

Operational experience and effects of IDs at SIRIUS

Gabriel Rezende da Ascensão - On behalf of IDS group



Parameter	Symbol	Currently	Phase II
Emittance	ϵ	250 pm rad	250 pm rad
Energy	E_0	3 GeV	3 GeV
Current	I_0	200 mA	350 mA
Number of beamlines		13	28
Number of IDs beamlines		8	16
Energy loss p/ turn	U_0	528 KeV	667 KeV
Operation mode		Top-up	Top-up
Lifetime	τ	8h	> 10h
Energy spread	σ_δ	8.5×10^{-4}	8.7×10^{-4}
Bunch length	σ_z	2.5 mm	12 mm
RF frequency	f_{rf}	499.667 MHz	499.667 MHz
Harmonic number	h	864	864
Momentum compaction	α	1.6×10^{-4}	1.6×10^{-4}



Phase I IDs beamlines



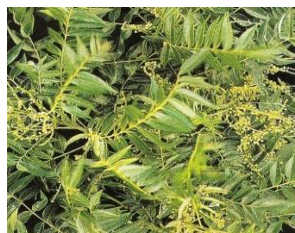
Beamline	ID type	Length [m]	Period [mm]	Max field [T]	Min. gap [mm]	Photon Energy [KeV]	Beta section
IPÊ	Apple-II	3.4	44	0.85	-	0.1 - 2	low
SABIÁ	Delta	1.2	52.5	1.25	-	0.1 - 2	low
CARNAÚBA	VPU	1.5	29	0.85	9.7	2.05 - 15	low
CATERETÊ	VPU	1.5	29	0.83	9.7	3 - 24	low
SAPUCAIA	APU	1.2	22	0.71	-	6 - 17	high
MANACÁ	APU	1.2	22	0.71	-	5 - 20	high
EMA	IVU	2.0	18.5	1.23	4.3	2.7 - 30	low
PAINEIRA	IVU	2.0	18.5	1.23	4.3	5 - 30	low



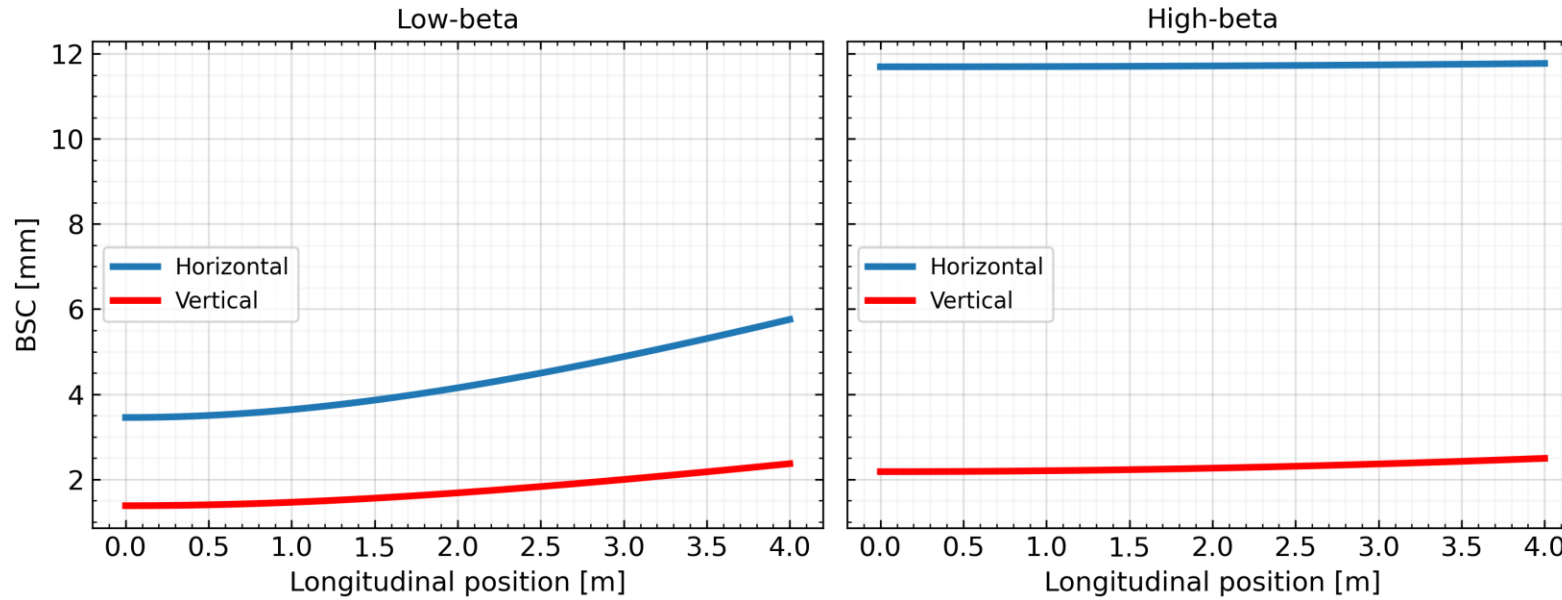
Phase II and Orion IDs beamlines



Beamline	ID type	Length [m]	Period [mm]	Max field [T]	Min. gap [mm]	Photon Energy [KeV]	Beta section
TIMBÓ	CPMU	2.0	15.8	1.50	3.80	5 - 20	<i>low</i>
ARIRANHA	APU	1.2	22	0.71	-	5 - 25	<i>low</i>
HIBISCO	CPMU	2.0	13.6	1.04	4.85	16 - 45	<i>high</i>
QUIRIQUIRI	CPMU	2.0	14.2	1.83	3.80	5 - 50	<i>low</i>
INGÁ	CPMU	2.0	15.3	1.49	3.80	2 - 30	<i>low</i>
SUSSUARANA	WLS	0.4	-	6.6	-	30 - 200	<i>low</i>
PITANGA	EPU	3.0	50.0	1.10	10.3	0.2 - 2.0	<i>low</i>
SAGUI	APU	1.0	58.0	0.96	15.8	0.1 - 2.0	<i>low</i>



Sirius straight sections



Low-beta optics: improved beam matching and reduced ID impact on beam dynamics!

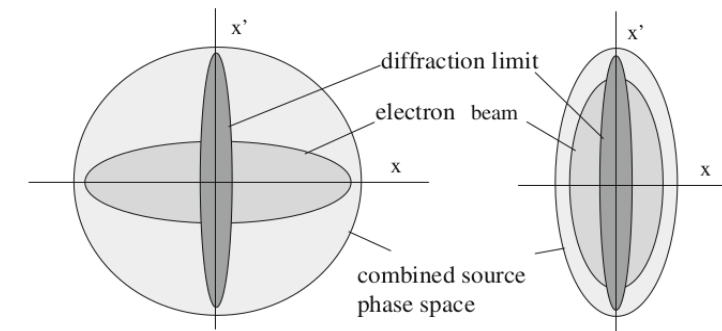


Figure from Wiedemann – Particle Accelerator Physics (2015)

	Low- β	High- β
SS length [m]	6.5	7.5
Hor. BSC @ SS center [m]	3.45	11.70
Vert. BSC @ SS center [m]	1.38	2.18

	Low- β	High- β
SS length [m]	6.5	7.5
Hor. beta SS center [m]	1.49	17.20
Vert. beta SS center [m]	1.43	3.60

IDs: Current Status and Challenges

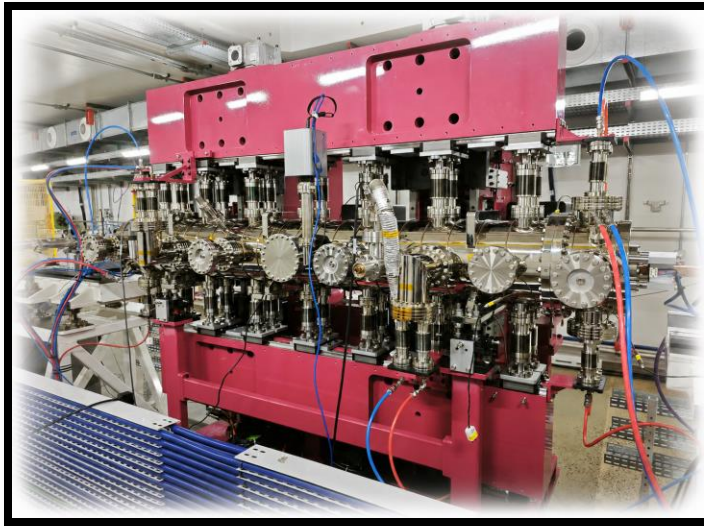
APU22



- Manufactured by Kyma.
- No correctors for orbit feedforward are necessary.
- Effects in optics are negligible – short IDs with small field.
- $L = 1.2 \text{ m}$
- $B_{\text{max}} = 0.71 \text{ T}$

IDs: Current Status and Challenges

IVU18



- $L = 2 \text{ m}$
- $B_{\text{max}} = 1.23 \text{ T}$

VPU29



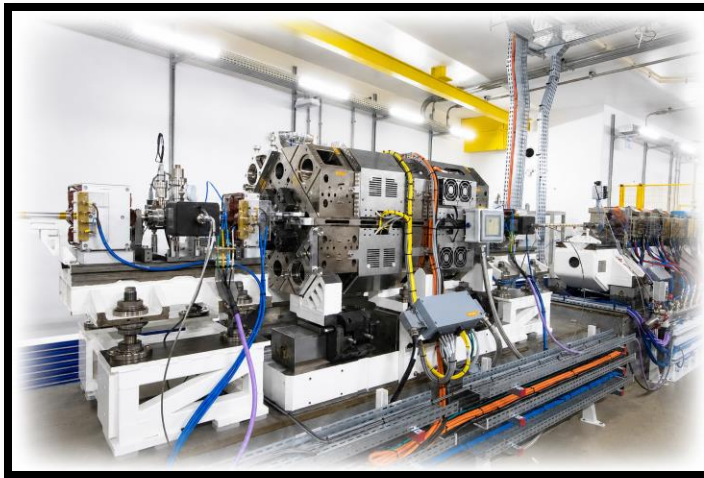
- $L = 1.5 \text{ m}$
- $B_{\text{max}} = 0.85 \text{ T}$

- Manufactured by SSRF (IVU) and Kyma (VPU)
- Orbit feedforward is necessary!
- Effects in tune are small. The effects in the beta functions are negligible!
- Good synchronization with monochromator!



