# Radiation Field Studies around the 130 m long SASE 3 Undulators at the European XFEL by a modified LB 6419 probe mounted on the MARWIN4 robot

Leuschner, Albrecht and co-authors: Gerdt S.-L., Karabekyan S., Dehne A.

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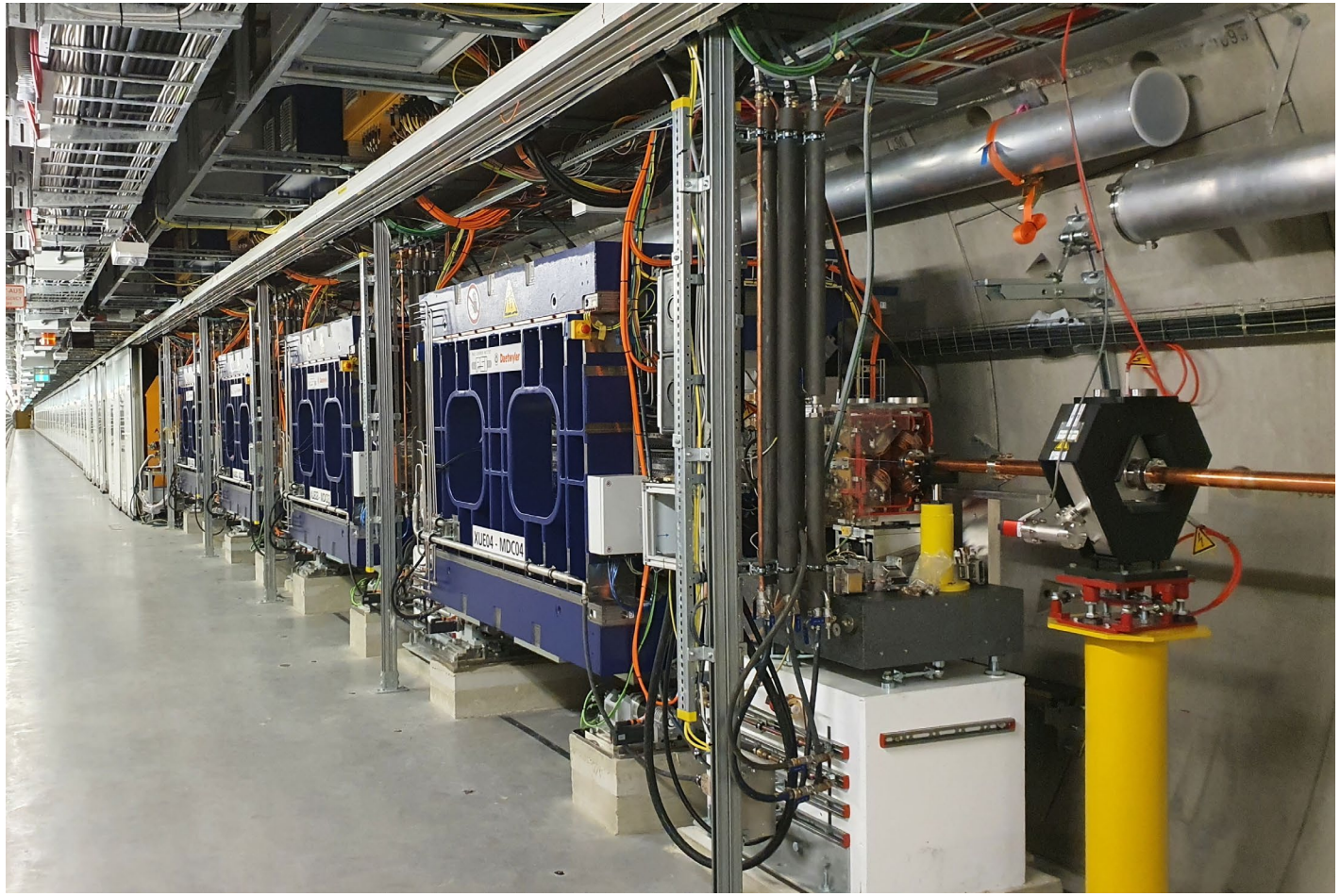
HELMHOLTZ

DESY.

