A Quarter-Wave-Resonator based SRF Gun for the LCLS-II High Energy project

Rong Xiang

MT annual meeting , Sep 26 – 27, 2022, DESY Hamburg

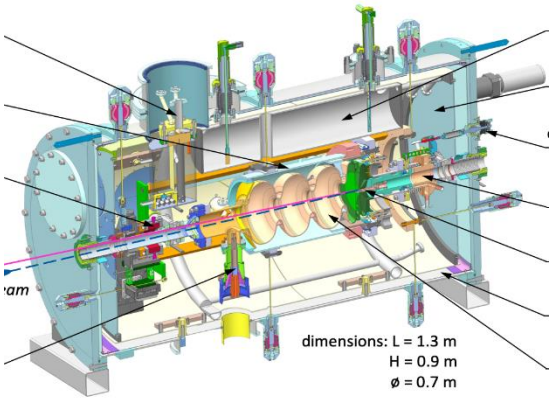
Outline

1. Background
2. Status of LCLS-II HE SRF gun
3. Roadmap

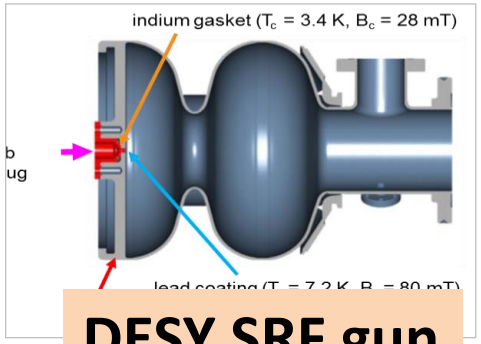
HZDR

HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

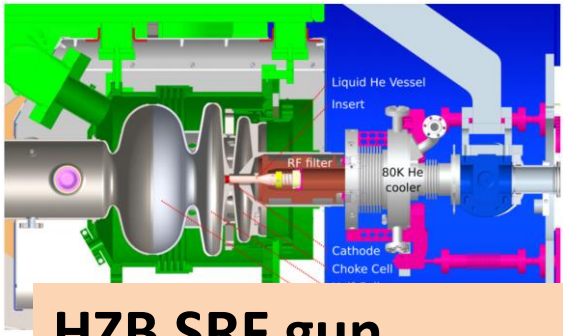
1. Background SRF guns concepts for CW high brightness beam



