PAUL SCHERRER INSTITUT

V. Schlott

Short Report on Photon BPM WS for SLS 2.0

DEELS

DLS, April 18th, 2018

PAUL SCHERRER INSTITUT

Brainstorming on SLS 2.0 Photon BPMs

Brainstorming on Photon Beam Position Monitors for SLS 2.0

Thursday, 5 April 2018 from **09:00** to **13:00** (Europe/Zurich)
at **PSI (WBGB 019)**

Description Based on experience with SLS photon beam position monitors (P-BPM) and the requirements for SLS 2.0, this brainstorming workshop aims to find out, if there is potential to improve the beam stability and reproducibility of beamline operation by optimizing P-BPM designs and integrating their readings in a global (fast) orbit feedback for SLS 2.0. Options and R&D activities for different P-BPM types will be presented and discussed.

Thursday, 5 April 2018

09:00 - 09:10 Introduction *10'*
Speaker: Dr. Oliver Bunk (Paul Scherrer Institut)

09:10 - 09:20 "Wish List" for SLS 2.0 P-BPMs *10'*
Speaker: Meitian Wang (Paul Scherrer Institut)

09:20 - 09:40 P-BPM Options - Some Pros and Cons *20'*
Speaker: Volker Schlott (Paul Scherrer Institut)
Material: **Slides**

09:40 - 10:00 SLS Photon BPMs - Present Use and Status *20'*
Speaker: Dr. Michael Boege (Paul Scherrer Institut)
Material: **Slides**

10:00 - 10:15 Diamond Quad P-BPMs at SLS *15'*
Speaker: Meitian Wang (Paul Scherrer Institut)

10:15 - 10:30 Diamond Quad PBPM - Recent Developments / Results *15'*
Speaker: Volker Schlott (Paul Scherrer Institut)
Material: **Slides**

present situation and experience with existing devices

10:30 - 10:50 Coffee Break

10:50 - 11:10 Plans for SLS 2.0 Insertion Devices *20'*
Speaker: Thomas Schmidt (Paul Scherrer Institut)
Material: **Slides**

11:10 - 11:30 Plans for SLS 2.0 RF BPMs and FOFB *20'*
Speaker: Boris Keil (Paul Scherrer Institut)
Material: **Slides**

SLS 2.0 specific issues

11:30 - 11:50 Recent Results from SiC Detectors *20'*
Speaker: Dr. Massimo Camarda (Paul Scherrer Institut)
Material: **Slides**

11:50 - 12:10 Gas-based Photon BPMs *20'*
Speaker: Pavle Juranic (Paul Scherrer Institut)
Material: **Slides**

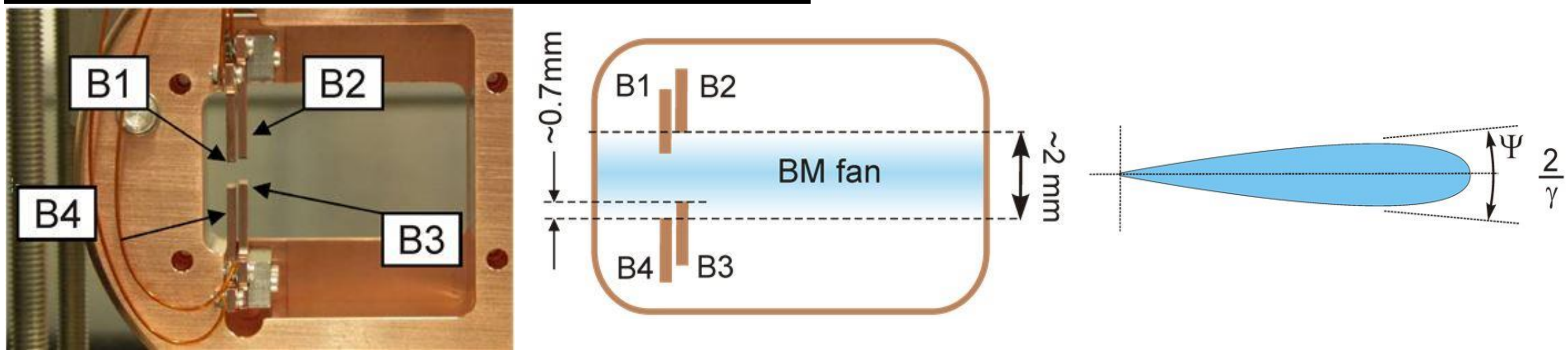
Options for novel / improved photon BPMs

