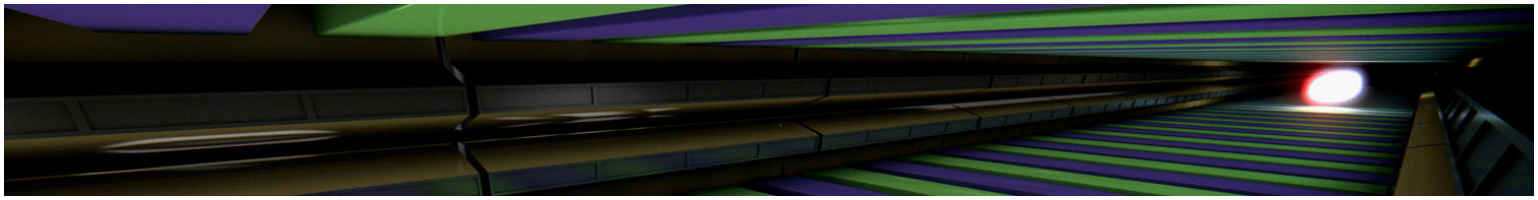
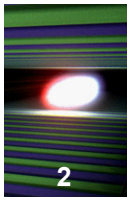


Commissioning of the New Online-Radiation-Monitoring-System at the New European XFEL Injector with First Tests of the High-Sensitivity-Mode for Intra-Tunnel Rack Surveillance

Frank Schmidt-Föhre, DESY

IBIC 2015
International Beam Instrumentation Conference

Overview

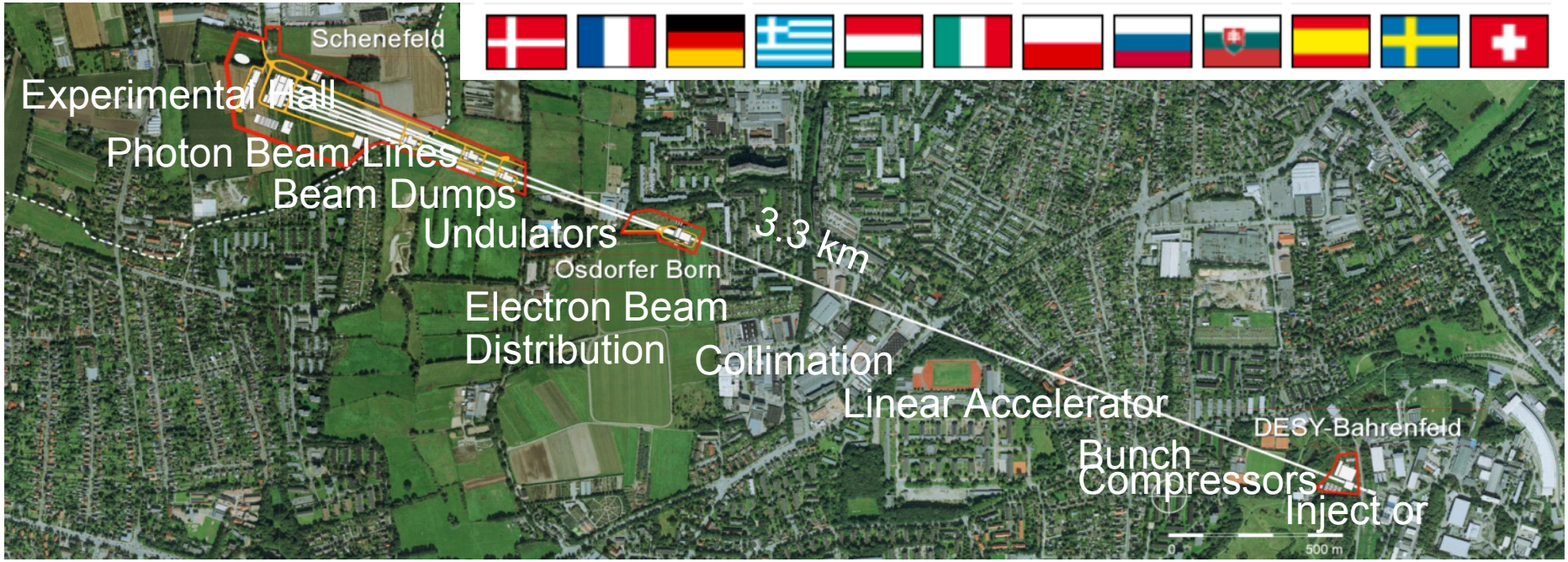


Overview

- Short overview of the European XFEL
- The online machine dosimetry purposes at the XFEL
  - Radiation monitor positions along the XFEL
  - System design goals
- Overview of the DosiMon Online-Radiation-Monitoring system
  - system concept & topology
  - components and connections
  - RadFet & TLD sensors at different locations
- DosiMon test setup at the XFEL injector
- DosiMon system commisioning at the FLASH gun
- Cs-137 calibration measurement
- Test setup at DESY2 booster ring
- Results of tests and measurements
- Outlook

European XFEL at a Glance

International project realised in Hamburg, Germany
17.5 GeV superconducting linac, almost 1 MW beam power
27000 pulses per second in 10 Hz burst mode
Three variable gap undulators for hard and soft X-rays
Initially 6 equipped experiments

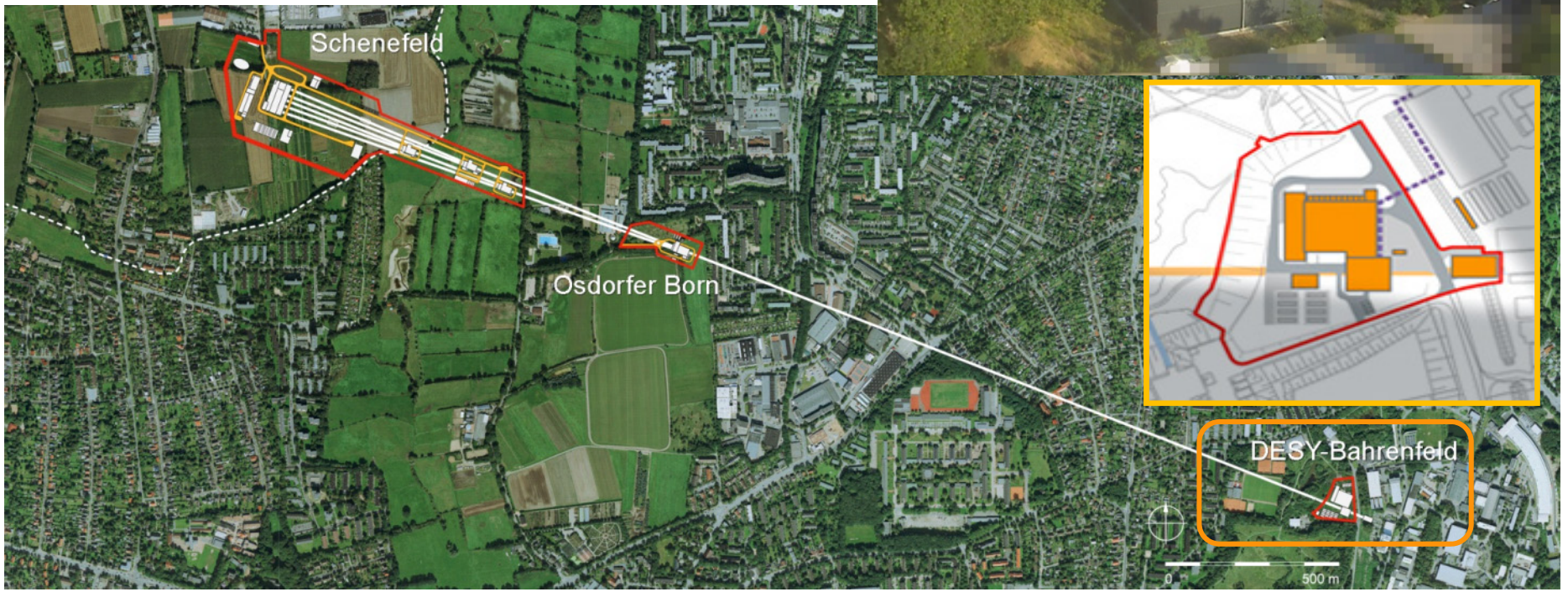


(Courtesy W. Decking, DESY)

