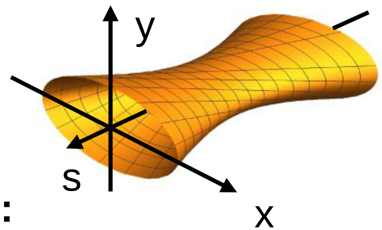
ESRF | The European Synchrotron

Insertion Devices Control

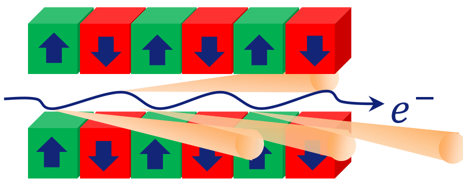
ASD Workshop 2023

Reine Versteegen for ASD/IDM and ISDD/ACU

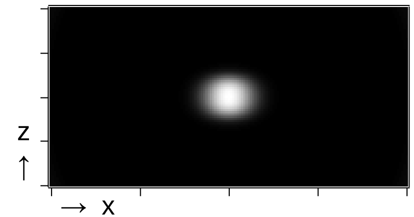
INTRODUCTION (1/2)



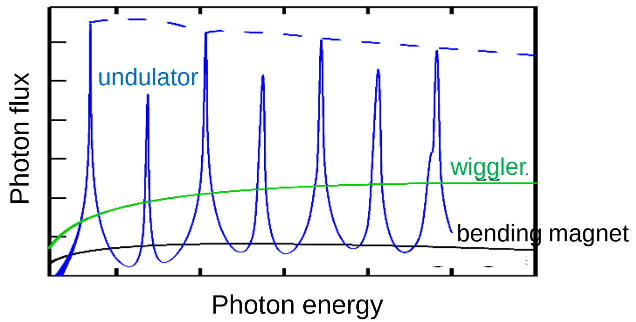
***e-* beam:**
- energy + energy spread
- size + divergence at the source
- intensity



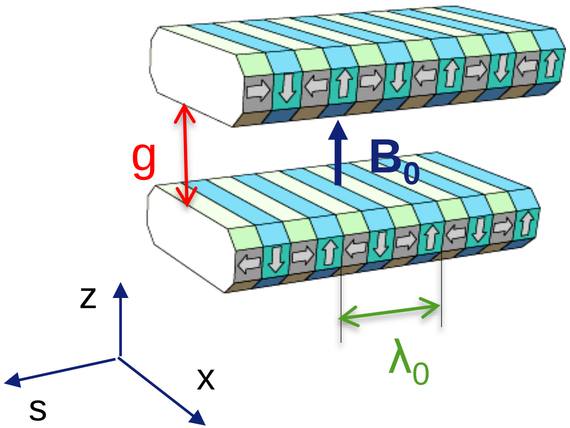
Insertion device:
- length
- period
- magnetic field orientation + amplitude



photon beam:
- energy spectrum
- size + divergence
- flux through the slit
- polarization



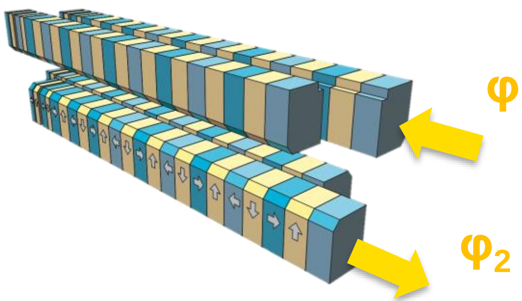
INTRODUCTION (2/2)



$$E_n = n\frac{hc}{\lambda} \qquad \lambda = \frac{\lambda_0}{2\gamma^2\left(1+\frac{(0.0934\lambda_0 B_0)^2}{2}\right)}$$

$$\frac{d\Phi_n}{d\omega/\omega} \propto \frac{L}{\lambda_0} Q_n(B_0, \lambda_0)$$

$$B_0 \propto \exp\left(-\pi\frac{g}{\lambda_0}\right)$$



Photon beam property	Energy E_n	spectral flux $\frac{d\Phi_n}{d\omega/\omega}$	polarization
Physical parameter	B_0, λ	L, B_0	B_0, (B_x, B_z)
ID knob	g, λ_0	g, λ_0, L	g, φ_1, φ_2

