X-ray Gas Monitor operation above 25 keV

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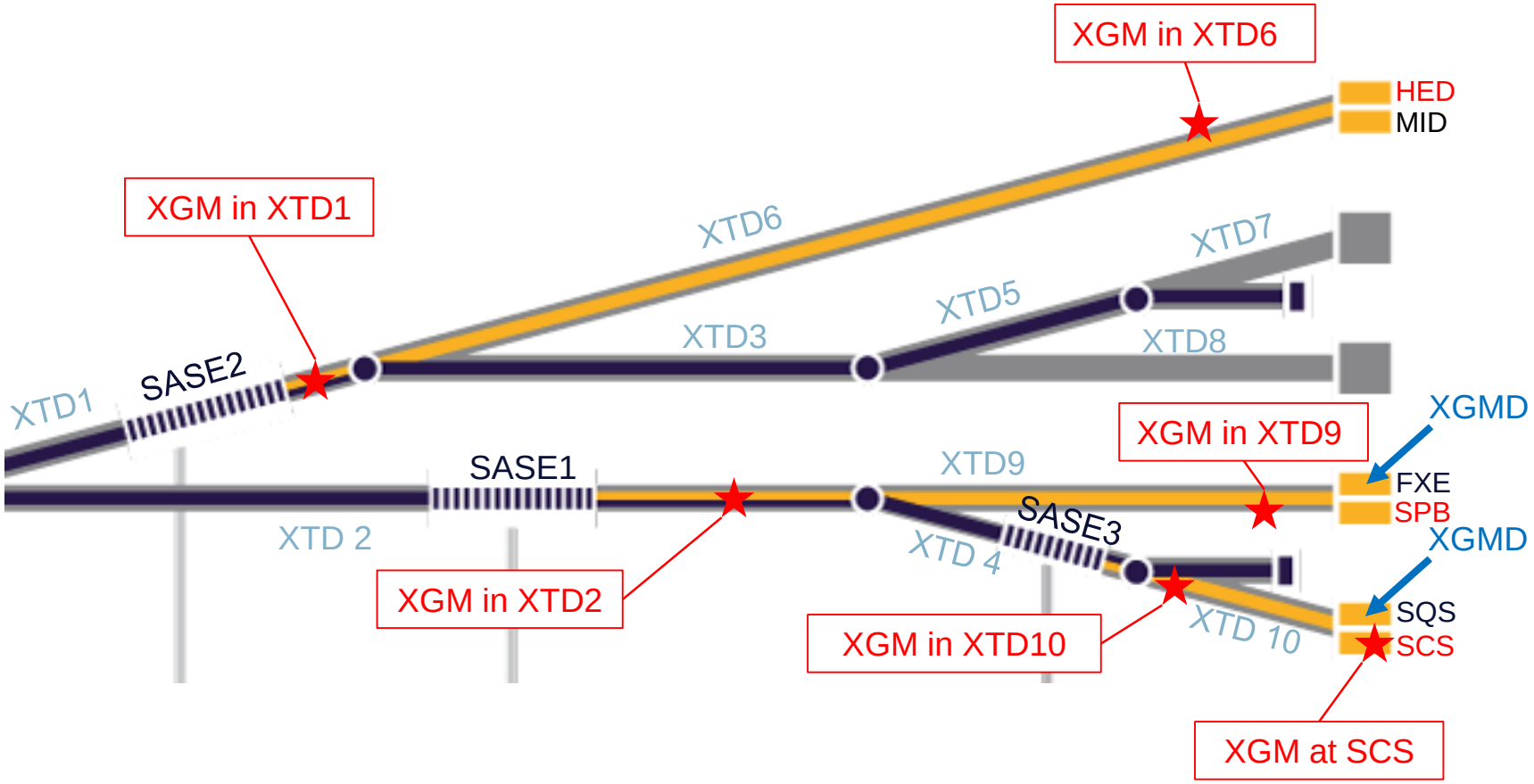
- Basic concept of XGM
- Photoionization cross-section
- HAMP as single-shot detector
  (intra-train non-linearity and repetition rate limit)
- XGMs operated successfully up to 30 keV

X-ray Gas Monitor (XGM) setup

Single-shot non-invasive pulse energy and average beam position measurement

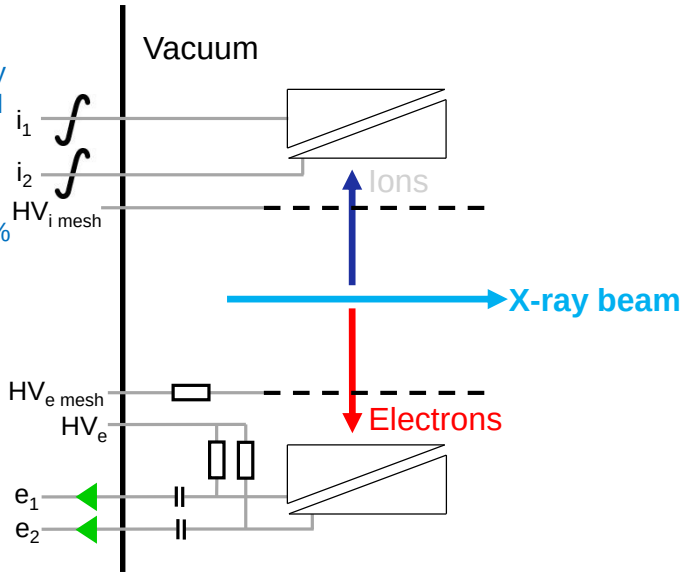
- Big brother
- Users
- Radiation safety
- Operators