European XFEL

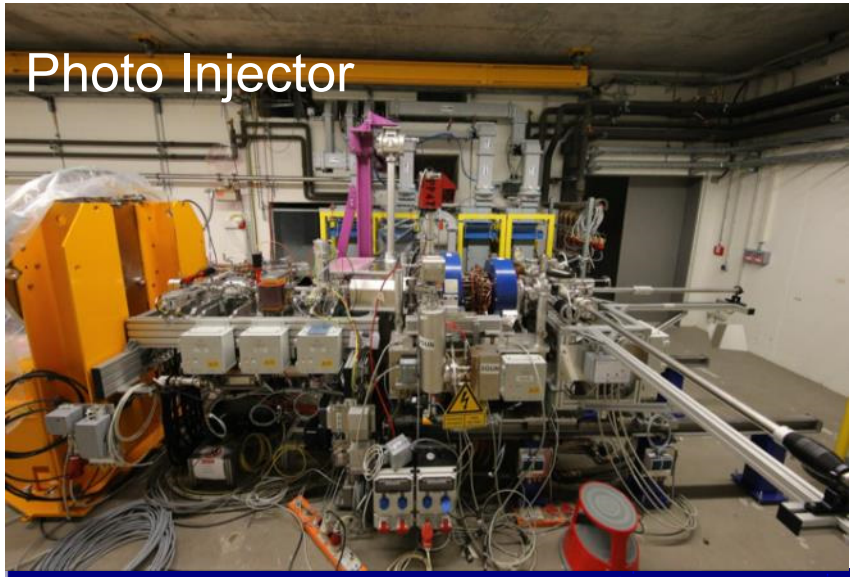
Infrastructure & Injector

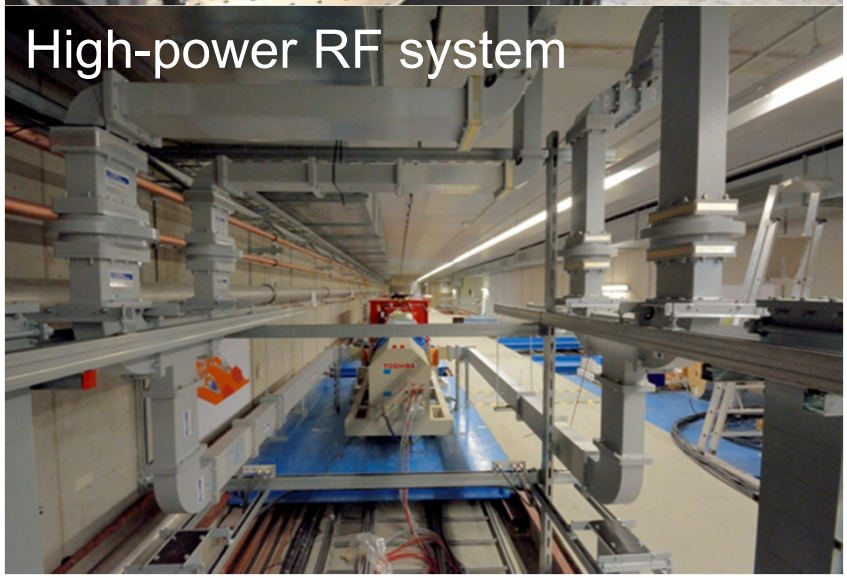
- On DESY campus
- Primary access to accelerator
- Linear accelerator infrastructure
- Injector

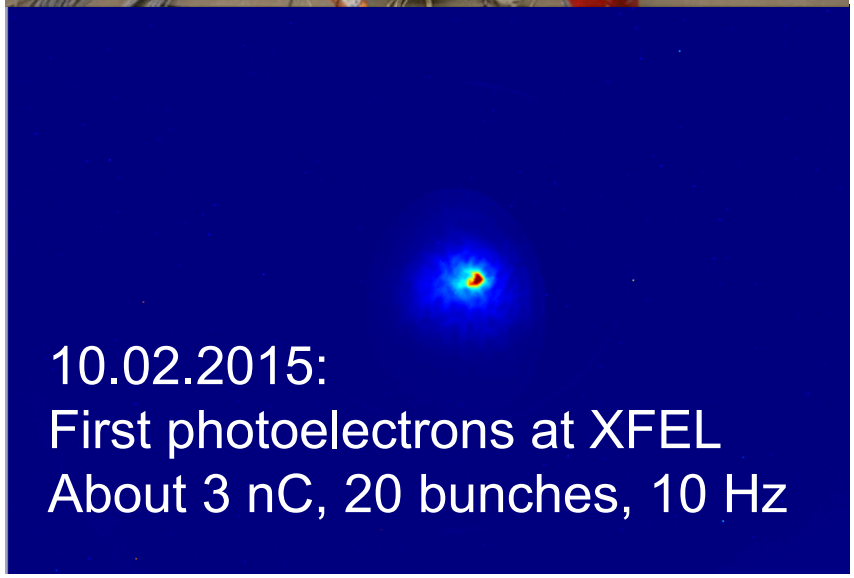


(Courtesy W. Decking, DESY)

RF Photo Injector







(Courtesy W. Decking, DESY)

European XFEL

Tunnel installation status of today

(Courtesy W. Decking, DESY)