OUTLINE

I. IDs control system

1. Carriage control
2. Operation requirements
3. High level control

II. Energy scans for spectroscopy beamlines

1. Motivation
2. Status
3. Variable gap speed implementation

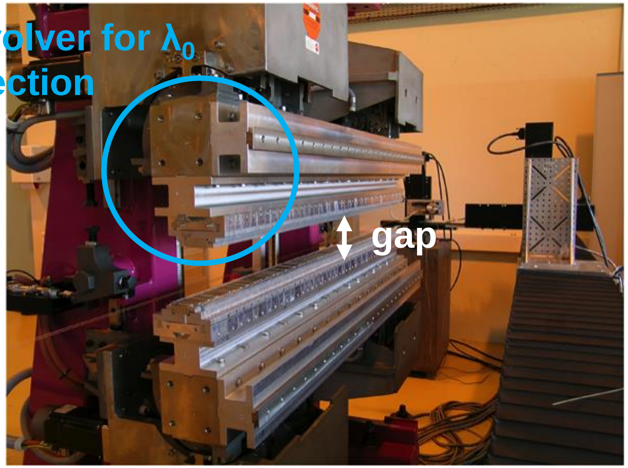
III. Upgrade project

1. Heterogeneity of controls
2. ID control upgrade

I. IDs control system

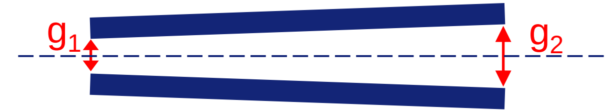
I. 1. CARRIAGE CONTROL (1/2)

Revolver for λ_0 selection



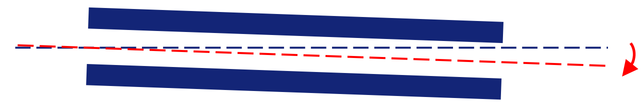
Relative girder movements for polarization (helicals)

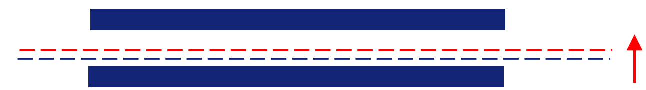
- **Spectrum** tuning:



gap = $(g_2+g_1)/2$
taper = g_2-g_1

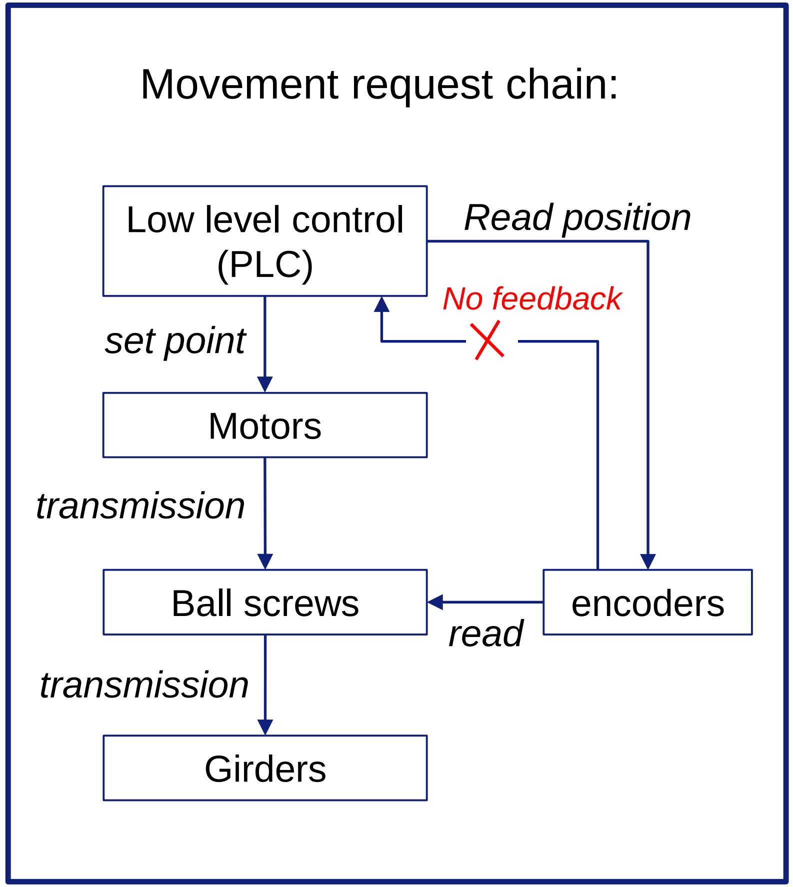
- Undulator **alignment** with the beam:





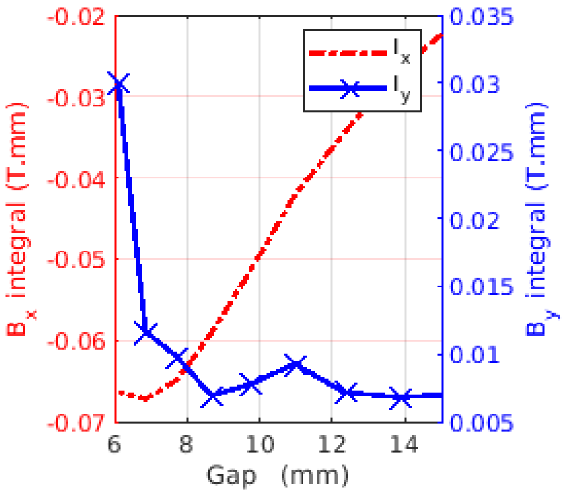
- **Rotating girders** for period selection (revolver)
- **Two to four** girders depending on type (helical)
- Taper, pitch and offset available depending on the carriage **generation**

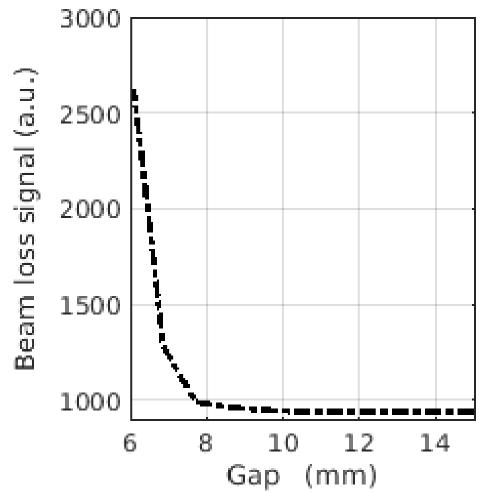
I. 1. CARRIAGE CONTROL (2/2)

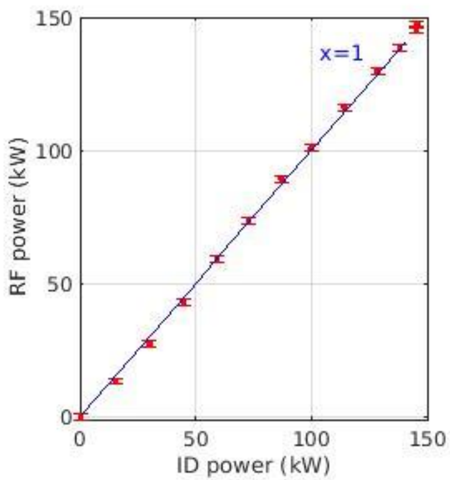


I. 2. OPERATION REQUIREMENTS

- **Control of field - flux tuning knobs**
- **MDT/USM modes** of control for IDs studies and accelerator tuning (RF conditioning, lattice and injection tuning)
- **Machine protection** (ID chamber, ID power on front end)
- Protection against **demagnetization** (movements procedures, injection interlocks at low gap)