Locations of XGMs in the tunnels

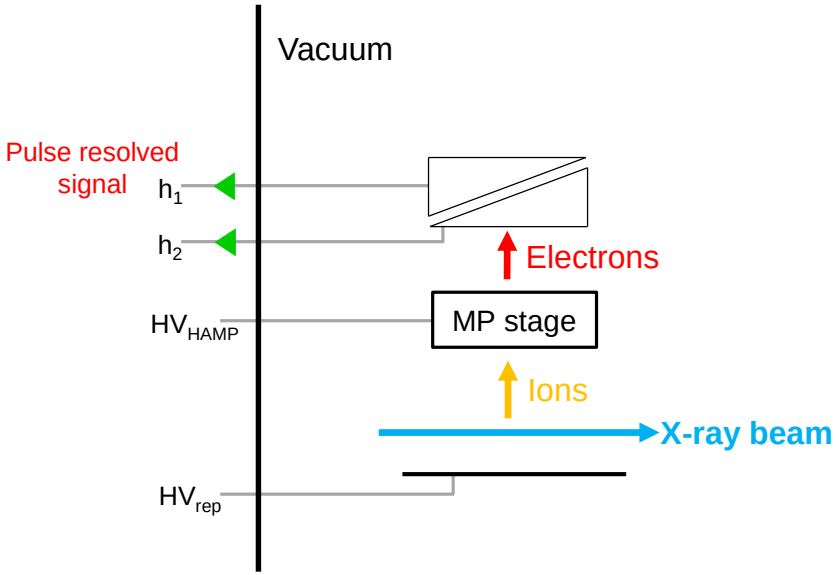


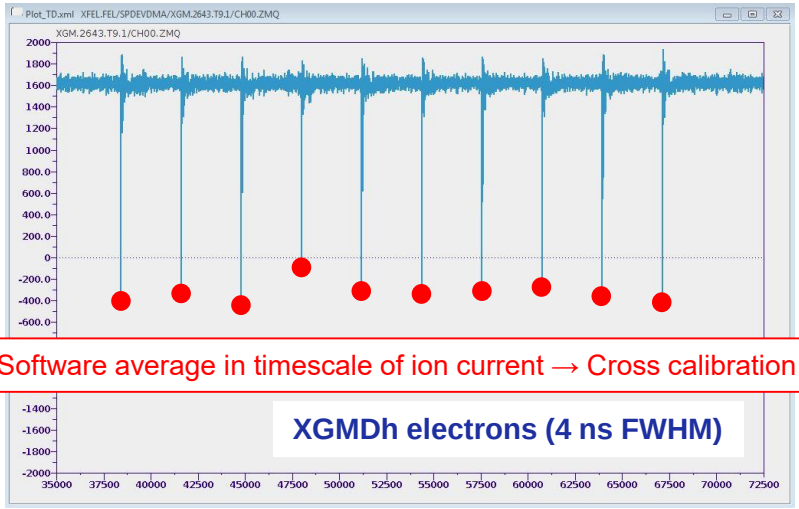
XGMD

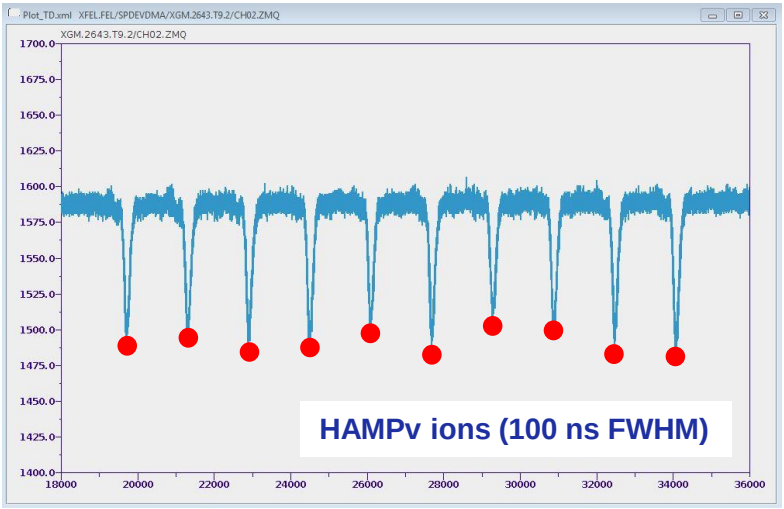
Averaged absolutely calibrated ion signal
↓
Photon flux with measurement uncertainty of 7-10 % and position measurement with 10 μm accuracy.



HAMP







XGMD fast signal up to ~ 18 keV … then only HAMP !!!

XGM equations

Number of ions created per pulse in the XGMD:

$$N_{ion} = \frac{N_{ph} * \sigma_{ph}(\hbar\omega) * z_{XGMD} * p_{atom}}{k * T}$$

N_{ph}	Number of photons per pulse
σ_{ph}	Photoionization cross section
z_{XGMD}	Length of Faraday cup (27.8 cm)
p_{atom}	Target gas pressure
k	Boltzmann constant
T	Temperature