# Content

# Radiation Damage at the APPLE-X Undulators

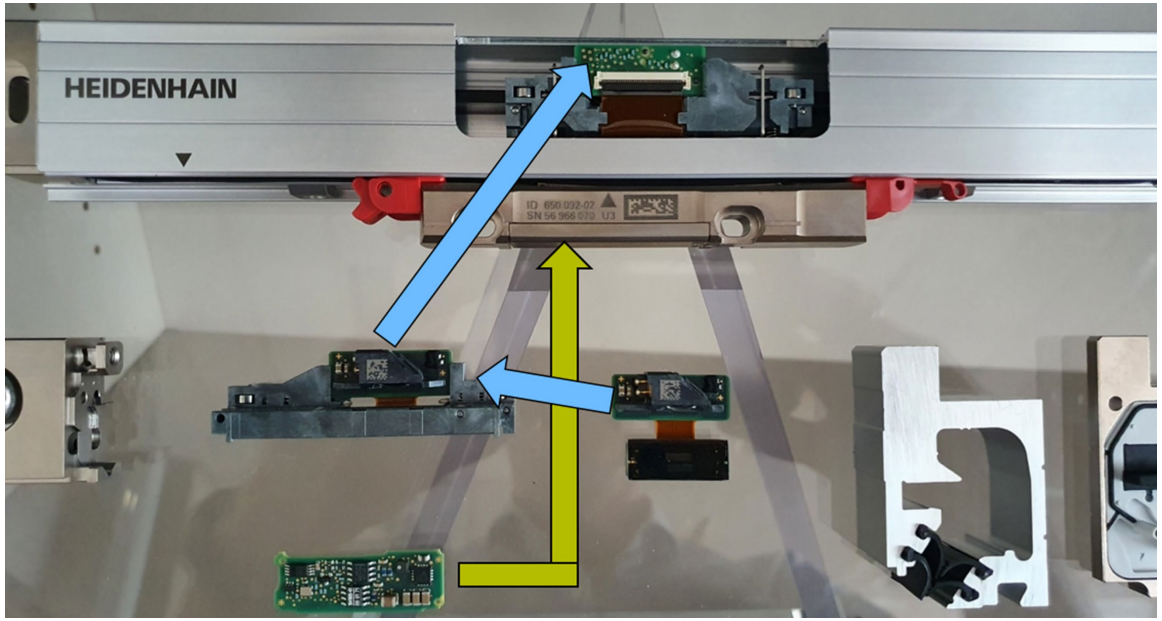
# SASE3 with APPLE-X afterburner

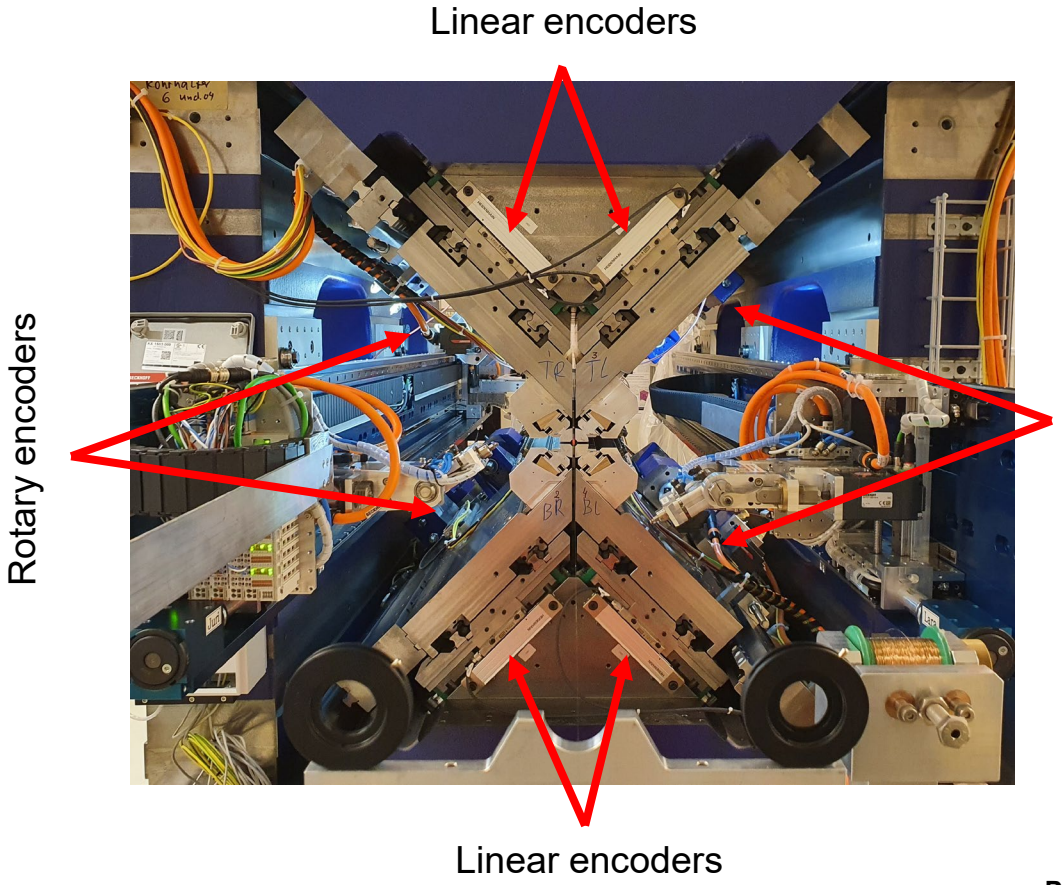


- All APPLE-X undulators were installed in the tunnel during the 21/22 winter shutdown
  - The undulators and the intersection components were aligned using a laser tracker
  - They were connected to the control system and integrated into the control network
- The helical afterburner was prepared for the first beam through
  - APPLE-X undulators were set to the so-called Zero Light Mode to minimize the impact on the beam trajectory
  - The very first beam with an energy of 14 GeV reached the beam dump without any losses.

# APPLE-X: Location of the affected components

- Linear encoders are located on the downstream side of the undulator, ~30 cm away from the electron beam
- Rotary encoders are mounted on the motors. They are located on the sides of the undulator at a distance of ~30-40 cm from the electron beam.

