XFEL Accelerator R&D Status
RP 212 – SRF Photoinjector

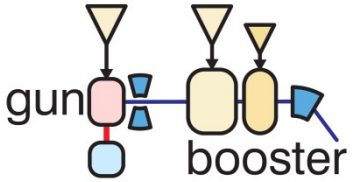
Elmar Vogel & Dmitry Bazyl

September 12, 2025

European XFEL

Scope of the R&D activity (1/2)

- high gradient photoinjector operating CW for the European XFEL High Duty Cycle (HDC) operation

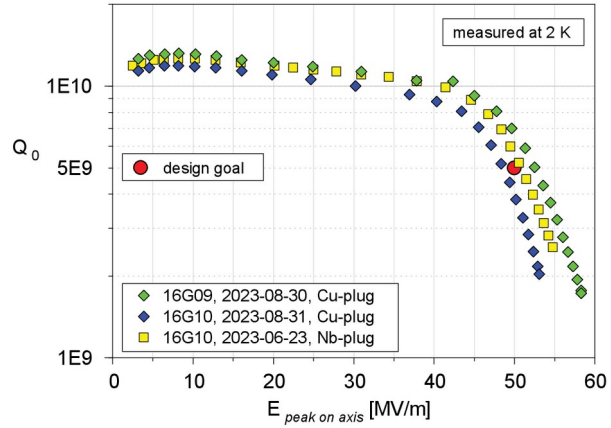


- direct matching into subsequent linac
- no buncher cavity!
- possible with L-band SRF technology

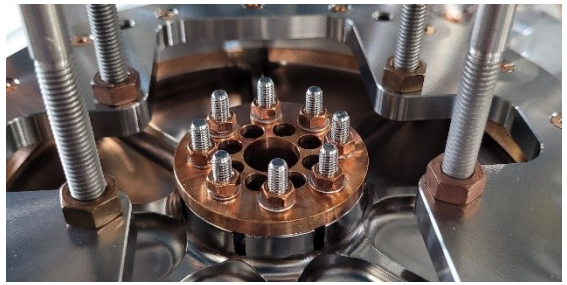
- interfaces with other XFEL R&D: R&D Pillar CW

- promised deliverables: SRF gun cavities with peak field on axis ≥ 40 MV/m

- **with copper cathode plugs ≥ 50 MV/m obtained**
  arXiv:2310.02974v1 [physics.acc-ph] 4 Oct 2023

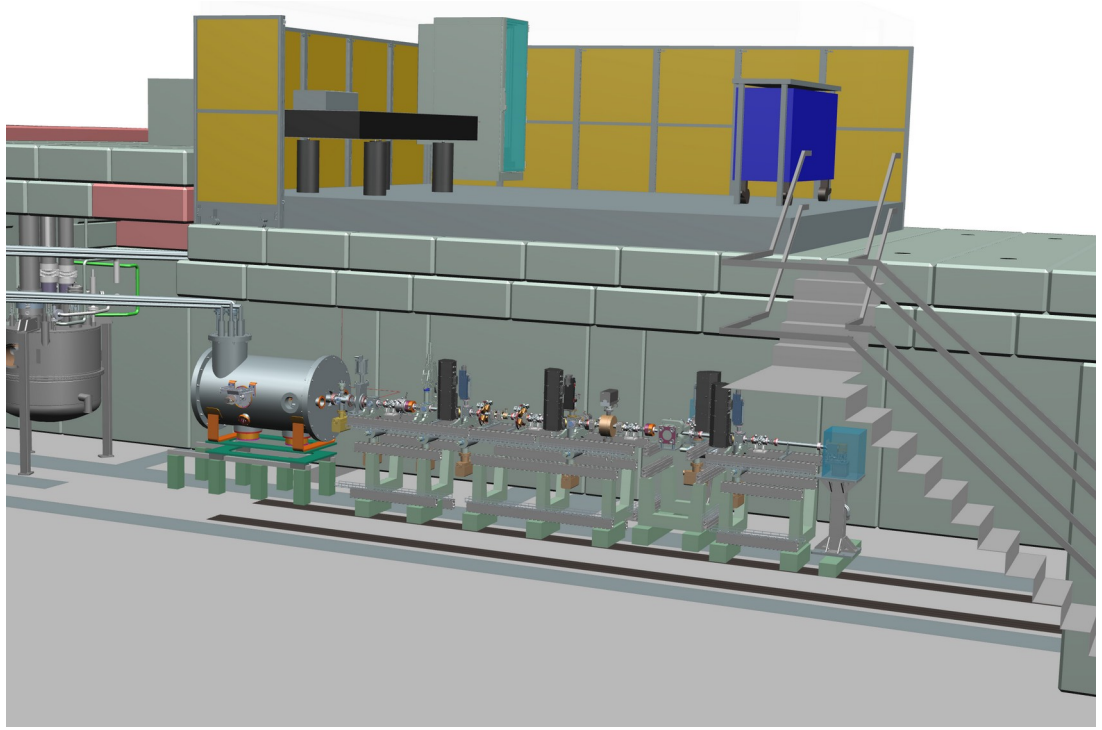


- It is counter intuitive – NC part in SC cavity – but the magnetic field vanishes near the cathode area!



Scope of the R&D activity (2/2)

- Now, we have the building blocks of a high gradient photoinjector in hand!
- The next step required is the production and characterization of electron beam!