12:10 - 13:00 Discussion on SLS 2.0 P-BPMs
Convener: Volker Schlott (Paul Scherrer Institut), Meitian Wang (Paul Scherrer Institut)

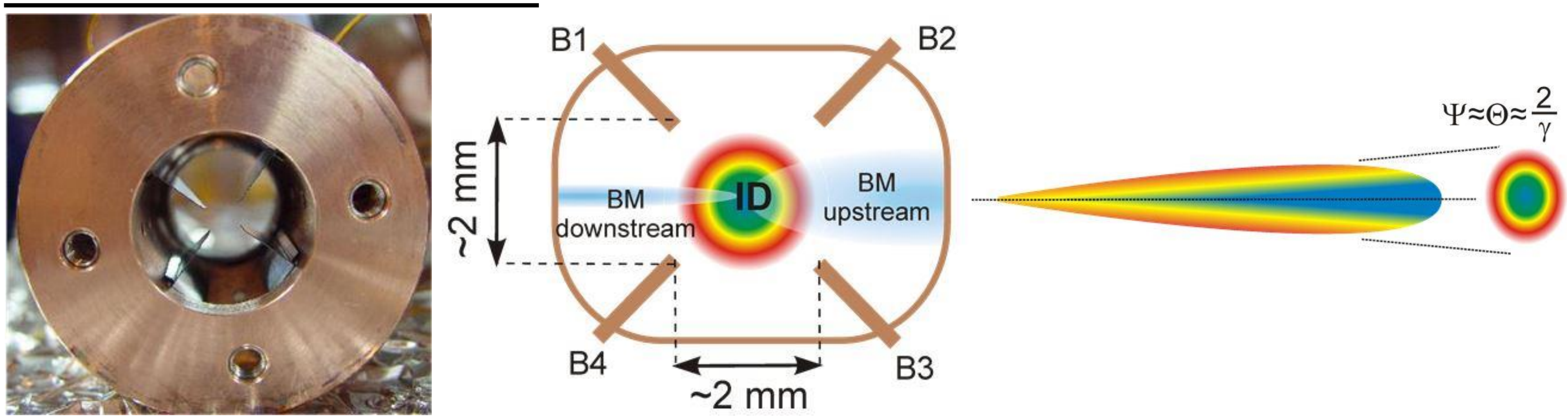
"Blade Monitors" as Photon BPMs

"blade monitors" are successfully used in many SR facilities over many years

staggered pair monitors for bending magnet BLs



X-BPM for undulator beam lines

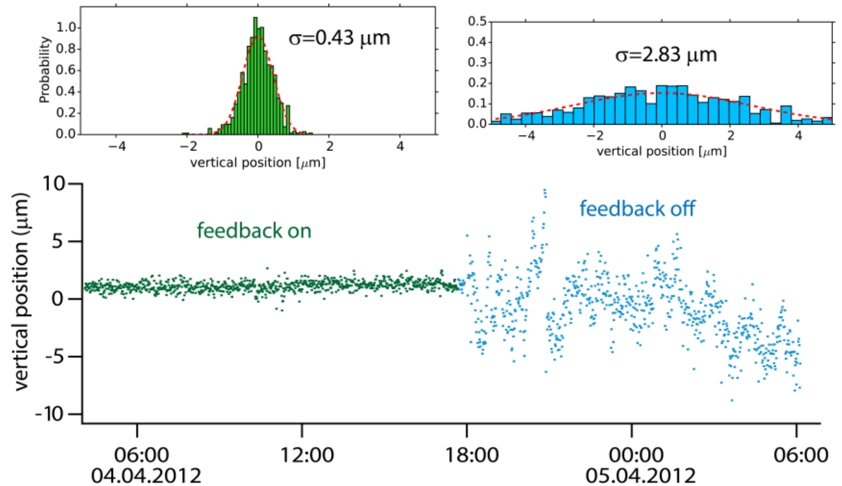


Photon BPMs for SLS 2.0 – Motivation

"Blade Monitors" at SLS

all SLS BL front ends are equipped with two blade monitors

- → **providing sub-µm photon beam readings**
- → **revealing systematic effects of RF BPMs and girder misalignments around IDs**
  (e.g. beam current dep. during top-up asymmetries of buttons during coupling optimizations)
- → **used for ID feed forwards and feedbacks at specific photon energies (ID gap settings)**

