SLAC Injector R&D

J. Schmerge for injector team

October 24, 2016

U.S. DEPARTMENT OF ENERGY
Office of Science

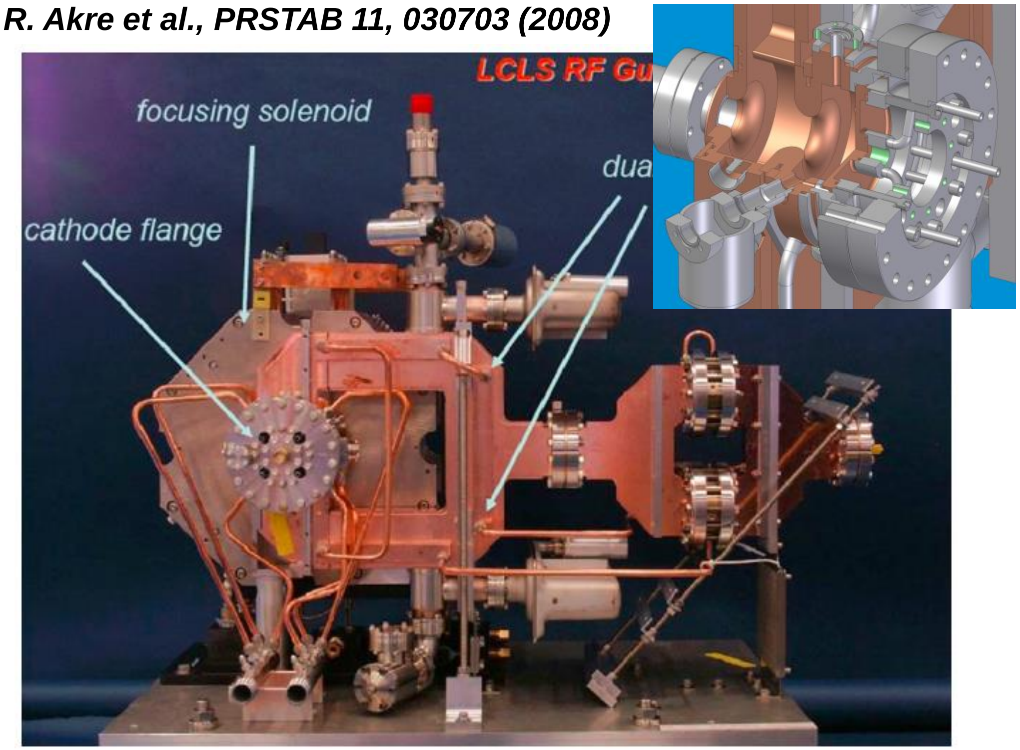
SLAC NATIONAL ACCELERATOR LABORATORY

Outline

- Status
- Motivation
- R&D approach
- Timeline and Budget
- Long term future

LCLS gun and injector

R. Akre et al., PRSTAB 11, 030703 (2008)



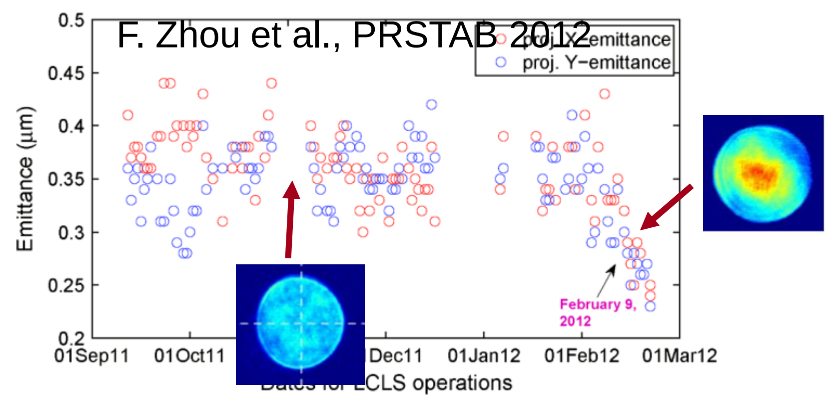
- Cathode laser cleaning

  A. Brachmann et al., IPAC 2011

  F. Zhou et al., PRSTAB 2012, NIMA 2015

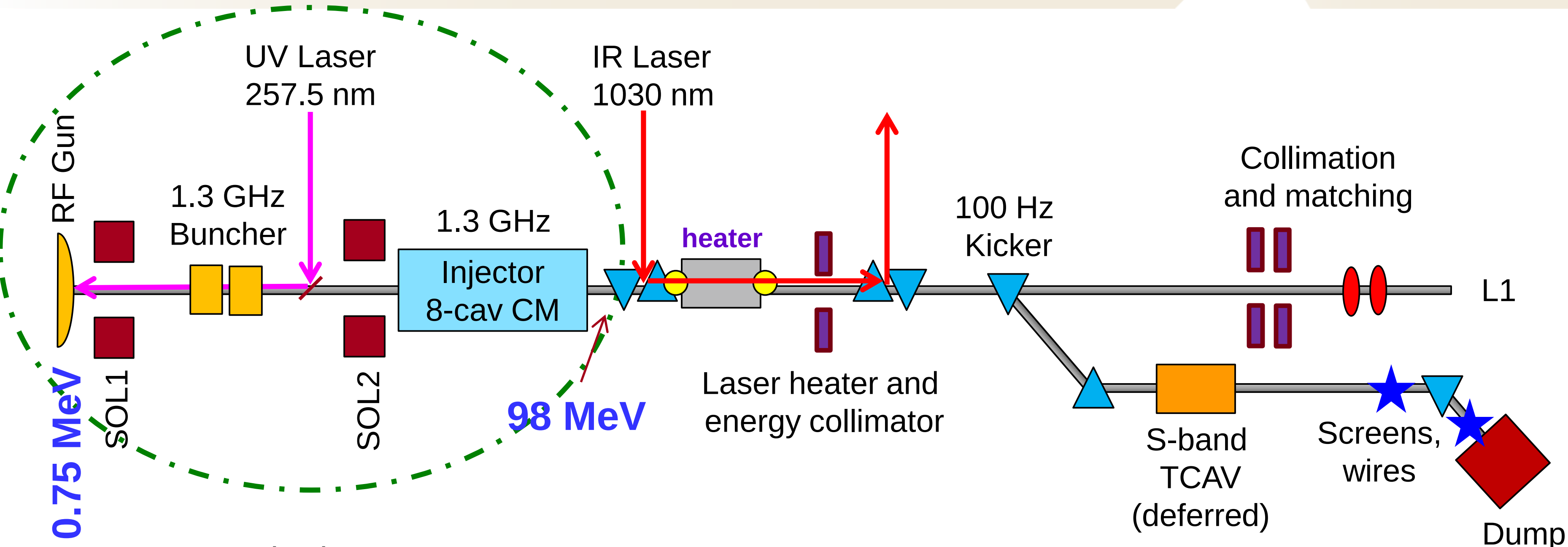
