Riccardo Bartolini, DESY

I.FAST 5th Annual Meeting, CERN, 22.10.2025

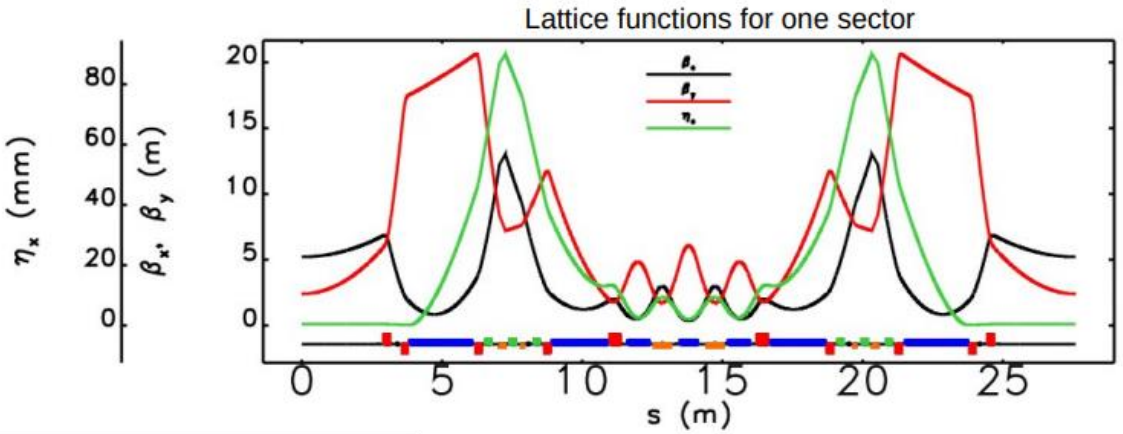
Outline

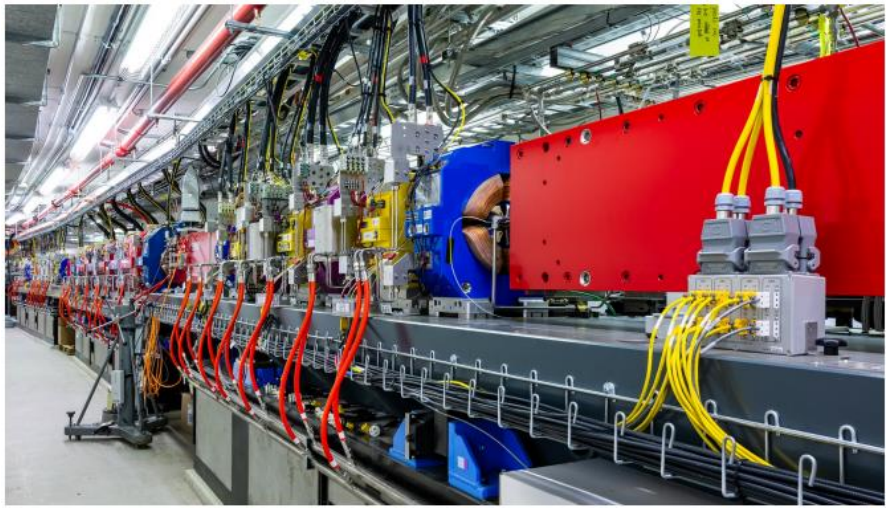
- *Ongoing upgrades*
- *Ultra-low emittance rings challenges*
  design and technology
- *Ultra-low emittance rings network*
  summary of IFAST activities in Task 7.2
- *Conclusions and future work*

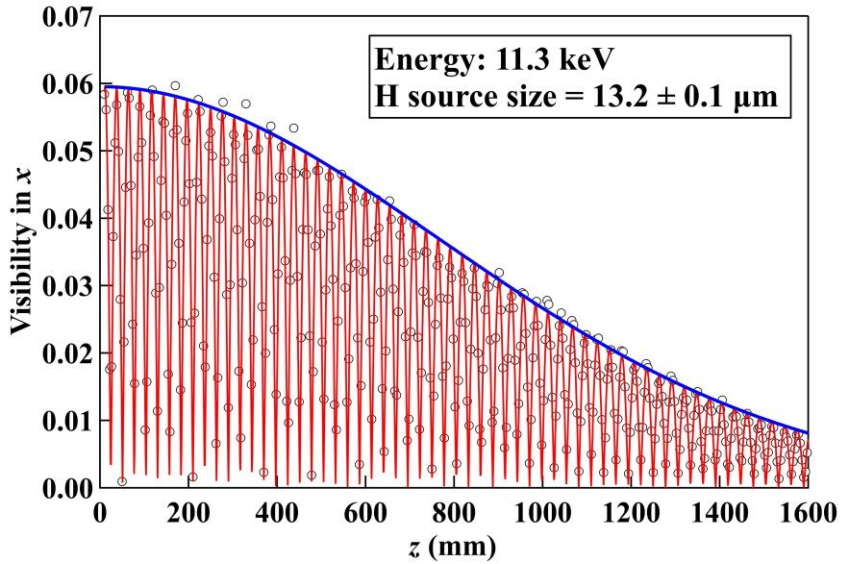
Harvesting successes with the projects launched in the last years

- **APS-U (Argonne, USA)**

First stored beam **April 2024**
Nominal optics August 2024 (42 pm)
Nominal current 200 mA February 2025