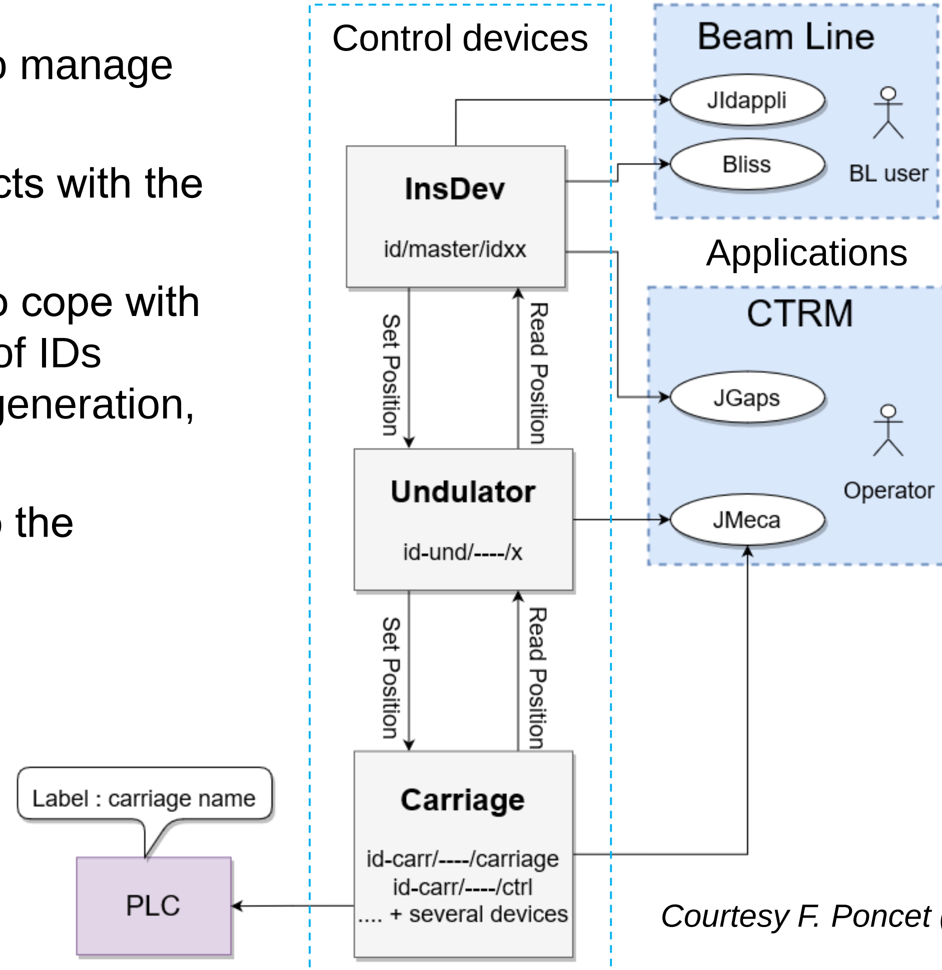






I. 3. HIGH LEVEL CONTROL

- The soft control is made of **3 layers** to manage the operation modes,
- Only the **first layer** ('Carriage') interacts with the low level control of the ID,
- Several 'Carriage' types are defined to cope with the **large variety of PLCs** and types of IDs (definition of axis to control, carriage generation, PLC version…),
- The 'Undulator' device corresponds to the **magnetic assembly**,
- From the 'Undulator' level the control should be **independant** on the type of the motorized device.



Courtesy F. Poncet (ACU)

II. Energy scans for spectroscopy beamlines

III. 1. MOTIVATION

- Absorption/emission of X-Rays at **spectroscopy beamlines** (7 ID-beamlines),
- Need for **continuous scans** (time resolution, data quality, sample preservation, beamtime optimisation)

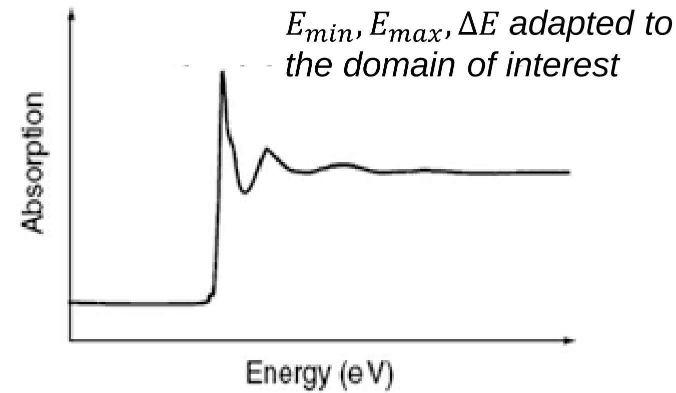
  → Gap speed control instead of position