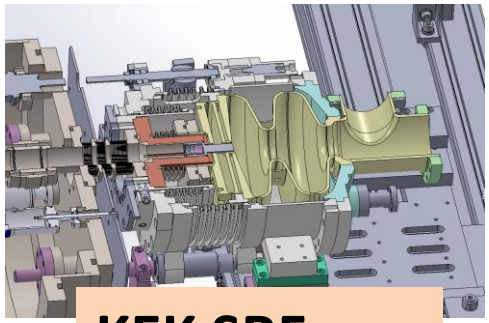
HZDR SRF gun-II in user operation



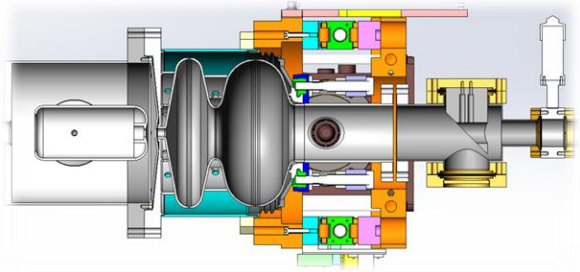
DESY SRF gun



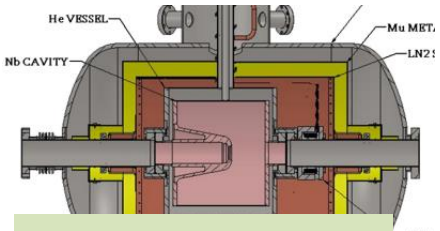
HZB SRF gun



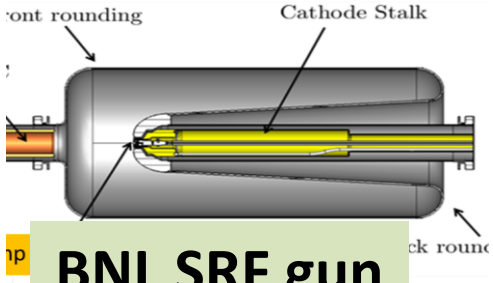
KEK SRF gun



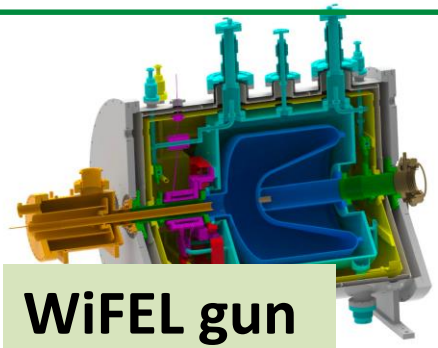
PKU DC SRF gun



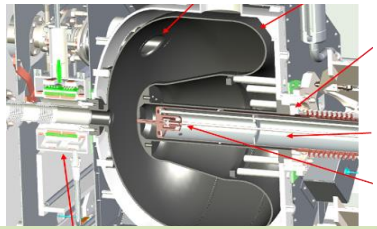
NPS SRF gun



BNL SRF gun



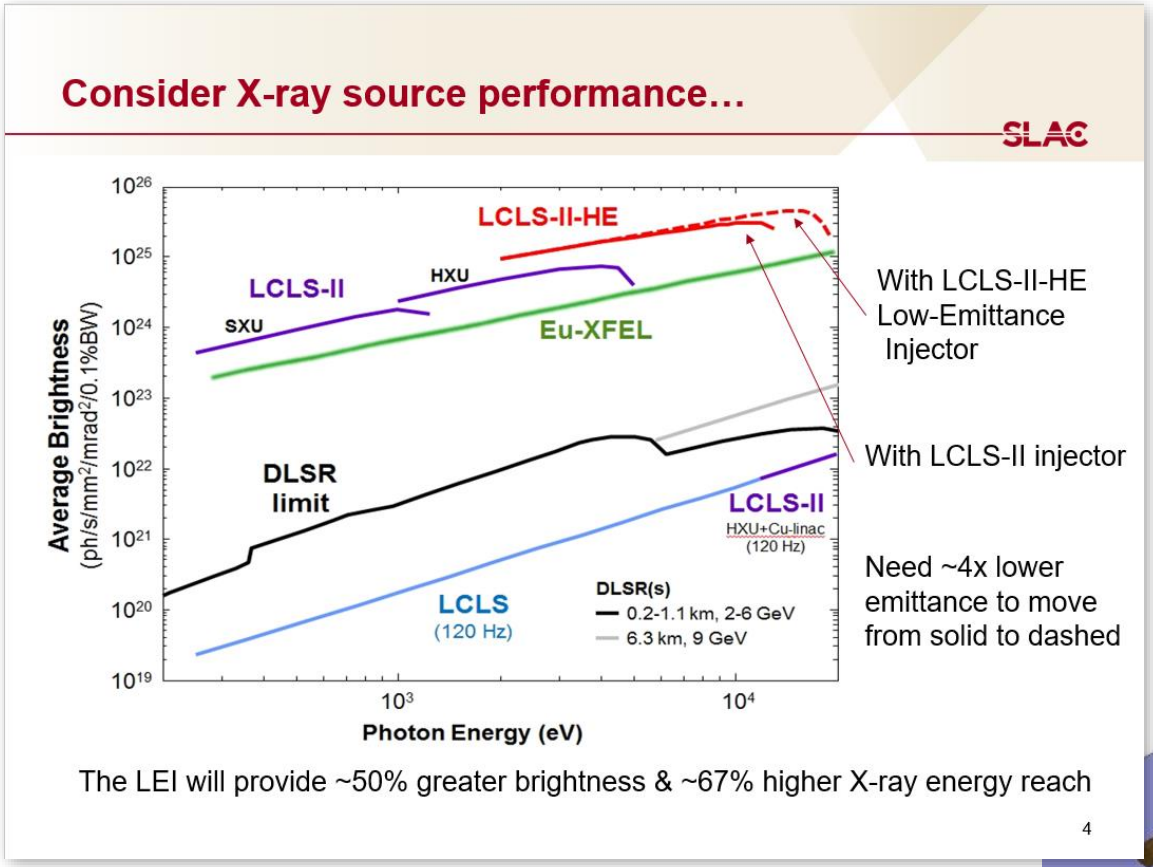
WiFEL gun



LCLS-II HE gun

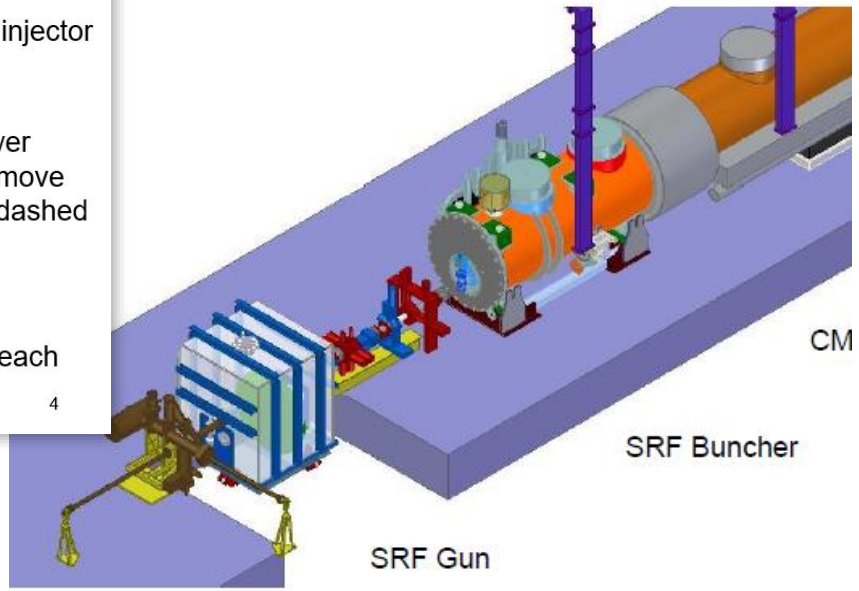
1. Background

SLAC is going to build a **low emittance LCLS-II-HE Injector (LEI)** to extend photon energy range of XFEL, enabling broader photon physics program.



