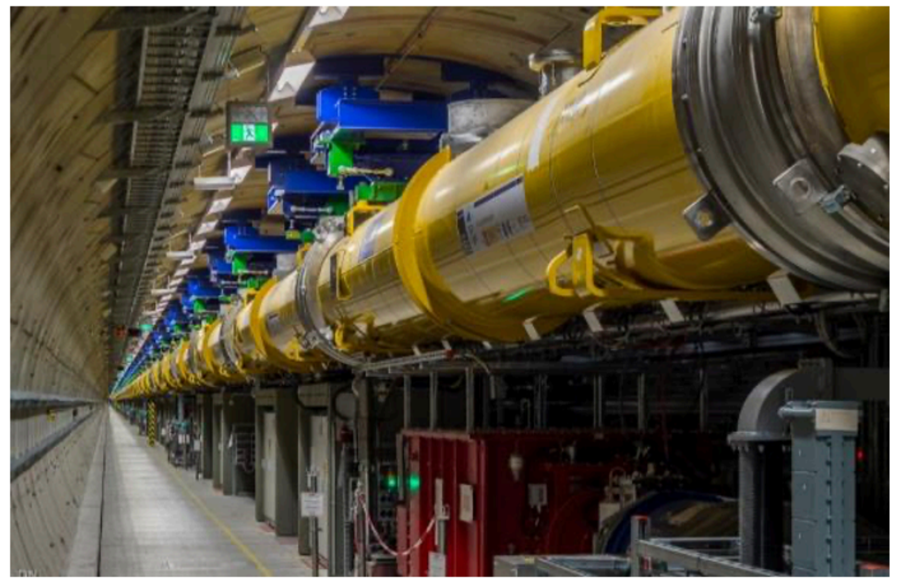
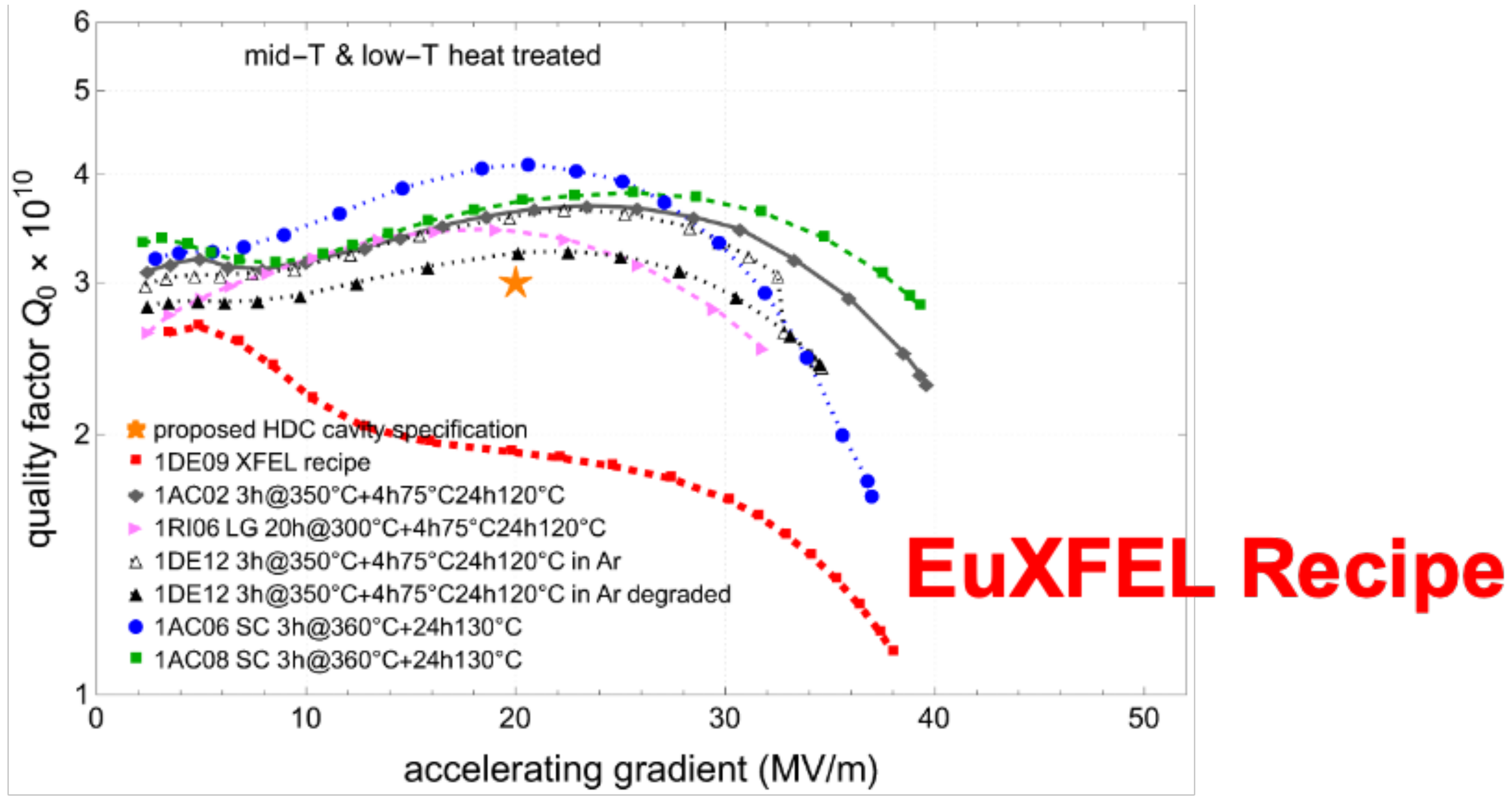
HOM damping requirements for future facilities