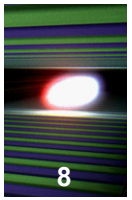
Undulator

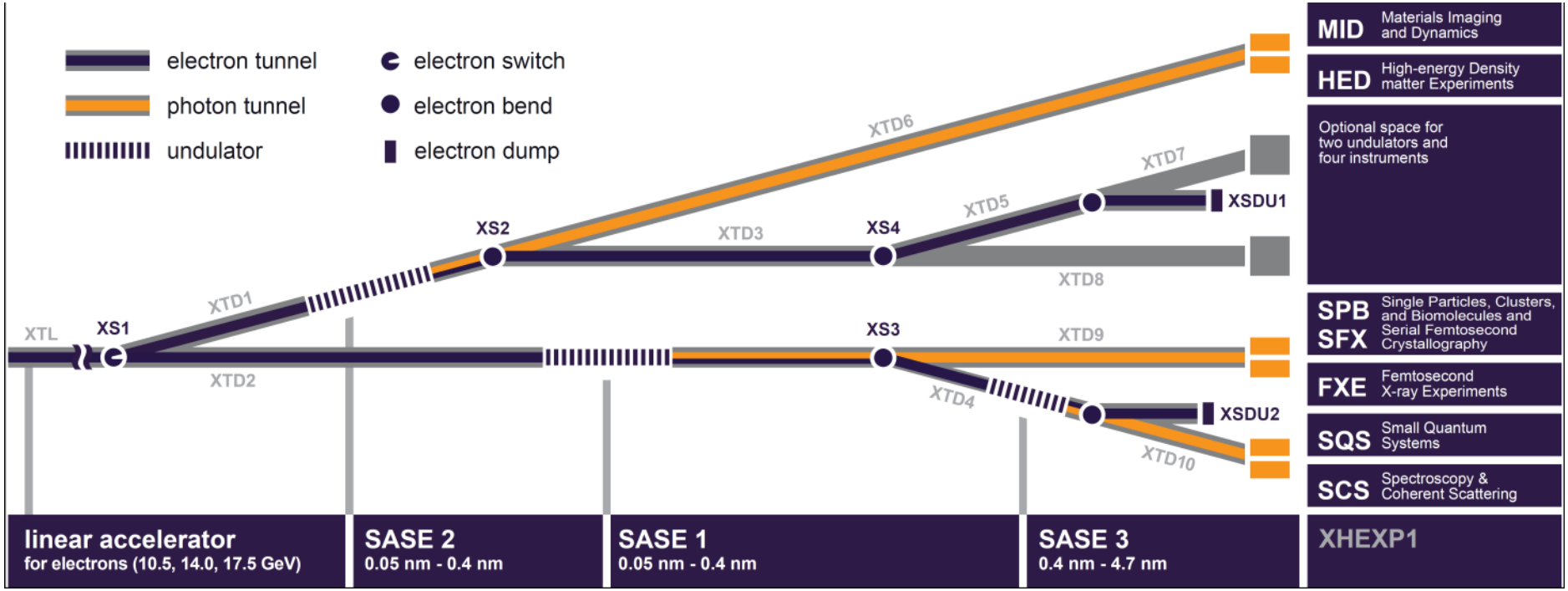
First undulator installed in the tunnel

(Courtesy W. Decking, DESY)

European XFEL

Photon System

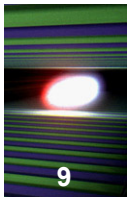




3 SASE sections (SASE1, SASE2, SASE3) with ~35 undulators each

(Courtesy W. Decking, DESY)

Radiation monitor positions along the XFEL



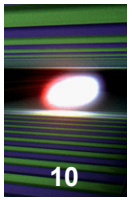
- Radiation monitors (estimation) foreseen at …

- *(External sensors ...)*
- Undulators (~100 pcs., 2 sensors per undulator): ~200 sensors
- Linac section, cold (25 RF-stations incl. LLRF, ~4 sensors per RF-station): ~100 sensors
- Linac section, warm (~ 10 sections incl. Bunch Compressor, ~4 sensors per section): ~ 40 sensors
- Beam stop (D3) permanent magnets: 16 sensors

- *(Internal sensors ...)*
- Machine Protection System (MPS) modules: ~150 sensors
- Modular BPM Units (MBU, PSI): ~180 sensors

- => Total: 340 external sensors + 330 internal sensors

The radiation monitoring system – features list

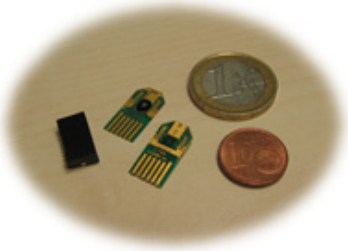


DosiMon system design goals (*)

- System integrates internal & external sensors (**)
- Use of small, self-integrating (by physical nature) radiation sensors
- γ-dose range (external sensors): 0.1 Gy – 2 kGy (***)
  (up to 10 kGy => reduced resolution)
- γ -dose range (internal sensors): 0.01 Gy – 10 Gy (***) ← +18V bias mode!
- Internal sensor for estimation of integrated n fluence -> under development
- Reference temperature logging at internal & external radiation sensors
- Scalable frontend (# of channels, # of readout electronics, cabling)
- Alarm generation into the machine protection system (dose rate, dose limits)
- Plug-in readout-module on standardized small form factor mezzanine (FMC)
- Compatible to XFEL machine protection system host board (DAMC2)
- Easily integratable into other host systems (e. g. PSI MBU carrier board)

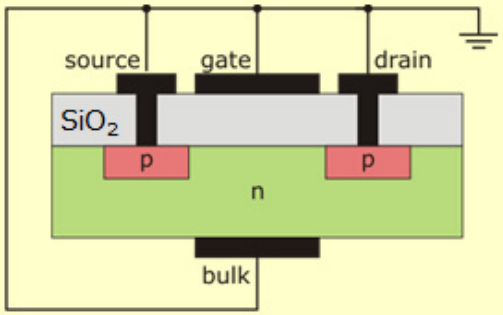
(*) Only main features listed important for integration into typical XFEL environment (host systems, frontend)
(**) Internal/external = inside/outside of electronic racks (shielded)
(***) Exact feasable limits currently under investigation (design ongoing)

P-channel MosFet - principle

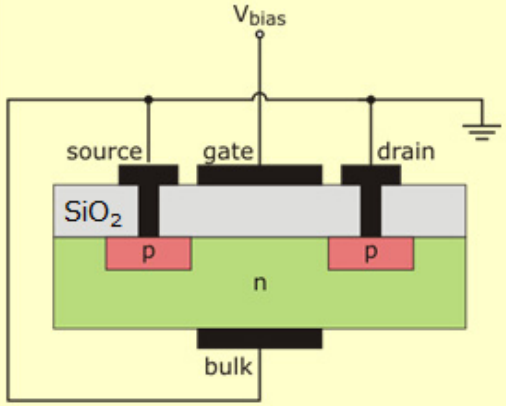


- REM Oxford Ltd. RADFET RFT-300-CC10G1
- Chip contains 2 p-channel MOSFETs with 300 nm insulator layer

exposure "zero bias"