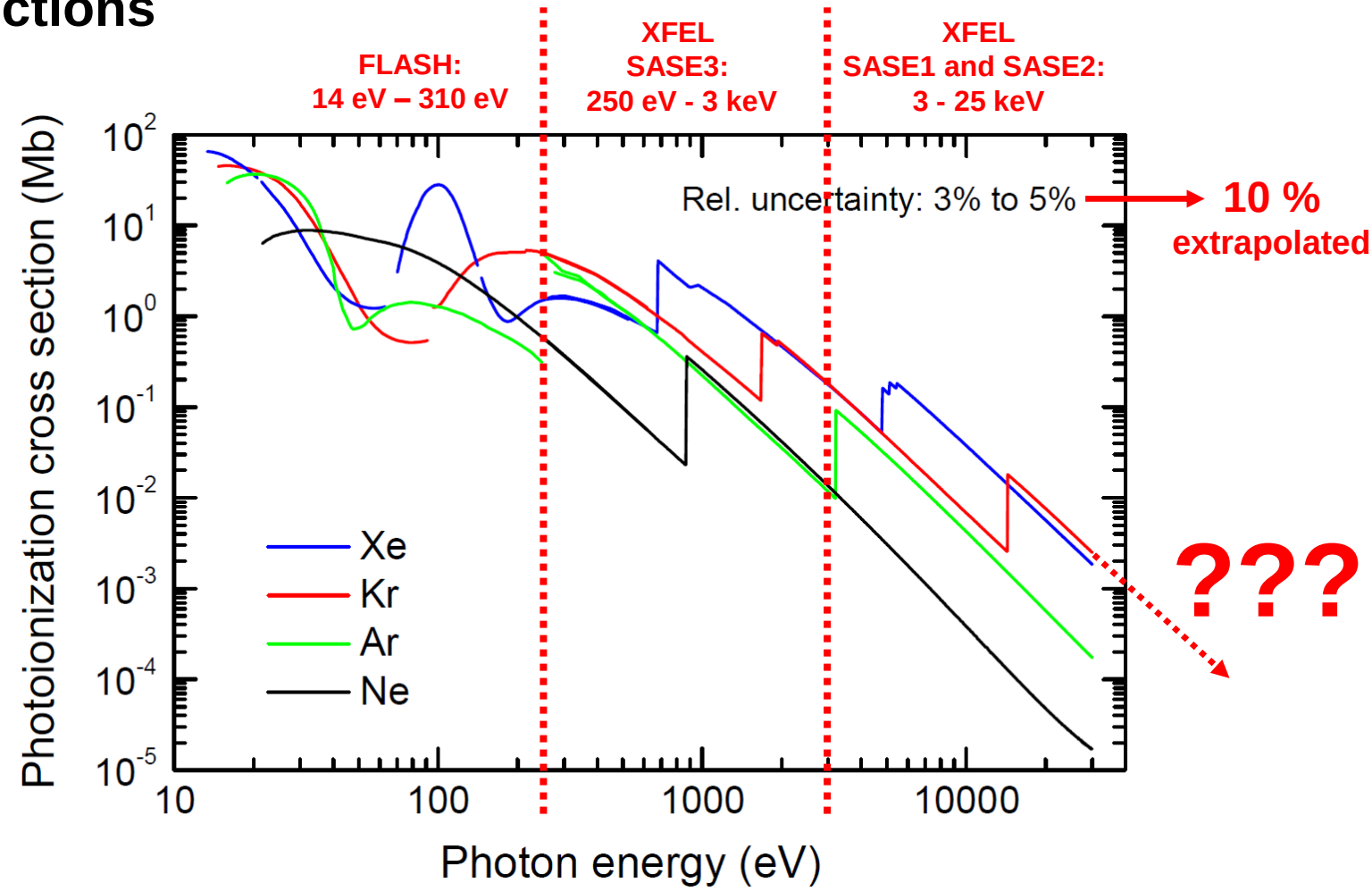
Ion current measured by Faraday cup of the XGMD:

$$I_{ion} = N_{ion} * T_{Ni} * q_{ph}(\hbar\omega) * N_{pulses} * R_{rep} * e$$

q_{ph}	Ion mean charge
T_{Ni}	Transmission of Ni mesh in front of the Faraday cup (80%)
N_{pulses}	Number of pulses per train
R_{rep}	Train repetition rate (10 Hz)
e	Elementary charge

From A. Sorokin and K. Tiedtke

Cross sections



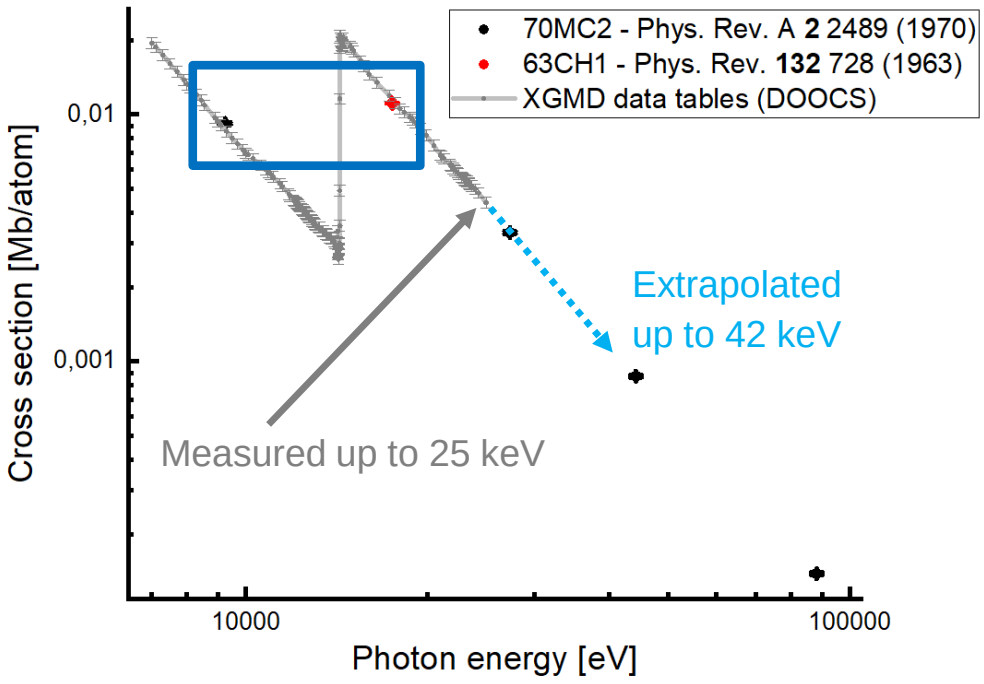
Total cross section =
photoelectric cross-section + scattering cross-section

