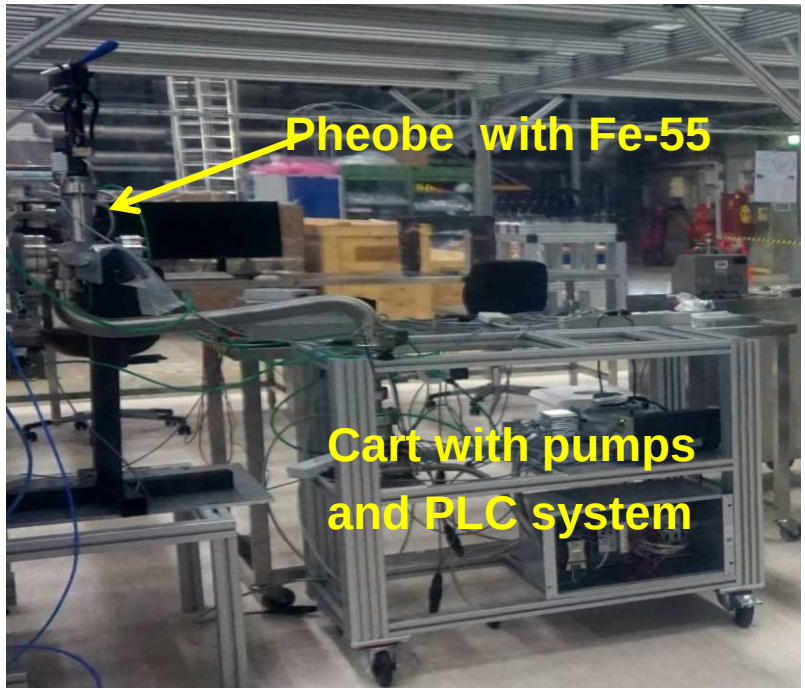


European XFEL

Vacuum compatible X-ray setup - PHEOBE

Status since the last XDAC:

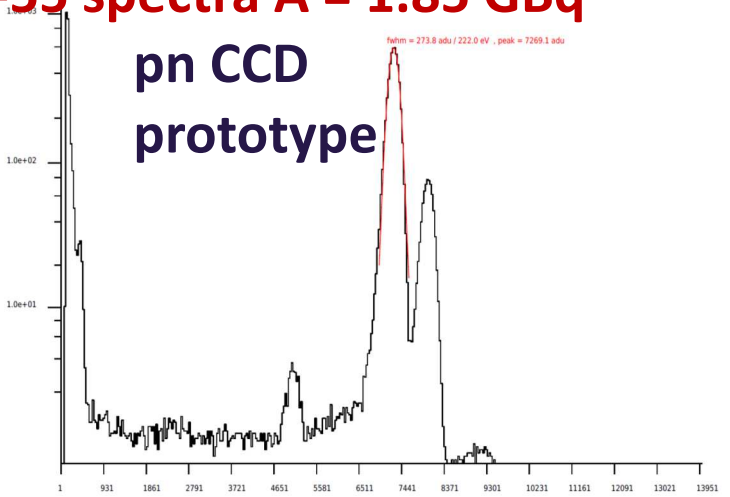
- **Operational with radioactive source (Fe-55)**
- First measurements with pnCCD
- Cart assembled
- PLC: Firmware for control of valves, pumps and manipulators installed



Next steps:

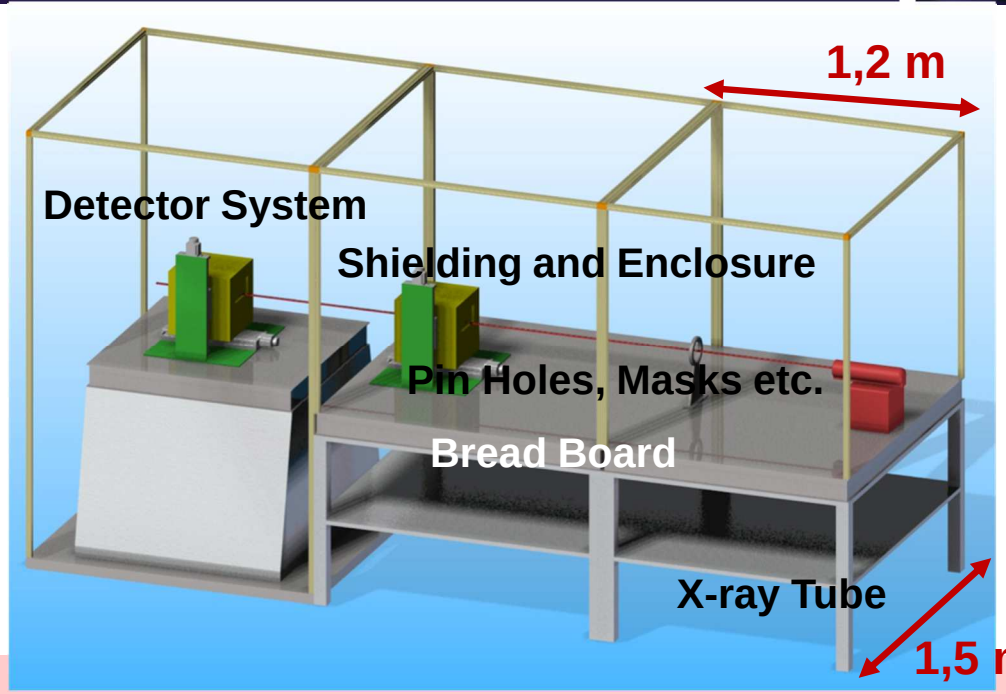
- Install filters
- Test/commissioning control system
- GUI for pump system
- Commissioning of the setup with PLC , motor position calibration
- Next use-cases: SDD detector and fastCCD
- Extension of the system with portable X-ray tube → Q1/Q2 2015

Fe-55 spectra A = 1.85 GBq



Permanent Ambient X-ray Test Setup – Big Amber

- Modular setup for large area and small area detectors
- Interlock system with safety sensors on the doors and between the modules



X-ray sources:

- **Commercial high power X-ray tubes:** (V < 60 kV and P < 2 kW), anodes: Cu (8 keV) and Mo (17 keV) + Polycapillary focusing optics → estimated intensity for Cu target 10^9 cps/50μm
- **PANTER source with exit window** (V < 15kV, I < 5mA) multi-target anode
- **PulXar with exit window:** pulsed mode (V< 50kV, I<20mA with pulse length > 25 ns and XFEL timing), DC mode (V<60kV, I<5mA), multi-target

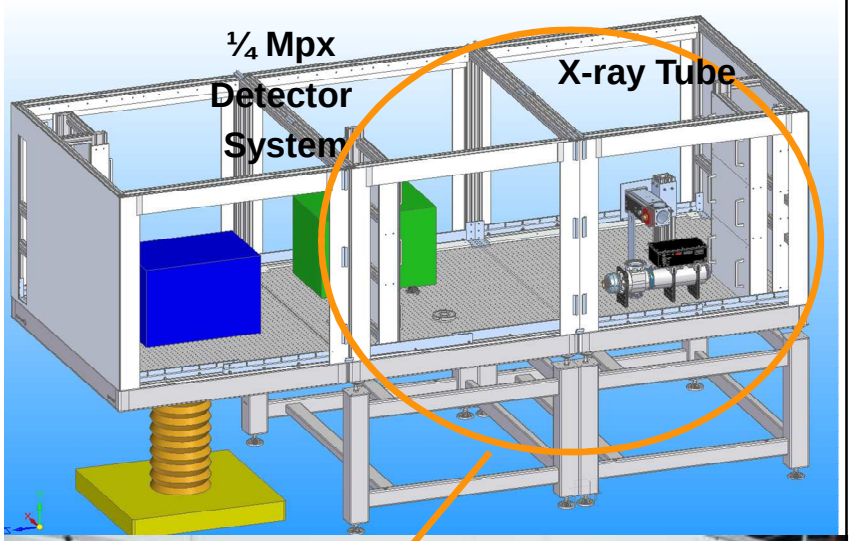
European XFEL

Permanent Ambient X-ray Test Setup – Big Amber

Preliminary setup with first two modules (big enough for ¼ LPD and AGIPD single module)

Status since the last XDAC:

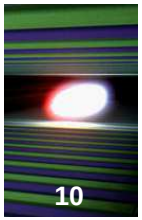
- Shielding assembled
- Interlock system defined (extended for use with electron gun and PANTER) → installation ongoing
- Documentation for TÜV approval exists → discussed with Safety group
- X-ray tubes will be delivered in January including housing, collimator, HV - generator and cooling
- Tube support exists
- Offer for optics and optic holder exists
- Requirements for the 3rd module are defined