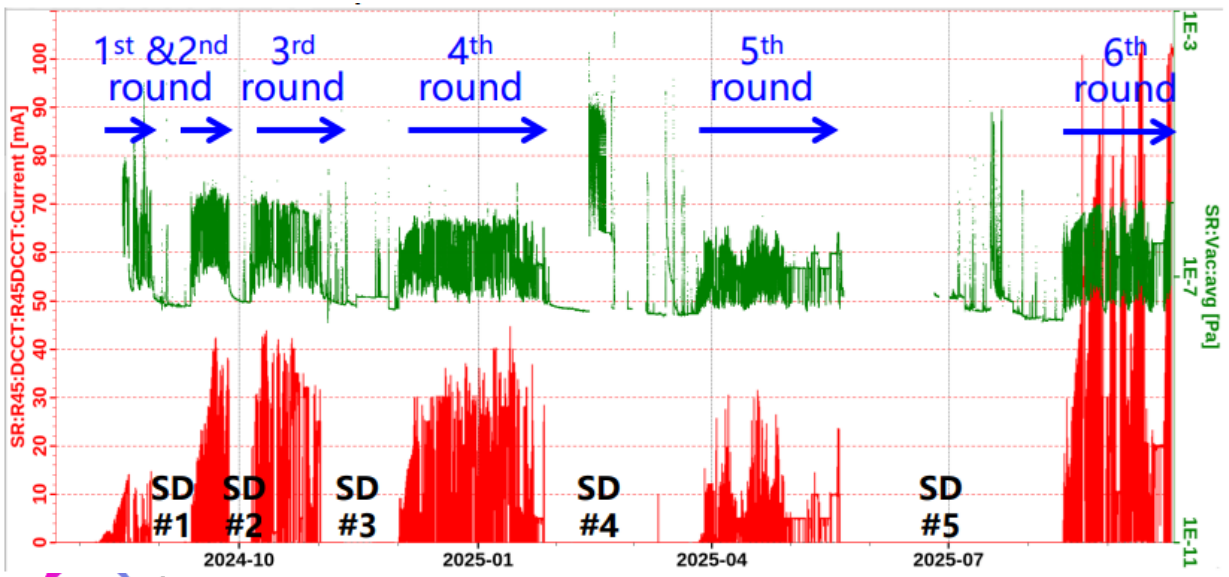
Operation in full coupling
29 pm * 29 pm

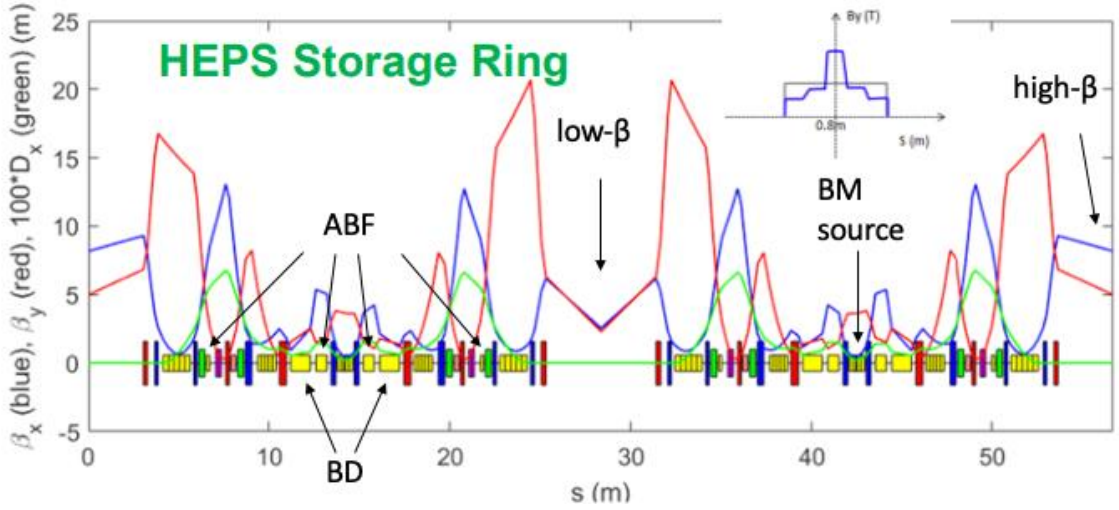
working to reach specs in timing mode
(16 nC per bunch)

Harvesting successes with the projects launched in the last years

- **HEPS (Beijing, China)**

First turn **August 2024**
40 mA in December 2024
current limited by RF system installed





1st round:
1, from first turn to 12 mA
2nd round:
1, ramp up current to ~40mA
3rd round:
1, first light from ID, beamline tuning
4th round:
1, optics corrections, < 100 pm emittance
2, demonstration of the injection scheme
3, beamline tunings
5th round:
1, more optics corrections
2, beamline tunings

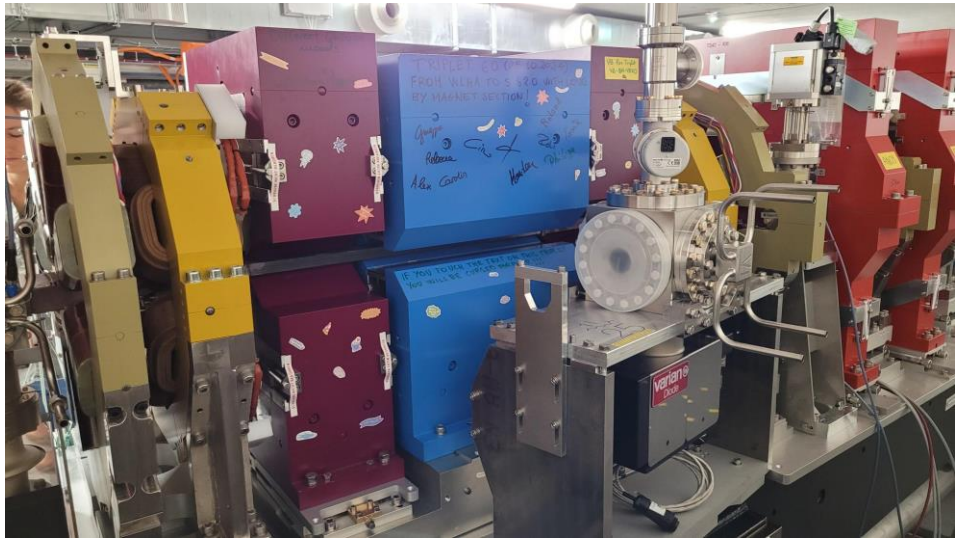
Commissioning interleaved with installation

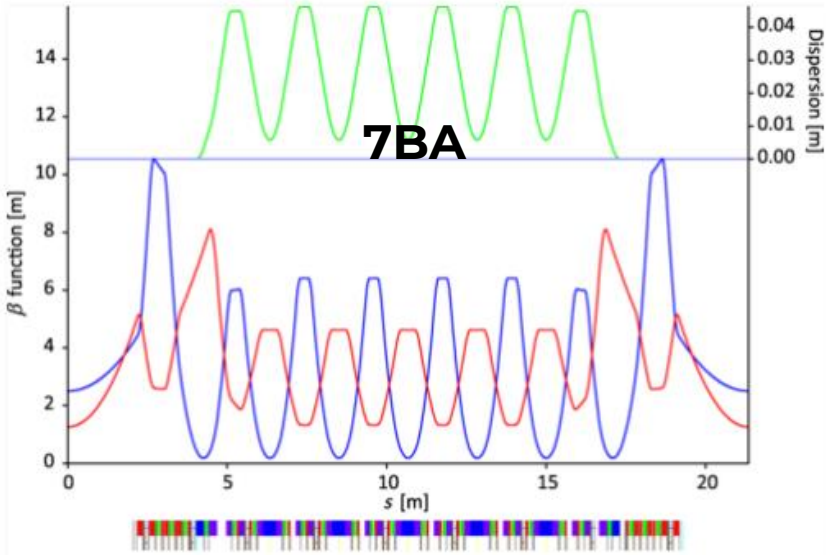
emittance larger than expected
57 pm vs 35 pm