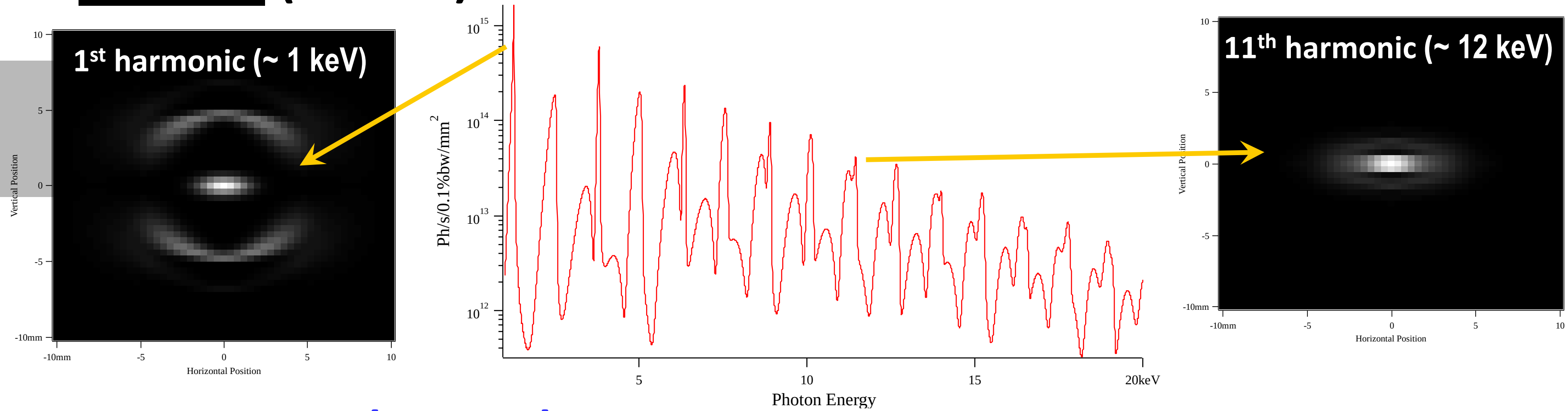


users viewpoint – they are still not happy ☹

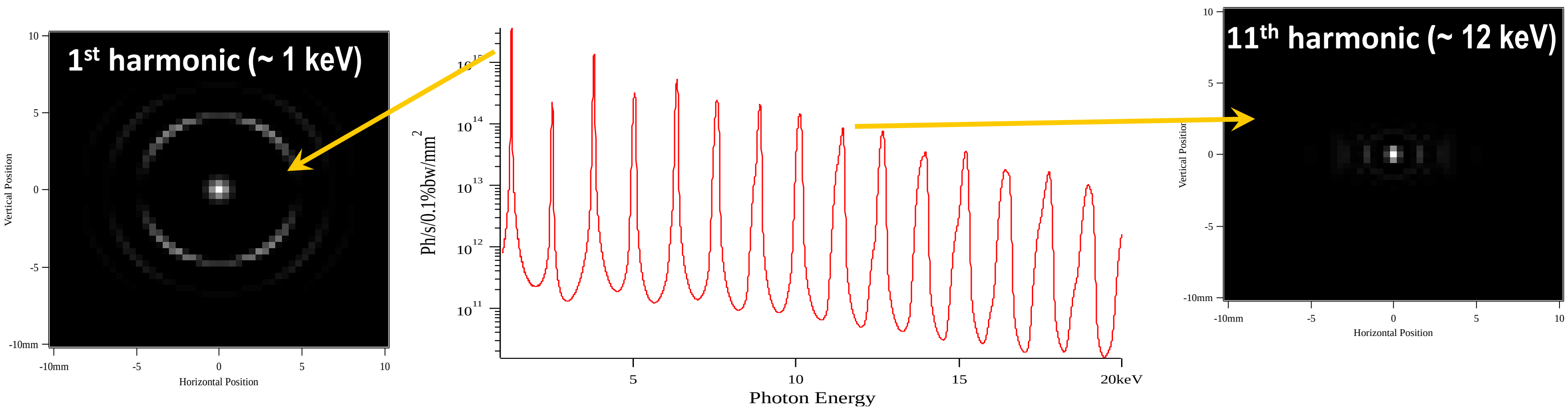
- → **absolute photon beam position readings over long times seems not possible**
- → **after shut-downs blade resistivity seems to change (sudden jumps) due to heat load changes**
- → **further reliability issues – also within (longer) experimental runs**
- → **beam line specific position stabilization loops implemented, which have no connection to FOFB or Diamond quad detectors (hard X-ray photon BPMs) behind mono-chromators**
- → **present photon BPM (blade monitor) geometries are not possible or have to be modified for SLS 2.0**
- → **substantially higher resolutions are required (at least for PX beamlines up top a factor of 10)**

From SLS to SLS 2.0 – Insertion Devices