J. Lewellen, T. Xu et al., P3 workshop2021 SLAC, 10-12.10.2021

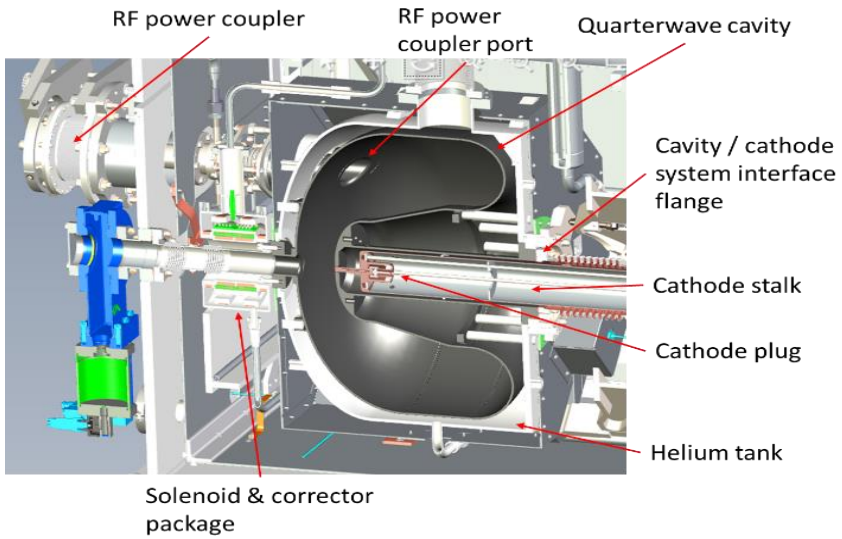
https://lcls.slac.stanford.edu/lcls-ii-he

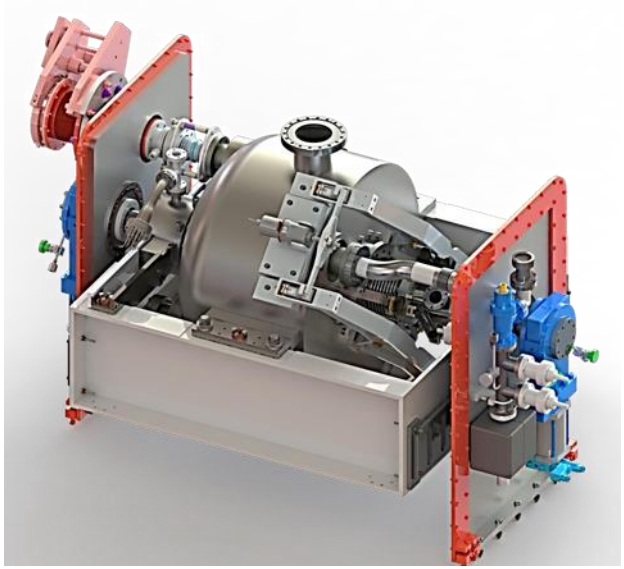


2. Status of LCLS-II HE SRF gun

LCLS-II-HE SRF gun design parameters

Parameters	Final Design Value
cavity frequency	185.7 MHz
cathode field	30 MV/m
photo-cathode	Alkali Antimonide
bunch charge	100 pC
Emittance @ 100 MeV	< 0.1 µm @ 100pC
Laser flattop pulse length	10-30 ps

