Preference of L-band SRF over VHF for high repetition rate injector for EuXFEL

compiled by Elmar Vogel

DESY-STFC-XFEL collaboration meeting, DESY, Hamburg
December 5, 2024

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

Two types of SRF gun cavities

Parameter range, laboratories and projects

VHF-band quarter wave resonator (QWR) SRF guns

RF frequency: 113 MHz to 200 MHz

exit energy: 1 MeV to 1.8 MeV

cathode *E* field: 6 MV/m to 30 MV/m

peak on axis *E* field: 6 MV/m to 30 MV/m

laboratories & projects:

- SLCS-II HE Low-Emittance Injector
  by SLAC/FRIB/ANL/HZDR collaboration
- BNL – SRF gun for hardon cooling
- (Wisconsin/SLAC/ANL SRF gun – no longer used)

L-band (elliptical shaped) SRF guns

RF frequency: 1.3 GHz

exit energy: 1 MeV to 4 MeV

cathode *E* field: 7.5 MV/m to > 40 MV/m (> 60 MV/m?)

peak on axis *E* field: 7.5 MV/m to > 40 MV/m (> 60 MV/m?)

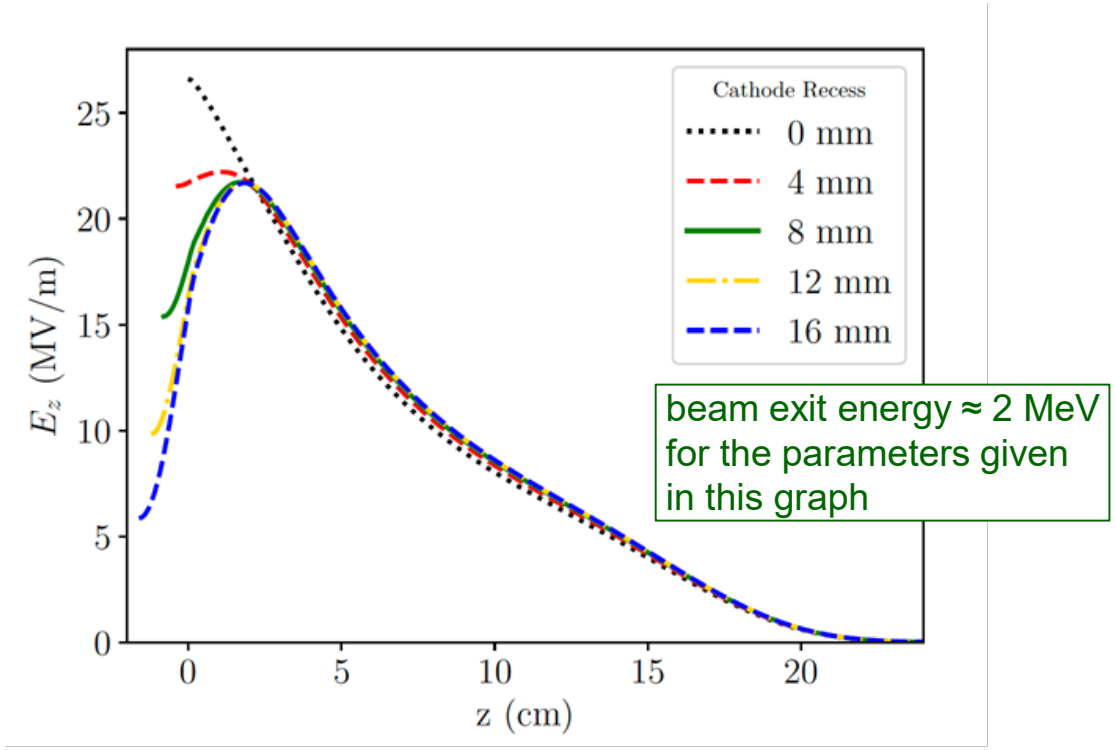
laboratories & projects:

- HZDR – photoinjector for ELBE (THz FEL)
- HZB – for bERLinPro (ERL)
- MSU/KEK – for photocathode R&D (former KEK-ERL)
- Osaka University – for electron microscopy
- PKU – DC-SRF gun
- DESY – for Eu XFEL HDC operation, cavity for PolFEL