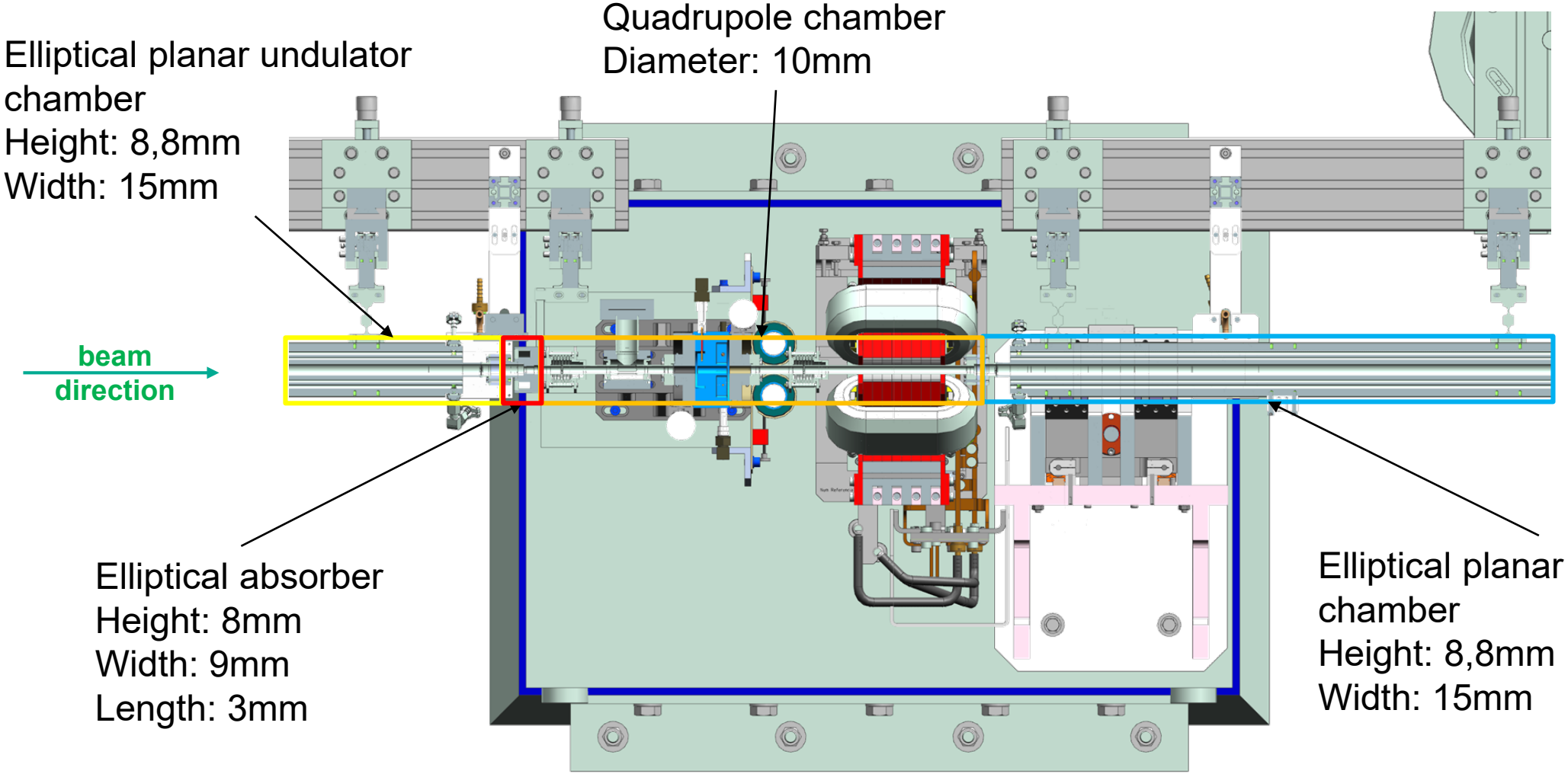


# Geometry of the vacuum system: Planar undulator–Intersection–Planar undulator

Elliptical planar undulator chamber
Height: 8,8mm
Width: 15mm

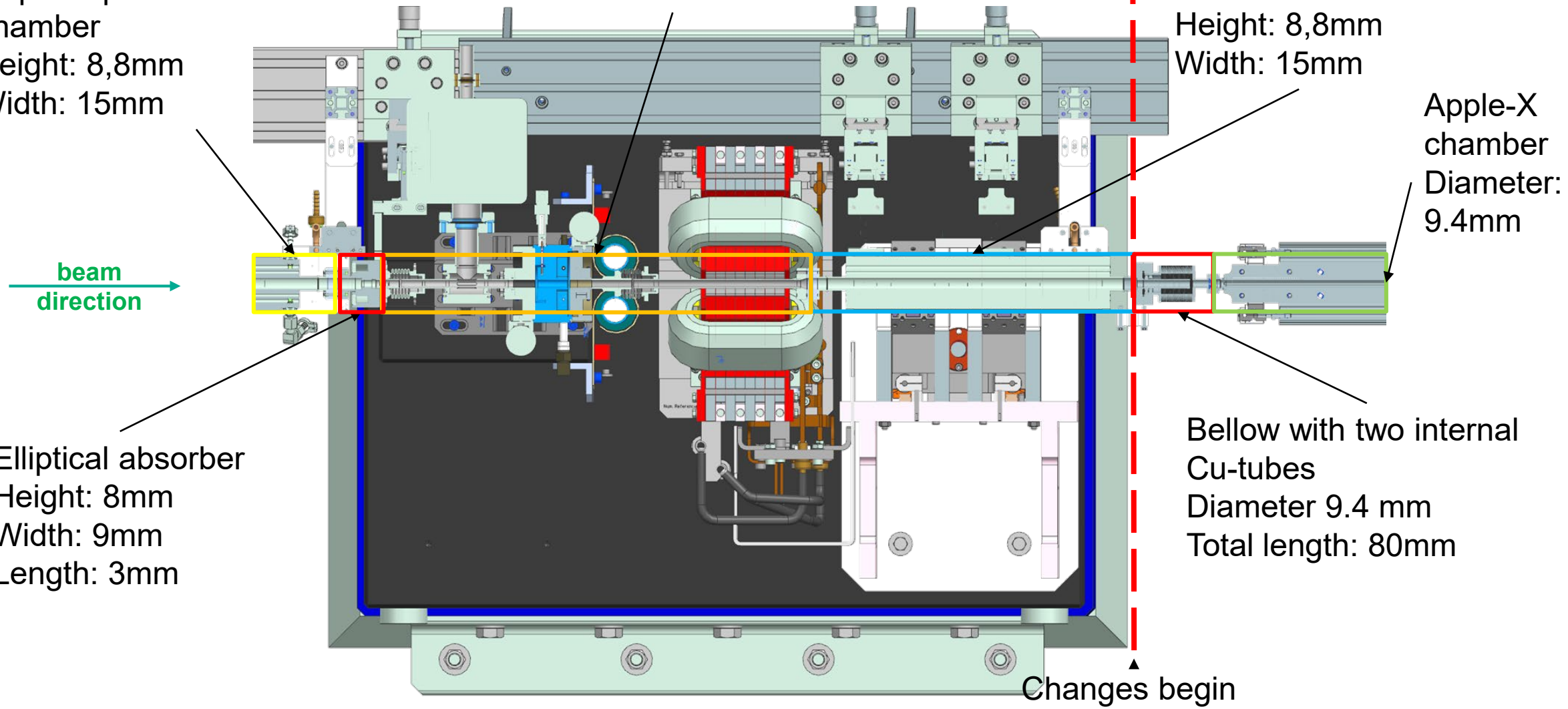
Quadrupole chamber
Diameter: 10mm




Elliptical absorber
Height: 8mm
Width: 9mm
Length: 3mm

Elliptical planar undulator chamber
Height: 8,8mm
Width: 15mm

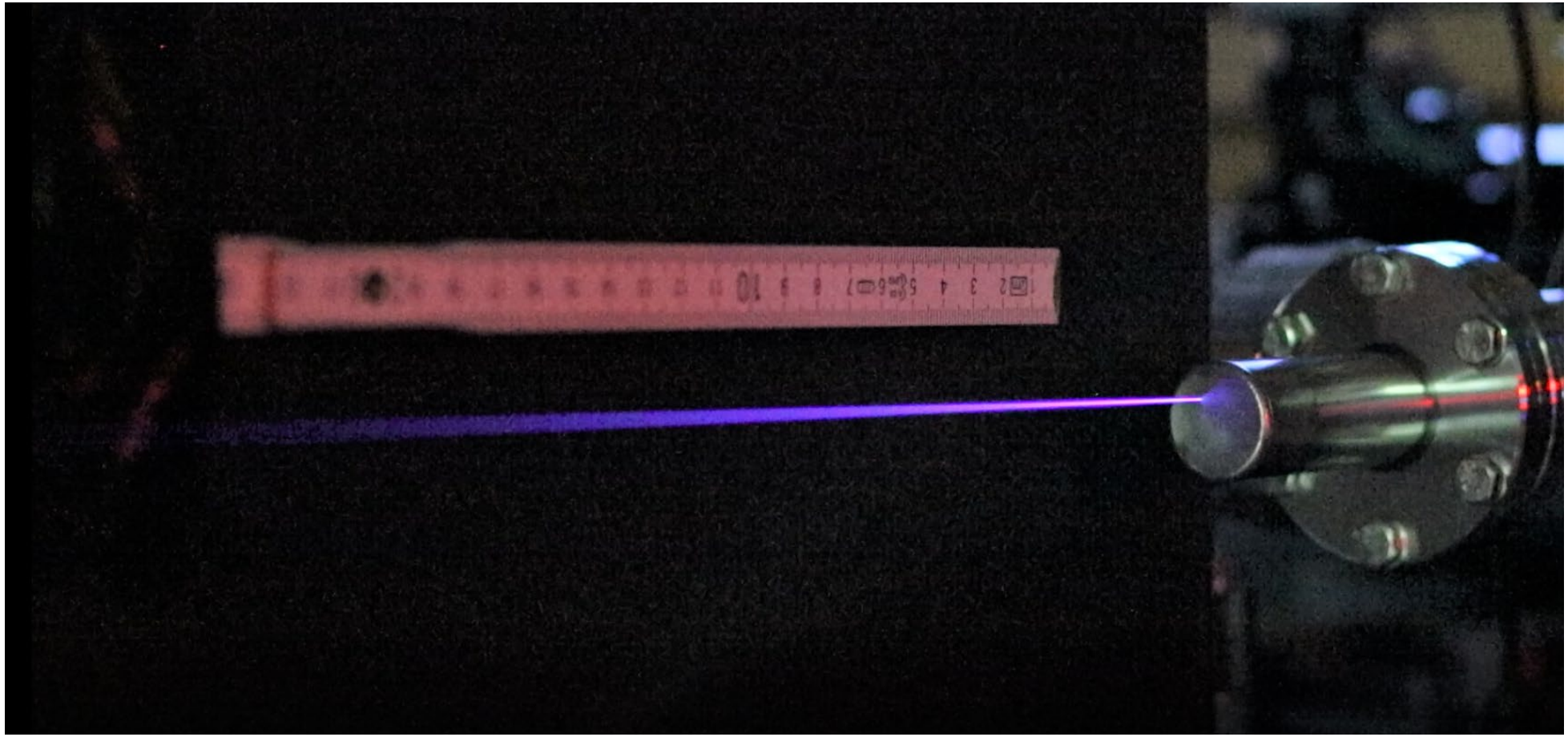
# Geometry of the vacuum system: Planar undulator–Intersection–Apple-X undulator



# Challenges for Active Dose Rate Meters

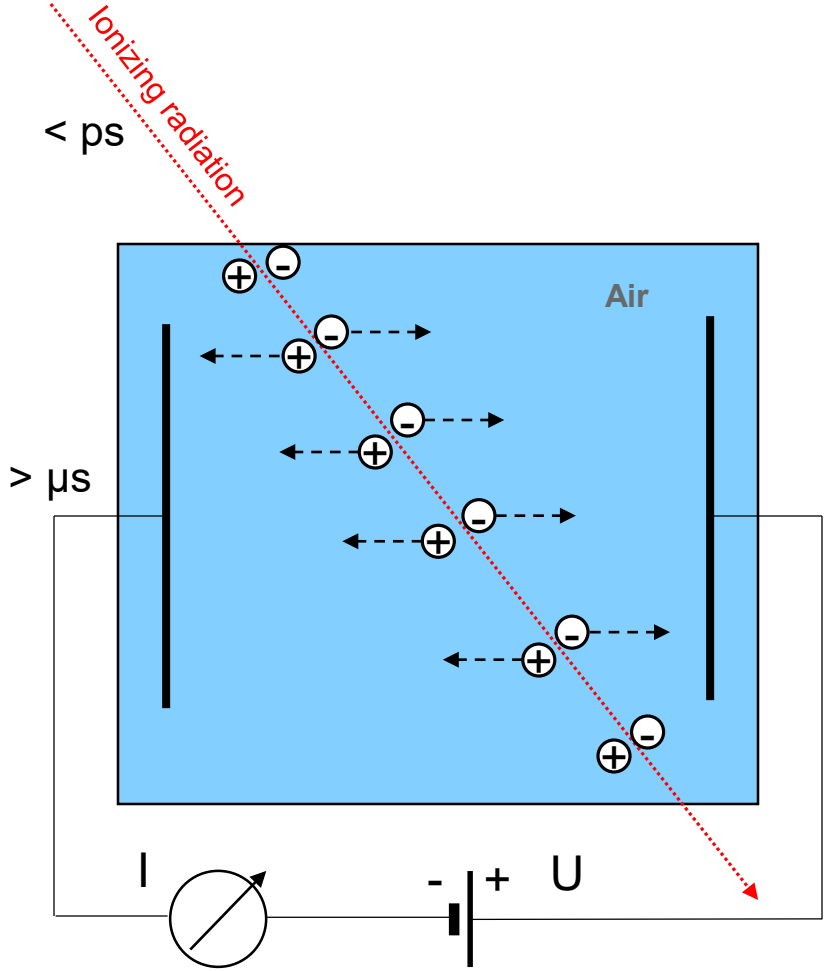
- Free electron lasers and laser driven accelerators generate photon pulses shorter than a picosecond.
- Leads to pileup of many photons to a single response.
- Leads to saturation.
- Leads to fake neutron counts due to photon pileup, separation of true neutrons