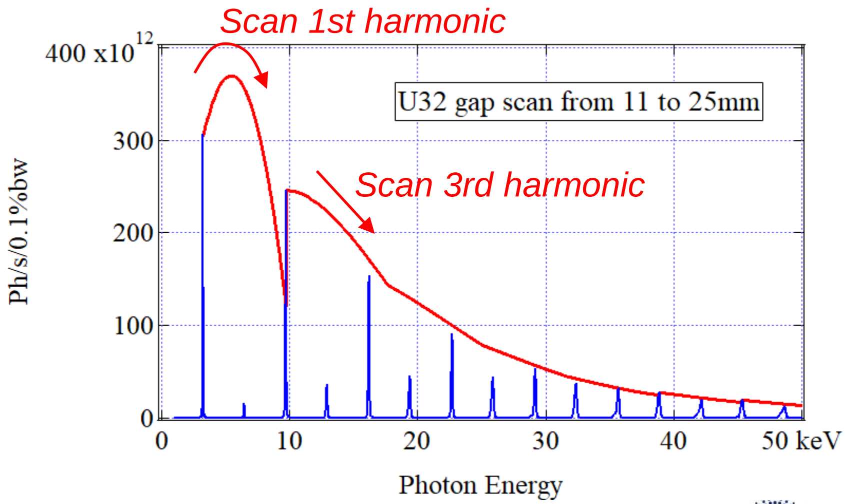
- $E(gap)$ **not linear** ($E_n(gap)$, slit aperture …)

  → Variable gap speed depending on beamline calibration

- Energy selection performed by the **monochromator** via the angle

  → Synchronization ID gap(s) – Mono. angle

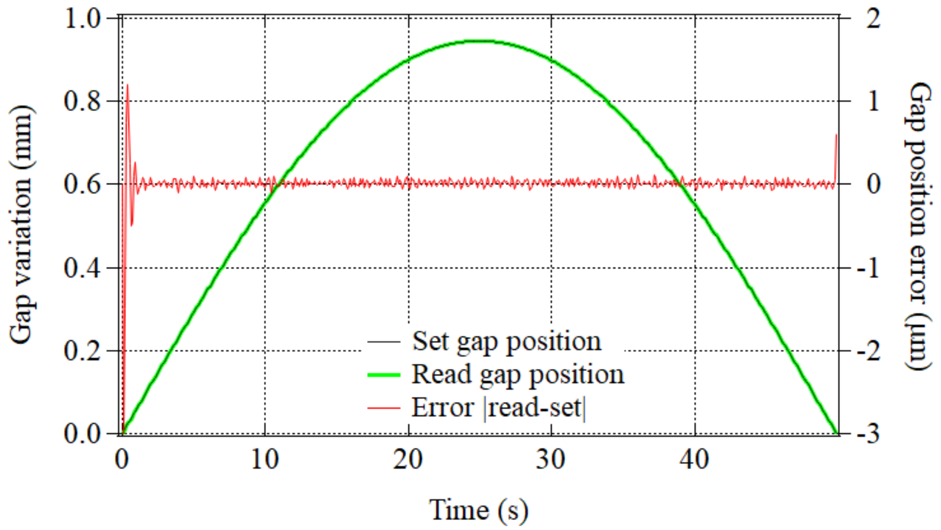




III. 2. STATUS

- Only **constant gap speed**, monochromator needs to follow the gap(s)
- Communication only at the **start** of scan (hard or soft trigger)
- **Speed & acceleration** limits driven by the least performing ID in case of 2 or 3 synchronized devices

- First version of **variable speed** gap scan tested in the lab in 2020 (C. Penel)
- **Tested successfully** with ID26 in 2021
- Characterization of gap motion **repeatability**, network and soft **delays** started at ID24 and ID26



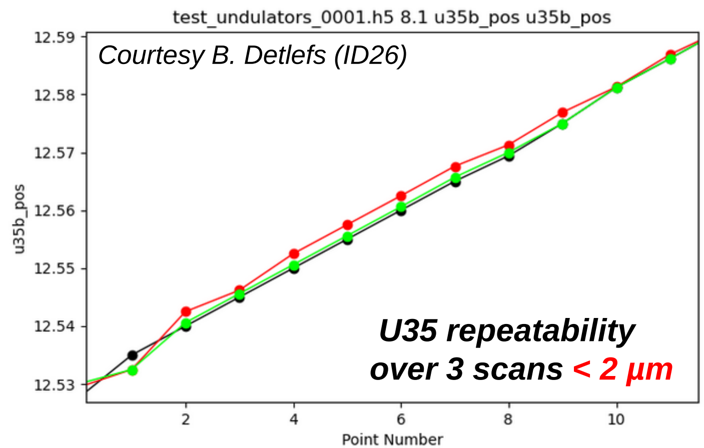
III. 3. VARIABLE SPEED IMPLEMENTATION (1/2)