IDs: Current Status and Challenges

DELTA52



- $L = 1.2 \text{ m}$
- $B_{\text{max}} = 1.25 \text{ T}$

UE44



- $L = 3.4 \text{ m}$
- $B_{\text{max}} = 0.85 \text{ T}$

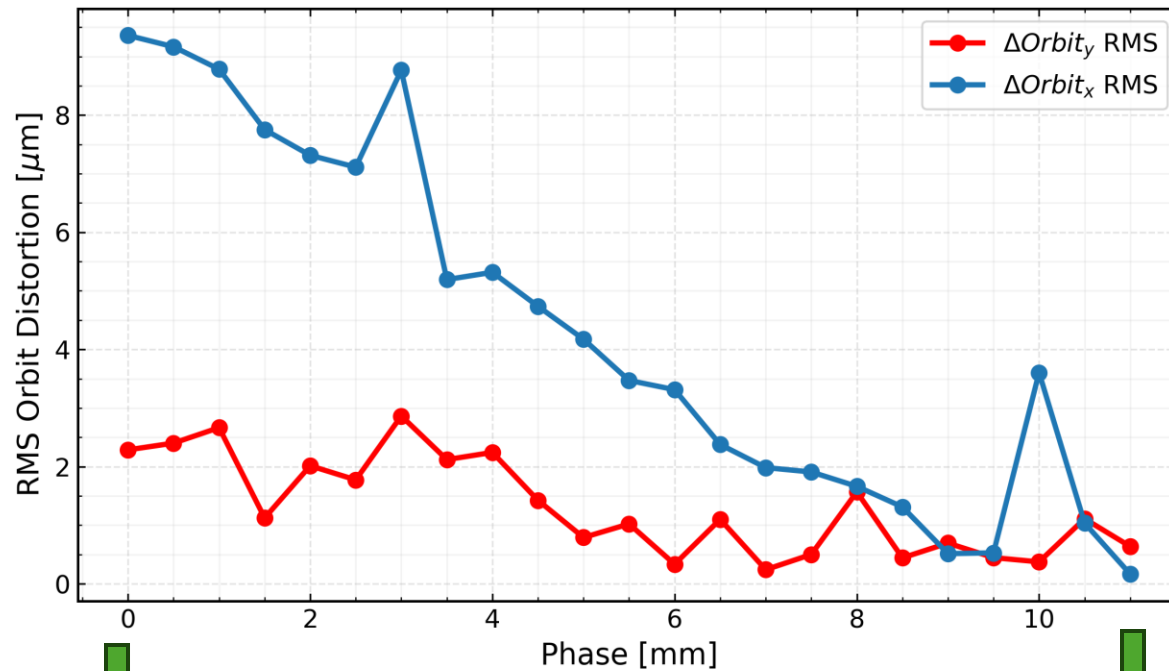
- In-house development (DU52) and acquired from PSI (UE44).
- Orbit feedforward is necessary! 2D config. Space.
- Effects in tune are small. The effects in the beta functions are negligible!
- Problems with motion!



APU22 effect on orbit

APU22 in High-beta section

Orbit Distortion RMS vs Phase

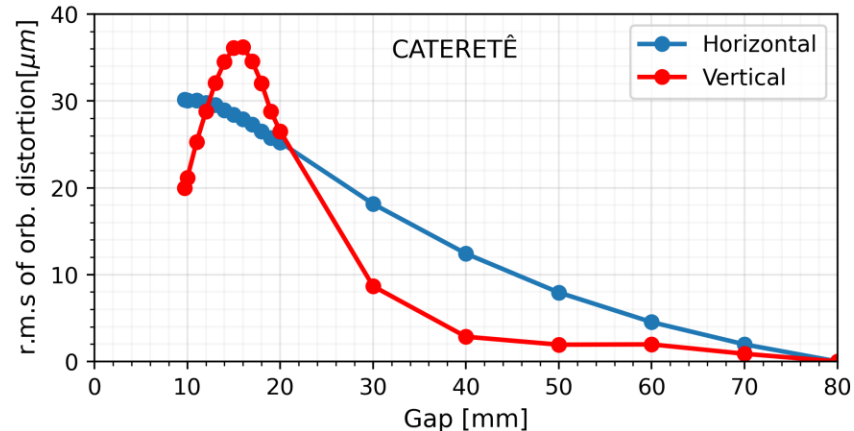
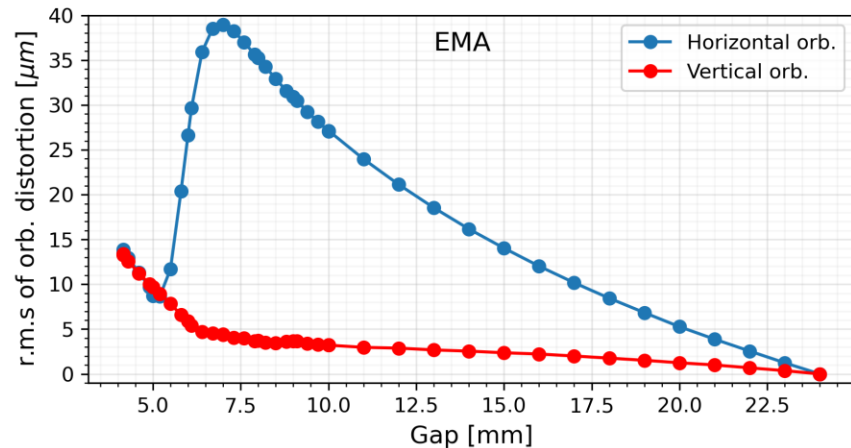
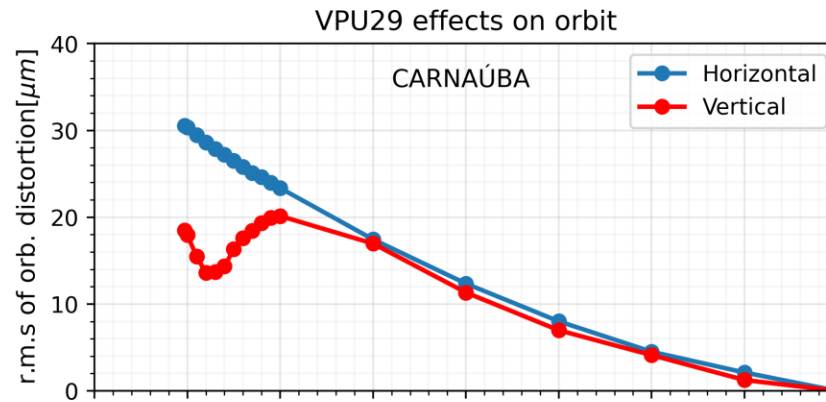
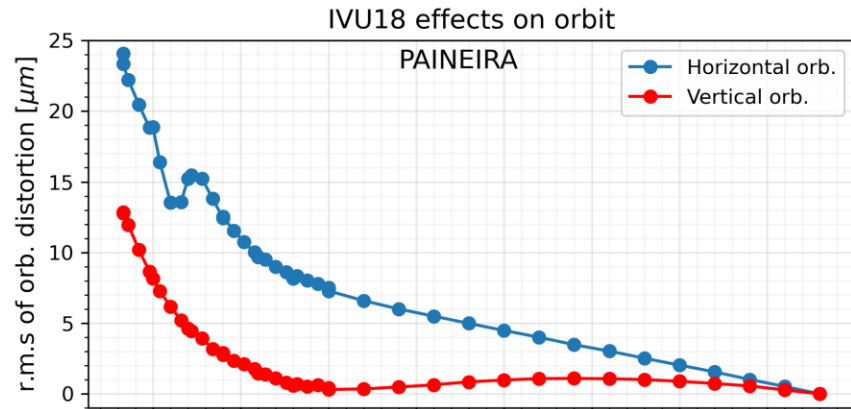


Max. Transverse field

Min. Transverse field

- Small orbit distortion (less than 10 μm).
- No high orbit distortion gradient – Fast Orbit Feedback System (FOFB) is completely able to correct these distortions during ID movement.

IVUs and VPUs effects on beam



- Large orbit distortions.
- High orbit distortions gradients - \rightarrow FOFB may be not able to correct for such distortions.

Orbit feedforward approach in SIRIUS

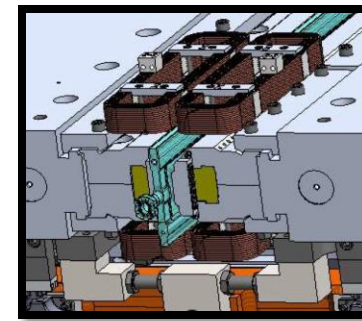
- Practical approach to measure for ID orbit distortions – SOFB filter:

$$\Delta\vec{r}_f = M_S P M_S^+ \Delta\vec{r}$$

- This approach allows us to measure the ID feedforward tables in few minutes.

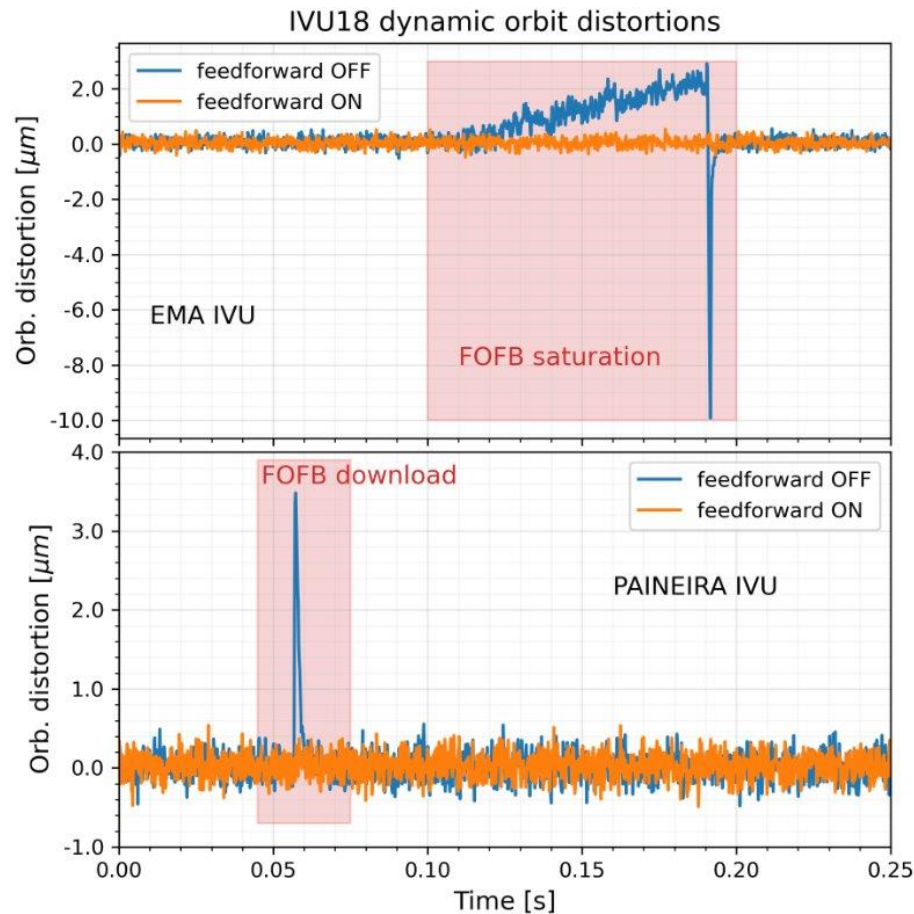
- $\Delta\vec{r}$ is the measured orbit distortion
- M_S is the SOFB response matrix
- M_S^+ is SOFB resp. mat. pseudo-inverse
- P is a projection matrix to select the closest correctors
- $\Delta\vec{r}_f$ is the filtered orbit distortion

- For the VPU's case, a gap-dependent matrix response is necessary for the correctors.