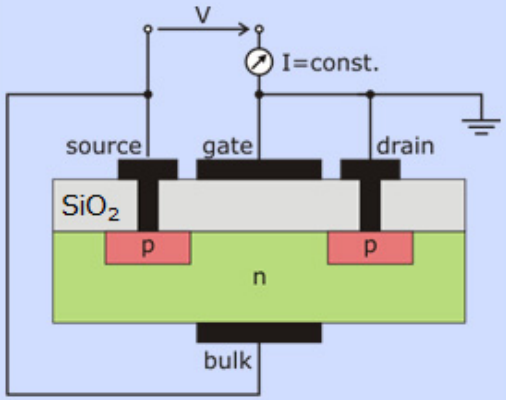
exposure with bias voltage



$V_{bias} > 0$: more sensitive

$V_{bias} < 0$: more linear

read-out



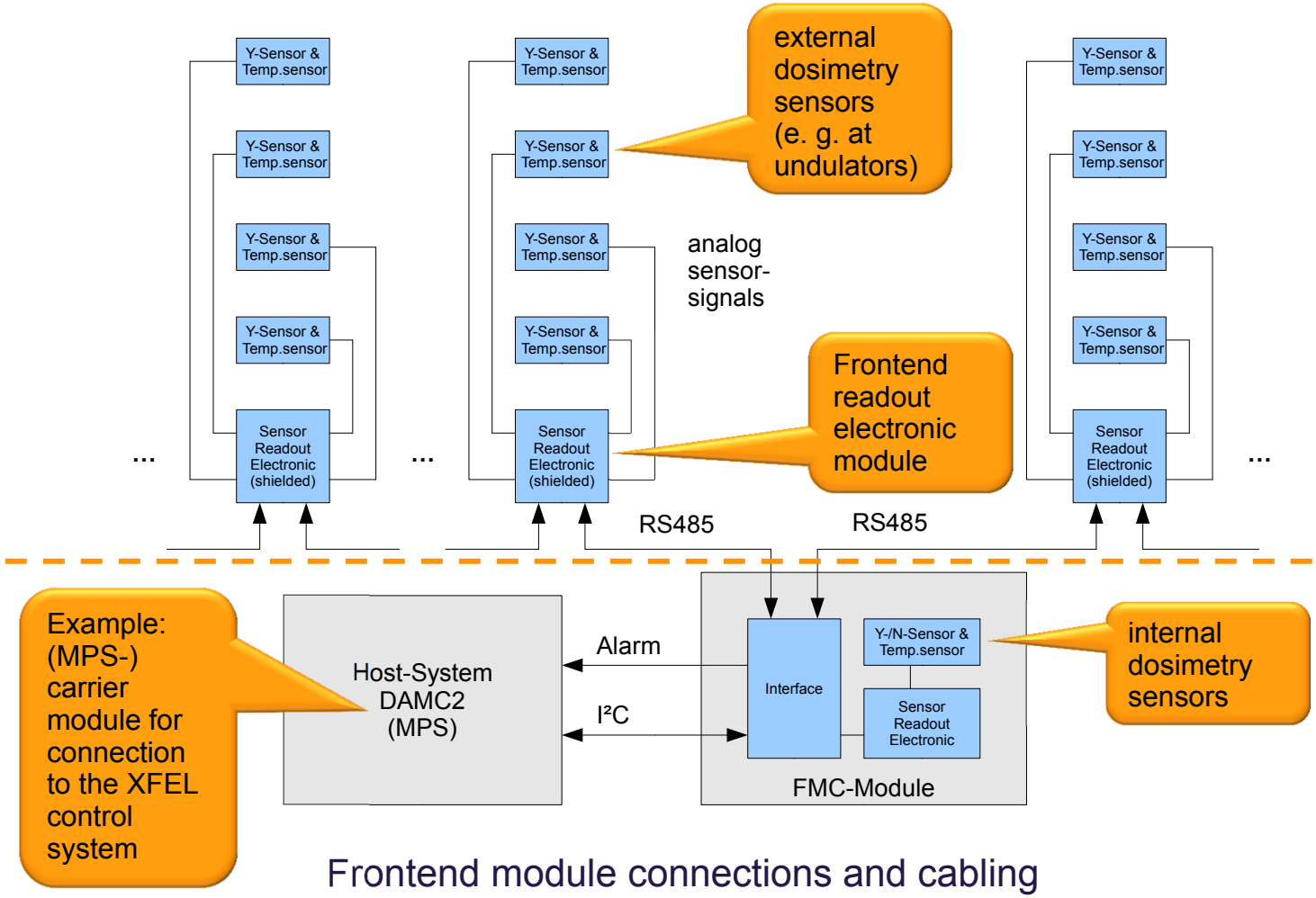
Track voltage for constant current (490 µA) between source and drain

(Courtesy L. Fröhlich, DESY)