SLS U19 (K = 1.6)



SLS 2.0 U19 (K = 1.6) → cleaner spectrum, more confined beam



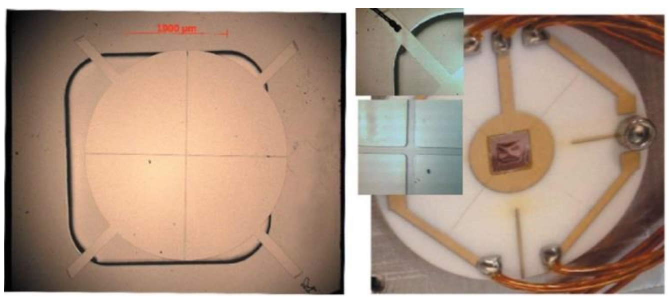
New APPLE-X / twin APPLE undulators will provide variable polarization (10 – 1000 eV) and complex / changing transverse beam distributions

Photon BPMs – Monochromatic Beam

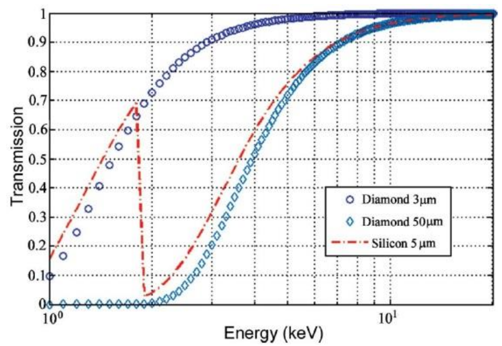
Ultra-thin CVD Diamond Membrane Quadrant Detectors as Hard X-ray Photon BPMs

- K. Desjardins, et al., *Ultra-thin Optical Grade scCVD Diamond as X-ray Beam Position Monitors*
  J. Sync. Rad. (2014) 21, doi:10.1107/S1600577514016191
- E. Griesmayer, et al., The Use of Single-Crystal CVD Diamond as a Position Sensitive X-ray Detector
  Proc. IBIC 2016, Barcelona, Spain, 71 (MOPG14)

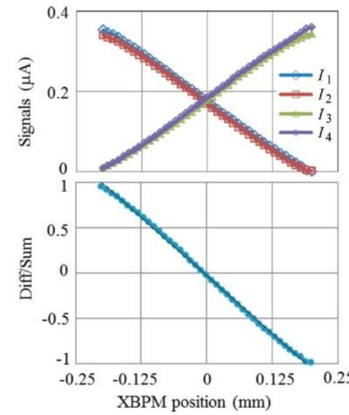
CVD Diamond Membrane Quadrant Detectors (3 μm thick)