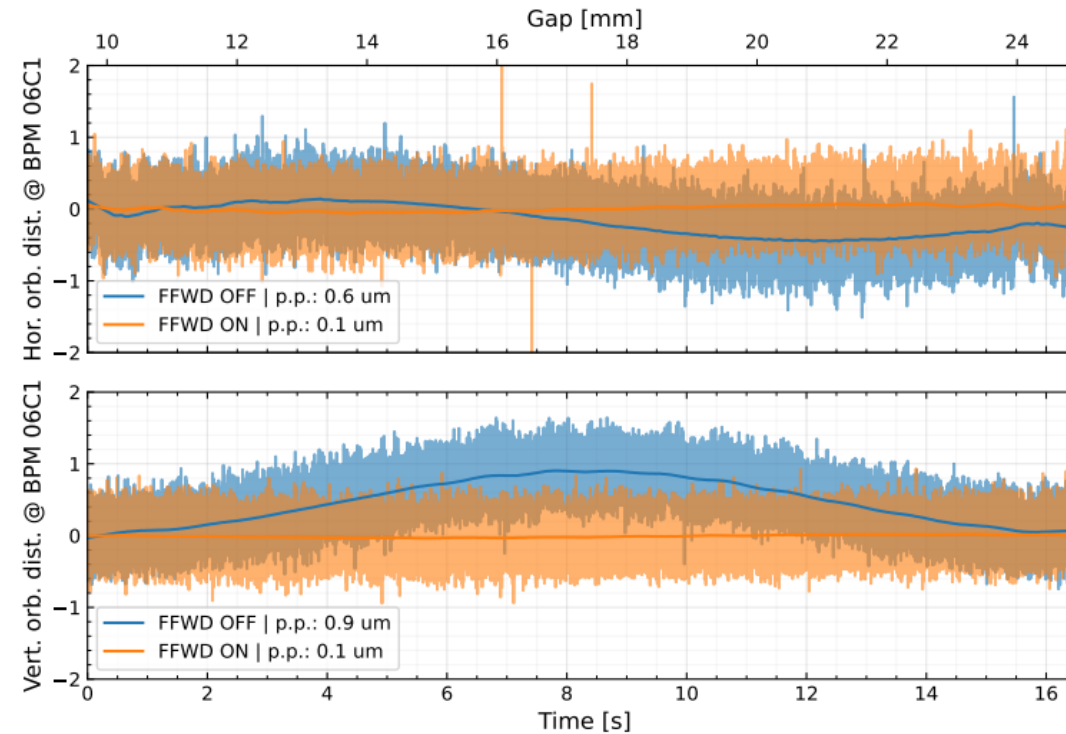


- Impact of Delta undulator on SIRIUS beam dynamics - [10.18429/JACoW-IPAC2024-THPS18](https://doi.org/10.18429/JACoW-IPAC2024-THPS18)

IVUs and VPUUs effects on beam



VPU29 CARNAÚBA



- FF running at 1 KHz.
- Based on BeagleBone Black plataform.

- Real-time embedded feedforward correction for SIRIUS undulators - [10.18429/JACoW-IBIC2025-TUPCO29](https://doi.org/10.18429/JACoW-IBIC2025-TUPCO29)