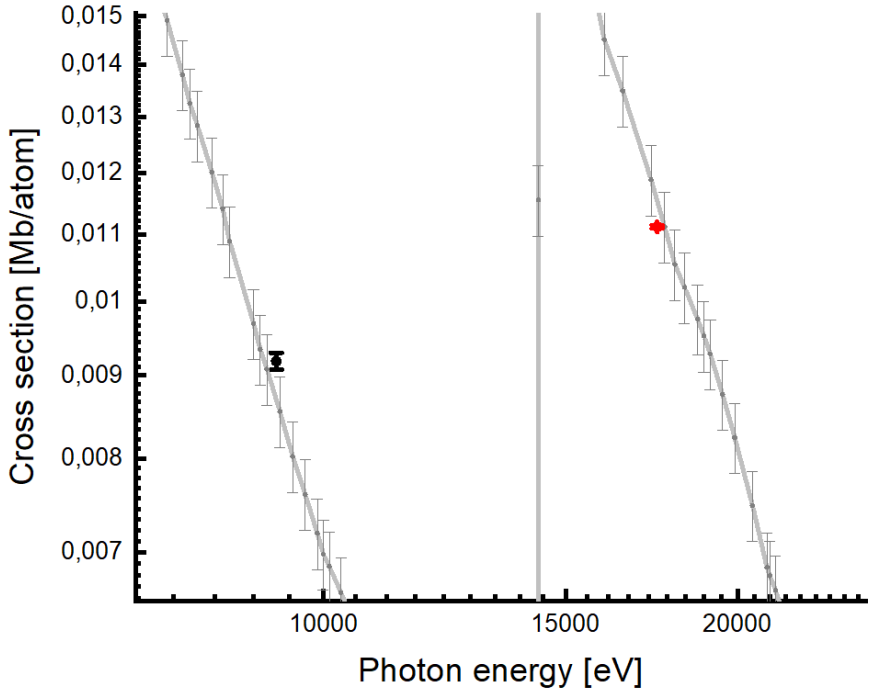
Forbidden for Krypton
1644 eV - 1707 eV
1883 eV - 1963 eV
13409 eV - 15382 eV

Forbidden for Xenon:
635 eV - 765 eV
881 eV - 1005 eV
4569 eV - 5664 eV
> 34.4 keV

Cross sections for Kr

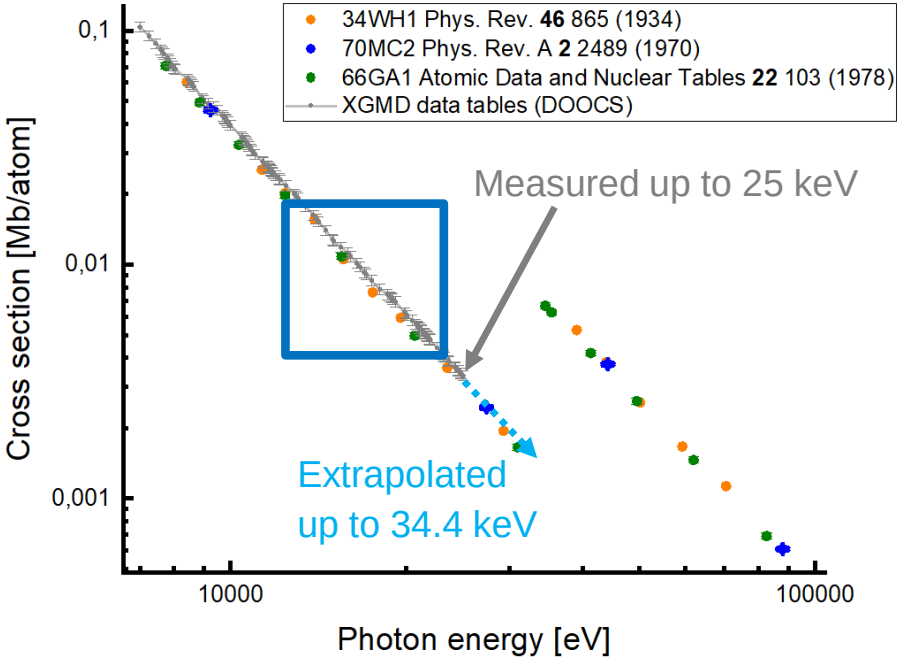
Overview paper: Total cross sections from 100 eV up to 100 keV:
Atomic data and nuclear tables **38** 1-197 (1988) with 20000 data points