Harvesting successes with the projects launched in the last years

- **SLS-II (PSI, Switzerland)**

first stored beam **January 2025**
optics corrected (130 pm)
full current 400 mA April 2025





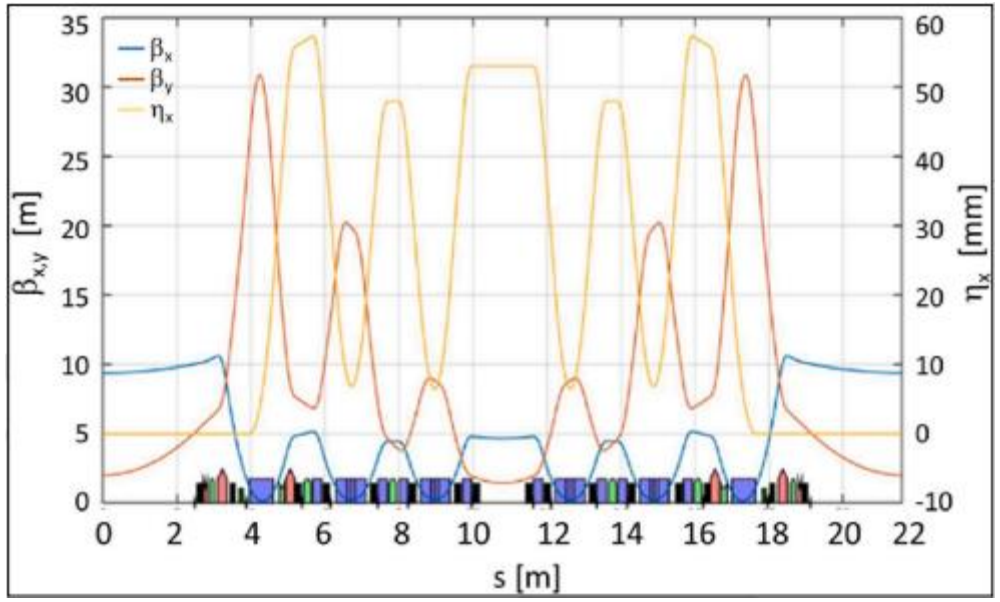
extensive use of permanent magnets (also for quadrupoles)
reduction of the energy consumption (from 24 GWh/year to 17 GWh/year) despite increase in operation energy (from 2.4 GeV to 2.7 GeV)

Several other projects are in the execution phase

- Elettra 2.0 in shutdown July 2025
- Diamond II in shutdown December 2027
- SPRing8-II (50 pm, 6GeV), funded
- Korea-4GSR (58 pm, 4 GeV) funded
- SOLEIL-II (83 pm, 2.75 GeV), partially funded
- PETRA-IV funding expected 2026, shutdown in 2030

- ALBA in prototype phase, shutdown in 2030
- NSLS-III lattice and prototype phase

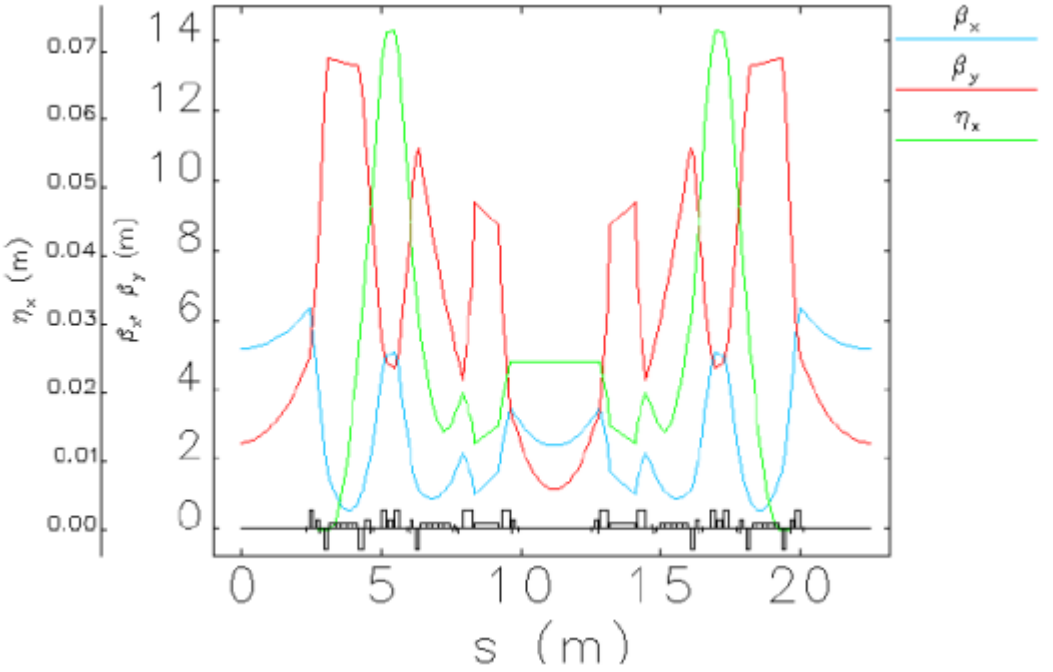
ELETTRA 2.0 and Diamond II – variants of 6BA



Elettra 2.0 will operate mostly at 2.4 GeV with an emittance of 212 pm-rad.