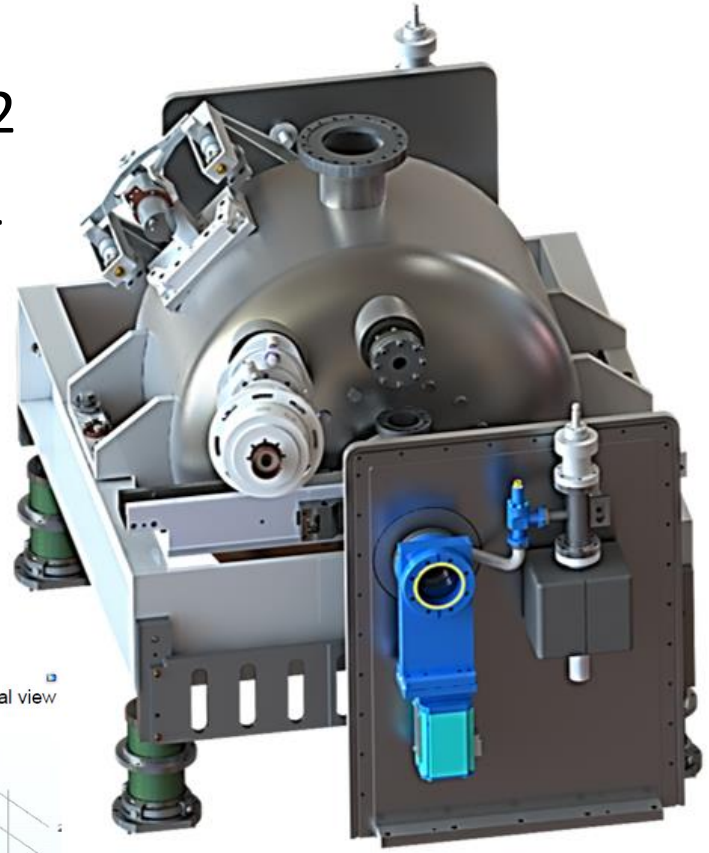


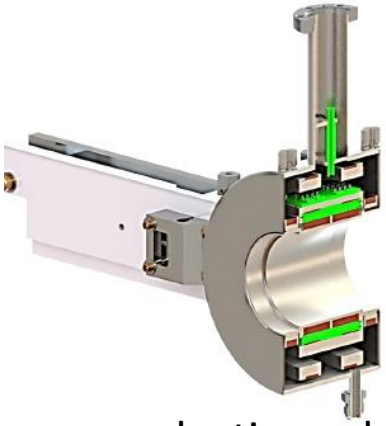


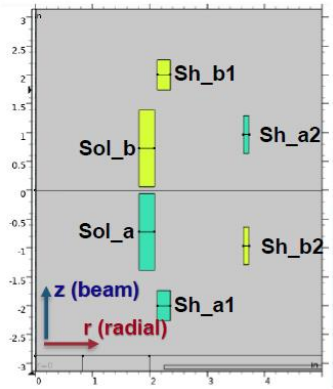
J. W. Lewellen, WEPA03, NAPAC 2022

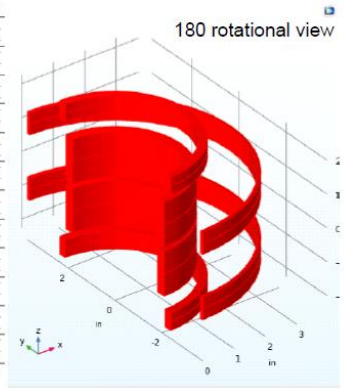
2. Status of LCLS-II HE SRF gun

- Preliminary design passed in April 2022
- Final design review will be in Oct. 2022
  - Cavity processing plan
  - Cryomodule, SC solenoid, coupler
  - Clean room assembly plan
  - RF, Cryogenic, vacuum, interface ...









superconducting solenoid

Y. Choi, April 2022 SRF Gun Preliminary Design Review, 7, Slide 6

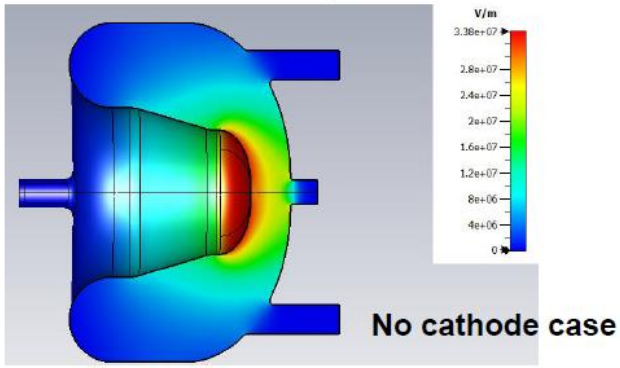
S. Miller, April 2022 SRF Gun Preliminary Design Review, 06, Slide 3

2. Status of LCLS-II HE SRF gun

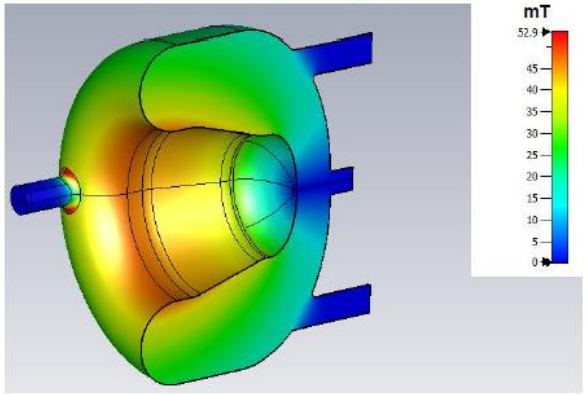
185.7MHz SC Cavity

- Optimize field distribution
- Modify multipacting performance
- Stress calculation, manufacturability