# X-ray Laser Sword

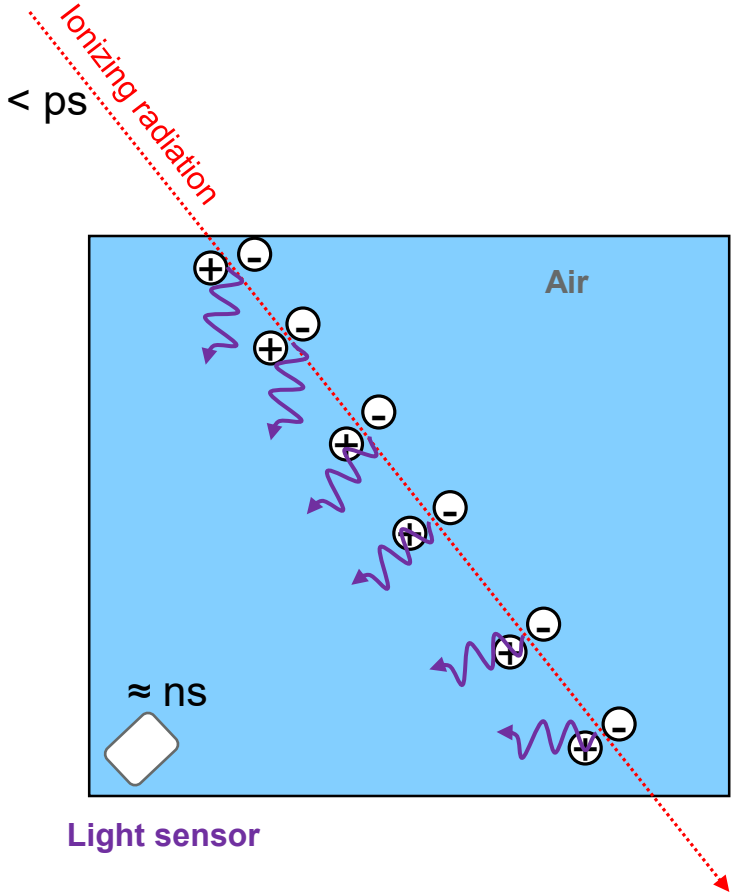


In the experimental hall at the European XFEL: The X-ray laser beam of 2.66 keV photons comes from the right, drills though the 2mm steel cap and generates a violet light phenomenon

# Ionization / Fluorescence chamber




The measured quantity current I is a measure of the dose rate.




The fluorescence light intensity is a measure of dose rate.

# Fluorescence Dosimeter – a modified LB 6419

Plastic tube filled with air

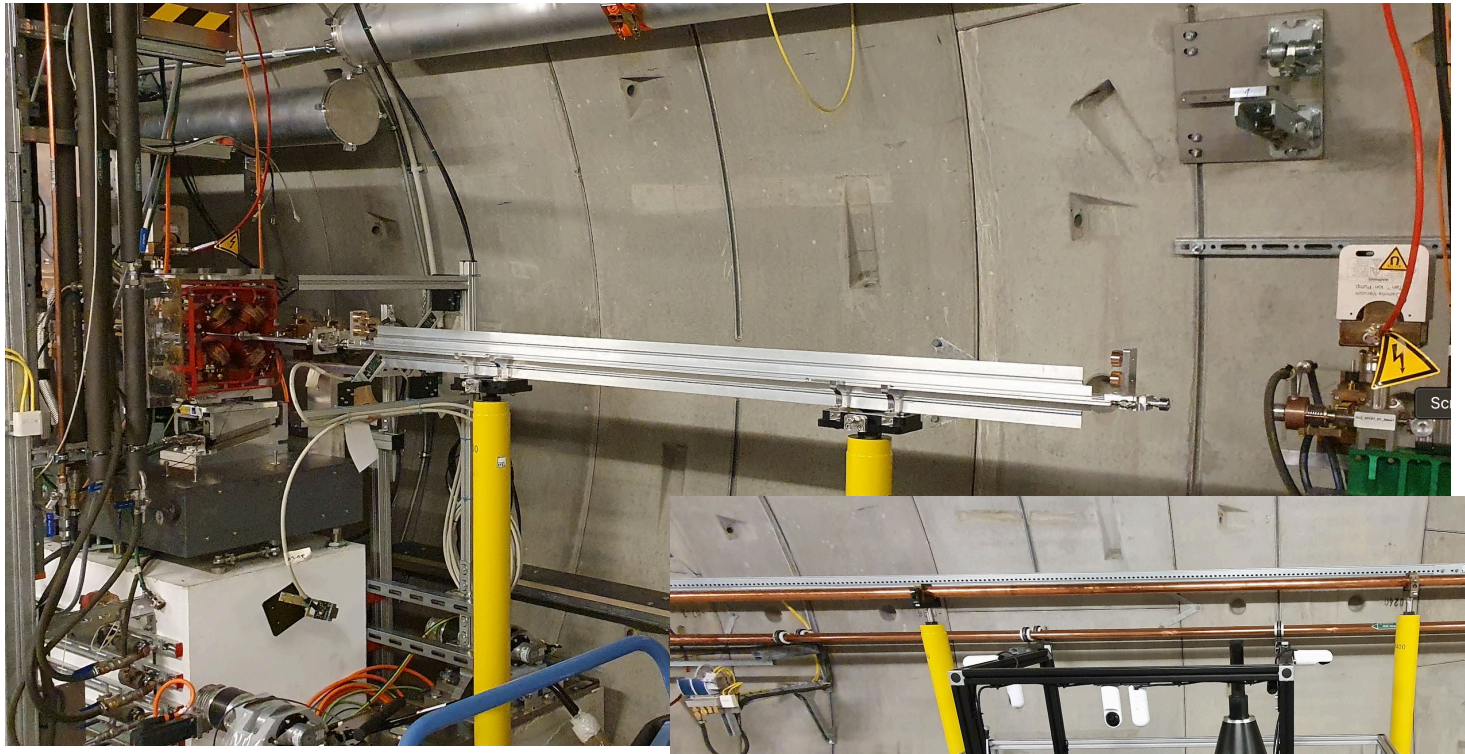
Photomultiplier

Moderated rem counter: $^{3}$He-tube

Why to put it on top of a LB 6419: Replacing the plastic scintillator by an air-filled light-tight tube was the easiest way for this test of principle. The complete measuring chain from the light sensor (photomultiplier) to data acquisition, archiving and data analysis is available.