Shutdown since July 2025

Restart foreseen in Sep 2026

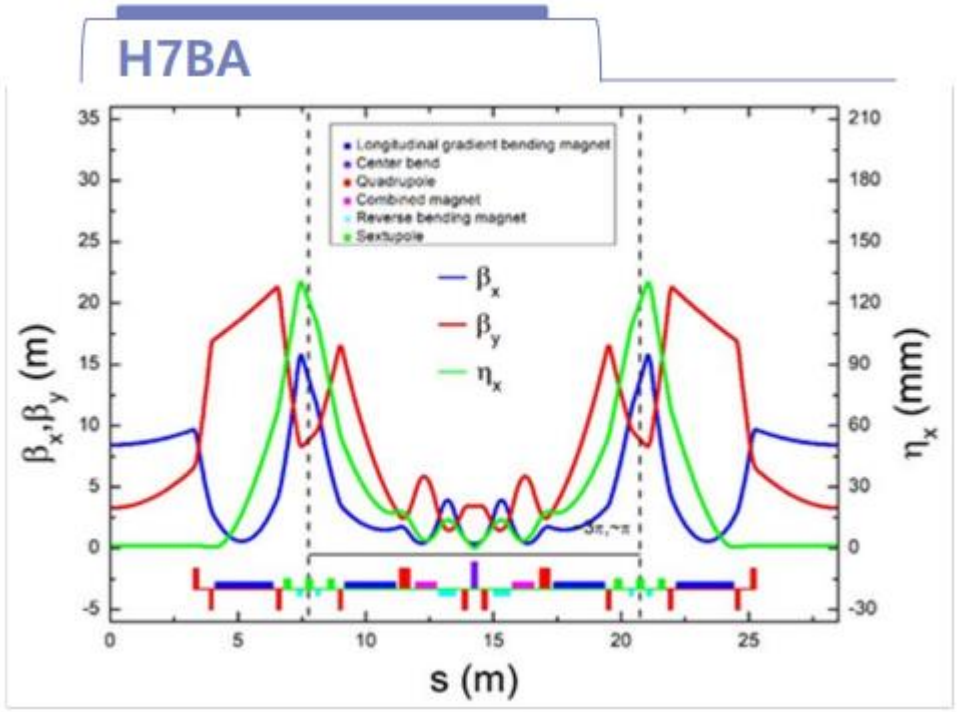


Diamond II will operate at 3.5 GeV with an emittance of 160 pm-rad.

Shutdown since December 2027

Restart foreseen in December 2028

Korea 4th Generation Radiation Source (4GSR)



Green field facility located in Ochang

Beam Energy 4 GeV
Circumference 800 m
Beam Emittance 62 pm·rad

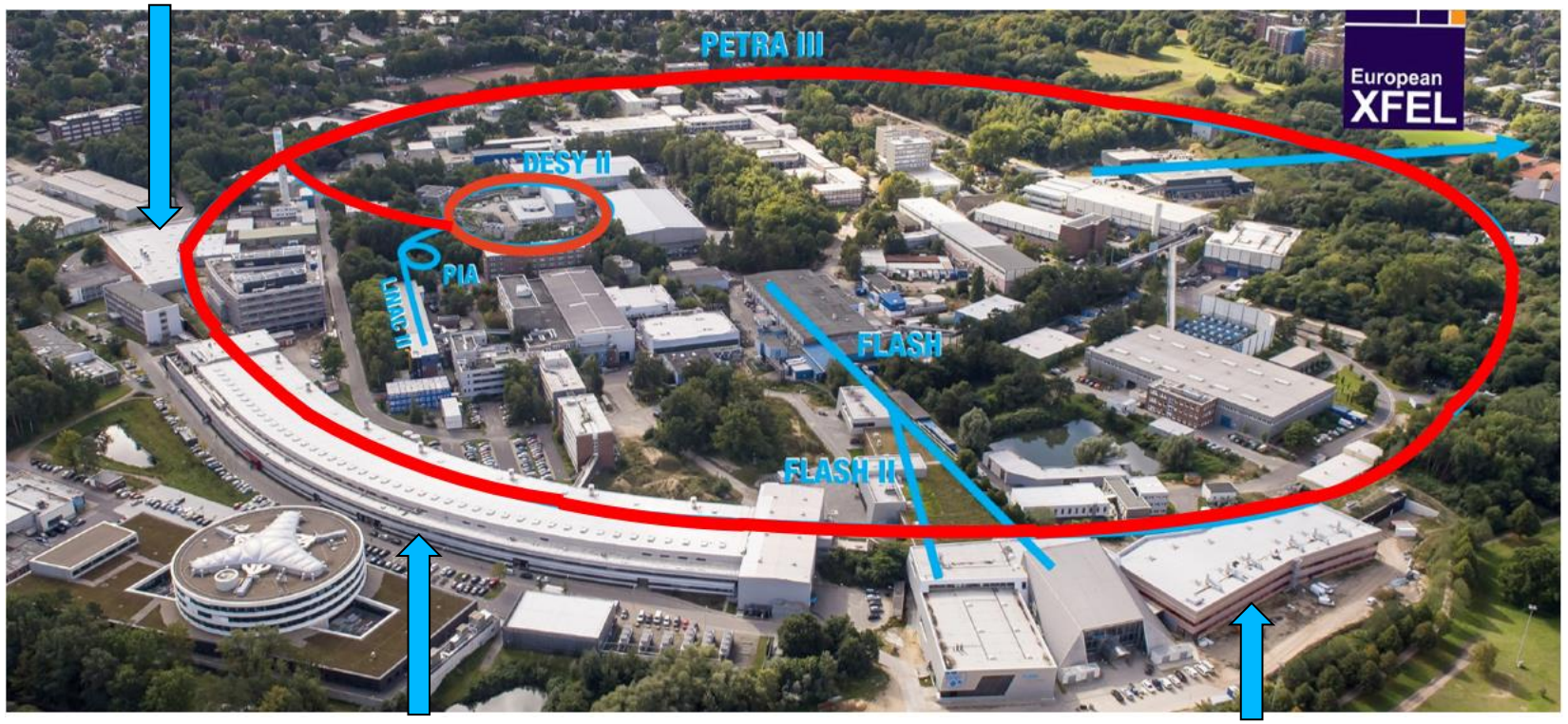
Injection scheme 4 Kicker bumps, off-axis, 2Hz

Installation starting in January 2029
First beam in January 2030

PETRA IV at DESY

Replacing PIII with an ultra-low emittance ring, adding a new Experimental Hall in two more octants. Replacing DESY II with a new low emittance booster

Ada Yonath Hall



Max von Laue Hall

Paul P. Ewald Hall

Parameter	PETRA III
Energy [GeV]	6
Circumference [m]	2304
Emittance (hor./vert.) [nm]	1.3 / 0.013
Total current [mA]	100