→ Operational Q1 2015 for detector systems up to ¼ Mpx

European XFEL

Permanent Ambient X-ray Test Setup – Big Amber



Next steps (two modules):

- Install moving stages for tube (200 mm travel, position resolution: 10 µm)
- Install interlock system
- TÜV approval
- Preliminary cooling (ventilation) for the 2 module setup to be installed (heat dissipated to air of ¼ LPD ~2kW)
- Housing for N_2 atmosphere for AGIPD single module
- Commissioning of the X-ray tubes

Further steps – final (three-module) setup:

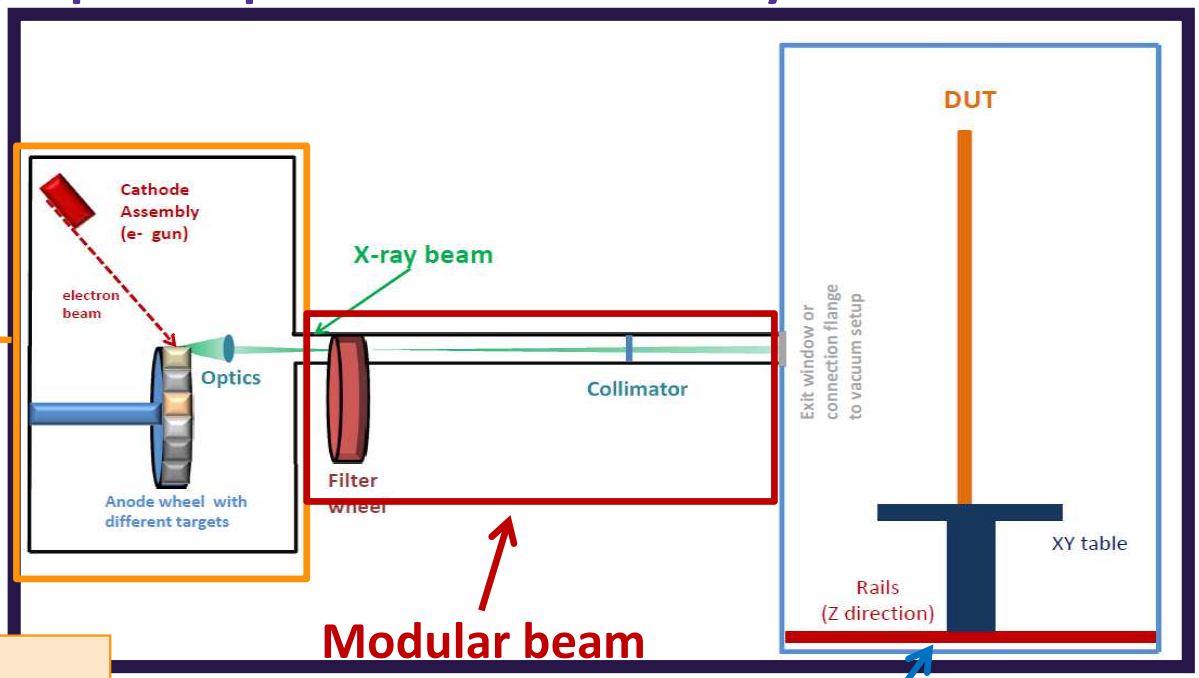
- Finalize design of the third module
- Focusing optics (focus sizes of <50 µm) from IFG with holders attached to the tube housing
- Moving stage for detectors to be installed
- Water cooling for the 3rd module necessary, ventilation not feasible in the clean room laboratory at XHQ

Multi-Target (Pulsed) X-ray Setup PulXar – reminder

Laboratory multi-purpose X-ray setup for up to 1MPix detector systems

Exchangeable

- ✓ **Pulsed X-ray /electron source**
- ✓ DC X-ray tubes /electron source
- ✓ Radioactive isotopes



Modular beam pipe/filters

Detector Test Chamber

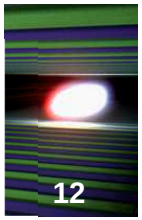
Vacuum and ambient operation

First step: Copy of PANTER X-ray source* assembled & operated at the XFEL as test bed

Next step: Replace the existing electron source with a customized pulsed electron source by Kimball

*Collaboration with PANTER X-ray test facility of the Max-Planck Inst. for extraterrestrial Physics

Pulsed Multi-target X-ray Test Setup - PulXar



PANTER X-ray source as a testbed towards a pulsed sources

Status since the last XDAC:

- Complete PANTER system including tube, filter wheel, detector vessel, support structure and pumping system assembled and pumped (<1.0 x 10^{-6} mbar → sufficient for PANTER operation)
- First bake-out of the filament was successful
- Control system:

✓ Power supplies for PANTER integrated and functionality was tested

✓ PLC Control system (pumping system + manipulator for detector)

- Hardware ready

- Firmware was installed last week → to be tested

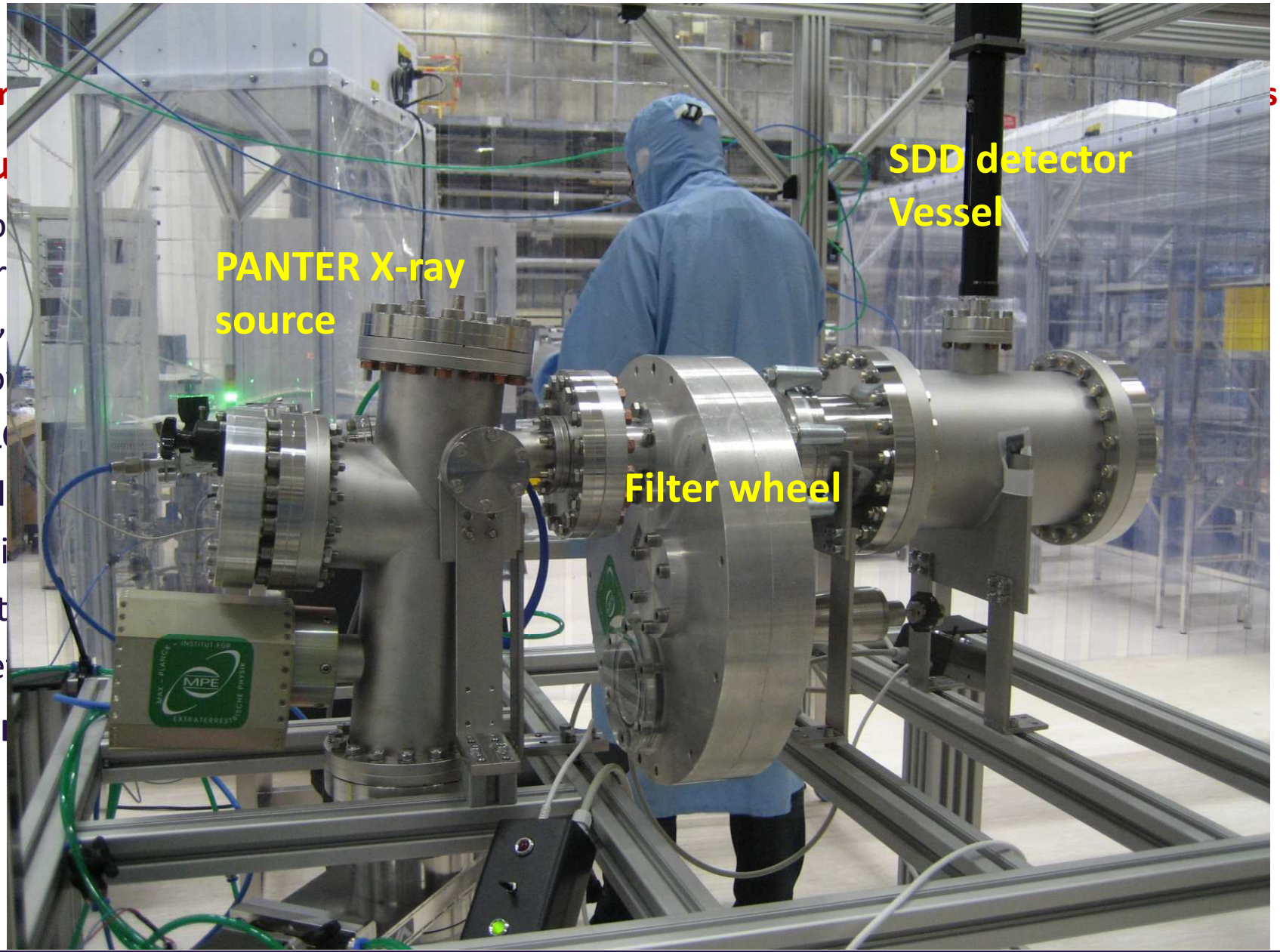
- Interlock system for the tube installed → to be tested next week
- Reference detector setup exists (fast SDD + vacuum vessel + manipulator)
- Documentation for TÜV exists → under discussion with Safety Group