# Instalations in the tunnel during the winter shutdown 22/23

- A robot equipped with PANDORA (Photon And Neutron Dose Rate meter for Accelerators) detector was installed in the tunnel during the winter shutdown 22/23
- In Cell 24, located after the last planar undulator, a phase shifter vacuum chamber + bellow + an Apple-X vacuum chamber were installed



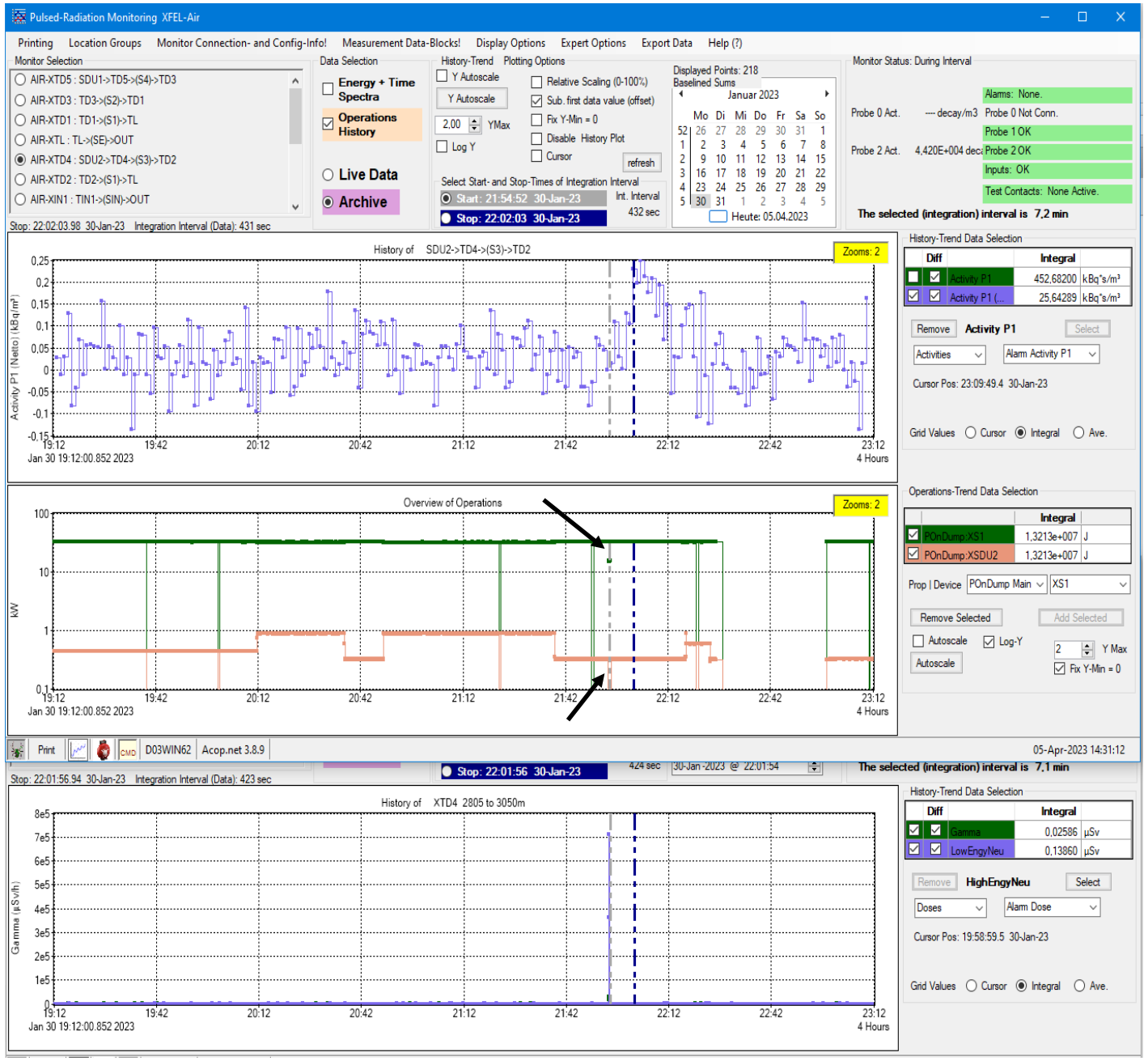
# Beam losses or synchrotron radiation ?

# Beam Loss
# How does it look like ?

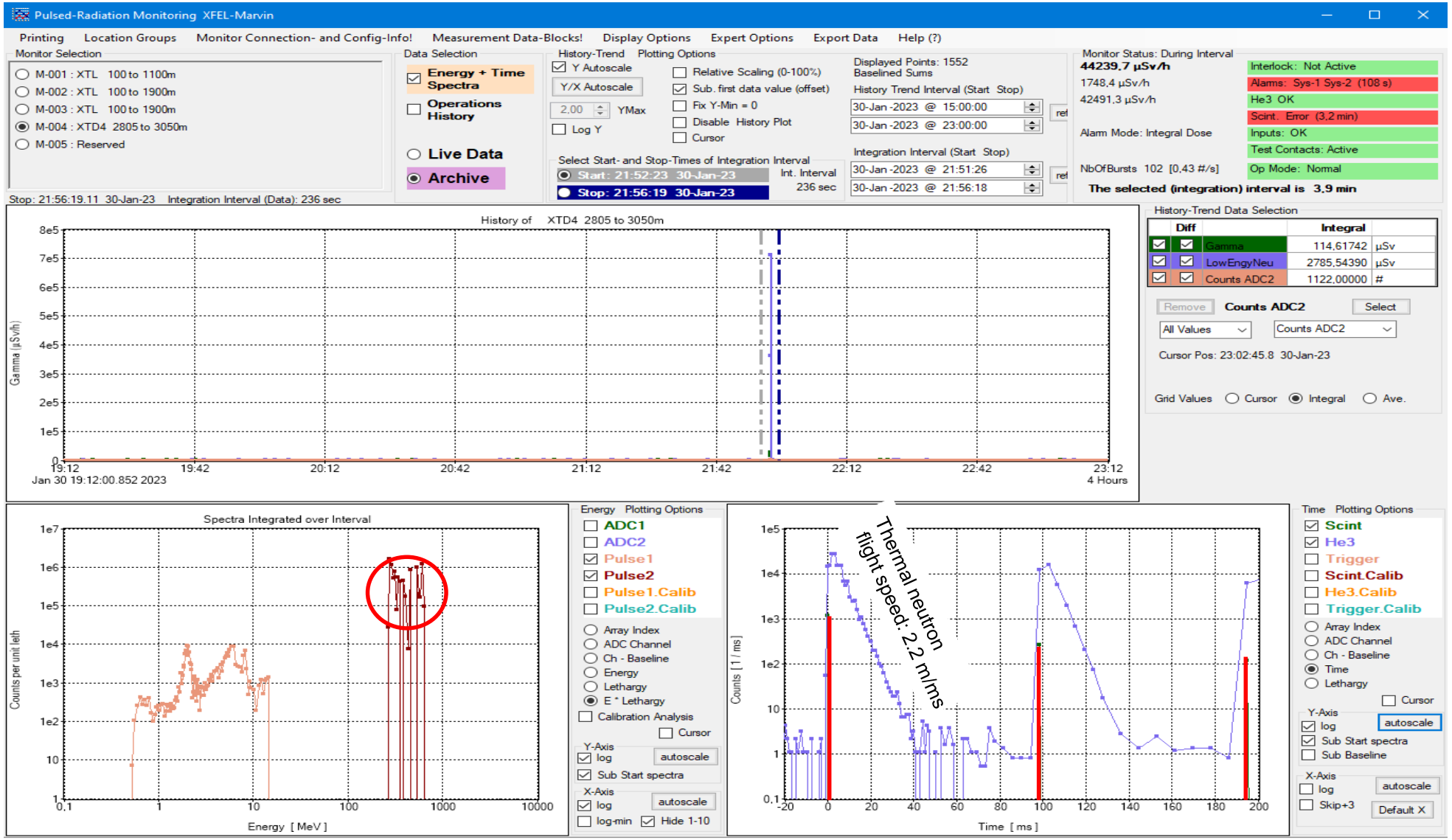
Icing on the cake:
Airborne Activity measured by a beta-probe
In the XS3 air shaft with a delay of  7 min,
Distance ≈ 200 m, air speed 0.5 m/s !