PETRA III emittance 1300 pm

65 times smaller

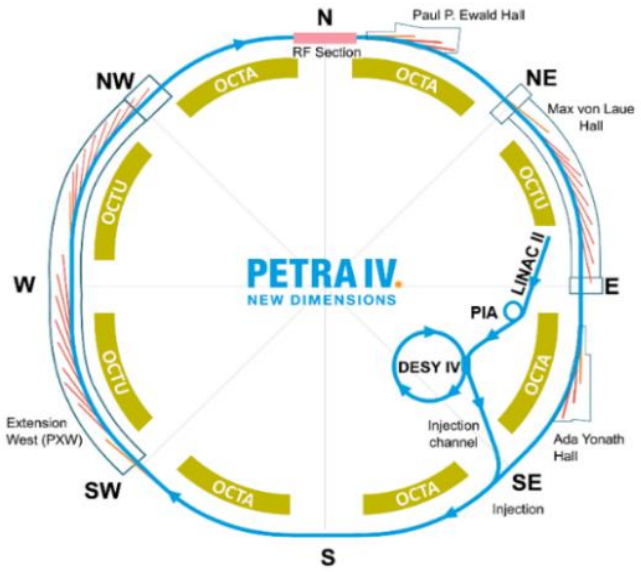
PETRA IV emittance 20 pm

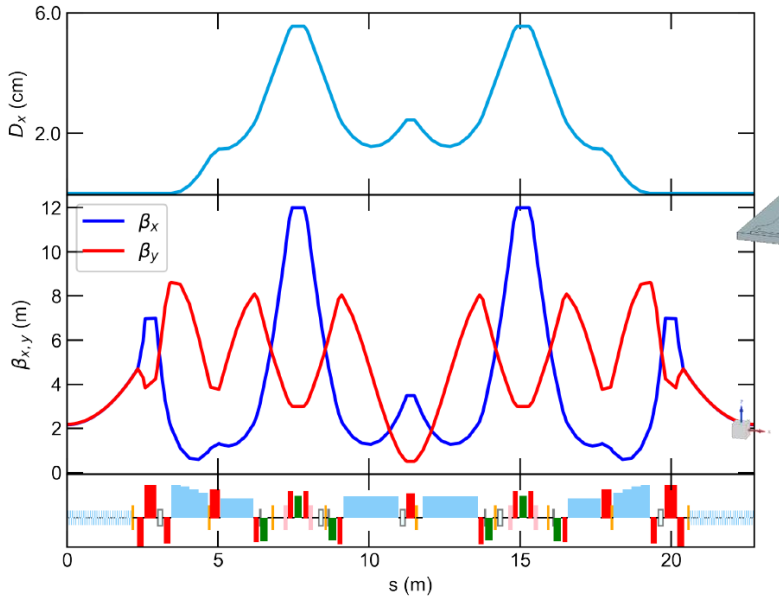
12 pm * 12pm in full coupling mode

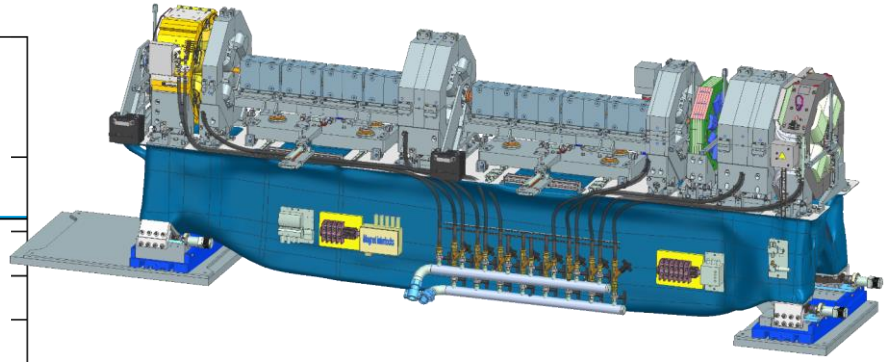
enabling > 500 times larger X-ray beams brightness

PETRA IV at DESY

The lattice is based on a novel cell structure (**H6BA**) that is replicated identical across all octants (72 cells)







Prototyping activity ongoing

Shutdown January 2030
2.5 year shutdown due to the large new experimental hall
Restart of operation July 2032

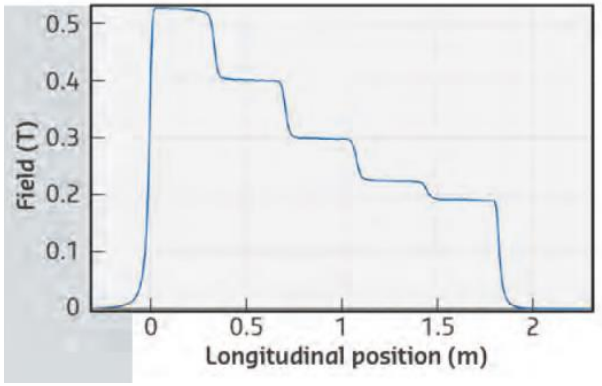
Challenges

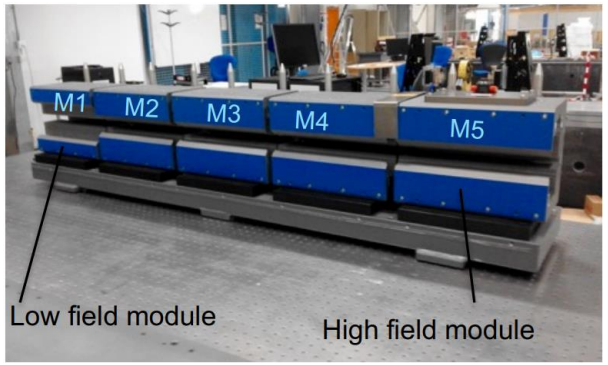
The development of ultra-low emittance rings is underpinned by a number of accelerator physics science and technology advances:

- Hybrid Multi-Bend Achromat design
- Extensive use of permanent magnet - sustainability
- HOM damped single cell cavities and SSA
- Extensive use of NEG coated vacuum chambers
- High voltage fast pulsers and ultra-fast kicker kickers

New magnets concepts

- Extensive use of permanent magnet based dipoles pioneered at the ESRF-EBS in the longitudinal gradient dipoles