- Transverse shaping

  F. Zhou et al., PRSTAB 2012



- Built on SLAC’s technical excellence and GTF experience (’96-’05)
- Routine performance: 0.4-0.5 µm emittance, 50 A current, 200 pC
- Highly successful, but we can do better

LCLS-II CW (1MHz) injector

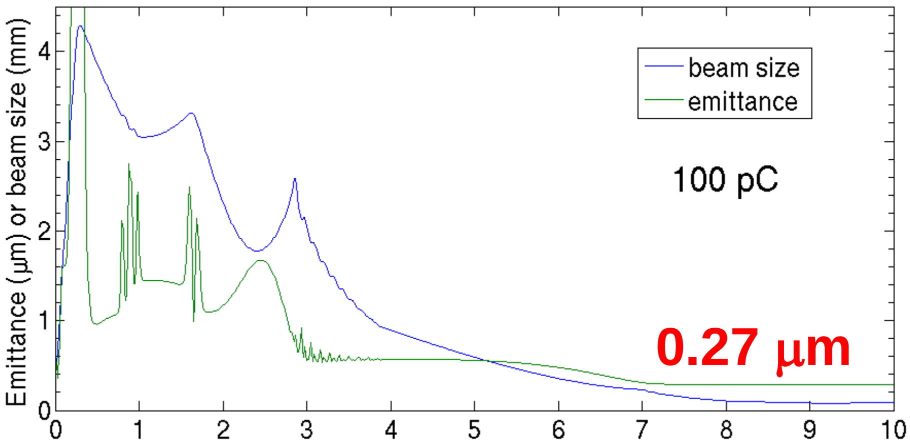


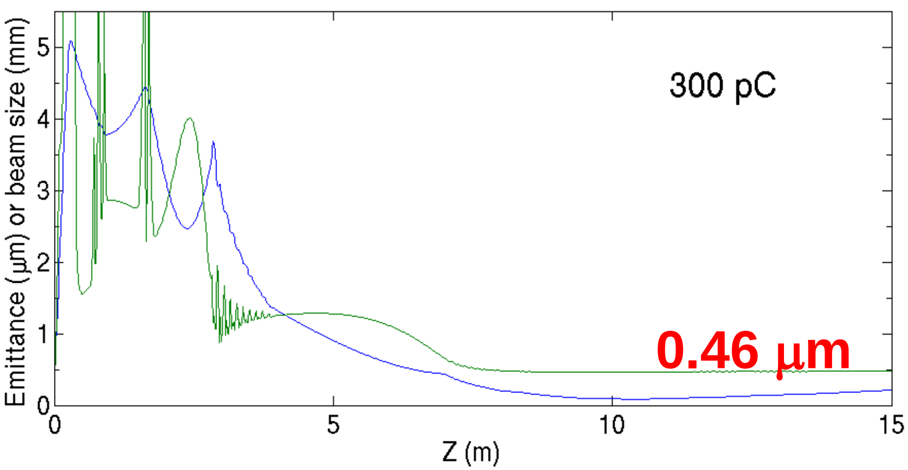
- Cs_2Te cathode
- UV/IR lasers for cathode/laser heater
- 185.7 MHz NC RF gun
- NC 1.3 GHz 2-cell buncher
- SC 1.3 GHz 8-cavity CM
- 2 emittance compensating solenoids with quad correctors
- BPM Diagnostics