Pulsed Multi-target X-ray Test Setup - PulXar

(Collabor ... s)

Statu

- Co
  str
  (1,
- Po
- PL
  - H
  - Fi
- Int
- Re
- **Ki**



Pulsed Multi-target X-ray Test Setup - PulXar

Next steps - PANTER:

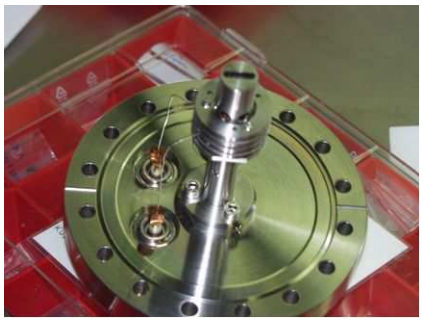
- Commissioning of the PANTER tube system with HV < 5kV
- TÜV approval
- Commissioning for up to 15 kV

→ **Operational Q1 2015**

Next steps - PulXar :

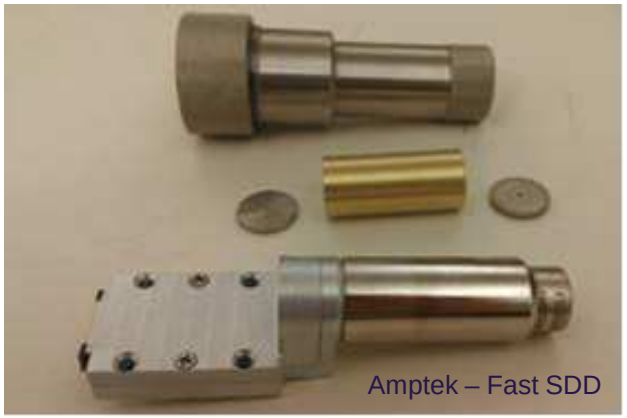
- Replace PANTER e- source with the Kimball e- gun → electron gun delivered to XFEL.EU
- Synchronization of the electron gun with XFEL timing system
- Commissioning of Kimball e- gun

→ **Operational with PANTER mechanics Q2 2015**



Reference detector for characterization of X-ray sources

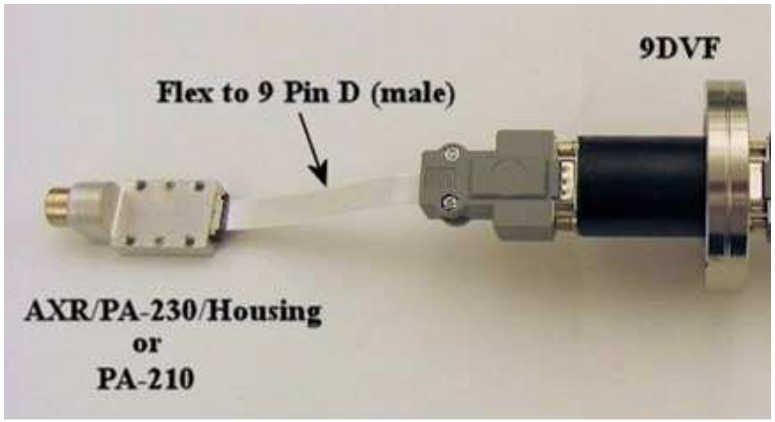
Reference detector for characterization and measurement of spectral distribution of X-rays emitted by the X-ray sources



Status:

- SDD detector including collimator with pinholes (25-2000 µm) delivered
- Vacuum tests with detector collimator and feed through: 4 x 10^{-7} mbar
- Movement system for vacuum operation
- SDD detector operational

- 160 eV FWHM resolution @ 5.9 keV and 100ns peaking time
- Peak-to-Background Ratio - 20,000:1
- High Count Rate > 10^6 cps
- 25 mm^2 X 500 µm



Next steps:

- Detailed tests and calibration with X-rays (PHEOBE setup and/or Mini-X)
- Synchronization of the detector with XFEL timing (needed for PulXar)

HERA South Detector Laboratory
May 2014

- Clean room and Detector Lab Space at HERA South – 1st floor

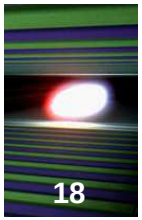
- Clean room ISO Class 6

HERA South Detector Laboratory
November 2014

- Clean room and Detector Lab Space at HERA South – 1st floor

- Clean room ISO Class 6

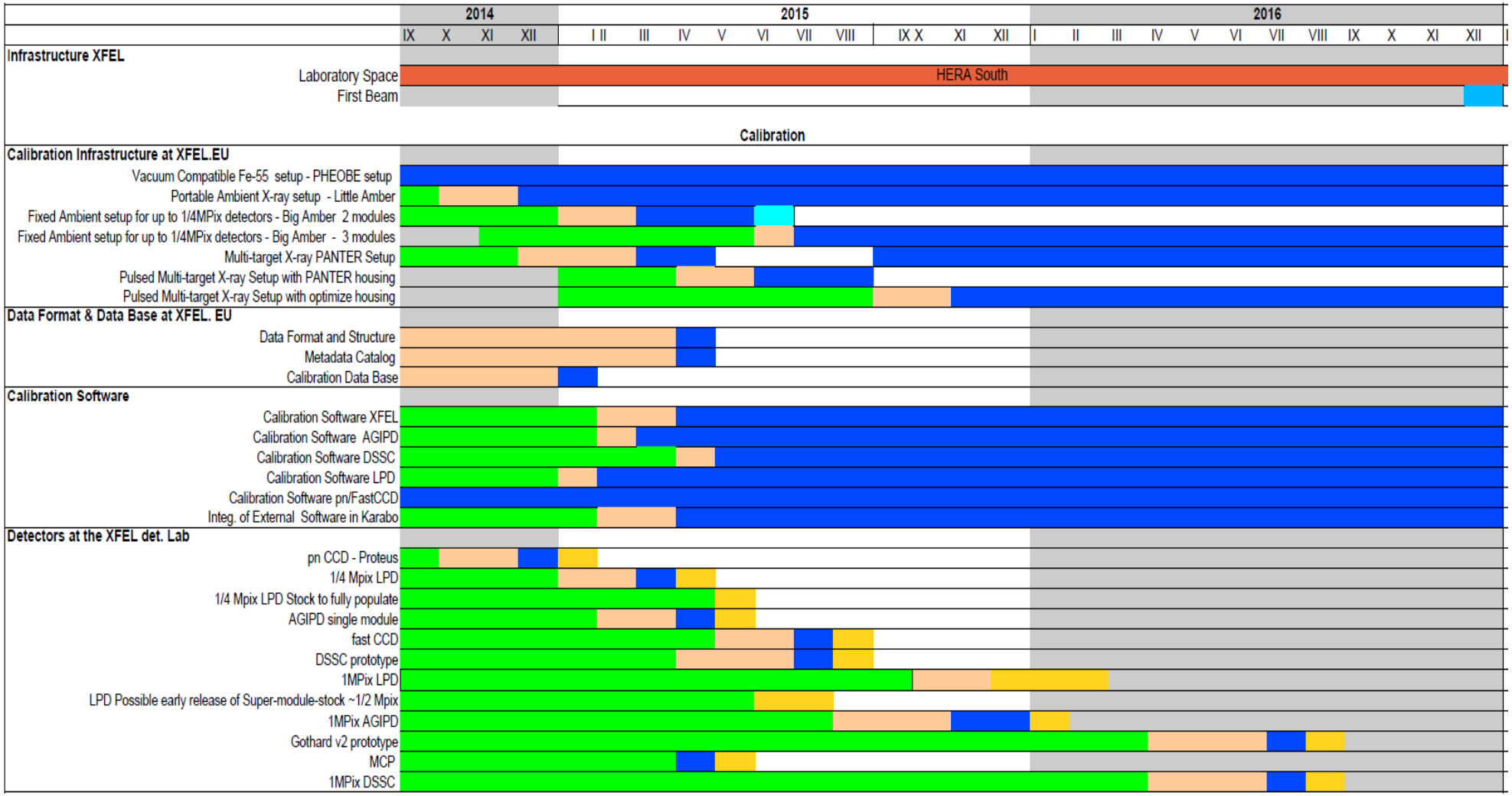
Calibration Plan & Schedule for Lab. Infrastructure at XFEL.EU