HOMSC’25 Workshop Summary

Dmitry Bazyl on behalf of WG1 (Vyacheslav Yakovlev (FNAL), Pei Zhang (IHEP), Dmitry Bazyl (DESY))

- **Hans Weise (*DESY, Germany*)** reported on SRF activities at DESY in context of the upcoming high-duty-cycle (HDC) upgrade of the European XFEL. Promising results of cavity heat treatment at DESY have been presented. It was emphasized that new SRF technologies are being developed at DESY (e.g. CW SRF photoinjector).

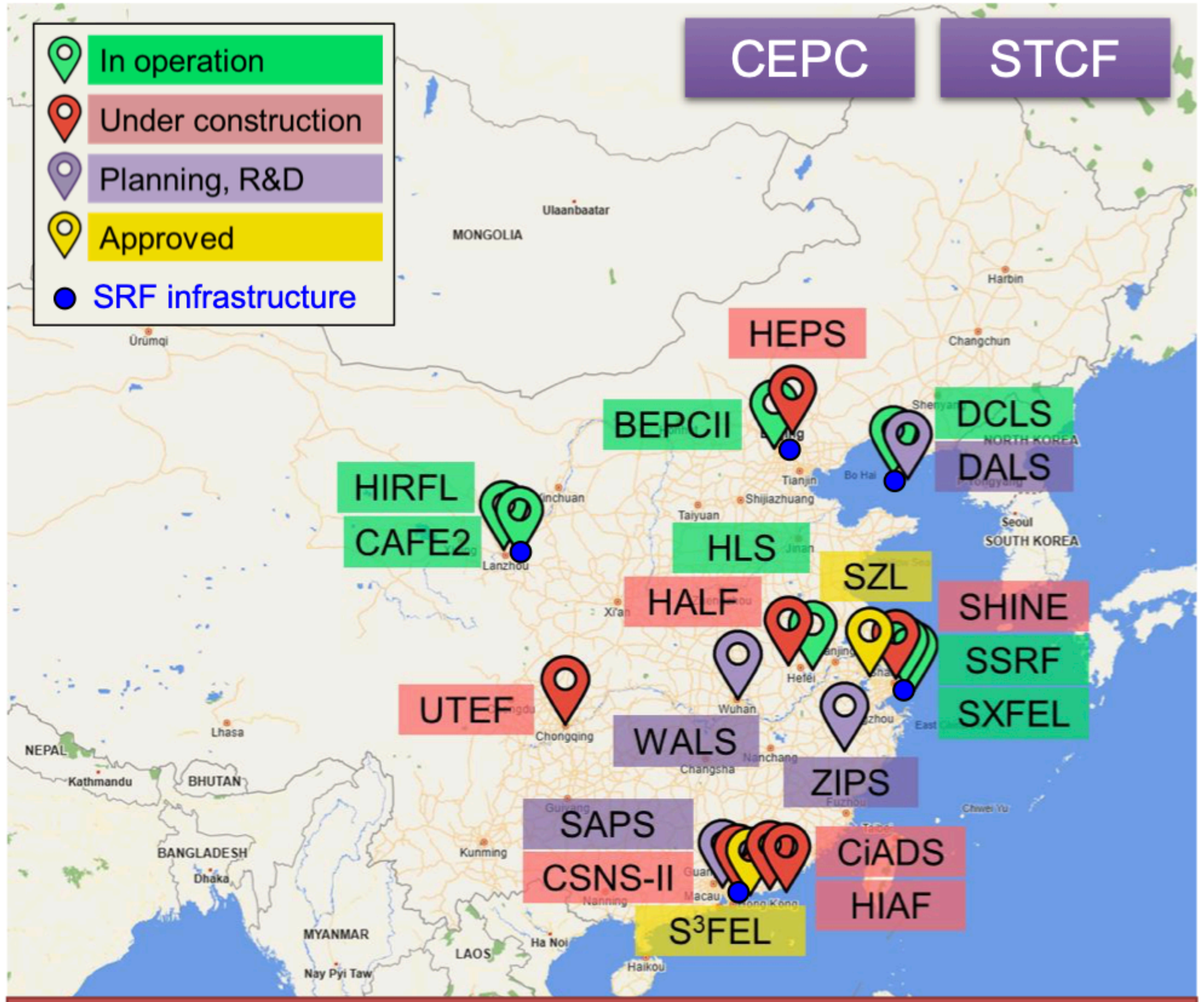




European XFEL

MATTER AND TECHNOLOGIES MT DESY.

- **Pei Zhang (IHEP, China)** provided a comprehensive overview of the upcoming projects in China. SRF technology adopted by most projects under construction, while new proposals mixed with NCRF and SRF. SRF infrastructures at various facilities have been built and in operation.