Missing power of the XS1 AND XDU2 dumps

Response of MARWIN4's Pandora on charger station

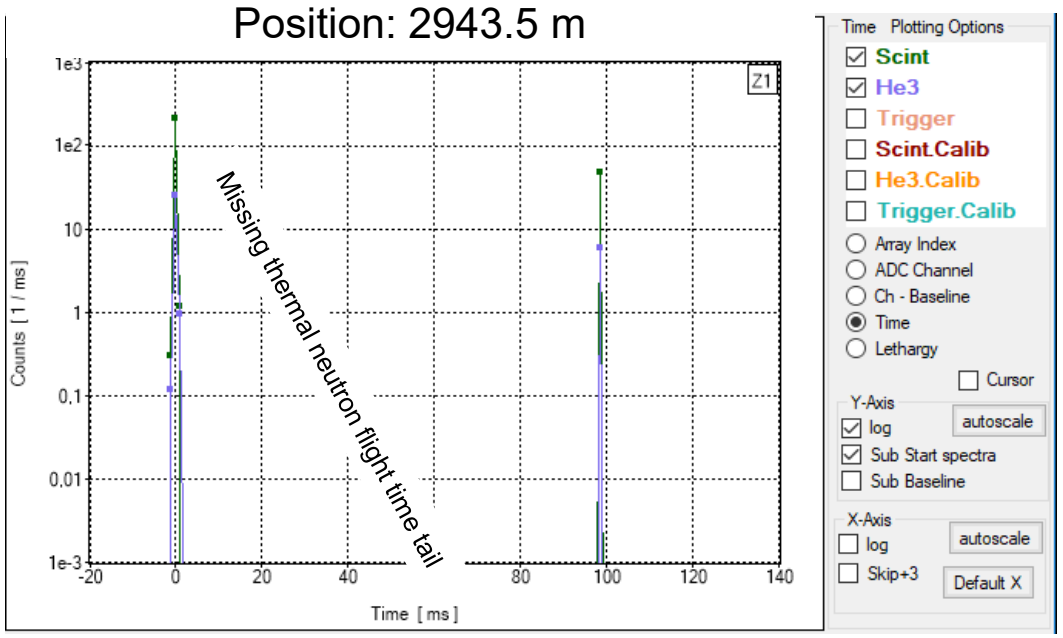


# Beam Loss: 102 trains à 11 Bunches

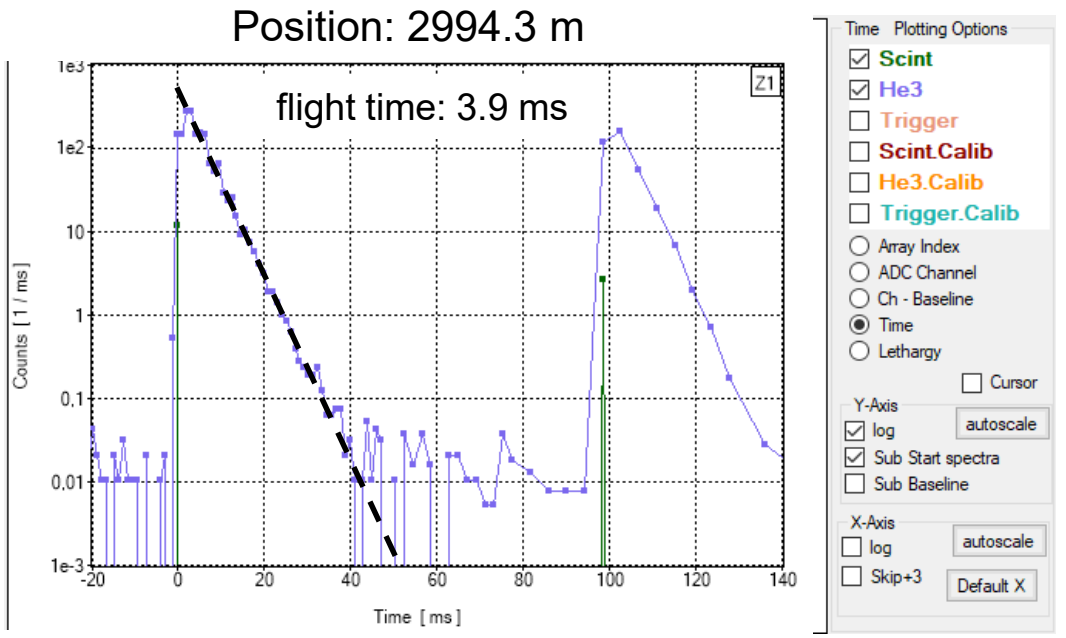


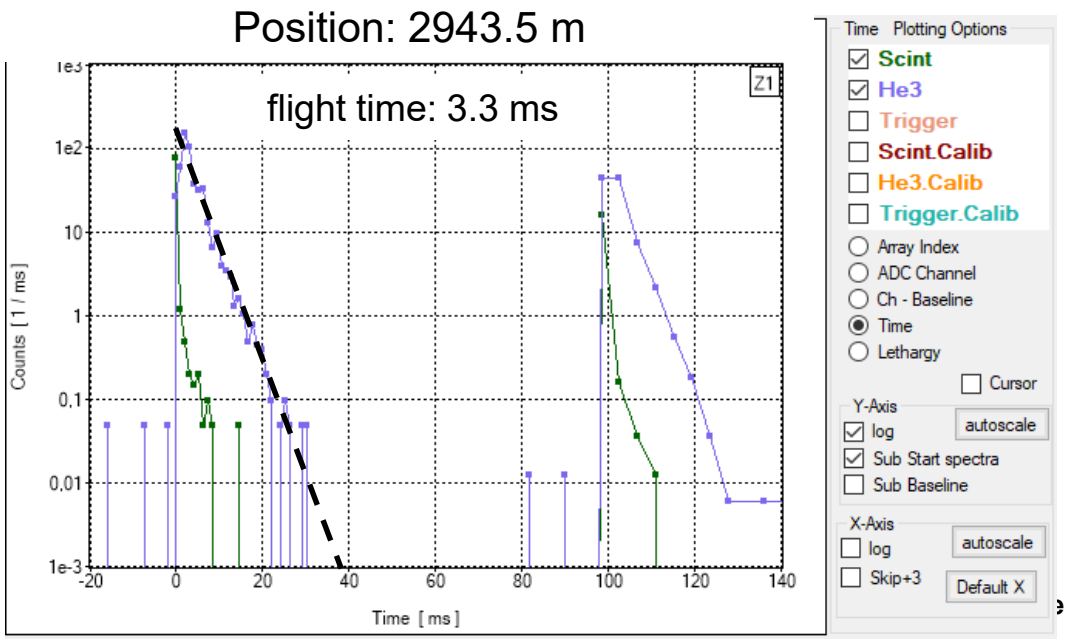
# Synchrotron Radiation vs Beam Loss

Counts per pulse train



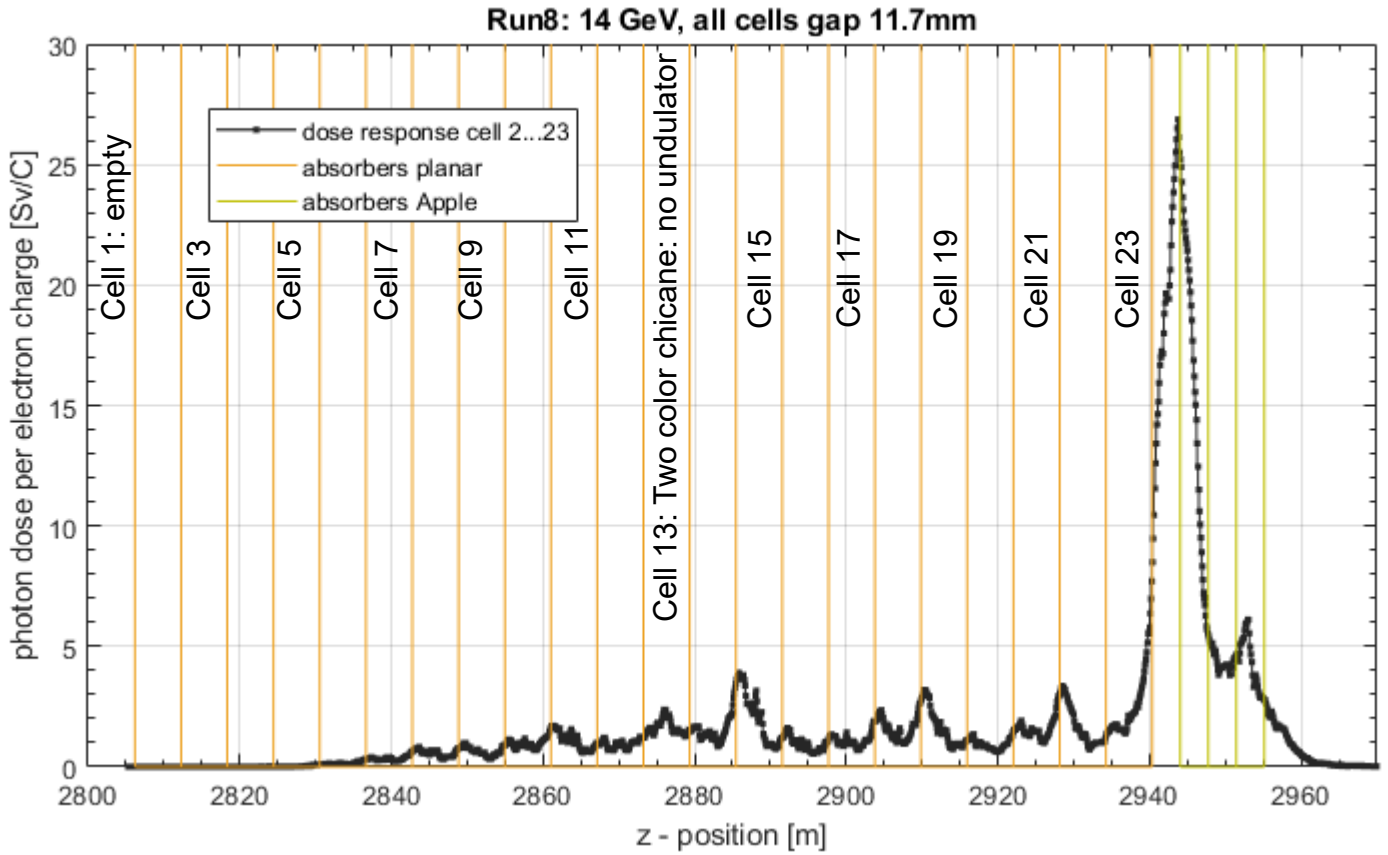