LCLSII-2.2-PR-0084-R0

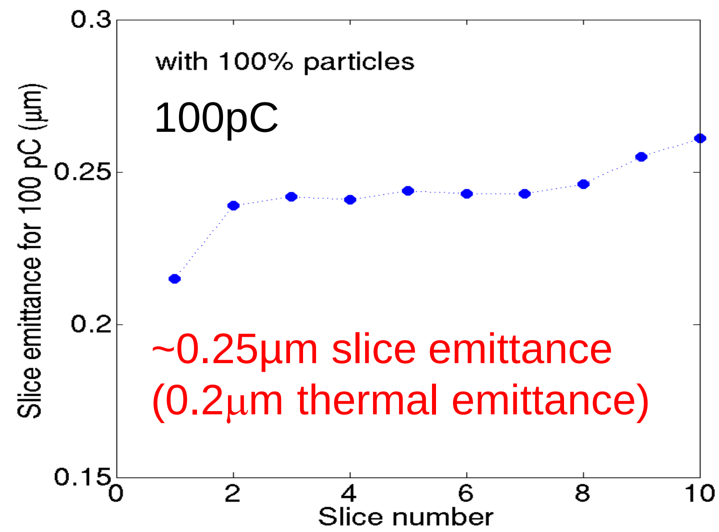
LCLS-II emittance

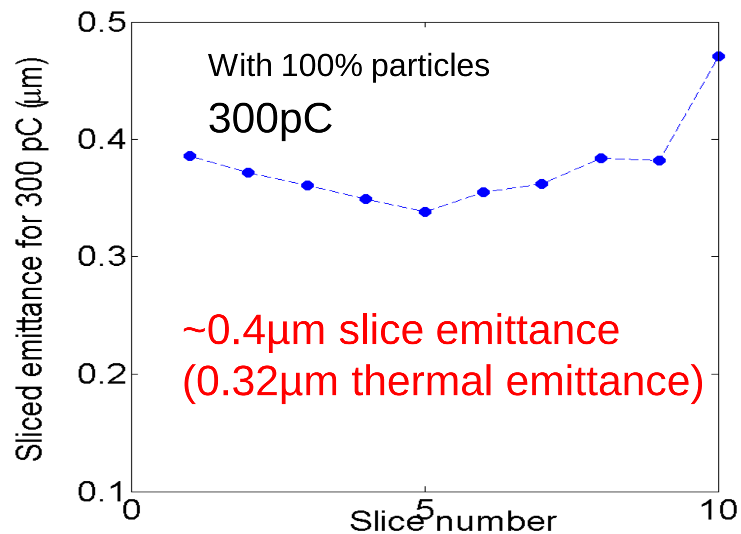
W/ Astra code





Assumes thermal emittance 1μm/mm



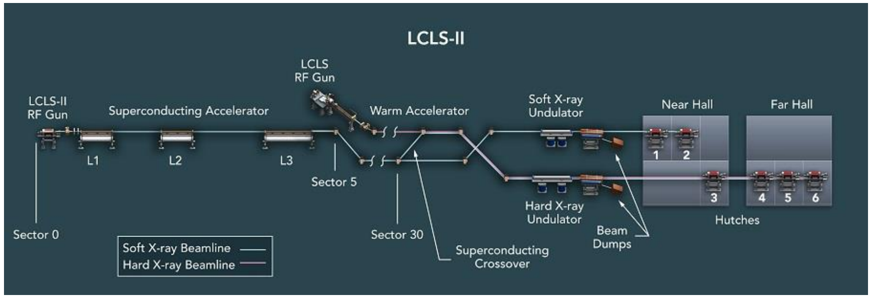


Motivation

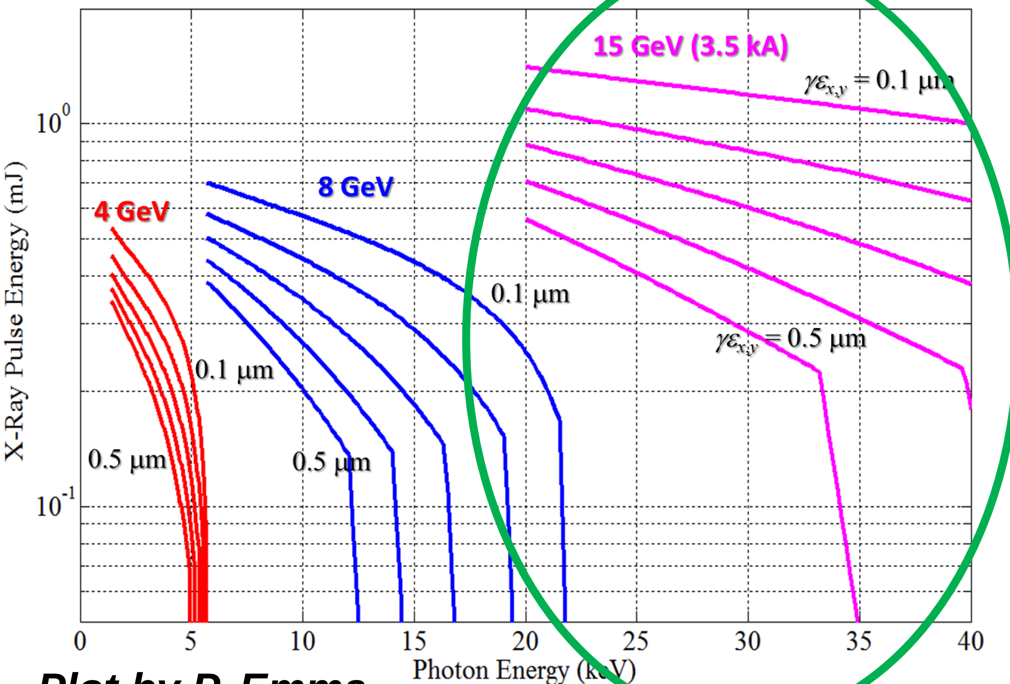
- **Lower Emittance** leads to *higher FEL power* and *increased spectral range*

- **Improved Reliability**
  - more consistent $\varepsilon_{thermal}$ and QE
  - fast cathode swap
  - Example is a load lock like originally planned for LCLS

- Benefits other programs also such as SLAC UED and FACET-II



HXR (λ_u=26 mm) with SC-Linac (red, blue) & Cu-Linac (magenta) and emittance of 0.1, 0.2, 0.3, 0.4, and 0.5 μm



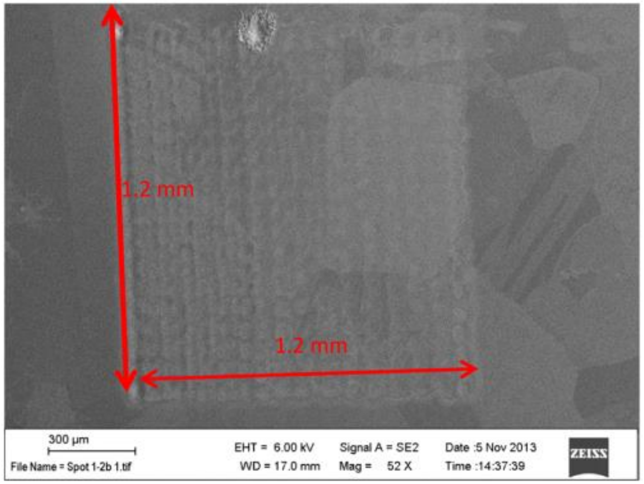
Plot by P. Emma

How to Improve Brightness

- Reduce thermal emittance
  - Smooth surface without laser cleaning
  - Wavelength dependence, temperature and single crystals
- Increase gradient
  - Novel structures
  - SRF guns
- Optimize
  - Pulse shaping
  - Match operational (200 pC) charge to injector design (1000 pC)