- First (preliminary) version of Calibration/Characterisation plan and schedule for the XFEL Laboratory Test Infrastructure exists → discussed with the Detector Consortia at the last Calibration Meeting
- In general the Consortia are interested to use our infrastructure
- Constant feedback from the Consortia is needed → What are their plans & schedule for calibration and testing of the full detector system in our Laboratory? → shall be worked out together with the corresponding XFEL contact persons

European XFEL

Calibration Schedule - General Plan



Def./R&D/Construction

Commissioning/ Ready to use/ in operation

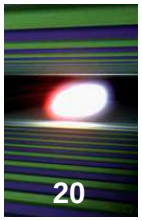
Ready for Calibration and Characterization at XFEL.EU

Integration in our systems/Bringing to live

Upgrade/ transportation/ no operation

European XFEL

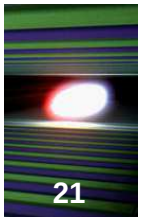
First X-ray tests in the Detector Lab – Q1 and Q2 2015



- **pnCCD detector prototype**
  - → X-ray test Setup: PHEOBE and later PANTER
- **¼ Mpix LPD**
  - → Cooling and DAQ infrastructure ready
  - → X-ray test setup Big Amber with high-power X-ray tube
- **AGIPD single module prototype**
  - → N_2 atmosphere setup and cooling is needed
  - → X-ray test setup: Big Amber and later PulXar (with exit window)
- **Fast CCD detector**
  - → vacuum system and housing to be built
  - → X-ray test setup: PHEOBE and PANTER

European XFEL

Procedures for Scheduling the WP-75 test facility usage



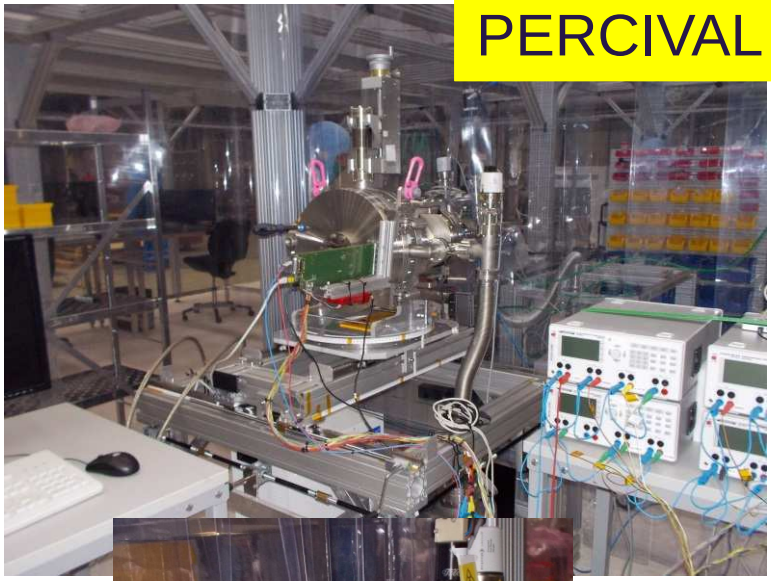
- The procedures for scheduling the usage of the WP-75 test facility are under development → no show-stoppers were identified
- Involved parties:
  - **External users:** test proposal including requirements for the test infrastructure, schedule and risk assessment
  - **WP-75:** evaluate the requirements, preparation and support before and during the tests as well as technical trainings
  - **Safety Group**: evaluate the risk assessment, safety trainings , access rights
- The safety aspects which have to be taken into account (access of the external groups to our laboratory, required trainings etc.) are currently under discussion with the Safety Group

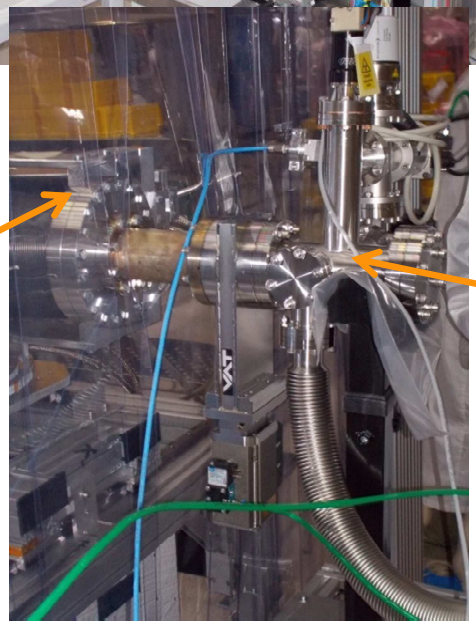
- The first friendly users (DESY group) used our PHEOBE (vacuum Fe-55 test setup) system for testing their detector prototype. The organization of the work, safety training and access permission to the HERA South laboratory for the guests went all smooth and no show-stopper appeared.

First Friendly Users at WP-75 Detector Laboratory

- Percival prototype at HERA South (October 2014):

PERCIVAL setup



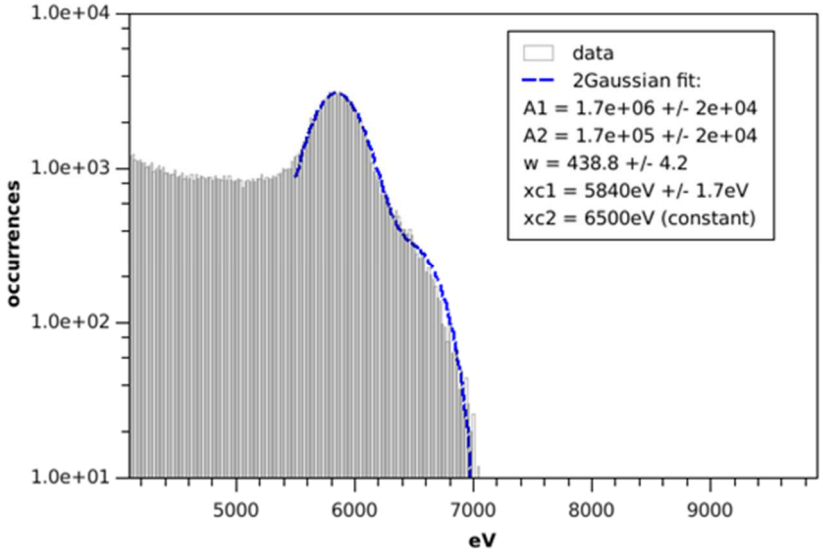


Percival setup

PHEOBE (vacuum compatible Fe-55 source)

PHEOBE setup

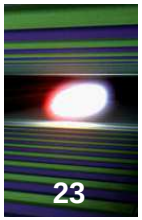
Fe 55 spectrum (500ms)