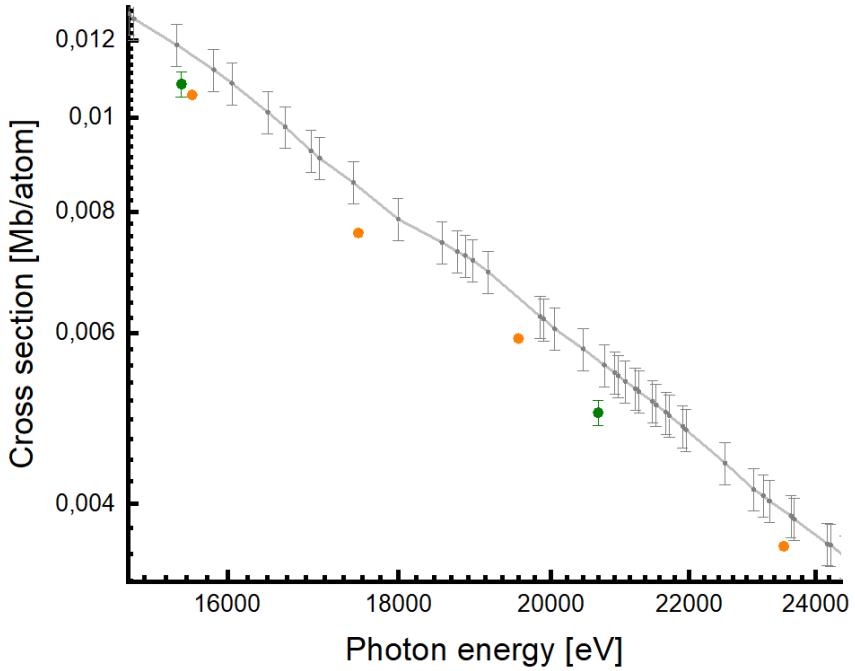




Cross sections for Xe

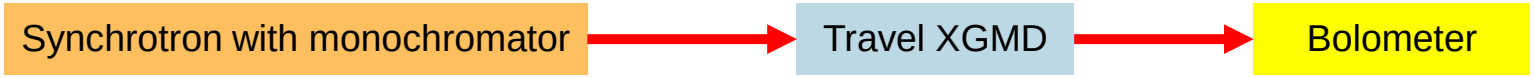
Overview paper: Total cross sections from 100 eV up to 100 keV:
Atomic data and nuclear tables **38** 1-197 (1988) with 20000 data points





Plans for measuring photoionization cross-sections > 25 keV

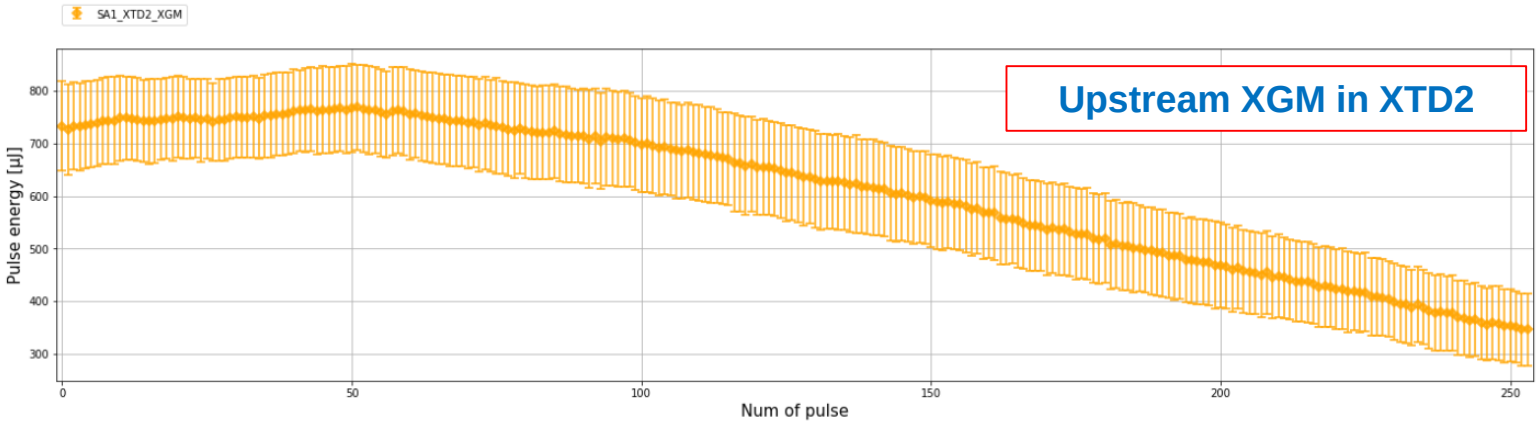
BAM PTB line B8 at BESSY II from 8 keV up to 60 keV, but only 10^7 photons/sec, not enough for XGMD, for 30 keV only ~ 1 Xe ion / sec, corresponds to ~ 10^{-18} A NIM A **467** 703 (2001)

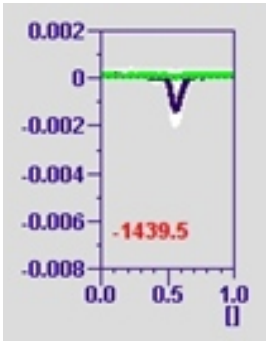


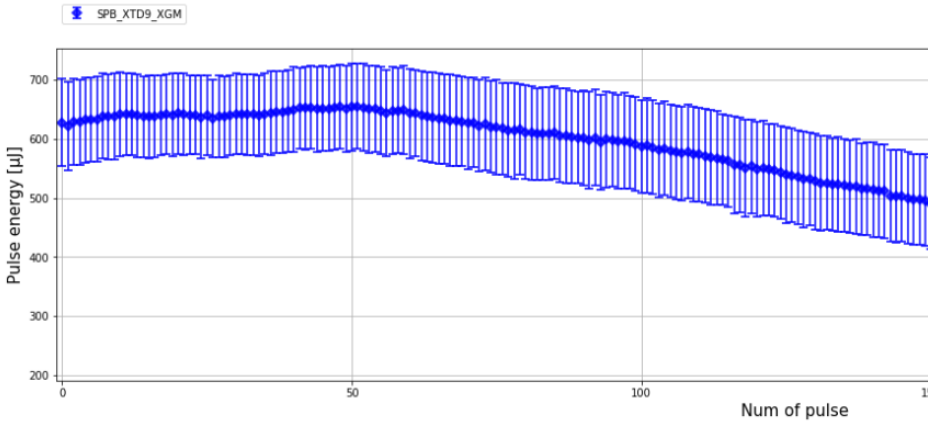
PETRA III line P01 at DESY from 2.5 keV up to 80 keV, with up to 10^{12} photons/sec, for 35 keV about ~ 10^5 Xe ions / sec, corresponds to ~ 10^{-13} A, at the edge for an XGM DESY homepage P01