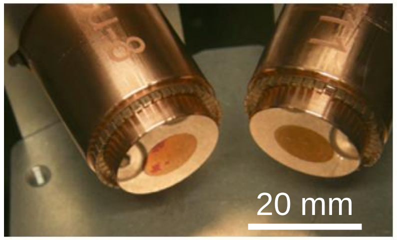
Reduce Thermal Emittance

- Laser cleaning being used to restore QE, however cause surface roughness
- Roughness induced emittance growth not quantitatively studied
  - Roughness creates transverse fields which add transverse energy



F. Zhou et al., NIMA 2015

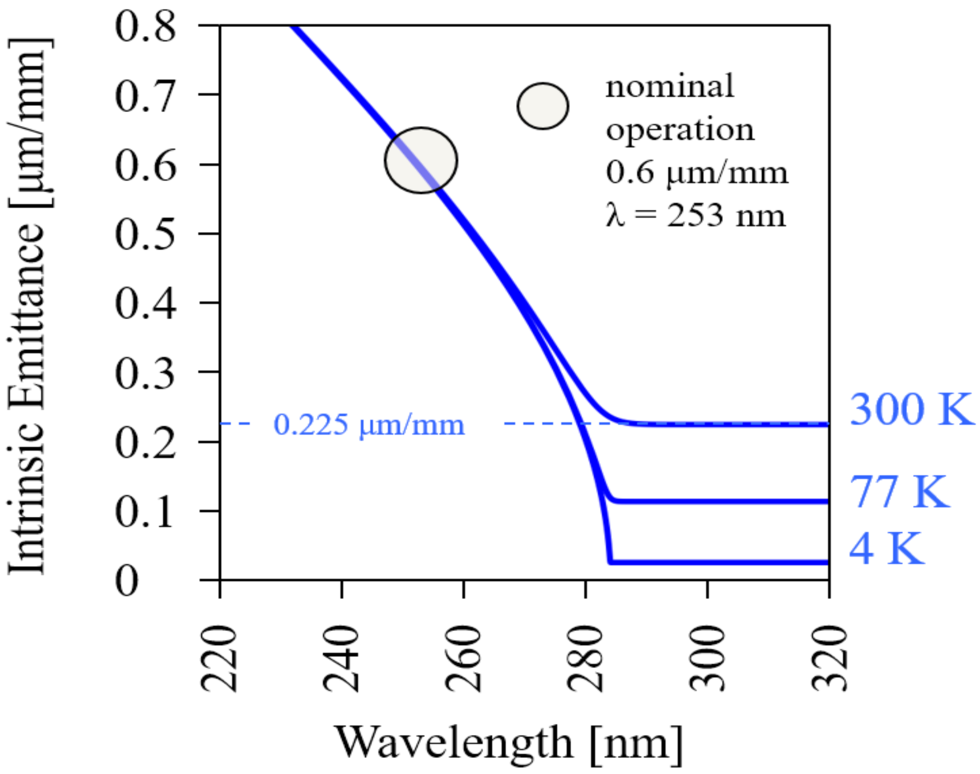
- **Load-lock system** for the cathode
  - Preparation in better controlled environment
  - Vacuum cathode storage &transfer
  - Fast cathode swap



Cathode plug for an S-band CuRF gun (PSI)

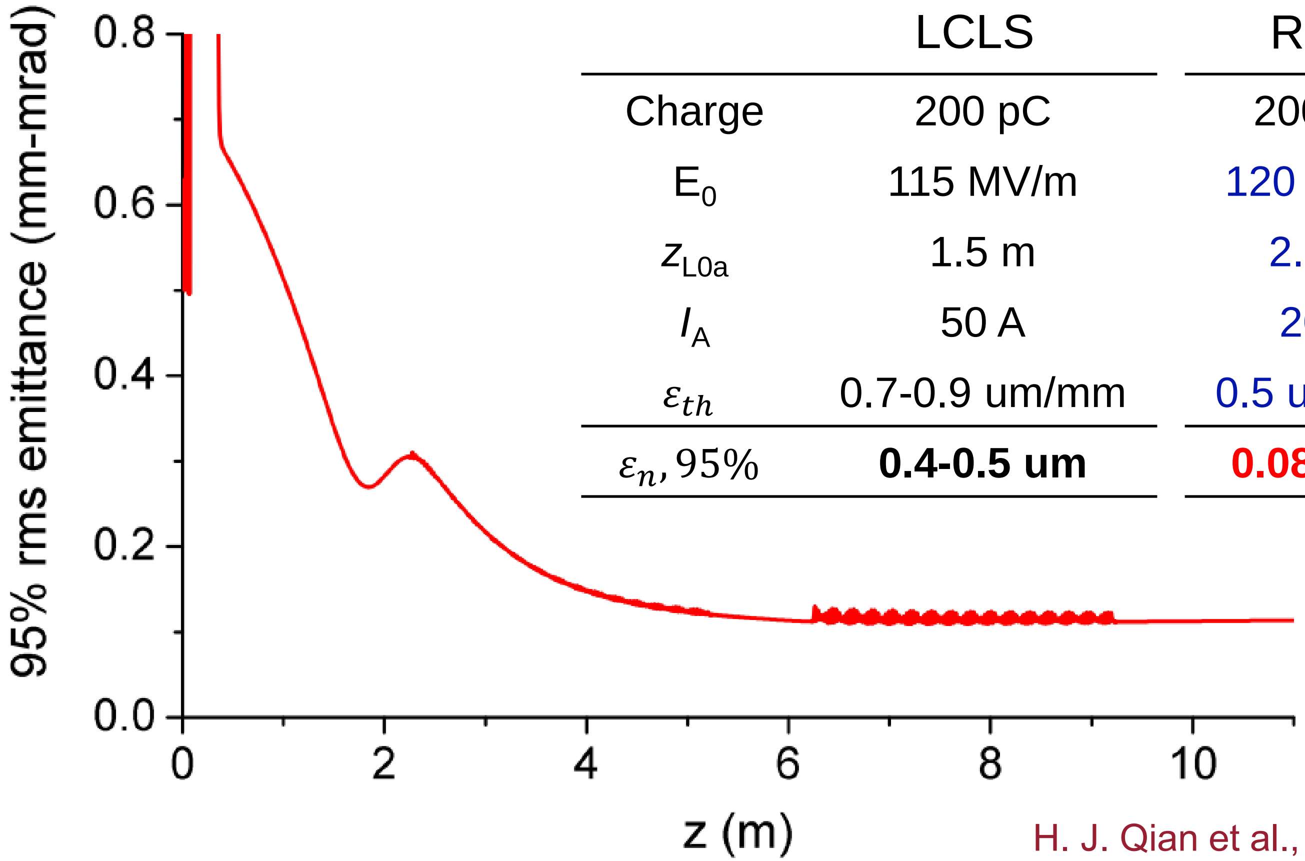
Reduce Thermal Emittance

- Wavelength
- Temperature
- Crystal orientation dependence/polarization
- Semi-conductors
- Benefit from a load lock