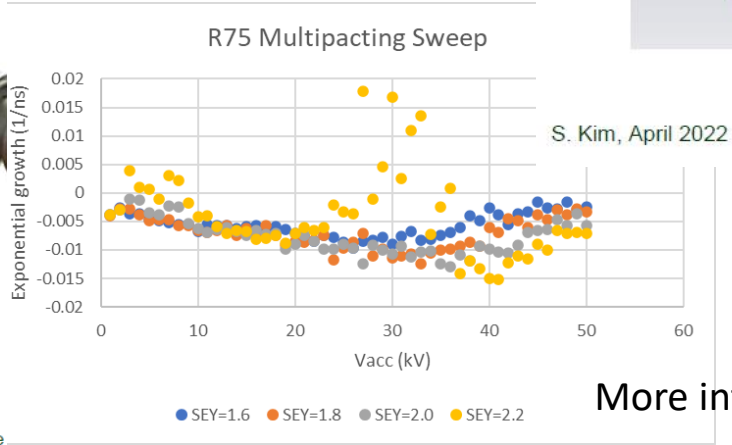
E-field at E_c = 30 MV/m, E_{peak} = 33.7 MV/m



B-field at E_c = 30 MV/m, B_{peak} = 52.9 mT



S. Miller, April 2022 SRF Gun Preliminary Design Review, 06, Slide



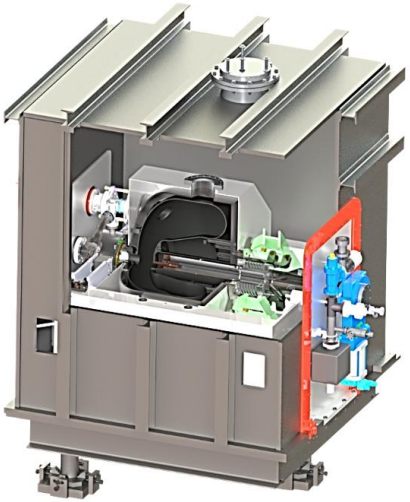
S. Kim, April 2022 SRF Gun Preliminary Design Review - 04, Slide 5

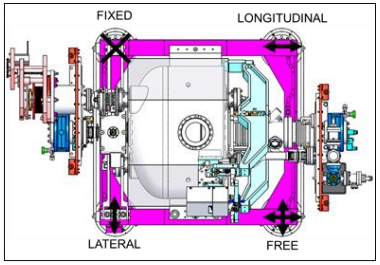
More info: S.Kim, MOPA85, NAPAC22

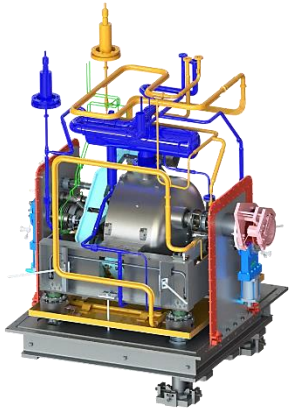
2. Status of LCLS-II HE SRF gun

Cryomodule Design Based on FRIB Bottom-up Approach

- Room temperature strongback to ensure alignment
- Cryogenic system suspended from the top to decouple from cold mass and minimize cryogen induced microphonics
- Cavity and solenoid design to operate at 4K
- Unique 3-D vacuum vessel seal allows cold mass to be completely assembled in cleanroom including cathode stalk adjustment features





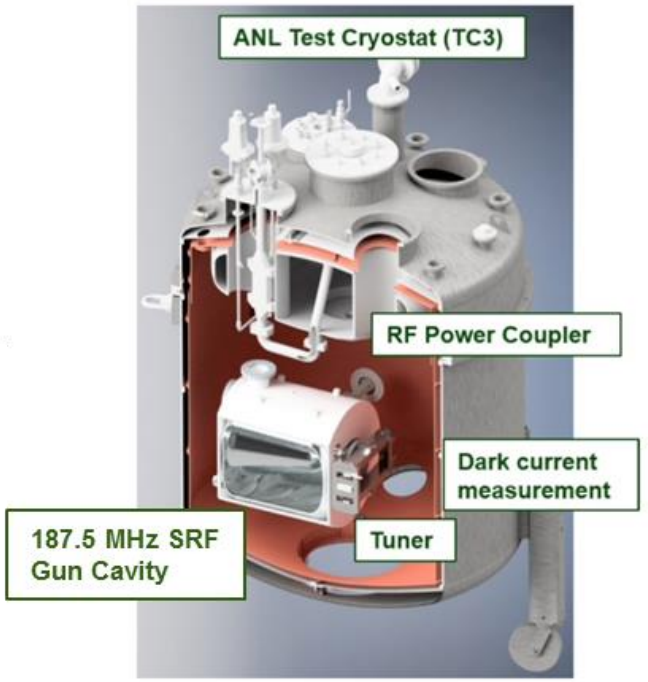


Contact: xuti@frib.msu.edu

2. Status of LCLS-II HE SRF gun

SRF Cavity Testing Approach

Conceptual – does not reflect latest design



"Two-prong" testing:

- Type of test
  - VCM (MSU)
  - Horizontal "tank" test (Argonne)
  - Integrated into CM
- Device being tested
  - "Blank" cavity
  - Gun cavity w/ cathode system

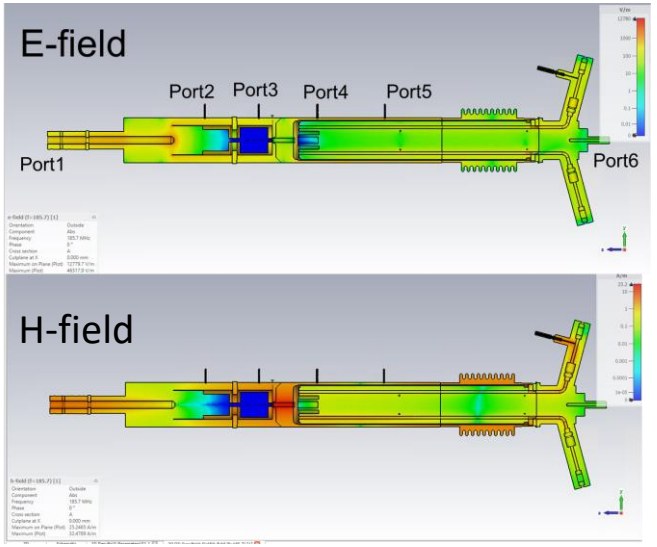
Allows finer-grained and earlier identification and mitigation of problems, e.g. multipacting, manufacturing

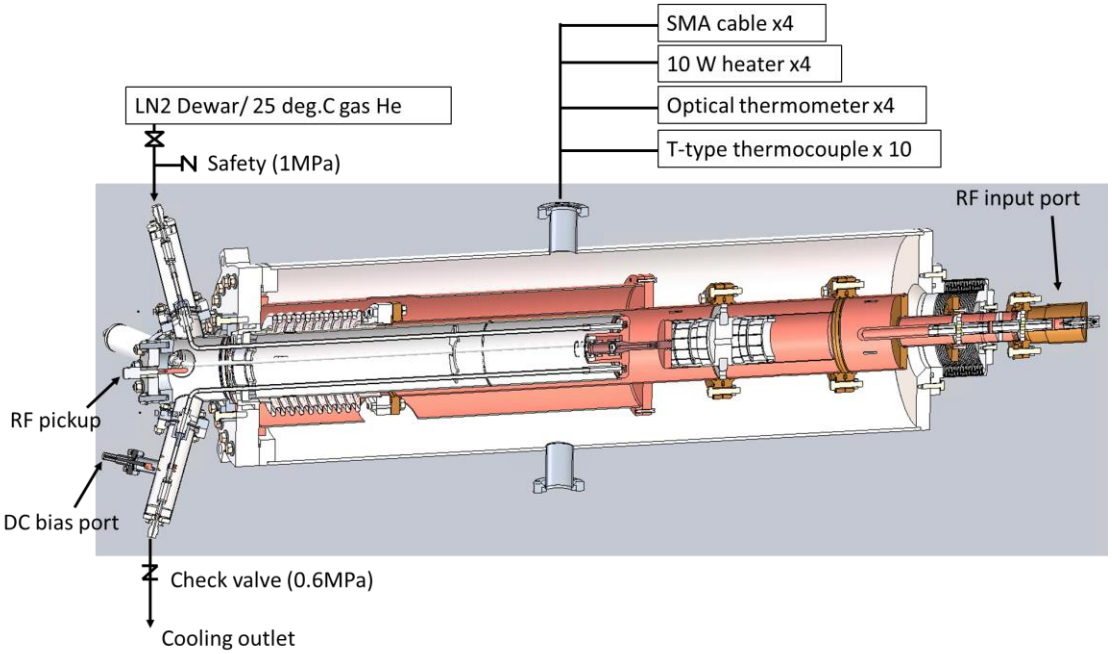
Contact: xuti@frib.msu.edu

2. Status of LCLS-II HE SRF gun

Cathode stalk RF/ DC test at RT / LN_2

- Bias 0-5 kV test
- RF Frequency and Filed distribution check.
- Thermal function test with heater.
- ~100W RF Test