Courtesy DESY Percival team

European XFEL

Summary



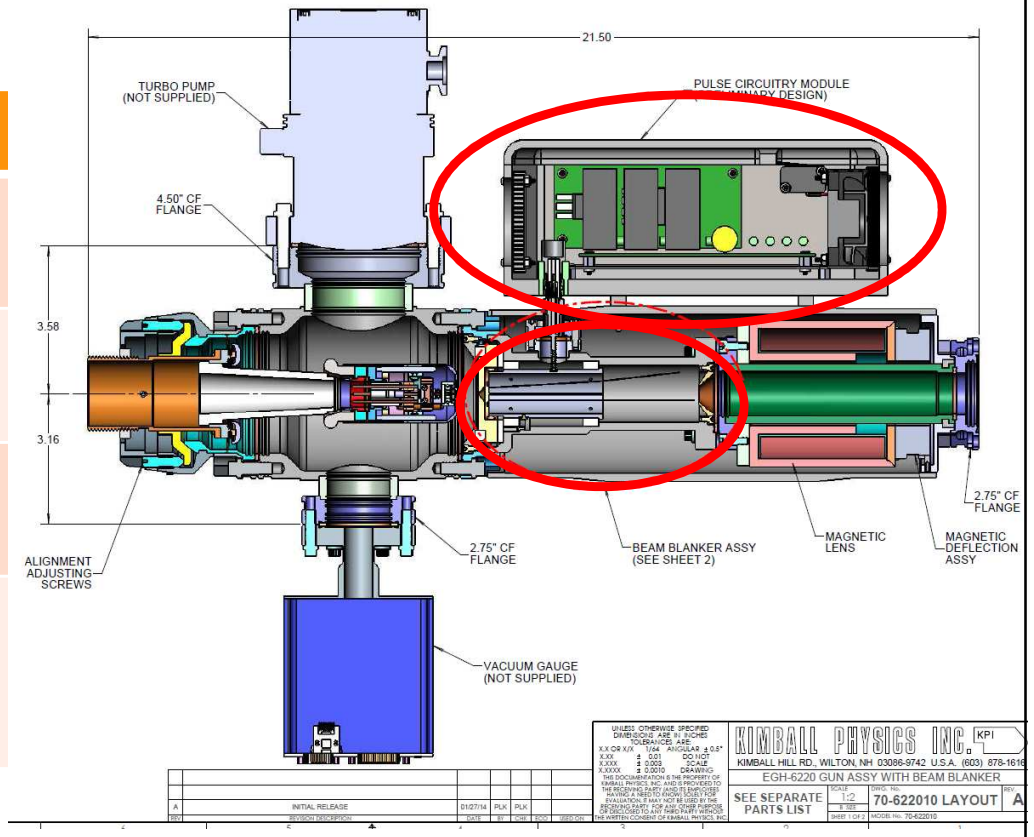
- Construction and commissioning of calibration infrastructure is progressing well
- First X-ray setups are operational and can be used for tests
- Procedures of scheduling and access of external groups to WP-75 infrastructure is in preparation and under discussion with Safety Group
- Calibration Infrastructure – schedule:
  - First laboratory X-ray detector test setups Little Amber and PHEOBE operational (to be used for small prototypes or small detectors)
  - Ambient X-ray Test Setup for ¼ Mpix detectors operational (up to ¼ Mpix) Q1 2015
  - Pulsed Multi-Target X-ray Test Setup operational (up to 1 Mpix) Q3 2015
- Preliminary plan for testing the first detectors at the detector Lab exists
- Calibration software and alignment concept → see S. Hauf's talk

Thank You

Additional information including introductory & Backup Slides

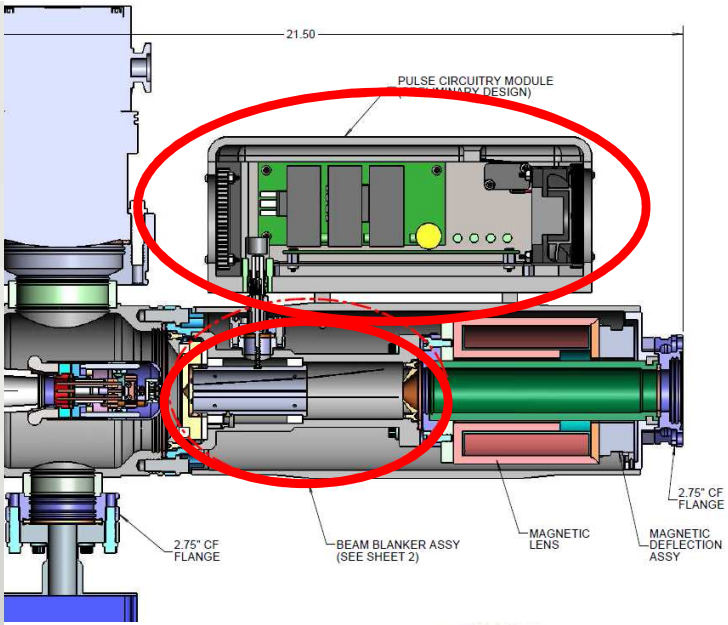
Kimball Physics Electron Gun for PulXar

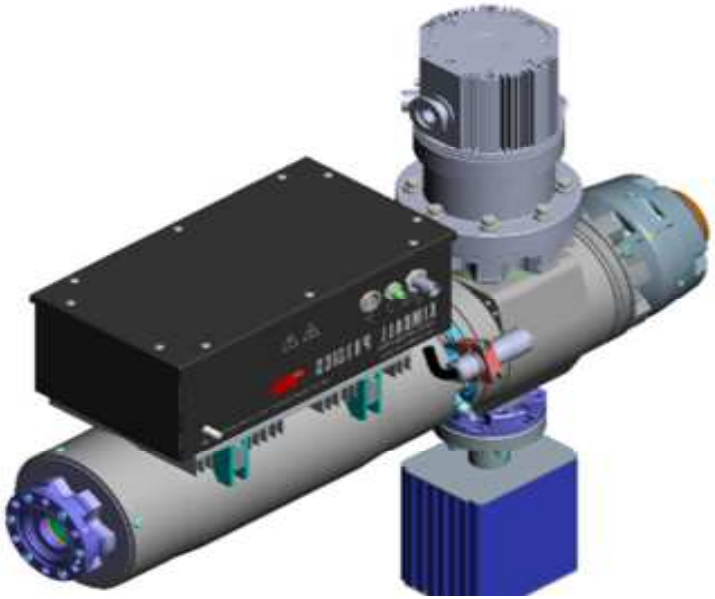
Parameter	Pulsed mode	DC mode
Electron energy	1 - 50 keV	1- 60 keV
Electron beam current	10µA - 20 mA	10µA – 6mA
Beam diameter	0.15 – 10 mm	0.1-10 mm
Pulsed beam parameters	- Length: τ = 50 -150 ns rise: 2 ns / fall: 3-4 ns - XFEL burst mode	n.a.