$^3$He tube counts photon pile ups
but no neutrons !



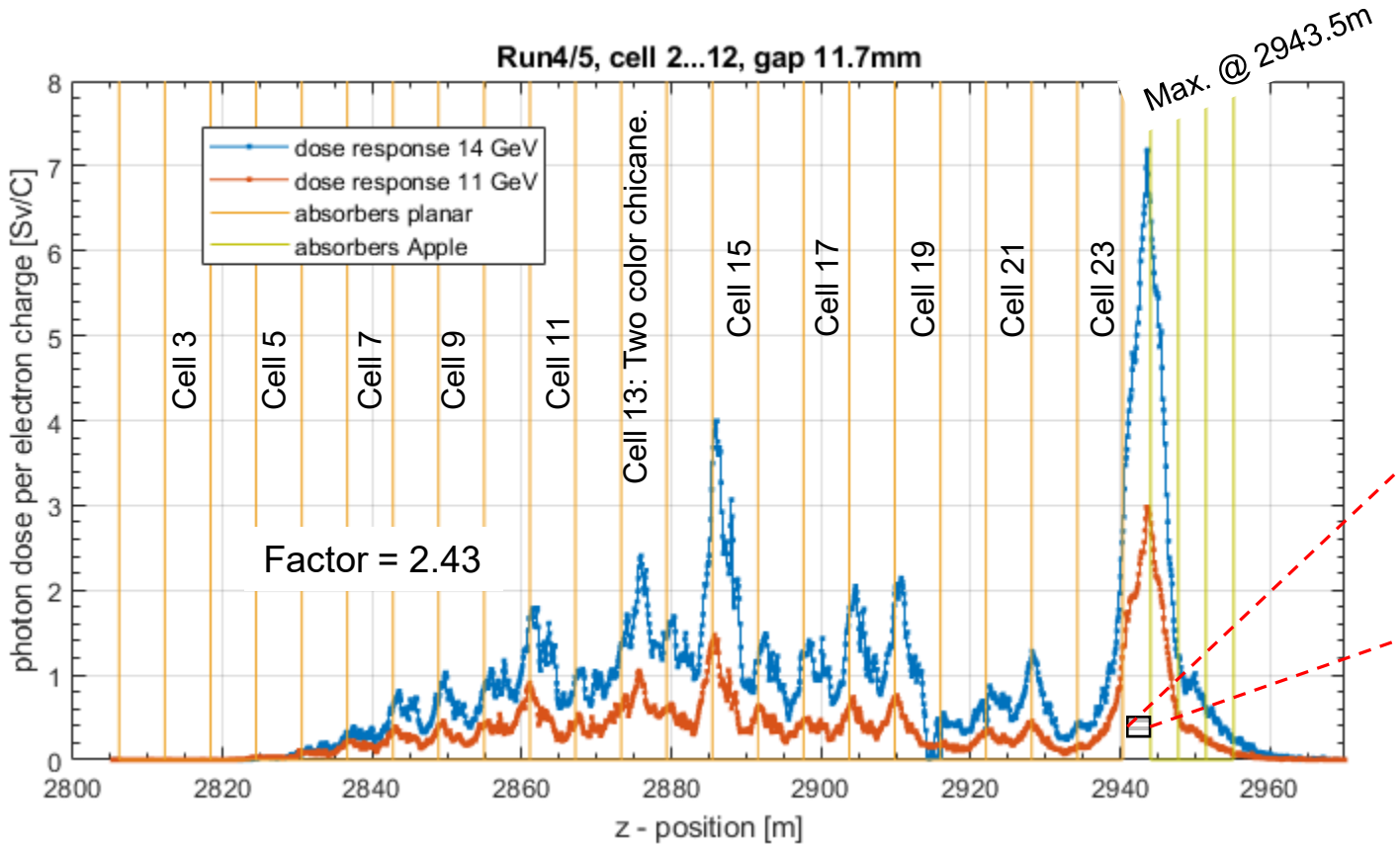
# Beam losses haven't been the cause for damage. What about synchrotron radiation ?

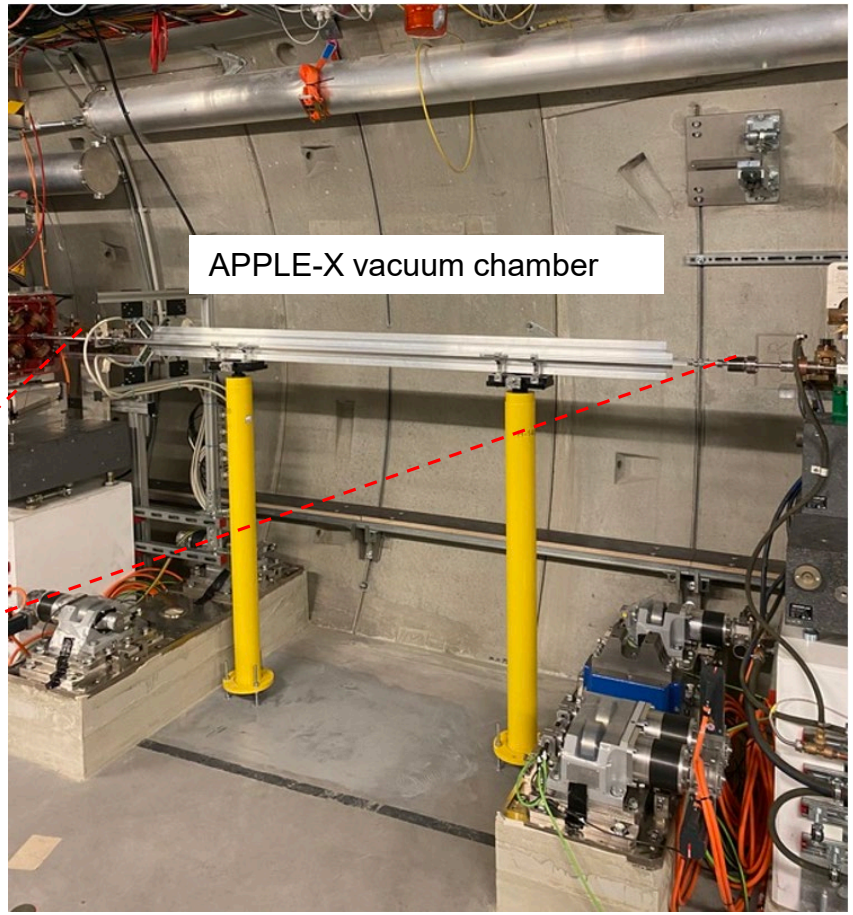
- First harmonics: 0.787 keV, critical energy: 190 keV (K=8.2)
- Radiation profile is reproducible, not noisy.
- Radiation profile is independent from lasing.