Plot by T. Vecchione

Optimize



	LCLS	R&D
Charge	200 pC	200 pC
E_0	115 MV/m	120 MV/m
z_{L0a}	1.5 m	2.2 m
I_A	50 A	20 A
ε_{th}	0.7-0.9 um/mm	0.5 um/mm
$\varepsilon_n, 95\%$	**0.4-0.5 um**	**0.084 um**

H. J. Qian et al., IPAC'16

- More detailed/systematic injector simulation ongoing
- Also studying emittance preservation for FEL (Panos, Yuantao, Zhirong)

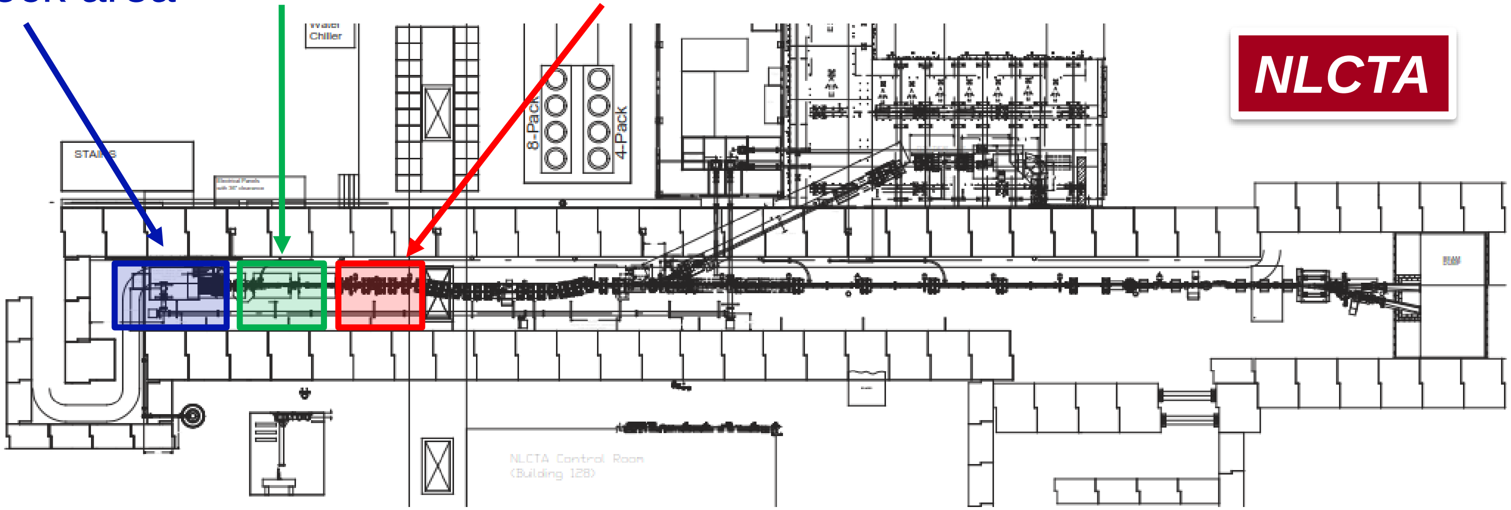
Test facility at NLCTA

- NLCTA (Next Linear Collider Test Accelerator) ideal candidate
- moderate upgrade needed: S-band dual-feed linac, etc.
- Laser improvements