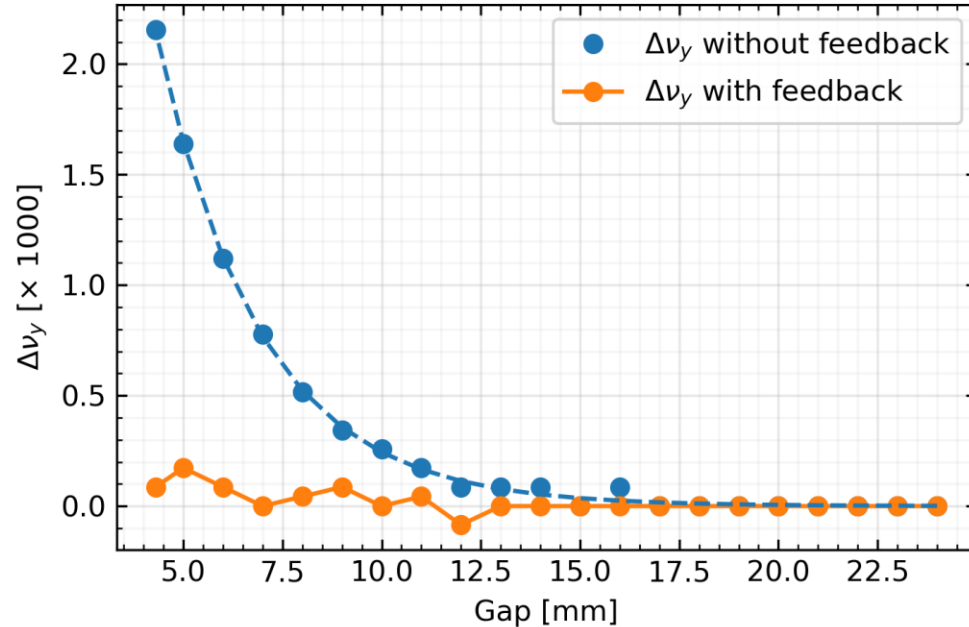
IVUs and VPUs effects on beam



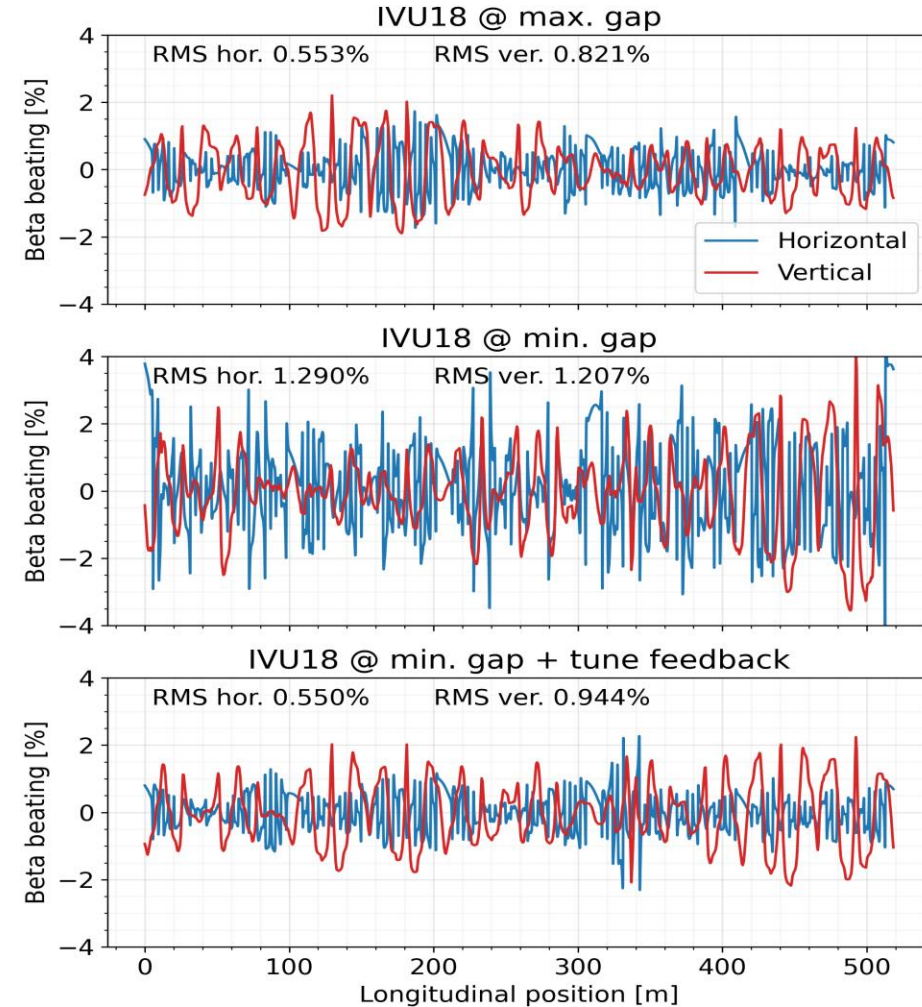
CNPEM

Effects on linear optics

IVU18 focusing effect



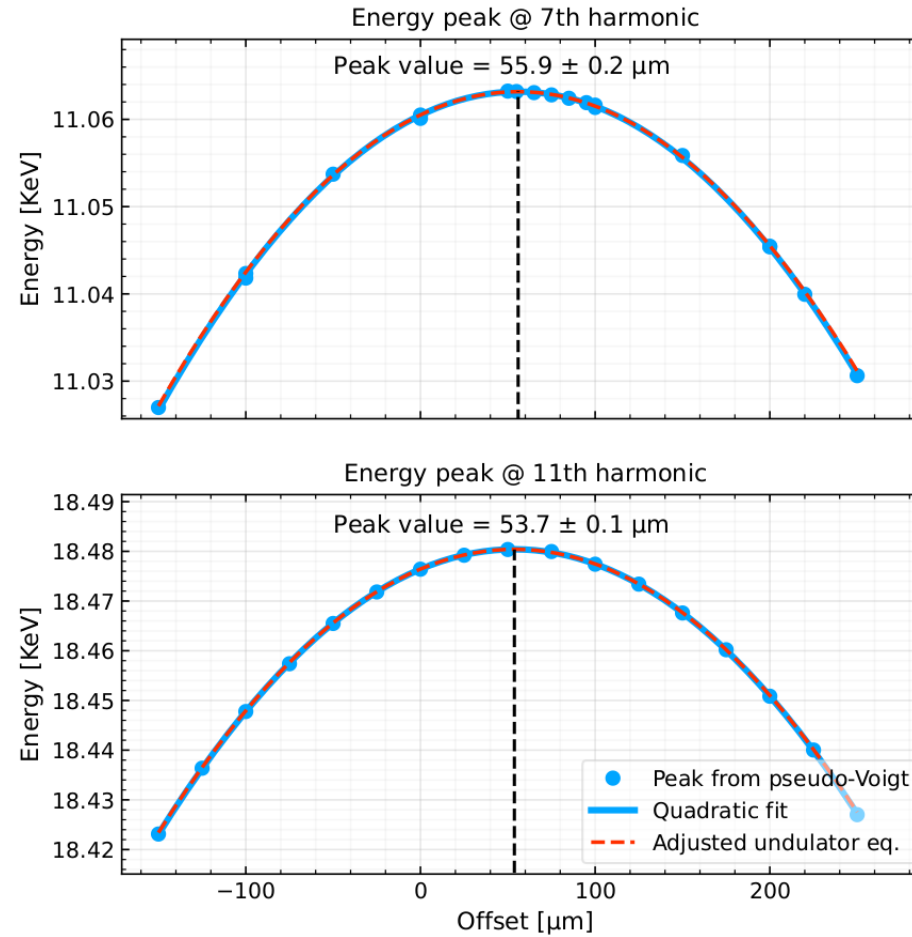
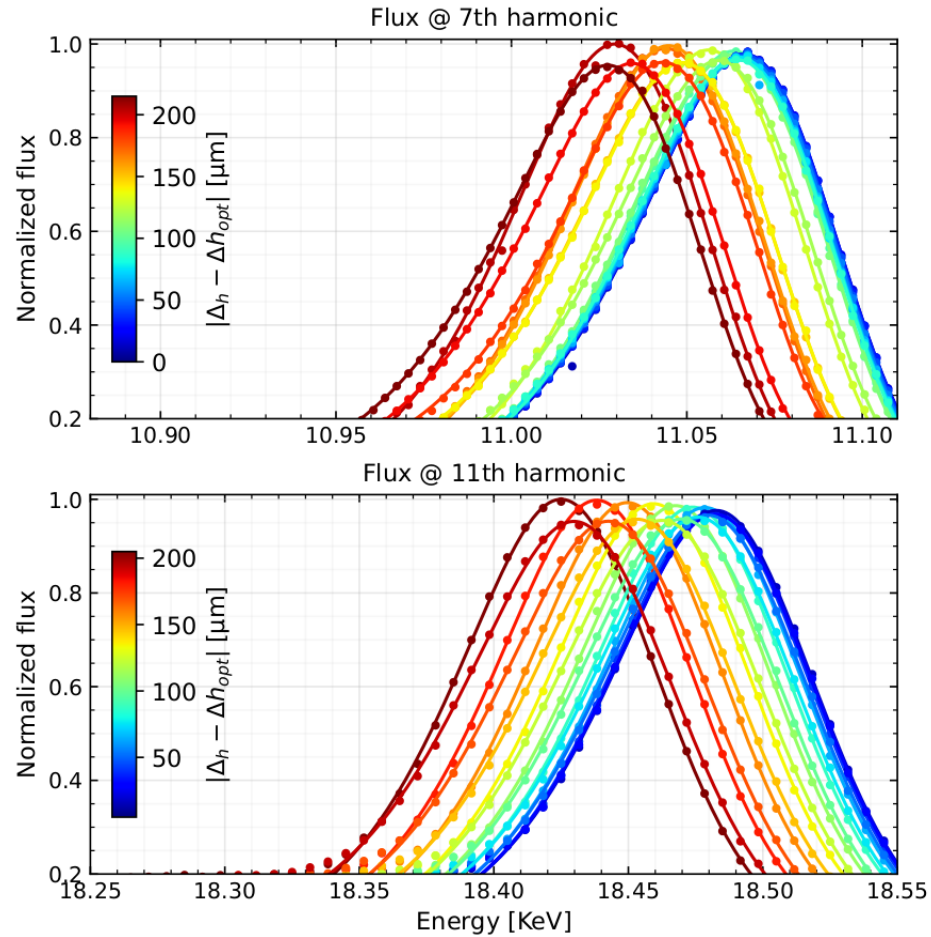
- The effects on tune are small, but measurable. The beta-beating is mostly due to tune shifts.



- Effects of new SIRIUS IVUs on electron beam dynamics - [doi:10.18429/JACoW-IPAC2025-WEPM002](https://doi.org/10.18429/JACoW-IPAC2025-WEPM002)
- Impact of VPU on beam dynamics in the SIRIUS storage ring - IPAC26

IVUs and VPU – photon beam

Spectrum-based alignment



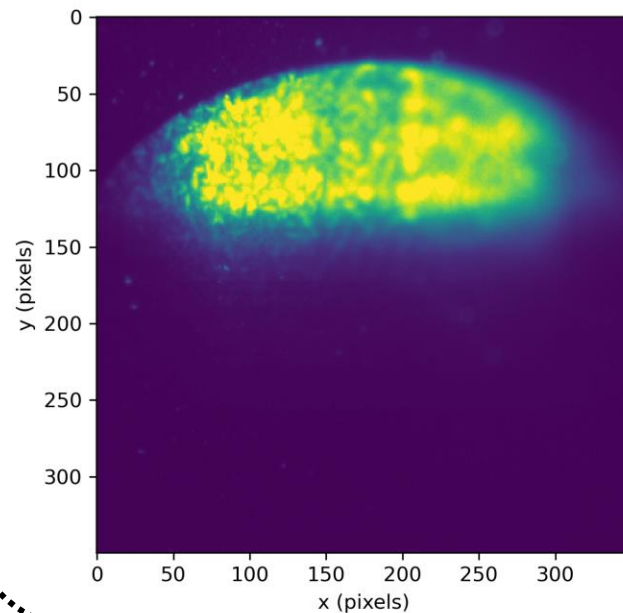
- IVU measurement
- Spectrum-based alignment of SIRIUS undulators - <https://doi.org/10.1088/1742-6596/3094/1/012011>

IVUs and VPU – photon beam

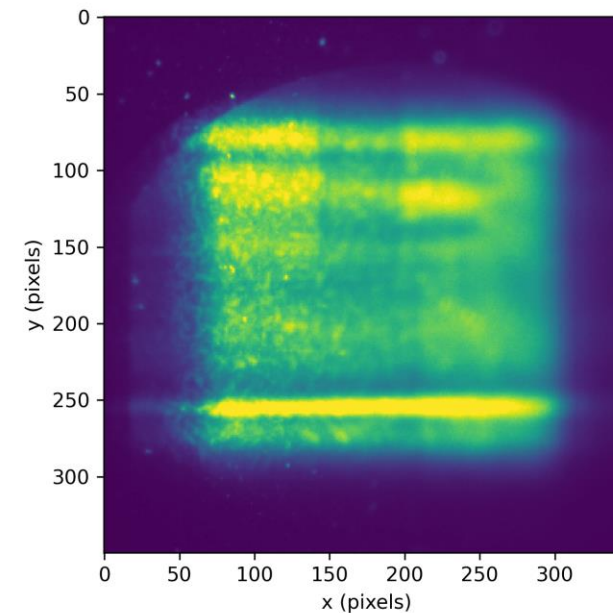
Photon beam misalignment at CARNAÚBA

- CARNAÚBA beamline misalignment probably associated with ORION construction activities
- Use of ID FF corrector to steer the beam to the correct position

• Before correction

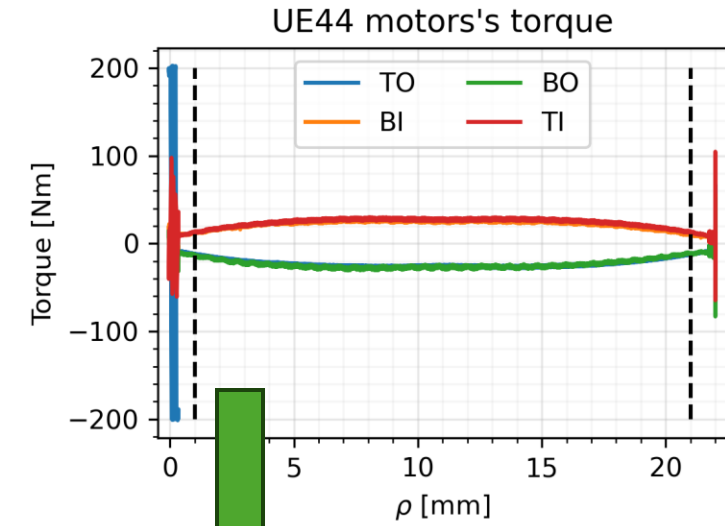
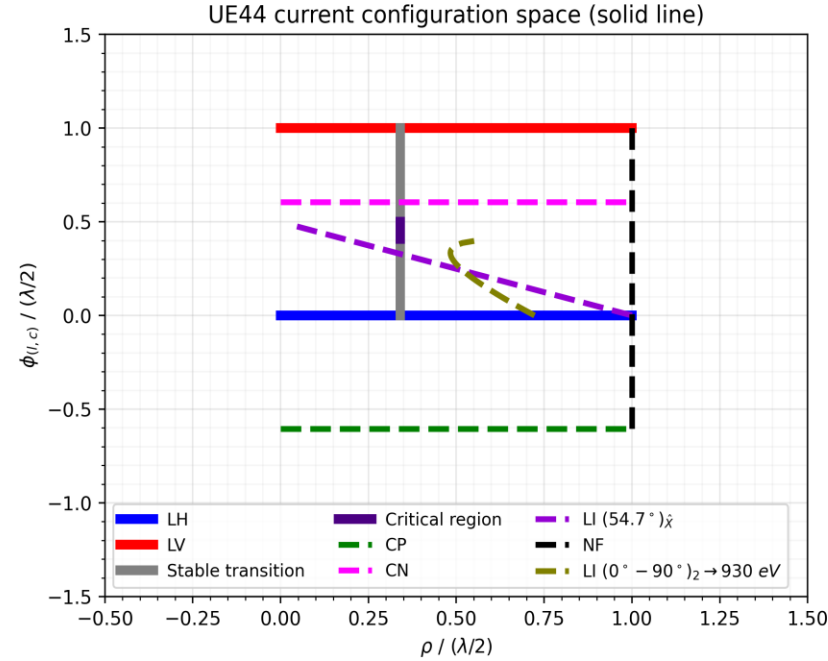
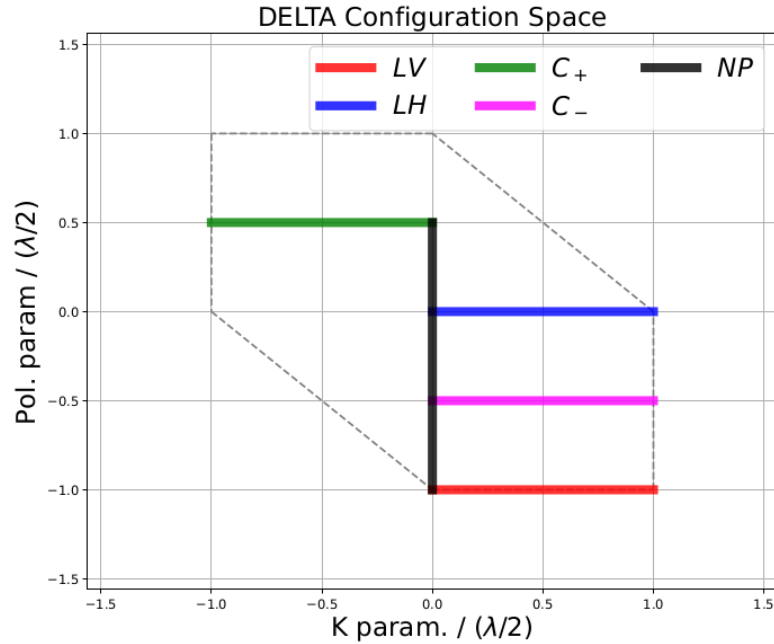