European XFEL

Kimball Physics Electron Gun for PulXar



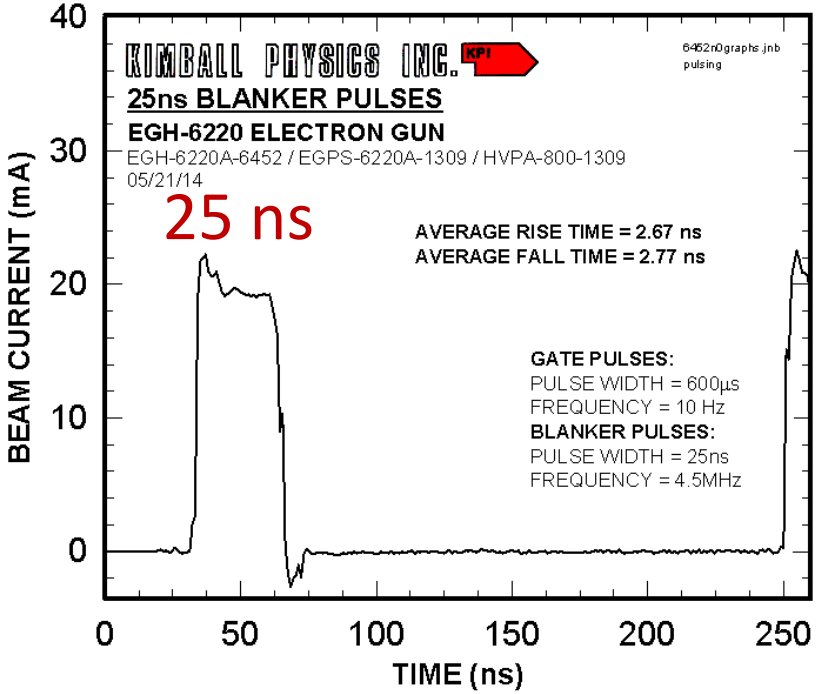


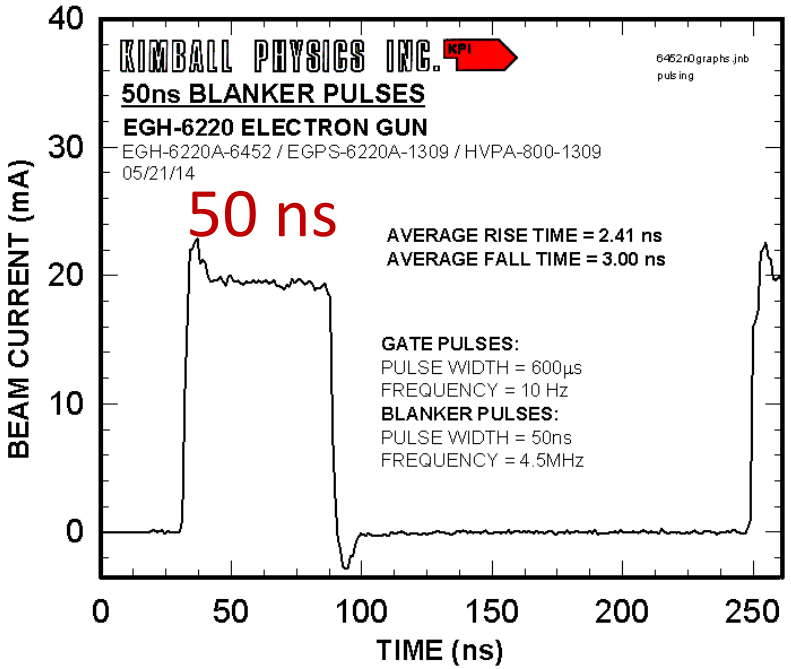
pulses are achievable

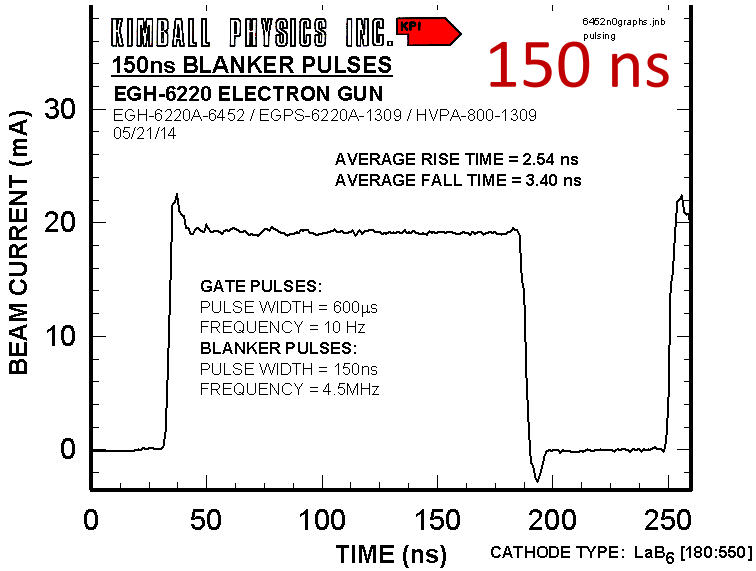
- Custom pulse generator with burst operation designed ar
- Electron gun is in the testing phase → performance with
- Expected delivery date: June 2014 (on schedule)