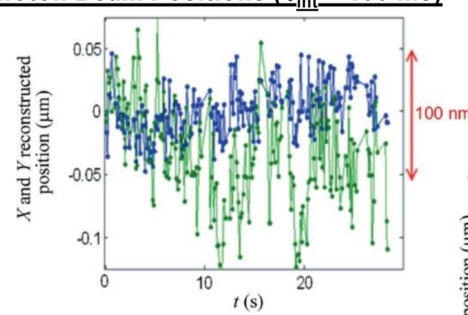
CVD Diamond and Si Transmission



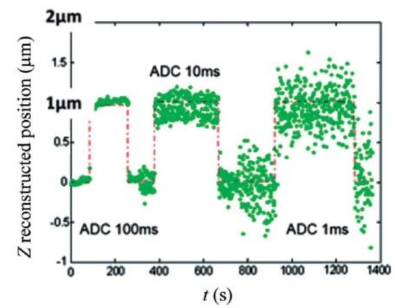
X-BPM and Δ/Σ Signals



Photon Beam Positions (τ_{int} = 100 ms)



Resolution vs. Integration Time



Hard X-Ray Photon BPMs for SLS-2

→ make use of latest developments
(e.g. SOLEIL or commercial supplier)

→ evaluate CVD diamond vs. SiC at SLS-1

→ study their use for white beams
(X-BPMs in the hard X-ray ID front ends)

→ develop suitable electronics for read-out of low currents at high BW

images and measurements are courtesy of K. Desjardins, et al.

Photon BPMs – Monochromatic Beam

Diamond Quad Detectors (@ SLS PX beamlines)

→ are successfully used for photon beam alignment and monitoring (~ 1 s update rate) in front of and behind focusing optics and at location of beam focus / sample

→ primary slits used for determination of photon beam position at mono-chromator

→ SLS: 5 – 50 µm crystal size; photon energy range 6 – 18 keV
1 µm stability over hours, reproducibility and automatic alignment

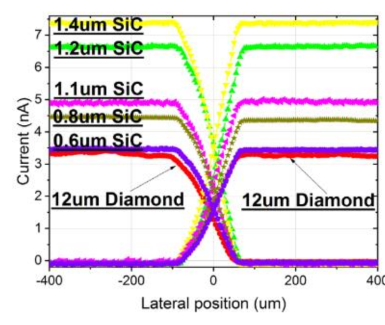
→ SLS 2.0: 1 – 10 µm crystal size; photon energy range 3 – 25 keV
0.1 µm stability, full reproducibility, automatic alignment and data-taking

…but for SLS 2.0:

- better resolution from Diamond quad detectors
- faster read-out
- integration in (fast) orbit feedback (connection between machine and beamline)
- experience shows that incoming beam position (front end) needs to be known better

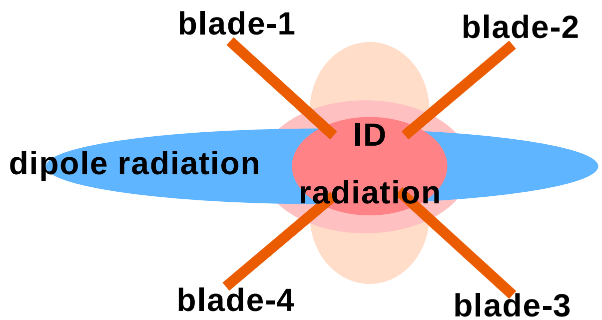
- SiC is investigated as alternative material

→ similar transmission and radiation hardness as Diamond
→ provides higher signal / higher bandwidth (?)
→ less expensive, better material quality