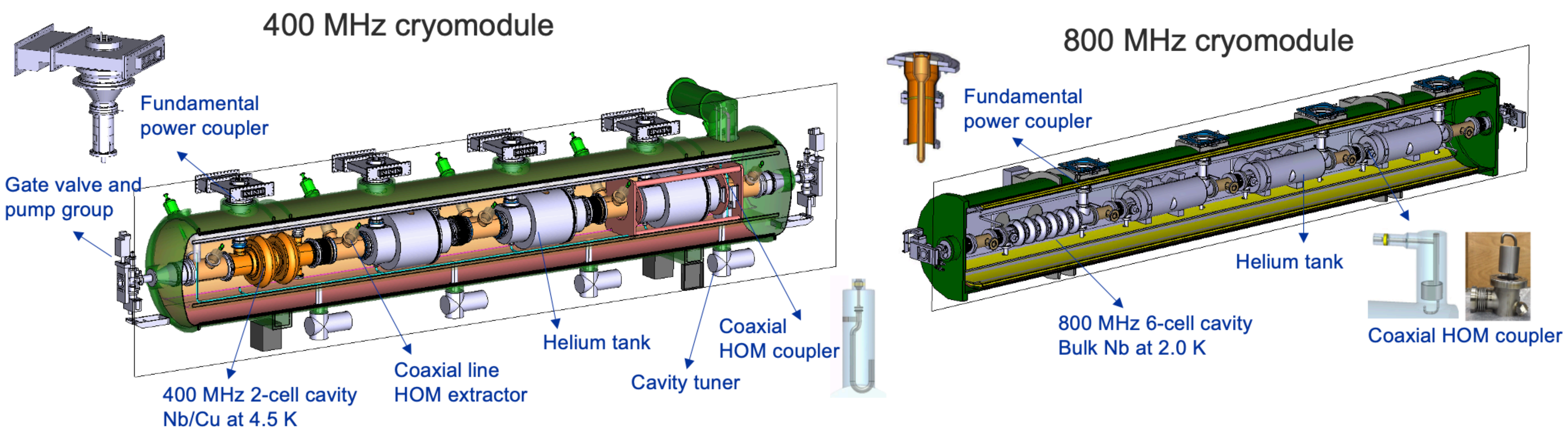


~1000 SRF cavities approved in 2015-2026
~700 SRF cavities in the next decade (proposed)

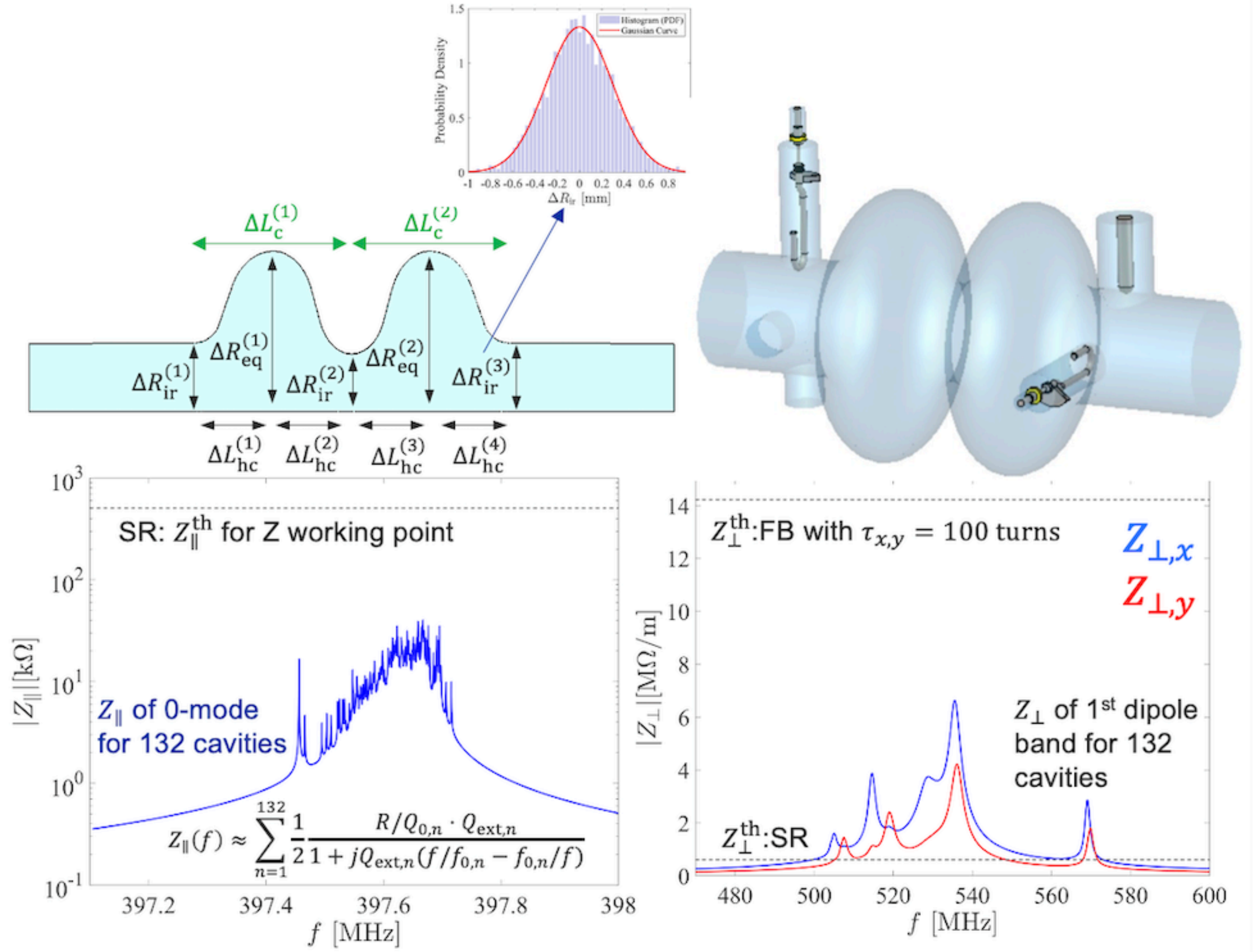
- Large accelerator facilities have seen rapid development in the last decade in China, including light sources, FELs, proton & heavy ion facilities
- Large collider projects after BEPCII are under discussion
- SRF technology adopted by most projects under construction, while new proposals mixed with NCRF and SRF
- SRF infrastructures at various facilities have been built and in operation