European XFEL

Electron Gun for PulXar – first test results

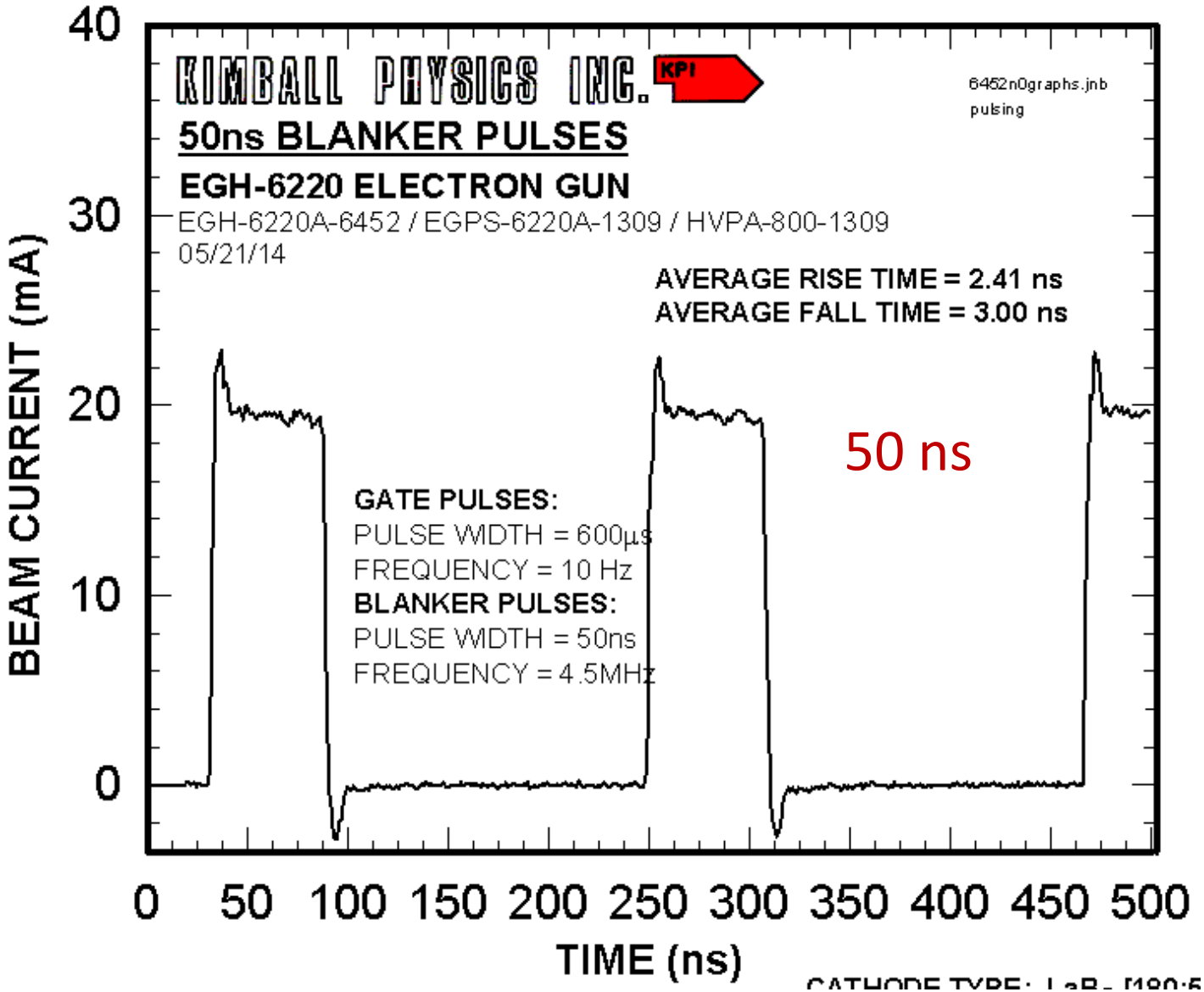




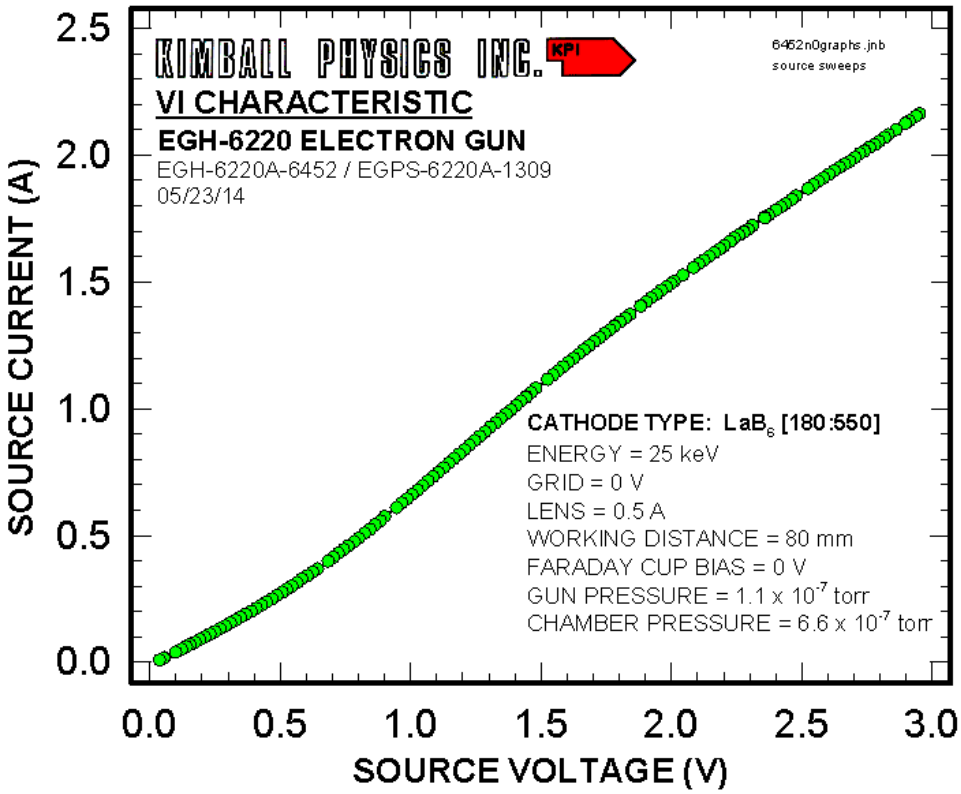


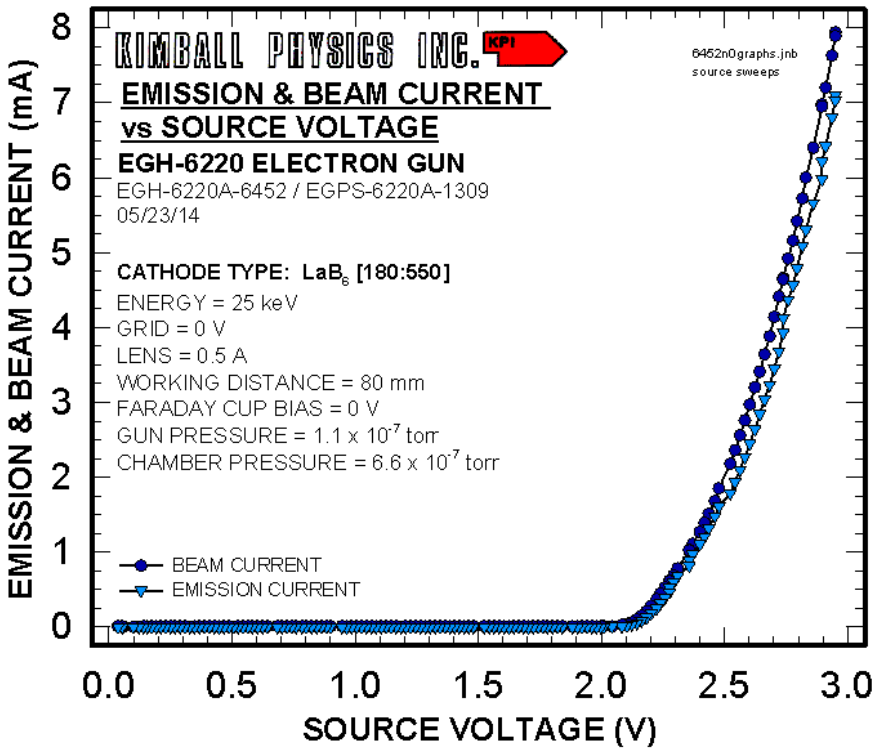
- Oscilloscope measuring the electron beam into the lab Faraday cup
- Blanker pulses 25, 50, 150 ns
- Electron energy Ee=50 keV
- Gun pressure p=2x10^{-8} mbar
- Rise/fall time 2.5-3.5 ns

Electron Gun for PulXar – first test results



Electron Gun for PulXar – first test results

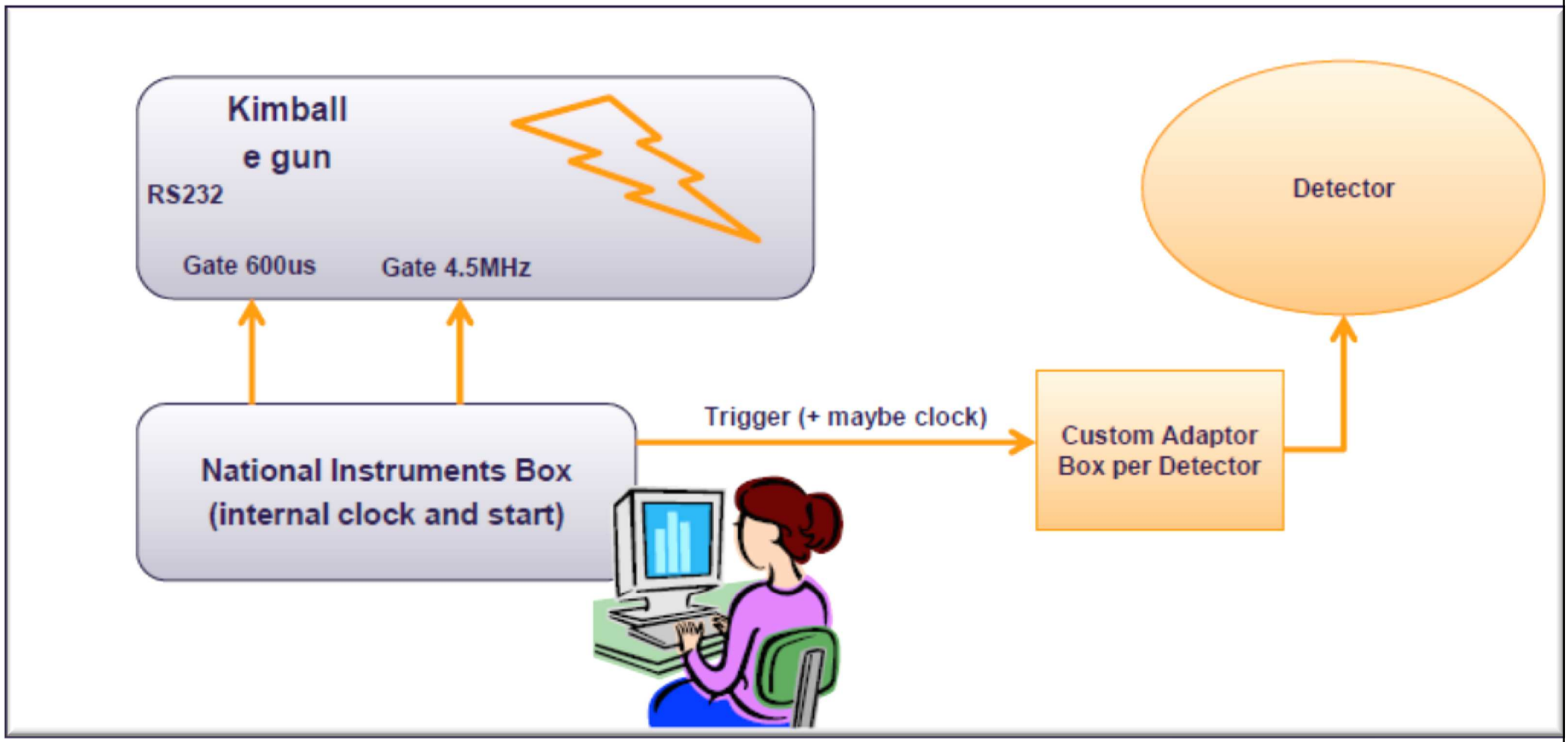




Multi-target Pulsed X-ray source

Clock and Control system (P. Gessler)

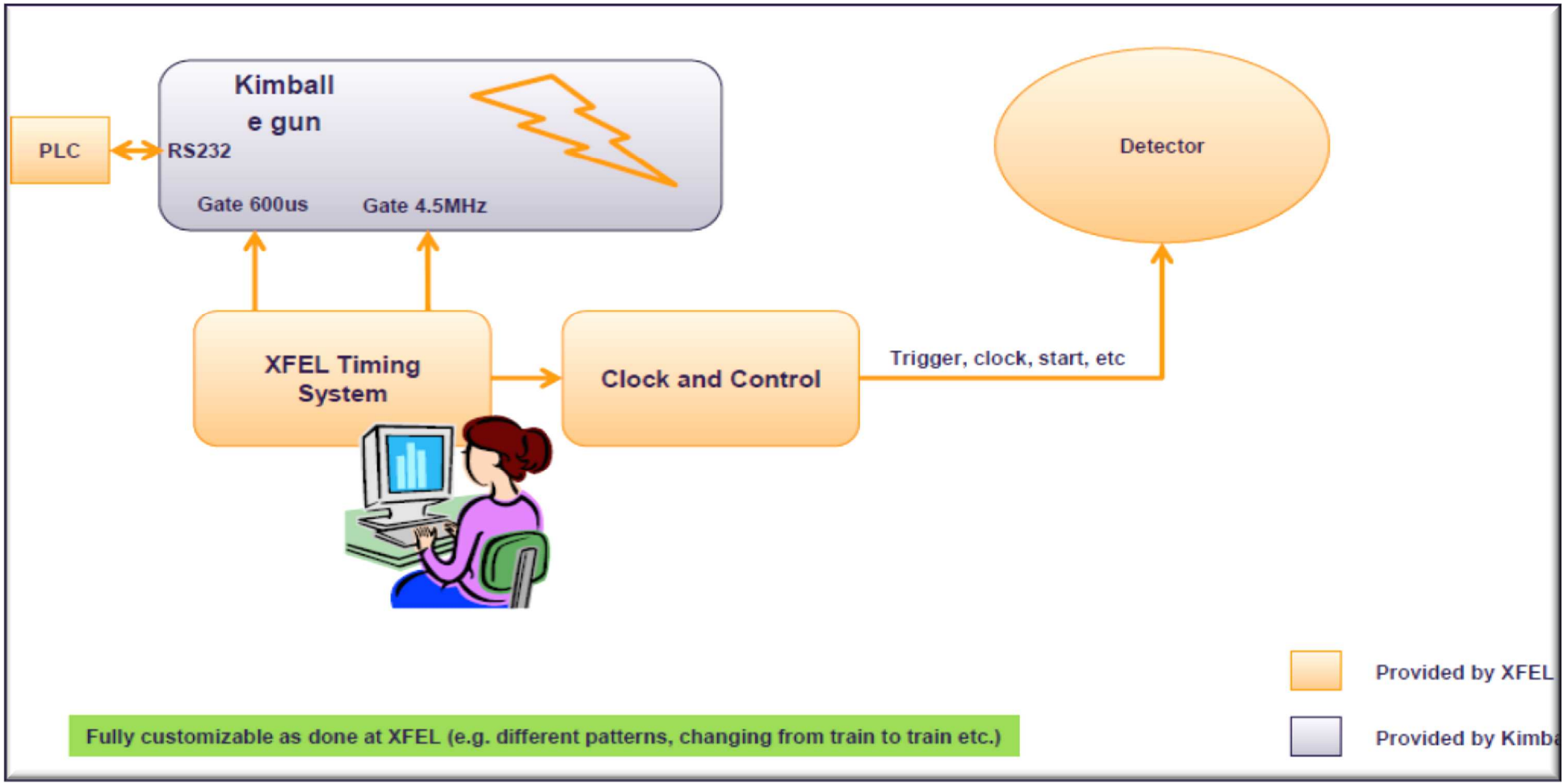
- Day one solution – detector “triggered” by the source