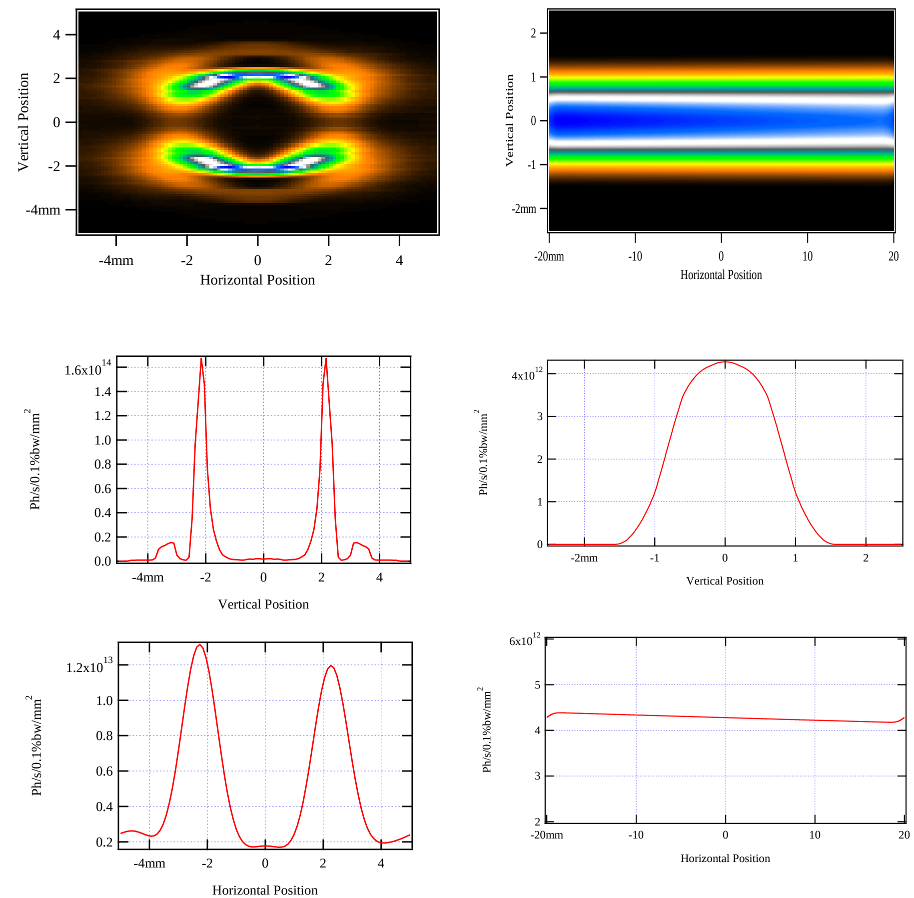
Photon BPMs – The Issue(s) in the Front End

Idealized Situation (a sketch)



More realistic... (SRW simulation)

SLS-1: U14 @ 2 keV @ 8.5 m & downstream dipole



→ **Cu blades touch only the outer fringes of the photon beam from the IDs**

→ **contamination from dipole radiation is comparable to ID beam signals**

→ **ID gap changes influence optical modes and photo-emission yield from blades (especially in the low energy beamlines**

→ **heat load / changing heat load leads to systematic errors (e.g. jumps) and low reproducibility (after SDs, beam losses)**