European XFEL

DosiMon system concept & topology

- Scalable frontend :
  - # of channels
  - # of readout modules
  - cabling

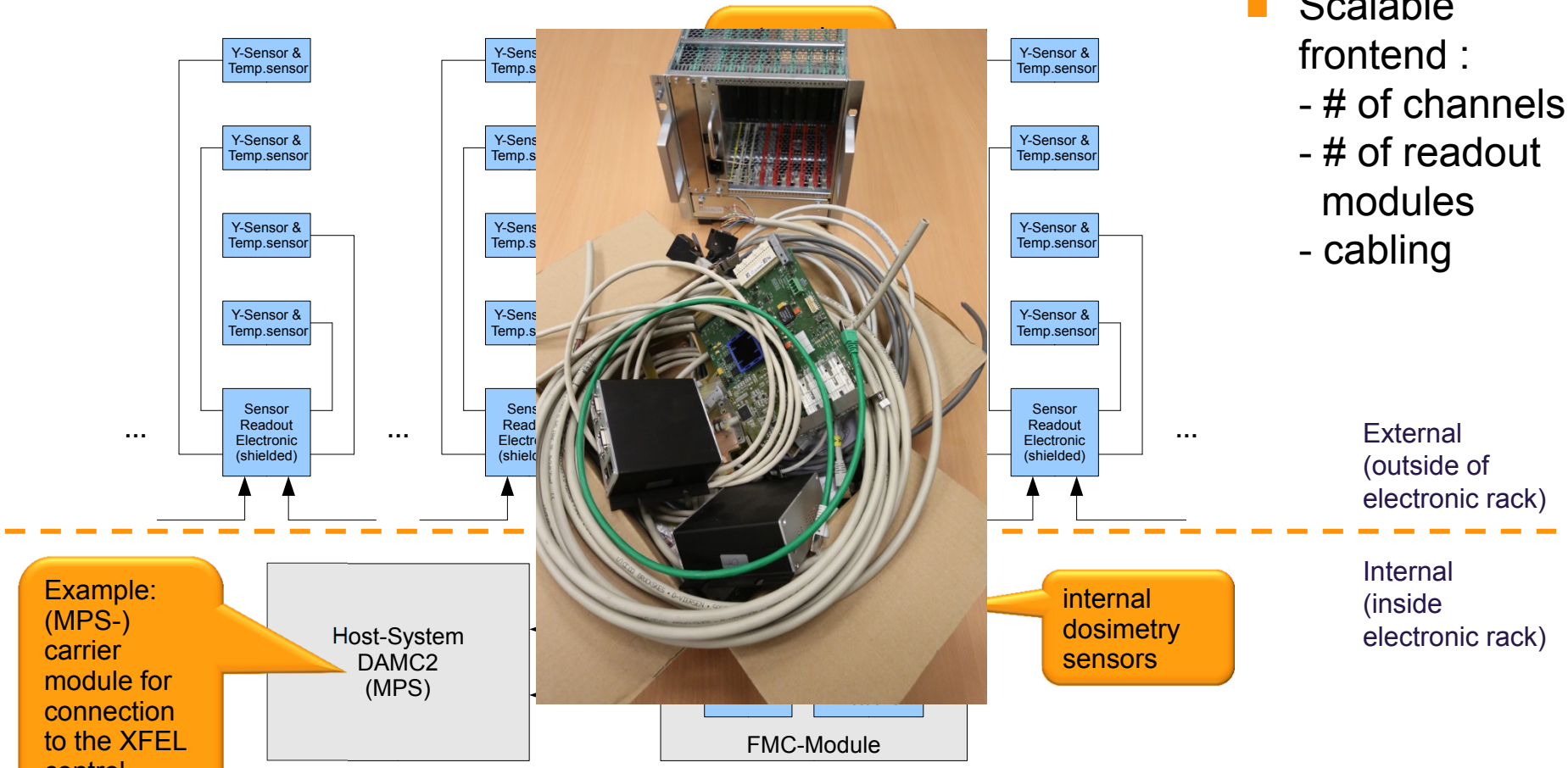


Frontend module connections and cabling

European XFEL

DosiMon system – out-of-the-box …

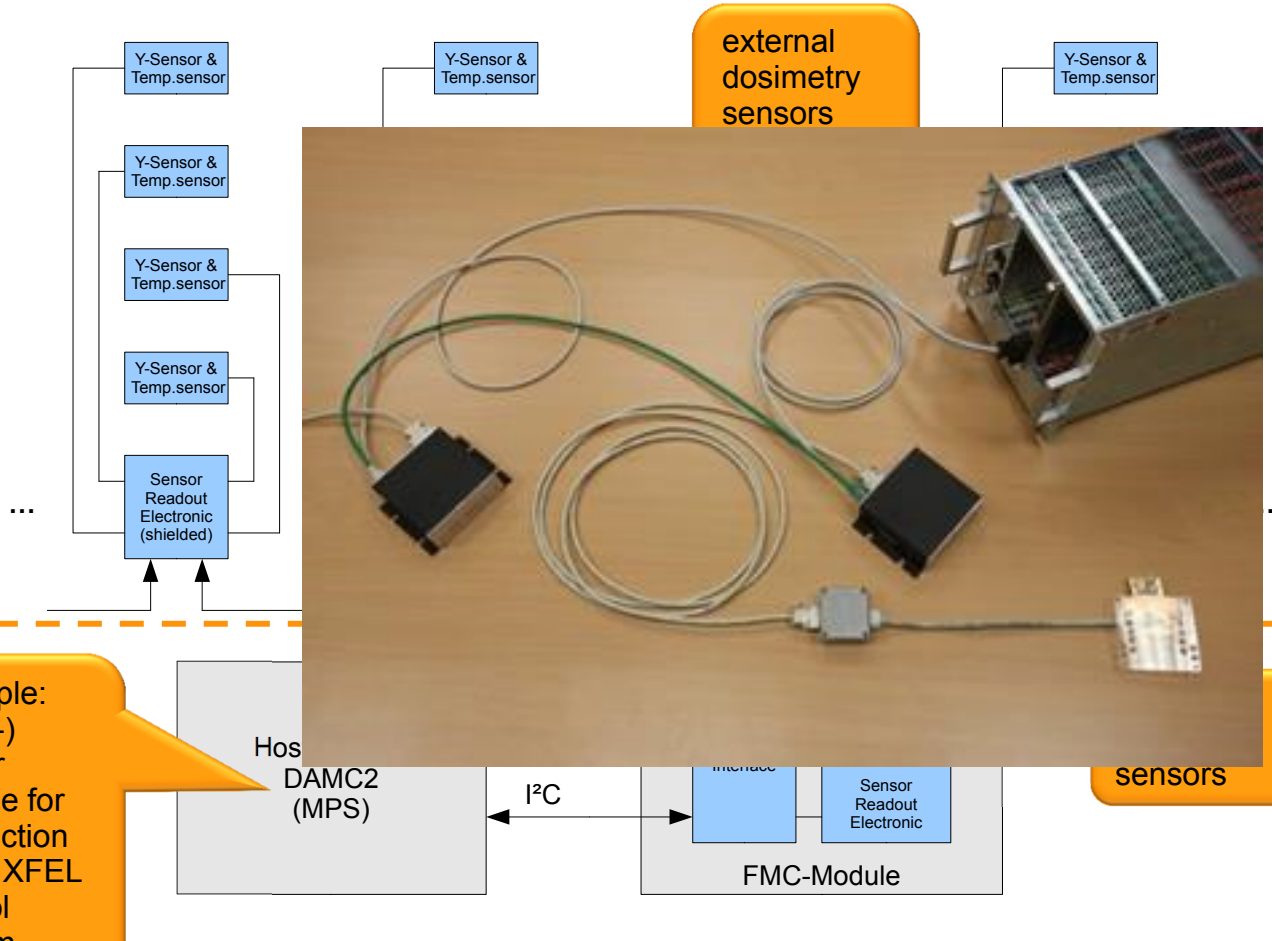
- Scalable frontend :
  - # of channels
  - # of readout modules
  - cabling



Frontend module connections and cabling

European XFEL

DosiMon system – components & connections



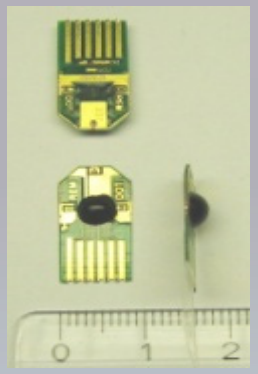
- Scalable frontend :
  - # of channels
  - # of readout modules
  - cabling

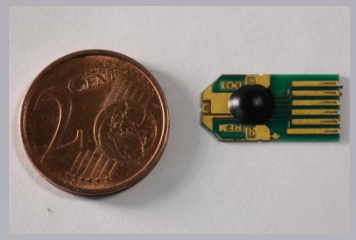
Frontend module connections and cabling

European XFEL

RadFet & TLD sensors at different locations

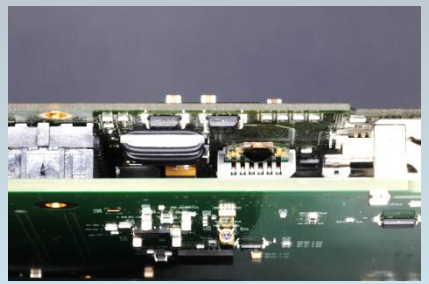
- Very small RadFet Sensor, type RFT-300-CC10G1 (REM Oxford Ltd.), 2 channels, integrated diode





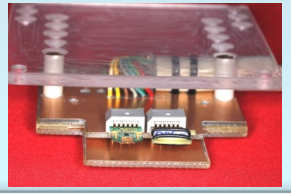
- RadFet of comparable size as the well-known TLD-type reference sensors used

- 1 RadFet/TLD pair located on the DosiMon FMC



- 1 RadFet located in each DosiBox →

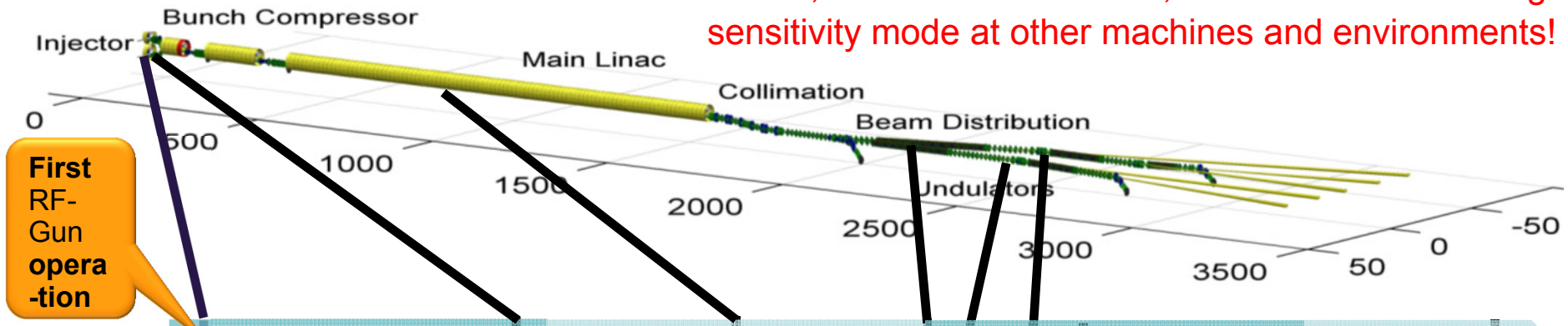
- 1 RadFet/TLD pair located on the external sensor-holder



European XFEL

Timeline for the XFEL project

Hence, a decision was made, to test the DosiMon high-sensitivity mode at other machines and environments!