Two types of SRF gun cavities

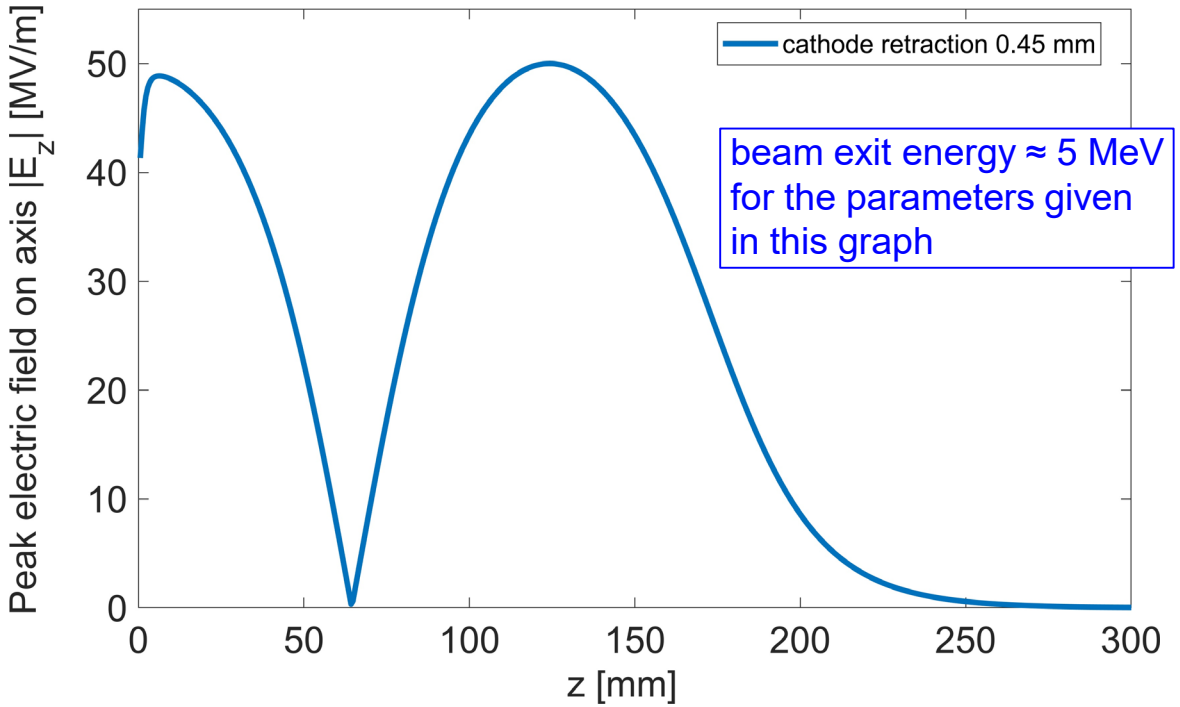
Electric field distribution – difference between quarter wave resonators and elliptical cavities

VHF-band QWR SRF guns – example BNL SRF gun



electric field distribution in 113 MHz BNL QWR SRF gun, graph taken from Irina Petrushina's (BNL) talk for NAPAC19

L-band SRF guns – example DESY SRF gun

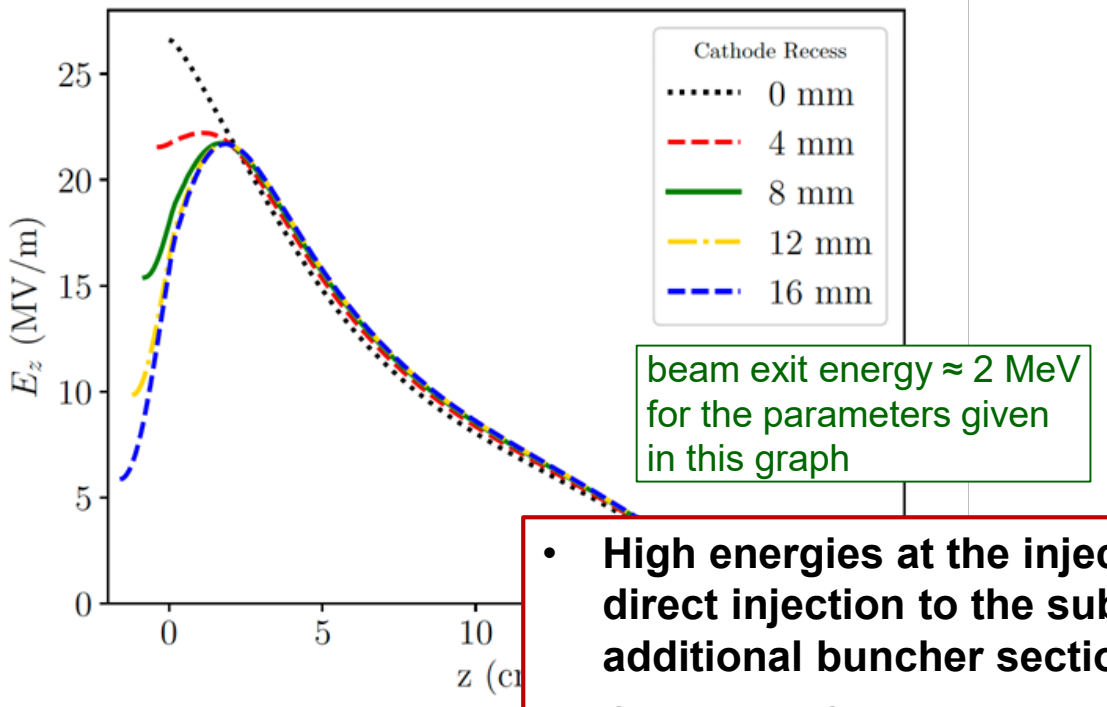


electric field distribution in 1.3 GHz DESY L-band SRF gun, graph generated by Dmitry Bazyl (DESY)