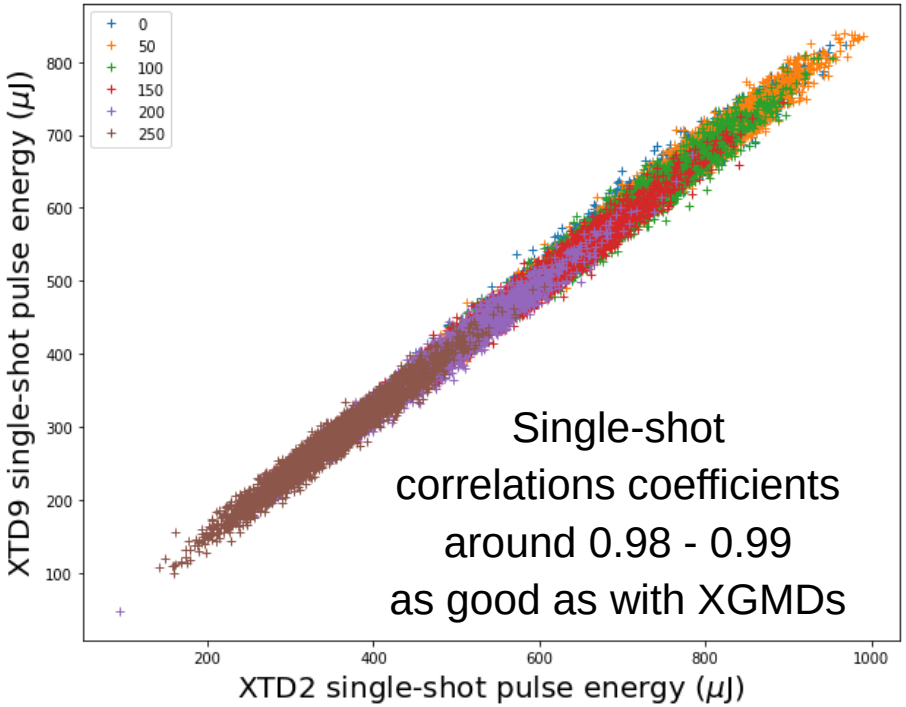
Measure directly at XFEL, but Bolometer measures main line and harmonics, thus we have to suppress the fundamental photon energy and measure the harmonic background on the bolometer, or we use a monochromator, which we do not have above 24 keV, or 3rd harmonic, but difficult. Additionally, Bolometer can only be installed in a hutch, thus sufficient transmission is needed (has to be practically realized above 30 keV, theoretically ~ 70 %).