Principle

- Table of $v(t)$ computed by **IDJOG2** tango device from **$E(t)$ and calibration $E(gap)$**,
- $E(gap)$ depends on the **experiment properties** (gap range, slit aperture…)
- Version 2: trajectory **loaded in the PLC** instead of speed set points

Properties

- Relies on the undulators' **motion repeatability**
- Minimum speed **0.1 or 1µm/s** depending on carriage
- Minimum update rate **5 ms** (PLC cycle)
- Acceleration transition < PLC cycle up to ~ 50 µm/s

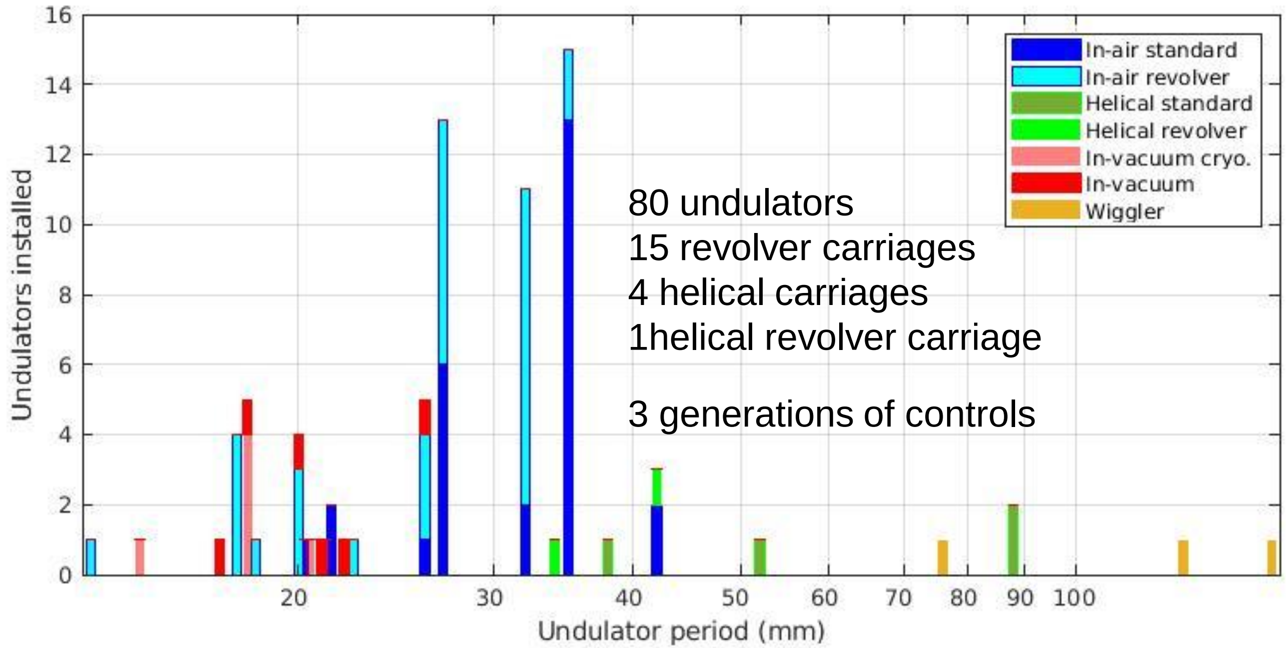


Status

- Test in the lab foreseen in **January 2023** (F. Revol)
- Available for MDT from **March 2023** shutdown
- IDJOG2 not yet ready for Operation (integration in the machine control system)

III. ID control upgrade project

II. 1. HETEROGENEITY OF CONTROLS (1/2)



- EBS started with the same IDs as in 2019, some of them are up to 30 years old
- The progressive update of controllers has been initiated in 2018
- Oldest IDs are replaced as ID production goes on
- Three generations of controls (motors + controllers) remain

II. 1. HETEROGENEITY OF CONTROLS (2/2)

- 5 phases motor – updated controller
  - 18 devices
  - Schneider PLC M241 – updated for MODBUS protocol
  - Minimum gap speed ~ 1µm/s + integer value constraint