• After correction



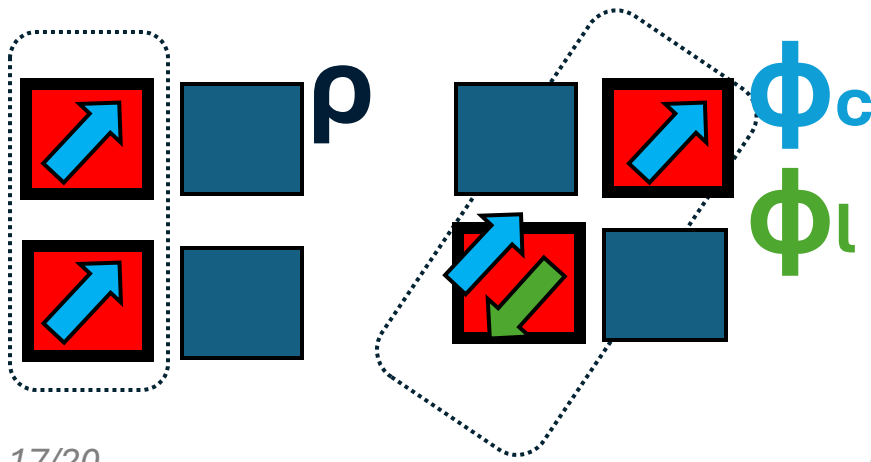
DU52 and UE44

Configuration space



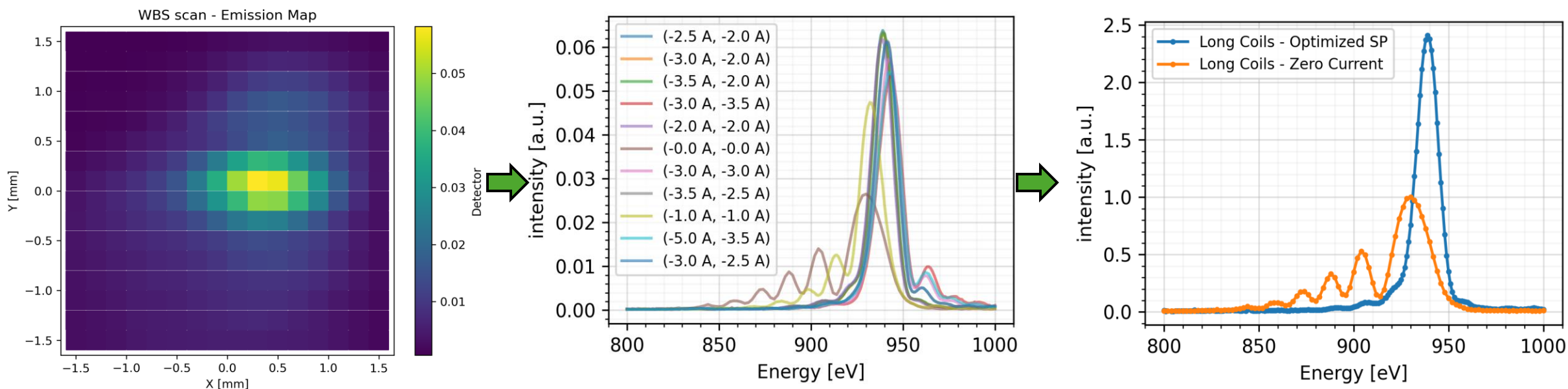
Stable region

- Complex config. space with many points to avoid.



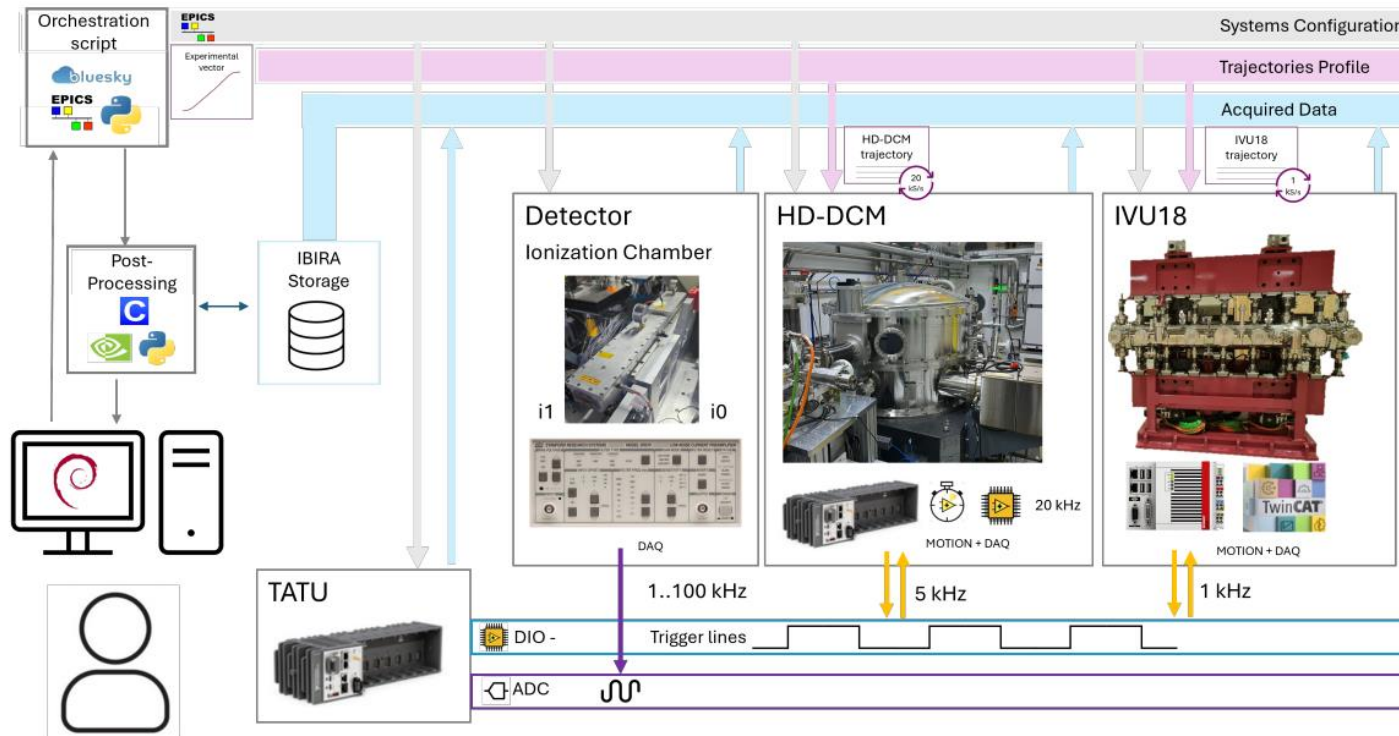
Long coil use

- The long coil currents (LCH, LCV1/2) were scanned around a pre-optimized point.
- The measurements below were performed with a $0.2 \times 0.2 \text{ mm}^2$ aperture at the WBS (very narrow slit opening).
- The slit was centered at the emission centroid, determined after a previous optimization with open slits.
- Polarization: LH; $\rho = 15.965 \text{ mm}$ (930 eV photon energy).