Gun and load-lock area

Upgrade to S-band linac

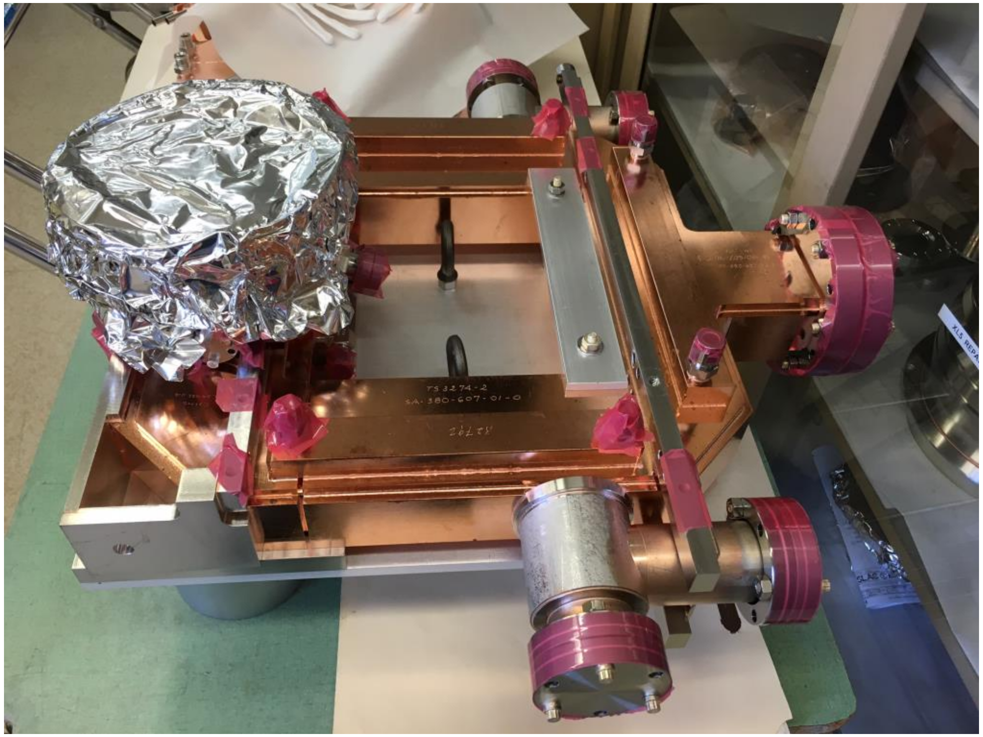
Beam diagnostic section



M. Dunning

LCLS-I Spare Gun 2

Final vacuum assembly and heater tape bake mid-September

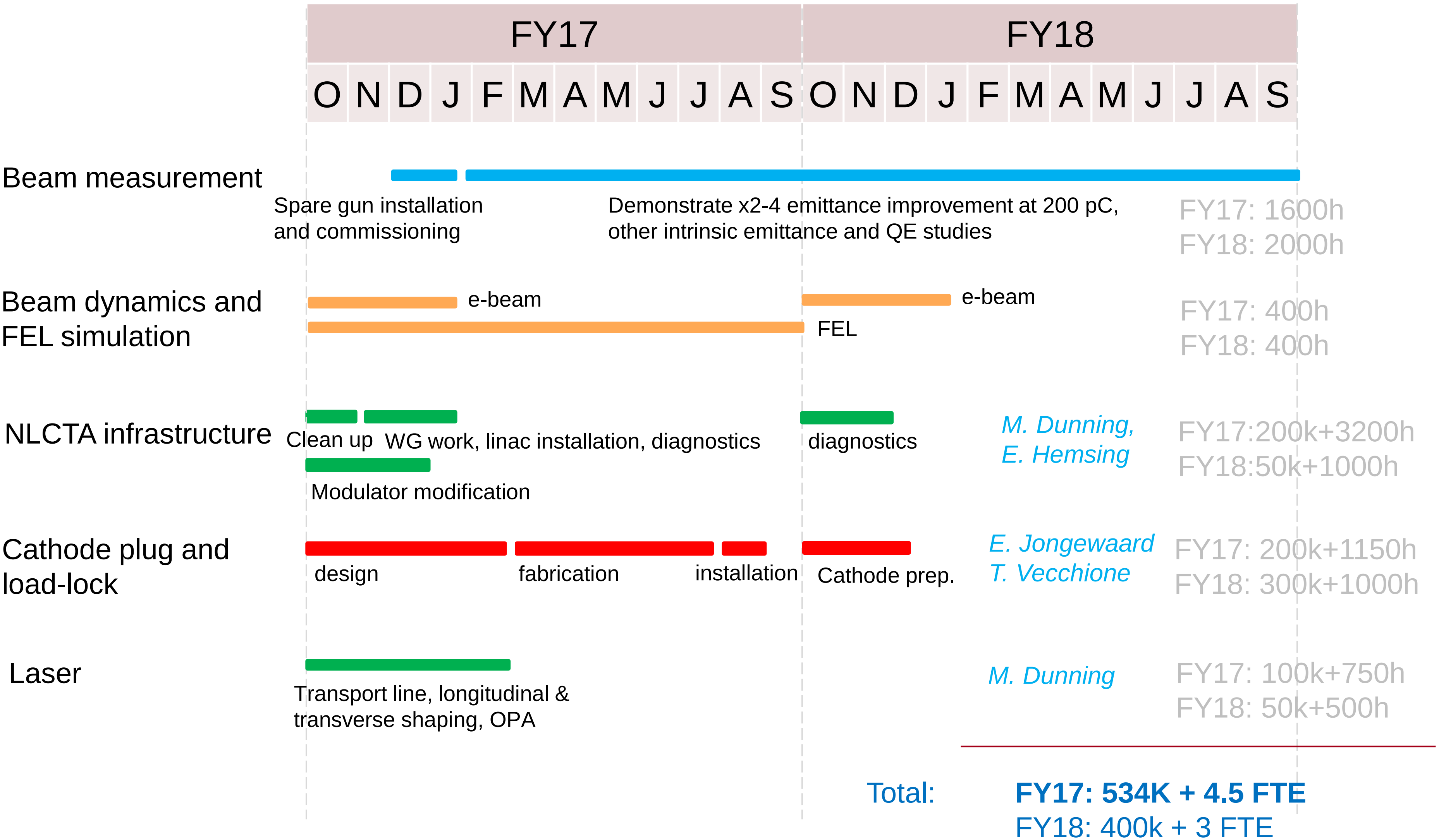


RF Gun Body

RF Window Spools

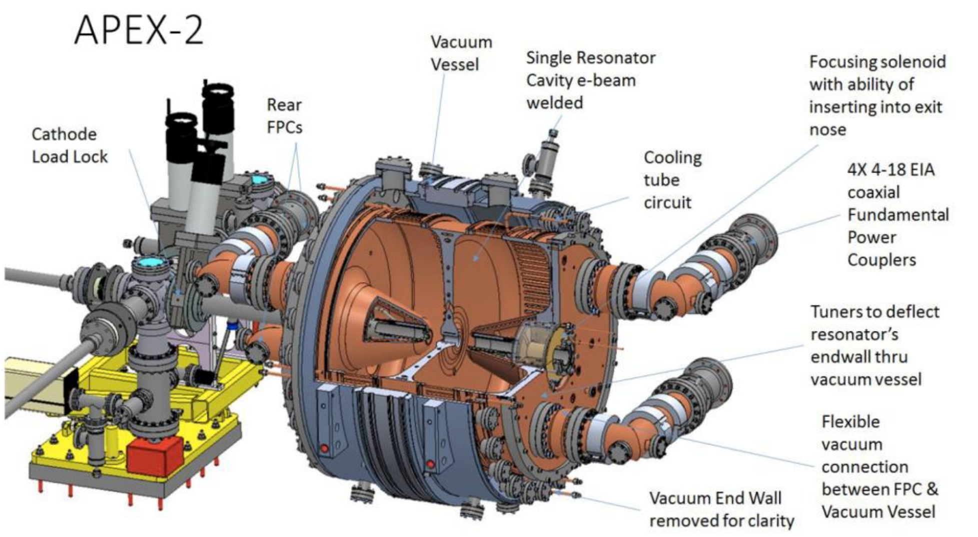