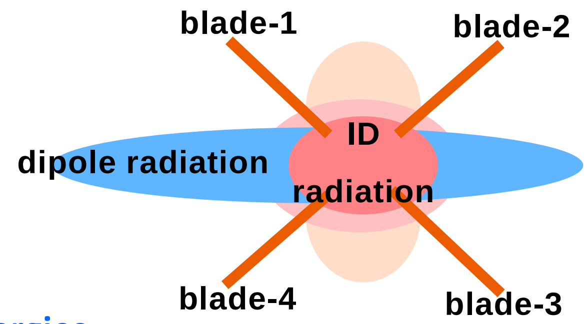
A Remedy (?): Gas-based Photon BPMs

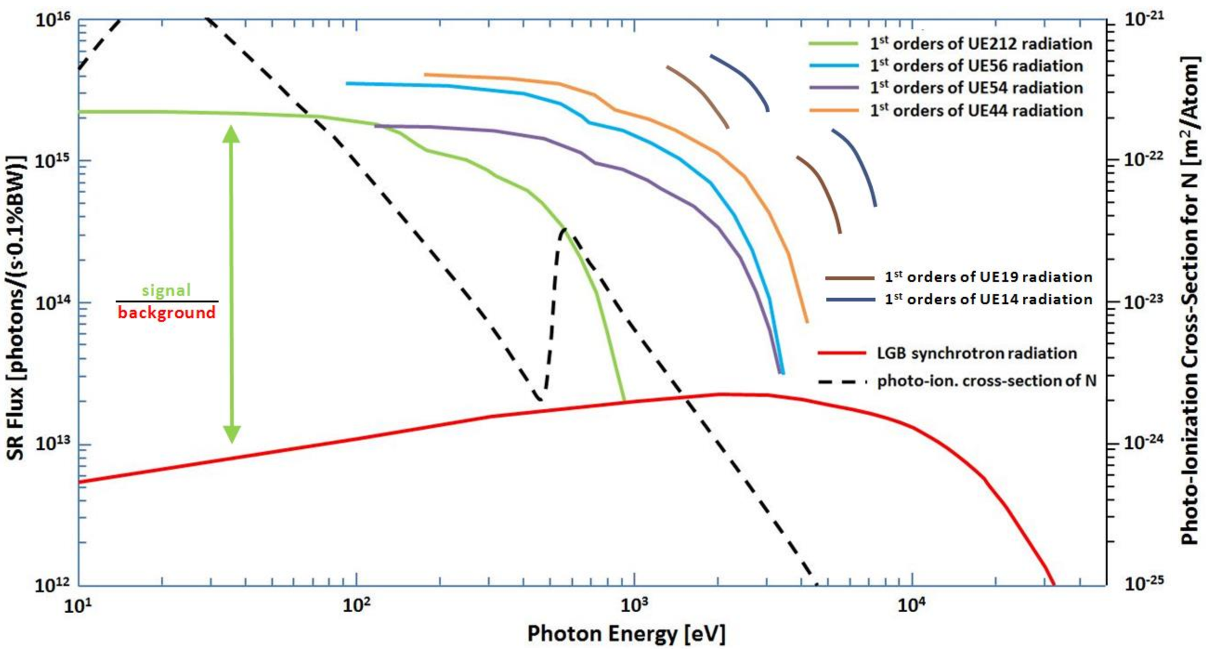
<u>Gas-based Photon BPMs for VUV and Soft X-ray SR</u> (white beam)

How to overcome the contamination from dipole radiation and optical mode changes in case of ID gap changes for <u>blade monitors</u>…?

→ **measure the center of mass of ID radiation**
by using photo-ionization in nitrogen gas
being transparent to VUV / soft X-ray SR

→ **suppress the (high photon energy) contamination**
from dipole radiation
as photo-ionization cross-section falls off for higher energies





<u>Signal Estimation (~ 1 keV)</u>

$$N_{ions} \approx \frac{L_{Ph-BPM}\cdot\alpha\cdot\sigma(\eta\omega)\cdot p_N\cdot N_{photons}}{k_B\cdot T}$$

with…:

$p_N \approx 10^{-6}$ mbar
$L_{ph-BPM} = 0.3$ m
$\alpha_{Cu-plate} \approx 1$
$N_{photons} \approx 10^{15}\ s^{-1}$
$T = 300$ K

→ $N_{ions} \approx 10^{9}\ s^{-1}$

Photon BPMs – Monochromatic Beam

Gas-Based Photon BPMs (white beam in front ends)

→ gas monitors (intensity, position, polarization) are used in FELs
they are single-shot devices for photon energy ranges between few eV to 12 keV

→ they are long (meters) and expensive (250 kCHF) and operated at gas pressures between 10^{-4} and 10^{-6} mbar

→ signal levels (for nitrogen gas compared to Xenon) seem to be comparable at kHz update rates (optional integration in FOFB)

Some Conclusions from Brainstorming Workshop

→ PSI PSD is highly interested in and supports improved photon BPMs for SLS 2.0

→ R&D should be done for SiC (alternative material to Diamond), Diamond quad detectors and gas-based monitors for use in the front ends

→ project groups should be set-up; project proposal should be submitted

→ parameters (for gas monitors) need to be clarified and vacuum issues addressed

→ prototype should be built and tested in SLS (2020+) before dark period