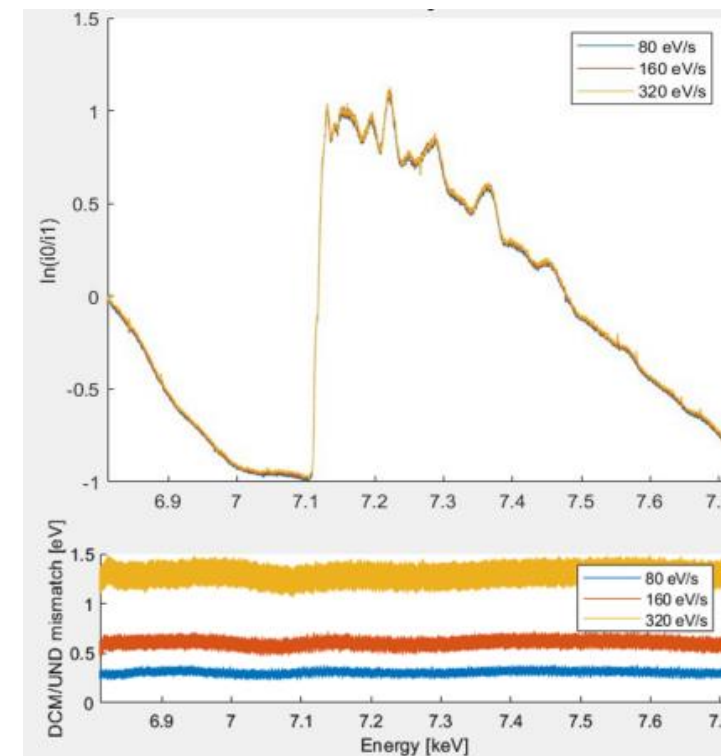


IDs synchronization

IVU18



Synchronization architecture for EMA beamline



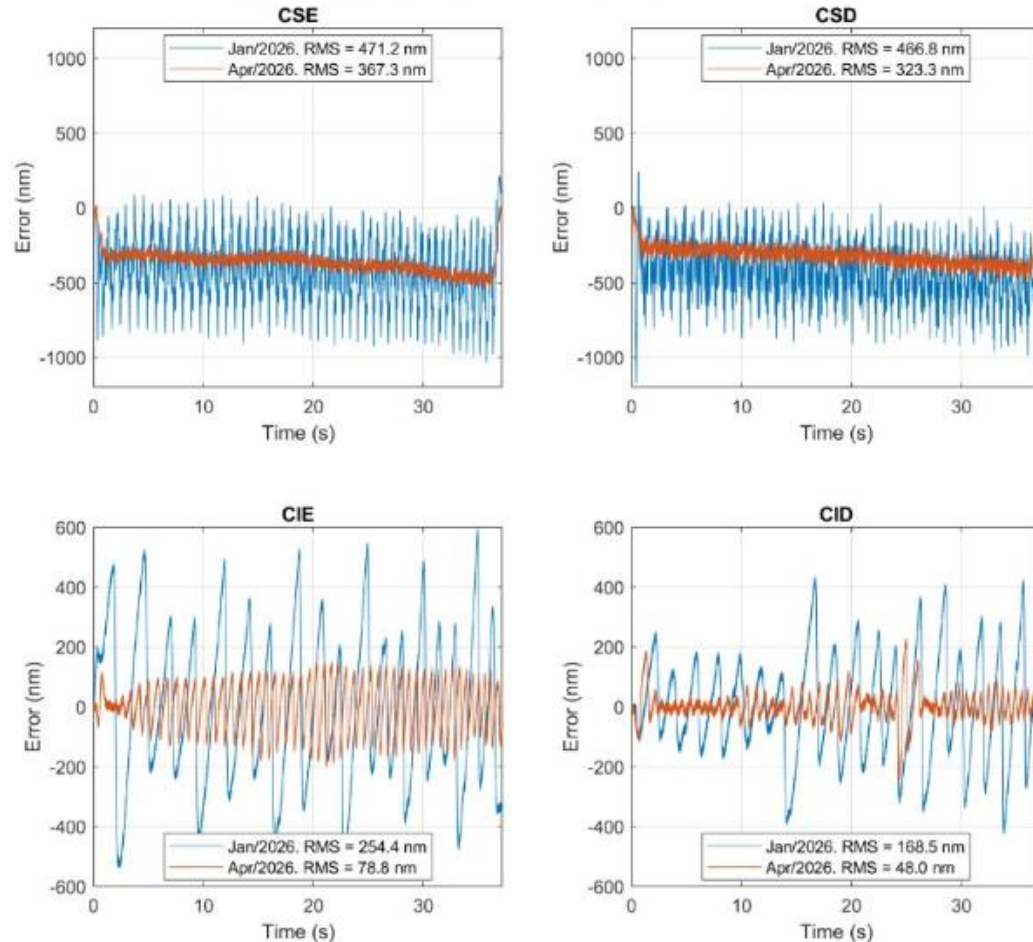
Energy mismatch between IVU18 and HD-DCM for Iron sample.

- "Hardware orchestration architecture for fly and step scan at SIRIUS/LNL S beamlines: a distributed, multi-platform system for sub-micrometer motion and data acquisition synchronization in on-the-fly synchrotron measurements" - [ICALEPCS2025-THMR012](#)

IDs synchronization

DELTA52

Comparison DU525 Jan/2026 - Apr/2026
Linear Horizontal from 1200 eV to 1500 eV, 8.571 eV/s



- Increased controller bandwidth after gearbox replacement, significantly reducing trajectory tracking errors during motion.

Thank you!

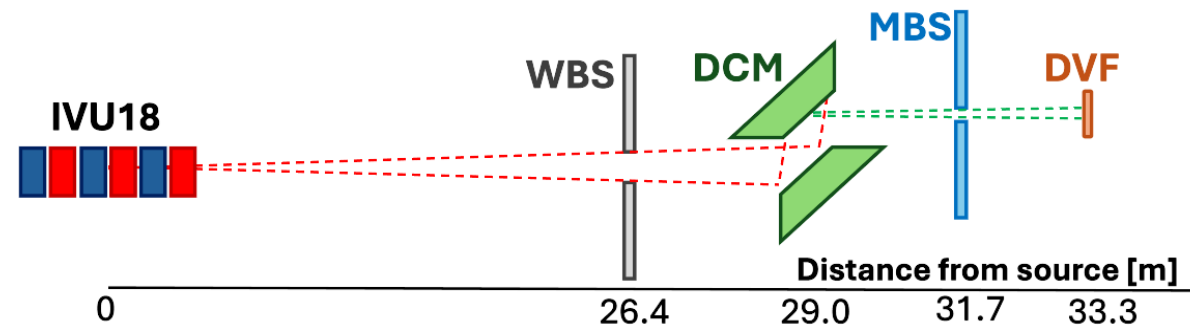
I would like to thank Sergio Lordano and Jefferson Vieira, my colleagues from the IDS Group who helped me with this presentation. I also thank the colleagues from the Accelerator Physics Group, IDS group and COI group for their support and valuable discussions and help.



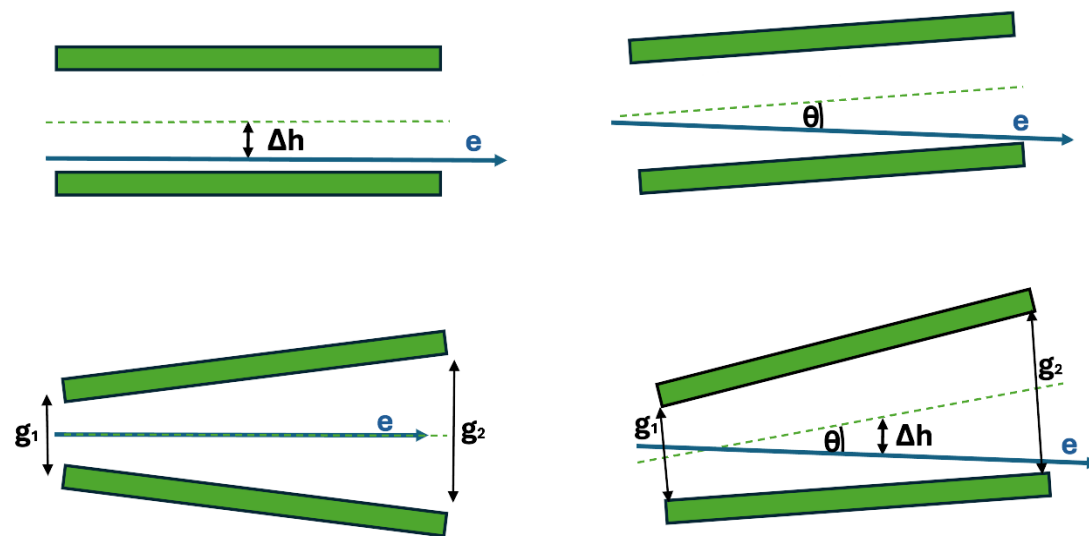
IVUs and VPU – photon beam

Spectrum-based alignment

- The goal is to diagnose ID misalignments with respect to the electron beam orbit