First RF-Gun **opera-tion**

Next RF-Gun **opera-tion**

2015	2016	2017	2018
First e-beam out of RF gun installed at XFEL	Injector cooldown	Linac tunnel closed	SA1, SA3, SA2; 1st lasing possible	Start user operation	Full TDR performance

e^-	Gun and injector laser com.	Injector com. up to full XFEL performance (varying charges and bunch patterns)	Initial linac com. with reduced performance	Continued accelerator com. to full performance (high beam power, bunch length flexibility, multiple bunch properties per rf-pulse, full wavelength tuneability, ….)
γ				Beam line and experiment com.
				. First user operation

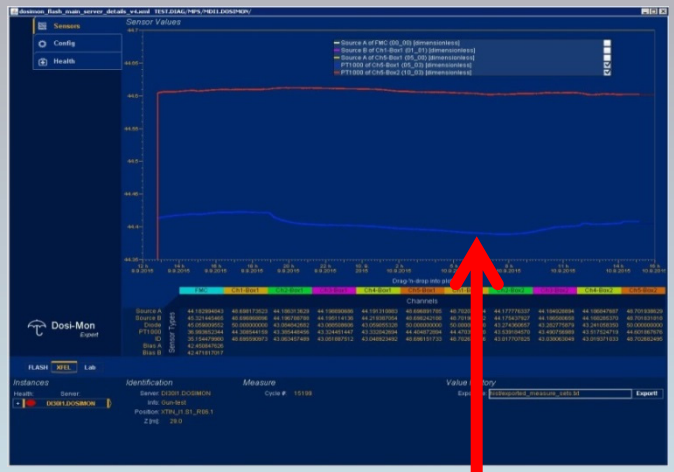
(Courtesy W. Decking, DESY)

European XFEL

DosiMon test setup at the XFEL injector

- … DosiMon +18V bias test setup at XFEL injector operational since mid of August 2015 …

- DosiMon test setup at the XFEL injector …



- … today only noise on RadFet radiation channels + operating temperature measurement
- … next beam not before November 2015 (injector commisioning)
- Hence, a decision was made, to test the DosiMon high-sensitivity mode at other machines and environments!

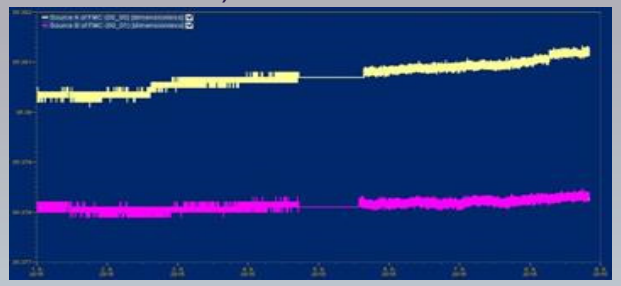
DESY HELMHOLTZ ASSOCIATION

DosiMon system commisioning at the FLASH gun

- DosiMon system at FLASH gun in operation since mid of August 2015

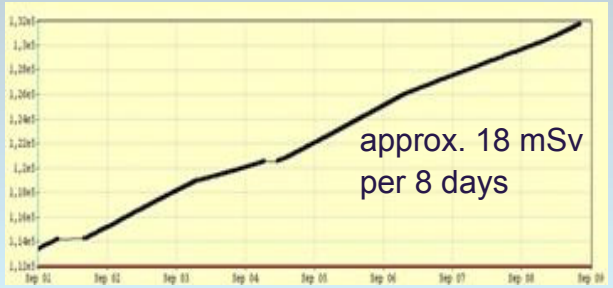
(The energy of FLASH at that position (~130 MeV) and the bunch timing is similar to the XFEL)

- full +18V bias system setup at the FLASH RF-Gun Rack (FMC with RadFet & TLD100 ref. sensor)
- DosiBox behind rack shielding
- 2 external RadFet with TLD100s



(data analysis ongoing, based on calibration measurement presented in this talk)

- example: uncorrected RadFet threshold voltages vs time show increasing signal (interrupted due to archive work)



- dose level [uSv] vs time (personal safety online dosimeter, ‘Pandora’)

Cs-137 calibration measurement (1)

- RadFet (RF) sensors have been irradiated at +18V bias mode by a Cs-137 calibration source over 2 weeks…

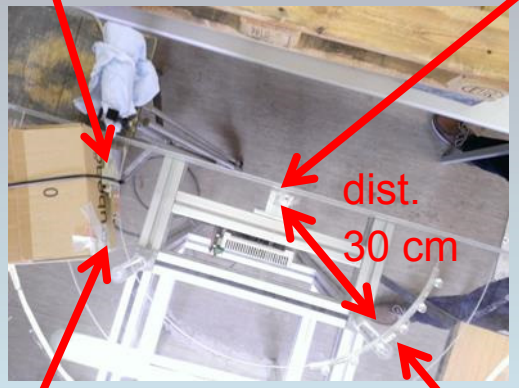
PC for stand-alone data readout

Readout electronics (similar to DosiMon series system)

Cs-137 calibration setup

4(-6) TLD100 reference sensors

Cs-137 source position (pellet)



Cs-137 calibration setup (top view)

2 TLD100 reference sensors in direct vicinity to RadFets

4(-6) TLD100 reference sensors

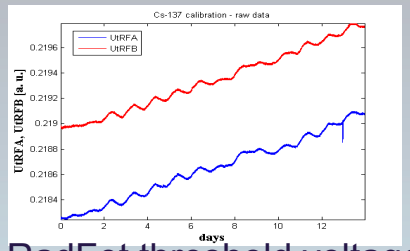
European XFEL

Cs-137 calibration measurement (2)

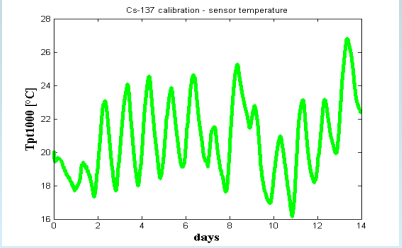
Results of Cs-137 calibration measurement at +18V bias-mode …

- correction of electronical errors
- correction of ambient temperature at the RadFet
- yet no correction of statistical errors
- good compliance former positive bias calibration measurements achieved
- Estimation of the Sensitivity in the startup-range yields an initial sensitivity < 20-30 mGy