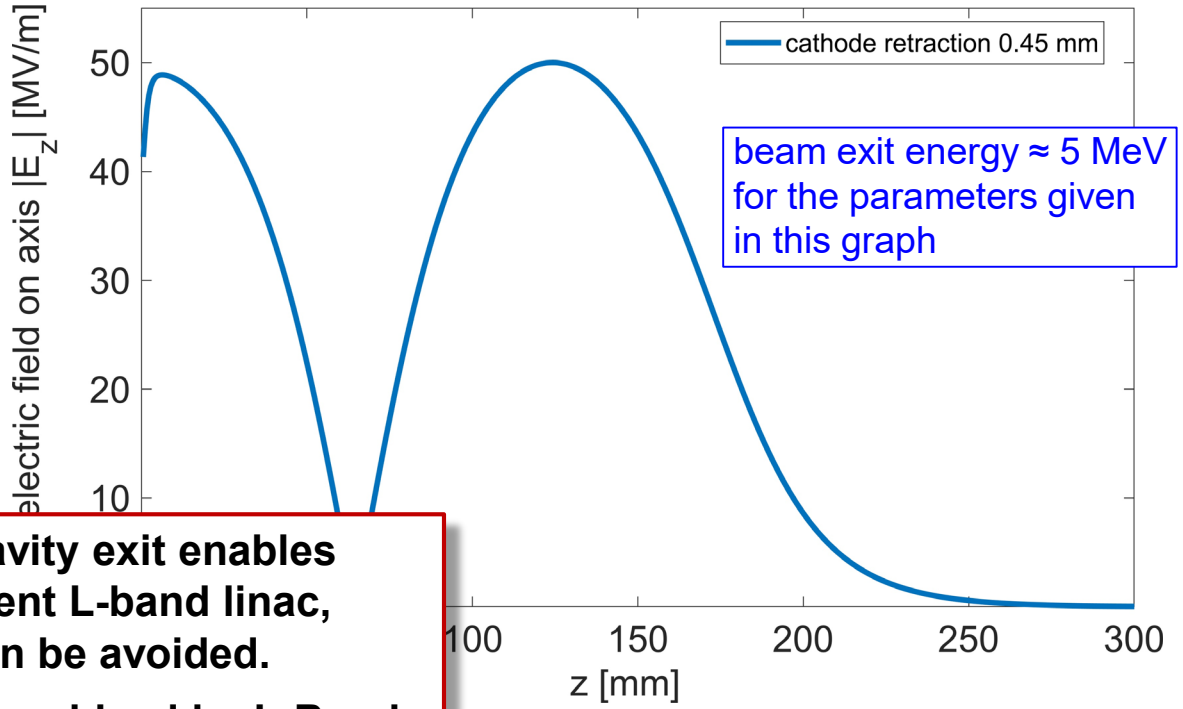
Two types of SRF gun cavities

Electric field distribution – difference between quarter wave resonators and elliptical cavities

VHF-band QWR SRF guns – example BNL SRF gun



L-band SRF guns – example DESY SRF gun



- **High energies at the injector cavity exit enables direct injection to the subsequent L-band linac, additional buncher sections can be avoided.**
- **Operating CW this can only be archived by L-Band SRF cavities.**
- **In pulsed mode, the NC L-band injector cavities at FLASH and EuXFEL operate for direct injection at about 55 to 60 MV/m peak filed on axis gradient.**

electric field distribution in 11 … in 1.3 GHz DESY L-band SRF gun, graph taken from Irina Petrus… …nitry Bazyl (DESY)

L-Band SRF Photoinjector

assumed parameters, archived and demonstrated values, still to be done

pragmatic adaptation of design goal(s)

- form 40 MV/m & $Q_0 = 10^{10}$ to 50 MV/m & $Q_0 = 5x10^9$
- consequences
  - 25 W at 2 K needed for RF
  - 5 W at 2 K reserved for cathode laser
  - design value for cryo-system: 30 W at 2 K
  - we expect getting higher Q_0 but we do not need it
  - higher Q_0 will permit higher $E_{peak\ on\ axis}$ and better efficiency
  - we gain margin for combined cavity and cathode treatments
- target QE ≥ 10^{-4}
  - with QE ≈ 10^{-4} about 5 W laser power for 100 pC & 1 MHz
  - QE ≈ 10^{-4} demonstrated at LCLS (NC linac)
- still to be done
  - demonstrating low field emission & dark current
  - demonstrating cathode cooling is fine
  - demonstrating QE ≥ 10^{-4} in our SC cavities and at about 2 K
  - producing beam