	Op.	Const.	Proposed
Collider	1	0	2
Sync. LS	3	3	4
FEL	2	1	2
Proton & Heavy ion	3	3	2

- **Shahnam Gorgi Zadeh (CERN, Switzerland)** reported on HOM damping strategies for FCC-ee SRF cavities. Two-cell 400 MHz and and six-cell 800 MHz have been discussed. Multiphysics analysis results have been presented including sensitivity analysis of the cavity and multipacting of the HOM coupler.



- **4 cavities per cryomodule**
- **Fundamental Power Coupler (FPC):** fixed antenna, coupling tuned by varying the waveguide on the air side
- **HOM damping**: coaxial HOM couplers close to cavity and beamline absorbers located at the module extremities
- **Prototype development**: 400 MHz cryomodule under development at CERN; 800 MHz cryomodule design ongoing with Fermilab



- **Na Wang (IHEP, China)** provided overview on HOM Damping requirements for new circular accelerators. HOM parasitic power loss and coupled bunch instabilities are the main constraints from SRF HOMs.

Requirements from different machines

High energy e-p circular colliders

- HOM power and coupled bunch instabilities due to the HOMs are concentrated at Z mode.

	Higgs	W	Z	ttbar
Multi-bunch SR threshold (Long) $f\mathrm{Re}Z_{\|\|}e^{-(2\pi f\sigma_l)^2}$[GHz·GΩ]	4.5	0.1	6.5E-4	171.2
Multi-bunch SR threshold (Trans) $\mathrm{Re}Z_y e^{-(2\pi f\sigma_l)^2}$[GΩ/m]	3.0	0.08	8.9E-4	72.7

Tight narrowband impedance requirements for Z (at least ~two orders lower compare to other energies)