- Measurement setup

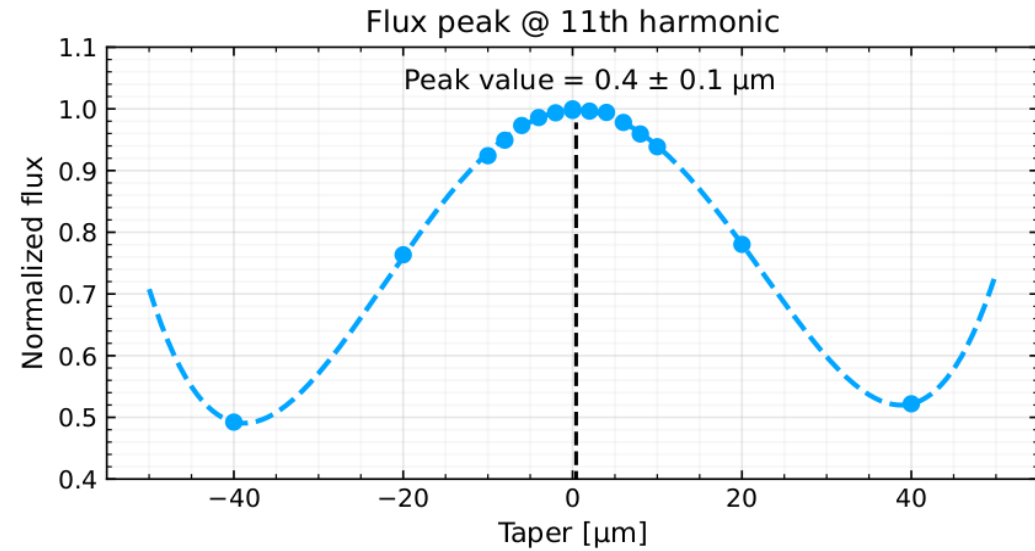
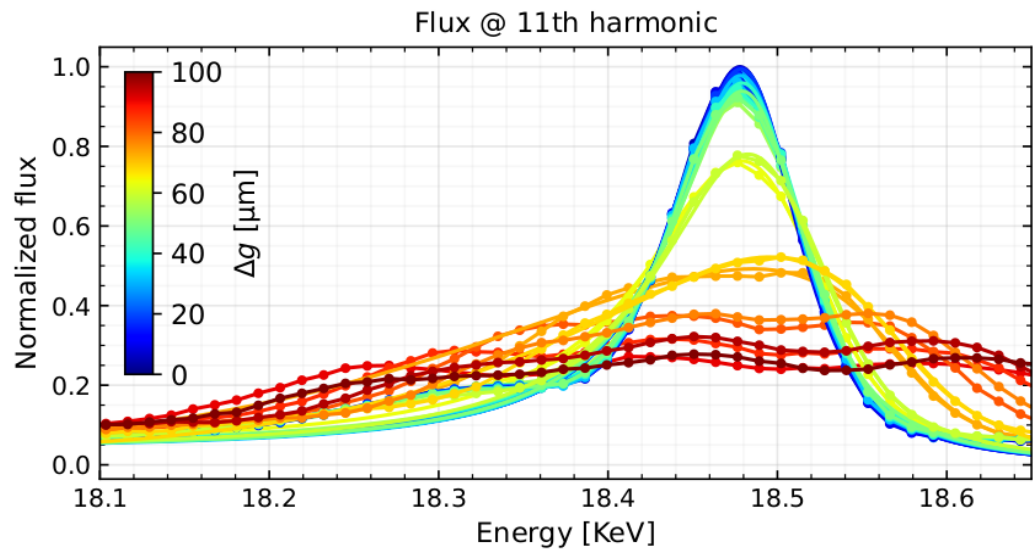
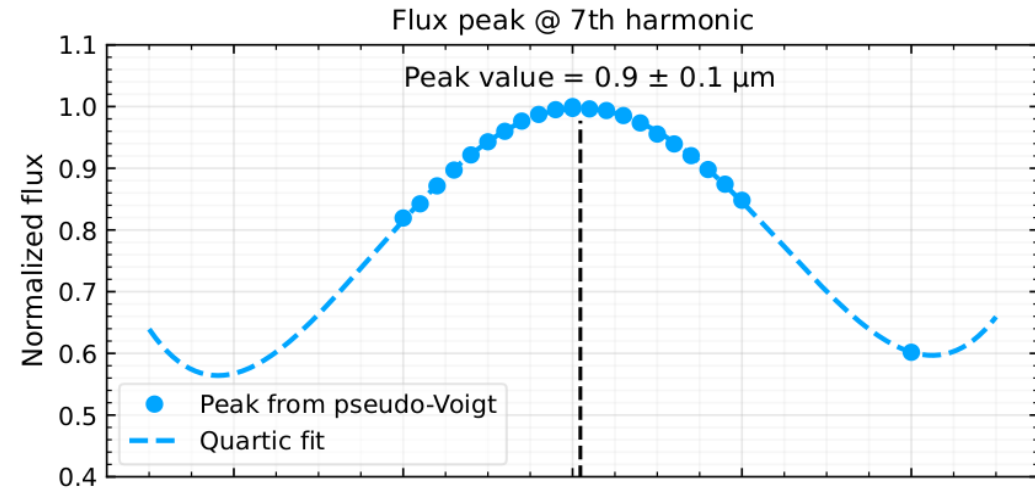
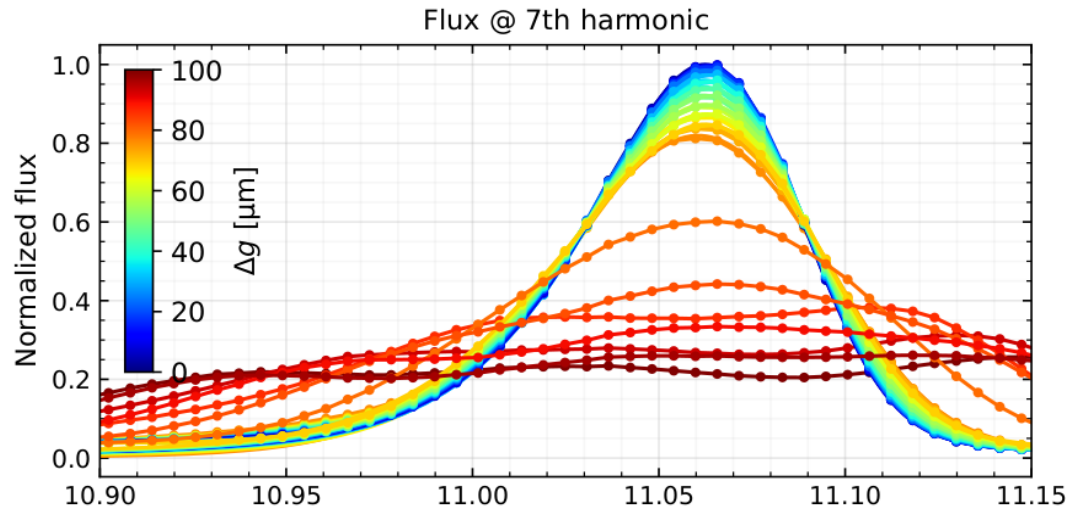


- Independent motor control of IVUs and VPUs enables offset, taper, and pitch adjustment.

- Spectrum-based alignment of SIRIUS undulators - <https://doi.org/10.1088/1742-6596/3094/1/012011>

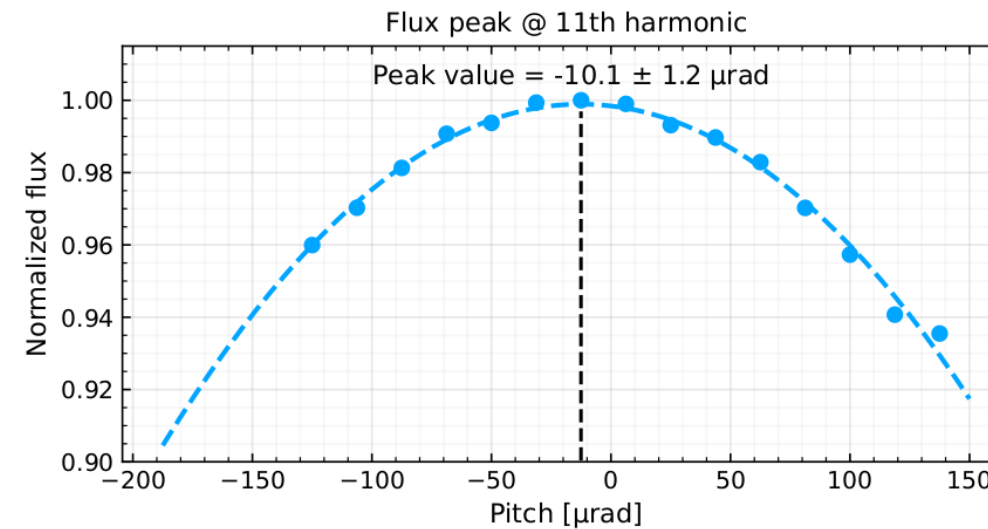
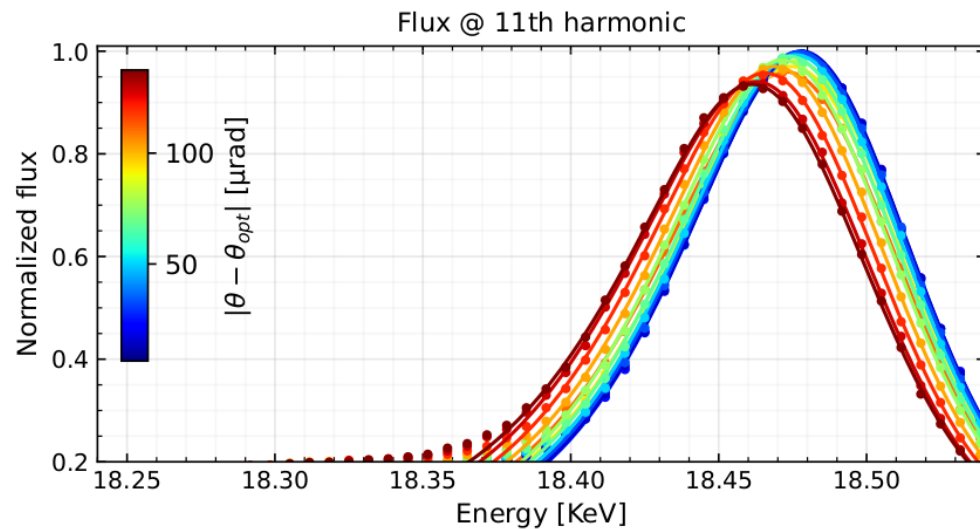
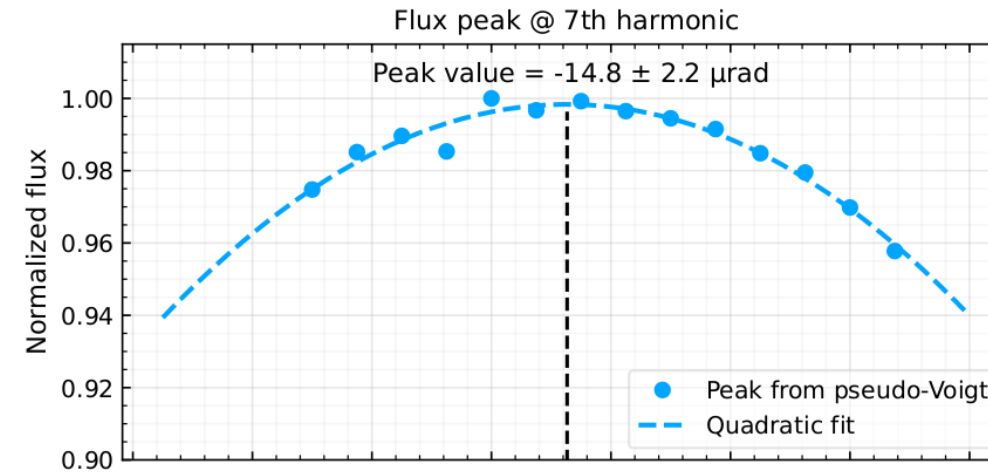
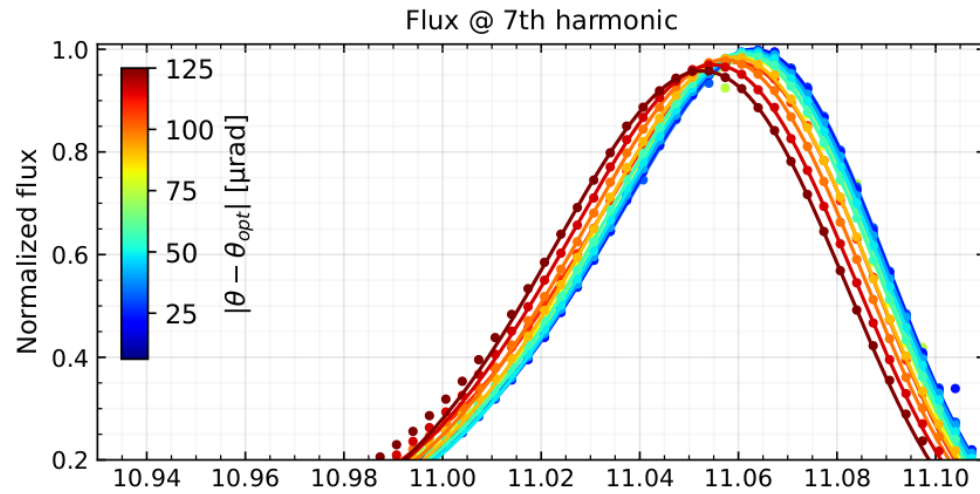
Backup slides