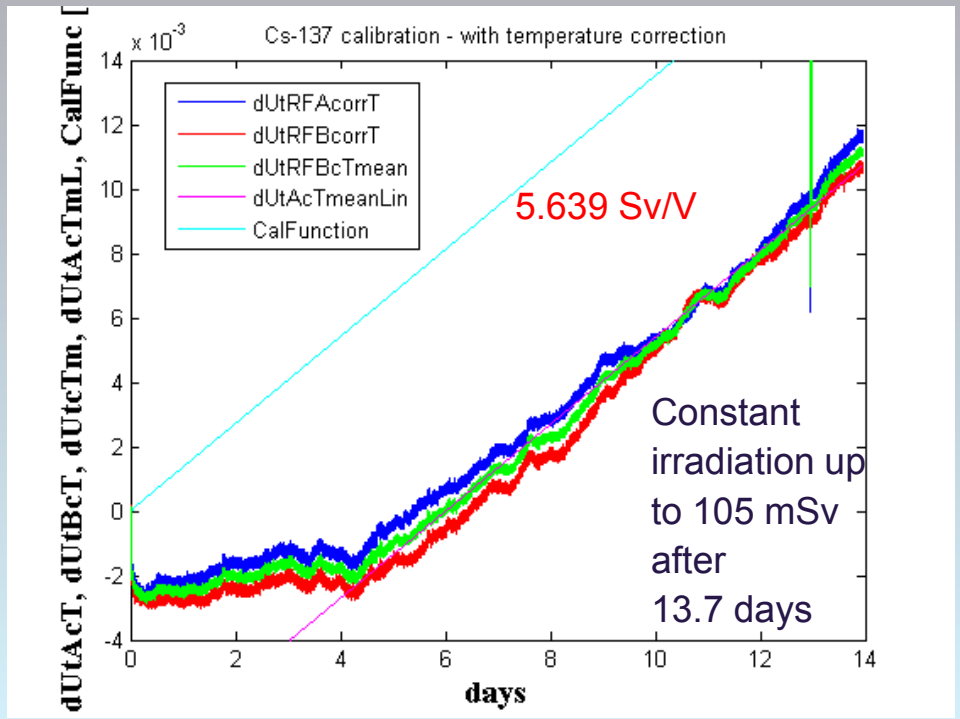
(TLD reference sensors are calibrated against dose in Sv;
a relative error below 0.1% due to short breaks during the irradiation phase the was neglected in the calibration)



RadFet threshold voltage raw data (both channels)



RadFet ambient temperature vs time



Temperature-corrected threshold voltage vs time
(startup phase 0-4 days yet not clearly understood)

DESY HELMHOLTZ ASSOCIATION

Cs-137 calibration measurement (3)

- Cs-137 calibration measurement at +18V bias-mode in comparison to other bias measurements …

- Estimated calibration factor of 5.639 Sv/V for DosiMon +18V calibration
- Quality factor for equivalent dose in Gy was estimated to be ~ 1
- As expected, this result falls in between the measurements of +9V and +25V bias

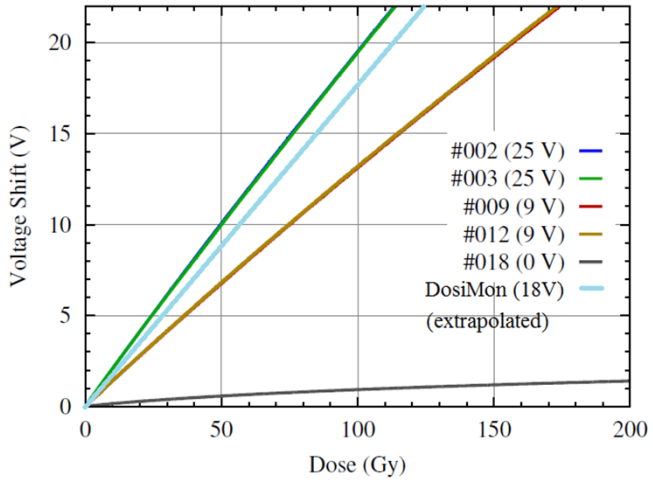


Figure 4: Measured calibration curves for bias voltages of 0, 9, and 25 V.
(Extrapolated DosiMon 18V bias data added for reference)

L. Fröhlich, S. Grulja, and F. Löhl,
DOSFET-L02: An advanced online dosimetry system for RADFET sensors.
Proc. IBIC'13, pp. 481–484, Oxford, UK, September 2013.

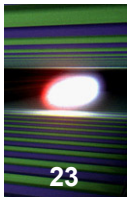
Test setup at DESY2 booster ring

- Desy2 long-term measurement at +18V bias ongoing since April 1, 2015 …

- Normal accelerator operation with long breaks during regular service times
- Goal: study and estimation of fading effects at +18V bias mode, at low dose levels up to 100 mGy, high energy (6GeV) and high bunch rate (1MHz)
- System seems to show plausible results corresponding to irradiation status
- Data interpretation is hampered by strong neutron dose at this position
- TLD100 reference sensors are influenced by neutrons

- TLD reference results have been corrected
- data analysis based on these corrected reference values is ongoing

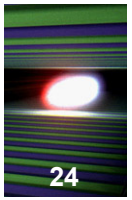
Test and measurement results



Results

- The DosiMon system has shown a sufficient dynamic range at the high-sensitivity mode (+18V bias) based on the extrapolation of dose-range from the calibration data
- A single calibration measurement with a Cs-137 gamma source showed overlaying effects in the startup region of the +18V bias in the DosiMon system, that have to be investigated in further measurements. Estimation of the Sensitivity in the startup-range yields an initial sensitivity < 20-30 mGy, sufficient for XFEL rack-surveillance
- Overall sensitivity of the +18V bias mode has been estimated on the assumption of an ideal physical model for the used RadFet sensors. It showed reasonable results in comparison to former measurements of zero bias, +9V bias and +25V bias mode
- A 1st complete installation of the DosiMon system inside the XFEL injector shows reasonable data without beam -> system performance will be investigated with beam after start of the XFEL injector commissioning in November 2015
- An installation of a complete DosiMon reference system at the FLASH RF-gun rack shows reasonable results – data analysis based on calibration presented here is ongoing
- Further tests of fading effects at the +18V bias mode at the Desy2 accelerator have been hampered by strong neutron radiation – TLD reference sensor performance was evaluated for such conditions
- The +18V bias mode in the DosiMon system has proven to be adequate for rack-surveillance at intra-rack measurements in the XFEL

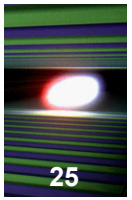
Outlook



Outlook

- Commisioning of the DosiMon system at the XFEL injector with beam (Nov. 2015)
- Measurements for the estimation of impact from the readout timing on RadFet response
- Release of the pre-series design for series produktion of components
- Additional calibration measurements for the external and the high-sensitive internal mode must be done (removal of statistical errors, clarification of the overlaying effects at the startup range of the high-sensitiity mode)
- Measurements for the estimation of fading influence on the measured dose values in external sensor- and high-sensitivity internal sensor-mode
- Calibration measurements in high-sensibility mode at Co-60 source for improved calibration up to 1.2MeV energy range
- Measurements for the estimation of neutron impact on RadFet response
- Measurements for the estimation of energy impact on RadFet response