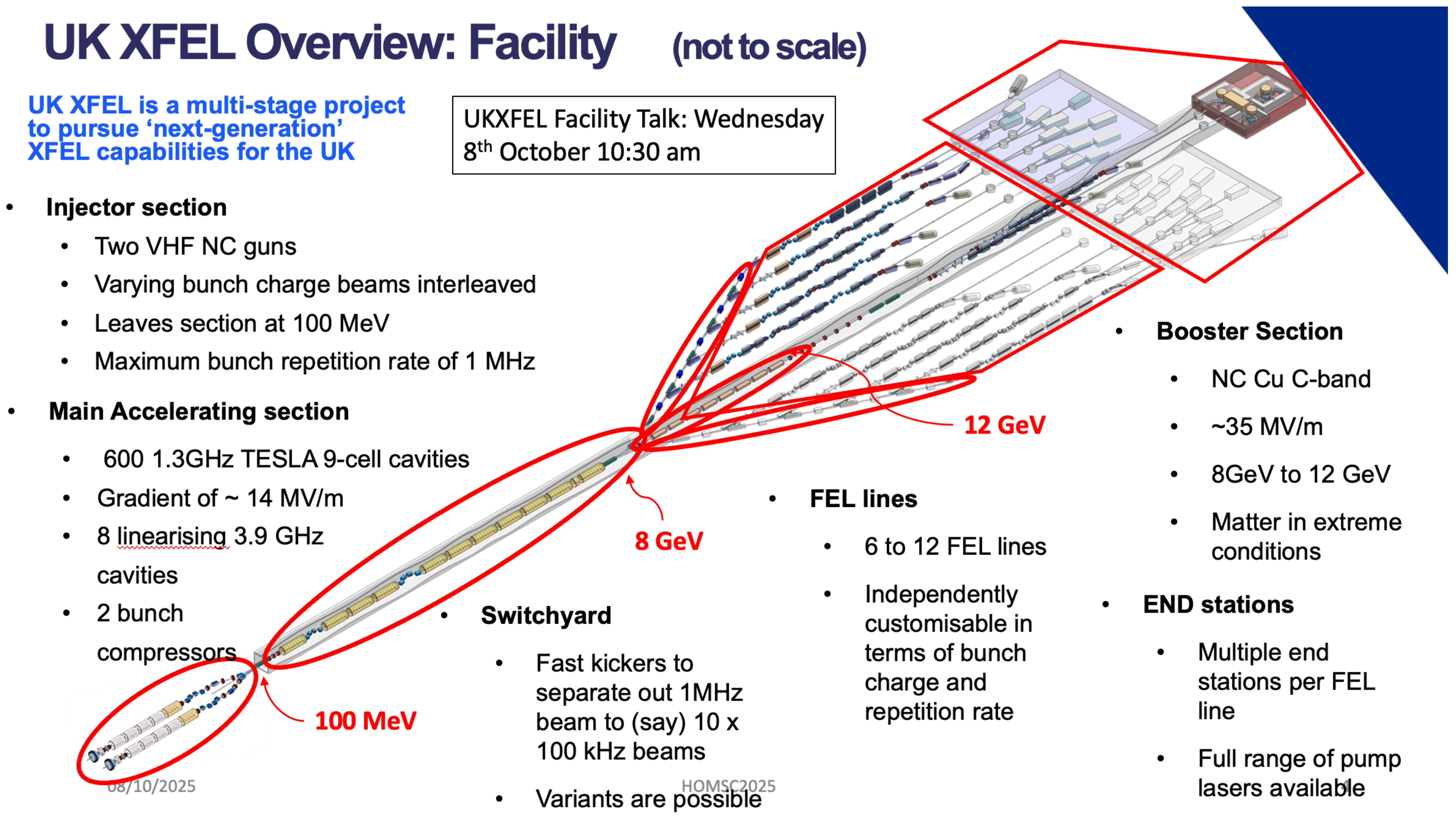
- Due to the large circumference, the chromatic phase shift could not provide enough damping to the transverse coupled bunch instability, and the feedback damping is challenging to reach the required damping time within limited number of turns ⇒ The coupled bunch instability induced by the HOMs should be handled by the synchrotron radiation damping.
- The filling pattern is restricted by the HOM power if the Q is not well controlled.
- To meet these requirements, one cell cavities with deep HOM damping are dedicated in both CEPC and FCC-ee Z mode.