# Marwin4 Runs 4/5: 11.5 GeV vs. 14 GeV @ 11.7mm gap (i.e. first harmonics 531eV and 787eV)

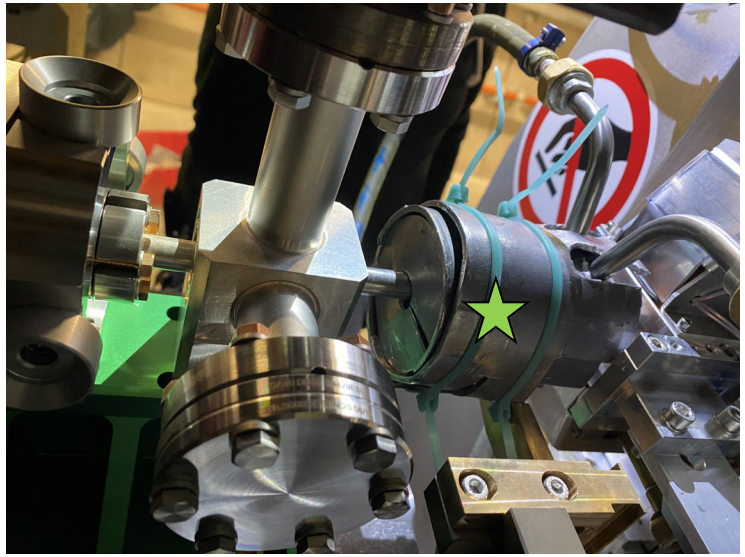
- Radiation peaks in planar undulators area coincide with the position of the absorbers
- Maximum peak observed at the location of the Apple-X vacuum chamber

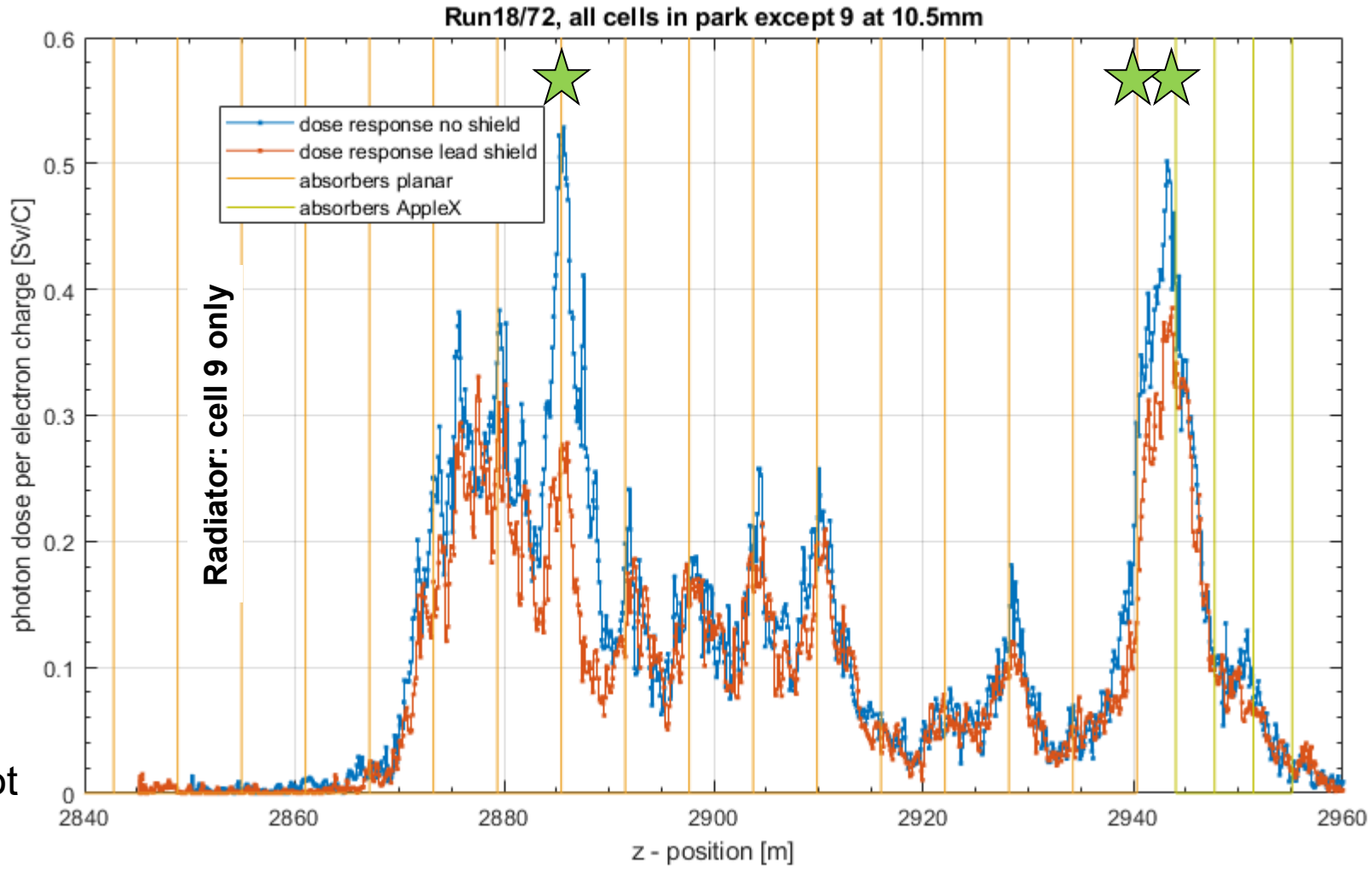


# Marwin4 Runs 18/72: 14 GeV, cell 9 @ 10.5mm gap
# 3 absorbers (☆) shielded with 6mm lead

6 mm lead @ 500 keV
half value layer thickness






- Yes, it works in planar section.
- Lower impact in the APPL-X vacuum chamber region, perhaps because the radiation generated in the absorber is not the main source in that area.

# Findings and Assumptions

**Findings:**

- Synchrotron radiation in the energy range 100 keV to 1 MeV is detected but no beam losses
- Planar section: A 6mm lead shield of the absorbers reduces the stray radiation by a factor of 2. So the absorber scatters the radiation out.
- APPLE-X section: A 6mm lead shield of the absorbers has almost no effect. The absorber doesn't scatter.

**Assumptions:**

- APPLE-X: Most likely, the source of the strong radiation produced in the APPLE-X section is due to the interaction of the spontaneous radiation with the bellows tubes of 9.4 mm diameter and with the vacuum chamber, which have the same inner diameter.
- APPLE-X: Redesign of the absorber scheme for the horizontal plane (cells 16…21 contribute most) . Absorbers of the 2$^{nd}$ half must be modified.

# Thank you

## Contact

Deutsches Elektronen-
Synchrotron DESY

www.desy.de

Albrecht Leuschner
Radiation Protection Group D3
Albrecht.Leuschner@desy.de
+49 40 8998 2043