Acknowledgements



Acknowledgements

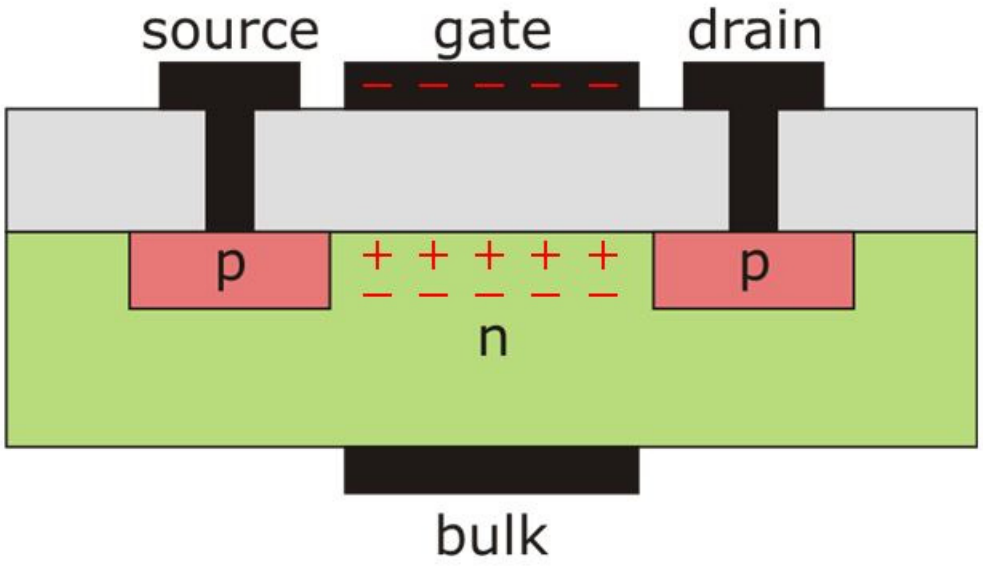
- Sincere thanks to the whole XFEL online-radiation-monitoring team …

- J. Pflüger, WP71 team (all XFEL GmbH)
- F. Hellberg, A. Hedqvist (all Stockholm University, Sweden)
- A. Holmes-Siedle (REM Oxford Ltd.)
- W. Decking, D. Nölle, K. Wittenburg, L. Fröhlich, R. Susen, B. Lemcke, J. Neugebauer, J. Jaeger, S.Karstensen (all DESY Hamburg)

- … and all those who might have been forgotten (sorry!)
- … and many more helping hands!

Thanks for your attention!

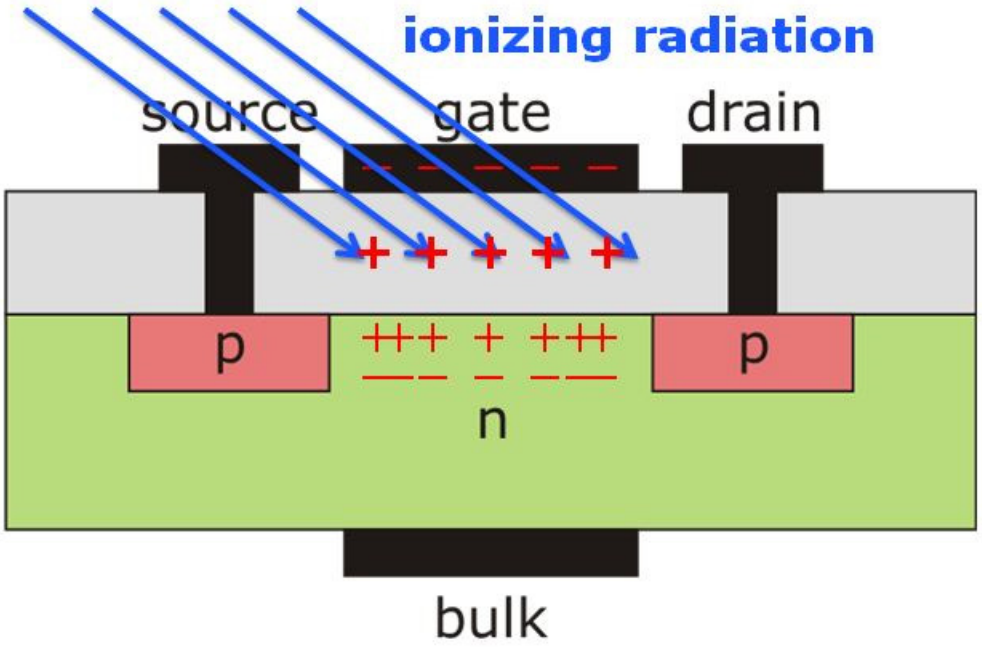
P-channel MosFet - principle



negative gate potential → conductive inversion layer

(Courtesy L. Fröhlich, DESY)

P-channel MosFet - principle



ionizing radiation → stationary charges in insulation layer

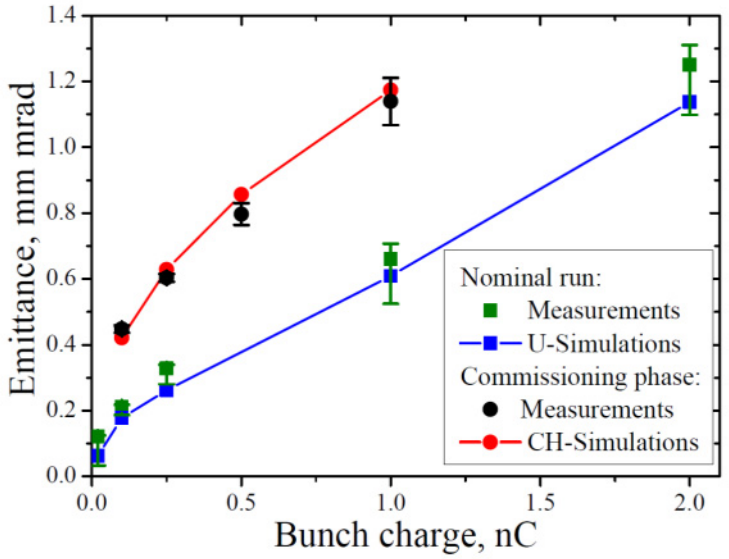
(Courtesy L. Fröhlich, DESY)

European XFEL

Injector parameters

Gain material	Yb:YAG
Intra burst rate	4.5/n MHz, n≥1
Pulse properties	Short pulse: < 3 ps (FWHM), > 0.7 µJ per pulse Long pulse: ~10 ps (FWHM), > 3 µJ per pulse Shaped 20 ps with 2 ps rising edges (Phase 2)

System	Modulator in separate building Long HV pulse cable Pulse Transformer Multi beam klystron
Parameters	1.3 GHz, 10 Hz, 1.3 ms., 10 MW
Waveguide	Four 50 m long air-filled, 1.5 MW each

Type	1.3 GHz, 1.6 cell nc cavity
Cathode	CsTe
Peak Power	6.5 MW (5.5 MW during fist operation) 0.02 C– 1 nC
Average Power	60 kW
Charge	0.02 nC – 1 nC
Proj. emittance (PITZ)	 See G. Vashchenko, MOD04

(Courtesy W. Decking, DESY)

Thanks for your attention!