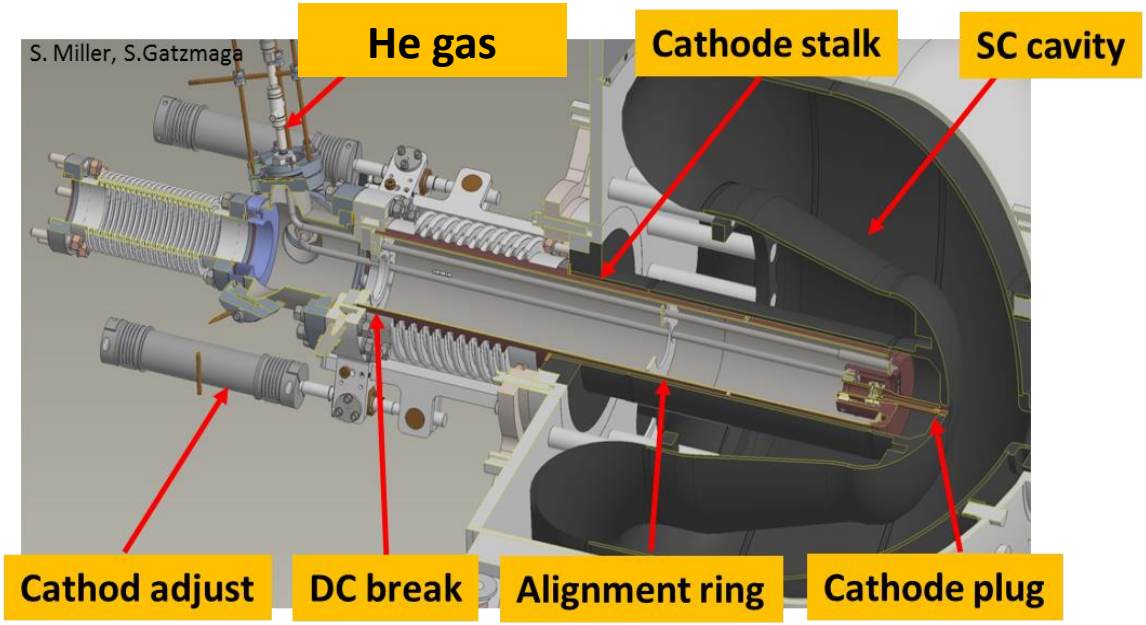


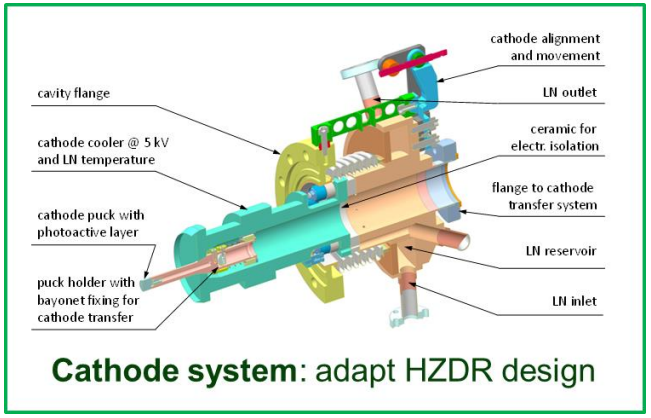
T. Komoni, et al., MOPA87, NAPAC 2022

2. Status of LCLS-II HE SRF gun

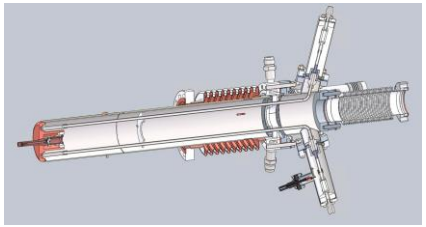
Cathode and load lock system

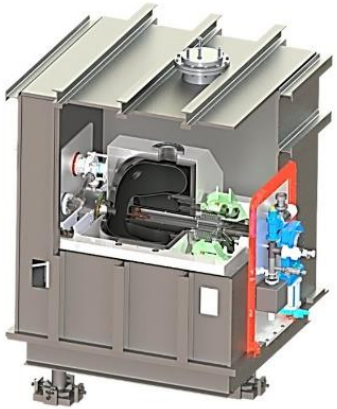
- Accurate, reliable
- Particle free operation
- Good vacuum 10^{-10} mbar
- Adaptable to different cathode materials

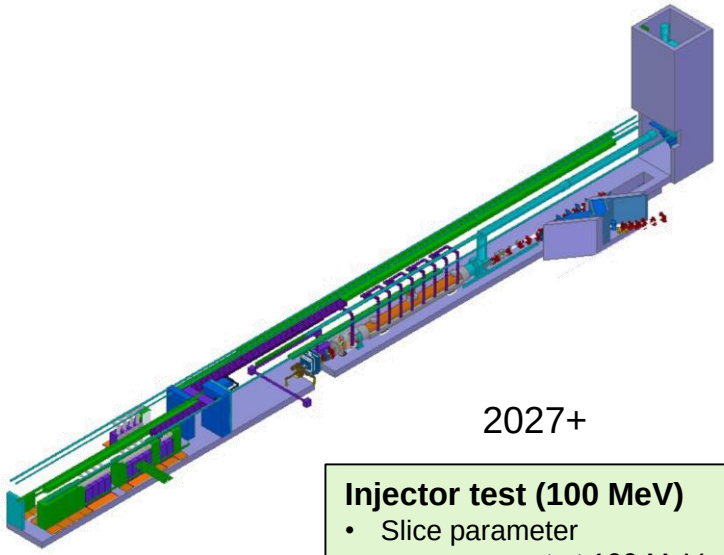




3. Roadmap for LCLS-II-HE injector







2022-2024

Cathode stalk bench tests
- Particle-free operation
- RF losses & cooling
- MP suppression