XGM operation at 20 keV with HAMP as single-shot detector



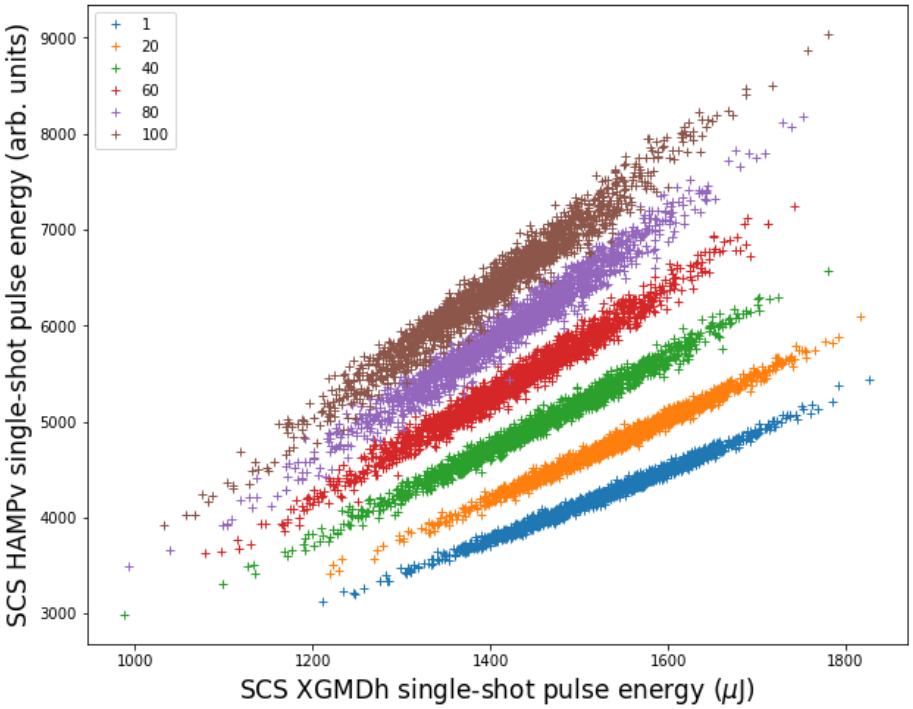


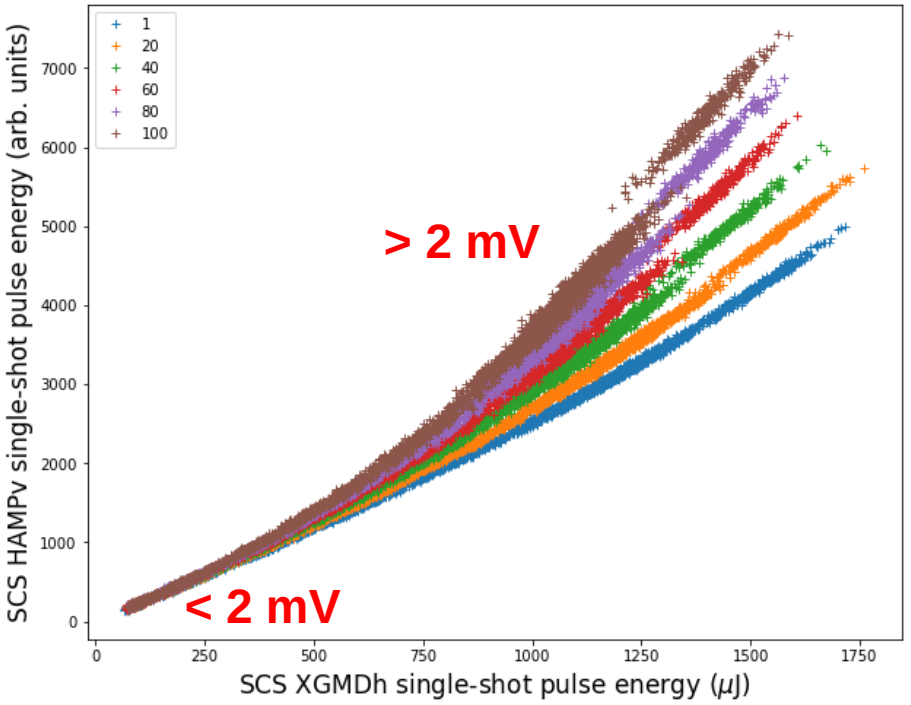




SASE1 at 20 keV with 254 pulses per train
16.09.2022, proposal 900307, run 101,
statistics over 2893 train

HAMP intra-train non-linearity

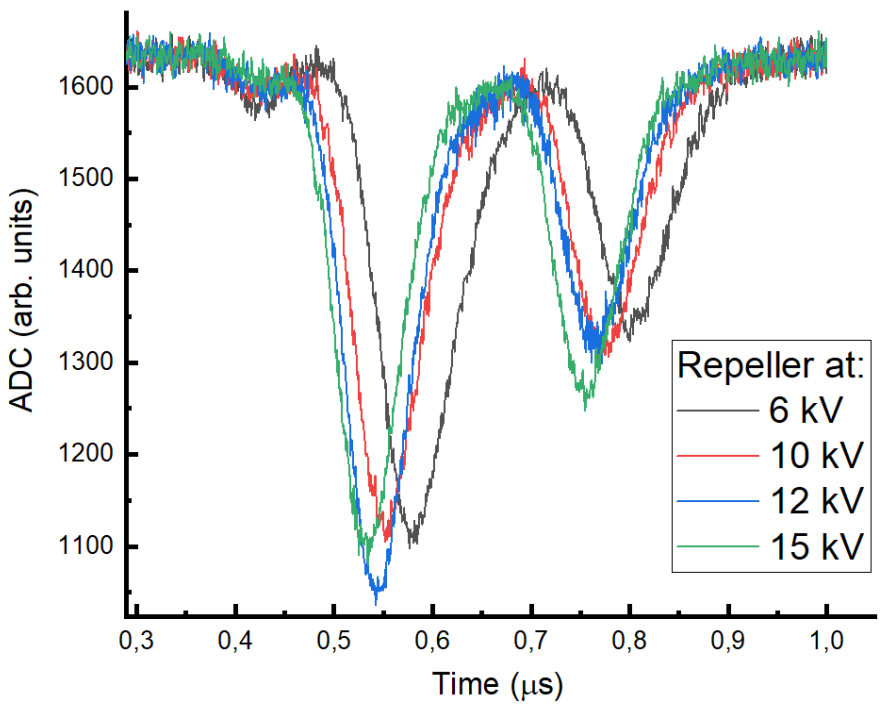


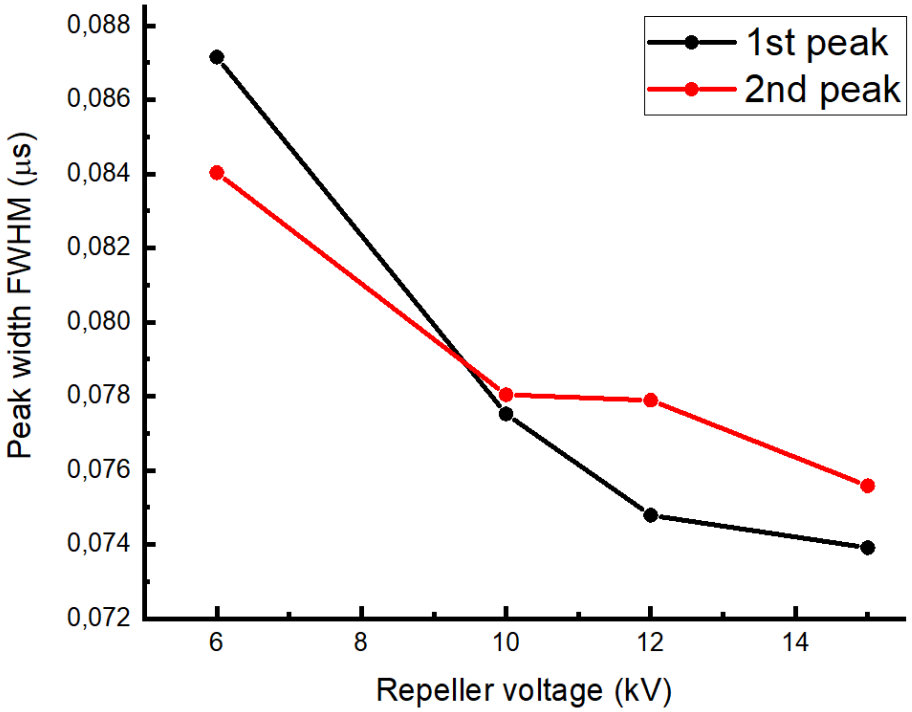


SASE3 at 780 eV with 120 pulses per train
13.04.2023, proposal 900349, run 6 and 8