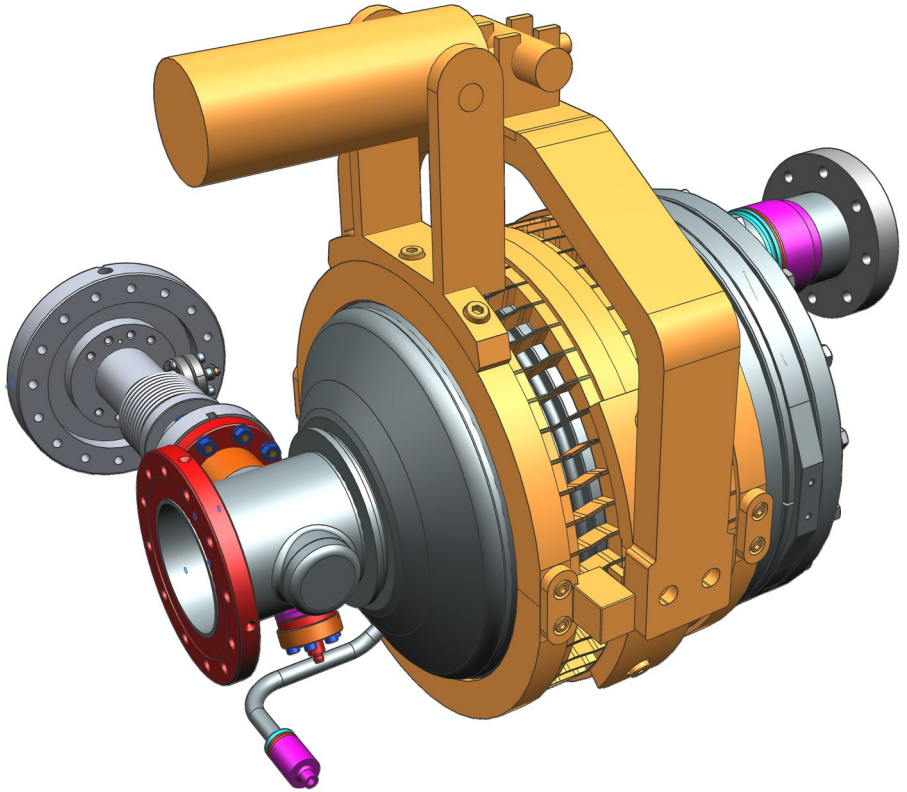
- small test accelerator Ts4i in the AMTF for
  - testbed for the various new technologies needed
  - demonstration of the production of beam with the desired properties
  - later with an Eu XFEL CW injector in user operation: qualification of the SRF photoinjector cryostat assemblies before tunnel installation
- further improvement of SRF photoinjector cavities
  - cathode plug sealing
  - meeting all the various tolerances due to beam dynamics
  - improving the quality factor at high gradients
- R&D activity closely linked
  - the here presented R&D topic is closely linked to the topic "Nanostructured and other metal photocathodes"

Achievements in the past year

- mechanical layout (incl. all accessories) of the warm beam-line is reviewed and fixed
- basic Ts4i bunker structure fixed
- integration work (position of cabinets, …) is progressing, e.g. purchases of electronic cabinets are ongoing
- bunker adaptation started well ahead of time
- small distribution box and the cryo-line almost installed

Deviations from plan

- work on the cavity tank and tuner is progressing much slower than anticipated
- procurement process of the next SRF injector cavities meanwhile delayed by two years
- As countermeasure we (the Ts4i PM) worked on the redistribution of tasks by organizing support from other DESY groups in adjacent subjects and we worked on hiring additional personnel to cover construction work. Specifically:
  - work on cathode plugs has been shifted from the group MSL to the group MVS to newly hired personnel
  - position to support our mechanical construction needs at the group ZM, we successfully filled this position



Timeline of this R&D activity

Proposed Date	Milestone Description	Updated Date
Q2/2024	official approval to continue with the SRF photoinjector R&D and launching Ts4i	done
Q3/2024	all required resources (personnel) available to the project	almost done
Q3/2024	Ts4i bunker structure layout reviewed and fixed	almost done
Q3/2024	production readiness review of cryogenic supply (JC-box, cryo-lines, …)	done
Q4/2024	design readiness review of SRF cavity tank and tuner	Q4/2025 ?
Q1/2025	production readiness review of SRF photoinjector (prototype) cryostat	Q4/2025 ?
Q4/2024	mechanical layout (incl. all accessories) of warm beam-line reviewed and fixed	done
Q3/2025	Ts4i integration complete (cabling, position of cabinets, …) reviewed and fixed	almost done
Q2/2026	Ts4i bunker structure adaptation started	done
Q2/2026	construction work on cryogenic supply started	done
Q3/2026	construction work on laser installation started	
Q3/2026	construction work on warm beam line started	
Q3/2026	start of first cyo-module assembly	Q1/2027 ?
Q3/2027	Ts4i construction work finalized	
Q4/2027	start commissioning	

Risks to R&D Project

- our main goal is getting some first beam in Ts4i before the End of 2027
  - this does not include demonstrating design values e.g. for the QE already End 2027
  - instead, Ts4i is needed to work on reaching and demonstrating design values
- risks that may prevent us getting first beam in Ts4i before the End of 2027
  - further delays with the cavities 16G11 to 16G13
  - delays with the design and purchase of the diverse subsystems (helium vessel, tuner, clean-room support structure, …)

Outlook / Summary

- key items for the next reporting period (until in about one year from now)
  - obtaining cavities 16G11 to 13
  - design readiness review of SRF cavity tank and tuner
  - production readiness review of SRF photoinjector (prototype) cryostat
  - Ts4i integration complete (cabling, position of cabinets, …) reviewed and fixed