Multi-target Pulsed X-ray source

Clock and Control system (P. Gessler)

- Final solution – XFEL Timing system



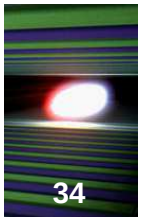
Calibration Strategy - what is needed to calibrate detectors

- Infrastructure to run detector (DAQ, data storage, data base, cooling, cabling etc..)
- Data analysis tools
- Different kind of stimulus (X-rays, charged particles, etc..)

Required	Parameter	Comments
Internal charge injection	Gain conversion, Memory Charge Looses (Droop)	Internal source needs to be cross calibrated with the real X-rays
Laboratory X-ray sources (isotopes, X-ray tubes)	Gain conversion, Detector Response Function, Flat-field, Charge Transfer Inefficiency, Quantum Efficiency	Measurements which do not require high intensity and XFEL timing structure at the same time
Beam from FELs/Synchrotrons/ Particle Accelerators	Flat-field, Splitting Events – Crosstalk	All measurements which require high intensity and appropriated XFEL timing

European XFEL

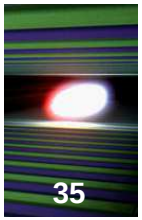
Calibration Strategy – where calibration will be done



XFEL.EU Project Phase	Detector Laboratory	FELs/Synchrotrons/ Particle Accelerators		
		External Sources	XFEL. EU	
			Instr. Hutches	Dedicated beam
Start-up	Initial detailed calib. and characterization of det. prototypes, modules	Response of detector vs. either rep. rate or intensity		
Commissio -ning	Initial detailed calib. and characterization of full systems	**Calibration of 1MPix 2D cameras is NOT feasible due to the demanding infrastructure requirements**	• Cross-check lab. calibration • Characterization of the detector response under real conditions (rep.rate and intensity)	
User Operation	Calibration of the full system only if necessary (accident, detailed detector response investigation, etc..)		**Scientific. exp:** Part of regular exp. procedure (shall take a few mins) **Maintainance time** - Calibration/tests using in-hutch sources	Detailed detector response investigation under real conditions (rep.rate and intensity)

European XFEL

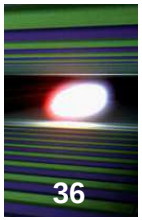
Detectors in Experimental Hutch



- Work on definition of calibration procedure during operation phase is ongoing
- Discussion with instrument scientists
  - Required accuracy for calibration parameters
  - Specific online monitoring in addition to „standard“ detector performance monitors
  - Calibration data which can/should be taken as part of an experimental campaign/run
  - Detector alignment
  - X-ray calibration sources within the hutches → agreed with the instrument scientists

European XFEL

Detector Calibration & Characterization Priorities



Parameter	Priority	Target Accuracy
Conversion gain ***G*(x,y)**	**High**	**< Poisson statistic**
Dark signal ***O*(cell nr,x,y)**	**High**	**< detector noise**
Noise ***N*(x,y)**	**High**	**< 1%**
Bad pixel ***B*(cell nr,x,y)**	**High**	
Quantum efficiency ***QE***	**High**	**5-10 % (simulation uncertainty)**
Dynamic range ***DR*(x,y)**	**High**	**< Poisson statistic**
Memory cell droop (signal losses) ***MD*(cell nr, x,y)**	**High**	**< detector noise**
Charge transfer inefficiency ***CTI*(x,y)**	**High**	**< 1%**
Point spread function ***PSF*(x,y)**	**Low**	**to be defined**
Line spread function ***LSF*(x,y)**	**Low**	**to be defined**
Spectral response	**Medium**	**< 10%**
Flat field corrections	**High**	**< 10%**
Common mode	**High**	**to be defined**
Event splitting	**High**	**to be defined, for low rate applications**
Alignment (position calibration)	**High**	**< pixel size**

Measurement

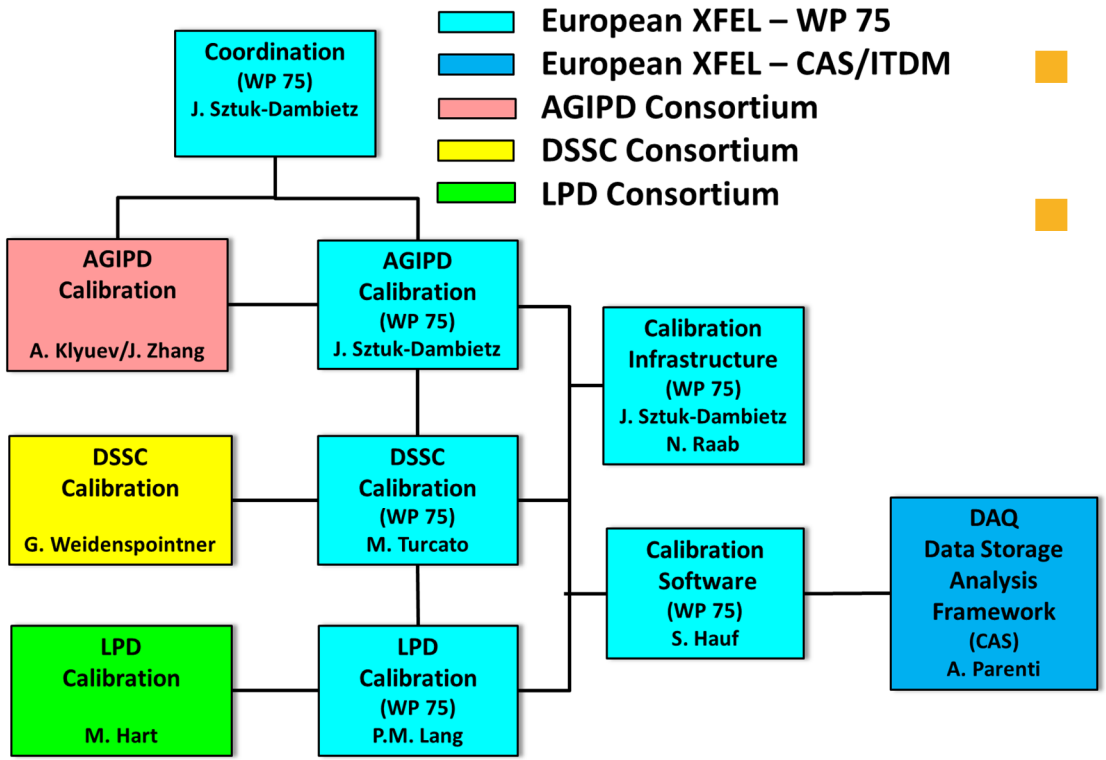
Simulation

Algorithm/ reconstruction

Required (motivated by science) accuracy for calibration parameters → input from scientific groups is needed

Calibration Working Group

Responsible contact persons of the group:



- Work done by detector consortia, WP-75, CAS
- Experts from consortia available beyond start-up phase of the project

- **Meetings:** every 6 months → Last meeting November 2014
- Exchange information and discuss progress and open issues, define next steps
- Available documentation

Indico page with presentations and documents:
https://indico.desy.de/categoryDisplay.py?categId=278
Calibration Working Group site @ Alfresco -
https://docs.xfel.eu/share/page/site/calibration/dashboard