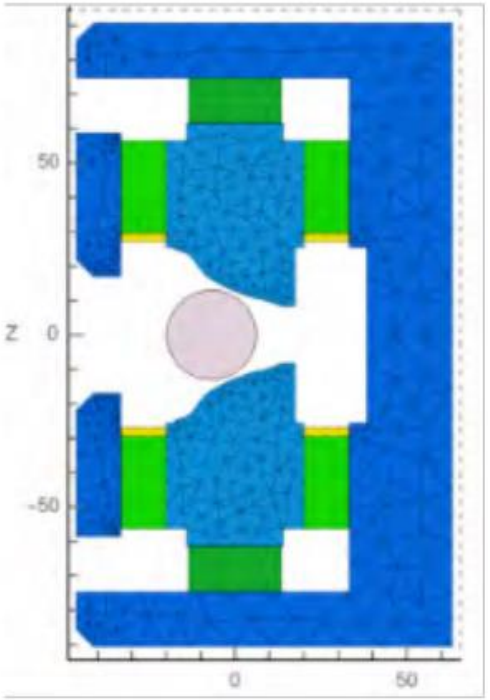
Similar route followed up and extended in many projects

Diamond II

Spring 8 – II

PETRAIV:

longitudinal and transverse gradient dipoles



New magnets concepts

- Extension to quadrupole (SLS-II and SOLEIL–II)

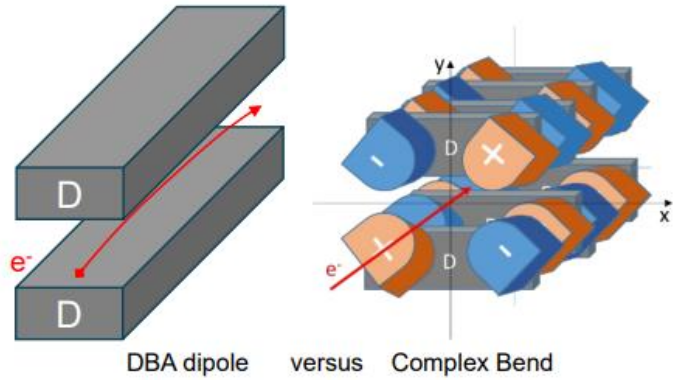
Permanent Magnets			
BN	56	Dipole	Triplet 60 (LGB) 5 x Arc
BS2	4	Dipole z-gradient	
VB	96	Quad+Dipole	
VBX	24	Quad+Dipole	
AN	120	Quad	
ANM	24	Quad	
BE	24	Dipole	½ LGB 24 2 x Arc
VE	24	Quad	
Total : 372			

Electromagnets			
QP	55	Quad	
QPH	53	Quad	
SXQ	24	6-Poles	½ LGB
SX	264	6-Poles	SOQ 264
OC	264	8-Poles+ 2 x 4 Poles	
CH	112	Dipole	CHV 112
CV	112	Dipole	
Total: 884			

SOLEIL II
small magnet bore diameter (16 mm) and avery dense magnetic lattice.

110 T/m in 8 mm radius

- Complex bends at NSLS-II



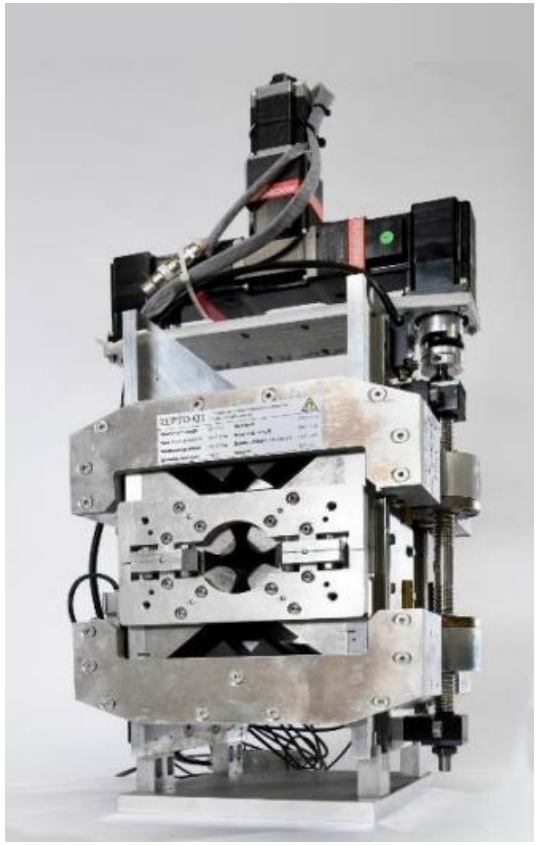
DBA dipole versus Complex Bend

Halbach PMQ

Permanent Magnet Quadrupoles in EPITA

The use of tunable permanent magnet based multipole elements is supported in the EPITA Project