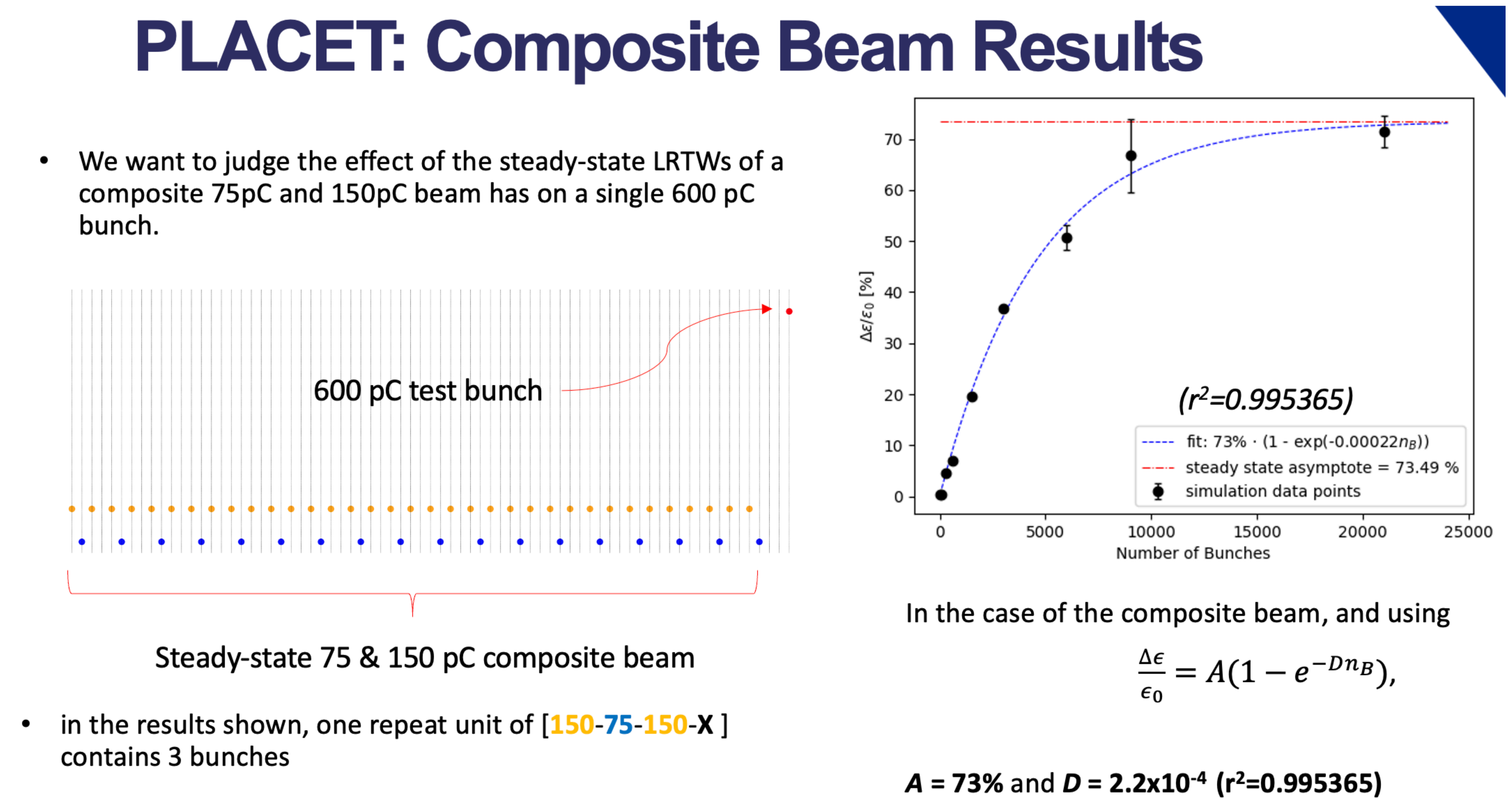
Requirements from different machines

Synchrotron radiation light sources

- As a user facility with many beamlines, beam stability/beam quality is more prominent → HOMs should not dilute emittance or beam energy spread even in resonance.
- Transverse HOMs are normally not dominant in the circular accelerators, either due to the strong feedback damping requirement given by the resistive wall instability or effective landau damping from chromaticity.
- Longitudinal HOMs are not easily to be damped by feedback, especially when interact with harmonic RF cavities, and better take care of during the design stage.
- A more comprehensive consideration can reduce redundancy in hardware design.

- **Anthony Gilfellon (UKRI STFC, United Kingdom)** reported on dipole mode wakefields and beam dynamics tracking simulations for the UK XFEL main accelerating linac. Multiphysics analysis has been presented including kick factor analysis and particle tracking.





- **Alexei Blednykh (BNL, United States)** discussed beam stability in the EIC ESR: Contribution of the 591 MHz RF Cavities. 2-cavity 591 MHz string contribution analyzed for single-bunch dynamics and HOM-driven effects. A longitudinal damper is required to suppress coupled-bunch instabilities driven by HOMs from the 2-cavity string.