- 3 phases motor – initial controller
  - 27 devices
  - Berger Lahr WDPM 3, integrated PLC – still no MODBUS protocol
  - Minimum gap speed ~ 1µm/s
  - Problematic hardware maintenance, update campaign on going

- 3 phases motor – up to date controller
  - 19 devices
  - Schneider SD328 + PLC LMC058 - MODBUS protocol
  - Minimum gap speed ~ 0.1µm/s

II. 2. ID CONTROL UPGRADE

Motivations

- **Obsolescence** of the low level control (motors, encoders, PLCs and drivers)
- **Maintenance** and standardization
- Need for **new functionalities** (position feedback, synchronization)

Status

- Project identified as a **major project** of ESRF in November 2022
- **Specifications** are being reviewed
- May impact on the **software** control
- **Gap scans** implementation with existing devices is necesssary and will help to identify the limitations of the control with respect to the BL needs.
- (Very) first estimate of budget for one ID carriage, including motors: **~20k€ / ID**

CONCLUSION AND PERSPECTIVES

- 65 ID carriages are currently installed at ESRF,
  8 new ones already planned for installation

→ **large variety** of control types and generations
→ difficult **maintenance** of hardware and software (soft evolution + properties)

- **Ageing of control components and technology** may impose a full upgrade from the motors to the encoders

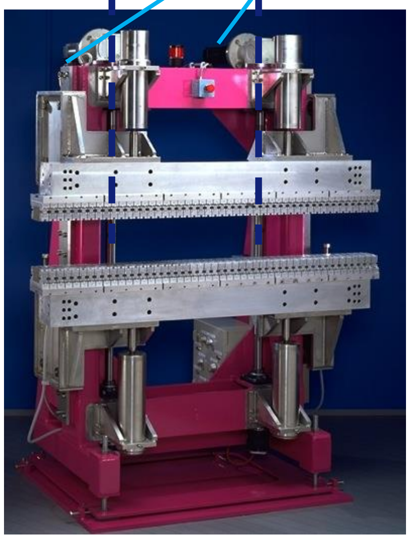
- Gap position **feedback** needs to be explored

- The new control would have to be optimized for **variable speed** gap scans and ID-Monochromator synchronization

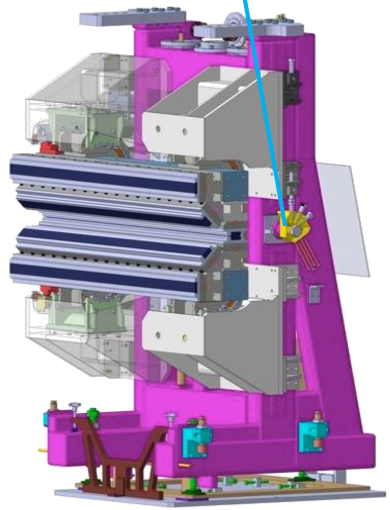
Thanks to IDM, ACU, BCU, BL, Electronic Unit