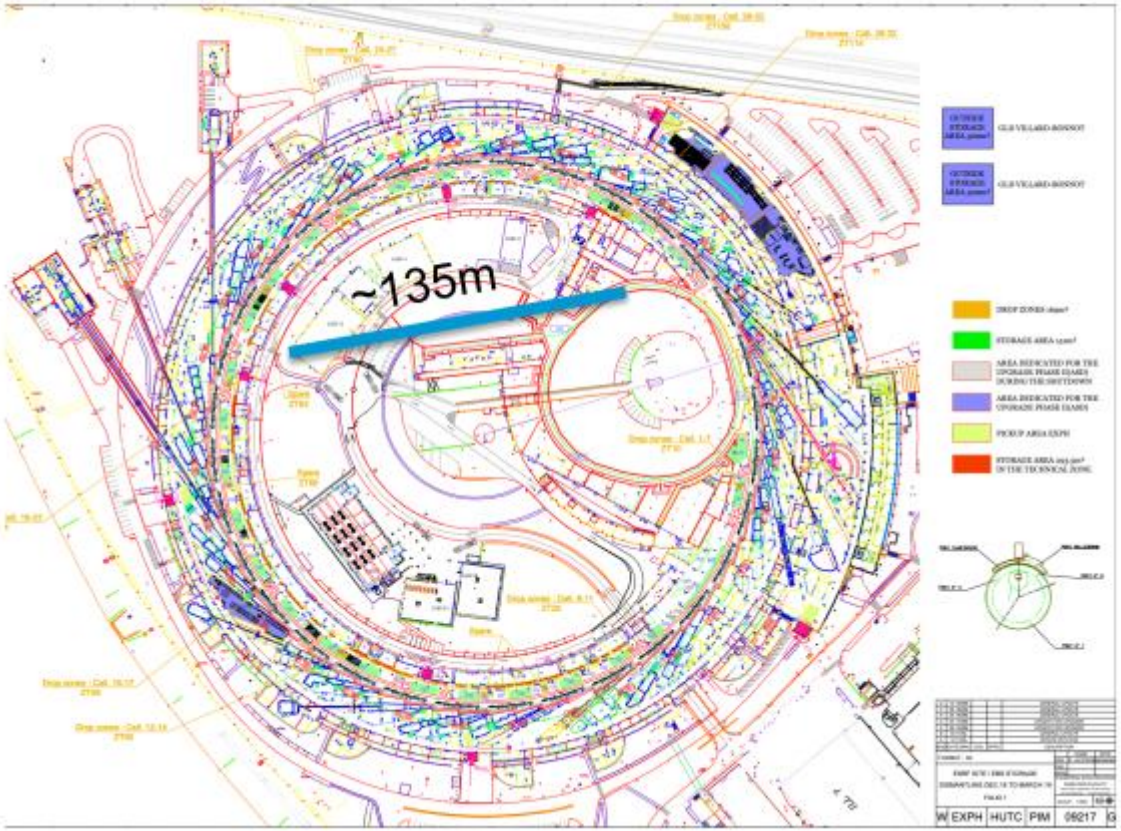
- STFC Daresbury
- Kyma
- DESY



Task 1: ZEPTO Performance Review & Accelerator Quadrupole Specification

Task 2: Modular ZEPTO Product Line Engineering

Alternative options for the pre-accelerator: the ESRF LINAC upgrade

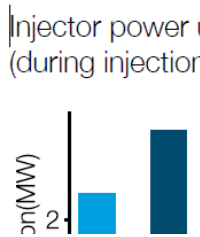


Full energy injector with a 6 GeV LINAC

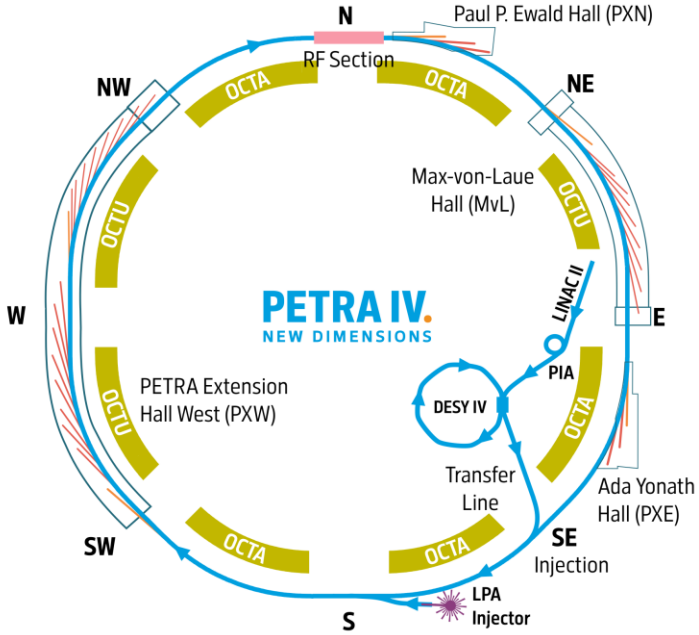
C-band
Cool structures (LN_2)
84 MV/m
~100 m length
4-10 Hz rep. rate

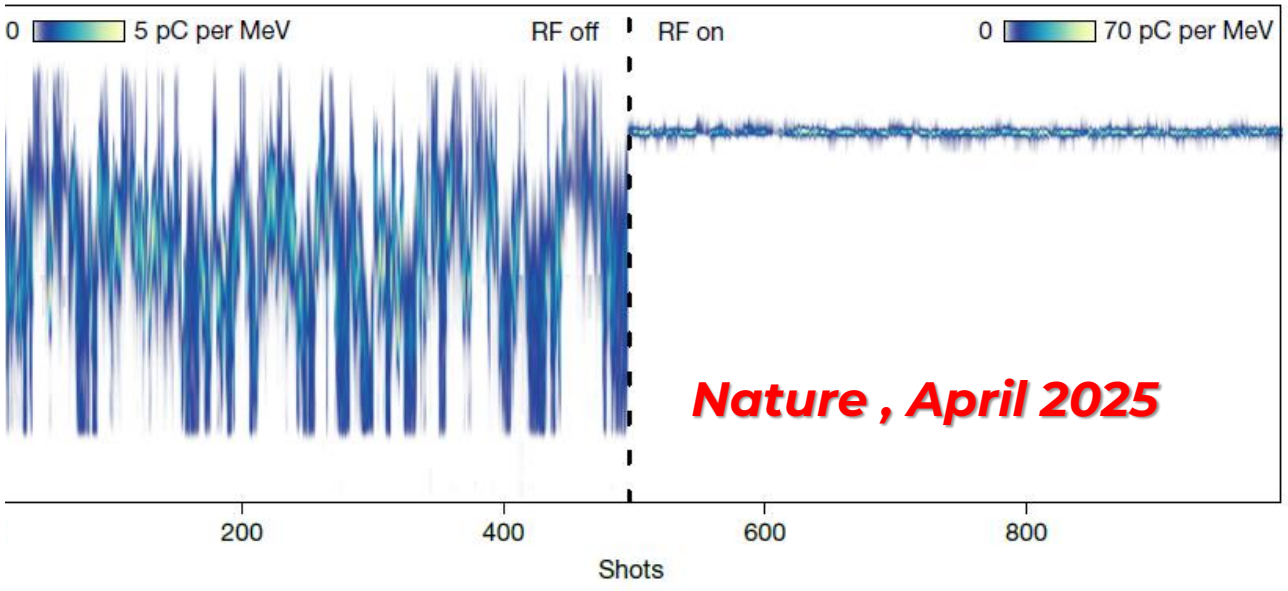
The shortest, cheapest and less consuming solution is a cryo C-band distrib. coupling acc. structure