“Blank” cavity test
- Cavity multipacting
- Tuner operation
- Max. gradient, losses
- Power coupler

2025

Gun RF test
- Gradient & phase stability
- Field emission
- Multipacting
- Cathode stalk heating
- Stalk operating temp
- Solenoid perf.
- Field emission

2025-2027

Production gun fabricate & install
- Include updates from prototype program

2027+

Injector test (100 MeV)
- Slice parameter measurement at 100 MeV
- Beam capture
  - Bunch compression
  - Emittance damping
- Operating stability
- Cathode lifetime
- Beam quality optimization
- Coupler kick correction

(part of Injector commissioning)

Contact: lewellen@slac.stanford.edu

Acknowledgements

Collaborators in the LCLS-II-HE SRF gun project

SLAC: C. Adolphsen, R. Coy, J. Fuhao, G. Hays, R. Legg, J. Lewellen, D. Li, G. Lixin, C. Mayes, C. Mitchell, M. Murphy, C-K Ng, Y. Nosochkov, T. Raubenheimer, M. Ross, M. Santana, X. Wang, M. Woodley, F. Zhou

MSU/FRIB: C. Compton, Y. Choi, W. Hartung, S-h. Kim, S. Lidia, S.J. Miller, J. Popielarski, L. Popielarski, K. Saito, T. Xu

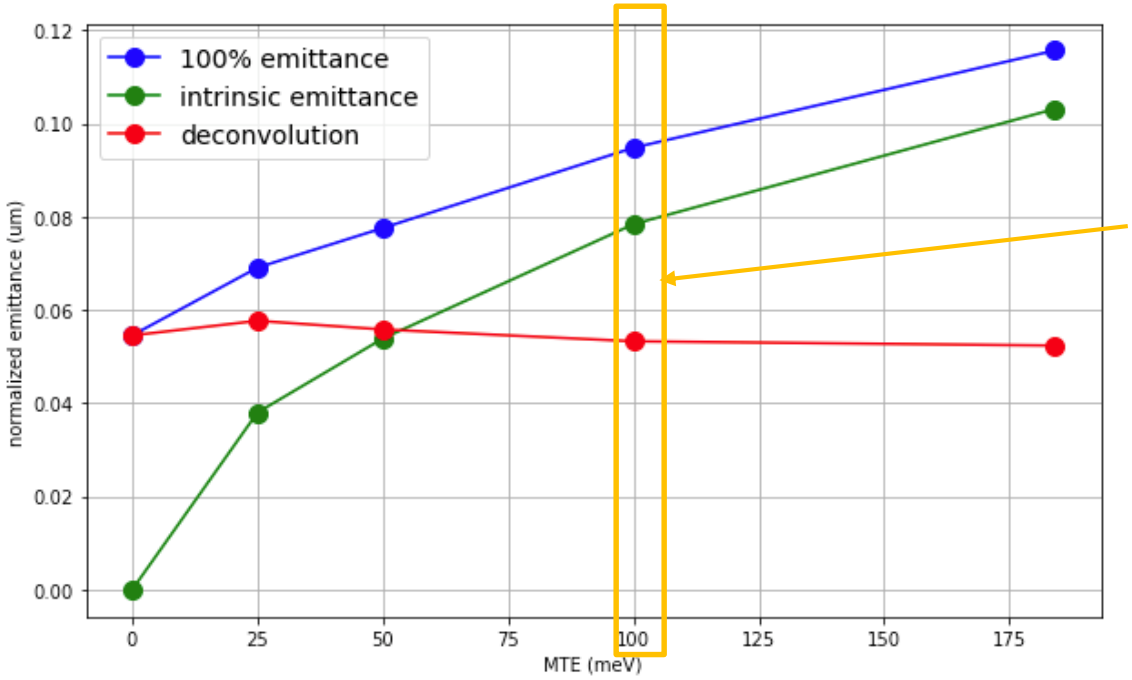
HZDR: A. Arnold, S.Gatzmaga, S. Ma, P. Murcek, J. Teichert, R. Xiang

Argonne: M. Kelly, P. Piot, Troy Peterson

Thank you!

Many thanks to Dr. John Lewellen, Dr. Ting Xu
and other colleagues for the slides!

Beam Emittance vs. Mean Transverse Energy for LEI*



MTE	0 meV	25 meV	50 meV	100 meV	184 meV
100% emit	0.054 um	0.069 um	0.078 um	0.095 um	0.115 um
95% emit	0.037 um	0.052 um	0.059 um	0.075 um	0.093 um

An S-20 photocathode (Cs_3Sb on Na_2KSb) with ~ 600 nm drive laser †

Substantial body of literature on photocathode performance

* Using 100 pC, 30 MV/m, "complex" injector config, doublet solenoid

† Appl. Phys. Lett. 108, 134105 (2016); https://doi.org/10.1063/1.4945091