Thank you for your attention

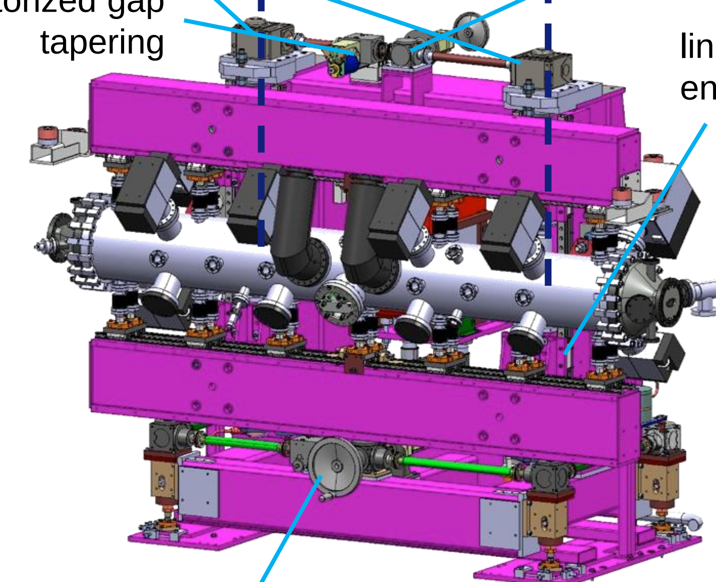
ID CARRIAGES AT ESRF



In-air carriage

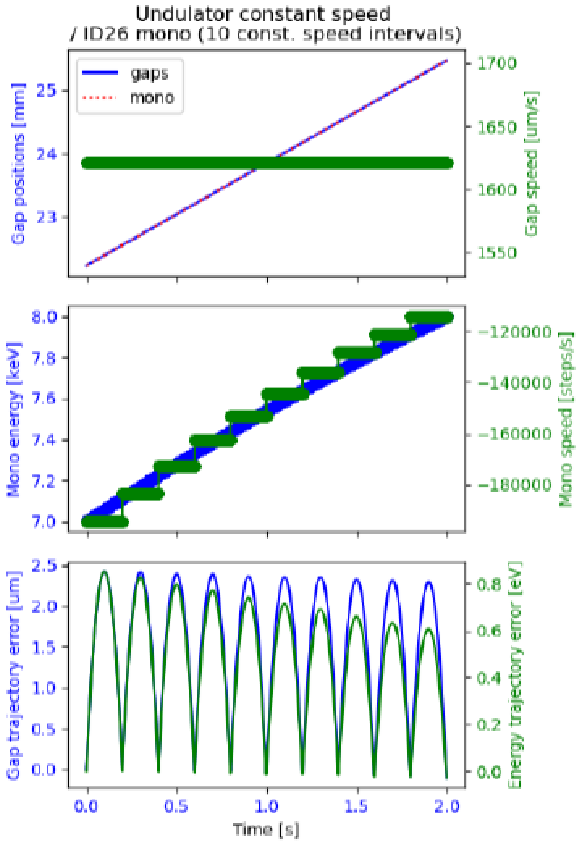


3-slot revolver carriage



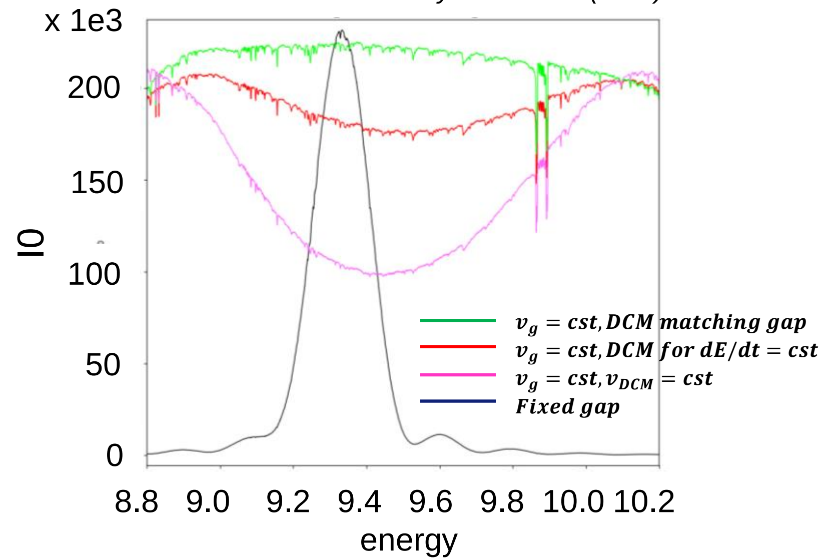
In-vacuum carriage

GAP SCANS AND SYNCHRONISATION



Courtesy B. Detlefs (ID26)

Courtesy O. Mathon (ID24)



IDS ON SPECTROSCOPY BEAMLINES

	Installed IDs	Min. gap speed	Scheduled Project
ID12	Helicals λ_0 = 34, 38/42, 52 mm	1 µm, 0.1 µm	-
ID16b	CPMU λ_0= 20.5 mm	0.1 µm	-
ID20	3 Revolvers λ_0 = 26/32	1 µm	-
ID21	λ_0 = 32, 42, 42 mm	1 µm	-
ID24	λ_0 = 32, 32, 27/32 mm	0.1µm, 1µm	2 Revolvers λ_0 = 27/32 mm
ID26	λ_0 = 35, 35, 27/35 mm	0.1 µm	-
ID32	Helicals λ_0 = 88, 88	0.1 µm, 1 µm	Helicals λ_0 = 70, 70 mm