Intra-train non-linearity only for > 10 pulses per train and only if HAMP signal > 2 mV

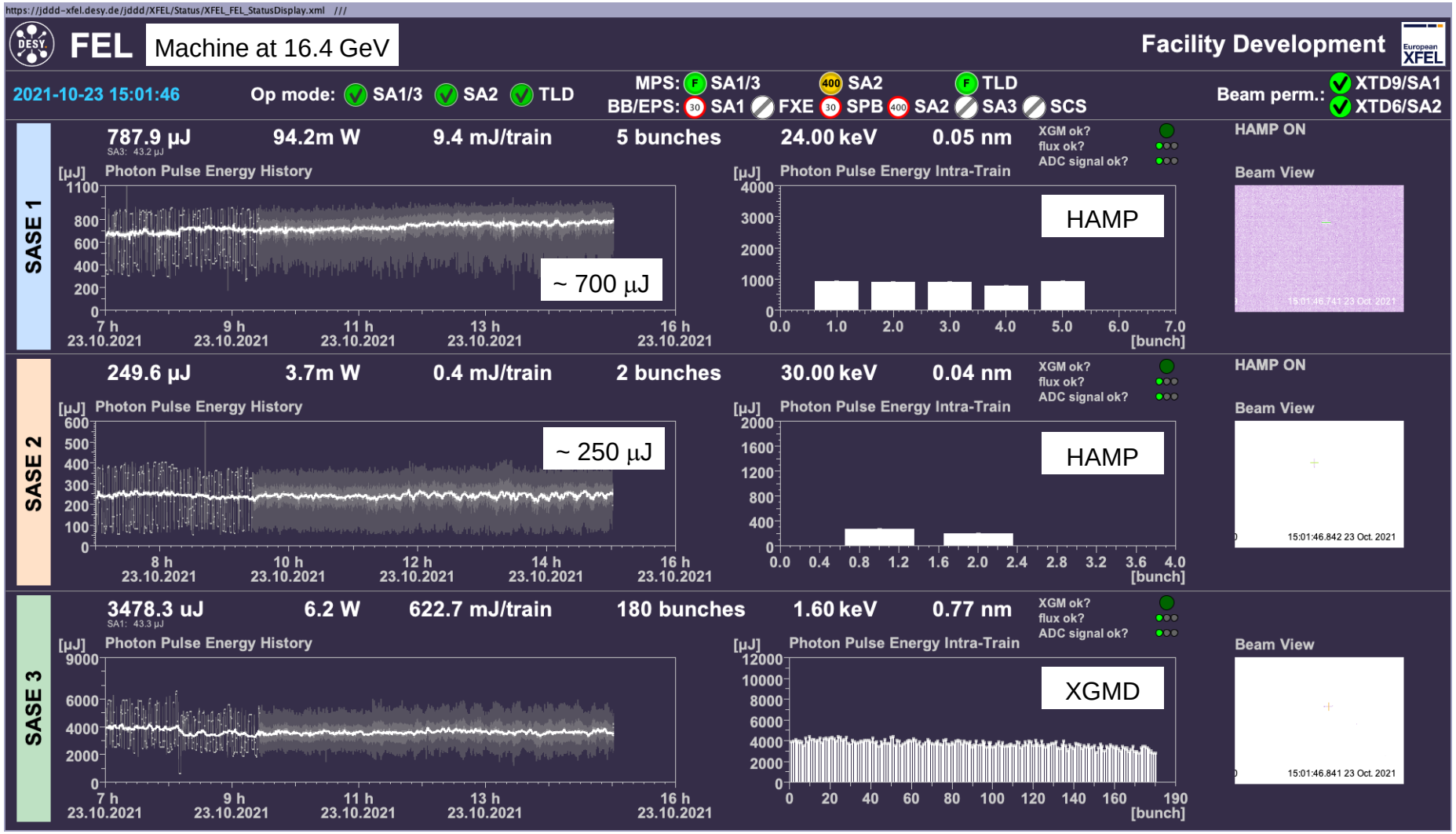
HAMP operation reach limit at 4.5 MHz (0.22 μs) repetition rate





Maybe use electrons instead of ions for HAMP ???

XFEL operation at hard X-rays



European XFEL

Y. Chen, F. Brinker, W. Decking, M. Scholz, L. Winkelmann, and Z.-H. Zhu
Proceedings IPAC 2022 - TUPOPT010

Summary:

- Basic concept of XGM (integrational and pulse resolved signal)
- Extrapolation of photoionization cross-section data
- Above 18 keV operation with HAMP with excellent single-shot correlations
- Strategy to suppress intra-train non-linearity and limit at 4.5 MHz
- XGMs operated successfully up to 30 keV

Outlook:

If we get ~ 10^9 photons/pulse at 50 keV, with Xe after last resonance,
we would get 138 ions/pulse (maybe still acceptable with HAMP)
corresponds to $1.35*10^{-15}$ A (1 pulse/train and 10 Hz), below XGMD resolution,
but at 100 pulses/train we would have $1.35*10^{-13}$ A
which is at the edge of the XGMD resolution.

Publications:

- A. A. Sorokin et al., J. Synchrotron Rad. **26** 1092 (2019)
- Th. Maltezopoulos et al., J. Synchrotron Rad. **26** 1045 (2019)

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Thank you for your attention !!!