Alternative options for the pre-accelerator: LPA injector

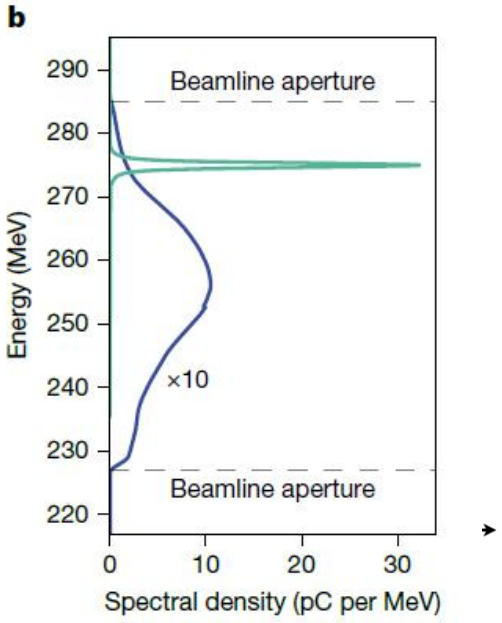


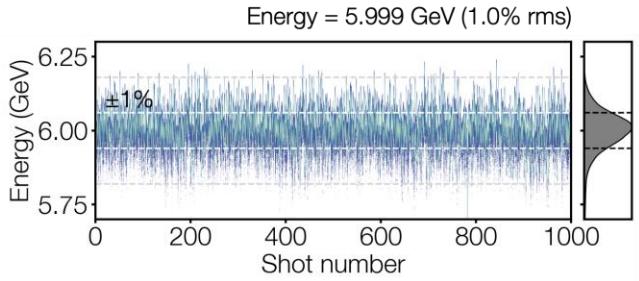
Building on the strong R&D for the development of LPA at DESY, we propose to build a 6 GeV LPA injector for PETRA IV.

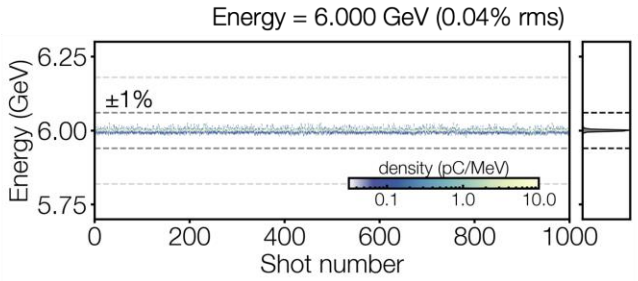


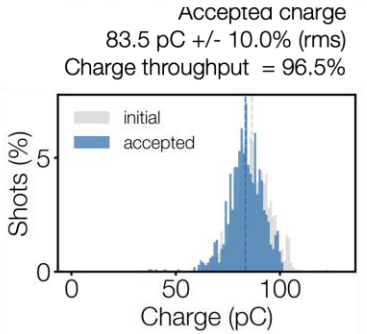


Nature , April 2025









Simulations courtesy A. de la Ossa, S. Antipov

The Low Emittance Ring (LER) workshops

1th Low Emittance Rings Workshop, 12-15 January 2010 CERN – participants 70
https://ler2010.web.cern.ch/
2th Low Emittance Rings Workshop, 3-5 October 2011 Heraklion, Crete
https://lowering2011.web.cern.ch/
3th Low Emittance Rings Workshop 8-10 July 2013 Oxford University – participants 80
https://indico.cern.ch/event/247069/overview (EuCARD-2)
4th Low Emittance Rings Workshop, 17-19 September 2014, INFN-LNF Frascati – participants 67
https://agenda.infn.it/event/7766/ (EuCARD-2)
5th Low Emittance Rings Workshop, 15-17 September 2015 ESRF, Grenoble
https://indico.cern.ch/event/395487/overview (EuCARD-2)
6th Low Emittance Rings Workshop, 26-28 October 2016, Synchrotron SOLEIL
https://www.synchrotron-soleil.fr/en/events/low-emittance-rings-workshop-2016 (EuCARD-2)
7th LER Workshop, 15-17 January 2018 CERN
https://indico.cern.ch/event/671745/ (ARIES)
8th LER Workshop 26-30 October 2020 INFN-LNF Frascati (**held remotely)** (ARIES) – participants 160
https://agenda.infn.it/event/20813/overview
9th LER Workshop 13-16 February 2024 CERN (I-FAST) – participants 99
https://indico.cern.ch/event/1326603
10th LER Workshop 8-10 October 2025 DESY (I-FAST) – participants 93
https://indico.desy.de/event/49686/

10th LER workshop at DESY 8th-10th Oct. 2025

10th Low Emittance Rings Workshop 2025

Oct 8 – 10, 2025
Europe/Berlin timezone

Enter your search term

- Overview
- Timetable
- Registration
- Participant List
- Accomodation
- Venue

Support
p4-project-office@desy.de

The **10th Low Emittance Rings Workshop 2025**, supported by the I.FAST EU project Work Package 7 on High brightness accelerators for light sources, will be held at DESY, Hamburg (Germany) on **8-10 of October 2025**. The goal of the workshop is to bring together experts from the scientific communities working on low emittance lepton rings, including light source storage rings, damping rings and e+/e- circular colliders.

The workshop will feature sessions on:

- Lesson learned from the recent commissioning of 4-th generation light sources
- Upcoming and new projects including trends for 5-th generation light sources
- R&D on technical subsystems
- Injector options
- Machine learnign tools for rings desing and operation

The programme will be organised by the Sceinitfic Programme Committe:

- Masamitsu Aiba, PSI
- Riccardo Bartolini, DESY
- Yi Jiao, HEPS
- Akira Mochihashi, KIT
- Yannis Papaphilippou, CERN
- Vadim Sajaev, APS
- Simon White, ESRF

Proposals for contributions to the workshop can be addressed to any member of the scientific programme committee or directly to the local workshop organisers

- Ilya Agapov, Riccardo Bartolini, Stephan Klumpp, @desy.de

https://indico.desy.de/event/49686/

Starts Oct 8, 2025, 9:00 AM
Ends Oct 10, 2025, 5:45 PM
Europe/Berlin

Interactive map of DESY campus

The series will continue with support from the labs:
2027 PSI
2028 ELETTRA
DESY/CERN/ESRF

Conclusions and perspectives

Ultra low emittance ring community is very active with several projects

being commissioned (APS-U, HEPS, SLS II)

funded (ELETTRA 2.0, Diamond II, KOREA-4GSR)

in TDR/CDR phase (PETRA IV, SOLEIL-II, ALBA-II, ..)

WP7 Task 7.2 has supported and fostered interactions in the community of ultralow emittance rings in the last 4 years, with about 15 workshops and experimental sessions

iFAST

Special thanks to Y. Papaphilippou (CERN)

and

M. Vrenatar (CERN), A. Mochihashi (KIT),
M. Biagini (INFN), S. Guiducci (INFN)
R. Nagaoka (SOLEIL) and M. Böge (PSI)

Thank you for your attention!

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