RF Cavity Probes

Timeline and Resources



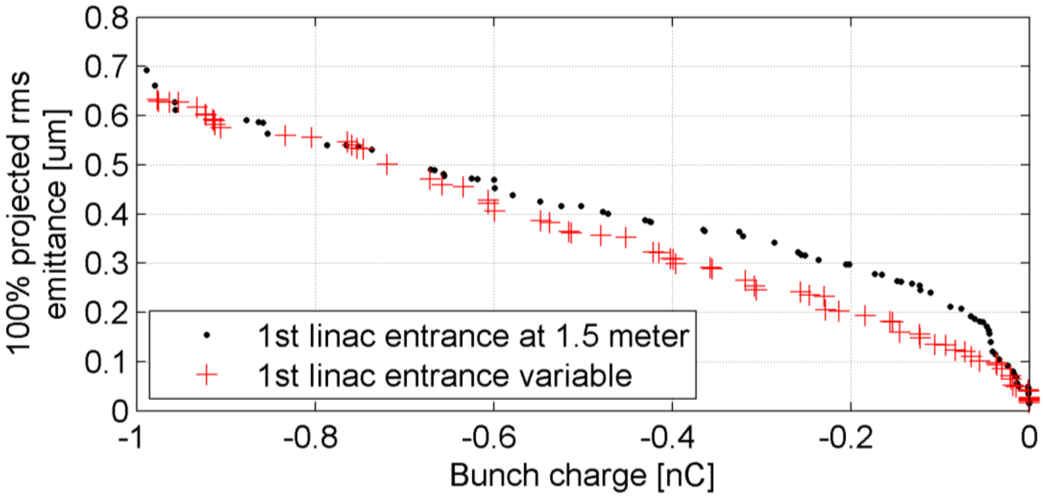
Future

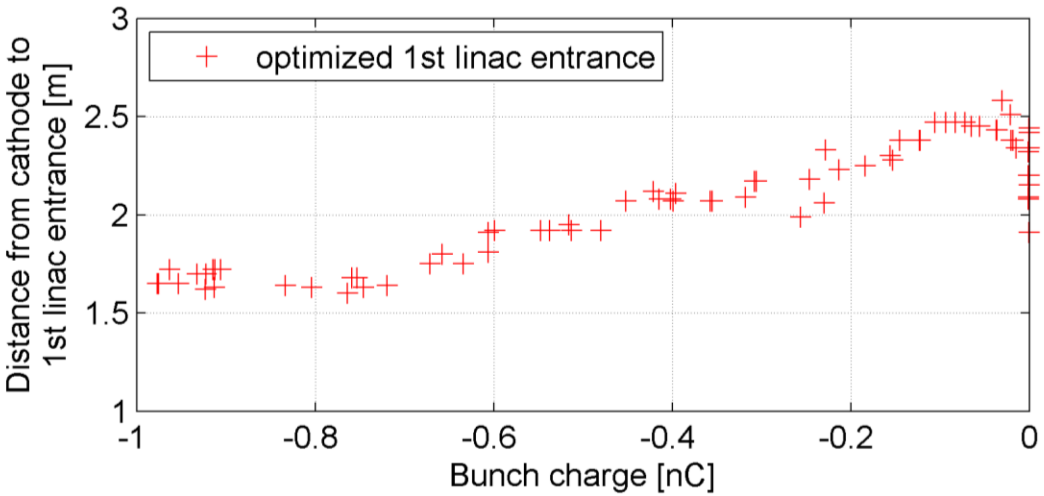
- Higher gradient CW guns
  - SRF - WiFEL gun now at SLAC
  - Room temperature guns can push gradient to approximately 30 MV/m such as APEX-2



Thank you!