Taper scan



Backup slides

Pitch scan

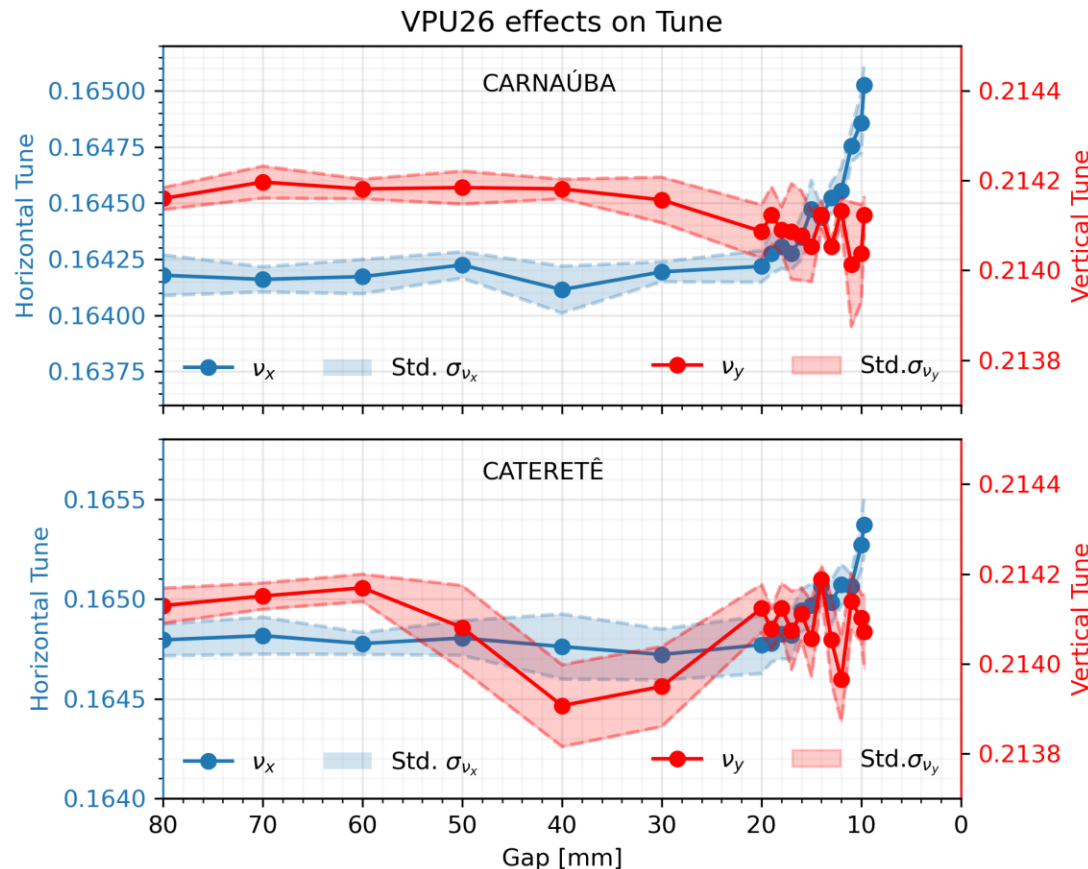


IVUs and VPUs effects on beam



CNPEM

Effects on linear optics



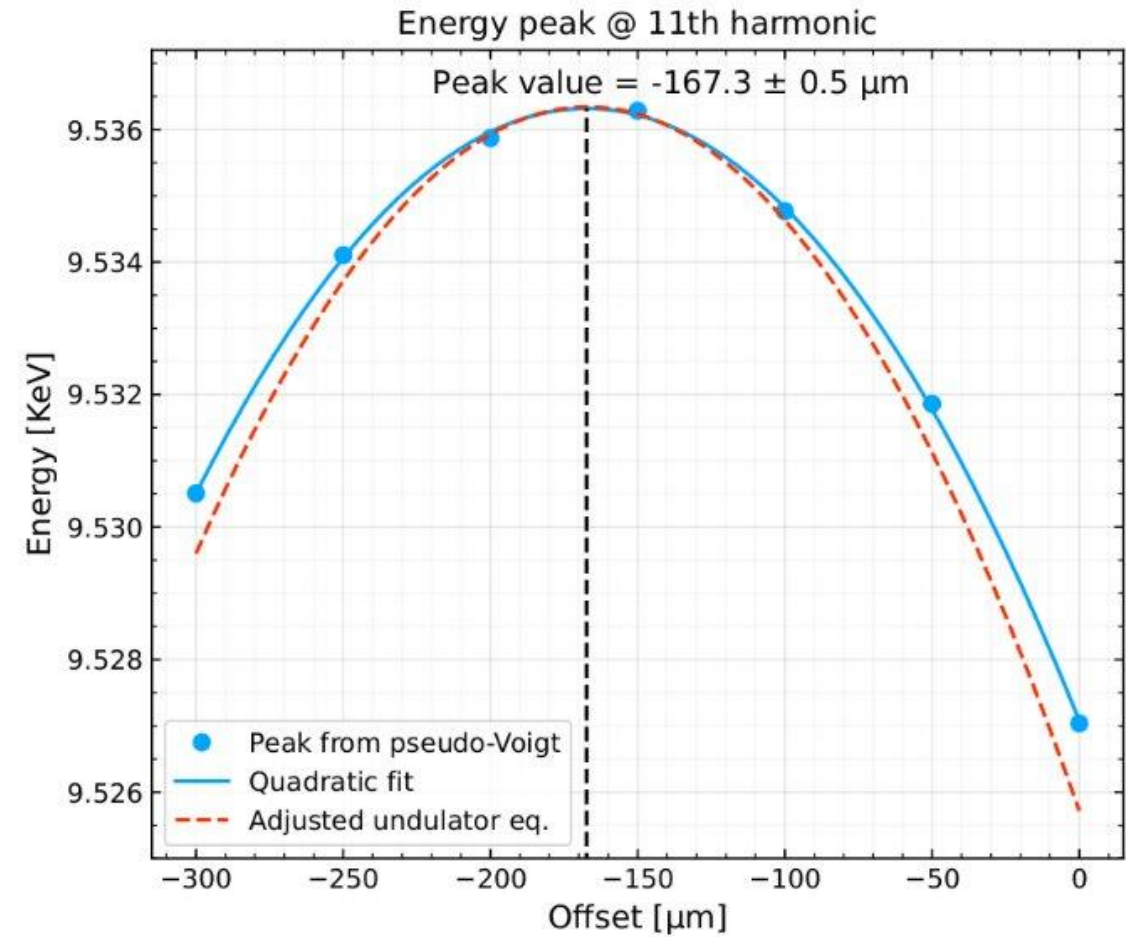
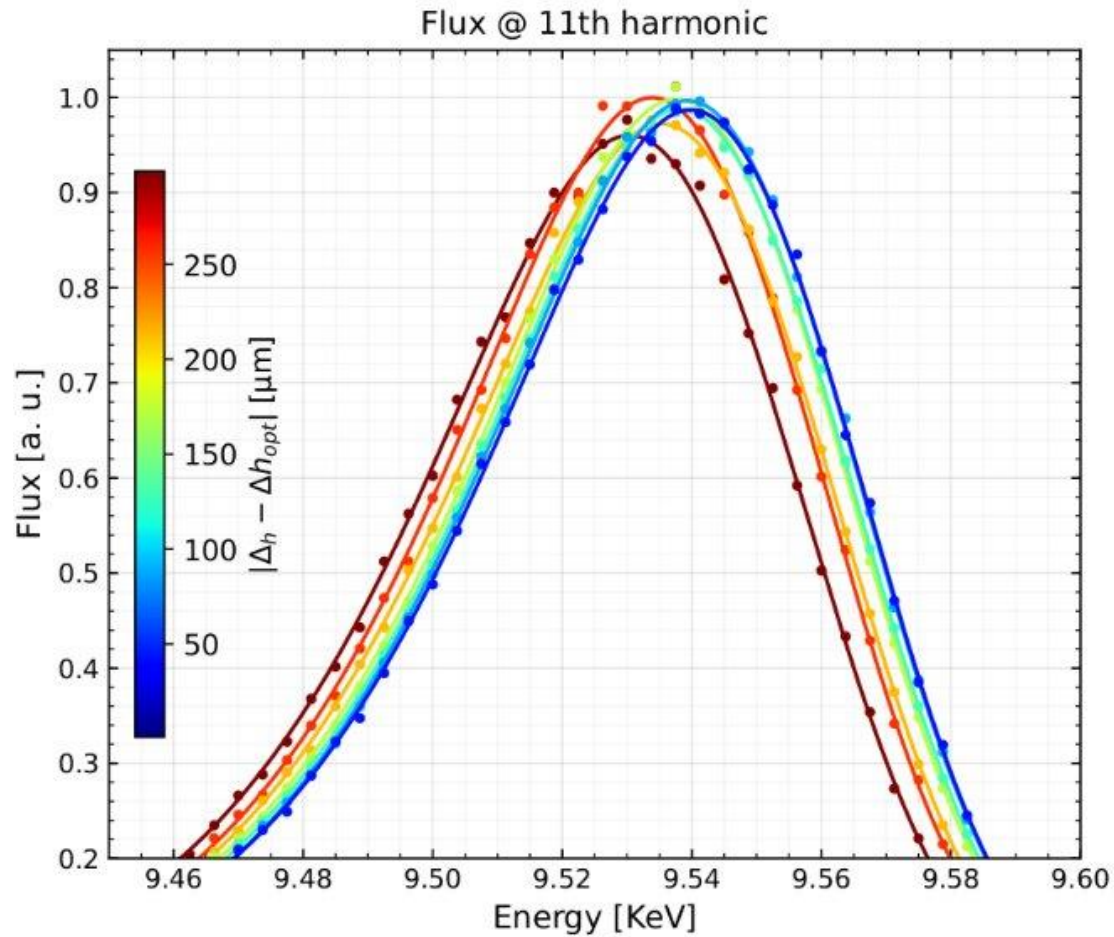
- The effects on tune are small, but measurable. There is a strange behavior of the vertical tune -> probably due orbit distortion!

- Effects of new SIRIUS IVUs on electron beam dynamics - [doi:10.18429/JACoW-IPAC2025-WEPM002](https://doi.org/10.18429/JACoW-IPAC2025-WEPM002)
- Impact of VPU on beam dynamics in the SIRIUS storage ring - IPAC26

ID26 workshop | May 16, 2026

IVUs and VPU – photon beam

Spectrum-based alignment



- VPU measurement