Injector location

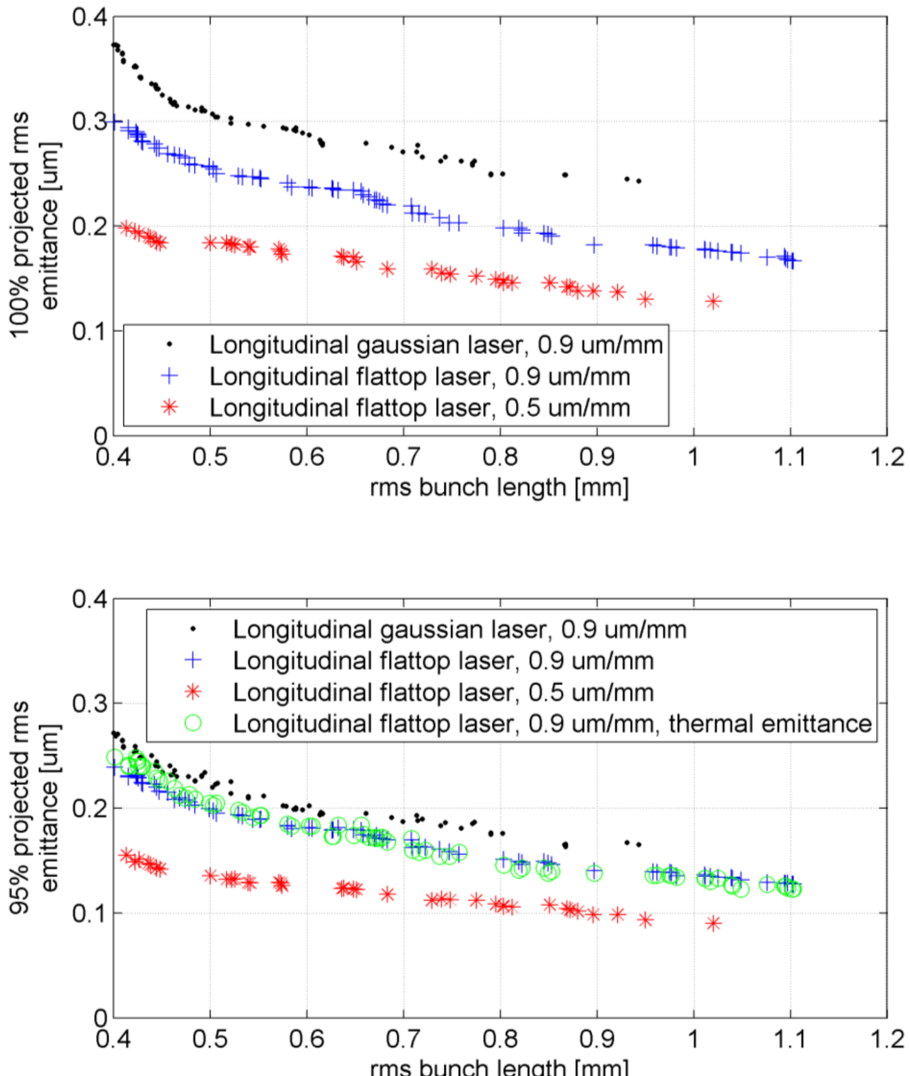




Injector layout optimizations (ASTRA simulations with 10 k macro particles), (a) Pareto front of emittance vs charge with rms bunch length shorter than 1 mm and injector beam energy above 100 MeV, (b) optimized location of first linac vs bunch charge.

H. J. Qian et al., IPAC'16

Emittance versus bunch length

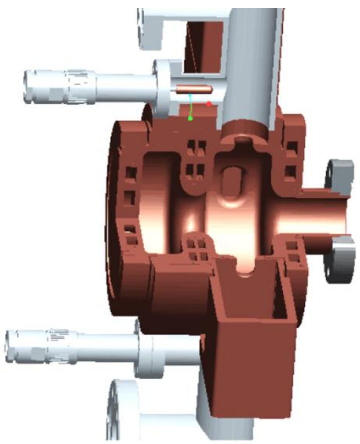


Pareto front of emittance vs rms bunch length for 200 pC bunch charge (ASTRA simulations with 10 k macro particles), (a) Pareto front of 100% emittance vs bunch length, (b) corresponding 95% emittance vs bunch length.

H. J. Qian et al., IPAC’16

PAL and PSI Injectors

- PAL ITF (2012-2015)

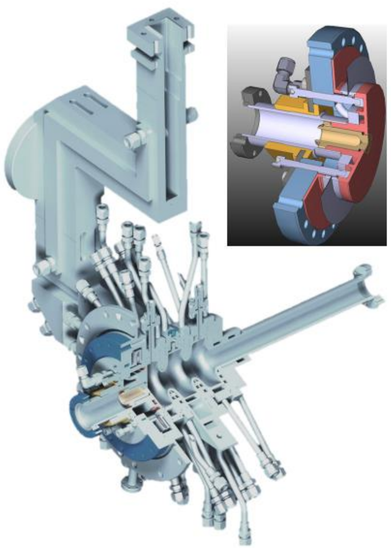


  - 1.5 cell, 60-120 Hz
  - 120 MV/m
  - 100 nm roughness Cu cathode w/ laser cleaning
  - Linac entran. 2.2 m

- Commissioning status: $\varepsilon_{x/y}$=0.8/0.4 um at 200 pC

J. H. Han et al, IPAC'16

- PSI ITF (2012-2015)



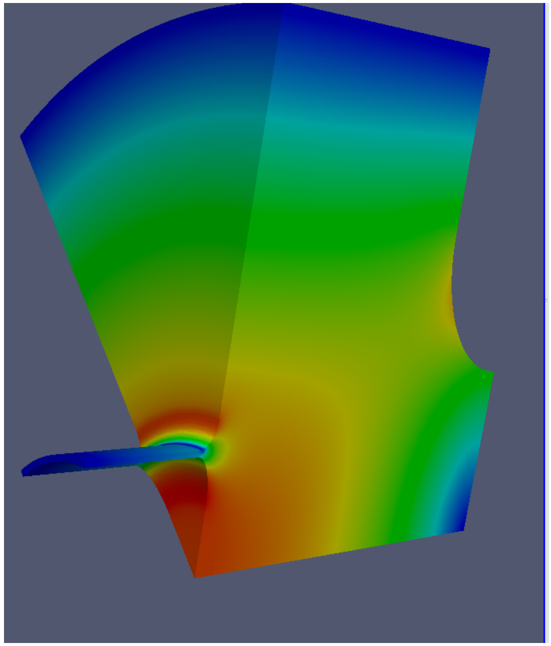
  - 2.6 cell, 10-100 Hz
  - 85-100 MV/m
  - Cathode plug + load lock system
  - 3 nm roughness Cu cathode w/o laser cleaning
  - Cs_2Te cathode
  - Linac entran. 2.65 m

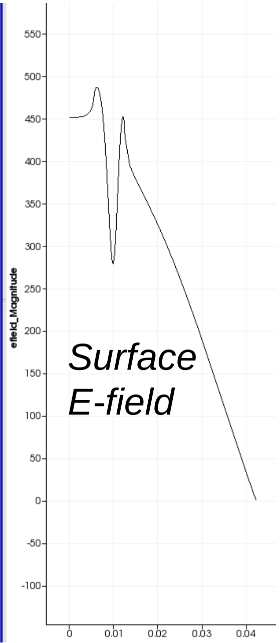
- Demonstrated $\varepsilon_{x/y}$=0.3 um at 200 pC and 20 A

arXiv:1606.02586

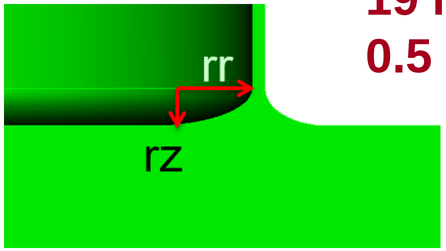
Optimize the cathode plug design

- **Compatible with LCLS-II CW gun load-lock and preparation system**
- Optimize rf and thermal design





Z. Li



19 mm diameter plug, 0.5 mm gap (PSI, KEK)

rz	rr	$E_{Max}/E(r=0)$
0.25	0.25	1.77
0.5	0.5	1.41
1.0	1.0	1.30
1.5	1.5	1.26
1.5	2.5	1.15
1.5	4	1.08

PSI
KEK